Preliminary Results on Crab from Pachmarhi Array of Čerenkov Telescopes

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Plan of Talk

1. Introduction
2. Pachmarhi Array of Čerenkov Telescopes
3. System Parameters of PACT
4. Observations on Crab Nebula
5. Data Analysis and Results
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Introduction

- Crab nebula has been the most intensively studied object in the field of Very High Energy (VHE) $\gamma-$ ray astronomy.
- Positive detections of signals from the Crab nebula have been made by the *imaging* arrays operating all around the world and few *non-imaging groups* also.

$$I\ (> 1\ \text{TeV}\ ) \sim (2.1 \pm 0.2 \pm 0.3) \times 10^{-7}\ \text{m}^{-2}\ \text{s}^{-1}$$

given by Whipple Group (Hillas *et. al*, ApJ 503, 744, (1998))

- A new atmospheric Cerenkov array has been set up at Pachmarhi in Central India whose main aim is to exploit the *temporal* and *spatial* distributions of Čerenkov photons in distinguishing between gamma ray and hadron showers for increase of sensitivity of atmospheric Cerenkov telescopes.
- Such a distributed array of telescopes with very good angular resolution will be able to throw away a large fraction of *off-axis* showers and reduce cosmic ray background
- We present here preliminary results of data taken on Crab nebula over the period from October 1999 to January 2002.

Figure 1: Bird's Eye View of PACT

PACT Experiment

- Pachmarhi Array of Čerenkov Telescopes (PACT) consists of 5×5 array of 25 telescopes spread over a rectangular area of 80 m $\times$ 100 m .
- The array is divided into 4 sectors with 6 telescopes in each
- Each telescope consists of seven parabolic mirrors of diameter 0.9 m and f/d $\sim$ 1 (A total of 175 mirrors)
- Total reflector area per telescope $\sim 4.45m^2$
- Each mirror is looked at by a fast phototube (EMI 9807B) behind a 3° circular mask
- High Voltage to PMTs fed through CAEN HV Controller and controlled by a computer
- The pulses from 7 PMTs are added linearly to form a telescope pulse called *'royal sum'* pulse.
- A four fold coincidence of these 'royal sum' pulses generates the event trigger for a sector
- Event trigger rate for a sector is $\sim$ 2-5 Hz
- For each event TDC(timing) and ADC(density) information of 6 peripheral mirrors in each telescope are recorded. Relative arrival times of telescope trigger pulses and information on triggered telescopes are recorded in central control room along with other housekeeping information

Latitude	$22^\circ\ 28'$ N
Longitude	$76^\circ\ 26'$ E
Altitude	1075 mts
Telescopes	25(7 mirrors in each telescope)
Mirrors	175, f/d $\sim$ 1
Reflector Area per telescope	$\sim 4.45m^2$
Trigger Logic	4/6 Telescope majority logic in a sector
Timing Resolution	1.0 *ns*
Angular Resolution (Majumdar *et al*, to appear in Astroparticle Physics)	$0^\circ.24$ for Royal Sum pulses $2.4'$ for individual mirrors
Energy Threshold	$\sim$ 850 GeV for γ
Collection Area	$\sim 10^5$ m^2
Expected Sensitivity @ 1 TeV for 50 hrs and 5σ	$\sim 4.1 \times 10^{-12}$ cm^{-2} s^{-1}

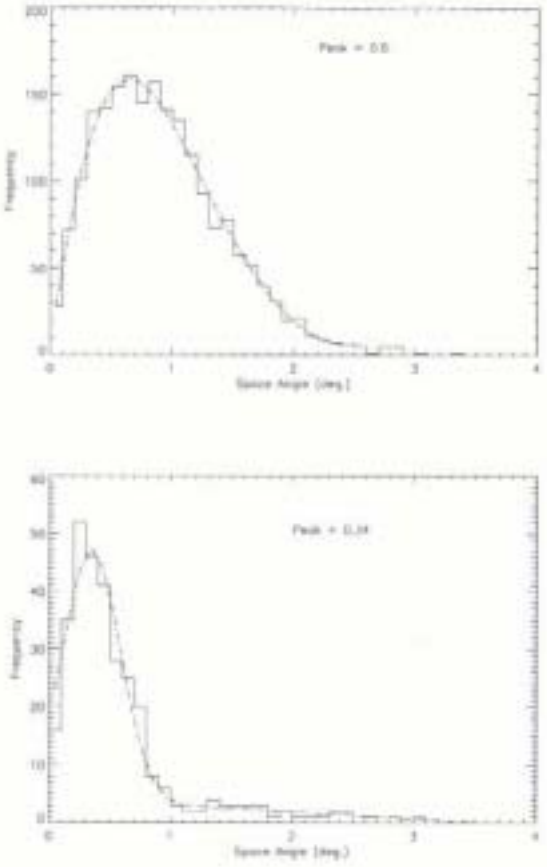
Angular Accuracy of PACT

- The angular resolution or the error in the estimation of direction is given by

$$\delta\theta = \frac{c\ \delta t}{D\cos\theta}\sqrt{\frac{2}{n}}$$

where θ is the zenith angle, D the distance between the telescopes, δt the uncertainity in the measurement of arrival time of photons at the telescopes and n the total number of telescopes.

- Estimation of *timing accuracy* done by taking TDC data in the vertical direction.
- Use *TDC difference distribution* to estimate timing resolution, δt =1.0ns .
- *Reconstruction* of arrival direction is done by approximating the shower front to a plane.
- *Angular Resolution* is estimated by *split array* method. Available telescopes are divided into two groups and two independent estimates on the arrival directions are obtained. The space angle between the two directions is a measure of angular resolution



gure 2: Angular Resolution of PACT using (a) *Royal Sum* pulses and (b) Individual Mirror Information

- Angular Resolution has been estimated to be $0^{\circ}.24$ using *Royal Sum* pulses and $\sim 2.4'$ using *individual mirror* information

Ref: Majumdar et.al. To appear in Astroparticle Physics
astro-ph/0204112

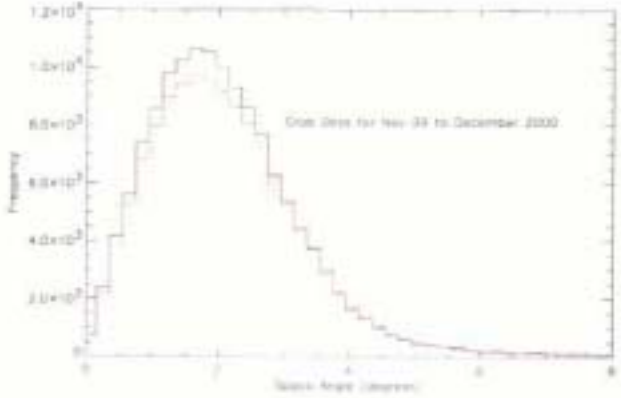
Observations on Crab Nebula

- Data Period November 99 to February 2000 (Data I), October to December 2000 (Data II), January 2001 (Data III) and October 2001 to January 2002 (Data IV)
- A total of 95 hrs (52 runs) of data taken on the source and about 50 hrs (31 runs) on the background regions
- After a preliminary health check-up, only runs during good weather conditions are accepted. Runs with technical problems concerning the telescopes and electronis were rejected. One is left with 70 hrs of ON source data and 41 hrs of OFF source data.
- In all 12 telescopes (in the southern half of the array) were used for analysis and 24 telescopes used for runs in January 2001
- Reconstruction of arrival direction(space angle difference between the events and the source direction) has been done using the TDC information of the *royal sum* pulses using a plane front approximation
- The angular distributions from source and background were then compared over the same zenith angle range

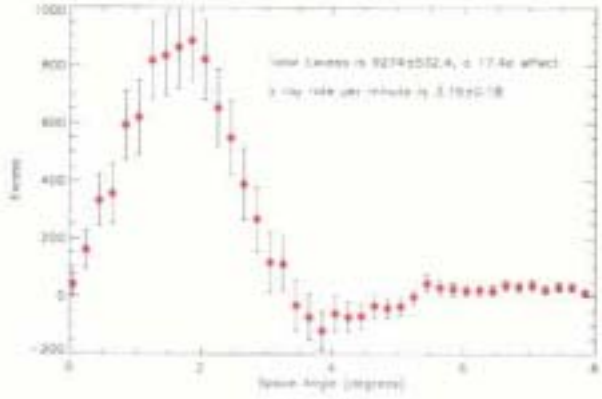
Table 1: Preliminary Data Set of Crab

Period	Region	Total Number of Events		
		Raw	ndf cut	χ^2 cut
Nov 99-Feb 2000	ON	98875	71208	53987
	OFF	103521	65546	46641
Oct 2000-Dec 2000	ON	165165	103203	92352
	OFF	103521	65546	46641
Oct 2001-Jan 2002	ON	112120	92575	87380
	OFF	142618	90940	82130

- A cut on the number of degrees of freedom(ndf) has been put such that the ratio of average ndf of source to background is same for different degrees of freedom
- Reject events with large χ^2 values while comparing the distributions
- *Normalisation* of distributions has been done using the number of events at > 3 degrees



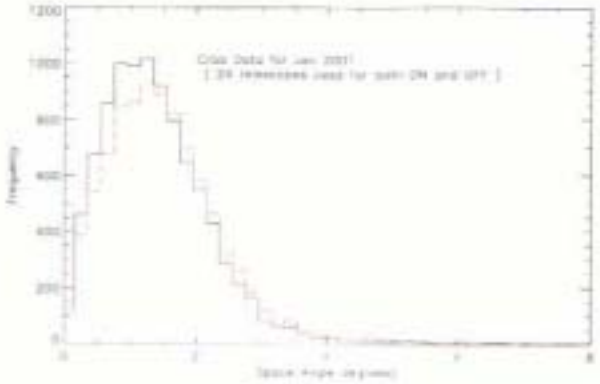
Angular Distributions for Crab for **Data I and II**
Solid Line refers to **Source** and **Dotted (Red)** Line refers to **Background**



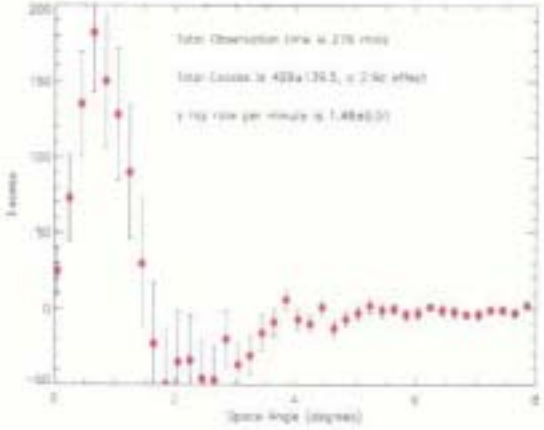
Excess Events from Crab

Table 1: **Results on Crab Nebula for Data I and II**

Data Period	ON	OFF	Duration (mins)	Excess	γ ray rate/min	σ
Data I	53987	50217	1011	3770±322	3.42±0.32	11.7
Data II	92352	86848	1924	5504±423.3	2.86±0.22	13.0



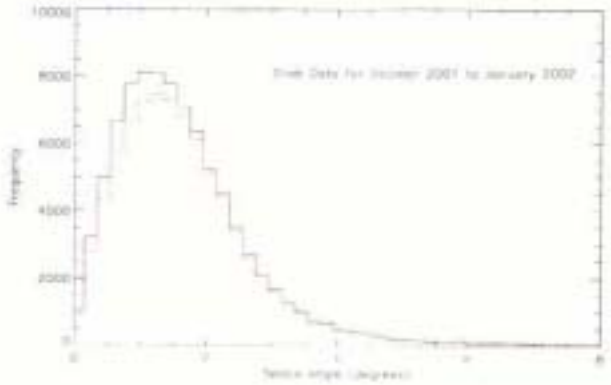
Angular Distributions for Crab for **January 2001**
Solid Line refers to **Source** and **Dotted (Red)** Line refers to **Background**



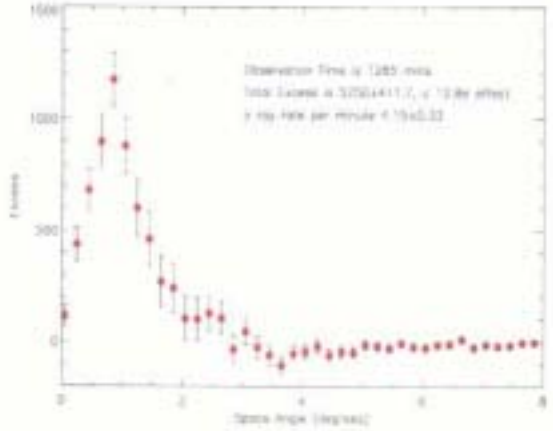
Excess Events from the direction of Crab

Table 3: **Results on Crab Nebula during Jan 2001**

Data Period	ON	OFF	Duration (mins)	Excess	γ ray rate/min	σ
Jan 2001	9934	9525	276	409±139.5	1.48±0.51	2.9



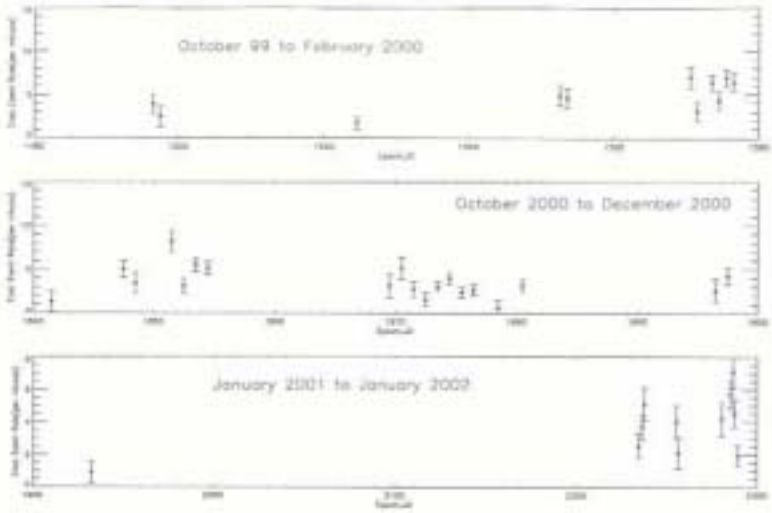
Angular Distributions for Crab for **Data IV**
Solid Line refers to **Source** and **Dotted (Red)** Line refers to **Background**



Excess Events from the direction of Crab

Table 2: **Results on Crab Nebula for Data IV**

Data Period	ON	OFF	Duration (mins)	Excess	γ ray rate/min	σ
Data IV	87380	82130	1265	5250±411.7	4.15±0.33	12.8



Excess from the direction of **Crab** in various seasons

Table 1: **Results on Crab Nebula in Different months**

Season	ON	OFF	Duration (mins)	Excess	γ ray rate/min	Sigma
Nov99	3152	2843	90.1	309±77.4	3.43±0.86	4.0
Dec99	1337	1209	71.5	128±50.5	1.79±0.71	2.5
Jan2000	16567	15536	220	1031±179.2	4.69±0.81	5.8
Feb2000	32184	29308	550	2876±248.0	5.23±0.45	11.6
Oct2000	13806	12280	474.4	1526±161.5	3.22±0.34	9.4
Nov2000	58249	54479	1410	3770±335.9	2.67±0.24	11.2
Dec2000	17910	17102	239.4	808±187.1	3.38±0.78	4.3
Jan2001	9934	9525	276	409±139.5	1.48±0.51	2.9
Nov2001	6481	5683	174	798±110.3	4.59±0.63	7.2
Dec2001	12655	12066	209	589±157.2	2.82±0.75	3.7
Jan2002	68244	64091	882	4153±363.8	4.71±0.41	11.4

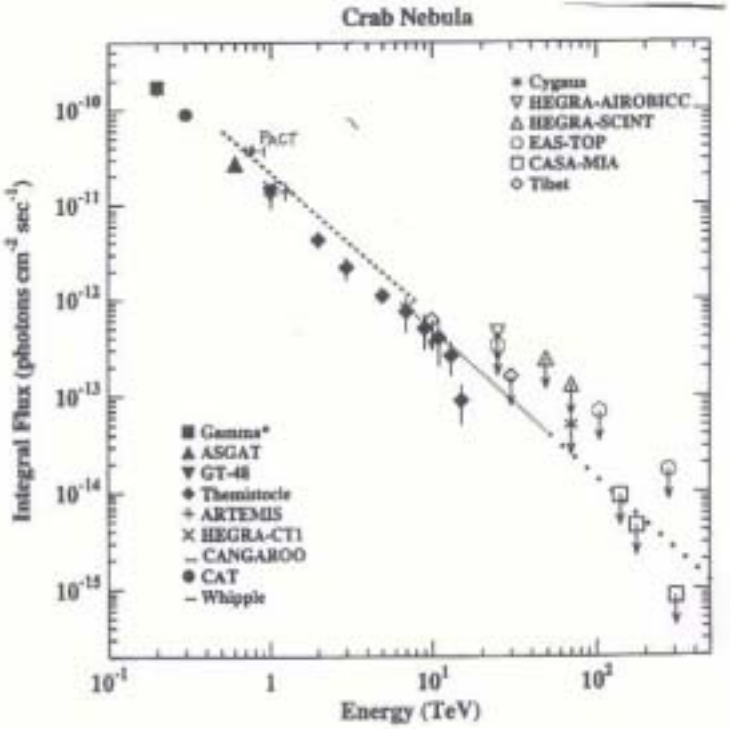
Adding up Runs in Various Seasons.....

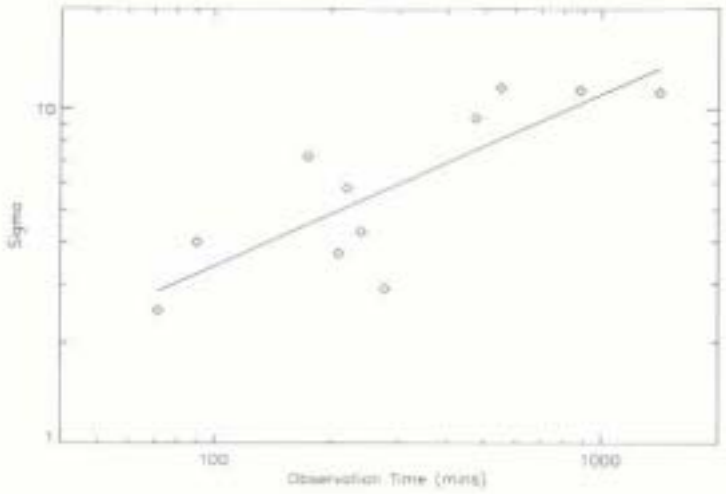
Total Excess amounts to 14933 ± 687.3

Excess Rate $\sim 3.34 \pm 0.15$ per minute

Integral Collection Radius (R) $\sim 220\ m$, one gets a flux

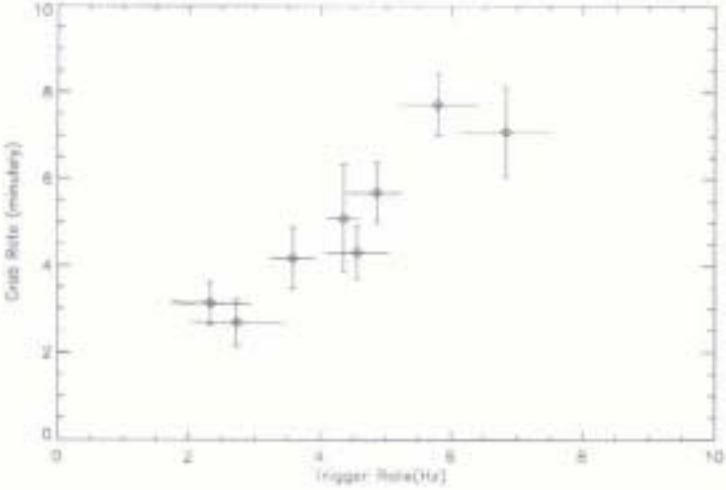
$$I\ (> 850\ \text{GeV}) \sim 3.67 \times 10^{-11}\ \text{cm}^{-2}s^{-1}$$





Sigma *vs* Observation Time (mins)

$$\sigma \propto T^{0.51 \pm 0.12}$$



Crab Rate as a function of Trigger Rate

Conclusions

- PACT commissioned in 1999 and since then taking data on various TeV sources
- Signal from Crab nebula has been established at a high significance level ($> 15\sigma$)
- Preliminary flux estimation is in good agreement with other experiments
- Analysis on other sources to get flux and spectrum in progress

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