Measuring Space Radiation with the Angle Detecting Inclined Sensor (ADIS) Method

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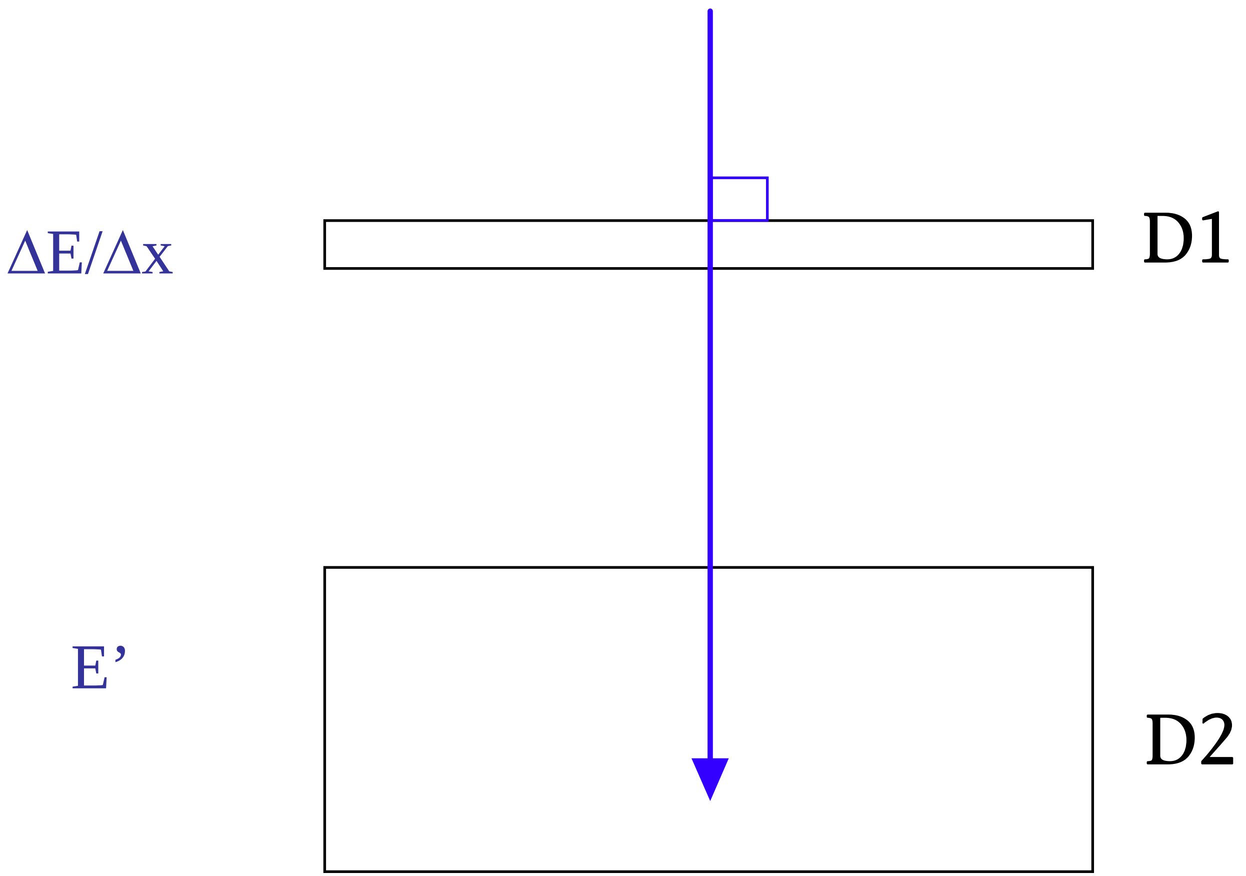
Measuring Energetic Ions in Space



ΔE/Δx versus residual energy (E')

IMP-4 Telescope (circa 1967)

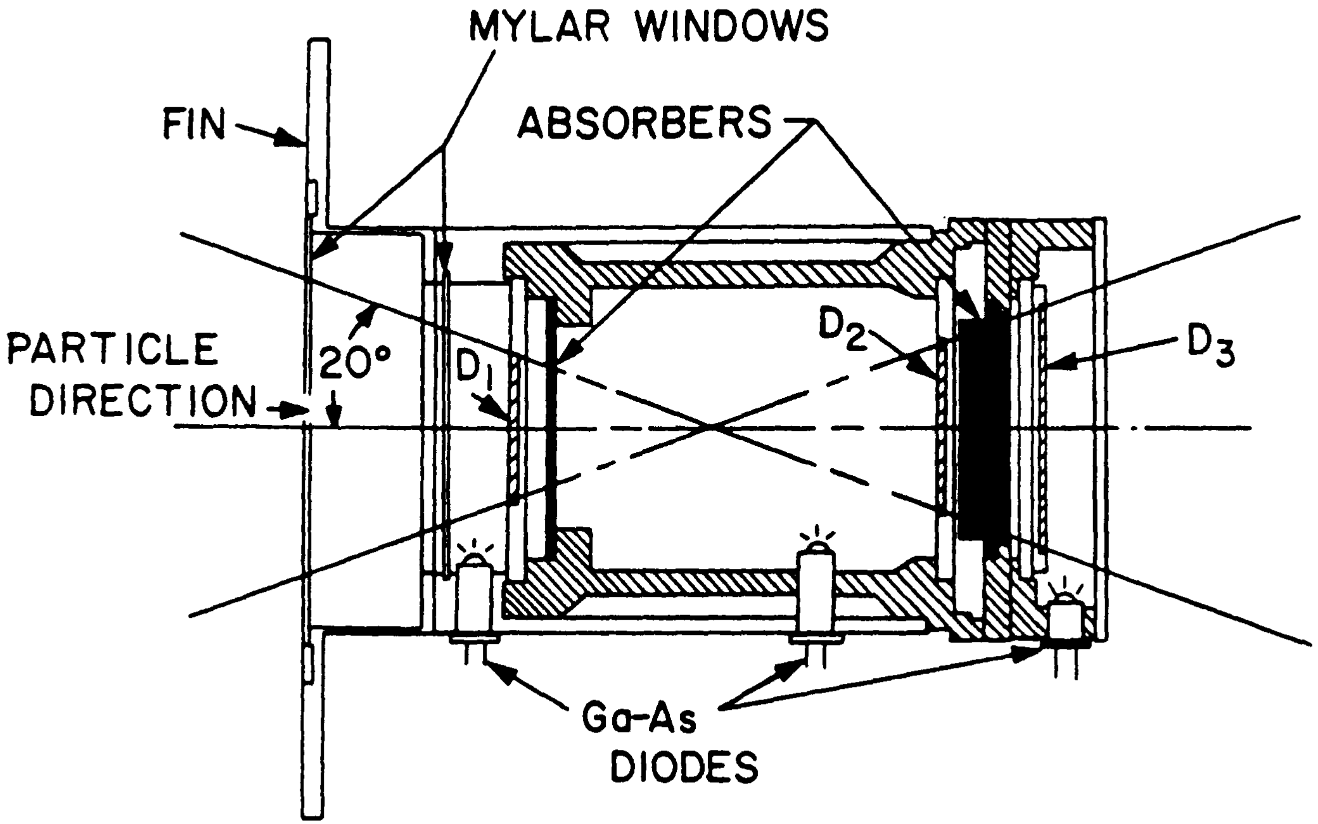


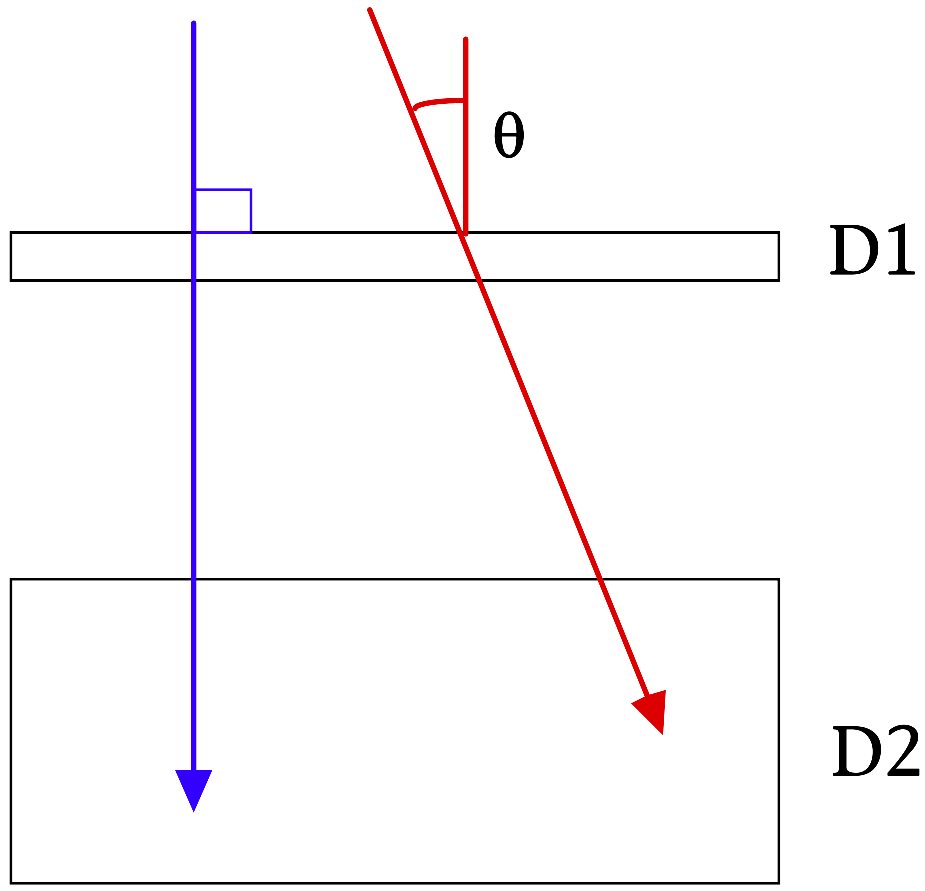
Fig. VI-2. Cross section of telescope showing sensors

Measuring Energetic Ions in Space

$\Delta E/\Delta x$

but

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



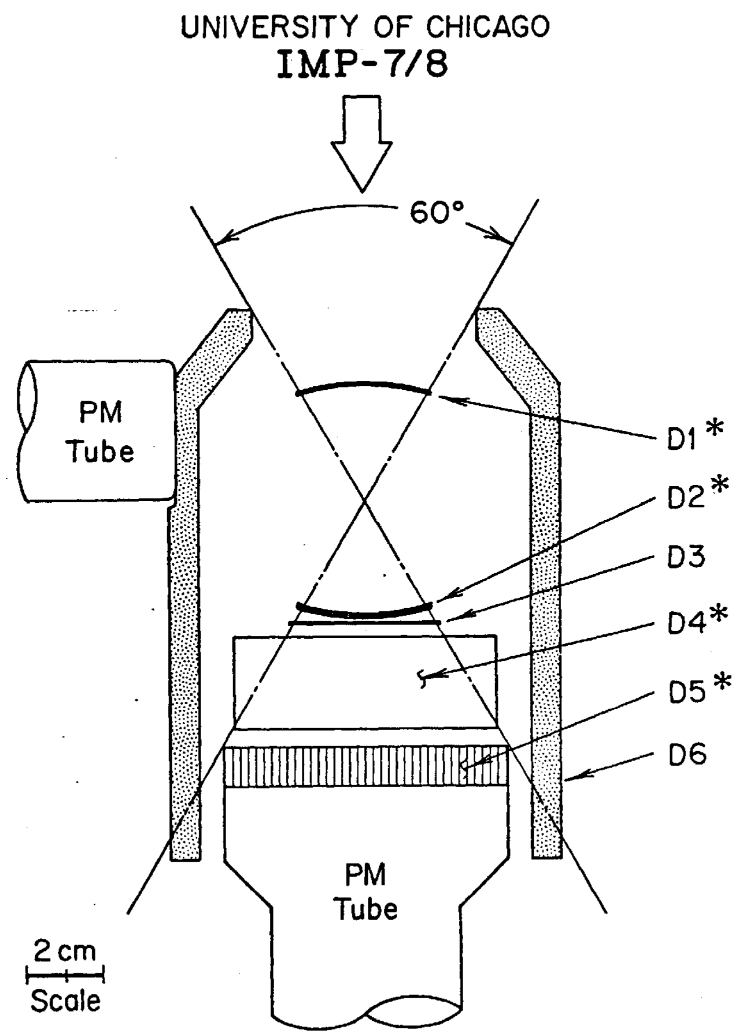
$E' = E'$

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

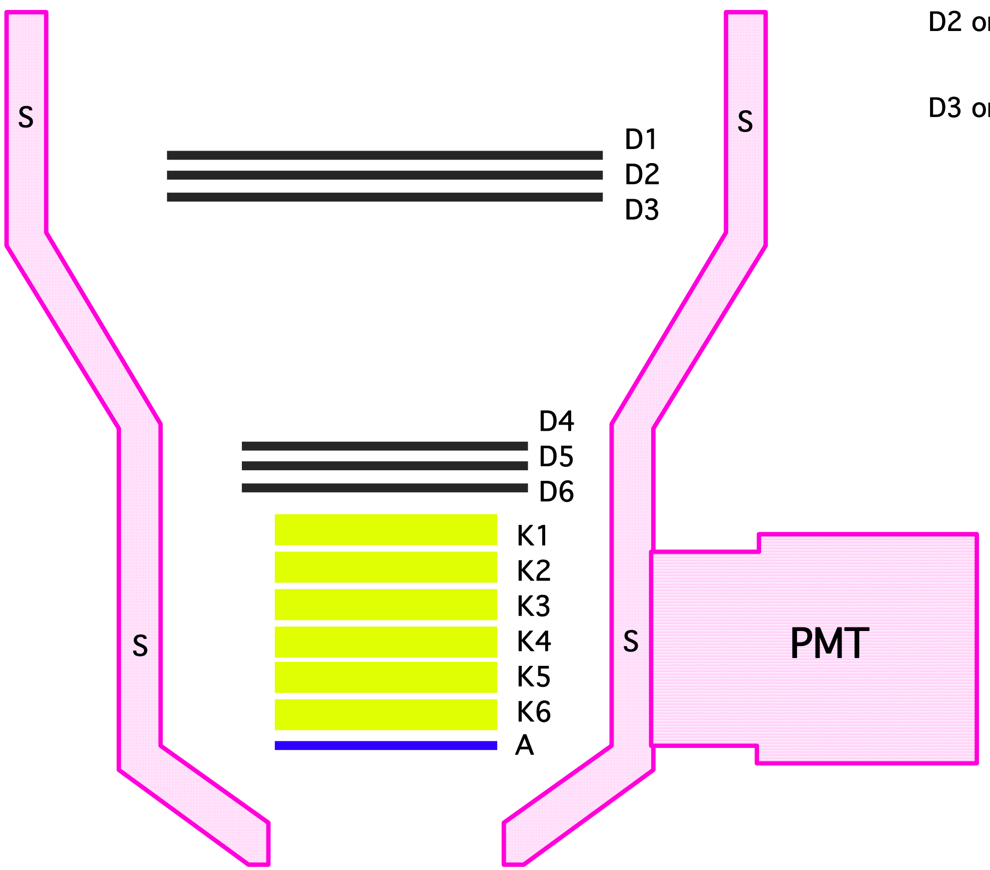
Charge resolution improved by using curved detectors

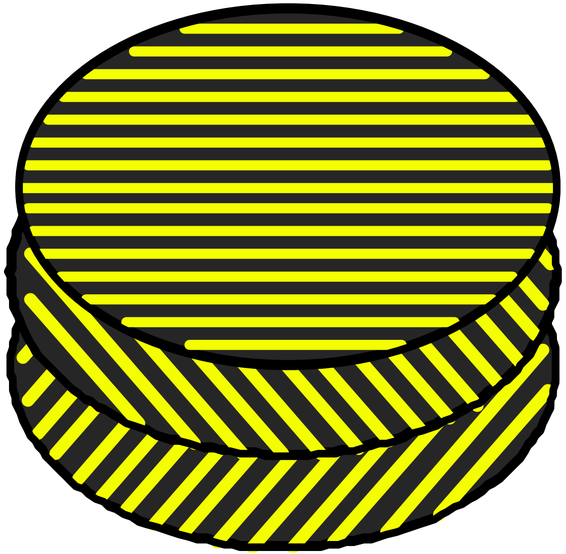
Curved detectors reduce the variations in thickness with angle of incidence

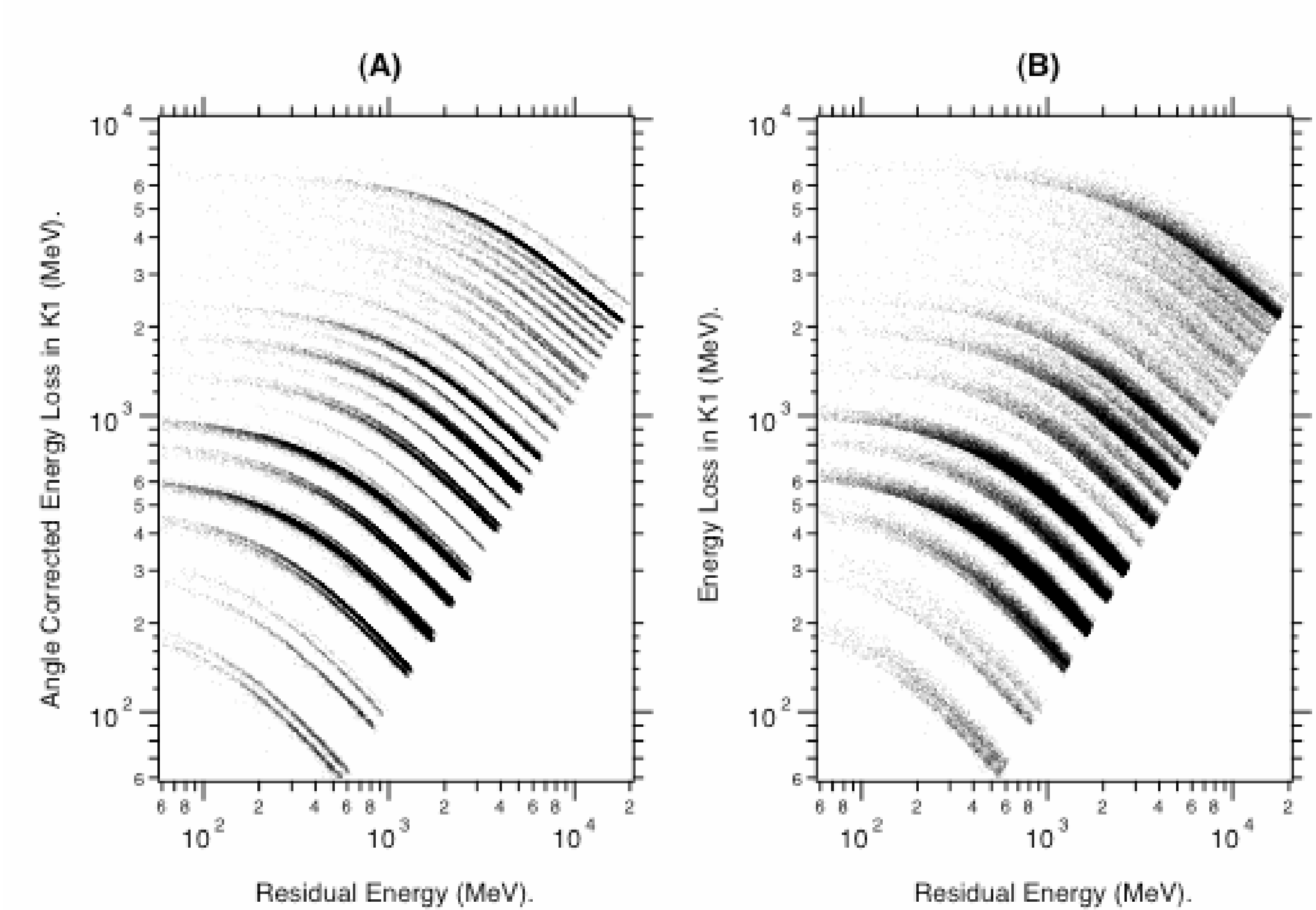
Used on IMP-6, 7 & 8
Pioneer-10 & 11
Voyager-1 & 2



Ulysses High Energy Telescope (HET)







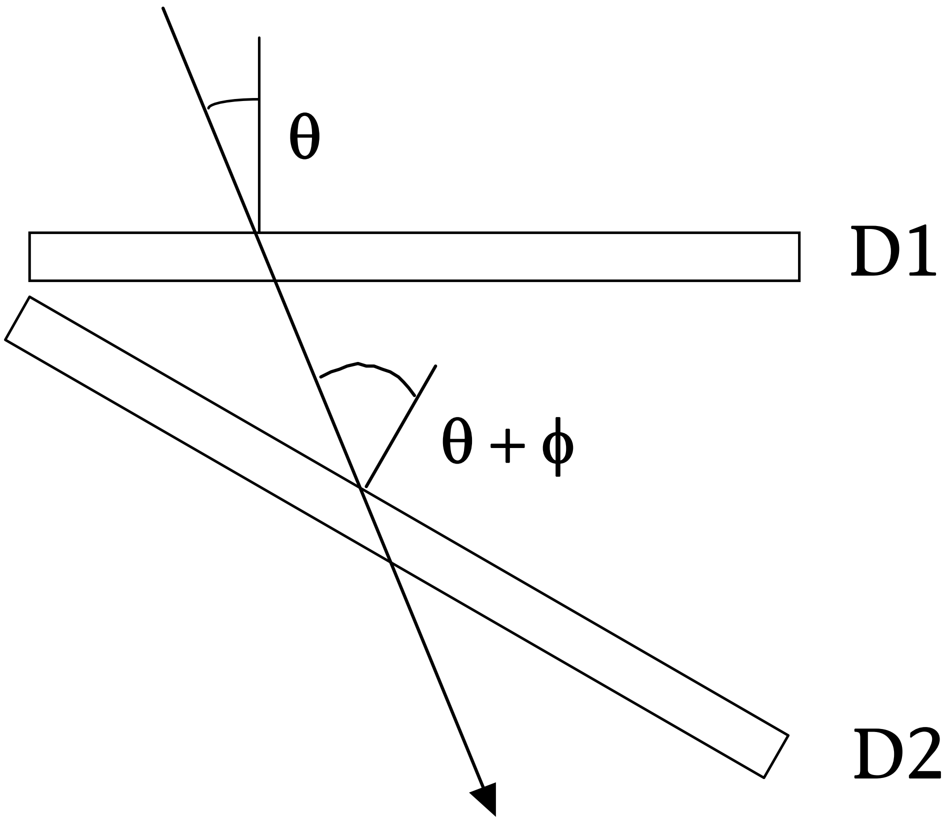
Ulysses HET flight data with (A) and without (B) correcting for particle angle of incidence—corrections need to identify elements.

Angle Detecting Inclined Sensor (ADIS)

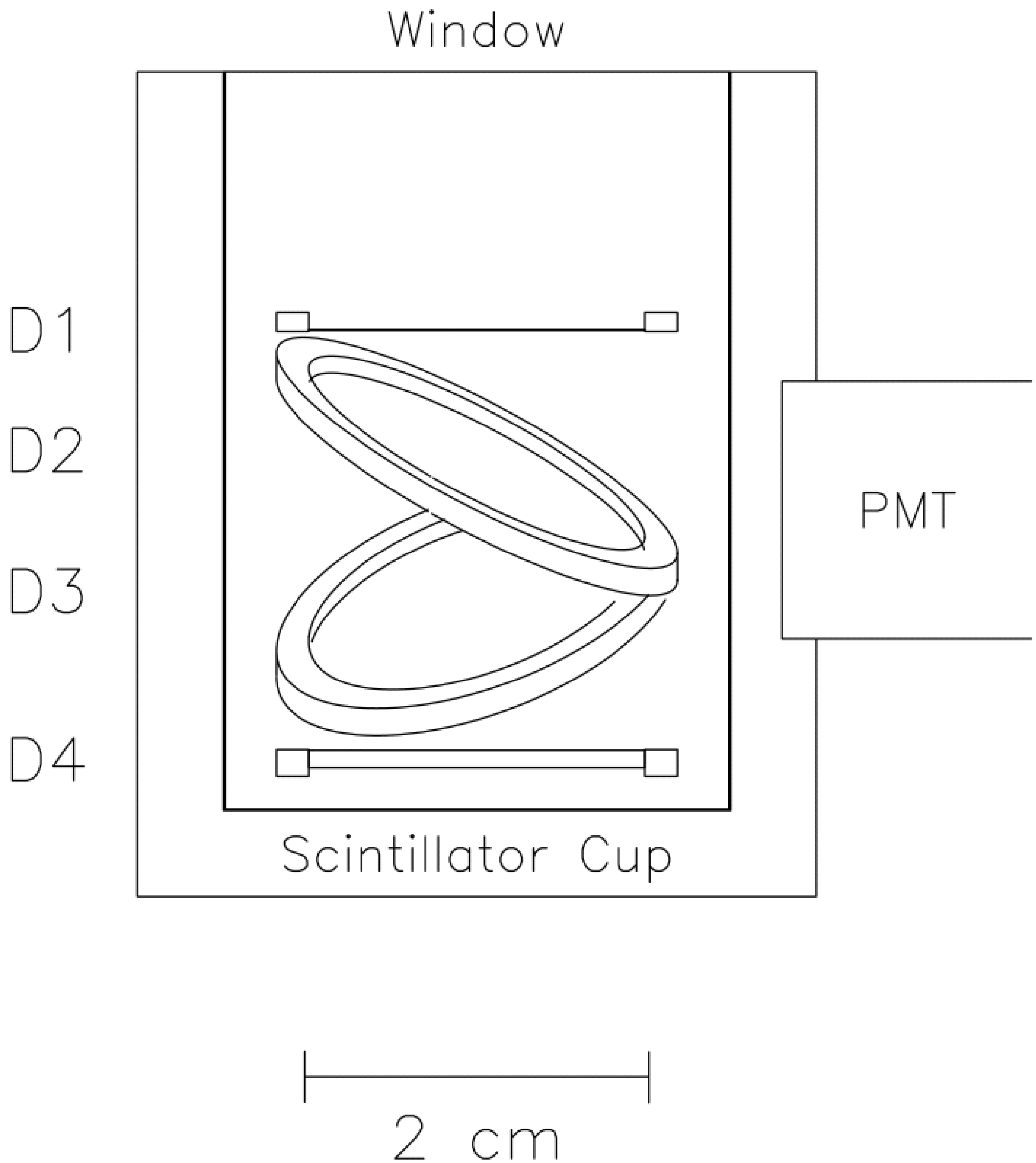
- Different geometry in telescope stack
- Uses standard Si detector technology
- Low risk
- Low mass
- Low power
- On-board event processing possible

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.

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

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

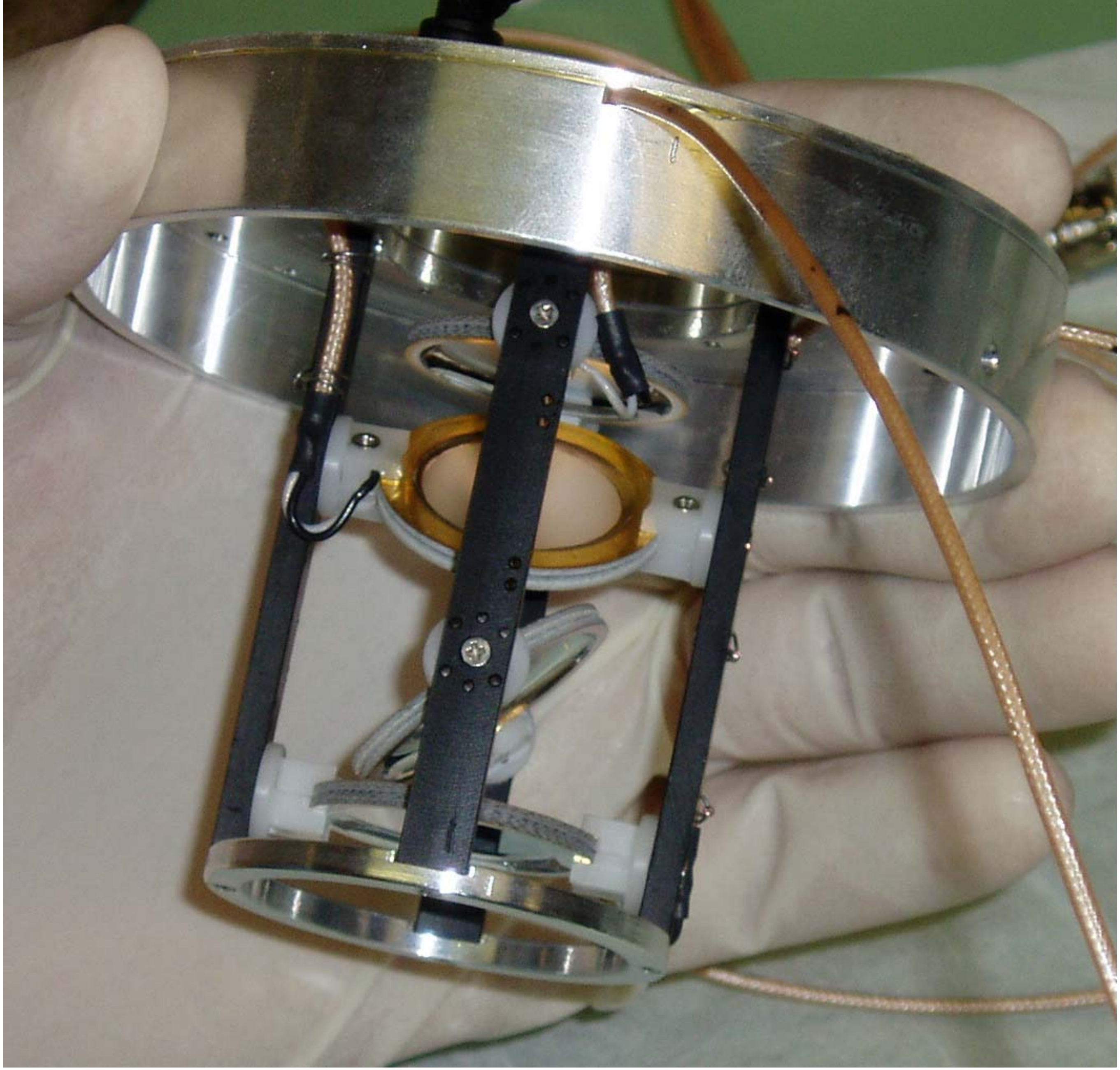
Calculation simple enough to be done by on-board processor

Greatly reduces telemetry requirements

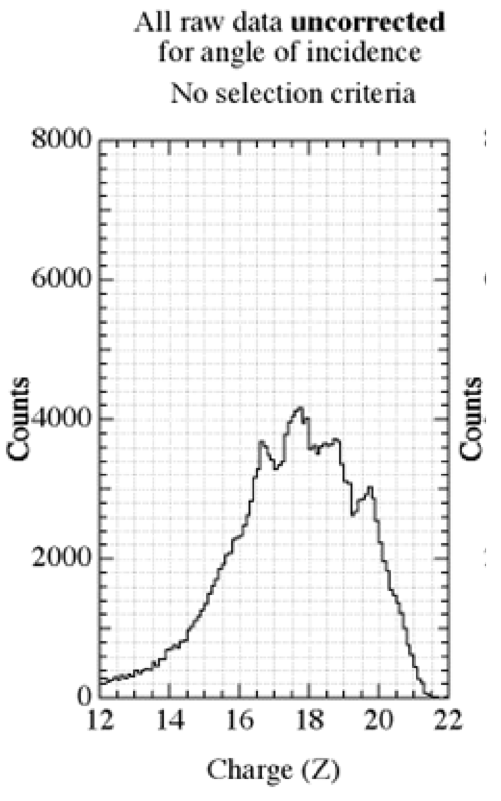
ADIS Tested with ^{48}Ca at the National Superconducting Cyclotron Laboratory

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 mm D1-3 detectors at 15, 30 and 45 degrees inclination
5. D2-3 detectors circular, NOT oval

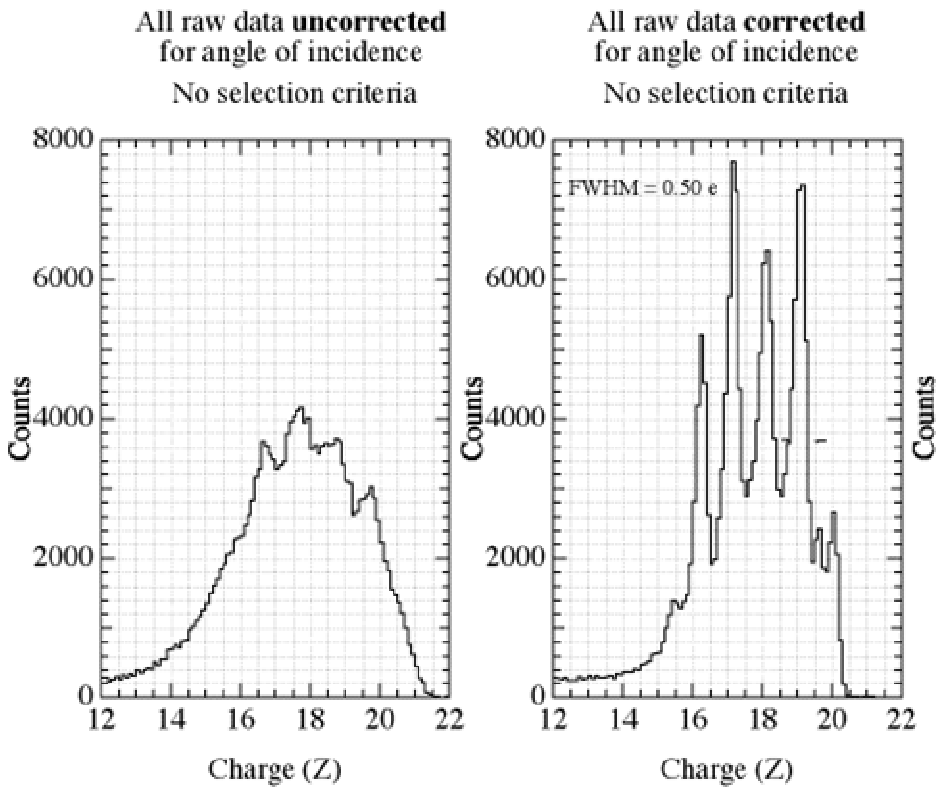
Large amounts of dead material degraded performance



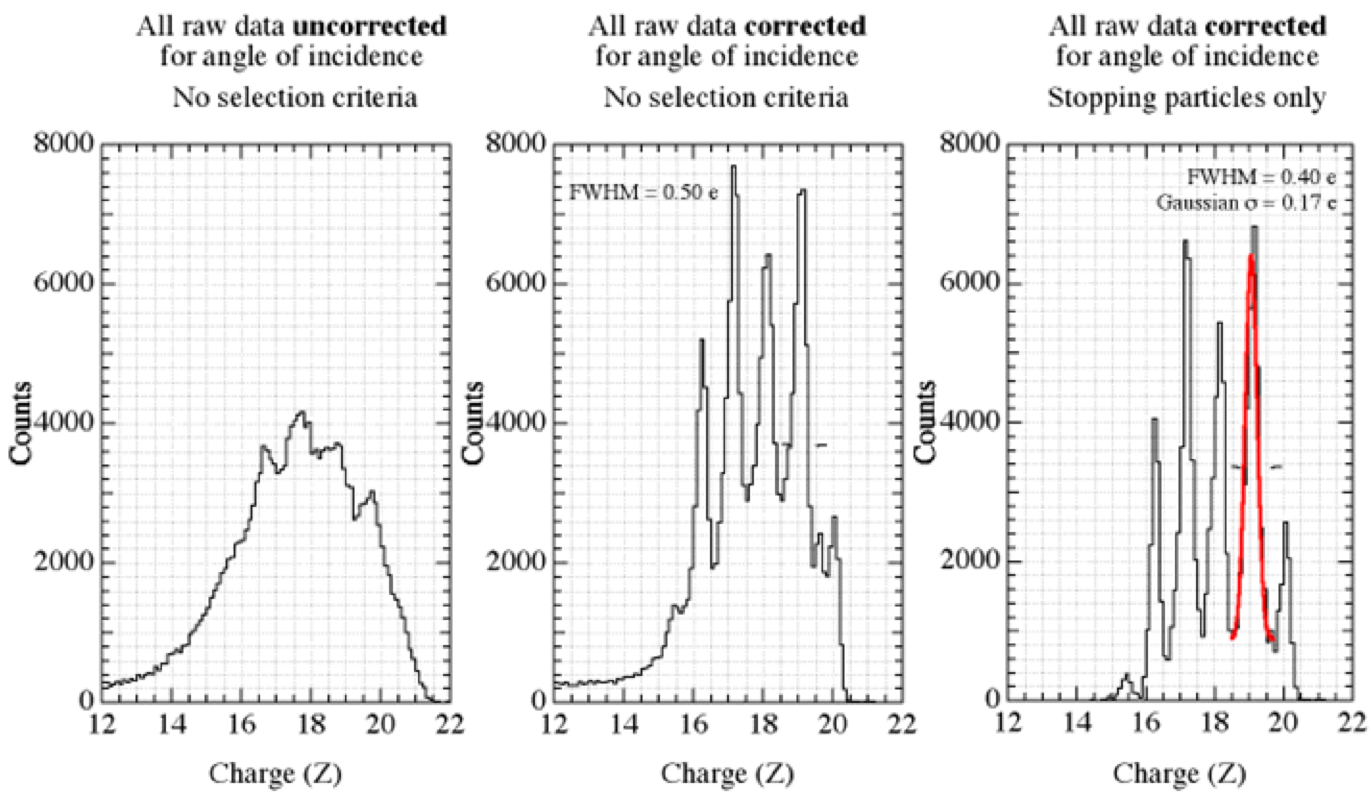
ADIS NSCL ^{48}Ca Fragment Beam D1, D2 and D3 200 μm thick 30 degree D2, D3 inclinations



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



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		Low	~5	~4 W	Low

An ADIS based Instrument had been selected for the High Energy Particle Sensor (HEPS) for NPOESS

The High Energy Particle Sensor (HEPS) will be a component of the Space Environment Sensor Suite (SESS).

The goal: A simple but capable instrument.

HEPS 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.

The High Energy Particle Sensor (HEPS)

Fluxes of H ions in six logarithmic energy intervals from 10 to ~320 MeV/u plus a seventh integral flux.

Fluxes of He ions in three logarithmic energy intervals from 10 to ~320 MeV/u plus a fourth integral flux.

Heavy ion fluxes through Ni at corresponding energies (but no integral) with individual charge resolution ($\sigma < 0.25$ e).

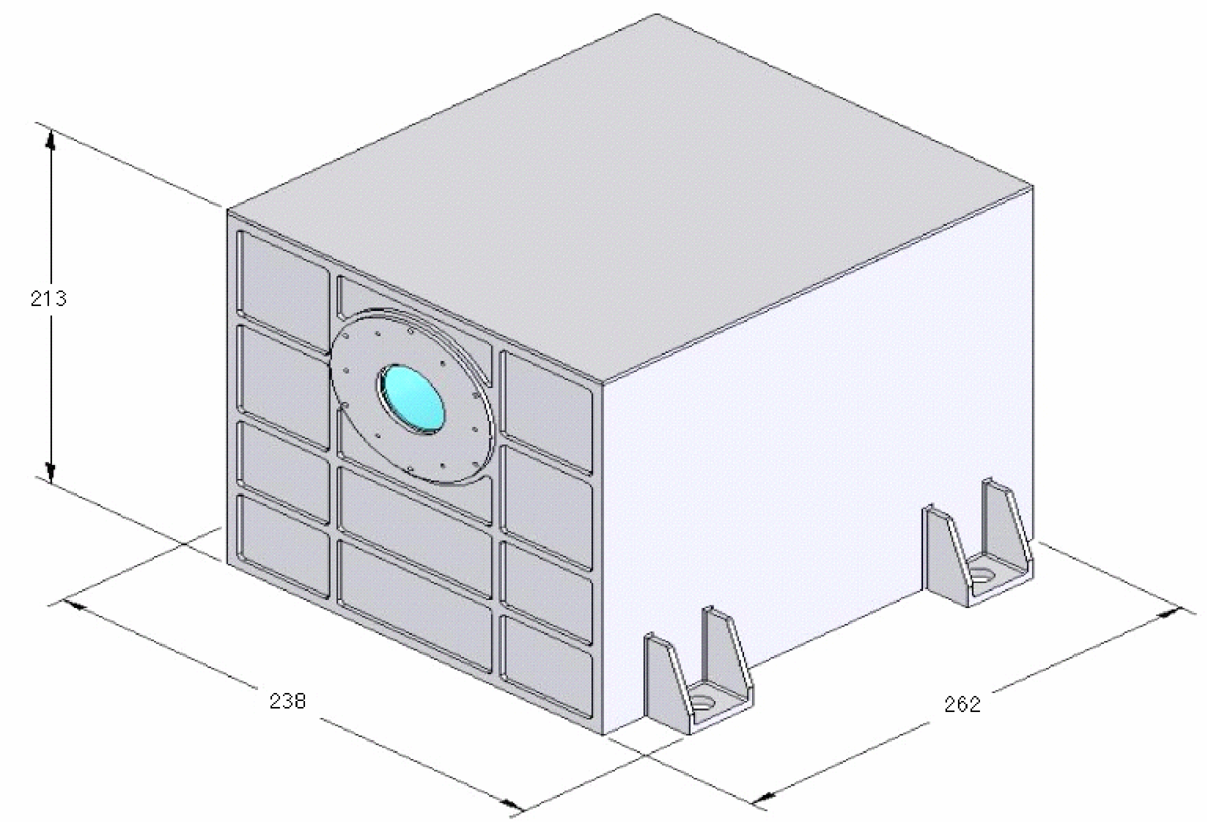
Linear Energy Transfer (LET) calculated from these data.

The geometrical factor will be ~1 cm^2-sr

HEPS is designed not to saturate at the highest fluxes of SEPs thus far observed.

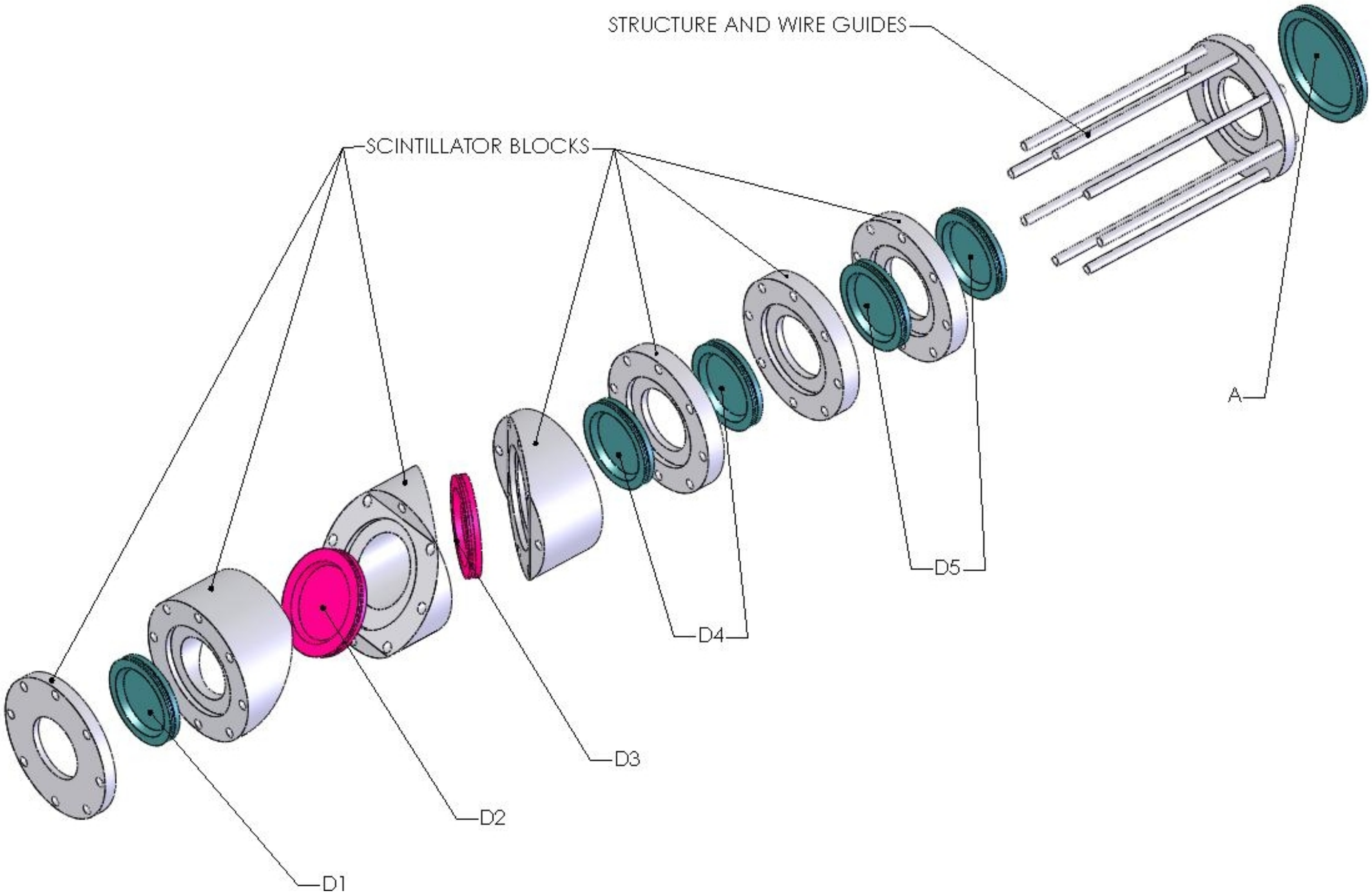
HEPS will provide data on Solar Energetic Particles (SEP), Galactic Cosmic Rays (GCR) and Anomalous Cosmic Rays (ACR) as well as trapped radiation.

Present HEPS Resource Estimates are Preliminary



Mass: ~4 kg
Power: ~3.6 W
Telemetry: 350 bps

HEPS


STRUCTURE AND WIRE GUIDES
SCINTILLATOR BLOCKS
A
D5
D4
D3
D2
D1

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

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

D1 is a circular detector of ~600 mm^2 area.

D2 and D3 are oval and inclined at 30 degrees.

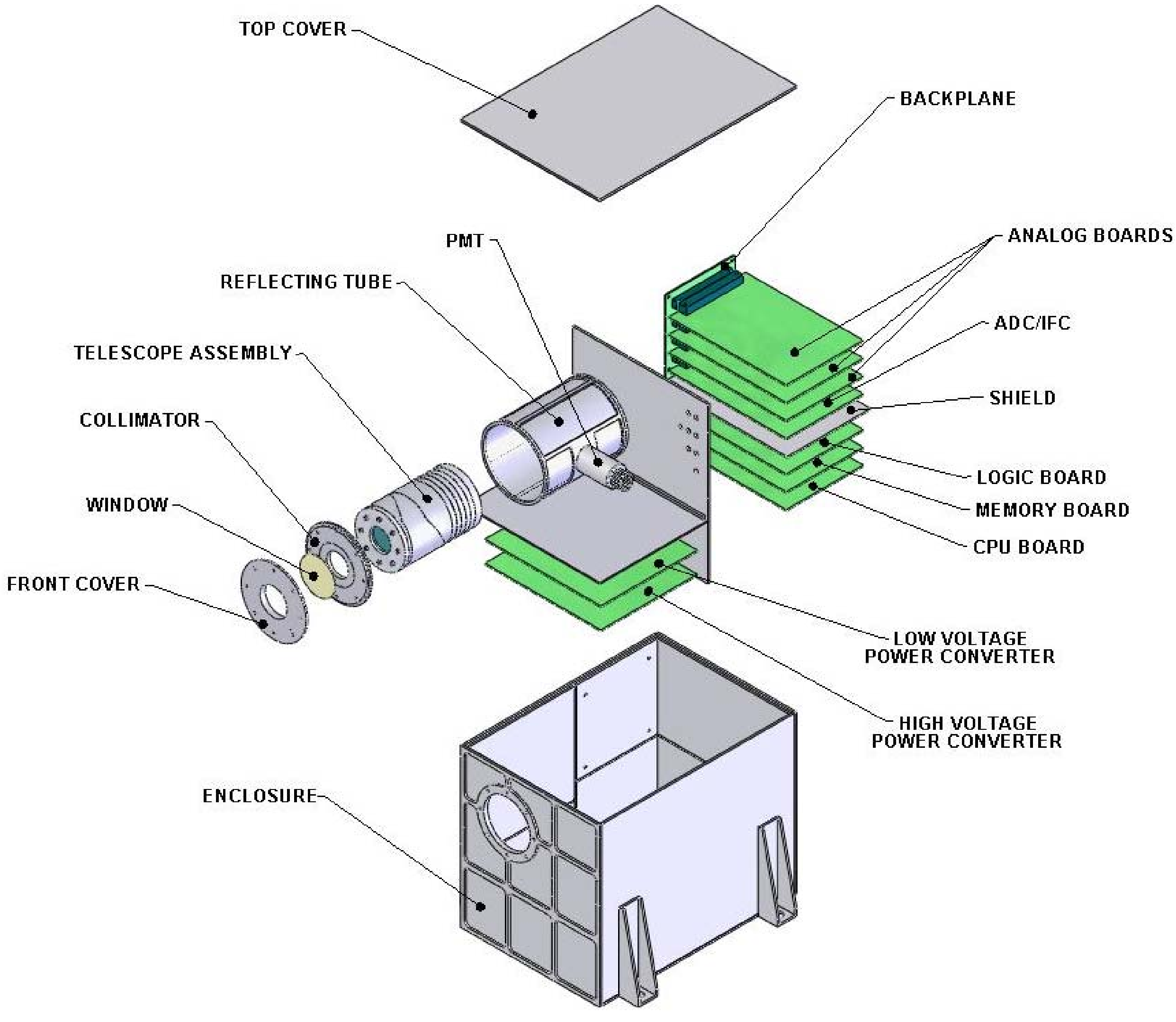
D2 and D3 have a semi-minor axis equal to the D1 radius and semi-major axis a factor 1.155 longer.

D4 and D5 are logical detector each consisting of a pair of 2000 micron thick, 600 mm^2 detectors.

D1-D5 are pulse-height analyzed.

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

HEPS


TOP COVER
BACKPLANE
PMT
REFLECTING TUBE
ANALOG BOARDS
TELESCOPE ASSEMBLY
ADC/IFC
SHIELD
COLLIMATOR
LOGIC BOARD
MEMORY BOARD
WINDOW
CPU BOARD
FRONT COVER
LOW VOLTAGE
POWER CONVERTER
HIGH VOLTAGE
POWER CONVERTER
ENCLOSURE

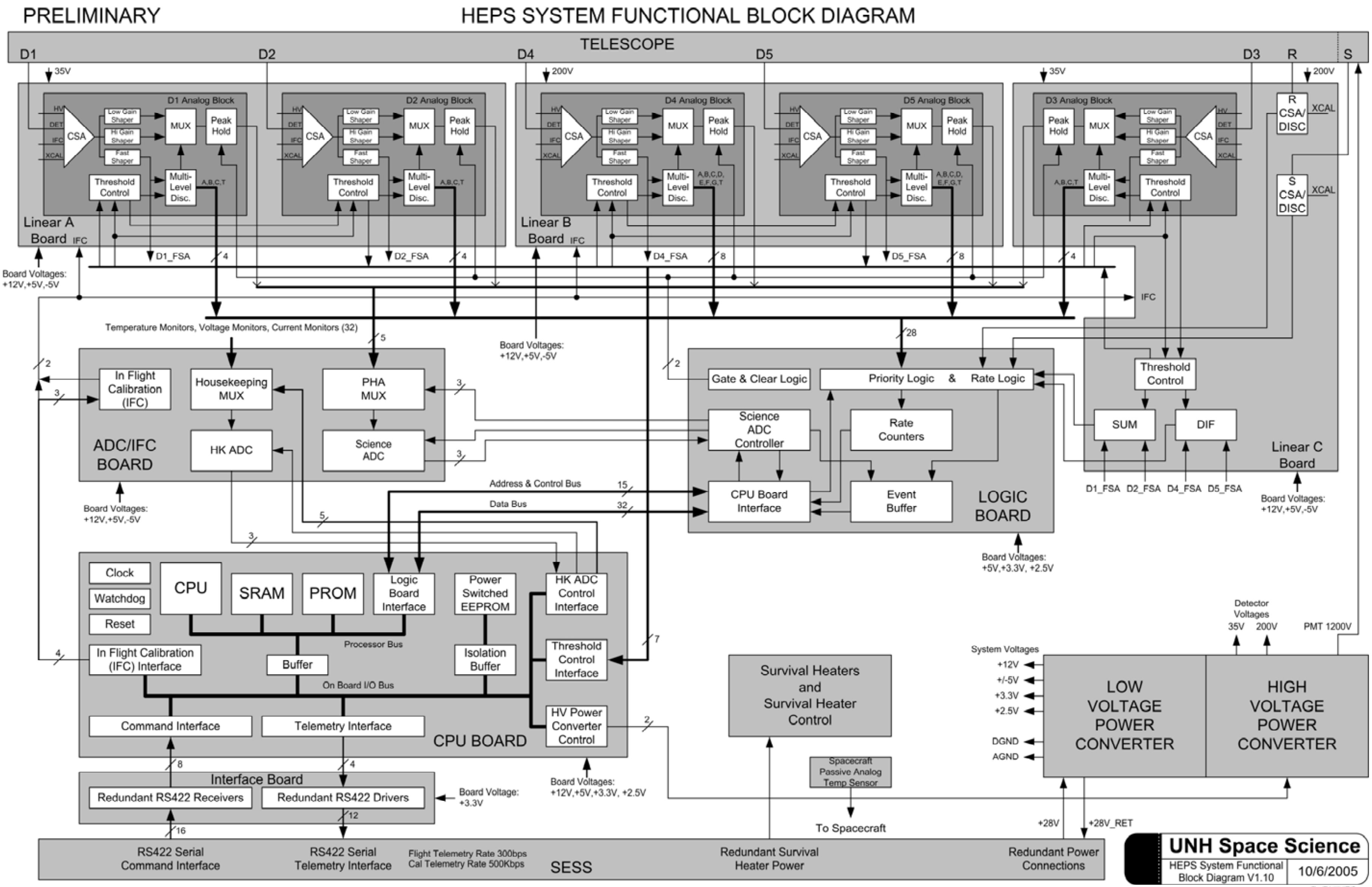
The instrument will be housed in a single box that includes electronics boards.

The box is divided to isolate the converter boards, the analog electronics boards and the digital electronics boards.

Board attachment is modular for relatively simple replacement.

Minimal box thickness for NPOESS is currently 0.25 cm (100mils) to reduce radiation exposure.

This would hardly be needed on a manned flight.


PRELIMINARY
HEPS SYSTEM FUNCTIONAL BLOCK DIAGRAM
TELESCOPE
D1
D2
D4
D5
D3
R
S
35V
200V
D1 Analog Block
D2 Analog Block
D4 Analog Block
D5 Analog Block
D3 Analog Block
HV
DET
IFC
XCAL
CSA
Low Gain Shaper
Hi Gain Shaper
Fast Shaper
MUX
Peak Hold
Threshold Control
Multi-Level Disc.
A,B,C,T
A,B,C,D, E,F,G,T
R CSA/ DISC
S CSA/ DISC
Linear A Board
Linear B Board
Linear C Board
D1_FSA
D2_FSA
D4_FSA
D5_FSA
Board Voltages: +12V,+5V,-5V
IFC
Temperature Monitors, Voltage Monitors, Current Monitors (32)
In Flight Calibration (IFC)
Housekeeping MUX
PHA MUX
HK ADC
Science ADC
ADC/IFC BOARD
Gate & Clear Logic
Priority Logic & Rate Logic
Science ADC Controller
Rate Counters
CPU Board Interface
Event Buffer
LOGIC BOARD
Threshold Control
SUM
DIF
Address & Control Bus
Data Bus
Board Voltages: +5V,+3.3V, +2.5V
Clock
Watchdog
Reset
CPU
SRAM
PROM
Logic Board Interface
Power Switched EEPROM
HK ADC Control Interface
Processor Bus
In Flight Calibration (IFC) Interface
Buffer
Isolation Buffer
Threshold Control Interface
On Board I/O Bus
Command Interface
Telemetry Interface
HV Power Converter Control
CPU BOARD
Interface Board
Redundant RS422 Receivers
Redundant RS422 Drivers
Board Voltage: +3.3V
Board Voltages: +12V,+5V,+3.3V, +2.5V
Survival Heaters and Survival Heater Control
Spacecraft Passive Analog Temp Sensor
To Spacecraft
System Voltages
+12V
+/-5V
+3.3V
+2.5V
DGND
AGND
LOW VOLTAGE POWER CONVERTER
HIGH VOLTAGE POWER CONVERTER
Detector Voltages
35V
200V
PMT 1200V
+28V
+28V_RET
RS422 Serial Command Interface
RS422 Serial Telemetry Interface
Flight Telemetry Rate 300bps
Cal Telemetry Rate 500Kbps
SESS
Redundant Survival Heater Power
Redundant Power Connections
UNH Space Science
HEPS System Functional Block Diagram V1.10
10/6/2005
D. RHINES

The HEPS electronics will consists of eight main boards plus a backplane motherboard

3 Linear boards

1 ADC /IFC board

1 Logic board

1 CPU board

Power converter board

HV board

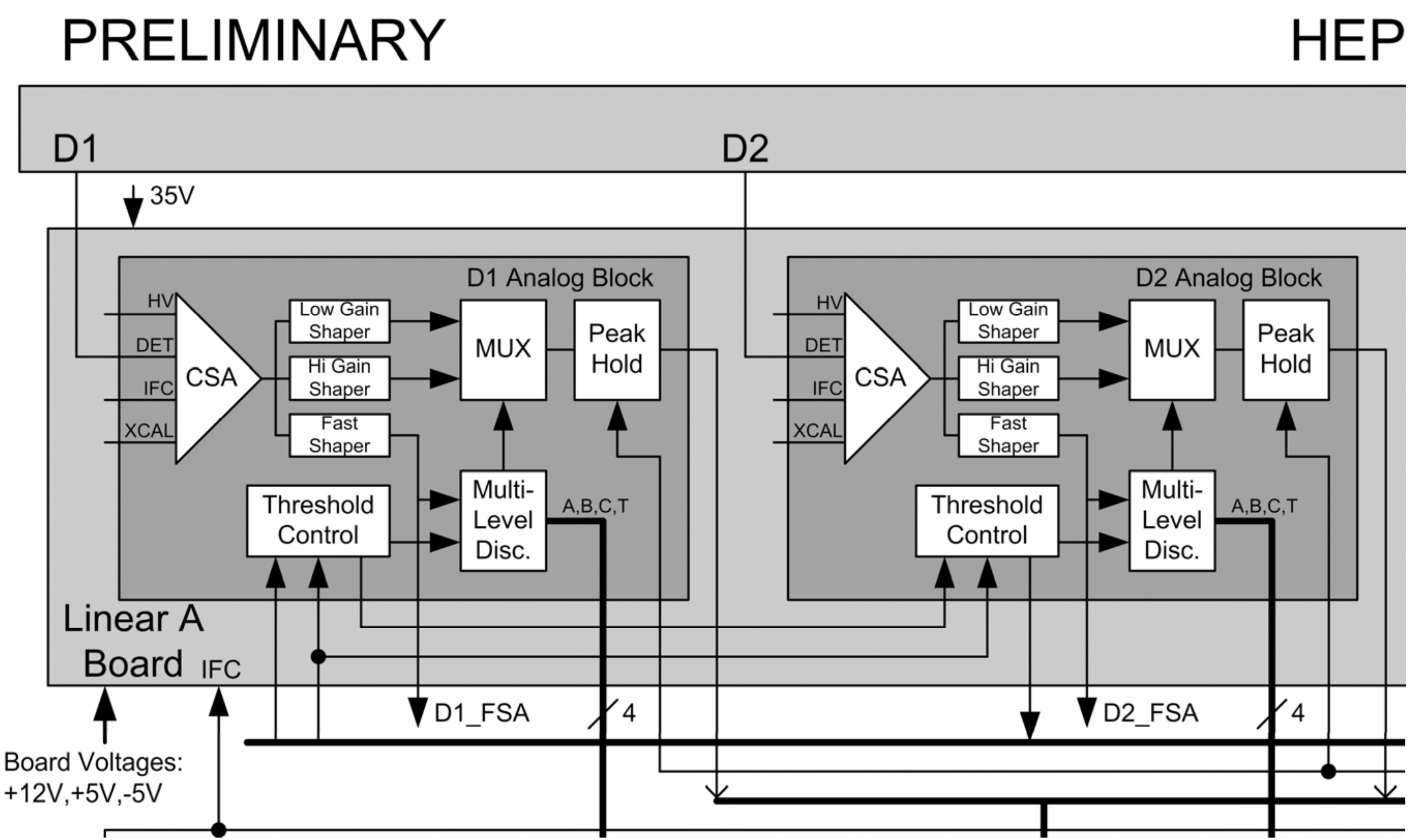
A small I/O board supports the RS 422 interface.

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

Priority system used to give preference to heavy ion species for PHA.

On-board analysis means relatively large sample of PHA events: 1000's identified per second.

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


PRELIMINARY
HEP
D1
D2
35V
D1 Analog Block
D2 Analog Block
HV
DET
IFC
XCAL
CSA
Low Gain Shaper
Hi Gain Shaper
Fast Shaper
MUX
Peak Hold
Threshold Control
Multi-Level Disc.
A,B,C,T
Linear A Board
IFC
D1_FSA
D2_FSA
4
Board Voltages:
+12V,+5V,-5V

Two slower amps are used for events that will be pulse height analyzed.

Because of the large dynamic range of the signals (~7000) there is both a high gain and a low gain shaping amplifier. These feed via an analog mux to a peak detect sample and hold (PDSH).

The highest level discriminator determines which amplifier (the high or low gain) feeds the sample and hold.

Thus, small signals are processed through the high gain amp while large signals are processed through the low gain amp.

ADIS
Simple
Capable

A Phoswich-based Detector for Fast (~0.5-10 MeV) Neutrons

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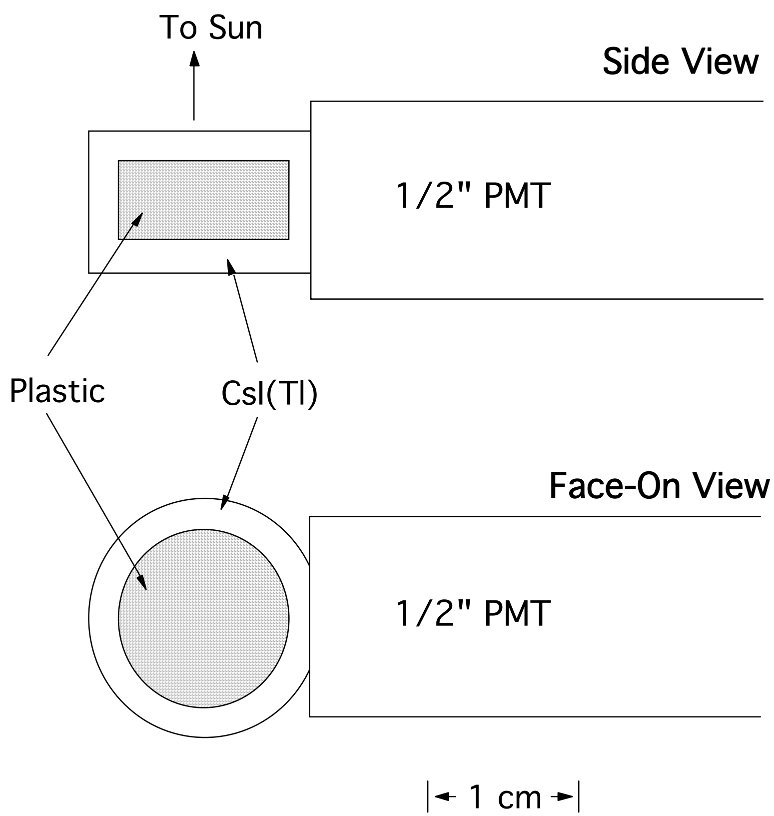
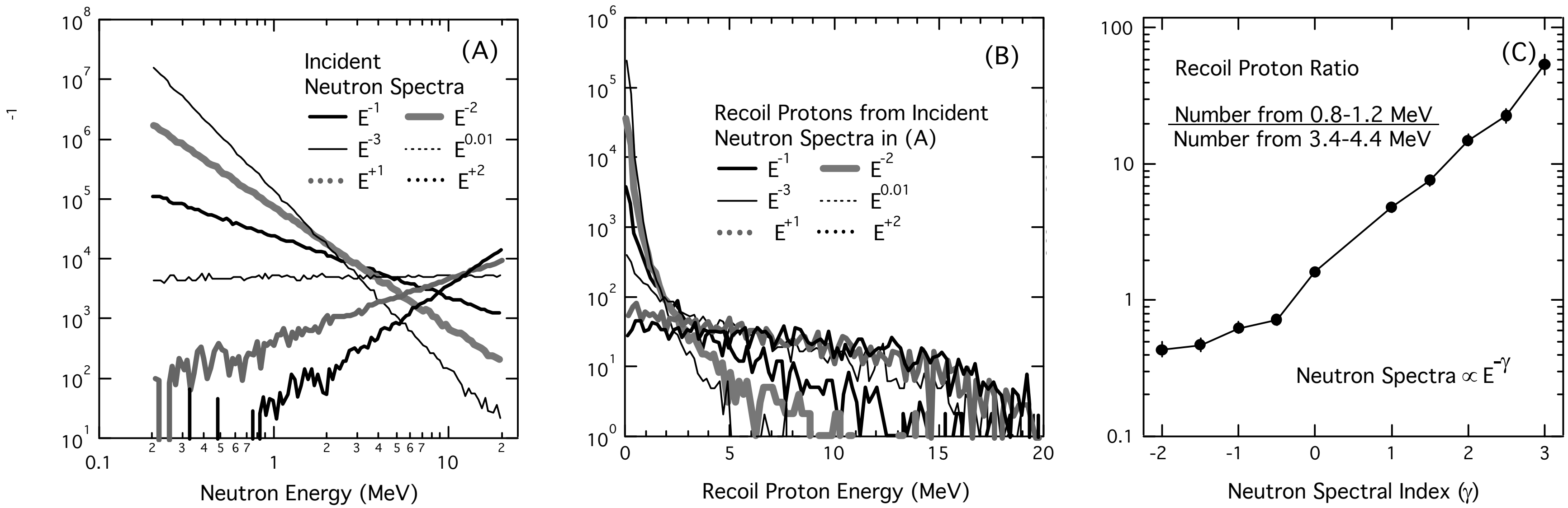
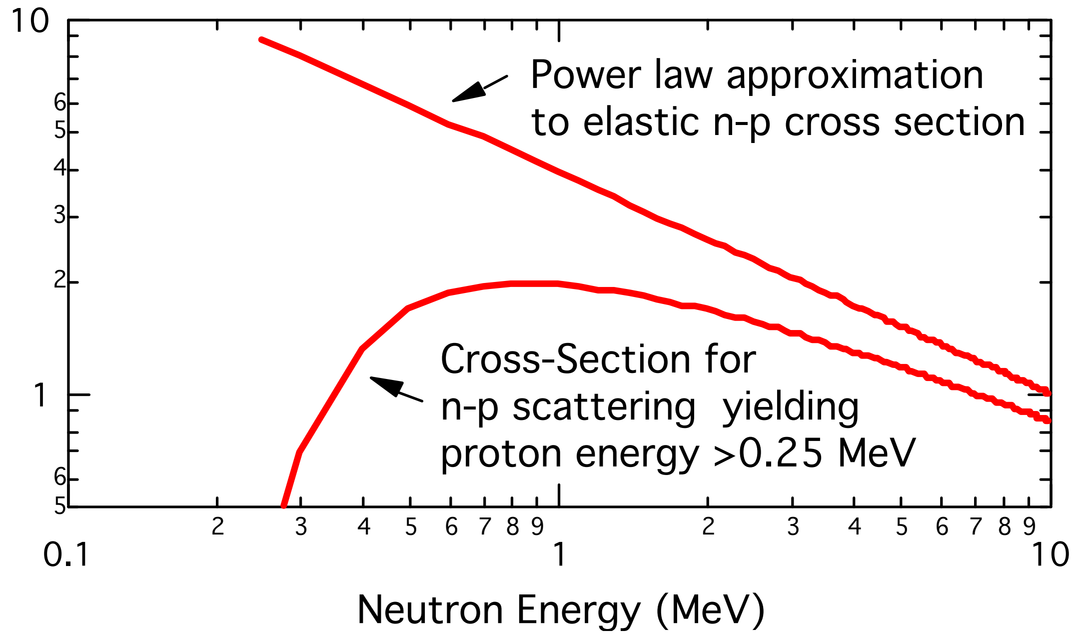

To Sun
Side View
1/2" PMT
Plastic
CsI(Tl)
Face-On View
1/2" PMT
1 cm

Normalized to neutrons expected in 1 day on 0.78 cm^2 detector for flux of 1 n/(cm^2 s) in range 1 < E < 20 MeV



A) Incident neutron spectra. B) Energy distribution of recoil protons in the detector from spectra in (A), C) Ratio of numbers of recoil protons in two energy bands vs. spectral index of incident neutrons.



Scattering cross-section and effective cross-section for producing a >0.25 MeV recoil proton

A Phoswich-based Detector offers the potential for a very simple, low mass, low power monitor for neutrons.