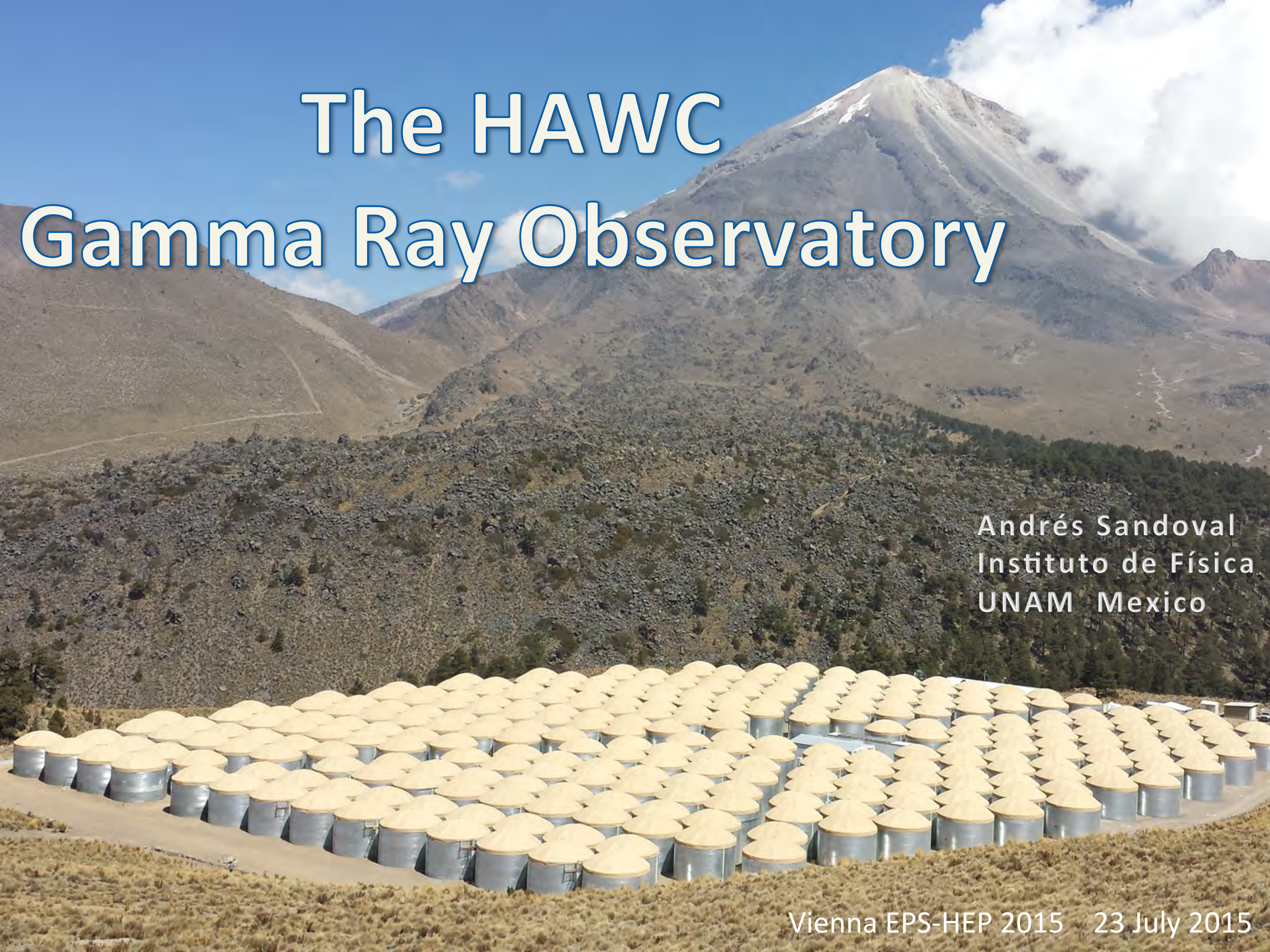

The HAWC Gamma Ray Observatory

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Instituto de Física
UNAM Mexico

Vienna EPS-HEP 2015 23 July 2015

High **A**ltitude **W**ater **C**herenkov

detector for gammas and cosmic rays in the 100 GeV to 100 TeV energy range
situated on the slopes of Volcan Sierra Negra, central Mexico
at 4,100 masl and (19^o N, 97^o W)

HAWC Collaboration

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

Mexico:
Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE)
Universidad Nacional Autónoma de México (UNAM)
- Instituto de Física
- Instituto de Astronomía
- Instituto de Geofísica
- Instituto de Ciencias Nucleares

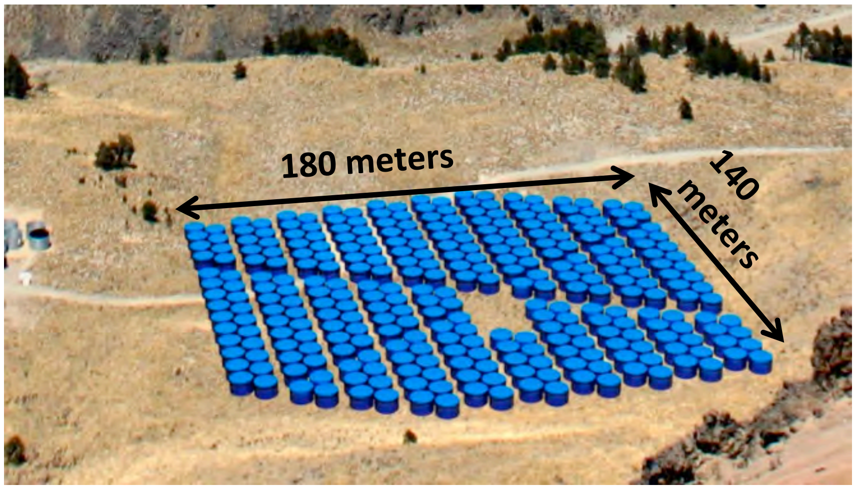
Universidad Politécnica de Pachuca
Benemérita Universidad Autónoma de Puebla
Universidad Autónoma de Chiapas
Universidad Autónoma del Estado de Hidalgo
Universidad de Guadalajara
Universidad Michoacana de San Nicolás de Hidalgo
Centro de Investigación y de Estudios Avanzados
Instituto Politécnico Nacional
Centro de Investigación en Computación - IPN

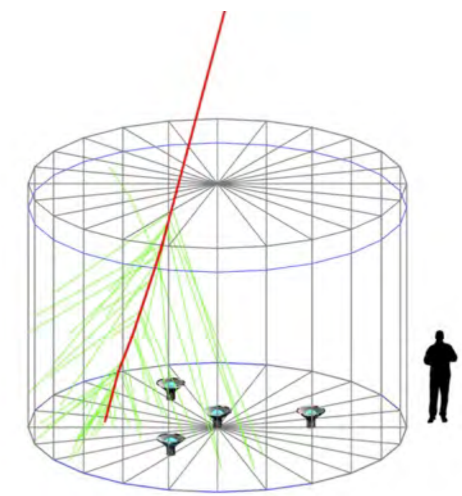

Detects continuously airshower particles
with 300 Water Cherenkov Detectors
over a large aperture
day and night

surveying every day 2/3 of the sky

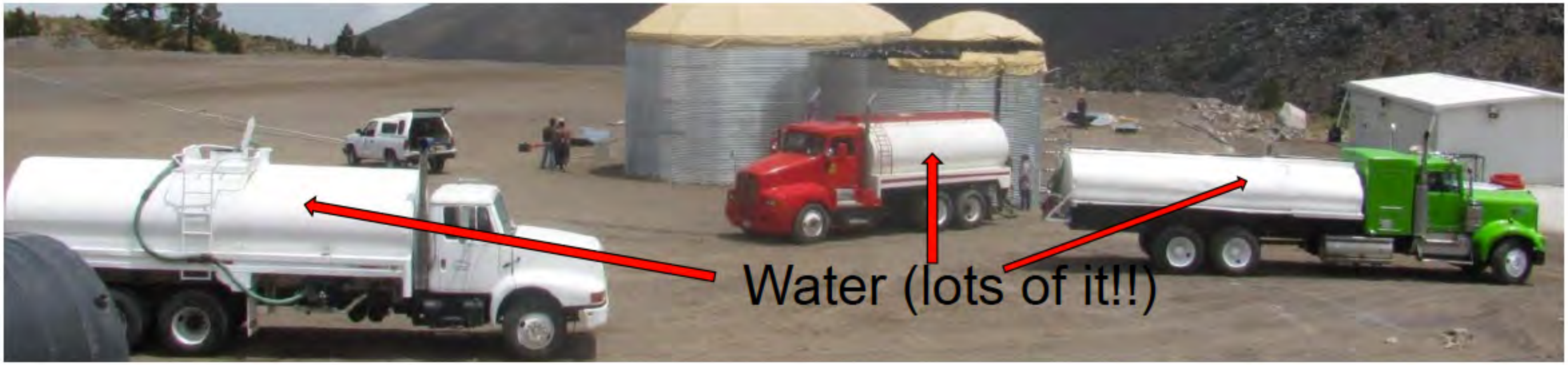
HAWC Design

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





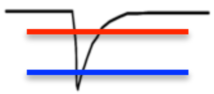
Components of the Water Cherenkov Detectors (WCD)



Front End Electronics

ToT (Time over Threshold)

Photo-multiplier Tube

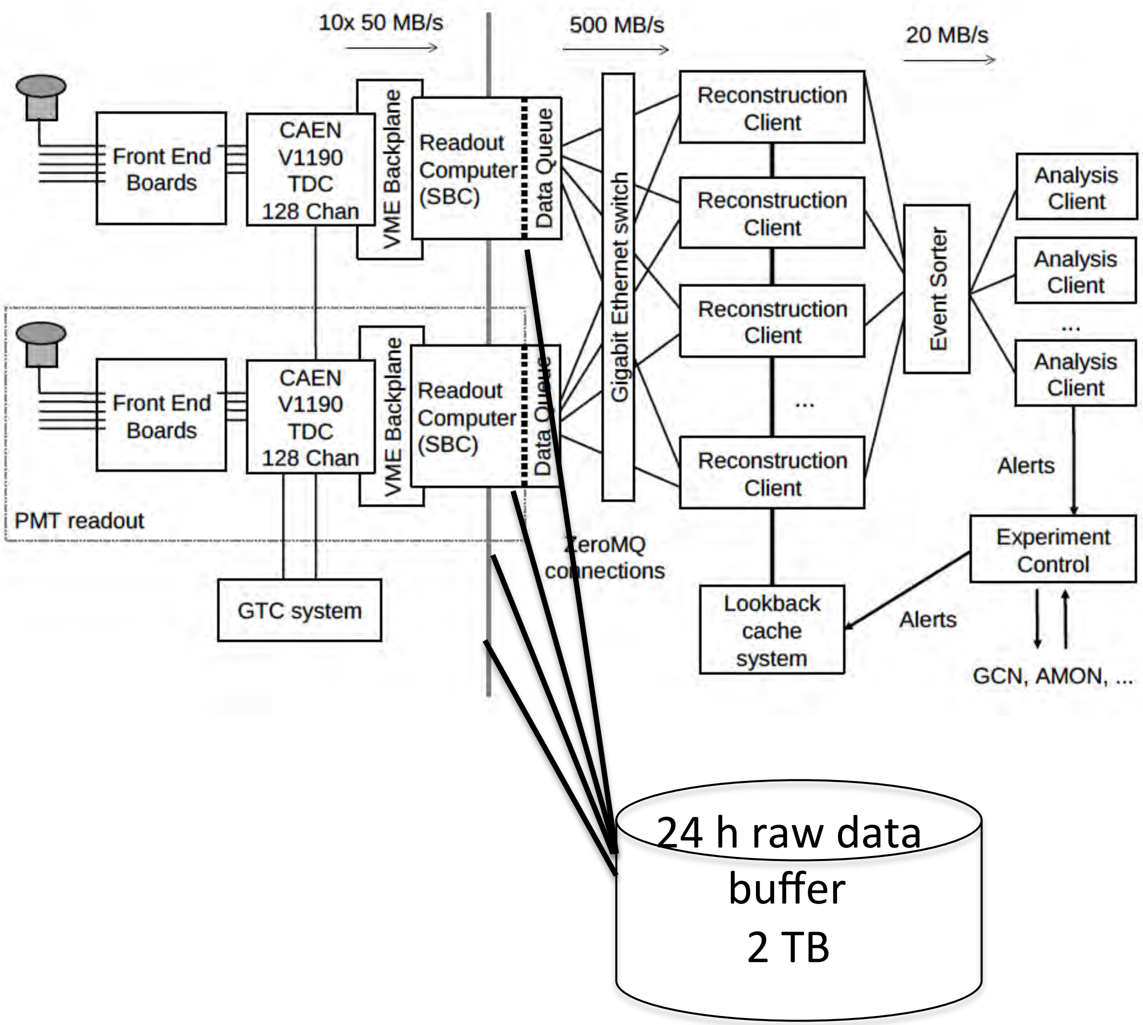


Custom Front-End Electronics
Pick-off circuits and discriminators.

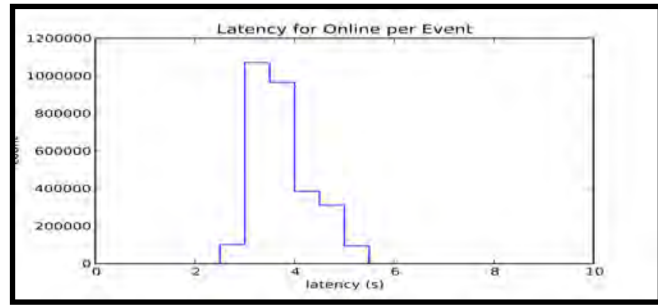
CAEN Vx1190
Time-to-Digital
Converters

Digitizing the times with 100 ps least count
20 – 40 kHz signal rate per PMT (8”, 10”)

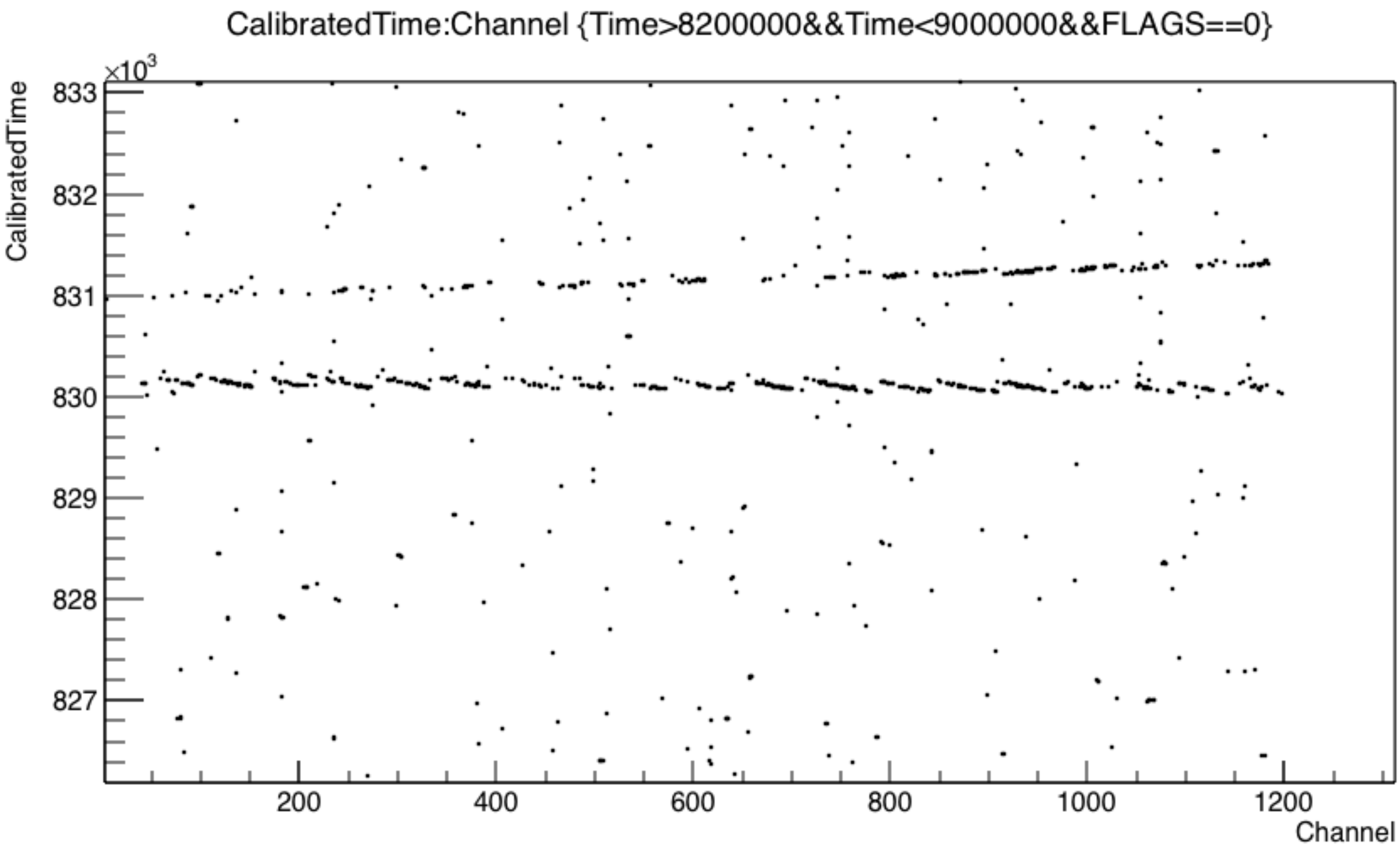
HAWC data acquisition and online analysis



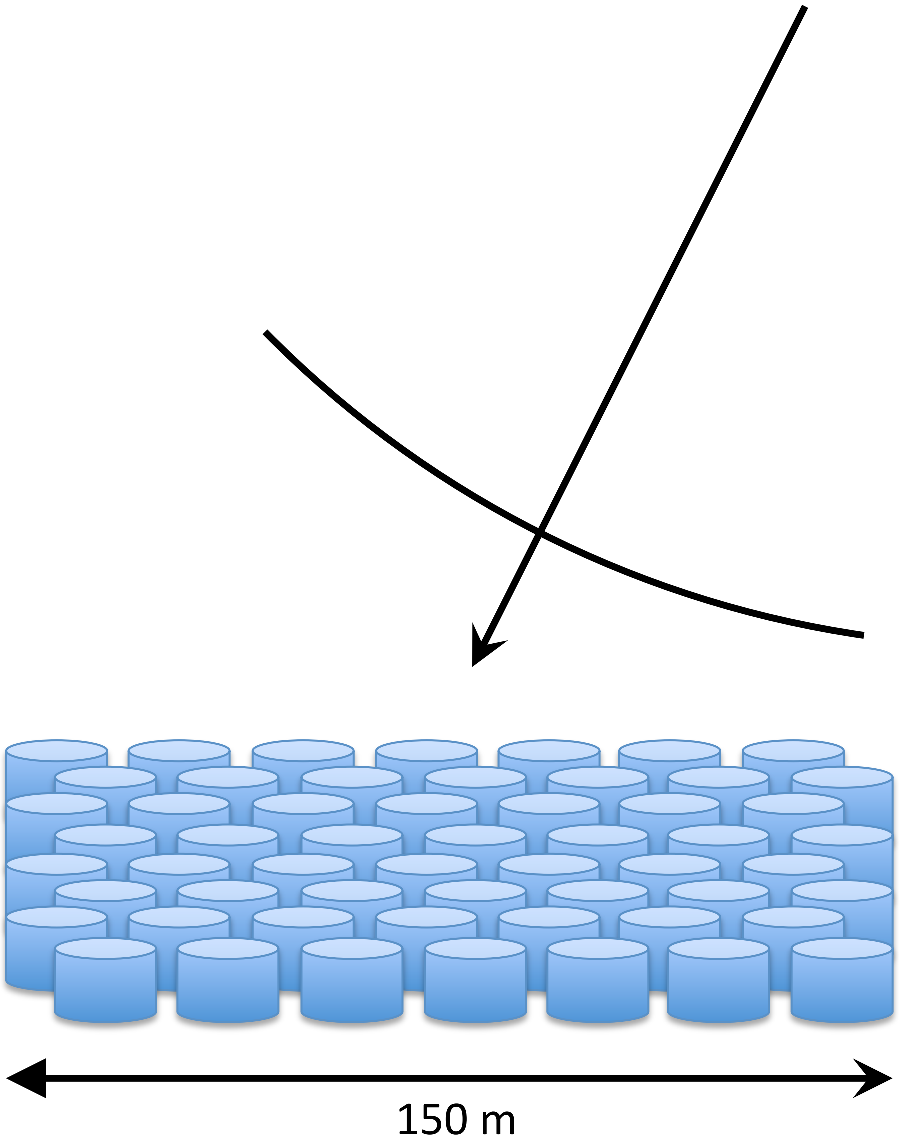
On line transient analysis
4s latency
to generate
alarms and save ROI



Raw Data
1200 PMTs – 6 μs



Event reconstruction



Shower core position

- Center of Gravity, NKG lateral distribution, others.

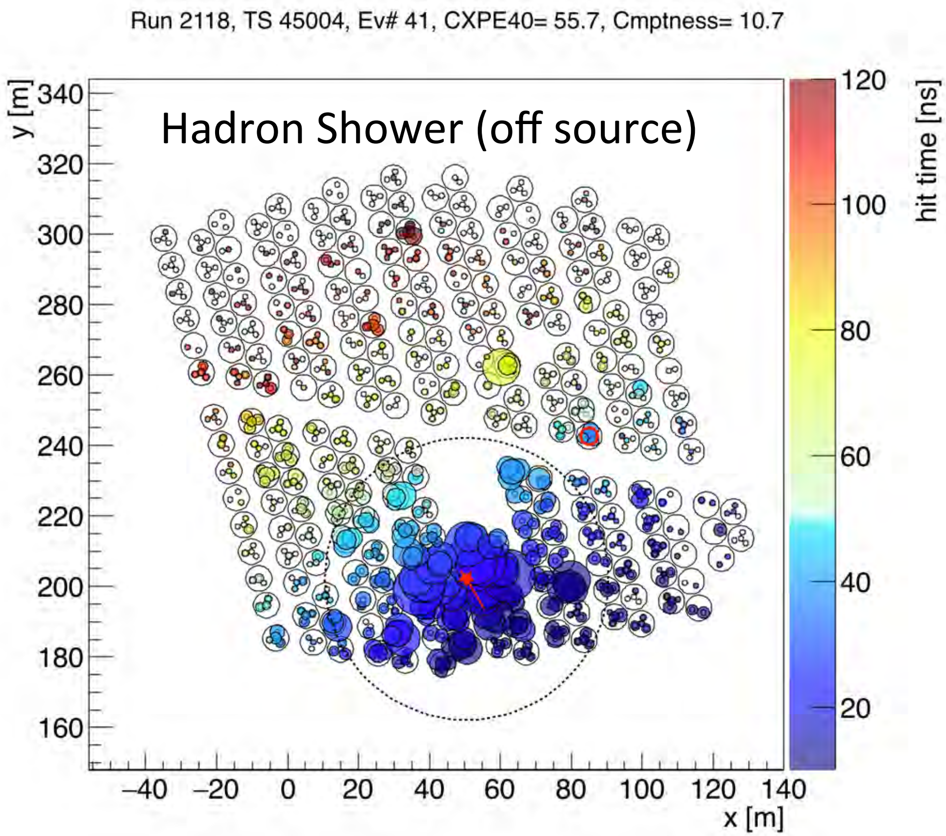
Shower direction

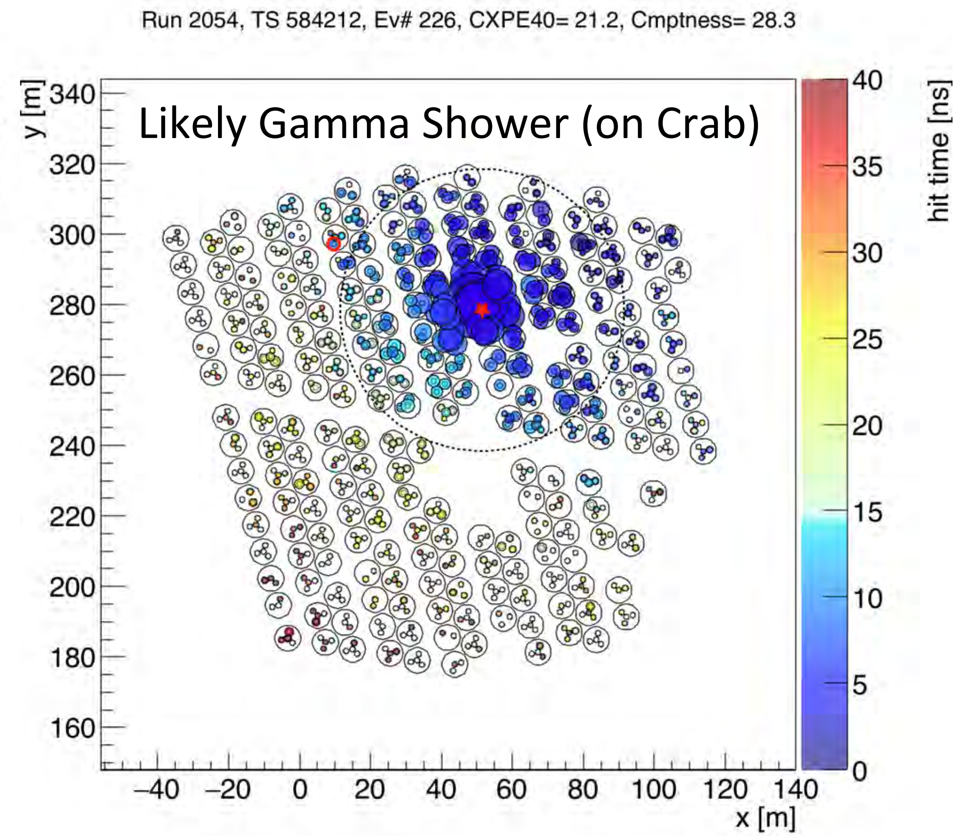
- Time of arrival of each signal. Shower front curvature.
- Direction of primary is the perpendicular to the shower front

Shower energy

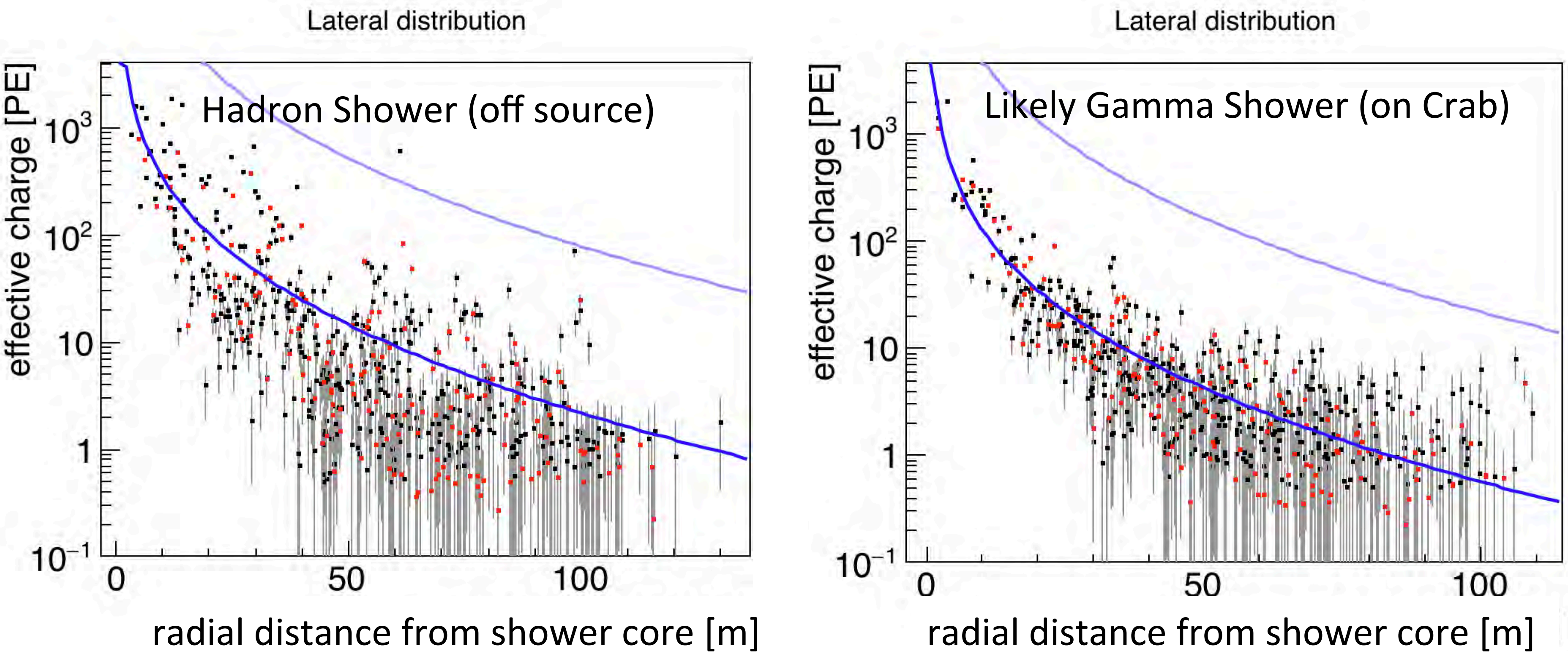
- Event size, PMT charge, etc.

HAWC-250 gamma/hadron





HAWC-250 gamma/hadron



NKG (Nishimura-Kamata-Greisen) fits to lateral distribution function of an EM shower.

Kamata, Nishimura Prog. Theo. Phys. (1958)
Greisen Ann. Rev. Nucl. Sci. (1960)

HAWC Cost and Funding

- $15 million USD shared equally between 3 funding agencies and managed by 4 PIs

CONACYT, Mexico

Andres Sandoval UNAM

Alberto Carramiñana INAOE

NSF, US

Jordan Goodman, Univ. Maryland

DoE, US

Brenda Dingus, Los Alamos National Lab

Time Line

- Site selected in 2007 at the ICRC meeting in Merida
- 2008 – 2010 construction of prototypes and writing of proposals
- February 2011 project funded
- 2011 site preparation and procuring of components
- 2012 – 2014 construction of the 300 WCD
- 1 August 2013 start of continuous operations HAWC-100

- HAWC inauguration 19-20 March 2015


October 2011

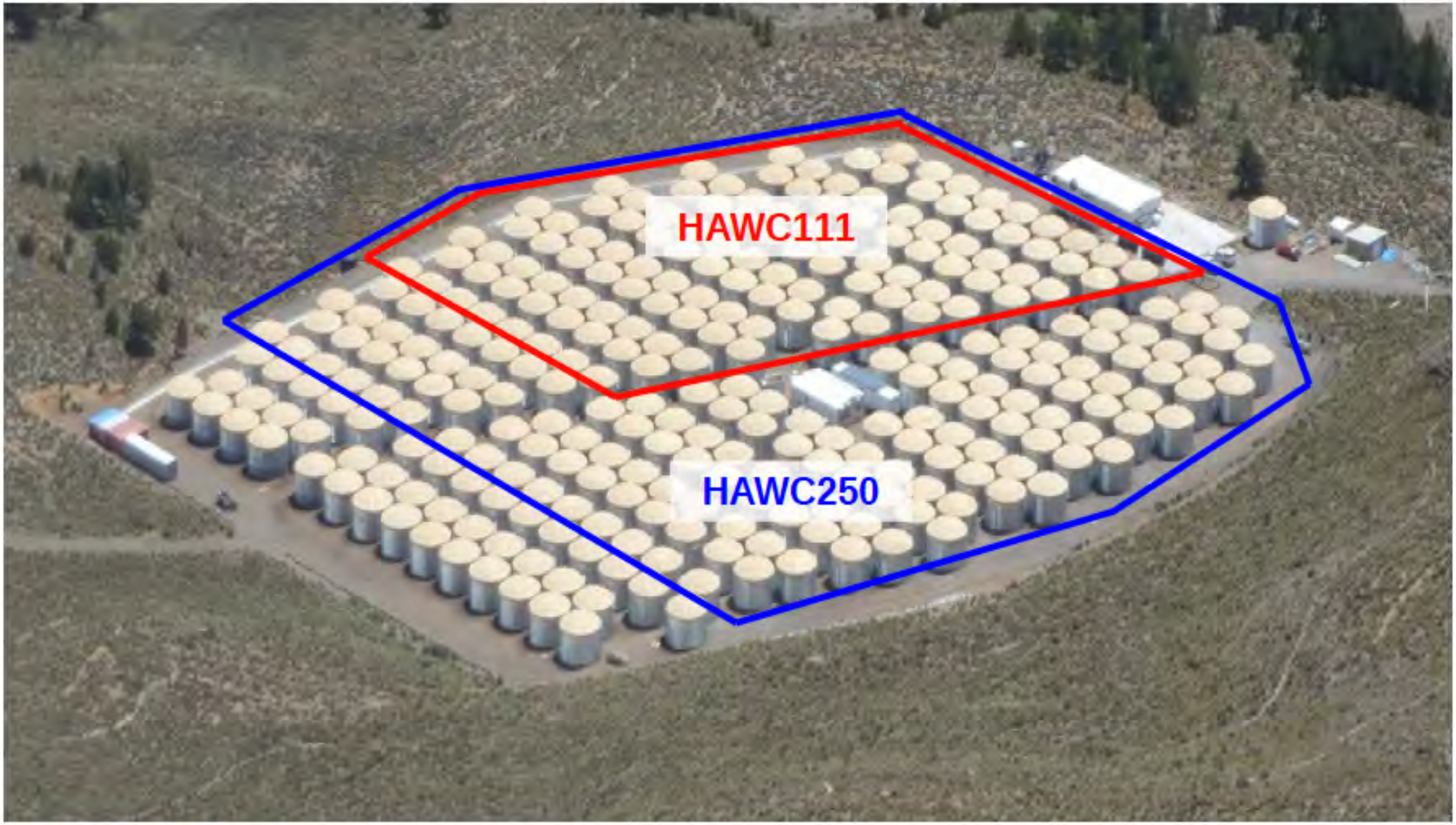

August 2012


October 2013


January 2014

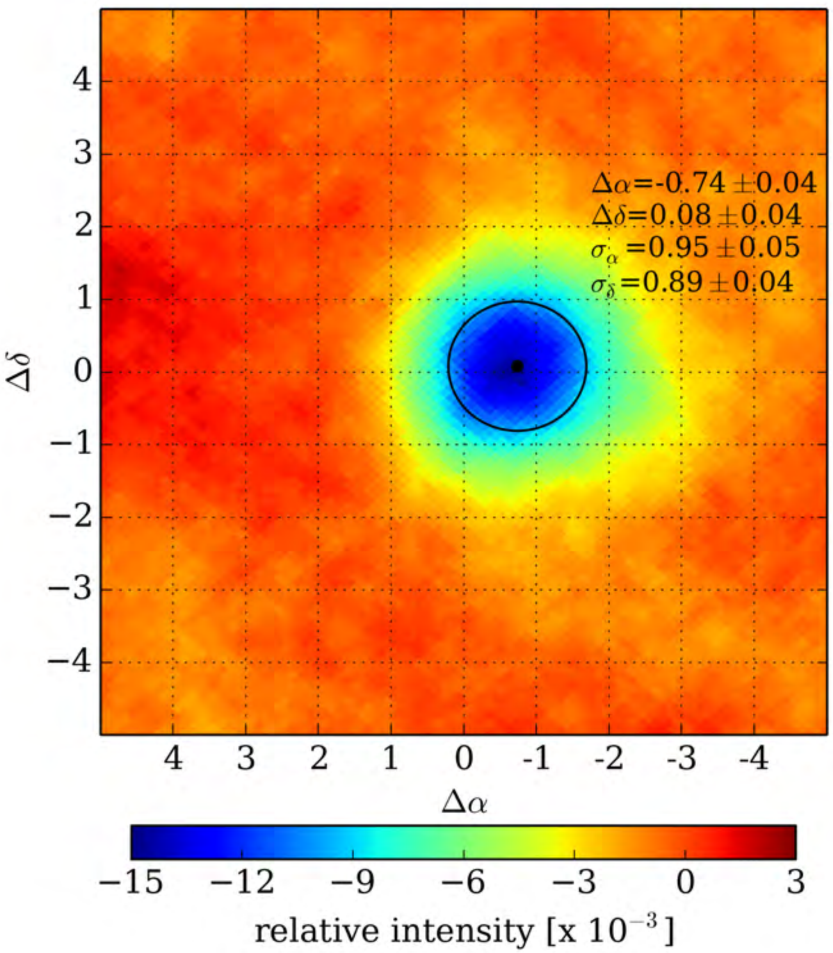

HAWC Inauguration
March 20 2015

Data sets



HAWC111: Aug 2nd 2013 – Jul 7th 2014 (106 - 133 WCDs)
HAWC250: Nov 26th 2014 – May 6th 2015 (247 - 293 WCDs)

Cosmic Ray Moon Shadow



HAWC-250

- 52 full sidereal days
- 32 billion events
- 2 TeV median energy

- Center displacement

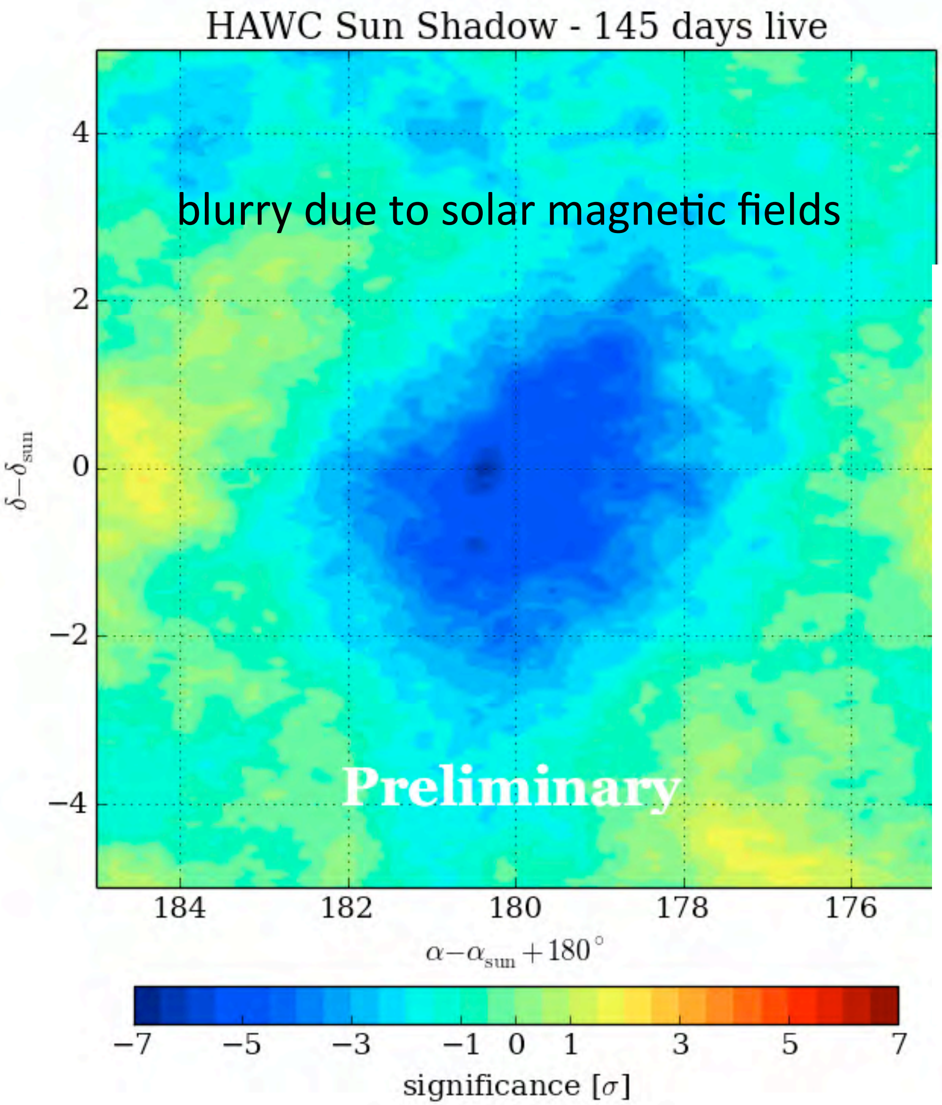
$\Delta\alpha = -0.74^{o} \pm 0.04^{o}$

$\Delta\delta = 0.08^{o} \pm 0.04^{o}$

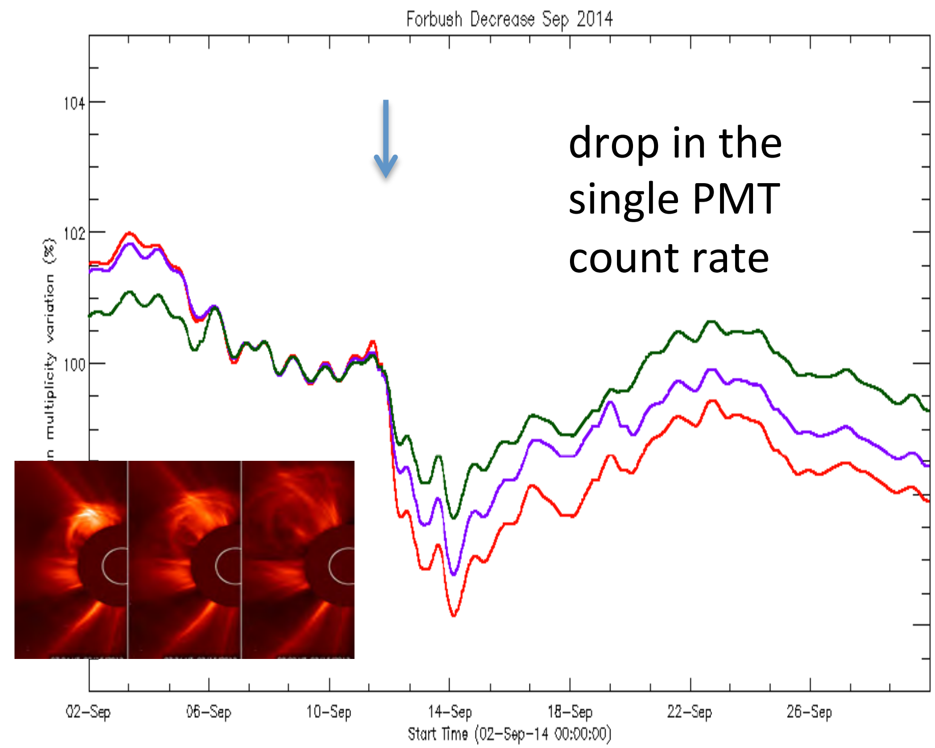
agrees with deflection of CR due to the Earth B field

$\Delta\alpha = 1.6^{o}$ Z/E [TeV]

Sun Shadow and Forbush Decreases

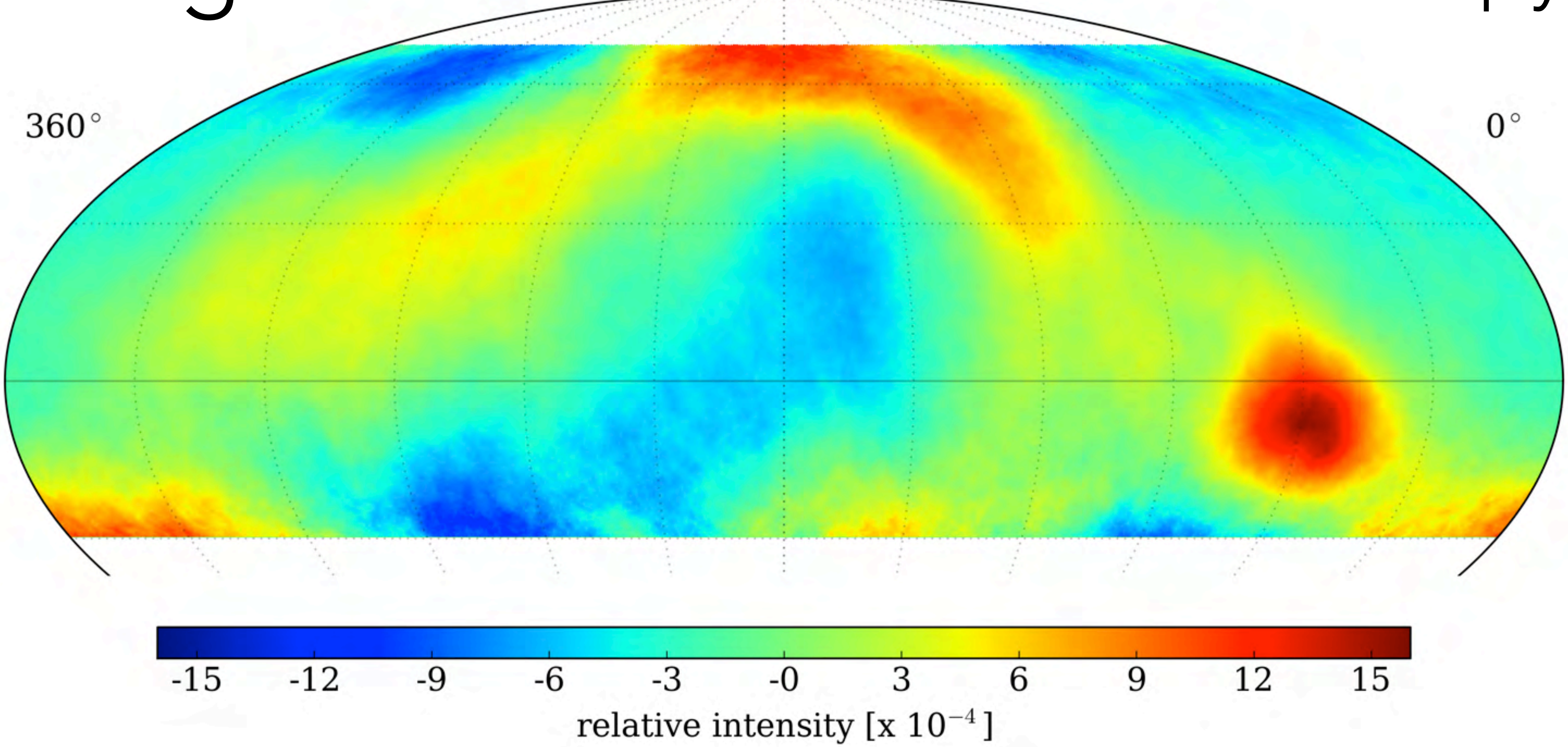


- CME in Earth direction modify the geomagnetic environment



HAWC-111

Large-Scale CR Anisotropy



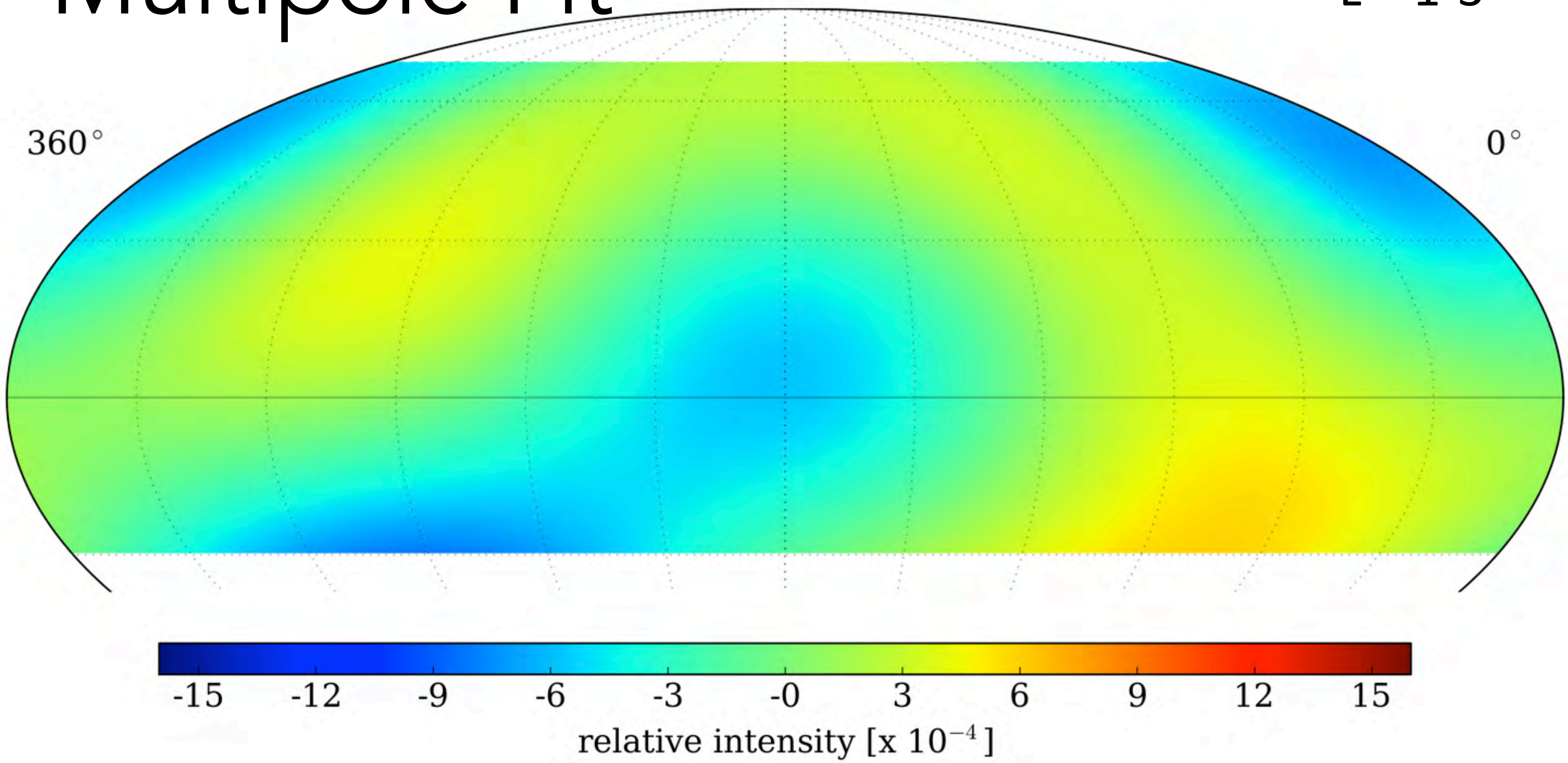
Contains sidereal signal — Expected: Dipole of 10^{-3} strength
Minimum at RA=200°

Contains Solar signal — Expected: Dipole of 10-4 strength.
Maximum in direction of Earth motion

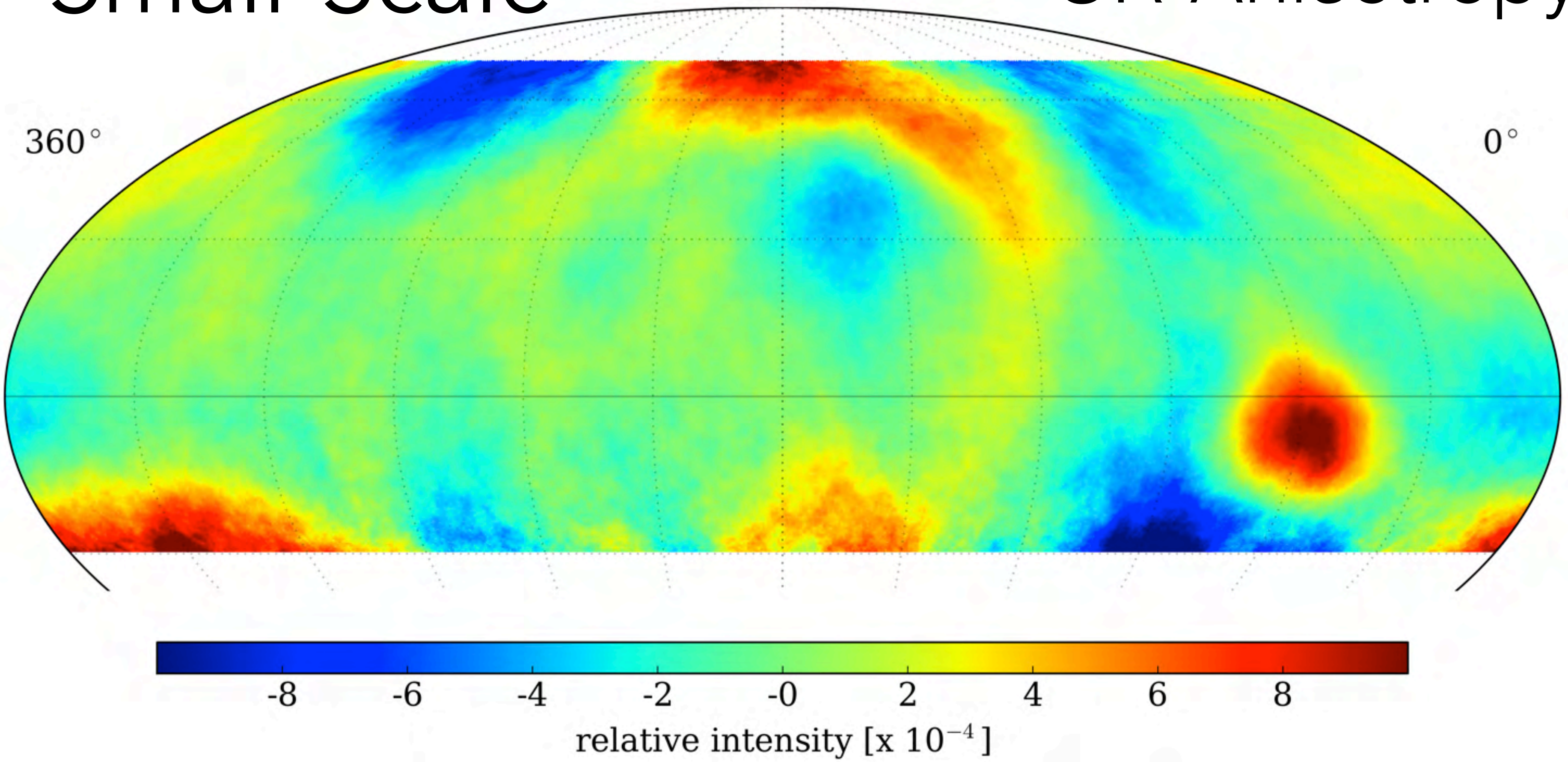
See http://private.hawc-observatory.org/wiki/index.php/HAWC_Large-Scale_Cosmic-Ray_Anisotropy_Map

Multipole Fit

L = 1-3



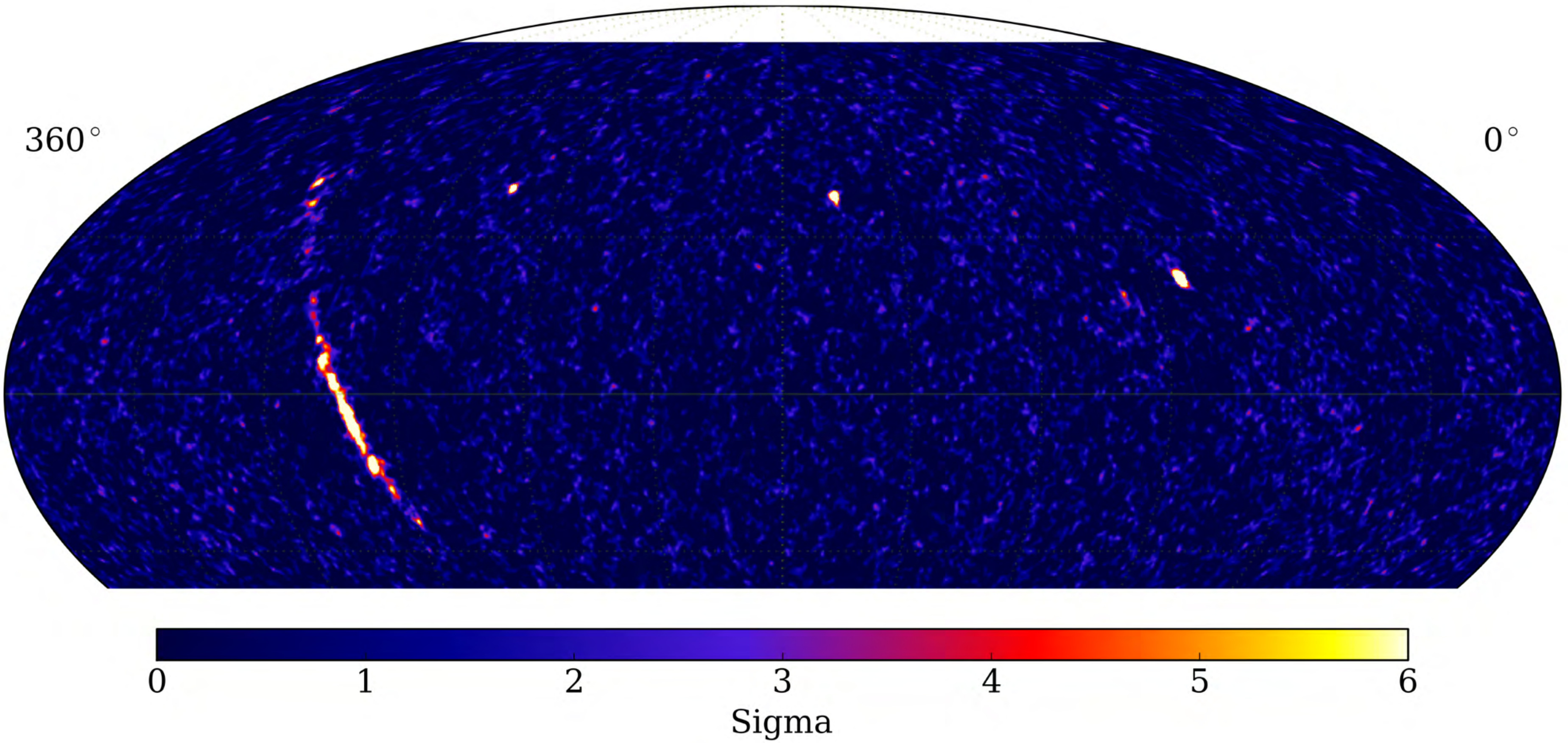
Small-Scale HAWC-111 CR Anisotropy



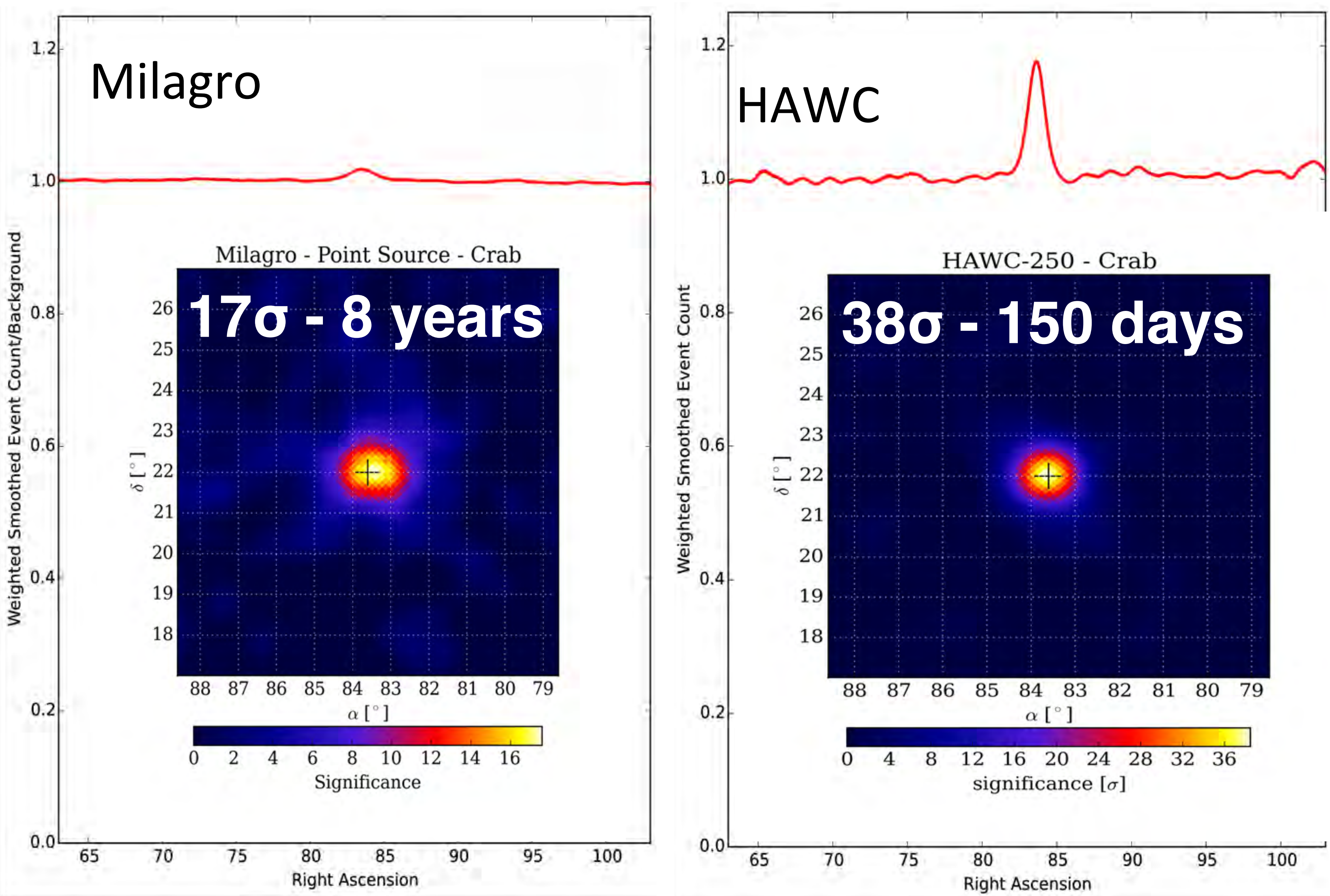
Detailed studies will be made over the next few years
already did a combined fit with IceCube CR data

The HAWC γ-ray Sky

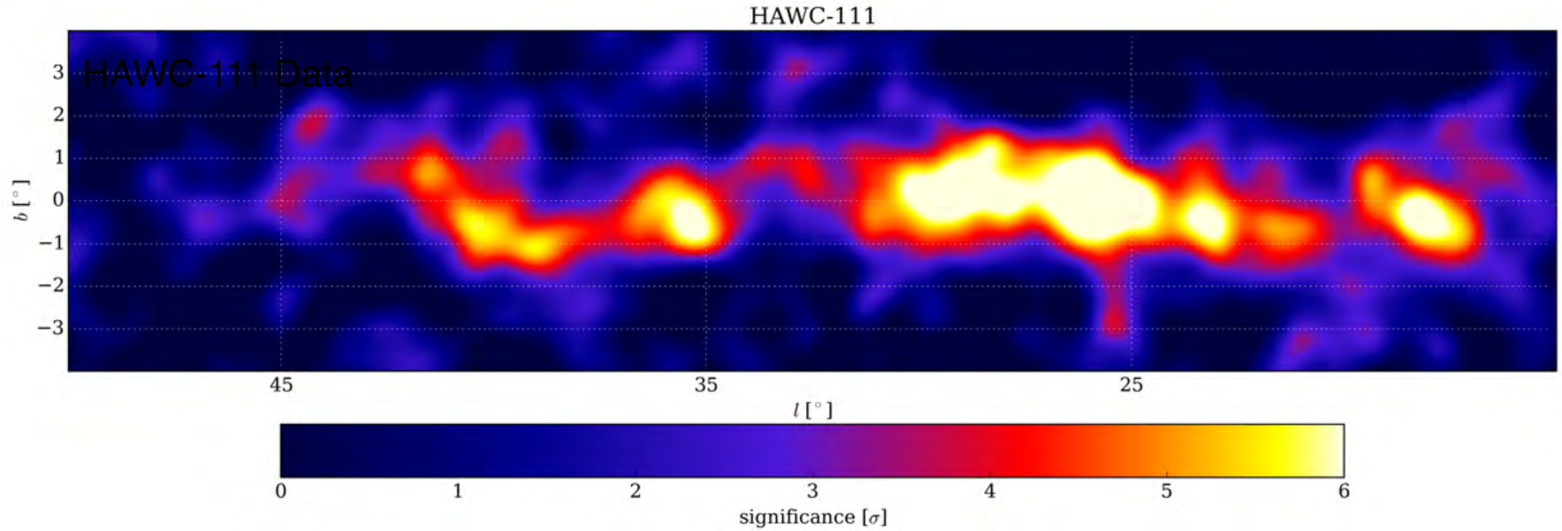
HAWC-111 + HAWC-250

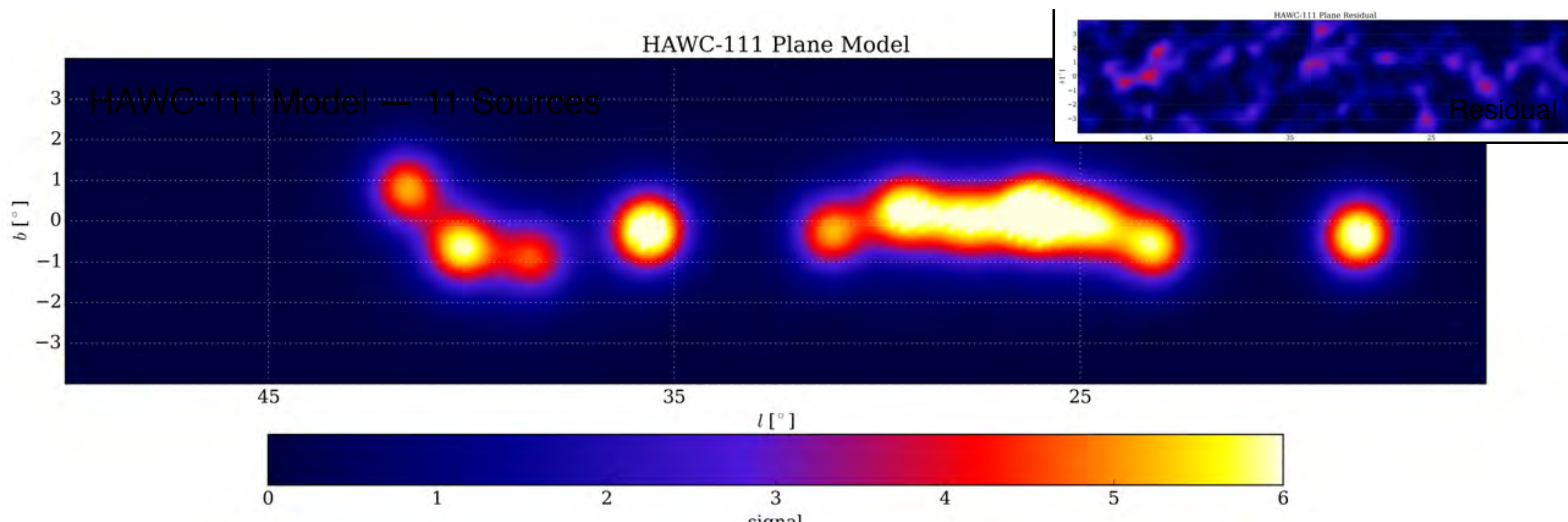


Crab Nebula

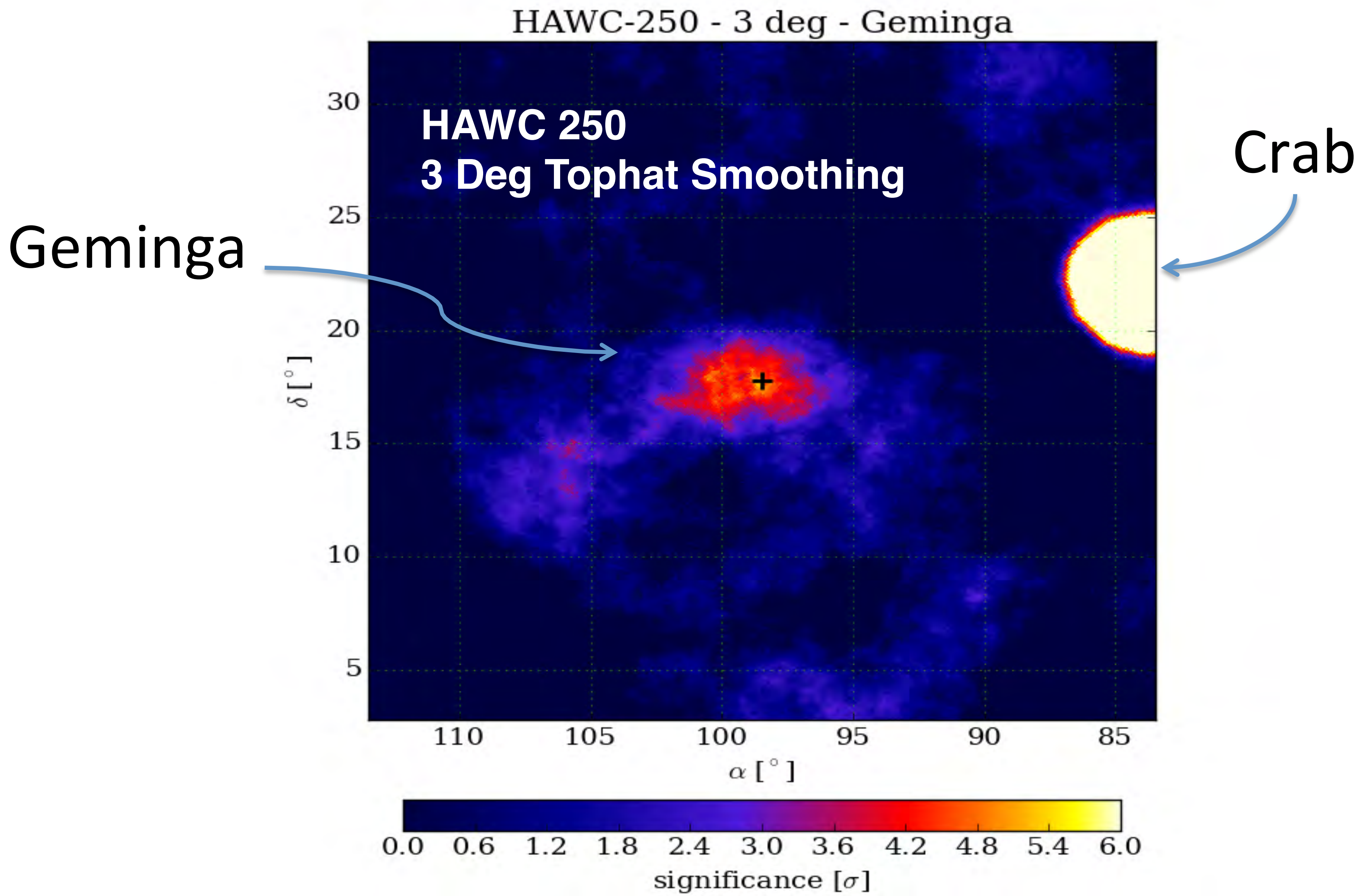

Milagro
Milagro - Point Source - Crab
17σ - 8 years
Weighted Smoothed Event Count/Background
Right Ascension
δ [°]
α [°]
Significance
HAWC
HAWC-250 - Crab
38σ - 150 days
Weighted Smoothed Event Count
significance [σ]

HAWC-111 Galactic Plane Analysis : 11 sources





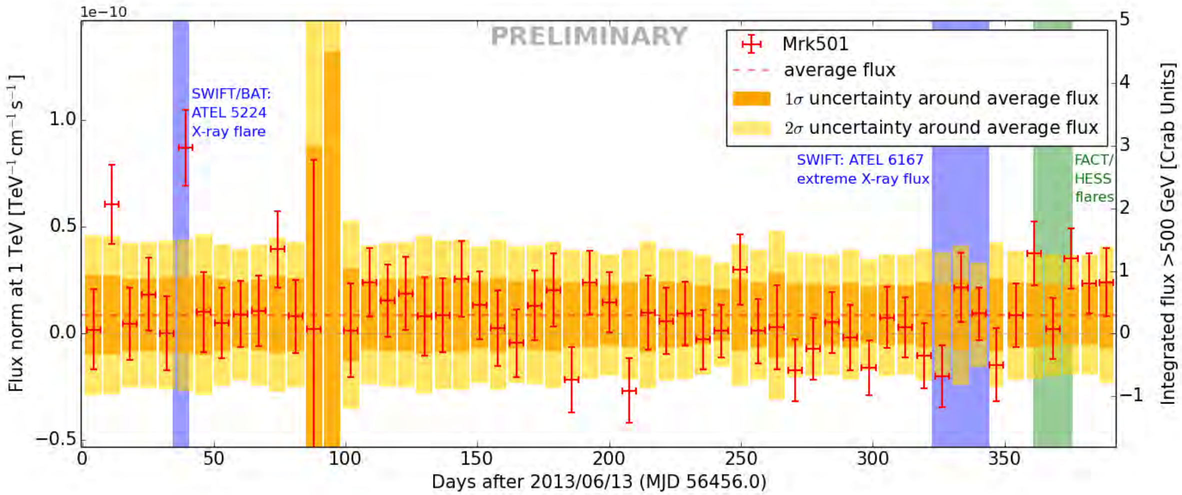
Detection of extended sources

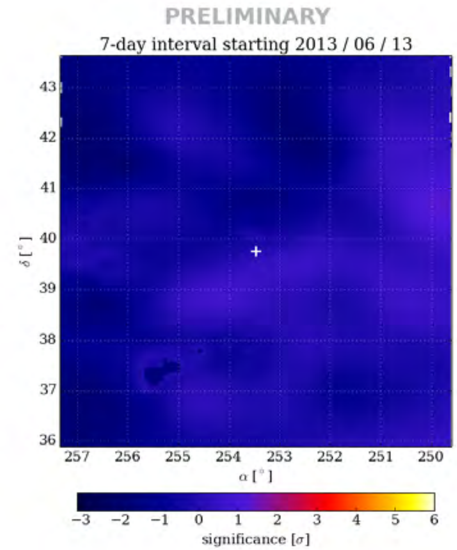


Blazar light curves and flares

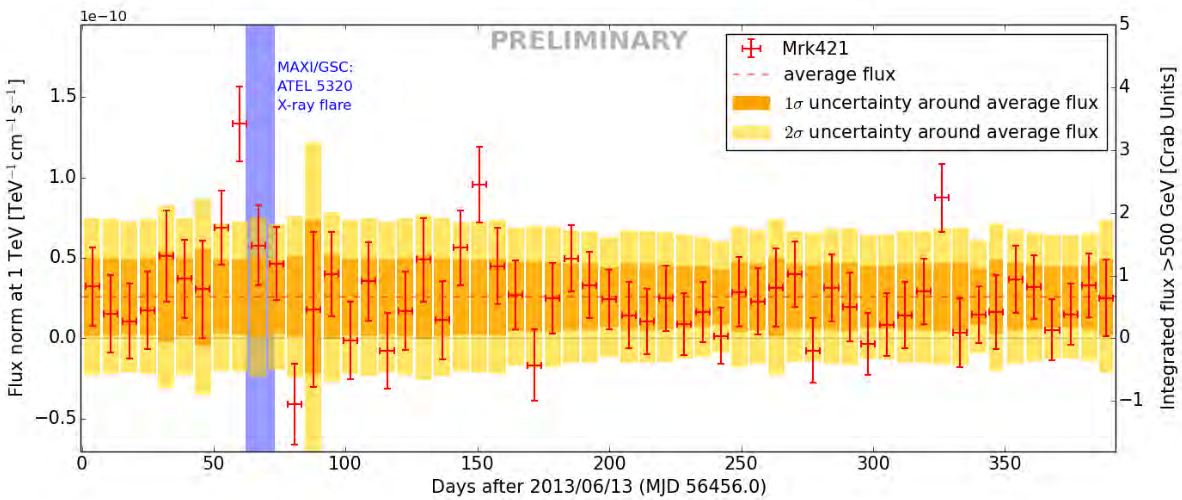
HAWC-111

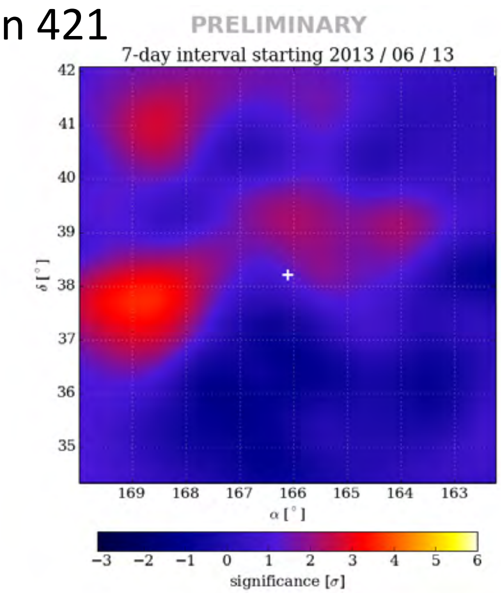
Markarian 501





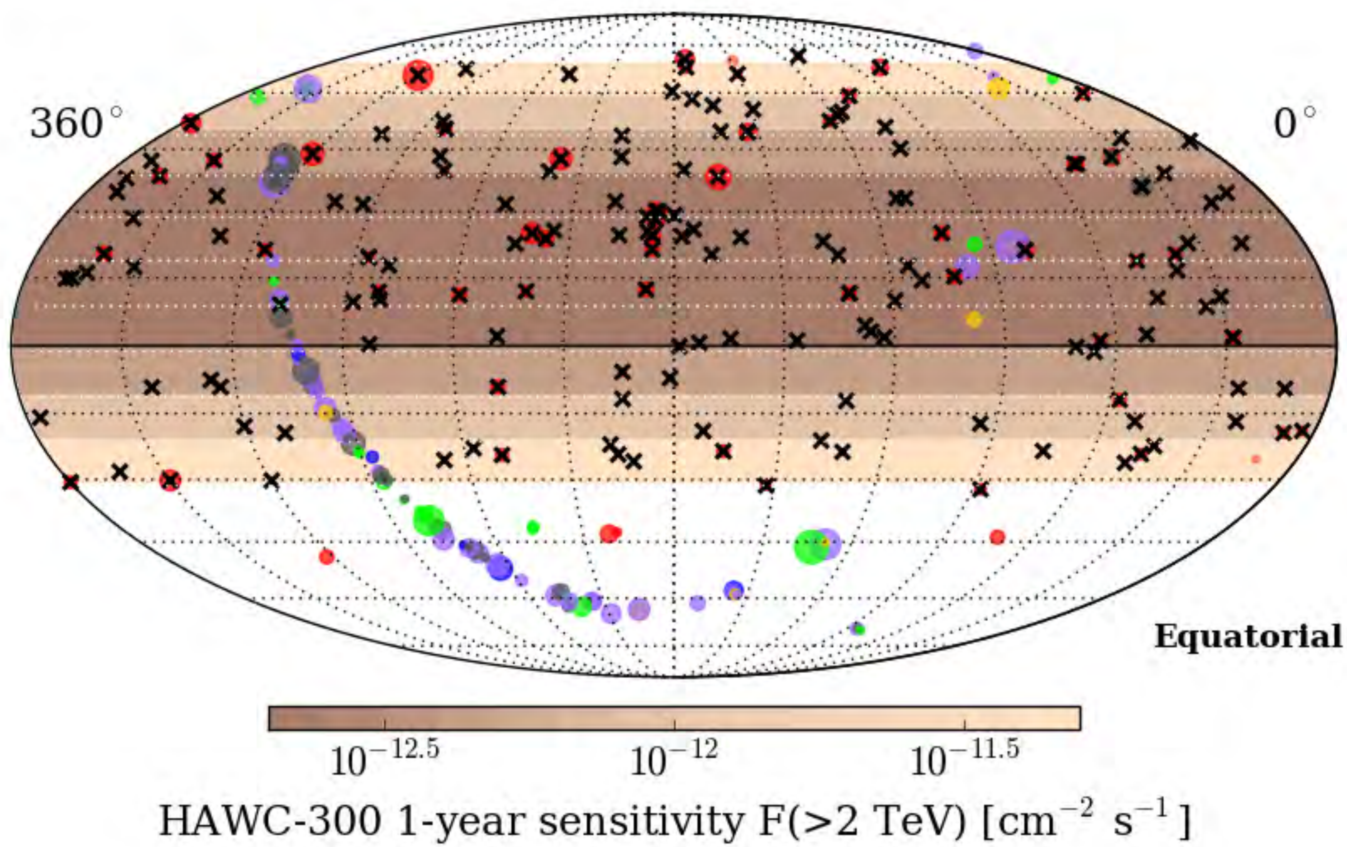
Markarian 421



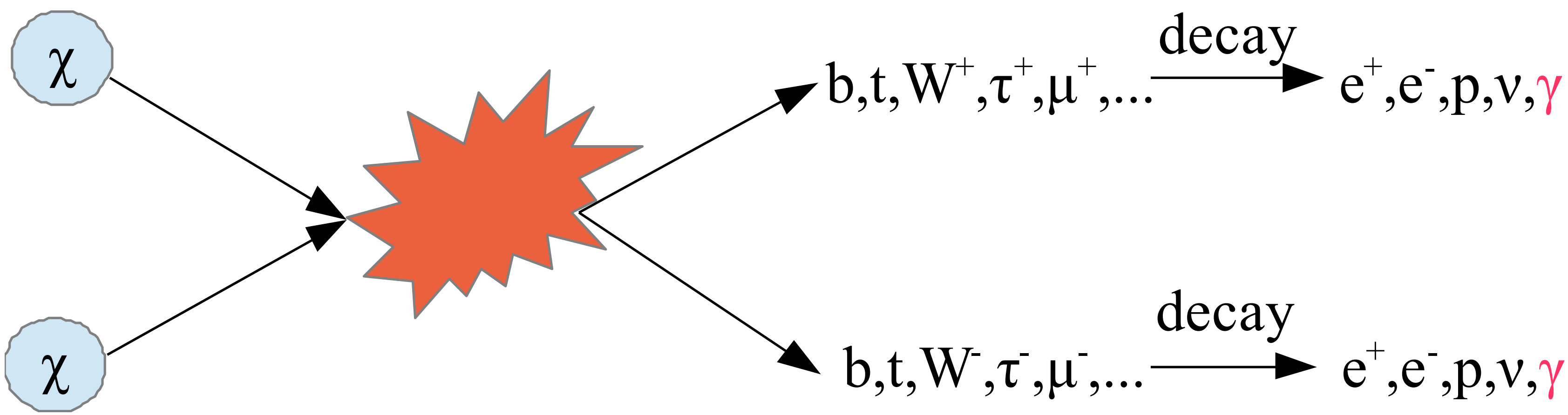


HAWC Online Monitoring

Presently monitoring daily 170 sources: all VHE Blazars and 1FHL blazars with z<1



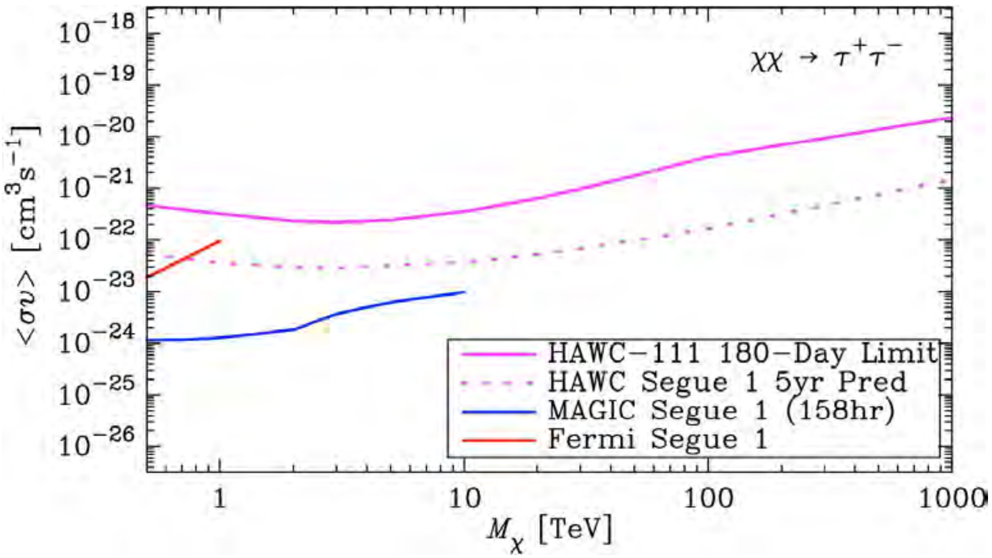
Dark Matter indirect detection

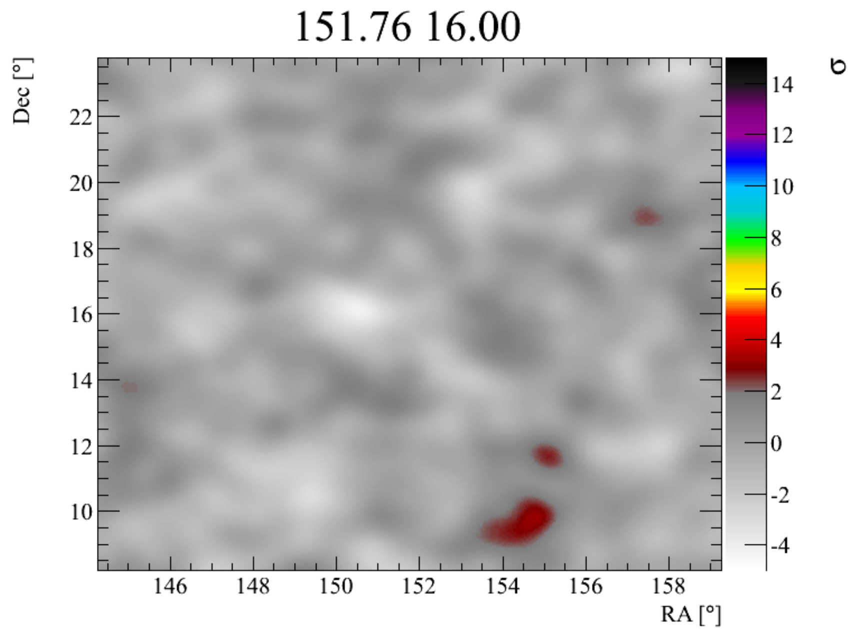


$$Flux_{Annihilation} \propto \frac{\langle \sigma v \rangle}{M_\chi^2} \frac{dN_\gamma}{dE} \int_{l.o.s.} dx \rho^2(r)$$

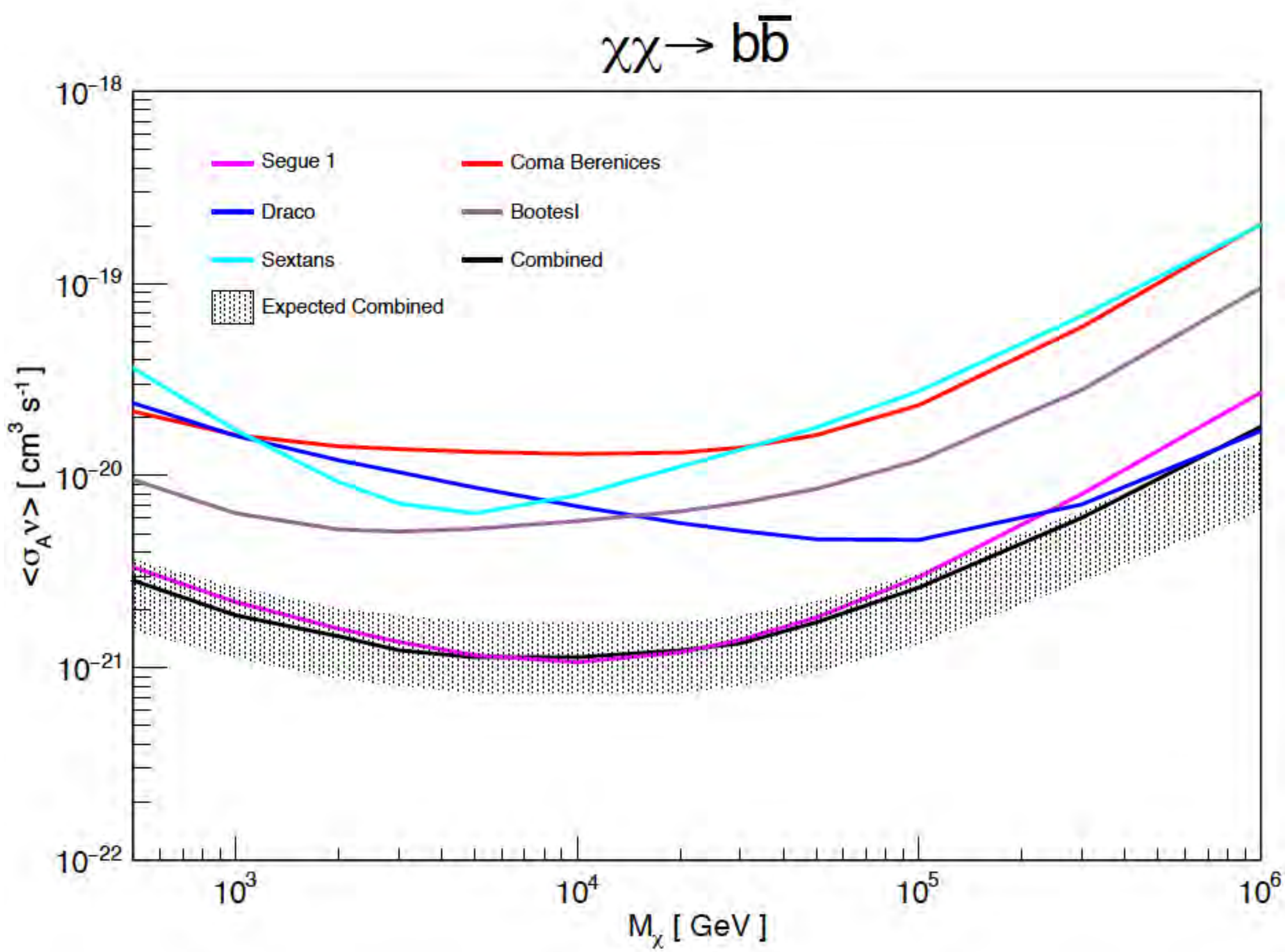
$$Flux_{Decay} \propto \frac{1}{\tau} \frac{1}{M_\chi} \frac{dN_\gamma}{dE} \int_{l.o.s.} dx \rho(r)$$

HAWC-111 DM limit for Segue-1

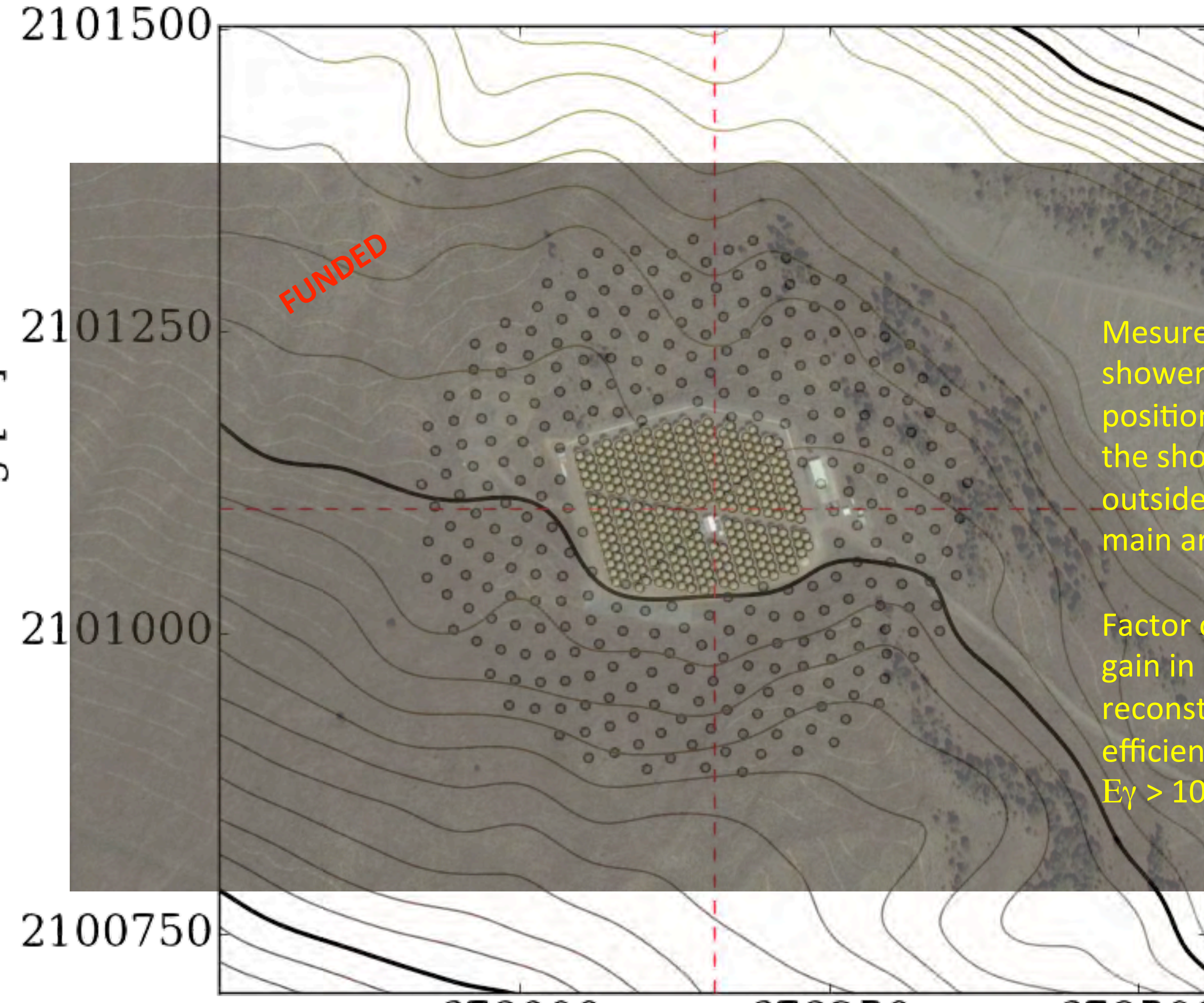




HAWC 5 year DM limit
for the best 5 dwarf spheroidal galaxies



HAWC upgrade with a sparse outrigger array



Mesure the shower core position when the shower falls outside of the main array.

Factor of 3-4 gain in reconstruction efficiency for $E\gamma$ > 10 TeV


HAWC is working and
in full operation