Search for Cosmic Point Sources of High Energy Gamma Radiation above 40 TeV

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Abstract

The HEGRA scintillator array is a large-area ground-based air shower detector designed to observe cosmic ray particles of energy greater than 40 TeV. A search has been made for steady and periodic emission of ultra-high energy γ-rays from 25 galactic and 144 extragalactic potential sources. At a trigger rate of about 11 Hz more than 270 million air shower events were recorded from 1992 June until 1993 May. No statistically significant steady-state or periodic excess above the isotropic background has been found, and 90 % confidence-level upper flux limits are presented.

1 Introduction

Satellite experiments found many galactic and extragalactic γ-ray sources. With ground-based Cherenkov telescopes a few of them showed a significant long-term excess at energies up to some TeV. Above $\sim$ 15 TeV no steady-state excess from a point source has been observed. In this paper we report on a search for steady and also for periodic emission from potential sources using 270 million events, taken in the observation period between June 1992 and May 1993 with the HEGRA scintillation detector.

2 The HEGRA experiment

The HEGRA experiment is located on the Canarian island La Palma (28.76^{0}N, 17.89^{0}W) at 2200m altitude ($\equiv 790\frac{\mathrm{g}}{\mathrm{cm}^2}$ atmospheric depth). The scintillation detector started in 1988 with a 5x5 scintillator matrix and 12 additional counters in some distance from the matrix. The experiment has been extended several times by additional scintillation counters, wide-angle Cherenkov detectors (AIROBICC), Geiger towers and Cherenkov telescopes. In the observation period the scintillator matrix consisted of 167 counters of 1m^2 sensitive area each at a distance of 15 m. This matrix covers an area of $3.2 * 10^4\mathrm{m}^2$. Additional 52 scintillation counters increase the detector density in the center.

[1] for a complete author list, see V.Fonseca, this conference

At a trigger condition of ≥ 14 counter signals per shower coinciding within 150 nsec the event rate was 11 Hz. In the observation time 270 million air showers were recorded. This corresponds to a total on-time of ~ 6820 hours. The precise event time was provided by a Rubidium clock controlled by a GPS system. For further information refer to [1, 5].

3 The reconstruction procedure

For the analysis only information from the scintillator array was used. Several steps are necessary to derive the direction of the primary cosmic-ray particle and the shower parameters from the measured pulse heights and arrival times. First, the position of the shower core is determined by a modified weighting method. The center of gravity of the 24 counters surrounding the counter with the highest electron density is calculated. By fitting a cone to the relative arrival times of all counters the direction of primary particle is derived. This is done by a χ^2 minimisation with two different cones, one with a fixed slope of $0.14\frac{\mathrm{ns}}{\mathrm{m}}$ and a second with a variable slope. With knowledge of the shower axis the mean electron density in 20 concentric rings around the axis is calculated. By making a χ^2 fit to the NKG-function we get the lateral density distribution providing the shower size $\mathrm{N_e}$ and the age parameter s.

4 The angular resolution and energy threshold

We estimated the angular resolution via Monte Carlo simulations, by measuring the shadow of the Moon and the Sun, and by the so-called chessboard method (dividing the matrix into two independent sub-arrays). The resolution depends on the number of triggered counters and is $\sim 1.2^0$ in the case of ~ 14 triggered counters for all three methods. For events with ≥ 100 counters the resolution is $< 0.4^0$. The energy threshold is determined with Monte Carlo simulations. The trigger probability for simulated vertical showers of different given energies is estimated. The energy for 50% trigger probability is defined as energy threshold $\mathrm{E}_{50\%}$. It depends on the type of the primary cosmic particle. The values for the scintillator matrix with the increased detector density in the center are:

particle	photons	protons	iron
$\mathrm{E}_{50\%}$	35 TeV	40 TeV	98 TeV

5 Search for steady-state and periodic emission

We defined a circular area of 1.6 times the angular resolution as source region. Under this assumption 72% of the source events are inside this area. A

concentric ring from 2^0 to 5^0 around the source position defines the off-source region. The significance of an excess is calculated by the method proposed by Li and Ma [2].
When looking for pulsed emission with periods in the range of milliseconds it is necessary to apply a barycentric correction to the event time [3]. The ephemerides of a number of pulsed γ sources are well known from other energy ranges. We calculated in the Taylor approximation the phase of each event and produced a histogram of the whole period. This phasogram is a rough estimate of the light curve but not sufficiently significant to verify a periodic emission. Therefor we tested the phases with a generalized circular Rayleigh statistics proposed by Buccheri [4].

6 Conclusion

For all analyzed astronomical objects no statistically significant steady or periodical excess above the isotropic background has been found. The determined upper flux limits for 25 galactic and 9 of the extragalactic sources are shown in Table 1, for further information see [1]. Compared with former measurements the energy threshold decreased due to the higher detector density in the center of the matrix.
The fluxes are in agreement with the results of other ground-based air shower scintillation detectors. Compared with them the HEGRA experiment has the advantage of additional detectors. By combining the scintillator information with data from the HEGRA wide-angle Cherenkov detectors and the Geiger towers an analysis of much better γ/hadron separation is provided. The corresponding combined analysis is under development, see other HEGRA proceedings for more information.

7 Acknowledgements

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References

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Source	N_{Source}	N_{Back}	Sigma	$S_{lim,90\%}$	Φ_{lim} x 10^{-13} $[cm^{-2}s^{-1}]$	E_{th} [TeV]
			galactic sources			
Cygnus-X3	69651	69605.3	0.17	642.5	3.6	50
Cygnus-X1	76638	76179.0	1.59	987.5	5.0	48
Hercules-X1	76510	75951.1	1.94	1075.4	5.5	48
Crab-Nebula	69631	69987.7	−1.29	435.6	2.4	49
Geminga	60184	59971.7	0.83	716.2	4.4	51
AM-Her	48276	48185.3	0.40	569.7	3.6	59
AE-Aqr	15864	15632.2	1.77	468.9	5.3	82
V404-Cyg	77384	77100.8	0.97	845.0	4.0	48
SS-Cyg	64976	65003.3	−0.10	576.5	3.2	51
SS433	26588	26501.3	0.51	436.1	4.0	69
4U0115+63	15800	15915.6	−0.88	231.0	2.8	81
1E2259+586	25612	25843.5	−1.38	258.5	2.1	72
PSR-1855+09	36413	37101.8	−3.43	195.6	1.4	62
PSR-1937+21	65385	65179.4	0.77	734.7	4.2	50
PSR-1953+29	75852	76121.1	−0.93	498.4	2.3	47
PSR-1957+20	63700	63566.0	0.51	675.1	3.3	51
2CG-028+15	21305	21153.9	0.99	445.1	4.6	75
2CG-034+00	18931	18894.9	0.25	342.9	3.4	78
2CG-054+03	60871	60864.7	0.03	577.8	2.9	51
2CG-070+06	76062	75940.7	0.42	720.3	3.7	48
2CG-076+00	74709	74378.3	1.16	872.1	4.2	49
2CG-078+02	70519	70554.3	−0.13	596.6	3.3	50
2CG-082+03	61538	61791.5	−0.98	443.9	2.6	53
2CG-135+01	19884	20060.9	−1.20	238.6	2.4	77
2CG-139+00	28485	28668.9	−1.04	297.2	2.3	71
			extragalactic sources			
3C273	21229	21461.0	−1.52	227.5	2.41	72.8
3C279	9222	9272.5	−0.50	195.0	3.28	90.4
Mrk421	76029	75763.4	0.92	825.7	4.27	48.0
Mrk501	70716	70985.7	−0.97	476.8	2.29	49.6
Mrk1505	72123	71443.3	2.43	1168.8	6.70	49.3
Mrk1506	29005	28788.6	1.22	551.5	4.33	66.8
QSO-2200+420	68003	67799.8	0.75	744.5	4.29	49.8
3C454.3	53170	53408.0	−0.99	411.6	2.43	53.3
PKS0235+164	56189	56263.1	−0.30	508.2	2.93	52.3

Table 1: Results for the selected sample of 25 galactic and 9 extragalactic sources. The events fulfil the following criteria: number of counters with information ≥ 12, distance core to edge of matrix ≥ 2 m and a shower size $\log N_e \geq 4.0$.