

Gamma ray sources observation with the ARGO-YBJ detector

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for the ARGO-YBJ collaboration

22nd ECRS – Turku, August 6th 2010

Yangbajing Cosmic Ray Laboratory - TIBET

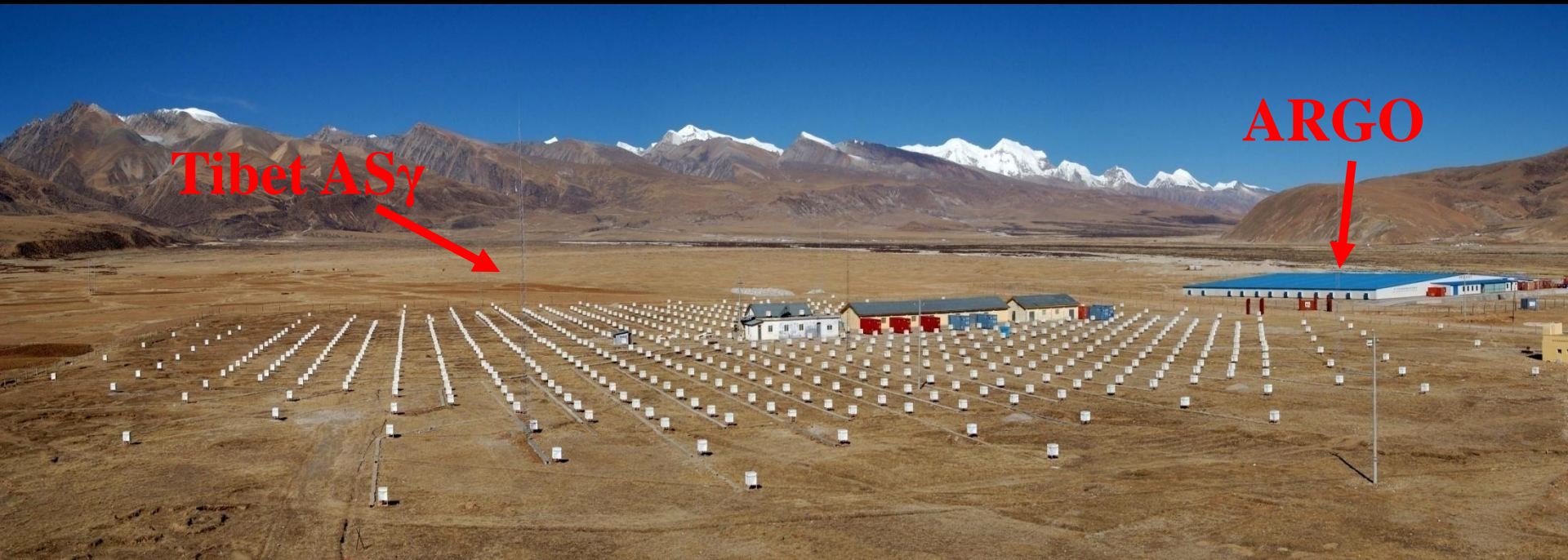
ARGO-YBJ



4300 m a.s.l.

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

The Yangbajing Cosmic Ray Laboratory





Resistive Plate Chambers carpet

The ARGO-YBJ detector

Nov 2007 : Start Data acquisition with the full detector

Single layer of
RPCs detectors

- **Central carpet**

78 x 75 m²

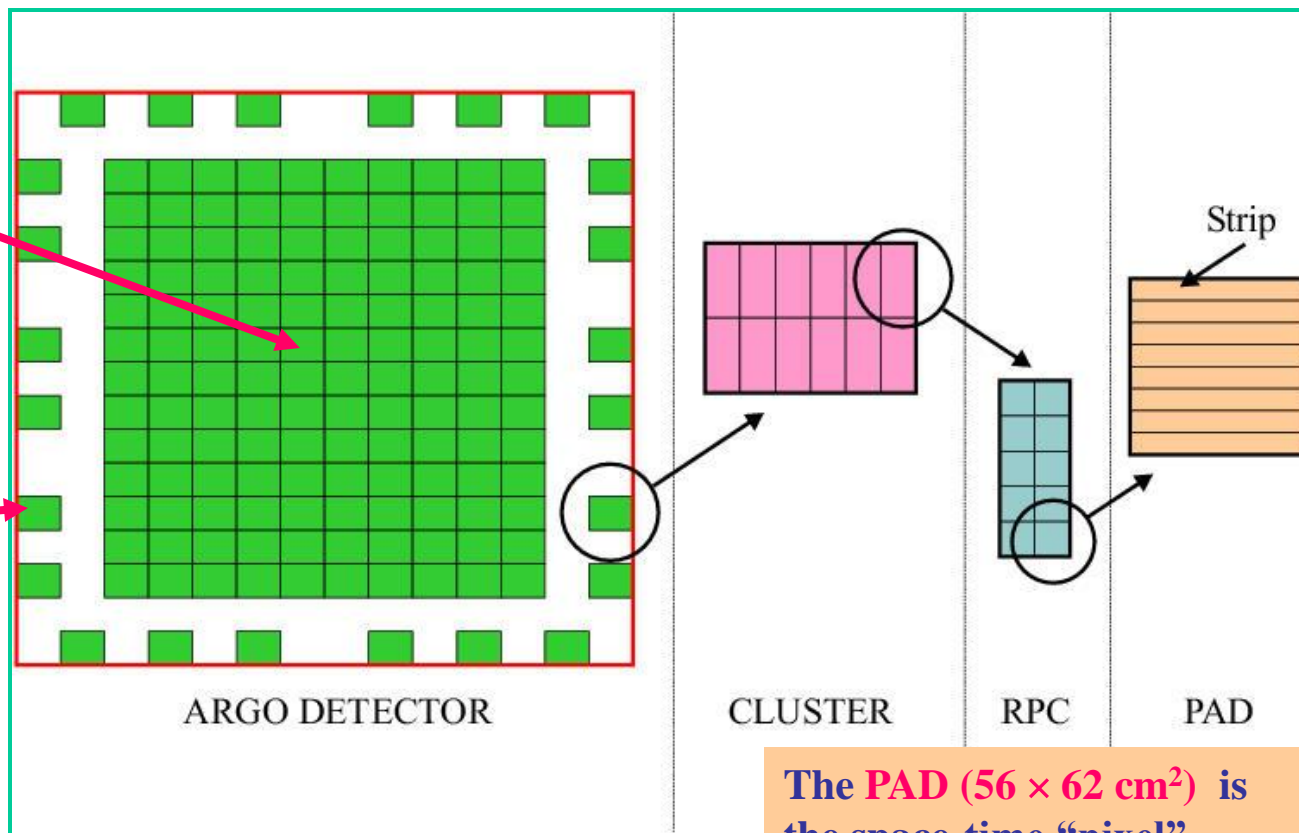
(95 % of active surface)

- **Sampling ring**

surrounds the carpet up to

111 x 99 m²

(20 % of active surface)



The **PAD** (**56 × 62 cm²**) is
the space-time “pixel”

Time resolution $\approx 1\text{-}2\text{ ns}$

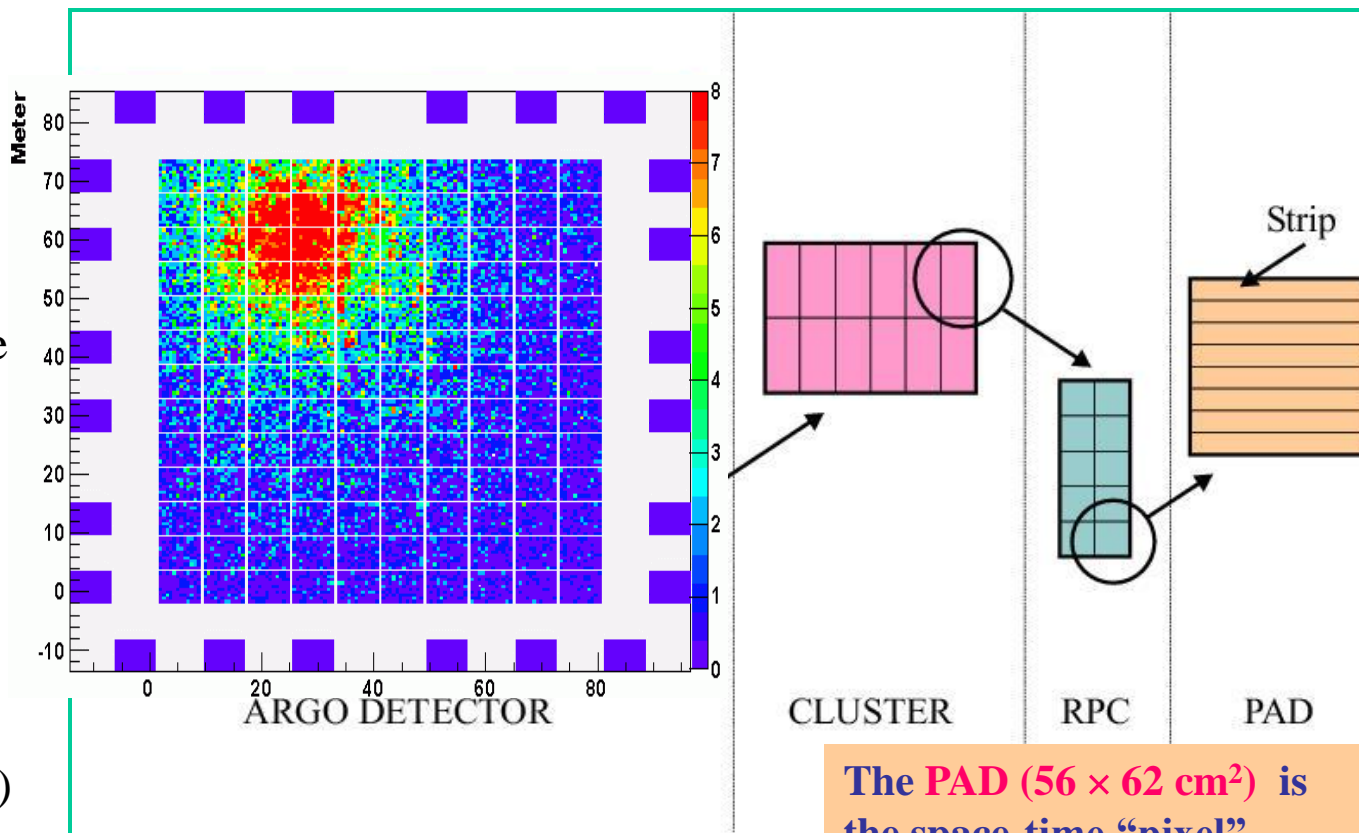
ARGO has **18480** PADs

The ARGO-YBJ detector

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- **Central carpet**
 $78 \times 75 \text{ m}^2$
(95 % of active surface)
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 $111 \times 99 \text{ m}^2$
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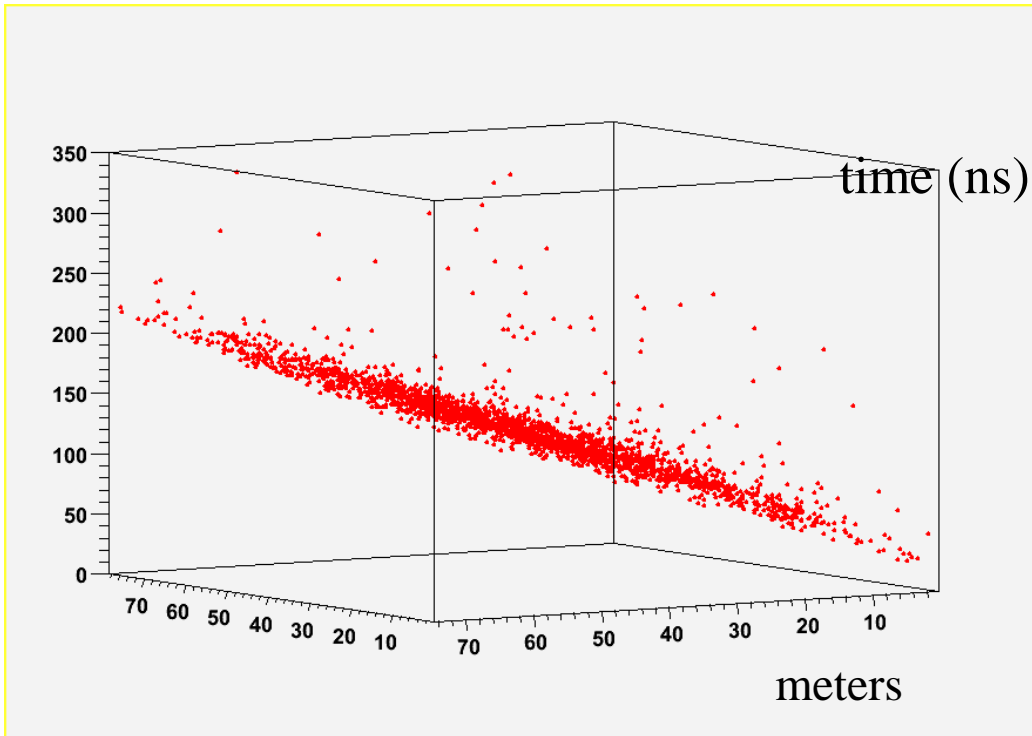


The **PAD** ($56 \times 62 \text{ cm}^2$) is
the space-time “pixel”

Time resolution $\approx 1\text{-}2 \text{ ns}$

ARGO has **18480** PADs

Shower reconstruction



Current trigger:

Number of PADs ≥ 20

rate ≈ 3.8 KHz

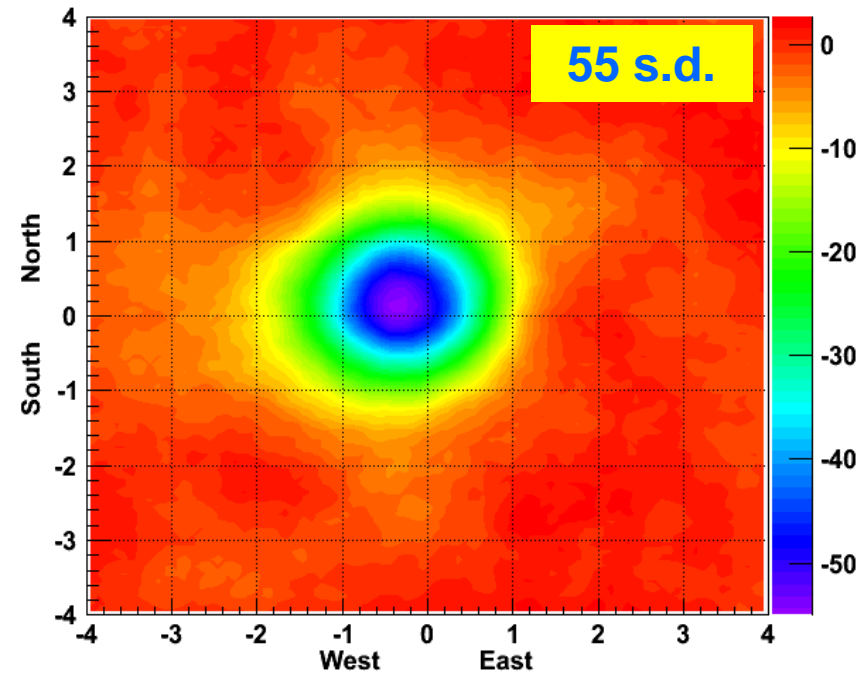
Arrival direction measurement:

- Core reconstruction: Maximum Likelihood Method applied to the lateral density profile of the shower
- Fit of the shower front with a conical shape

The Moon shadow

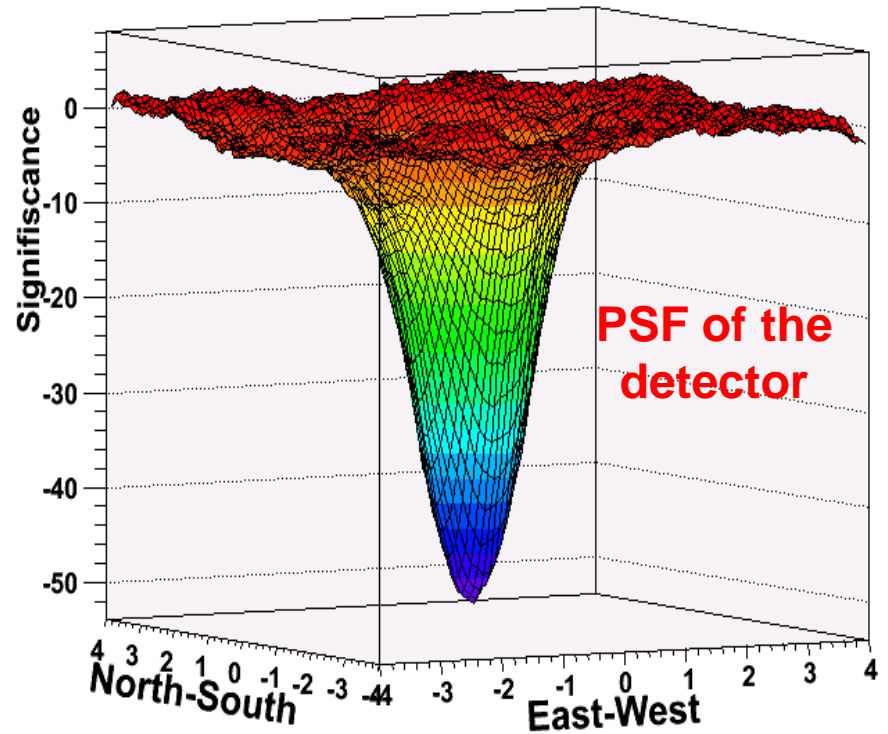
Data 2006 - 2009

3200 hours on-source

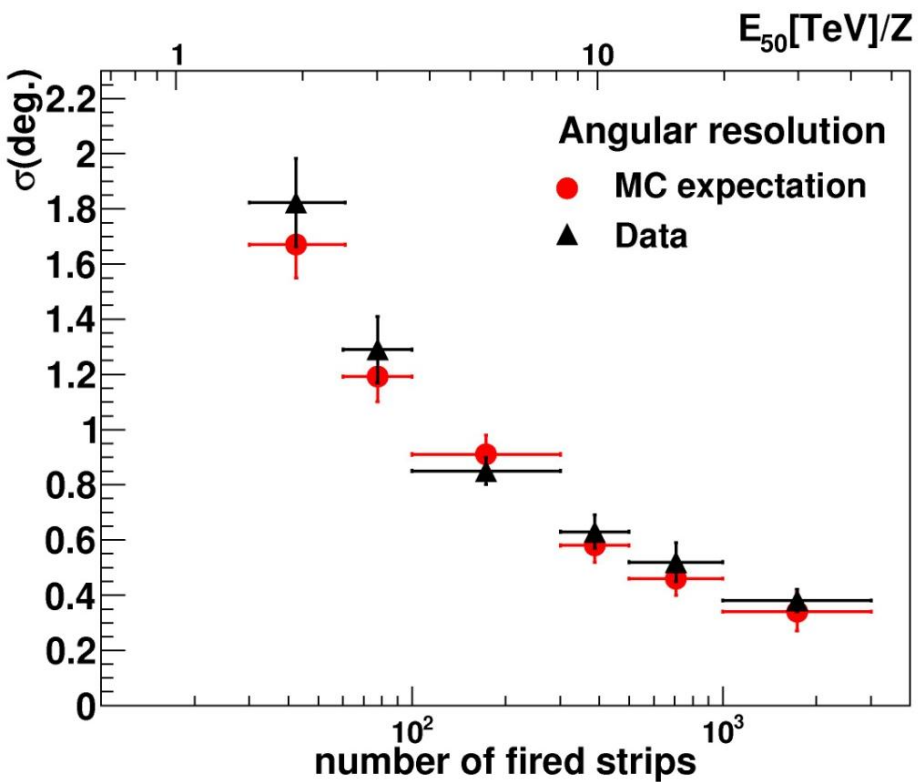


$n_{\text{hit}} > 100$

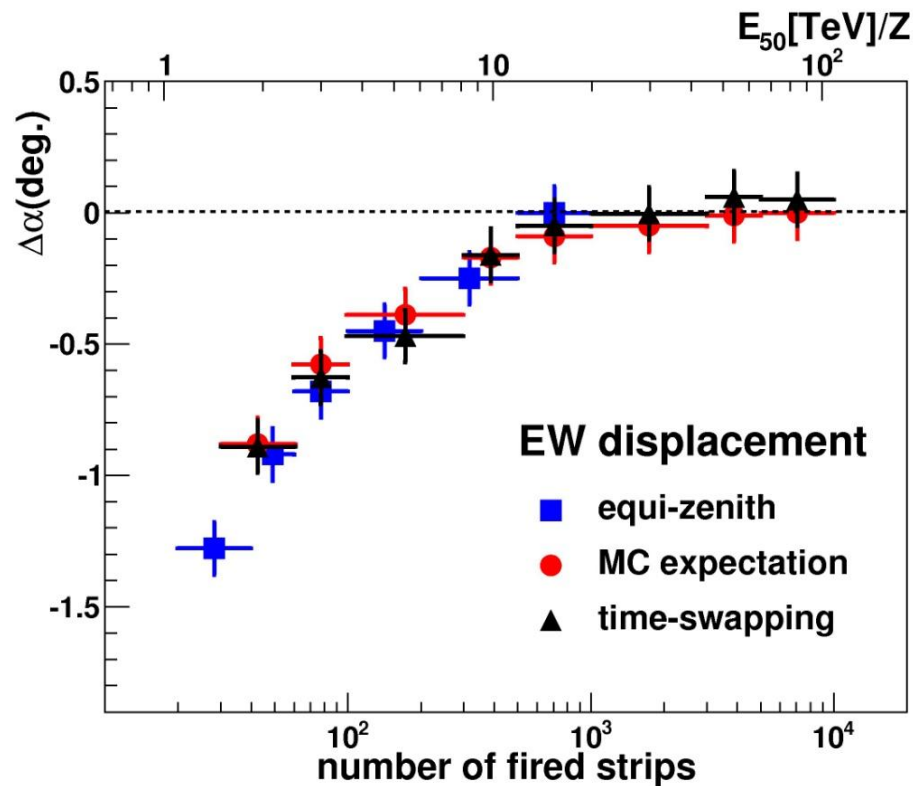
≈ 10 standard deviations /month



Angular Resolution



West displacement of the Moon shadow caused by the Geomagnetic field



Physics Goals

- **Gamma-ray Astronomy:**

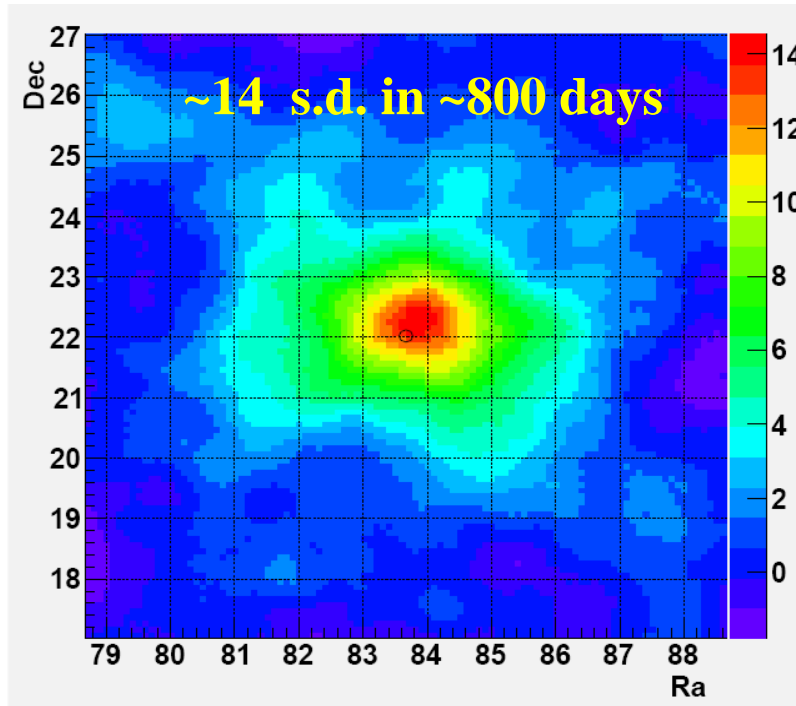
- large field of view (~ 2 sr)
- duty cycle $\sim 100\%$
- energy threshold: few hundreds of GeV .

- **Gamma Ray Burst (GRB) physics** **C.Vigorito (poster 6.22)**
in the full GeV – TeV energy range

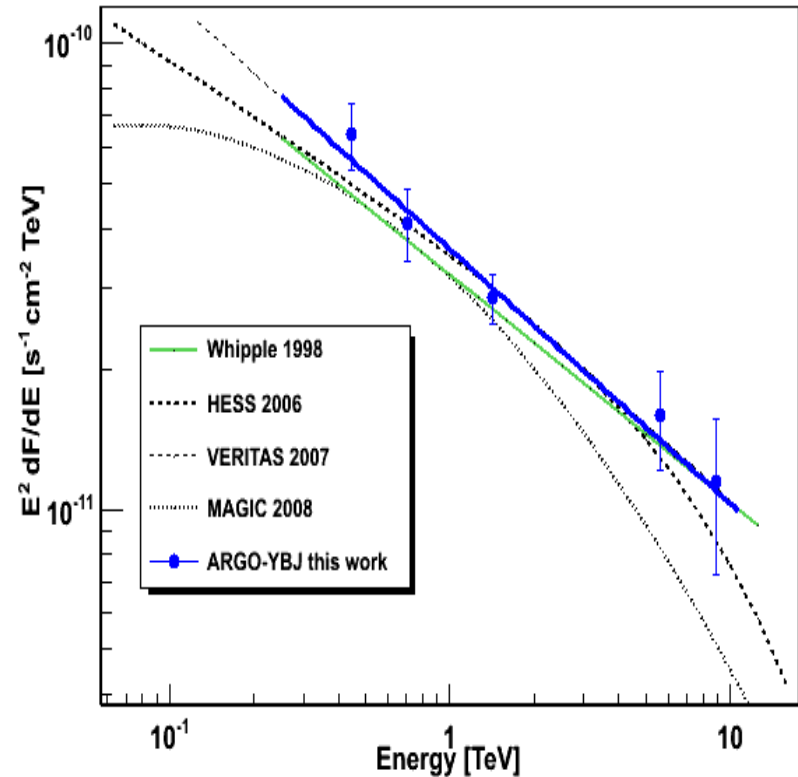
- **Cosmic Ray physics:** **A.Surdo (talk on Aug 4th)**

- Proton-air cross section measurement
- anti-p /p ratio at energy \approx TeV with the Moon Shadow
- spectrum and composition up to $\approx 10^3$ TeV
- anisotropy

Crab Nebula



NO γ/h discrimination
Sens. ~ 0.5 Crab/year

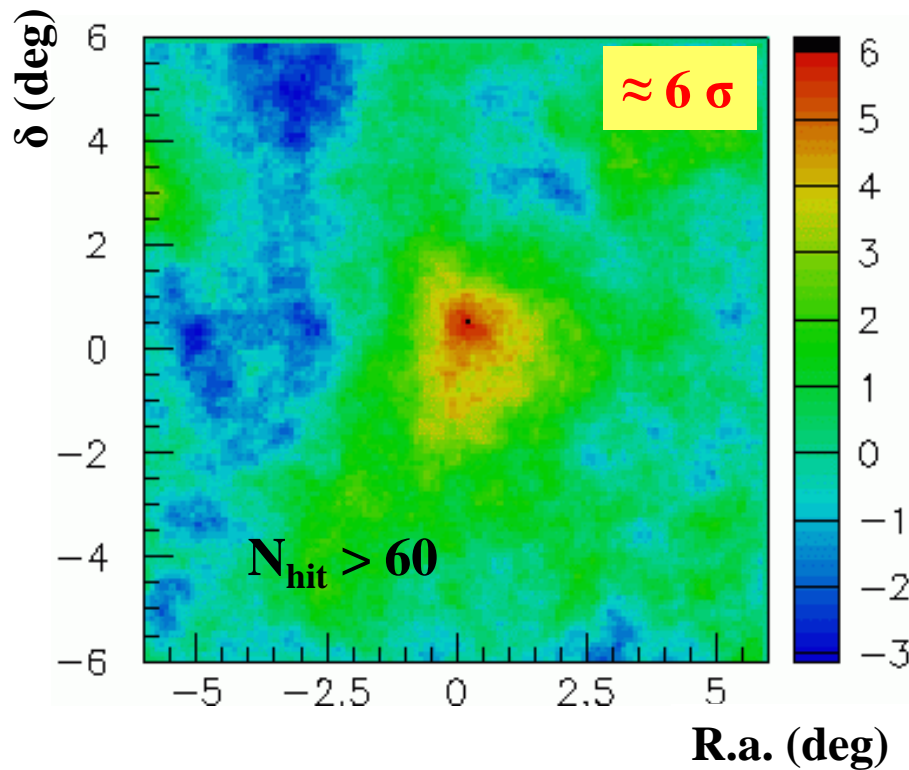


$$\frac{dN}{dE} = (3.62 \pm 0.29_{stat}) (E / 1 TeV)^{(-2.55 \pm 0.10_{stat})} \times 10^{-11} cm^{-2} s^{-1} TeV^{-1}$$

Mrk 421

the first source observed by ARGO

July 2006 flare



ARGO Test Data

2006 days 187-245 (110 hours)

Flux \approx 3-4 Crab

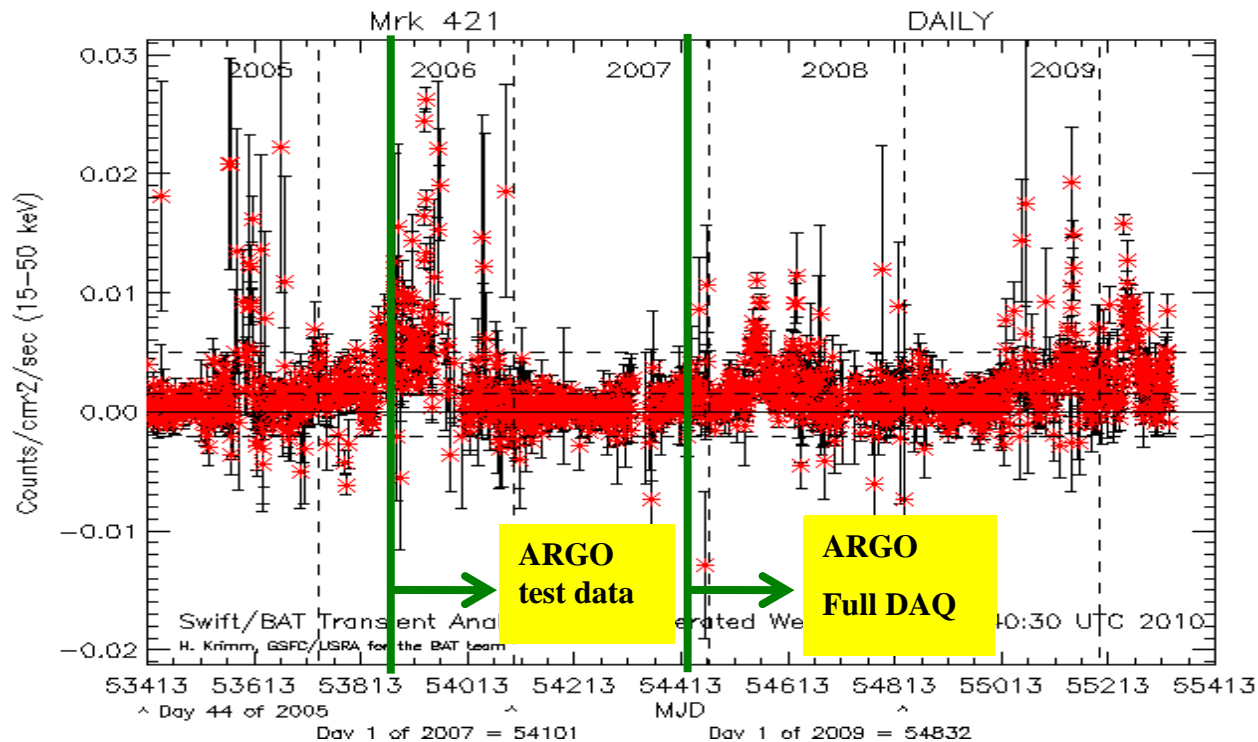
NO Cerenkov measurements at that time

Mrk421 flaring activity

July 2006

June 2008

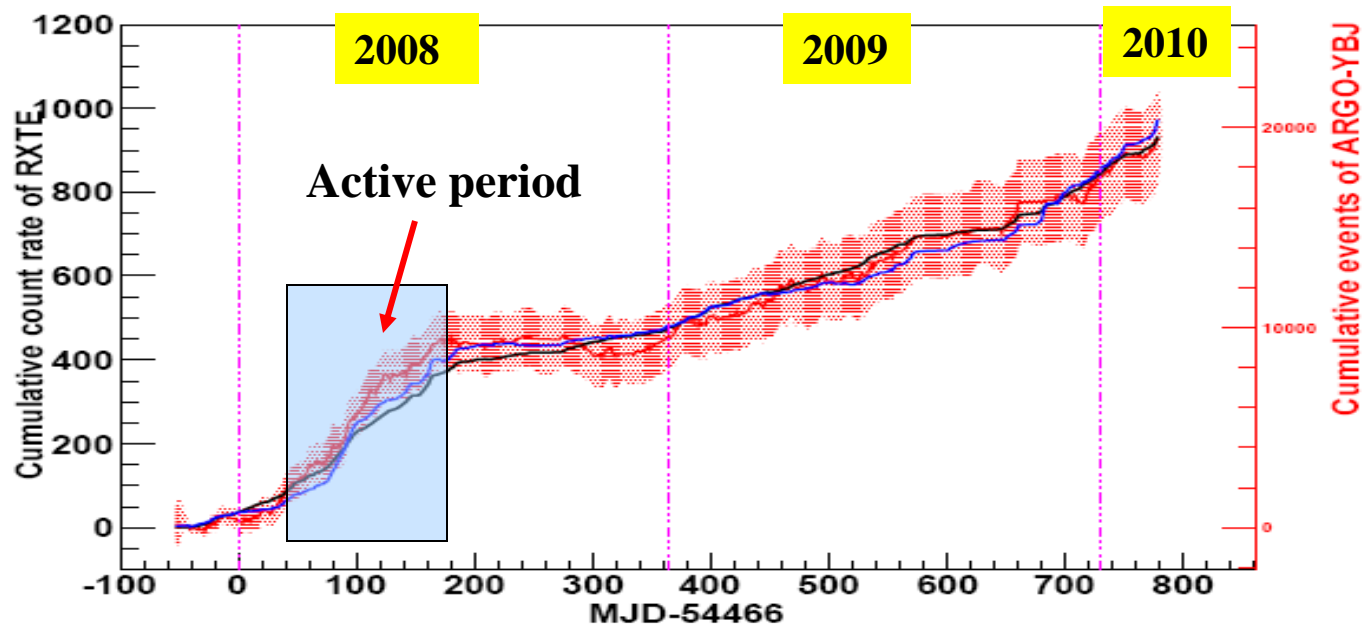
Feb 2010



SWIFT
X-rays
(15-50 keV)

Mrk421 - Correlation with X-rays

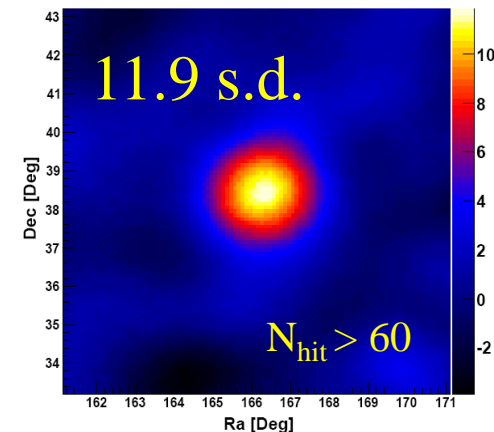
Integrated counting rate



- TeV γ rays ARGO
- X- rays 2-12 KeV RXTE/AMS
- X- rays 15-30 KeV SWIFT/BAT

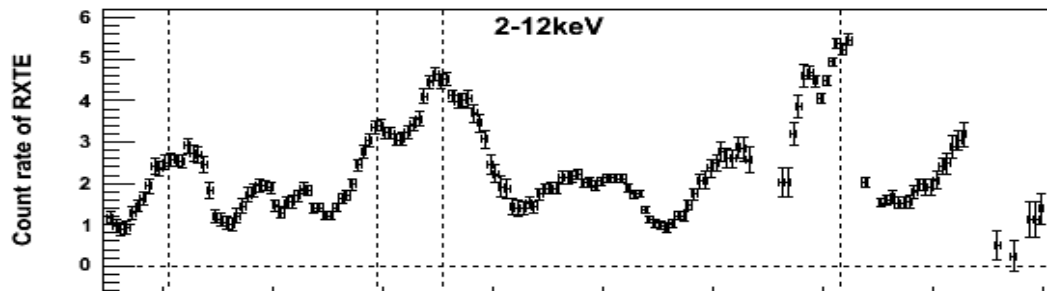
Data sample:

- Nov 2007 – Feb 2010
- effective time: 676 days

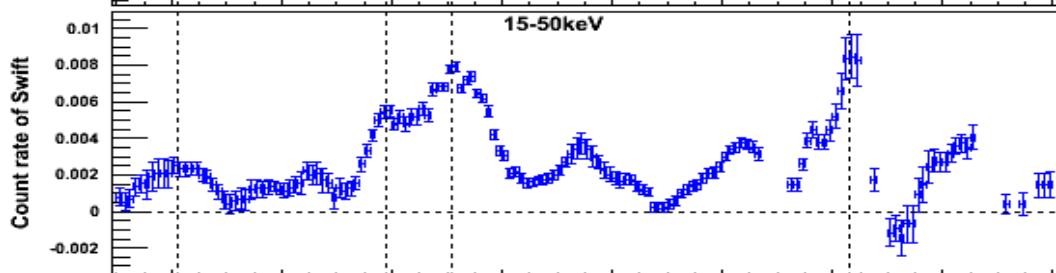


Ligth curve during the 2008 active period

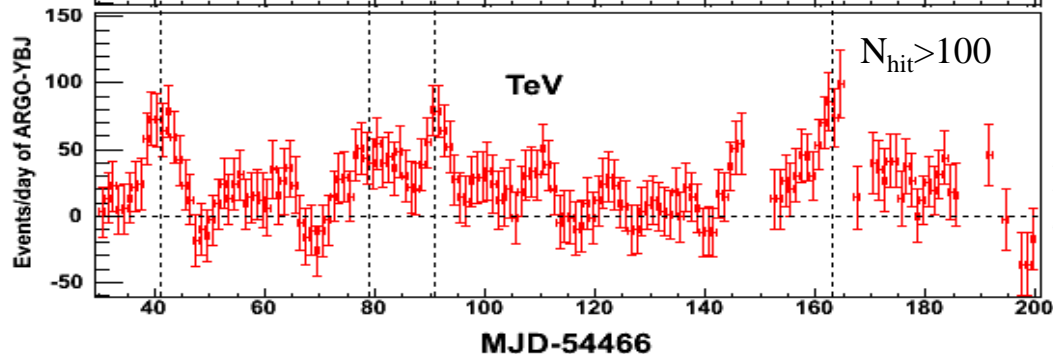
RXTE



SWIFT

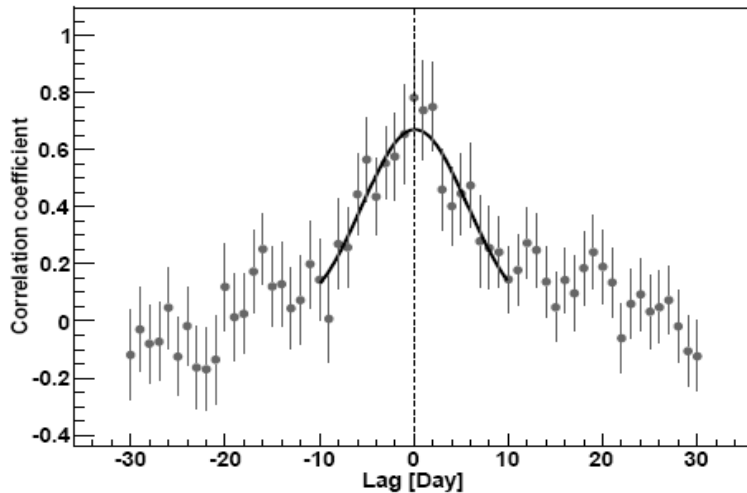


ARGO



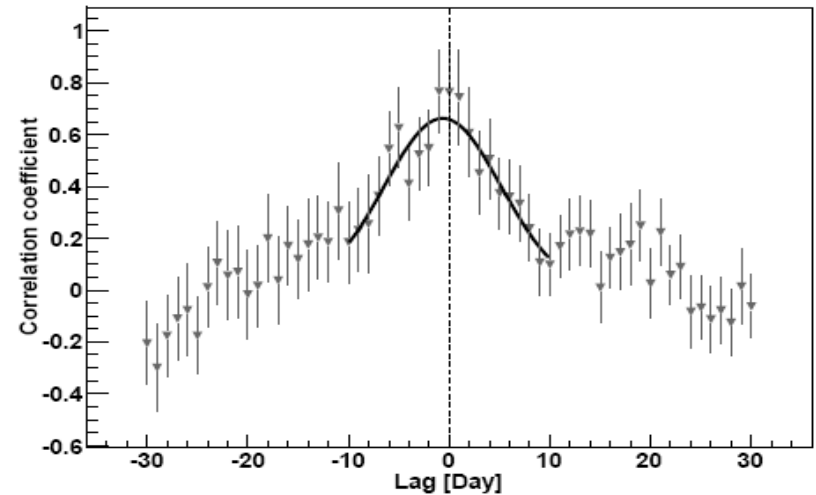
Correlation between X-rays and gamma rays

Correlation coefficient vs. time lag



RXTE & ARGO

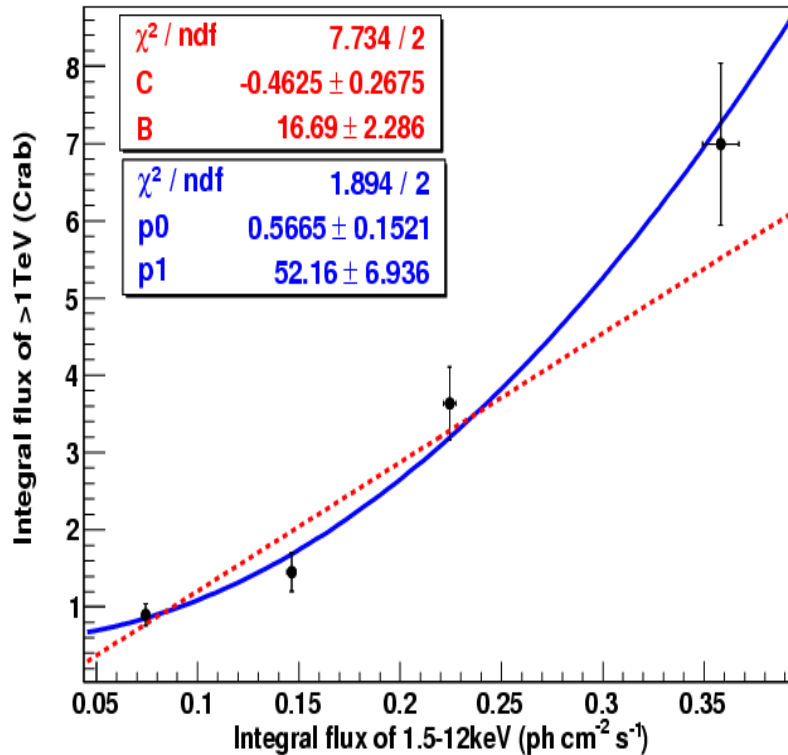
Time lag = 0.11 ± 0.55 days



Swift & ARGO

Time lag = -0.65 ± 0.61 days

TeV flux vs. X-ray flux



The relation between
TeV and X-ray fluxes
seems to be quadratic
as expected from the
SSC model

Mrk421

June 2008 flare

from optical to TeV energies

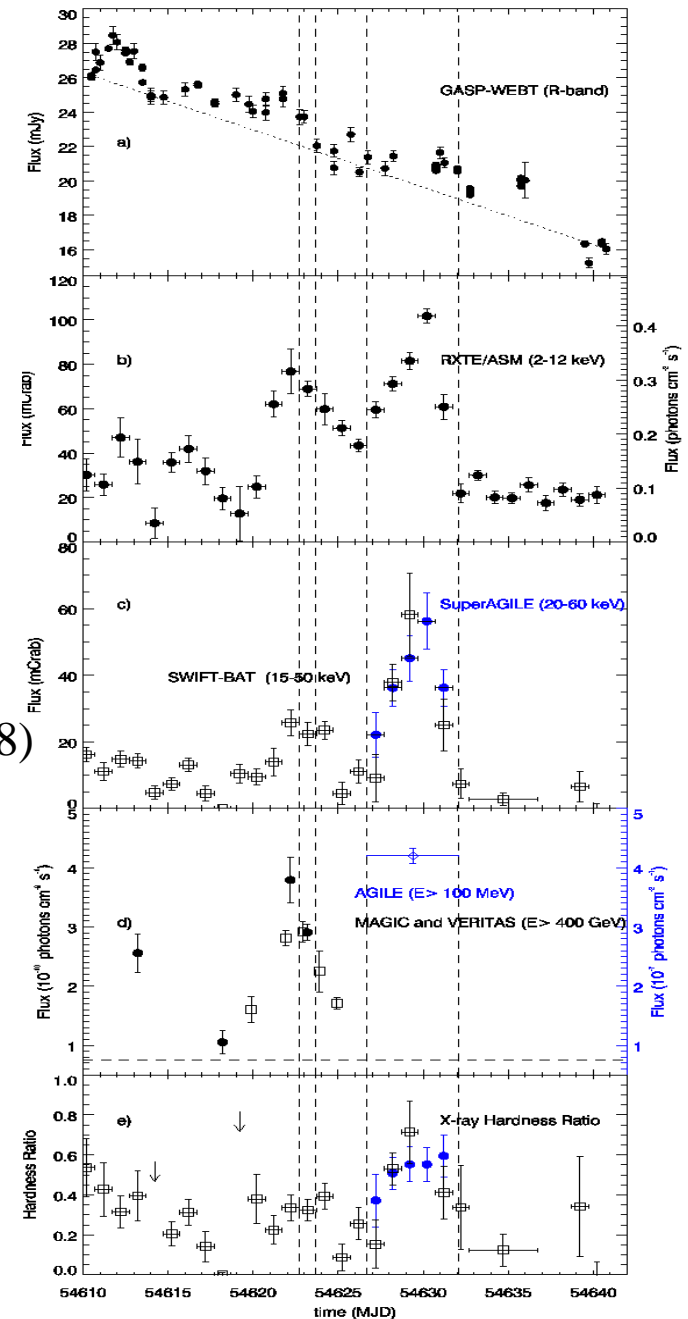
data from:

- GASP-WEBT (R-band)
- Rossi RXTE/ASM (2-12 keV)
- Swift/BAT (15-50 keV)
- SWIFT (UVOT & XRT; June 12-13)
- AGILE ($E > 100$ MeV; June 9-15)
- MAGIC and VERITAS ($E > 400$ GeV; May 27 - June 8)

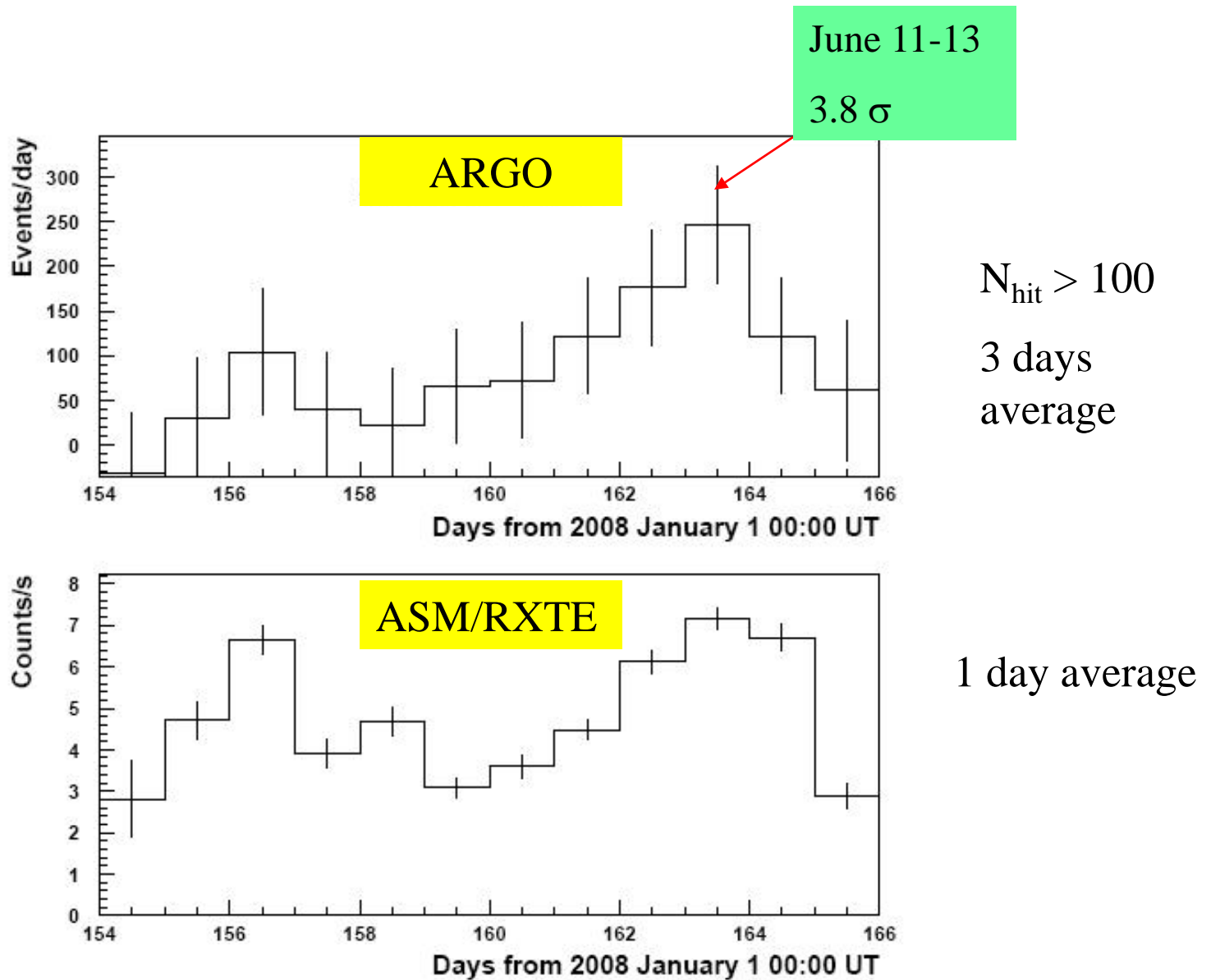
2 flaring episodes: June 3-8 and June 9-15

No Cherenkov data after June 8

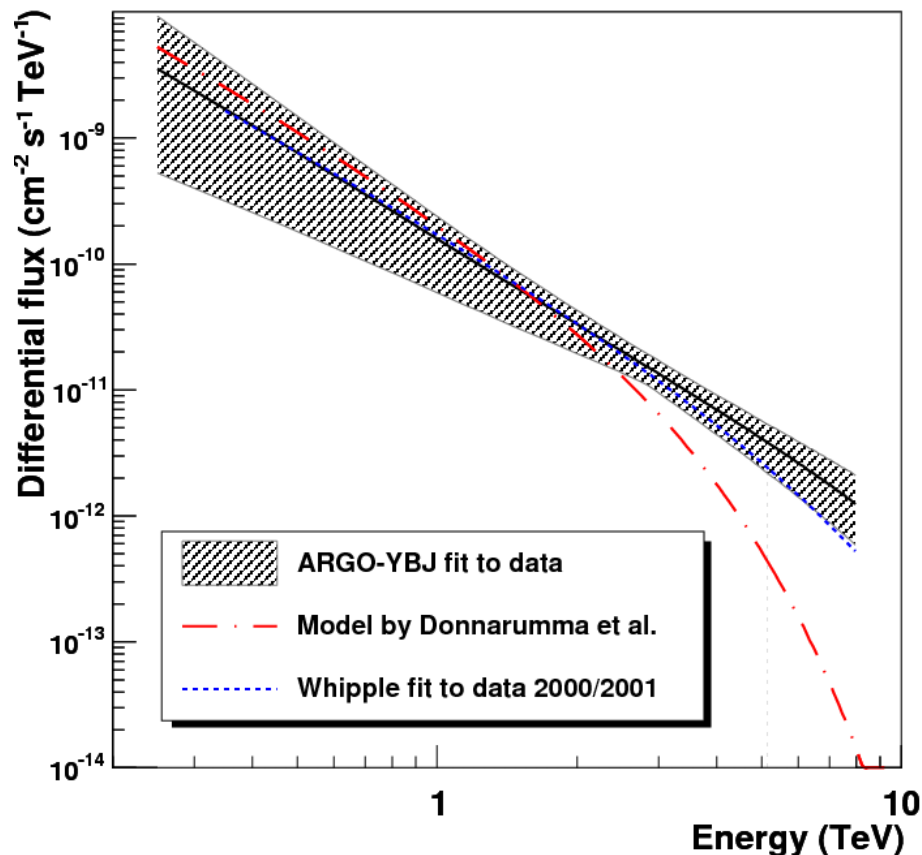
the moonlight hampered the Cherenkov telescopes measurements



Mrk 421 - June 2008 flare



Mrk 421 11-13 June 2008 flare



The spectrum slope is consistent with that measured by Whipple in 2000/2001 observing a similar flare

Flux ($E > 1 \text{ TeV}$) $\sim 6 \text{ Crab}$

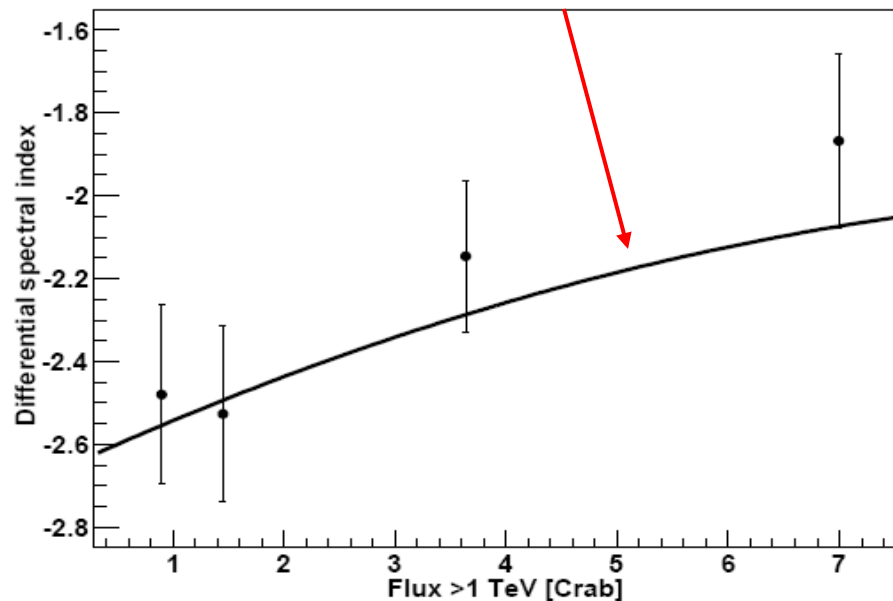
G. Aielli et al. – ApJL 714 (2010) L208

Power law spectrum + EBL absorption :

$$\frac{dN}{dE} = (3.2 \pm 1.0) \cdot 10^{-11} \left(\frac{E}{2.5} \right)^{-2.1 \pm 0.7} e^{-\tau(E)} \text{ ev cm}^{-2} \text{ s}^{-1} \text{ TeV}^{-1}$$

Spectral index vs. flux - 2 years data

Fit with Whipple data - Krennrich et al. (2002)



The TeV spectrum hardens increasing the flux

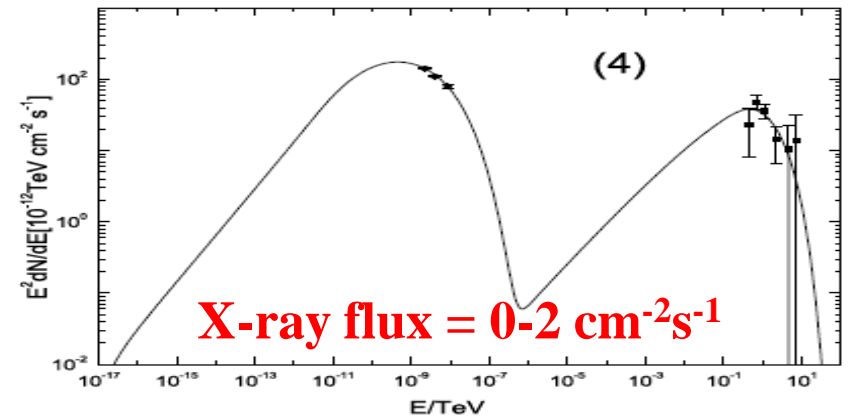
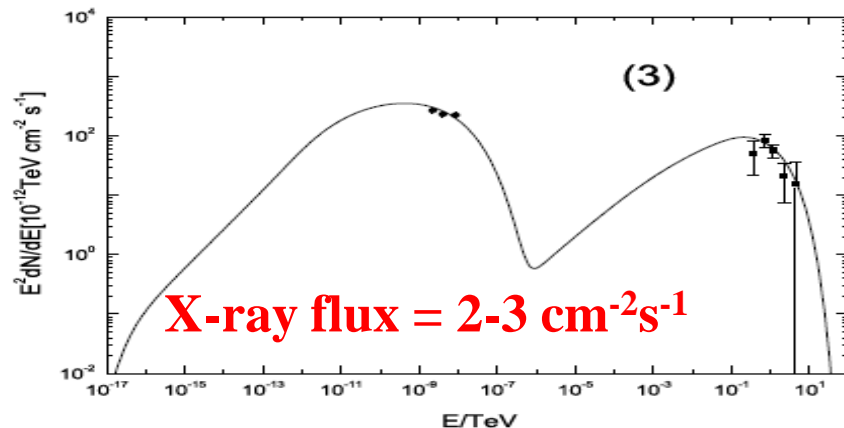
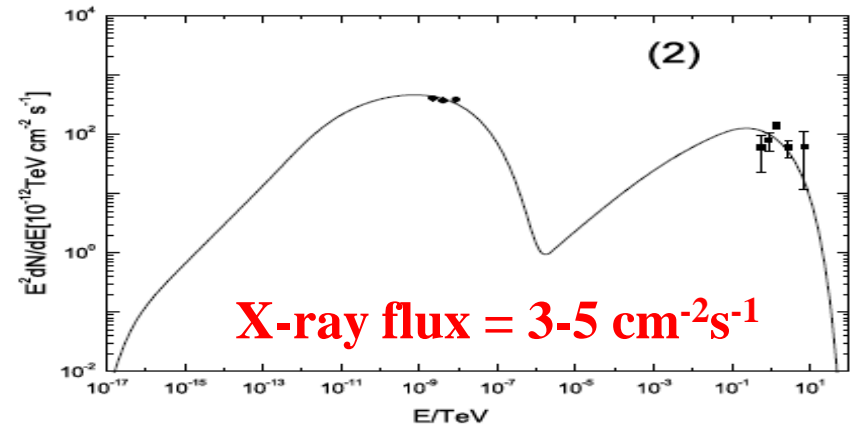
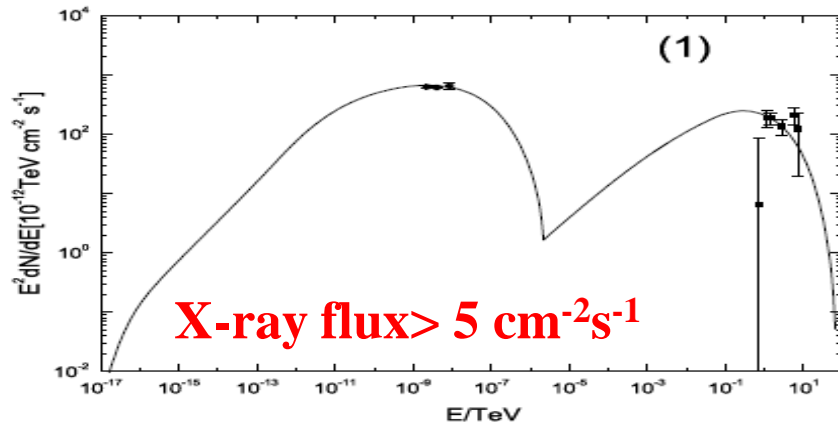
Spectral Modeling

2 year data

One-zone SSC model

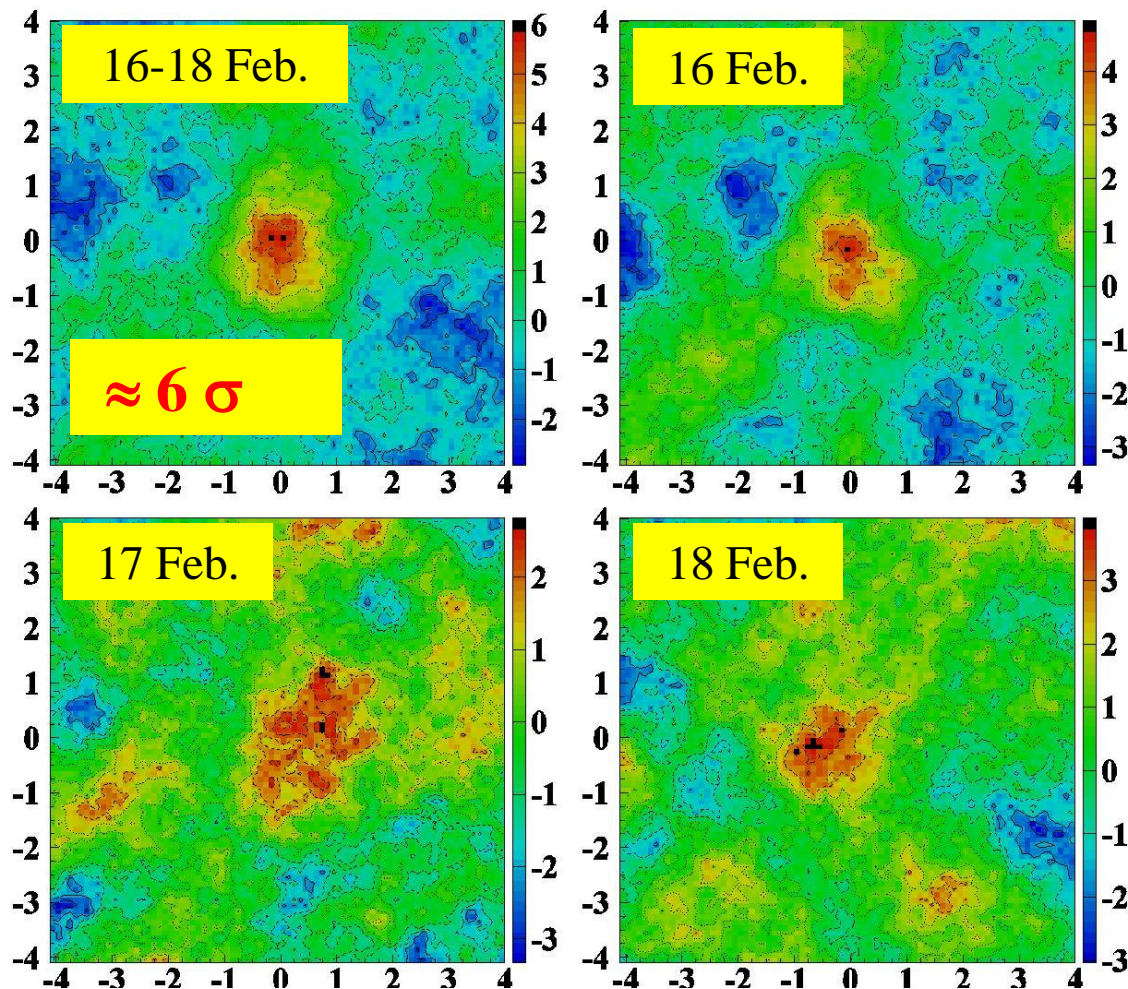
(Mastichiadis & Kirk, 1997, Yang et al., 2008)

flux level	γ_{max}	L_e	B (G)	R (cm)	δ	α
1	2×10^6	1.4×10^{-5}	0.15	5×10^{16}	15	1.7
2	1×10^6	1×10^{-5}	0.15	5×10^{16}	15	1.7
3	7×10^5	1×10^{-5}	0.15	5×10^{16}	15	1.7
4	7×10^5	6×10^{-6}	0.08	5×10^{16}	16	1.7



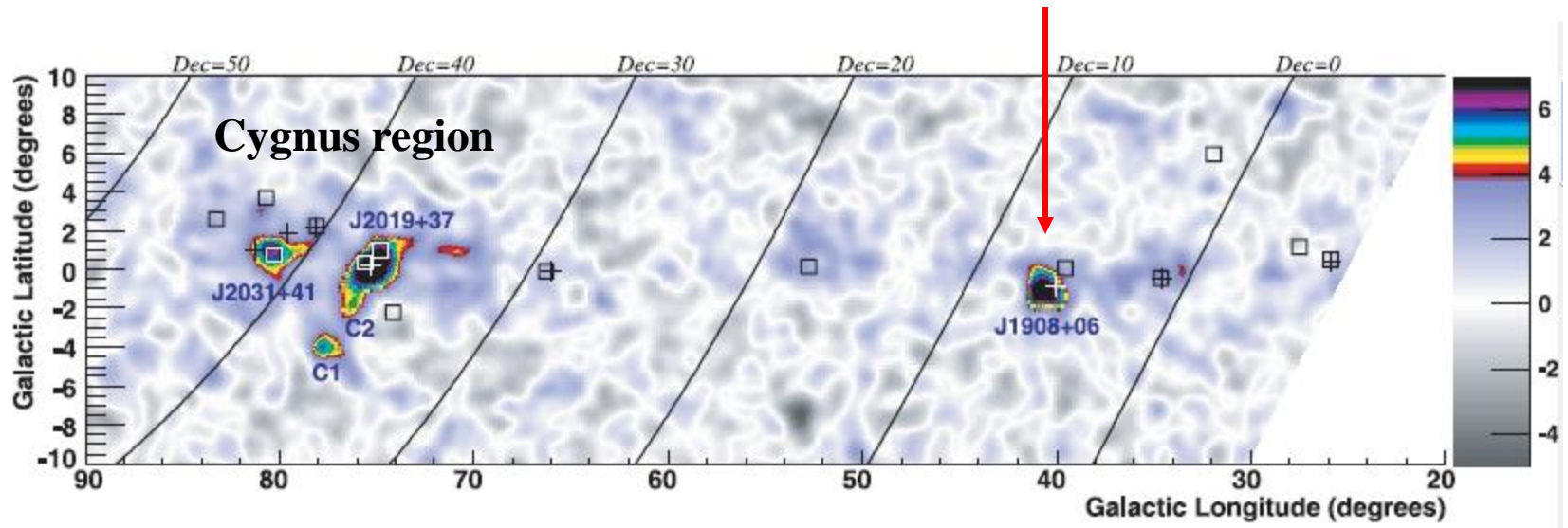
Mrk421 16-18 Feb 2010

- ARGO observed a strong flare on 16-18 Feb. at 6 s.d.
- Flux > 3 Crab
- Peak flux (16 Feb) > 10 Crab
- For the first time an EAS-array observed a TeV flare at 4-5 σ in **one day**.
- VERITAS reported similar observation in Atel #2443.



MILAGRO galactic plane survey

MGRO J1908+06



2000-2006 data

Abdo et al., 2007

Median energy ≈ 20 TeV

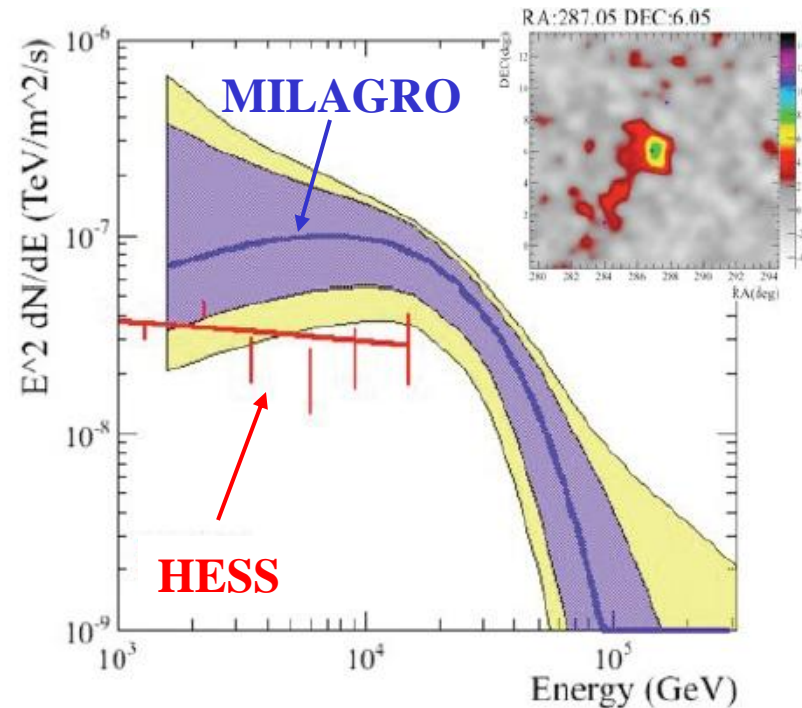
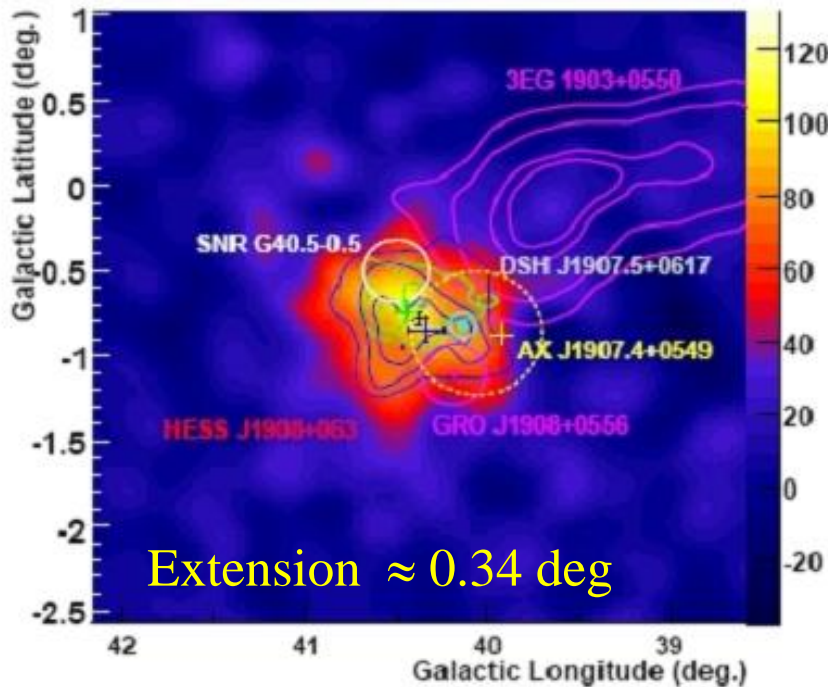
Extended source: extension < 2.6 deg

Flux $\approx 80\%$ Crab

Detected by Tibet AS- γ
at 4.4 s.d. (ICRC proc, 2005)

MGRO J1908+06 confirmed by HESS (2009)

Inside the nebula FERMI detected
a pulsar with period 106.6 ms



HESS spectrum:

$$\frac{dN}{dE} = 4.14 \cdot 10^{-12} E^{-2.1} \text{ sec}^{-1} \text{ cm}^{-2} \text{ TeV}^{-1}$$

(Aharonian et al., 2009)

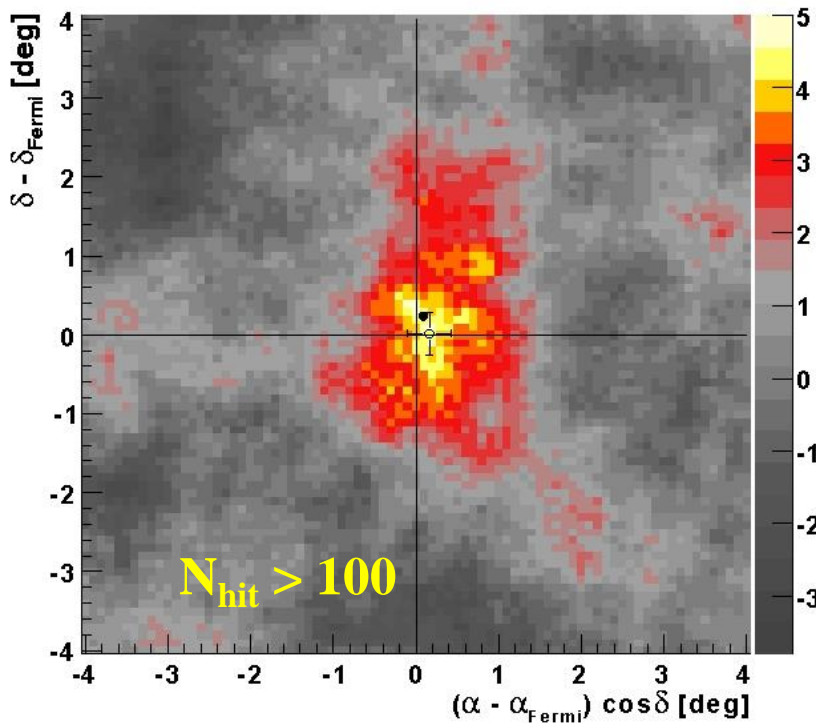
Milagro spectrum:

$$\frac{dN}{dE} = 6.2 \cdot 10^{-12} E^{-1.5} \exp(-E/14.1) \text{ sec}^{-1} \text{ cm}^{-2} \text{ TeV}^{-1}$$

(Smith et al., 2009)

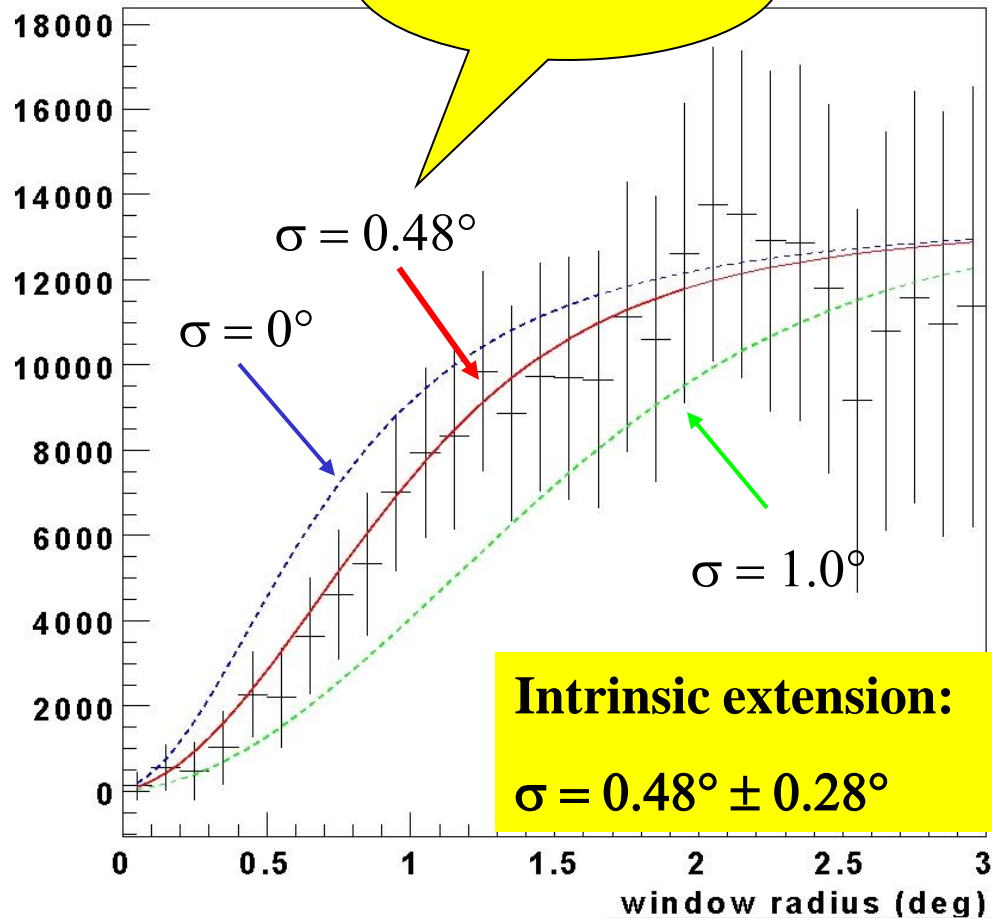
MGRO J1908+06 by ARGO

Integral angular distribution



730.5 days

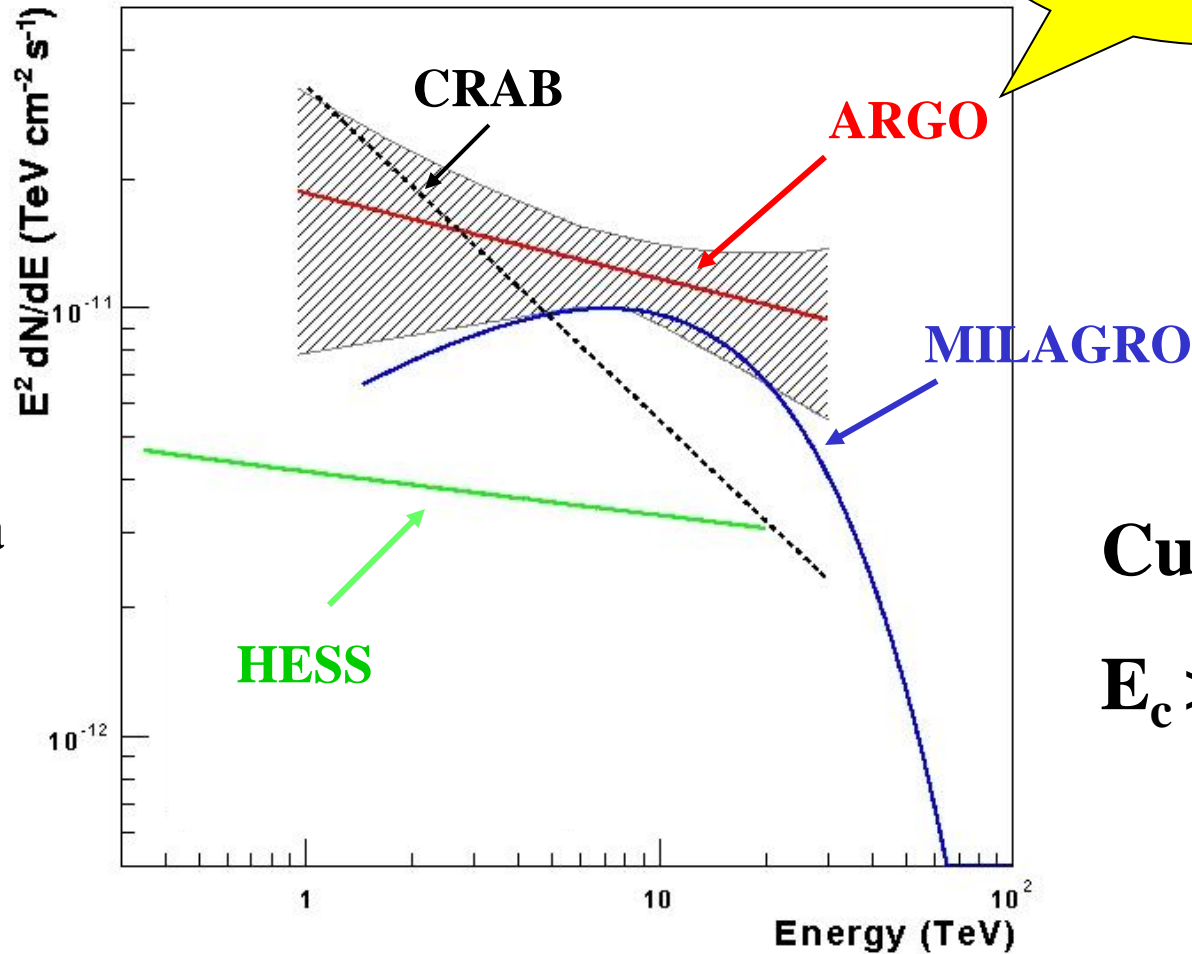
Number
of events



MGRO J1908+06

Preliminary !!!

Assumed a
power law
spectrum



Cutoff ?

$E_c > 7 \text{ TeV}$

$$dN/dE = (3.6 \pm 0.8) 10^{-13} (E/6 \text{ TeV})^{-2.2 \pm 0.3} \text{ ph sec}^{-1} \text{ cm}^{-2} \text{ TeV}^{-1}$$

Conclusions

ARGO has been taking data since Dec 2007 with duty cycle $> 90\%$

In the first 2 years :

- **Crab Nebula** : spectrum in agreement with other experiments
- **Mrk421** : - **continuously** monitored
 - VHE flux correlated with X-rays
 - observed flares in 2006, 2008, 2010
 - flare in February 2010 detected in only one day
- **MGRO J1908+06** : measured extension and spectrum
 - observed flux larger than HESS one
- Studies to increase the sensitivity are in progress
- Sky survey going on