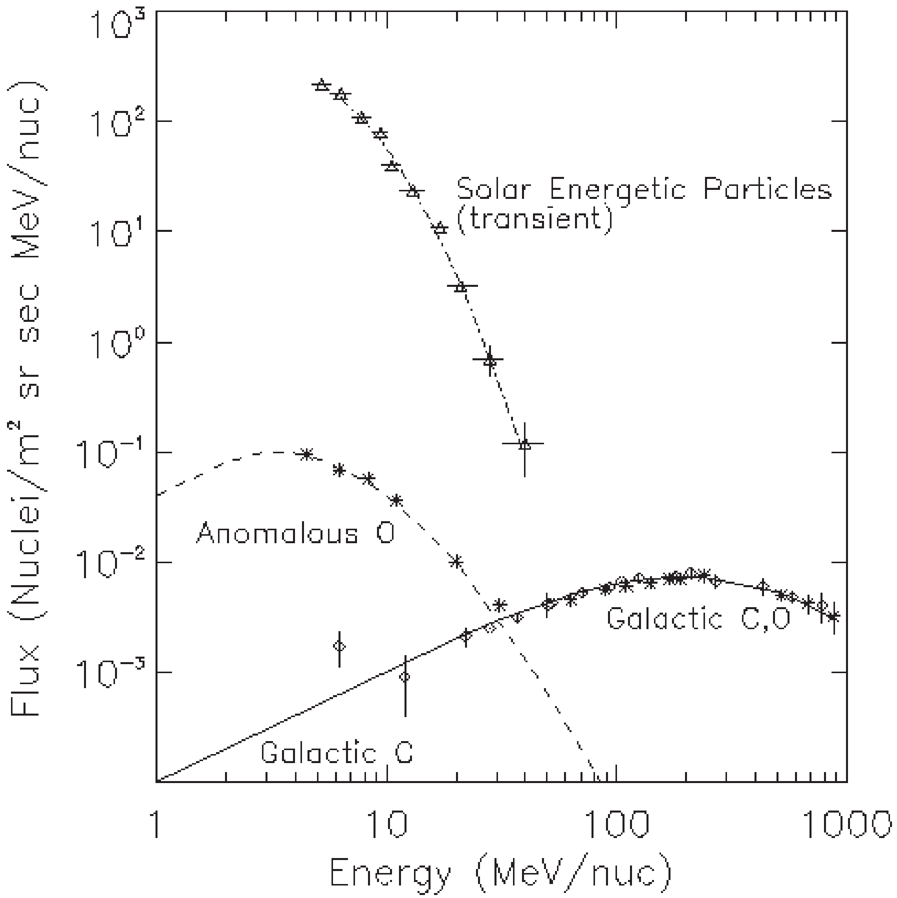
Outline

A. Measurement techniques (with a little history)
B. Angle Detecting Inclined Sensor (ADIS) technique
C. The Energetic Heavy Ion Sensor (EHIS) for GOES-R

Charged Particle Spectrum



- Ions not marked by source
- Energy and timing help separate sources
- Charge state also:
  - AC singly charged
  - GCR full stripped
  - SEP partially stripped

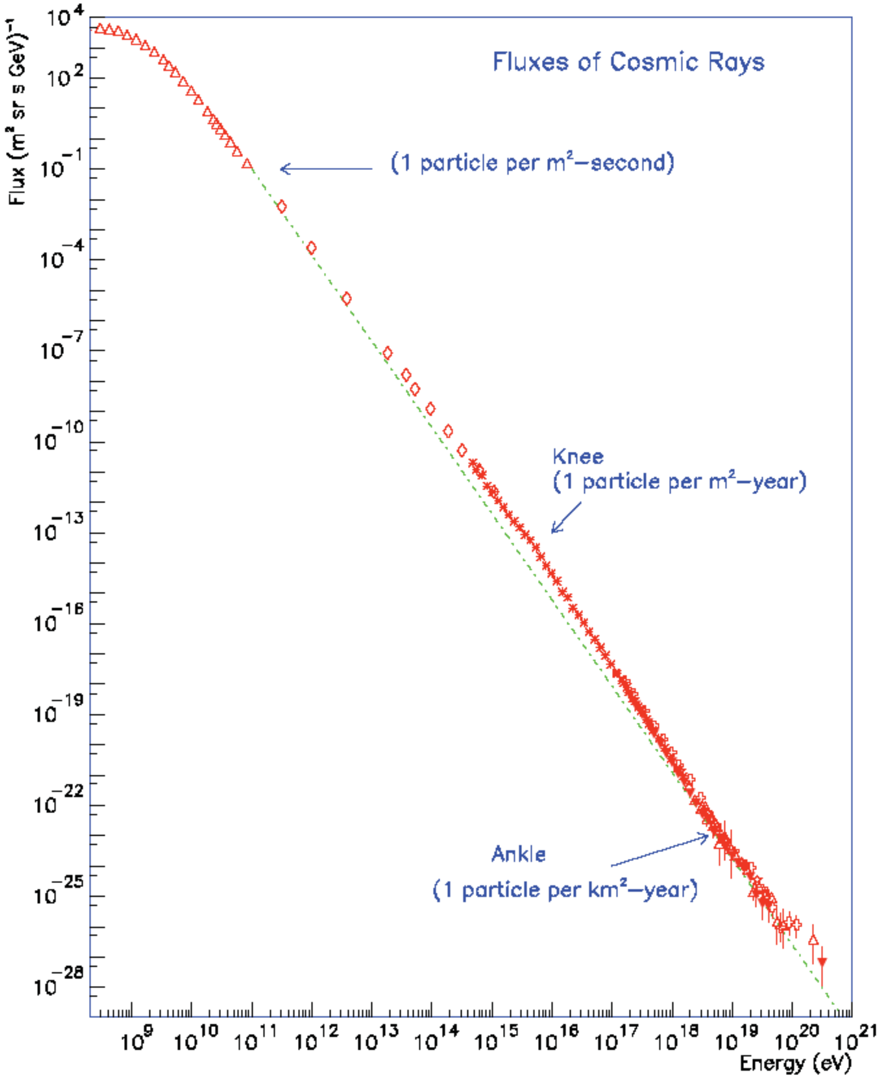


Figure 1. The all particle spectrum of cosmic rays - Cronin, Gaisser, Swordy 1997

The GCR spectrum continues as a power, in energy (index of about -2.7)

Highest energy cosmic rays have the kinetic energy of a major league baseball.

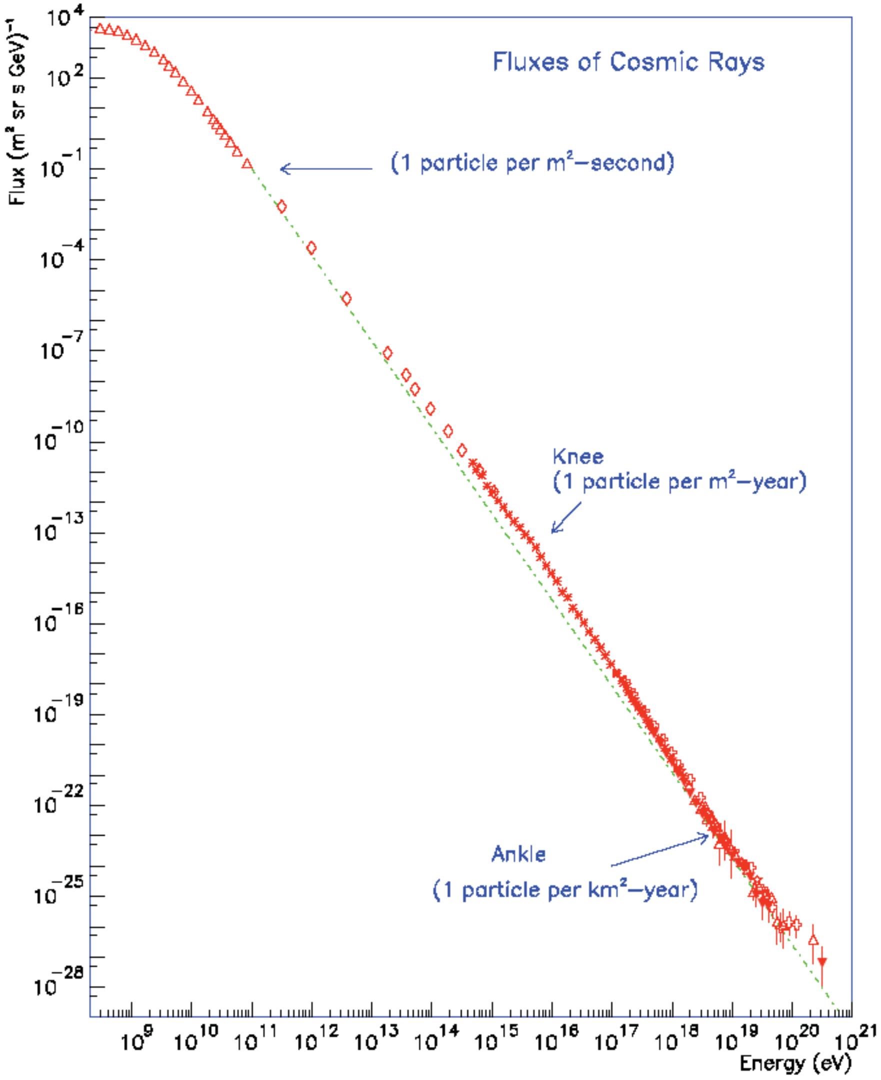
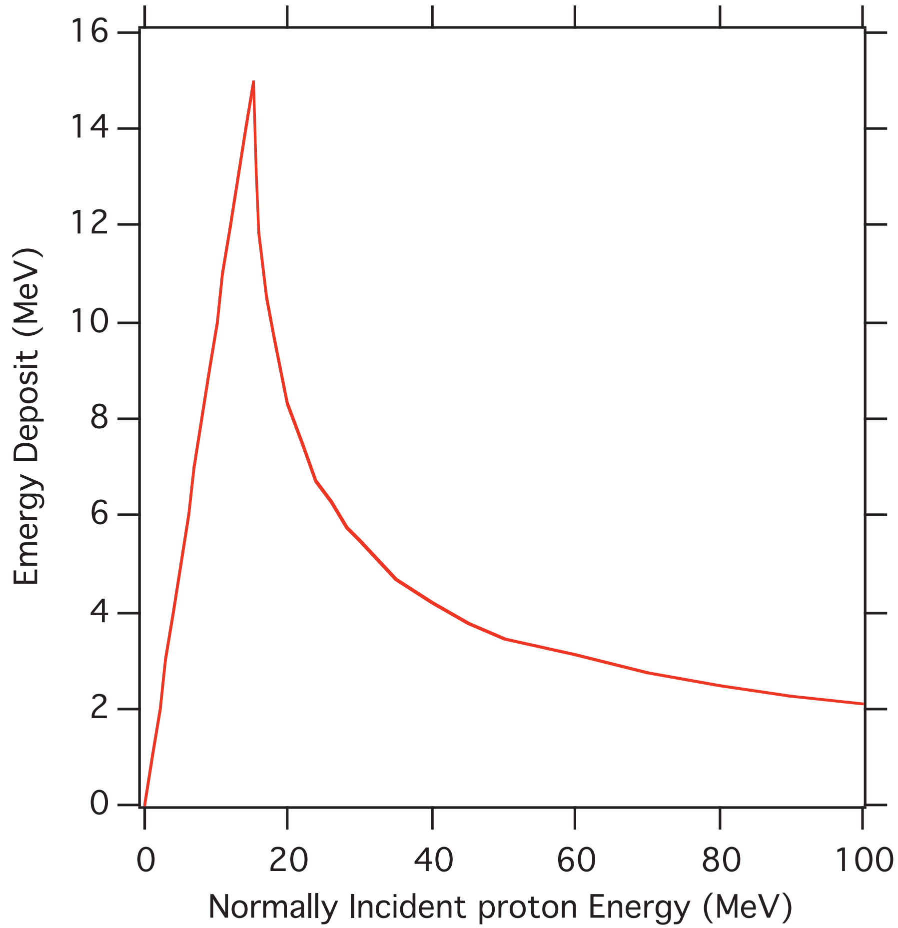
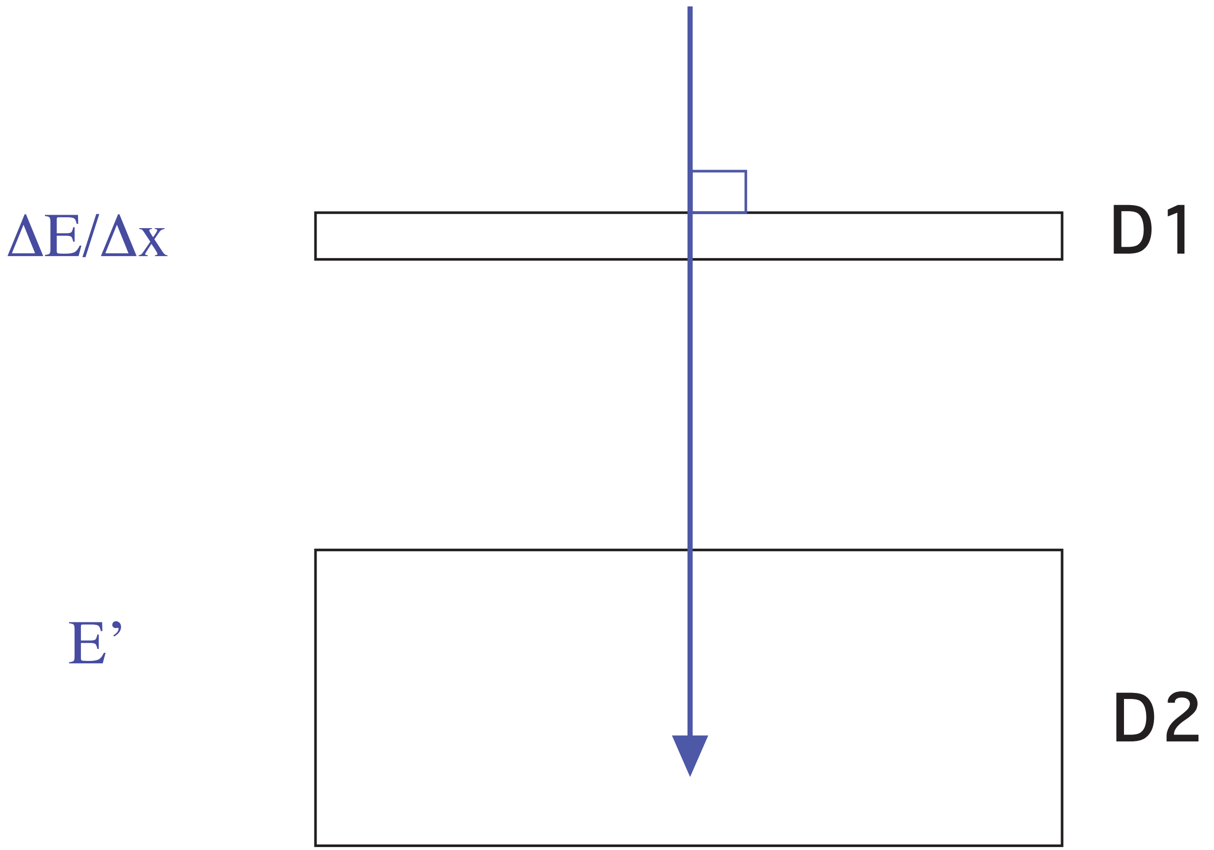


Figure 1. The all particle spectrum of cosmic rays - Cronin, Gaisser, Swordy 1997

Proton Energy deposition in 1500 μm Si



Measuring Energetic Ions in Space



$\Delta E/\Delta x$ versus residual energy (E’)

IMP-4 Telescope (circa 1967)

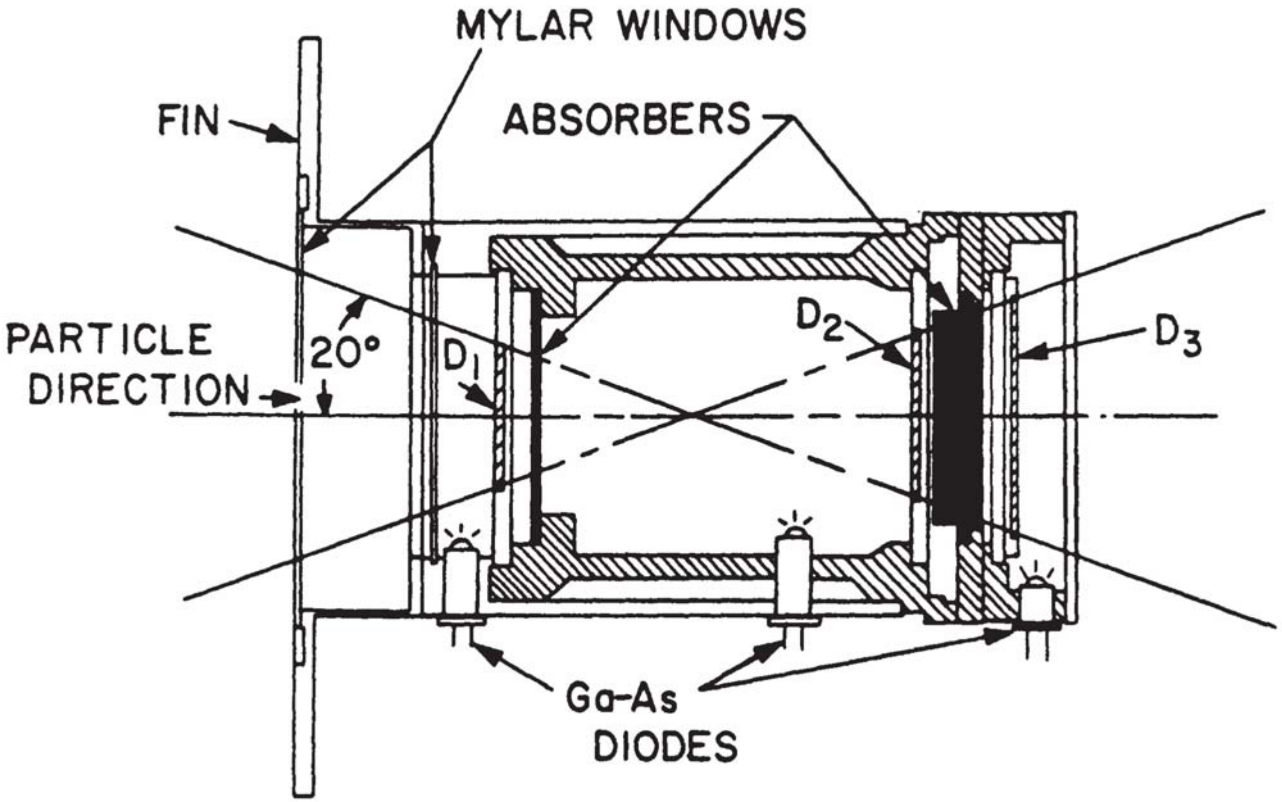


Fig. VI-2. Cross section of telescope showing sensors

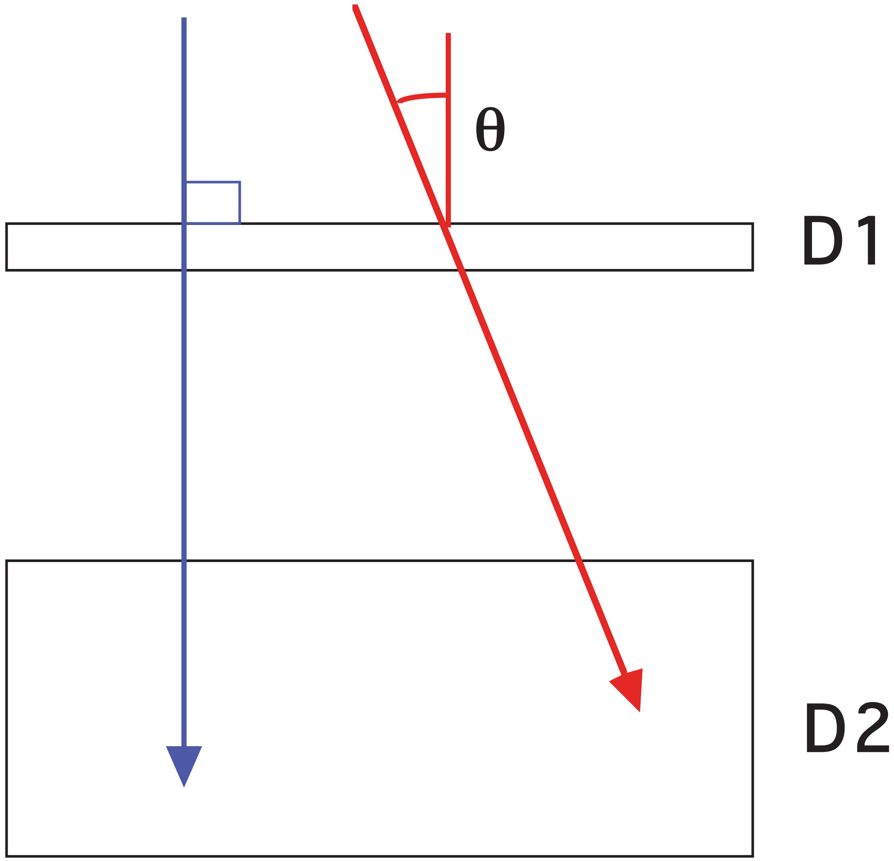
Measuring Energetic Ions in Space

$\Delta E/\Delta x$

but

$\Delta x \sim \sec(\theta)$

$E' = E'$

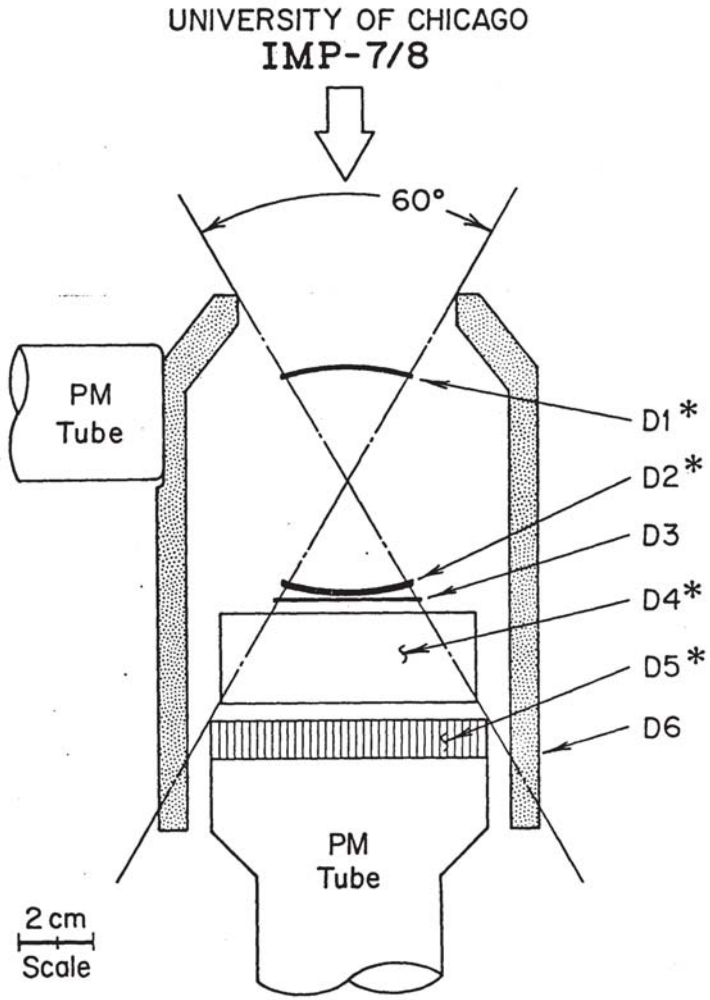


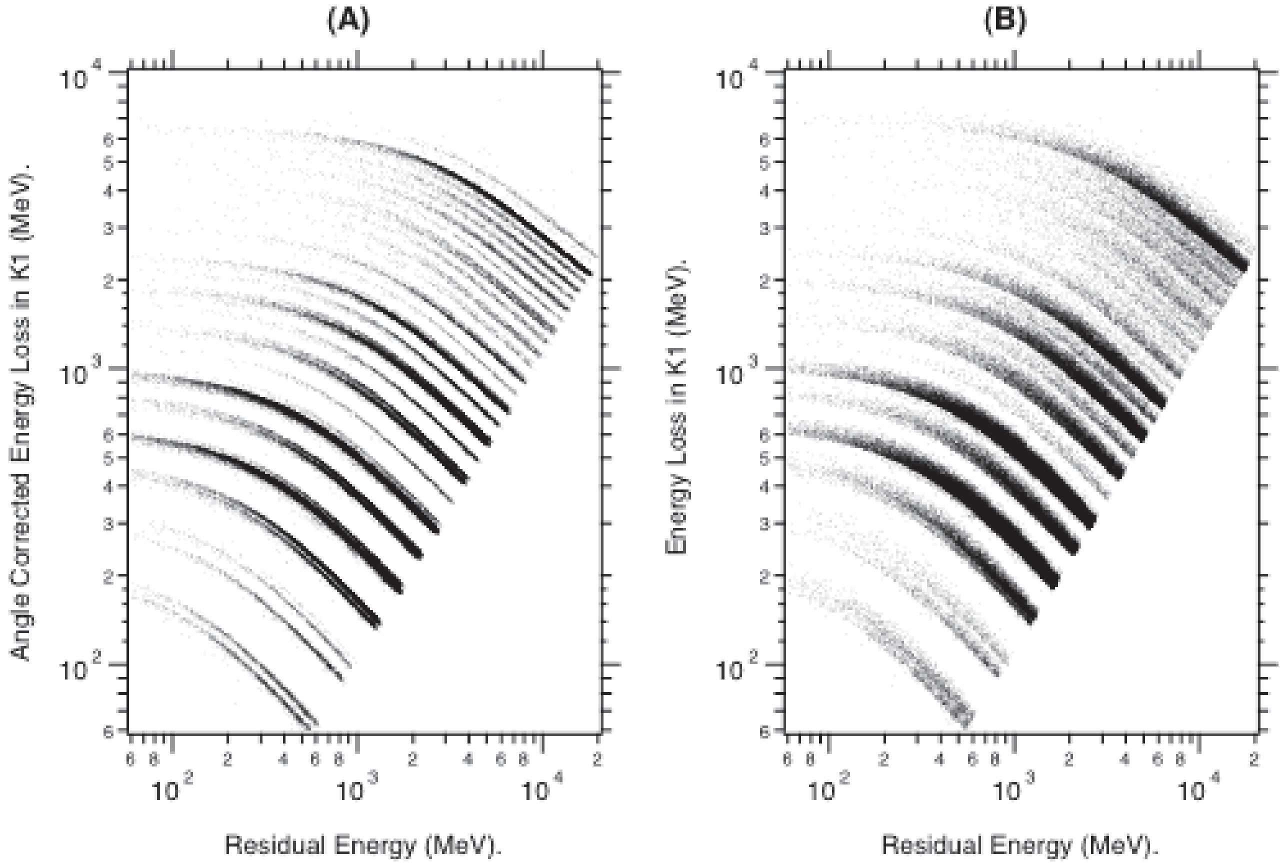
$\Delta E/\Delta x$ versus residual energy (E')

Charge resolution improved by using curved detectors

Curved detectors reduce the variations in thickness with angle of incidence

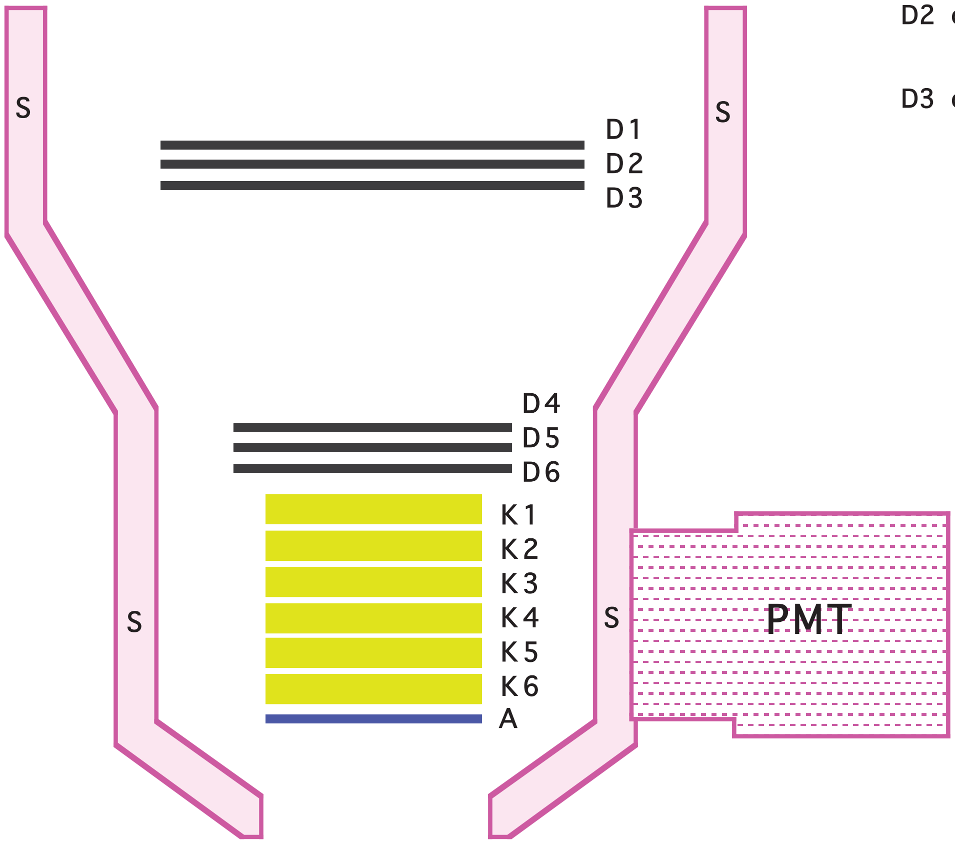
Used on IMP-6, 7 & 8
Pioneer-10 & 11
Voyager-1 & 2



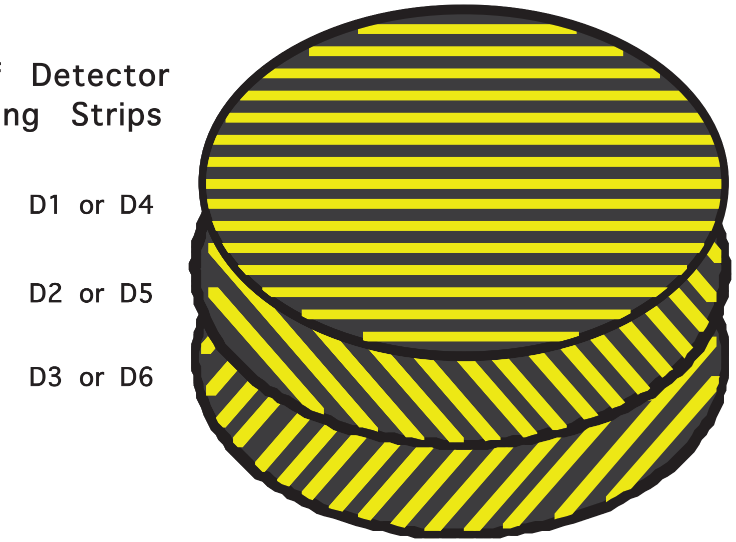


Ulysses HET flight data with (A) and without (B) correcting for particle angle of incidence—corrections need to identify elements.

Ulysses High Energy Telescope (HET)



Orientation of Detector Position Sensing Strips

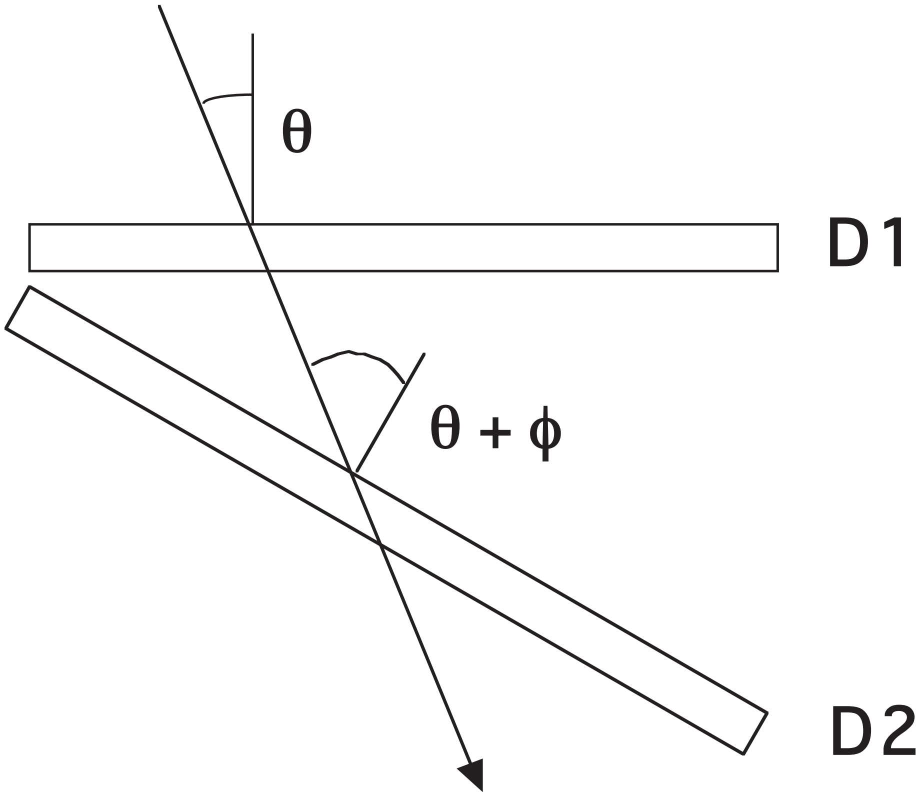


Angle Detecting Inclined Sensor (ADIS)

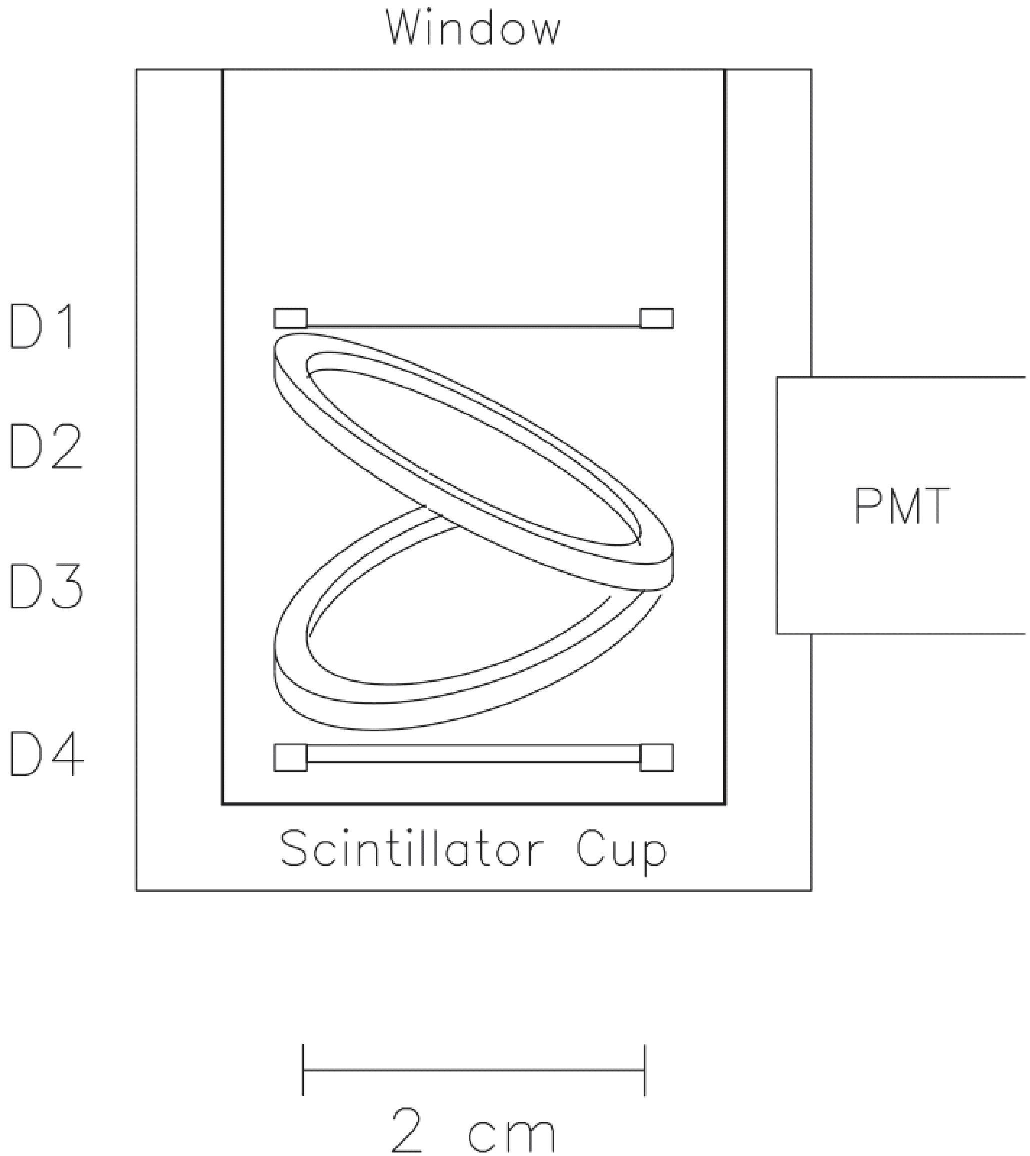
- Different geometry in telescope stack
- Uses standard Si detector technology
- Low risk
- Low mass
- Low power
- On-board event processing possible

Tested at an accelerator, and it works!

ADIS Concept



$$\frac{E_1}{E_2} = \frac{\sec(\theta)}{\sec(\theta + \phi)}$$


Window
D1
D2
D3
D4
PMT
Scintillator Cup
2 cm

Simplest ADIS instrument just uses four solid
state detectors.

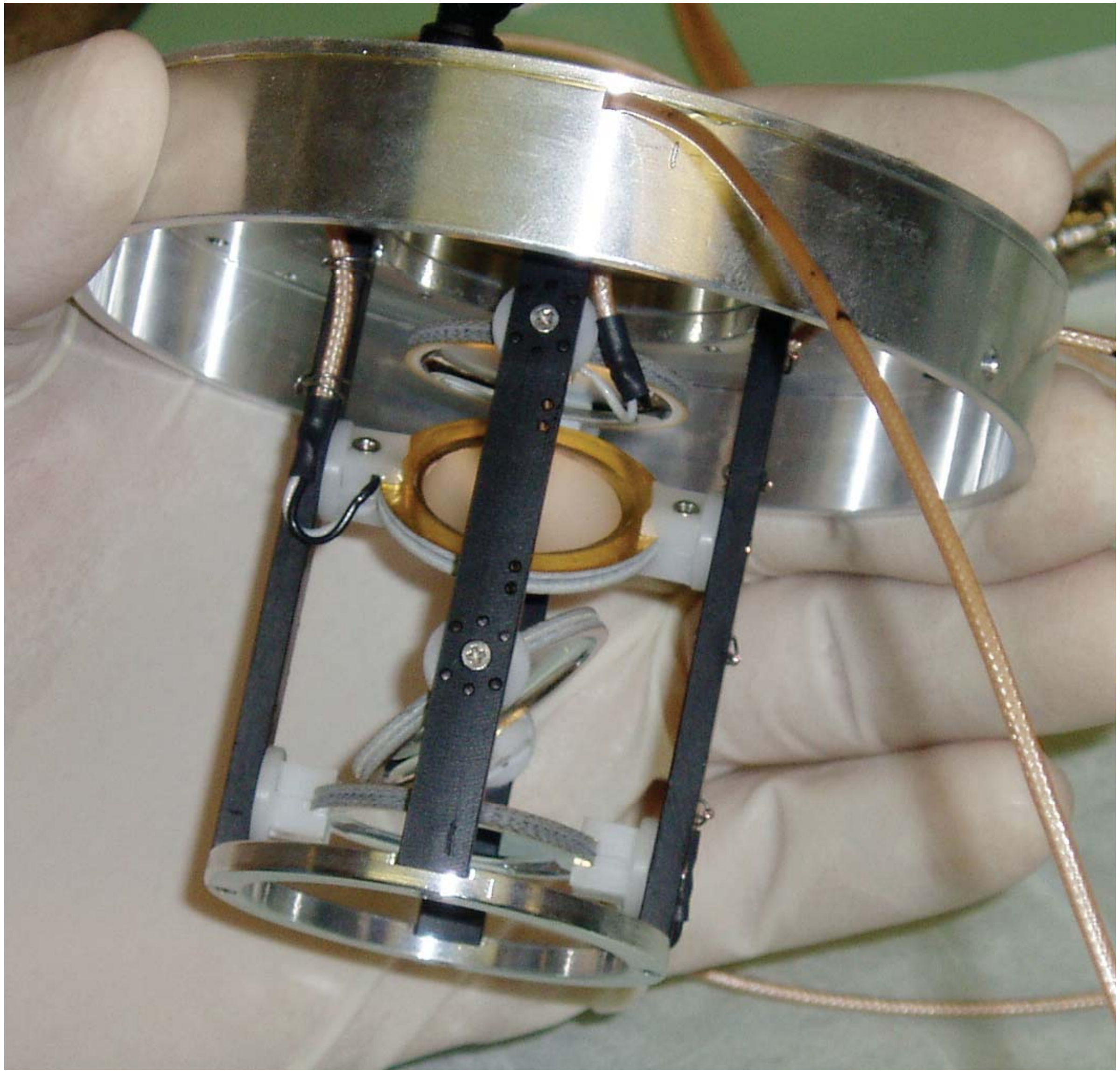
Can add detectors for specific applications.
Not limited to solid state detectors.

Can add others below:
Scintillator for thicker detector (as on IMP).
Cherenkov to extend energy range.

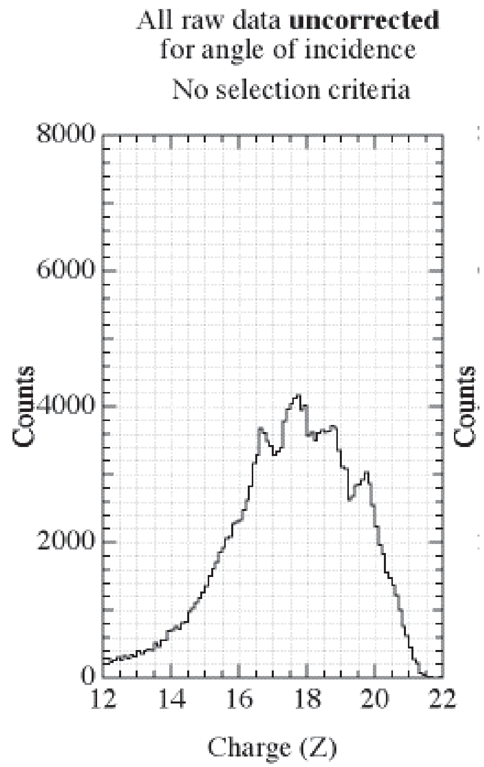
ADIS Tested with ^{48}Ca at the National Superconducting Cyclotron Laboratory

1. Instrument rotated in beams to simulate omni-directional flux in space
2. Energies varied by a moving absorber
3. Primary and fragmented beams use
4. Data taken with 50, 100 and 200 μm D1-3 detectors at 15, 30 and 45 degrees inclination
5. D2-3 detectors circular, NOT oval

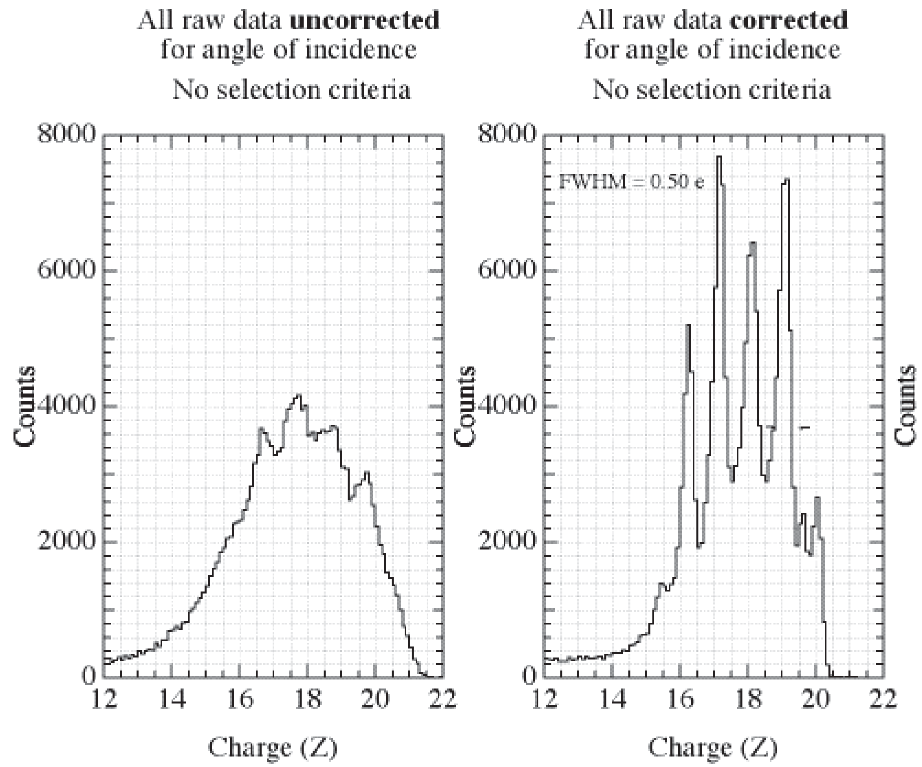
Large amounts of dead material degraded performance



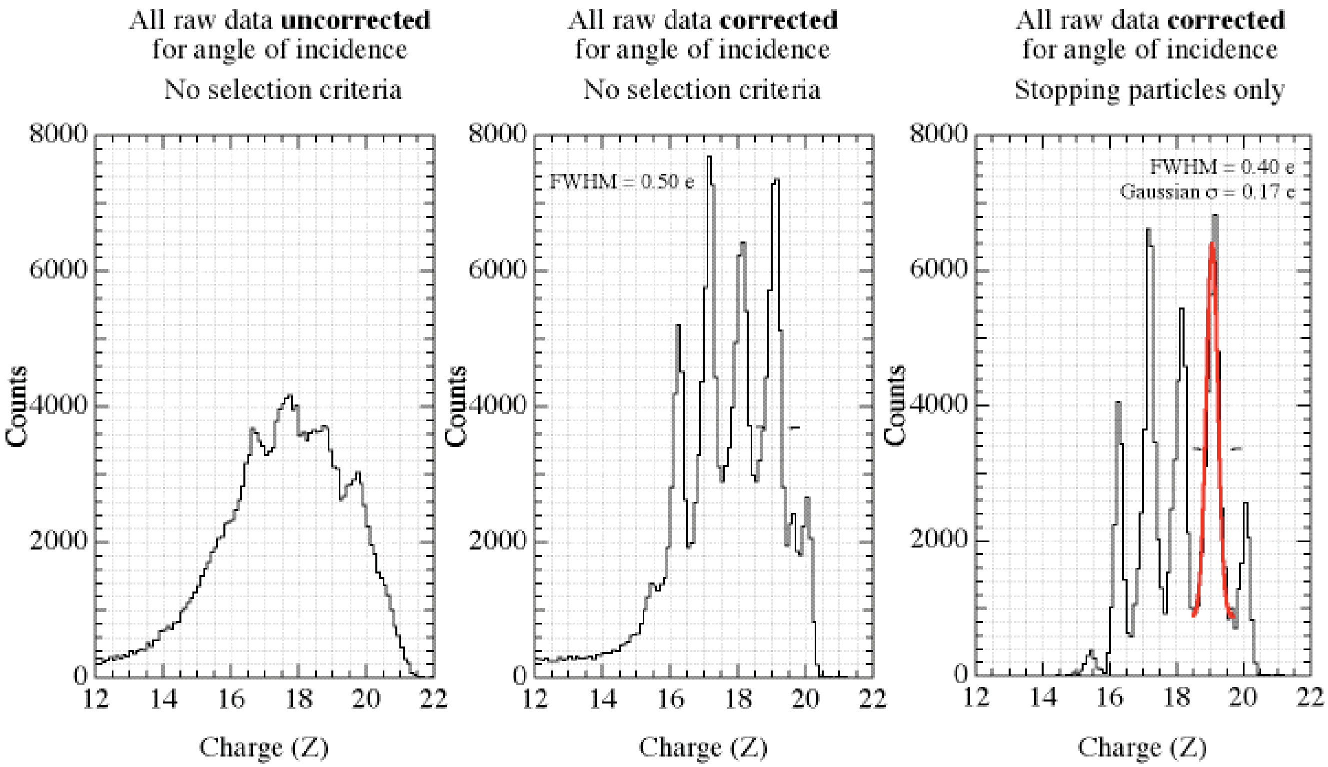
ADIS NSCL ^{48}Ca Fragment Beam D1, D2 and D3 200 µm thick 30 degree D2, D3 inclinations



ADIS NSCL ^{48}Ca Fragment Beam D1, D2 and D3 200 μm thick 30 degree D2, D3 inclinations



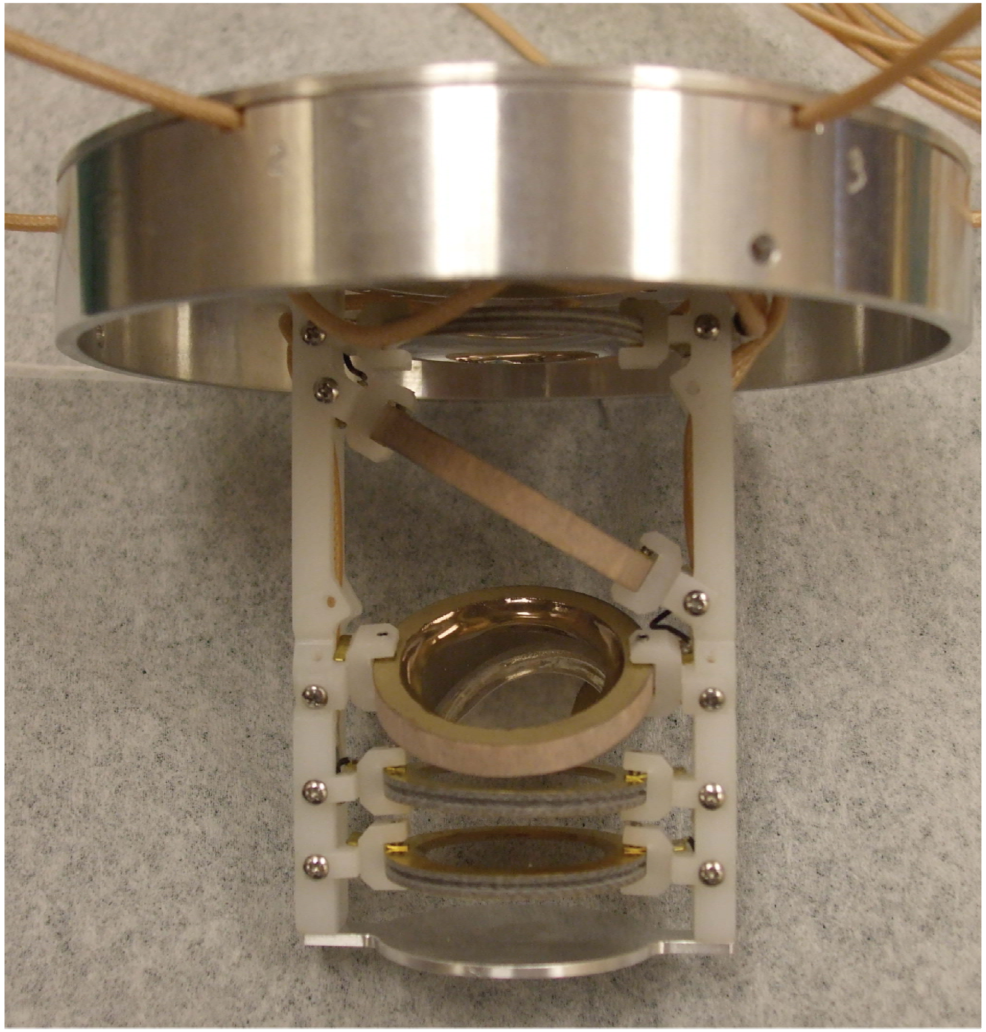
ADIS NSCL ^{48}Ca Fragment Beam D1, D2 and D3 200 μm thick 30 degree D2, D3 inclinations



Improved ADIS Tested with ^{78}Kr at the National Superconducting Cyclotron Laboratory

1. Fixed inclination (30 degrees)
2. Oval detectors
3. Reduced mass support structure
4. Instrument rotated in beams to simulate omni-directional flux in space
5. Energies varied by a moving absorber

Improved ADIS Test Model



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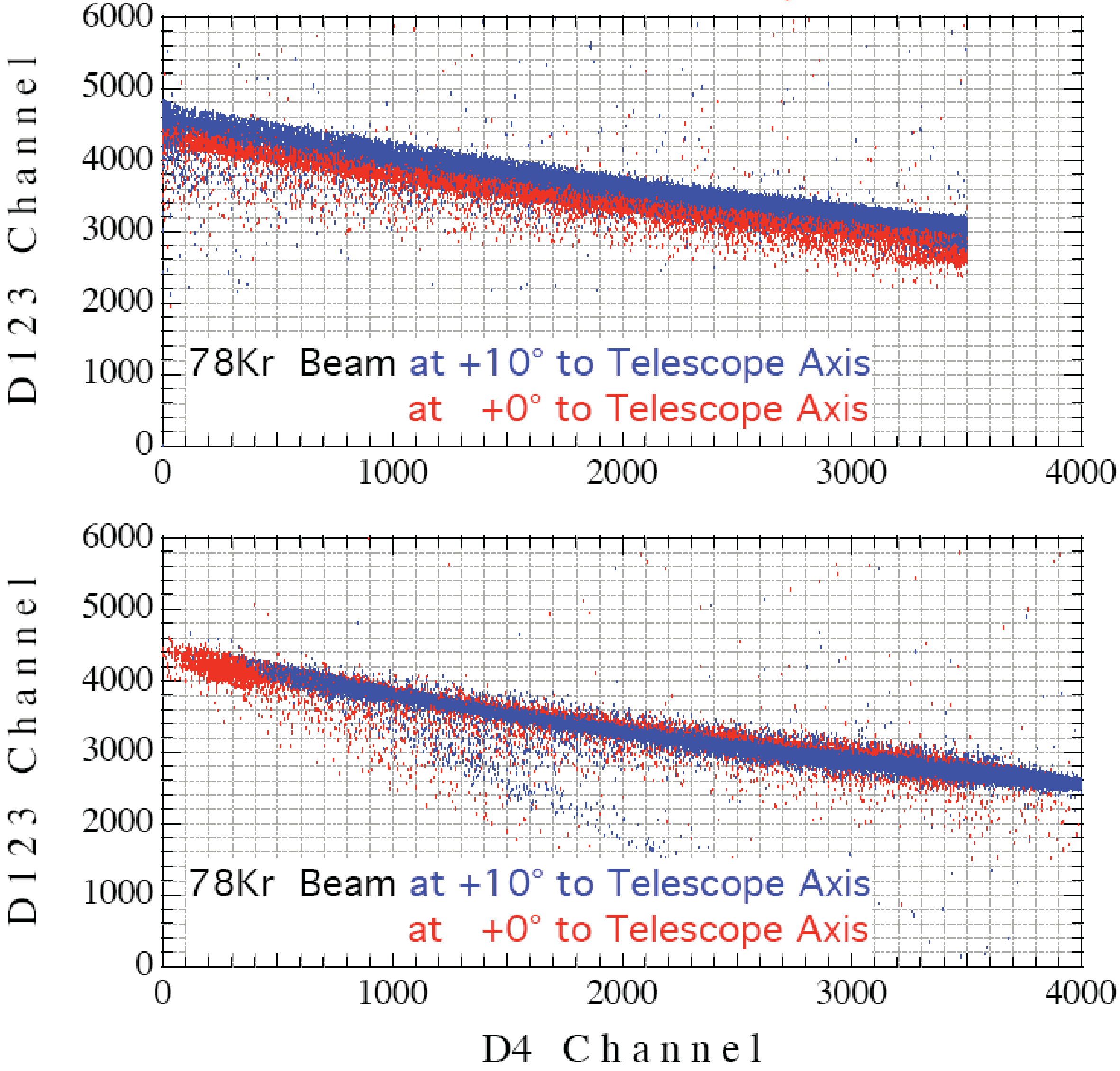
ADIS NSCL ^{78}Kr Primary Beam



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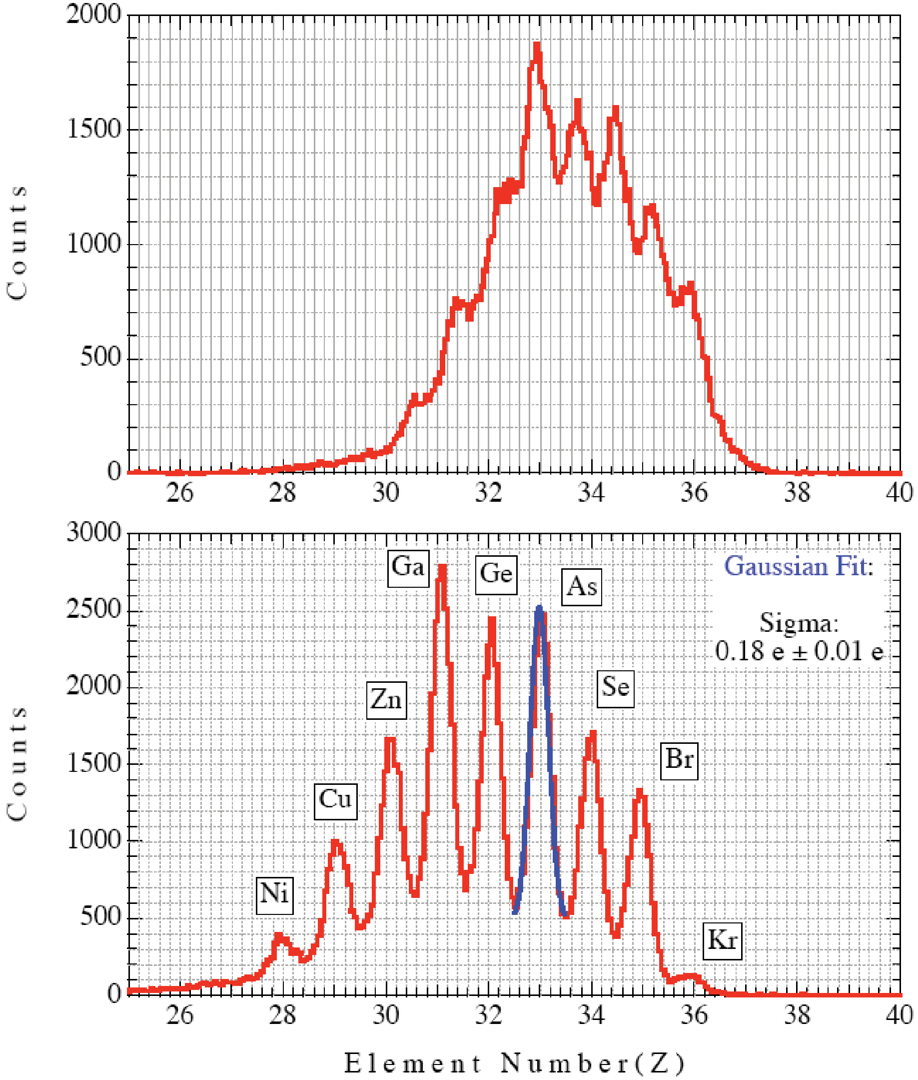
ADIS NSCL ^{78}Kr Fragment Beam



ADIS Compared to Other Instrument Architectures

System	Flight Examples	Complexity	PHA channels	Power	Risk
Curved detectors (Not made since 1970's)	IMP-8, Pioneer, Voyager	Medium	~5	~4 W	High
Segmented detectors	SOHO	High	~10	~8 W	Low
Position Sensing detectors	Ulysses, CRRES, ACE/SIS	Very High	18 20 >500	4.5 W 6 W 18 W	Low
ADIS	EHIS (to be flown)	Low	~5	~4 W	Low

An ADIS-based Instrument was selected for the High Energy Particle Sensor (HEPS) for National Polar-orbiting Operational Environmental Satellite System (NPOESS)

NPOESS

Northrop Grumman

Raytheon

DoD • DOC • NASA


R.I.P.

Energetic Heavy Ion Sensor (EHIS) for GOES-R

The Energetic Heavy Ion Sensor (EHIS) will be part of the Space Environment In-Situ Suite (SEISS)

The goal: A simple but capable instrument.

EHIS design draws on the heritage of earlier instruments from our group on IMP-8, *Ulysses* and CRRES.

It combines an instrument of complexity comparable to our IMP-8 instrument with electronics concepts used on *Ulysses* and CRRES.

The Angle Detecting Inclined Sensor (ADIS) system provides good charge resolution without the complexity of position sensing detectors.

EHIS will provide measurements of Solar Energetic Particles (SEP), Galactic Cosmic Rays (GCR) and Anomalous Cosmic Rays (ACR).

Individual elements H through Ni

- 0.25 e charge resolution (sigma) at Fe

Energy interval 10-200 MeV for protons

- Very significant for manned exposure
- Corresponding energy ranges for heavy ions
- Five Approx. Logarithmic Energy Bands

EHIS uses the standard approach of combining discriminator-based logic rates with pulse height analysis of a sample of events to determine fluxes for each measured species.

Three level priority system (H, He, heavies) used to give preference to heavy ion species for PHA.

Use priority rates to normalize PHA data.

Five logic rates for H (~log spaced in energy, 3 s)

Five logic rates for He (~ log spaced in energy, 3 s)

Singles rate for instrument health.

If you approximate the range of a ion as a power law:

$$R = \kappa_0 \frac{A}{Z^2}\left(\frac{E}{A}\right)^{\alpha}$$

$$= \kappa_0 \frac{1}{Z^2 A^{\alpha - 1}} E^{\alpha}$$

(Basis of charge and mass analysis for *Ulysses* HET)

$$D_x = 2\,\frac{T_2}{T_1}\left[\frac{(E_4 + E_3 + E_2 + E_1)^{\alpha} - (E_4 + E_3 + E_2)^{\alpha}}{(E_4 + E_3 + E_2)^{\alpha} - (E_4 + E_3)^{\alpha}}\right] - \sqrt{3}$$

$$D_y = 2\,\frac{T_3}{T_1}\left[\frac{(E_4 + E_3 + E_2 + E_1)^{\alpha} - (E_4 + E_3 + E_2)^{\alpha}}{(E_4 + E_3)^{\alpha} - (E_4)^{\alpha}}\right] - \sqrt{3}$$

and

$$Z = \frac{\kappa}{T_1}\left[\frac{(E_4 + E_3 + E_2 + E_1)^{\alpha} - (E_4 + E_3 + E_2)^{\alpha}}{\left(1 + D_x^2 + D_y^2\right)^{1/2}}\right]^{1/(\alpha+1)}$$

ADIS calculations simple enough to be done by on-board processor

Greatly reduces telemetry requirements

Large number of PHA events analyzed
Greatly improved statistics and cadence

Well suited to real-time monitoring systems for manned use.

EHIS analyzes 2000+ PHA events per second.

Determined by speed of CPU

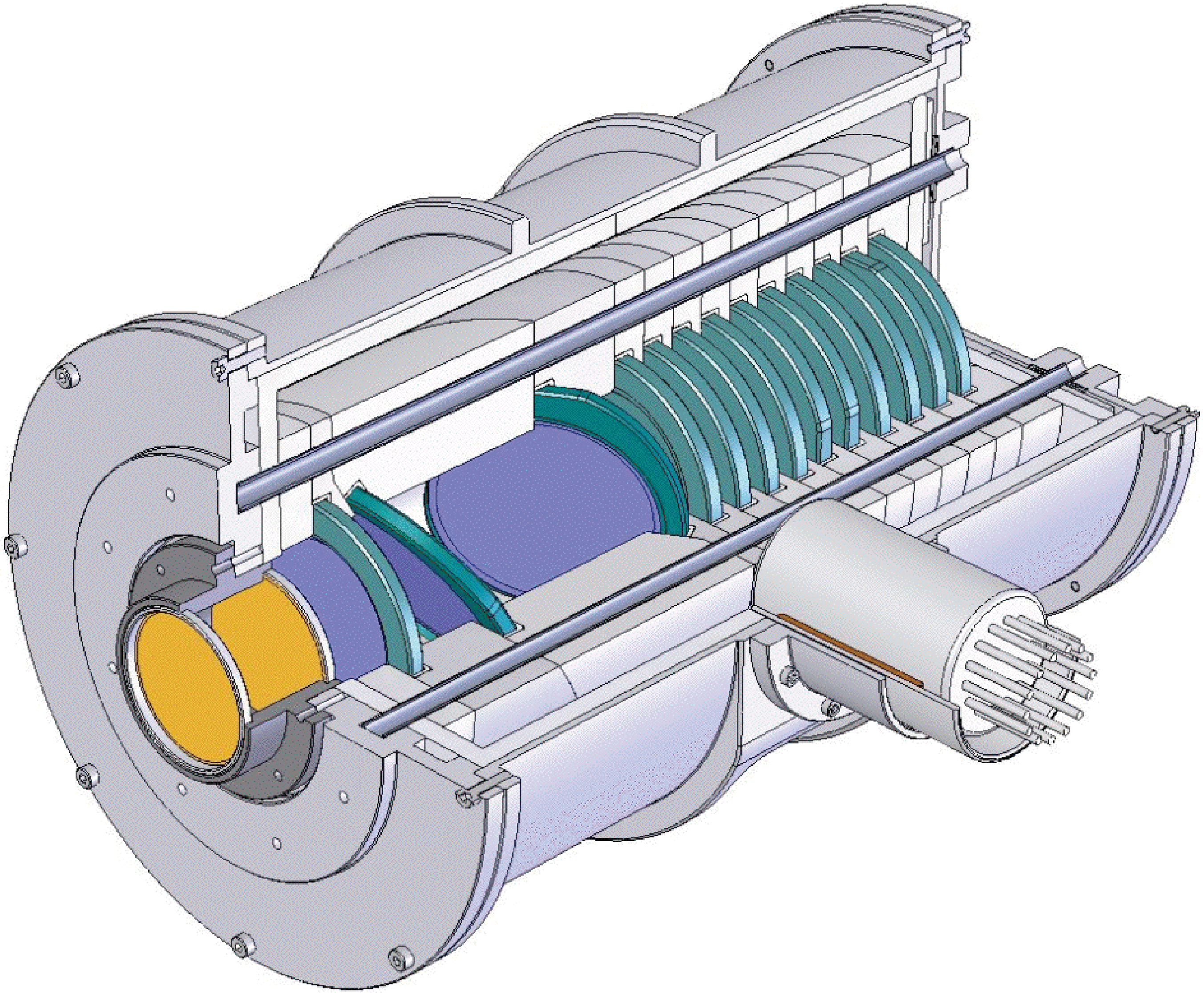
Composition data compiled as histograms on-board

"Summary" histograms come down every minute

Data rate ~1500 bps

EHIS does not measure electrons, but logic could be added to give electron rates as in *Ulysses* and IMP-8. Energy range would be ~0.5 to ~10 MeV.

EHIS



EHIS is based on the Angle Detecting Inclined Sensor (ADIS) system.

There are three thin 50 μm detectors D1, D2 and D3:

D1 is a circular detector of area.

D2 and D3 are oval and inclined at 30 degrees.

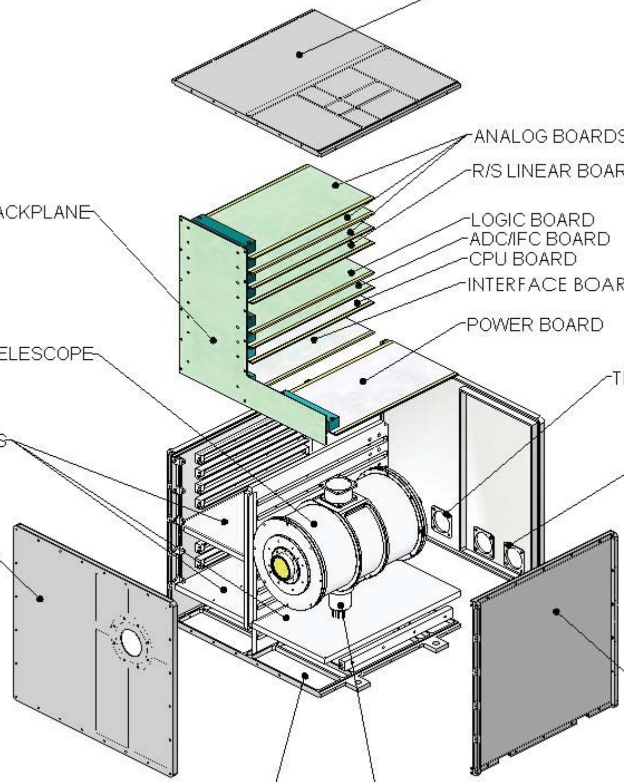
D4, D5 and D6 are logical detector each consisting of three 1500 μm thick detectors.

D1-D6 are pulse-height analyzed.

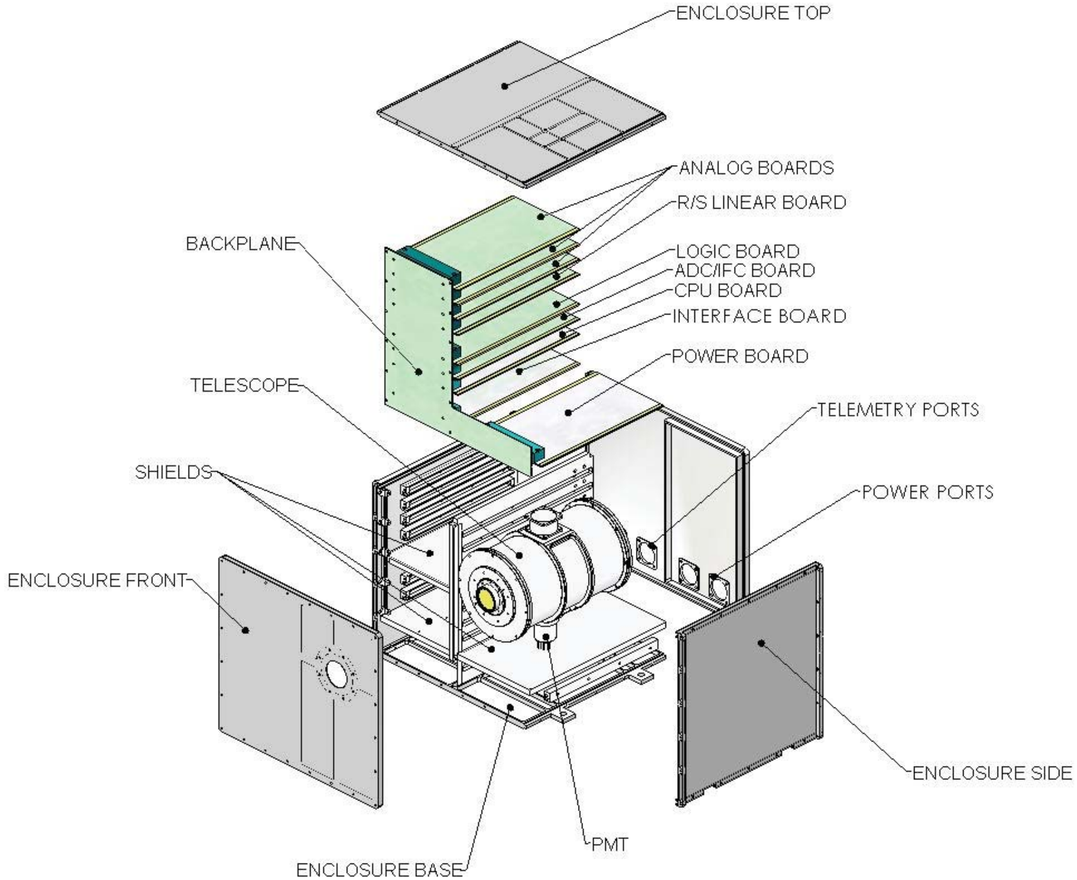
R is a single detector to flag penetrating particles. It is not pulse-height analyzed.

EHIS

Mass: 9.2 kg
Power: 4.9 W
Telemetry: 1536 bps
Geometry factor:
1.1 to 0.5 cm^2-ster



Operational mission where resources are more generous: Much lower mass and lower power levels achievable.



The EHIS electronics consists of eight main boards plus a backplane motherboard

4 Linear boards (dual gain)

1 ADC /IFC board

1 Logic board

1 CPU board

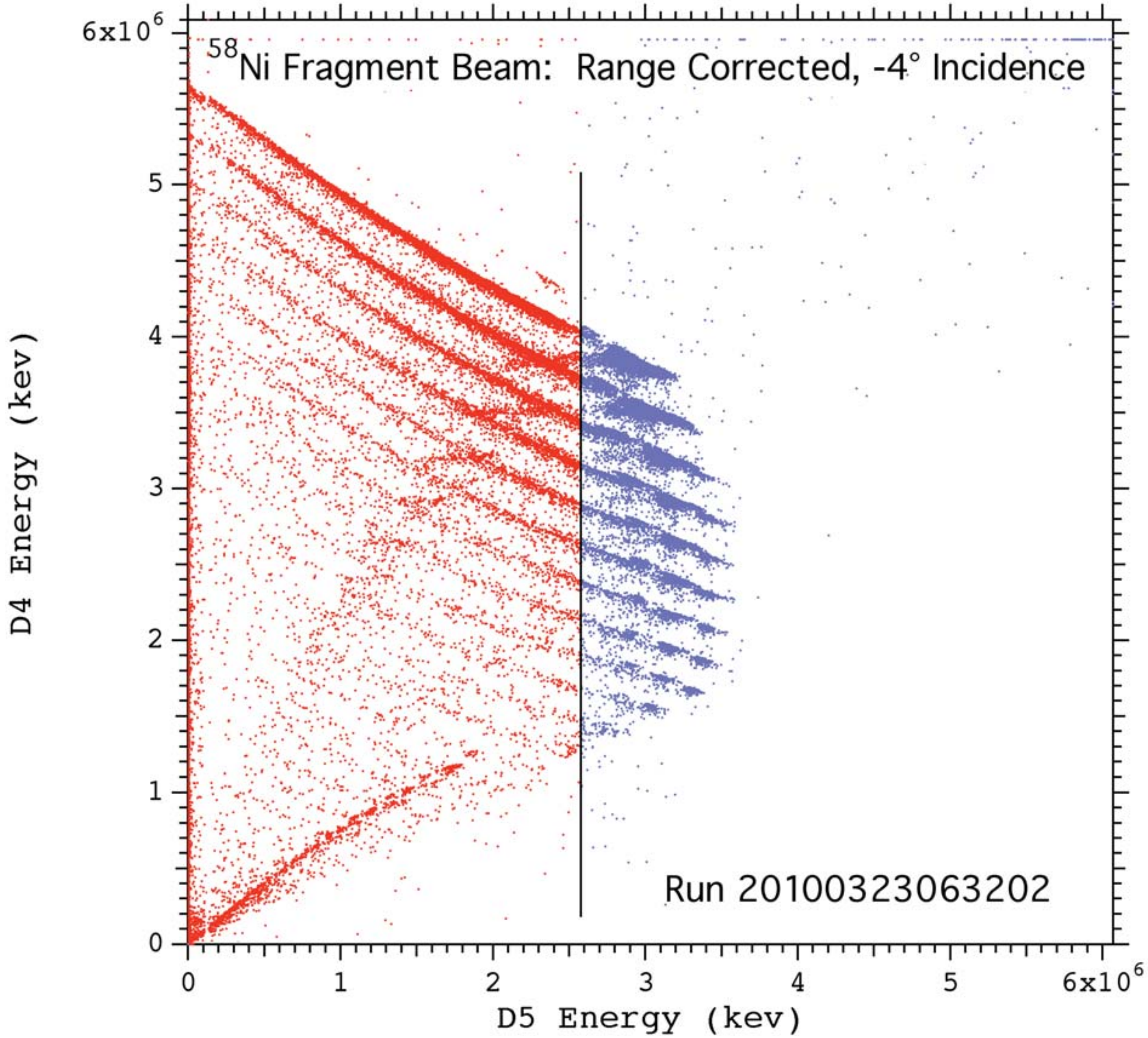
Power converter board

HV board

A small I/O board supports the RS 422 interface.

EHIS

EHIS


58Ni Fragment Beam: Range Corrected, -4° Incidence
Run 20100323063202
D4 Energy (kev)
D5 Energy (kev)
6x10^6
5
4
3
2
1
0

EHIS

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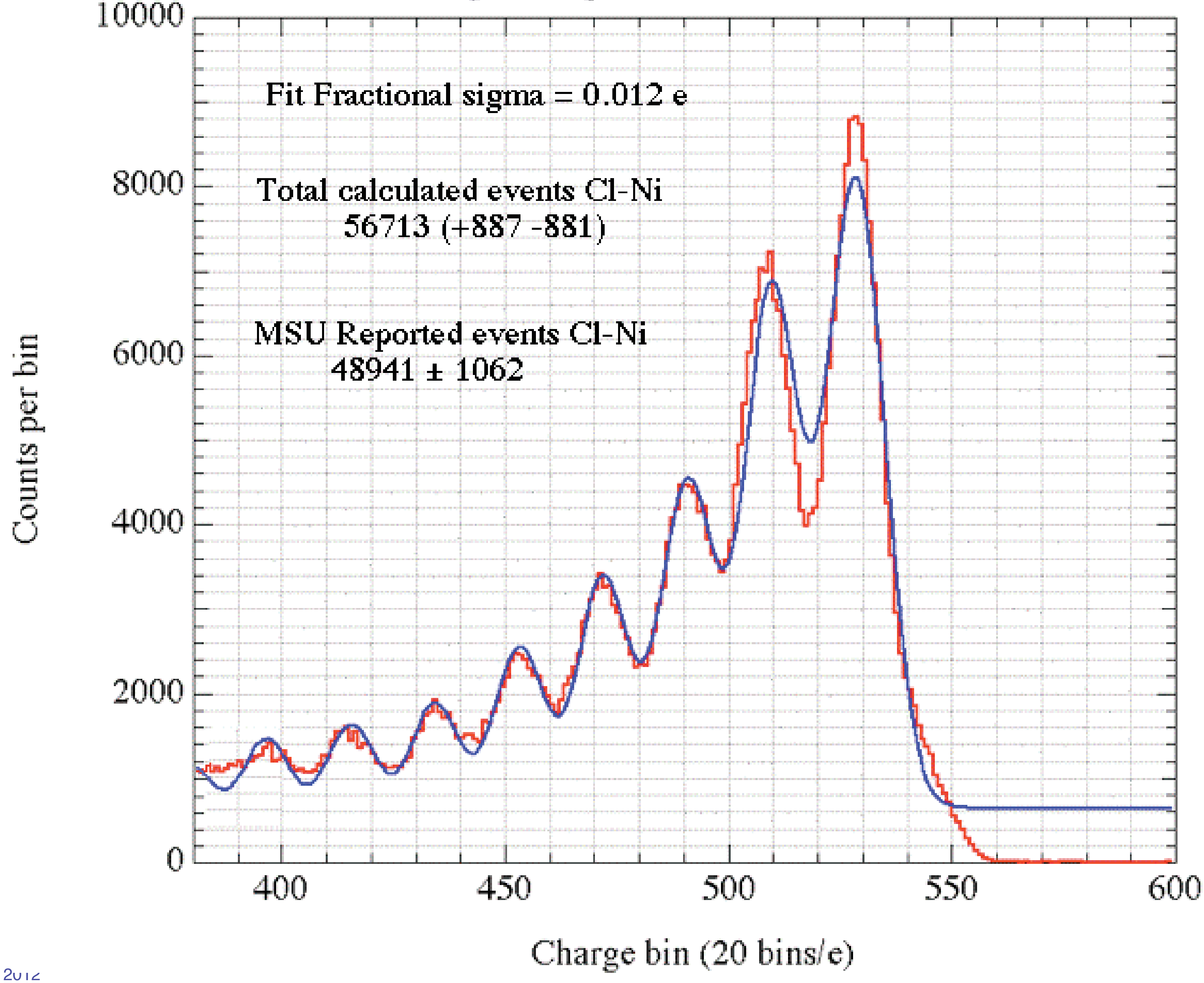
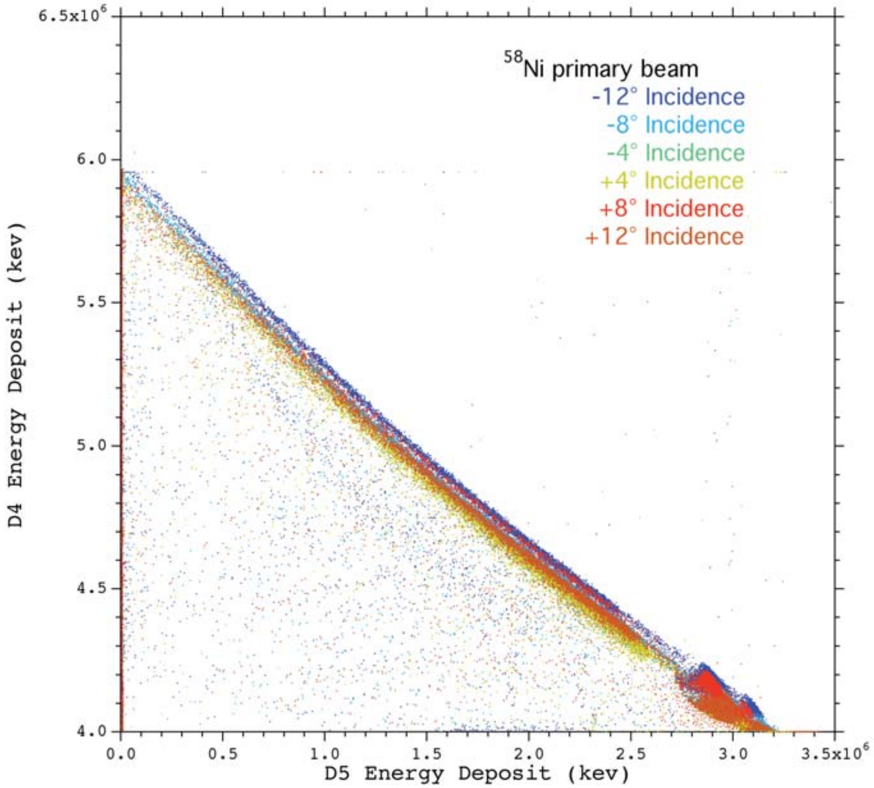
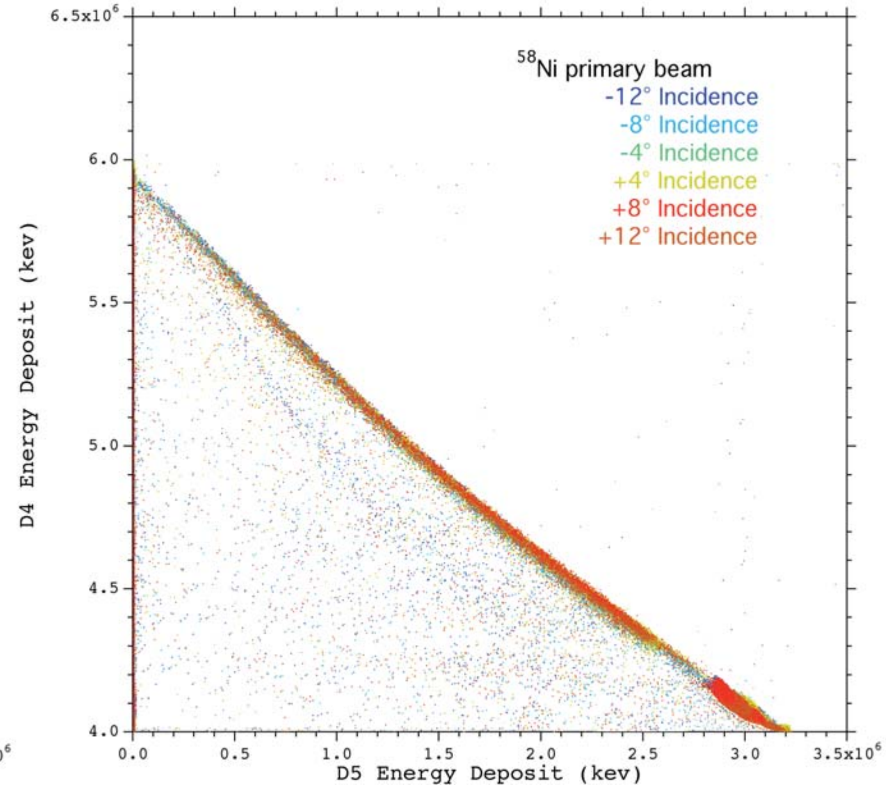


EHIS


6.5x10^6
6.0
5.5
5.0
4.5
4.0
D4 Energy Deposit (kev)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5x10^6
D5 Energy Deposit (kev)
58Ni primary beam
-12° Incidence
-8° Incidence
-4° Incidence
+4° Incidence
+8° Incidence
+12° Incidence


6.5x10^6
6.0
5.5
5.0
4.5
4.0
D4 Energy Deposit (kev)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5x10^6
D5 Energy Deposit (kev)
58Ni primary beam
-12° Incidence
-8° Incidence
-4° Incidence
+4° Incidence
+8° Incidence
+12° Incidence

EHIS

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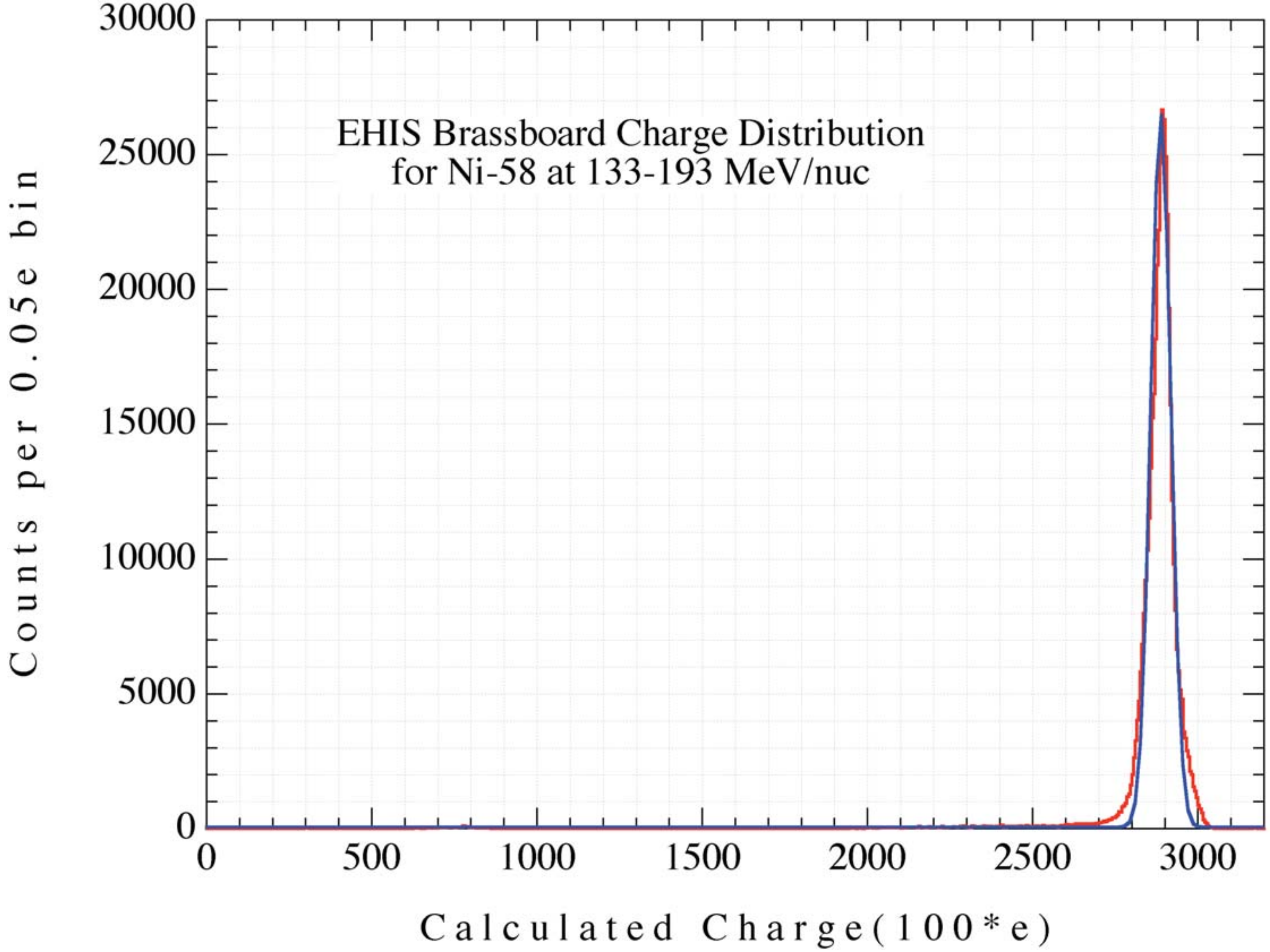

EHIS

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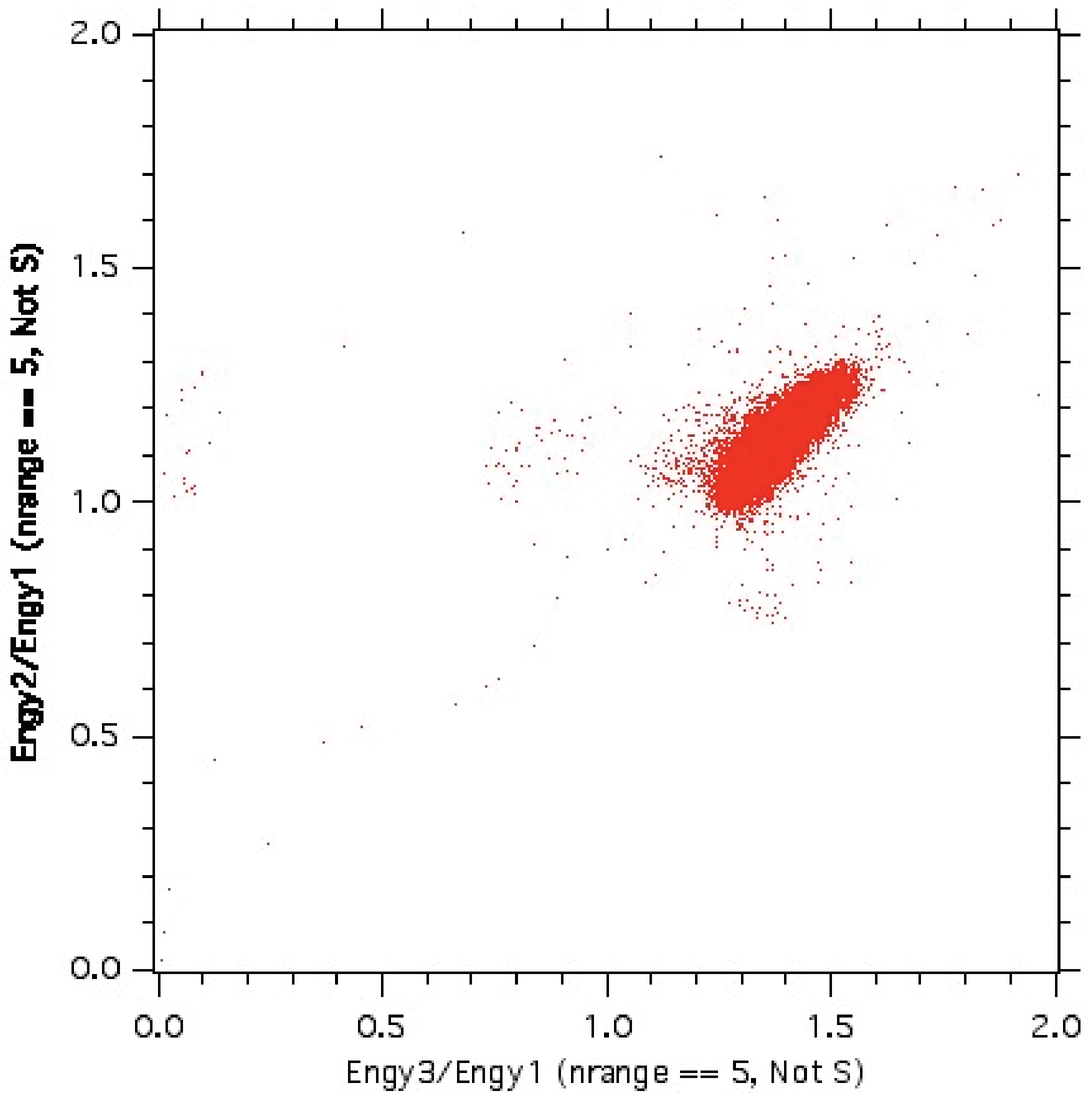

EHIS will provide high quality measurements (fluxes) of the energetic charged particle environment at geostationary orbit.

Can provide some input (at least composition) for dose models.

An EHIS/ADIS-type instrument would make an excellent spectrometer for manned missions

- Reduce mass
- Make suitable for a manned environment

Reduce Mass

EHIS significantly more massive than required for a manned application

- Radiation shielding not required
  - 15 years on orbit, ~100 kRad
  - Minimal 2.5 mm Al thickness

New telescope design reduces structural mass

Electronics next target. EHIS very conservative

- ASIC for analog would be ideal
  - Preliminary design for CubeSat circuit
- Processor embedded in FPGA
  - Already developed for MMS

Suitable for a manned environment

Round off corners!

Seal box

- Avoid surface contamination of Si detectors
- Dry nitrogen fill preferred
- Design to survive depressurization

ADIS

Simple

Capable