The MAGIC Telescope project

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Abstract

The 17 m diameter MAGIC telescope aims for gamma-ray astronomy above 15 GeV. The technical concept and status of the detector component developments for the first phase with a classical photomultiplier camera (threshold 30 GeV) will be given. The physics program will be reviewed in a separate contribution.

1 Introduction

Gamma ray (shortcut γ) astronomy is at present the only well established method to explore the relativistic universe. Due to technical limitations the energy range between 20 GeV, the upper limit of contemporary γ satellites, and 300 GeV, the lower limit of large air cerenkov telescopes (ACT), is up to now inaccessible to research. Satellites are flux limited due to their small collection area of typically $0.1\,m^2$. Costs become prohibitively high for detection areas above a few m^2. On the other hand 20 GeV electro-magnetic air showers contain still enough high momentum electrons above the Cerenkov threshold such that ACTs should be able to detect them provided the signal is large enough and can be discriminated against the night sky background light (NSB). Here we will report on the status of the proposed $17\,m\oslash$ MAGIC telescope for γ-astronomy in the above quoted unexplored energy range.

2 The scientific objectives

The main research targets for MAGIC will be:

a) The study of active galactic nuclei (AGN) up to $z \approx 3$. Measurements of the energy flux between 20 GeV and 1 TeV will allow one to set stringent constraints on the existence and size of the (up to now unquantified) infrared (IF) background.

b) The systematic study of possible galactic γ emitters such as supernova remnants (SNR), plerions, x-ray binaries, unidentified EGRET sources etc. which will hopefully lead to the identification of the main sources of cosmic radiation up to about $10^{15}\,eV$.

c) Testing of gamma ray bursts (GRB) in the new energy window. EGRET recently reported a GRB associated with γ up to $\approx 20\,GeV$ (K. Hurley et al.). A telescope like MAGIC with a 10^5 - 10^6 times larger collection area should be able to provide an answer to the 'galactic halo' vs. cosmological distance scenario by measuring the γ energy spectrum in the range where it could be affected by IR and 2.7° K absorption.

d) Search for exotic such as for the lightest supersymmetric particles (SUSY) etc.

Details of the program will be presented in a separate contribution by N. Magnussen.
Finally it should be mentioned that it is of utmost importance to overlap satellite and ground based observations for cross calibrations (for example for multiwavelength observations).

3 The telescope

The telescope will incorporate many new elements in order to achieve its goal of a threshold of 30 GeV (phase 'I', classical photomultiplier camera) and later 12-25 GeV (phase 'II', high QE, red extended hybrid photosensors). Table 1 summarizes the main performance parameters. Fig. 2 shows the sensitivity curve ($> 5\,\sigma/50\,h$ observation time, phase 'II' camera) as a function of energy. Operation in the presence of moonlight

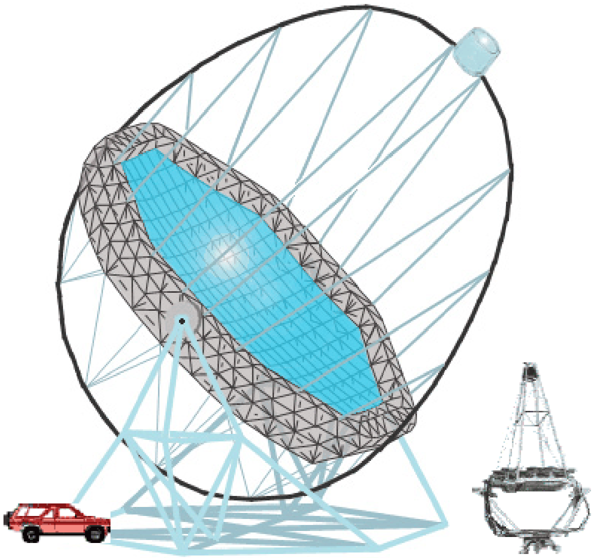

Figure 1: An artist's view of the telescope

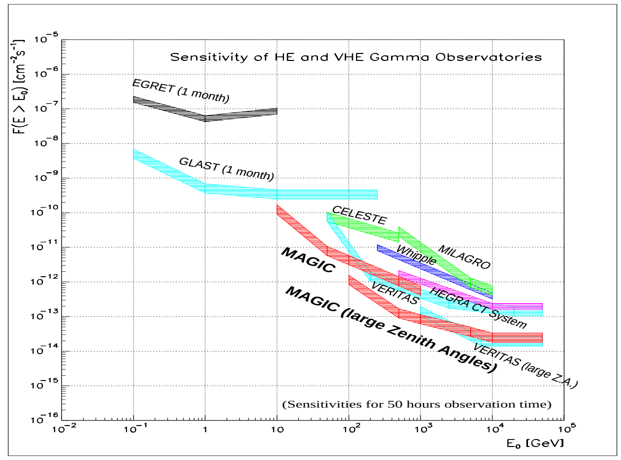

Figure 2: The sensitivity as a function of energy in comparison with some other designs. The HESS and Cangaroo arrays have a comparable sensitivity as VERITAS

and at large zenith angles is taken into account in the design parameters. On a cost comparison the performance of this telescope will be marginally worse than an array at higher energies, but be able to reach much lower thresholds. Details of the design can be found in Barrio et al. (1998) and the letter of intent.

4 The main building blocks of the telescope

The main elements of MAGIC are (see also Fig. 1):

- Alt azimuth mount. Range: $400°$ in ϕ, $180°$ in θ.
- Lightweight carbon fiber space frame construction for rapid repositioning in case of GRB studies.
- Novel light weight all-aluminum, diamond turned sandwich mirrors with integrated heating, anodic oxidation protection. The mirror profile is parabolic and composed of 980 individual elements. The overall mirror area is $234\,m^2$ with an $f/d = 1$. Prototype mirrors are already tested successfully for 2 years.
- Active mirror control to counteract small dish deformations and facilitating adjustments.
- Phase 'I' camera composed of new hemispherical PMs of only 6 stages and low gain. Central camera with $0.1°$ pixels up to $2.5°$ diameter. Outer section with $0.2°$ pixels up to $4°$ diameter.
- Signal transmission $(150\,m)$ to the control room by optical analog fibers with $> 400\,MHz$ bandwidth and dynamical range of 5000.
- Double range 300 MHz FADC readout with a dynamic range > 4000 (phase 'II' camera 1GHz FADC).

All components have been thoroughly tested and camera production has started.

5 Site

The telescope will be installed at the current HEGRA site on La Palma ($28.8°$ latitude, $-17.8°$ longitude, 2225 m asl). The telescope will run in parallel to the existing 6 HEGRA telescopes. Coincidence operation for special investigations are under study. The site has enough room for the addition of 2 more large telescopes (OUO project).

6 Status

The project is pursued by a collaboration of 15 groups[1], with two more groups in the decision making process. First funds have been allocated for some groups and first long-lead items (mainly the camera) have been ordered.

7 Costs

The first phase, MAGIC with a classical photomultiplier camera, will cost about 2.4 M ECU + 0.3 M ECU for contingency. The ongoing development of high QE-red extended photosensors does not yet allow to make a reliable estimate for the phase 'II' camera.

8 Time schedule

The current plan foresees a construction time of 2.3 years, i.e., first test data are expected in summer 2001.

Acknowledgments

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References

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Table 1: The main parameters characterizing the performance of the MAGIC Telescope.The main parameters are given for the camera equipped with hybrid PMTs.

Parameter	Value	Comments
Trigger threshold (= differential flux peak)	8–10 GeV ($\theta_z < 20^\circ$)	Fourfold coincidence of neighbor pixels with $\geq$ 7 ph.e.
Physics threshold	15 GeV ($\theta_z < 20^\circ$)	Tailcutγ ph.e., light sum $\geq$ 80 ph.e./image, various filter cuts
Collection area for γ	5000 m^2 ($\theta_z <$) 20000 m^2 90000 m^2 300000 m^2	10 GeV 20 GeV 100 GeV 1 TeV (wide trigger area)
γ selectivity after software cuts	45 - 70%	
hadron rejection $Q(\gamma$/ h rejection) = f(E)	$\approx$ 200 $Q \approx 2. \cdot E^{0.4}$, E in GeV	$\geq$ 10 GeV γ energy estimate for E$\leq$500 GeV
Energy resolution dE/E	$\approx$ 50% $\approx$ 20%	at 10 GeV at 100 GeV
	$\approx$ 10%	at 1 TeV
Energy resolution as function of energy $\frac{dE}{E} = f(E)$	$\approx \frac{180\%}{E^{0.45}}$ (E in GeV)	estimate; impact parameter < 130 m, up to 1 TeV
Angular resolution, single shower	$\Delta_{\theta_{\mathrm{transverse}}} \approx 0.05^\circ$ $\Delta_{\theta_{\mathrm{longitudinal}}} \approx 0.2^\circ$	200 GeV, scales approx with $\frac{1}{\sqrt{E}}$ + *const* (rough estimate)
muon rejection	very high	μ-images are part of hadron images
Cosmic electron rejection	$\geq$ 12	for given camera FOV
Sensitivity	6 $\cdot 10^{-11}$cm^{-2} s^{-1}	source with power law dependence as CR background, 5 sigma , 50 h on source, 20 GeV threshold
Precision of point source location	$\leq 0.02^\circ$	large statistics sample
Separation limit for 2 close point sources	0.2°	equal strength sources (E$\geq$10 GeV)
Trigger threshold in presence of moonlight	$\approx$ 30 GeV ($\theta_z < 20^\circ$)	moon 66%, source $> 30^\circ$ away from moon
Physics threshold in presence of moonlight	$\approx$ 45 GeV ($\theta_z < 20^\circ$)	
Trigger threshold classical MAGIC	about 30 GeV ($\theta_z < 20^\circ$)	classical PMTs
Physics threshold classical MAGIC	$\approx$ 30 GeV ($\theta_z < 20^\circ$)	$\geq$ 80 ph.e./image
Sensitivity classical MAGIC	$8 \cdot 10^{-11}$ cm^{-2}s^{-1}	5 σ, 50 h on source, 25 - 30 GeV threshold