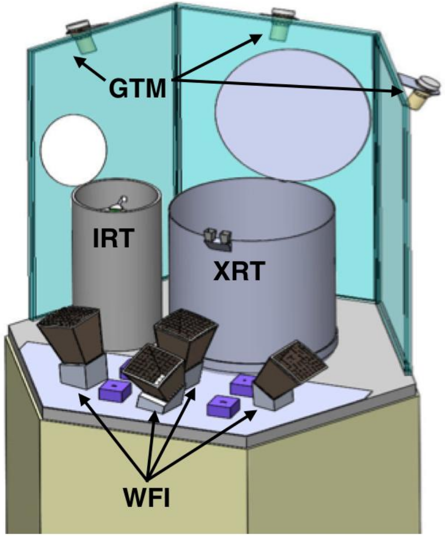
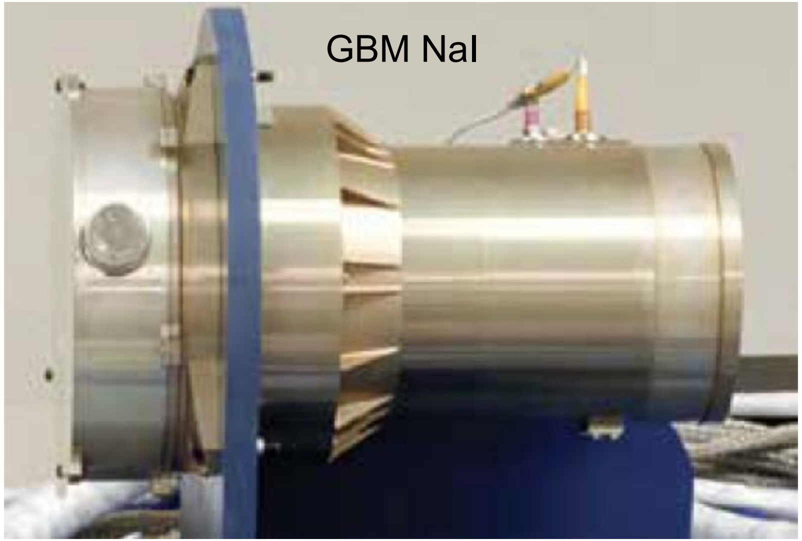
Gamma-ray Transient Monitor (GTM)





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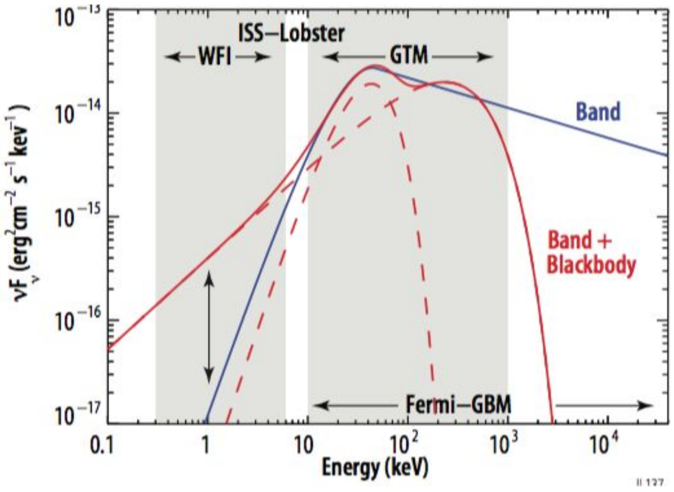
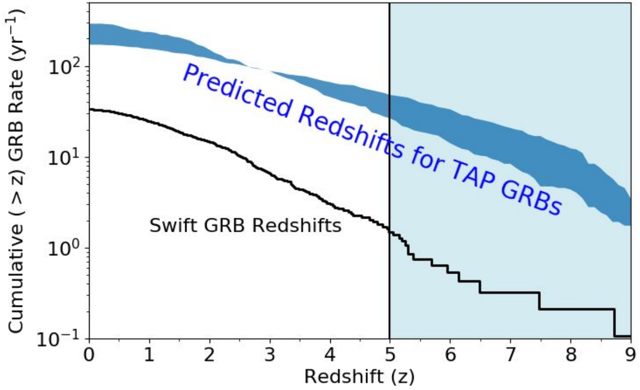
With help from Peter Shawhan (UMD), Jeremy S. Perkins (GSFC),
Judy Racusin (GSFC), and Regina Caputo (GSFC)

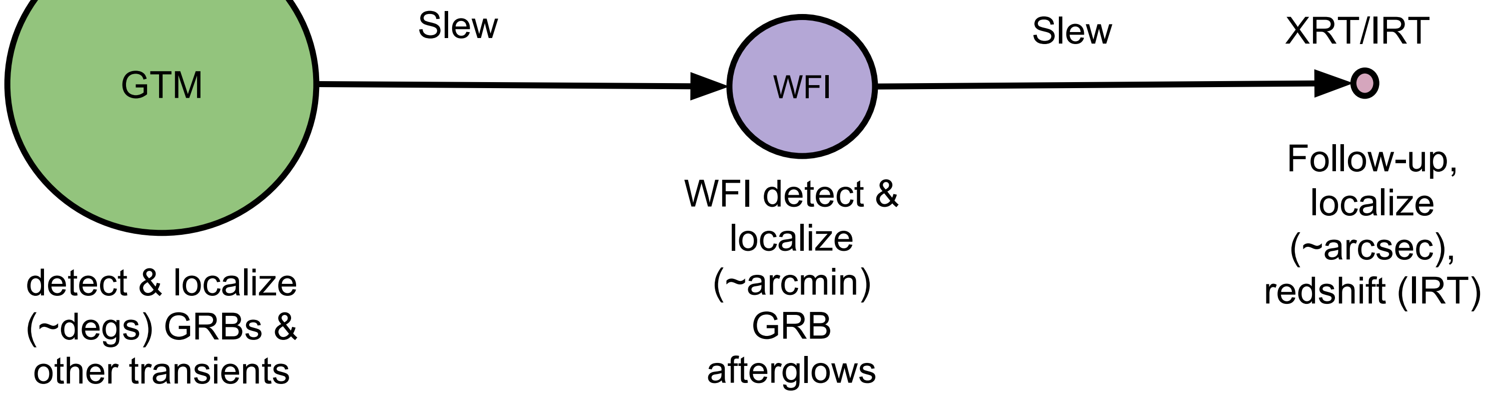
GTM Science

- GRB science
  - Extend prompt emission spectra from WFI to GTM (0.3 - 1000 keV)
  - Continue population studies from BATSE-GBM-BAT-etc
  - Provide triggers for follow-up including high-redshift GRBs
- GW counterpart science
  - Temporal coincidence with GW detectors
  - Duration measurement to determine progenitor
    - short (NS-NS, NS-BH merger)
    - long (massive star collapse)
- Solar Flares, Terrestrial Gamma-ray Flashes, Magnetar Flares, Occultation Measurements, etc.

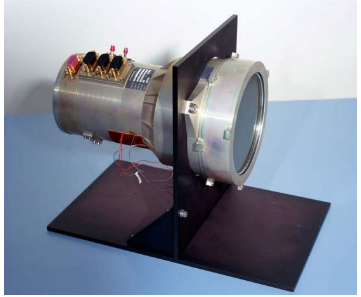


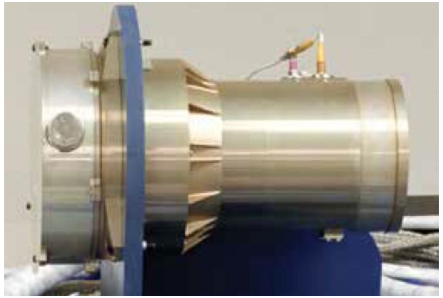


GTM Operations



Baseline: *Fermi*-Gamma-Ray Burst Monitor (GBM)





- GTM design based on the Fermi-GBM (NaI only)
  - Simplifies proposal and reduces risk (as-flown design)
- Fermi Gamma-ray Burst Monitor (GBM)
  - 12 NaI scintillators
    - 8 keV to 1 MeV
    - 12.7 cm radius disk, 1.27 cm thickness
    - Localizes bursts using relative rates in the detectors
    - Optimal orientations given by table
  - 2 BGO
    - Extends energy range: 150 keV to 30 MeV
    - 12.7 cm diameter cylinder with 12.7 cm height
    - Not used for localization

Detector ID #	Azimuth (deg)	Zenith (deg.)
0	45.9	20.6
1	45.1	45.3
2	58.4	90.2
3	314.9	45.2
4	303.2	90.3
5	3.4	89.8
6	224.9	20.4
7	224.6	46.2
8	236.6	90.0
9	135.2	45.6
10	123.7	90.4
11	183.7	90.3

Source: Fermi-GBM Performance (ArXiv:0908.0450)

Study Tasks

- Develop Software Tools to
  - Optimize Number of Detectors, Layout, and Placement
  - Determine Detector Response
  - Investigate Detector Materials
  - Investigate Optimal Design
    - Shielding?
    - Size
  - Investigate impact of other instruments and spacecraft
- Need to iterate with the science case and engineering constraints

Goal is to come up with a preliminary design that can be used to develop a science case. We expect this to be a feedback loop.

What I tried to answer

Things Needed / Trades

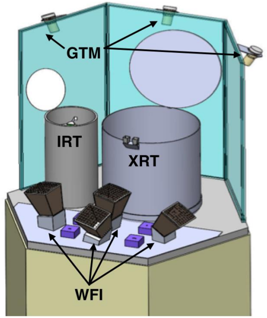
- Single detector response vs theta,phi,energy. [AM]*
  - Versus scintillator material (NaI, CsI, BGO) (S)
- Localization accuracy vs number of detectors and s/c mounting location patterns. (S) [JP]*

*[NK]

This slide is borrowed from the May 31st 2017 telecon

Objective

- Characterize a single GTM
  - Energy range, response, comparisons to Fermi GBM
- Localizations
  - Use custom program to optimize detector orientations
  - Vary # of detectors available in order to identify amount necessary
  - Determine overall localization uncertainties (comparisons to Fermi GBM)
  - Fermi GBM has alert short GRB location ~15° errors [1]
- Placement(s)
  - On top of TAP (unblocked)
  - On optical bench (partially blocked)



MEGAlib and Python Code

MEGAlib:

“The Medium Energy Gamma-ray Astronomy library (MEGAlib) is a set of software tools which are designed to simulate and analyze data of gamma-ray detectors, with a specialization on Compton telescopes. While MEGAlib was originally developed for astrophysics, it has been expanded and used for ground based applications such as medical imaging and homeland security. The library comprises all necessary data analysis steps from simulation/measurements via event reconstruction to image reconstruction” [2].

- Used MEGAlib to assume single detector properties

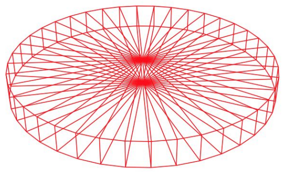
- Assumed every detector’s properties were the same, used these results for creating my own program to optimize detector arrangements [3].

What I didn’t answer (for now)

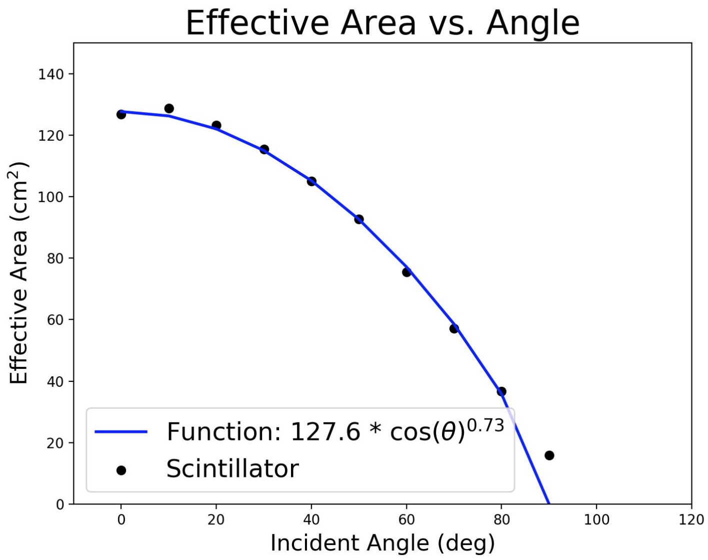
- Scintillator compositions
  - Only considering CsI for now, as opposed to NaI, BGO, etc.
- For shadowing effects, WFI, Deck, IRT, Sunshade
  - A matter of building TAP more fully on geo files, but just looking now at shadowing features created by XRT.
  - No occultation due to Earth, Moon, etc.

Properties of a single GTM

- Using MEGAlib...
  - Created geo file of the scintillator
  - 12.7 cm x 1.27 cm CsI disk
- Theta (zenith):
  - Sampled 100 keV bursts along
  - Relationship between source's position and normal of detector is found based on this trend
  - Trend: cos^0.73 dependence
- Phi (azimuth):
  - No changes to effective area when tested along const. zenith
  - A disk can't tell the difference



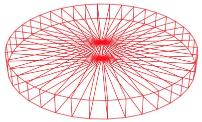
MEGAlib Detector Model

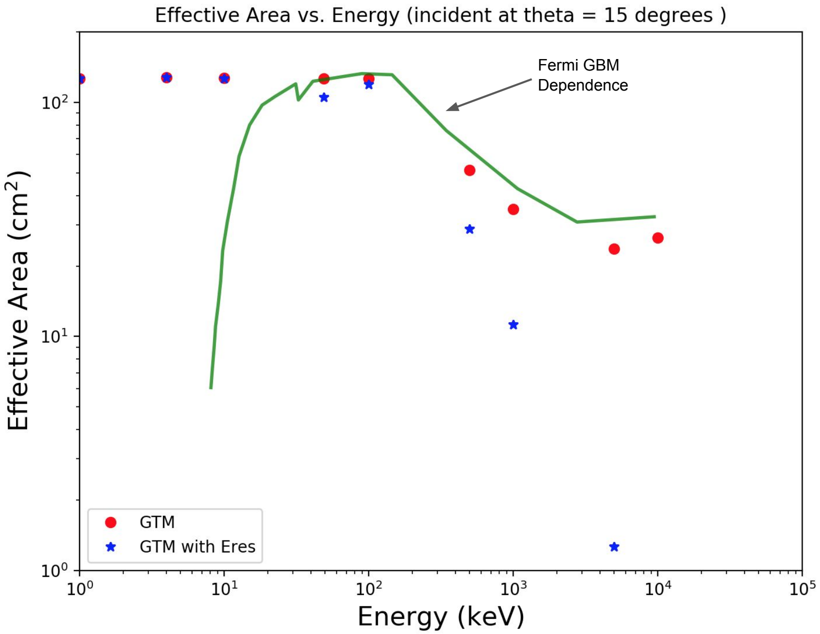


Properties cont.

- Energy Window
  - Tested source between 1 keV to 1 MeV @ a 15° tilt
- Apparent high end drop around 1 MeV
- Low end not dropping off…
  - Was supposed to be at 10 keV
- No casing around scintillator
- Next time, add some Al

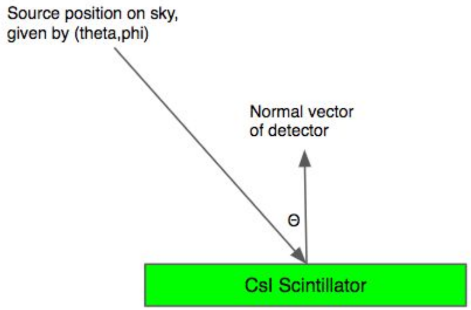
Eres ≡ Added term to energy, (approximately a + 1/sqrt(E))





Localizations

- Designed to find the optimal arrangements of these detectors
- Using python code…
  - Artificially created source of 500 counts at some given position
    - 1000 counts background w/ gaussian fluctuations
  - Solve for relative # of counts in each detector
    - **counts=500*cos(Θ)^.73 + 1000, unc = unc=√(counts)**
    - **Relative counts = random numbers drawn from a gaussian distribution**
  - Only allowed GRBs to strike face of detectors (Graded-Z Shielding)



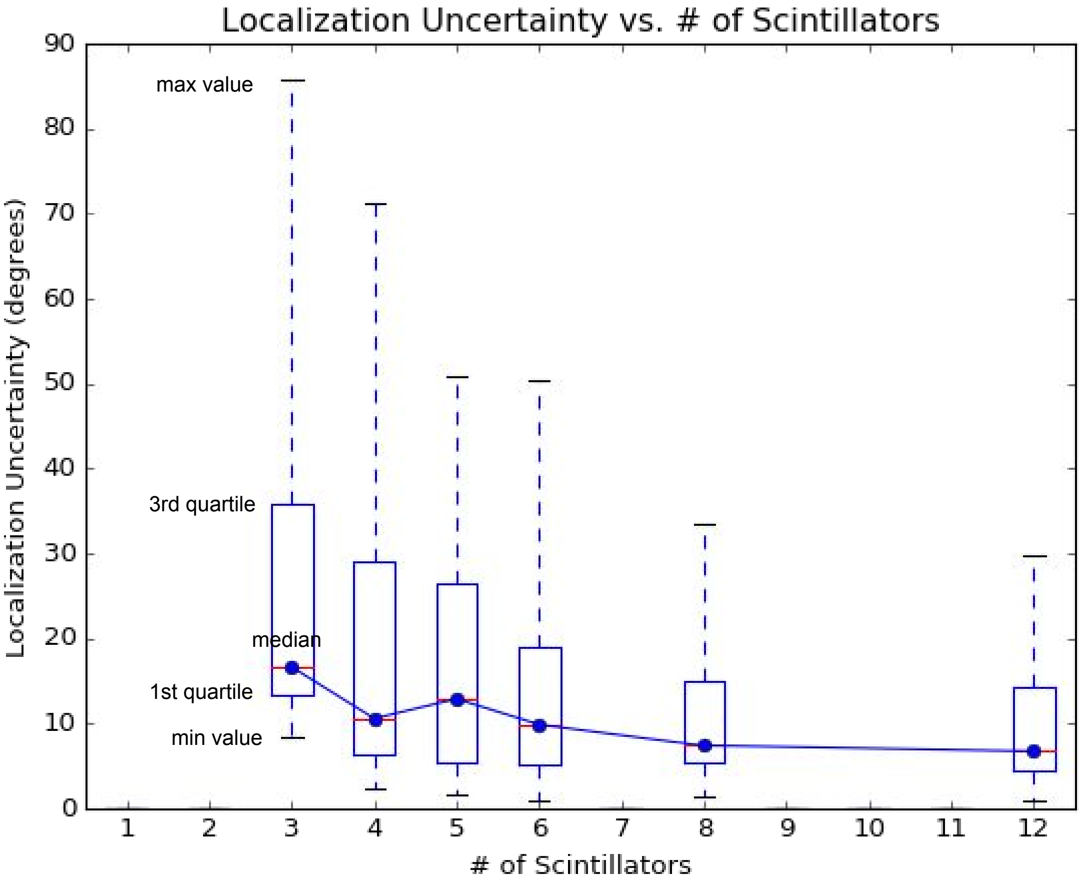
Θ = angular separation between normal of detector and source position

Localizations cont.

- After creating relative # of counts in each detector, figure out where the GRB that would make this impression would have had to happen:
    - Sample entire sky + source strength
    - Using chi-squared best fit
- Repeat for same sky position x times to characterize instrument
    - Currently trying 100 times to get average separation btw reconstructed and actual position.
- Repeat this process over entire sky for overall localization uncertainty
- Repeat over new instrument geometries and # of scintillators
    - Use this as a quantitative means to describe TAP
    - 2 indicators of optimization, sky coverage, and localization uncertainty
- Trying to keep median <15°

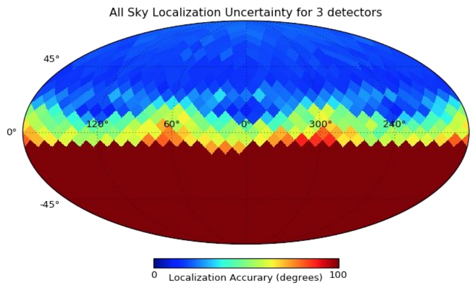
Disclaimer: more advanced algorithms [4] can get these localizations down much more than I can.

Results

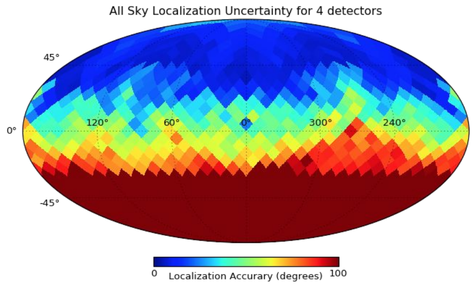


These values only reflect GRBs tested over ½ of the sky!

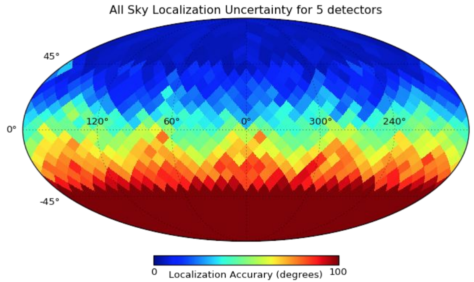
#	Optimal Geometry (tilted down from midplane)	Median Localization Uncertainty (degrees) Over Half The Sky
3	15°	16.6
4	30° by 45 °	10.6
5	45°	12.9
6	30° by 45 °	9.9
8	30°	7.4
12	30°	6.7

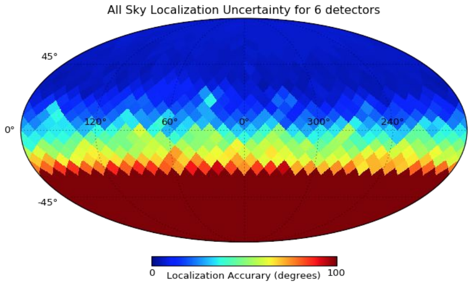


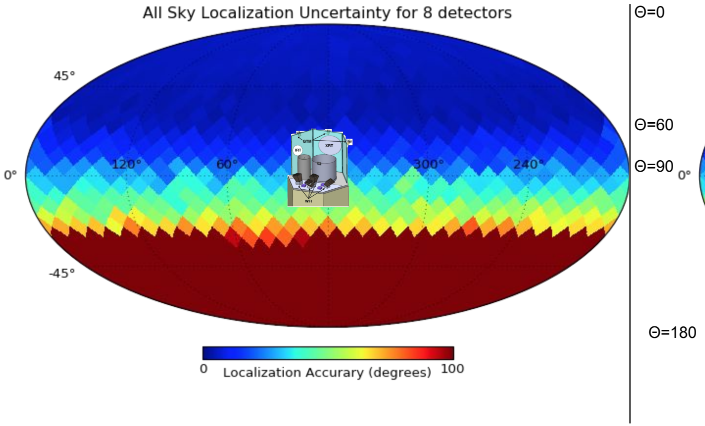
All tilted down by 15°

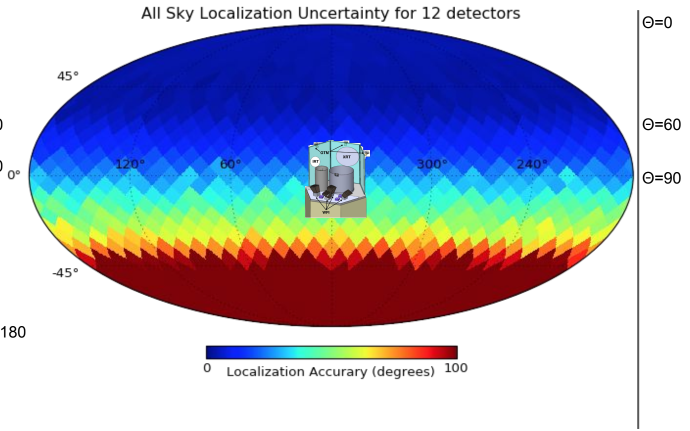


Alternating tilts of 30°x45°°





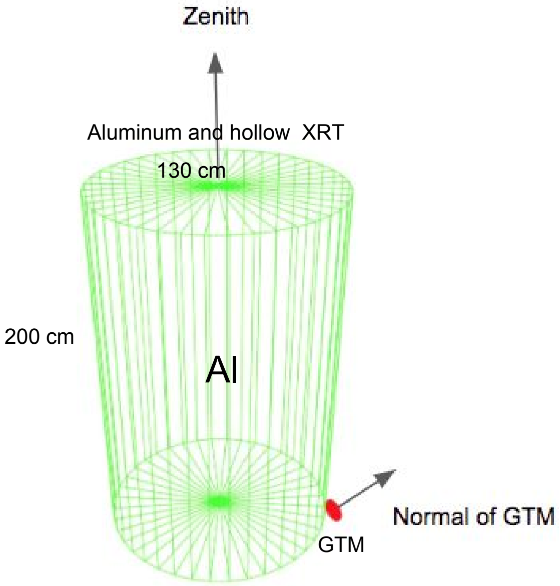




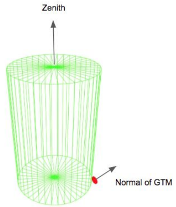
Emphasizing the 8 and 12 scintillator arrangements, fewer # systems are unlikely choices

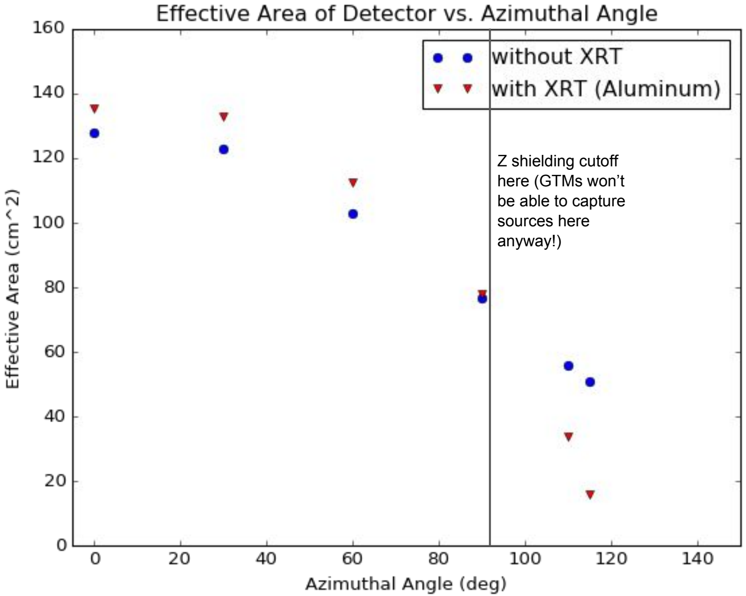
Shadowing

- Now going to try sampling theta,phi for this model
- Find new azimuthal and zenithal dependence
- Reconstruct skymaps with these conditions
  - Determine influence
- Current Specifications:
  - XRT 130 cm x 200 cm hollow cylinder with 1 cm walls
- On optical bench, assuming goes through
  - Showing effect of one object

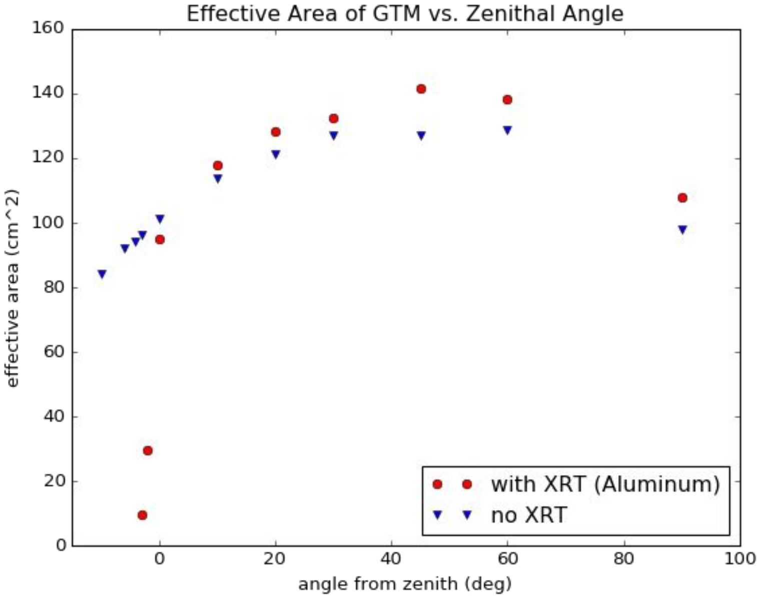


Changes along Azimuth and Zenith due to XRT



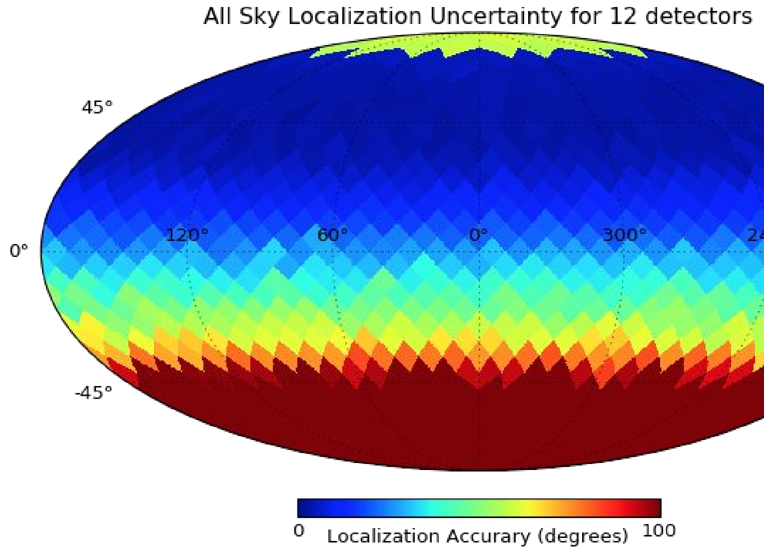


Azimuthal dependence at Θ=45°, right above the GTM



Influence cont.

Based on these conditions, it is (somewhat) possible to create a newly constructed skymap of this new setup



Conclusion

- 12 scintillator arrangements are best
- Lowest median uncertainty, most sky coverage
- For ~10° from zenith down, significantly worse localizations compared to original mounting location
    - This is a problem, as this is what every other instrument is pointed at
- Don’t have GTMs *right* next to XRT… this should free up some more of its available range
    - Still need to add the rest of TAP
- config is not flight config
- preliminary for the purpose of simplifying things to explore basic configuration of detector number, angle, and shadowing

Acknowledgments

Thanks to Peter Shawhan, Jeremy Perkins, Judy Racusin, and Regina Caputo for helping me set up, build, and debug the programs I used for my project.

To do (left as an exercise for the reader):

1. Bring more sophisticated modelling into the fold
   a. Eventually, geo file used should look exactly like TAP
2. Skymaps are preliminary for the purpose of simplifying things to explore basic configuration of detector number, angle, and shadowing
   a. Should be modified for any sort of positioning of TAP, not just precisely at the zenith
3. Different scintillator materials
4. Model Eres + escape
5. Think about arrangement under other technical constraints
   a. Fermi GBM for instance aren't arranged in a circle

References

[1]: https://fermi.gsfc.nasa.gov/science/instruments/table1-2.html

[2]: http://megalibtoolkit.com/

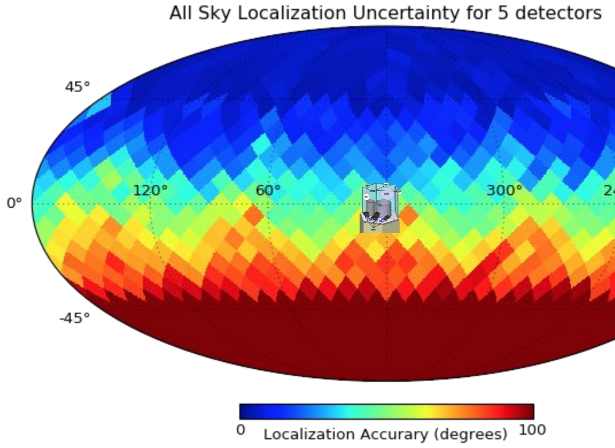
[3]: https://github.com/nkasmanoff/Localizing-Simulations

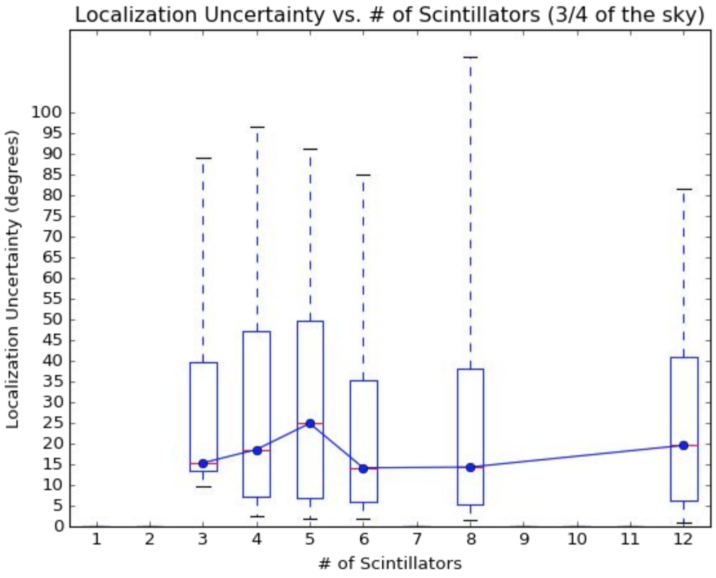
[4]: Connaughton et al 2015

Backup Slides

¾ of the Sky Plot

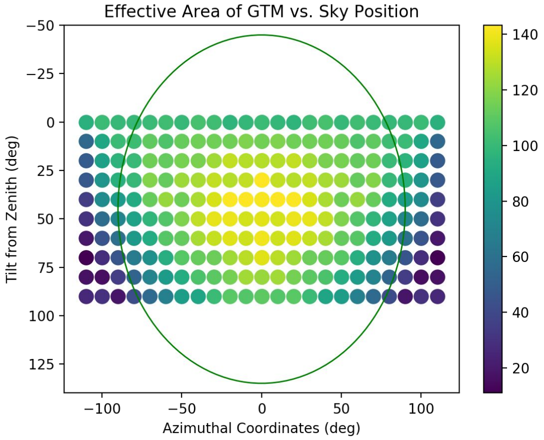
- Only optimized geometries over half of the sky, almost all of these arrangements had significantly dropped off past the midplane.

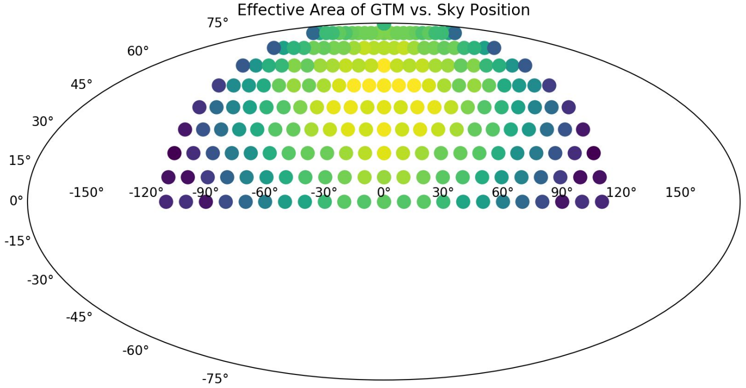




Exposure

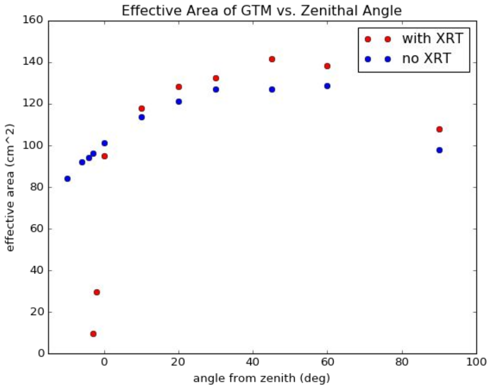
- Despite blocking on the side, this will be blocked anyway
- Real problems occur around zenith, and points past there are blocked
- Some reflection off of aluminum XRT?

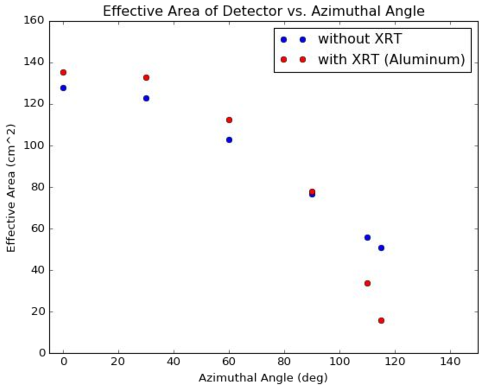




Influence

- Changes along azimuthal and zenithal lines
  - Cut off along azimuthal lines around 115°, which is past the z shield anyway.
  - Larger problem at the top, significant shadowing effects once sources come on other side of XRT.





Potential changes to geo files?

Could be useful to make some new designs and put them here