NASA Magnetospheric Multiscale (MMS)
Instrument Data Products Guide

Energetic Particles Detector (EPD) Investigation

Energetic Ion Spectrometer (EIS) &
Fly's Eye Energetic Particle Spectrometer (FEEPS)
Instruments

Version 4.0

1 August 2021

Change Record

Version	Date	Modifications
1.0	13 Apr 2016	Initial version
2.0	20 Mar 2018	Formatting changes, sections reordered, TOC and cross-reference linking inserted, content updated based on experience from prime mission.
3.0	16 Apr 2020	Updated to reflect changes in operations, calibrations, etc. – updated FEEPS data quality flags, sunlight contamination (Exhibit 28) FEEPS flat-fielding (Exhibits 30-31), EIS cross-calibration, and added Appendix on EIS rate-dependent corrections
4.0	1 Aug 2021	Updates on: FEEPS data quality flags, sunlight contamination, flat-fielding, and percent uncertainty variables; EIS cross-calibration, variable names changes, and file versioning; EPD L3 data products and "MMS-X" combined products; and overall editing and formatting.

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0 Important information for EPD data users

0.1 EIS data warnings and caveats

EIS points of contact:
- Ian Cohen, *APL* (Ian.Cohen@jhuapl.edu)
- Barry Mauk, *APL* (Barry.Mauk@jhuapl.edu)

a) **<u>Telescopes (T3-ion, T2-electron) affected by sun shield</u>**: Ion telescope T3 and electron telescope T2 are substantially blocked by the instrument's sun shield. Although these telescopes obtain valid data and are supplied in the EIS data products, care should be exercised in using these telescopes if anomalies are seen.

b) **<u>EIS1 telescope (T4) SSD anomaly</u>**: On MMS1, the solid-state detector (SSD) utilized in telescope T4 (for both ExTOF ion and electron data), is responding anomalously and should not be used at this point in time. It acts like it is under-biased, but the true cause is unknown.

c) **<u>EIS1 HV micro-discharges anomalies</u>**: For the MMS1 spacecraft, the HV system experienced micro-discharge anomalies that caused the HV to be shut down by the onboard software on 30 January 2016, with some anomalous behavior seen for the first time on 21 January 2016, about 6 months after HV turn on. Because only 3 EIS units were required, the HV on EIS1 was disabled for the rest of the prime mission. EIS1 data prior to 21 January 2016 are assumed to be unaffected by these anomalies.
   i. Beginning on 18 April 2016, EIS1 was put into high-resolution electron mode with "electronenergy" burst data enabled.
   ii. HV (and ion species data) on MMS1 was re-enabled beginning on 31 January 2018. No further issues have been recorded to-date.

d) **<u>HV turnoff in inner magnetosphere</u>**: From launch through 8 August 2016, the high voltage (ion data) on all EIS units was turned off inside a radial distance of 7 R_E. The disabling of the HV system does not affect the collection of electron data.
   i. Beginning on 8 August 2016, this turn on/off point was reduced to 6 R_E on MMS2; the change to 6 R_E was implemented on all spacecraft beginning on 22 March 2017.
   ii. On 1 March 2018, the HV on/off flight rule was changed from 6 R_E to L=6.
   iii. On 12 March 2019, the HV on/off flight rule was changed from L=6 to L=5 for MMS4; after analysis revealed little degradation this was applied to MMS1-3 on 4 June 2019.

e) **<u>HV turnoffs during long eclipse seasons and campaigns</u>**: At the following times, certain or all EIS units had the HV disabled or were entirely powered off – affecting data availability.
   i. 12-30 June 2016 – *Long-eclipse season*
   ii. 6-15 March 2019 – *Turbulence campaign*
   iii. 17-31 August 2019 – *Long-eclipse season*
   iv. 8-19 August 2020 – *Long-eclipse season*

f) **<u>EIS electron data availability</u>**: Because of data volume limitations, and because the FEEPS sensors are the primary energetic electrons sensors, electrons are only measured on certain EIS units at any given time; which units are used for electrons was switched approximately every 14 orbits (~14 days) during MMS Phases 1, and was changed to every 3 orbits (~15 days) before the beginning of Phase 2b. Prior to the EIS1 HV anomaly detailed in item c), electrons were measured either on EIS1/3 or EIS 2/4. The units that are not generating electron data are instead generating what is called "event" data for diagnosing instrument performance.

  i. After the EIS1 high-resolution electron mode was enabled, the swapping was disabled for EIS1, but remains in effect for EIS2-4.
  ii. Beginning on 15 March 2017, this swapping was changed to every 5 orbits (~15 days). Burst electron data is obtained only from EIS1 and only following the reconfiguration of EIS1 into a high-resolution electron sensor.
  iii. EIS electron data collection beyond 6 RE was discontinued for MMS2-4 on 14 November 2017; electron data ceased on MMS1 with the re-enabling of the HV on 31 January 2018 (see item c.ii above).
  iv. EIS electron data was re-enabled on MMS4 *only* on 5 December 2019 with new energy channels covering from ∼300 keV to >1.8 MeV

g) **Cosmic ray background in electron data**: Penetrating cosmic rays generate a low-level band of contamination in the electron spectra (at about 1 count/s) centered between 150-200 keV. This contamination has not been subtracted from the foreground.

h) **Helium charge-state**: Despite being labeled as "alpha" in the ExTOF files, the charge state of the helium (and oxygen) ions is unmeasured.
  i. New vX.Y.100+ files of L2 EIS data, produced and made publicly available in Summer 2021 changed the names of these "alpha" variables to "helium" to more accurately represent their content. *These corrections were not applied to L1a/b data files and older data files that include the original "alpha" variable names should not be used.*

i) **PHxTOF species determination**: While in principle the low energy PHxTOF data products are able to discriminate between proton and oxygen, this discrimination works only when the heavy and light ion intensities are similar. Given the reality of the relative intensities, there is no automated procedure that can cleanly separate the light and heavy ion intensities for the PHxTOF lower energies, and the PHxTOF oxygen measurements are deemed unreliable and should be used with great caution. As such, several PHxTOF oxygen channels were reallocated to allow for better proton energy resolution beginning on 26 September 2016.

j) **Solar proton contamination in electron measurements**: Because of the technique used by EIS to measure electrons, a simple SSD with 2 μm of aluminum flashing on top, there will be periods of time (for solar proton events in particular) when the electron measurements are contaminated with >250 keV protons.

k) **Cross-calibration efforts:** During the first half of 2017, a considerable effort went into cross calibrating the EIS, FPI, HPCA, and FEEPS-ion sensors in their overlap regions. Based on this effort, the calibration matrices for EIS were substantially modified. As of this writing the new calibration matrices have been applied to all data following 1 November 2016. It is our intention to apply the calibration matrices on earlier data over time. The major change is in the efficiencies of protons at energies less than 50 keV, yielding intensities near 30 keV that are a factor of 5 higher than originally estimated. See §5.1 for more details.
  i. The results of these cross-calibration efforts were implemented in the reprocessing of the complete L2 EIS dataset (new vX.Y.100+ files) that were made publicly-available in Summer 2021. *These corrections were not applied to L1a/b data files.*

l) **Flat-fielding:** An initial flat-fielding attempt has been made to adjust the EIS intensities. This initial attempt is known to be imperfect and is expected to be improved over time.

m) **Efficiency effects on flux determinations**: The efficiency of ion detection for making ExTOF and PHxTOF ion measurements evolves over time because of variations of the gain of the microchannel plate in each of the EIS units. To-date a nominal efficiency multiplier is utilized with the Level 2 data, but slow evolutions of those efficiencies have not been folded into the data processing. The multiplicative error is up to about ±30%.

n) **EIS file versioning**: The full reprocessing of the L2 EIS dataset in Summer 2021 (new vX.Y.100+ files) updated the file versioning reported in Exhibit 18.

0.2 FEEPS data warnings and caveats

FEEPS points of contact:

- Joe Fennell, *The Aerospace Corp.* (Joseph.F.Fennell@aero.org)
- Christine Gabrielse, *The Aerospace Corp.* (Christine.Gabrielse@aero.org)
- Drew Turner, *APL* (Drew.Turner@jhuapl.edu)

a) **Sunlight contamination in survey data:** Many of the FEEPS eyes suffer from light contamination, likely due to direct sunlight and glint coming through foils that were damaged during launch. This light contamination is identifiable using spin sector spectra and correctable in burst mode data, but prior to the CIDP changes implemented in October 2016, this contamination has an uncorrectable effect on all survey data products for some of the FEEPS eyes. Since the survey data products are produced using burst resolution data onboard each spacecraft for some eyes, the sunlight-contaminated sectors are unfortunately being combined with good sectors to produce the lower resolution survey sectors. This and other issues have been corrected via a series of CIDP updates implemented between October 2016 and August 2017; however, the fix is not perfect; some sunlight contamination still manages to make its way into the data product and should always be considered first when spin tones are clear in the data products. For all data before and after these changes, please be aware of this contamination source and account for it in your studies. With burst data, please ensure that the affected eyes/sectors have been removed for analysis, and with survey data, be aware of the presence of this contamination in the data and proceed with caution for any scientific studies with that portion of the dataset. Badly affected telescopes can also be removed from studies using survey data. More details, including examples of the sunlight contamination and examples of maps of the affected eyes and sectors from each spacecraft (NOTE: they change over time!) are provided in §6.1.1. The FEEPS team is in the process of implementing a quality flag to be provided in Level 2 data to aid in the cautious use of survey data products. The MMS-specific IDL-based SPEDAS routines for FEEPS have been implemented with a hardwired filtering for eliminating the bad eyes and sectors.

b) **Sunlight contamination in burst data:** For data between October 2016 and August 2017, some burst data were also adversely affected; please refer to §6.1.1 and contact members of the EPD team for guidance on any data analyses using data during this period.

c) **Spin tone:** Despite flat fielding efforts (see §6.1.4), the spin tone is still often visible in FEEPS electron data binned by pitch angle or gyro-phase. This is because the flat fielding changing the energy channel bounds for each FEEPS eye and sunlight contamination removes sectors from some telescopes in each spin. Basically, different telescopes are measuring slightly different energies, which can have a noticeable effect when combined with exponentially decaying energy spectra, and/or max/min in the spin distribution might be missed if they fall in a contaminated sector. In a future version of the Level 2 data product, the data will be interpolated onto a common energy grid, which should mostly remove the spin-tone due to flat fielding.

d) **FEEPS unit timing:** Prior to the October 2016 Central Instrument Data Processor (CIDP) changes, the FEEPS top and bottom units used independent times for the initial (i.e., 0^{th}) sector of each spin. This misalignment is being accounted for in the data products, and the onboard correction was implemented on each spacecraft with the CIDP changes in October 2016. The CIDP changes will ensure that both top and bottom instruments trigger simultaneously on the sun-pulse signal on each spacecraft and that no alignment on the ground will be necessary. Prior to this date, the science data will show NAN for any sectors that were affected by the misalignment. This effect is mostly superficial but is documented here for completeness.

e) **Energy thresholds for lowest energy channels:** The first energy channels (i.e., lowest energy channel, with index 0) from FEEPS ion and electron instruments have their threshold set very near to or within the noise threshold (see §6.1.3). These channels from most (but not all) eyes are often measuring noise and should not be used for scientific data analysis. When included in the omni-directional product, these eyes result in a large spike at the lowest energy channel(s). On several of the FEEPS eyes, the second energy channels also require threshold adjustment as of 04 April 2016. The effect of this is clear when comparing energy spectra from independent eyes during periods with high count rates and isotropic angular distributions. The affected eyes/energy-channels will show large (factor of 5 or more) drops or enhancements in the count rates compared to the other eyes. An example of this is shown in Exhibit 27. The affected channels should **not** be included for any scientific analysis. Exhibit 30 indicates which eyes are affected by this caveat, though this is also time-sensitive in some cases.

f) **Integral channels:** The last energy channels (i.e., highest energy channel, with index 15) for FEEPS ion and electron instruments are effectively integral channels, combining counts from all energies greater than those in index 14. Thus, these data are an independent and different dataset from the other channels and should not be included in combined spectra or energy distributions with the other channels.

g) **SEP contamination in electrons:** Electron measurement contamination by high energy protons: based on the solar energetic particle (SEP) events that have occurred throughout the course of the mission to date (as of 04 April 2016), the electron measurements seem to be relatively unaffected by SEPs, however some response is expected, so please proceed with caution using the data during SEP events.

h) **Ion contamination:** Ion measurement contamination by electrons: due to the ultra-thin (i.e., <15 μm) detectors used in the FEEPS ion eyes, the ion measurements are largely unaffected by energetic electron contamination.

i) **Radiation belts**: As of 04 April 2016, the FEEPS responses in Earth's radiation belts have not been thoroughly analyzed. It is expected that radiation belt particles introduce some level of contamination to the FEEPS instruments. This contamination will be characterized and quantified with data from Phase 1x of the mission, in which MMS has many good conjunctions with the Van Allen Probes spacecraft. Until this response is properly characterized and accounted for in the data, proceed with caution when using FEEPS data in Earth's radiation belts (i.e., inside of ~7 R_E). As of 3 April 2020, the FEEPS data agree well with Van Allen Probes in Earth's outer radiation belt, however, some contamination of the electron data may be present due to enhanced background levels during times of very hard radiation belt spectra (i.e., high intensities of >1 MeV electrons). Caution should still be taken when using these data in the radiation belts, but they do provide a reasonably accurate measure of outer radiation belt electrons.

j) **X-ray response**: Based on tests conducted during solar X-ray flares on 04 and 09 November 2015, the FEEPS ion and electron instruments have no significant response to solar X-rays.

k) **Cross-calibration efforts:** Preliminary cross-calibration has been conducted between FEEPS with EIS and FPI (see §6.1.5). Those results show good agreement between the instruments, however no formal cross-calibration factors have been applied to the dataset, so use caution when combining these data products. Combined distributions are expected to be officially produced as a Level 3 data product.

l) **Data quality flags:** Data quality flags are not yet available in Level 2 data products, but are expected to be introduced in the future.

m) **Cosmic ray background in electron data**: Penetrating cosmic rays generate a low-level band of contamination in the electron spectra (at about 1 count/s) centered on about ~300-350 keV. *This contamination has not been subtracted from the foreground.*

1 EPD Instrumentation Description

The science objectives and an overview of the Energetic Particle Detector (EPD) investigation are provided in *Mauk et al.* (2016). EPD comprises two different instrument types: the Energetic Ion Spectrometer (EIS; with a detailed description provided by *Mauk et al.*, 2016) and the Fly's Eye Energetic Particle Spectrometer [FEEPS; with detailed descriptions provided by *Blake et al.,* 2016]. Summary and supplementary information is provided here. Schematics of the two sensor types, along with the EPD Team members, are shown in Exhibit 1.

The Energetic Particle Detector suite of sensors supports the study of the fundamental physics of magnetic reconnection by:

1. Remotely sensing the positions and speeds of boundaries and other structures near reconnection sites using energetic ions.
2. Sensing the magnetic topology of near reconnection sites using energetic electrons.
3. Remotely sensing reconnection acceleration sites using both electrons and ions.
4. Determining the cause of energization of energetic electrons and ions by reconnection.

The flow down from those science goals to the EPD measurement and performance requirements is shown in Exhibit 2. The allocations of those requirements for the two EPD sensors (EIS and FEEPS) as derived from Exhibit 1, and the connection to the Program Level (Level-1) requirements, are shown in Exhibit 3.

1.1 Suite Overview

The Energetic Particle Detector (EPD) investigation suite includes an Energetic Ion Spectrometer (EIS) and an all-sky particle sampler called the Fly's Eye Energetic Particle Sensor (FEEPS). These instruments (Exhibit 4) measure: 1) the energy-angle distribution and composition of ions (20-500 keV, with a goal of 10-1000 keV) at a time resolution of <30 seconds, 2) the energy-angle distribution of total ions (45-500 keV, with a goal of 40-1000 keV) at a time resolution of <10 seconds, and 3) the coarse and fine energy-angle distribution of energetic electrons (25-500 keV, with a goal of 20-1000 keV) at time resolutions of <0.5 and <10 seconds, respectively.

There are two FEEPS instruments and one EIS instrument on each spacecraft to yield an instantaneous all-sky view for electrons and fast all-sky sampling for ions. This set of sensors (two FEEPS instruments plus one EIS instrument) is identical on all four of the MMS spacecraft. Exhibit 4 shows where the sensors reside on each spacecraft and Exhibit 5 shows how those sensors are configured to give the maximum sky coverage. FEEPS provides an instantaneous all-sky view of the electrons (with course angular resolution), and then turns course into more refined angular resolution by means of rotation. The two FEEPS ion "fans", in conjunction with the one EIS ion fan, provides all-sky total-ion coverage every ⅓ of a spin.

1.2 EIS Overview and Viewing

Each EIS instrument contains a microchannel plate (MCP) detector that, with the help of thin foils from which secondary electrons are generated, measure particle time-of-flight (TOF) and pulse height (PH); and six solid-state detectors (SSDs) that measure particle energy (E). The MCP has

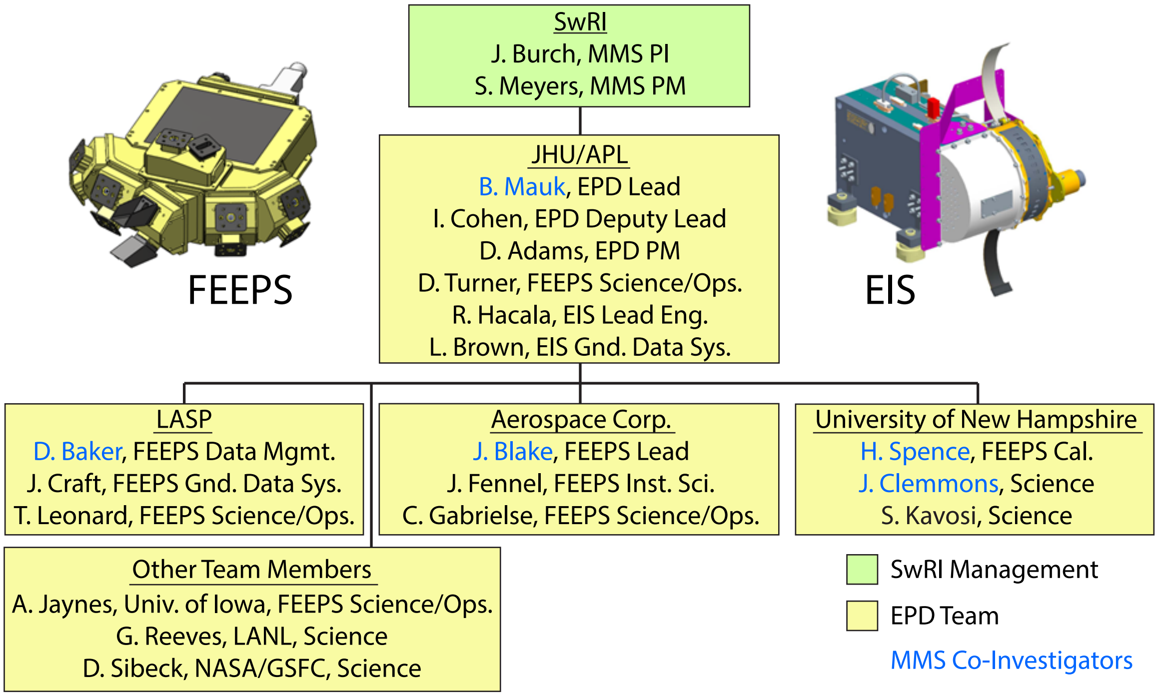


Exhibit 1. *(updated from* Mauk et al. *[2016]) The EPD Investigation is led by APL, home of the EIS Instrument Team. The FEEPS Instrument Team comprises members at APL, The Aerospace Corporation, LASP, and UNH. Additional EPD team members are located at Iowa, LANL, and NASA/GSFC.*

Science Requirements	1) Remotely Sense the positions and speeds of boundaries and other structures. 2) Sense magnetic topology with energetic electrons. 3) Remotely sense reconnection acceleration sites. 4) Determine causes of energization of energetic electrons and ions by reconnection.
Measurement Requirements	Electron and Ion Intensities versus energy, angle, and composition such that: • Energies >> electric potentials to sense magnetic geometry free of electrostatics. • Electron all-sky views in time for 100 km/s motion over 1 electron gyro-radii. • Total ion all-sky view in time for 100 km/s motion over 0.5 proton gyro-radii. • Multiple ion / electron energies and resolution for energy/time dispersion analysis. • Ion composition to quantify distances, scale sizes and acceleration processes. • Sufficient sensitivity for 25 RE ions and electrons at needed time scales.
Performance Requirements	1) Electron energies: 25 keV – 500 keV for remote sensing. Ion energies: 20 keV – 500 keV for probing boundaries and particle acceleration. 2) Electron sampling time for coarse and full electron distribution: 0.5 s and 10 s. 3) Total-Ion / Composition-Ion complete angle sampling time: 10s / 30 s. 4) Ion and electron energy resolution: $\Delta E/E < 50\%$. 5) Electron angular resolutions: < 60 degrees for remote sensing, < 30 degrees for probing particle acceleration. 6) Ion angular resolution: < 45 degrees probing boundaries and particle acceleration. 7) Ion composition requirements: distinguish H and O. 8) Electron / ion geometric factors ($cm^2 sr$ per pixel): $G_I > 0.003$; $G_e > 0.02$.

Exhibit 2. *(from* Mauk et al. *[2016]) Summary of the EPD requirements.*

Level-1 Drivers	FEEPS (1 – 7)	Required	Goal (Capability)
STP-MMS-M70 STP-MMS-I90	1. Energy range:	Elec.:25–500 keV Ions:45–500 keV	Elec.:20–1000 keV Ions:40–1000 keV
	2. Energy resolution:	Elec.:50% Ions: 50% at > 100 keV	Elec.:35% Ions: 35% at > 100 keV
STP-MMS-M70	3. Time elect. fine/course angle coverage	10 sec/0.5 sec	4 sec/0.33 sec
STP-MMS-I90	4. Angle Coverage	3.2 π sr	4 π sr
	5. Electron (deconvolved) / Ion Angle Res.	30 deg / 60 deg	25 deg / 60 deg
	6. Sensitivity electron (Pixel / Total) cm^2.sr	0.02 / 0.36	0.04 / 0.72
	7. Sensitivity Ions (Pixel / Total) cm^2.sr:	0.003/0.02	0.01 / 0.06
	EIS (1-7)	Required	Goal (Capability)
STP-MMS-M80 STP-MMS-I90	1. Energy (protons) :	20-500 keV	10-1000 keV
	2. Energy resolution:	50% at < 100 keV	35 % at < 100 keV
STP-MMS-M80 STP-MMS-I90	3. Time: all sky coverage.	30 sec	20 sec
STP-MMS-I90	4. Angle coverage:	3.2 π sr.	3.2 π sr.
	5. Angular resolution	< 45 deg.	< 30 deg.
STP-MMS-M80	6. Composition	H and O	H, He, and O
	7. Sensitivity Ions (Pixel/Total) cm^2.sr	0.003/0.02	0.01 / 0.06
	EPD-1 (EIS + FEEPS)	Required	Goal (Capability)
STP-MMS-M70 STP-MMS-I90	1. Time: Total ion angle coverage	10 sec	7 sec

Exhibit 3. *(from* Mauk et al. *[2016]) Traceability of the EPD requirements and performance to mission Level-1 drivers.*

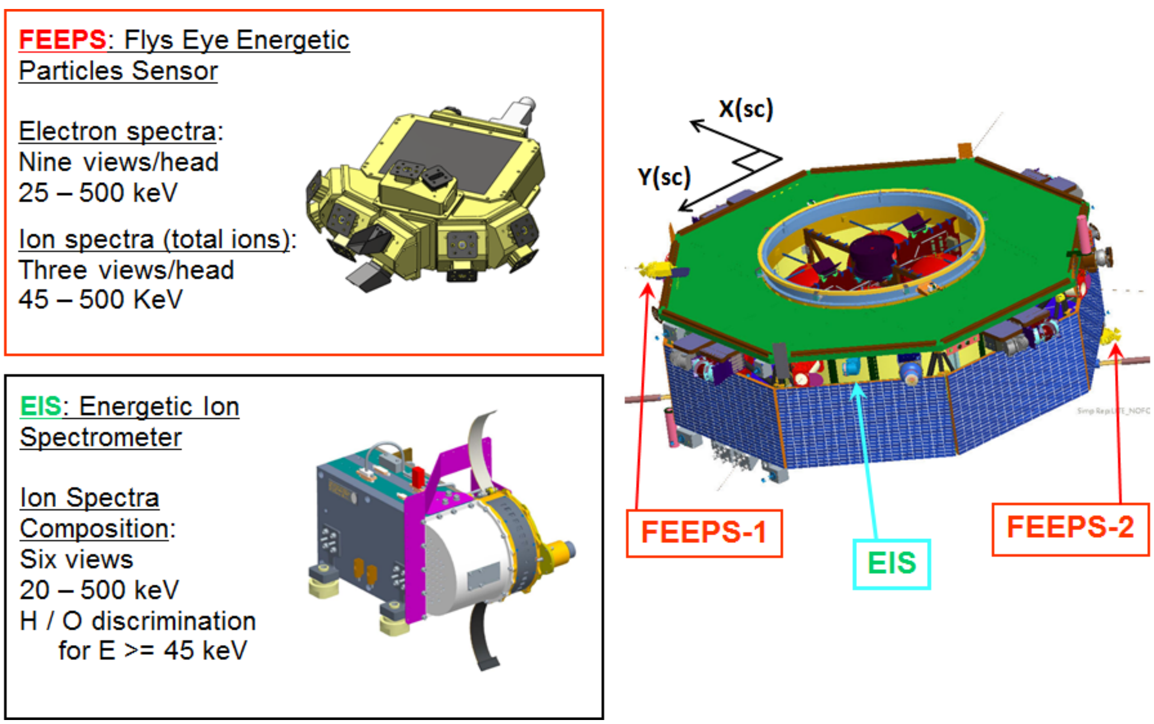


Exhibit 4. *(from* Mauk et al. *[2016]) Summary of the capabilities and spacecraft mounting of the EPD instruments: EIS and FEEPS. Note that the energy ranges of measurements have varied somewhat over the course of the mission.*

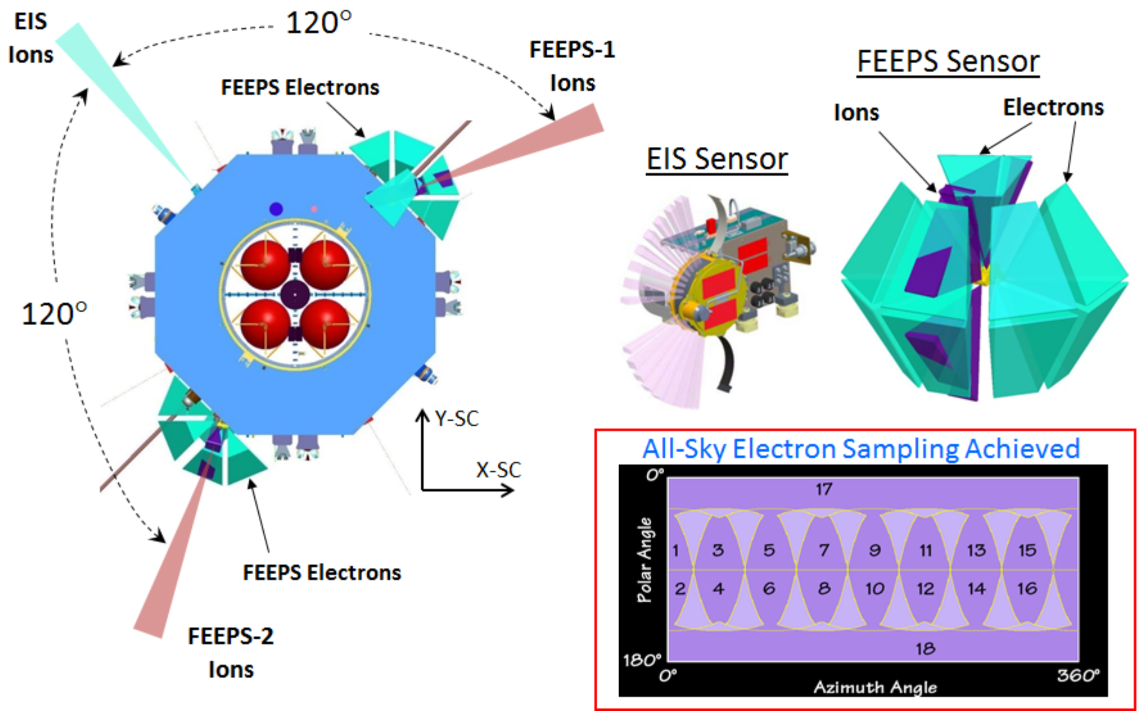


Exhibit 5. *(from* Mauk et al. *[2016]) The EPD fields-of-view are configured to provide maximum sky coverage of energetic particles. The two FEEPS sensor provide nearly simultaneous full-sky electron coverage, whereas the two FEEPS sensors complement the EIS fan-shaped FOV to provide ion coverage in approximately ⅓ of a spin.*

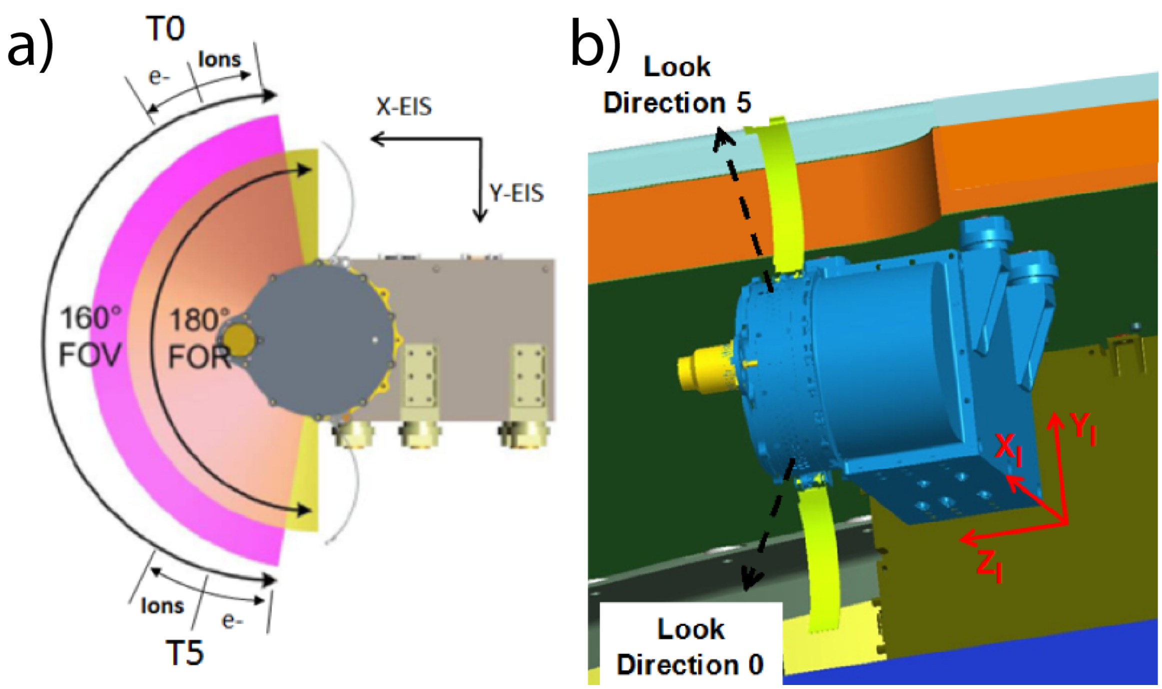


Exhibit 6. *(from* Mauk et al. *[2016]) a) The 160° fan-shaped EIS FOV is separated into 6 independent telescopes, defined by individual SSDs with electron and ion detectors. b) The EIS instruments are mounted on the MMS spacecraft such that T0 and T5 are oriented downward and upward, respectively.*

	TOF x PH				TOF x E and Ions				Electrons			
	Degrees	Unit-X	Unit- Y	Unit-Z	Degrees	Unit-X	Unit- Y	Unit-Z	Degrees	Unit-X	Unit- Y	Unit-Z
T0	72.18	0.306	-0.952	0.000	72.18	0.306	-0.952	0.000	61.12	0.483	-0.876	0.000
T1	45.56	0.700	-0.714	0.000	45.56	0.700	-0.714	0.000	34.5	0.824	-0.566	0.000
T2	20	0.940	-0.342	0.000	20	0.940	-0.342	0.000	9	0.988	-0.156	0.000
T3	-9	0.988	0.156	0.000	-9	0.988	0.156	0.000	-20	0.940	0.342	0.000
T4	-34.5	0.824	0.566	0.000	-34.5	0.824	0.566	0.000	-45.56	0.700	0.714	0.000
T5	-61.12	0.483	0.876	0.000	-61.12	0.483	0.876	0.000	-72.18	0.306	0.952	0.000

Exhibit 7. *(from* Mauk et al. *[2016]) The unit vectors of the look directions of the EIS telescopes. Care should be exercised when considering the telescopes highlighted in the differently-shaded rows as these look directions are substantially blocked (see §0.1a).*

start and stop anodes. Measuring the time difference between start and stop determines the particle's TOF. The anodes are divided into six angular segments; these provide a measure of the particle's direction of travel. EIS measures ion energy, directional, and compositional distributions using "Energy by Time-of-Flight" (ExTOF) for the higher energy ions and "MCP-Pulse-Height by Time-of-Flight" (PHxTOF) for the lower energy ions. EIS also measures electron energy and directional distributions using collimated SSD energy measurements (these electron SSDs, as opposed to the ion SSDs, have 2 μm of aluminum flashing deposited on them to keep out protons with energies less than about 250 keV). EIS combines multi-directional viewing into a single compact sensor head (Exhibit 6).

The EIS coordinate system and defined viewing directions are shown in Exhibit 6a-b, respectively. There are six view directions (telescopes) per data product (T0, T1, …, T5), but only T0 and T5 are shown on the figure, along with (Exhibit 6a) the ordering of the electron (e^-) and ion SSD pixels within those fields of view (Note that the PHxTOF pixels encompass the entire telescope (sector), not just what is designated as "ions" on the figure. However, the response of those six PHxTOF views are centered on the ion SSD's.

The quantitative centroids of the view directions for all six look directions, within the EIS coordinate system, for each of the EIS data products, are shown in Exhibit 7. The central direction of the center of each PHxTOF, ExTOF, Ion-SSD (the same as ExTOF), and Electron-SSD pixel is given as the angle from the *X*-axis within the *XY*-plane, with positive angles towards the –*Y*-axis (also toward the direction that has been designated the "T0" direction; we realize that it is unusual to have positive angles towards the –*Y*-axis rather than the +*Y*-axis). To the right of each angle in Exhibit 7 is the unit vector of the view direction in the instrument coordinate system. Views T2 for electrons and T3 for ions have substantial obstruction from the shielding needed to keep the sun out (see Figure 10 in *Mauk et al.* [2016]). The off-color rows are the views that are substantially obstructed. Nonetheless these views corrected to the best of our ability and are represented in our data products. Care should be exercised for these particular views.

The transformation matrix that transforms a vector (e.g., a unit view direction such as those provided in Exhibit 7) into the MMS Spacecraft Frame (Exhibits 5-6) is provided here. $\mathrm{v}_{sc} = \mathrm{T}_{EIS} \cdot \mathrm{v}_{EIS}$, where v_{EIS} is the vector in the EIS frame of reference, T_{EIS} is the 3 x 3 transformation matrix, and v_{sc} is the vector in the spacecraft frame. For this expression:

$$T_{EIS} = \begin{pmatrix} \frac{-1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \\ 0 & 1 & 0 \end{pmatrix}$$

***NOTE**: The version of this transformation matrix reported in* Mauk et al. *(2016) is incorrect and this one should be used instead.*

1.3 FEEPS Overview and Viewing

Each of the two FEEPS instruments on each spacecraft comprises 12 individual fields of view; 9 electron views (Exhibit 8a) and 3 ion views (Exhibit 8b). Eight of the electron views are clustered into four "heads" comprising two "eyes" each (Exhibit 8c). Each electron eye comprises a shaped pinhole, a 1.8-μm aluminum foil that keeps out protons with energy >200 keV (not shown in Exhibit 8c), and a shaped, 1-mm SSD to measure the energy of the incoming electron. The shapes of the pinhole and of the SSD work together to yield a trapezoidal shape for the field of view of each eye (Exhibit 8a).

Two of the ion sensors (i.e., "eyes") on each FEEPS instrument are combined into a single "head" (Exhibit 8d). Each ion eye comprises a slot shaped pin hole followed by a rectangular shaped, nominally 9-μm thick, SSD to measure the ions. The response of these detectors to electrons is minimized by the thinness of the SSD's; electrons tend to pass right through leaving a signal below the detection threshold, and ions are stopped, leaving above-threshold energies. There will be residual electron contamination in the ion responses that needs to be managed. The two "equatorial" ion sensors each have a sun shade (Exhibit 8d) to keep the sun from

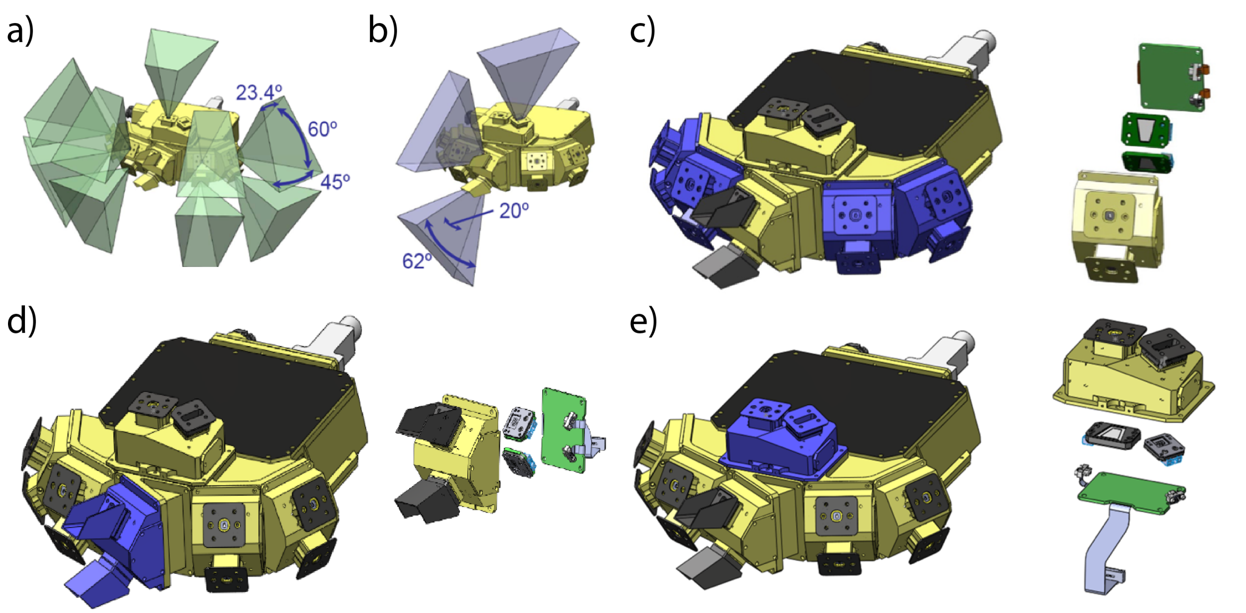


Exhibit 8. *(from* Blake et al. *[2016]) The FOVs of the FEEPS (a) electron and (b) ion sensors, or "eyes". Highlighted in blue, and shown in expanded view, are (c) electron heads, (d) the sun-shaded "equatorial" ion sensors, and (e) the "Electron-Ion Head". Recall that there are two FEEPS sensor-heads on each MMS spacecraft (the model for only one sensor-head is shown here).*

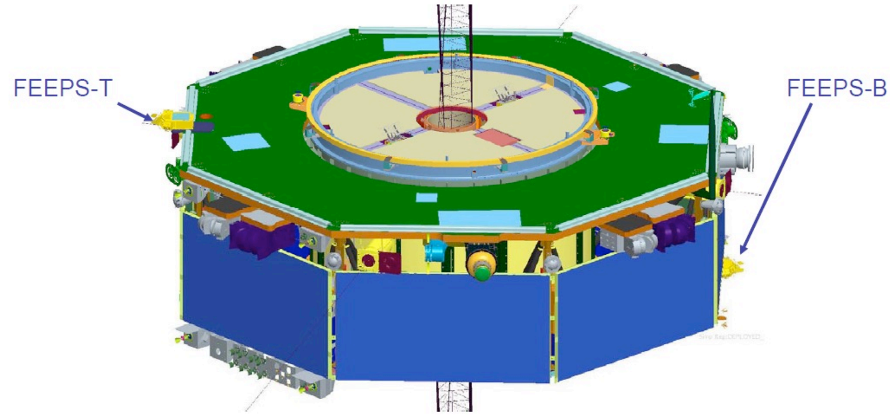
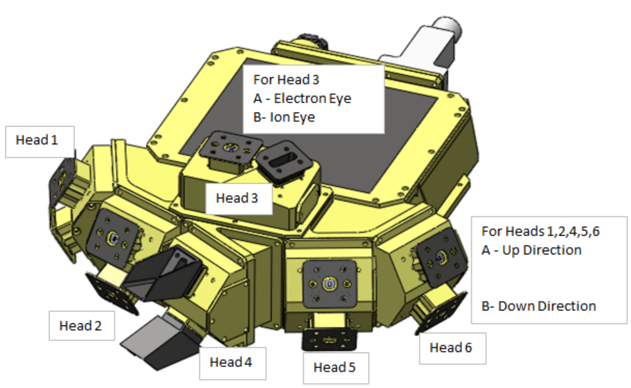


Exhibit 9. *(from* Blake et al. *[2016]) Two FEEPS sensors, a top (-T) and bottom (-B), are mounted on each spacecraft.*

illuminating the entrance slot (the ion sensors are very sensitive to the sun, whereas the electron sensors should not be because of the thin foils placed over the telescope apertures). The slot shape of the pinhole and the rectangular shape of the SSD yields a fan-like field of view (Exhibit 8a-b) of about 20° x 60°.

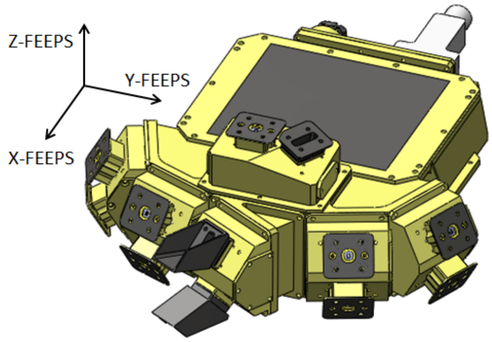
A final set of electron and ion views is held by a 3rd type of head, the Electron-Ion Head (Exhibit 8e). This head contains 1 electron eye and 1 ion eye. Ideally, the field-of-view of the third ion head should be carefully aligned with the views of the other two ion heads to effectively yield a broad, 280° fan-shaped field of view. However, to keep the third ion sensor from viewing the axial electric field sensors, the third view had to be tilted somewhat away from the ideal configuration (Exhibit 8b).

In order to get a true "all-sky" view from FEEPS, it was necessary to mount just one of the instruments on the instrument deck and the other onto the spacecraft subsystem deck (Exhibit 9). The two instruments are identical to each other, and they are designed such that when one of them is turned upside down with respect to the other around the correct axis, the fields of view of one of the instruments exactly fills in the missing portions of the other (Exhibit 5).



Head	Look Direction	Type	TM ID #
Head 1			
DAPPER E			
A	Up	Electron	1
B	Down	Electron	2
Head 2			
DAPPER E			
A	Up	Electron	3
B	Down	Electron	4
Head 3			
DAPPER EI			
A	Top	Electron	5
B	Top	Ion	6
Head 4			
DAPPER I			
A	Up	Ion	7
B	Down	Ion	8
Head 5			
DAPPER E			
A	Up	Electron	9
B	Down	Electron	10
Head 6			
DAPPER E			
A	Up	Electron	11
B	Down	Electron	12

Exhibit 10. *(from* Blake et al. *[2016]) Mapping of the individual FEEPS sensors (or "eyes") to their respective heads and identification numbers. Note that the DAPPER is the front-end electronics board for FEEPS*



ID#	Head	Orientation	Species	Azimuth	Elevation	Weighted Elevation	Unit-X	Unit- Y	Unit-Z
1	1	Up	Electons	-67.5	30	25	0.347	-0.837	0.423
2	1	Down	Electons	-67.5	-30	-25	0.347	-0.837	-0.423
3	2	Up	Electons	-22.5	30	25	0.837	-0.347	0.423
4	2	Down	Electons	-22.5	-30	-25	0.837	-0.347	-0.423
5	3	Top	Electons	0	90	95	-0.087	0.000	0.996
6	3	Top	Ions	60	78	78	0.104	0.180	0.978
7	4	Up	Ions	-30	41	41	0.654	-0.377	0.656
8	4	Down	Ions	-30	-41	-41	0.654	-0.377	-0.656
9	5	Up	Electrons	22.5	30	25	0.837	0.347	0.423
10	5	Down	Electrons	22.5	-30	-25	0.837	0.347	-0.423
11	6	Up	Electrons	67.5	30	25	0.347	0.837	0.423
12	6	Down	Electrons	67.5	-30	-25	0.347	0.837	-0.423

Exhibit 11. *(from* Blake et al. *[2016]) The look direction unit vector (v) of each FEEPS eye in FCS.*

Also, the orientation of the ion sensors is such that the resulting two fan-shaped fields of view are configured to provide 2 out of 3 of the fans spaced 120° apart, with EIS providing the 3rd fan (Exhibit 4).

Exhibit 10 shows the labeling for the 12 different fields of view on each FEEPS instrument, 9 electron views and 3 ion views. Note that all 12 of these views are used for generating burst data, however only a subset is used in the generation of survey data. For survey data, all of the ion views are used, but only the electron views with ID's 3, 4, 5, 11, and 12 used (see the ID's in Exhibit 10). Because of some light contamination within some of the eyes, the FEEPS eyes that are used for the survey data have been made configurable via the Central Instrument Data Processor (CIDP) [*Raphael et al.*, 2014] as of August 2017. Prior to that date, the survey eyes were a fixed set common to each spacecraft and FEEPS unit. The FEEPS coordinate system is shown in Exhibit 11 shows a FEEPS sensor along with the unit vectors for each of the 12 eyes in the FEEPS coordinate system. The "elevation" angle is the angle made by unit vectors out of the *XY*-plane in the FEEPS coordinate system depicted in Exhibit 11. The "weighted elevation" accounts for the non-symmetric shape of the electron fields of view (centered on the centroid of the solid angle viewed). Note that the transformation of vectors (v) from the FEEPS_1 (FEEPS-payload-deck or the "up" direction) or FEEPS-2 (FEEPS-bottom-deck) to the spacecraft coordinate system (BCS) is achieved using $\mathrm{v}_{FEEPS} = \mathrm{T1{,}2}_{FEEPS_{1,2}} \cdot \mathrm{v}_{FEEPS}$, where

$$\mathrm{T1}_{FEEPS_1} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad \text{and} \quad \mathrm{T2}_{FEEPS_2} = \begin{pmatrix} \frac{-1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \\ \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & -1 \end{pmatrix}.$$

These are just rotation matrices to convert the FEEPS telescope look direction vectors (v_{FEEPS}), from the FEEPS coordinate frame (FCS) to BCS. These vectors are defined looking out to space along the center line for each telescope's field-of-view and are the same for both the top and bottom units. v_{FEEPS} in FCS is given in Exhibit 11 for each sensor.

1.2 EPD Burst Triggers

All MMS instrument investigations generate "burst trigger flags" onboard the spacecraft to provide summary information that might indicate that reconnection activity or some other interesting activity is occurring in the vicinity of the spacecraft. The EPD data is different from other MMS instrument data in that there are no reliable or consensus simulations of the response of energetic particles to reconnection that can provide guidance as to as to what the EPD burst trigger flags will tell us about the activity in the vicinity of the spacecraft. The EPD burst triggers have not been, and likely will not be, utilized for finding reconnection sites and other interesting features within the MMS burst data. Thus, to-date the efficacy of the EPD burst triggers has not been evaluated and no further information is provided on them.

2 EPD Science Algorithms

The data that comes down from both EIS and FEEPS is mostly in the form of counts per accumulation period (i.e., spin sector) per channel. A "channel" is a small portion of measurement parameter space, where the parameters correspond to "look direction" (in 2 dimensions), "species" (e.g., electrons or ions; and sometimes for the ion portion: protons, helium ions, and oxygen ions), and "energy". For FEEPS electrons for the Burst data products and for each accumulation period, there are 18 instantaneous look directions per spacecraft (9 per instrument) and 4 linearly and 11 logarithmically space energy channels (channels 0-3 are linearly spaced) for each look direction. For FEEPS electron survey products (fast and slow), only 10 of the 18 electron look directions are used (§1.3.2). For FEEPS ions for both burst and survey data products and for each accumulation period, there are 6 look directions per spacecraft (3 per instrument) and, again, 4 linearly and 11 logarithmically energy channels (channels 0-3 are linearly spaced). For EIS, there are 6 look directions for each of the standard data products for both burst and survey (ExTOF ions, PHxTOF ions, and electrons). At burst resolution, there are up to 73 channels for various combinations of ExTOF species and energy for each look direction, and up to 33 channels for each look direction for various PHxTOF combinations of species and energy. For electrons, there are up to 24 energy channels for each look direction. Thus, with 96 FEEPS telescopes each with 16 energy channels and 64 raw spin sectors, there are 98,304 channels that represent the measurements that are made by FEEPS sorted by look direction, energy, and species. There are many more considering the EIS product as well.

As of 13 March 2017, the FEEPS slow survey product is operating at the same cadence (1/8th of a spin) as the fast survey product. Prior to that, the slow survey product was produced once every 10 spins. As of the CIDP changes made in March 2017, the slow survey cadence is now a configurable parameter.

The prime challenge for ground processing is to turn each of these channels from a "counts per accumulation" (*C/A*) to intensity [1/(cm^2-s-sr-keV)] for the particular parameter state represented by the channel. The algorithm for doing so is documented here.

1) Because an SSD response (output rate for a given channel) tends to be roughly linear when rates are low, but non-linear when rates are high, for high rates one must be prepared to perform a "dead-time correction" to reconstruct the true input rates. That

correction is performed using a "live-time (*LT*) counter" (for FEEPS) or a "dead-time counter" (for EIS). Depending on how this number is generated, there is a conversion procedure to convert it into a "fractional live-time" (e.g., *FLT* = accumulation time / *LT*). For EIS there are other factors that go into the dead-time correction (e. g., processor speed) and the full algorithm is documented elsewhere.

2) Convert *C/A* to *counts per second* ($C/S \equiv R$) using:

$$R = \frac{C/A}{TA \times FLT},$$

where TA is the channel accumulation period and FLT is the aforementioned live-time correction.

3) If judged to be needed, subtract off a background, general caused by cosmic rays:

$$RC = R - CR\_BG.$$

To-date, this correction remains unapplied in EPD data. This background is apparent in instances of low counting statistics (see §0.1f and §0.2n). Note that CR_BG is energy-dependent with a peak corresponding to a minimum ionizing energy near 300 keV for FEEPS and 160 keV for EIS (with its thinner detectors).

4) Convert *R* to *Intensity* (*I*) as such:

$$I = \frac{R}{(E_2 - E_1) \times eG},$$

where *eG* is the efficiency (*e*) times the geometric factor (*G*) and E_1 and E_2 are the lower and upper energy bounds of the channel, respectively. *Note that* eG*,* E_1*, and* E_2 *are "calibration factors" that are provided in the "Calibration Matrix" spreadsheet (see Appendix A) to the processing software. There is one complete set of numbers for each of the hundreds of channels. More about these factors is provided in §5.1*

5) When plotting the data or using it for calculations, the intensity if often identified with a central energy, often estimated as the geometric mean $\left(E_{\mathrm{gm}} = \sqrt{E_1 \times E_2}\right)$, an estimate that would be exact if the spectral index (*g*) were equal to 2 in the expression $I + C \times E^{-g}$, where *C* is a constant and *E* is energy.

The result of all of this processing can be notionally thought of as filling one or more spreadsheets with the column headings for each look direction like:

- Spacecraft
- Instrument
- Direction (θ,φ)
- Pitch Angle
- Species
- Energy (E_1, E_2, E_{gm})
- Counts per Accumulation (*C/A*)
- Counts per Second (*C/S*)
- Intensity (*I*)

The pitch angle (PA) is the angle of the look direction with respect to the magnetic field ($PA = \cos^{-1}[\vec{d} \times \vec{b}]$), where $\vec{d}$ is minus the unit view direction vector in spacecraft coordinates (i.e., the look direction in GSE coordinates) and $\vec{b}$ is the unit magnetic field vector in spacecraft coordinates (BCS). This angle is needed immediately because ordering the particle data by the magnetic field is central to understanding the data. More about look directions is provided in §4.2

The generation of low and high-level data products from this notional spreadsheet is all about organizing the data in different ways (e.g., choose one look direction – or average all look directions - and one species generate an energy spectrum, etc.).

3 EPD Data Processing

Exhibit 12 shows the plan for processing the EPD (FEEPS and EIS) data. Algorithms for generating Levels 1a and 1b data are generated by the EPD Team at LASP (FEEPS) and APL (EIS), and are transferred to the MMS SOC at LASP for execution. Level 2 data for FEEPS and EIS are generated by the EPD Team at LASP (with certification by Aerospace) and APL, respectively. The Level 2 products are then delivered to the MMS SOC. Exhibit 12 shows details of the processing, including highlighting the need for the availability of magnetic field data and ephemeris data at various stages of the production. Exhibit 13 shows additional details of the more complex FEEPS data production chain.

4 EPD Data Levels, Requirements, and Non-Science (<L2) Data

4.1 EPD Data Levels

This section will briefly define the four levels of EPD data currently in production and/or development (L1a-b, L2, L3), providing succinct overviews; formatting, variable names, and other details of the respective data products will be provided in later sections (e.g., §5-7).

Level 1a: These are instrument level data products (one set for each instrument; which means 2 sets for FEEPS and one set for EIS for each spacecraft). The data are organized closely in the same way that the data packets onboard the spacecraft are organized. The channel contents are in "counts per accumulation". No live-time or dead-time correction is applied to these counts. For each record, the spacecraft time must be recorded and a standard for whether that time is the beginning or the middle of an accumulation time. Also, for each record the "accumulation time" must be reported, unless a single accumulation time for a data product file suffices and is reported in a file header. For each SSD detector (12 for FEEPS and 12 out of the possible 24 for EIS) the "live-time" or "dead-time" must be recorded. For each channel, the "counts per accumulation" must be recorded. The following is a preliminary list of the key Level 1a data products for both **FEEPS (in black)** and **EIS (in green)**. Note that the "survey" data includes both Fast Survey and Slow Survey because these products have identical formats with the Fast Survey including every spin and the Slow Survey including only every 10^{th} spin. Note that during the commissioning phase in 2015 it was decided that the EIS Slow Survey would be identical to Fast Survey (one record per spin). In March 2017, the FEEPS Slow Survey was also made identical to the Fast Survey. The data products with the notation (*diagnostic*) at the end are data products used primarily by the instrument providers for better understanding the health and performance of the instrument and for cross comparisons between FEEPS and EIS (electron products from EIS, for example). They will not be generally provided to the scientific community (they are not

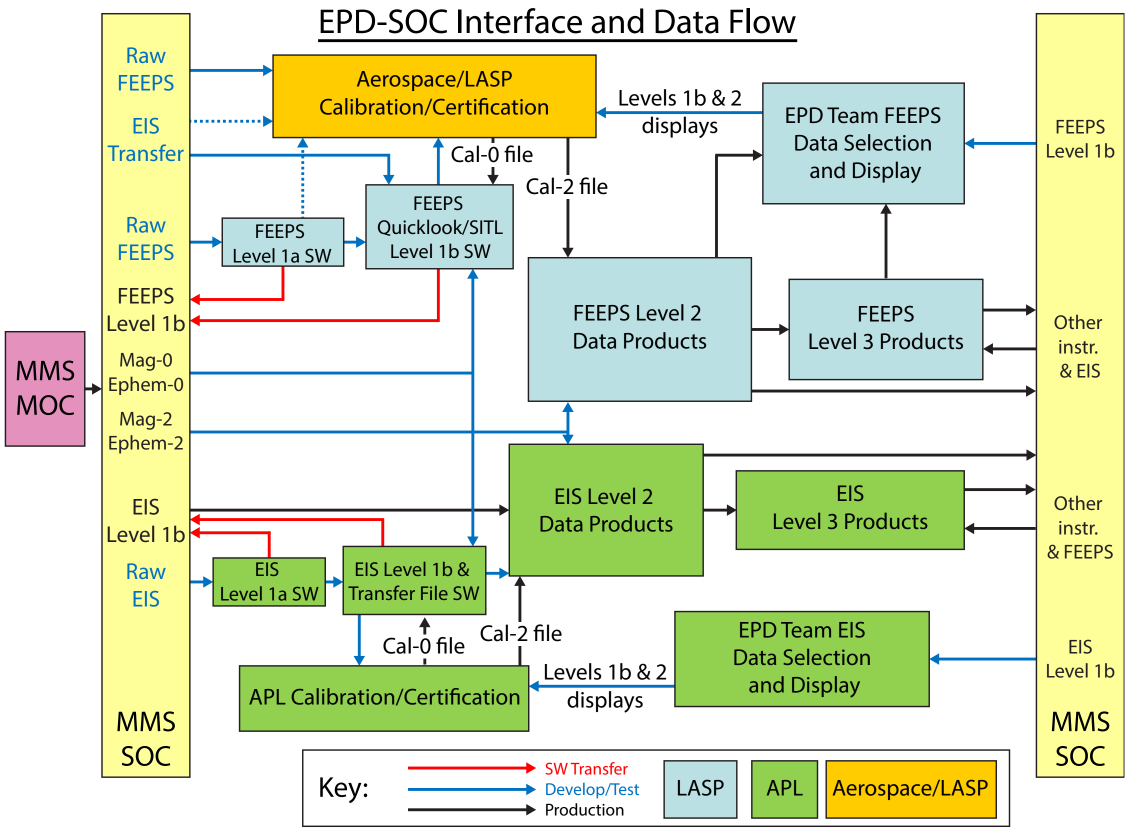


Exhibit 12. *Details of the EPD-SOC interface and data flow. Levels 1a and 1b data products are generated by the MMS SOC at LASP, while Level 2 and higher data products are generated by the EPD Team at LASP (FEEPS) and APL (EIS).*

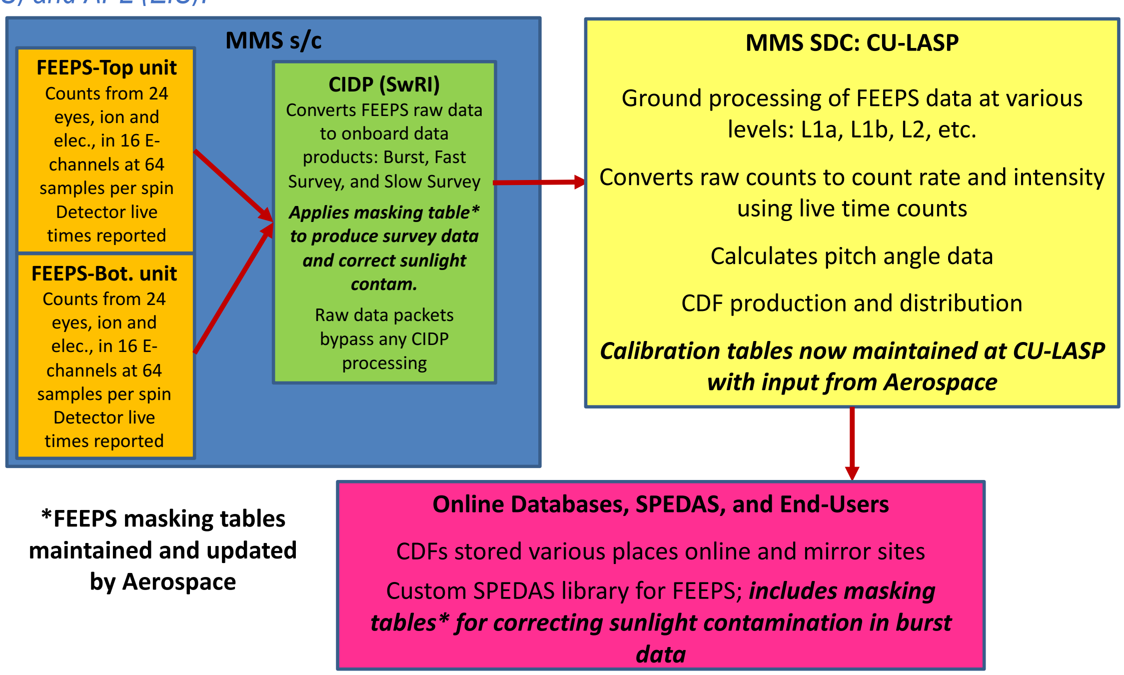


Exhibit 13. *Four institutions are involved in producing the final FEEPS dataset: SwRI (responsible for the CIDP units onboard each spacecraft), LASP (responsible for calibration tables and data processing), Aerospace (responsible for data calibration factors and updates), and APL (responsible for validation and management).*

secret; we just will not go to the effort to make them accessible). Below is a list of key Level 1a EPD data products for each spacecraft (note that "top" and "bottom" refer to the FEEPS units mounted at the top (payload) and bottom (spacecraft) mounting plates):

01. **L1a-bottom-FEEPS-Electron- Survey**
02. **L1a-bottom-FEEPS-Ion-Survey**
03. **L1a-bottom-FEEPS-HK-Status-Fast** (*diagnostic*; less complete than Slow)
04. **L1a-bottom-FEEPS-HK-Status-Slow** (*diagnostic*)
05. **L1a-bottom-FEEPS-Burst-Trigger** (*diagnostic*)
06. **L1a-EIS-PhxTOF-Ion-Burst**
07. **L1a-EIS-ExTOF-Ion-Burst**
08. **L1a-EIS-PhxTOF-Ion-Survey**
09. **L1a-EIS-ExTOF-Ion-Survey**
10. **L1a-EIS-HK-Status** (*diagnostic*)
11. **L1a-EIS-Ion-Energy-Burst** (*diagnostic*)
12. **L1a-EIS-Electron-Energy-Burst** (*diagnostic*)*
13. **L1a-EIS-Electron-Events** (*diagnostic*)
14. **L1a-EIS-Ion-Events** (*diagnostic*)
15. **L1a-EIS-Species-Events** (*diagnostic*)
16. **L1a-EIS-Ion-Energy-Survey** (*diagnostic*)
17. **L1a-EIS-Electron-Energy-Survey** (*diagnostic*)
18. **L1a-EIS-Electron-Basic-Rates-Survey** (*diagnostic*)
19. **L1a-EIS-Ion-Basic-Rates-Survey** (*diagnostic*)
20. **L1a-EIS-Ion-Diagnostic-Rates-Survey** (*diagnostic*)
21. **L1a-EIS-Species-Basic-Rates-Survey** (*diagnostic*)
22. **L1a-EIS-Species-Diagnostic-Rates-Survey** (*diagnostic*)
23. **L1a-EIS-Electron-Basic-Rates-Burst** (*diagnostic*)
24. **L1a-EIS-Ion-Basic-Rates-Burst** (*diagnostic*)
25. **L1a-EIS-Ion-Diagnostic-Rates-Burst** (*diagnostic*)
26. **L1a-EIS-Species-Basic-Rates-Burst** (*diagnostic*)
27. **L1a-EIS-Species-Diagnostic-Rates-Burst** (*diagnostic*)
28. **L1a-EIS-Burst** Trigger (*diagnostic*)

**EIS Electron Energy Burst became a standard data product for EIS1 in April 2016 (see §0.1e).*

1) **Level 1b**: These are observatory level data products; for each spacecraft, there would be one set from FEEPS (the two instruments combined) and one set from EIS. At the "Record" level there is time (UTC), a quality flag, (bad sector flag but no quality flag in FEEPS L1b) an accumulation time for each channel, a spin sector, perhaps a spin number, and magnetic field and ephemeris data (§4.2). At the detector or look direction level there is pitch angle, GSE look direction (Solar Angle + Elevation), live-time (not in FEEPS L1b) or dead-time, and the E1 of the lowest energy channel. At the channel level, there are 4-position "vectors", specifically: {EGM, counts-per-accumulation, counts-per-second, rough-intensity}, where EGM is the geometric mean of E_1 and E_2 [$\sqrt{E_1 \times E_2}$], the energy bounds of the energy channel. The deviations of E_1 and E_2 for each channel from EGM are also reported. Here the "rough-intensity" is results from the conversion of "counts-per-second" to "intensity" using

only approximate, uncertified calibration matrices, as are the energies, E_1 and E_2. No live-time or dead-time correction is applied to the counts, the counts/second, or the rough intensity. As with the Level 1a product, for each record the UTC time (or equivalent) must be recorded and a standard for whether that time is the beginning or the middle of an accumulation time. The needed preliminary magnetic field data in spacecraft lcoordinates and predict-ephemeris data is defined in §4.2. Quicklook data displays (§4.4) and any needed SITL data products (§4.5) are generated at this level. Note that there are no EIS and FEEPS data that are joined together at this point in time. The Level 1b data products are listed here, with **FEEPS in black** and **EIS in green** (note that "top" and "bottom" FEEPS sensors are now combined):

01. **L1b-FEEPS-Electron-Burst**
02. **L1b-FEEPS-Electron-Survey**
03. **L1b-FEEPS-Ion-Burst**
04. **L1b-FEEPS-Ion-Survey**
05. **L1b-EIS-PhxTOF-Ion-Burst**
06. **L1b-EIS-ExTOF-Ion-Burst**
07. **L1b-EIS-PhxTOF-Ion-Survey**
08. **L1b-EIS-ExTOF-Ion-Survey**
09. **L1b-EIS-Electron-Energy-Survey** (*diagnostic*)*
10. **L1b-EIS-Electron-Energy-Burst** (*diagnostic*)**
11. **L1b-EIS-Ion-Energy-Burst** (*diagnostic*)
12. **L1b-EIS-Ion-Energy-Survey** (*diagnostic*)

**EIS Electron Energy Survey is only available on select spacecraft at any given time (see §0.1e).*
***EIS Electron Energy Burst became a standard data product for EIS1 in April 2016 (see §0.1e).*
***NOTE**: EIS Level 1b data is used for QuickLook Plotting and Scientist-in-the-Loop (SITL) considerations.*

2) **Level 2:** These data are identical in format and content as the Level 1b dataset. The difference is: 1) live-time or dead-time corrections are applied to the counts per second as reported in this product, and before the generation of intensity. 2) "rough-intensity" values are replaced with "refined-intensity", 3) rough values of E1 and E2 are replaced with refined values, 4) preliminary magnetic field is replaced with updated magnetic field, 5) predict ephemeris is replaced with updated ephemeris, and 6) the record-level quality flag is updated. The list of Level 2 data products is nearly identical to the Level 1b products. Note that only Level 2 products 1-8 are generally available to the scientific community, with 9 and 10 selectively available. Again, products from **FEEPS are in black** and those from **EIS are in blue**:

01. **L2-FEEPS-Electron-Burst**
02. **L2-FEEPS-Electron-Survey**
03. **L2-FEEPS-Ion-Burst**
04. **L2-FEEPS-Ion-Survey**
05. **L2-EIS-PhxTOF-Ion-Burst**
06. **L2-EIS-ExTOF-Ion-Burst**
07. **L2-EIS-PhxTOF-Ion-Survey**
08. **L2-EIS-ExTOF-Ion-Survey**

09. **L2-EIS-Electron-Energy-Survey** (*diagnostic*)*
10. **L2-EIS-Electron-Energy-Burst** (diagnostic)**
11. **L2-EIS-Ion-Energy-Burst** (*diagnostic*)
12. **L2-EIS-Ion-Energy-Survey** (*diagnostic*)

**EIS Electron Energy Survey is only available on select spacecraft at any given time (see §0.1e).*
***EIS Electron Energy Burst became a standard data product for EIS1 in April 2016 (see §0.1e).*

3) **Level 3**: This constitutes a set of EPD investigation-level products that are, as of April 2021, still in preliminary development. These products require: 1) Extensive calculations requiring hands-on certification, or 2) the joining of multiple datasets. Two specific data products are already known to be required and are under development: i) the Fast Ion products described in §4.3; and ii) a product that generates full ion spectra by combining the EIS ExTOF and PHxTOF datasets. Other future Level 3 products may include a product that converts the rough all-sky electron images into high resolution all-sky electron images via a field-of-view deconvolution process with the FEEPS sensors moments, and spectra derived by combining some combinations of EPD with HPCA and FPI, as well as others. All of these products are at the observatory level. The following list of Level 3 EPD investigation-level data products are currently under development. Again, products from **FEEPS are in black** and those from **EIS are in green**, while those combining data from **both instruments are in orange**.
   1. **EIS** (survey/burst) **omni-directional energy spectrograms** [PHxTOF & ExTOF]
   2. **EIS** (survey/burst) **PAD for each channel** [PHxTOF & ExTOF]
   3. **EIS** (survey/burst) **integrated PAD** [PHxTOF & ExTOF]
   4. **EIS** (survey/burst) **combined ExTOF & PHxTOF proton omni-directional energy spectrum**
   5. **EIS** (survey/burst) **MMSX** (all-s/c) **energy spectrograms**
   6. **FEEPS** (survey/burst) **omni-directional energy spectrograms** [electron & ion]
   7. **FEEPS** (survey/burst) **PAD for each channel** [electron & ion]
   8. **FEEPS** (survey/burst) **integrated PAD** [electron & ion]
   9. **FEEPS** (survey/burst) **MMSX** (all-s/c) **energy spectrograms** [electron]
   10. **EIS & FEEPS combined** (burst only) **Fast Ion energy spectrogram**
   11. **EIS & FEEPS combined** (burst only) **Fast Ion PAD for each channel**
   12. **EIS & FEEPS combined** (burst only) **Fast Ion integrated PAD**

Future Level 3 data products that the EPD instruments may contribute to might include:
1. **L3-FEEPS-Common-Energy-Bin-Electron-Burst**: After flat-fielding, interpolating spectra from all telescopes onto a common energy grid*
2. **L3-FEEPS-Common-Energy-Bin-Electron-Survey**: After flat-fielding, interpolating spectra from all telescopes onto a common energy grid*
3. **L3-FEEPS-Common-Energy-Bin-Ion-Burst**: After flat-fielding, interpolating spectra from all telescopes onto a common energy grid*
4. **L3-FEEPS-Common-Energy-Bin-Ion-Survey**: After flat-fielding, interpolating spectra from all telescopes onto a common energy grid*
5. **L3-EPD-Particle-Moments**: Combines all EPD sources to generate total electron and ion integrated intensities, pressures, betas, energy-intensity)***
6. **L3-EIS-and-FEEPS-Angle-Angle-Plots**: All-sky maps plotted vs. gyro-phase (azimuth)

and pitch angle (elevation)

7. **L3-EPD-and-Plasma-Ion-Spectra**: Combines EPD, FPI, and HPCA to generate complete ion spectra, $f(E, \alpha, \varphi)$
8. **L3-EPD-and-Plasma-Electron-Spectra**: Combines FEEPS and FPI electron spectra into complete electron spectra, $f(E, \alpha, \varphi)$
9. **L3-EPD-and-Plasma-moments**: Combines all particle sources to generate total electron and ion integrated intensities, pressures, densities, and energy-intensity***

**Because of the light contamination problems with FEEPS, this product in not likely to be generated any time soon.*

***High-fidelity cross-calibrations have made this product quite achievable within the MMS project IDL-based SPEDAS routines for data obtained after 1 November 2016.*

****Some limited EPD moment calculations (e. g., spin-based ion pressure) are available in the Project IDL-based SPEDAS routines.*

4.2 Ephemeris and Magnetic Field Information Requirements

Because EPD is spin-based and the spin phase relative to the sun is known onboard, the transformation matrix between the SC coordinate system and GSE can be estimated for Level 1b data (only) by the EPD team by assuming that the following is roughly true: $SC_{Z(\mathrm{GSE})} = (\sin 2.5°, 0, \cos 2.5°)$. While this estimate suffices for Level 1b where ephemeris data is not available on the correct timescale, it **DOES NOT** for Level 2. For Level 1b data, there will be about ±30-degree uncertainty in the angle that the SC_Z axis makes with respect to the XZ_{GSE}-plane. Ideally that angle would be zero (as assumed with the $SC_{Z\,(\mathrm{GSE})}$ vector defined above), but the mission allows a substantial amount of variability in that angle. The following list provides a minimal set of needed information. Other information has been added for convenience (see §5 and §6).

- For Each Detector Look Direction (within each spin sector)
  1. Pitch Angle (using available magnetic field vector in SC coordinates)
  2. Unit Vector in GSE of Look Directions.

- One set for each spin sector
  3. B_X, B_Y, B_Z in SC coordinates*
  4. SC position (*X, Y, Z*) in GSE*
  5. SC position (*X, Y, Z*) in GSM*
  6. Moon position in GSE* (Alternatively, the GSE unit vector pointing from the spacecraft to the Moon. Needed because moonlight can contaminate FEEPS ions.)
  7. SC to GSE Transformation Matrix* (9 numbers)
  8. GSE to GSM Transformation Matrix* (9 numbers)
  9. MET of Sun Pulse
  10. Spin Rate

  **These required parameters are provided for users in the L1b and L2 EIS data files.*

To within the accuracy required for Level 2 data, the vector formed by the negative of #4 above combined with knowledge of the detector look directions in GSE (derived using the look direction in SC coordinates and #7) suffices for determining the possibility of Earth-Shine contamination of FEEPS ion detectors. This will be accurate at Level 2 but less so at Level 1b. For Level 1b, there will be about ±30° uncertainty in the angle that the SC_Z axis makes with respect to the XZ_{GSE}-plane. Furthermore, to within the accuracy required, the angle that the detector look direction in GSE (derived using the look direction in SC coordinates and #7) makes with respect to the X_{GSE}-axis suffices for determining the possibility of sunshine contamination of FEEPS ion detectors. This will be accurate at Level 2 and also fairly accurate at Level 1b. It is fairly accurate at Level 1b because the primary uncertainty in the spacecraft orientation resides in the role angle about the spacecraft-sun line.

a. $\langle E \rangle = \frac{P}{n}$

4.3. EPD QuickLook Data Plots

Quicklook (QL) plots are generated at the MMS SDC from Level 1b data and are available at https://lasp.colorado.edu/mms/sdc/public/quicklook/. Quicklook data are presented as plotted information only, it does not exist as separate digital data other than the Level 1b source data.
QL plots are generated using the MMS-specific IDL-based SPEDAS software to allow easy reconfiguration and recombination of multiple data variables. Exhibit 14 shows an example of the "mms#_eis_omni_flux" QL plot. The green and red bars at the top indicate the periods of burst and fast survey data availability, respectively. The subsequent panels show: a) magnetic magnitude and vector in Despun Major Principal Axis (DMPA) coordinates from the FGM instrument and omni-directional (average over all telescopes) energy-time spectrograms in units of intensity of b) electrons, c) high-energy (ExTOF) protons, d) low-energy (PHxTOF) protons, e) helium ions (ExTOF), and f) oxygen ions (ExTOF). Exhibit 15 shows an example of the at the top and the following panels: a) magnetic field data in DMPA coordinates and pitch angle distributions in units of counts/second for the lowest energy channel of b) electrons, c) high-energy (ExTOF) protons, d) low-energy (PHxTOF) protons, e) helium ions (ExTOF), and f) oxygen ions (ExTOF).

An example of the FEEPS QL plot ("mms#_feeps_summ") is shown in Exhibit 16. It shows from top to bottom: flags for burst (green) and fast survey (red) periods; a) magnetic field magnitude and vector in DMPA coordinated from the FGM; b) omni-directionally-averaged energy spectra "mms#_eis_pad_cps" QL plot (for the same date as Exhibit 14) with the data availability indicators from the electron eyes; pitch angle distributions for electrons at c) ~70 and d) ~200 keV; e) omni- directionally- averaged energy spectra from the ion eyes; and pitch angle distributions for ion at f) ~80 and g) ~210 keV.

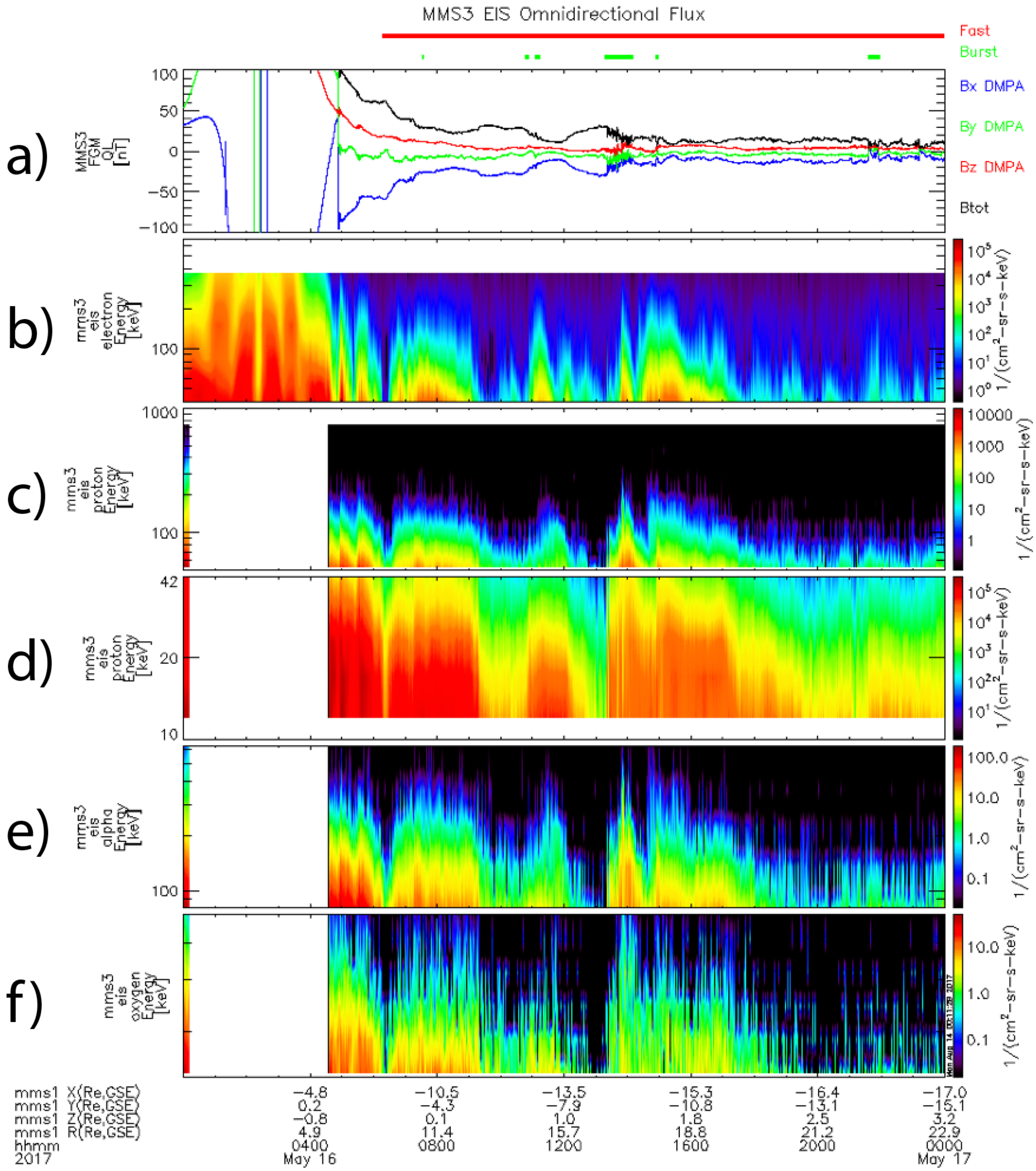


Exhibit 14. *An example of the "mms3_eis_omni_flux" QL plot for 16 May 2017 available from the MMS SDC. The panels show: a) magnetic field from the FGM instrument and omni-directional (average over all telescopes) energy-time spectrograms in units of intensity of b) electrons, c) high-energy (ExTOF) protons, d) low-energy (PHxTOF) protons, e) helium ions (ExTOF), and f) oxygen ions (ExTOF).*

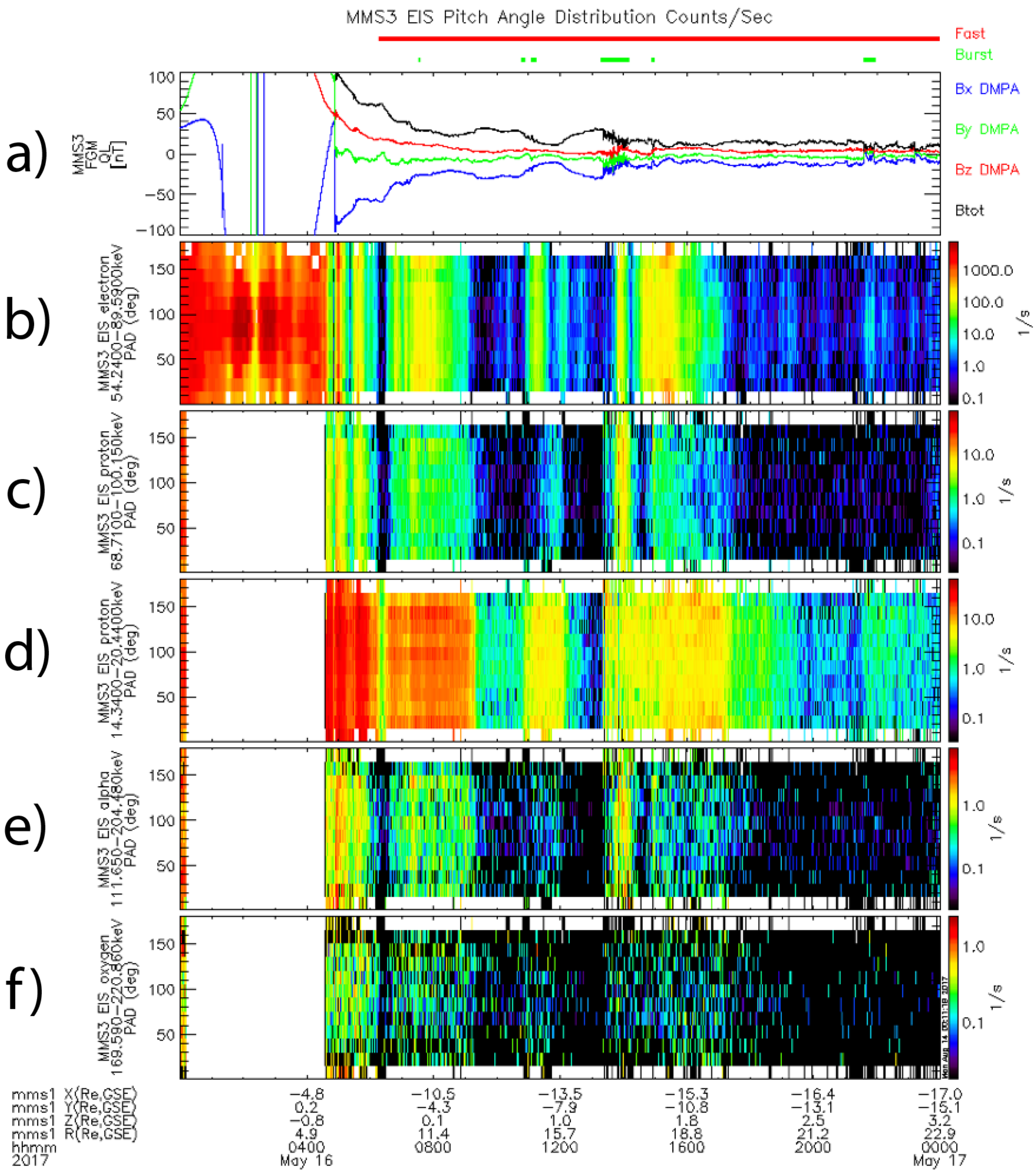


Exhibit 15. *An example of the "mms3_eis_pad_cps" QL plot for 16 May 2017 available from the MMS SDC. The panels show: a) magnetic field data from the FGM instrument and pitch angle distributions in units of counts/second for the lowest energy channel of b) electrons, c) high-energy (ExTOF) protons, d) low-energy (PHxTOF) protons, e) helium ions (ExTOF), and f) oxygen ions (ExTOF).*

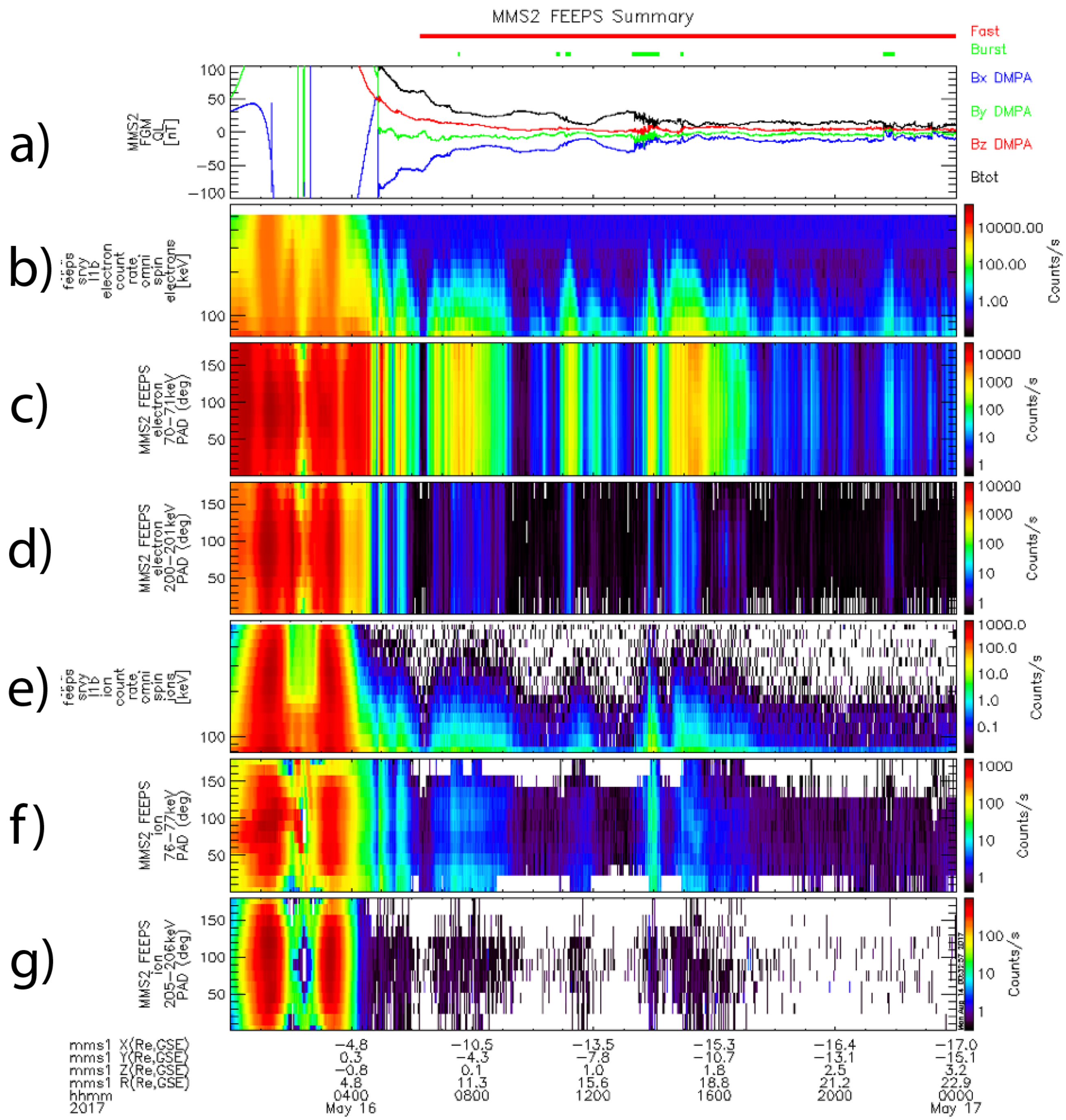


Exhibit 16. *An example of the "mms3_feeps_summ" QL plot for 16 May 2017 available from the MMS SDC. The panels from top to bottom are: a) magnetic field from the FGM instrument;* b) "omni" electron energy spectrogram; c) ~70 and d) ~200 keV electron pitch angle distributions; e) "omni" ion energy spectrogram; and f) ~80 and g) ~210 keV ion pitch angle distributions.

4.4 EPD SITL Data

As described in §1.4, EPD (EIS & FEEPS) generates onboard Burst Trigger Flags. However, unlike data from the other investigations, there are no reliable or consensus simulations that predict the behaviors of energetic particles in the vicinity of reconnection sites. Therefore, the EPD trigger data is unlikely to be used. However, it is likely that EPD data will be very useful for providing the context for using other parameters to make decisions about the selection of burst data. EPD SITL data are derived from Level 1b data and displayed in the form of the QuickLook data (e.g., color spectrograms like those shown in Exhibits 14-16).

5 Detailed EIS Ground Data Description

5.1 EIS Calibration

5.1.1 EIS Calibration

Details of the EIS calibration matrix are provided in Appendix A. The parameters that go into this matrix are complicated. The full range of parameters (azimuth angle, elevation angle, particle input position, energy, species) could not be exercised within calibration facilities. Instead, a combination of theory, empirical expressions, and spot validation were used to construction the calibration matrix. Initial estimates of the particle energies throughout the sensor, scattering efficiencies, and detection efficiencies was developed with a Mathematica routine that utilized various available empirical relationships (energy losses in materials, scattering characterizations, efficiency of secondary electron generation, solid-state-detector pulse-height-defect, etc., etc.). That routine created numerous 6-order polynomials for the functional relationships between the various parameters. Those polynomials were then tweaked according to beams calibration runs, cross-checks with similar instruments that had gone through cross-calibration activities (RBSPICE on Van Allen Probes), and then, flight cross-calibration on MMS as described in the next subsection.

The EIS calibration matrix carries parameters that correct for different responses of the six different telescopes within each unit. Flat-fielding has been carried out by examining the relative responses of the six different telescopes in each EIS unit to environments that are roughly isotropic. Because of some residual variations, the EIS team will be re-performing the flat-fielding procedures.

5.1.2 EIS Cross-Calibration

As summarized in §0.1k, considerable efforts were made in Spring/Summer 2017 regarding the cross-calibration of ion (specifically proton) measurements amongst the MMS instruments: EIS, FEEPS, FPI/DIS, and HPCA. The basic gain state of the EIS sensor for measuring protons, which is variable because of changing microchannel plate efficiencies, is established by comparing the EIS and FEEPS ion measurements at ~80 keV. That energy is low enough to where we have become confident that protons dominate over heavy ions, and it is high enough to avoid energy-dependent efficiency problems that occur at lower energies. Additional cross-calibration efforts revealed that the EIS PHxTOF data, which bridges the energy gap between the upper energy limits

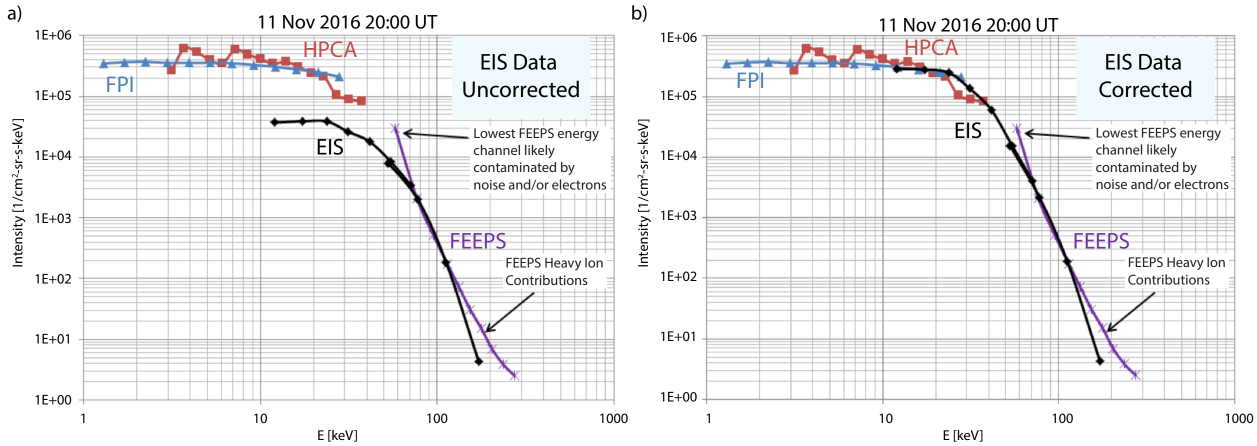


Exhibit 17. *Example of the comparison of omni-directional proton spectra from the EIS, FEEPS, HPCA, and FPI/DIS sensors on MMS 3 (a) before and (b) after the EIS data was corrected. L2 data was used for all sensors except HPCA (L1b), which did not have L2 data available at the time that the cross-calibration efforts were made.*

of FPI/DIS (30 keV) and HPCA (40 keV) and the lower energy limit of the ExTOF (~50 keV) and FEEPS (~60 keV) data, was underestimating the flux by approximately a factor of 5. Based on the strong agreement between the plasma sensors (FPI/DIS and HPCA) and the high confidence in the relatively "pure" ion measurement by FEEPS (due to their very thin SSDs), the decision was made to adjust the EIS PHxTOF data by applying an energy-dependent numerical correction of the form:

$$E_{\mathrm{PHxTOF}} = \frac{1}{\frac{1}{2} * \left[1+\alpha_{\mathrm{PH}}\left(\tanh\left(\frac{E-\beta_{\mathrm{PH}}}{\gamma_{\mathrm{PH}}}\right)+1\right)\right]},$$

where E is energy and α_{PH}, β_{PH}, γ_{PH} are coefficients equal to 0.3, 45, and 1, respectively. Exhibit 17 shows an example comparing the proton spectra from the various instruments (a) before and (b) after the EIS data was corrected. Minor adjustments were also made to the lowest energy EIS ExTOF data to correct for foil efficiencies. This correction is of the form:

$$E_{\mathrm{ExTOF}} = \frac{1}{\frac{1}{2} * \left[1+\alpha_{\mathrm{E}}\left(1-\tanh\left(\frac{E-\beta_{\mathrm{E}}}{\gamma_{\mathrm{E}}}\right)+1\right)\right]},$$

where E is energy and α_{E}, β_{E}, γ_{E} are coefficients equal to 0.3, 45, and 1, respectively. Comprehensive implementation of these cross-calibration corrections is ongoing.

Cross calibration has also taken place for electrons between EIS and FEEPS. Pre-launch characterization for EIS has been found to be adequate (see §6.1.5). Efficiencies for EIS electrons were obtained from cross-calibration activities that took place with EIS's sister instrument, RBSPICE, on the Van Allen Probes mission. FEEPS has demonstrated consistency with FPI electrons at lower energies (again, §6.1.5).

5.2 EIS file versioning

To optimize scientific return, the instrument team may infrequently alter the onboard lookup tables (LUT), which define the spectral "channels" (see instrument description below) in a given EIS data product over the course of the mission. Each such change defines a new "LUT period"

Regime		***Period Start***	***Period End***	***Changes***
(New 2021)	***(Old)***			
v1.0	*v1.0*	2015-03-12 (Launch)	2015-07-29/00:00:00	Initial LUT & processing state
v2.0	*v2.0*	2015-07-29/00:00:00	2015-08-29/00:00:00	Changes to *extof* & *electronenergy* channels
v2.1	*v2.1*	2015-08-29/00:00:00	2015-09-24/00:00:00	*phxtof* decimation changed
v3.0	*v3.0*	2015-09-24/00:00:00	2015-11-20/00:00:00	Changes to *phxtof* channelization
v3.1	*v3.1*	2015-11-20/00:00:00	2016-01-30/00:00:00	Changes to post-processing calibration factors
v3.2		2016-01-30/00:00:00	2016-08-04/00:00:00	HV raised to improve MCP gain on MMS4
v3.3	*v3.2*	2016-08-04/00:00:00	2016-08-06/00:00:00	*phxtof* decimation changed
v3.4	*v3.3*	2016-08-06/00:00:00	2016-09-26/00:00:00	HV raised to improve MCP gain on MMS3
v4.0	*v4.0*	2016-09-26/00:00:00	2016-11-01/00:00:00	Changes to *extof*, *phxtof*, & *electronenergy* channels
v4.1	*v4.1*	2016-11-01/00:00:00	2017-04-30/00:00:00	Changes to post-processing calibration factors
v4.2		2017-04-30/00:00:00	2017-11-17/00:00:00	Changes to post-processing calibration factors
v4.3	*v4.2*	2017-11-17/00:00:00	2018-04-30/00:00:00	Changes to *phxtof* and *extof* efficiencies/spectra, etc.
v4.4		2018-04-30/00:00:00	2018-11-30/00:00:00	Changes to post-processing calibration factors
v4.5		2018-11-30/00:00:00	2019-05-01/00:00:00	Changes to post-processing calibration factors
v4.6		2019-05-01/00:00:00	2019-12-05/00:00:00	Changes to post-processing calibration factors
v5.0	*v5.0*	2019-12-05/00:00:00	Present	Changes to electronenergy channels on MMS4

Exhibit 18. *Record of different EIS data processing "regimes" and specific changes implemented. The "vX.Y" naming scheme is used to record updates to the onboard LUTs ("X", which corresponds to the "P_<X>" portion of the name of affected variables in the CDF) and changes to the "Calibration Matrices" used for ground processing ("Y").*

with each LUT period containing its own unique set of spectral channels. This means that over the course of the mission, a given data variable may change in structure (i.e., number or species specification of energy channels). To highlight and record these changes, the LUT period of a given spectral variable is indicated by a "*_P<n>_*" in the names of affected variables. Additionally, regular changes in the "Calibration Matrices" used for ground-based data processing, which do not require the introduction of a new LUT, such as adjusting high voltage states to address MCP gain levels or data optimization (i.e., changing decimation factors). These changes will affect the nature of the data within data files, but not the variable names.

Changes to both the onboard LUTs and ground-based "Cal Matrices" define specific data "regimes", which are indicated using a unique EIS file versioning paradigm where the version indices "**_x.y.z.cdf*" correspond to:

- *x*: the LUT period and associated "*P<n>*" in CDF variable names
- *y*: the specific iteration of the Cal Matrix used for data processing
- *z*: processing iteration of specific file

Each "v*X.Y*" combination corresponds to a given data "regime", summarized Exhibit 18 below.

5.3 EIS Ground Data Product Details

Level 1B (L1B) files are exactly the same format as Level 2 (L2) files, they have merely been produced with less reliable data including some or all of the following: predicted ephemeris and attitude information (as opposed to definitive information), lower level FGM data, preliminary calibration tables.

The files are International Solar-Terrestrial Physics/Space Physics Data Facility (ISTP/SPDF) standard Common Data Format (CDF) files. There are three L2 files, one for each data type.

1. ***electronenergy**:* (note that electron data may be contaminated with (>250 keV protons, see §0.1i).
2. ***extof***: High-energy (ExTOF) ion spectra organized by particle species.
3. ***phxtof***: Low-energy (PHxTOF) ion spectra organized by particle species.

All the principal variables in each file have the same "time axis" (DEPEND_0 attribute), so the file can be thought of as a simple rectangular "table" with each time value of the Epoch variable defining a "row" and each non-constant CDF variable as a "column". The Epoch is the midpoint of the accumulation interval. *Time_Minus* and *Time_Plus* (DELTA_PLUS and DELTA_MINUS attributes) give the start and stop edges of the time bin as specified by the ISTP CDF standard.

There is one spectral variable for each "species": electron, proton, alpha, oxygen, or "dump" (where "dump" captures every event that was not classified as one of the defined species). Each spectral variable has a DEPEND_1 attribute that points to a (constant) variable which gives the centers of the energy bins and that variable, in turn, has DELTA_PLUS and DELTA_MINUS attributes that point to variables giving the bin edges (as described in the ISTP CDF standard). Each spectrum is given in three data units (or using three "calibrations"):

1. ***counts***: The raw number of counts collected during the current accumulation interval (see discussion of the "Timing and Geometry Block" below). This value is uncorrected in any way and may be used to calculate the relative uncertainty of all three "calibrations" using standard Poisson statistics.
2. ***cps***: The count rate [*counts/s*] in each energy bin. This quantity may be corrected for instrument saturation effects (this procedure is still in development).
3. ***flux***: The calibrated differential intensity [*1/cm^2-sr-s-keV*] of charged particles in each energy bin.

There are 6 spectral variables for each calibration (numbered 0-5) corresponding to the 6 look directions (or "telescopes") of the instrument.

The variables in each spectral file can be grouped into four conceptual "blocks":

1. Timing and Geometry: Describes the time period over which the measurement was taken and low-level attitude and instrument configuration data needed to calibrate the raw counting rates in these files.
2. Spectral: One CDF variable for each species and calibration.
3. *Ephemeris, Attitude, and Pitch Angle*: Spacecraft position, look direction, pitch angle, and magnetic field.
4. *Basic Rates*: Raw total counting rates in various instrument subsystems. These give a quick overview of the measured environment and state of the instrument.

Apart from the Epoch variables, which follow the general ISTP standard, the EIS variables all begin with a "prefix" following the standard MMS naming scheme:

*<eis_prefix> = mms**<#>**_epd_eis_**<DATA_RATE>**_**<LEVEL>**_**<DATA_TYPE>**_**,*

indicated in the variables below by "*".

1) The *Timing and Geometry* block consists of the following variables:

- *epoch, time minus, time plus* – Standard CDF time specifications for the measurement window.

- *starttai, *midtai, *endtai – The beginning, middle, and end of the measurement window in International Atomic Time (TAI) expressed as seconds since 1958 (standard MMS spacecraft time).
- *spin – A 16-bit spin counter (0-65535). This is retained in L2 data for instrument team use in file validation.
- *sector – The first sector (0-31) of the measurement that may include multiple sectors. A full revolution of the spacecraft is divided into 32 evenly spaced sectors. Several sectors are combined for measurements in most data products so that only 8 or 16 measurements, for example, are made in a revolution. Data products may be collected only every nth spin. This is retained in L2 data primarily for instrument team use in validation, but it may prove useful to other investigators as a simple way of performing rough attitude filtering or grouping.
- *quality – bit flags indicating reliability of the data, these values are still under development.

2) The <u>Spectral</u> block variables are named with the form:

***<SPECIES>_P<LUT_PERIOD>_<DATA_UNITS>_T<#>**

3) The <u>Ephemeris, Attitude, and Pitch Angle</u> block consists of the following variables:

- *pitch_angle_t<#> - The angle between the particle flow vector and the magnetic field for each of the 6 “telescopes”. The particle flow vector is the negative of the telescope look direction.
- *look_t<#> – The look direction of the telescope in the standard GSE coordinate frame.
- *b – The magnetic field used to derive the pitch angle.
- *position_gse – The spacecraft position with respect to the Earth in the GSE frame
- *position_gse – The spacecraft position with respect to the Earth in the GSM frame
- *moon_gse – The spacecraft position with respect to the Moon in the GSE frame
- *sc_to_gse – Transformation matrix for rotating a vector from the spacecraft frame (BCS) to the GSE frame [entries are by row: row1 = row1, row2 = 4-6, row3 = 7-9]
- *gse_to_gsm – Transformation matrix for rotating a vector from the GSE frame to the GSM frame [entries are by row: row1 = row1, row2 = 4-6, row3 = 7-9]
- *r – Spacecraft distance from Earth in kilometers
- *l – Spacecraft position L-shell for a dipole magnetic field
- *gse_lat, *gse_lon, *gsm_lat, *gsm_lon, *sm_lat, *sm_lon – Spacecraft position latitude and longitude in GSE, GSM, or SM frame.
- *orbit_num – MMS mission orbit number

4) The <u>Basic Rates</u> block consists of the following variables:

For all data types:

- *ssd<#> – Number of pulses detected on the solid-state energy detector for telescope number 0-5

- ******vep* – Valid Events Processed – Number of events actually processed by the flight software

For electron data:

- **vee* – Valid Energy Events – Total number of events in all SSD (Energy) detectors.

For ion data types:

- **start0anode*, **stop0anode* – Number of pulses on the end of the Start or Stop anode nearest to look direction 0
- **pulseheight* – Number of events above TOF pulse height threshold
- **vtofxee* – Number of valid ExTOF events counted.
- **vtofxphe* – Number of valid PHxTOF events counted.

As of Summer 2021 (see §0.h.i), the EIS data variables listed in Exhibits 19-24 all include the following <eis_prefix> = *mms**<#>**_epd_eis_**<DATA_RATE>**_l2*, where ***<#>*** is the spacecraft number and ***<DATA_RATE>*** is the sampling mode ("srvy" or "brst").

5.4 Level 2 EIS Products

Level 2 EIS Burst Data Products

Data Parameter	Description	Units
Time_Minus	<support data> Delta from measurement window start to midpoint	s
Time_Plus	<support data> Delta from midpoint to measurement window end	s
<eis_prefix>_extof_duration	<support data> Total exposure time for accumulation	s
<eis_prefix>_extof_deadtime	<support data> Instrument deadtime	s
<eis_prefix>_extof_largepixel	<support data> Instrument large pixel in use (yes/no)	-----
<eis_prefix>_extof_starttai	<support data> Begin measurement window, TAI since 1958	s
<eis_prefix>_extof_midtai	<support data> Nominal measurement time, TAI since 1958	s
<eis_prefix>_extof_endtai	<support data> End measurement window, TAI since 1958	s
<eis_prefix>_extof_spin	<support data> Spacecraft spin number	-----
<eis_prefix>_extof_sector	<support data> Spacecraft spin sector	-----
<eis_prefix>_extof_quality	<support data> Quality word	-----
<eis_prefix>_extof_proton_P<X>_counts_t<#>	Individual telescope (look direction) proton counts for each energy channel	counts
<eis_prefix>_extof_proton_P<X>_cps_t<#>	Individual telescope (look direction) proton counts per second for each energy channel	1/s
<eis_prefix>_extof_proton_P<X>_flux_t<#>	Individual telescope (look direction) proton intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)

<eis_prefix>_extof_helium_P<X>_counts_t<#>	Individual telescope (look direction) helium (charge state unmeasured) counts for each energy channel	counts
<eis_prefix>_extof_helium_P<X>_cps_t<#>	Individual telescope (look direction) helium (charge state unmeasured) counts per second for each energy channel	1/s
<eis_prefix>_extof_helium_P<X>_flux_t<#>	Individual telescope (look direction) helium (charge state unmeasured) intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_oxygen_P<X>_counts_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) counts for each energy channel	counts
<eis_prefix>_extof_oxygen_P<X>_cps_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) counts per second for each energy channel	1/s
<eis_prefix>_extof_oxygen_P<X>_flux_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_dump_counts_t<#>	Individual telescope (look direction) ion counts dump bin for each energy channel	counts
<eis_prefix>_extof_dump_cps_t<#>	Individual telescope (look direction) ion counts per second dump bin for each energy channel	1/s
<eis_prefix>_extof_dump_flux_t<#>	Individual telescope (look direction) ion intensity (flux) dump bin for each energy channel	-----
<eis_prefix>_extof_pitch_angle_t<#>	Pitch angle for individual telescope (look direction)	degrees
<eis_prefix>_extof_look_t<#>	Look direction vector in GSE for individual telescope	-----
<eis_prefix>_extof_b	Magnetic field in BCS coordinates	nT
<eis_prefix>_extof_position_gse	Spacecraft position vector in GSE	km
<eis_prefix>_extof_position_gsm	Spacecraft position vector in GSM	km
<eis_prefix>_extof_moon_gse	Spacecraft-to-moon vector in GSE	km
<eis_prefix>_extof_sc_to_gse	Transformation matrix from SC to GSE coordinates	-----
<eis_prefix>_extof_gse_to_gsm	Transformation matrix from GSE to GSM coordinates	-----
<eis_prefix>_extof_r	Magnitude of radial distance	km
<eis_prefix>_extof_l	L-shell value (dipole approximation)	-----
<eis_prefix>_extof_gse_lat	Latitude in GSE frame	degrees
<eis_prefix>_extof_gse_lon	Longitude in GSE frame	degrees
<eis_prefix>_extof_gsm_lat	Latitude in GSM frame	degrees
<eis_prefix>_extof_gsm_lon	Longitude in GSM frame	degrees
<eis_prefix>_extof_sm_lat	Latitude in SM frame	degrees
<eis_prefix>_extof_sm_lon	Longitude in SM frame	degrees
<eis_prefix>_extof_orbit_num	Orbit number	degrees
<eis_prefix>_extof_ssd<#>	Raw count rate from individual SSD	1/s
<eis_prefix>_extof_vep	Number of electron events processed and binned by onboard processor per second	1/s

<eis_prefix>_extof_start0anode	Count rate from all start anode regions	1/s
<eis_prefix>_extof_stop0anode	Count rate from all stop anode regions	1/s
<eis_prefix>_extof_pulseheight	Count rate from all start anode regions that satisfy a minimum MCP pulse height	1/s
<eis_prefix>_extof_vtofxee	Number of valid energy by time-of-flight (ExTOF) events per second	1/s
<eis_prefix>_extof_vtofxphe	Number of valid pulse height by time-of-flight (PHxTOF) events per second	1/s

Exhibit 19. *List of the variables included in the L2 EIS extof burst data product.*

Data Parameter	Description	Units
Time_Minus	<support data> Delta from measurement window start to midpoint	s
Time_Plus	<support data> Delta from midpoint to measurement window end	s
<eis_prefix>_phxtof_duration	<support data> Total exposure time for accumulation	s
<eis_prefix>_phxtof_deadtime	<support data> Instrument deadtime	s
<eis_prefix>_phxtof_largepixel	<support data> Instrument large pixel in use (yes/no)	-----
<eis_prefix>_phxtof_starttai	<support data> Begin measurement window, TAI since 1958	s
<eis_prefix>_phxtof_midtai	<support data> Nominal measurement time, TAI since 1958	s
<eis_prefix>_phxtof_endtai	<support data> End measurement window, TAI since 1958	s
<eis_prefix>_phxtof_spin	<support data> Spacecraft spin number	-----
<eis_prefix>_phxtof_sector	<support data> Spacecraft spin sector	-----
<eis_prefix>_phxtof_quality	<support data> Quality word	-----
<eis_prefix>_phxtof_proton_P<X>_counts_t<#>	Individual telescope (look direction) proton counts for each energy channel	counts
<eis_prefix>_phxtof_proton_P<X>_cps_t<#>	Individual telescope (look direction) proton counts per second for each energy channel	1/s
<eis_prefix>_phxtof_proton_P<X>_flux_t<#>	Individual telescope (look direction) proton intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)
<eis_prefix>_phxtof_oxygen_P<X>_counts_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) counts for each energy channel	counts
<eis_prefix>_phxtof_oxygen_P<X>_cps_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) counts per second for each energy channel	1/s
<eis_prefix>_phxtof_oxygen_P<X>_flux_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)
<eis_prefix>_phxtof_dump_counts_t<#>	Individual telescope (look direction) ion counts dump bin for each energy channel	counts
<eis_prefix>_phxtof_dump_cps_t<#>	Individual telescope (look direction) ion counts per second dump bin for each energy channel	1/s
<eis_prefix>_phxtof_dump_flux_t<#>	Individual telescope (look direction) ion intensity (flux) dump bin for each energy channel	-----

<eis_prefix>_phxtof_pitch_angle_t<#>	Pitch angle for individual telescope (look direction)	degrees
<eis_prefix>_phxtof_look_t<#>	Look direction vector in GSE for individual telescope	-----
<eis_prefix>_phxtof_b	Magnetic field in BCS coordinates	nT
<eis_prefix>_phxtof_position_gse	Spacecraft position vector in GSE	km
<eis_prefix>_phxtof_position_gsm	Spacecraft position vector in GSM	km
<eis_prefix>_phxtof_moon_gse	Spacecraft-to-moon vector in GSE	km
<eis_prefix>_phxtof_sc_to_gse	Transformation matrix from SC to GSE coordinates	-----
<eis_prefix>_phxtof_gse_to_gsm	Transformation matrix from GSE to GSM coordinates	-----
<eis_prefix>_phxtof_r	Magnitude of radial distance	km
<eis_prefix>_phxtof_l	L-shell value (dipole approximation)	-----
<eis_prefix>_phxtof_gse_lat	Latitude in GSE frame	degrees
<eis_prefix>_phxtof_gse_lon	Longitude in GSE frame	degrees
<eis_prefix>_phxtof_gsm_lat	Latitude in GSM frame	degrees
<eis_prefix>_phxtof_gsm_lon	Longitude in GSM frame	degrees
<eis_prefix>_phxtof_sm_lat	Latitude in SM frame	degrees
<eis_prefix>_phxtof_sm_lon	Longitude in SM frame	degrees
<eis_prefix>_phxtof_orbit_num	Orbit number	degrees
<eis_prefix>_phxtof_ssd<#>	Raw count rate from individual SSD	1/s
<eis_prefix>_phxtof_vep	Number of electron events processed and binned by onboard processor per second	1/s
<eis_prefix>_phxtof_start0anode	Count rate from all start anode regions	1/s
<eis_prefix>_phxtof_stop0anode	Count rate from all stop anode regions	1/s
<eis_prefix>_phxtof_pulseheight	Count rate from all start anode regions that satisfy a minimum MCP pulse height	1/s
<eis_prefix>_phxtof_vtofxee	Number of valid energy by time-of-flight (ExTOF) events per second	1/s
<eis_prefix>_phxtof_vtofxphe	Number of valid pulse height by time-of-flight (PHxTOF) events per second	1/s

Exhibit 20. *List of the variables included in the L2 EIS phxtof burst data product.*

Data Parameter	Description	Units
Time_Minus	<support data> Delta from measurement window start to midpoint	s
Time_Plus	<support data> Delta from midpoint to measurement window end	s
<eis_prefix>_electronenergy_duration	<support data> Total exposure time for accumulation	s
<eis_prefix>_electronenergy_deadtime	<support data> Instrument deadtime	s

<eis_prefix>_electronenergy_largepixel	<support data> Instrument large pixel in use (yes/no)	-----
<eis_prefix>_electronenergy_starttai	<support data> Begin measurement window, TAI since 1958	s
<eis_prefix>_electronenergy_midtai	<support data> Nominal measurement time, TAI since 1958	s
<eis_prefix>_electronenergy_endtai	<support data> End measurement window, TAI since 1958	s
<eis_prefix>_electronenergy_spin	<support data> Spacecraft spin number	-----
<eis_prefix>_electronenergy_sector	<support data> Spacecraft spin sector	-----
<eis_prefix>_electronenergy_quality	<support data> Quality word	-----
<eis_prefix>_electronenergy_electron_P<X>_counts_t<#>	Individual telescope (look direction) counts for each energy channel	counts
<eis_prefix>_electronenergy_electron_P<X>_cps_t<#>	Individual telescope (look direction) counts per second for each energy channel	1/s
<eis_prefix>_electronenergy_electron_P<n>_flux_t<#>	Individual telescope (look direction) intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)
<eis_prefix>_electronenergy_dump_counts_t<#>	Individual telescope (look direction) counts dump bin for each energy channel	counts
<eis_prefix>_electronenergy_dump_cps_t<#>	Individual telescope (look direction) counts per second dump bin for each energy channel	1/s
<eis_prefix>_electronenergy_dump_flux_t<#>	Individual telescope (look direction) intensity (flux) dump bin for each energy channel	-----
<eis_prefix>_electronenergy_pitch_angle_t<#>	Pitch angle for individual telescope (look direction)	degrees
<eis_prefix>_electronenergy_look_t<#>	Look direction vector in GSE for individual telescope	-----
<eis_prefix>_electronenergy_b	Magnetic field in BCS coordinates	nT
<eis_prefix>_electronenergy_position_gse	Spacecraft position vector in GSE	km
<eis_prefix>_electronenergy_position_gsm	Spacecraft position vector in GSM	km
<eis_prefix>_electronenergy_moon_gse	Spacecraft-to-moon vector in GSE	km
<eis_prefix>_electronenergy_sc_to_gse	Transformation matrix from SC to GSE coordinates	-----
<eis_prefix>_electronenergy_gse_to_gsm	Transformation matrix from GSE to GSM coordinates	-----
<eis_prefix>_electronenergy_r	Magnitude of radial distance	km
<eis_prefix>_electronenergy_l	L-shell value (dipole approximation)	-----
<eis_prefix>_electronenergy_gse_lat	Latitude in GSE frame	degrees
<eis_prefix>_electronenergy_gse_lon	Longitude in GSE frame	degrees
<eis_prefix>_electronenergy_gsm_lat	Latitude in GSM frame	degrees
<eis_prefix>_electronenergy_gsm_lon	Longitude in GSM frame	degrees
<eis_prefix>_electronenergy_sm_lat	Latitude in SM frame	degrees
<eis_prefix>_electronenergy_sm_lon	Longitude in SM frame	degrees

<eis_prefix>_electronenergy_orbit_num	Orbit number	degrees
<eis_prefix>_electronenergy_ssd<#>	Raw count rate from individual SSD	1/s
<eis_prefix>_electronenergy_vep	Number of electron events processed and binned by onboard processor per second	1/s
<eis_prefix>_electronenergy_vee	Number of valid electron events per second	1/s

Exhibit 21. *List of the variables included in the L2 EIS electronenergy burst data product.*

Level 2 EIS Survey Data Products

Data Parameter	Description	Units
Time_Minus	<support data> Delta from measurement window start to midpoint	s
Time_Plus	<support data> Delta from midpoint to measurement window end	s
<eis_prefix>_extof_duration	<support data> Total exposure time for accumulation	s
<eis_prefix>_extof_deadtime	<support data> Instrument deadtime	s
<eis_prefix>_extof_largepixel	<support data> Instrument large pixel in use (yes/no)	-----
<eis_prefix>_extof_starttai	<support data> Begin measurement window, TAI since 1958	s
<eis_prefix>_extof_midtai	<support data> Nominal measurement time, TAI since 1958	s
<eis_prefix>_extof_endtai	<support data> End measurement window, TAI since 1958	s
<eis_prefix>_extof_spin	<support data> Spacecraft spin number	-----
<eis_prefix>_extof_sector	<support data> Spacecraft spin sector	-----
<eis_prefix>_extof_quality	<support data> Quality word	-----
<eis_prefix>_extof_proton_P<X>_counts_t<#>	Individual telescope (look direction) proton counts for each energy channel.	counts
<eis_prefix>_extof_proton_P<X>_cps_t<#>	Individual telescope (look direction) proton counts per second for each energy channel	1/s
<eis_prefix>_extof_proton_P<X>_flux_t<#>	Individual telescope (look direction) proton intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_helium_P<X>_counts_t<#>	Individual telescope (look direction) helium (charge state unmeasured) counts for each energy channel.	counts
<eis_prefix>_extof_helium_P<X>_cps_t<#>	Individual telescope (look direction) helium (charge state unmeasured) counts per second for each energy channel	1/s
<eis_prefix>_extof_helium_P<X>_flux_t<#>	Individual telescope (look direction) helium (charge state unmeasured) intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_oxygen_P<X>_counts_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) counts for each energy channel	counts
<eis_prefix>_extof_oxygen_P<X>_cps_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) counts per second for each energy channel	1/s
<eis_prefix>_extof_oxygen_P<X>_flux_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)

<eis_prefix>_extof_dump_counts_t<#>	Individual telescope (look direction) ion counts dump bin for each energy channel	counts
<eis_prefix>_extof_dump_cps_t<#>	Individual telescope (look direction) ion counts per second dump bin for each energy channel	1/s
<eis_prefix>_extof_dump_flux_t<#>	Individual telescope (look direction) ion intensity (flux) dump bin for each energy channel	-----
<eis_prefix>_extof_pitch_angle_t<#>	Pitch angle for individual telescope (look direction)	degrees
<eis_prefix>_extof_look_t<#>	Look direction vector in GSE for individual telescope	-----
<eis_prefix>_extof_b	Magnetic field in BCS coordinates	nT
<eis_prefix>_extof_position_gse	Spacecraft position vector in GSE	km
<eis_prefix>_extof_position_gsm	Spacecraft position vector in GSM	km
<eis_prefix>_extof_moon_gse	Spacecraft-to-moon vector in GSE	km
<eis_prefix>_extof_sc_to_gse	Transformation matrix from SC to GSE coordinates	-----
<eis_prefix>_extof_gse_to_gsm	Transformation matrix from GSE to GSM coordinates	-----
<eis_prefix>_extof_r	Magnitude of radial distance	km
<eis_prefix>_extof_l	L-shell value (dipole approximation)	-----
<eis_prefix>_extof_gse_lat	Latitude in GSE frame	degrees
<eis_prefix>_extof_gse_lon	Longitude in GSE frame	degrees
<eis_prefix>_extof_gsm_lat	Latitude in GSM frame	degrees
<eis_prefix>_extof_gsm_lon	Longitude in GSM frame	degrees
<eis_prefix>_extof_sm_lat	Latitude in SM frame	degrees
<eis_prefix>_extof_sm_lon	Longitude in SM frame	degrees
<eis_prefix>_extof_orbit_num	Orbit number	degrees
<eis_prefix>_extof_ssd<#>	Raw count rate from individual SSD	1/s
<eis_prefix>_extof_vep	Number of electron events processed and binned by onboard processor per second	1/s
<eis_prefix>_extof_start0anode	Count rate from all start anode regions	1/s
<eis_prefix>_extof_stop0anode	Count rate from all stop anode regions	1/s
<eis_prefix>_extof_pulseheight	Count rate from all start anode regions that satisfy a minimum MCP pulse height	1/s
<eis_prefix>_extof_vtofxee	Number of valid energy by time-of-flight (ExTOF) events per second	1/s
<eis_prefix>_extof_vtofxphe	Number of valid pulse height by time-of-flight (PHxTOF) events per second	1/s

Exhibit 22. *List of the variables included in the L2 EIS extof survey data product.*

Data Parameter	Description	Units
Time_Minus	<support data> Delta from measurement window start to midpoint	s

Time_Plus	<support data> Delta from midpoint to measurement window end	s
<eis_prefix>_phxtof_duration	<support data> Total exposure time for accumulation	s
<eis_prefix>_phxtof_deadtime	<support data> Instrument deadtime	s
<eis_prefix>_phxtof_largepixel	<support data> Instrument large pixel in use (yes/no)	-----
<eis_prefix>_phxtof_starttai	<support data> Begin measurement window, TAI since 1958	s
<eis_prefix>_phxtof_midtai	<support data> Nominal measurement time, TAI since 1958	s
<eis_prefix>_phxtof_endtai	<support data> End measurement window, TAI since 1958	s
<eis_prefix>_phxtof_spin	<support data> Spacecraft spin number	-----
<eis_prefix>_phxtof_sector	<support data> Spacecraft spin sector	-----
<eis_prefix>_phxtof_quality	<support data> Quality word	-----
<eis_prefix>_phxtof_proton_P<X>_counts_t<#>	Individual telescope (look direction) proton counts for each energy channel	counts
<eis_prefix>_phxtof_proton_P<X>_cps_t<#>	Individual telescope (look direction) proton counts per second for each energy channel	1/s
<eis_prefix>_phxtof_proton_P<X>_flux_t<#>	Individual telescope (look direction) proton intensity (flux) for each energy channel	1/(cm2-s-sr-keV)
<eis_prefix>_phxtof_oxygen_P<X>_counts_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) counts for each energy channel	counts
<eis_prefix>_phxtof_oxygen_P<X>_cps_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) counts per second for each energy channel	1/s
<eis_prefix>_phxtof_oxygen_P<X>_flux_t<#>	Individual telescope (look direction) oxygen (charge state unmeasured) intensity (flux) for each energy channel	1/(cm2-s-sr-keV)
<eis_prefix>_phxtof_dump_counts_t<#>	Individual telescope (look direction) ion counts dump bin for each energy channel	counts
<eis_prefix>_phxtof_dump_cps_t<#>	Individual telescope (look direction) ion counts per second dump bin for each energy channel	1/s
<eis_prefix>_phxtof_dump_flux_t<#>	Individual telescope (look direction) ion intensity (flux) dump bin for each energy channel	-----
<eis_prefix>_phxtof_pitch_angle_t<#>	Pitch angle for individual telescope (look direction)	degrees
<eis_prefix>_phxtof_look_t<#>	Look direction vector in GSE for individual telescope	-----
<eis_prefix>_phxtof_b	Magnetic field in BCS coordinates	nT
<eis_prefix>_phxtof_position_gse	Spacecraft position vector in GSE	km
<eis_prefix>_phxtof_position_gsm	Spacecraft position vector in GSM	km
<eis_prefix>_phxtof_moon_gse	Spacecraft-to-moon vector in GSE	km
<eis_prefix>_phxtof_sc_to_gse	Transformation matrix from SC to GSE coordinates	-----
<eis_prefix>_phxtof_gse_to_gsm	Transformation matrix from GSE to GSM coordinates	-----
<eis_prefix>_phxtof_r	Magnitude of radial distance	km

<eis_prefix>_phxtof_l	L-shell value (dipole approximation)	-----
<eis_prefix>_phxtof_gse_lat	Latitude in GSE frame	degrees
<eis_prefix>_phxtof_gse_lon	Longitude in GSE frame	degrees
<eis_prefix>_phxtof_gsm_lat	Latitude in GSM frame	degrees
<eis_prefix>_phxtof_gsm_lon	Longitude in GSM frame	degrees
<eis_prefix>_phxtof_sm_lat	Latitude in SM frame	degrees
<eis_prefix>_phxtof_sm_lon	Longitude in SM frame	degrees
<eis_prefix>_phxtof_orbit_num	Orbit number	degrees
<eis_prefix>_phxtof_ssd<#>	Raw count rate from individual SSD	1/s
<eis_prefix>_phxtof_vep	Number of electron events processed and binned by onboard processor per second	1/s
<eis_prefix>_phxtof_start0anode	Count rate from all start anode regions	1/s
<eis_prefix>_phxtof_stop0anode	Count rate from all stop anode regions	1/s
<eis_prefix>_phxtof_pulseheight	Count rate from all start anode regions that satisfy a minimum MCP pulse height	1/s
<eis_prefix>_phxtof_vtofxee	Number of valid energy by time-of-flight (ExTOF) events per second	1/s
<eis_prefix>_phxtof_vtofxphe	Number of valid pulse height by time-of-flight (PHxTOF) events per second	1/s

Exhibit 23. *List of the variables included in the EIS phxtof survey data product.*

Data Parameter	Description	Units
Time_Minus	<support data> Delta from measurement window start to midpoint	s
Time_Plus	<support data> Delta from midpoint to measurement window end	s
<eis_prefix>_electronenergy_duration	<support data> Total exposure time for accumulation	s
<eis_prefix>_electronenergy_deadtime	<support data> Instrument deadtime	s
<eis_prefix>_electronenergy_largepixel	<support data> Instrument large pixel in use (yes/no)	-----
<eis_prefix>_electronenergy_starttai	<support data> Begin measurement window, TAI since 1958	s
<eis_prefix>_electronenergy_midtai	<support data> Nominal measurement time, TAI since 1958	s
<eis_prefix>_electronenergy_endtai	<support data> End measurement window, TAI since 1958	s
<eis_prefix>_electronenergy_spin	<support data> Spacecraft spin number	-----
<eis_prefix>_electronenergy_sector	<support data> Spacecraft spin sector	-----
<eis_prefix>_electronenergy_quality	<support data> Quality word	-----
<eis_prefix>_electronenergy_electron_P<X>_counts_t<#>	Individual telescope (look direction) counts for each energy channel	counts

<eis_prefix>_electronenergy_electron_P<X>_cps_t<#>	Individual telescope (look direction) counts per second for each energy channel	1/s
<eis_prefix>_electronenergy_electron_P<X>_flux_t<#>	Individual telescope (look direction) intensity (flux) for each energy channel	1/(cm^2-s-sr-keV)
<eis_prefix>_electronenergy_dump_counts_t<#>	Individual telescope (look direction) counts dump bin for each energy channel	counts
<eis_prefix>_electronenergy_dump_cps_t<#>	Individual telescope (look direction) counts per second dump bin for each energy channel	1/s
<eis_prefix>_electronenergy_dump_flux_t<#>	Individual telescope (look direction) intensity (flux) dump bin for each energy channel	-----
<eis_prefix>_electronenergy_pitch_angle_t<#>	Pitch angle for individual telescope (look direction)	degrees
<eis_prefix>_electronenergy_look_t<#>	Look direction vector in GSE for individual telescope	-----
<eis_prefix>_electronenergy_b	Magnetic field in BCS coordinates	nT
<eis_prefix>_electronenergy_position_gse	Spacecraft position vector in GSE	km
<eis_prefix>_electronenergy_position_gsm	Spacecraft position vector in GSM	km
<eis_prefix>_electronenergy_moon_gse	Spacecraft-to-moon vector in GSE	km
<eis_prefix>_electronenergy_sc_to_gse	Transformation matrix from SC to GSE coordinates	-----
<eis_prefix>_electronenergy_gse_to_gsm	Transformation matrix from GSE to GSM coordinates	-----
<eis_prefix>_electronenergy_r	Magnitude of radial distance	km
<eis_prefix>_electronenergy_l	L-shell value (dipole approximation)	-----
<eis_prefix>_electronenergy_gse_lat	Latitude in GSE frame	degrees
<eis_prefix>_electronenergy_gse_lon	Longitude in GSE frame	degrees
<eis_prefix>_electronenergy_gsm_lat	Latitude in GSM frame	degrees
<eis_prefix>_electronenergy_gsm_lon	Longitude in GSM frame	degrees
<eis_prefix>_electronenergy_sm_lat	Latitude in SM frame	degrees
<eis_prefix>_electronenergy_sm_lon	Longitude in SM frame	degrees
<eis_prefix>_electronenergy_orbit_ num	Orbit number	degrees
<eis_prefix>_electronenergy_ssd<#>	Raw count rate from individual SSD	1/s
<eis_prefix>_electronenergy_vep	Number of electron events processed and binned by onboard processor per second	1/s
<eis_prefix>_electronenergy_vee	Number of valid electron events per second	1/s

Exhibit 24. *List of the variables included in the EIS electronenergy survey data product.*

6 Detailed FEEPS Data Description

6.1 FEEPS In-Flight Calibration

6.1.1 Sunlight Contamination

As summarized in §0.2a, many of the FEEPS eyes suffer from light contamination, likely due to sunlight and glint coming through foils (on electron eyes) that were perforated during launch. An example of the light contamination is shown in Exhibit 25, which plots FEEPS burst data from electron eye #9 on the bottom deck instrument (note: "top" on *Y*-axis labels is *not* the instrument deck in this figure). The *Y*-axis is the spin sector, the *X*-axis is time, and intensities are plotted in color. This shows how MMS1 (top panel) has a "perfect" eye-9, with no sunlight contamination, while MMS2 (second panel from top), -3 (third panel from top), and -4 (bottom panel) have various sectors affected by sunlight contamination. In this format, contaminated sectors appear as horizontal lines that either have no counts or consistently exhibit much higher or lower counts than surrounding channels. The plots in the right column, marked "Masked", show how those sunlight contaminated sectors can be effectively removed.

Using such FEEPS burst data sector maps, one can identify the affected sectors during any period of the mission on all eyes for the FEEPS instruments. Sector masks were produced after a survey of contamination conducted during August-September 2015. These masks flag all sectors that were affected by contamination during the period examined. Exhibit 26 shows the contaminated sectors (*X*-axis) from each eye (*Y*-axis) for each of the spacecraft during this period. Yellow blocks identify affected eyes/sectors, while blue blocks are good, unaffected eyes/sectors.

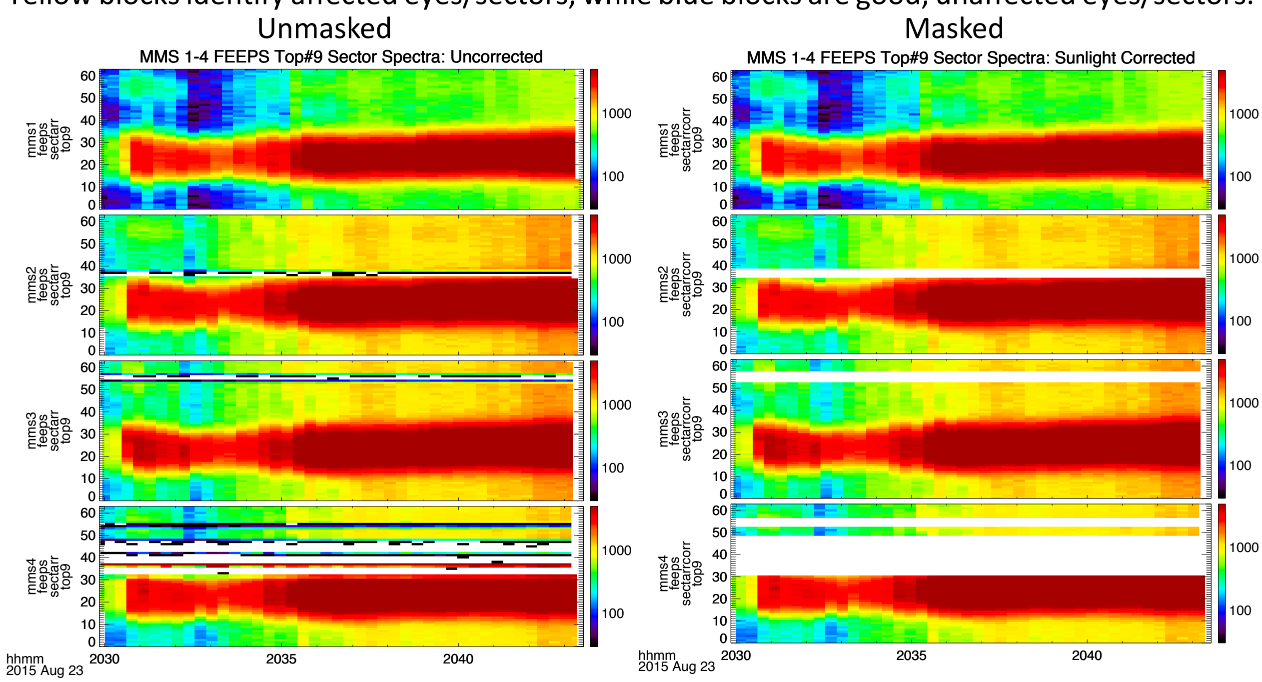


Exhibit 25. *An example of the effects of sunlight contamination in the FEEPS burst data. This data shows intensity for time versus spin sector for each spacecraft (MMS1-4 from top to bottom) for 23 August 2015. The white and black splotched horizontal lines permeating the MMS2-4 data on the left shows the effect of sunlight contamination on certain sectors. The panels on the right show the same data with the affected sectors appropriately masked.*

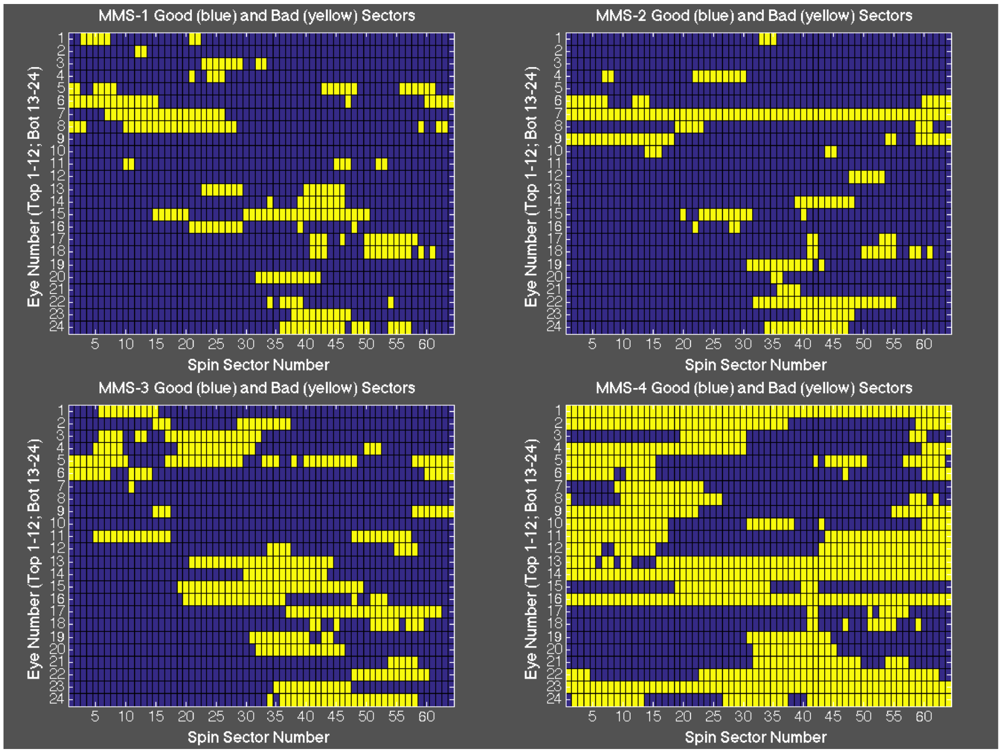


Exhibit 26. *Mapping of those sectors from each eye affected (yellow) and unaffected (blue) by sunlight contamination on each spacecraft during August-September 2015.*

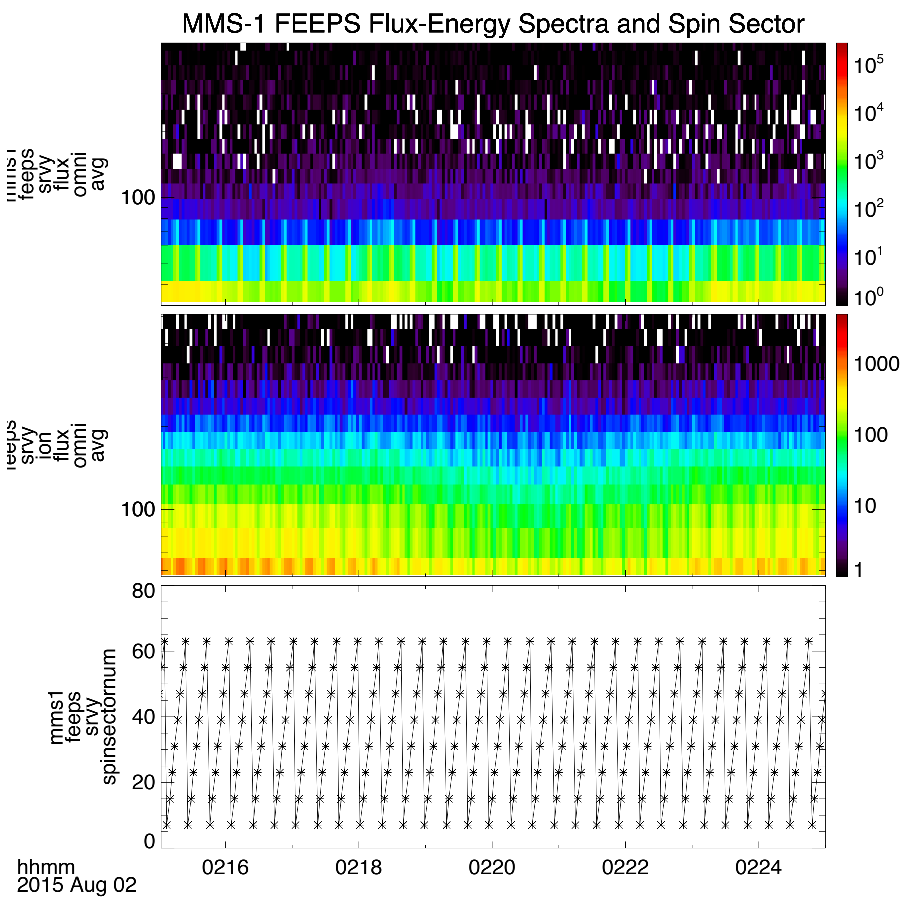


Exhibit 27. *Example of the effect of sunlight contamination on FEEPS survey data. Omni-directionally-averaged energy spectra for electrons and ions are shown in the top and middle panels, respectively. The bottom panel shows the spin sector.*

Upload/Change	MMS1 Execution	MMS2 Execution	MMS3 Execution	MMS4 Execution
1st onboard table[1]	2016-08-05/20:05:00	2016-08-05/21:17:40	2016-08-06/02:04:13	2016-08-06/03:46:46
Fix to 1st onboard table[2]	2016-09-14/16:15:00	2016-09-14/17:30:00	2016-09-14/18:44:51	2016-09-14/19:59:46
Fix to 1st onboard table[3]	2017-02-16/19:30:05	2017-02-14/23:29:54	2017-02-17/14:20:14	2017-02-17/15:50:07
2nd onboard table (top)	2017-08-16/19:40:06	2017-08-16/21:45:38	2017-08-16/23:41:07	2017-08-17/13:34:12
2nd onboard table (bottom)	2017-08-16/19:44:03	2017-08-16/21:48:55	2017-08-16/23:44:24	2017-08-17/13:31:15
3rd onboard table	2018-01-24/01:43:31	2018-01-24/22:08:27	2018-01-18/16:11:39	2018-01-18/17:54:34

[1]*incorrectly applied masking table for top units to the count observations on both top and bottom units, failed to mask live-time correction (LTC), & applied the masking tables to all burst count observations;* [2]*removed masking of survey & burst count observations in the bottom units - no changes to top units;* [3]*implemented correct unit specific onboard masking to survey counts and LTC along with removing masking of burst count observations;*

Exhibit 28. *History of sunlight contamination masking tables implemented to-date onboard the MMS spacecraft.*

Exhibit 27 presents an example of the effect of the light contamination in survey data. From top to bottom it shows: electron omnidirectional averaged energy spectra from survey data, ion omnidirectional averaged energy spectra from fast survey data, and the spin sector number from a period 02 August 2015. Note that the spin-tone signatures in the electron and ion data are the result of sunlight contamination in the survey data product. This is masked onboard via masking tables loaded onto the spacecraft periodically since August 2016. Exhibit 28 records the onboard masking tables used to-date to mask sunlight-contaminated raw spin sectors in the onboard production of FEEPS fast and slow survey data. ***For data products prior to these changes, please refer to the data quality flags when using any FEEPS survey data for science. Sunlight contamination is removable from burst data products using masks identified from sector masks as described above for Exhibits 25-26.***

6.1.2 FEEPS Data Quality Flags

MMS FEEPS data quality indicators allow the scientific community access to the most comprehensive FEEPS data set without being overwhelmed by detailed characteristics of the instrument health. A simple system of quality indicators is advantageous for encouraging the correct usage of the MMS FEEPS data by scientists within and outside the MMS team. The system of data quality indicators is identical for Burst and Survey data products, although some quality indicators will be unique to Survey data and unused for Burst data. A quality indicator is assigned to each time step for each FEEPS eye (i.e., telescope).

The FEEPS data quality indicators combine knowledge of contamination features in the FEEPS observations and onboard operations. FEEPS Team members have used the high resolution FEEPS observations (burst mode) to identify sun contamination features which are dependent on the spacecraft spin, i.e., dependency on spin sector. Onboard spin sector masking has been implemented before the summation of high-resolution observations into low resolution Survey sectors to avoid the irreversible contamination of Survey data. Furthermore, the FEEPS instrument is routinely operated in an instrument calibration mode which is unsuitable for scientific research. In summary, the quality indicators are a product of the comparison between sun contamination tables, onboard masking tables, and onboard calibration times.

The highest resolution FEEPS observations are recorded in Burst mode at a rate of 64 samples per spin, which are referred to as spin sectors. In Survey mode, the FEEPS observations are recorded at an eighth of the Burst mode resolution by summing the 64 spin sectors into 8 Survey sectors per spin onboard the spacecraft. Removing sunlight contamination from the Survey data requires masking contaminated spin sectors onboard before summing into Survey sectors and transmitting to Earth. The EPD Data Products Guide contains a more detailed description of the sunlight contamination. A spin sector mask table can be updated on each of the MMS spacecraft to avoid contamination in future Survey mode observations and since the Burst data contains the highest available angular resolution, onboard Burst masking is not necessary.

The time dependent contamination tables and onboard masking tables share a similar structure where both tables for a single spacecraft consist of a 64x24 table, with the 64 rows representing the 64 spin sectors in a spin and each column representing a FEEPS eye/sensor (top 1 – 12 and bottom 1 – 12). In a contamination table, each individual entry consists of a "0" or "1", representing "clean" or "contaminated". In an onboard masking table, each individual entry consists of 4 digits where each digit indicates if each of the following values have been masked (=1) or not masked (=0): Survey counts, Survey LTC, Burst counts, Burst LTC. The onboard calibration time periods are marked with the binary L1a variable "…calstate". The corresponding time dependent contamination table and onboard masking table is included in the FEEPS data products for transparency in the assignment of the quality indicators. *The more advanced user does have the option to pick and choose whether to accept these quality indicators, although, this more advanced option is highly discouraged without the guidance of a FEEPS team member.*

An overview of the quality indicators can be found below and is followed by a detailed description of each quality indicator assignment. While the following description uses a color scheme to indicate data quality, similar to a traffic light, the quality indicators are reported as integers in the data products. The quality indicators are listed in order from the best quality data to the worst quality data:

- **Green (Quality Indicator = 0):** No contaminated or masked spin sectors (best data quality); used for both Survey and Burst products
- **Yellow (Quality Indicator = 1):** Onboard masking successfully applied to a total of 1 to 7 spin sectors before summing into one Survey sector and contains no contamination (caution, not all spin sectors observed); used only for Survey products with onboard masking applied
- **Orange (Quality Indicator = 2):** Survey sector contains less than 50% contaminated spin sectors which were not masked onboard (warning, data contains contamination); used only for Survey products
- **Red (Quality Indicator = 3):** Survey sector contains 50% or greater contaminated spin sectors which were not masked onboard OR onboard masking applied to all 8 spin sectors within the Survey sector OR contaminated spin sector in Burst data (data not recommended for scientific use); used for both Survey and Burst products
- **Grey (Quality Indicator = 4):** Survey or Burst sector contains FEEPS calibration testing data (data not recommended for scientific use); used for both Survey and Burst products

The Burst observations only use the Green, Red, and Grey quality indicators. If a Burst spin sector is contaminated and/or masked in any way (counts or LTC), the spin sector is recorded with the Red quality indicator (1) and is not recommended for scientific use. Without contamination and masking, a Burst spin sector is recorded with the Green quality indicator (0), representing the best available data. The Grey quality indicator will be described later in this document. Using the contamination table and onboard masking table to assign a quality indicator is described in pseudo code below. Remember, the onboard masking table entry contains 4 digits, with the third and fourth digit recording the Burst count masking and LTC masking.

```
IF (Contamination EQ 1) OR (Onboard[3] EQ 1) OR (Onboard[4] EQ 1) THEN Quality = 1
```

All five quality indicators (Green, Yellow, Orange, Red, Grey) can be assigned to the Survey observations. In Survey mode, eight spin sectors are accumulated onboard into a single Survey sector and thus, onboard masking is used to remove contamination, although, not always successfully. If a Survey sector does not contain any contaminated or masked spin sectors, then the Survey sector is recorded with the Green quality indicator (0) and represents the best available data. If a Survey sector does not contain any contamination and includes a total of 1 to 7 masked spin sectors, then the Survey sector is recorded with the Yellow quality indicator (2). The Yellow quality indicator shows the user that not all spin sectors have been observed within the Survey sector and thus the data will not represent the full angular coverage of the Survey sector. Both Green and Yellow quality indicators do not contain any contamination and are encouraged for scientific use.

Since the onboard masking began in August 2016 and the contamination identification has evolved over time, not all contamination has been masked onboard before summing into Survey sectors. The Orange quality indicator (3) is recorded when a Survey sector contains less than 50% contaminated spin sectors. The user should exercise caution when using Orange quality data and is encouraged to contact FEEPS team members for guidance when publishing scientific results. Lastly, data recorded with the Red quality indicator (1) is not recommended for scientific use. The Red quality indicator applies to any Survey sector which contains more than 50%. The Grey quality indicator will be described later in this document.

As a reminder, an onboard masking table entry contains 4 digits, with the first and second digit recording the Survey count masking and LTC masking. The onboard masking must include counts and LTC to be considered completely masked and a partially masked spin sector is considered the same as a contaminated spin sector. Partially masked spin sectors are primarily a concern during the initial implementation of onboard masking between July 2016 and February 2017. Assigning a quality indicator to a Survey sector requires examining the contamination and masking status of each of the eight summed spin sectors and comparing the total masked and contaminated spin sectors with the above quality indicator criteria. Again, pseudo code for the Survey quality indicator is below.

```
Clean = 0 ;Initialize clean spin sector counter at 0
Bad = 0 ;Initialize bad spin sector counter at 0
Masked = 0 ;Initialize masked spin sector counter at 0
FOR spinSect = 1, 8 DO BEGIN
    Onboard = the 4-digit Onboard masking table entry for current spin sector
    Contamination = the sun contamination table entry for the current spin sector
    IF (Onboard[1] NE Onboard[2]) THEN BEGIN
        Bad = Bad + 1 ; Increment bad counter bc current spin sector is not completely masked
        STOP
    ENDIF ELSE IF (Contamination EQ 1 ) AND ( Onboard[1] EQ 0 ) THEN BEGIN
            Bad = Bad + 1 ; Increment bad counter bc current contaminated spin sector is not
        masked
        STOP
```

```
        ENDIF ELSE IF (Onboard[1] EQ 1 ) THEN BEGIN
            Masked = Masked + 1 ; Increment masked counter
            STOP
            ENDIF ELSE Clean = Clean + 1 ; Increment clean counter
    ENDFOR
    IF (Clean EQ 8 ) THEN BEGIN
        Quality = 0 ; All 8 spin sectors are clean, assign Green quality indicator
    ENDIF ELSE IF (Masked EQ 8 ) THEN BEGIN
        Quality = 1 ;All 8 spin sectors are masked, assign Red quality indicator
    ENDIF ELSE IF ( (Bad EQ 0) & (Masked > 0) ) THEN BEGIN
        Quality = 2 ;Masked sectors total between 1 and 7, assign Yellow quality indicator
    ENDIF ELSE IF ( Bad/(Bad+Clean) < 0.5 ) THEN BEGIN
        Quality = 3 ;Less than 50% spin sectors are bad, assign Orange quality indicator
    ENDIF ELSE Quality = 1 ;50% or greater spin sectors are bad, assign Red quality indicator
```

The final input into the assignment of data quality indicators is the timing of onboard calibration testing. The time intervals when the FEEPS instrument is in the onboard calibration mode are marked with the binary L1a variable "…calstate" and the data is not suitable for scientific research. If a Burst sector or Survey sector contain calibration testing data, the sector is assigned the Grey quality indicator (4).

```
IF (calstate EQ 1 ) THEN Quality = 4
```

These data quality indicators allow for quick sorting of the FEEPS data for scientific use, although the more advanced user does have the option to pick and choose whether to accept these quality indicators. This more advanced option is highly discouraged, but is provided to show transparency in the assignment of the quality indicators. The FEEPS data sets contain variables for the sun contamination tables, onboard masking tables, and calibration mode, such that the data quality indicators can be reproduced by others.

6.1.3 Energy Channel Thresholds

As summarized in §0.2e, the first energy channels (i.e., lowest energy channel, with index 0) from FEEPS ion and electron instruments have their threshold set very near to or within the noise threshold. These channels from most (but not all) eyes are thus measuring noise and should not be used for scientific data analysis. Additionally, on several of the FEEPS eyes, the second and/or third energy channels require threshold adjustment as of 04 April 2016. An example of the effects from this are shown in the energy distributions in Exhibit 29. Here, energy distributions (in count rates) from a relatively isotropic angular distribution with high-count-rates from 02 August 2015 are shown from each of the electron eyes on MMS1. Different colors show the different eyes, as labeled, with eyes from the top deck instrument (e.g., T10) shown with stars and those from the bottom deck instrument (e.g., B10) shown with diamonds. These distributions show how the first few channels on several eyes are counting lower than the other eyes. These affected eyes should not be included for science analysis.

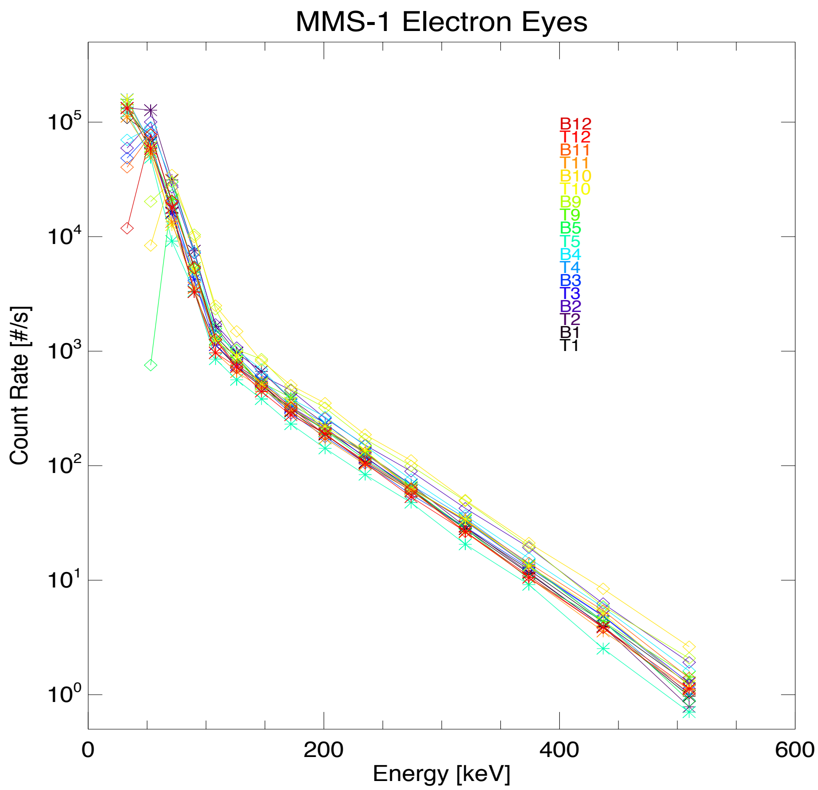


Exhibit 29. *Energy spectra of the 24 individual FEEPS eyes (3 ion and 9 electron per sensor, top and bottom) on MMS1. The reduced count rates observed in the lowest energy channel for multiple eyes is contributed to thresholds set near or at the sensor's noise threshold.*

6.1.4 FEEPS Flat-Fielding

As summarized in §0.2c, A flat-fielding effort has been made to ensure that FEEPS data from all of the FEEPS telescopes are consistent. For the electron data, the correction involves a linear shift in the energy channels. For these, a constant energy is added or subtracted to each eye's energy channels' limits (see energy ranges provided in Exhibit 30). That method was deemed necessary due to the nature of the disagreement from eye to eye, which showed a stronger disagreement at lower energies. Also, the effectiveness of this correction was clear during injection events, in which energy dispersed enhancements of electrons were observed by the spacecraft. To determine these energy offset corrections, we examined a number of periods (>10) during 2016 that exhibited steady local plasma conditions and high FEEPS count rates. During these periods, we compared the 1-spin averaged omnidirectional distributions from all of the eyes on each spacecraft and calculated the correction offsets that brought each closest to the mean distribution from all eyes. That method assumes that the correction factors are all spread around the true distribution, which is confirmed by comparisons to the EIS average distributions from the same times (e.g., Exhibit 31).

The same method was applied for the ion eyes, though (interestingly) the corrections for the ion eyes were best when applied using a gain (i.e., multiplicative) factor. These correction factors are listed in tables collected in Exhibit 31 for each FEEPS eye, unit, and spacecraft. Eyes labeled "Bad Eyes" are returning all null counts as of April 2020. Exhibit 31 also indicates which eyes are affected by noisy channels 1 and 2.

MMS1																
Eye: Top-1			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.4	43.6	62.9	82.2	99.0	115.9	135.1	159.2	185.7	217.0	253.1	296.5	344.6	402.4	472.2	549.3
Upper	41.2	60.5	79.8	96.6	113.5	132.7	156.8	183.3	214.6	250.7	294.1	342.2	400.0	469.8	546.9	585.4
Center	32.8	52.1	71.3	89.4	106.2	124.3	146.0	171.3	200.2	233.9	273.6	319.3	372.3	436.1	509.6	567.4
Eye: Top-2			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 7 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	Ch14	Ch15
Lower	32.8	49.6	68.7	87.9	107.1	123.9	143.0	167.0	193.4	224.5	260.5	303.6	351.6	411.5	478.6	557.7
Upper	47.2	66.3	85.5	104.7	121.5	140.6	164.6	191.0	222.1	258.1	301.2	349.2	409.1	476.2	555.3	586.5
Center	40.0	58.0	77.1	96.3	114.3	132.3	153.8	179.0	207.8	241.3	280.9	326.4	380.3	443.9	517.0	572.1
Eye: Top-3			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 16 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	41.3	60.0	78.8	97.6	116.3	132.7	151.5	174.9	200.7	233.6	268.7	310.9	362.5	418.8	486.8	566.5
Upper	57.7	76.5	95.2	114.0	130.4	149.1	172.6	198.4	231.2	266.4	308.6	360.2	416.4	484.4	564.2	571.2
Center	49.5	68.2	87.0	105.8	123.4	140.9	162.0	186.7	216.0	250.0	288.7	335.6	389.5	451.6	525.5	568.9
Eye: Top-4			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	38.0	58.8	77.2	95.7	114.1	130.2	151.0	174.0	199.3	231.6	268.5	309.9	360.6	418.3	485.1	563.4
Upper	56.5	74.9	93.3	111.8	127.9	148.6	171.7	197.0	229.3	266.2	307.6	358.3	415.9	482.8	561.1	574.9
Center	47.3	66.8	85.3	103.7	121.0	139.4	161.3	185.5	214.3	248.9	288.1	334.1	388.3	450.5	523.1	569.2
Eye: Top-5			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	38.9	58.1	77.3	94.1	113.4	130.2	149.4	173.5	199.9	231.2	267.2	310.5	358.6	416.2	485.9	562.9
Upper	55.7	74.9	91.7	111.0	127.8	147.0	171.1	197.5	228.7	264.8	308.1	356.1	413.8	483.5	560.5	594.1
Center	47.3	66.5	84.5	102.5	120.6	138.6	160.2	185.5	214.3	248.0	287.6	333.3	386.2	449.9	523.2	578.5
Eye: Top-6			***Species: Ions***									***Note: Gain = 0.7; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	48.8	67.6	86.3	105.1	123.9	145.3	166.8	190.9	220.4	255.2	292.8	338.4	392.0	451.0	520.7	601.1
Upper	64.9	83.7	102.4	121.2	142.6	164.1	188.2	217.7	252.6	290.1	335.7	389.3	448.3	518.0	598.4	611.8
Center	56.9	75.6	94.4	113.2	133.3	154.7	177.5	204.3	236.5	272.7	314.2	363.8	420.1	484.5	559.5	606.5
Eye: Top-7			***Species: Ions***									***Note: Gain = 2.5; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	48.9	68.9	86.1	106.2	126.3	143.5	166.4	192.2	220.8	255.2	295.4	338.4	390.0	450.1	518.9	599.2
Upper	66.1	83.3	103.3	123.4	140.6	163.5	189.3	218.0	252.4	292.5	335.5	387.1	447.3	516.1	596.3	650.8
Center	57.5	76.1	94.7	114.8	133.4	153.5	177.9	205.1	236.6	273.9	315.4	362.7	418.6	483.1	557.6	625.0
Eye: Top-8			***Species: Ions***									***Note: Gain = 1.5; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	49.1	69.6	87.1	107.6	125.2	142.7	166.1	192.5	221.7	253.9	294.9	338.7	391.4	449.9	520.1	599.1
Upper	66.7	84.2	104.7	122.2	139.8	163.2	189.5	218.8	251.0	291.9	335.8	388.5	447.0	517.2	596.2	654.7
Center	57.9	76.9	95.9	114.9	132.5	153.0	177.8	205.6	236.3	272.9	315.3	363.6	419.2	483.6	558.2	626.9
Eye: Top-9			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	39.5	58.8	75.7	95.0	114.3	131.2	150.4	172.1	201.1	230.0	268.6	309.6	360.2	418.1	485.6	565.1
Upper	56.4	73.3	92.6	111.9	128.7	148.0	169.7	198.7	227.6	266.2	307.2	357.8	415.6	483.2	562.7	591.6
Center	48.0	66.1	84.1	103.4	121.5	139.6	160.1	185.4	214.3	248.1	287.9	333.7	387.9	450.6	524.1	578.4
Eye: Top-10			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	39.1	58.2	77.3	94.1	113.2	129.9	151.4	172.9	199.2	230.3	268.5	309.1	359.3	416.7	486.0	564.8
Upper	55.8	74.9	91.7	110.8	127.5	149.0	170.5	196.8	227.9	266.1	306.7	356.9	414.3	483.6	562.4	581.6
Center	47.5	66.6	84.5	102.4	120.4	139.5	161.0	184.9	213.5	248.2	287.6	333.0	386.8	450.1	524.2	573.2
Eye: Top-11			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 17 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	42.3	61.1	79.8	98.5	117.2	133.6	152.3	175.8	203.8	234.3	269.4	313.8	363.0	421.5	487.0	566.6
Upper	58.7	77.5	96.2	114.9	131.3	150.0	173.4	201.5	231.9	267.0	311.5	360.6	419.2	484.7	564.3	576.0
Center	50.5	69.3	88.0	106.7	124.3	141.8	162.9	188.6	217.9	250.6	290.4	337.2	391.1	453.1	525.6	571.3
Eye: Top-12			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 15 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	39.7	58.1	76.4	97.1	115.4	131.5	152.1	175.1	200.3	232.4	269.1	310.4	360.9	418.2	487.1	565.0
Upper	55.8	74.2	94.8	113.1	129.2	149.8	172.8	198.0	230.1	266.8	308.1	358.6	415.9	484.8	562.8	571.9
Center	47.8	66.1	85.6	105.1	122.3	140.7	162.5	186.6	215.2	249.6	288.6	334.5	388.4	451.5	524.9	568.5

Eye: Bot-1			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	25.4	43.9	62.5	81.0	99.5	115.6	136.5	159.6	185.0	217.4	254.4	296.0	344.6	402.4	471.8	550.4
Upper	41.6	60.1	78.6	97.1	113.3	134.1	157.3	182.7	215.1	252.1	293.7	342.3	400.1	469.5	548.1	566.6
Center	33.5	52.0	70.5	89.0	106.4	124.9	146.9	171.2	200.1	234.8	274.1	319.2	372.4	436.0	510.0	558.5
Eye: Bot-2			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	40.2	56.7	75.5	94.4	113.3	129.8	151.0	172.2	200.5	231.1	266.5	309.0	358.5	417.4	485.8	563.6
Upper	54.3	73.2	92.0	110.9	127.4	148.6	169.8	198.1	228.8	264.2	306.6	356.1	415.1	483.4	561.2	577.7
Center	47.2	64.9	83.8	102.6	120.3	139.2	160.4	185.2	214.6	247.6	286.6	332.5	386.8	450.4	523.5	570.7
Eye: Bot-3			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	38.0	57.3	76.7	96.0	113.0	129.9	149.3	173.5	200.1	231.5	267.8	309.0	359.8	417.9	485.6	563.0
Upper	54.9	74.3	93.6	110.6	127.5	146.8	171.0	197.7	229.1	265.4	306.6	357.4	415.4	483.2	560.6	589.7
Center	46.4	65.8	85.1	103.3	120.2	138.4	160.2	185.6	214.6	248.5	287.2	333.2	387.6	450.5	523.1	576.4
Eye: Bot-4			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 13 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	37.2	57.0	74.3	94.2	114.0	128.8	148.6	173.4	198.2	230.4	267.5	309.7	359.2	416.2	483.0	562.3
Upper	54.5	71.9	91.7	111.5	126.4	146.2	170.9	195.7	227.9	265.1	307.2	356.7	413.7	480.6	559.8	604.4
Center	45.9	64.4	83.0	102.8	120.2	137.5	159.8	184.6	213.1	247.7	287.4	333.2	386.4	448.4	521.4	583.4
Eye: Bot-5			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	38.9	58.0	77.2	96.4	113.1	129.9	151.4	173.0	199.3	230.5	266.4	309.5	359.8	417.3	484.3	563.4
Upper	55.6	74.8	94.0	110.7	127.5	149.0	170.6	196.9	228.1	264.0	307.1	357.4	414.9	481.9	561.0	582.5
Center	47.3	66.4	85.6	103.5	120.3	139.5	161.0	185.0	213.7	247.2	286.8	333.5	387.3	449.6	522.7	573.0
Eye: Bot-6			***Species: Ions***									***Note: Gain = 0.9; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	51.2	69.8	88.4	106.9	125.5	144.1	165.3	191.8	221.0	255.5	295.2	340.3	390.7	451.7	520.7	600.3
Upper	67.1	85.7	104.3	122.8	141.4	162.6	189.1	218.3	252.8	292.6	337.7	388.1	449.1	518.1	597.6	608.2
Center	59.2	77.7	96.3	114.9	133.4	153.3	177.2	205.1	236.9	274.0	316.5	364.2	419.9	484.9	559.2	604.3
Eye: Bot-7			***Species: Ions***									***Note: Gain = 2.2; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	49.2	67.9	86.6	105.2	123.9	145.3	166.6	190.6	220.0	254.7	294.7	340.1	390.8	452.2	521.6	599.0
Upper	65.2	83.9	102.6	121.3	142.6	164.0	188.0	217.3	252.0	292.1	337.4	388.1	449.5	518.9	596.3	604.3
Center	57.2	75.9	94.6	113.2	133.3	154.6	177.3	204.0	236.0	273.4	316.1	364.1	420.2	485.5	558.9	601.6
Eye: Bot-8			***Species: Ions***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	49.4	68.3	87.1	106.0	124.9	143.8	165.4	192.3	222.0	254.4	294.8	338.0	391.9	451.2	521.3	599.5
Upper	65.6	84.4	103.3	122.2	141.1	162.7	189.6	219.3	251.7	292.1	335.3	389.2	448.5	518.6	596.9	626.5
Center	57.5	76.4	95.2	114.1	133.0	153.2	177.5	205.8	236.8	273.2	315.0	363.6	420.2	484.9	559.1	613.0
Eye: Bot-9			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	39.7	57.2	77.1	94.5	114.4	131.9	149.3	174.2	199.1	231.5	266.3	308.7	358.5	418.2	485.5	565.2
Upper	54.7	74.6	92.0	111.9	129.4	146.8	171.7	196.6	229.0	263.8	306.2	356.0	415.7	483.0	562.7	602.5
Center	47.2	65.9	84.5	103.2	121.9	139.3	160.5	185.4	214.0	247.7	286.3	332.3	387.1	450.6	524.1	583.8
Eye: Bot-10			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	40.0	58.5	77.0	95.5	114.0	130.1	151.0	174.1	199.5	231.9	266.6	310.5	359.0	416.8	483.9	564.8
Upper	56.2	74.7	93.2	111.7	127.8	148.6	171.8	197.2	229.6	264.2	308.2	356.7	414.5	481.6	562.5	567.1
Center	48.1	66.6	85.1	103.6	120.9	139.4	161.4	185.6	214.5	248.1	287.4	333.6	386.8	449.2	523.2	566.0
Eye: Bot-11			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.4	43.4	62.3	81.3	100.3	116.9	135.9	159.6	185.7	216.5	254.5	294.8	344.6	403.9	470.4	551.0
Upper	41.0	60.0	79.0	97.9	114.5	133.5	157.2	183.3	214.2	252.1	292.4	342.3	401.6	468.0	548.6	572.4
Center	32.7	51.7	70.6	89.6	107.4	125.2	146.6	171.5	199.9	234.3	273.5	318.5	373.1	436.0	509.5	561.7
Eye: Bot-12			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	39.3	58.0	76.8	95.5	114.2	130.6	149.3	172.7	200.8	231.2	266.3	310.8	360.0	418.5	484.0	563.6
Upper	55.7	74.4	93.1	111.9	128.3	147.0	170.4	198.5	228.9	264.0	308.5	357.6	416.1	481.7	561.3	577.6
Center	47.5	66.2	84.9	103.7	121.2	138.8	159.8	185.6	214.9	247.6	287.4	334.2	388.1	450.1	522.6	570.6

OMNI			**Species: Electrons**									***Note: Gain = 1.0; Eoffset = 14 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	36.5	55.2	73.9	92.7	111.3	127.8	147.6	170.8	197.2	228.6	264.9	307.2	356.9	414.9	482.5	561.5
Upper	52.8	71.5	90.4	108.9	125.4	145.2	168.4	194.8	226.2	262.5	304.8	354.5	412.6	480.1	559.1	581.2
Center	44.7	63.4	82.1	100.8	118.4	136.5	158.0	182.8	211.7	245.5	284.8	330.8	384.7	447.5	520.8	571.3
OMNI			***Species: Ions***									***Note: Gain = 0.84; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	49.4	68.7	86.9	106.2	124.9	144.1	166.1	191.7	221.0	254.8	294.6	339.0	391.1	451.0	520.6	599.7
Upper	65.9	84.2	103.4	122.2	141.4	163.3	189.0	218.2	252.1	291.9	336.2	388.4	448.3	517.8	597.0	626.1
								MMS2								
Eye: Top-1			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -1 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	23.9	43.5	60.7	80.3	99.9	114.6	134.2	158.7	185.7	215.1	251.8	296.0	345.0	401.4	470.0	548.4
Upper	41.0	58.2	77.8	97.4	112.1	131.7	156.2	183.2	212.6	249.4	293.5	342.5	398.9	467.5	546.0	597.5
Center	32.5	50.8	69.2	88.8	106.0	123.2	145.2	171.0	199.1	232.2	272.7	319.3	372.0	434.5	508.0	572.9
Eye: Top-2			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 6 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	31.5	48.8	68.6	88.4	105.8	123.1	142.9	165.2	192.4	222.1	259.2	301.3	350.8	410.2	477.1	556.3
Upper	46.4	66.2	86.0	103.3	120.6	140.4	162.7	189.9	219.6	256.8	298.8	348.4	407.8	474.6	553.8	615.7
Center	38.9	57.5	77.3	95.9	113.2	131.8	152.8	177.6	206.0	239.4	279.0	324.8	379.3	442.4	515.4	586.0
Eye: Top-3			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -2 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	22.1	42.1	59.7	79.8	97.3	114.9	135.0	157.5	182.6	215.2	250.4	293.0	343.2	400.9	468.6	548.9
Upper	39.6	57.2	77.3	94.8	112.4	132.5	155.0	180.1	212.7	247.9	290.5	340.7	398.4	466.1	546.4	611.6
Center	30.8	49.7	68.5	87.3	104.9	123.7	145.0	168.8	197.7	231.5	270.4	316.8	370.8	433.5	507.5	580.3
Eye: Top-4			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -1 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.7	41.9	61.6	81.2	98.4	115.6	135.2	157.3	184.3	216.3	253.1	294.9	344.0	402.9	469.2	547.8
Upper	39.4	59.1	78.7	95.9	113.1	132.8	154.9	181.9	213.8	250.7	292.4	341.5	400.5	466.8	545.4	599.4
Center	32.1	50.5	70.1	88.6	105.8	124.2	145.1	169.6	199.1	233.5	272.8	318.2	372.2	434.8	507.3	573.6
Eye: Top-5			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	26.1	43.0	62.3	81.6	100.9	117.8	137.1	158.8	185.4	216.8	253.0	296.4	344.7	402.6	470.2	549.8
Upper	40.6	59.9	79.2	98.5	115.4	134.7	156.4	183.0	214.4	250.5	294.0	342.3	400.2	467.7	547.4	593.2
Center	33.4	51.5	70.8	90.1	108.2	126.3	146.8	170.9	199.9	233.7	273.5	319.3	372.4	435.2	508.8	571.5
Eye: Top-6			***Species: Ions***									***Note: Gain = 1.3; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	51.1	69.8	88.5	107.2	125.9	144.6	166.0	192.7	222.1	254.2	294.3	339.7	390.5	451.9	521.4	598.9
Upper	67.1	85.9	104.6	123.3	142.0	163.3	190.1	219.5	251.5	291.6	337.0	387.8	449.2	518.7	596.2	601.5
Center	59.1	77.8	96.5	115.2	133.9	154.0	178.0	206.1	236.8	272.9	315.6	363.7	419.9	485.3	558.8	600.2
Eye: Top-7			***Species: Ions***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	48.9	67.8	86.6	105.5	124.3	143.1	167.4	191.6	221.2	256.2	293.9	339.7	390.8	450.0	520.0	600.8
Upper	65.1	83.9	102.8	121.6	140.5	164.7	188.9	218.5	253.5	291.2	337.0	388.1	447.3	517.3	598.1	622.3
Center	57.0	75.9	94.7	113.5	132.4	153.9	178.1	205.1	237.4	273.7	315.4	363.9	419.1	483.7	559.0	611.5
Eye: Top-8			***Species: Ions***									***Note: Gain = 0.8; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	48.9	67.9	86.8	105.7	124.7	143.6	165.2	192.3	222.0	254.5	295.0	338.3	392.4	451.9	519.5	600.6
Upper	65.2	84.1	103.0	122.0	140.9	162.5	189.6	219.3	251.8	292.3	335.6	389.7	449.2	516.8	597.9	624.9
Center	57.1	76.0	94.9	113.8	132.8	153.1	177.4	205.8	236.9	273.4	315.3	364.0	420.8	484.3	558.7	612.8
Eye: Top-9			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 4 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	29.5	46.7	66.3	85.9	103.1	120.2	139.9	164.4	188.9	220.8	257.6	299.3	348.4	407.2	475.9	554.4
Upper	44.2	63.8	83.5	100.6	117.8	137.4	161.9	186.5	218.4	255.2	296.9	345.9	404.8	473.5	552.0	608.4
Center	36.8	55.2	74.9	93.3	110.4	128.8	150.9	175.4	203.6	238.0	277.2	322.6	376.6	440.4	513.9	581.4
Eye Eye: Top-10			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -1 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	22.9	42.8	62.6	79.9	99.8	114.7	134.5	159.3	184.1	216.3	253.5	295.7	345.3	402.3	469.2	548.6
Upper	40.3	60.1	77.5	97.3	112.2	132.0	156.8	181.6	213.8	251.0	293.2	342.8	399.8	466.8	546.1	610.6
Center	31.6	51.4	70.0	88.6	106.0	123.3	145.7	170.5	199.0	233.7	273.4	319.2	372.5	434.5	507.7	579.6

Eye: Top-11			Species: Electrons									Note: Gain = 1.0; Eoffset = -1 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	23.4	43.1	60.4	80.1	99.9	114.7	134.4	159.1	183.8	215.9	252.9	294.9	344.3	403.5	470.1	549.1
Upper	40.6	57.9	77.7	97.4	112.2	132.0	156.7	181.3	213.4	250.5	292.4	341.8	401.0	467.7	546.7	608.4
Center	32.0	50.5	69.0	88.8	106.1	123.3	145.6	170.2	198.6	233.2	272.7	318.3	372.6	435.6	508.4	578.8

Eye: Top-12			Species: Electrons									Note: Bad Eye				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	25.9	44.0	62.2	80.3	101.1	116.6	137.4	158.1	186.6	217.7	254.0	295.5	344.7	404.3	471.7	549.5
Upper	41.5	59.6	77.7	98.5	114.0	134.8	155.5	184.0	215.1	251.4	292.9	342.1	401.7	469.1	546.9	635.0
Center	33.7	51.8	70.0	89.4	107.5	125.7	146.4	171.0	200.9	234.5	273.4	318.8	373.2	436.7	509.3	592.2

Eye: Bot-1			Species: Electrons									Note: Gain = 1.0; Eoffset = -2 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	22.1	42.4	60.1	80.4	98.2	115.9	133.6	156.5	184.3	214.8	250.2	293.3	344.0	402.3	468.2	546.8
Upper	39.8	57.6	77.9	95.6	113.4	131.1	153.9	181.8	212.2	247.7	290.8	341.5	399.8	465.7	544.3	620.3
Center	31.0	50.0	69.0	88.0	105.8	123.5	143.8	169.1	198.3	231.2	270.5	317.4	371.9	434.0	506.3	583.6

Eye: Bot-2			Species: Electrons									Note: Bad Eye				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	25.0	44.2	63.5	80.3	99.5	116.3	135.6	159.6	186.0	217.3	253.3	296.6	344.6	402.3	472.0	548.9
Upper	41.8	61.1	77.9	97.1	113.9	133.2	157.2	183.6	214.9	250.9	294.2	342.2	399.9	469.6	546.5	592.2
Center	33.4	52.6	70.7	88.7	106.7	124.7	146.4	171.6	200.4	234.1	273.7	319.4	372.3	436.0	509.3	570.5

Eye: Bot-3			Species: Electrons									Note: Gain = 1.0; Eoffset = -2 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	23.9	41.3	61.1	78.5	98.4	115.7	135.6	157.9	182.7	214.9	252.1	294.3	343.9	401.0	468.0	547.3
Upper	38.8	58.7	76.0	95.9	113.2	133.1	155.4	180.2	212.5	249.7	291.8	341.4	398.5	465.5	544.9	606.9
Center	31.4	50.0	68.6	87.2	105.8	124.4	145.5	169.0	197.6	232.3	272.0	317.9	371.2	433.2	506.4	577.1

Eye: Bot-4			Species: Electrons									Note: Gain = 1.0; Eoffset = 0 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	25.3	44.6	61.5	80.8	100.2	117.1	136.4	158.2	184.7	216.1	252.4	295.9	346.6	404.6	469.8	549.6
Upper	42.2	59.1	78.4	97.8	114.7	134.0	155.7	182.3	213.7	250.0	293.5	344.2	402.2	467.4	547.1	597.9
Center	33.7	51.9	70.0	89.3	107.4	125.5	146.1	170.2	199.2	233.1	272.9	320.0	374.4	436.0	508.5	573.7

Eye: Bot-5			Species: Electrons									Note: Gain = 1.0; Eoffset = -2 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	22.5	42.2	59.4	79.0	98.6	115.8	135.4	157.5	184.5	214.0	250.8	295.0	344.1	400.5	469.2	547.8
Upper	39.7	56.9	76.5	96.2	113.4	133.0	155.1	182.1	211.5	248.3	292.5	341.6	398.1	466.8	545.3	599.3
Center	31.1	49.5	67.9	87.6	106.0	124.4	145.3	169.8	198.0	231.2	271.7	318.3	371.1	433.6	507.3	573.5

Eye: Bot-6			Species: Ions									Note: Gain = 1.4; Eoffset = 15 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	64.3	82.4	103.5	121.5	139.6	157.7	181.8	205.9	236.0	269.1	308.3	353.5	404.7	464.9	534.2	615.5
Upper	79.4	100.5	118.5	136.6	154.7	178.8	202.9	233.0	266.1	305.3	350.5	401.7	461.9	531.2	612.5	678.8
Center	71.8	91.4	111.0	129.1	147.1	168.2	192.3	219.4	251.1	287.2	329.4	377.6	433.3	498.0	573.3	647.1

Eye: Bot-7			Species: Ions									Note: Bad Eye				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	50.3	69.3	88.3	107.4	123.7	145.4	167.1	191.6	221.5	254.1	294.9	338.3	390.0	452.5	520.4	599.2
Upper	66.6	85.6	104.6	121.0	142.7	164.4	188.9	218.8	251.4	292.1	335.6	387.3	449.8	517.7	596.5	623.7
Center	58.5	77.5	96.5	114.2	133.2	154.9	178.0	205.2	236.4	273.1	315.2	362.8	419.9	485.1	558.5	611.4

Eye: Bot-8			Species: Ions									Note: Gain = 1.6; Eoffset = 15 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	65.7	84.7	103.7	120.0	139.0	158.0	182.5	207.0	236.8	269.5	310.2	353.7	405.3	465.1	535.8	614.6
Upper	82.0	101.0	117.3	136.3	155.3	179.8	204.2	234.1	266.7	307.5	351.0	402.6	462.4	533.0	611.8	639.0
Center	73.8	92.8	110.5	128.2	147.2	168.9	193.4	220.5	251.8	288.5	330.6	378.2	433.9	499.1	573.8	626.8

Eye: Bot-9			Species: Electrons									Note: Gain = 1.0; Eoffset = -1 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	22.9	42.5	62.2	79.3	99.0	116.1	135.7	157.8	184.8	216.7	253.5	295.2	344.2	403.1	469.3	550.2
Upper	40.1	59.7	76.9	96.5	113.7	133.3	155.4	182.3	214.2	251.0	292.7	341.7	400.6	466.8	547.8	601.7
Center	31.5	51.1	69.5	87.9	106.3	124.7	145.5	170.1	199.5	233.8	273.1	318.5	372.4	434.9	508.5	576.0

Eye: Bot-10			Species: Electrons									Note: Gain = 1.0; Eoffset = -2 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	22.6	42.7	60.3	80.4	98.0	115.5	133.1	158.3	183.4	216.0	251.2	293.9	344.2	402.0	469.8	547.7
Upper	40.2	57.7	77.8	95.4	113.0	130.6	155.7	180.9	213.5	248.7	291.4	341.7	399.5	467.3	545.2	613.1
Center	31.4	50.2	69.1	87.9	105.5	123.1	144.4	169.6	198.5	232.4	271.3	317.8	371.8	434.7	507.5	580.4

Eye: Bot-11			Species: Electrons									Note: Gain = 1.0; Eoffset = -1 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	25.1	42.4	62.2	79.6	99.4	116.7	136.5	158.8	186.1	215.8	252.9	295.0	344.6	401.5	470.9	550.1
Upper	39.9	59.8	77.1	96.9	114.2	134.1	156.4	183.6	213.3	250.5	292.6	342.1	399.1	468.4	547.7	607.1
Center	32.5	51.1	69.7	88.2	106.8	125.4	146.4	171.2	199.7	233.1	272.8	318.6	371.8	435.0	509.3	578.6

Eye: Bot-12			Species: Electrons									Note: Bad Eye				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	24.3	44.5	62.2	82.4	100.1	117.8	135.5	158.2	186.0	216.3	254.2	294.6	345.2	403.3	471.5	549.8
Upper	42.0	59.7	79.9	97.6	115.3	133.0	155.7	183.5	213.8	251.7	292.1	342.6	400.8	469.0	547.3	615.5

OMNI			Species: Electrons									Note: Gain = 1.0; Eoffset = -1 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	24.6	43.5	62.0	81.0	99.8	116.6	135.9	159.0	185.4	216.6	253.1	295.5	345.1	403.1	470.6	549.5
Upper	41.0	59.5	78.5	97.3	114.1	133.5	156.5	182.9	214.1	250.7	293.1	342.6	400.7	468.2	547.0	608.3
Center	32.8	51.5	70.3	89.1	106.9	125.0	146.2	170.9	199.7	233.6	273.1	319.1	372.9	435.6	508.8	578.9

OMNI			Species: Ions									Note: Gain = 1.0; Eoffset = 0 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	54.9	73.6	92.9	111.2	129.5	148.8	171.7	196.8	226.6	259.6	299.4	343.9	395.6	456.0	525.2	604.9
Upper	70.9	90.2	108.5	126.8	146.0	168.9	194.1	223.9	256.8	296.7	341.1	392.8	453.3	522.4	602.2	631.7
Center	62.9	81.9	100.7	119.0	137.8	158.8	182.9	210.4	241.7	278.1	320.3	368.4	424.4	489.2	563.7	618.3

MMS3

Eye: Top-1			Species: Electrons								Note: Bad Eye					
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	24.6	44.6	62.1	82.0	99.5	117.0	136.9	159.4	186.9	216.8	254.2	296.7	346.6	404.0	471.4	548.8
Upper	42.1	59.6	79.5	97.0	114.5	134.4	156.9	184.4	214.3	251.8	294.2	344.1	401.5	468.9	546.3	613.7
Center	33.4	52.1	70.8	89.5	107.0	125.7	146.9	171.9	200.6	234.3	274.2	320.4	374.1	436.5	508.8	581.2

Eye: Top-2			Species: Electrons								Note: Bad Eye					
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	26.1	43.5	63.5	80.9	100.9	115.8	135.8	158.2	185.6	218.0	252.9	295.3	345.2	402.5	469.8	549.6
Upper	41.0	61.0	78.4	98.4	113.3	133.3	155.7	183.1	215.6	250.5	292.8	342.7	400.0	467.4	547.1	612.0
Center	33.6	52.3	71.0	89.7	107.1	124.6	145.7	170.7	200.6	234.2	272.9	319.0	372.6	434.9	508.5	580.8

Eye: Top-3			Species: Electrons									Note: Gain = 1.0; Eoffset = 2 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	26.8	46.9	64.5	82.1	102.2	119.8	137.3	162.4	187.6	220.2	255.3	298.0	348.3	406.0	473.8	551.7
Upper	44.4	62.0	79.6	99.7	117.2	134.8	159.9	185.0	217.7	252.8	295.5	345.7	403.5	471.3	549.1	624.5
Center	35.6	54.5	72.0	90.9	109.7	127.3	148.6	173.7	202.6	236.5	275.4	321.9	375.9	438.7	511.5	588.1

Eye: Top-4			Species: Electrons									Note: Gain = 1.0; Eoffset = -1 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	23.0	43.4	61.2	81.5	99.3	114.5	134.9	157.8	185.7	216.2	251.8	295.0	343.3	401.8	470.4	549.2
Upper	40.8	58.6	79.0	96.7	112.0	132.3	155.2	183.2	213.7	249.3	292.5	340.8	399.3	467.9	546.7	620.4
Center	31.9	51.0	70.1	89.1	105.6	123.4	145.0	170.5	199.7	232.7	272.1	317.9	371.3	434.8	508.6	584.8

Eye: Top-5			Species: Electrons									Note: Gain = 1.0; Eoffset = -1 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	19.3	39.6	57.3	75.1	95.3	110.6	130.8	153.7	181.5	212.0	247.5	290.6	341.3	399.6	465.5	544.1
Upper	37.0	54.8	72.5	92.8	108.0	128.3	151.1	179.0	209.4	244.9	288.0	338.7	397.1	463.0	541.6	607.5
Center	28.2	47.2	64.9	83.9	101.7	119.4	141.0	166.3	195.5	228.5	267.8	314.7	369.2	431.3	503.5	575.8

Eye: Top-6			Species: Ions									Note: Gain = 0.7; Eoffset = 0 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	49.9	68.4	86.9	105.3	123.8	144.9	166.0	192.4	221.4	255.7	295.3	340.2	390.3	451.0	519.6	598.7
Upper	65.8	84.2	102.7	121.2	142.3	163.4	189.8	218.8	253.1	292.7	337.5	387.7	448.3	516.9	596.1	619.8
Center	57.8	76.3	94.8	113.2	133.0	154.1	177.9	205.6	237.3	274.2	316.4	363.9	419.3	484.0	557.8	609.3

Eye: Top-7			Species: Ions									Note: Gain = 0.8; Eoffset = 0 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	50.1	68.9	87.7	106.4	125.2	144.0	165.4	192.2	221.7	253.9	294.1	339.7	390.7	452.4	519.4	599.9
Upper	66.2	85.0	103.7	122.5	141.3	162.7	189.6	219.1	251.2	291.5	337.1	388.0	449.7	516.7	597.2	610.6
Center	58.2	76.9	95.7	114.5	133.2	153.4	177.5	205.7	236.5	272.7	315.6	363.9	420.2	484.5	558.3	605.2

Eye: Top-8			***Species: Ions***									***Note: Gain = 1.0; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	48.9	69.9	88.3	106.8	125.2	143.6	167.3	191.0	219.9	254.1	293.6	338.3	391.0	451.5	519.9	598.9
Upper	67.3	85.7	104.1	122.5	141.0	164.6	188.3	217.3	251.5	291.0	335.7	388.3	448.9	517.3	596.2	614.6
Center	58.1	77.8	96.2	114.6	133.1	154.1	177.8	204.1	235.7	272.5	314.6	363.3	419.9	484.4	558.1	606.8
Eye: Top-9			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -3 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	22.9	40.4	60.3	77.8	97.7	112.7	132.6	155.1	182.5	214.9	249.8	292.2	342.0	399.3	469.1	546.4
Upper	37.9	57.8	75.3	95.2	110.2	130.1	152.6	180.0	212.4	247.3	289.7	339.5	396.9	466.7	543.9	611.2
Center	30.4	49.1	67.8	86.5	104.0	121.4	142.6	167.5	197.4	231.1	269.7	315.8	369.4	433.0	506.5	578.8
Eye: Top-10			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -1 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.2	41.8	62.0	79.7	99.8	115.0	135.2	157.9	185.6	215.9	251.2	294.1	344.5	402.5	470.7	548.9
Upper	39.3	59.5	77.1	97.3	112.4	132.6	155.3	183.1	213.4	248.7	291.6	342.0	400.0	468.1	546.3	622.0
Center	31.7	50.6	69.6	88.5	106.1	123.8	145.2	170.5	199.5	232.3	271.4	318.0	372.3	435.3	508.5	585.4
Eye: Top-11			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -3 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	22.6	40.2	60.2	77.7	97.8	112.8	132.8	155.3	182.9	212.9	250.5	293.1	343.1	400.7	468.3	546.0
Upper	37.7	57.7	75.2	95.2	110.3	130.3	152.8	180.4	210.4	248.0	290.6	340.6	398.2	465.8	543.5	613.6
Center	30.1	48.9	67.7	86.5	104.0	121.5	142.8	167.9	196.7	230.5	270.5	316.8	370.7	433.3	505.9	579.8
Eye: Top-12			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	25.1	43.3	61.6	82.4	100.6	116.2	137.1	157.9	186.6	217.8	254.3	295.9	345.4	402.7	470.4	551.1
Upper	40.7	59.0	79.8	98.0	113.6	134.5	155.3	184.0	215.2	251.7	293.3	342.8	400.1	467.8	548.5	639.7
Center	32.9	51.1	70.7	90.2	107.1	125.4	146.2	170.9	200.9	234.7	273.8	319.4	372.7	435.2	509.5	595.4

Eye: Bot-1			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -7 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	19.1	36.7	54.3	74.3	91.9	109.5	129.6	152.2	179.8	209.9	247.6	287.7	337.9	395.7	463.5	543.8
Upper	34.2	51.7	71.8	89.4	107.0	127.1	149.7	177.3	207.4	245.1	285.2	335.4	393.2	461.0	541.3	609.1
Center	26.6	44.2	63.0	81.9	99.4	118.3	139.6	164.7	193.6	227.5	266.4	311.6	365.6	428.3	502.4	576.4
Eye: Bot-2			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.4	44.1	61.3	81.1	100.8	115.6	135.3	160.0	187.1	216.7	253.6	295.6	344.9	404.0	470.6	549.5
Upper	41.6	58.9	78.6	98.3	113.1	132.8	157.5	184.6	214.2	251.2	293.1	342.4	401.6	468.2	547.0	608.7
Center	33.0	51.5	70.0	89.7	106.9	124.2	146.4	172.3	200.6	233.9	273.4	319.0	373.2	436.1	508.8	579.1
Eye: Bot-3			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -5 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	19.5	39.6	57.2	77.2	94.8	112.4	132.4	155.0	180.1	212.7	247.8	290.5	340.7	398.4	466.1	543.9
Upper	37.1	54.7	74.7	92.3	109.9	129.9	152.5	177.6	210.2	245.3	288.0	338.2	395.9	463.6	541.4	609.1
Center	28.3	47.1	66.0	84.8	102.3	121.1	142.5	166.3	195.2	229.0	267.9	314.3	368.3	431.0	503.7	576.5
Eye: Bot-4			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -6 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	20.0	37.8	55.5	75.7	93.4	111.1	131.3	154.1	179.4	212.2	247.7	290.6	338.7	396.9	465.1	543.5
Upper	35.2	52.9	73.2	90.9	108.6	128.8	151.6	176.8	209.7	245.1	288.1	336.2	394.3	462.6	541.0	614.4
Center	27.6	45.3	64.3	83.3	101.0	119.9	141.4	165.5	194.5	228.7	267.9	313.4	366.5	429.7	503.1	578.9
Eye: Bot-5			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.1	44.0	61.4	81.4	98.8	116.2	136.2	158.6	186.0	215.9	253.2	295.6	345.4	402.7	469.9	549.6
Upper	41.5	58.9	78.9	96.3	113.7	133.7	156.1	183.5	213.4	250.7	293.1	342.9	400.2	467.4	547.2	614.4
Center	32.8	51.5	70.1	88.8	106.3	124.9	146.1	171.0	199.7	233.3	273.2	319.2	372.8	435.1	508.5	582.0
Eye: Bot-6			***Species: Ions***									***Note: Gain = 0.9; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	48.9	70.0	88.5	107.0	125.5	144.0	165.1	191.5	220.6	254.9	294.6	339.5	392.3	450.4	519.1	601.0
Upper	67.4	85.8	104.3	122.8	141.3	162.5	188.9	217.9	252.3	291.9	336.8	389.7	447.8	516.5	598.4	614.2
Center	58.1	77.9	96.4	114.9	133.4	153.2	177.0	204.7	236.4	273.4	315.7	364.6	420.1	483.5	558.8	607.6

Eye: Bot-7			***Species: Ions***									***Note: Gain = 0.9; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	49.0	67.8	86.6	105.4	124.2	143.0	167.2	191.4	221.0	256.0	293.6	339.3	390.4	452.2	519.4	600.0
Upper	65.1	83.9	102.7	121.5	140.4	164.6	188.7	218.3	253.3	290.9	336.6	387.7	449.5	516.7	597.3	616.2
Center	57.0	75.8	94.7	113.5	132.3	153.8	178.0	204.9	237.1	273.4	315.1	363.5	419.9	484.4	558.4	608.1
Eye: Bot-8			***Species: Ions***									***Note: Gain = 1.3; Eoffset = 12 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	62.7	81.4	100.1	118.8	137.4	156.1	177.5	204.2	233.5	268.2	305.6	350.9	404.3	463.0	532.4	612.5
Upper	78.7	97.4	116.1	134.8	153.5	174.8	201.5	230.8	265.5	302.9	348.3	401.7	460.4	529.8	609.8	612.5
Center	70.7	89.4	108.1	126.8	145.4	165.5	189.5	217.5	249.5	285.6	326.9	376.3	432.3	496.4	571.1	612.5
Eye: Bot-9			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	25.6	44.3	63.1	81.8	100.5	116.6	135.3	159.4	186.2	218.3	253.1	295.9	346.8	403.0	469.9	550.2
Upper	41.6	60.4	79.1	97.8	113.9	132.6	156.7	183.5	215.6	250.4	293.2	344.1	400.3	467.2	547.5	662.6
Center	33.6	52.3	71.1	89.8	107.2	124.6	146.0	171.5	200.9	234.4	273.2	320.0	373.5	435.1	508.7	606.4
Eye: Bot-10			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -2 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	23.1	41.1	61.6	79.6	97.6	115.5	133.5	156.6	184.9	215.7	251.6	292.7	344.0	400.5	469.8	546.8
Upper	38.5	59.1	77.0	95.0	113.0	130.9	154.0	182.3	213.1	249.0	290.1	341.5	397.9	467.3	544.3	626.4
Center	30.8	50.1	69.3	87.3	105.3	123.2	143.8	169.4	199.0	232.3	270.9	317.1	371.0	433.9	507.0	586.6
Eye: Bot-11			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.8	42.8	63.4	81.5	99.5	117.6	135.6	158.8	187.1	218.1	254.1	295.4	344.3	403.6	470.6	550.5
Upper	40.2	60.9	78.9	96.9	115.0	133.0	156.2	184.6	215.5	251.6	292.8	341.8	401.0	468.1	547.9	630.4
Center	32.5	51.8	71.2	89.2	107.3	125.3	145.9	171.7	201.3	234.8	273.5	318.6	372.7	435.8	509.3	590.5
Eye: Bot-12			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -3 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	23.0	41.1	59.1	77.1	97.8	113.2	133.8	157.0	182.8	213.8	249.8	293.7	342.6	399.3	468.9	546.3
Upper	38.5	56.5	74.6	95.2	110.6	131.3	154.5	180.2	211.2	247.3	291.1	340.1	396.8	466.4	543.7	631.3
Center	30.7	48.8	66.8	86.2	104.2	122.2	144.2	168.6	197.0	230.5	270.5	316.9	369.7	432.8	506.3	588.8
OMNI			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -3 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	23.5	42.1	60.7	79.6	98.4	114.8	134.4	157.4	184.5	215.6	251.7	294.0	343.8	401.4	469.3	548.0
Upper	39.6	58.2	77.1	95.9	112.3	131.9	154.9	182.0	213.1	249.2	291.5	341.2	398.9	466.8	545.5	621.4
Center	31.5	50.1	68.9	87.7	105.3	123.4	144.7	169.7	198.8	232.4	271.6	317.6	371.3	434.1	507.4	584.7
OMNI			***Species: Ions***									***Note: Gain = 1.0; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	51.6	71.1	89.7	108.3	126.9	145.9	168.1	193.8	223.0	257.1	296.1	341.3	393.2	453.4	521.6	601.8
Upper	68.4	87.0	105.6	124.2	143.3	165.4	191.1	220.4	254.5	293.5	338.7	390.5	450.8	519.0	599.2	614.7
Center	60.0	79.0	97.6	116.3	135.1	155.7	179.6	207.1	238.8	275.3	317.4	365.9	422.0	486.2	560.4	608.2
MMS4																
Eye: Top-1			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.3	44.2	61.6	81.5	98.9	116.2	136.1	158.5	185.8	218.1	252.8	295.1	344.7	404.3	471.4	550.9
Upper	41.7	59.1	79.0	96.4	113.8	133.6	156.0	183.3	215.6	250.4	292.6	342.2	401.9	468.9	548.4	610.5
Center	33.0	51.7	70.3	88.9	106.3	124.9	146.0	170.9	200.7	234.2	272.7	318.7	373.3	436.6	509.9	580.7
Eye: Top-2			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	26.0	43.3	63.1	80.4	100.2	117.5	137.2	159.5	186.7	216.3	253.4	295.4	344.9	404.2	470.9	550.0
Upper	40.8	60.6	77.9	97.7	115.0	134.8	157.0	184.2	213.9	250.9	293.0	342.4	401.7	468.4	547.5	609.3
Center	33.4	52.0	70.5	89.0	107.6	126.1	147.1	171.8	200.3	233.6	273.2	318.9	373.3	436.3	509.2	579.7
Eye: Top-3			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -2 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	21.8	42.4	60.5	78.5	99.1	114.6	135.2	158.4	184.2	215.1	251.2	295.0	344.0	400.7	470.3	547.6
Upper	39.9	57.9	75.9	96.6	112.0	132.6	155.8	181.6	212.5	248.6	292.4	341.4	398.1	467.7	545.0	632.6
Center	30.8	50.2	68.2	87.5	105.6	123.6	145.5	170.0	198.4	231.9	271.8	318.2	371.0	434.2	507.6	590.1

Eye: Top-4			Species: Electrons									Note: Gain = 1.0; Eoffset = -5 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	19.0	38.5	57.9	77.4	94.4	111.5	131.0	155.3	182.1	211.3	247.8	291.6	340.3	398.7	466.8	544.7
Upper	36.0	55.5	75.0	92.0	109.0	128.5	152.9	179.6	208.8	245.3	289.2	337.8	396.2	464.4	542.3	595.8
Center	27.5	47.0	66.5	84.7	101.7	120.0	141.9	167.5	195.4	228.3	268.5	314.7	368.3	431.5	504.5	570.3

Eye: Top-5			Species: Electrons									Note: Gain = 1.0; Eoffset = -5 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	20.2	39.9	57.2	76.9	94.1	111.3	131.0	153.2	180.3	212.3	249.3	291.1	340.4	399.5	466.0	544.8
Upper	37.4	54.7	74.4	91.6	108.9	128.6	150.8	177.8	209.9	246.8	288.7	337.9	397.1	463.6	542.4	599.0
Center	28.8	47.3	65.8	84.2	101.5	120.0	140.9	165.5	195.1	229.6	269.0	314.5	368.7	431.5	504.2	571.9

Eye: Top-6			Species: Ions									Note: Gain = 0.8; Eoffset = 0 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	49.9	68.4	86.9	105.3	123.8	144.9	166.0	192.4	221.4	255.7	295.3	340.2	390.3	451.0	519.6	598.7
Upper	65.8	84.2	102.7	121.2	142.3	163.4	189.8	218.8	253.1	292.7	337.5	387.7	448.3	516.9	596.1	622.5
Center	57.8	76.3	94.8	113.2	133.0	154.1	177.9	205.6	237.3	274.2	316.4	363.9	419.3	484.0	557.8	610.6

Eye: Top-7			Species: Ions									Note: Bad Eye				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	50.4	68.6	86.9	105.2	126.1	144.3	165.2	191.3	220.1	254.0	293.2	340.2	392.4	449.8	520.3	601.3
Upper	66.0	84.3	102.6	123.5	141.7	162.6	188.7	217.5	251.4	290.6	337.6	389.8	447.2	517.7	598.7	609.1
Center	58.2	76.5	94.7	114.3	133.9	153.5	177.0	204.4	235.7	272.3	315.4	365.0	419.8	483.8	559.5	605.2

Eye: Top-8			Species: Ions									Note: Gain = 1.0; Eoffset = 0 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	49.8	68.5	87.1	105.7	124.3	142.9	164.2	190.8	220.1	254.6	291.9	337.1	390.3	451.4	520.6	597.7
Upper	65.8	84.4	103.0	121.7	140.3	161.5	188.1	217.4	252.0	289.2	334.4	387.6	448.8	517.9	595.1	611.0
Center	57.8	76.4	95.1	113.7	132.3	152.2	176.2	204.1	236.0	271.9	313.1	362.3	419.5	484.7	557.8	604.4

Eye: Top-9			Species: Electrons									Note: Gain = 1.0; Eoffset = -1 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	24.7	41.9	61.5	81.1	98.3	115.5	135.1	157.2	184.2	216.1	252.9	294.6	343.6	402.5	471.2	549.7
Upper	39.4	59.1	78.7	95.9	113.0	132.7	154.7	181.7	213.6	250.4	292.1	341.2	400.1	468.8	547.3	601.2
Center	32.1	50.5	70.1	88.5	105.7	124.1	144.9	169.5	198.9	233.2	272.5	317.9	371.9	435.6	509.2	575.5

Eye: Top-10			Species: Electrons									Note: Gain = 1.0; Eoffset = -3 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	21.5	41.0	60.5	77.6	97.1	114.2	133.7	155.6	182.5	214.2	250.7	292.2	343.4	399.5	467.8	545.8
Upper	38.6	58.1	75.2	94.7	111.7	131.2	153.2	180.0	211.7	248.3	289.8	341.0	397.1	465.3	543.4	594.6
Center	30.0	49.5	67.8	86.1	104.4	122.7	143.4	167.8	197.1	231.2	270.2	316.6	370.2	432.4	505.6	570.2

Eye: Top-11			Species: Electrons									Note: Gain = 1.0; Eoffset = -6 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	19.2	37.6	56.0	74.4	92.8	111.2	129.6	153.3	179.5	211.1	247.9	289.9	339.9	397.7	466.0	544.9
Upper	35.0	53.4	71.8	90.2	108.6	127.0	150.6	176.9	208.5	245.3	287.3	337.3	395.1	463.4	542.3	639.5
Center	27.1	45.5	63.9	82.3	100.7	119.1	140.1	165.1	194.0	228.2	267.6	313.6	367.5	430.6	504.2	592.2

Eye: Top-12			Species: Electrons									Note: Gain = 1.0; Eoffset = -6 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	19.7	37.3	57.5	75.1	92.8	110.4	130.5	153.2	180.9	211.2	246.4	289.3	339.7	397.6	465.6	543.7
Upper	34.8	55.0	72.6	90.2	107.9	128.0	150.7	178.4	208.7	243.9	286.8	337.1	395.1	463.1	541.2	611.8
Center	27.3	46.1	65.0	82.7	100.3	119.2	140.6	165.8	194.8	227.6	266.6	313.2	367.4	430.4	503.4	577.8

Eye: Bot-1			Species: Electrons									Note: Gain = 1.0; Eoffset = -8 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	17.5	36.8	53.7	73.0	92.3	109.2	128.5	150.3	176.8	208.2	244.4	287.9	338.6	396.5	464.1	541.4
Upper	34.4	51.3	70.6	89.9	106.8	126.1	147.9	174.4	205.8	242.0	285.5	336.2	394.1	461.7	539.0	582.4
Center	25.9	44.0	62.1	81.5	99.6	117.7	138.2	162.3	191.3	225.1	265.0	312.0	366.4	429.1	501.6	561.9

Eye: Bot-2			Species: Electrons									Note: Bad Eye				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	24.5	43.6	62.8	81.9	101.0	117.8	136.9	158.4	184.8	215.9	254.1	294.8	345.0	402.4	471.8	550.7
Upper	41.2	60.4	79.5	98.6	115.4	134.5	156.1	182.4	213.5	251.7	292.4	342.6	400.0	469.4	548.3	591.4
Center	32.9	52.0	71.1	90.3	108.2	126.2	146.5	170.4	199.1	233.8	273.3	318.7	372.5	435.9	510.1	571.1

Eye: Bot-3			Species: Electrons									Note: Gain = 1.0; Eoffset = -2 keV				
Energy	Ch0	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14	Ch15
Lower	24.2	41.0	60.3	79.5	98.7	115.6	134.8	156.5	182.9	214.2	250.3	293.5	344.0	401.8	469.1	548.5
Upper	38.6	57.9	77.1	96.3	113.2	132.4	154.1	180.5	211.8	247.8	291.1	341.6	399.4	466.7	546.0	589.3
Center	31.4	49.4	68.7	87.9	106.0	124.0	144.4	168.5	197.3	231.0	270.7	317.6	371.7	434.2	507.6	568.9

Eye: Bot-4			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	25.9	44.9	61.6	80.7	99.7	116.4	135.4	159.2	185.4	216.4	254.5	294.9	344.9	404.4	471.1	549.7
Upper	42.6	59.2	78.3	97.3	114.0	133.0	156.8	183.0	214.0	252.1	292.5	342.5	402.1	468.7	547.3	585.4
Center	34.2	52.1	69.9	89.0	106.8	124.7	146.1	171.1	199.7	234.2	273.5	318.7	373.5	436.6	509.2	567.5
Eye: Bot-5			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.9	44.5	61.8	81.5	101.2	116.0	135.7	160.3	184.9	216.9	253.8	295.7	344.9	404.0	470.5	549.3
Upper	42.1	59.3	79.0	98.7	113.5	133.2	157.8	182.4	214.4	251.4	293.2	342.5	401.6	468.1	546.9	603.5
Center	33.5	51.9	70.4	90.1	107.3	124.6	146.7	171.4	199.7	234.1	273.5	319.1	373.3	436.1	508.7	576.4
Eye: Bot-6			***Species: Ions***									***Note: Gain = 0.8; Eoffset = -8 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	42.7	61.3	80.0	98.7	117.3	136.0	157.3	184.0	213.3	248.0	285.3	330.7	384.0	442.7	512.0	592.0
Upper	58.7	77.3	96.0	114.7	133.3	154.7	181.3	210.7	245.3	282.7	328.0	381.3	440.0	509.3	589.3	610.7
Center	50.7	69.3	88.0	106.7	125.3	145.3	169.3	197.3	229.3	265.3	306.7	356.0	412.0	476.0	550.7	601.3
Eye: Bot-7			***Species: Ions***									***Note: Gain = 0.6; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	49.3	67.9	86.5	105.1	123.7	144.9	166.2	192.8	222.0	253.8	293.7	338.8	392.0	450.4	519.4	599.1
Upper	65.3	83.9	102.4	121.0	142.3	163.5	190.1	219.3	251.2	291.0	336.2	389.3	447.7	516.8	596.5	615.1
Center	57.3	75.9	94.5	113.1	133.0	154.2	178.1	206.0	236.6	272.4	314.9	364.1	419.8	483.6	558.0	607.1
Eye: Bot-8			***Species: Ions***									***Note: Gain = 0.9; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	49.8	68.5	87.2	105.8	124.5	143.2	167.2	191.2	220.5	255.2	295.2	340.5	391.2	449.8	519.2	599.2
Upper	65.8	84.5	103.2	121.8	140.5	164.5	188.5	217.8	252.5	292.5	337.8	388.5	447.2	516.5	596.5	612.5
Center	57.8	76.5	95.2	113.8	132.5	153.8	177.8	204.5	236.5	273.8	316.5	364.5	419.2	483.2	557.8	605.8
Eye: Bot-9			***Species: Electrons***									***Note: Gain = 1.5; Eoffset = -2 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	23.8	41.1	60.8	78.1	97.8	115.1	134.8	157.1	184.2	213.8	250.8	292.8	344.6	401.4	468.0	547.0
Upper	38.6	58.3	75.6	95.4	112.6	132.4	154.6	181.7	211.4	248.4	290.3	342.2	398.9	465.6	544.5	606.2
Center	31.2	49.7	68.2	86.7	105.2	123.7	144.7	169.4	197.8	231.1	270.6	317.5	371.8	433.5	506.3	576.6
Eye: Bot-10			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.8	44.1	63.3	80.2	99.5	116.3	135.6	159.6	186.1	217.4	253.5	296.9	345.0	402.8	470.2	549.6
Upper	41.7	60.9	77.8	97.0	113.9	133.2	157.2	183.7	215.0	251.1	294.5	342.6	400.4	467.8	547.2	590.6
Center	33.3	52.5	70.6	88.6	106.7	124.7	146.4	171.7	200.6	234.3	274.0	319.7	372.7	435.3	508.7	570.1
Eye: Bot-11			***Species: Electrons***									***Note: Bad Eye***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	24.0	43.5	63.1	80.2	99.8	116.9	136.5	158.5	185.4	217.2	253.9	295.5	344.4	403.1	471.6	549.9
Upper	41.1	60.6	77.8	97.3	114.5	134.0	156.0	182.9	214.7	251.4	293.0	341.9	400.7	469.1	547.4	606.1
Center	32.5	52.1	70.4	88.8	107.1	125.5	146.3	170.7	200.1	234.3	273.5	318.7	372.5	436.1	509.5	578.0
Eye: Bot-12			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -4 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	22.1	40.0	57.9	78.3	96.2	111.5	132.0	155.0	183.1	213.8	249.5	293.0	341.5	400.3	466.8	546.0
Upper	37.4	55.3	75.8	93.6	109.0	129.4	152.4	180.5	211.2	247.0	290.4	339.0	397.8	464.2	543.4	620.1
Center	29.8	47.6	66.8	86.0	102.6	120.5	142.2	167.8	197.1	230.4	270.0	316.0	369.6	432.3	505.1	583.0
OMNI			***Species: Electrons***									***Note: Gain = 1.0; Eoffset = -3 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	22.8	41.5	60.2	78.8	97.6	114.5	134.0	156.8	183.5	214.5	251.1	293.4	343.1	401.3	469.0	547.6
Upper	39.1	57.8	76.3	95.2	112.0	131.6	154.3	181.0	212.1	248.6	290.9	340.7	398.8	466.6	545.1	604.1
Center	30.9	49.6	68.3	87.0	104.8	123.0	144.2	168.9	197.8	231.6	271.0	317.0	371.0	433.9	507.1	575.9
OMNI			***Species: Ions***									***Note: Gain = 1.0; Eoffset = 0 keV***				
Energy	*Ch0*	*Ch1*	*Ch2*	*Ch3*	*Ch4*	*Ch5*	*Ch6*	*Ch7*	*Ch8*	*Ch9*	*Ch10*	*Ch11*	*Ch12*	*Ch13*	*Ch14*	*Ch15*
Lower	48.7	67.2	85.8	104.3	123.3	142.7	164.4	190.4	219.6	253.6	292.4	337.9	390.0	449.2	518.5	598.0
Upper	64.6	83.1	101.7	120.6	140.1	161.7	187.8	216.9	250.9	289.8	335.3	387.4	446.5	515.9	595.4	613.5
Center	56.6	75.2	93.7	112.5	131.7	152.2	176.1	203.7	235.2	271.7	313.8	362.6	418.3	482.5	556.9	605.7

Exhibit 31. *Summary of the eyes flat-fielding correction factors for each FEEPS eye, as well as indication of "BAD EYES" which are returning NAN data values as of April 2020.*

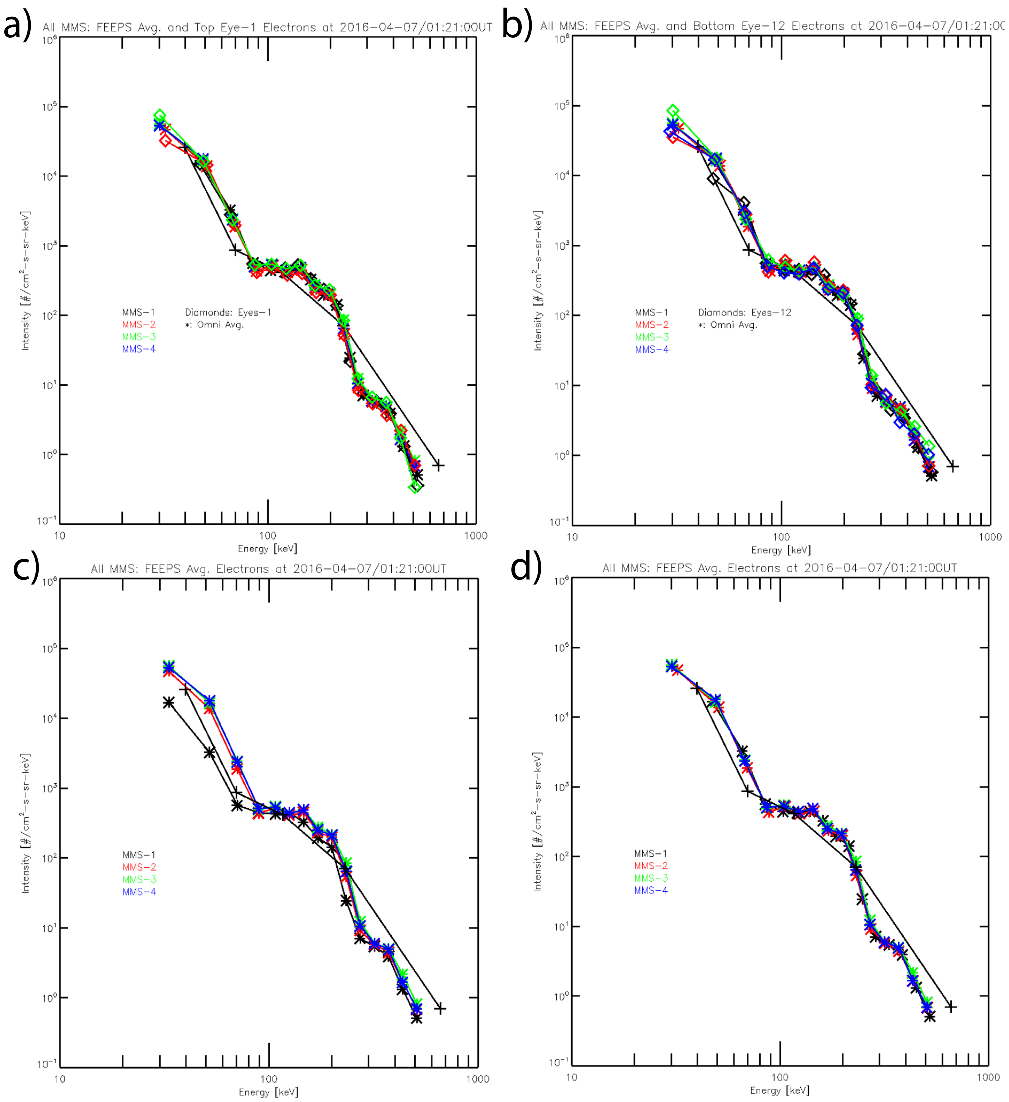


Exhibit 31. *FEEPS 1-spin-average omni-directional energy spectra compared with the spectrum from a) Top Eye-1 and b) Bottom Eye-12 on each of the four spacecraft. Such comparisons were used to determine flat-fielding corrections for each eye. FEEPS 1-spin-average omni-directional energy spectra are shown c) before and d) after flat-fielding corrections are applied. In all panels, EIS data from MMS1 are shown with black "+" symbols.*

6.1.5 FEEPS Electron Cross-Calibration

As summarized in §0.2k, preliminary comparisons of electrons have been made between FEEPS with EIS and FPI. However, note that no cross-calibration correction factors have been applied to the data as of August 2017. Despite that, the instruments generally show good agreement when counts are high across the full range of each instruments. Exhibit 32 shows an example.

6.2 FEEPS Onboard Data Production

Onboard each MMS spacecraft, FEEPS instruments generate a raw frame that is ingested and processed by the CIDP software to produce the FEEPS telemetry products. The CIDP generates the following telemetry products for FEEPS:

- *Housekeeping*
- *Slow Survey Data*
- *Fast Survey Data*
- *Burst Data*
- *Trigger Data*

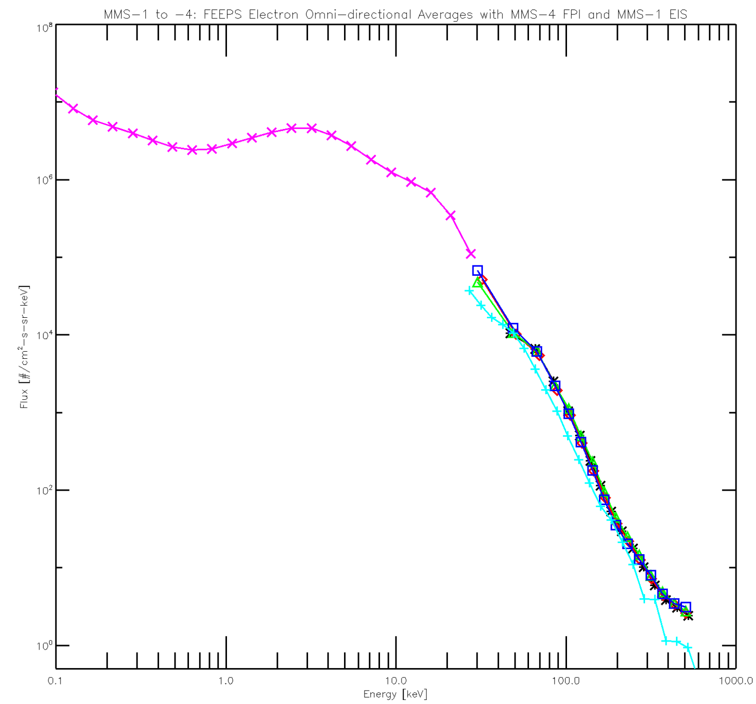


Exhibit 32. *Example comparison 1-spin-average omni-directional electron energy spectra from FPI (magenta "×"), EIS from MMS1 (cyan "+"), and FEEPS (MMS1: black "*"; MMS2: red "◊"; MMS3: green "△" ; MMS4: blue "□").*

FEEPS instruments generate sixty-four (64) raw frames per spacecraft (S/C) rotation. Each frame corresponds to a spin sector. The nominal spin rate for the S/C is 3 ± 0.2 revolutions per minute (rpm). At rates much higher than this (e.g., 4 RPM), the FEEPS instruments may not be able to produce data for a particular sector. In these instances, the sectors will be missing in the accumulated data products (e.g., survey data).

6.2.1 Burst Data Generation

Each FEEPS produces a raw data packet sixty-four (64) times per spin, one for each spin sector. A packet is produced approximately every 0.3125 s for a nominal 20-s spin period. The CIDP does some logarithmic compression to reduce the data volume and produces one (1) burst packet for each raw data packet. The burst packet contains the following information:

- *Header information*
- *Sensor rates*
- *Live times*
- *Integral rates*

6.2.2 Fast Survey Data Generation

In order to construct the fast survey packet, the raw data from only eight (8) of the twelve (12) sensors is used. Exhibit 33 describes the mapping used from launch to August 2017. By taking data from five (5) electron and three (3) ion sensors on each head, the data form essentially two complete fan views of the environment. To further reduce data volume, the CIDP sums the data for eight (8) contiguous sectors (1/8 of a spin) and then does logarithmic compression. The integral rates from the raw data packet are not included. After the CIDP changes implemented in August 2017, this table will be configurable on board each spacecraft to ensure the best eyes are being used for the survey data products.

Date Implemented	MMS s/c	FEEPS Unit	Survey Eyes
Launch	1	Top:	3,4,5,6,7,8,11,12
		Bottom:	3,4,5,6,7,8,11,12
	2	Top:	3,4,5,6,7,8,11,12
		Bottom:	3,4,5,6,7,8,11,12
	3	Top:	3,4,5,6,7,8,11,12
		Bottom:	3,4,5,6,7,8,11,12
	4	Top:	3,4,5,6,7,8,11,12
		Bottom:	3,4,5,6,7,8,11,12
16 August 2017	1	Top:	3,5,6,7,8,9,10,12
		Bottom:	2,4,5,6,7,8,9,10
	2	Top:	1,2,3,5,6,8,10,11
		Bottom:	1,4,5,6,7,8,9,11
	3	Top:	3,5,6,7,8,9,10,12
		Bottom:	1,2,3,6,7,8,9,10
	4	Top:	3,4,5,6,8,9,10,11
		Bottom:	3,5,6,7,8,9,10,12

Exhibit 33. *Summary of the eyes used to create the fast survey data packet for each sensor over the mission lifetime.*

6.2.3 Slow Survey Data Generation

The slow survey packet is formed identically to the fast survey packet but is given a different identifier in order to differentiate it. To reduce the data volume, the packets are nominally produced only once every 10 spins. On 13 March 2017, an update to the CIDP software set the slow survey cadence to the same as that for the fast survey product (i.e., 1/8th of a spin per sector).

6.2.4 Trigger Data Generation

The CIDP computes three trigger data numbers (TDNs) for FEEPS in Fast Survey mode: electron intensity, electron variability, and electron anisotropy. Exhibit 34 denotes which sensors contribute to the TDN calculations. After the CIDP changes to be implemented in October 2016, this table will be configurable on board each spacecraft to ensure the best eyes are being used for the trigger data products. As previously stated, this data product had not been used to-date and thus, in general, its usefulness has not been determined.

Sensor	Type	Electron Intensity	Electron Variability	Electron Anisotropy
1	Electron	Used	Used	Used
2	Electron	Used	Used	Used
3	Electron	Used	Used	Not Used
4	Electron	Used	Used	Not Used
5	Electron	Used	Used	Not Used
6	Ion	Not Used	Not Used	Not Used
7	Ion	Not Used	Not Used	Not Used
8	Ion	Not Used	Not Used	Not Used
9	Electron	Used	Used	Not Used
10	Electron	Used	Used	Not Used
11	Electron	Used	Used	Used
12	Electron	Used	Used	Used

Exhibit 34. *Summary of which sensors contribute to the FEEPS trigger data numbers.*

6.3 FEEPS Ground Data Product Details

There are two FEEPS instruments on each of the four MMS Spacecraft labeled "top" and "bottom" for the mounting location on either the top or bottom deck of each spacecraft. A FEEPS instrument contains twelve sensors, nine electron sensors and three ion sensors, for a total of ninety-six sensors aboard the four MMS S/C. Each instrument operates continuously, generating 64 data records per spin. The data stream is fed to the MMS CIDP, which is responsible for properly formatting the instrument data into the correct CCSDS packet. The CIDP arranges data from each FEEPS instrument data into burst, fast-survey, slow-survey, or housekeeping packets. Once the packets arrive at the MMS Science Data Center (SDC) they are processed by FEEPS Processing Software into higher-level L2 and Quicklook products. These products, Level 2 and Quicklook, are made available by the SDC through the SDC web page or by remote connection from the FEEPS ITF to the MMS SDC.

6.3.1 FEEPS Measurement Algorithm Definitions

Live Time (LT):

$$LT = C \times LTC,$$

where C = 8E-6 and LTC is the Live Time Counts.

Count Rate (CtRt):

$$CtRt = \frac{Ct}{LT} - CRBG = \frac{Ct}{C \times LTC} - CRBG,$$

where Ct is the counts and $CRBG$ is the cosmic ray background, which is currently defined in the FEEPS calibration file as a constant ($CRBG$ = 0.0).

Intensity (I):

$$I = \frac{CtRt}{(E2 - E1) \times Eff \times GF},$$

where $E1$ and $E2$ are the energy step bounds, Eff is the efficiency, and GF is the geometric factor defined in the FEEPS calibration file.

Percent uncertainty (%σ):

$$\%\sigma = (100\%)\frac{\sqrt{Ct}}{Ct} = \frac{(100\%)}{\sqrt{Ct}},$$

where the one standard deviation measurement uncertainty of the counts is defined by the standard Poisson counting error $\sigma_{Ct} = \sqrt{Ct}$.

Corrected Count (CorCt) – *unreported*:

$$CorCt = Ct \times \frac{AT}{LT},$$

where AT is the accumulation time, or time spent in current spin sector, and LT is the live time, or actual time the instrument is able to make an observation during the current spin sector (Burst mode: AT = spin period / 64; Survey mode: AT = spin period / 8)

6.4 Level 2 FEEPS Products

The variables contained within the FEEPS Level 2 Products generated within the MMS Science Data Center (SDC), are outlined in Tables 16-19 below. All of these FEEPS variables begin with,

*<feeps_prefix> = mms**<#>**_epd_feeps_**<DATA_RATE>**_l2,*

where ***<#>*** is the spacecraft number and ***<DATA_RATE>*** is the telemetry mode ("srvy", "brst", or "raw"). ***<SIDE>*** will be "top" or "bottom" to indicate which FEEPS unit the data correspond to. The ***<#>*** portion found in several variables below represents the sensor identifier number.

Level 2 FEEPS Products

Data Parameter	Description	Units
epoch	UTC timestamp at sector center	TT2000
<feeps_prefix>_electron_spinsectnum	Spin sector in which the spacecraft was oriented during data acquisition	-----
<feeps_prefix>_electron_energy	Centroid of differential energy channels associated with each of 16 FEEPS channels	keV
<feeps_prefix>_electron_energy_lower_bound	Lower bound of differential energy channels associated with each of 16 FEEPS channels	keV
<feeps_prefix>_electron_energy_upper_bound	Upper bound of differential energy channels associated with each of 16 FEEPS channels	keV
<feeps_prefix>_<SIDE>_electron_count_rate_sensorid_<#>	Count rate	counts/s
<feeps_prefix>_<SIDE>_electron_intensity_sensorid_<#>	Unidirectional differential flux per spin sector	$1/(cm^2\text{-s-sr-keV})$
<feeps_prefix>_<SIDE>_electron_sector_mask_sensorid_<#>	Array of bad sector flags for a packet	-----
<feeps_prefix>_electron_spin	Number of spacecraft rotations	seconds
<feeps_prefix>_electron_spin_duration	Period of the spin	-----
<feeps_prefix>_electron_integration_sectors	Integration sectors	-----
<feeps_prefix>_electron_bfield	Magnetic field vector	nT
<feeps_prefix>_electron_pitch_angle	Pitch angle with respect to local magnetic field	degrees
<feeps_prefix>_electron_scpos_ec_gse	Spacecraft position in Earth-centered geocentric solar ecliptic coordinates	km
<feeps_prefix>_electron_scz_vec_gse	Spacecraft Unit Vector Z-Axis in Earth-centered Geophysical Coordinates	-----
<feeps_prefix>_electron_scy_vec_gse	Spacecraft Unit Vector Y-Axis in Earth-centered Geophysical Coordinates	-----
<feeps_prefix>_electron_scx_vec_gse	Spacecraft Unit Vector X-Axis in Earth-centered Geophysical Coordinates	-----
<feeps_prefix>_electron_moon_pos_gse	Position of the Moon in Earth-centered Geophysical Coordinates	km
<feeps_prefix>_electron_radius	Radial distance in Earth radii	R_E (Earth radii)

<feeps_prefix>_electron_lat_gse	Latitude in Earth-centered Geophysical Coordinates	degrees
<feeps_prefix>_electron_lon_gse	Longitude in Earth-centered Geophysical Coordinates	degrees
<feeps_prefix>_electron_l_shell	Dipole L shell in Earth radii determined using Solar Magnetospheric latitude	R_E (Earth radii)
<feeps_prefix>_electron_lat_gsm	Latitude in Solar Magnetospheric Coordinates	degrees
<feeps_prefix>_electron_lon_gsm	Longitude in Solar Magnetospheric Coordinates	degrees

Exhibit 35. *List of the variables included in the L2 FEEPS electron burst/survey data products, the only differences in the variables is the <DATA_RATE> in the prefix.*

Data Parameter	Description	Units
epoch	UTC timestamp at sector center	TT2000
<feeps_prefix>_ion_spinsectnum	Spin sector in which the spacecraft was oriented during data acquisition	-----
<feeps_prefix>_ion_energy	Centroid of differential energy channels associated with each of 16 FEEPS channels	keV
<feeps_prefix>_ion_energy_lower_bound	Lower bound of differential energy channels associated with each of 16 FEEPS channels	keV
<feeps_prefix>_ion_energy_upper_bound	Upper bound of differential energy channels associated with each of 16 FEEPS channels	keV
<feeps_prefix>_<SIDE>_ion_count_rate_sensorid_<#>	Count rate	counts/s
<feeps_prefix>_<SIDE >_ion_intensity_sensorid_<#>	Unidirectional differential flux per spin sector	1/(cm^2-s-sr-keV)
<feeps_prefix>_<SIDE>_ion_sector_mask_sensorid_<#>	Array of bad sector flags for a packet	-----
<feeps_prefix>_ion_spin	Number of spacecraft rotations	-----
<feeps_prefix>_ion_spin_duration	Period of the spin	seconds
<feeps_prefix>_ion_integration_sectors	Integration sectors	-----
<feeps_prefix>_ion_bfield	Magnetic field vector	nT
<feeps_prefix>_ion_pitch_angle	Pitch angle with respect to local magnetic field	degrees
<feeps_prefix>_ion_scpos_ec_gse	Spacecraft position in Earth-centered geocentric solar ecliptic coordinates	km
<feeps_prefix>_ion_scz_vec_gse	Spacecraft Unit Vector Z-Axis in Earth-centered Geophysical Coordinates	-----
<feeps_prefix>_ion_scy_vec_gse	Spacecraft Unit Vector Y-Axis in Earth-centered Geophysical Coordinates	-----
<feeps_prefix>_ion_scx_vec_gse	Spacecraft Unit Vector X-Axis in Earth-centered Geophysical Coordinates	-----
<feeps_prefix>_ion_moon_pos_gse	Position of the Moon in Earth-centered Geophysical Coordinates	km
<feeps_prefix>_ion_radius	Radial distance in Earth radii	R_E (Earth radii)
<feeps_prefix>_ion_lat_gse	Latitude in Earth-centered Geophysical Coordinates	degrees

<feeps_prefix>_ion_lon_gse	Longitude in Earth-centered Geophysical Coordinates	degrees
<feeps_prefix>_ion_l_shell	Dipole L shell in Earth radii determined using Solar Magnetospheric latitude	R_E (Earth radii)
<feeps_prefix>_ion_lat_gsm	Latitude in Solar Magnetospheric Coordinates	degrees
<feeps_prefix>_ion_lon_gsm	Longitude in Solar Magnetospheric Coordinates	degrees

***Exhibit 36.** List of the variables included in the L2 FEEPS ion burst/survey data products, the only differences in the variables is the <DATA_RATE> in the prefix.*

7 EPD Higher-Level (L3+) Data Description

7.1 Overview of MMS-X Data Products

Because the spacing between the MMS spacecraft is generally much smaller than the gyroradii of the energetic particles measured by EPD, it is often advantageous to combine (i.e., average) measurements across the spacecraft to increase the EPD counting statistics. This multi-spacecraft combined data product is referred to as "MMS-X". This was initially implemented via capabilities embedded in the EIS- and FEEPS-specific routines in the SPEDAS framework and will be included in the publicly-available Level 3 data products summarized in §4.1-4.

7.2 EPD Fast Ion Data Products

In Fall 2017, the decision was made to create the ability to generate EPD Fast Ion data products within the MMS-specific IDL-based SPEDAS software, with the intent that such products would be available for limited production based on individual requests. Procedures were developed to create combined EPD ion spectrograms, pitch angle distributions, and select moments (density, pressure, and characteristic energy) from EIS and FEEPS burst data over the 60-560 keV energy range. In Summer 2021, preliminary EPD Level-3 Ion data products were released that provided combined Fast Ion energy spectrogram and pitch angled distribution products, (#5-6 below), but not combined moments (#7 below). The logic for the generation of these products from are roughly outlined as follows:

1. Interpolate the FEEPS (total) ion data onto a common 15-channel EPD energy grid.
2. Separate of the FEEPS ion burst data (at ⅓-s cadence) into two separate variables, i.e., the two FEEPS measurements made for each one EIS measurement (at ⅔-s cadence).
3. Generate an interpolated EIS proton spectrum by calculating a flux for each channel in the common EPD energy grid via a linear fit in log-log space between the data points for the EIS energy channels above and below the desired EPD energy channel.
4. When desired (and possible), include the EIS helium and oxygen data to create an EIS total ion spectrum. When sufficient data is available, a model power law spectrum is fit to the highest and lowest energy channels with valid data; otherwise, an $I=E^{-2}$ model is used.
5. Average the interpolated FEEPS (x2) and interpolated EIS proton (or total ion) intensity data to create an EPD total ion energy spectrogram at ⅔-s resolution.

6. Calculate a pitch angle distribution from using the combined spectrogram and the preserved pitch angle data from the individual sensors
7. ***<NOT PUBLICLY AVAILABLE>*** Calculate partial moments over 60-560 keV energy range using the following definitions:
   a. $P\ [\text{dynes cm}^{-2}] = 4\pi\sqrt{\frac{m}{2}}\left[\sqrt{E}^3\left(\frac{I}{E}\right)dE\right]$, from *Mauk et al.* [2004]
   b. $n\ [\text{cm}^{-3}] = 4\pi\sqrt{\frac{m}{2}}\left[\left(\frac{I}{E}\right)\sqrt{E}dE\right]$, from *Mauk et al.* [2004]

7.3 Level 3 EPD Products

The variables contained within the EPD Level-3 products available from the MMS Science Data Center (SDC), are outlined in Exhibits 37-38 below. All of these variables begin with either,

<feeps_l3_prefix> = *mms**<#>**_epd_feeps_**<DATA_RATE>**_l3_* *OR*

<eis_l3_prefix> = *mms**<#>**_epd_eis_**<DATA_RATE>**_l3_*,

where ***<#>*** is the spacecraft number and ***<DATA_RATE>*** is the telemetry mode ("srvy" or "brst"). The data files from each MMS spacecraft will include the variables below from both that spacecraft as well as combined across all available spacecraft ("mmsx").

Data Parameter	Description	Units
<feeps_prefix>_electron_intensity_omni	Omni-directional (averaged over all eyes/sensors) intensity (flux) from FEEPS	1/(cm^2-s-sr-keV)
<feeps_prefix>_electron_intensity_omni_###-###keV_pad	3-sample smoothed omni-directional pitch angle distribution for specified FEEPS energy channel(s)	1/(cm^2-s-sr-keV)
<feeps_prefix>_electron_intensity_omni_integral_gt##kev_pad	3-sample smoothed omni-directional pitch angle distribution for all FEEPS energies above specified value	1/(cm^2-s-sr-keV)
<feeps_prefix>_electron_SCincluded	Binary indicator of which S/C FEEPS data are included in the MMS-X products	-----
<eis_prefix> electron_flux_omni	Omni-directional (averaged over all telescopes) intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_electron_flux_omni_###-###keV_pad	Omni-directional pitch angle distribution for specified EIS energy channel(s)	1/(cm^2-s-sr-keV)
<eis_prefix>_electron_SCincluded	Binary indicator of which S/C EIS data are included in the MMS-X products	-----

Exhibit 37. *List of the variables included in the L3 EPD electron survey and burst data products, the only differences in the variables is the <DATA_RATE> in the prefix.*

Data Parameter	Description	Units
<feeps_prefix>_ion_intensity_omni	Omni-directional (averaged over all eyes/sensors) intensity (flux) from FEEPS	1/(cm^2-s-sr-keV)
<feeps_prefix>_ion_intensity_omni_###-###keV_pad	3-sample smoothed omni-directional pitch angle distribution for energy channel(s) specified by range from FEEPS	1/(cm^2-s-sr-keV)
<feeps_prefix>_ion_intensity_omni_integral_gt##kev_pad	3-sample smoothed omni-directional pitch angle distribution for all energies above specified value from FEEPS	1/(cm^2-s-sr-keV)
<feeps_prefix>_ion_SCincluded	Binary indicator of which S/C FEEPS data are included in the MMS-X products	-----

<eis_prefix>_extof_proton_flux_omni	Omni-directional (averaged over all telescopes) intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_helium_flux_omni	Omni-directional (averaged over all telescopes) intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_oxygen_flux_omni	Omni-directional (averaged over all telescopes) intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_ ###-###keV_proton_flux_omni_pad	Omni-directional pitch angle distribution for energy channel(s) specified by range from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_ ###-###keV_helium_flux_omni_pad		
<eis_prefix>_extof_ ###-###keV_oxygen_flux_omni_pad		
<eis_prefix>_phxtof_proton_flux_omni	Omni-directional (averaged over all telescopes) intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_phxtof_ ###-###keV_proton_flux_omni_pad	Omni-directional pitch angle distribution for energy channel(s) specified by range from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_combined_proton_flux_omni	Omni-directional (averaged over all telescopes) intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_combined_ ###-###keV_proton_flux_omni_pad	Omni-directional pitch angle distribution for energy channel(s) specified by range from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_ion_SCincluded	Binary indicator of which S/C EIS data are included in the MMS-X products	-----

Exhibit 38. *List of the variables included in the L3 EPD ion survey data product.*

Data Parameter	Description	Units
<feeps_prefix>_ion_intensity_omni	Omni-directional (averaged over all eyes/sensors) intensity (flux) from FEEPS	1/(cm^2-s-sr-keV)
<feeps_prefix>_ion_intensity_omni_###-###keV_pad	3-sample smoothed omni-directional pitch angle distribution for energy channel(s) specified by range from FEEPS	1/(cm^2-s-sr-keV)
<feeps_prefix>_ion_intensity_omni_integral_gt##kev_pad	3-sample smoothed omni-directional pitch angle distribution for all energies above specified value from FEEPS	1/(cm^2-s-sr-keV)
<feeps_prefix>_ion_SCincluded	Binary indicator of which S/C FEEPS data are included in the MMS-X products	-----
<eis_prefix>_extof_proton_flux_omni	Omni-directional (averaged over all telescopes) proton energy-by-TOF intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_helium_flux_omni	Omni-directional (averaged over all telescopes) helium energy-by-TOF intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_oxygen_flux_omni	Omni-directional (averaged over all telescopes) oxygen energy-by-TOF intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_ ###-###keV_proton_flux_omni_pad	Omni-directional proton energy-by-TOF pitch angle distribution for energy channel(s) specified by range from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_extof_ ###-###keV_helium_flux_omni_pad	Omni-directional helium energy-by-TOF pitch angle distribution for energy channel(s) specified by range from EIS	

<eis_prefix>_extof_ ###-###keV_oxygen_flux_omni_pad	Omni-directional oxygen energy-by-TOF pitch angle distribution for energy channel(s) specified by range from EIS	
<eis_prefix>_phxtof_proton_flux_omni	Omni-directional (averaged over all telescopes) proton pulse height-by-TOF intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_phxtof_ ###-###keV_proton_flux_omni_pad	Omni-directional proton pulse height-by-TOF pitch angle distribution for energy channel(s) specified by range from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_combined_proton_flux_omni	Omni-directional (averaged over all telescopes) proton combined pulse height-by-TOF and energy-by-TOF intensity (flux) from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_combined_ ###-###keV_proton_flux_omni_pad	Omni-directional proton combined pulse height-by-TOF and energy-by-TOF pitch angle distribution for energy channel(s) specified by range from EIS	1/(cm^2-s-sr-keV)
<eis_prefix>_ion_SCincluded	Binary indicator of which S/C EIS data are included in the MMS-X products	-----
mms<#>_epd_brst_fast_ion_flux_omni'	Omni-directional total ion intensity (flux) combined from EIS (protons only) and FEEPS	1/(cm^2-s-sr-keV)
mms<#>_epd_brst_fast_ion_###-###keV_pad'	Omni-directional total ion pitch angle distribution for energy channel(s) specified by range combined from EIS (protons only) and FEEPS	1/(cm^2-s-sr-keV)

Exhibit 39. *List of the variables included in the L3 EPD ion burst data product.*

Appendix A: Structure of the EIS Calibration Matrix

The response of the EIS sensors is complicated, and our understanding is based on a coordinated array of approaches, specifically: i) bench testing of channel gains and other characteristics based on calibrated pulse inputs; ii) calibrations using particle accelerator beams; iii) calibrations using radiation sources; iv) simulations of particle interactions with matter using such tools as GEANT4; and v) geometric calculations. All of this information is captured within an Excel Spreadsheet, with one sheet per sensor head (sample images of portions of a sheet are provided in Exhibits A1-A2. This spreadsheet captures various functional relationships with polynomial fits up to the

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**Note: All Energies are in keV**															
2																
3	**Linear-Linear: SSD Measured-Energy = P6[SSD Energy-Channel]**															
4	**Large Pixel Electrons**							**Large Pixel Ions**								
5		**Sec 0**	**Sec 1**	**Sec 2**	**Sec 3**	**Sec 4**	**Sec 5**		**Sec 0**	**Sec 1**	**Sec 2**	**Sec 3**	**Sec 4**	**Sec 5**		
6	**a0**	-4.22E+00	-4.22E+00	-4.22E+00	-4.22E+00	-4.22E+00	-4.22E+00	**a0**	-4.2741	-4.2741	-4.2741	-4.2741	-4.2741	-4.2741		
7	**a1**	9.85E-01	9.85E-01	9.85E-01	9.85E-01	9.85E-01	9.85E-01	**a1**	9.73E-01	9.73E-01	9.73E-01	9.73E-01	9.73E-01	9.73E-01		
8	**a2**	-8.48E-04	-8.48E-04	-8.48E-04	-8.48E-04	-8.48E-04	-8.48E-04	**a2**	-8.53E-04	-8.53E-04	-8.53E-04	-8.53E-04	-8.53E-04	-8.53E-04		
9	**a3**	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	**a3**	1.07E-06	1.07E-06	1.07E-06	1.07E-06	1.07E-06	1.07E-06		
10	**a4**	-5.89E-10	-5.89E-10	-5.89E-10	-5.89E-10	-5.89E-10	-5.89E-10	**a4**	-7.02E-10	-7.02E-10	-7.02E-10	-7.02E-10	-7.02E-10	-7.02E-10		
11	**a5**	1.62E-13	1.62E-13	1.62E-13	1.62E-13	1.62E-13	1.62E-13	**a5**	2.35E-13	2.35E-13	2.35E-13	2.35E-13	2.35E-13	2.35E-13		
12	**a6**	-1.56E-17	-1.56E-17	-1.56E-17	-1.56E-17	-1.56E-17	-1.56E-17	**a6**	-3.14E-17	-3.14E-17	-3.14E-17	-3.14E-17	-3.14E-17	-3.14E-17		
13								**Transition**	1707	1707	1707	1707	1707	1707		
14								**a0**	-50205.45	-50205.45	-50205.45	-50205.45	-50205.45	-50205.45		
15								**a1**	29.41155	29.41155	29.41155	29.41155	29.41155	29.41155		
16								**a2**	0	0	0	0	0	0		
17																
18	**Small Pixel Electrons**							**Small Pixel Ions**								
19		**Sec 0**	**Sec 1**	**Sec 2**	**Sec 3**	**Sec 4**	**Sec 5**		**Sec 0**	**Sec 1**	**Sec 2**	**Sec 3**	**Sec 4**	**Sec 5**		
20	**a0**	-4.22E+00	-4.22E+00	-4.22E+00	-4.22E+00	-4.22E+00	-4.22E+00	**a0**	-4.2741	-4.2741	-4.2741	-4.2741	-4.2741	-4.2741		
21	**a1**	9.85E-01	9.85E-01	9.85E-01	9.85E-01	9.85E-01	9.85E-01	**a1**	9.73E-01	9.73E-01	9.73E-01	9.73E-01	9.73E-01	9.73E-01		
22	**a2**	-8.48E-04	-8.48E-04	-8.48E-04	-8.48E-04	-8.48E-04	-8.48E-04	**a2**	-8.53E-04	-8.53E-04	-8.53E-04	-8.53E-04	-8.53E-04	-8.53E-04		
23	**a3**	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	**a3**	1.07E-06	1.07E-06	1.07E-06	1.07E-06	1.07E-06	1.07E-06		
24	**a4**	-5.89E-10	-5.89E-10	-5.89E-10	-5.89E-10	-5.89E-10	-5.89E-10	**a4**	-7.02E-10	-7.02E-10	-7.02E-10	-7.02E-10	-7.02E-10	-7.02E-10		
25	**a5**	1.62E-13	1.62E-13	1.62E-13	1.62E-13	1.62E-13	1.62E-13	**a5**	2.35E-13	2.35E-13	2.35E-13	2.35E-13	2.35E-13	2.35E-13		
26	**a6**	-1.56E-17	-1.56E-17	-1.56E-17	-1.56E-17	-1.56E-17	-1.56E-17	**a6**	-3.14E-17	-3.14E-17	-3.14E-17	-3.14E-17	-3.14E-17	-3.14E-17		
27								**Transition**	1707	1707	1707	1707	1707	1707		
28	**Time of Flight: Linear-Linear**							**a0**	-50205.4	-50205.45	-50205.45	-50205.45	-50205.45	-50205.45		
29	**TOF(ns) = P6[TOF-channel]**							**a1**	29.41155	29.41155	29.41155	29.41155	29.41155	29.41155		
30								**a2**	0	0	0	0	0	0		
31	**a0**	0														
32	**a1**	0.25		**Time-of-Flight**						**Time-of-Flight**						
33	**a2**	0		**Log10(TOF(ns)) = P6[Log10(Energy-into-sensor)]**						**Log10(Energy-into-Sensor) = P6[Log10(TOF(ns)**						
34	**a3**	0			**H**	**He**	**O**	**S**			**H**	**He**	**O**	**S**		
35	**a4**	0		**a0**	4.07022	6.67771	30.4431	22.8091		**a0**	4.27224	4.85607	5.20187	5.21416		
36	**a5**	0		**a1**	-4.44458	-9.48197	-53.3389	-36.9054		**a1**	-2.00664	-1.82712	-0.27687	1.0163		
37	**a6**	0		**a2**	3.57637	8.05253	41.8469	27.7864		**a2**	0.168871	-0.502946	-4.28586	-6.45182		
38				**a3**	-1.76968	-3.81436	-17.5368	-11.2656		**a3**	-0.531903	0.629342	5.45036	7.0375		
39				**a4**	0.49005	0.996382	4.09294	2.55162		**a4**	0.598064	-0.338004	-3.67144	-4.08484		
40				**a5**	-0.070962	-0.135639	-0.503966	-0.305732		**a5**	-0.241902	0.080924	1.24278	1.19879		
41				**a6**	0.004173	0.007517	0.025568	0.015132		**a6**	0.03666	-0.002469	-0.160795	-0.136054		
42																
43	**Pulse-Height Defect**							**Given SSD energy, What are the input energies coming into the sensor**								
44	**Log10[SSD Deposited-Energy] = P6[Log10(SSD Measured-Energy)]**							**Log10[Input Energy] = P6[Log10(SSD Deposited Energy)]**								
45		**e**	**H**	**He**	**O**	**S**			**e**	**H**	**He**	**O**	**S**			
46	**a0**	0	0.11867	0.307255	0.529719	0.550292		**a0**	1.05307	1.25705	1.54463	1.2593	1.26368			
47	**a1**	1	0.896368	0.776169	0.920533	0.958583		**a1**	0.14046	0.171718	-0.34265	2.27329	2.42085			
48	**a2**	0	0.02439	0.035927	-0.080915	-0.030018		**a2**	-0.373825	0.087186	0.579905	-2.62401	-2.82329			
49	**a3**	0	0.000589	0.005311	-0.025027	-0.049949		**a3**	0.647852	-0.004526	-0.187744	1.49633	1.63798			
50	**a4**	0	-0.000518	-0.001249	0.032986	0.028446		**a4**	-0.274551	0.027604	0.043237	-0.404066	-0.456966			
51	**a5**	0	0	0	-0.008163	-0.00513		**a5**	0.049721	-0.009543	-0.005471	0.053539	0.063008			
52	**a6**	0	0	0	0.000636	0.000314		**a6**	-0.003351	0.000892	0.000268	-0.002806	-0.003447			
53																
54	**Scatter Efficiency**										**For Foil Efficiences**					
55	**Log10(Efficiency) = P6[Log10(incoming Energy]**										**Log10(dE/dX (keV/mic)) = P6[Log10(E inTOF chamber)**					
56		**e 3-Sec**	**p 1-Sec**	**p 3-Sec**	**He 1-Sec**	**He 3-Sec**	**O 1-Sec**	**O 3-Sec**	**S 1-Sec**	**S 3-Sec**	**Note: E-TOF is calculated from TOF(ns) and 6 cm flight path**					
57	**a0**	-21.897	-23.1498	-17.0693	-35.4583	-24.5146	-60.122	-30.9256	4.80265	2.77665		**H**	**He**	**O**	**S**	
58	**a1**	46.2624	49.6625	35.5823	69.4742	45.9133	87.6626	34.7874	-50.9711	-39.7241	**Start norm**	1.8	1.8	1.8	1.8	
59	**a2**	-39.7908	-43.3106	-30.1752	-55.6854	-35.0682	-49.4277	-10.1167	66.6342	53.1123	**Stop norm**	1.4	1.4	1.4	1.4	
60	**a3**	17.8517	19.6744	13.3435	23.3922	13.9965	13.1316	-2.23677	-36.4353	-29.3104	**a0**	1.498410	1.597758	1.788343	1.864166	
61	**a4**	-4.41111	-4.91613	-3.24984	-5.43708	-3.08225	-1.48922	1.84537	10.0107	8.10283	**a1**	0.558056	0.833696	0.154667	0.433350	
62	**a5**	0.569924	0.641564	0.413957	0.663662	0.355483	0.011999	-0.369034	-1.37094	-1.11556	**a2**	-0.386226	-0.962019	0.794291	0.376468	
63	**a6**	-0.030119	-0.034211	-0.021576	-0.033269	-0.016793	0.007043	0.02497	0.074683	0.061086	**a3**	0.544472	0.825306	-0.689586	-0.461162	
64											**a4**	-0.331377	-0.308763	0.260376	0.208833	
65											**a5**	0.076581	0.049080	-0.044271	-0.040284	
66											**a6**	-0.006107	-0.002818	0.002726	0.002726	

Exhibit A1. *Example of coefficients of up to the 6^{th}-order used to define the functional relationship of multiple parameters in the EIS Calibration Matrix.*

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
69	NOTE: BELOW ARE SAMPLE CHANNELS OF EACH TYPE THAT THE MMS EIS INSTRUMENT GENERATES.																					
70		THE USER FILLS IN THE INFORMATION IN COLLUMNS A-H, AND THE REST IS AUTOMATICALLY CALCULATED BASED ON POLYNOMIAL REPRESENTATIONS GIVEN ABOVE																				
71																						
72	**Electron Energy Spectra**																					
73	Sensor	Type	Direction	Species	Pixel	Channel	Echan 1	Echan 2	Emeas 1	Emeas 2	Edpos 1	Edepos 2	Ein 1	Ein 2	mean Ein	Eff-2						
74	MMS-EIS-1	e-spec	0	electrons	Large	1	20	30	15.14557	24.58765	15.15	24.59	21.64	29.88	25.43	0.58						
75	MMS-EIS-1	e-spec	0	electrons	Large	2	30	45	24.58765	38.46701	24.59	38.47	29.88	42.44	35.61	0.82						
76	MMS-EIS-1	e-spec	0	electrons	Large	3	45	60	38.46701	52.02233	38.47	52.02	42.44	55.05	48.34	0.95						
77	MMS-EIS-1	e-spec	0	electrons	Large	4	60	75	52.02233	65.27149	52.02	65.27	55.05	67.60	61.00	1.00						
78																						
79	**Ion Energy Spectra**																					
80	Sensor	Type	Direction	Species	Pixel	Channel	Echan 1	Echan 2	Emeas 1	Emeas 2	Edepos 1	Edepos 2	Ein 1	Ein 2	mean Ein	Eff-2						
81	MMS-EIS-1	I-spec	0	ions	Large	1	10	20	5.3684	14.84669	6.11	15.93	28.28	41.50	34.26	0.82						
82	MMS-EIS-1	I-spec	0	ions	Large	2	20	30	14.84669	24.16695	15.93	25.40	41.50	52.48	46.67	0.95						
83	MMS-EIS-1	I-spec	0	ions	Large	3	30	45	24.16695	37.86412	25.40	39.19	52.48	67.32	59.44	1.00						
84	MMS-EIS-1	I-spec	0	ions	Large	4	45	60	37.86412	51.23879	39.19	52.59	67.32	81.09	73.88	1.02						
85																						
86	**TOF x E**																					
87	Sensor	Type	Direction	Species	Pixel	Channel	Echan 1	Echan 2	Emeas 1	Emeas 2	Edepos 1	Edepos 2	Ein 1	Ein 2	mean Ein	TOF(ns)	eff-start	eff-stop	Eff-scat-1	Eff-scat 2	Eff-1	Eff-2
88	MMS-EIS-1	TOFxE	0	p	Large	1	15	25	10.12768	19.5262	11.08	20.70	35.37	47.15	40.84	24.91301	0.77941	0.691357	0.92	0.90	0.493303	0.48504
89	MMS-EIS-1	TOFxE	0	p	Large	2	25	35	19.5262	28.7697	20.70	30.05	47.15	57.58	52.11	21.46006	0.803266	0.717645	0.99	0.97	0.57197	0.561829
90																						
91	MMS-EIS-1	TOFxE	0	he	Large	5	40	60	33.33519	51.23879	38.43	56.89	85.70	110.04	97.11	31.54834	0.725248	0.633882	1.00	0.99	0.458281	0.452898
92	MMS-EIS-1	TOFxE	0	he	Large	6	60	75	51.23879	64.30977	56.89	70.20	110.04	126.73	118.09	28.2416	0.752966	0.662946	1.02	1.01	0.509424	0.50598
93																						
94	MMS-EIS-1	TOFxE	0	o	Large	10	75	90	64.30977	77.09509	99.73	115.38	223.07	242.17	232.42	40.71375	0.649571	0.557616	0.95	0.93	0.342723	0.338427
95	MMS-EIS-1	TOFxE	0	o	Large	11	90	120	77.09509	101.8772	115.38	144.81	242.17	277.84	259.39	38.22334	0.66946	0.57727	0.98	0.97	0.38023	0.375225
96																						
97	MMS-EIS-1	TOFxE	0	s	Large	16	85	120	72.86397	101.8772	141.01	184.21	306.30	363.03	333.46	48.16824	0.594778	0.504695	0.89	0.88	0.26607	0.264761
98	MMS-EIS-1	TOFxE	0	s	Large	17	140	200	117.8664	163.663	207.03	269.72	392.57	472.53	430.70	41.69015	0.641973	0.550173	1.00	0.98	0.35294	0.346089
99																						
100	**TOF x PH**																					
101	Sensor	Type	Direction	Species	Pixel	Channel	TOFchan1	TOFchan2			TOF-1(ns)	TOF-2(ns)	Ein 1	Ein 2	mean Ein	TOF(ns)	eff-start	eff-stop	Eff-scat-1	Eff-scat 2	Eff-1	Eff-2
102	MMS-EIS-1	TOFxPH	0	p	N/A	1	100	120			25.00	30.00	40.75	30.85	35.46	27.22998	0.761229	0.671748	0.85	0.84	0.432892	0.42819
103	MMS-EIS-1	TOFxPH	0	p	N/A	2	120	140			30.00	35.00	30.85	24.64	27.57	32.09448	0.720623	0.629098	0.68	0.69	0.308026	0.312783
104	MMS-EIS-2	TOFxPH	0	p	N/A	3	140	160			35.00	40.00	24.64	20.44	22.44	36.97979	0.679634	0.587425	0.51	0.54	0.204652	0.216937
105																						
106	MMS-EIS-1	TOFxPH	0	o	N/A	31	550	640			137.50	160.00	54.00	49.45	51.68	148.7031	0.269094	0.216363	0.04	0.07	0.002044	0.003796
107	MMS-EIS-1	TOFxPH	0	o	N/A	31	500	600			125.00	150.00	57.67	51.22	54.35	138.2072	0.290143	0.233973	0.05	0.08	0.003062	0.00535
108	MMS-EIS-2	TOFxPH	0	o	N/A	31	400	500			100.00	125.00	69.60	57.67	63.35	113.0189	0.344556	0.280045	0.09	0.13	0.008573	0.012791

Exhibit A2. *Example of how the parameters defined in Exhibit A1 are used to determine the energy and efficiency characteristics for a selection of channels in the EIS onboard data products.*

6th order. We will be referencing various portions of this spreadsheet and will often do so by specifying the cell that is in the upper left had corner of the referenced region of the spreadsheet. All of the information described below, plus an additional hard-wired geometric factor and flat-fielding function for the 6 electron and 6 ion telescopes (look directions) per sensor (not shown), is sufficient to determine the efficiency of detection of particles within an EIS sensor. Exhibit A1 specifically captures:

1) Rows 5-12: The coefficients of the 6th-order polynomial fit expressing the SSD-measured energy in keV as a function of the internal sensor SSD data numbers (E-DN) for the 6 large electron (columns B-G) and 6 large ion (columns I-N) SSD pixels.

2) Rows 20-26: The coefficients of the 6th-order polynomial fit expressing the SSD-measured energy in keV as a function of the internal sensor SSD data numbers (E-DN) for the 6 small electron (columns A-G) and 6 small ion (columns H-N) SSD pixels.

3) Cells B31-37: The coefficients of the 6th-order polynomial fit expressing the ion TOF in nanoseconds (ns) as a function of the internal TOF data number (TOF-DN).

4) Cells D35-H41: The coefficients of the 6th-order polynomial fit expressing the TOF in ns (TOF[ns]) as a function of the ion energy in keV coming into the sensor for different species (H, He, O, and S), taking into account the amount of materials in the form of foils that the ion must pass through to get the time-of-flight section.

5) Cells J35-N41: The inverse of the cells in 4) for each species, i.e. the coefficients of the 6th-order polynomial fit expressing the ion energy coming into the sensor in keV as a function of the TOF(ns) in ns.

6) Cells B45-F52: The coefficients of the 6th-order polynomial fit expressing the SSD deposited energy in keV as a function of the measured energy in keV, taking into account the pulse-height defect associated with SSD measurements.

7) Cells I45-M52: The coefficients of the 6th-order polynomial fit expressing the energy input to the sensor in keV as a function of the energy deposited within the sensitive volume of the SSD, accounting for all of the materials that an ion must pass through before getting to the sensitive area of the SSD, including the SSD dead-layer.

8) Cells B57-J63: The coefficients of the 6th-order polynomial fit expressing the scattering efficiency of the sensor (efficiency between 0 and 1) as a function of the incoming energy in keV for different particle species (e^-, H, He, O, and S), taking into account the scattering within the collimator foil and the start foil and considering two possible software constraints on the valid time-of-flight (designated "P-1 sec" and "P-3 sec"). For electrons, this information includes scattering within the 2 μm of Al flashing that is deposited on the front surface of the SSD to keep out energetic protons.

9) Cells L61-O66: The coefficients of the 6th-order polynomial fit expressing the *dE/dX* (electronic) in keV/μm as a function of the ion TOF in ns, based on the laboratory-validated finding that the efficiency of emission of secondary electrons from the start and stop foils scales according to the dE/dX(electronic) within the emitting surfaces of the foil. Cells L58-O59 provide the laboratory-determined number of secondary electrons emitted for a "standard candle" of ~4.5 MeV alpha particles from a slightly degraded Am241 radiation source (with *dE*/*dX* of approximately 160 keV/μm within carbon).

In Exhibit A2, the information described above is used to determine the energy and efficiency characteristics for the various channels comprising the EIS onboard data products (the channels shown are notional, not comprehensive). Four different kinds of channels are defined: 1) electron energy channels (rows 74-77); 2) ion energy channels (derived strictly from SSD measurements; rows 81-84); 3) TOFxE channels (rows 88-98); and 4) TOFxPH channels (rows 102-108). The user of this spreadsheet fills out the information in Columns A through H (which includes the data numbers for the range of energy or TOF, depending on the channel type), and the spreadsheet automatically calculates all of the other columns, including incoming energy ranges ("Ein1", "Ein2") and various contributions to the detection efficiency. The final intensity of a channel is derived by normalizing the channel count-rate by a geometric factor (not shown), a flat-fielding function (now shown), and by the "Eff-2" shown in the right-most column of each row. This energy assigned to each channel is the geometric mean of the energy range, called "mean Ein" in column O.

Appendix B: Structure of the FEEPS Calibration Matrix

To be Added

Appendix C: CIDP FEEPS Onboard Data Production Guide

To be Added

Appendix D: EIS Rate-dependent Corrections to Data Products

[Originally prepared for Van Allen Probes/RBSPICE instrument by Don Mitchell and Matina Gkioulidou, APL]

This note provides formulae for converting count-based data products into rates. Corrections are made for various deadtime and veto effects. However, no corrections are made for energy dependent effects such as particle scattering or SSD dead layer.

D1. Parameters and Counters used in the formulae

Exhibits D1 and D2 below list the parameters used in the correction and conversion of the counters to rates. With the exception of the first item all time intervals are listed in units of the FPGA clock period. Default values are given in square brackets.

Parameter	Description
Clk_period	period of clock used in event logic [100ns].
Max_IDLE	interval during which counts are accumulated [969938]
ST_dead	Start counter deadtime due to synchronization logic [2]
SP_dead	Stop counter deadtime…..
SP_veto	Interval during which additional SP pulses cause the event to be discarded [2]
Rdt_veto	interval for inhibiting ST and SP counters during TOF chip reset [1]
PUR_veto	interval during which a second SSD pulse causes the event to be discarded [24]
PKD_reset	interval for resetting the Peak-Detector [4]
PKD_dt	minimum duration of Peak-Detector busy [17], (busy extended for >1MeV)

Exhibit D1. Description of the parameters used in the rate-dependent EIS data corrections.

ITEM	Description
Start0	Counts pulses on the end of the Start Anode delay line nearest to look direction 0
Stop0	Counts pulses on the end of the Stop Anode delay line nearest to look direction 0
SSD*n*	Counts pulses on SSD of look direction *n*, *n*=0,1,2…5.
SSD*n*_dt	Counts clock periods that SSD*n* is above threshold and blind to additional pulses.
IDLE	Counts clock periods that Event State machine is free and able to accept new events
Valid_TOFXE	Counts coincident Start, Stop and SSD pulses satisfying valid-event criteria.
Valid_Energy	Counts SSD pulses satisfying valid-event criteria.
Valid_Proc	Counts valid events processed by the software.
Rdt	Counts the number of TOF chip resets.

Exhibit D2. List of basic counters used in the rate-dependent EIS corrections.

D2. Correction and Conversion of Singles Counts to Rates

The corrections detailed below are non-linear combinations of the counters and therefore the integration period should be short enough that the counts per sector are reasonably constant.

D3.1. Start and Stop Anode Rates: Only Start0 and Stop0 (from the Basic Rate Counters) are used since Start5 and Stop5 (available only in Diagnostic Rate Counters) should be nearly identical to their look-direction 0 counterparts if the CFD thresholds are properly equalized. These pulses have a fixed deadtime and also counting is inhibited during TOF chip resets. This means that the true number of pulses is diminished by the average number of pulses occurring during these deadtimes. Therefore, correction from raw counts to anode rate is given by

$$\text{ST\_rate} = \frac{\text{Start0}/(\text{Max\_IDLE} * \text{Clk\_period})}{1 - (\text{Start0} * \text{ST\_dead}/\text{Max\_IDLE}) - (\text{Rdt} * \text{Rdt\_veto}/\text{Max\_IDLE})} \quad \text{(D1)}$$

$$\text{SP\_rate} = \frac{\text{Start0}/(\text{Max\_IDLE} * \text{Clk\_period})}{1 - (\text{Start0} * \text{SP\_dead}/\text{Max\_IDLE}) - (\text{Rdt} * \text{Rdt\_veto}/\text{Max\_IDLE})} \quad \text{(D2)}$$

D3.2. SSD Rates: The pulse from the PKD leading-edge discriminator for SSD*n* has a deadtime equal to the time over threshold which is variable, being longer for larger pulses. Because of the variable deadtime the rate is determined by using the observation that the average time for a pulse to occur starting from an arbitrary point is equal to the reciprocal of the rate. Therefore, the correction from raw counts to rate is given by

$$\text{SSD}n\text{\_rate} = \frac{\text{SSD}n}{(\text{Max\_IDLE} - \text{SSD}n\text{\_dt}) * \text{Clk\_period}} \quad \text{(D3)}$$

D3. Correction and Conversion of Energy Mode Spectra to Rates

An energy spectrum is a two-dimensional histogram indexed by look-direction (SSD channel), $i \in \{0..5\}$ and energy bin, $j \in \{0..63\}$. The histogram contents h_{ij} are the number of events accumulated in bin ij over the integration interval. Before describing all of the correction factors the result for the rate in bin ij is given by

$$R_{ij} = \frac{h_{ij}}{\text{Valid\_Proc}} * \frac{\text{Valid\_Energy}}{\text{IDLE}} * C^{i}_{\text{PKD\_reset}} * C^{i}_{\text{PUR\_veto}} \quad \text{(D4)}$$

The first term in Equation D4 is the fraction of processed events found in bin ij, which should be identical to the fraction of Valid_Energy events which would be assigned by the software to bin ij if the software could handle the full rate[1]. The second term is the Valid_Energy rate corrected for deadtime of the Event state machine. The Event state machine deadtime includes a contribution from the Peak-Detector (PKD) state machines which feed it. Each PKD state machine (one for each SSD) becomes busy when its input pulse exceeds threshold and remains busy for an interval of clock periods given by max(TOT,17) where TOT is the time-over-threshold expressed in clock periods. After this interval the Event state machine becomes again live while the PKD is reset for 4 clock periods. Subsequent pulses on this SSD occurring during the reset period are ignored, that is they do not cause new events to be initiated. The third term in Equation D4 corrects for this loss of events by the reciprocal of the probability of having no pulses in the PKD reset interval and is given by

$$C^{i}_{\text{PKD\_reset}} = \exp(\text{SSD}i\text{\_rate} * \text{PKD\_reset} * \text{Clk\_period}) \quad \text{(D5)}$$

A further loss of events occurs if one or more additional SSD*i* pulses are detected within 7 clock periods after the initial pulse. Such pile-up events are discarded by the Event state machine to

[1]This is because Valid_Proc counts events processed by the software, even those that fail software selections.

avoid recording an erroneous pulse height measurement. The last term in Equation D4 corrects for this effect and is given by

$$C^{i}_{\mathrm{PUR\_veto}} = \exp\left(\frac{\mathrm{SSD}i * \mathrm{PUR\_veto}}{\mathrm{Max\_IDLE}}\right) \quad (\mathrm{D6})$$

The raw SSD*i* counter (rather than corrected rate) is used in Equation D6 because pile-up is only detected if the initial pulse falls below threshold before a subsequent pulse arrives, an effect which is incorporated in the raw counter behavior but removed in the corrected rate (Equation D3).

D5. Correction and Conversion of Ion Species Mode Spectra to Rates

The spectra are two-dimensional histograms, h_{ij} . For the Ion Species Counts histograms (TOFxE and TOFxPH) i indexes the look direction calculated from the position of the hit on the start anode and j indexes the bin in the Ion ID "space". For example, for TOFxE the bins are distributed along the trajectories of different mass ions in a TOF-vs.-Energy scatter plot. For TOFxE events there is also a high-energy resolution histogram indexed by SSD channel and energy bin.

There is a subtle issue that makes the conversion of the TOFxE spectra to rates somewhat more complicated than the multiplication of factors given in Equation D4. The look-direction index is given by the Start Anode position rather than the SSD channel, but it's the latter that determines the correction factors in Equations D6 and D7. One could blend a mix of correction factors involving the different SSDs hit by a given Start-determined look-direction. However, since the correction factors will be most important at high-rate conditions, in which the Start=Stop=SSD matching would likely be enabled, a simpler practical approach is to assume that Start look direction and SSD channel are identical for the purpose of converting the spectrum to rates.

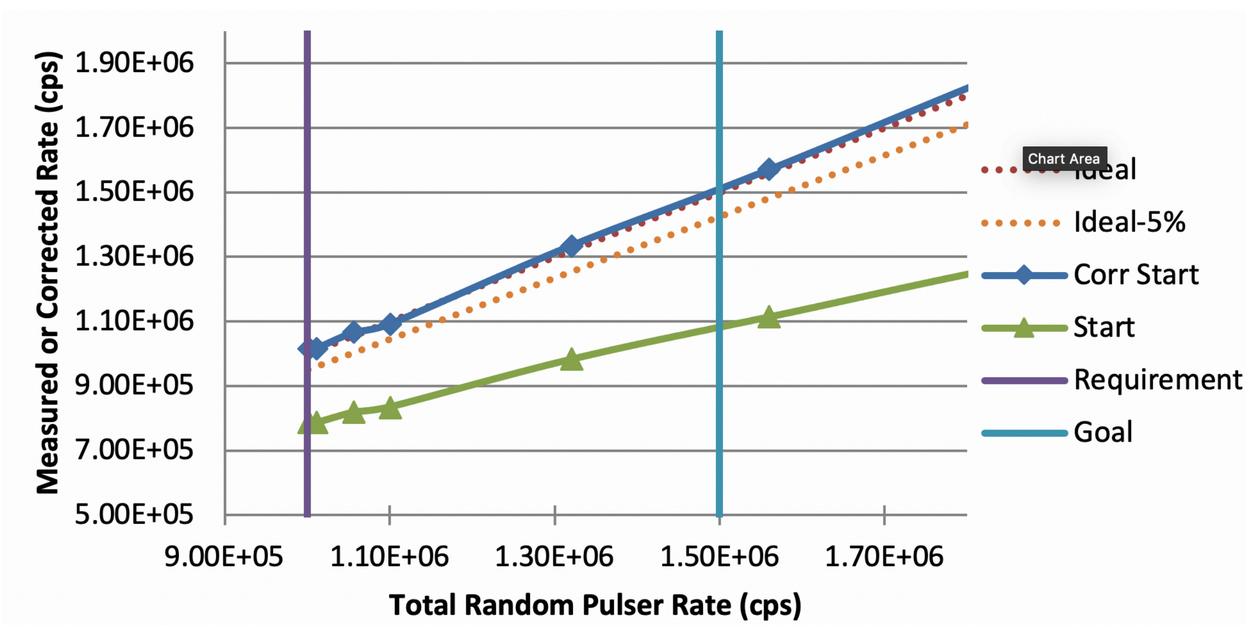


Exhibit D3. *Start Anode singles rates: raw (green) and corrected (blue).*

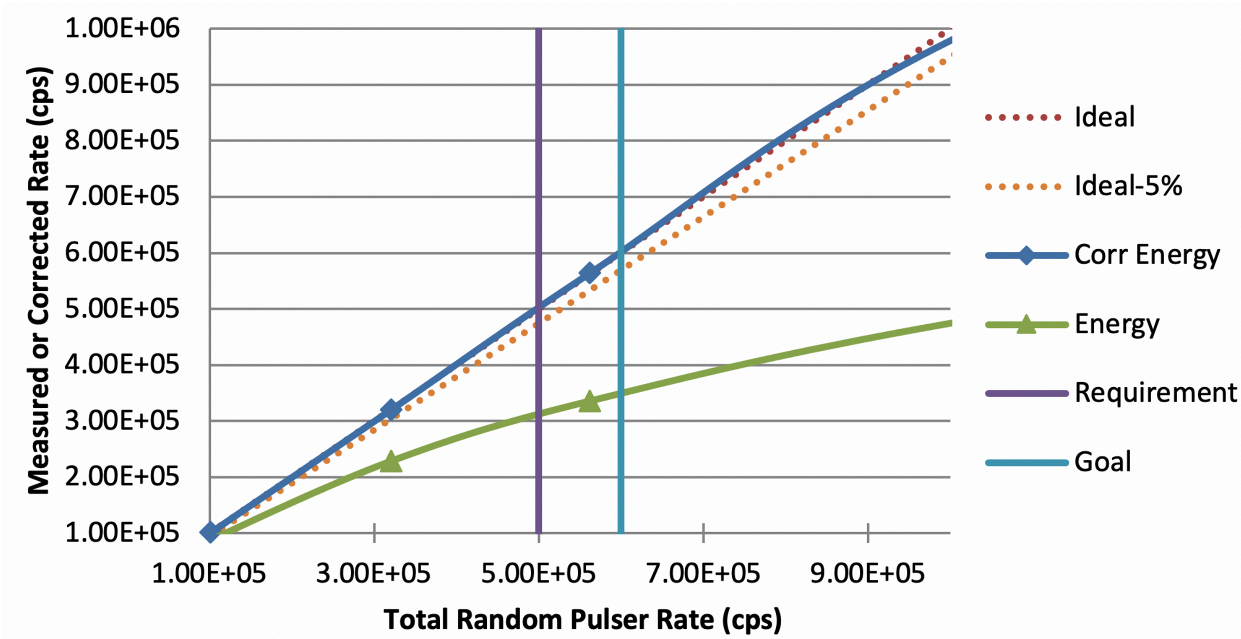


Exhibit D4. *SSD3 singles rates; raw (green) and corrected (blue).*

The conversion from TOFXE spectrum to rates is then given by

$$R_{ij} = \frac{h_{ij}}{\text{Valid\_Proc}} * \frac{\text{Valid\_TOFXE+Valid\_TOFxPH}}{\text{IDLE}} * C^{i}_{\text{PKD\_reset}} * C^{i}_{\text{PUR\_veto}} * \exp\left(\frac{\text{Stop0} * \text{SP\_veto}}{\text{Max\_IDLE}}\right) \quad \text{(D7)}$$

This expression is nearly identical to Equation D4, the exception being the last term which corrects for non-isolated Stop hits. The event logic requires no Stop hit in the two clock periods ±2 from the triggering clock period. Note, the clock periods adjacent to the triggering period are guaranteed to be empty by the synchronization logic.

An additional correction to the TOFxE rates may be necessary in a situation having a large SSD background, e.g., SSD hits from X-rays, electrons or penetrators which are not correlated with hits in the Start and Stop anodes. A potential TOFxE event would be lost if the PKD state machine were already busy from a previous background hit. The deadtime of the foreground hits (i.e., coincident with TOF hits) is at least partially accounted for by the Event state machine IDLE counter. The presence of background, whose deadtime is not counted, will lead to an inefficiency of triggering TOFxE events that needs to be studied further.

D6. Laboratory Measurements

Random pulsers were used to stimulate the Start and Stop Anodes as well as a single SSD of an Engineering Model. The uncorrelated (background) rates were 1.0E6, 5.6E5 and 1.0E3/s on the Start, Stop and SSD. Addition random coincident Start, Stop and SSD (foreground) pulses were superimposed on the “background”. The foreground pulses were generated with a fixed TOF, position on anode and SSD energy. The foreground rates were varied from 1.0E3/s to 7.5E6/s.

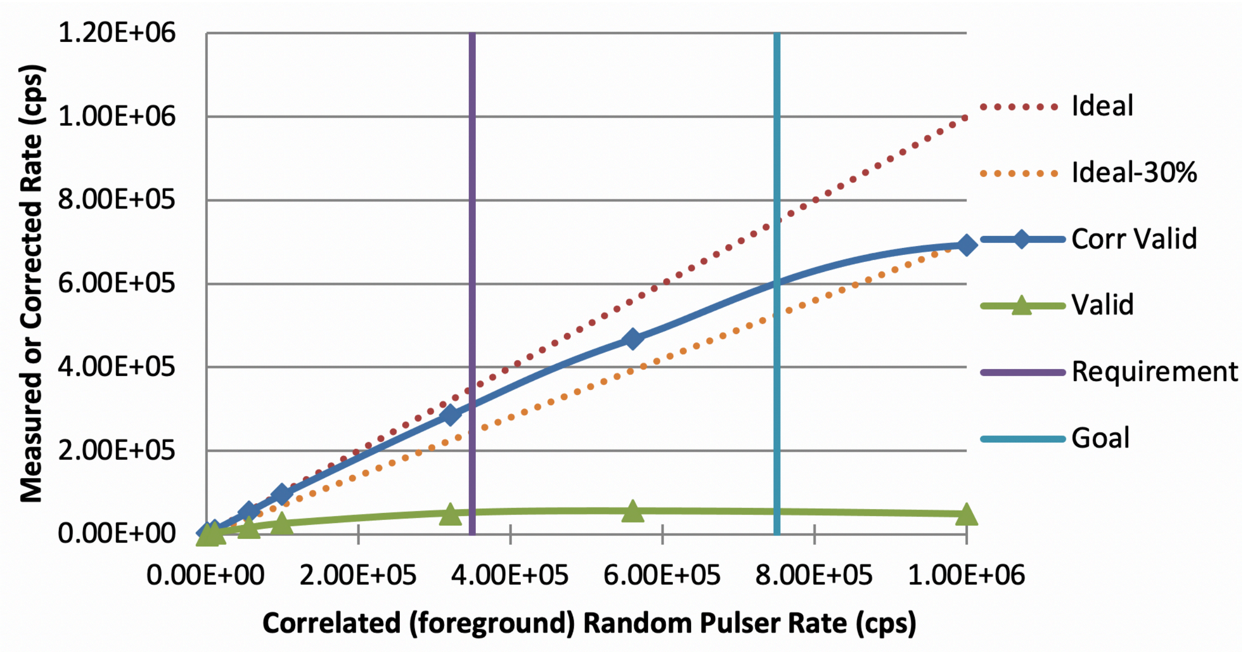


Exhibit D5. *Valid TOFxE rate; raw (green) and corrected (blue).*

The conversion and correction of Start Anode counts (Equation D1) and SSD counts (Equation D3) for varying input rates are shown in Exhibits D3-D4 with markers indicating the location of the instrument's required and goal rates.

Because a monoenergetic pulse was used to excite only one SSD the lab data cannot test the formula for correcting the bins of the spectra. Nevertheless, one can apply a reduced form of Equation D7, in which the first factor is omitted, to correct the measured Valid event rate. That is shown in Exhibit D5 for TOFxE events.

Because the Start Anode pulses start the Event state machine one sees that in this dataset, in which there is a large (>1E6/s) Start Anode rate, the raw valid rate saturates at a somewhat low value due to the state machine deadtime. Nevertheless, after the corrections are made there is reasonably good tracking of the corrected rate with the foreground input rate.

D7. Future Corrections Work

1. Vary SSD background (still one detector)
2. Stimulate SSDs with spectrum
3. Stimulate multiple SSDs

Appendix E: References

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