CANGAROO-III and beyond

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CANGAROO III

Pre-ICRC workshop: New Generation Cherenkov Imaging Telescopes

Aug 1-2, 2005, Mumbai, India

“CANGAROO”

=

Collaboration of **A**ustralia and **N**ippon for a **GA**mma **R**ay **O**bservatory in the **O**utback

Woomera, South Australia

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
- Shinshu University
- Institute of Space and Astronautical Science
- Tokai University
- ICRR, University of Tokyo
- Yamagata University
- Yamanashi Gakuin University

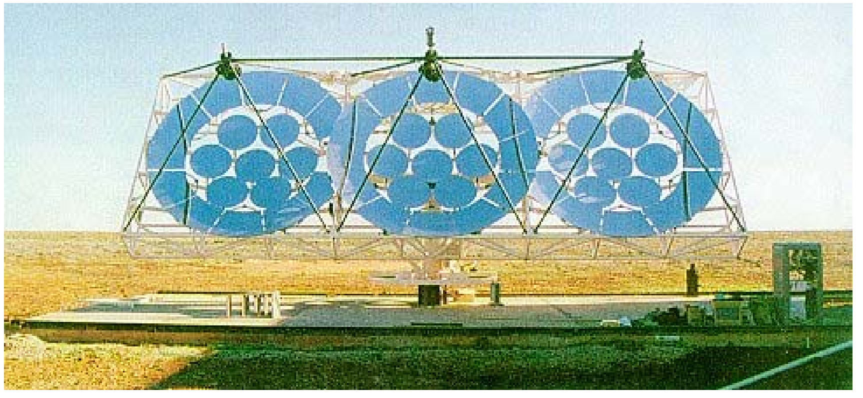
Brief history of CANGAROO

- 1987: SN1987A
- 1990: 3.8m telescope
- 1990: ICRR-Adelaide Physics agreement
- 1992: Start obs. of 3.8m tel.
- 1994: PSR 1706-44
- 1998: SNR1006
- 1999: 7m telescope
- 2000: Upgrade to 10m
- 2001: U.Tokyo-U.Adelaide agreement
- 2002: Second and third 10m tel.
- 2004: Four telescope system

Why Woomera?

- NZ: too wet, not many clear nights
- Woomera:
  - Former rocket range and prohibited area...infra-structure and support
  - Adelaide group was operating BIGRAT

ELDO rocket Launch site in ’60s

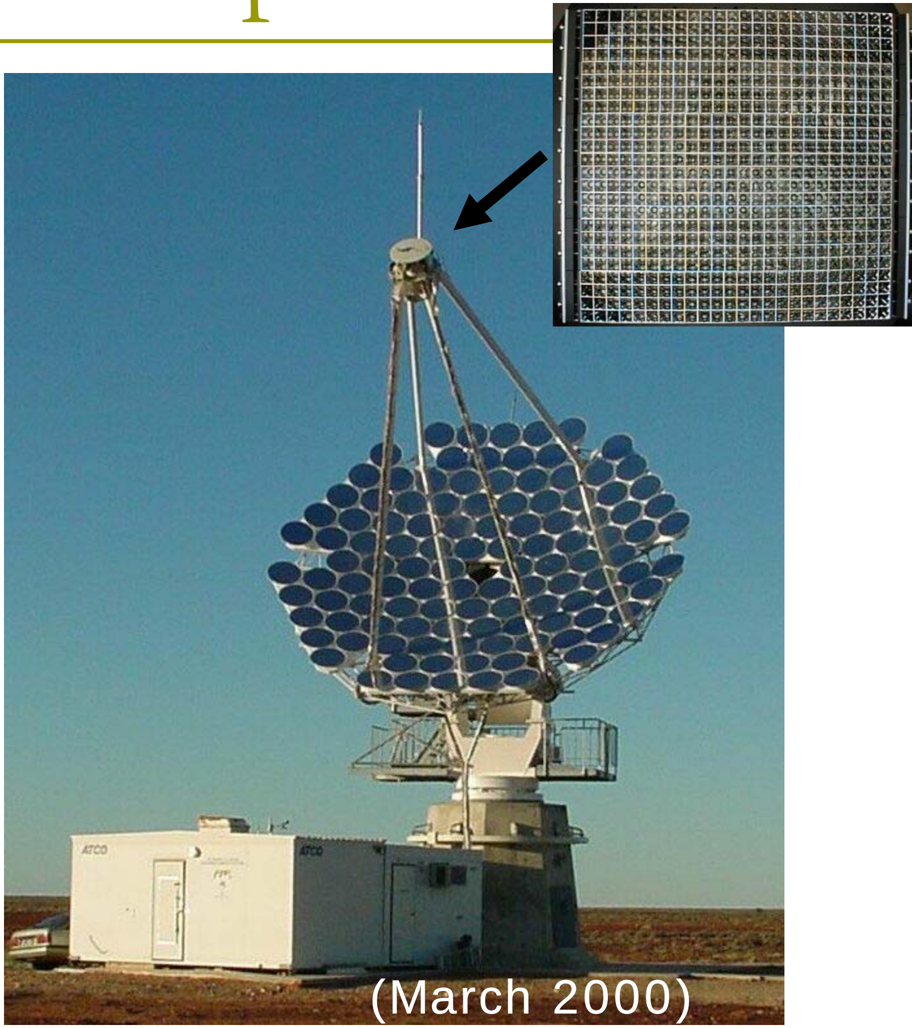


BIGRAT

(BIcentennial Gamma RAy Telescope)

CANGAROO-II telescope

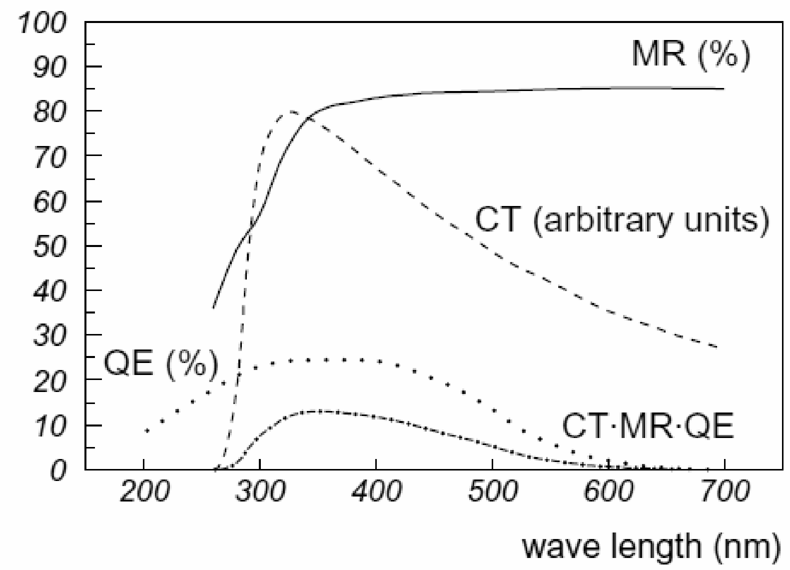
- Upgraded in 2000 from 7m telescope completed in 1999
- 114 x 80cm CFRP mirror segments in parabola *(first plastic-base mirror in the world!)*
- Focal length 8m
- Alt-azimuth mount
- 552ch imaging camera
- Charge and timing electronics

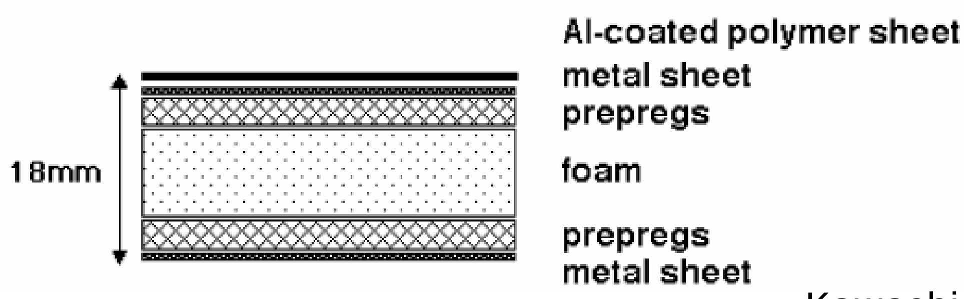


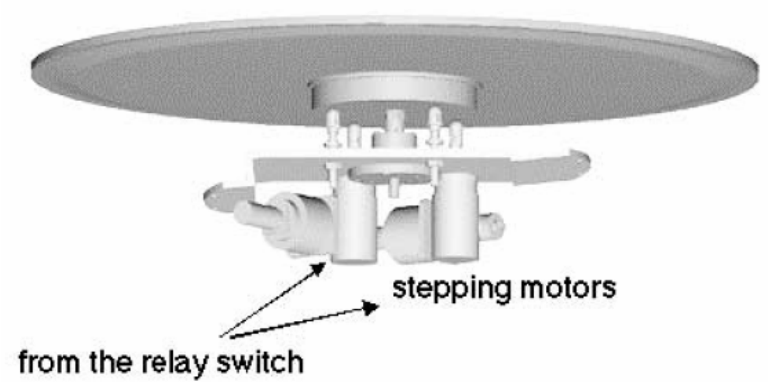
Tanimori et al., ICRC 1999

CFRP mirror & tuning system

80cmϕ, 5.5kg



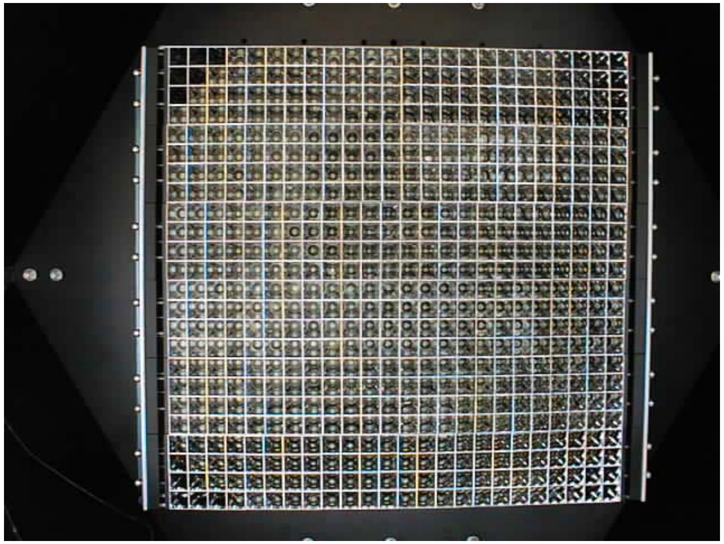




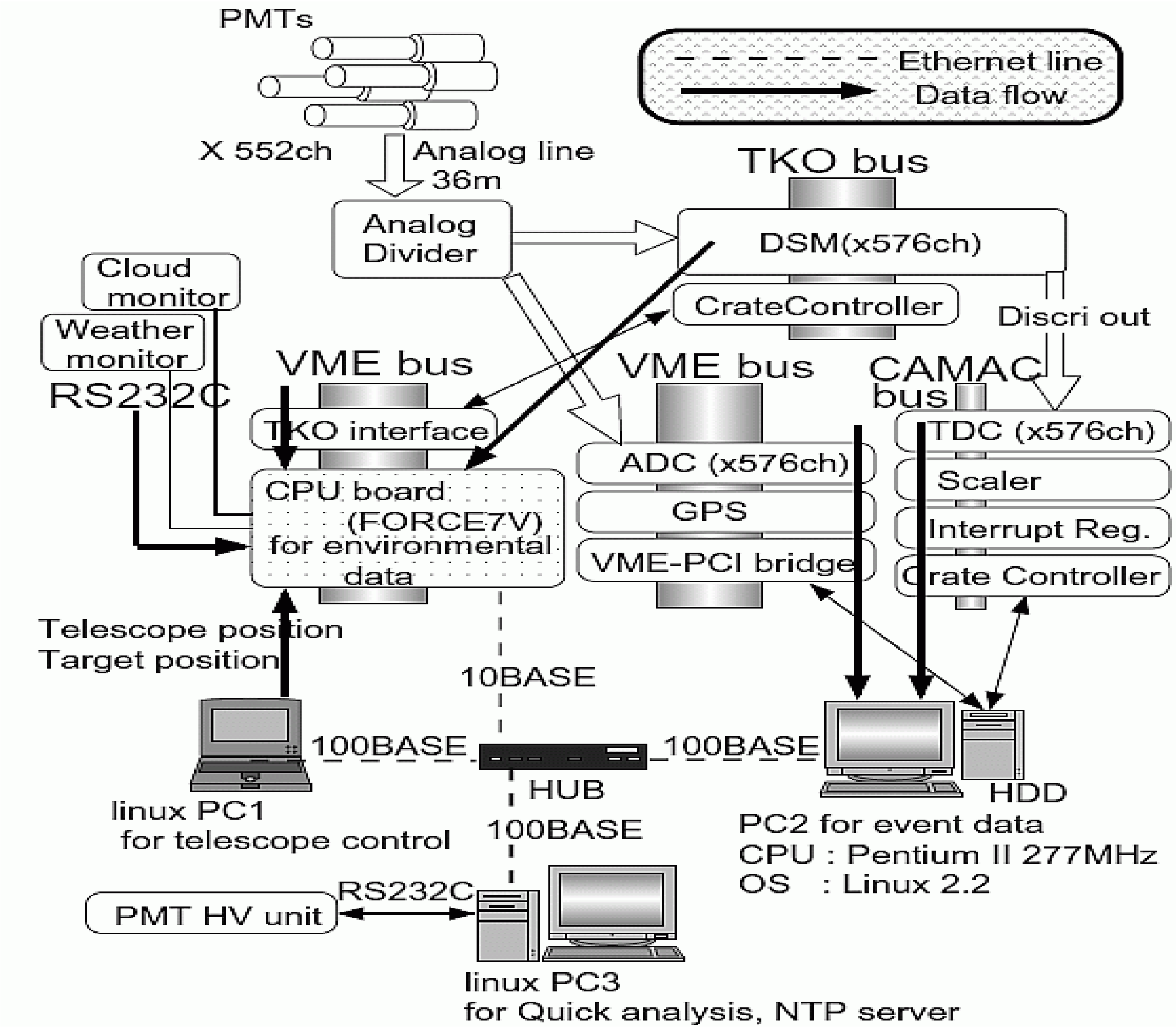
Kawachi et al., Astropart.Phys. 14, 261 (2001)

CANGAROO-II camera

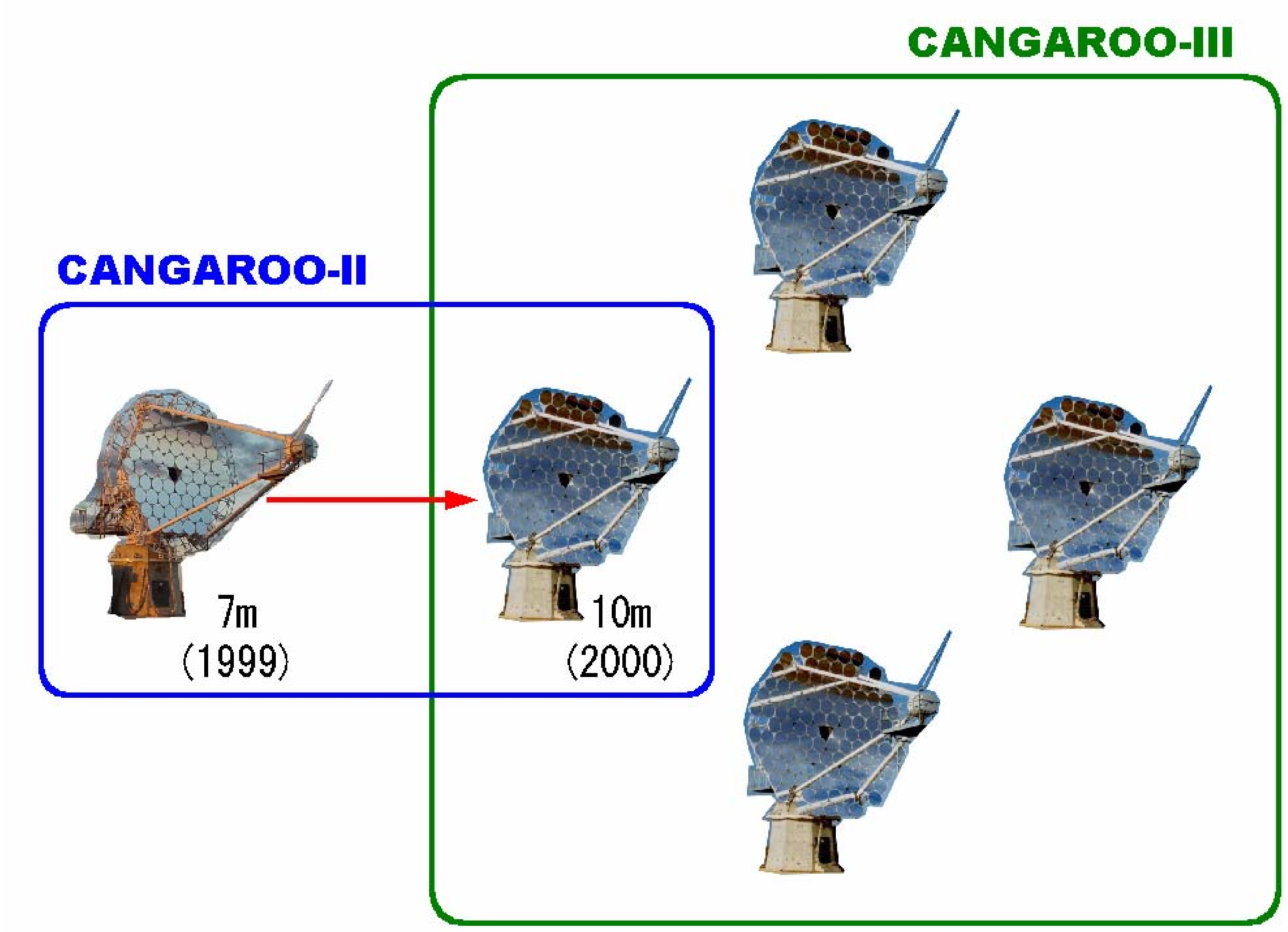
- 3° FOV
- R4124UV (Hamamatsu)
- 0.115° pixel
- Lightguide
- 16PMTs/module



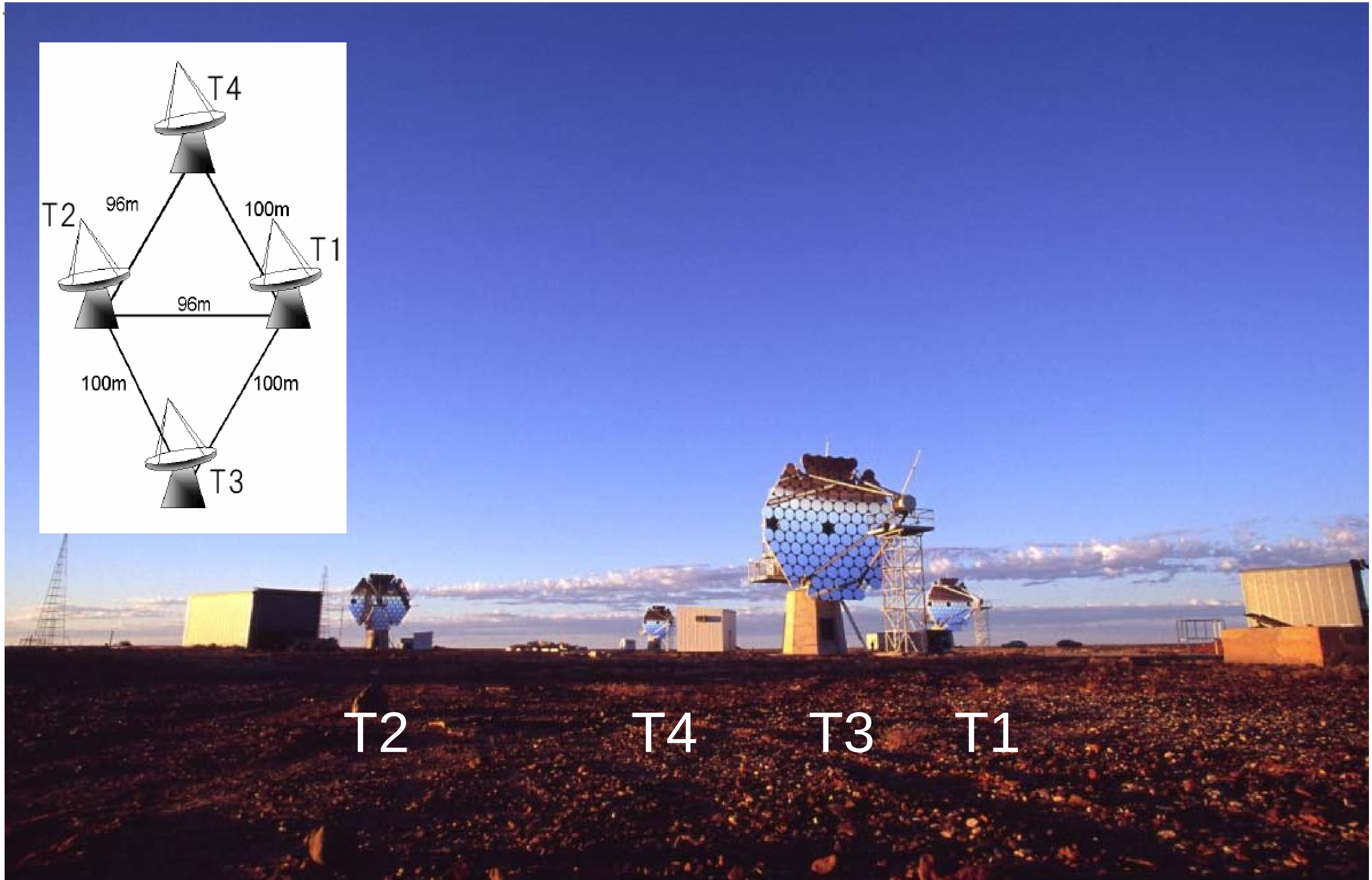
CANGAROO-II Electronics



CANGAROO-II & -III

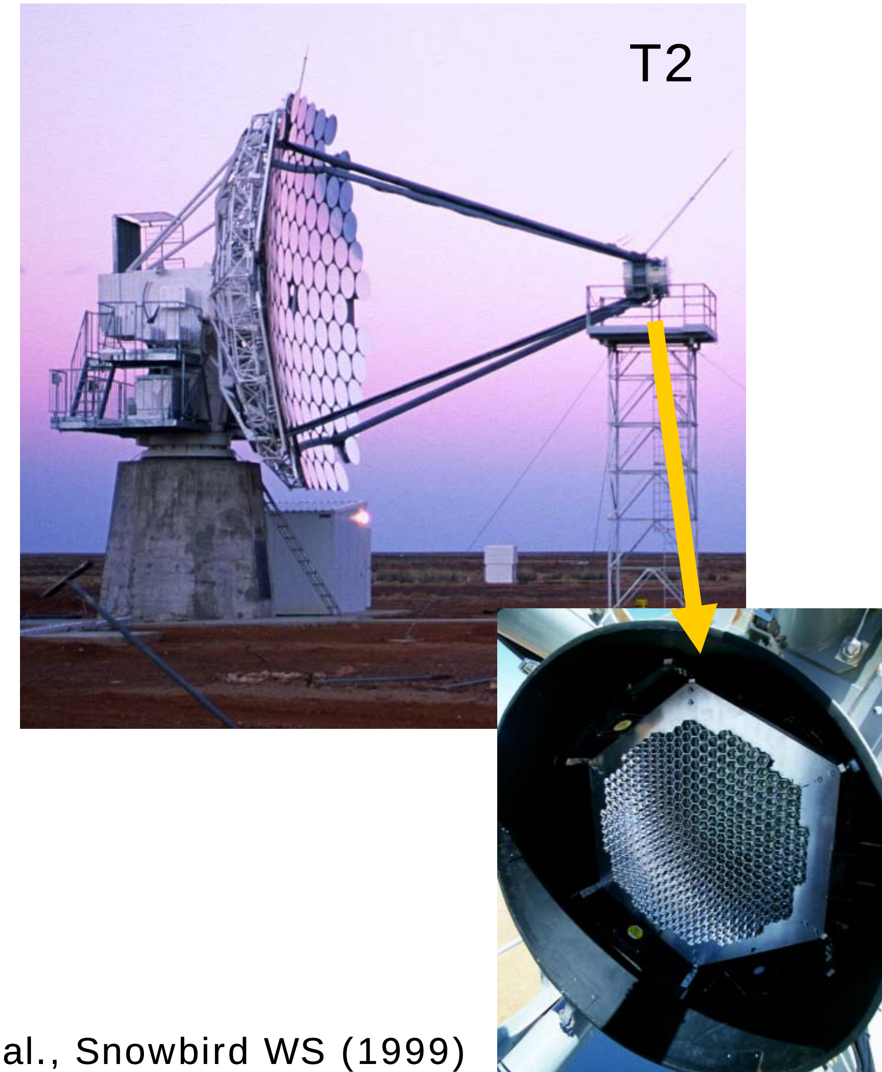


Woomera: 2004 March



Basic specifications of telescopes

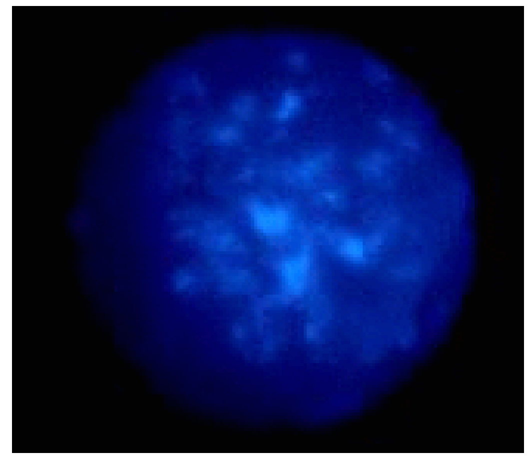
- Location:
  - 31°06'S, 136°47'E
  - 160m a.s.l.
- Telescope:
  - 114× 80cmϕ FRP mirrors (57m^2, Al surface)
  - 8m focal length
  - Alt-azimuth mount
- Camera:
  - T1: 552ch (2.7° FOV)
  - T2,T3,T4: 427ch (4° FOV)
- Electronics:
  - TDC+ADC



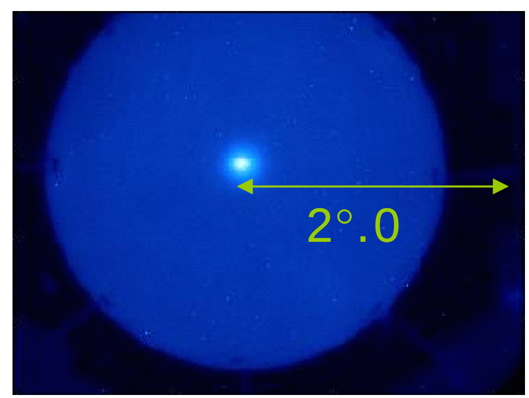
Mori et al., Snowbird WS (1999)

GFRP mirrors and tuning system

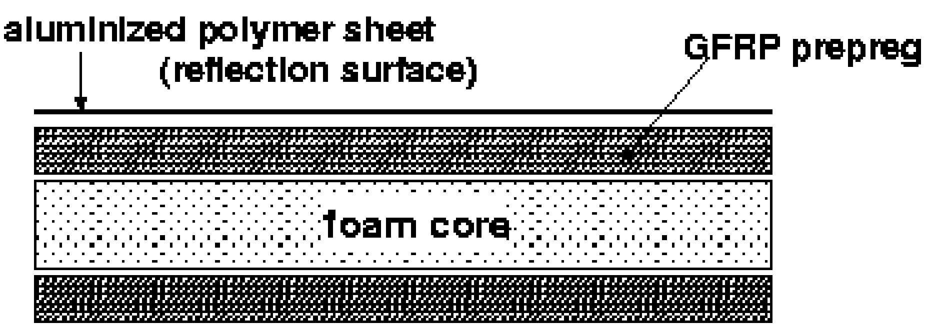
Tuning using star images via a CCD camera



Before tuning

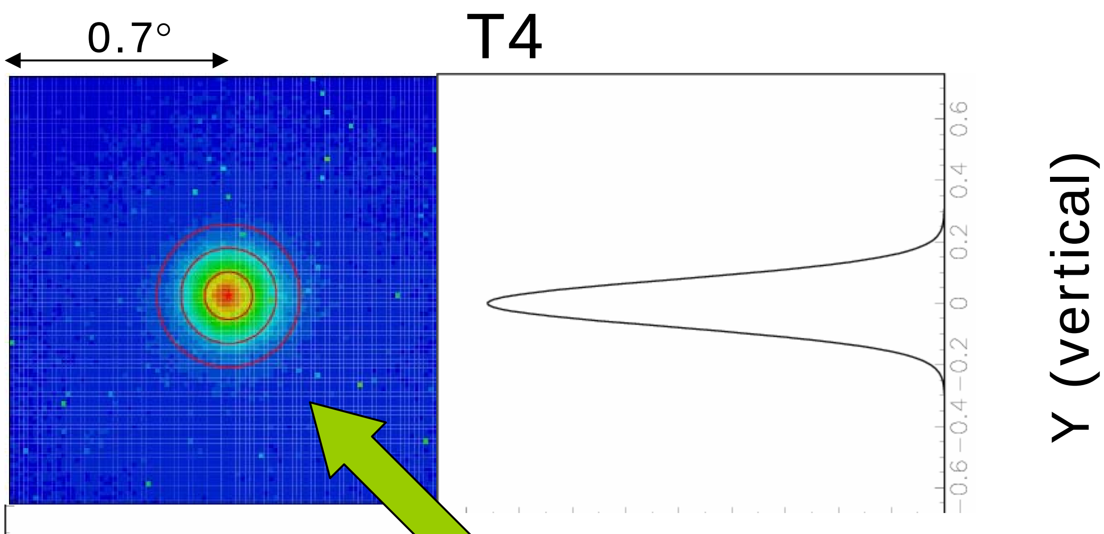


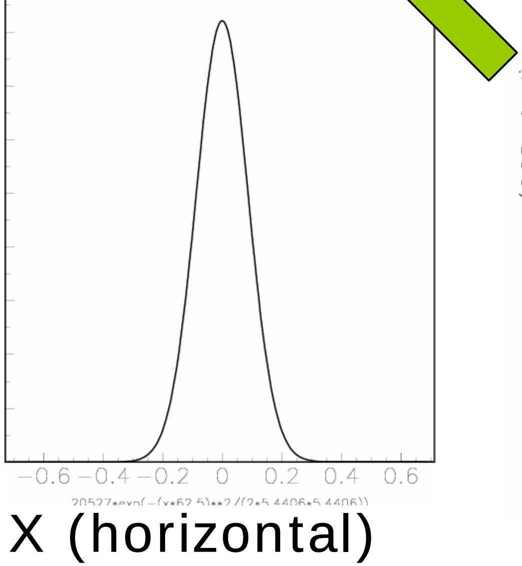
After tuning



Ohishi et al., ICRC 2003

Spot size





Point Spread Function (FWHM)

T1: 0.20°

T2: 0.21°

T3: 0.14°

T4: 0.16°

(measured at construction time)

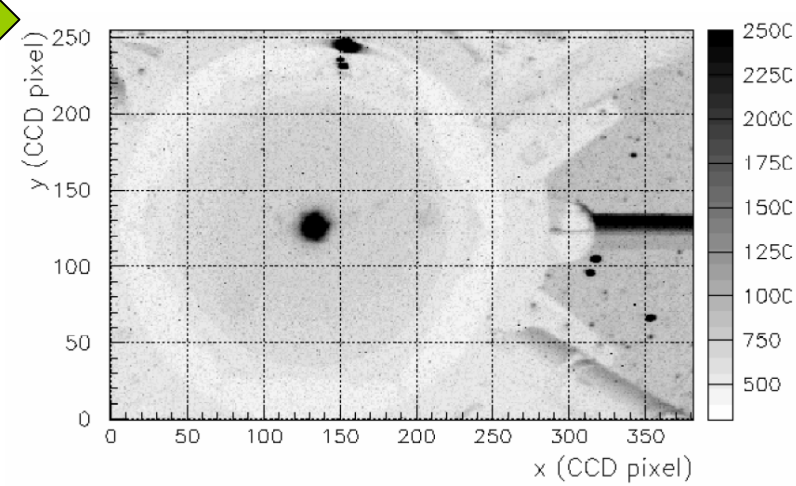
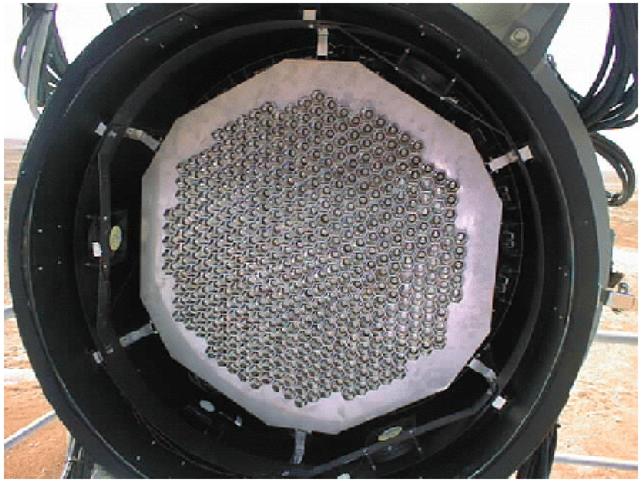
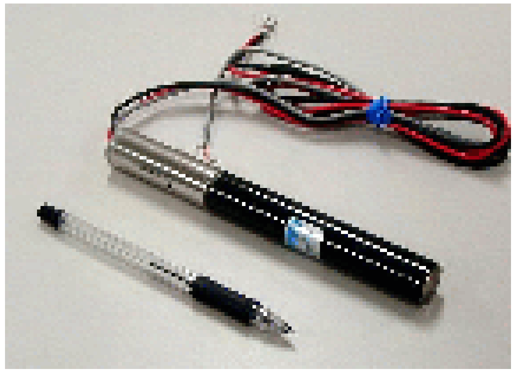


Image of a star on camera observed by a CCD camera

CANGAROO-III camera



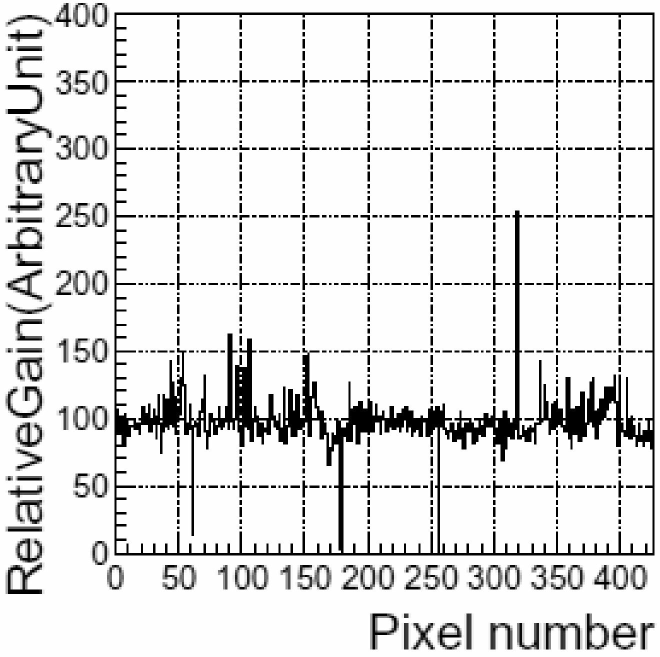


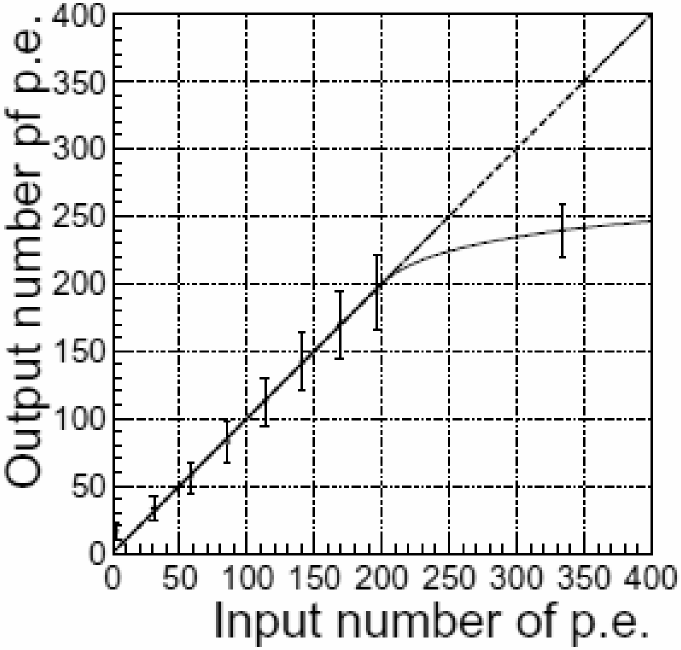
R3479 (Hamamatsu)

Lightguide (T1/T234)

	T1	*T2,T3,T4*
FOV	3°	4°
Num.of pixel	552	427
Weight	~110kg	~110kg
Size of PMT	½”	¾”
Pixel arrangement	square	hexagonal
HV polarity	negative	positive
HV supply unit	1ch/16 PMTs	1ch/1 PMT

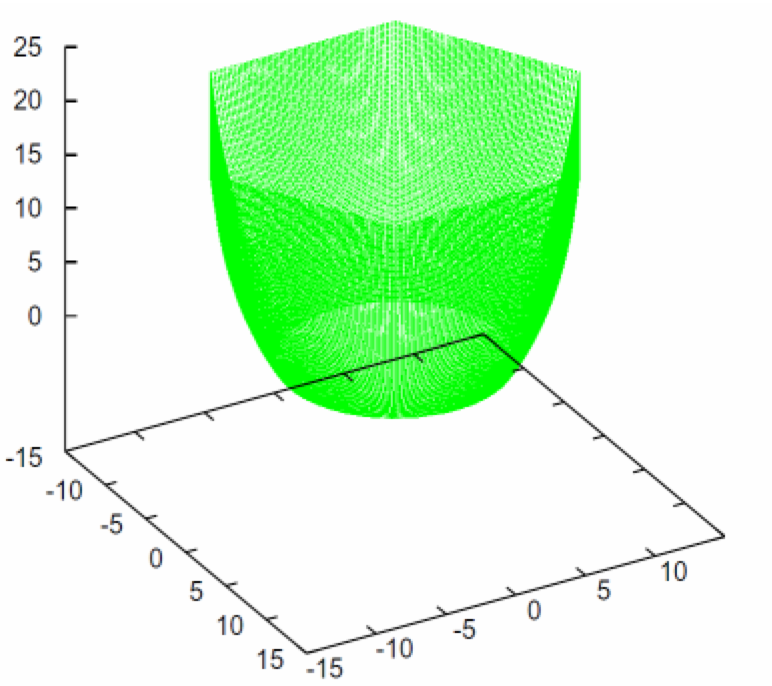
PMT gain uniformity and linearity



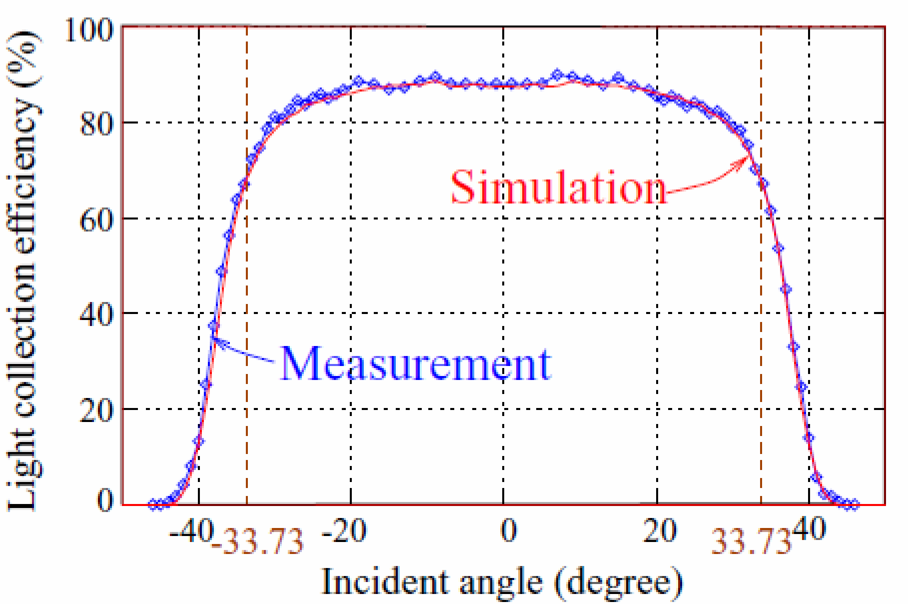


Kabuki et al., Nucl. Instr. Meth. A500, 318-336 (2003)

Lightguide design



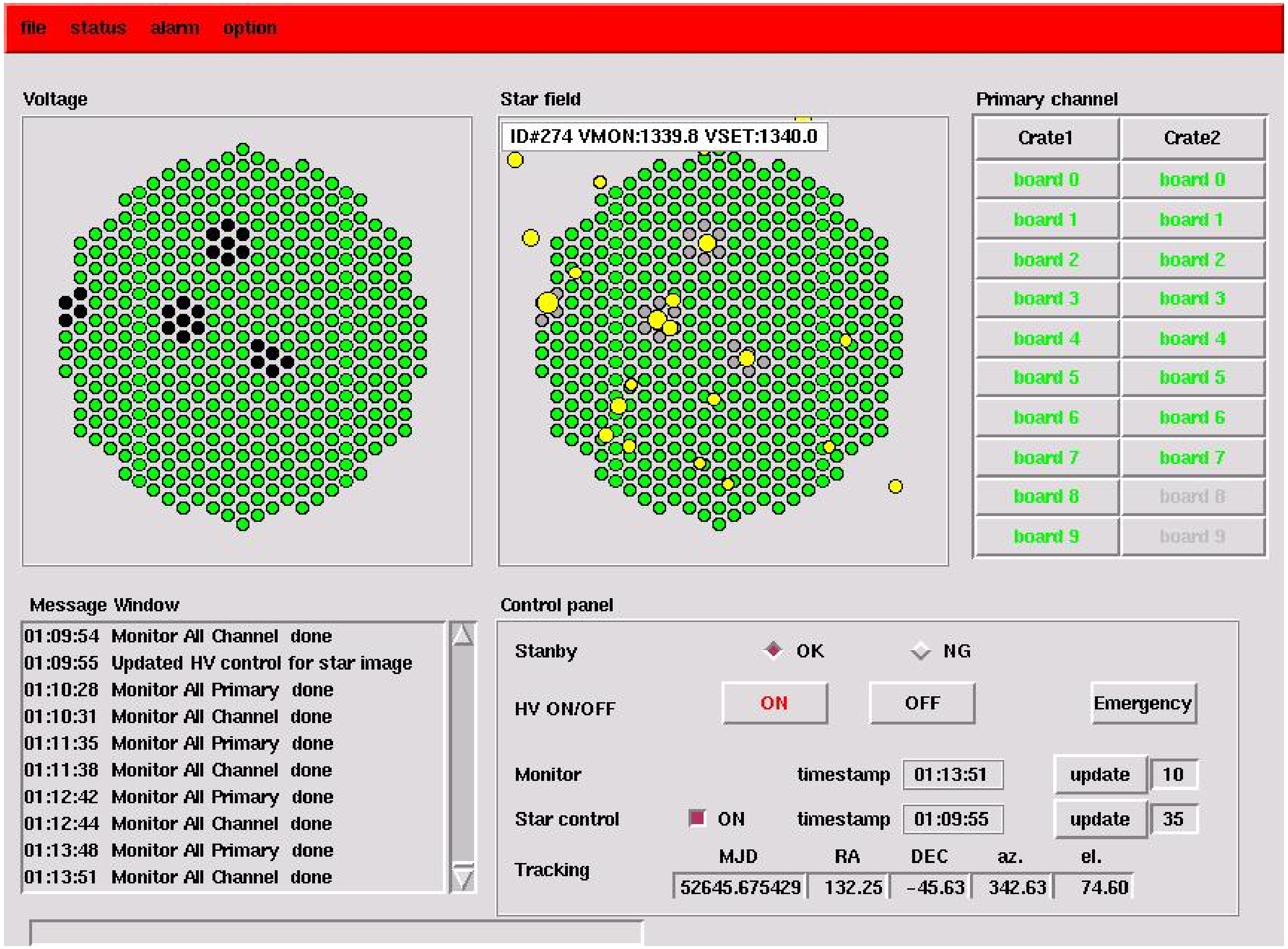
Winstone cone cross section



Efficiency vs. incident angle

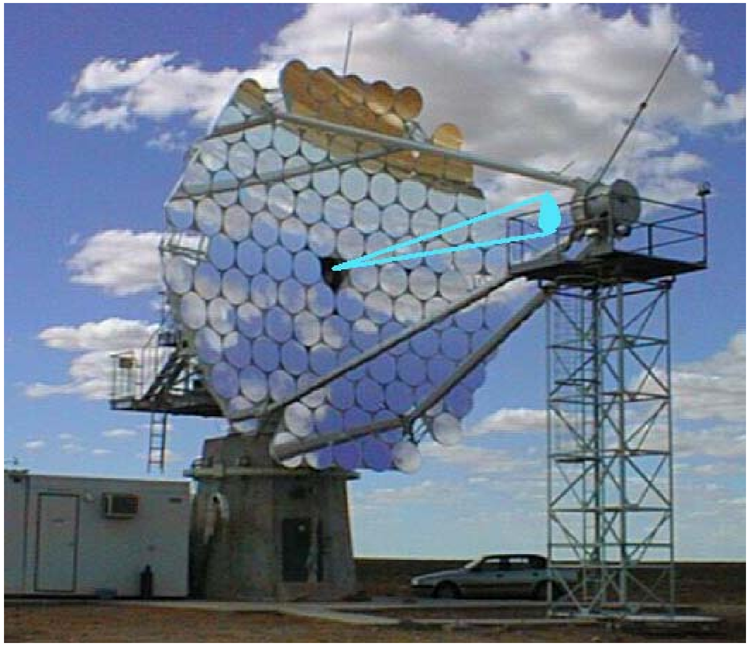
Kajino et al., ICRC2001

High voltage control & monitor

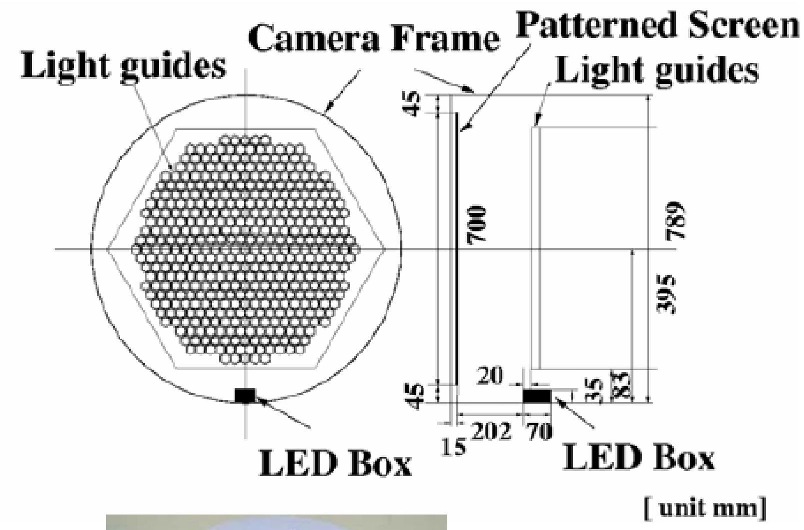


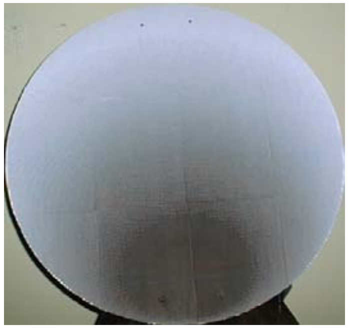
Camera calibration

Blue LED flasher at the reflector center



Blue LED flasher in the camera box

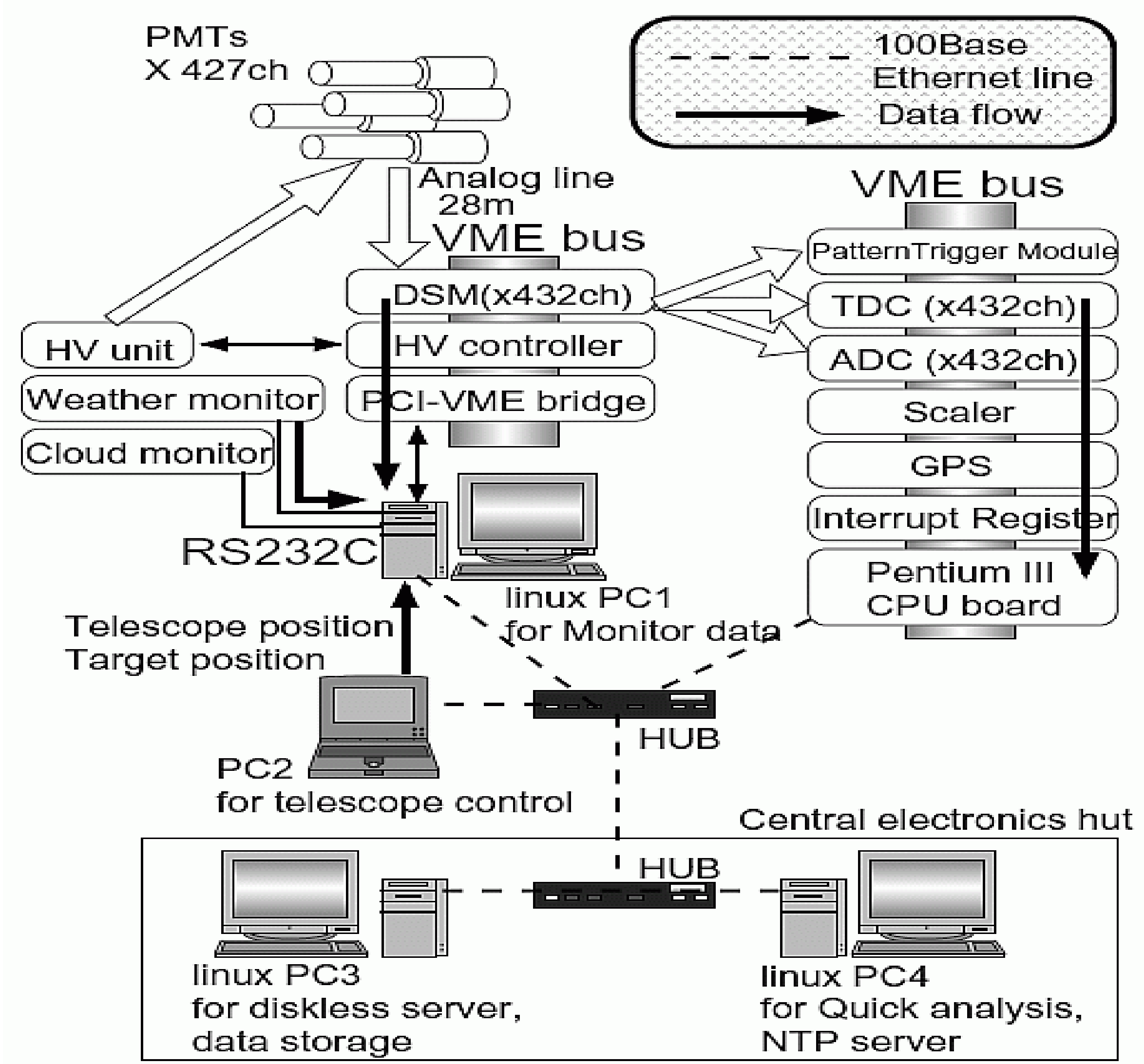




Patterned screen

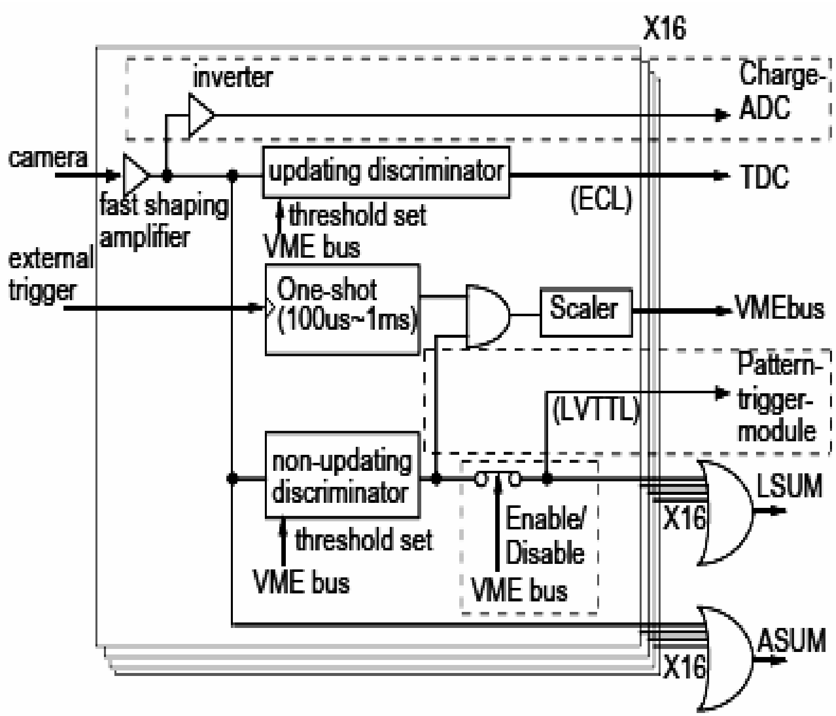
Yamaoka et al., ICRC2003

CANGAROO-III Electronics (1)

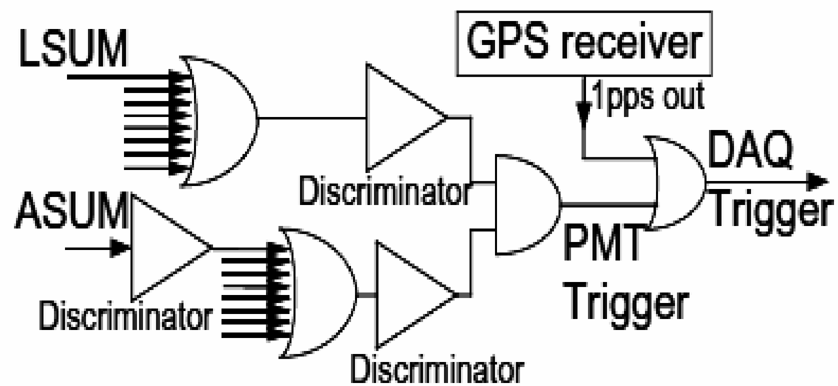


Kubo et al., ICRC 2003

CANGAROO-III Electronics (2)

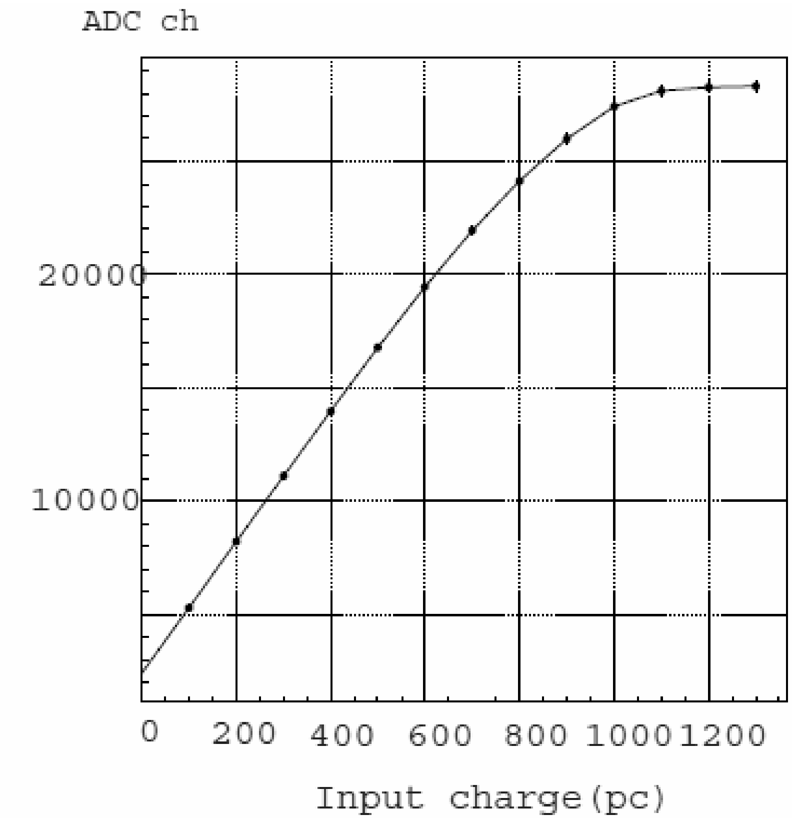


Discriminator and
summing module (DSM)

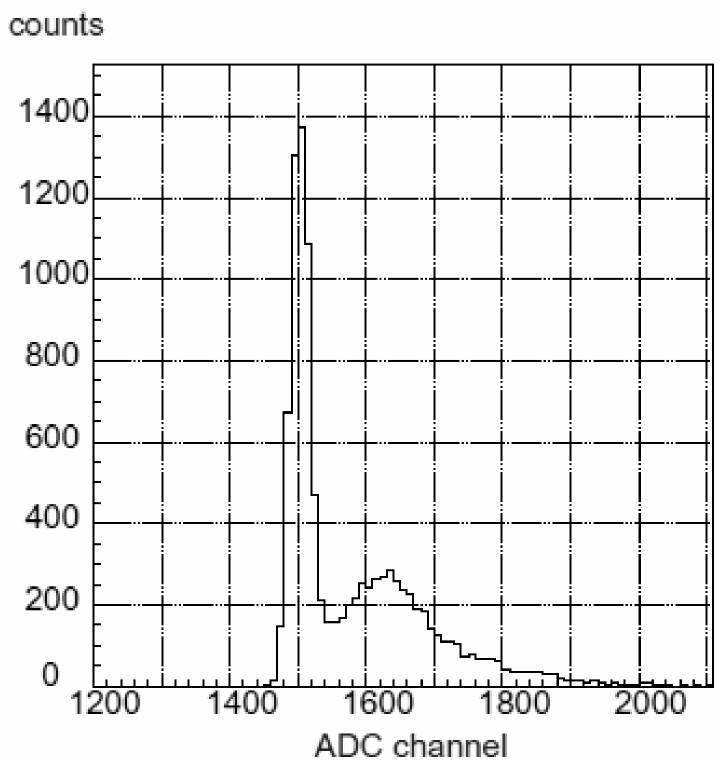


Trigger logic

CANGAROO-III Electronics (3)



ADC linearity



Single photoelectron spectrum measured with DSM and ADC

Telescope control

Telescope control unit

Position data (every 100ms)

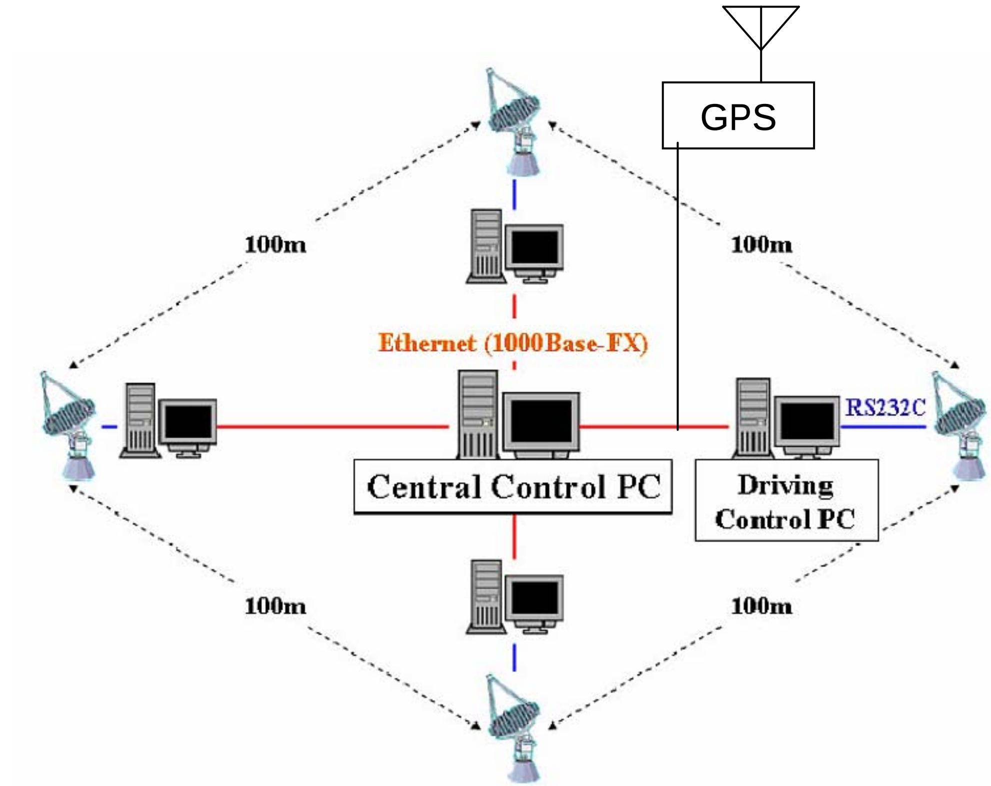
RS-232C

Position command (alt-azimuth)

Driving control PC

Remote command/position data/NTP

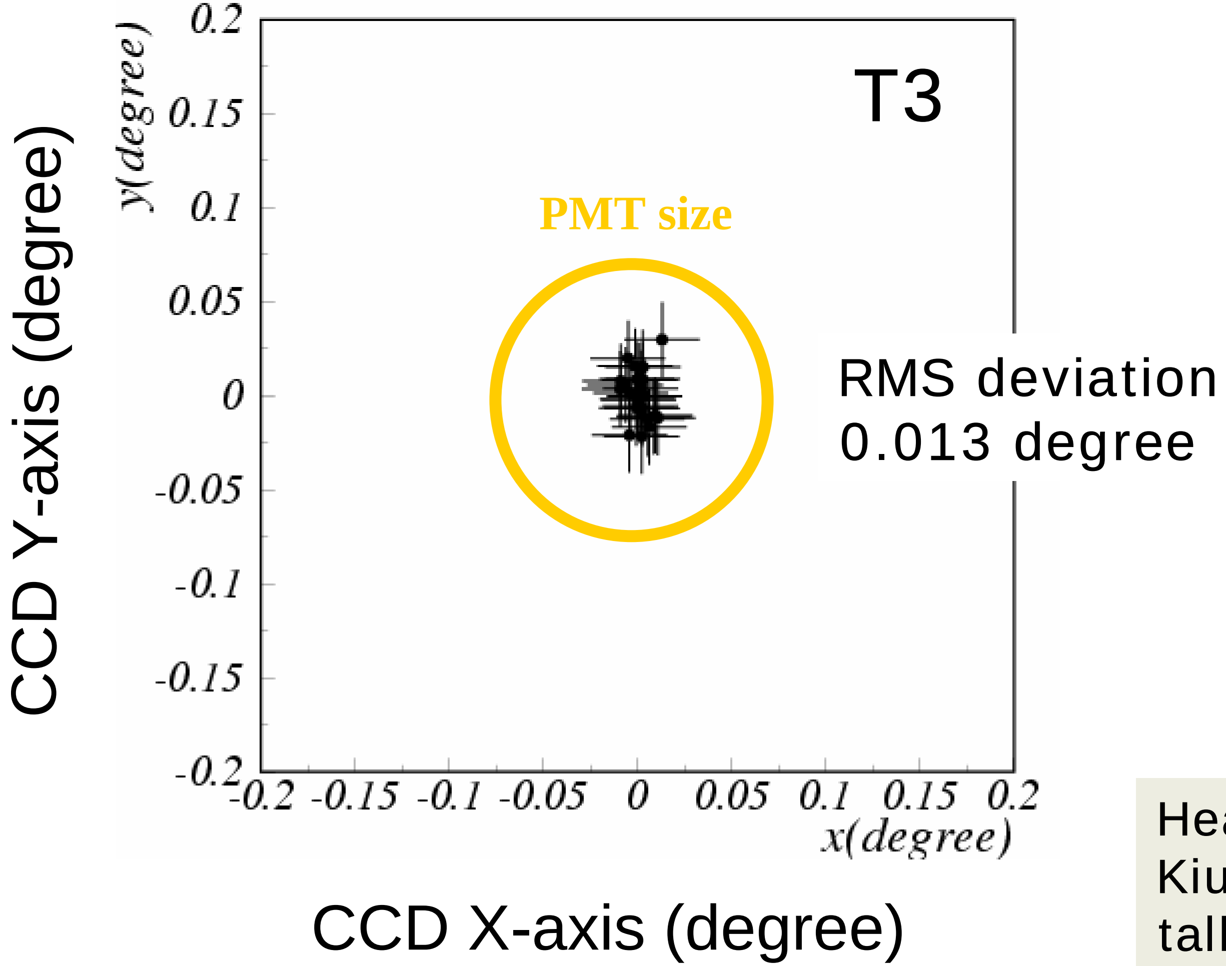
Local area network



Hayashi et al., ICRC2003

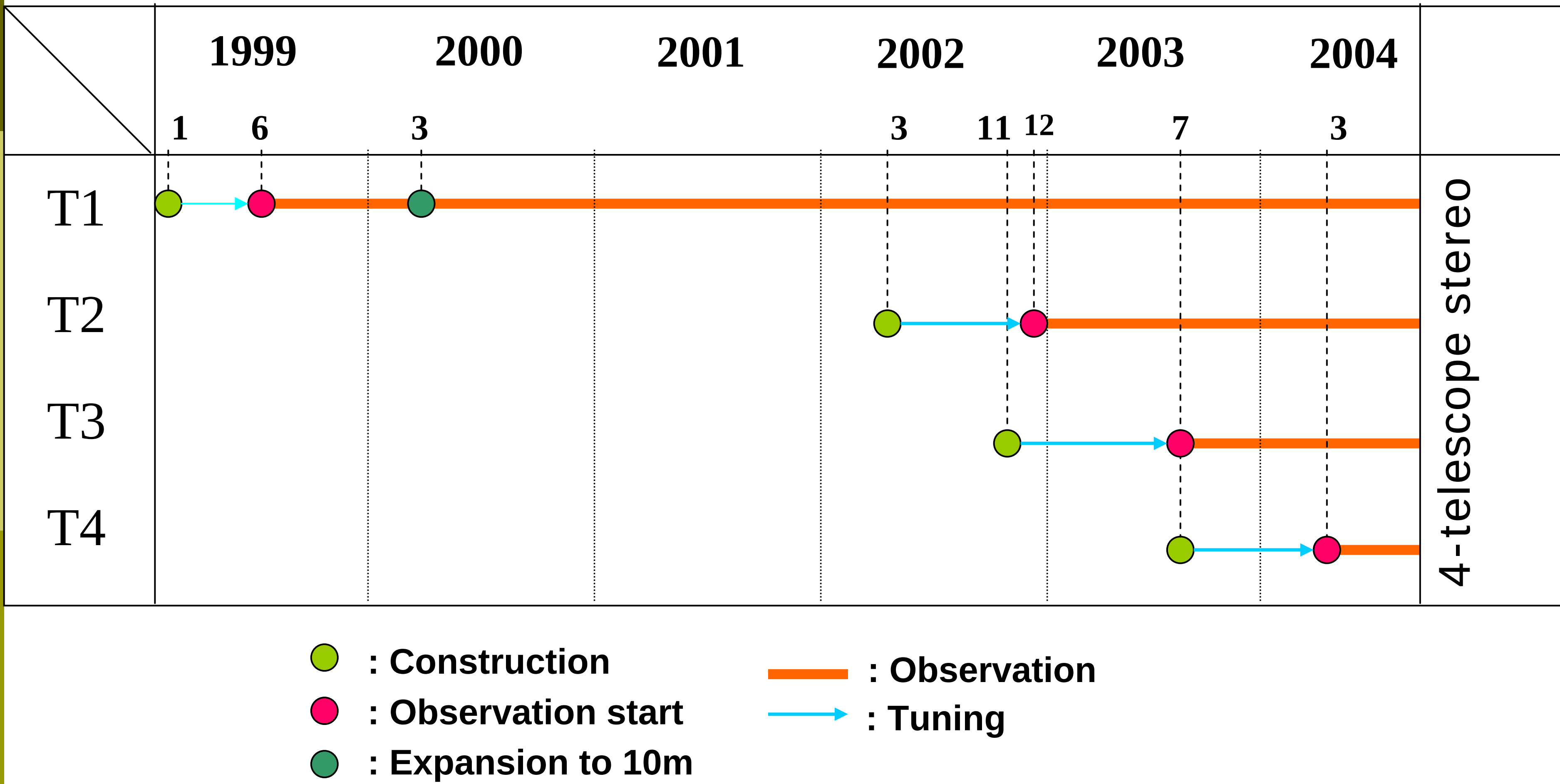
Star tracking

Star position error observed by a CCD camera

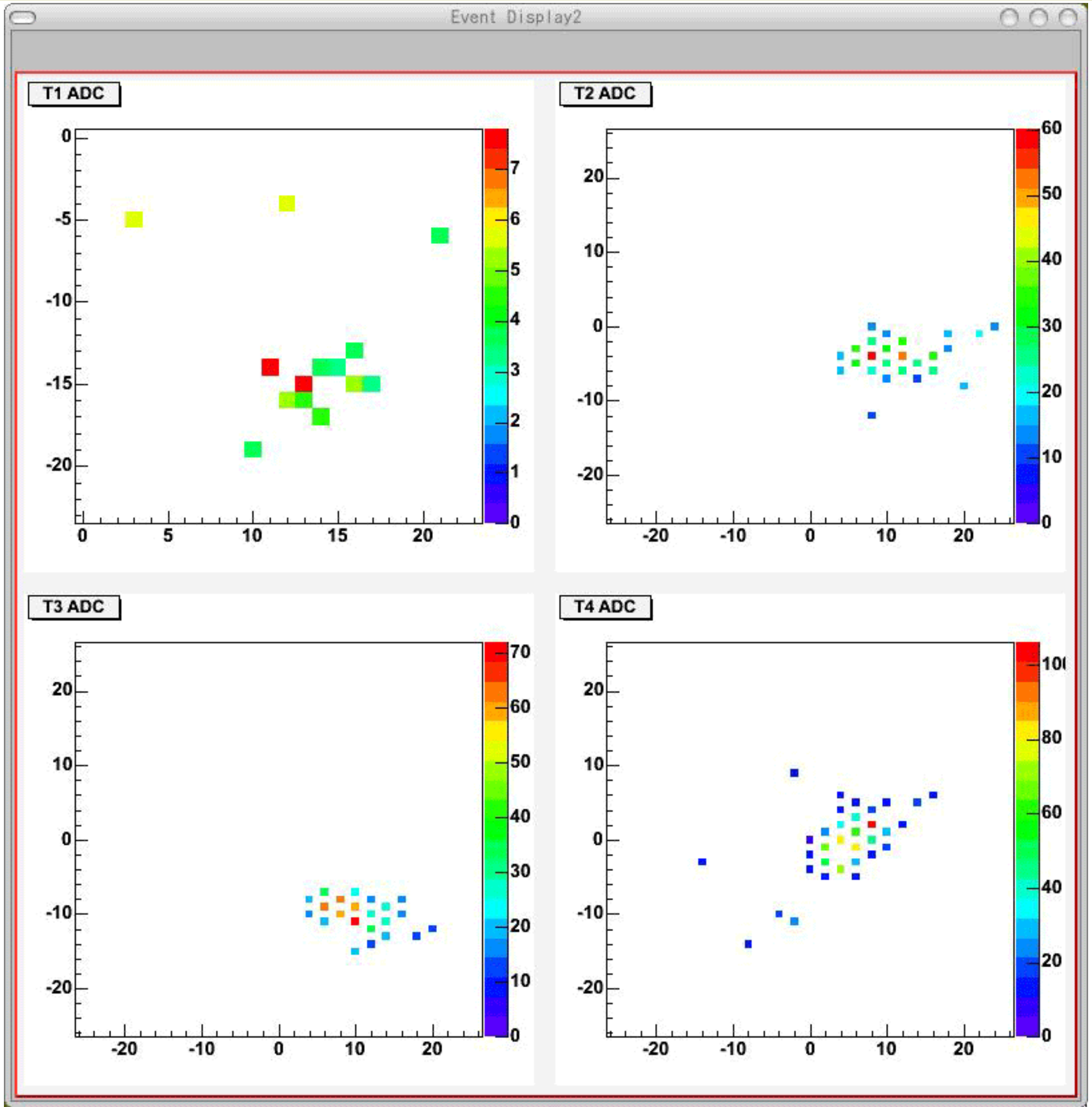


Hear Kiuchi's talk!

Construction of CANGAROO-III



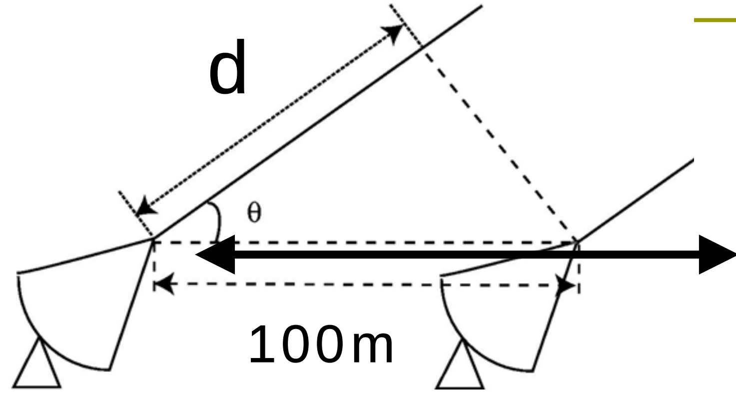
Sample of 4-fold stereo events



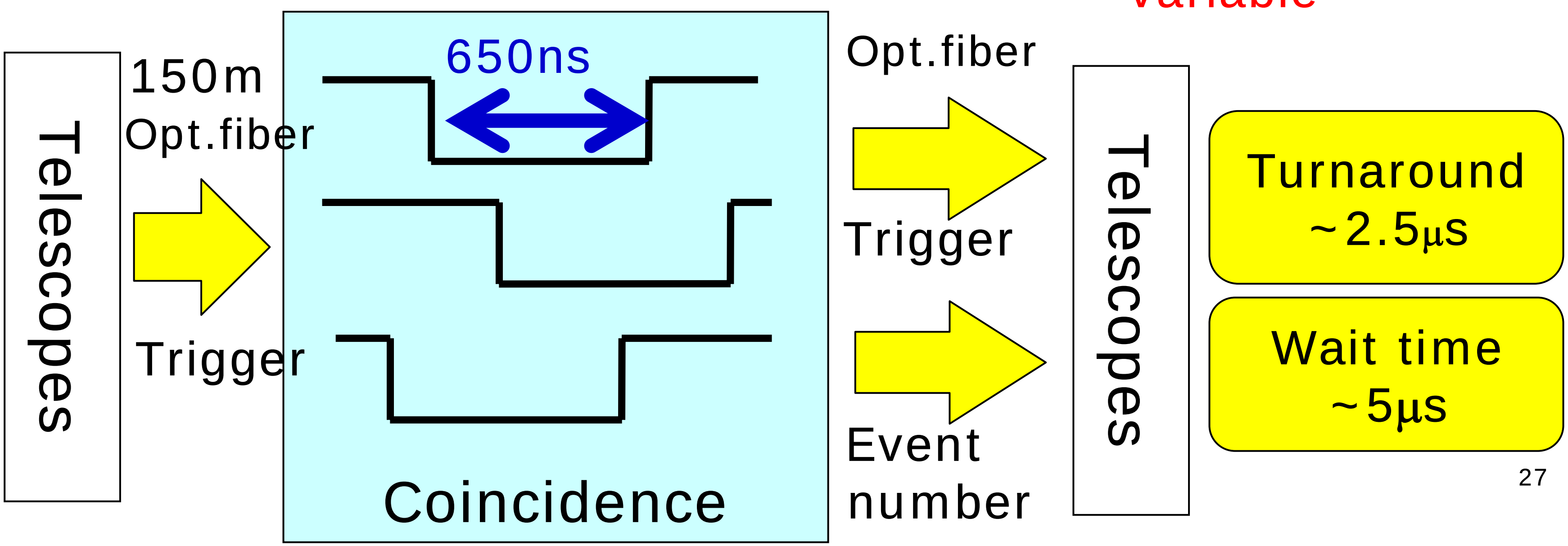
Data:
2004
March

Global trigger system

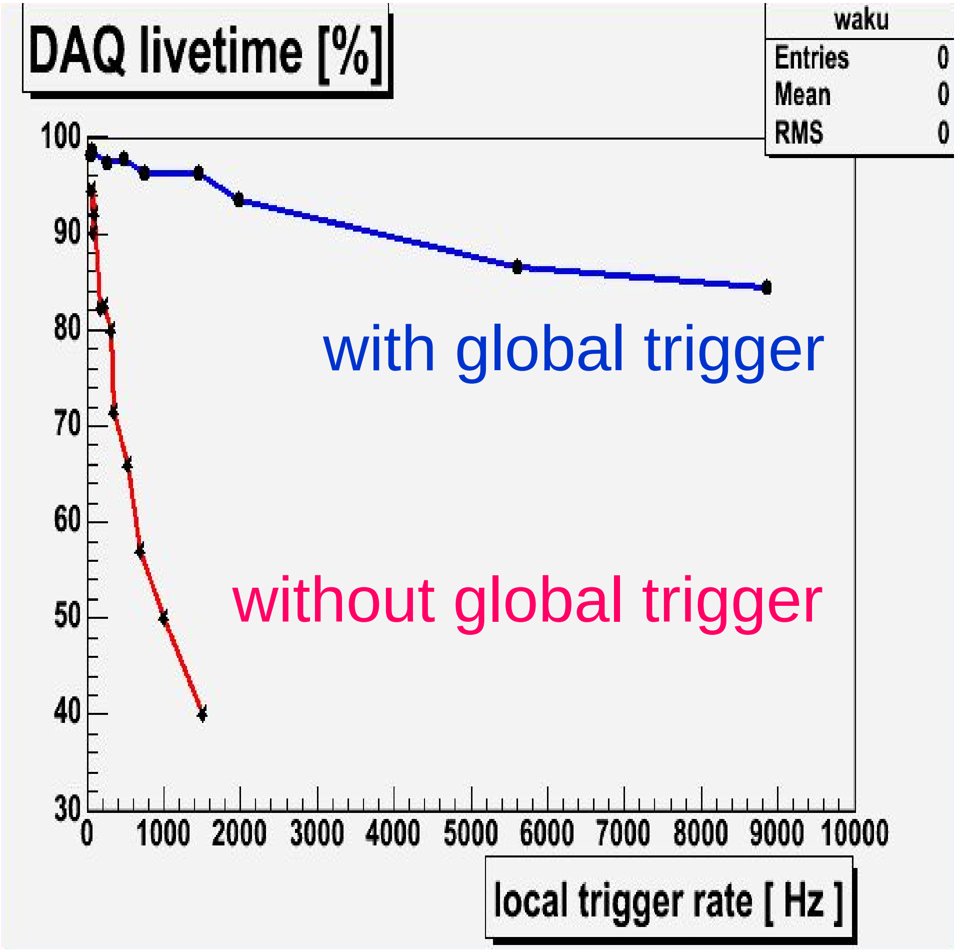
- Before: "software trigger"
  - Each telescopes triggered independently
- Now: "hardware stereo"
  - Requires at least 2 telescopes
- If no coincidence ⇒ Reset
  - Dead time ×1/100

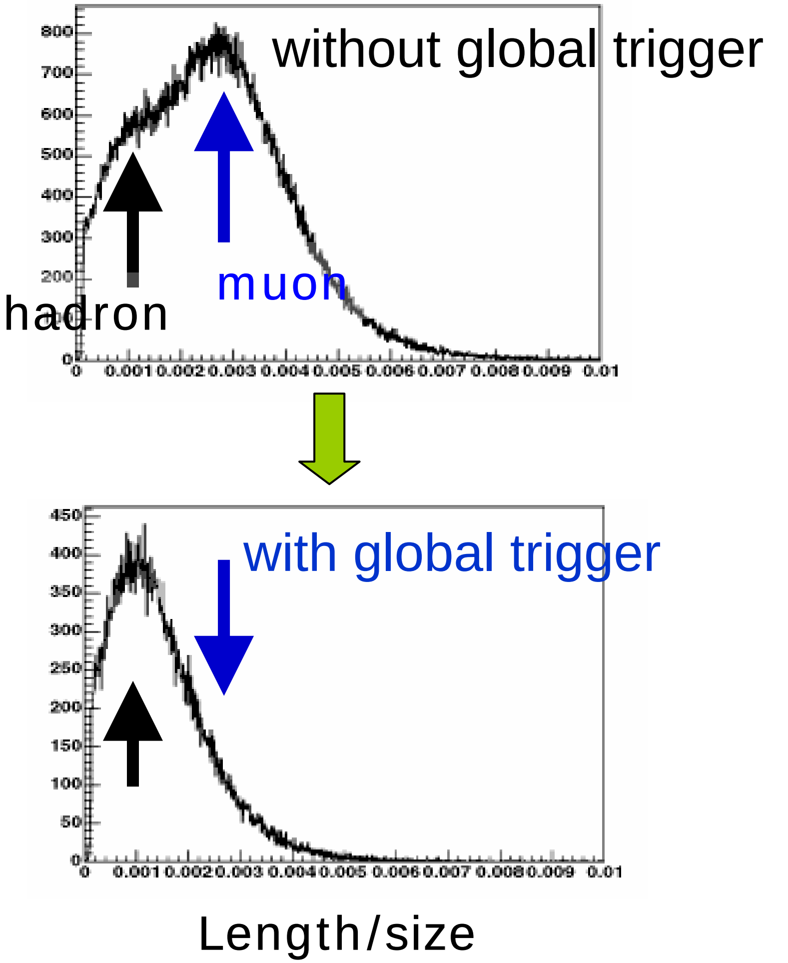


$\Delta t = d/c$ < 500ns
variable



Effect of global triggers



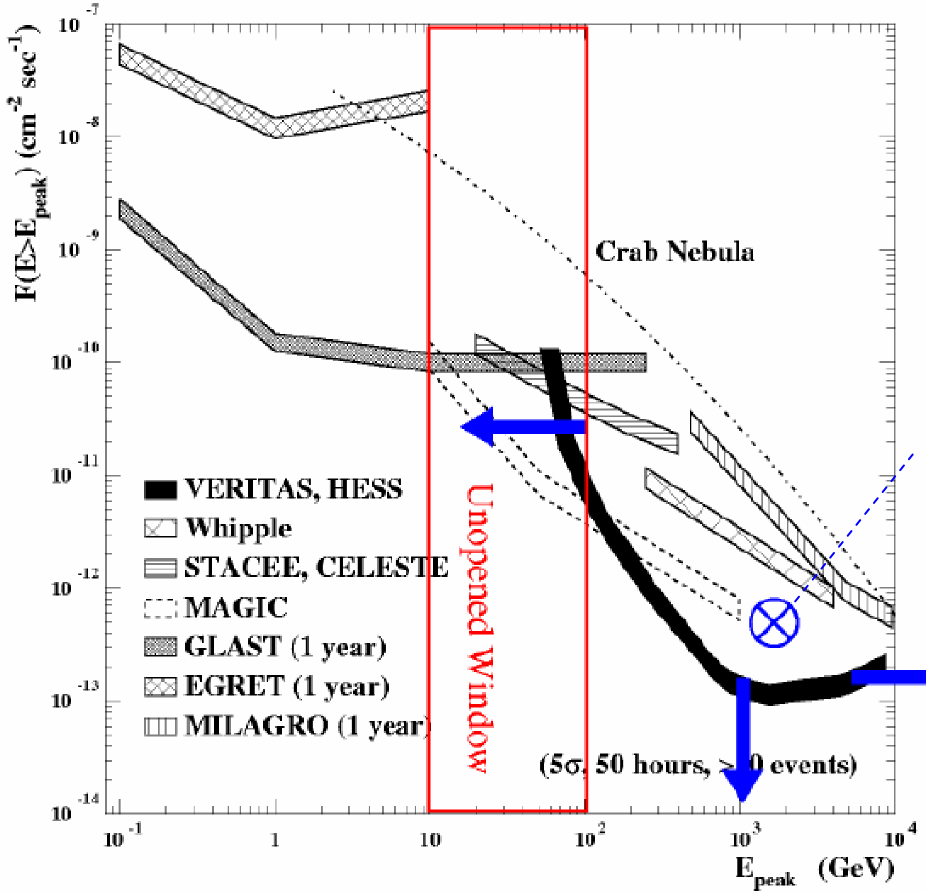


Muon events are removed!

Beyond CANGAROO-III

- In the near future
  - Improvement of old T1 and others
- In the long range
  - No unified plan yet…
  - Started brainstorming, technical and physical considerations…

Where should we go?



Lower Energy

Large reflector/ high altitude

Wider coverage

Wide FOV camera

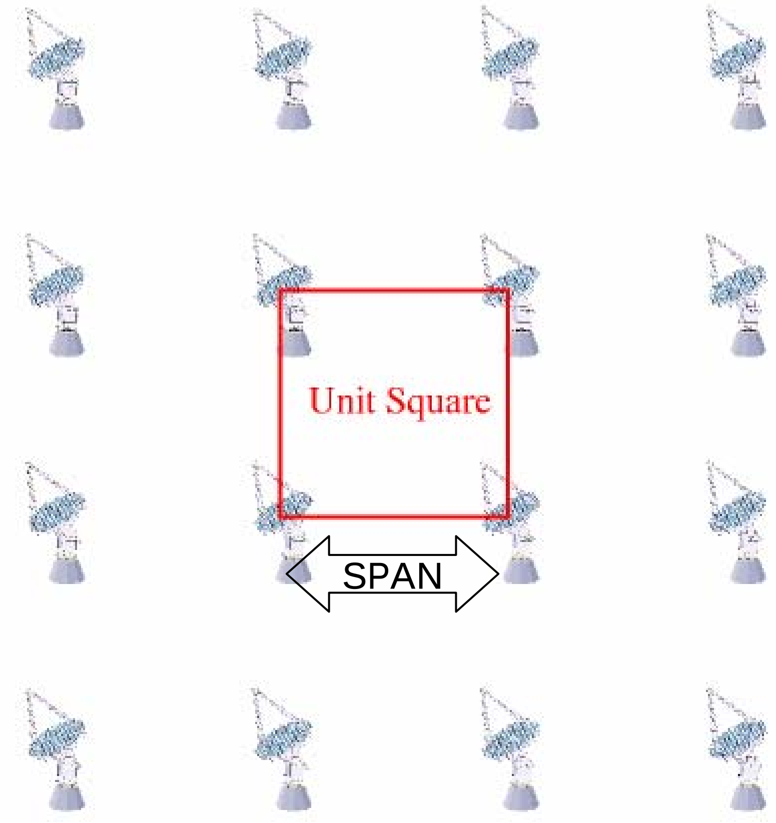
Higher Energy

Higher sensitivity

Large effective area

A case study: array of telescopes

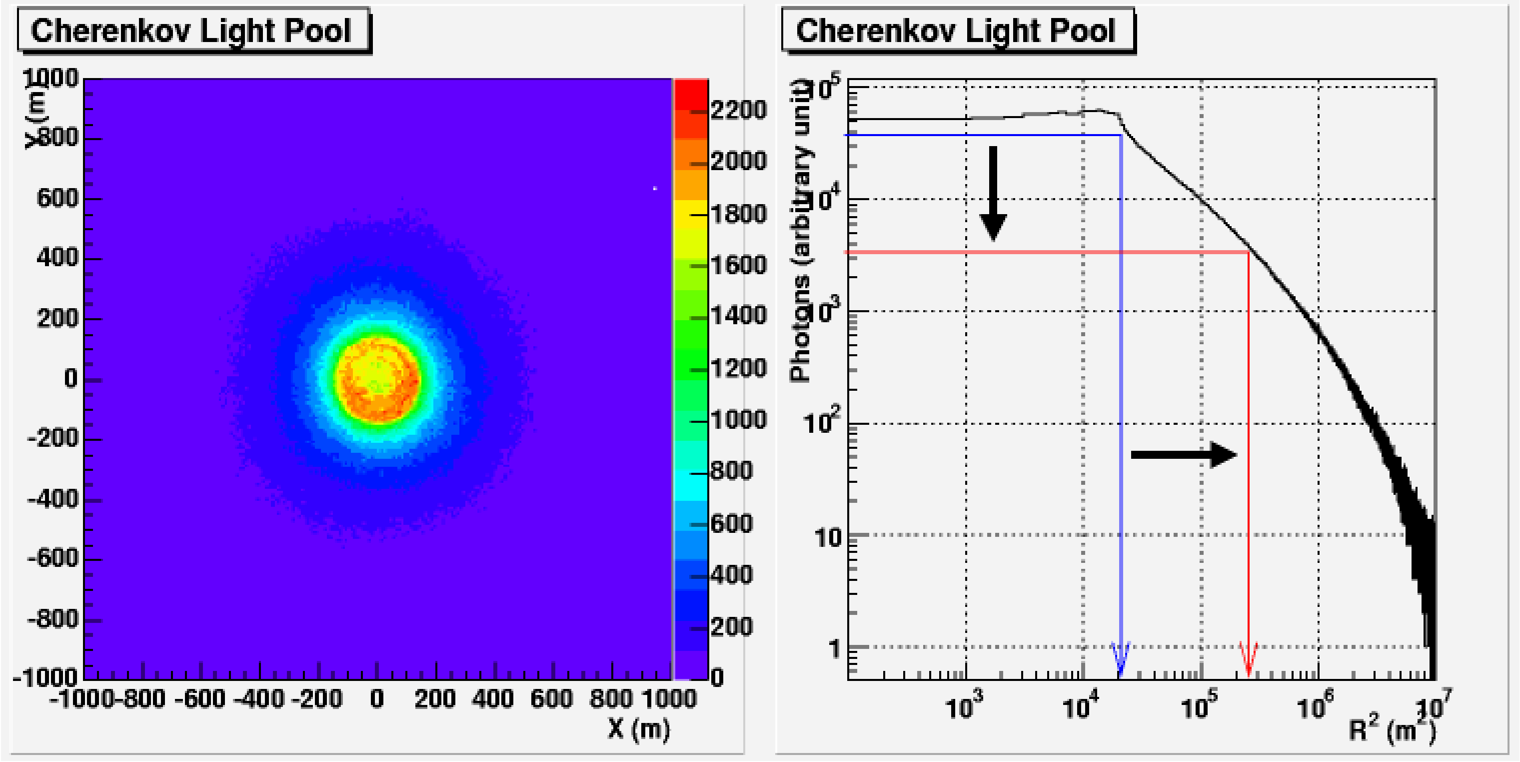
- How to achieve large effective area in modest cost?
- Large span array with wide cameras?



Yoshikoshi et al. Paleiseau WS (2005)

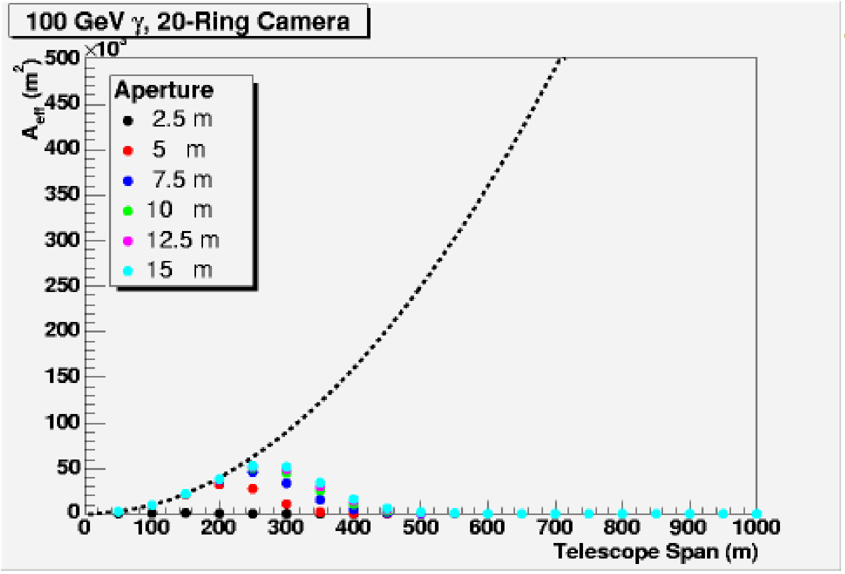
Lateral distribution of light

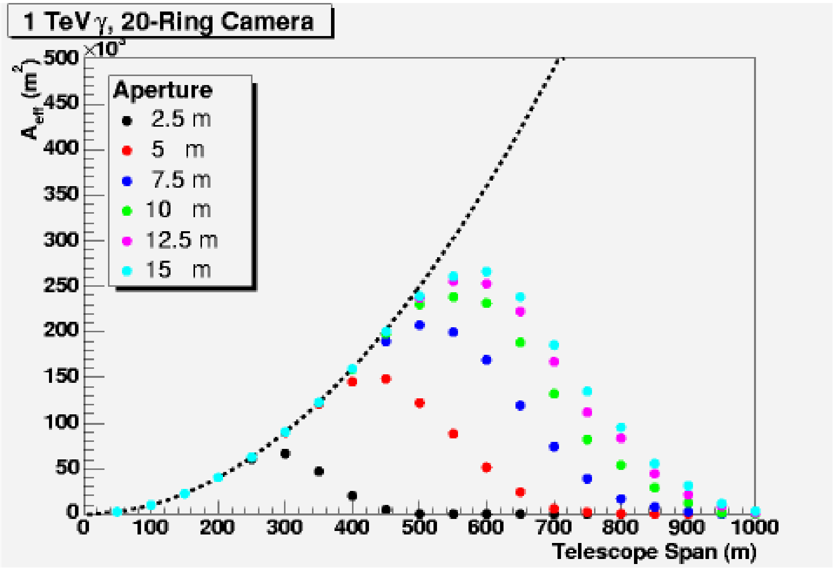
- Tail is extended beyond 150m!

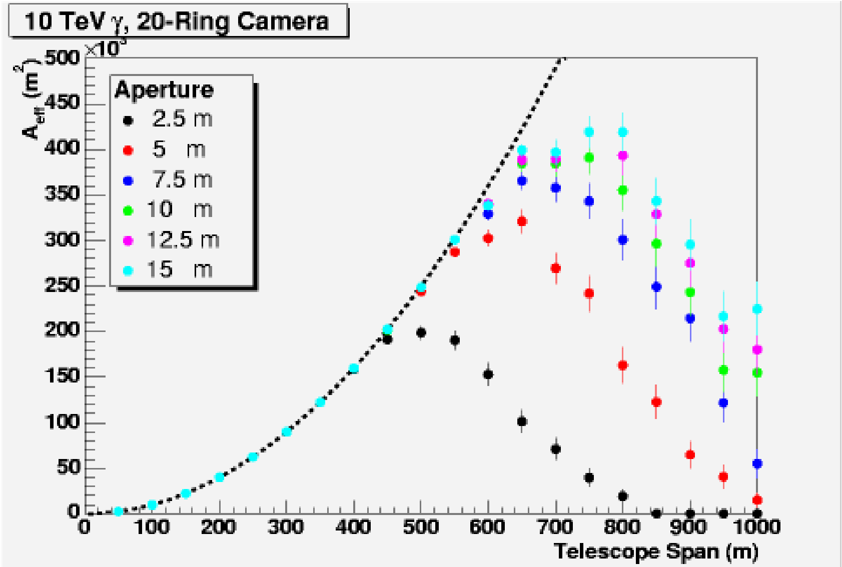


Array span vs. effective area

- 6° FOV camera
- Gamma-ray energy: 100 GeV, 1 TeV, 10 TeV







Summary

- CANGAROO-III is a system of 10m imaging Cherenkov telescope build by Japanese-Australian collaboration.
- We have been carrying out 4-telescope stereo observations of sub-TeV gamma-rays since 2004 March. Now we have incorporated a global trigger system to reduce muons.
- We are studying the next-generation telescopes. One option could be a large-span array of telescopes to increase the effective area.