Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun Energetic Particles

Preliminary Design Review

05 – 06 NOV 2013

EPI-Lo Sensor

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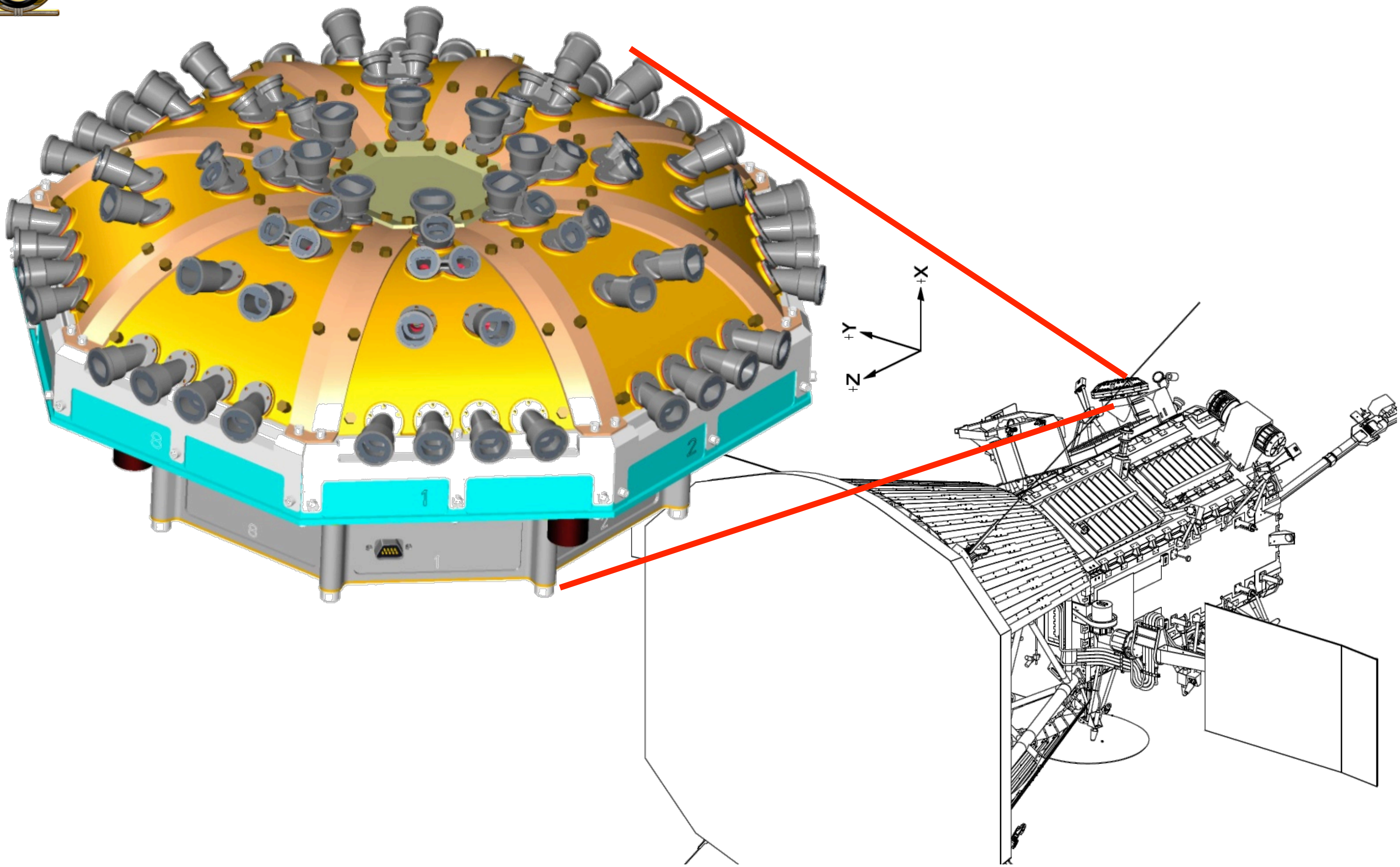
EPI-Lo Sensor Design

- EPI-Lo Instrument Requirements
- EPI-Lo Instrument on SPP, Sky Coverage
- Principles of Operation
- Block Diagram
- Electrostatic Optics, Position Sensing
- Microchannel Plate (MCP)
- Collimators and Start Foils
- Solid State Detectors & Stop Foils
- Light and Dust Mitigation
- Follow-up from peer reviews
- Summary

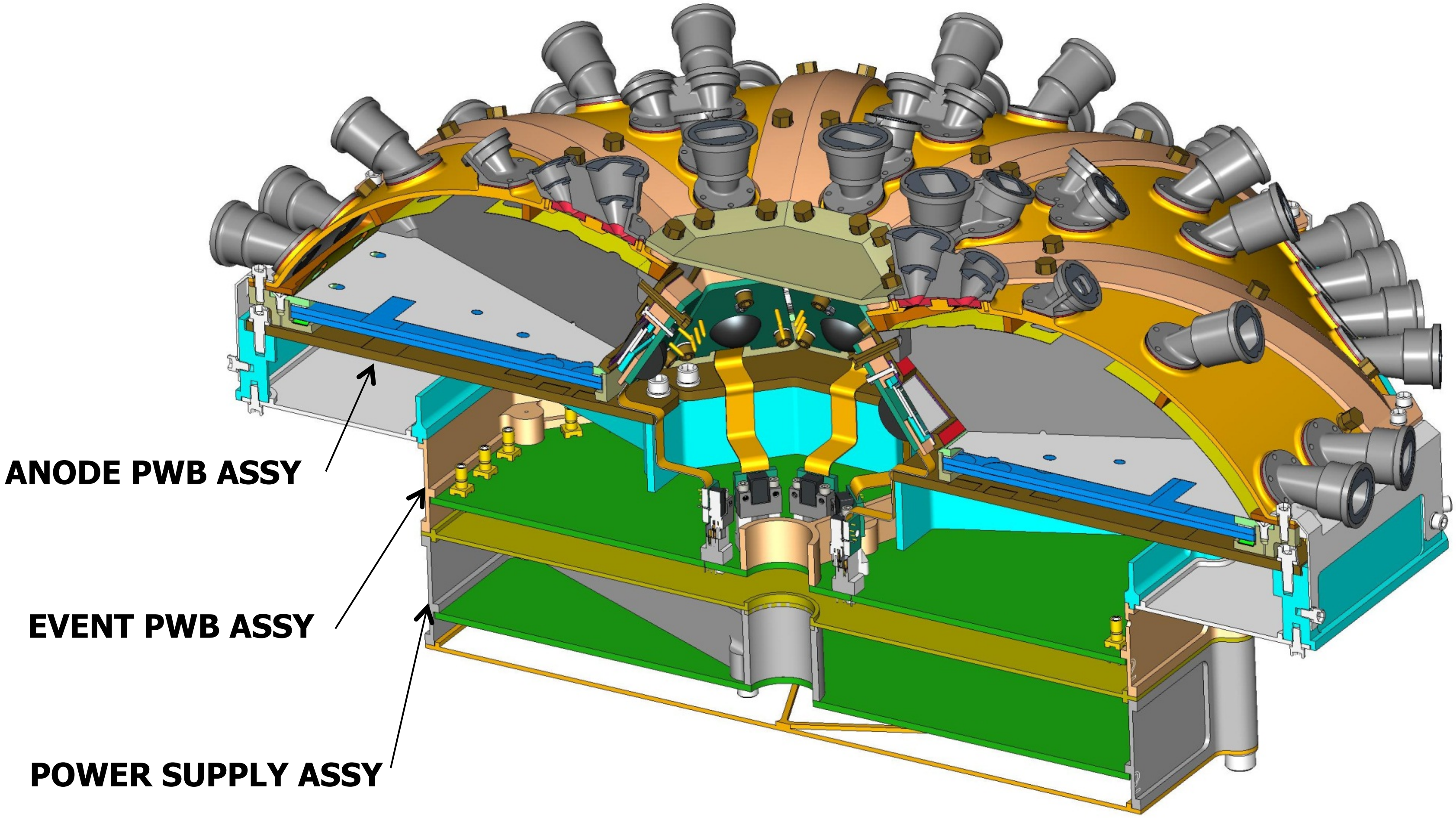
The EPI-Lo Instrument Requirements

Parameter	Required	Goal (Capability)	Comment/Heritage
Electron Energies	50 – 500 keV	25 - 1000 keV	Electron capability from JEDI, RBSPICE
Ion Energies	50 keV/nucleon – 15,000 keV Total E	50 keV/nucleon – 15,000 keV Total E	Capability based on that of RBSPICE. Maximum energy ~250keV/nuc for Fe
Energy Resolution	45% for required energy range	40% for required energy range	Telemetry limited
Time sampling	5 sec	1 sec	Telemetry and/or statistics limited
Angle resolution	<30° x <30°	Ions, ~15° x 12° to <30° x <30° e-, 45°	Varies with elevation
Pitch Angle (PA) Coverage	0°-90° or 90°-180°, some samples in both hemispheres	0°-90° or 90°-180°, some samples in both hemispheres	
Time for Full PA	1 – 5 sec	1 – 5 sec	Telemetry limited
Ion Composition	H, ^{3}He, ^{4}H4, C, O, Ne, Mg, Si, Fe	H, ^{3}He, ^{4}He, C, O, Ne, Mg, Si, Fe	^{3}He / ^{4}He ~50 to 1000 keV/nuc
Electron Sensitivity	j = 10-10^6 / cm^2-s-sr	Sensor-G:0.144 (cm^2.sr) Pixel-G: ~0.02 (cm^2.sr) Up to 6E6 1/s counting	j=Intensity (1 / cm^2-s-sr) G=Geometric factor (cm^2-sr) 8 pixels/sensor
Ion Sensitivity	j = 10-10^6 / cm^2-s-sr	Sensor-G:0.16 (cm^2.sr) Pixel-G: ~0.002 (cm^2.sr) Up to 3.5x10^6/s rate (TOF x E)	80 pixels/sensor

EPI-Lo Instrument Placement

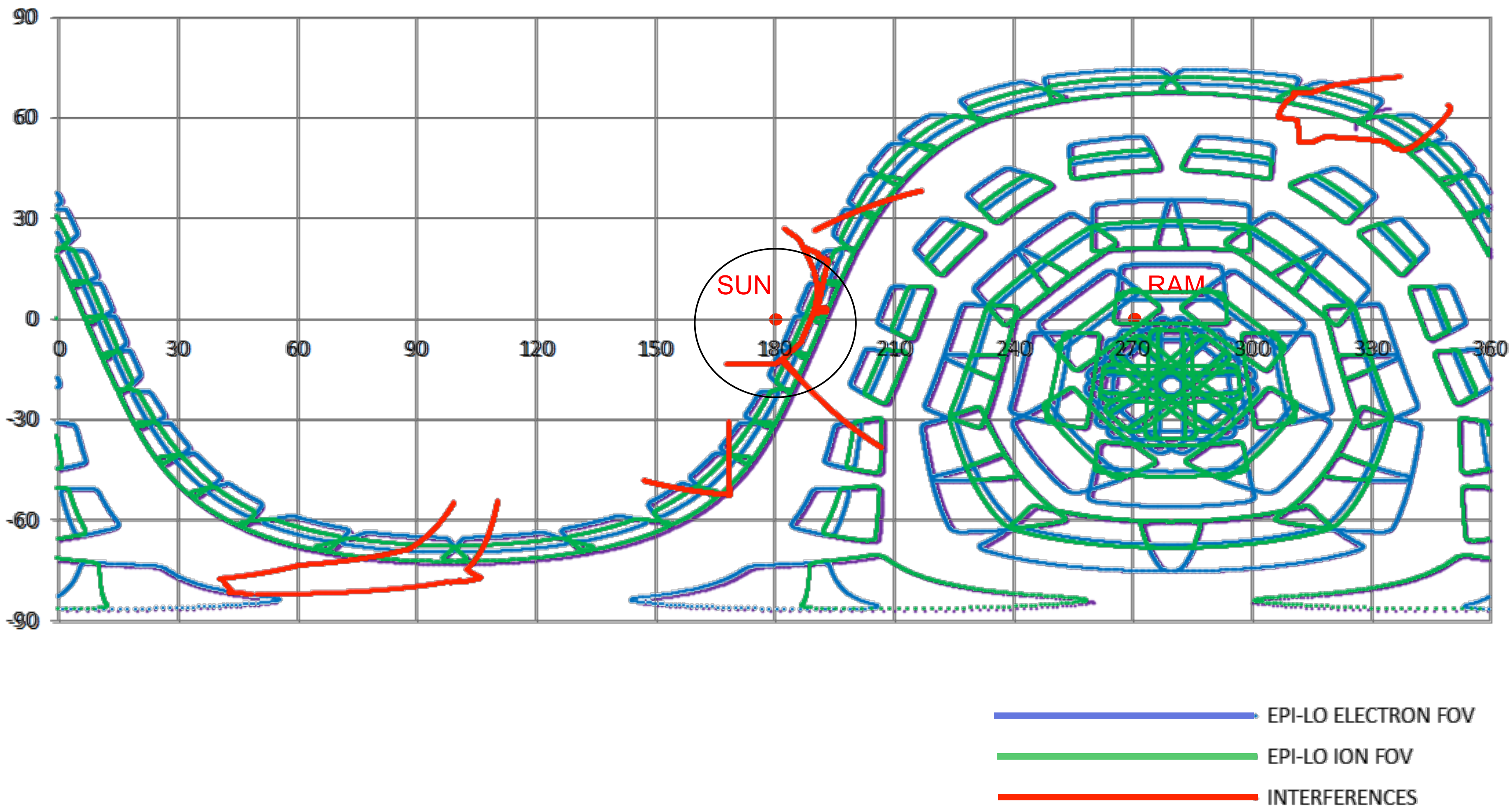


EPI-Lo Instrument Cross Section

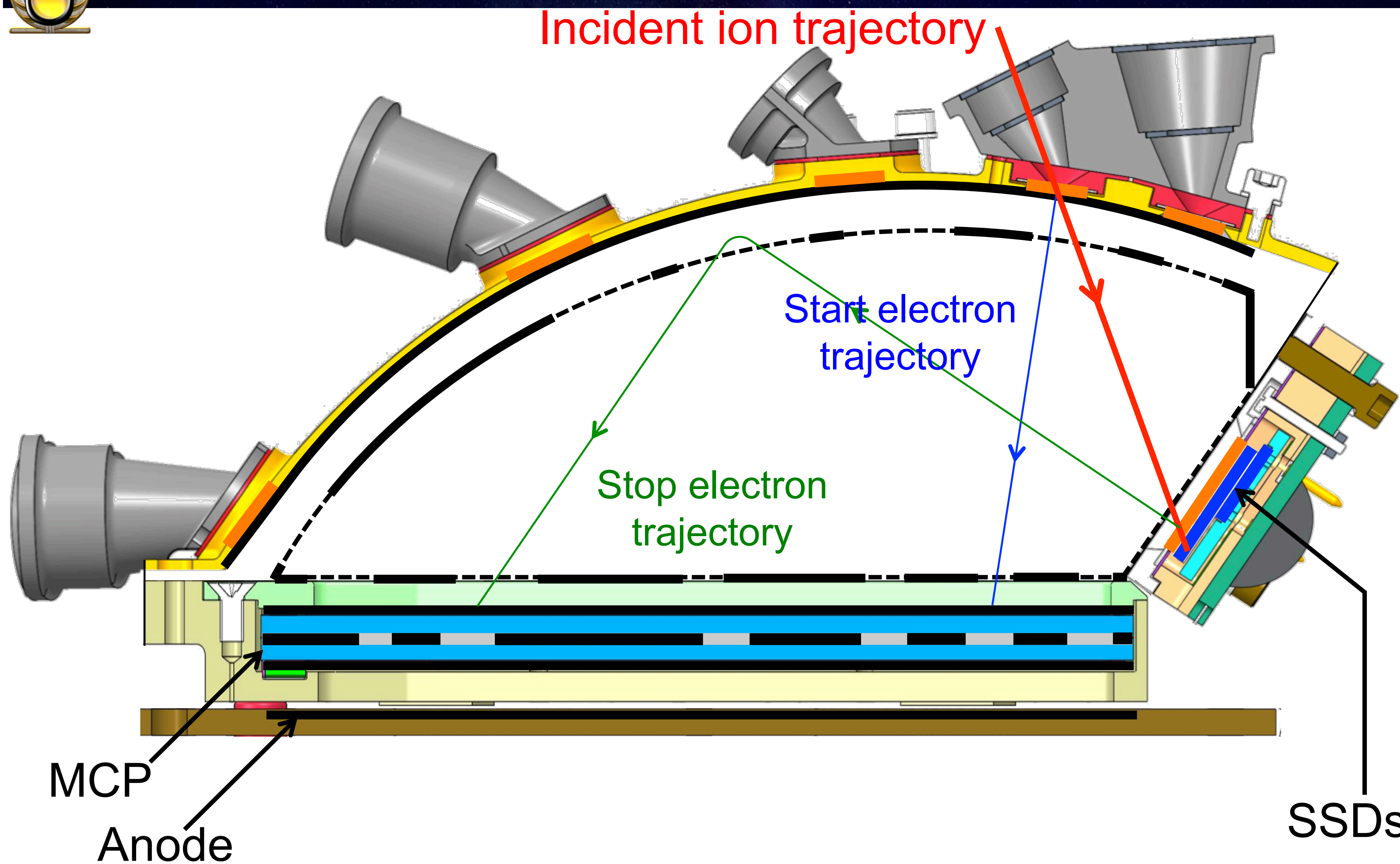


EPI-LO CROSS-SECTION VIEW ISOMETRIC

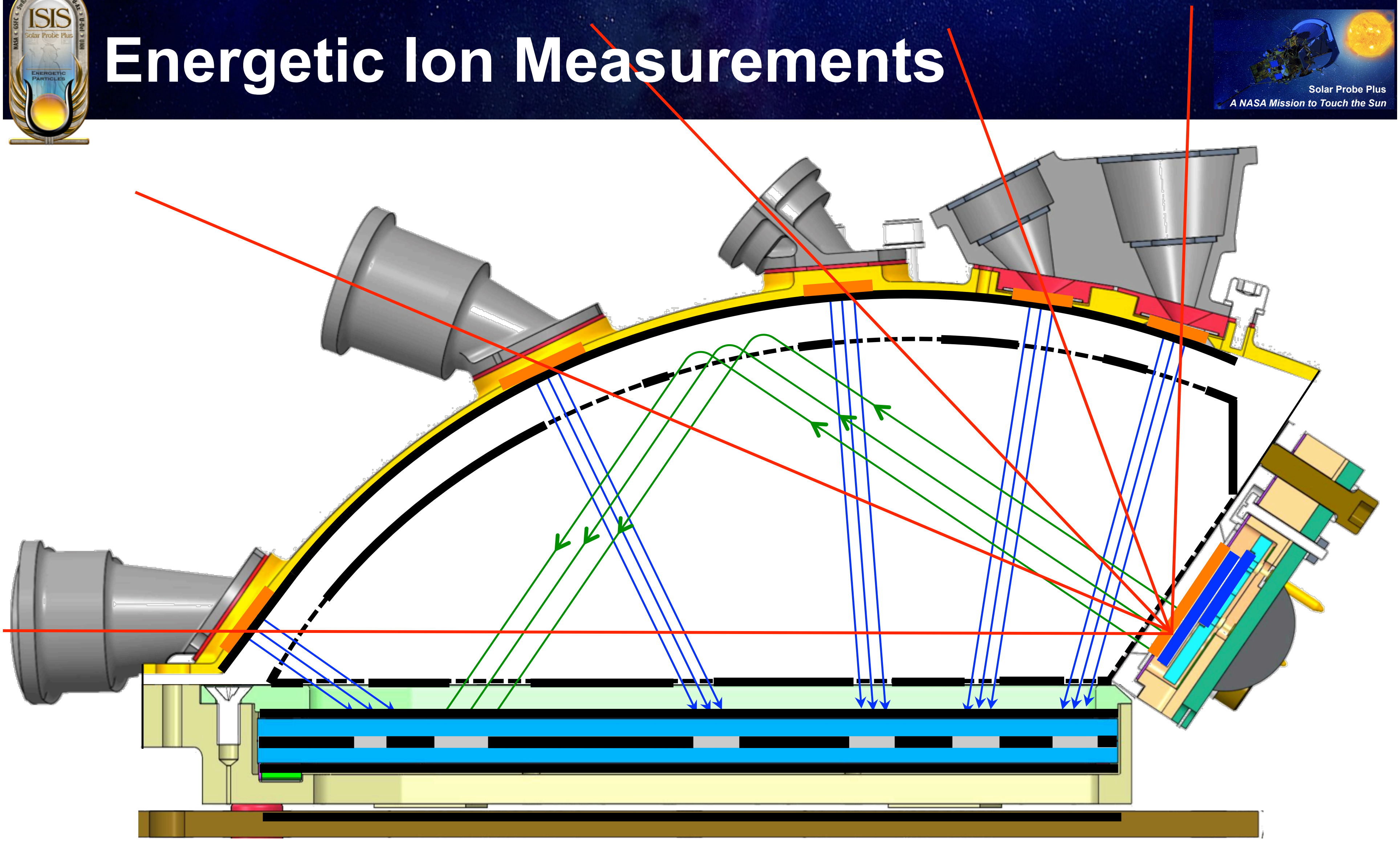
EPI-Lo Field(s) of View



Ions (Energy, TOF, and Position)

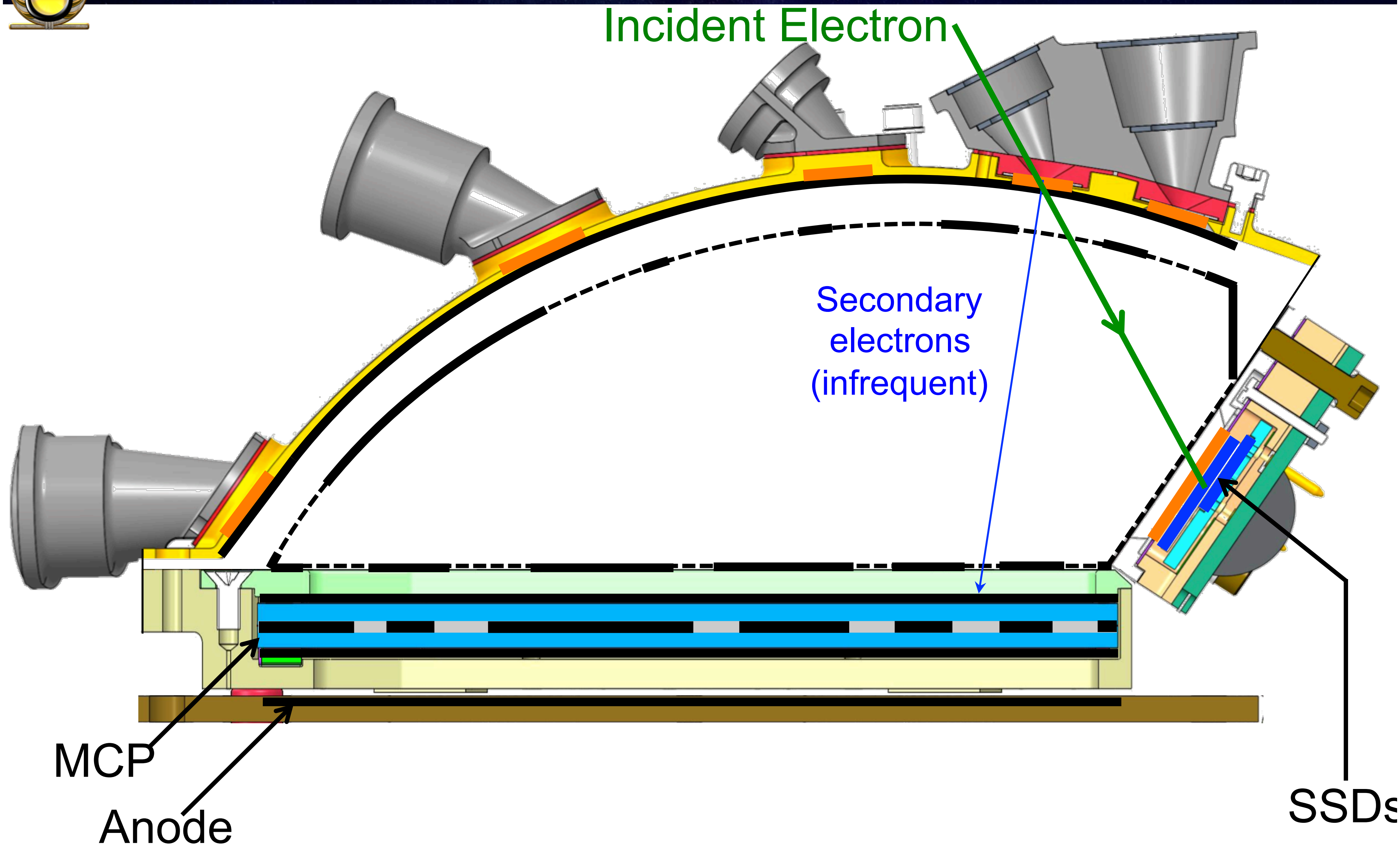


Energetic Ion Measurements

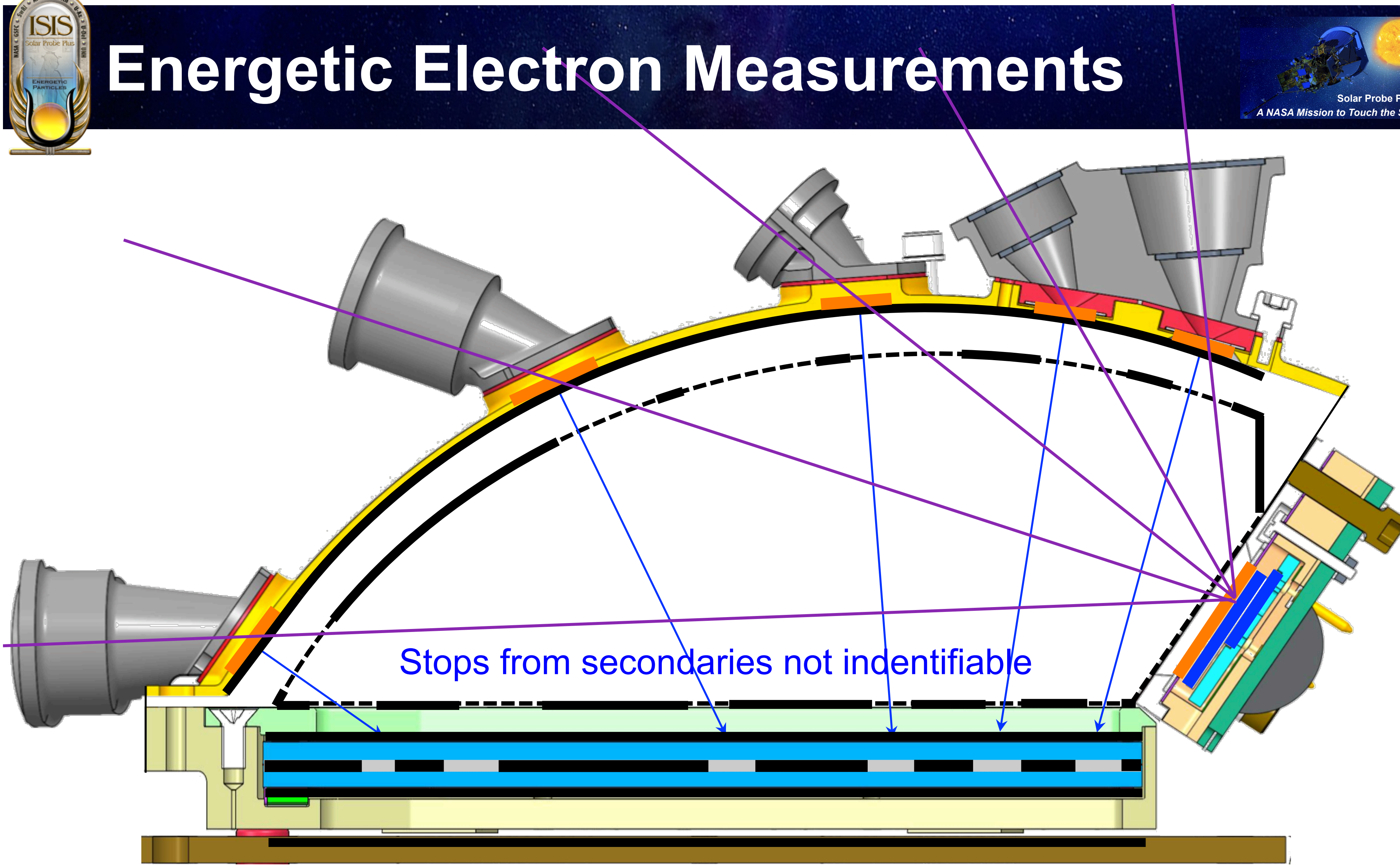


Ion Measurement Logic can toggle TOF, but no TOF ➔ no species identification

Electrons: Energy (& Position)

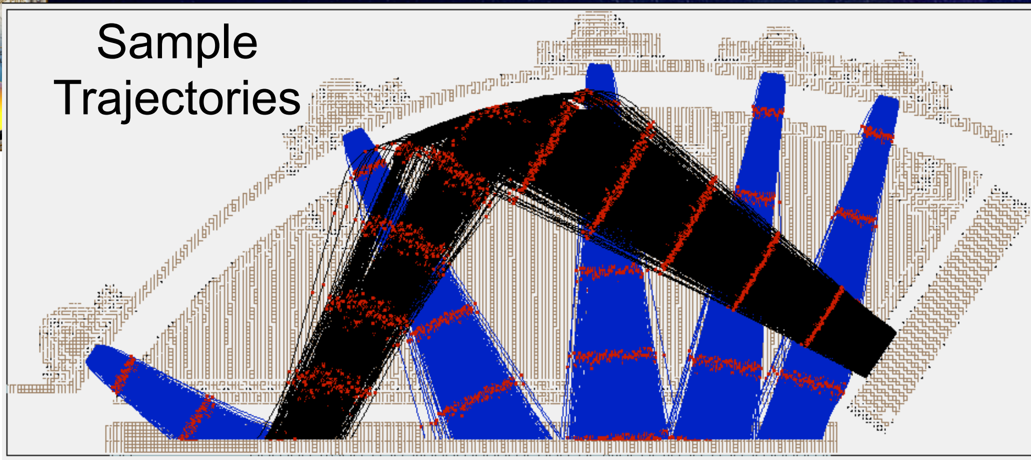


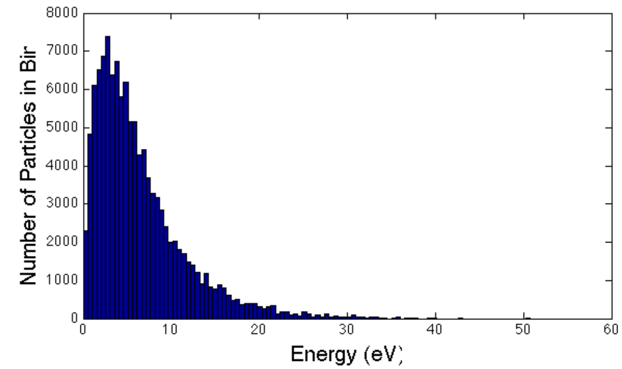
Energetic Electron Measurements

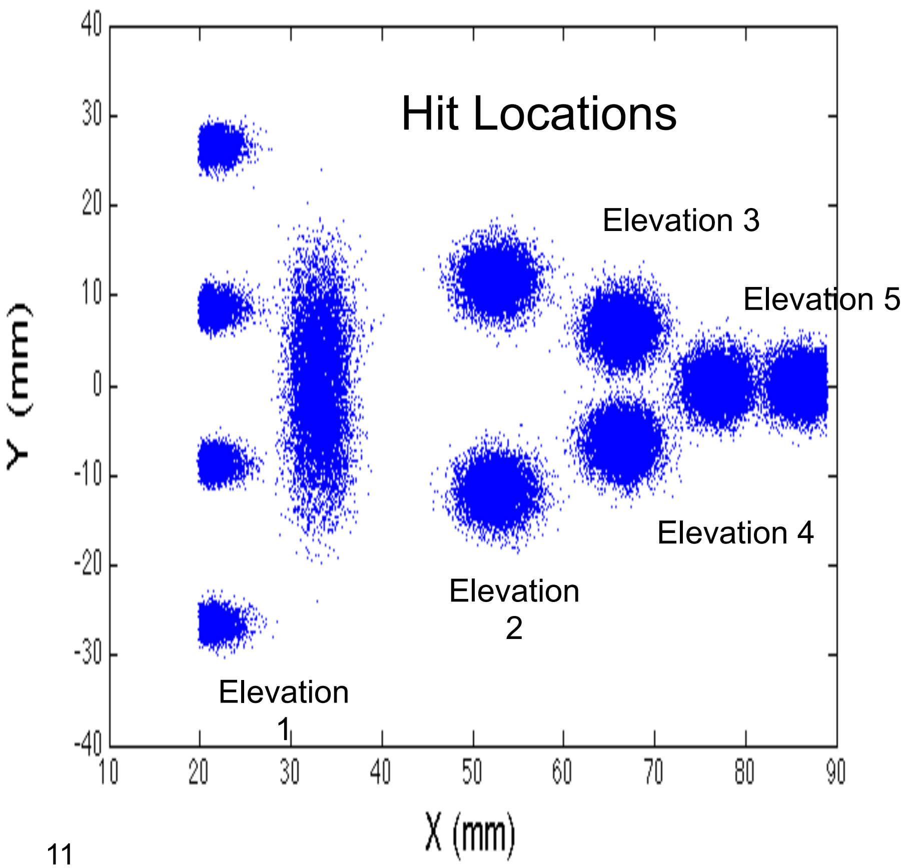


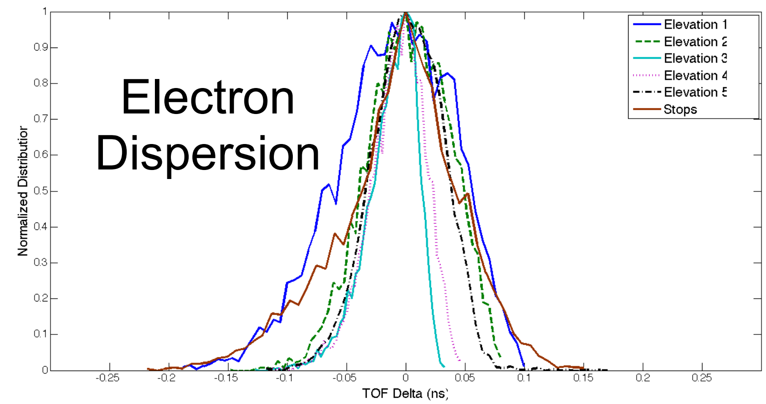
Secondary Electrons from Start Foils possible, but Low Probability;
Start Electron only identifies entrance aperture

SIMION, Allegrini Energy Distribution









Name	Mean TOF (ns)	FWHM (ns)
Elevation 1	0.93	0.12
Elevation 2	2.12	0.08
Elevation 3	2.35	0.04
Elevation 4	2.32	0.05
Elevation 5	2.26	0.08
Stops	5.23	0.09

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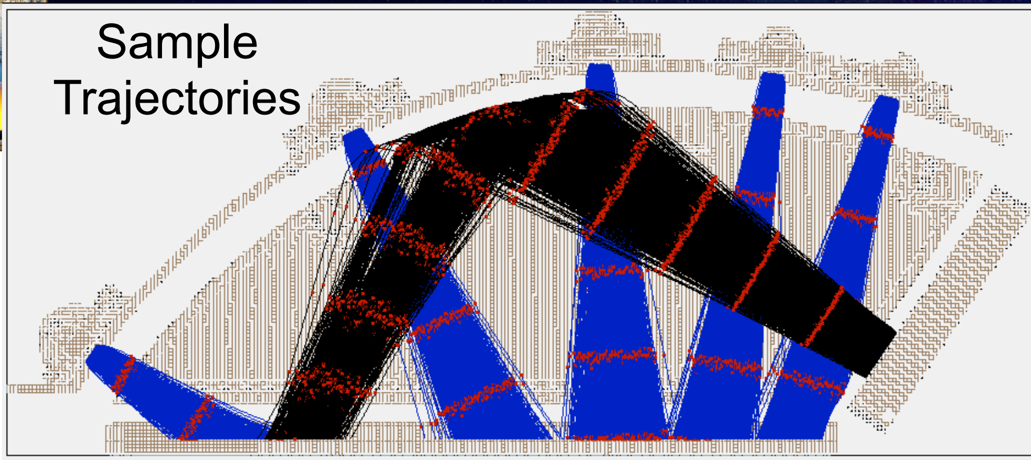

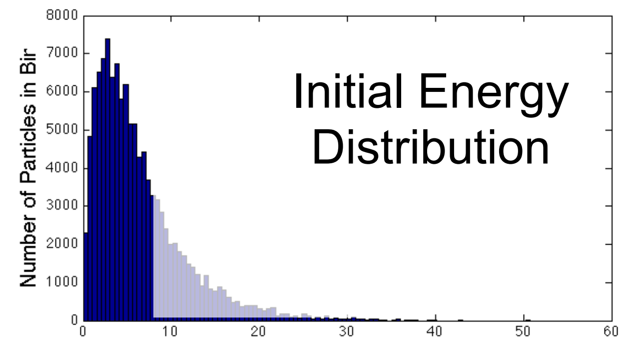

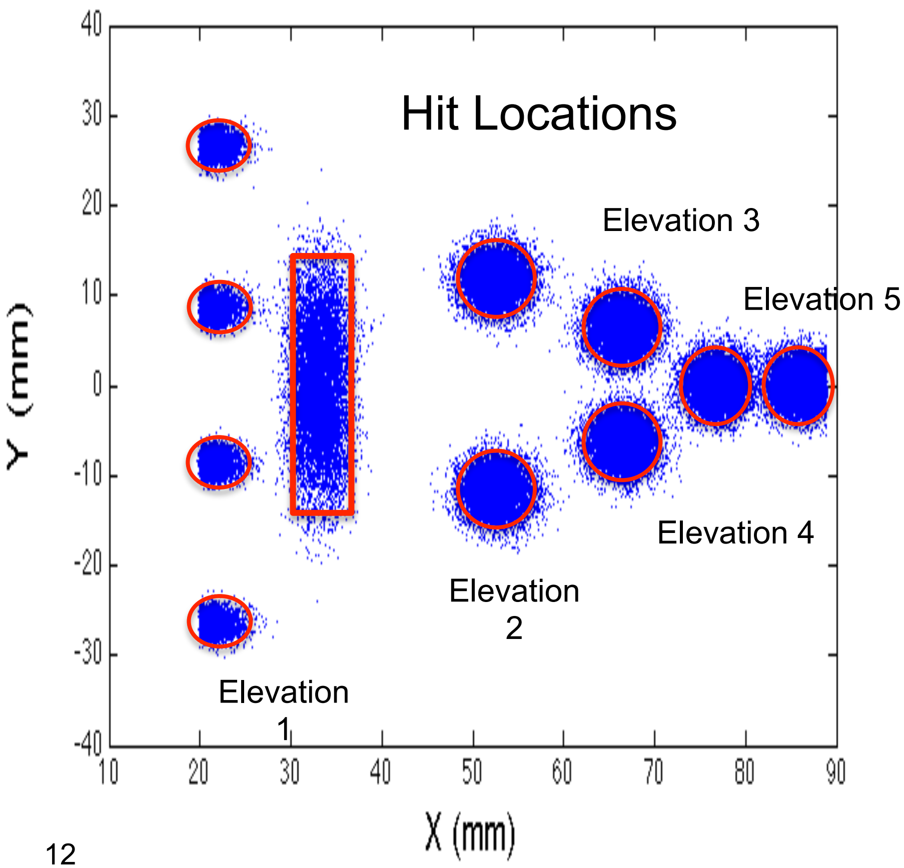

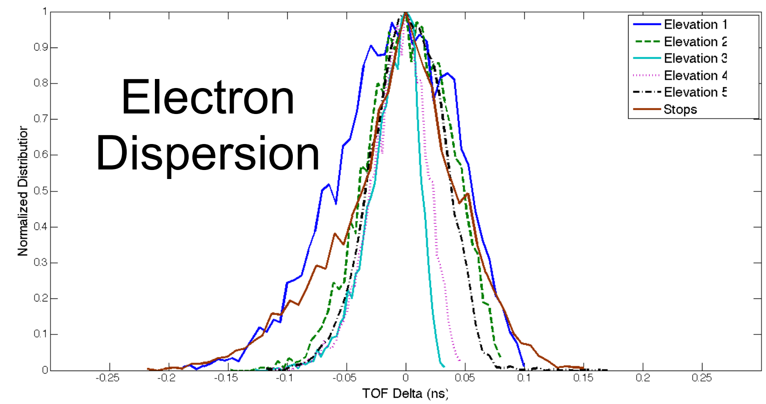

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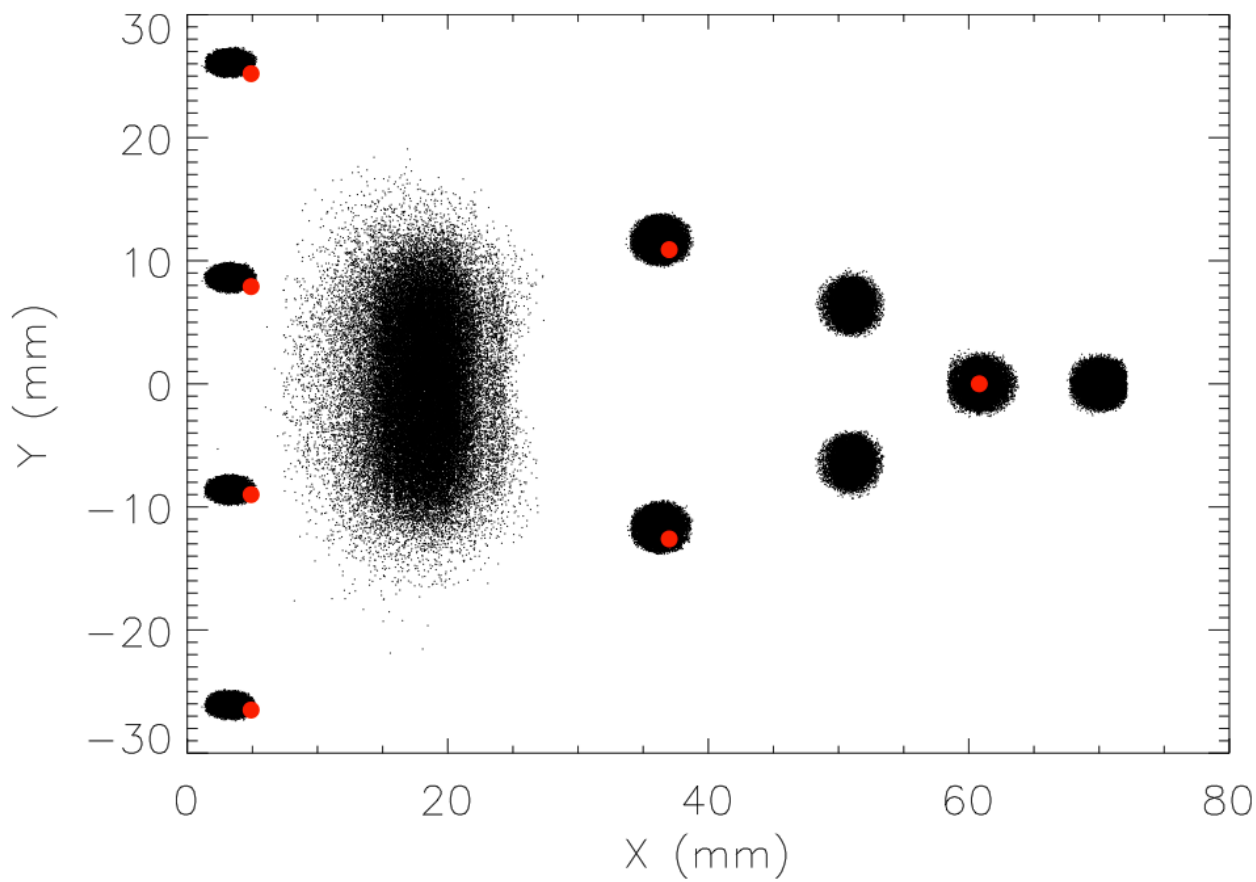
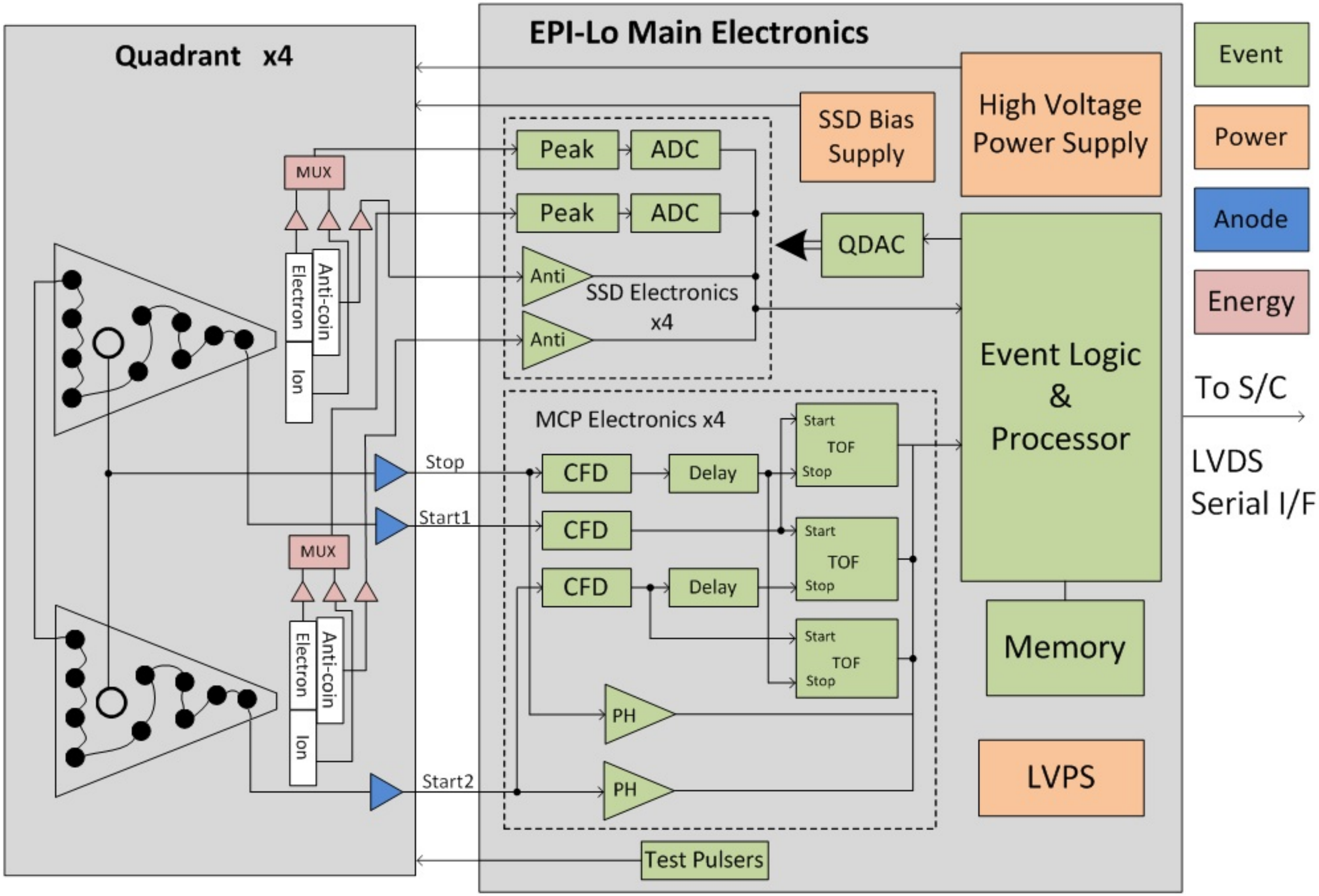
Microchannel Plate (MCP)

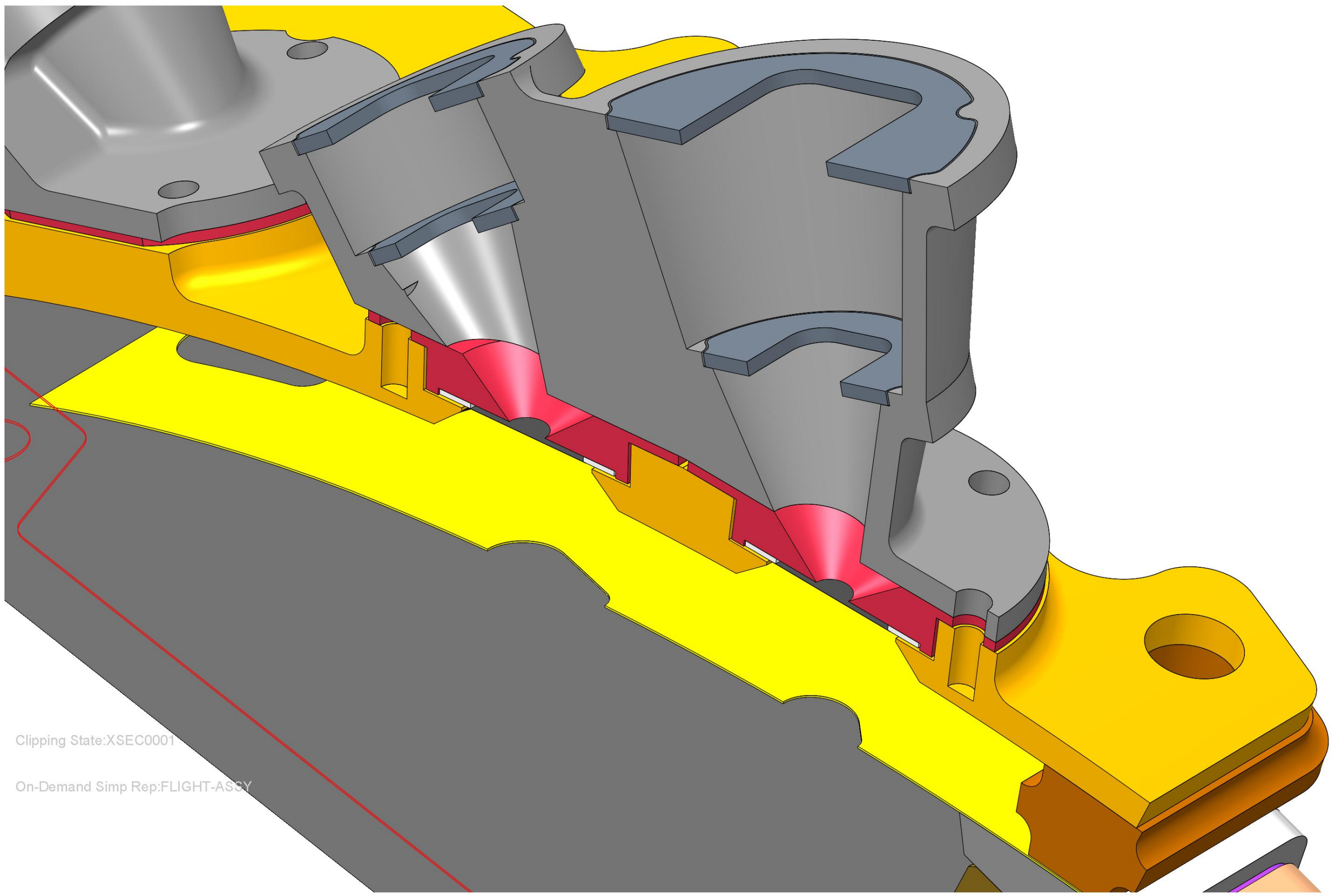
- Simulation (black) versus measured centroids (red).
- The misalignment in Y-direction was due to a registration offset in the setup
- The offset in the X direction for the left-most data was caused by an obstruction at the edge of the MCP mount that has since been eliminated.



EPI-Lo Block Diagram

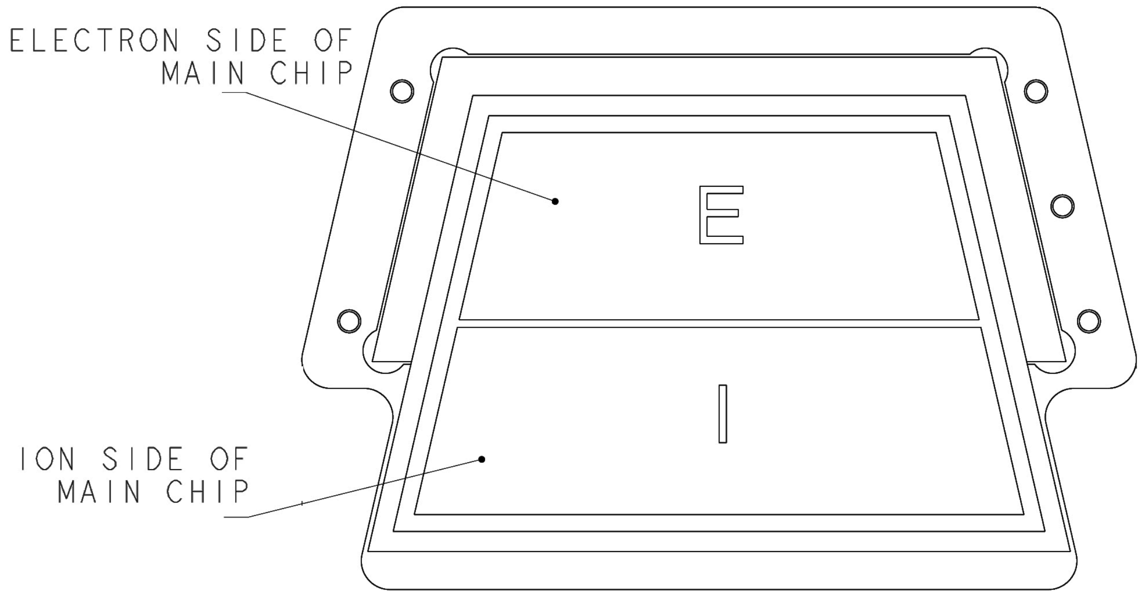


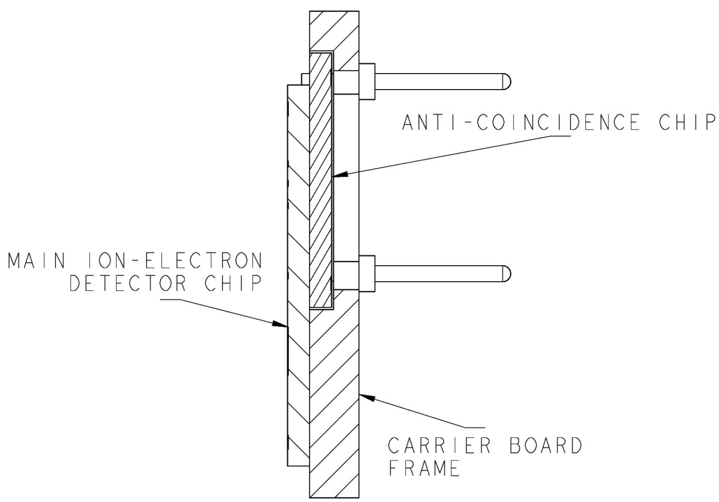
Collimators and Start Foils

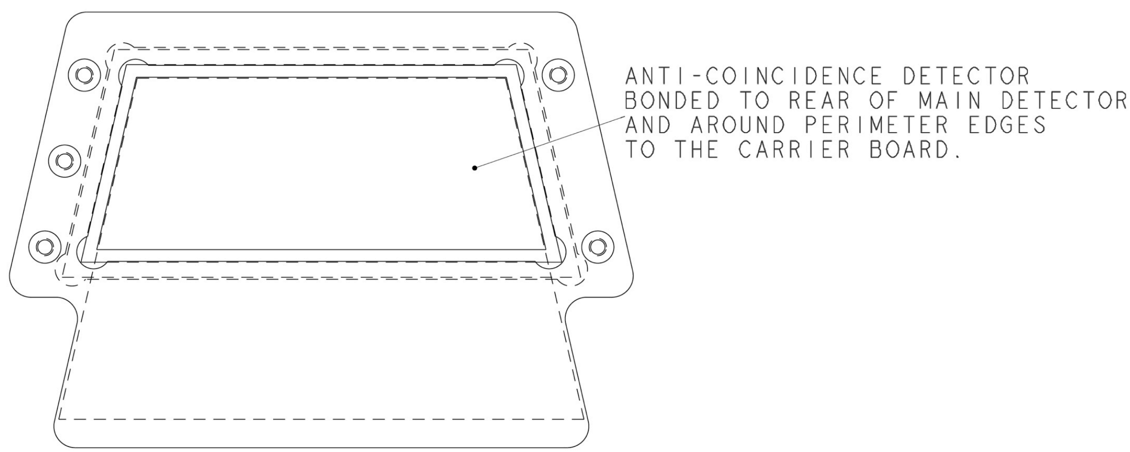


Anti-coincidence System

- **Electron SSD is backed by an anti-coincidence SSD**
- **Improves S/N for electrons by a factor ~1.3/0.3 ~4**

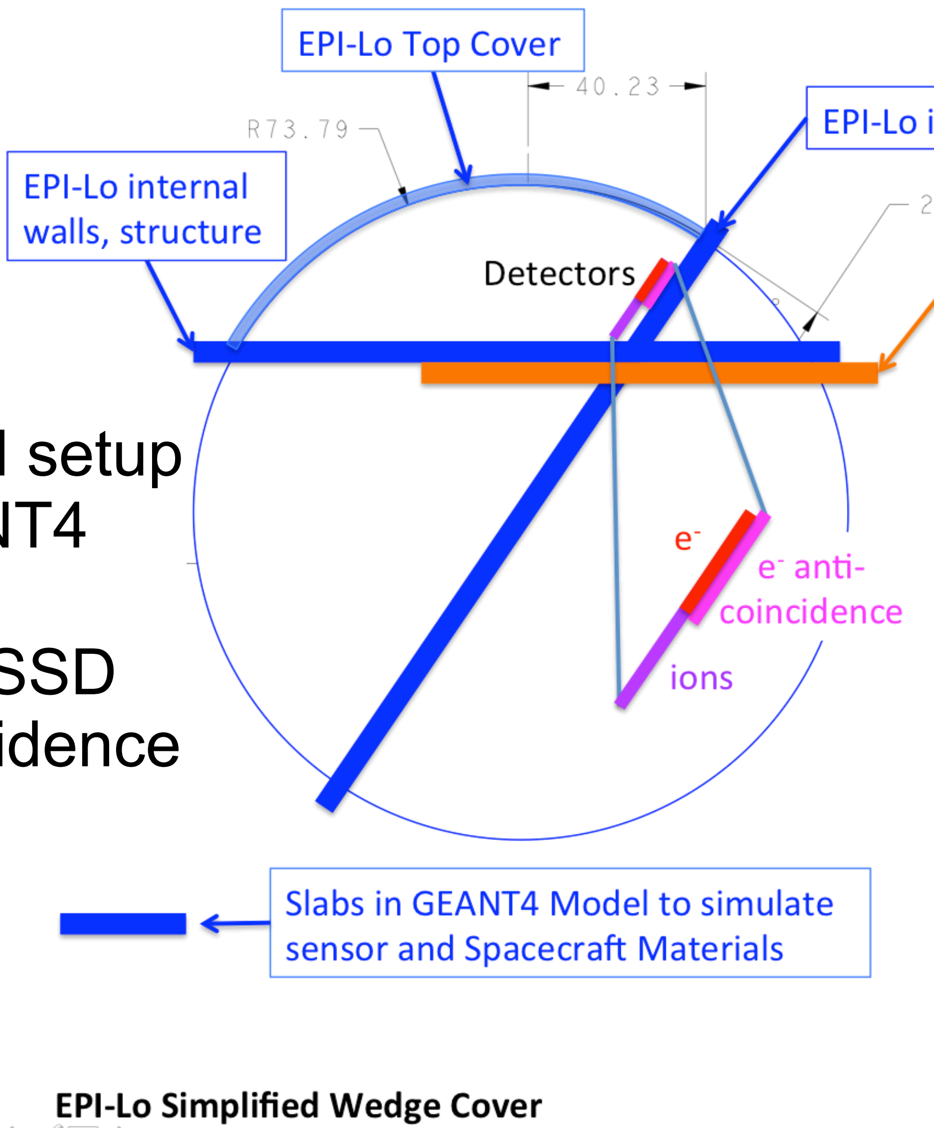


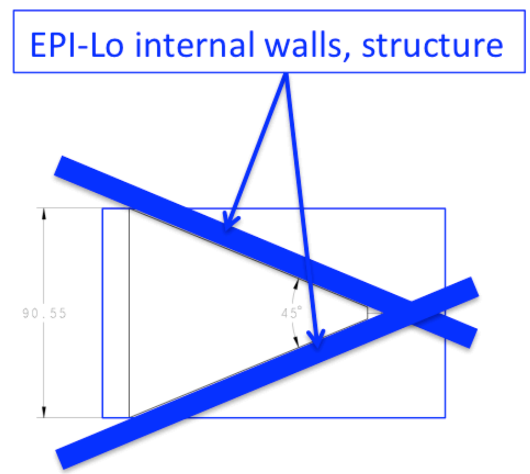




Anti-coincidence System: GEANT Setup

- Improved setup for GEANT4 model of electron SSD anticoincidence





cylinder envelope
h = 91 mm, R= 74 mm

Anti-coincidence System: GEANT Results

Assumed electron flux of $j(E) \sim E^{-2.65}$ from ~10 keV to ~5 MeV

Penetrator rejection efficiency range from 83% to 95% from 1 MeV up to 10 MeV incident electron energy

Following peer review result of S/N of ~0.3 for foreground electrons with anti-coincidence, higher fidelity sensor model yields S/N ~1.3

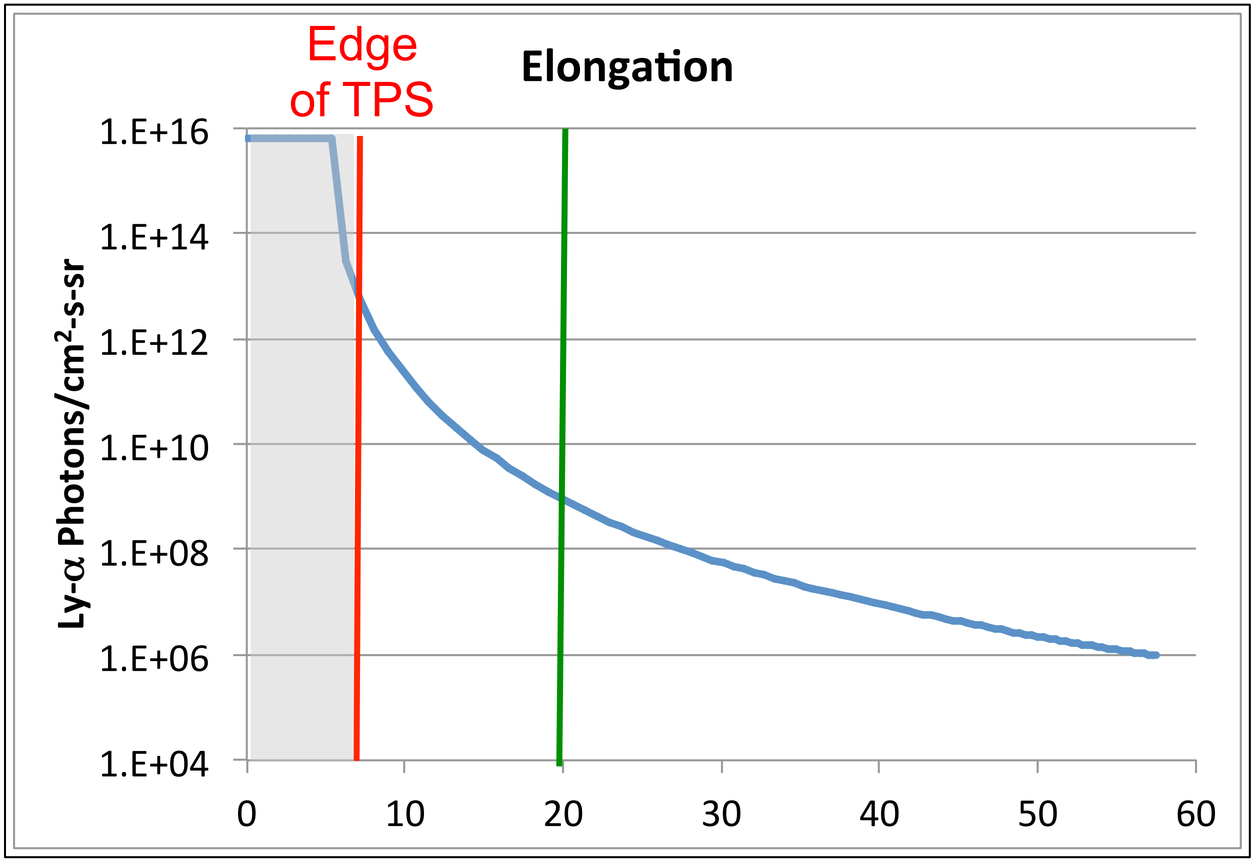
New GEANT model accounts for more realistic geometry and extra shielding by structure

Only ~1% of electrons below 2 MeV penetrate to detectors in this model

Light & Dust Mitigation

- Dust may produce pinholes in the Start and collimator foils
- Foils are designed to reduce UV by ~3 orders of magnitude.
- Pinholes may account for as much as ~0.4% of a foil area.

- For the 4 foils closest to the TPS edge, the suppression factor must be ~4 orders of magnitude. For these, pinholes are important to UV suppression.



- Intensity of Ly-α EUV vs elongation. Most EPI-Lo entrances at >20 degrees elongation
- 4 apertures near the TPS 8-20 degrees, max UV ~10^{12}, average ~10^{10}

Light and Dust Mitigation

- Dust may produce pairs of pinholes in the Start and collimator foils
  - Foils are designed to stop solar-wind-energy electrons
  - Pinhole pairs allow will still allow access to solar-wind electrons

- Solar wind electrons have an energy of ~100eV or less
- Electrons that "leak in" through apertures are indistinguishable from Start secondary electrons

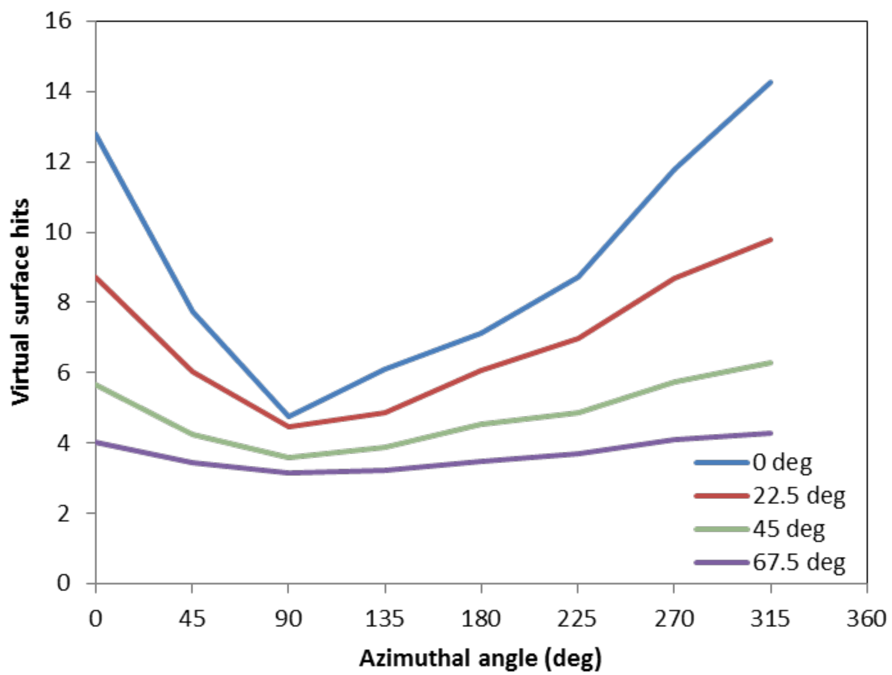
- Solar wind electron flux ~2×10^{12}/cm^2-s-sr
- Estimate foil pinhole as size of a support grid element is ~4.9×10^{-5} cm^2
- Geometric factor of a pair of pinholes separated by ~0.5cm is ~1.3×10^{-8}
  - The flux through a pinhole pair can be estimated as ~2.6×10^4/s
  - If every aperture had 1 grid-element pinhole, the total for a quadrant would be ~5.0×10^5/s
  - This rate would be well tolerated by the electronics processing

- Such a pinhole pair would result in UV induced counting rates ~10/s

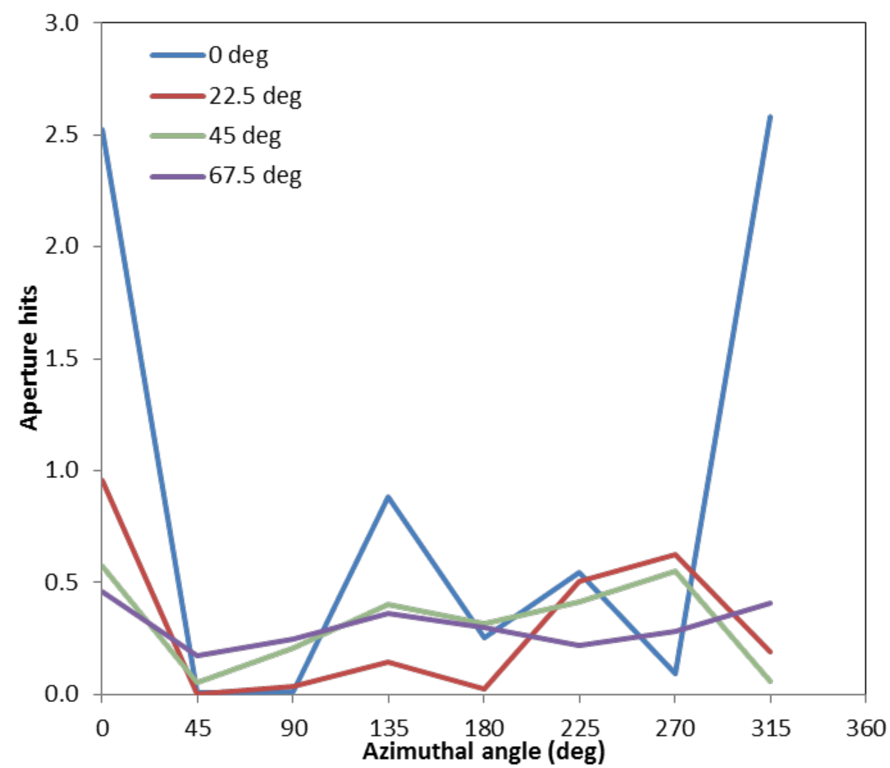
Dust: Simulating the Environment

- Expect ~10 damage-inducing hits on each unprotected foil during entire mission
- Reduced to ~1 hit per mission with collimator
- Can lower further with pairs of pinholes

Bare Start Foil



Start Foil Behind Collimator



Follow Up from Peer Review

Area of Concern/Action	Resolution/Comment	Status
1. Photoelectron flux false starts.	Second start foil reduces flux of e- accelerated.	Closed
2. MCP count rate density > 1 MHz/cm2	Simulations show density below this.	Closed
3. Rates, S/N, efficiency compilation.	Draft closure memorandum complete 10/25/2013	Closed
4. Electron measurement poor S/N.	Higher resolution GEANT runs completed	Closed
5. Incorrect plug power co-ax.	Use labeling and/or color-coding.	Closed
6. Alternate internal e- noise sources.	In equipotential 100 V retarding potential rejects e-	Closed
7. Reject false signals w/ redundant info.	Consistency checks will be done b/w 3 TOF chains.	Closed
8. In-flight pulser for rate correction.	Mewaldt et al, Space Sci Rev (2008) 136:285-362.	Closed
9. HV discharge secondary effects.	Addressed by design and testing	Closed
10. Fasteners w/o locking features.	Locking inserts, Bellville washers, etc. added.	Closed
11. Wishbone webbing field deformation.	Webs removed, extra 0-1kV surface length added.	Closed
12. Bonded external baffles allowed?	Preliminary answer is yes; final requires thermal specs	Closed
13. EPI-Lo/Hi electron energy gap.	Additional GEANT simulations complete	Closed
14. Thicker foil effect on lookup tables.	Not a problem on board, just science interpretation.	Closed
15. Dual foils near sun handle pinholes.	Second foil is under consideration.	Closed
16. Neutrals/photoelectrons/plasma bkg.	Solar wind electron fluxes cut-down by dual foil.	Closed
17. Auto use of extra data allocation.	Too complicated to implement.	Closed
18. Spare MCP assembly plans.	Spares plan held at ISIS level.	Closed
19. Vent back cover of SSD assembly.	Vent is added.	Closed
20. Mounting structure for tags/handling.	Plan is in place.	Closed
21. How are foils marked/serialized?	Labels laser etched prior to assembly.	Closed
22. Sensor purging plan.	Purge IN in center and vent OUT in each octant.	Closed

Summary

- EPI-Lo Sensor Development is on schedule and on budget
- Peer review held and action items have been responded to or are in progress
  - 22 items
  - All Closed
  - Sensor design and approach are matured through Technical Readiness Level 6:
    - **System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space):** Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
- Ready to proceed to Phase C