# 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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DRAFT 2013-10-14 5:53 PM

# Outline EPI-Lo Sensor Design

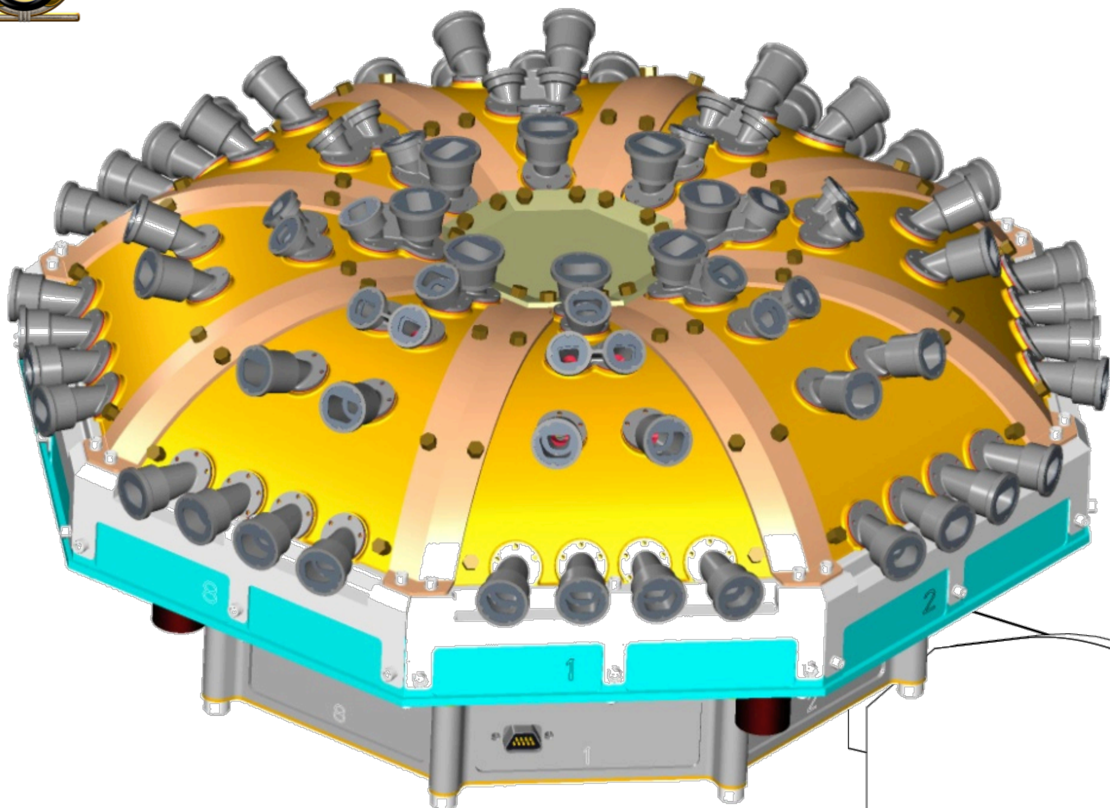
- ISIS Science Requirements Relevant for EPI-Lo
- EPI-Lo Instrument
- Block Diagram(s)
- Principles of Operation Overview
- Sensor Voltages
- Electrostatic Optics
- Collimators and Start Foils
- Solid State Detectors & Stop Foils
  - Anti-coincidence System
  - GEANT
- Microchannel Plate (MCP)
- Mass Resolution
- Light & Dust Mitigation
- Follow-up from peer reviews
- Summary

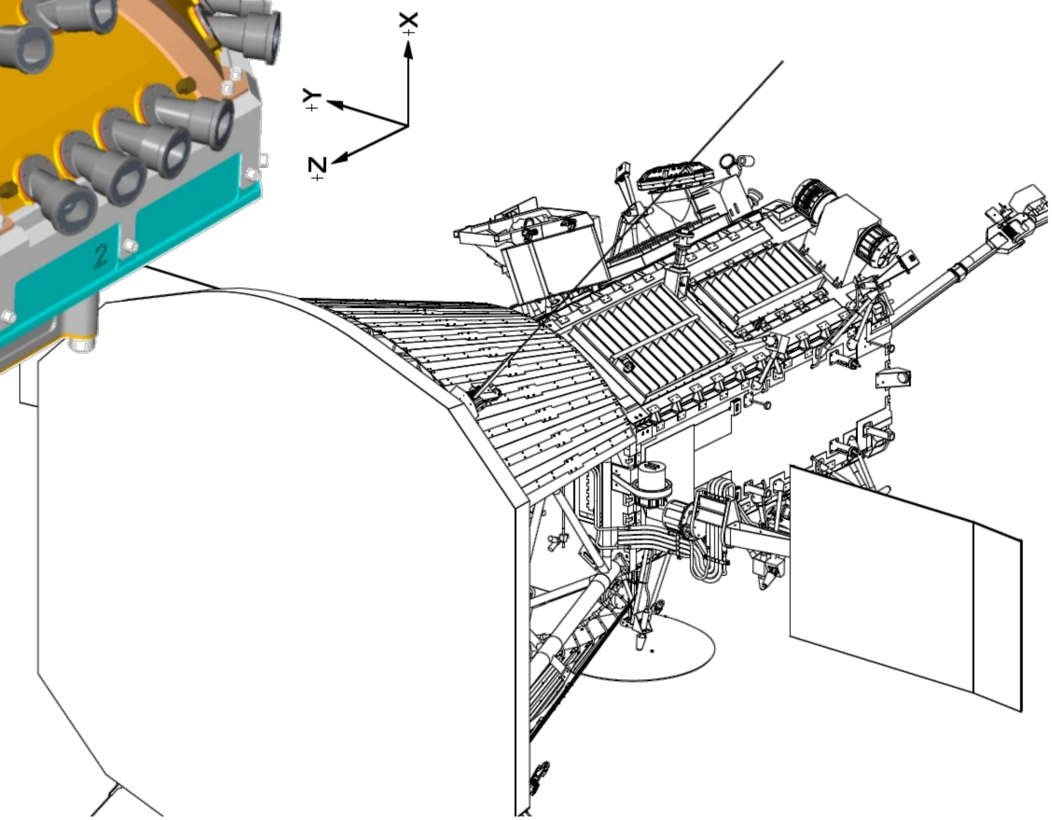
- **THIS IS NOT UP TO DATE...IGNORE THIS PAGE.**

# The EPI-Lo Instrument Requirements

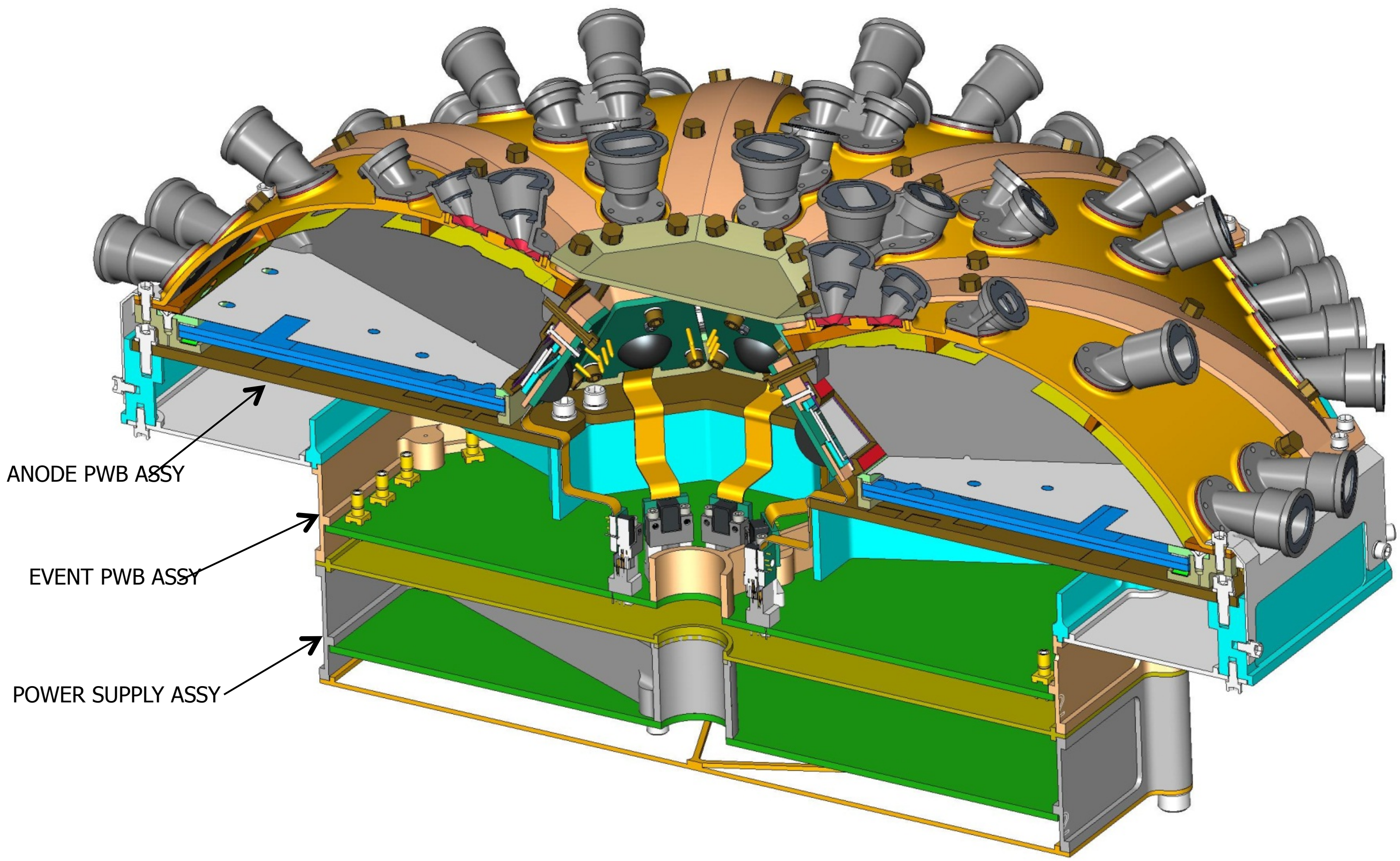
| Parameter | Required | Goal (Capability) | Comment/Heritage |
|---|---|---|---|
| **Electron Energies** | 50 - 500keV | 25 - 1000 keV | Electron capability from JEDI, RBSPICE |
| **Ion Energies** | **50 keV/nucleon – 15000 keV Total E** | **50 keV/nucleon – 15000 keV Total E** | Capability partially based on RBSPICE capabilities. Top 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, He3, He4, C, O, Ne, Mg, Si, Fe | H, He3, He4, C, O, Ne, Mg, Si, Fe | He3/He4 ~50 to 1000 keV/nuc |
| **Electron Sensitivity**: j=Intensity | j = 1E1-1E6/$cm^2$-s-sr | Sensor-G:0.144 ($cm^2$.sr)<br>Pixel-G: ~0.02 ($cm^2$.sr)<br>Up to 6E6 1/s counting | j=Intensity (1/$cm^2$-s-sr)<br>G=Geom. Factor ($cm^2$-sr)<br>8 pixels/sensor |
| **Ion Sensitivity** | j = 1E1-1E6/$cm^2$-s-sr | Sensor-G:0.16 ($cm^2$.sr)<br>Pixel-G: ~0.002 ($cm^2$.sr)<br>Up to 3.5E6/s rate (TOFxE) | 80 pixels/sensor |

# The EPI-Lo Instrument



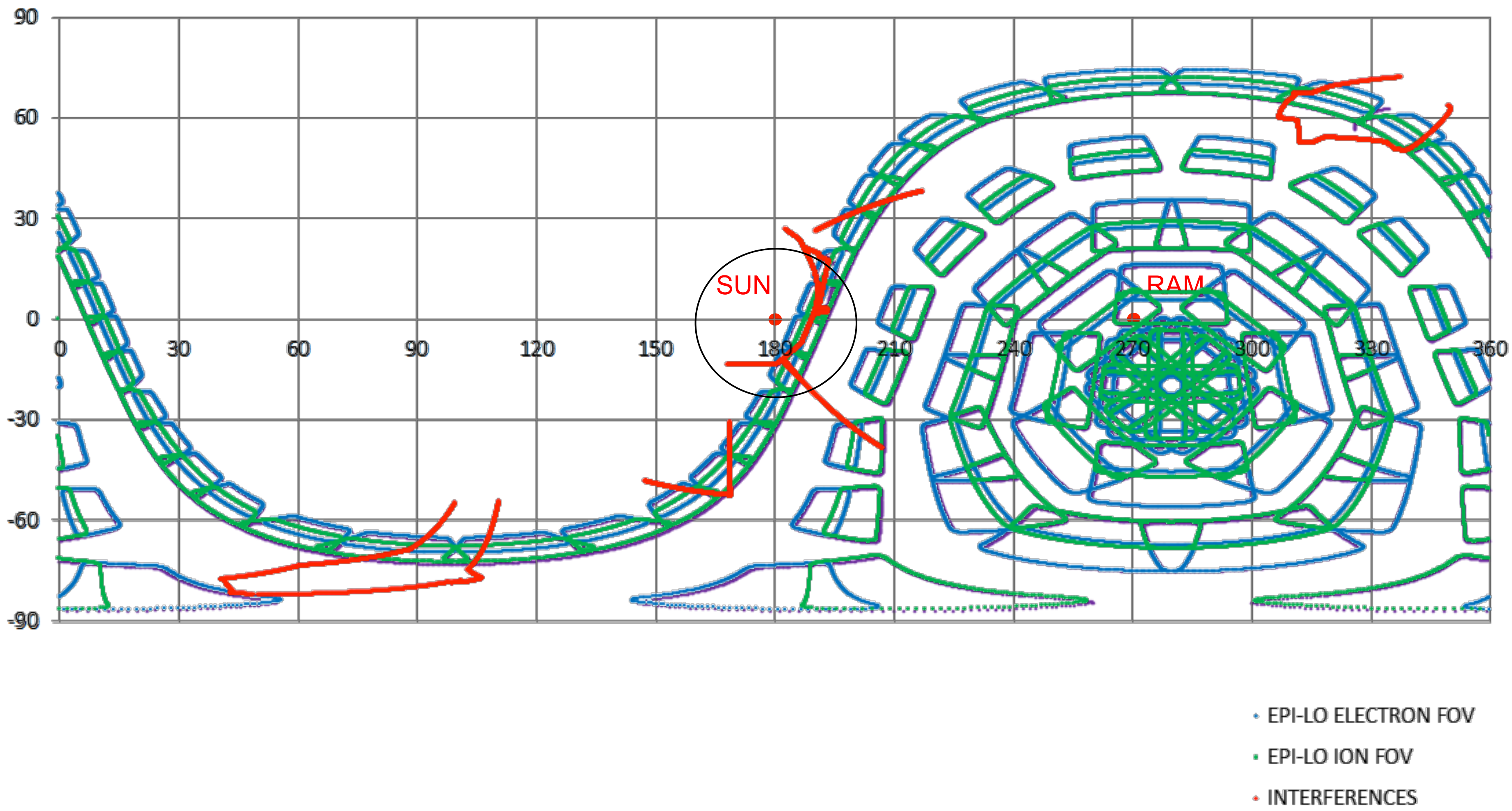


# EPI-Lo Instrument, cut-away

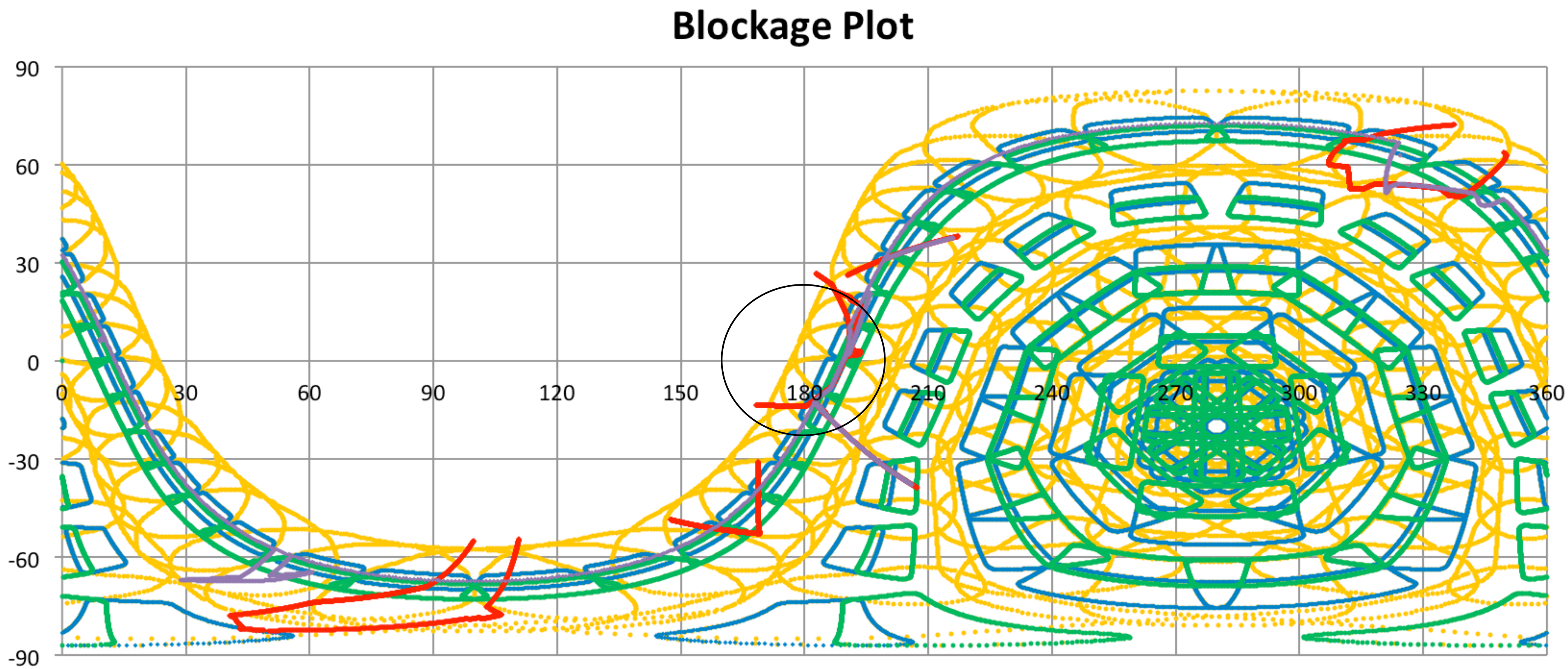



**EPI-LO CROSS-SECTION VIEW ISOMETRIC**

# The EPI-Lo Field of View



# Collimator Foil FOV

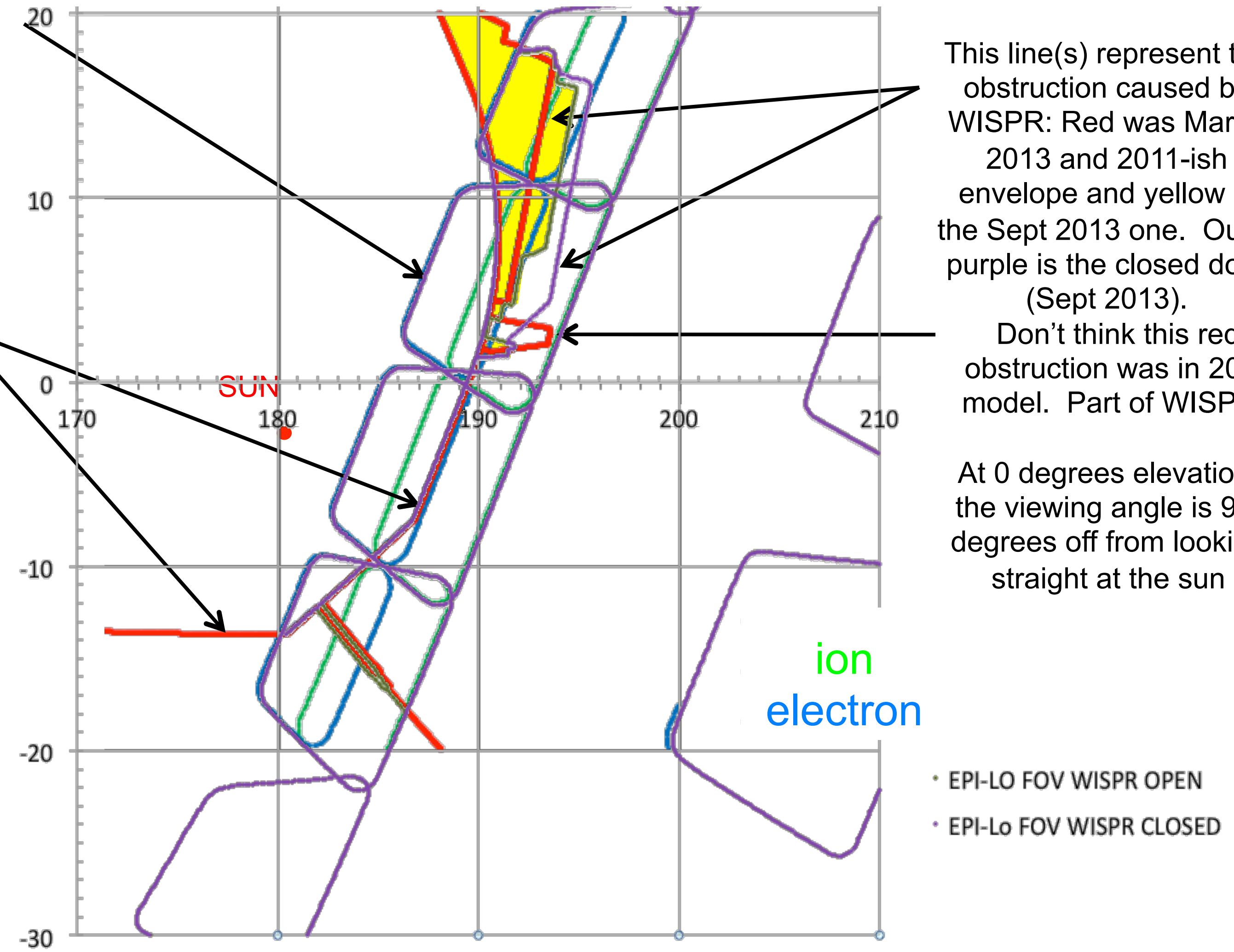



- Foil FOVs shown in yellow (these are not with the latest collimators).

# The EPI-Lo Field of View

These trapezoids, with the rounded corners, represent EPI-Lo unobstructed FOV's

This line(s) represents the obstruction caused by the TPS

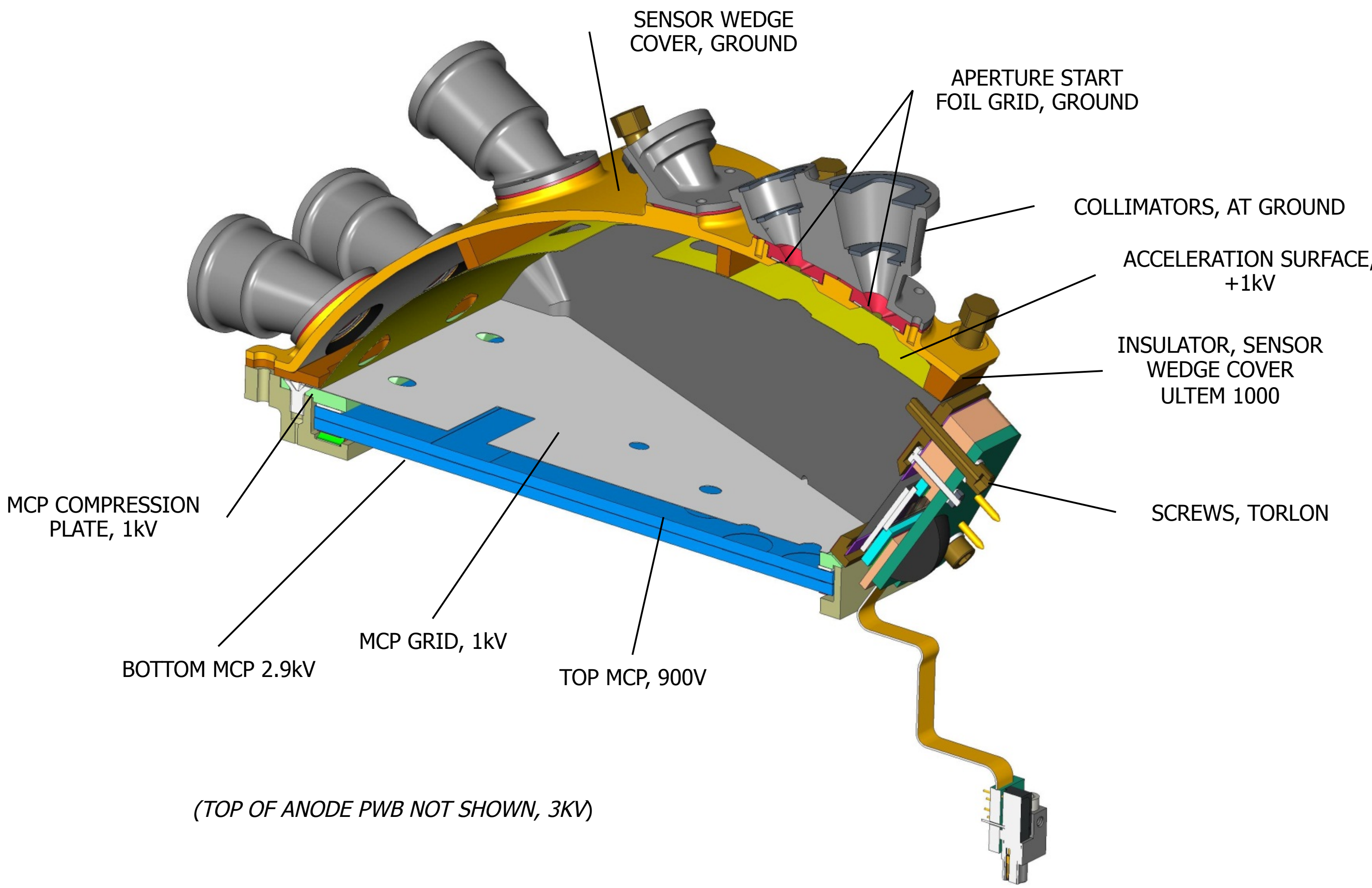



This line(s) represent the obstruction caused by WISPR: Red was March 2013 and 2011-ish envelope and yellow is the Sept 2013 one. Outer purple is the closed door (Sept 2013).

Don't think this red obstruction was in 2011 model. Part of WISPR?

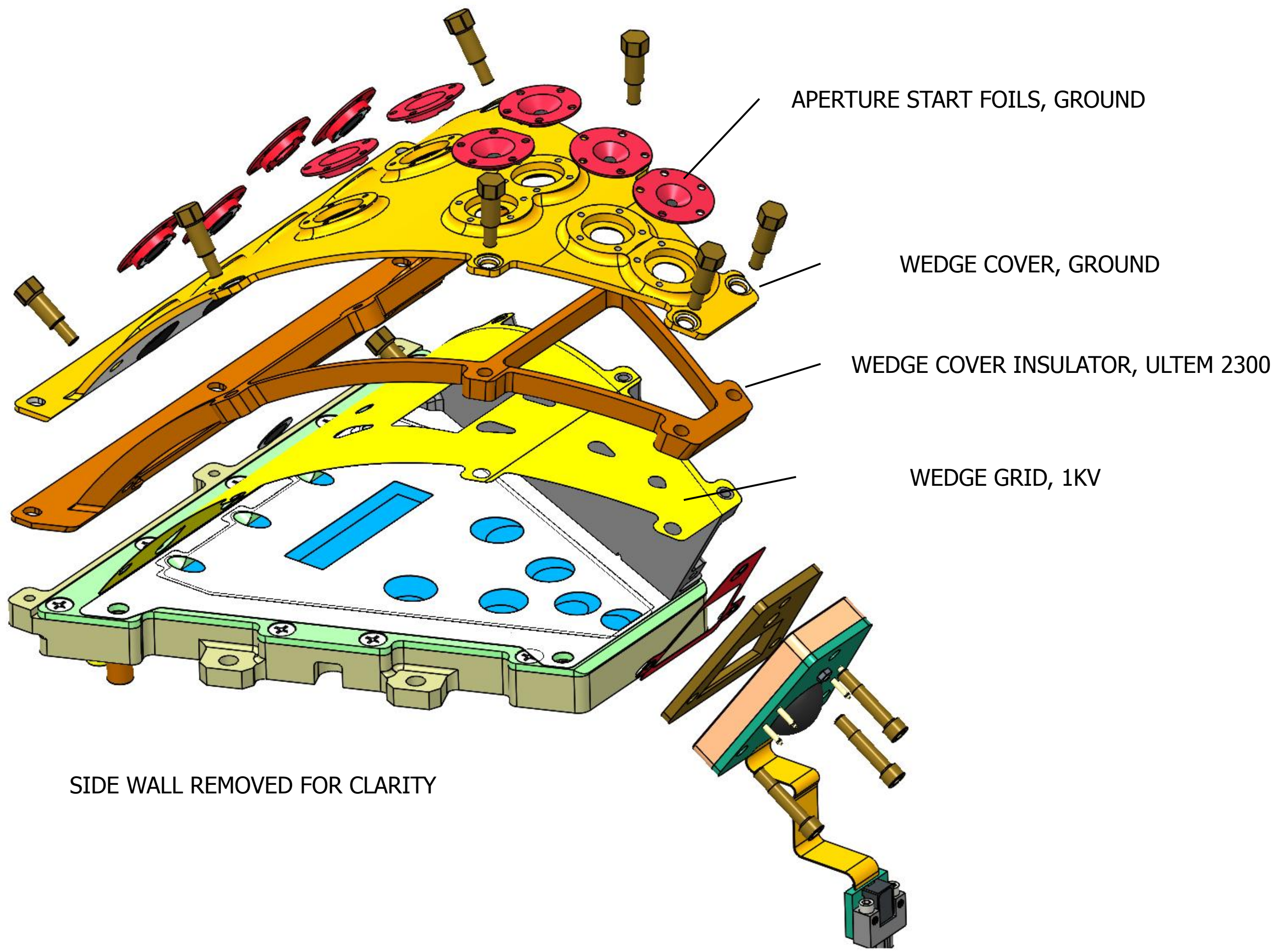
At 0 degrees elevation, the viewing angle is 9.4 degrees off from looking straight at the sun

# EPI-Lo Wedge Components



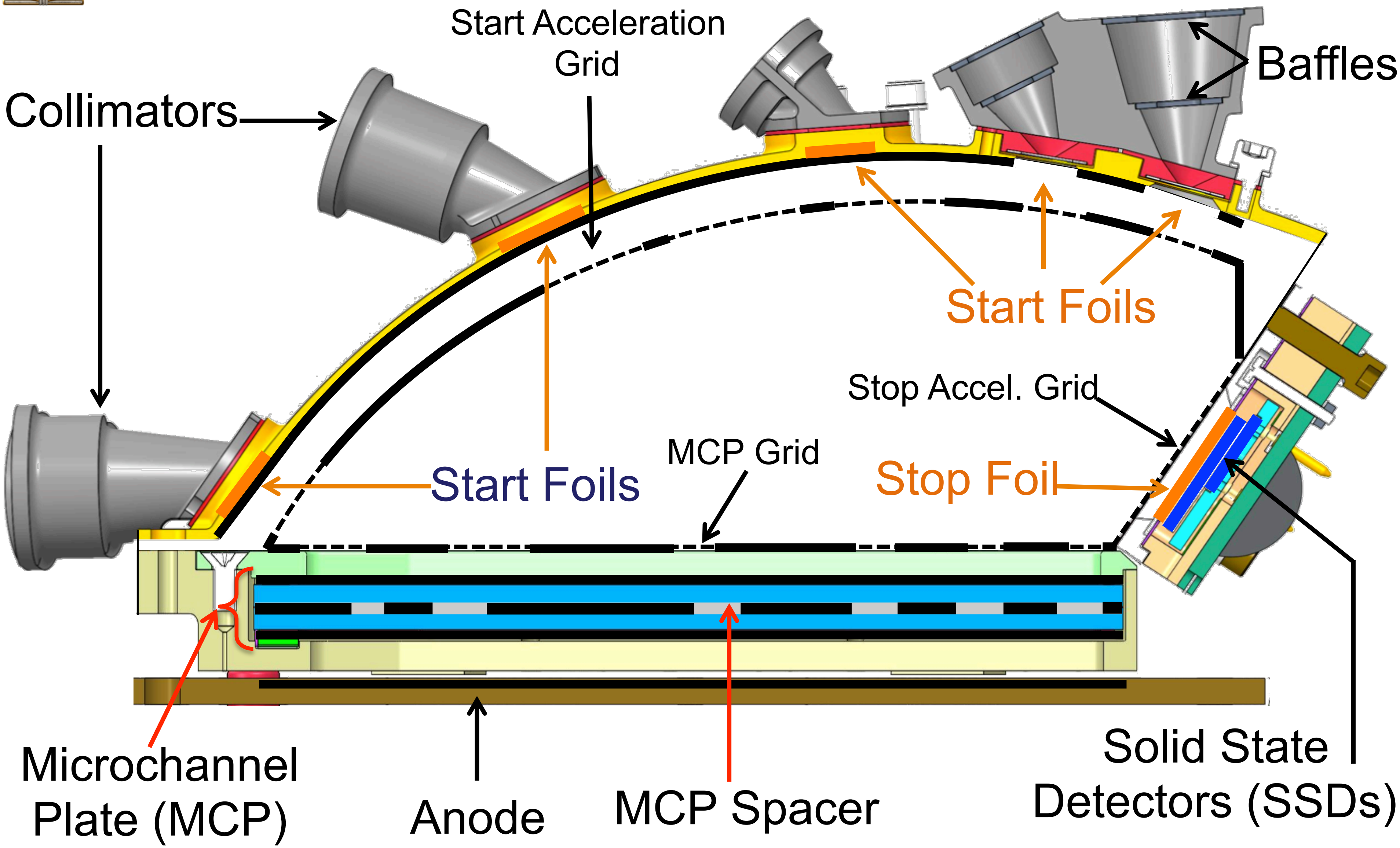

**EPI-LO INDIVIDUAL SENSOR WEDGE ASSY CROSS SECTION**

# EPI-Lo Wedge, Exploded View

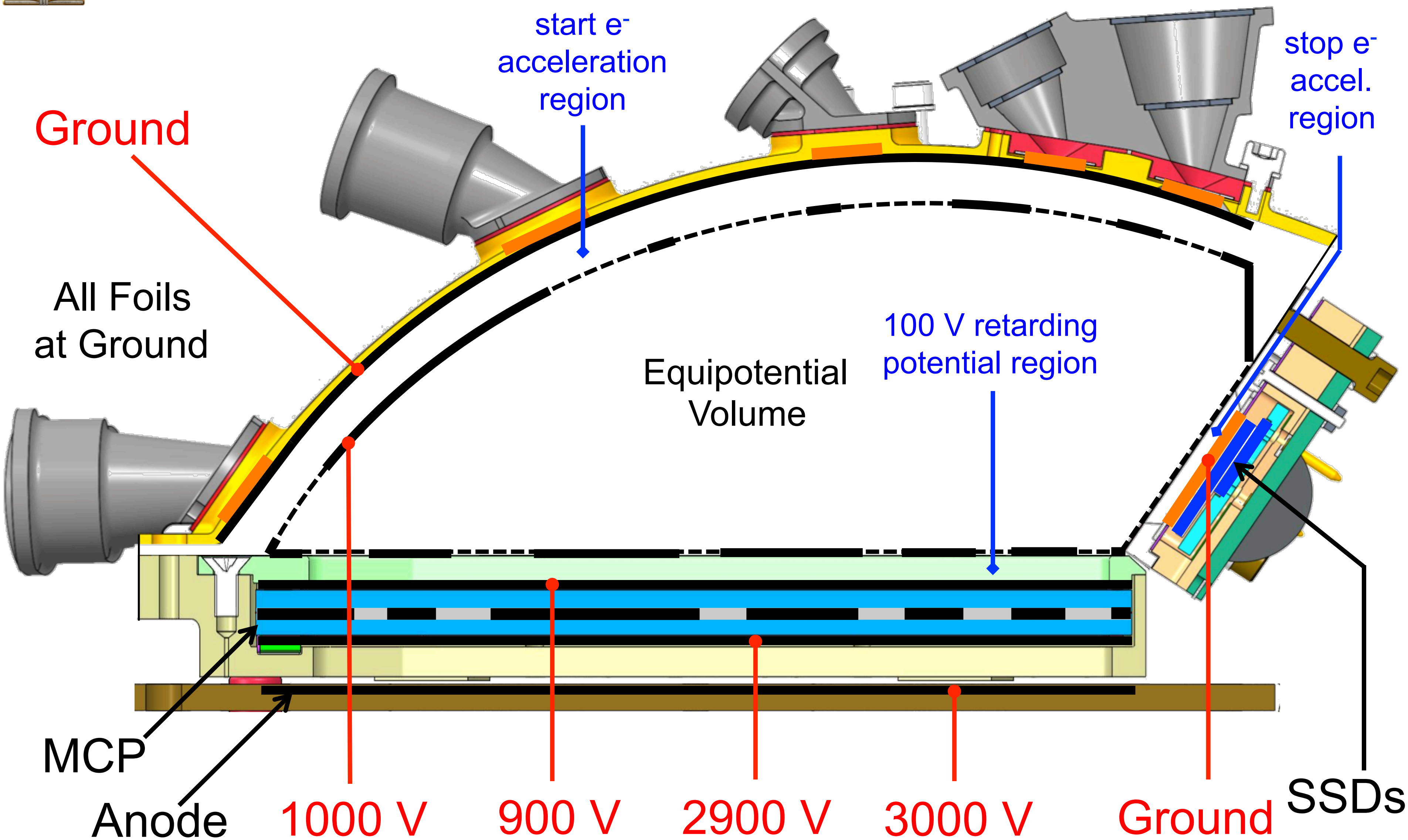



**EPI-LO INDIVIDUAL SENSOR WEDGE ASSY CROSS SECTION**

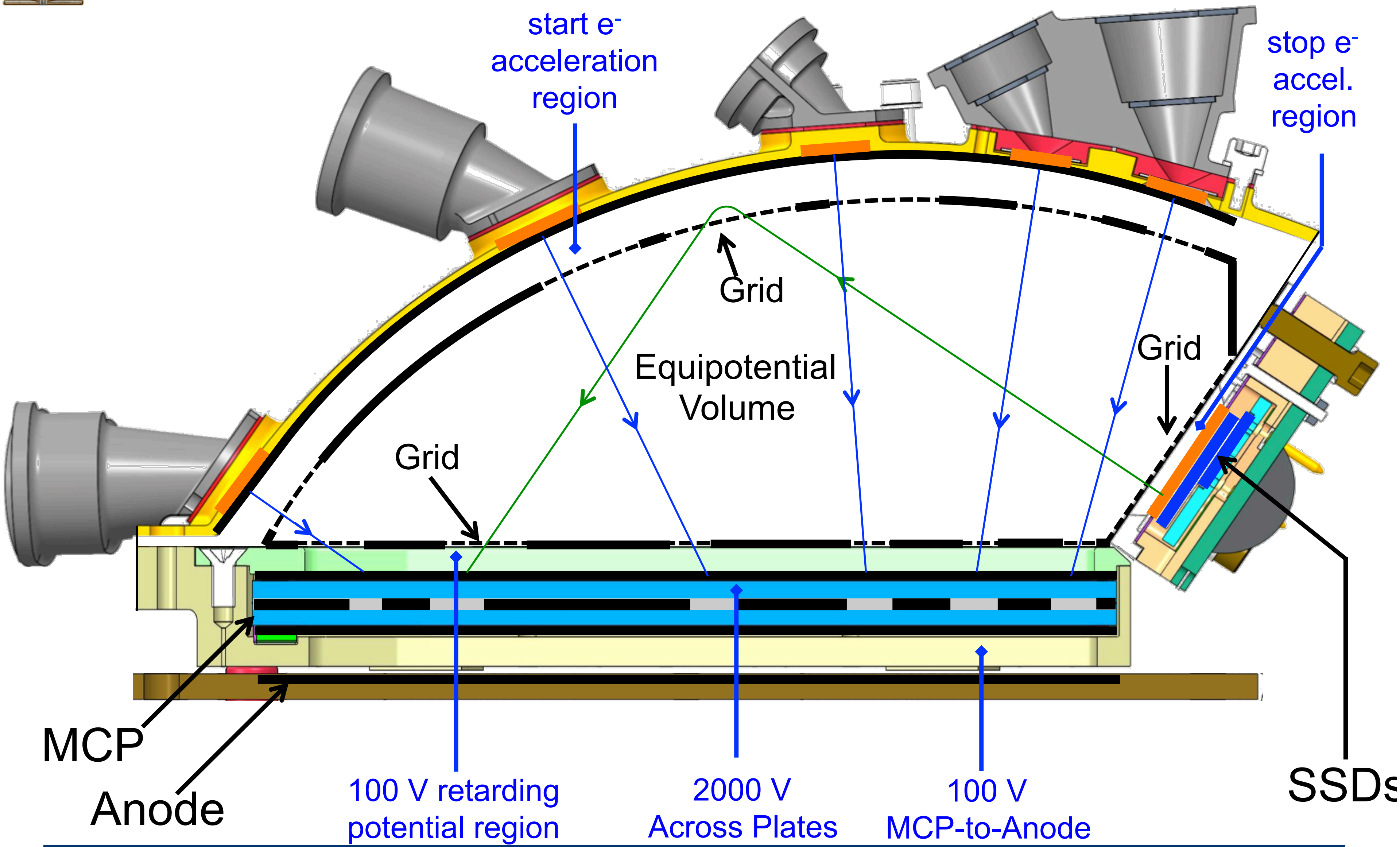
# Sensor Functional Schematic



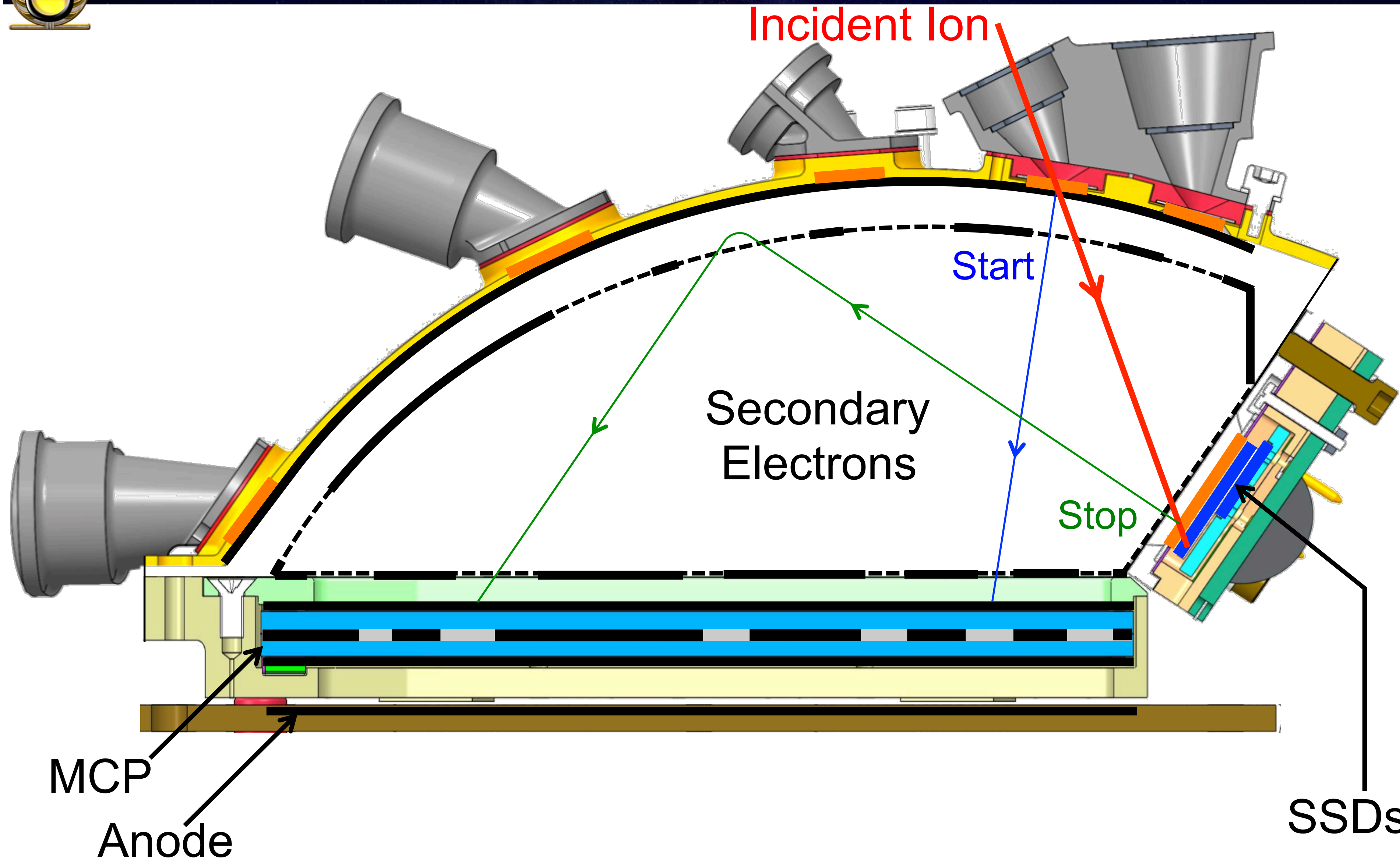
# Sensor Voltages



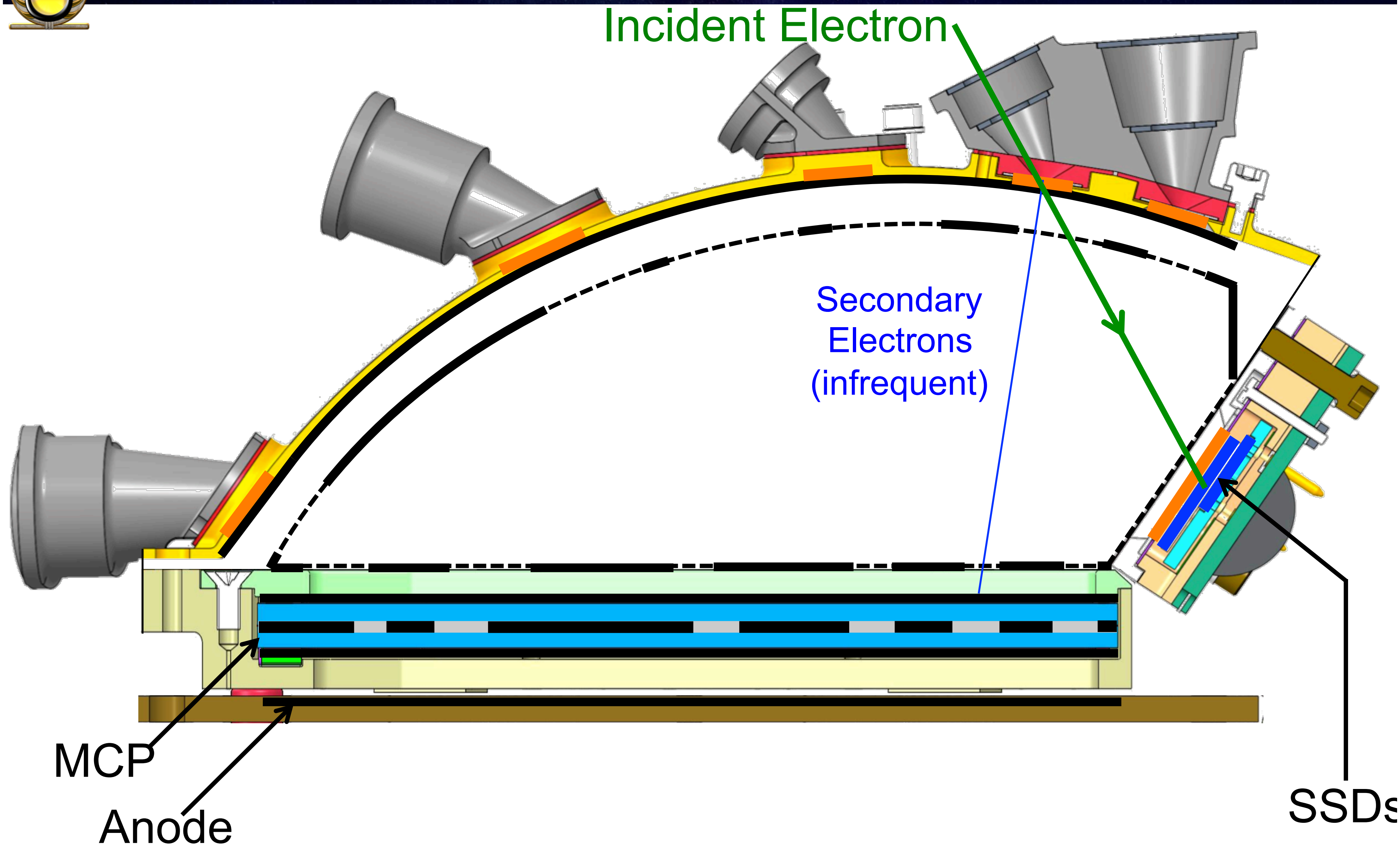
# Secondary Electrons & Potentials



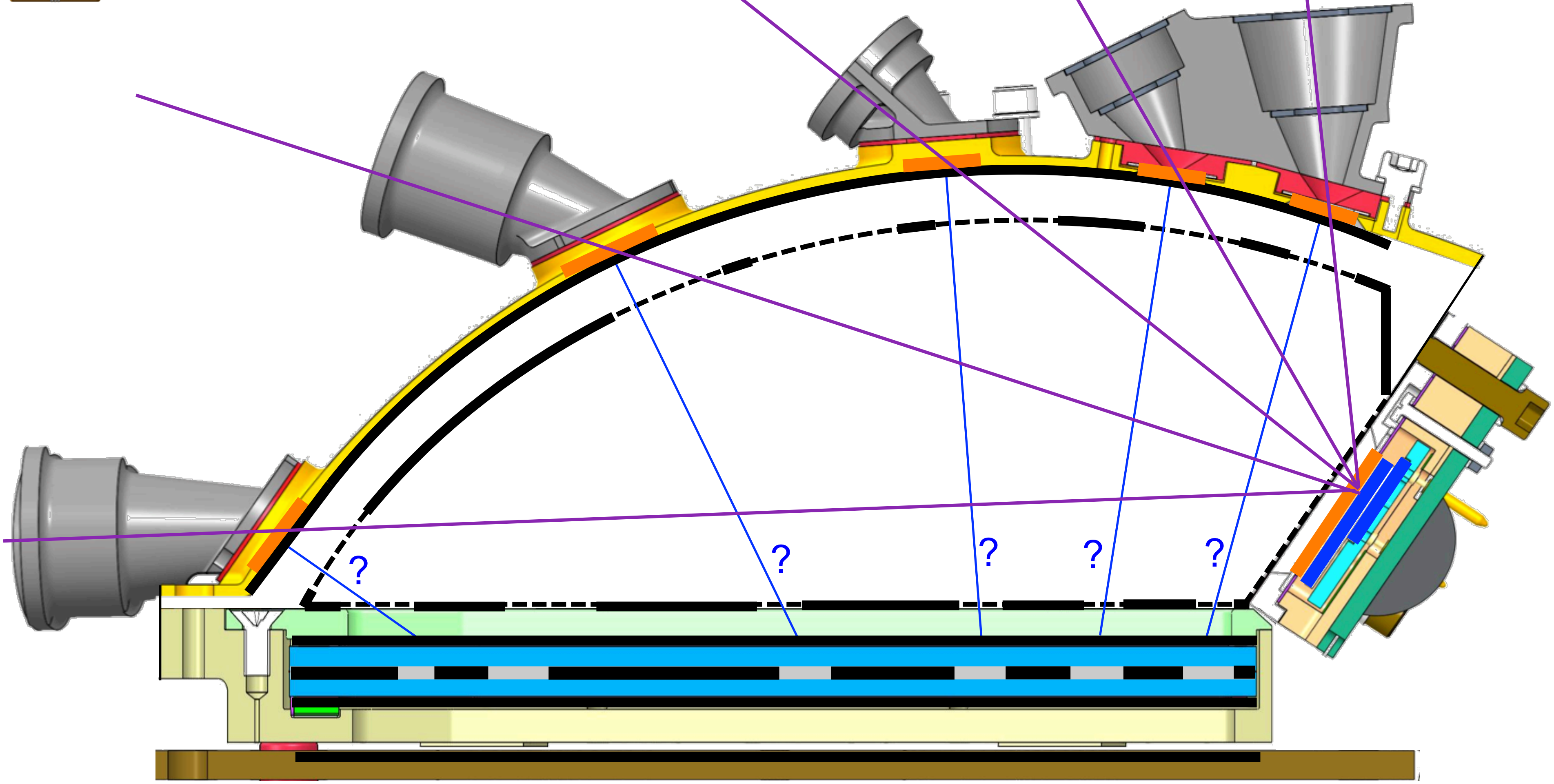
# Ions (Energy, TOF, and Position)



# Electrons: Energy (& Position)

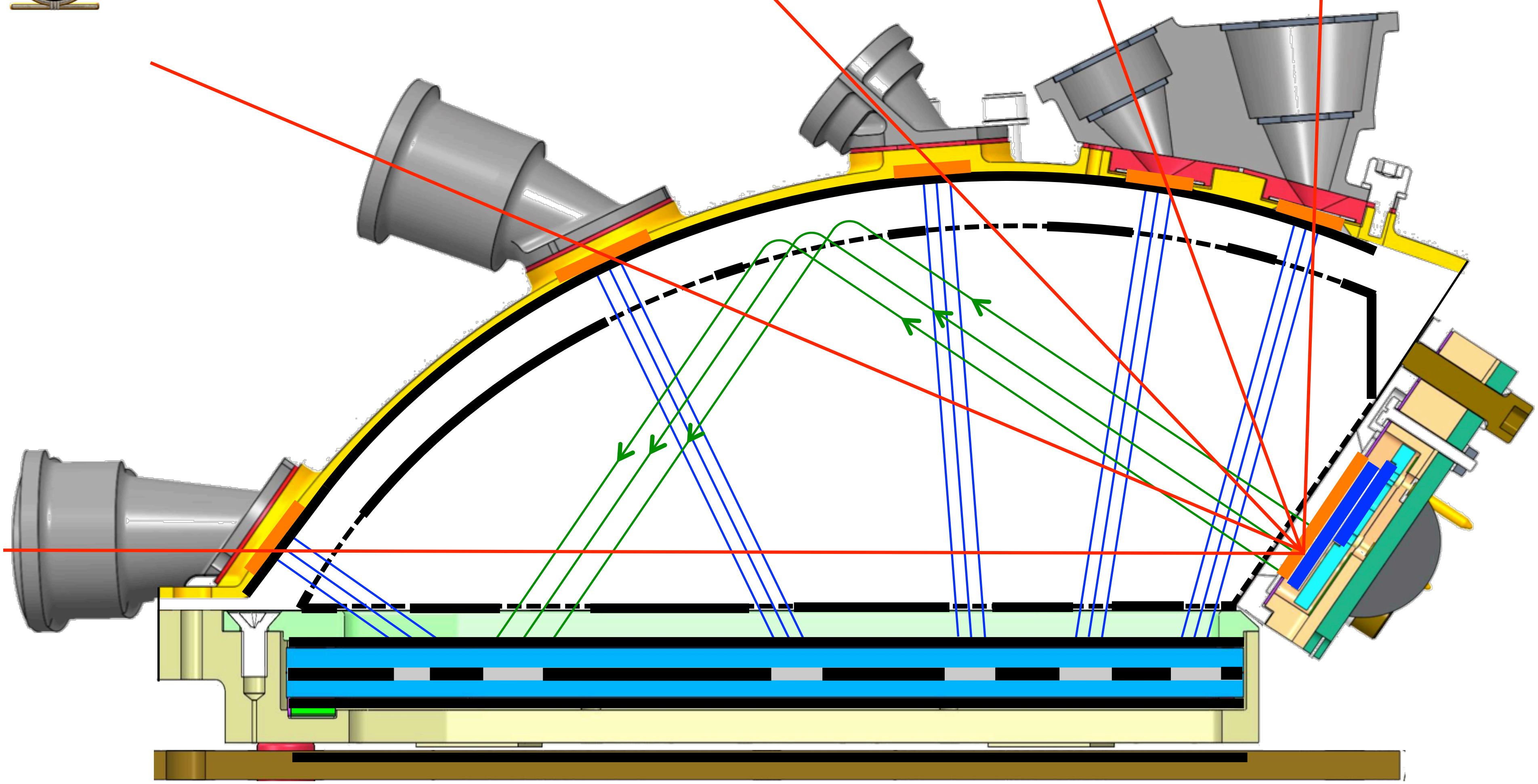


# Energetic Electron Measurement



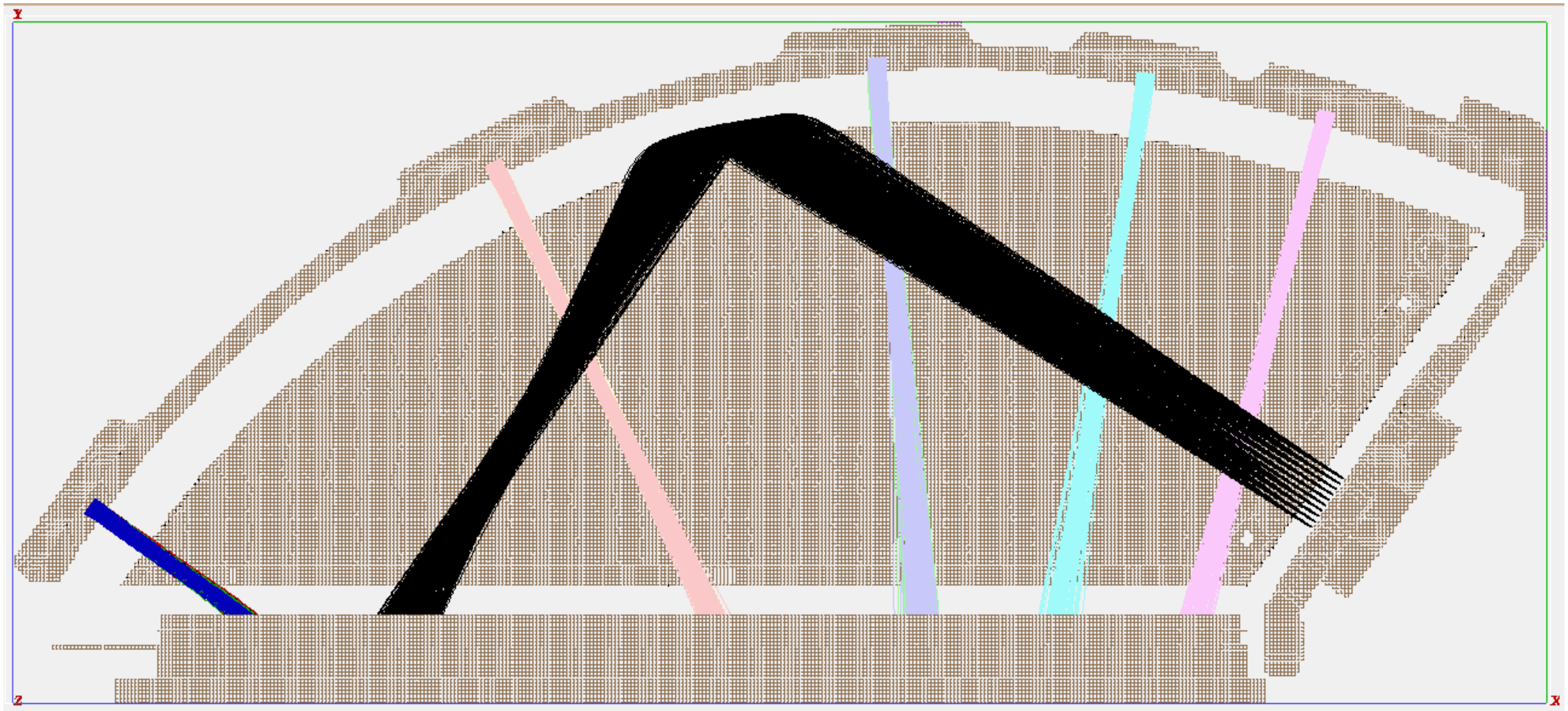

Secondary Electrons from Start Foils possible, but Low Probability;
Start Electron present identifies entrance aperture

# Energetic Ion Measurement



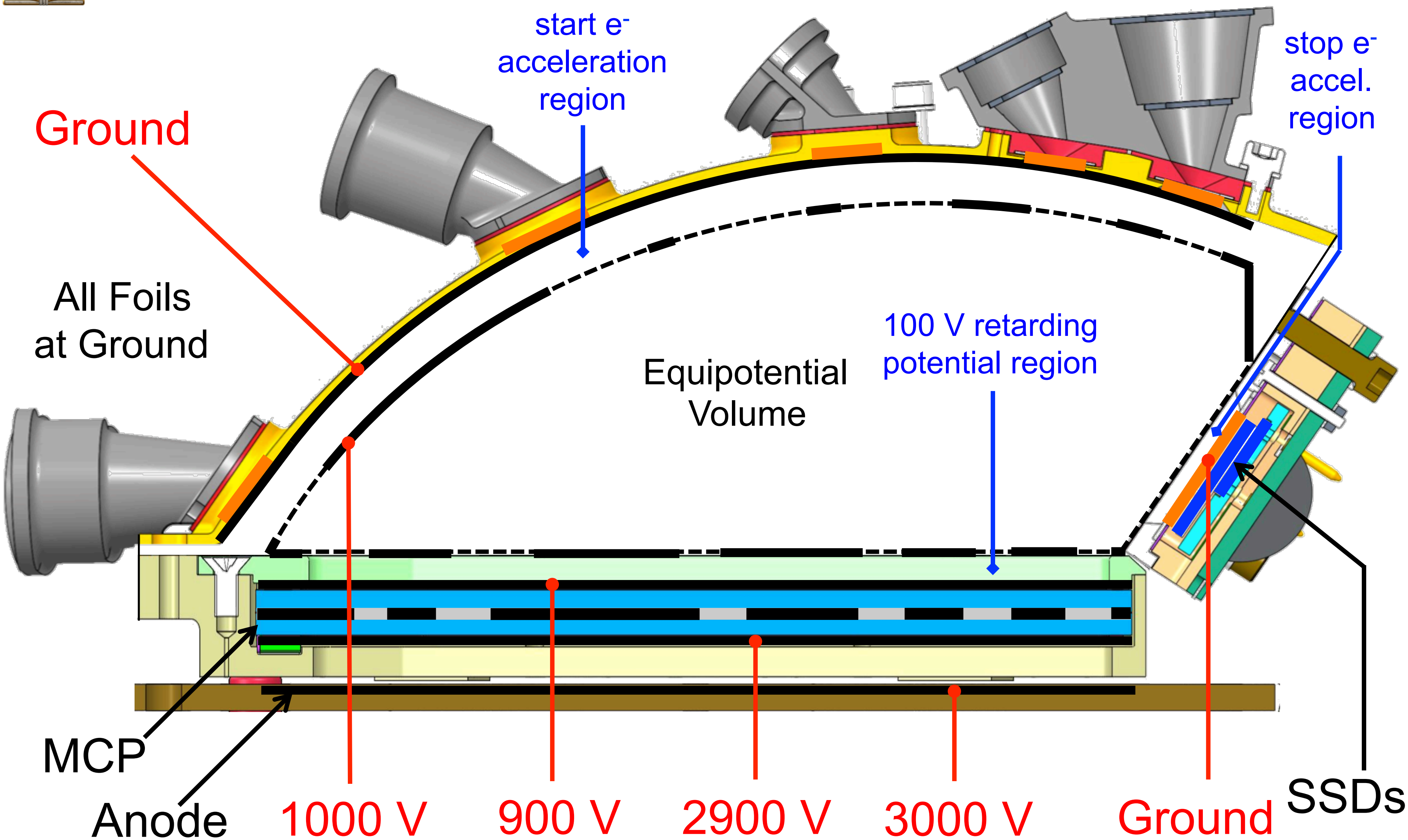
Ion Measurement Logic can require TOF or not, but with no TOF, no species

# Electrostatic Optics

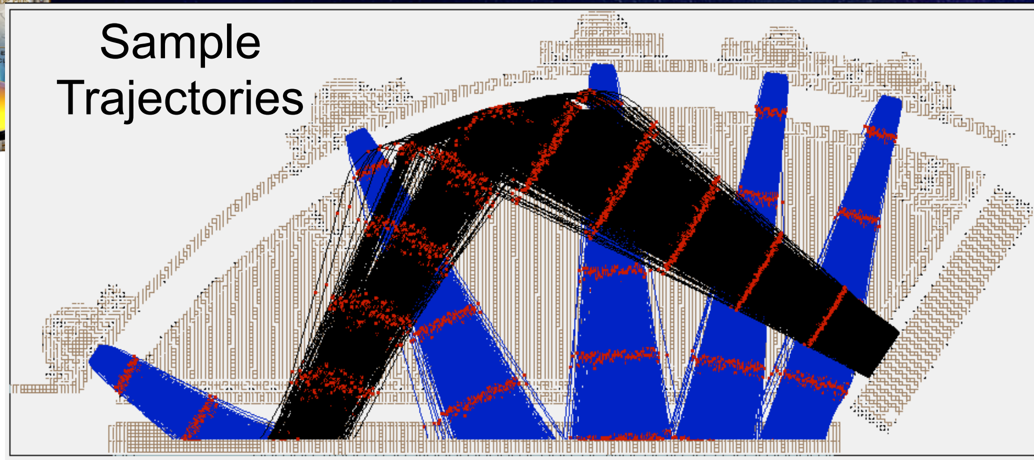


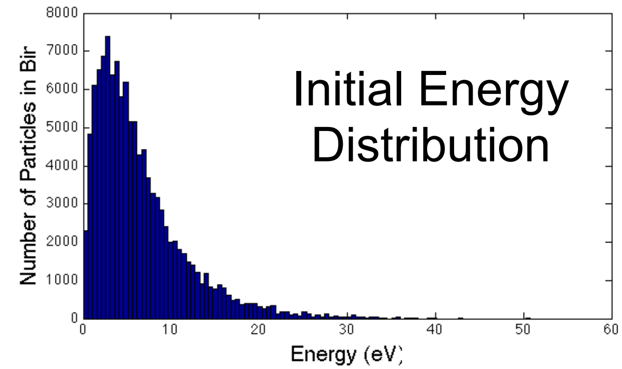
- SIMION simulation of electron optics using ~3eV random initial electron velocities.

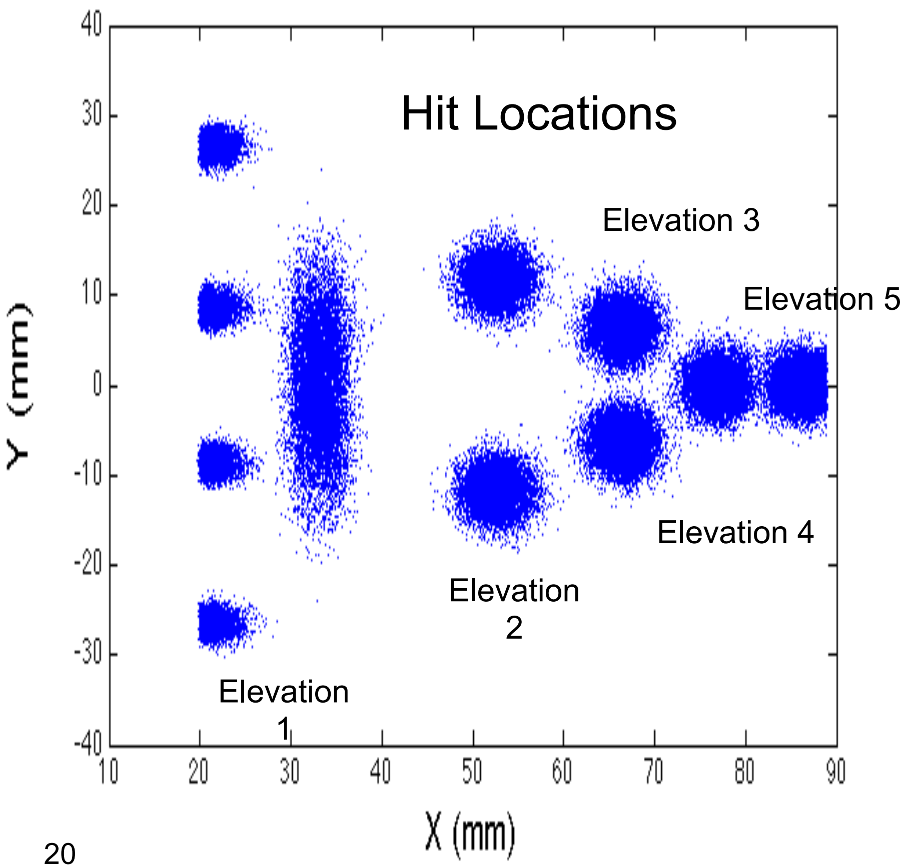
# Sensor Voltages

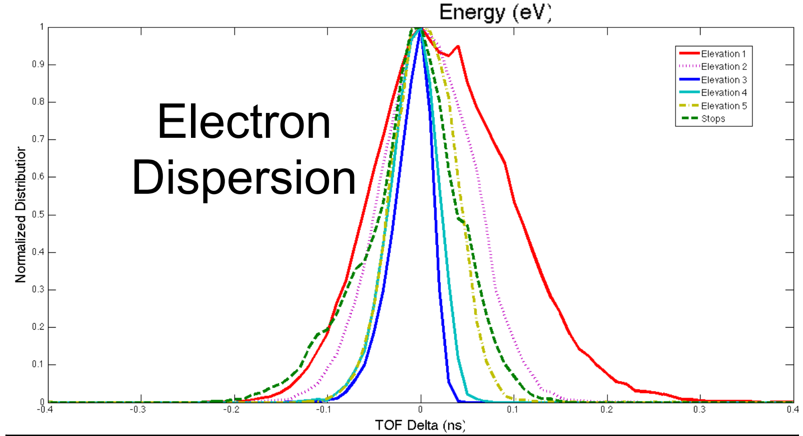


# SIMION, Allegrini Energy Distribution



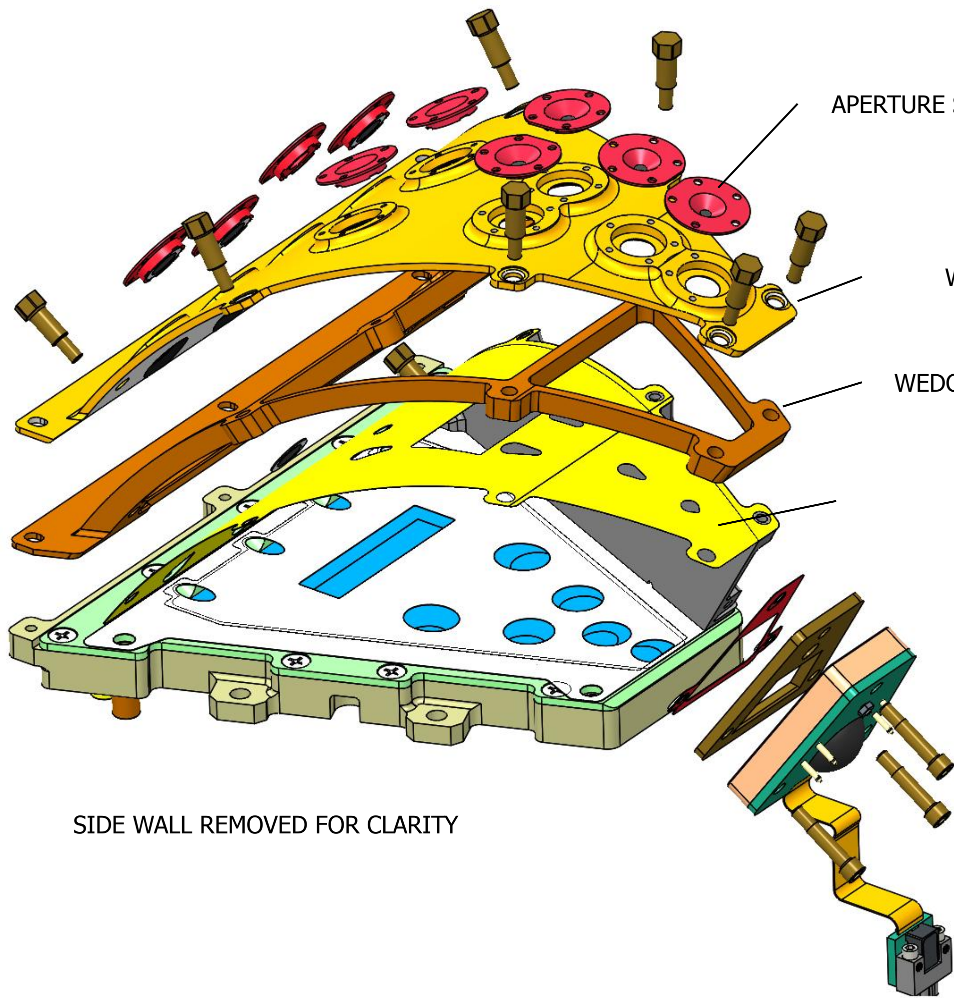



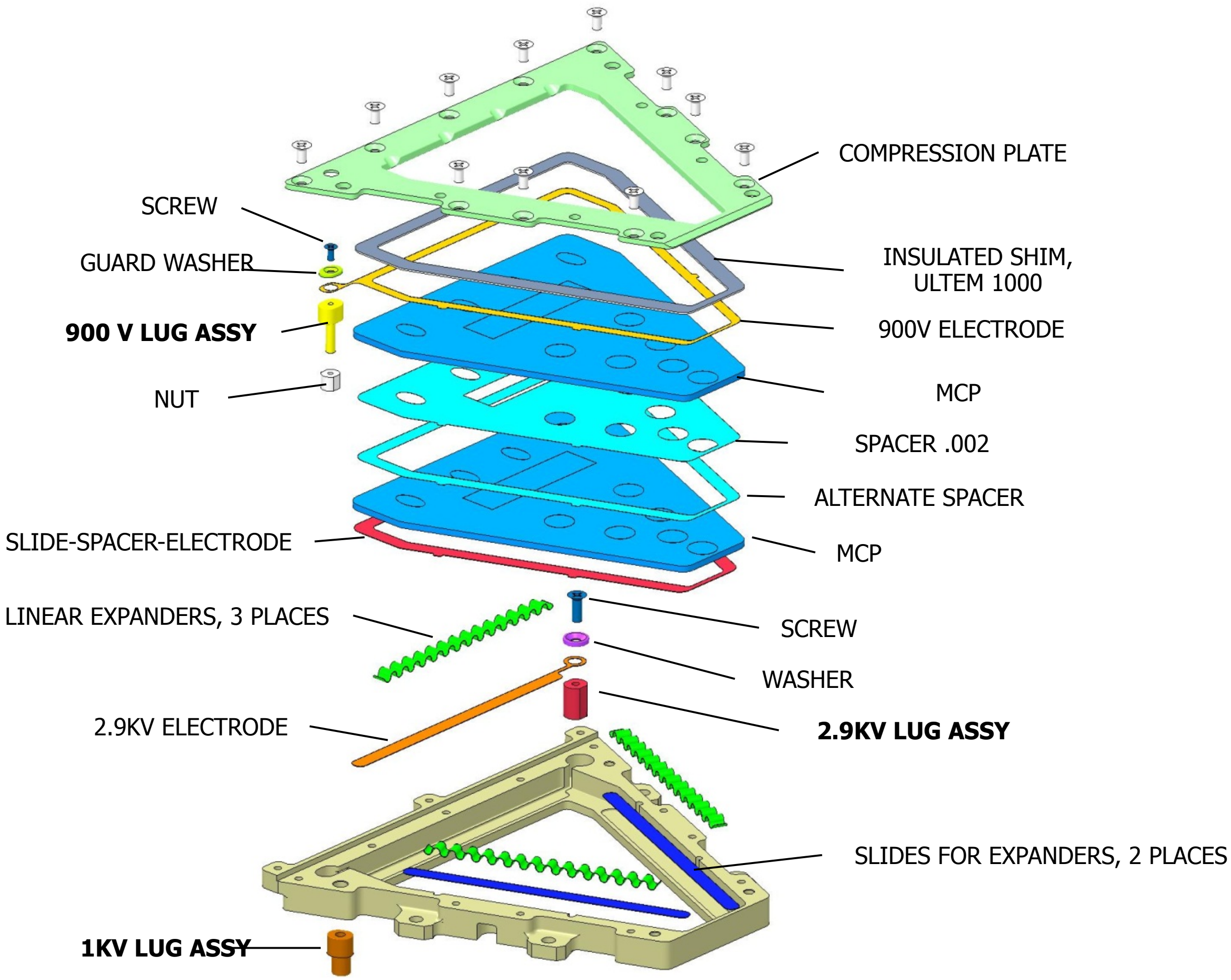

| Name | Mean TOF (ns) | TOF Sigma (ns) |
|---|---|---|
| Elevation 1 | 1.06 | 0.19 |
| Elevation 2 | 2.17 | 0.13 |
| Elevation 3 | 2.35 | 0.05 |
| Elevation 4 | 2.33 | 0.06 |
| Elevation 5 | 2.32 | 0.12 |
| Stops | 5.23 | 0.11 |

# EPI-Lo Wedge, Exploded View



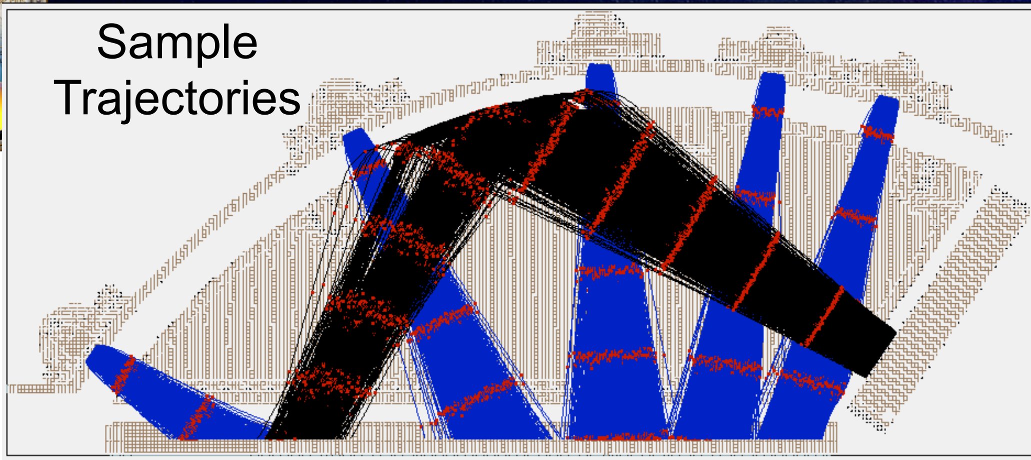

**EPI-LO INDIVIDUAL SENSOR WEDGE ASSY CROSS SECTION**

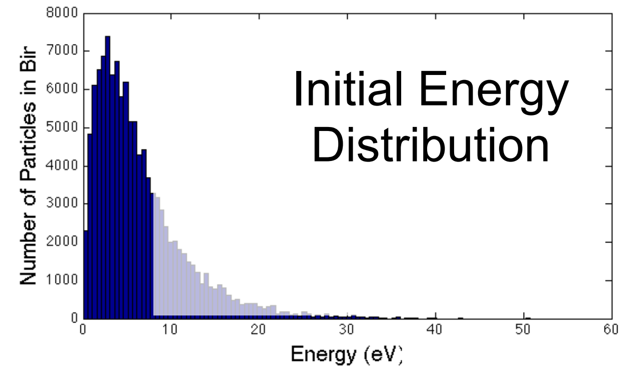
# MCP Inter-Plate Spacer also a mask

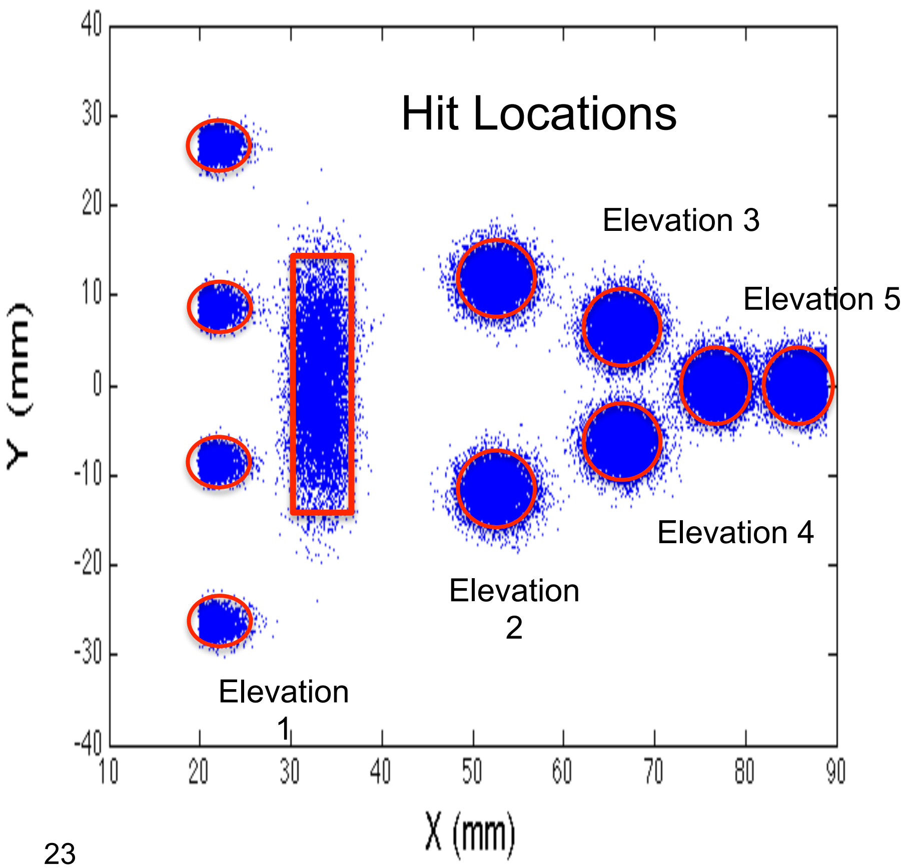


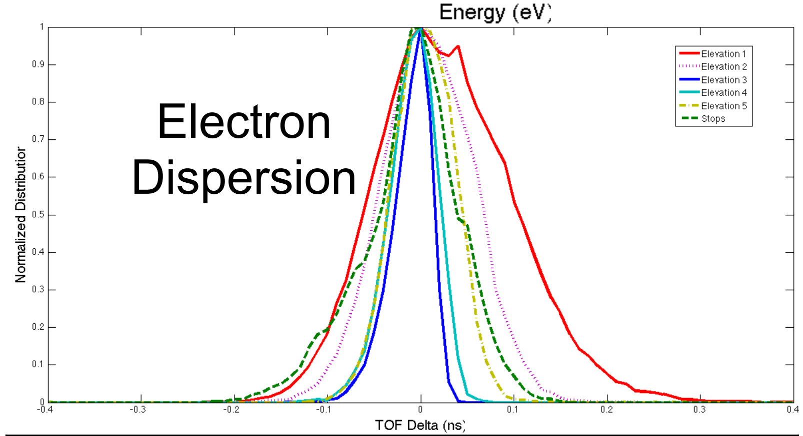

**EXPLODED VIEW "NEW" MCP ASSEMBLY**

# SIMION, Alegrini Energy Distribution




| Name | Mean TOF (ns) | TOF Sigma (ns) |
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| Elevation 1 | 1.06 | 0.19 |
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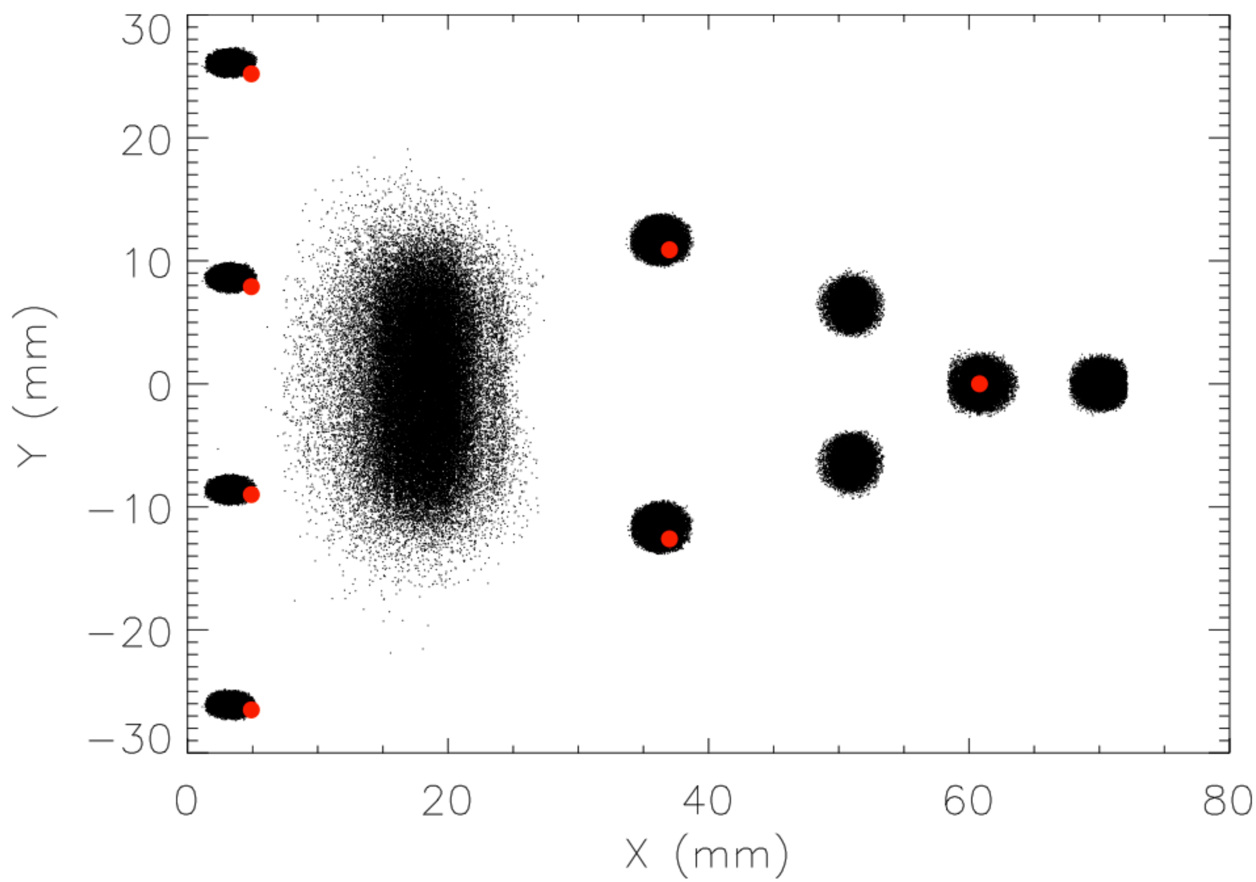
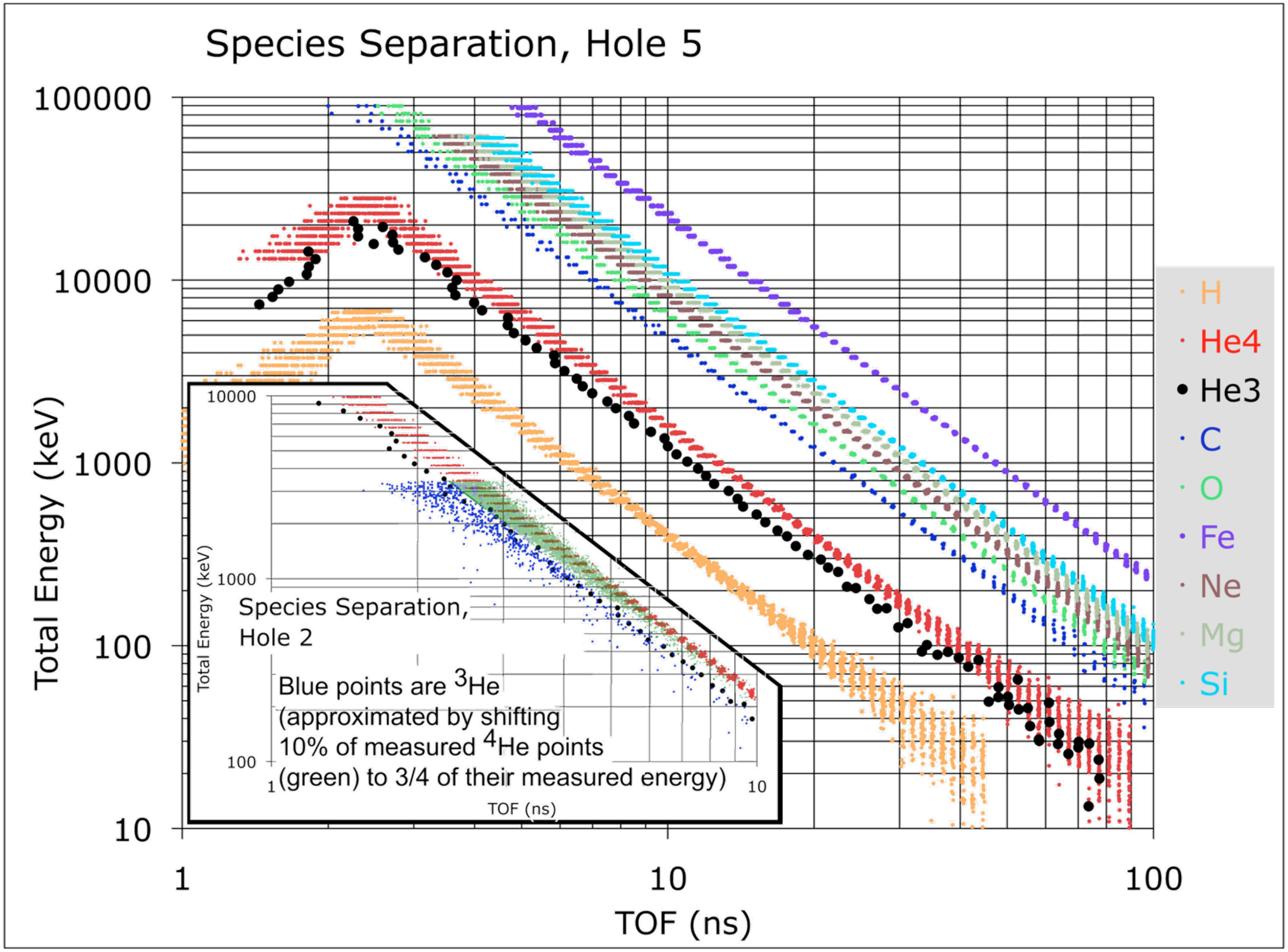
| Elevation 4 | 2.33 | 0.06 |
| Elevation 5 | 2.32 | 0.12 |
| Stops | 5.23 | 0.11 |

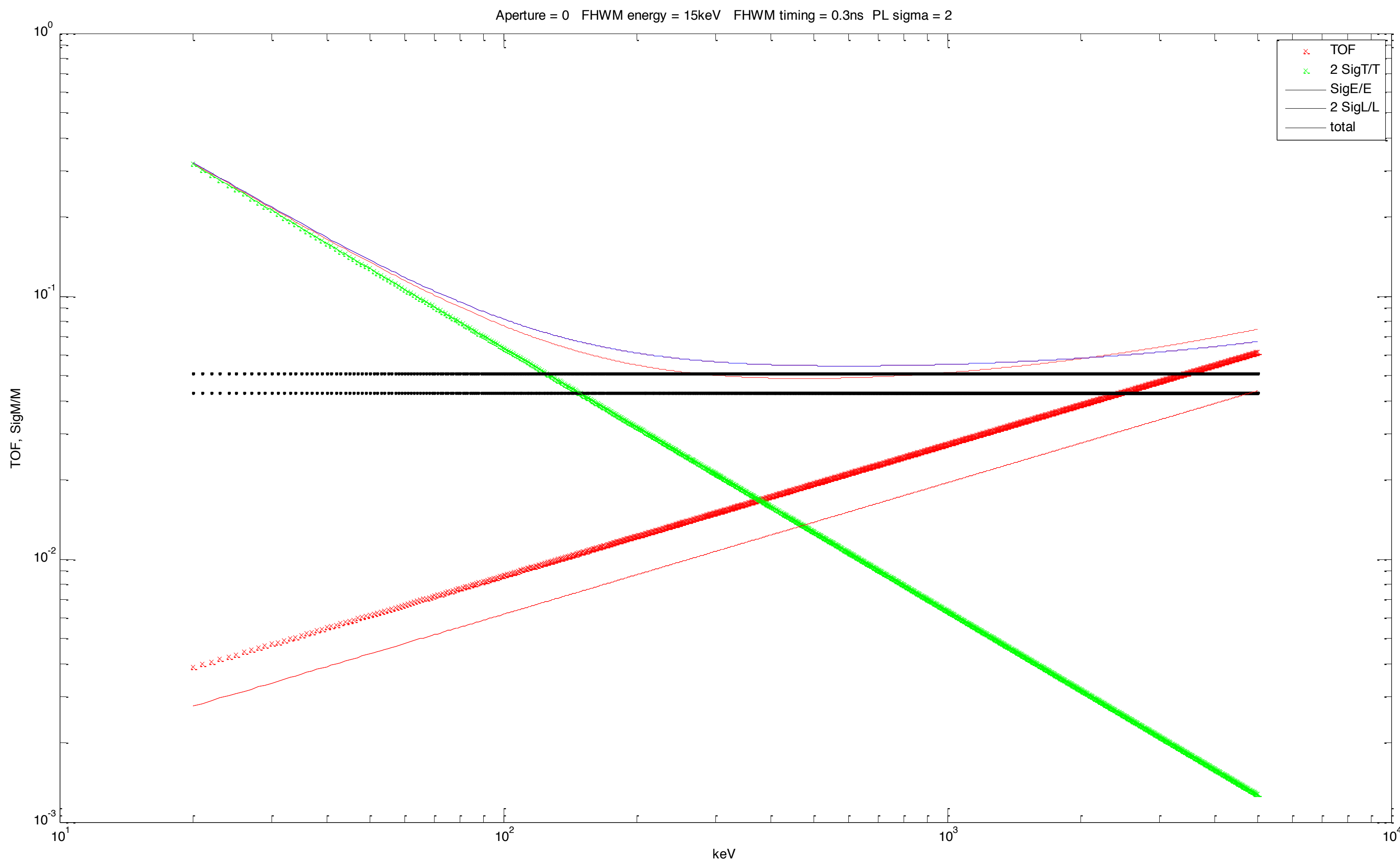
# Microchannel Plate (MCP)



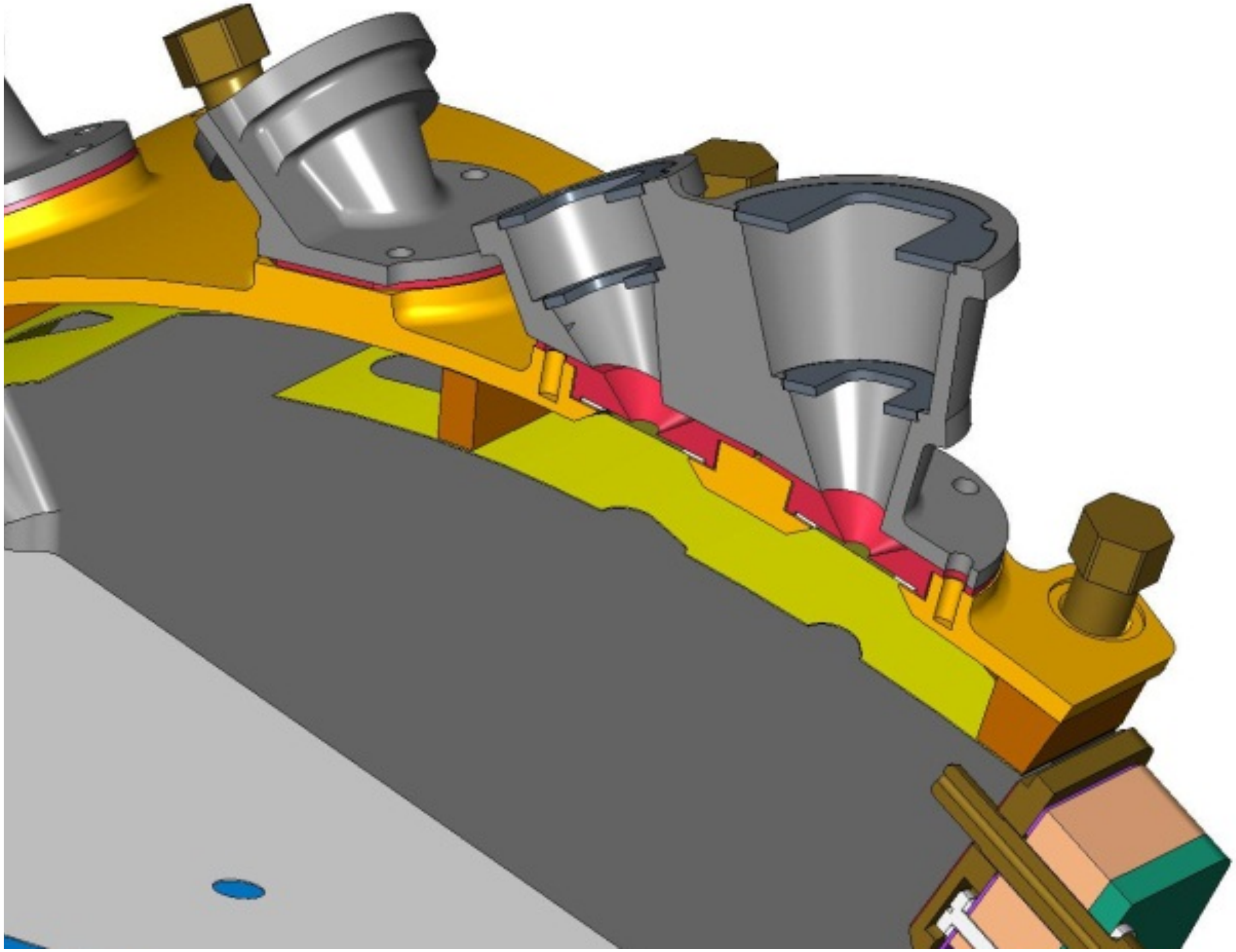
# Mass Resolution



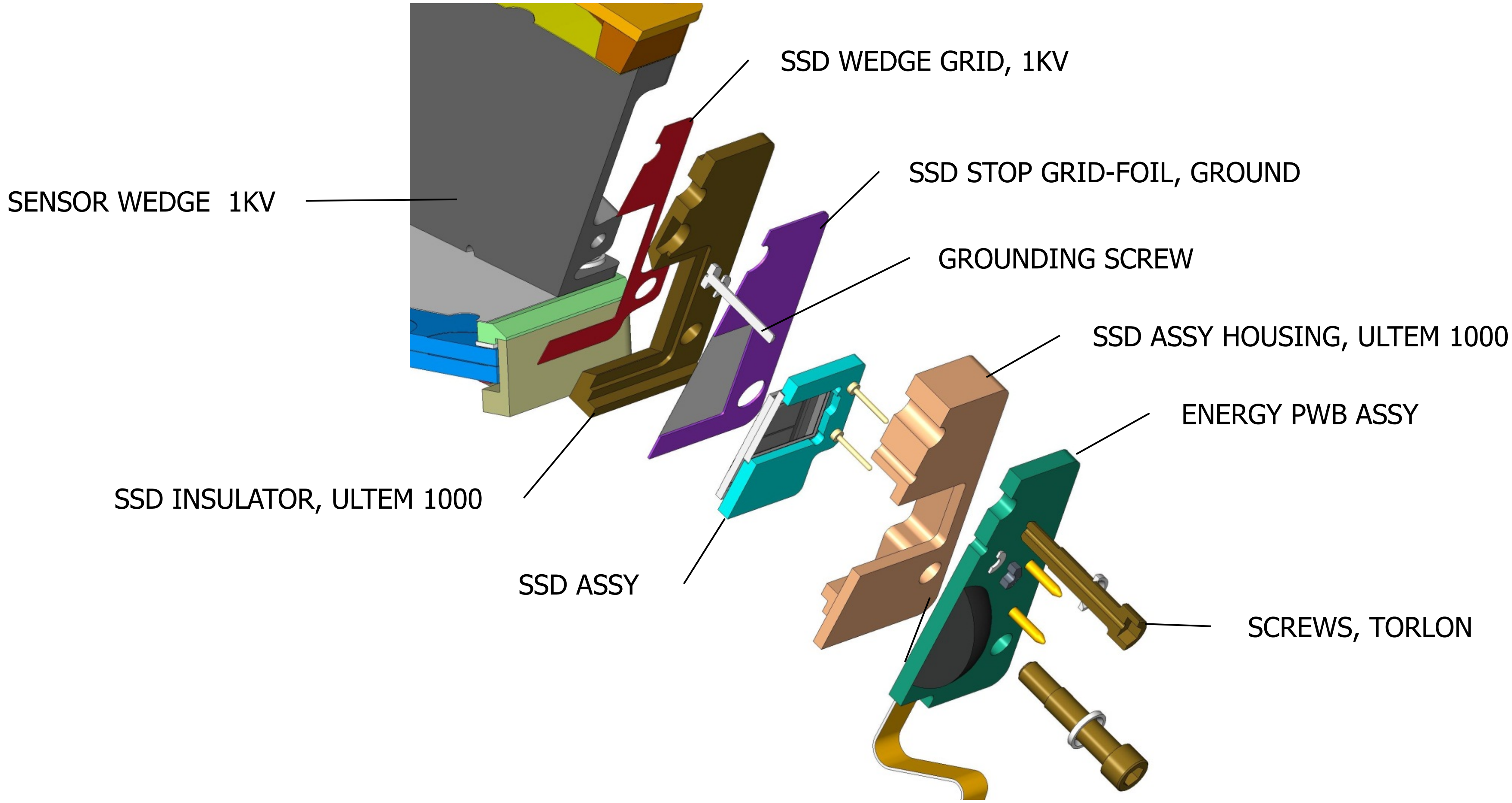
# Mass Resolution



# Collimators and Start Foils



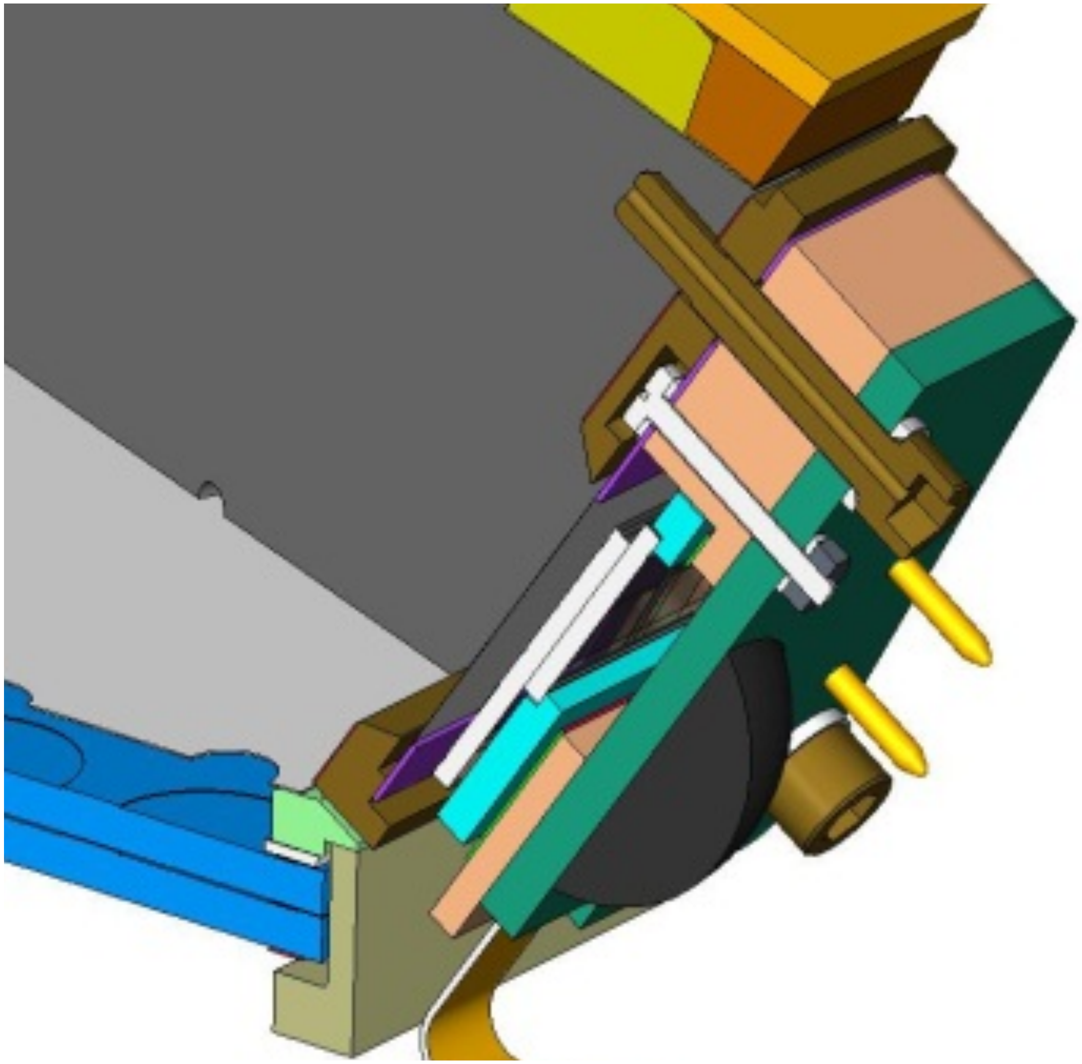
# EPI-Lo SSD Assemblies (8)



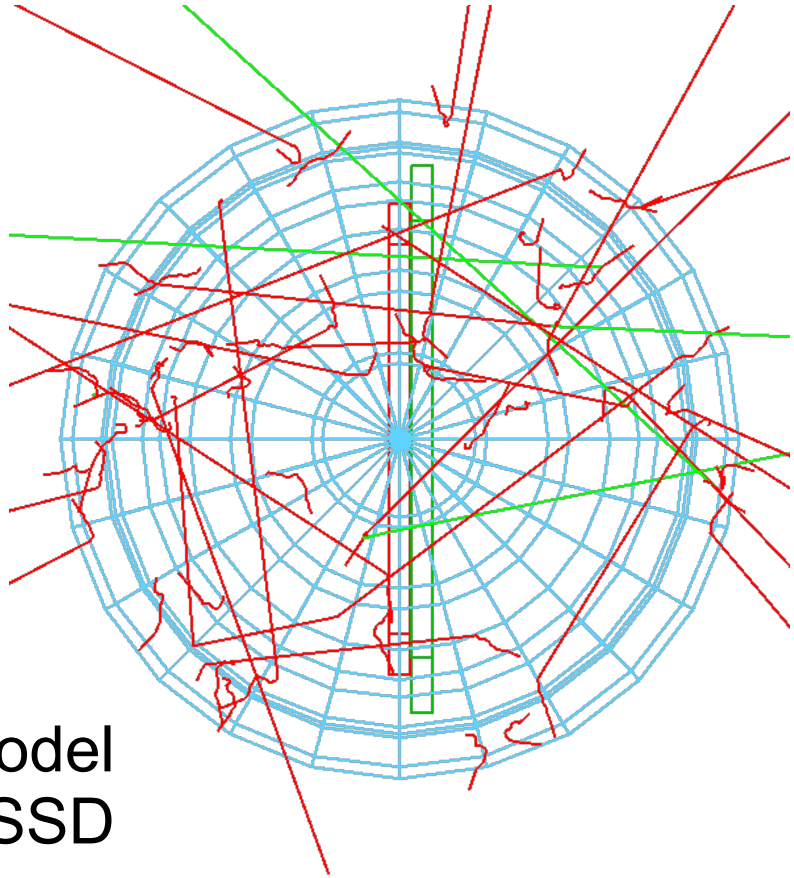

**SSD ASSY TO WEDGE EXPLODED CROSS SECTION**

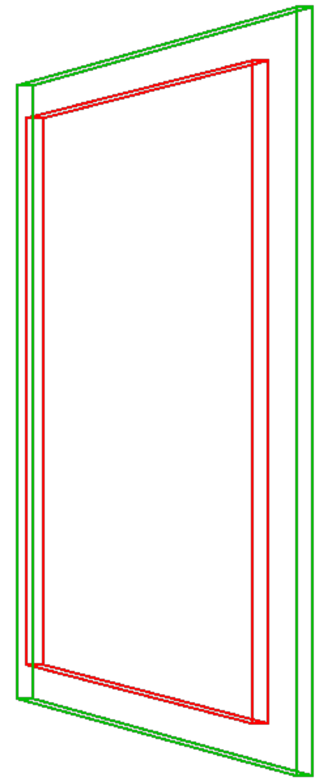
# Anti-coincidence System

- Electron SSD is backed by an anti-coincidence SSD



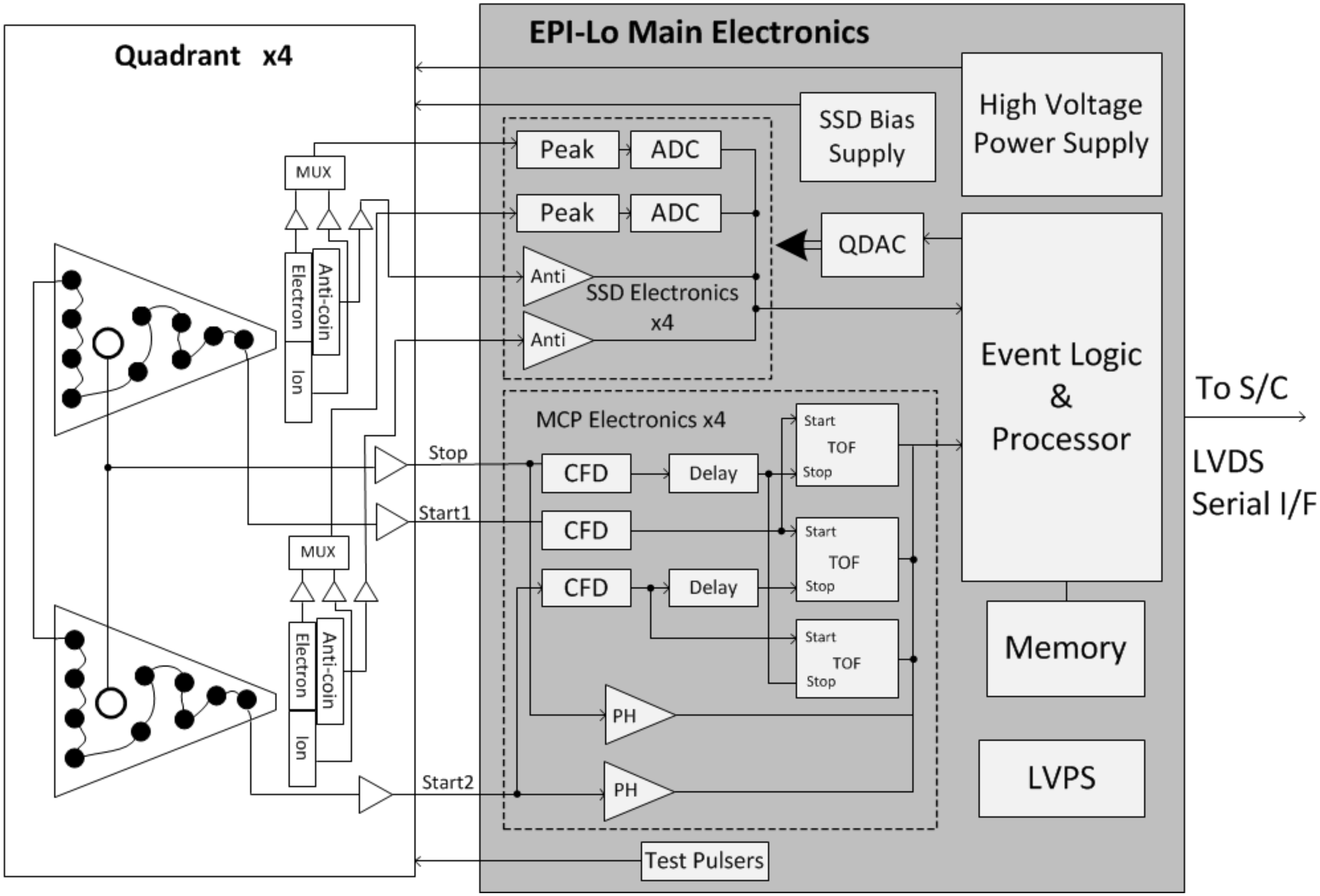
# Anti-coincidence System: GEANT



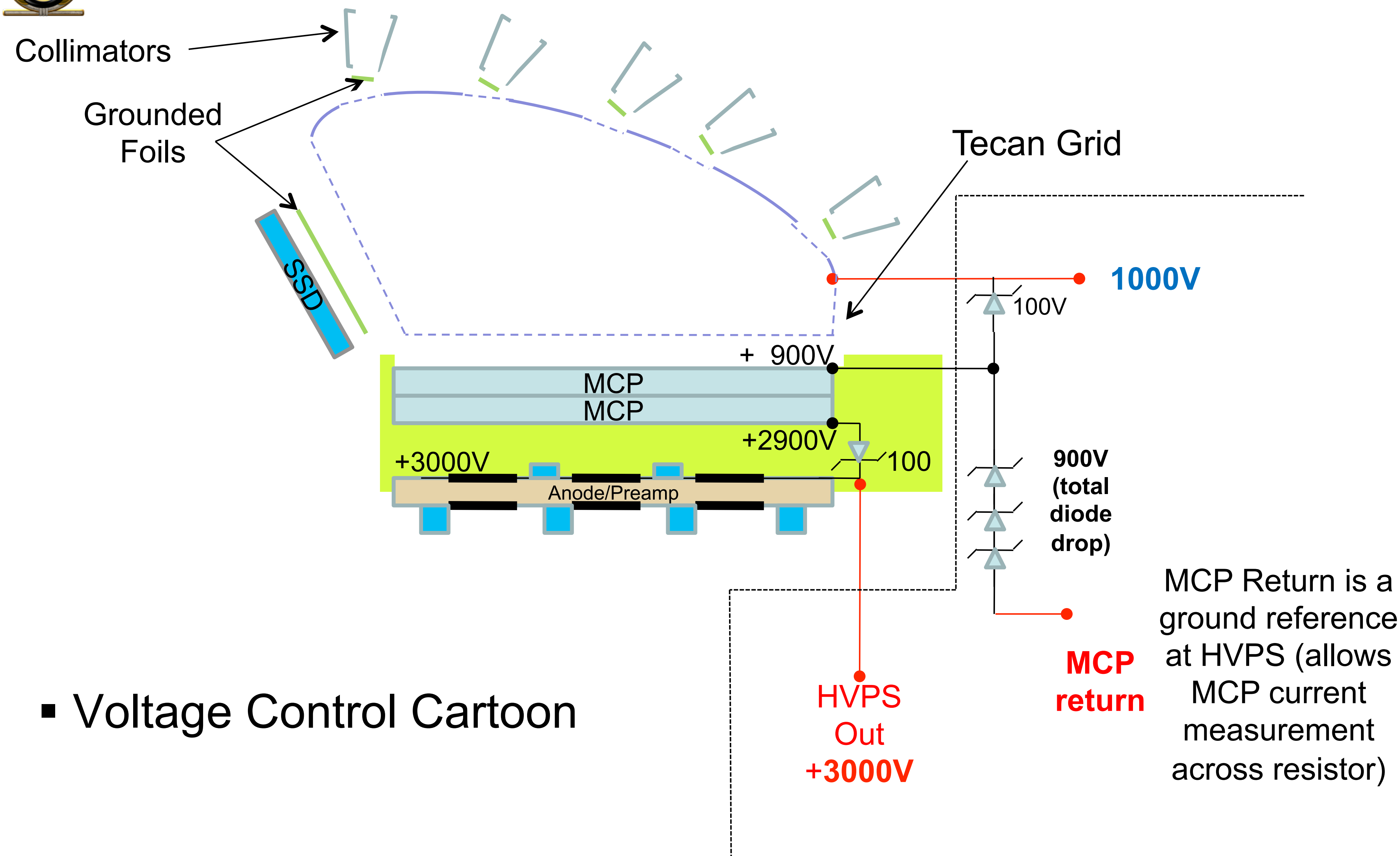


- Setup for GEANT4 model of electron SSD anticoincidence

# EPI-Lo Block Diagram

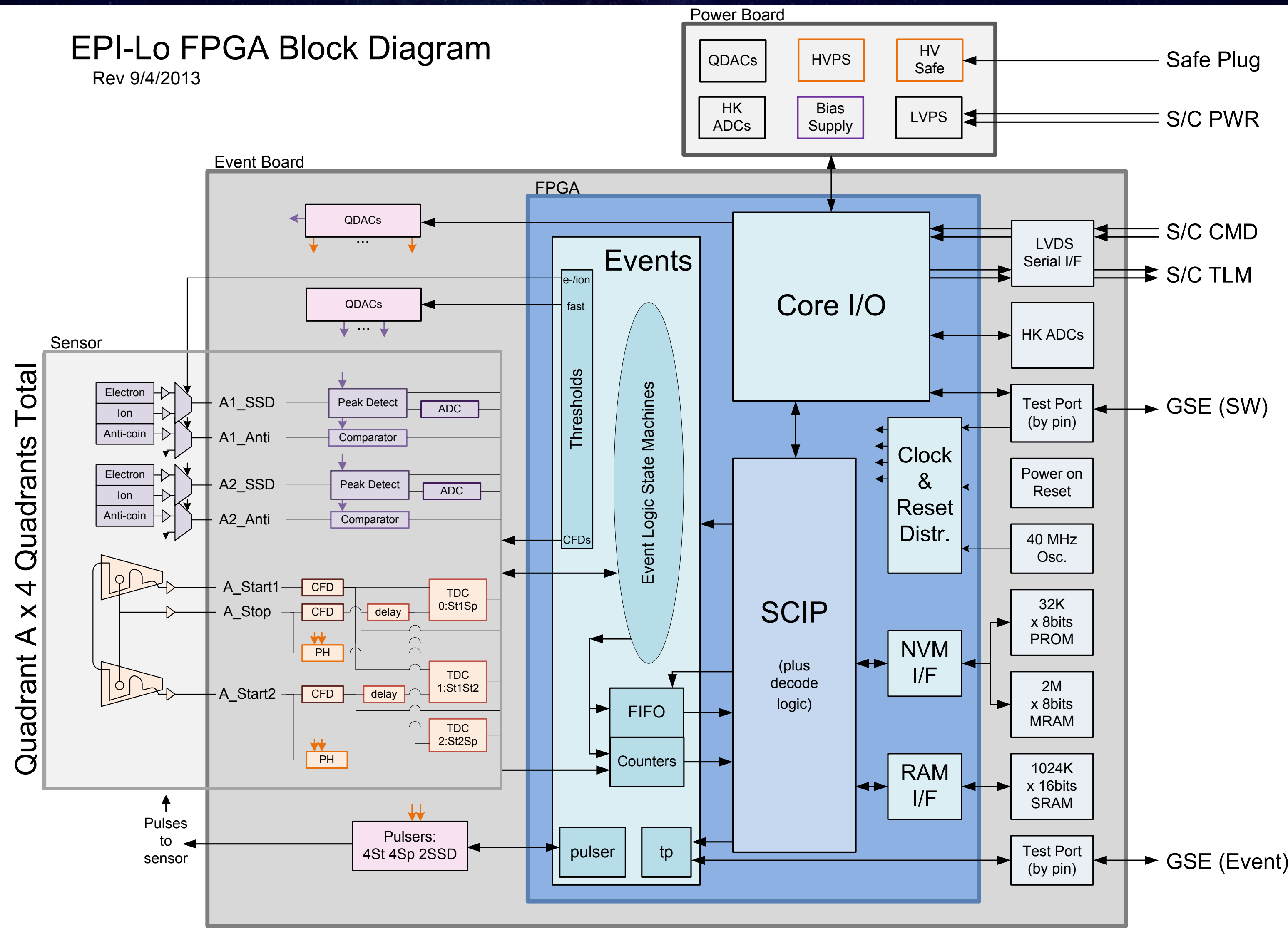


# Sensor Voltages




- Voltage Control Cartoon

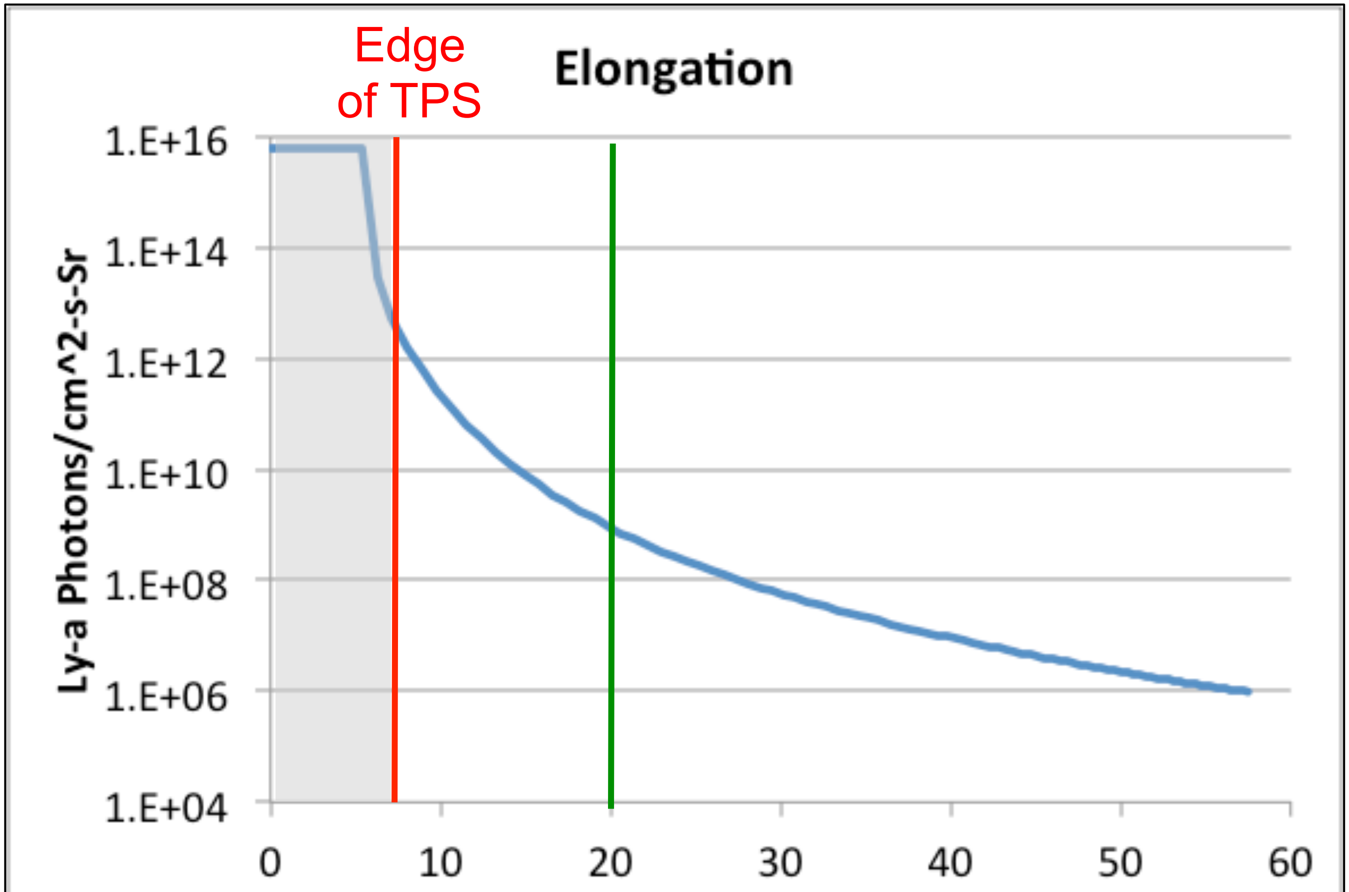
# EPI-Lo Block Diagram



# 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 ~3.5% of a foil area, so one pinhole can reduce effectiveness of attenuation to ~1/30.

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

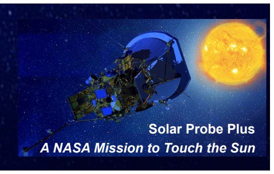



Intensity of Ly-α EUV vs elongation. Most EPI-Lo entrances include angles no closer than 20 degrees elongation (which implies a maximum Ly-α intensity of ~$10^9$). For 4 apertures close to the TPS, the maximum is ~$10^{12}$, but average ~$10^{10}$.

# Light & Dust Mitigation

- Dust may produce pinholes in the Start and collimator foils. Foils are designed to stop solar wind energy electrons. Pinholes may account for as much as ~3.5% of a foil area, so one pinhole can reduce effectiveness of attenuation to ~1/30.
- Solar wind electrons have an energy of ~100eV or less. If these enter the Start foils (through a pin hole), the electron optics will nominally guide them to the Start areas of the MCP.
- The solar wind electron flux is ~$2 \times 10^{12}$/cm$^2$-s-sr. A foil pinhole, if it includes the full area of a support grid element, is ~$6.25 \times 10^{-4}$ cm$^2$. The angular acceptance of a collimator is ~.02 sr. So the geometric factor of a pinhole is ~$1.25 \times 10^{-5}$cm$^2$sr. So the flux through a pinhole would be expected to be ~$2.5 \times 10^7$/s. If every aperture had 1 pinhole, the total for a quadrant would be ~$5 \times 10^8$/s, clearly too much.
- Adding a second foil in each aperture would greatly reduce the number of solar wind electrons expected to enter the TOF volume, but would still result in ~$5 \times 10^6$/s, a bit more than we would like.
- Mitigation might involve either a third foil, or a design for which pinholes are either much smaller than a grid element, or low probability.

# Light & Dust Mitigation




| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Ly-α Flux** | **Near TPS** | | Elevation | 0 | 22.5 | 45 | 67.5 | 90 | **total** |
| Photons/cm2-s | | | Total EPI-Lo GF (front foils) | 0.312 | 0.062 | 0.048 | 0.022 | 0.026 | **0.470** |
| 1.00E+11 | **Quadrant** | | Quadrant EPI-Lo GF (front foils) | 0.078 | 0.016 | 0.012 | 0.006 | 0.006 | **0.117** |
| **Photons/cm2-s-Sr** | | | UV rates (#/s/foil-elev) | 1.24E+09 | 2.47E+08 | 1.89E+08 | 8.94E+07 | 1.03E+08 | **1.869E+09** |
| **1.59E+10** | | | Single Foil projected area | 0.103 | 0.046 | 0.022 | 0.015 | 0.014 | **0.200** |
| | Pinhole Area | 0.0005 | Pinhole fraction | 0.005 | 0.011 | 0.022 | 0.034 | 0.036 | **0.107** |
| | # pinholes/foil | 1 | UV Flux Holes | 6.01E+06 | 2.70E+06 | 4.23E+06 | 3.01E+06 | 3.66E+06 | **1.96E+07** |
| | 2nd foil pinhole | 1 | UV Flux Hole 2nd foil | 2.91E+04 | 2.95E+04 | 9.47E+04 | 1.01E+05 | 1.31E+05 | **3.85E+05** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Ly-α Flux** | **>20° Elongation** | | Elevation | 0 | 22.5 | 45 | 67.5 | 90 | **total** |
| Photons/cm2-s | | | Total EPI-Lo GF (front foils) | 0.312 | 0.062 | 0.048 | 0.022 | 0.026 | **0.470** |
| 1.00E+10 | **Quadrant** | | Quadrant EPI-Lo GF (front foils) | 0.078 | 0.016 | 0.012 | 0.006 | 0.006 | **0.117** |
| **Photons/cm2-s-Sr** | | | UV rates (#/s/foil-elev) | 1.24E+08 | 2.47E+07 | 1.89E+07 | 8.94E+06 | 1.03E+07 | **1.87E+08** |
| **1.59E+09** | | | Single Foil projected area | 0.103 | 0.046 | 0.022 | 0.015 | 0.014 | **0.200** |
| | Pinhole Area | 0.0005 | Pinhole fraction | 0.005 | 0.011 | 0.022 | 0.034 | 0.036 | **0.107** |
| | # pinholes/foil | 1 | UV Flux Holes | 6.01E+05 | 2.70E+05 | 4.23E+05 | 3.01E+05 | 3.66E+05 | **1.96E+06** |
| | 2nd foil pinhole | 1 | UV Flux Hole 2nd foil | 2.91E+03 | 2.95E+03 | 9.47E+03 | 1.01E+04 | 1.31E+04 | **3.85E+04** |

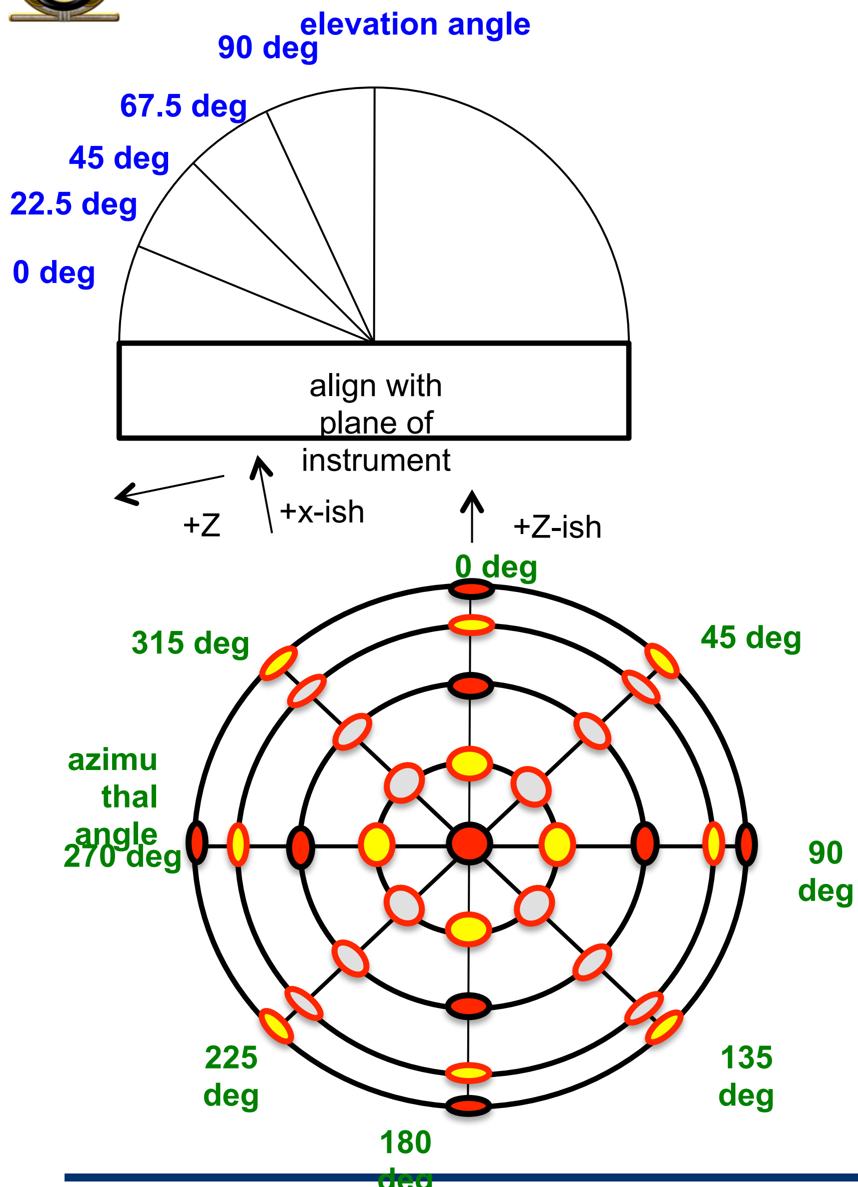
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Solar Wind Electron flux** | | | Elevation | 0 | 22.5 | 45 | 67.5 | 90 | **total** |
| electrons/cm2-s | | | Total EPI-Lo GF (front foils) | 0.312 | 0.062 | 0.048 | 0.022 | 0.026 | **0.470** |
| 2.00E+12 | **Quadrant** | | Quadrant EPI-Lo GF (front foils) | 0.078 | 0.016 | 0.012 | 0.006 | 0.006 | **0.117** |
| **electrons/cm2-s-Sr** | | | Elecrtron rates (#/s/foil-elev) | 2.48E+10 | 4.94E+09 | 3.78E+09 | 1.79E+09 | 2.05E+09 | **3.739E+10** |
| **3.18E+11** | | | Single Foil projected area | 0.103 | 0.046 | 0.022 | 0.015 | 0.014 | **0.200** |
| | Pinhole Area | 0.0005 | Pinhole fraction | 0.005 | 0.011 | 0.022 | 0.034 | 0.036 | **0.107** |
| | # pinholes/foil | 1 | Electron Flux Holes | 1.20E+08 | 5.40E+07 | 8.46E+07 | 6.01E+07 | 7.32E+07 | **3.92E+08** |
| | 2nd foil pinhole | 1 | e Flux Hole 2nd foil | 5.82E+05 | 5.90E+05 | 1.89E+06 | 2.02E+06 | 2.61E+06 | **7.70E+06** |

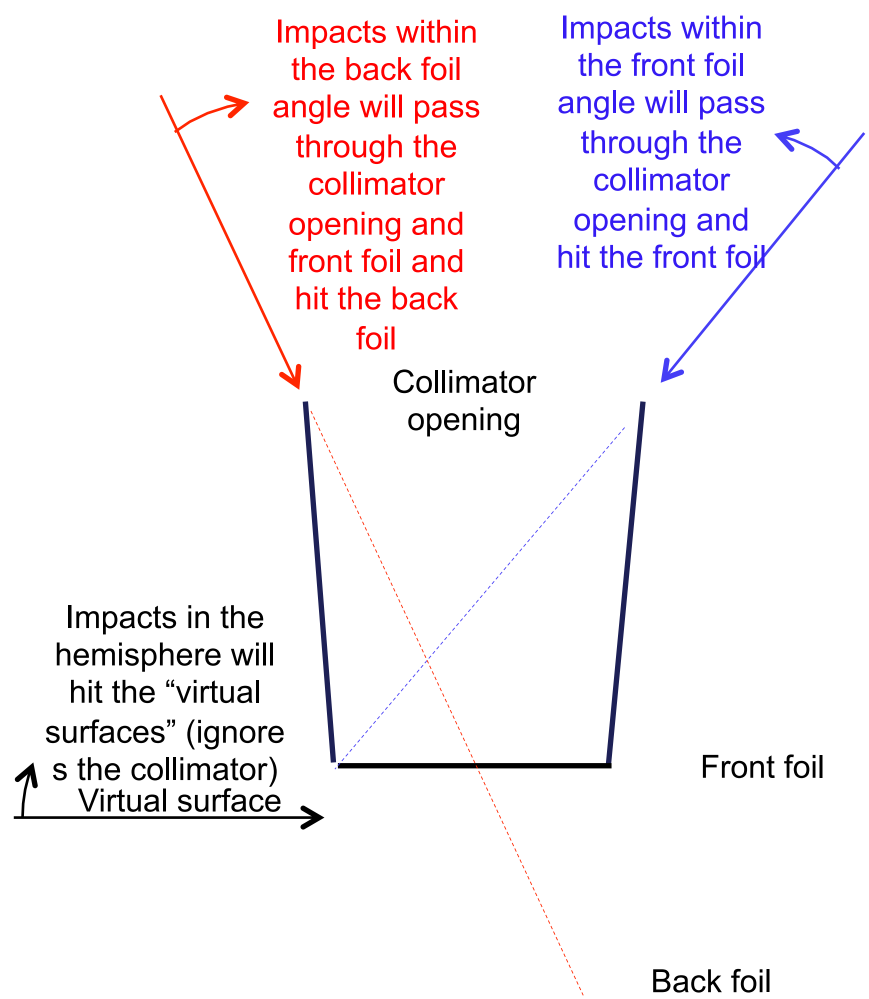
Calculation of impact of pinholes on rates. Because photoelectron efficiency is <10%, the UV rates are not a problem. The solar wind electron rates could be a problem.

# Light & Dust Mitigation

- TBD

# Dust: Simulating the Environment

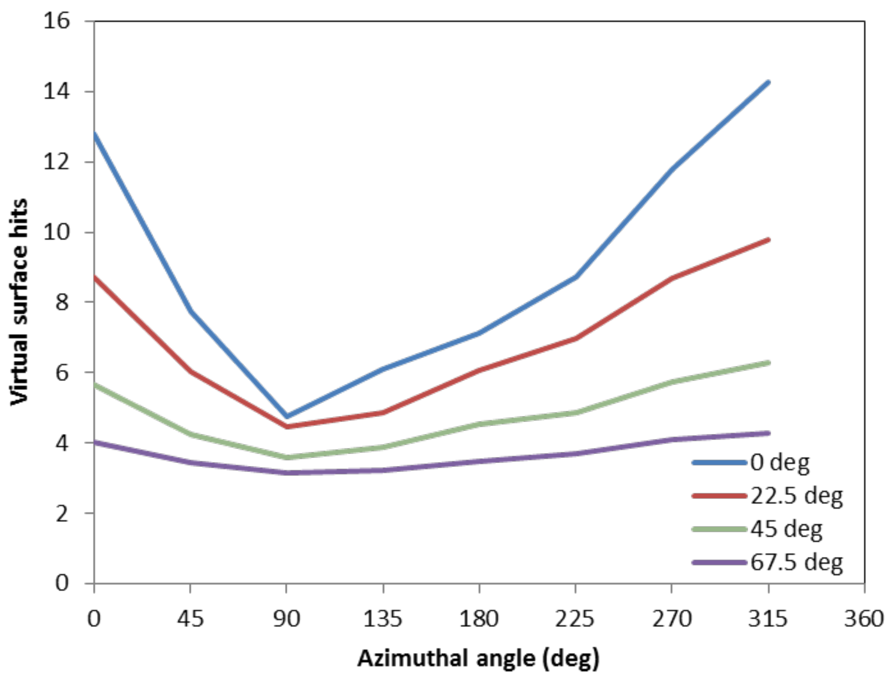


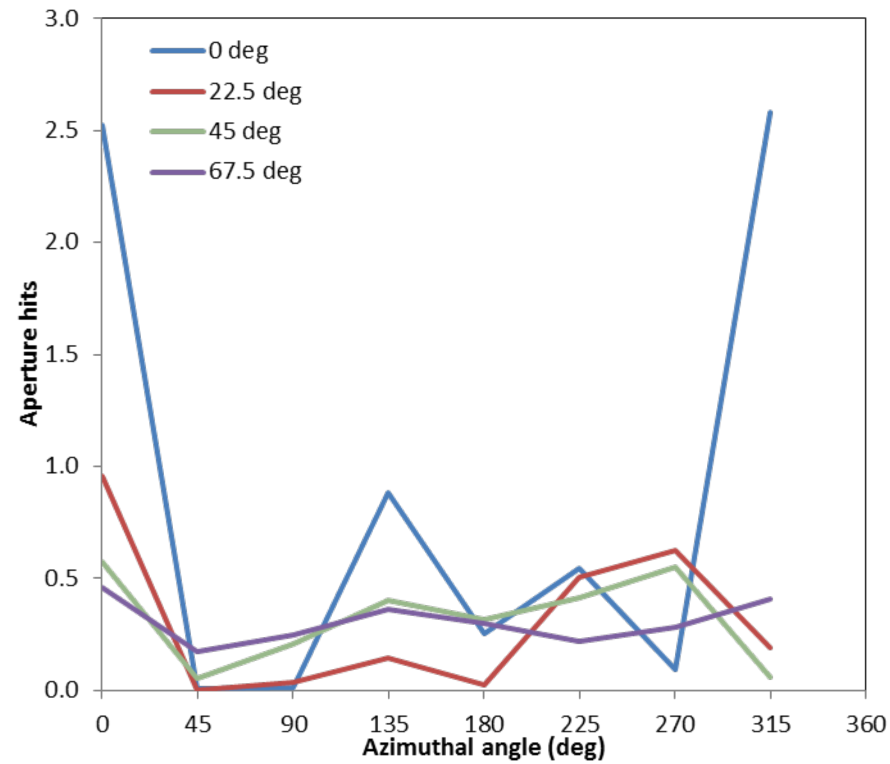




NOTE: actually only polar angle is limited, not position on surface, so foil area was adjusted to account for this and produce actual foil geometry factors,

# Dust: Simulating the Environment

- Each unprotected foil would expect ~10 damage-inducing hits per mission. Reduced to ~1 hit per mission with collimator. Order of magnitude decrease.



# Dust: Lab tests

- TBD

# SLIDE PREPARATION NOTES

Are we handling dust in this presentations?  Assuming yes.

Should we discuss photons suppression here?  Assuming yes, it's background.

How about details like how the MCPs work (in general)?  Or this could be handled when someone discusses the anode boards.  Special features like the inter-plate mask (or is that handled in a mechanical section)?

Backup slides: MCPs

We are only supposed to respond to requirements, so I wasn't going to go into any of the rate estimates from the work that I (Matt) and Rob D. did since that is for goals.  Is this the right approach?

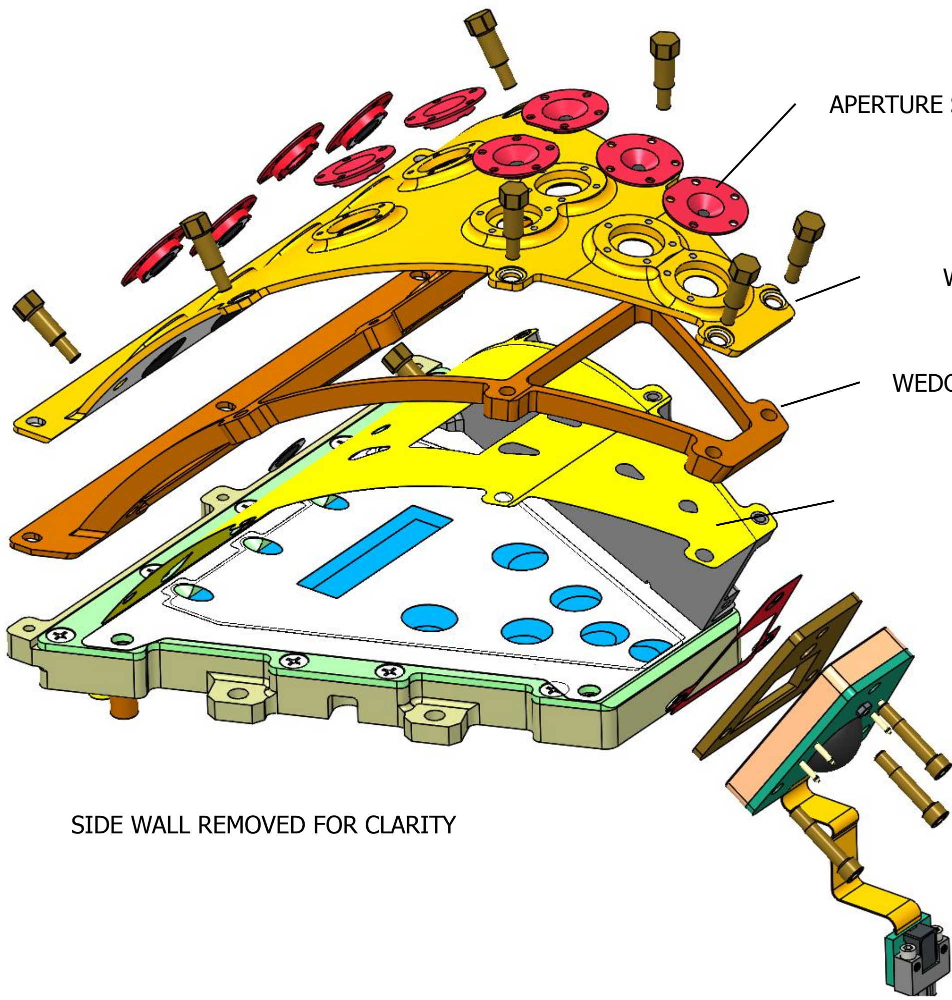
# Follow Up from Peer Reviews

- TBD

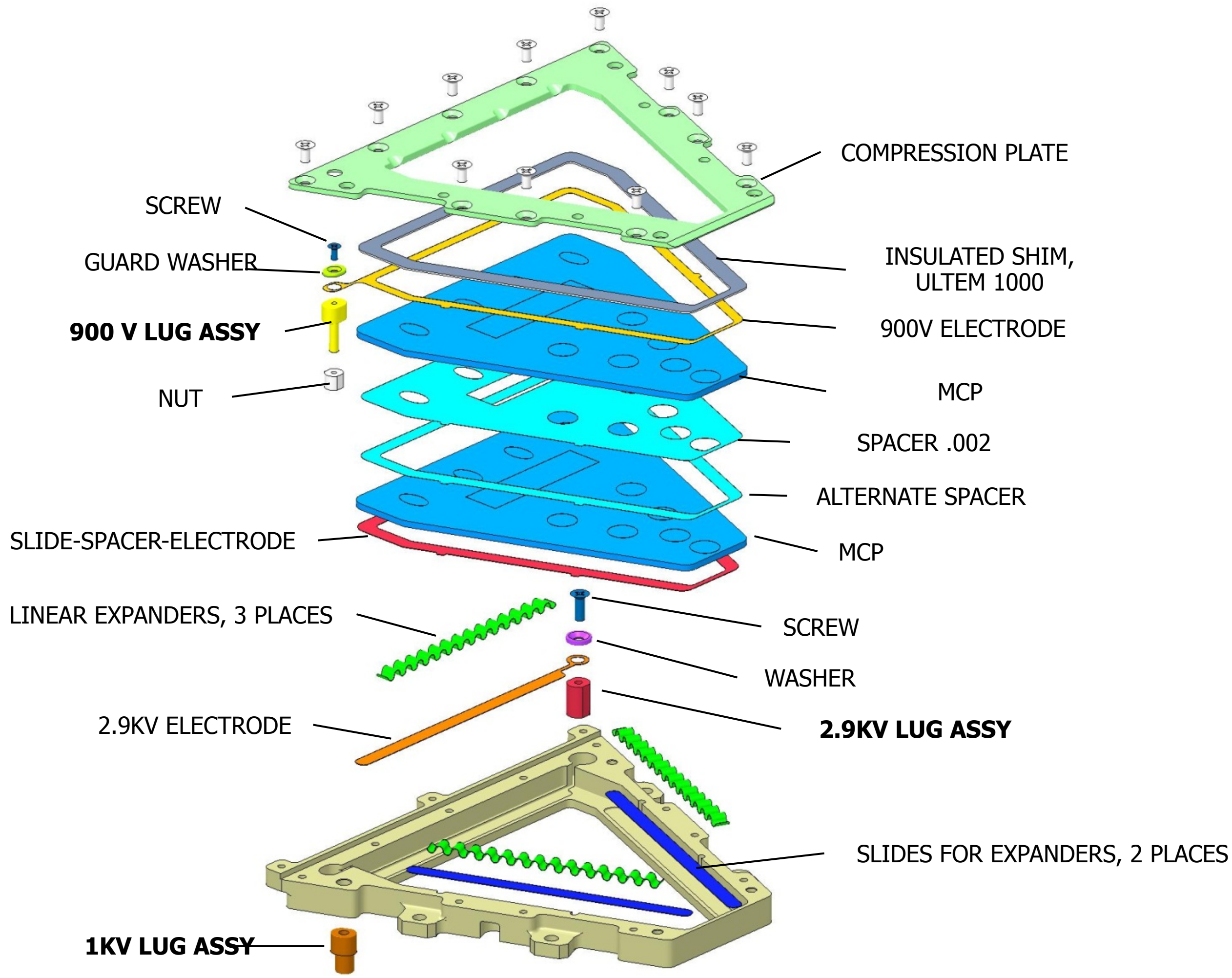
# Summary

- TBD

# Backup




**EPI-LO INDIVIDUAL SENSOR WEDGE ASSY CROSS SECTION**




**EXPLODED VIEW "NEW" MCP ASSEMBLY**

# Principles of Operation