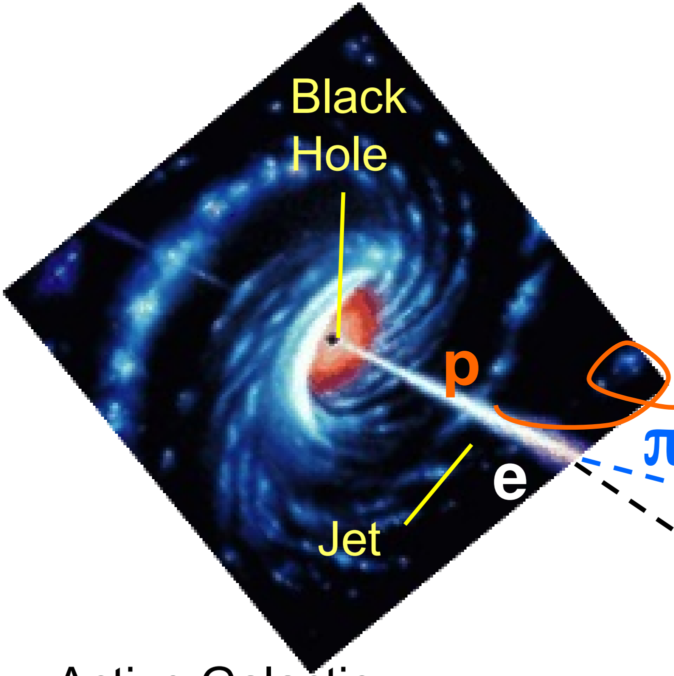
Simulations for VERITAS on the OSG

Nepomuk Otte

School of Physics
&
Center for Relativistic Astrophysics

Multi-Messenger Astroparticle Physics

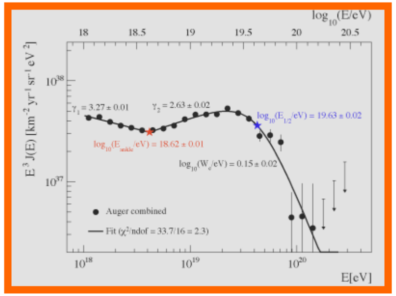


Active Galactic Nucleus (AGN)

p

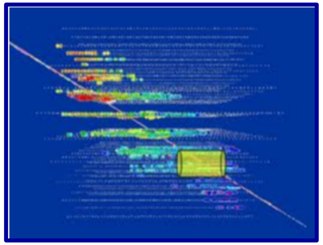
π

EeV
Cosmic Rays



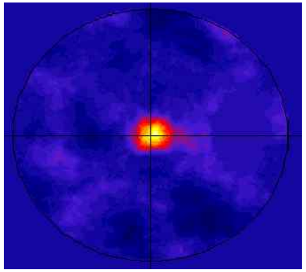
ν

PeV
Neutrinos



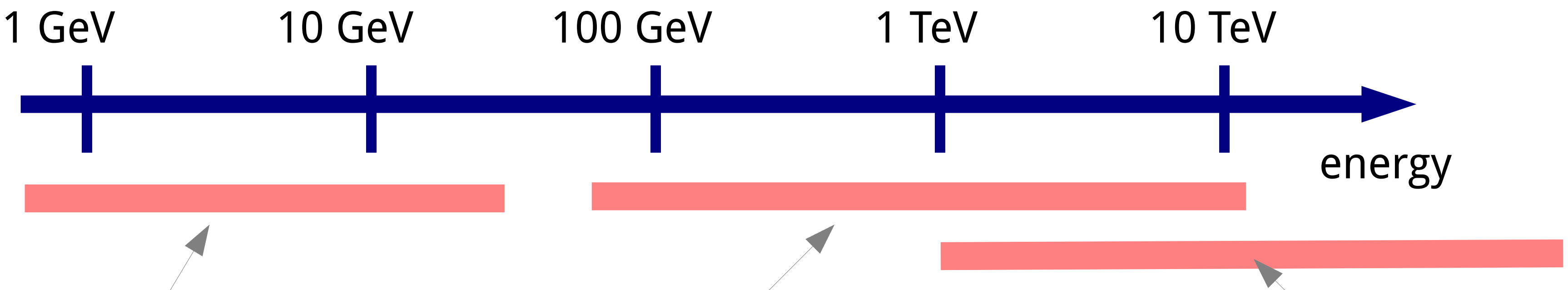
γ

GeV/TeV
γ-rays



VHE: E > 100 GeV
Highly Non-Thermal

Gamma-Ray Instruments



Satellites: Fermi-LAT

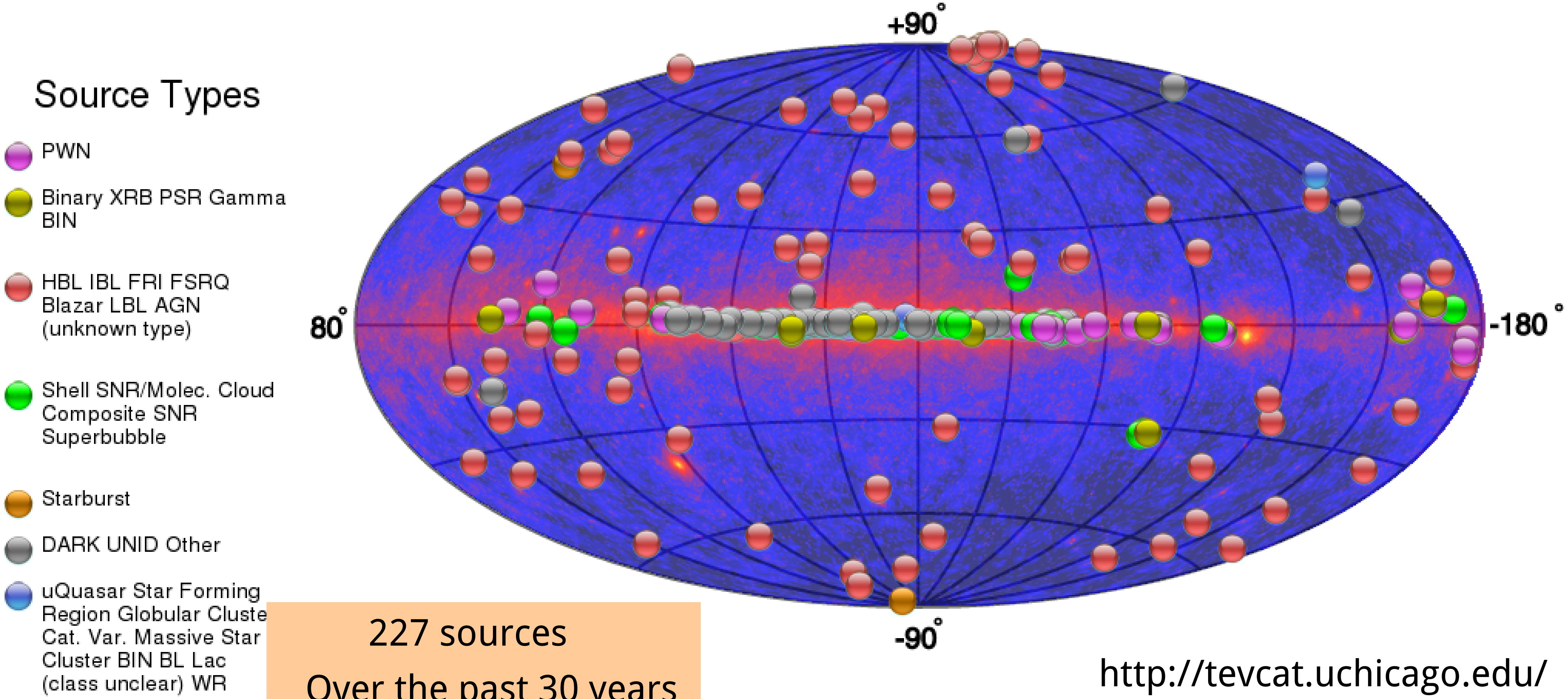
Cherenkov telescopes:
like VERITAS and CTA

Water Cherenkov detectors: HAWC

VERITAS in a Nutshell

- Four 12 m Cherenkov telescopes in southern Arizona
- 499 high efficiency PMTs per camera
- 3.5° field of view
- Energy range from ~85 GeV to >10 TeV
- Sensitivity of 1% Crab in < 24 hours
- ~1200 hours of observations per year (including observation under bright moon light)

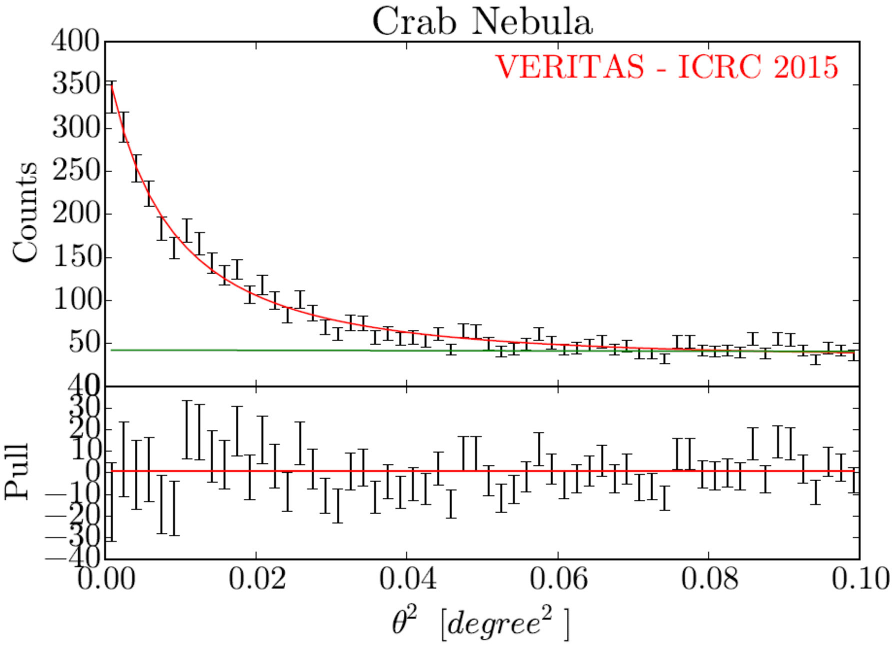
VHE Gamma Ray Sky



227 sources
Over the past 30 years

http://tevcat.uchicago.edu/

Challenge: Measuring small Source Extensions

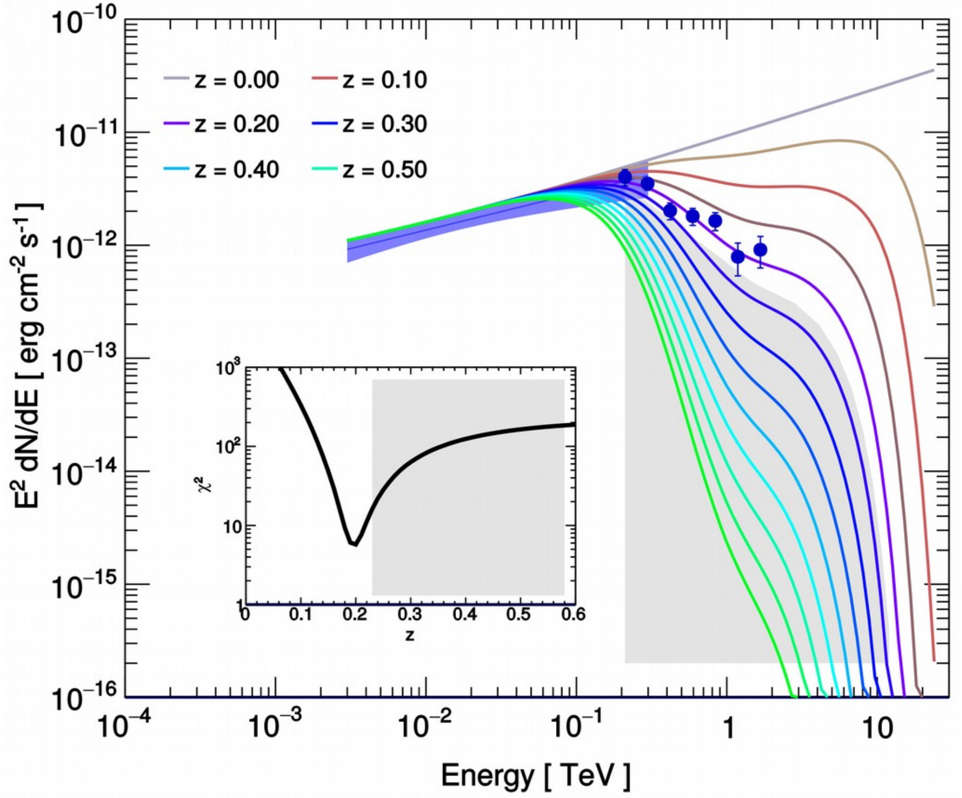


- Measure ~1 arcminute source extension with ~10 arcminute angular resolution?
- Can one determine the minute spatial broadening of gamma-ray excess
- Need accurate Monte-Carlo simulations
  - Trigger
  - Optics, photosensors, signal chain

Extragalactic Background Light

Ultra-high frequency BL Lac (UHBL) HESS J1943+213

- Spectra at TeV energies are sensitive to EBL absorption
- Imprint of evolution of universe
- Spectral shape impacted by inaccurately simulated signal chain
- High statistics MC simulations needed at highest energies



Imaging Atmospheric Cherenkov Technique

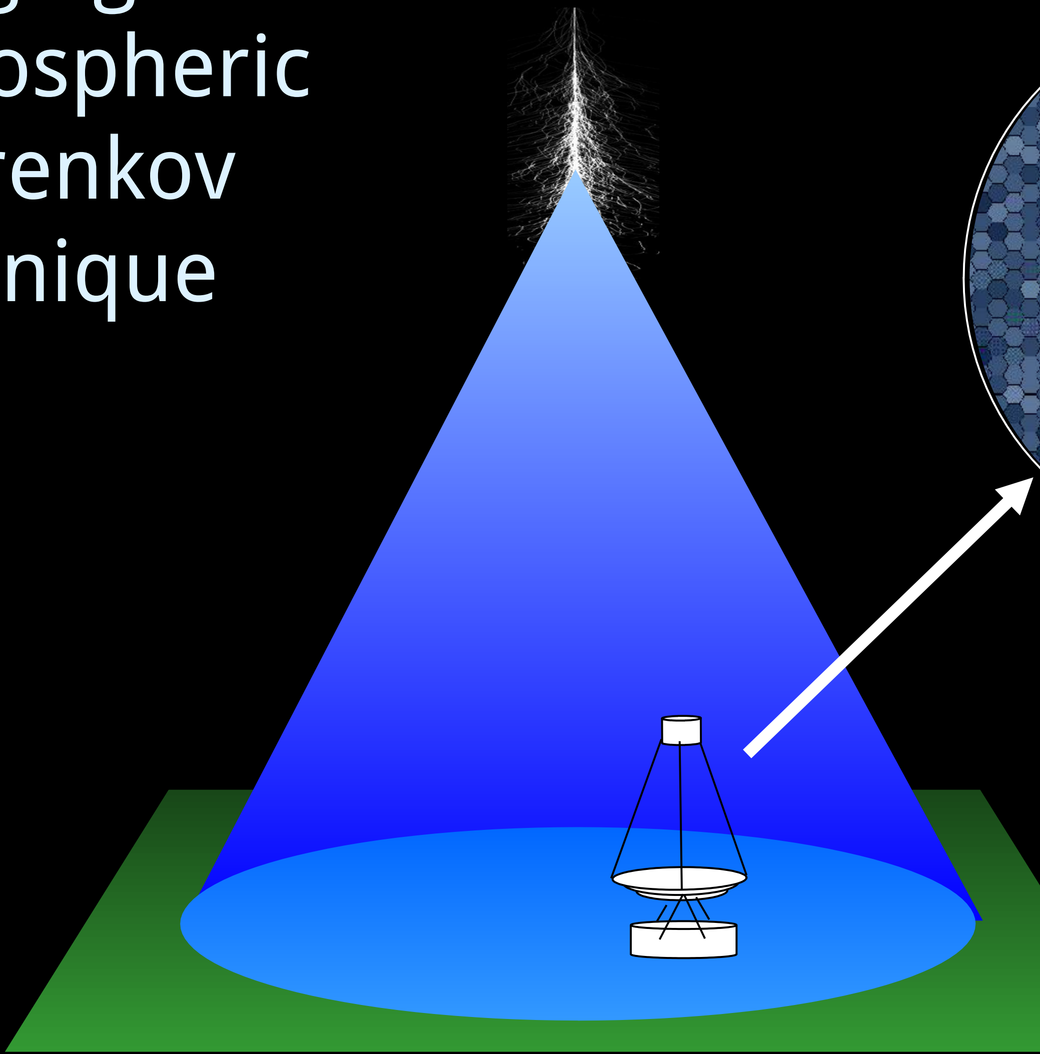
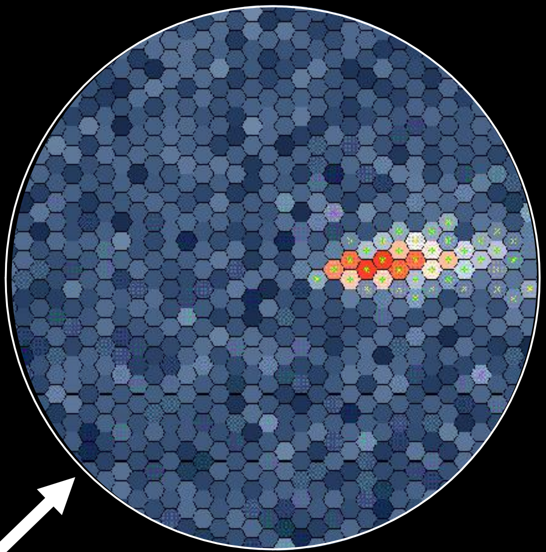


Image in camera



Pulse lasts a few nanoseconds

Effective area =
Cherenkov light pool~10^5 m^2!

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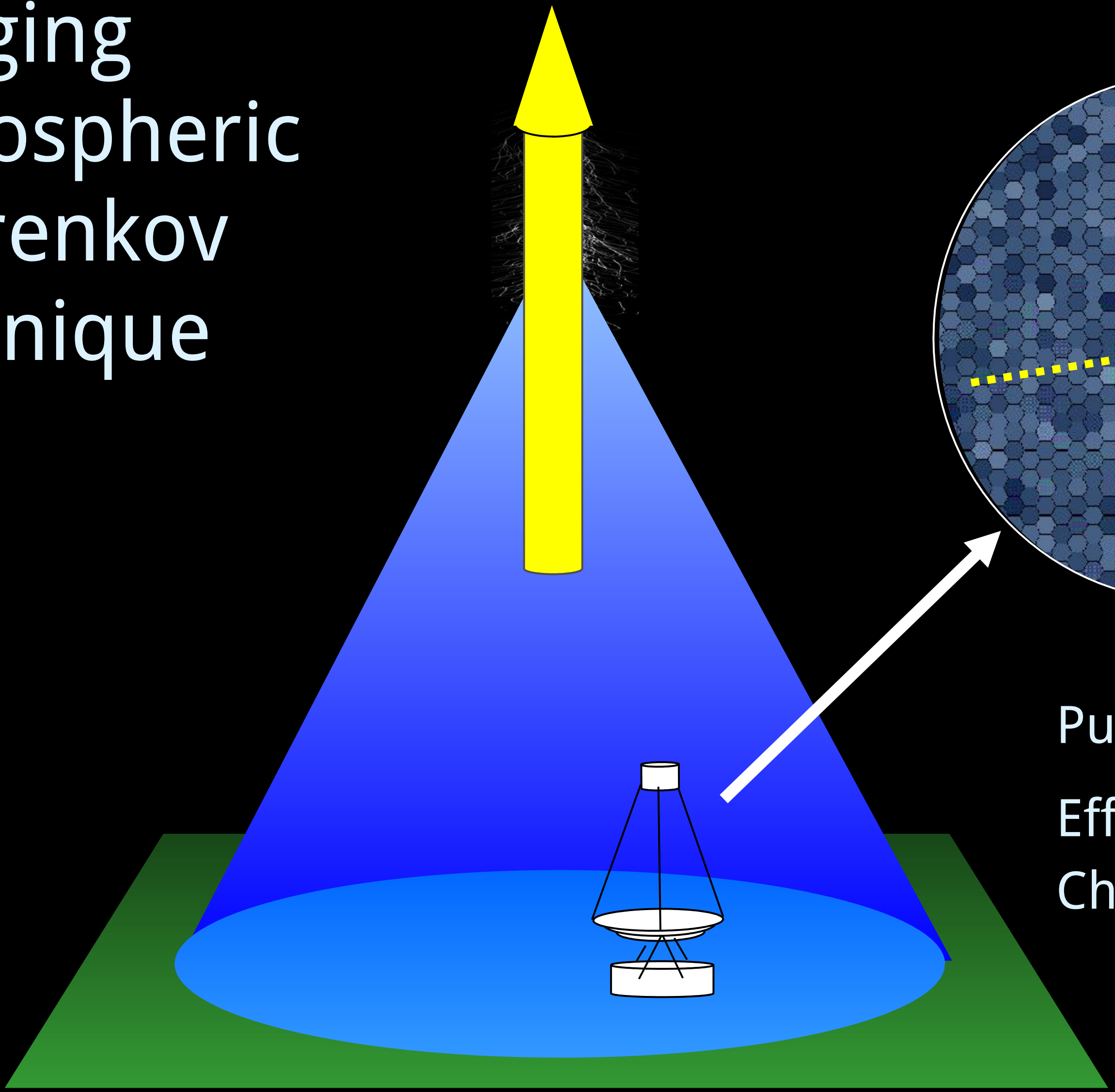

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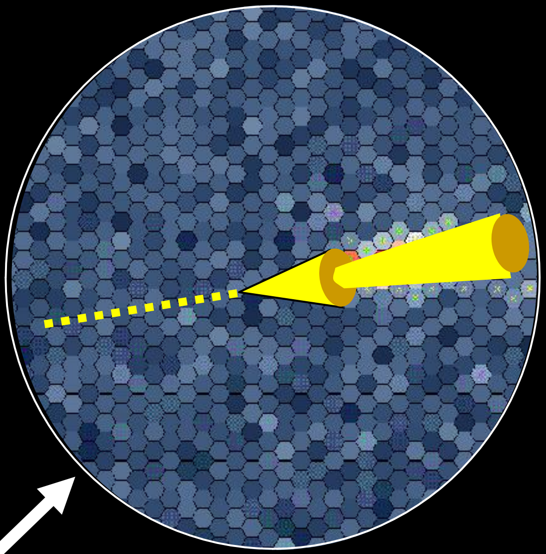

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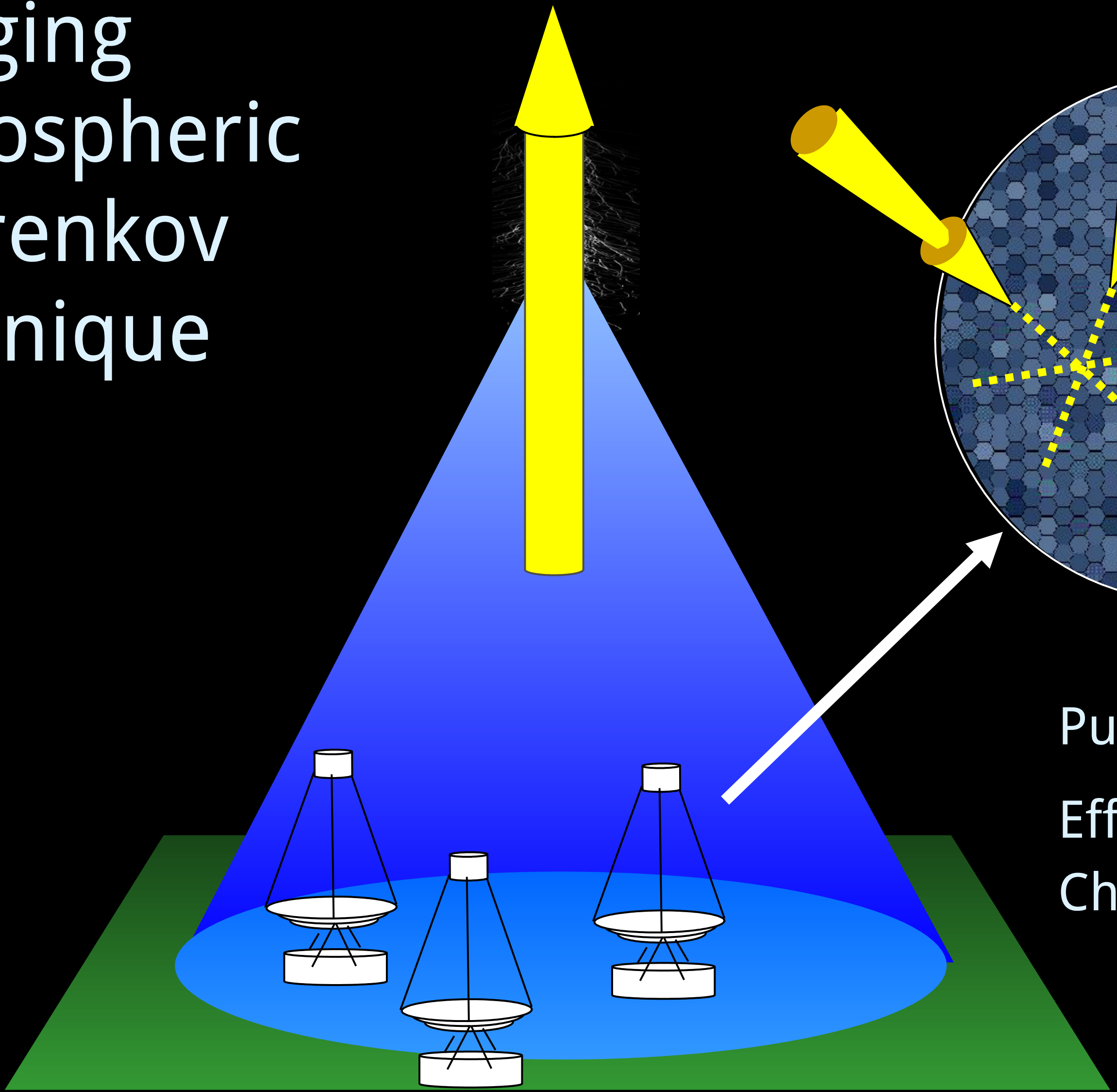

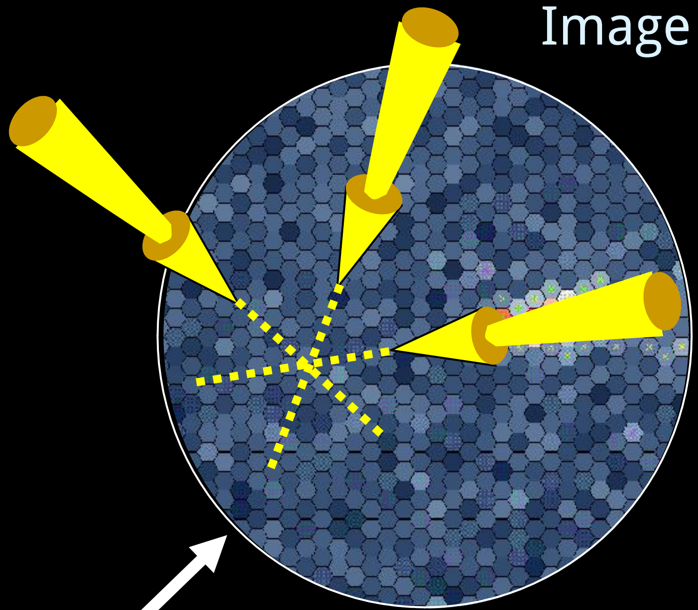

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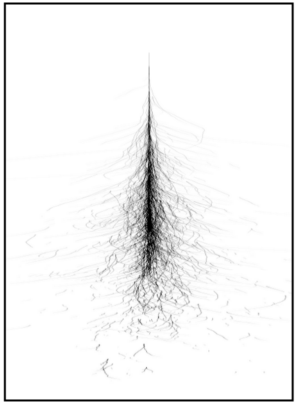
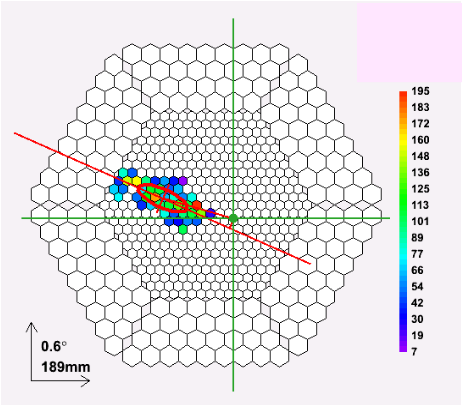
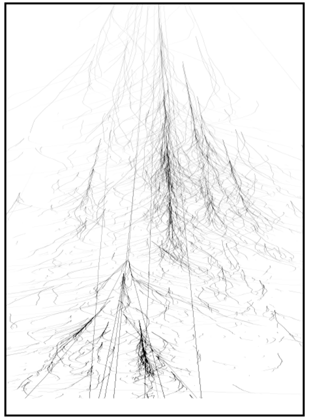
Background Rejection

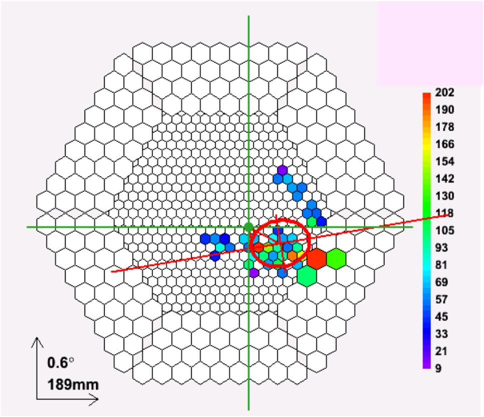
γ–ray shower





hadron shower (background)





Main background:

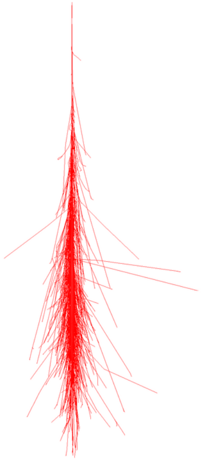
- cosmic ray (hadron) showers
- 10^3...10^4 times more abundant than γ-ray showers
- rejection based on
  - shower shape (hadrons are broader and longer)
  - orientation of the image

Performance of rejection depends on:

- Resolution of image
- Investment in Computing
- Quality of Monte Carlo

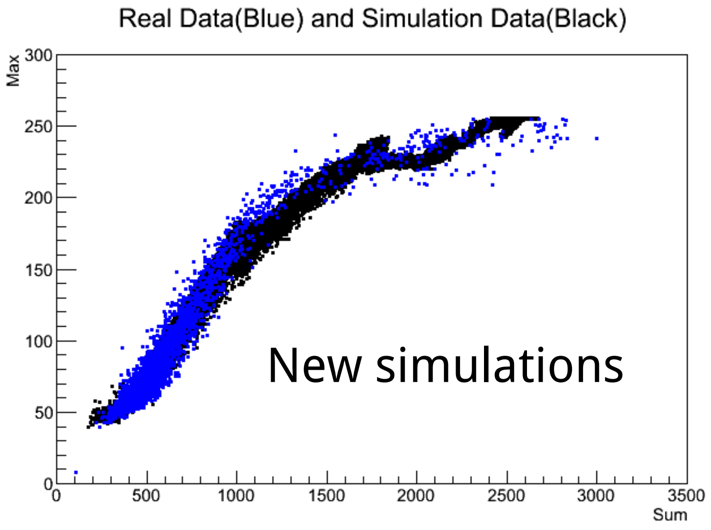
Simulation Chain

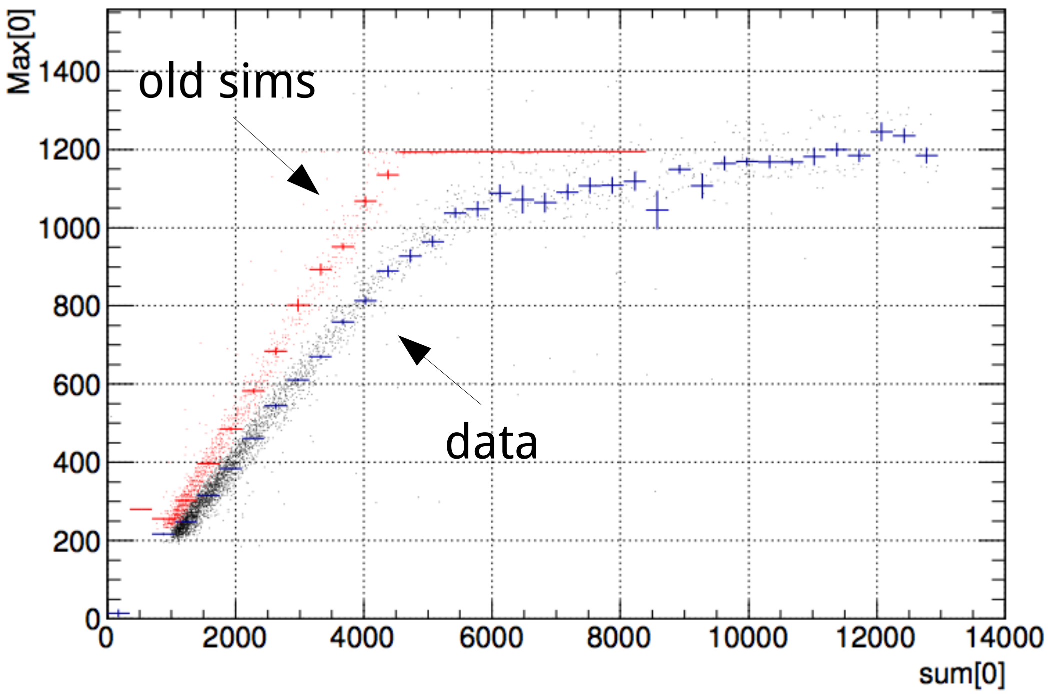
Air Shower (particle physics) → Telescope Optics (ray tracing) → Camera Response (electronics)



High-Low Gain Switch / Saturation

- Non-linearities in signal chain
- High/low gain switching





New Monte Carlo Production

- More events above 10 TeV → air-shower simulations are most costly part of effort
- Includes saturation of signal chain
- Better description of trigger
- Better description of optics
- Simulation of night sky background photon fields for proper trigger simulation → most costly part of detector simulation

10^9 particle showers, $2 \cdot 10^7$ CPU hours, 400 TB

Need large scale computing infrastructure

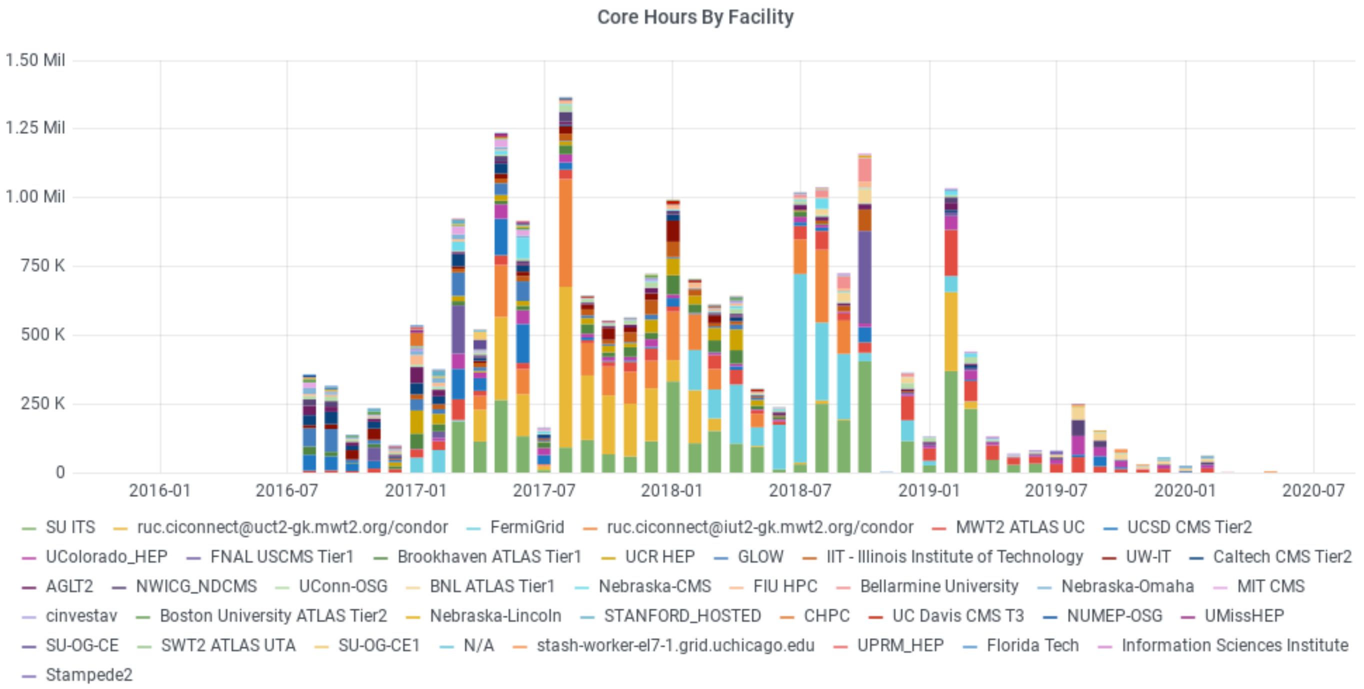
OSG Production

- Production finished end of 2019 (20M CPU hours or 2% of OSG lifetime resources)
- Thanks for all the great support from OSG (Thanks Mats Rynge and everyone else)

3 years of production on the OSG

Shower simulations:
- 14M CPU hours

Detector simulations:
- 6M CPU hours



Summary

- VERITAS is one of the worlds best gamma-ray instruments.
- New Monte Carlo Simulation set is crucial to extract more science from our data.
- MC Production completed after three years → use simulations in data analysis now.
- Support from OSG team and a lot of disk space at Chicago had been instrumental to the effort.

Thanks for all the cycles and the great support