L'esperimento ARGO-YBJ: stato e primi risultati

Miler[illegible]i per la Collaborazione ARGO-YBJ

IV Congressino di Sezione INFN – 23/01/2007

The ARGO-YBJ experiment

- **Collaboration between:**
  - Istituto Nazionale di Fisica Nucleare (INFN) – Italy
  - Chinese Academy of Science (CAS)

High Altitude Cosmic Ray Laboratory @ YangBaJing

The YangBaJing High Altitude Cosmic Ray Laboratory

Longitude 90° 31' 50" East
Latitude 30° 06' 38" North

4300 m above the sea level
≈ 600 g/cm²

90 Km North from Lhasa (Tibet)

Astrophysical Radiation with Ground-based Observatory

ARGO-YBJ Physics Goals

VHE γ-Ray Astronomy:

Search for point-like (and diffuse) galactic and extra-galactic sources at few hundreds GeV energy threshold

Search for GRB's (full GeV / TeV energy range)

Cosmic ray physics:

Spectrum and composition (Eth few TeV)
Study of the shower space-time structure
p-Air cross section

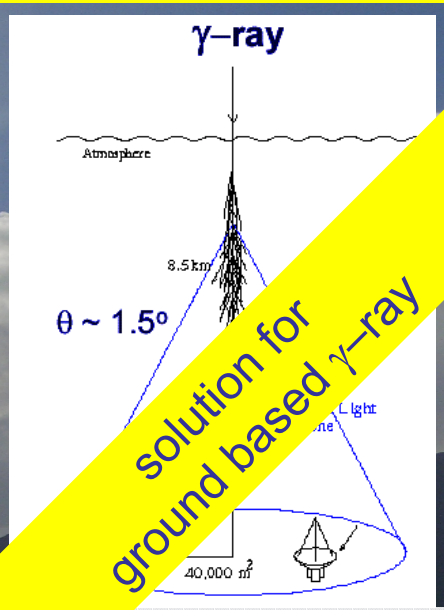
Sun and Heliosphere physics (E_{th} ~ few GeV)

Through..

Observation of *Extensive Air Showers* produced in the atmosphere by primary γ's and nuclei

Detecting Air Showers

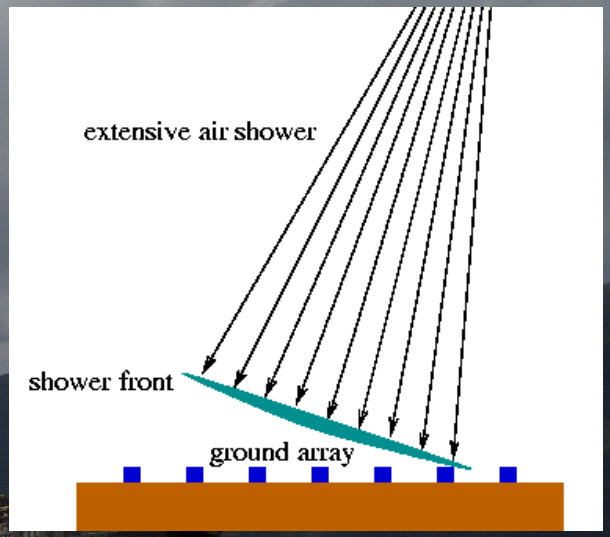
Air Cherenkov Telescopes



solution for ground based γ–ray

- ...w energy threshold (≈ 60 GeV)
- ...background rejection (99.7 %)
- High sensitivity (< 10^{-2} Φ_{crab})
- Good energy resolution
- Low duty-cycle (~ 5-10 %)
- Small field of view $\Delta\theta < 4°$

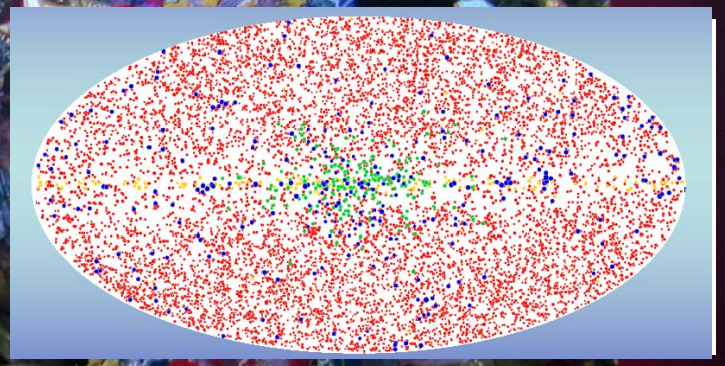
EAS arrays



- High energy threshold (≈ 50 TeV)
- Moderate bkg rejection (≈ 50 %)
- Modest sensitivity (≈ Φ_{crab})
- Modest energy resolution
- High duty-cycle (> 90 %)
- Large field of view (~ 1-2 sr)

Why an EAS array in the GLAST era ?

- See an entire hemisphere every day
- Large fov & high duty-cycle
  - GRB's
  - Transient astrophysics
  - Extended objects
  - New sources



Simulated GLAST survey

Excellent complement to GLAST

With > 1000 sources (many variables !) need an **all-sky instrument in VHE**

ACTs can monitor only ~ 15 sources / year at stated sensitivity

A sensitive EAS array is needed to extend GLAST measurements at > 100 GeV.

A new generation EAS array

The (

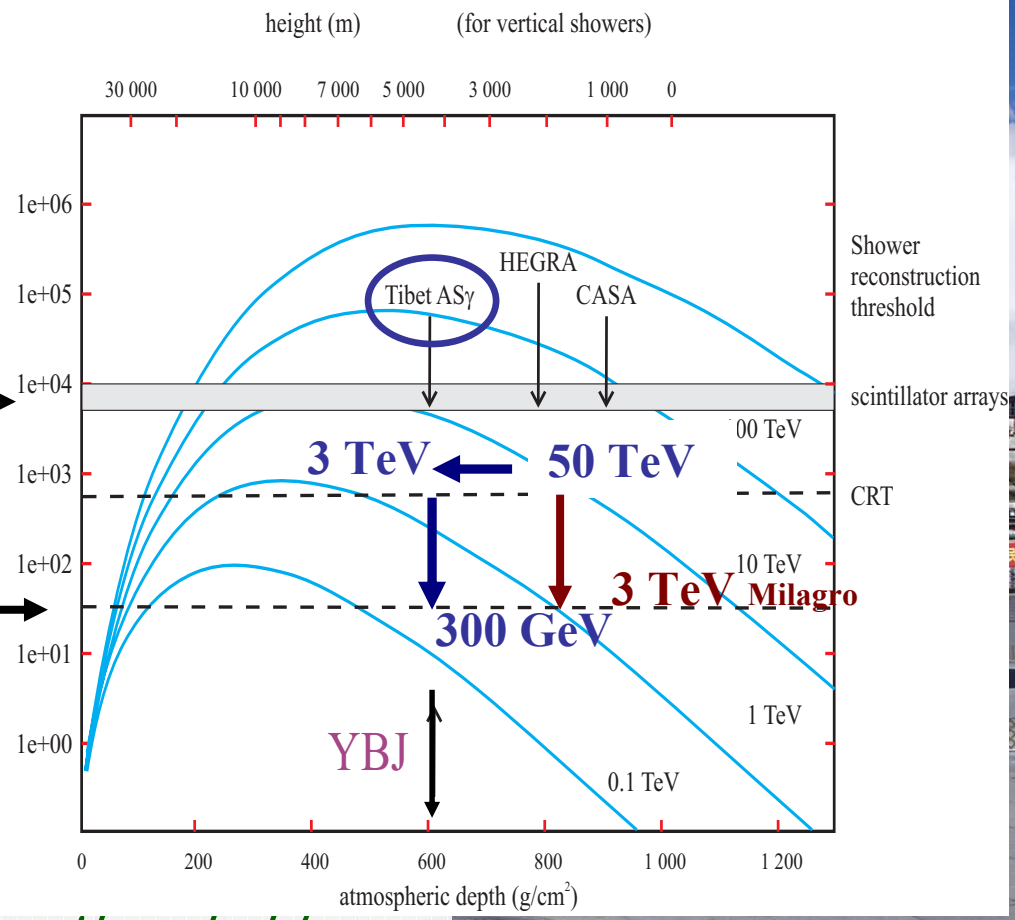
- **Low**
- **Incr**

The S

- **Hig**
- **Sec**
- **Incr**

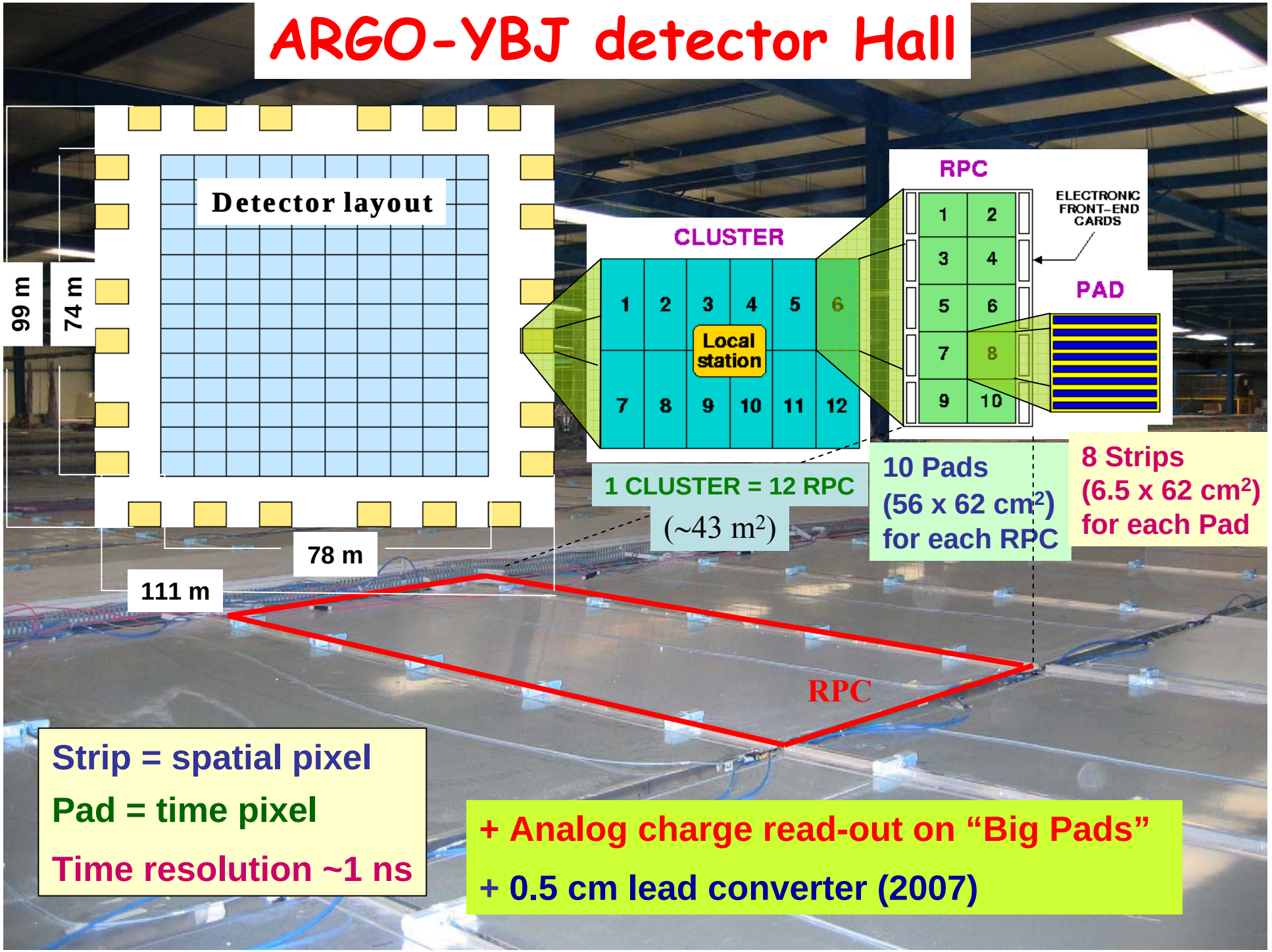
SAMPLING
(traditional arrays)

FULL COVERAGE

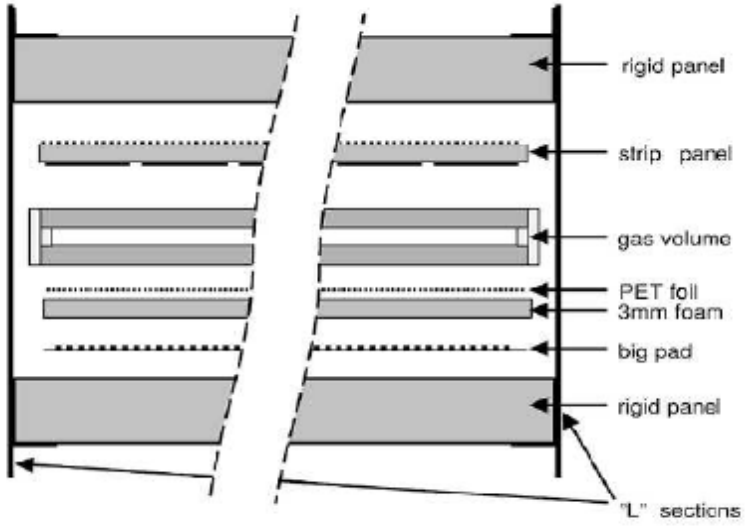


Lowers energy threshold

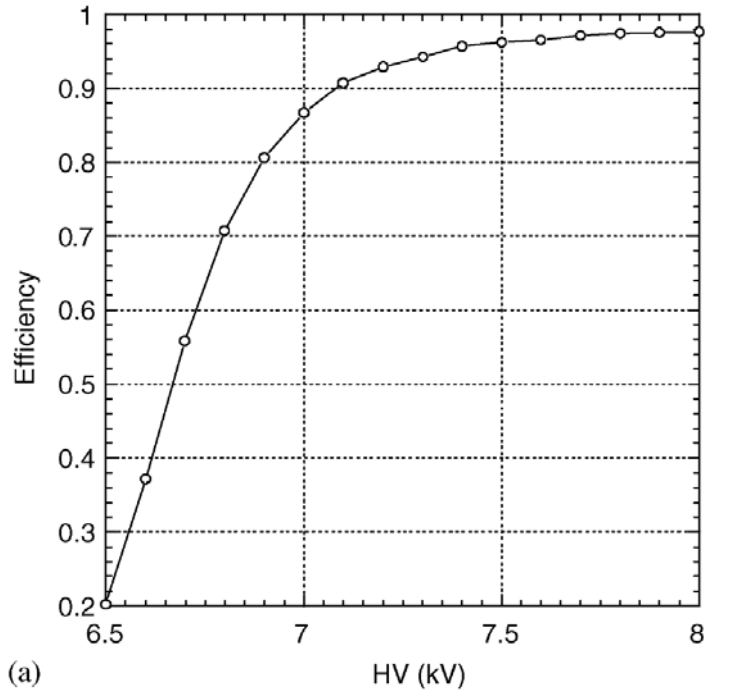
ARGO-YBJ detector Hall

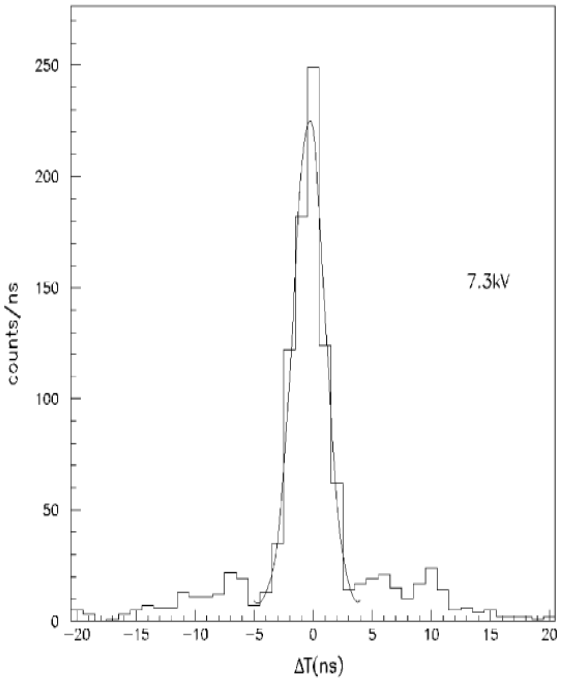


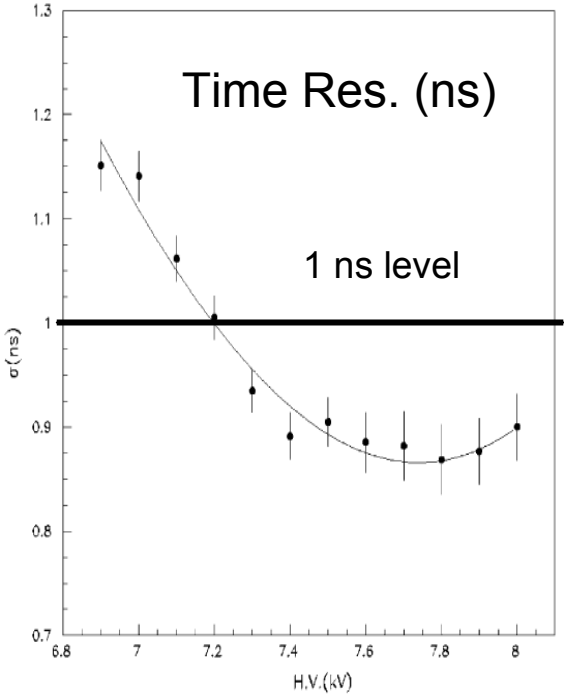
RPC layout & performance



- Bakelite RPC ($5 \cdot 10^{11}\ \Omega \cdot cm$)
- Operation in streamer mode
- Ar/Isobuthane/TFE 15/10/75 gas mixture
- Efficiency > 92 % at 7.2kV (10kV at s.l)
- Time resolution: ~ 1 ns

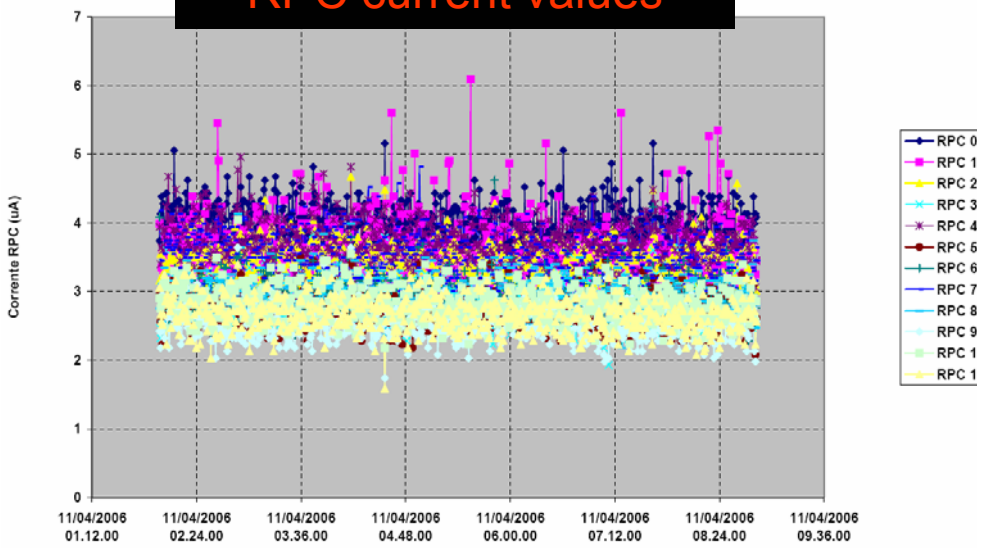




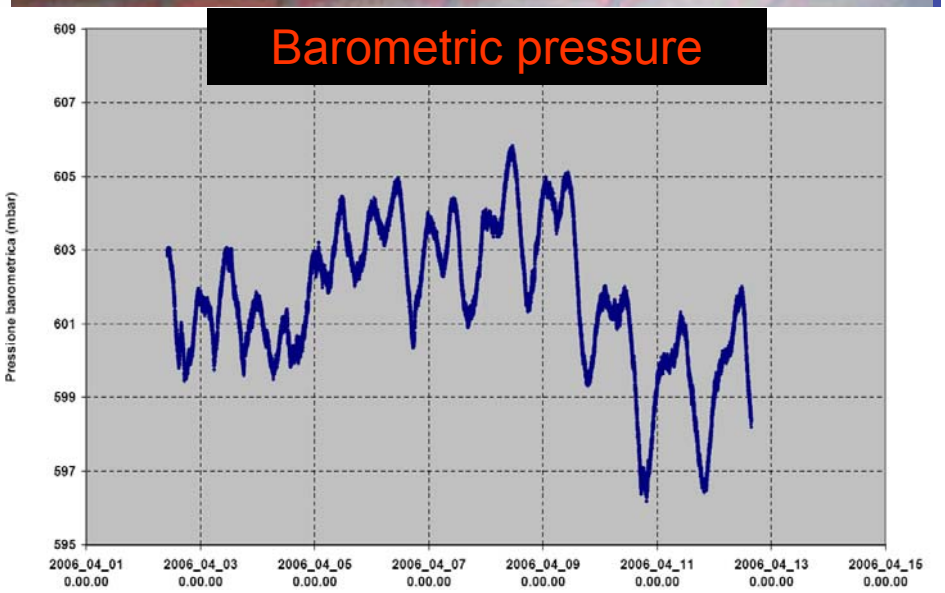


DAQ and DCS

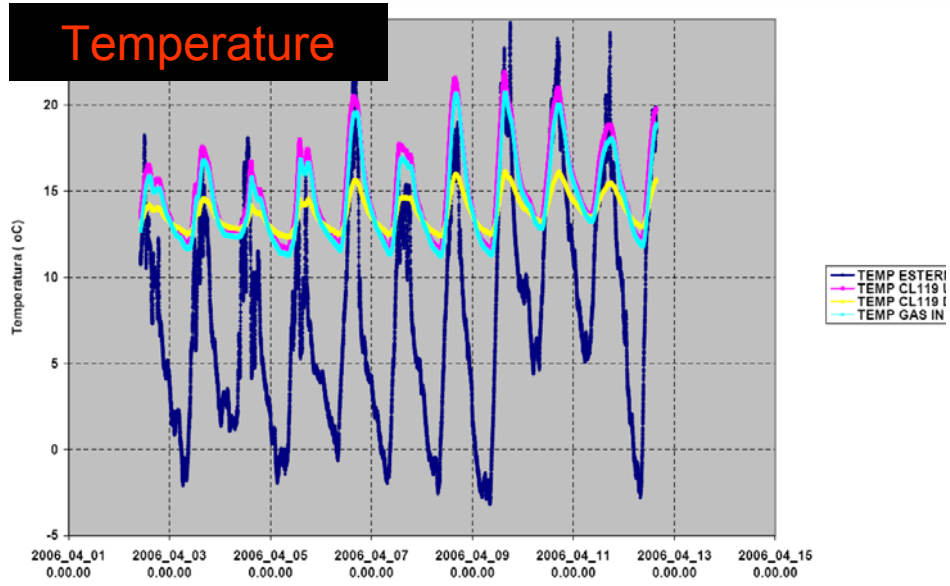
RPC current values



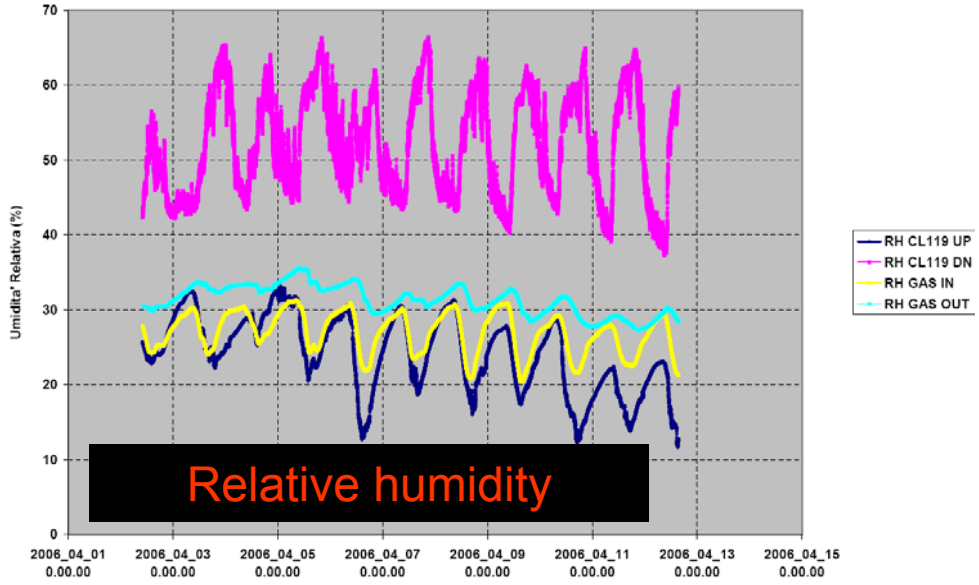
Barometric pressure



Temperature



Relative humidity



Detector configuration and data taking

Near past …

- 42/154 clusters (~1900m^2) in DAQ

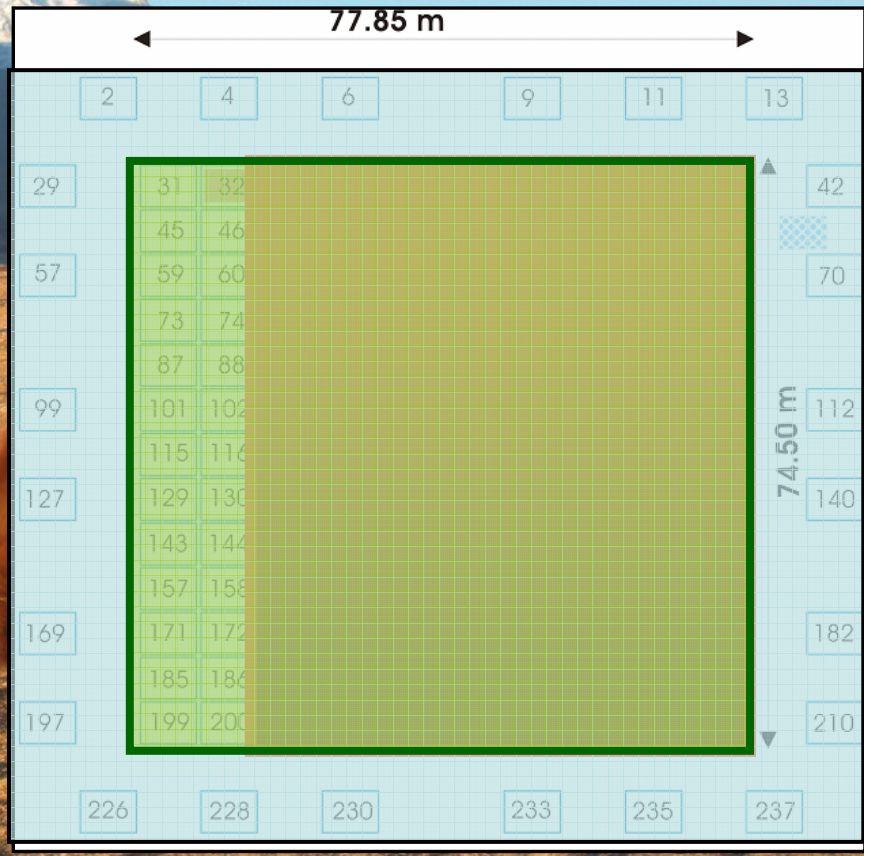
  ⇒ First results (next slides)

present..

- **130/154 clusters (~5600m^2) now in DAQ**
- Detector debugging ~ ok
- trigger: $N_{pad} \geq 20$, rate: 3.5 kHz, data flow: 5 MB/s

..and near future

- 154/154 in acquisition

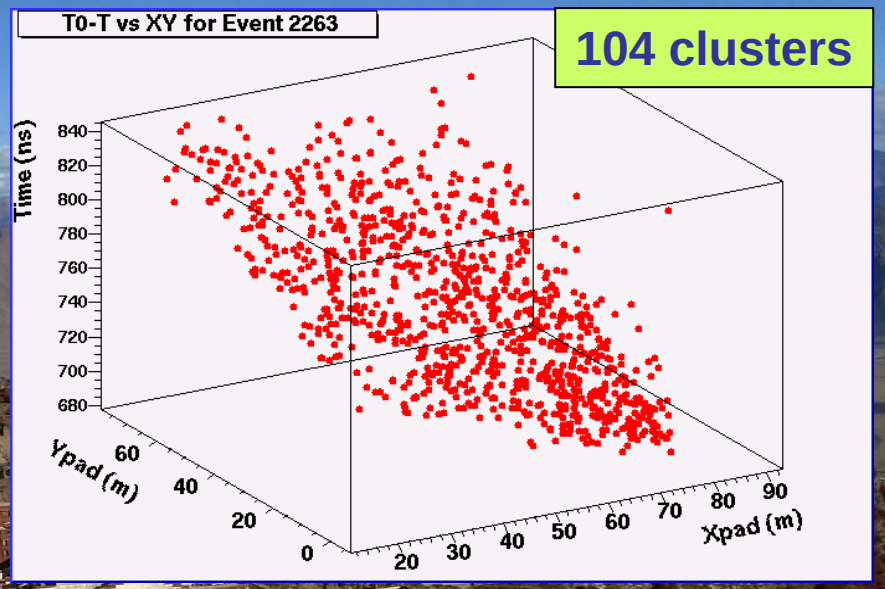


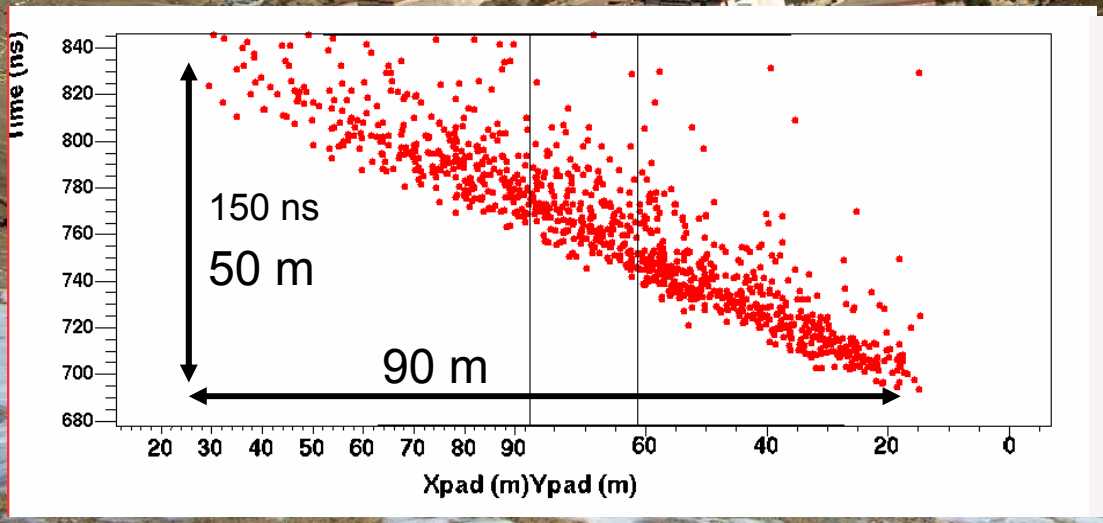
Detector performances

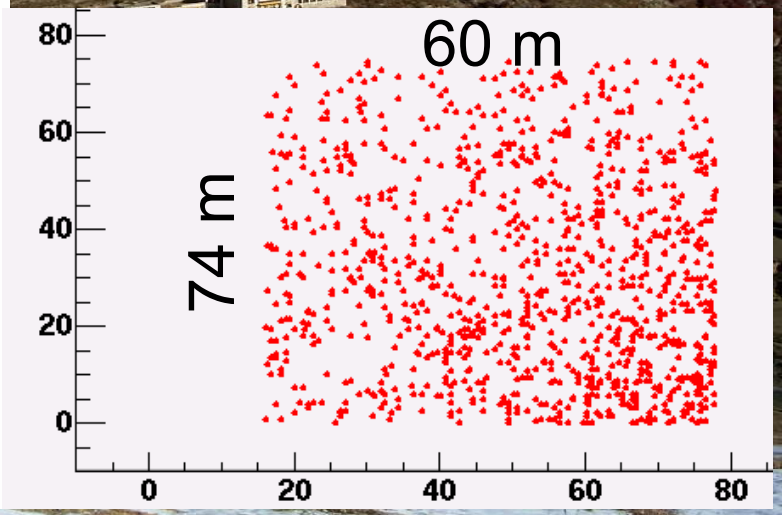
High space-time granularity
+ Full coverage technique
+ High altitude

⇓

a unique way to study EAS

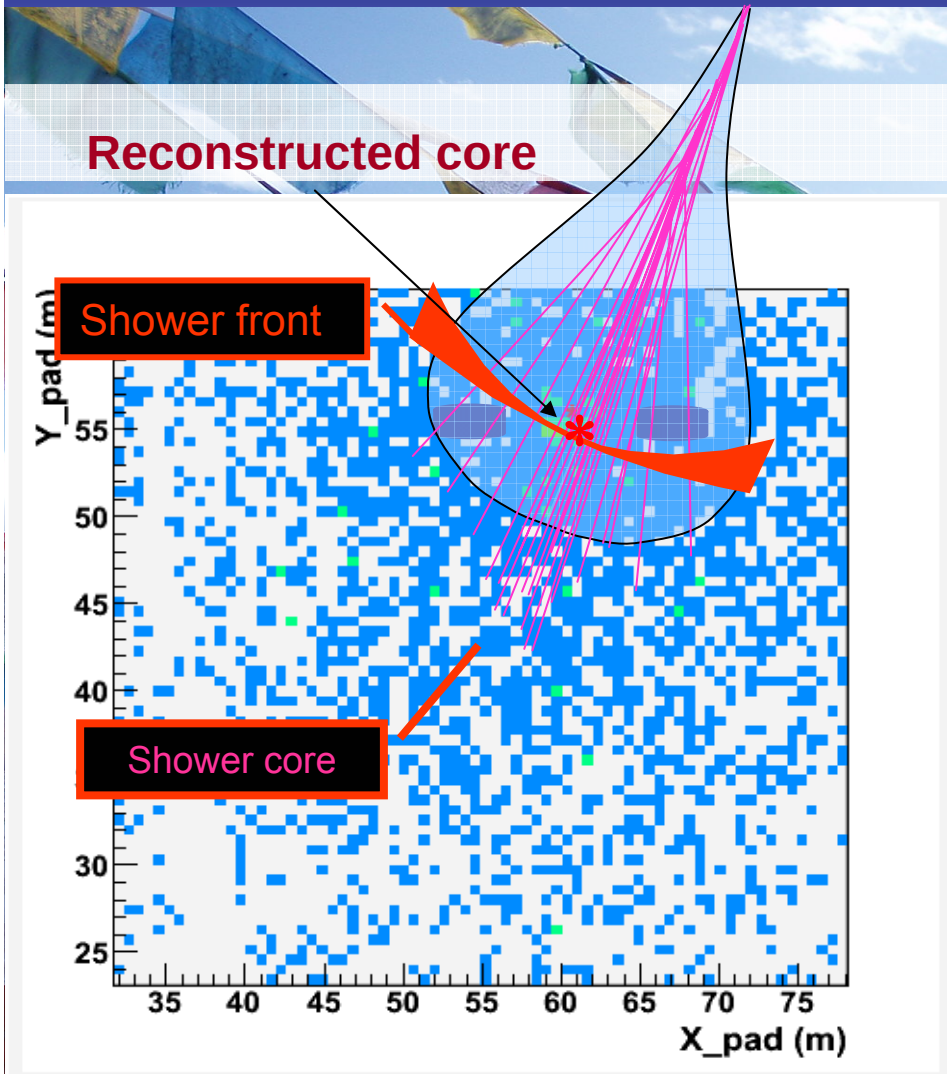




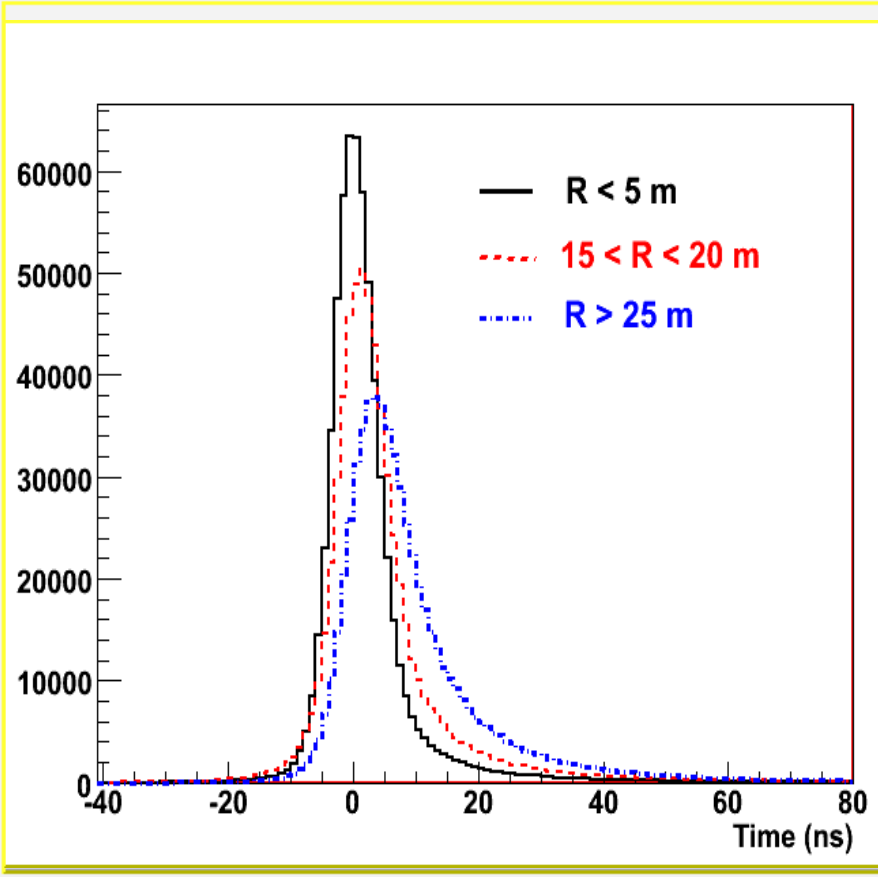


EAS space-time structure (I)

Reconstructed core

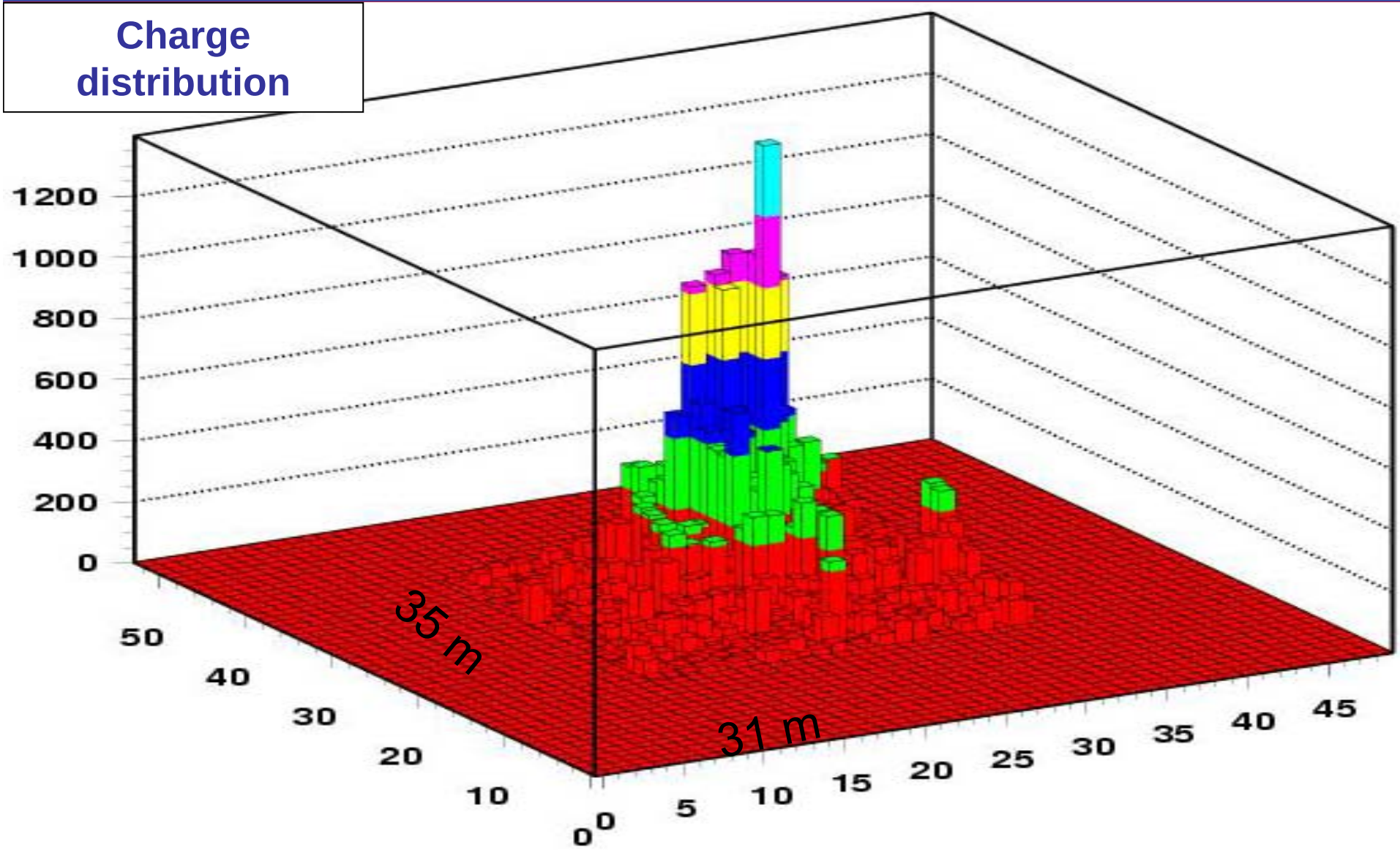


Time width of the shower front

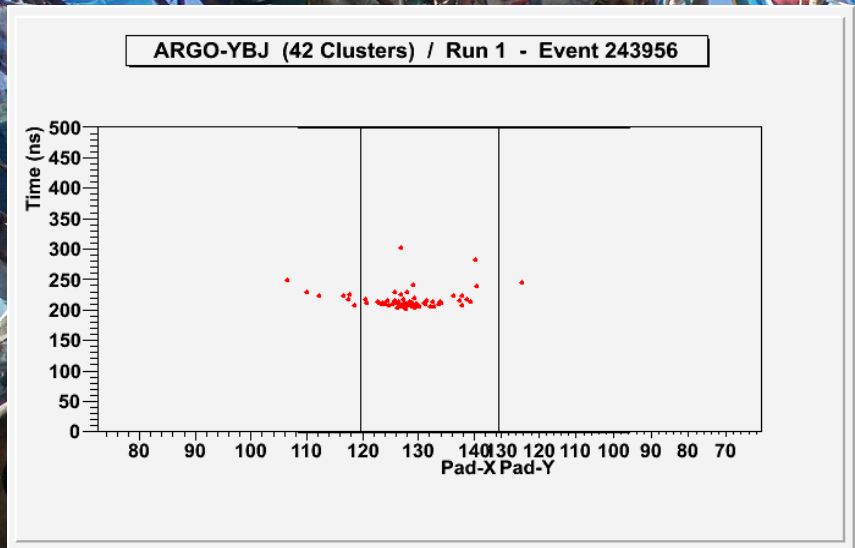


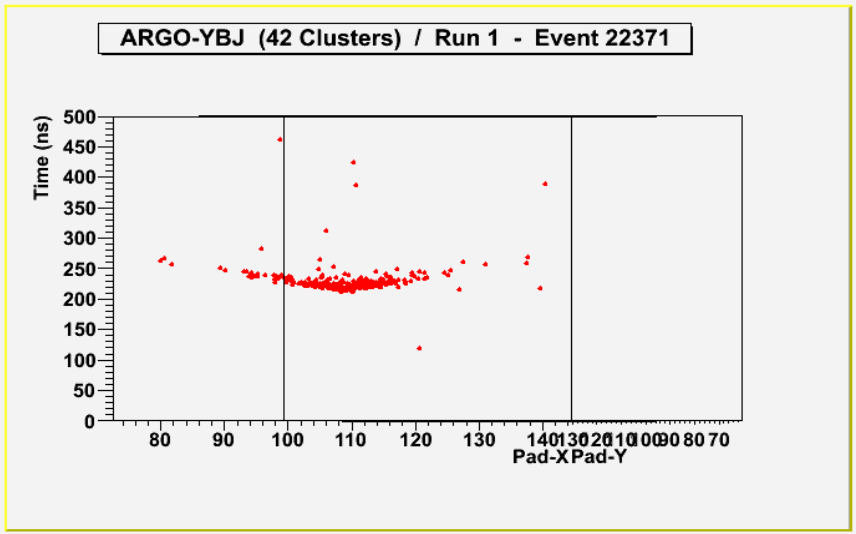
EAS space-time structure (II)

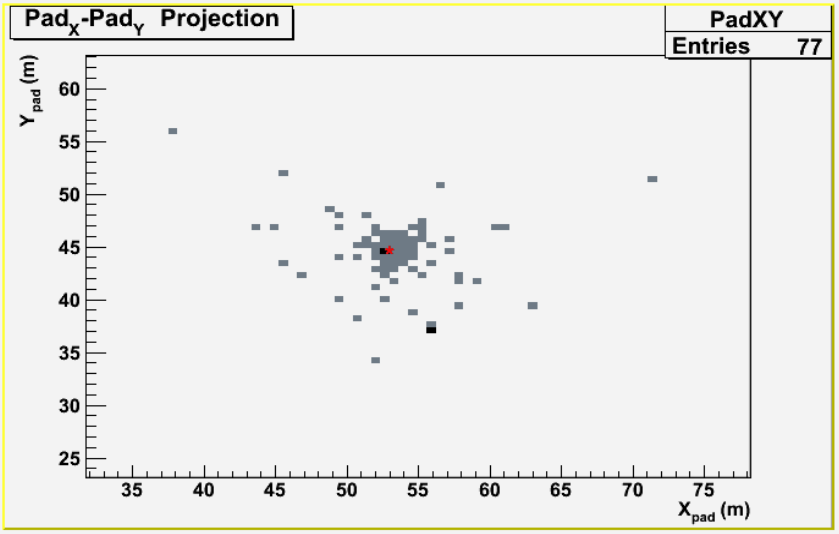
Charge distribution

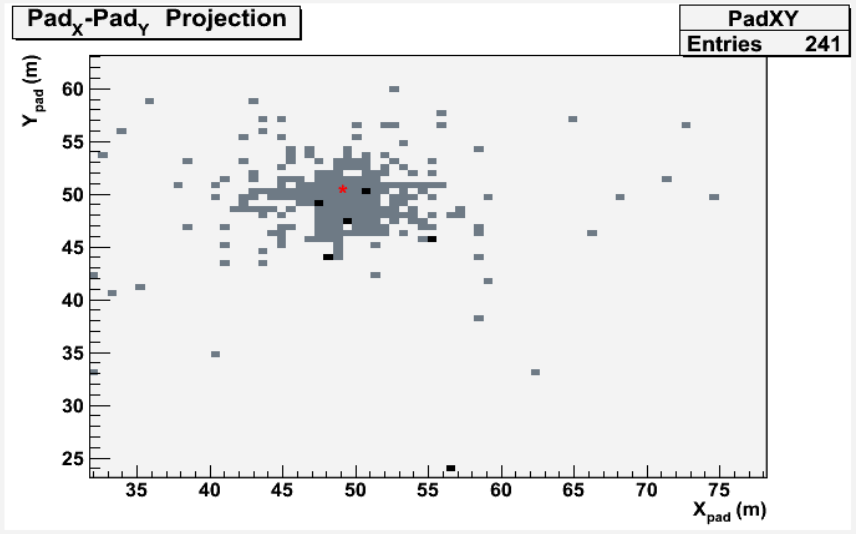


EAS space-time structure (III)









Sensitivity

The observation of γ sources is affected by the huge background due to ordinary cosmic rays

$\phi_{CRAB}(>1\ \text{TeV}) \sim 2\cdot10^{-11}\ \text{ph/cm}^2\cdot\text{s}$

$\phi_{bkg}(>1\ \text{TeV})\cdot\Delta\Omega(=2\cdot10^{-4}\ \text{sr}) \sim 3\cdot10^{-9}\ \text{nuclei/cm}^2\cdot\text{s}$

$$\phi_{signal} \approx 10^{-2}\bullet\phi_{bkg}$$

Sensitivity can be expressed as

$$S=\frac{N_\gamma}{\sqrt{bkg}}=\frac{\phi_\gamma(>E_{th})}{\sqrt{\phi_{bkg}(>E_{th})}}\cdot\frac{A_{eff}^{\gamma}(>E_{th})}{\sqrt{A_{eff}^{bkg}(>E_{th})}}\cdot\sqrt{\frac{T\cdot f}{\pi}}\cdot\sqrt{d.c.}\cdot\frac{\varepsilon(\Delta\vartheta)}{\Delta\vartheta}\cdot Q$$

$$Q=\frac{\varepsilon_\gamma}{\sqrt{1-\varepsilon_{bkg}}}$$

Angular resolution

- True-rec
  sp
  tr
  di
- Chess-b
  sp
  di
  w

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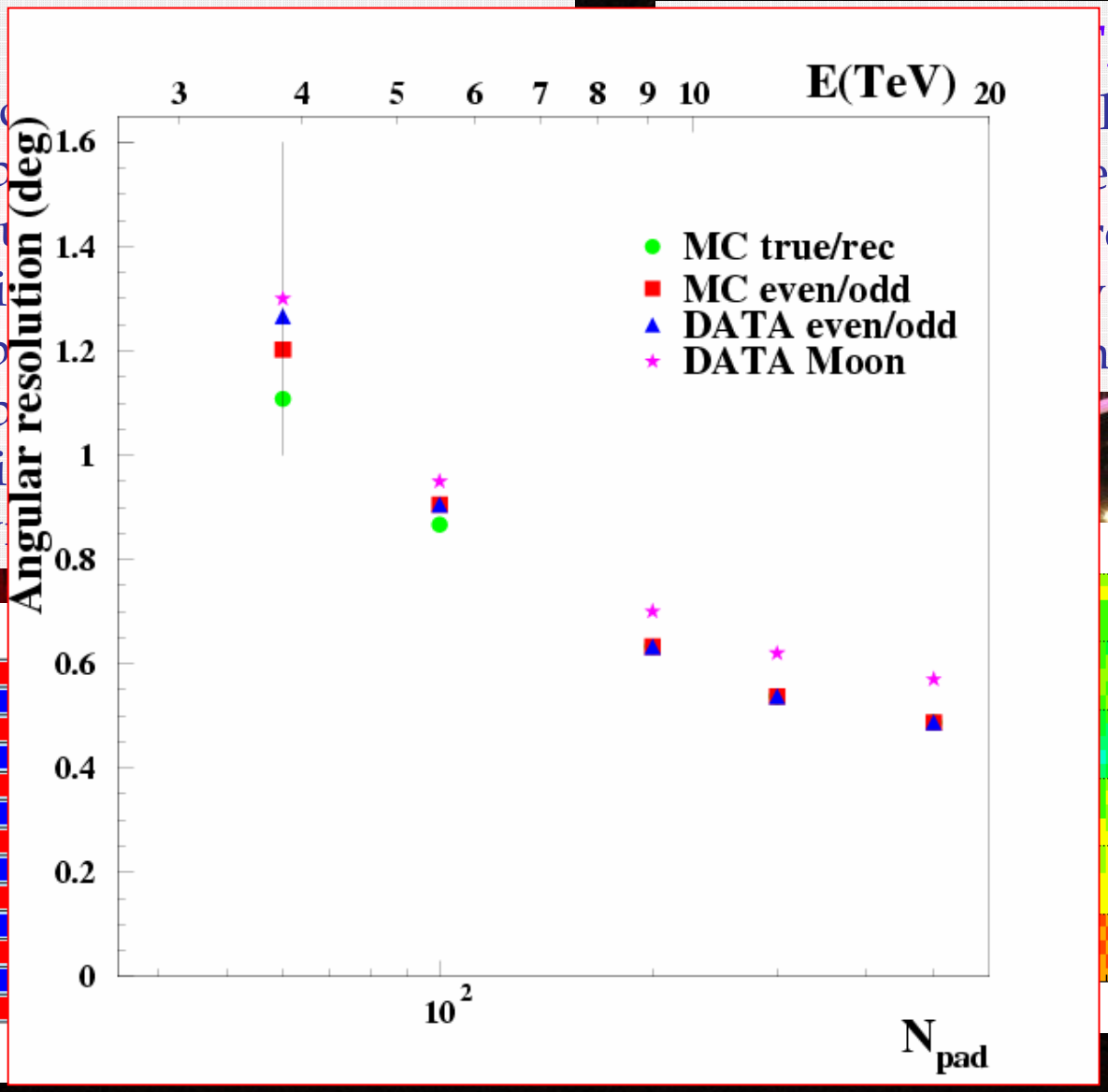
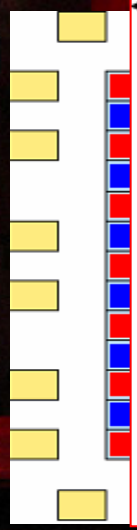
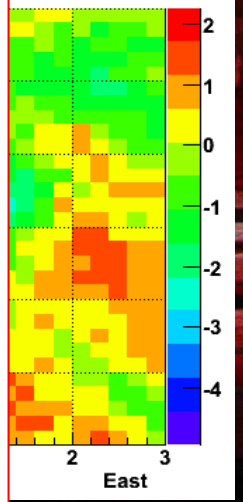
reconstructed
o subarrays
he Moon







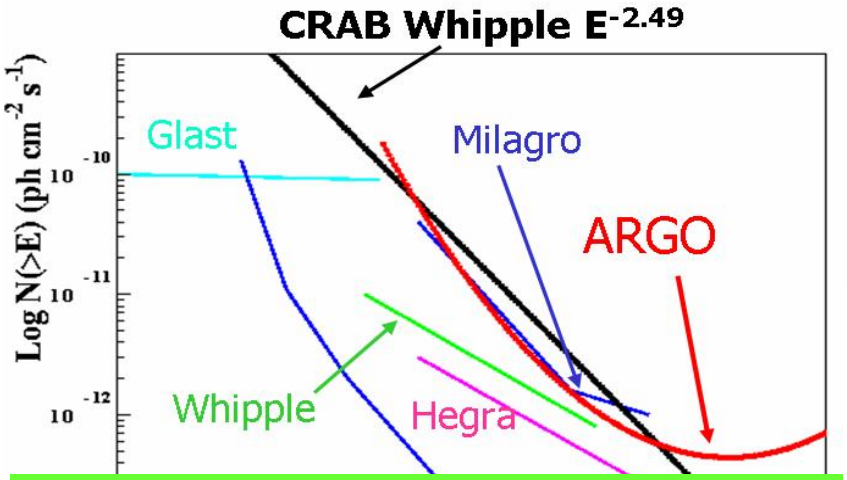
Hadron-γ discrimination

Discrimination made exploiting the excellent spatial resolution of the detector. Search for parameters based on the features of the lateral distribution of the eletromagnetic component, on simmetry and compactness properties and on the analysis of the fluctuations.

Check of the efficacy of the parameters made by using Linear Discriminant Analysis

N_{pad}	$<E_\gamma>$	$<E_p>$	Q
100÷300	1.6 TeV	2.6 TeV	1.6
300÷1000	2.8 TeV	4.2 TeV	1.7
1000÷3000	4.5 TeV	6.7 TeV	1.7

VHE γ astronomy



ARGO can observe in 1 year a Crab-like source of intensity 0.7 (0.4) Crab units at energies E > 0.5 (1.0) TeV, with a significance of 4 standard deviations.

- Run time:

62.3 days (24/12/2004–17/07/2005)

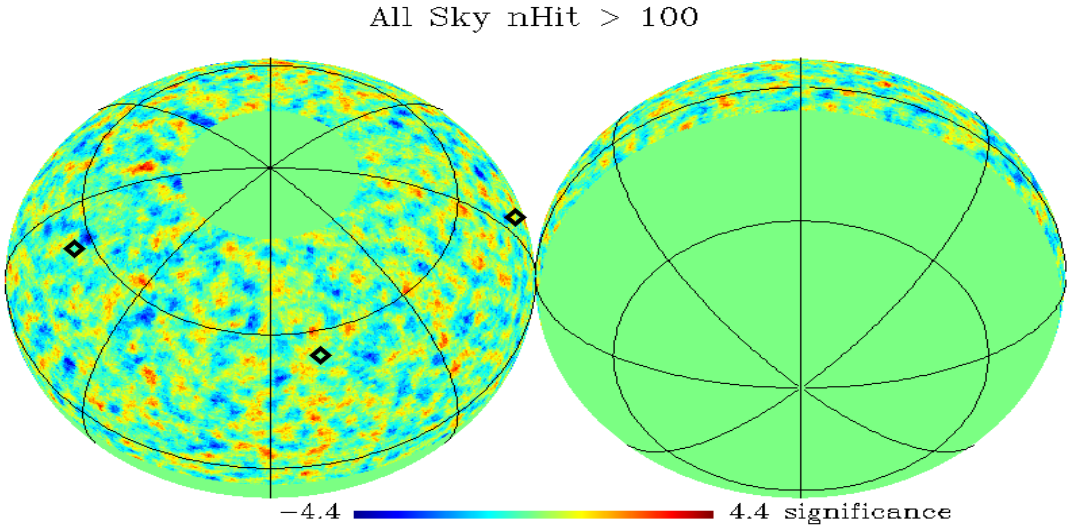
- Number of events:

7.6×10^8 (5.3×10^8 with nHit > 100)

Selection of showers with zenith angle $\theta < 40°$ (Maximum is 60°)

ARGO-YBJ latitude = 30°

observed declination band $-10° < \delta < 70°$



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

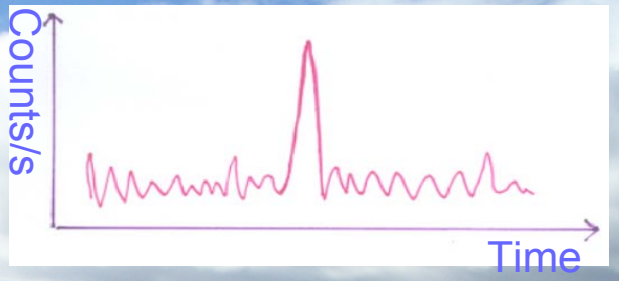
N_s = observed events

N_b= expected background events (time swapping method)

Sensitivity to GRB's

1) Single Particle technique

- The counting rate of the singles particles hitting the detector is recorded at fixed time intervals.
- An excess is registered if the counting rate is significantely higher than the background.
- No arrival direction reconstruction.

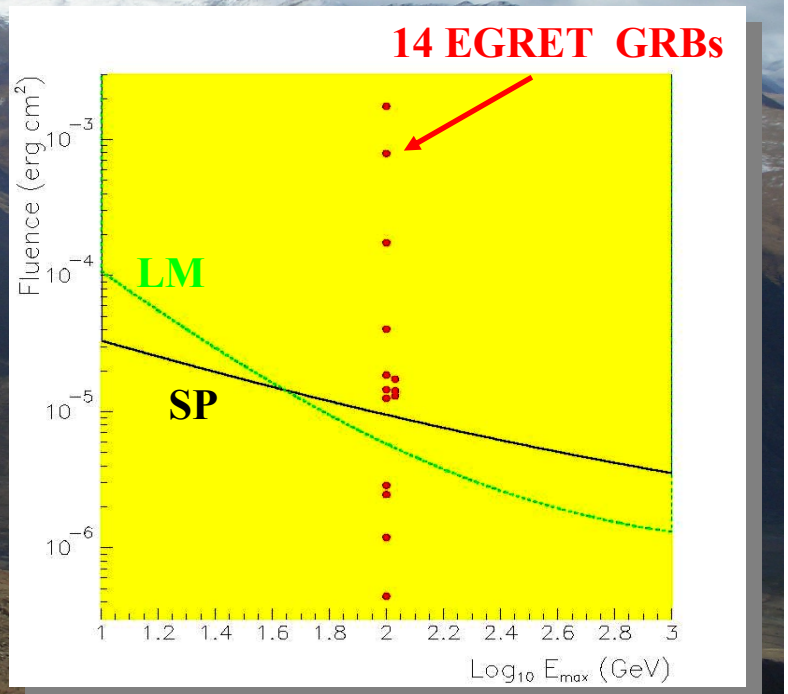


2) Low Multiplicity technique

- Detection of showers with ≥ 6 fired pads .
- Angular resolution ≈ 5° .

γ-ray flux from the GRB:

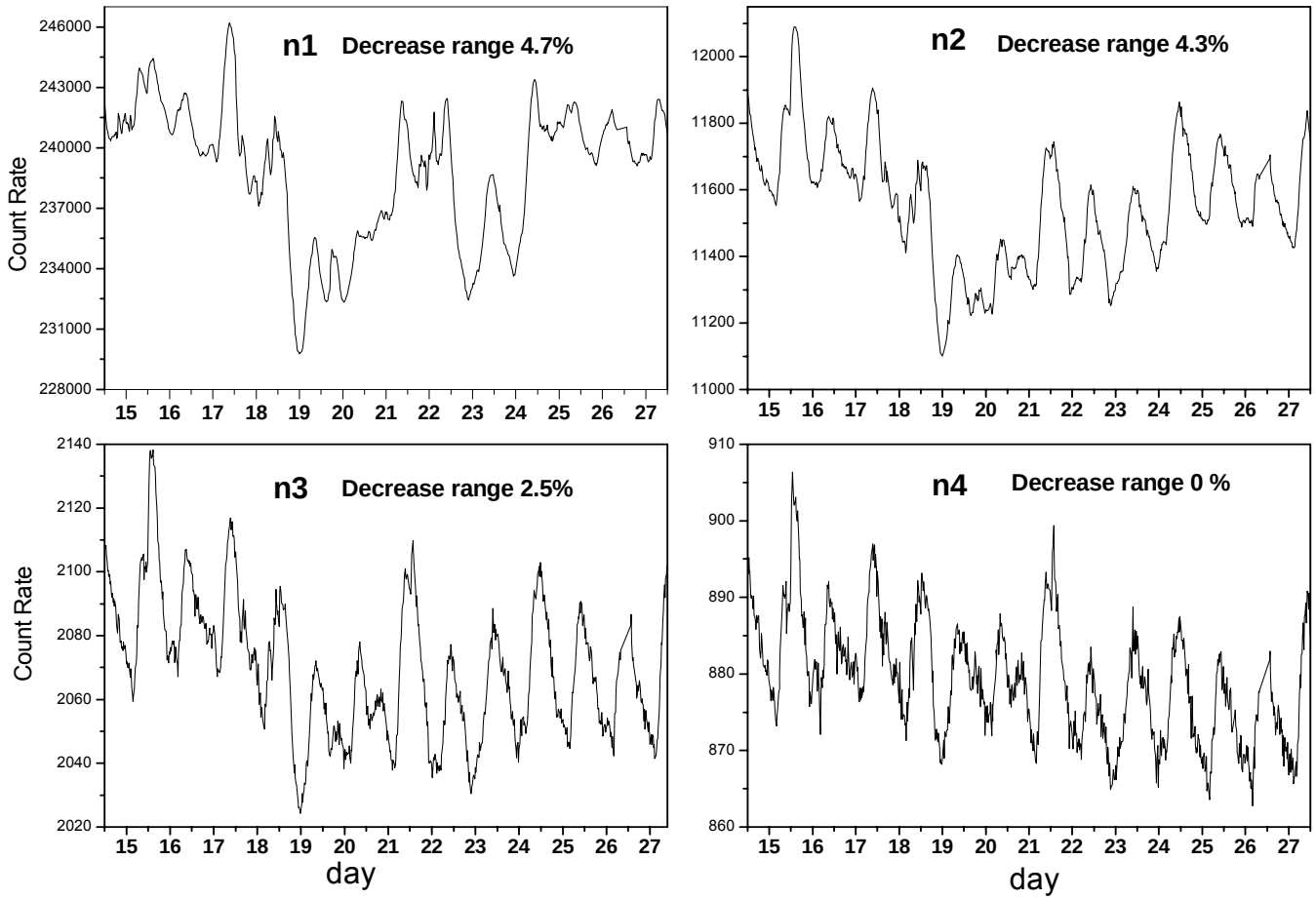
$$\frac{dN}{dE} = K \cdot E^{-\alpha} \; ph \cdot m^{-2}$$



Upper limit to the 3σ fluence in the energy range 1-100 GeV: 10^{-4}-10^{-5} erg/cm^2

Solar Physics

Forbush decrease observed on 19/jan/05 using the Single Particle Technique (SPT)



SPT 1second coincidence rate:

>1 (5GeV)

>2 (15GeV)

>3 (25GeV)

>4 (100GeV)

Observed decreases

4.7%

4.8%

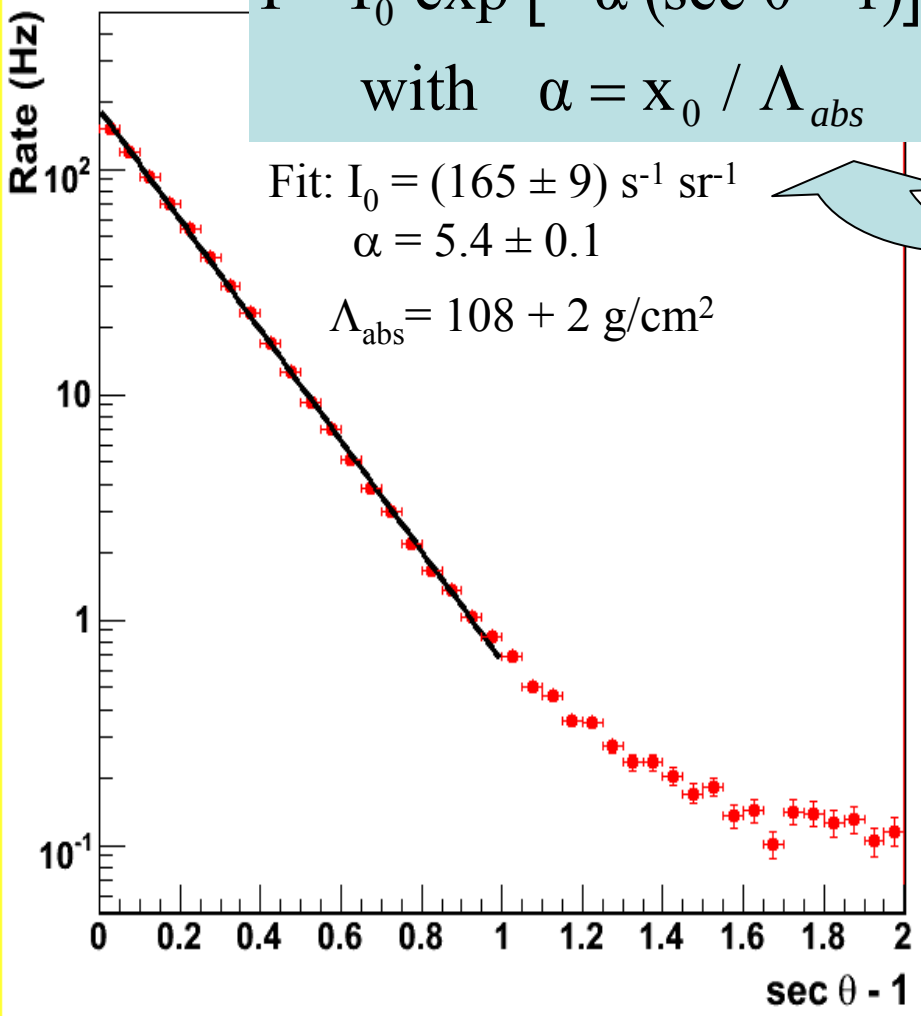
2.6%

0%

Angular distribution

$$I = I_0 \exp\left[-\alpha\left(\sec\theta - 1\right)\right]$$

$$\text{with} \quad \alpha = x_0 / \Lambda_{abs}$$



Fit: $I_0 = (165 \pm 9)$ s^{-1} sr^{-1}

$\alpha = 5.4 \pm 0.1$

$\Lambda_{abs} = 108 + 2$ g/cm^2

From an ARGO data sample

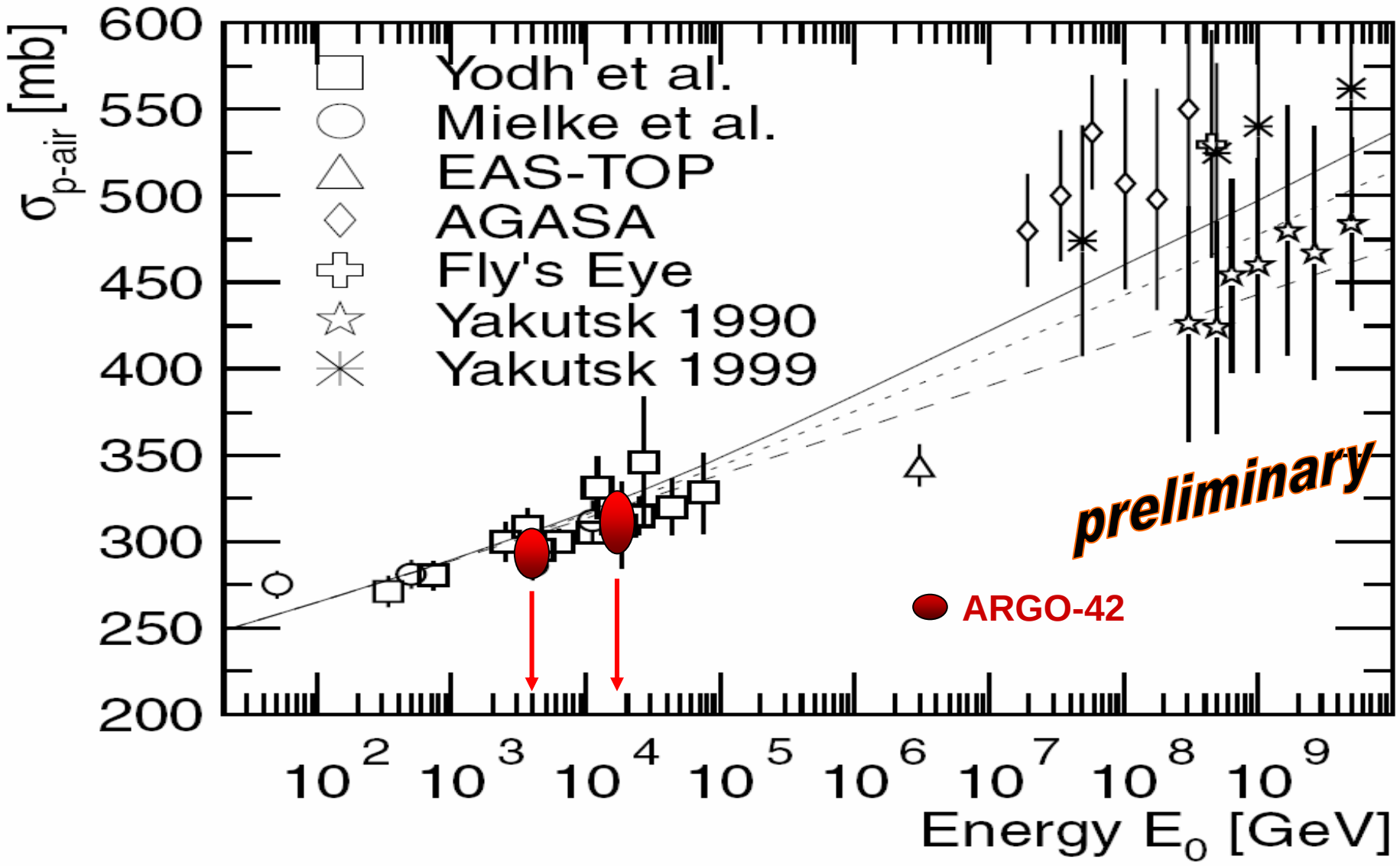
Expected behaviour:

x_o = vertical depth (606 g/cm^2 at YBJ)

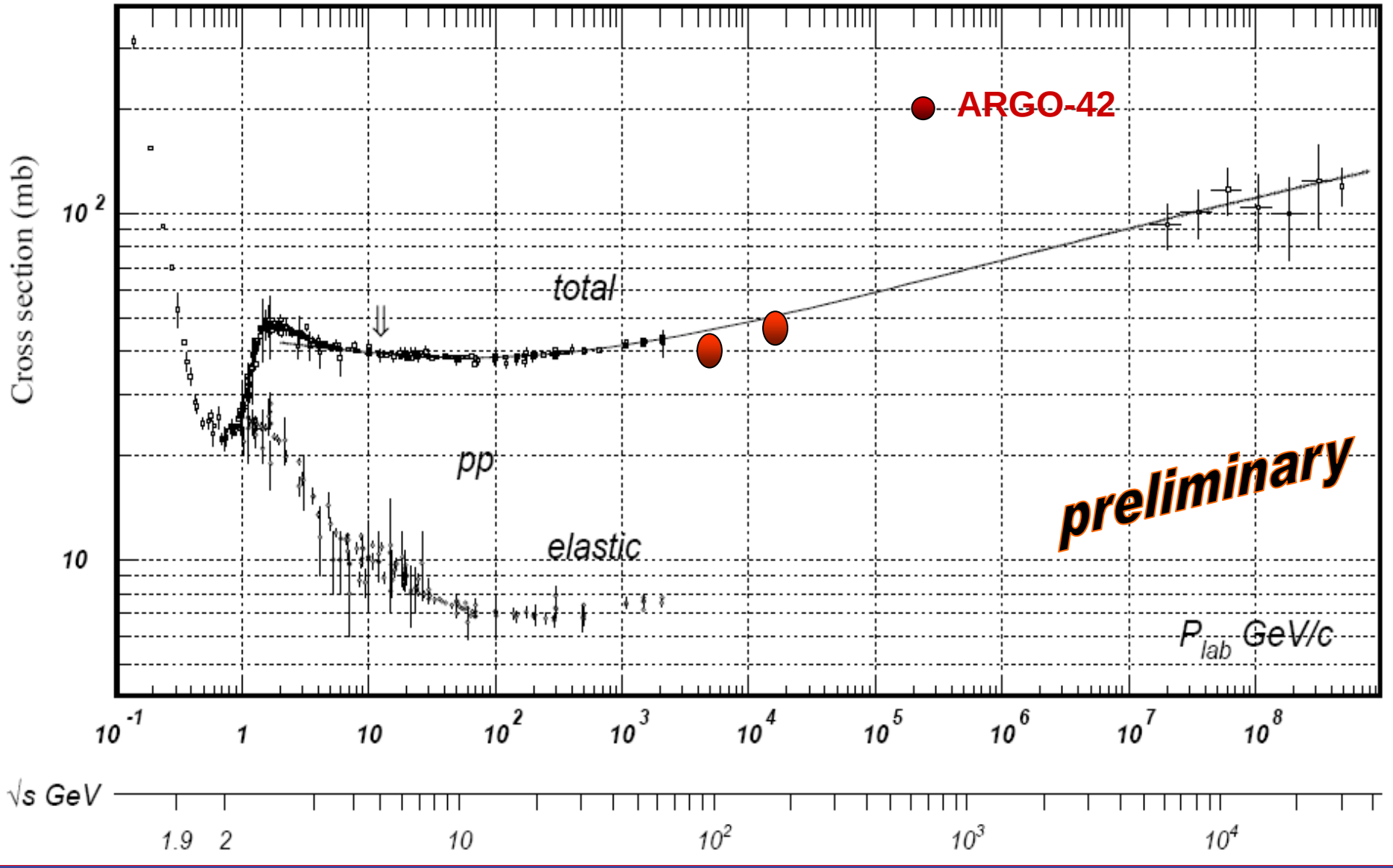
Λ_{abs} = absorption length of showers

The validity of such behaviour extends over an angular range where the overburden atmosphere increases as 1/cos θ.

p-Air cross-section



p-p cross-section



Conclusions

- The whole carpet of the ARGO-YBJ detector is in data taking since July 2006
- The guard ring has been installed and will be put in data acquisition quite soon
- The lead plates will be put on the detector in summer 2007
- Firts estimates on the angular resolution,togheter with the moon observation, make us confident that ARGO-YBJ would perform efficiently γ-astronomy
- The Forbush decrease observation confirms the potentiality of the apparatus with respect to transient phenomena and solr physics
- A GRB search in scaler mode has been carried out and, although no evidence for signal has been found till now, the most stringent upper limits have been put
- On the cosmic ray side we have preliminary results on the measurement of the p-Air and p-p cross sections
- The analysis of the data acquired with the central carpet (130 cluster) is going on

Pictures by F.Budano, M.Dattoli, G.Di Sciascio and S.Vernetto