AtmoHEAD: Atmospheric Monitoring for High-Energy Astroparticle Detectors

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cta cherenkov telescope array

IFAE

UAB Universitat Autònoma de Barcelona

Design of a 2-elastic plus 2-Raman lines optical module for a Raman lidar for CTA

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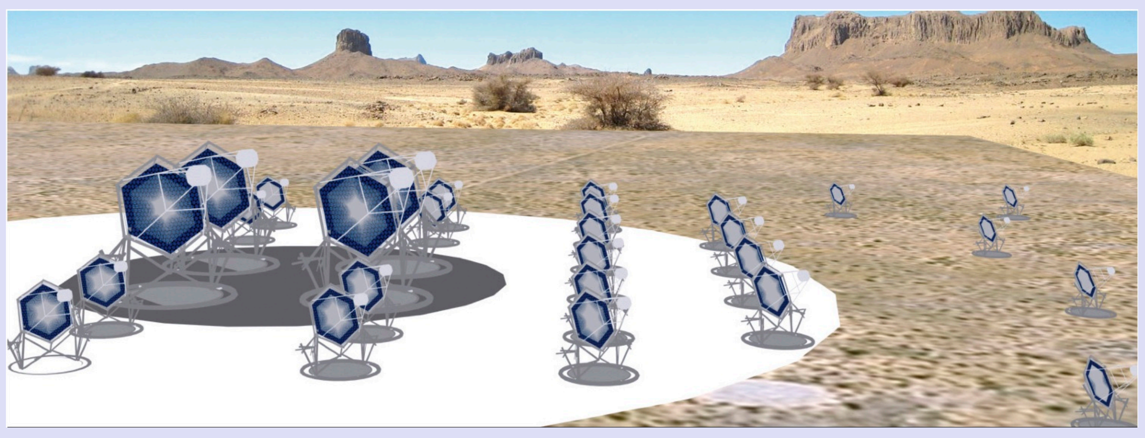
ABSTRACT

CTA is an advanced facility for ground-based gamma-ray astronomy in the GeV-TeV regime, currently in the Preparatory Phase. For a correct reconstruction of gamma-ray energies and fluxes, a precise monitoring of the atmospheric transmission is needed. With this aim, the IFAE and UAB institutes are building a specific Raman lidar. For the optical module, we have foreseen to read-out from the lidar return 2 elastic (355 and 532 nm) and two Raman (387, 607) lines. In this contribution, we will discuss the design of the optical module, the light beam transportation, the solution for the custom made dichroic mirrors, interference filters.

Introduction

CTA is an advanced facility for ground-based gamma-ray astronomy in the GeV-TeV regime. The project is currently in the Preparatory Phase and it is planned to start installation in 2014. It foresees an array of tens of next-generation Cherenkov telescopes. The CTA project is being designed both to provide an expansion of the energy range down to a few tens of GeV and up to about 100 TeV and with about 10 times improvement in sensitivity compared to current installations. This goal will be achieved using several tens of telescopes of 2–3 different sizes distributed over a large area (several square kms) and having a Field Of View (FOV) up to 10°. It currently involved more than a thousand scientists and engineers in more than 20 countries across the world. It may comprise two sites (soon to be fixed): one in the Southern hemisphere mainly for galactic studies, and one in the Northern hemisphere mainly for extragalactic studies.



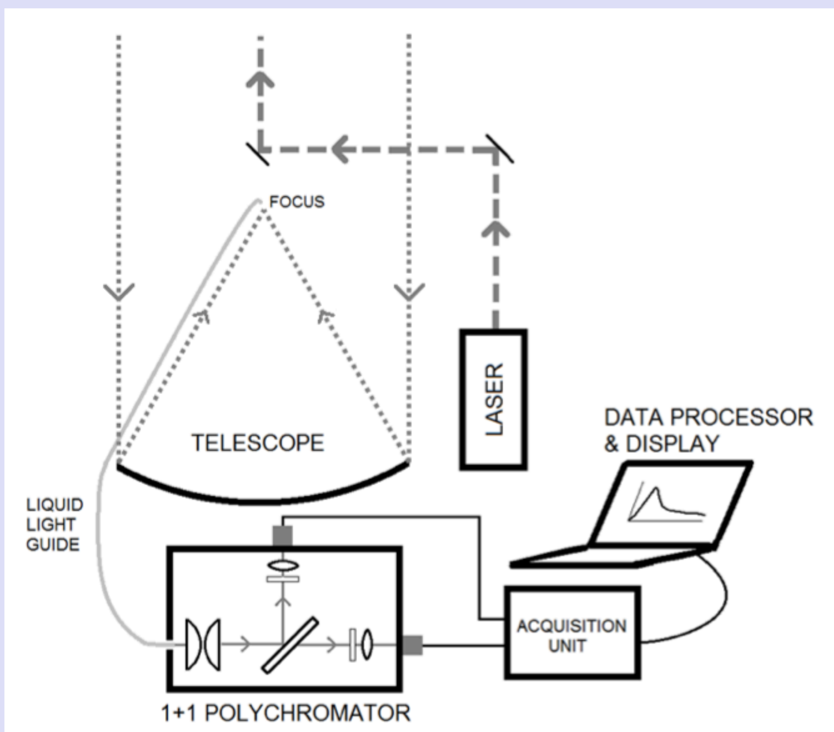
Artistic view of the compound different sizes telescope CTA system

Lidars have already been proven powerful tools in environmental studies, and the characterization of the atmosphere can be successfully done at day and night using elastic/Raman lidar systems. However, this technique is also viable for the needs of atmospheric characterization for CTA. With this aim, several member institutes of CTA are currently designing Raman lidar systems: a) the Institut de Física d`Altes Energies (IFAE) and the Universitat Autònoma de Barcelona (UAB), located in Barcelona (Spain), b) the LUPM (Laboratoire Univers et Particules de Montpellier) in Montpellier (France) and c) the CEILAP (Centro de Investigaciones Láser y sus Aplicaciones) group in Villa Martelli (Argentina). The different groups are designing independently the lidar systems with different mechanical, optical and steering solutions, which are presented elsewhere at this conference.

The Barcelona Raman lidar

Two institutes in the Barcelona area are collaborating toward the construction of a Raman lidar for the purpose of atmospheric calibration of CTA. The Barcelona Raman lidar consists of:

- A telescope structure and hosting folding container obtained from a former dismissed experiment called CLUE
- A 1.8 m solid glass parabolic mirror of f-number 1
- A powerful pulsed laser of the kind Nd:YAG with the first two harmonics available at 355 and 532 nm
- Tranmission of light from the focal plane to the optical module via liquid light guide
- A non-commercial optical module for the readout of 2 elastic and 2 Raman lines
- A LICEL commercial read-out system for analog and digital sampling



Barcelona Raman lidar schematics

EMITTER		
Laser	Type	Nd:YAG
	Emitted wavelength	355 nm(/532 nm)
	Pulse Energy/	60 mJ/
	Beam waist (diameter)	6 mm
RECEIVER		
Telescope	Layout	1-mirror parabolic
	Mirror diameter	1.8 m
	Focal length	1.8 m
	F number	1
	Shadow diameter	0.08 m
Liquid guide	Coupling efficiency	0.9
	Active area diameter	8 mm
	Numerical aperture	0.59 (34° half angle)
	Transmissivity	>0.7 (in the UV)
Photon detectors	Type	PMT
	Active area diameter	22 mm

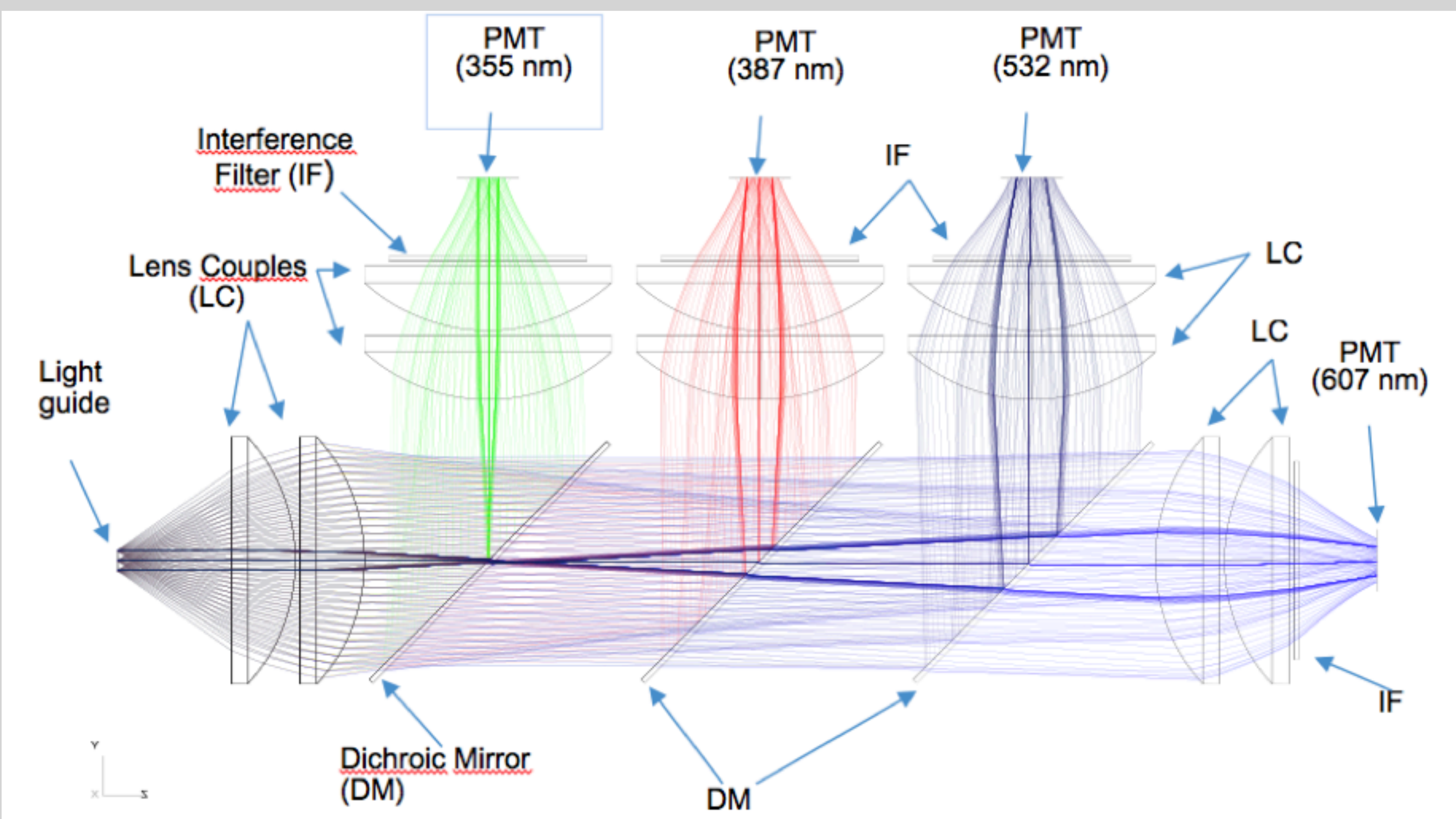
Barcelona Raman lidar characteristics

DESIGN OF THE OPTICAL MODULE

Polychromator layout

The light received by the telescope and transported by the optical fiber is re-emitted at its exit with a 70° aperture angle and collected by a couple of identical lenses. To collimate such a diverging beam, a system of two plano-convex lenses is necessary. The lens are made of BK7, have 100mm diameter and were produced by Lobre Srl (Brescia, Italy). These lenses have also an antireflective coating.

After first lens doublet, the light is separated in its different components via dichroic mirrors. A dichroic mirror (DM) reflects below a certain wavelength and transmit above, therefore the three DMs are not identical. With 3 DMs, the 4 wavelengths are completely separated. After this, in each channel, a second lens doublet, identical to the first, but not coated, focalizes the beam towards the photon detector, with the additional use of an interference filter (IF) for a further selection of the wavelength. The dichroic mirror are made of 100x140mm BK7 glass and produced by BTE (Germany).



Polychromator unit layout

Polychromator performance

The polychromator is conceived so that the light emitted by the fiber is collected and collimated, then the different wavelengths are successively separated using dichroic mirrors and at the end each beam is focalized on the detector passing through a narrow band filter for the final wavelength selection. The present design foresees four readout channels: two for the elastic backscattered at the 355 and 532 nm laser lines, and two for the Raman Nitrogen lines at the 387 and 607 nm.

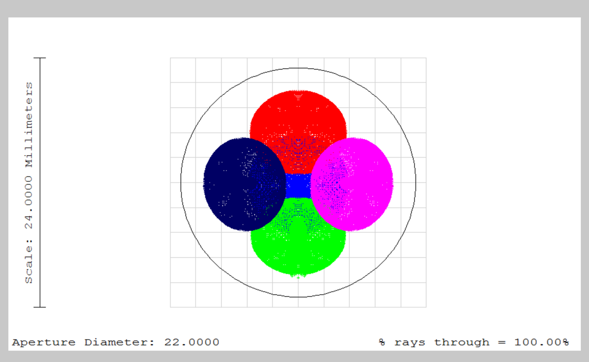
Polychromator requirements

Input FoV	70°
Input source diameter	8 mm
Encircled Energy	> 80% inside the detector
Wavelength coverage	355/387/532/607 nm
Filters	4 filters: one per each sub-channel

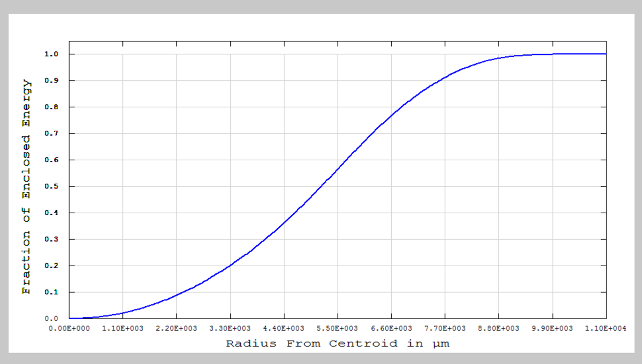
Polycromator design characteristics

Optical concept	Simple identical plano-convex lens couples
Lens Couple Focal length	60 mm
Lens diameter	100 mm
Lens Focal ratio	*F*/1.5
Detector	PMT QE @355&387 15% QE @532 10% QE @607 5%
Dichroic mirror band pass	15 nm (TBC)
Filter band pass	10 nm (TBC)

The performance of each channel is satisfying the requirement that at least 80% of the image energy has to be enclosed on the detector useful area. In fact, the image footprint is always completely enclosed inside the foreseen detector active area. The two-lens design is a trade-off between the need to collect as much light as possible, maintain the system compact and have a relative high throughput to observe all the lines.



Footprint diagram on PMT active area



Ensquared Energy on PMT active area