

Status of CANGAROO-III
















Masaki Mori*

for the CANGAROO team

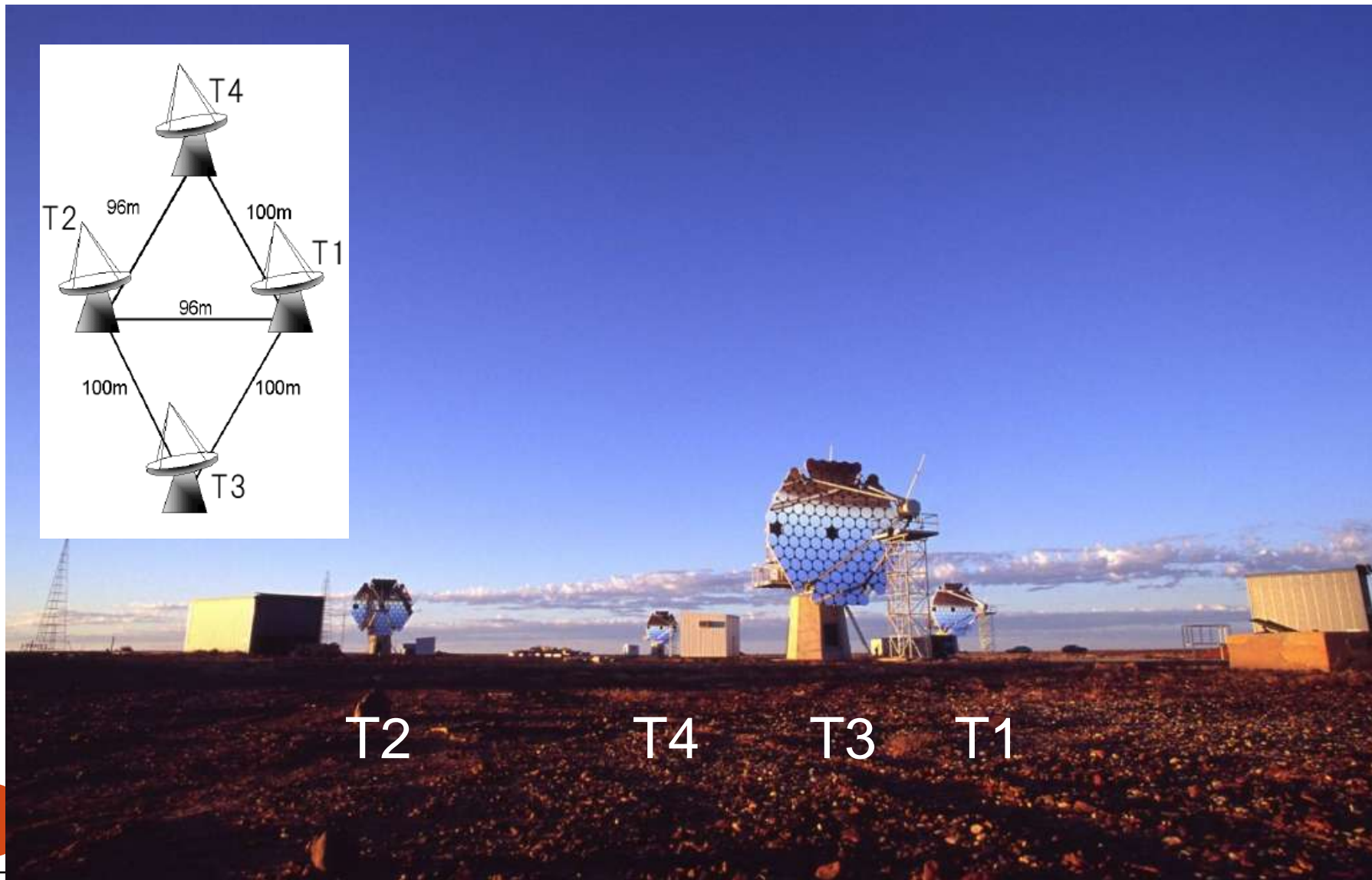
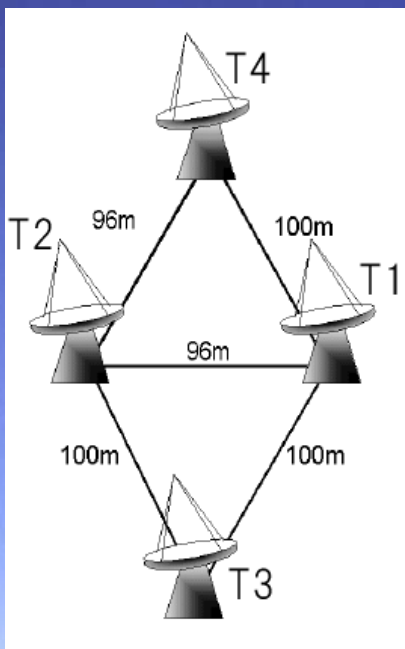
**ICRR, The University of Tokyo*



CANGAROO team

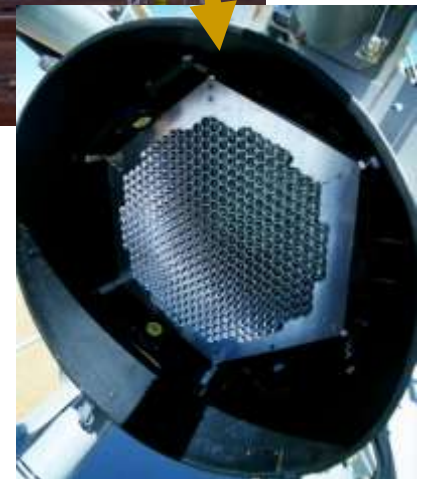
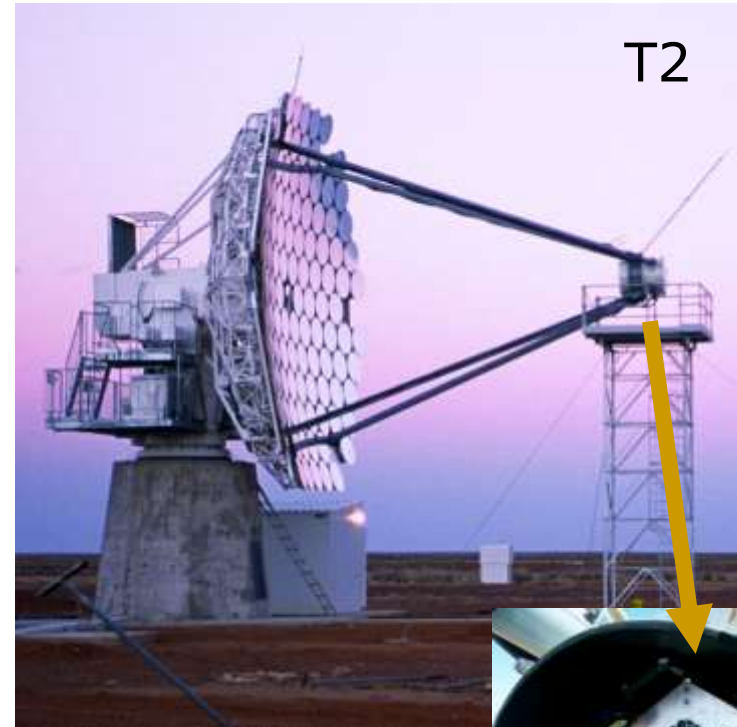
- University of Adelaide 
- Australian National University 
- Ibaraki University 
- Ibaraki Prefectural University 
- Konan University 
- Kyoto University 
- STE Lab, Nagoya University 
- National Astronomical Observatory of Japan 
- Kitasato University 
- Australia Telescope National Facility 
- Tokai University 
- ICRR, University of Tokyo 
- Yamagata University 
- Yamanashi Gakuin University 
- Hiroshima University 

CANGAROO-III: since 2004 March

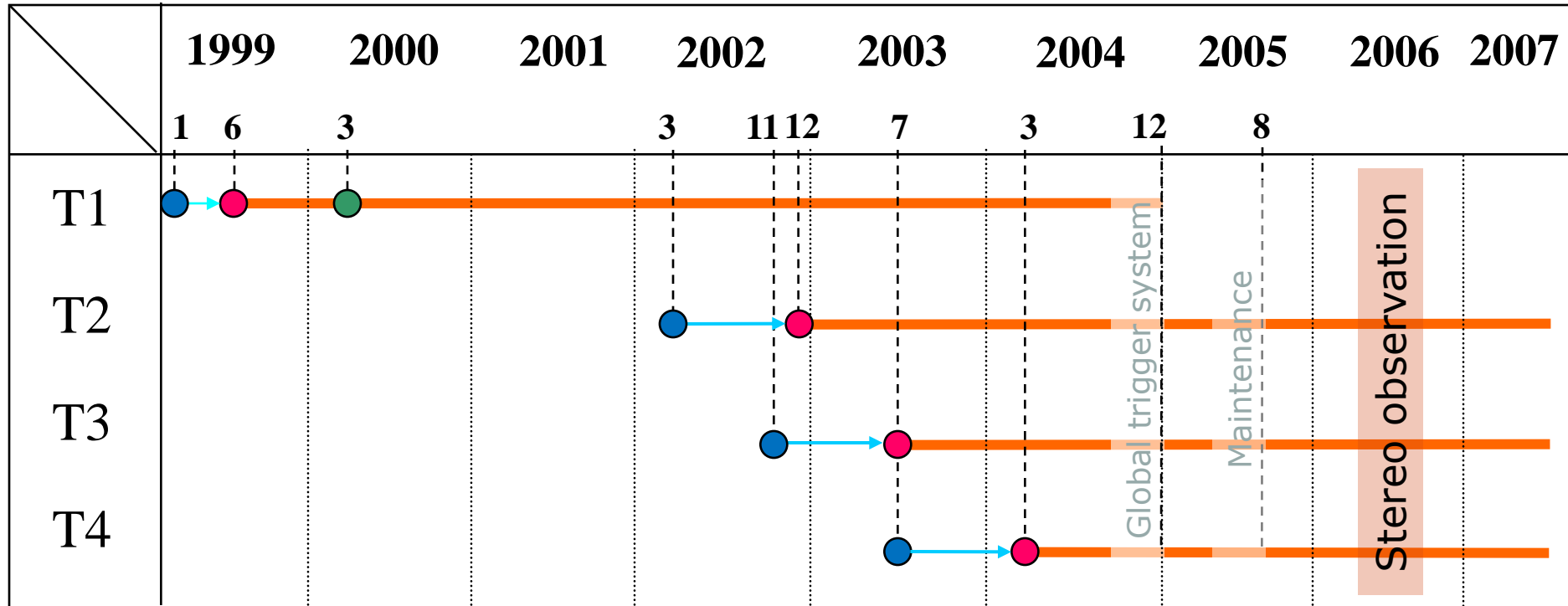


Basic specifications of telescopes

- Location:
 - $31^{\circ}06'S$, $136^{\circ}47'E$
 - 160m a.s.l.
- Telescope:
 - $114 \times 80\text{cm}\phi$ FRP mirrors (57m², Al surface)
 - 8m focal length
 - Alt-azimuth mount
- Camera:
 - T1: 552ch (2.7° FOV)
 - T2,T3,T4: 427ch (4° FOV)
- Electronics:
 - TDC+ADC



History of CANGAROO-III



- : Construction
- : Observation start
- : Expansion to 10m
- : Observation
- : Tuning

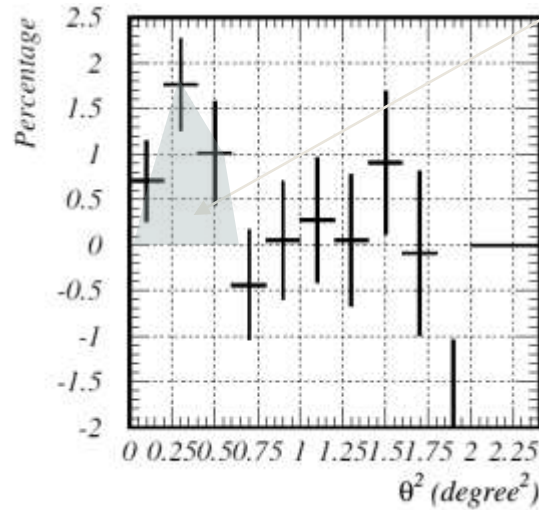
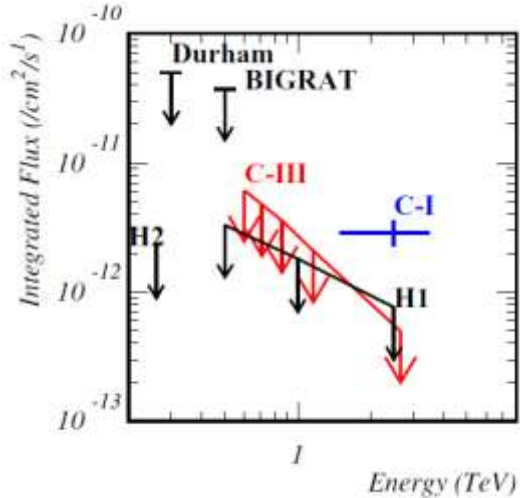
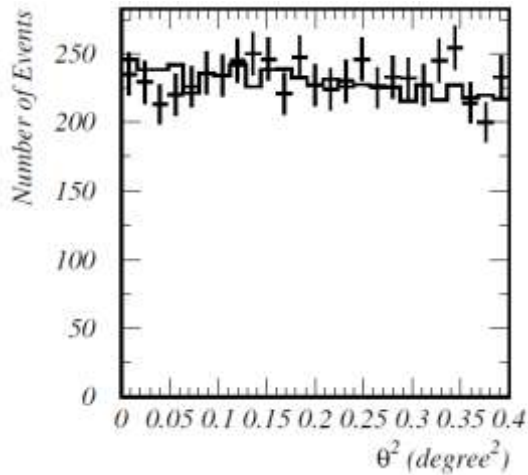
Gamma/hadron separation

- Square cut
 - Limit image moments (width, length) in gamma-ray domains
 - Ex. “Supercut” (Whipple group)
- Likelihood ratio
 - Probability density functions for image moment distributions
 - Gamma-rays: Monte Carlo, hadrons: background (off-source) data
 - Cut by certain Likelihood ratio $L \equiv \text{Prob}(\gamma) / [\text{Prob}(\gamma) + \text{Prob}(\text{bkgd})]$
- Fisher discriminant ← Now standard in CANGAROO-III
 - $F \equiv$ linear combination of image moments, with coefficients are uniquely determined by matrix inversion to maximize gamma/background separation
 - Free from selection bias

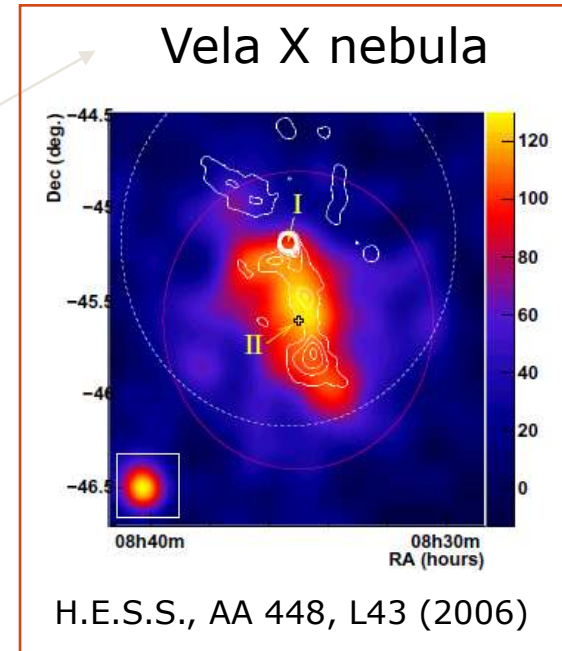
Vela pulsar/nebula

Pulsar position

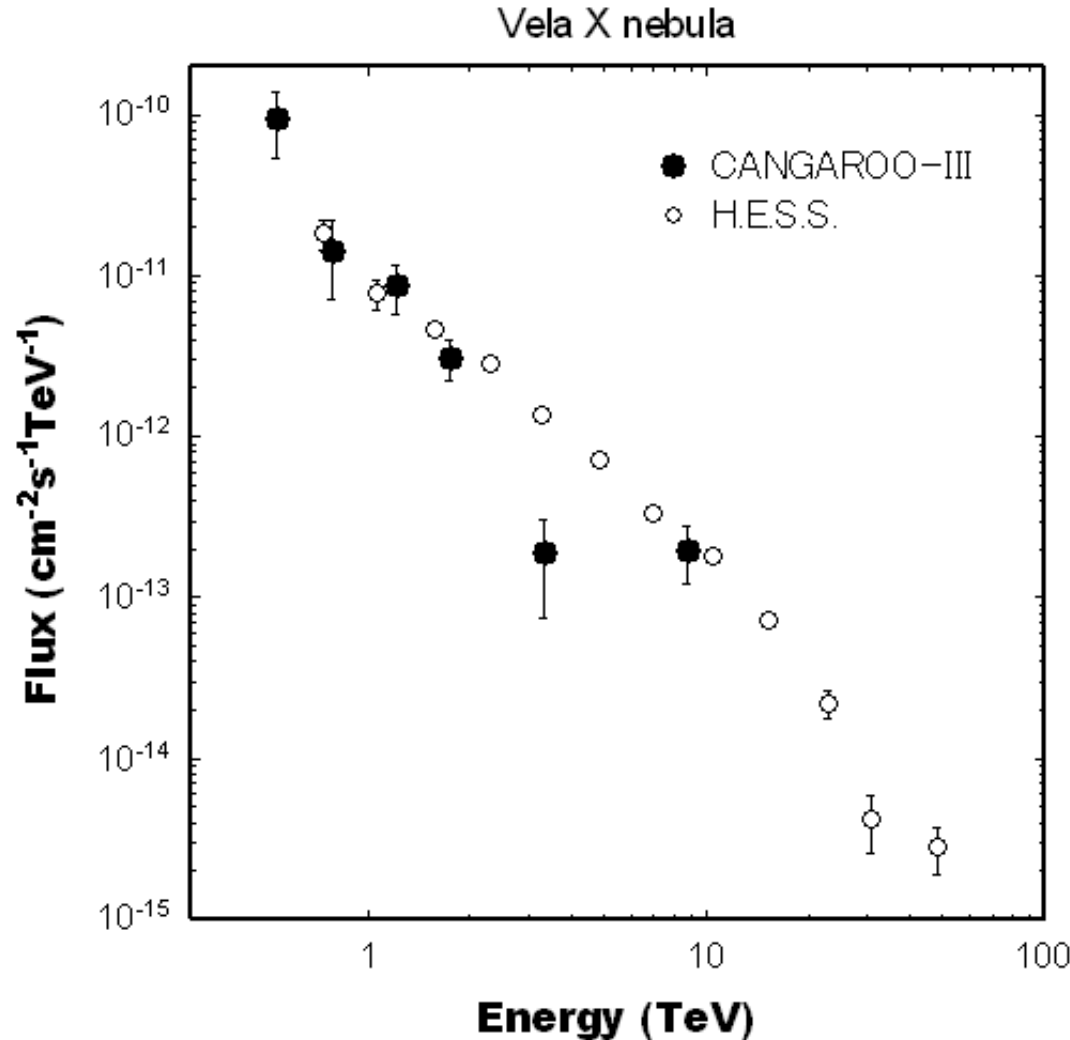
- Pulsar pointing (2004 Jan/Feb)
- Stereo (T2 & T3 wobble), 1,311 min.
- Fisher discriminant



θ^2 from Vela X center



Vela X nebula: spectrum



$\theta^2 < 0.6 \text{ deg}^2$

Excess 561 ± 114

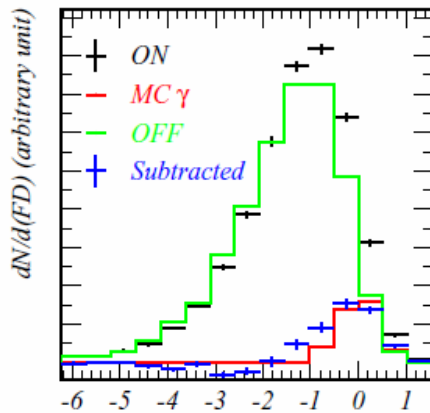
H.E.S.S.:

Aharonian et al.,

AA 448, L43 (2006)

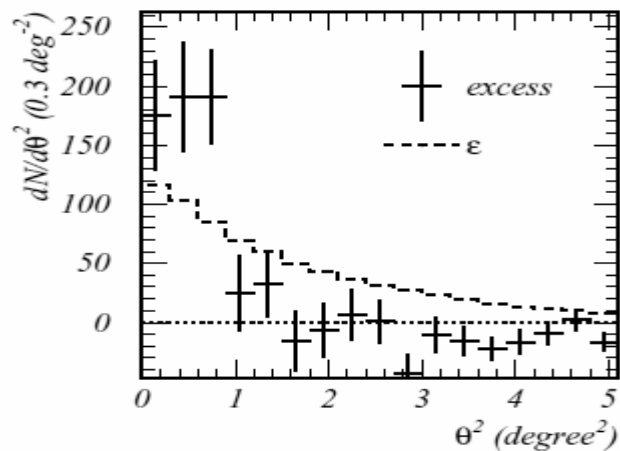
$\propto E^{-1.45} \exp(-E/13.8 \text{ TeV})$

SNR RX J0852.0-4622



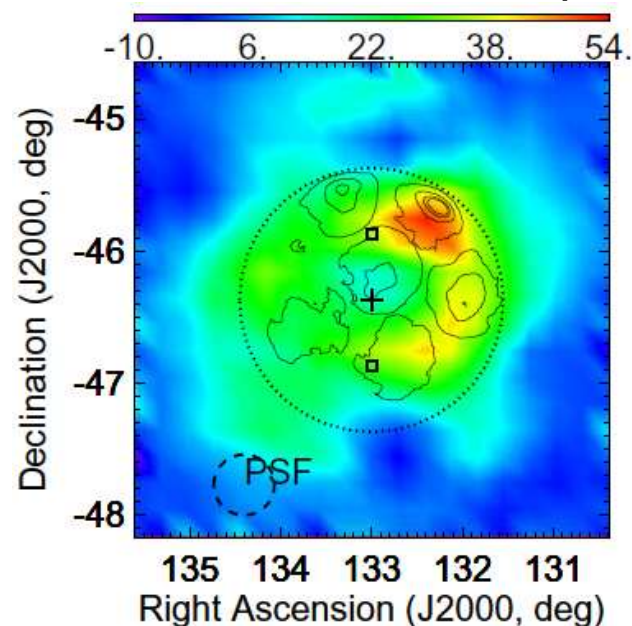
Fisher discriminant

- Distance ~ 1 kpc
(NANTEN: Moriguchi et al. ApJ 2005)
- Stereo (T2 & T3 & T4 wobble)
- 1,129 min. ON, 1,081 min OFF (2005 Jan/Feb)
- Independent analysis (ICRR, Kyoto)

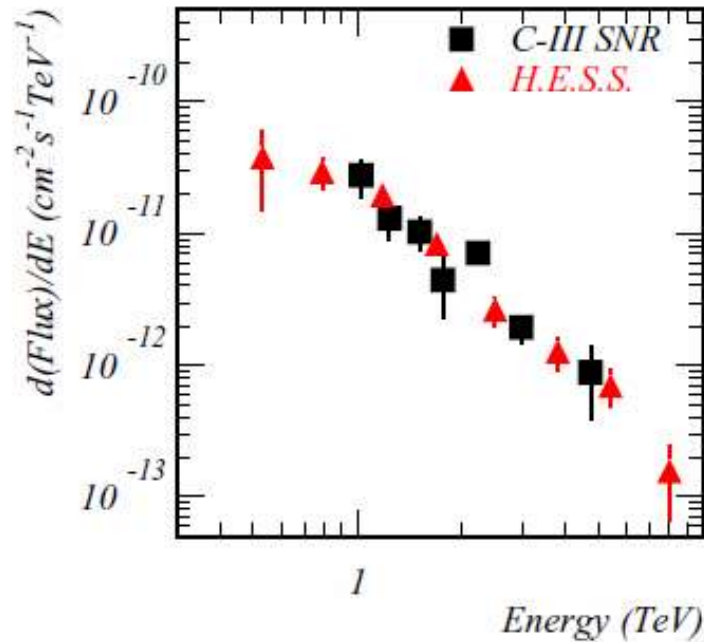


θ^2 from SNR center

Excess event map



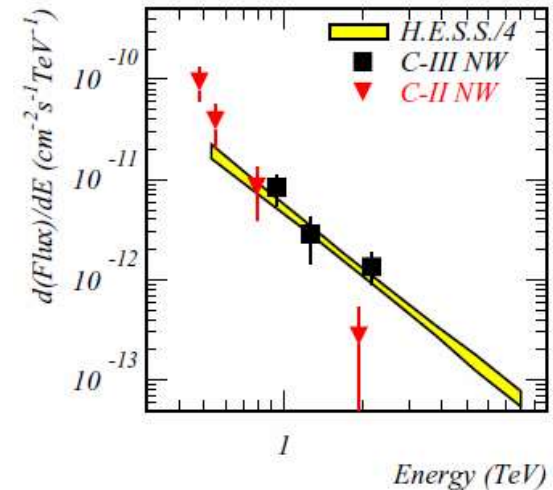
SNR RX J0852.0-4622: spectrum



$$\frac{dF}{dE} = [2.5 \pm 0.6(\text{stat.}) \pm 0.6(\text{sys.})] \times 10^{-11} \cdot \left(\frac{E}{1 \text{ TeV}}\right)^{2.2 \pm 0.3(\text{stat.}) \pm 0.3(\text{sys.})} [\text{cm}^{-2} \text{s}^{-1} \text{TeV}^{-1}]$$

FIG. 7.— Differential energy spectra; the red points by H.E.S.S. are for the whole remnant and the black points from these CANGAROO-III observations are also for the whole remnant. The error bars are statistical.

Comparison with C-II



Starburst galaxy NGC253

- 3-fold, 2004 Oct, 1179min (ON), 753min (OFF)

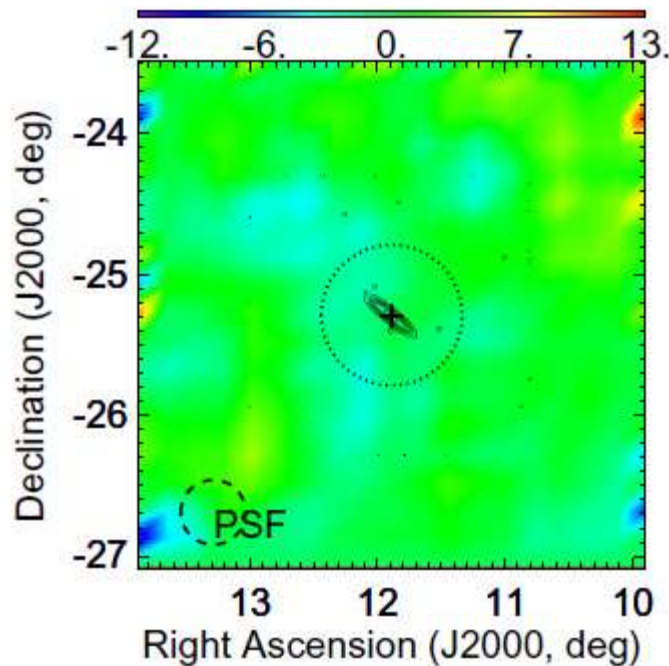


Fig. 3. Excess count map. The rainbow map is the excess count. The black contour is DSS2 (second version of Digital Sky Survey) data. The dotted circle is 0.5 degree radius. The point spread function is shown in left-below corner (the dashed line).

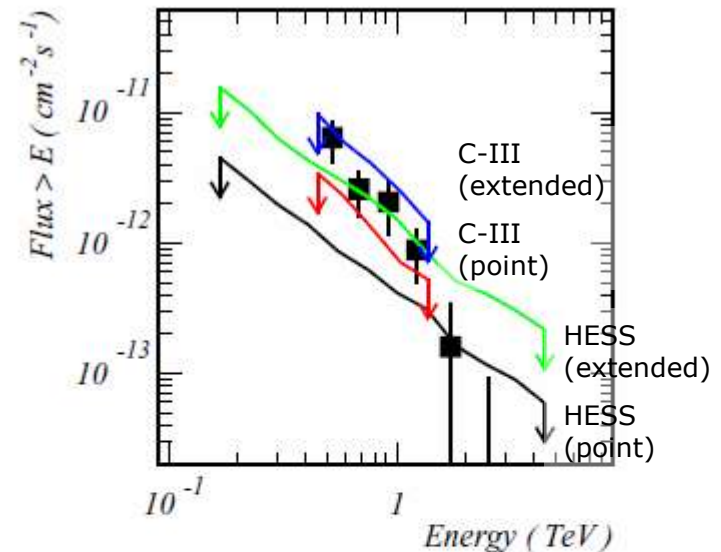
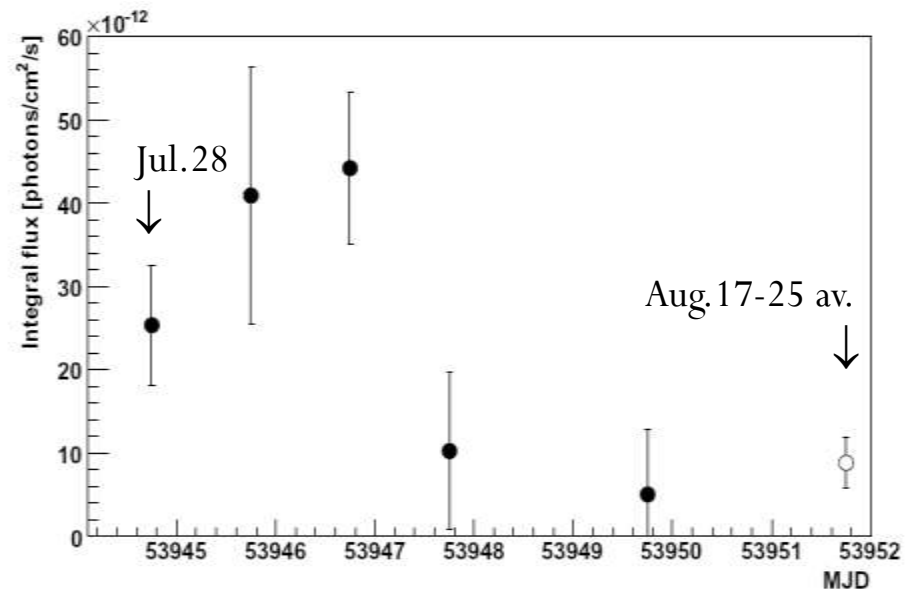
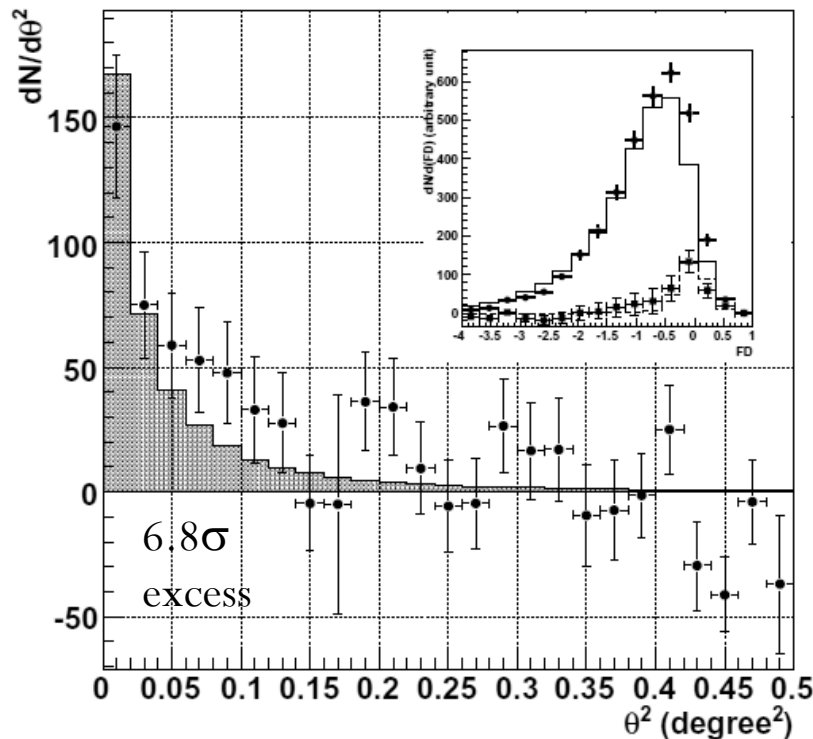


Fig. 4. Integral fluxes. The points with error bars are the CANGAROO-II's ones (see text for the detail). The black curve is 99% upper limit (UL) by H.E.S.S. for point source assumption. The green is that for 0.5 degree diffuse source. The red is 2σ UL for this observation for point source assumption and the blue for 0.5 degree diffuse.

Flare of Blazar PKS 2155-304

- Nearby high-frequency BL Lac ($z=0.117$)
- TeV flare report by H.E.S.S. in July-Aug 2006 (ATel#867)
- 1,053 min (wobble), 3-fold [8 hour difference in Time-zone!]
- Analyzed by independent teams (ICRR, Tokai, Kyoto)



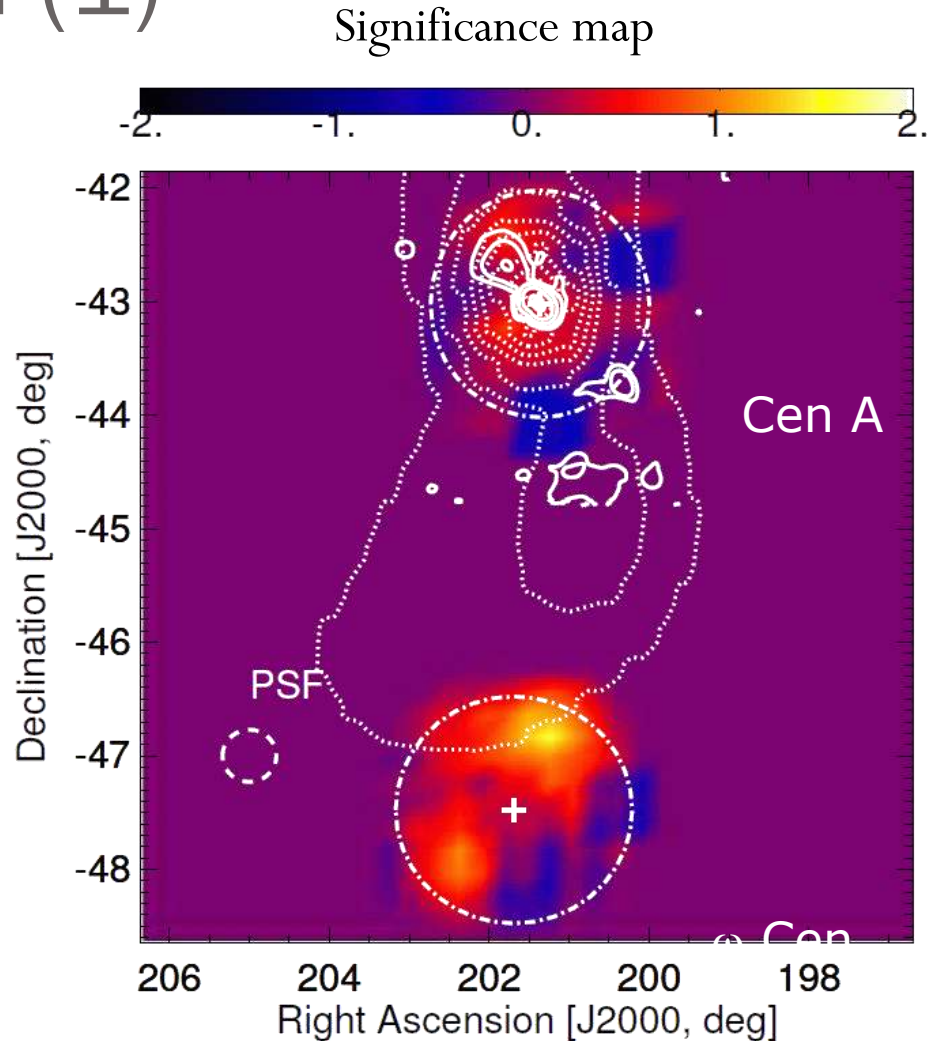
Cen A and ω Cen (1)

Cen A

- Radio galaxy, Fanaroff-Riley type I
- “Misaligned” BL Lac ($\sim 60^\circ$)
- Distance 3.5 Mpc ($z=0.00183$)
- Observations:
639min (ON), 587min (OFF)

ω Cen

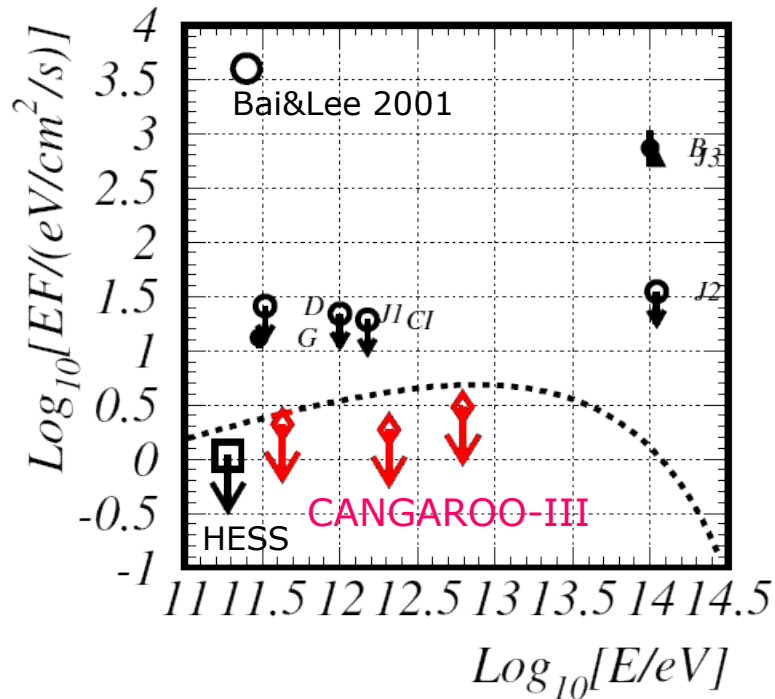
- Old, heavy globular cluster
- Many millisecond pulsars
- Distance 4.9 kpc
- Observations:
601min (ON), 429min (OFF)



Solid: 4850MHz radio (inner lobes and middle lobe)
Dotted: 408MHz radio (outer lobes)

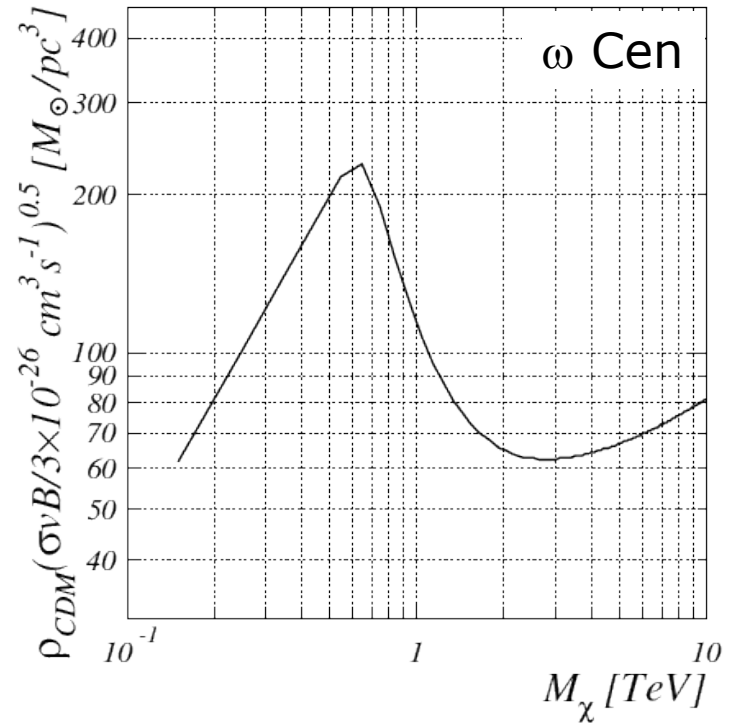
Cen A and ω Cen (2)

SED for the jet region of Cen A



Dotted: IC with 10^{54} erg, 100 TeV cutoff

Upper limits of the CDM density



CDM density $< 100 M_{\odot} \text{pc}^{-3}$: less than its gravitational mass!

Summary of TeV source status claimed by CANGAROO compared with H.E.S.S. results

Table 1: Summary of TeV source status claimed by CANGAROO compared with H.E.S.S. results.

Object	C-I	C-II	C-III	H.E.S.S.
Crab	Yes	Yes	Yes [2]	Yes
PSR 1706-44	Yes	†	U.L. [1]	U.L.
Vela pulsar	Yes (0.13° offset)	N/A	U.L. [2]	U.L.
Vela X	N/A	N/A	Yes [2]	Yes
SN1006	Yes	†	U.L. [1]	U.L.
RX J1713.7-3946	Yes	Yes	under analysis	Yes
PSR 1509-58	Yes	N/A	under analysis	Yes (MSH15-52)
Mrk 421	N/A	Yes	N/A	Yes
NGC 253	N/A	Yes	U.L.[4]	U.L.
Galactic center	N/A	Yes	under analysis	Yes
RX J0852.0-4622	N/A	Yes	Yes [3]	Yes

‘C-I’ means CANGAROO-I, etc. ‘Yes’: detection, ‘U.L.’: upper limit, ‘N/A’: not available. † means the result is not published yet.

[1] “Status of the CANGAROO-III Project”

T. Tanimori et al., 29th International Cosmic Ray Conference, Pune, India (August 3-10, 2005), published in Proceedings (Tata Institute of Fundamental Research, Mumbai, India, 2006) Vol.4, pp.215-218

[2] “A Search for sub-TeV Gamma-rays from the Vela Pulsar Region with CANGAROO-III”

Enomoto, R. et al., *Astrophys. J.*, 638, 397–408 (2006)

[3] “CANGAROO-III Observations of the supernova remnant RX J0852.0–4622”

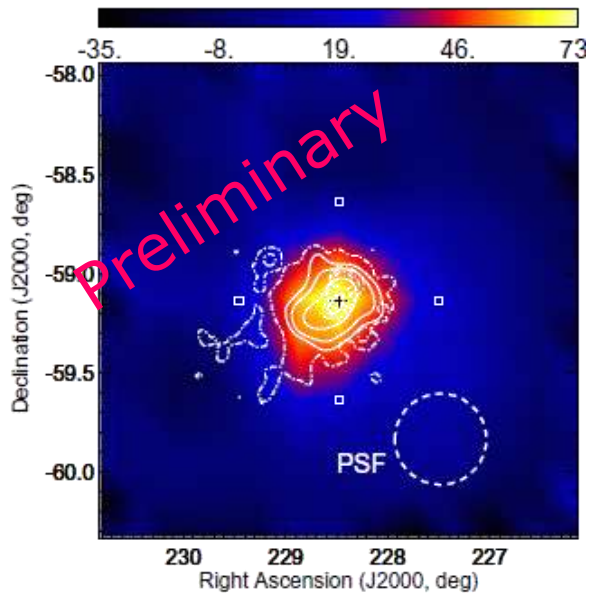
Enomoto, R. et al., *Astrophys. J.*, 652, 1268–1276 (2006)

[4] “Erratum: Detection of diffuse TeV gamma-ray emission from the nearby starburst galaxy NGC 253”

Itoh, C. et al., *Astron. Astrophys.*, 462, 67–71 (2007)

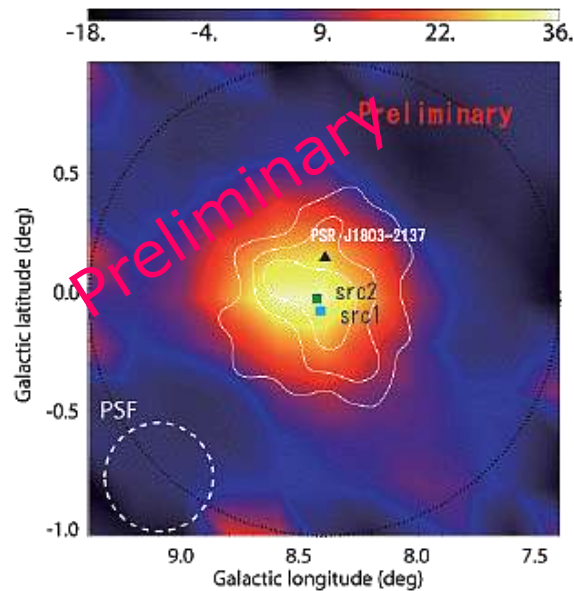
More detections are coming!

MSH15-52
Pulsar wind nebula



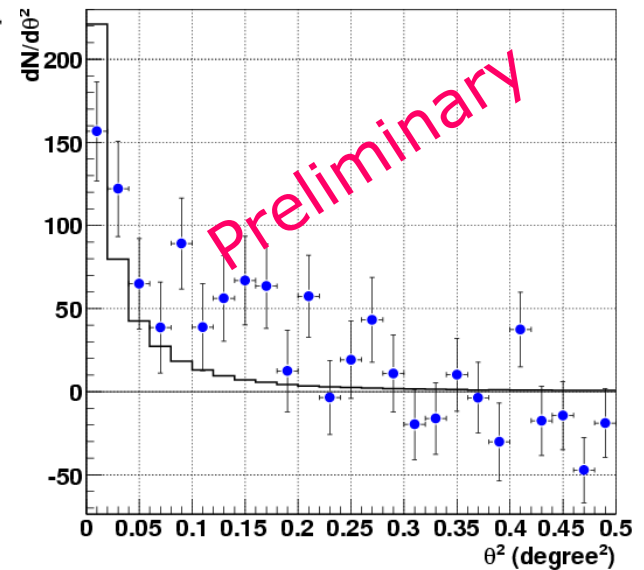
See: Nakamori et al., in this conference

HESS J1804-216
UnID



See: Higashi et al., in this conference

HESS J1303-631
UnID



See: Kushida et al., in this conference

Summary



- CANGAROO-III atmospheric Cherenkov telescope system is observing sub-TeV gamma-rays since 2004 March in stereoscopic mode.
- Observation of Vela pulsar showed no gamma-ray signal, but there is a hint of signal in the Vela X nebula.
- SNR RX J0852.0-4622 was detected as an extended source, and the morphology seems to follow the X-ray emission profile.
- Starburst galaxy NGC 253 was observed with CANGAROO-III but the signal reported by CANGAROO-II was not confirmed.
- A flaring activity of a blazar PKS 2155-304 was detected in July-August 2006 showing rapid time variation.
- Radio galaxy Cen A nor globular cluster ω Cen were not detected.
- Conflicts with H.E.S.S. results are mostly resolved. Analysis of stereo observations are now established, and application to other sources are underway.