The HAWC Gamma Ray Observatory

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High Altitude Water Cherenkov 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° N, 97° W)
<table>
<thead>
<tr>
<th>USA:</th>
<th>Mexico:</th>
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</thead>
<tbody>
<tr>
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<td>Universidad de Guadalajara</td>
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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

24 h raw data buffer
2 TB
Raw Data
1200 PMTs – 6 µs

CalibratedTime:Channel {Time>8200000&&Time<9000000&&FLAGS==0}
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

Run 2118, TS 45004, Ev# 41, CXPE40= 55.7, Cmptness= 10.7

Hadron Shower (off source)

Run 2054, TS 584212, Ev# 226, CXPE40= 21.2, Cmptness= 28.3

Likely Gamma Shower (on Crab)
HAWC-250 gamma/hadron

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

Kamata, Nishimura Prog. Theo. Phys. (1958)
HAWC Cost and Funding

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

CONACYNT, 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

Save the date!
March 19-20, 2015 Puebla, Mexico
HAWC Inauguration
March 20 2015
Data sets

**HAWC111**: Aug 2\textsuperscript{nd} 2013 – Jul 7\textsuperscript{th} 2014 (106 - 133 WCDs)

**HAWC250**: Nov 26\textsuperscript{th} 2014 – May 6\textsuperscript{th} 2015 (247 - 293 WCDs)
Cosmic Ray Moon Shadow

HAWC-250

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

- Center displacement
  \[ \Delta \alpha = -0.74^\circ \pm 0.04^\circ \]
  \[ \Delta \delta = 0.08^\circ \pm 0.04^\circ \]
  agrees with deflection of CR due to the Earth B field
  \[ \Delta \alpha = 1.6^\circ Z/E [\text{TeV}] \]
Sun Shadow and Forbush Decreases

- CME in Earth direction modify the geomagnetic environment

Preliminary

**HAWC Sun Shadow - 145 days live**

blurry due to solar magnetic fields

- drop in the single PMT count rate
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

Multipole Fit

$L = 1-3$

relative intensity $[\times 10^{-4}]$
Detailed studies will be made over the next few years already did a combined fit with IceCube CR data
The HAWC $\gamma$-ray Sky

HAWC-111 + HAWC-250

Sigma

0 1 2 3 4 5 6
Crab Nebula

**Milagro**

17σ - 8 years

**HAWC**

38σ - 150 days
HAWC-111 Galactic Plane Analysis: 11 sources
Detection of extended sources

HAWC 250
3 Deg Tophat Smoothing

Geminga

Crab
Blazar light curves and flares

HAWC-111

Markarian 501

PRELIMINARY

7-day interval starting 2013/06/13

Markarian 421

PRELIMINARY

7-day interval starting 2013/06/13
Presently monitoring daily 170 sources: all VHE Blazars and 1FHL blazars with $z<1$
Dark Matter indirect detection

\[
\begin{align*}
\text{Flux}_{\text{Annihilation}} & \propto \frac{\langle \sigma v \rangle}{M_\chi^2} \frac{dN_\gamma}{dE} \int_{\text{l.o.s.}} dx \rho^2(r) \\
\text{Flux}_{\text{Decay}} & \propto \frac{1}{\tau} \frac{1}{M_\chi} \frac{dN_\gamma}{dE} \int_{\text{l.o.s.}} dx \rho(r)
\end{align*}
\]
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
Measure the shower core position when the shower falls outside of the main array.

Factor of 3-4 gain in reconstruction efficiency for $E_y > 10$ TeV.
HAWC is working and in full operation