

GAMMA RAY ASTRONOMY WITH ARGO-YBJ

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per la Collaborazione ARGO-YBJ**

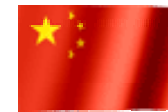


53° Congresso SAIT
Pisa, 4-8 Maggio 2009

ARGO-YBJ

*Astrophysical **R**adiation with **G**round-based **O**bservatory*

@ ***YangBaJing***



Site location:

90 km North of Lhasa
(Tibet, P.R. China)

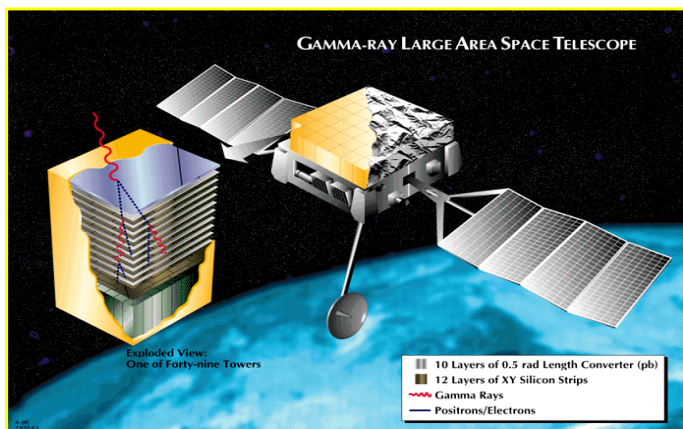
Long: 90° 31' 50" E;

Lat: 30° 06' 38" N

4300 m a. s. l. ($\approx 606 \text{ g/cm}^2$)



GAMMA ASTRONOMY INSTRUMENTS



Satellites

IACTs

EAS arrays

ARGO-YBJ

MeV

GeV

TeV

PeV

EeV

Medium

HE

VHE

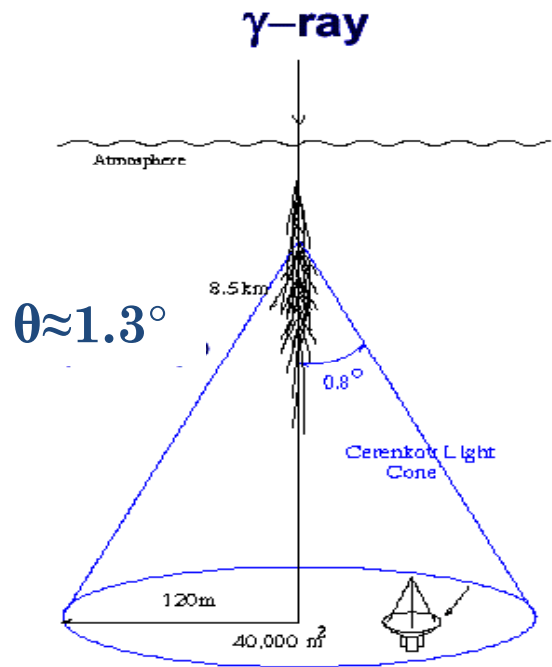
UHE

EHE

DETECTING EXTENSIVE AIR SHOWERS

Air Cherenkov Telescopes

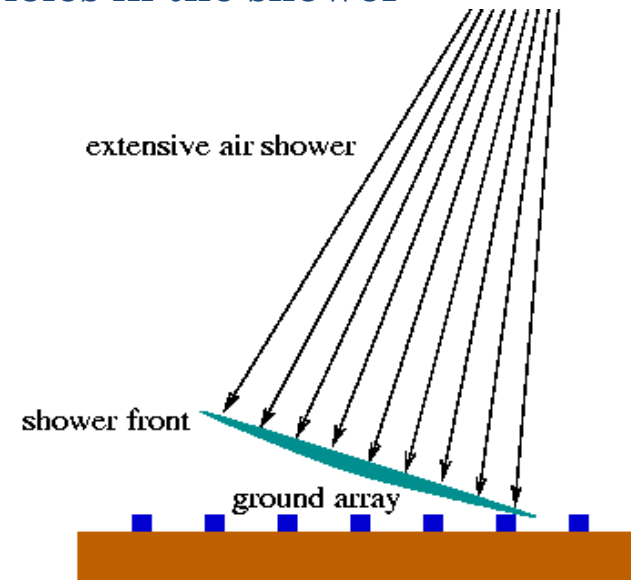
detection of the Cherenkov light from charged particles in the EAS



Very low energy threshold (≈ 60 GeV)
 Good background rejection (99.7 %)
 High sensitivity ($< 10^{-2} \Phi_{\text{crab}}$)
 Good energy resolution
 Low duty-cycle ($\sim 5\text{-}10\%$)
 Small field of view $\Delta\theta < 4^\circ$

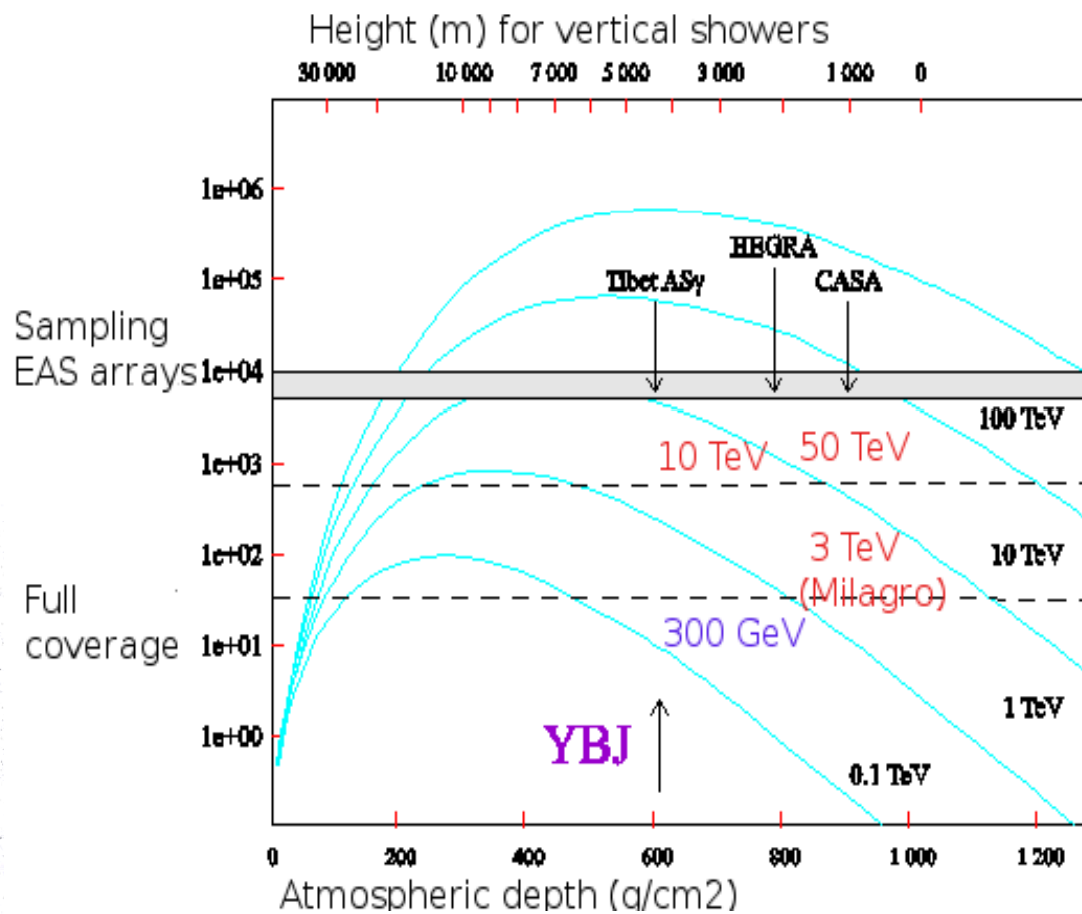
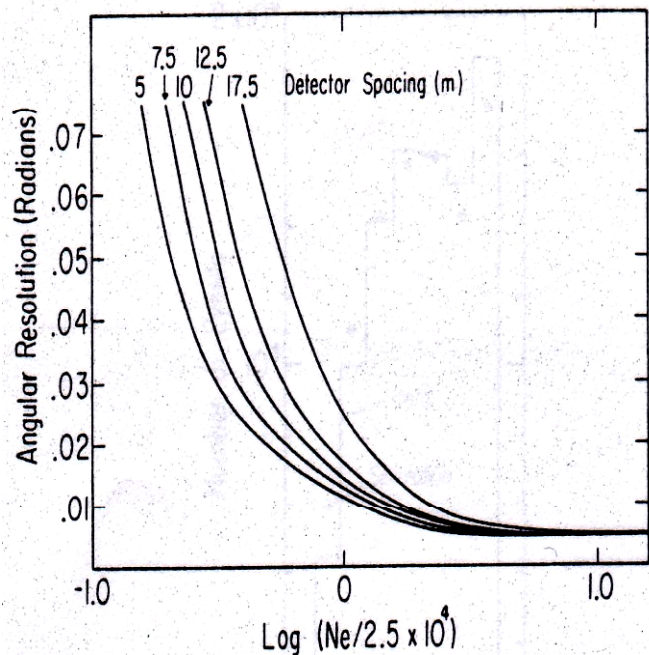
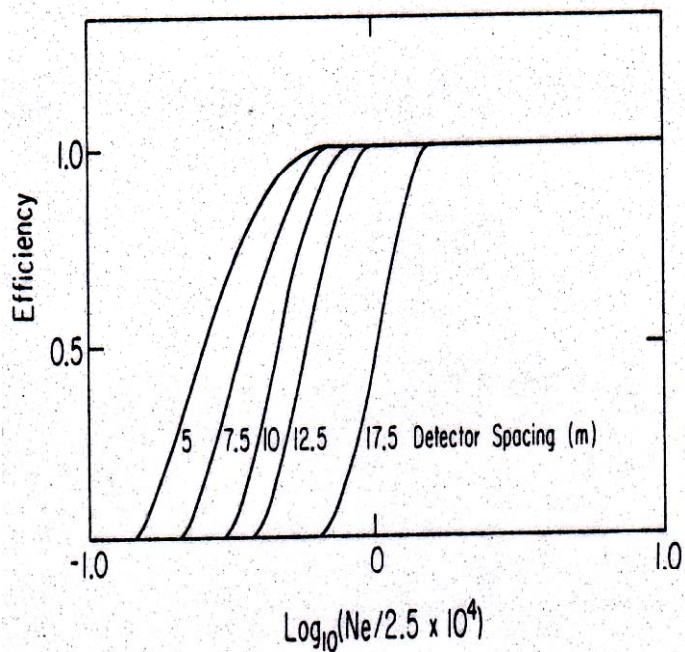
EAS arrays

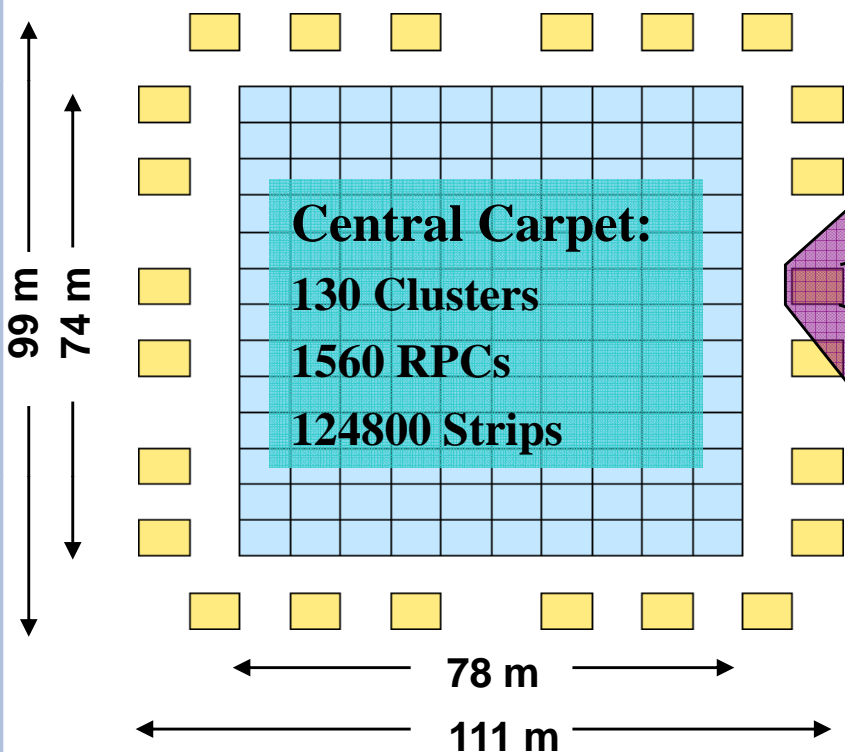
detection of the charged particles in the shower



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

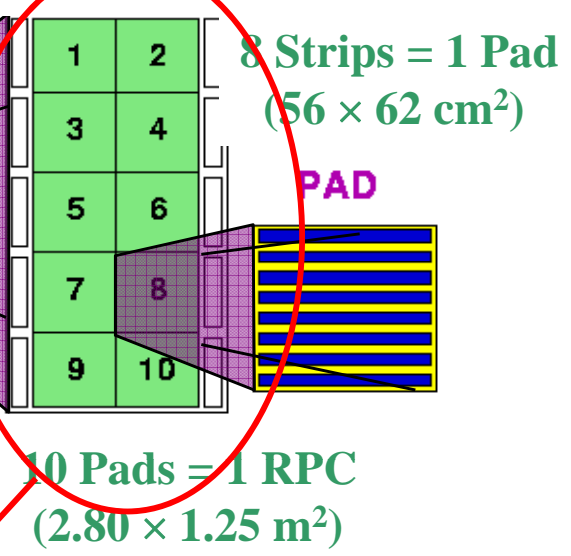
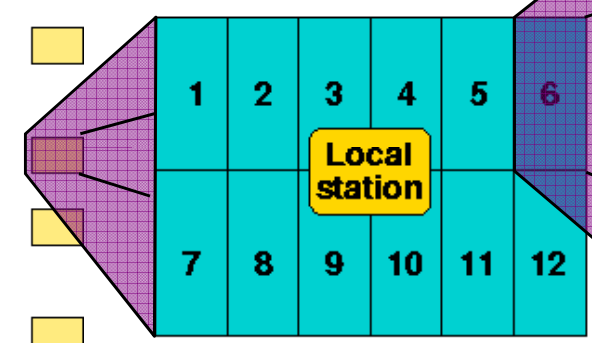
A NEW GENERATION EAS DETECTOR





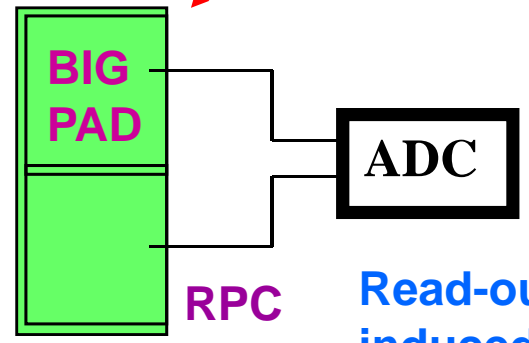
Central Carpet:
130 Clusters
1560 RPCs
124800 Strips

12 RPC = 1 Cluster
(5.7 × 7.6 m²)



Gas Mixture: Ar/ Iso/ TFE = 15/10/75, HV = 7200 V

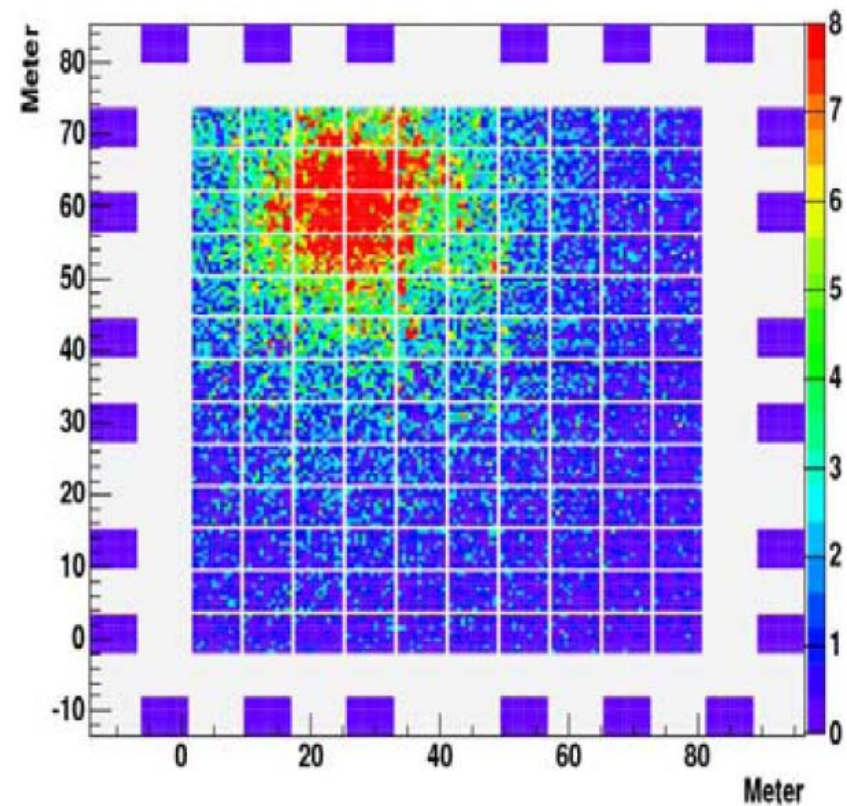
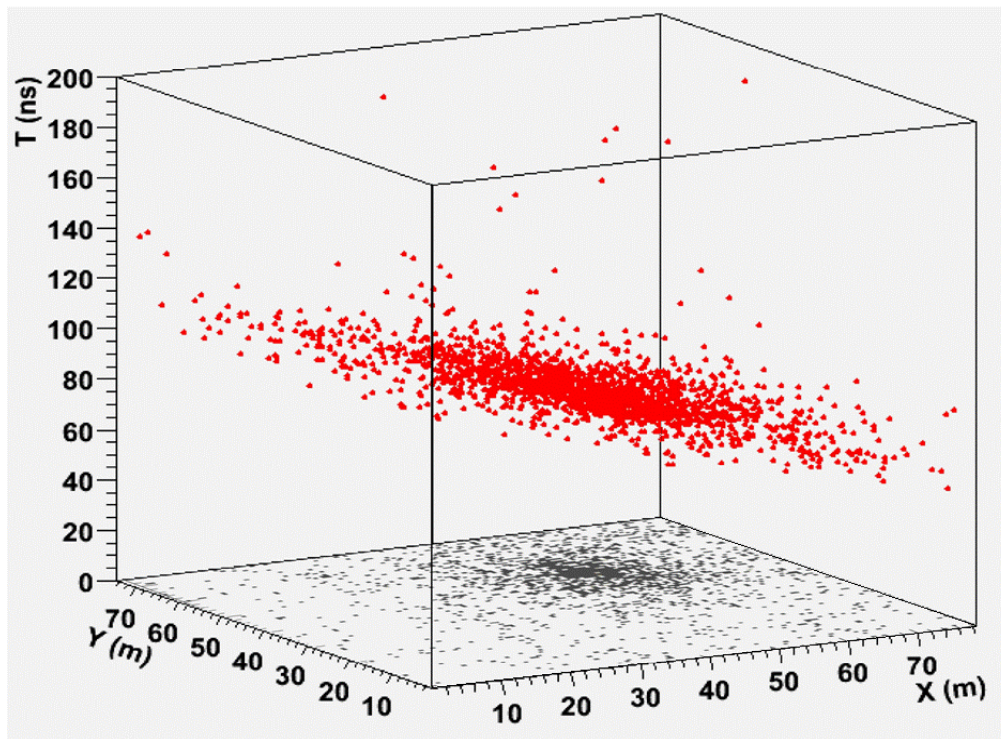
Layer of RPC covering ~5600 m²
(~ 93% active surface)
+ sampling guard-ring



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

DATA ACQUISITION

- Coincidence of different detector units (pads) within 420 ns;
- Trigger: ≥ 20 fired pads on the central carpet (rate: ≈ 4 kHz)
- Reconstruction of core position, arrival direction, size..



ARGO-YBJ PHYSICS GOALS

- VHE γ -Ray Astronomy
- Transient phenomena
 - Gamma Ray Bursts
 - Solar physics (Forbush decreases, GLEs)
- Cosmic Ray Physics
 - Spectrum, composition
 - Time structure of the shower front
 - Antiproton/proton ratio
 - Inelastic p-air cross section

VHE γ ASTRONOMY: ANALYSIS PROCEDURE

- Source follow up when $\theta < 40^\circ$
- Build the event map $20^\circ \times 20^\circ$ around the source; bin: $0.1^\circ \times 0.1^\circ$
- Build the background map with the *time swapping method*: random background events are generated for each observed event by associating the event coordinates (δ, α) with times selected randomly from all event times recorded within a 3 h period.
- Map smoothing: all events inside a window of radius ω are summed up
- The background map is subtracted from the event map
- Calculation of the excess significance for each bin:

$$N_\sigma = \frac{S - B}{\sqrt{B + 0.1B}}$$

S = number of events in the event map bin

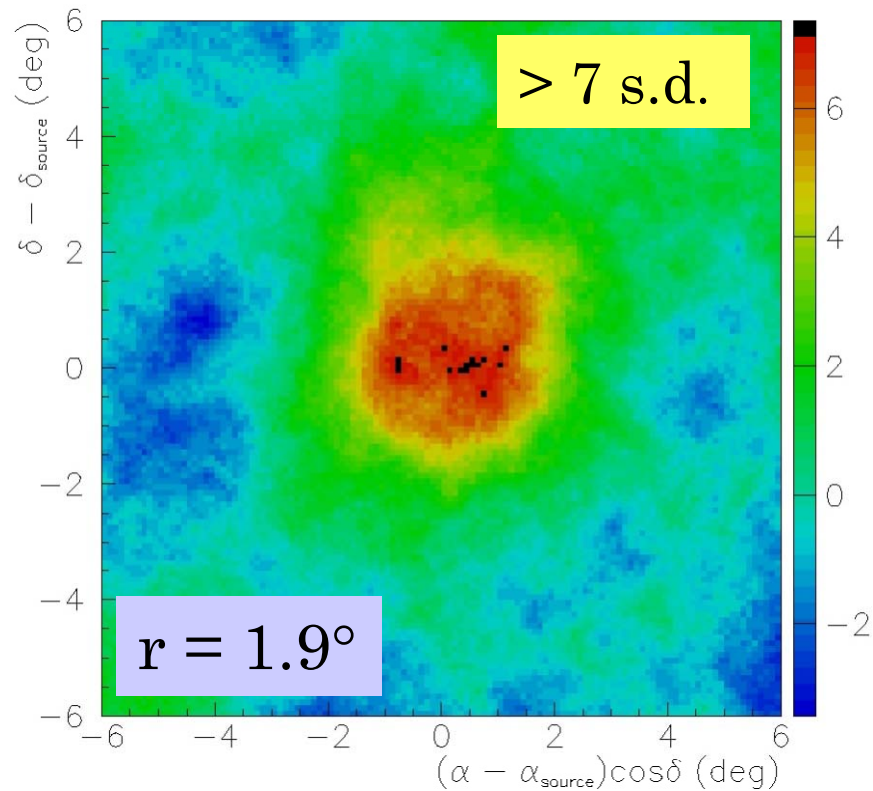
B = number of events in the background map bin

CRAB NEBULA

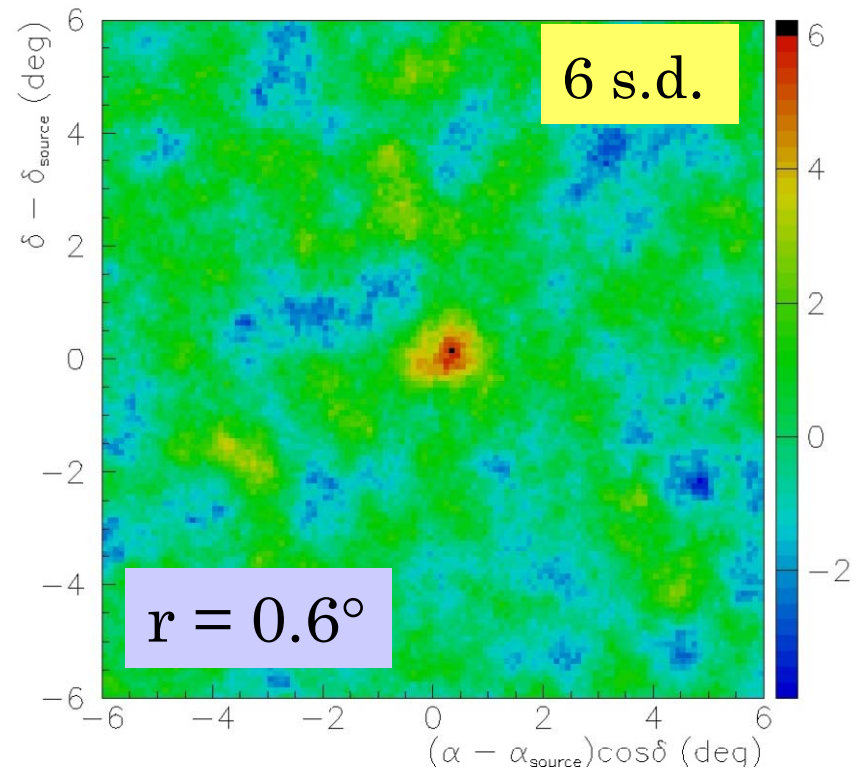
Standard Candle in Gamma Astronomy

5.8 h/day spent within ARGO-YBJ FoV ($\theta < 40^\circ$)

328 observation days



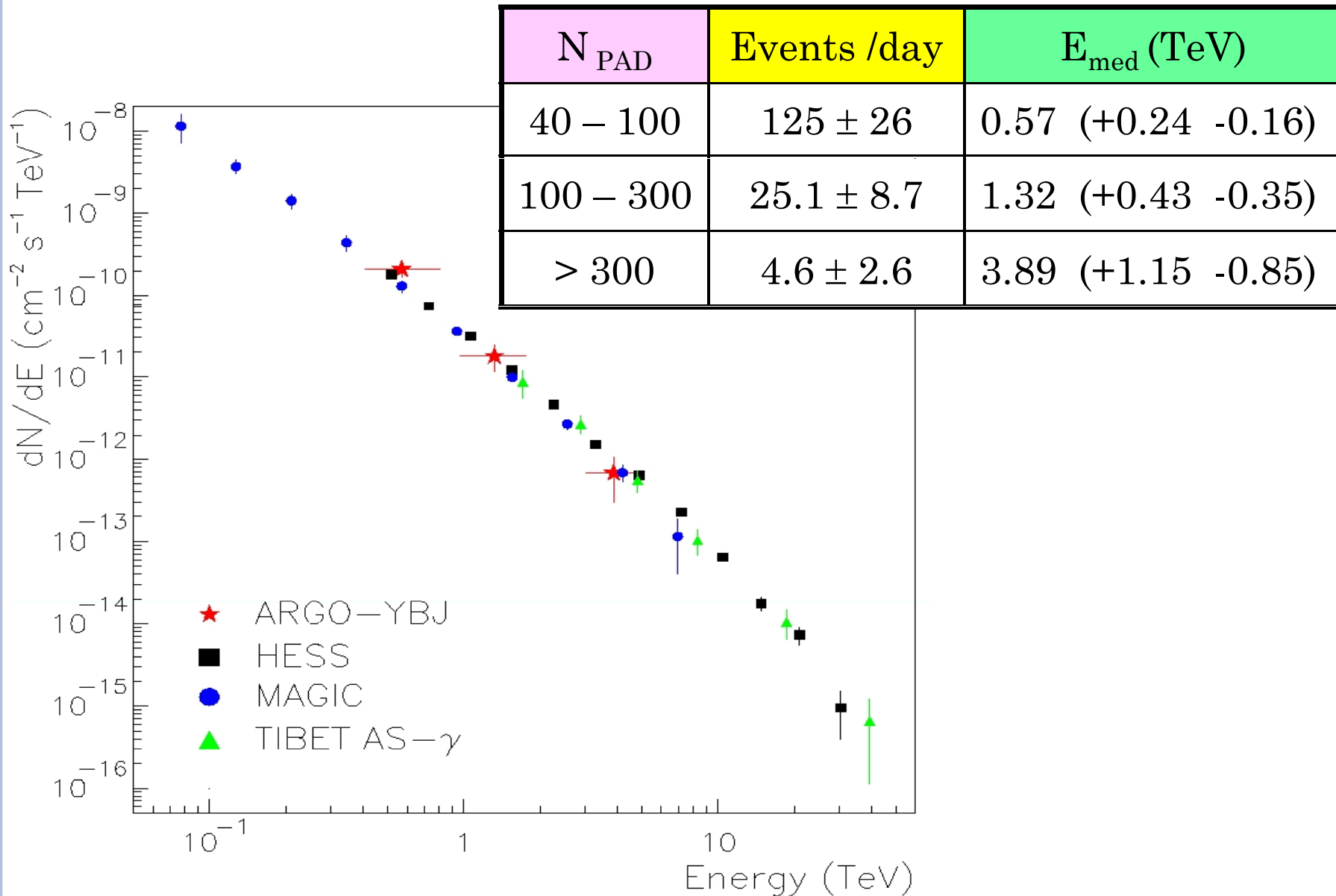
$N_{\text{PAD}} > 40; E_{\text{med}} \approx 0.7 \text{ TeV}$



$N_{\text{PAD}} > 200; E_{\text{med}} \approx 3 \text{ TeV}$

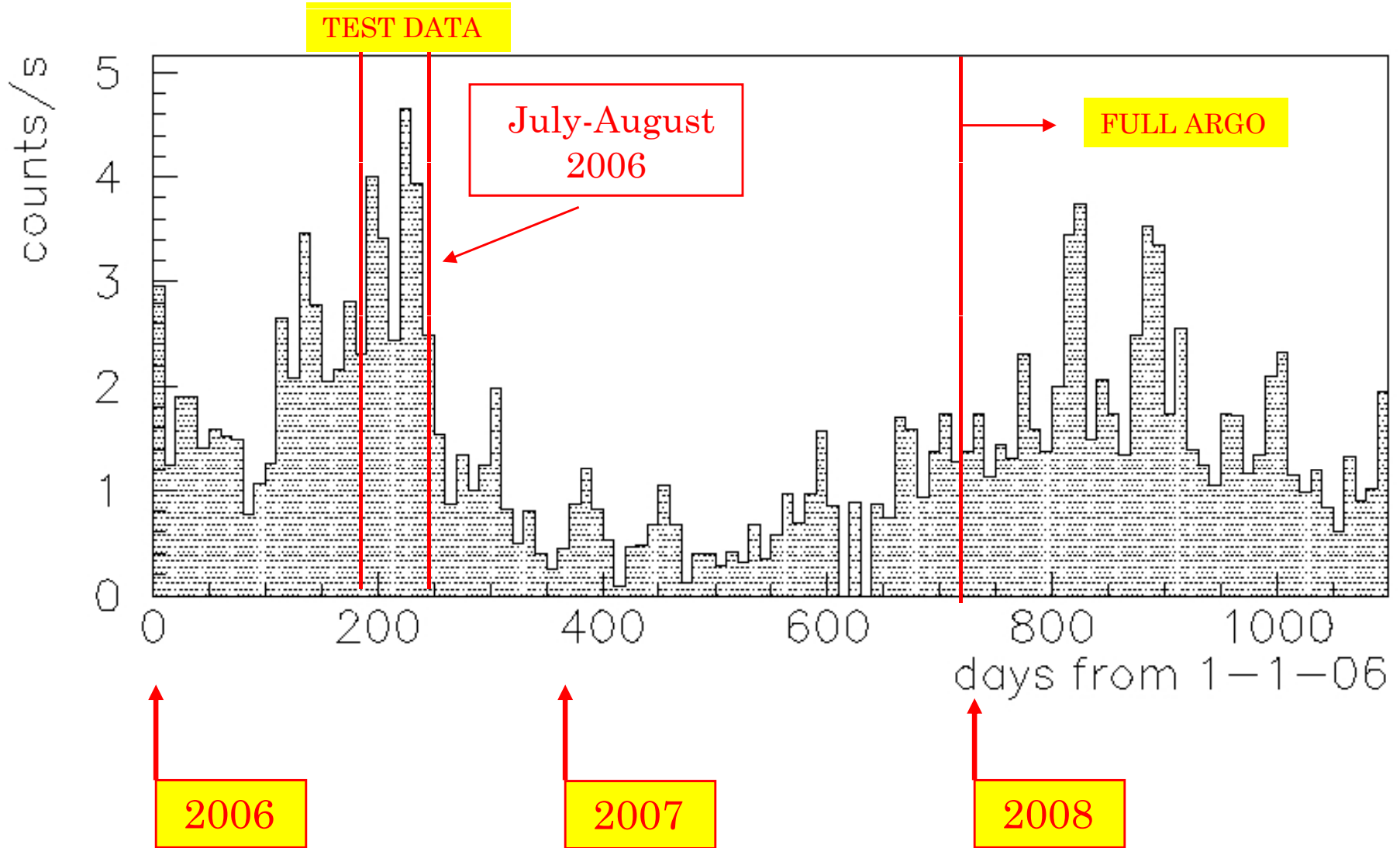
CRAB NEBULA ENERGY SPECTRUM

$$dN/dE = 3.97 \pm 0.68 \cdot 10^{-11} E^{-2.98 \pm 0.32} \text{ ev cm}^{-2} \text{ s}^{-1} \text{ TeV}^{-1}$$

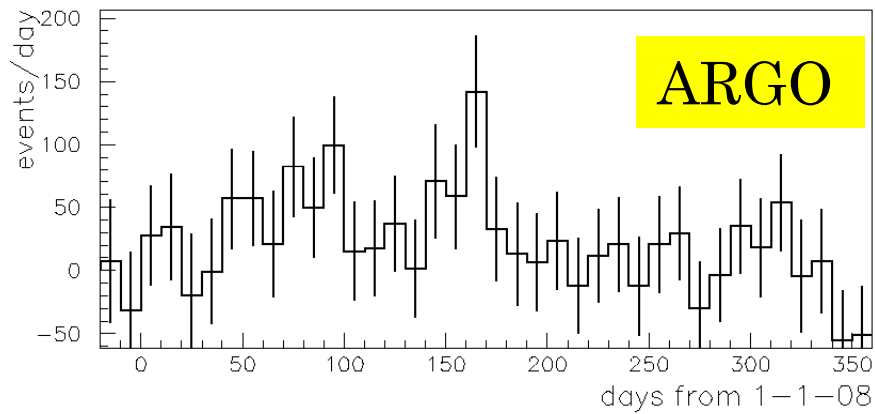


MARKARIAN 421 – X RAYS

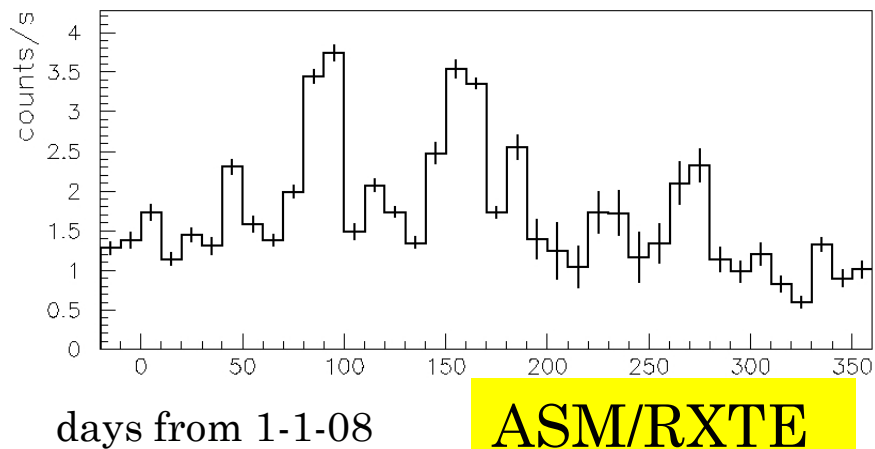
ASM/RXTE



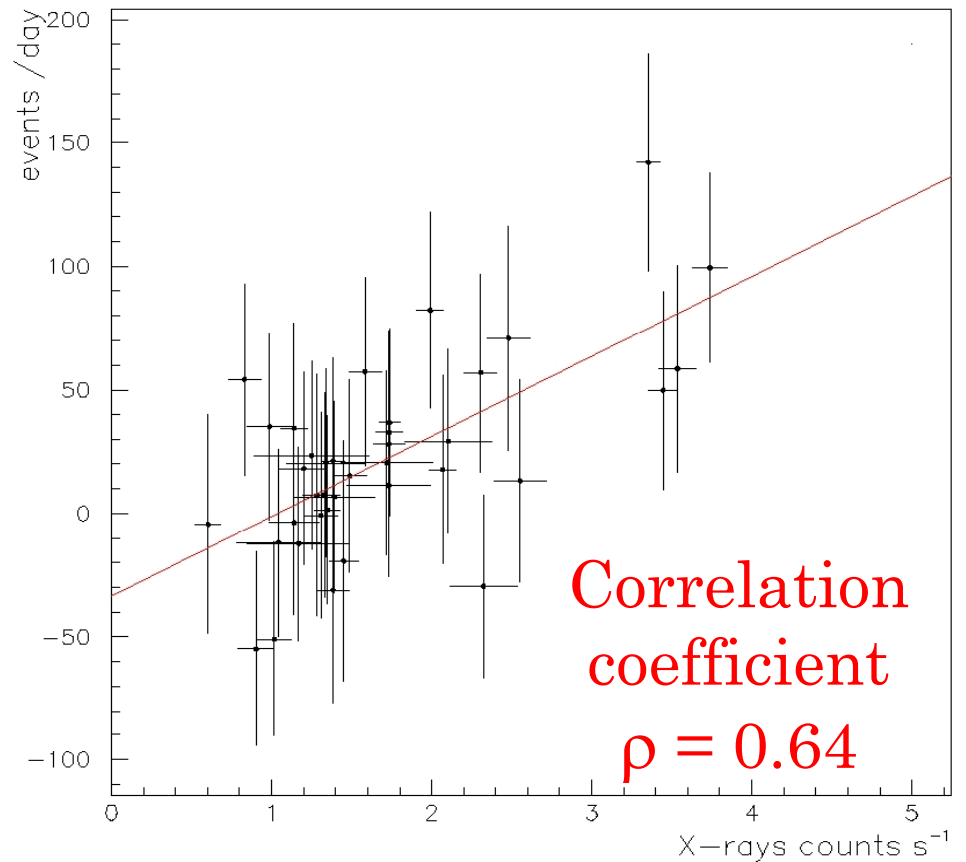
MRK 421 - 2008



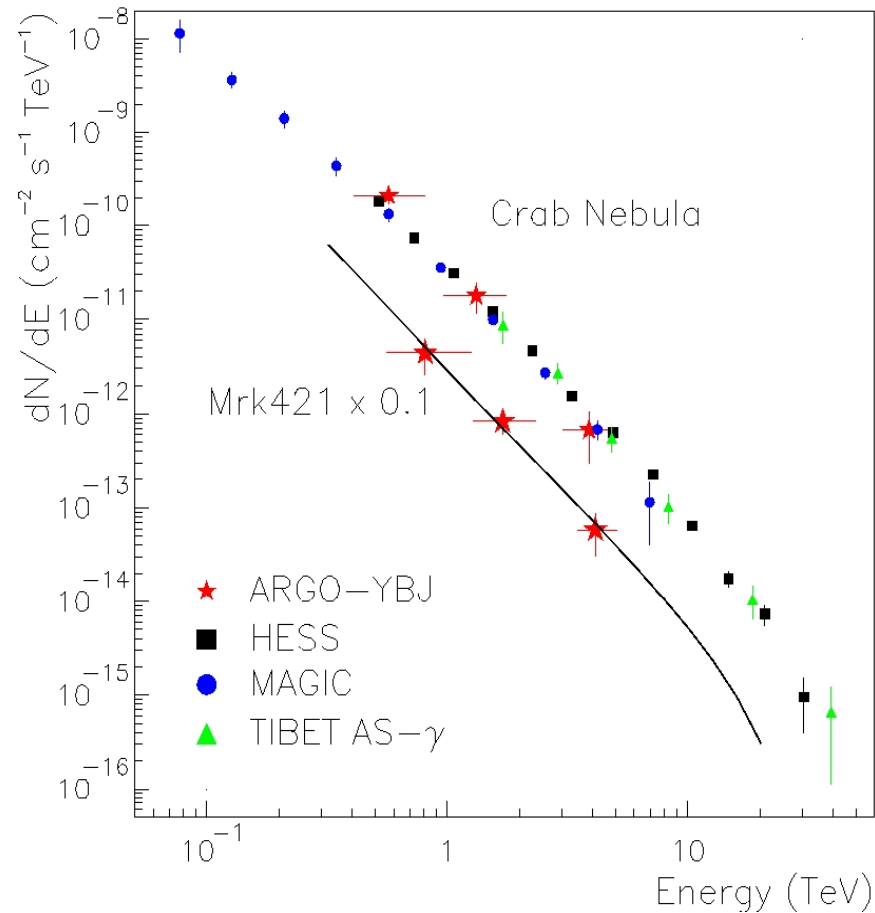
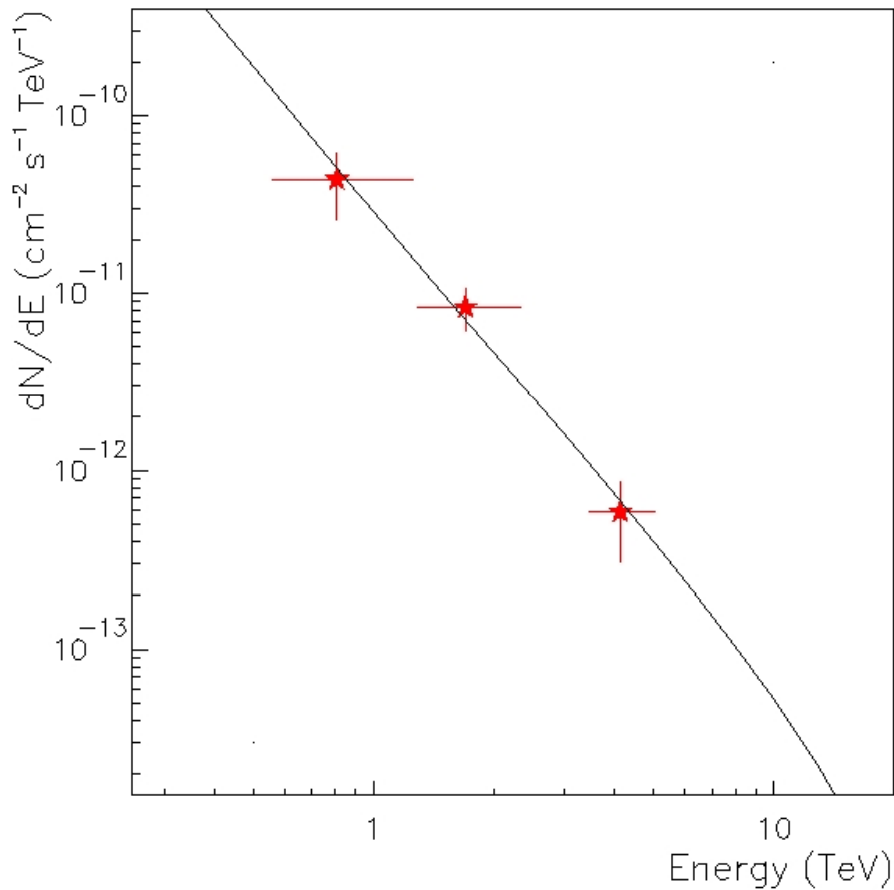
$$N_{\text{PAD}} > 100$$



10 days
average



MRK421 SPECTRUM (2008 FEB 11 – SEPT 5)



From: Primack et al.
AIP conf Proc 745, 23,2005

5.8 σ significance
@ $N_{\text{pad}} > 100$

Power law spectrum + EBL absorption :

$$dN/dE = 3.74 \pm 1.14 \cdot 10^{-11} \cdot E^{-2.54 \pm 0.34} \cdot e^{-t(E)} \text{ ev cm}^{-2} \text{ s}^{-1} \text{ TeV}^{-1}$$

THE JUNE 2008 FLARE OF MRK421 FROM OPTICAL TO TEV ENERGIES

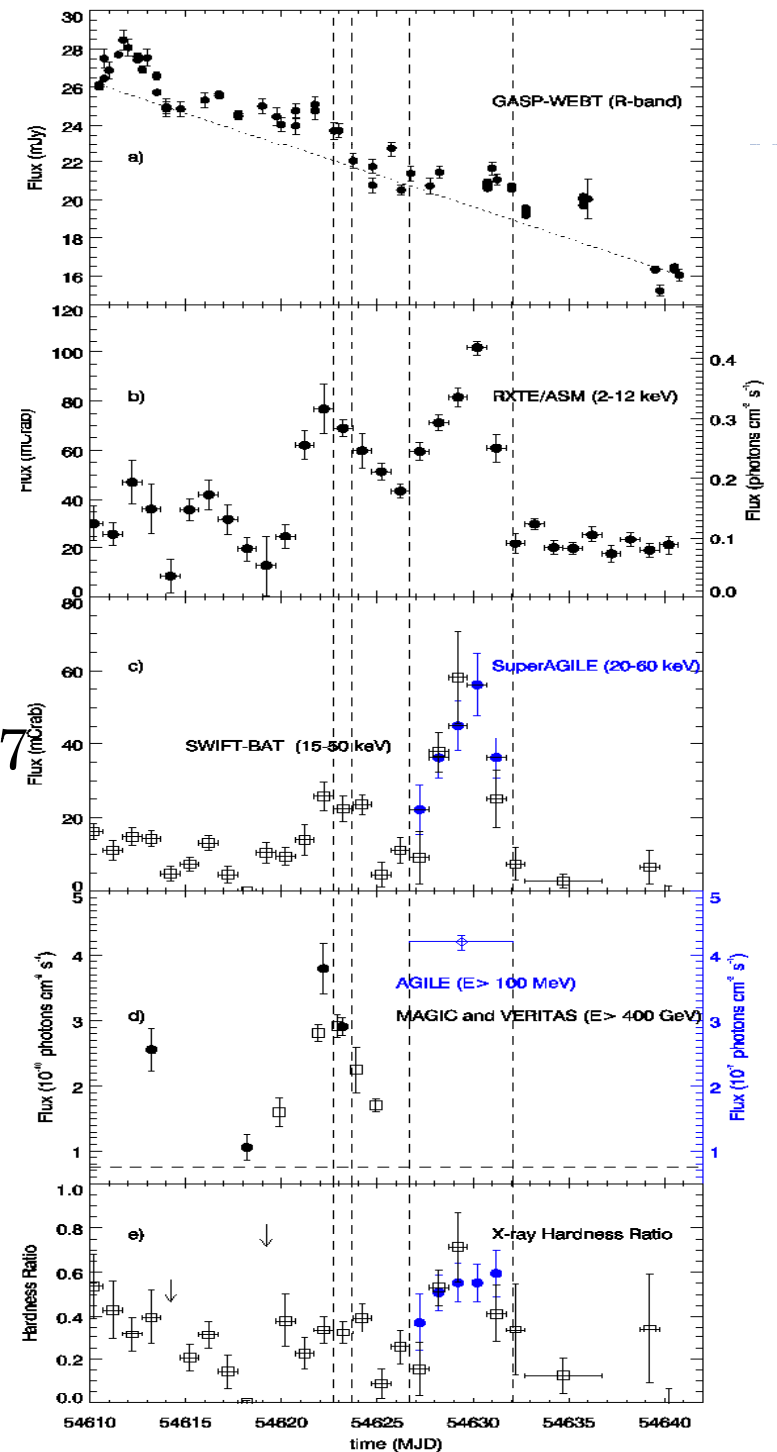
DONNARUMMA ET AL.
APJ 691 L13 (2009)

data from:

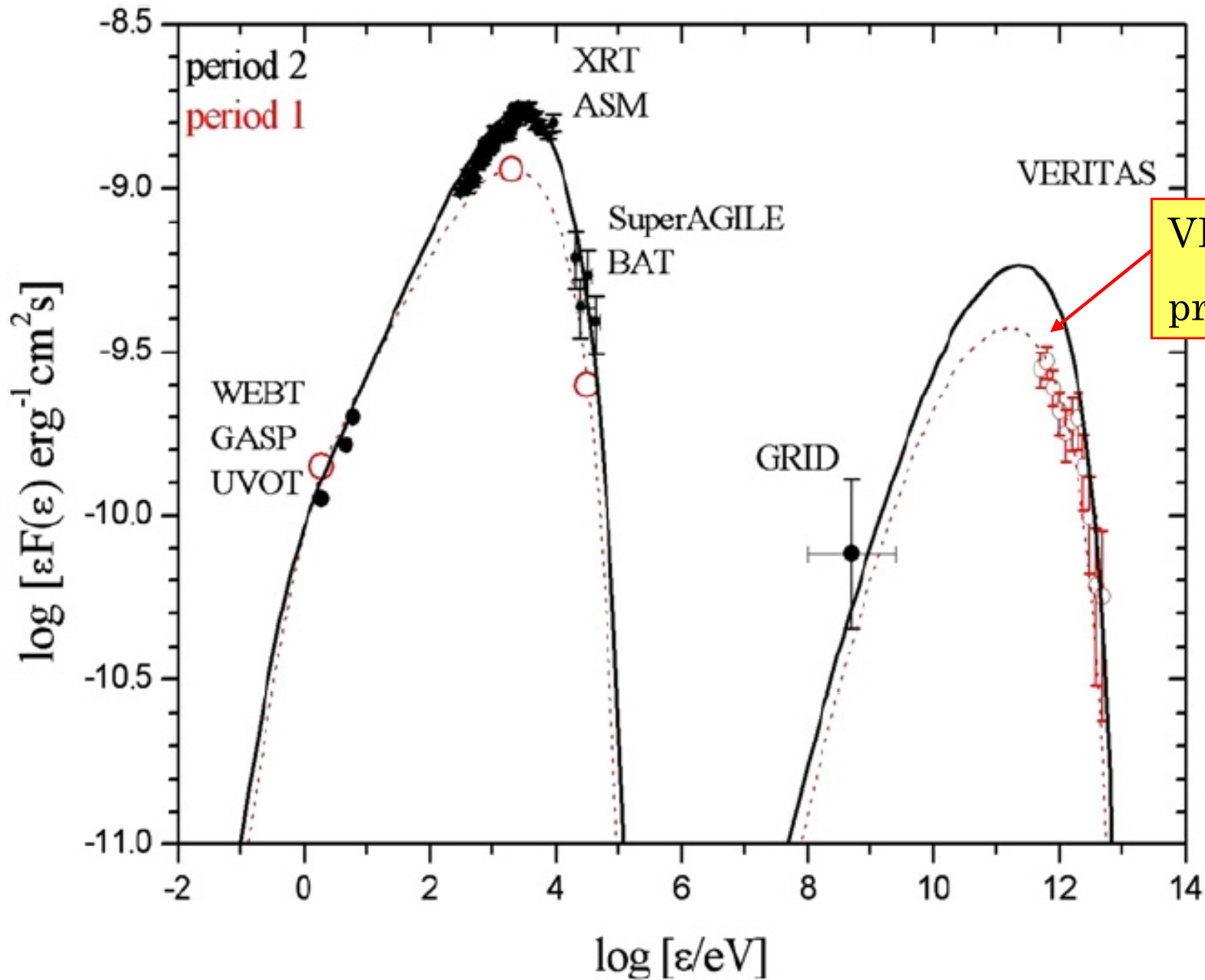
- GASP-WEBT (R-band; May 24 to June 23)
- SWIFT (UVOT & XRT; June 12-13)
- AGILE ($E > 100$ MeV; June 9-15)
- MAGIC and VERITAS ($E > 400$ GeV; May 27 - June 8)

complemented by publicly-available data from
RossiXTE/ASM (2-12 keV)
and Swift/BAT (15-50 keV).

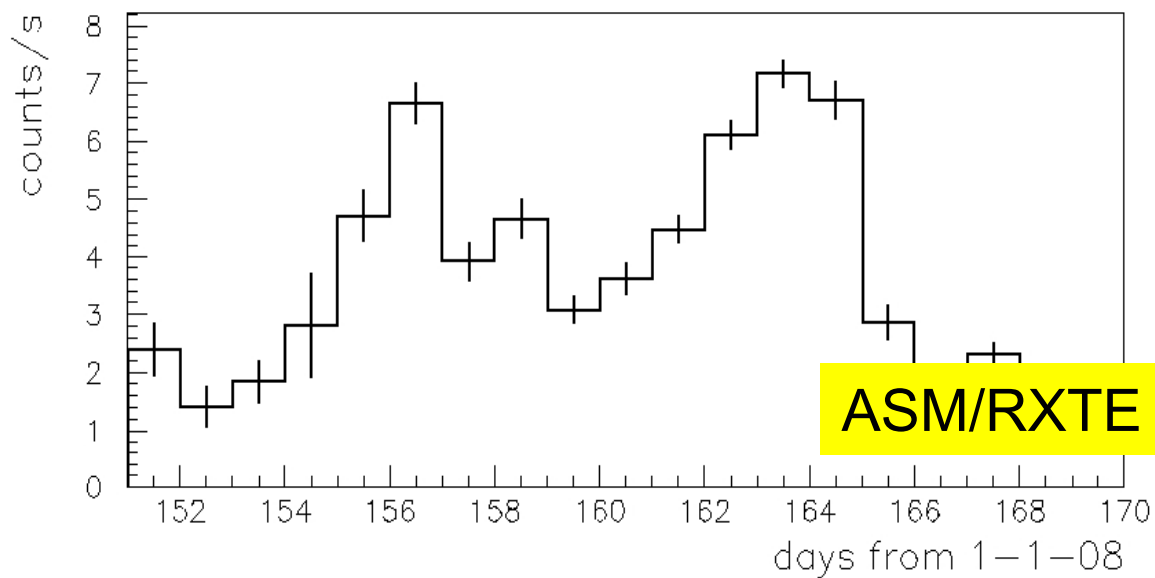
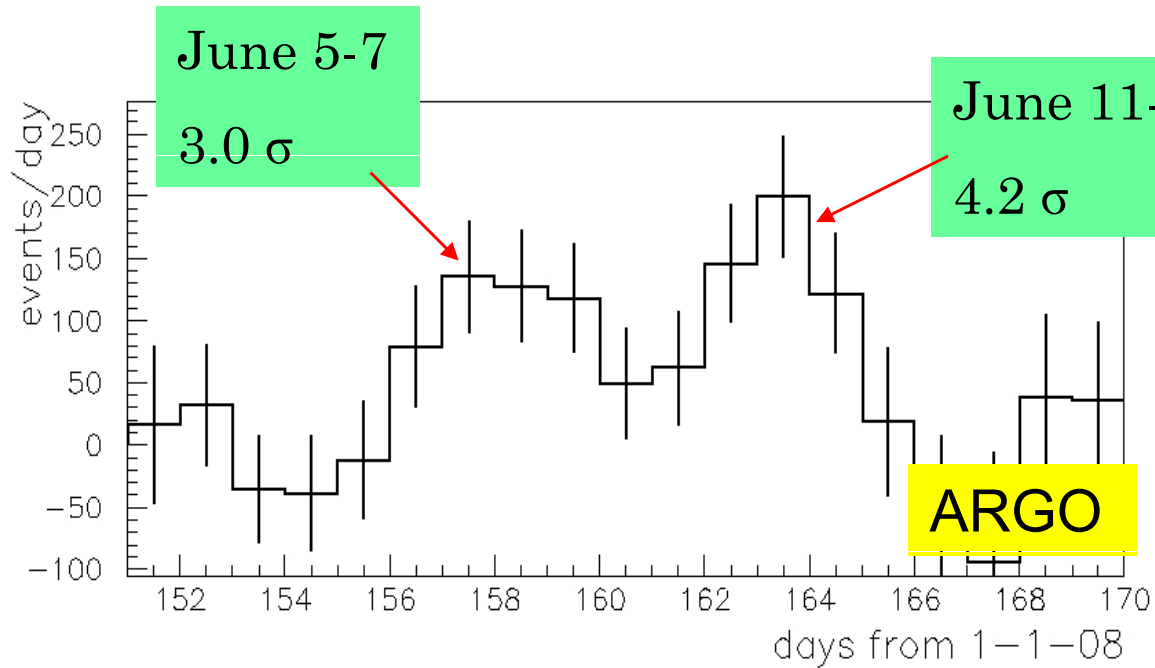
No VHE data after June 8



SEDs FOR JUNE 2008 FLARES



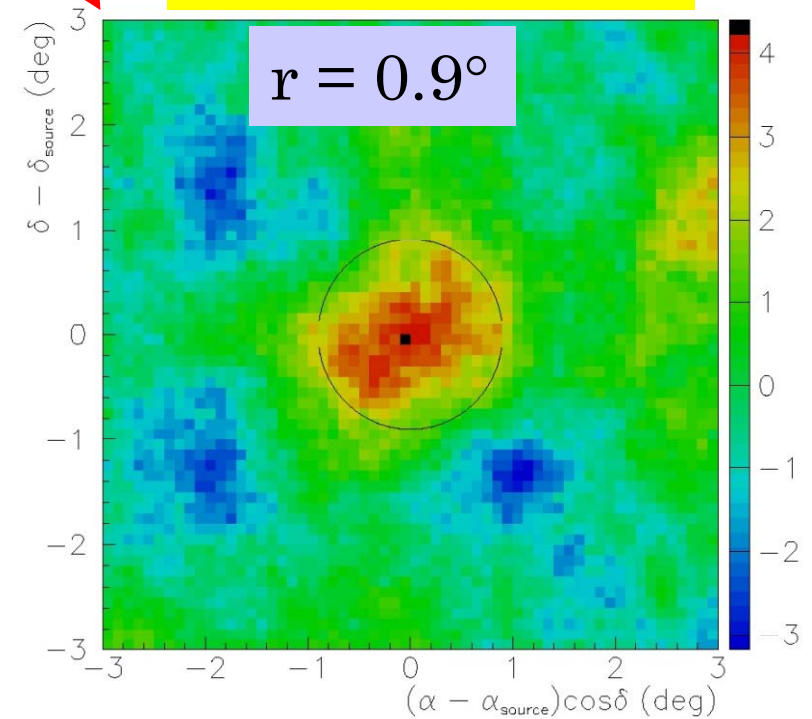
MARKARIAN 421 – JUNE 2008



$N_{\text{PAD}} > 100$

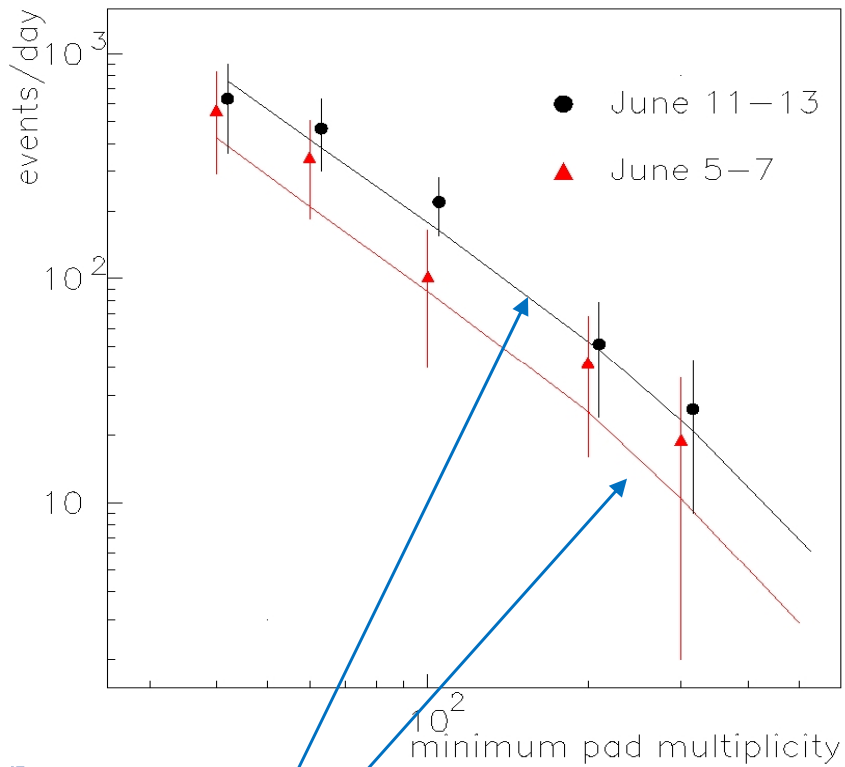
3 days average

≈ 7 Crab units

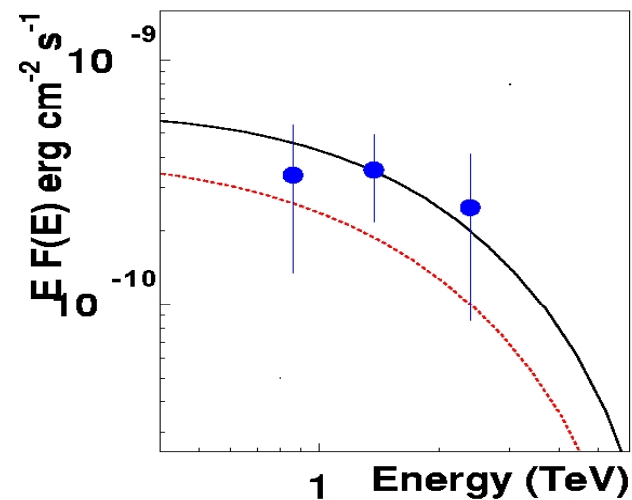
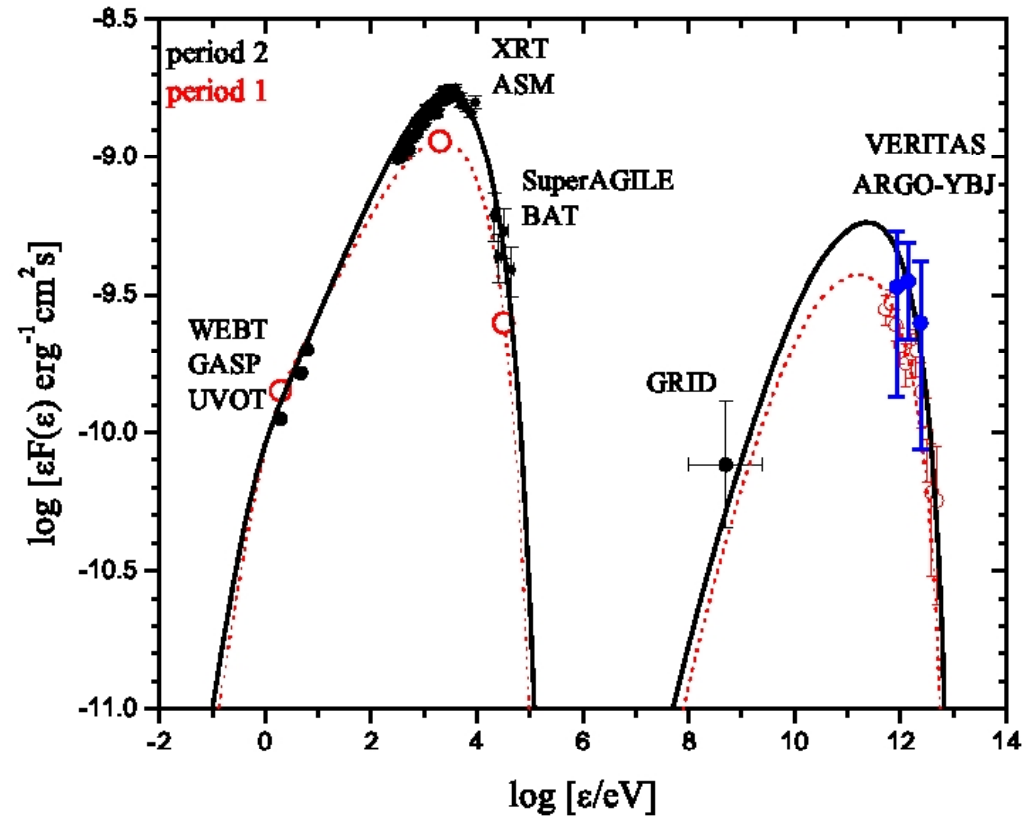


1 day
average

MARKARIAN 421- JUNE 2008



Expected from
theoretical SED



CONCLUSIONS

Detector setup:

- The ARGO-YBJ detector has been completely installed ;
- Stable data taking since Nov. 2007 (d.c. > 90%) with the full detector

Results:

- Crab Nebula
 - detected with $> 7\sigma$ significance @ $E_{\text{med}} \approx 0.7$ TeV in 328 days
 - energy spectrum
- Mrk 421 flaring state observation during June 2008
 - completion of the multifrequency observation
 - first detection of a gamma-ray flaring activity below the TeV energy on a few days period