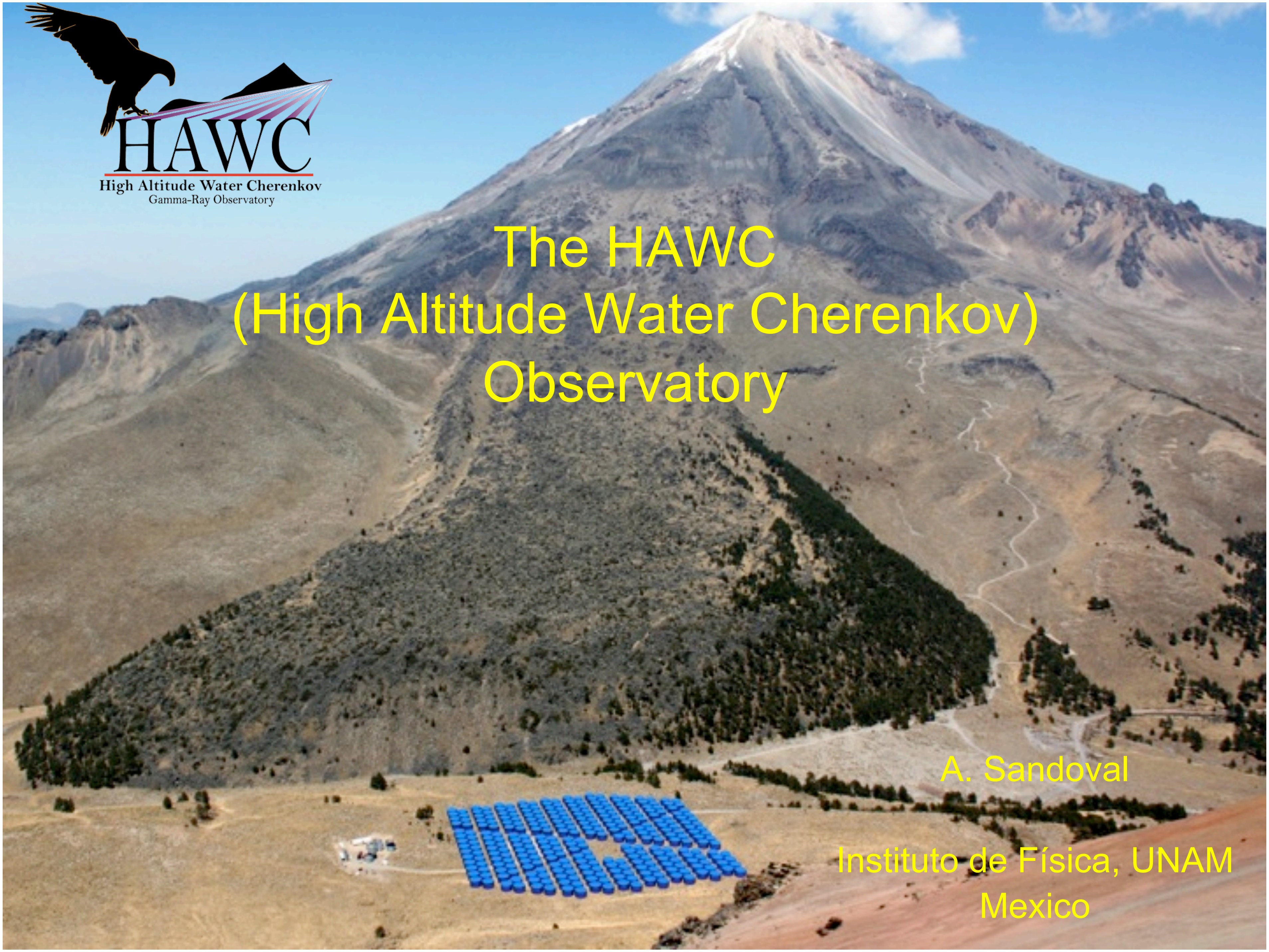


HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

The HAWC (High Altitude Water Cherenkov) Observatory

A. Sandoval

Instituto de Física, UNAM
Mexico

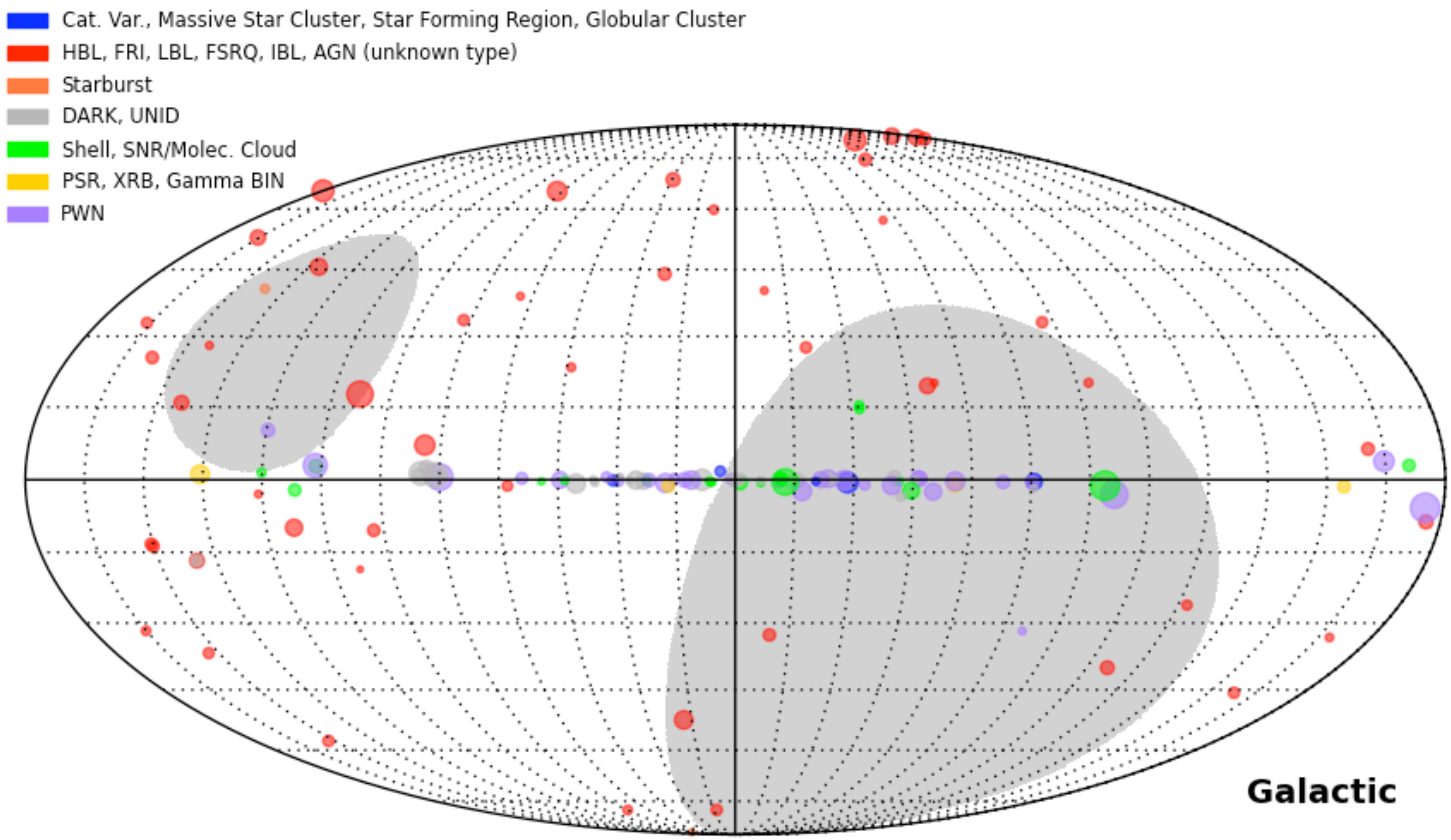
HAWC

Large field of view, continuously operating high energy gamma ray observatory (100 GeV- hundreds of TeV)

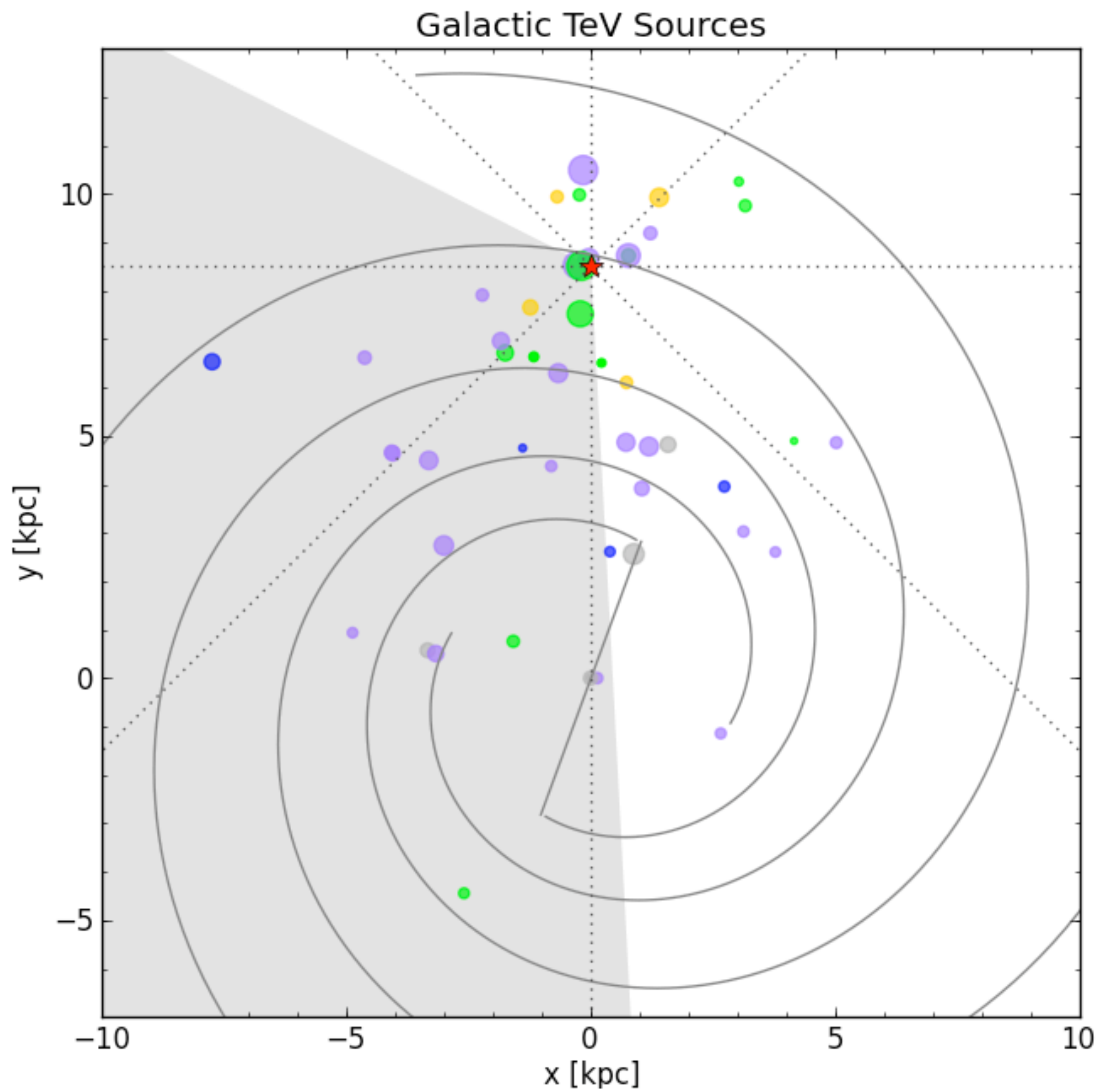
Aims

- Provide an unbiased map of the TeV sky (2π sr/day).
- Study transient emission from sources like AGN.
- Search for >100 GeV emission from GRBs.
- Measure the energy spectrum of Galactic sources up to the highest energies.
- Measure diffuse emission between 1 and 100 TeV
- Study small and large scale anisotropy of cosmic rays at energies > 1 TeV
- Search for new physics at TeV energies
- Provide TeV alerts for other instruments

TeVCAT sources accessible to HAWC



Galactic sources monitored for several hours every day by HAWC

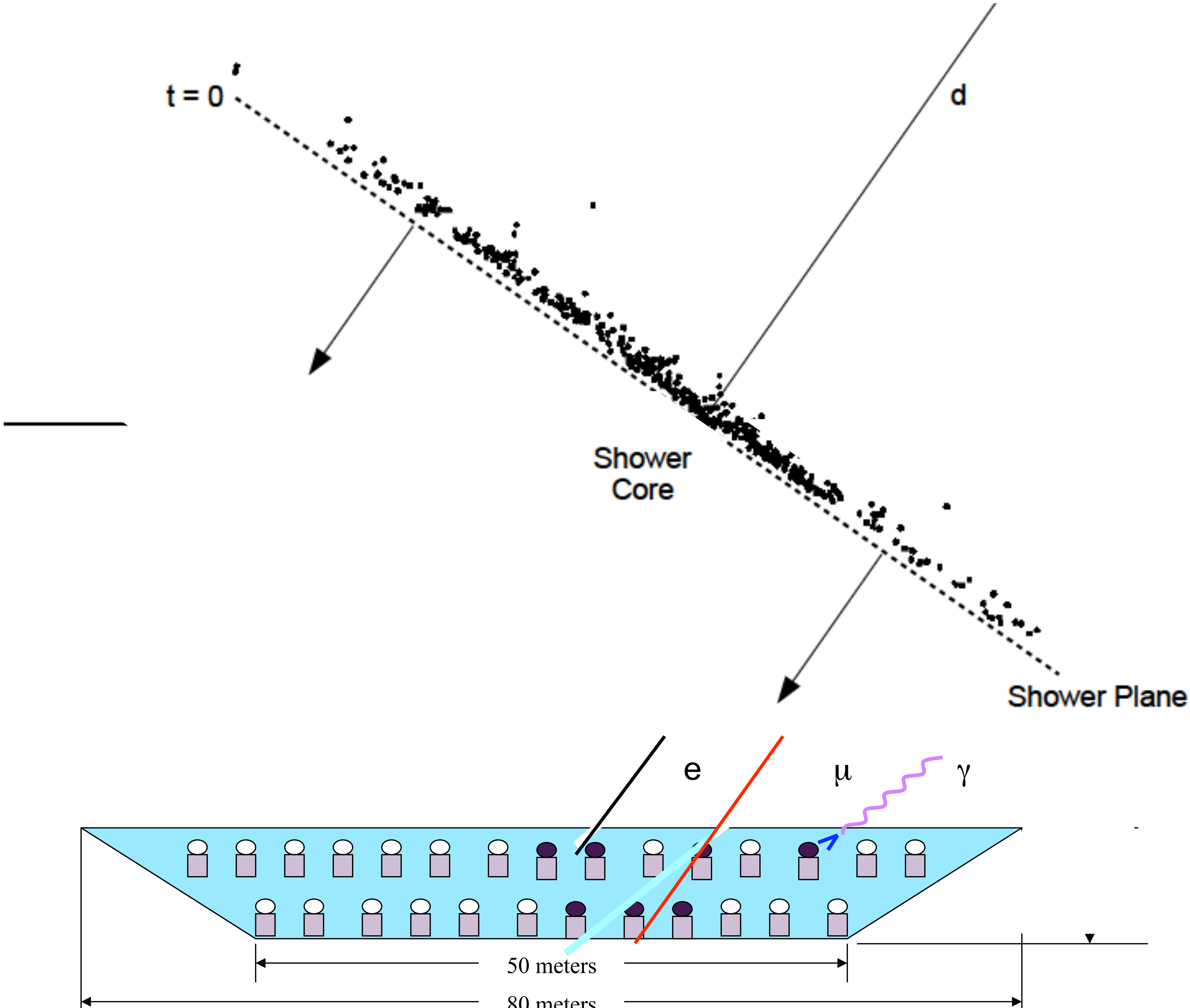


Precursor: Milagro Gamma Ray Observatory @ 2650m altitude near Los Alamos, NM

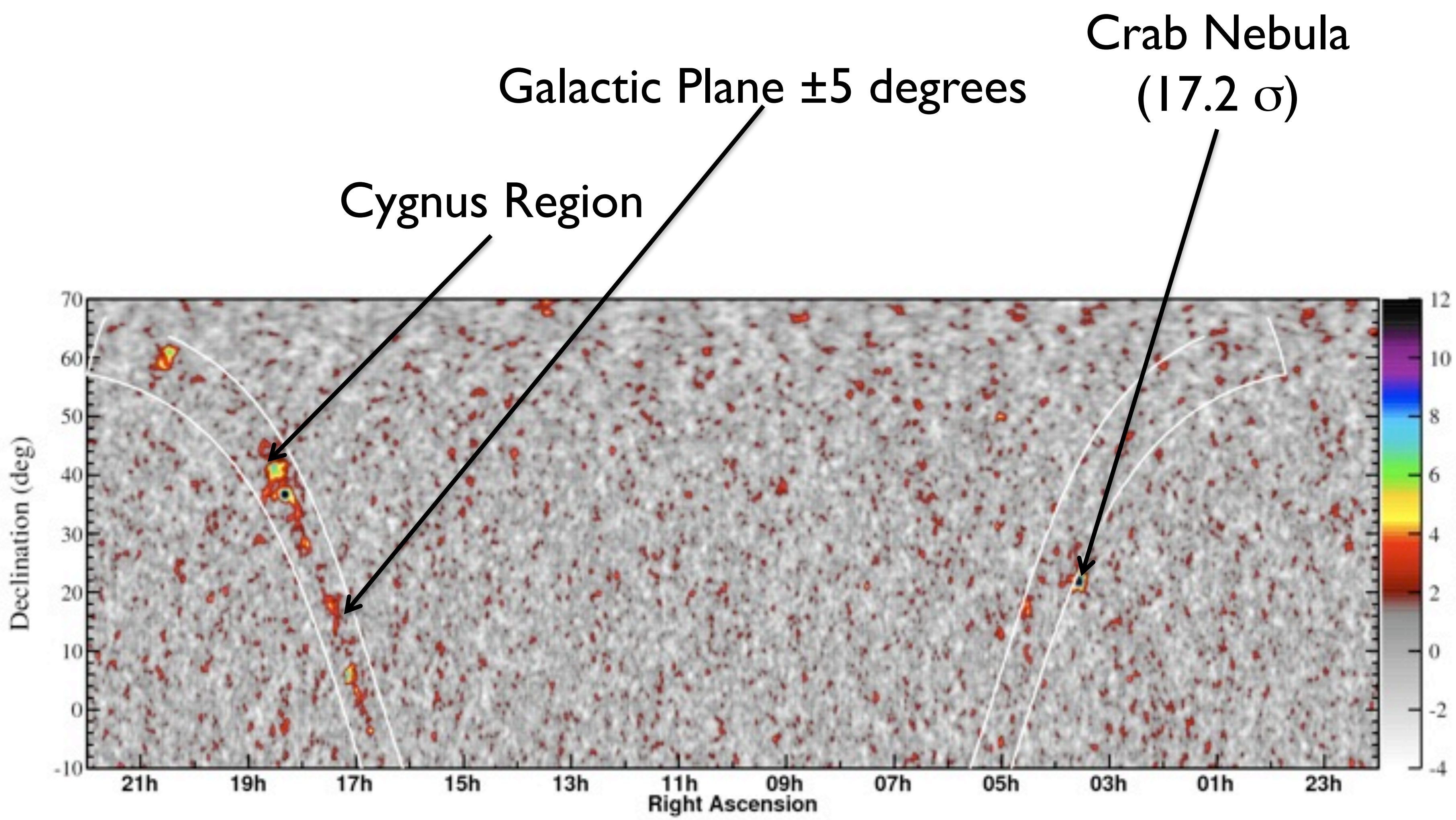
2000-2008

Inside the Milagro Detector

80m x 60m, 8m deep


t = 0
d
Shower
Core
Shower Plane
e
μ
γ
50 meters
80 meters

Milagro's Survey of the TeV Sky

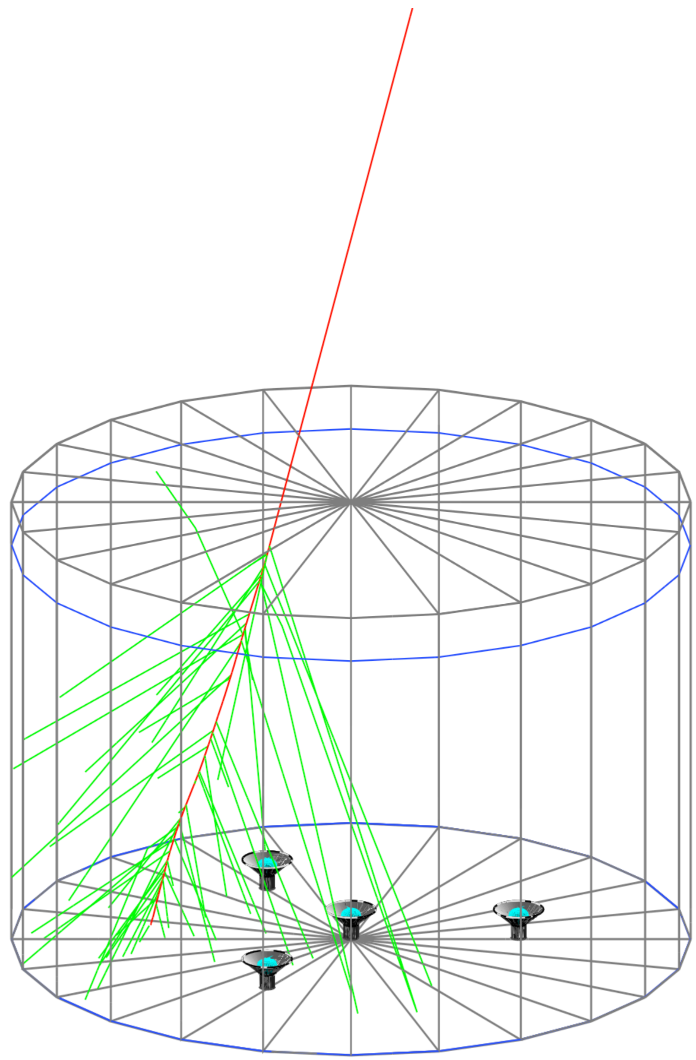


HAWC will detect Milagro sources with 15x significance.

From Milagro to HAWC

HAWC "2nd Generation" Water Cherenkov gamma-ray detector (2012 - ?)

- 300 water Cherenkov detectors (WCD)
- 7.3m ϕ, 4.5m high, 200,000 l purified water
- spread over 25000 m^2
- 4100 m elevation near Puebla, Mexico
- Construction 2010-2014
- 15 x Milagro's sensitivity with 10 x lower energy threshold



HAWC Collaboration

México

- Benemérita Universidad Autónoma de Puebla
- CINVESTAV
- INAOE Site
- Instituto Politecnico de Pachuca
- Universidad Autónoma de Chiapas
- Universidad Autónoma de Hidalgo
- Universidad de Guadalajara
- Universidad de Guanajuato
- Universidad Michoacana de S N de Hidalgo
- Universidad Nacional Autónoma de México
  - Instituto de Astronomía
  - Instituto de Física CONACYT funding
  - Instituto de Ciencias Nucleares
  - Instituto de Geofísica

USA

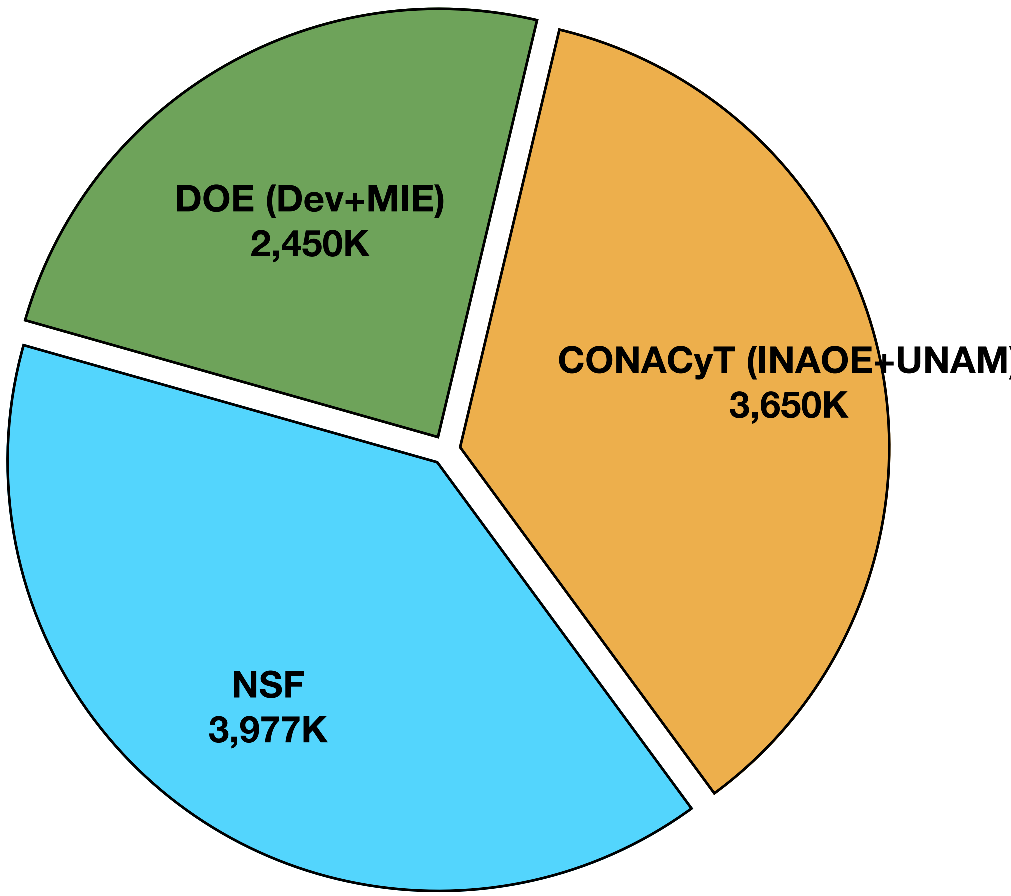
- Colorado State University
- George Mason University
- Georgia Institute of Technology
- Harvey Mudd College
- Los Alamos National Laboratory DoE funding
- Michigan State University
- Michigan Technological University
- NASA/Goddard Space Flight Center
- Ohio State University at Lima
- Pennsylvania State University
- University of California, Irvine
- University of California, Santa Cruz
- University of Maryland NSF funding
- University of New Hampshire
- University of New Mexico
- University of Utah
- University of Wisconsin-Madison

HAWC financing

Total construction cost
$10 million USD

(plus $3.9 million personnel)

Invested up to 1/05/2012
$6.3 million USD



HAWC Site Located in CentralMexico

Volcan Sierra Negra
- Latitude of 19 deg N
- Temperature 2-5^{o}C
- Existing Infrastructure
  - 1 km from >$100M US/Mexico Large Millimeter Telescope
  - Power, Internet, Roads

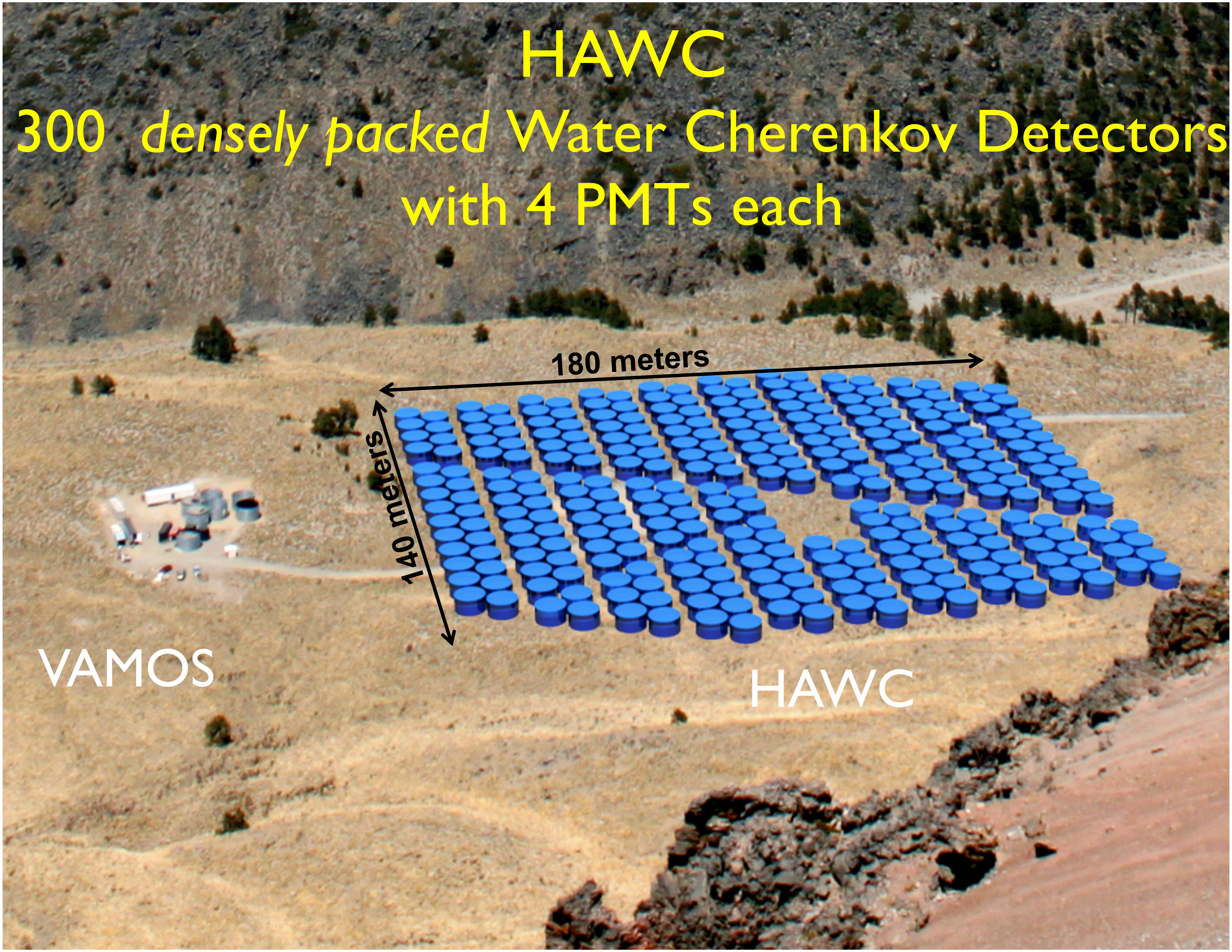
Large Millimeter Telescope
4600 m elevation

HAWC
4100 m elevation

Pico de Orizaba
5600 m elevation

HAWC

300 *densely packed* Water Cherenkov Detectors with 4 PMTs each



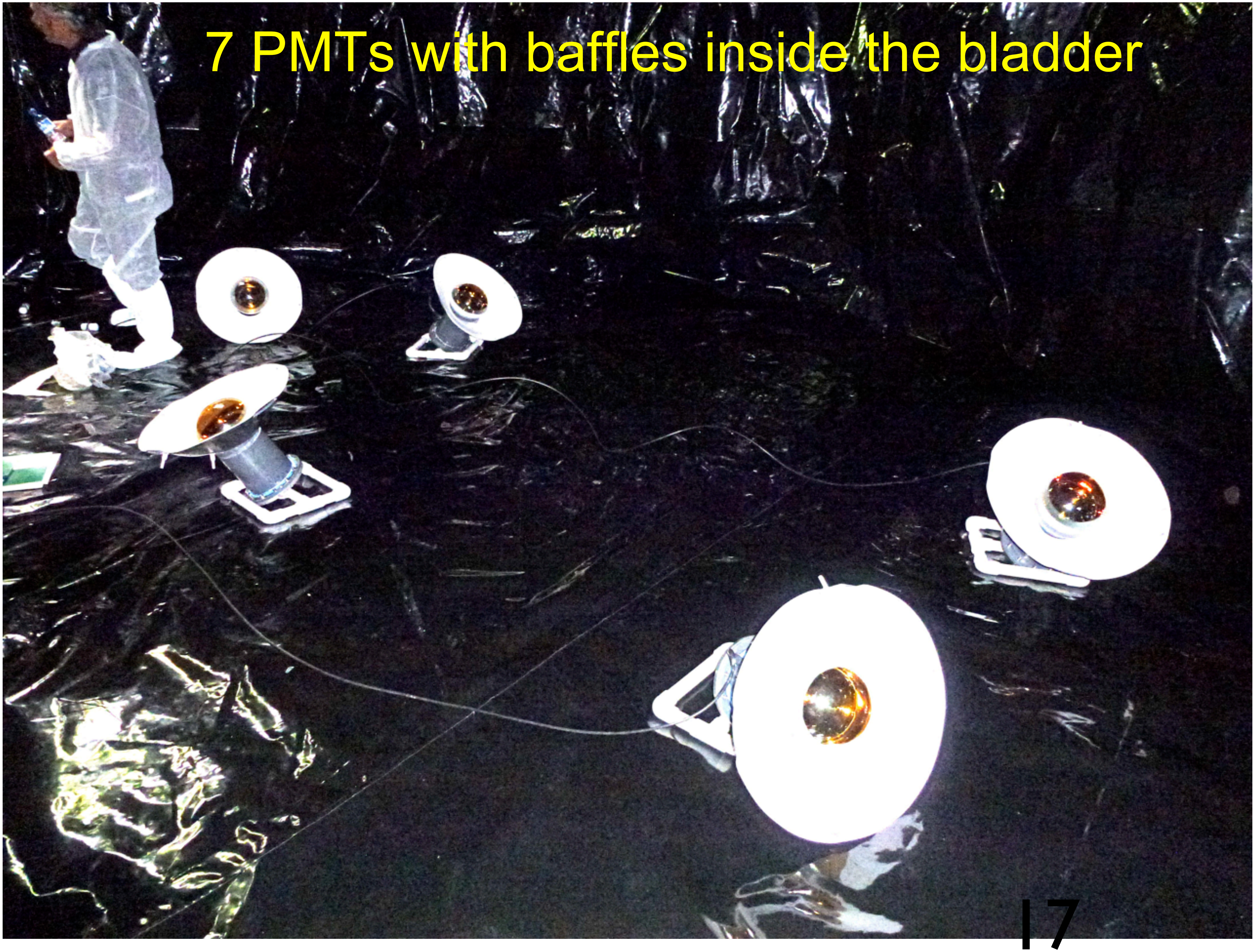
Detector container made of a corrugated metal tank

Light and water-tight Bladders

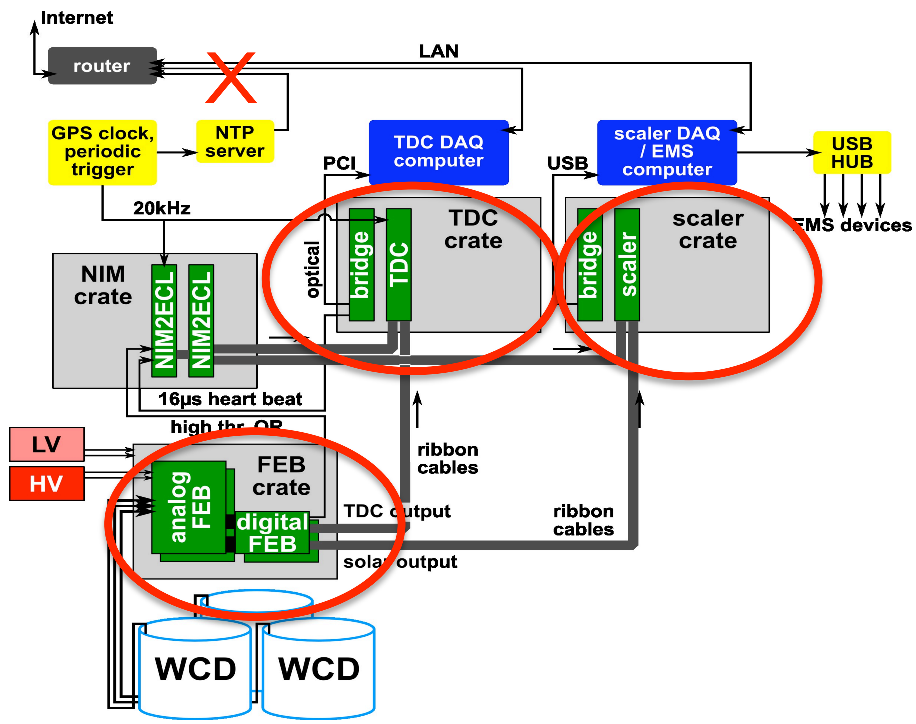
Made by CSU with plastic film similar to Auger liners.

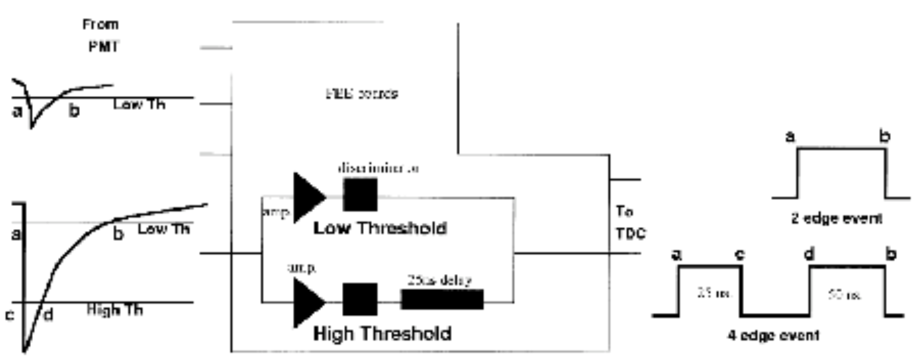
Each bladder weighs < 140 Kg and fits in a 75cmx2.7m tube.


VAMOS array of 7 WCDs
engineering prototype to test HAWC
construction methods
took data Oct 2011- April 2012


7 PMTs with baffles inside the bladder

Front End Electronics and DAQ as in HAWC





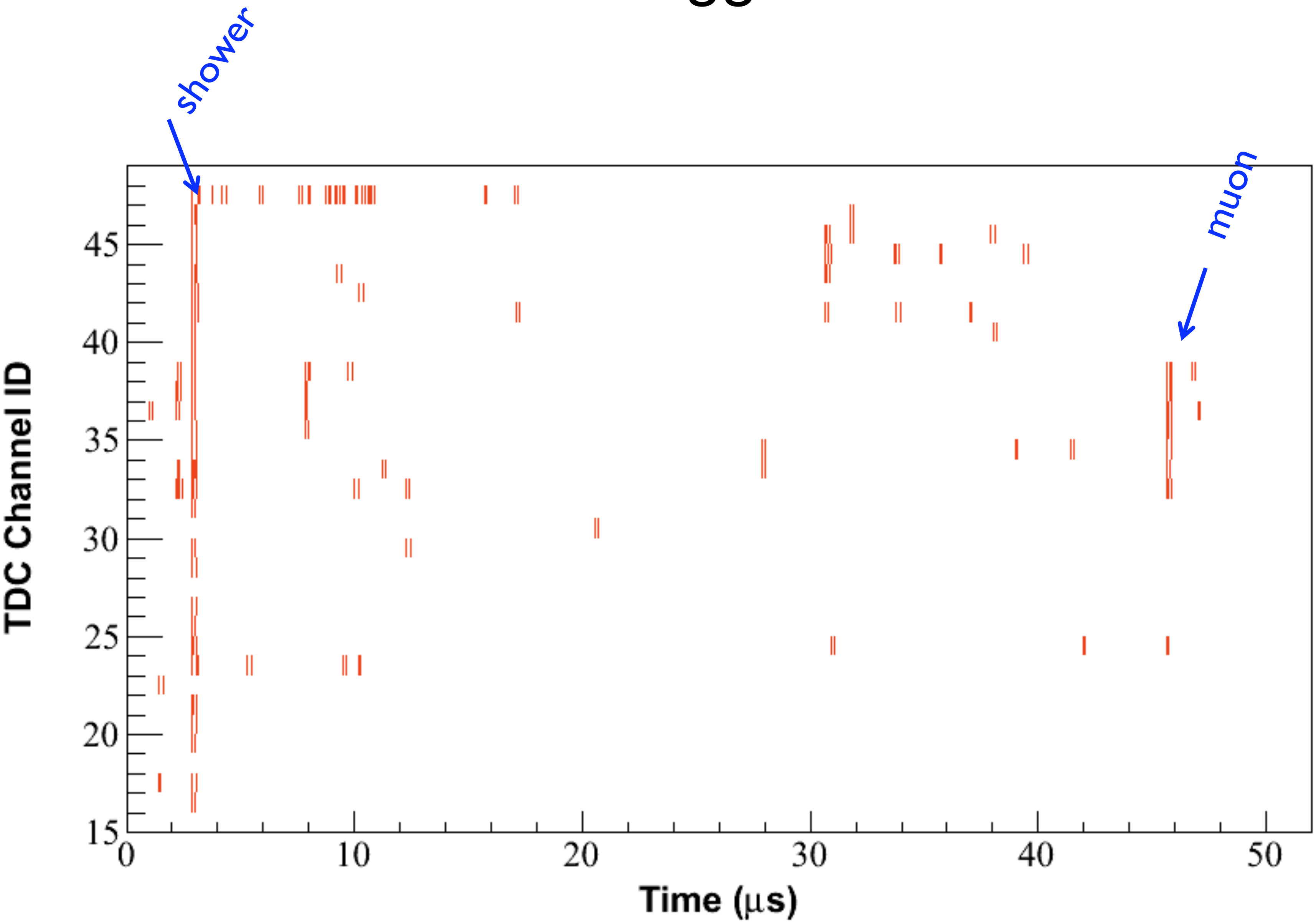
EMS records pressure, temp, water level

Scalers take single rates and are readout every 10 ms

TDC record the ToT of every signal above ¼ and 5 single photo electrons
~30 kHz/PMT
11 MB/s to disk

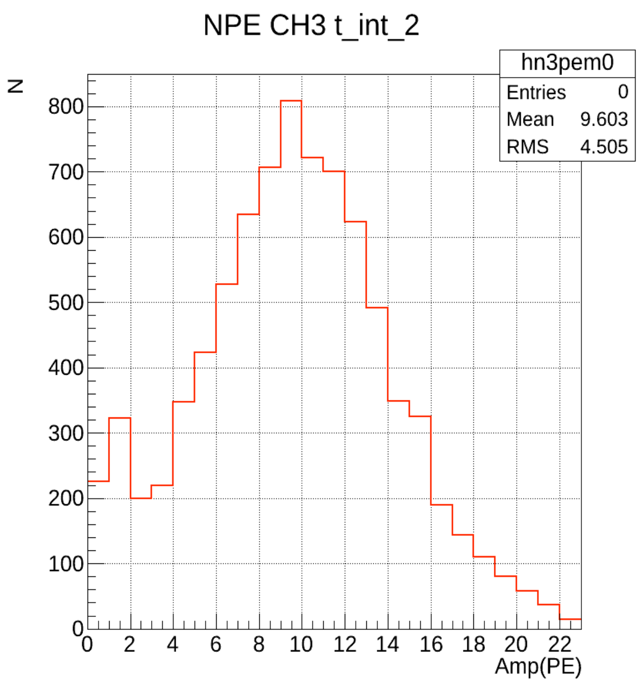
Data stored in 8 TB portable disk arrays
they are transported to UNAM
read into the ICN cluster and mirrored to UMD
26 TB recorded during October

Data taken un-triggered at 11 Mb/s

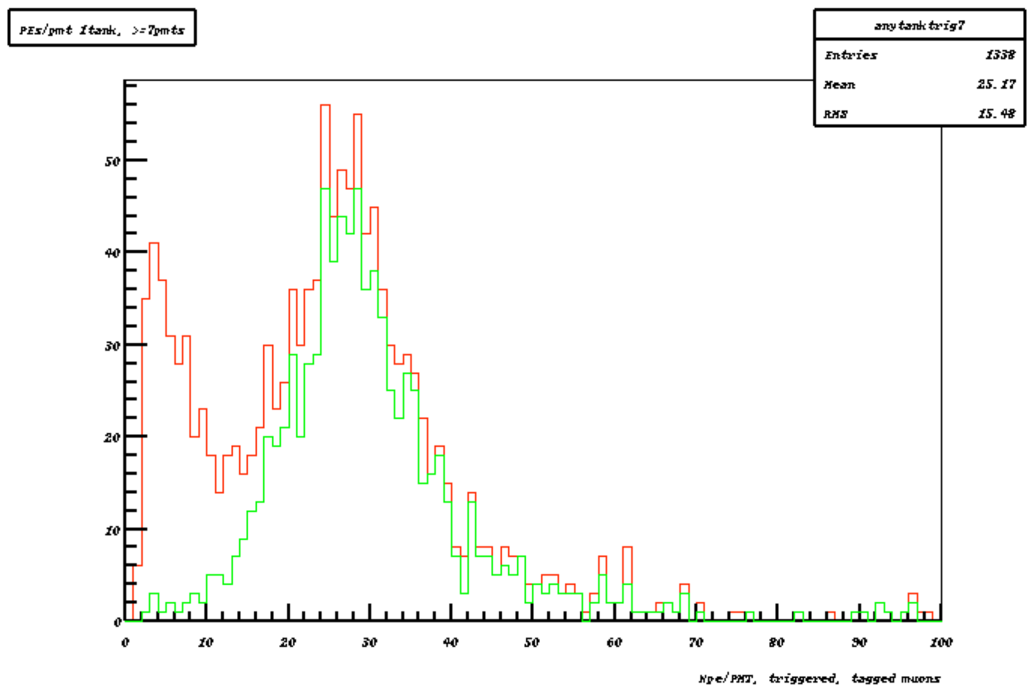


Vertical muon signature compared to simulation

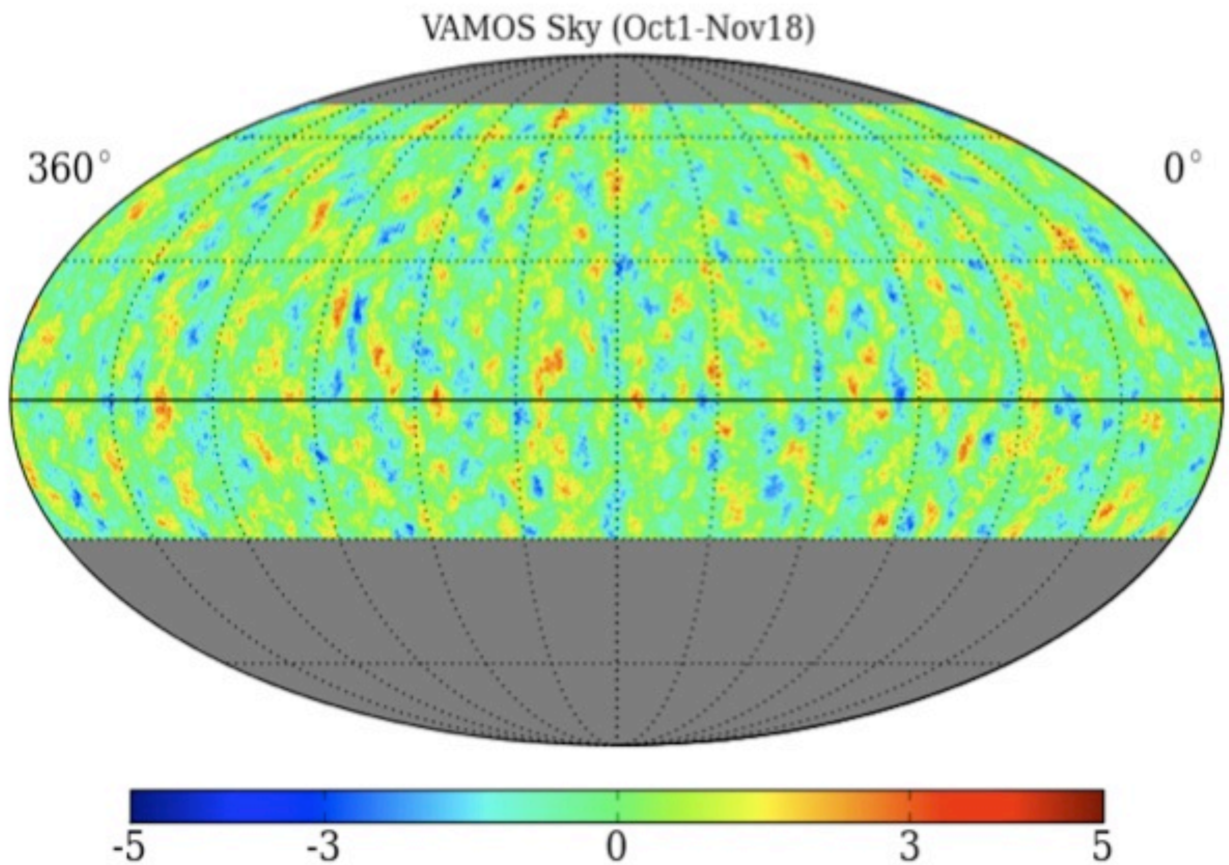
4 PMT in 2 ns
coincidence



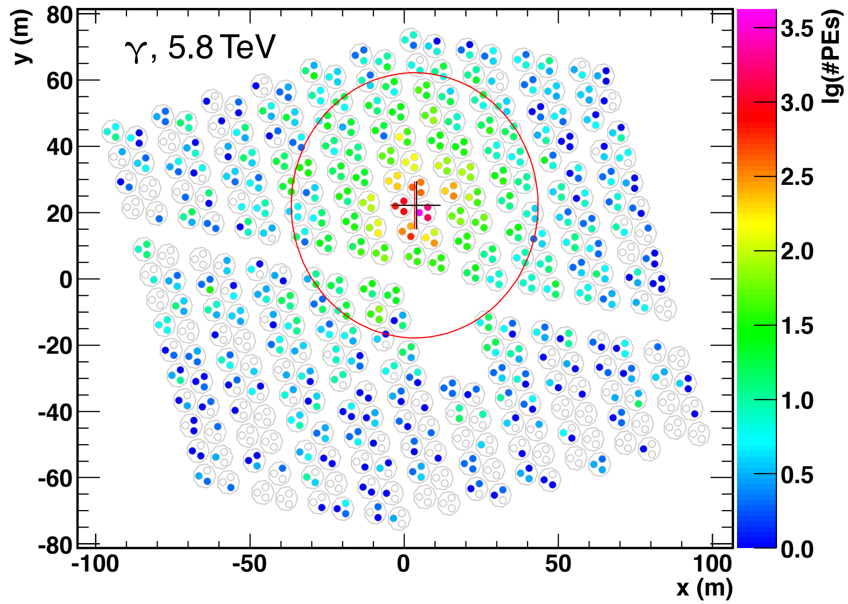
Monte Carlo simulation
red all particles
green muons

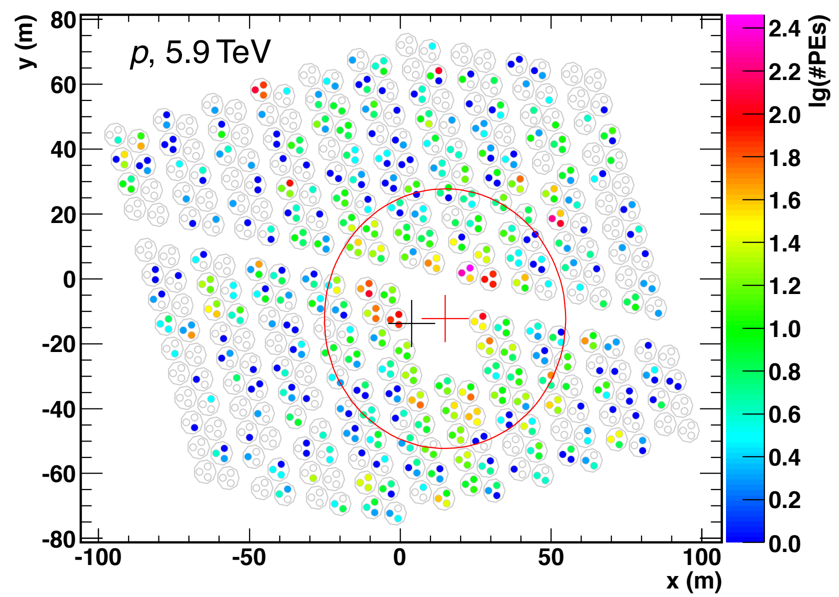


VAMOS Skymap
2 x 10^9 reconstructed showers



HAWC gamma/hadron discrimination



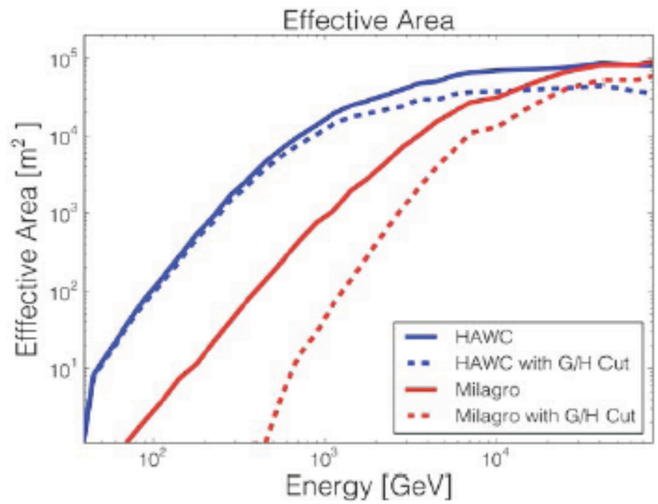


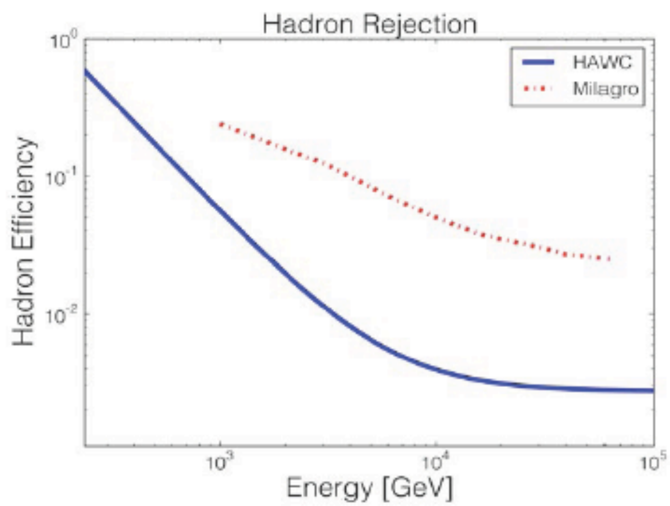
Use the topology of the shower amplitude distribution

- **gamma showers**
  electromagnetic
  smooth

-**hadron showers**
  high energy particles at large angles, pions → muons
  spotty

Performance





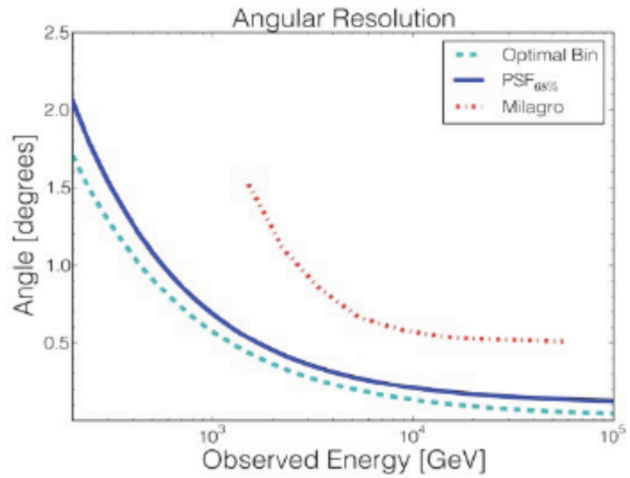
Effective area:

- HAWC has a lower threshold and a much better low energy response than Milagro.
- HAWC and Milagro have a similar effective area at high energy.
- Effective area at 100 GeV is still about ~100 m^2.
- At 2 TeV, the effective area of HAWC is ~7 times larger than Milagro.

Hadron rejection:

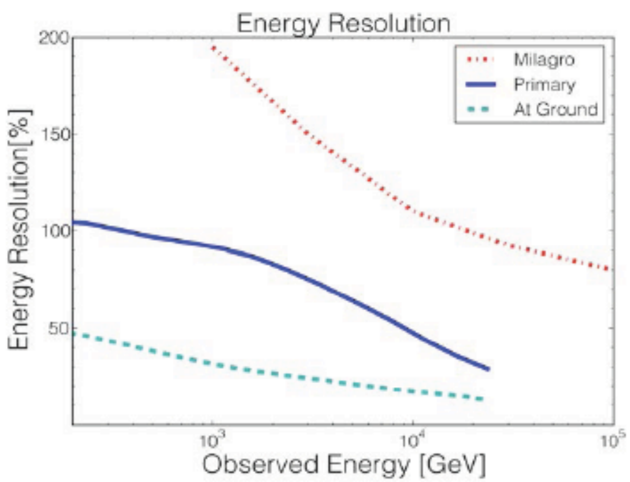
- Plot shows hadron efficiency for a 50% gamma efficiency.
- At 2 TeV, hadron rejection is ~10 times better than Milagro.

Performance



Angular resolution:

- Resolution is <0.5° above TeV.
- Even at low energies, the resolution is better than 2°.
- At 2 TeV, the angular resolution is ~2 times better than Milagro.

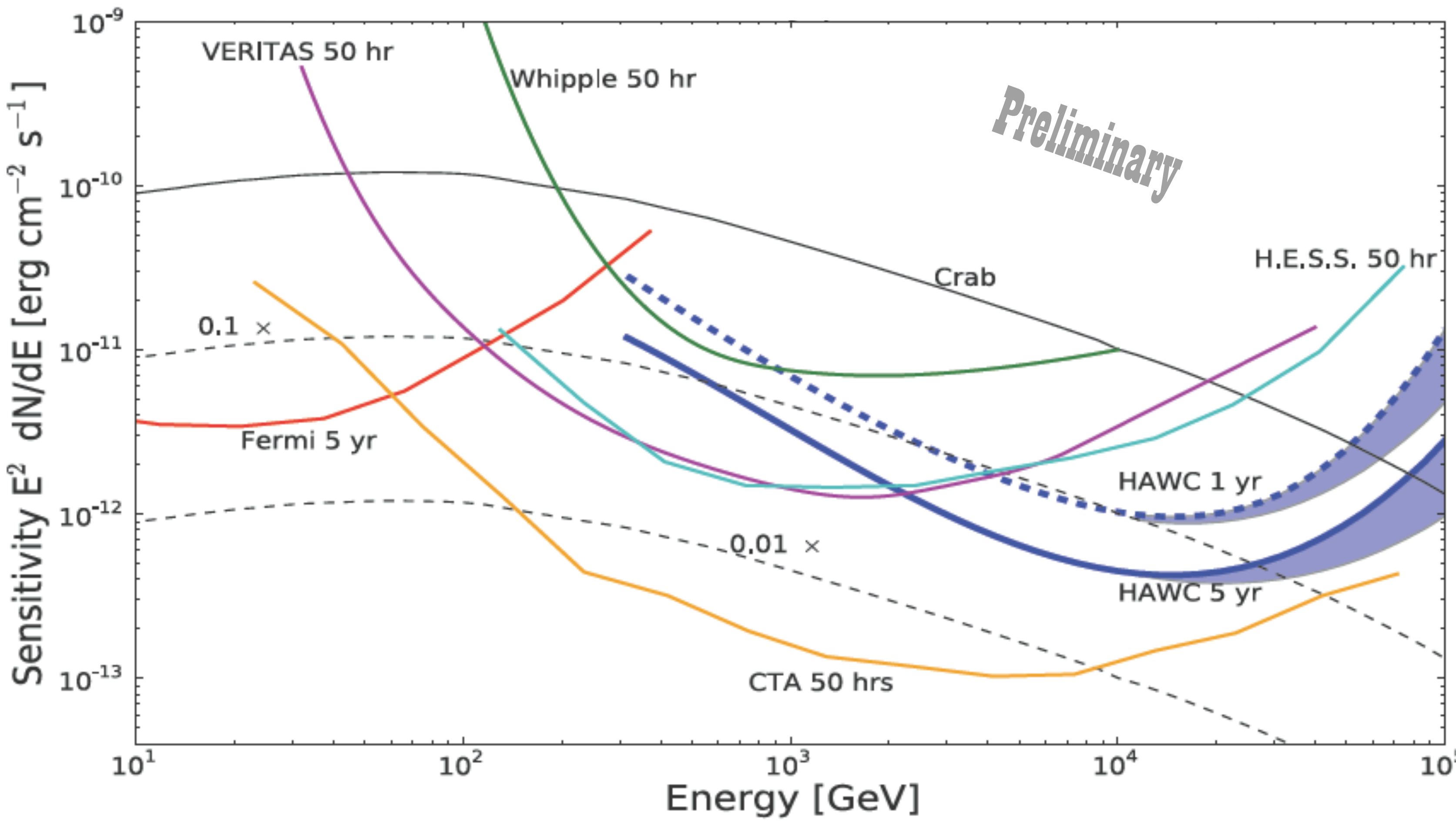


Energy resolution:

- At the ground better than 50%
- For the primary a factor of 2 worse

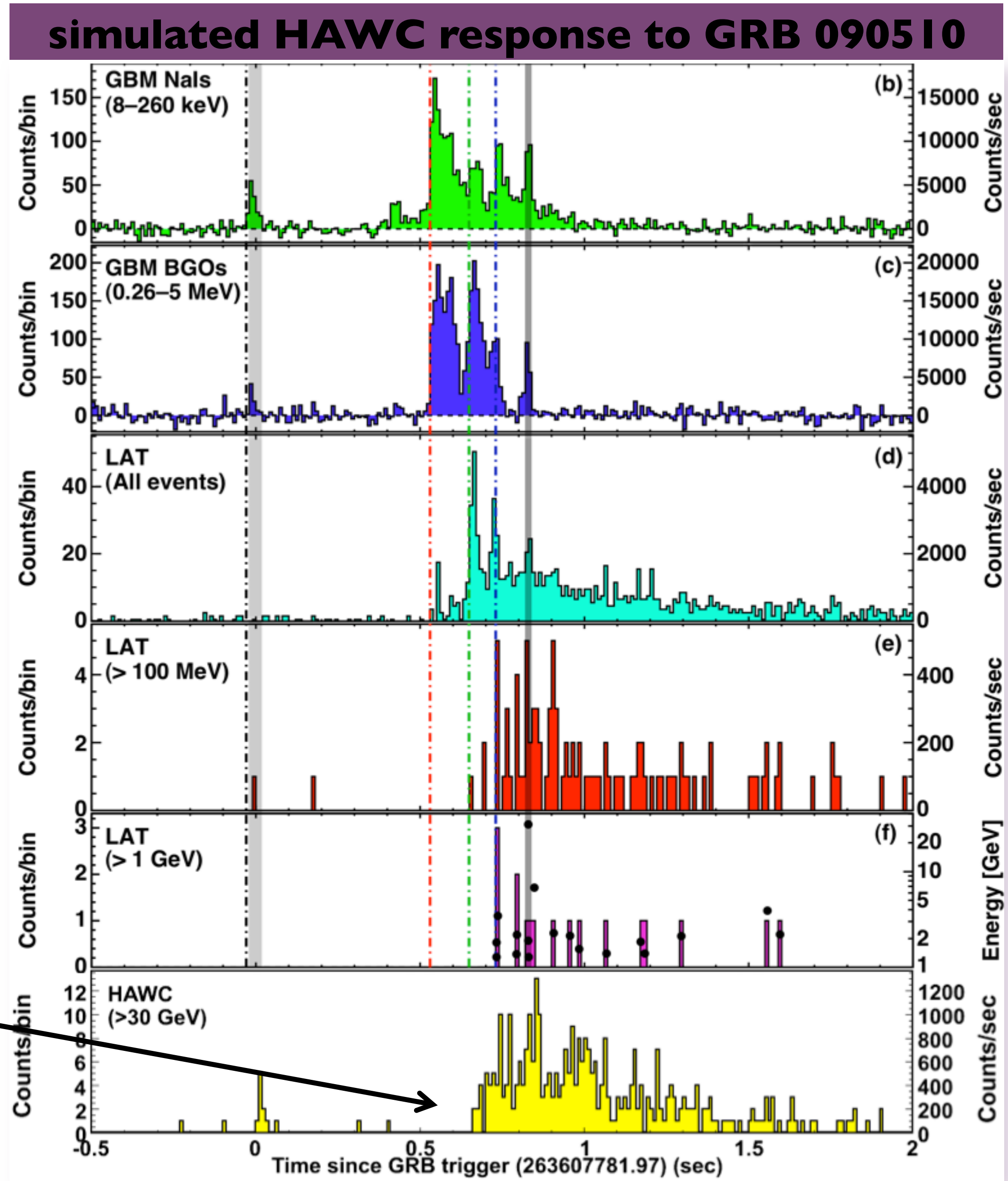
Performance

Flux in ¼ decade energy bins for 5σ detection



HAWC: Gamma-Ray Bursts

I. Taboada: P4-15 poster Sensitivity of HAWC to Gamma Ray Bursts



- Fermi observation of GRB 090510 (z = 0.9)
  Highest observed energy 31GeV
  16 γ-rays > 1 GeV
- Detection (5σ) by HAWC if emission extended to 50 GeV
- If spectrum extends to 125 GeV (attenuated by Gilmore EBL model), the HAWC would detect 200 γ-rays

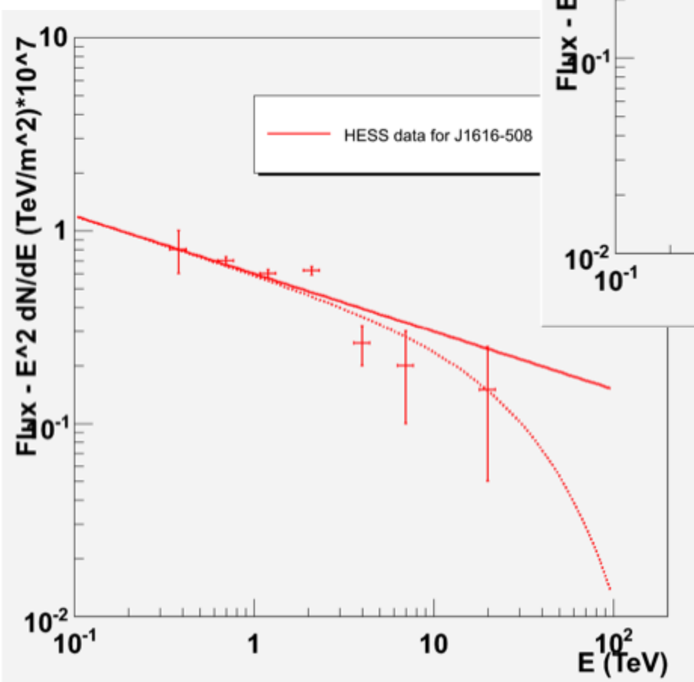
High-Energy Spectra with HAWC

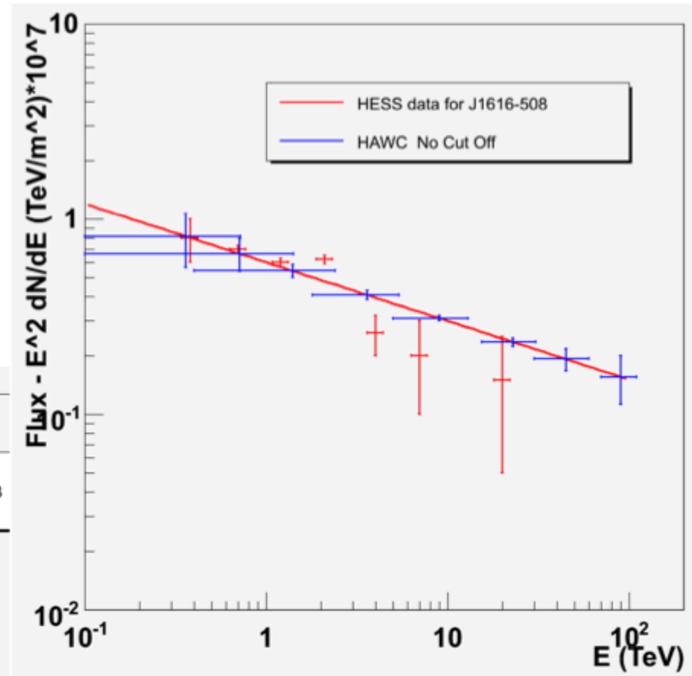
<u>HESS J1616-508</u>

0.2 Crab @ 1 TeV

dN/dE α -2.3

Highest energy
~20 TeV



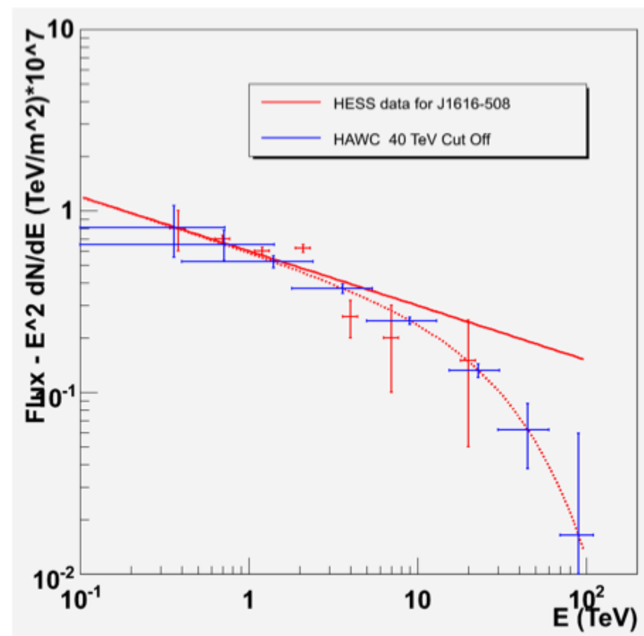


<u>Simulated HAWC data</u>

1 year no cutoff

<u>Simulated HAWC data</u>

1 year 40 TeV cutoff



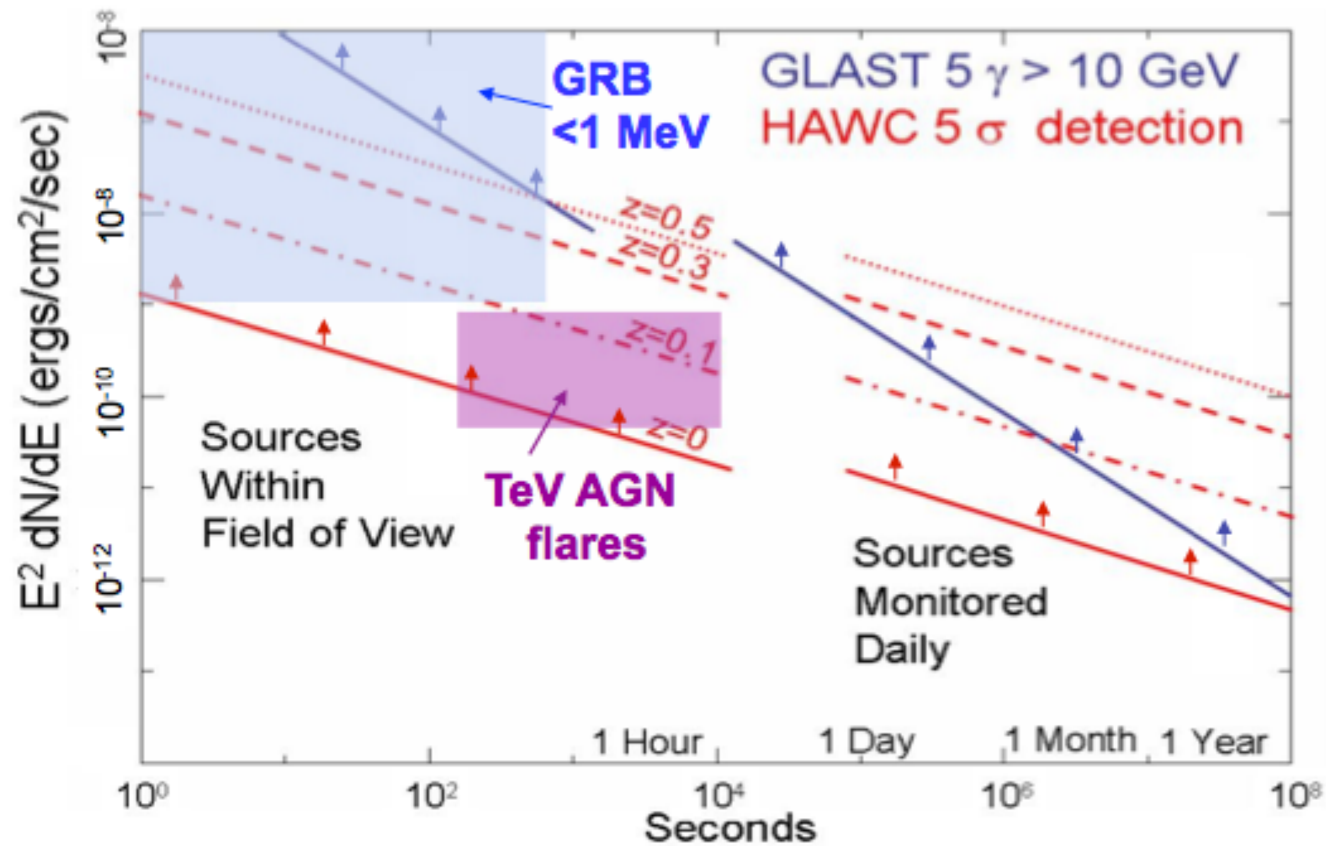
Transient Phenomena

PKS J2155-304 (z=0.117) 50*x* quiescent (1 hr) $dN/dE=kE^{-3.5}$

6 σ in HAWC

GLAST and HAWC sensitivity for a source of spectrum $dN/dE=KE^{-2}$

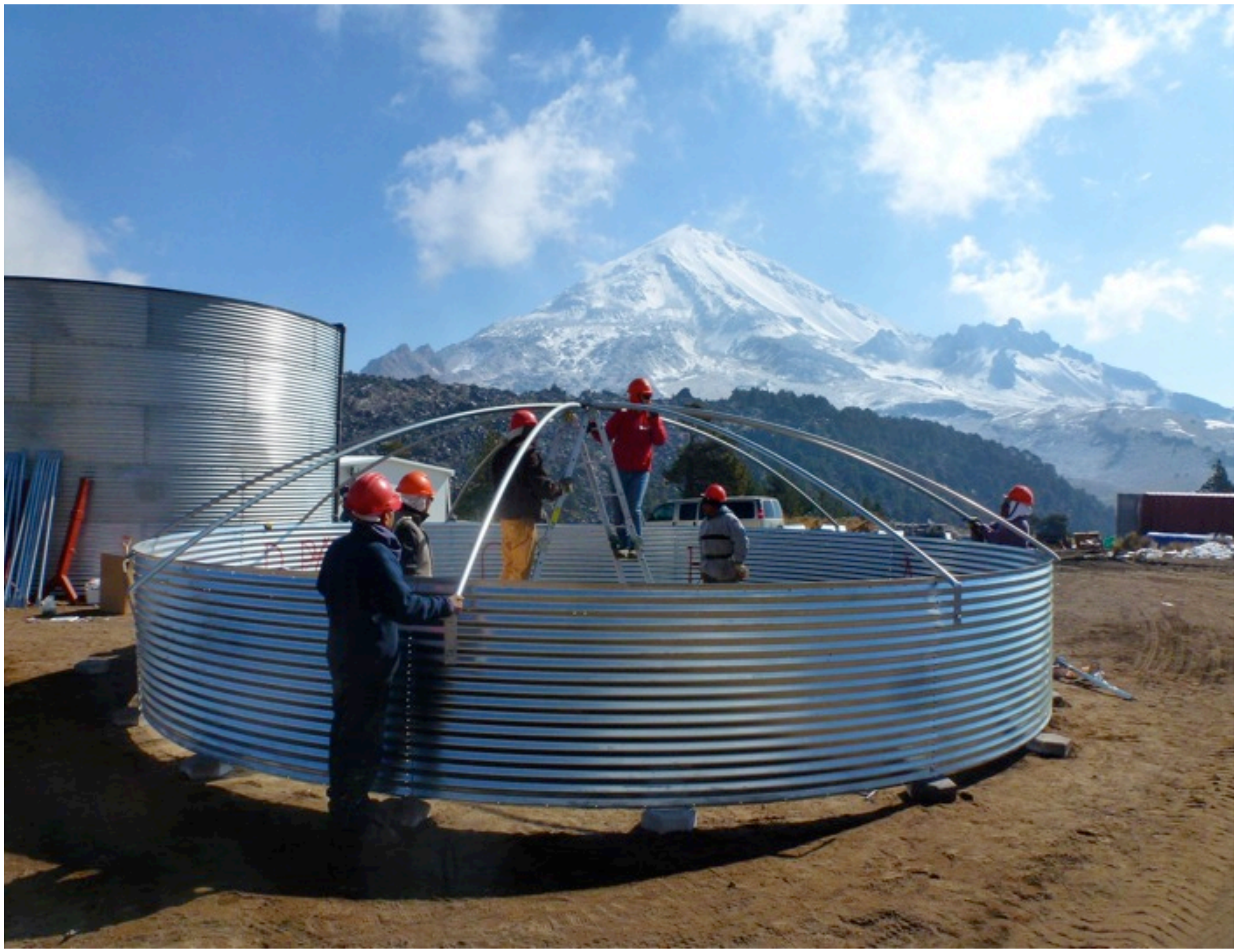
z=0 no E cutoff
z=0.1 E_{exp}~700GeV
z=0.3 E_{exp}~260GeV
z=0.5 E_{exp}~170GeV



HAWC construction
April 27, 2011
Site clearing begins


October 25, 2011

The metal tanks are constructed from the top down



Water treatment plant makes clean water (λ_{abs}>15m)

HAWC Milestones

- VAMOS 7 Summer 2011
- <u>HAWC 30 Summer 2012</u>
- HAWC 100 Summer 2013
- HAWC 300 Fall 2014