Muons with the GCT

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Presented by
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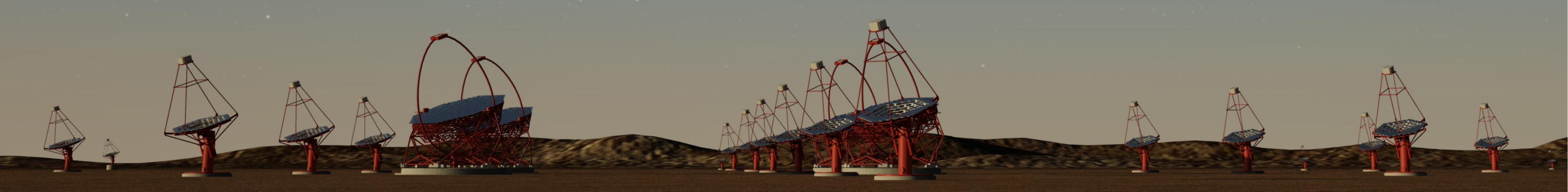
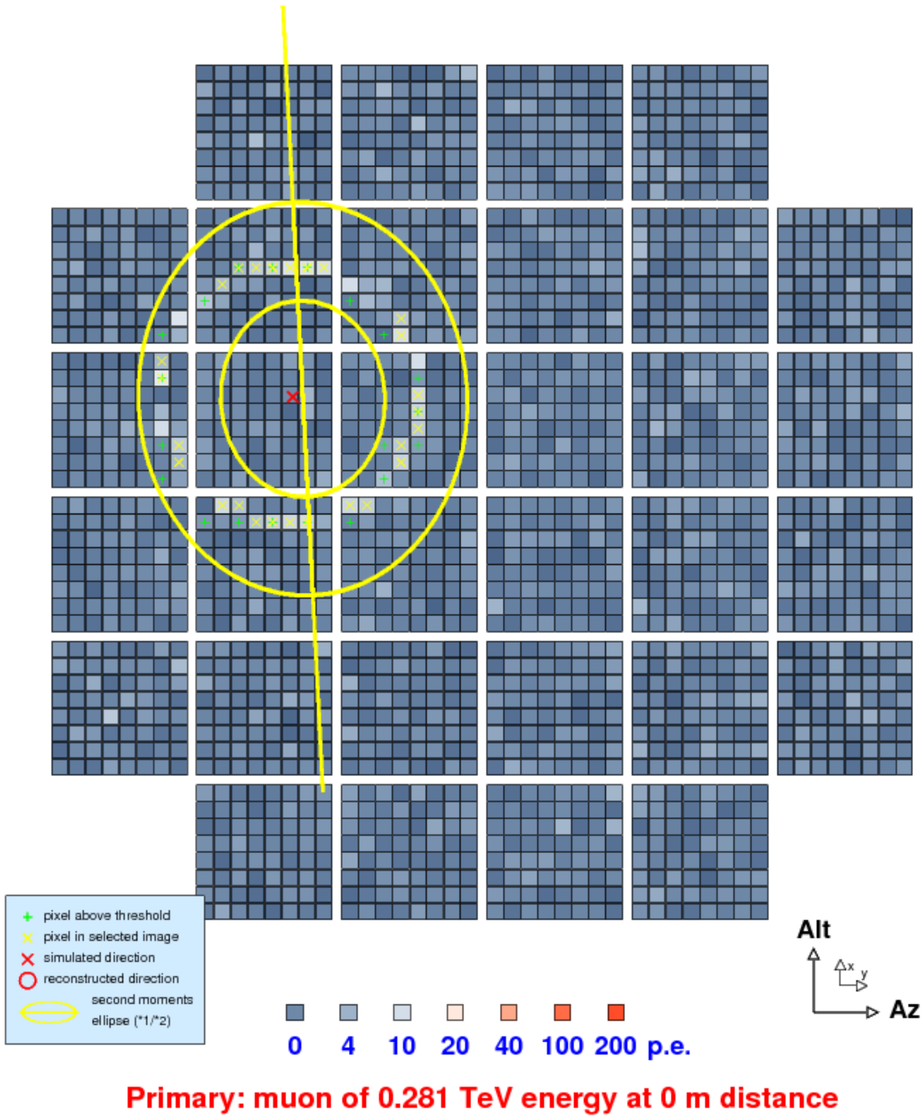


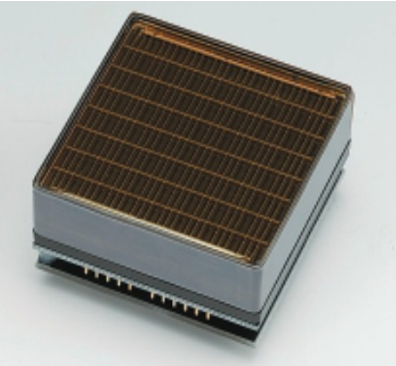
Outline

- Configurations
- Method
- Efficiency
- Degradation
- Reconstruction Resolution
- Impact parameter

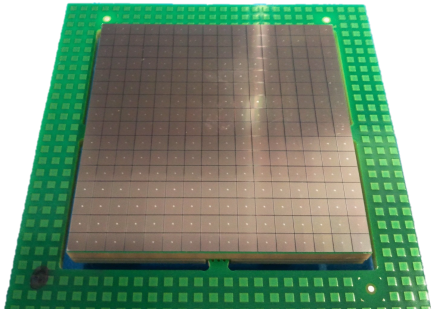


Camera configurations

- Using Most up to date Prod 3 configuration files



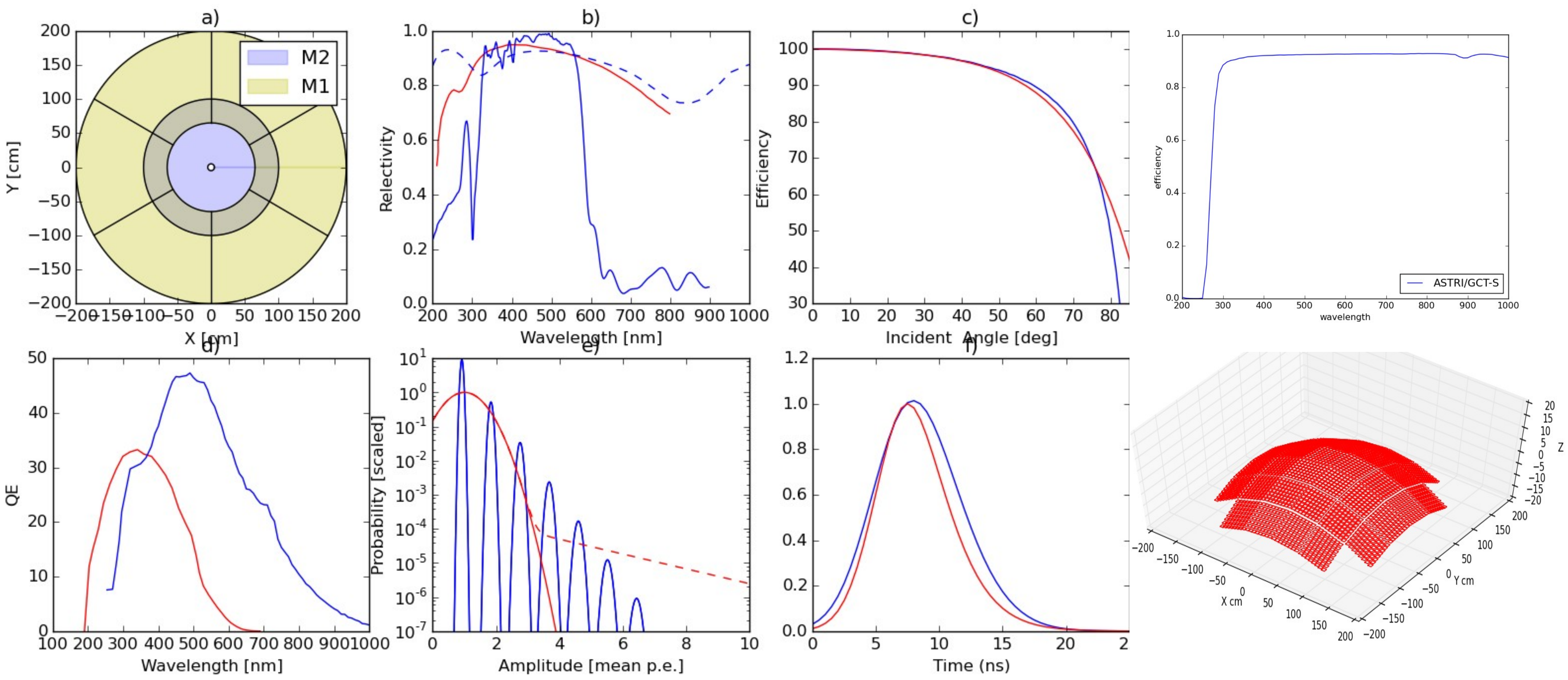
- GCT-M
  - SST-GATE structure with MaPM based camera
  - Most past muon work has been carried out using this set up



- GCT-S
  - SST-GATE structure with SiPM based camera

Configuration Plots

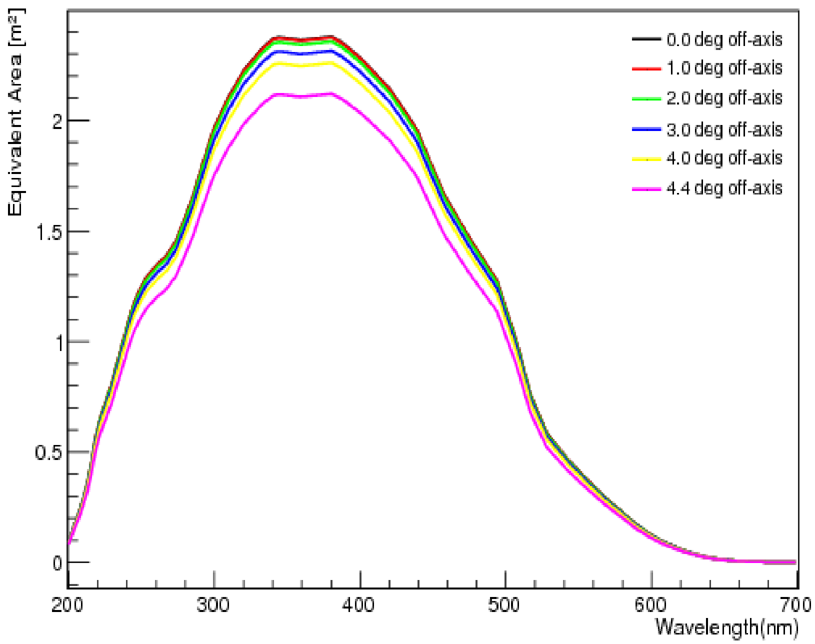
GCT-M and GCT-S



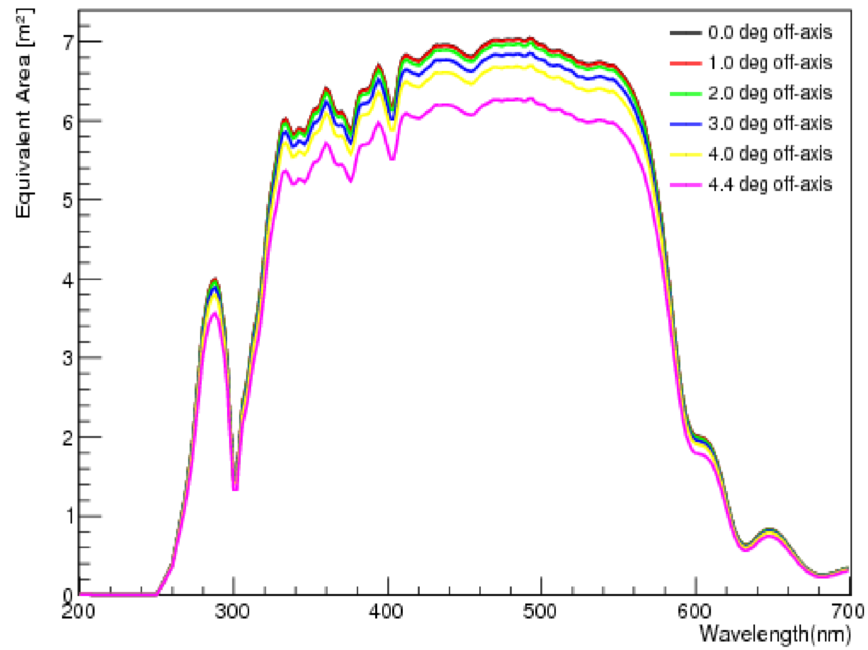
Using common SiPM parameters between GCT and ASTRI for Mirror reflectivity, SPE and PDE (provided by ASTRI)

Equivalent Area

GCT-M



GCT-S



Gives a good idea of the relative sensitive ranges of GCT-M and GCT-S. Shorter wavelengths more important for muons.
GCT-M reaches shorter wavelengths however GCT-S has an overall larger equavalent area.
Includs: Reflectivity, Angular and wavelength response of detector/window, Shadowing and PDE

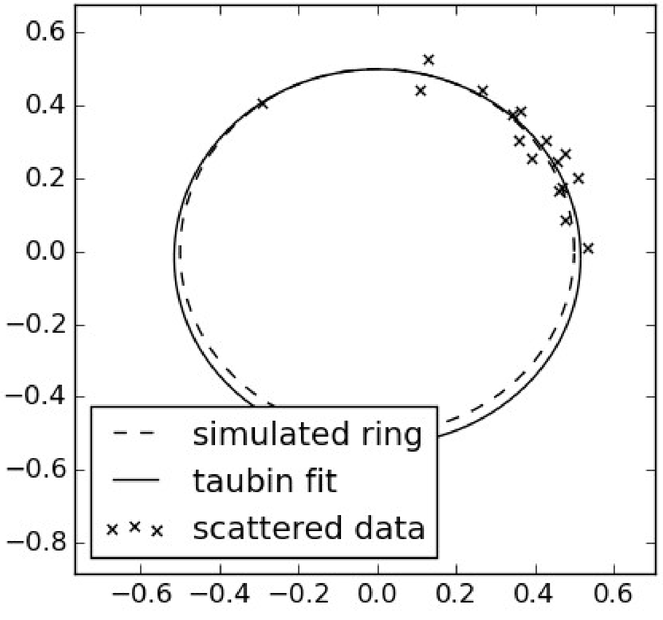
Muons

- Using the same data choice as previously
  - Number of showers: 1e6
  - Site: Aar
  - Energy range: 4 GeV –> 1 TeV *
  - From Zenith
  - Scattered within primary mirror (R=2.2)
  - Emission at h=2.057 km a.s.l. (within 4.400 m. of the telescope)

Reconstruction method

- Performed in read_hess
- Find pixels that are in the image (calibrated and cleaned data)
  - Two tailcut levels, 5/10 and 3/6
- Use fast and robust circle fitting algorithm (Taubin)
  - Minimises the function:

$$\xi = \frac{\sum[(X-X_c)^2 + (Y-Y_c)^2 - R^2]}{\sum[(X-X_c)^2 + (Y-Y_c)^2]}$$



- Performs well even for arcs
- Returns fit parameters and all pixels within +/- 2 cm of the ring

Initial Cuts

- Initial, non optimised, cuts performed:
  - Fit radius 0.5 < R < 1.5
  - Number of Pixels in image > 10
  - Number of p.e. In image > 20
  - Ring c.o.g. + ring radius < camera radius (edge)
  - Fit quality ξ < 0.05, using the equation:

$$\xi = \frac{\sum[(X - X_c)^2 + (Y - Y_c)^2 - R^2]}{\sum[(X - X_c)^2 + (Y - Y_c)^2]}$$

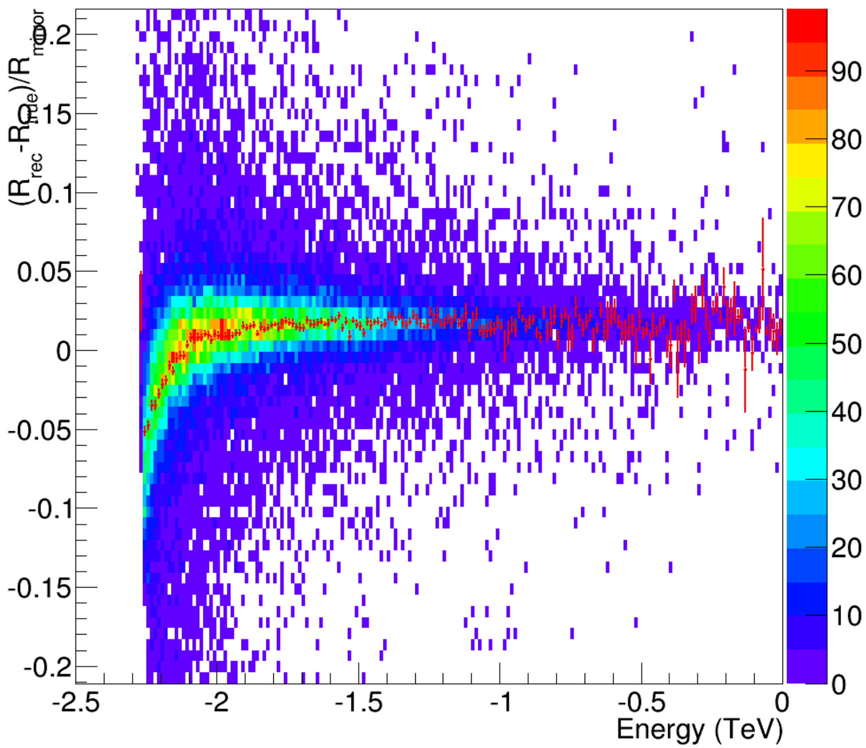
These will have to be optimised to achieve best performance

Reconstruction - Radius

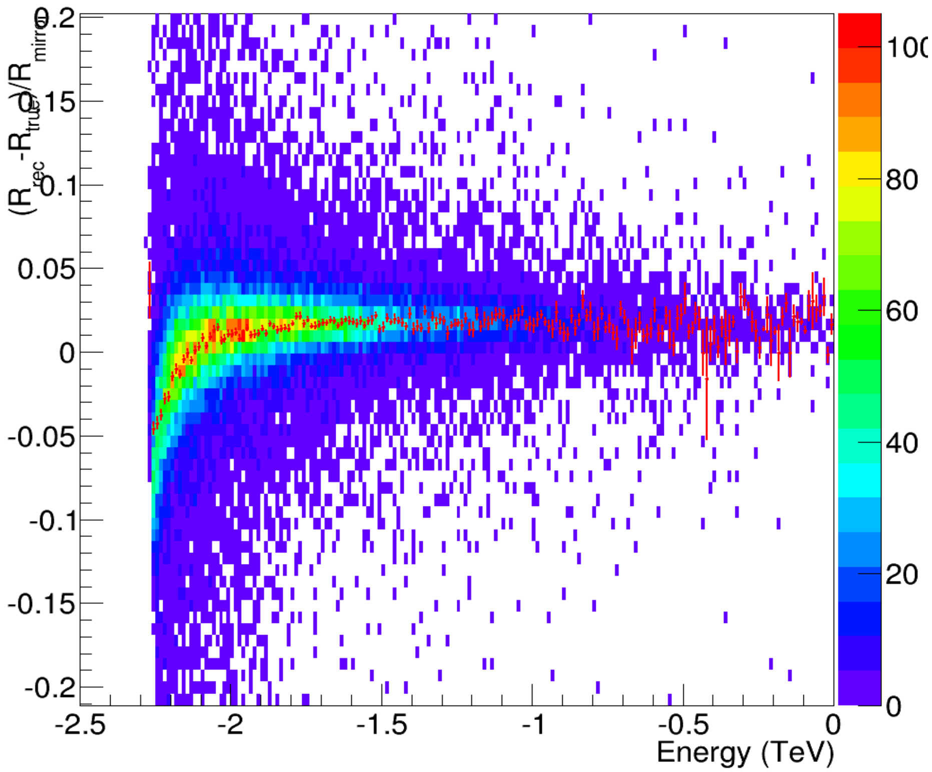
Comparing Reconstructed radius of ring (in deg, converted using known plate scale) to the cherenkov opening angle

$$R_{true} = acos\left\{\frac{1}{n\sqrt{1-(E_o/E_\mu)^2}}\right\}$$

GCT-M



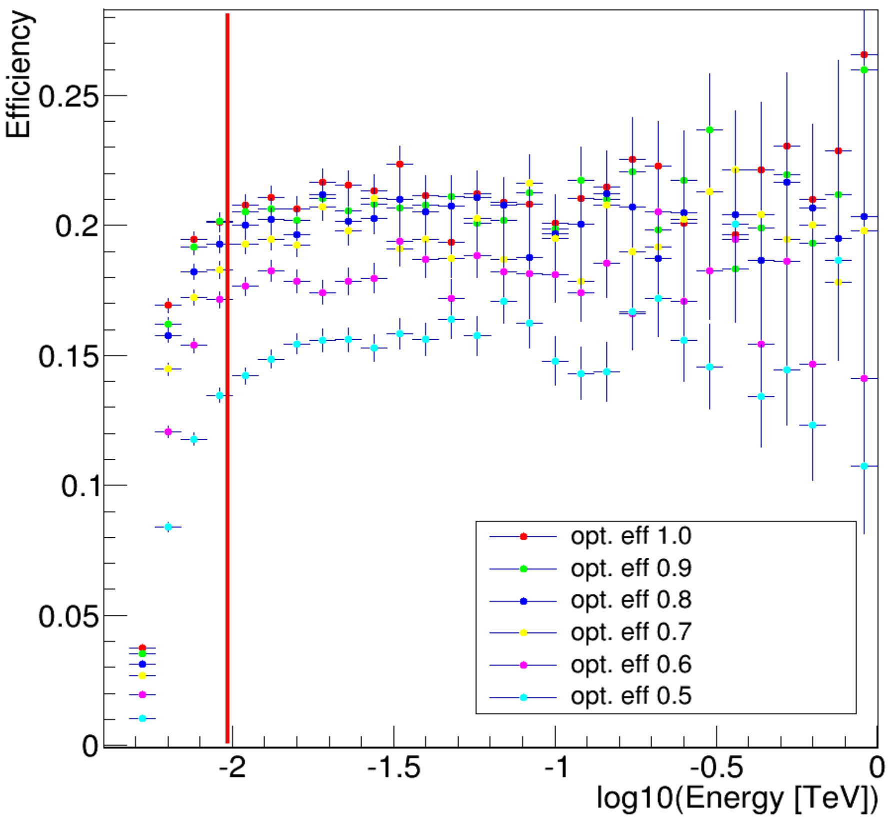
GCT-S



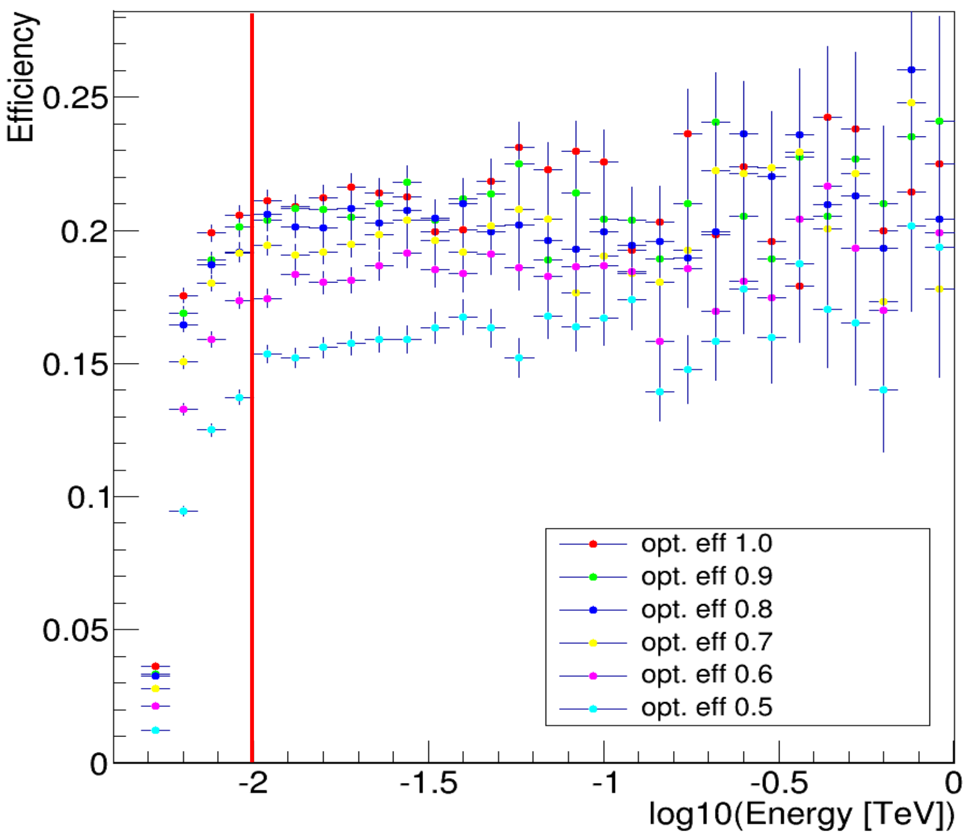
Efficiency

- Efficiency (post initial cuts) as a function of energy.
- Drops off rapidly below ~10 GeV
  - Results would see an improvement with a low energy cut.

GCT-M

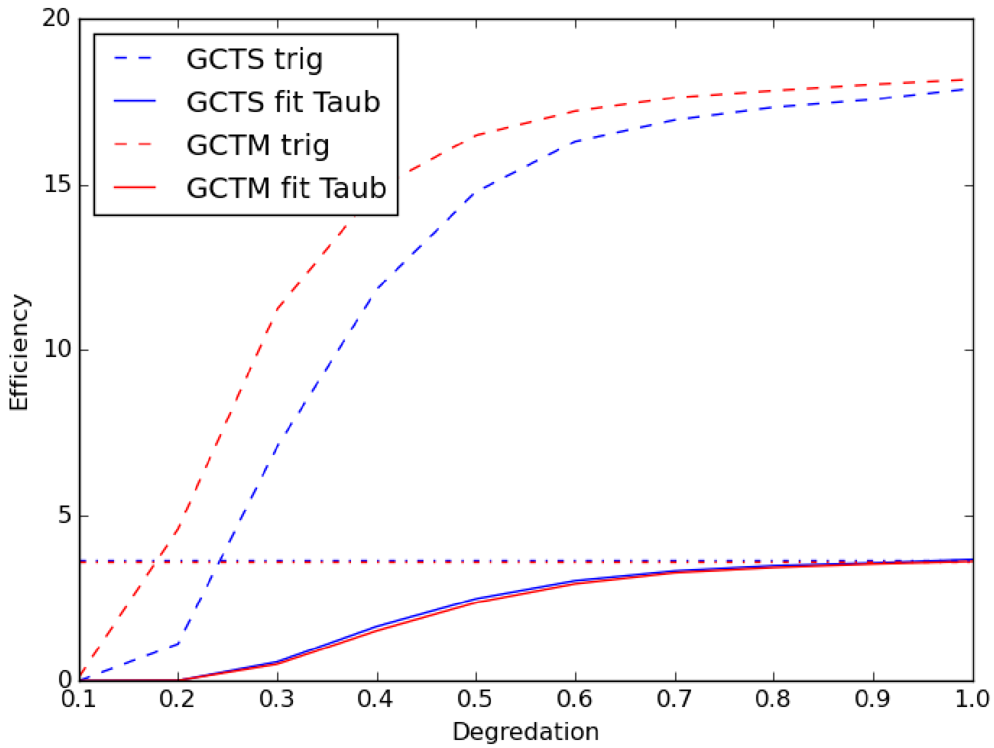


GCT-M



Degradation

- Efficiency as a function of system degradation (such as deterioration of mirrors).
- For 4 < E < 1e3 GeV.
- If using a cut at 10 GeV the efficiency is increased to ~ 20 %



Trigger efficiency

Post cut efficiency

Reconstruction - Impact

- Important parameter to retrieve from fitting procedure is the impact parameter.
- Obtained by looking for modulation around the muon ring.

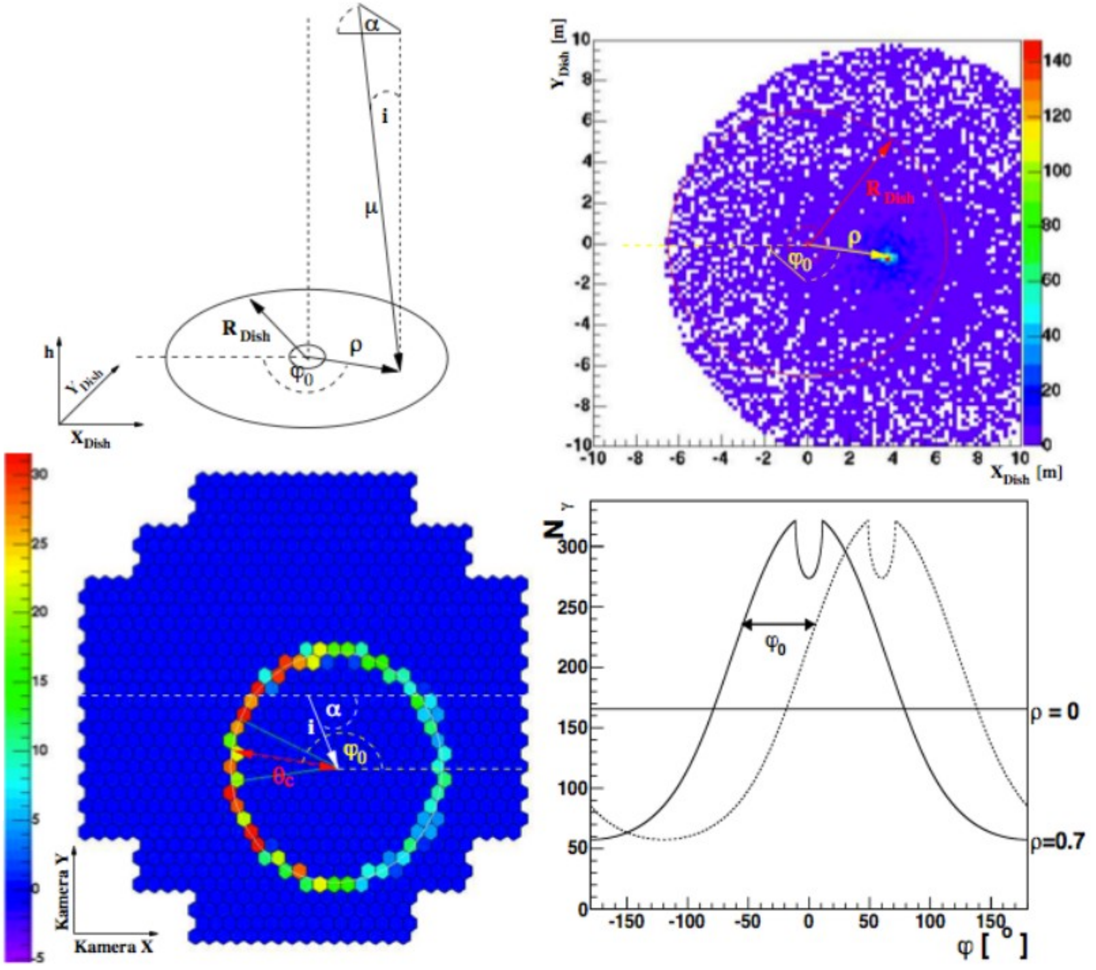
Simple case for one mirror system:

$$\frac{\mathrm{d}N_{\mathrm{obs}}}{\mathrm{d}\phi}(\rho,\phi_0) = \alpha\cdot\sin^2(\theta_c)\cdot L\cdot I\cdot T\cdot\varepsilon_\mu \quad ,$$

$$= \frac{\alpha}{2}\cdot\sin(2\theta_c)\cdot D(\rho,\phi-\phi_0)\cdot I\cdot\varepsilon_\mu \quad , \quad \text{with :}$$

$$D(\rho,\phi-\phi_0) = \begin{cases} 2R\sqrt{1-\left(\frac{\rho}{R}\right)^2\sin^2(\phi-\phi_0)} & \text{for :}\quad \rho > R \\ R\left[\sqrt{1-\left(\frac{\rho}{R}\right)^2\sin^2(\phi-\phi_0)}+\frac{\rho}{R}\cos(\phi-\phi_0)\right] & \text{for :}\quad \rho \le R \end{cases}$$

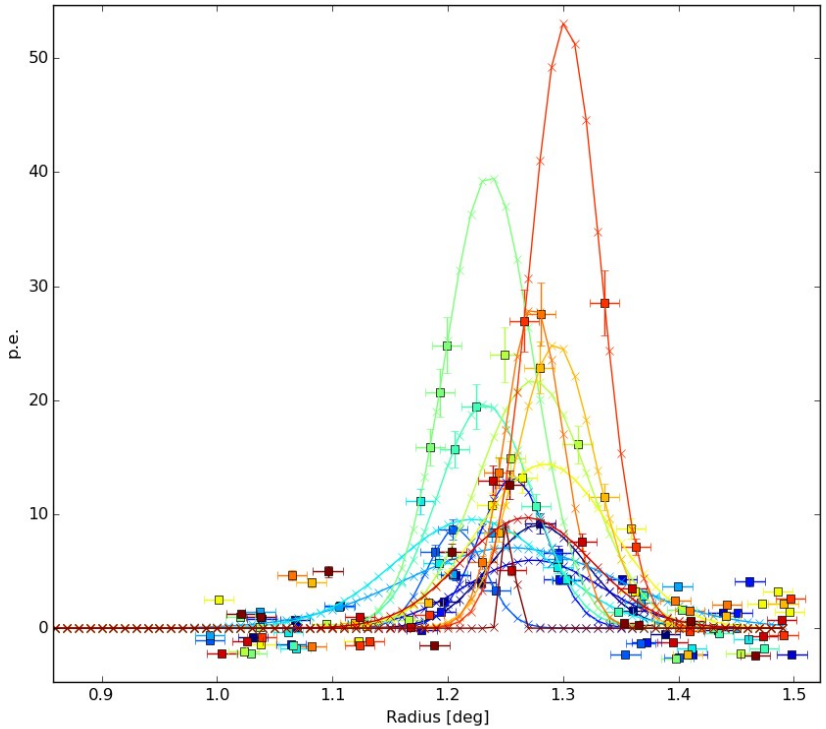
Need to consider effect of shadowing from the secondary.

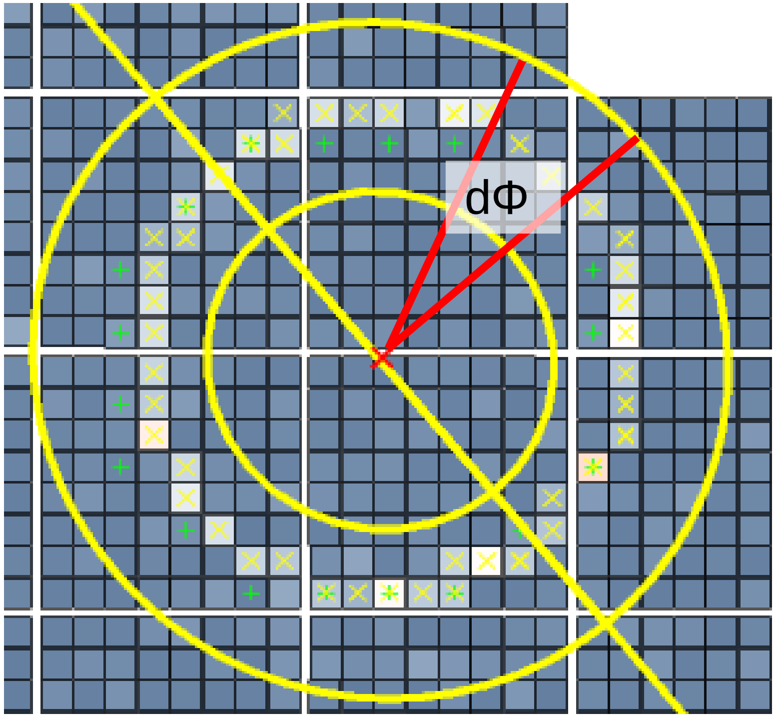


Reconstruction - Impact

- Take all pixels within +/- 2cm of the fit on the muon ring.
- Divide into dΦ and fit with Gaussian to find peak p.e.

Each colour represents a different bin

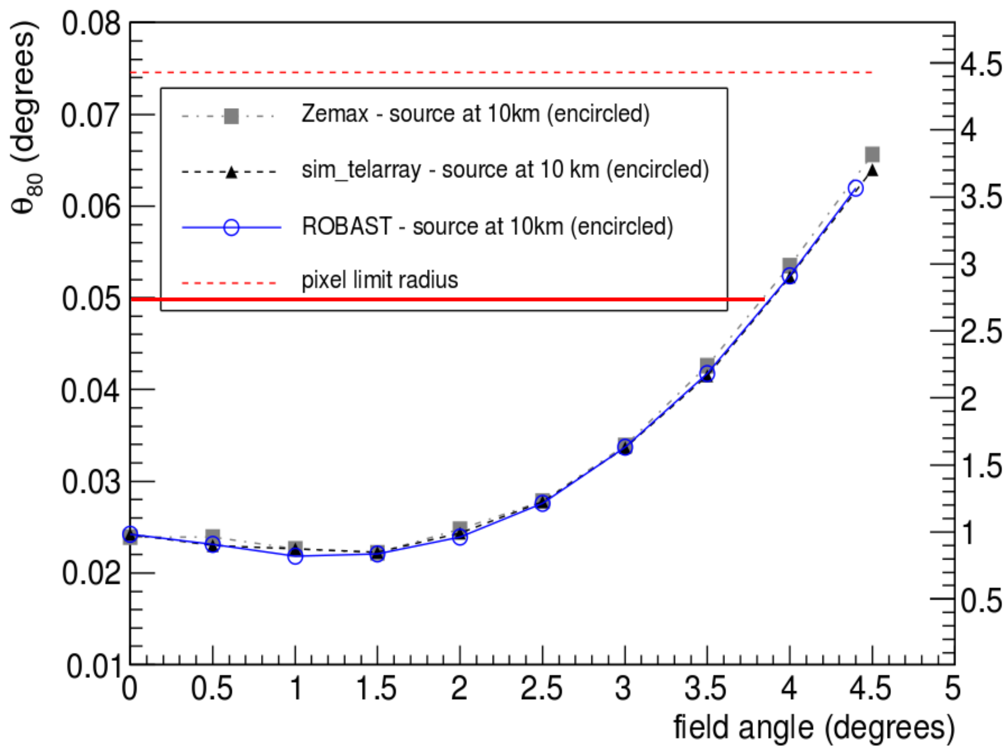




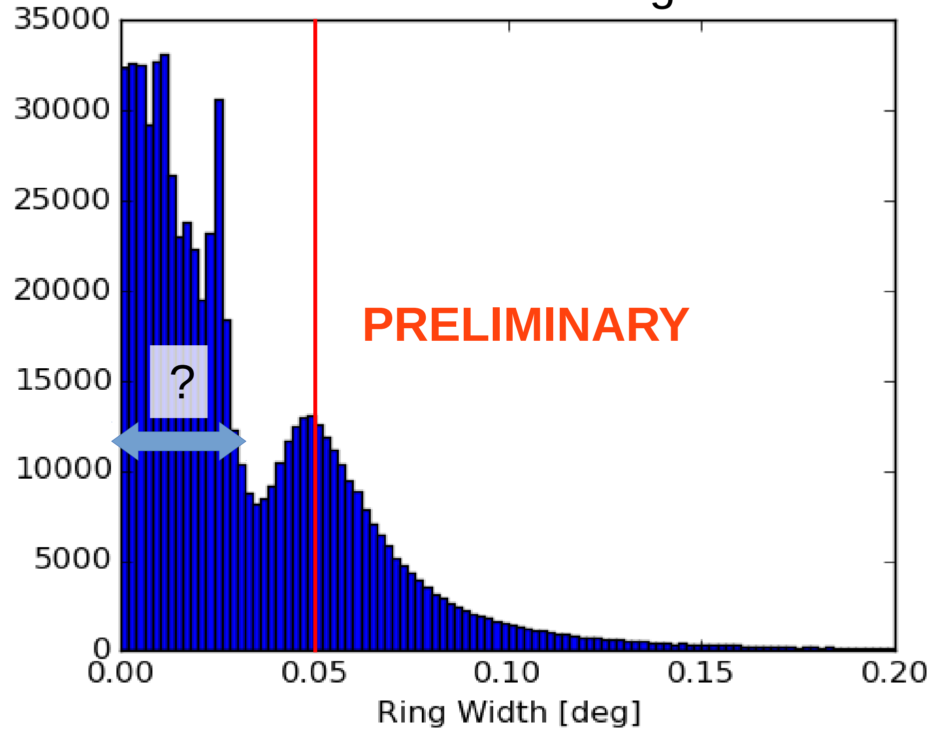
Reconstruction - Impact

- Take all pixels within +/- 2cm of the fit on the muon ring.
- Divide into dΦ and fit with Gaussian to find peak p.e.
- Bonus: This can be used to estimate the PSF

Ray tracing simulation



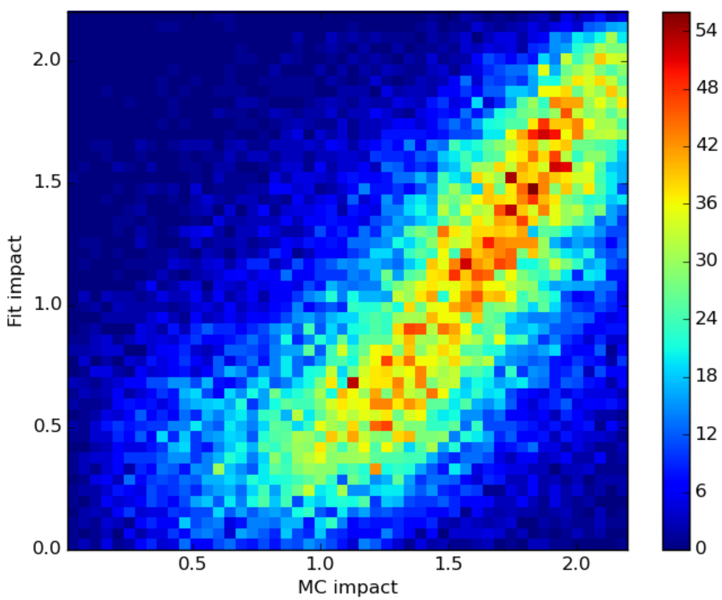
Preliminary results from muon ring

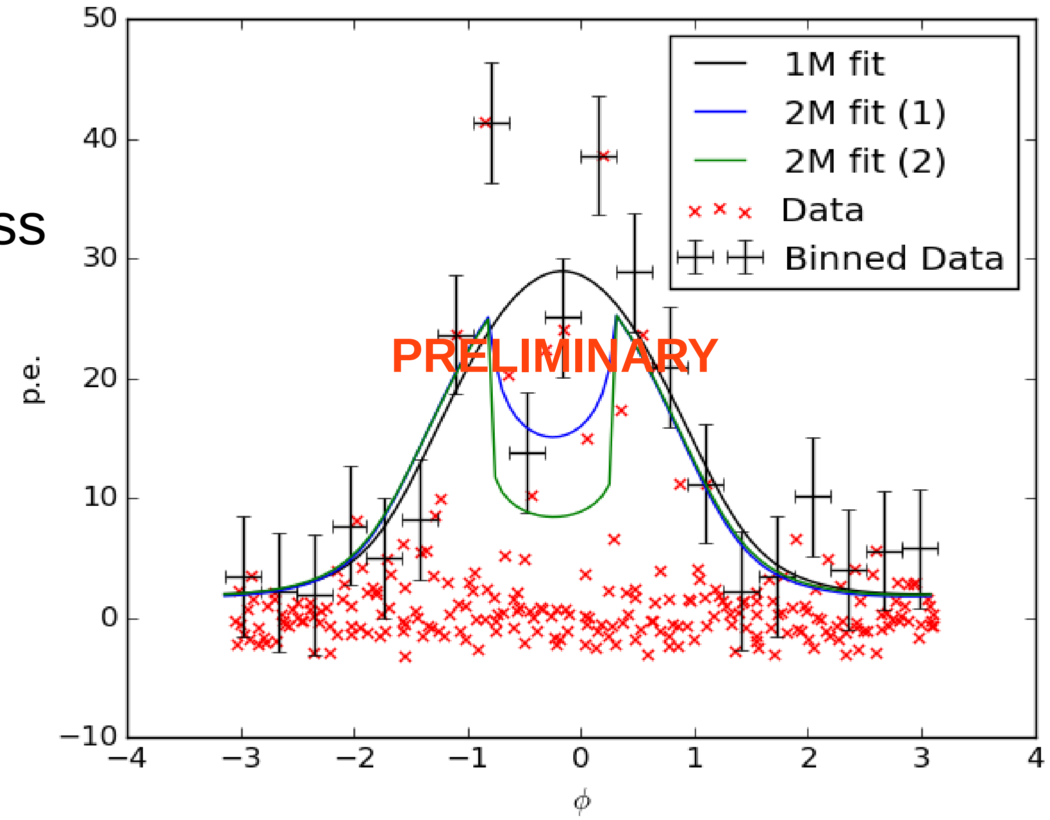


Reconstruction - Impact

- Very preliminary results...
- Simulated data only has ρ < R
- Fitting is far from optimal
  - Two mirror fitting in progress

Simple single mirror fit:





Conclusion

- GCT-S and GCT-M have very similar results.
  - Surprising? Recall equivalent area. While MaPMs are sensitive to shorter wavelengths, SiPMs are a lot more efficient over all.
- Reconstruction of muon ring performs well using a hack to read_hess (hack available on request)
- Reconstruction of impact parameter (and efficiency) still needs work.