The HAWC experiment and its sensitivity to gamma-ray bursts

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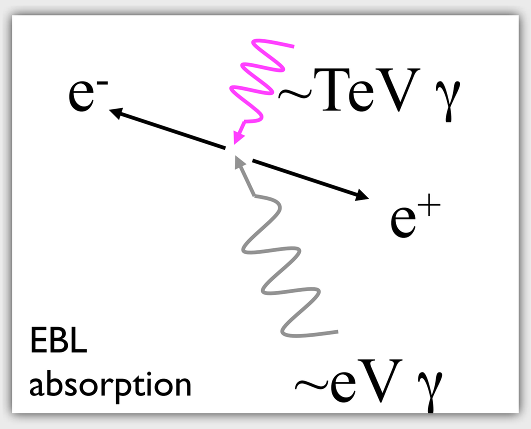
Introduction

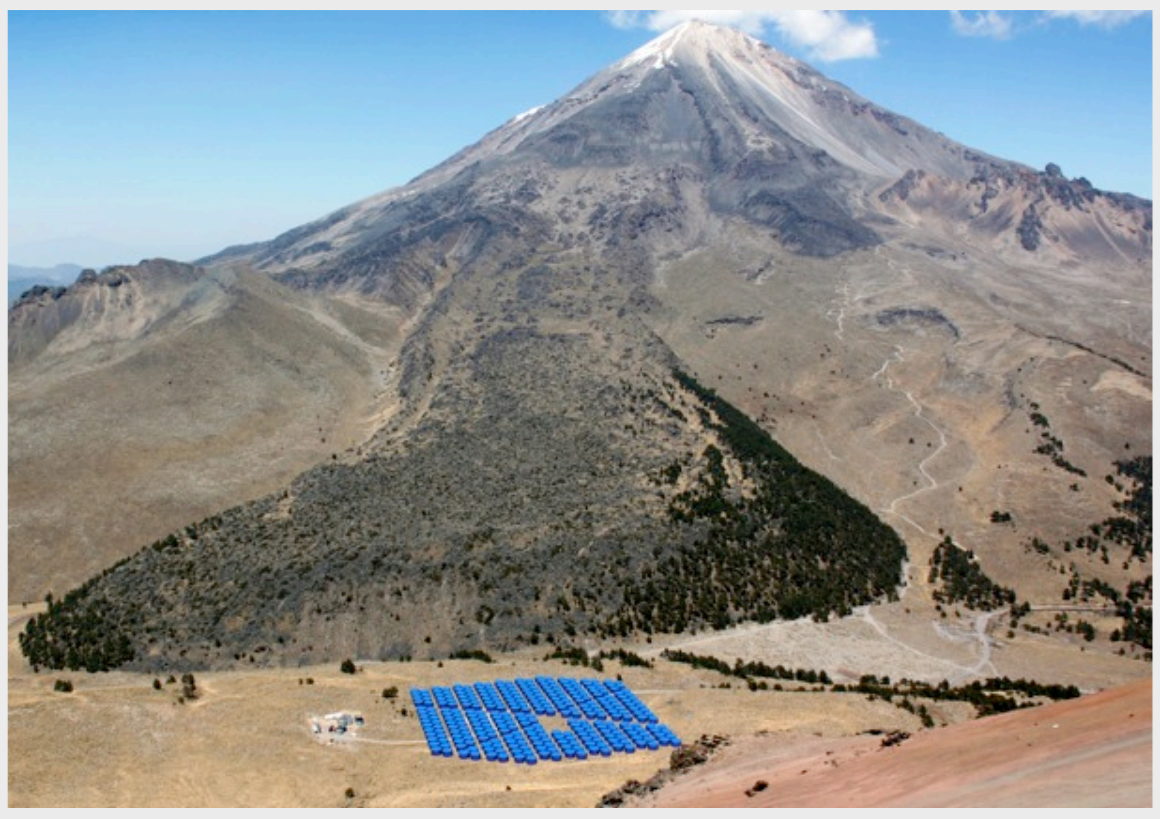
Recent observations by Fermi LAT [1,2] suggest that the high-energy emission of some GRBs extend at least to 30 GeV (90 GeV when corrected for redshift). However at energies above 10 GeV, the data are very sparse due to limited effective area of Fermi LAT (0.8 m^2) and the decrease of the gamma-ray flux with energy. 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

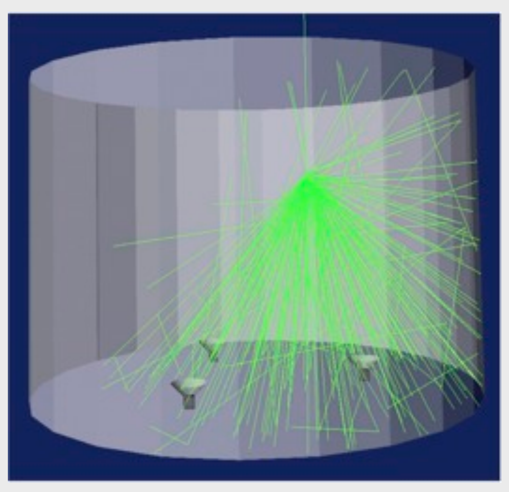
The High Altitude Water Cherenkov Observatory (HAWC) is an air shower array currently under construction in Mexico at an altitude of 4100 m. HAWC will consist of 300 large water tanks covering an area of about 22000 square meters and instrumented with 4 photomultipliers each.



Saddle point between Pico de Orizaba and Sierra Negra with a simulated view of HAWC. 97.3°W, 19.0°N, 240 km East of México City.

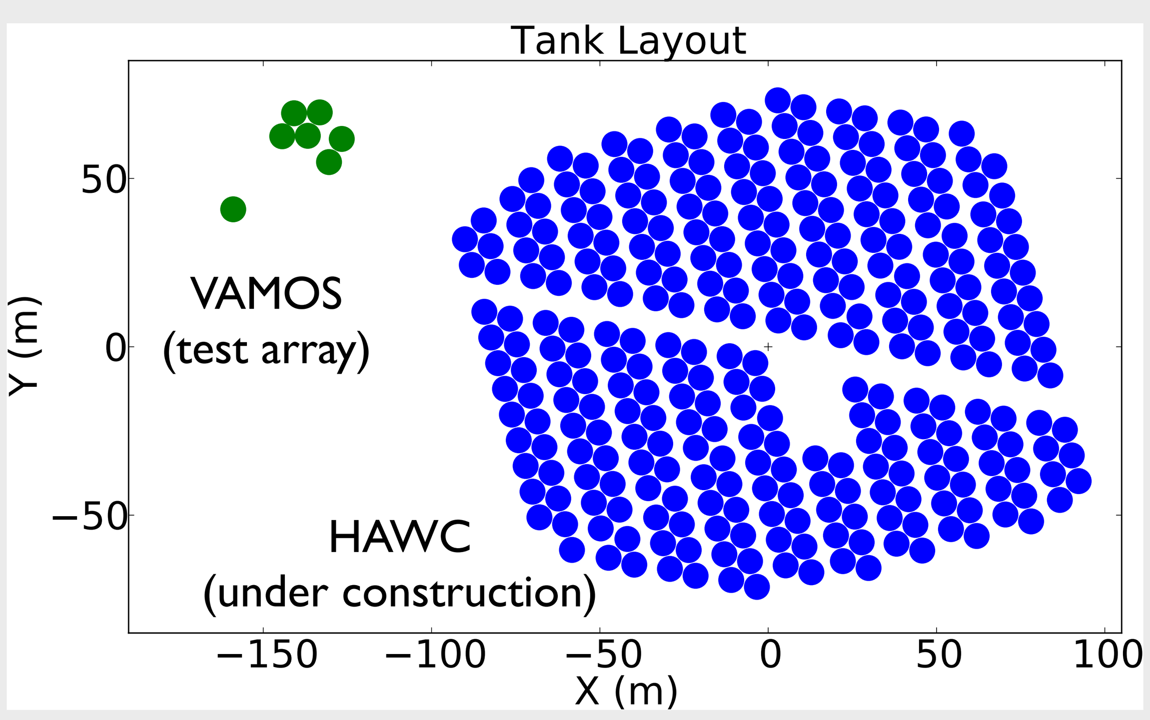
Water tanks are 7.3 m in diameter and 4.5 m tall. Each tank will contain 200,000 liters of water and 4 upward looking PMTs (three 8" and one 10" tube)

Gamma-induced atmospheric showers can be directly detected at HAWC altitude.



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.

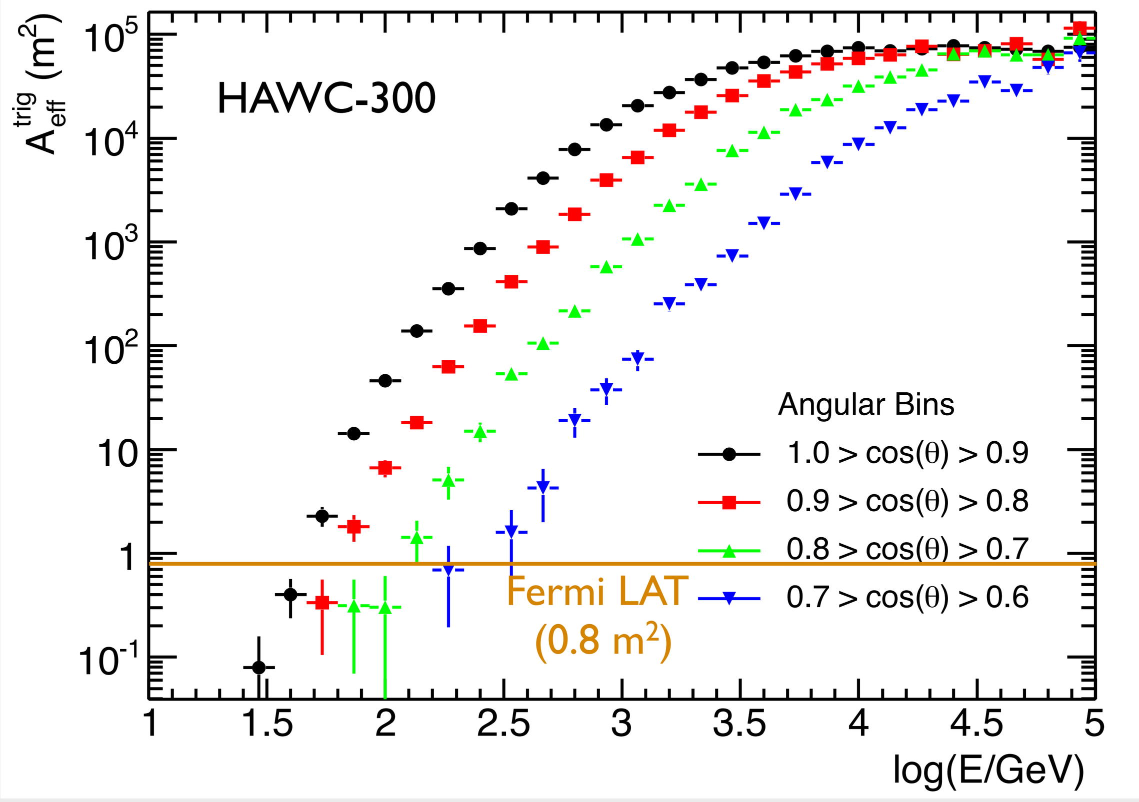
The experiment is built by a collaboration of ~100 scientists and engineers from US & Mexico. The VAMOS engineering array, consisting of 6 water tanks with 31 PMTs, is operational since summer 2011.



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. Effective area approaches ≈10^5 m^2 at high energy (E > 3 TeV). The energy threshold in triggered mode is about 30 GeV.

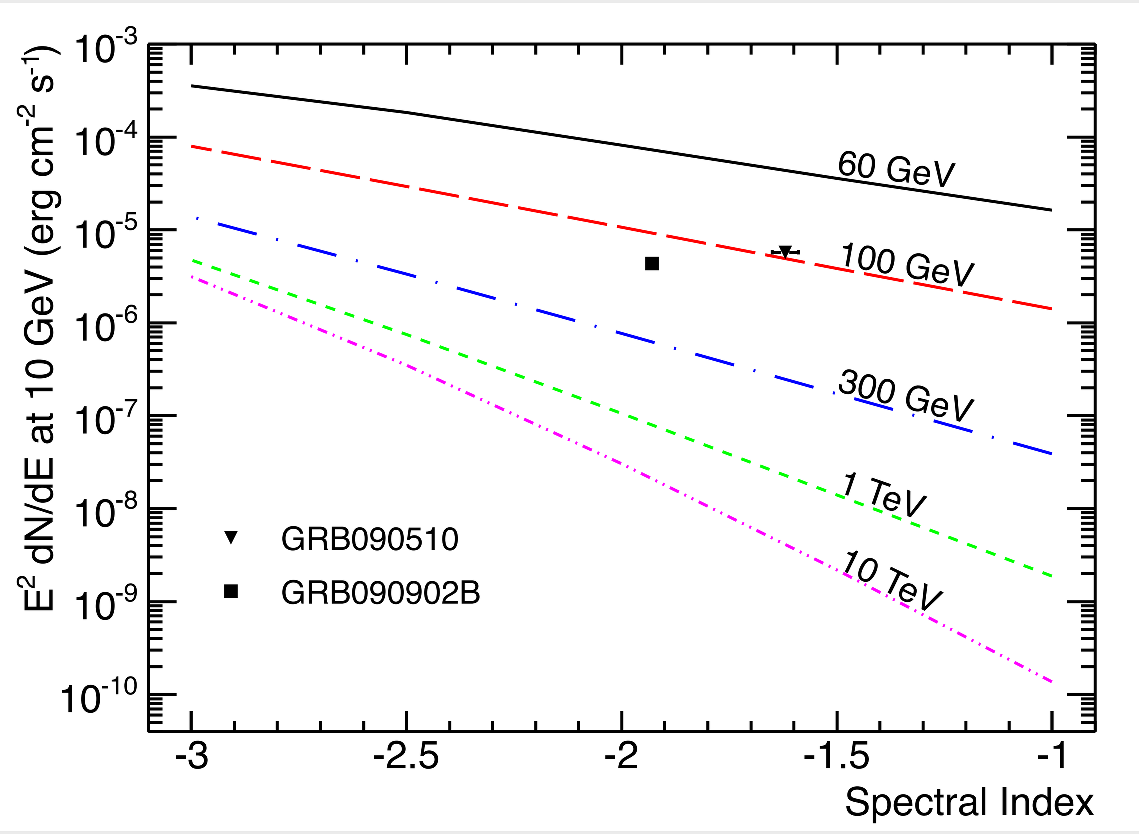


Above: Effective area using the main DAQ system. A trigger threshold of 70 PMT hits is assumed. Showers reconstructed with > 0.8° error are excluded. No gamma-hadron separation cut is applied.

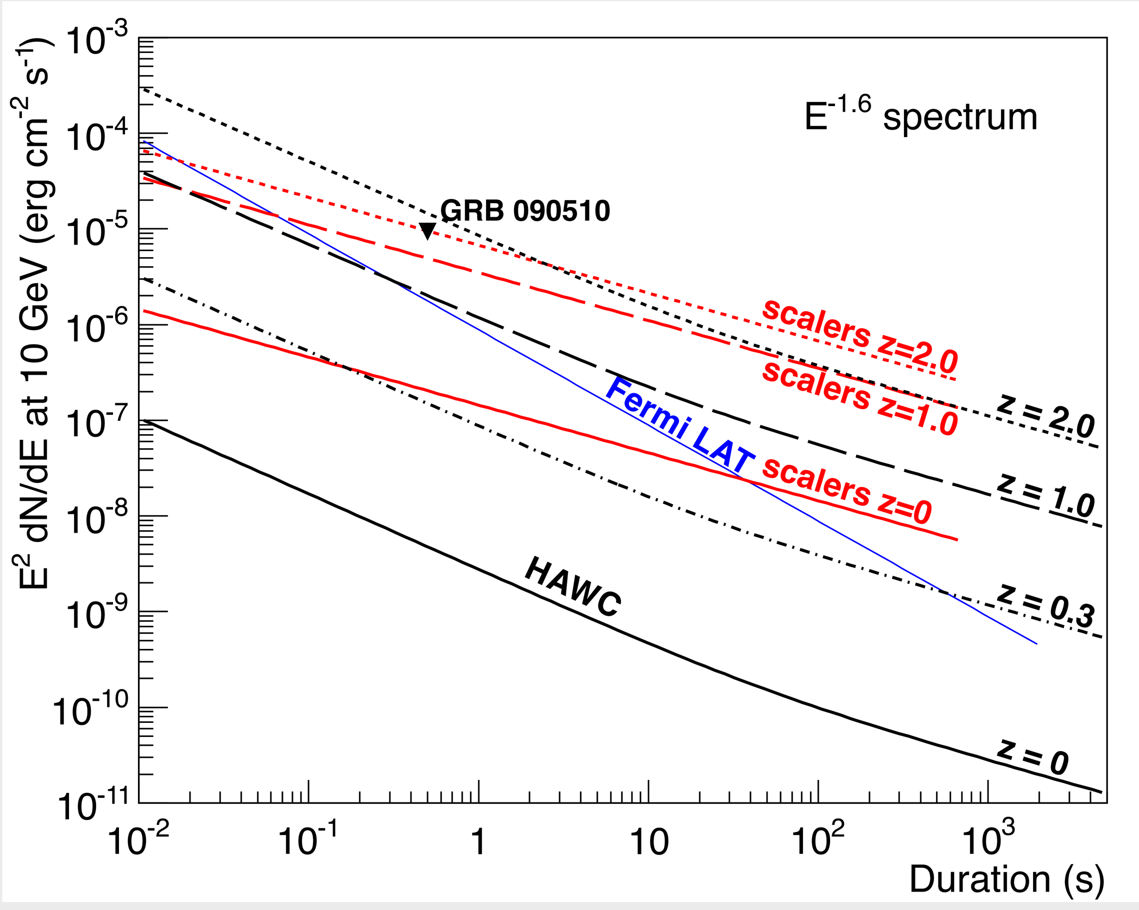
Angular resolution of 0.1° can be achieved at E > 5 TeV. Rejection of hadronic showers relies on the shower lateral size and high amplitude pulses produced by muons. Scalers, the second HAWC DAQ, will measure PMT counting rates. A sudden increase in counting rates may reveal a GRB. This method provides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



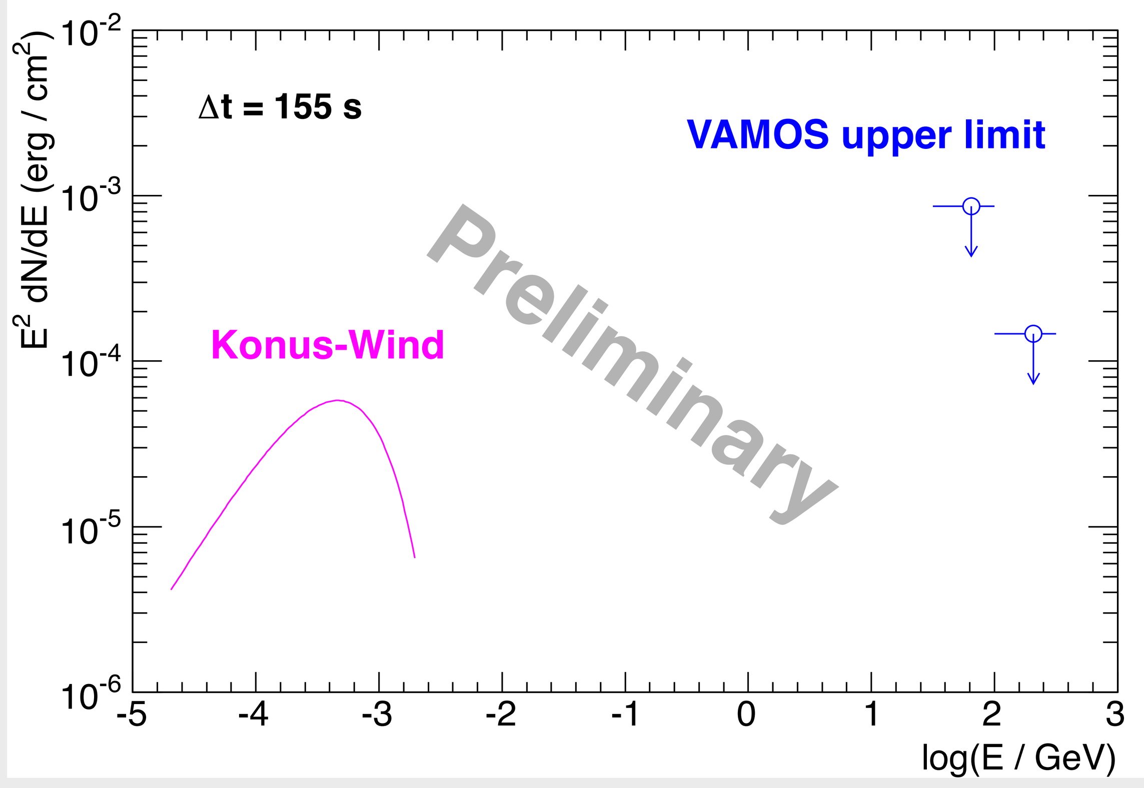
Above: The sensitivity (flux level detectable at 5σ significance with 50% probability) using the main DAQ as a function of spectral index for various values of a sharp high-energy spectral cutoff. The duration of the burst is fixed to 1 s and the zenith angle is 20°.



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 ≈3 months of raw data (live time) starting October 2011. 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 exercised for a long-duration, intense GRB 111016B, detected by the IPN network, including Konus-Wind.



Above: Upper limit on high energy emission from GRB 111016B imposed by VAMOS main DAQ data. The limit is given at 90% confidence level for two energy bands (31.6 to 100 GeV and 100 to 316 GeV). The spectral fit reported by Konus-Wind (GCN circular 7482) is shown for comparison. The scalers analysis provides further improvement upon the limits presented here.

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. HAWC measurements will provide valuable information on the high-energy cutoff in the intrinsic GRB spectra and/or EBL absorption cutoff. While the main detector array is being constructed, first science results already start coming, one of them being the study of 111016B with VAMOS presented above.

Acknowledgements

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References

[1] A. Abdo et al., Fermi Observations of GRB 090902B: A Distinct Spectral Component in the Prompt and Delayed Emission, Astrophys.J. Vol. 706L p 138 (2009)
[2] M. Ackermann et al., Fermi Observations of GRB 090510: A Short Hard Gamma-Ray Burst with an Additional, Hard Power-Law Component from 10 keV to GeV Energies, Astrophys. J. 716, 1178 (2010)
[3] R.C. Gilmore, P. Madau, J.R. Primack, R.S. Somerville, and F. Haardt, GeV Gamma-Ray Attenuation and the High-Redshift UV Background, Mon. Not. R. Astron. Soc., Vol. 399 Issue 4 pp. 1694-1708 (2009)
[4] A.U. Abeysekara et al., On the sensitivity of the HAWC observatory to gamma-ray bursts, Astropart. Phys., Vol. 35, Issue 10, pp. 641-650 (2012)