The HAWC Gamma Ray Observatory

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VHE Gamma Ray Telescopes

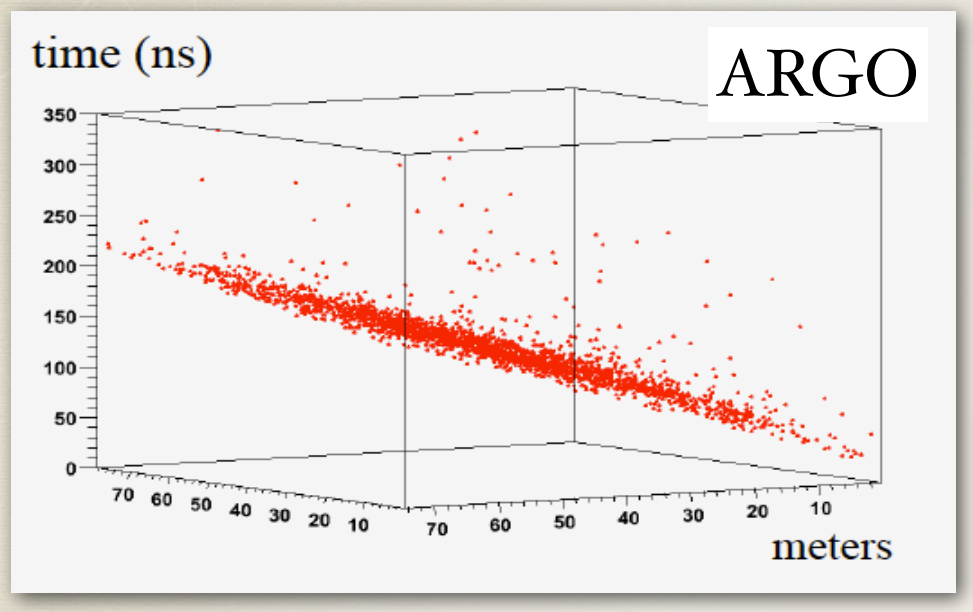
IACTs
H.E.S.S./VERITAS/MAGIC

50 GeV - 100 TeV
High Instantaneous Sensitivity
Excellent background rejection
Small Aperture/Low Duty Cycle

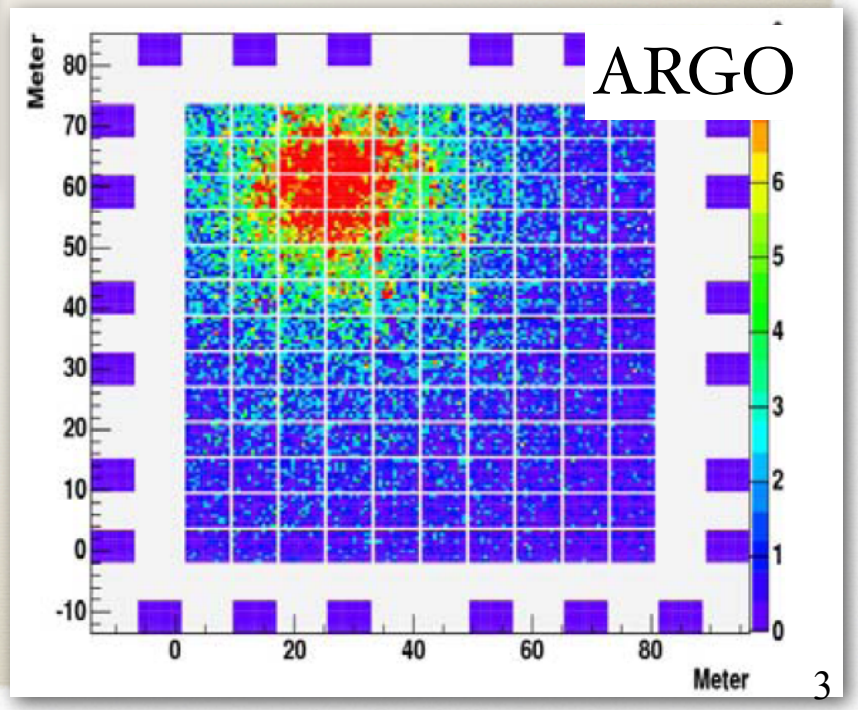
EAS Arrays
Milagro/Tibet/ARGO/HAWC

100 GeV - 100 TeV
Large Exposure to Entire Sky
Good background rejection
Large Aperture & Duty Cycle

Angular & Energy Reconstruction



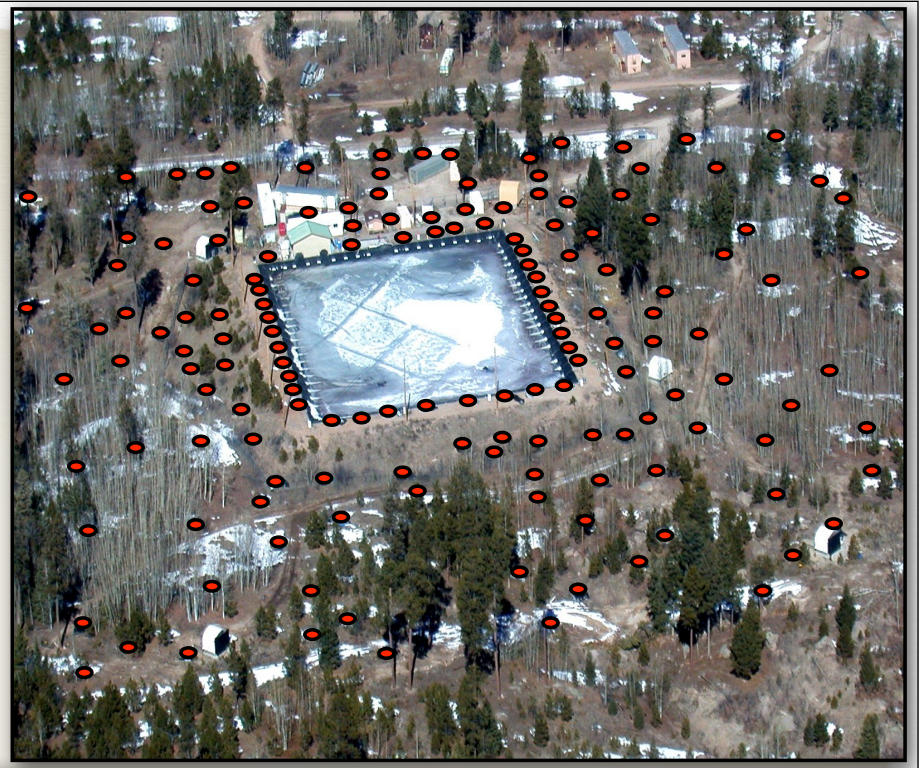
Direction via timing
(~ns timing = 0.1°-1° resolution)

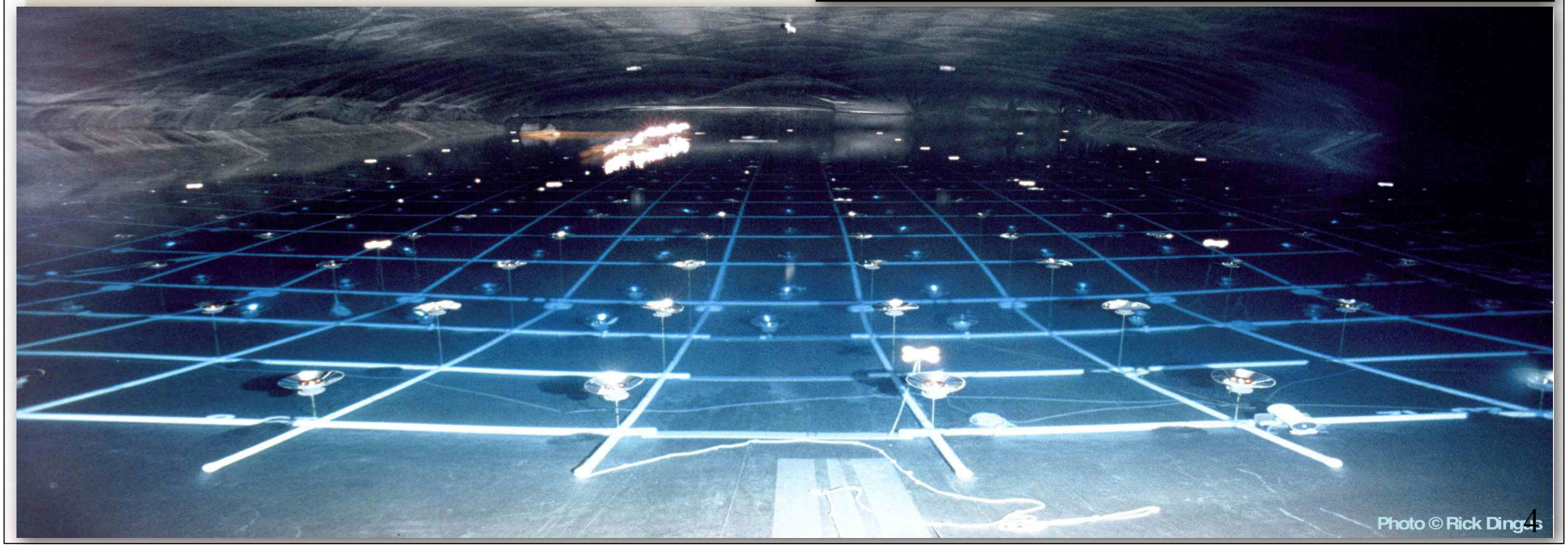


Primary Energy via #particles @ground
shower fluctuations dominate ~40%

Milagro

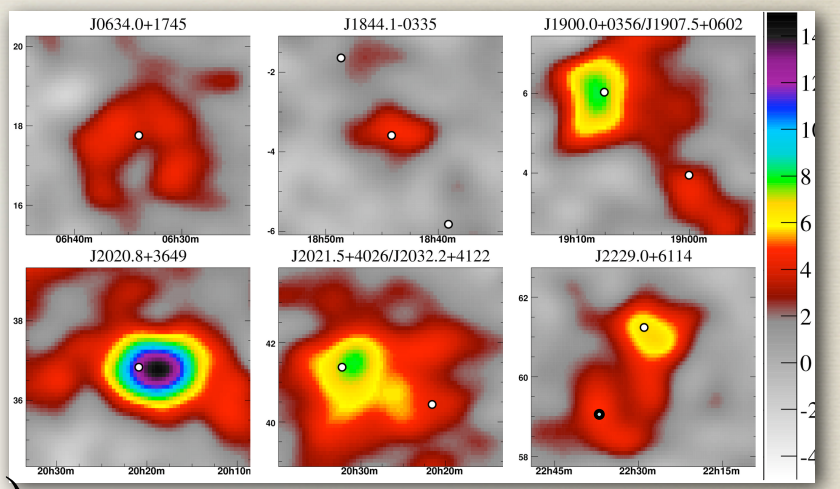
- 2600m asl (NM, USA)
- Water Cherenkov detector
  - 5000 m^2 reservoir
  - 2000 m^2 muon detector
  - 40,000m^2 outrigger array
- 1700 Hz trigger rate
- 2-40 TeV median energy

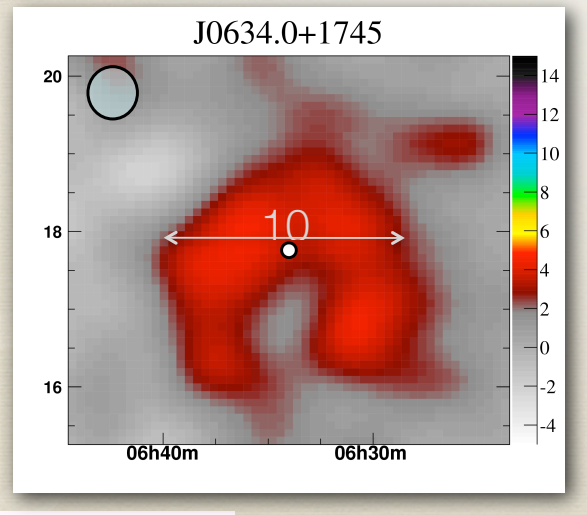


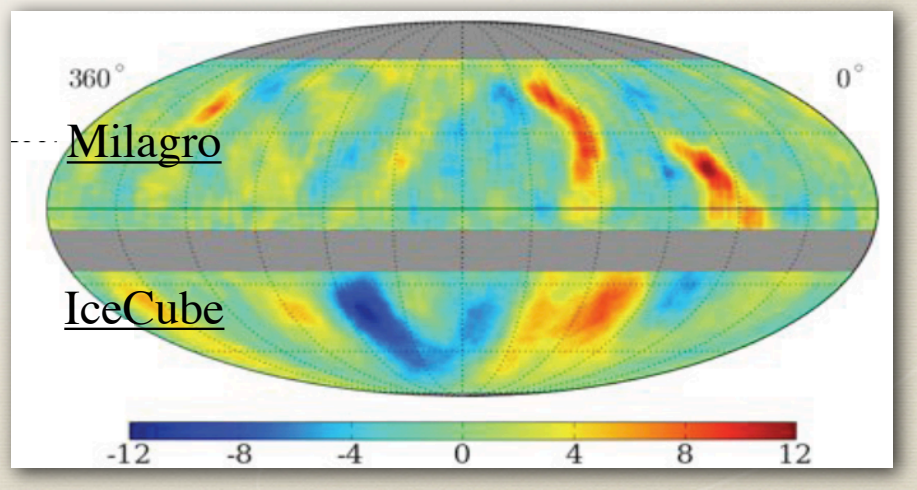


Milagro Key Discoveries

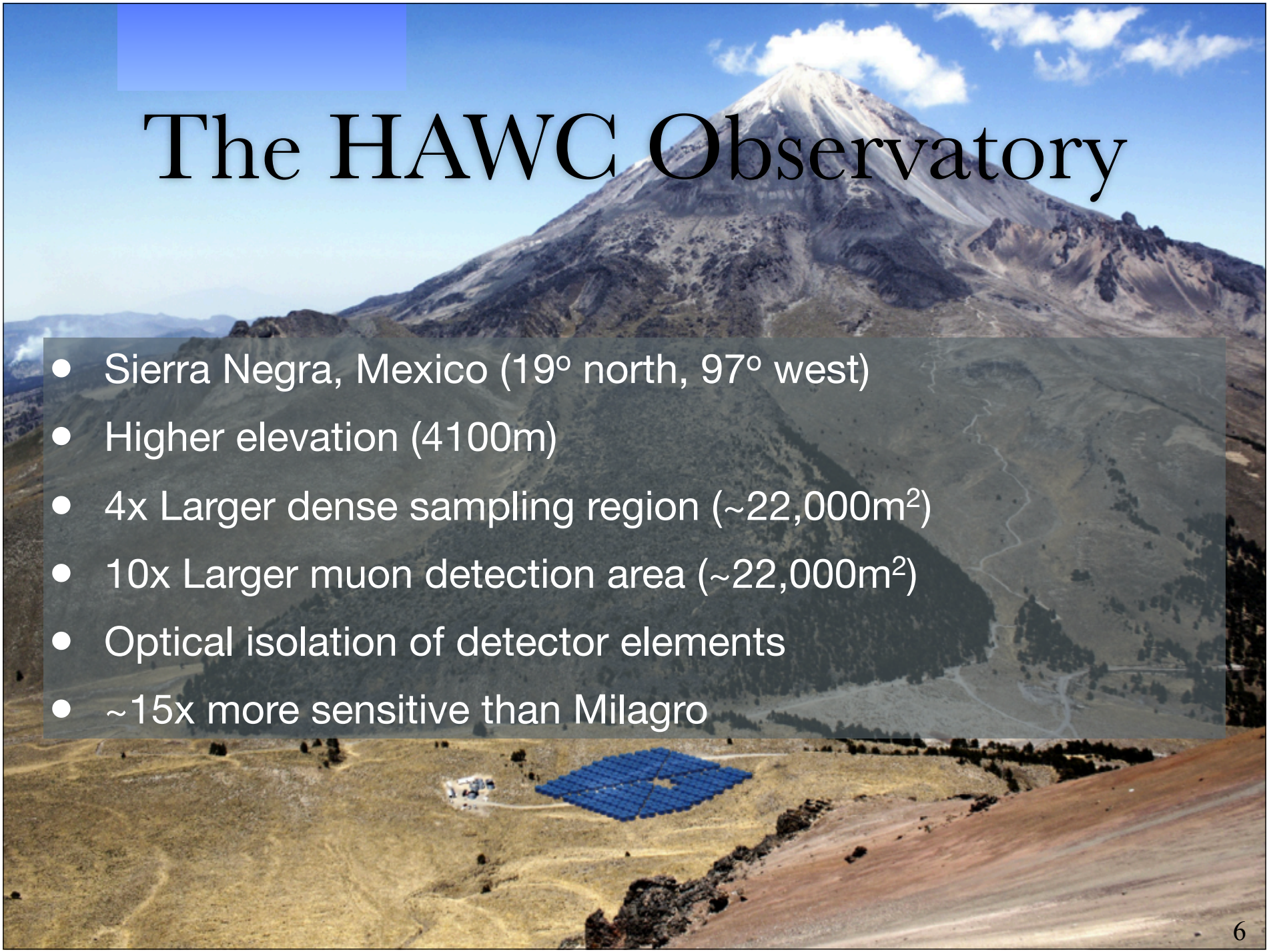
- Galactic diffuse emission at ~20 TeV
- Galactic sources GeV-TeV correlation (PWN)
- Cosmic-ray anisotropy
- Geminga (explain positron excess)







The HAWC Observatory



- Sierra Negra, Mexico (19° north, 97° west)
- Higher elevation (4100m)
- 4x Larger dense sampling region (~22,000m^2)
- 10x Larger muon detection area (~22,000m^2)
- Optical isolation of detector elements
- ~15x more sensitive than Milagro

HAWC Collaboration

Los Alamos National Laboratory
University of Maryland
University of Wisconsin
University of Utah
Univ. of California, Irvine
Michigan State University
George Mason University
University of New Hampshire
Penn State University
University of New Mexico
Michigan Technological U
NASA/Goddard
Georgia Institute of Technology
University of Alabama
Colorado State University
UC Santa Cruz

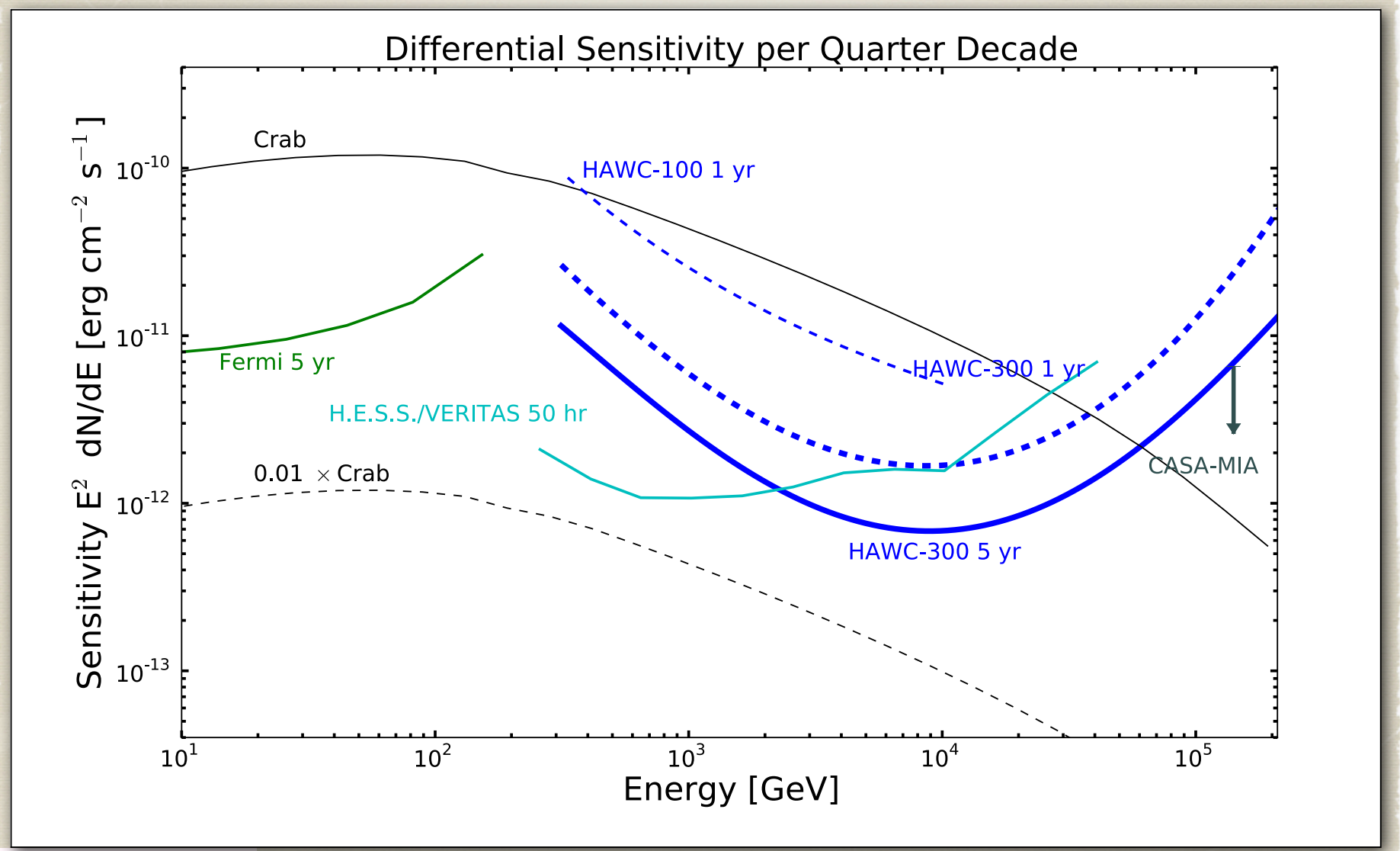
Instituto Nacional de Astrofísica Óptica y Electrónica (INAOE)
Universidad Nacional Autónoma de México (UNAM)
Benemérita Universidad Autónoma
Universidad Autónoma de Chiapas
Universidad Autónoma del Estado de Hidalgo
Universidad de Guadalajara
Universidad Michoacana de San Nicolás de Hidalgo
Centro de Investigacion y de Estudios Avanzados
Universidad de Guanajuato

25 Institutions
145 members

Science Goals of HAWC

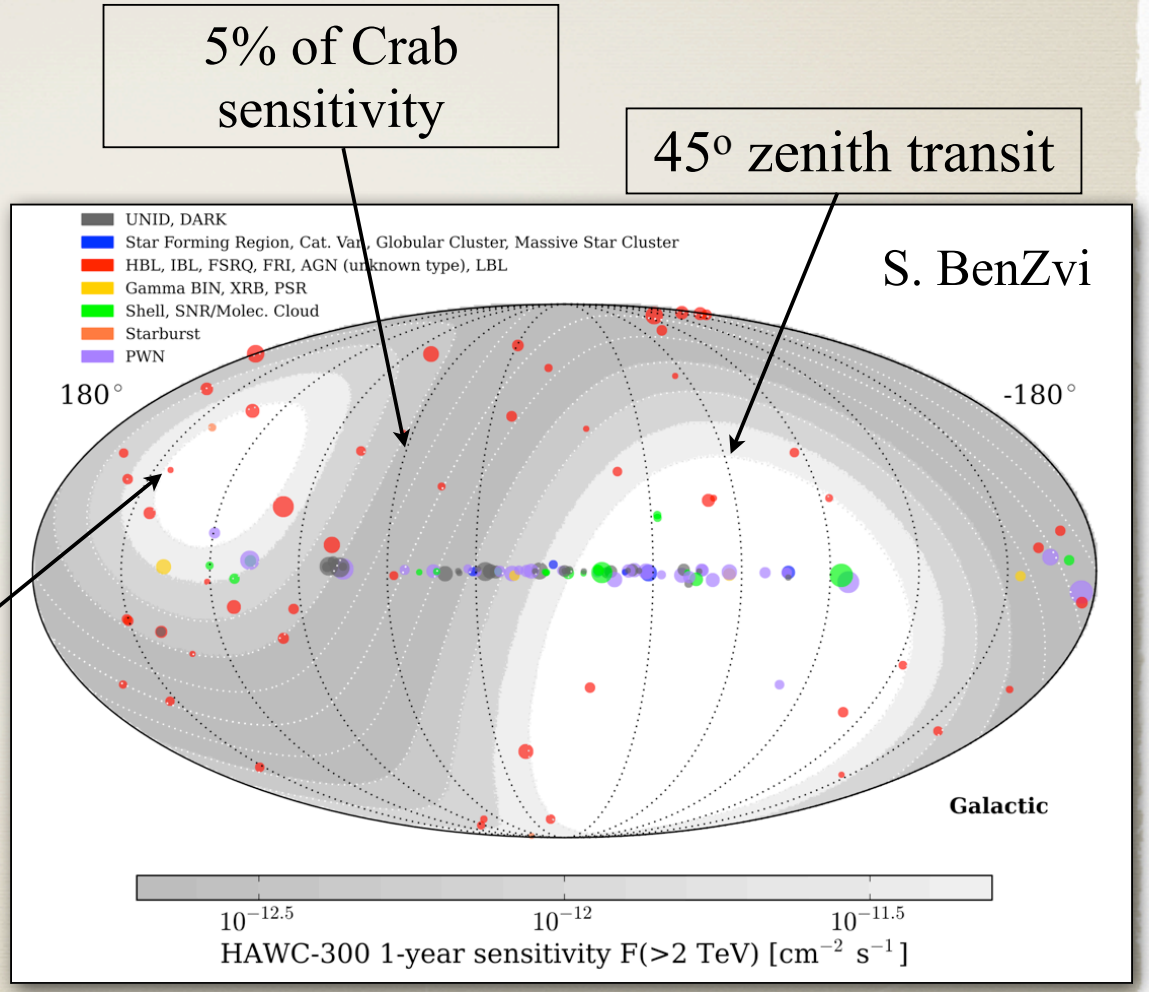
- Astrophysics
  - Particle acceleration
  - Transient phenomena
  - Galactic accelerators (spectra to ~100 TeV)
  - Cosmic-Ray origins
  - Discovery, unbiased sky survey over 8π sr
- Particle Physics
  - Dark Matter (Direct and Indirect detection)
  - Primordial Black Holes
  - Lorentz Invariance Violation
- Multi-Messenger/Wavelength alert system

HAWC Sensitivity



HAWC Sky Coverage

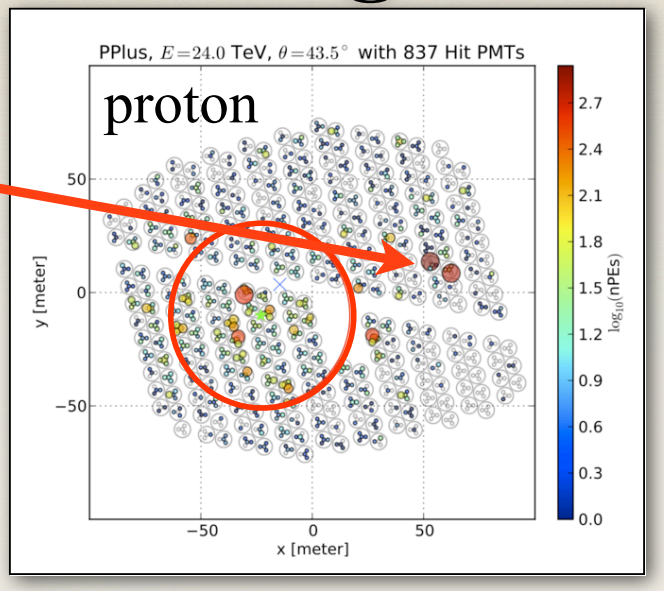
- Same sky viewed by IceCube
- Simultaneous sky with VERITAS
- Crab Nebula overhead
- Galactic center visible (~45º transit)

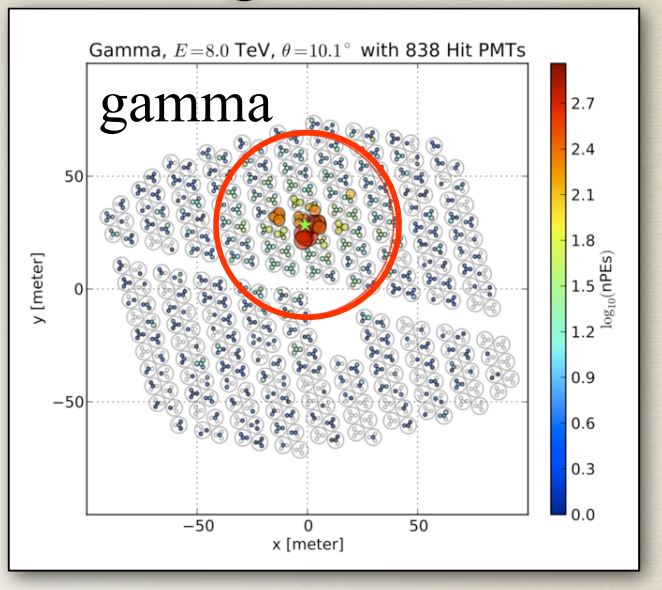


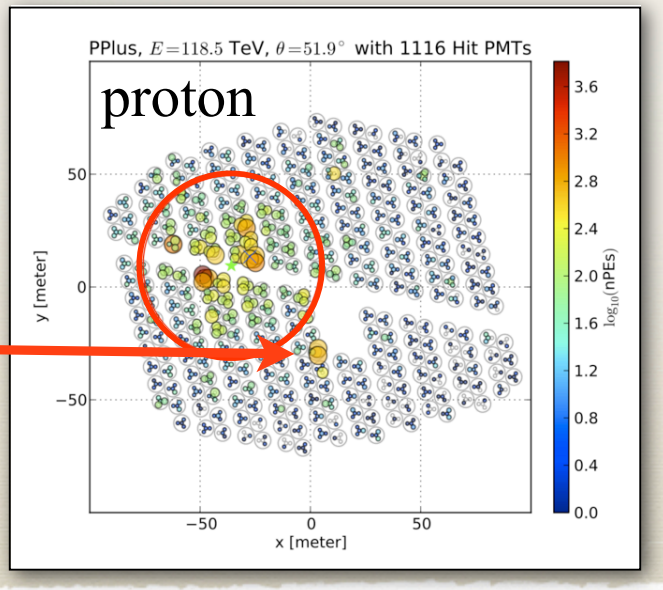
HAWC: Background Rejection

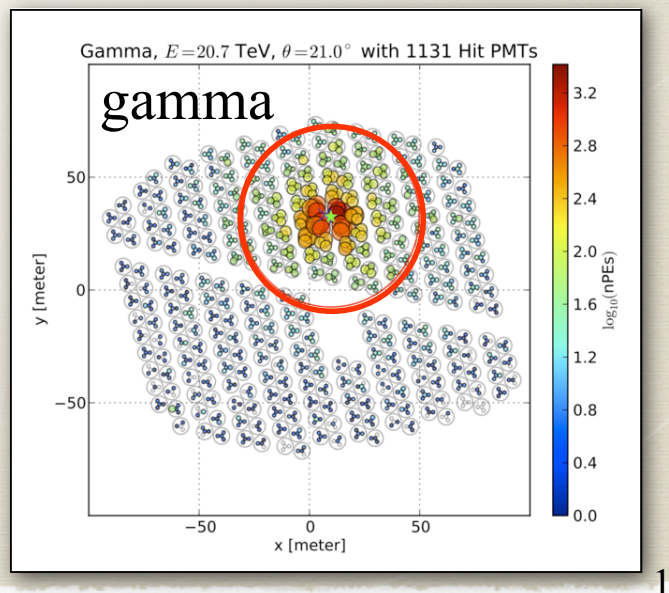
Hadronic signature

Large amplitude >40m from core

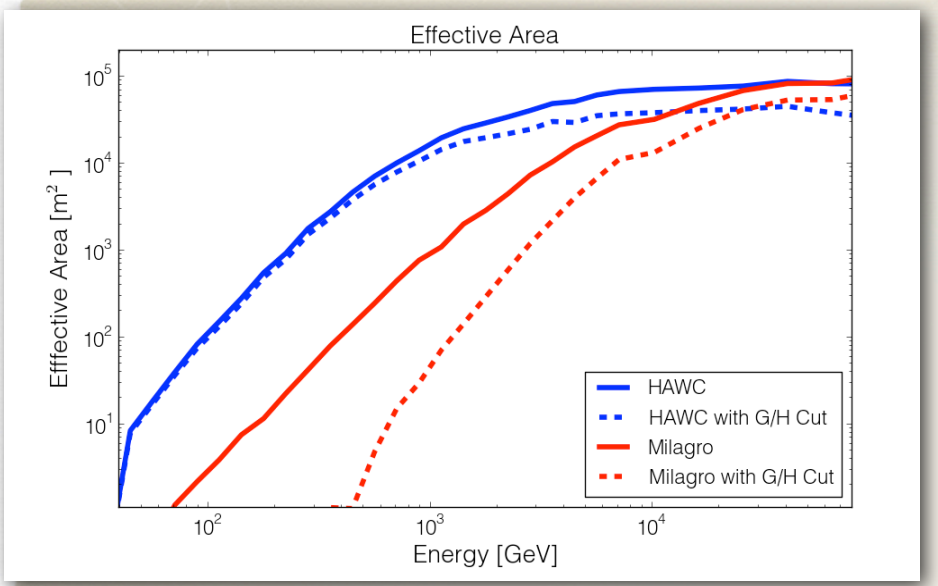


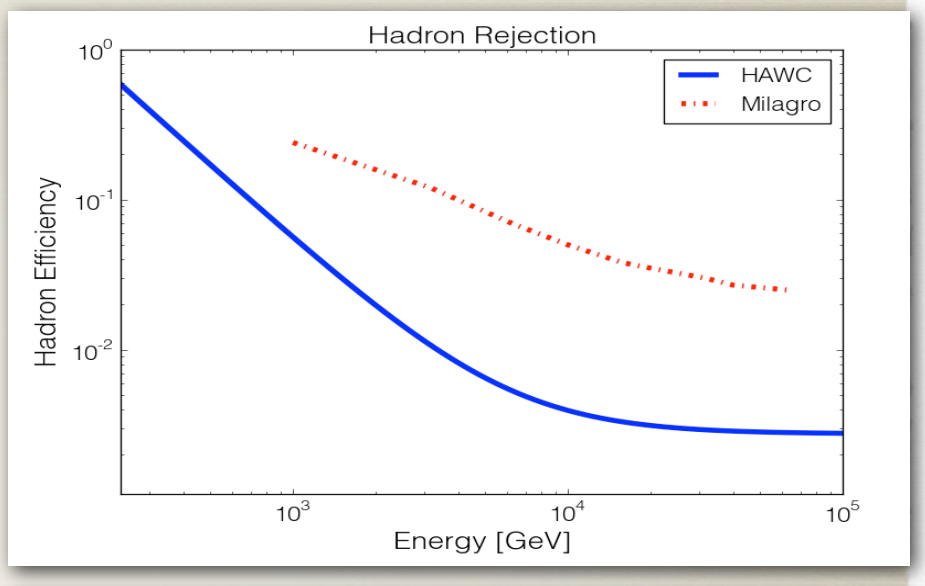


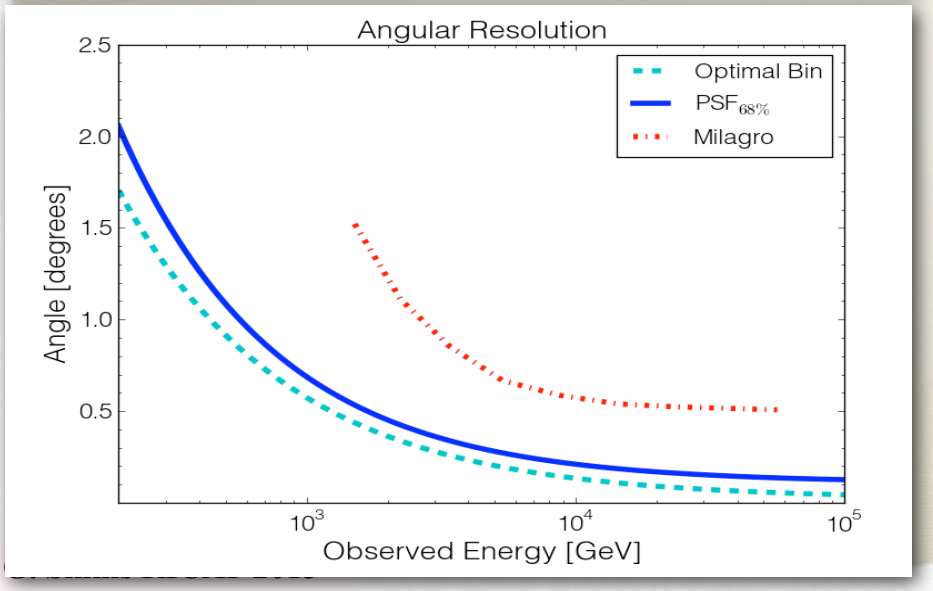


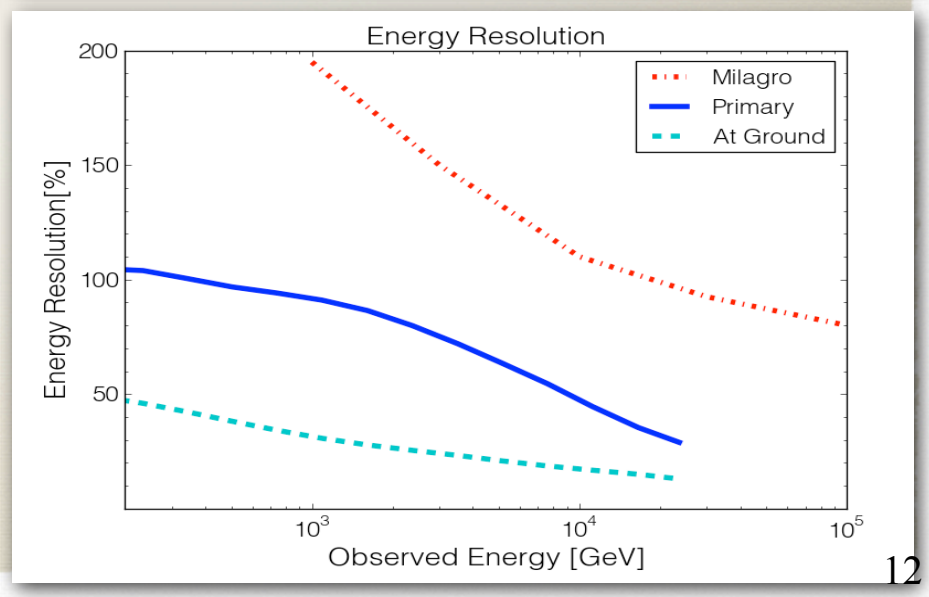


HAWC Performance



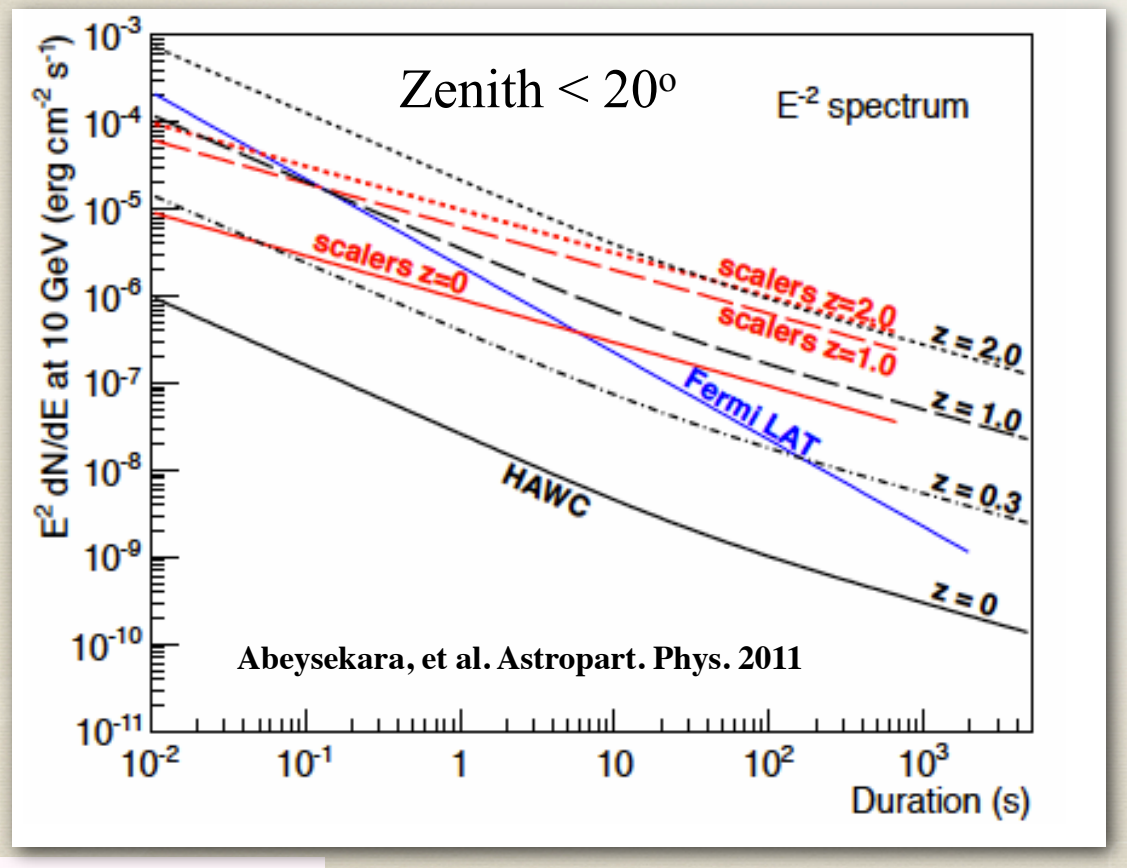






Transient Sensitivity

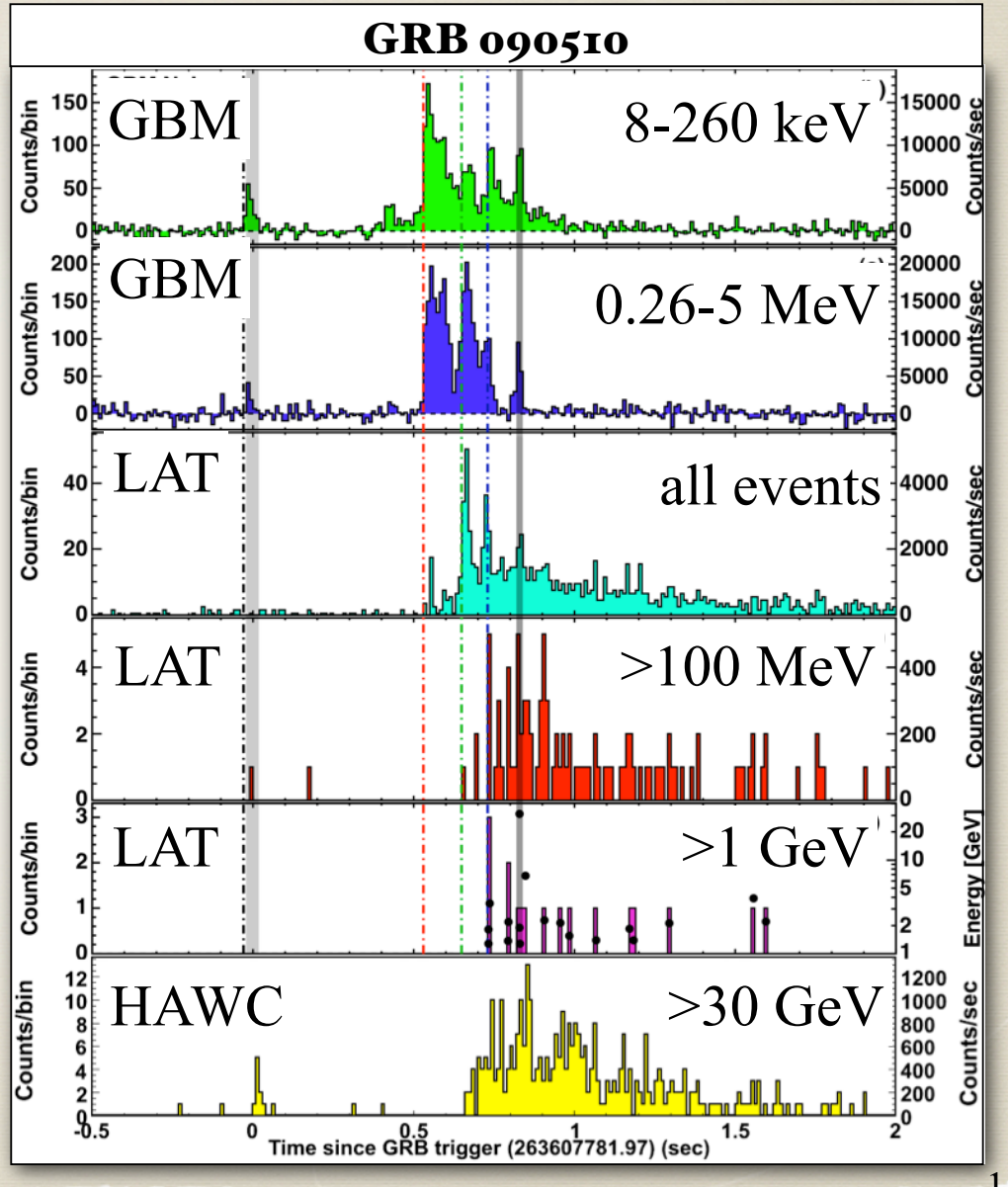
- Scaler sensitivity uses sum of single PE hits in PMTs
- Fermi sensitivity assumes 1 photon > 10 GeV
- EBL model of Gilmore 2009



For short transients HAWC will be more sensitive than Fermi above 10 GeV

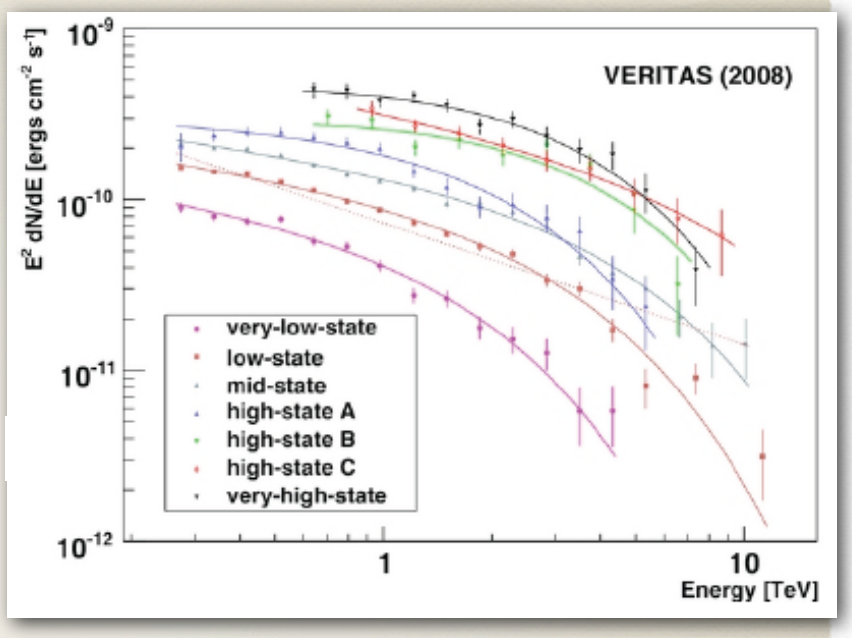
GRB Sensitivity

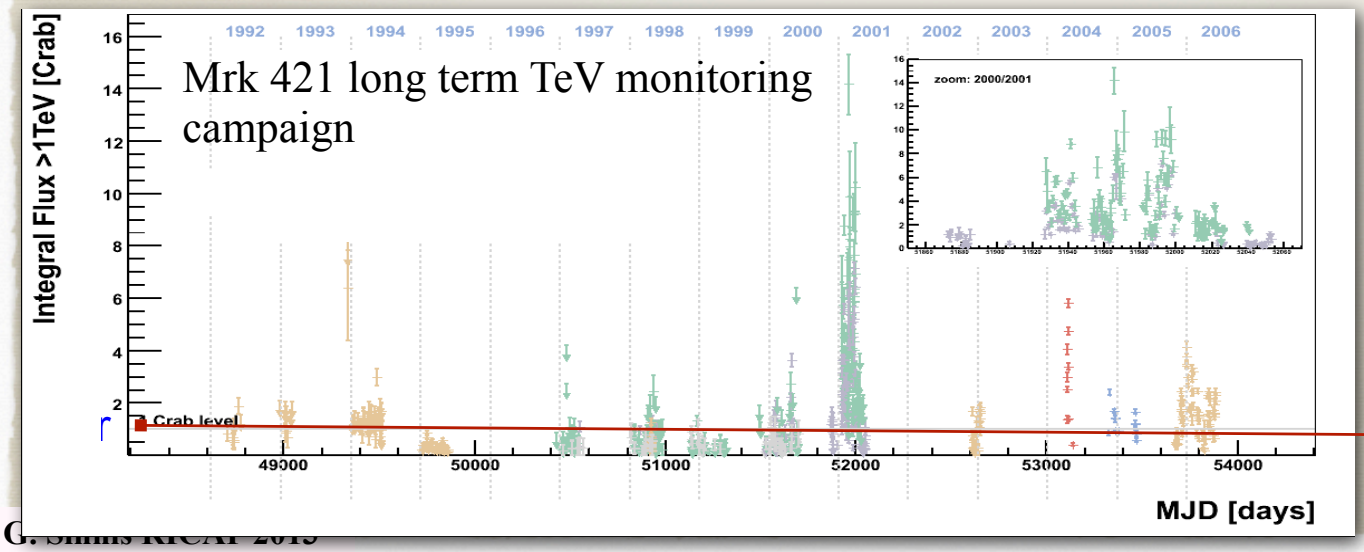
- Fermi observation of GRB 090510 (z = 0.9)
- Simulated HAWC light curve assuming extension of spectrum with LAT index
  - EBL absorption included
- ~200 events expected above 30 GeV
- Detection (5σ) by HAWC if emission cuts off at 50 GeV



Active Galactic Nuclei

- >50 AGN detected at TeV energies
- HAWC will observe all northern hemisphere AGN for ~5 hours/day
- Mrk 421 "very-high-state" detectable (8σ) in 30 minutes
- Mrk 421 "high-state-A" detectable in 1 day
- Mrk 421 "very-low-state" 1 month





HAWC 1-day sensitivity

HAWC Dark Matter Sensitivity

- Galactic Center transits at ~47 degrees
  - Best target for HAWC (black curve)
- For m_χ >10 TeV HAWC most sensitive instrument
- Bottom curve for HAWC-like instrument at -22° declination

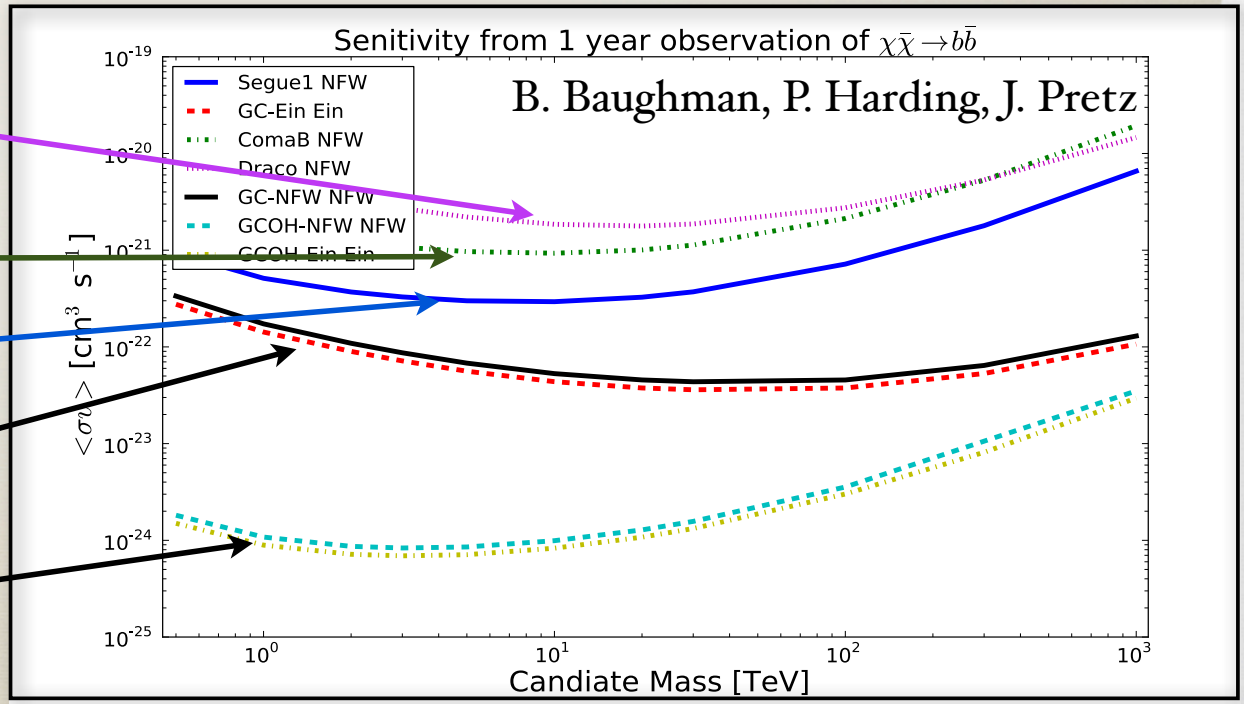
Draco

Coma Berenices

Segue-1

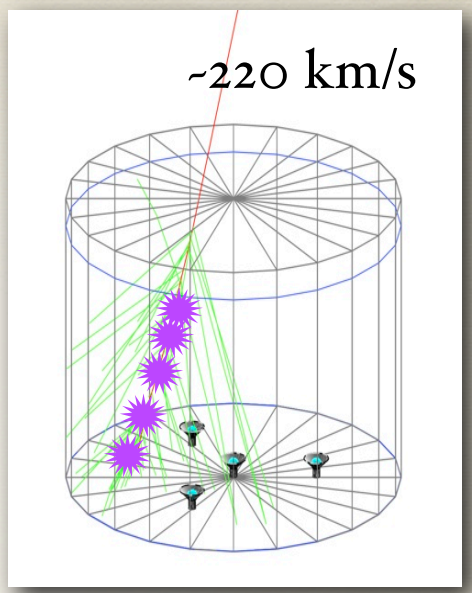
Galactic Center

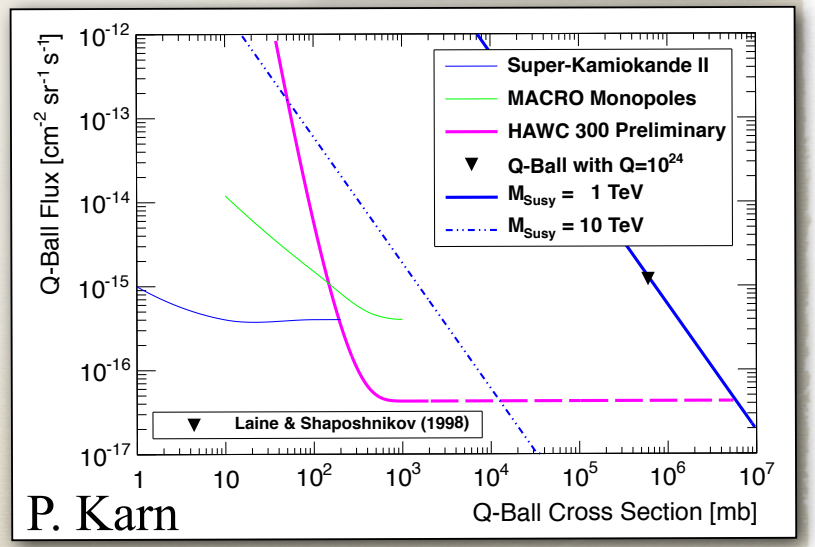
Galactic Center overhead



Q-BALLS

- Created by Affleck-Dine mechanism in early universe
  - condensates of squark fields
  - dark matter candidate
  - large mass (~10^{20} GeV) and cross section (600 mbarn)
  - low flux (<10^{-16}/cm²/sr/s) requires large detection volumes
- HAWC - directional, direct dark matter experiment
  - >>10 GeV deposited in single tank
  - trigger on slow-moving particles



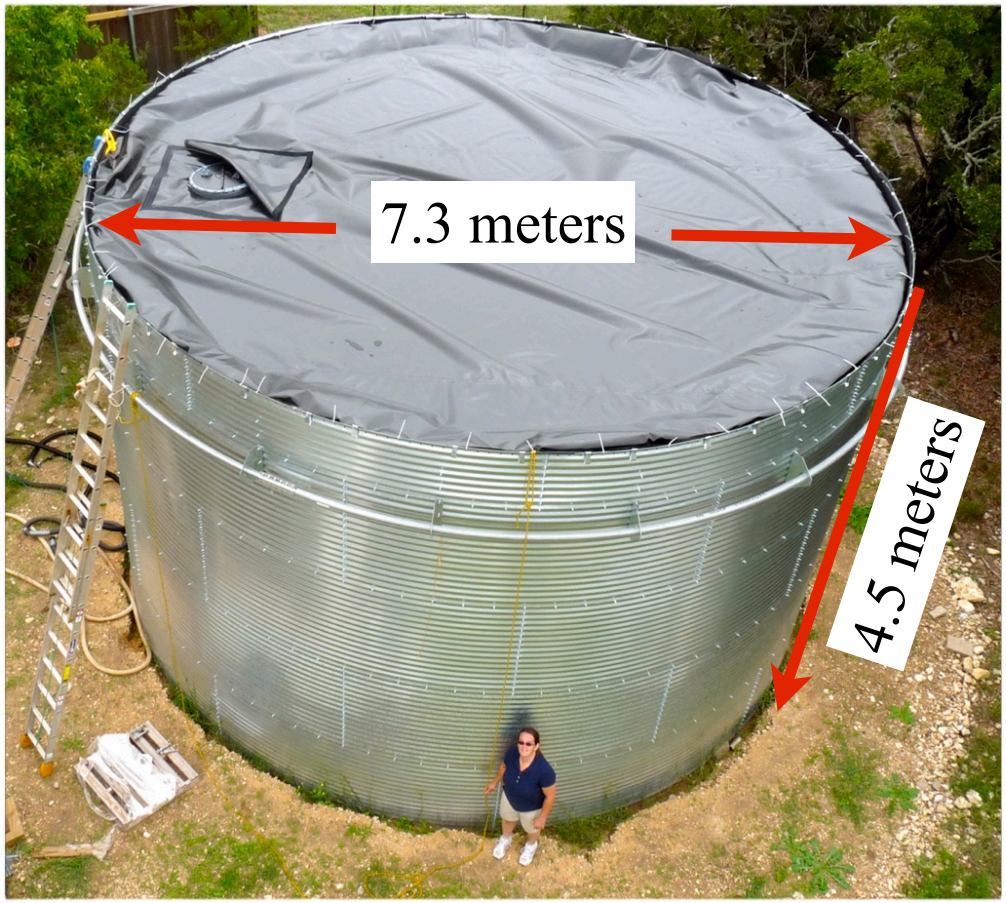


HAWC Construction

- 300 large water tanks
- 4100m asl
- 22,000 m^2 area
- 4 PMTs per tank
- 4m water above PMTs

The HAWC Detector

- 300 Steel Tanks
- 4 PMTs per tank
- No hardware trigger
  - all hits read out
  - software trigger
- Data ~500 MB/sec
- Retain all raw data for 24 hrs (40 TBytes)
- Reconstructed data ~600 TBytes/year



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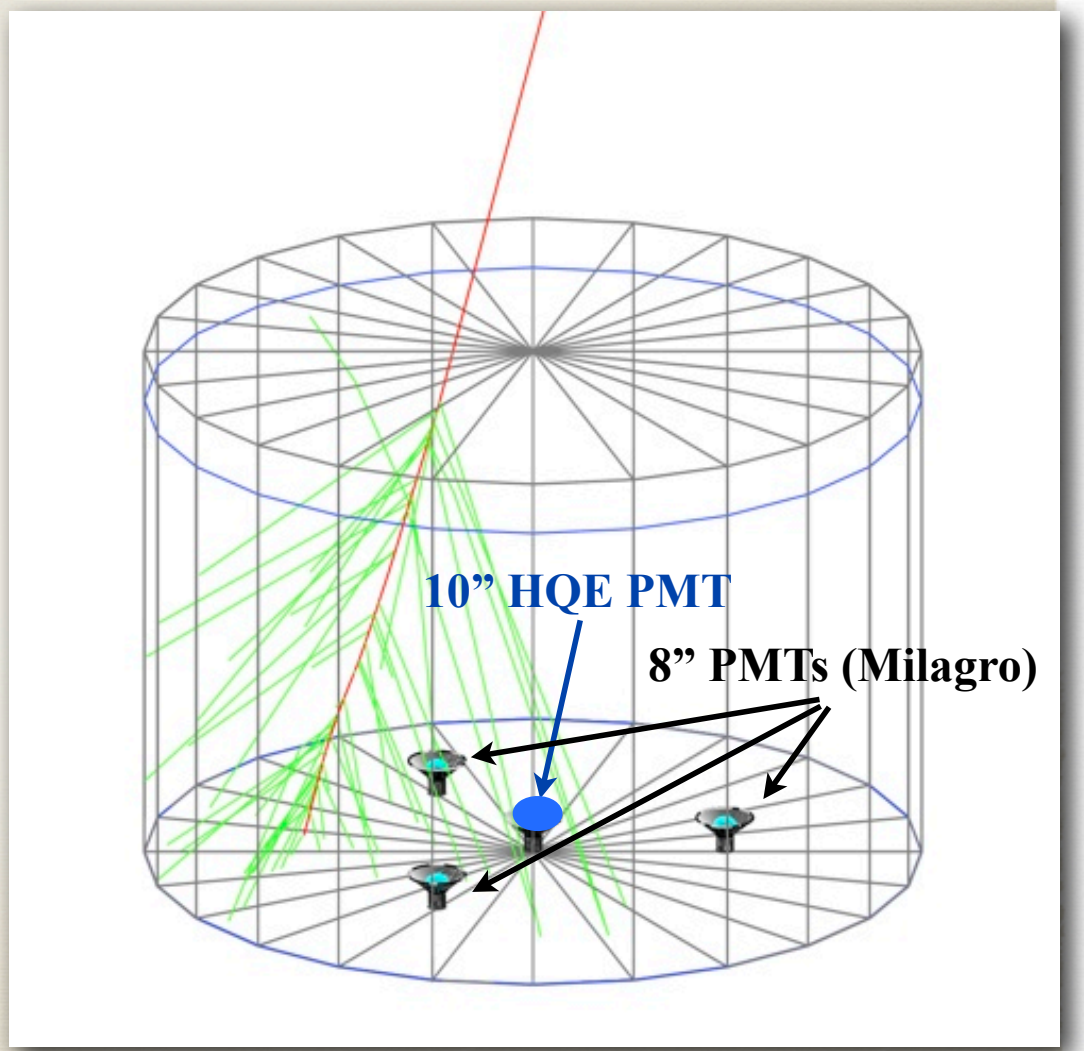


G. Sinnis RICAP 2013


1/23/2011
003
2012
January 2011
Image NASA
Image © 2013 DigitalGlobe
Google ear
Imagery Date: 1/23/2011 18°59'38.82" N 97°18'25.67" W elev 13474 ft eye alt


5/21/2011
May 2011
Image © 2013 DigitalGlobe
Imagery Date: 5/21/2011 19°00'28.63" N 97°18'52.80" W elev 13341 ft eye alt

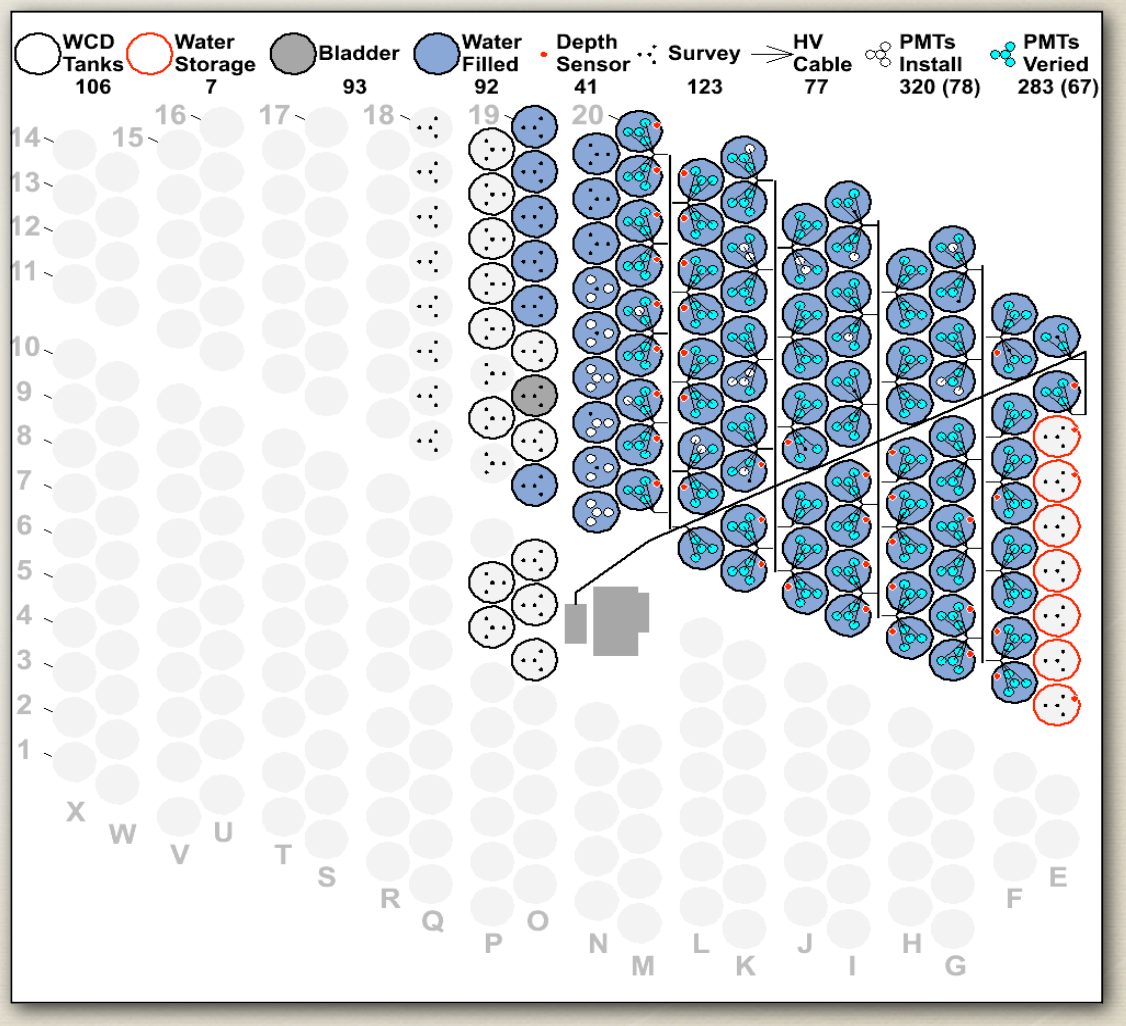

5/15/2013
003
2012
Image © 2013 DigitalGlobe
Google ear
Imagery Date: 10/10/2012 18°59'38.82" N 97°18'25.67" W elev 13474 ft eye alt 15058 f


April 2012

Construction Progress

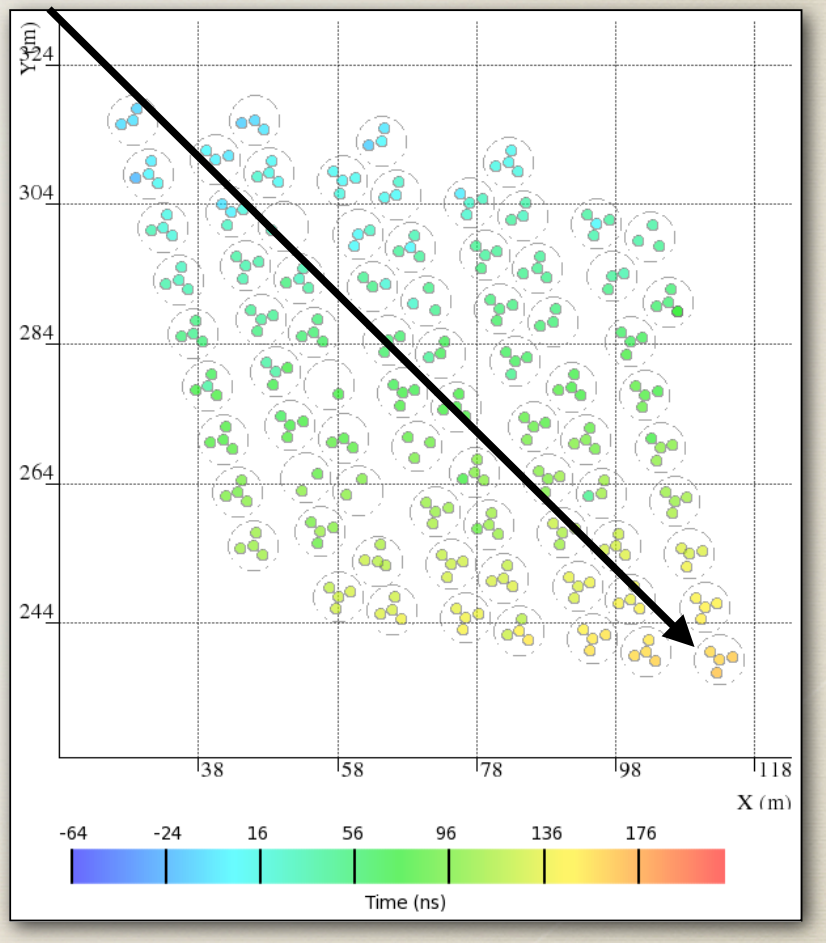
21 May 2013

- 106 tanks complete
- 92 with clean water
- 320 PMTs installed
  - 78 tanks
- 283 PMTs verified
  - 67 tanks



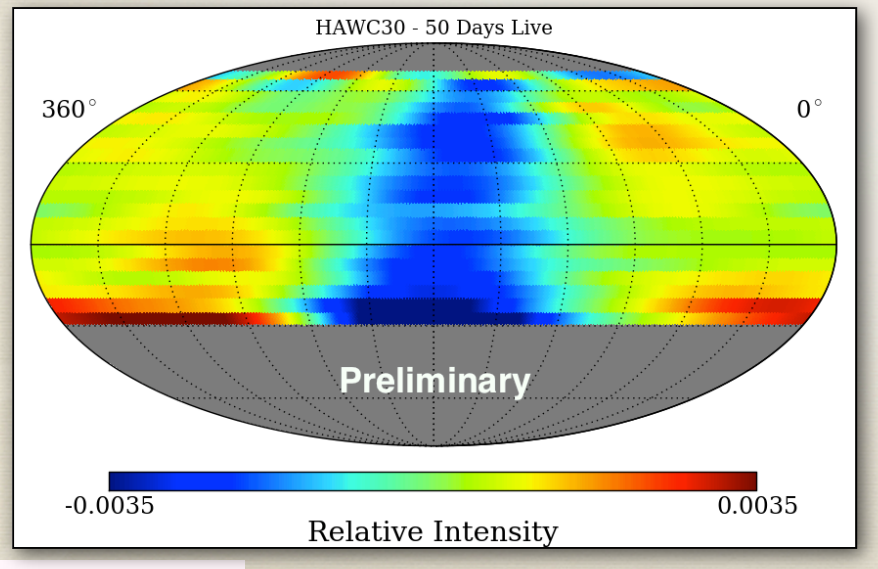
HAWC Event (77 tanks)

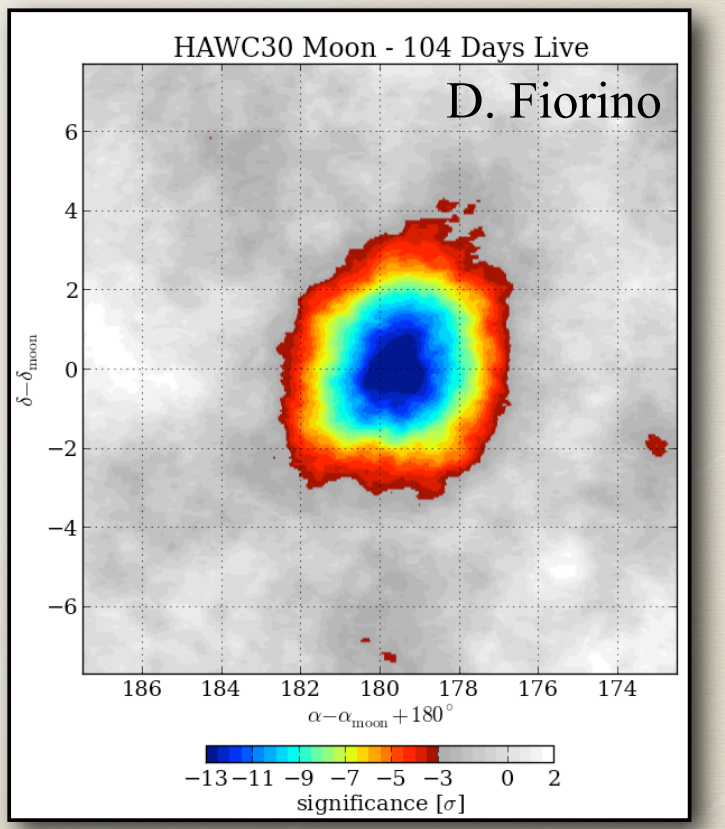
- Event from May 20, 2013
- 77 tanks hit
- 283 PMTs hit
- Color is timing
- Blue early & red late



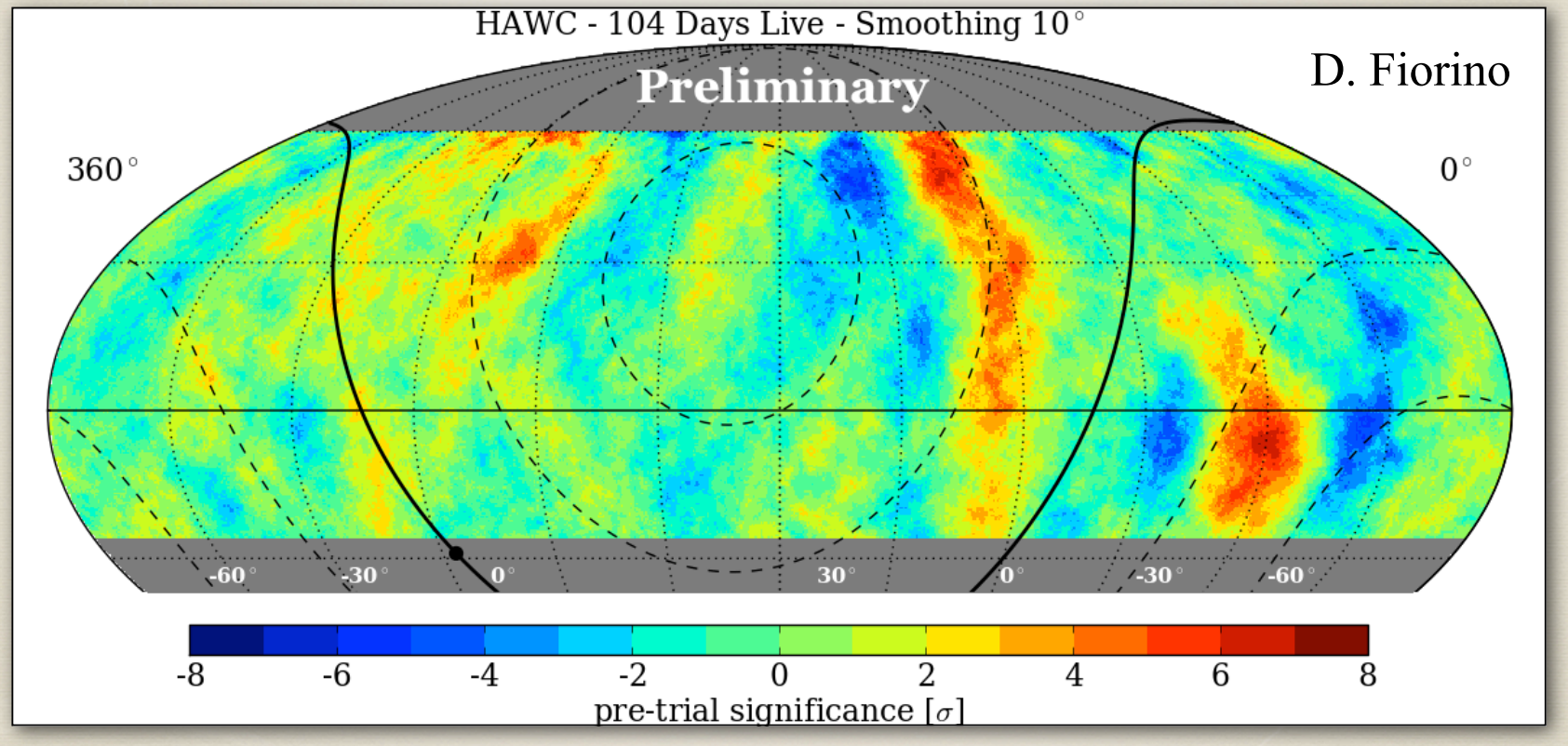
HAWC-30 RESULTS

- Moon Shadow detected at high significance
  - Verification of instrument
- Detection of cosmic-ray anisotropy
  - Large scale
  - Small/intermediate scale



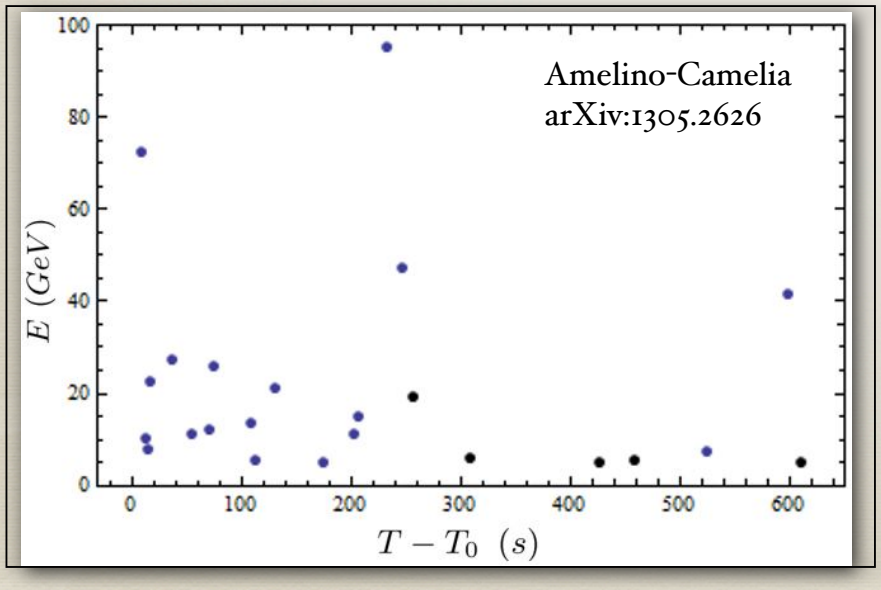


Cosmic-Ray Anisotropy

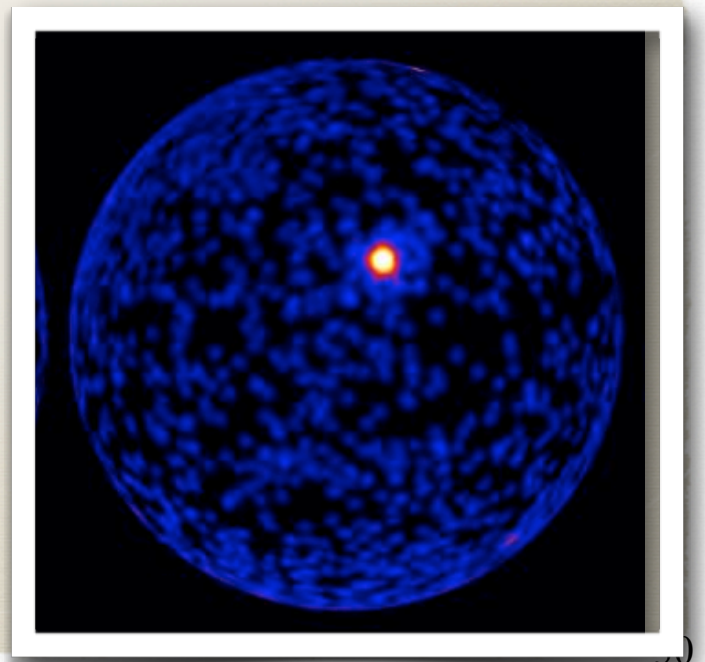


GRB130427A

- One of the brightest GRBs detected (2×10^{-3} ergs/cm^2)
- Highest energy photon detected (95 GeV) in GRB
- Redshift 0.34
- RAPTOR found 7.4 magnitude optical counterpart 50 sec before SWIFT trigger
- Would be detectable by HAWC

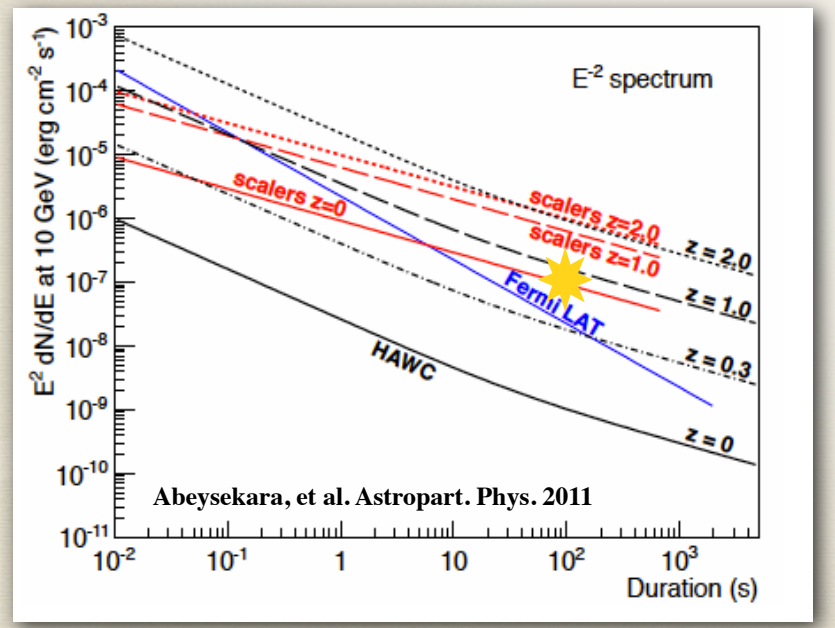


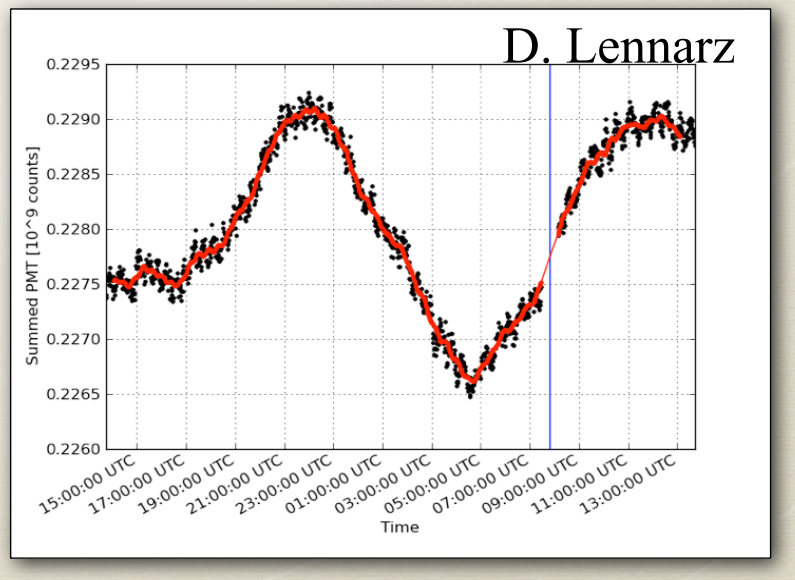
Fermi LAT



GRB130427A

- HAWC main data acquisition system not running
- Large zenith angle (57º) - high threshold, low sensitivity (1/100 of that at zenith)
- Scaler daq was running (recorded singles rates in all PMTs)
- Searched 6 time windows - no evidence of a signal





Summary

- Milagro demonstrated capability of water Cherenkov technique for Gamma-Ray astronomy
- HAWC will survey the sky with ~50 mCrab sensitivity over 8sr of sky at ~1 TeV
- Good sensitivity to transient phenomena
- HAWC construction on schedule
  - HAWC-30 complete 9/2012
  - HAWC-100 complete 8/2013
- HAWC-30 data looks excellent.
  - Sensitivity comparable to Milagro
- Full HAWC Observatory Complete in Summer/Fall 2014