UCL Department of Space and Climate Physics
Mullard Space Science Laboratory

Cluster Active Archive

Scientist's User Guide for Cluster PEACE Data

A. Fazakerley and the PEACE team at MSSL

Instrument Description

Data Products

Data Products Prepared for the Cluster Active Archive

Operations and Instrument Status

Instrument Description

Data Products

Data Products Prepared for the Cluster Active Archive

Operations and Instrument Status

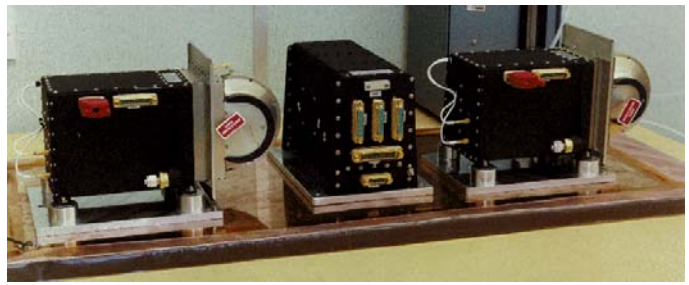
Instrument Description

A PEACE Instrument consists of:

Data Processing Unit

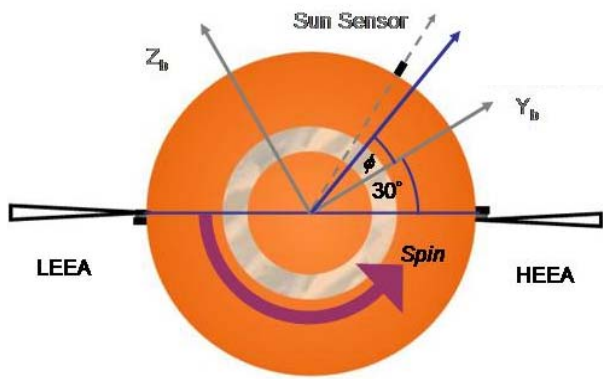
HEEA Sensor: higher sensitivity

LEEA Sensor: lower sensitivity



The sensors are mounted on opposite sides of the spacecraft

Their instantaneous look directions are fan-shaped, and after a satellite rotation these fans have both been swept through 4π solid angle, giving 3D coverage of *f(v)*



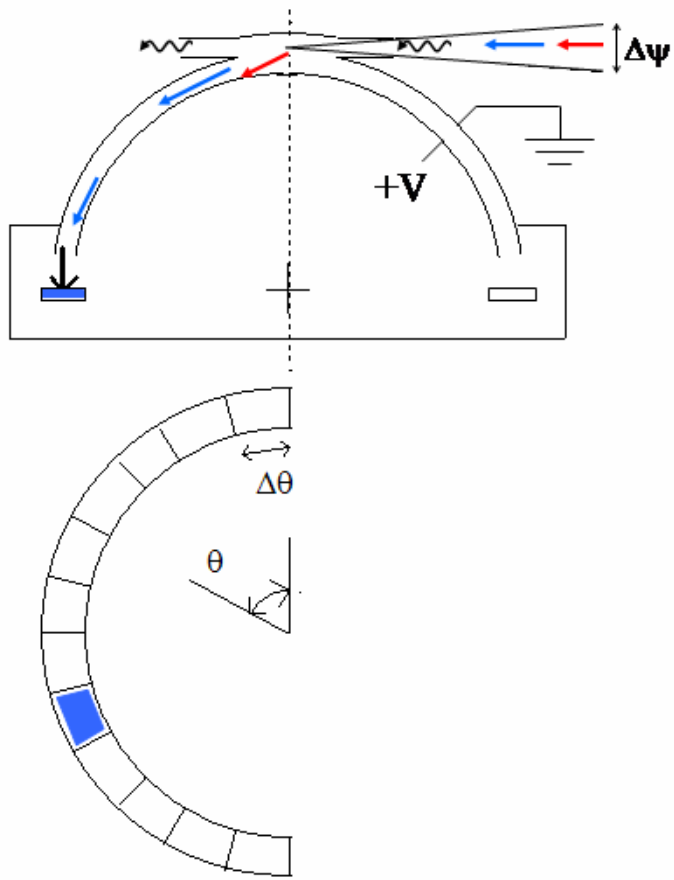
The PEACE instruments are designed to use the pair of sensors to characterise *f(v)* the velocity distribution function of electrons in the plasma environment local to the spacecraft for an energy range from the spacecraft potential up to 26 keV.

Spacecraft potentials as low as a few eV can be handled.

Instrument Description

How the Sensors work:

Electrons from the plasma surrounding the spacecraft are sampled using a “Top Hat” electrostatic analyser. Electrons and photons enter through a collimator. Most photons pass straight through and do not generate a signal. Electrons with the energy to be sampled are diverted into the electrostatic analyser (a pair of hemi-spherical plates with an electric field between them). The analyser selects electrons of a specific narrow energy band and transmits only those electrons to the detector.



The detector is a half-annular microchannel plate, MCP (to amplify the signal corresponding to an incident electron). The charge from the MCP is collected on an anode, which can detect which of twelve 15° sectors the electron arrived in. Signals are collected during 4 millisecond intervals.The electric field in the analyser is varied through a range of energies, to cover the full energy range several times per spin.

Instrument Description

How the Sensors work:

The sensors can operate in any of three energy sweep modes.

(i) The most commonly used is MAR.

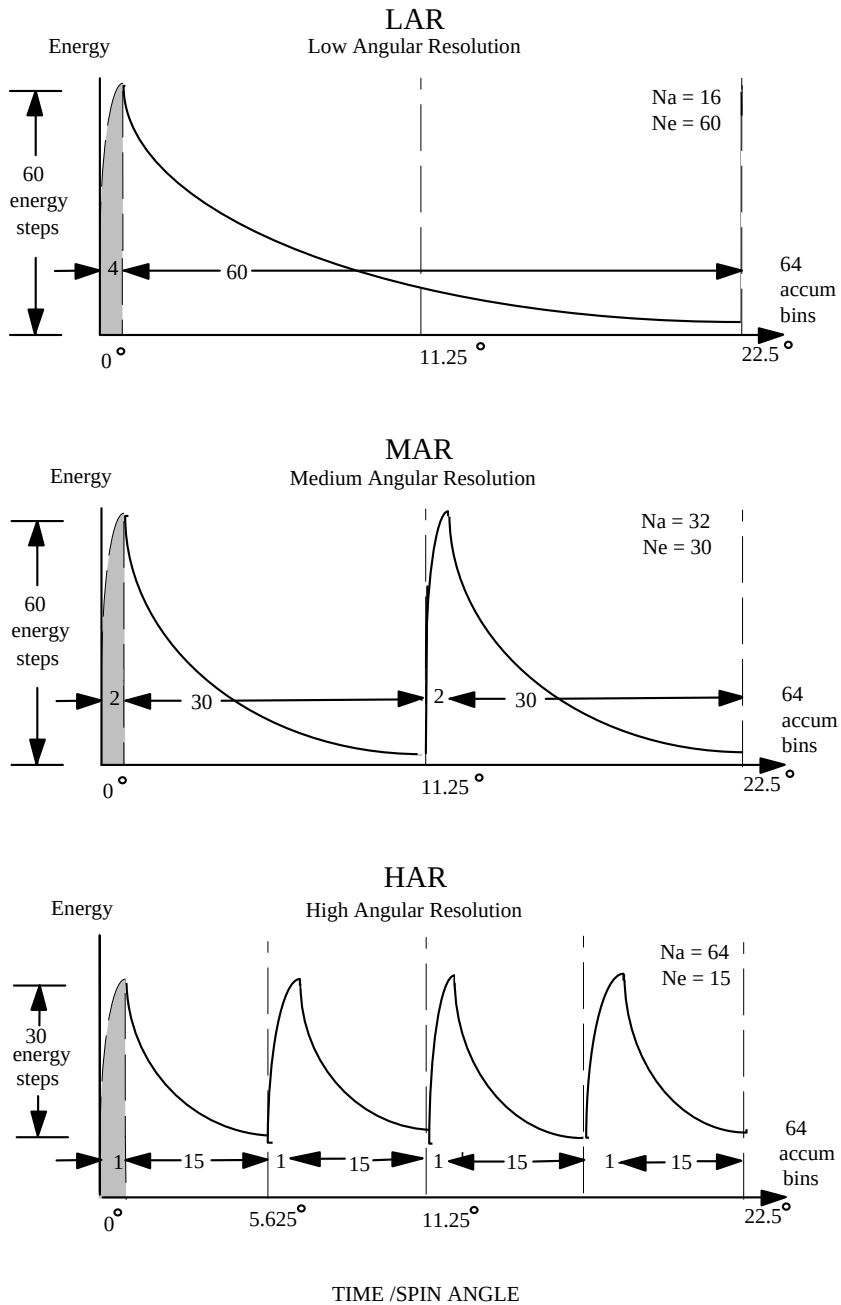
32 energy sweeps per spin gives azimuth resolution of 11.25° degrees.

(ii) The HAR mode is also often used.

64 energy sweeps per spin gives azimuth resolution of 5.625° degrees, over half the MAR energy range.

(iii) The least commonly used is LAR.

16 energy sweeps per spin gives azimuth resolution of 22.5° degrees, over the same energy range as MAR, but with twice the resolution.



Instrument Description

Data Products

Data Products Prepared for the Cluster Active Archive

Operations and Instrument Status

Data Products

Transmitted Data Products

Pre-Science Data Products

- OMS (onboard moments sums)
- PAD (onboard selected pitch angles)

Science Data Products

- 3DF (full measured dataset per spin)
- 3DX (compressed version of 3DF)
- 3DR (x8 compressed version of 3DF)

Non-science Data Products

- NOI (for MCP performance monitoring)
- LER (usually <10 eV data)

Science Data Products

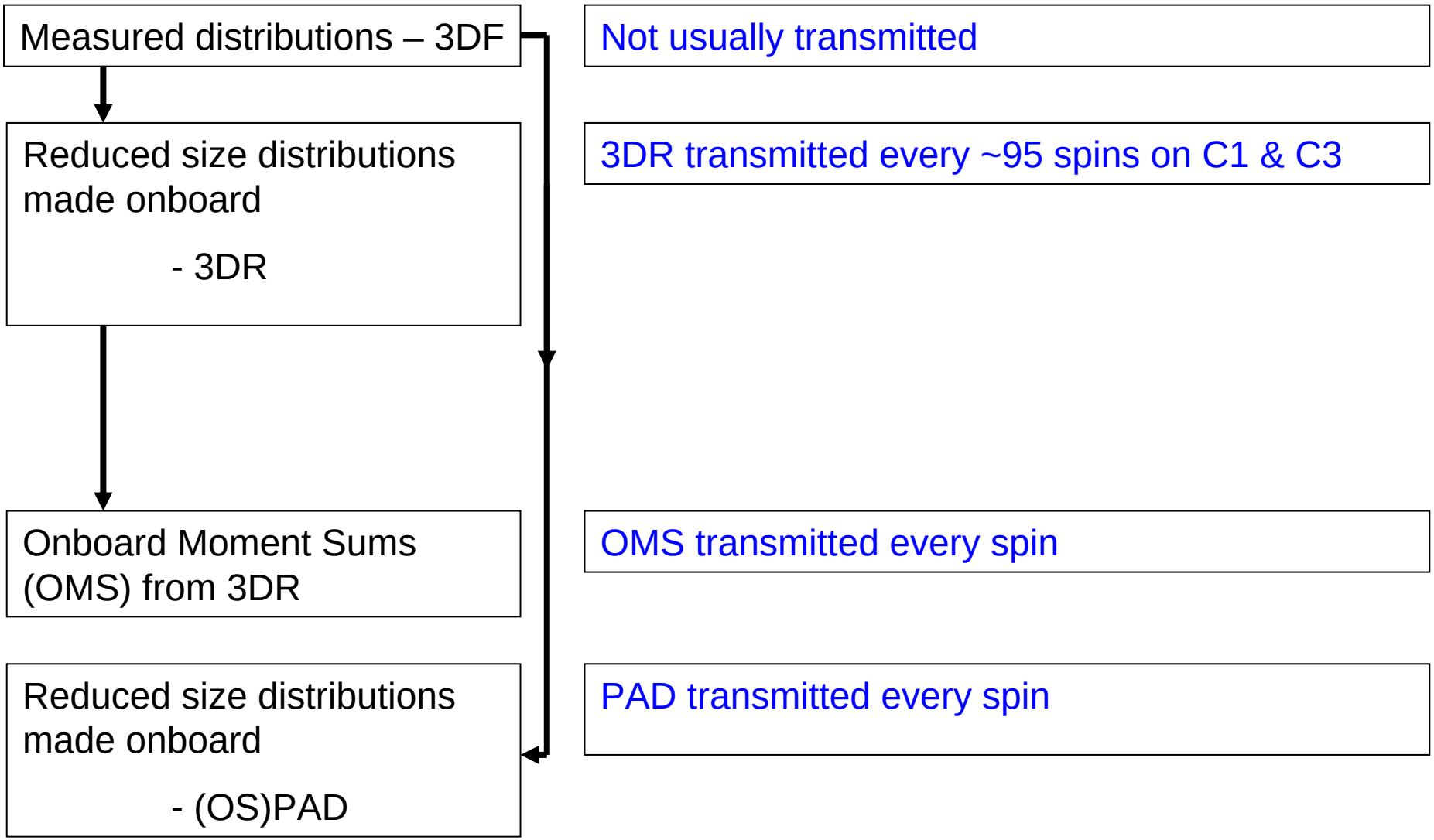
Science Data Products

- 3DF
- 3DX
- 3DR

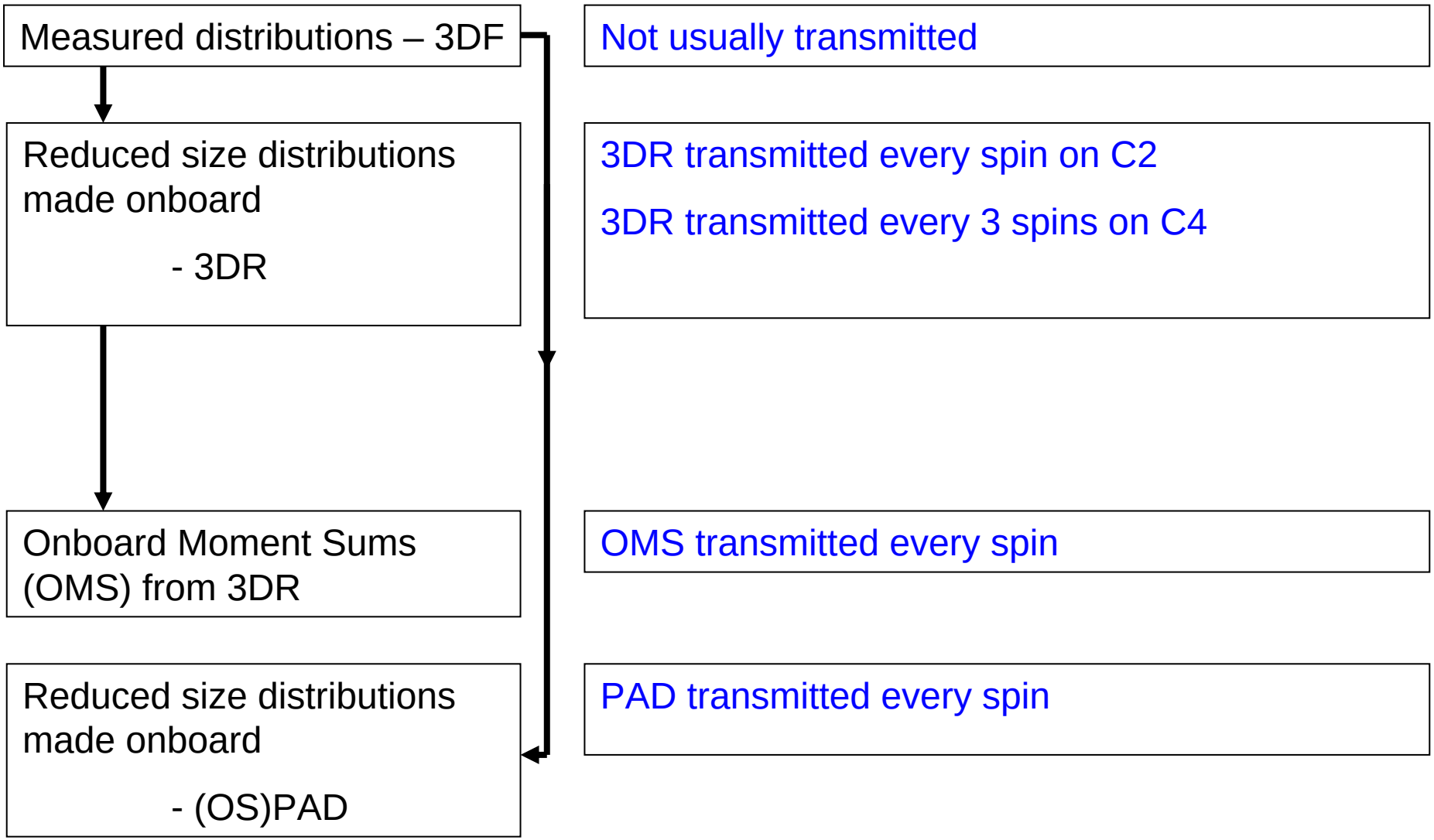
Value Added Science Data Products

- Moments (from OMS)
- Best Moments (from 3D data)
- SPINPAD
- Rebinned Pitch Angle (from PAD)

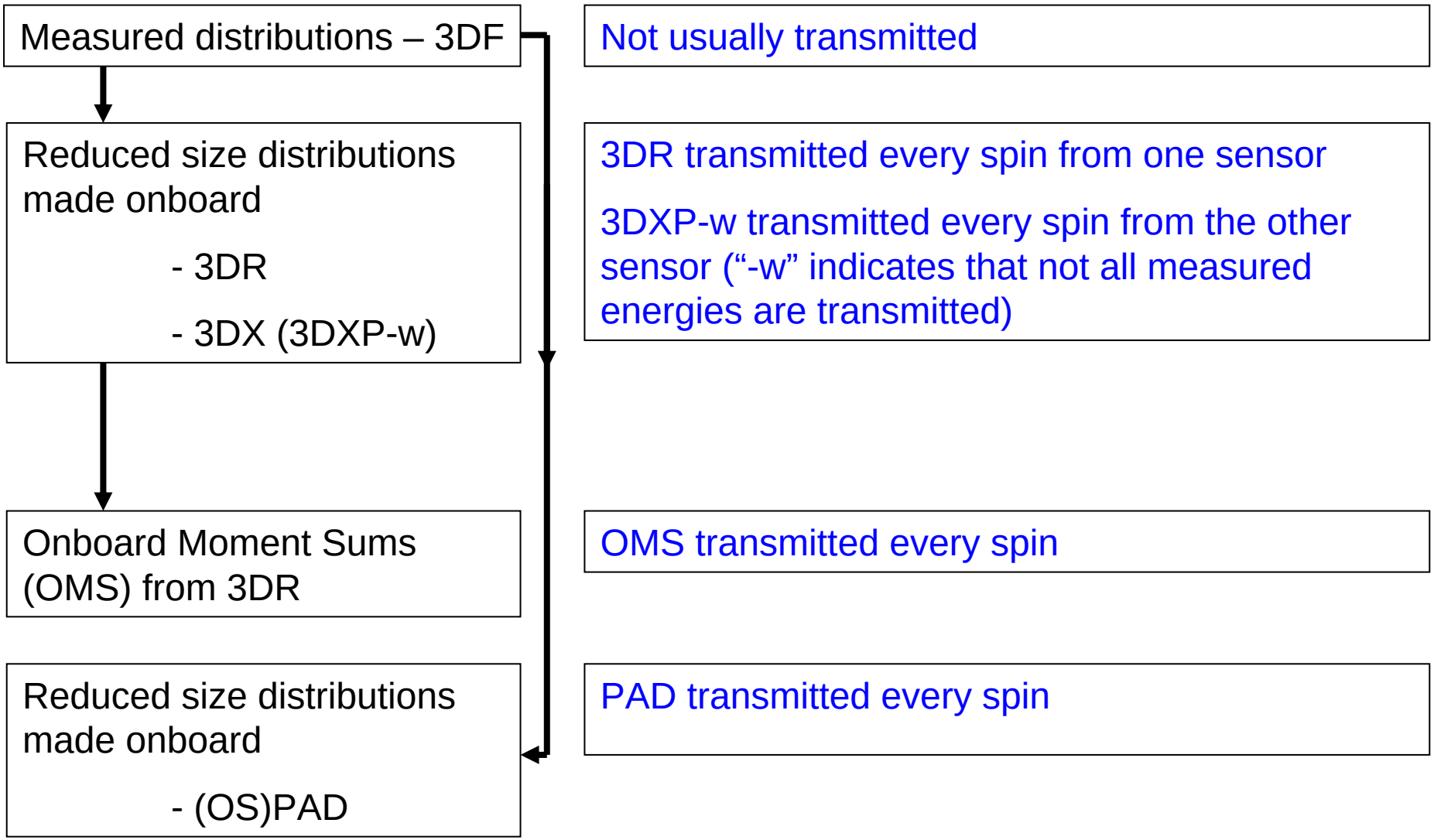
PEACE Data in normal operations (NM1: C1, C3)



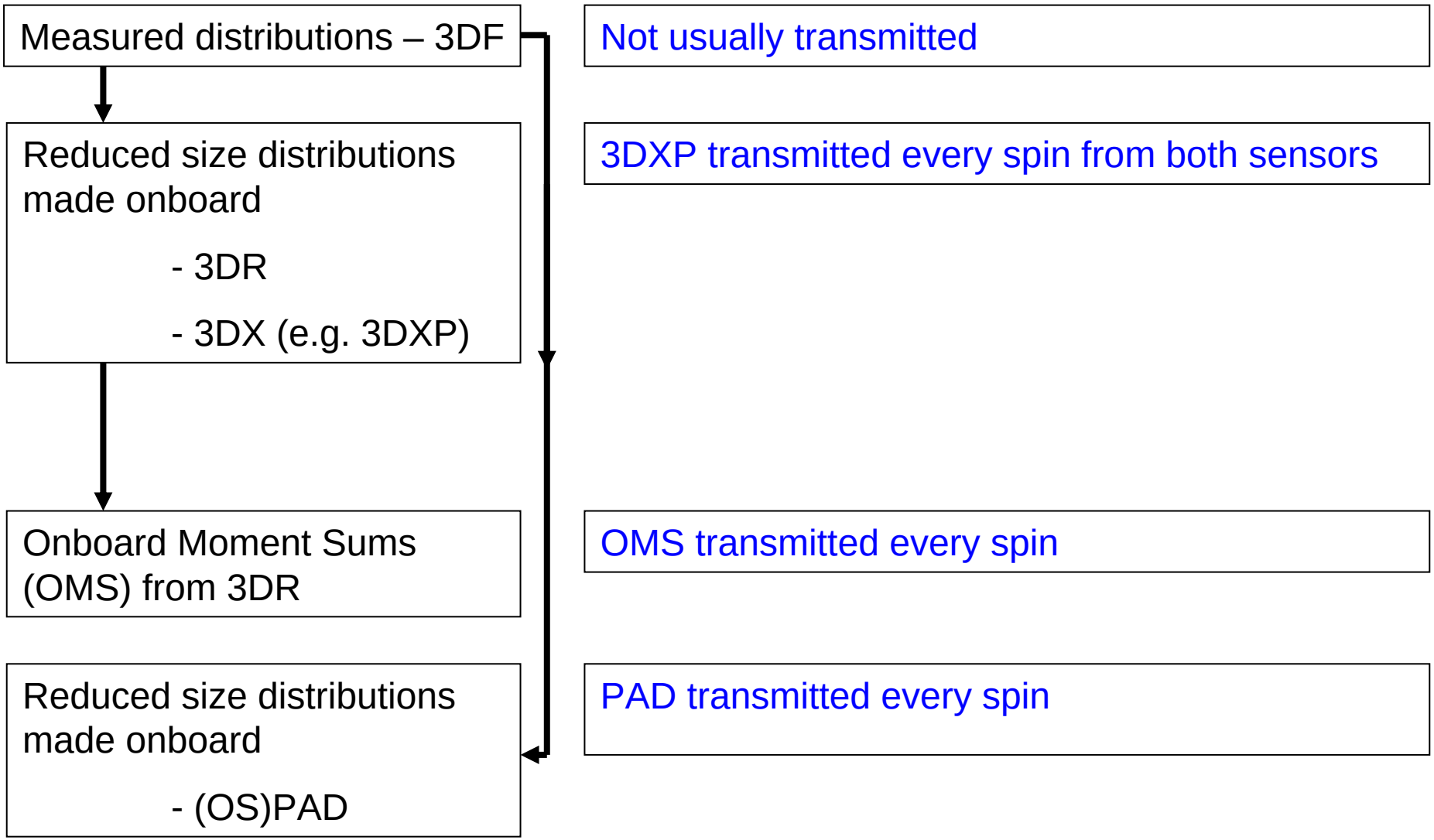
PEACE Data in normal operations (enhanced NM1: C2, C4)



PEACE Data in burst TM operations (BM1: C1, C3)



PEACE Data in burst TM operations (enhanced BM1: C2, C4)



Data Products

3DF

The measured 3D dataset from each sensor (very large so not usually available)

3DR

A reduced resolution 3D dataset which is routinely produced onboard.

3DX

Several variants of 3DX exist. Less compressed than 3DR. Designed to maximise the resolution and coverage of 3D data transmitted at spin-rate time resolution.

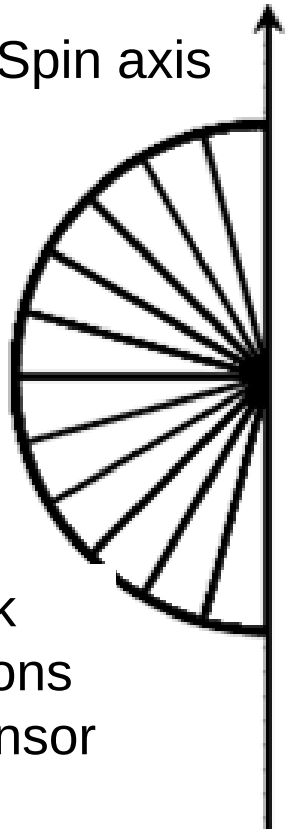
OMS *Onboard moment sums*

These are routinely calculated using 3DR, and calibration data stored onboard.

However there is no correction for spacecraft potential and only limited opportunities to discard measured photoelectrons.

PAD *(OSPAD) Onboard selected pitch angle data*

These are routinely calculated onboard using magnetometer data provided onboard.



12 look directions per sensor

Telemetred vs Measured Data

"Resolution" = 1.000

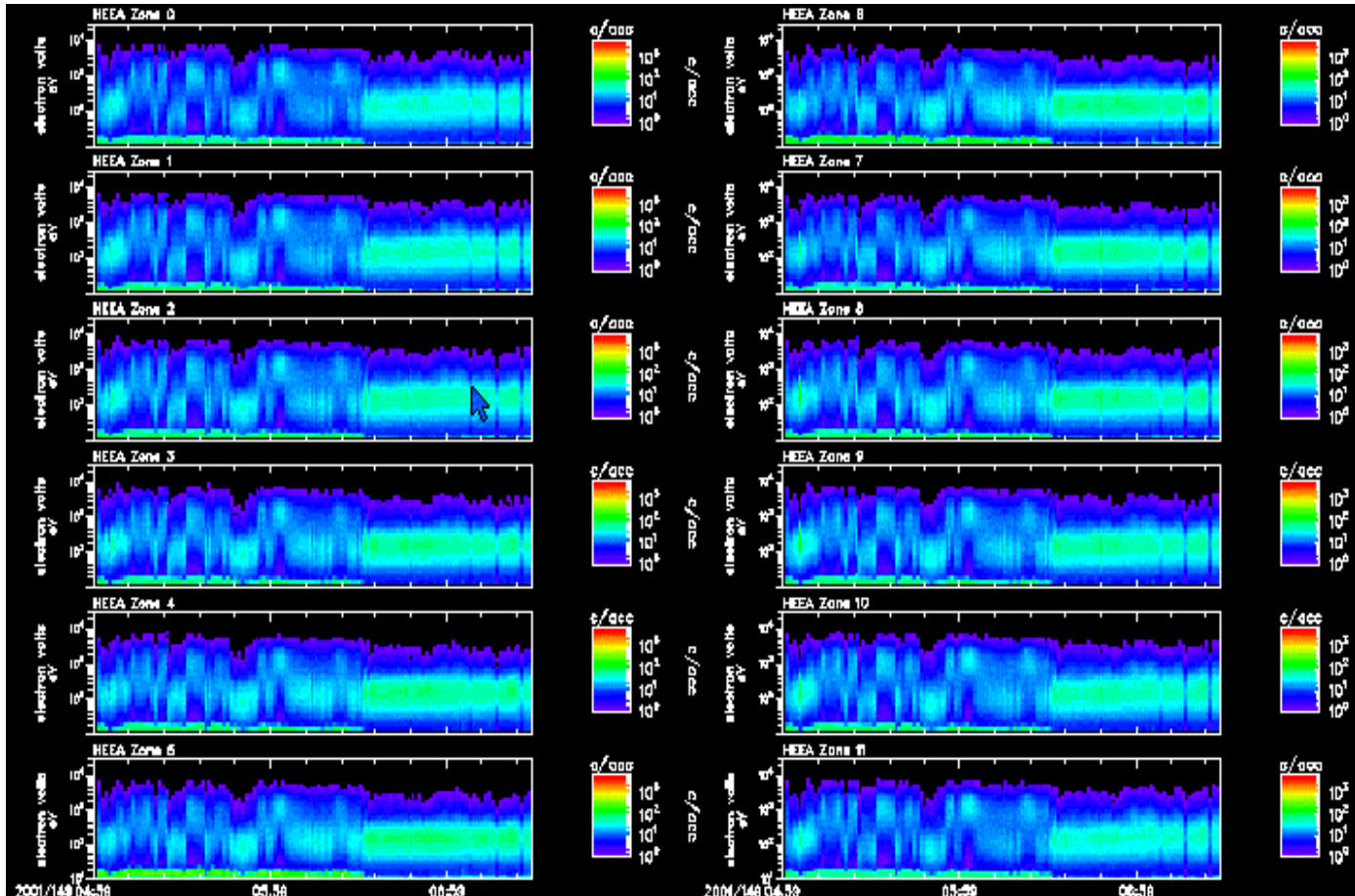
3DF can't be sent every spin (NM or BM)

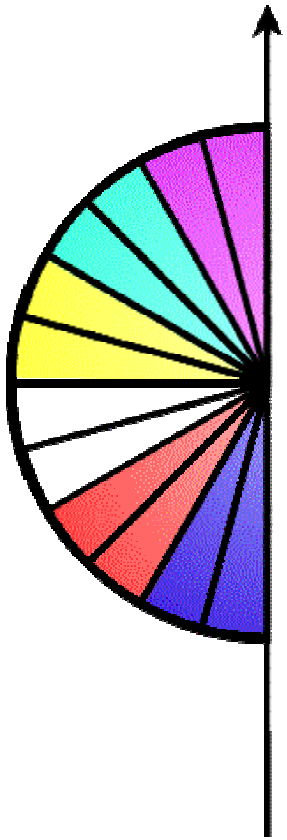
3DF (two sensor) and **3DX** (one sensor)

15° polar resolution (as measured)

2 step energy resolution (measured MAR)

22.5° azimuth resolution, (measured MAR)





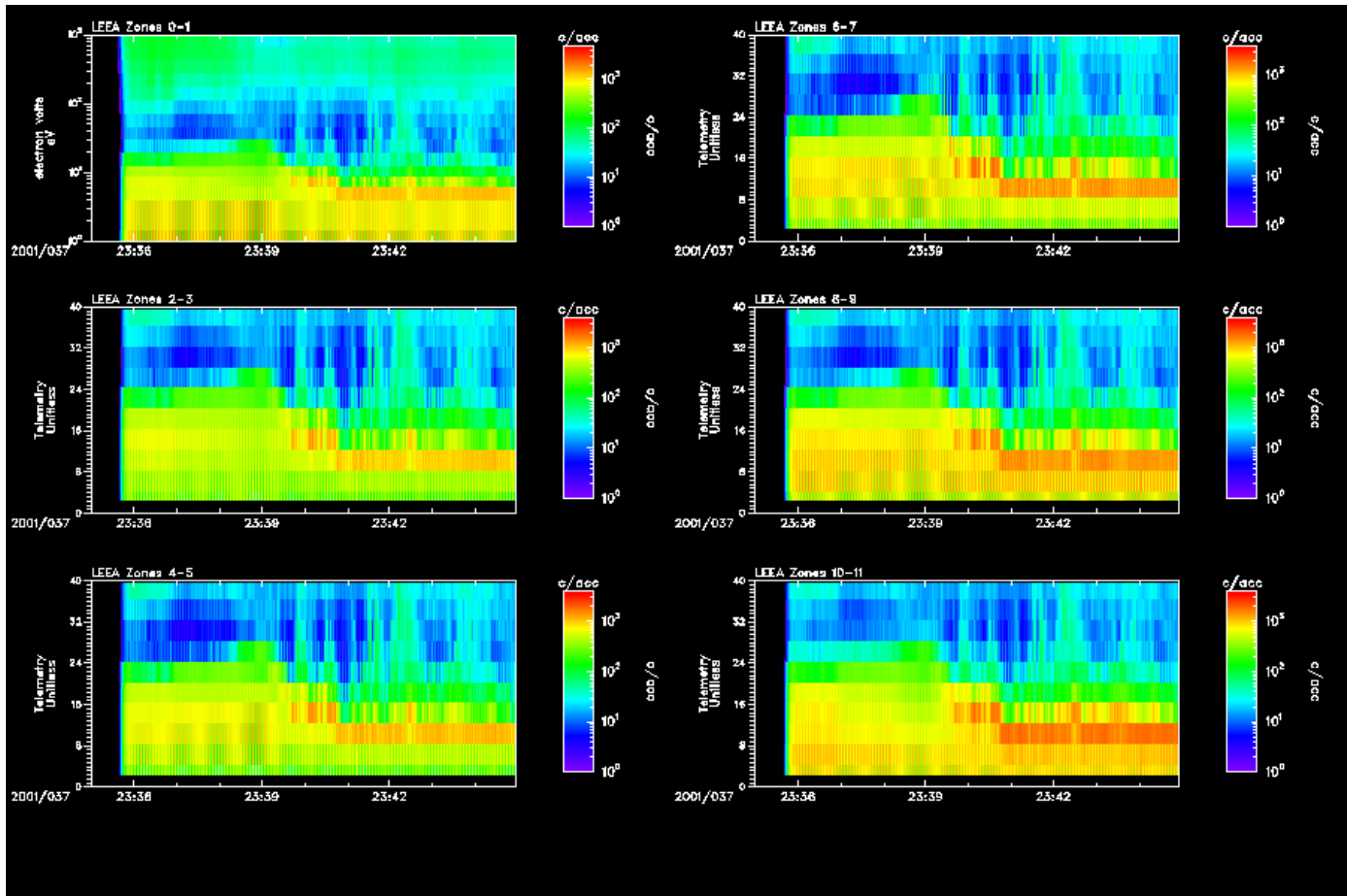
3DR MAR mode (one or two sensor options)

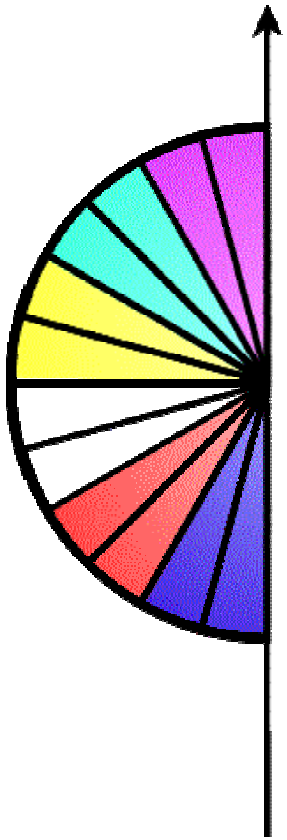
30° polar resolution (measured/2)

4 step energy resolution, MAR (measured/2)

45° azimuth resolution, MAR (measured/2)

Telemetred vs Measured Data
“Resolution” = 0.125





3DR HAR mode (one or two sensor options)

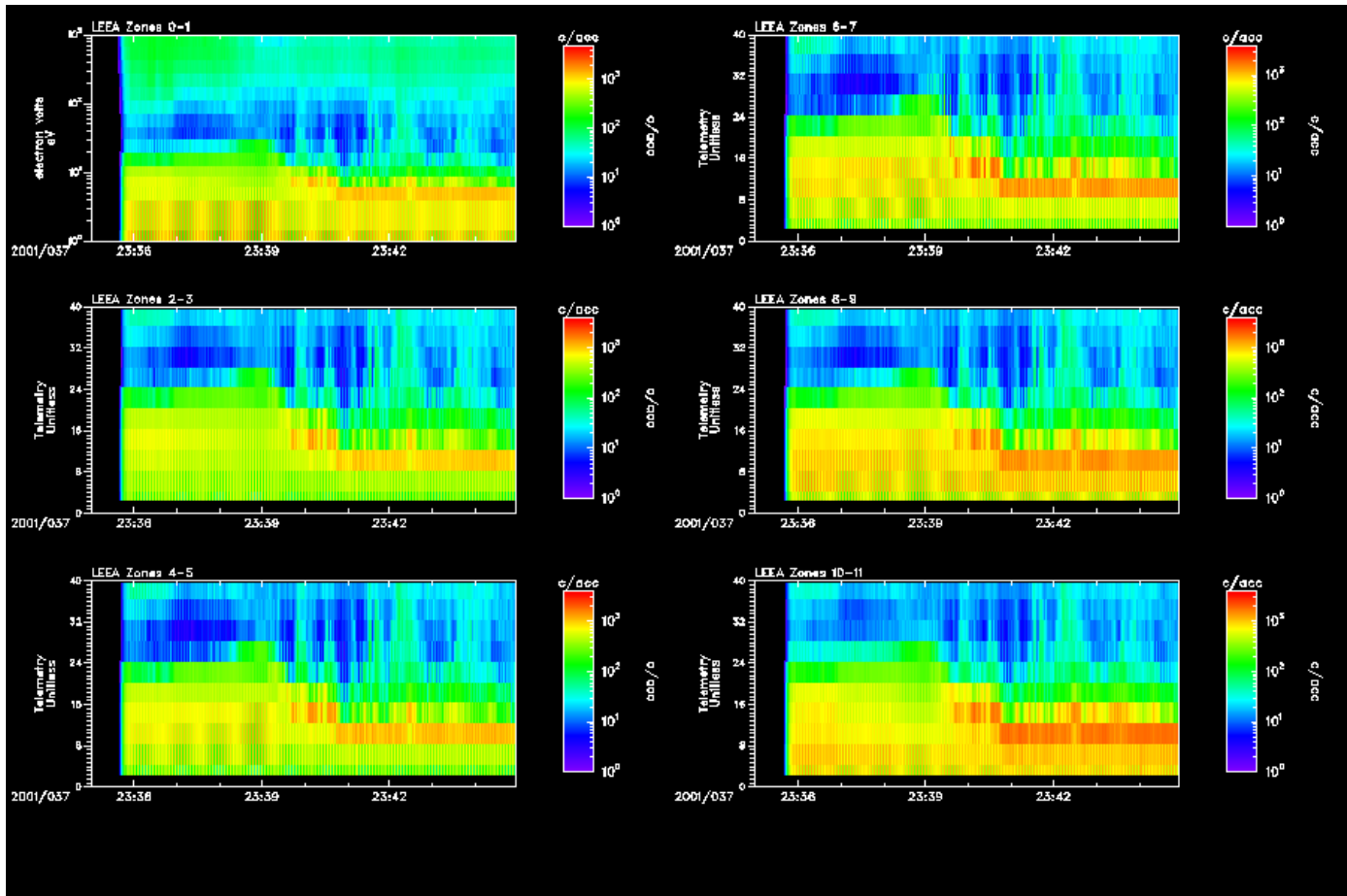
30° polar resolution (measured/2)

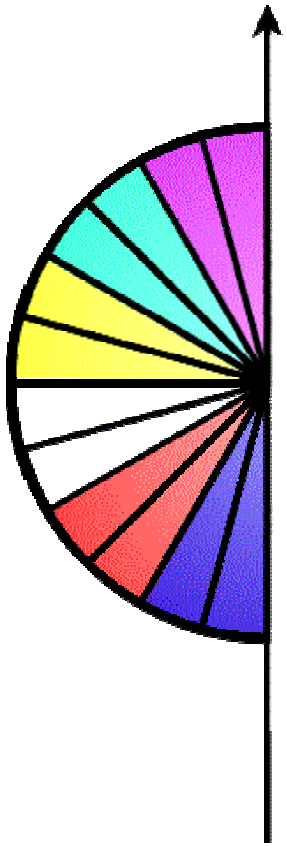
2 step energy resolution, HAR (measured)

45° azimuth resolution, HAR (measured/4)

Telemetred vs Measured Data

“Resolution” = 0.125



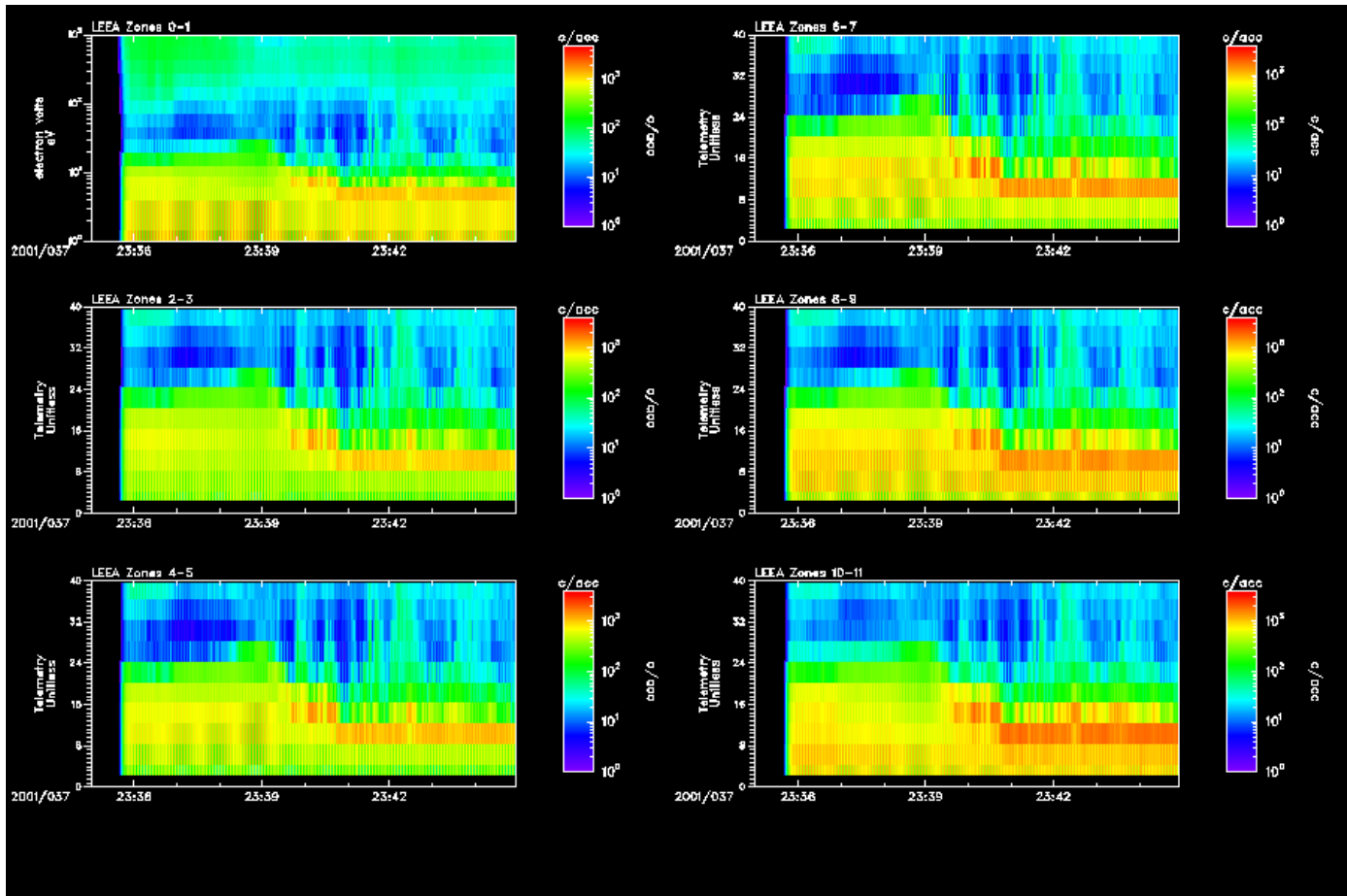


3DR LAR mode (one or two sensor options)

30° polar resolution (measured/2)

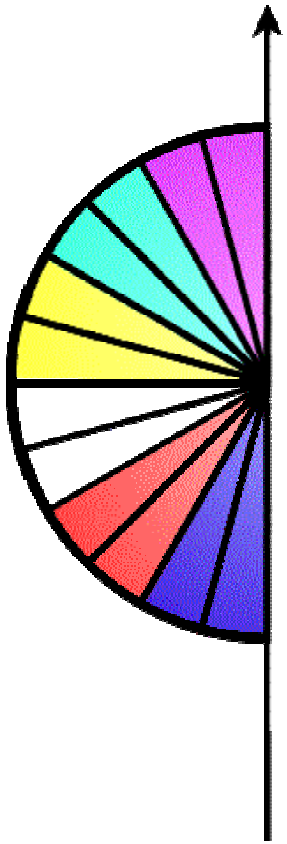
4 step energy resolution, LAR (measured/4)

45° azimuth resolution, LAR (measured)



Telemetred vs Measured Data

"Resolution" = 0.125



3DX-sp (one or two sensor option)

30° polar resolution (measured/2)

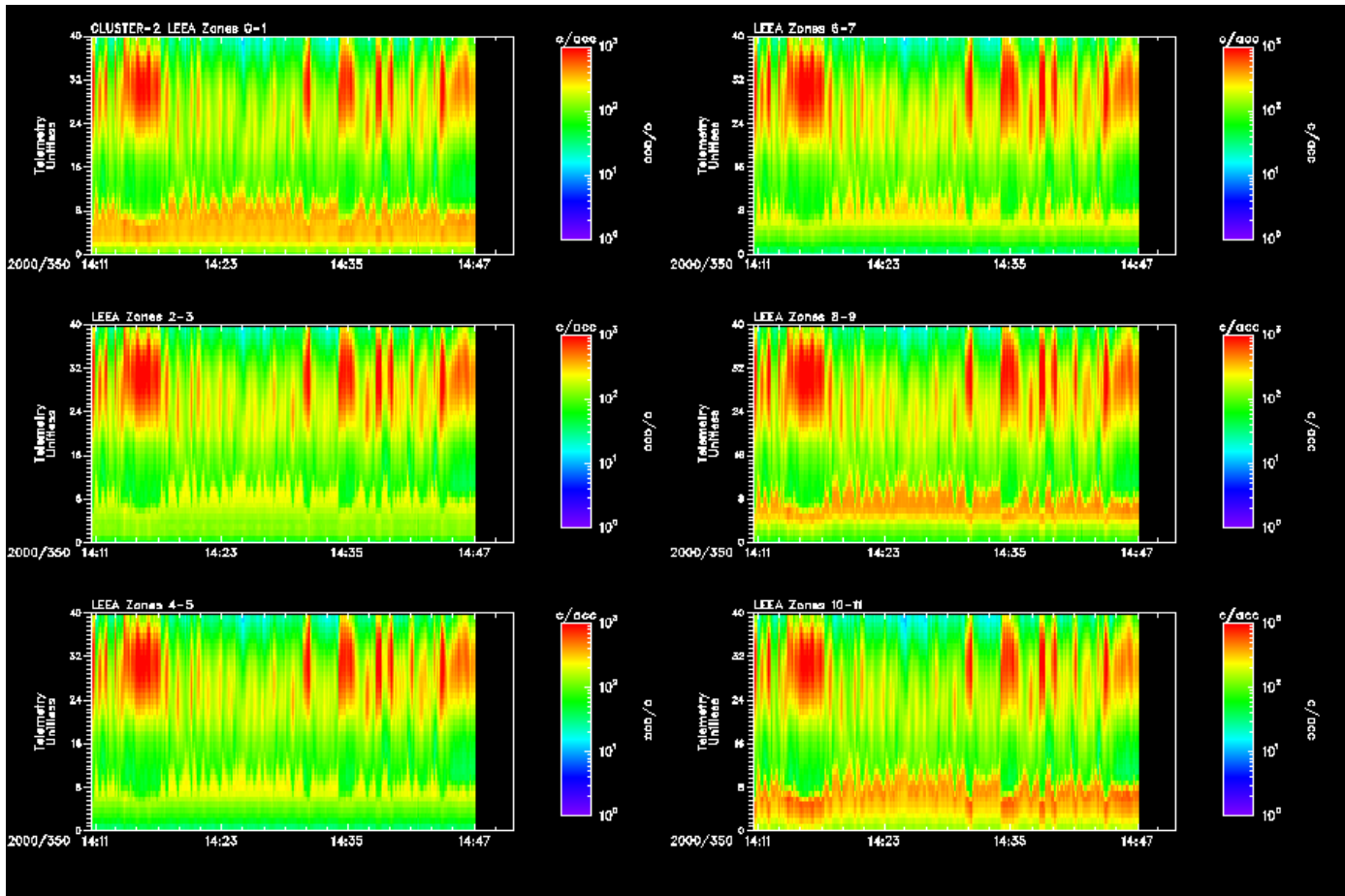
2 step energy resolution (measured MAR)

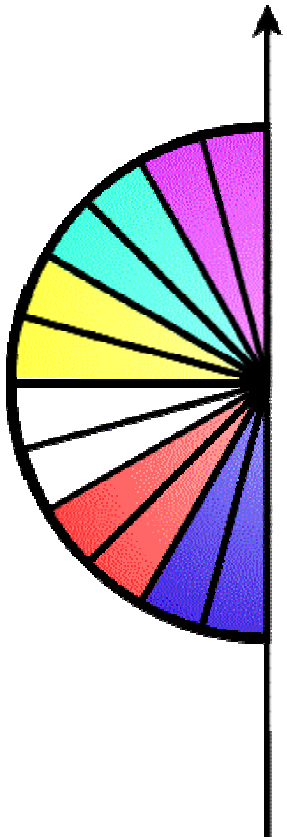
22.5° azimuth resolution, (measured MAR)

Telemetred vs Measured Data

"Resolution" = 0.500

Polar bins summed in consecutive pairs



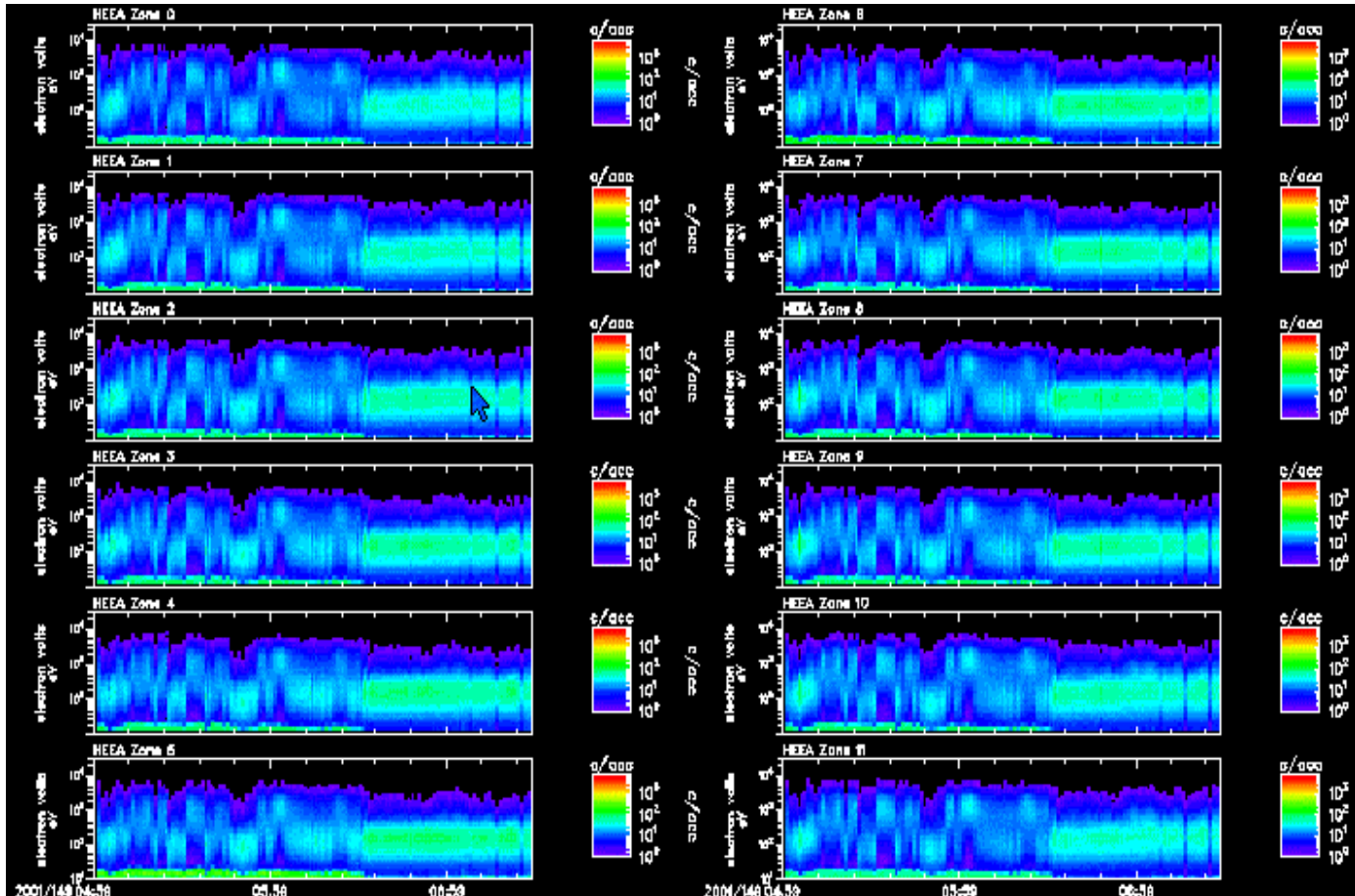


3DX-se (one or two sensor option)

15° polar resolution (as measured)

4 step energy resolution (measured MAR/2)

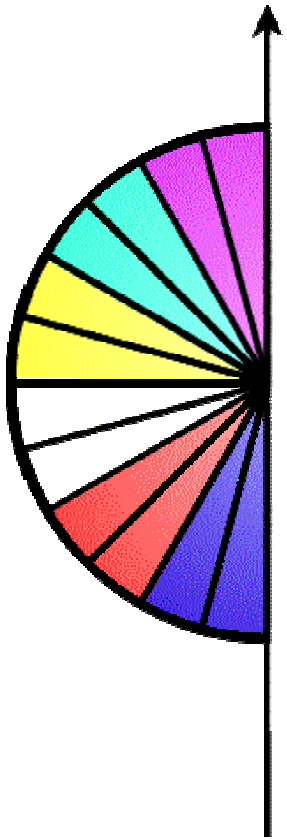
22.5° azimuth resolution, (measured MAR)



Telemetred vs Measured Data "Resolution" = 0.500

Energy bins summed in consecutive pairs

(Rarely used…)

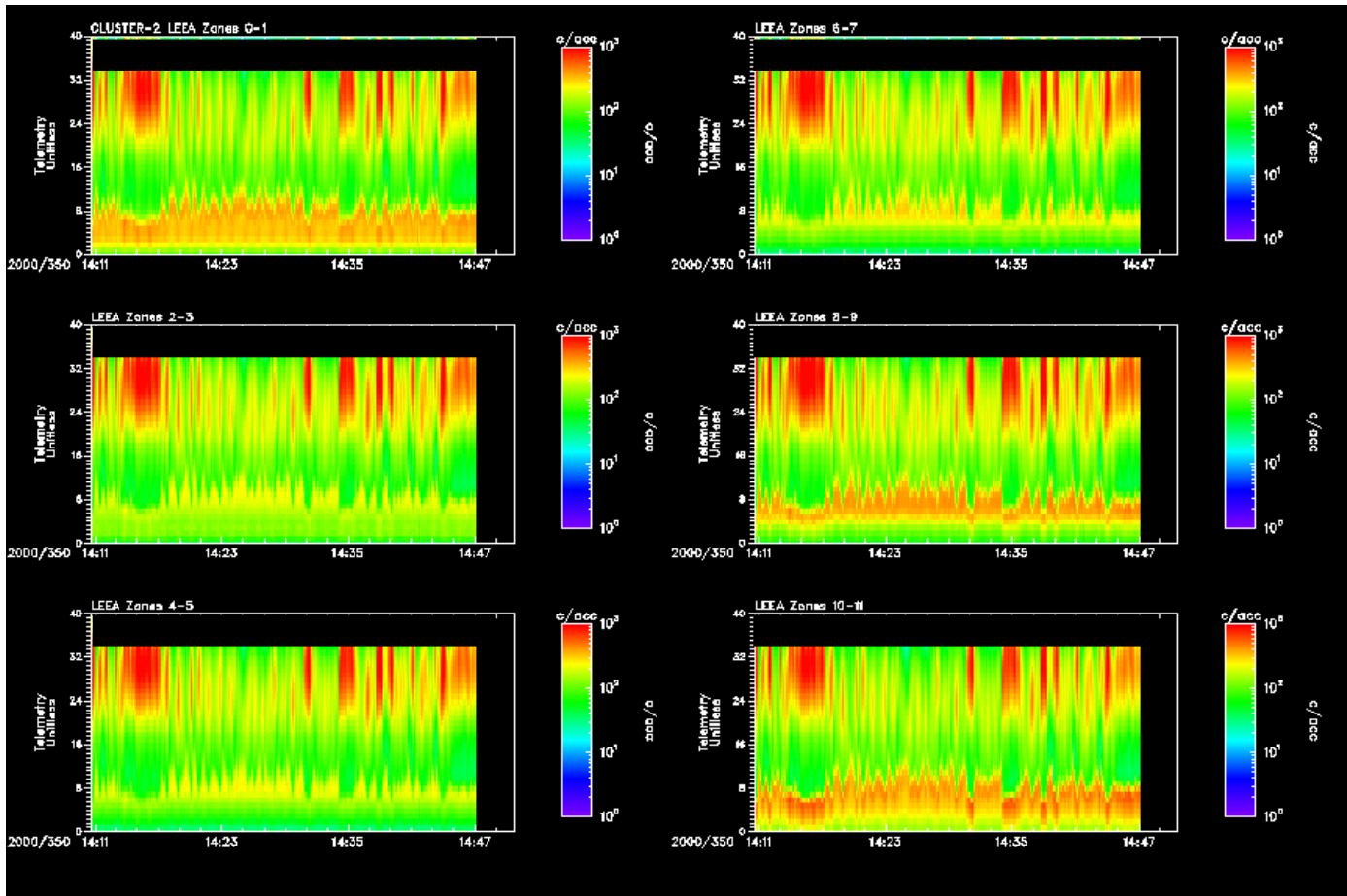


3DX-sp-w (one or two sensor option)

30° polar resolution (measured/2)

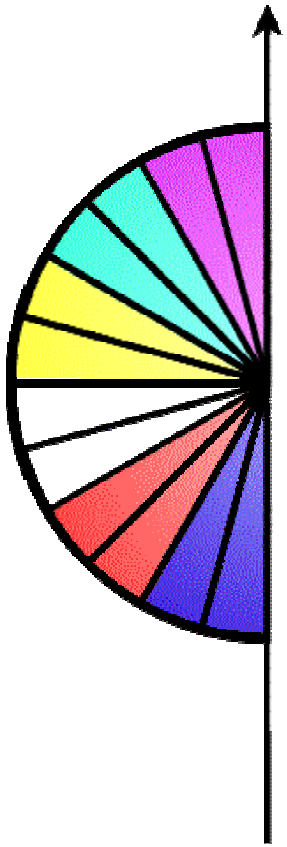
2 step energy resolution (measured MAR)

22.5° azimuth resolution, (measured MAR)



Telemetred vs Measured Data "Resolution" < 0.500

"-w" indicates that a subset of energy bins are not transmitted e.g. high energy

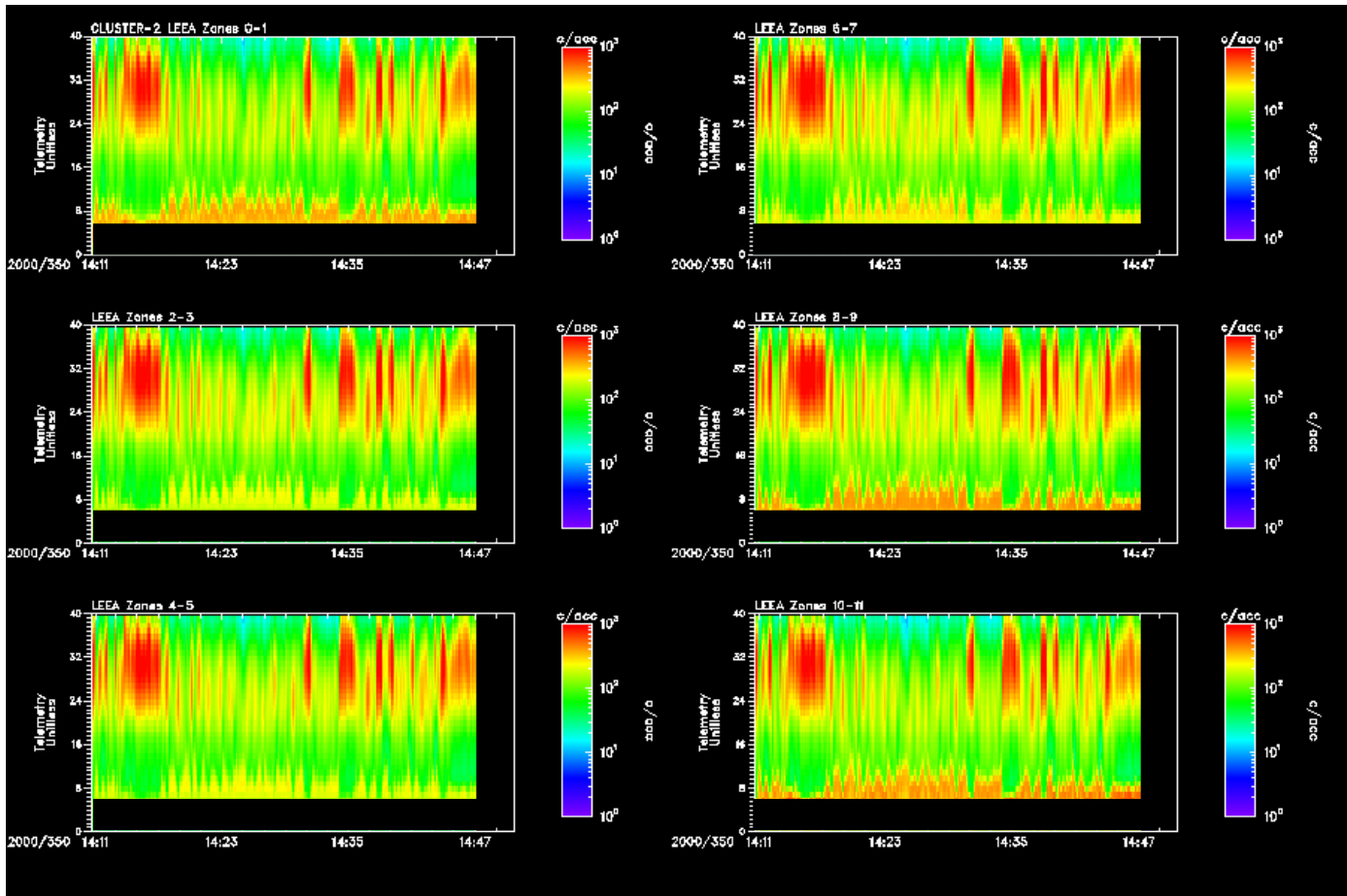


3DX-sp-w (one or two sensor option)

30° polar resolution (measured/2)

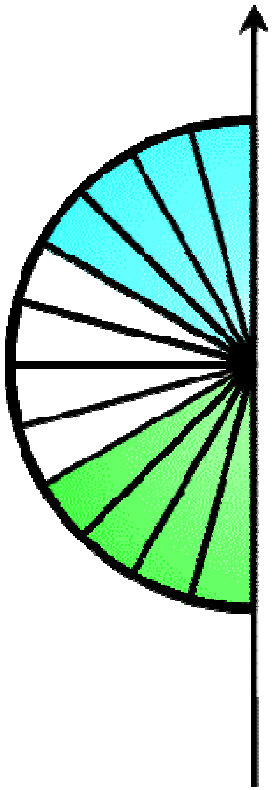
2 step energy resolution (measured MAR)

22.5° azimuth resolution, (measured MAR)



Telemetred vs Measured Data "Resolution" < 0.500

"-w" indicates that a subset of energy bins are not transmitted e.g. low energy

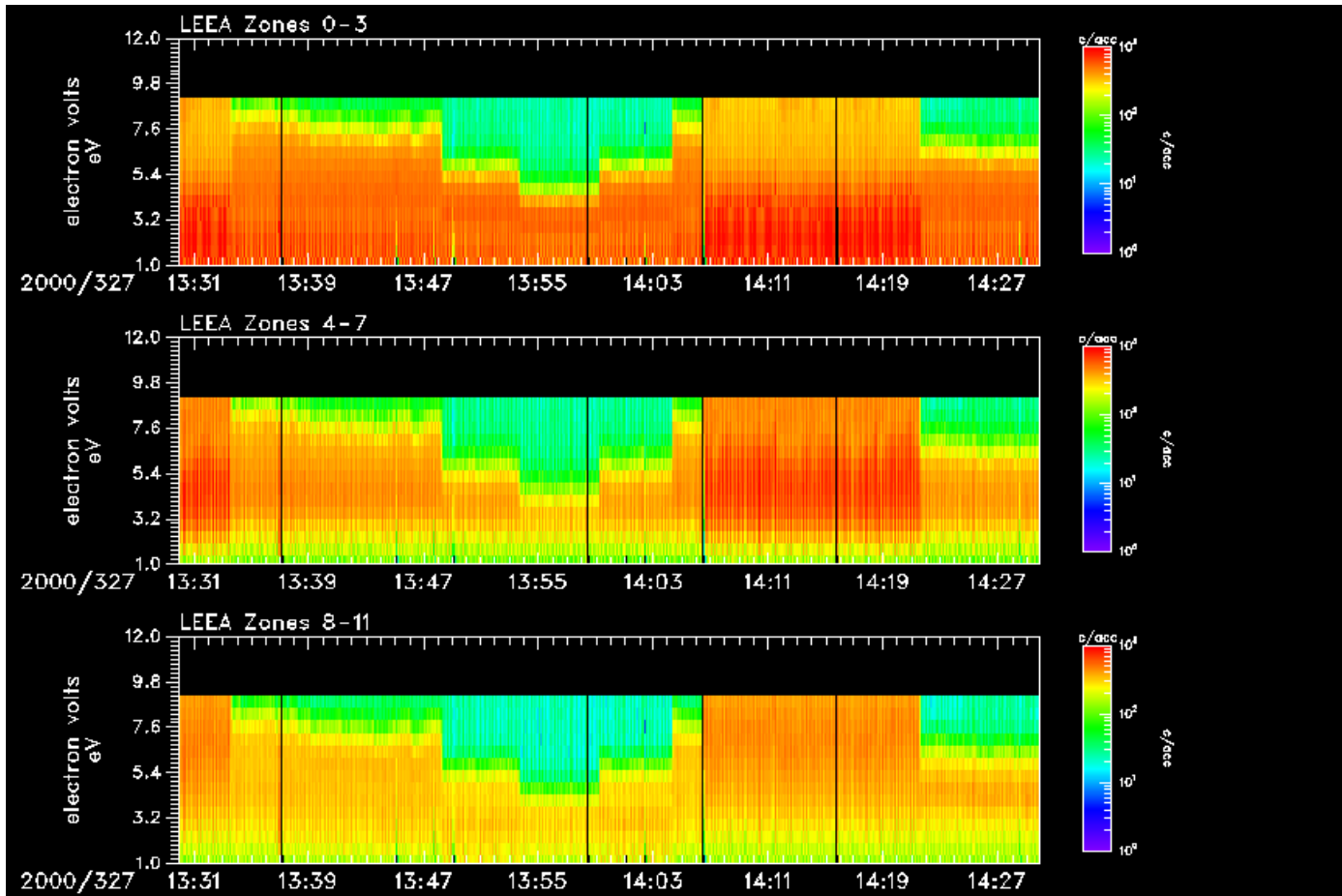


LER (one sensor)

60° polar resolution, (measured/4)

2 step energy resolution (measured MAR) 16/60 steps

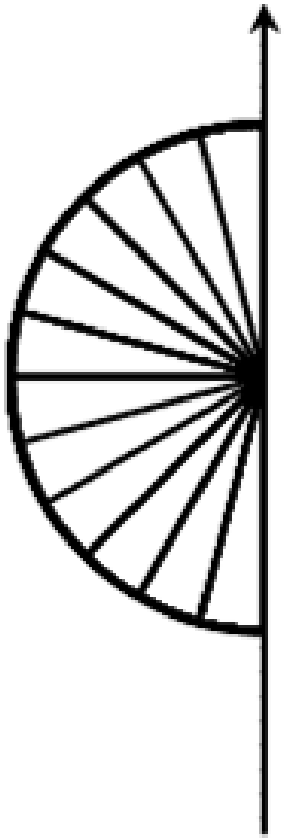
Subset of azimuths each spin (8 of 32 in MAR)



Telemetred vs Measured Data "Resolution"

= 0.016/spin

= 0.066/cycle

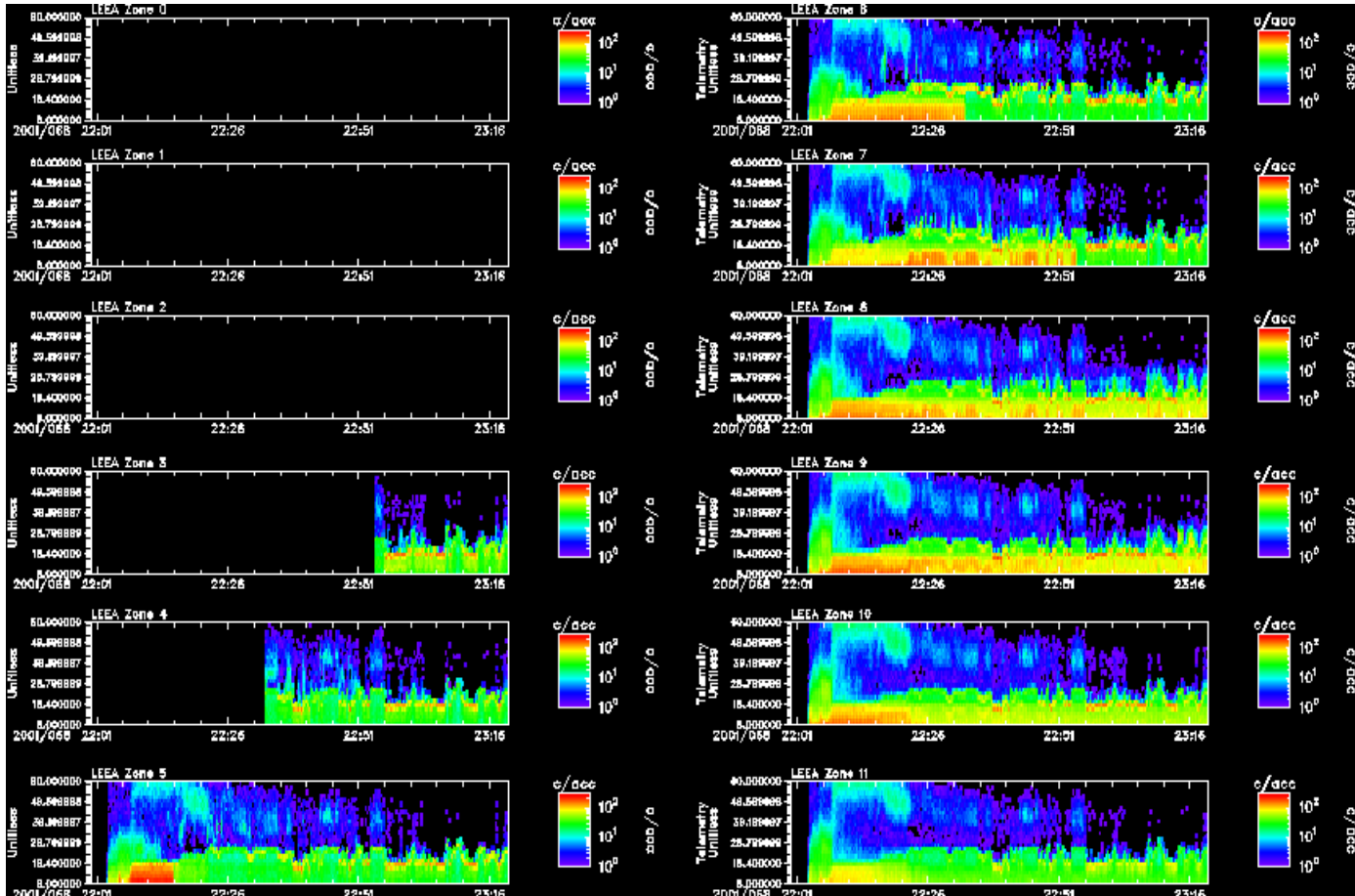


PAD (two sensor) on-board selected pitch angle data

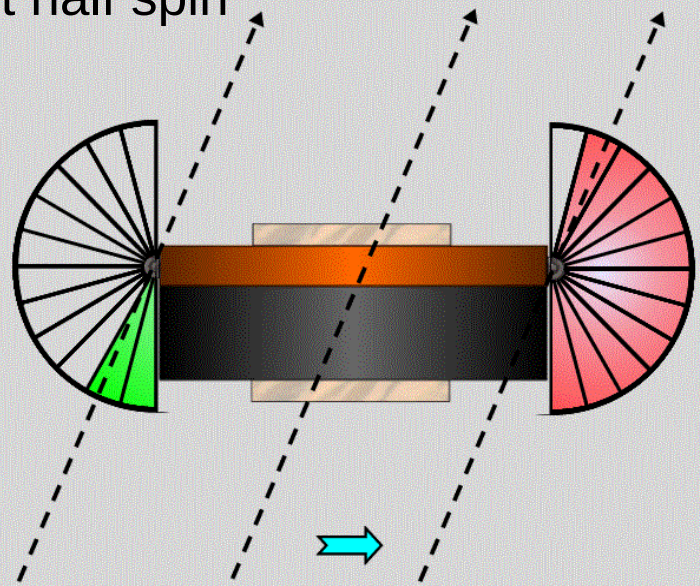
15° polar resolution (measured) subset selected

2 step energy resolution (measured MAR)

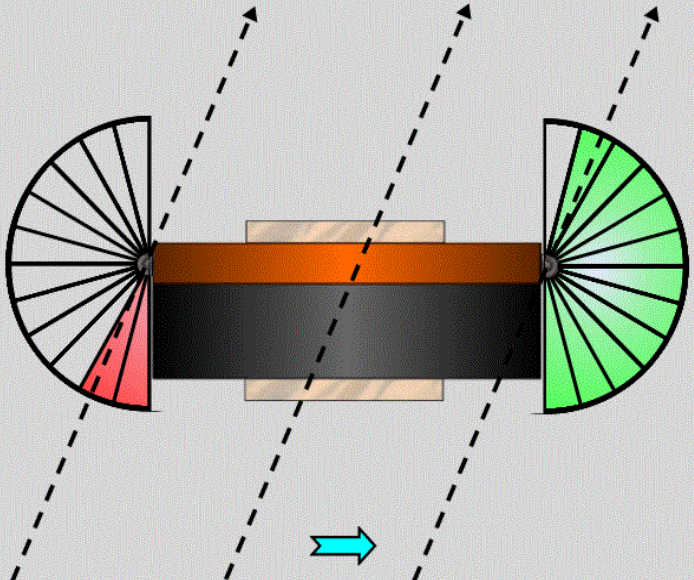
22.5° azimuth resolution, (measured MAR) 2/32 selected



First half spin



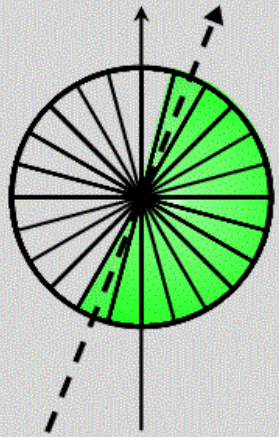
Second half spin

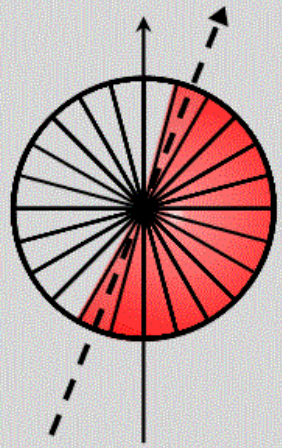


Collection of pitch angle data

Dashed lines are magnetic field
(data onboard from FGM on IEL)

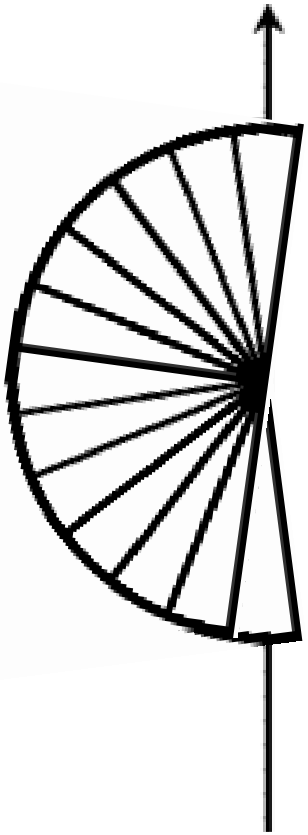
LEEA and HEEA





Assembling pitch angle data

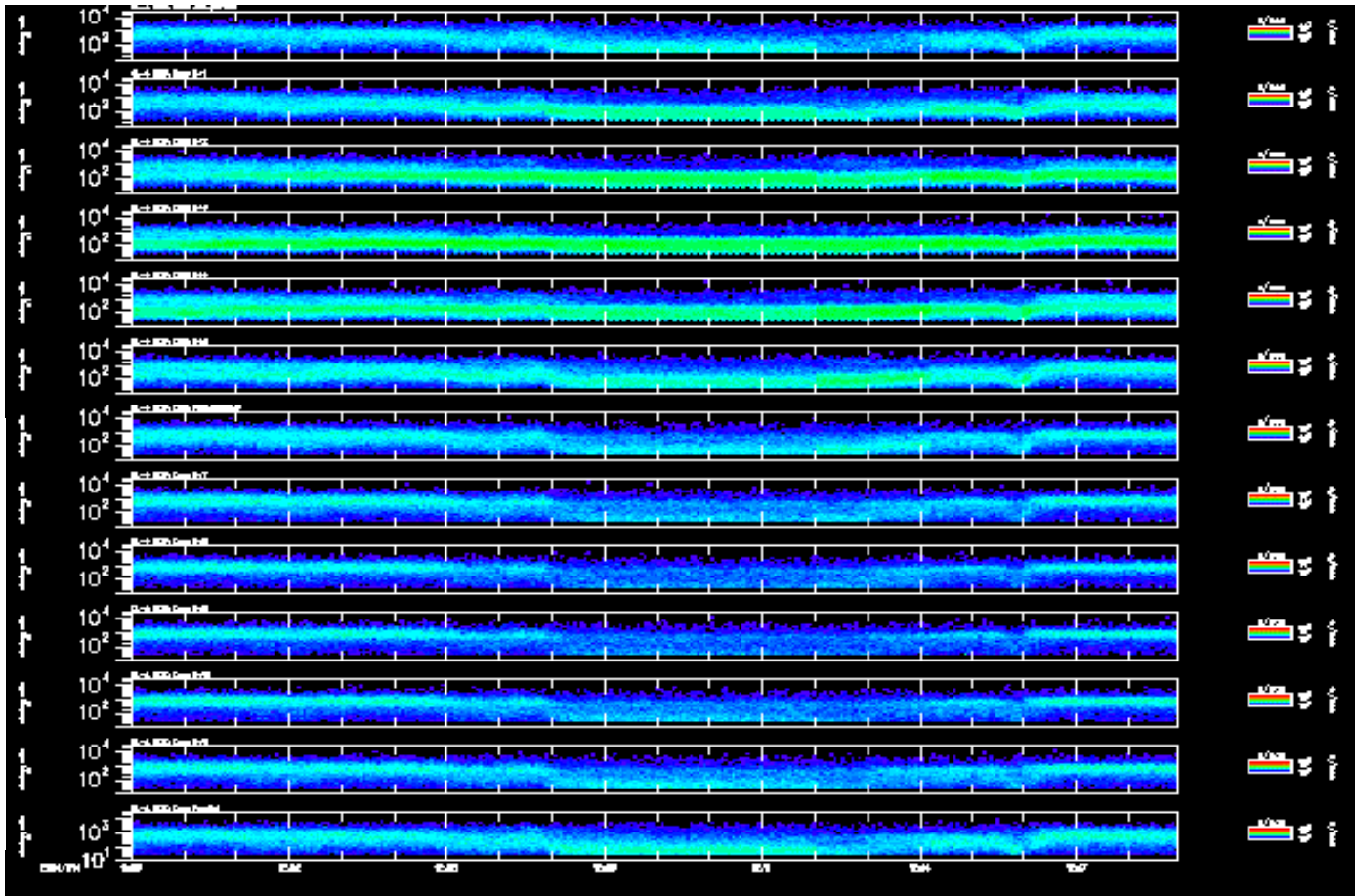
Can assemble spin rate data for each of LEEA and HEEA, or half spin rate from both in energy overlap region



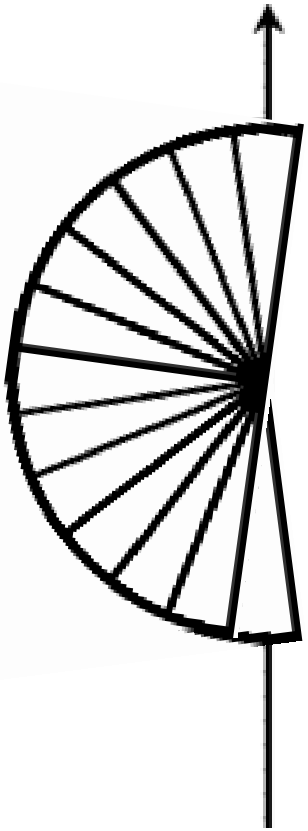
SPINPAD (one sensor)

Produced in ground processing. Two PAD segments are merged to produce a 13 look direction data product.

A dual sensor snapshot each half spin for overlapping energies is possible in principle.



Note that the two segments are collected half a spin apart. Each is a snapshot: a single energy sweep



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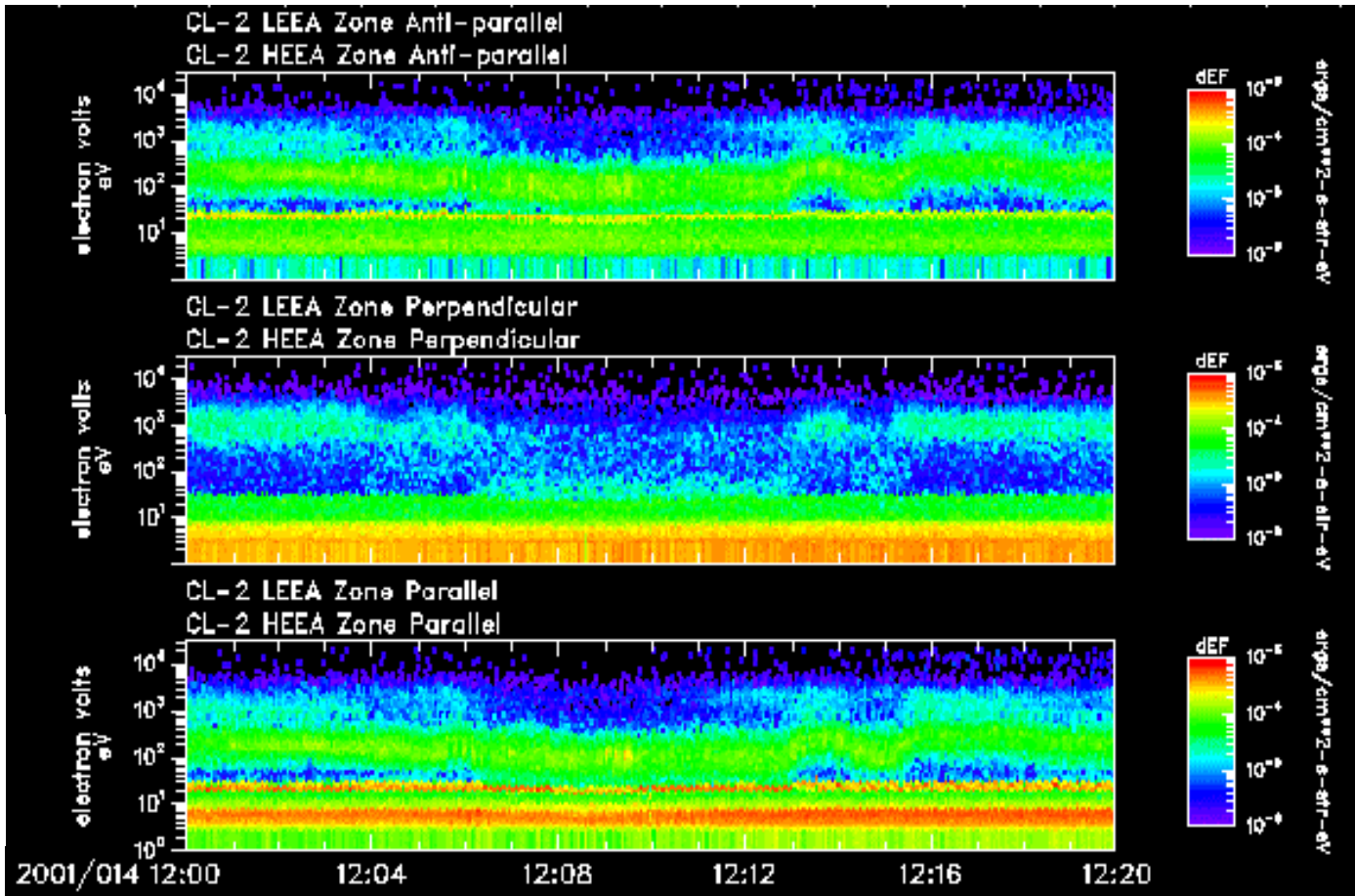
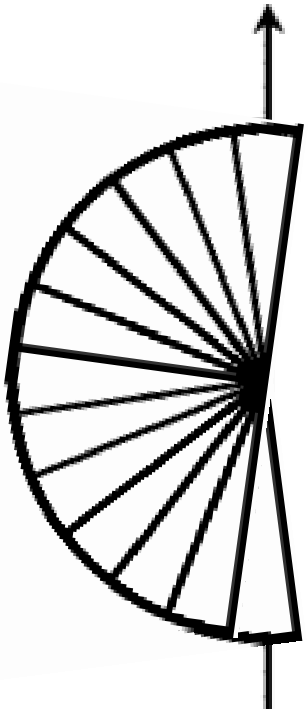
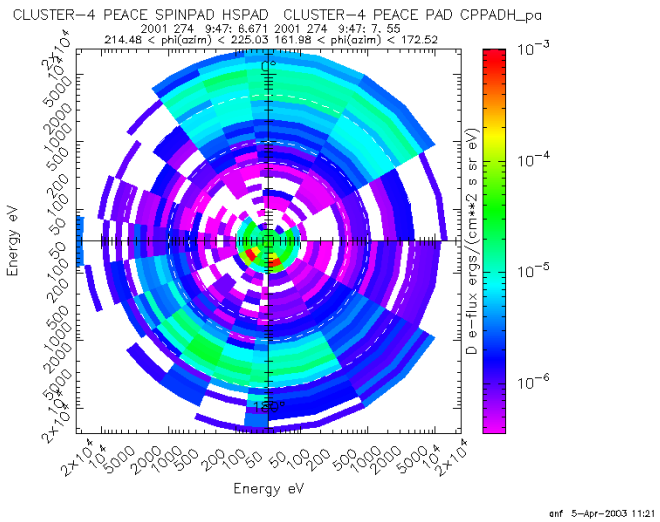


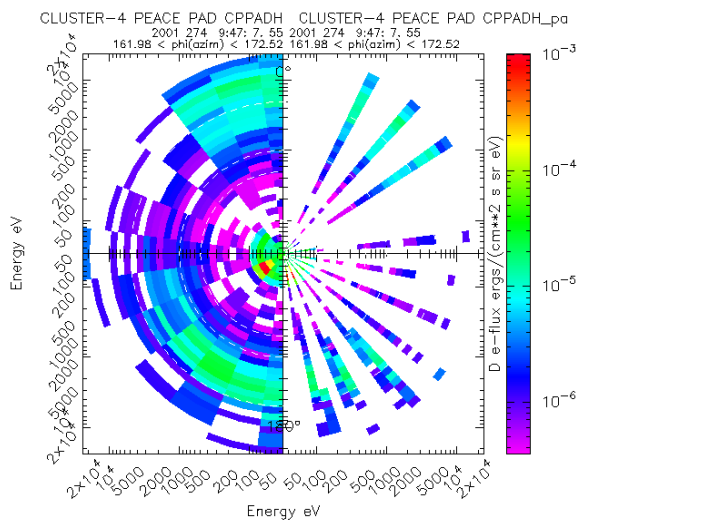


PAD/SPINPAD

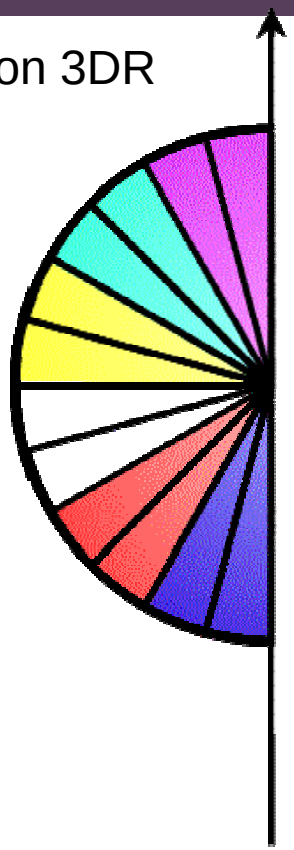
We note that the onboard selected pitch angle data is not always correctly selected (due to rapidly varying magnetic field for example). We plan to provide to CAA a pitch angle data product in which the correct pitch angles are determined using magnetometer data supplied by FGM after ground checks.

A (fairly extreme) case of this being useful is shown below (SPINPAD on the left; actual measured pitch angles shown on the right.





Based on 3DR

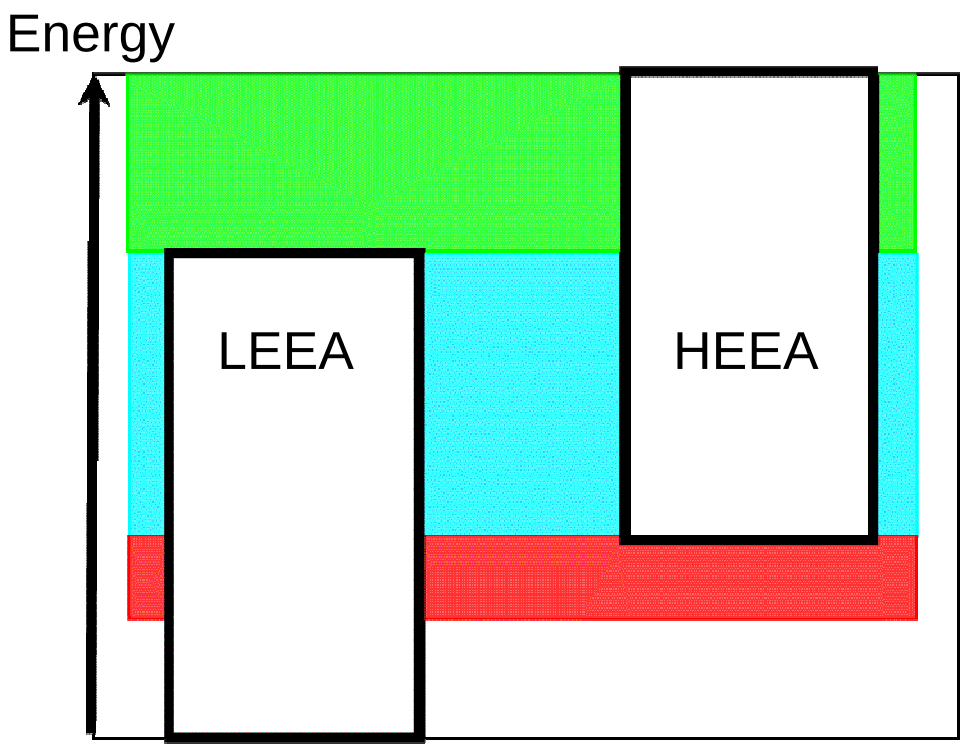


Onboard Moments Sums (one/two sensor options)

Moment sums calculated for up to 3 energy bands, and at half spin rate where sensor energies overlap.

Moment sums are not calculated below 10 eV

Ground processing is needed to produce moments in scientific units



Onboard Moments Sums (one/two sensor options)

Moment sums calculated for up to 3 energy bands, and at half spin rate where sensor energies overlap.

Moment sums are not calculated below 10 eV

Ground processing is needed to produce moments in scientific units

CSDS PP/SP data are produced from onboard moment sums

They are subject to limitations mentioned already. This is consistent with the CSDS policy that PP/SP data is for quicklook and event selection, but data quality may not be the best achievable.

We have produced upgraded versions which make all practical corrections and remove data that cannot be readily improved.

No correction for electron acceleration by the spacecraft potential!

Energy-dependent efficiency calibration data used onboard does not always match sensor characteristics

Spacecraft electrons may be included in sums

Moments data

A specially prepared moments data product will be provided to the CAA. It will be based on transmitted 3D data where possible, using the best available calibrations, calculated allowing for spacecraft potential, and with photoelectrons removed where necessary.

As such these moments data will generally be superior to CSDS Prime Parameter data

Cases where moments do not fully describe the plasma

Only partial moments can be provided when only part of the distribution is measured!

At sharp gradients of flux (i.e. transited in less than 4 seconds) time aliasing will occur – the moment are some sort of average of the conditions during the spin and potentially misleading

Instrument Description

Data Products

Data Products Prepared for the Cluster Active Archive

Operations and Instrument Status

PEACE Data for the Cluster Active Archive

PEACE data files in the CAA have been designed to

(i) Use fewer distinct file types than the database used by PEACE CoIs

(ii) Minimise file sizes while following the CAA defined file formats (e.g. this is why some products have a separate LAR version)

(iii) Include pitch angle information calculated using high quality magnetometer data

Pre-Science Data Products

- Onboard moment sums
- PAD

Science Data Products

- 3DF, 3DX (3DX1/2, 3DXE1/2)
- 3DX (3DXP1/2)
- 3DX (3DXPAD)
- 3DR

Non-science Data Products

- NOI
- LER

Value Added Science Data Products

- Moments / Best Moments
- SPINPAD/ Rebinned Pitch Angle

CAA Pre-Science Data Products

- CPCMOM
- PADMAR, PADHAR, PADLAR

CAA Science Data Products

- 3DX, 3DXLAR
- 3DXP, 3DXPLAR
- 3DXPA, 3DXPALAR
- 3DR

CAA Non-science Data Products

- NOI
- LER

CAA Value Added Science Data

- Moments (in development, 2007/04)
- PitchAngle Not yet available 2007/04

Instrument Description

Data Products

Data Products Prepared for the Cluster Active Archive

Operations and Instrument Status

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1. Sensor and DPU lifetime
   - Operations below L = 6 prohibited during original 2 year mission, and on occasional basis subsequently => Routine off/on cycles each orbit
   - Avoidance of photoelectrons after year 2
   - Reduction of 4 spacecraft operations in magnetosheath/solar wind
   - Reduction of HEEA operations
2. Optimising coverage of the plasma
   - In first 2 years, full sensor overlap in magnetosheath/solar wind
   - In later years, attempting to arrange sensors to maximise useful onboard moments data (minimise spacecraft electrons in overlap and bottom ranges)
3. Utilising available telemetry
   - Choice of 3D data in BM sometimes driven by science aims
   - Where possible, use telemetry allocations not used by other instruments
   - No internal burst memory (BM3 intervals are unhelpful)
4. Special operations
   - Routine MCP tests
   - Real time MCP tests

Typical Operations

The sensors are typically operated in MAR sweep mode in which the energy range is swept 32 times during a spin.

The HEEA sensor covers the upper part of the instrument energy range and the LEEA sensor covers the lower part – there is partial overlap of energy coverage.

In the MAR mode, the energy is measured at medium resolution (2 steps per bin)

The DPU calculates “onboard moment sums”, onboard-selected pitch angle data and 3D datasets which are available for transmission to Earth, telemetry permitting.

The spacecraft telemetry can be the routine “NM1” normal rate or occasionally a higher “BM1” burst rate. On Cluster 2 and Cluster 4, enhanced rates have been available to PEACE since 2002.

Instrument Status (April 2007)

All PEACE instrument hardware is working well (apart from one recent failure – Anode 2 on HEEA 3 no longer delivers data, since 22 Aug 2005)

Main challenge is MCP sensitivity variation and lifetime management

Version 3 Calibrations onboard (a Version 4 uplink is planned)

Upgraded TM allocations on SC2 (shared with RAPID on occasions) and SC4

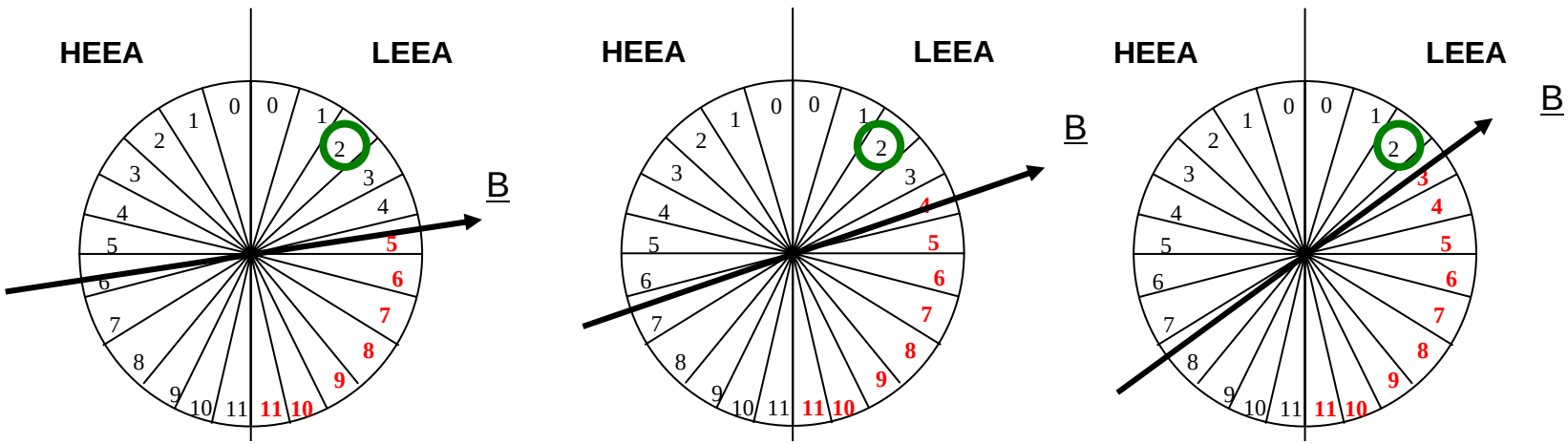
Minor Issues:

Some early difficulties with FGM Offsets; two intervals in 2002 where FGM data provided to PEACE onboard went bad on SC2, corrupting onboard pitch angle selection

A few data gaps due to commanding error/instrument anomaly.

Instrument Status: C3 PEACE HEEA Anode 2

- *Onboard Selected Pitch Angle Data*
  - Only affected when the magnetic field comes within 45º of the spin axis.



- *Moments Data* from this sensor in principle cannot be determined correctly with this zone missing, i.e. without full coverage of the 3D distribution. Possibly, reasonably good pseudo-moments could be produced by fitting the expected distribution there. So far we have done no work on a method to handle this.

The End

See also resources at the Cluster PEACE Home Page

http://www.mssl.ucl.ac.uk/www_plasma/missions/cluster/