MACE

Astrophysical Sciences Division
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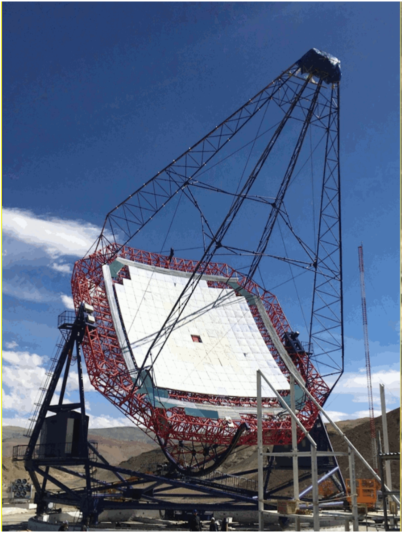
Picture Gallery



MACE gamma-ray telescope @ Hanle

MACE (Major Atmospheric Cherenkov Telescope)

The MACE is a 21m diameter telescope installed at Hanle in Ladakh at an altitude of 4270m above sea level, highest for any IACT based telescope. It follows a wheel and track design for the ± 270 azimuthal movements. Four booms hold the camera at a focal distance of 25 m from the reflecting surfaces of the mirror facets clamped on the mirror basket. The entire reflecting surface will thus be at a distance of 25 m from the focal plane. The novel feature of the telescope is the design of the integrated imaging camera, which contain 1088 photomultiplier-based pixels and all the signal processing and data acquisition electronics. Only a few power cables and optical fiber based data cables links the camera to the central control room, where a computer network is housed for telescope control, monitoring and archiving the data. The azimuthal track of the telescope is about 27 m in diameter and the overall height of the telescope is about 43 m. The overall weight of the telescope works out to about 170 tonnes, including the mirror panels and their motion control systems, which weighs about 25 tonnes.

The MACE

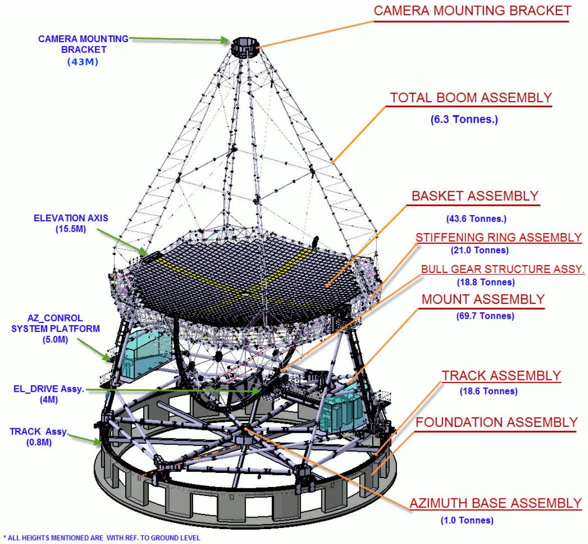


Figure: Drawing showing different MACE mechanical assemblies.

MACE optics

MACE light collector details

Number of Mirrors	1564
Reflector Geometry	Paraboloid Segmented
Mirror Profile	Spherical Facets
Surface Accuracy	DT Reflecting surface of λ /2 quality
Facet Material	Al MgSi0.5 (Al alloy)
Spot Size	80 % of light in about 6mm circle (ROC)
Mirror Reflectivity	80 % or higher
Surface Finish	20nm RMS or better
Protection coat (SiO_2)	100 -150nm
PSF MACE reflector	15 mm
Mirror Facet Size	488 x 488 mm
Mirror Facet Shape	Square with chamfered corners
Facet Front plate /back plate	5mm(+0.5,-0.0) /(1-1.2)mm
Substrate	26mm honeycomb (+0.2, -0.0)

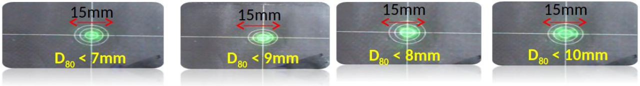
The MACE gamma-ray telescope consist of a large tesselated light collector of area 356 m^2 made up of 984 X 984 mm size mirror panels. Each of these mirror panels comprising of 4 diamond turned aluminum spherical honeycomb mirror facets and aligned in such a manner that the panel functions as a single spherical mirror. The radius of curvature (ROC) of the mirror panels will vary from 50000 to 52500 mm from the centre of the light collector to its periphery. This variation in the ROC of the mirrors will help in minimizing the on-axis spotsize of the light collector. Each individual mirror panel will be mounted on the space frame using a 3-point support mechanism which has linear actuators with single and double ball joints coupled to it.

MACE optics

- Fabrication of diamond turned metallic mirrors for MACE telescope : Fabrication and evaluation of 1564 (0.5m X 0.5m), Diamond turned Aluminium honeycomb mirrors developed for the first time in India. As the telescope would be employing these mirrors as a part of the light collector optics, metallic mirrors made of honeycomb (light weight) have been preferred over the conventionally used glass mirrors. With a spot size of 7 mm at the radius of curvature, surface accuracy of $\lambda/4$ and surface finish of $\sim$20nm, the mirrors fabricated are comparable to the best in the class fabricated worldwide. The mirrors have also been coated with a SiO_2 layer, $\sim$100-150nm thickness for surface protection.

Experimental setup for mirror alignment at ECIL

Spot Sizes at ROC for 4 aligned panels



MACE optics

- Fabrication of Compound Parabolic Concentrators for MACE telescope : Fabrication of high quality $\sim$ 3500 Compound Parabolic Concentrators (CPC's) for MACE telescope was developed within the country. The telescope employs PMTs as the basic detector in the focal plane. These PMT's have a wide Field of View (FOV) and can collect background stray light as well in addition to the genuine signal from potential gamma ray sources. A CPC will be placed on top of all PMT's to maximize the light collection efficiency and to block any stray light to the telescope camera. CPC is a non-imaging light concentrator made of ABS plastic for ruggedness. It is a hexagonal concentrator with a height of $\sim$74mm with each face parallel to the optic axis of the CPC.

Motivation

The MACE telescope is among a very few current generation state of the art ground-based gamma-ray instruments world wide. These include MAGIC (set of two telescopes with a diameter of 17 meters each at the Canary Island of La Palma, 2.2 km asl), VERITAS (an array of four telescopes with a diameter of 12 meters each in Arizona, 1.3 km asl) and HESS (system of four telescopes with a diameter of 12 meters each and a much bigger fifth telescope of 28 meter diameter in Namibia, 1.8 km asl) telescopes. Thus, MACE is the second largest telescope after HESS-II (28 meter diameter) at the highest altitude in the world. The main mandate of the MACE telescope is to enable the researchers to explore the high energy gamma radiation in the Universe. The high energy gamma radiation is produced along with the energetic cosmic rays at various astronomical sites. Therefore, origin and propagation of the gamma ray photons provide a unique experimental tool in the Astrophysics and Cosmology research. The MACE telescope is expected to play a very important role to study the sources of cosmic gamma radiation like Active Galactic Nuclei (AGNs),

Motivation

Gamma Ray Bursts (GRBs), Pulsars, Binary Star Systems, Remnants of Supernova explosions (SNR), Giant Molecular Clouds (GMC), Star Burst Galaxies and other objects in our Milky-Way Galaxy through observations of gamma rays with energies above 20 GeV. Another major scientific motivation of MACE is the discovery of new gamma-ray sources and identification of unidentified sources in the high energy Fermi catalog. Beyond probing the non-thermal Universe and cosmic accelerators, MACE telescope is also expected to address a range of cosmological topics such as constraining the intensity of Extragalactic Background Light (EBL) and strength of Intergalactic Magnetic Field (IGMF), cosmic ray electron spectrum, search for Dark Matter (DM) particles and some fundamental physics problems like Lorentz Invariance Violation (LIV), anamoly in photon-photon pair production and photon-Axion Like Particle (ALP) oscillations.

Salient features of MACE telescope:

- Energy range : $\sim$20 GeV - 10 TeV
- Light collector : $\sim$ 21 m diameter (Quasi-paraboloid shape)
- Mirror facets : 356 x 4 $=$ 1424 (diamond turned aluminium)
- Tracking accuracy : $\sim$ 1 arc-min
- Imaging camera : 1088 photomultiplier tubes
- Signal digitization : 1 GSPS using Domino Ring Sampler
- Data volume : $\sim$ 40 GB / hr
- Expected Sensitivity : 5 sigma detection of the Crab Nebula in few minutes of observation (above 30 GeV).

Physics

Cosmic-rays were discovered by Victor Hess in 1912. Even after one hundred years of their discovery it is not known how and where cosmic-rays are originated. There are some hints which indicate that Supernova Remnants (SNR), Pulsar Wind Nebulae (PWN), Active Galactic Nuclei (AGNs) etc., are the possible sites where cosmic-rays can be produced. As cosmic-rays are charged particles and they get deflected in interstellar and intergalactic magnetic field therefore from the direct detection of cosmic-ray particles on the Earth one can't trace back to their site of origin. But an alternative path was suggested by astrophysicists. Cosmic-rays can interact with the ambient medium at the site of their origin and can produce gamma-rays. This gamma-ray can reach the Earth without any deviation in their path. Therefore if one can detect such gamma-ray from the astrophysical sources then one can trace back their origin. Infect in early 80's the first gamma-ray satellite Cos-B send by NASA detected 25 sources in million electronvolt (MeV, 1 MeV $= 10^6$ eV) energy range. This detection gave birth to gamma-ray astronomy and it became the most favorable path to study cosmic-ray origin. With time the field of gamma-ray astronomy evolved, more sensitive technique called Imaging Atmospheric Cherenkov Technique (IACT) came up which work in the giga electronvolt (GeV, 1 GeV $= 10^9$ eV) to tera electronvolt (TeV, 1 TeV $= 10^{12}$ eV) energy range.

In India, the first IACT telescope TACTIC (TeV Atmospheric Cherenkov Telescope with Imaging Camera) started operating in the year 1997 at Mount Abu, Rajasthan. Now a more sensitive telescope the MACE is installed at Hanle to study the gamma-ray sky in the energy range 20 GeV - 10 TeV. The higher photon density along with the low background light level at this site helps in lowering the energy threshold of the Cherenkov telescope.

One can study different types of astrophysical sources with the MACE telescope such as supernova remnants, pulsar wind nebula, active galactic nuclei, gamma-ray bursts, pulsars, star burst galaxies, gamma-ray binary and dark matter.

Physics

The fundamental questions that can be addressed using MACE telescope:

- Origin of cosmic rays, i.e. how cosmic rays are energized and where?
- Characterize the extra-galactic background light (EBL). This has immense importance in understanding the evolution of the Universe.
- Detection of dark matter through gamma-rays produced in the decay or annihilation of dark matter.
- Signatures of quantum gravity by measuring the time delay between two photons of highest energies.

Location

Figure: The MACE gamma-ray telescope @ Hanle. Hanle is a located in Leh region of Union Territorie of Ladakh in India.

Location

HOW TO GET THERE

Air:

Direct domestic flights from Delhi, Jammu and Mumbai is available to Leh airport. From airport one can hire taxi, Hanle is around 260 km from Leh.

Local Transport: It is advisable to hire taxi from Leh.

GENERAL INFORMATION

Temperature (Winter): Minimum: -30 to -10 Degree C, Maximum: -1 to 2 Degree C

Temperature (Summer): Minimum: 2-10 Degree C, Maximum: 10-20 Degree C

Hanle is a dry cold area, it is always advisable to bring very heavy woolen clothes and jackets. The altitude of the place is around 4270 m above sea level. One must stay at Leh for may be 1-2 days for acclimatization before going to Hanle. To visit Hanle, special entry permit from Government is essential.