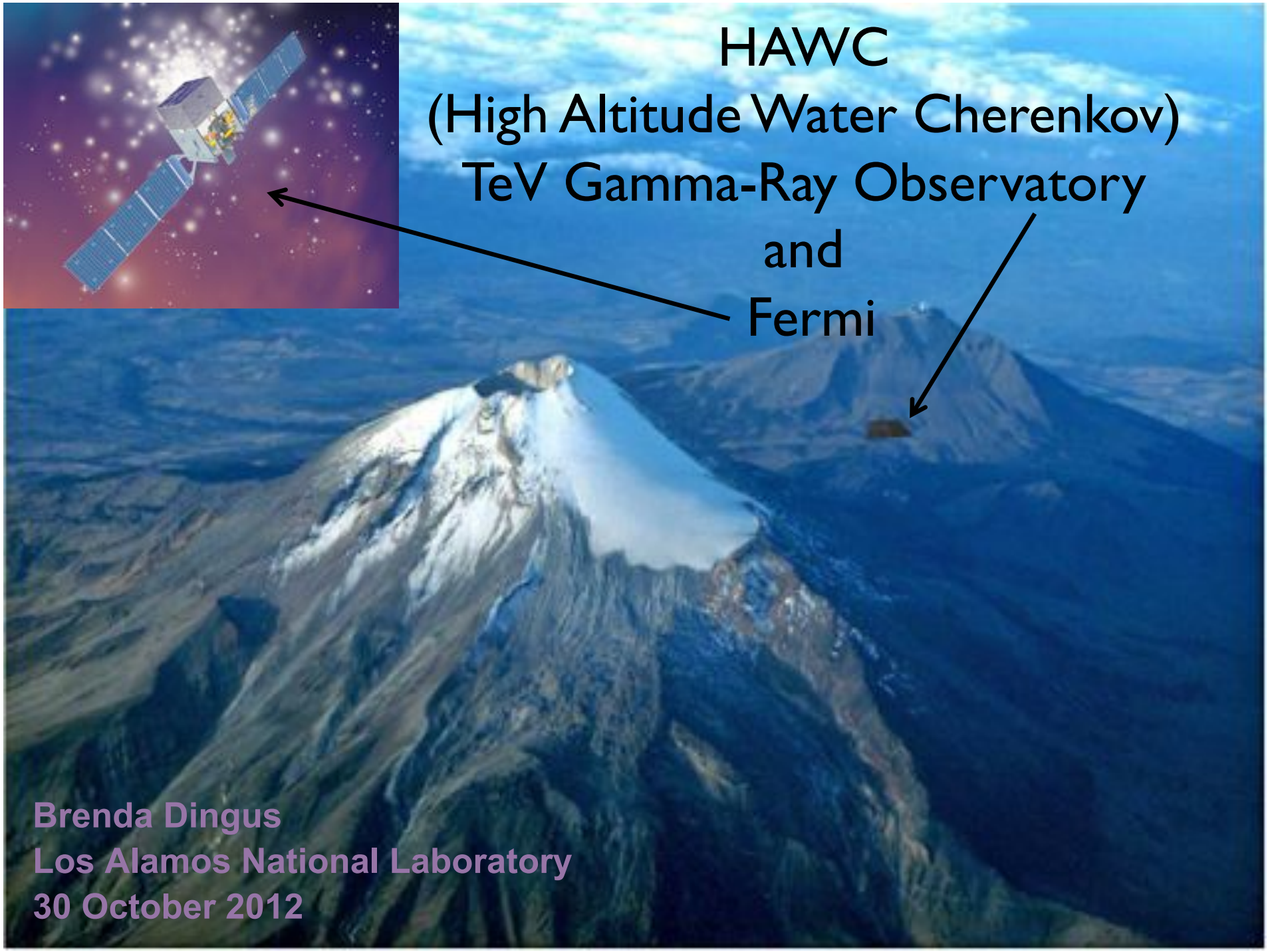
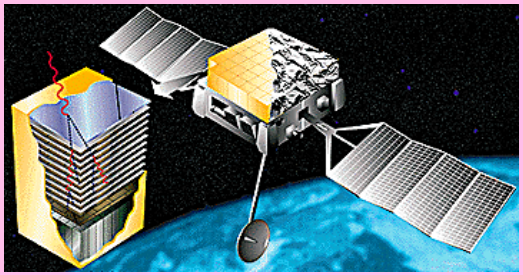


Brenda Dingus
Los Alamos National Laboratory
30 October 2012

Gamma-Ray Detectors

Wide Field of View,
Continuous Operations

TeV Sensitivity



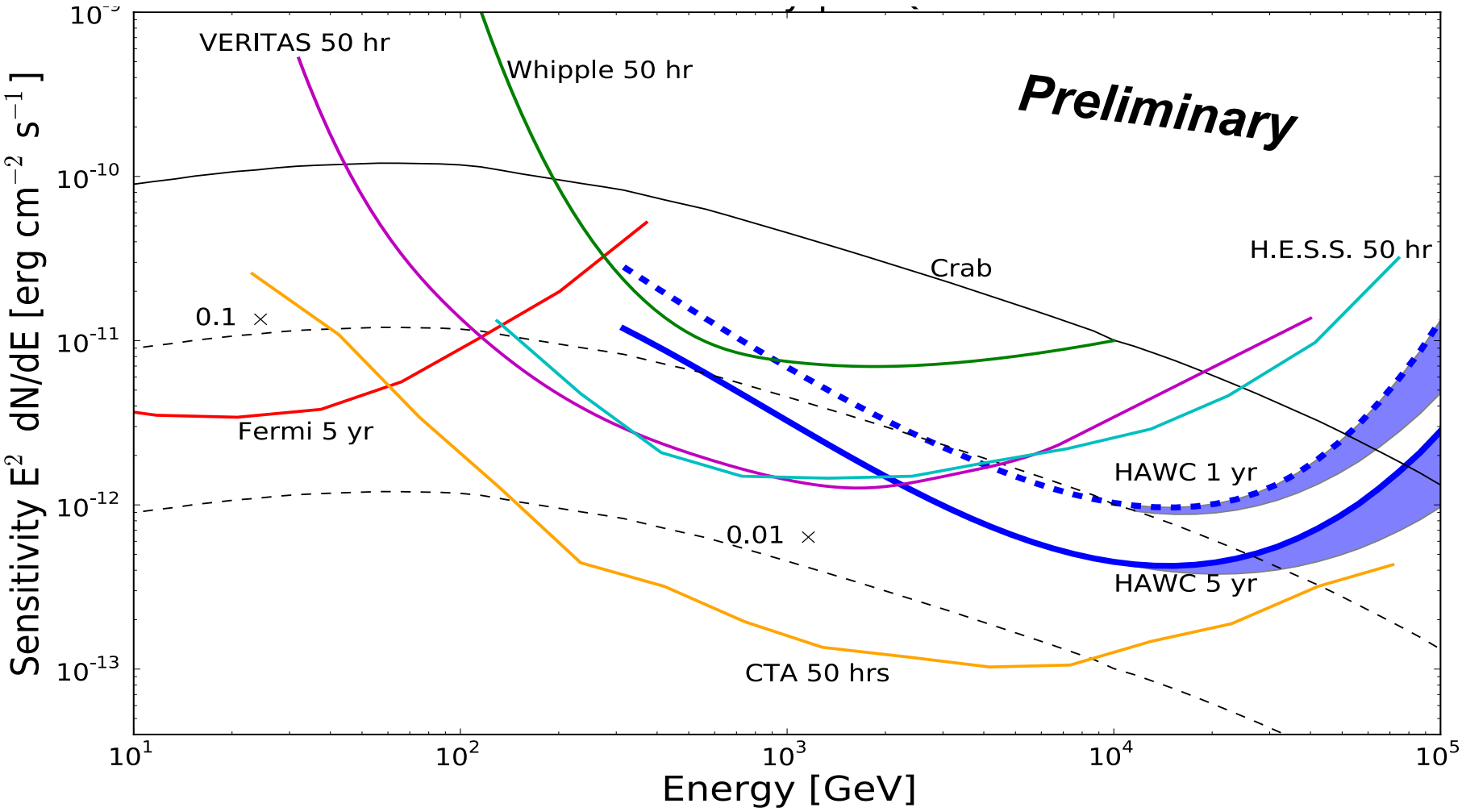
EGRET
AGILE
FERMI

HAWC
Milagro
Tibet ASγ
ARGO

VERITAS
HESS
MAGIC

HAWC Differential Sensitivity

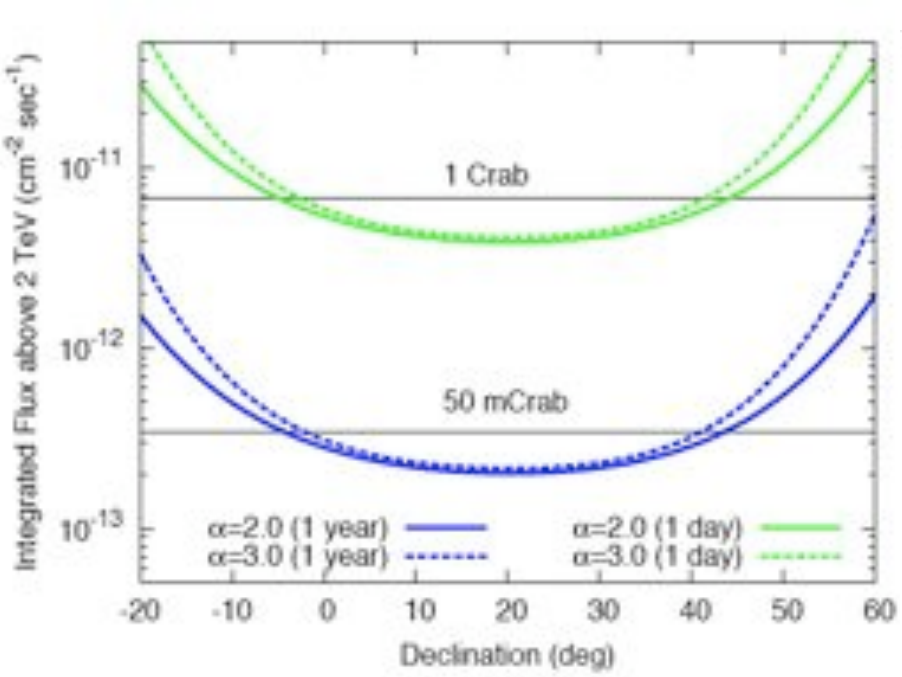
(Flux per ¼ decade for 5 σ detection)



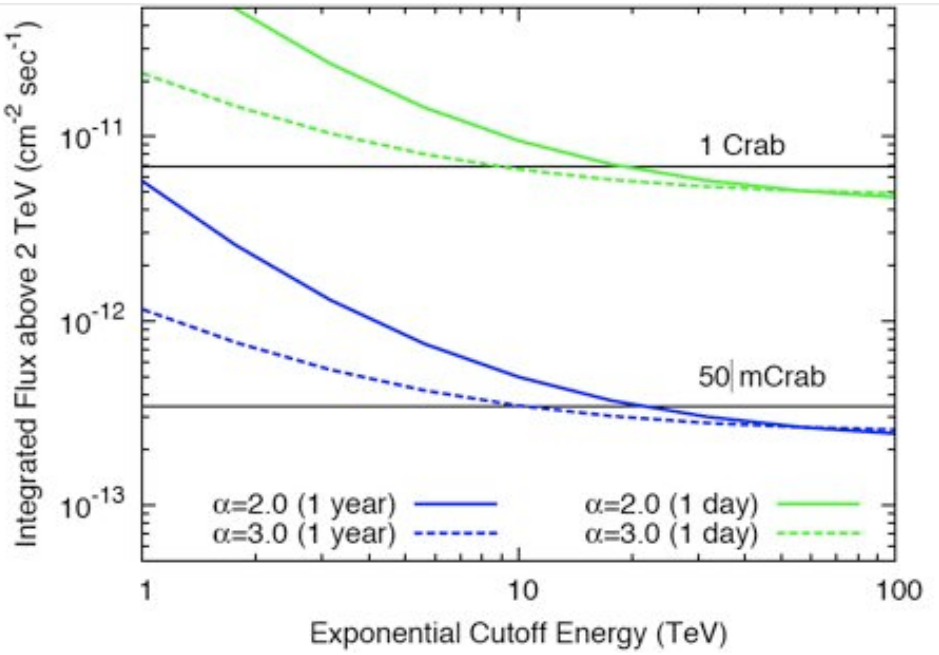
Astroparticle Physics, in preparation
Point of Contact: Brian Baughman

HAWC Integral Sensitivity

vs. Declination
for 1 day and1 year



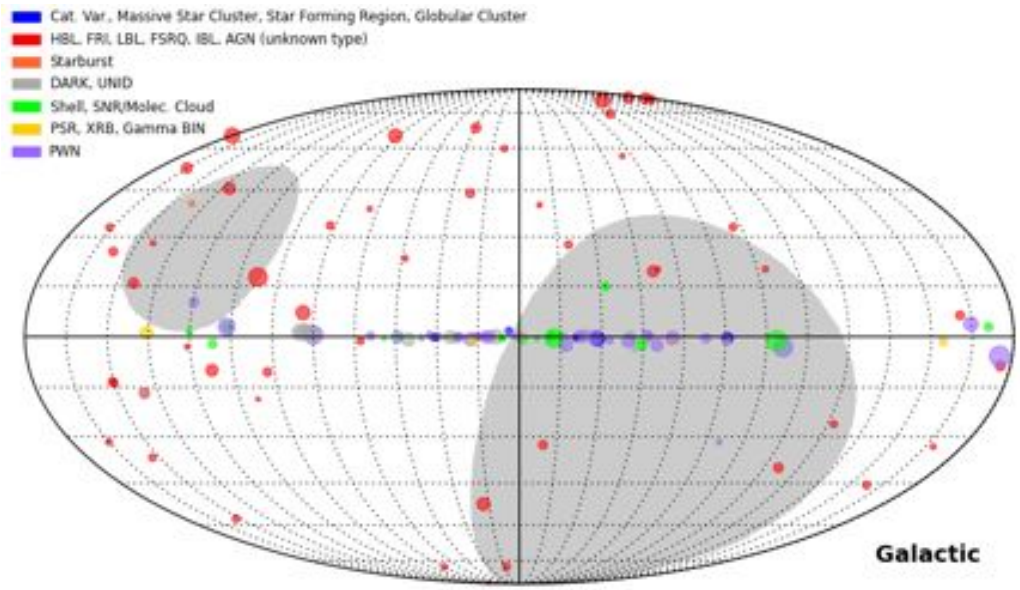
vs. High Energy Cut off
for 1 day and1 year

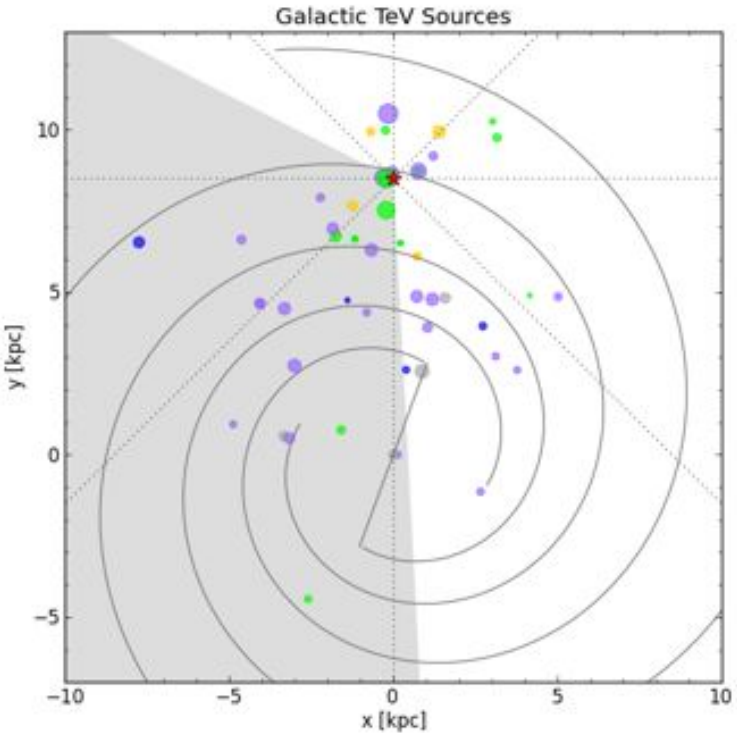


Astroparticle Physics, in preparation
Point of Contact: John Pretz

Known TeV Sources in HAWC FOV

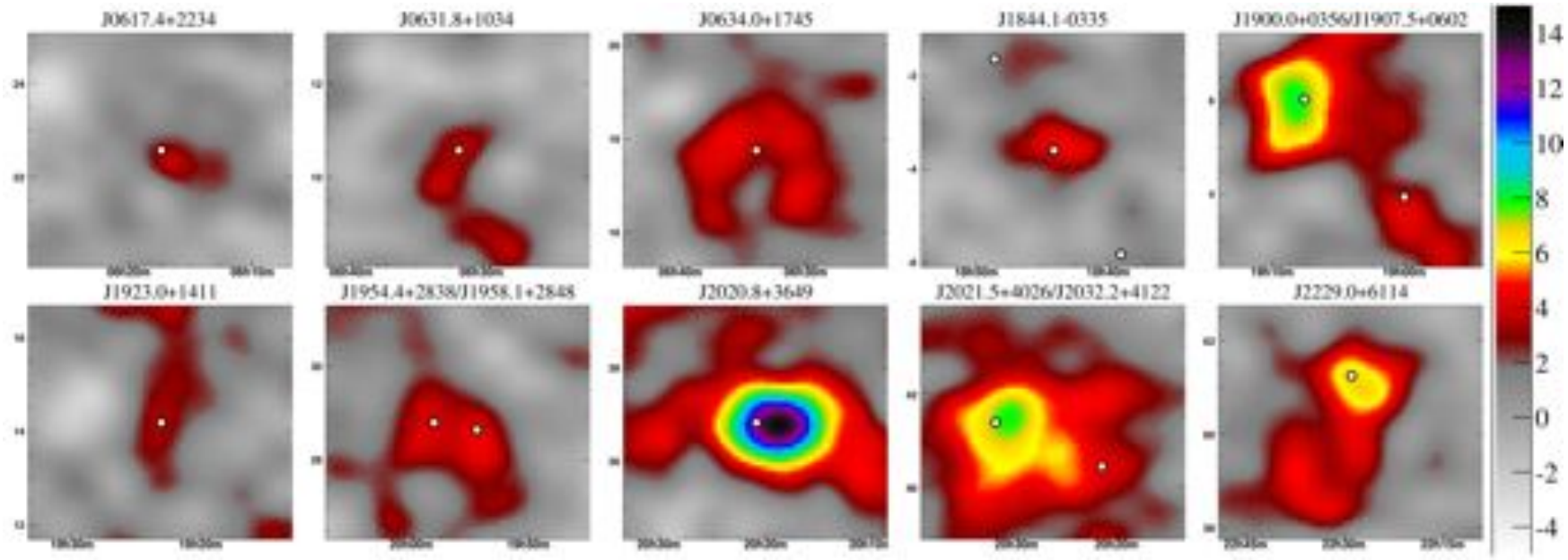
And most of the high latitude sky has not been observed at TeV energies





White is within 45° of HAWC's Zenith
From TeVCAT.uchicago.edu plotted by Segev BenZvi

Milagro Sources are Coincident with Fermi Sources



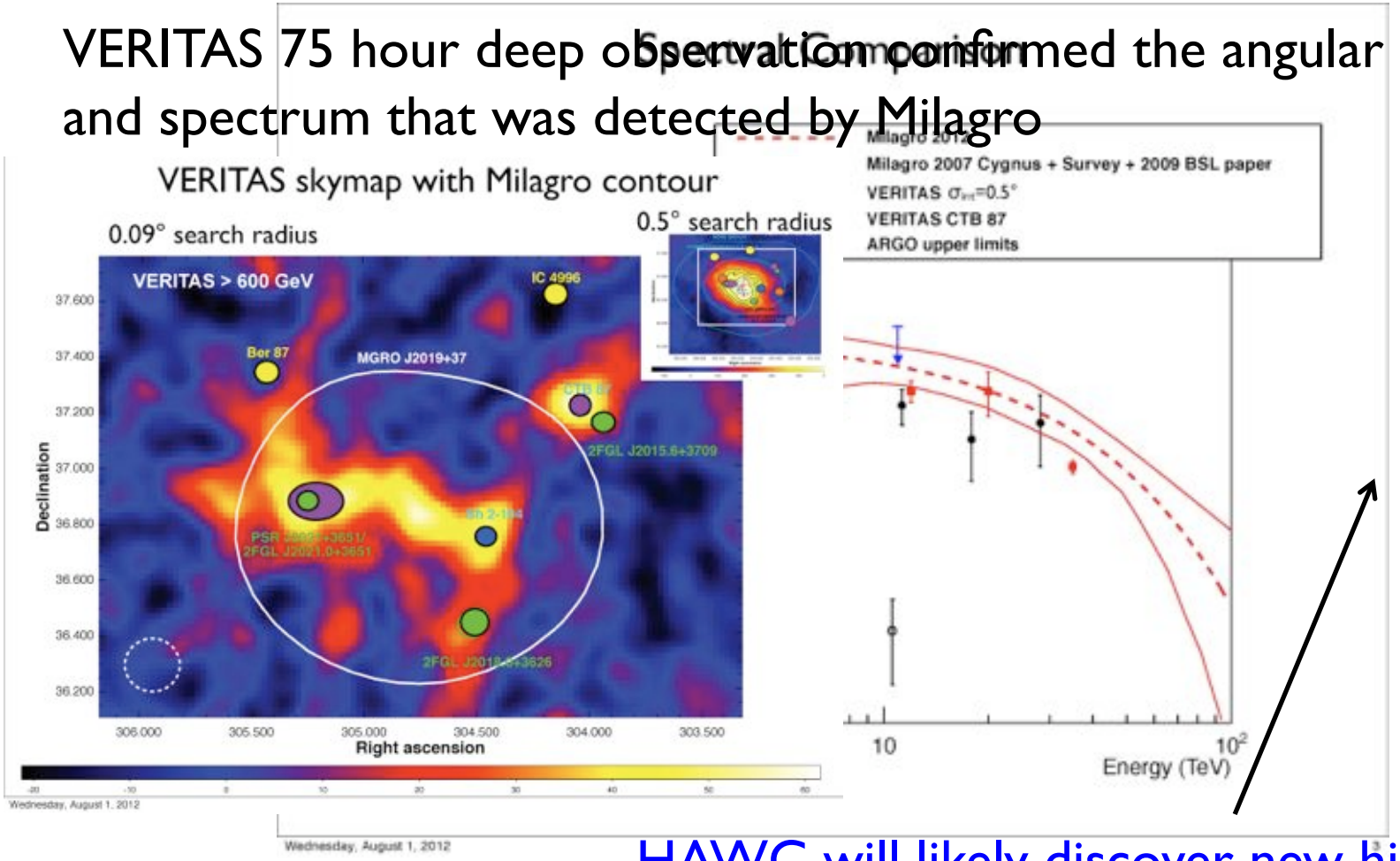
Abdo et al., ApJ Lett 2009

Bright GeV pulsars are coincident with TeV emission.

HAWC will observe Galactic GeV sources with the same significance as Fermi.

Milagro's Brightest Discovery

VERITAS 75 hour deep observation confirmed the angular extent and spectrum that was detected by Milagro

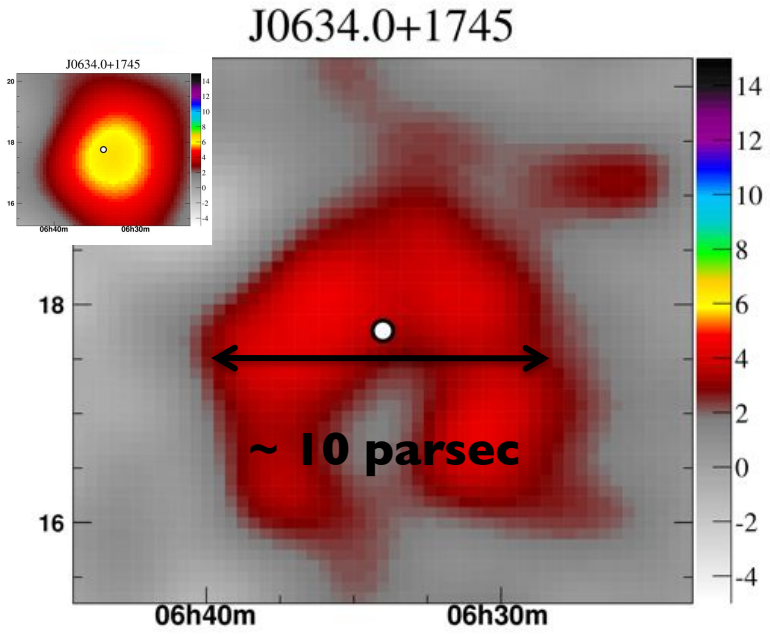


HAWC will likely discover new higher energy peaked sources.

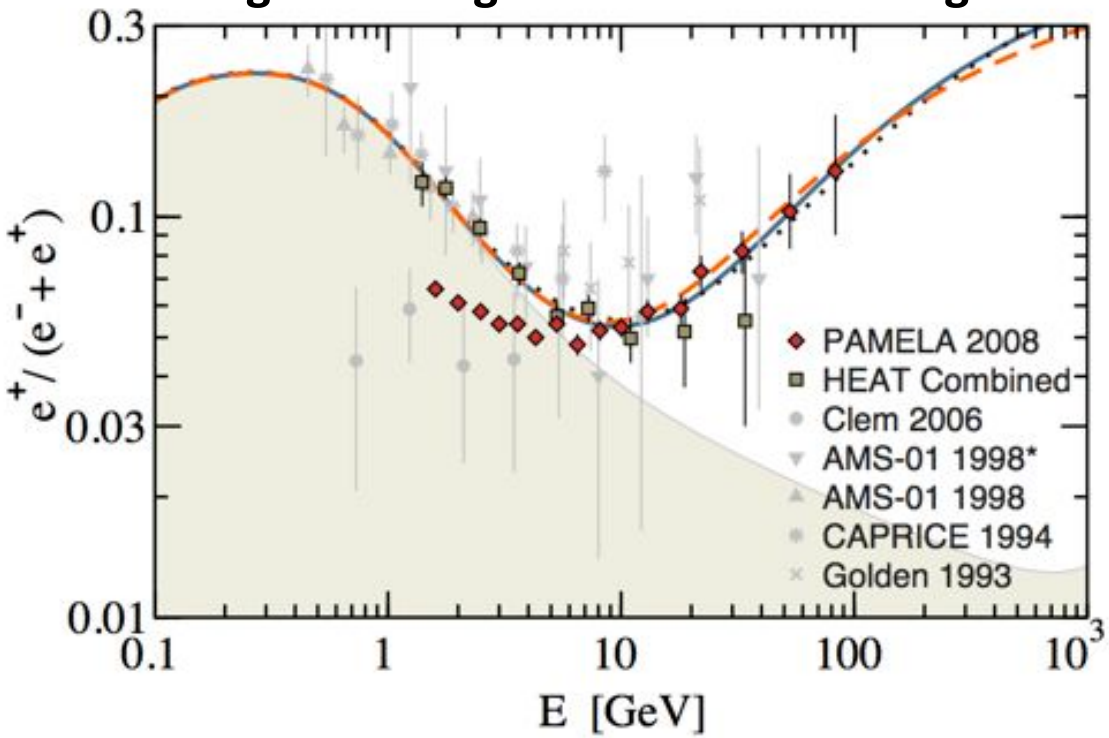
See Posters of Michelle Hui and Petra Huentemeyer

Geminga: a Nearby Positron Source

Milagro's Detection of an extended excess coincident with Geminga



PAMELA's positron excess is well fit given Milagro's flux from Geminga



The confirmed presence of a nearby, ancient source of high-energy electrons and positrons immediately suggests an explanation for the positron excess. -Yüksel, Kistler, Stanev PRL 2009

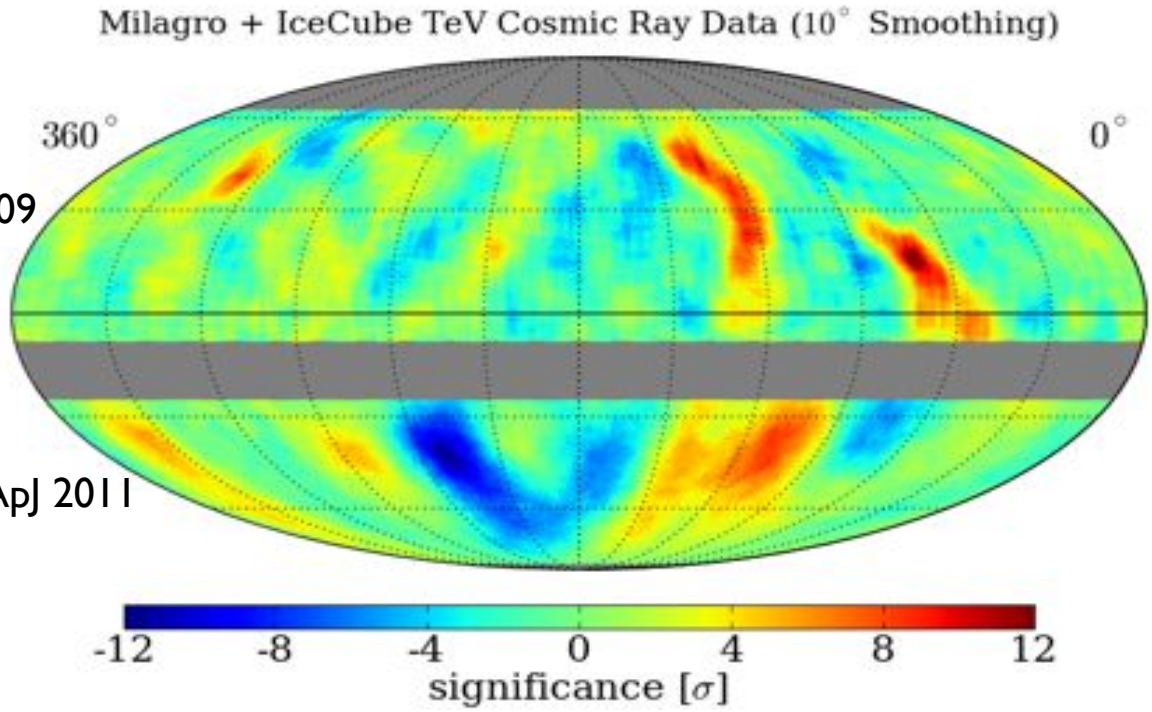
HAWC will detect Geminga with >100σ to map diffusion near source.

CR Propagation is NOT understood

Milagro Observed Anisotropy in 10 TeV Cosmic Rays

- Localized excess of ~ 5° (15σ) of hadronic cosmic rays (7σ)
- Explanations are difficult due to Gyroradius of 10TeV proton in 1μG field is 0.01parsecs=2000 AU
- Solar effect? Propagation effect? Unknown nearby source?

HAWC will measure spectrum of excesses and to lower energies.



Abdo, et al. PRL, 2009

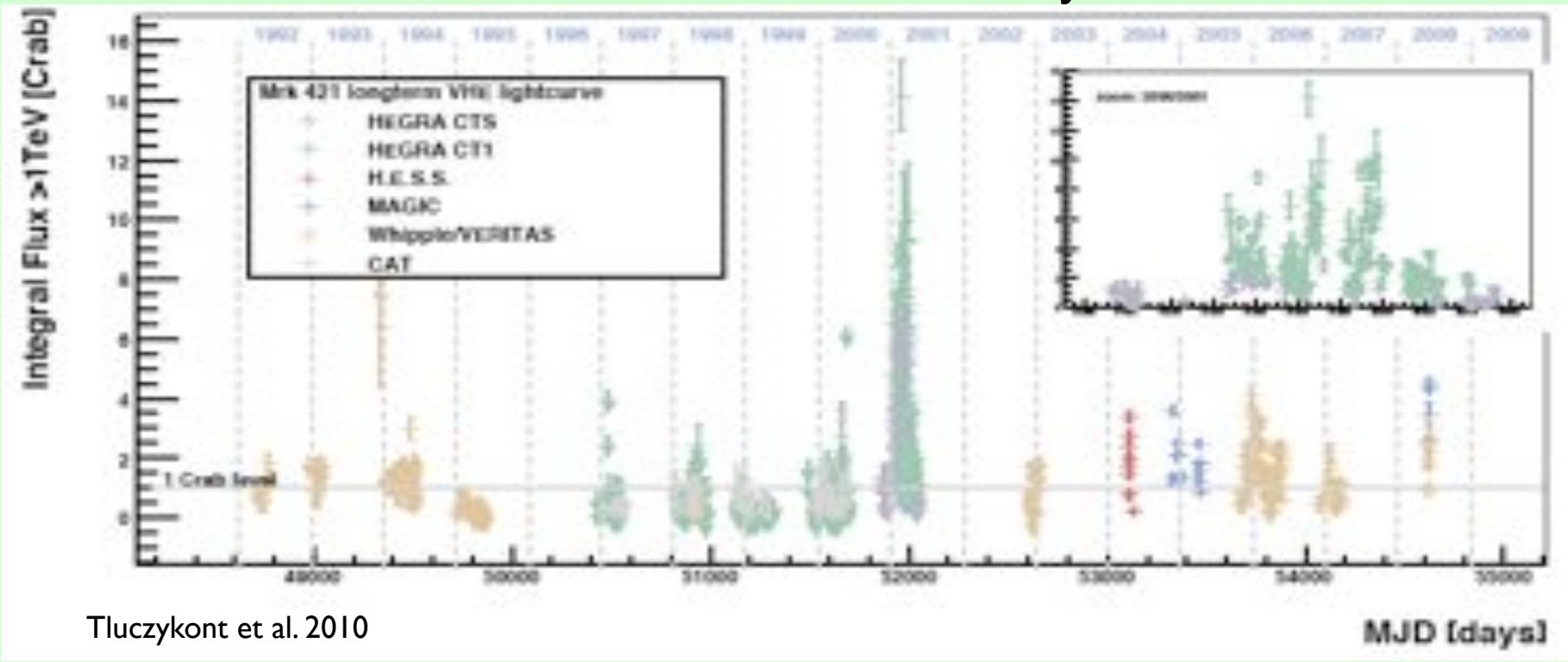
R. Abbasi, et al., ApJ 2011

Active Galactic Nuclei Flares

- ~ 40 known TeV AGN
- IACT observations with <0.1% duty cycle/AGN detect no flaring in most AGN, but a few AGN have >10x flares

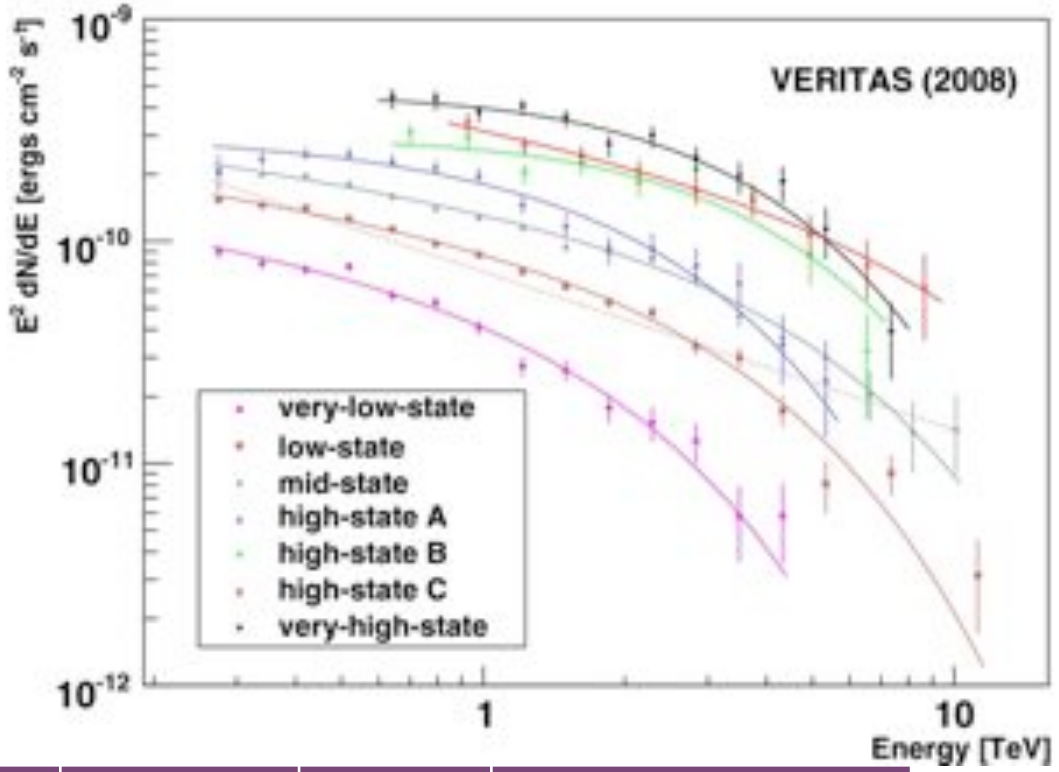
HAWC's will monitor all Northern AGN with 20% duty cycle/day (5 hrs) regardless of sun, moon, or weather.

Worldwide Dataset of TeV Observations by IACTs of Mrk421



Tluczykont et al. 2010

Mrk421

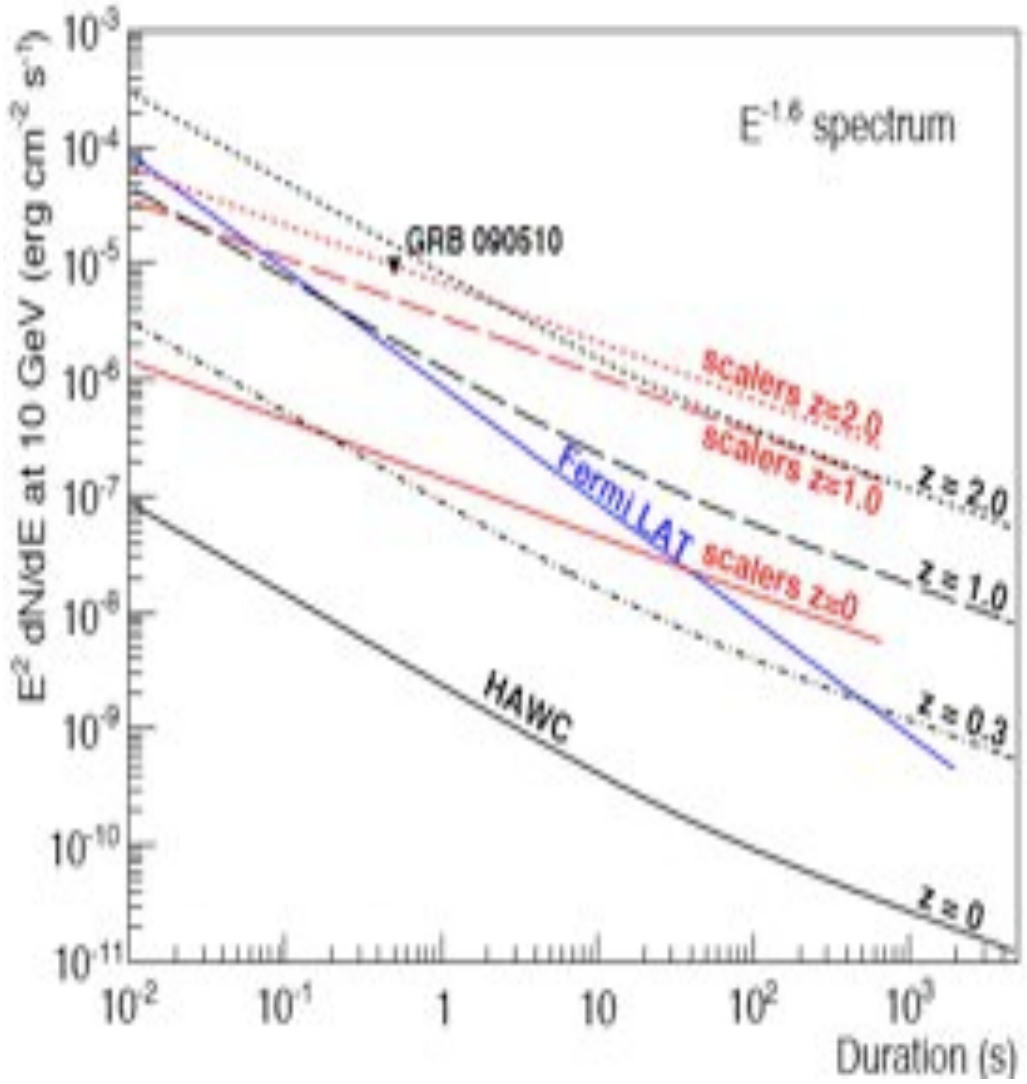


Preliminary

	ph/cm2/sec/ TeV @ 1 TeV *10^13	Diff. spec. index	Cutoff in TeV	Time for HAWC to detect 8 σ
Very low state	478	2.29	1.59	1 month
High-state A	1908	2.01	1.91	1 day
Very high state	3577	1.87	2.74	1/2 hour

Astroparticle Physics, in preparation
Point of Contact: John Pretz

HAWC GRBs Sensitivity



- Fermi LAT sensitivity assumes 1 gamma-ray > 10 GeV
- Scaler sensitivity uses sum of single photoelectron rates in individual PMTs to observe shortest and most distant transients
- Assume cutoff due to Extragalactic Background Light (Gilmore, 2009)

Abeysekara et al., Astroparticle Physics, 2011
Point of Contact: Ignacio Taboada

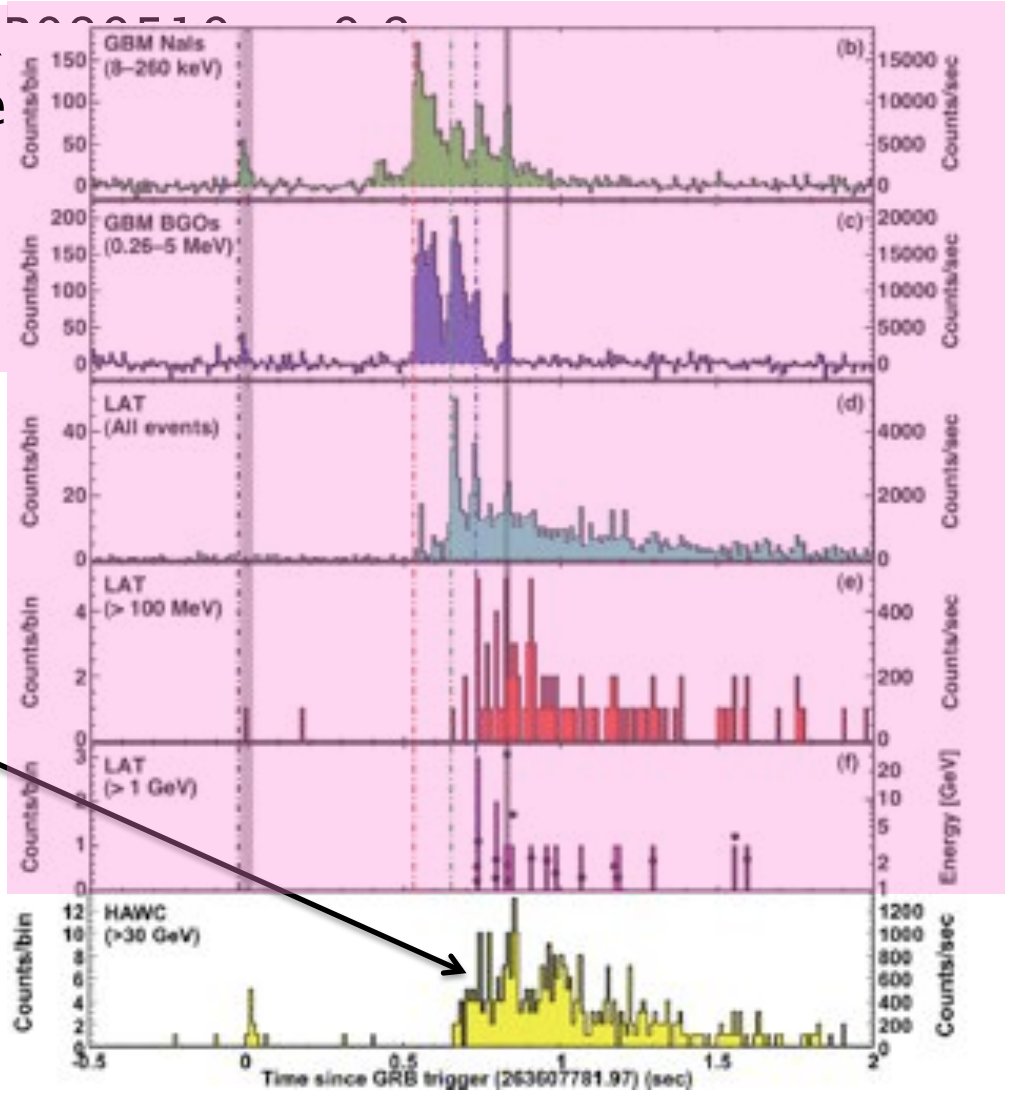
See Posters of Ian Wisher and Dmitry Zaborov

HAWC could detect GRB090510

Fermi observation of GR

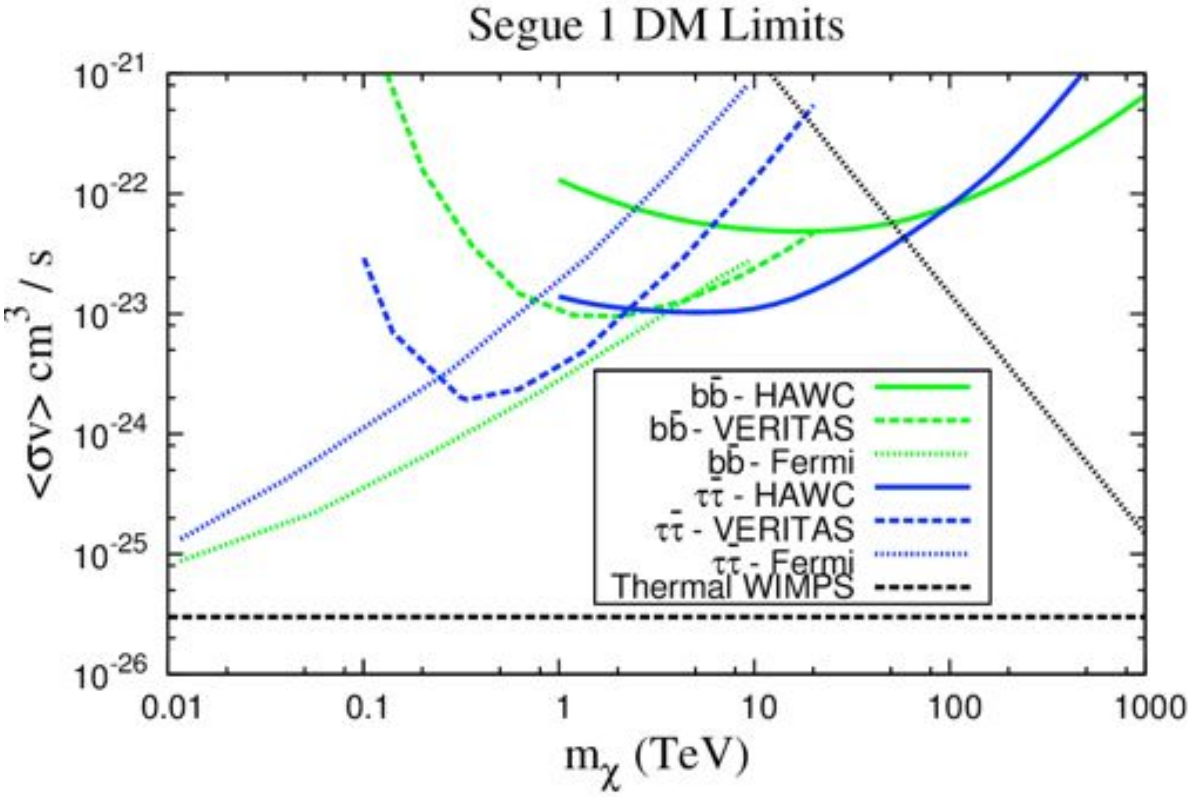
- Highest Observed Ene
  was 33 GeV with
  16 γ-rays >1 GeV

HAWC would detect this



WIMPS

- Annihilation of WIMPs produces gamma rays (E continuum and line)
- Nearby satellite galaxies have large Mass, but small Luminosity and are thus dark matter rich
  - 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*
  - HAWC has sensitivity to higher mass WIMPS



The 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
- 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 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

145 Members

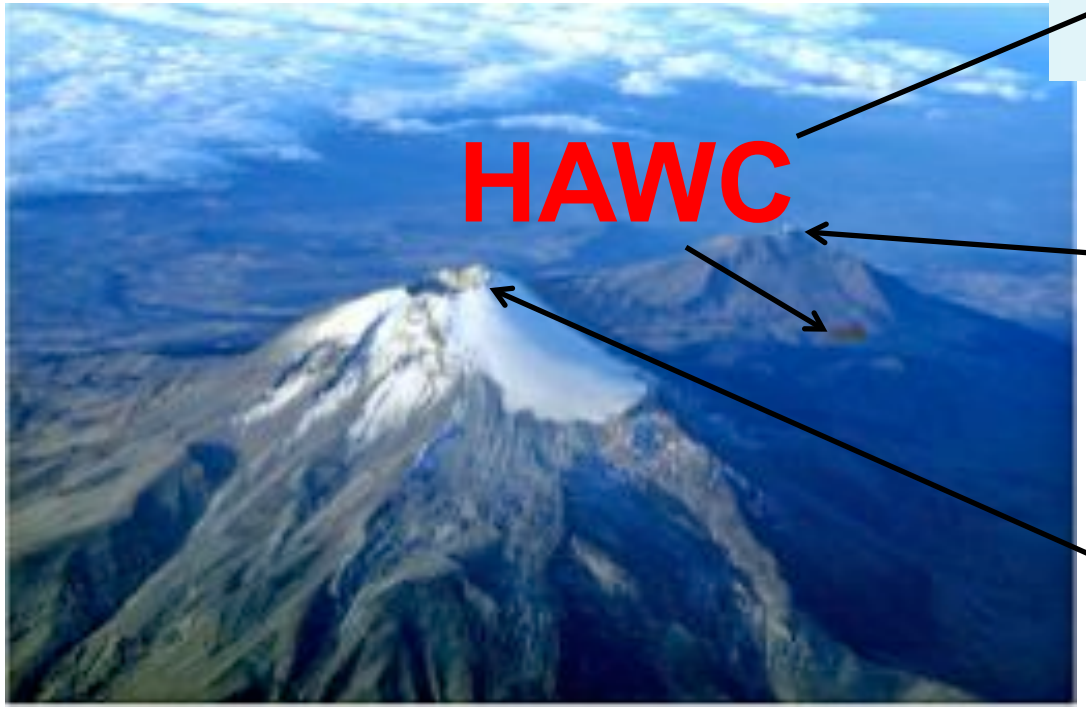
USA

Mexico

HAWC Site Location in Mexico

- 4100 m (13,500') above sea level
- Latitude of 19 deg N
- Temperate Climate
- Existing Infrastructure

See Poster of Alberto Carramiñana

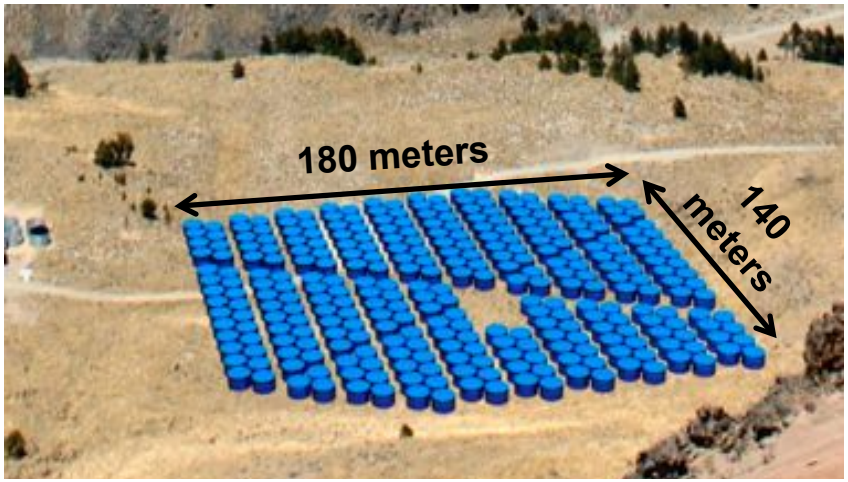


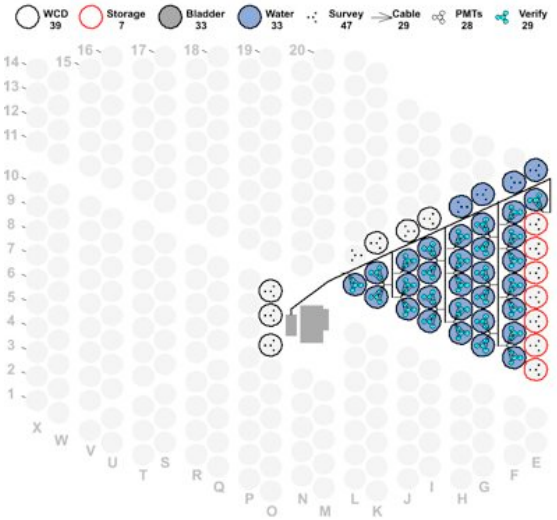
Large Millimeter Telescope (50m dia. dish)

Pico de Orizaba 5600 m (18,500')

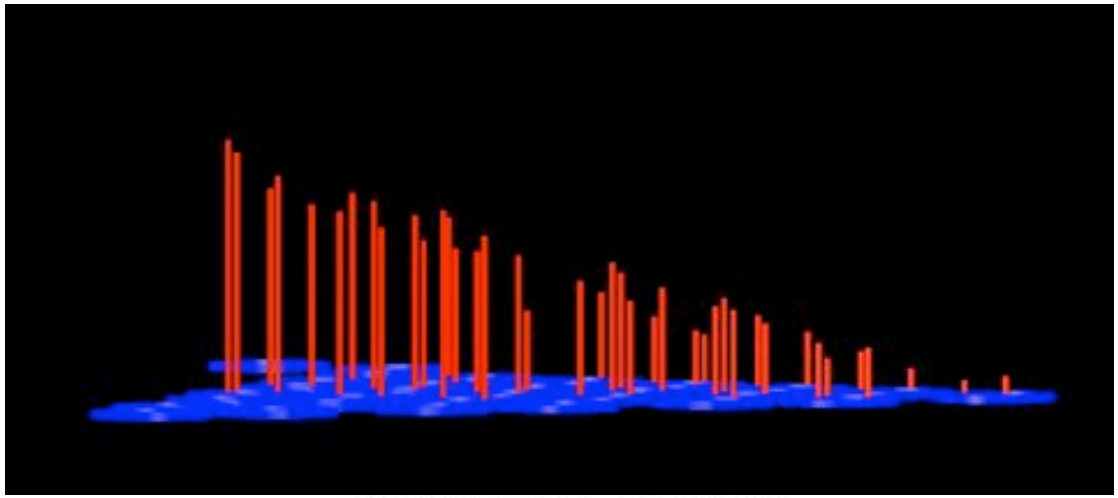
HAWC Design

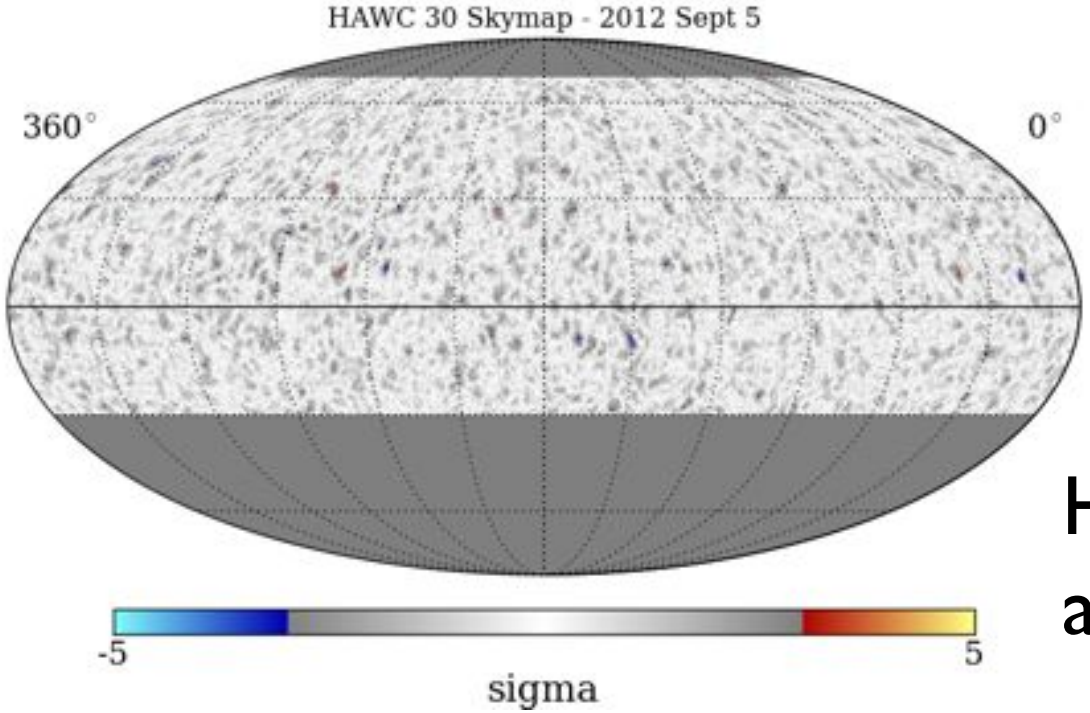
300 close packed water tanks (7.3m dia x 4.5 m deep of 200,000 liters) each with 4 upward facing photomultiplier tubes at the bottom

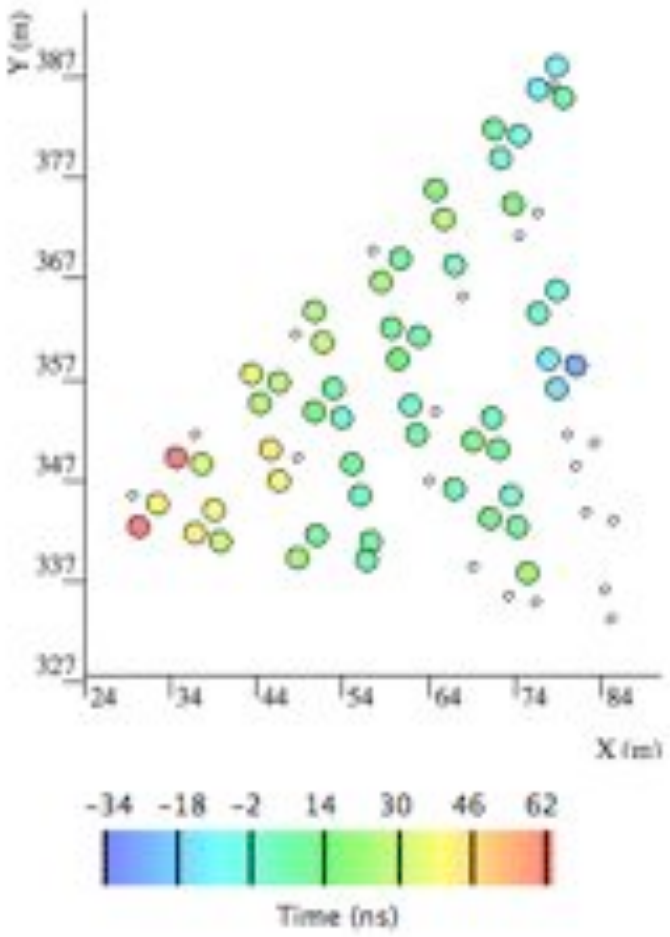




HAWC-30 Completed Sept 2012





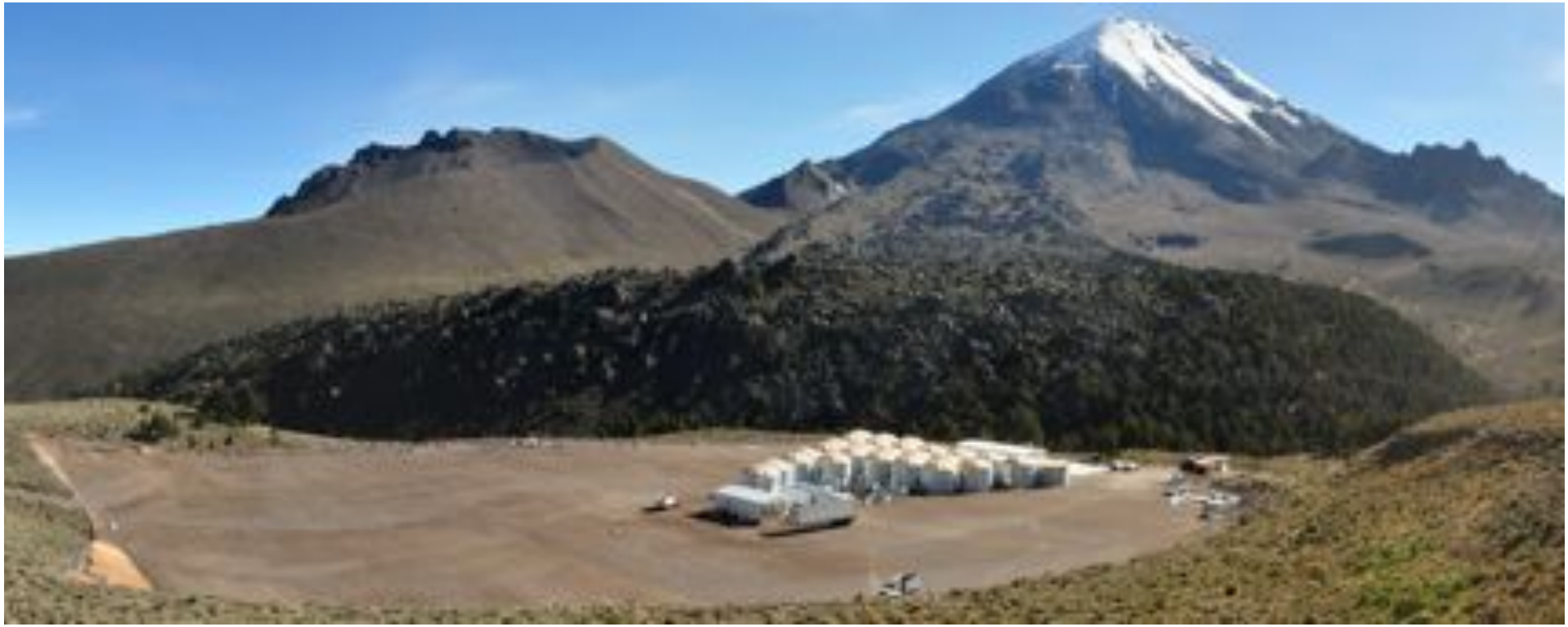


HAWC 30 Events
and one day Skymap

Construction Progressing Well

HAWC Science Soon

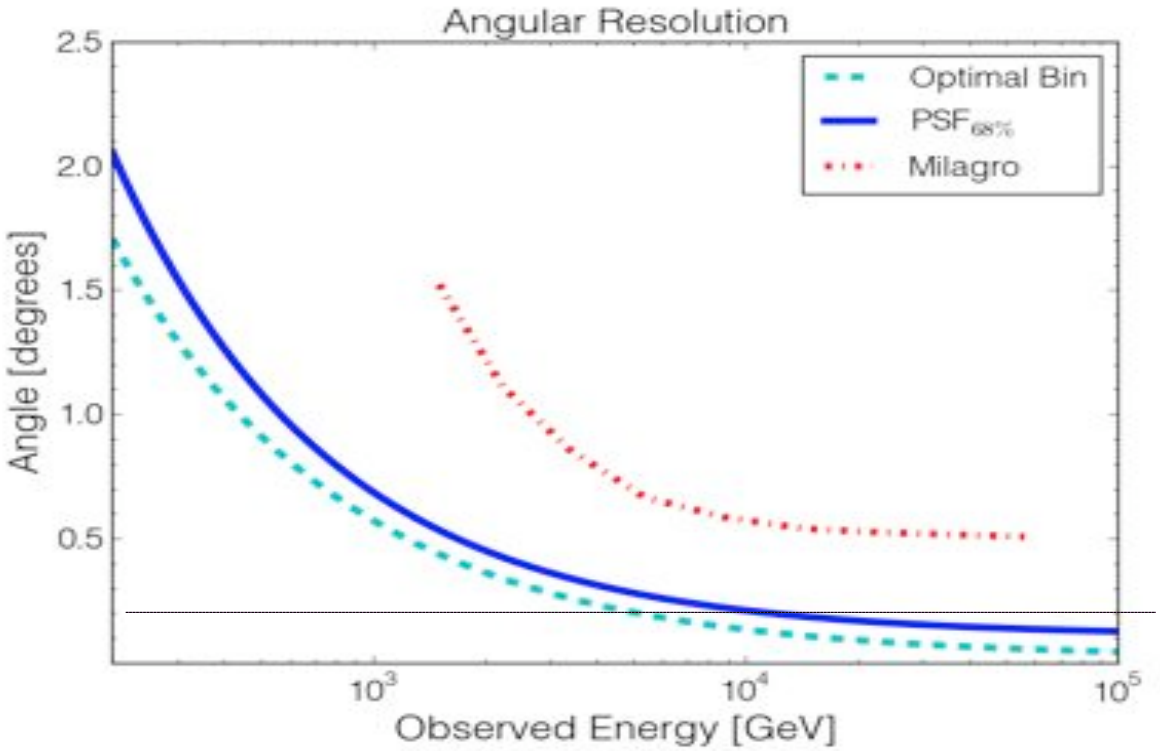
- Funding of 12M USD split between NSF, DOE, and CONACYT began Feb 2011
- 30 of 300 Water Cherenkov Detectors installed in Sept 2012
- 100 will be continuously operating August 2013 (with sensitivity to detect Crab in < 1 week)
- 300 expected to be complete in August 2014 (with sensitivity to detect Crab in < 1 day)



BACKUP

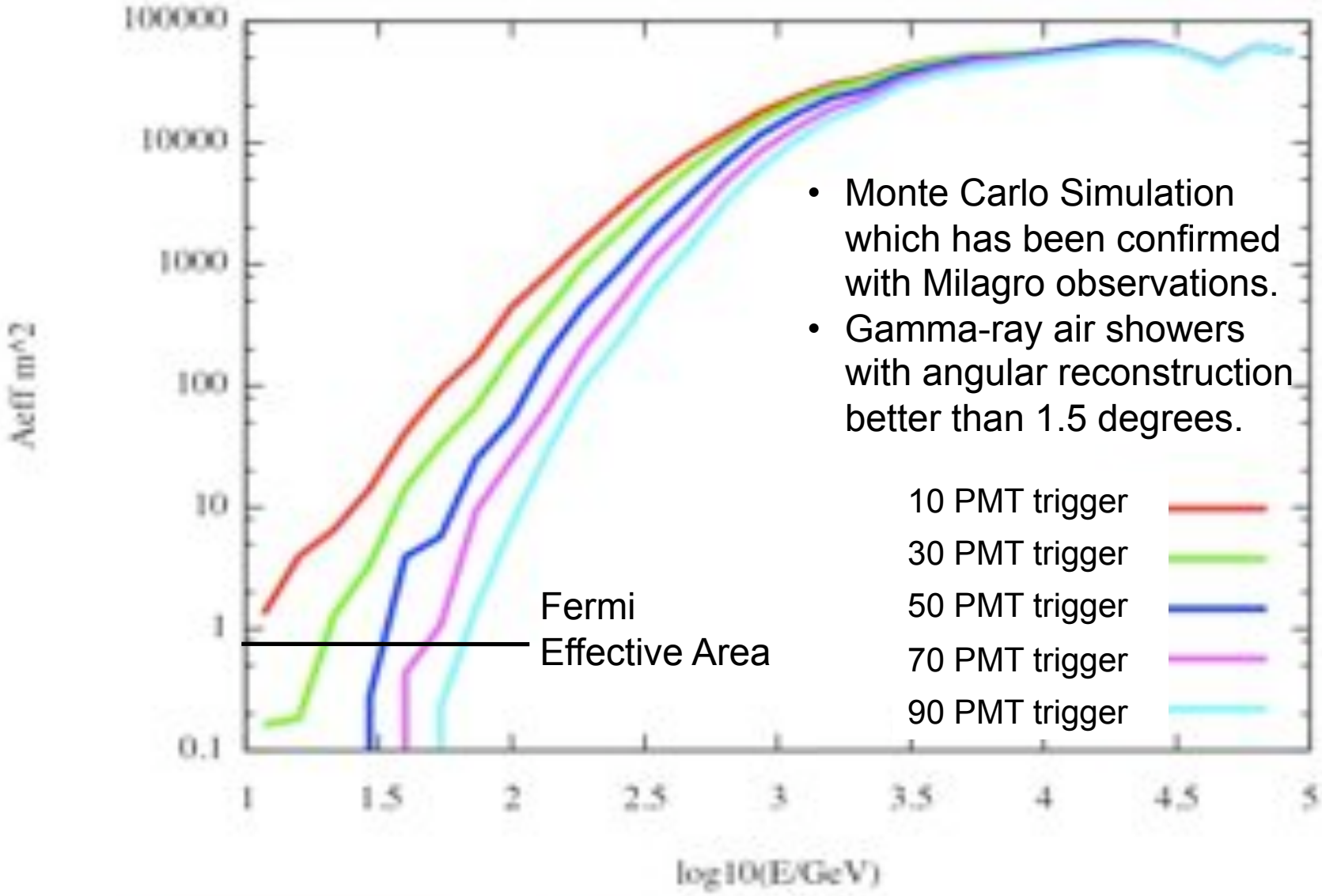
Angular Resolution

- Improved Angular Resolution from Milagro with larger detector and more particles detected at higher altitude



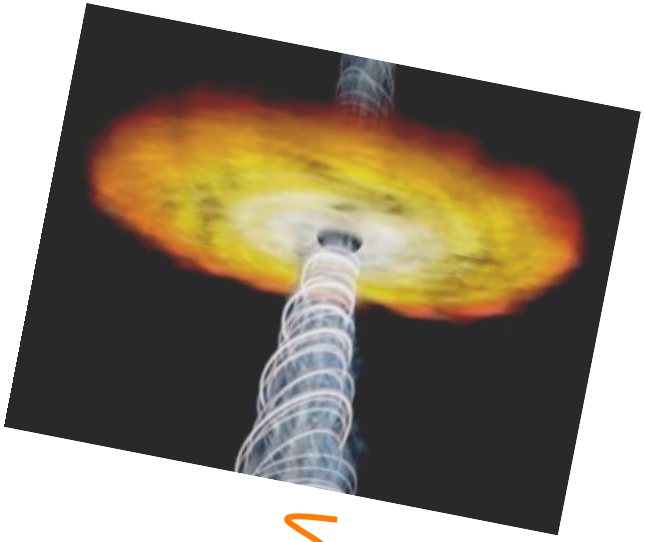
0.2 deg

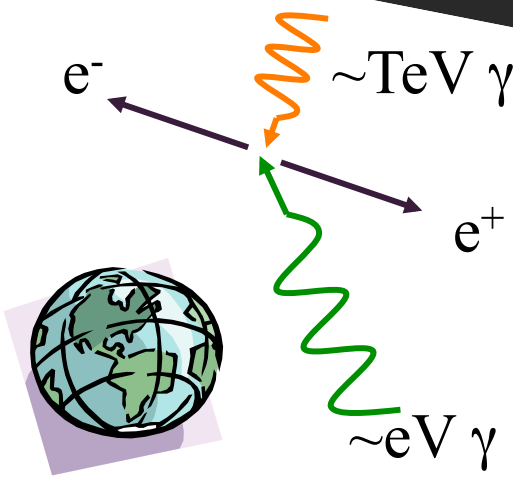
Pushing HAWC's Low Energy Response



- Monte Carlo Simulation which has been confirmed with Milagro observations.
- Gamma-ray air showers with angular reconstruction better than 1.5 degrees.

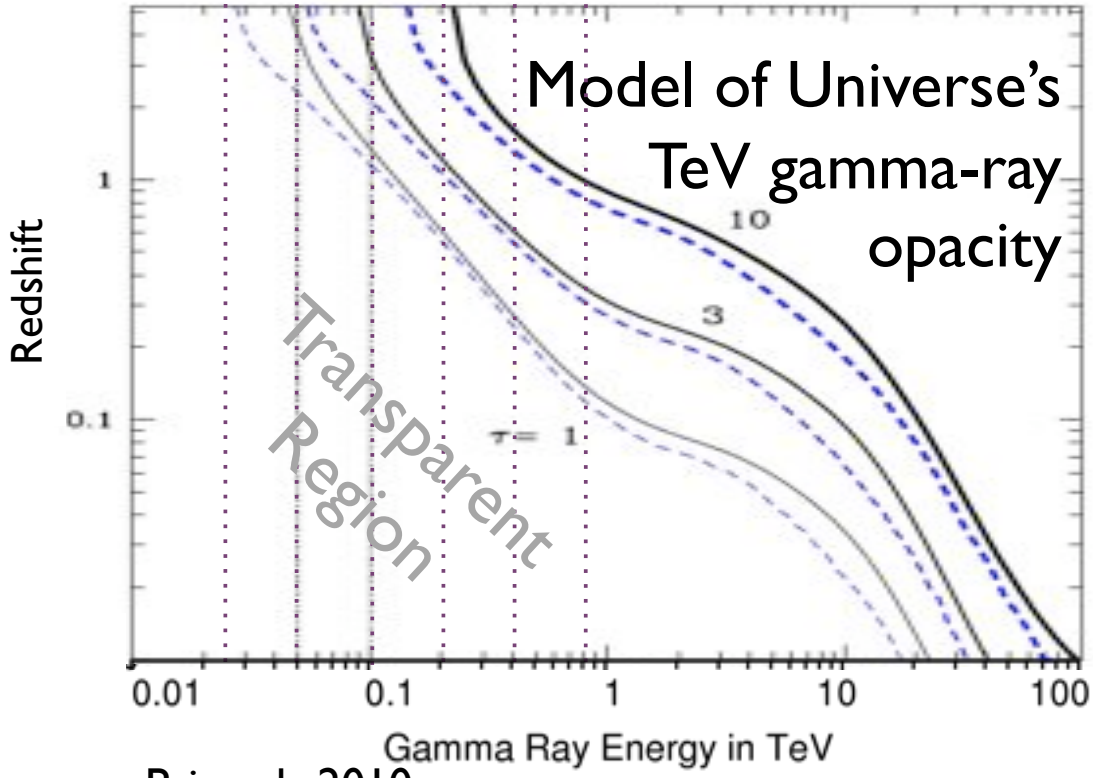
Extragalactic γ-ray Absorption





$I = I_o e^{-\tau}$

- High energy gamma rays pair produce with the infrared to UV extragalactic background light (EBL)
- EBL not well constrained by direct measurements due to foreground light
- EBL is constrained by galaxy and star formation history



Primack, 2010

Distinguishing Fundamental Physics from Astrophysics

Lorentz Invariance OR Astro Particle Acceleration

- HAWC will detect multiple flaring extragalactic sources (AGN and GRBs) to resolve distance vs source mechanisms

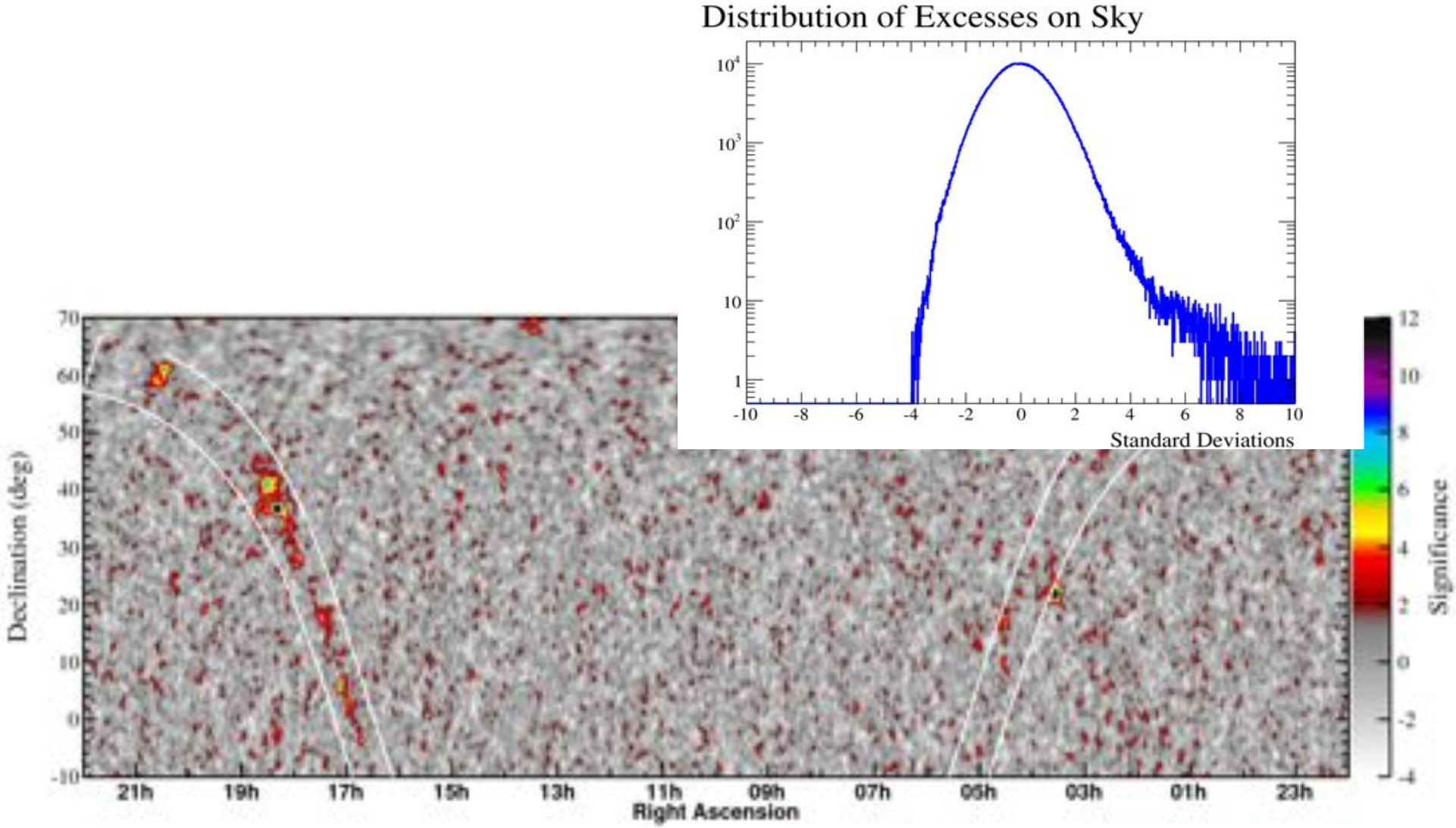
Axions or UHECRs or Cosmology OR Astro High E Cut-offs

- HAWC will measure the highest energy spectra of AGN
- HAWC will trigger multiwavelength observations of flaring AGN to obtain best measured and modeled TeV spectra

Dark Matter Annihilation OR Astro Source

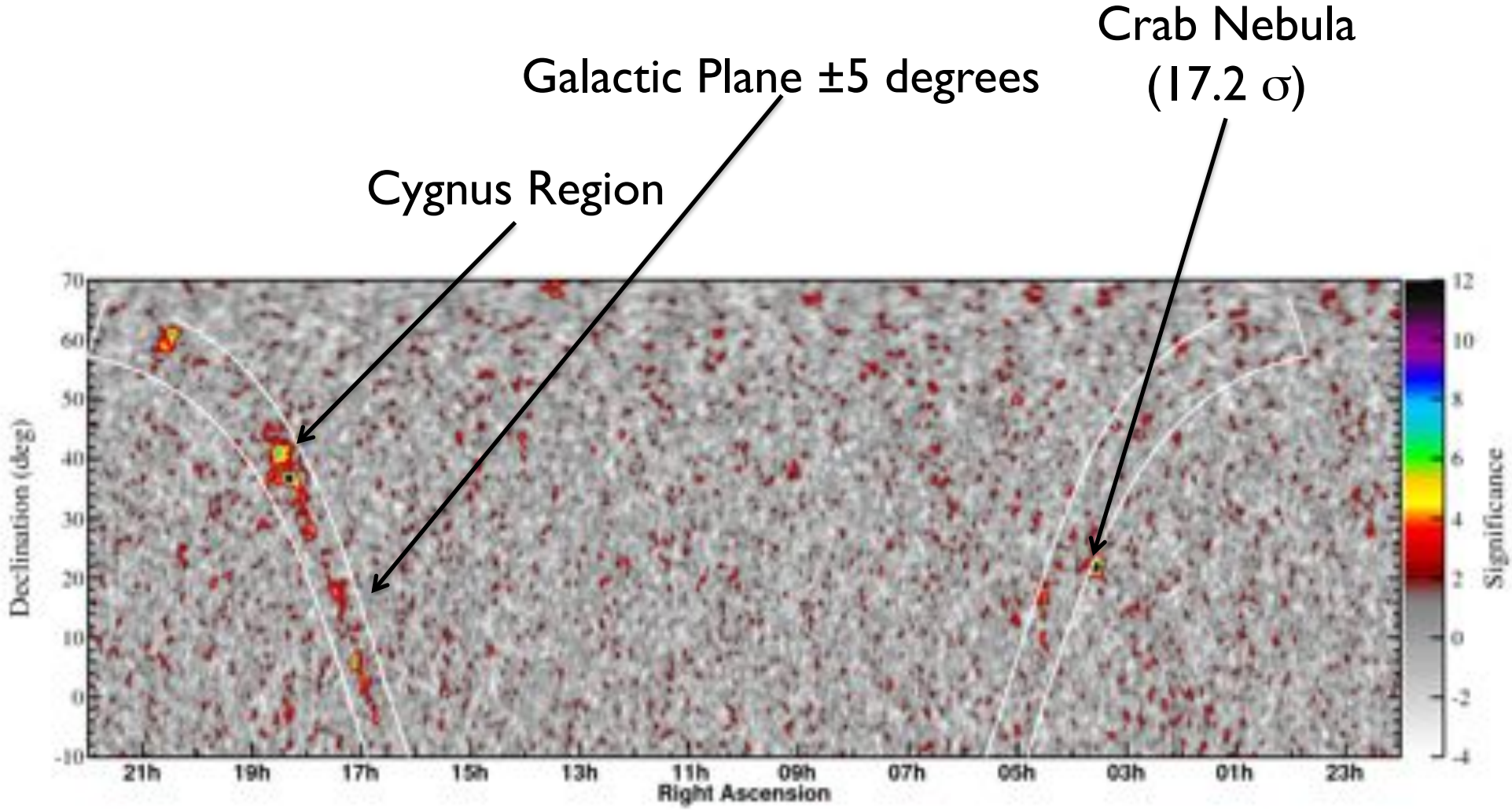
- HAWC will search for >10 TeV WIMPs from all M/L satellites, even when L=0, and from large regions around the Galactic center
- HAWC will search for time variability in gamma-ray sources (e.g.Galactic center) to rule out Dark Matter origin

HAWC Science Builds of Success of Milagro

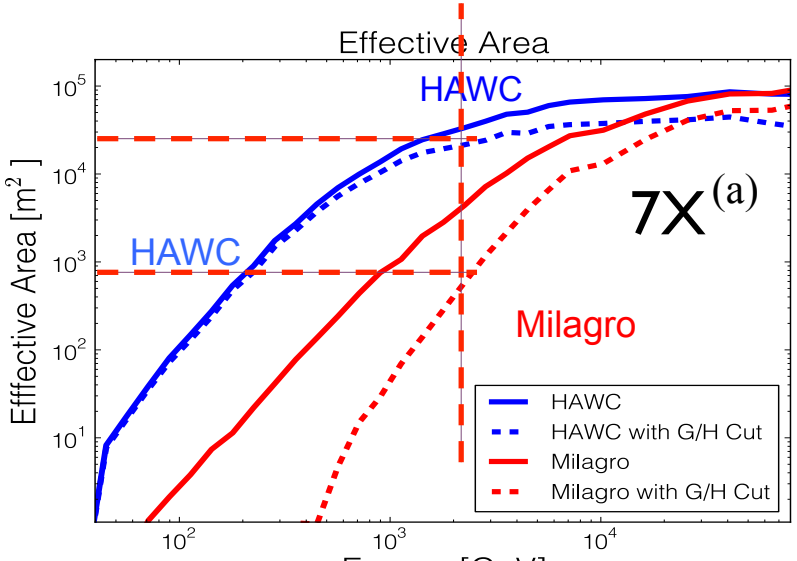


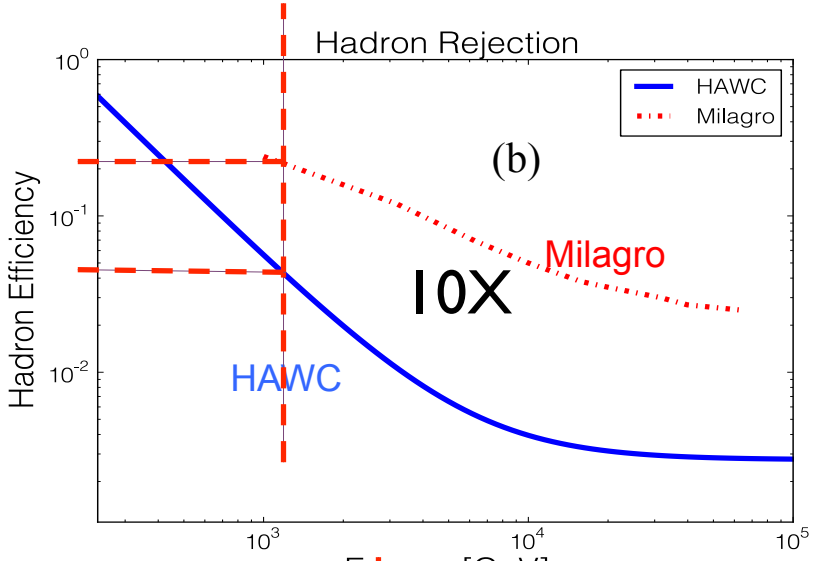
Milagro All Sky Map

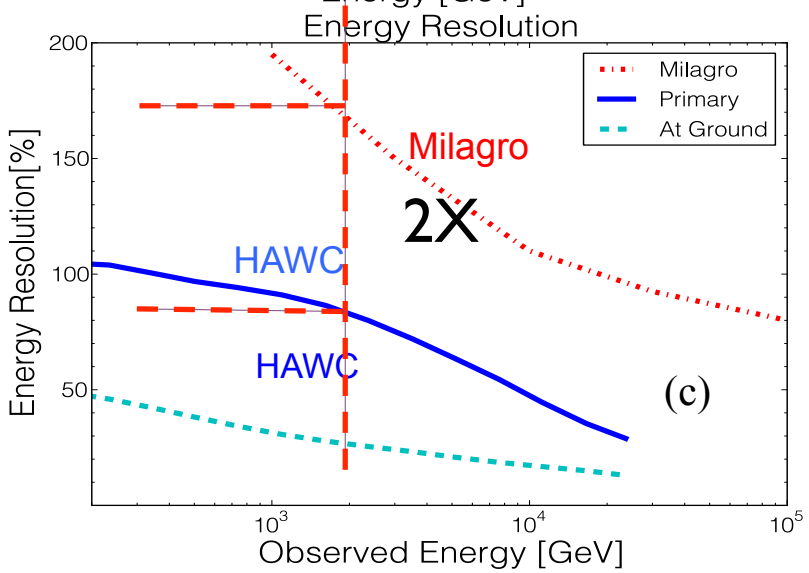
HAWC Science Builds of Success of Milagro

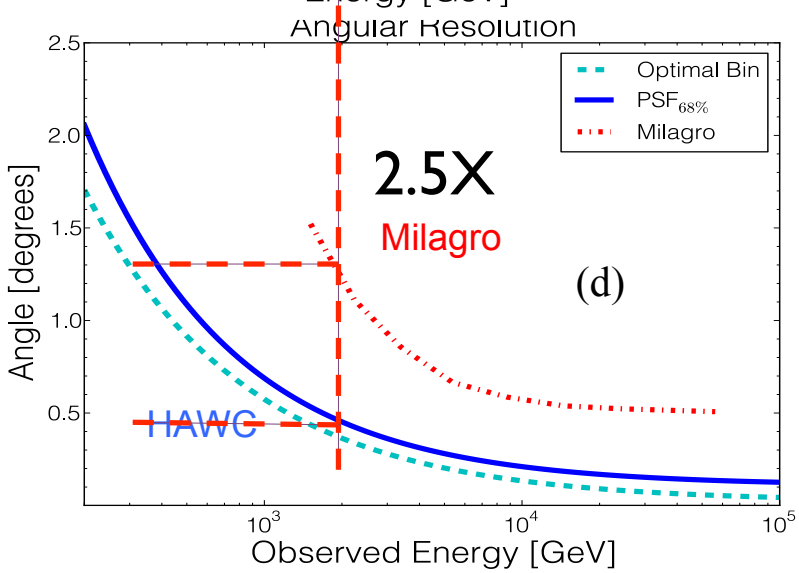


HAWC Performance at 2 TeV





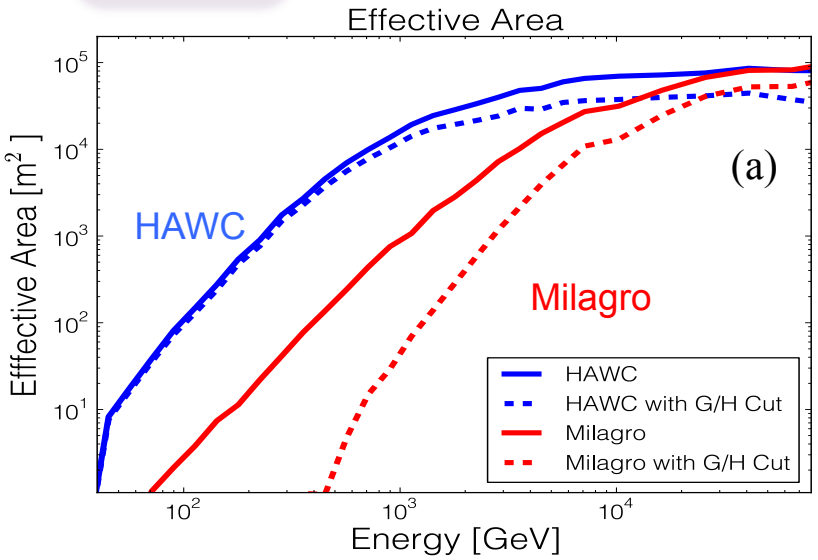


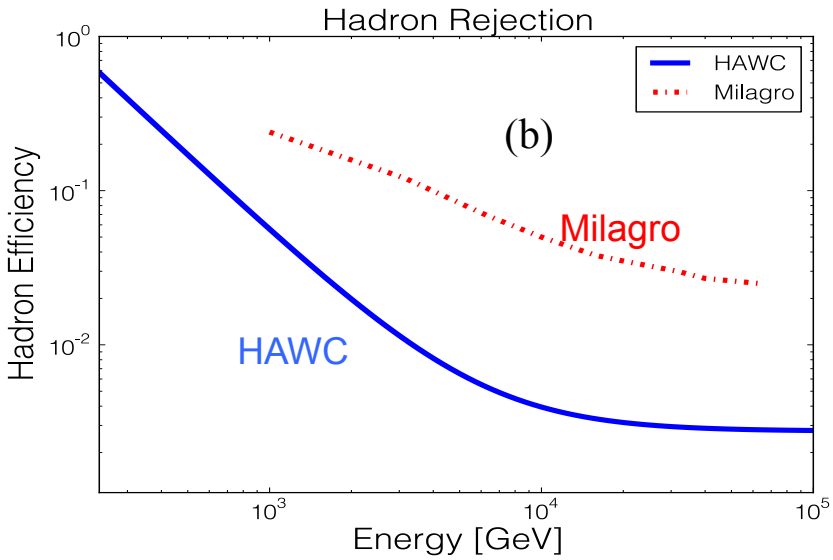


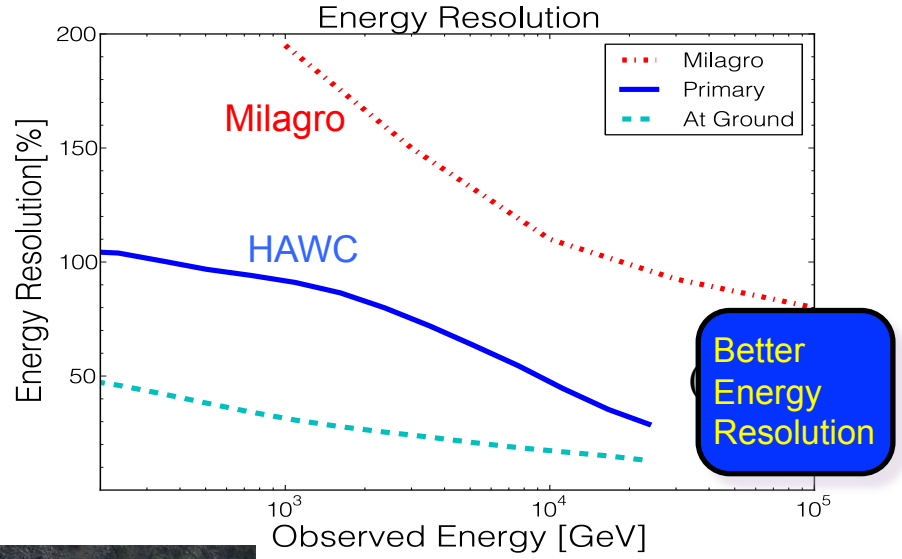
HAWC Performance

Much Better Low Energy Response

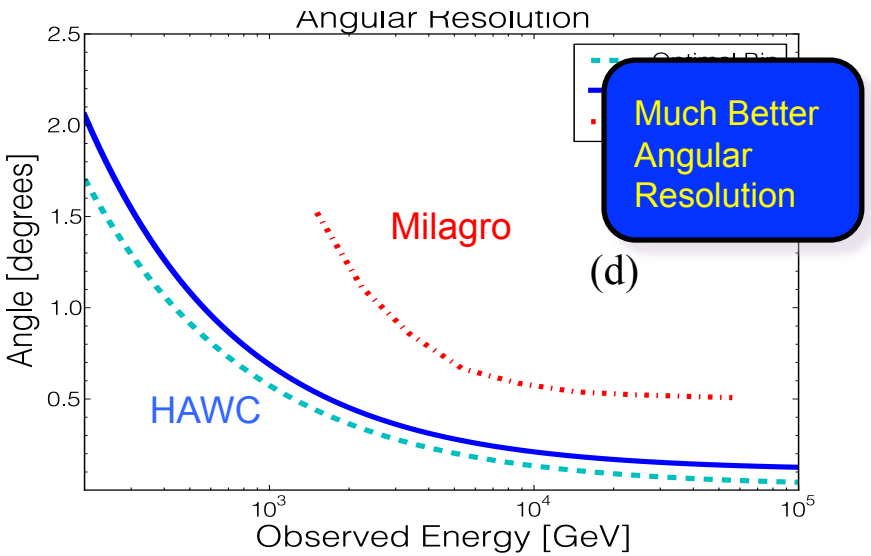
Much Better Background Rejection







Better Energy Resolution



Much Better Angular Resolution