EPI-Hi Sensor System

Outline

- requirements
- system overview (?)
- detector telescopes
- measurement capabilities
    - energy range and resolution
    - fields of view and angular sectoring
    - species coverage / composition
    - cadences
    - dynamic range in particle intensities
- expected performance compared with requirements
- maturity of design
- system testing approach
- summary and peer-review follow-up

EPI-Hi Measurement Requirements

Protons and Heavy Ions

- energy range: 1 MeV/nuc (TBR) to ≥50 MeV/nuc
- energy binning: ≥6 bins per decade
- cadence: at least energy bin with time resolution of 5 s or better
- FoV: ≥π/2 sr in sunward and anti-sunward hemipsheres (incl. 10° from S/C-Sun line)
- angular sectoring: ≤30° sector width
- composition: at least H, He, C, O, Ne, Mg, Si, Fe, ^{3}He
- species resolution: FWHM ≤ 0.5 (TBR) × separation from nearest abundant neighbor
- max intensity: up to 10% (TBR) of upper limit proton spectrum from EDTRD

Electrons

- energy range: 0.5 MeV (TBR) to ≥3 MeV
- energy binning: ≥6 bins per decade
- cadence: at least energy bin with time resolution of 1 s or better
- FoV: ≥π/2 sr in sunward and anti-sunward hemipsheres (incl. 10° from S/C-Sun line)
- angular sectoring: ≤45° sector width
- max intensity: up to 10% (TBR) of upper limit electron spectrum from EDTRD*

*Note: upper limit electron spectrum not yet specified in EDTRD

EPI-Hi Sensor System Overview

Sensor Approach:

- all sensor elements are silicon solid state detectors
- multiple detector telescopes to provide large energy range and sky coverage
- some telescopes double ended to increase sky coverage
- detector segmentation to provide angular sectoring and adjustable geometrical factor

Heritage:

- numerous energetic particle instruments over the past 40 years
- direct predecessor: STEREO/LET & HET

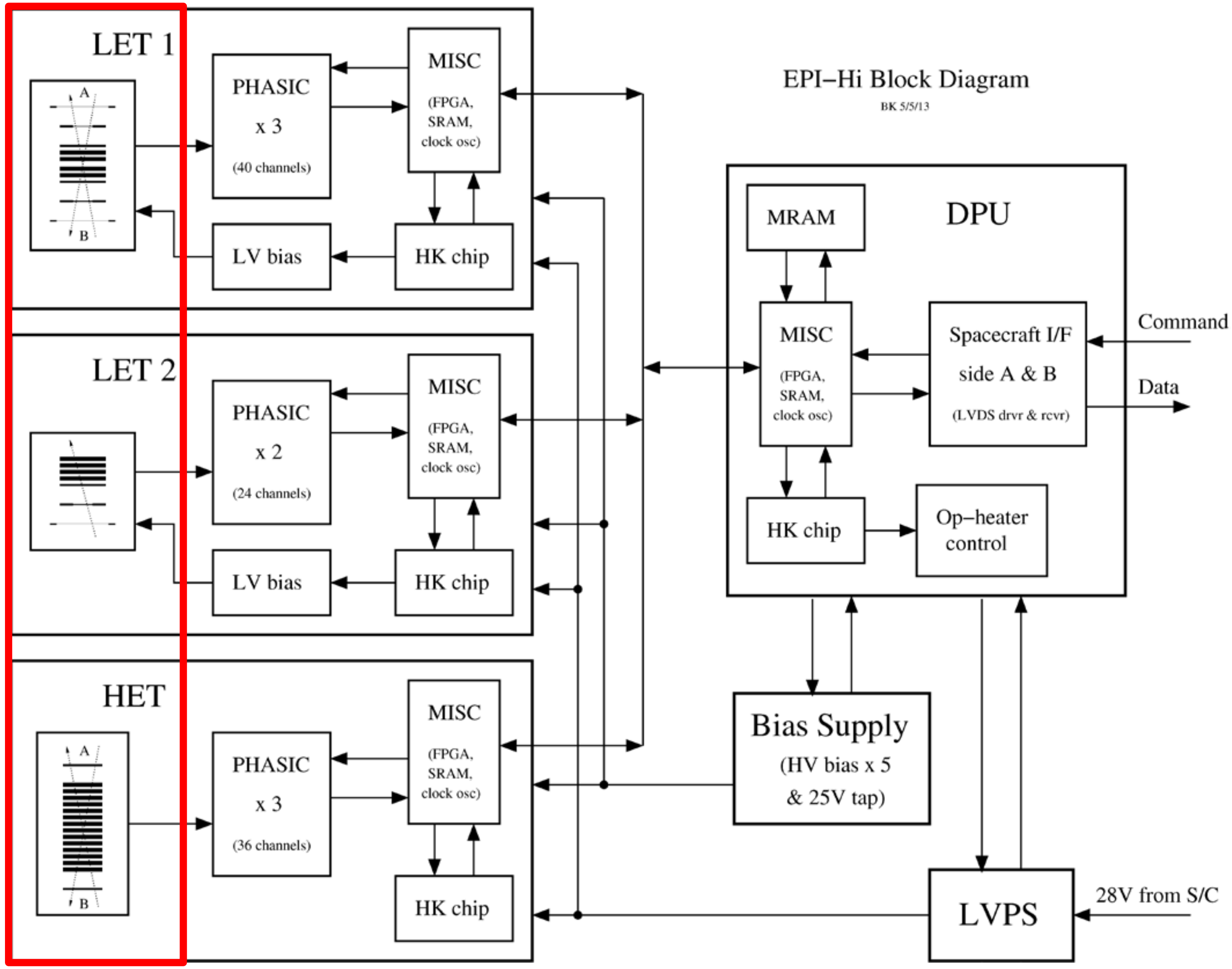
Key Differences:

- thinner detectors and windows to reduce energy threshold
- compact telescope designs to reduce saturation at high particle intensities and backgrounds at low intensities

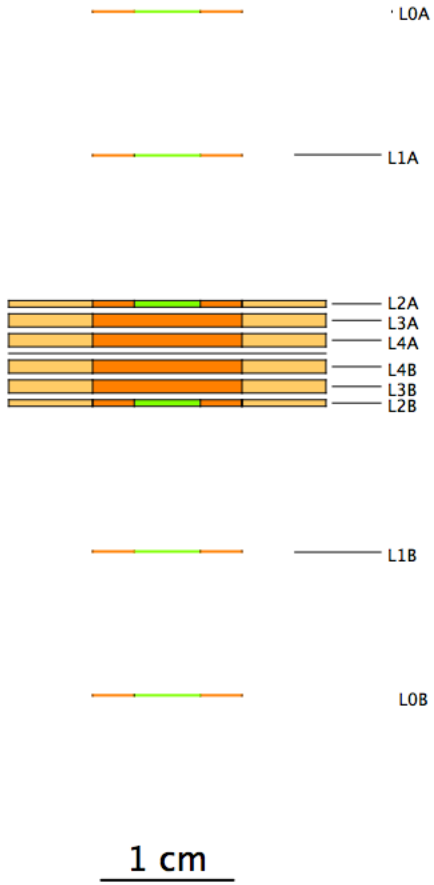
EPI-Hi Block Diagram

3 detector telescopes:

- one double-ended low-energy telescope (LET1)
- one single-ended low-energy telescope (LET2)
- one double-ended high-energy telescope (HET)
- all sensor elements are ion-implanted silicon solid-state detectors
- signals from each telescope processed by an individual electronics board



Low-Energy Telescopes: LET1 and LET2



HET2 is single ended and identical to HET1 down through L3B

Need to replace figure with version that includes inactive elements (windows, housing, etc.)

Energy Range

Stack Thickness through L4B: 3.5 mm of Si

highest stopping energies:

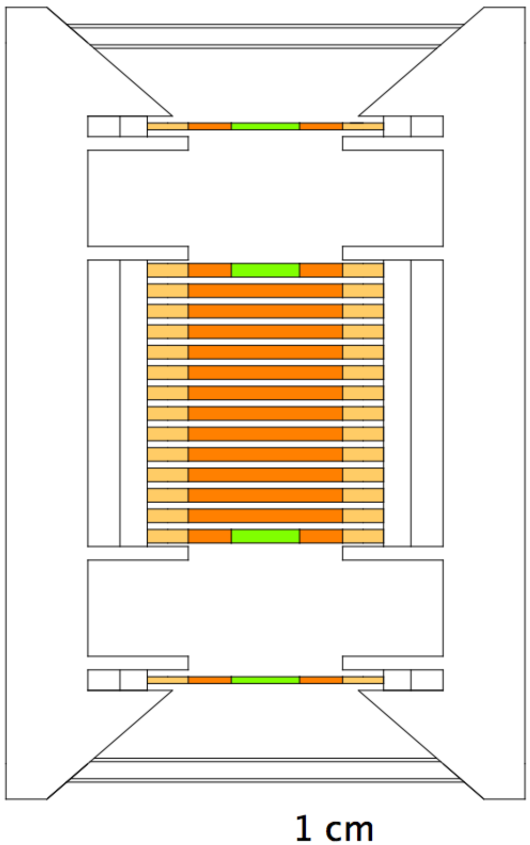
- H & He: ~25 MeV/nuc
- C: ~45 MeV/nuc
- Fe: ~100 MeV/nuc
- e: ~1.3 MeV

Front Detector Thickness: 12 μm Si
Combined window thicknesses: 3 μm Si equiv.

energies to penetrate windows + first detector:

- H: ~1.0 MeV
- He: ~0.9 MeV/nuc
- C: ~1.3 MeV/nuc
- Fe: ~1.5 MeV/nuc
- e: ~0.4 MeV (penetration to L3)

High-Energy Telescope: HET



colored regions: active Si
uncolored: inactive material

Energy Range

Stack Thickness: 15 mm of Si

highest stopping energies:
- H & He: ~55 MeV/nuc
- C: ~100 MeV/nuc
- Fe: ~230 MeV/nuc
- e: ~6 MeV

Front Detector Thickness: 0.5 mm Si

energies to penetrate windows + first detector:
- H & He: ~10 MeV/nuc
- C: ~18 MeV/nuc
- Fe: ~36 MeV/nuc
- e: ~0.4 MeV

Solid State Detector Designs

Add table of thicknesses, sizes, segmentation with accompanying drawings or photographs, as available.

Indicate that the thin detectors are technology development item that will be discussed in a subsequent presentation.

Measurement Capabilities:
Energy Range and Resolution

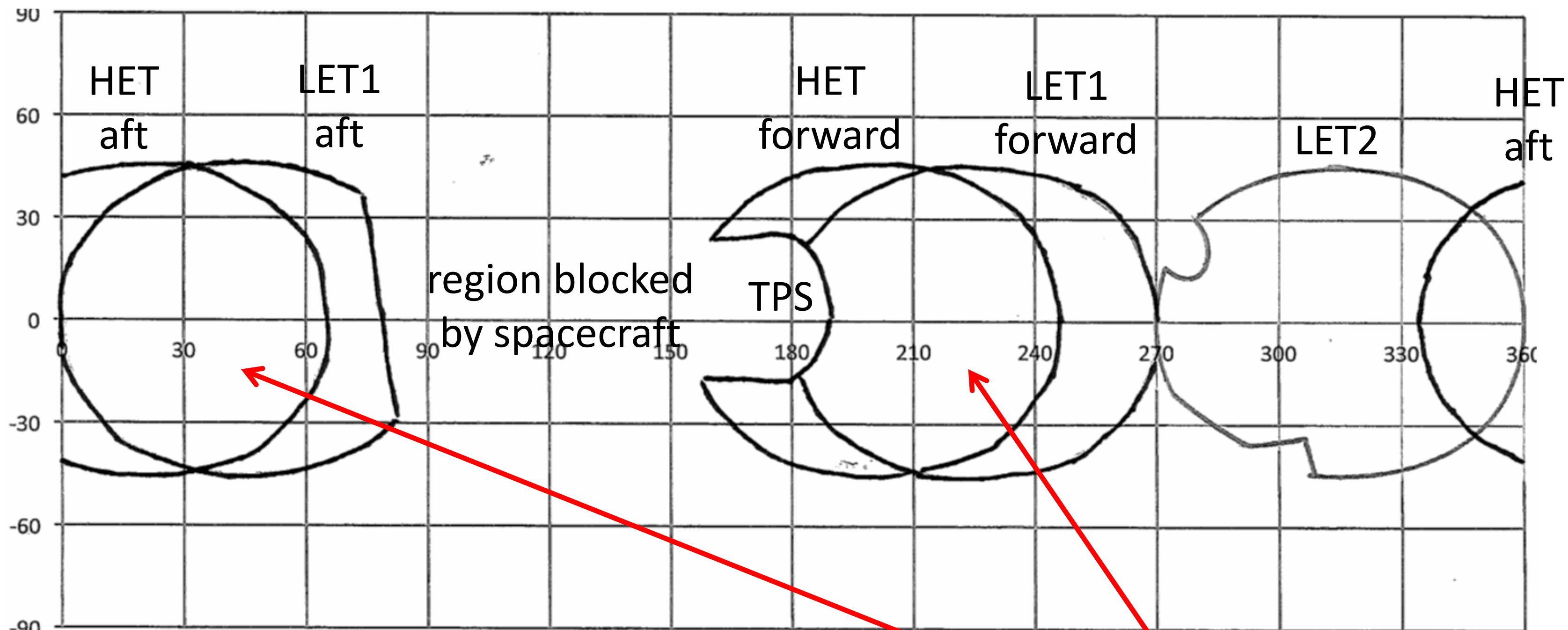
Insert Species versus Energy Plot Showing Planned Binning

- Include both LETs and HET
- Include show bins both with and without sectoring

This is similar to the chart needed for showing measurement cadences (for which there is presently a placeholder slide later in this package). It may be possible to combine the two into a single slide.

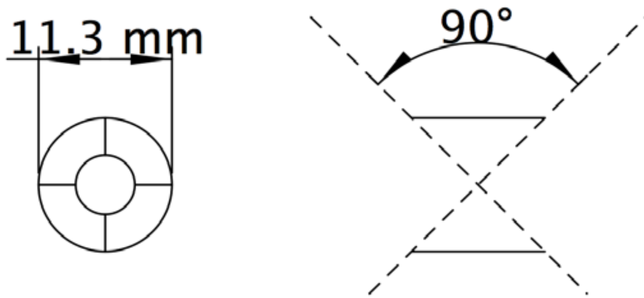
Measurement Capabilities:
Fields of View

five 45°-degree half-angle view cones



replace with better version of this figure after confirming determining whether the FoVs shown here (from January 2011) are still correct

Measurement Capabilities: Angular Sectoring



Particle direction of incidence determined based on active element hit in two position-sensitive Si detectors (L0 and L1, L1 and L2, or H1 and H2)
- each of these detectors has central bull's eye surrounded by 4 quadrants
- area of each active element is 0.2 cm^2
- quadrants in the second detector rotated 45° relative to those in the first first
- 25 combinations of hit elements in the two detectors used to assign event to a viewing sector
- HET provides sectored electron data, LET1 provides only front-back direction information for electrons

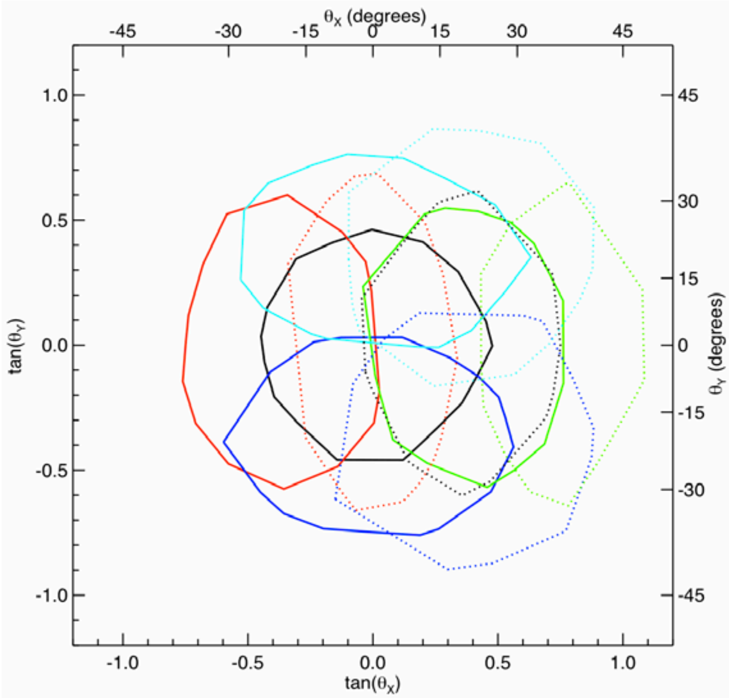
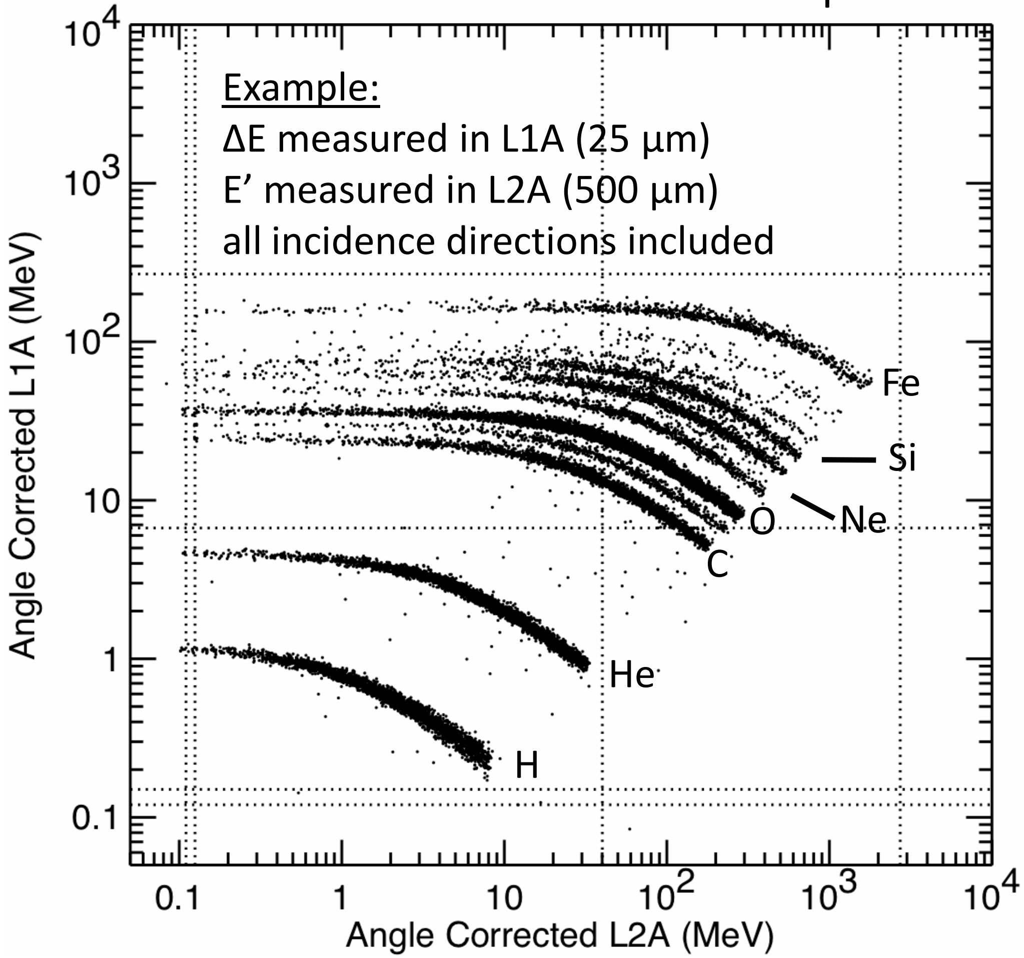


Illustration of selected angular sector boundaries: to be replaced with new version including all 25 sectors made with higher statistics to better define boundaries and with boundaries adjusted to enclose selected fraction (e.g., 90%) of the particles in the sector.

Measurement Capabilities:
Species Coverage / Elemental Composition

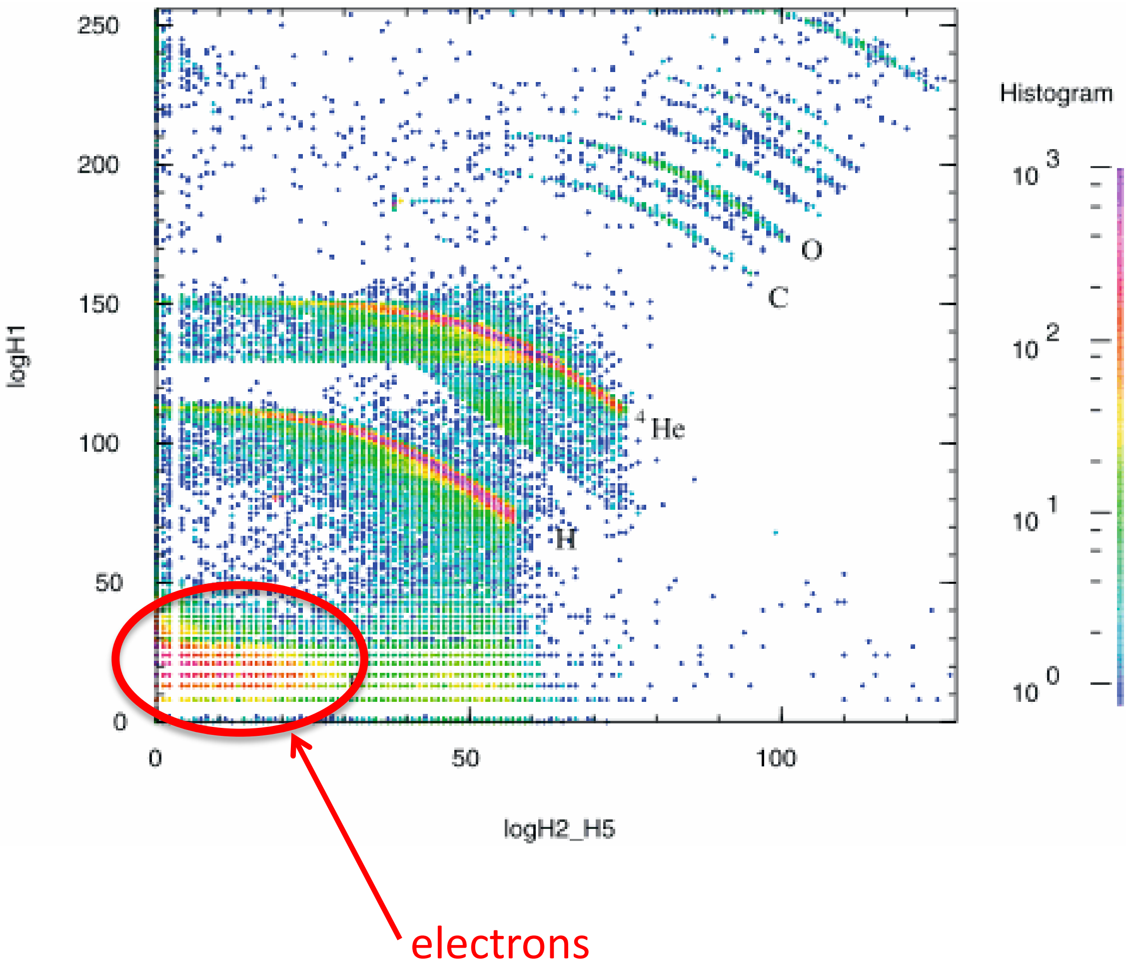
Monte Carlo simulation of ion response.



- Energy loss measurements from the detector in which a particle stops (E′) and the preceding detector (ΔE) organize the data into distinct tracks for the various elements.
- Sector information is used to obtain mean thickness penetrated in the ΔE detector and make an on-board correction to the measured energies to optimize species resolution.
- Energy assigned on board includes energies measured in overlying detectors and calculated energy loss in windows.

Species resolution for L0 vs L1 will be a bit poorer than shown in this example. Could include L0 vs L1 plot as a backup slide.

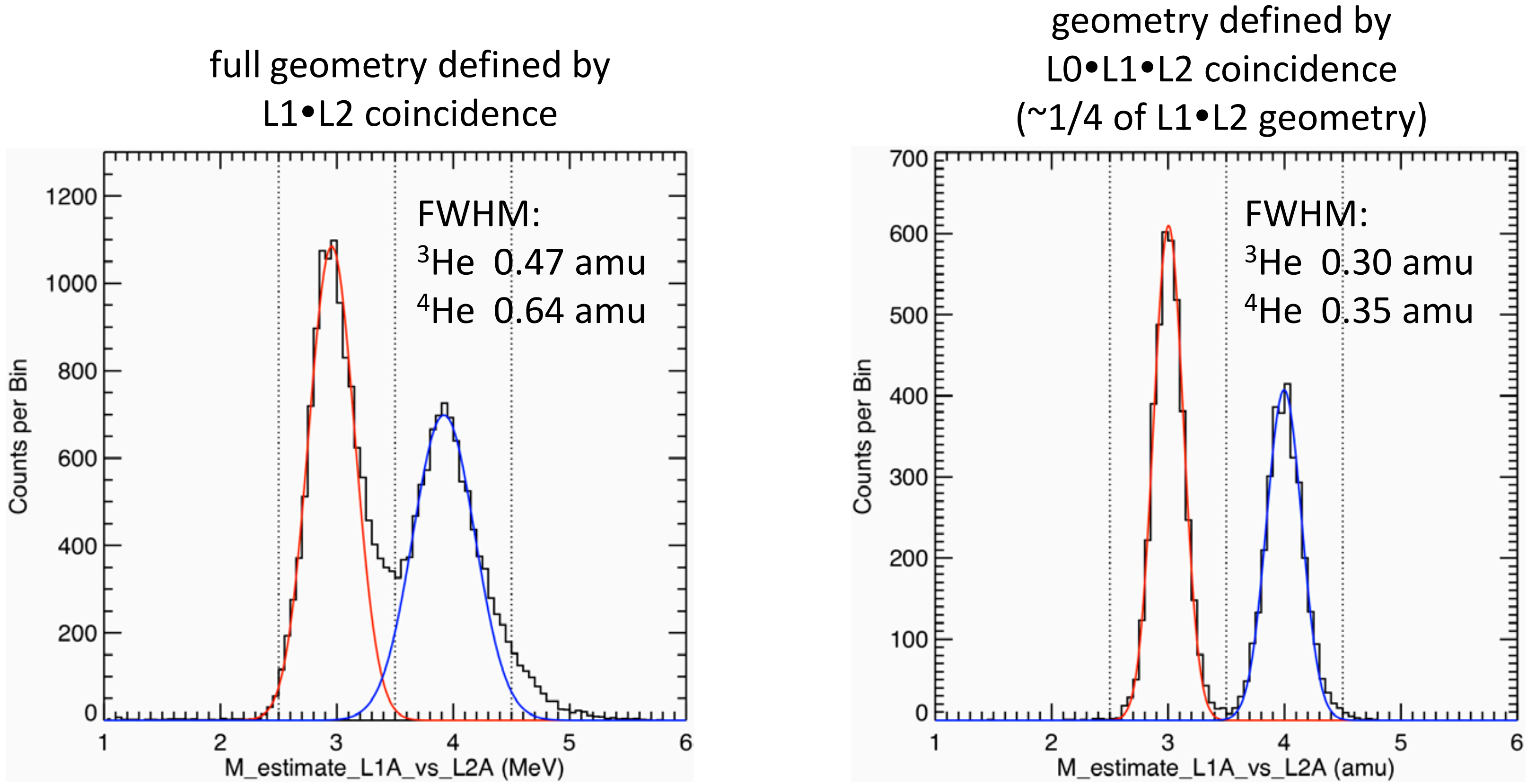
Measurement Capabilities:
Electron Identification



Measurements from the STEREO/HET telescope in the 13 Dec 2013 SEP event (von Rosenvinge et al. 2008)

Ideally we should replace this figure with a Monte Carlo simulation of the EPI-Hi/HET electron response because the front detector in EPI-Hi is thinner than that used for STEREO/HET (500µm vs 1000µm). It is not clear that there will be time to do the necessary simulation before the PDR package needs to be finalized in mid-October.

Measurement Capabilities:
Helium Isotope Identification



- Monte Carlo simulation of He isotope resolution: example based on L1A vs L2A
- resolution dominated by effect of incidence angle uncertainty on ΔE thickness penetrated
- restricting analysis to narrow-angle sectors gives higher resolution dataset
- other effects (e.g., channeling) limit measurable ^{3}He/^{4}He ratio at energies of a few MeV/nuc to >~5%

Measurement Capabilities:
Cadences

Insert a table containing high-level summary of cadences for the various species/energy/angle bins for both telescopes.

It may be possible to combine this slide with that showing energy range and resolution.

Measurement Capabilities:
Dynamic Range in Particle Intensities

- Close to perihelion the expected peak intensities in the largest SEP events are extreme: ~6×10^7 protons/cm^2-sr-s above 5 MeV estimated as worst-case (95% confidence) peak intensity in EDTRD
- Calculated count rates for this worse case spectrum:
  - LET1
  - LET2
  - HET
- Front-end electronics can process slightly more than 10^5 events/s, as demonstrated on STREREO
- Instrument design allows reduction of geometrical factor in a series of steps to allow measurements over a large dynamic range in intensities
- “Dynamic threshold” approach successfully used in STEREO/LET and HET instruments

Need to add additional text (possibly with a figure) discussing successive steps used to handle high rates: dynamic threshold approach (example from STEREO?), small pixels, reliance on HET when LET becomes saturated. Also need to discuss expected capabilities in small events.