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Status of the H.E.S.S. experiment and first results

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Abstract. The High Energy Stereoscopic System (H.E.S.S.) consists of four 12m diameter imaging Cherenkov telescopes, and is presently under construction in the Khomas Highland region of Namibia, 1.8 km above sea level (23°16′18″ S, 16°30′00″ E). The H.E.S.S. telescopes provide very good angular resolution and background rejection capability resulting in a sensitivity $\sim$ 10 mCrab with an energy threshold of around 100 GeV. The first two telescopes are currently operating, and the array will be complete in early 2004. This paper provides a description of the H.E.S.S. telescopes and reports preliminary results obtained with the first telescope.

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1 Introduction

The atmospheric Cherenkov technique uses the Cherenkov light produced by secondary showers in the atmosphere to detect gamma rays. Imaging atmospheric Cherenkov telescopes (IACTs) have much larger effective areas than satellite-borne gamma ray telescopes, which enables IACTs to provide high sensitivity despite their relatively high energy thresholds, and excellent background rejection. The next generation of imaging atmospheric Cherenkov telescopes offers unprecedented sensitivity to gamma rays of energy $\geq$ 50 GeV, and as such provides unique insights into some of the most extreme environments in the universe as well as aspects of particle astrophysics.

2 The H.E.S.S. telescopes

At the time of writing (July 2003), the steel structures of all four telescopes have been constructed and equipped with alt-azimuth drive systems. Two telescopes are complete, and have been taking data since June 2002 and March 2003, respectively. The final two telescopes will be commissioned in early 2004. The site infrastructure is complete and includes the telescope control room, offices and a workshop, as well as a residence building. A microwave transmitter links the site to the Namibian capital, Windhoek, about 100 km distant and thence to the internet.

The four telescopes are arranged on a square of side 120 m. Each telescope has a mirror area of 107 m^2, and a focal length of 15 m. The camera at the focus of each telescope consists of 960 PMTs, providing a pixel size of 0.16° and a large field of view of 5°. The total weight of each telescope is around 60 tonnes.

The mirrors of a H.E.S.S. telescope consist of 380 individual facets, each of diameter 60 cm. The facets are made of quartz-coated aluminized glass, and have reflectivities of between 80% and 90%. They are arranged in a Davies-Cotton configuration, to provide a 15 m focal length dish with focal ratio $\sim$ 1.2. Each facet is equipped with two motors to allow for remote alignment. The on-axis point spread function is better than originally specified for the telescopes, with a measured spot width of 0.02°. This image quality is stable over the elevation range 30° to 0°, the most common operating range for IACTs. Over most of the field of view, light is well contained within a single camera pixel.

The 960 photon detector elements of the cameras are 29 mm diameter Photonis 8-stage photomultiplier tubes (PMTs) with borosilicate windows. They are fitted with light-gathering (Winston) cones to improve light detection. The PMTs are individually equipped with DC-DC converters to supply a regulated high voltage to the dynodes. All the electronics required for high-voltage supply, signal processing, triggering, and digitization are contained within the camera, such that only a power cable and a few optical fibres connect the cameras to the outside world. For ease of maintenance, the cameras have a modular construction. Groups of 16 PMTs together with their associated electronics form 'drawer' modules, 60 of

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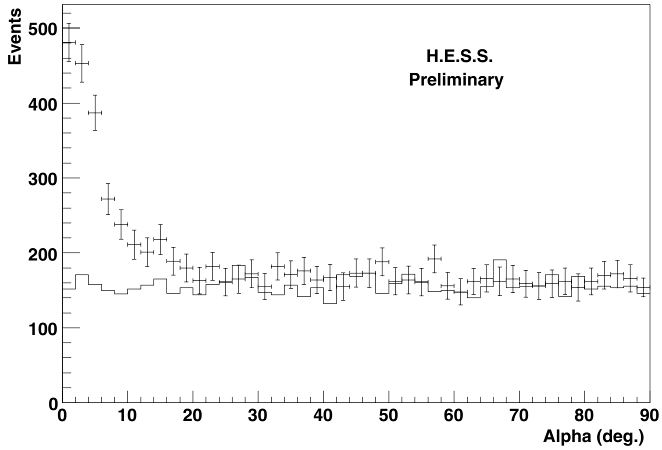

Fig. 1. The γ-ray excess from the Crab nebula, shown as an excess of events at small values of *alpha*. On-source data are represented by *points with error bars*, and the OFF-source data by a *histogram*. The OFF data are normalized to take into account differences in exposure time ON- and OFF-source

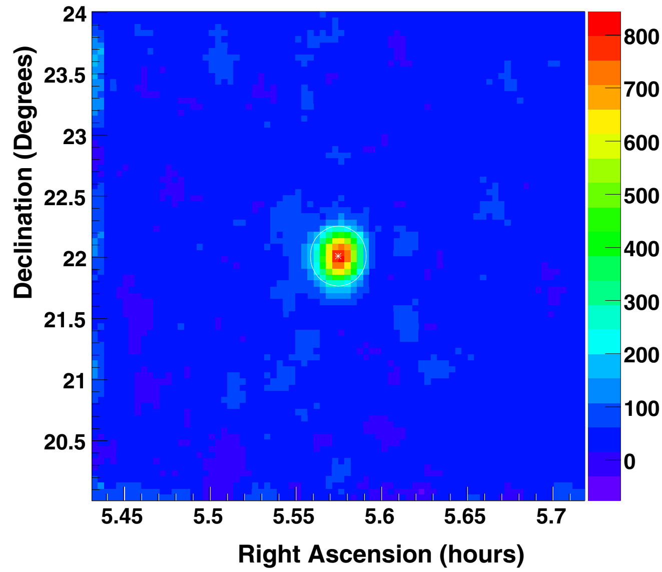

Fig. 2. Reconstructed skyplot of the γ-ray excess around the position of the Crab nebula

which are inserted from the front of the camera body. The final result weighs about 950 kg, and is 1.6 m in diameter.

A number of auxiliary instruments are used to monitor telescope performance and atmospheric quality. At the centre of each dish, a laser or LED pulser provides for flat-fielding of the cameras. Another LED pulser delivers single photoelectrons to each PMT for gain calibration. Each telescope is equipped with an infrared radiometer operating between 8 and 14 μm to detect atmospheric water vapour along the line of sight. There is also a LIDAR system, to detect clouds and characterize aerosol scattering, and a weather station on site.

Telescope pointing is monitored using CCD-images of stars on the camera lid. Without any corrections, star images were centered on the camera lid with an rms error of 28”. Correction for slight misalignment of the telescope axes etc., produces a pointing precision of 8”; finally, by using a guide telescope attached to the dish for further corrections, the pointing resolution is 2.5”. H.E.S.S. should therefore be able to locate gamma ray sources to a few arcseconds.

Also on site is the ROTSE 3c telescope. This is a 0.45 m diameter optical telescope, primarily designed for the optical identification of gamma ray bursts; some time is available to H.E.S.S. for the optical monitoring of gamma ray sources.

3 First results

The data reported in this paper were taken with the first H.E.S.S. telescope operating alone. Data were taken in an ON-OFF observation mode, with 25-minute observations of the source paired with similar observations of a control region offset by 30 min in right ascension from the source. After observations taken under good weather conditions were selected, the raw data, consisting of images produced by cosmic ray showers and muons as well as gamma rays, were calibrated using a range of LEDs to measure the gain of the system and a laser to allow flat-fielding of the camera. Images were then cleaned using simple image/border criteria, whereby pixels in the image are required to be above a threshold of 5 photoelectrons and have a neighbouring pixel containing a signal greater than 10 photoelectrons. A conventional moments analysis of the resulting images was then used to provide image shape and orientation parameters (Hillas parameters) which were used to discriminate against the cosmic ray background [1]. The selection criteria for each object were optimized using Monte Carlo simulations which were tested against the real background events available from OFF-source observations. The discrimination is based on the length and width of the image, distance of the image barycentre from the source position and the ratio of the length to the total charge detected by the camera pixels. The pointing angle, α, of the images remaining after selection is then plotted. This parameter is the angle between the actual source position and the reconstructed image axis of the gamma ray candidate and essentially provides a plot of the gamma ray excess from the object.

3.1 The Crab nebula

The Crab nebula was first detected as a TeV source in 1989 [2], and since that time has been regarded as a ‘standard candle’ for TeV gamma ray astronomy. It was observed with the first H.E.S.S. telescope in October and November 2002 for a total of 4.65 hours ON source. The observations were taken over a zenith angle range of 45° to 50°, typical visibility of the Crab nebula from the Southern hemisphere H.E.S.S. site.

Using the simple analysis described in Sect. 3, the Crab nebula was detected at a significance level of 20.1 σ, giving a steady gamma ray detection rate of 3.6 γ min^{-1}. The

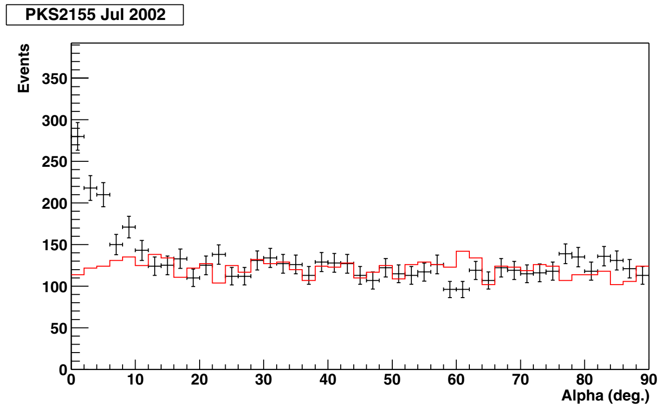

Fig. 3. Plot showing the γ-ray excess from the PKS2155-304 in July 2002. ON-source data are represented by *points with error bars*, and the OFF-source data by a *histogram*. The OFF data are normalized to take into account differences in exposure time ON- and OFF-source

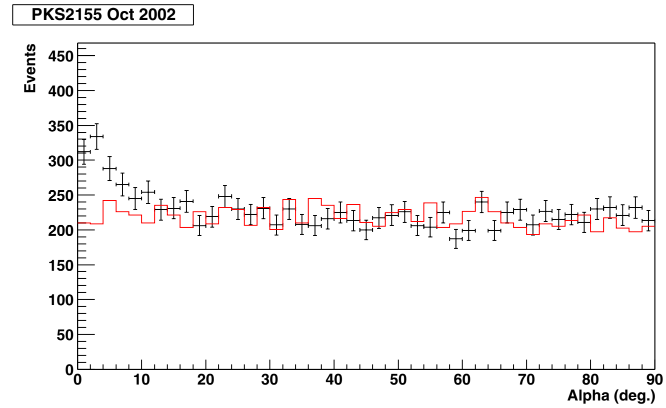

Fig. 4. Plot showing the γ-ray excess from PKS2155-304 in October 2002. Data representation is as for Fig. 3

α parameter distributions for the ON and OFF source observations after the application of cuts are shown in Fig. 1. The source reconstruction is shown in Fig. 2. The energy threshold before cuts is 590 GeV, and after cuts it is 780 GeV, as defined by the peak in the differential rate distribution. A preliminary estimate of the integral fluxes based on a Monte Carlo simulation is $(2.64 \pm 0.20_{stat}) \times 10^{-7}$ photons m^{-2} s^{-1} at $E \geq 1$ TeV, without including systematic errors.

3.2 PKS 2155-304

The AGN PKS 2155-304 is a bright, nearby (z=0.116) blazar, and was discovered as an X-ray source during observations made with the *HEAO*-1 satellite [3], [4]. It has been the subject of many multiwavelength campaigns (see, e.g. [5], [6]). It is known to be highly variable; it is the brightest known BL Lac at UV wavelengths and its synchrotron emission extends well into the X-ray region of the spectrum [7], [8]. It was first detected as a TeV source in 1997 [9].

Observations of PKS 2155-304 were made with the first H.E.S.S. telescope in July and October 2002, yielding 2.2 and 4.7 hours of ON source observations respectively. The signal excess in July 2002 was 404 events, corresponding to the γ-ray rate of 3.1 min^{-1} and providing a detection significant at the 9.9 σ level. In October 2002, 337 excess events were observed, 1.2 γ min^{-1}, giving a detection significant at the 6.6 σ level. The total significance is 11.9 σ. Figures 3 and 4 show the *alpha* plots for the ON and OFF source data after selection cuts.

The difference in the gamma ray rates in July and October is evidence for the diminution of the gamma ray flux from PKS 2155-304 by a factor of approximately 3 between the two H.E.S.S. observations. The weekly averaged X-ray count rates as measured with the *RXTE* All Sky Monitor show that the source was slightly brighter in July 2002 than October of the same year. However, it is not possible to make a quantitative correlation of the gamma ray and X-ray fluxes due to the low level of the X-ray flux.

4 Conclusions

The first two telescopes of the H.E.S.S. array have been operating since June 2002 and March 2003 respectively. Mechanical, electronic and optical performance has been good, and the telescope design is mature. Early data taken with the first telescope operating on its own have given strong detections of the Crab nebula and the blazar PKS 2155-304. The array is expected to be fully operational in early 2004.

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References

1. A.M. Hillas: Proc. 19th International Cosmic Ray Conference **3**, 445 (1985)
2. M. Punch et al.: Proc. 22nd International Cosmic Ray Conference **1**, 464 (1991)
3. D.A. Schwartz et al.: Astrophys. J. **229**, L53 (1979)
4. R.E. Griffiths et al.: Astrophys. J. **234**, 810 (1979)
5. W. Brinkmann et al.: Astron. Astrophys. **288**, 433 (1994)
6. T. J.-L. Courvoisier et al.: Astrophys. J. **438**, 108 (1995)
7. A. Wandel and C.M. Urry: Astrophys J. **367**, 78 (1991)
8. L. Chiappetti et al.: Astrophys. J. **521**, 552 (1999)
9. P.M. Chadwick et al.: Astrophys. J. **513**, 161 (1999)