Observation Of Galactic TeV Gamma Ray Sources With H.E.S.S.

Conor Masterson[1], for the H.E.S.S. Collaboration[2]
(1) *MPI fuer Kernphysik, P.O. Box 103980, D-69029 Heidelberg, Germany*
(2) http://www.mpi-hd.mpg.de/HESS/collaboration

Abstract

The first telescope of the H.E.S.S. stereoscopic Cherenkov telescope system started operation in summer 2002. In spring 2003 a second telescope was added, allowing stereoscopic observations. A number of known or potential TeV gamma-ray emitters in the southern sky were observed. Data on the Crab nebula taken at large zenith angles show a clear signal and serve to verify the performance and calibration of the instrument. Observations of other Galactic sources are also summarized.

1. Introduction

The H.E.S.S. experiment commenced operations on-site in Namibia in June, 2002, with the first of four Cherenkov telescopes. With its high resolution camera (0.16° pixel size) and large mirror area (107 m^2) the single H.E.S.S. telescope is a sensitive instrument in its own right, comparing favourably with existing detectors. The large field of view of the detector, ($\approx 5°$) makes it a good choice for observations of extended galactic objects. Observations were made of a number of candidate γ-ray sources with the single telescope, pending the installation of the rest of the array. These sources included the Crab nebula, an established TeV source, as well as a number of other Galactic sources.

The Crab nebula was discovered at TeV energies in 1989 [6] and is conventionally used as a standard reference source of TeV γ-rays, due to its relative stability and high flux. It was observed with the first telescope in October and November 2002 for a total of 4.65 hours (live-time). Due to the latitude of the H.E.S.S. experiment (21° South), observations were taken over a zenith angle range of 45° to 50°.

2. Analysis of Data

Since the data reported in this paper were taken with the first H.E.S.S. telescope operating in single telescope mode, a standard analysis of type Supercuts [5] was applied in order to extract a γ-ray signal. This uses simple selection criteria

pp. 2323–2326

Table 1. Optimized γ-ray selection criteria.

Parameter	Cut	
Length	4.8	mrad
Width (lower)	0.05	mrad
Width (upper)	1.3	mrad
Length/Amp.	0.016	mrad/p.e.
Distance	17.0	mrad
α	9.0	deg.

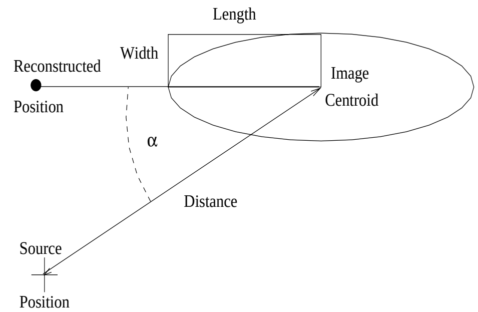

Fig. 1. Definition of Hillas Parameters

based on parameters calculated from the moments of the Cherenkov images.

Data were taken in ON-OFF observation mode, with 25-minute observations of the source accompanied by similar observations of a control region offset by 30 minutes in Right Ascension from the source. In order to calibrate the system, a number of artificial light sources are used, including an array of light emitting diodes on the inside of the camera lid. These LEDs are used to measure the single photo-electron gain of the system. Also, a laser mounted on the dish allows flat-fielding of the camera [3].

Images were cleaned using a two-step technique, requiring pixels in the image to be above a lower threshold of 5 photo-electrons and to have a neighbour above 10 photo-electrons. Second-moment parameters were calculated for each cleaned image using the Hillas [1] definitions and these parameters were used to select candidate γ-ray events. The selection criteria were optimized using Monte-Carlo simulated γ-ray showers and real background runs at the same zenith angle range as the observations. The selection cuts are summarized in table 1, a diagram illustrating the parameter definitions is shown in figure 1.

3. Results

The data from the Crab nebula observations have been analysed using the above technique, giving a steady rate of 3.6 γ min^{-1} with a significance of 20.1 σ after applying the above-mentioned selection cuts. The α parameter distributions for the ON and OFF data are shown in Figure 2. The two-dimensional skyplot is shown in figure 3. The source reconstruction for the skyplot uses a simple single telescope source reconstruction scheme based on Hillas parameters [4].

The effective area for γ-rays has been estimated for one of the Monte Carlo simulations described in the accompanying article using the above selection cuts. The pre- and post-selection effective area distributions as a function of the true Monte Carlo input energy are shown in figure 4 for simulated γ-rays at a zenith angle of 45°. The differential γ-ray rate for a source with a spectrum similar to that of the Crab is given in figure 5. It can be seen that the energy threshold after

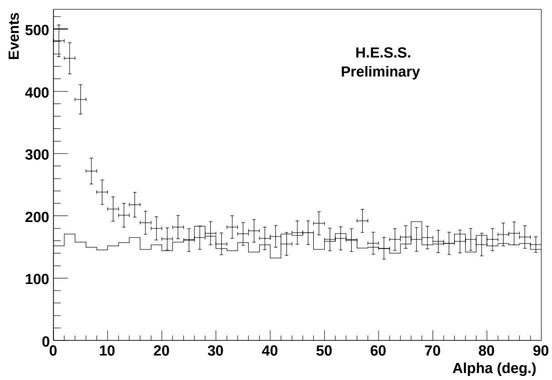

Fig. 2. Alpha plot, 2d plot of γ-ray excess from the Crab nebula, the OFF data is normalized to take account of the exposure time differences.

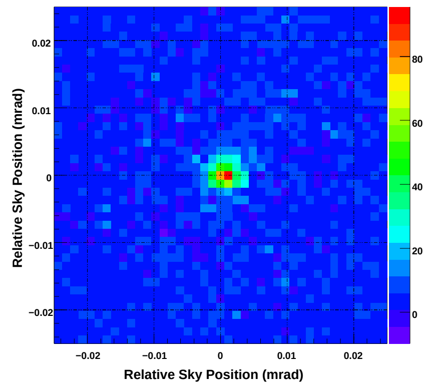

Fig. 3. Reconstructed skyplot of γ-ray excess in mrad around the source position

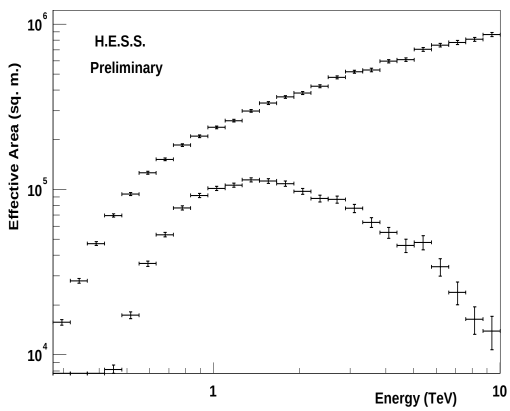

Fig. 4. Effective areas before and after selection cuts as a function of true simulated energy

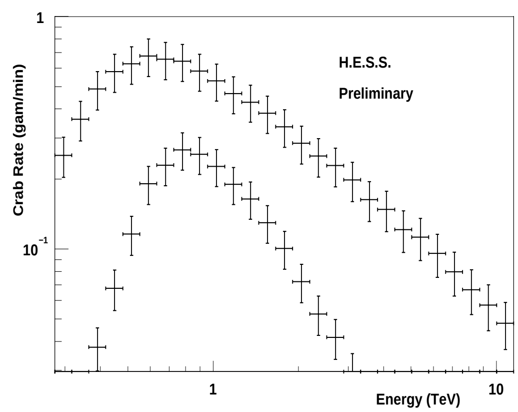

Fig. 5. Differential rate for a source with a spectrum similar to the Crab at 45° zenith angle.

the above selection cuts, as defined by the peak in the differential rate distribution, is 780 GeV. The energy threshold before selection cuts is 590 GeV. The fixed cuts on Hillas parameters described reject most γ-rays at high energies, this may be remedied by varying the cuts with image amplitude, which is currently under study.

A preliminary estimation of the integral flux based on one of the Monte Carlo simulations gives a value of $(2.64 \pm 0.20) \times 10^{-7}$ m^{-2} s^{-1} ($>$ 1 TeV), for which the quoted error include only the statistical errors; no systematic errors are included. Preliminary analysis of the spectral energy distribution indicates that the signal follows a power-law form with a slope not inconsistent with measurements by other instruments. Uncertainties in the energy threshold and spectral analysis are in large part due to differing estimates of the collection efficiency for

γ-rays from different Monte Carlo simulations, which is the subject of ongoing study.

4. Observations of other Galactic Sources

Observations were made of a number of other Galactic sources with the first H.E.S.S. telescope during 2002 and early 2003, calibration and analysis of these data will be presented in the talk accompanying this paper. Observations are summarized in table 2, with live time corrected exposures on the sources and the mean zenith angle of the observation. The remaining Crab data is currently under analysis.

Table 2. Summary of galactic Source Observations up to beginning May 2003

Source	Obs. Time (hrs)	Mean Zenith Angle (°)	Type
Crab (total)	14.2	47.7	Plerion
Vela	22.4	28.6	Plerion
Cen X-3	29.6	38.27	X-Ray Binary
SN1006	41.0	23.6	SNR
Vela Jr	1.2	24.9	SNR
RXJ 1713	1.2	16.7	SNR

5. Conclusions

A strong signal has been detected from the Crab nebula during the first few months of operation of the first H.E.S.S. instrument. Preliminary work suggests that the spectral slope is consistent with measurements from other instruments, while the absolute flux normalization is the subject of further study. The second telescope of the H.E.S.S. system has been commissioned and stereo observations have commenced. Calibration and analysis of data taken in stereo mode will also be reported on in the talk accompanying this paper.

6. References

1. Hillas A. 1985, in Proc. 19nd I.C.R.C. (La Jolla), Vol. 3, p. 445.
2. Konopelko A. et al., These Proceedings.
3. Leroy N. et al., These Proceedings.
4. Lessard R. W. et al., 2001, Astroparticle Physics, 15, 1.
5. Punch M. 1991, in Proc. 22nd I.C.R.C. (Dublin), Vol. 1, p. 464.
6. Weekes T. C. et al. 1989, Astrophysical Journal, 342, 379 (1989).