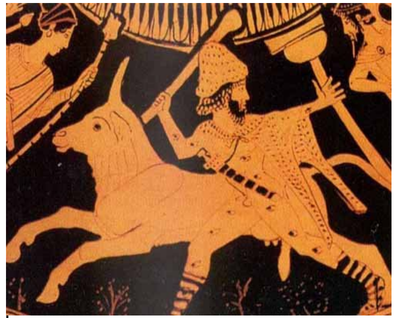

# First Results from the ARGO-YBJ Experiment


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Lecce, Italy


**On behalf of the ARGO-YBJ Collaboration**


**TeV Particle Astrophysics, TeV 2007**

**Venice, Italy, August 27-31, 2007**



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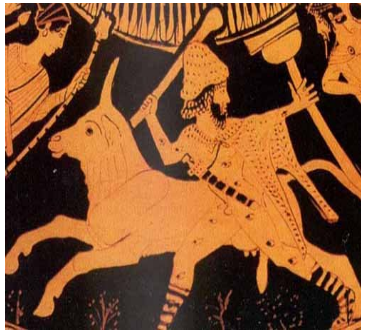
# The ARGO-YBJ experiment


**High Altitude Cosmic Ray Laboratory @ YangBaJing, Tibet, China**

<u>**Site Altitude: 4,300 m a.s.l. , ~ 600 g/cm$^2$**</u>

# ARGO-YBJ physics goals



- **Cosmic ray physics**:
  - ✓ study of the shower space-time structure,
  - ✓ p-Air cross section,
  - ✓ spectrum and composition ($E_{th}$ ~ 1 TeV),
  - ✓ anti-p / p ratio at TeV energy, ….

- **VHE γ-Ray Astronomy**:

  search for point-like (and diffuse) galactic
  and extra-galactic sources at few hundreds GeV energy threshold

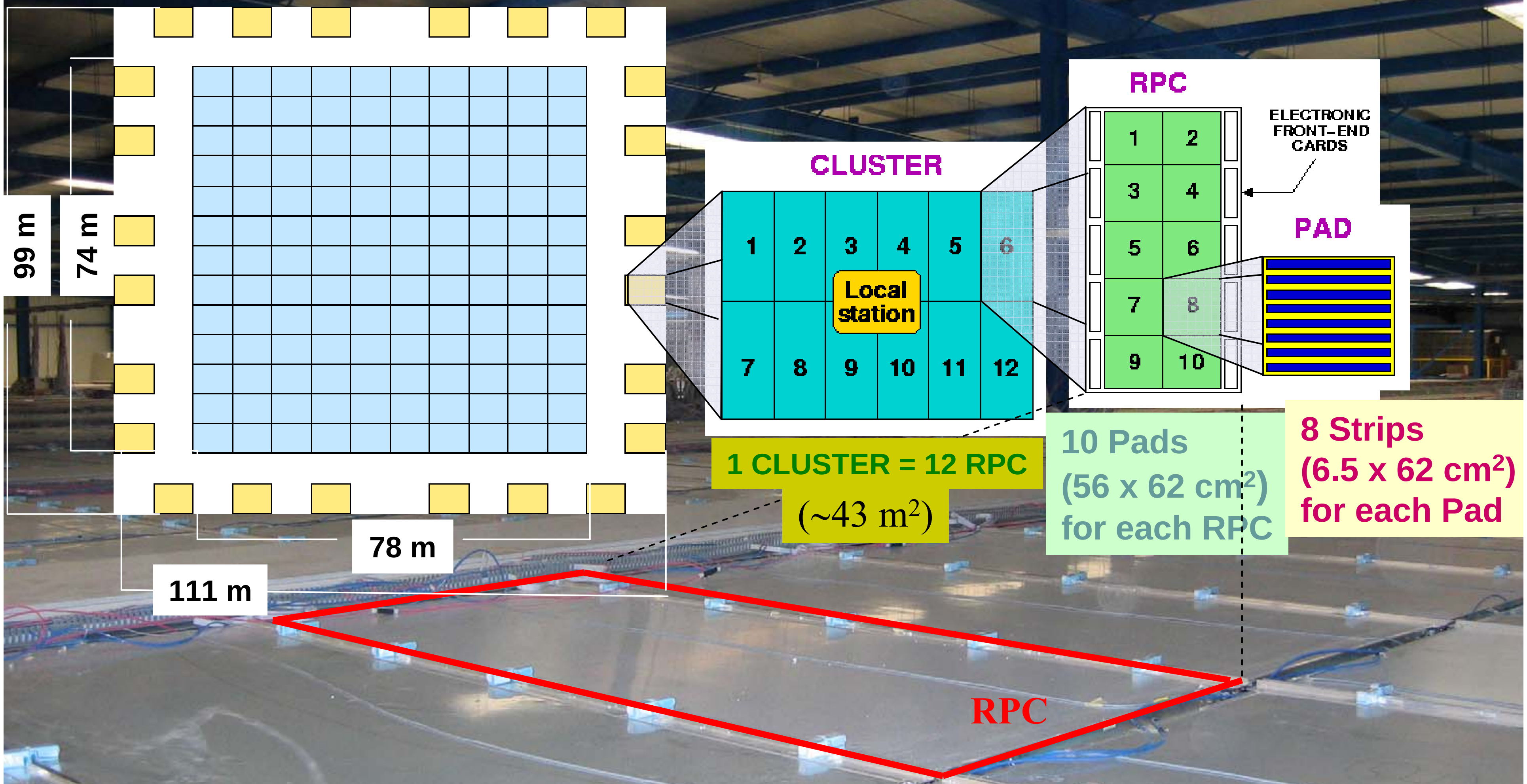
- **Search for GRB's** (full GeV / TeV energy range)

- **Sun and Heliosphere physics** ($E_{th}$ ~ few GeV)

through the …

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

# The ARGO-YBJ detector




Strip = space pixel

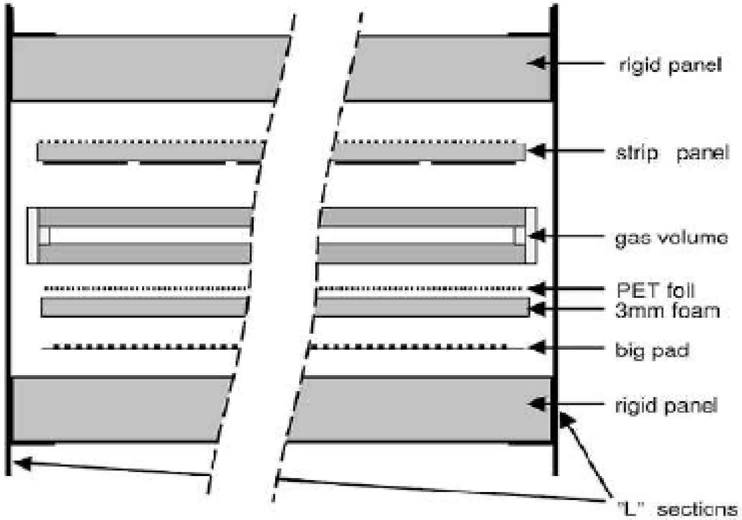
Pad = time pixel

Time resolution ~1 ns

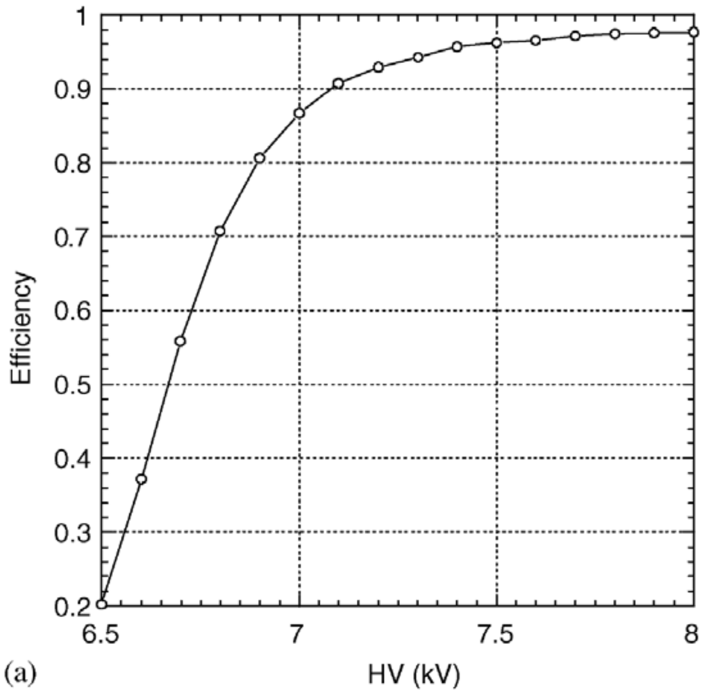
+ Analog charge read-out on "Big Pads"

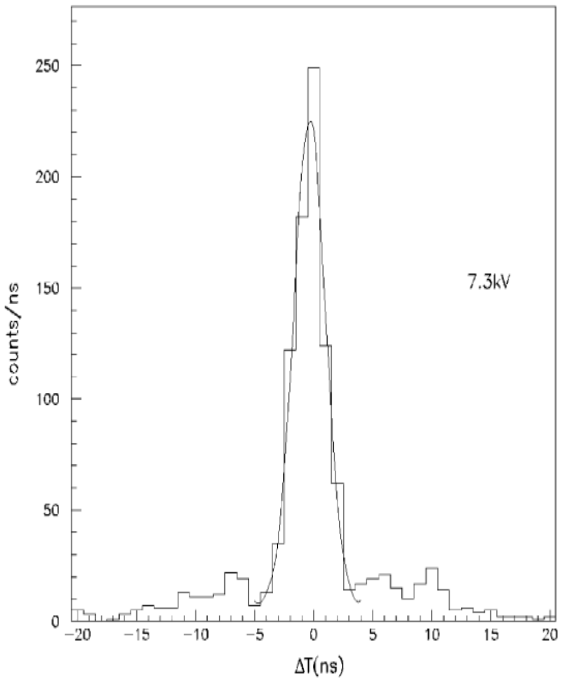
+ 0.5 cm lead converter (2008)

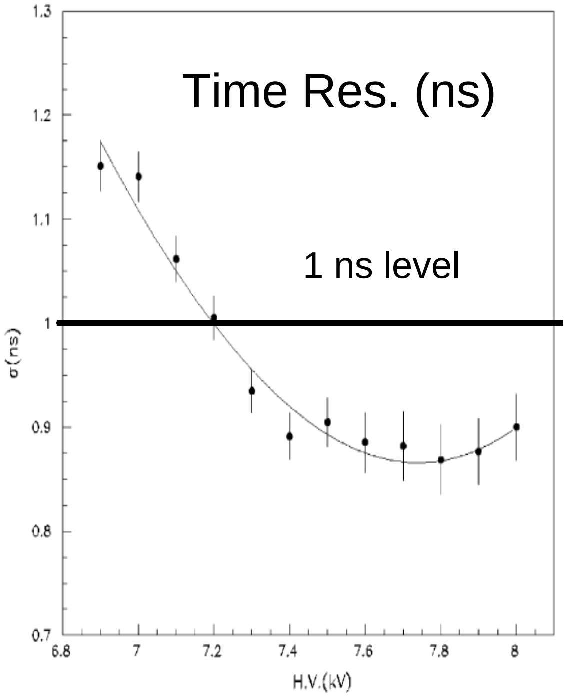
# RPC layout & performance




- Bakelite RPC ( 5·$10^{11}$ $\Omega$m )
- Operation in streamer mode
- Ar/Isobuthane/TFE 15/10/75 gas mixture
- Efficiency > 95 % at 7.5kV (10kV at s.l.)
- Time resolution: ~ 1 ns



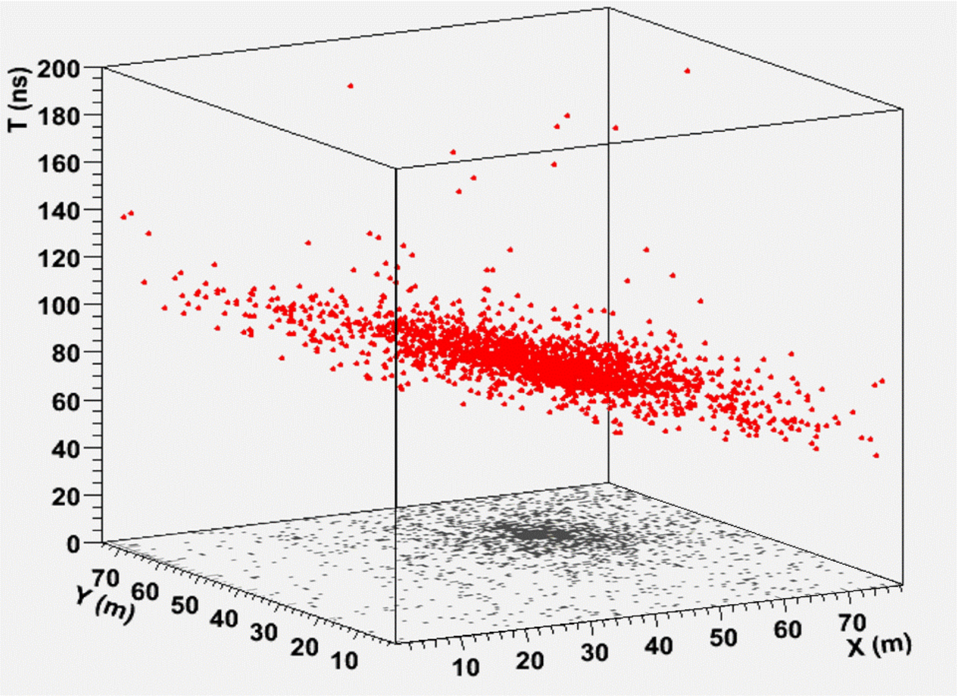
# EAS reconstruction

Event Rate ~ 4 kHz for $N_{hit}$ >20

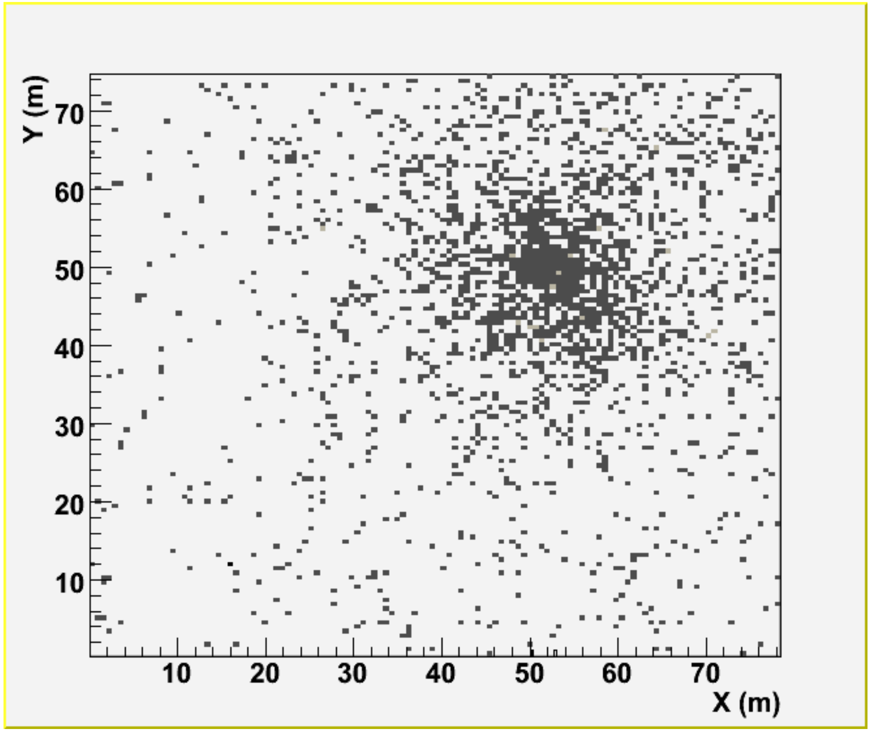
**High space/time granularity**
**+ Full coverage**
**+ High altitude**

→

**detailed study on the EAS space/time structure with unique capabilities**
(see G.Marsella's talk in the CR session)




**3-D view of a detected shower**




**Top view of the same shower**

# First Results

Since 2006 July, during the detector calibration and debugging in the 130-clusters configuration, the first preliminary physics results have been obtained in different items.

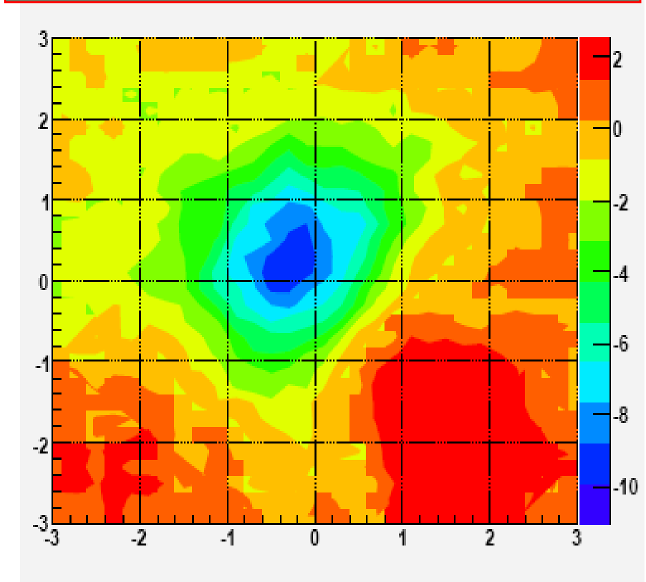
Among them:

- Moon and Sun shadows
- Gamma ray sources
- High energy Gamma Ray Bursts
- p-Air cross section
- ……..

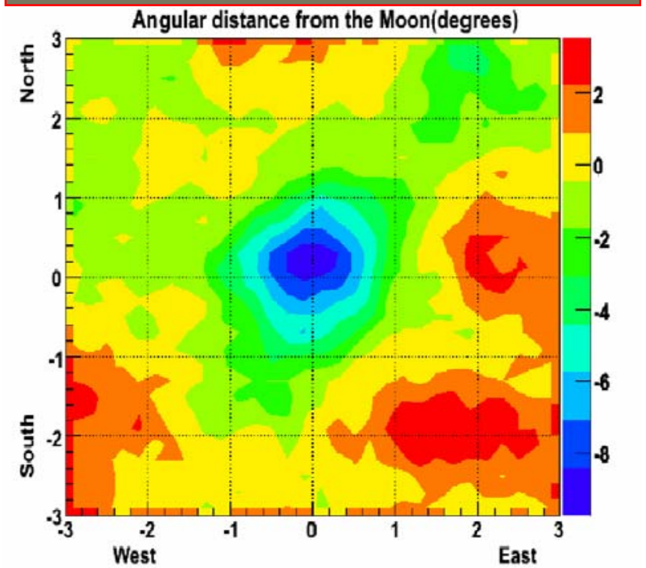
# The Moon Shadow

**July 2006 to February 2007 data, with ARGO-130**
- **reconstructed core position inside the array**
- **1.16 x $10^6$ events in a window 6°x 6° around the moon**
- **560 hours of Moon observation with zenith angle < 45°**

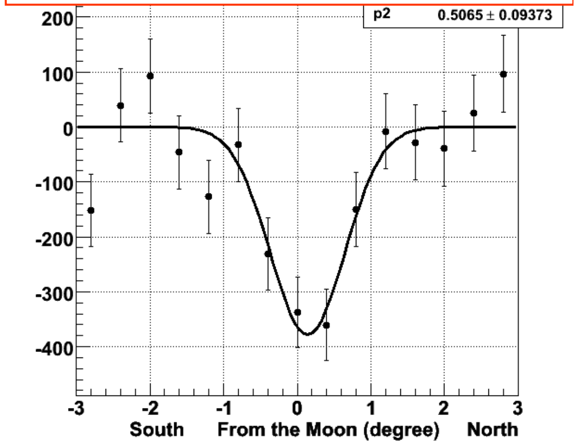
$N_{pad}$ > 120, **<E> = 2 TeV** :
A peak at 11 σ significance.
Shifting:
**West 0.23°** ,North 0.27 °
with respect to the nominal moon position



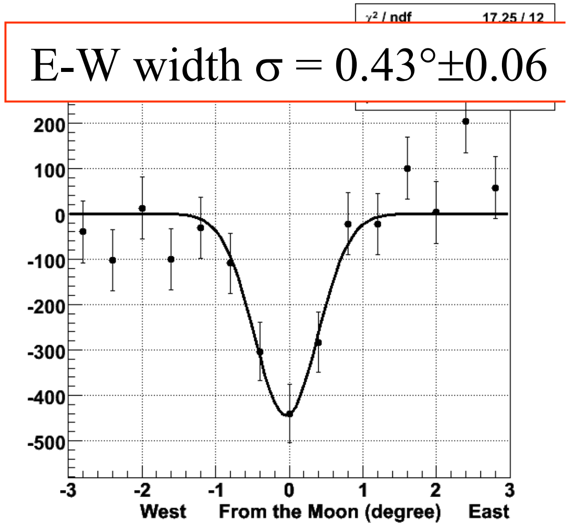
$N_{pad}$ > 500, **<E> = 5 TeV** :
A peak at 10 σ significance.
Shifting:
**West 0.04°** , North 0.14°
with respect to the nominal moon position




N-S width σ = 0.51°±0.09




E-W width σ = 0.43°±0.06

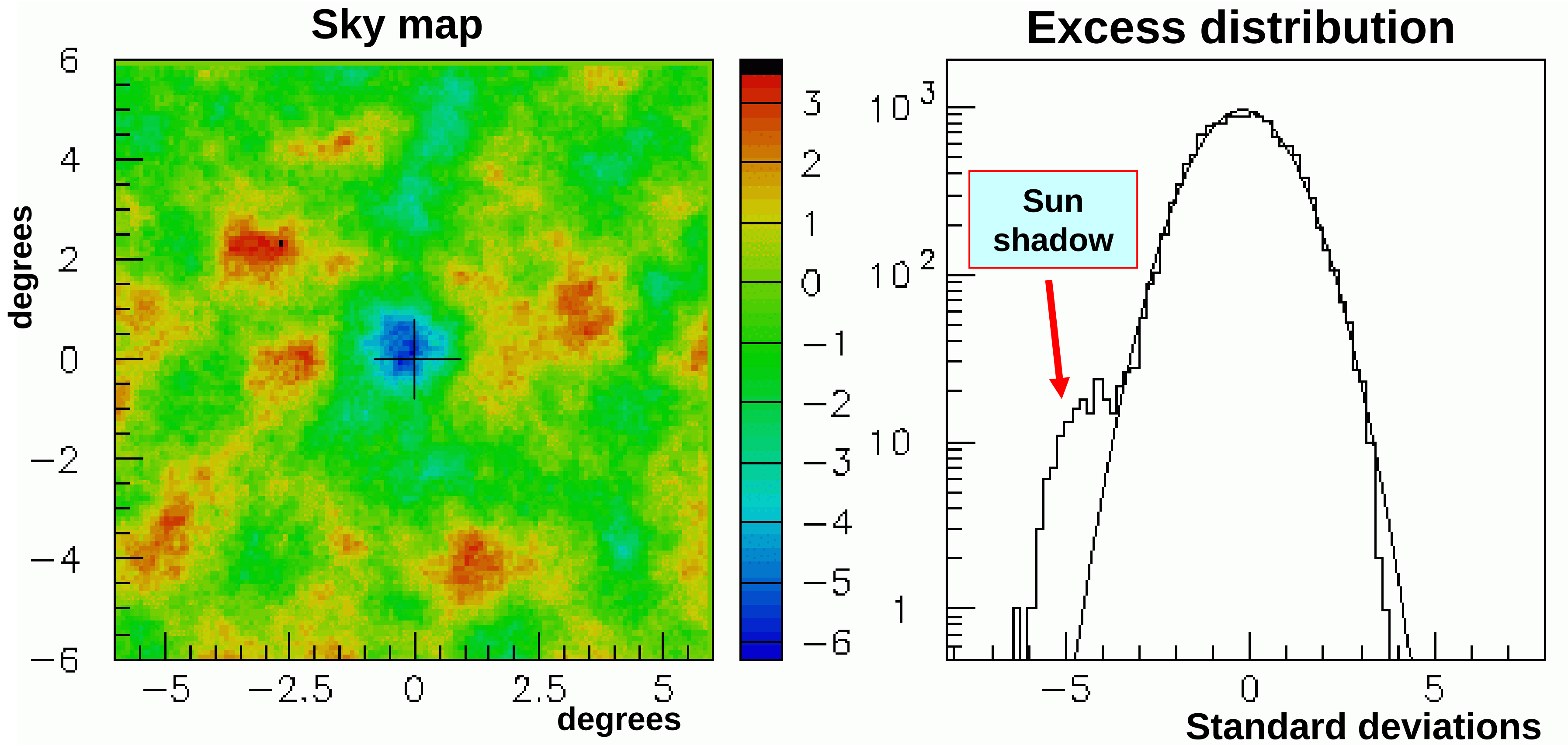


# The Sun Shadow

**July 2006 to October 2006 data, with ARGO-130**

➢ **208 hours of Sun observation with zenith angle < 50°.**

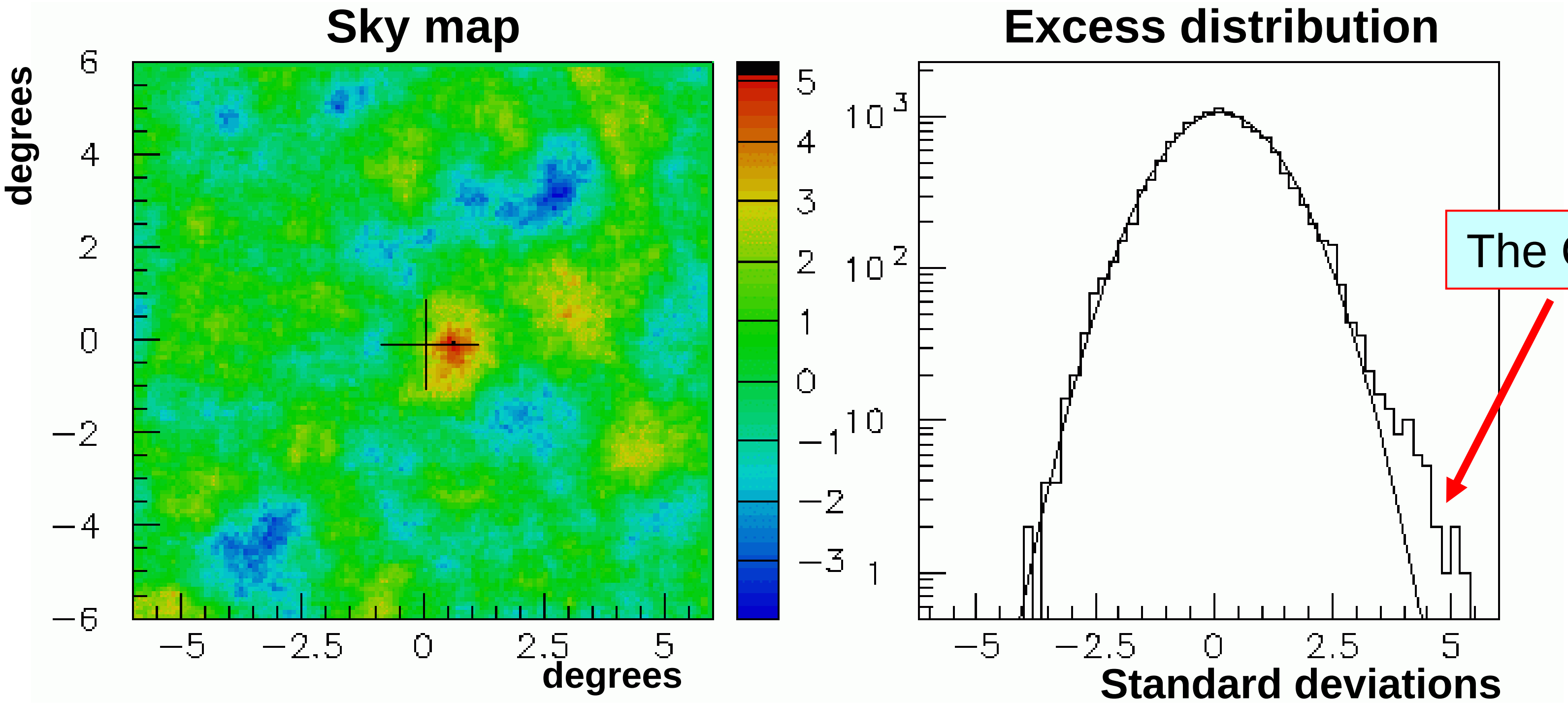
**$N_{pad}$ > 500, <E> = 5 TeV :**
**A peak at <u>6 σ significance</u>**



# The Crab

**July 2006 to March 2007 data, with ARGO-130**

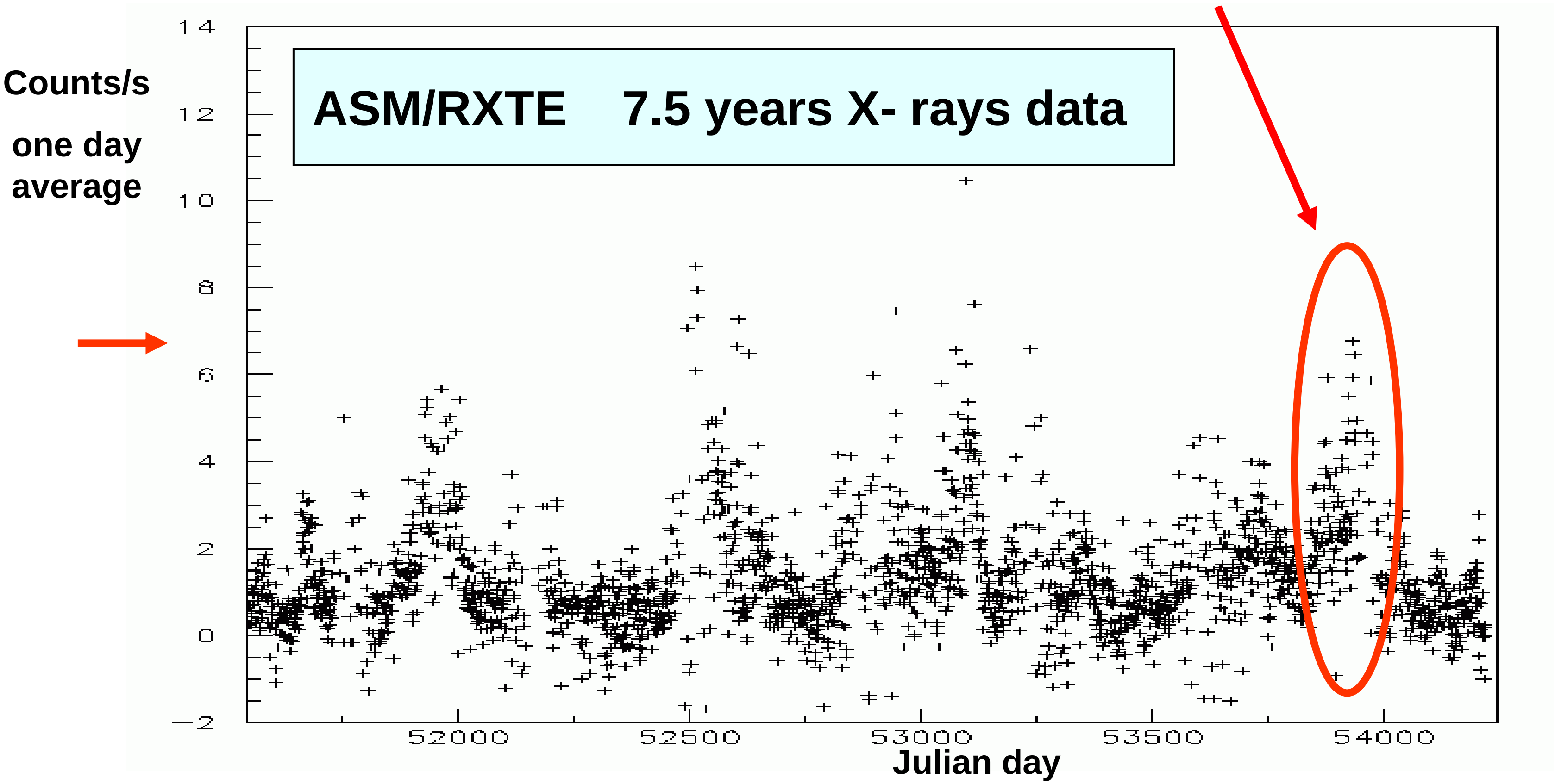
- **$N_{pad}$ > 200**
- **Data selection for a total live time of ≈ 50 days**
- **Crab observation time ≈ 290 hours**
- **A signal with <u>5 σ significance</u>**
- **Gamma-hadron discrimination tools not yet used**



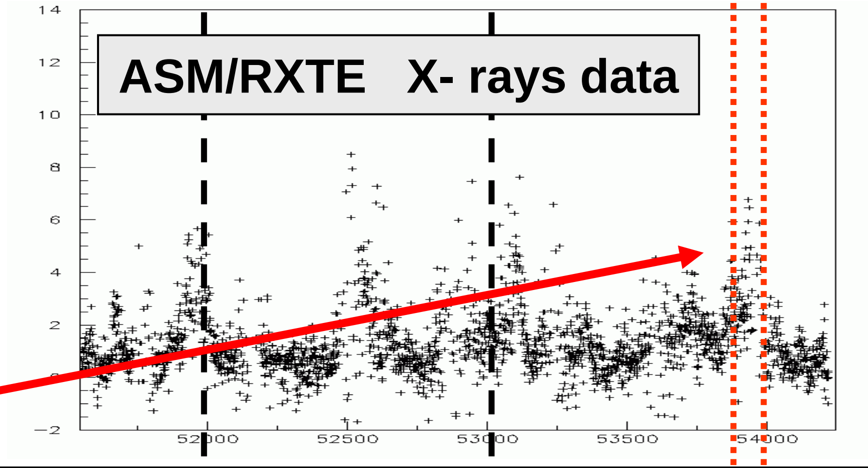
# The Mkn421 Flare in 2006

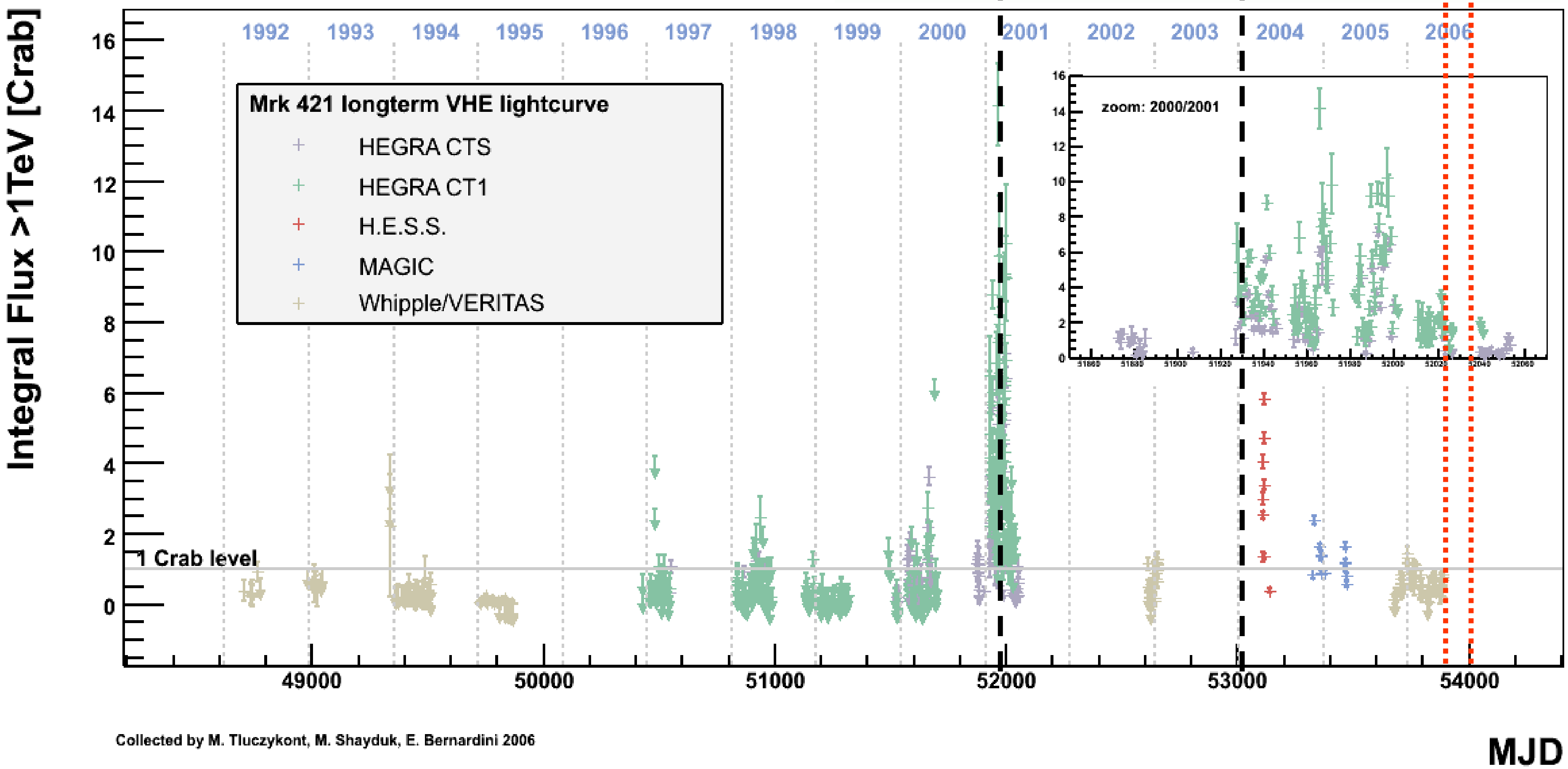
July-August 2006

active period



# The Mkn421 Flare In 2006

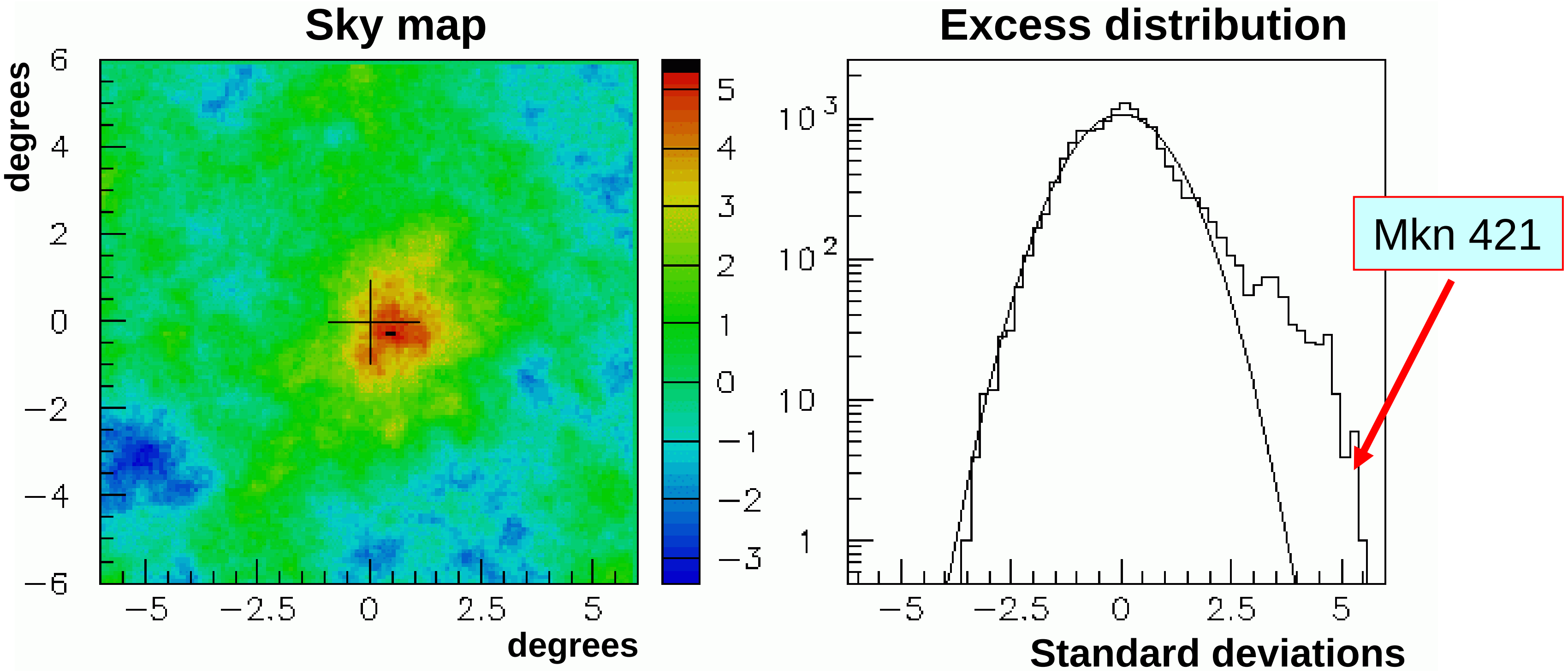


# The Mkn421 Flare

**July and August 2006**

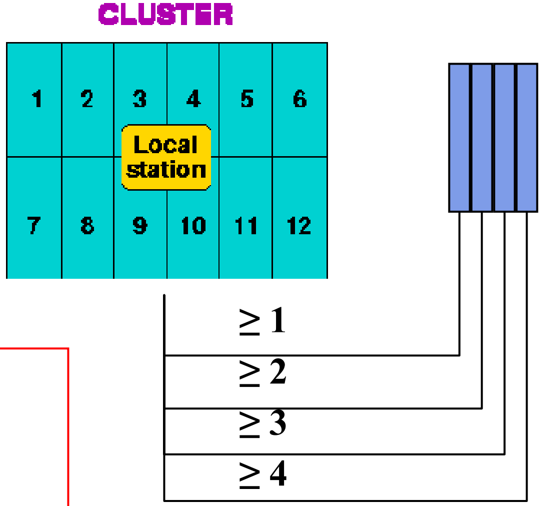
- **$N_{pad}$ > 60**
- **Mkn421 observation time ≈ 80 hours**
- **A signal with 5.5 σ significance**
- **No significant excess at Npad > 100**
- **γ-h discrimination tools not yet used**



# Search for GRBs

Recording the counting rates from each clusters at different time interval, lower the energy threshold down to 1 Gev and allow the observation flaring phoenomena.
For instance:
the possible high energy tail of GRBs from 1GeV to 100GeV

The counts of each cluster are recorded every 0.5 seconds for 4 levels of coincidence:
n ≥ 1, 2, 3, 4




130 independent detectors in coincidence

- Data from December 2004 to April 2007
- 24 of the 47 GRBs detected by satellites in the field of view of ARGO-YBJ have been analyzed

1) Search for an excess in coincidence (T90)
2) Search in an interval of ± 1 hour around the GRB time

**No excess has been observed**

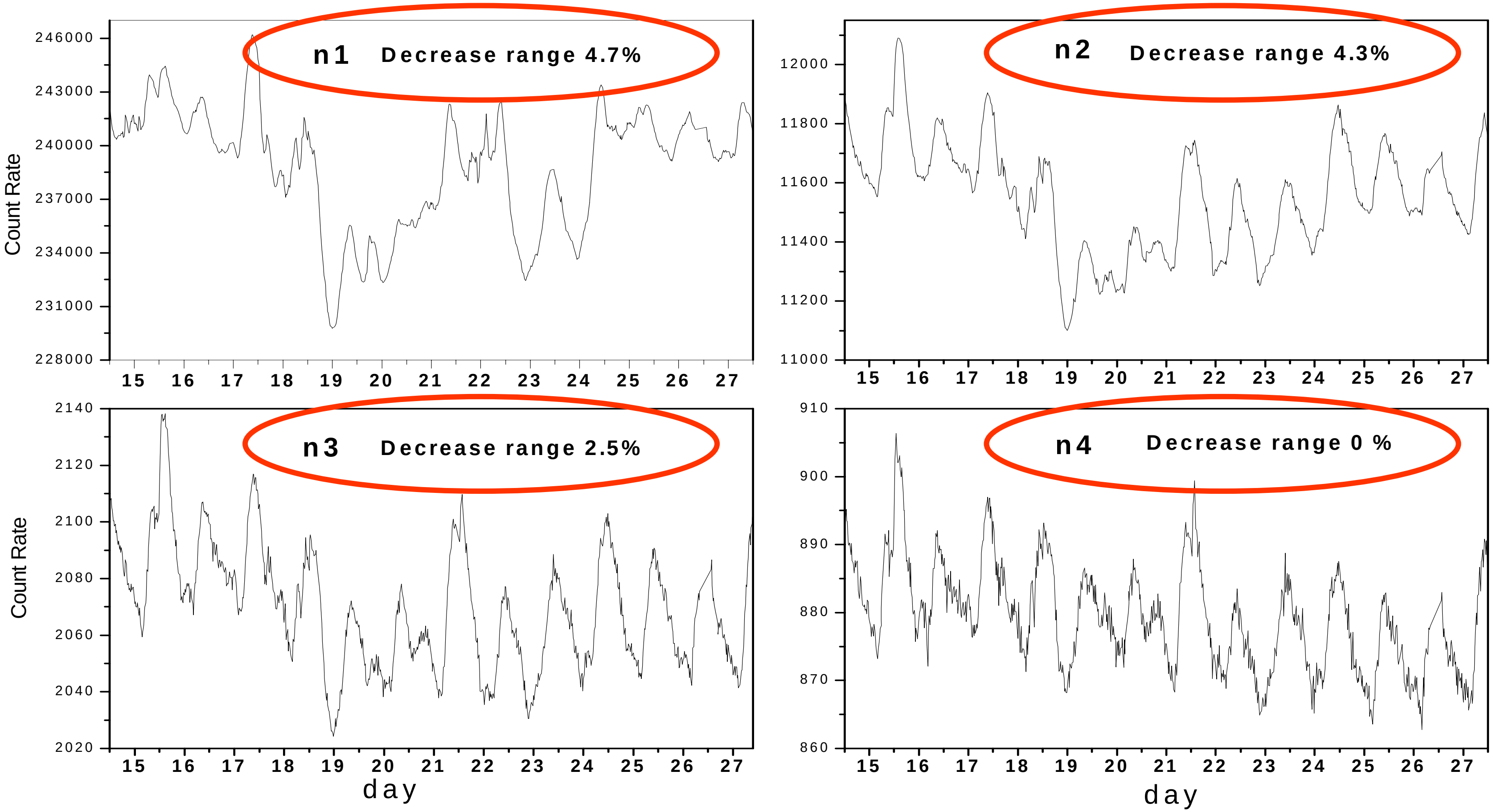
# Search for GRBs

Upper limits in the 1-100m GeV energy range and $\theta \leq 45°$

| GRB | Satel | T90/dur (s) | $\theta$(°) | Redshift z | $\Gamma$ | Carpet Area (m²) | $n_\sigma$ | $4\sigma$ U.L. (erg/cm²) |
|---|---|---|---|---|---|---|---|---|
| 041228 | Swift | 62 | 28.1 | … | 1.56 | 693 | -0.34 | $5.8 \cdot 10^{-4}$ |
| 050408 | HETE | 15 | 20.4 | 1.24 | 1.98 | 1820 | -1.2 | $1.1 \cdot 10^{-4}$ |
| 050509A | Swift | 12 | 34.0 | … | 2.10 | 1820 | 0.44 | $1.8 \cdot 10^{-4}$ |
| 050528 | Swift | 11 | 37.8 | … | 2.30 | 1820 | -0.03 | $6.2 \cdot 10^{-4}$ |
| 050802 | Swift | 13 | 22.5 | 1.71 | 1.55 | 1820 | 0.82 | $8.5 \cdot 10^{-5}$ |
| 051105A | Swift | 0.03 | 28.5 | … | 1.33 | 3379 | -1.5 | $1.3 \cdot 10^{-5}$ |
| 051114 | Swift | 2 | 32.8 | … | 1.22 | 3379 | 1.2 | $2.5 \cdot 10^{-5}$ |
| 051227 | Swift | 8 | 22.8 | … | 1.31 | 3379 | -0.89 | $2.1 \cdot 10^{-5}$ |
| 060105 | Swift | 55 | 16.3 | … | 1.11 | 3379 | 1.3 | $1.6 \cdot 10^{-4}$ |
| 060111A | Swift | 13 | 10.8 | … | 1.63 | 3379 | -0.54 | $3.4 \cdot 10^{-5}$ |
| 060115 | Swift | 142 | 16.6 | 3.53 | 1.76 | 4505 | 0.17 | $1.2 \cdot 10^{-3}$ |
| 060421 | Swift | 11 | 39.3 | … | 1.53 | 4505 | -0.71 | $1.9 \cdot 10^{-4}$ |
| 060424 | Swift | 37 | 6.7 | … | 1.72 | 4505 | -0.05 | $7.6 \cdot 10^{-5}$ |
| 060427 | Swift | 64 | 32.6 | … | 1.87 | 4505 | -0.39 | $4.1 \cdot 10^{-4}$ |
| 060510A | Swift | 21 | 37.4 | … | 1.55 | 4505 | 2.0 | $3.4 \cdot 10^{-4}$ |
| 060526 | Swift | 14 | 31.7 | 3.21 | 1.66 | 4505 | 0.63 | $1.5 \cdot 10^{-4}$ |
| 060717 | Swift | 3 | 7.4 | … | 1.72 | 5632 | 1.08 | $1.3 \cdot 10^{-5}$ |
| 060801 | Swift | 0.5 | 16.8 | … | 0.47 | 5632 | 0.10 | $4.8 \cdot 10^{-6}$ |
| 060807 | Swift | 34 | 12.4 | … | 1.57 | 5632 | 0.61 | $7.6 \cdot 10^{-5}$ |

# Solar Physics

Counting rates summed up for 12 clusters.
Forbush decrease observed on 19/jan/05.



# Inelastic proton-air cross section measurement

Use the shower frequency vs (sec$\theta$ -1)

$$I(\theta) = I(0) \cdot e^{-\frac{h_o}{\Lambda}(\sec(\theta)-1)}$$

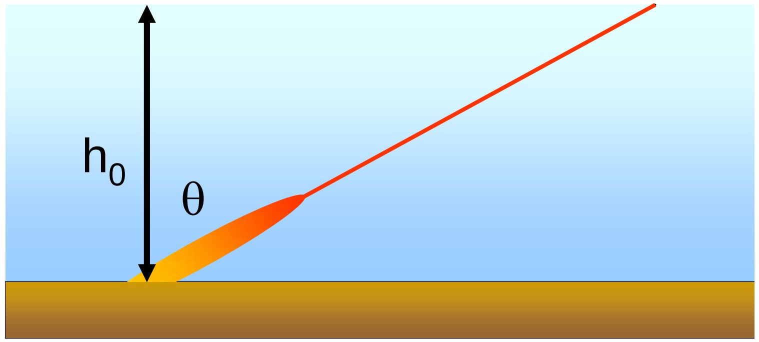
for fixed energy and shower age.

However $\Lambda$ **= k** $\lambda_{int}$ mainly because of shower fluctuations.

It is determined by simulations and depends on:

- interaction model
- actual set of experimental observables
- energy
- ……..

Then: **$\sigma_{p\text{-}Air}$ (mb) = 2.4 $10^4$ / $\lambda_{int}$(g/cm$^2$)**

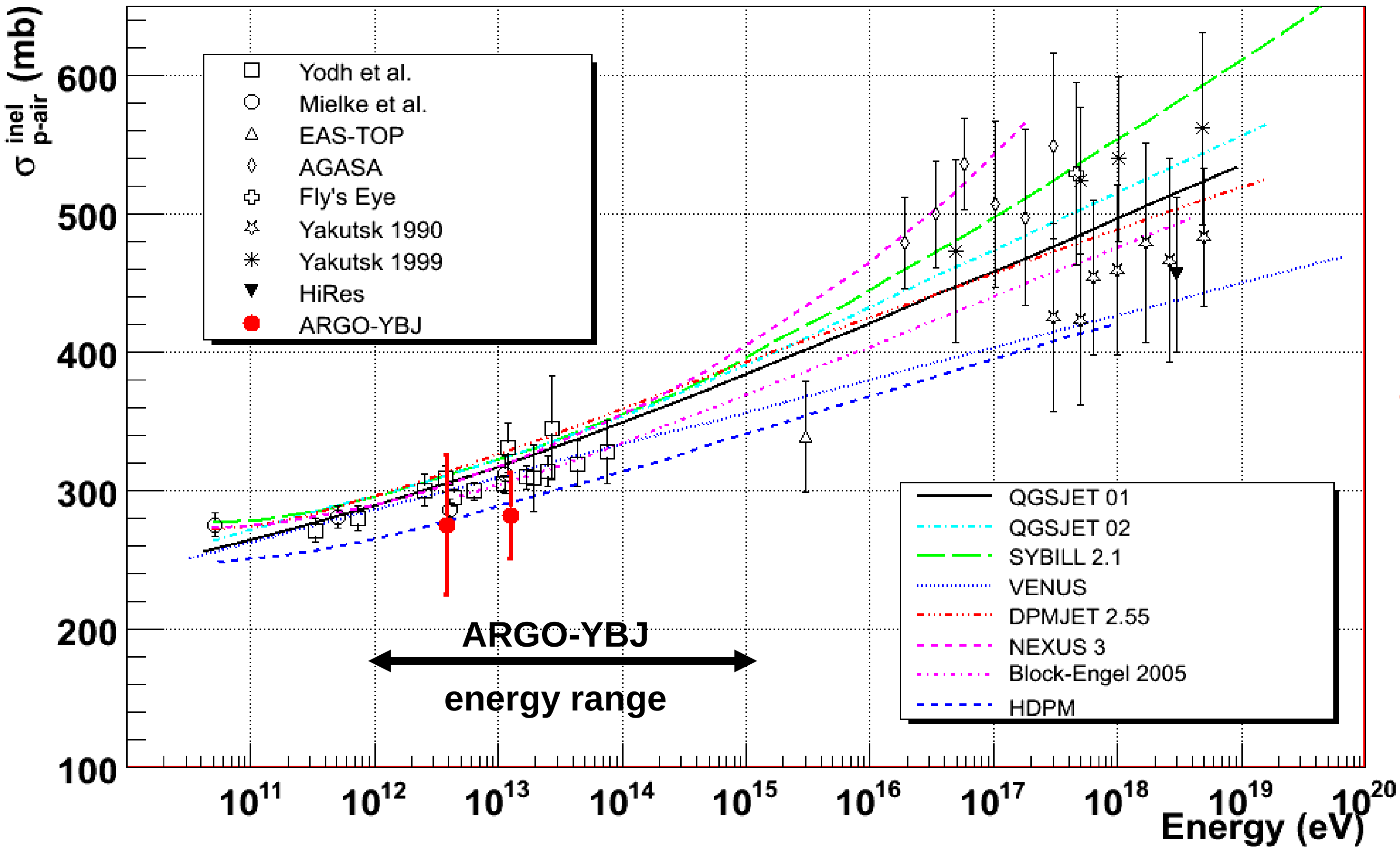



Warning

Take care of shower fluctuations

- **Constrain** $X_{DO} = X_{det} - X_0$ or better $X_{DM} = X_{det} - X_{max}$
- **Select** deep showers (large $X_{max}$, i.e. small $X_{D0}$ or $X_{DM}$)
- **Exploit** detector features (space-time pattern) and location (depth).

# Inelastic proton-air cross section measurement




**In this plot ARGO-YBJ data points have been already corrected for the effect of primaries heavier than protons.**

| Nhit | <E> | k | $\sigma_{CR-Air}$ (mb) | $\sigma_{p-Air}$ (mb) |
|---|---|---|---|---|
| 300 ÷ 1000 | 3.9 ± 0.1 TeV | 1.6 ± 0.3 | **299 ± 55** | **275 ± 51** |
| > 1000 | 12.7 ± 0.4 TeV | 1.2 ± 0.1 | **306 ± 34** | **282 ± 31** |

In agreement with a previuos work based on 42 clusters data

(ECRS, Lisbon 2006)

# Summary and Outlook

## Detector setup:

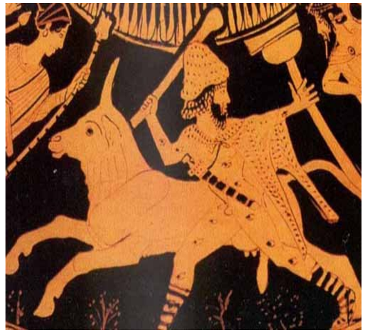
- The ARGO-YBJ detector has been completely installed
- Data taking with 130/154 clusters (the whole central carpet)
- The guard ring (24 clusters) in data taking at the end of 2007
- Lead plate installation during 2008

## Results from preliminary data :

- Moon and Sun shadows observed
- Mrk421 flare observed in July-August 2006 at > 5 s.d.
- Crab Nebula observed at > 5 s.d. in $\approx$ 50 days (no $\gamma$/h discrimination yet !).
- inelastic p-air cross section measurements at $\sqrt{s}$ ~ 0.1TeV
- Forbush decrease observed at low energy

## Near future:

- Study other point/extended $\gamma$-ray sources
- Better limits on GRB and transient low energy flux modulations
- Study the hadronic CR flux (cross section, spectrum, composition, …..)

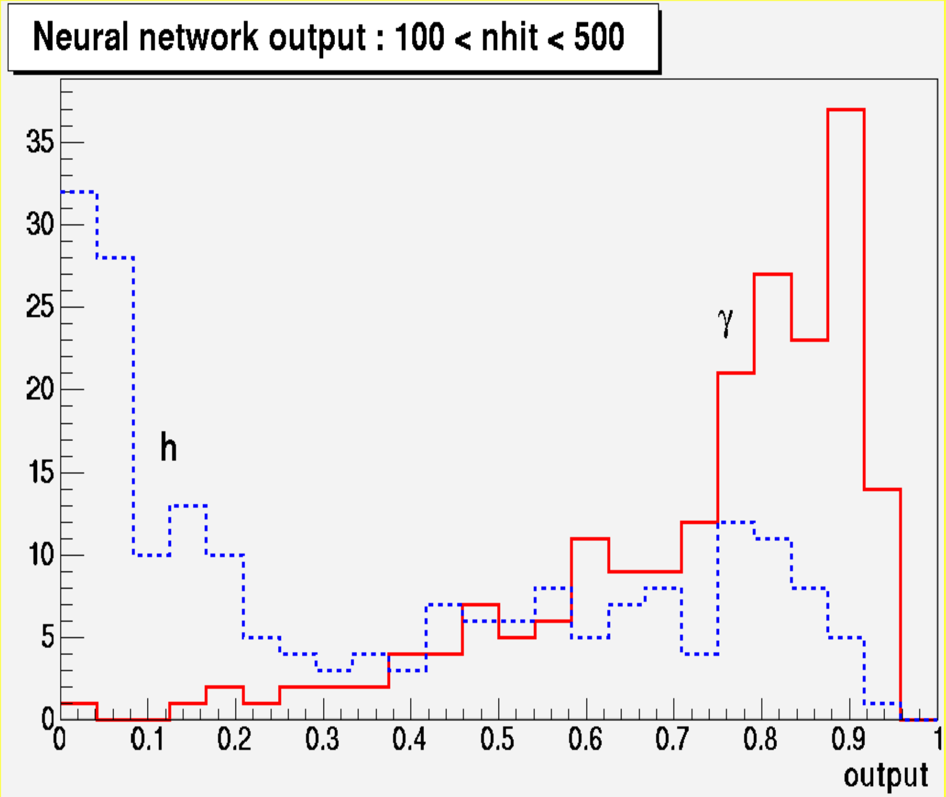


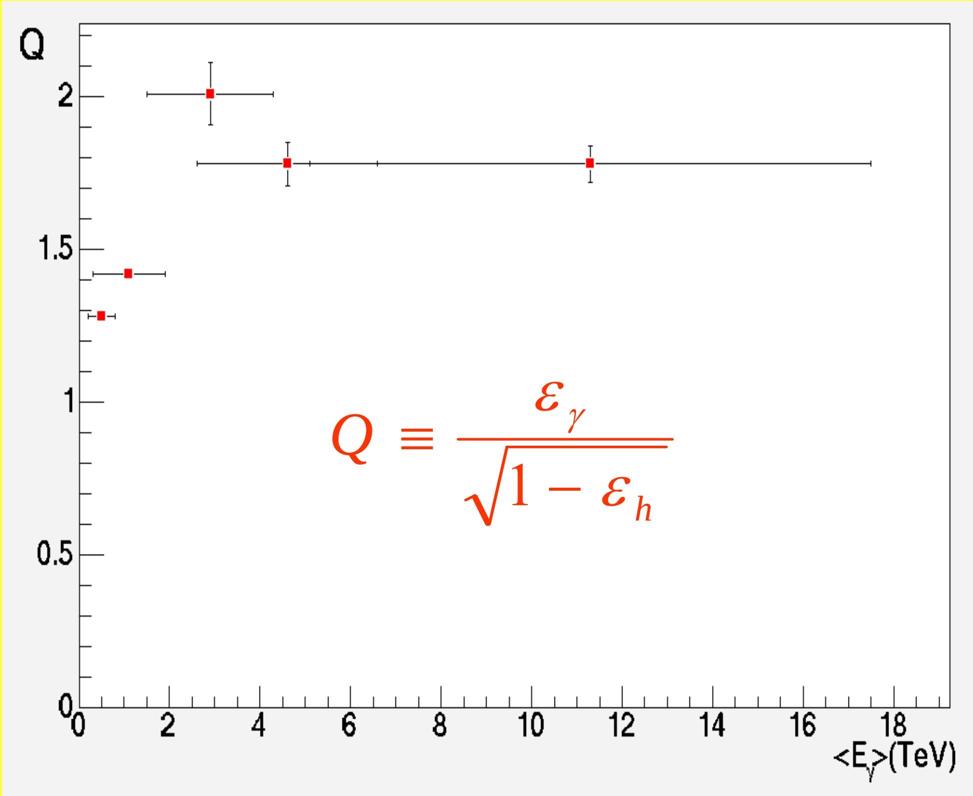
# Insights

# γ/h discrimination

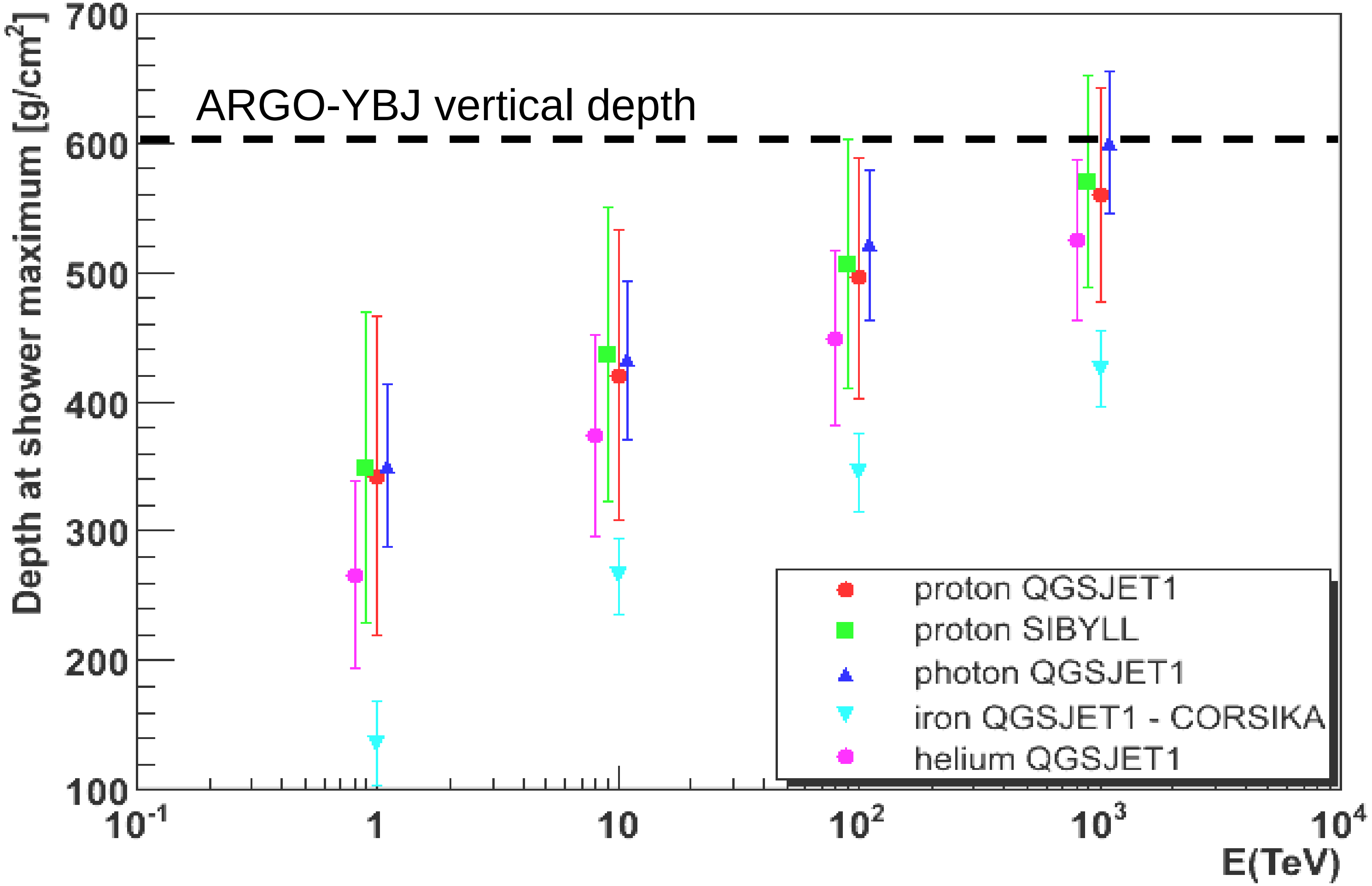
Several approaches based on the space-time topology of the shower front.

One example: Multi Fractal shower image analysis

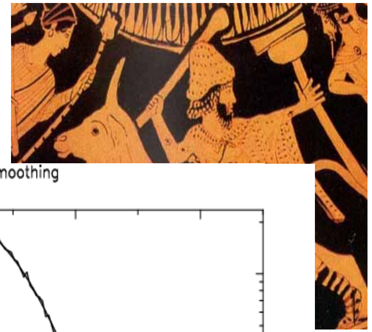


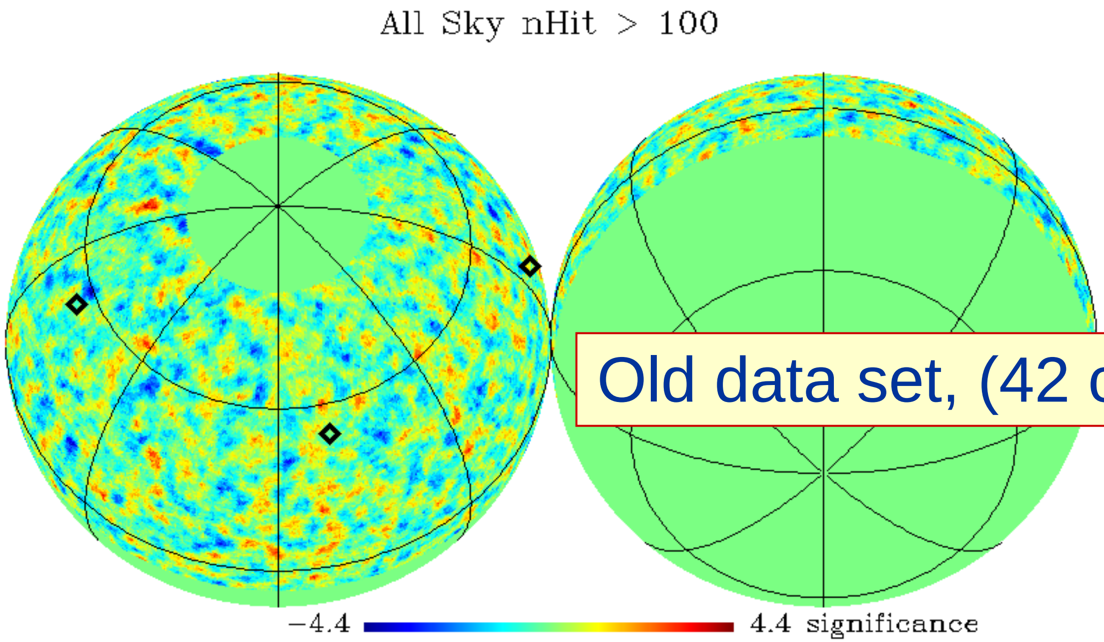



# The position of the shower maximum (and its rms)

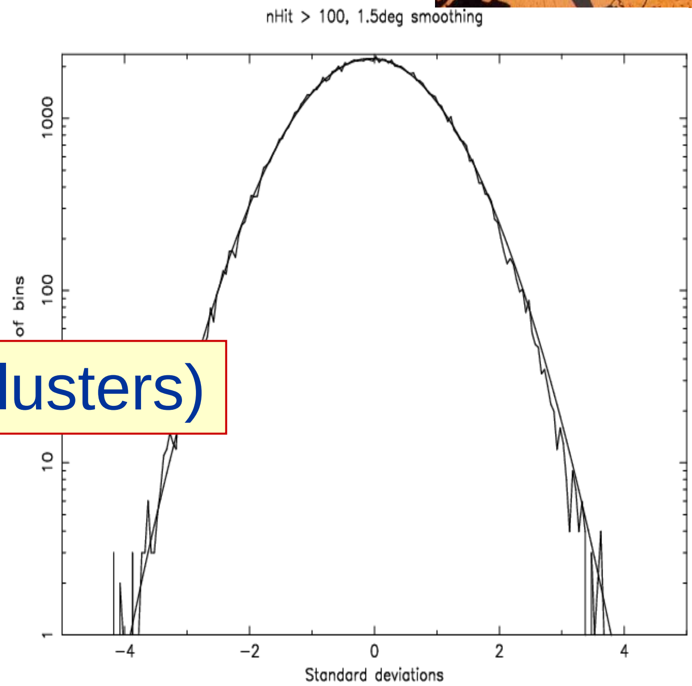


# Search for point γ ray sources – The Analysis






Old data set, (42 clusters)




In each bin: **$n_\sigma = (N_s - N_b) / N_b^{1/2}$**

$N_s$ = observed events

$N_b$= expected background events

The background is evaluated with the “time swapping” method

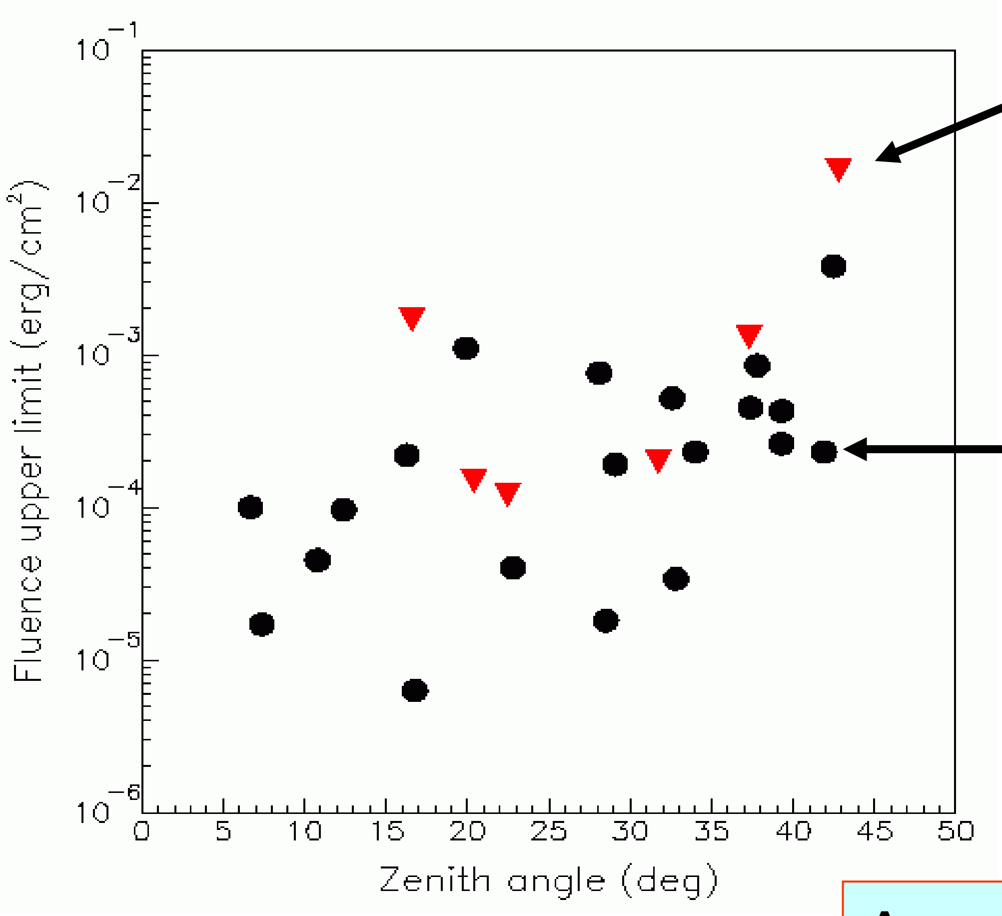
No excess > 4 standard deviations

Expected Crab signal, 0,8 σ

The detector and the analysis method seem to work properly

# GRB fluence upper limits

Energy range 1-100 GeV




**Red triangles**

- redshift is known
- extragal. asbsorption: YES

**Black dots**

- redshif is unknown
- extragal. asbsorption: NO

Assumed GRB spectrum: $\propto E^{-2.5}$

# p-air cross section analysis: Data selection

- **Event selection based on:**

  **(a) “shower size” on detector, $N_{hit}$ (pad multiplicity)**

  **(b) core reconstructed in a fiducial area (60 x 60 m$^2$)**

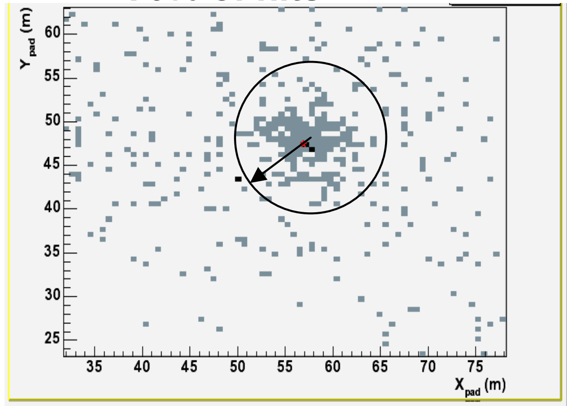
  **(c) constraints on Strip density (> 0.2/m$^2$ within $R_{70}$ )**

  **and shower extension ($R_{70}$ < 25m)**

**$N_{hit}$ is used to get two separated E sub-samples**

**($N_{hit}$= 300÷1000, $N_{hit}$ > 1000)**

**$R_{70}$: radius of circle including 70% of hits**



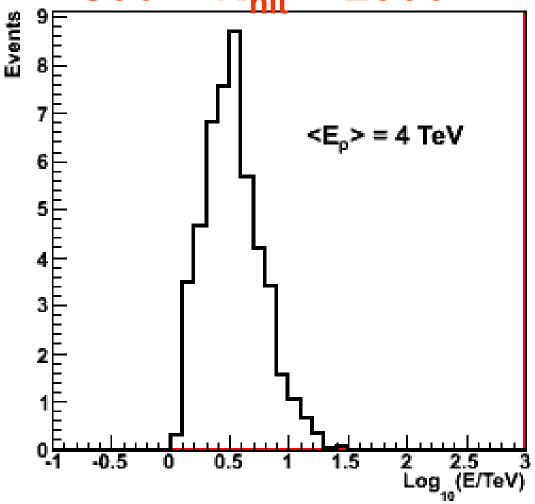

## Full Monte Carlo simulation:

Corsika showers

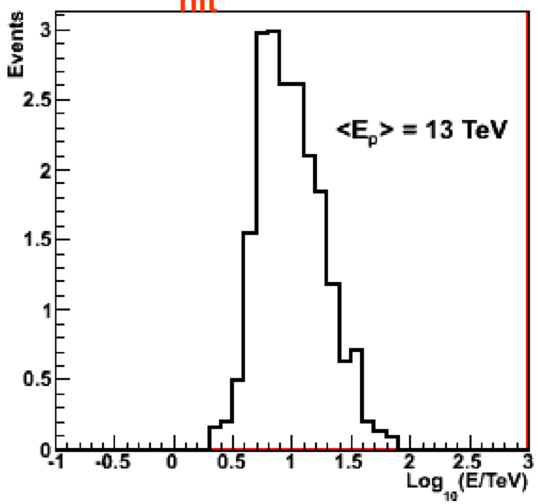
QGSJET int. model

GEANT detector simulation

**300 < $N_{hit}$ < 1000**

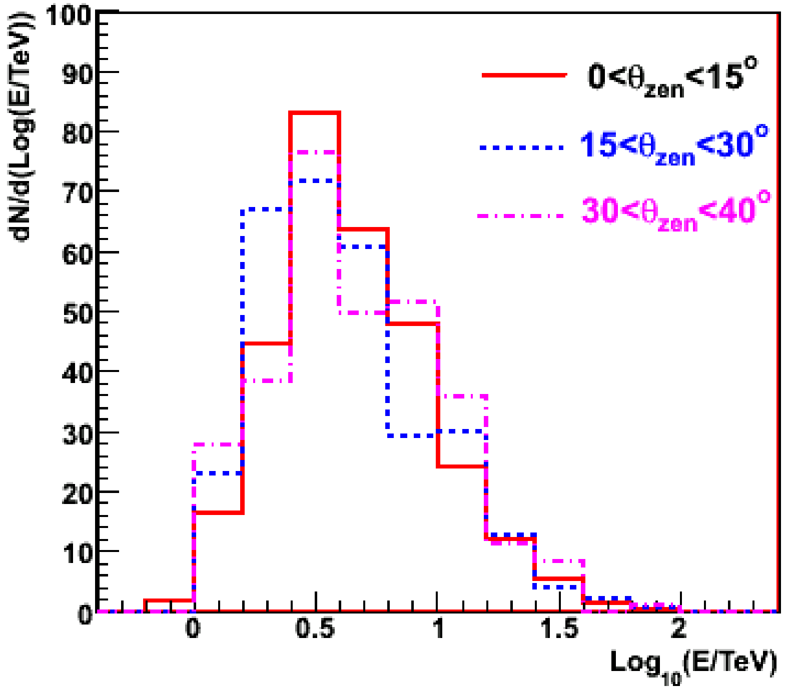



**$N_{hit}$ > 1000**

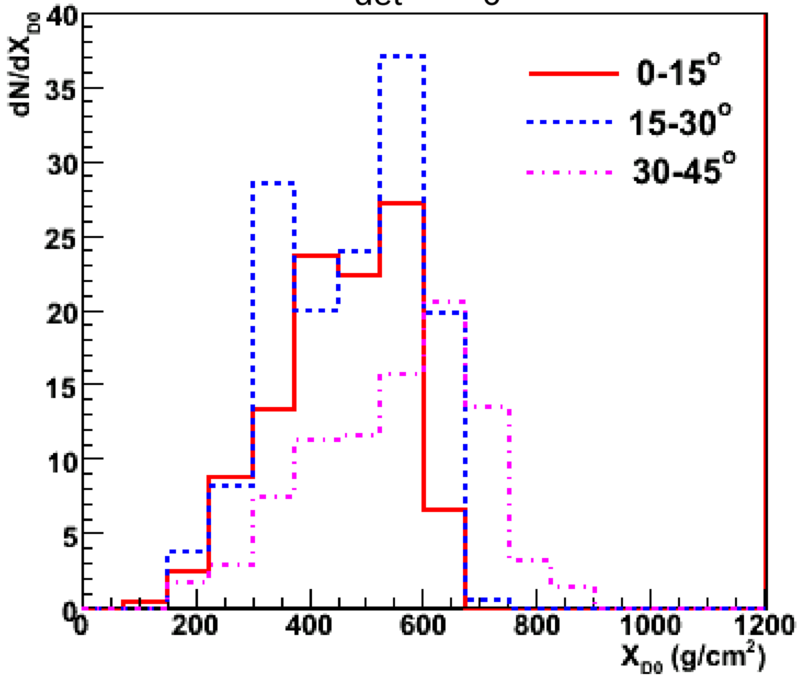


# p-air cross section analysis: Cuts in-dependence on the zenith angle

Energy




$X_{det} - X_0$

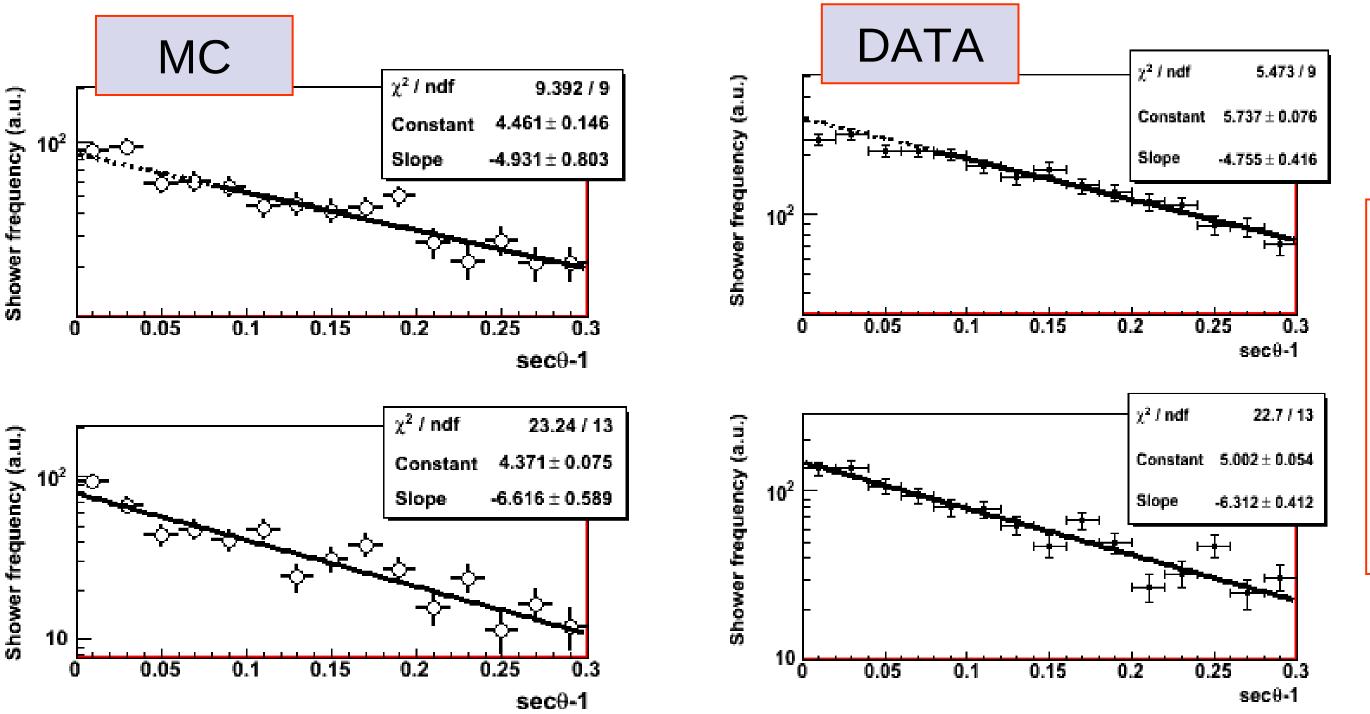



**No significant zenith angle dependence below 30 degrees.**

**A slight shift might be seen above 40 degrees.**

**In this analysis we stop at 40 degrees**

# p-air cross section analysis: The sec(θ) distributions




Exponential dependence in both MC and real data.

Larger contamination of "external" showers in the low energy bin

| Nhit | <E> | k | $\sigma_{CR\text{-}Air}$ (mb) |
|---|---|---|---|
| 300 ÷ 1000 | 3.9 ± 0.1 TeV | 1.6 ± 0.3 | **299 ± 55** |
| > 1000 | 12.7 ± 0.4 TeV | 1.2 ± 0.1 | **306 ± 34** |

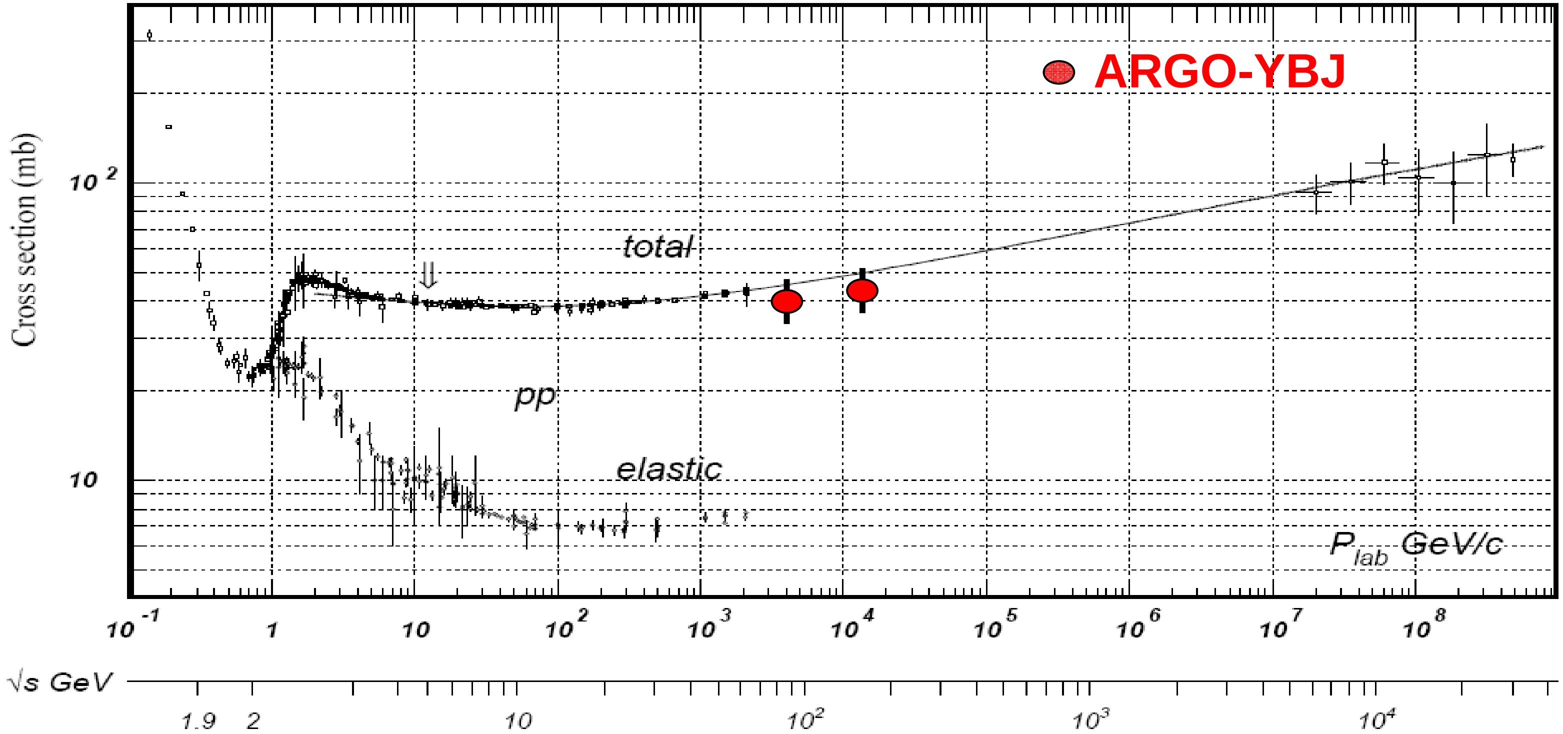
The contribution of **He primaries** has been checked to increase the cross section values by **7-9%** (depending on the assumed primary spectra).

Correction for heavier primaries are expected to be negligible.

$\sigma^{inel}_{p\text{-}Air} \Rightarrow \sigma^{tot}_{p\text{-}p}$

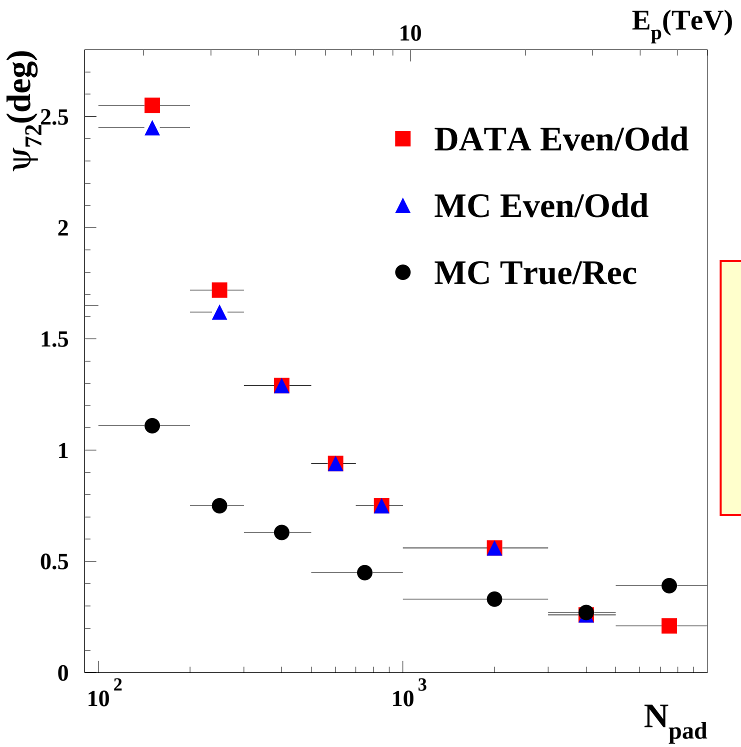
- **Glauber – Matthiae theory**
- **Durand – Pi**
- **Wibig – Sobczynska**
- **….**

**Models agree within few % in our energy range**



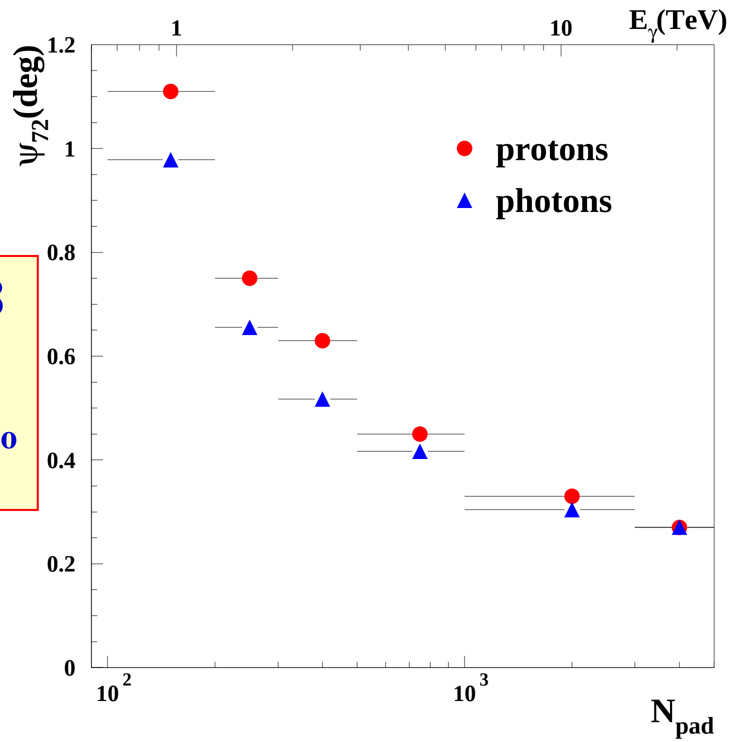

| Nhit | <E> | k | $\sigma_{CR\text{-}Air}$ (mb) | $\sigma_{p\text{-}Air}$ (mb) | $\sigma_{p\text{-}p}$ (mbarn) |
|---|---|---|---|---|---|
| 300 ÷ 1000 | 3.9 ± 0.1 TeV | 1.6 ± 0.3 | 299 ± 55 | 275 ± 51 | **40 ± 7** |
| > 1000 | 12.7 ± 0.4 TeV | 1.2 ± 0.1 | 306 ± 34 | 282 ± 31 | **43 ± 5** |

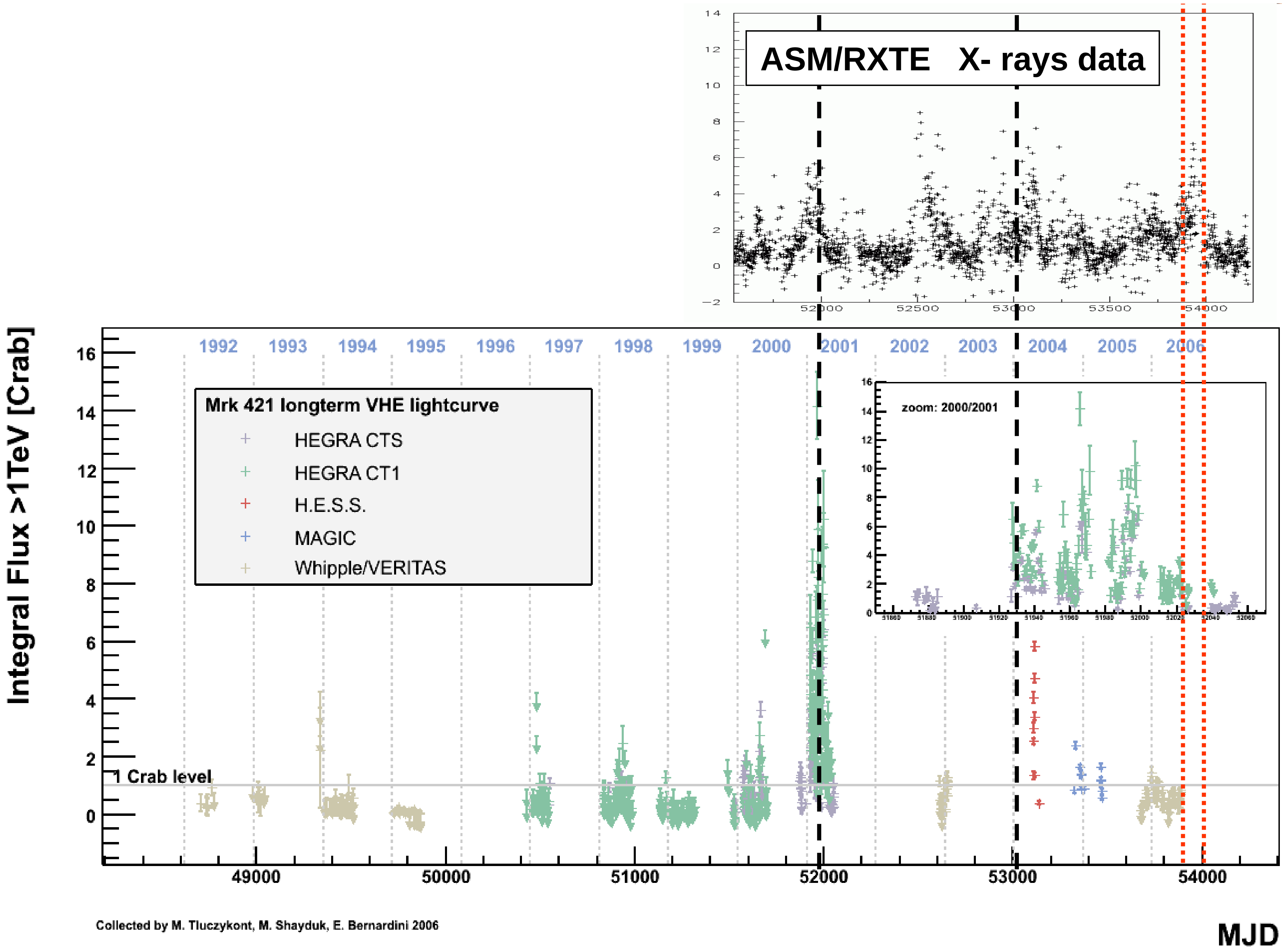
# Angular resolution




$\sigma_\theta = \Psi_{72}/1.58$

$\sigma_{\theta,mc}$=0,5 $\sigma_{\theta,eo}$
pure statistics




ASM/RXTE X- rays data
Mrk 421 longterm VHE lightcurve
HEGRA CTS
HEGRA CT1
H.E.S.S.
MAGIC
Whipple/VERITAS
zoom: 2000/2001
1 Crab level
Integral Flux >1TeV [Crab]
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
MJD
Collected by M. Tluczykont, M. Shayduk, E. Bernardini 2006

# *The ARGO-YBJ Experiment*

*A Sino-Italian Scientific Collaboration by*

Chinese Academy of Science (CAS)

Istituto Nazionale di fisica Nucleare (INFN)

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**Spokesmen**

**Prof. B. D’Ettorre Piazzoli**

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# Detector Control System

**Many detector and site parameter are continuously monitored**