On temporal variations of the multi-TeV cosmic ray anisotropy using Tibet Air Shower Array

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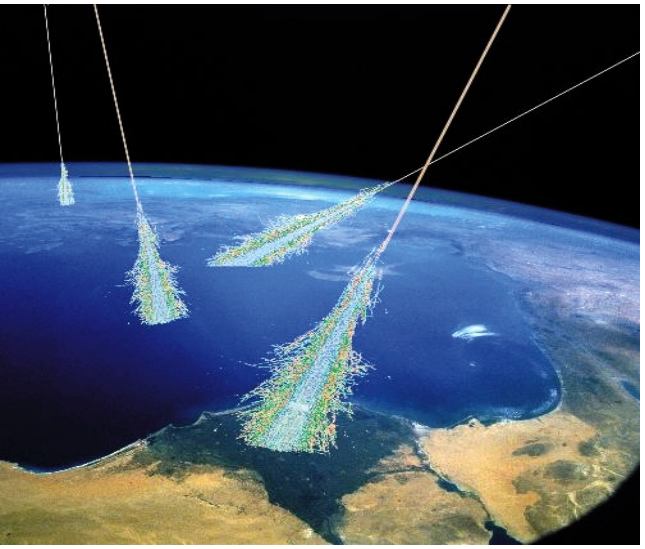
(For the Tibet ASγ Collaboration)

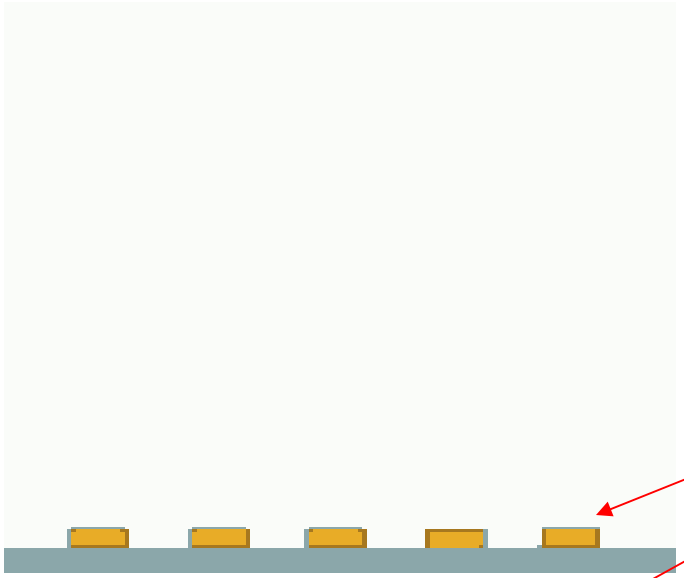
32 ICRC. Beijing'2011

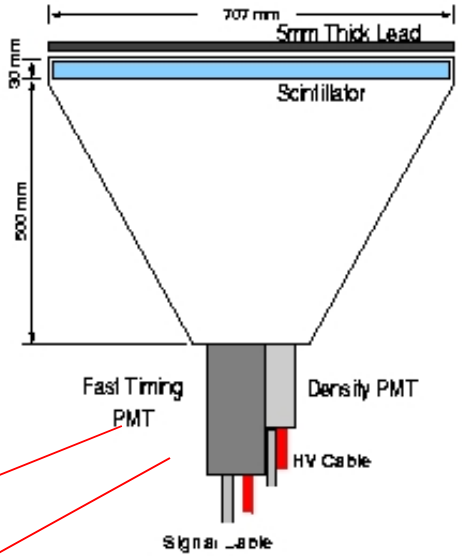
OUTLINE

- Tibet Air shower Array
- Motivation
- Analysis method
- Time evolution of the anisotropy
- Summary

Tibet Air shower Array

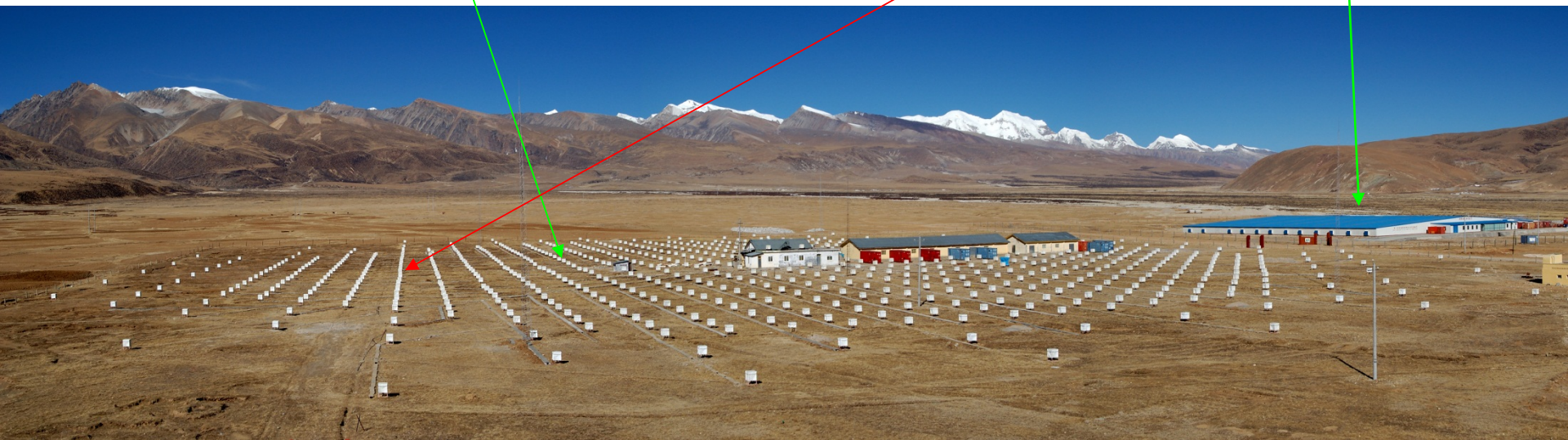




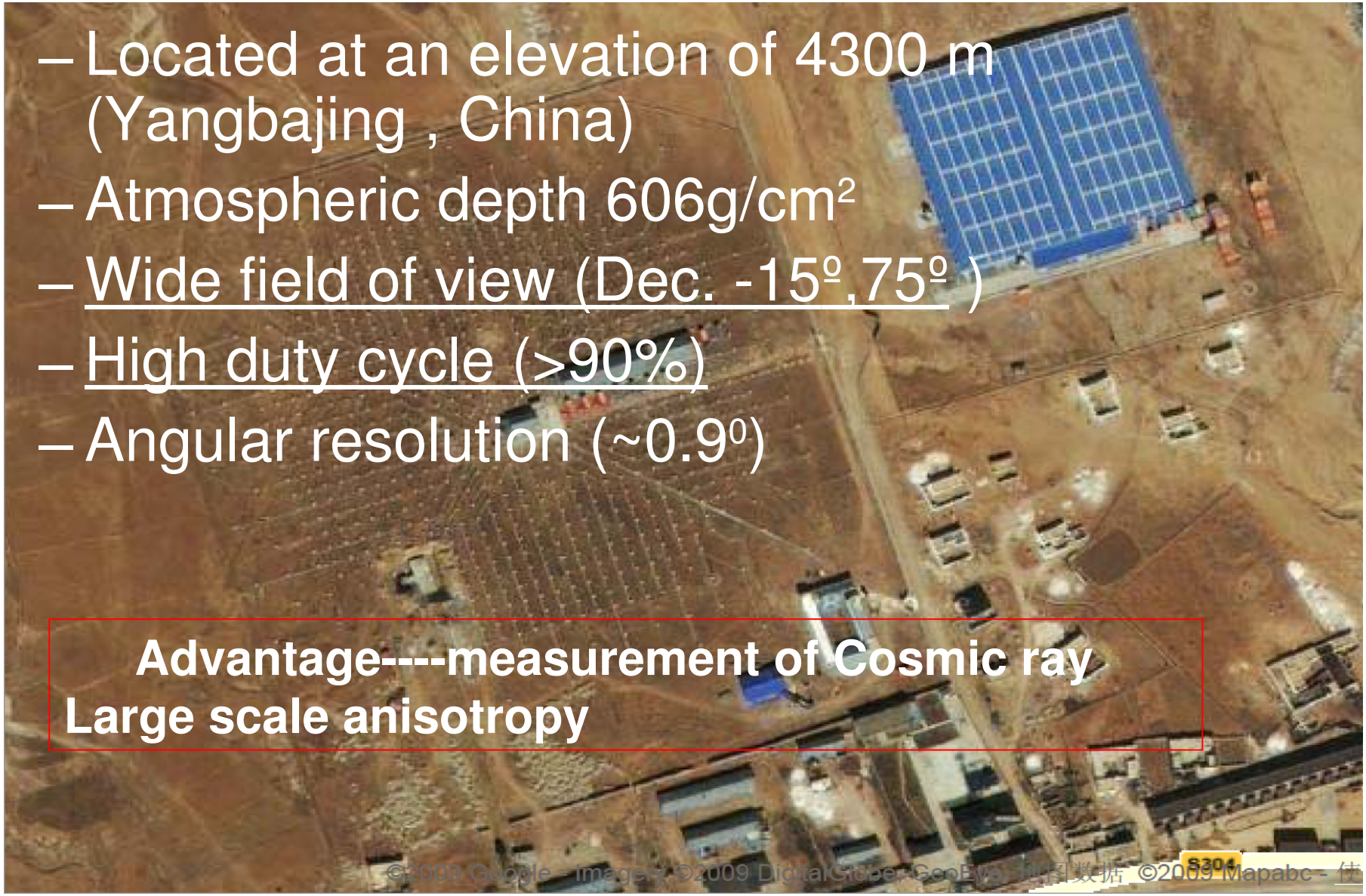


Tibet ASγ array

ARGO Hall



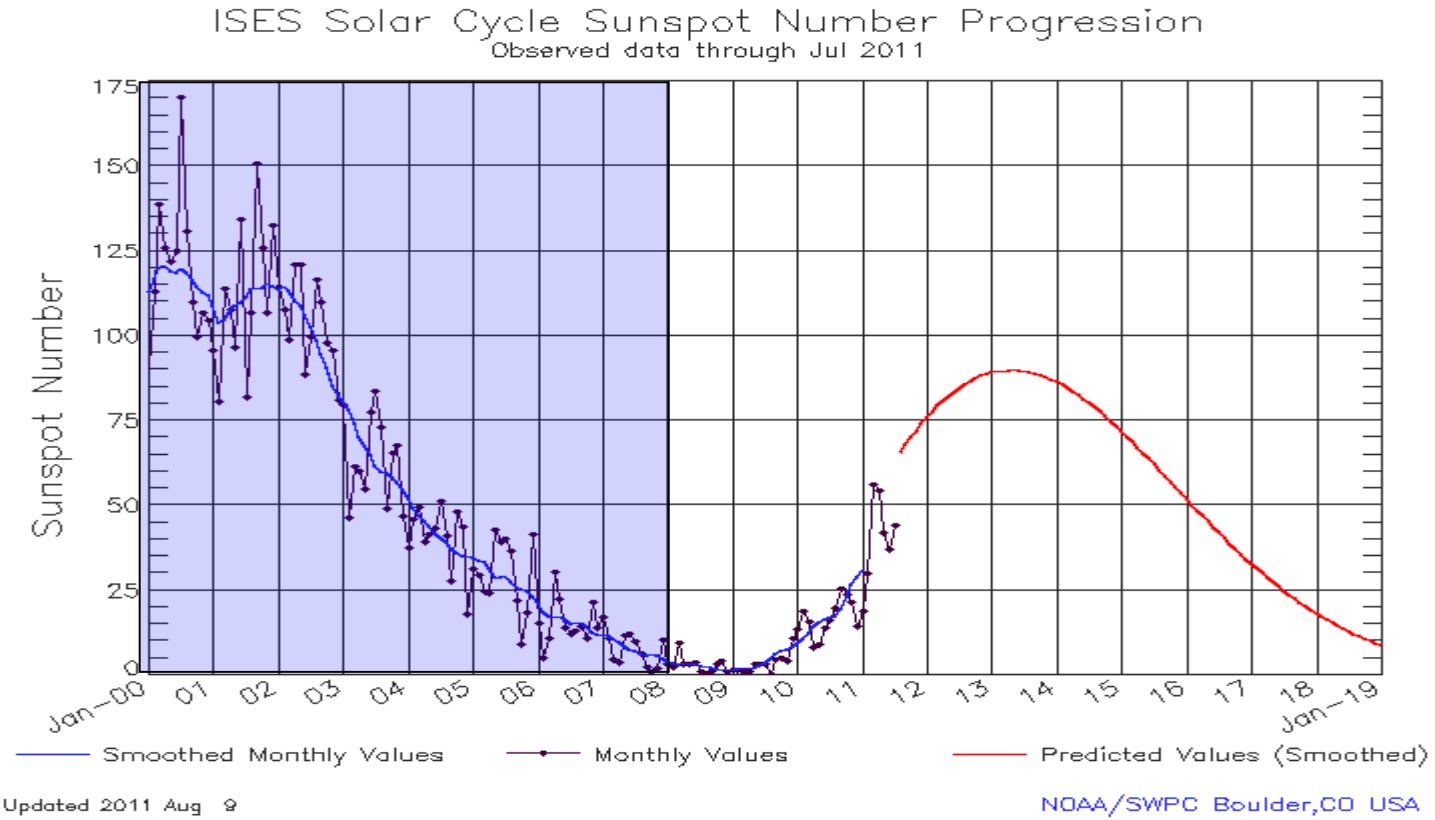
Tibet Air shower Array



- Located at an elevation of 4300 m (Yangbajing , China)
- Atmospheric depth 606g/cm^2
- Wide field of view (Dec. -15º,75º)
- High duty cycle (>90%)
- Angular resolution (~0.9^0)

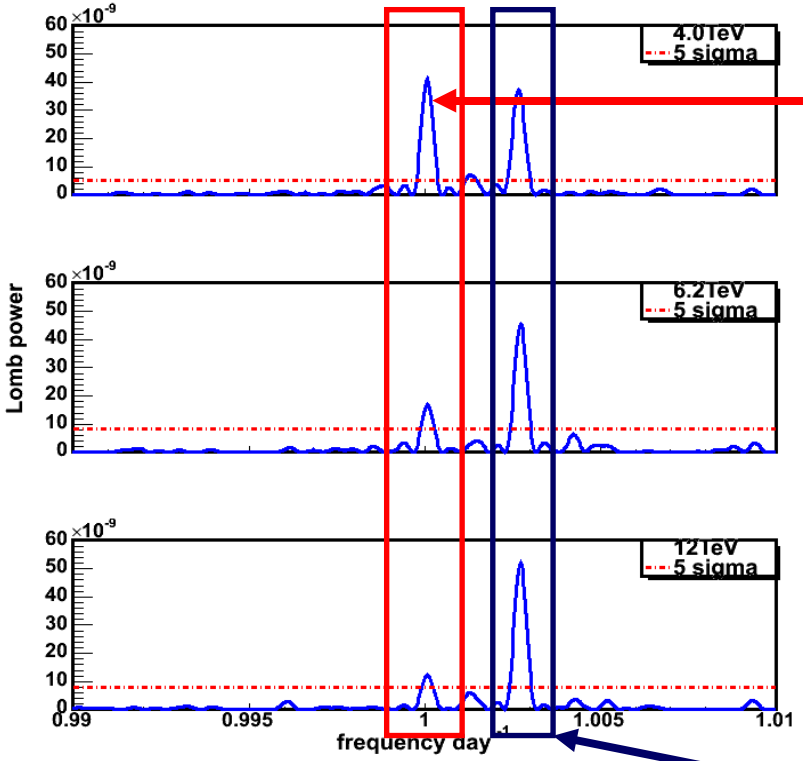
Advantage----measurement of Cosmic ray Large scale anisotropy

Motivation

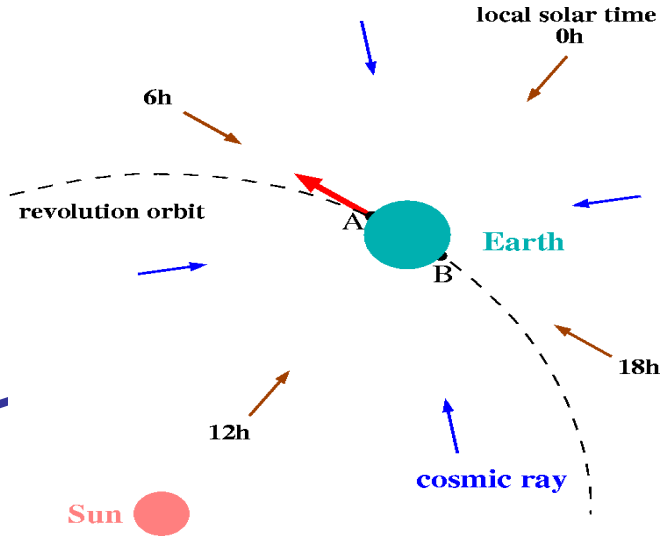


- Tibet array has successfully observed the Cosmic ray anisotropy. (4TeV-300TeV)
- Tibet array has obtained the data from 1999-2008. The solar activity is from maximum to minimum in this time range.
- Analysis of the time evolution of the anisotropy---the influence of the solar activity to the anisotropy.

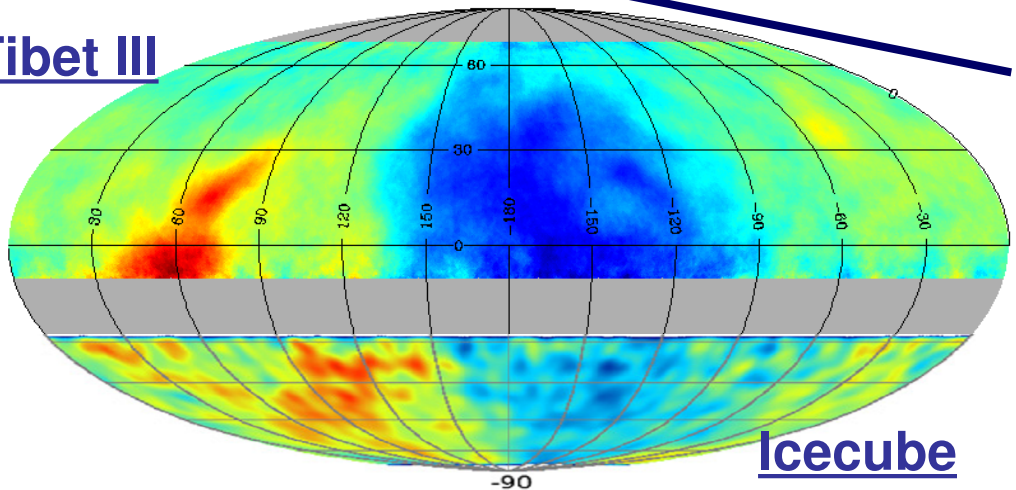
Periodicity search in 3 energy ranges



Solar diurnal anisotropy----due to terrestrial orbital motion around the Sun



Tibet III

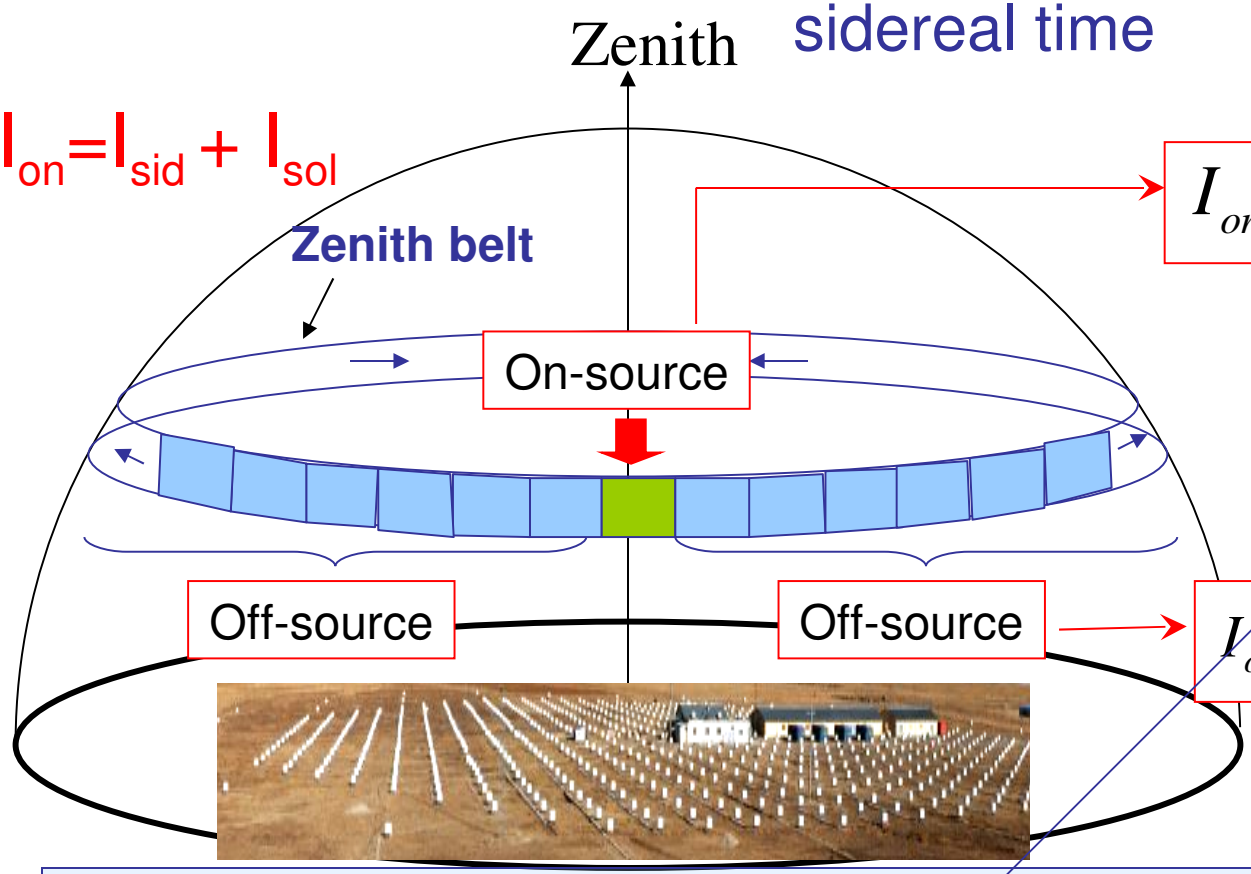


Sidereal-diurnal anisotropy

Problem to distinguish the two kinds of anisotropy ---------- the data taken is incontinues and less than 1 year.

Icecube

Simultaneously fit the anisotropy in local solar and sidereal time



I_{on}, N_{on} → $\frac{N_{on}}{I_{on}}$

I_{off}, N_{off} → $\frac{N_{off}}{I_{off}}$

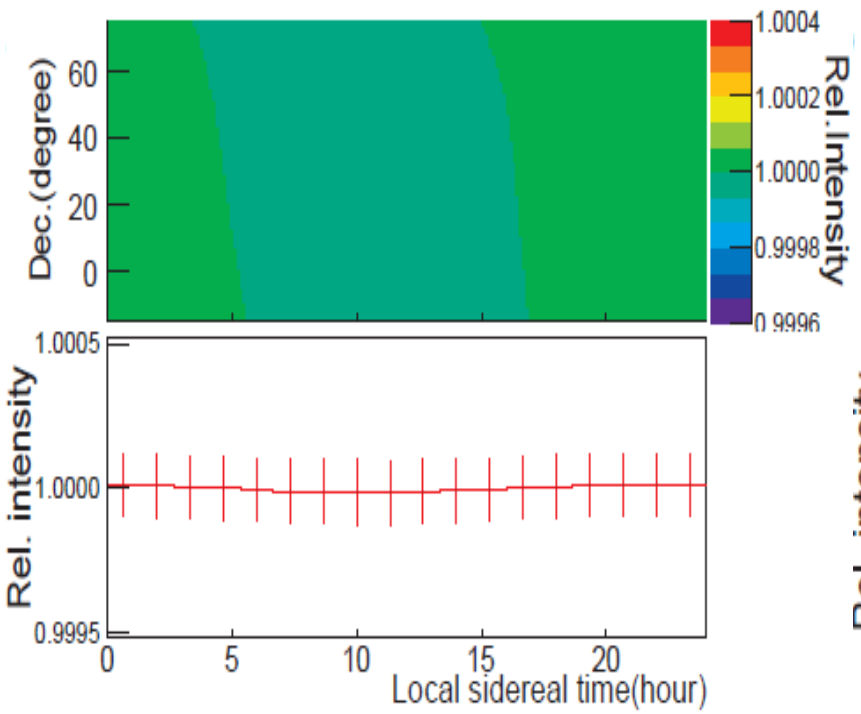
Equal

$$\chi^2_{on} = \frac{(N_{on}/I_{on} - \langle N/I \rangle)^2}{\sigma^2} = \frac{\left(N_{on}/I_{on} - \frac{1}{n}\sum_i N_{off,i}/I_{off,i}\right)^2}{N_{on}/I^2_{on} + \frac{1}{n^2}\sum_i N_{off,i}/I^2_{off,i}}$$

$$\chi^2 = \sum_{t,on} \chi^2_{t,on}$$

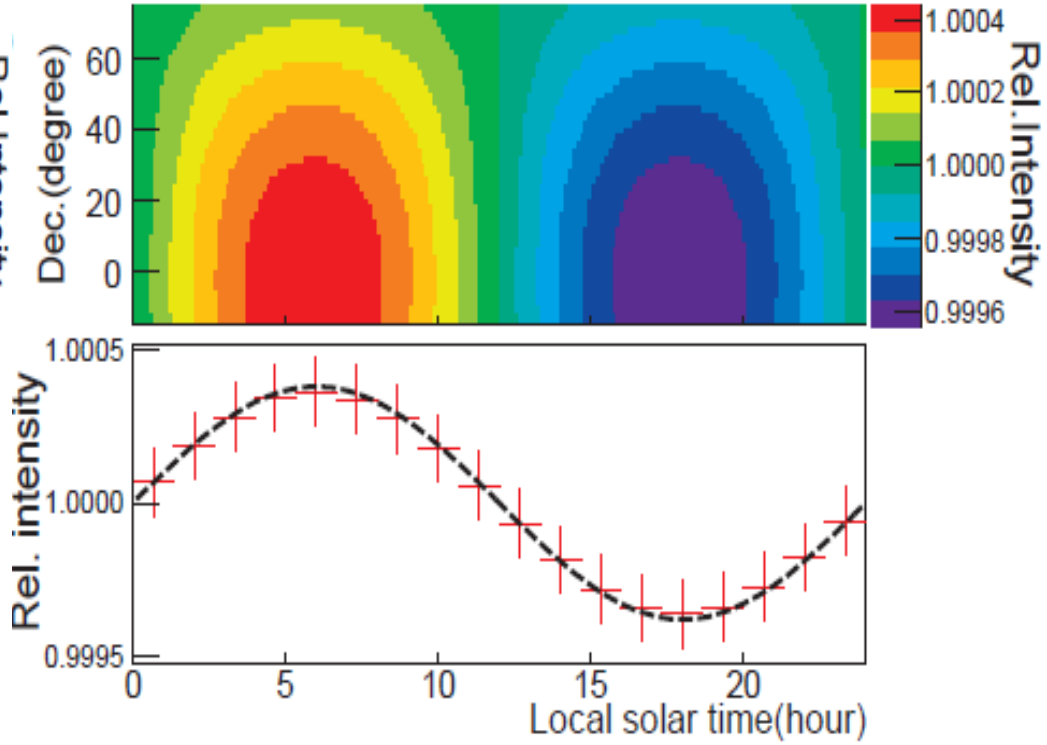
Monte Carlo simulation

Local sidereal time



Expected: no signal

Local solar time



Expected: Compton-Getting effect

MC shows this method can simultaneously obtain anisotropy in local solar and sidereal time. (incontinuous data set, less than 1 year)

Data selection

- Fire four or more FT detectors
- The estimated shower center inside the array
- The zenith angle < 45^0

Nine phases of the Tibet III data

Definition of Nine Phases of Tibet III from 1999 November to 2008 December

Phase	Start Time	End Time	Live Days	Number of Used CR Events
1	1999 Nov 18	2000 Jun 29	173.1	5.16×10^9
2	2000 Oct 28	2001 Oct 11	283.7	8.14×10^9
3	2001 Dec 5	2002 Sep 19	201.8	5.59×10^9
4	2002 Nov 18	2003 Nov 18	259.1	6.34×10^9
5	2003 Dec 14	2004 Oct 10	123.6	3.07×10^9
6	2004 Oct 19	2005 Nov 15	277.6	6.79×10^9
7	2005 Dec 7	2006 Nov 3	114.5	2.71×10^9
8	2006 Nov 6	2008 Feb 25	269.2	6.36×10^9
9	2008 Mar 2	2008 Dec 3	212.9	4.91×10^9

Sidereal time anisotropy in 9 Phases (1999-2008)

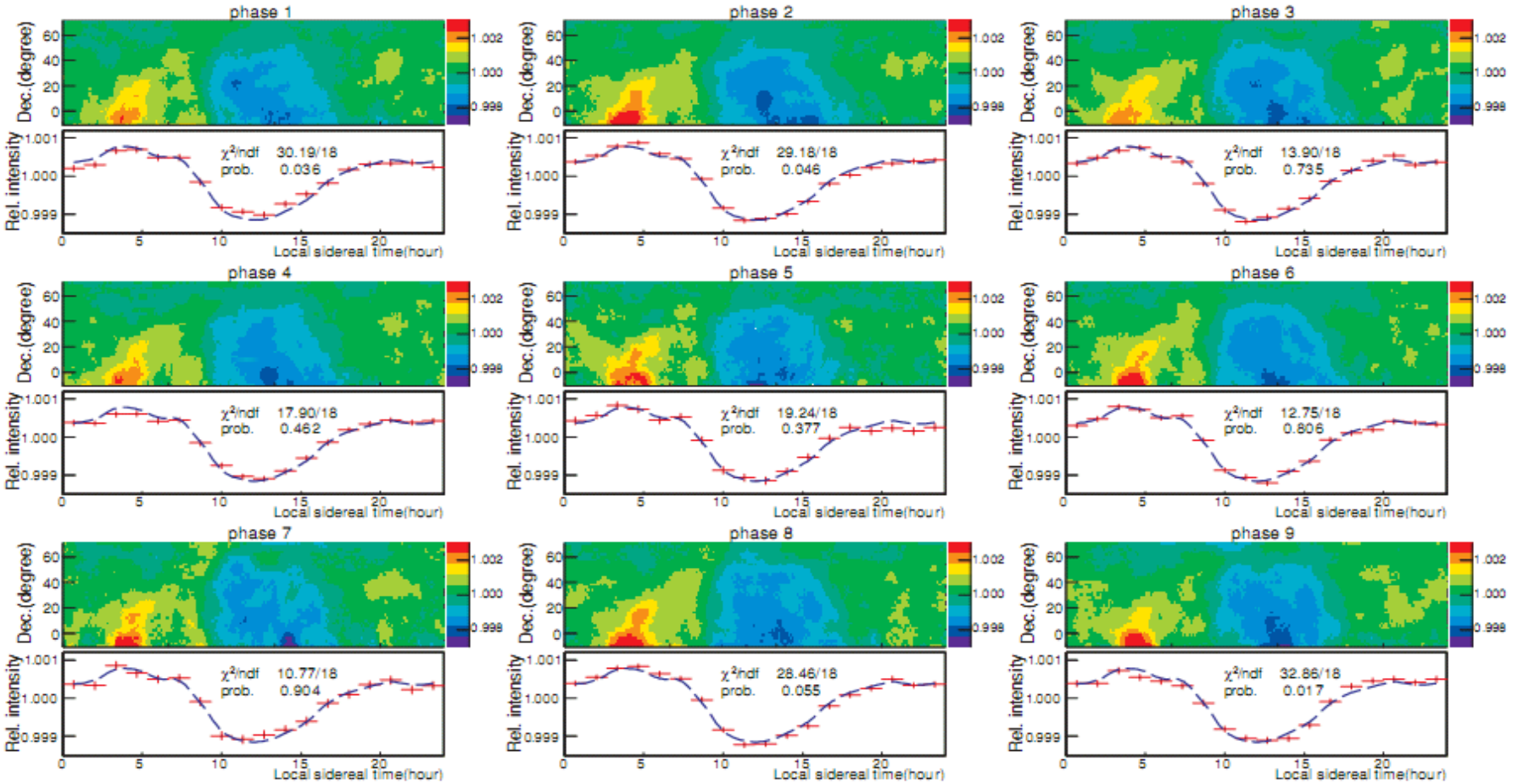
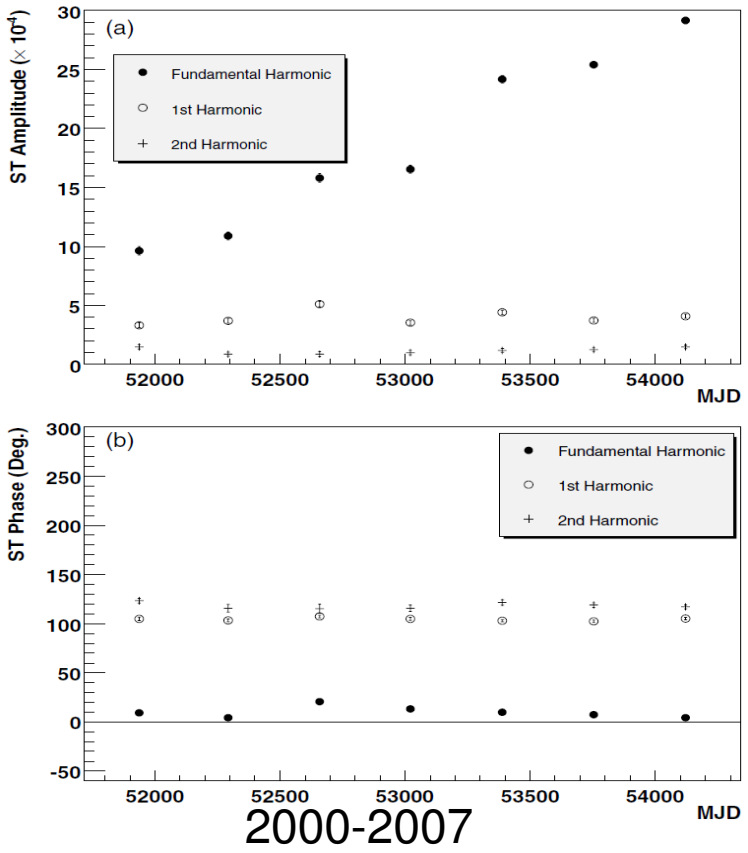


Figure 2. CR intensity variation in the local sidereal time frame for CRs with the modal energy around 5 TeV in the nine phases of Tibet III array. Top: two-dimensional intensity map of each phase; Bottom: one-dimensional projection averaged over all declinations. In bottom plots of each panel, the red crosses in each plot show the intensity variation over each phase respectively, while the dashed blue lines represent the intensity averaged over all nine phases of Tibet III array.

Stable and insensitive to solar activities

<<On Temporal Variations of the Multi-TeV Cosmic Ray Anisotropy Using the Tibet III Air Shower Array >>, M. Amenomori et al., ApJ 711, 119 (2010)

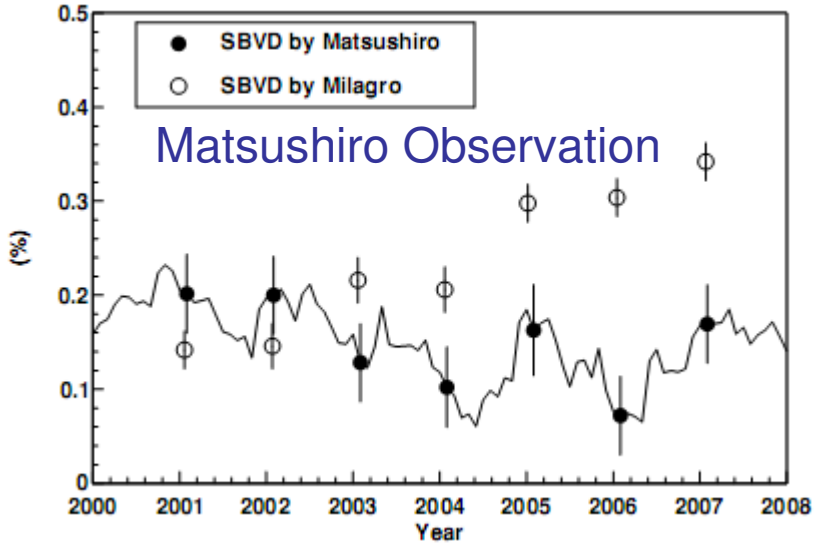
Time Evolution of the Sidereal Anisotropy



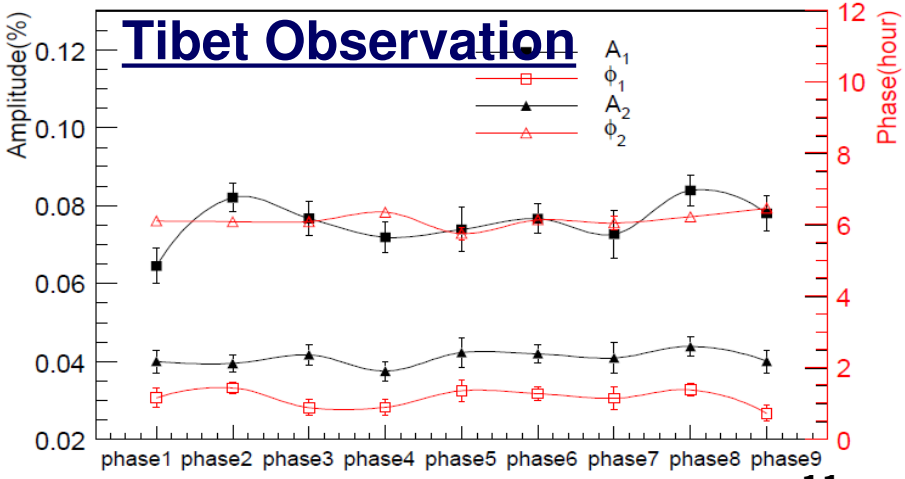
2000-2007

Milagro observation

The fundamental harmonic increase in amplitude with time.



No steady increase



1999-2008

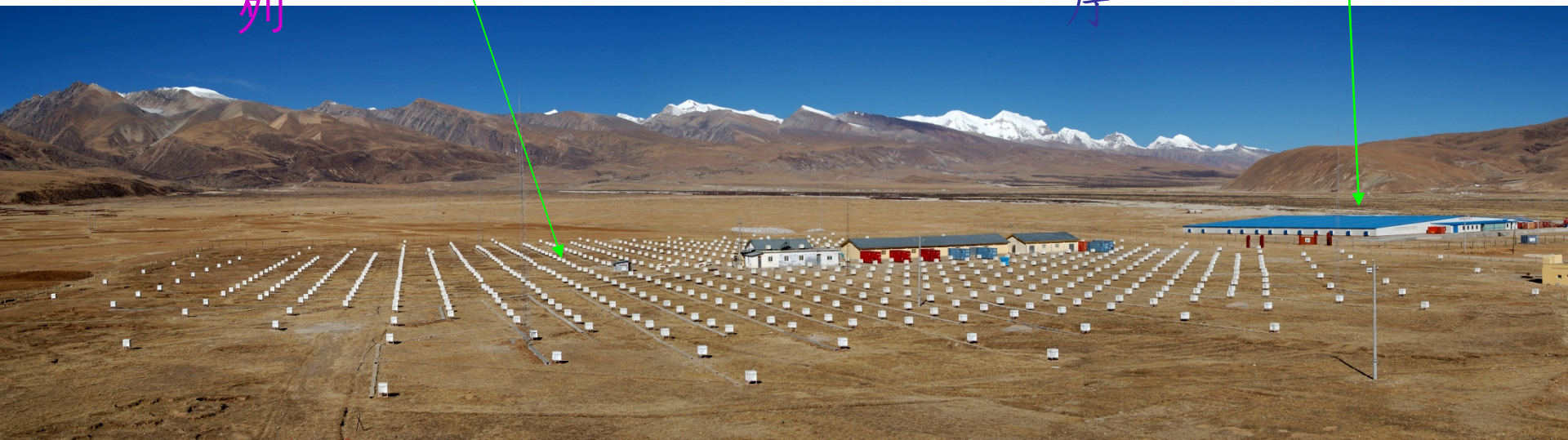
Summary

- We developed a method, which could simultaneously analysis anisotropy in the two time frames.
- Time evolution of sidereal anisotropy in multi-TeV energy range are obtained from 1999 to 2008.
- The multi-TeV cosmic ray anisotropy are stable and insensitive to the solar activities.
- Further analysis will be done with more data.

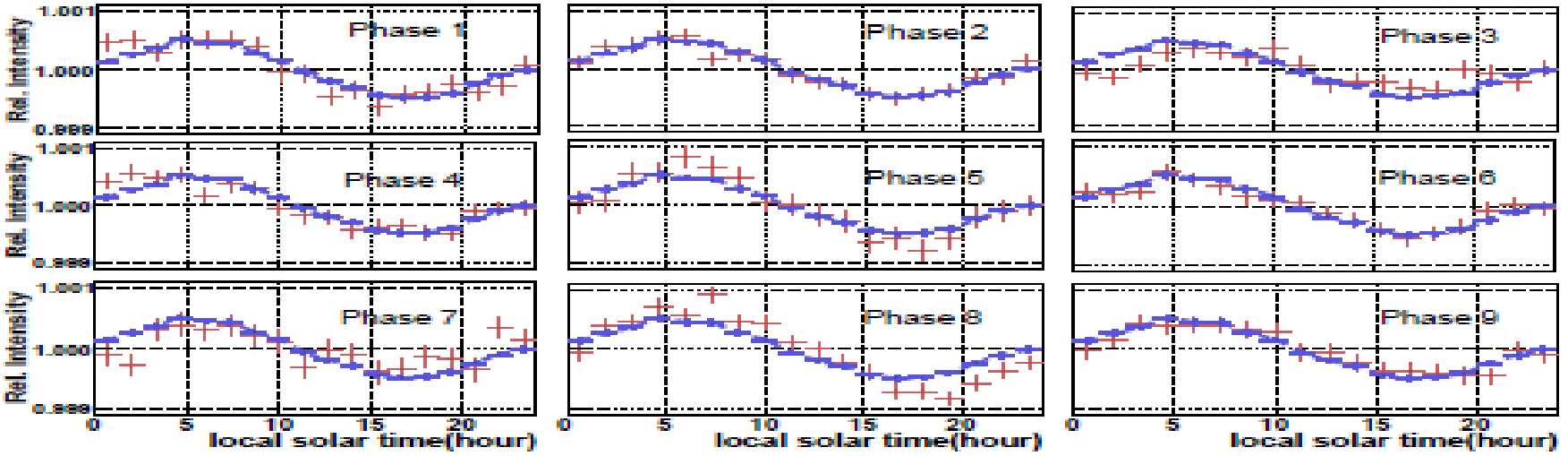
Thanks for your attention !

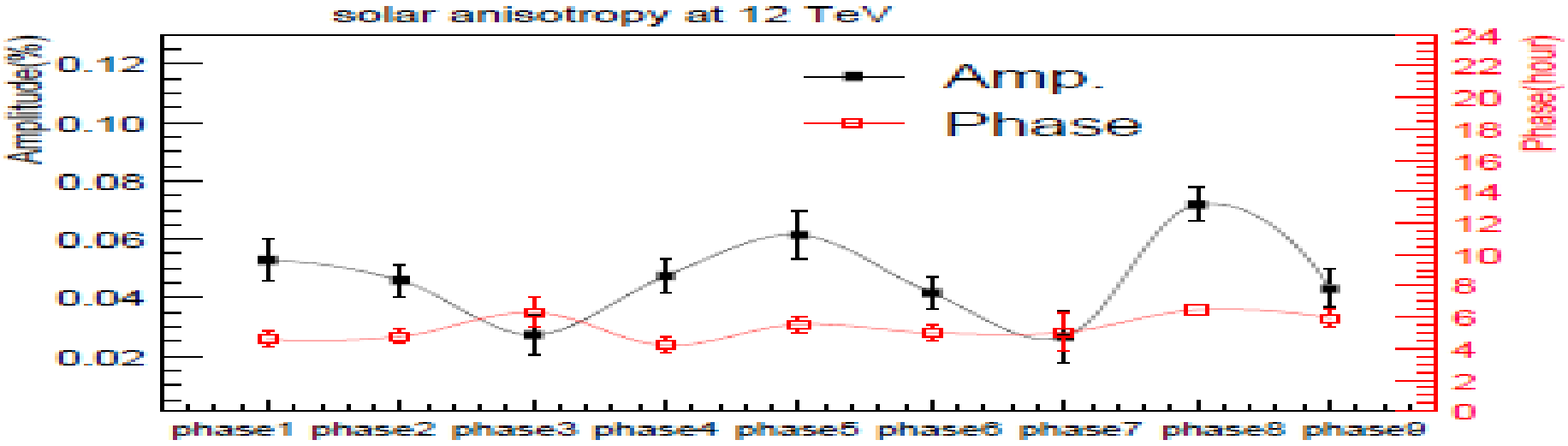
中日 ASγ 探测阵列

中意 ARGO 实验大厅

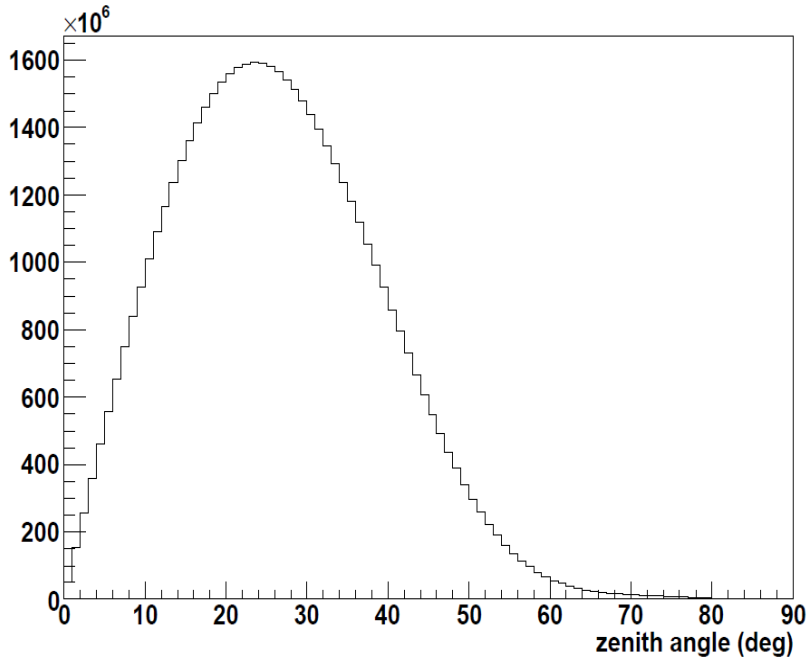


Time evolution of the anisotropy in local solar time



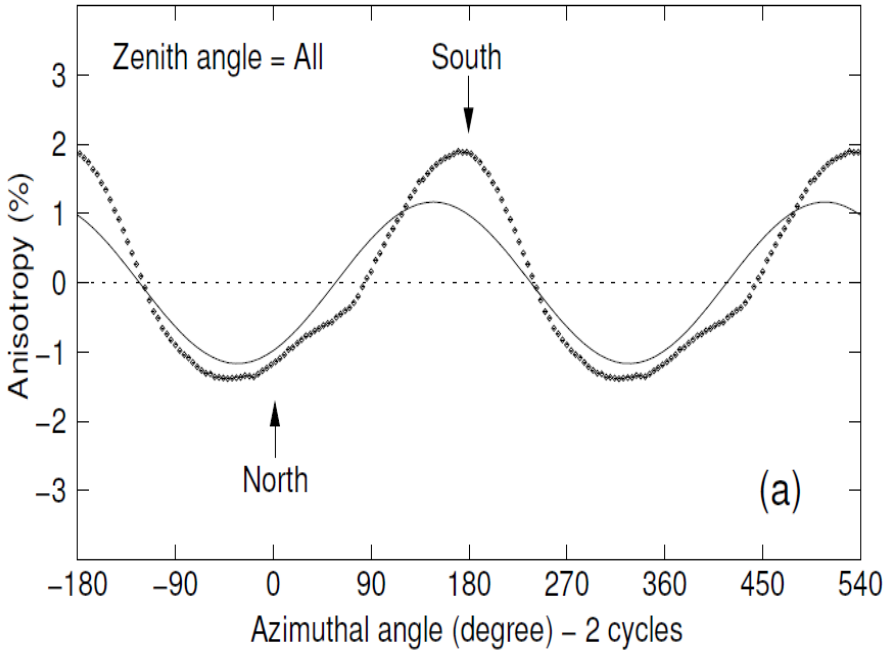


➢Tibet III 数据分布特性



Tibet III 事例的
天顶角分布示意

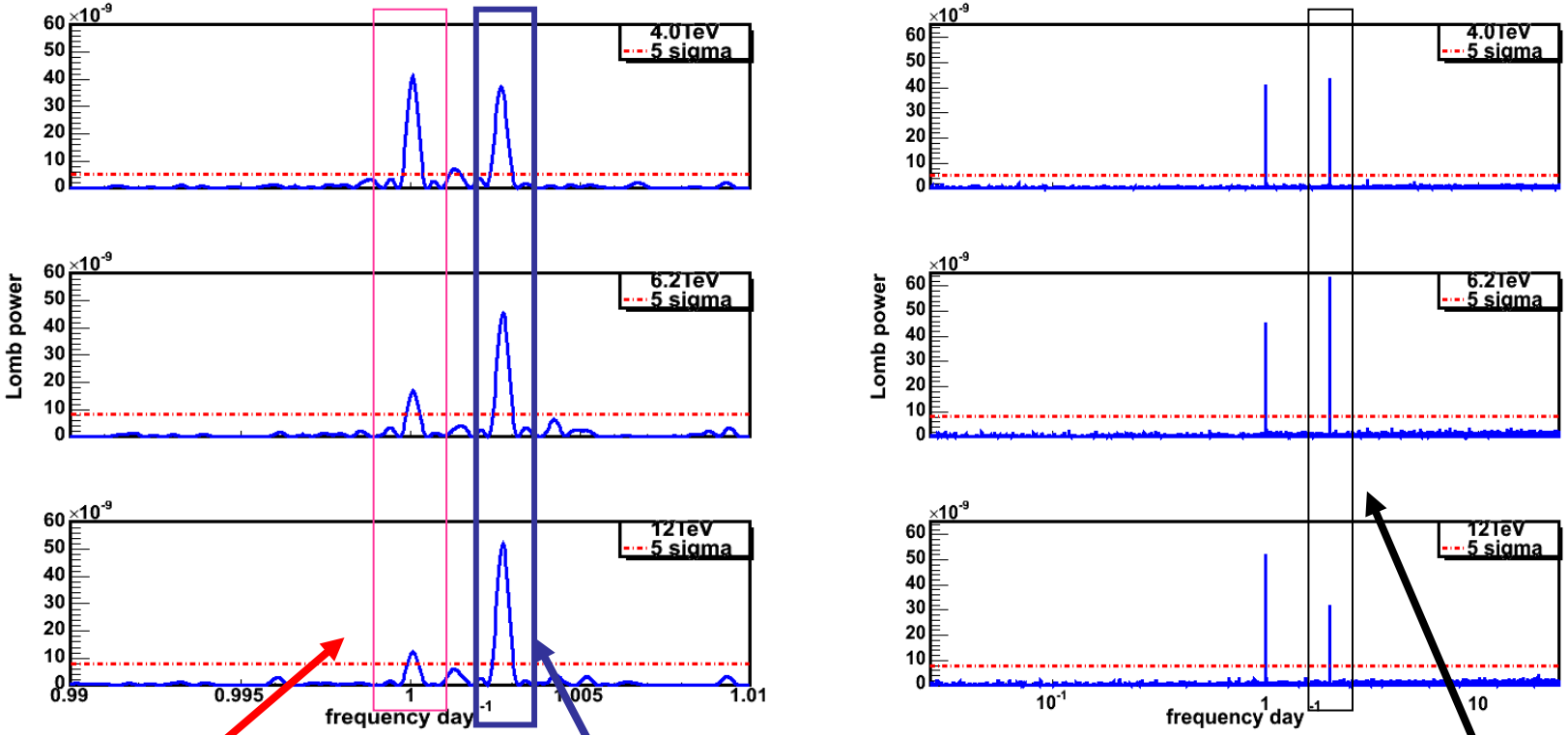
天顶角和方位角分布



Tibet III 事例的全天顶角的
方位角分布示意

由于探测器所处位置不水平、地磁场影响以及其它未知效应共同造成

Periodicity search in 3 energy ranges

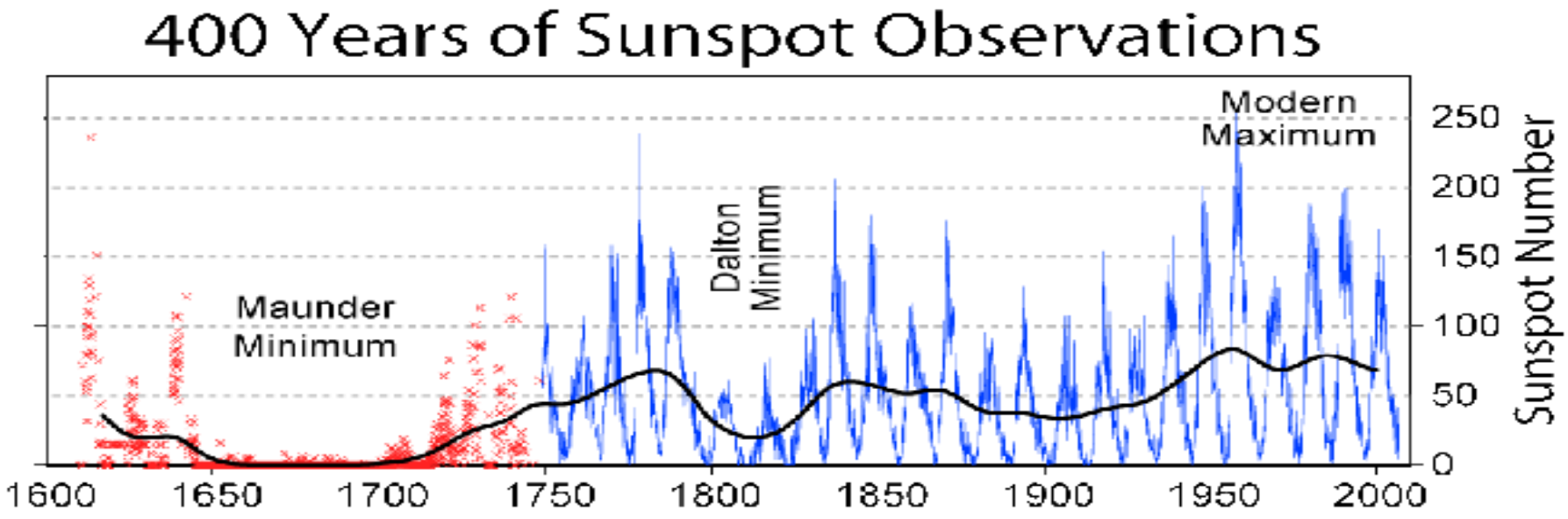


Solar diurnal.
Compton-Getting effect

Sidereal-diurnal

Sidereal semi-diurnal

<<Observation of Periodic Variation of Cosmic Ray intensity with the Tibet III Air Shower Array>>, A.-F. Li Nuclear Physics B,, 529, 2008.


400 Years of Sunspot Observations
Modern
Maximum
Dalton
Minimum
Maunder
Minimum
250
200
150
100
50
0
Sunspot Number
1600
1650
1700
1750
1800
1850
1900
1950
2000