29th International Cosmic Ray Conference Pune (2005) **5**, 243-246

The Himalayan Gamma – Ray Observatory at Hanle

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A new gamma ray observatory comprising a large stereo imaging cherenkov telescope and an array of wave front sampling telescopes is being set up at the high altitude astronomical site at Hanle in the Ladakh region of Northern India. Using the high altitude and low night sky background of the site to advantage, the two telescope systems will access the important region of very high energy gamma rays in the 10's of GeV energy range.

1. Introduction

The rapid developments in the field of Very High Energy (VHE) gamma ray astronomy during the last two decades have led to the discovery of more than a dozen galactic and extragalactic objects in the TeV energy range [1]. While most of these detections have been made with systems operating at energy thresholds of a few hundred GeV, more recently instruments with energy thresholds of about 100 GeV like the HESS telescope have produced several exciting results[2] . The energy band between 10 GeV and 100 GeV which is still largely unexplored is expected to give clues to the mystery of spectral cutoffs in AGN spectra and the pulsed emission from Pulsars. It is also expected to lead to a potentially rich harvest of astrophysical discoveries like high energy tails of gamma-ray bursts, Supernova remnants and plerions and unidentified EGRET sources . These low threshold energies can be attained by increasing the light collector area of the telescopes and installing them at higher altitudes where the photon density of atmospheric Cherenkov events is higher [3]. As a collaborative effort of the Indian Institute of Astrophysics, Bangalore, Tata Institute of Fundamental Research, Mumbai and Bhabha Atomic Research Centre, Mumbai, the Himalayan Gamma Ray Observatory (HIGRO) is being set up at Hanle (32.8^{o}N, 78.9^{o} E, 4200m asl) in the Ladakh region of Northern India to address this important energy range using the two techniques of 'imaging' and 'wavefront sampling' of atmospheric Cherenkov photon showers produced by cosmic gamma rays. The site offers an average of about 260 uniformly distributed spectroscopic nights per year which is a major advantage in terms of sky coverage for source observations. Located closer to the shower maximum the Cherenkov photon density at Hanle is a factor of about 4 -5 more than at sea level [4]. This increase in photon density along with the low background light level at the site help in lowering the threshold energy of the Cherenkov telescopes being set up there. This high altitude observatory will be located in close proximity to a 2 m optical telescope which has been operating for the last several years and can provide concurrent optical monitoring of the objects of interest.

2. Stereo MACE imaging telescope

The MACE (Major Atmospheric Cherenkov Experiment) telescope is planned to be a system of two high resolution imaging Cherenkov telescopes operating in a stereoscopic mode for gamma ray investigations in the sub TeV energy range. As depicted in Figure1a each telescope element will be based on the track and wheel design concept and will deploy an altitude-azimuth mounted parabolic light collector of 21 m diameter. The drive control system of the telescope is being designed around electronically commutated motors using digital controllers, PC compatible hardware and software and Ethernet connectivity for remote monitoring and control. The light collector will be made of 356 panels of 984 mm x 984 mm size with each panel consisting of 4/9 spherical mirror facets of 488 mm x 488 mm/323 mm x 323 mm size. Each aluminium alloy (Al-6063T6) facet is diamond turned to a mirror finish yielding a reflectivity of >85% in the visible band. The focal length of the facets which increases towards the periphery will range from 2109 cm – 2245 cm. The use of graded focal length mirrors reduces the D_{95} spot size (defined as the diameter of the circle within which 95% of the reflected rays lie) of the light collector to ~29 mm (=0.080^o) for on-axis incidence and ~85 mm (=0.23^o) for incidence angle of 1^o. The Davies Cotton design on the other hand, although found to yield slightly better off-axis characteristics at incidence angles beyond 0.75^o, introduces a time spread of ~ 9ns which can lead to a contamination of the genuine Cherenkov signal from unwanted light of night sky background. Each of the 356 mirror panels will be equipped with motorized orientation controllers for aligning them to form a single parabolic light collector. The hardware and software requirements of the system have been worked out and image processing algorithms for mirror alignment based on the use of 'alignment lasers' and 'star image' methods have been evolved [5].

The focal plane instrumentation will comprise 832 pixels imaging camera providing a field of view of 4^{o}x4^o. While the inner 576 pixels covering a field of view of 2.4^o x 2.4^o will have a pixel resolution of 0.1^o for generating the event trigger, the surrounding 256 pixels will have a coarser resolution of 0.2^o. The photomultiplier tubes (PMT) will be provided with acrylic front-aluminized light cones for enhancing the photo-sensitive area of the camera. The signal processing instrumentation will also be housed within the camera and the digital data will be sent over optical fibers to the computer network in the control room for processing and archiving. Preliminary simulation studies using the CORSIKA [6] air shower simulation code have been conducted to evaluate the expected performance parameters of the MACE telescope. Based on the measured value of the night sky background and a coincidence gate width of ~10 ns, we have evaluated the single pixel threshold to be ~4 pe at a single channel rate of ~26KHz using the Nearest Neighbour Quadruplet (NNQ) trigger. As shown in Figure1b and Figure1c, the γ-ray threshold energy of a single MACE element works out to ~15 GeV and ~25 GeV at zenith angles of 10^o and 30^o respectively while the proton threshold is ~60GeV and 80GeV respectively [7]. Detailed simulation studies which include the stereo-mode operation of the MACE are in progress.

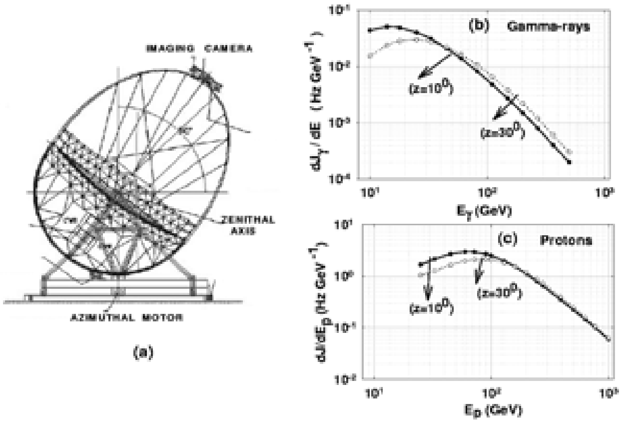
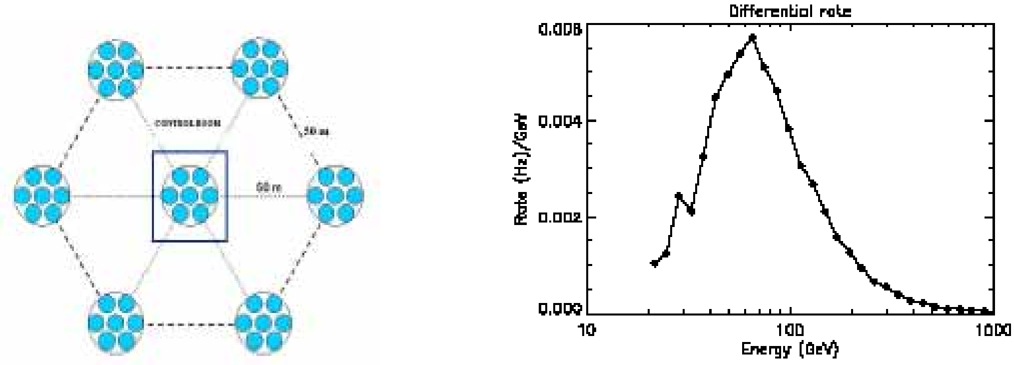


Figure 1. (a) A schematic of the MACE gamma-ray telescope planned to be set up at Hanle. (b) Differential detection rate for gamma-rays as a function of the primary energy. (c) Differential detection rate for protons as a function of the primary energy.

3. HAGAR telescope array

The HAGAR (High Altitude GAmma Ray) experiment [8] will deploy 7 altitude – azimuth mounted telescope elements at the centre and corners of a hexagon of 50 m side as shown in Fig2a. Each element comprises 7 paraxially mounted front-coated F/1 mirrors of 90cm diameter each with a PMT at its focus. The signals from the 7 PMT in each element will be added linearly before amplitude discrimination to yield a suitable count rate. It will use CAMAC instrumentation controlled by a LINUX platform.

Studies for the HAGAR experiment have been carried out with the CORSIKA air shower simulation code. Showers initiated by gamma rays, electrons, protons and alpha particles incident vertically at the top of the atmosphere were simulated using appropriate spectral shapes. The differential γ-ray count rate expected from the Crab nebula for a PMT gain of $\sim 10^7$ is shown in Figure2b. The peak of the distribution at ~ 60GeV defines the energy threshold of the telescope for vertically incident showers. The event rate for a coincidence trigger based on 4 out of 7 telescope elements at a PMT gain of $\sim 10^7$ is expected to be about 55Hz from protons, 16Hz from alpha particles, 1.3 Hz from electrons and ~ 0.8 Hz from gamma rays from the Crab Nebula.



(a) **(b)**

Figure 2. (a) Layout of the HAGAR array. (b) Expected differential γ-ray count rate spectrum from Crab nebula.

Monte-Carlo simulation studies for assessing the segregation potential of various parameters along with their dependence on observation height has been investigated. The results indicate that while the radius of curvature of the Cherenkov light front is more sensitive to primary species as compared to lower observation altitudes, the relative timing jitter remains almost constant as a function of observation height. Further more it is also found that the Cherenkov pulse delay time which is more sensitive to the presence of hump is relatively less sensitive to the primary species compared to that at lower observation altitudes. Thus using relative timing jitter and pulse decay time in tandem it is expected that about 98% proton showers will be rejected while retaining about 35% γ ray showers. Use of parameters based on Cherenkov photon density including local and medium range photon density fluctuations have also yielded promising results to discriminate γ-ray events from the more abundant cosmic ray events.

4. Implementation status

The first element of the HAGAR experiment has been recently installed at site and preliminary functional tests have been successfully carried out. The other six elements of the telescope will be in place in the next one and a half years and the complete array is expected to be operational by early 2007. The detailed engineering and structural design of the MACE telescope is being started soon and the mechanical structure of one element will be installed at site by 2008. The first imaging element will be fully operational by 2010 and will subsequently be augmented by a stereo element.

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