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

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LHC

Log (Energy/eV)

Log (frequency/Hz)

Log (Intensity/(W/m² Hz sr))

Galactic Cosmic Rays

Extra Galactic Cosmic Rays
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
Astrophysical Radiation Ground-based Observatory @ YangBaJing
High Altitude Cosmic Ray Laboratory @ YangBaJing
(Site Coordinates: longitude 90° 31’ 50” E, latitude 30° 06’ 38” N)
Layer (~92% active surface) of Resistive Plate Chambers (RPC), covering a large area (5600 m²) + sampling guard ring + 0.5 cm lead converter.

Time resolution ~1 ns
Space resolution = strip

1 CLUSTER = 12 RPC
(~43 m²)

10 Pads (56 x 62 cm²) for each RPC
8 Strips (6.5 x 62 cm²) for each Pad

Read-out of the charge induced on “Big Pads”

BIG PAD

ADC

RPC
### Main detector features and performances

- **Active element:** Resistive Plate Chamber ⇒ time resolution ~1 ns
- **Time information from Pad** (56 x 62 cm²)
- **Space information from Strip** (6.5 x 62 cm²)
- **Full coverage and large area** (~ 10,000 m²)
- **High altitude** (4300 m a.s.l.)

- **good pointing accuracy** (≤0.5°)
- **detailed space-time image of the shower front**
- **capability of small shower detection** (⇒ low E threshold)
- **large aperture** (⇒ $2\pi$) and high “duty-cycle” (⇒ 100%)

⇒ **continuous monitoring of the sky** (-10°<\(\delta\)<70°)
Simulated Photon Event

≈ 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
T0-T vs XY for Event 1209276
Time Calibration & Angular Resolution

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

Before

After

42 clusters
First Measurements

Angular distribution

Expected behaviour:

\[ I = I_0 \exp\left(-\alpha (\sec \theta - 1)\right) \]
with \( \alpha = \frac{x_0}{\Lambda_{\text{att}}} \)

\[ x_0 = \text{vertical depth (606 g/cm}^2) \]
\[ \Lambda_{\text{att}} = \text{attenuation length of showers} \]

The validity of such behaviour extends over an angular range where the atmospheric overburden increases as \(1/\cos \theta\).
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
- Cosmics 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 $\gamma/h$ discrimination and increase flux sensitivities

First Results with 42 clusters.

0.6 billion events in 1000 hours live time
Gamma/hadron discrimination

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

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

\[ Q = \frac{\varepsilon_{\gamma}}{\sqrt{1 - \varepsilon_{h}}} \]

\[ S = \frac{N_{\gamma}}{\sqrt{N_h}} \times \frac{\varepsilon_{\gamma}}{\sqrt{1 - \varepsilon_{h}}} \]

\[ T_{\text{Crab}}^{5\sigma}(Q = 1) = 120\text{ days} \]

\[ T_{\text{Crab}}^{5\sigma}(Q = 2) = 30\text{ days} \]
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 $\gamma$ sources, but systematics are under control
- Detector completion in about one year
- Very interesting results are beyond the corner