Early Results from the HAWC Observatory

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The HAWC Observatory

- 300 large water tanks
- 4100m asl
- 22,000 m^2 area
- 4 PMTs per tank
- 4m water above PMTs
- 15 x more sensitive than Milagro

The HAWC Collaboration

University of Maryland
Los Alamos National Laboratory
University of Wisconsin
University of Utah
Univ. of California, Irvine
Michigan State University
George Mason University
University of New Hampshire
Pennsylvania State University
University of New Mexico
Michigan Technological University
NASA/Goddard Space Flight Center
Georgia Institute of Technology
University of Alabama
The Ohio State University
Colorado State University
University of California Santa Cruz

Instituto Nacional de Astrofísica Óptica y Electrónica (INAOE)
Universidad Nacional Autónoma de México (UNAM)
- Instituto de Física
- Instituto de Astronomía
- Instituto de Geofisica
- Instituto de Ciencias Nucleares

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

~120 Members

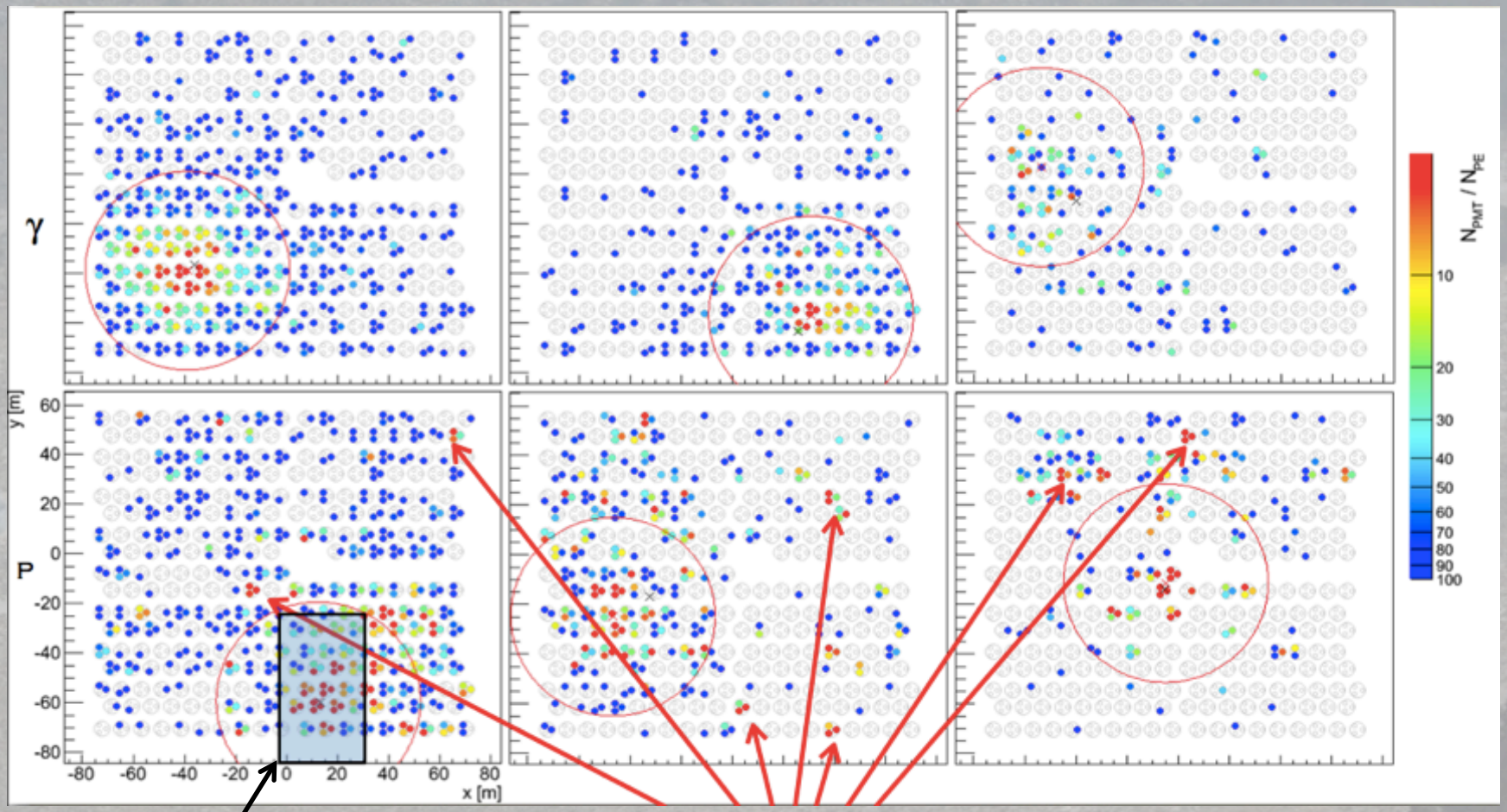
USA

Mexico

How can HAWC be so much sensitive than Milagro with the same number of PMTs?

- Three main reasons:
  1. Hadron rejection area and shower sampling
     - 10x Larger muon detection area (~22,000m^2)
     - 4x Larger dense sampling region (~22,000m^2)
  2. Altitude
     - >5x # of detectable shower particles relative to Milagro
  3. Improved Angular & Energy Resolution
     - Optical isolation of detector elements

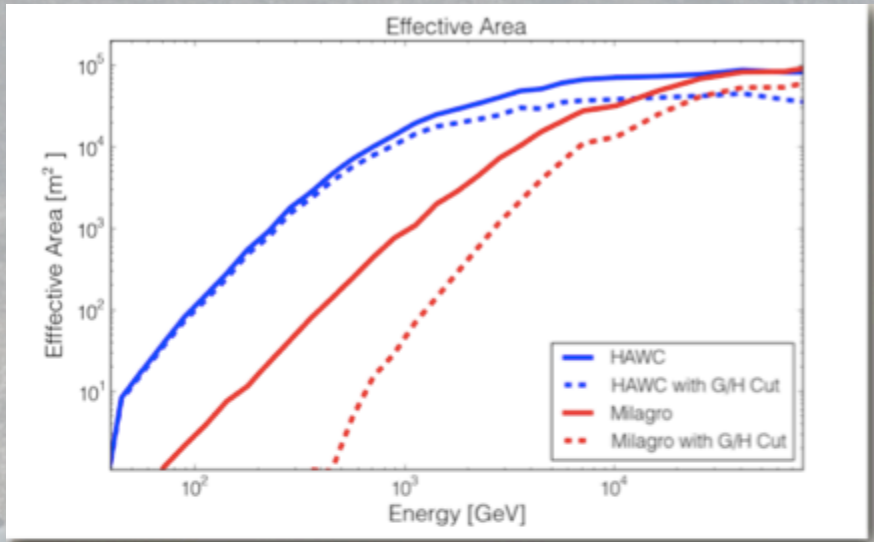
Background Rejection with HAWC

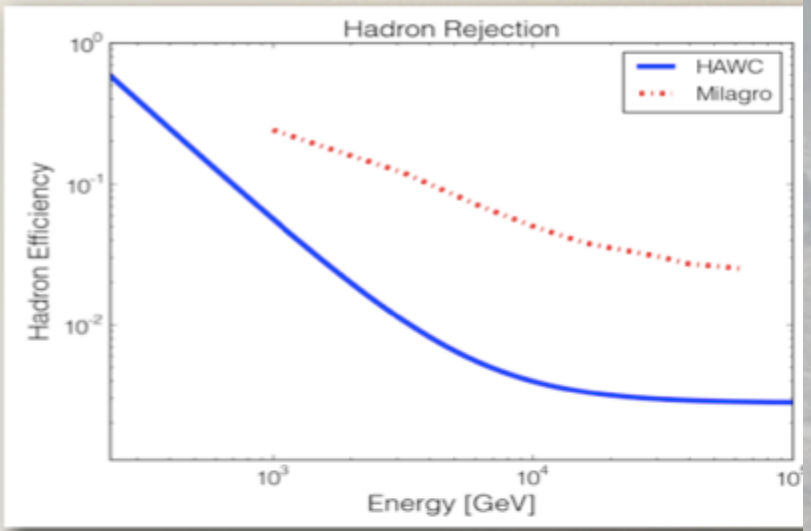


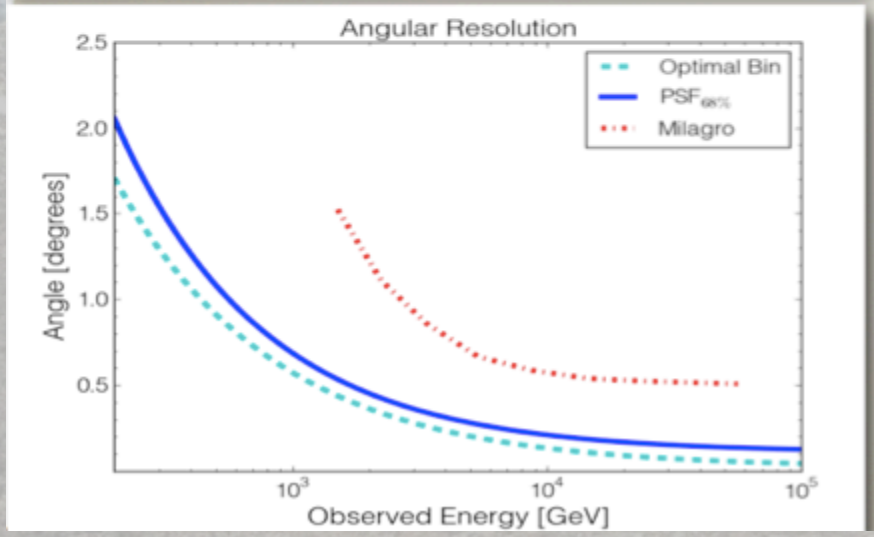
Milagro bottom layer size

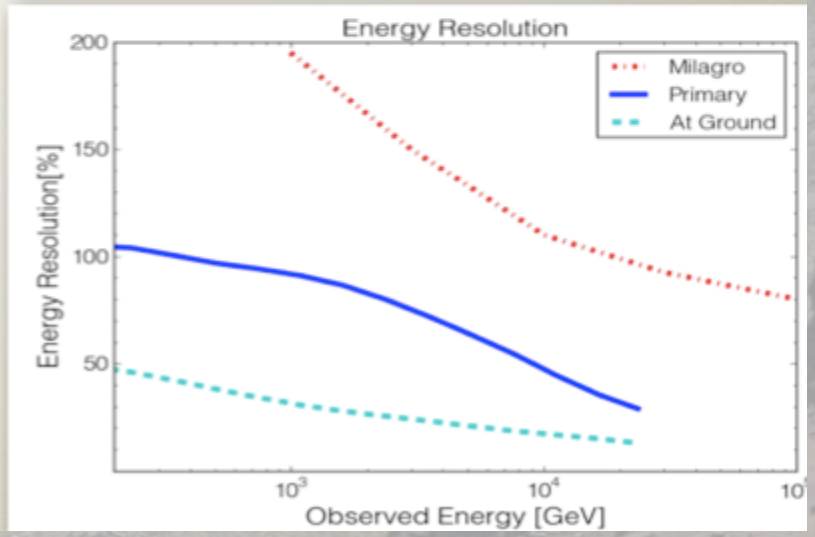
Algorithm looks for high-amplitude hits more than 40 m from the reconstructed core location

Performance of HAWC

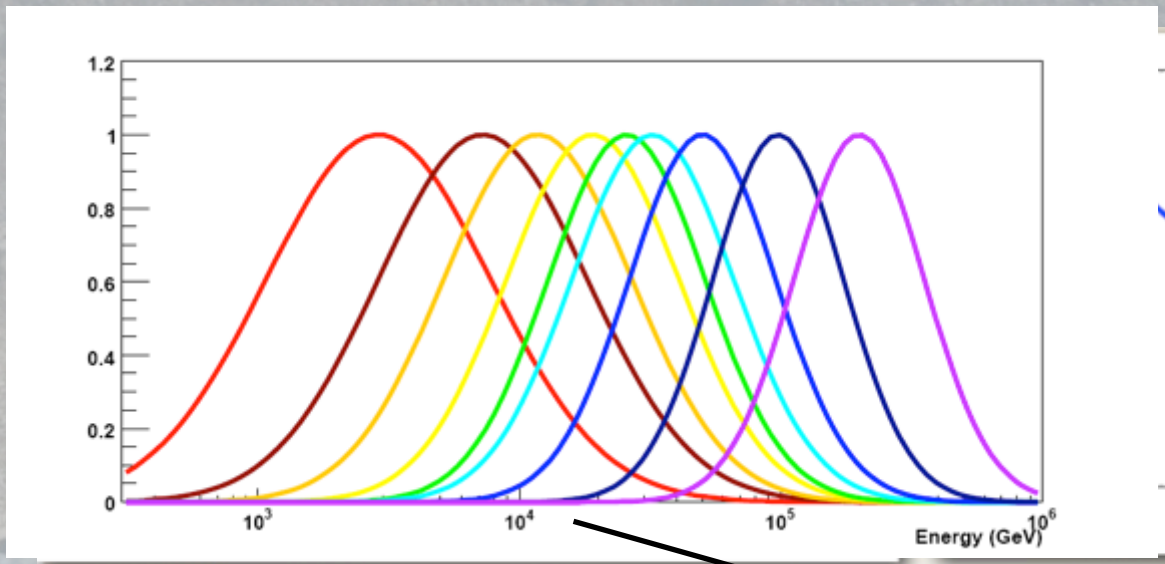


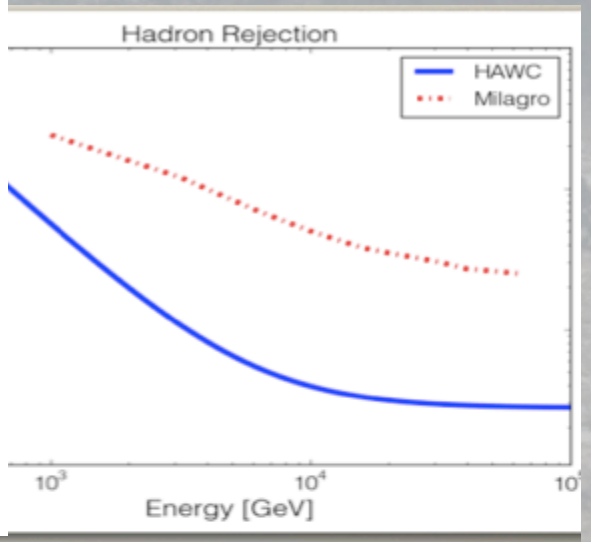


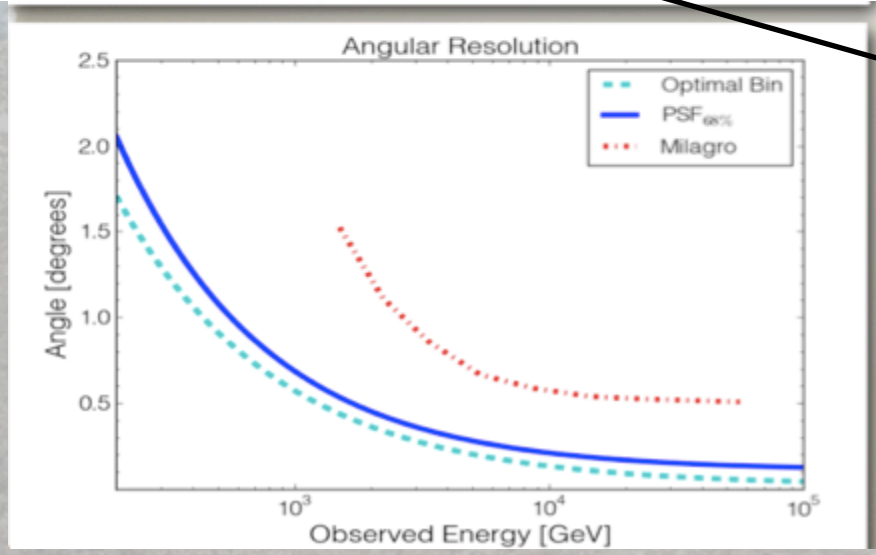


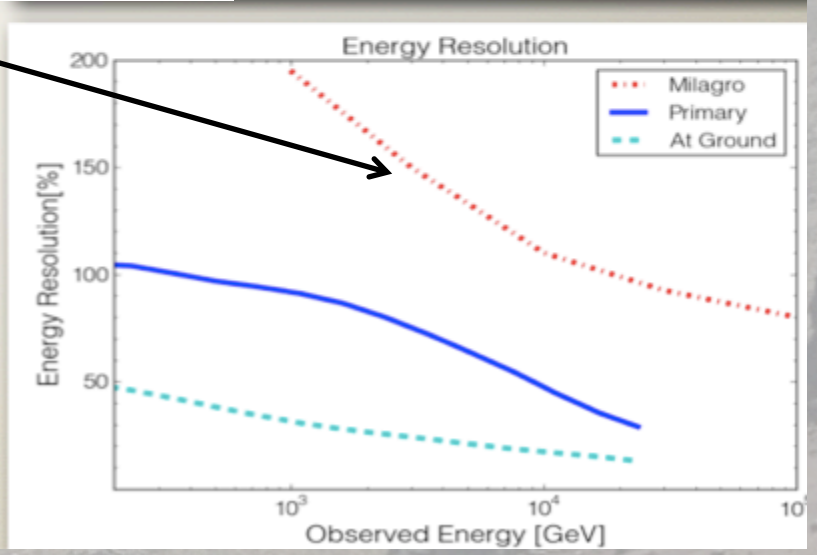


Performance of HAWC

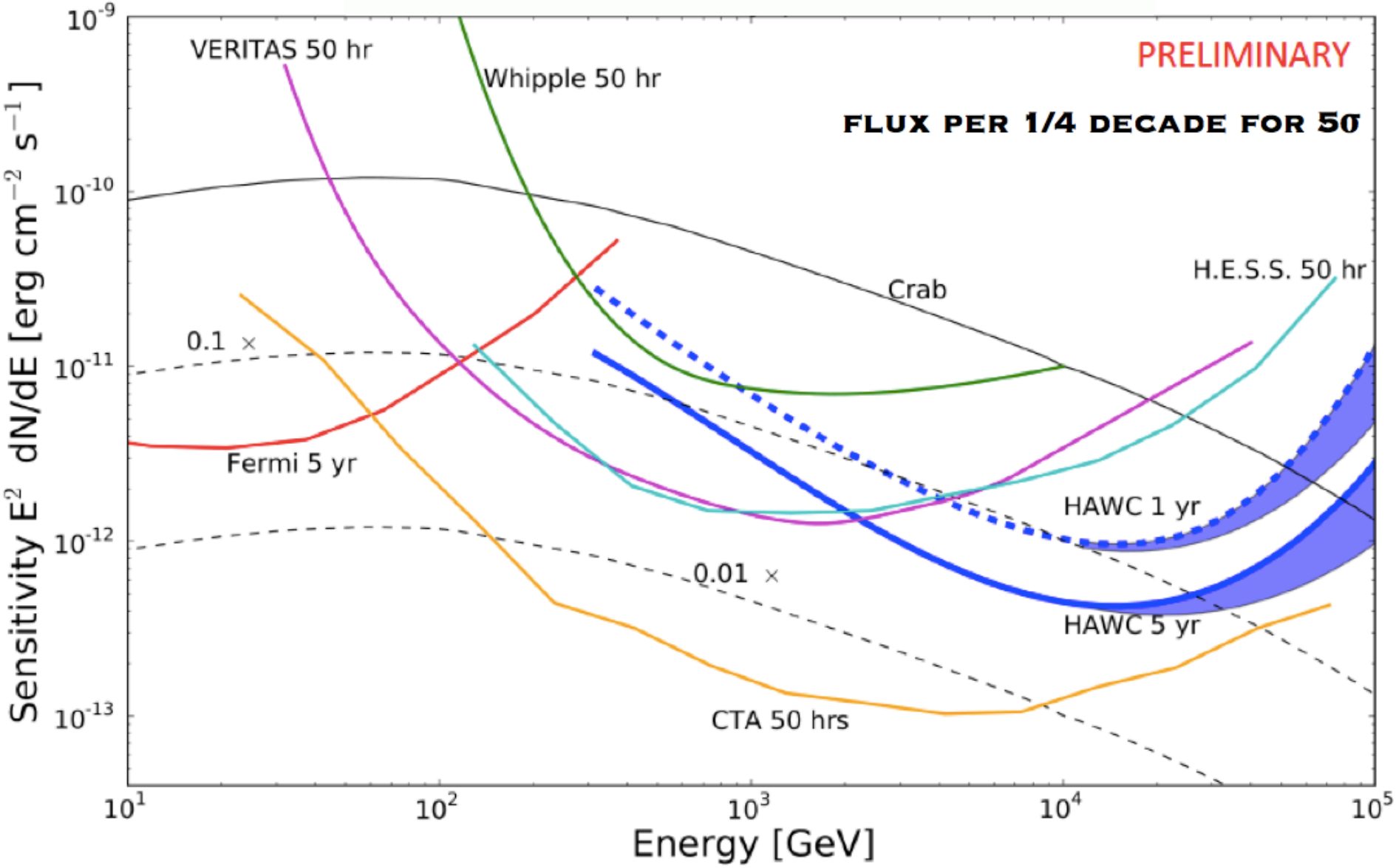






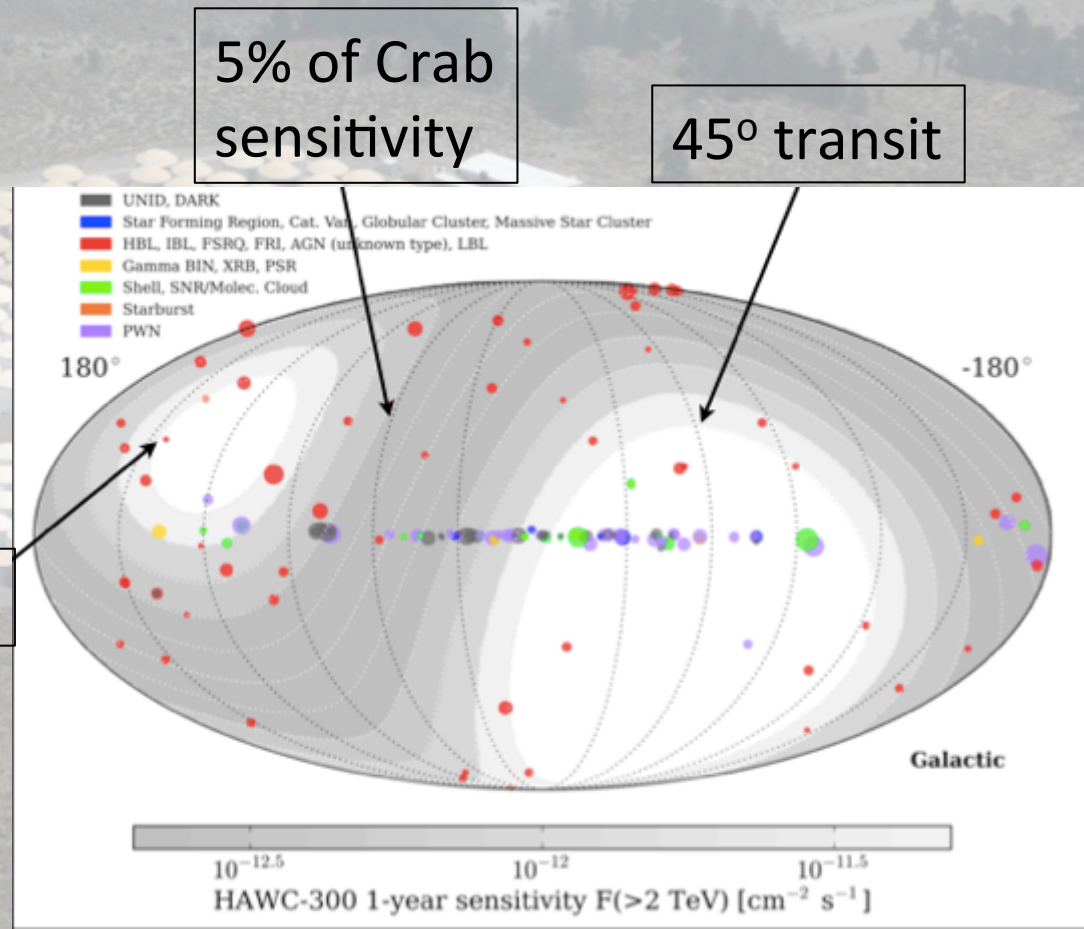


HAWC Sensitivity Compared



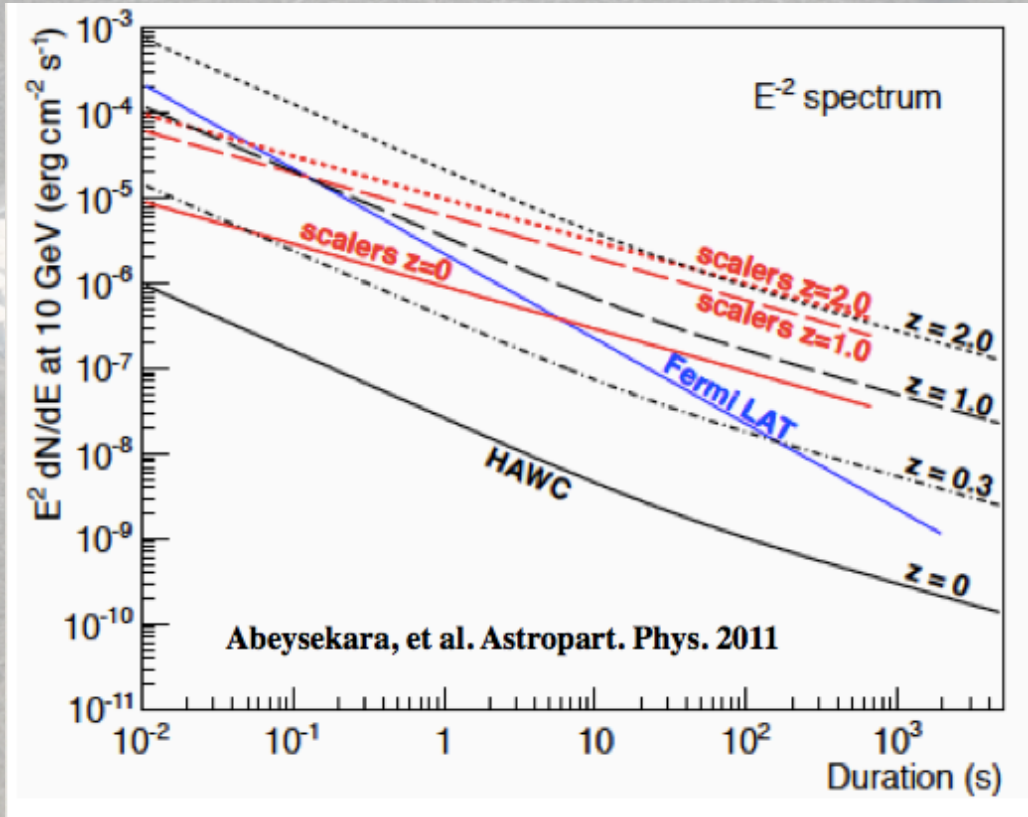
HAWC Sky Coverage

- Same sky viewed by IceCube
- Simultaneous sky with VERITAS
- Crab Nebula overhead, (so is Geminga)
- Galactic center visible (~45° transit)



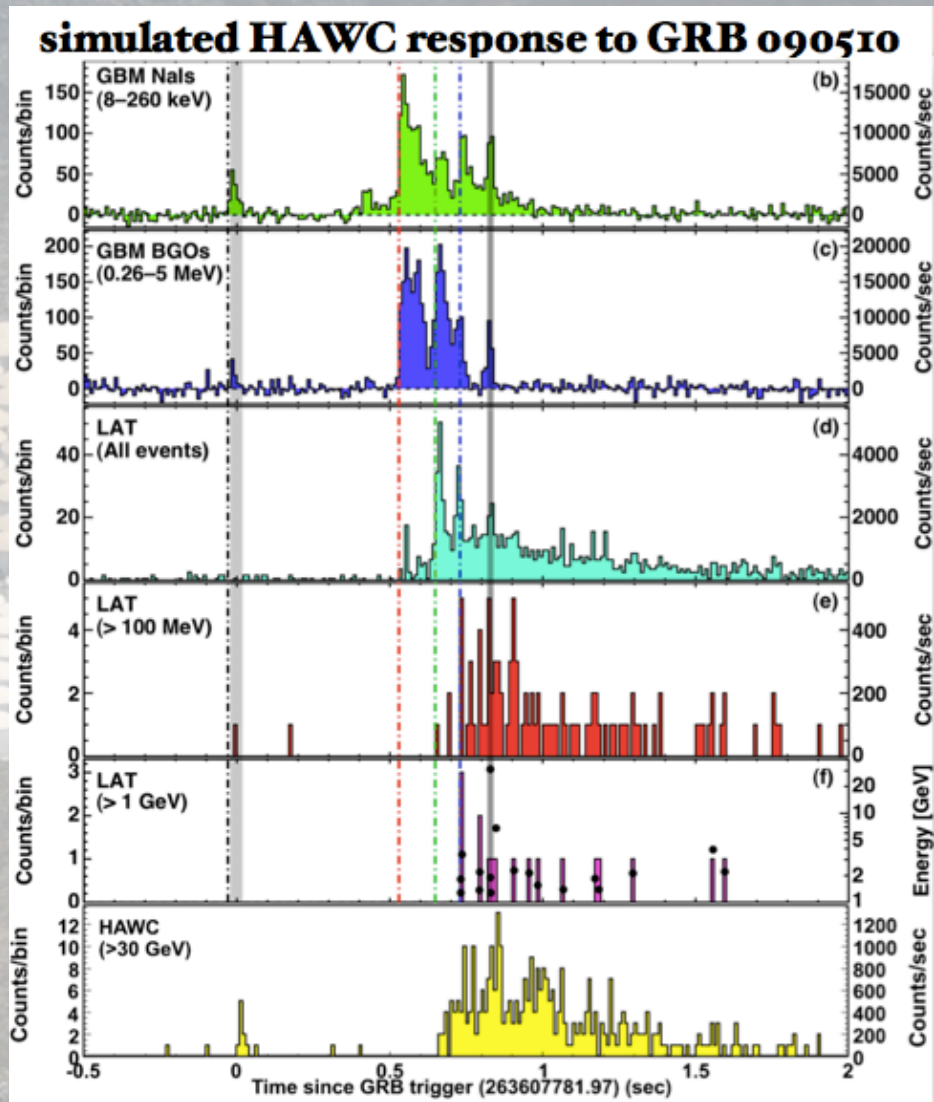
Transient Sensitivity

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



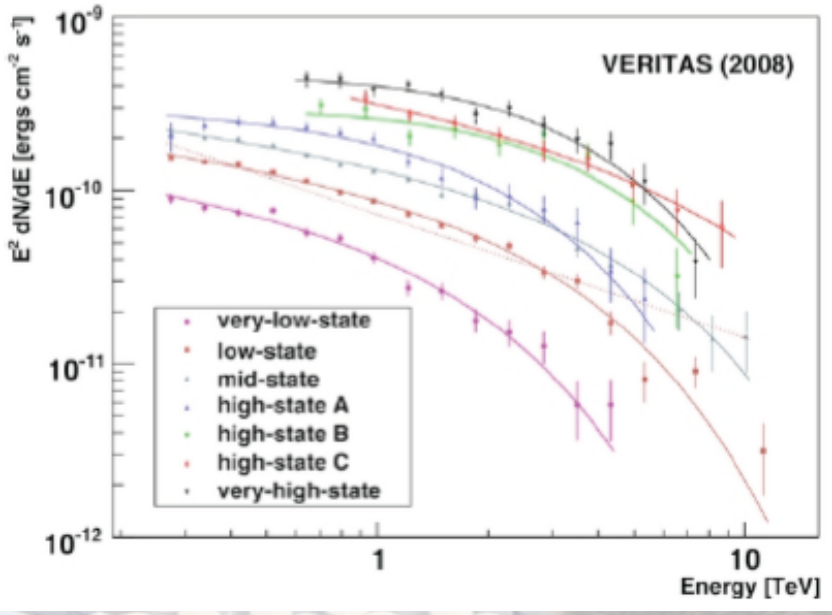
GRB Sensitivity

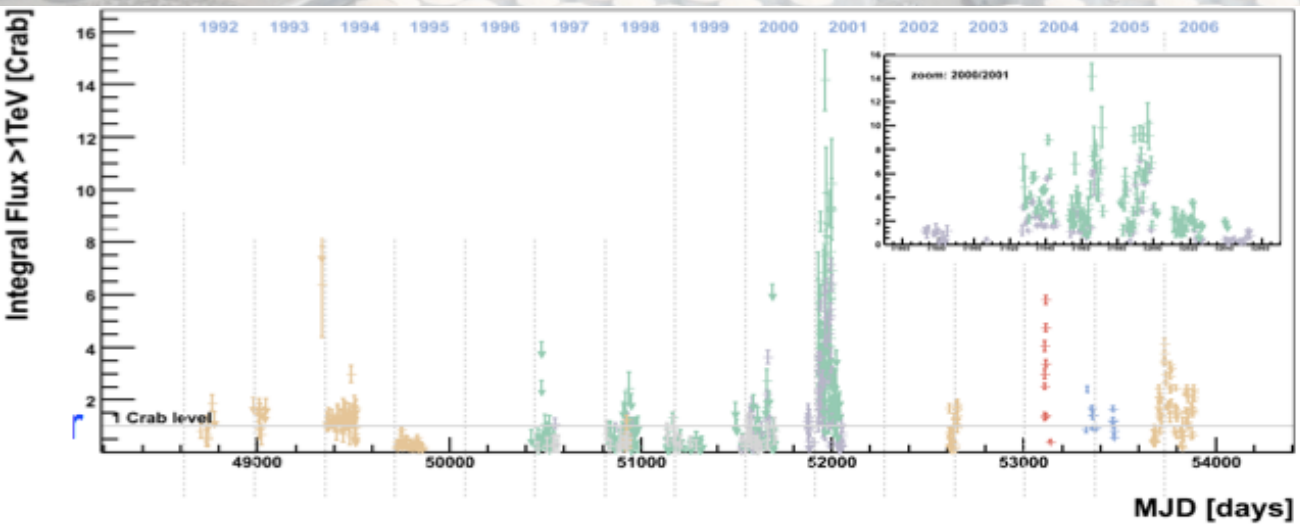
- Fermi observation of GRB 090510 (z = 0.9) in GBM and LAT
- Simulated HAWC light curve assuming extension of spectrum with LAT index
  - EBL absorption included
  - Cosmic ray background included
- ~200 events expected above 30 GeV
- Detection (5σ) by HAWC if emission extended to 50 GeV
- With simultaneous Fermi detection will constrain E_{max}



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

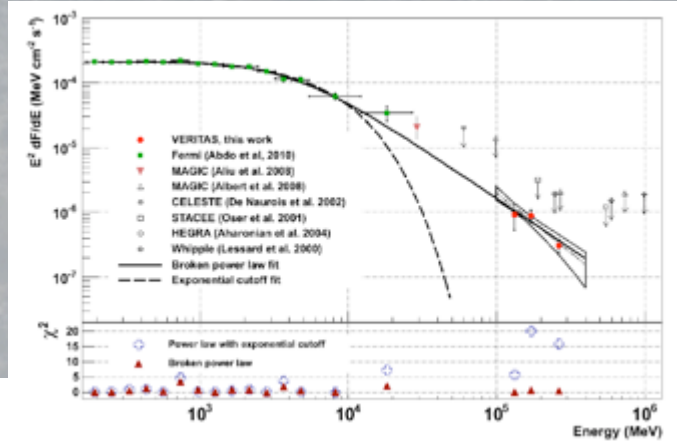


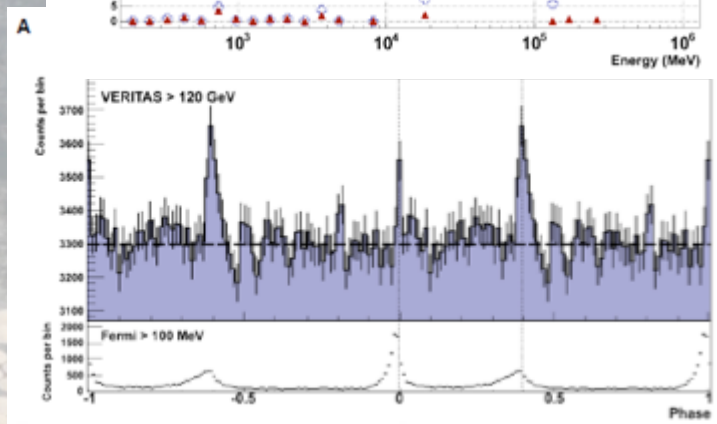


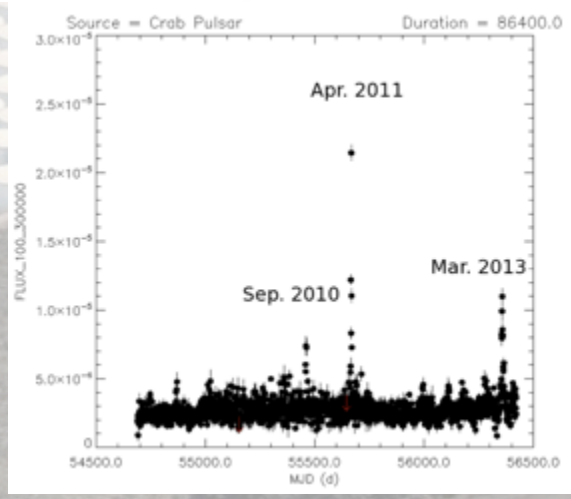
G. Sinnis

Crab

- Spectral at highest energies with unprecedented sensitivity
- Time variable behavior: Pulsing and Flaring
  - Pulsing:
    - Measurements can be used to constrain LIV
    - Upper limits on LIV could be improved by detection > TeV
  - Flaring:
    - At MeV to GeV energies the emission is believed to be produced by synchrotron radiation from a population of freshly accelerated PeV electrons.
    - At TeV to PeV energies: though previous flares not seen by MAGIC/VERITAS, a detection of accompanying IC at TeV by HAWC (intensity and spectrum) could constrain properties of the emission region.

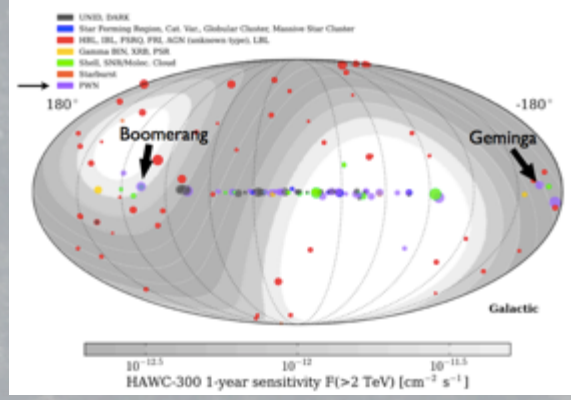


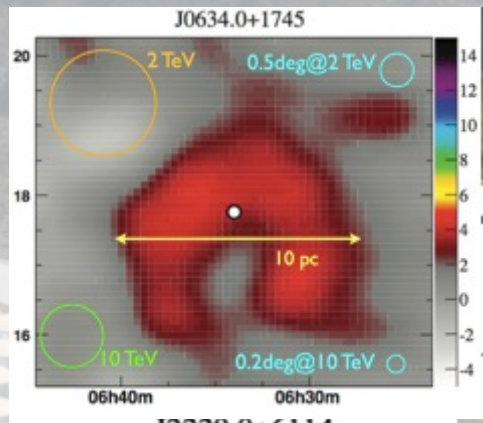


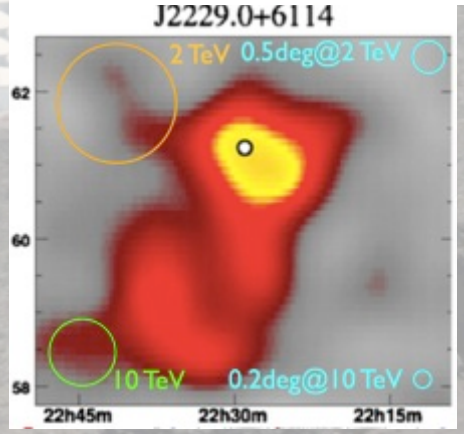


Pulsars/PWNe

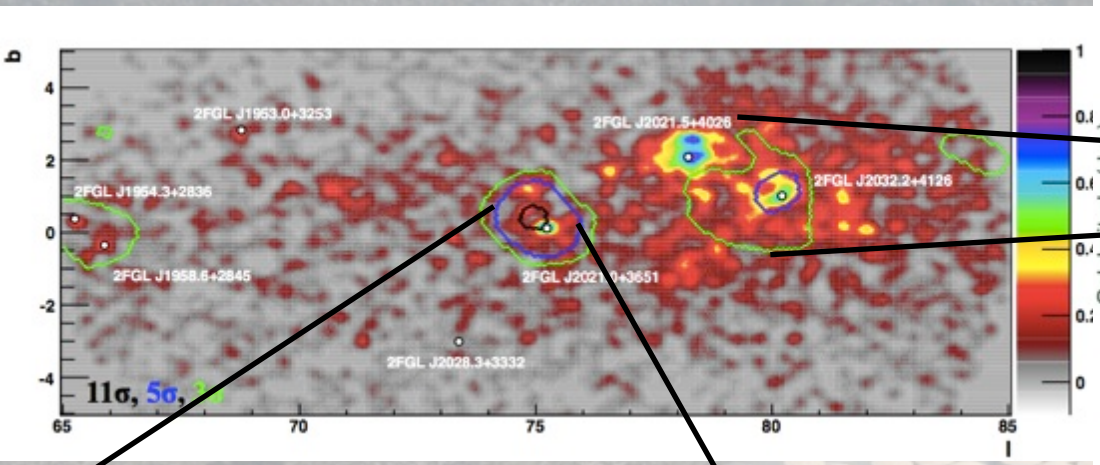
- On the right: Geminga, Boomerang
- Milagro is the only TeV instrument that has measured significant emission from the Geminga region
- Geminga and other nearby pulsars are candidates for the explanation of the recently measured positron excess
- Spectral measurements at TeV energies will help constrain acceleration processes and parameters such as the B field in these sources
- Time variability:
  - a wide-field, high duty cycle telescope like HAWC is ideally suited for a sensitive exploratory study of the VHE emission from multiple pulsars (not only the crab, see previous slide)

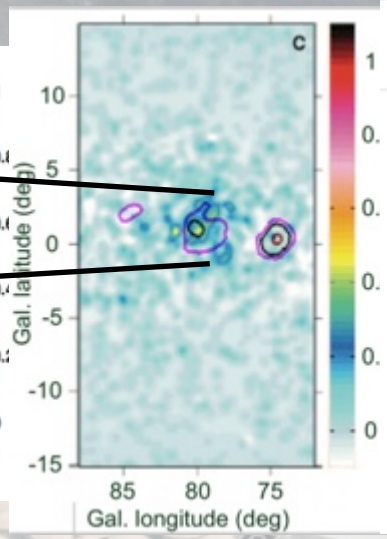


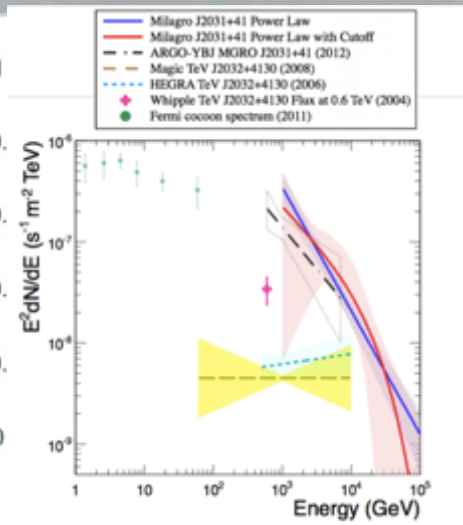


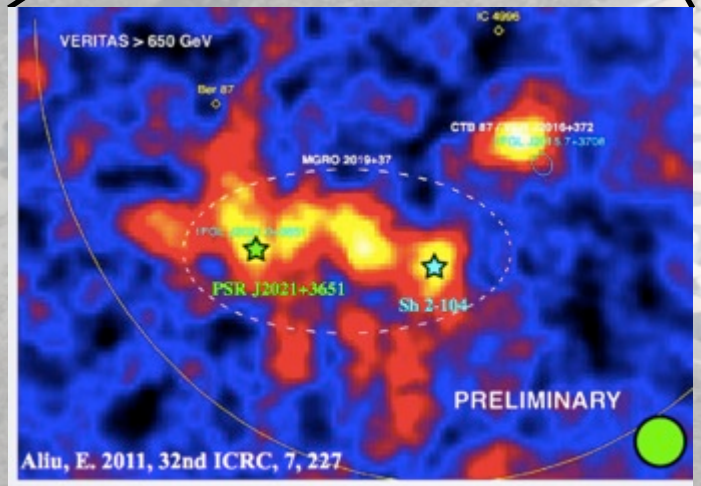


Cygnus









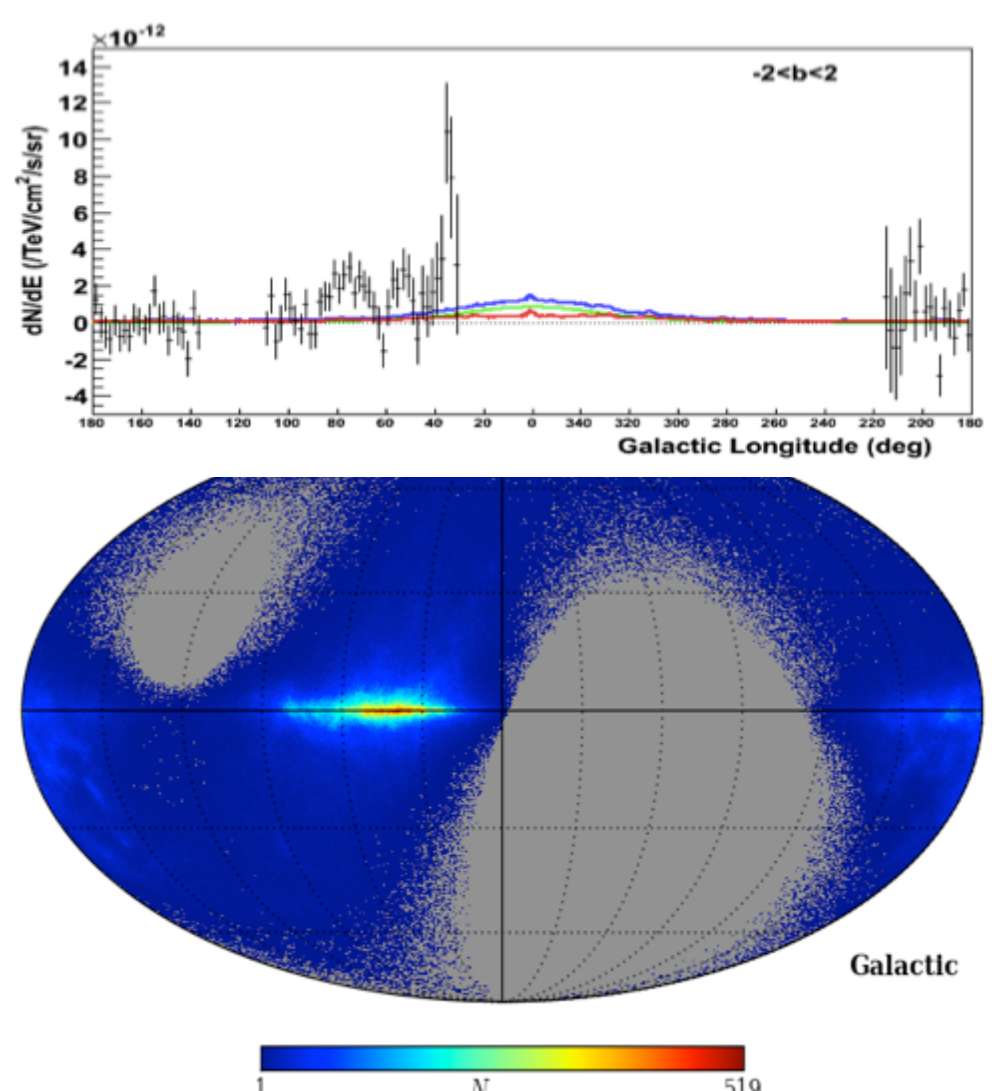
Aliu, E. 2011, 32nd ICRC, 7, 227

HAWC angular resolution at 10 TeV ($PSF_{68\%}$=0.16°)

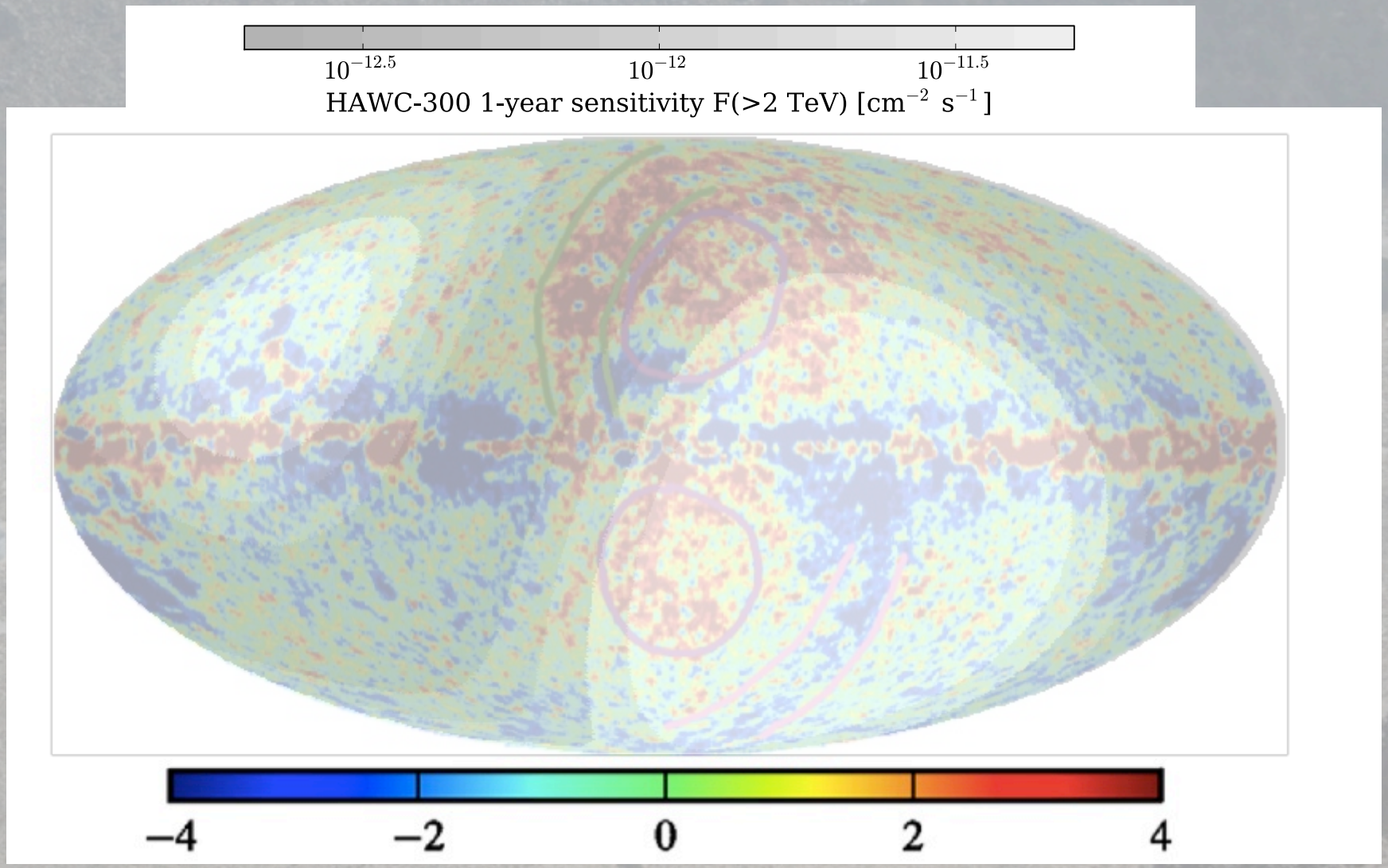
- ~ 1 week of HAWC data will reproduce Milagro map
- MGRO J2019+37: VERITAS detected correlated emission (75 hrs observation), probably a complex of several sources
- MGRO J2031+41:
  - Collocated extended emission detected by IACTs, Milagro, and ARGO
  - Spectrum appears to line up with the Fermi cocoon cosmic ray acceleration model can explain the diffuse emission in the cocoon

Diffuse Emission

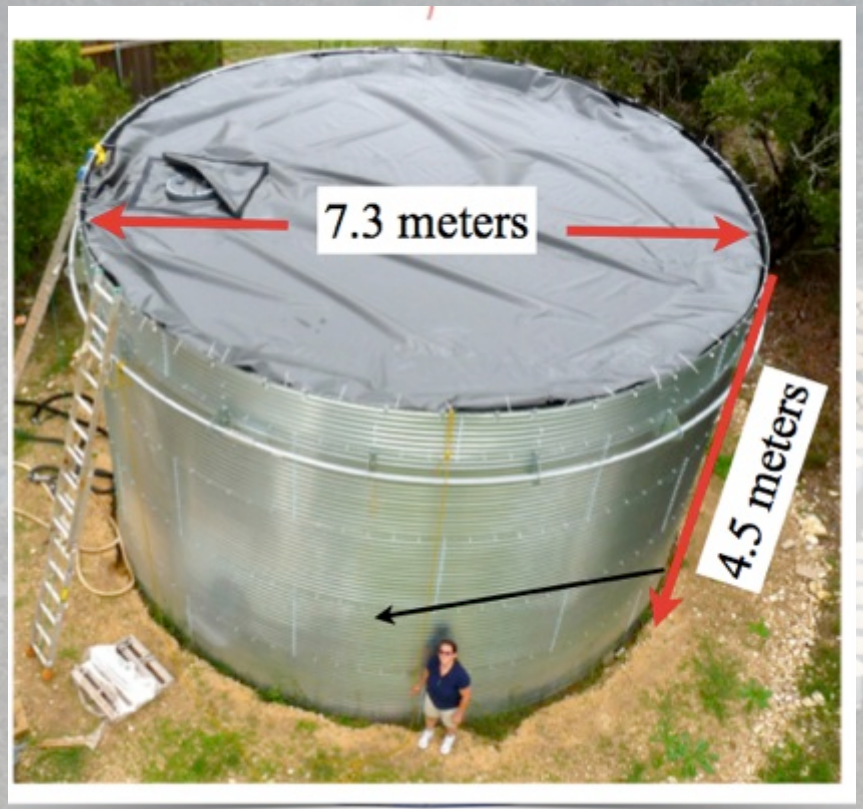
- Milagro measured diffuse excesses in the Cygnus region (-2 deg<b<2 deg, 65 deg<l<85 deg) and the inner galaxy (-2 deg<b<2 deg, 30 deg<l<65 deg) that are 8 and 5 x larger than predicted by the cosmic ray propagation model GALPROP assuming the locally measured cosmic ray spectrum
- With one year of HAWC we will be able to tell if this excess is caused by unresolved sources
- spectral and morphological analysis of the emission (needed for studying the origin of the galactic diffuse emission)



Diffuse Emission – Fermi Bubbles



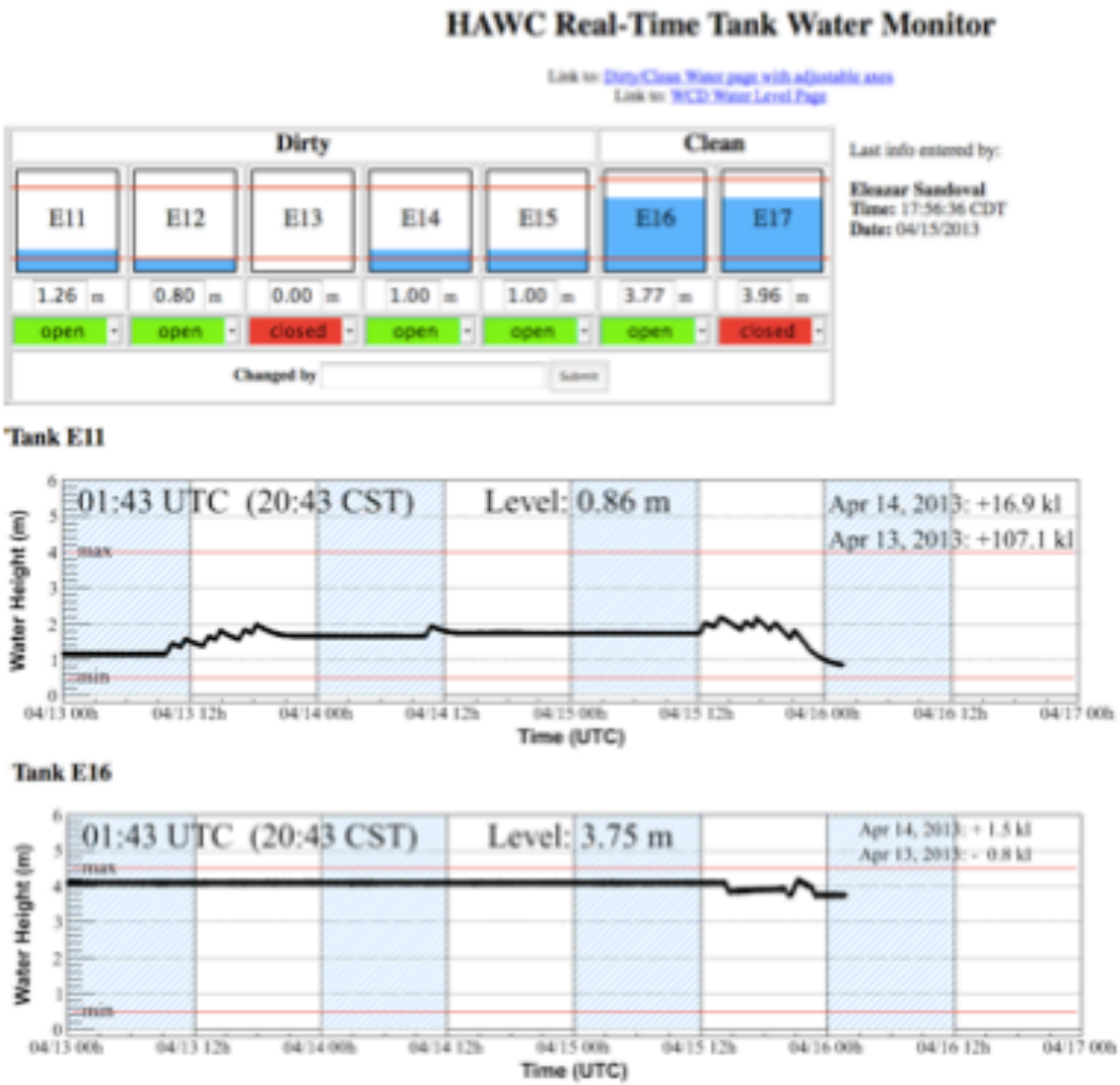
The HAWC Detector



- 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

HAWC Water System

- Water trucked to site:
  - Spring on mountain
  - Well in nearby town
- Incoming "Dirty" water is purified:
  - Micron filtration
  - UV sterilization
- Attenuation length >30 m
- 200 kL of water per tank
- ~5 hours to fill a tank

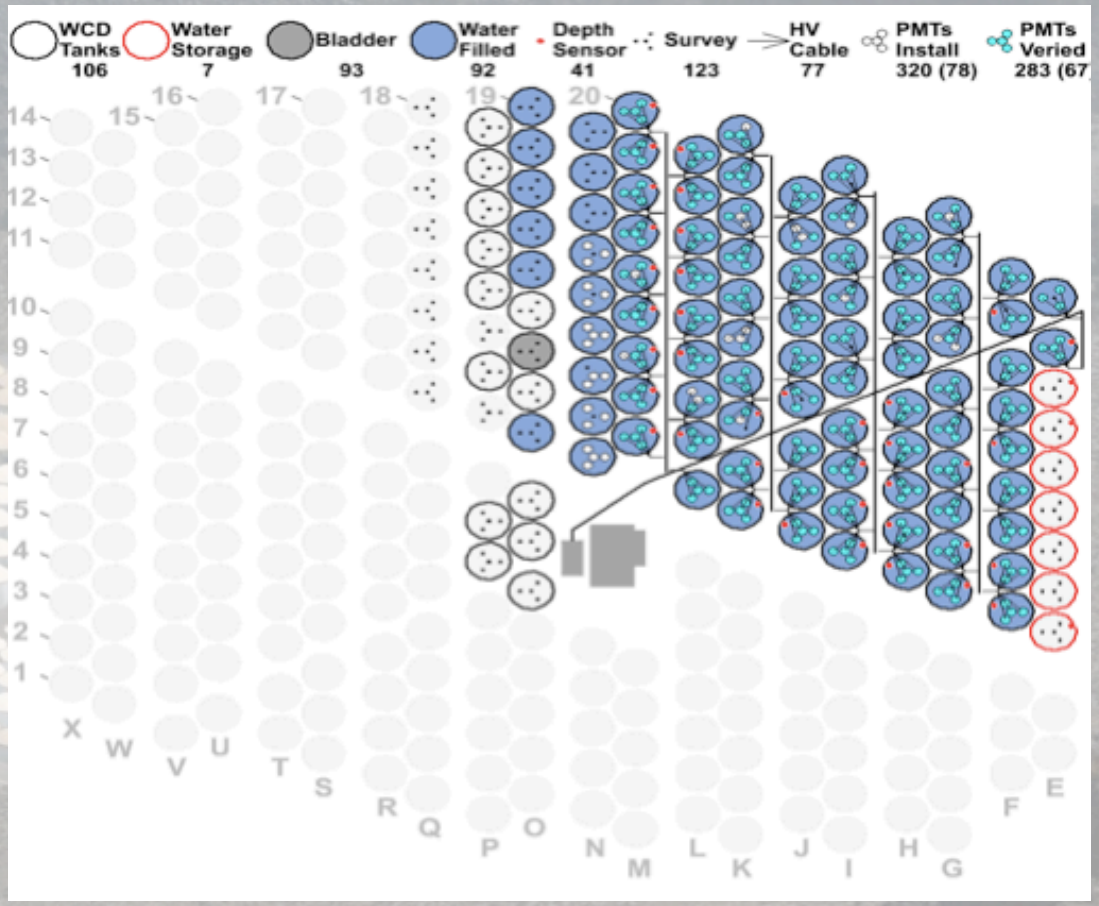


J. Goodman

Construction Progress

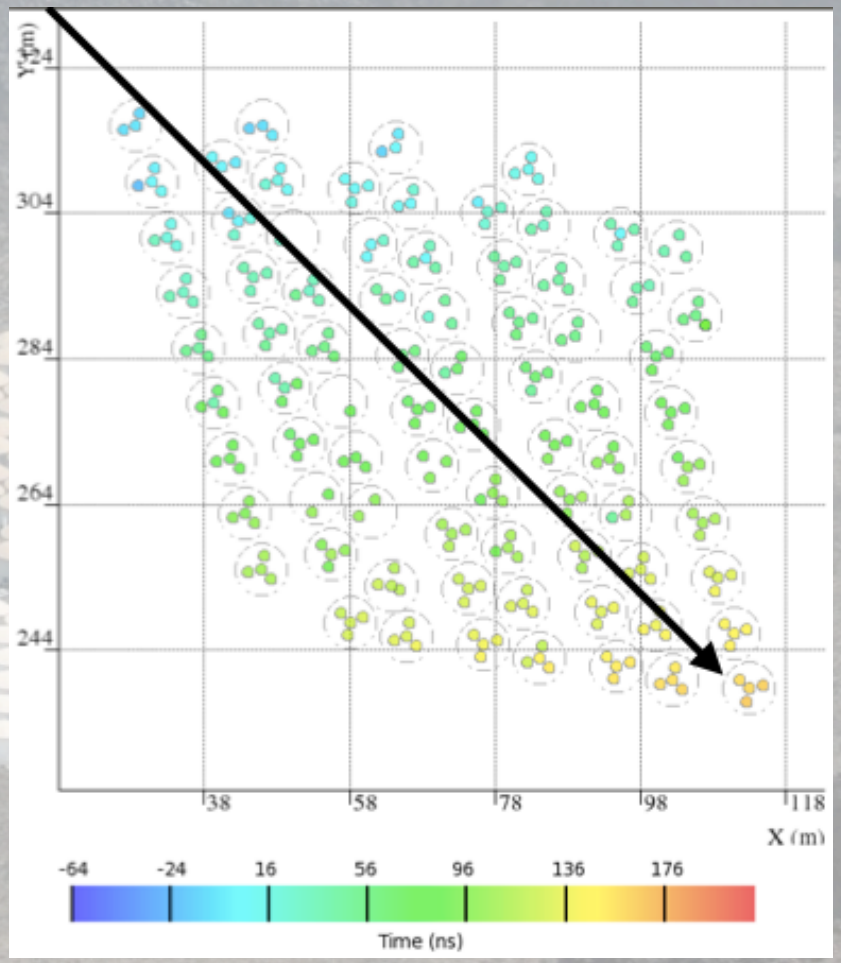
May 21, 2013

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



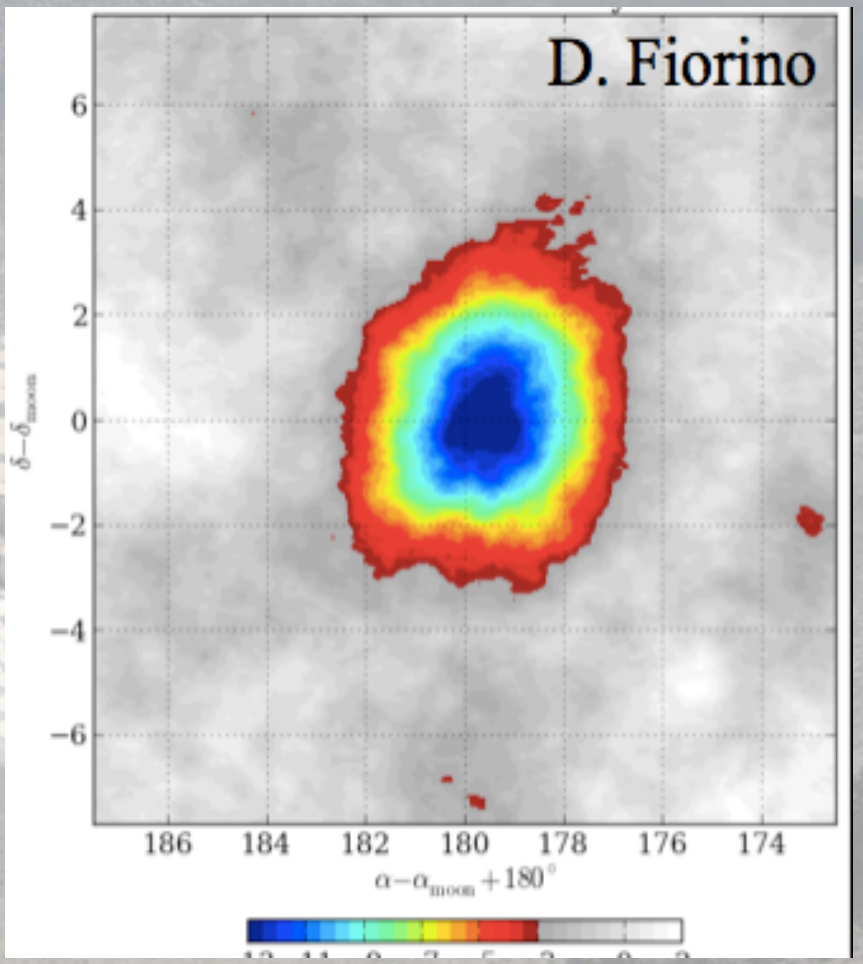
HAWC Event (77 Tanks)

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

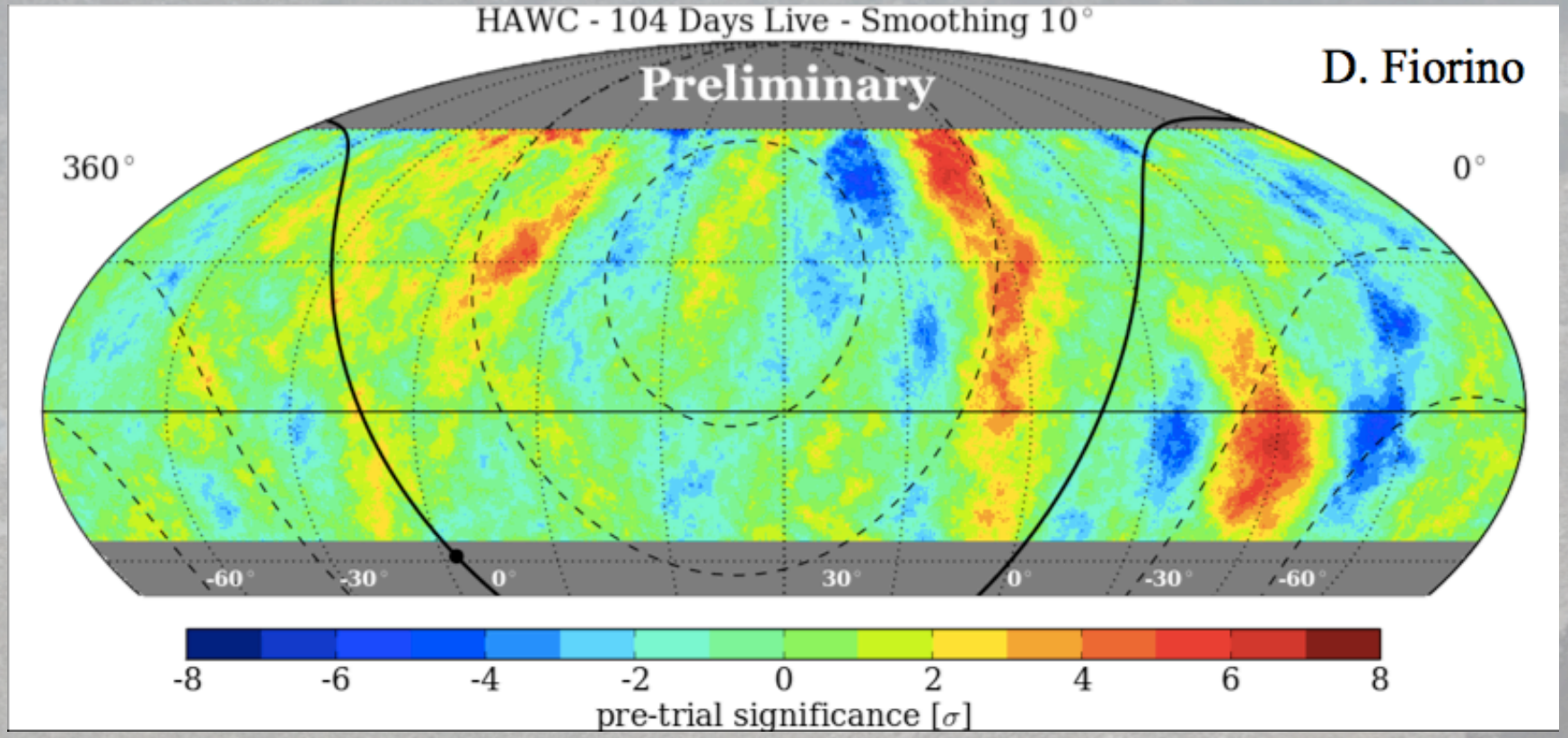


HAWC 30 Results

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

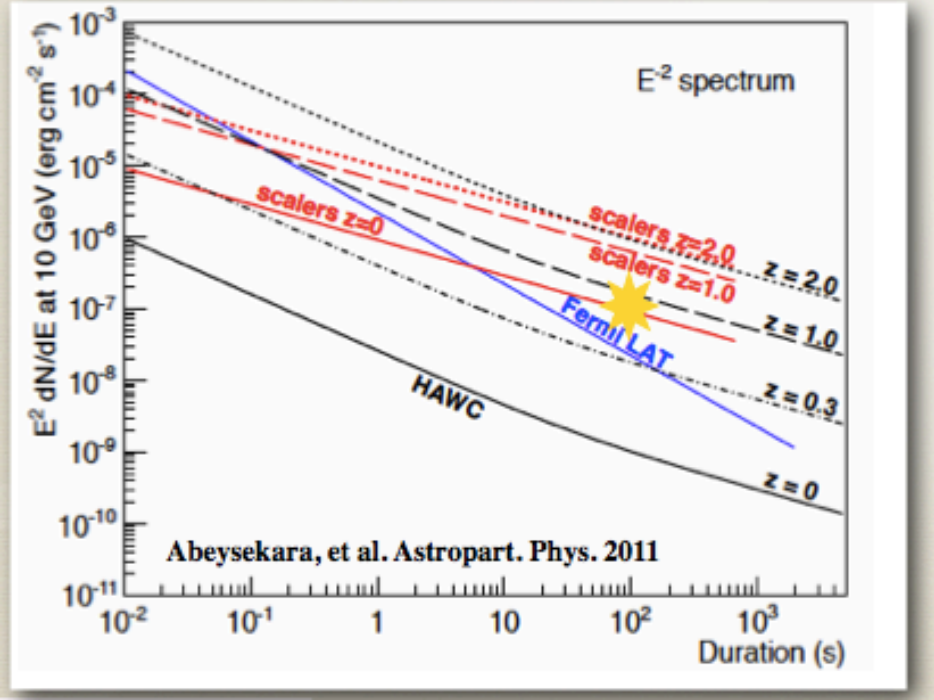


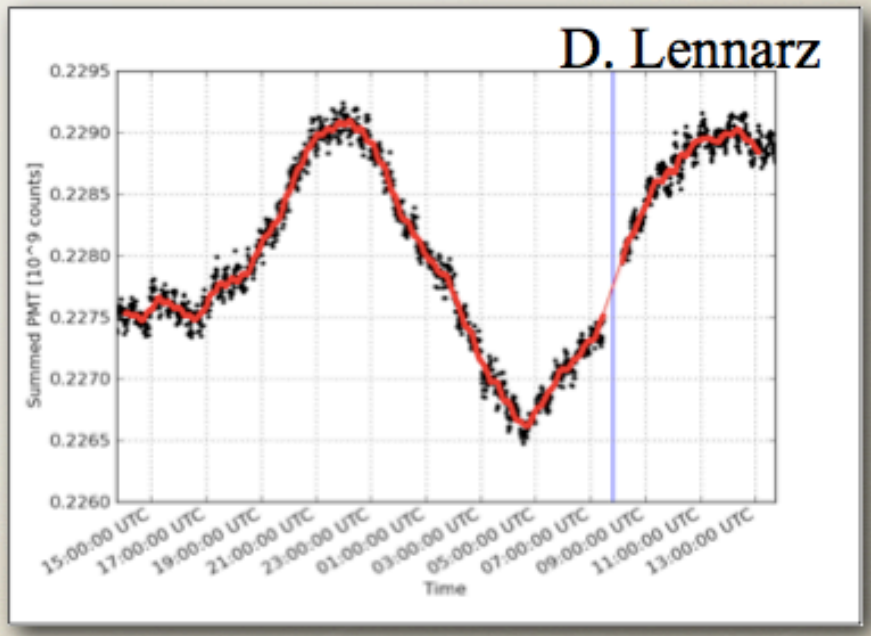
Cosmic Ray Anisotropy



GRB130427A

- 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 (record singles rates in all PMTs)
- Searched 6 time windows - no evidence of a signal





HAWC Summary and Outlook

- HAWC will survey the sky with ~50 mCrab sensitivity over 8sr of sky at ~1 TeV
- 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