HAWC:
Continuous, Wide Field of View Observations of the Very High Energy Sky

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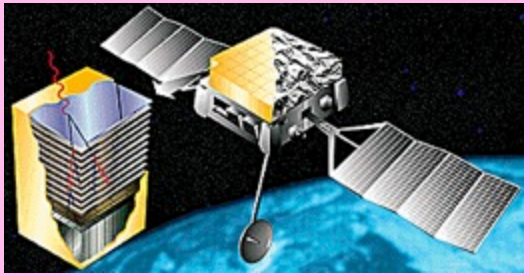
HAWC US Spokesperson
11 February 2014

Gamma-Ray Detectors

Wide Field of View,
Continuous Operations



Fermi
AGILE
EGRET

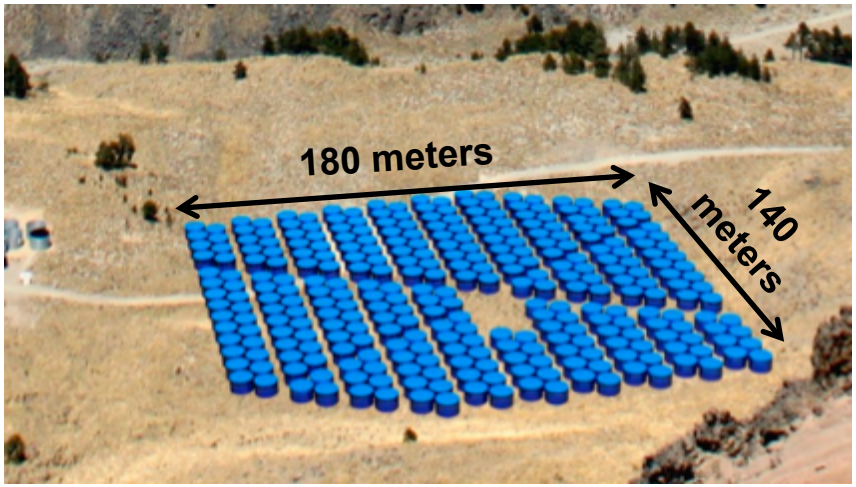
TeV Sensitivity

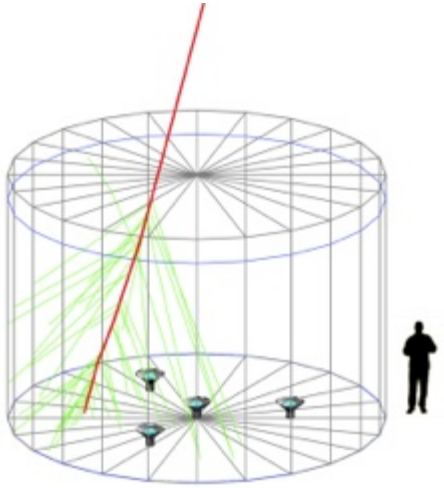
HAWC
ARGO
Milagro

VERITAS
HESS
MAGIC

HAWC Design

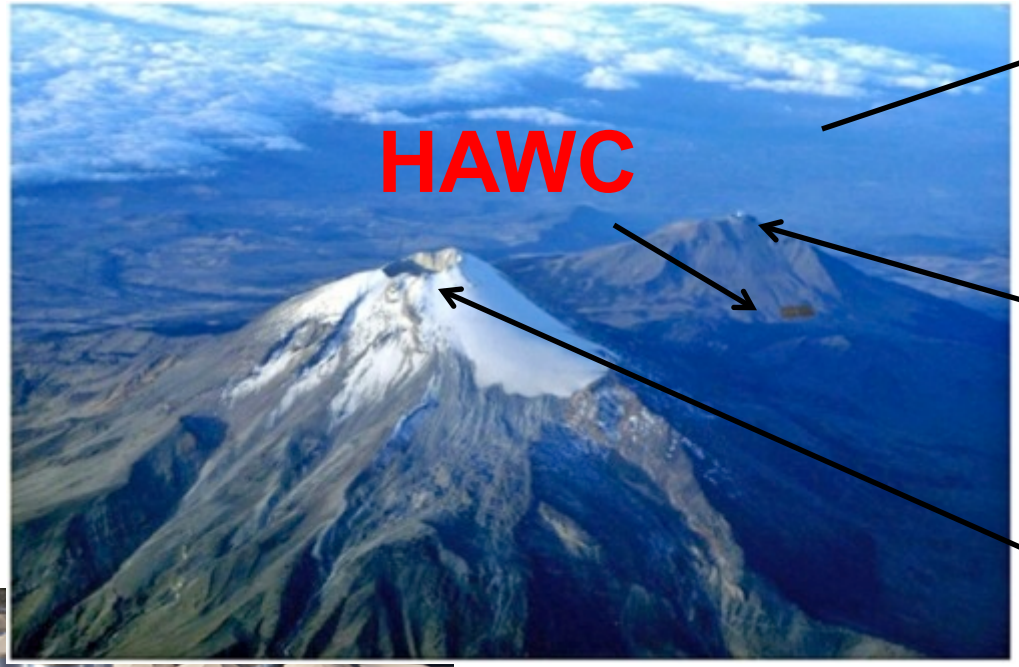
300 close packed water tanks (7.3m dia x 4.5 m deep of 200,000 liters) each with 4 upward facing photomultiplier tubes at the bottom





HAWC Site Location in Mexico

- High Altitude Site of 4100 m with temperate climate and existing infrastructure
- 17 R.L. of atmospheric overburden vs 27 R.L. at sea level
- Latitude of 19 deg N



Large Millimeter Telescope (50m dia. dish)

Pico de Orizaba 5600 m (18,500')

The HAWC Collaboration

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

USA

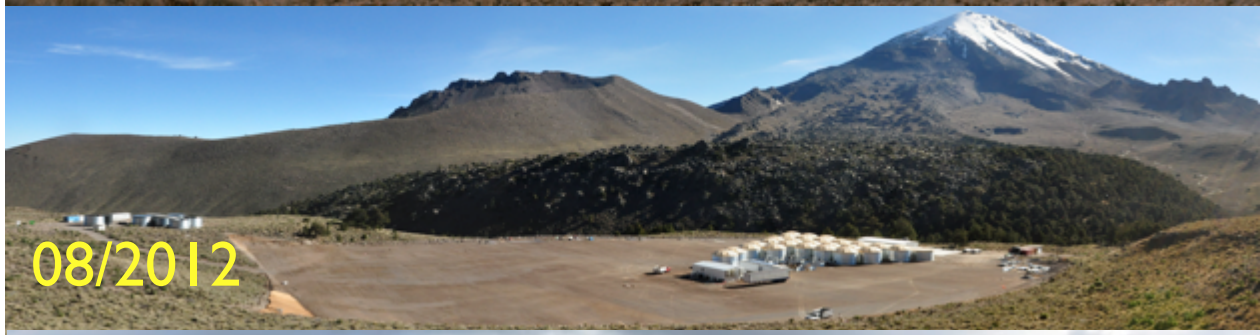
- Instituto Nacional de Astrofísica Óptica y Electrónica
- Universidad Nacional Autónoma de México
  - Instituto de Física
  - Instituto de Astronomía
  - Instituto de Geofisica
  - Instituto de Ciencias Nucleares
- Benemérita Universidad Autónoma de Peubla
- Universidad Autónoma de Chiapas
- Universidad 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

Mexico

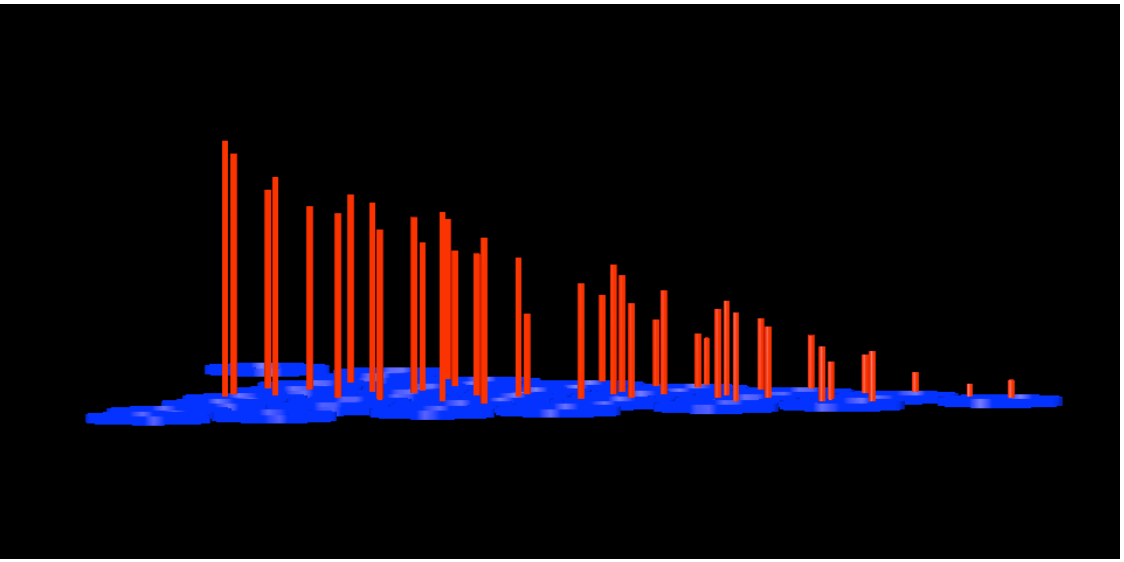
HAWC

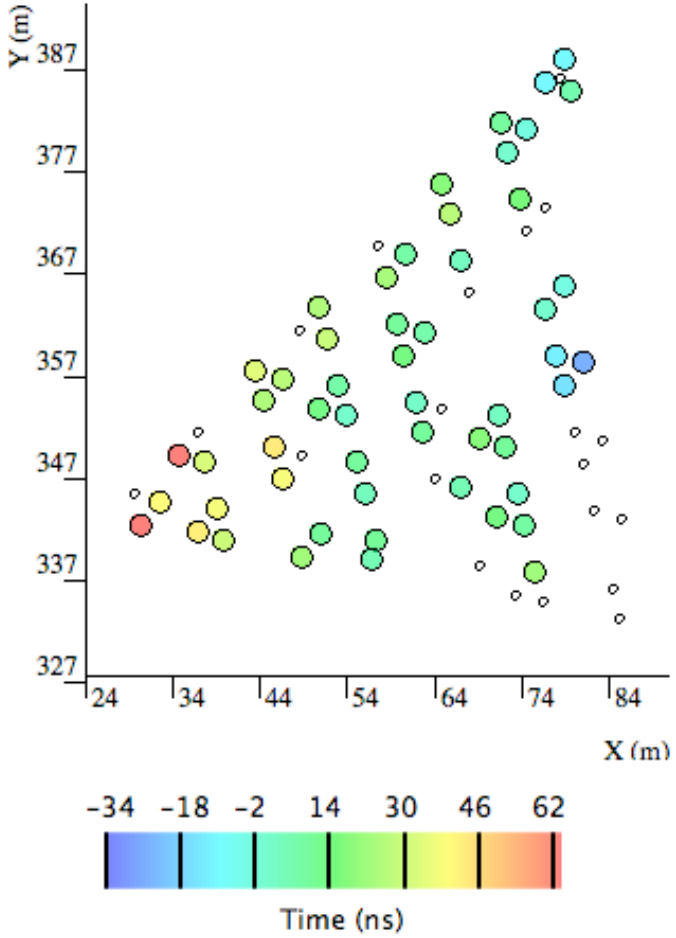
Timeline

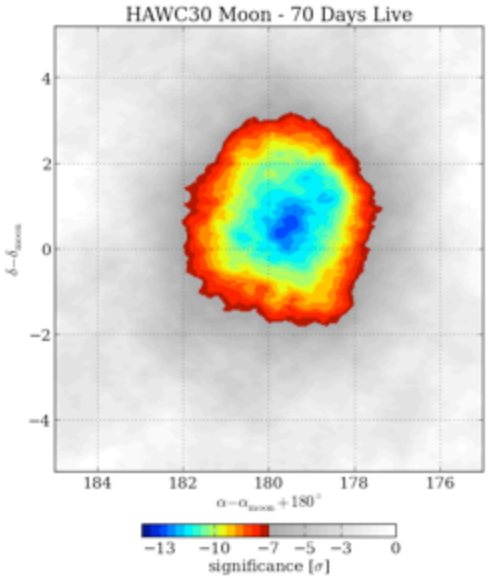
- 13M USD project funding began Feb 2011
- Operations with 111 water Cherenkov detectors began Aug 2013
- Currently, 200 water Cherenkov detectors have been built.
- Construction will be complete by end of 2014



HAWC-30 Completed Sept 2012







HAWC 30 Events and
Observation of cosmic-ray shadow
of Moon with 70 days of data

HAWC 100 Preliminary Sky

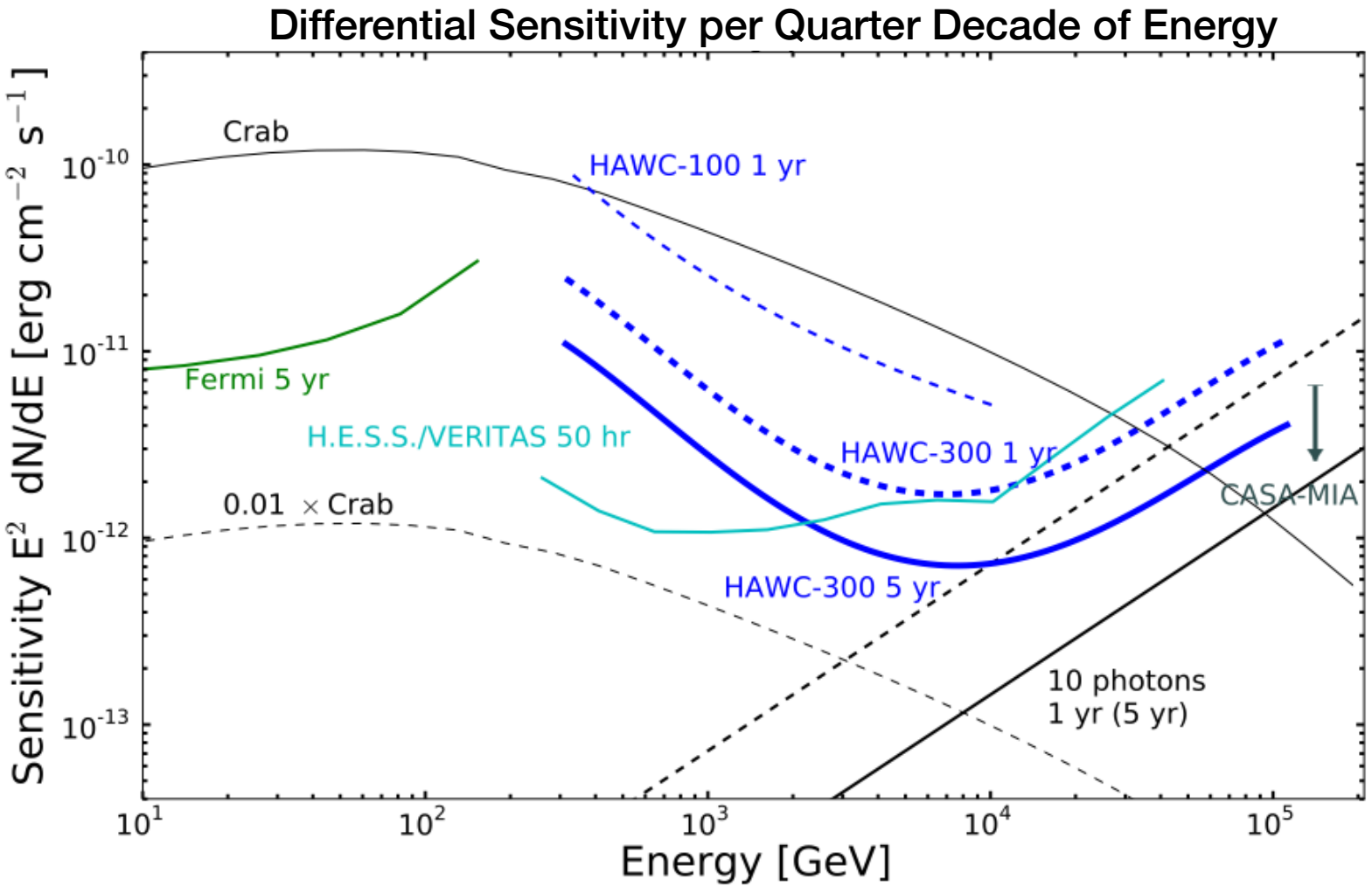
Mrk 421

Crab >10 σ

Galactic Plane →

Began operations Aug 2013 with ~1/3 of the array while still constructing

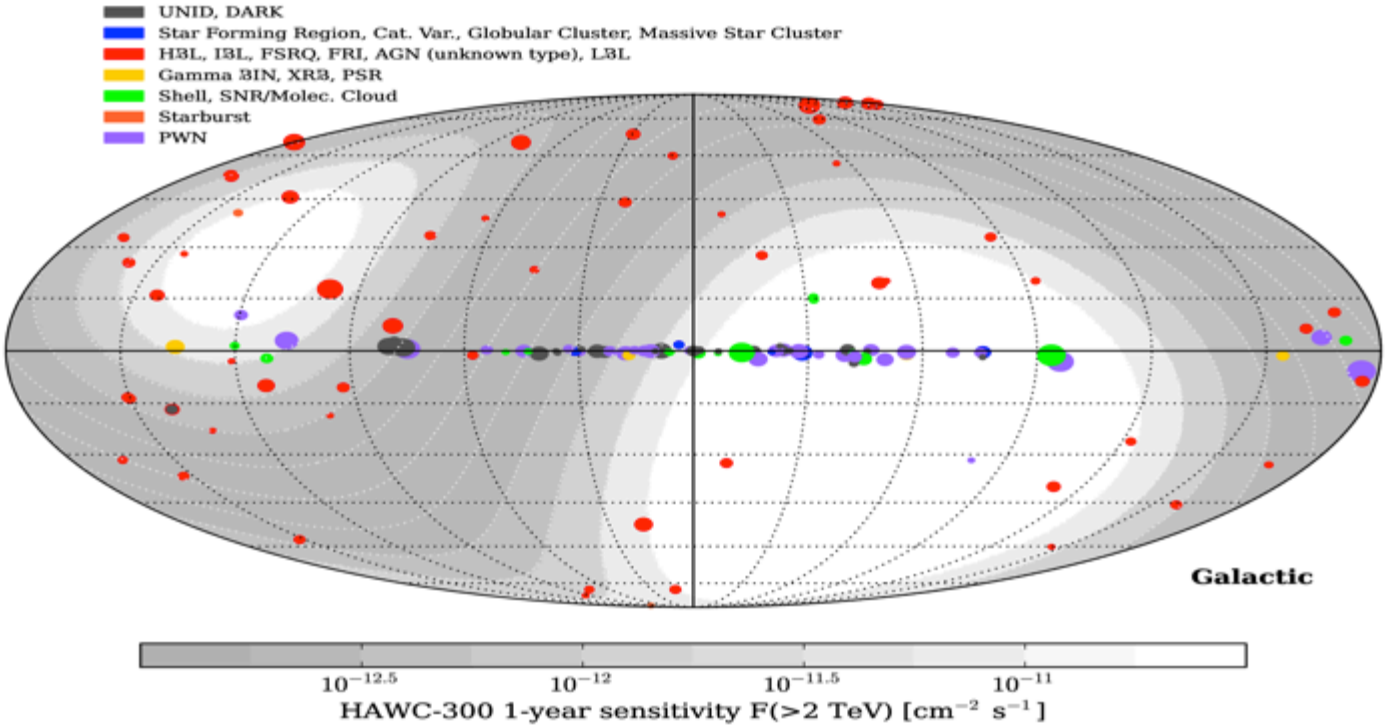
HAWC Sensitivity



http://arxiv.org/abs/1306.5800 Astroparticle Physics 2013

HAWC's Field Of View

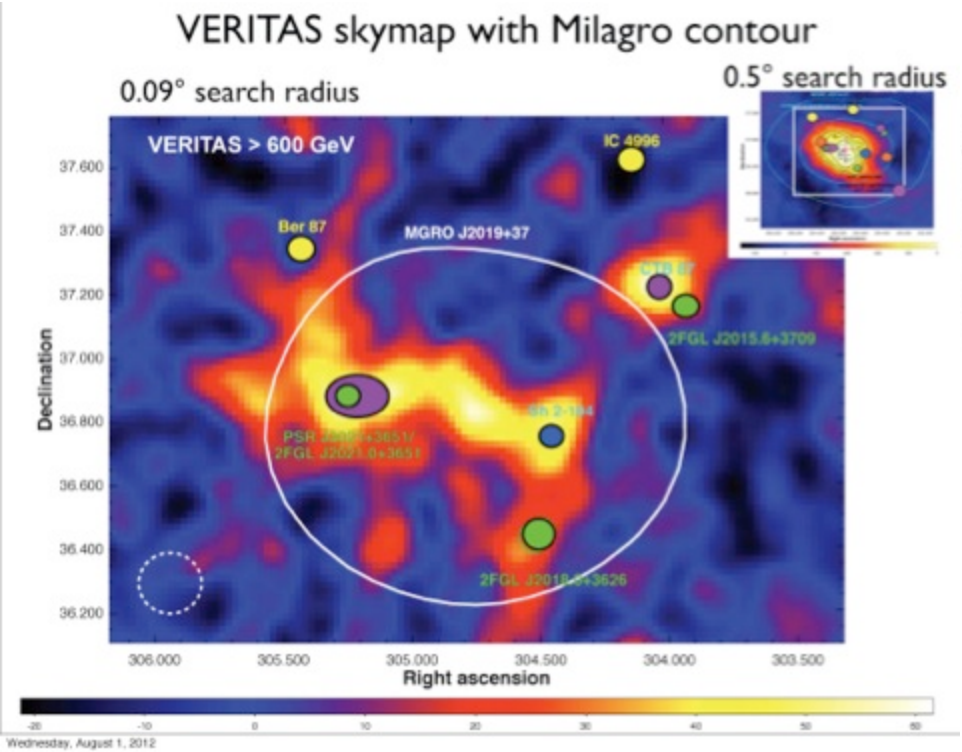
Known sources are shown, but most of the high latitude sky has not been observed at TeV energies

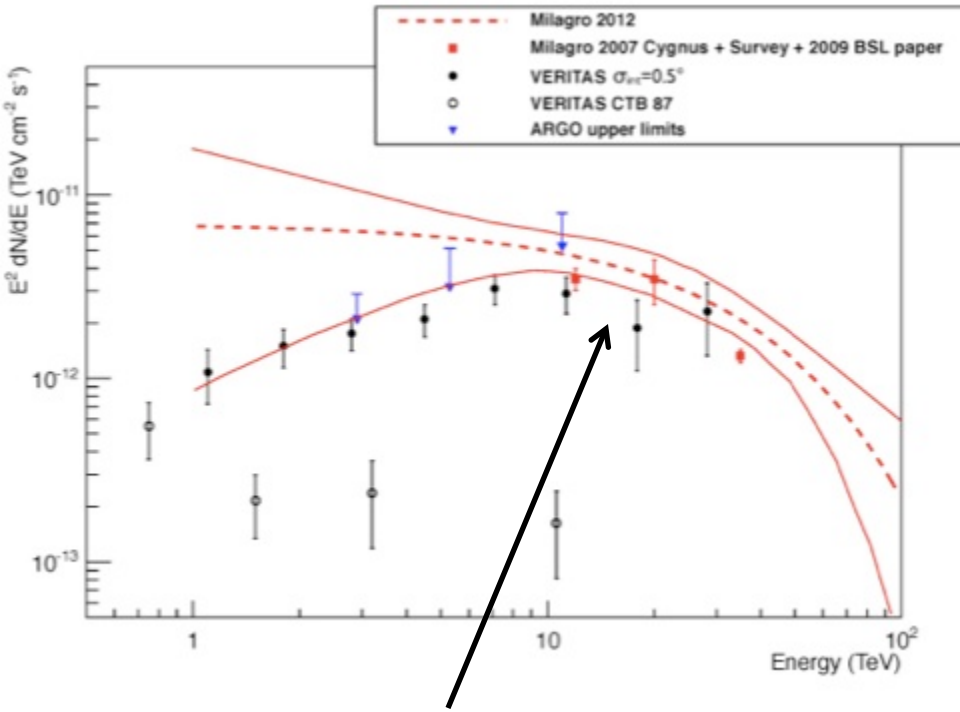


Sources from TeVCAT.uchicago.edu

Highest Energy Sources

For example, MGRO J2019+37 SED peaks >10 TeV.
HAWC will likely discover new higher energy peaked sources.

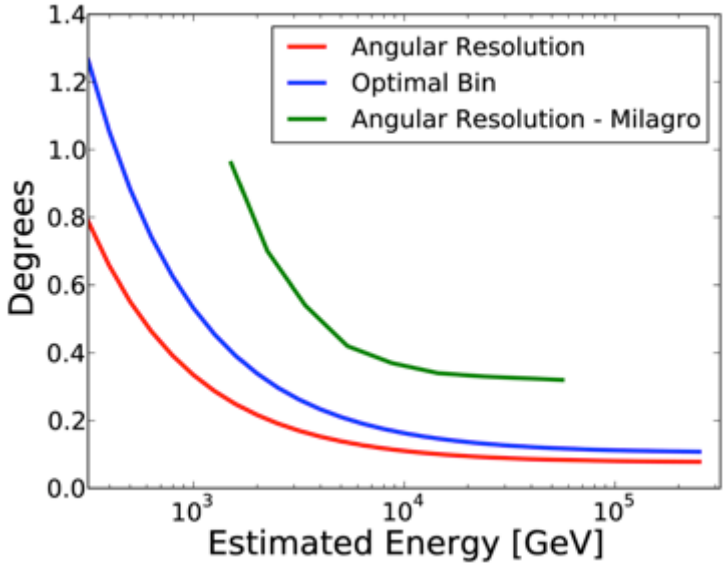




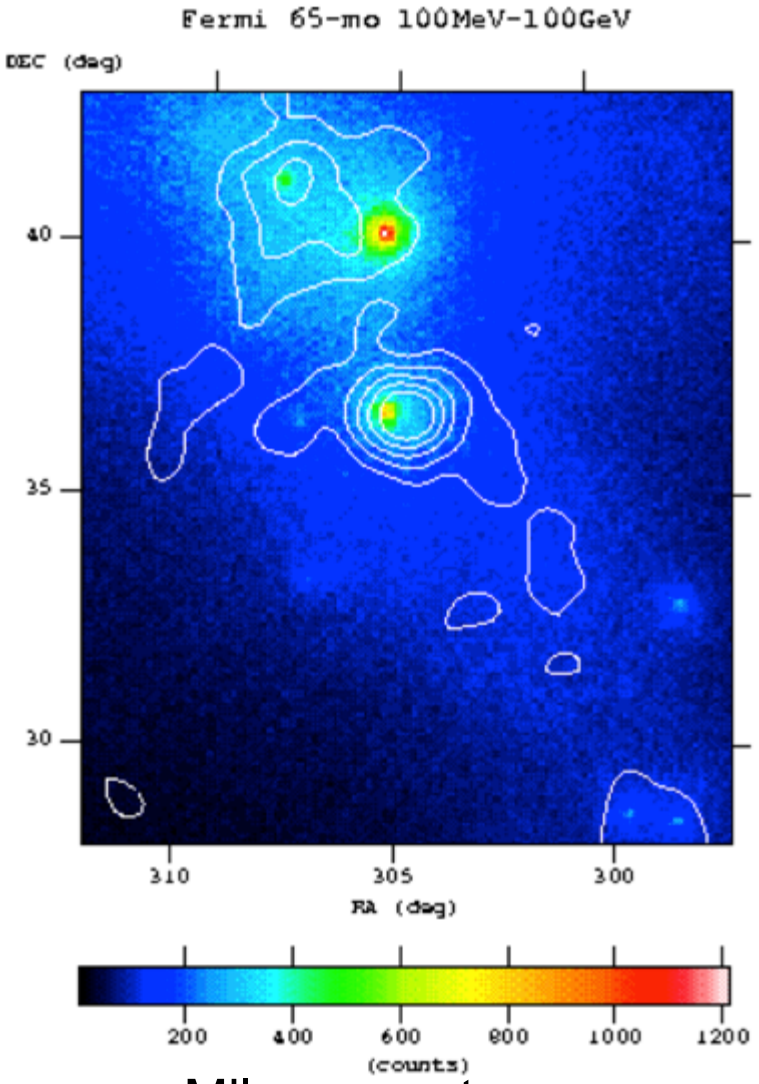
Need HAWC-VERITAS-Fermi joint spectral fits.
Need VERITAS to resolve smaller angular structure.

Very Extended Sources

Galactic Plane
Cygnus Region (and cocoon)
Fermi Bubbles
Nearby Supernova Remnants
Pulsar Wind Nebula



Need HAWC and Fermi joint spatial morphology. HAWC and Fermi have similar point spread functions.



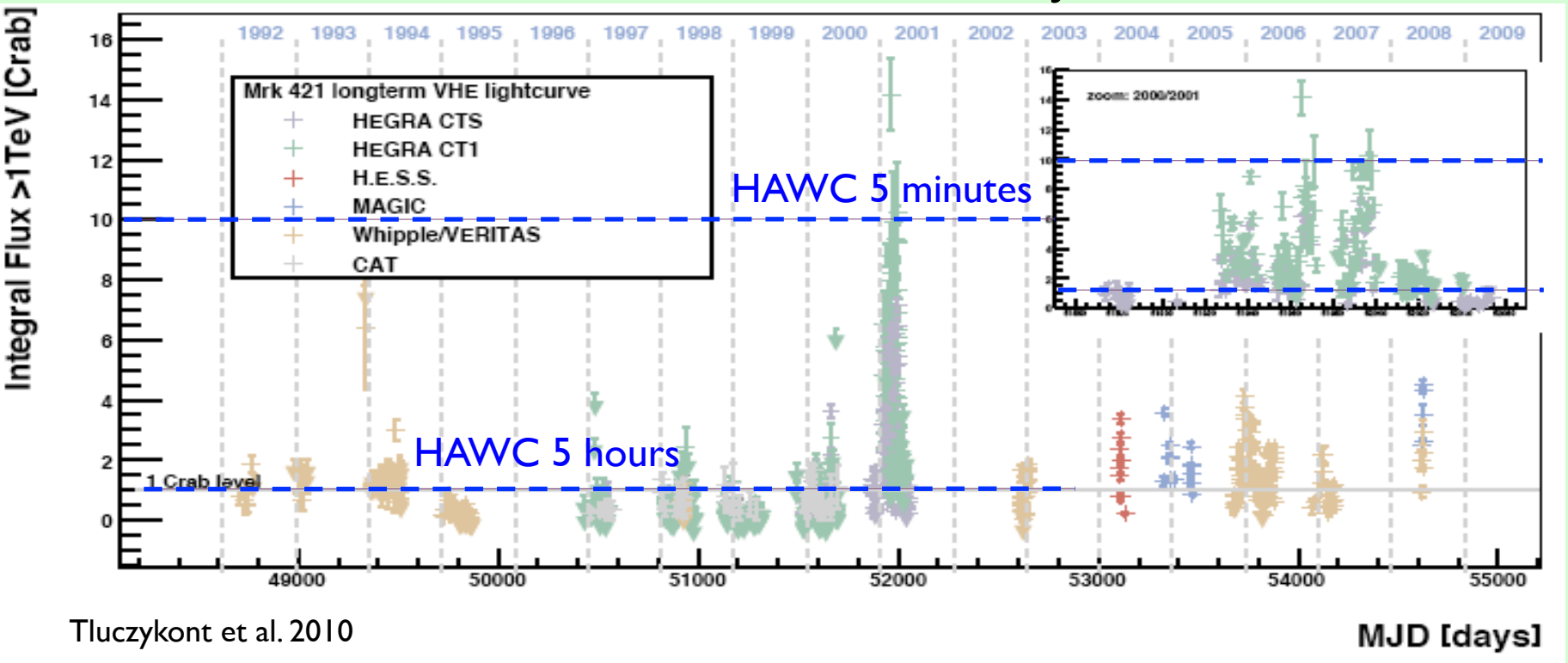
Milagro contours on Fermi counts map

Active Galactic Nuclei Flares

HAWC will monitor AGN within 2/3 of the sky with 20% duty cycle/day (5 hrs) regardless of sun, moon, or weather

VERITAS follow up observations to HAWC's prompt notifications will result in shorter time variability in new and known TeV sources.

Worldwide Dataset of TeV Observations by IACTs of Mrk421



Tluczykont et al. 2010

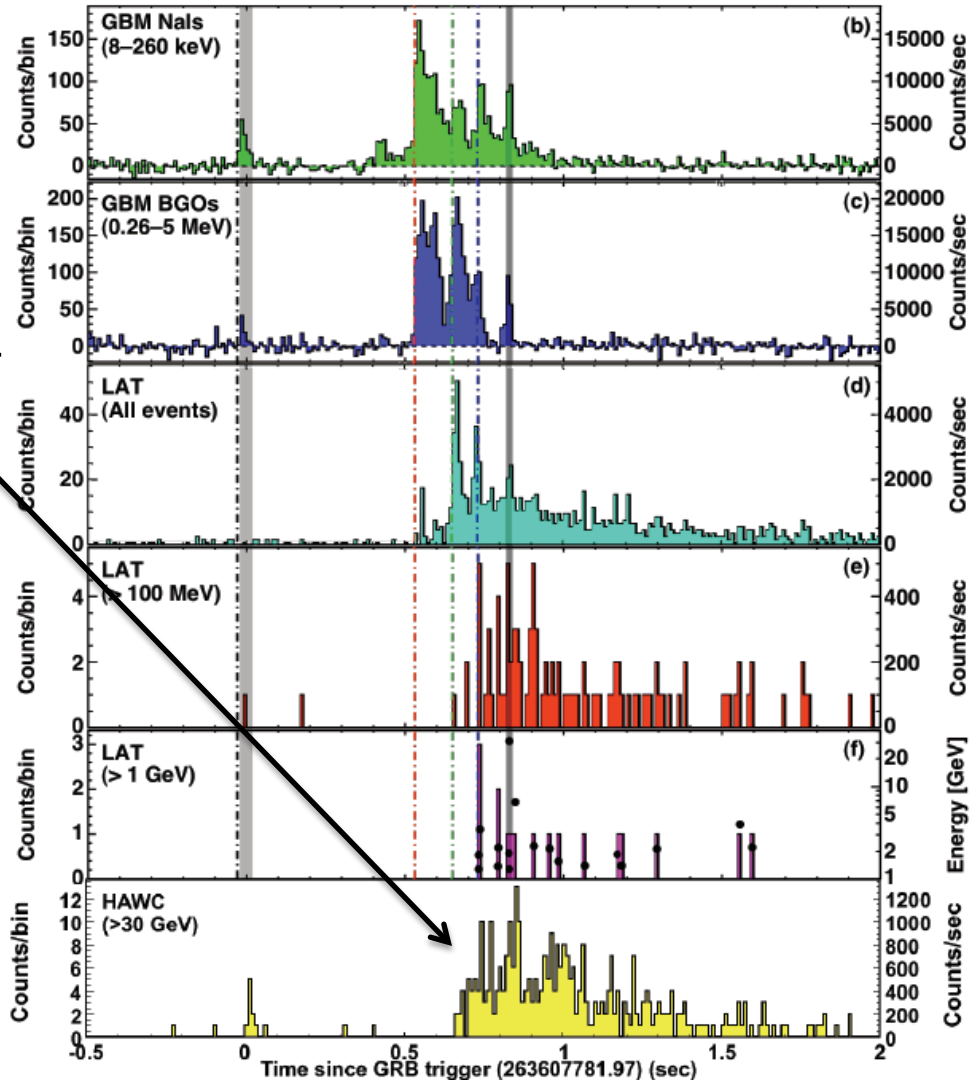
Gamma-Ray Bursts

Fermi observation of GRB090510, z=0.9

- Highest Observed Energy was 33 GeV with 16 γ-rays >1 GeV
- Constrained Lorentz Invariance at the Plank Mass scale

HAWC would detect this GRB if it occurred in FOV

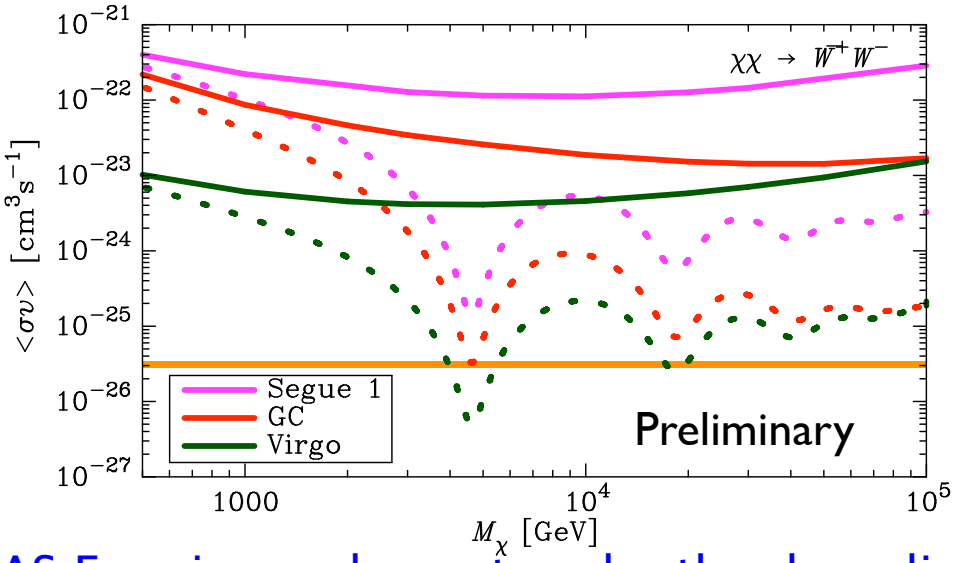
HAWC will promptly search satellite notifications and will promptly notify community of detections. Fermi spectra allows HAWC to constrain max energy. VERITAS follow up could likely detect TeV afterglow.



Dark Matter

- HAWC has sensitivity to indirect detection of multi-TeV WIMPs in satellite galaxies, the Galactic Center, and galaxy clusters
- Cosmological simulations predict more satellite galaxies than observed
  - Recently higher M/L galaxies have been found by Sloan Deep Survey
  - HAWC will observe all M/L galaxies in half the sky, ***even if L=0***

- Solid lines are 5 sigma sensitivity.
- Dashed lines show sensitivity with the expected Sommerfeld enhancement due to additional resonances.
- Horizontal line is the cross section for thermal production of WIMPs.



HAWC-VERITAS-Fermi complement each other by ruling out different mass scales and channels.

VERITAS deep observations of HAWC unidentified high lat sources would reveal spectral and spatial signatures.

The Unexpected

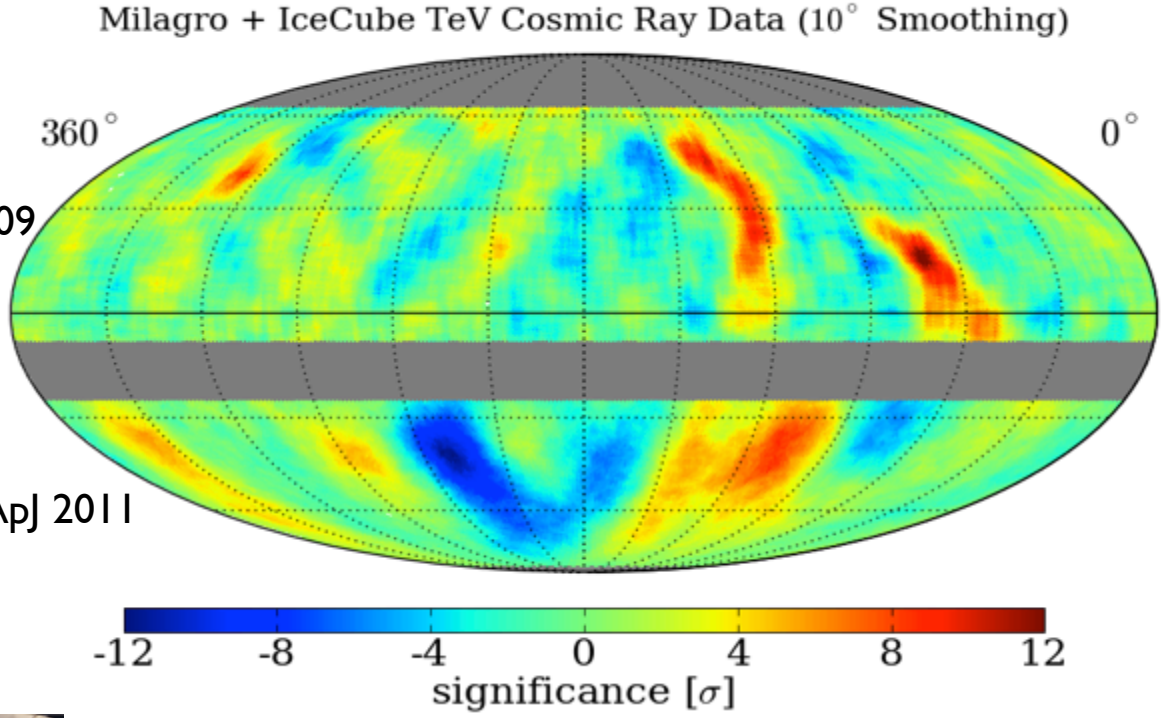
Milagro Discovered an Anisotropy of 10 TeV Cosmic Rays

- Gyroradius of 10TeV proton in 2mG field is 0.005 parsecs=1000 AU
- No known sources within this distance
- Annihilation in protons of nearby Dark Matter? (Harding, astroph/1307.6537)
- Strangelets (stable quark matter)? (Kotera, Perez-Garcia, Silk astroph/1303.1186v1)

HAWC already detects this anisotropy

Milagro:
Abdo, et al. PRL, 2009

IceCube
R. Abbasi, et al., ApJ 2011



Any ideas on how Fermi or VERITAS can help?

Summary:HAWC-VERITAS-Fermi

- Powerful Triumverate covering broad energy range with different angular and spectral capabilities
- Coordinated observations are important
- Joint analysis is needed
  - Spectral
  - Spatial
  - Temporal
  - Scientific
- All projects benefit from other observatories successes!