The High Altitude Water Cherenkov Experiment: HAWC

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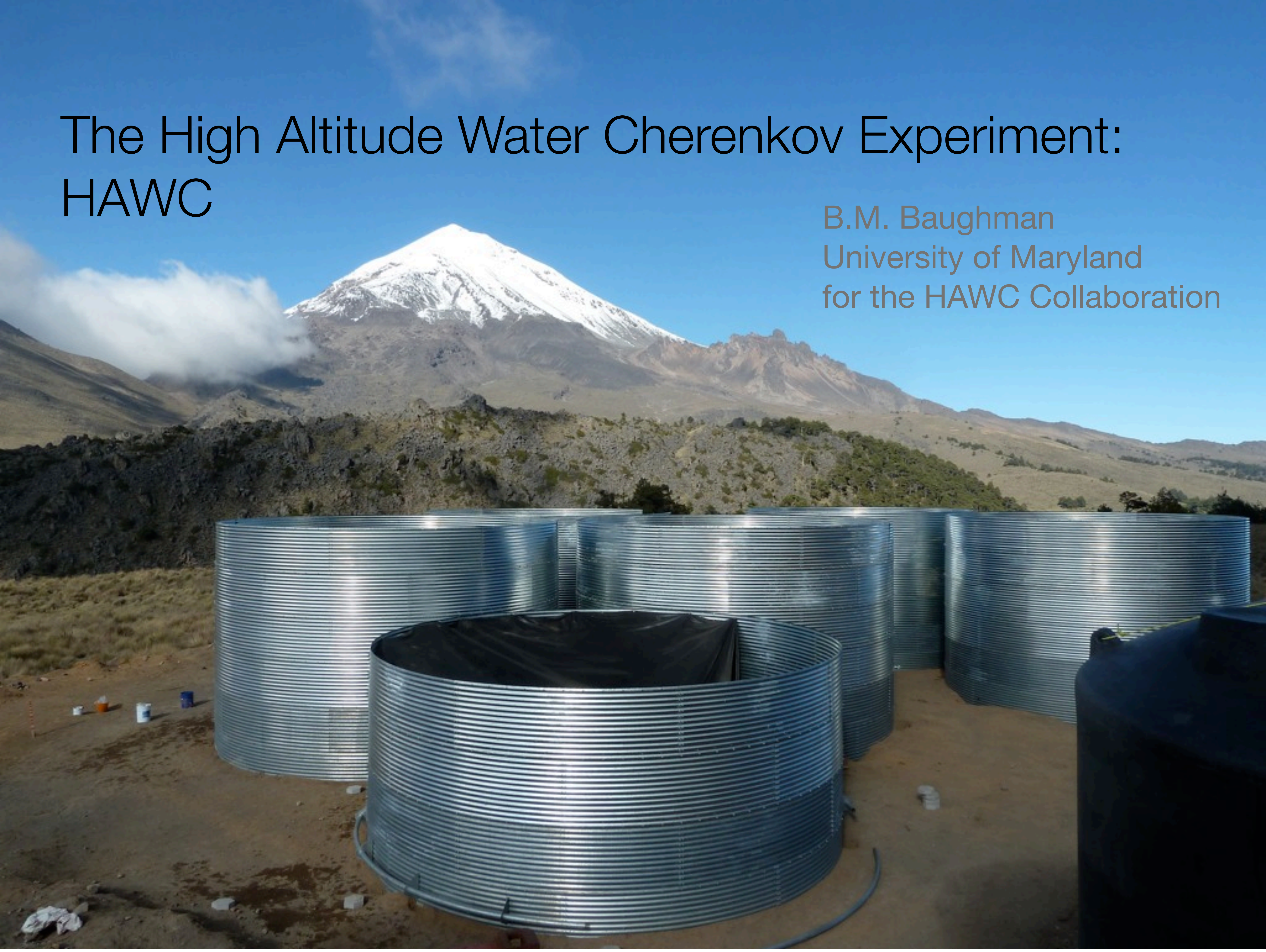
for the HAWC Collaboration



Observing Gamma Rays
Air Shower Detection

- The photons which do not reach the ground produce a cascade of particles within the atmosphere.
- Some daughter particles may reach the ground.
- Shower particles will produce Cherenkov light

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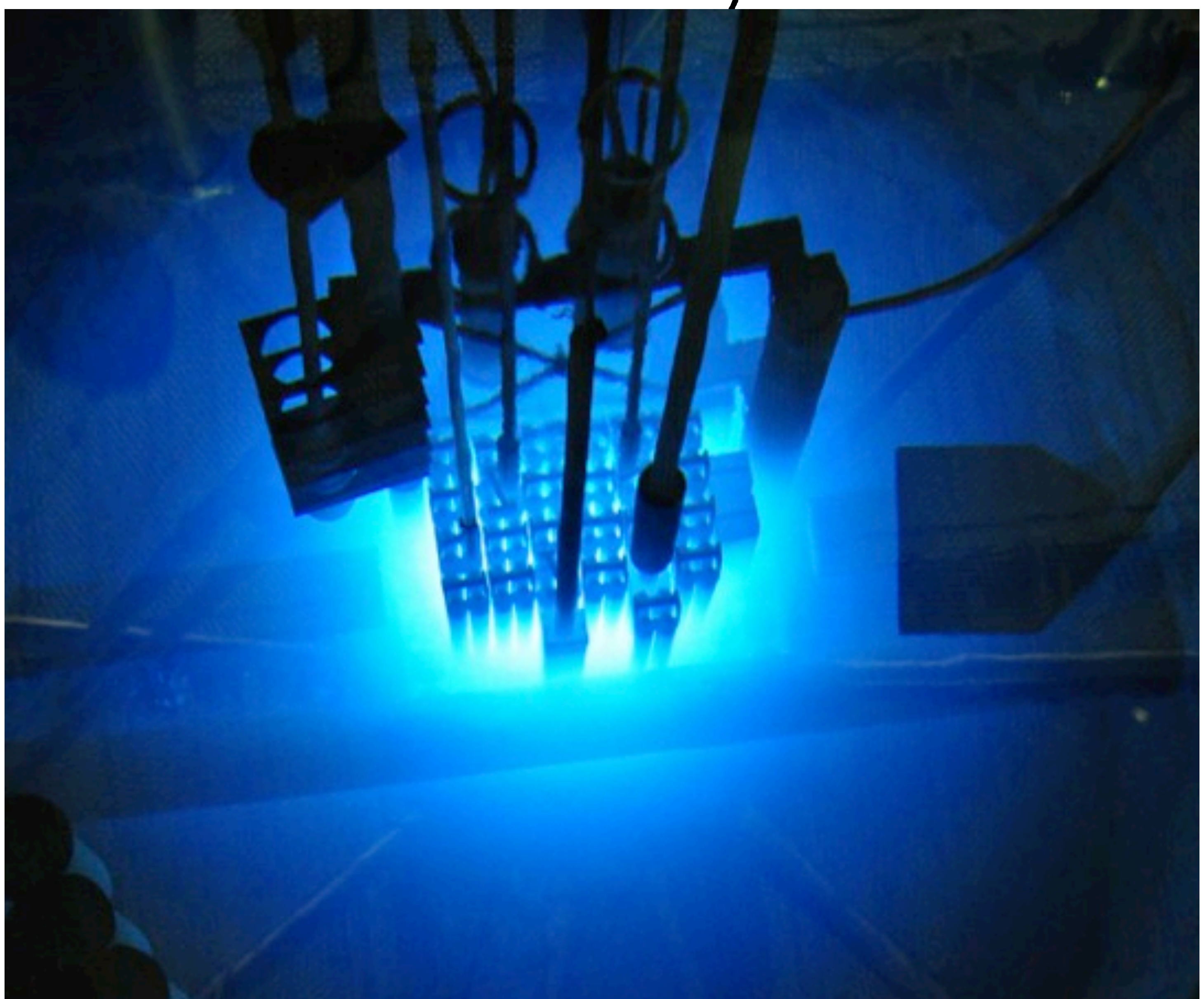
Observing Gamma Rays
Air Shower Detection

Cherenkov light from reactor core



Thanks to J. Goodman

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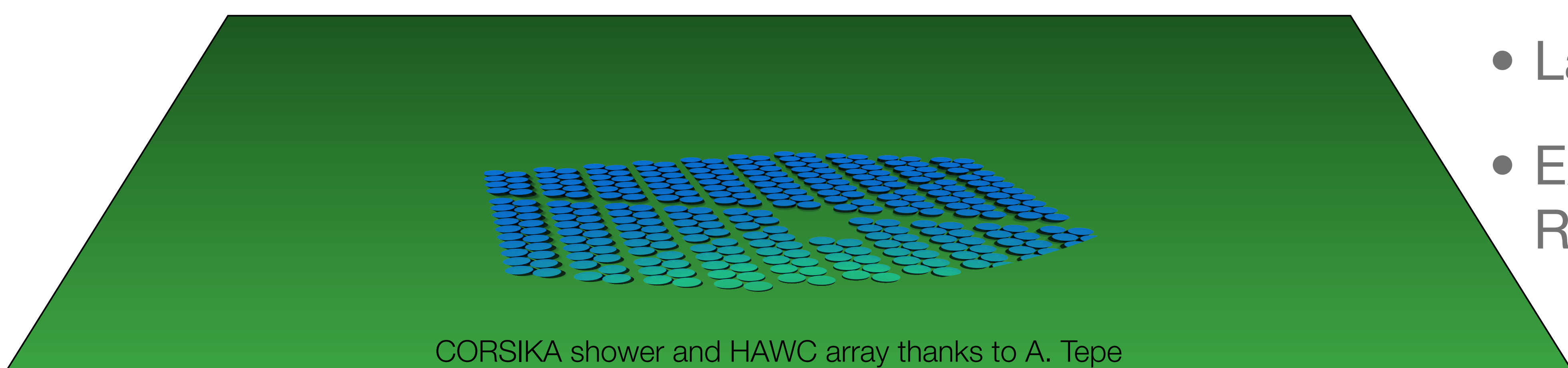
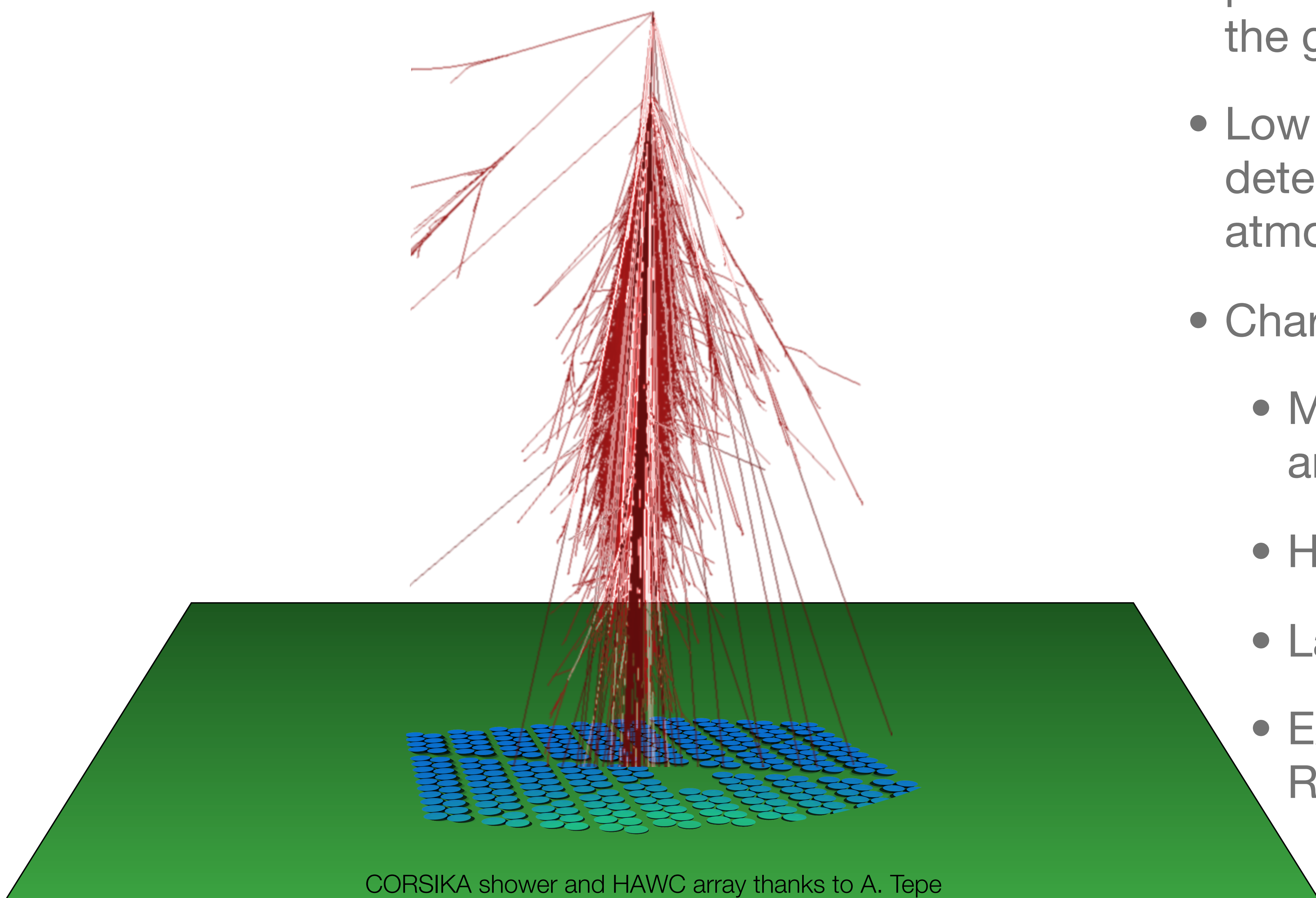
Observing Gamma Rays
Ground Array Detection

- Detects the shower particles as they reach the ground
- Low energy threshold determined by depth in atmosphere.
- Characteristics
  - Moderate collection area
  - High duty cycle
  - Large Aperture
  - Excellent background Rejection



CORSIKA shower and HAWC array thanks to A. Tepe

Observing Gamma Rays
Ground Array Detection



CORSIKA shower and HAWC array thanks to A. Tepe

- Detects the shower particles as they reach the ground
- Low energy threshold determined by depth in atmosphere.
- Characteristics
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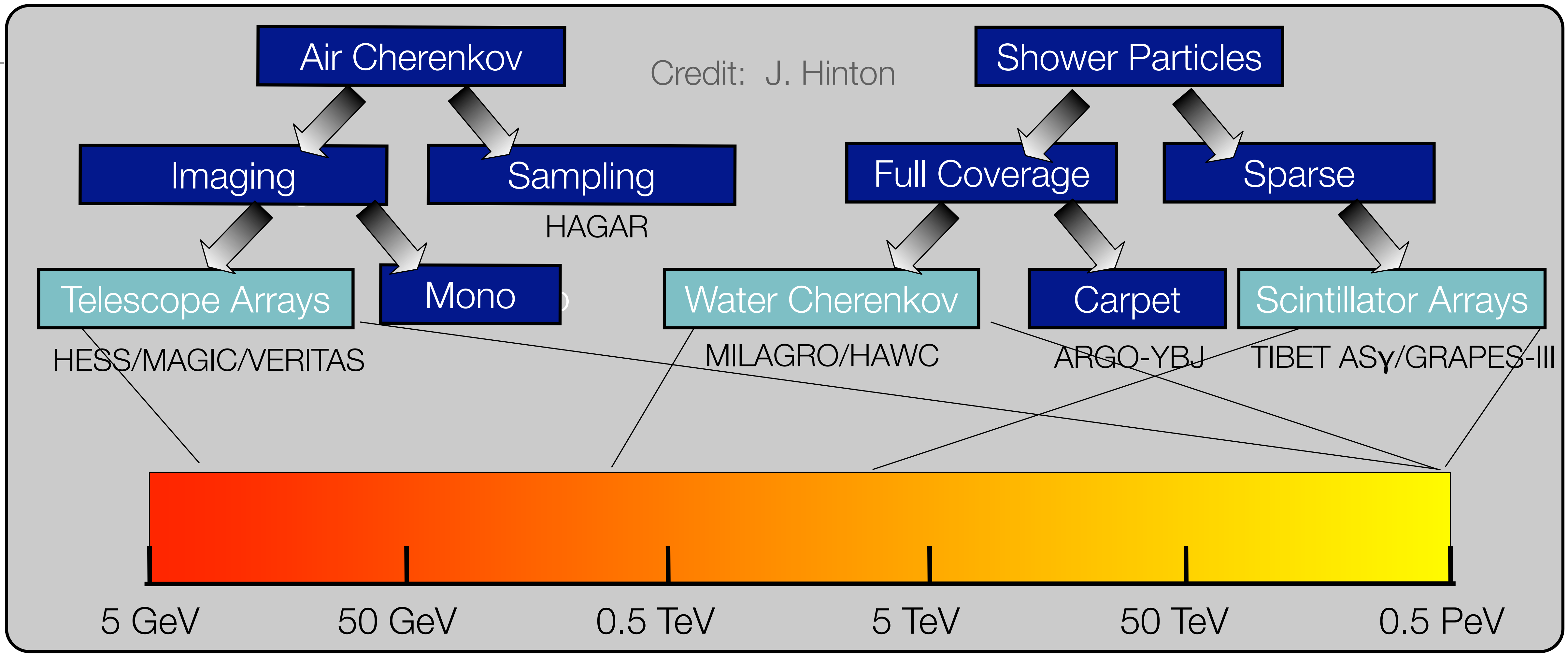
Observing the VHE Sky



- The two observation classes for the VHE sky complement each other in energy range.
- Combined with pair-production telescopes cross instrument calibrations can be accomplished from a few MeV to 10s of TeV (>6 orders of magnitude)

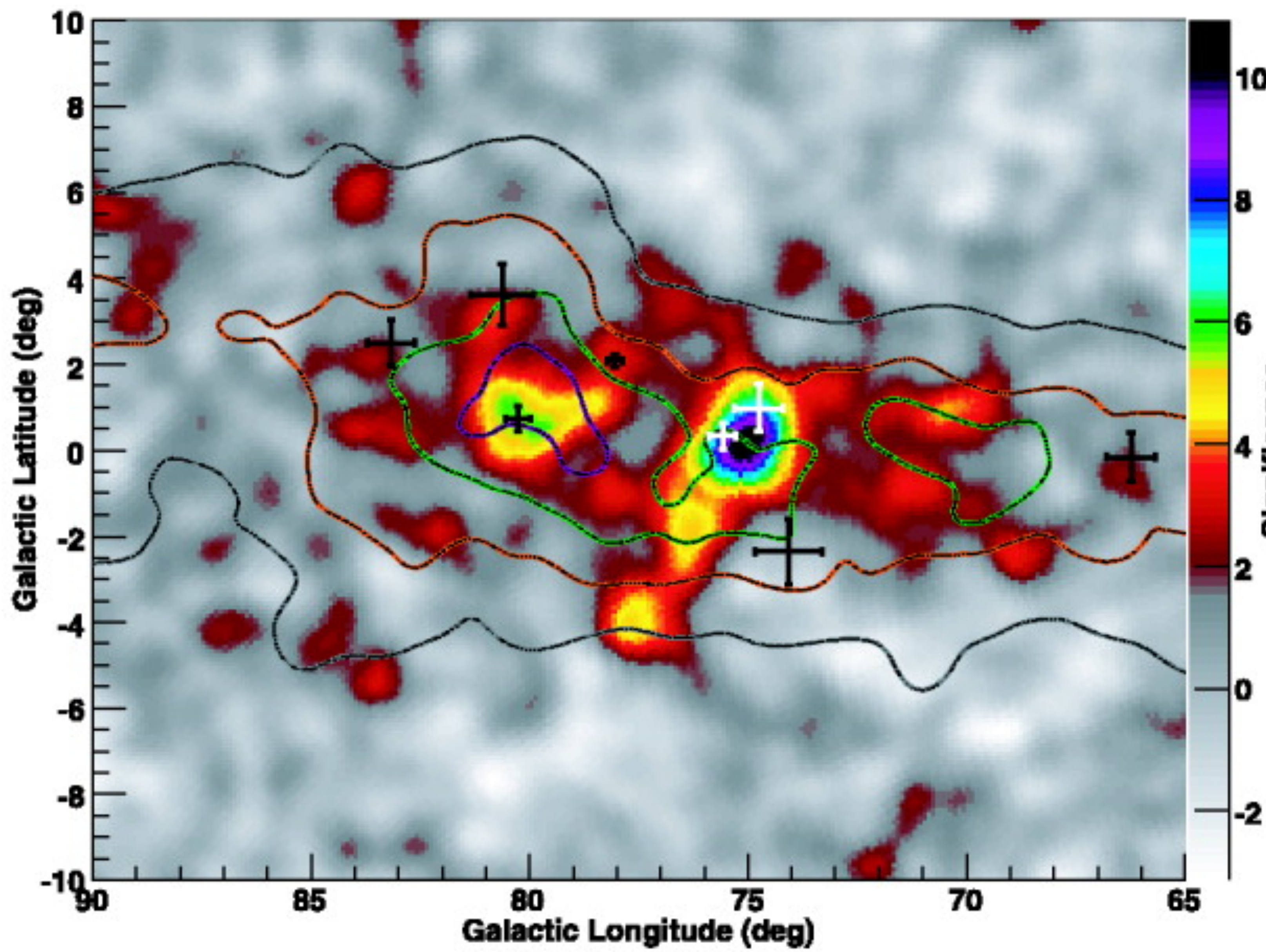
Milagro
Overview

- Deployed at Los Alamos, NM at an elevation of 2350 m
- Central Water Pond (80x60 meter)
- 450 PMTs under 1.5 m water
- 273 PMTs under 6 m water
- 175 Outriggers
- 2.4 m diameter x 1.4 m tall
- Increased area to 40000 m2

Milagro Highlights

- Discovered diffuse emission from the Cygnus region.
- Provided a survey of a swath of the Galactic plane.
- Discovered 3 TeV sources.
- Observed the large scale cosmic-ray anisotropy

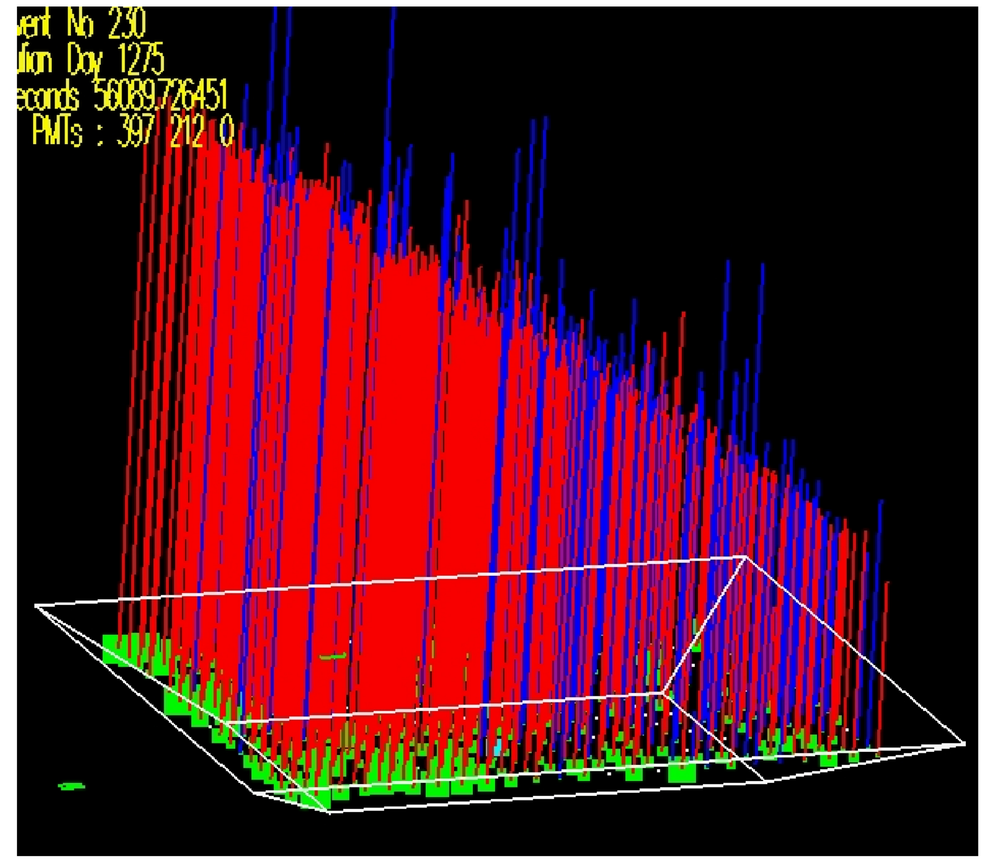
The Astrophysical Journal, 658:L33-L36, 2007 March 20

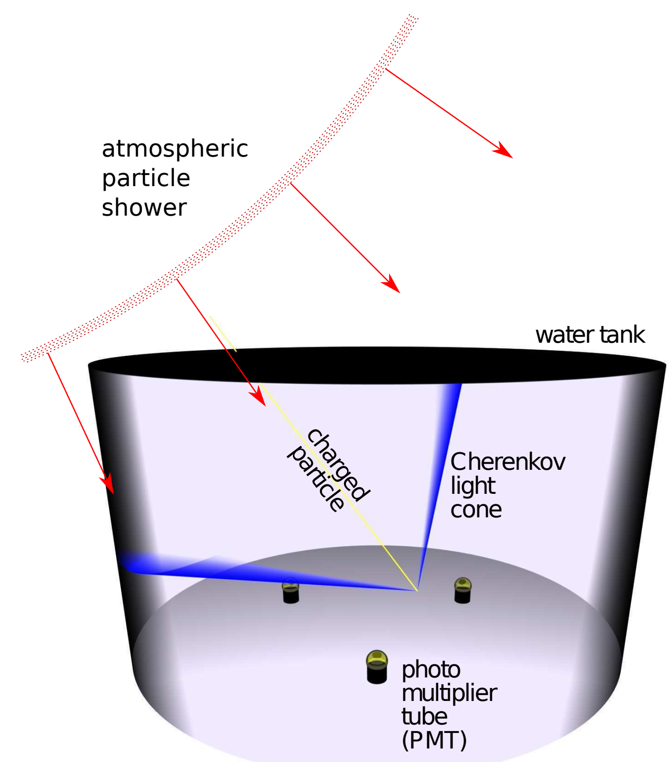


Milagro
Lessons Learned

- The lack of optical isolation between PMTs made it difficult to disentangle large events.
- The morphological differences between hadronic and gamma induced air showers is a powerful discriminator between the two.
- Reconstruction of the shower wave front provides an accurate estimation of the primaries original trajectory.
- Outrigger tanks provided significant increased effective area and improved angular resolution.

Thanks to B. Dingus

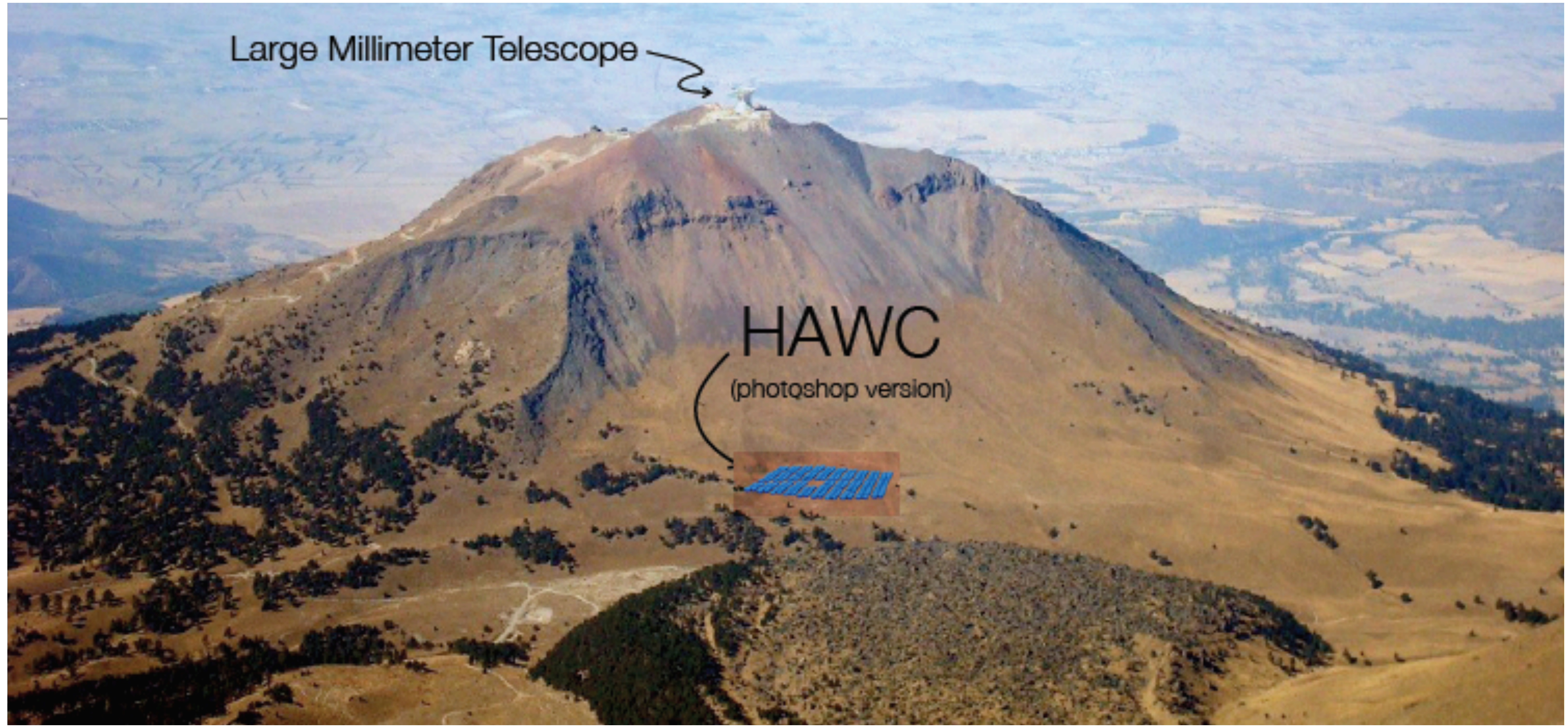




Thanks to A. Tepe

The High Altitude Water Cherenkov Experiment HAWC

Thanks to Ignacio Taboada



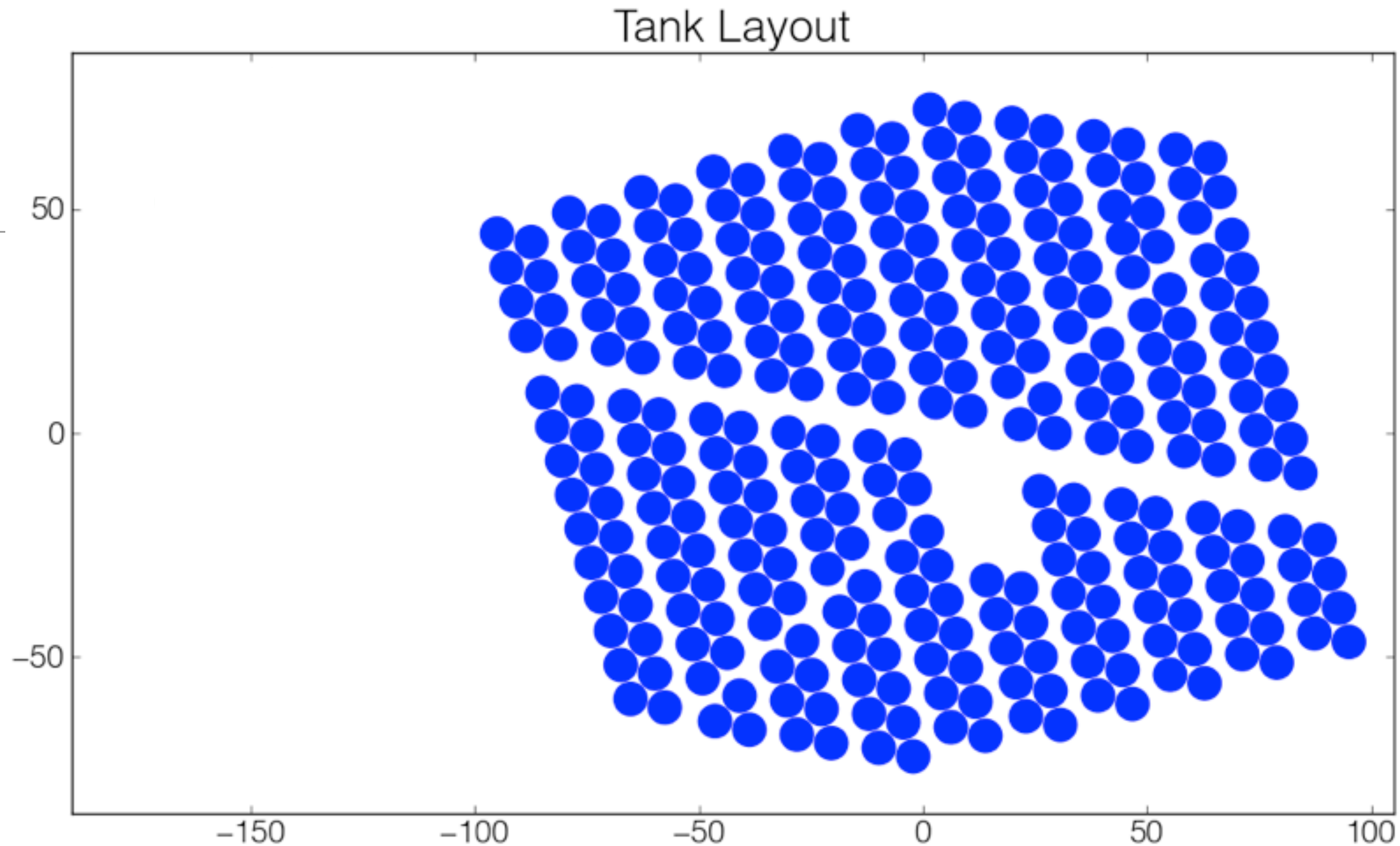
- Site is at ~4100 m on the slopes of Sierra Negra about 100 km outside of Puebla, Mexico
- Consist of 300 water tanks 7.3 m in diameter and filled to a water height of 4.5 m

HAWC Collaboration

- George Mason University
- Georgia Institute of Technology
- Harvey Mudd College
- Los Alamos National Laboratory
- Michigan State University
- Michigan Technical University
- NASA/Goddard Space Flight Center
- Ohio State University at Lima
- Pennsylvania State University
- Univ. of California, Irvine
- University of Maryland
- University of New Hampshire
- University of New Mexico
- University of Utah
- University of Wisconsin

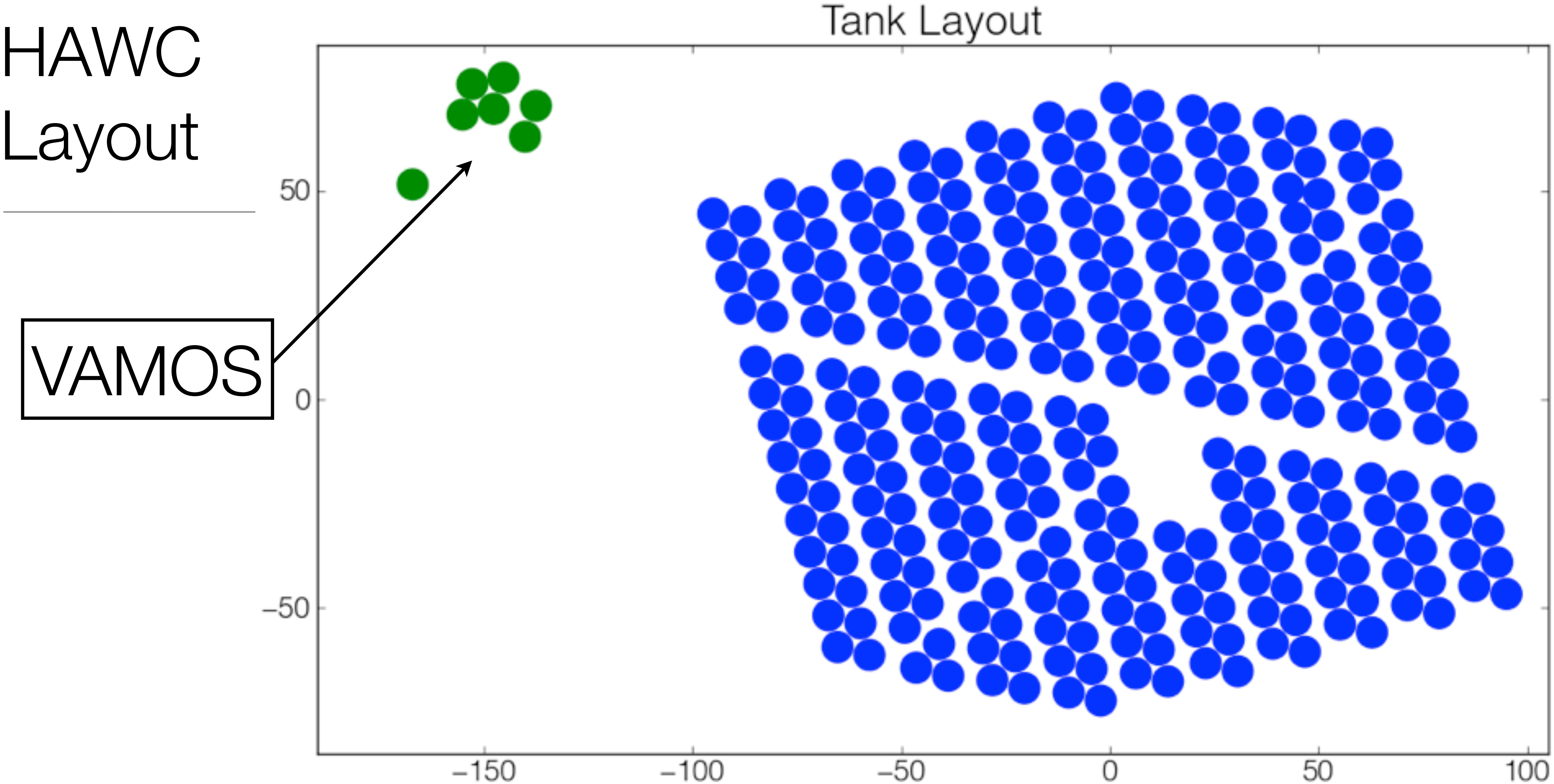
- Instituto Nacional de Astrofísica Óptica y Electrónica
- Universidad Nacional Autónoma de México
  - Instituto de Astronomía
  - Instituto de Física
  - Instituto de Ciencias Nucleares
  - Instituto de Geofísica
- Benemérita Universidad Autónoma de Puebla
- Universidad Autónoma de Chiapas
- Universidad de Guadalajara
- Universidad Michoacana de San Nicolás de Hidalgo
- Centro de Investigación y de Estudios Avanzados
- Universidad de Guanajuato

HAWC Layout



- HAWC will physically cover approximately 20,000 m^2
- Each tank has an area of approximately 40 m^2
- Each tank will contain a total of 4 PMTs; 3 from Milagro and 1 high quantum efficiency PMT (same model as used by IceCube).

HAWC Layout



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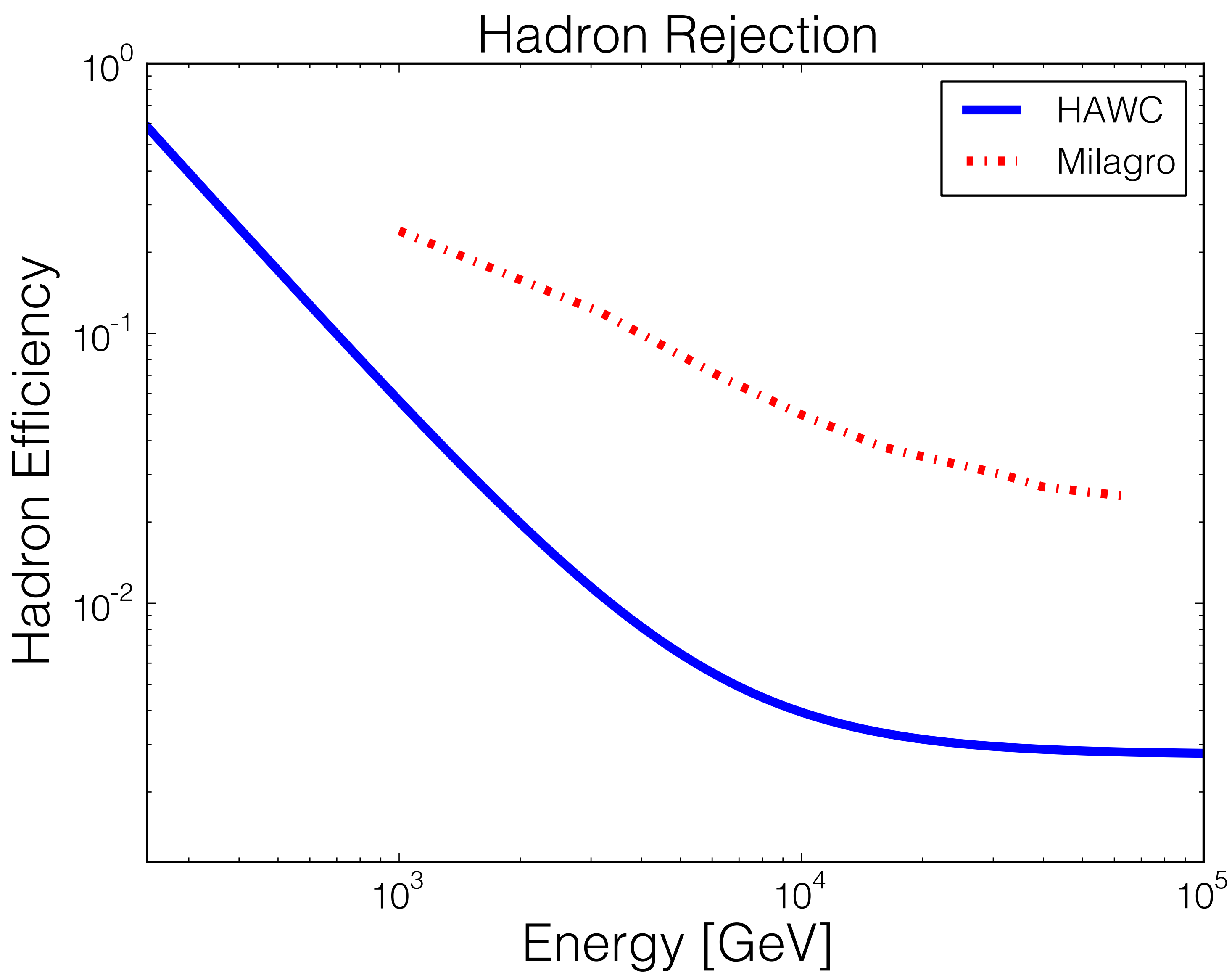
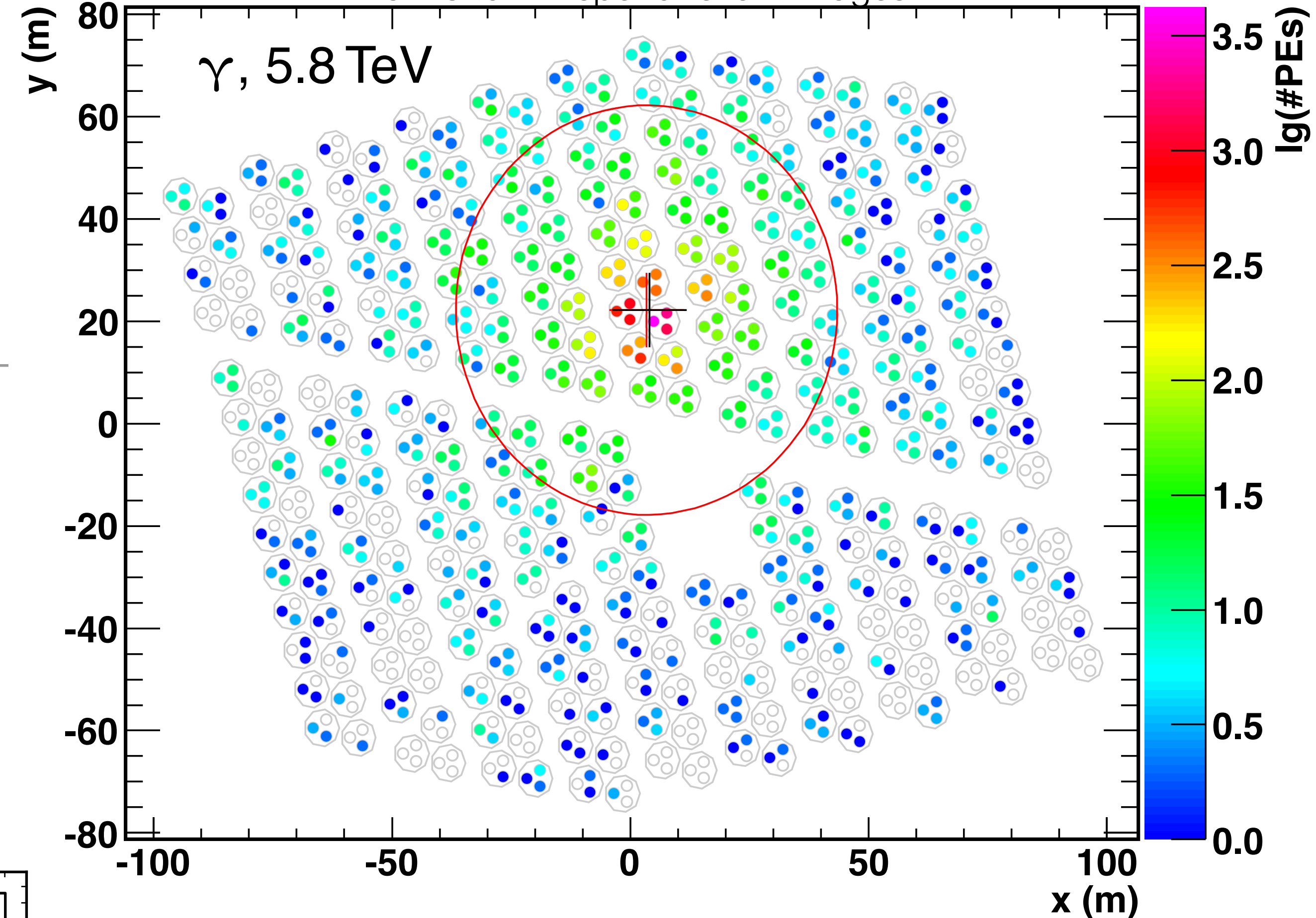
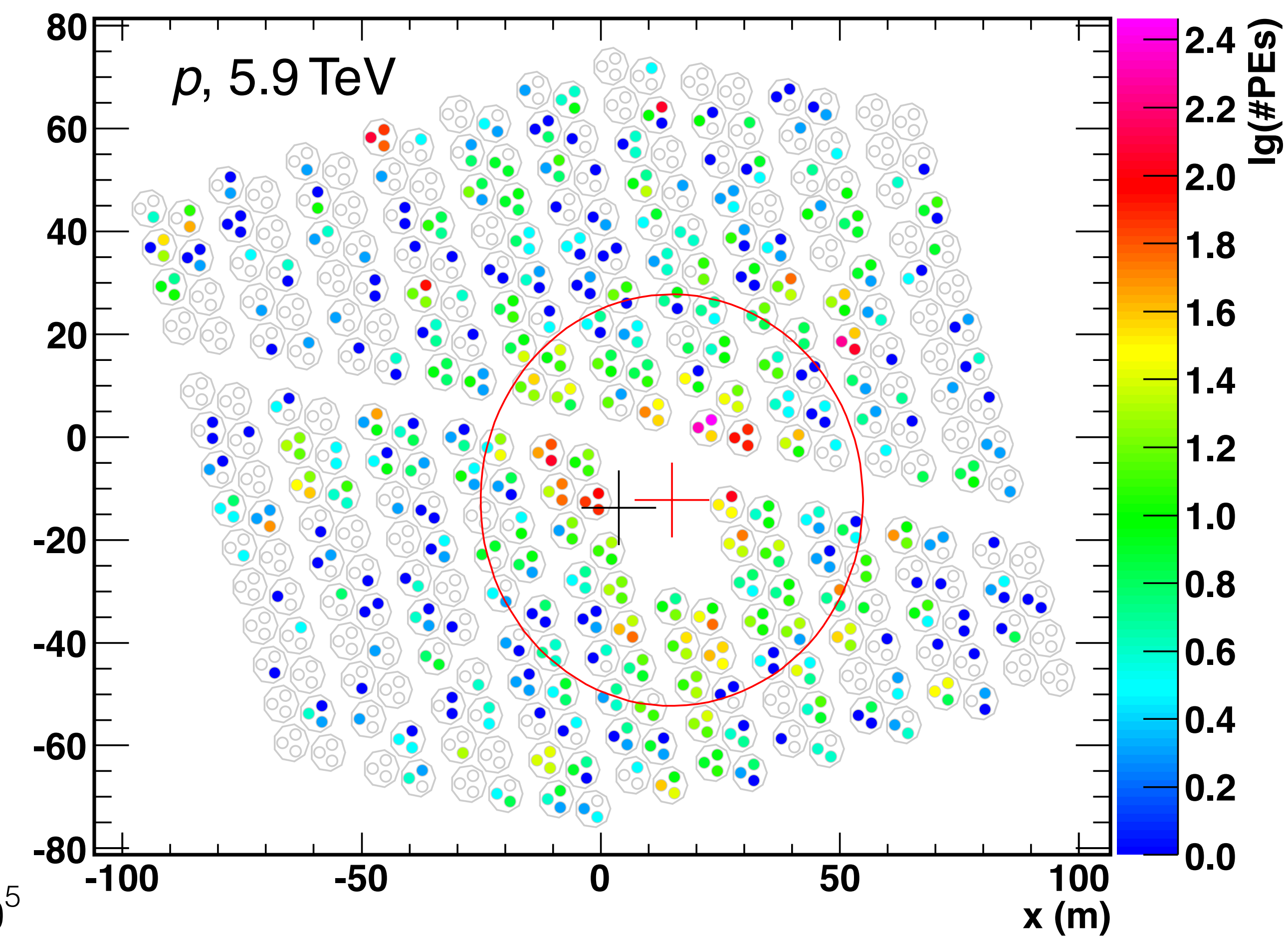
HAWC
Design Characteristics

- Background rejection is accomplished by the morphological differences between gamma and hadronic induced air showers



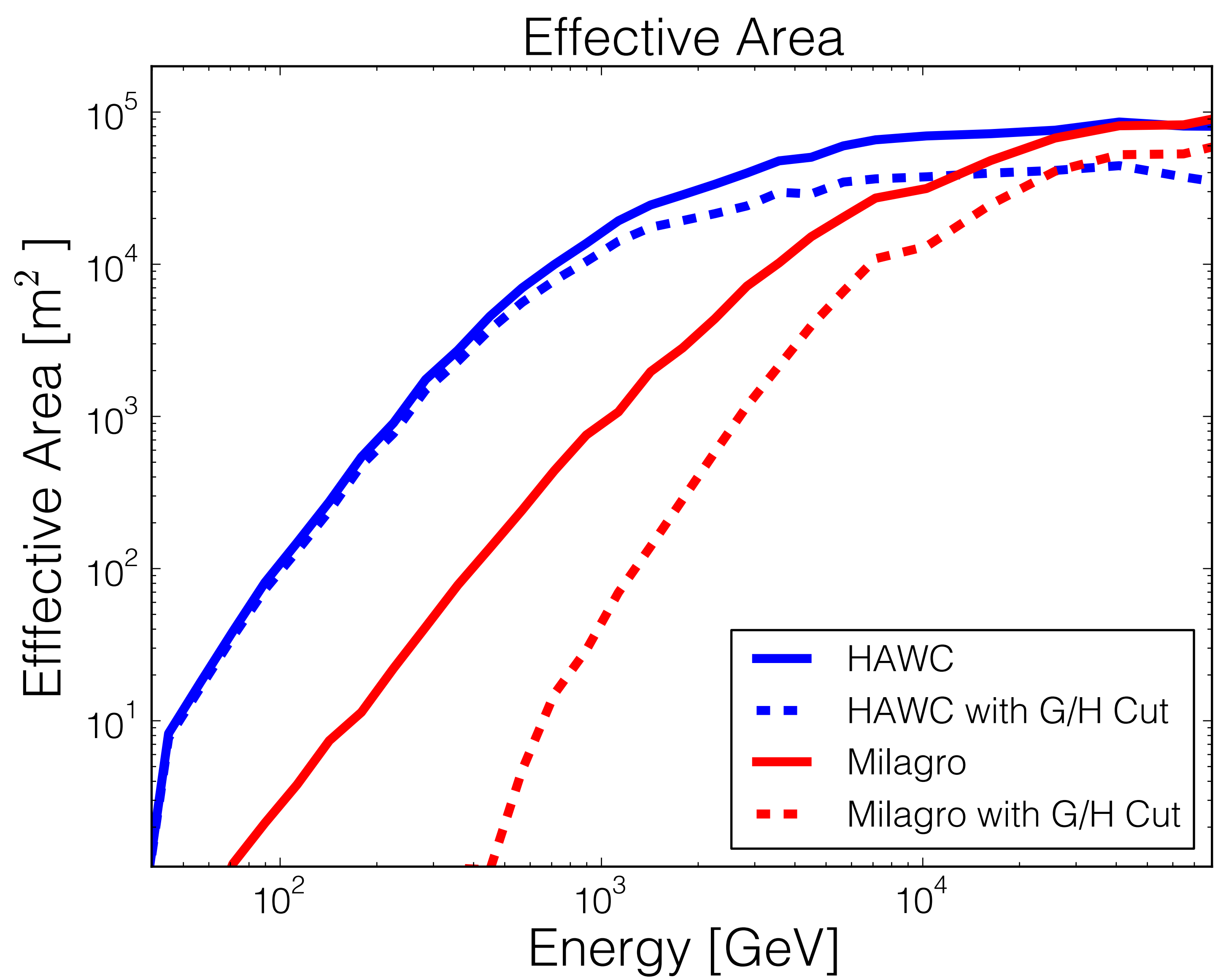
Thanks to A. Tepe for event images





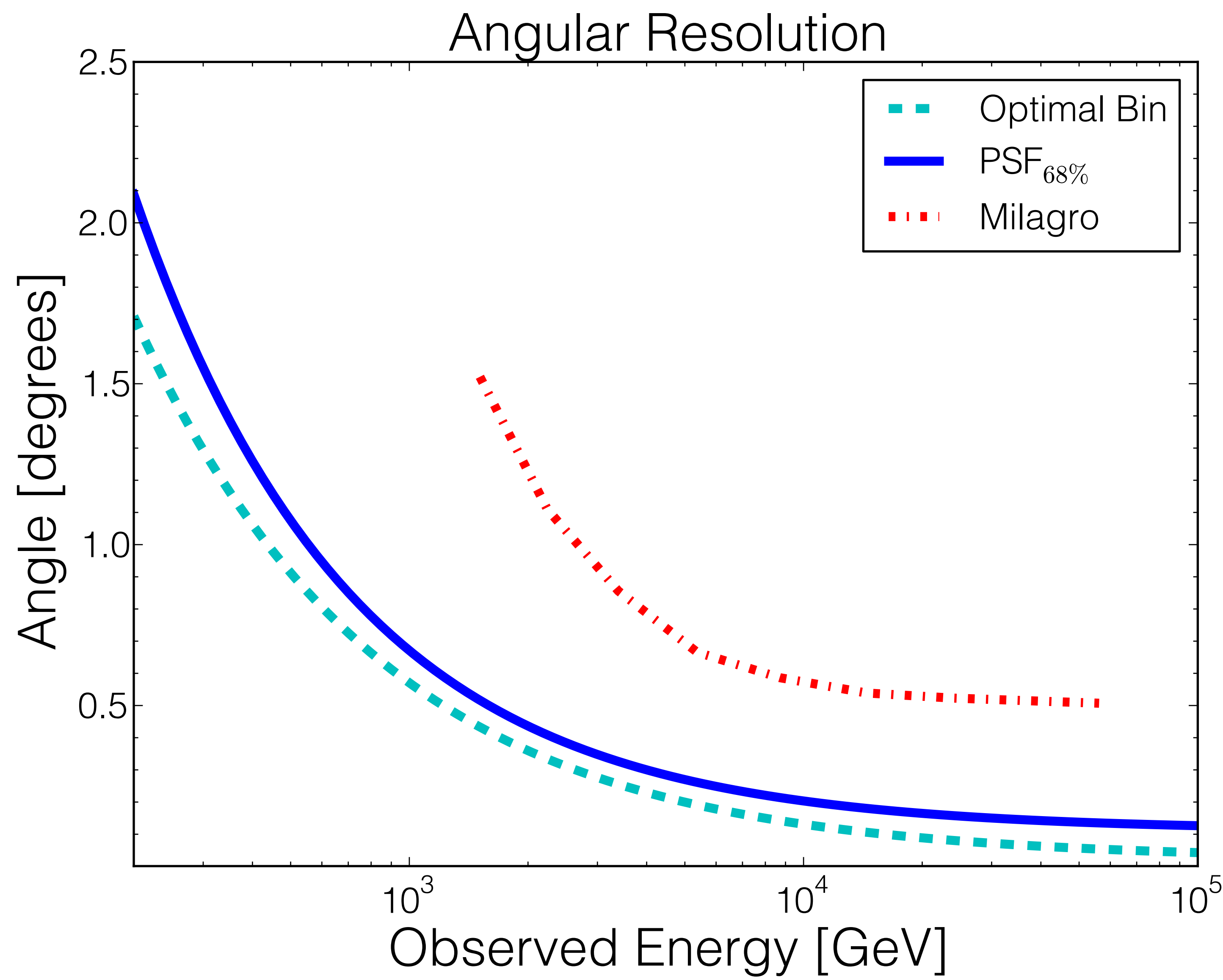
HAWC
Design Characteristics

- The effective area of HAWC is a significant improvement over Milagro at the lowest energies
- The dramatically improved background rejection of HAWC will allow for lower energy studies
- High energy gamma/hadron separation is undergoing significant improvements and the resulting effective area will improve.



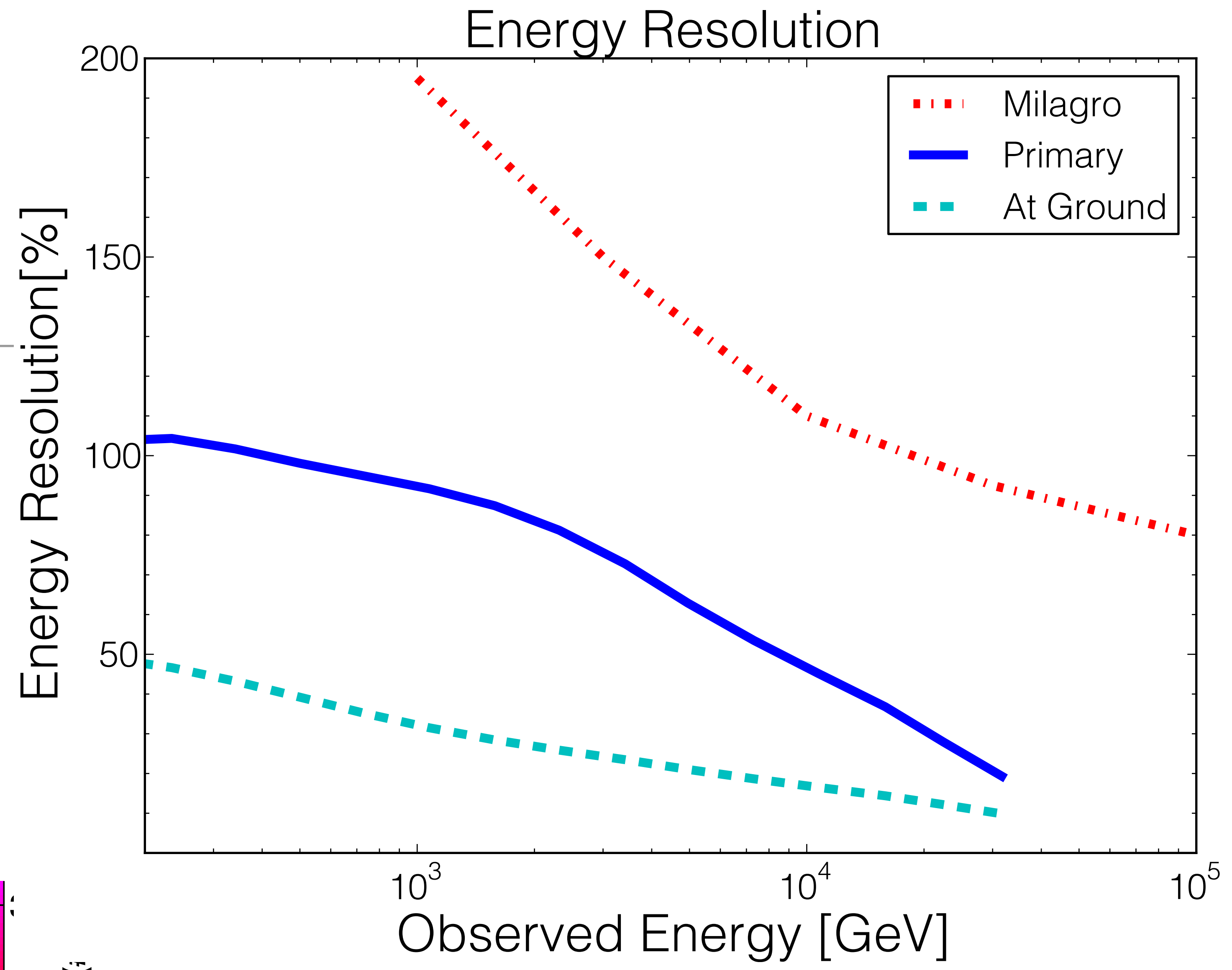
HAWC
Design Characteristics

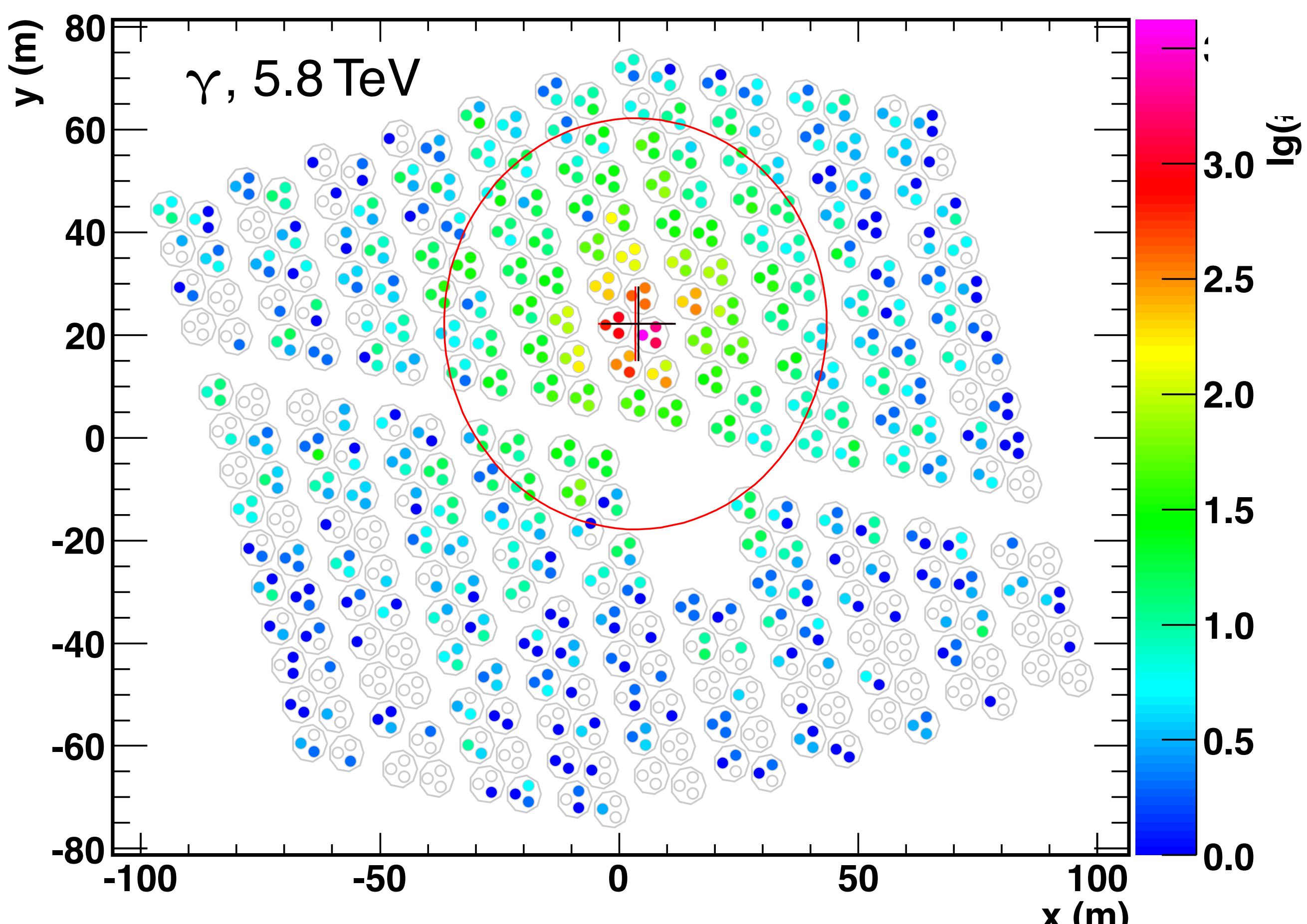
- The improved angular resolution of HAWC will allow for better studies of both point and diffuse sources.
- Some transient sources will have error ellipses useful for multi-wavelength correlations



HAWC
Design Characteristics

- The energy reconstruction of HAWC uses the deposition of energy on the ground
- Majority of error comes from shower to shower fluctuations





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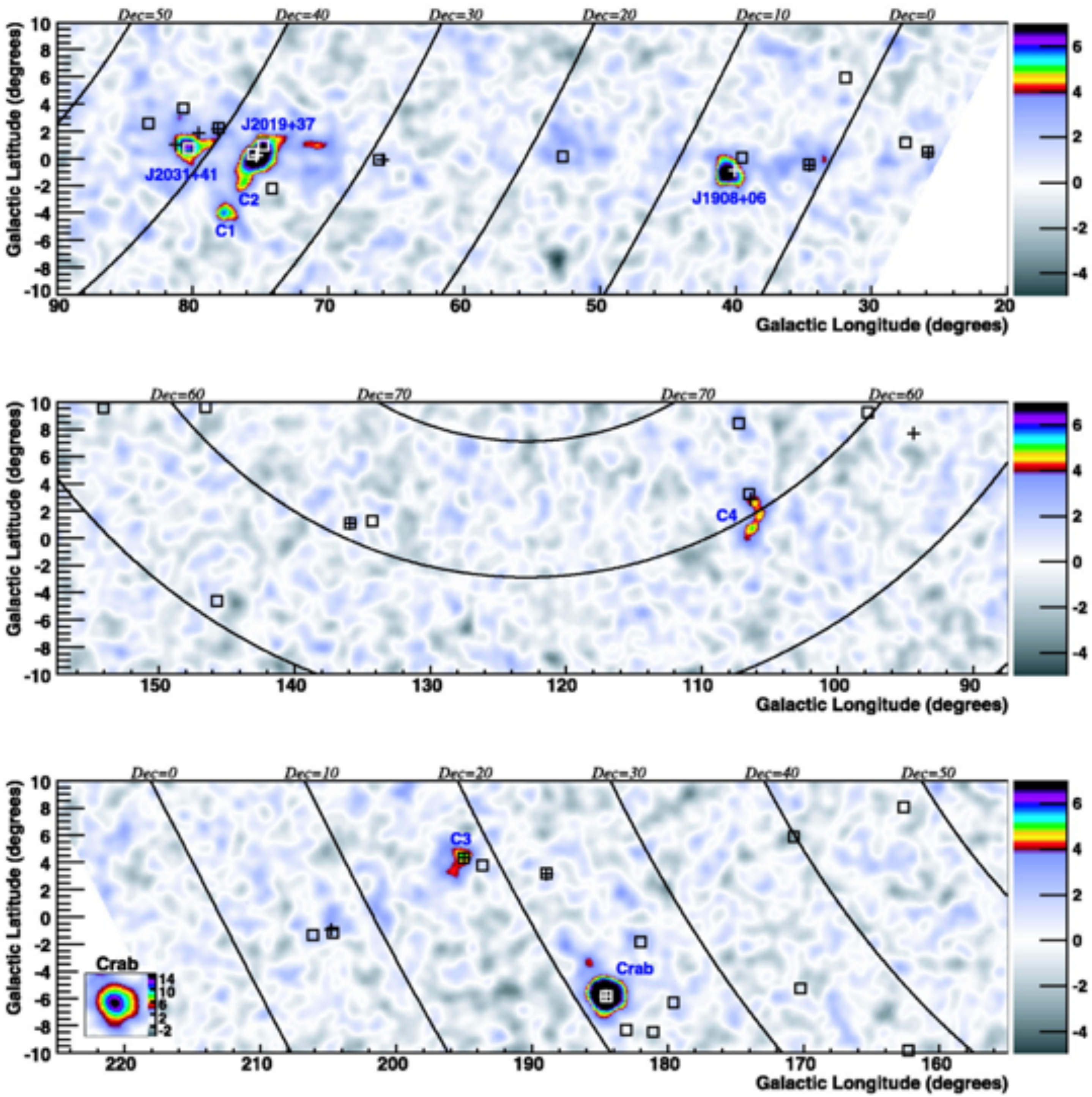
Astrophysics with HAWC Diffuse Sources

HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

The Astrophysical Journal, 664:L91-L94, 2007 August 1



- Milagro observed regions of diffuse emission along the Galactic plane
- HAWC will be able to improve our understanding of these regions.

Astrophysics with HAWC
Diffuse Sources

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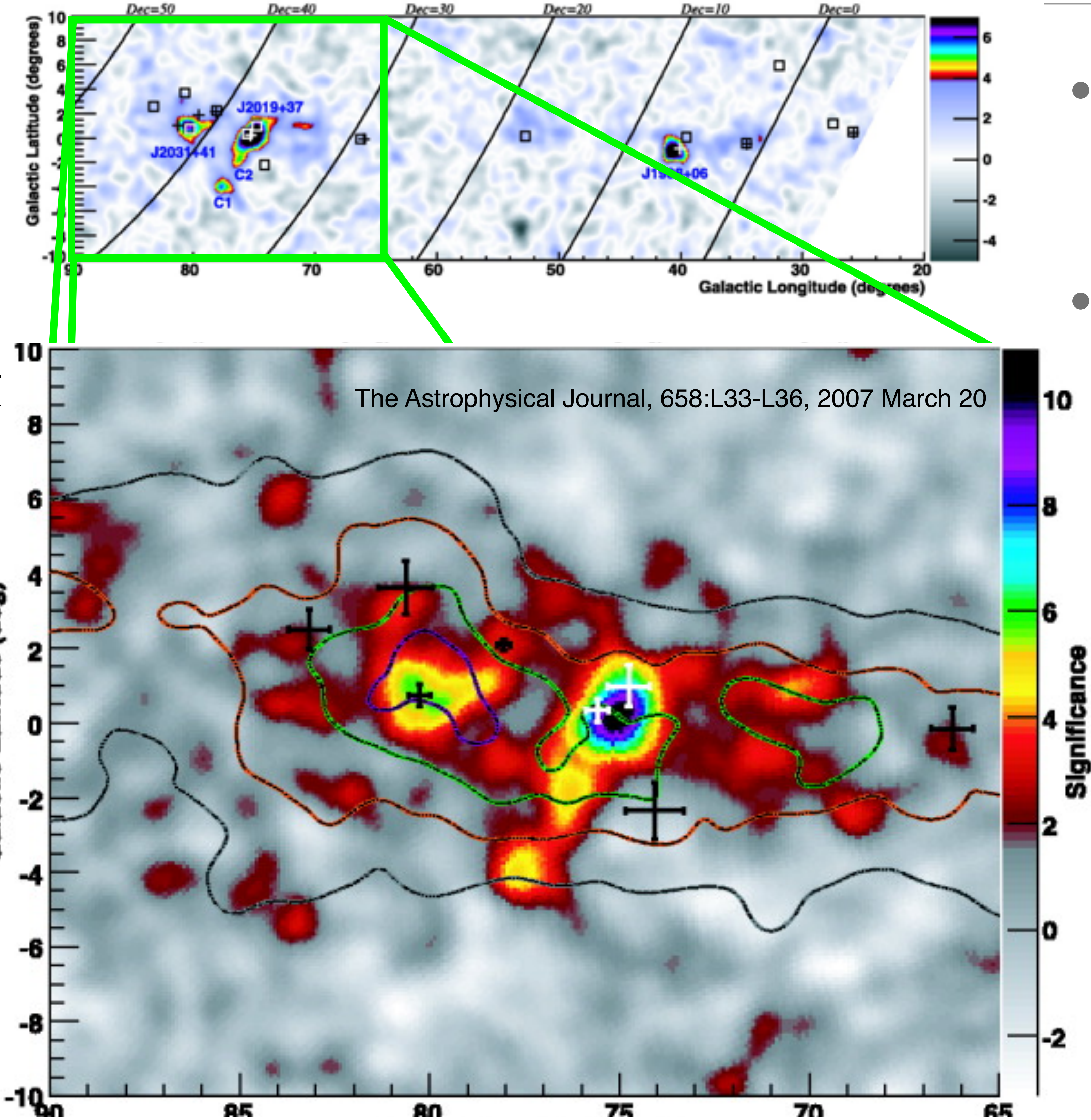

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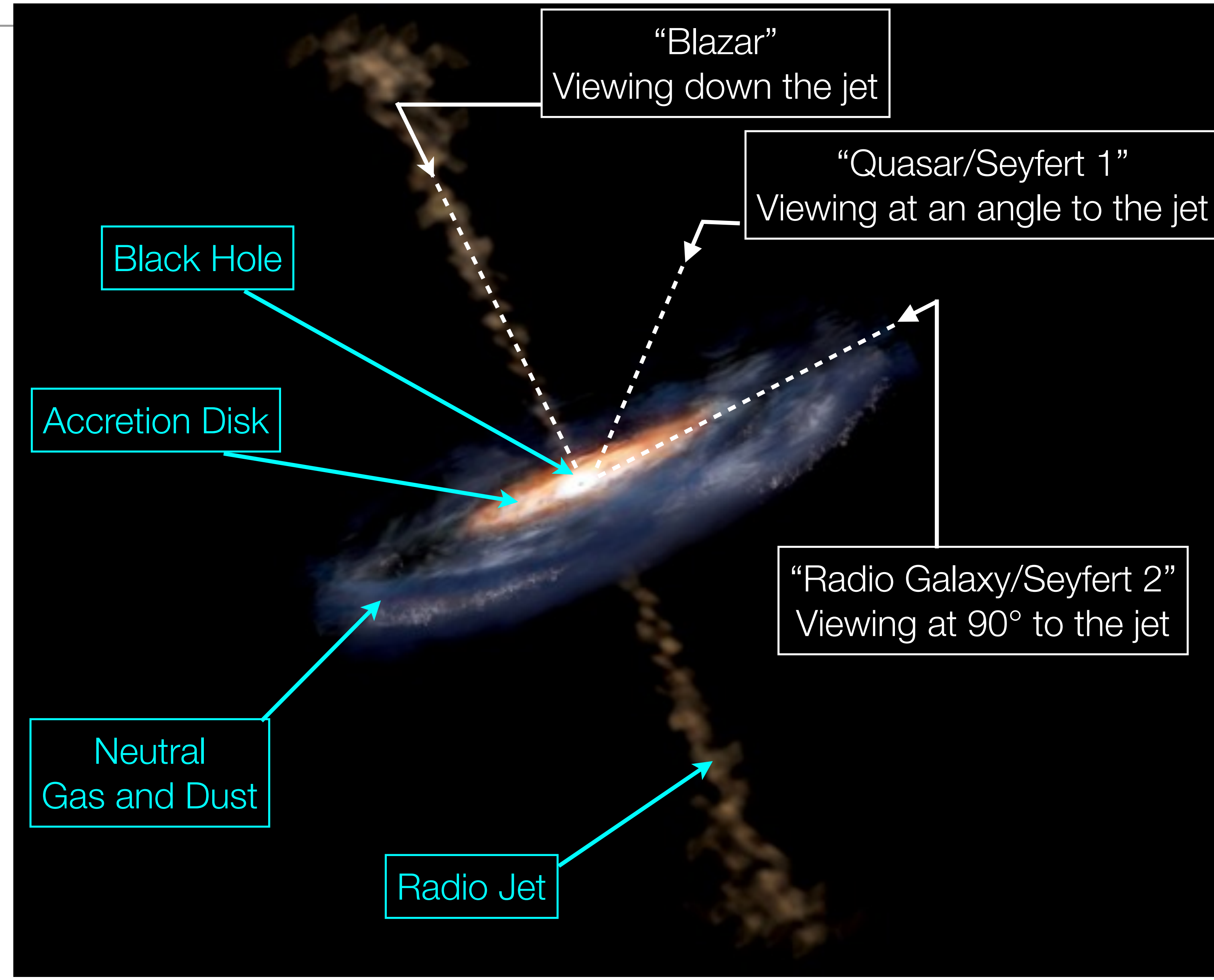
HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

Astrophysics with HAWC
AGN

- The acceleration of particles within AGN has yet to be fully understood.
- VHE measurements can help disentangle what is going on in these extremely powerful objects.
- Study cosmic radiation fields:
  - Gamma rays at HAWC energies can pair produce off cosmic radiation fields, this would cause an attenuation of flux.

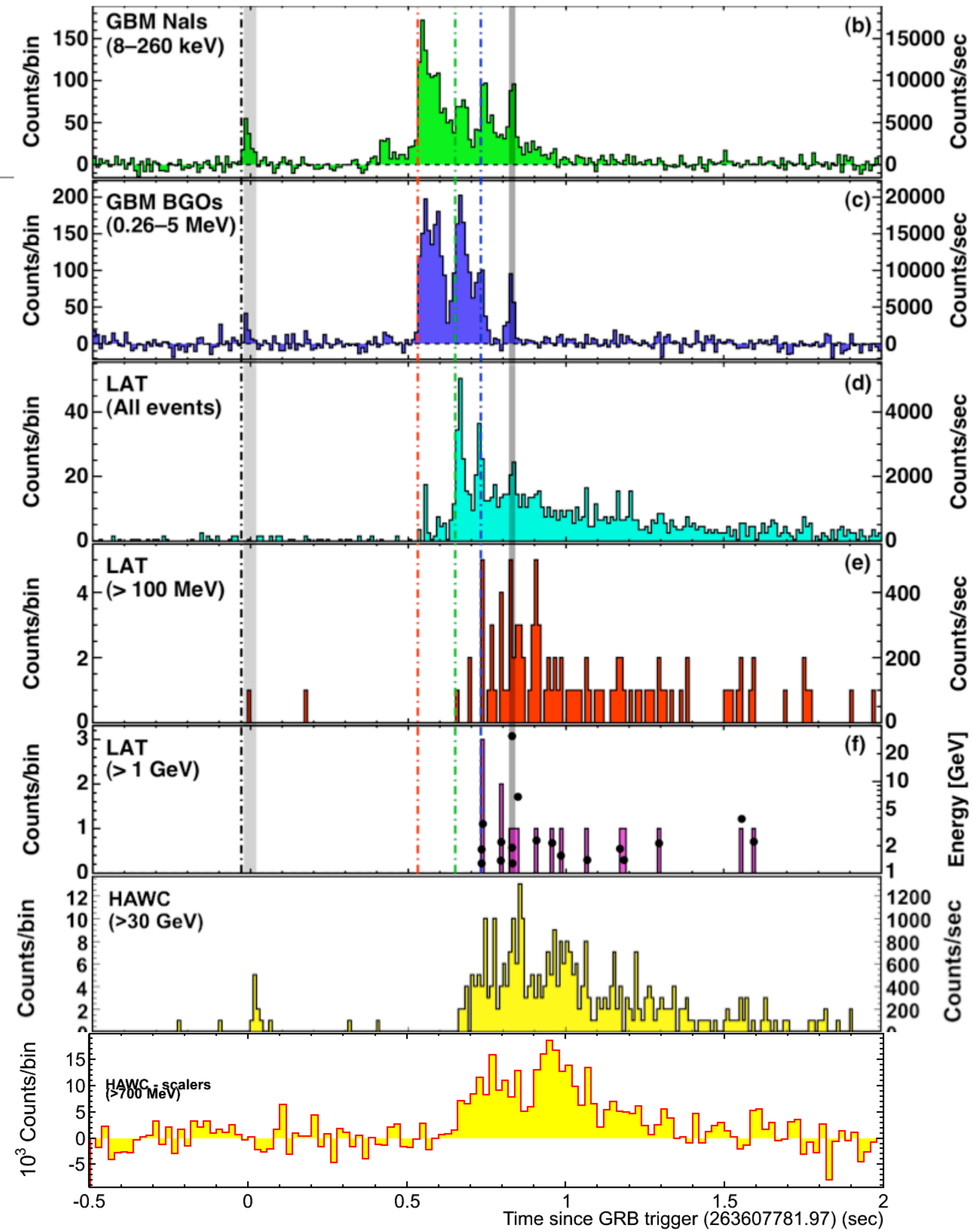


Artists rendition of AGN thanks to NASA

Astrophysics with HAWC GRBs

- HAWC will be a excellent always on sky survey instrument.
- The large aperture yields a sky coverage of 1.8 steradians
- The high duty cycle ensures HAWC will be on when a GRB is within its field of view.

Abdo et al. Science 2009

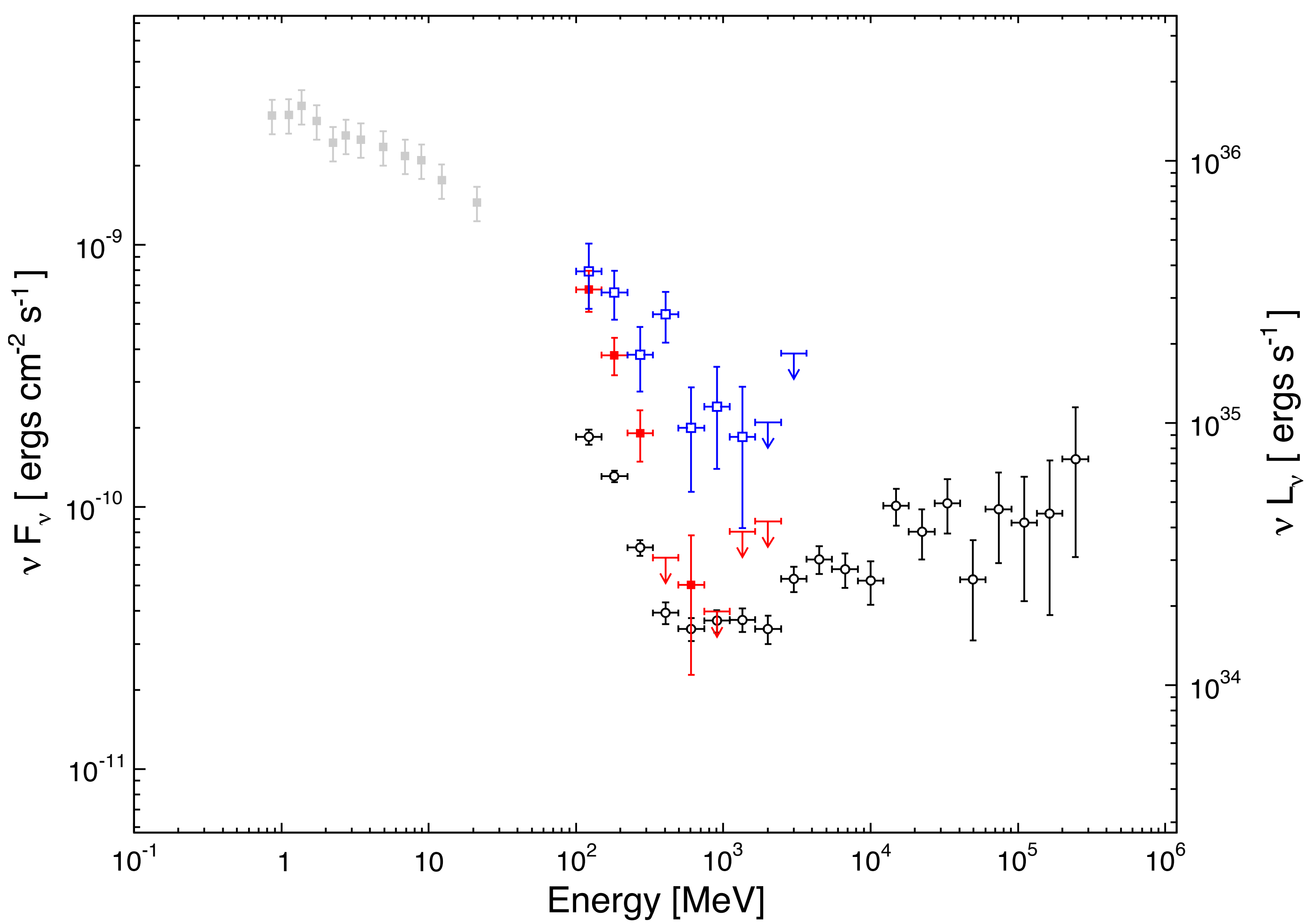


Taboada et al. HAWC GRBs 32nd ICRC

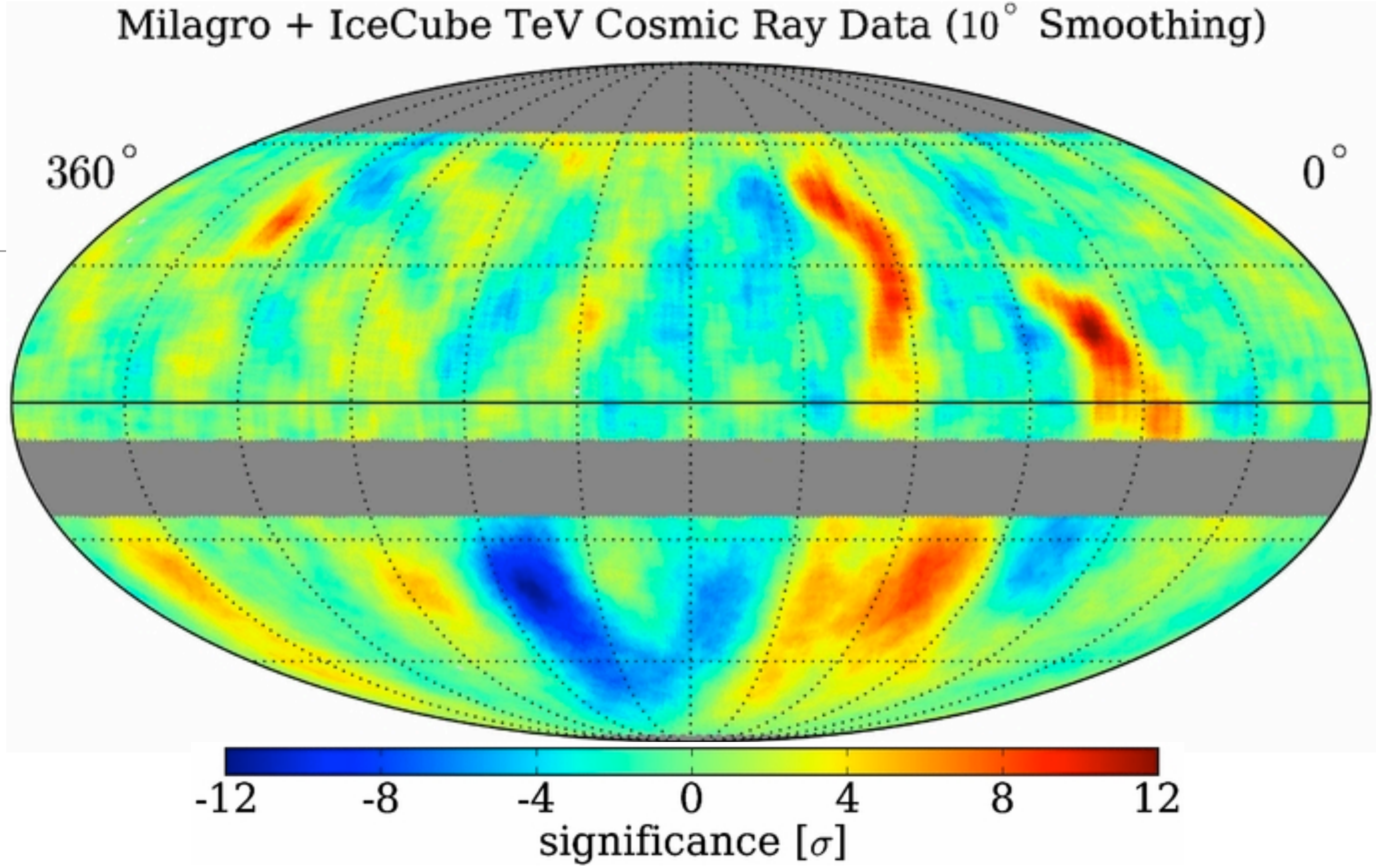
Astrophysics with HAWC Variability Monitor

- The Crab nebula, considered one of the most steady sources in the sky, has recently been observed to have variability at the GeV energy range.
- If these flares extend up to the VHE regime then spectral characteristics (not possible with the lower energy statistics) may shed light as to their origin.

Science, Jan 2011 DOI: 10.1126/science.1199705



R. Abbasi *et al.* 2011 *ApJ* **740** 16 doi:10.1088/0004-637X/740/1/16



- HAWC will be able to improve on the successes of Milagro in the observation of the cosmic ray anisotropy.
- The improved instrument performance will yield more statistics in a shorter time with better energy and angular resolution.

HAWC Timeline

- February 2011 - Construction began (e.g. leveling surface)
- Summer 2012 - 30 HAWC tanks deployed (sensitivity comparable to Milagro)
- Summer 2013 - 100 tanks deployed, begin regular science operation
- Fall 2014 - 300 tanks deployed, array complete, data taking continuous

HAWC
Current Status

- About 20 tanks constructed
- Water filtration system installed and operational
- PMTs have been tested and characterized
- On track to deliver approximately 30 fully operational water cherenkov detectors by September.

Onward to HAWC!

The End