Tibet実験(現状と将来)

瀧田正人　ICRR

(For Tibet As γ collaboration)

宇宙線研究所シンポジウム

「法人化後の宇宙線研究所研究プロジェクトについて」

@ICRR　01/02/2003

Collaborators

The Tibet AS γ Collaboration

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17 Shonan Institute of Technology, Fujisawa 251-8511, Japan
18 Solar-Terrestrial Environment Laboratory, Nagoya University, Nagoya 464-8601, Japan

Our site : Tibet

Yangbajing , Tibet, China

90˚ 53**E**, 30˚ 11**N**, 4,300 m a.s.l. (606g/cm^2)

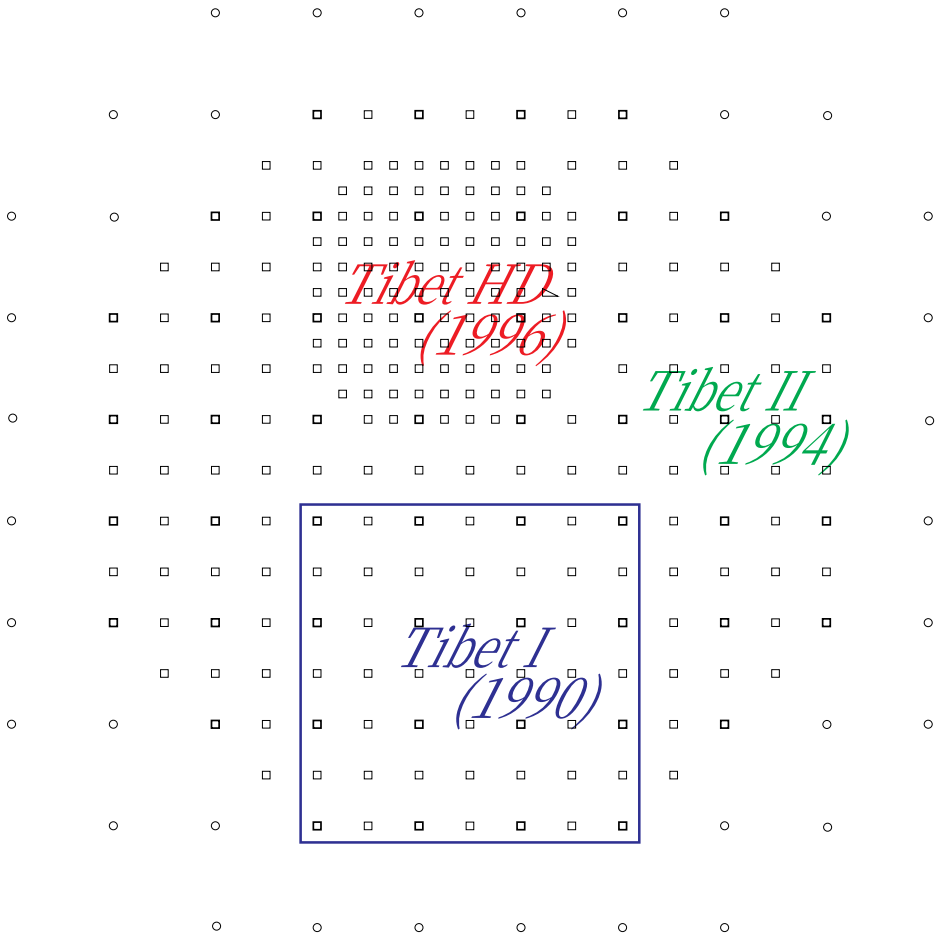
研究目的

大気チェレンコフ望遠鏡と相補的な
広視野（約2sr）連続観測高エネルギー宇宙線望遠鏡

3～100TeVの高エネルギーガンマ線放射天体の探索、10^{14}～10^{17}eVの一次宇宙線の観測から、宇宙線の起源、加速機構の研究を行う。

太陽活動期における“太陽の影”（太陽による宇宙線の遮蔽効果）を観測し、太陽近傍および惑星間磁場の大局的構造を知る。

Tibet-I to Tibet-II/HD



Number of detector

I : 45

II : 185

HD: 109

Mode Energy

I : 10 TeV

II : 10 TeV

HD: 3 TeV

Area

I : 7 ,650 m^2

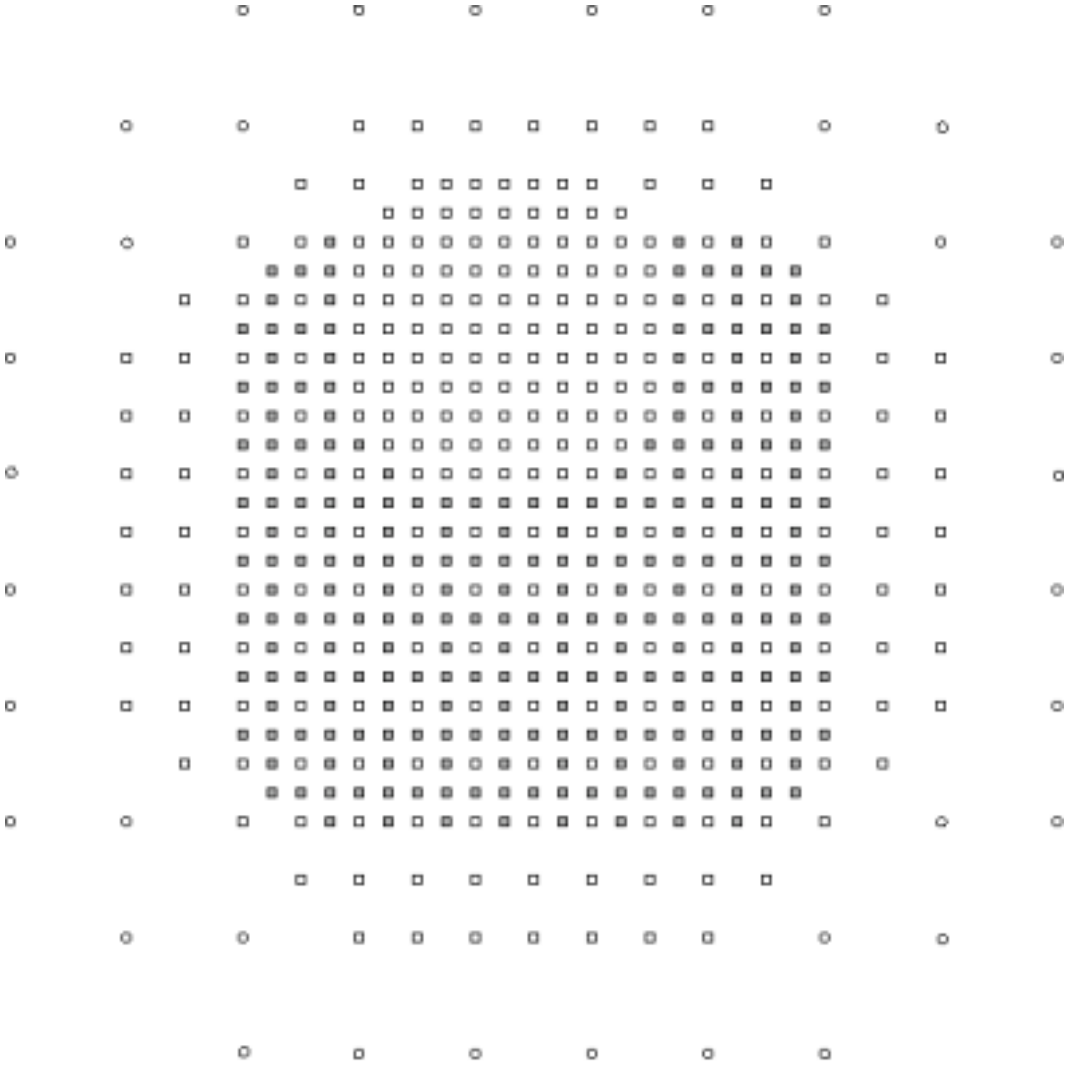
II : 37,000 m^2

HD: 5,200 m^2

Tibet III (22000m^2)

Yangbajing (4300a.s.l.=606g/cm^2), Tibet, China

Tibet III (22000m^2)



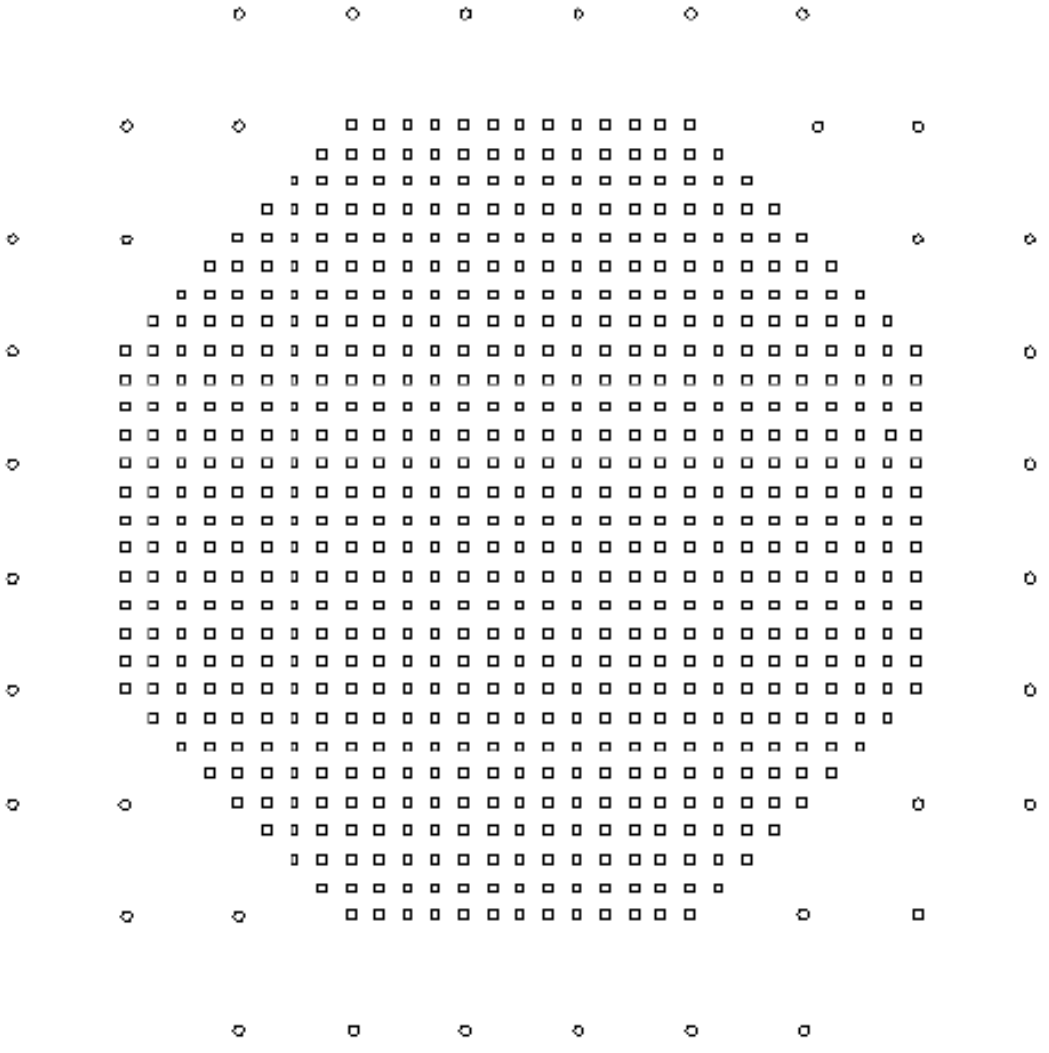
Total 545 detectors
Mode Energy
~ 3 TeV
Angular Resolution
~ 0.9 deg@3TeV
Trigger Rate
~680 Hz
Data size
~20GB/day

Operation
1999 October-
2002 September

Tibet III (37000m^2)

Yangbajing (4300a.s.l.=606g/cm^2), Tibet, China

Tibet-III (37000m^2)



Total 733 detectors

Mode Energy

~3 TeV

Angular Resolution

~0.9 deg @3TeV

Trigger Rate

~1500 Hz

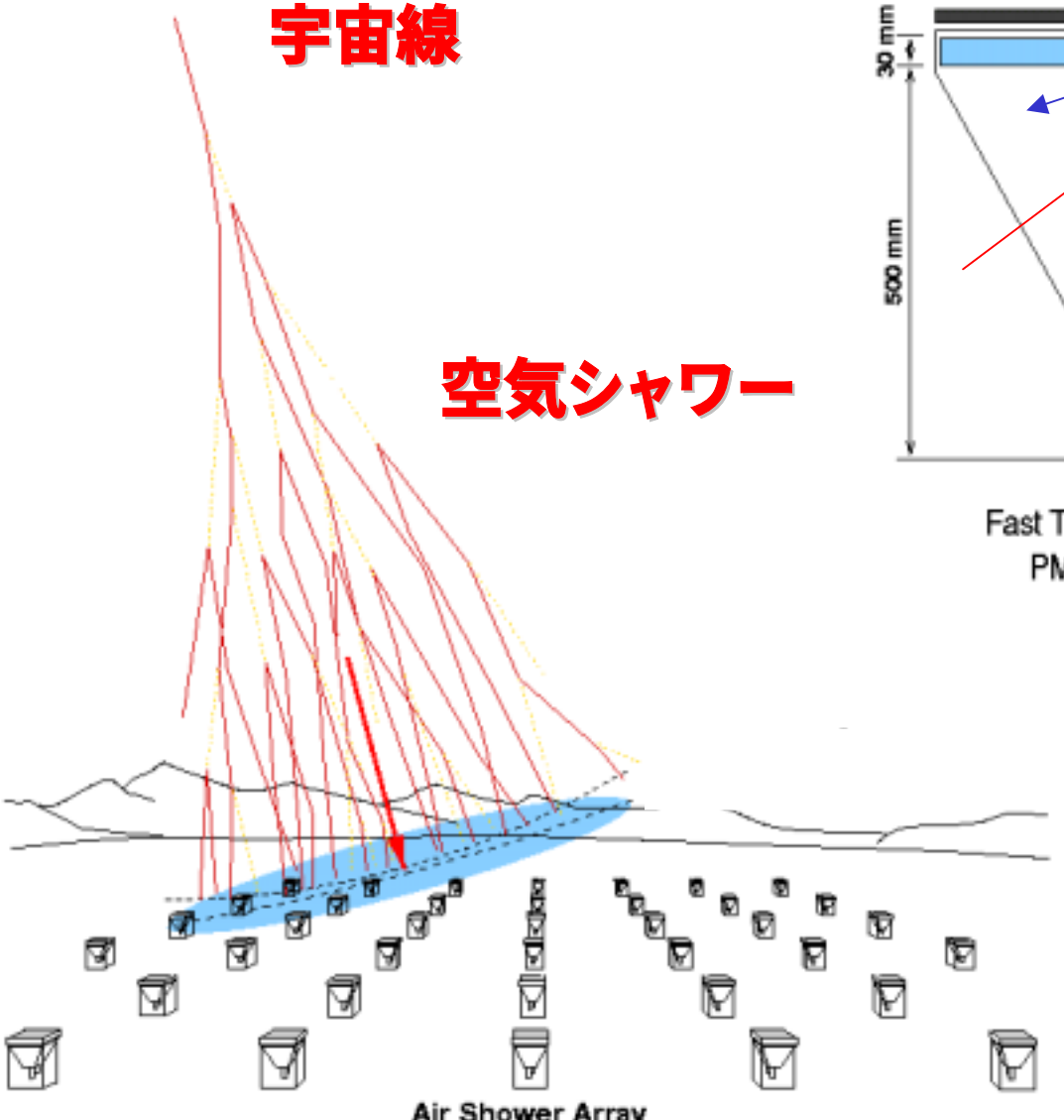
Operation

November 2002 ~

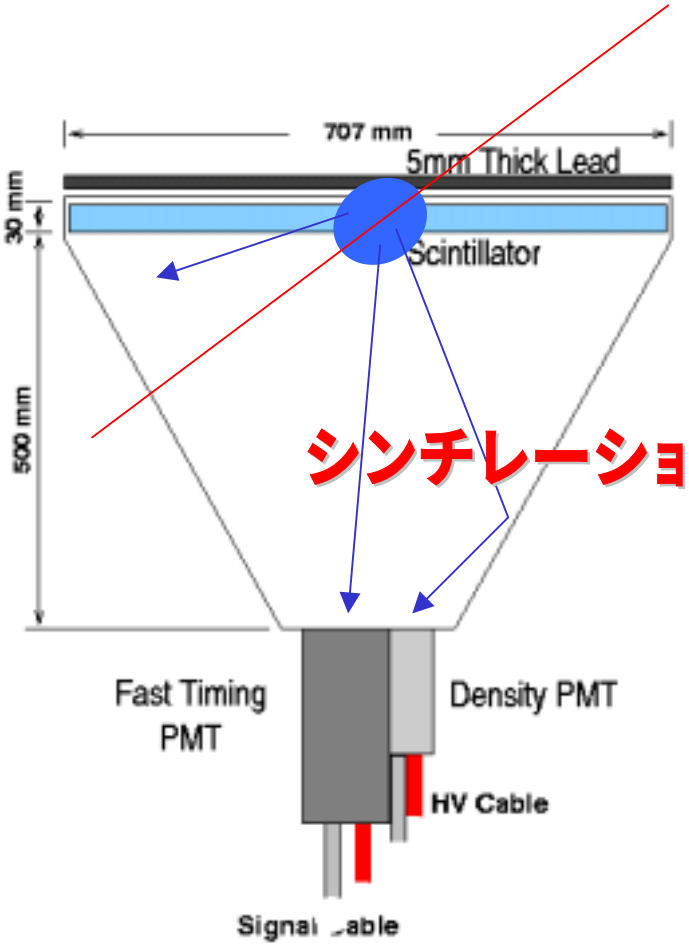
検出方法

宇宙線

空気シャワー



シンチレーション光

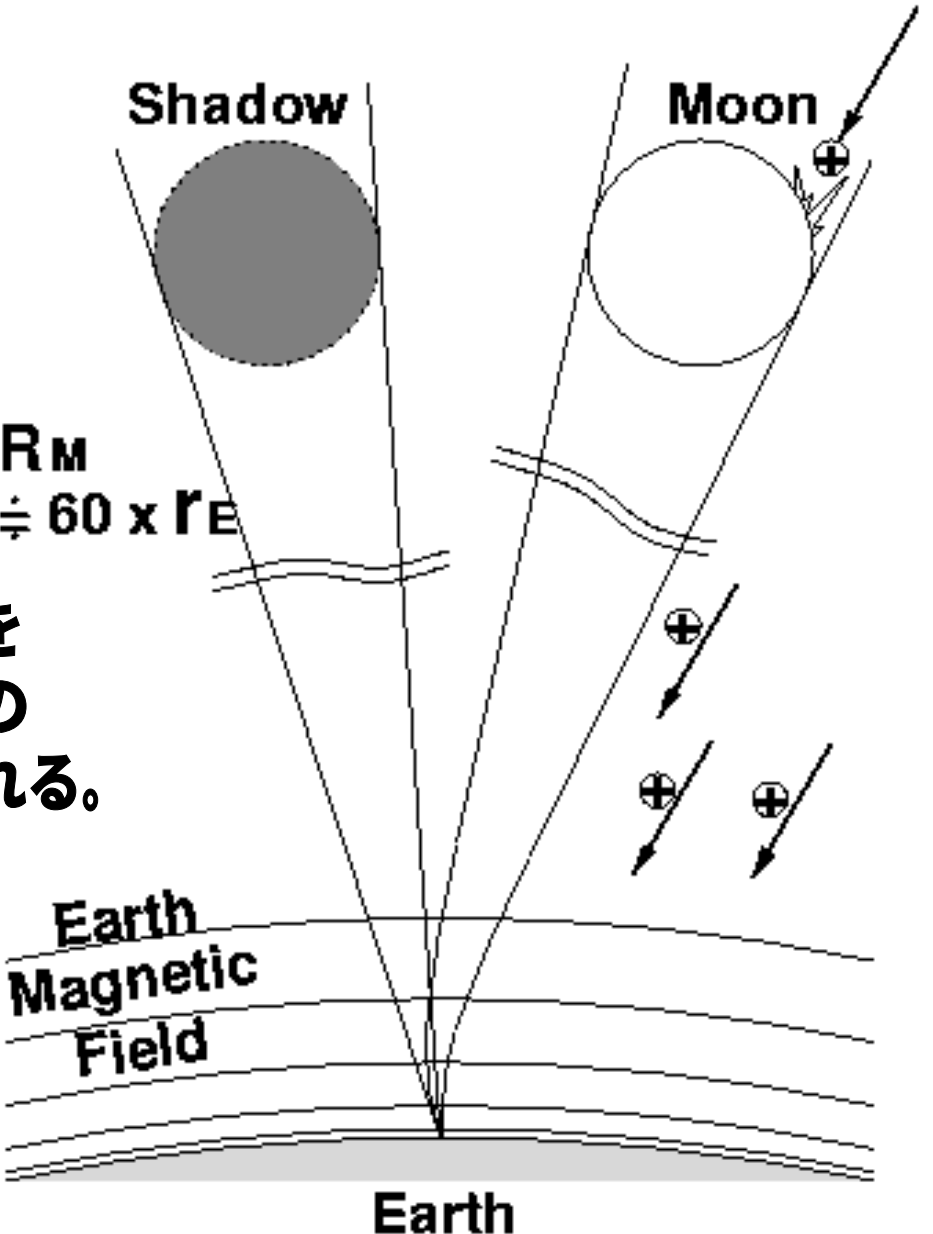


性能評価　月の影

地球に到来する宇宙線は
月によって遮蔽されるため、
ある程度の角度分解能を
備えた装置で観測すると
その方向に“へこみ”がみられる。

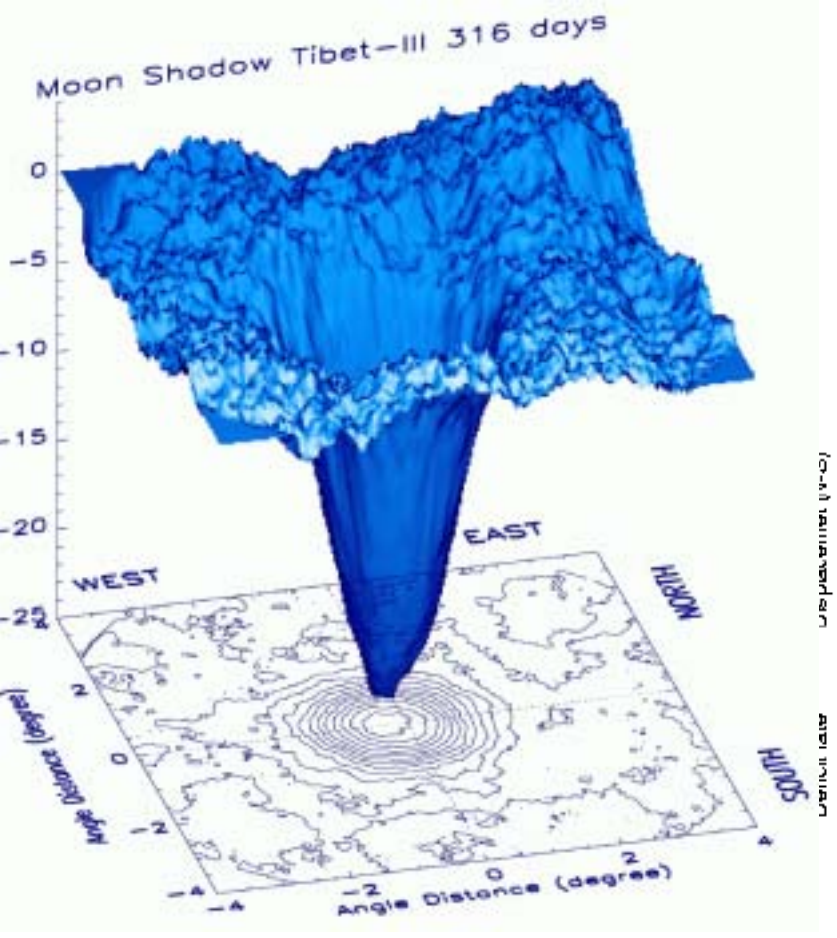
ほとんどの宇宙線は陽子などの
荷電粒子のため、地磁気の影響を
受け曲がるため“へこみ”は実際の
月の方向からは“ずれ”て観測される。

この“へこみ”と“ずれ”から
装置の性能評価が可能になる。



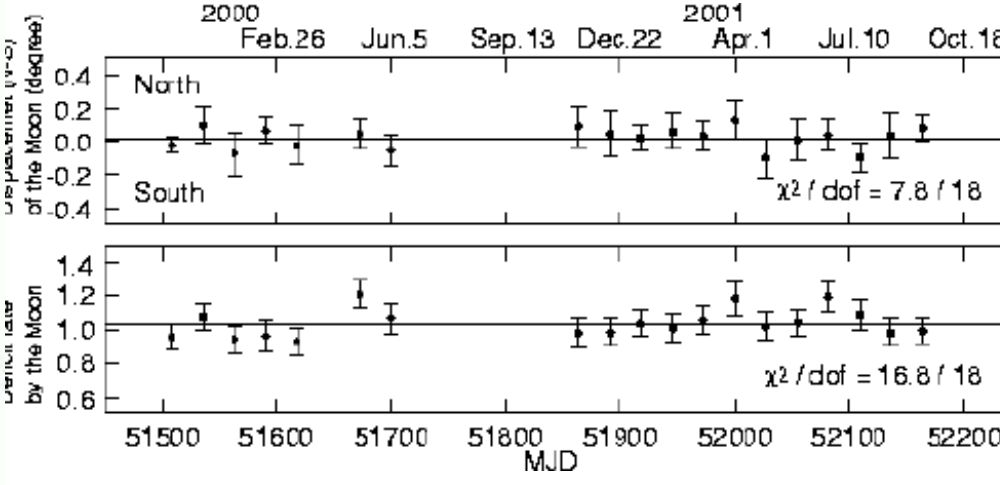
How to point? (**Airshower** detector)

Moon's shadow in Cosmic Rays



North-South Displacement (geomagnetic field free):

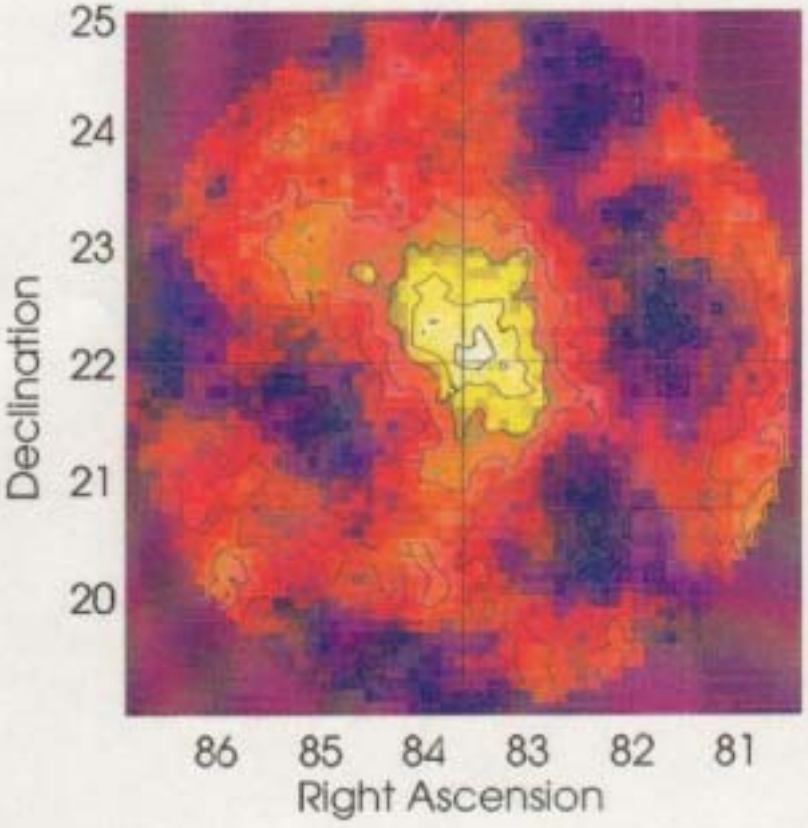
Pointing Accuracy <0.02deg (Tibet)



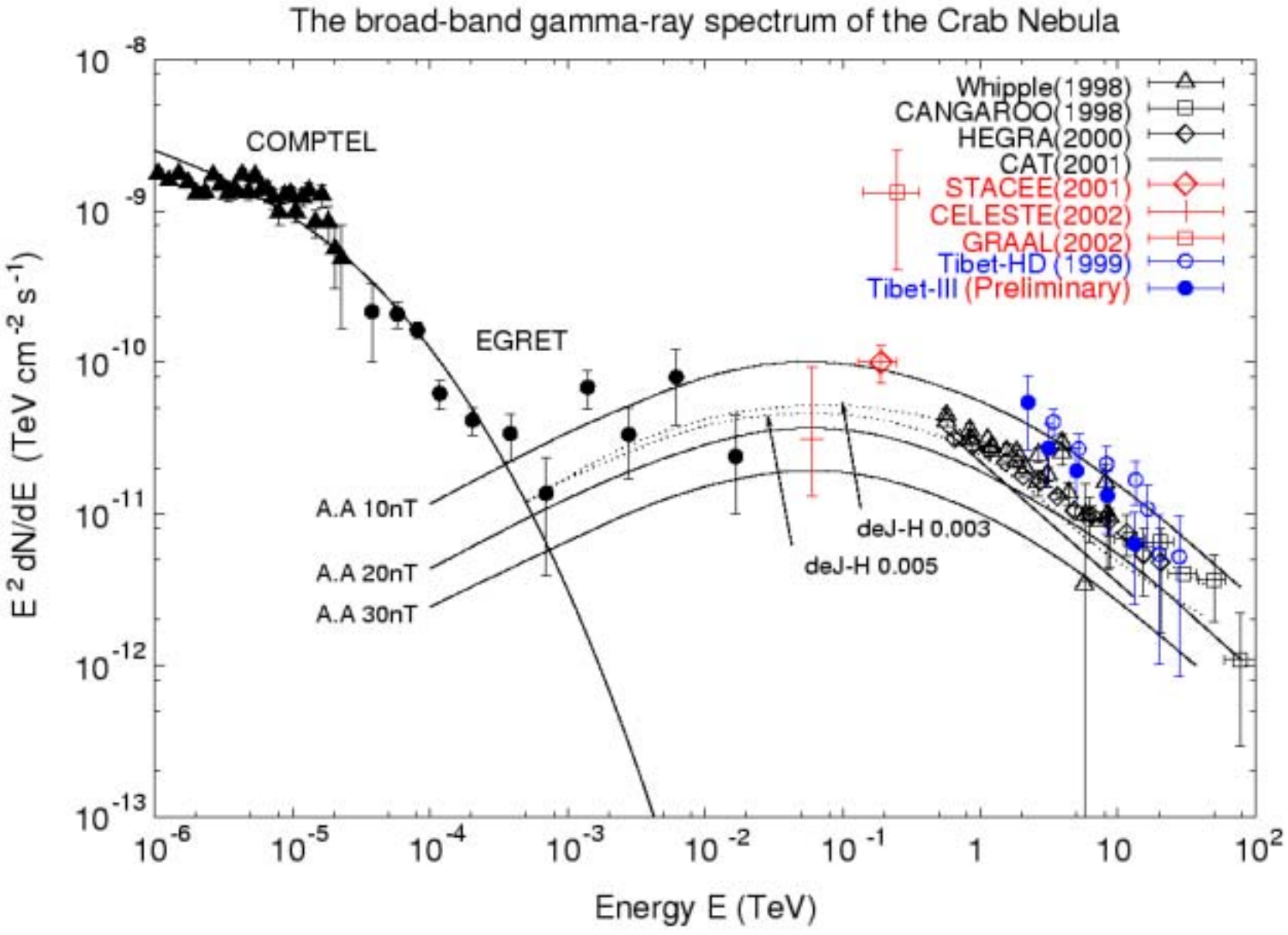
Crab

Tibet-II HD (1999年)
~500 day

5.5σ excess
First γ source observed
by Air shower array.



Crab γ unpulsed



Tibet-II HD Mrk 501
(1997年)
3.7σ excess

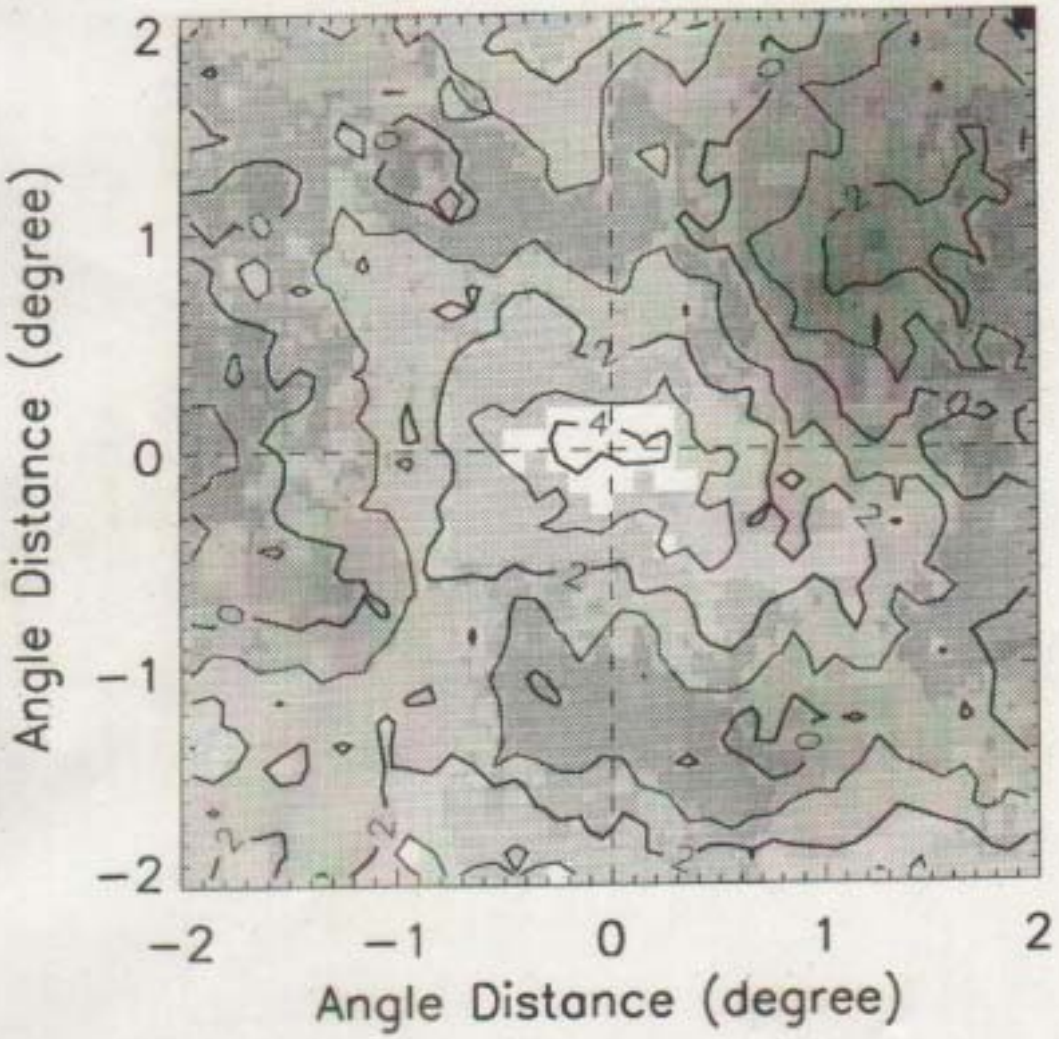
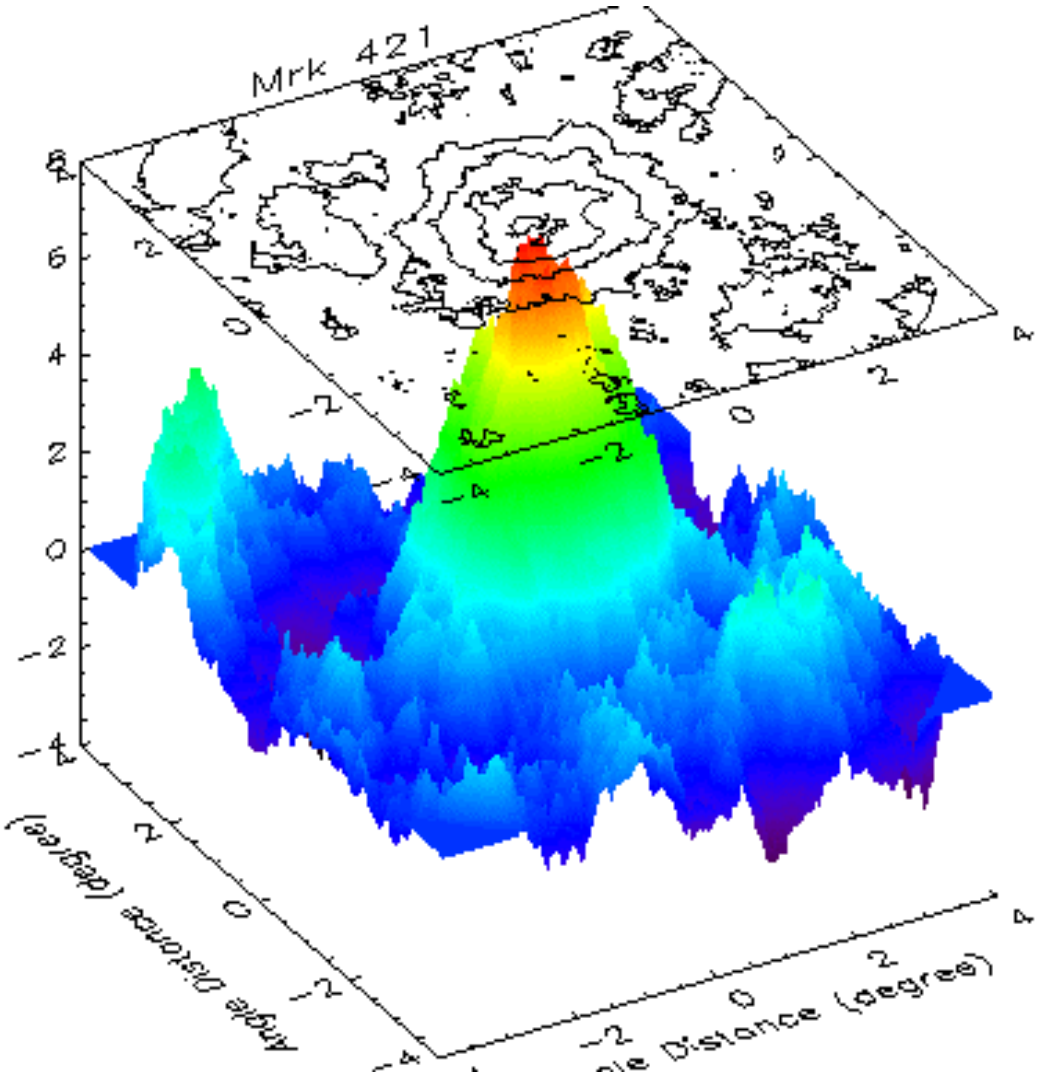


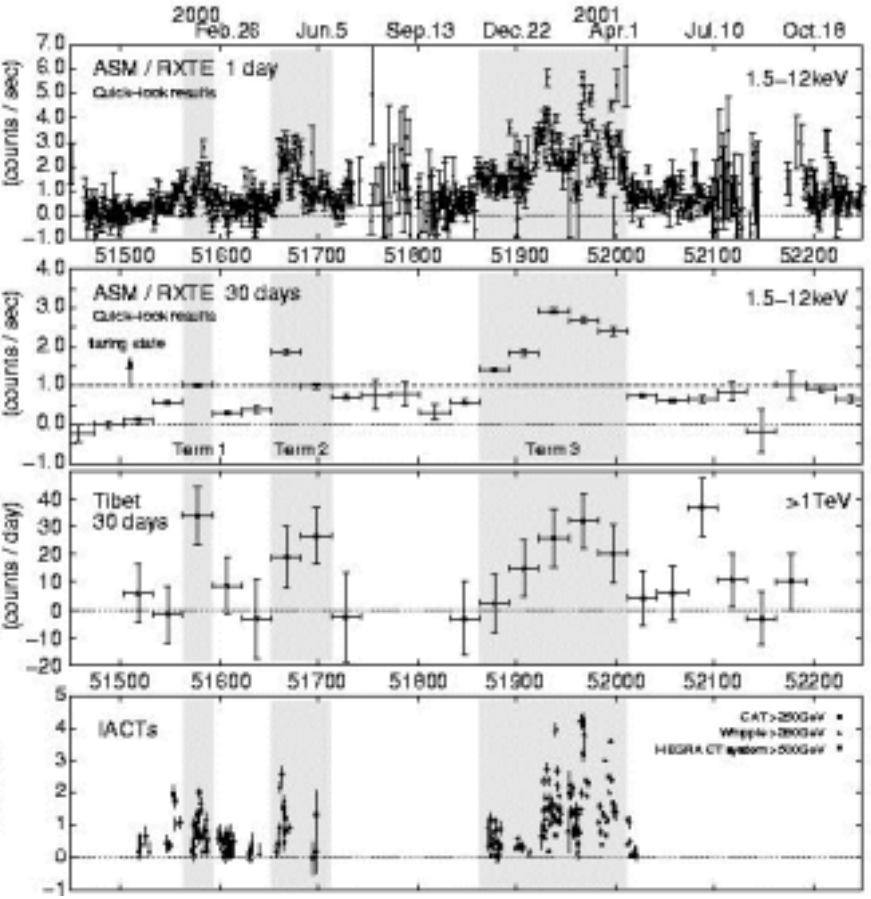
FIG. 4.—Contour map of the weights of excess event densities around Mrk 501, observed between 1997 April 7 and 1997 June 16, in an area of 4° × 4° centered on the direction of Mrk 501. The contour lines are drawn with a step of 1 σ. Angle distance is measured from the direction of Mrk 501 along the right ascension (*abscissa*) and the declination (*ordinate*).

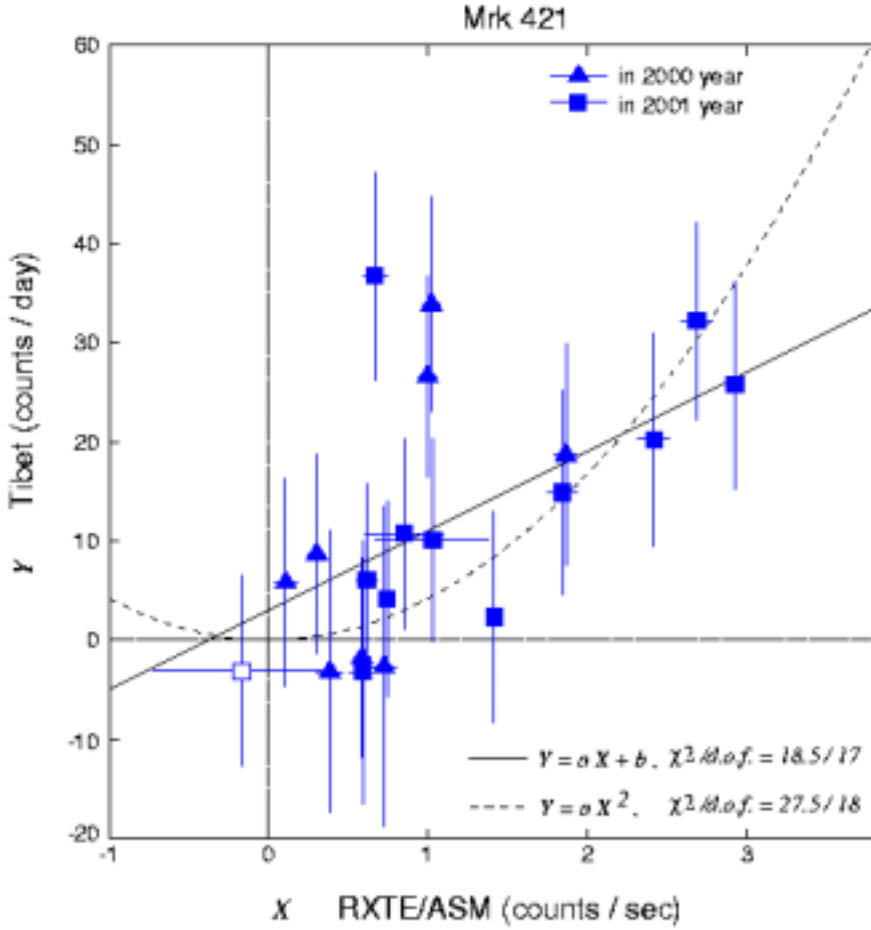
Flare γ from Mrk421 (2000-2001)

Tibet-III (22000m^2)



Mrk421 X線データとTeV γデータの長期相関

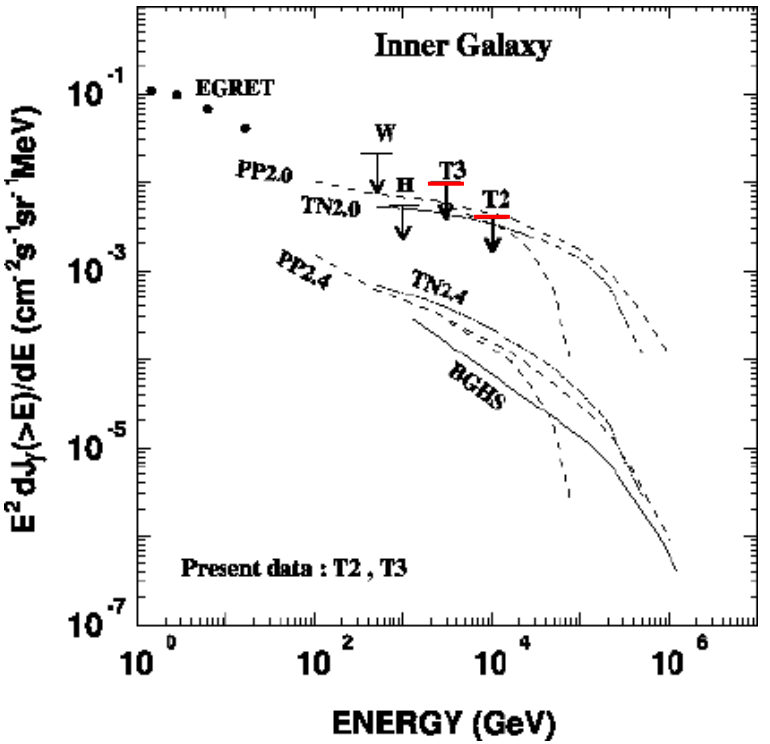




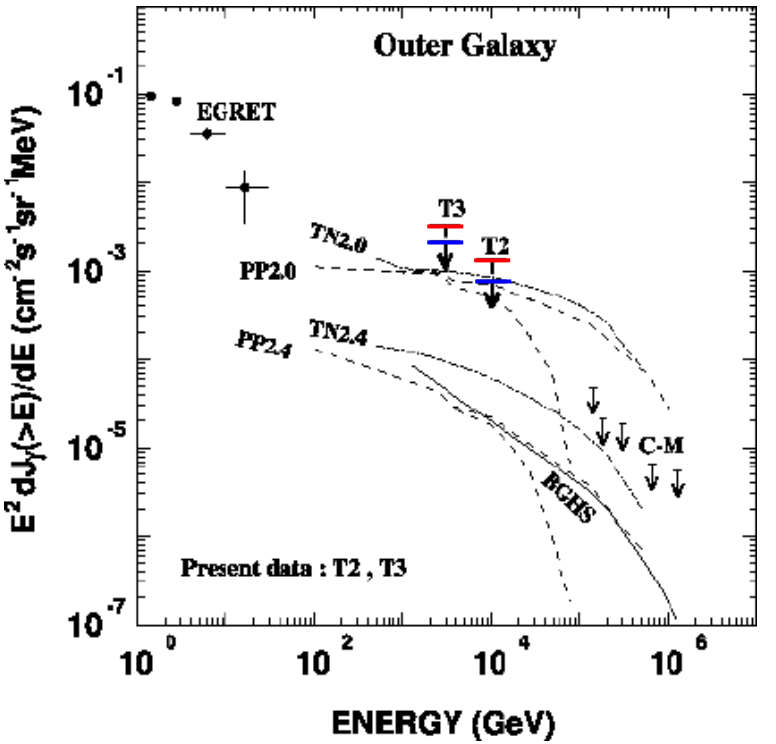
Draft under circulation among Tibet group

Upper limits on galactic diffuse γ rays

Inner galaxy

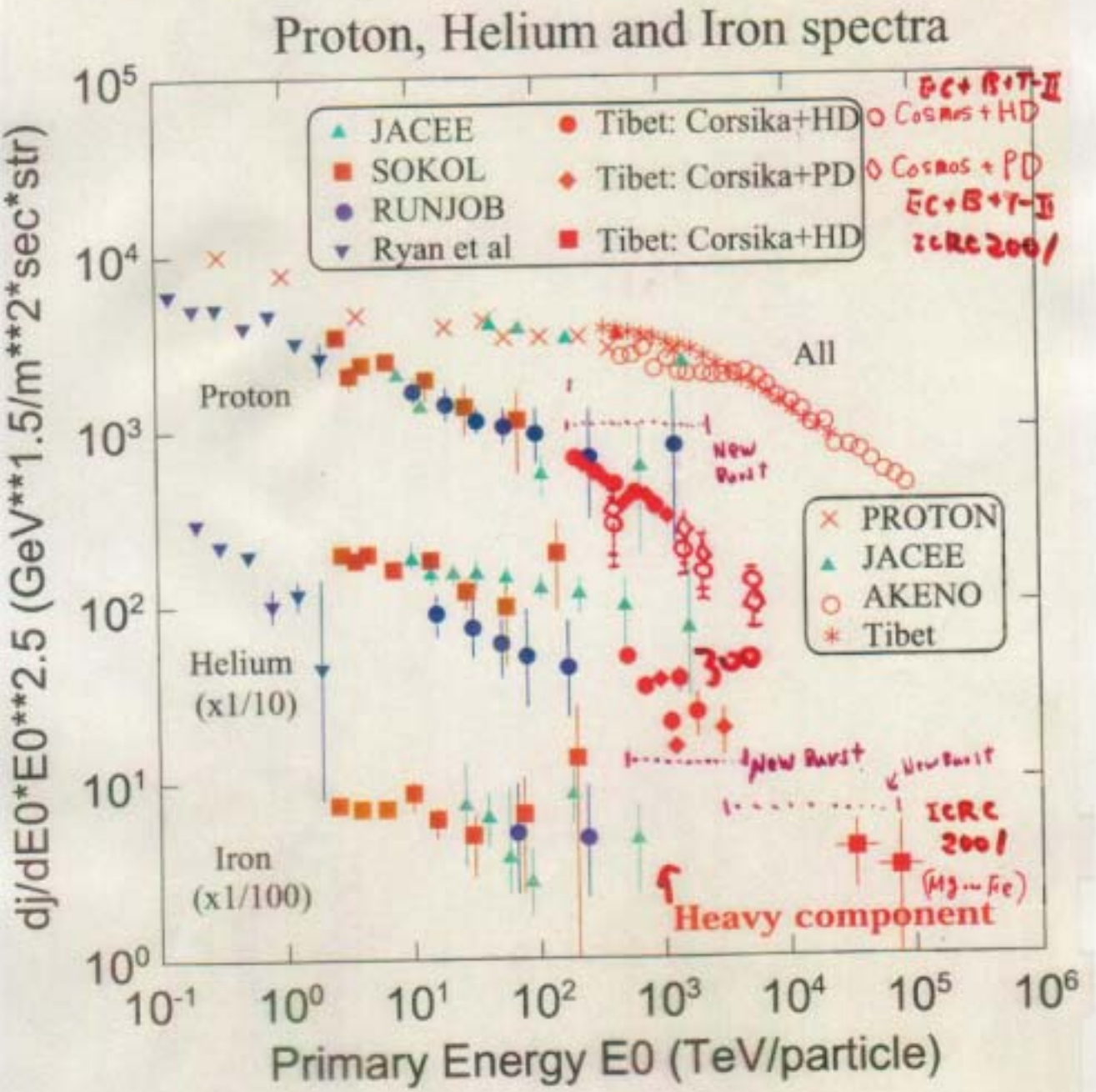


Outer galaxy



Red:99%CL, Blue:90%CL

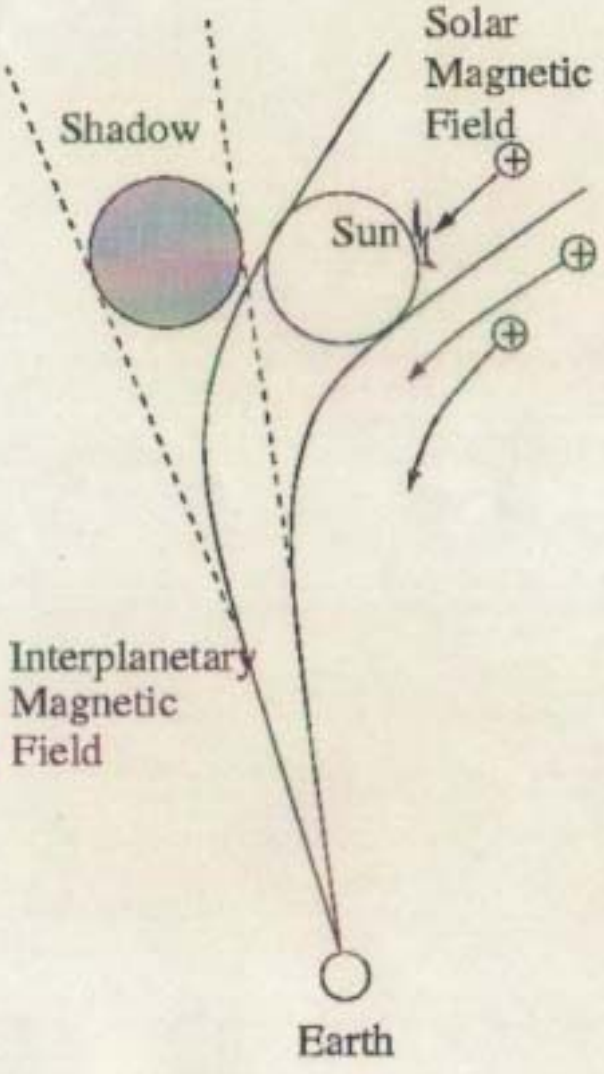
Published in ApJ, 580, Dec01,2002

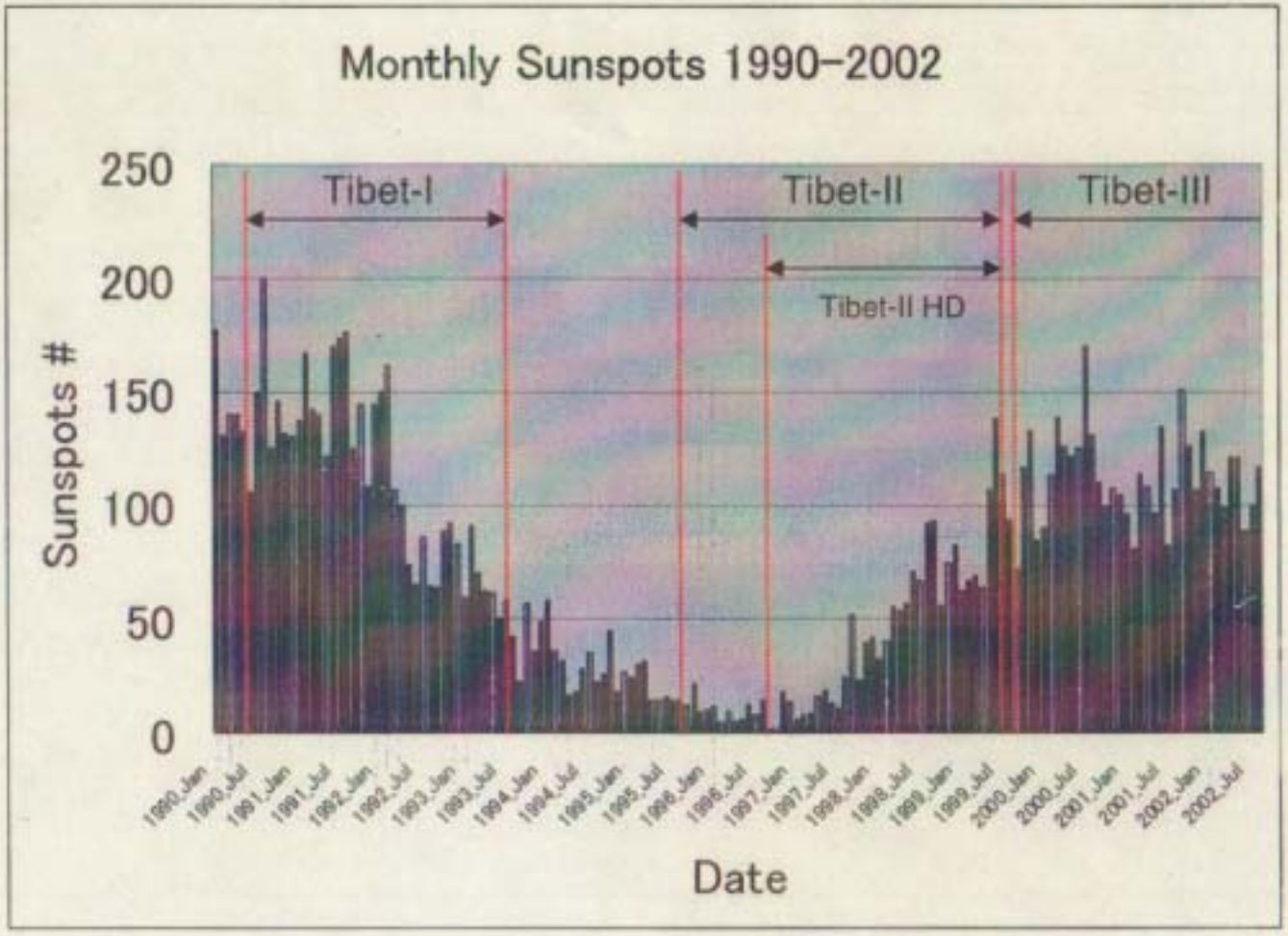

Proton, Helium and Iron spectra
JACEE
SOKOL
RUNJOB
Ryan et al
Tibet: Corsika+HD
Tibet: Corsika+PD
Tibet: Corsika+HD
Cosmos + HD
Cosmos + PD
All
Proton
Helium
(x1/10)
Iron
(x1/100)
PROTON
JACEE
AKENO
Tibet
New Burst
ICRC 2001
Heavy component
dj/dE0*E0**2.5 (GeV**1.5/m**2*sec*str)
Primary Energy E0 (TeV/particle)

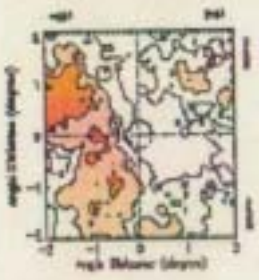
惑星間磁場　太陽の影

宇宙線は太陽によって遮蔽される。
正電荷をもった宇宙線は
太陽磁場、惑星間磁場によって
曲げられ、観測される“へこみ”は
磁場の変動によって“移動”する。

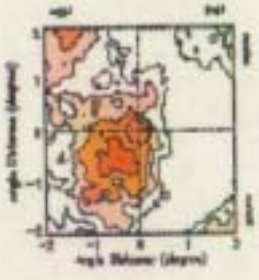
太陽活動は11年周期で極大期を迎え、
磁場の変動も活発になる。
この“へこみ”の“移動”を観測すること
によって、太陽磁気圏の大局的磁場構造
を知ることができる。



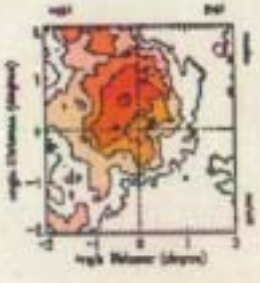

Monthly Sunspots 1990-2002
Tibet-I
Tibet-II
Tibet-III
Tibet-II HD
Sunspots #
250
200
150
100
50
0
Date



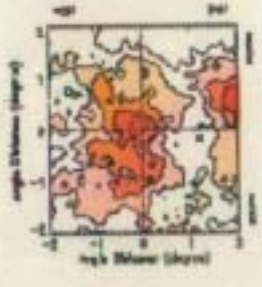
1990 (Tibet-I)



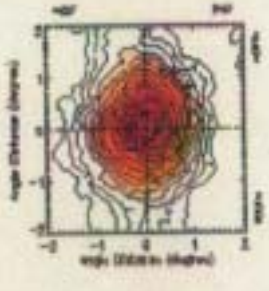
1991 (Tibet-I)



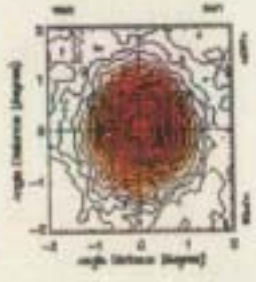
1992 (Tibet-I)



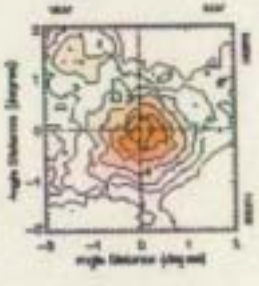
1993 (Tibet-I)



1996 (Tibet-II)

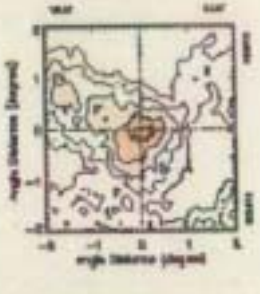


1997 (Tibet-II)

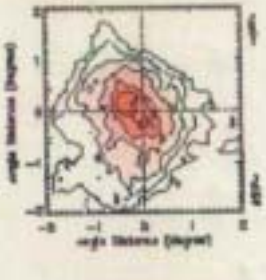


1998 (Tibet-II)

1999 (Tibet-II)



2000 (Tibet-III)



2001 (Tibet-III)

10TeV以上の宇宙線が作る太陽の影の年変化。
2002年データは現在解析中。

The Tibet AS gamma Collaboration Publication List (03/01/2003)

Diffuse

1 Observation of multi-TeV diffuse gamma rays from the Galactic plane with the Tibet air shower array
ApJ, 580, 887-895 (2002) T-II + T-III (22000 m²)

Primary

2 Primary proton spectrum between 200 TeV and 1000 TeV observed with the Tibet burst detector and air shower array
Phys. Rev. D, 62, 112002 (2000) T-II + Burst

Primary

3 Measurement of air shower cores to study the cosmic ray composition in the knee energy region
Phys. Rev. D, 62, 072007 (2000) T-II + Burst

⊙

4 A Study of the Shadowing of Galactic Cosmic Rays by the Sun in a Quiet Phase ofSolar Activity with the Tibet Air Shower Array
The Astrophysical Journal, 541, 1051-1058 (2000) T-II

Mrk501

5 Detection of Multi-TeV Gamma Rays from Markarian 501 During an Unforeseen Flaring State in 1997 with the Tibet Air Shower Array
ApJ, 532, 302-307 (2000) T-II HD

Crab

6 Observation of Multi-TeV Gamma Rays from the Crab Nebula using the Tibet Air Shower Array
ApJ, 525, L93-L96 (1999) T-II HD

⊙

7 Shadowing of Cosmic Rays by the Sun Near Maximun or at the Declining Phase of Solar Activity
ApJ, 464, 954-958 (1996) T-I

Primary

8 The Cosmic Ray Energy Spectrum between 10^14.5 and 10^16.3 eV covering the "Knee" Region
ApJ, 461, 408-414 (1996) T-I

9 Search for 10 TeV Burst-Like Events Coincident with the BATSE Bursts Using the Tibet Air Shower Array
A&A, 311, 919-926 (1996) T-I

10 Search for 10 TeV Gamma-Ray Emission from Active Galactic Nuclei with the Tibet Air Shower Array
ApJ, 429, 634-637 (1994) T-I

⊙

11 Direct Evidence of the Interplanetary Magnetic Field Effect on the Cosmic-Ray Shadow by the Sun
ApJ, 415, L147-L150 (1994) T-I

DO

12 Cosmic Ray Deficit from the Directions of the Moon and the Sun Detected with the Tibet Air Shower Array
Phys. Rev., D47, 2675-2681 (1993) T-I

13 Search for Steady Emission of 10-TeV Gamma Rays from the Crab Nebula, Cygnus X-3 and Hercules X-1 Using the Tibet Air Shower Array
Phys. Rev. Lett., 69, 2468-2471 (1992) T-I

Tibet Group Related Publication List

1 Primary proton spectrum around the knee deduced from the emulsion chamber data obtained at Mts. Fuji and Kanbala
Astroparticle Physics, In press (2002)

2 Neural Network Approach to Obtain the Primary Proton Flux at the Knee from a Hybrid-Experiment of EC and AS Array in Tibet
NIM, A376, 263 (1996)

3 Intensity of Protons at the "Knee" of the Cosmic Ray Spectrum
Astrop. Phys., 1, 257-267 (1993)

4 Photodiode senced scintillation counter for detection of a large number of cascade shower electrons
NIM, A300, 202-206 (1991)

5 DEVELOPMENT AND PERFORMANCE TEST OF A PROTOTYPE AIR SHOWER ARRAY FOR SEARCH FOR GAMMA RAY POINT SOURCES IN THE VERY HIGH ENERGY REGION
NIM, A288, 619-631 (1990)

6 A MONITORING SYSTEM FOR FAST-TIMING SCINTILLATION COUNTERS USED FOR DETECTION OF AIR SHOWERS
NIM, A285, 532-539 (1989)

Forthcoming publication.

γ: Mrk 421 T-II (22000m²) draft in circulation

γ: 全天γ (DC) T-IIHD + T-II (22000m²) draft in preparation.

No significant point source.

Crab : the brightest.

Physics with Tibet-III (37000m^2)

- Primary : All particle 10^{16}-10^{17} eV
  (consistency with UHECR)
  Modulation
- **γ** : Unknown DC & AC sources
  (~0.5crab/yr@5**σ** for DC)
  Crab multi-10 TeV **γ** (IC or **π**^{0})
  Single Counter Trigger mode
  (sub100GeV GRB with GLAST)
  Long-term AGN Observation
- Sun : Solar Cycle 24
- Etc…

What's After Tibet-III

Tibet-III Grants in Aid for Scientific Research:
Until March 2005

Next Plan under Discussions

Upgrade of Burst Detectors?

Higher Density in Tibet-III?

Cherenkov Detectors?