Status of the H.E.S.S. Project

Werner Hofmann, for the H.E.S.S. collaboration
Max-Planck-Institut für Kernphysik, D 69029 Heidelberg, P.O. Box 103989

Abstract

H.E.S.S. - the High Energy Stereoscopic System - is a system of four large imaging Cherenkov telescopes under construction in the Khomas Highland of Namibia, at an altitude of 1800 m. With their stereoscopic reconstruction of air showers, the H.E.S.S. telescopes provide very good angular resolution and background rejection, resulting in a sensitivity in the 10 mCrab range, and an energy threshold around 100 GeV. The H.E.S.S. experiment aims to provide precise spectral and spatial mapping in particular of extended sources of VHE gamma rays, such as Supernova remnants. The first two telescopes are operational and first results are reported; the next two telescopes will be commissioned until early 2004.

1. The H.E.S.S. Telescopes

The H.E.S.S. Cherenkov telescopes are characterized by a mirror area of slightly over $100\,\mathrm{m}^2$, with a focal length of 15 m, and use cameras with fine pixels of 0.16° size and a large field of view of 5°.

Construction of telescopes is well underway; the steel structures of all four telescopes have been erected and equipped with drive systems; two telescopes are fully equipped with mirrors and cameras and take data since June 2002 and March 2003, respectively. The final two telescopes will be commissioned early in 2004; all parts, such as mirrors, phototubes etc. are in hand, and the cameras are under assembly in France. The site infrastructure is complete and includes a building with the experiment control room, offices, and workshops, a residence building, Diesel power generators and a Microwave tower linking the site to Windhoek and from there to the internet.

The H.E.S.S. telescopes use an alt-az mount, which rotates on a 15 m diameter rail. The steel structures are designed for high mechanical rigidity. Both azimuth and elevation are driven by friction drives acting on auxiliary drive rails, providing a positioning speed of 100°/min. Encoders on both axes give 10” digital resolution; with the additional analogue encoder outputs, the resolution is improved by another factor 2 to 3. After initial tests and a few months of operation of the first telescope, the drives were slightly modified for smoother

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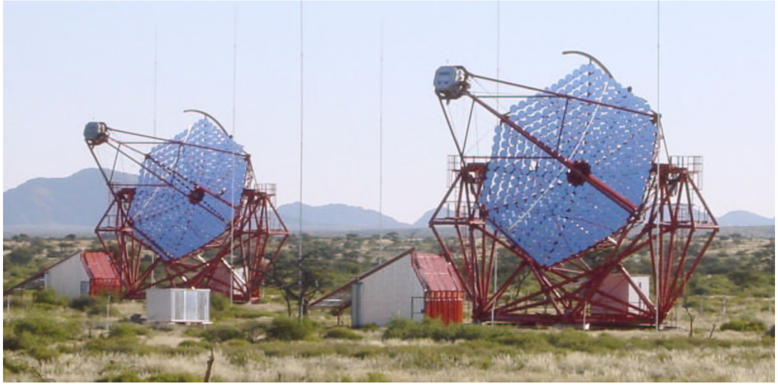

Fig. 1. The first two H.E.S.S. telescopes, ready to take data.

operation; the telescope design is now quite mature.

The mirror of a H.E.S.S. telescope is composed of 380 round facets of 60 cm diameter; the facets are made of ground glass, aluminized and quartz coated, with reflectivities in the 80% to 90% range. The facets are arranged in a Davies-Cotton fashion, forming a dish with 107 m^2 mirror area, 15 m focal length and $f/d \approx 1.2$. To allow remote alignment of the mirrors, each mirror is equipped with two alignment motors with internal resolvers. The alignment procedure uses the image of a star on the closed lid of the PMT camera, viewed by a CCD camera at the center of the dish. The procedure and the resulting point spread function are described in detail elsewhere in these proceedings. Due to the superior quality of both the mirrors and the alignment system, the on-axis point spread function is significantly better than initially specified. The imaging quality is stable over the elevation range from 30° to the Zenith. The point spread function varies with distance θ (in degr.) to the optical axis as $r_{80} = (0.42^2 + (0.71\theta)^2)^{1/2}$ [mrad]; r_{80} is the circle containing 80% of the light of a point source at the height of the shower maximum. Over most of the field of view, light is well contained within a single pixel.

Telescope pointing was verified using the images of stars on the camera lid. Without any corrections, star images were centred on the camera lid with a rms error of 28". Using a 12-parameter model to correct for misalignments of the telescopes axes etc., a pointing precision of 8" rms is reached. Finally, using a guide telescope attached to the dish for further corrections, the pointing can be good to 2.5" rms. H.E.S.S. should therefore be able to locate gamma ray sources to a few arc-seconds.

The PMT cameras of the H.E.S.S. telescopes provide 0.16° pixel size over a 5° field of view, requiring 960 PMT pixels per telescope. The complete electronics for signal processing, triggering, and digitization is contained in the camera body; only a power cable and a few optical fibers connect the camera. For ease of maintenance, the camera features a very modular construction. Groups of 16 PMTs together with the associated electronics form so-called "drawer" modules, 60 of which are inserted from the front into the camera body, and have backplane connectors for power, a readout bus, and trigger lines. The rear section of the camera contains crates with a PCI bus for readout, a custom crate for the final stages of the trigger, and the power supplies. The camera uses Photonis XP2960 PMTs, operated at a gain of 2×10^5. The PMTs are individually equipped with DC-DC converters to supply a regulated high voltage to the dynodes; for best linearity, the four last dynodes are actively stabilized.

The key element in the signal recording of the H.E.S.S. cameras is the ARS (Analogue Ring Sampler) ASIC, which samples the PMT signals at 1 GHz and provides analogue storage for 128 samples, essentially serving to delay the signal until a trigger decision is reached. To provide a large linear dynamic range in excess of 10^4 up to 1600 photoelectrons, two parallel high/low gain channels are used for each PMT. A camera trigger is formed by a coincidence of some number of pixels (typically 3-5) within an 8×8 pixel group exceeding an adjustable threshold; typical operating thresholds are in the range of 3 to 5 photoelectrons. The pixel comparators generate a pixel trigger signal; the length of the signal reflects the time the input signal exceeds the threshold. Since typical noise signals barely exceed the threshold and result in short pixel trigger signals, the effective resolving time of the pixel coincidence is in the 1.5 to 2 ns range, providing a high suppression of random coincidences. At the time of this writing, the two telescopes are triggered indepedently, and stereo images are combined offline using GPS time stamps. A central trigger processor controlling electronic delays and coincidence logic will soon be installed. This will allow to impose arbitrary telescope configurations in the trigger, and to operate the telescopes either as a single four-telescope system, or as subsystems, up to four individual telescopes pointed at different objects.

A number of auxiliary instruments serve to monitor telescope performance and atmospheric quality. These include laser and LED pulsers at the center of a dish for flatfielding, and infrared radiometers and a lidar system to detect clouds and characterize aerosol scattering. Details are given elsewhere in these proceedings.

2. First data

After the first telescope was equipped with mirrors in autumn of 2001, the camera was installed in May 2002 and first data were taken in June 2002. As expected for a single telescope, a significant fraction - roughly half - of the images are caused by muons, either in the form of full rings or of short ring segments.

The night-sky background - predicted to be about 100 MHz photoelectron rate per pixel - induces a noise of 1.2 to 1.5 photoelectrons rms in the PMT pixels, consistent with expectations.

Muon rings are used to verify the overall performance and calibration of the telescopes. Rings are classified according to their radius - related to the muon energy - and by the impact parameter, which governs the intensity distribution along the ring. The observed photoelectron yield agrees to better than 15% with expectations, indicating that the optical system, the PMTs and electronics calibration are quite well understood. This tool can be used to monitor the evolution of the detectors, as explained in greater detail in an accompanying paper.

Another important check for the performance of the telescope is the trigger rate. The rate varies smoothly with threshold. Even for thresholds as low as four photoelectrons, trigger rates are governed by air showers rather than by night-sky noise, which would induce a much faster variation with threshold. With a typical threshold of 4-5 photoelectrons, event size distributions peak around 100 to 150 photoelectrons; for the H.E.S.S. telescopes one photoelectron corresponds approximately to one GeV deposited energy.

Objects observed so far include SN 1006, RXJ 1713-3946, PSR B1706-44, the Crab Nebula, and NGC 253, PKS 2005-489, PKS 2155-304 as extragalactic source candidates. Clear signals are detected from the Crab Nebula and for PKS 2155, confirming the earlier detection by the Durham telescopes. The spectral shape of the Crab data agrees well with other measurements; for PKS 2155, a slightly steeper spectrum is measured. Details are given in other contributions to this conference. First stereo data were collected in March 2003, using the first two telescopes with an offline selection of concident events. As expected, muons rings were found to be absent in coincident events. A parallel trigger to retain some muon events when stereo coincidence operation begins is under consideration.

3. Conclusion

The first two H.E.S.S. telescopes are operational since June 2002 and March 2003, respectively, and first results concerning the technical performance of the telescopes, both for the optical system and the camera, look encouraging and did not expose major problems. Current schedules call for completion of the Phase-I four-telescope system in 2004. An expansion of the system - Phase II - with increased sensitivity is foreseen; the Phase II telescopes and their arrangement are under study.

Acknowledgement

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