Preliminary Results on the Flux of TeV γ-rays from Crab System Obtained with the PACT at Pachmarhi

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Abstract

We have observed the Crab system (Nebula and Pulsar) and the corresponding background regions during many clear nights in the years 1999-2002 using the atmospheric Čerenkov array at Pachmarhi, PACT. Preliminary results indicate a steady emission of TeV γ-rays from the Crab Nebula.

1. Introduction

The Crab nebula is one of the most comprehensively studied galactic objects at TeV energies. In this inverse Compton scattering of relativistic electrons on the ambient radiation fields results in the $\gamma-$ ray production at energies above 100 GeV [1]. The Whipple collaboration has established Crab Nebula as a standard VHE $\gamma-$ ray candle [2]. The differential energy spectrum of TeV $\gamma-$ rays from this source given by them is J = (3.2 $\pm$ 0.17 $\pm$ 0.6) $\times$ 10^{-7} $\times$ (E/1 TeV)$^{-2.49\pm0.06\pm0.04}$ m^{-2} s^{-1} TeV^{-1} and the integral flux at $>$ 1 TeV is $\sim$ (2.1 $\pm$ 0.2 $\pm$ 0.3) $\times$ 10^{-7} m^{-2} s^{-1} [3]. Many groups have successfully detected VHE signal from this object [4]. We have observed the Crab nebula using the Pachmarhi array of Čerenkov telescopes (PACT). In this paper we present the procedure and results of the data analysis.

2. Pachmarhi Array of Čerenkov Telescopes

The experiment at Pachmarhi (longitude: 78° 26′ E, latitude: 22° 28′N and altitude: 1075 m), is based on the wavefront sampling technique and employs an array of 25 telescopes. The set-up has been explained in detail elsewhere [5,6]. Each telescope, steerable independently, is mounted with 7 parabolic mirrors having fast PMTs at their focus. The pulses from 7 PMTs in a telescope are added linearly to form a telescope sum pulse called *royal sum*. The array has been divided into 4 sectors with 6 telescopes in each. A trigger is generated by a coincidence of any 4 of these 6 *royal sums* of a sector. The typical event rate is $\sim$ 2-5 Hz. For every event, information on the relative arrival times (TDC) and density

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(ADC) of Čerenkov photons are recorded for the 6 peripheral mirrors/PMTs of all telescope in each sector. The arrival direction of a shower is determined by measuring the relative arrival time of Čerenkov photon front at each telescopes and reconstructing the shower front assuming it to be a plane. The accuracy of timing measurement is ~ 1 ns. The angular resolution of PACT has been estimated to be $0^{\circ}.24$ using *Royal Sum* pulses and $\sim 2.4'$ using *individual PMT* information [7].

3. Observations on Crab Nebula

The Crab nebula has been observed for a total 95 hrs (52 runs) and about 50 hrs (31 runs) on several background regions, but with the same declination as Crab during November 1999 to January 2002. The background runs were taken either before or after the Crab run. Only those runs with good weather conditions are accepted. We are then left with 70 hrs of ON source data and 41 hrs of OFF source data which were subjected to further analysis. The data has been further sub-divided into 5 different sets, A to E, depending upon the offline trigger and the number of telescopes used in the analysis.

4. Data Analysis

The space angle is defined as the angle between the direction of arrival of the shower and the telescope axis. The space angle distributions of events from source and background were then compared over the same zenith angle range. Also a cut on the number of degrees of freedom (ndf) was imposed to ensure that both source and background have similar ndf distributions. Events with $\chi^2 > +2\ \sigma$ where σ is the standard deviation of the χ^2 distribution were rejected. Table 1 shows the offline trigger conditions. Since the trigger rates for source and background runs are often different, the two space angle distributions have to be normalised before one looks for any signal. The background distributions are normalised to the source distributions in the space angle region $> 3^{\circ}$. The background distribution is then subtracted from the source distribution. To check this method of analysis background runs are used as fake sources. The rate of excess events is shown in fig. 1 for 9 trials of fake sources. The mean excess rate is 0.06 ± 0.26, consistent with zero signal. The space angle distributions of events from Crab and background for one data set (D) are shown in the left panel of fig. 2 while the background subtracted distribution is shown in the right panel. Table 2 lists the results of the various sets of data.

We have looked for any variations in the excess event rate from the direction of Crab as a function of time, Julian Day (JD). The signal event rate for a given trigger is almost constant. The energy threshold and the integral collection radius have been estimated from simulations.

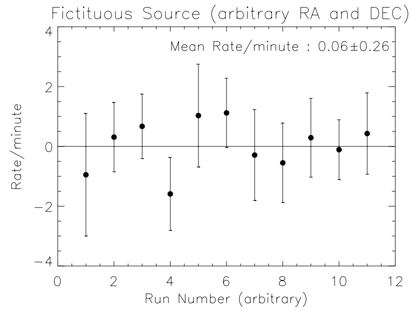

Fig. 1. Rate/min of Background runs on various nights

Table 1.

Data Period	Data set	Trigger
Nov 99-Feb 2000	Data set A	any 4 out of 6 Telescopes
Nov 99-Jan 2002	Data Set B	$\geq$ 8 out of 12 Telescopes
January 2001	Data Set C	18 Telescopes
Nov 99-Jan 2002	Data Set D	$\geq$ 1 PMT in each telescope
Nov 99-Jan 2002	Data Set E	$\geq$ 18 PMTs in a sector

5. Conclusions

The Crab nebula has been observed at a high confidence level with the Pachmarhi Array of Čerenkov Telescopes. The best fit to the slope of the energy spectrum is found to be -1.45 ± 0.15. However, the flux values are slightly higher than those obtained by others. The integral energy spectrum of VHE γ-rays from Crab nebula is shown in fig. 3 along with other results. Parameters like the timing jitter and lateral density distributions etc. are being evolved to reject the background events and to refine the flux and energy spectrum.

Table 2. Results on Crab nebula for Various Data Sets

Data	Duration (min)	γ-ray rate/min	E_{th} (GeV)	A_γ (m^2)	Flux$\times 10^{-11}$ $ph\ cm^{-2}\ s^{-1}$
Data A	1092.1	3.23±0.66	800 ± 100	61575.2	8.74 ± 2.00
Data B	1715.7	3.45±0.36	1100 ± 100	77437.1	7.43 ± 1.07
Data C	80.2	2.03±1.48	1300 ± 100	63347.1	5.34 ± 3.42
Data D	1817.0	1.44±0.22	1700 ± 150	70685.8	3.39 ± 0.62
Data E	1817.0	0.73±0.17	2500 ± 200	63347.1	1.95 ± 0.50

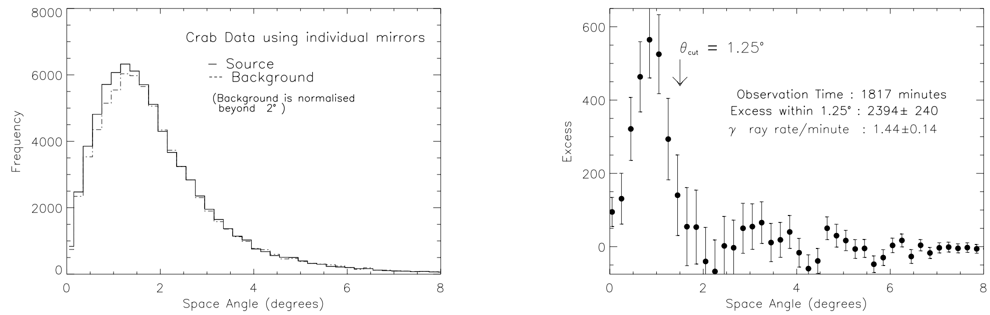

Fig. 2. *Left panel*: Space angle distributions of events from Crab for Data Set D. The solid line refers to source and dotted broken line refers to the background *Right panel*: Excess Events from Crab (Data Set D) as a function of space angle.

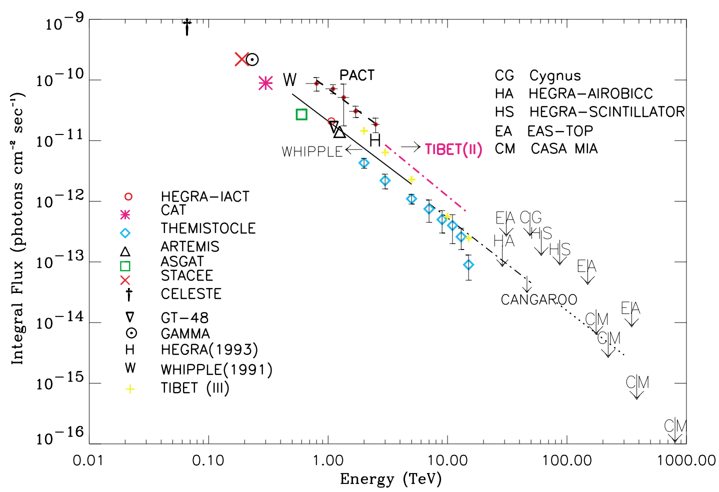

Fig. 3. Integral Spectrum of Crab Nebula

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