Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 3 (OG part 2), pages 1567–1570

30TH INTERNATIONAL COSMIC RAY CONFERENCE

HAWC @ Mexico

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Abstract: HAWC is a next generation large area water Cerenkov observatory for mapping and monitoring the high energy TeV γ-ray sky. To achieve optimum sensitivity HAWC requires an area $\gtrsim (150\ \mathrm{m})^2$ at an altitude higher than 4000 m. Following the Mexican proposal, the HAWC observatory will be located inside the Parque Nacional Pico de Orizaba, benefiting of the altitude and latitude of the zone together with the physical and scientific infrastructure developed around the Large Millimeter Telescope.

From Milagro to HAWC

HAWC, the High Altitude Water Cerenkov observatory is a proposal for surveying and monitoring the high energy γ-ray sky. Water Cerenkov detectors like Milagro and HAWC function as wide field monitors of photons of energies ~ 1 TeV, operating continuously -day and night- without interruptions due to weather conditions [1]. Their field of view extend up to 45° from the zenith, allowing to make a shallow survey of more than 7 sr every sidereal day. The continuous accumulation of homogeneous data permits a deep exposure of up to 2/3 of the sky after a few years of operation. The principle of these detectors has been demonstrated with the successful 8 years of operation of Milagro in New Mexico, at an altitude of 2650 m, and its detection of the Crab, Mrk 421 and the extended emission from the Cygnus region [2, 3]. Milagro has also acted as a γ-ray burst (GRB) monitor, set-

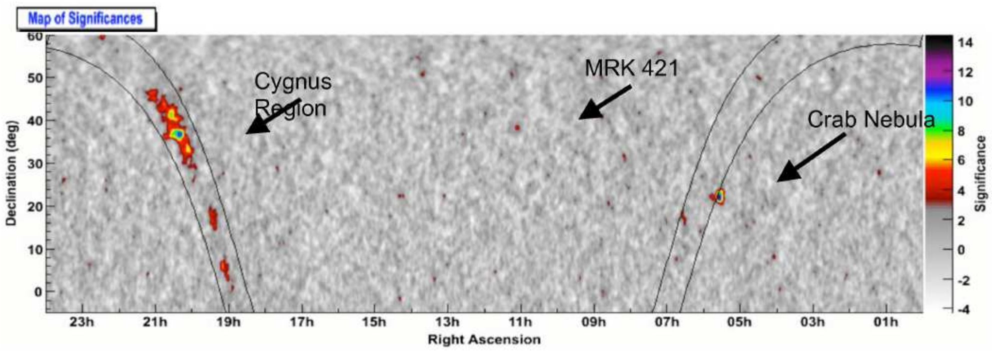

Figure 1: The Milagro view of the high energy γ-ray sky, showing the Crab nebula, Mrk 421 and diffuse emission along the Galactic plane. The extended Cygnus region is the most prominent in the TeV sky.

ting physically constraining upper limits for events like GRB 010921 [4].

The knowledge and resources are already available to build HAWC, a detector more than an order of magnitude more sensitive than Milagro at a reasonable cost ($\sim$ 6 MUSD). The science case for HAWC include mapping and continuous monitoring of the TeV sky; the study of the Galactic interstellar medium, together with the properties of cosmic rays throughout the Milky Way; the study of extended emission from Galactic nebulae; the persistent and transient emission active galaxies; monitoring prompt emission and searching high energy afterglows of GRBs; cosmological pair attenuation and the intergalactic infrared background. HAWC can also be used for studying the Sun, dark matter searches and coincident γ-ray and neutrino emission, in close synergy with IceCube.

Two basic conditions are needed to achieve a more sensitive water Cerenkov detector: a higher site and a larger area detector. Further improvements can be made in the design of the detector. Under these considerations HAWC is conceived to have a $150\,\mathrm{m} \times 150\,\mathrm{m} = 22,500\mathrm{m}^2$ detection area at an altitude above 4000 m. The detector will incorporate a single layer of 900 photomultipliers at a depth of 4 m with respect to the surface of water, arranged in a grid of 30×30 cells of 5 m side, each one optically isolated from the others. This arrangement allows direct rejection of atmospheric muons and an effective hadron-photon discrimination. HAWC will be able to achieve 5σ detections of the Crab nebula in single transits and detections of fluxes down to 50 mCrab after 1 year.

In April 2006 a group of astrophysicists and high energy physicists held a workshop on high energy astrophysics at Tonantzintla[1] and as a result decided to jointly support installing HAWC in Mexico. This group worked on site and design studies, a funding proposal submitted to CONACyT in May 2007 and the environmental impact declaration submitted to SEMARNAT in early June 2007.

The Sierra Negra site

Suitable sites above 4000 meters are hard to find. HAWC requires a flat area of about $200\ \mathrm{m}\times 200\ \mathrm{m}$, manageable weather conditions for human builders and operators, the availability of about 120 000 m^3 of water and of support infrastructure, namely an access road, electricity and internet. Two locations were studied as potential HAWC sites: Sierra Negra in Mexico and Tibet in China. The Sierra Negra volcano is the site of the Large Millimeter Telescope / Gran Telescopio Milimétrico (LMT/GTM), the largest scientific project ever in Mexico [5]. LMT/GTM is a 50 m antenna for millimeter wave astronomy located at the top of Sierra Negra -also known as Tliltepetl- at 4600 m. The development of the LMT/GTM site started in 1997 with the construction of the access road, followed with the installation of a power line and an optical fiber link to the Internet, both currently functional.

Sierra Negra is inside the Parque Nacional Pico de Orizaba, named after Pico de Orizaba or Citlaltepelt, the highest mountain in Mexico with 5610 m.

1. http://www.inaoep.mx/∼alberto/taae/

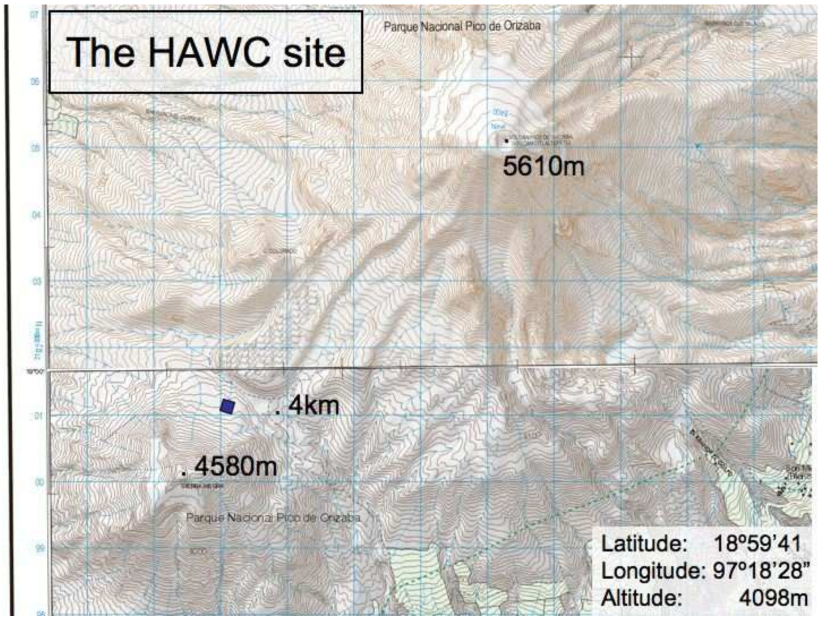

Figure 2: HAWC inside Parque Nacional Pico de Orizaba. The tops of Sierra Negra and Citlaltepetl are marked with their altitudes. HAWC is represented by the square 1 km NNE of the Sierra Negra top. The grid denotes Universal Transverse Mercator coordinates with a 1 km spacing. The geographical coordinates at the bottom right are for the HAWC site. The underlying maps are from INEGI - http://www.inegi.gob.mx

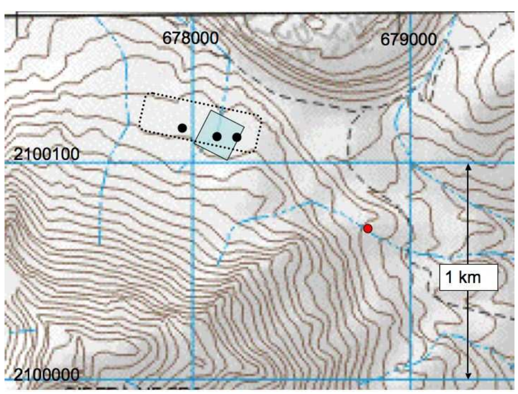

Figure 3: Zoom on the HAWC site. The square denotes a (172 m)^2 area topographically surveyed. HAWC can be located anywhere inside the dotted rectangle which covers $\gtrsim$ 90 000 m^2. The dot at the right marks the nearest point to the LMT/GTM road and electricity post. Map from INEGI - http://www.inegi.gob.mx

The National Park has an extension of 197.5 km^2, which comprises both strato-volcanoes, whose summits are separated by 7 km. The valley between them is at 4000 m. We selected as the HAWC site a relatively flat area at the base of Sierra Negra, which has an area of about 90 000 m^2 comprised within $\pm 10\ m$ altitude. We performed a topographic survey of a favorable location for HAWC with an area of about (210 m)^2, a mean altitude of 4099 m and a slope of 5°. Making a suitable pond requires moving $\gtrsim$ 60 000 m^3 of soil, eased by the softness of the terrain. The site is at $\lesssim 1$ km from the LMT road and power line, from where access, electricity and Internet can be extended to HAWC with very little cost and effort.

Water for HAWC

A challenging aspect of this project is the acquisition of water in a few months. The national park is located in the limits between the Mexican states of Puebla and Veracrúz, in a transition zone from a high altitude dry region (Puebla) to low altitude

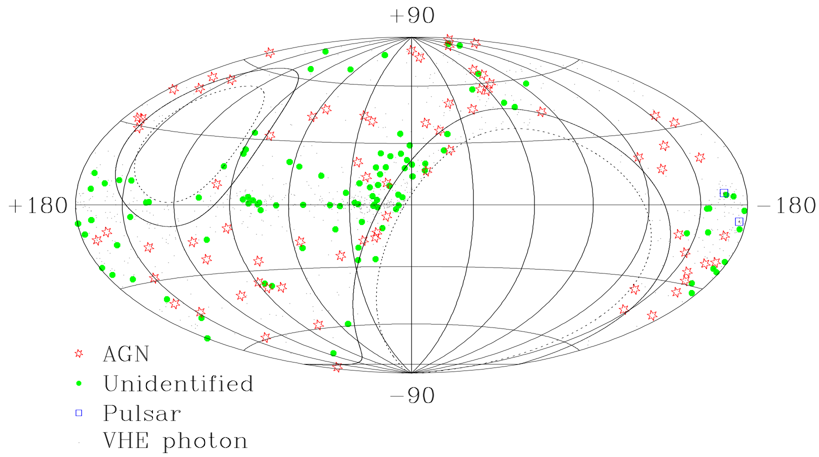

Figure 4: The high energy γ-ray sky as viewed from Sierra Negra. The solid lines represent points transiting $35°$ from zenith, while the dot lines span to $45°$. Show are EGRET sources and $E > 10$ GeV photons.

wet region influenced by the Gulf of Mexico (Veracrúz). The precipitation in the park amounts to 1000 mm/year, with a very marked seasonal modulation: 83% of the precipitation falling in the six months between 1^{st} of May and 31^{st} of October.

We performed geoelectrical studies in the zone, some 500 meters N of the HAWC site, which indicate water flows some 150 m underground along the geological structure of a former glacier. Suitable locations for water extraction wells have been defined and we are currently working on an exploratory well. Complementary water studies used a 3D model of the region to find natural nozzles where water converges during precipitation. One point identified through these studies corresponds to the convergence of precipitation falling in a physical area of just under 10^6 m^2. A concrete trap and pipe system can be used to capture and transport water from this point to the HAWC site.

HAWC astrophysics at Sierra Negra

HAWC will be located at Sierra Negra, where it will benefit from much more than a high altitude site. Sky survey coverage dependence on geographical latitude $\propto \cos(b)$ means that HAWC at $b \simeq 19°$N will cover 8.4 sr, gaining 17% more sky than the 7.2 sr reachable from the Milagro site. Fig. 4 shows the important coverage of the Galactic plane, even grazing the Galactic Center at $46°$ from the zenith. The longitude of the site ensures synchronization with US, Mexican and South American observatories for rapid follow up studies, including daytime LMT/GTM observations.

HAWC operations will be handled through the Consorcio Sierra Negra, whichs groups the scientific experiments in the site, including the largest single dish mm telescope in the world (LMT), the 5 m RT5 radio telescope, a solar neutron telescope (TNS), two atmospheric Cerenkov telescopes, a cosmic ray surface detector array and a fluorescence telescope. HAWC will form part of an unique multiwavelength multidisciplinary scientific complex able to perform combined astrophysical studies (LMT + ACTs), high energy solar physics (RT5 + TNS) and cross calibrated cosmic and γ-ray event reconstructions. Sierra Negra will provide HAWC with the required infrastructure added with extraordinary synergy and the support of Mexican scientists experienced in geophysics, astrophysics, solar and high energy physics.

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