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Status Report on the 17m Diameter MAGIC Telescope Project

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In this report we will present the current status of the MAGIC Telescope Project. Since the early fall 2004 the first MAGIC telescope is regularly collecting data from a long list of astrophysical objects. The main parameters of the telescope are experimentally evaluated and compared to the expectations and to the Monte Carlo simulations. For the time being we are able to analyze gamma energies as low as 60 GeV. The high sensitivity of the telescope could be demonstrated by the unprecedented measured rate of gamma rays from Crab Nebula of ~1Hz on the trigger level. Gamma ray signals from Crab Nebula, Mkn-421, Mkn-501, 1ES1959 and the Galactic Center were observed. Signals from a few more sources will be reported during this conference. Construction of the second MAGIC telescope has started. It will be located at 85m distance from the first MAGIC telescope. In the design of the second telescope we are planning to introduce several improvements compared to the first MAGIC telescope, especially in the light sensor part of the imaging camera. We are scheduling to operate the second telescope in the beginning of 2007.

1. Introduction

The window of ground-based γ astronomy was opened in 1989 by the observation of a strong signal from the first TeV γ source, the Crab Nebula by the Whipple collaboration [1]. As instrument the 10 m diameter Whipple atmospheric air Cherenkov imaging telescope on mount Hopkins in Arizona has been used. The breakthrough in the technique was achieved by means of the image parameterization suggested by Hillas [2] allowing one to separate the rare γ showers from the orders of magnitude more intense background from showers induced by the charged cosmic rays (CR). Since then the new field of astronomy was progressing very rapidly and all new source discoveries have been made by means of this new type of telescopes, the so-called imaging air Cherenkov telescopes (IACT).
Currently, a new generation of very large IACTs [3] have either started to operate or are in the final phase of completion. One hopes to exploit the energy window from a few tens of GeV (30-200 GeV, depending on the instrument) up to the multi-TeV energy range. Already the discussion and planning for the future IACTs with a threshold close to 5-10 GeV have begun.
In 1995 worldwide there were just a few instruments operational the largest one being the 10m diameter Whipple telescope with a lower threshold setting of > 300 GeV (in fact it was the largest telescope from 1968 till 2002). On the other hand there existed no instruments to measure in the energy range below 300 GeV and above 10 GeV (below 10 GeV recent satellite born EGRET instrument onboard of Compton Gamma Ray Observatory have performed numerous measurements of sources). The above mentioned energy gap seemed to be very interesting from the observational point of view because there was a discrepancy of more than an order of magnitude in the number of sources: the satellites have discovered and measured few hundred sources while the IACT telescopes have measured just few. It was very clear that some important astrophysical processes were happening in the energy gap not accessible to none of the known techniques. It was in this time that we came along with a project to build a 17m diameter imaging air Cherenkov telescope MAGIC [4]. Since then a large international collaboration, mostly from European countries, has been collected around the core groups of MAGIC. The design report of the project has appeared in spring 1998 [5] and the financial support was allocated in late 2000 and early 2001. In late 2001 the mechanical structure of the telescope was installed and in 2002-2003 it was equipped with

all the different components and put into operation. From fall 2003 till the early fall 2004 the telescope was in the commissioning phase. After that MAGIC started to regularly observe gamma ray source candidates and collect data.

1. The MAGIC-I Telescope

When starting to design MAGIC it was clear for us that one cannot build a large telescope just by up-scaling the size of the smaller, ~4m diameter telescopes of HEGRA (few members of MAGIC collected their experience in HEGRA). Moreover, in order to be able to re-position the telescope within ~20 seconds to the coordinates of a Gamma Ray Burst provided by detectors flown on satellites and thus to contribute in the understanding of the origin of those enigmatic sources, we have designed the telescope to be light-weight. This had immediately introduced lot of constraints in the design. We have suggested few new techniques and technologies to implemented in MAGIC-I (see Fig.1 below) in order to enable the fast re-positioning. Below we list the important innovations:

Figure 1. Photo of the MAGIC telescope. Location: 2200m a.s.l., Canary island of La Palma, Roque de los Muchachos Observatory

1. Reflector frame made from carbon-fiber tubes
2. All Al diamond milled light-weight mirrors with quartz protection and with internal heating
3. Active control of the reflector shape because of varying gravitational loads while moving the elevation axis

4. Transfer of ultra-fast analog signals from the camera to the experimental control room via optical fibers
5. 300 Msample/s FADC system for the readout of data
6. 6 dynode ultra-fast hemispherical photo multiplier tubes from *Electron Tubes*, England
7. Special milky coating of PMT input window for enhanced by about 20 % quantum efficiency
8. 10 layer printed circuit board in the imaging camera both for carrying the PMT pixels and for providing necessary power and connections to the computer readout system
9. Temperature controlled closed-loop water cooling system of the camera

All of the above listed techniques were thoroughly tested in several iterations over ~5 years and only after that implemented in the construction. Note please that the other leading gamma observatories are already using some of the innovations pioneered by MAGIC in the design of their telescopes.
Obviously implementation of so many innovations simultaneously made it necessary to allow for some time for understanding and when necessary improving the telescope's performance in real operating conditions. Moreover, hence from the beginning of our project it was clear for us that we have chosen a difficult way: we were consciously and consecutively working on opening of a new path with a new instrument in a not yet studied energy domain where we were intending to be the pioneering explorers.

2. Where We Are With MAGIC-I

Today we can say that to large extent we understand the performance of MAGIC. Our measurements of sources at energies above ~100GeV showed that we succeeded to built a very sensitive instrument. Also, we could measure gamma ray signals from Crab Nebula at energies as low as 50-60 GeV. Demonstration of the achieved unprecedented high sensitivity is the measured integral rate of ~1Hz of gamma rays from Crab Nebula (above the currently achieved analysis threshold, on the trigger level). Nevertheless we shall mention that we are still working on improving the sensitivity of the telescope for energies below 100GeV. Not all of the problems are yet fully understood at sub-10GeV energies and we are currently working to significantly improve the response of the telescope in that important energy domain.
The best sensitivity of the telescope in terms of Signal/Noise ratio of the measured signal from the standard candle, the Crab Nebula, is ~20 $\sigma \cdot h^{0.5}$ and is achieved for energies (150-180)GeV. The telescope has very high hadron rejection power for energies above (500-600)GeV; for sources strong as Crab Nebula the response is practically background free. Below ~100GeV energy regime the image shapes for gammas and hadrons are becoming more similar; still gammas could be selected but only at the expense of relatively high left-over background after the image analysis. Our studies indicate that the main reason for the high background should be the gamma ray showers induced by the decay of π^0 from hadron showers. Those gamma rays develop quite "normal" electromagnetic air showers that except for angular orientation can pass the genuine gamma selection criteria.
Since several months the telescope is running smooth without any major technical problems and we reached an efficiency of ~95 % in possible observation time. With MAGIC-I we succeeded to measure gamma ray signals from Crab Nebula (R. Wagner, et al., these proc.), from AGNs Mkn-421 (D. Mazin, et al., these proc.) and 1ES1959 (N. Tonello, et al., these proc.), from the Galactic Center (H. Bartko, et al., these proc). The measured signals allowed us to evaluate the performance of the telescope (J. Cortina, et al., these proc.) and to compare it with Monte-Carlo simulations. We found a satisfactory agreement with the predictions of extensive simulations, especially for energies above ~100GeV (P. Majumdar, et al., these proc.).
Also, we have measured gamma signals from a few more sources (or source candidates) but these data are still in extensive analysis and checking stage. We are hoping to present more about new results during the conference

3. Construction of MAGIC-II

Recently we have started the construction of the second telescope, MAGIC-II on 85m distance from MAGIC-I that will help to stronger suppress the backgrounds and to lower the threshold setting down towards 30 GeV. Operating two telescopes in coincidence will not only allow us to lower the threshold but also to essentially double the sensitivity. The second telescope will be similar to the first one with some improvements, especially in the camera design: we are intending to use very high quantum efficiency hybrid photo diodes with GaAsP photo cathodes that will double the light sensitivity (please see for details the talks Teshima, et al., and Hayashida, et al., these proc.).

4. Conclusions

Since early fall 2004 MAGIC-I is fully operational and is regularly observing sources or possible source candidates. Since several months the telescope is running smooth and we reached ~95 % efficiency in time for observations. Gamma signals from sources Crab Nebula, Mkn-421, Mkn-501, 1ES1959 and the Galactic Center have been measured and are presented at this conference. Gamma signals from few more sources or source candidates are also measured but these data are still under extensive checks. We are hoping to show more results during this conference. MAGIC-II telescope is under construction at 85m distance from MAGIC-I. Operation of both telescopes in coincidence is scheduled for early 2007 and will provide double sensitivity. Also, it will allow us to lower the threshold setting down towards the 30GeV energy regime.

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References

[1] T.C. Weekes, et al., ApJ. 342, 379 (1989).
[2] A.M. Hillas, 19th ICRC, La Jolla 3, 445 (1985).
[3] Proc. "Towards the Network of Atmospheric Cherenkov Detectors-VII", ed. B. Degrange, 27-29 April 2005, Palaiseau, France, to be published
[4] S.M. Bradbury et al., Proc. 'Towards a Major Atmospheric Cherenkov Detector-IV Int. Workshop', ed. M. Cresti, Padova, Italy, September 11-13, 277 (1995)
[5] J.A. Barrio, et al., preprint of the Max-Planck-Institute for Physics MPI-PhE/98-5 (1998).