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# Focal plane instrumentation of the MACE telescope

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**Abstract :** The 17m MACE telescope will employ high-resolution MACE imaging camera consisting of 832 PMTs and low resolution BEST camera consisting of 108 PMTs for γ-ray astronomical experiments. To enhance the duty cycle of the telescope it is proposed to have a liquid optical filter assembly in front of the MACE imaging camera. Associated electronics and mechanical components needed for successful data capturing and processing make the design of the camera an extremely challenging job. This paper presents the basic framework for the camera design currently under progress.
*Key words*: MACE telescope – Imaging camera – Mechanical design

## 1. Introduction

In gamma-ray astronomy, the energy range between ~ 20-100 GeV is essentially inaccessible at present due to limited effective geometrical factor (detector x solid angle) of current space based gamma ray telescope EGRET and the higher threshold energy (~TeV) of on-going ground based experiments. The main persuasive reasons for trying to explore the energy band in the GeV range are:

- Investigations of the spectral evolution of EGRET sources including γ-ray pulsars, supernova remnants, plerions, X-ray binaries and active galaxies.
- Understanding the nature of unidentified EGRET objects.
- Learning about galaxy evolutions in the early phases of universe
- Searching for high-energy spectral tails in the cosmic γ-ray bursts
- Searching for the lightest super-symmetric particles, test of gravity effects etc.

In view of these considerations, Central Workshops in collaboration with Nuclear Research Laboratory has decided to build the 17m imaging γ-ray telescope MACE, as a major component of the ongoing GRACE astronomy facility at Mt. Abu, Rajasthan. This paper describes the salient features of the camera layout of the telescope. The mechanical design of the focal plane instrumentation (camera) is currently under progress.

## 2. Camera Layout

The MACE telescope proposes to deploy a 17m diameter, quasi-paraboloid, graded focal length light-collector placed on a standard alt-azimuth mount provided with two axes steerability. Its focal plane instrumentation will consist of a high-definition photo-multiplier tube based MACE Cerenkov imaging camera. This instrument will allow high-sensitivity γ-ray investigations to be carried out in the MACE mode of operation. A piggyback focal-plane instrumentation, BEST, arranged in a square of 4m around the MACE imaging camera, will enable to carry out ground-based detection and localization of cosmic γ-ray bursts through the atmospheric scintillation technique (BEST mode of operation).
The telescope will deploy a high resolution imaging MACE camera and low resolution annular BEST camera, for gamma ray bursts exploration by the scintillation techniques. The imaging camera

will have a high-resolution central core with field-of-view of $2.4^0$ with a pixel size of ~ $0.1^0$, surrounded by a medium resolution guard ring of $0.8^0$ width and a pixel resolution of $0.2^0$. The central core will use 576 pixels while the guard ring will have 256 pixels. MACE camera will thus have a total of 832 PMT's. High resolution core of the imaging camera will use 25 ϕ mm diameter PMT's coupled to C.P.C.s with an entry aperture of 30 ϕ mm while the guard ring pixels will use 50 mm PMT's coupled to CPC's with and entry aperture of 60 ϕmm. The annular BEST camera will use 200 ϕ mm PMT's coupled with 250 ϕ mm CPC's. The outer edge of the camera will be at a distance of 2000 mm from the centre of the focal plane. The annular camera will use 108 pixels. The layout of the camera is shown in Figure 1.

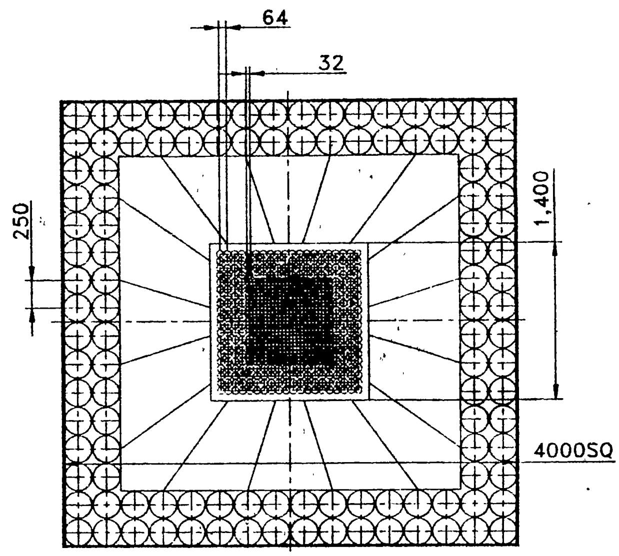


**Fig. 1: Layout of MACE and BEST Camera**

**a. Imaging camera dimensions (MACE)**

1) High resolution core :

| | |
|---|---|
| Edge thickness of CPCs | : 0.5 mm; |
| Internal entry diameter of CPC's | : 30 mm; |
| Effective pixel diameter | : 31 mm; |
| Gap between adjacent pixels | : 1.0 mm; |
| Effective pixel pitch | : 32 mm; |

2) Medium resolution core :

| | |
|---|---|
| Edge thickness of CPCs | : 1.0 mm; |
| Internal entry diameter of CPC | : 60 mm; |
| Effective pixel diameter | : 62.0 mm; |
| Gap between adjacent pixels | : 2.0 mm; |
| Effective pixel pitch | : 64 mm; |

**b. Annular camera dimensions (BEST)**

| | |
|---|---|
| Internal entry diameter of CPC | : 240 mm; |
| Effective pixel diameter | : 246 mm; |
| Gap between adjacent pixels | : 4 mm; |
| Effective pixel pitch | : 250 mm; |

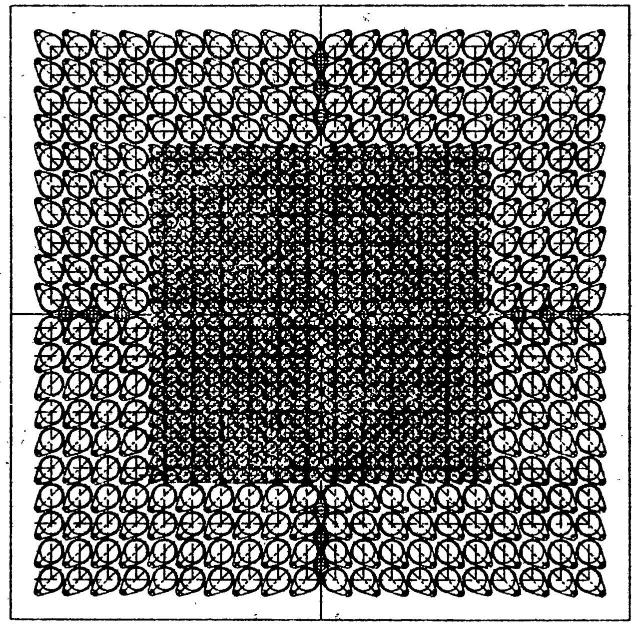

**Fig 2: MACE Camera Layout**

## 3. Requirements of cameras of MACE Telescope

The imaging (MACE) and Annular (BEST) cameras are important telescope components and their proper functioning is critical to the performance of the telescope. The camera includes instrumentation for the PMTs, other associated electronics and sensors, mechanical components including PMTs, CPCs, PMT holders, camera covers, mechanical structure, liquid filter assembly, fasteners etc. Additionally, the fibre optics cables connected to the PMTs are routed through appropriate connectors and channels to the coarse data-processing centre located below the Mirror Basket. These are critical components for the camera operations. This demands the camera to satisfy several functions :

- High mechanical stability
- Light weight
- Excellent ability to withstand environmental effects including heat, dust, high winds, rain etc.
- Compact shape of camera so as to minimise shadowing obstruction to optical view-path of the primary reflector and camera support structure.
- Provide a tight seal against light and exposure to sun
- Provide a housing of instrumentation for data-processing/capturing signals
- Minimise stray electrical noise

## 4. Camera components

The camera has the following components

Photo-multiplier tubes (PMT).
Compound Parabolic Concentrator (CPC).
Camera cover.

The camera cover has quite a few important functions :

Provision of a light tight seal during daytime.
Protection of camera against environmental effects like dust, sand, rain and bad weather.
Temporary shield in case of accidental exposure of the telescope towards the sun.
Sensors for checking the actual position and status of camera and cover

The camera cover will be operated using an electrical motor with emergency power backup systems. It will be designed in fail-safe mode so as to automatically close the camera in case of any emergency. Additionally, the camera will be designed with an appropriate heat shield to prevent camera damage during a short exposure to concentrated sunlight in case of accidental sunlight exposures.

**iv)Mechanical components including cooling arrangements :** The electronics in the camera will generate heat that needs to be carried away and uniform temperature needs to be maintained in the camera housing. Again, since the camera is being located in a hot temperature zone, cooling arrangements are to be designed to prevent temperature rise inside the housing. Arrangements also need to be made inside the housing for proper humidity maintenance and to prevent dew deposition. The design must be such that there is minimum obstruction to the optical view and the camera support ring. To allow for the camera cover to slide in and out from the optical view path, mechanical systems will be designed. These systems require low response time to prevent emergencies without creating vibrations or jerking of the camera housing base frame i.e. they are to be designed with appropriate passive damping elements. Designed in a fail- safe mode, the cover will operate mechanically and close down the camera in the event of power failures including failure of the backup power systems. Ingress and leaking of grease, lubricants etc. from the mechanical components also need to be prevented. Stray electrical noises generated due to the cooling arrangements and camera cover movements must also be minimised.

**v)Liquid optical filter assembly :** In order to improve upon the duty cycle of the telescope it is proposed to operate it during moonlit conditions also. This mode of operation would depend on the UV content of the atmospheric Cerenkov events in the 270-300 nm bands. A quartz container into which a liquid filter can be pumped will be placed in front of the imaging camera of the telescope. During moonlit operation, a liquid filter of the pre-requisite concentration will be pumped into the container. This filter will attenuate the light in the 300-650 nm bands by a factor of $10^3 - 10^4$ while the 270-300 nm band will experience a minor attenuation. During moonless night operation the liquid filter will be drained out.

## 5. Design of the MACE and BEST Camera

The MACE camera has 576 PMTs in the high-resolution zone with 256 PMT's surrounding it. The high resolution PMTs are arranged on a square pitch of 32mm and the medium resolution core is arranged in a square pitch of 64 mm. To keep the focal plane of all these 832 PMTs at the same level a box structure 1400 mm square x 85 mm high is used as the base and holes are made of appropriate sizes (32mm and 64mm dia respectively) to accommodate the PMTs. Connection slots are arranged in a rectangular pattern on the outside edge of this box so as to provide electrical wires to join. A second annular box is made in a 4000 mm square (outside) x 3000 mm square (inside) x 110 mm high to accommodate the 108 PMTs of the BEST Camera. These two cameras are then joined together to ensure that all the PMTs lie on the same focal plane. For protection of the cameras, a motorized shutter arrangement is being designed that will protect the PMTs from environmental effects like sunlight, dust etc.. Several design versions are being considered to achieve this. The shutter must have low response time to emergencies while being rigid and lightweight. It needs to be suitably damped so as to prevent jerking of the sensitive electronic instrumentation housed inside the camera box structure. Static and dynamic analysis are required to finalize the design. To allow for the optical liquid filter to be circulated, the necessary pumps and associated hydraulics will be mounted behind the camera frame. To minimize the deflection of the camera, the MACE and the BEST imaging cameras will be provided with separate supports connected to the elliptical arch.

## 6. Conclusions

The mechanical structures of the MACE light collector and camera presents many challenges which are being met with an optimum design configuration, using state-of-the-art technology. The mechanical structure of the first MACE telescope is likely to be fabricated by the end of 2004.