DETERMINING ANGLE DEPENDENT EFFECTIVE RIGHTY CUTOFFS FOR ISS-CALET ULTRA-HEAVY COSMIC RAY ANALYSIS

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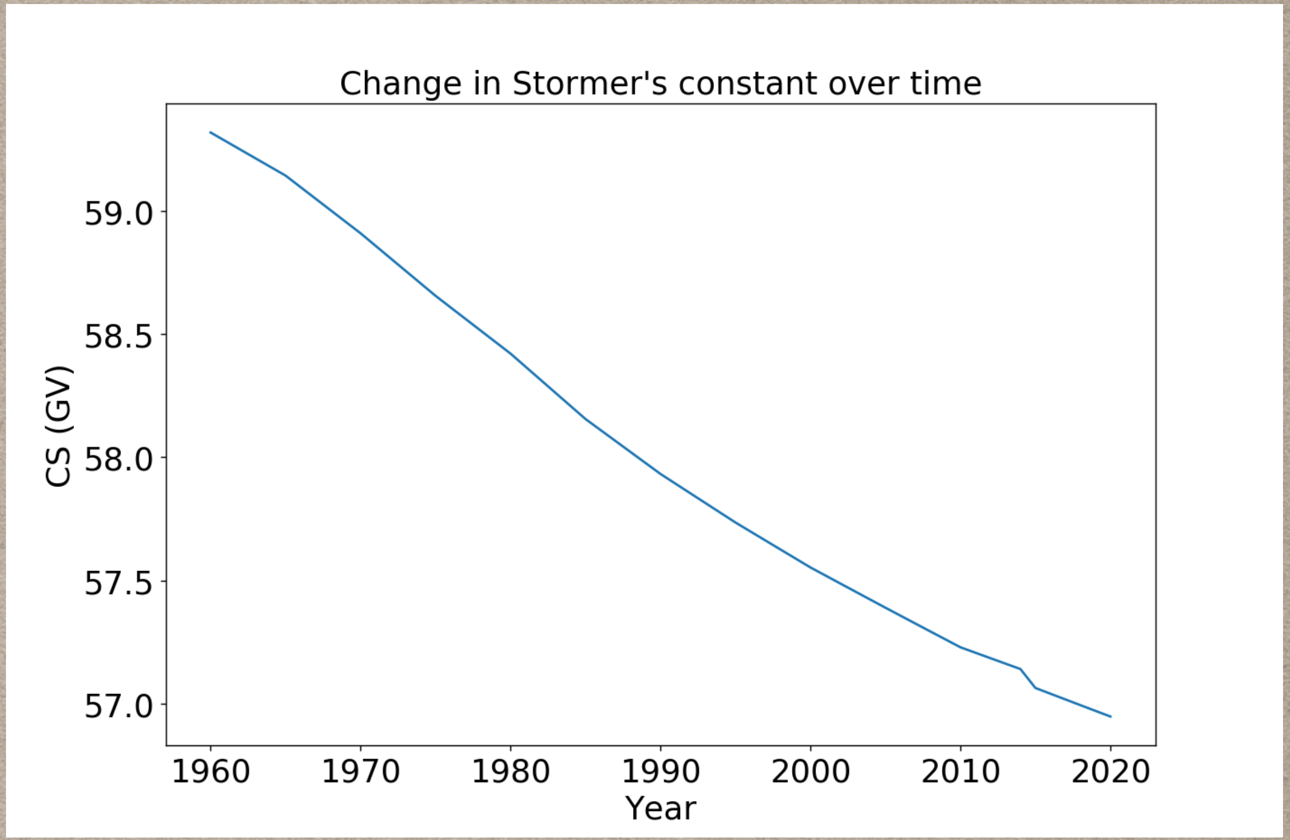
QUICK REVIEW

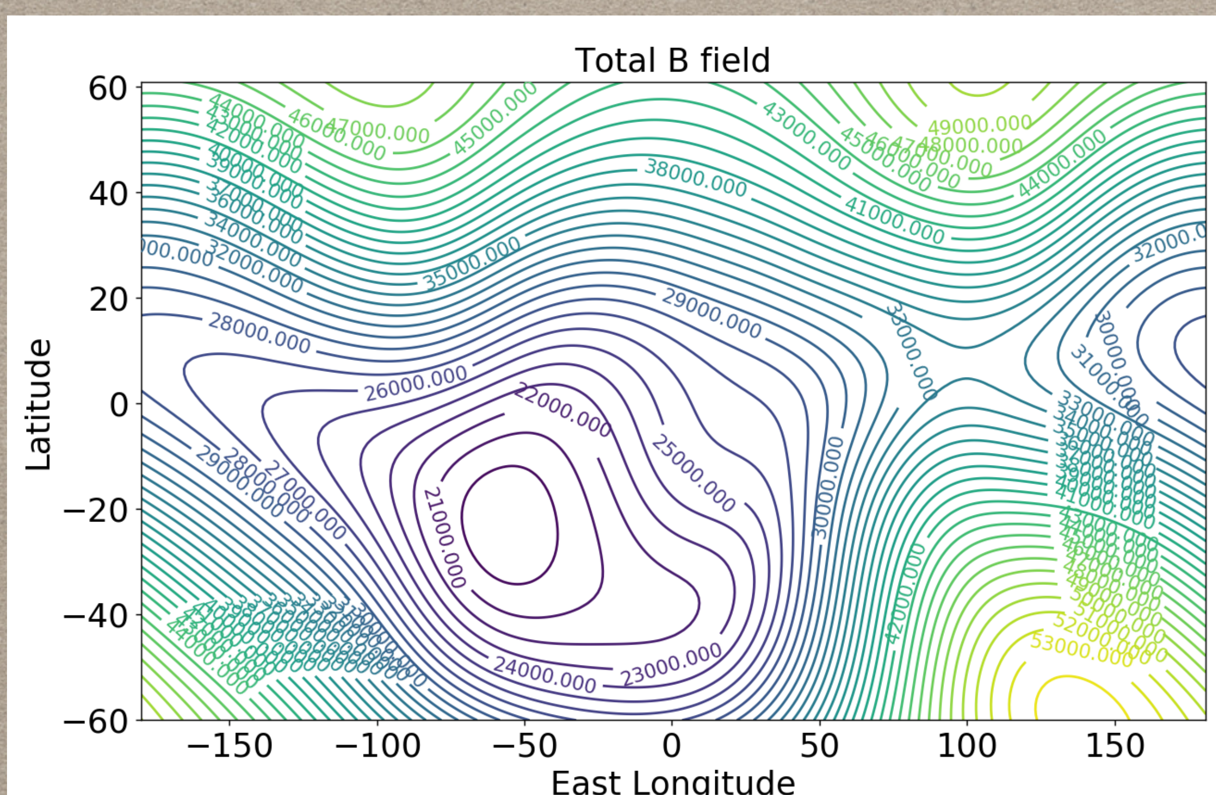


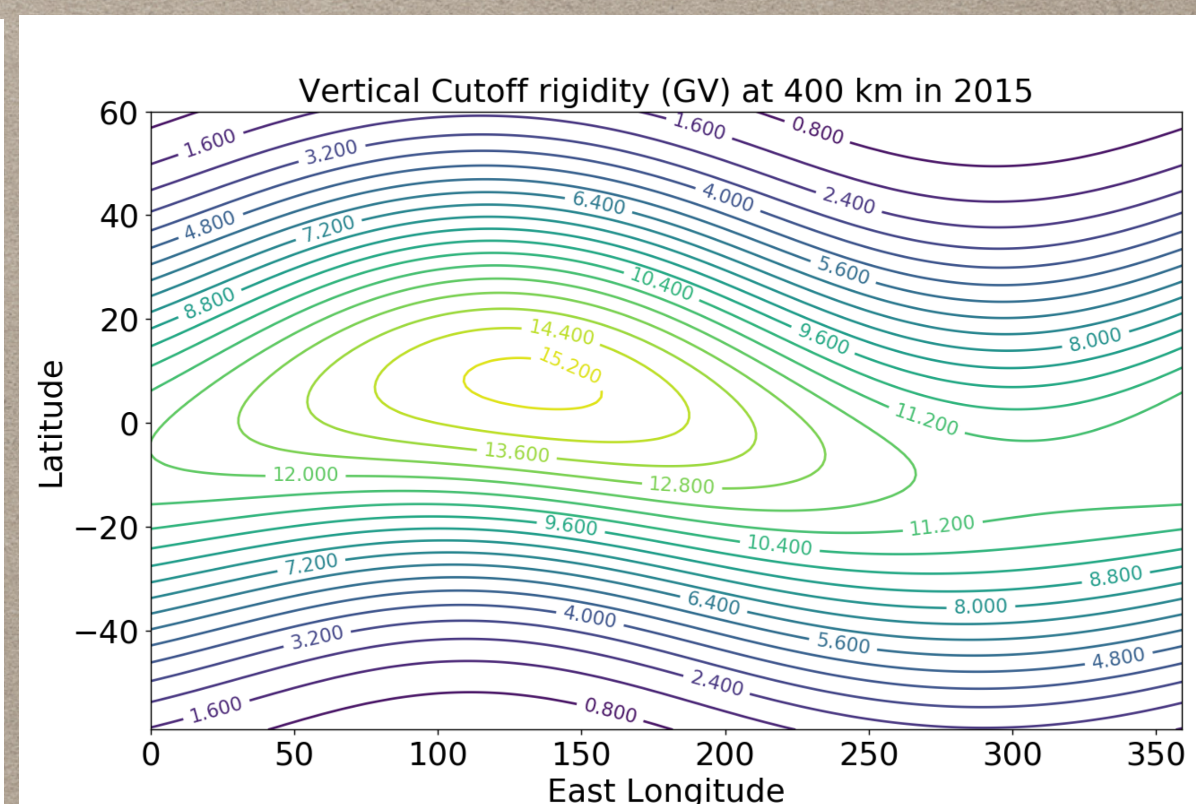
- I primarily work with incorporating Earth's magnetic field into our Ultra-Heavy Analysis
- Use the magnetic field to determine the geomagnetic rigidity for energy cutoff on UH events.
- I use current World Magnetic Model/ IGRF values, to allow the change in field over time.
- Use a Stoermer approximation for quick analysis, where λ is the magnetic latitude and γ is the east-west inclination. C_S is the stoermer constant which is derived from the magnetic pole moment.

$$P \geq \frac{1}{r^2} C_S \left[\frac{1 - \sqrt{1 - \cos\gamma \cos^3\lambda}}{\cos\gamma \cos\lambda} \right]^2$$

STOERMER ANALYSIS CODE

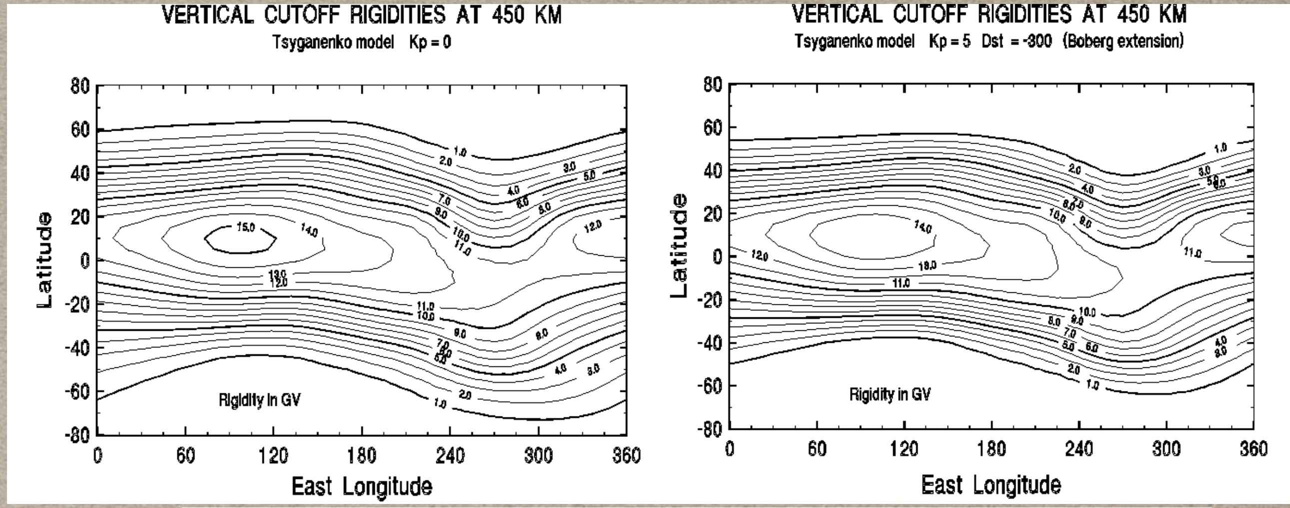
- My code is written to read the event data, use the trajectory and ISS position information in conjunction with the local magnetic field at the time of detection. The code determines the direction of the event with respect to the magnetic dipole approximation.

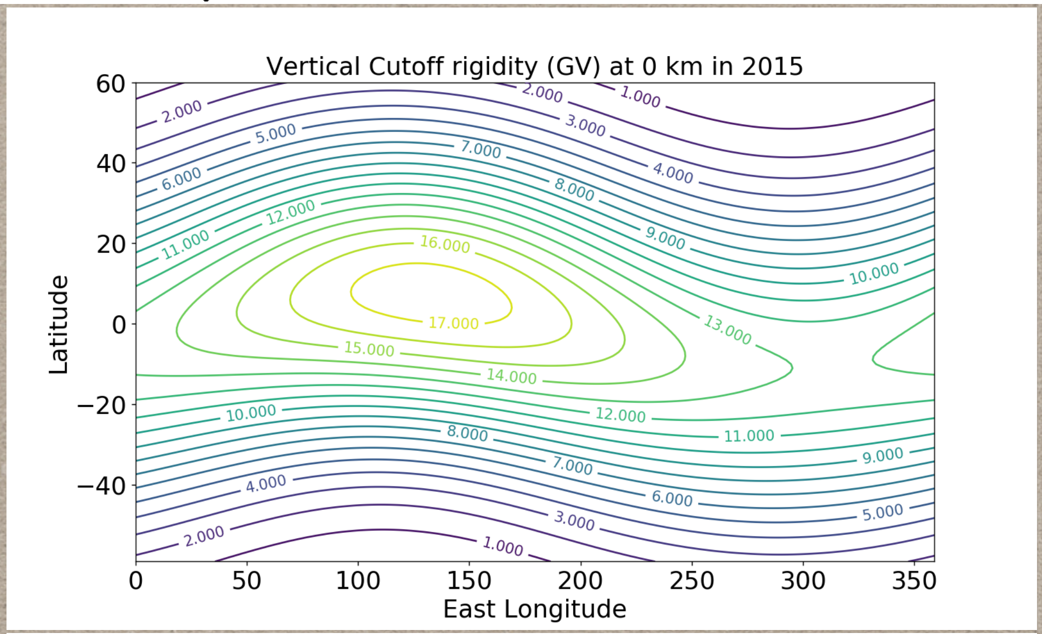


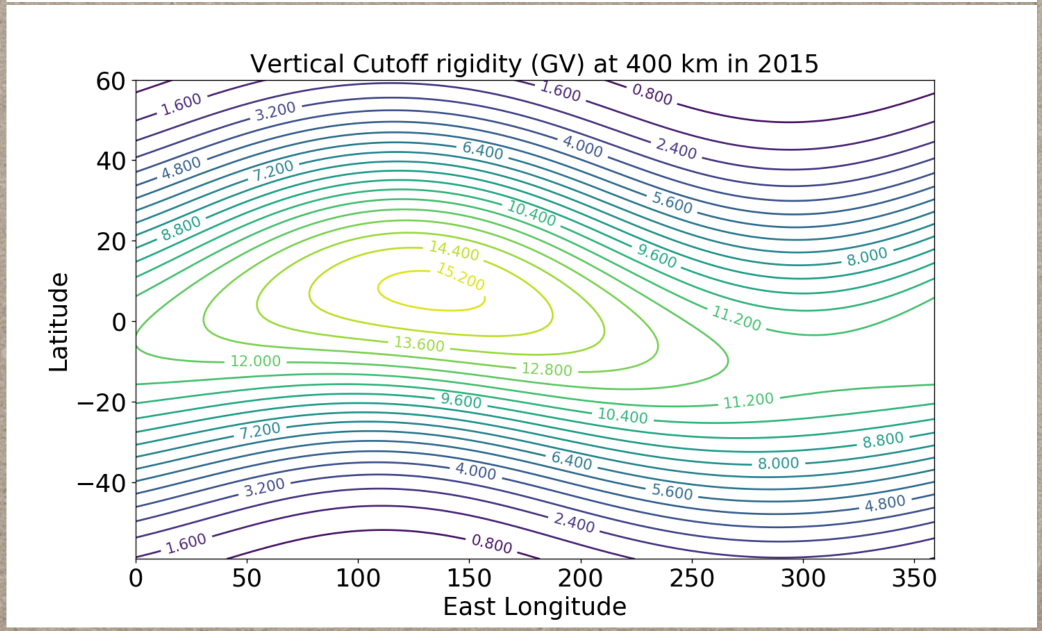


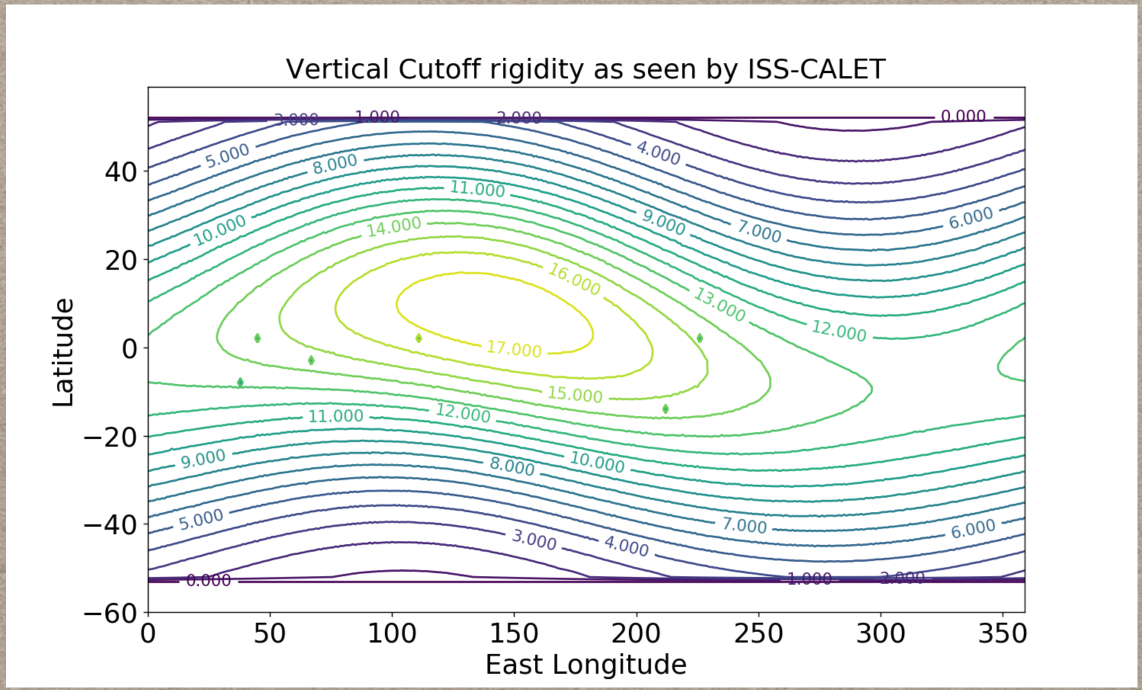
ISSUE WITH CALET STOERMER VALUE

- Through my Stoermer approximation, I found that the code for calculating "fStoermer" within CALET L2 was incorrect. It was not correctly using the altitude of the ISS, resulting in values that were ~10% larger.
- This has since been corrected by Paolo, although I am unsure if this fix was done in time for Pass4.
- Plot below shows vertical cutoff as seen by CALET, plots on right show what the cutoff should be for both via the stormer approximation and the ray-tracing code created by Smart an Shea at various altitudes.



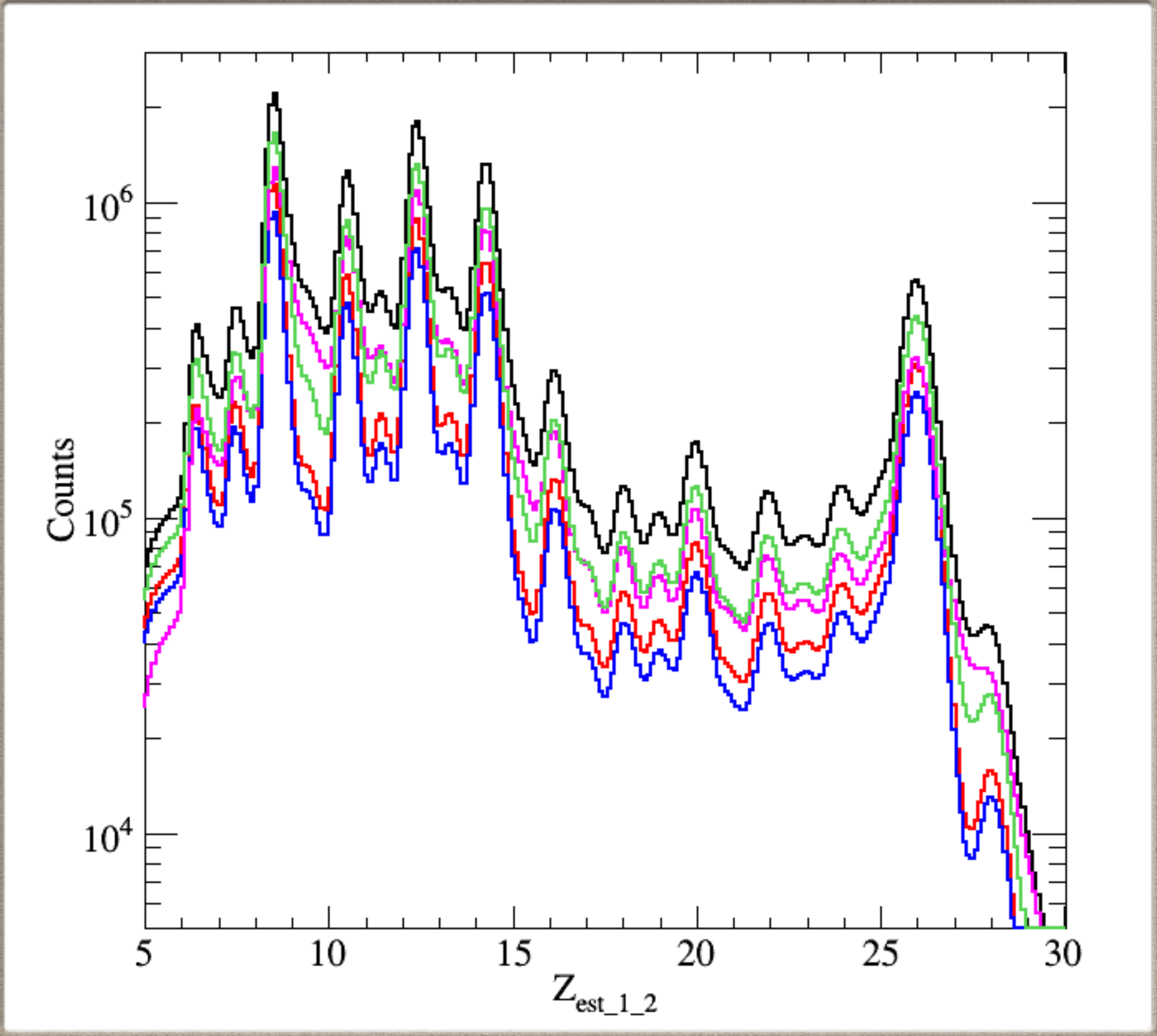






RESULTS

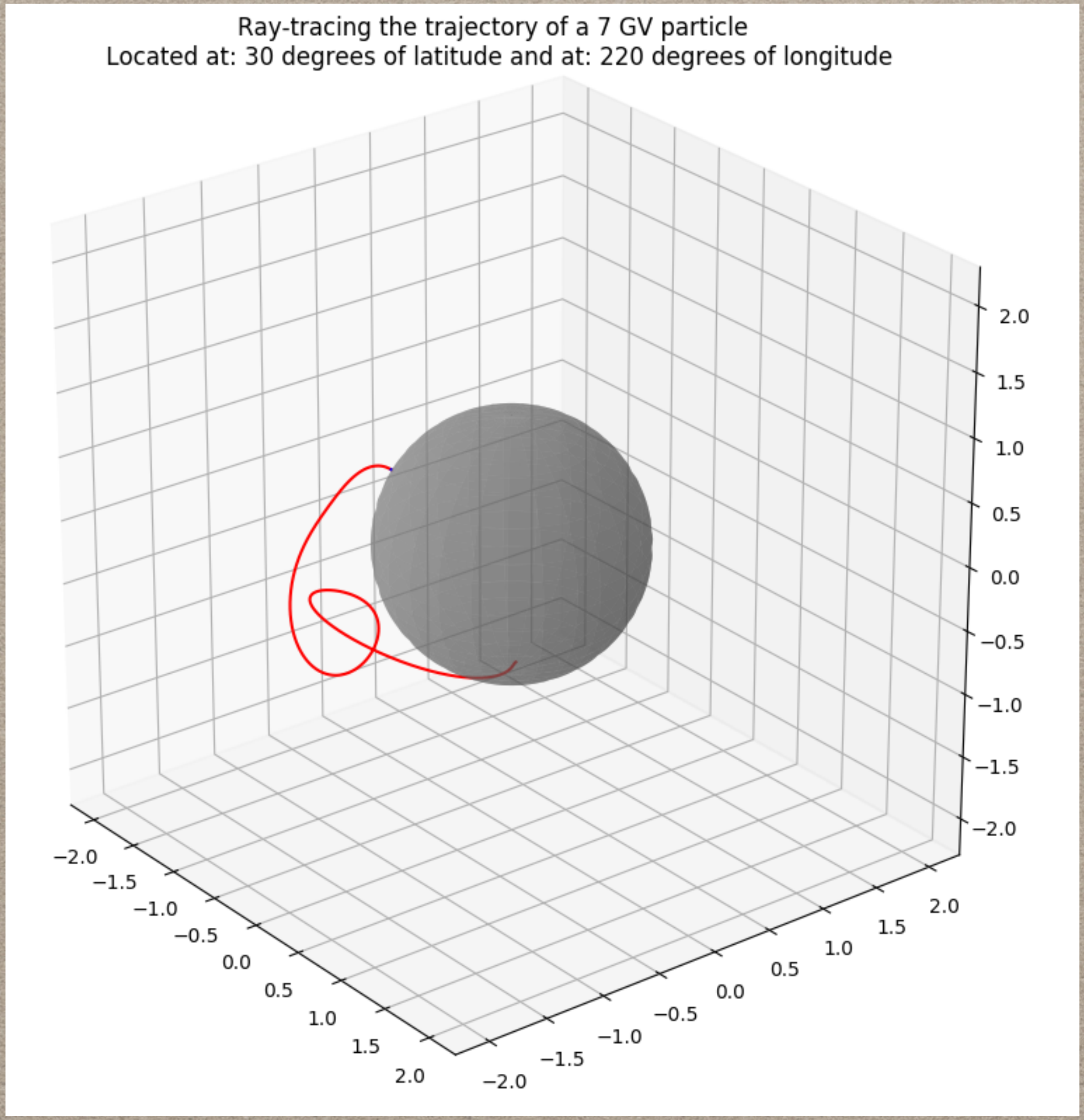
- My quick approximation data was given to Brian which lead to this improvement in our analysis (Pass3.1)
- Black is all data.
- Blue is the dataset post vertical cut (4 GV)
- Red is trajectory dependent cut (4 GV)
- Pink is below 4 GV
- Green s above 2 GV

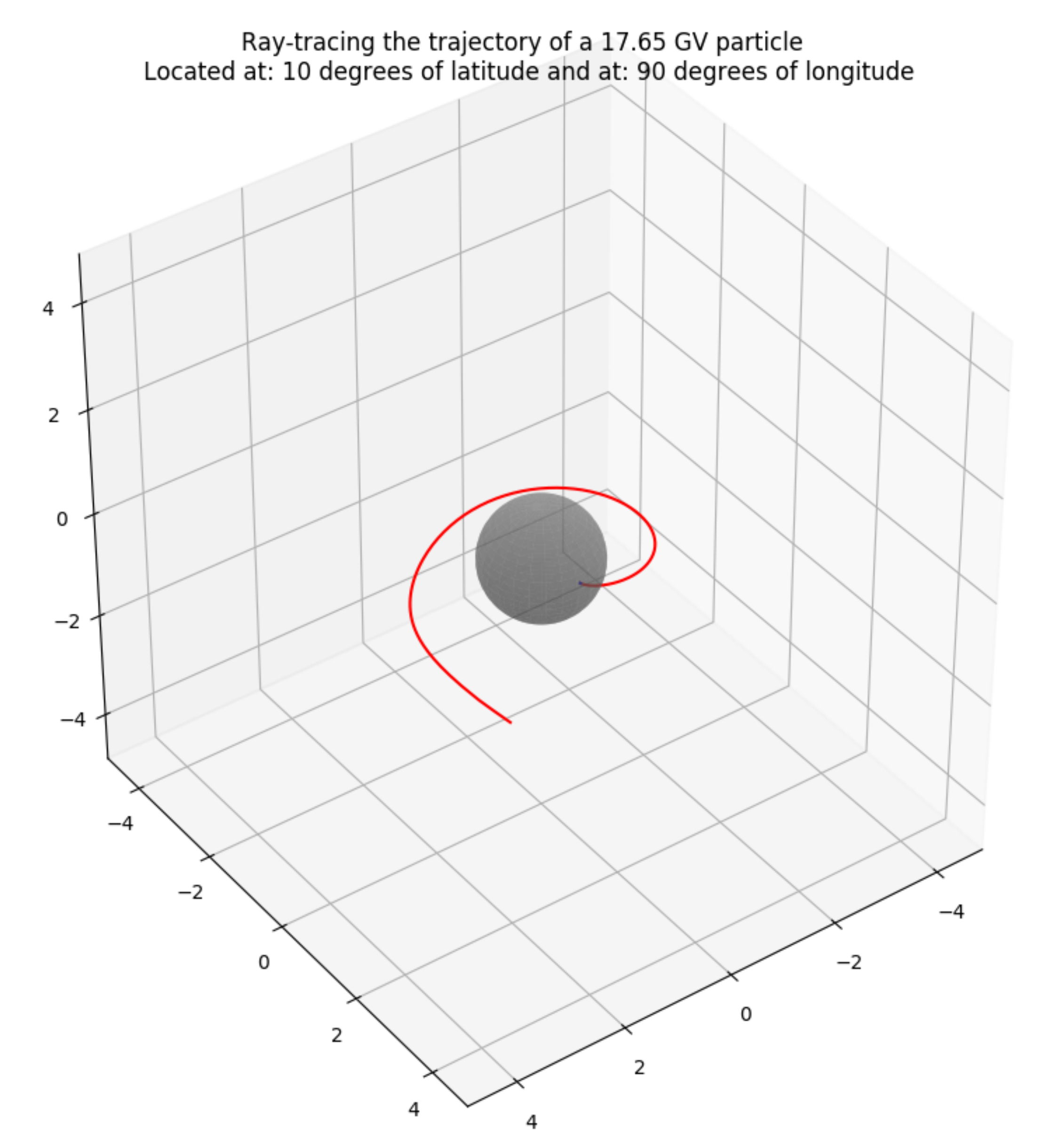


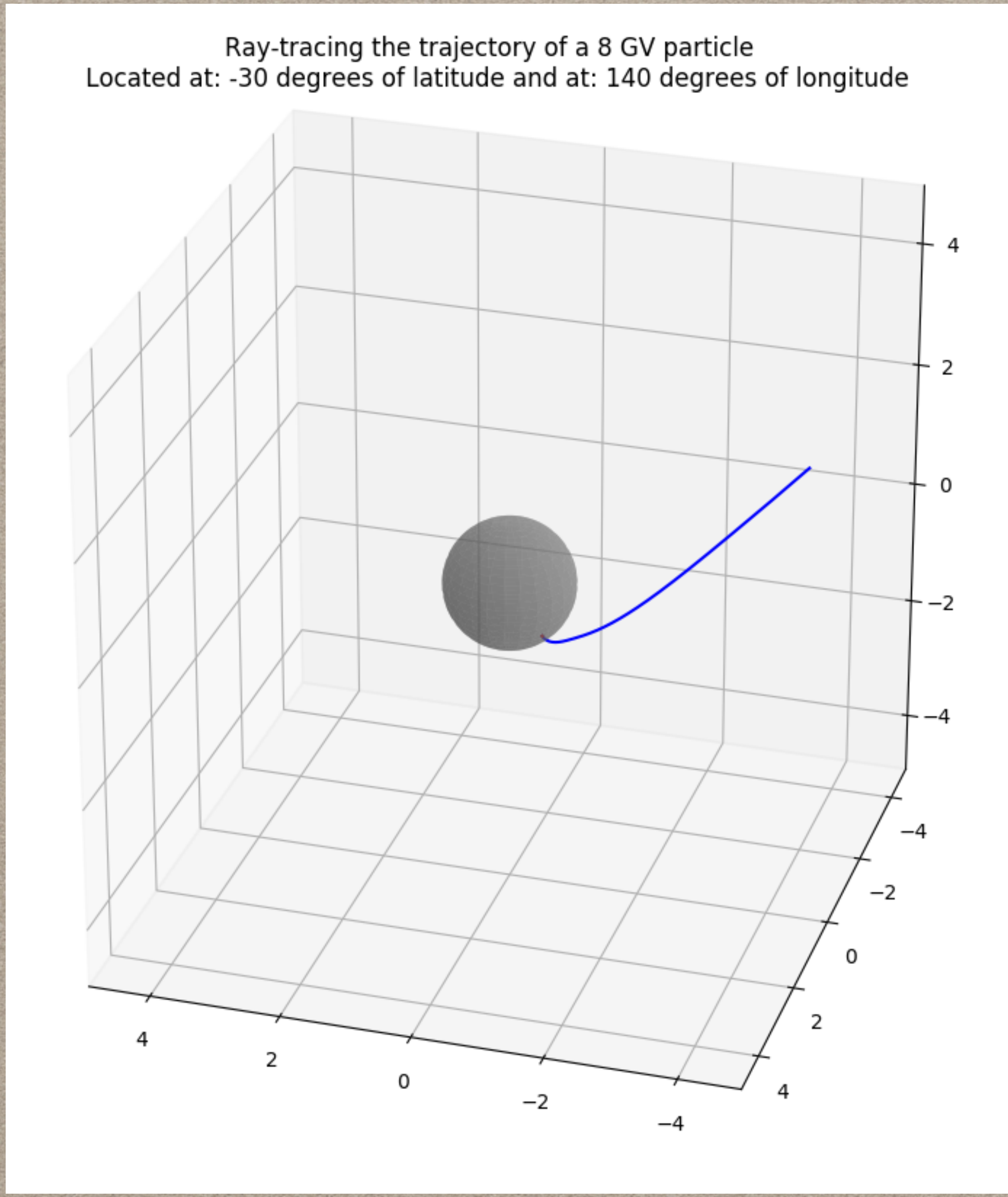
RAY-TRACING CODE

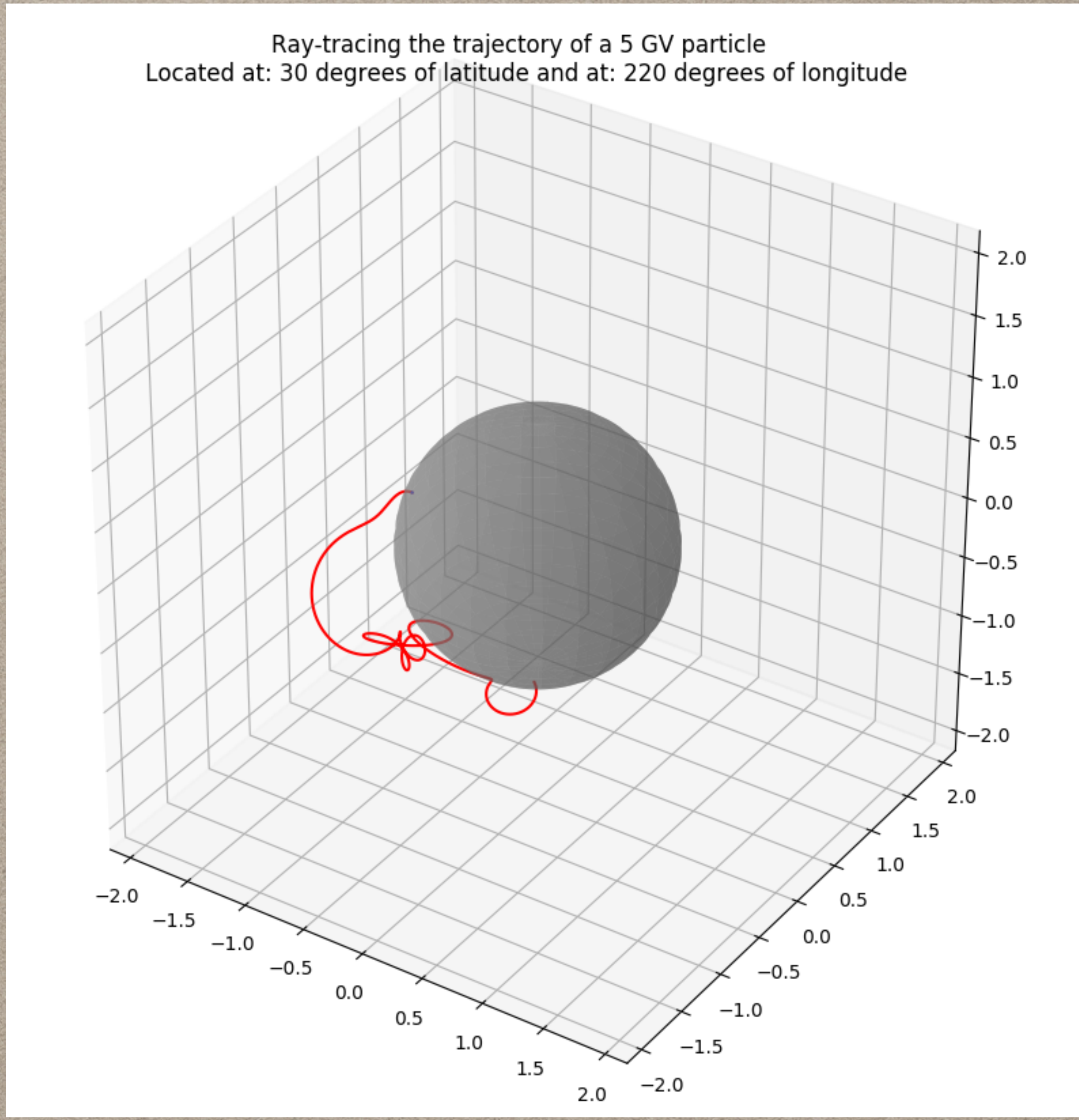
- I've continued development of a ray-tracing code that back traces detected events to see if it is an allowed trajectory or not.
- It is inspired from previous work done by Smart & Shea.
- It determines the highest trapped particle rigidity and minimum escape rigidity and averages the values of the allowed trajectories over the range between those values to determine the effective cutoff rigidity.
- Using a Cash-Karp Runge-Kutta. Which gives a fourth/fifth order approximation of the particles motion through Earth's magnetosphere.
- For quicker calculation, rather than using a preset rigidity range, it uses my stormer approximation to pin down a center value and then iterates over a 3 GV range around that initial guess. This range is used so all of the penumbra is fully covered by the for the cutoff energy.
- My results so far match up well with Smart and Shea's work.

- Some examples of individual trajectories are plotted.

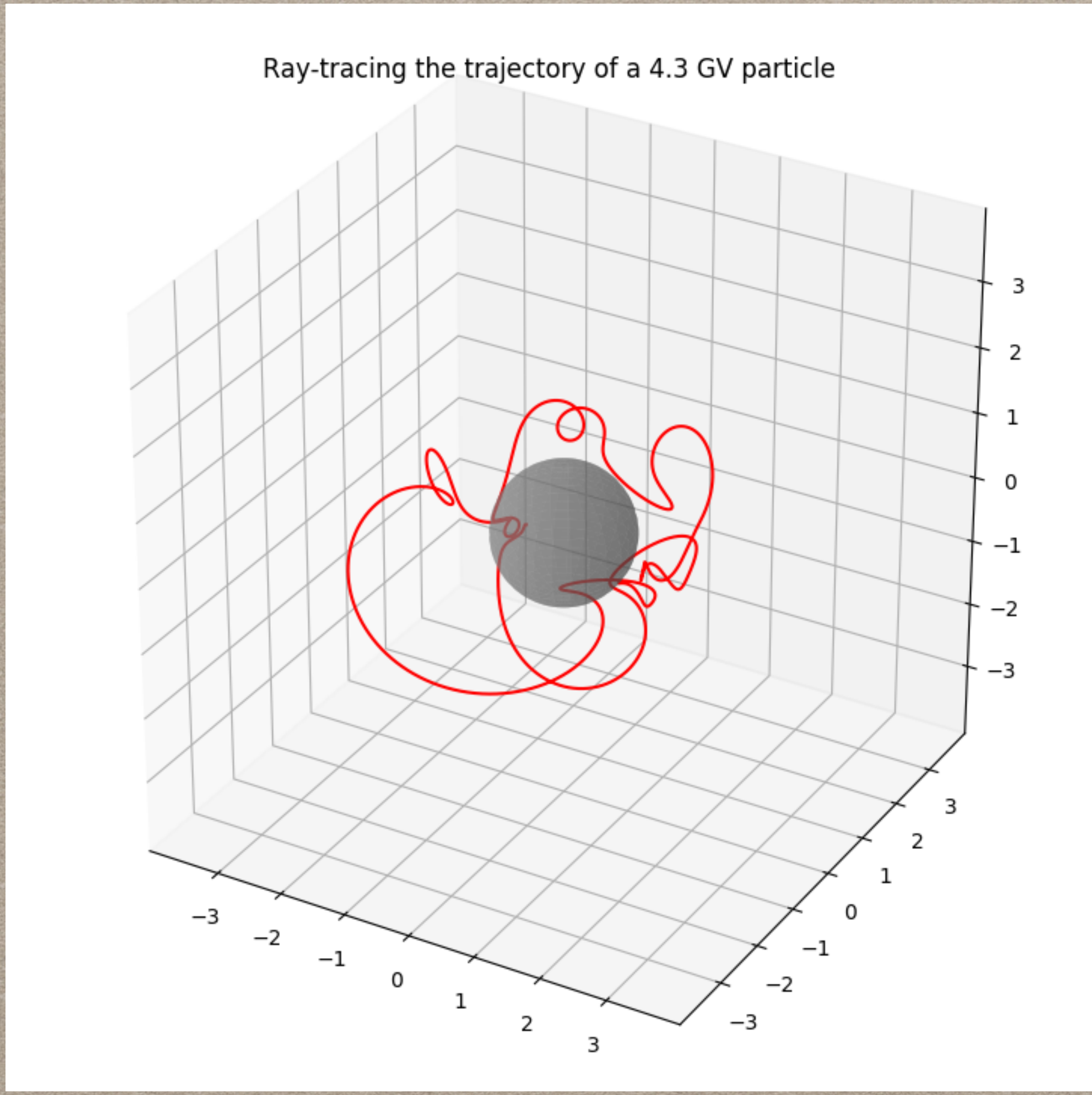


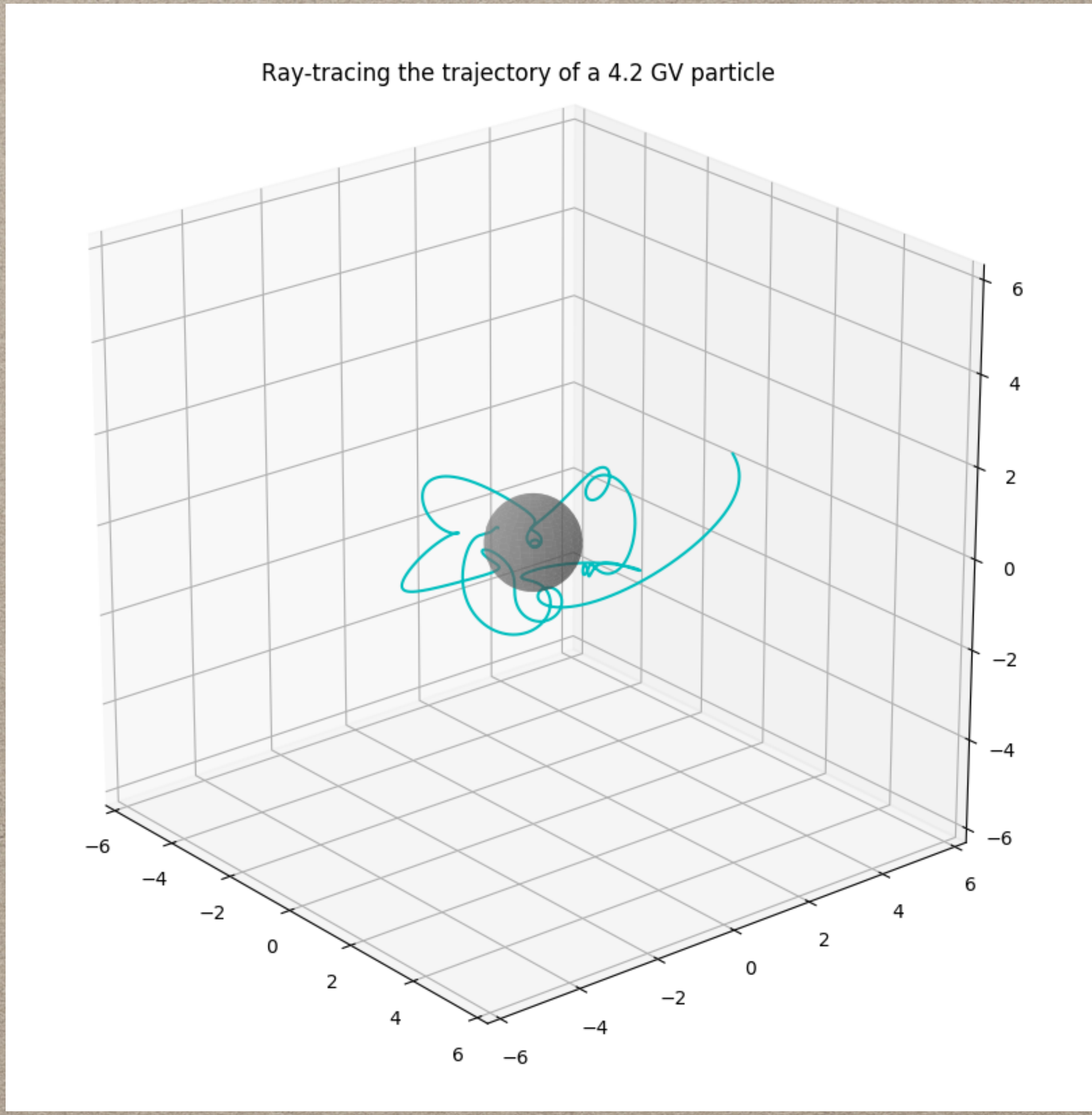



Ray-tracing the trajectory of a 8 GV particle
Located at: -30 degrees of latitude and at: 140 degrees of longitude


Ray-tracing the trajectory of a 5 GV particle
Located at: 30 degrees of latitude and at: 220 degrees of longitude

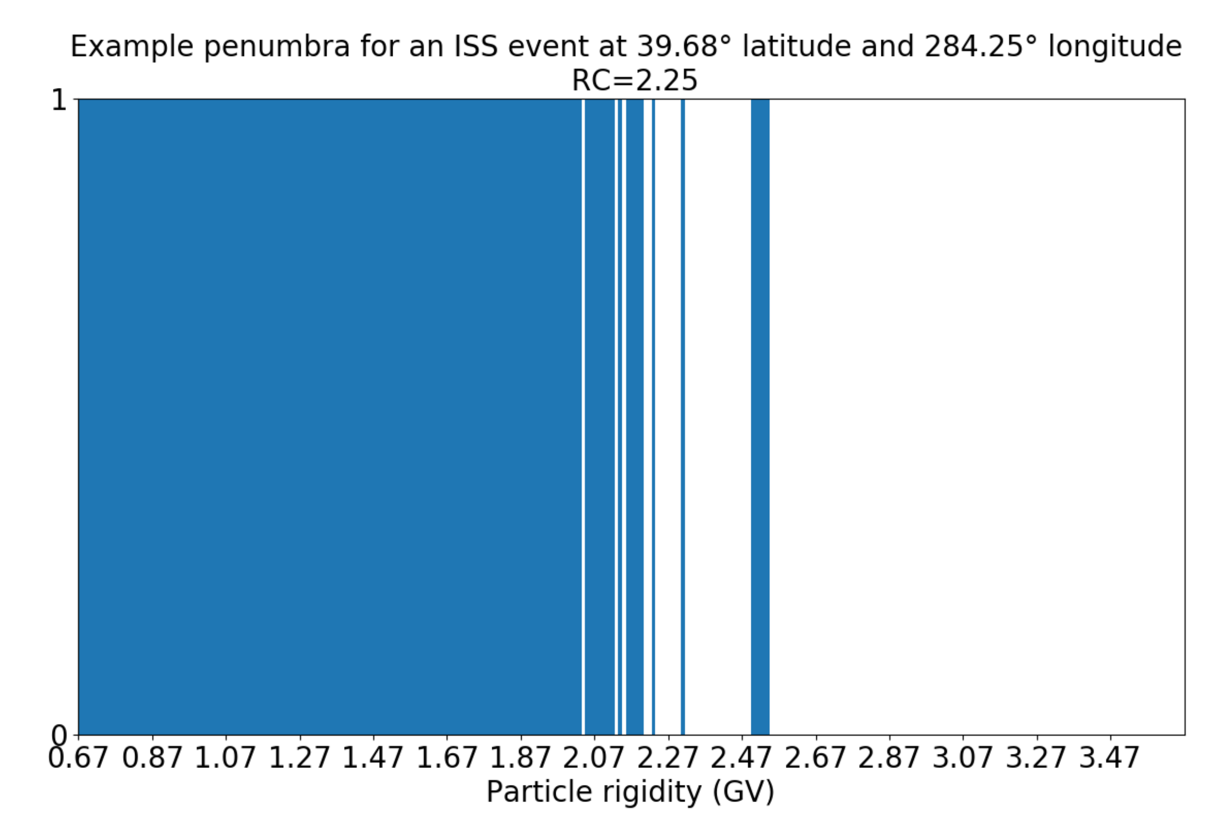
- Can find that small changes in GV can lead to very different paths

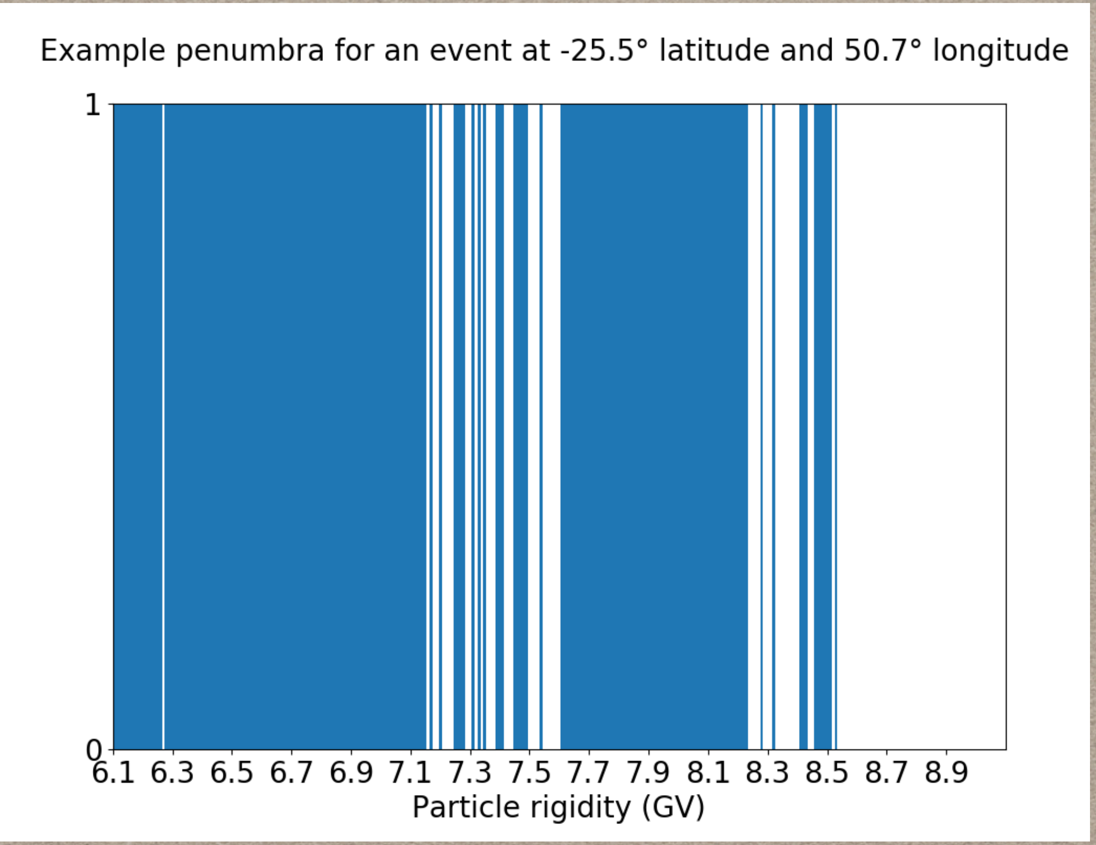


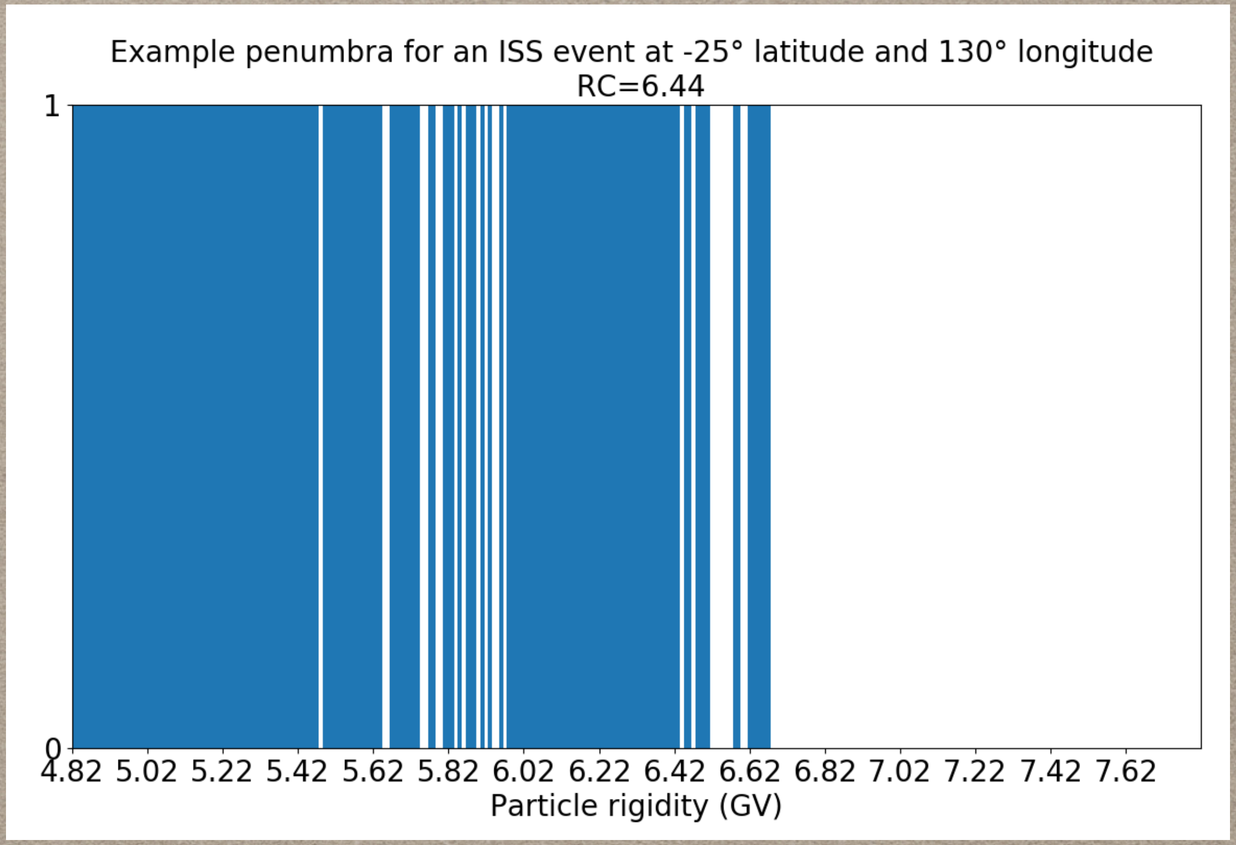


PENUMBRAS

- A few example penumbras are shown here. Filled in sections show regions of trapped particles.
- Bottom left shows vertical ground level particle.
- Top right shows vertical ISS altitude particle
- Bottom right shows a particle entering from the west with an inclination of 75 degrees.







EXAMPLE COMPARISONS

- Smart and Shea have kindly provided me some example cutoff rigidities at various locations and angles of inclination
- Table below compares their values to both my stoermer approximation and ray-tracing code

Alt (km)	Lat	Lon	Azimuthal	Inclination	Smart Shea (GV)	Stormer Approx (GV)	CK-RK (GV)
450	40.00	240.00	0	0	3.08	2.93	3.14
450	40.00	240.00	60	60	3.24	3.22	3.21
450	40.00	240.00	90	60	3.34	3.19	3.32
450	40.00	240.00	270	60	2.82	2.7	2.87
450	-25.00	130.00	0	0	6.87	6.76	6.88
450	-25.00	130.00	60	75	7.38	7.42	7.37
450	-25.00	130.00	90	75	7.45	7.33	7.51
450	-25.00	130.00	270	75	6.33	6.16	6.44

FUTURE WORK

- Will finish cleaning up my code for readability and place it on GitHub.
- I will run it on all valid UH events determining an effective cutoff for each.
- These effective cutoffs will then be used within Brian's analysis.
- I will do the UH analysis on the smaller TASC dataset.
- Potentially use this ray-tracing code for determining the positron-electron spectra in a similar fashion to what was done for FERMI-Lat.

COMPUTATIONAL IMPROVEMENTS AT WUSTL

- In anticipation of the new CALET data pass, we've recently purchased an upgrade to our computational system.
- New server with 4 nodes, each node has 24 cores (96 total) with 2.2 GHz processors and 384 GB ram per node.
- Additionally added ~400 TB of disk space.
- This will allow us to do simulation work and speed up analysis.