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Status of H.E.S.S. phase II construction

***Abstract*—H.E.S.S. is the most sensitive gamma ray Cherenkov telescope currently operating with a 100 GeV threshold. The construction of the H.E.S.S. II telescope has started last year and will be completed in 2008. It will allow observations down to 20 GeV, giving a useful overlap with the GLAST satellite sensitive range. I will review the design, the status of construction and the expected performances of H.E.S.S. II.**

I. Introduction

In December 2003, the last of the four mirrors of the H.E.S.S. phase I telescope was installed. Since then, this high energy gamma ray telescope has delivered a wealth of unprecedented results [1]. In order to increase the discovery potential of the detector, the collaboration has undertaken the construction of a fifth, larger mirror, that will be installed at the centre of the four existing ones. This will decrease the energy threshold of the system as well as improve the sensitivity and the angular resolution over the current energy range.

II. Physics Goals

In the Galaxy, supernova remnants, pulsar wind nebulae, microquasars and molecular clouds have been detected as sources of high energy gamma rays. Some of them are resolved as extended sources and their morphology could be compared with that obtained at other wavelengths. The H.E.S.S. phase II will allow to improve the understanding of these objects and detect more of them. We expect some of them to be the sources of Galactic charged cosmic rays. We may be able to identify these and distinguish between the various proposed acceleration mechanisms.

Gamma rays can also give evidence on the nature of dark matter. If it consists of self-annihilating massive particles, such as the neutralino conjectured by super-symmetric models, clumps of dark matter centred on dwarf galaxies or globular clusters could emit gamma rays produced in the cascade decays of the annihilation products. A lower gamma-ray threshold will improve the sensitivity to particles in the 100-GeV mass range.

The extra-galactic horizon is limited by gamma-ray absorption on infrared light. The lower threshold will extend this horizon to redshifts of the order of 1, increasing the number of detectable blazars and gamma-ray bursts.

III. The Mirror

In order to lower the gamma-ray detection threshold, we need to collect more and be more sensitive to Cherenkov light coming from the electromagnetic shower caused by the gamma ray interaction with the atmosphere. This can be obtained by increasing the mirror size and reflectivity, improving the light concentrator efficiency in front of the camera photomultiplier tubes and improving the photomultiplier tube quantum efficiency and collection efficiency.

The main increase in sensitivity comes from the 596 m^2 mirror compared with the 130 m^2 H.E.S.S. I mirrors. The dish is mounted on a alt-azimuth structure which elevation axis is supported 24 m above ground by two towers, rotating on a 36 m diameter azimuth rail (Fig. 1).

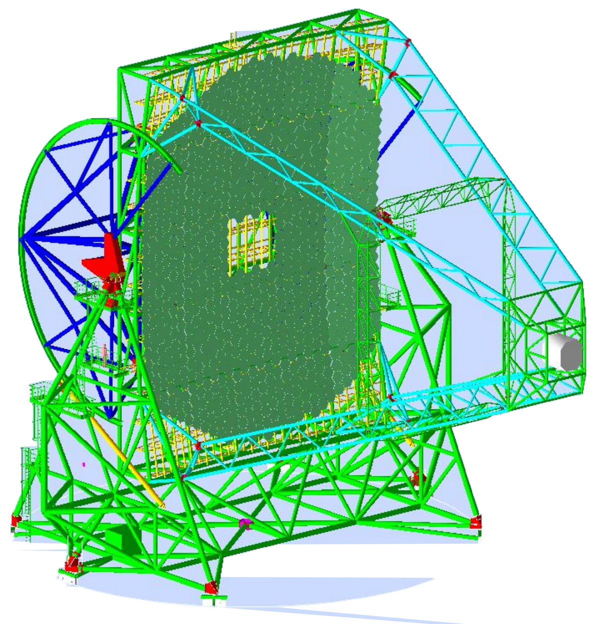

Figure 1 : View of the telescope mount.

The dish is rectangular, 32 m high, 24 m wide onto which 850 mirror facets are assembled to approximate a parabolic shape. It gives a smaller time dispersion than the Davis-Cotton shape used on the four smaller mirrors, limited to less than 250 ps over the whole camera field of view. Such geometry increases slightly the point spread function, which stays around 1 mrad, comparable to the smaller mirror one (Fig. 2).

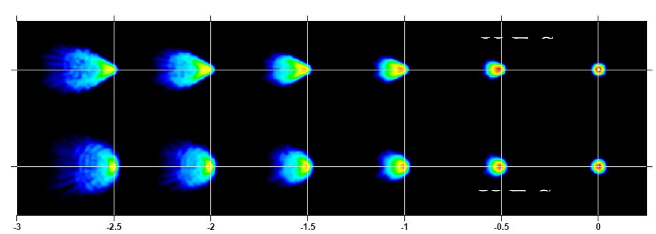

Figure 2 : Comparison of H.E.S.S. I and H.E.S.S. II mirror point spread functions.

Each hexagonal facet is fixed on the dish via motorized

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actuators for precise alignment.

The camera is mounted on a quadrupod at the focal plane, 36.74 m away from the dish, corresponding to a *f/d* ratio of 1.2. This limits the cost of the mount while giving a correct imaging over the field of view. The camera position can be tuned along the optical axis, to account for the average shower distance dependence with the azimuth angle.

IV. The Camera

The H.E.S.S. II camera design is inspired from the four H.E.S.S. I cameras already built and operating. However, the mirror surface increase causes a higher night sky background. In order to keep it to a similar level per pixel, the pixel aperture is four times smaller than for H.E.S.S. I. With a field of view reduced from 5°x5° to 3.2°x3.2°, the camera consists of 2048 pixels instead of 960 pixels.

A plane of hexagonal shape Winston cone is followed by photomultiplier tubes similar to the H.E.S.S. I camera ones (see Fig. 3), the readout electronics, the cooling system and the data acquisition system (DAQ). The camera container is 2 m long has a 2.5 m diameter. The camera weights 3 tons. It can be dismounted from the telescope arm and stored away in a shelter for calibration and maintenance purposes.

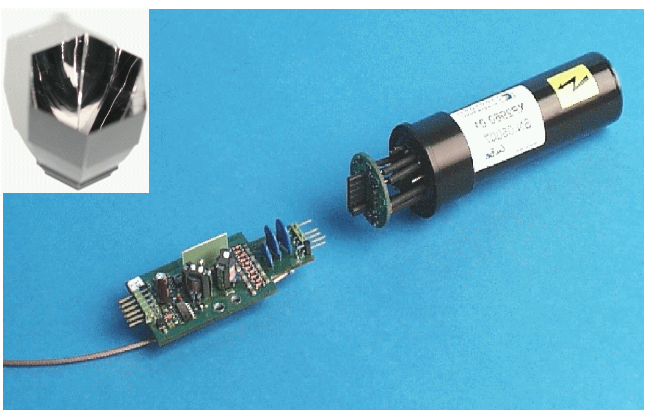

Figure 3 : A H.E.S.S. II camera pixel. Pictures of the Winston cones, the photomultiplier tube and the active base.

When the H.E.S.S. II telescope will be running in single mode, one expects a trigger rate up to 3 kHz. The electronics equipping the H.E.S.S. I. cameras is based on a GHz sampling circuit, the Analogue Ring Sampler (ARS) [2]. Its gives a 10% readout dead time at a 300 Hz trigger rate and would be obviously unfit for the new camera. A new electronics has been designed to cope with these new constraints. It is based on a new GHz sampling circuit, the Swift Analogue Memory (SAM) [3]. Its analogue bandwidth is 300 MHz, compared with 80 MHz for the ARS. In Fig. 4, the pulse shapes of a photomultiplier tube sampled by the ARS and the SAM are compared. The vertical lines show the size and position of the integration window used to measure the ARS pulse charge. The narrower pulse in the SAM will allow to use a smaller window and integrate much less night sky background.

The required camera dynamic range increases with respect to H.E.S.S. I as the physics threshold decreases. It ranges from 1/10 photo-electron for calibration purposes to 5000 photo-electrons for the highest energy events. It is obtained in two parts in the SAM which contains two channels with a gain ratio of 25. Fig. 5 shows the linear response of the SAM over the whole dynamic range and the large overlap between the two channels for cross-calibration purposes.

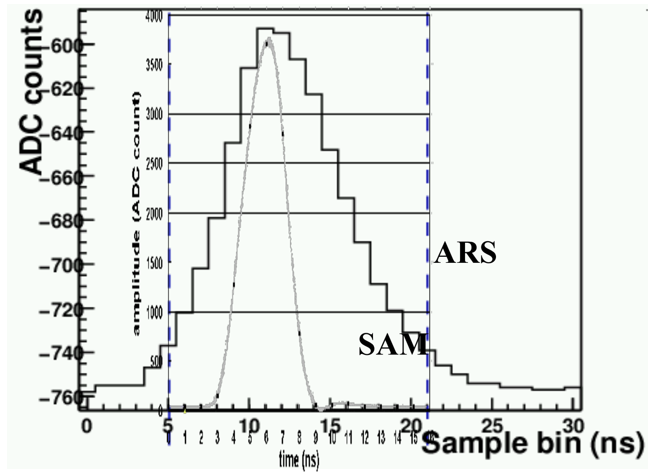

Figure 4 : A photomultiplier tube signal sampled by the ARS in H.E.S.S. I and the SAM in H.E.S.S. II.

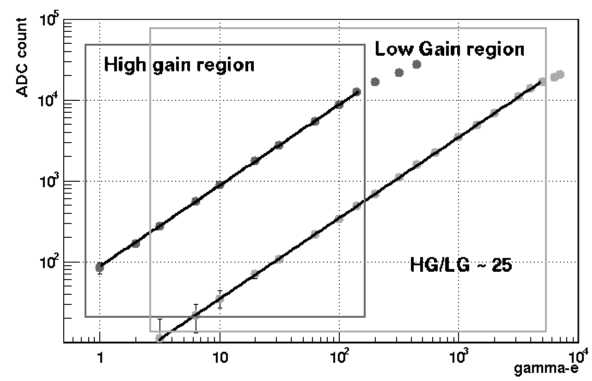

Figure 5 : The linear response of the SAM, using the two channels.

The SAM is an array of 256 switched capacitors arranged in a 16x16 matrix structure. The equivalent sampling frequency ranges from 1 GHz to 2 GHz. It is optimized for fast readout. Each capacitor cell can be read out in 90 ns, thus giving a readout dead time of less than 2 µs.

The level 1 trigger starts the readout of all the camera pixels. The camera trigger is based on a sectorization of the camera pixels. Taking into account the necessary overlaps it takes 96 sectors of 64 pixels to cover the whole camera. The level 1 trigger condition consist in predefined number of pixels simultaneously fired above an adjustable threshold in any sector. The events are stored in a FIFO memory which can contain up to 60 events. This will smooth out the rate fluctuations and allow to wait for a second-level trigger decision. In such architecture, the main contribution to the dead time comes from the memory readout which is less than 1%.

Accepted events are read out by an FPGA which formats data from 8 pixels and sends it via a custom designed bus to the central DAQ system at the rear of the camera and then via Ethernet to the local computer farm.

V. Expected Performances

In Fig. 6, we evaluate the sensitivity and threshold improvements brought by the fifth large mirror. In coincidence mode, we require that at least two of the five mirrors give an image of the event. The rate is improved by almost a factor two over the whole range, while the threshold goes down to about 50 GeV. In stand-alone mode, the threshold goes down to about 20 GeV.

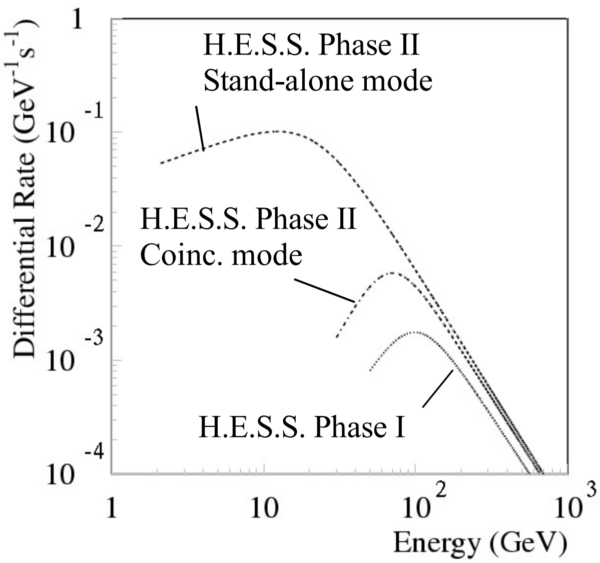

Figure 6 : Comparison of H.E.S.S. I and H.E.S.S. II sensitivities.

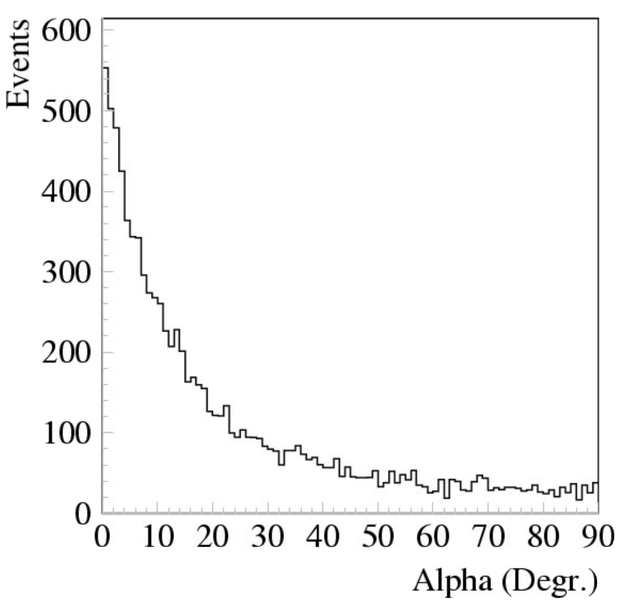

Figure 7 : H.E.S.S. II stand-alone mode angular resolution.

Figure 7 shows the expected angular resolution in stand-alone mode. While it cannot be compared with the 0.08° point spread function of the stereoscopic mode, we will still be able to look for counterparts at other wavelengths and associate our sources with those discovered by the GLAST satellite in the 20 GeV-300 GeV energy range, common to both experiments.

VI. Conclusion

The construction of the H.E.S.S. II telescope will be completed at the end of 2008. It will lower the ground-base observation threshold to 20 GeV for the rich southern sky. With the launch of the GLAST satellite at the end of 2007, it will give to the field of high energy gamma ray astronomy the unprecedented possibility to perform simultaneous measurements with these two techniques.

References

[1] P. Chadwick, these proceedings.

[2] P. Vincent et al., for the H.E.S.S. Collaboration, “Performance of the H.E.S.S. Cameras”, Proc. 28th Int. Cosmic Ray Conf., Tsukuba 2003 (Univ. Academy Press, Tokyo) p. 2887

[3] E. Delagnes, Y. Degerli, P. Goret, P. Nayman, F. Toussenel and P. Vincent,“SAM: a new GHz sampling ASIC for the H.E.S.S.-II Front-end electronics”, Nuclear Instruments and Methods in Physics Research A (In press)(Presented at the 2005 Beaune conference on Photodetection).