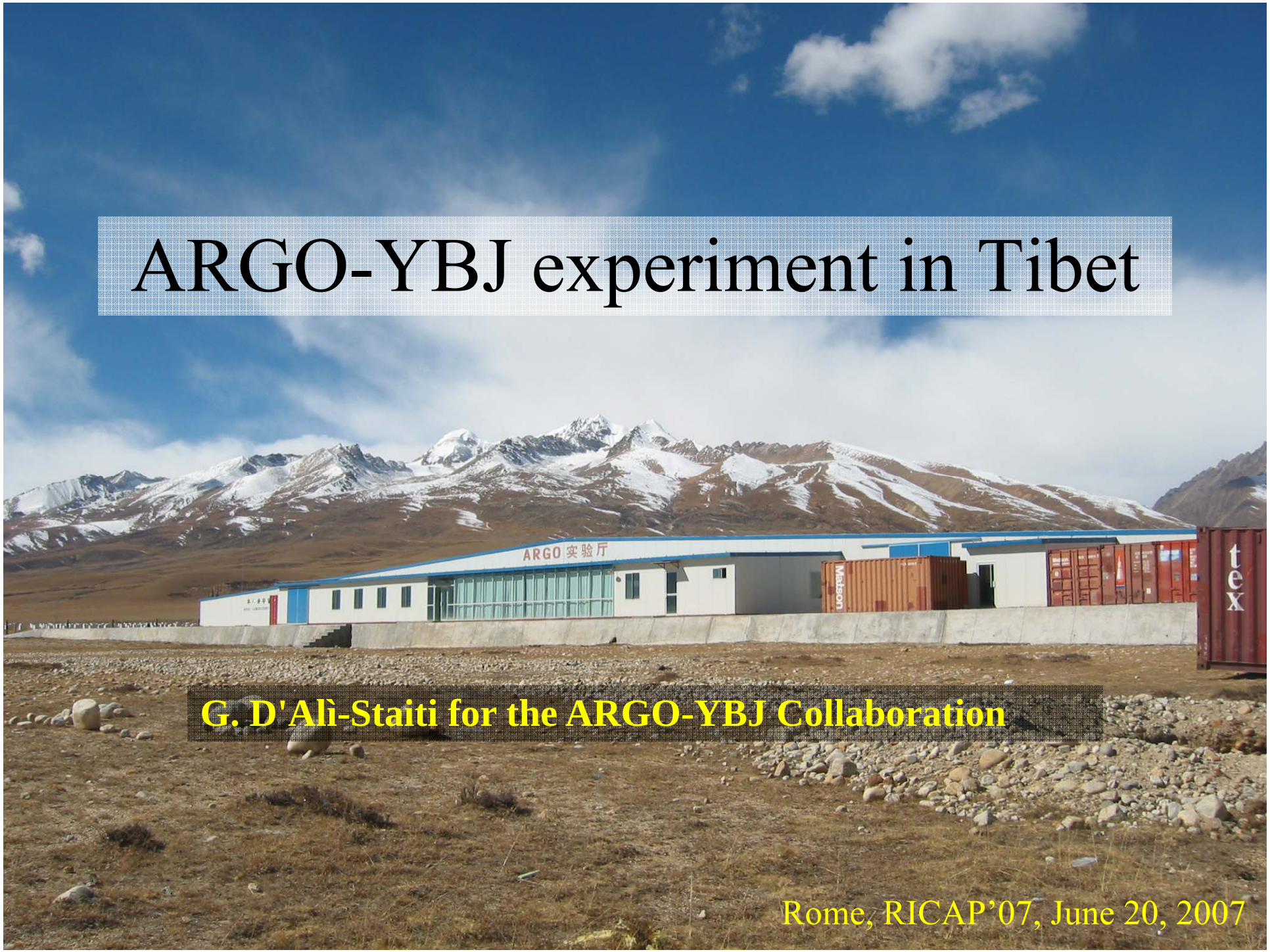


ARGO-YBJ experiment in Tibet

G. D'Alì-Staiti for the ARGO-YBJ Collaboration

Rome, RICAP'07, June 20, 2007

ARGO-YBJ Cooking

MENU

Continuous monitor of a large fraction of the sky:

- ♑ ray sources
- Cosmic Ray study
- transient events as AGN flares

in the energy range 300GeV÷10^4TeV

- GRBs high energy counterparts detection

with a low energy threshold of a few GeV

INGREDIENTS

An Extensive Air Shower detector located in Tibet at the Yangbajing Cosmic Ray laboratory:

- Very high altitude (4300 m)
- Compactness (6700m^2 active area on ~11000m^2 total surface)

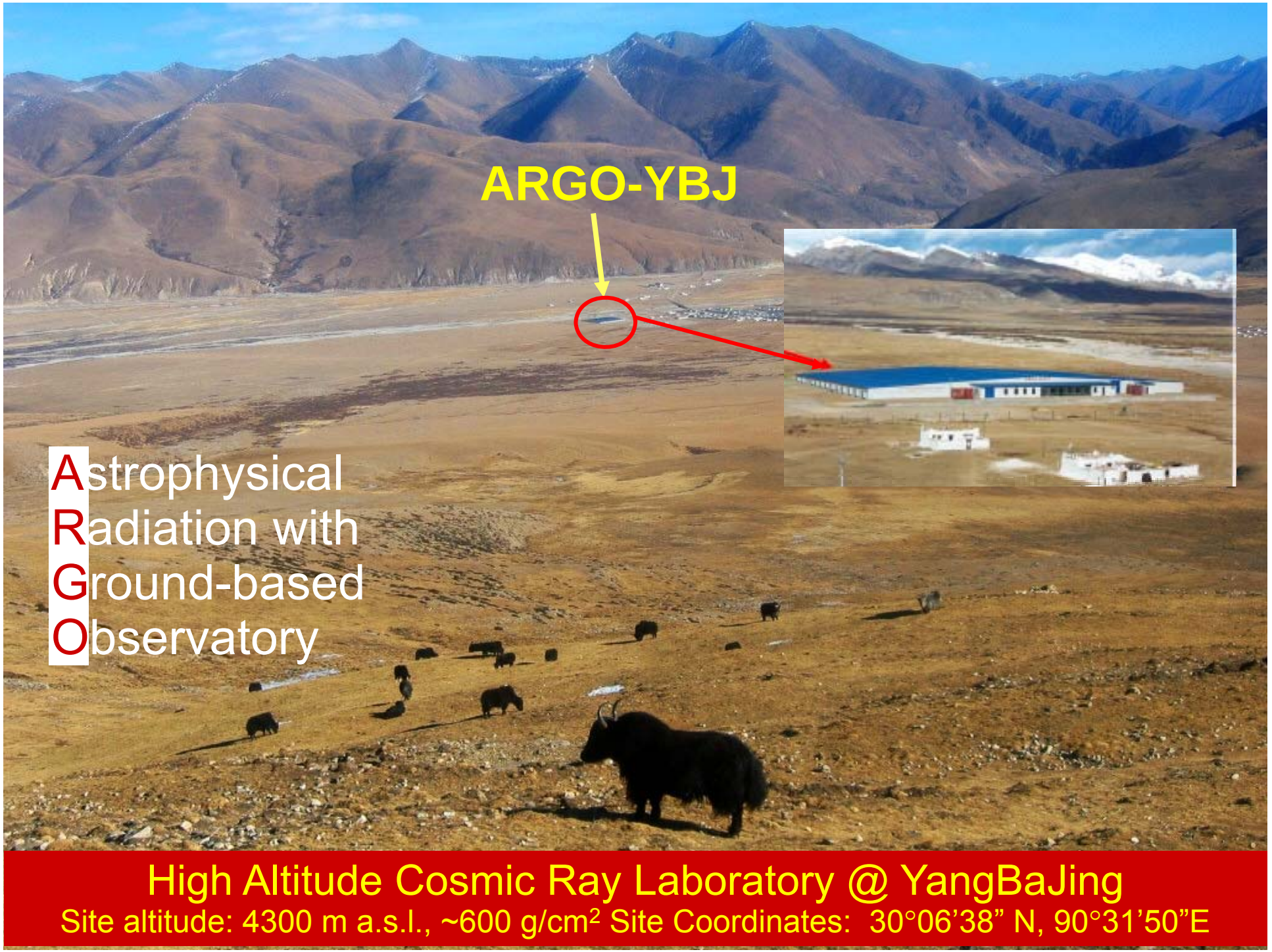
RESULTS

- low energy threshold
- high granularity imaging of the shower front
- large field of view (>2 sr)
- continuous monitoring of the sky $-10° < \delta < 70°$

Today's recipes

During the detector installation, data were taken to debug and calibrate the detector and the software. Despite this *highly fragmented and preliminary* data taking a first overlook of the system performances has been done:

- point gamma ray sources,
- the Moon and Sun shadow,
- p-air cross-section;
- transient events (GRBs).


ARGO-YBJ
Astrophysical
Radiation with
Ground-based
Observatory
High Altitude Cosmic Ray Laboratory @ YangBaJing
Site altitude: 4300 m a.s.l., ~600 g/cm^2 Site Coordinates: 30°06'38" N, 90°31'50"E

The ARGO-YBJ Experiment

A Sino-Italian Scientific Collaboration by

Chinese Academy of Science (CAS)

Istituto Nazionale di fisica Nucleare (INFN)

INSTITUTIONS

INFN and Università del Salento, Lecce
INFN and Università "Federico II" di Napoli
INFN Catania, Univ. and INAF/IASF di Palermo
INFN and Università di Pavia
INFN and Univ.ersità "Tor Vergata" di Roma
INFN and Università "Roma Tre" di Roma
INFN and INAF/IFSI di Torino

IHEP, Beijing
Shanding University,Jinan
South West Jaotong Univ., Chengdu
Tibet University, Lhasa
Junnang University, Kunming
Zhenghou University, Henan

Spokesmen

Prof. B. D'Ettorre Piazzoli

Prof. Cao Zhen

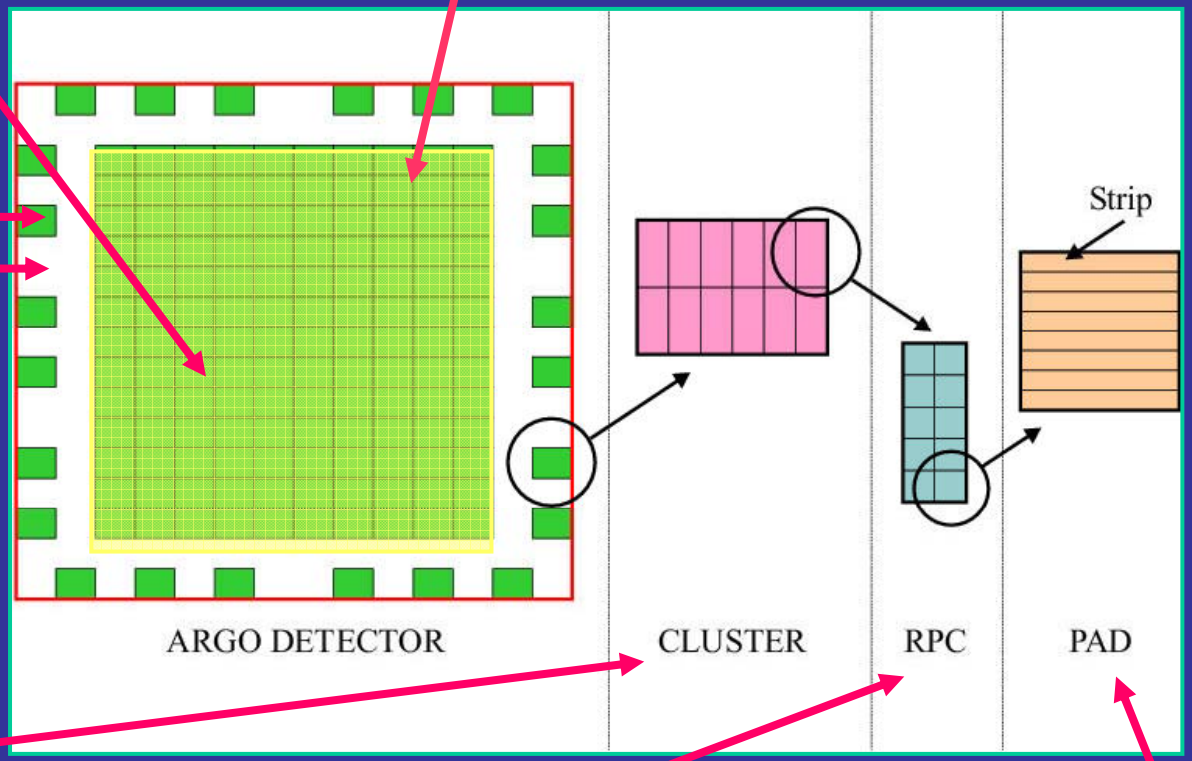
The ARGO-YBJ detector

Full coverage carpet
78 x 75 m² (130 clusters)
(93 % of active surface)

Guard ring surrounding the central carpet
24 clusters
(20 % of active surface)

Full ARGO Detector
111×99m² (154 clusters)

The data presented in this work refer to the CENTRAL CARPET (5800m² with 93% coverage), in the period july 2006-feb 2007



The central carpet will be covered by a lead preconverter layer 0.5 cm thick

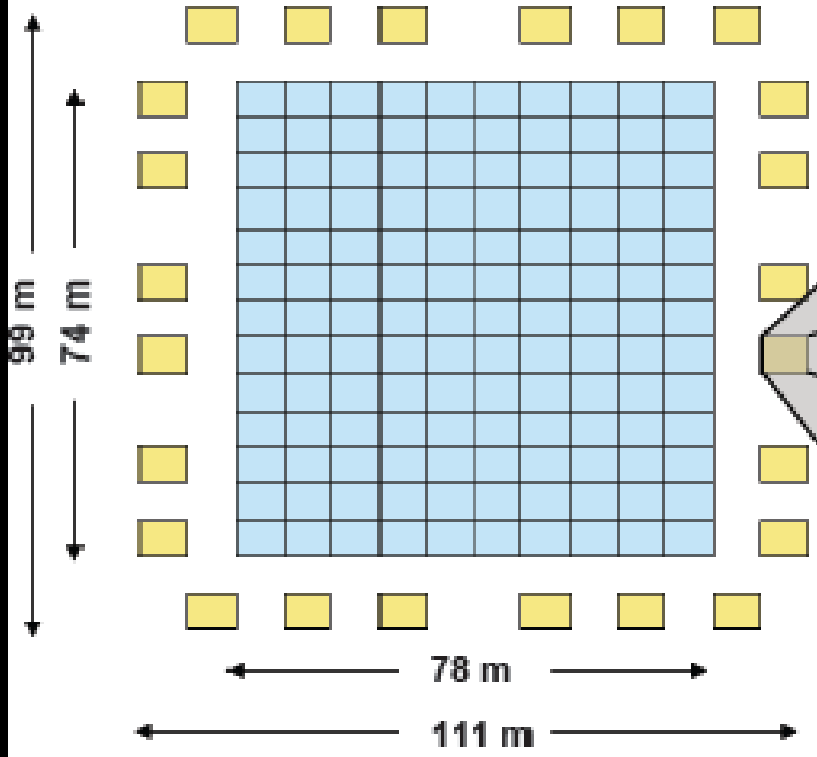
- **Angular resolution improvement**
- **Energy threshold lowering**

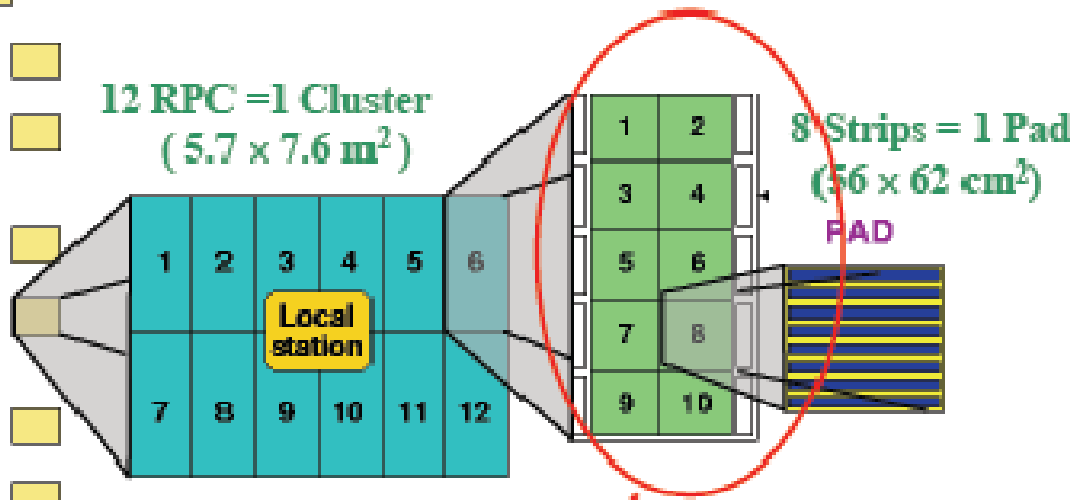
The basic ARGO detector module is the CLUSTER (grouping 12 RPCs) (154 CLUSTERS form ARGO)

The RPC chamber is the physical unit of ARGO detector (1848 RPCs in ARGO)

The PAD is the time "pixel", the STRIP is the space pixel ARGO has 18480 PADs and 147480 STRIPs

ARGO Detector Lay-out



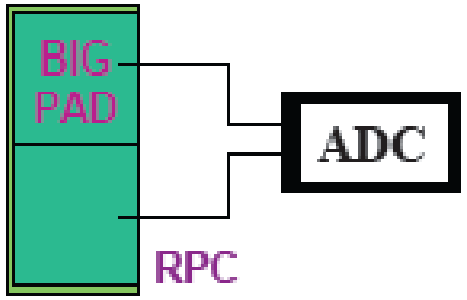


Gas Mixture: Ar/ Iso/TFE = 15/10/75

Layer of RPC covering ~5600 m²
(~ 92% active surface)
+ 0.5 cm lead converter
+ sampling guard-ring

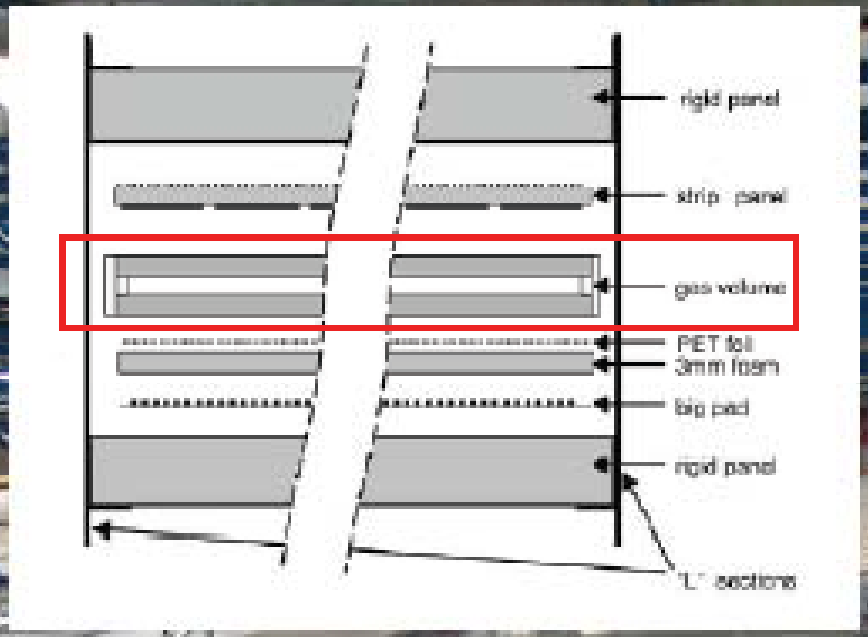
time resolution ~ 1 ns
space resolution = 6.5 × 62 cm² (1 strip)

Central Carpet:
130 Clusters, 1560 RPCs, 124800 Strips



Read-out of the charge induced on "Big-Pads"

Experimental Hall



- Bakelite RPC ($5 \cdot 10^{11}$ Ω·m)
- Operation in streamer mode
- Ar/Isobuthane/TFE 15/10/75 gas mixture
- Efficiency > 95 % at 7.5 kV (10 kV at s.l.)
- Time resolution: ~ 1 ns

Cluster

RPC chamber

ARGO-YBJ observational method

High time-space granularity + full coverage + high altitude
a unique way to study Extensive Air Showers

Space granularity

A single strip (7×62 cm^2 wide) signal is the digital space pixel unit.
8 strip signals are ORed to define a PAD signal:

Time Granularity

The PAD represents the time pixel unit, with an intrinsic resolution of ~1ns.
10 PADs are used to read-out a single RPC.

Trigger

✓**Shower mode**: a PAD majority, N_{pad}>20 on the central carpet in a short time window Δt< 420ns as a Shower trigger with roughly E>300GeV.

✓**Scaler mode**: single particle rate on a CLUSTER unit is recorded every 0.5s to monitor a sudden counting growth (GRB monitor with >1GeV threshold)

Detector performances

High time-space granularity + full coverage + high altitude
a unique way to study Extensive Air Showers

✓Angular resolution;

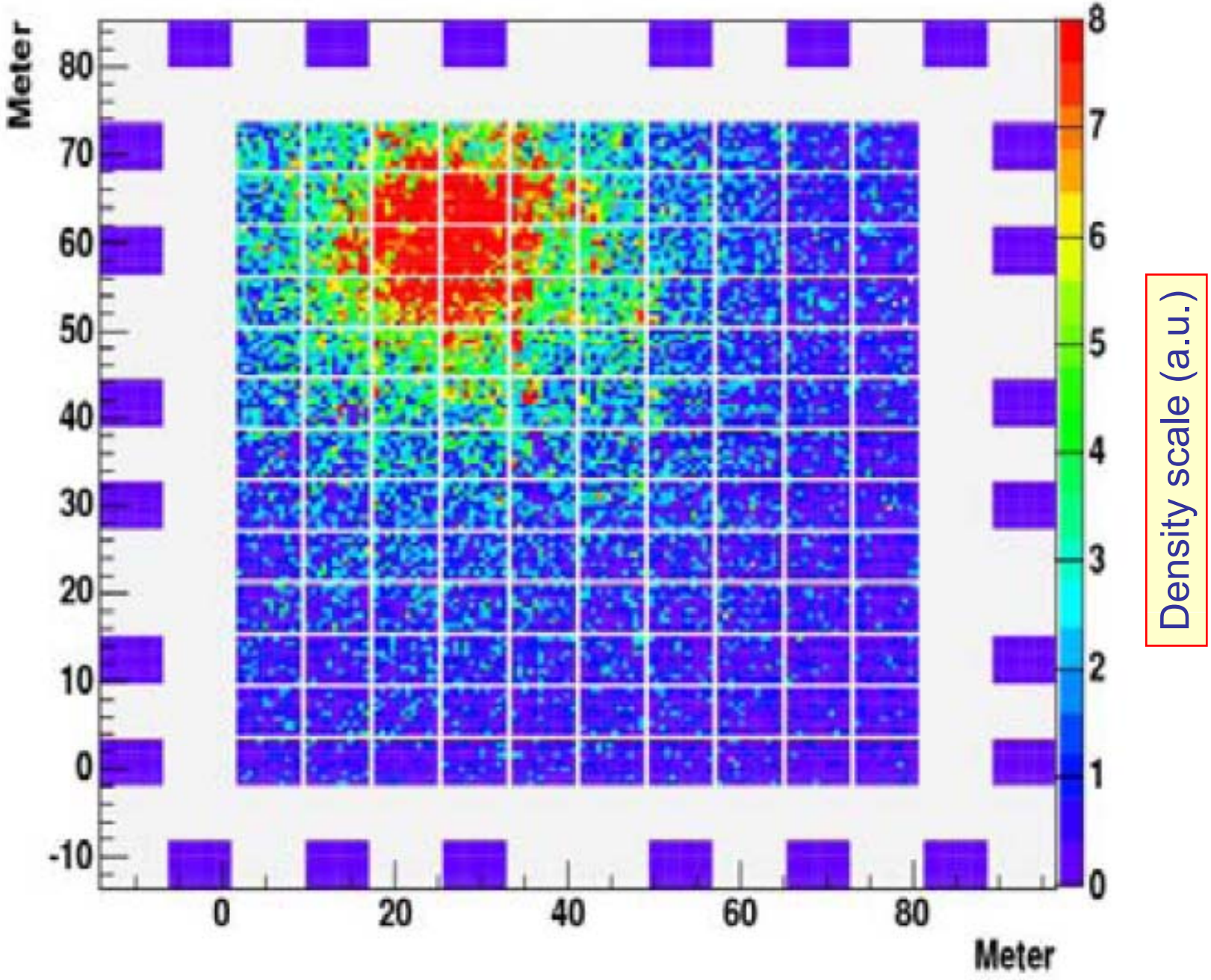
✓Size estimate;

✓Shower front pattern/topology;

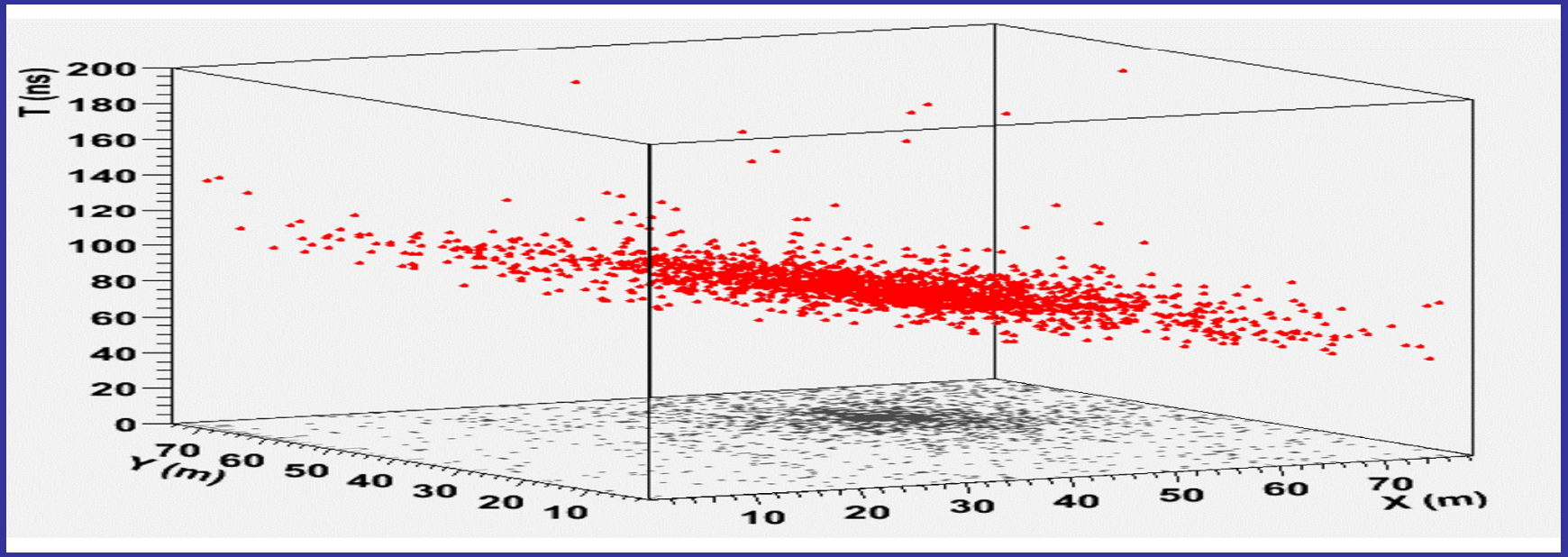
✓Extension of dynamical range.BIG PAD. Up to a density of $>10^4$ particles/m^2 (BTF, Frascati) can be measured close to the shower core:
$\Rightarrow$Argo dynamical range ~300GeV$\rightarrow\leq 10^4$TeV;

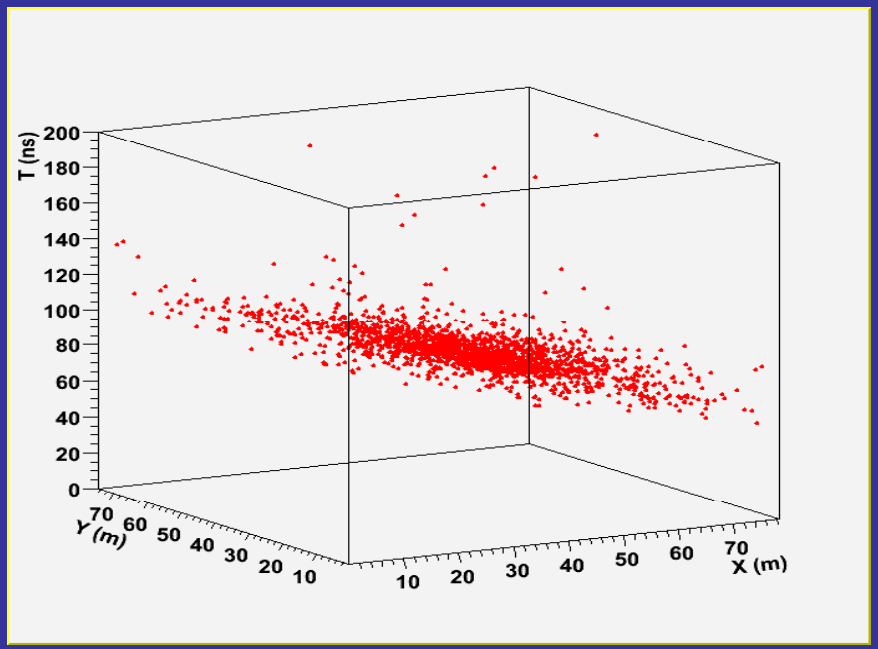
✓The technique of EAS detection allows a duty cycle limited only by maintenance and calibration run.

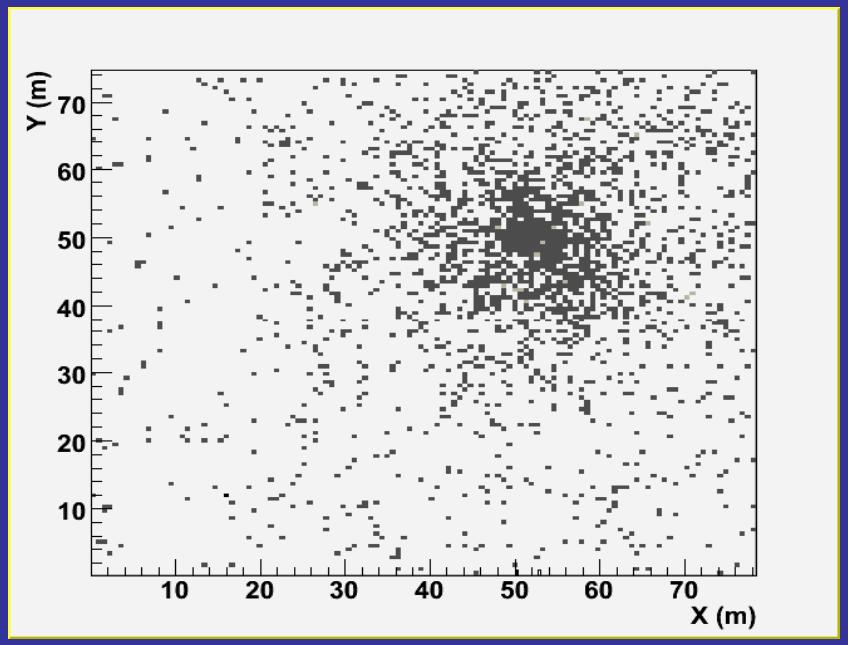
86% reached during May '07


Meter
80
70
60
50
40
30
20
10
0
-10
0
20
40
60
80
Meter
8
7
6
5
4
3
2
1
0
Density scale (a.u.)

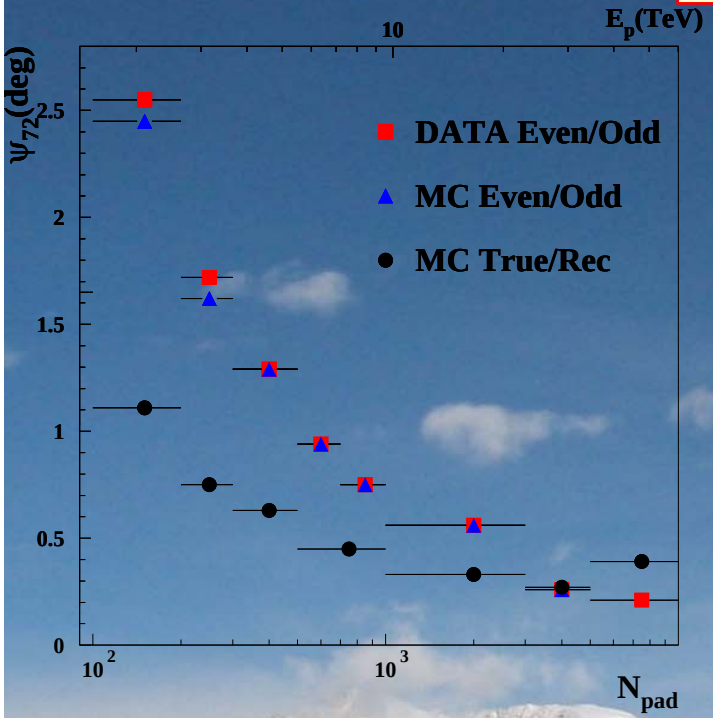
A typical event…





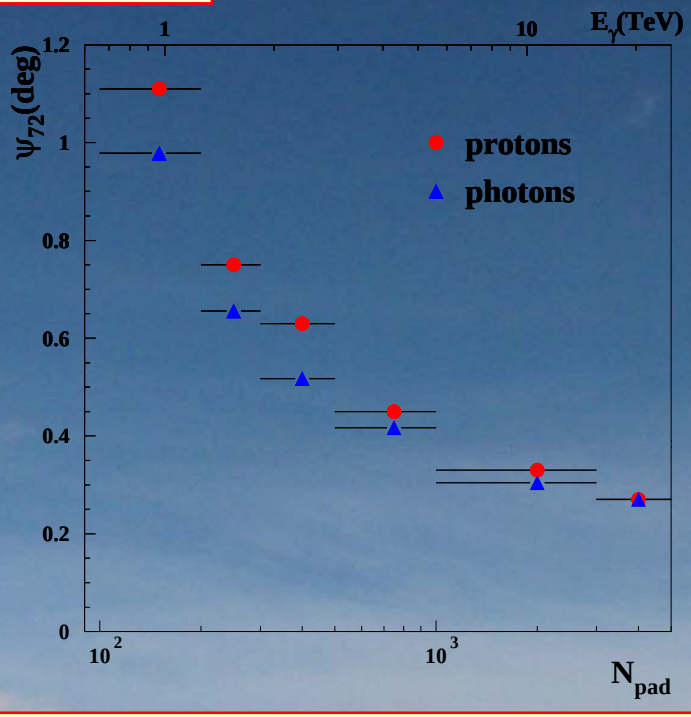


Angular resolution



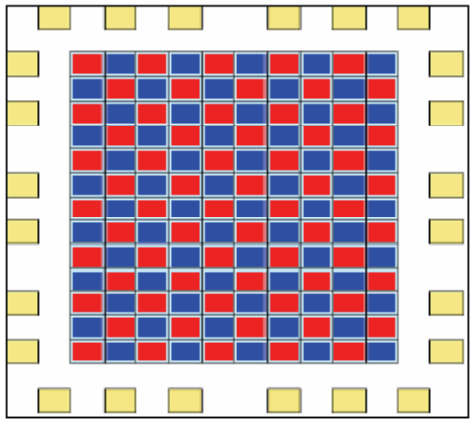
$\sigma_\theta = \Psi_{72}/1.58$

$\sigma_{\theta,mc}=0,5\ \sigma_{\theta,eo}$
pure statistics



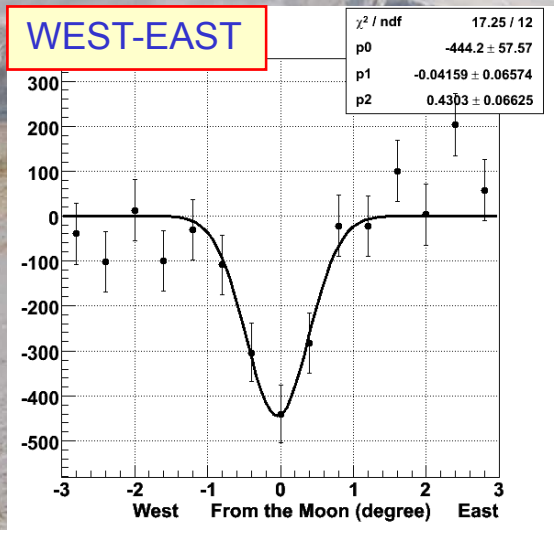
The "size of the Moon", $\sigma_{W\text{-}E}$= 0.43°±0.07°, $\sigma_{S\text{-}N}$= 0.51°±0.09°

The even-odd or "chess-board" method

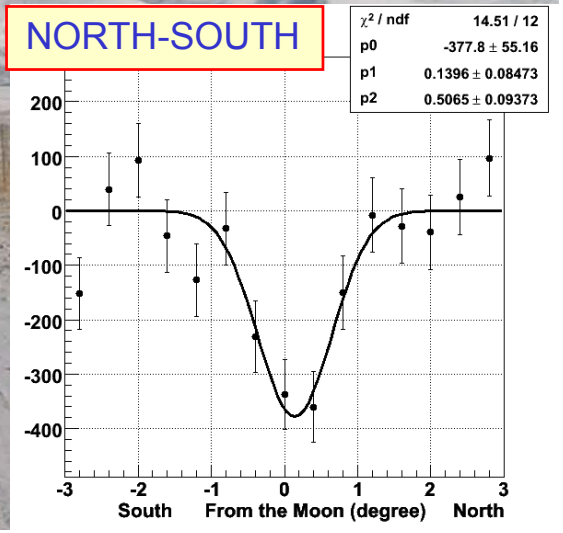


$$(\psi_{70})_{even/odd} = 2 \cdot (\psi_{70})_{true/rec}$$

WEST-EAST



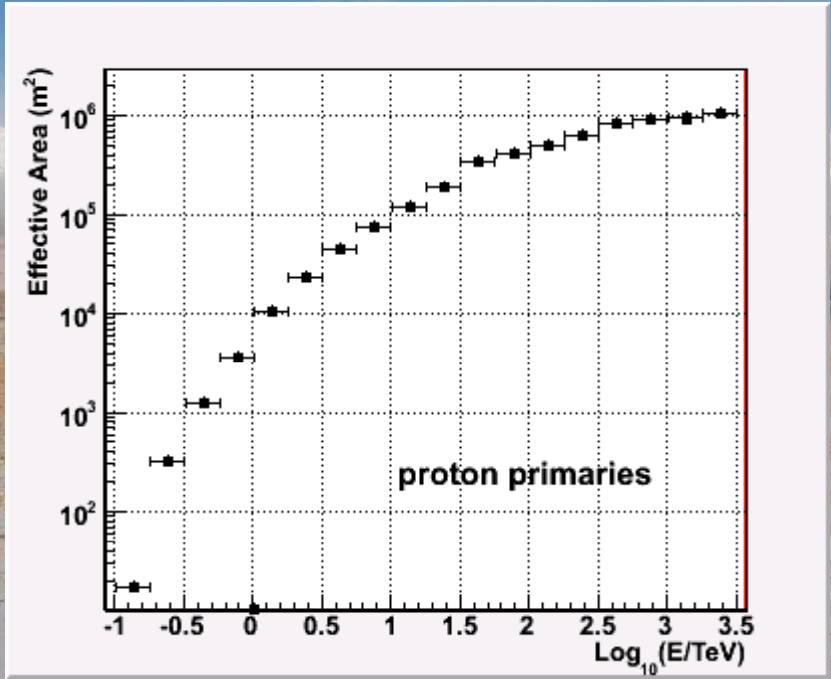
NORTH-SOUTH



Energy threshold

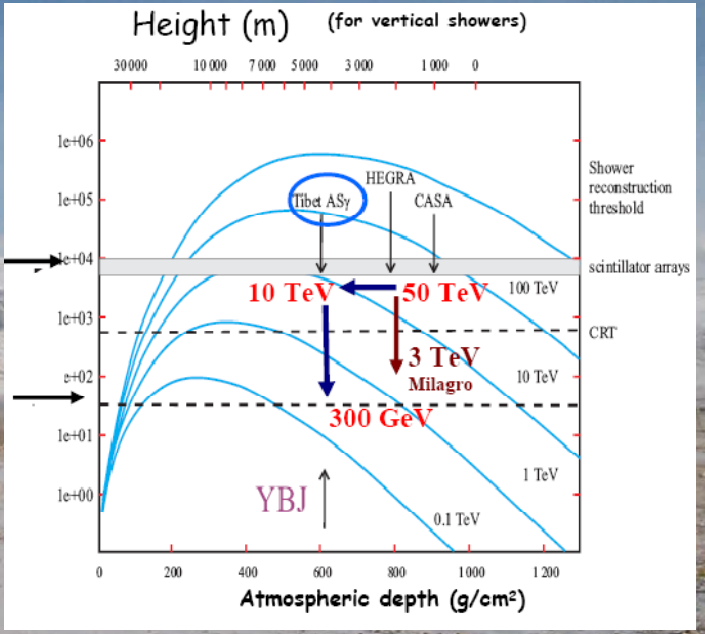
Size-Energy(Median) correspondence(vertical shower):

p-showers	Energy	γ-showers
• $N_{pad} \geq 50$	$E_{50\%}$=600GeV	$N_{pad} \geq 100$
• $N_{pad} \geq 350$:	$E_{50\%}$=4TeV	$N_{pad} \geq 650$
• $N_{pad} \geq 10^3$:	$E_{50\%}$=10TeV	$N_{pad} \geq 2\times10^3$
• $N_{pad} \geq 2.5\times10^3$:	$E_{50\%}$=20TeV	$N_{pad} \geq 4\times10^3$



Ground arrays

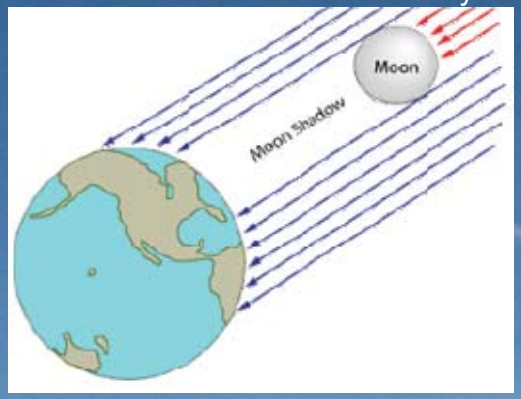
Full coverage



… folded to the primary spectrum

⇒ energy threshold of ~300 GeV

The shadow of the Moon at ARGO



Cosmic rays hampered by the Moon as an anti-source

⇒ **A deficit is expected from the Moon direction**

- **Width of the deficit: PSF/angular resolution of the Detector**
- **Position of the deficit: pointing accuracy (systematics)**
  geomagnetic effect

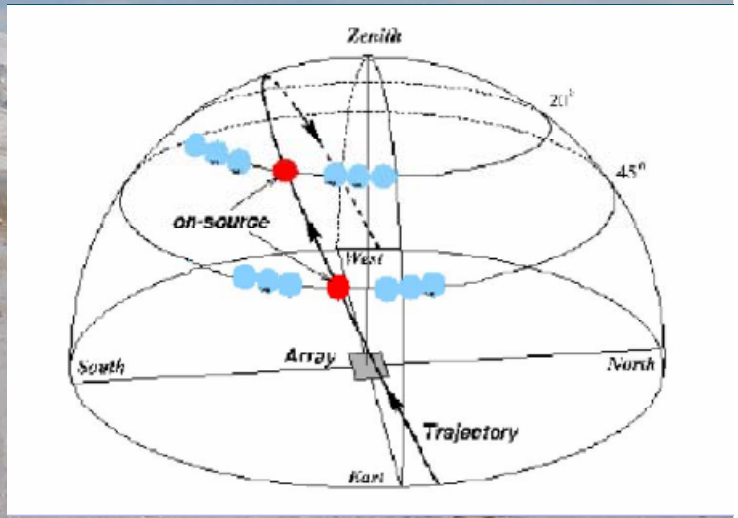
The geomagnetic field bending: $\Delta\theta = 1{,}7°/E(TeV)$

positively-charged particles are deflected Eastward

negatively-charged particles are deflected Westward

(possibility of measuring, with sufficient amount of data, p-antip ratio, from the moon shadow position/defocusing)

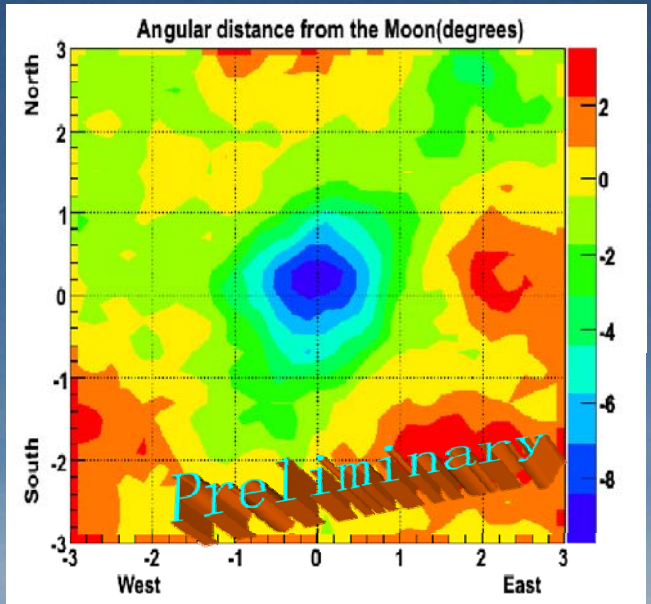
At YBJ the local zenith angle of the orbit culmination ranges from 2° to 52° in one lunar month:
Using data with zenith angles <40° reduces the duty cycle to ~20%.
Monte carlo simulation is used to account for the effect due to geomagnetic field bending.
Background is subtracted using the equi-zenith angle method



The shadow of the Moon at ARGO

July 2006 to February 2007 data, with ARGO-130

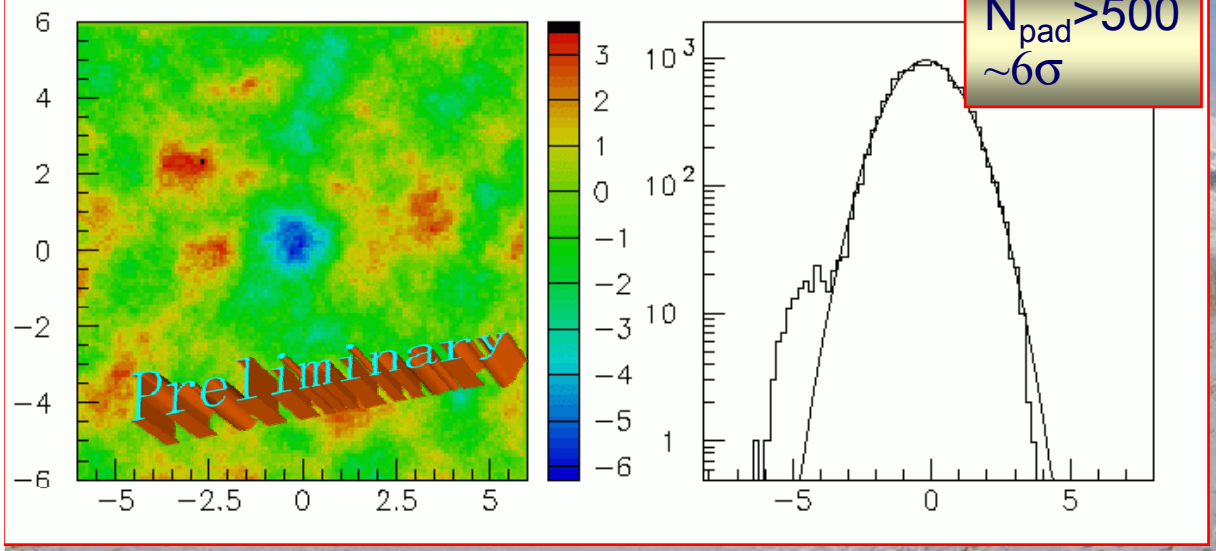
- reconstructed core position inside the array;
- 1.16 x 10^6 events in a window 6°x 6° around the moon.
- 560 hours of Moon observation with zenith angle < 45°.



N_{pad} > 500, <E> = 5 TeV : A peak at 10 σ significance. Shifting: West 0.04 °, North 0.14° with respect to the nominal moon position

…and the shadow of the Sun

…and ~210 hours looking at the Sun, from july to Oct. '06



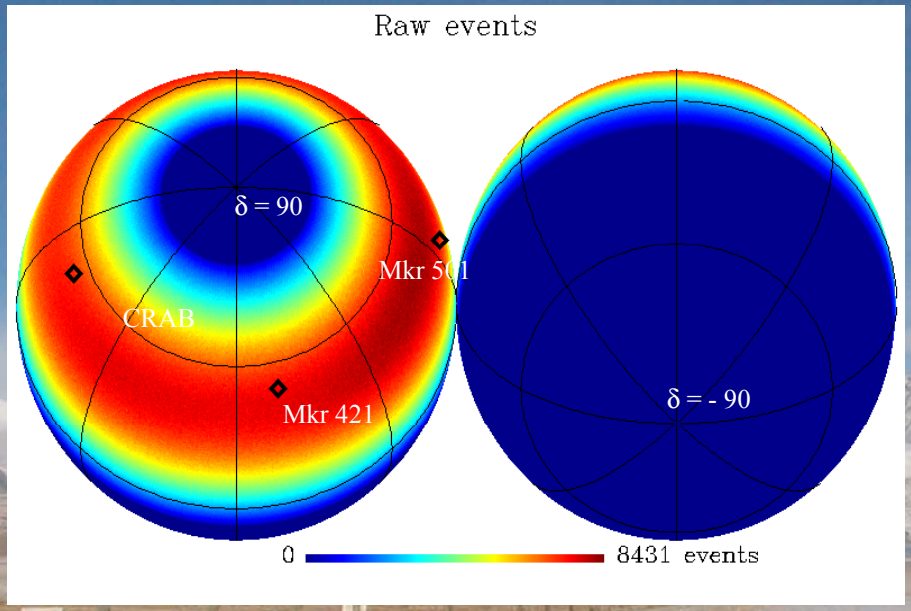
N_{pad}>500 ~6σ

The sky map

ARGO-YBJ latitude = 30°

Selection of showers with zenith angle $\theta < 40°$

⇒ observable declination band $-10° < \delta < 70°$



55% of the sky is monitored in this configuration.

Still some exposure irregularities due to the short time of data taking.

For the sky map binning we use the Healpix library (a genuinely curvilinear partition of the sphere into exactly equal area quadrilaterals of varying shape).

$N_{pix} = 12 \times 128^2$ (200 000 pixels of half degree side)

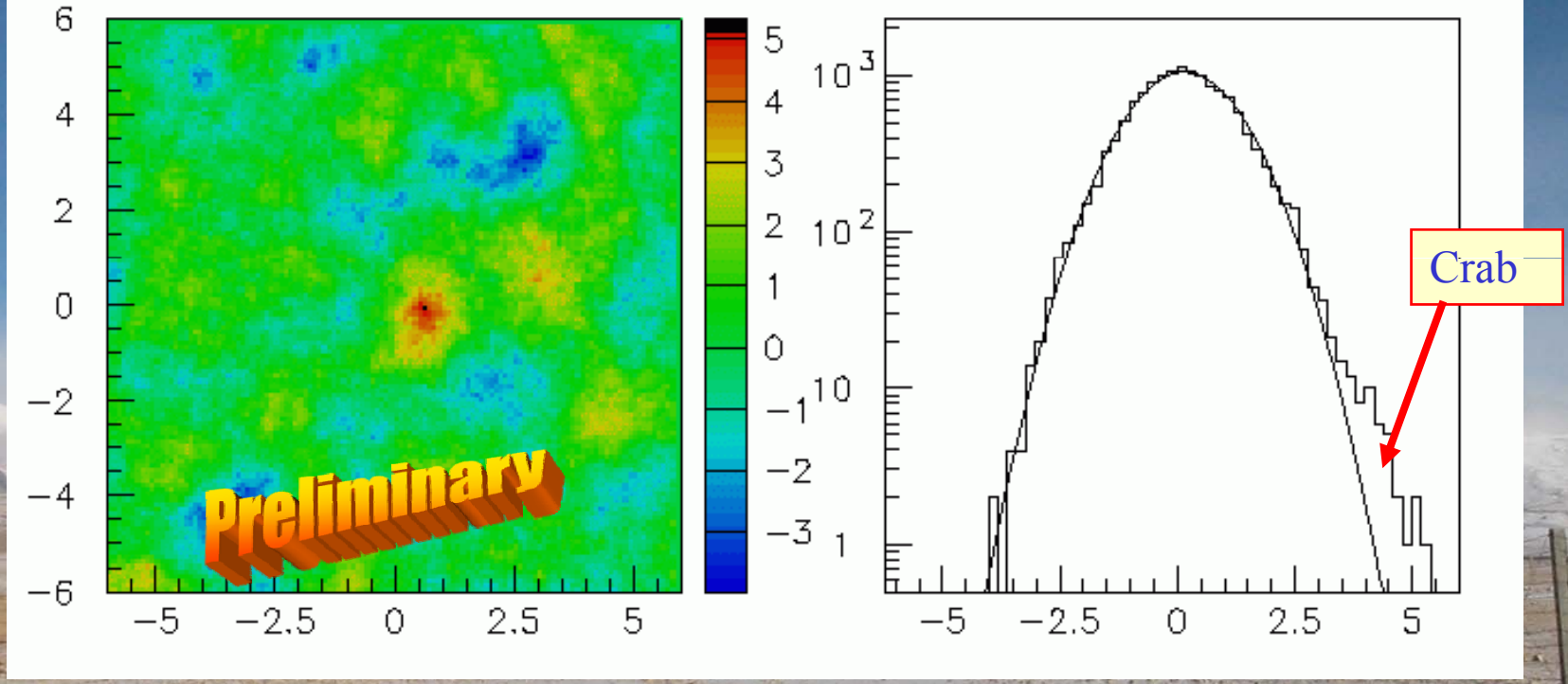
Search for point ♑ ray sources – Some preliminary result

The data:
July 2006-Feb 2007
290 hours, ~50 days

The Crab

Zenith angle<40°
N_{hit}>200
Window size: 0,6°

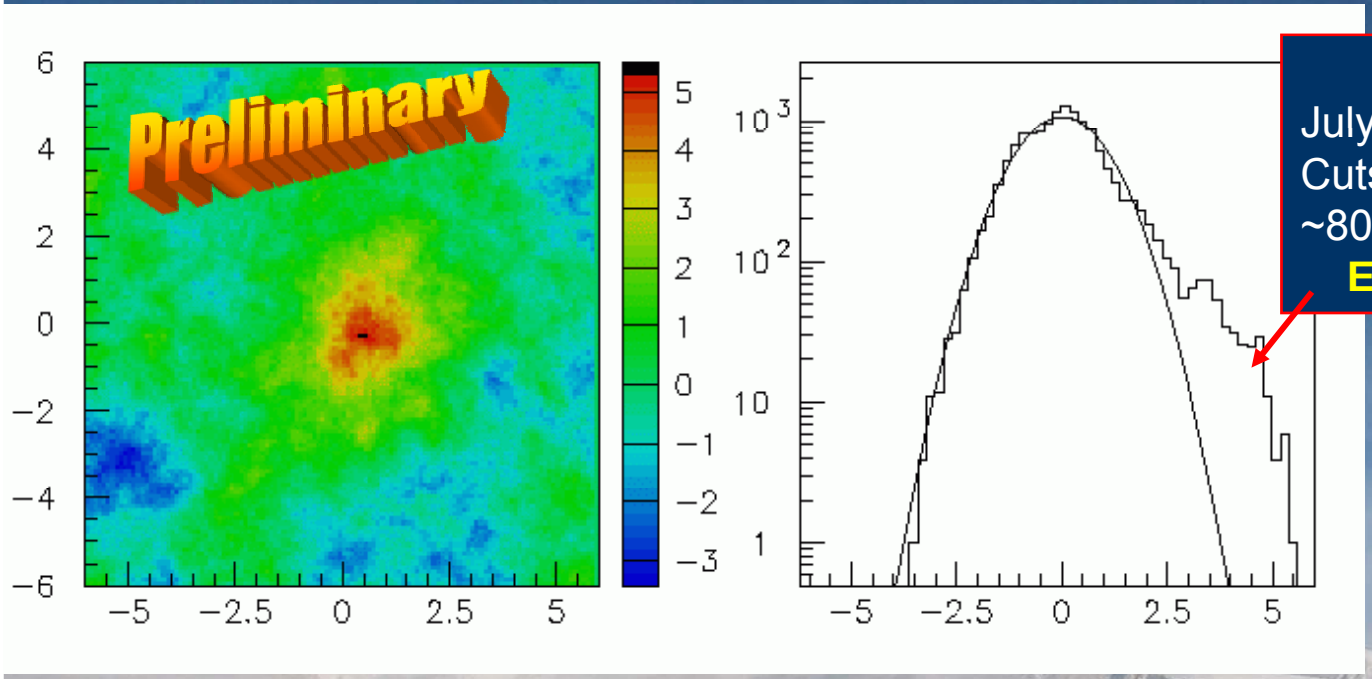
≈ 5 standard deviations



Systematics, calibration, analysis refinement under careful test and cross check between different analysis subgroups in the collaboration

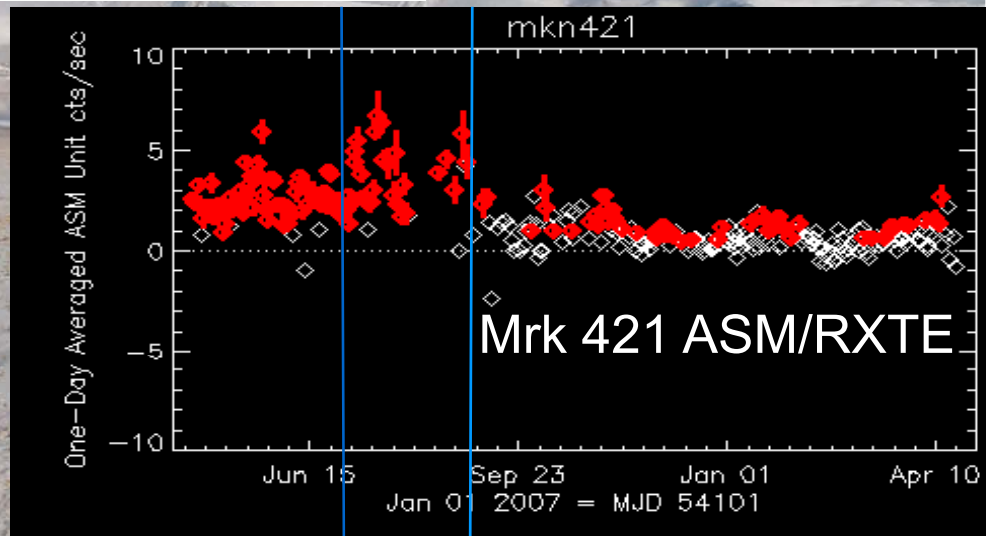
Search for point γ ray sources – Some preliminary result

The 2006 Markarian-421 Flare



Mrk421 region.
July and August 2006 data.
Cuts: Nhit>60 (<Eγ>~500GeV)
~80 hours oservation
Excess Significance: >5σ

Systematics, calibration, analysis refinement under careful test and cross check between different analysis subgroups in the collaboration



GRB Search with ARGO

Search is done in coincidence with detected GRBs by satellite (mainly SWIFT): GRB in the ARGO f.o.V (<40° zenith angle)

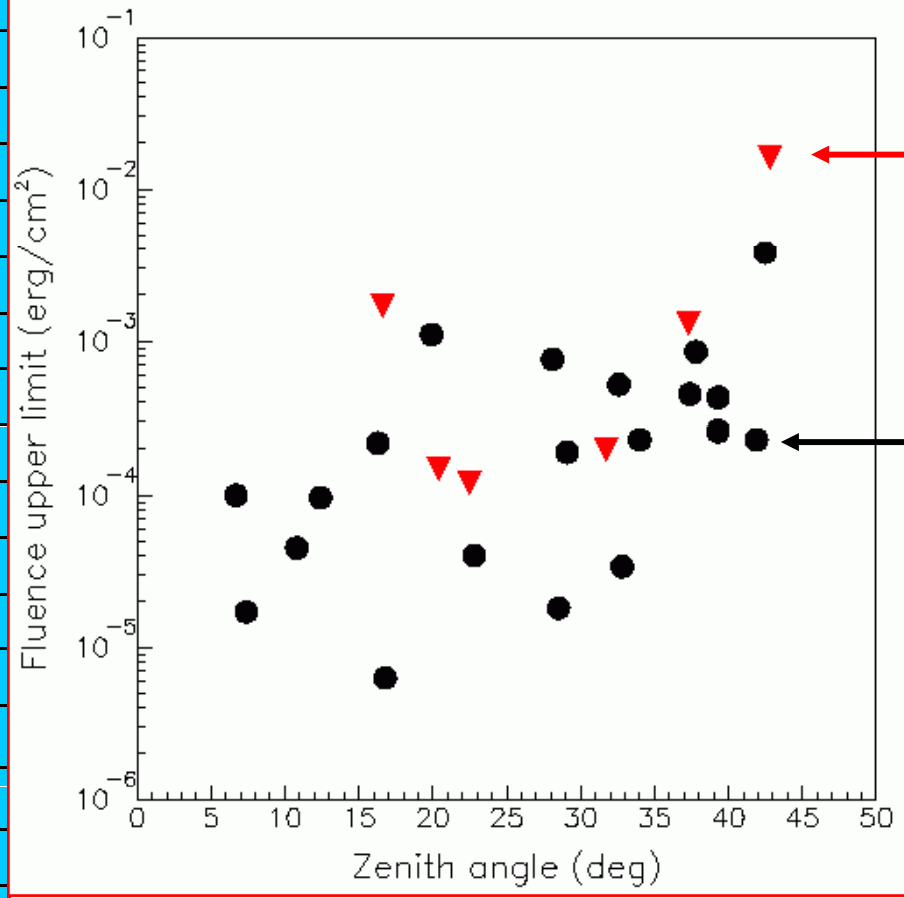
In scaler mode, look for a sudden increase of the counting rate:

- ✓Record particle counting every 0,5s:
  - $\geq 1, \geq 2, \geq 3, \geq 4$ counts in a single cluster within a coincidence window of 150ns
- ✓Look for a coincidence of rate change with detected GRBs:
  - in-time coincidence;
  - delayed or anticipated coincidence;

Energy threshold for ARGO GRB search in scaler mode: E~>1GeV

GRB	SAT	T90/dur (sec)	Zenith Angle (°)	Photon Index	Detector Area (m^2)	n_σ
041228						-0.45
050509A						-1.3
050528						0.78
051105A						
051114						
051227						1.5
060105						1.5
060111A						0.47
060121						
060421						
060424						0.86
060427						-0.65
060510A						2.4
060717						0.38
060801						1.1
060805B						-0.95
060807						0.96
061122						0.98
070201	HETE	0.3	26.0	CPL	3632	-1.4
070219	Swift	17	39.3	1.8	5632	-0.59
070306	Swift	210	19.9	1.72	5632	-0.27

Energy range 1-100 GeV



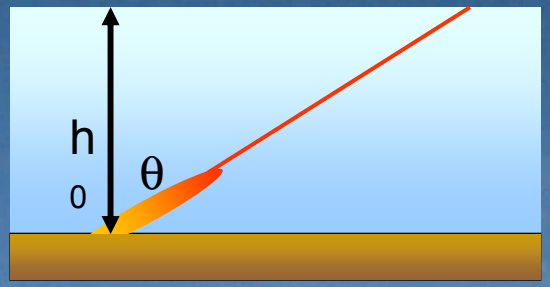
Redshift known
Extragal. abs. YES

Redshift unknown
Extragal. abs. NO

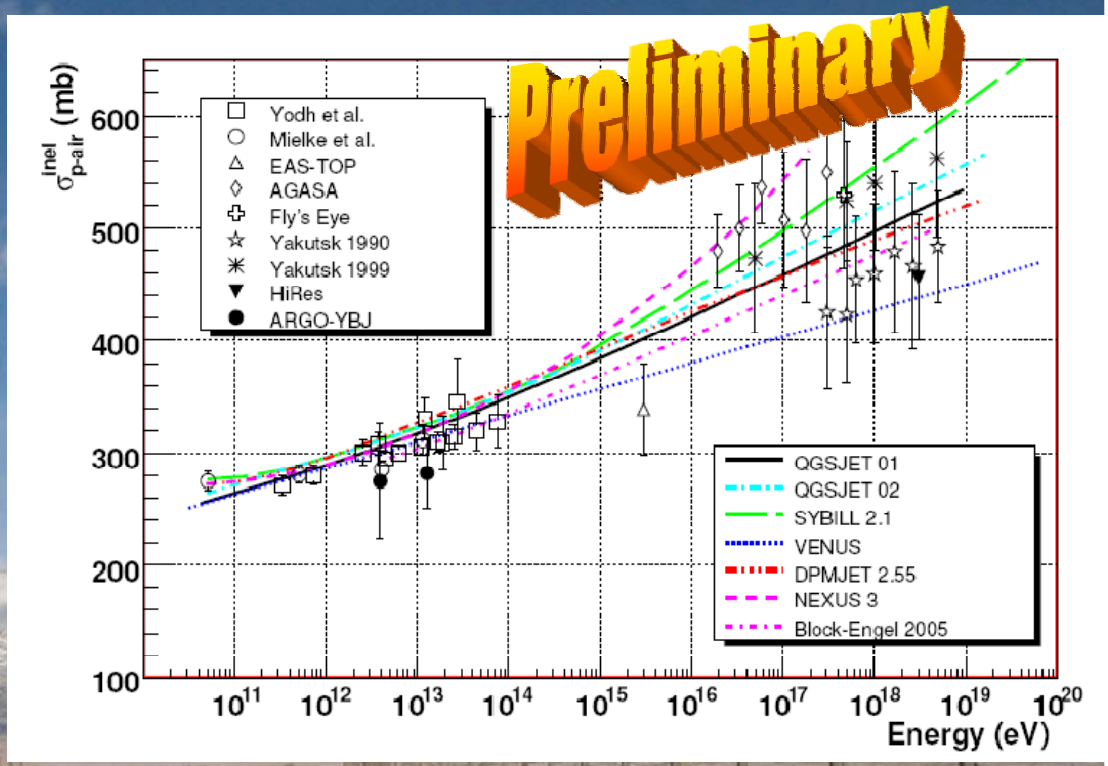
Assumed GRB spectral index: α=-2.5

Cosmic rays- Preliminary analysis

Flux attenuation and X-section



$$I(\theta) = I(0) \cdot e^{-\frac{h_o}{\Lambda}(\sec(\theta)-1)}$$



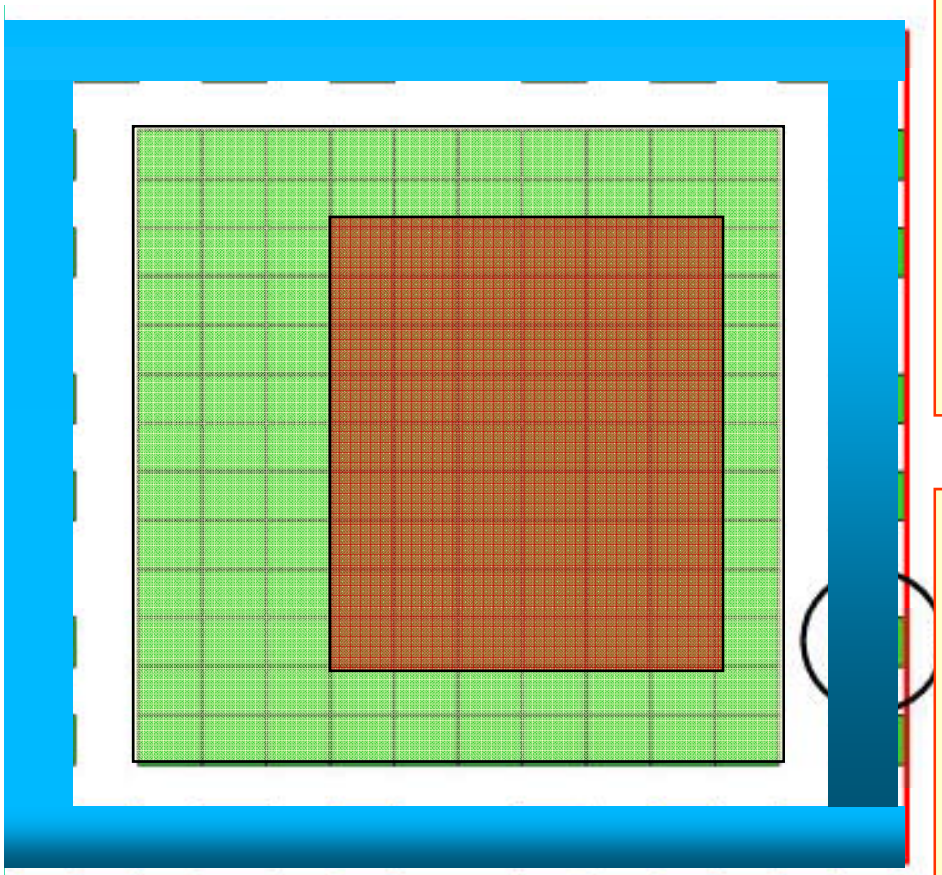
Select a given energy range (size).

The flux attenuation as a function of angle measures the interaction length (and is therefore a function of the p-Air X-section).

Look for more data to:

- ✓ **increase the statistics and the energy bins**
- ✓ **reduce the error bar**

ARGO-YBJ Status and Plans



ARGO DETECTOR

TODAY

- Central carpet (130 clusters – 5800 m^2) in Data Taking since july 2006.
- 54 Cluster with AnalogRO in Data taking
- Guard Ring (24 Clusters) in-situ, on-going final tests.

TOMORROW

- ✓ Continous Data Taking till August
- ✓ Autumn 2007:
  154 Cluster DataTaking without Pb
  110 Clusters with Analog-ReadOut
- ✓ During 2008:
  Pb pre-converter layer setting-up

Conclusion

ARGO-YBJ detector installed in Tibet (4300m a.s.l.) and taking data

- **Data taking includes 130/154 clusters (central carpet)**
- **24 external clusters will become full operating at the end of 2007**

Detector performances meet design requirements:

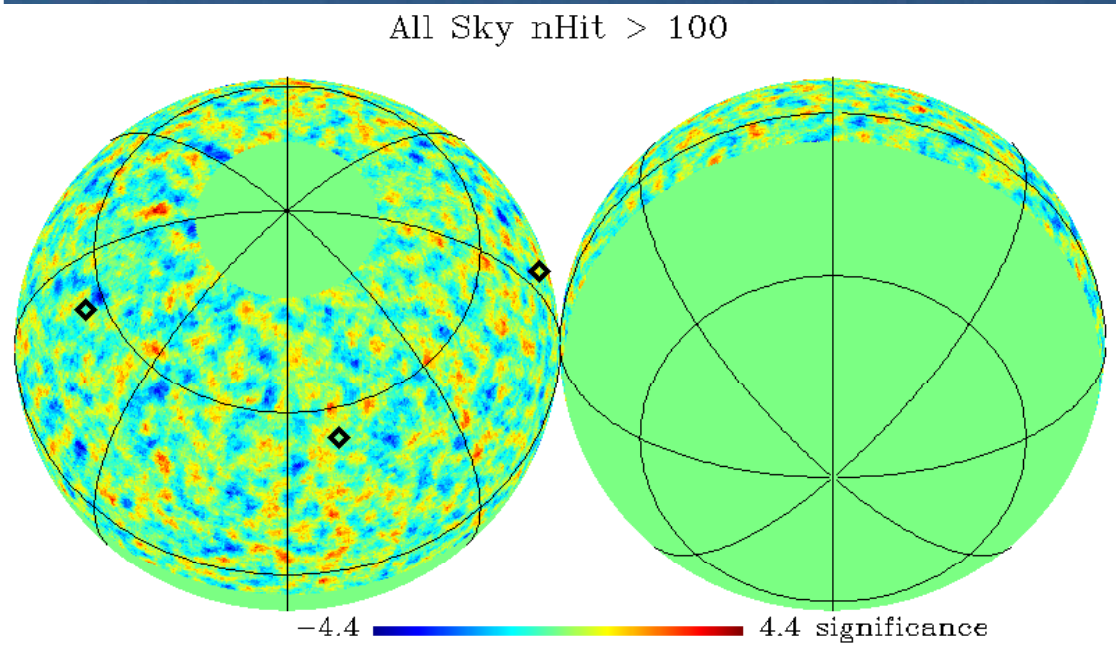
- **Angular Resolution ~0.5° from the Moon shadow and data confirm the MonteCarlo expected curves (<0.5° in the 10 TeV range)**
- **Energy threshold well below the TeV range (Mrk421 data)**

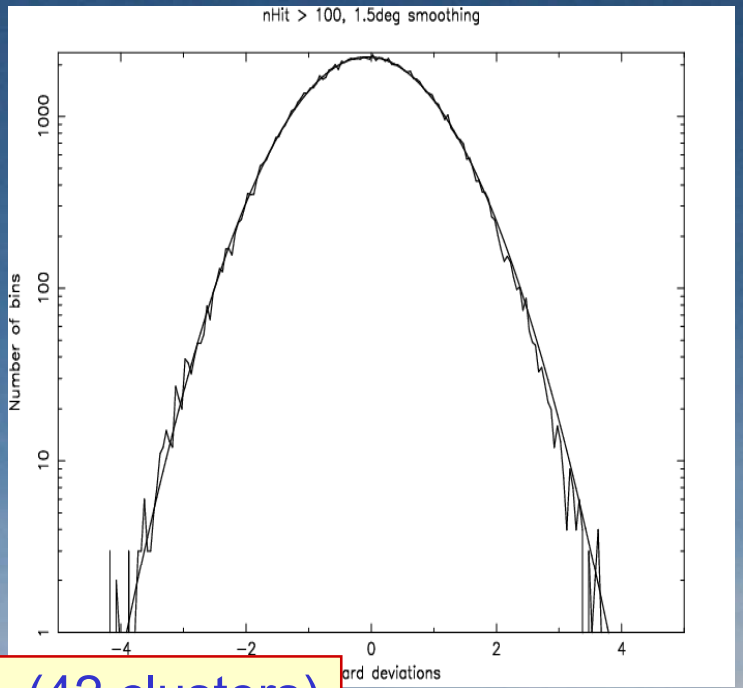
Preliminary analysis result:

- **Moon deficit observed according to the expected width and intensity;**
- **Preliminary data confirm a good sensitivity to the Crab flux.**
- **Markarian flare of July-August 2006 observed, detailed analysis in progress**
- **GRB fluence upper limits in the high energy region (>1GeV) measured in satellite slave modality.**
- **p-Air X-section analysis in progress to obtain larger accuracy in an extended energy range;**

The future: guard ring, more data, higher duty cycle, Pb preconverter

Search for point γ ray sources – The Analysis





Old data set, (42 clusters)

In each bin: $n_\sigma = (N_s - N_b) / N_b^{1/2}$

N_s = observed events

N_b = expected background events

The background is evaluated with the "time swapping" method

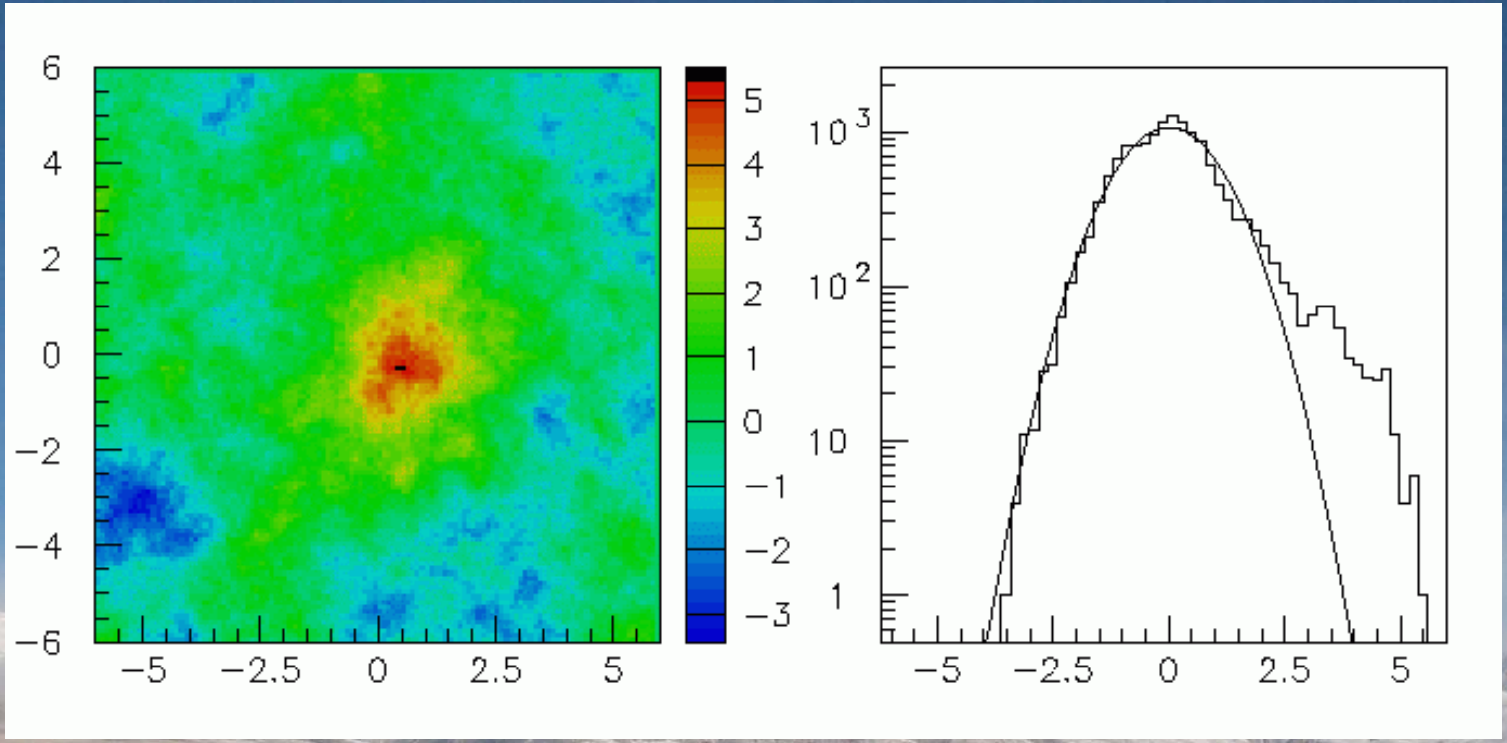
No excess > 4 standard deviations

Expected Crab signal, 0,8 σ

The detector and the analysis method seem to work properly

Search for point ♑ ray sources – Some preliminary result

The 2006 Markarian 421 Flare



PRELIMINARY Cross Check Analysis

July-August 2006 data:

~80 hours of Markarian 421 exposure

Result:

An observed excess with statistical significance: >5σ above the fluctuations

Data reduction:

- ✓Zenith angle <40°
- ✓Quality cut on the event rec. based on the χ^2 of the fit.
- ✓Nhit>60 (energy threshold)
- ✓Window size: 1°

GRBs with known redshift

GRB	SAT	T90/dur (sec)	Zenith Angle (°)	Redshift z	Photon Index	Detector Area (m^2)	n_σ
050408	HETE	15	20.4	1.24	1.98	1820	-1.3
050802	Swift	13	22.5	1.71	1.55	1820	-0.35
060115	Swift	142	16.6	3.53	1.76	4505	-0.07
060526	Swift	14	31.7	3.21	1.66	4505	0.68
060714	Swift	115	42.8	2.71	1.99	5632	-0.67
060927	Swift	23	31.6	5.6	1.65	5632	0.05
061110A	Swift	41	37.3	0.76	1.67	5632	-0.16

Search for point γ ray sources – Some preliminary result

The Crab

The DATA set:

- 2006 (days 184-335) ≈ 181 hours of observation
  (considering 25% of dead time)
- 2007 (days 35-106) ≈ 107 hours of observation

Equivalent time ≈ 50 days

The Event selection:

- Zenith angle <40°
- Different N_{hit} cuts
- Size of the ON/OFF window selected according to a MonteCarlo simulation of the Crab signal (spectrum and path), requiring the maximum signal/noise ratio

Some preliminary analysis of the γ/h discrimination implies an expected

$$Q_f = 1.45 \div 2,$$

according to the increasing number of hits in the detector, based on the different features of the photon/hadron lateral distribution.