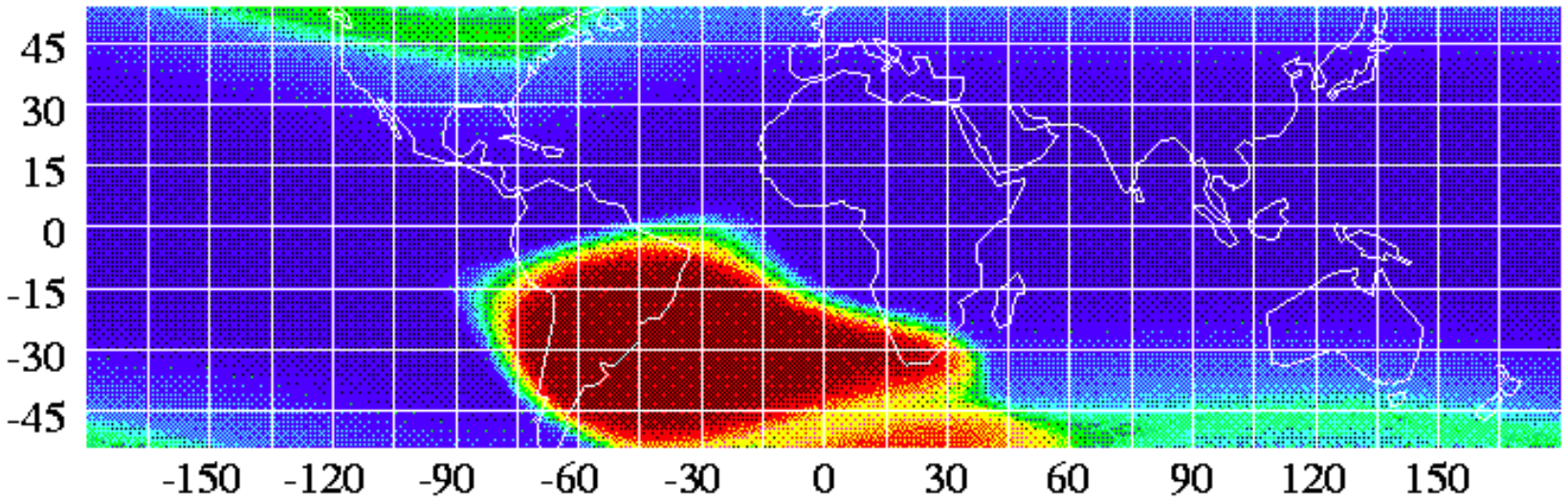
SWG 1st progress meeting

Background environment in an equatorial low-Earth orbit: on orbit trapped particles

P. Cumani, M. Hernanz, V. Tatischeff

South Atlantic Anomaly



Area where the inner Van Allen radiation belt comes closest to the Earth's surface:

- Anticoincidence bias voltage lowered (avoid damage to PMTs)
- Tracker saturates
- Special AC/TRK counters are sent to ground, used to update SAA definition

Why a study is necessary?

SAA shape and boundaries change both with the orbit altitude and the considered energy threshold

- Fermi: almost circular orbit of 565 km altitude and 25.58° inclination. Similar pre-launch study for protons only E>20 MeV. Anticoincidence energy threshold $\simeq$ 0.6 MeV
- AGILE: published results E>10 MeV, "3-out-of-4" tracker trigger de facto selects particles E>3-5 MeV

How is the study carried out?

- Choosing a model for the simulation of the on-orbit trapped particles spectra: AE9/AP9
- Simulating several orbits at different altitudes/inclination
- Studying the variation of the spectra/time passed in the SAA at the variation of the orbit parameters

The AE9/AP9 Model

- Updated version of the AE8/AP8 model: more accurate, comprehensive, and up-to-date
- Limitations (related to this case):
  - No solar cycle dependence
  - Large uncertainties protons for E<20 MeV, due to variability in the satellite sensor data, and sparse data coverage
  - Uncertainties in particle flux gradients for altitudes <800 km
  - Due to the limitations of the IGRF magnetic field model table of coefficients, the magnetic field results are fixed for all dates after 01 Jan 2020.
- The development team was contacted (SPENVIS does not allow to compute the flux along the orbit and limited amount of computing power allocated)

AE9/AP9: Simulations

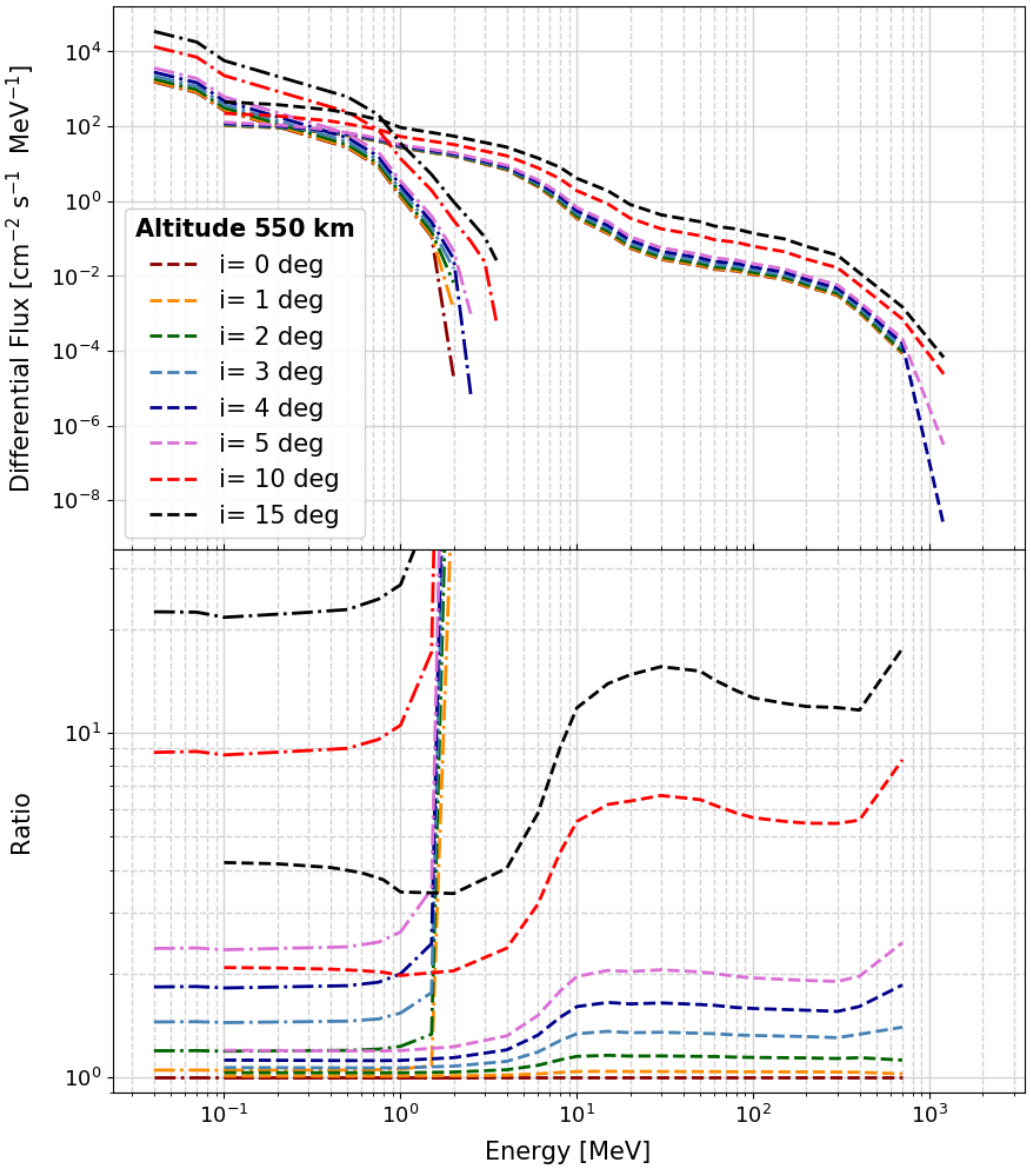
Orbit:

- Perigee/apogee altitude: 600 and 550 km
- Inclination: 0°, 1°, 2°, 3°, 4°, 5°, 10° and 15°
- Right ascension of ascending node: 0°
- Argument of perigee: 0°
- Mean anomaly: 0°

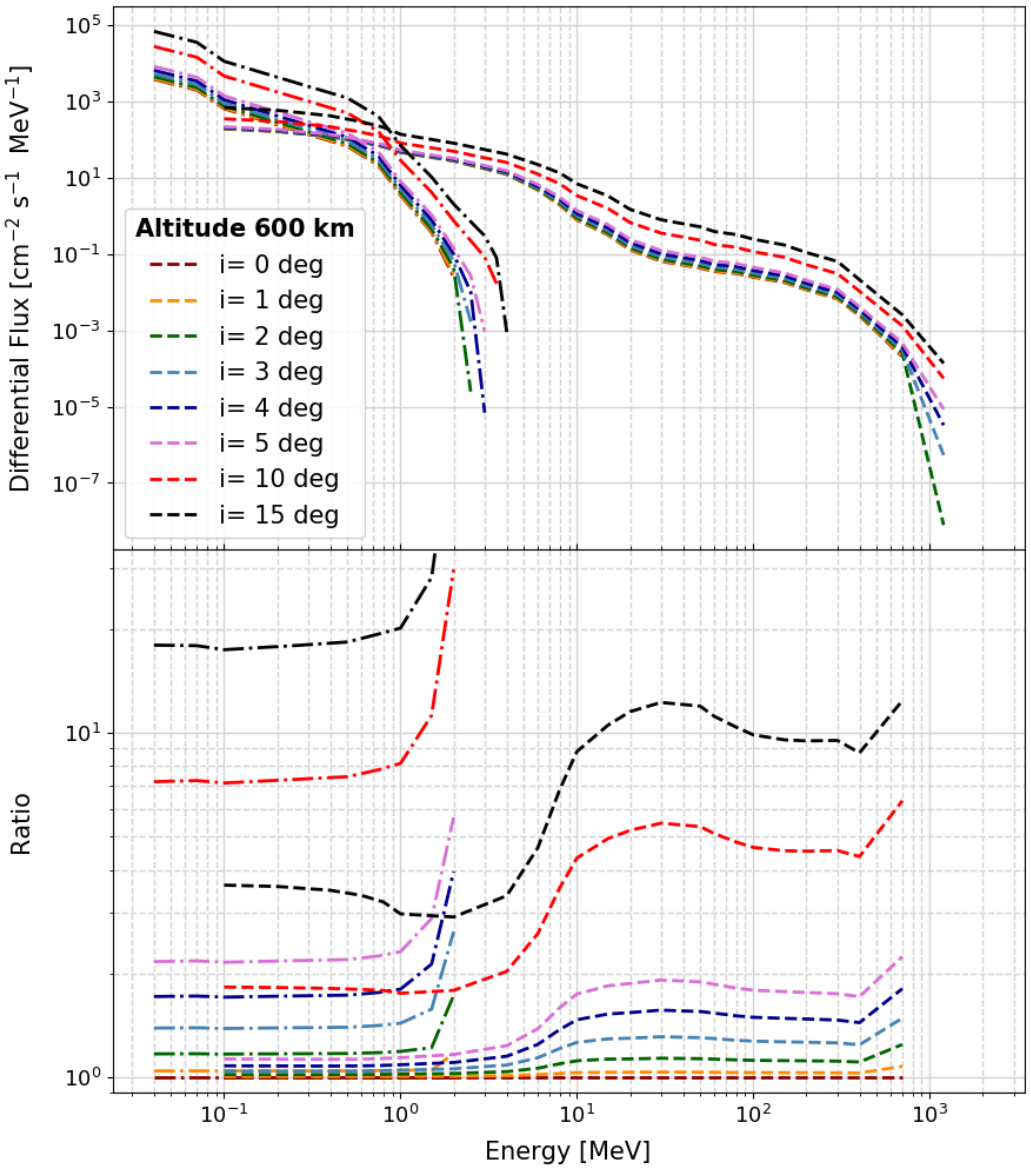
Model:

- Mean
- Integral and differential omnidirectional flux
- 1 month simulations, 10 seconds time step

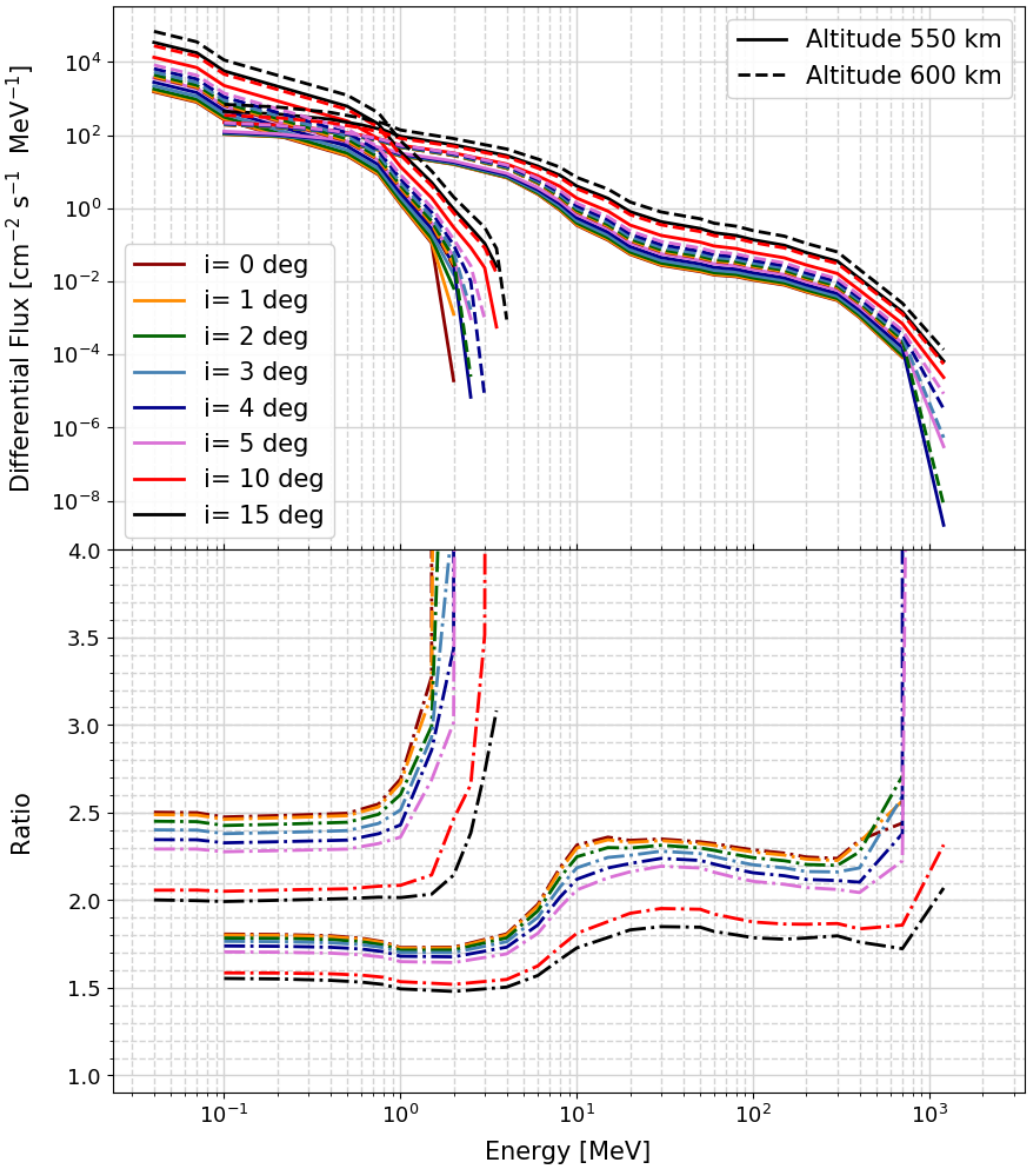
Differential Flux: Inclination variation at 550 km



Differential Flux: Inclination variation at 600 km

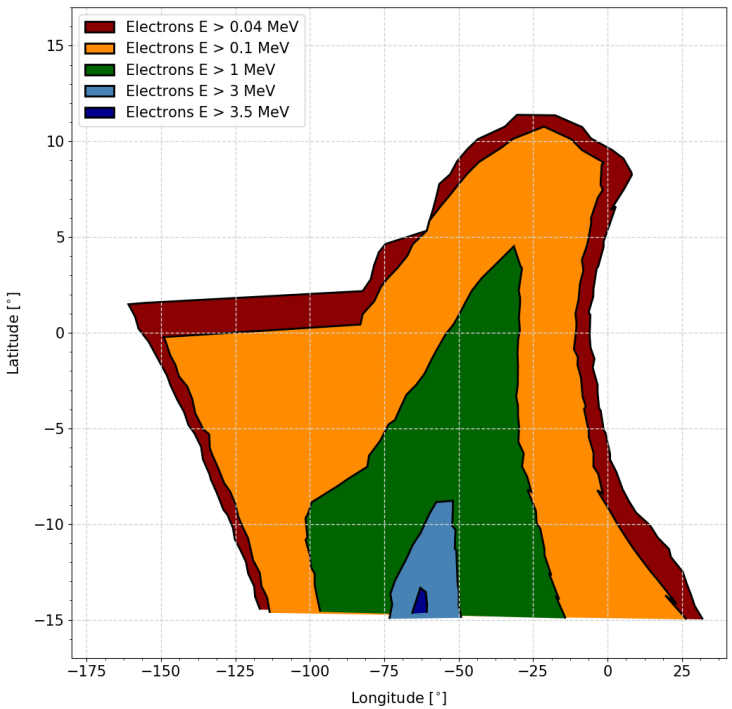


Differential Flux: Altitude

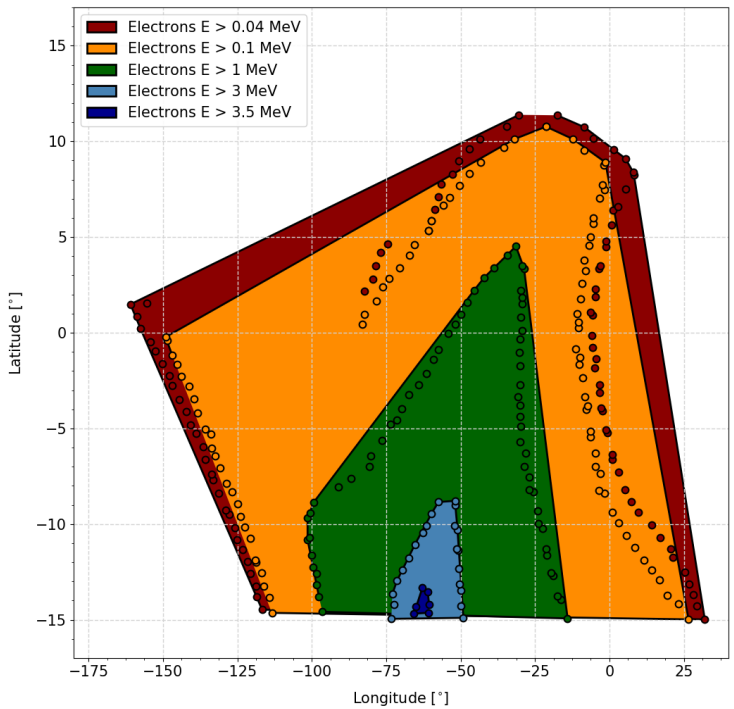


SAA: Electrons

Convex hull: is the smallest convex (1 passage per orbit) set that contains all the points.



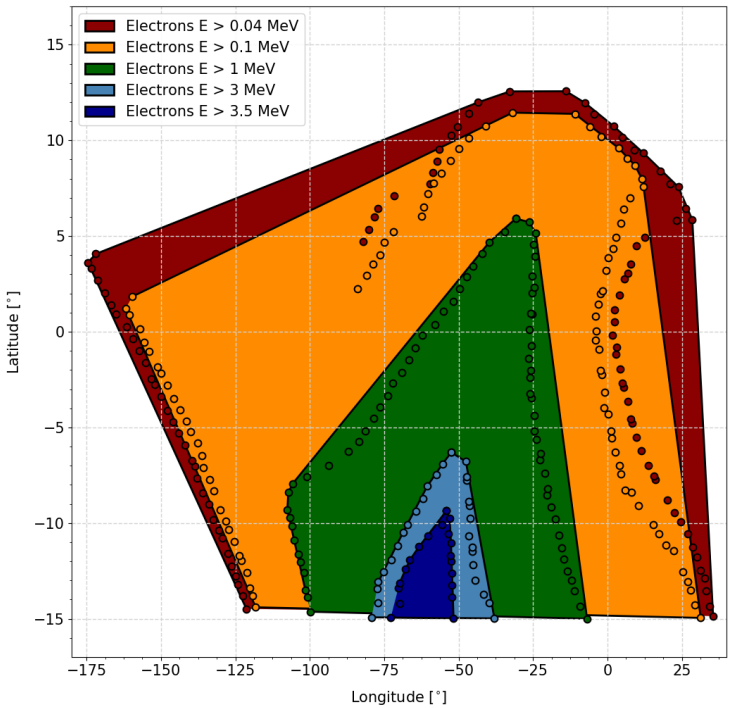
Original data



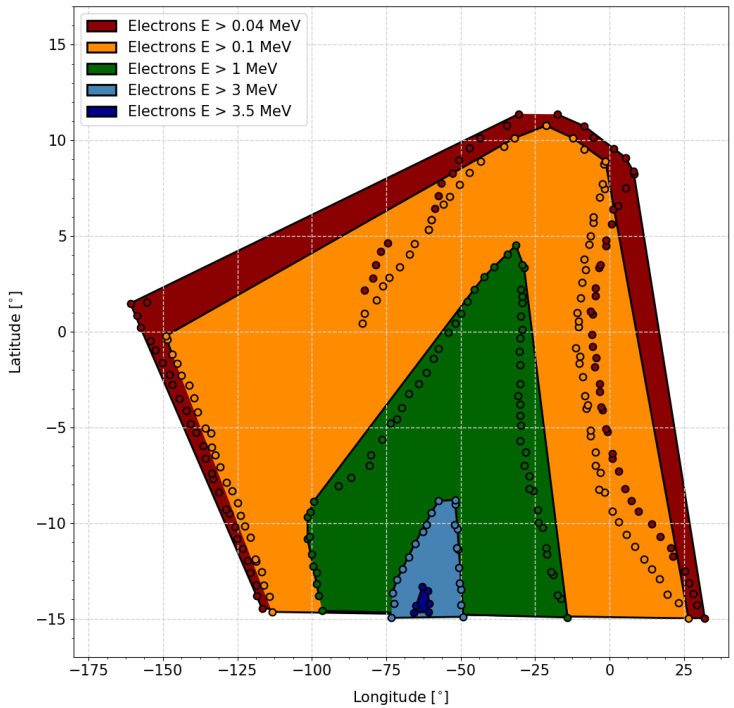
Convex hull

SAA: Electrons

600 km

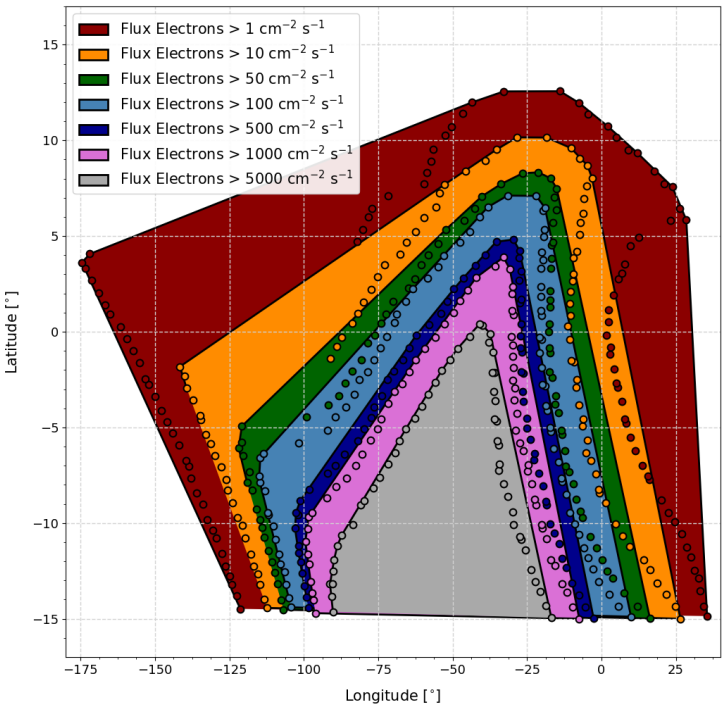


550 km

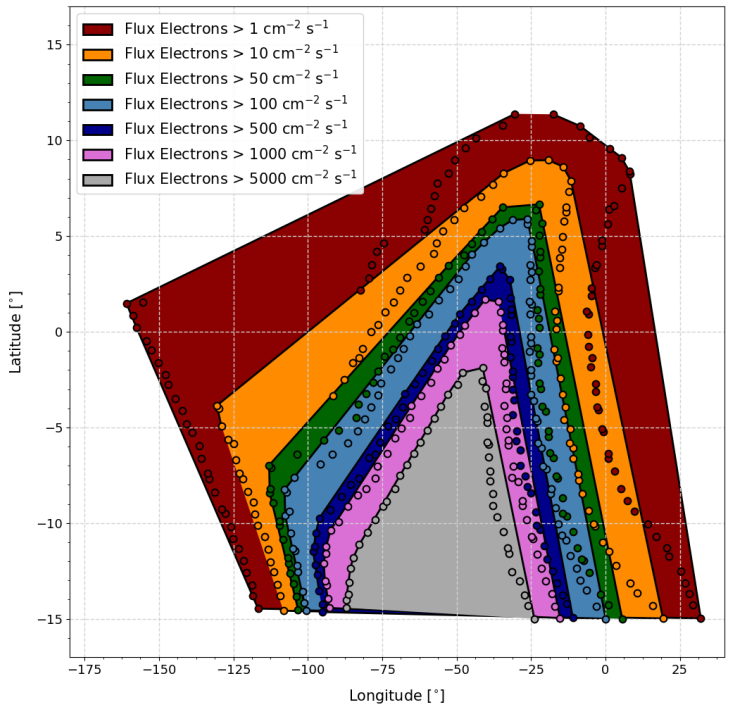


SAA: Electrons

600 km

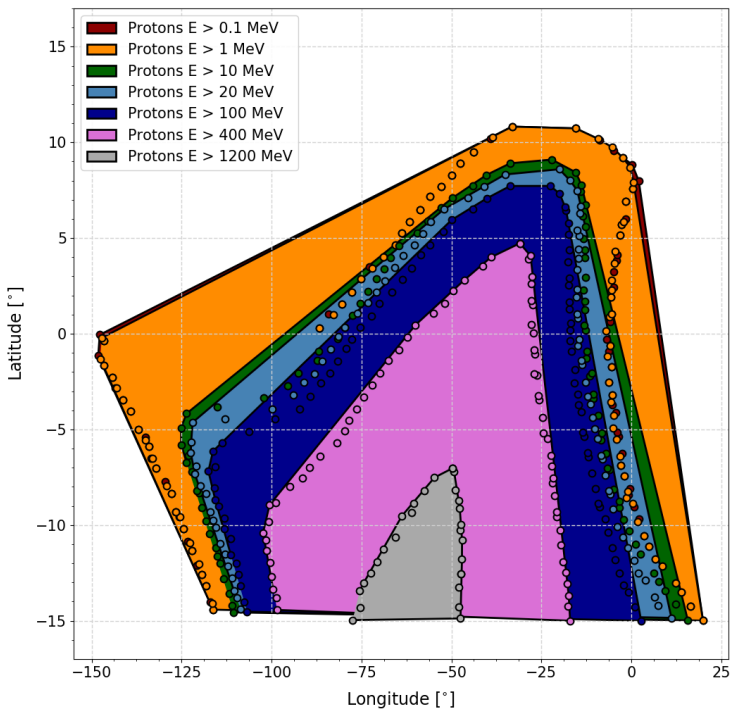


550 km

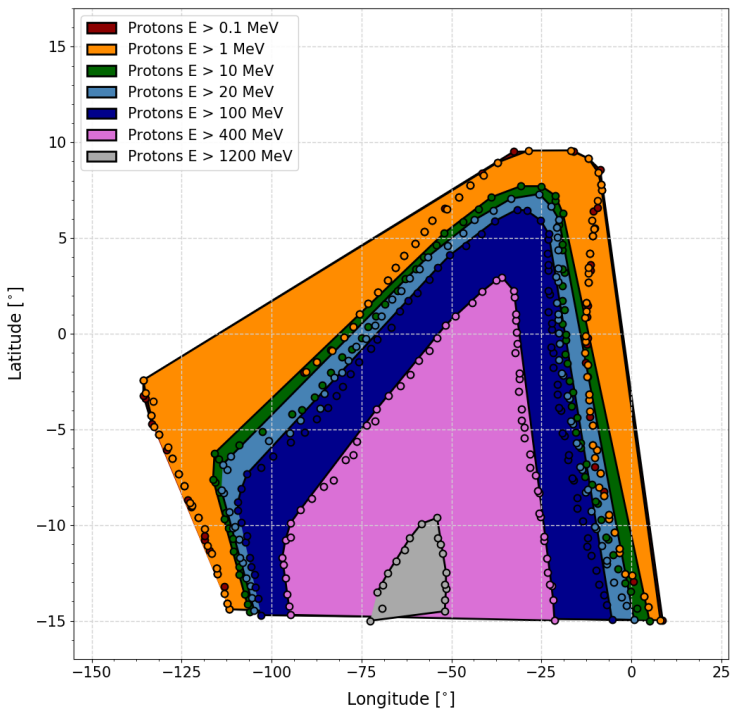


SAA: Protons

600 km

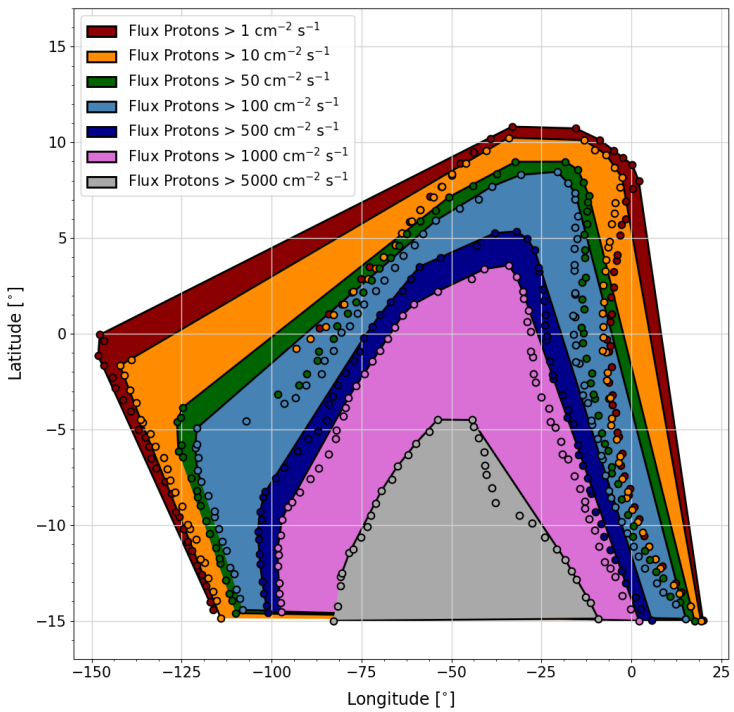


550 km

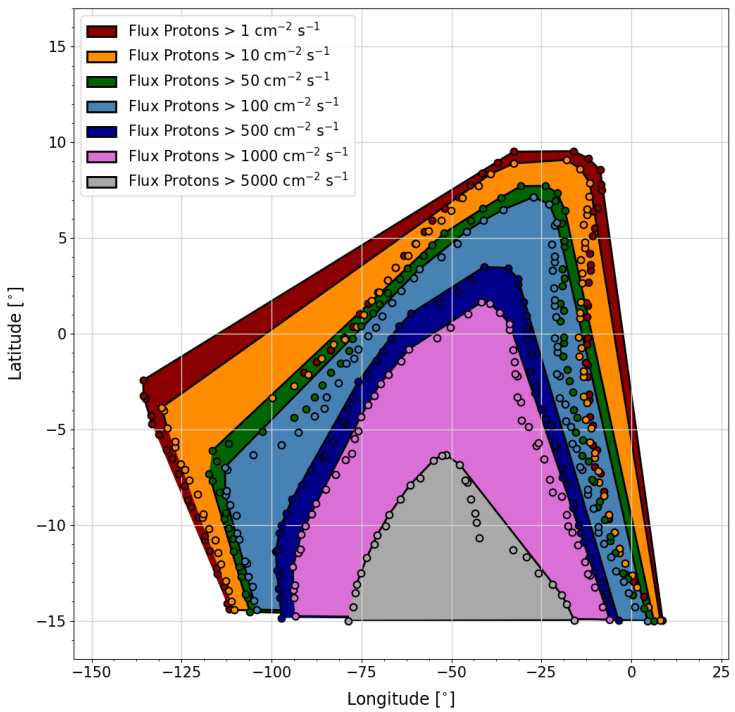


SAA: Protons

600 km

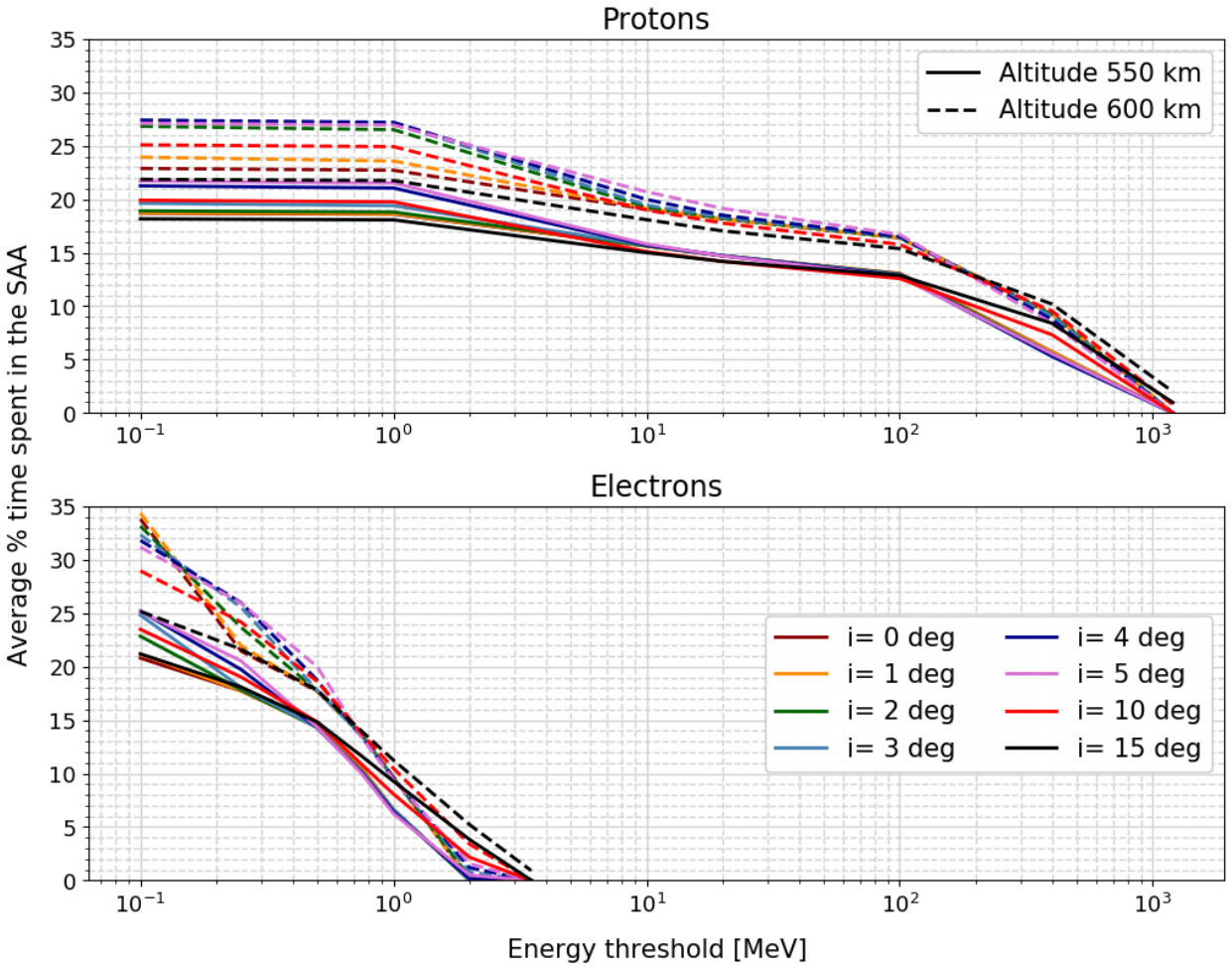


550 km

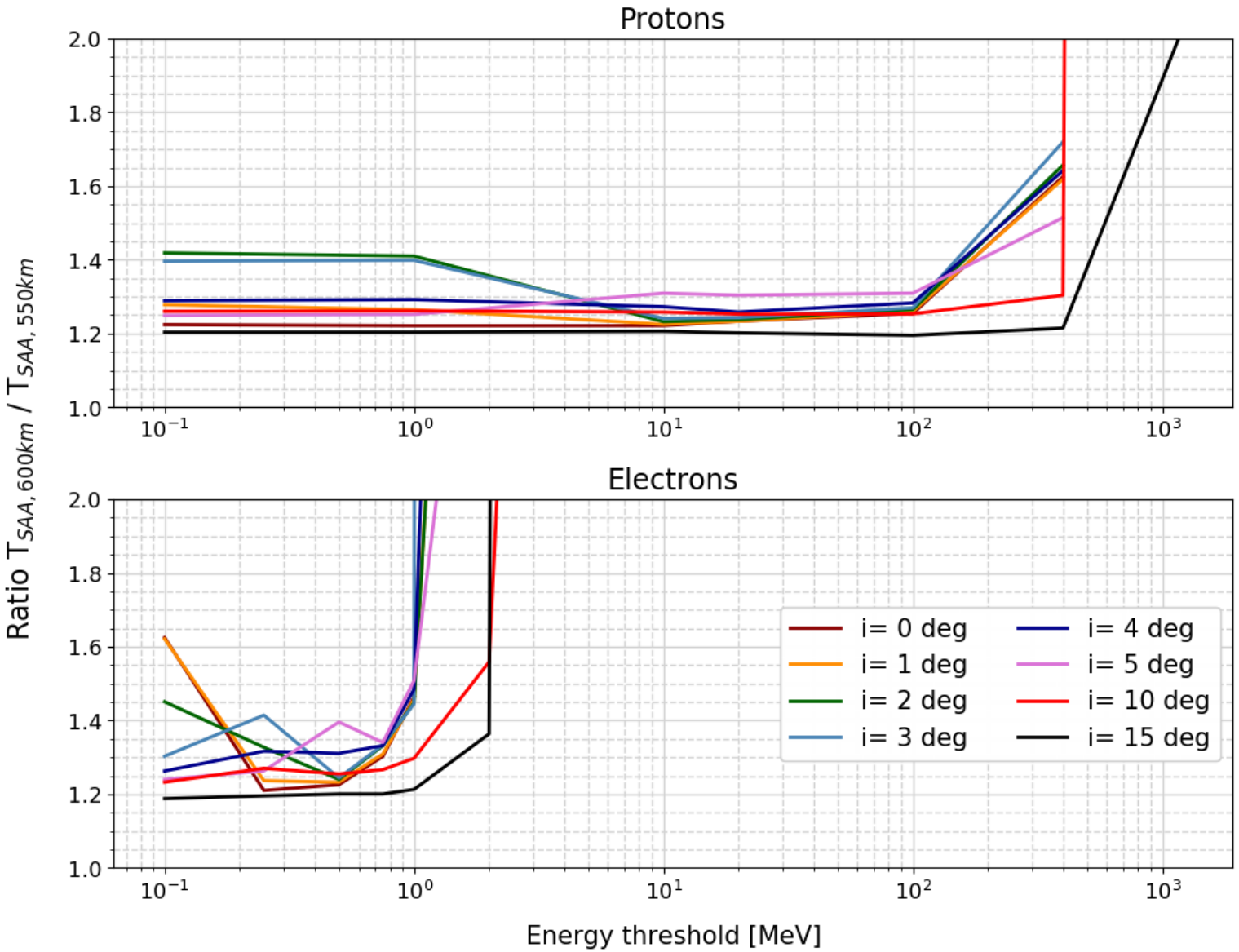


Time in SAA

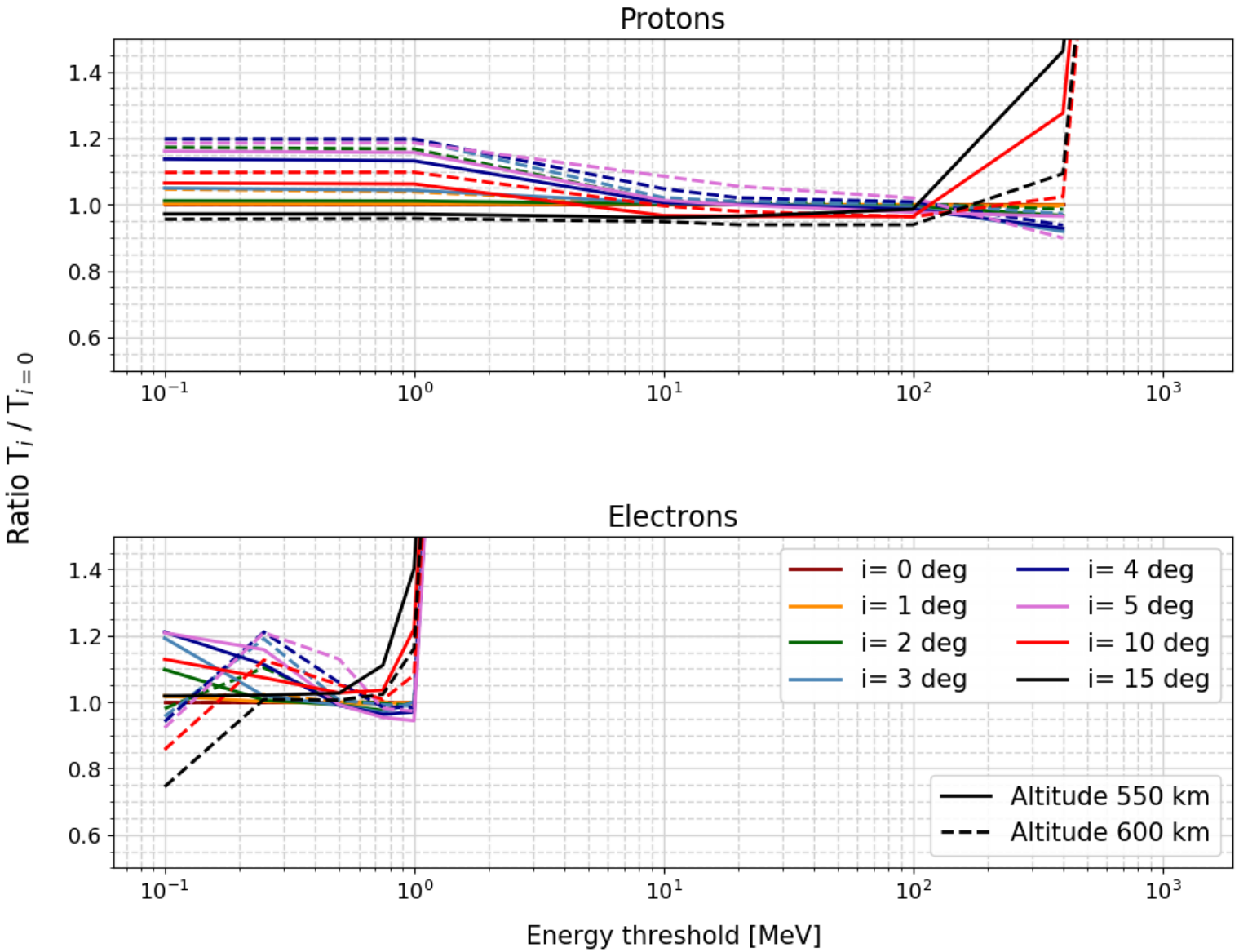
Average time in SAA (defined as the area in which flux of trapped particles >1 cm^{-2}s^{-1})



Time in SAA: Altitude



Time in SAA: Inclination



Conclusion

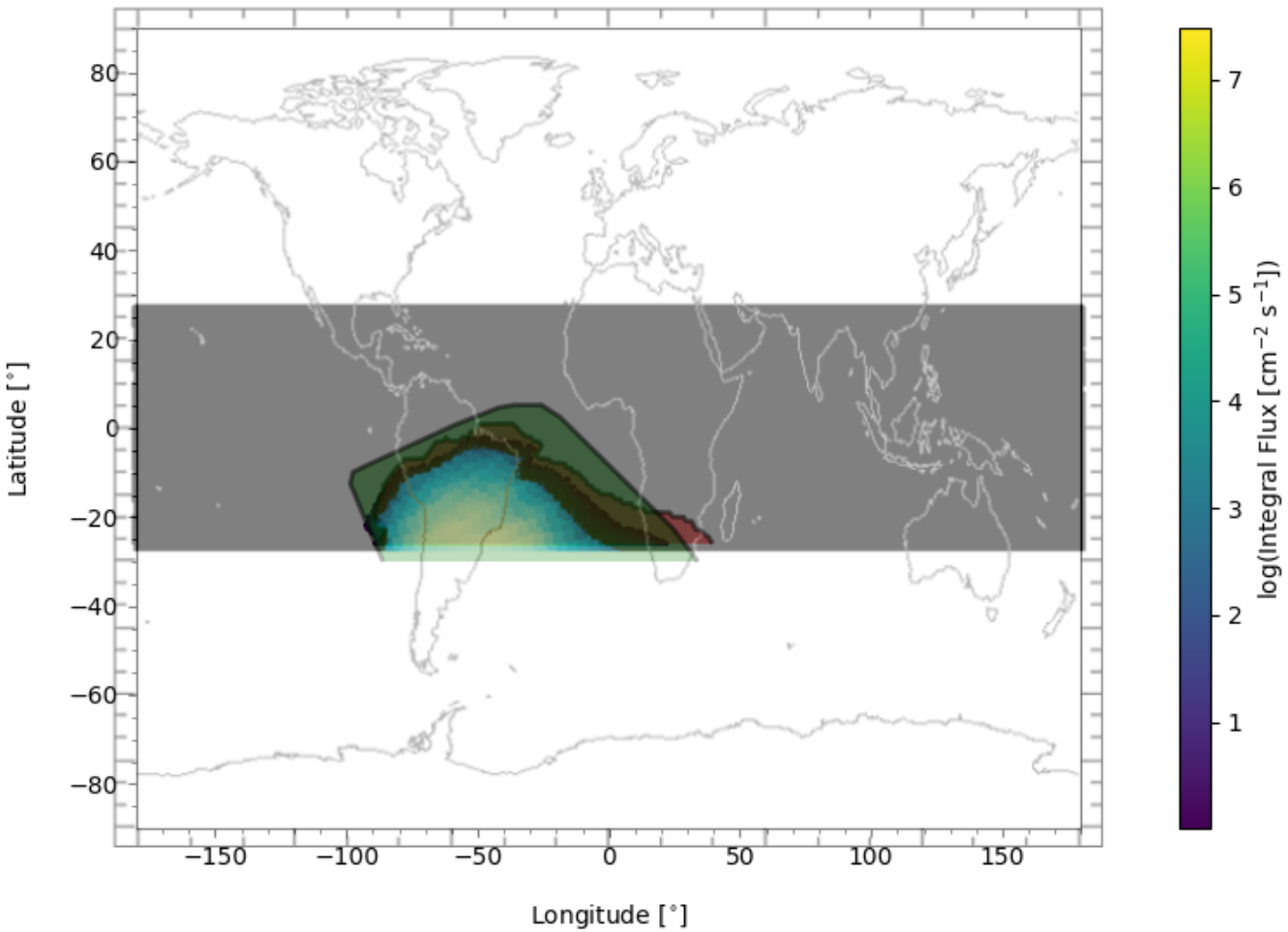
- 550 km altitude: trapped particles flux factor ~ 2 less than the flux at 600 km, time spent in the SAA is shorter by $\geqslant 20\%$
- Differential flux: Low inclination ($< 5^\circ$) orbits are favored. The best results are obtained for a perfectly equatorial orbit (i$= 0^\circ$) but small differences are observed up to 2°, especially for an altitude of 550 km.
- Average time spent in the SAA: $i < 3^\circ$ are favored. Higher inclinations are disfavored up to some MeV as well as at the highest energies for $i = 10^\circ$. $i = 15^\circ$: comparable or improved situation at the low-mid energies with respect to $i = 0^\circ$ but a worsening greater than the $i = 10^\circ$ case at the highest energies.

Conclusion

Considering everything, the best orbit for a Pair/Compton gamma-ray mission has

- an altitude of $\sim$550 km
- a low inclination $i \lesssim 3^\circ$

Thank you!



- Protons with energies E>20 MeV from SPENVIS: inner light blue area
- Paper: red shaded area
- AP9 black central area
- SAA as defined in the Fermi Science tools: green