D. Martello - Università and INFN, Lecce (Italy)

2009 Europhysics Conference on High Energy Physics
16-22 July 2009 Krakow

Results from the ARGO-YBJ experiment

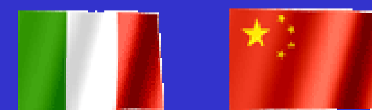
Outline

- ✓ Detector features and performance
- ✓ Cosmic rays and Moon shadow
- ✓ Gamma astronomy
- ✓ Search for Gamma Ray Bursts

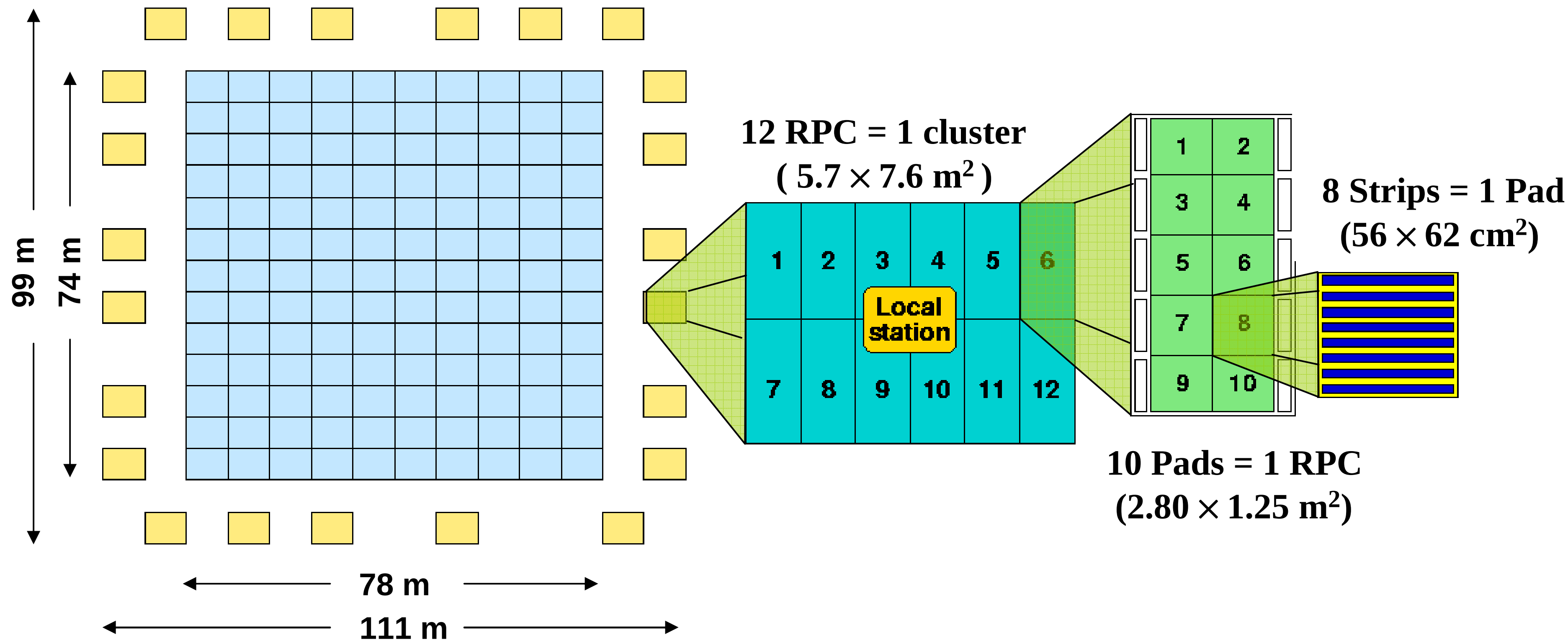
The YangBaJing Cosmic Ray Observatory (Tibet, China)

Altitude 4300 m a.s.l.

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



Astrophysical Radiation with Ground-based Observatory at YangBaJing



✓ Layer of Resistive Plate Chambers (RPC)

✓ Active area : central carpet ~ 5600 m^2
sampling guard-ring ~ 1000 m^2

✓ Data taking : since July 2006 with the central carpet
since November 2007 with the guard-ring

Installation of analog charge read-out in progress
→ dynamical range up to ~ 10^4 TeV

Operation modes

Shower mode

Trigger : number of fired pads (N_{pad}) within 420 ns
on the central carpet

for $N_{pad} \geq 20$, rate ~ 3.6 kHz (~220 GBytes/day)

Detection of Extensive Air Showers (direction, size, core …)

Aims : cosmic-ray physics (threshold ~ 1 TeV)
VHE γ-astronomy (threshold ~ 300 GeV)
gamma-ray bursts

Scaler mode

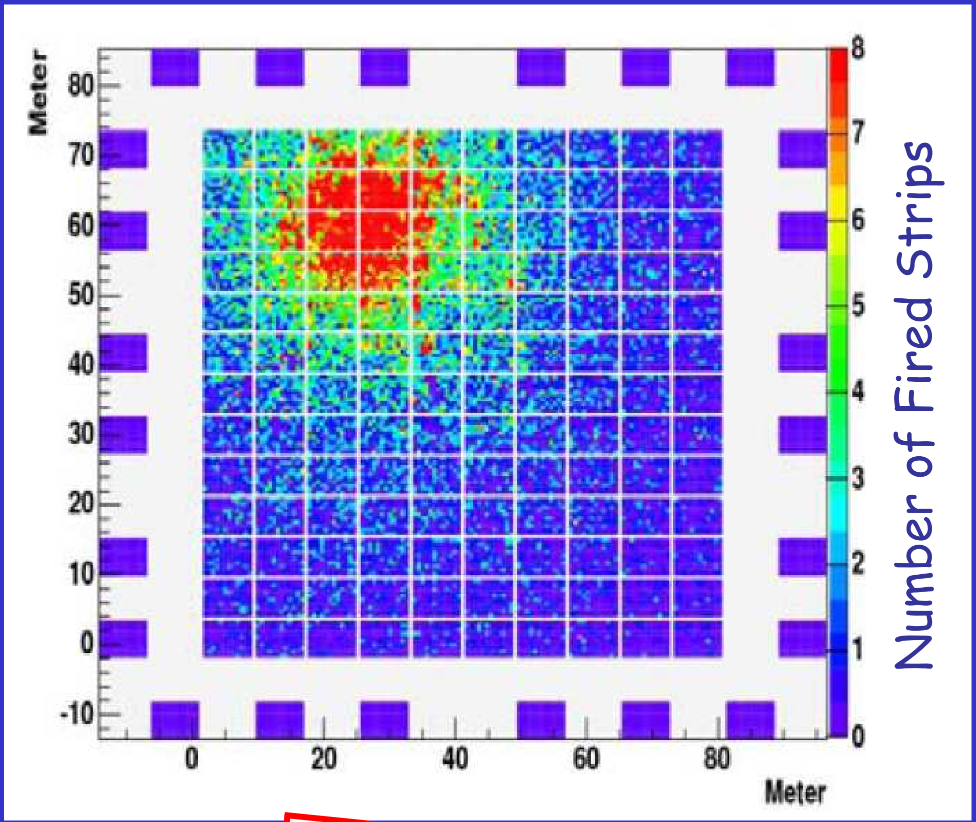
counting rates (≥ 1, ≥ 2, ≥ 3, ≥ 4 coincidences) for each cluster

Aims: detector and environment monitor
flaring phenomena (gamma ray bursts, solar flares)
with a threshold of few GeV

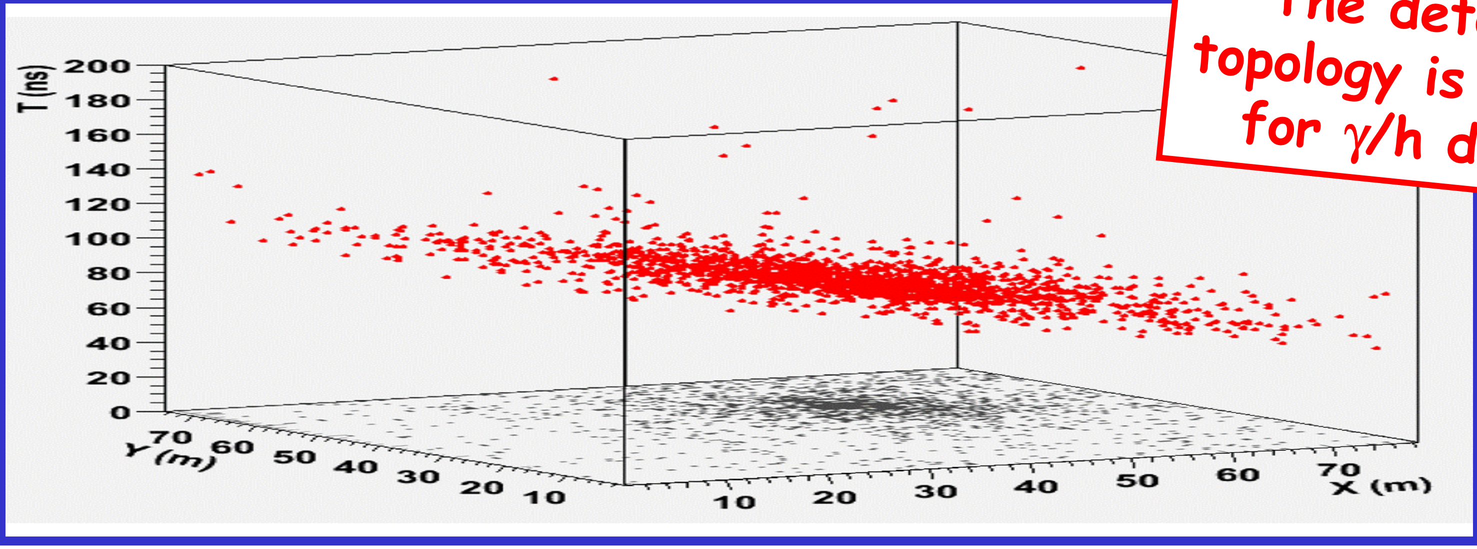
Shower mode

Space pixel: single strip (7×62 cm²)

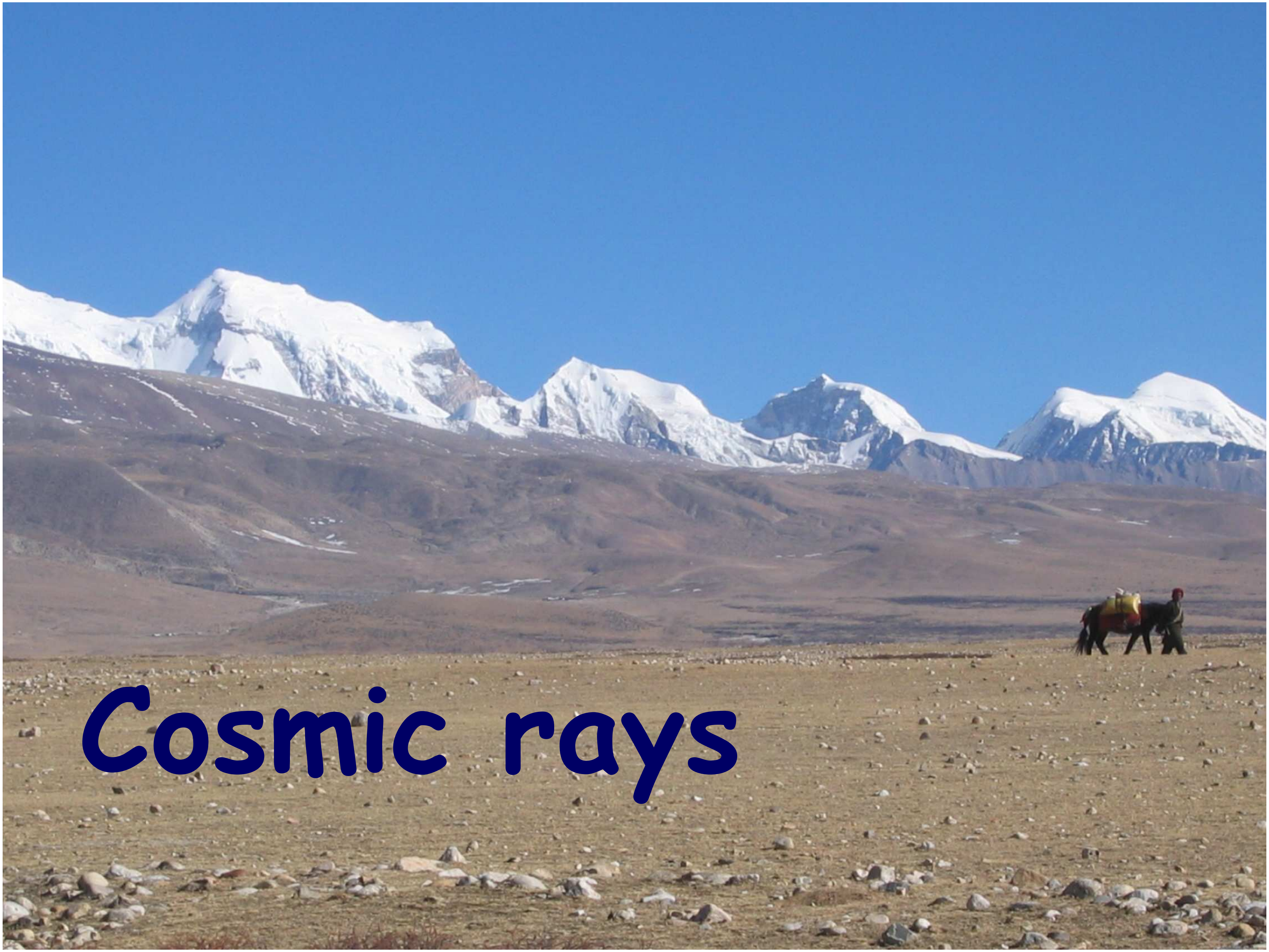
Time pixel: pad (56×62 cm²) is the OR of 8 strips, with a resolution of ~ 1.8 ns



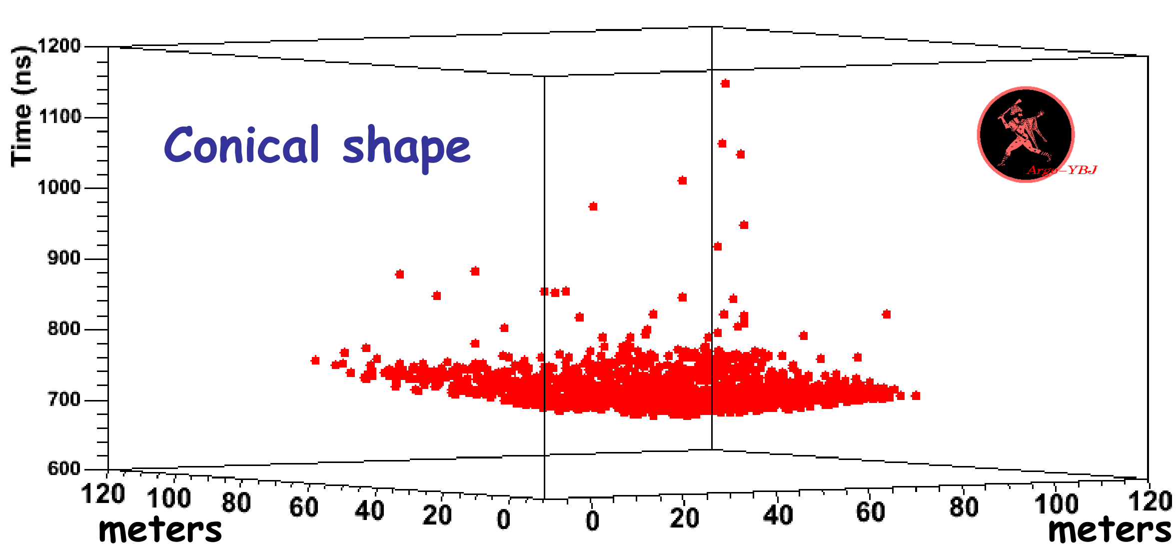
The number of pixels, the time resolution and the full coverage of the central carpet allow to reconstruct the shower with unprecedented details

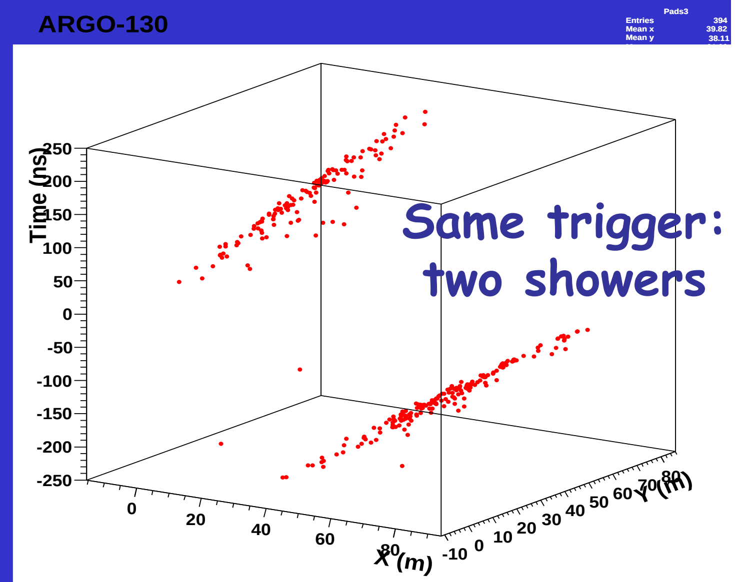


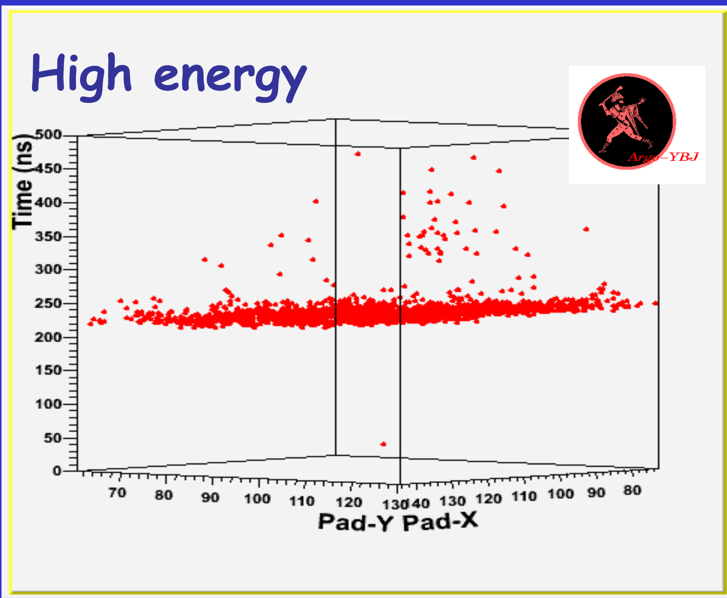
The detailed shower topology is a possible tool for γ/h discrimination

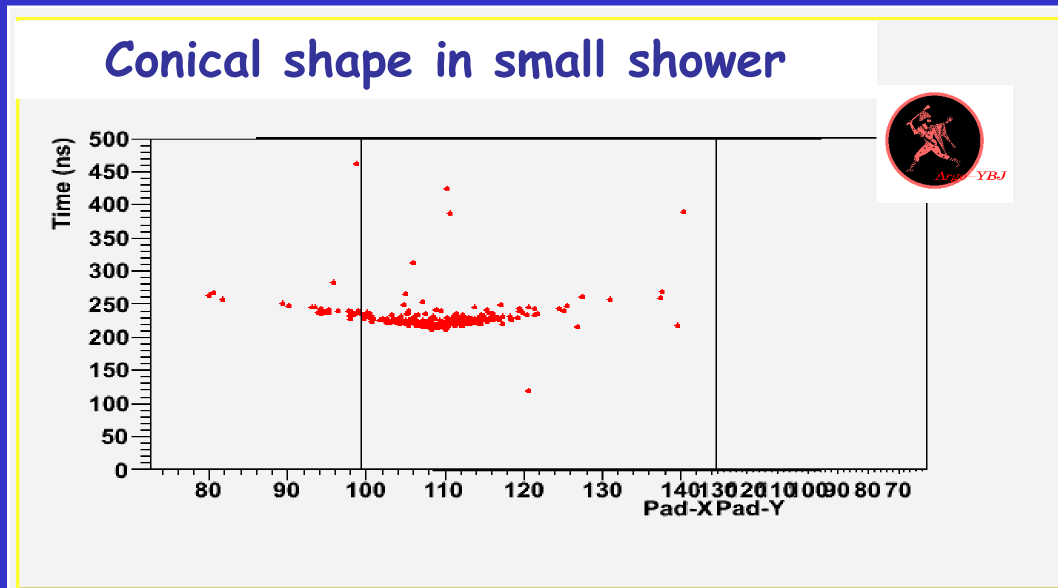

Cosmic rays

High space/time granularity allows unprecedeted studies on the EAS phenomenology (different topologies and time structures)

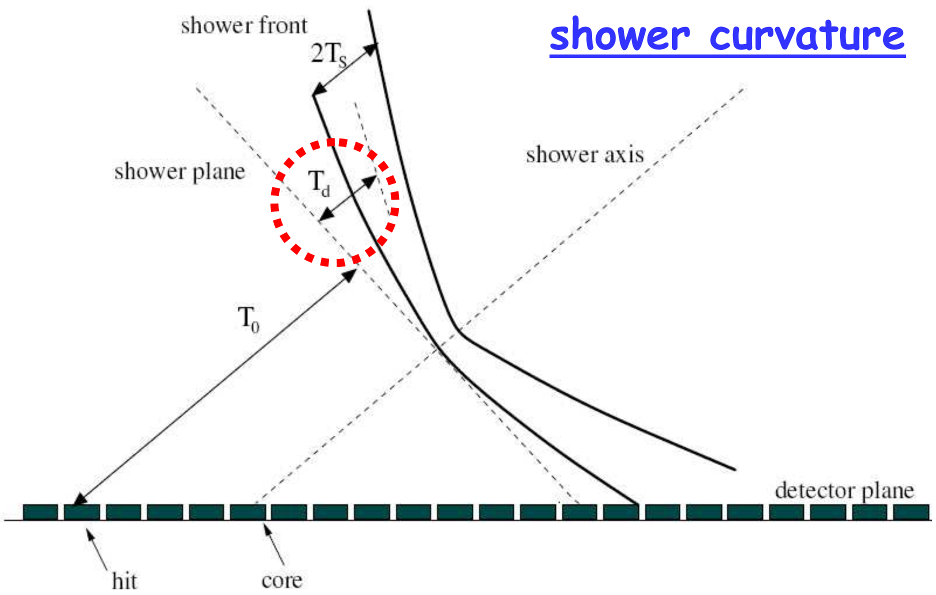




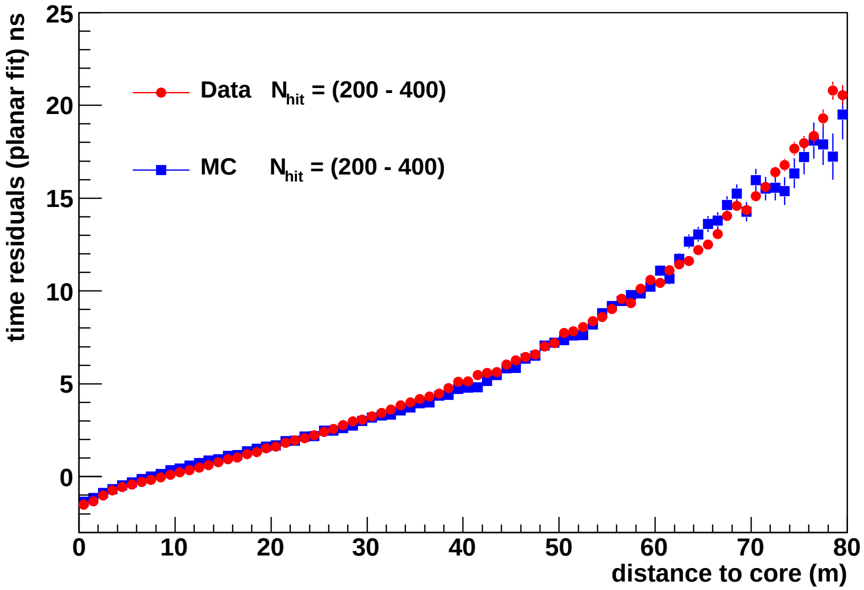


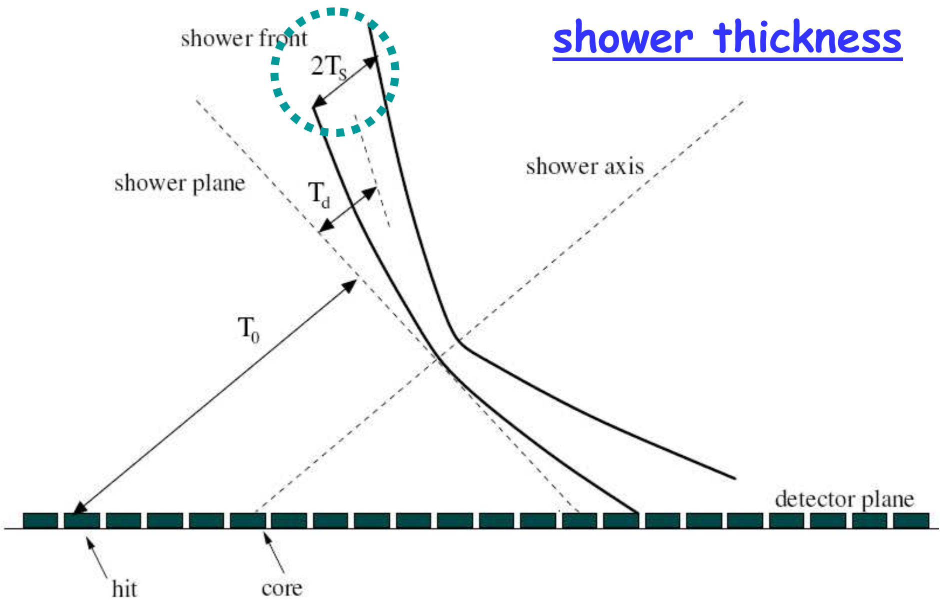


Studies in progress on the shower time structure

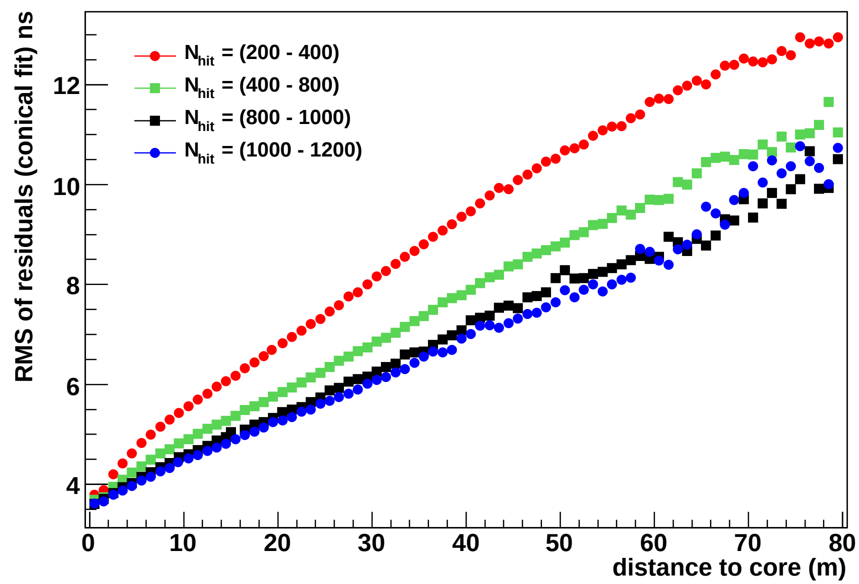


shower curvature





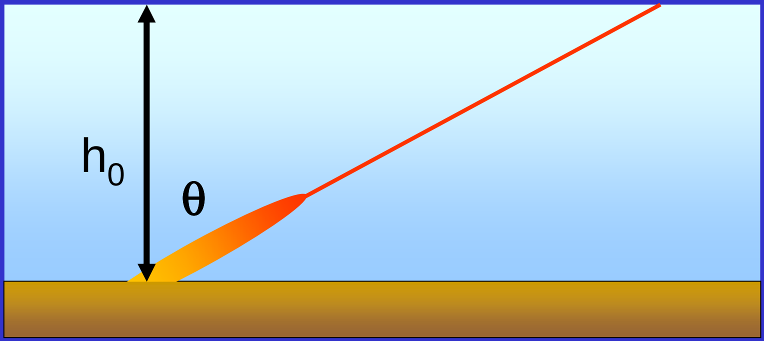
shower thickness



Measurement of attenuation length (Λ) and p-Air cross section

arXiv:0904.4198

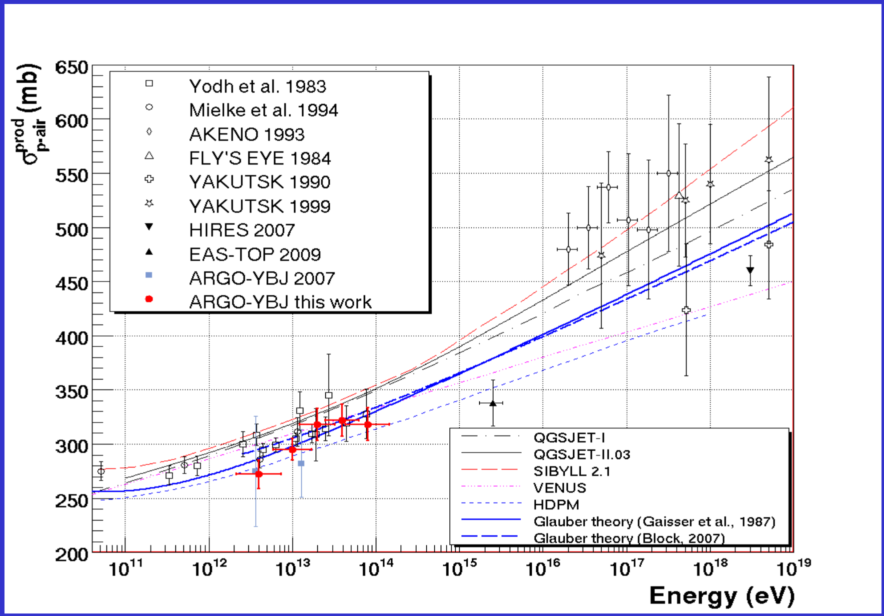
$$I(\theta) = I_0 \exp\left[-\frac{h_0}{\Lambda}(\sec\theta - 1)\right]$$

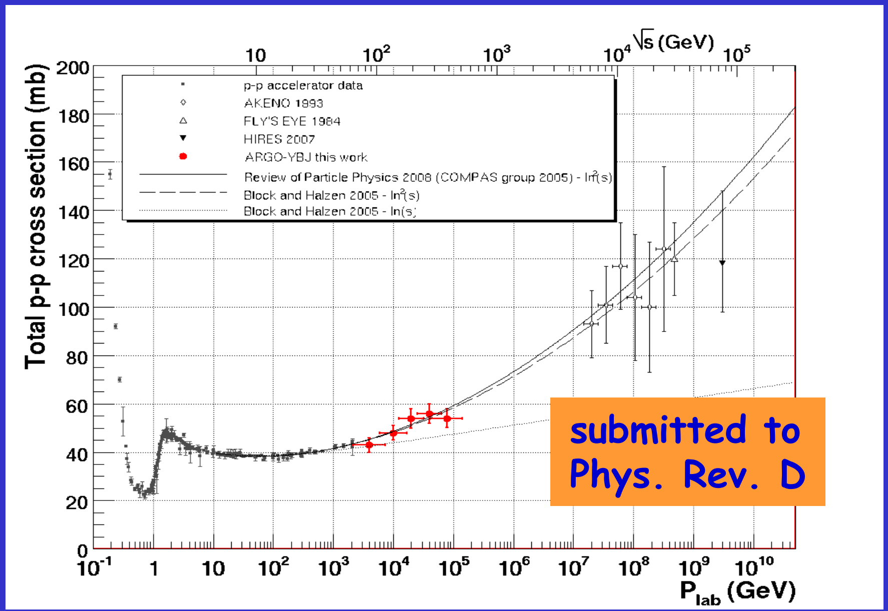


$$\Lambda = k\,\lambda_{\mathrm{INT}}$$

$$\sigma_{p-Air}[mb] = 2.4\times10^{4}/\lambda_{\mathrm{INT}}[g/cm^{2}]$$

$\Rightarrow$ $\sigma_{\text{p-Air}}$ $\Rightarrow$ $\sigma_{\text{p-p}}$

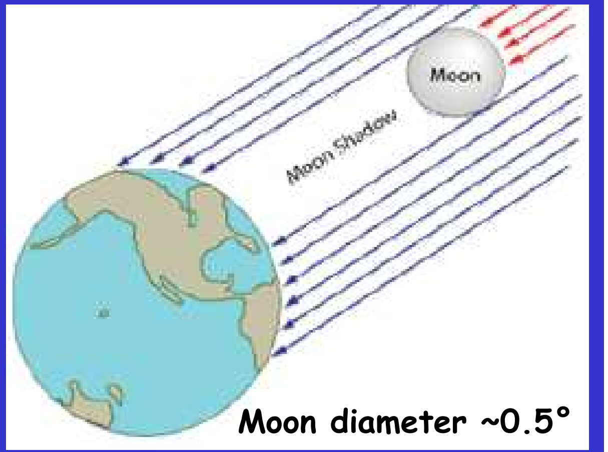




submitted to Phys. Rev. D

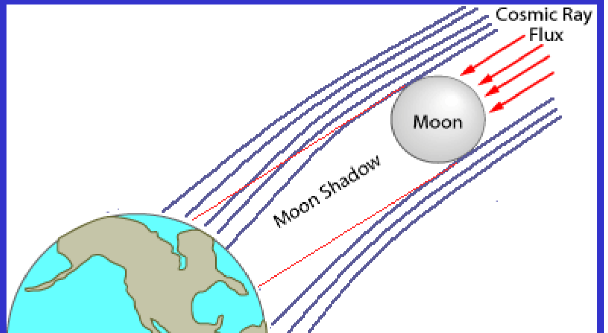

The shadow of the Moon

The shadow of the Moon



A deficit in the cosmic ray flux is expected from the Moon direction. Many items are connected:

- angular resolution (width of the deficit)
- pointing accuracy (position of the deficit)
- energy calibration (the westward deflection due to the geomagnetic field depends on the energy of cosmic rays)

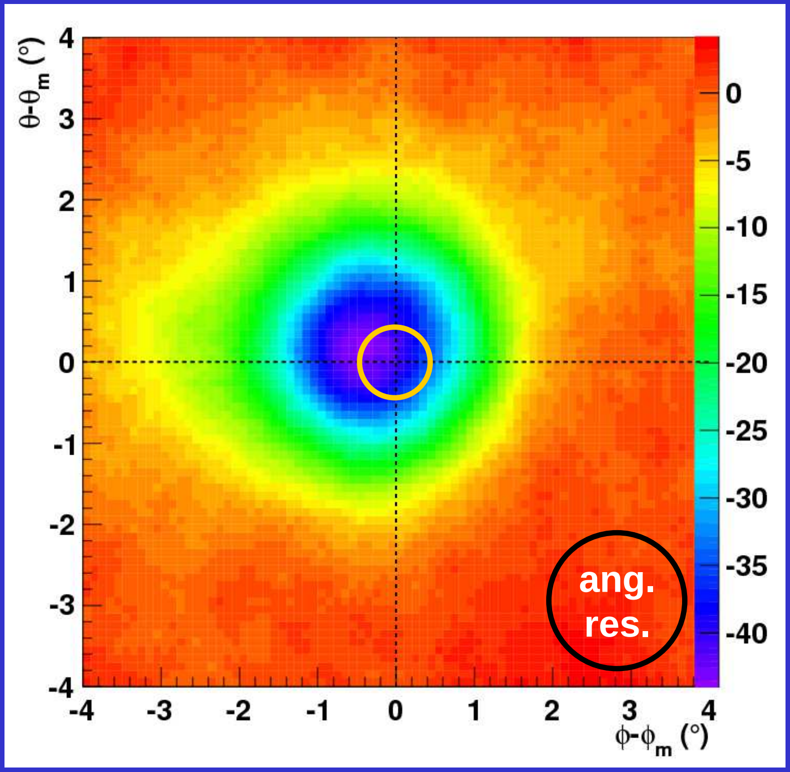


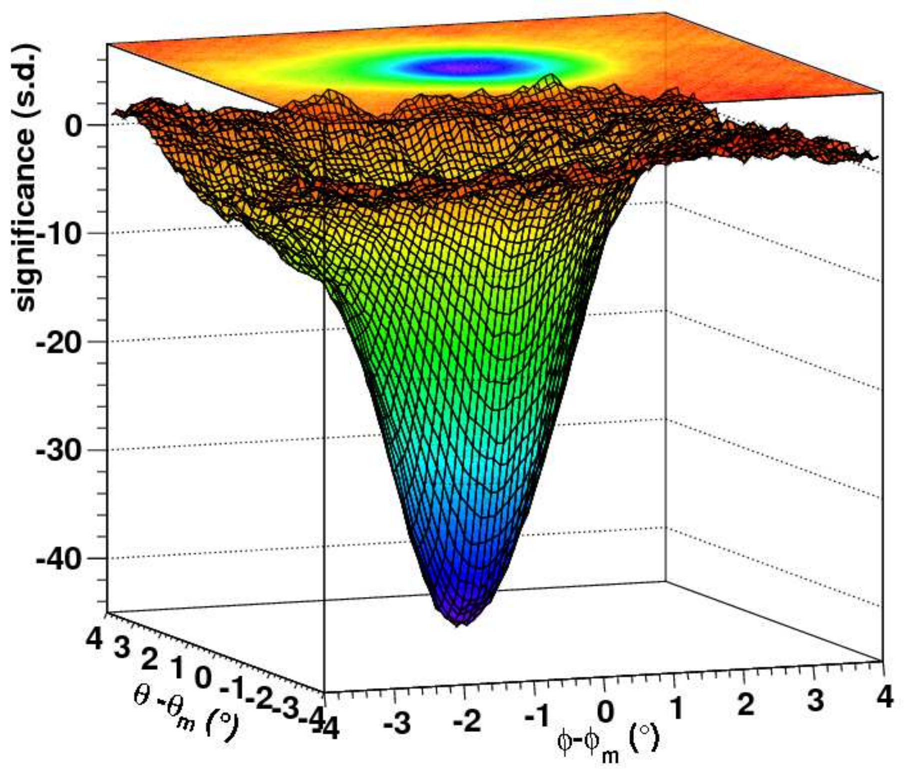
$$\Delta\theta \approx \frac{Z \times 1.6^\circ}{E\,[\mathrm{TeV}]}$$

- proton/antiproton ratio (antiprotons are deflected eastward)

2006-2008 data, with the cut N_{STRIP} > 60

Until November 2007 : installation and debug operations, low duty-cycle
Since December 2007 : stable data taking with high duty-cycle





The deficit surface is the convolution of the Point Spread Function of the detector and the widespread Moon disc

$$RMS \simeq \sigma\sqrt{1+\left(\frac{R}{2\sigma}\right)^2}$$

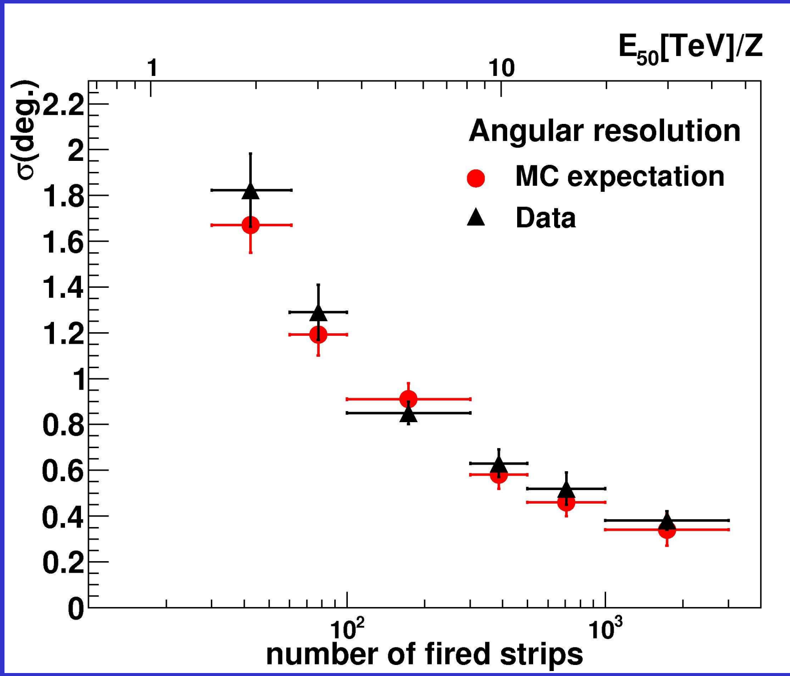
Selected sample (1-year data)

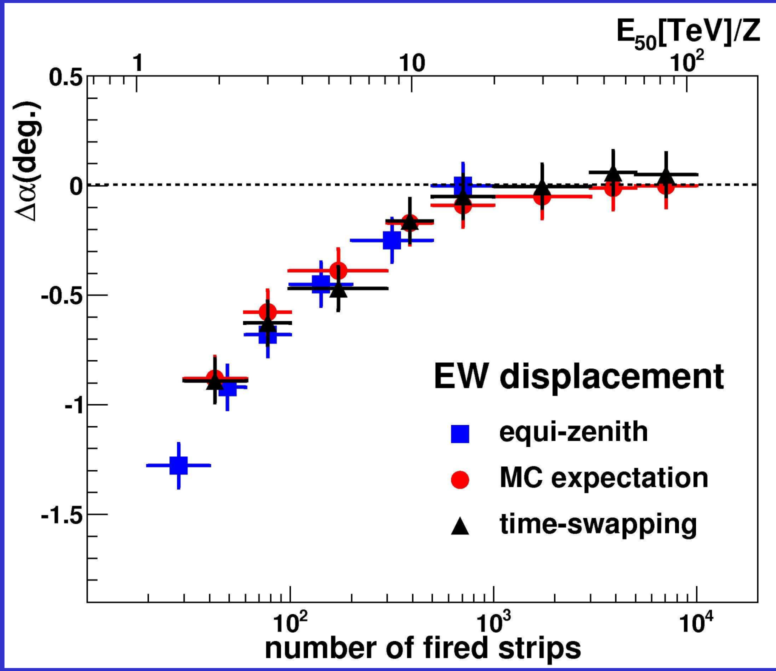
December 2007 – December 2008
$N_{STRIP} > 40$ .and. $\theta < 50°$

130×10^9 analyzed events

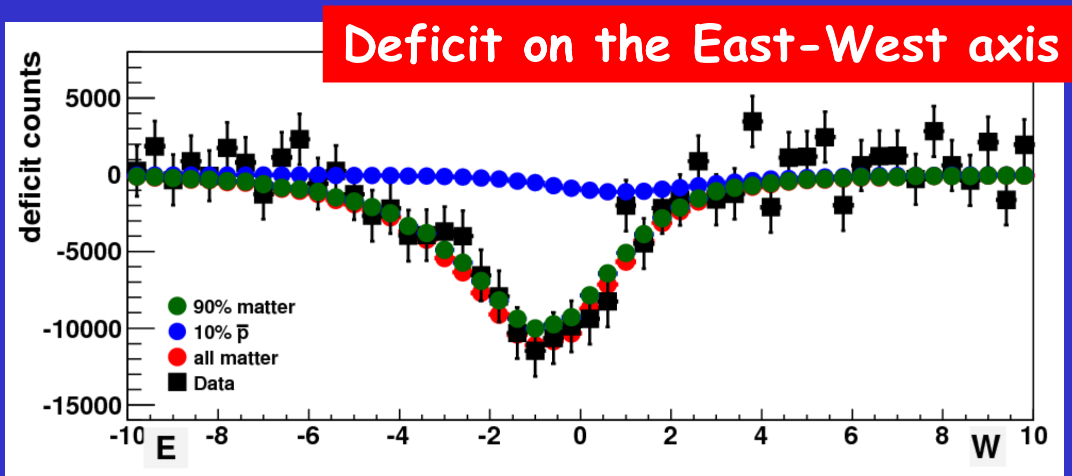
Observation time 1350 hrs
Source visibility time 1500 hrs On-source duty-cycle 90 %

Signal statistical significance 32 s.d. $n_\sigma \approx 0.88\sqrt{t\,[hrs]}$





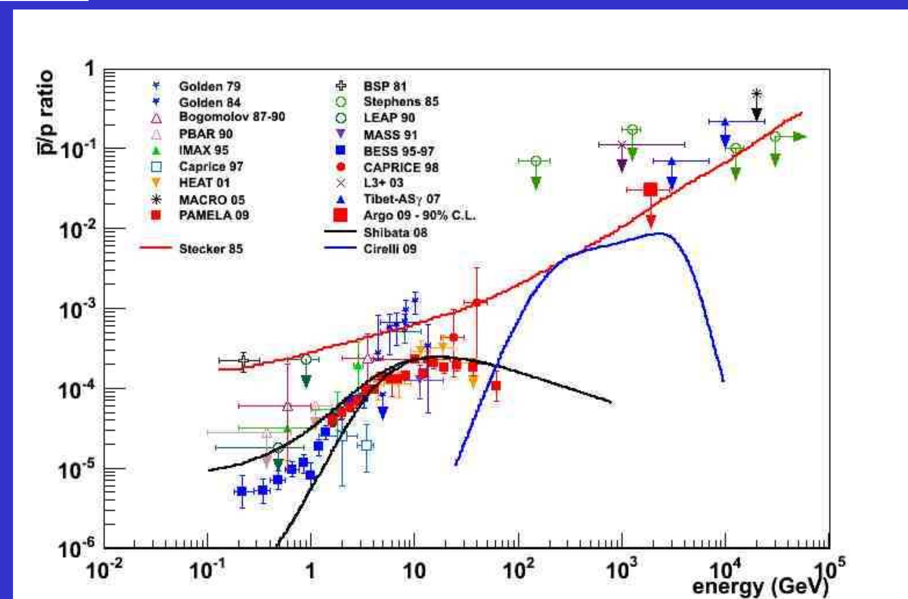
Looking for an antiproton signal (East deficit)



A likelihood method is applied to estimate the upper limit of the antiproton flux

$$\Phi(\bar{p}) < 0.03\ \Phi(p)$$

at 2.0 TeV (90% c.l.)



γ-astronomy

The technique of EAS detection allows a duty-cycle limited only by maintenance:

Duty-cycle $\rightarrow$ 100%

The field of view is limited only by the atmosphere thickness. Requiring zenith angle < 40° :

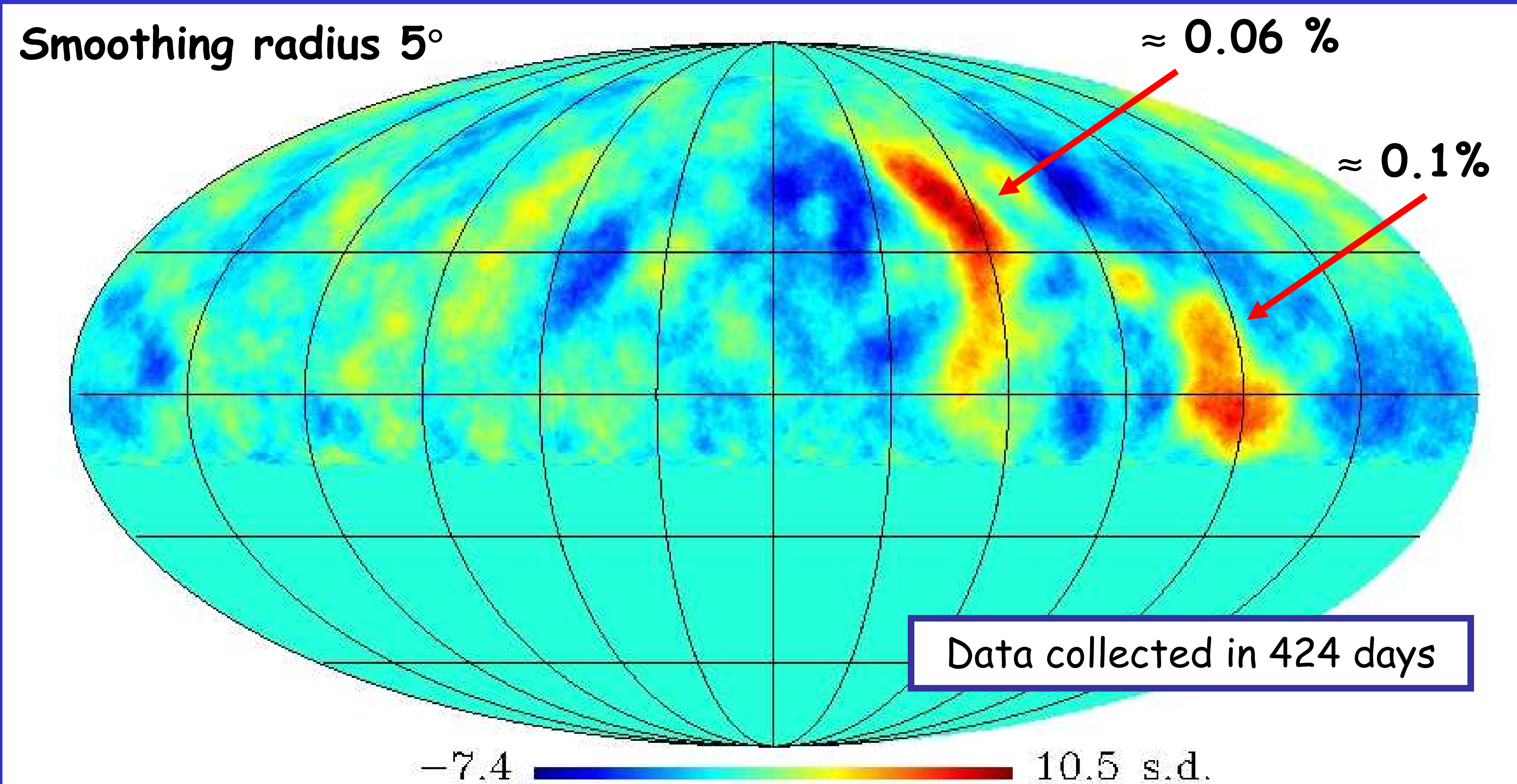
Field of View ~ 2 sr

Continuous monitoring of the sky in the declination band

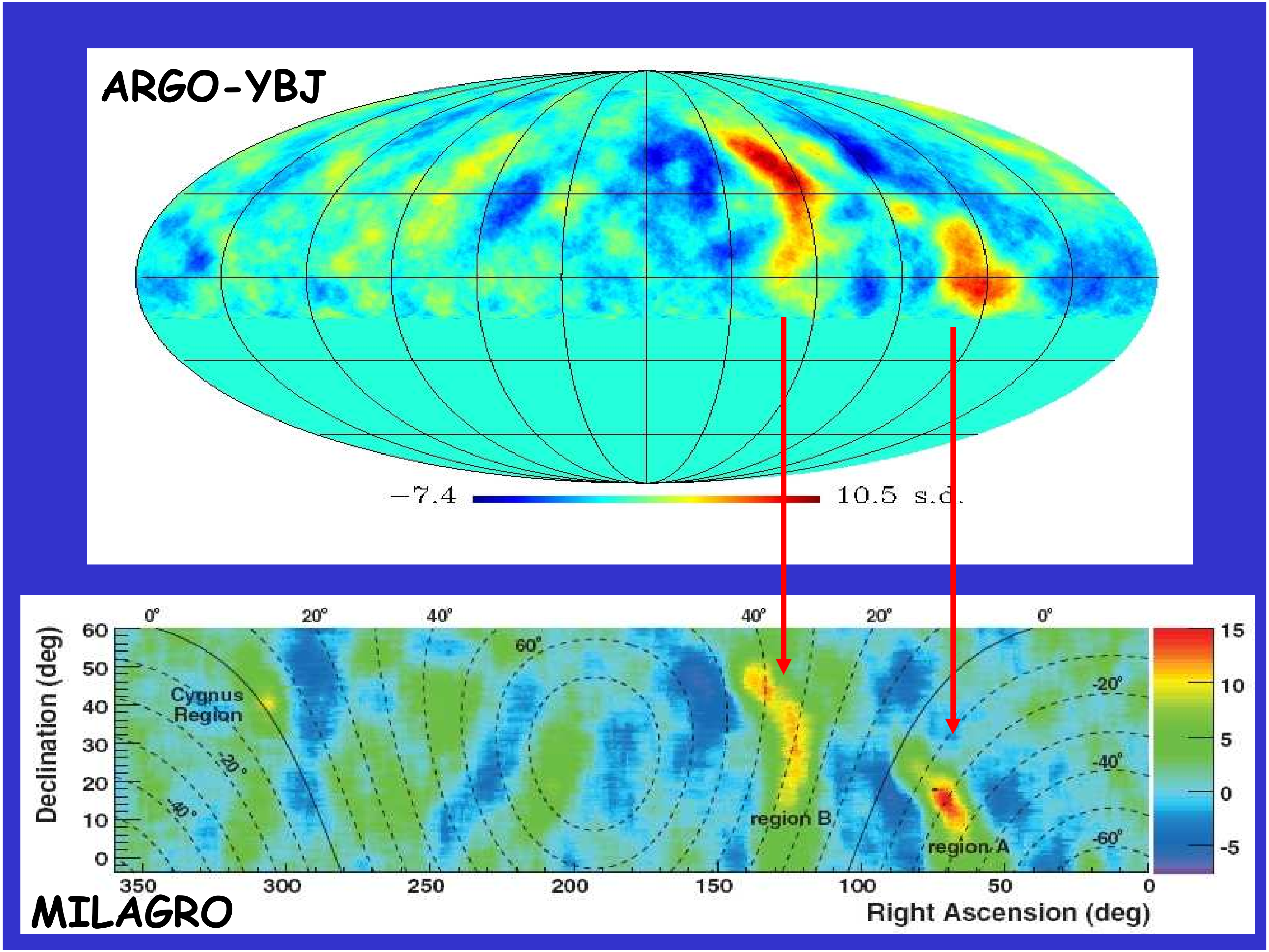
$-10° < \delta < 70°$

Presently ARGO-YBJ is the only wide-field-of-view γ-telescope able to detect AGN TeV flares on a few days

CR excesses in the sky map

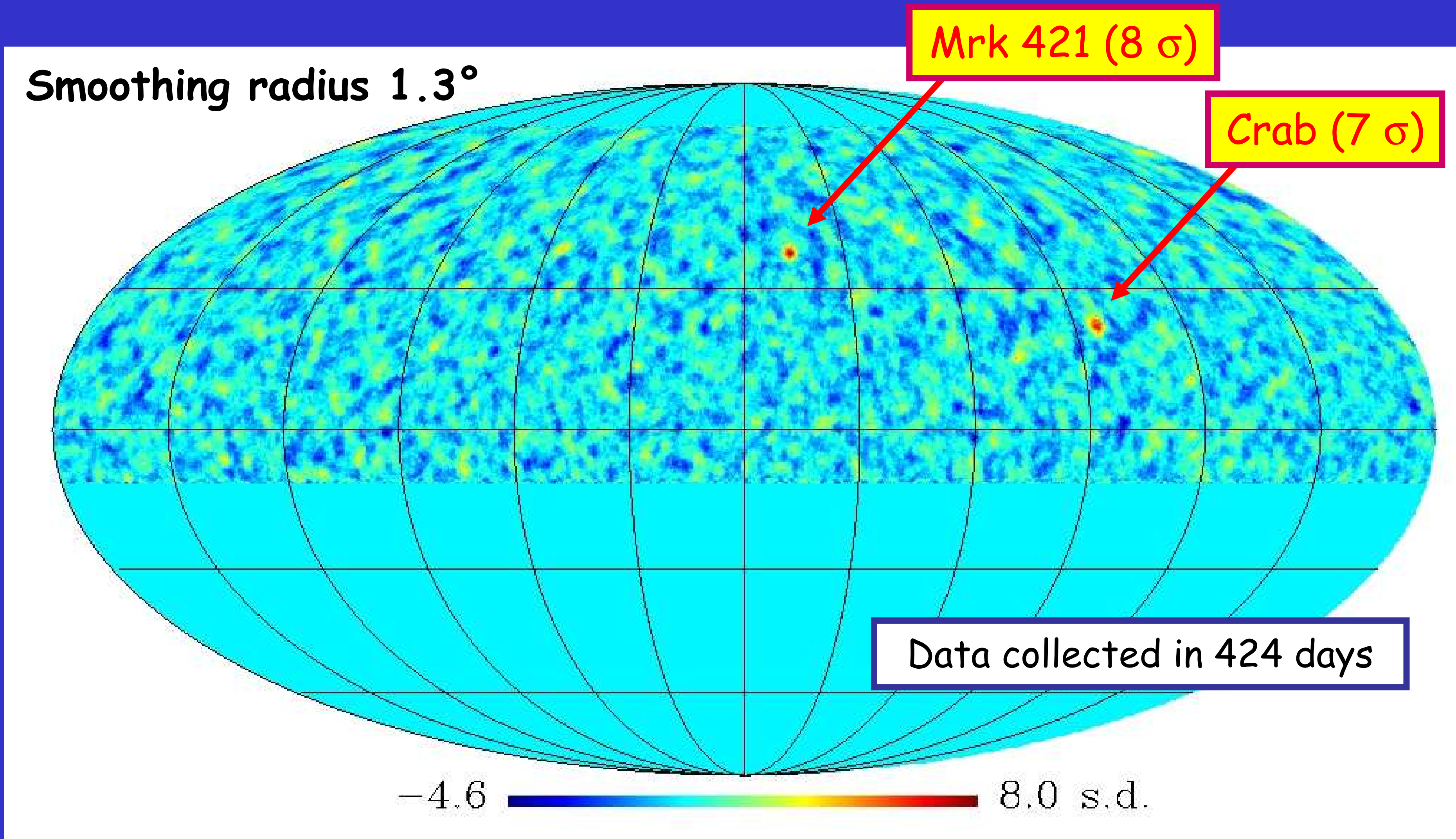


$N_{PAD} > 40 \rightarrow$ Proton median energy ≈ 2 TeV



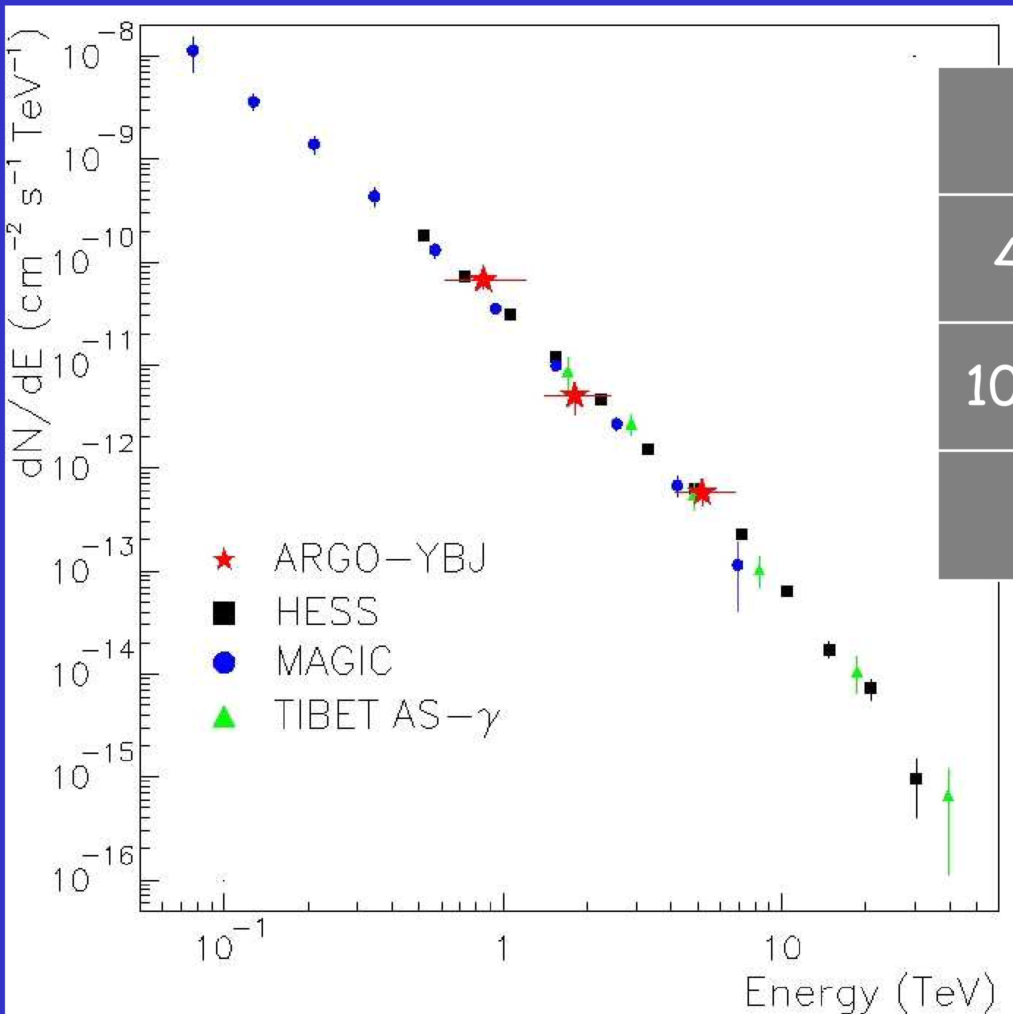
ARGO-YBJ
−7.4
10.5 s.d.
MILAGRO
Declination (deg)
Right Ascension (deg)
Cygnus Region
region B
region A
60
50
40
30
20
10
0
350
300
250
200
150
100
50
0
15
10
5
0
-5

Sky map after correction



N_{PAD} > 40 → Gamma median energy ≈ 0.6-2 TeV

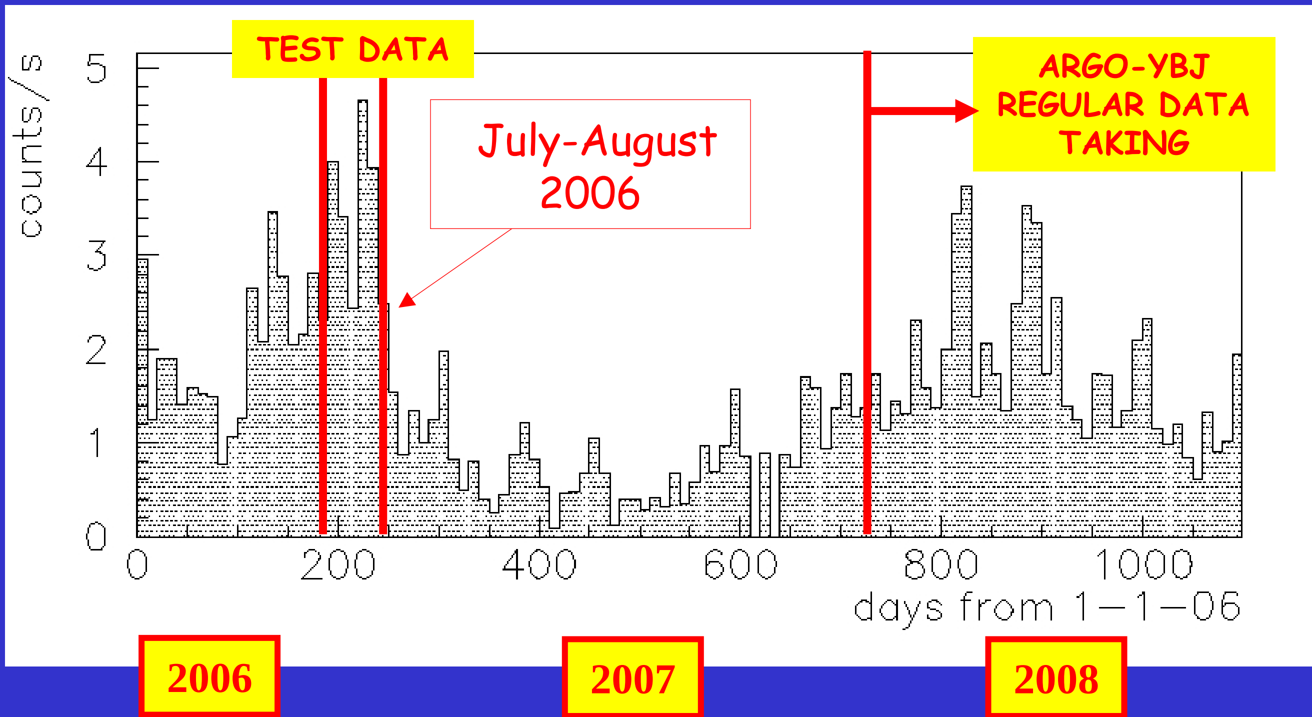
Crab Nebula energy spectrum



N_{PAD}	Events /day	E_{med} (TeV)
40 - 99	128 $\pm$ 24	0.85
100 - 299	17.9 $\pm$ 6.3	1.8
$\geq$ 300	9.2 $\pm$ 2.3	5.2

$$dN/dE = (3.73 \pm 0.80) \times 10^{-11}\ E^{-2.67\pm0.25}\ \gamma\ cm^{-2}\ s^{-1}\ TeV^{-1}$$

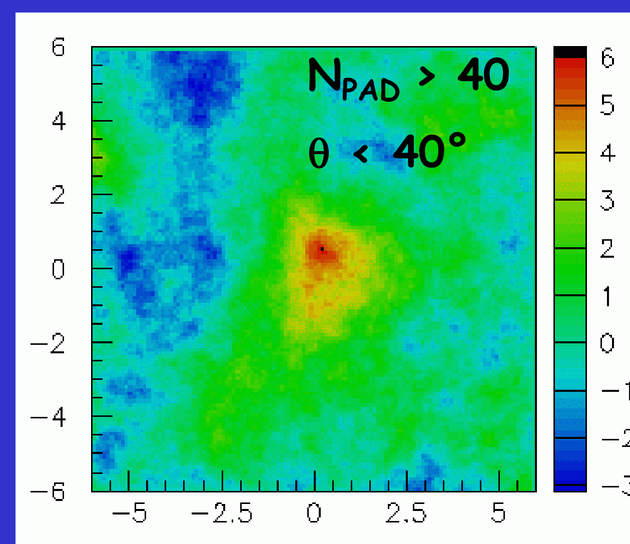
Mrk 421 X-ray data by ASM/RXTE



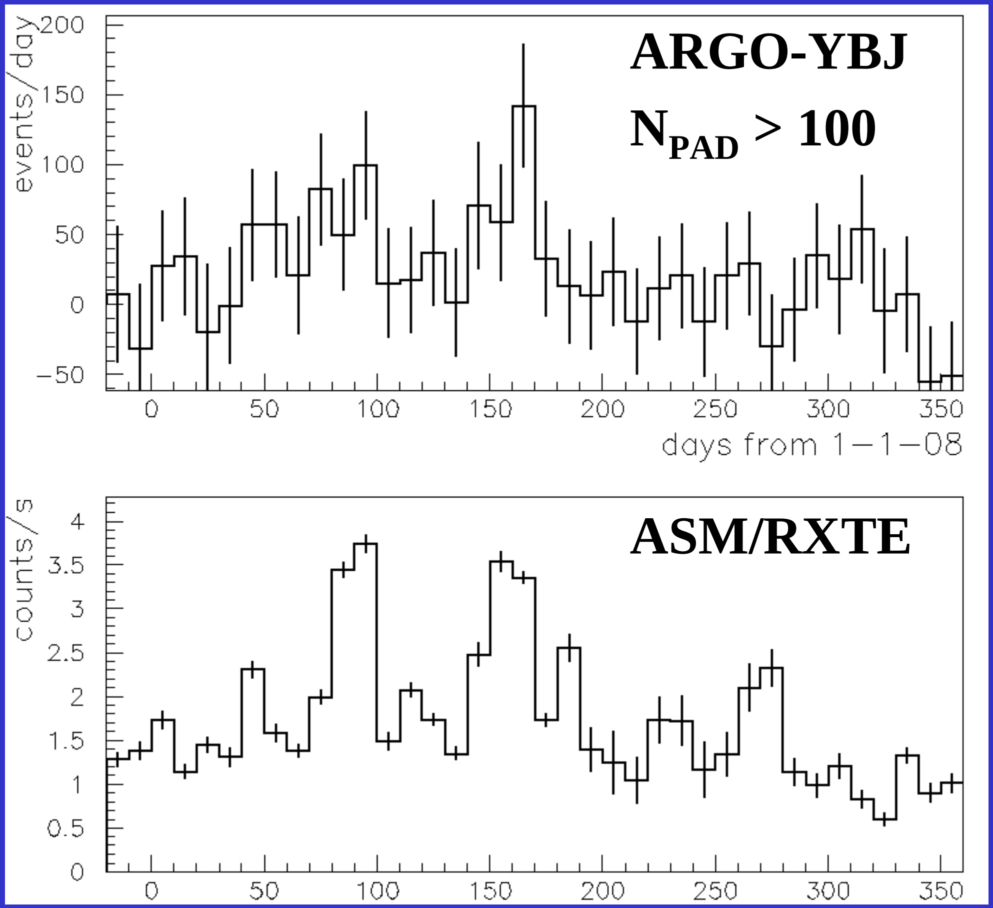
Mrk 421 - July-August 2006

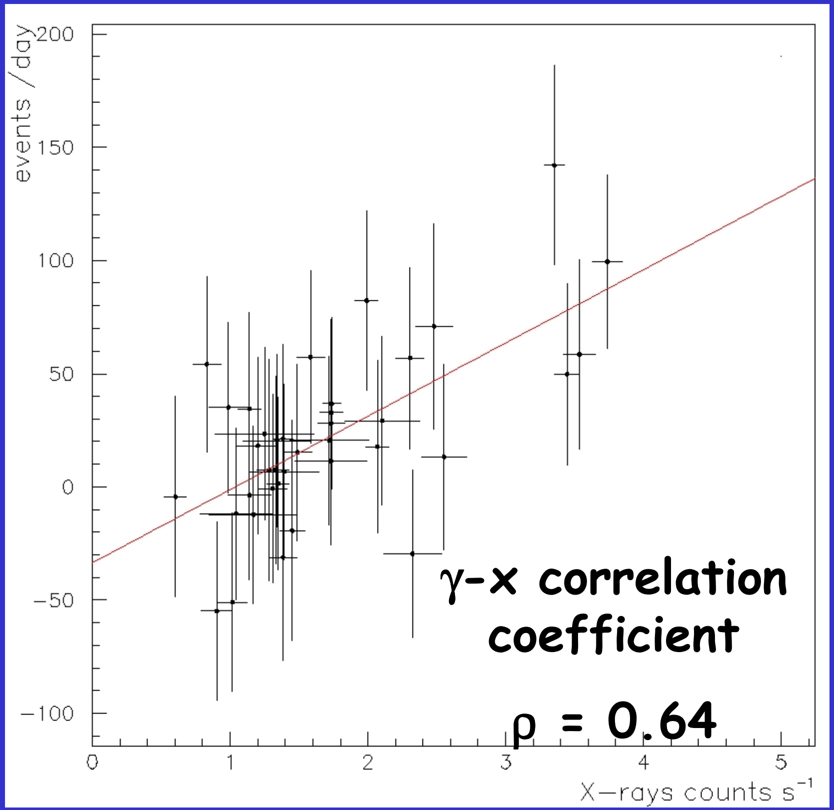
ARGO-YBJ test data collected during the x-ray flare

Observation time ≈ 109 hours
Flux ≈ 4 Crab units



Mrk 421
2008 activity





The June 2008 flare observed from optical to TeV energies (12 decades)

-- optical R-band (GASP-WEBT)

-- UV band (UVOT)

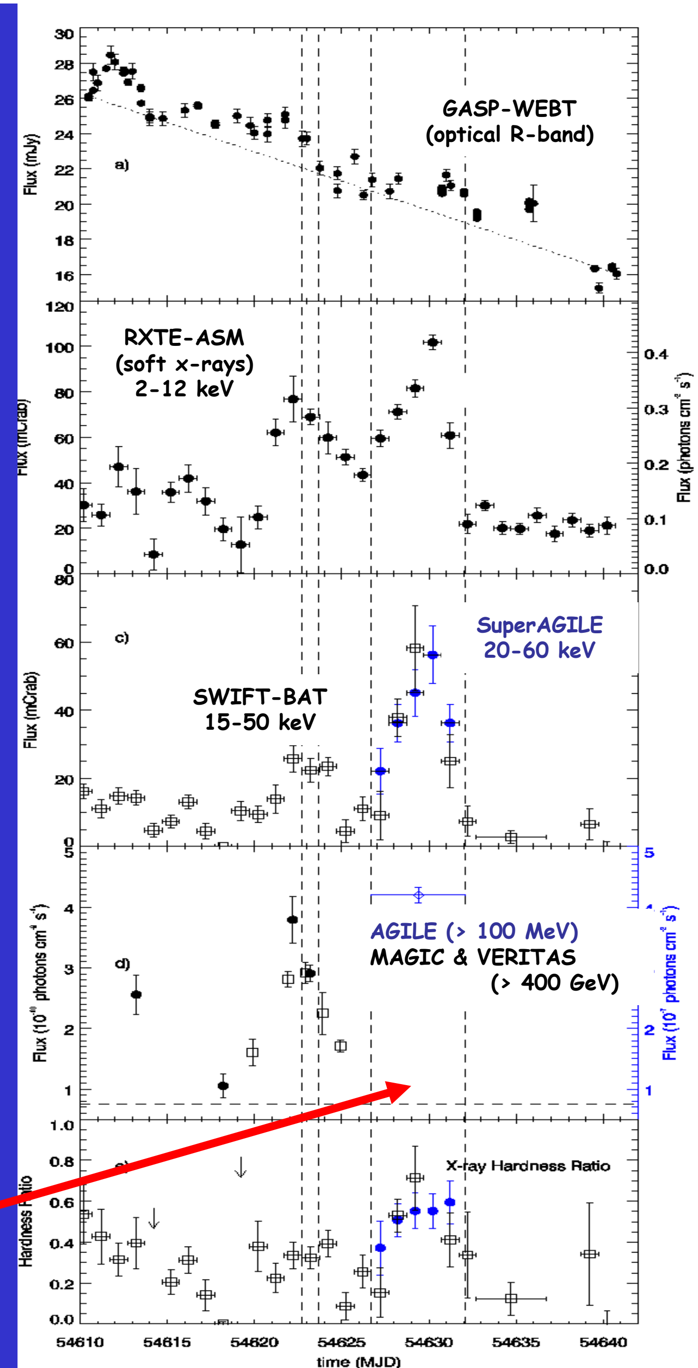
-- soft x-rays (ASM/RXTE and SWIFT)

-- hard x-rays (SWIFT and AGILE)

-- gamma rays (AGILE)

-- VHE gamma-rays (Veritas and Magic)

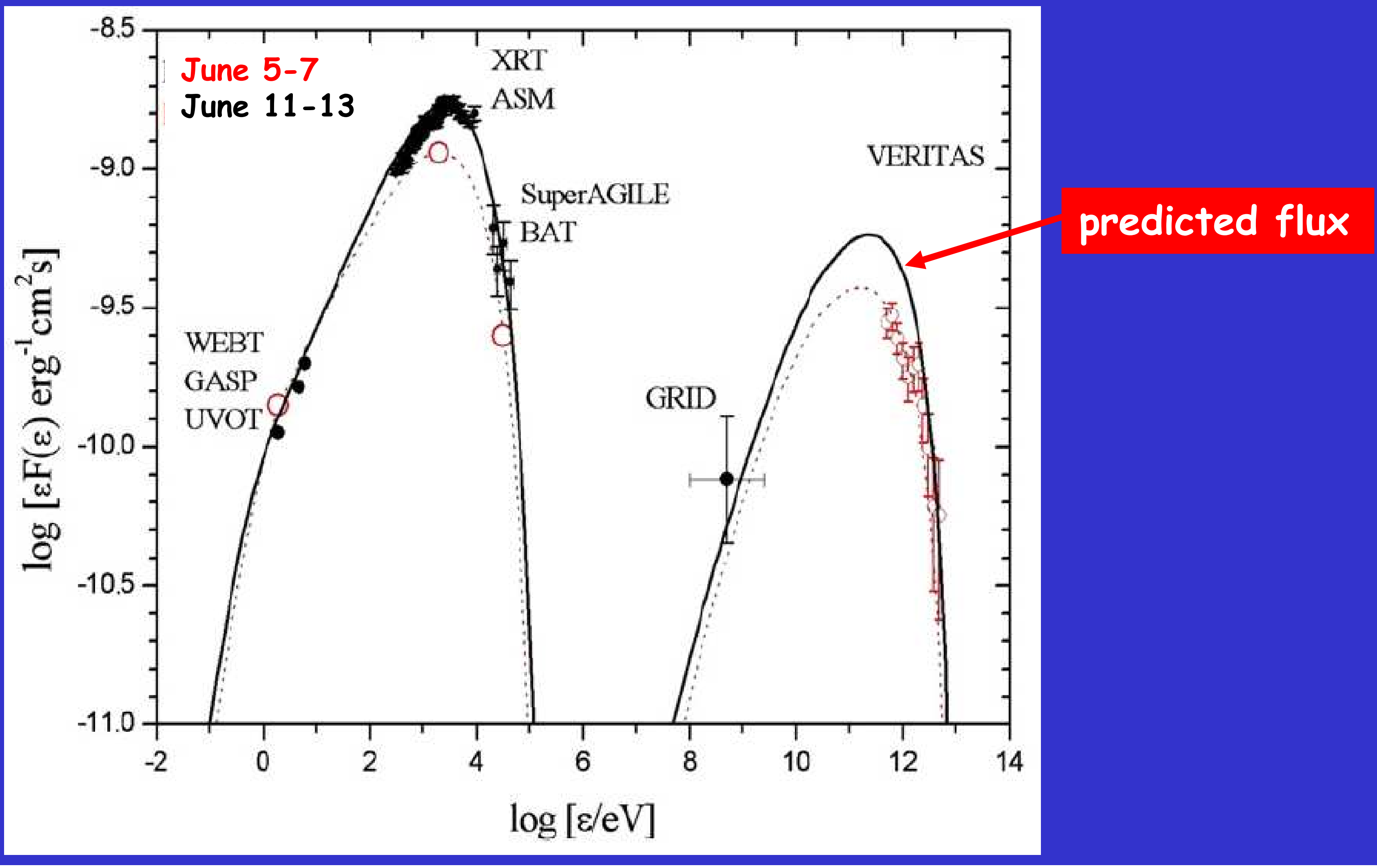
No VHE Cerenkov data after June 8



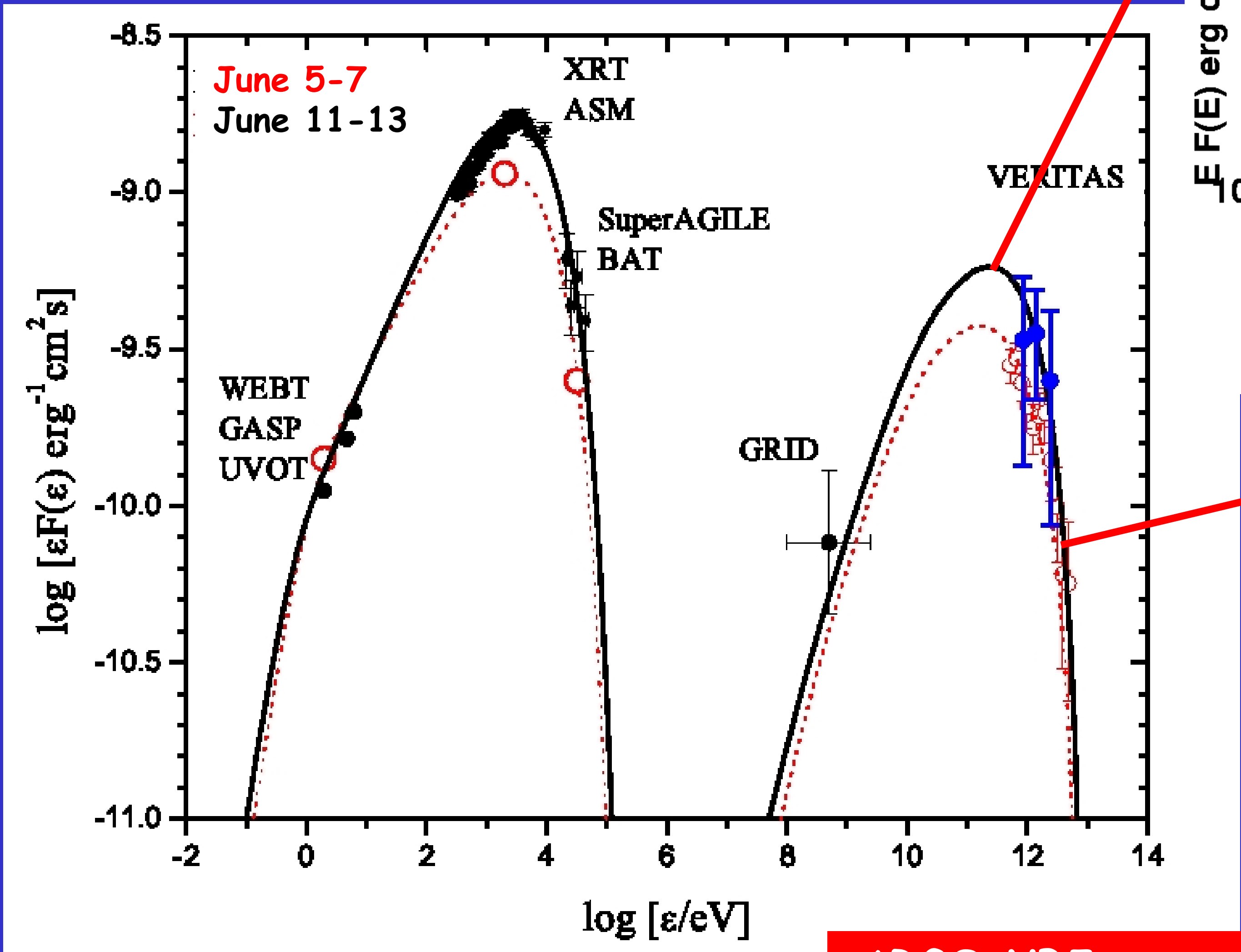
Donnarumma et al. ApJ 691 (2009) L13

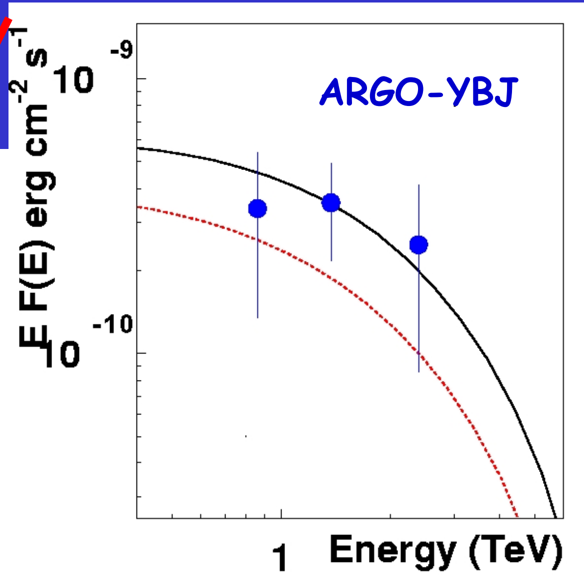
SEDs for June 2008 flares

Donnarumma et al, ApJ 691 (2009) L13 : the variability is due to the hardening/softening of the electron energy distribution, not to the increase/decrease of the particle density



SEDs for June 2008 flares





ARGO-YBJ measurements in agreement with the model by Donnarumma et al

Search for Gamma Ray Burst

Scaler mode: the counting rates ($\geq$1, $\geq$2, $\geq$3, $\geq$4 counts on each cluster) are measured each 0.5 s

Search for sudden increases of the counting rate in coincidence with GRBs observed by satellites

Energy range of the scaler mode search: 1 - 100 GeV

December 2004 – April 2009

66 GRBs in the ARGO-YBJ Field of View (θ < 40°)

11 with known redshift

59 long duration GRBs (> 2s)
7 short duration GRBs ($\leq$ 2s)

Look for coincidences :

1) in coincidence within ΔT_{90}
2) in different time intervals around the GRB time

Also the analysis of the stacked GRBs has been performed

The larger sample of GRBs studied on ground in the GeV energy region

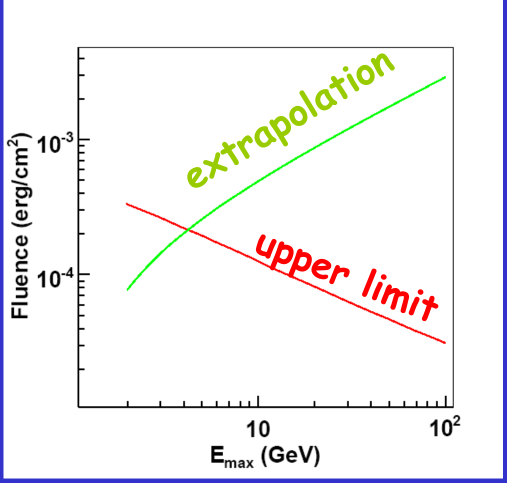
No signal detected (1-100 GeV)

Fluence Upper Limits of the order of

10^{-5} - 10^{-4} erg cm^{-2}

Upper Limits on the GRB cutoff energy

Intersection of the fluence upper limit with the extrapolation of the fluence measured by the satellites



just published
ApJ 699 (2009) 1281

These limits are a significant test for competing GRB models

Conclusions

- ✓ ARGO-YBJ detector (central carpet + guard ring) is taking data since November 2007 (duty-cycle > 90%)

- ✓ Studies on Cosmic Rays are going on (p-p cross section, anisotropies, shower profile, limit on antiproton flux …)

- ✓ First results on γ-astronomy (mainly 1-year data)
  - angular resolution as expected (Moon shadow)
  - limits on 1-100 GeV fluence from GRBs
  - Crab Nebula γ-spectrum in agreement with other measurements
  - continuous monitor of all sky

- ✓ Studies to increase the sensitivity are in progress (data quality, γ-hadron separation)

- ✓ VHE γ-sky survey is going on