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H.E.S.S. Phase II

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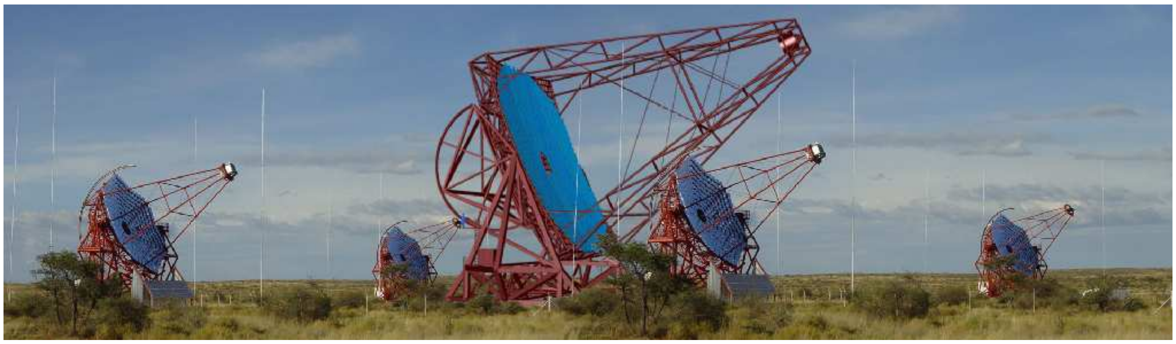
The first phase of the H.E.S.S. experiment was commissioned at the end of 2003 with the installation of the last of the four telescopes that equip this stereoscopic system. After more than a year of observation about twenty sources have been detected with an unequalled significance and an angular resolution that allows a fine study of extended source morphology. The second phase of the project is under construction. A new large telescope will be placed in the centre of the H.E.S.S.-I four-telescope array to lower the energy threshold and improve the sensitivity of the full system. After the presentation of physics goals we will describe the apparatus and present the predicted performance.

1. Introduction

The recent successes of the H.E.S.S. [1] phase-I instrument have demonstrated that the atmospheric Cherenkov detection technique, by detection and reconstruction of gamma-ray induced air showers using ground-based detectors, have reached maturity, and allow efficient detection of new sources and precise study of source characteristics. The morphology of RX J1713.7-3946 [2] and the new sources detected in the galactic scan [3] are two spectacular examples of these new possibilities. At this stage of the evolution of this discipline one can see two options to improve further the potential of detection of the H.E.S.S. system. One can increase the sensitivity of the system by adding more telescopes, also offering the possibility of observing several sources simultaneously with independent subsystems of four telescopes. The second option is to enlarge the energy range of gamma-ray detection and especially to decrease the energy threshold of the system. To do so, an additional—significantly larger—telescope in the centre of the current array can fulfil this goal and simultaneously increase the sensitivity of the experiment in the current H.E.S.S. energy range. Another advantage is the complementarity of instrument between the northern and the southern hemispheres. A wide variety of instruments are operational in the North, with the low-threshold MAGIC telescope and the non-imaging instruments using solar arrays currently taking data. At higher energies, other experiments will be commissioned in the near future, such as the VERITAS telescope array. In the southern hemisphere, no instrument operates below 100 GeV, so the second phase of H.E.S.S. fills the gap with the future satellite-borne detectors.

The southern hemisphere is a strategic position to investigate nearby sources. The central part of our Galaxy offers a unique selection of objects. The recent scan of the inner region by the H.E.S.S. experiment has revealed a number of unidentified source at high energies, similar to those which make up about half of the EGRET catalogue at lower energies. No obvious counterparts are found at other wavelengths, and a better energy measurement over a wider spectrum may help to understand their nature. Another potential dark source of very high energy radiation is the conjectured self-annihilation of the lightest super-symmetric particle, the neutralino, a candidate for dark matter. The H.E.S.S. phase-I telescopes have limited sensitivity to sub-TeV masses since the highest signal is expected to occur for gamma-rays produced in cascade decay of the annihilation products. Another aspect is the study of cosmological infra-red background, which is a trace of the history of star formation, for which one has to separate the effects of absorption of gamma-rays from distant sources on this extragalactic background from effects in the source environment. Measurements of sources at various red-shifts will allow to define separate samples at different energy ranges to identify the different contributions. With a threshold of 20 GeV we can have access to objects at cosmological distances up to a red-shift of the order of unity without dramatic losses due to absorption, and so also investigate GRBs. For the identification of the acceleration process near black holes in the inner region of active galaxies, the low threshold energy can provide the required high detection rate for the reconstruction of high variability emission that can distinguish between the different models of cosmic-ray acceleration. Also, the reconstruction of a wide spectrum in energy can gives useful information on gamma-ray production in supernovae remnants and allow to separate the contribution from inverse Compton emission from gamma-rays produced in π^o annihilation in hadronic processes. Other compact objects such as microquasars and pulsars are predicted to have spectral cut-offs below the current H.E.S.S. energy range. The microquasar LS 5039 [4] has been recently detected by H.E.S.S. and low energy coverage will allow to study this new class of object. Low-energy measurements will probably allow to distinguish between the two basic classes of models that describe the pulsars — the Polar Cap and Outer Gap models.



To lower the energy threshold of the H.E.S.S. system it is necessary to collect more Cherenkov light so as to be able to reconstruct the low-energy gamma-ray showers. This goal can be reached by increasing the size of the light collector, improving the reflectivity of the mirror and the light concentrator in front of the PMs (photomultipliers), enhancing the quantum efficiency of the PMs and their photo-electron collection efficiency. The first results from MAGIC confirms that a single large telescope can reach a low energy threshold with some sensitivity. For H.E.S.S.-II, a large telescope of about 500 tonnes with a mirror area of 596 m^2 and a camera of $3.5°$ FoV (Field of View) with a pixel size of $0.07°$ is scheduled to be installed in the centre of the current H.E.S.S. I array by 2008 (see artists view).

2. The telescope

Different solutions have been studied for the mount and the dish of the new large telescope. A alt-azimuth mounted structure with a mount rotating on a large circular rail, with two towers to support the elevation axis, was adopted mainly thanks to the experience gained with the H.E.S.S. phase-I telescopes. The mount will support the elevation axis of the dish at 24 meters above the ground. The diameter of the circular azimuth rail is 36 m. A dish support structure of 55 tonnes is hinged at two elevation bearings and supports the dish from the rear side at four points chosen to minimize the deformations of the dish shape. It also support two semi-circular elevation drive rails. The dish is a rectangular shape (32 m high, 24 m wide) with a depth varying from 2.7 m to 4.6 m. This structure is optimized concerning stiffness and high eigenfrequencies. The mirror is made up of 850 mirror facets. The mirror facets and the motorized mirror actuators are fixed to 25 identical planar mirror support segments (figure 1) welded to the dish to approximate a parabolic shape. The parabolic structure introduces a lower time-dispersion than the Davis-Cotton mirror geometry used for the first four telescopes, which is a gain for the integration window but increases the point spread function. Detailed description of the reflector performance will be presented at the conference [6]. Each tile has an hexagonal shape and is supported by a system which performs individual alignment.

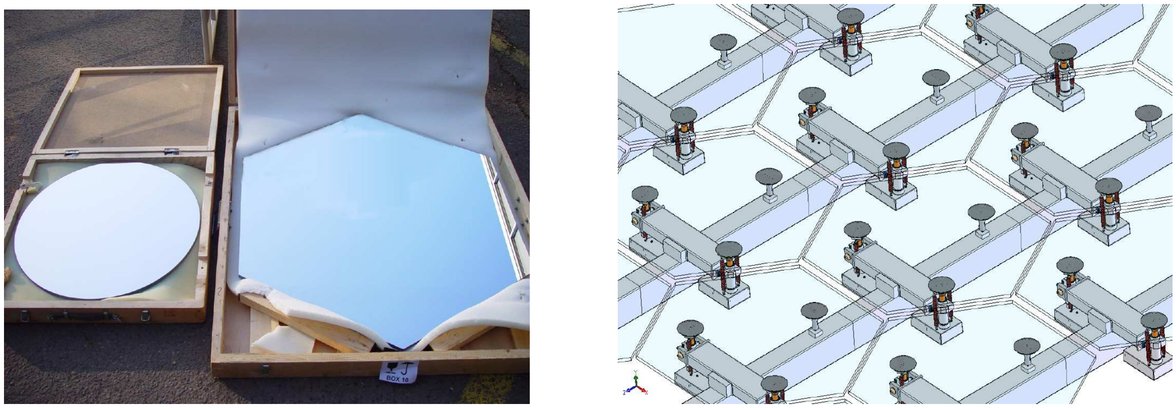


Figure 1. Comparison of a round 60 cm mirror of the phase-I telescope and the new 90 cm hexagonal glass mirror (left). Mirror support and alignment units attached to the rear of a mirror support segment (right).

A quadrupod maintain a camera of 3 tonnes at 36.74 metres away from the dish which correspond to a f/d ratio of 1.2. This value is a compromise between the quality of the imaging over the field of view and the cost of the structure of the telescope. The camera will be allowed to move along the optical axis in order to refocus the telescope depending on zenith angle (so on distance of the shower maximum [5]) to improve the image reconstruction.

3. The camera

To cope with the high trigger rate, the camera needs to be more sophisticated in the sense that a minimum dead-time is required to discriminate the low proportion of good gamma-ray candidate events from the large amount of background. The H.E.S.S.-I camera [7] was based on a fine pixelisation and a fast electronics, fully-integrated at the focal plane. For the second phase of H.E.S.S., the same principle is to be apply (figure 2) to a camera of 2048 pixels [8]. The readout front-end and the trigger channel has been redesigned.

To record and transfer a mean event rate of 3 kHz with a minimal dead time, a new analogue memory, named SAM ("Swift Analogue Memory") has been fabricated. Each chip contains two differential channels of 256 cells, with an input bandwidth of about 300 MHz and cross-talk lower than 0.1%. The sampling rate is controlled by an external clock and can be changed from 500 MHz up to 2.5–3 GHz, with power consumption is of the order of 300 mWatt. The signal from each PM is split into two channels with different gains to allow the signal from a single photo-electron (γ_e) to be measured and to cover a dynamic range up to 4,000 γ_e. Consecutively to a level-one trigger decision, the memories are read out and the data from all channels are digitized by external 12-bit ADC at 20 MSamples/s and transfered in parallel to a series of 1k $\times$ 18bits FIFO memories (capacity of 60 events) while awaiting a second-level trigger. This second-level trigger is under study to reject some of these events with more sophisticated criteria [9]. A second version of this chip will be produced by the end of 2005 and will include (in addition to the memories) 2 $\times$ 16 12-bit ADCs, which corresponds to one ADC for each of the 16 cells to be read out per channel. The time taken by the readout of 16 cells has been measured to be about 1.44 μs. The FIFO memories can store about 60 events, and this buffer will allow to wait for the decision of a second-level trigger and also to cope with variations in event rates. The H.E.S.S. camera trigger is based on a sectorization of the pixels. A minimal number of pixels in coincidence above a programmed threshold is identified within a sector of 64 pixels. 96 sectors are necessary to cover all the camera and a trigger in one of these sectors is sufficient to start an acquisition of all camera pixels. In the new telescope the pixel size will be smaller but the same number of pixels per sector will be used. The effect will be to limit the combinations and therefore limit the number of random triggers due mainly to night-sky background. Accepted events are read out by an FPGA which reads information from the 8 phototubes per analogue-memory card. The information is formatted and sent over 16 custom-designed buses to the central DAQ system installed in the rear of the camera an then sent to the farm on the network.

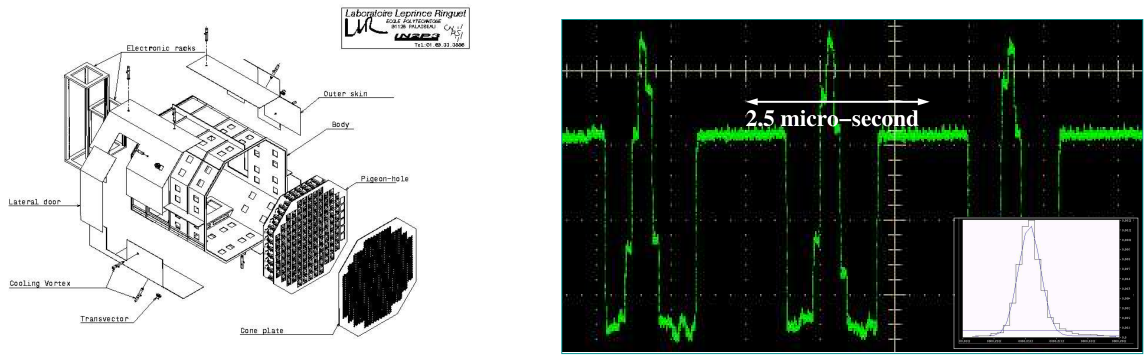


Figure 2. Mechanics of the H.E.S.S. II camera (left). Test of readout speed at 400 kHz (right)

The dead-time of the camera depends on the speed of the different components of the electronics. In this new architecture, due to the different stage of FIFO buffers which has been introduced, the unique limitation comes from the analogue memories used for data storage. The new readout speed is fast enough to introduce less than 0.7% dead-time at the expected 3 kHz acquisition rate.

4. Conclusions

The construction of the H.E.S.S. phase II has started, and according to current schedules, the telescope could be operational by late 2008. With this additionnal detector, a new window between about 20 GeV up to few tens of TeV, of gamma-ray detection will be opened on the southern sky.

References

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