Event Reconstruction for SWGO

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The Southern Wide-field Gamma-ray Observatory

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

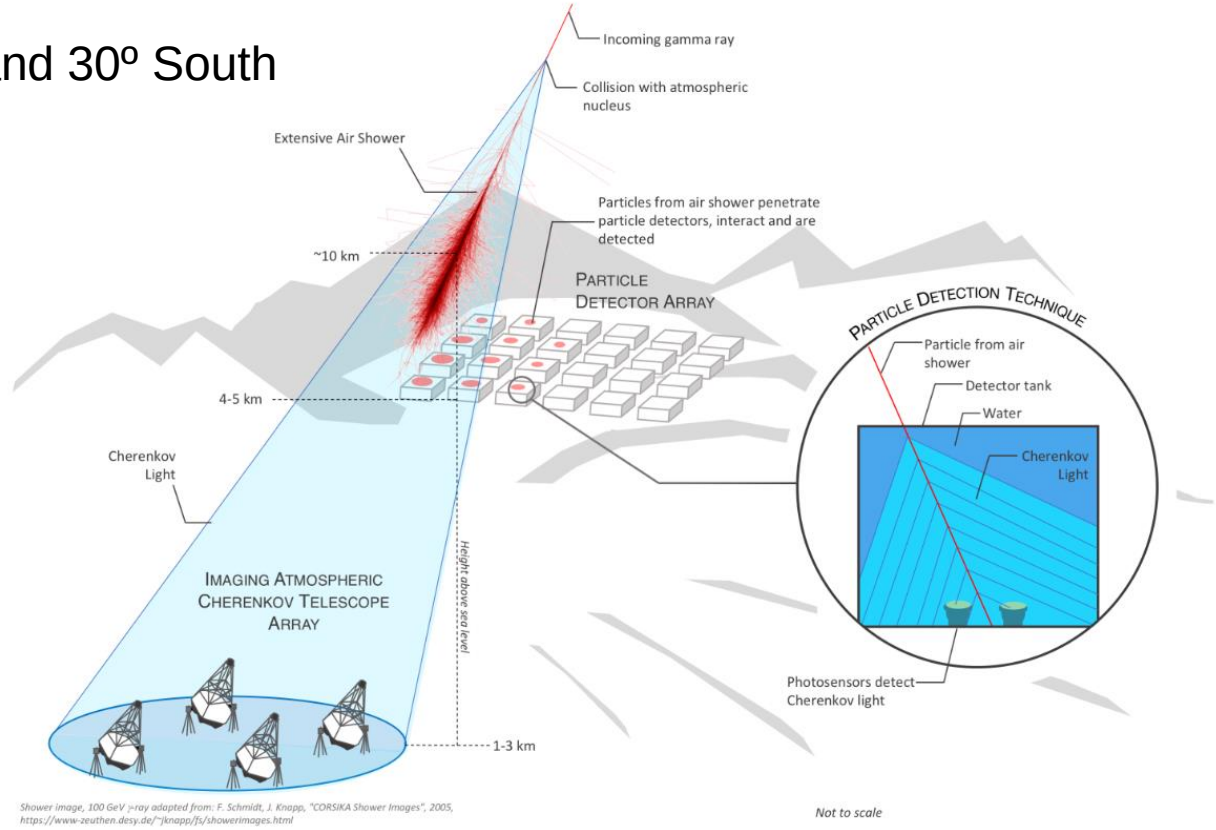
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Contents

The Southern Wide-field Gamma-ray Observatory (SWGO)

The Southern Wide-field Gamma-ray Observatory

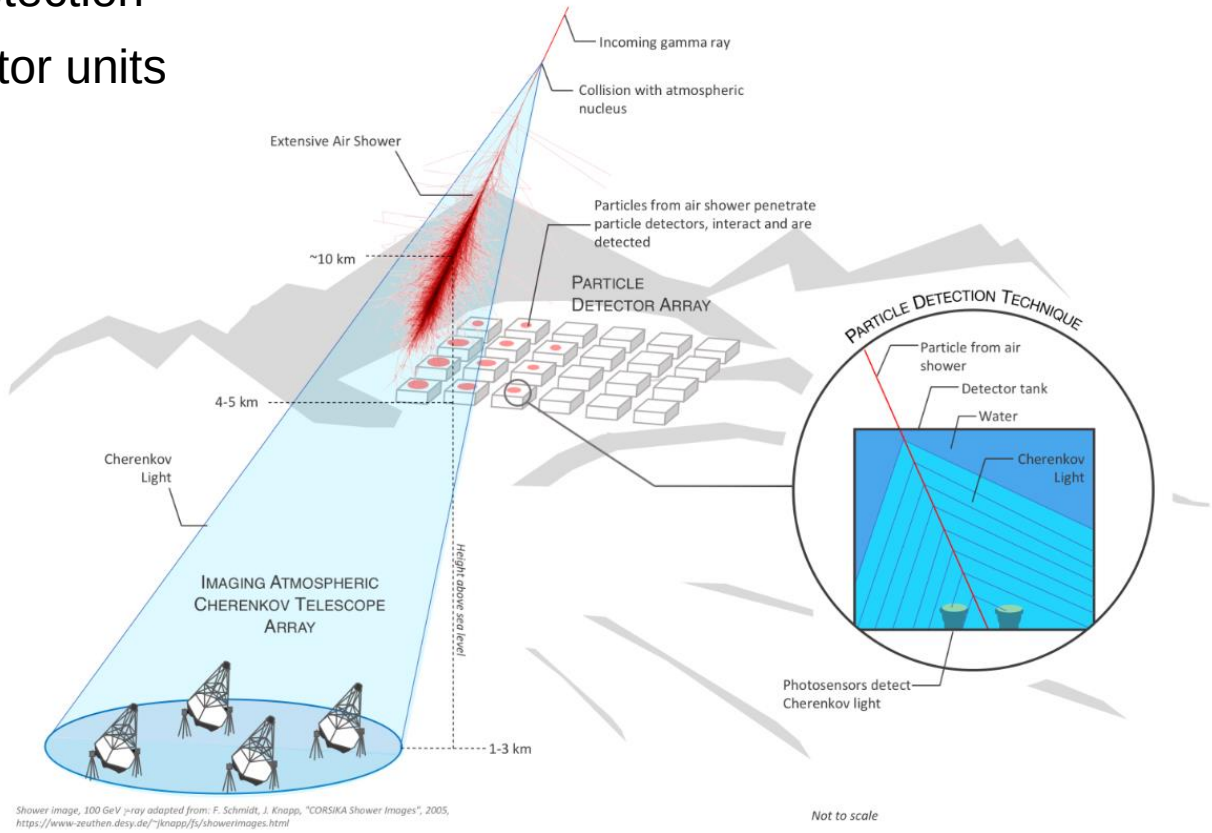
- Future particle detector array
- In South America
- Latitude: between 10º and 30º South
- Altitude ⩾ 4.4 km



(Schoorlemmer, 2019) [1]

The Southern Wide-field Gamma-ray Observatory

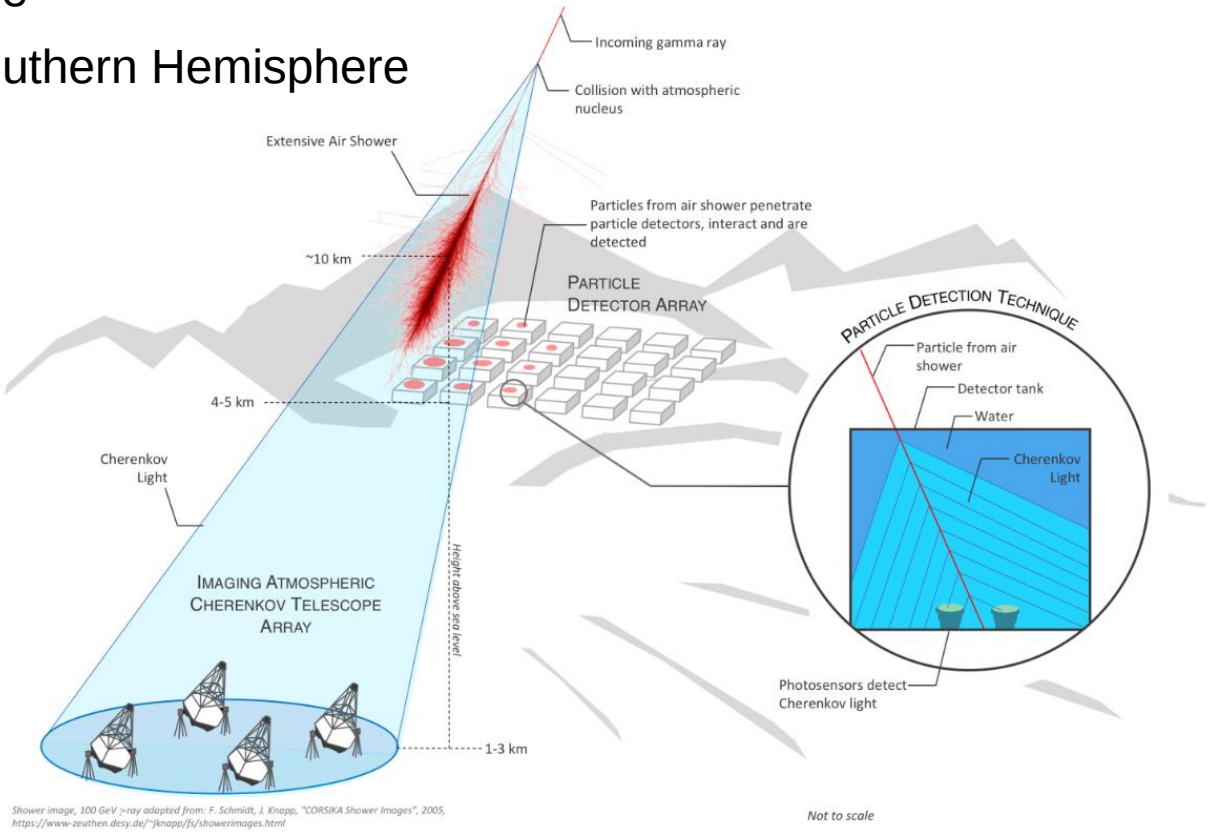
- Energy range: hundreds of GeV to hundreds of TeV
- Ground-level particle detection
- Water Cherenkov detector units



(Schoorlemmer, 2019) [1]

The Southern Wide-field Gamma-ray Observatory

- Field-of-view: 90º (± 45º zenith)
- Close to 100% duty cycle
- First of its kind in the Southern Hemisphere

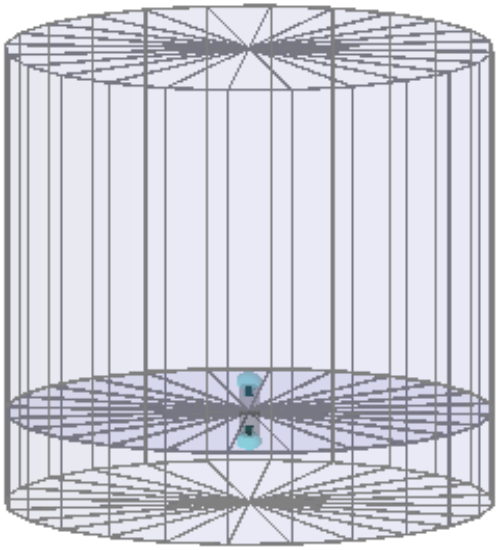


(Schoorlemmer, 2019) [1]

Reference Detection Units

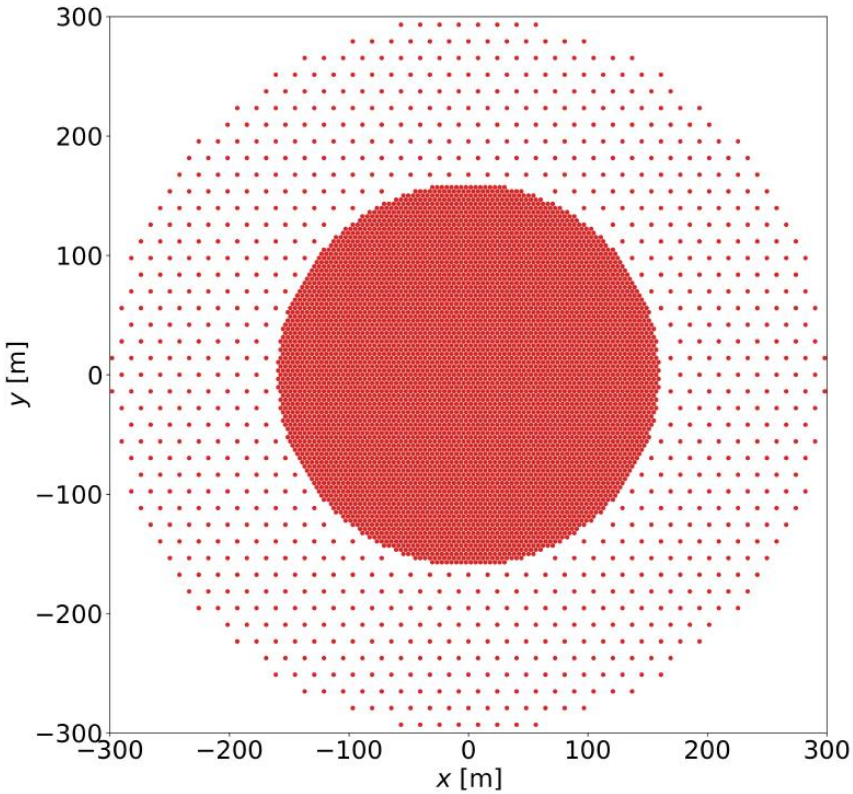
- Double-layered Water Cherenkov Detectors with cylindrical tanks
- One PMT in each cell

Characteristics	Upper Cell	Lower Cell
Radius [m]	1.91	1.91
Height [m]	2.5	0.5
Thickness [mm]	6.0	6.0
Cover lining	polypropylene	tyvek
Bottom lining	polypropylene	tyvek
Wall lining	tyvek	tyvek



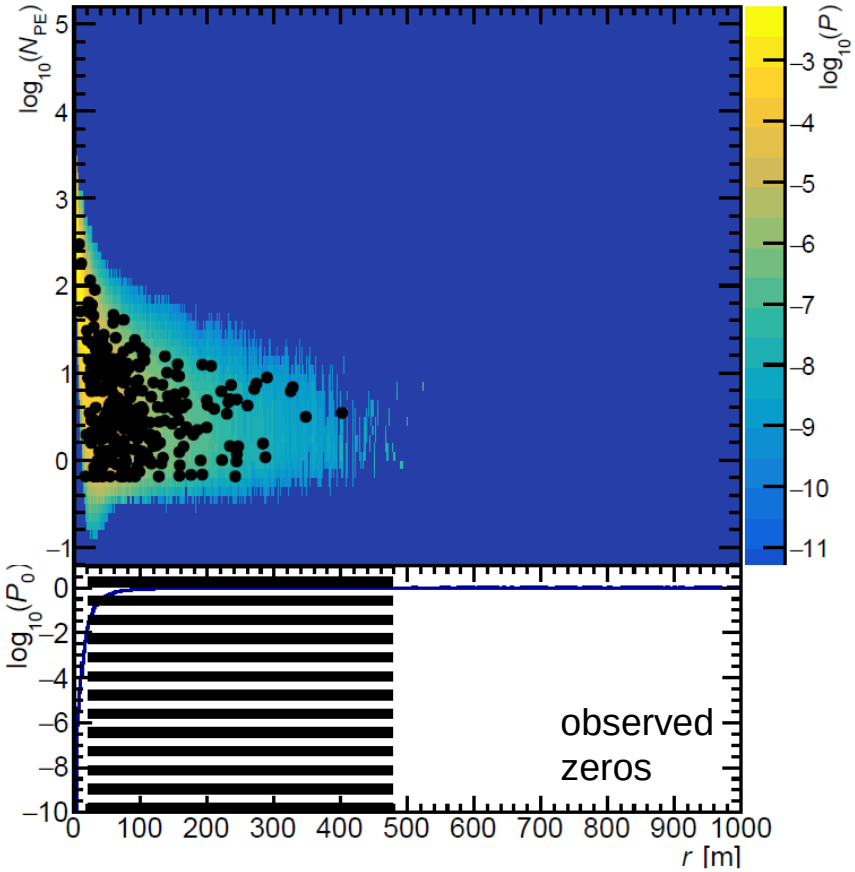
Reference Array Layout

- Dense inner array: r_{inner} = 160 m
- Sparse outer array: r_{outer} = 300 m
- Observation height: 4700 m



Reconstruction Method

Template-based Reconstruction



- Templates:

  MC simulations of gamma-induced EAS binned in $E,\ X_{max},\ \theta$

- Reconstruct incoming shower:

  Fit LDF of the shower to the templates

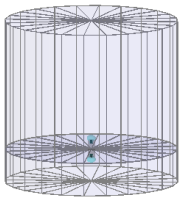
- Minimise log-likelihood

$$\log L = -2 \sum_i \log(F(\log_{10}(N_{PE})_i, r_i, X_{max}, E|\theta, \phi))$$

to get best fit parameters

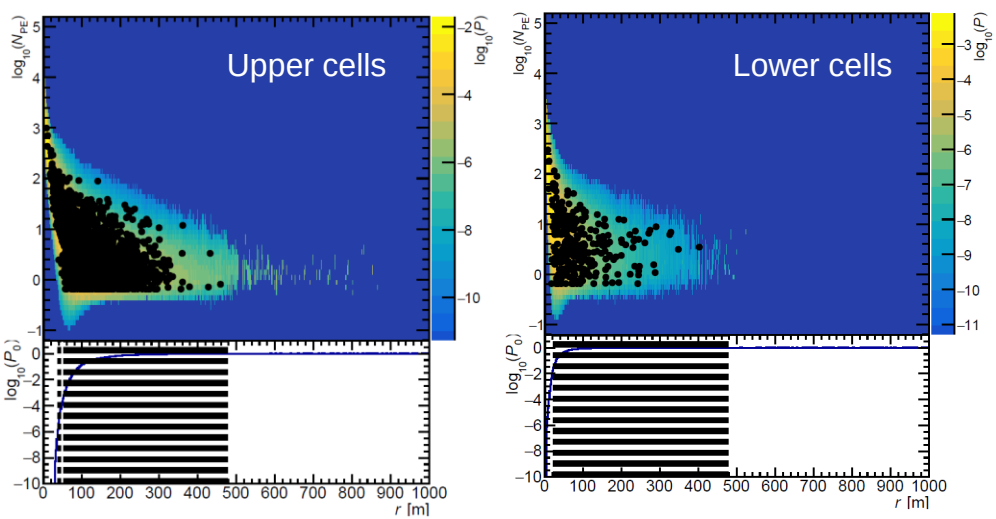
Example Event Reconstruction

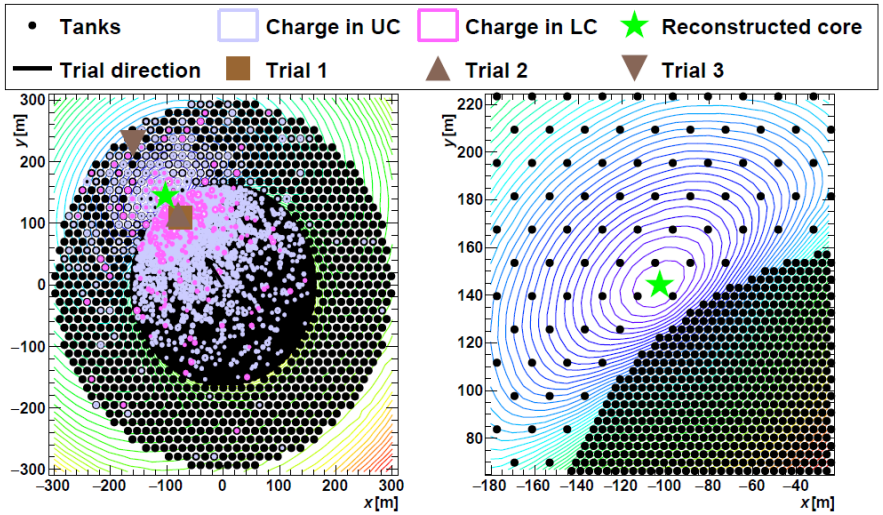
- E_{true} = 10.7 TeV $X_{max,true}$ = 432 g/cm² x_{true} = -104.3m y_{true} = 143.8 m
- E_{reco} = 10.6 TeV $X_{max,reco}$ = 436 g/cm² x_{reco} = -102.7m y_{reco} = 144.4m



Binning:
E = 10.0 TeV – 11.2 TeV;
θ = 0º - 19º
X_{max} = 400 g/cm² - 450 g/cm²;

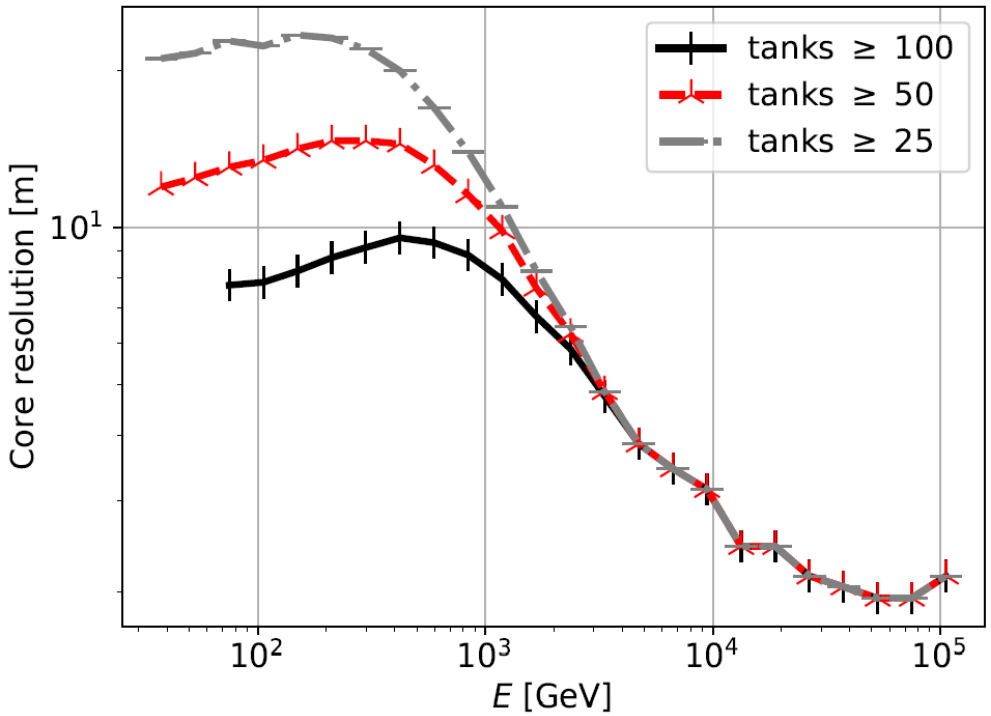
Likelihood surface: minimum → maximum





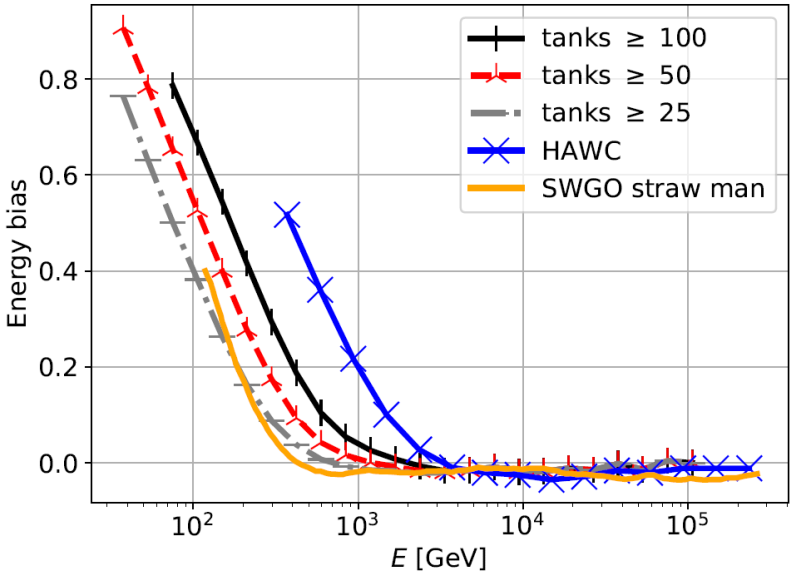
Core and Energy Estimations

Core Estimation

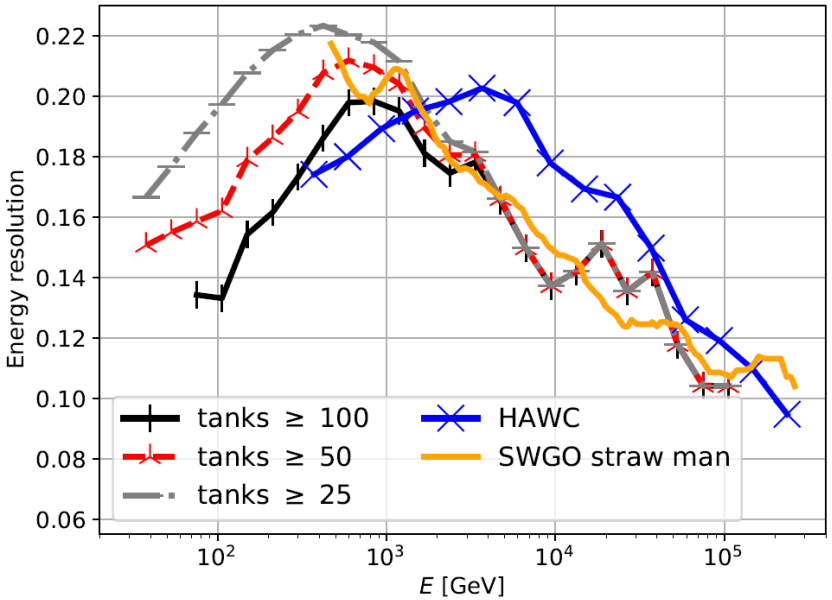


- Core resolution in the order of 1 TeV already below 10 m
- Better resolution at higher energies

Energy Estimation



HAWC [2], SWGO straw man [3]



HAWC [2], SWGO straw man [3]

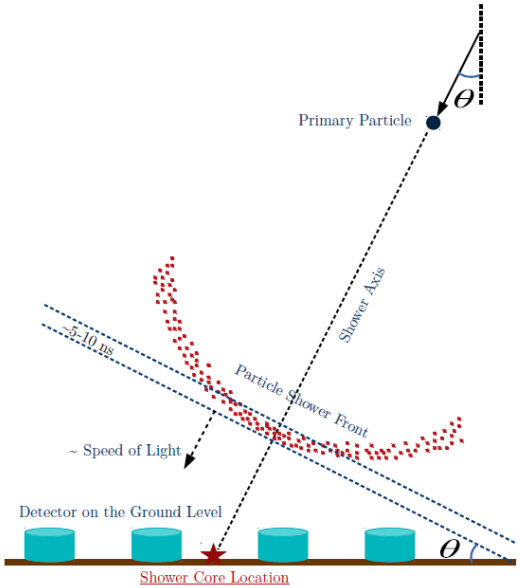
Energy bias: mean of $(\log_{10}(E_{reco}/\text{GeV}) - \log_{10}(E_{true}/\text{GeV}))$

Energy resolution: RMS of $(\log_{10}(E_{reco}/\text{GeV}) - \log_{10}(E_{true}/\text{GeV}))$

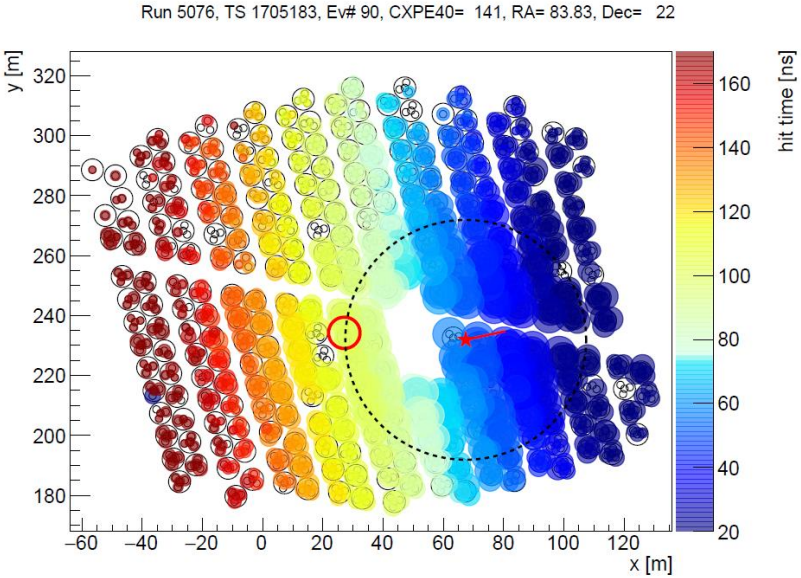
→ promising results when compared to HAWC and SWGO strawman for showers with 31.6 GeV < E < 100 TeV

Outlook: Direction Reconstruction

At HAWC: Shower front plane fit for the direction reconstruction



(Joshi, 2019) [4]



(Joshi, 2019) [4]

So far: No direction reconstruction for SWGO

→ Look into template-based method similar to energy reconstruction

Thank you for your attention

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References

[1] Schoorlemmer, H. (2019). A next-generation ground-based wide field-of-view gamma-ray observatory in the southern hemisphere. *Proceedings of Science*. ICRC2019. 785. DOI: https://doi.org/10.22323/1.358.0785

[2] Joshi, V. et al. (2019). A Template-based γ-ray Reconstruction Method for Air Shower Arrays. *arXiv e-prints*. arXiv: https://arxiv.org/abs/1809.07227

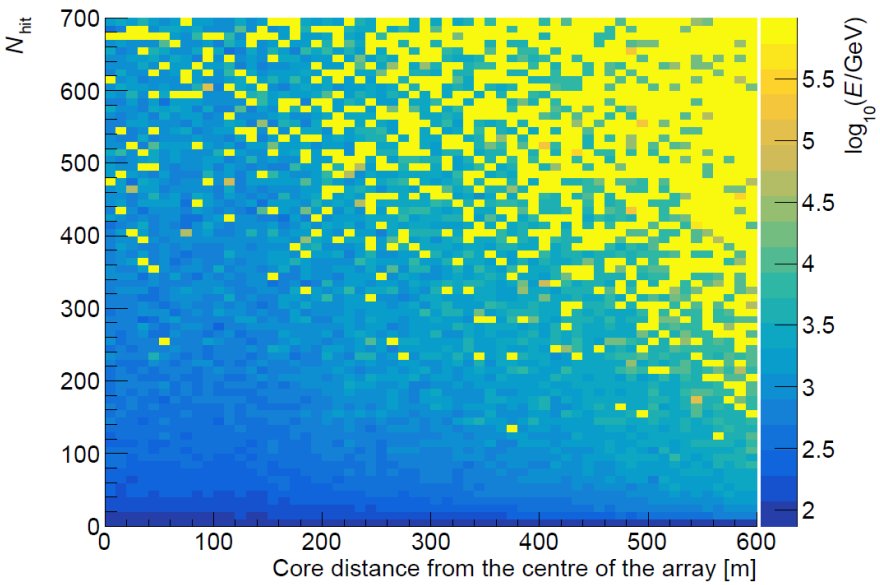
[3] Albert, A. et al. (2019). Science Case for a Wide Field-of-View Very-High-Energy Gamma-Ray Observatory in the Southern Hemisphere. *arXiv e-prints*. arXiv: https://arxiv.org/abs/1902.08429

[4] Joshi, V. (2019). Reconstruction and Analysis of Highest Energy γ-Rays and its Application to Pulsar Wind Nebulae. DOI: https://doi.org/10.11588/heidok.00026062

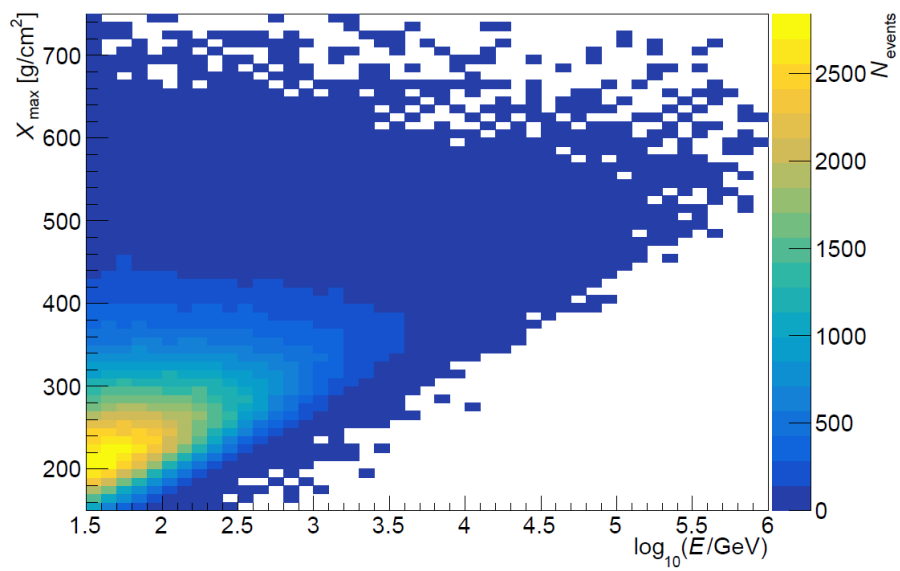
Backup

Reconstruction Method

- Core guess: centre of mass of the shower
- Angle guess: shower plane fit using the centre of mass as core
- E guess: number of tanks hit as a proxy for energy
- X_{max} guess: relation between E and X_{max} derived from MC simulations



E guess



X_{max} guess

Simulations

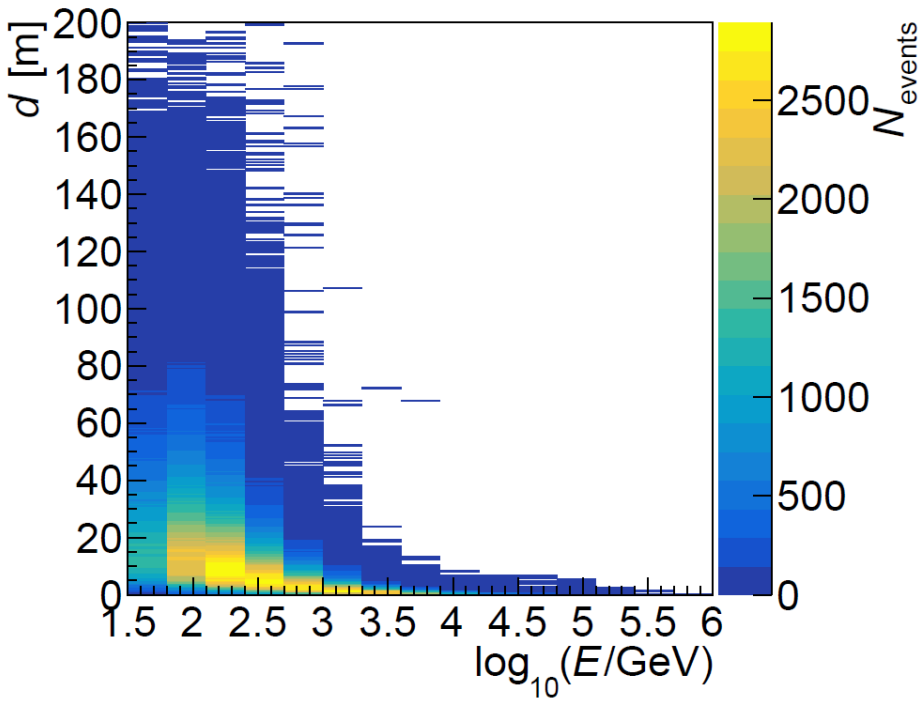
Templates:

Parameters	Range	Bin Size	Description
E	31.6 GeV - 1PeV	0.05	binned in $\log_{10}(E/\mathrm{GeV})$
X_{max}	150 g/cm^2 - 750 g/cm^2	50 g/cm^2	-
θ	0º - 50º	0.06	binned in cosθ

Reconstruction:

- Showers thrown within 160 m radius from array centre
- Only used the upper cells for the reconstruction
- 31.6 GeV < E < 100 TeV
- $\theta < 45$º

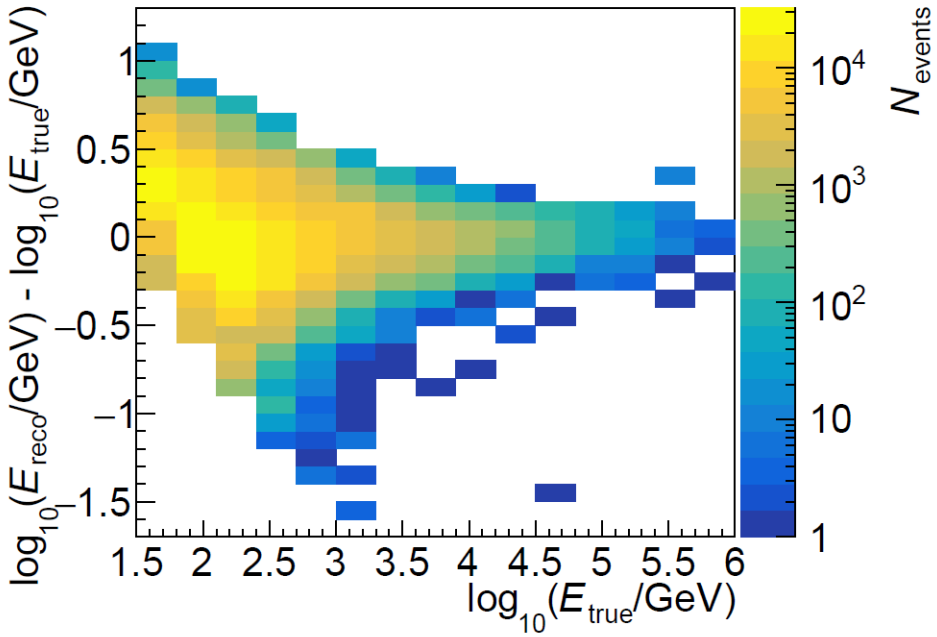
Core Resolution



Core resolution:

68% containment radius of the distribution of the distance between the reconstructed and true shower core

Energy Bias and Resolution



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