A High Altitude Mexican ACT Project, OMEGA

R. Alfaro[*], L.C. Alvarez[†], E. Belmont-Moreno[*], A. Bernal[†], O. Blanch [‖], A. Carramiñana[‡], O. Chapa[†], B.L. Dingus[§], F. Garfias[†], M.M. González [†], V. Grabski [*], F. Huidobro [*], A. Iriarte [†], A. Martínez-Dávalos [*], A. Menchaca-Rocha [*], R. Núñez [*], J.R. Sacahui [†], A. Sandoval [*], M. Schneider [¶], G. Tejada [†] and G. Tovmassian[†]

[*]*Instituto de Física, UNAM, México*
[†]*Instituto de Astronomía, UNAM, México*
[‡]*Instituto Nacional de Astrofísica, Óptica y Electrónica, México*
[§]*Los Alamos National Laboratory, U.S.A.*
[¶]*University of California - Santa Cruz, U.S.A.*
[‖]*Institut de Fisica d'Altes Energies, Espaa*

***Abstract*. Two of the former HEGRA atmospheric Cherenkov telescopes are being refurbished at the Universidad Nacional Autónoma de México (UNAM) with the purpose of being installed as the Observatorio MExicano de GAmmas (OMEGA, Mexican Observatory of Gammas). The Sierra Negra site, at an altitude of 4100m a. s. l. has been chosen to host OMEGA in order to test the performance, sensitivity and energy threshold of atmospheric Cherenkov telescopes at high altitude. OMEGA will also belocated adjacent to the HAWC TeV gamma-ray observatory in order tocross calibrate HAWC events and to follow upHAWC candidate sources. The primary scientific objective of OMEGA is to monitor TeV blazars, and OMEGA willwork in synergy with the Sierra Negraconsortium of observatories to perform broad band multi-wavelength observations. We will present the OMEGA project in detail and its status.**

***Keywords*: OMEGA, gamma rays, Sierra Negra**

I. INTRODUCTION

Recently ground-based telescopes have revealed a sky rich with objects that emit TeV gamma rays. Atmospheric Cerenkov Telescopes (ACT) have proved their remarkable sensitivity to discover and study individual sources and to perform surveys over a limited area of the sky. For instance, more than 60 TeV-sources with energy spectra reconstructed from about 100GeV up to almost 100TeV have been discovered and, HESS has surveyed [1] the central part of our galaxy showing a large number of new sources that line up with the galactic plane. However, the community of ACTs has realized the need of a telescope with higher sensitivity in a broader energy range with large field of view. In order to achieve this, the ACT community is designing the future generation of ACT telescopes as one or two arrays of tens of individual atmospheric Cerenkov telescopes. The sensitivity is expected to be improved by a factor of 5-10 in the current energy range and the energy range will be extended below 100GeV and up to 100TeV.

In other hand, some authors have been studied with Monte Carlo simulations, the sensitivity of a high altitude ACT. For instance, Aharonian et al. [2] showed that setting the detector closer to the shower (higher altitudes) it is possible to reduce the effective propagation lenght of the photons resulting on an increment of the number of Cherenkov light photons that reach the telescope reflector. At altitudes around 5000 m a.s.l. the density of Cherenkov photons could increase by a factor of 2 compared with the density measured around 2000 m a.s.l. In consequence just operating the same ACT at different altitudes could reduce the energy threshold by a factor of 2 [3]. However some authors [4], [5] pointed out that the topology of the Cherenkov light images recorded at high altitude could be different besides there will be an increment in the background light over the camera pixels, therefore the overall performance of an ACT at high altitude site would not be as good as it has been predicted. Then OMEGA will provided us with important experimental evidence to determine if operating an ACT at high altitude is an option for the next generation of gamma observatories.

Fig. 1. Google Earth images of Mexico. Puebla is a central state.

II. OMEGA

The Mexican Observatory of Gammas, OMEGA (Observatorio MExicano de GAmmas), is a proposed Atmospheric Cherenkov Observatory situated at 4100m a. s. l.

in the Volcano Sierra Negra. The idea is to test the performance of the Atmospheric Cherenkov telescopes at high altitudes using telescopes of the previous generation to lower the cost and more important to compare with the known performance and observations at 2200m a. s. l. eliminating discrepancies associated to the instruments.

The HEGRA observatory operated from 1997 until 2002 in La Palma Spain at 2200m a. s. l. Then, two of the four HEGRA telescopes were moved to Los Alamos National Laboratory in New Mexico, U. S. A. waiting to be installed at high altitude. In October 23rd, 2007, the two telescopes arrived to the Universidad Nacional Autonoma de Mexico, Mexico City, Mexico, to be part of OMEGA.

The first part of the OMEGA project includes the refurbishing, installation and operation of the two telescopes in the Volcan Sierra Negra. Depending on funding and the results of the first stage, an increase of the mirror collecting area, upgrade of the electronics and increasing the number of telescopes are being considered.

Although the main goal of OMEGA is to test its performance at high altitude it will also be a dedicated observatory to monitor the brightest blazars and it will follow up candidate HAWC sources. Since HAWC will be also located at Sierra Negra, OMEGA will help to cross calibrate the lowest energy HAWC gamma-rays events. Furthermore OMEGA will work in synergy with the Sierra Negra consortium of observatories to perform broad band multi-wavelength observations

A. *OMEGA site*

The volcano Sierra Negra or Tliltepetl is located in the state of Puebla in Mexico. The peak of Sierra Negra is 2hrs from Puebla and 3.5hrs from Mexico City, see Figures 1 and 2. Both cities with international airports. The site is inside the Parque Nacional Pico de Orizaba, a Mexican national park comprising Citlaltepetl or Pico de Orizaba, the highest peak in Mexico at 5610m, and Sierra Negra or Tliltepetl, a 4600m volcano 7km SW Citlaltepetl. OMEGA will be located on a 200m x 450m plateau near the saddle between the two peaks next to HAWC. The exact geographical coordinates of the site are latitude $18°59'41''$, longitude $97°18'28''$, altitude 4100 masl, in Central Mexico. The latitude of the Sierra Negra site provides an excellent visibility of celestial objects: the Crab, the Cygnus region, Mrk 421, MGRO J1908+06 and limited access to the Galactic center. OMEGA and the HAWC TeV observatory will share site, see Figure 3.

B. *Climate*

The site is located close enough to the equator to have weather conditions as benign as could be wished for its altitude. Weather conditions have been monitored for over six year at the summit of Sierra Negra, 500 meters above the site with a horizontal distance of 1km, see Figures 4 and 5. The median temperature (adding the $6.5°$ thermal gradient to the 4600m measurements)

Fig. 2. Google Earth images of Puebla. The distance between Mexico City and Puebla is about 103km. The cone of Citlaltepetl and its snow can be appreciated in the border between the states of Puebla and Veracruz, center of the figure.

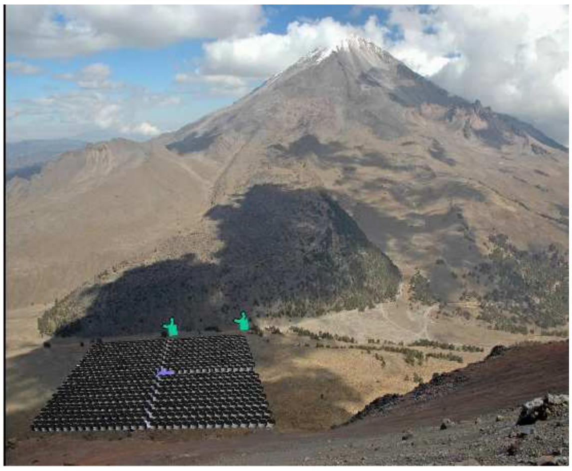

Fig. 3. The Pico de Orizaba Volcano observed from Sierra Negra at the LMT site. The black array simulates the position of the HAWC and the green figures simulate the two former HEGRA telescopes that will integrate the Observatorio MExicano de Gammas, OMEGA

becomes $4.3°C$ for the site, with sub-zero temperatures only 5% of the time (specifically 10% of the time during winter), see Figure 5. Freezing will not be an issue. Wind velocities are generally mild (Figure 6), with a median of 4 m/s for the recorded data. Occurrence of wind above 10 m/s is rare. Still, the passage of a hurricane Dean some 100 km North of the site provided winds up to 150 km/h, the largest measured in the 6 years of meteorological monitoring, see Figure 7. Lower wind velocities are expected for the OMEGA site since it is protected by the two volcanos.

C. *Status*

The equipment has been visually inspected. All the mechanical parts are in good conditions and without evident damage. The cameras and their housings are also in good conditions. One of them has being connected

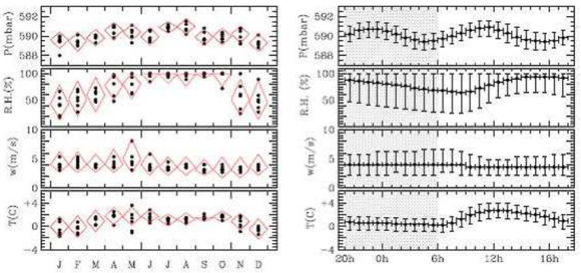

Fig. 4. Left: Monthly statistics of temperature, pressure, humidity and wind. Dots denote quartiles for each of the six years sampled, while diamonds indicate the overall median and lower and upper quartiles. Right: hourly statistics of the same quantities, with error bars going from lower to upper quartiles and using the same vertical scale as in left. The shaded zone denotes nighttime.

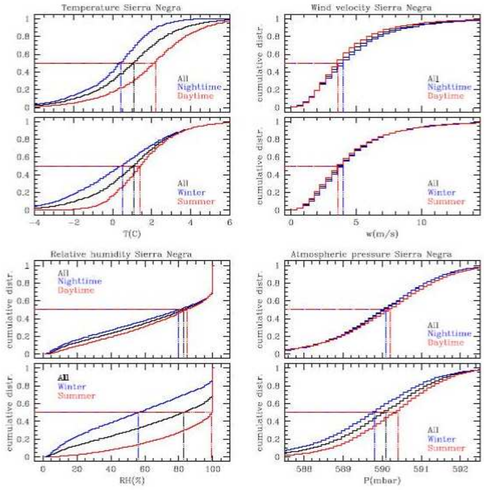

Fig. 5. Temperature (top-left), wind speed (top-right), relative humidity (bottom-left) and pressure (bottom-right) at Sierra Negra. Note the narrow range in the temperature scale and that the distribution of the wind is independent of night, day, summer and winter.

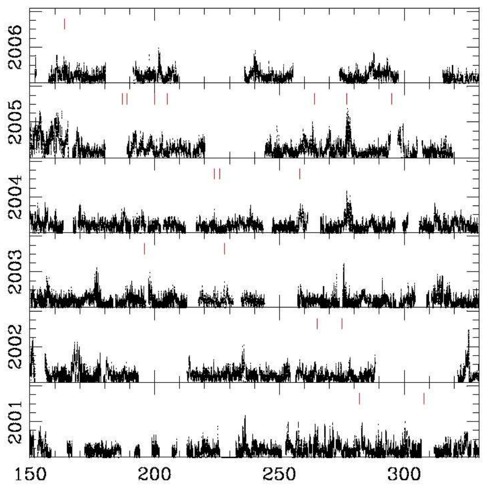

Fig. 6. Wind speed for the second semester of the year from 2001 to 2006 when highest wind speeds are expected because of hurricane effects. All panels have the same scale, x-axis indicates number of day in the year.

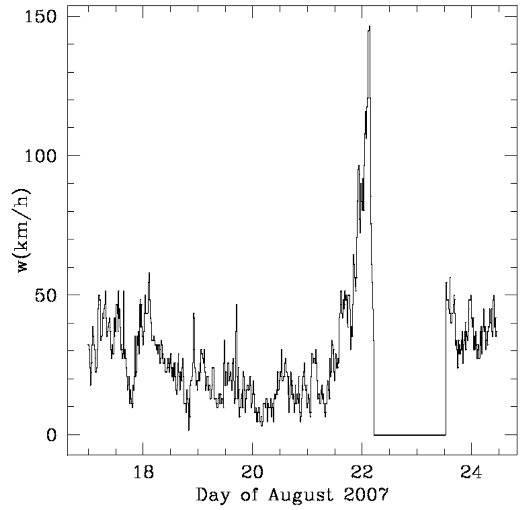

Fig. 7. Wind speed recorded at the LMT site with the pass of the DEAN Hurricane. The maximum speed was 145 km/hr.

Fig. 8. One of the HEGRA electronics as it is in UNAM. The monitor shows the computer interface running in test mode.

to the electronics. So far communication between the VME controller and the rest of the electronics has been established. The temperature and pressure sensors have being also accessed by the VME controller. All the system is being running in a test mode (Fig. 8) with fully control of the system except the motor encoder part that has not being installed and therefore no data can be storage. Eight anchors for the two telescopes are being made. The main computers with the original DAQ and control system are being used. Since they are more than 10 years old and we have had some failure problems that were temporally fixed, we are working on installing

TABLE I
REFLECTIVITY VALUES FOR DIFFERENT SPOTS IN TWO MIRRORS.

cleaned mirror	dirty mirror
0.795	0.813
0.766	0.808
0.759	0.802
0.757	0.797
0.783	0.787
0.777	0.809
0.868	0.809
0.793	0.806
	0.794
	0.767

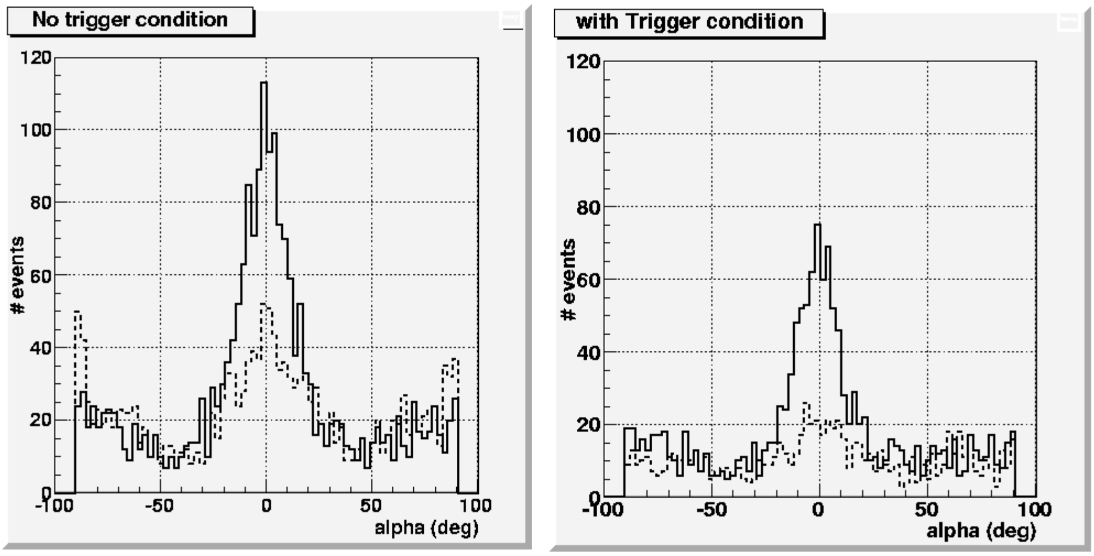

Fig. 9. Distribution of the Hillas parameter alpha for gammas of 800GeV (solid line) and 500GeV (dashed line) for at least one PMT hitted (left) and three PMTs hitted with more than 8 photo-electrons (right) in one telescope.

the DAQ and control system in newer computers.

Optical parts (mirrors) were also inspected one by one and so far only one is broken. The cleaning process is made is several steps. First, the dust is eliminated using water, then a commercial liquid soap (extran 2% 7.2 ph) is applied to the whole surface uniformaly with cotton, cleaned using destilled water and dried with ethylic and acetone alcohol (70 - 30). Finally, air pressure is applied to evaporate all the alcohol and the mirror is cleaned with cotton. This process does not damage the surface.

The reflectivity for two mirrors has been measured using a simple setup. The intensity of a laser was measured with a photometer before and after the mirror. The laser had a wavelength of 632.8nm and the reflection angle was 45 degrees. The photometer was located at a minimal distance of 5cm to avoid errors due to the curvature of the mirror. The process was performed in 8 (for a cleaned mirror) and 10 (dirty mirror) different spots of 1.5mm of diameter along two parallel lines, each one 15cm away from the center. The obtained reflectivity for each point is given in Table I. The average reflectivity for the cleaned mirror was $78.7 \pm 3.6\%$ and for the dirty one was $79.9 \pm 1.4\%$. Clearly, this test is not sensitive to dirt in the mirror surface because of the spot size but it estimates the general condition of the reflectivity for all mirrors. Values for 547 and 395nm will be measured in a future work as well as the reflectivity for the whole area of the mirrors.

A first version the Monte Carlo simulation of one of the telescopes is already available. This Monte Carlo simulates events with Corsika at an altitude of 2200 and 4500m a. s. l., the reflector and the camera. It includes the mirror geometry, reflectivity, PMT quantum efficiency, etc. The reconstruction of the Monte Carlo events uses the Hillas parameters and includes adjustable trigger and noise functions. Figure 9 shows some preliminary results for showers of gammas with an energy of 500GeV and 800GeV at 2200m a. s. l.

Omega was added in June 2008 to the site permit granted for HAWC. In March 2009, the permit for the road access to the site was granted. The construction of this road is in progress. The telescopes may be moved to the site by the end of this year.

III. ACKNOWLEDGMENTS

This work has been supported by Direccion General de Apoyo al Personal Academico (DGAPA), UNAM through the project number IN119708 and Consejo Nacional de Ciencia y Teconología (CONACyT) through the project number I82895.

REFERENCES

[1] Aharonian F., et al, Science, 307, (2005) 1938.
[2] Aharonian F.A. et al, Astrop. Phys. 15, (2001) 335.
[3] Horns D., et al, 29th ICRC, 5, (2005)187
[4] Konopelko A., J. Phys. G, 30, (2004) 1835.
[5] Acharya B.S., et al. 30th ICRC, (2007) to be published