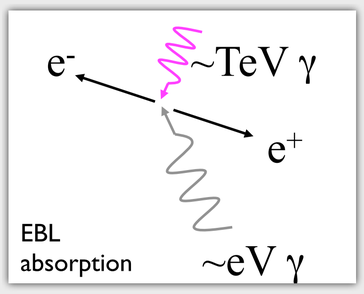
The HAWC observatory as a GRB detector

Dmitry Zaborov[1] for the HAWC collaboration
[1]Pennsylvania State University, University Park, PA, USA

Introduction

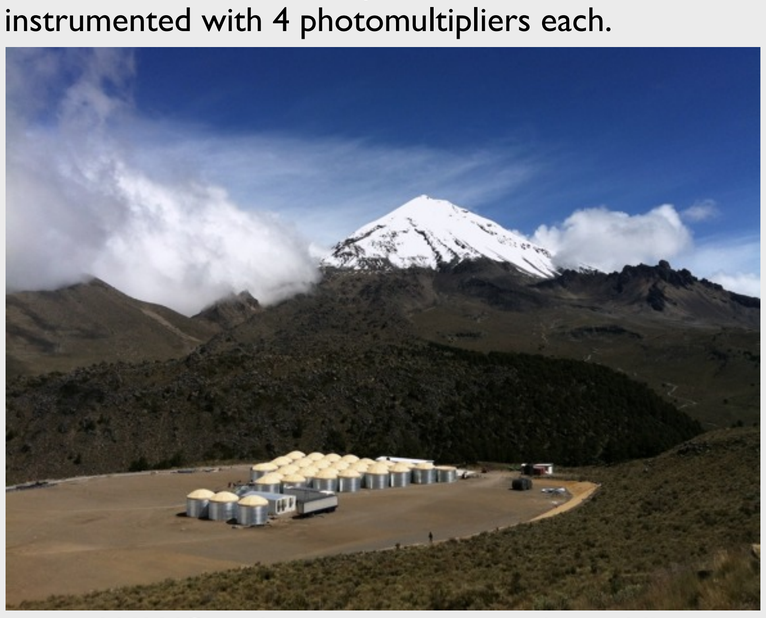
Recent observations by Fermi LAT [1,2] suggest that the high-energy emission of some GRBs extend at least to 30 GeV (90 GeV when corrected for redshift). However at energies above 10 GeV, the data are very sparse due to limited effective area of Fermi LAT (0.8 m^2). The extension of these observations to higher energies requires a detector with much larger effective area.



New observations at the highest energies will shed new light on the physics mechanisms responsible for GRBs and properties of the extragalactic background light (EBL).

The HAWC observatory

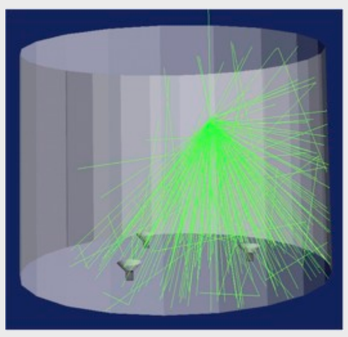
The High Altitude Water Cherenkov Observatory (HAWC) is an air shower array currently under construction in Mexico at an altitude of 4100 m. HAWC will consist of 300 large water tanks covering an area of about 22000 square meters and instrumented with 4 photomultipliers each.



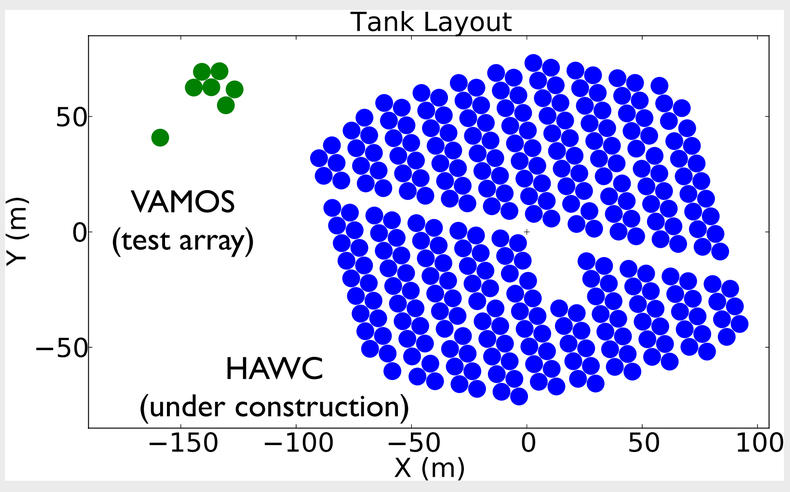
HAWC under construction at the saddle point between Pico de Orizaba and Sierra Negra. 97.3°W, 19.0°N, 240 km East of México City.

Water tanks are 7.3 m in diameter and 4.5 m tall. Each tank contains 200,000 liters of water and 4 upward looking PMTs (three 8" and one 10" high quantum efficiency PMT)

High-energy shower particles (e.g. electrons) hit a water tank, producing Cherenkov light which is then detected by PMTs. Hit arrival times are used to reconstruct the incident direction of the shower.



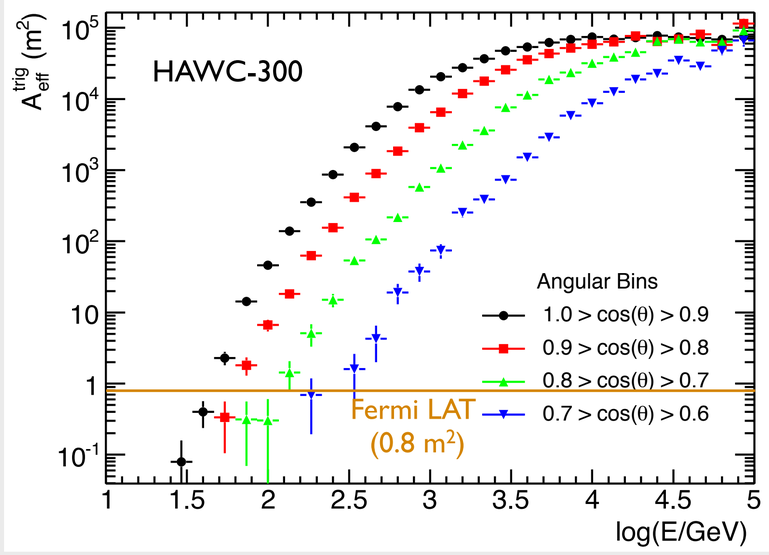
The experiment is built by a collaboration of ~150 scientists and engineers from US & Mexico.
An engineering array of 6 water tanks with 31 PMTs, VAMOS, was operated between Sep '11 and May '12.



The detector layout. Each circle represents one water tank. Tanks cover >60% of the detector area.

Detector performance

The detector is sensitive to photon-induced air showers in the TeV and sub-TeV range. The energy threshold in triggered mode is about 30 GeV.

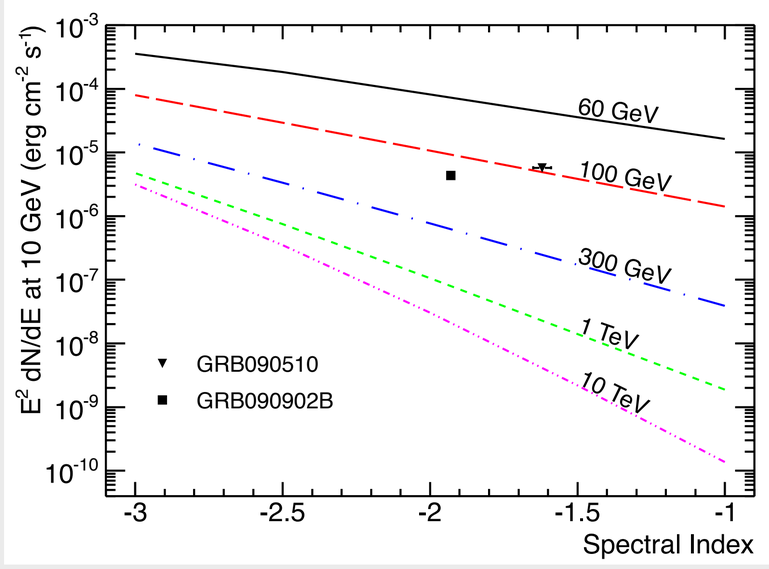


Above: Effective area using the main DAQ system. A trigger threshold of 70 PMT hits is assumed. Showers reconstructed with > 0.8° error are excluded. No gamma-hadron separation cut is applied.

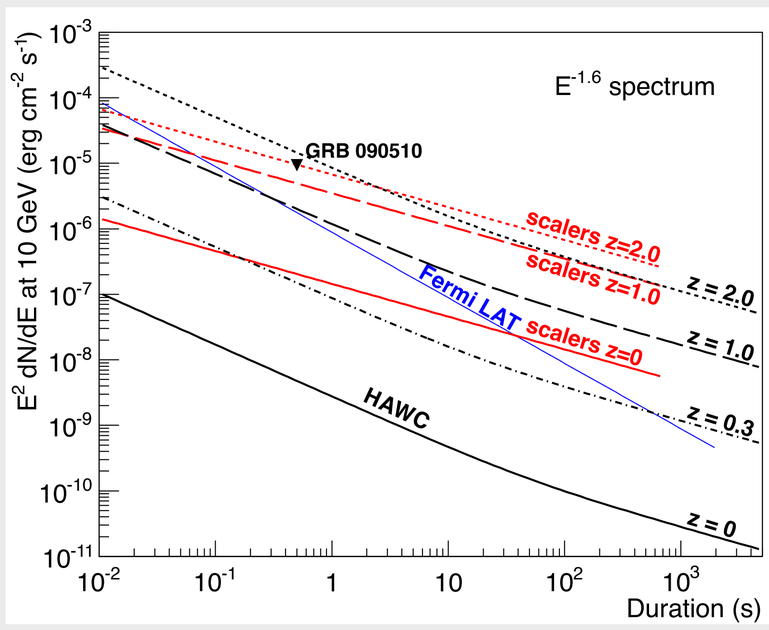
Angular resolution of 0.1° can be achieved at E>5 TeV. Rejection of hadronic showers relies on the shower lateral size and high amplitude pulses produced by muons. Scalers, the second data acquisition system (DAQ), will measure PMT counting rates. A sudden increase in counting rates may reveal a GRB. This method provides an energy threshold of a few GeV.

Sensitivity to GRBs

Brightest GRBs detected by Fermi should be observable with HAWC if the cutoff is above ~100 GeV.



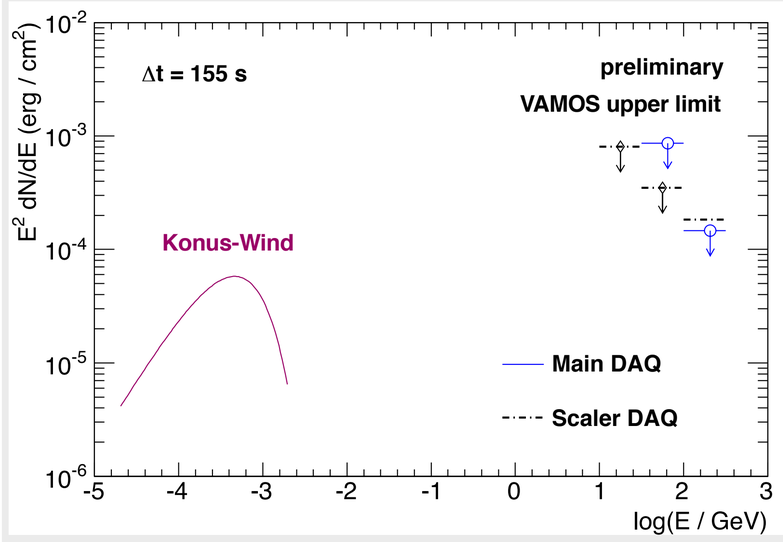
Above: The sensitivity (flux level detectable at 5σ significance with 50% probability) using the main DAQ as a function of spectral index for various values of a sharp high-energy spectral cutoff. The duration of the burst is fixed to 1 s and the zenith angle is 20°.



Above: Sensitivity of HAWC using the main DAQ and scalers as a function of burst duration. The source zenith angle is set to 20°. EBL absorption is modeled according to [3]. The Fermi LAT curve corresponds to 1 photon above 10 GeV. Scalers complement the main DAQ, covering short GRBs with soft spectra and cutoffs <100 GeV. For a detailed report on HAWC sensitivity to GRBs see [4].

First science with VAMOS

The VAMOS test array collected ≈4 months of raw data (live time) in 2011 and 2012. The data can be used to search for high energy emission from GRBs, although with a ≈20-fold reduced sensitivity compared to the full HAWC array. Such an analysis has been performed for GRB 111016B, detected by the IPN network.



Above: Upper limits on high energy emission from GRB 111016B imposed by VAMOS data (using two DAQ systems). The limits are given at 90% confidence level for three energy bands (10 to 31.6 GeV, 31.6 to 100 GeV and 100 to 316 GeV). The spectral fit reported by Konus-Wind (GCN circular 12456) is shown for comparison.
A similar analysis is prepared for GRB 120328B, which was detected by IPN (GCN circular 13157). Fermi LAT reported an 8σ excess for that GRB (GCN circular 13165).

Summary

HAWC is a new generation wide field of view gamma-ray telescope currently under construction in Mexico. The high altitude, high duty cycle and large field of view make HAWC a suitable detector of gamma-ray bursts. HAWC will provide a realistic opportunity to observe the high-energy power law components of GRBs that extend at least up to 30 GeV.

While the main detector array is being constructed, first data from a small HAWC prototype are analyzed. First analyses confirm good quality of the HAWC data, promising continuous improvement in HAWC sensitivity as the detector grows. HAWC is scheduled for completion in 2014.

Acknowledgements

The project is supported by the National Science Foundation, the US Department of Energy Office of High-Energy Physics, the LDRD program of Los Alamos National Laboratory and the University of Wisconsin Alumni Research Foundation, in U.S.; Consejo Nacional de Ciencia y Tecnología, Red de Física de Altas Energías, DGAPA-UNAM and VIEP-BUAP, in Mexico.

References

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