Very High Energy Gamma Ray Astronomy and Cosmic Ray Physics with ARGO-YBJ

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HEP 2005
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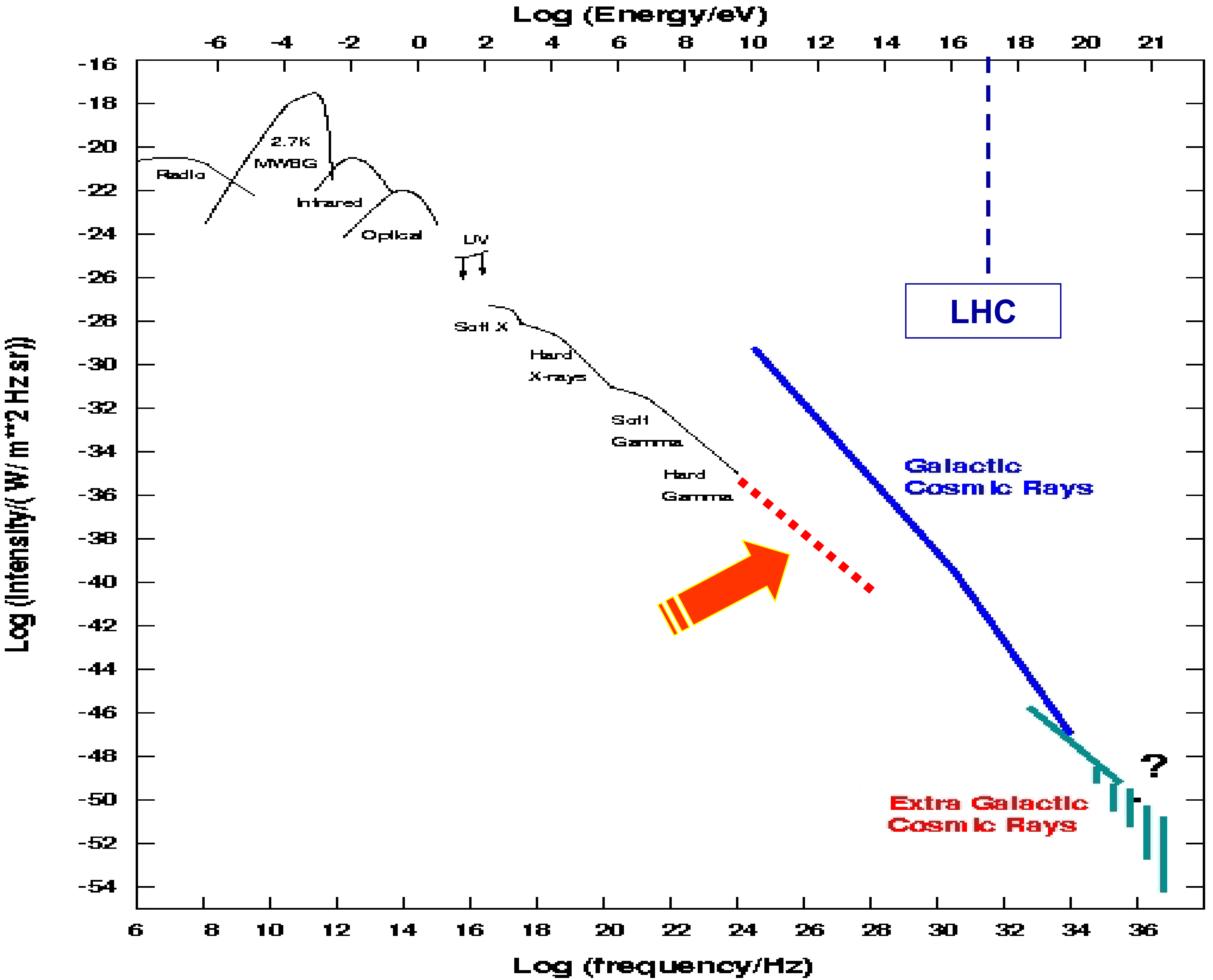


Log (Energy/eV)
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
21
-16
-18
-20
-22
-24
-26
-28
-30
-32
-34
-36
-38
-40
-42
-44
-46
-48
-50
-52
-54
Log (Intensity/(W/ m**2 Hz sr))
2.7K
MWBG
Radio
Infrared
Optical
UV
Soft X
Hard
X-rays
Soft
Gamma
Hard
Gamma
LHC
Galactic
Cosmic Rays
Extra Galactic
Cosmic Rays
?
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
Log (frequency/Hz)

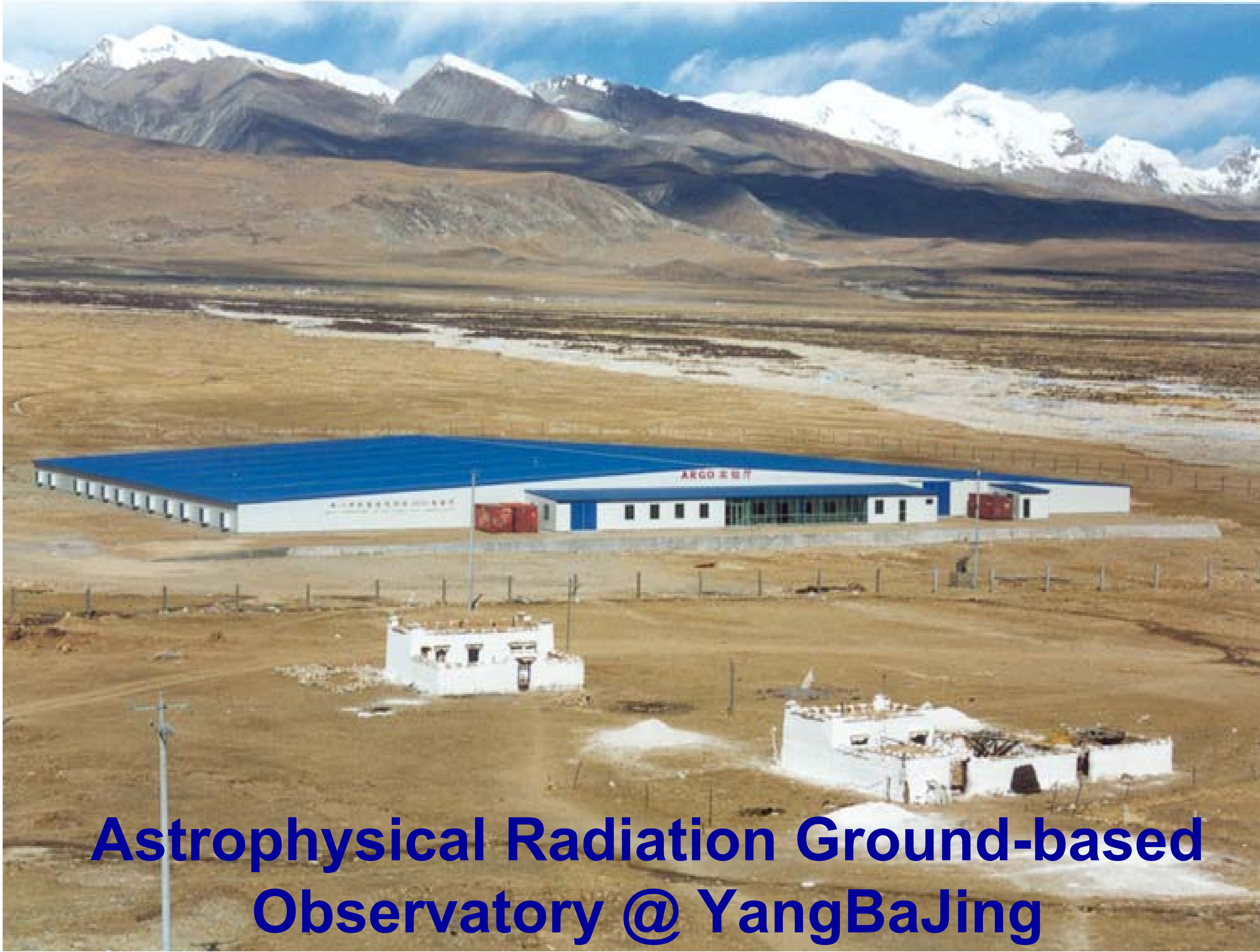
The ARGO-YBJ experiment

- **Collaboration between:**
  - **Istituto Nazionale di Fisica Nucleare (INFN) – Italy**
  - **Chinese Academy of Science (CAS)**
- **Site: Cosmic Ray Observatory @ Yangbajing (Tibet), 4300 m a.s.l.**

Physics goals

- **γ-Ray Astronomy**:
  Search for point-like galactic and extra-galactic sources at few hundreds GeV energy threshold
- **Diffuse γ-Rays**
  from the Galactic plane and SuperNova Remnants
- **Gamma Ray Burst physics** (full GeV / TeV energy range)
- **Cosmic ray physics**:
  - anti-p / p ratio at TeV energy
  - spectrum and composition around "knee" ($E_{th} \sim 10$ TeV)
- **Sun and Heliosphere physics** ($E_{th} \sim 10$ GeV)

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

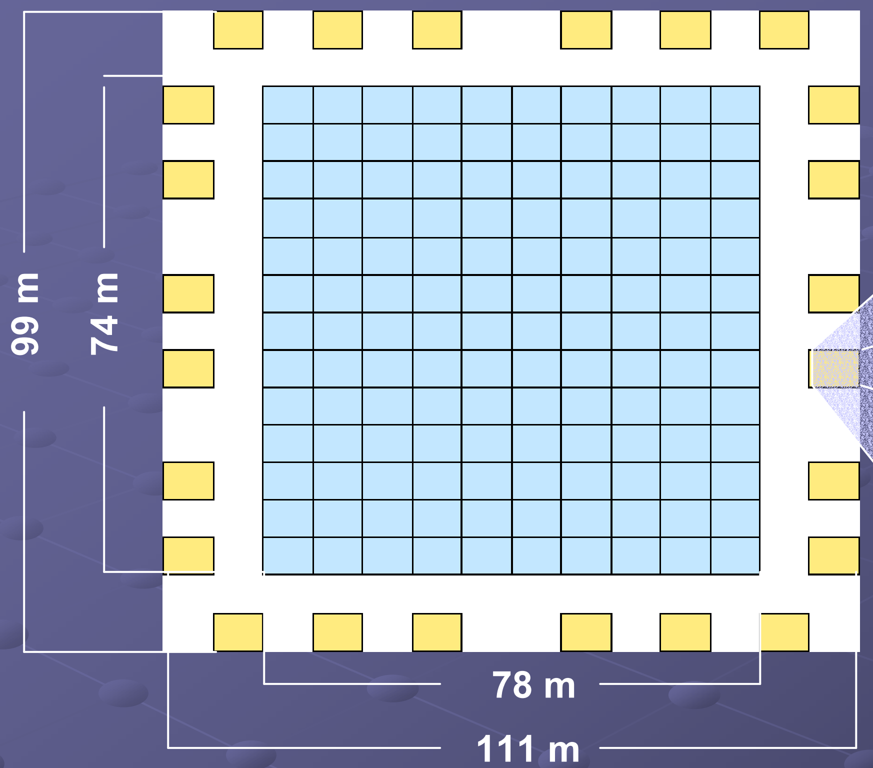

ARGO
Astrophysical Radiation Ground-based Observatory @ YangBaJing

High Altitude Cosmic Ray Laboratory @ YangBaJing

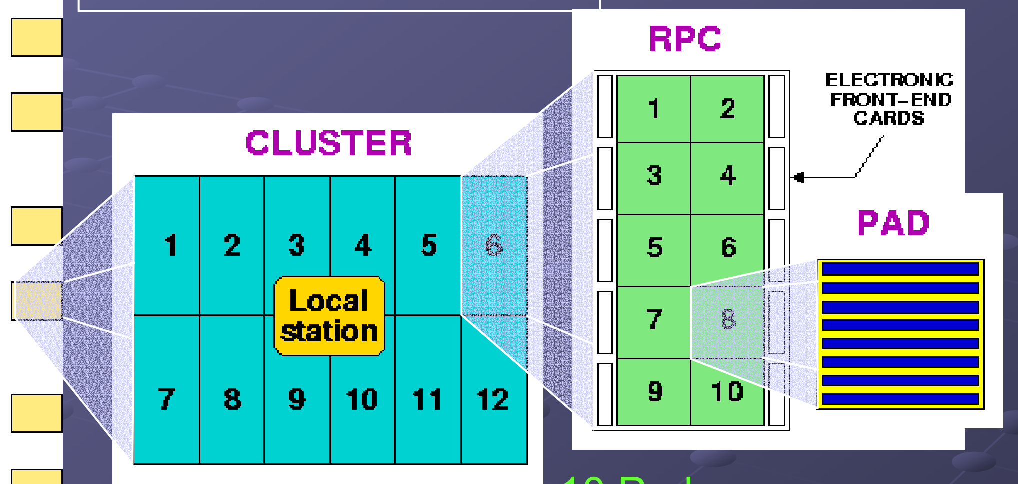
(Site Coordinates: longitude 90° 31’ 50” E, latitude 30° 06’ 38” N)

ARGO-YBJ layout

Detector layout



time resolution ~1 ns
space resolution = strip

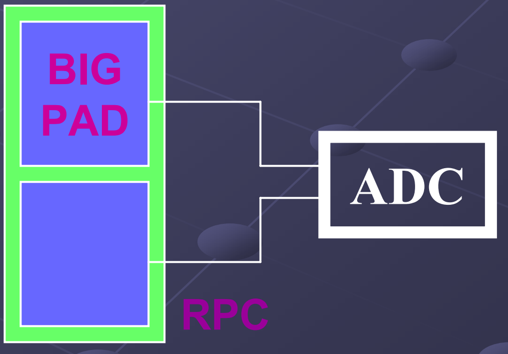


1 CLUSTER = 12 RPC
(~43 m^2)

10 Pads
(56 x 62 cm^2)
for each RPC

8 Strips
(6.5 x 62 cm^2)
for each Pad

Layer (~92% active surface) of Resistive Plate Chambers (RPC), covering a large area (5600 m^2)
+ sampling guard ring
+ 0.5 cm lead converter



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

Experiment Hall

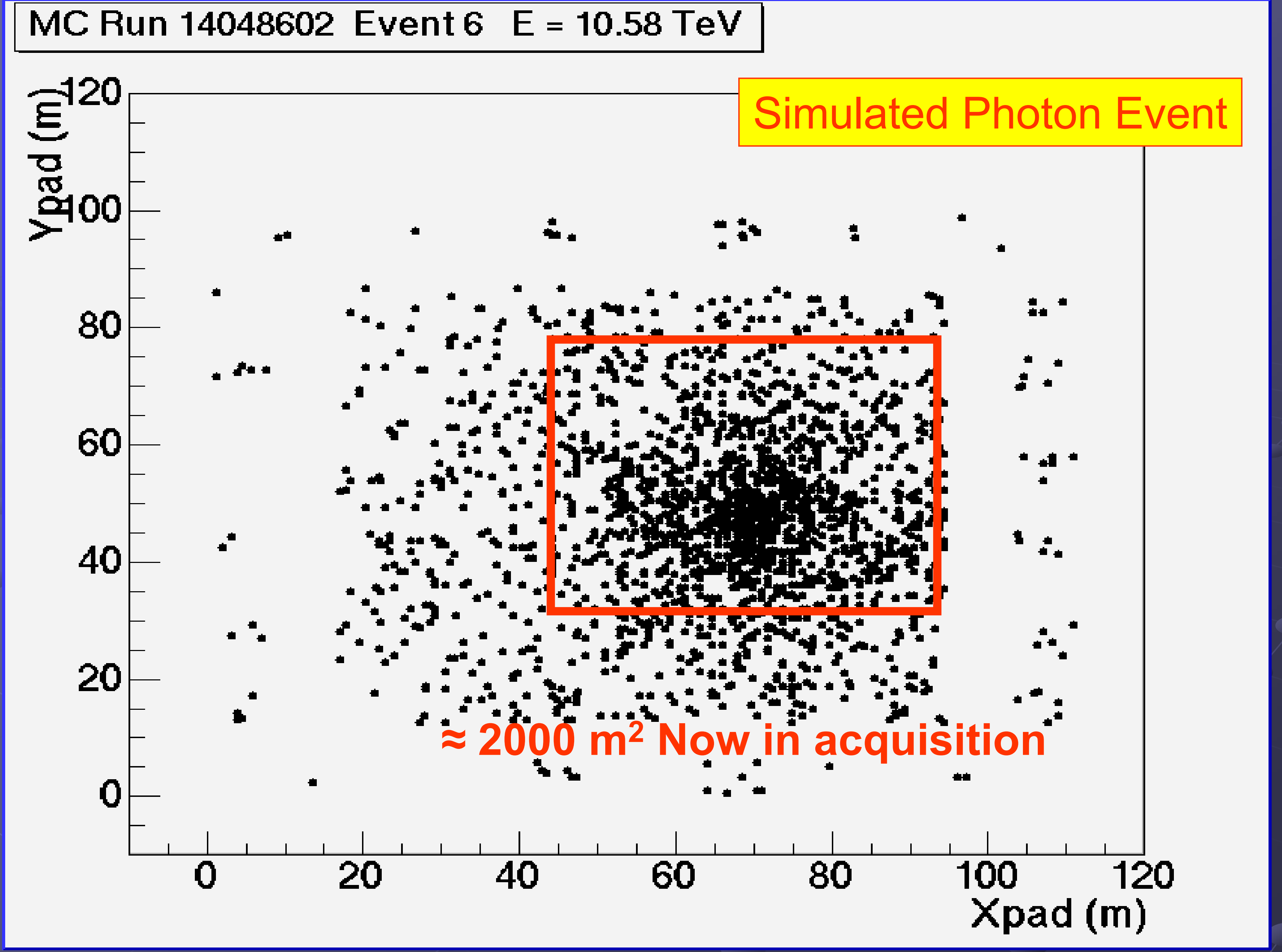
Main detector features and performances

- ✓ Active element: Resistive Plate Chamber ⇒ time resolution ~1 ns
- ✓ Time information from Pad (56 x 62 cm^2)
- ✓ Space information from Strip (6.5 x 62 cm^2)
- ✓ Full coverage and large area (~ 10,000 m^2)
- ✓ High altitude (4300 m a.s.l.)

▼

- good pointing accuracy ($\leq$0.5°)
- detailed space-time image of the shower front
- capability of small shower detection (⇒ low E threshold)
- large aperture (→2π) and high "duty-cycle" (→100%)

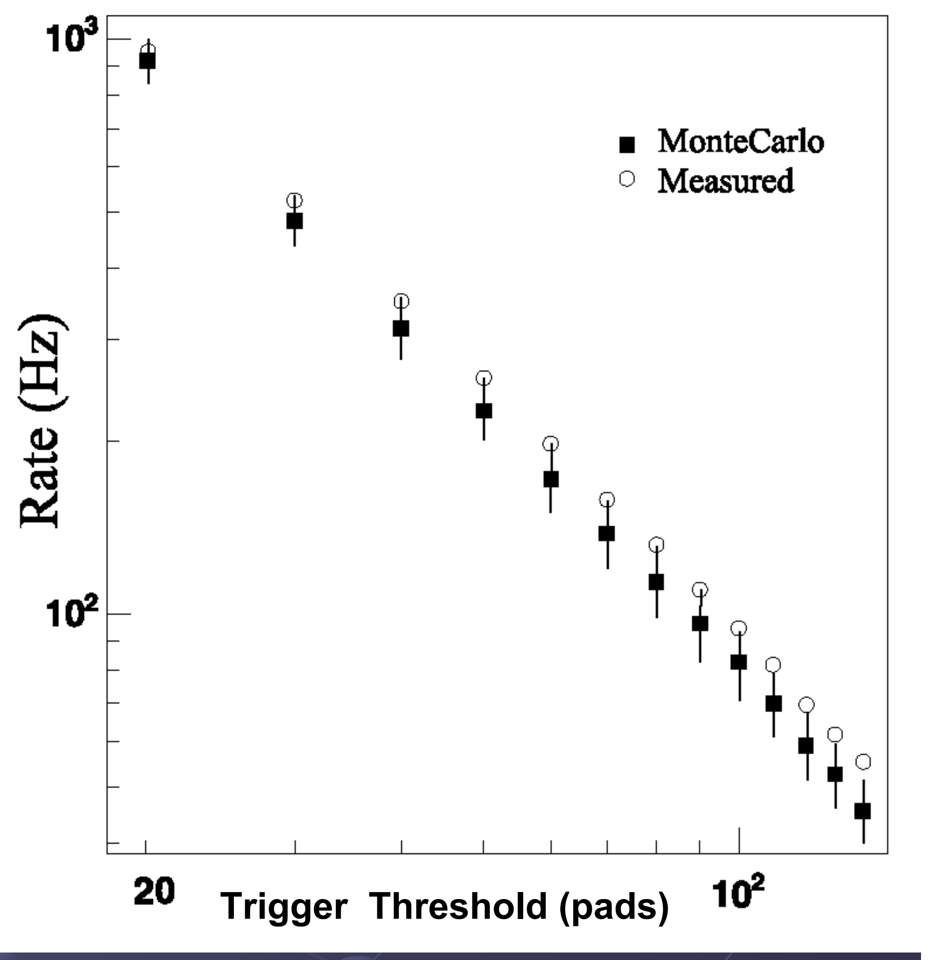
⇒ continuous monitoring of the sky (-10°<δ <70°)


MC Run 14048602 Event 6 E = 10.58 TeV
Simulated Photon Event
Ypad (m)
Xpad (m)
0
20
40
60
80
100
120
≈ 2000 m² Now in acquisition

Data Taking & Detector Configuration

Present …

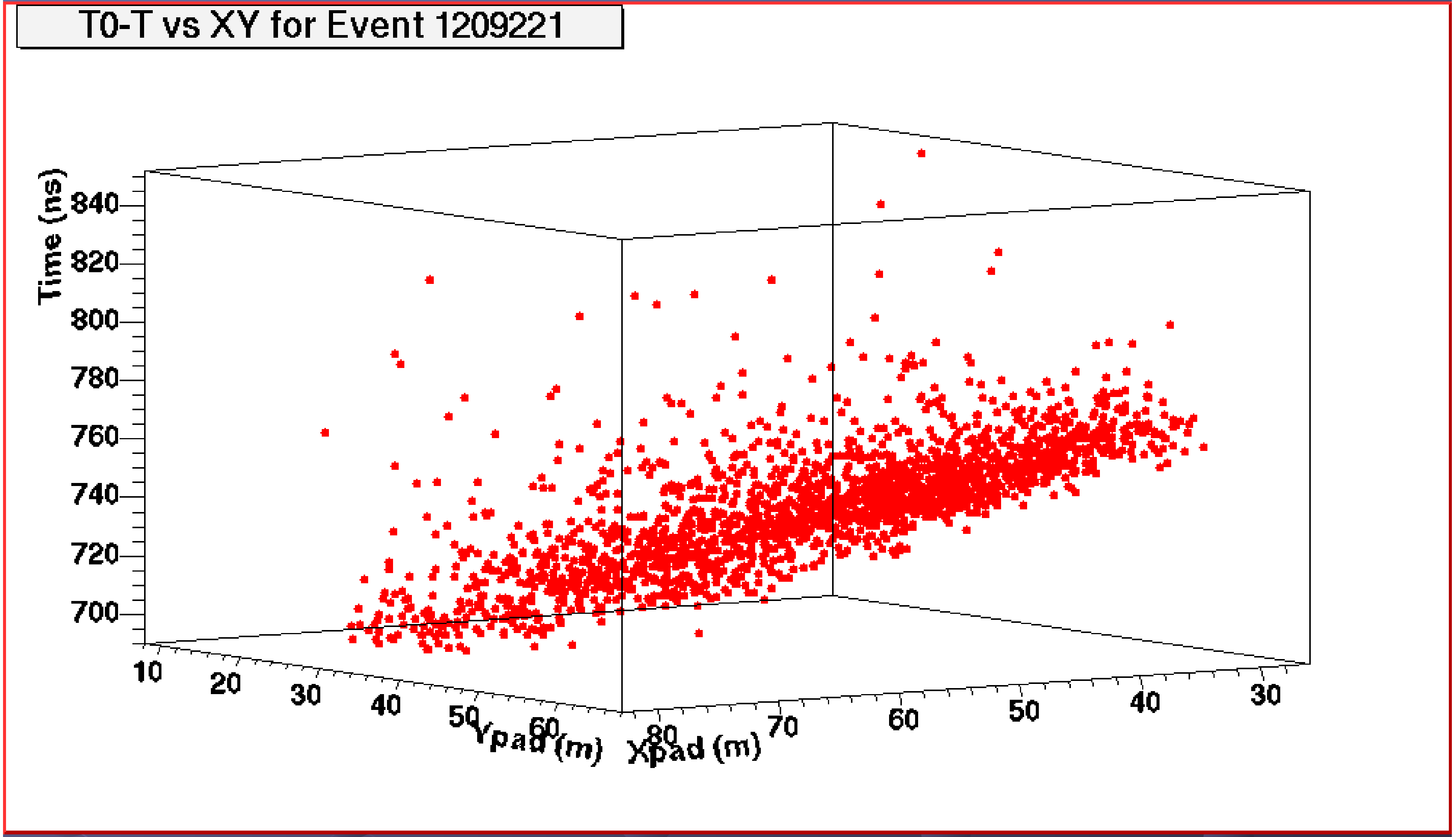
- 42 / 154 clusters in acq
- Detector debugging ok
- First physics results



… and Future

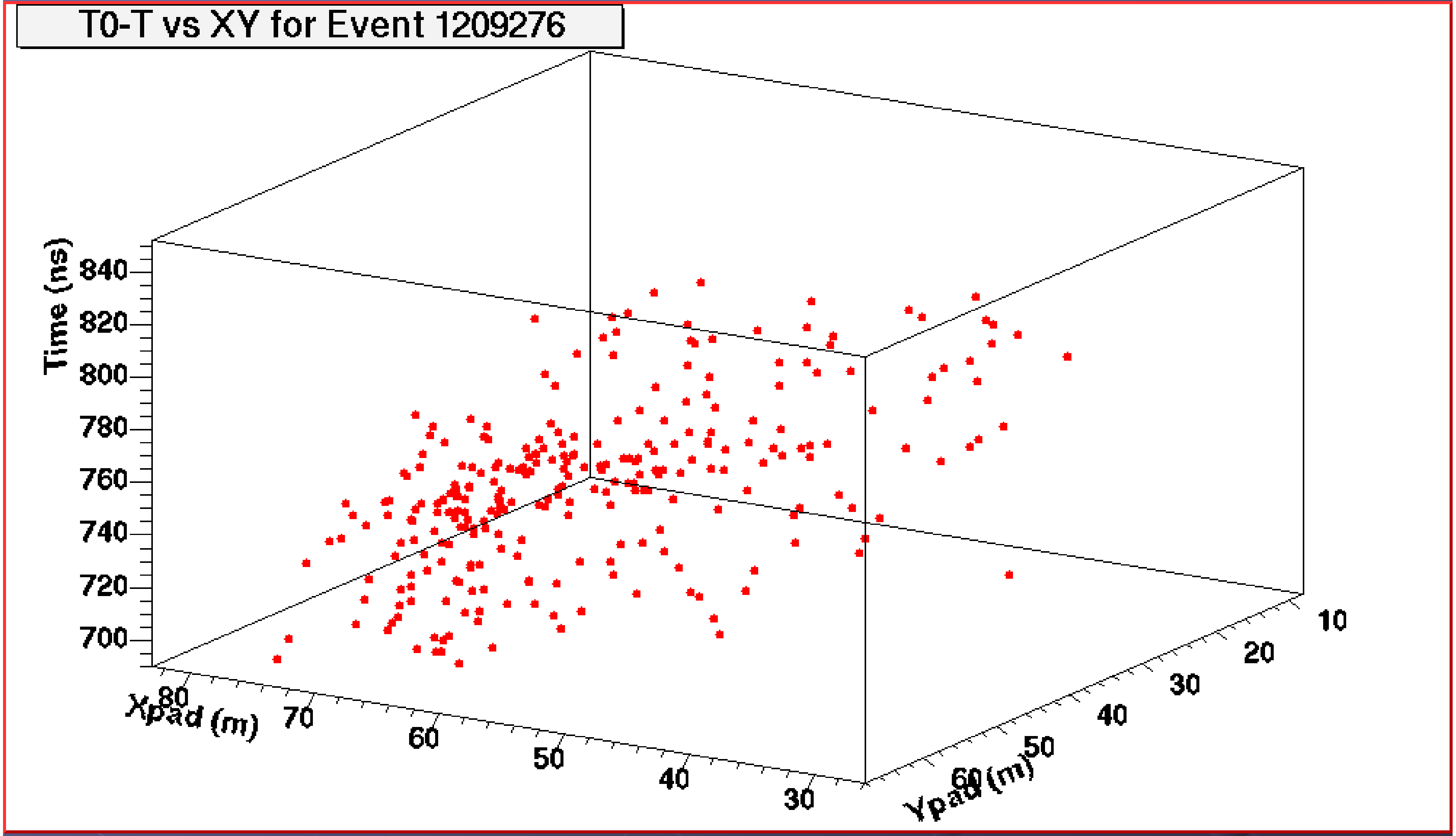
- 100 clusters in acquisition by the end of 2005
- Detector completion by next year

Real Event



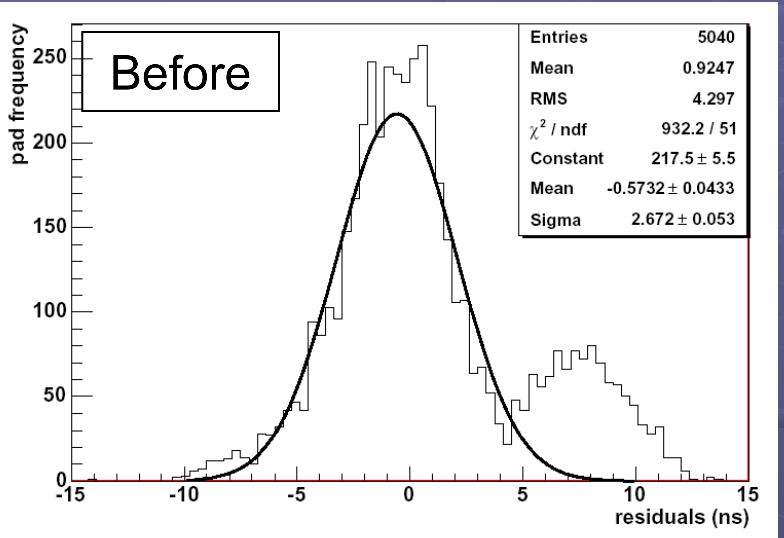
T0-T vs XY for Event 1209221
Time (ns)
840
820
800
780
760
740
720
700
10
20
30
40
50
60
80
70
60
50
40
30
Ypad (m)
Xpad (m)

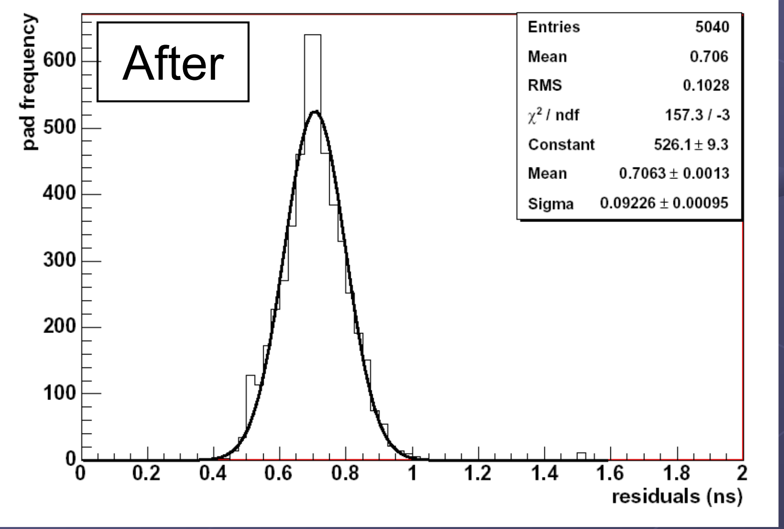
Real Event

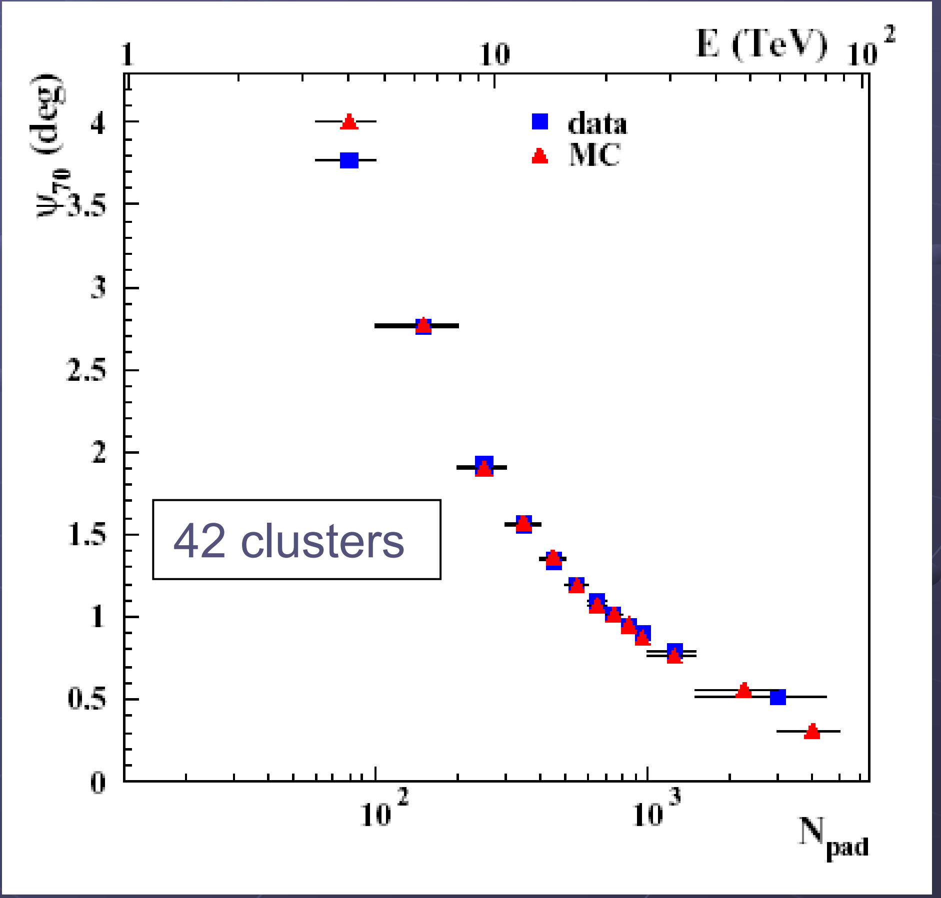

T0-T vs XY for Event 1209276
Time (ns)
840
820
800
780
760
740
720
700
Xpad (m)
80
70
60
50
40
30
Ypad (m)
10
20
30
40
50
60

Time Calibration & Angular Resolution

- ✓ Use the events to calibrate the detector.
- ✓ The measured angular resolution is in agreement with expectations.



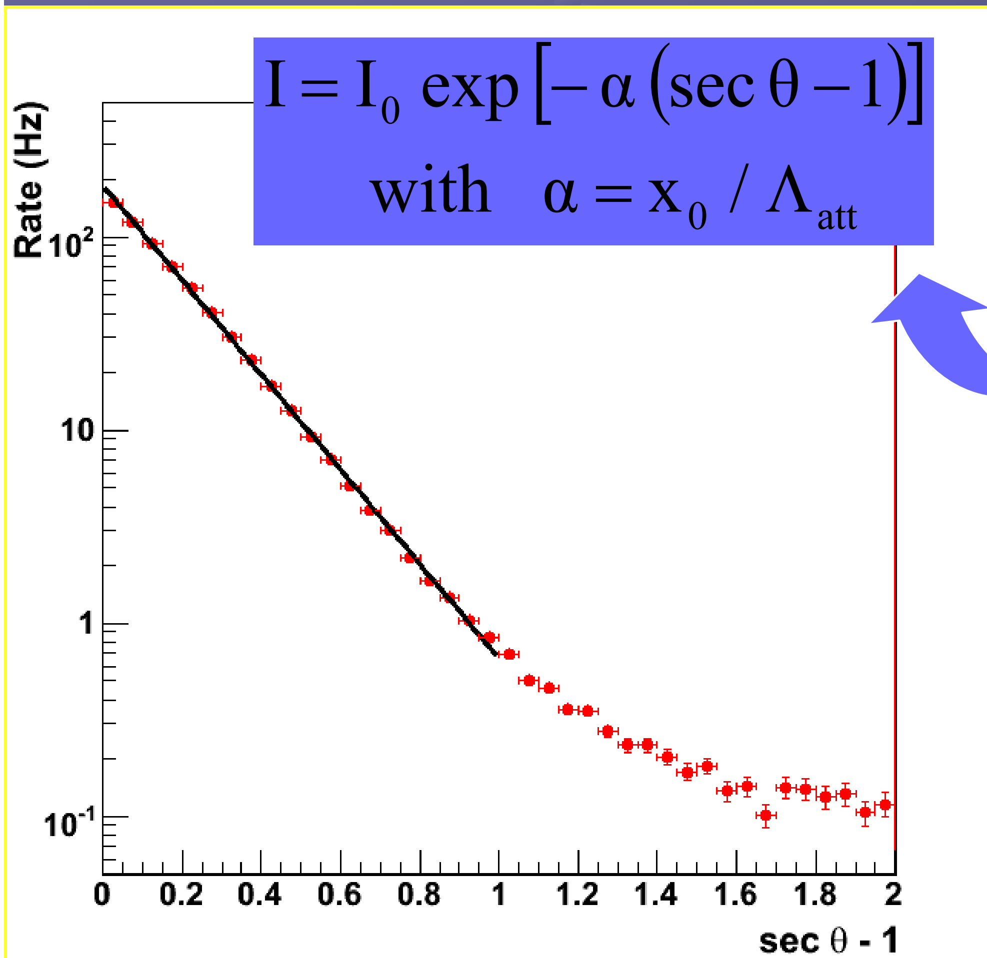




First Measurements

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

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

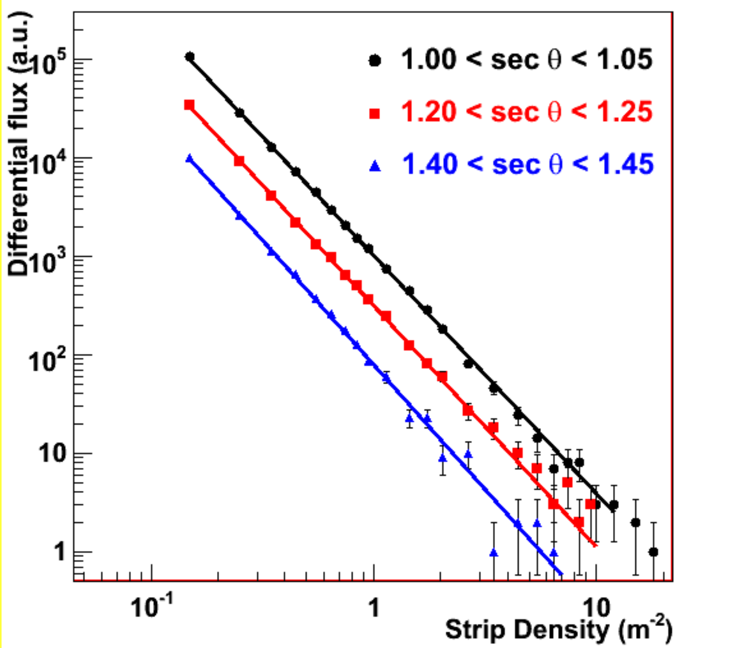


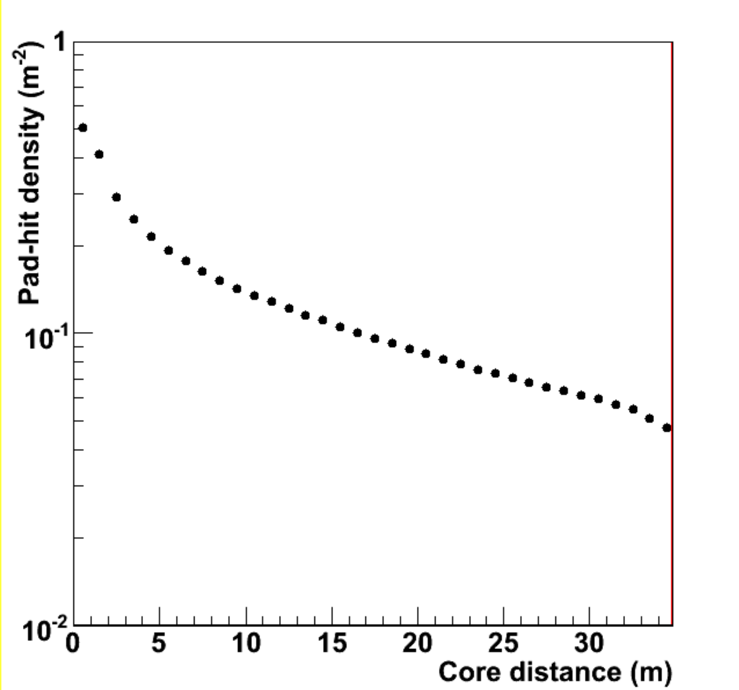
Angular distribution

Expected behaviour:

X_o = vertical depth (606 g/cm^2)
Λ_{att} = attenuation length of showers

The validity of such behaviour extends over an angular range where the atmospheric overburden increases as 1/cos θ.
The Earth curvature is also responsible for deviations from this law for slanted showers





First Measurements

- ✓ Hit multiplicity (hit and/or pad)
- ✓ Analog read-out of RPC pulse charges
- ✓ Lateral distribution
- ✓ ....

Cosmic ray

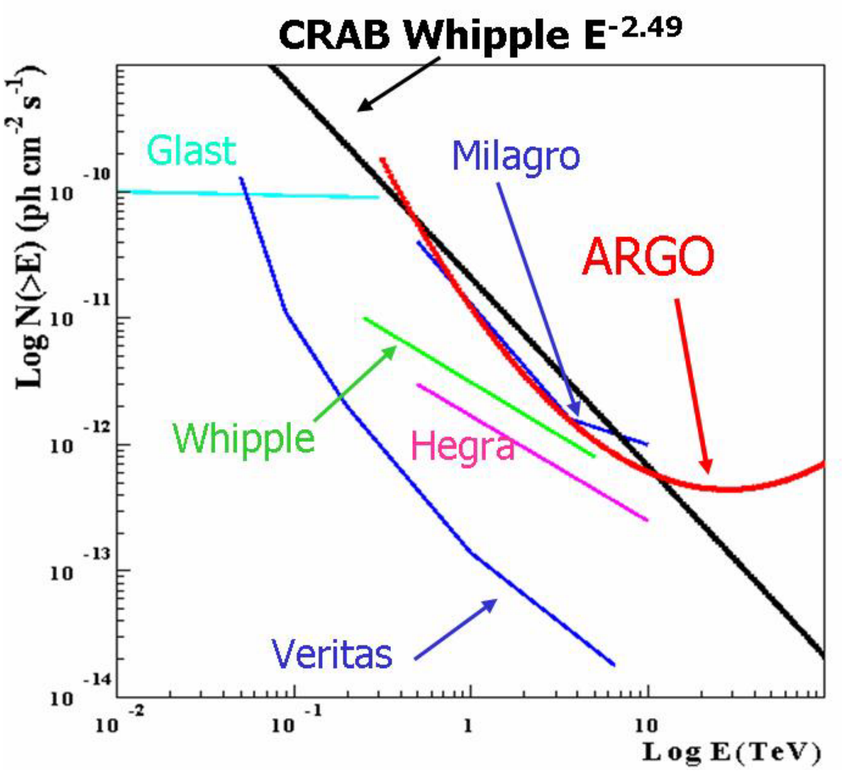
energy spectrum

&

chemical composition

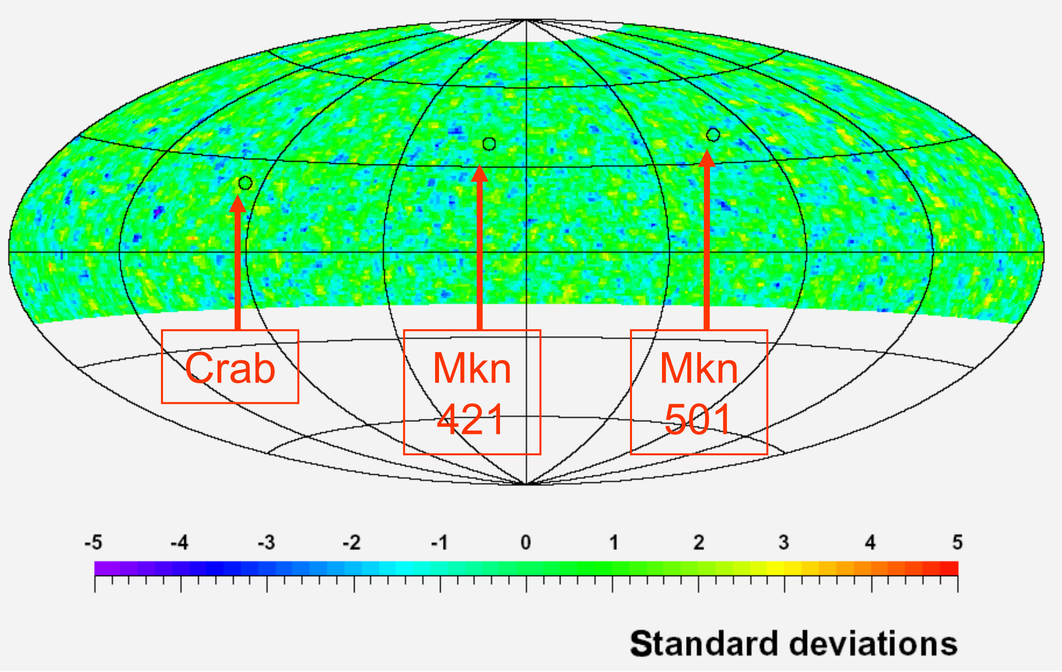
Gamma ray astronomy

- Detection of flux excess in proper angular bins to look for pointlike or extended sources
- Continuous monitoring of the whole sky over the horizon
- Use the detector capability to make γ/h discrimination and increase flux sensitivities



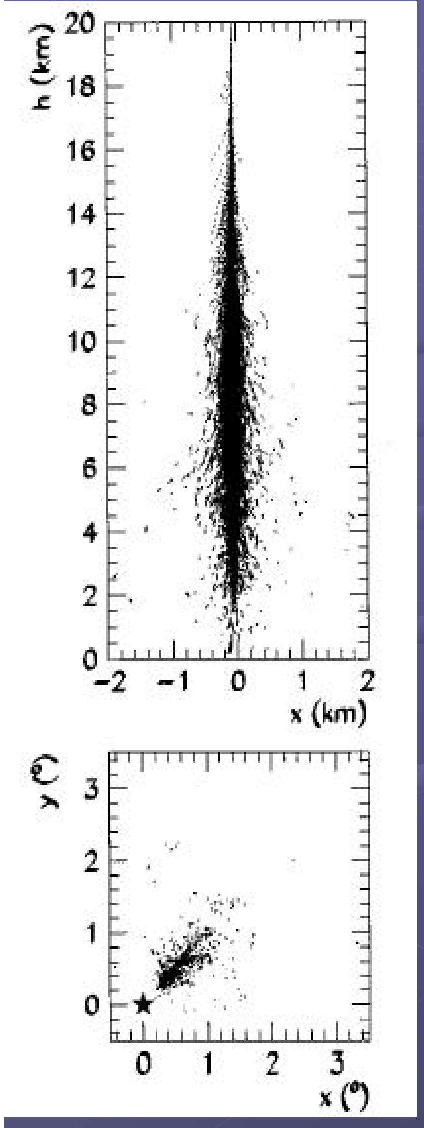
First Results with 42 clusters.

0.6 billion events in 1000 hours live time

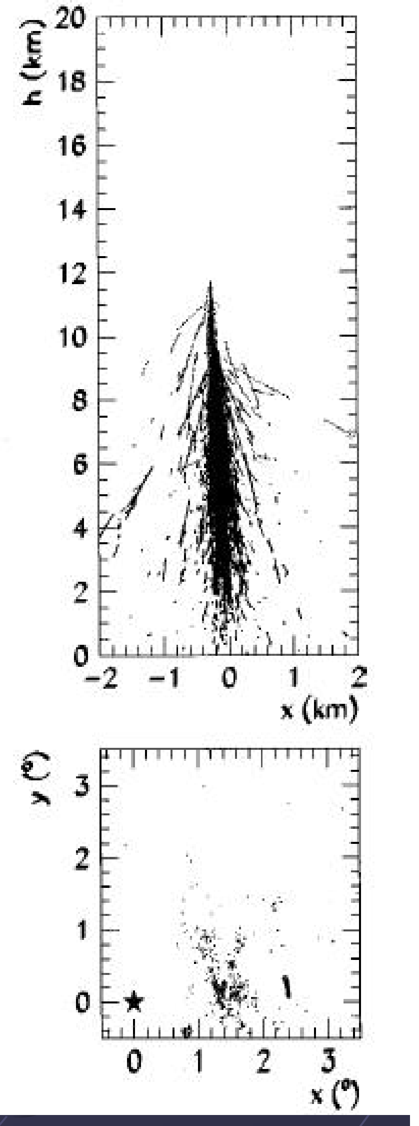


Gamma/hadron discrimination

Photon Shower



Proton Shower



The photon signal is statistically identified by looking for an excess, coming from a given direction, over the isotropic background due to charged cosmic rays (H, He, Li, .. nuclei)

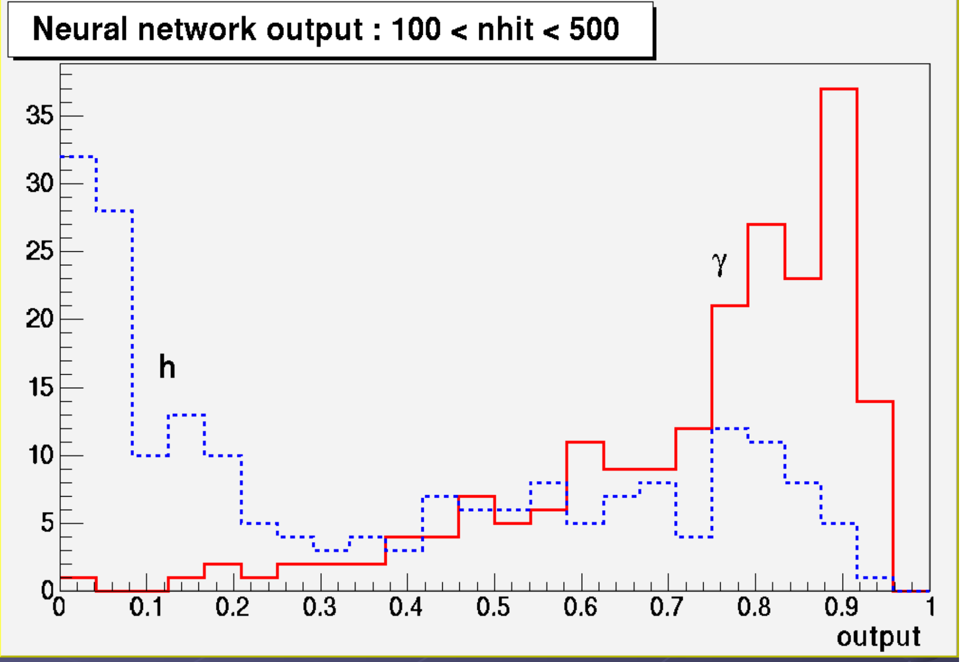
In addition to this tool the study of the shower

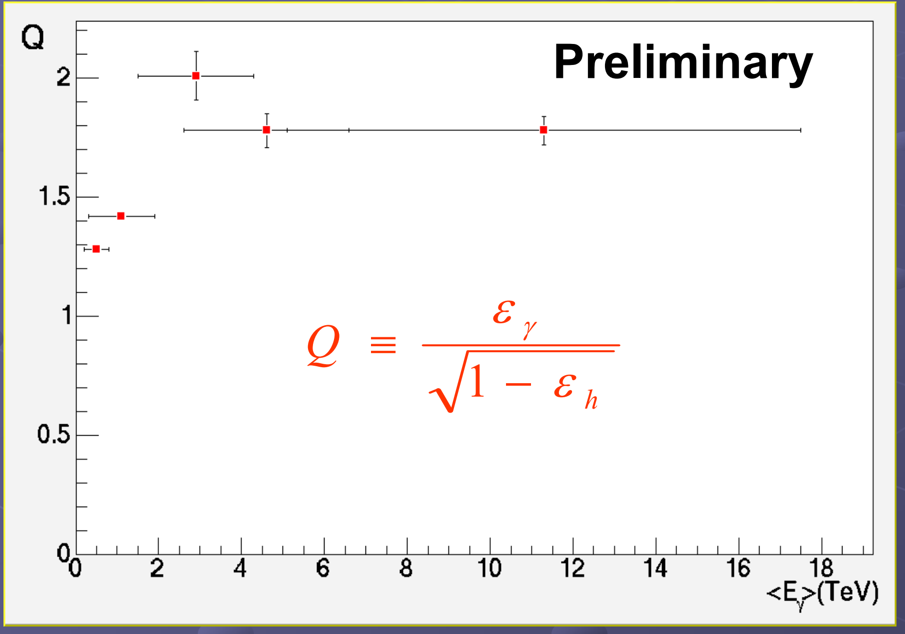
space-time patterns

can be useful to have higher discrimination power and then a larger sensitivity

Multiscale analysis + ANN gives first encouraging results ⇒

Multiscale Image Analysis + Artificial Neural Network





$$S \equiv \frac{N_\gamma}{\sqrt{N_h}} \times \frac{\varepsilon_\gamma}{\sqrt{1-\varepsilon_h}}$$

$$Q \equiv \frac{\varepsilon_\gamma}{\sqrt{1-\varepsilon_h}}$$

$$T^{5\sigma}_{Crab}(Q=1) = 120 days$$

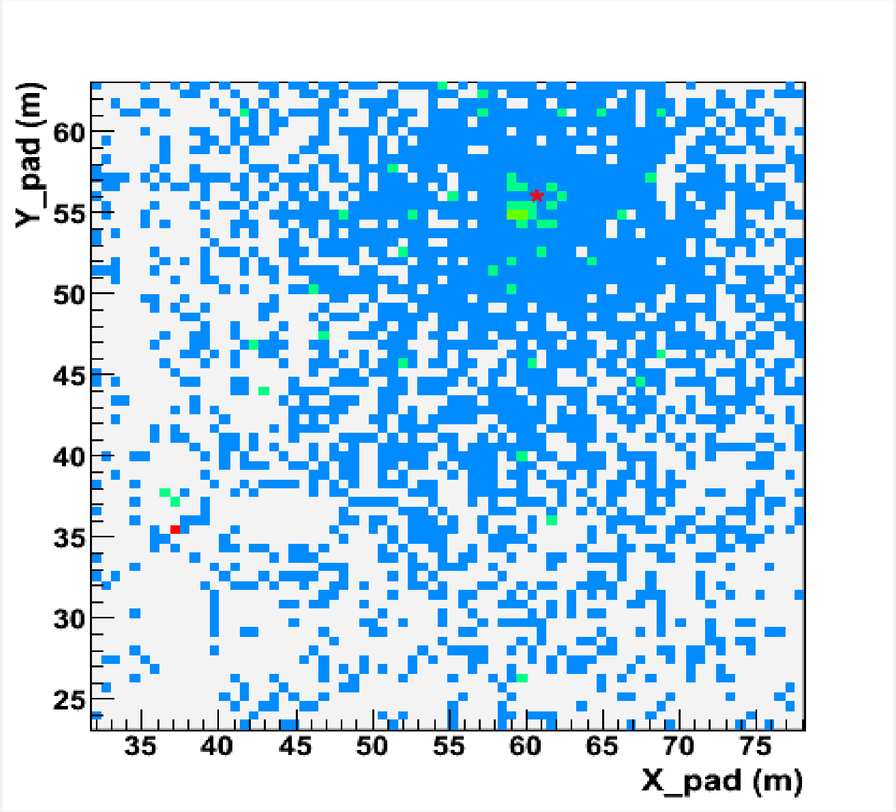
$$T^{5\sigma}_{Crab}(Q=2) = 30 days$$

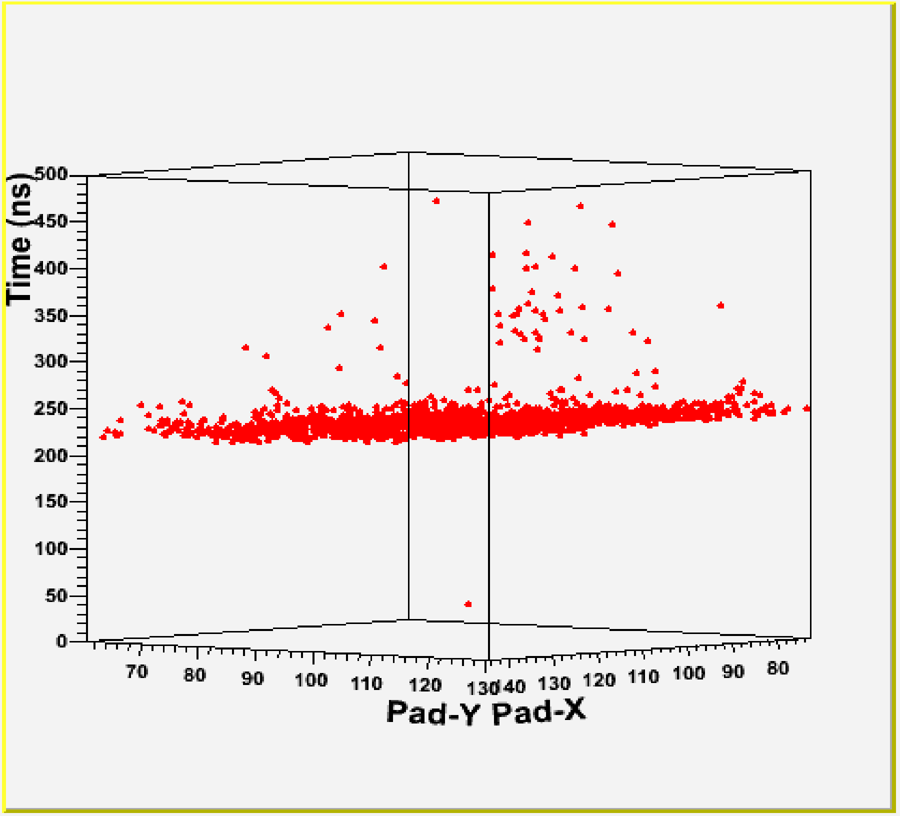
- ✓ Reduced time interval needed to identify sources
  - ✓ Larger equivalent effective area
    - ✓ Sensitivity to smaller fluxes

Shower Phenomenology

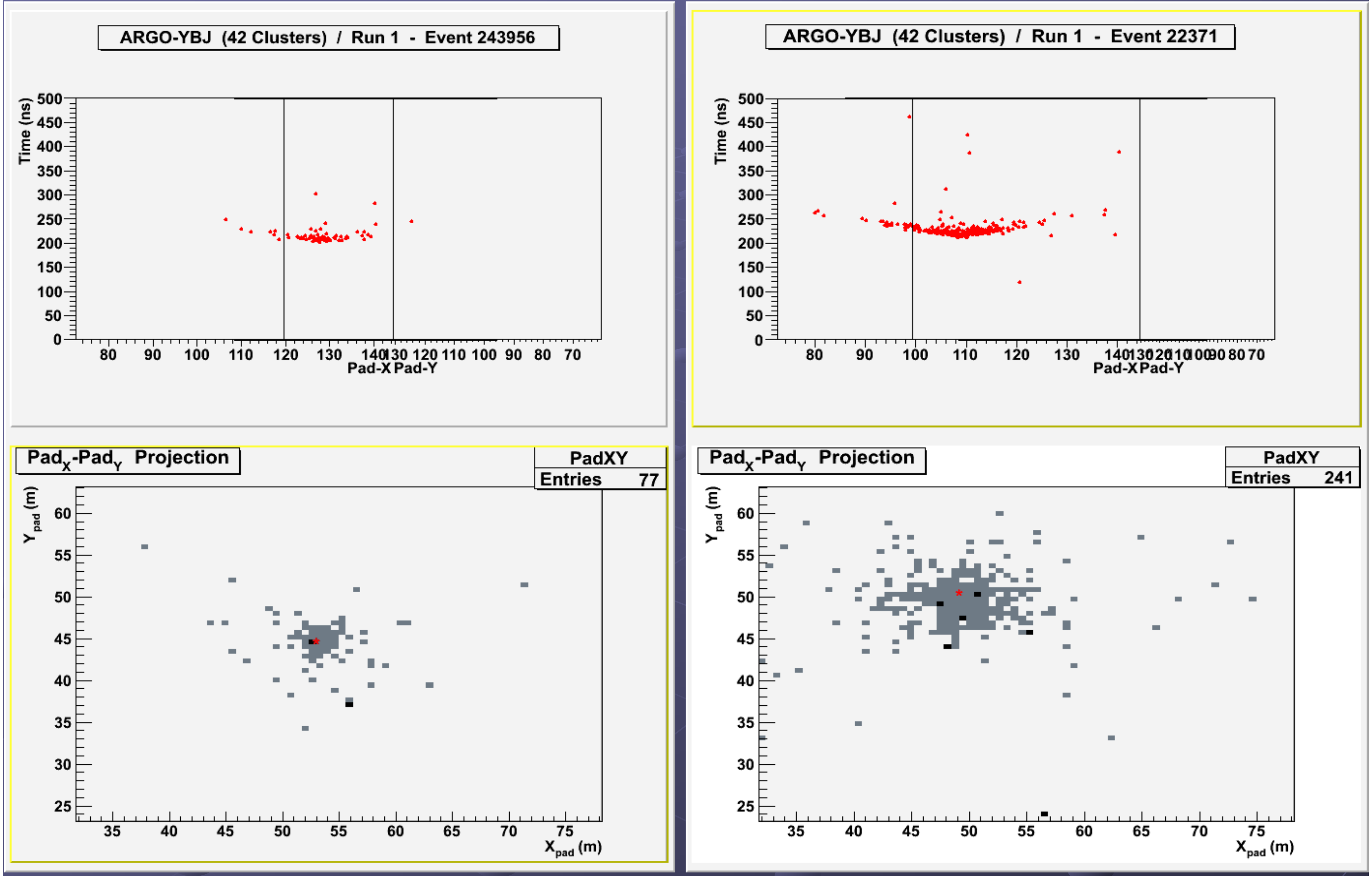
The High space/time granularity of the ARGO-YBJ detector allows a deep study of shower phenomenology with unique performances

Example 1: Very energetic shower

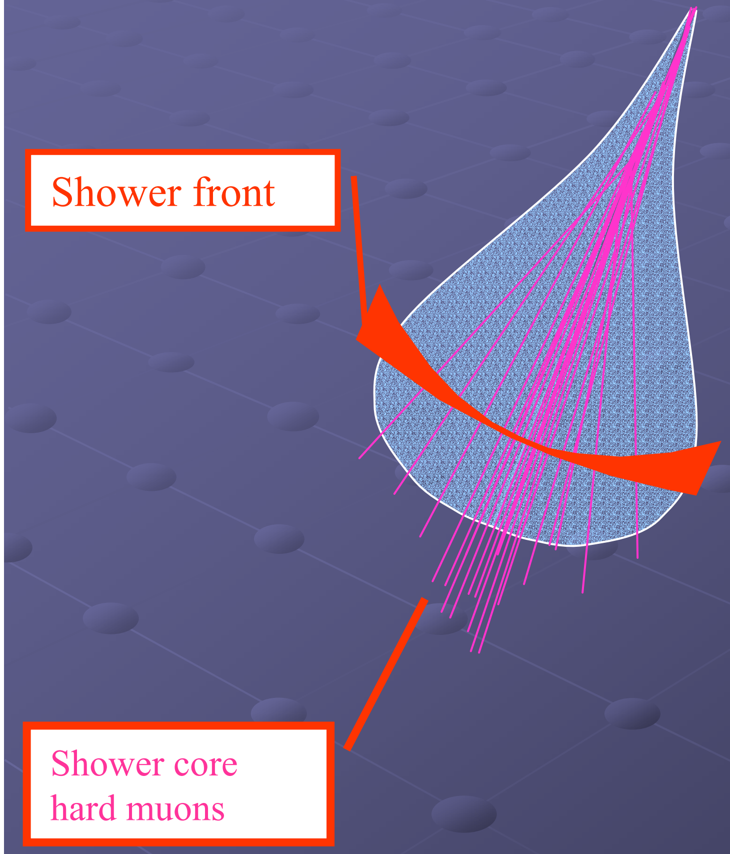


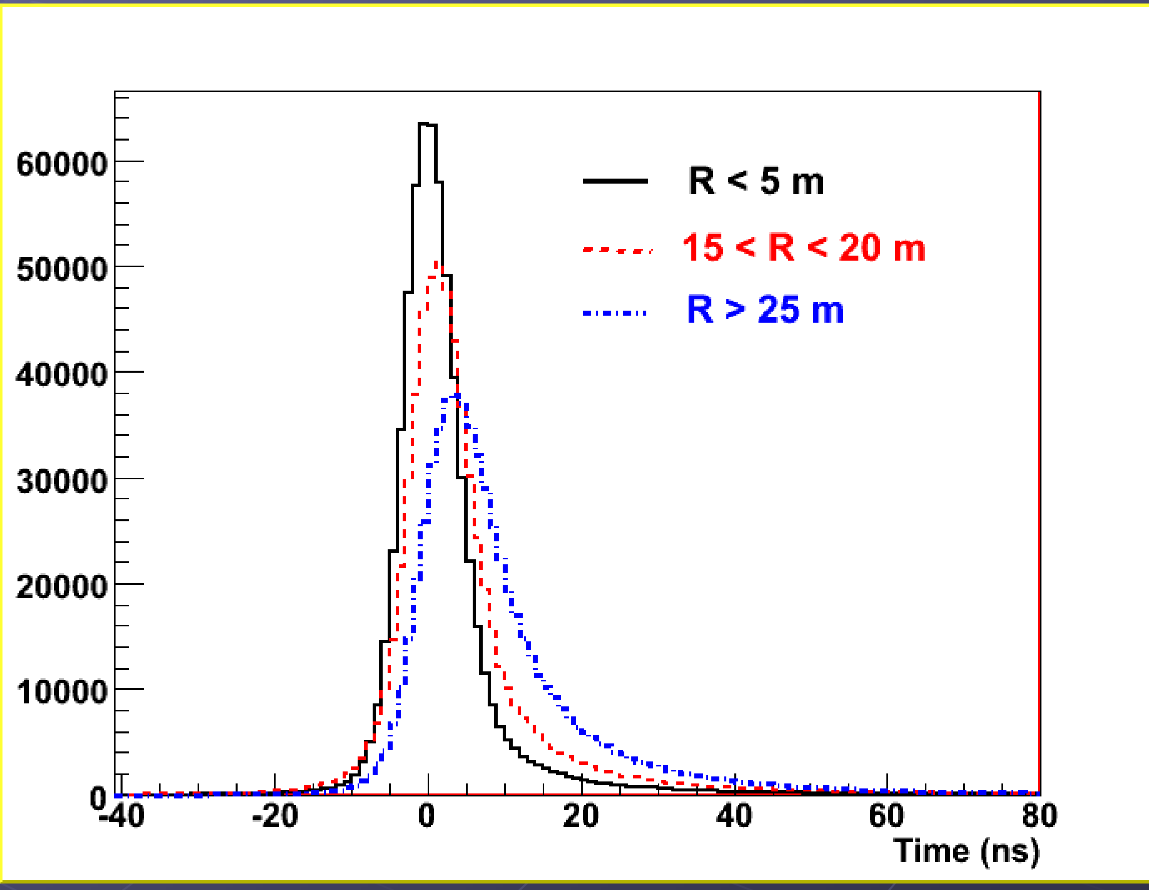


Example 2: Evidence of strong conical shape in small showers



Example 3: Study of the time structure of the shower





Conclusions

- Good performances obtained with a fraction of the detector which is already running (about 1/3 of the total area)
- First physics results are being obtained in Cosmic Ray Physics
- Statistics not yet sufficient to identify γ sources, but systematics are under control
- Detector completion in about one year
- Very interesting results are beyond the corner