On the suitability of CubeSats in Earth orbits for radiation testing of interplanetary payloads

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Effects of ionizing particle radiation

- Single Event Effects
- Charge build-up
- Displacement damage
- **False counts in sensors due to penetrating radiation**

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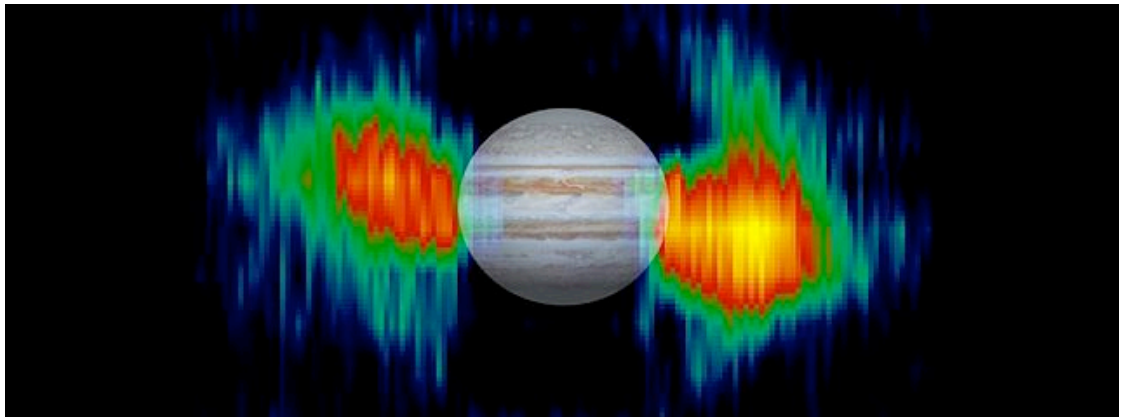
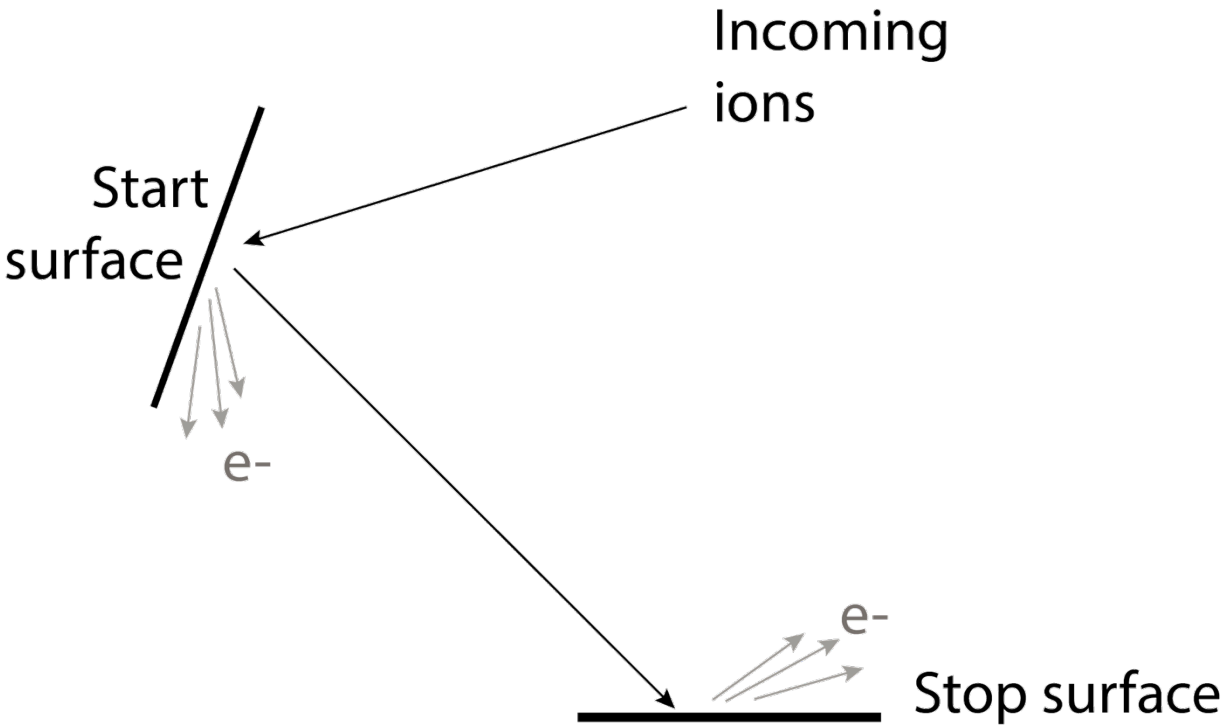


http://en.wikipedia.org/wiki/Magnetosphere_of_Jupiter#/media/File:Jupiter_radio.jpg

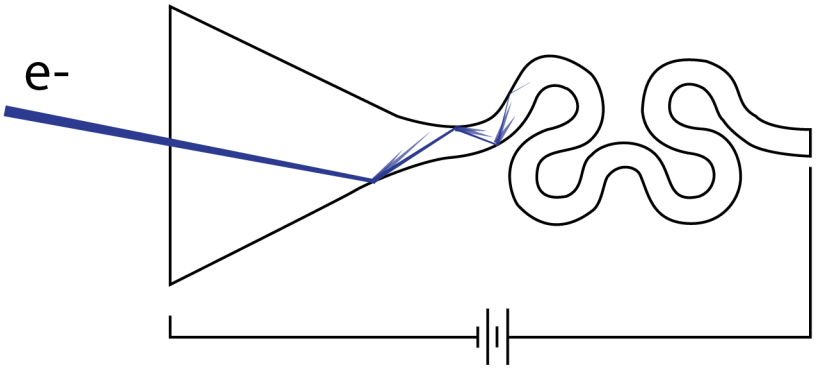
Time-of-flight chamber



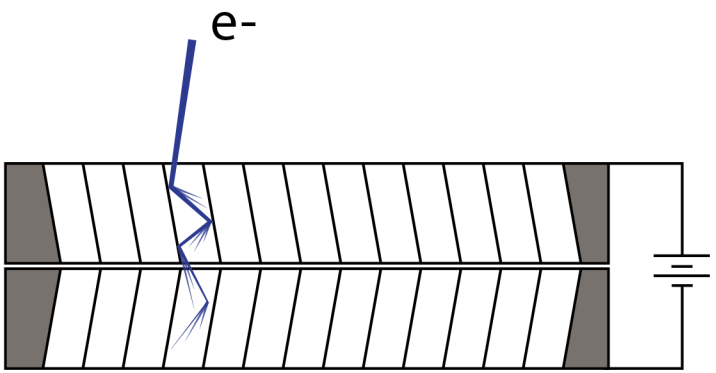
$$m = \frac{2W}{(\frac{L}{t_1 - t_0})^2}$$

Detecting secondary electrons

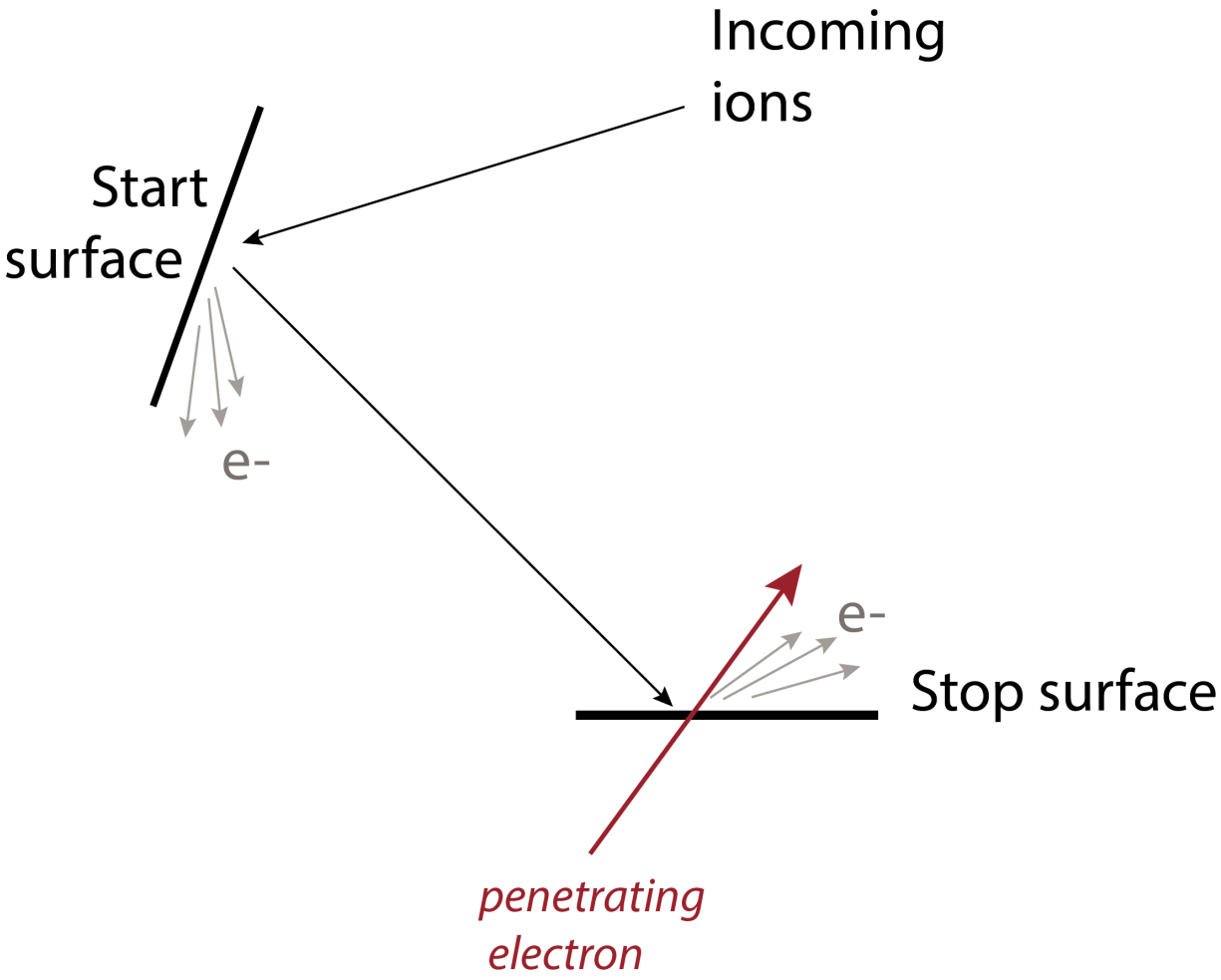
Channel Electron Multiplier (CEM)



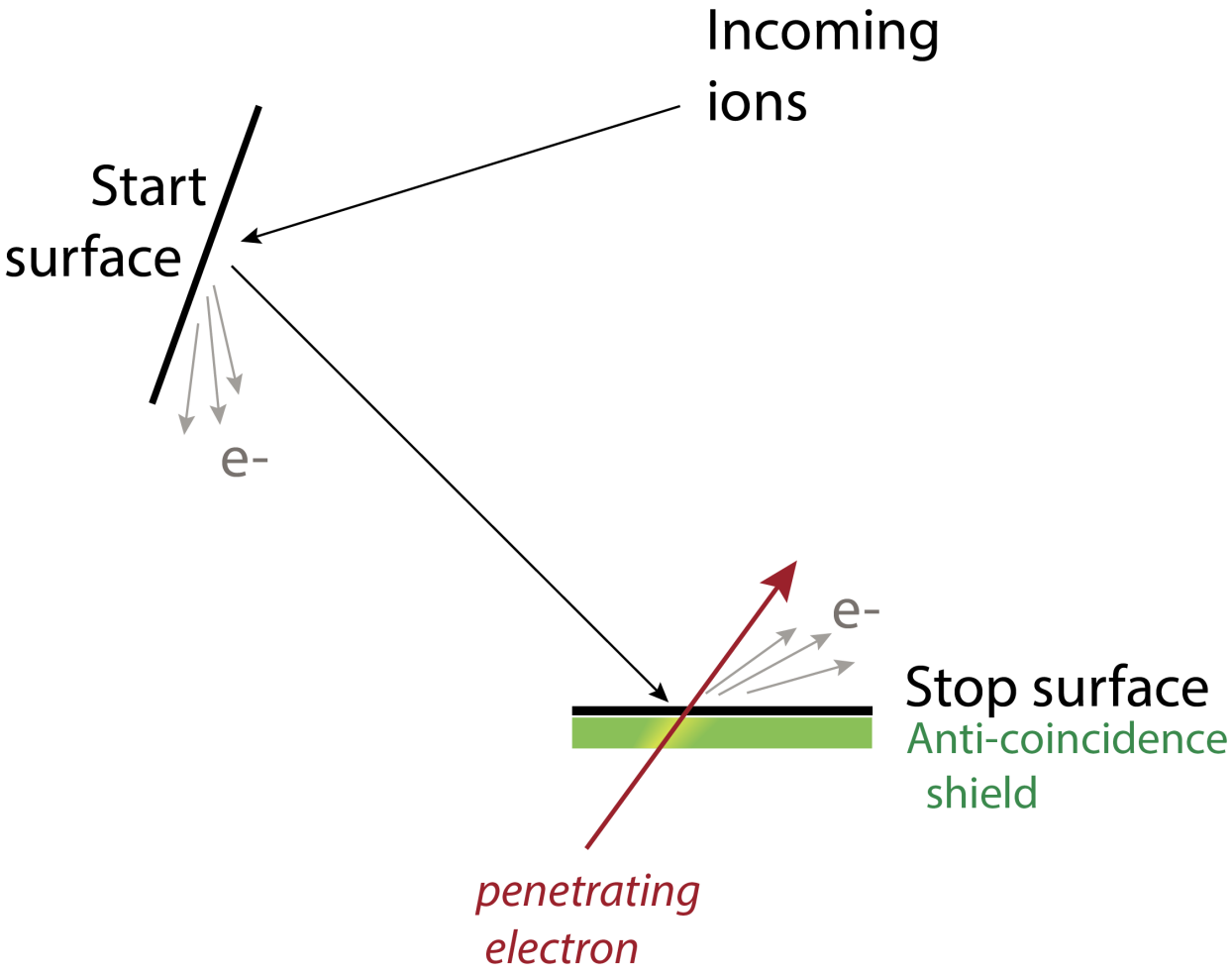
Micro-Channel Plate (MCP)



Time-of-flight chamber



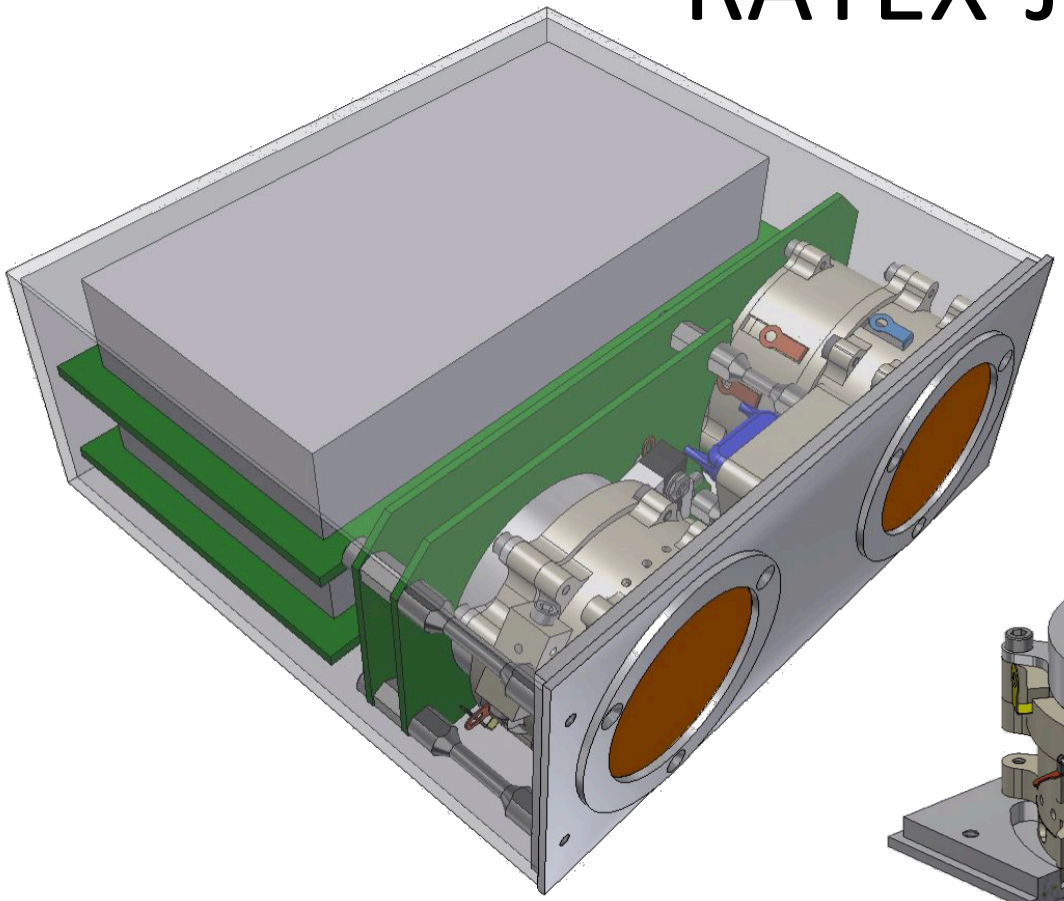
Time-of-flight chamber

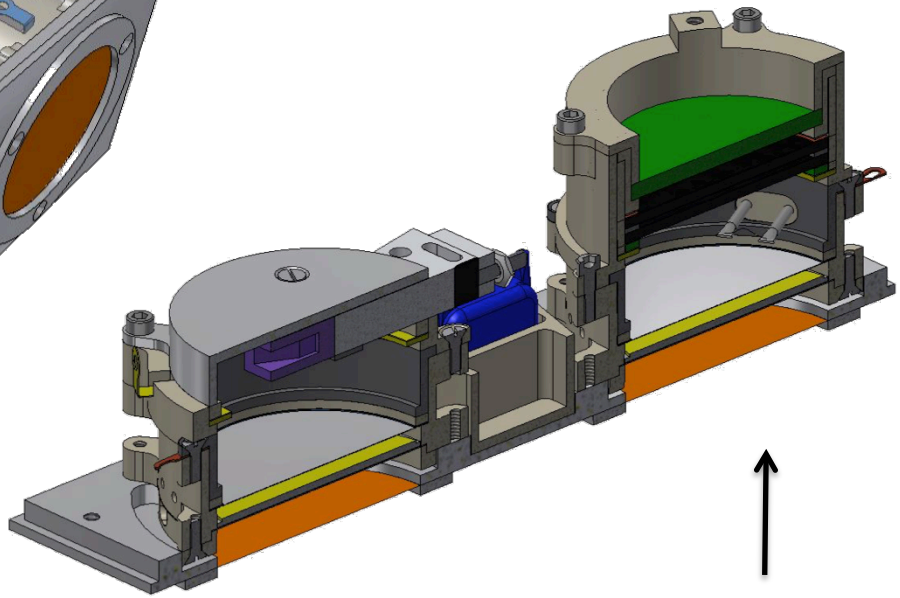


Case study: RATEX-J

- RAdiation Test EXperiment for JUICE
- Focuses on 2 radiation mitigation approaches:
  - Test of anti-coincidence system for the Jovian plasma Dynamics and Composition analyzer (JDC)
  - Characterization of MCP and CEM response to penetrating electrons
- Use of ground based and space borne testing platforms

RATEX-J

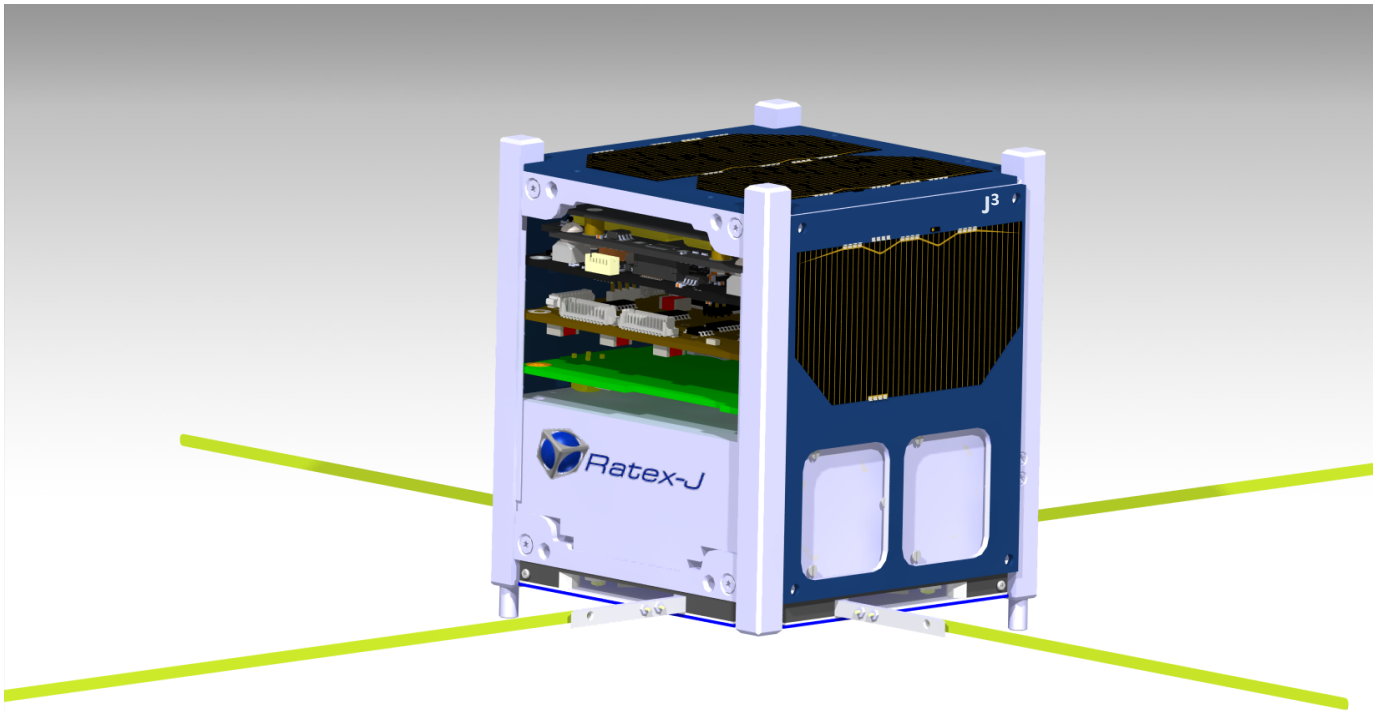




- 0.5 U
- Mass: 300 g
- Power consumption: 2.3 W

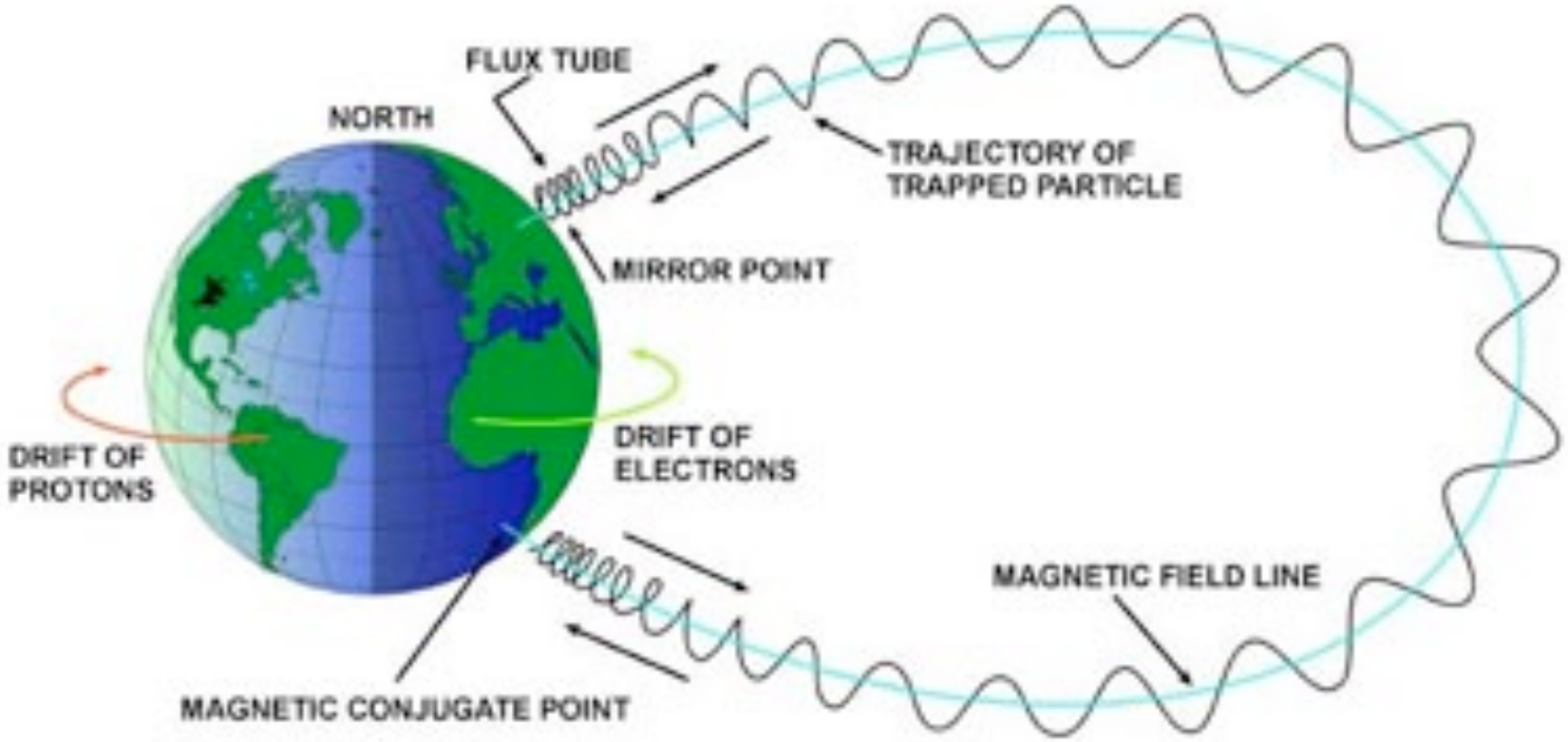
J3

- 1 U CubeSat, only COTS components



A.4.4-F6.: J³: CubeSats as a Platform for In-Orbit Verification of Scientific Instruments for Interplanetary Missions (Jonas Burgdorf, Atakan Sirin)

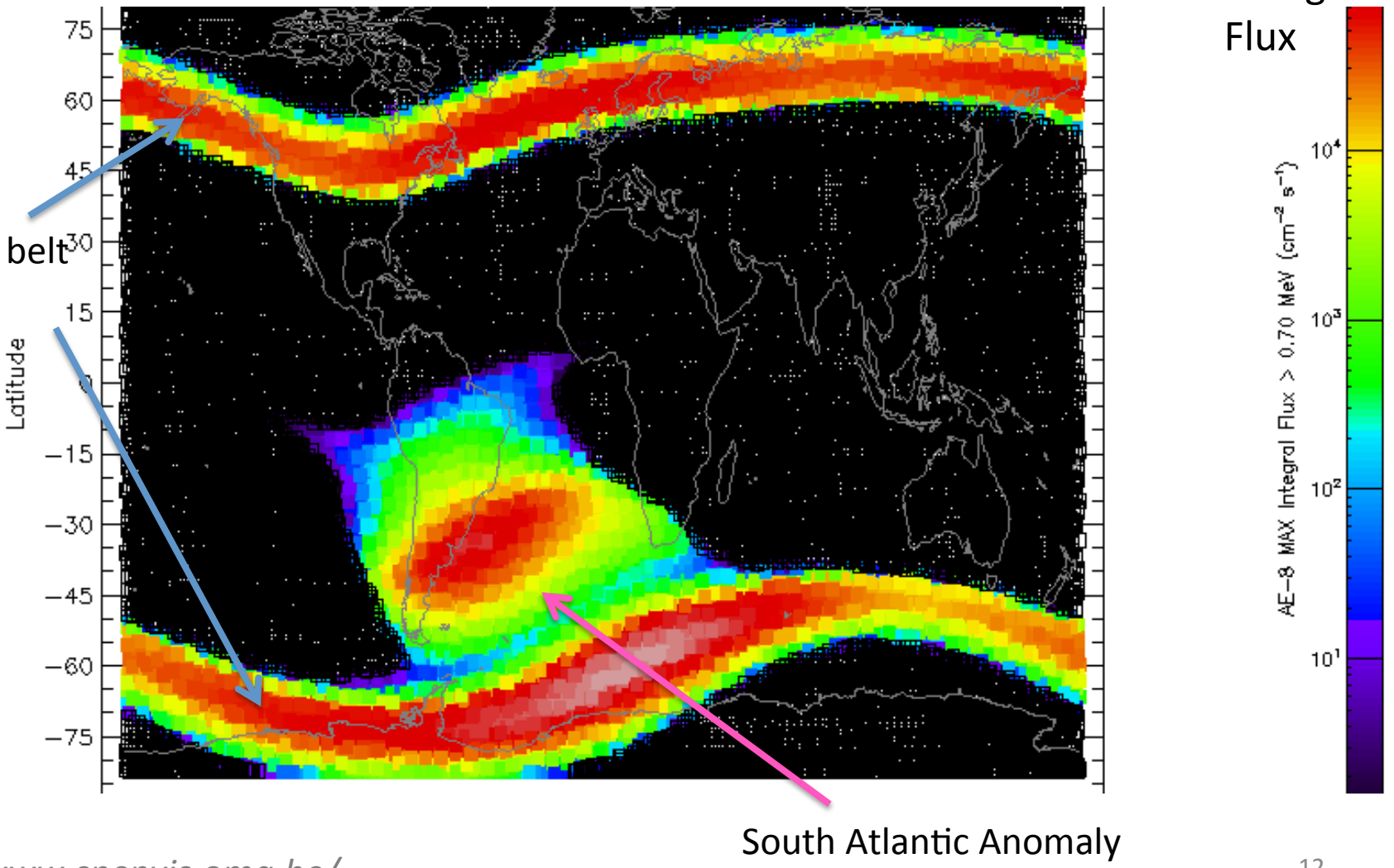
Electron motion



- **Gyration**
- **Bounce motion**
- Drift

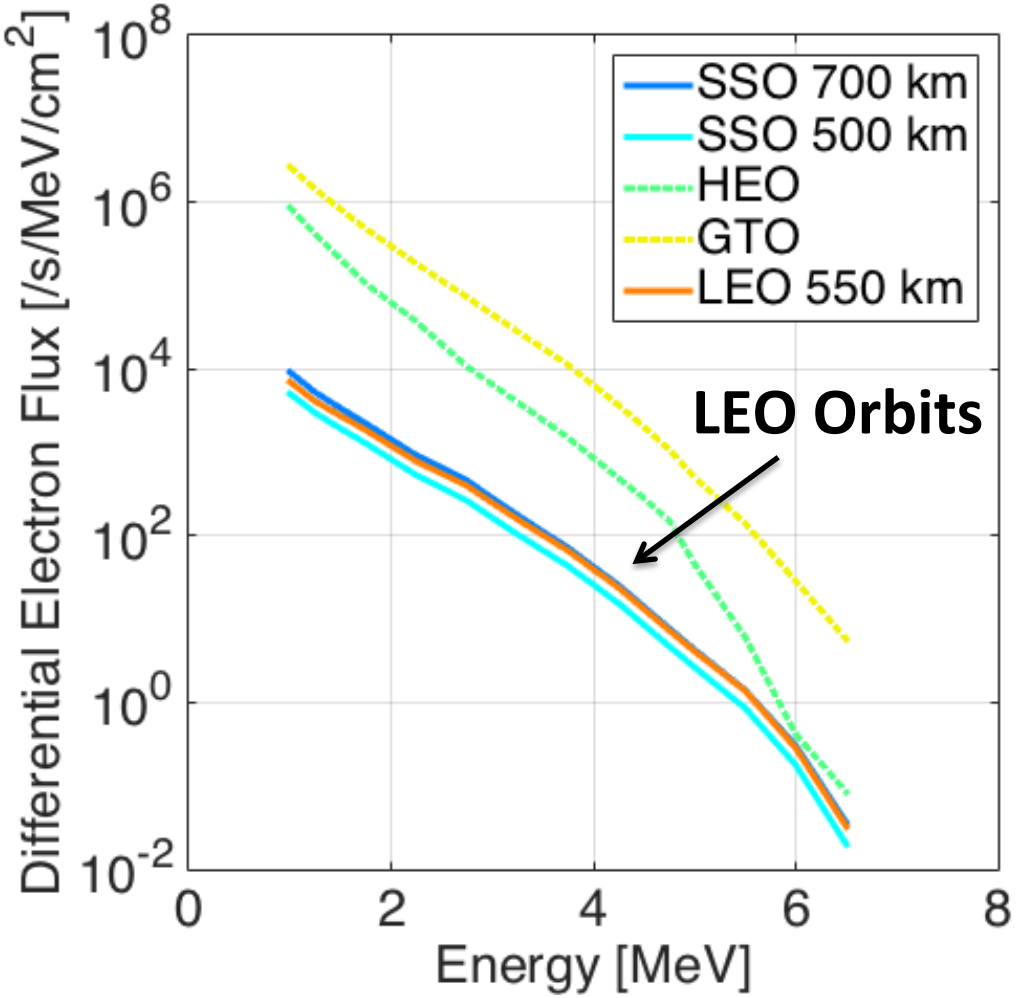
http://www.tethers.com/hivolt2.html

SPENVIS omnidirectional flux



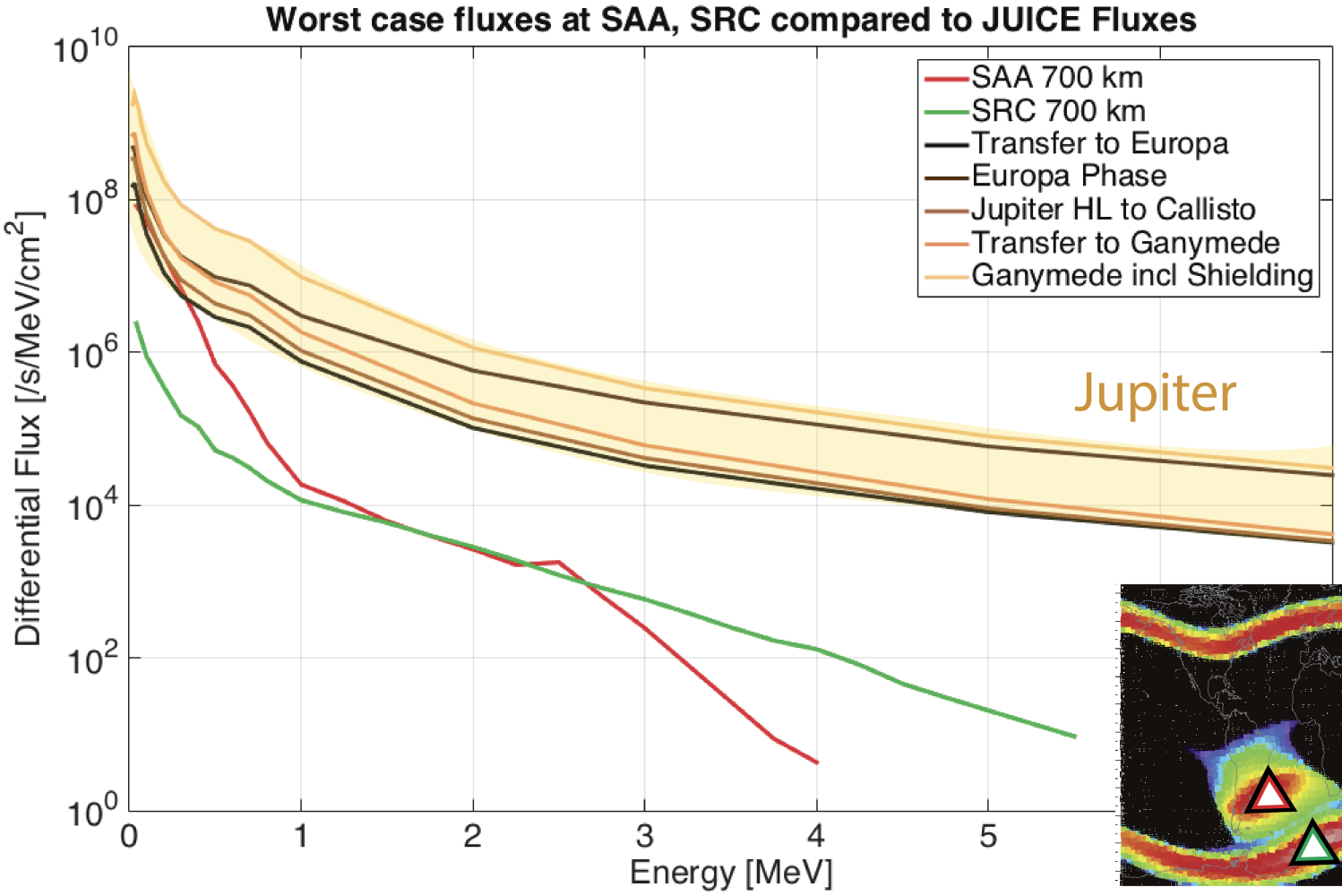
https://www.spenvis.oma.be/

Electron Fluxes in typical CubeSat Orbits

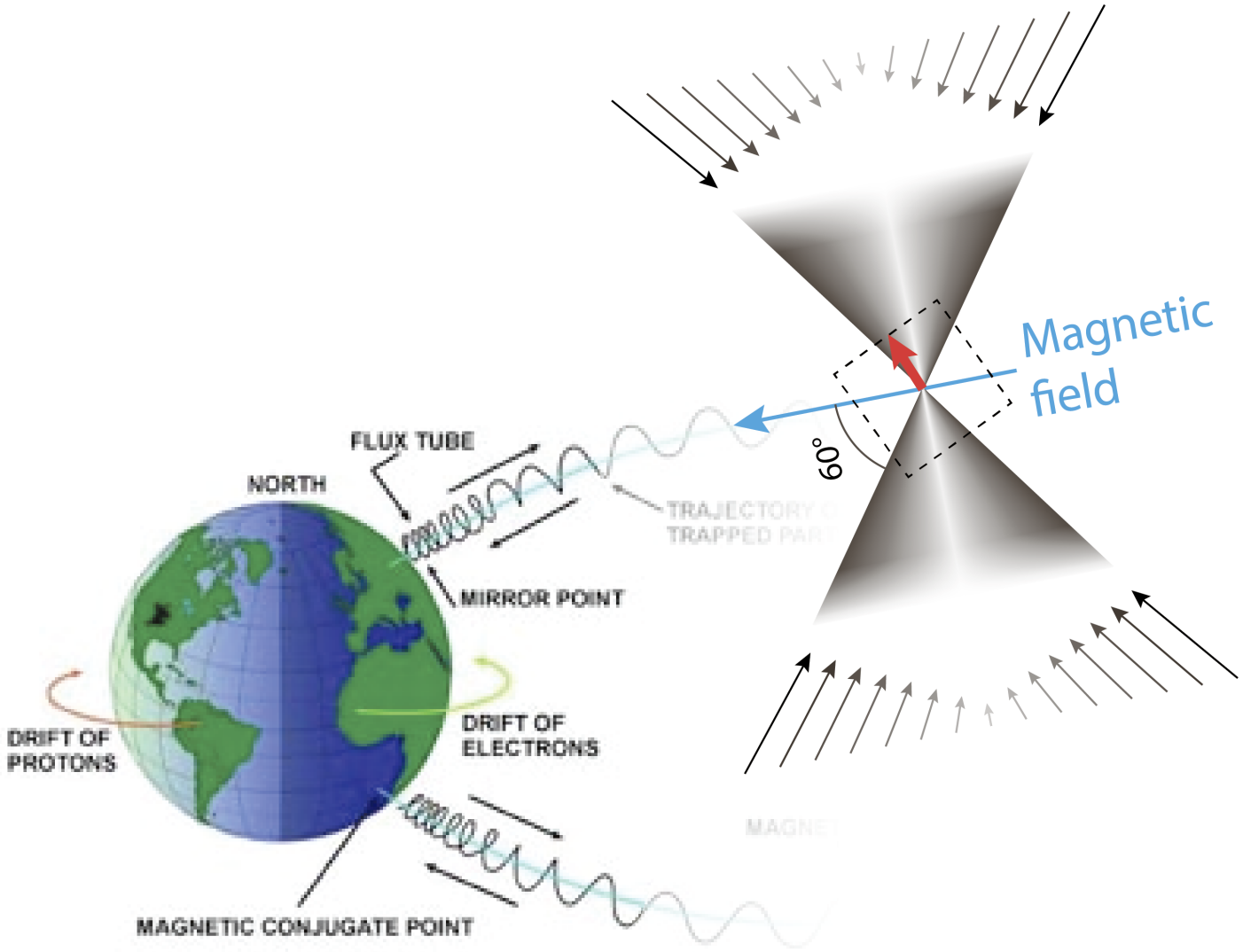


- Inclination > 63°
- Altitude is of minor importance considering the range feasible for CubeSats (<800 km)

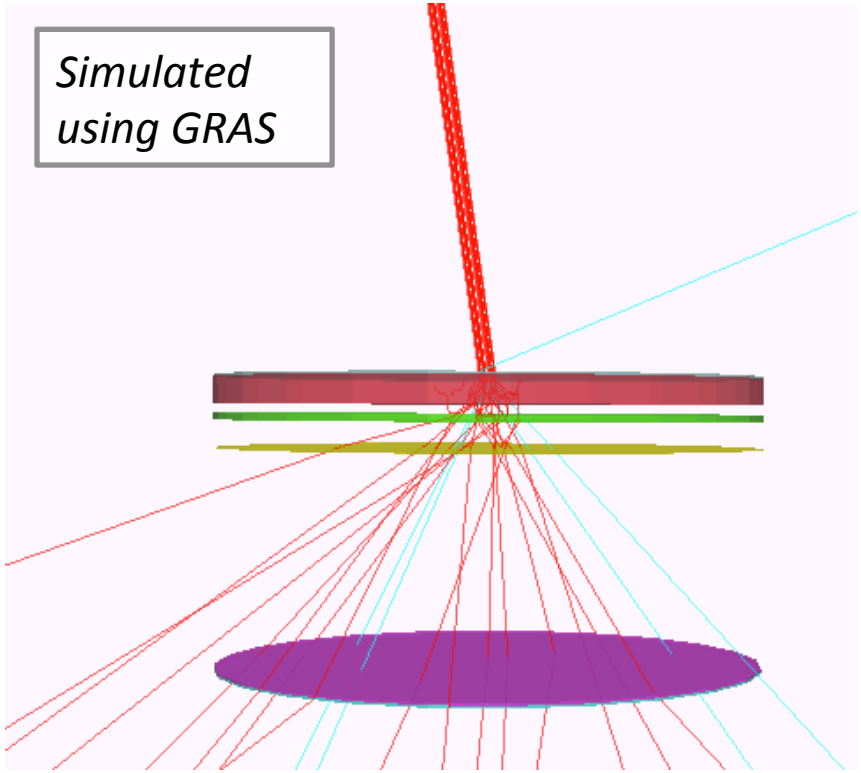
Maximum flux comparison: Earth-Jupiter

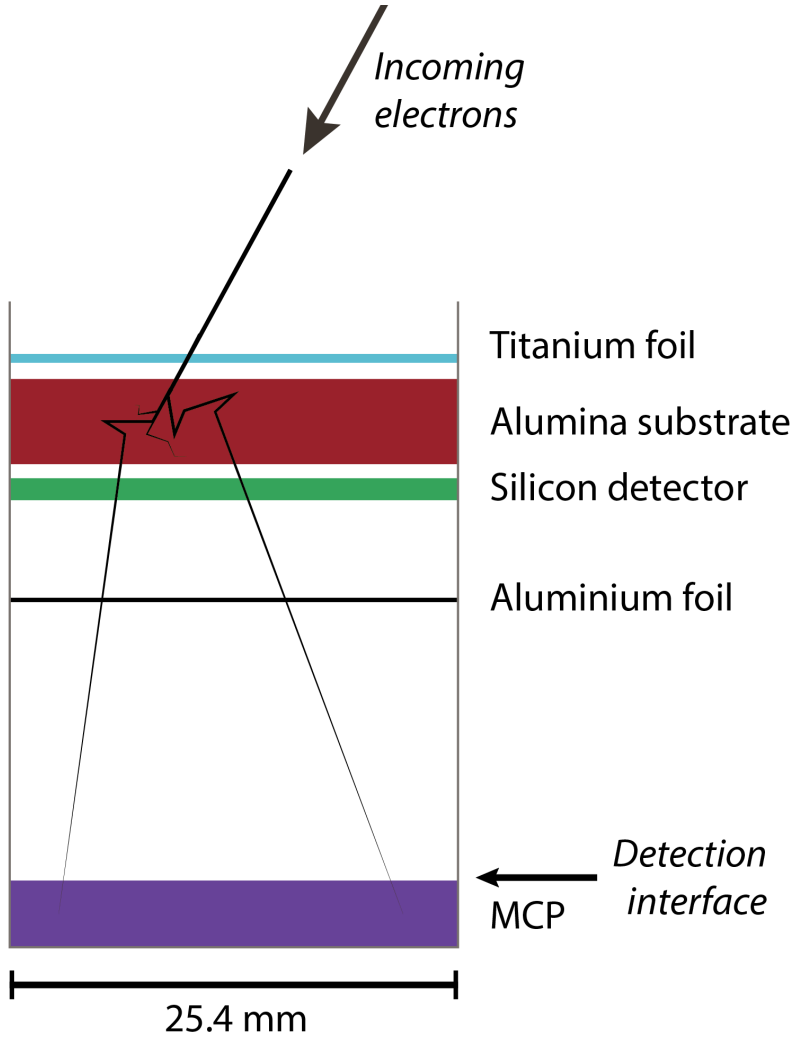


Directivity of Electron Flux



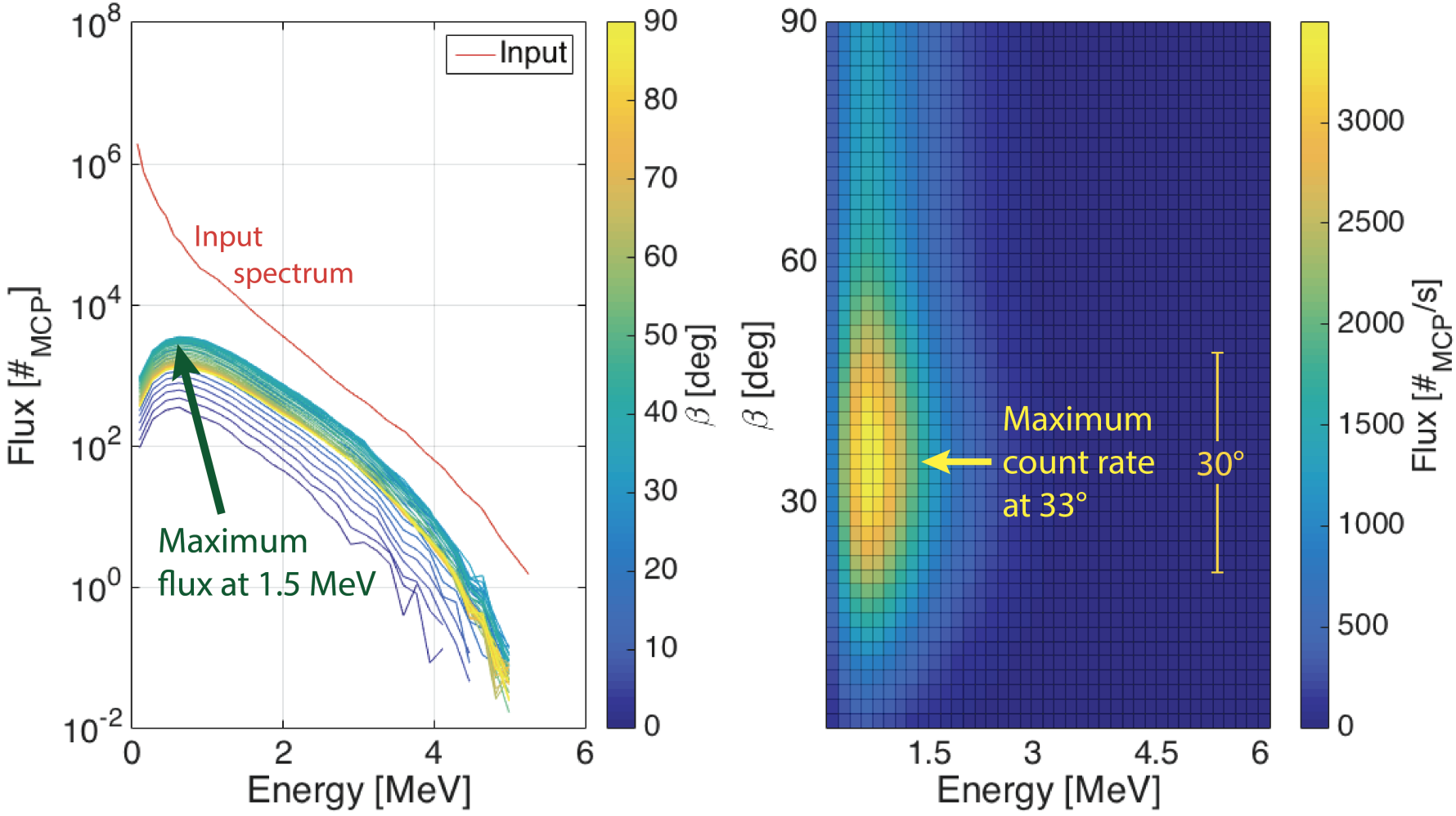
GRAS Simulations (Geant4)





http://space-env.esa.int/index.php/geant4-radiation-analysis-for-space.html

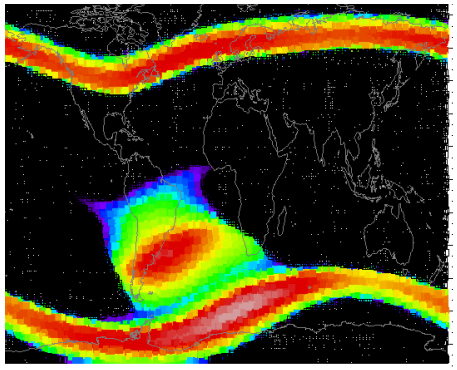
Expected Energy Spectrum



β: angle between instrument and magnetic field line

Summary of science requirements

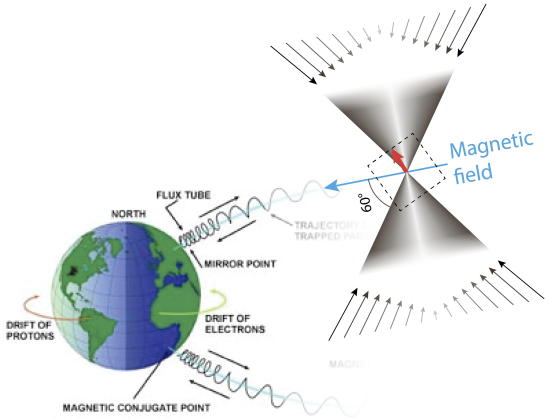
- Most interesting region: (southern) radiation belt crossing
  - SAA has higher fluxes but the electrons energy is too small to penetrate the sensor stack
  - Instrument duty cycle: ~20%



- Orbital inclination > 63°
  - Orbital altitude is of minor importance

- Attitude control: The angle the instrument makes with the local magnetic field vector shall be

  33° or 147° with an accuracy of ±15°



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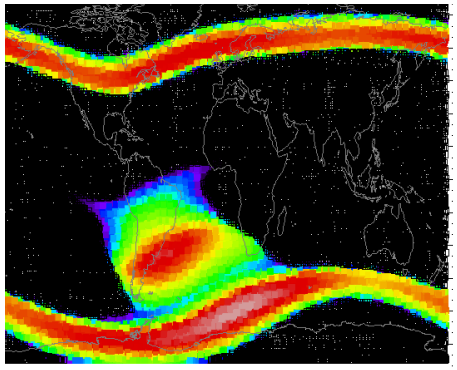

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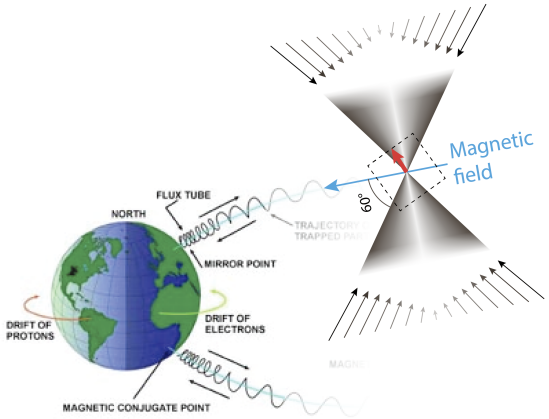
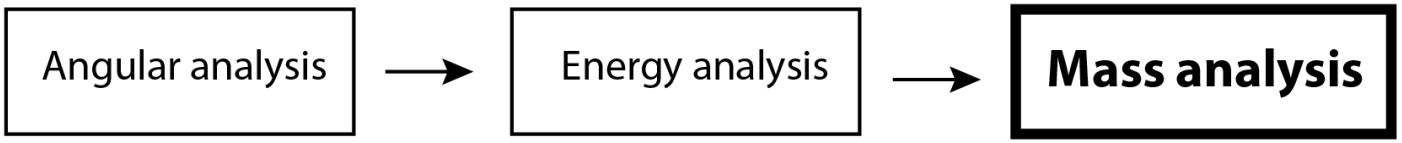


Thank you!

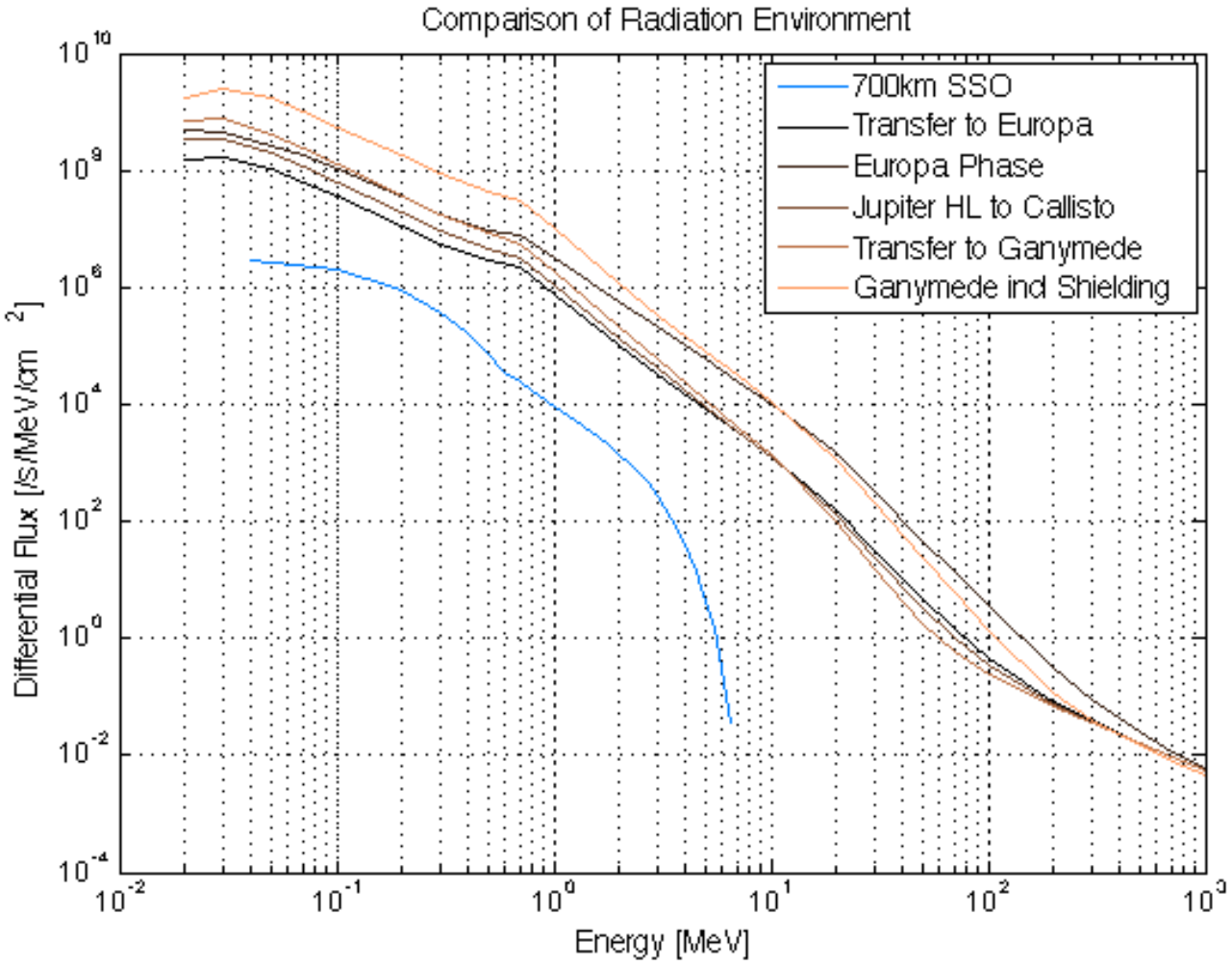
Backup slides

Particle Spectrometers

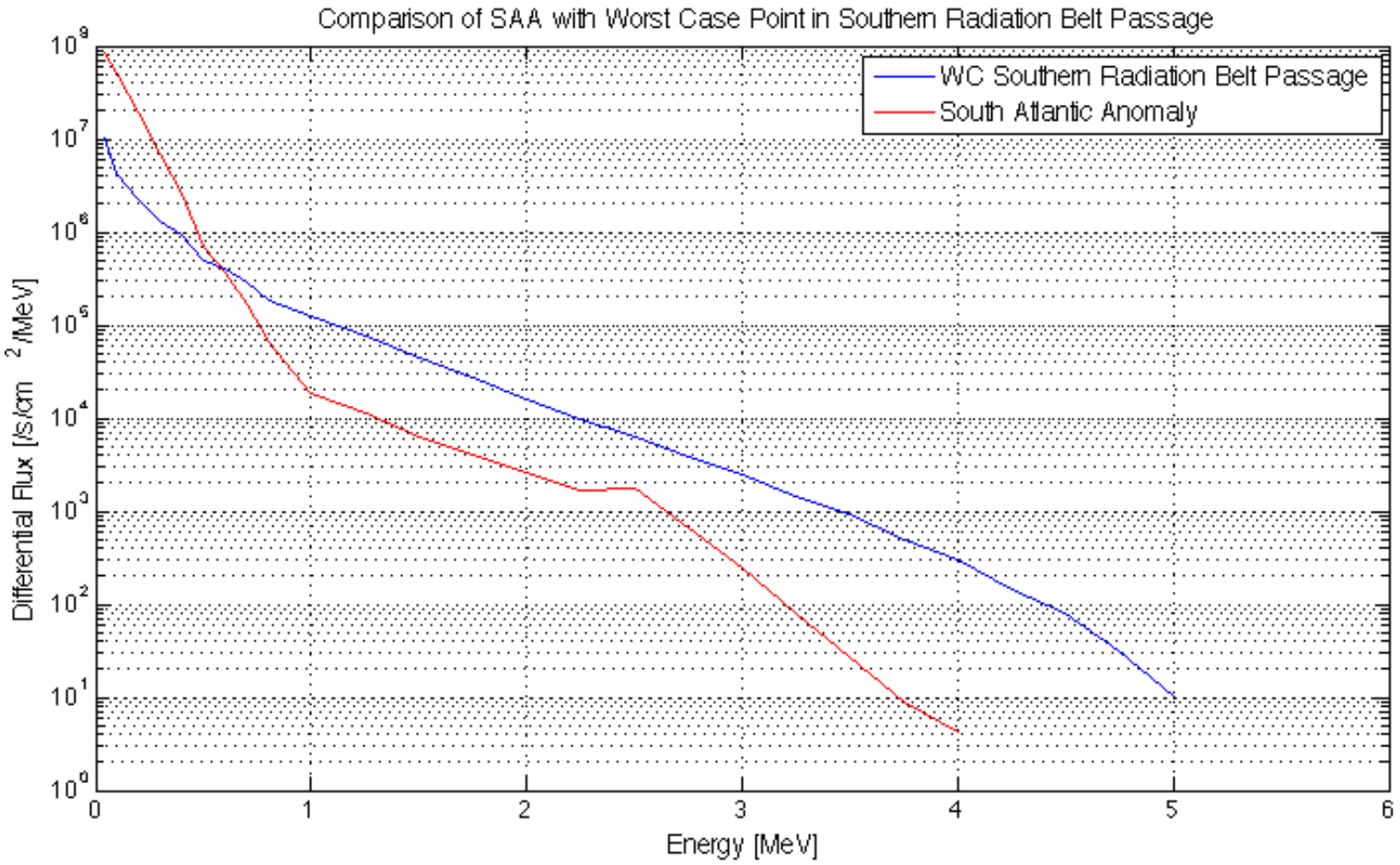
- If energy is known: mass can be determined via time-of-flight chamber



Average flux comparison: Earth-Jupiter

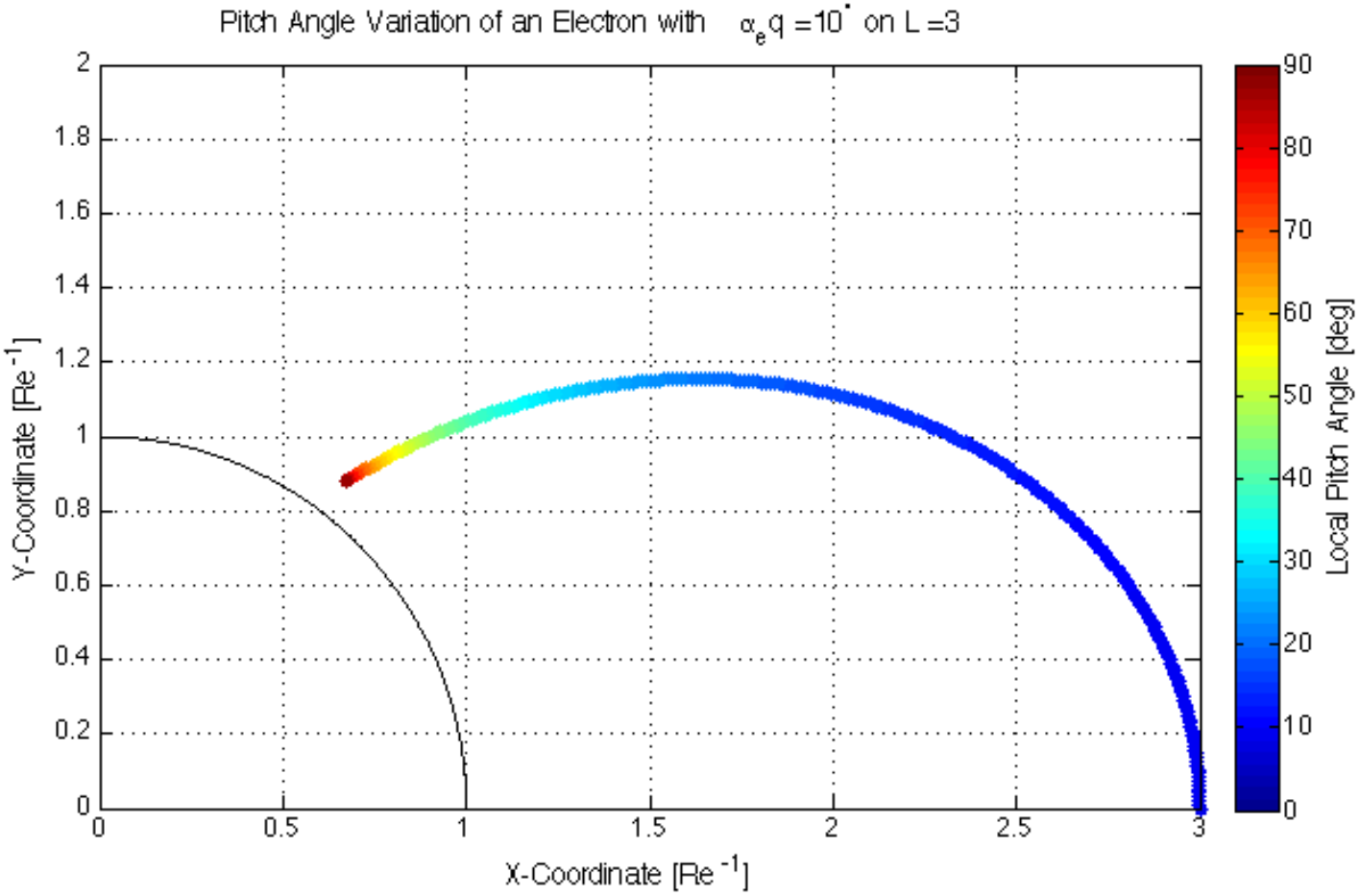


Highest Fluxes in Earth Orbit



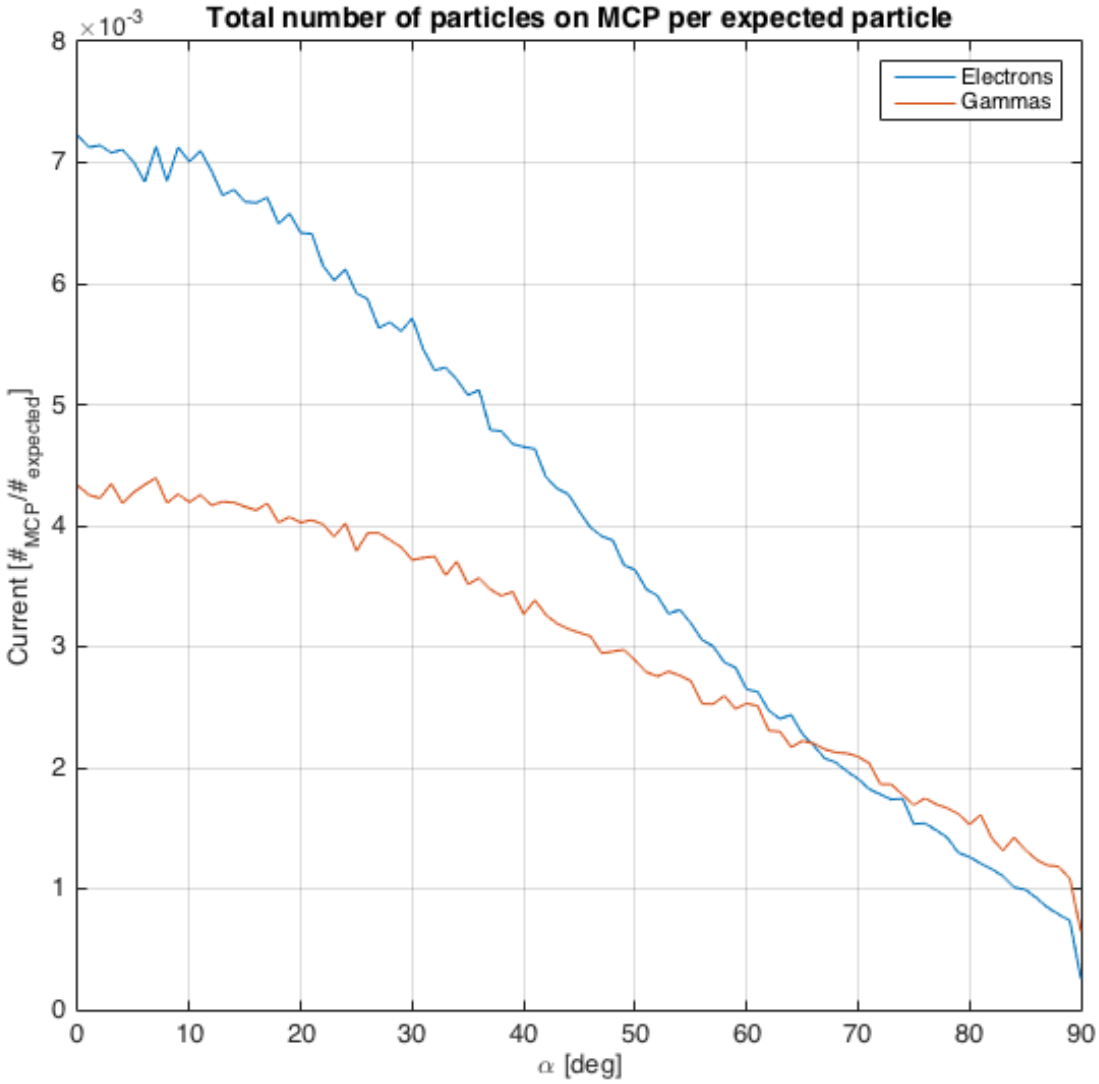
- Radiation belt crossing: higher fluxes at higher energies

Flux directionality: Pitch angle



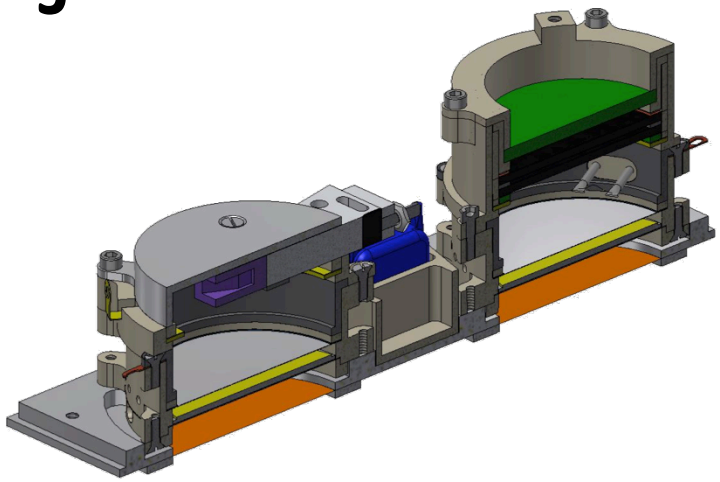
- Pitch angle increases with field strength

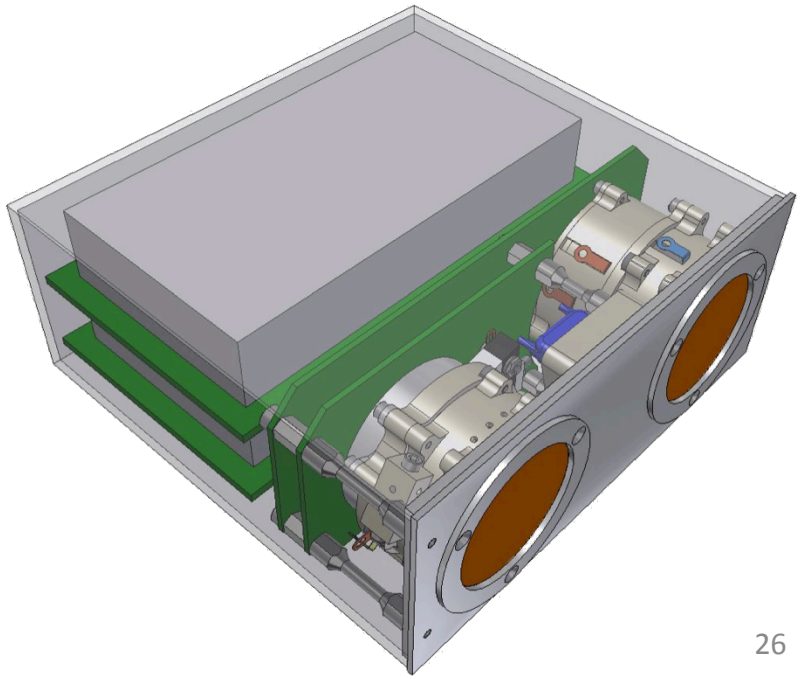
Expected Count Rate



RATEX-J

- 3 different particle detectors
  - Semiconductor Detector
    -> anti-coincidence shield
  - Multi Channel Plate (MCP)
  - Ceramic Channel Electron Multiplier (CCEM)





Choosing an orbit for radiation testing

- Evaluation of regularly orbits offered by Spaceflight:
  - 700 km SSO
  - 500 km SSO
  - 15 000 x 39 000 HEO
  - 185 x 36 000 GTO
  - 550 km 63.4° LEO

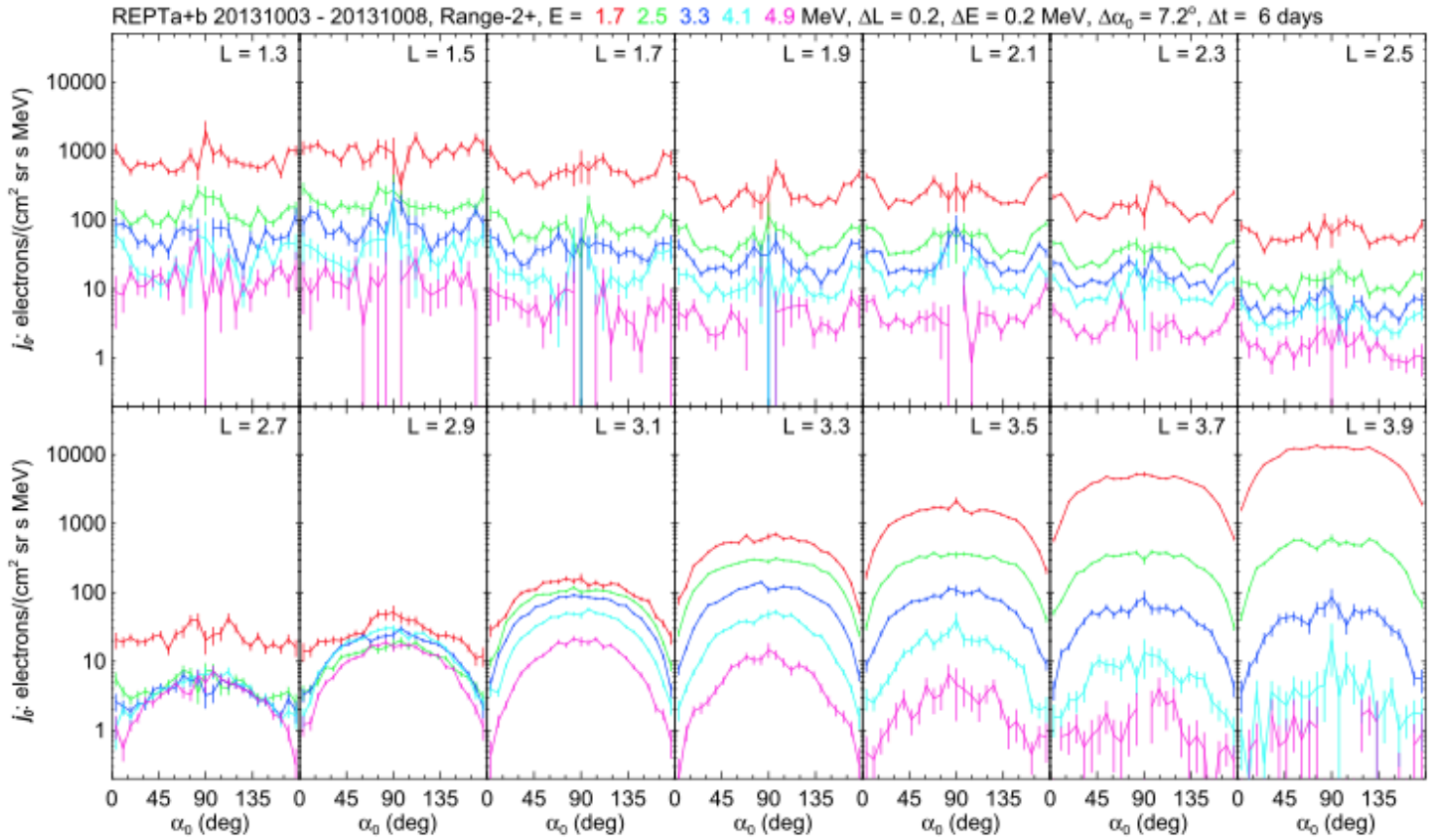
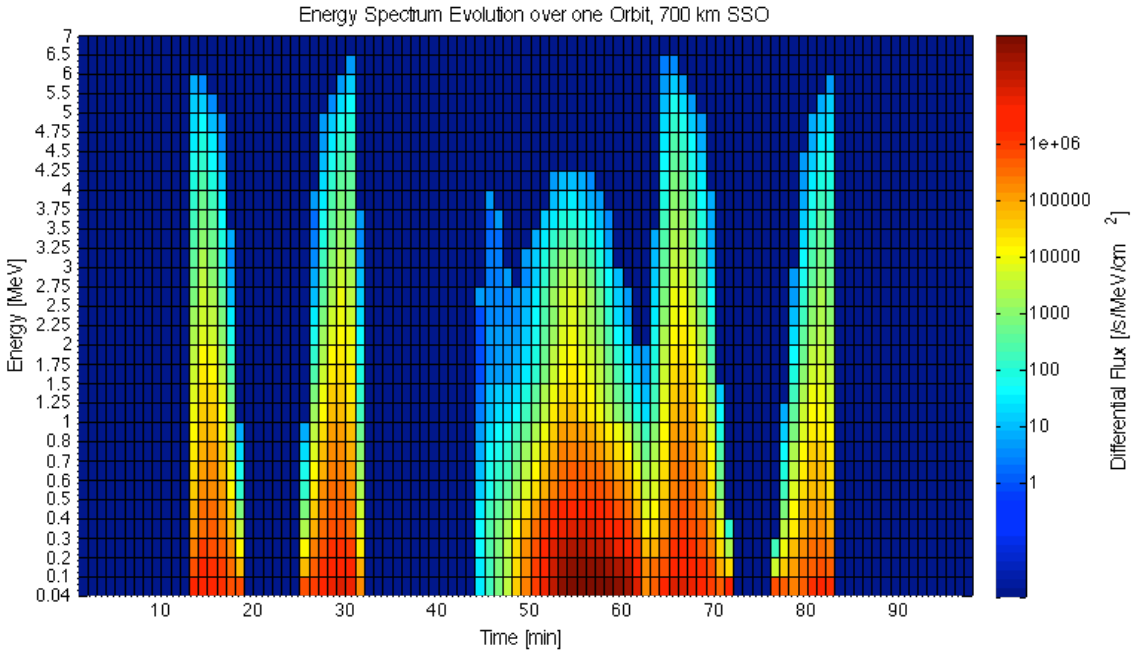
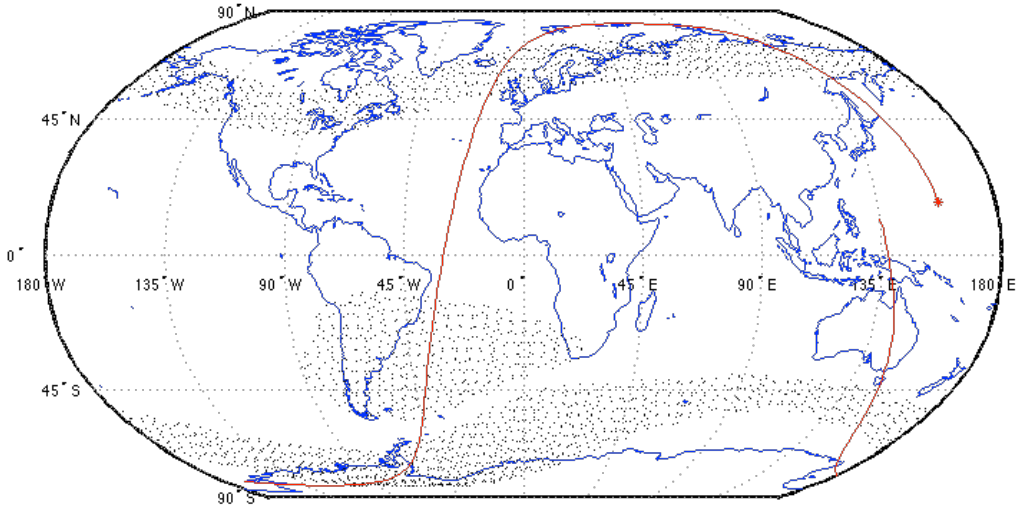


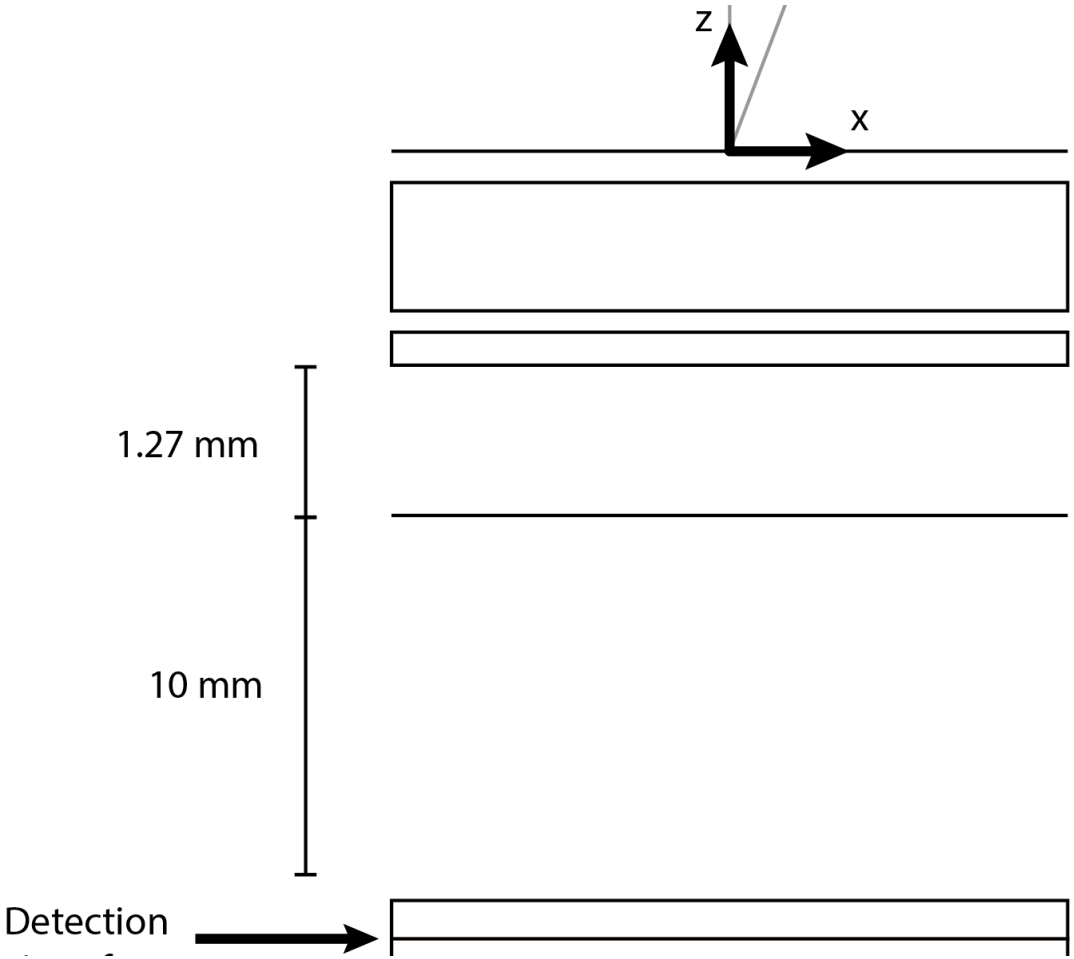
Figure 7. Similar to Figure 6 but from PHA data in Ranges 2 through 5 only.

Spectrum variation over orbit

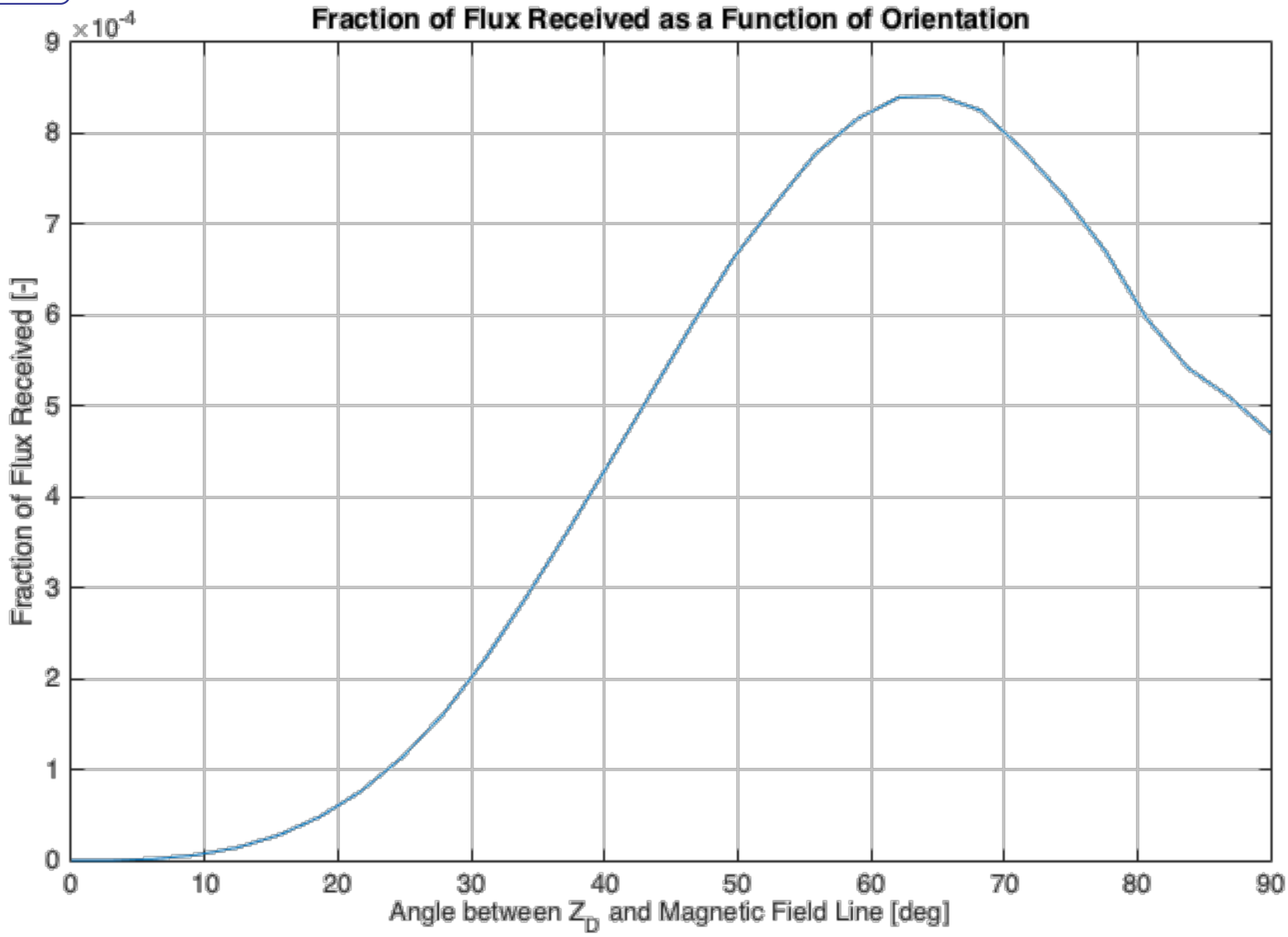




Model of Detector Stack



Titanium foil	0.1 mm
Alumina substrate	1.2 mm
Silicon detector	0.3 mm
Aluminium foil	6 µm
Dummy solid	


Fraction of Flux Received as a Function of Orientation
×10^-4
Fraction of Flux Received [-]
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
70
80
90
Angle between Z_D and Magnetic Field Line [deg]

Fraction of time in high-flux zones