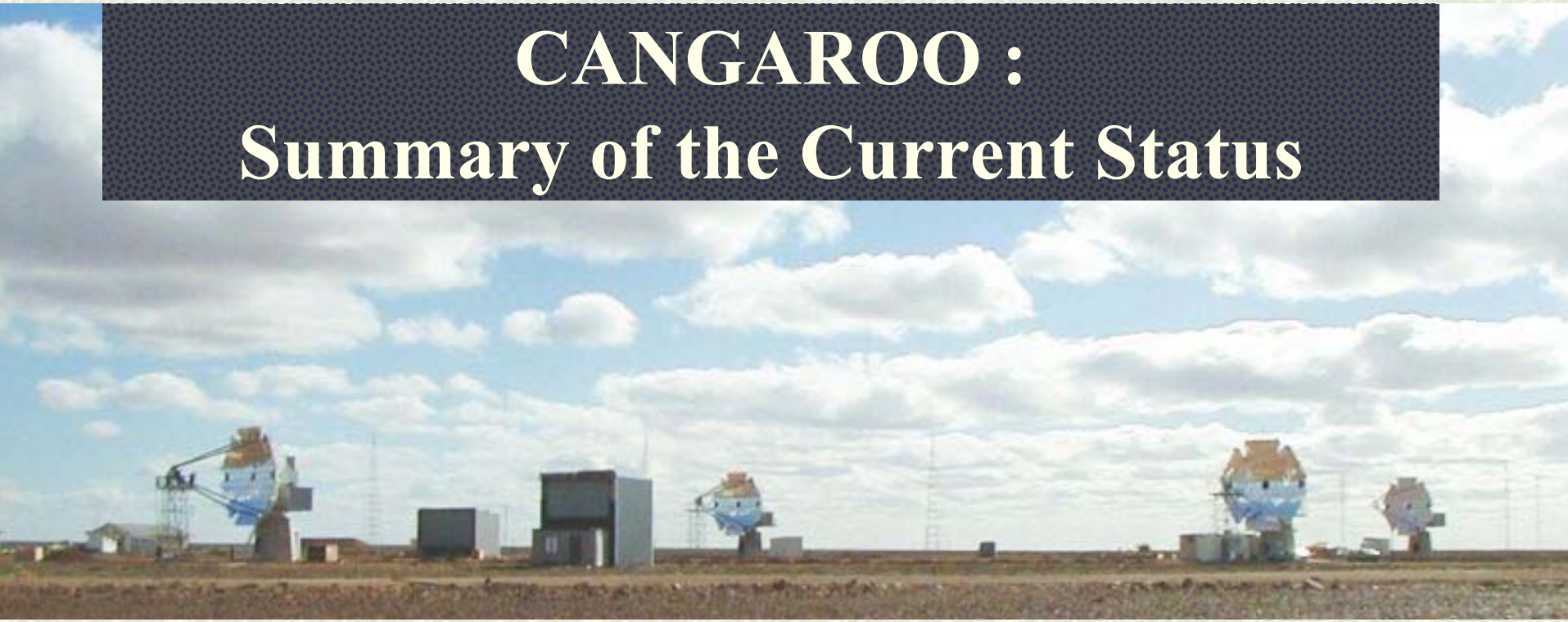
CANGAROO : Summary of the Current Status



Ken'ichi Tsuchiya

ICRR, University of Tokyo

"Towards Very High Energy Particle Astronomy 5" @ ICRR March 8 2005

From CANGAROO-II to CANGAROO-III

2000 ~ 2003 improvements and construction work
(Camera, Electronics, Mirror & Telescopes)

2004 March CANGAROO-III full install

2004 end of March ~ Full operation

Contents

- **CANGAROO-II Results**
  - **1-1. Publications**
  - **1-2. New source : SNR RXJ0852.0-4622**
  - **1-3. Galactic Center: inconsistency with HESS results**
- **CANGAROO-III Current status**
  - **2-1. Observations and analysis status**
  - **2-2. Calibration : muon analysis , mirror reflectivity**
    Night Sky Background
  - **2-3. Global trigger system and Wobble mode**
  - **2-4. Crab independent analysis : large zenith observations**

1-1. Publications (CANGAROO-II)

Published papers

- **Gamma-ray sources**

  SNR RXJ1713.7-3946 Enomoto et al. Nature (2002)

  AGN Mrk421 Okumura et al. ApJL (2002)

  Galaxy NGC253 Itoh et al. A&A (2003)

  Galactic Center Tsuchiya et al. ApJL (2004)

  SNR RXJ0852.0-4622 Katagiri et al. ApJL (2005) **New**

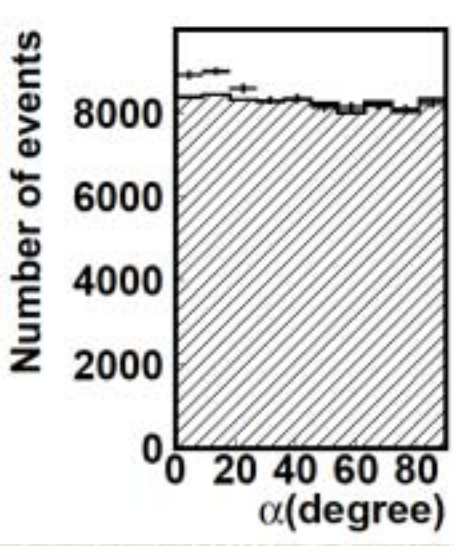
- **Upper limits**

  SNR SN1987A Enomoto et al. ApJL (2003)

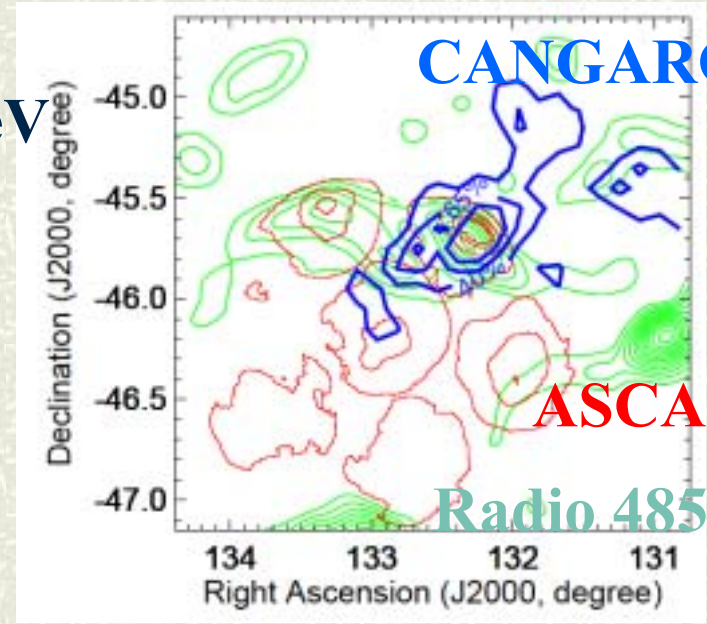
  Binary Pulsar PSR1259-63 Kawachi et al. ApJ (2004)

and many proceedings.

1-2. New Gamma-ray Source SNR RXJ0852.0-4622

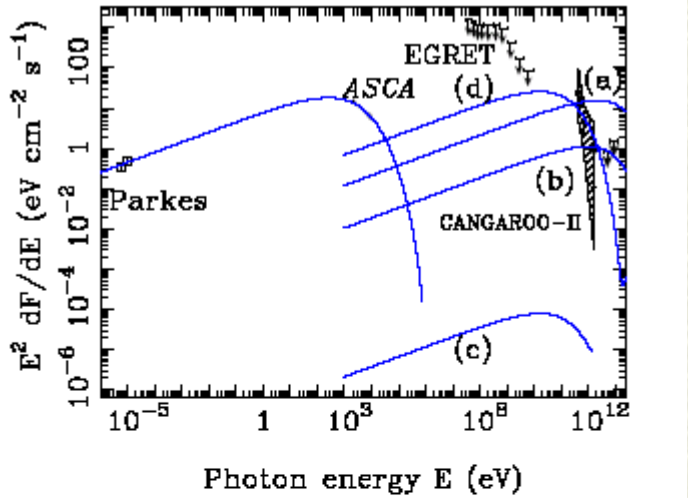


- RXJ0852.0-4622(G266.2-1.2) near Vela SNR
- Observations in 2002 and 2003 by CANGAROO-II
- Detection at the 6σ level
  in the energy region above 500GeV
- Signal center is consistent with
  the peak of X-ray emission
  in the north-west rim



Katagiri et al. (2005)

1-2. New Gamma-ray Source SNR RXJ0852.0-4622



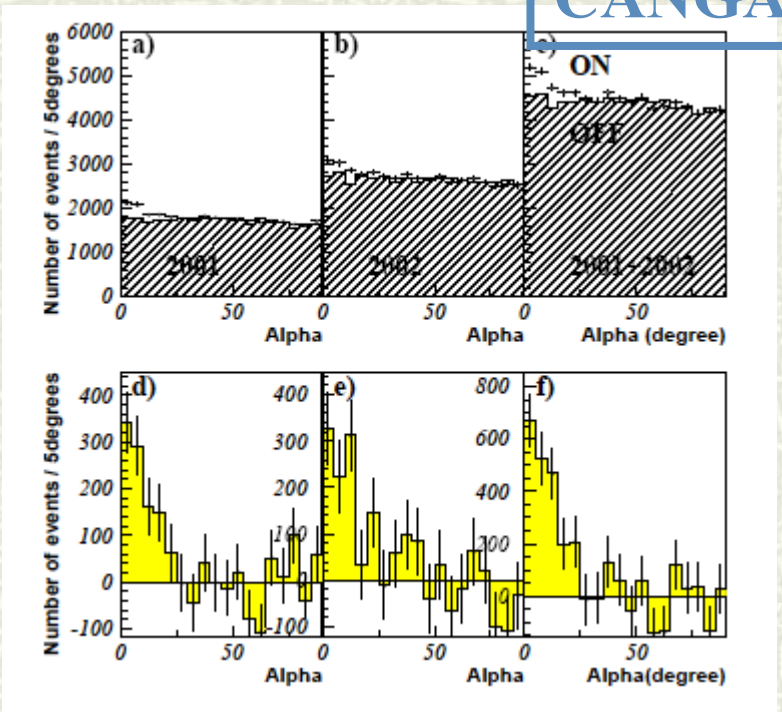
- **Electron origin**
  Synchrotron radiation (radio-X-ray)
  + Inverse Compton emission(TeV)
  (a)3uG (b)12uG (c)1.6mG
  difficult to explain it in 1 zone model.
  (d) Two zone model
  Too high size ratio 10^5

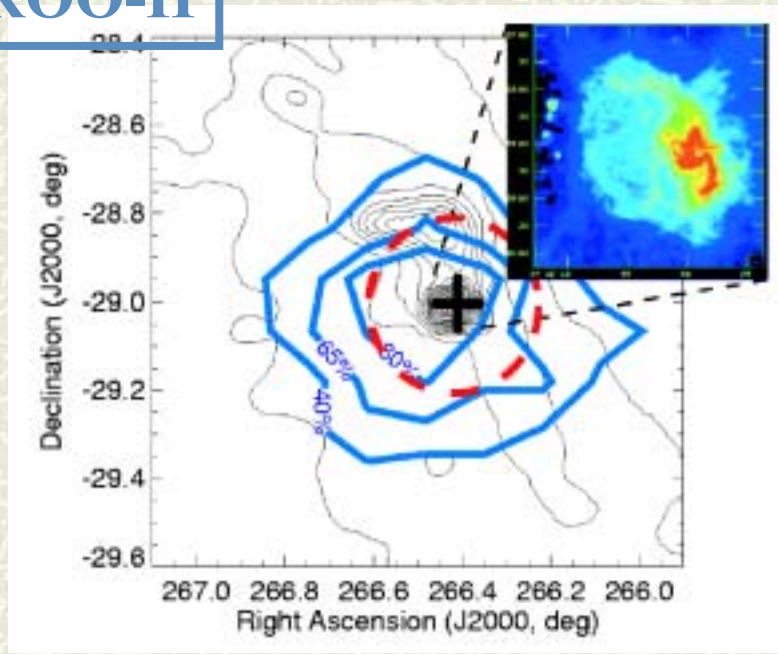
- **Proton origin**
  index=2.5 E_{max}=8TeV
  $E_{CR} = 10^{48}$ -10^{50}erg
  @target density n=230-23000/cm^3

Katagiri et al. (2005)

1-3. Galactic Center
First Detection of Gamma-rays

CANGAROO-II





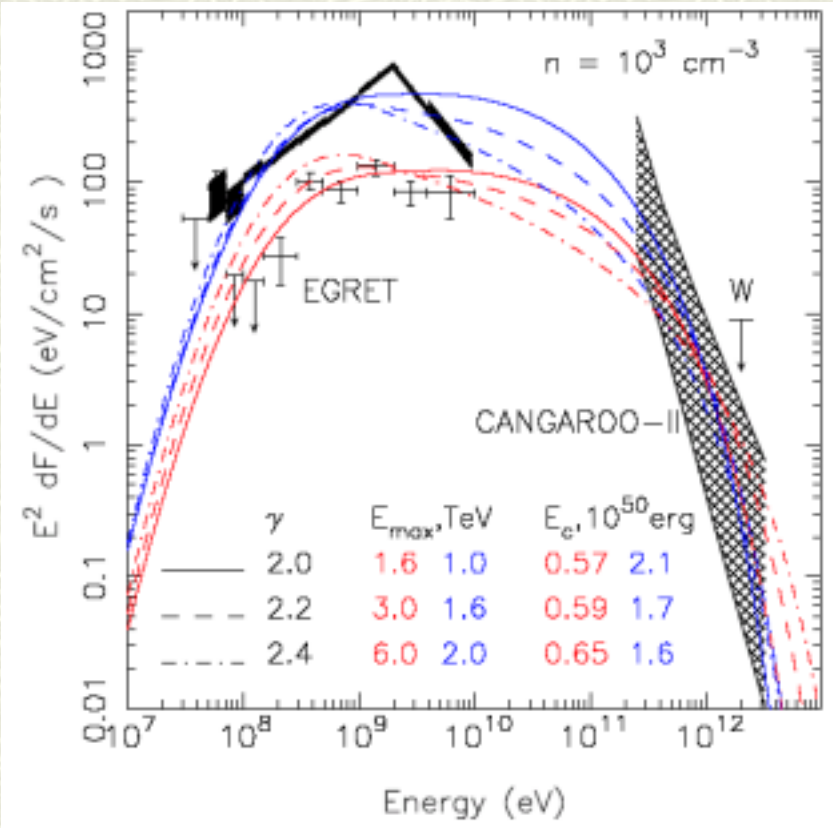
Point Spread Function (PSF) ~ 0.32° (index=-4.5)

α<15° / α< 30° ＝80.8%±6.7%　(MC：73.5%)

→ consistent with a point source

Tsuchiya et al. (2004)

Radiation Mechanism (1)
Proton acceleration



P+P→ π^0 →2 γ

target matter density

n = 10^3 cm^{-3}

CR power-law spectrum

index=2.0-2.4

CR maximum energy

E_{max} = 1.0 –3.0TeV

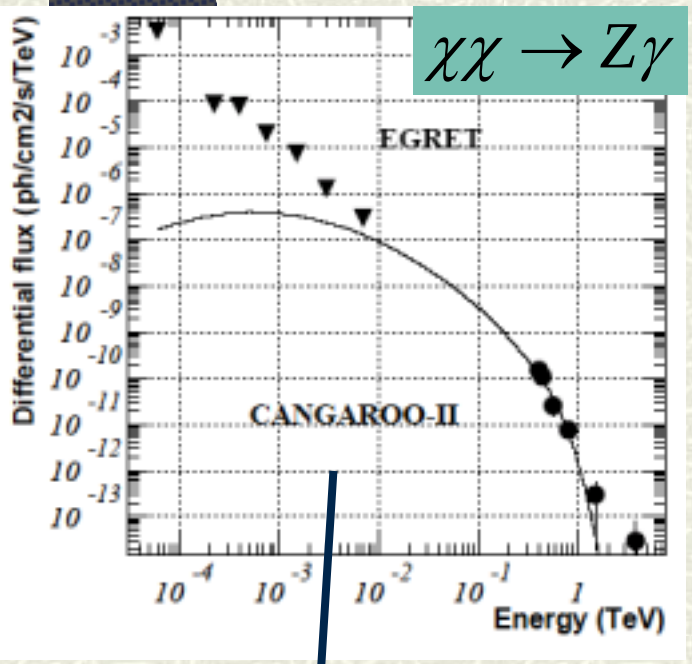
Total CR energy

0.6-2.1 10^{50}erg

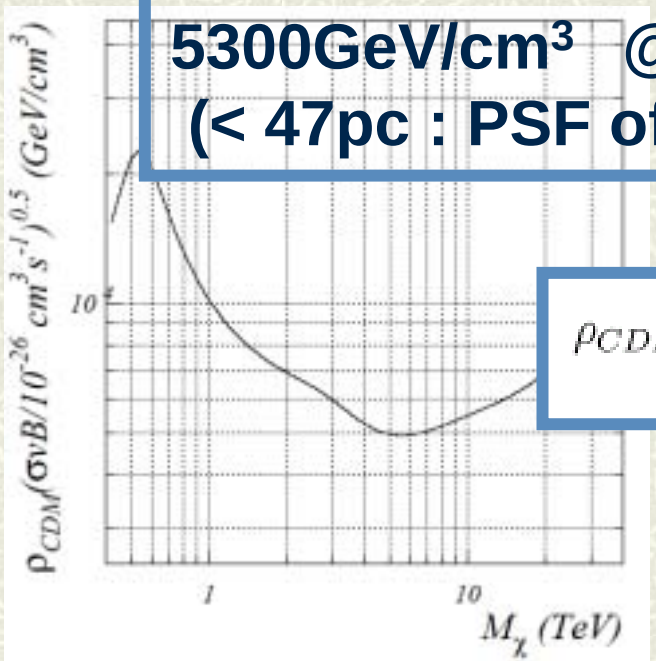
Tsuchiya et al. (2004)

Radiation Mechanism (2)
Cold Dark Matter

Tsuchiya et al. (2004)



$\chi\chi \rightarrow Z\gamma$



5300GeV/cm³ @ G.C.
(< 47pc : PSF of CANGAROO-II)

$$\rho_{CDM}(r) \propto \frac{\rho_0}{(\frac{r}{r_s})^{\alpha}(1+\frac{r}{r_s})^{3-\alpha}}$$

$$\frac{dF_\gamma}{dE_\gamma} \propto (\frac{\rho}{M_\chi})^2 <\sigma v>$$

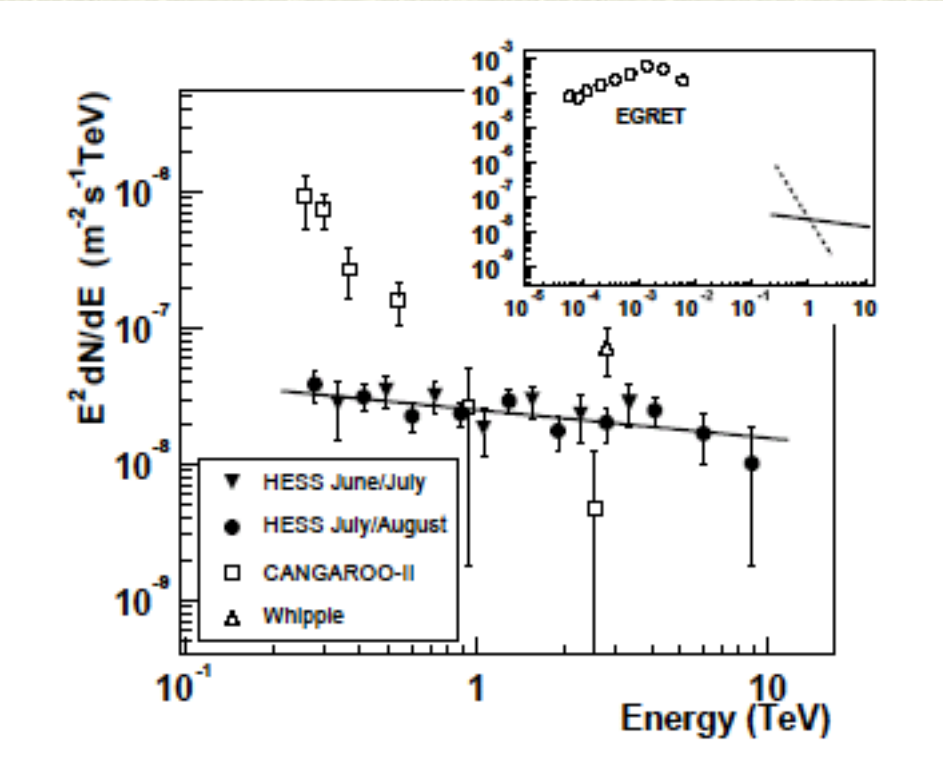
$$\Omega_{CDM} h^2 = 0.110 \pm 0.006$$

$$\Omega_{CDM} h^2 \approx \frac{3\times 10^{-27}}{<\sigma v>}$$

$$<\sigma v> \approx 10^{-26}\ cm^3/s$$

6GeV/cm³ around Sun (c.f. 0.3GeV/cc)

1-3. Galactic Center H.E.S.S. and CANGAROO-II



- **H.E.S.S.**

Stereoscopic observations in 2003 June-August
power law index (γ)
γ =-2.21±0.09 June-July
γ =-2.11±0.19 July-August

- **CANGAROO-II**

Monocular observations in 2001 and 2002
γ =-4.6±0.5

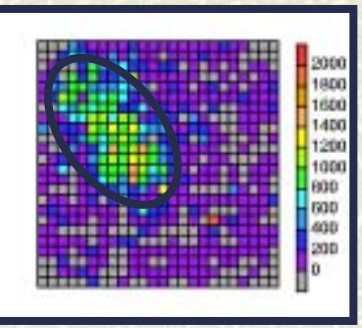
Aharonian et al. (2004)

Reanalysis for flux measurement

Inconsistency between H.E.S.S. and CANGAROO-II ?

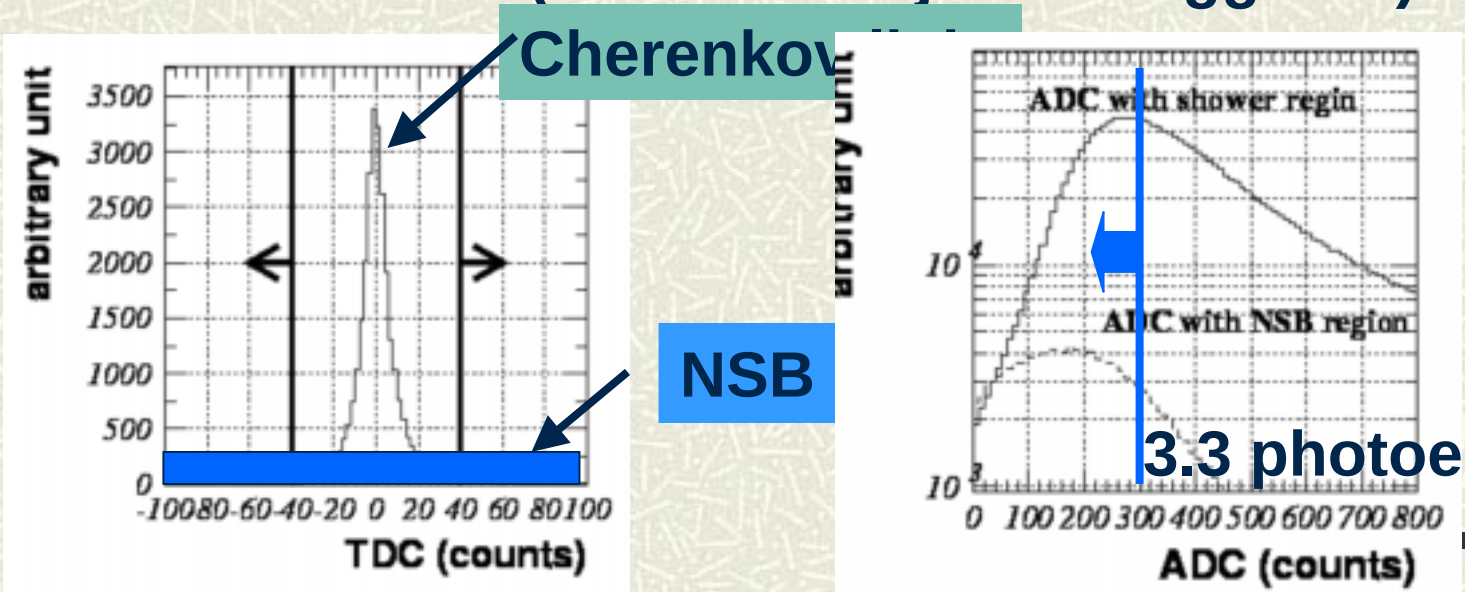
- **Effect of Night Sky Background**
- **Uncertainty in energy decision**
- **underestimation of effective area**

1) Night sky background



	NSBphotons	Cherenkov light
arrival time	random	concentrated
image	isolated	cluster
ADC counts	poisson	large + power law

After the Cluster cut (at least 5 adjacent triggered)



1) Effect of NSB

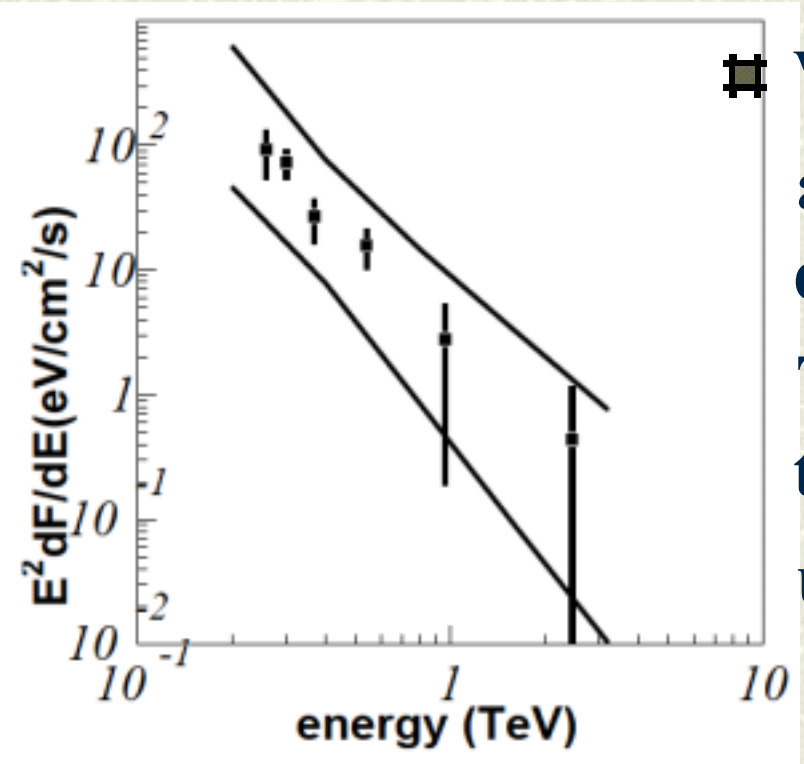
- The accidental hit by NSB was almost removed by clustering cut and TDC cut (99.8%).

Q) The effect of NSB is large in lower energy region. NSB → steep spectrum ?

A) We also estimated the power-law index of spectrum in higher energy region.

The index remains steep. (-4.6+-1.5 @ 2-4bin)

2) Uncertainty in energy decision



- **We applied the MC method assuming uncertainty in energy decision ~20%.**

The index is allowed from –3.4 to -8.7 with power-law fitting under the condition of $\chi^2 \leq \chi^2_{\min} + 1$

Power-law index considering uncertainty in energy decision

-4.6+1.2-4.1

3) Effective area

Gamma-ray MC (100GeV-10TeV)

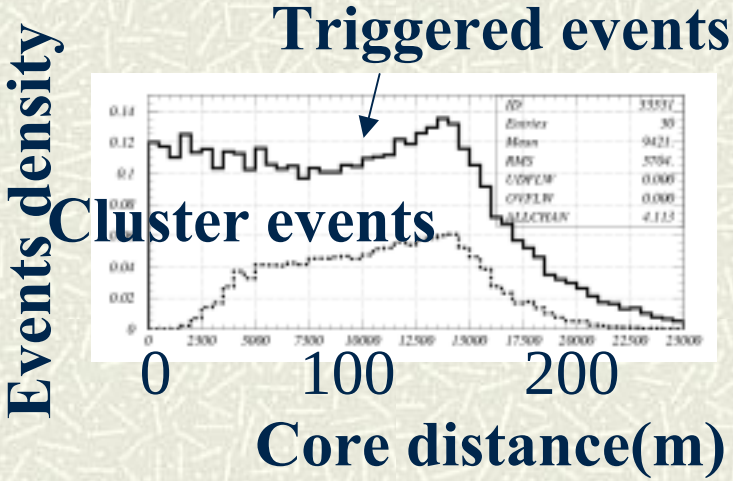
- **The radius of target area is 250m.**

  (Cherenkov light pool ~140m radius assuming the shower maximum at 8km)

- **Study for changing the radius**

  → 250m-1000m

  The effective area is stable.



250m is enough to estimate an effective area.

1-3. Galactic Center

CANGAROO-II

The inconsistency is still remained

- **No Effect of Night Sky Background**
- **Considering an energy ambiguity**
- **Estimation of Effective Area is correct**
- **Time variation ?**

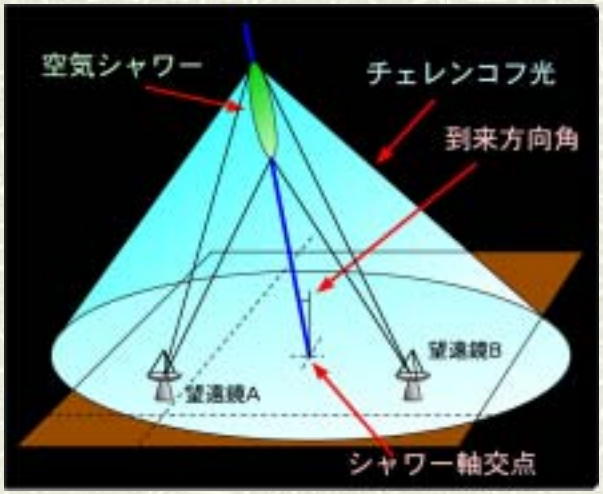
CANGAROO-III

Stereoscopic observations will be done in this summer !

→ It's important for the identification of target and radiation mechanism

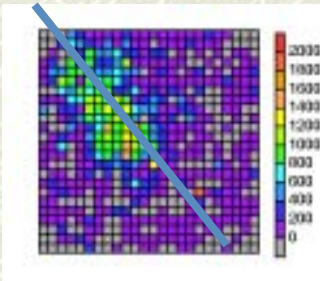
CANGAROO-III Current status

- Stereoscopic observations with 4 telescopes were started from March 2004.
- System calibrations and the TeV standard source "Crab" analysis are in progress carefully.



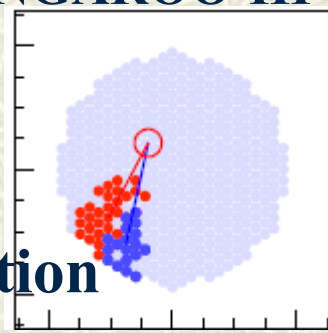
Monocular observations
→Ambiguity of arrival direction
→Decided by all events

CANGAROO-II



CANGAROO-III

Stereoscopic observations
→Arrival direction is decided event by event !
→ Good S/N and angular resolution



2-1. Observation summary 2004Jan-2005Feb (CANGAROO-III)

Galactic source

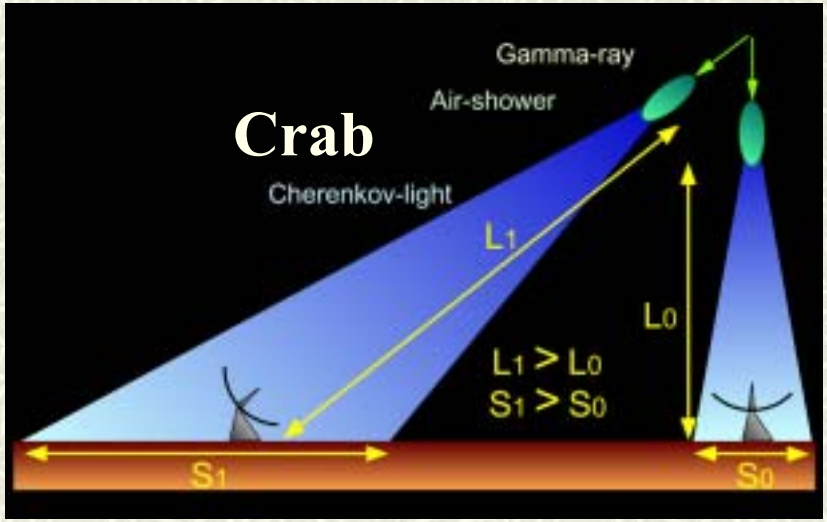
- **SNR SN1006 (39h)**
  RXJ0852.0-4622 center (52h)
  SN1987A(13h) W44(1.5h) Kepler(4.5h)
- **pulsar: PSR B1706-44 (36h) PSRB1259-63 (22h)**
  PSR B1509-58 (21h) Crab (52h)
- **Galactic Disk: l=+13(23h) l=-19.5(52h)**

Extragalactic source

- **AGN: Mrk421 (7h) PKS2155-304 (32h)**
  CenA (22h)
- **galaxy: NGC253 (32h)**
- **Globular cluster: Omega Cen (19h) 47Tuc (14h)**

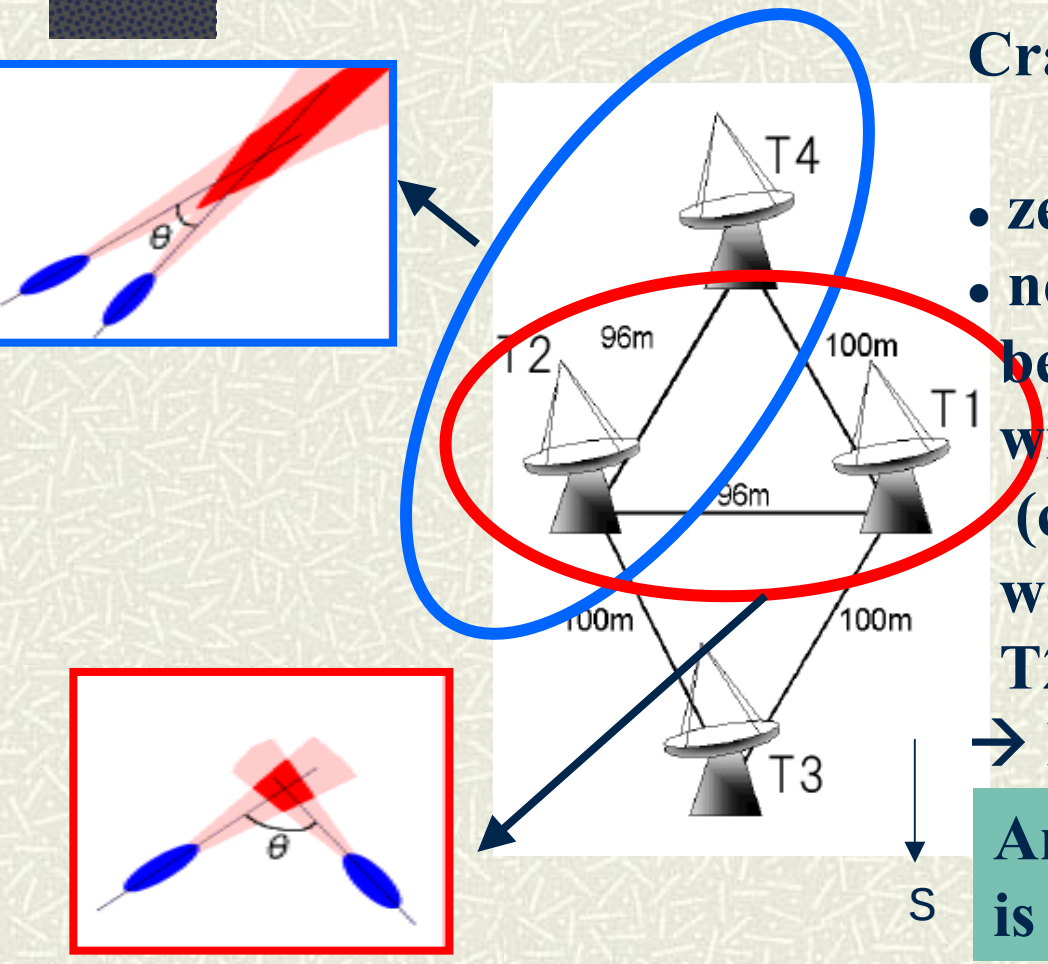
2-1. Analysis Status (CANGAROO-III)

- Before the analysis for each source, we have to apply the analysis for TeV standard source “Crab”data. Because we must check the analysis and optimize the MC simulation.



However, there is a problem for us to analysis large zenith angle sources.

Crab : Large zenith angle observations by stereoscopic system



Crab large zenith observations

- **zenith angle=60°@ Woomera**
- **new telescopes (T2-T4) have a better performance compared with T1(CANGAROO-II) (camera : noise and linearity…) we analysis stereo data with T2-T4 or T2-T3.**

→ Parallel images

Ambiguity of intersection point is large !

We need improvements of the analysis !

High priority sources : Inconsistency with H.E.S.S.

- **SN1006**

  At ICRC2001 we reported ~7σ @1.5 TeV for 2000 data, But we recently found some bug in calibration, and significance may be changed.

  CANGAROO-III stereo data : 39 hours → Under analysis

- **PSR1706-44**

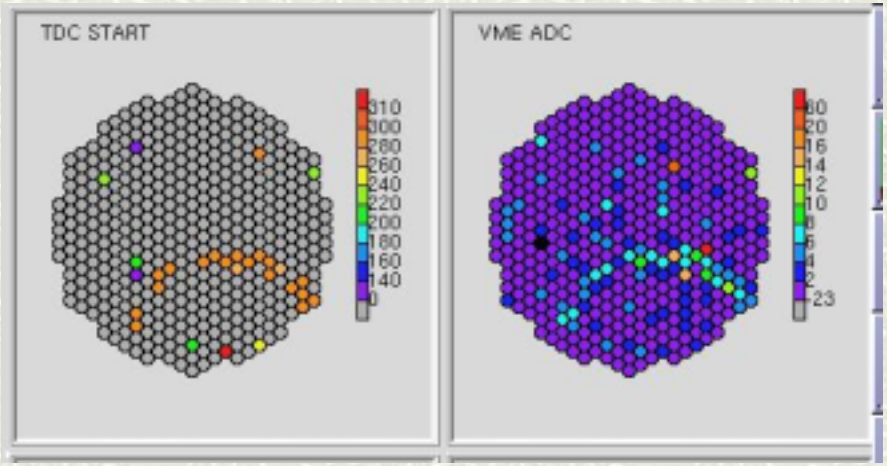
  There is a possibility that we have estimated a higher flux . (considering the number of excess events and flux)

  CANGAROO-III stereo data : 36 hours → Under analysis

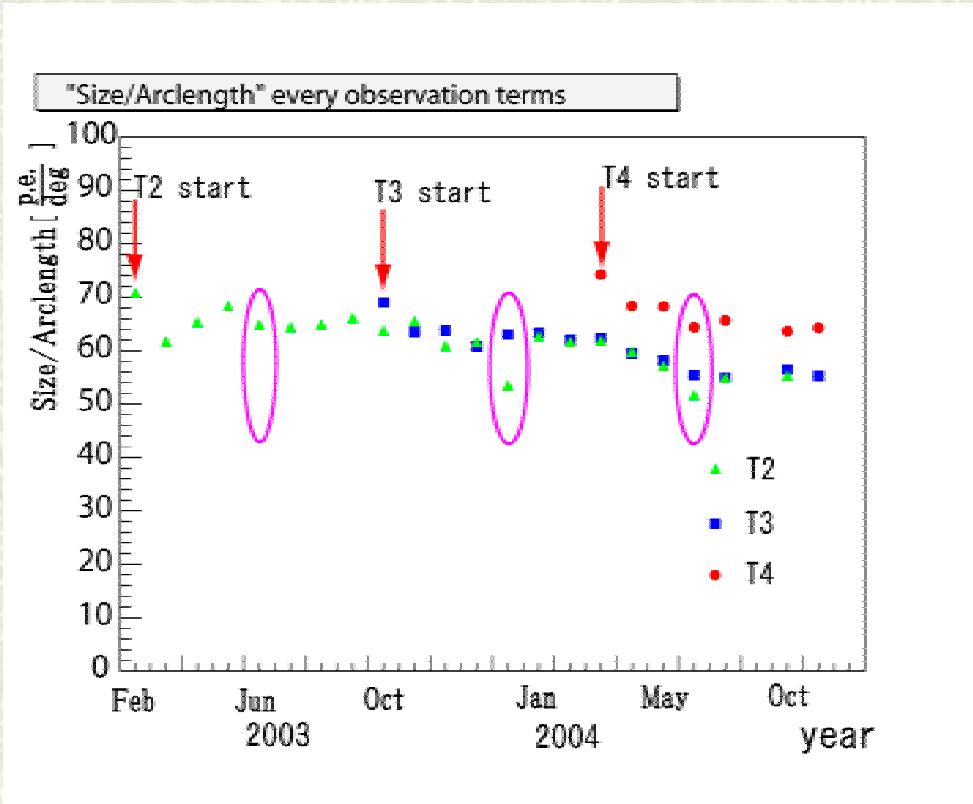
Better performance of CANGAROO-III → Check first !

2-2. Calibration muon

Arrival time **Number of Photon**



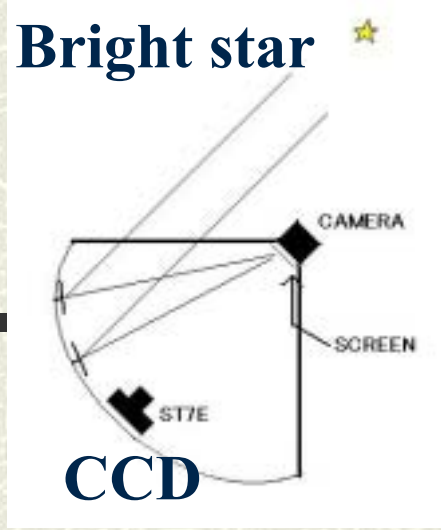
Size/Arc Length
→ Photon yield



Monitor of system efficiency
including a reflectivity and quantum efficiency

Adachi M-thesis (2005)

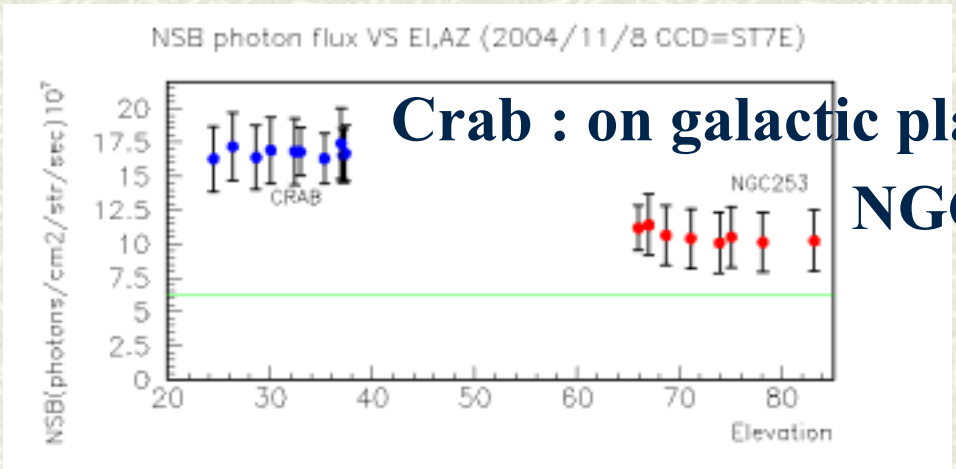
2-2. Calibration mirror reflectivity and NSB



- Monitor of mirror reflectivity
- Measurement of Night Sky Background

Number of typical NSB photon

$$\sum_{\lambda=430nm}^{550nm} \frac{2.125\times10^{-13}}{\frac{hc}{\lambda}} \sim 6.3\times10^{7} photons/cm^{2}/str/sec$$



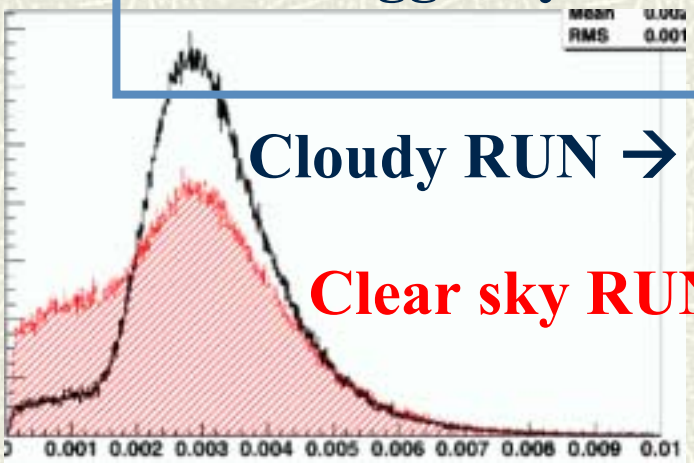
Crab : on galactic plane and large zenith angle

NGC253 : extragalactic source and zenith

Kiuchi M-thesis (2005)

2-3. Global Trigger System

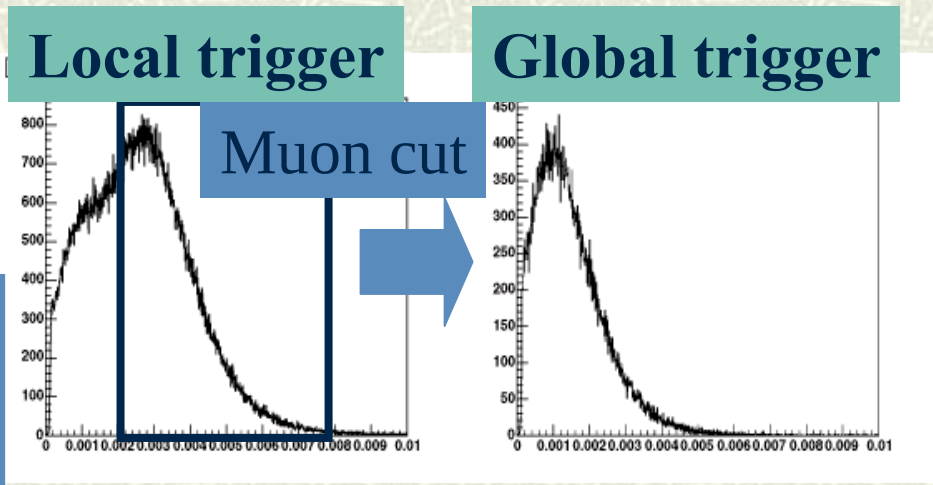
Local trigger system : software coincidence trigger at off-line analysis



Cloudy RUN → muon

Clear sky RUN → hadron (gamma-ray) + muon

Length/Size



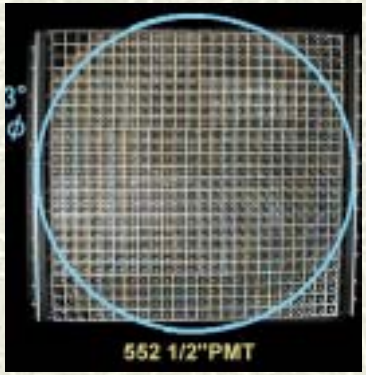
Global Trigger system
: On-line hardware coincidence trigger system

Nakamori M-thesis (2005)

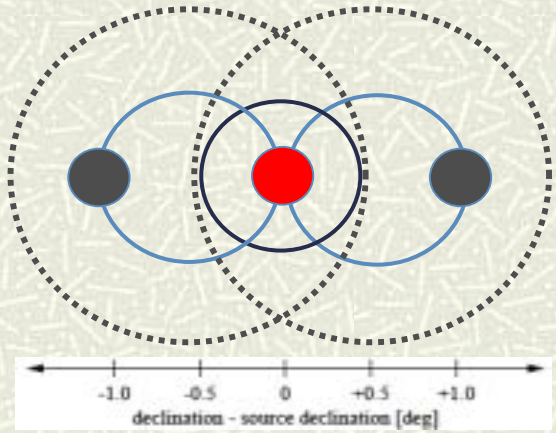
2-3. Wobble mode

CANGAROO-II CANGAROO-III

F.O.V 2.7º → 4.0º



OFF ON OFF



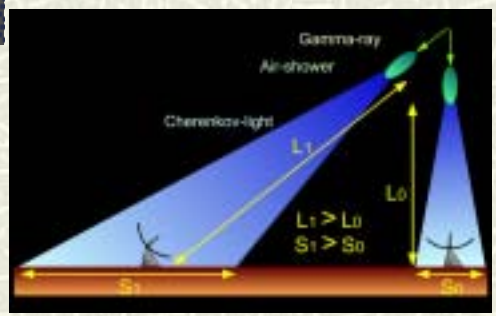
We need not observe OFF source region

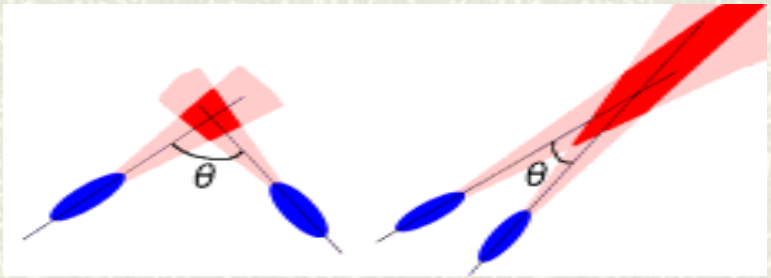
→ observation time is twice !

→ sensitivity, new source ,

no ambiguity of normalization

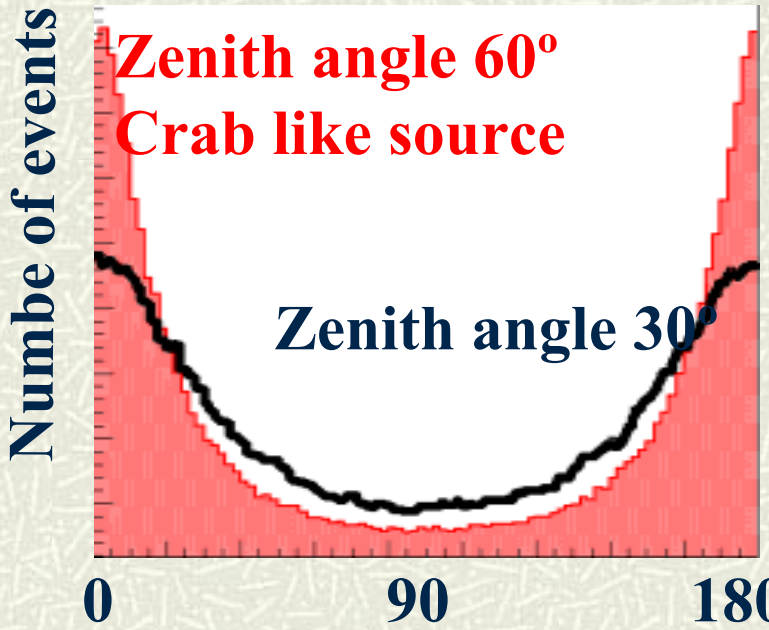
2-4. Crab independent analysis Large zenith observations (1)



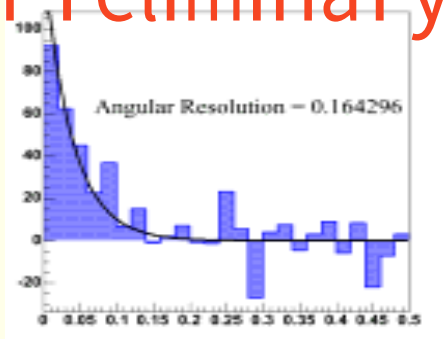


Ambiguity of intersection point is large at 0<θ<15 and 165<θ<180.

→ $15^\circ < \theta < 165^\circ$



Preliminary



Crab data

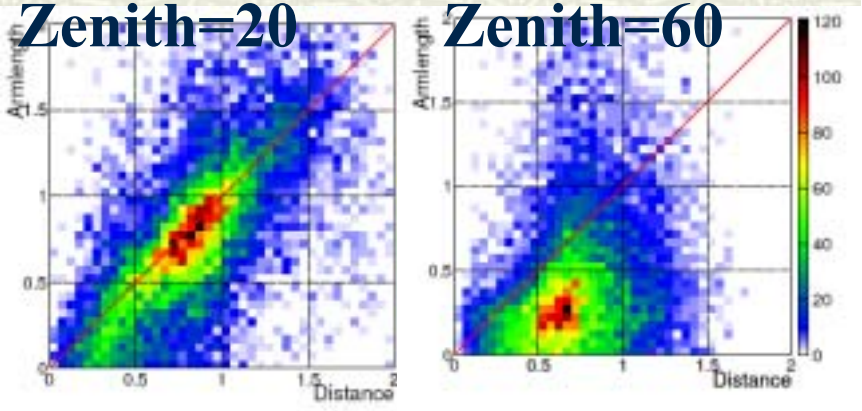
Kyoto group

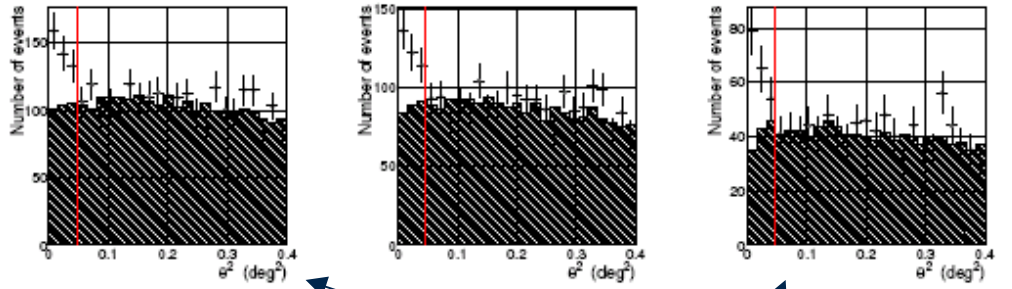
2-4. Crab independent analysis
Large zenith observations (2)

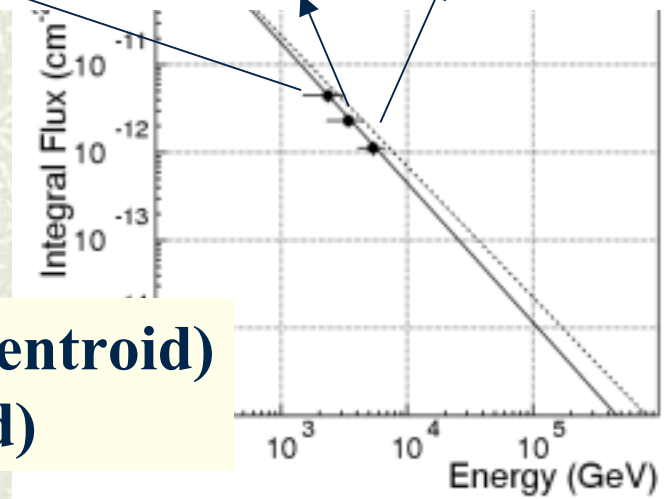
MC simulation

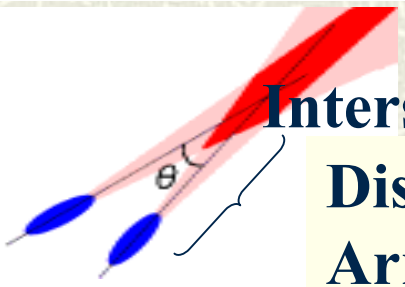
Zenith=20

Zenith=60







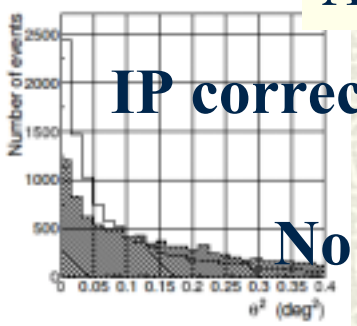


Intersection Point(IP)

Distance (source point -- image centroid)

Arm Length (IP – image centroid)

IP correction



No IP correction

Kabuki D-thesis (2005)

Summary

- We reported new gamma-ray detection from SNR RXJ0852.0-4622 by CANGAROO-II.
- We reconsidered the G.C. data. The inconsistency between HESS and CANGAROO-II is still remained.
- We analyze CANGAROO-III data.

System calibrations and the TeV standard source "Crab" analysis are in progress carefully.