Results from the ARGO-YBJ experiment

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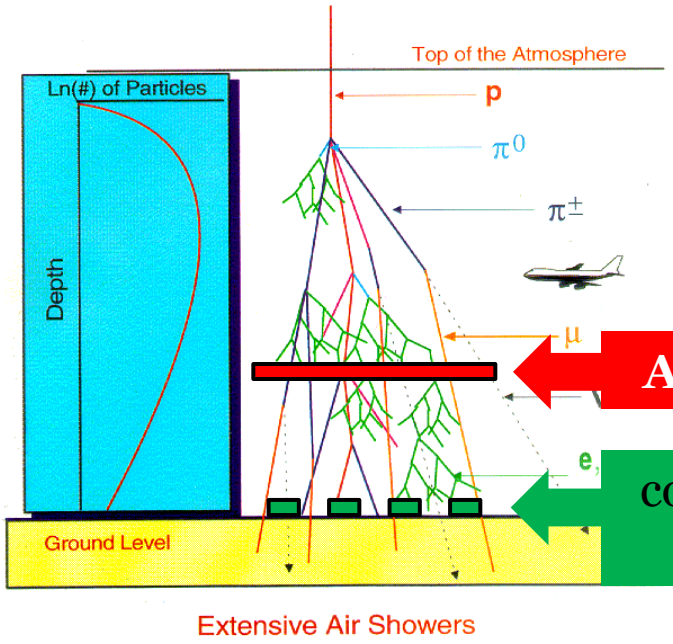
on behalf of the ARGO-YBJ collaboration

1. University of Rome Tor Vergata
2. INFN, sez.ne di Roma "Tor Vergata"

RPC2012

RPC2012

Frascati, February 6th, 2012

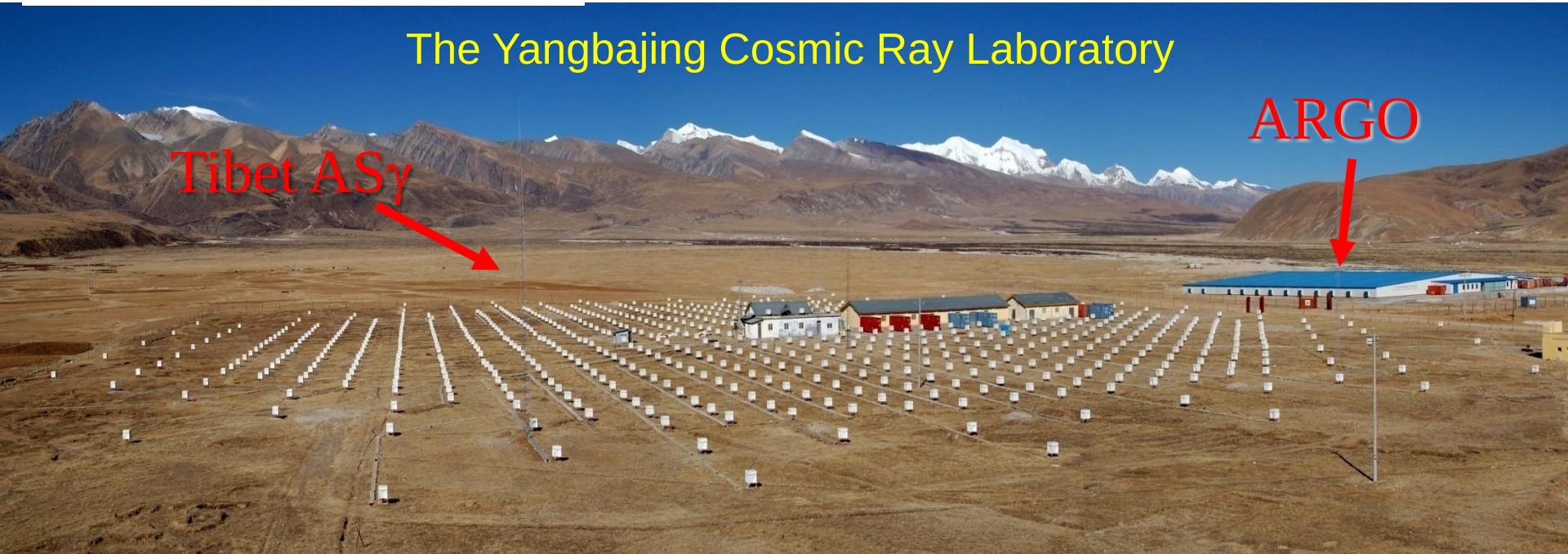


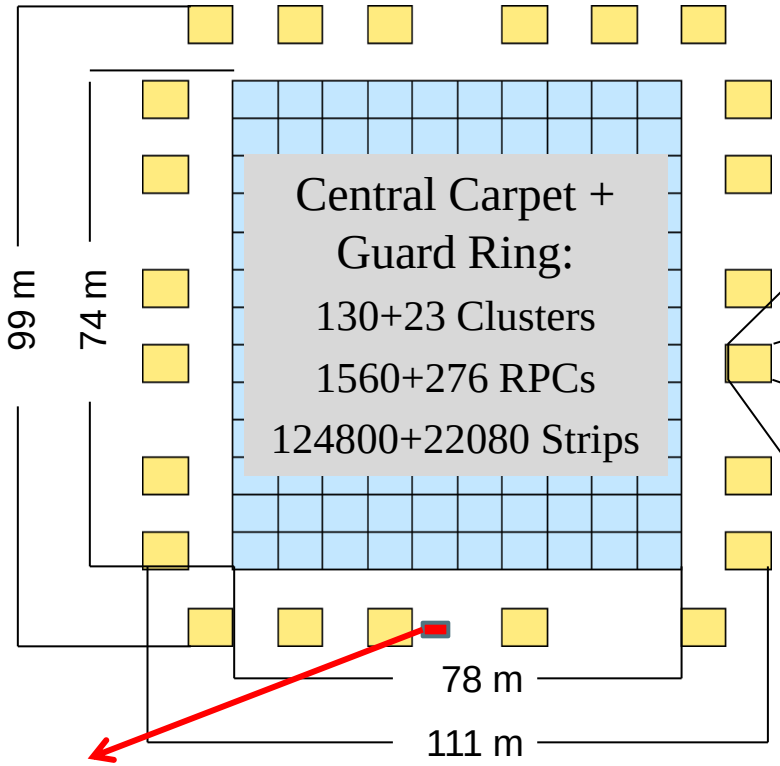
ARGO is an unconventional EAS-array exploiting the **full coverage** approach at **very high altitude** to detect small air showers at an energy threshold of a few hundreds of GeV.

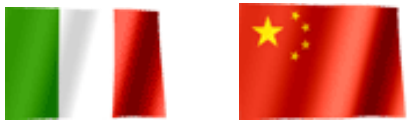
ARGO-YBJ **RPC technology** 1-technology experiment

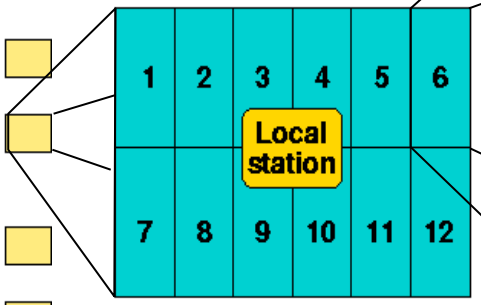
conventional EAS-array

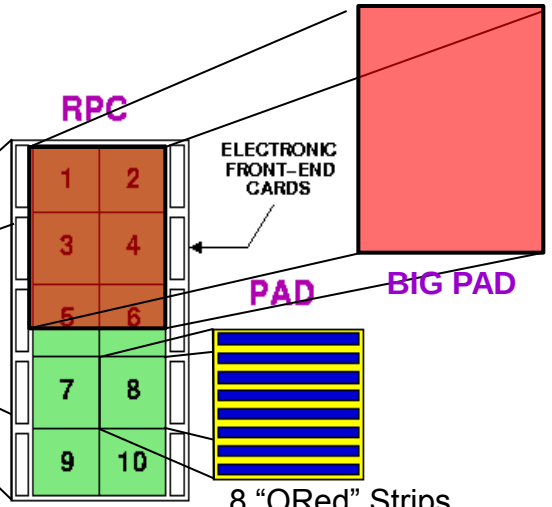
90 km Northward from Lhasa (Tibet)
4300 m above the sea level
~ 600 g/cm^2











1 CLUSTER = 12 RPCs
(5.7×7.6 m^2)

10 Pads
(56 x 62 cm^2)
for each RPC

8 "ORed" Strips
(6.5 x 62 cm^2)
for each Pad

BASIC D.A.Q. UNIT

Test telescope

large area:
5600+1100=6700 m^2
92% active surface

Scaler mode

Shower mode

DIGITAL readout
<23 part./m^2

ANALOG readout
<10^4 part./m^2

Primary energy

~GeV 0.6 – 100 TeV 0.1 –10 PeV

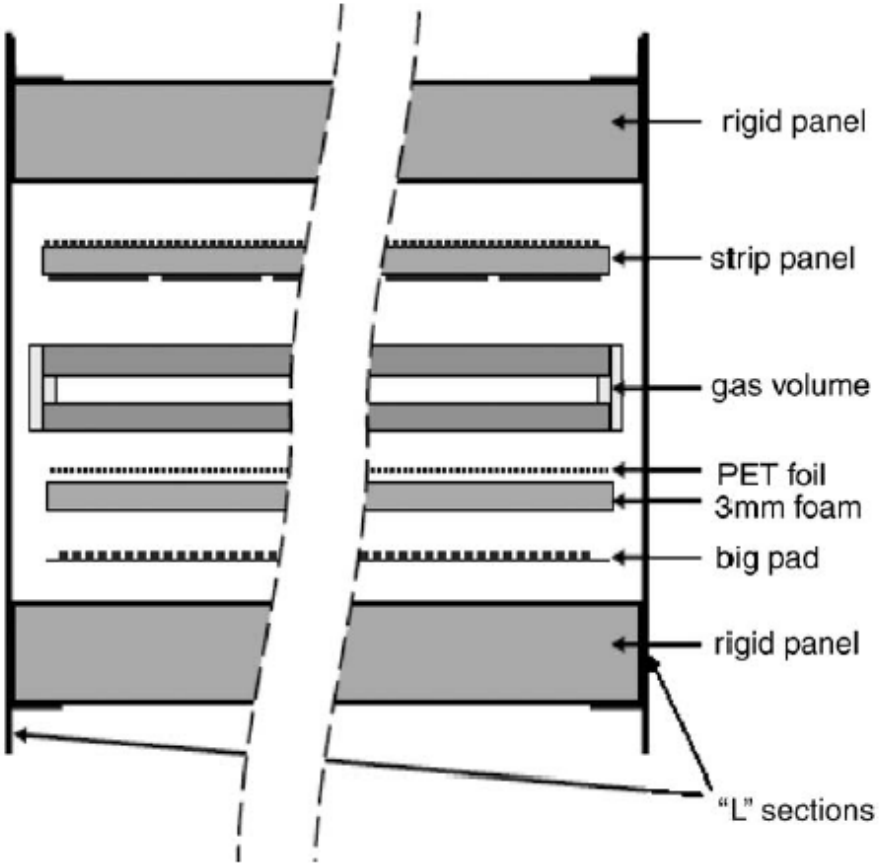


Fig. 1. Cross-view of the Argo-YBJ chamber.

Gas volume:

- 2 mm gap
- Plastic laminate electrodes (bakelite: $\rho \sim 5\ 10^{11}\ \Omega$ cm)
- Cylindrical spacers: 1 cm diameter, pitch 10 cm (~0.9% blind area)

Gas mixture:

$Ar/i\text{-}C_4H_{10}/C_2H_2F_4 = 15/10/75$
(RPCs operated in ***streamer regime***)
Gas flow: 4 volumes/day
No gas recover system implemented

Average strip multiplicity: 1.2

Applied **High Voltage = 7200 V**
No hardware correction for T/p effect applied

HV, LV, currents and operating conditions of all the RPCs, as well as the environment conditions (temperature, pressure, atmopheric electric field), are continuously monitored by the **D**etector **C**ontrol **S**ystem (**DCS**, see the poster by P. Camarri).

Operation modes

Shower mode

Trigger : number of fired pads (N_{pad}) within 420 ns
on the central carpet
for N_{pad} > 20, rate ~ 3.5 kHz (~220 GBytes/day)

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

Aims : cosmic-ray physics (threshold ~ 600 GeV)
VHE g-astronomy (threshold ~ 300 GeV)
gamma-ray burst physics

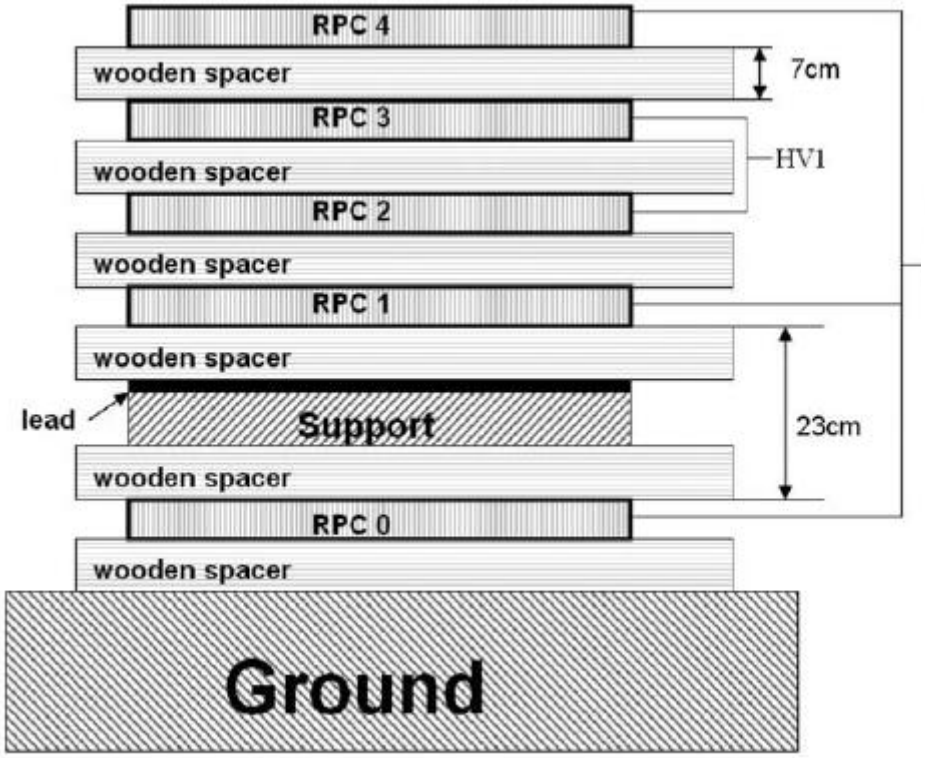
Scaler mode

counting rates (>1,>2,>3,>4 coincidences within 150 ns)
for each cluster, rate ~ 40 kHz

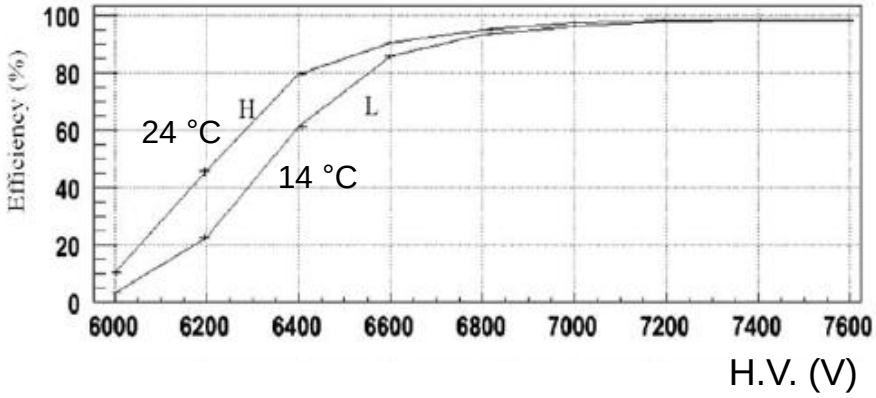
Aims: detector and environment monitor
flaring phenomena (gamma ray bursts, solar flares)
with a threshold of few GeV

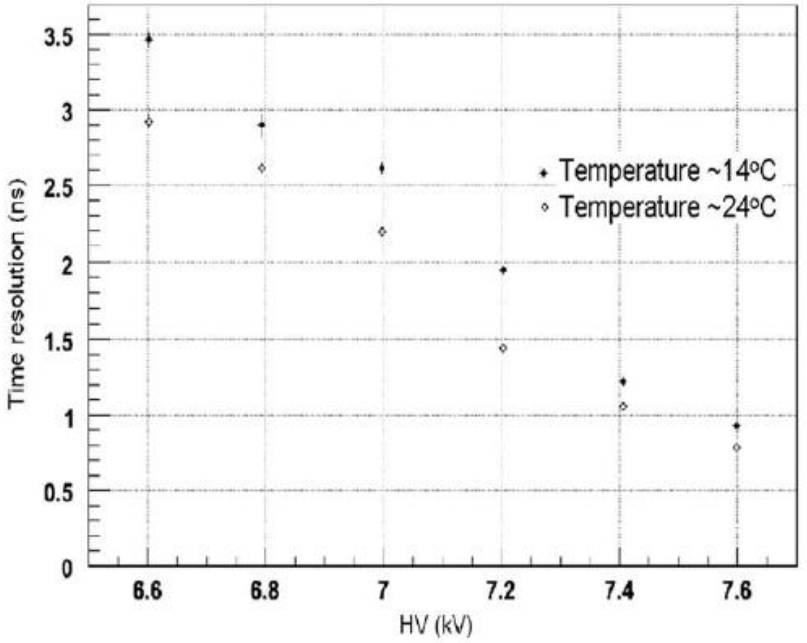
STABLE DATA TAKING SINCE NOVEMBER 2007
>3 10^{11} EVENTS COLLECTED

Performance of the ARGO-YBJ RPCs



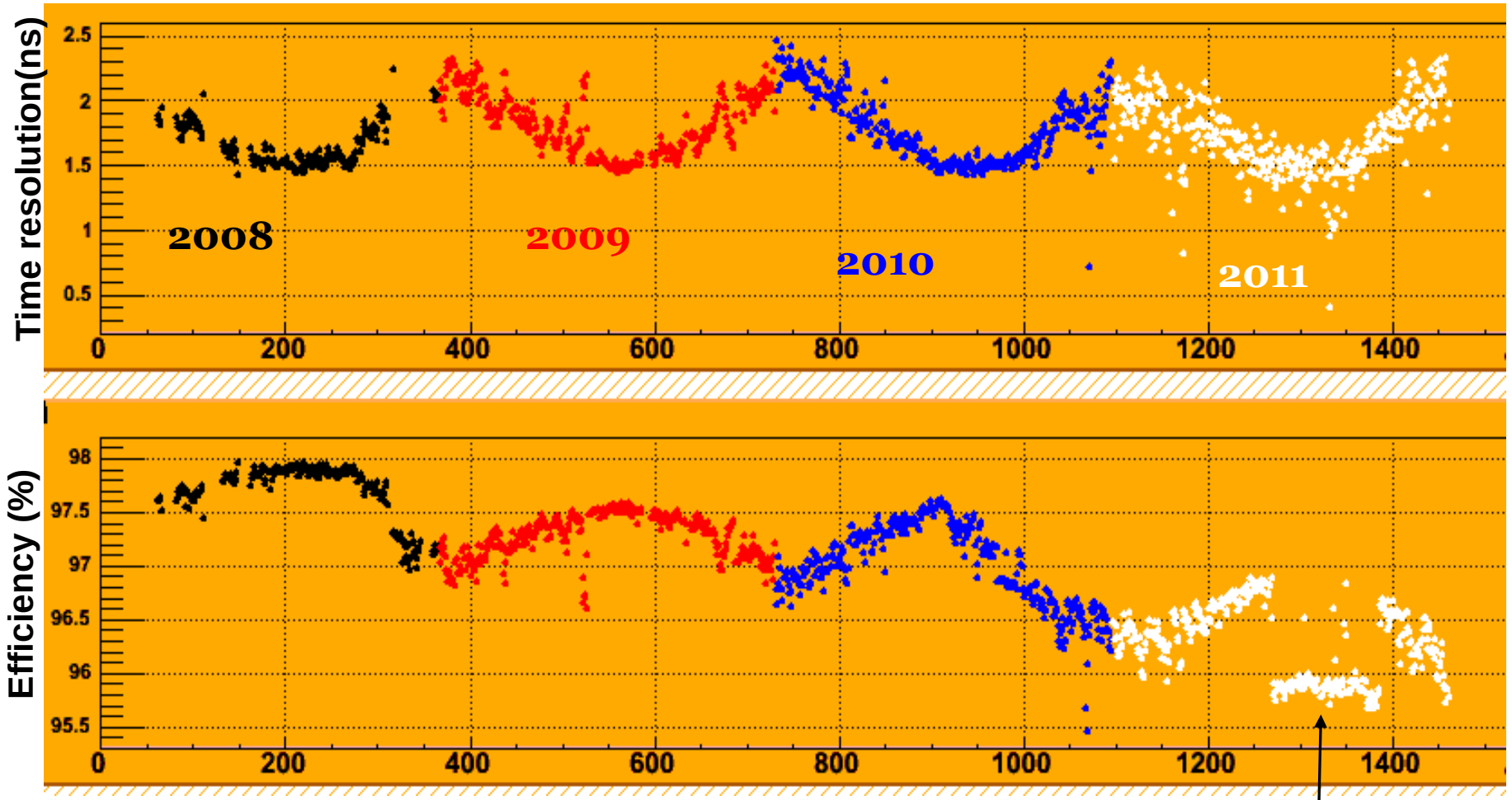
7°-10°C daily excursion



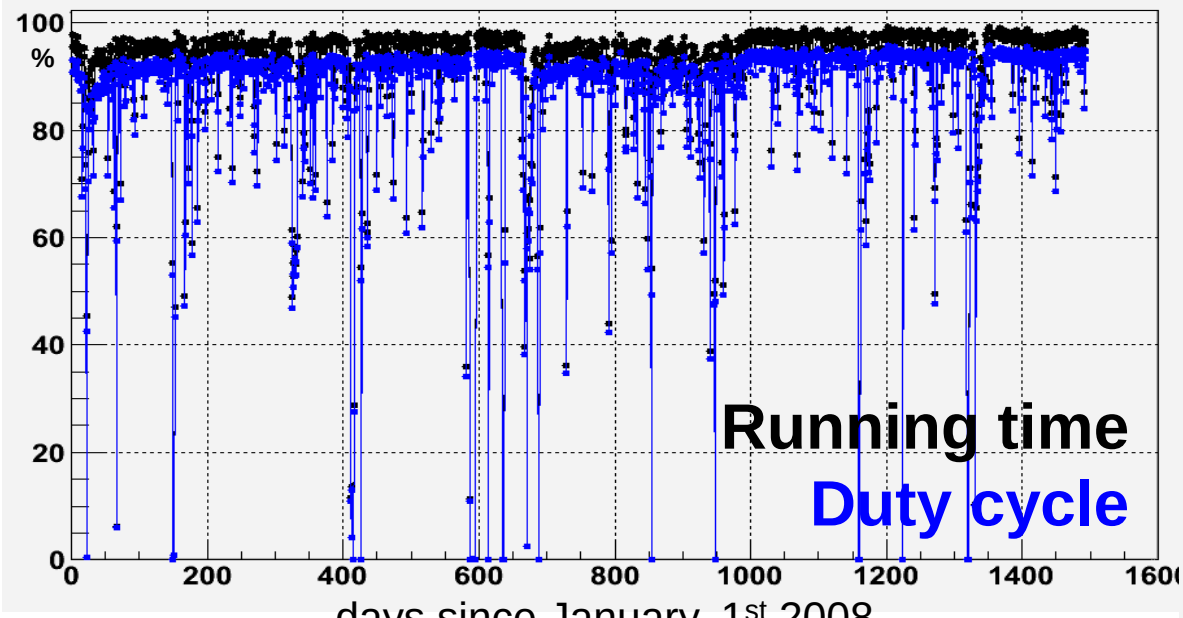


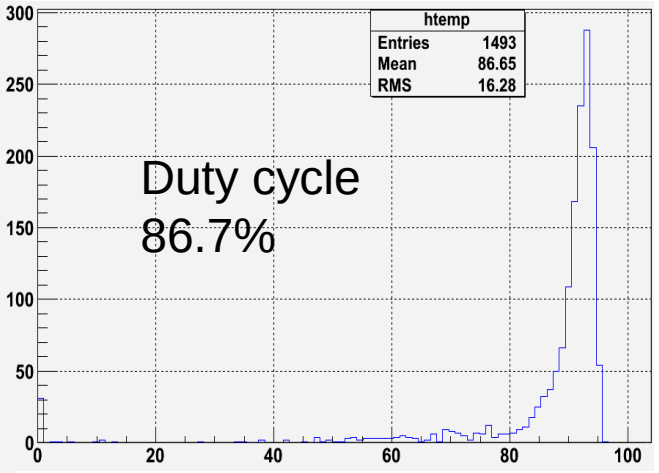
The test telescope is operated with the whole experiment. Data from the telescope are inserted and processed in the mainstream of the shower operating mode.

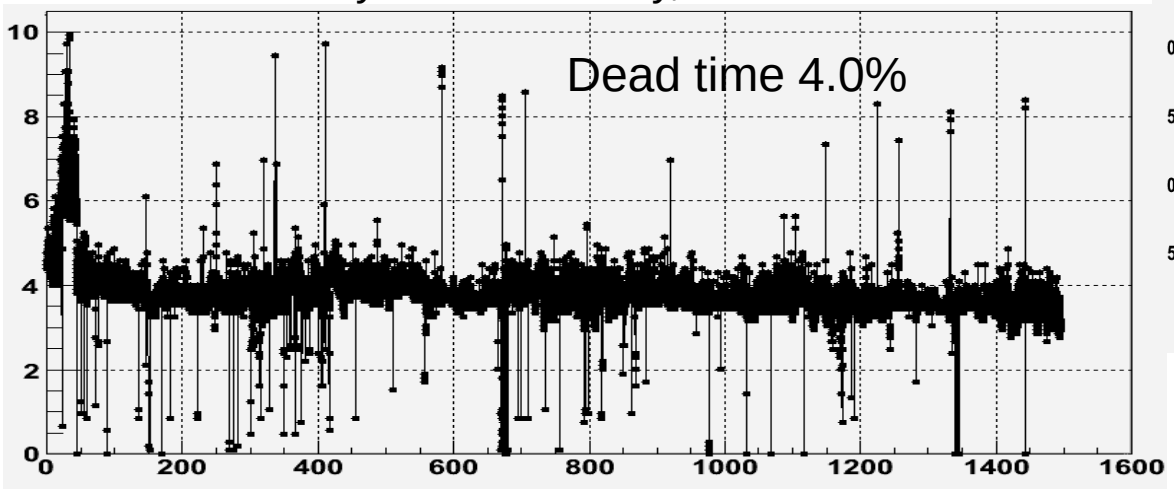
Performance of the ARGO-YBJ RPCs VS time

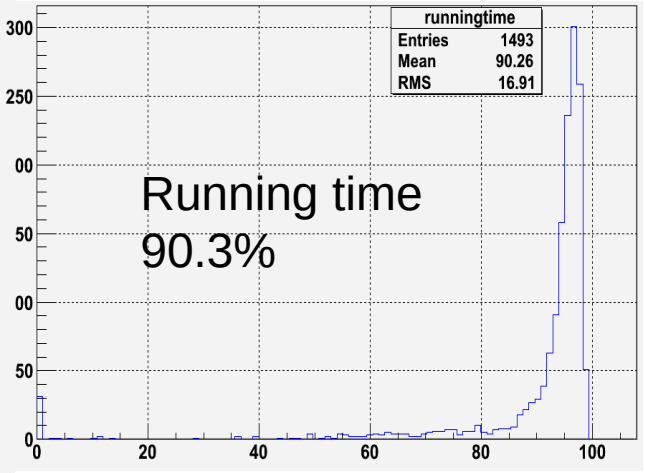


Performance of the ARGO-YBJ experiment



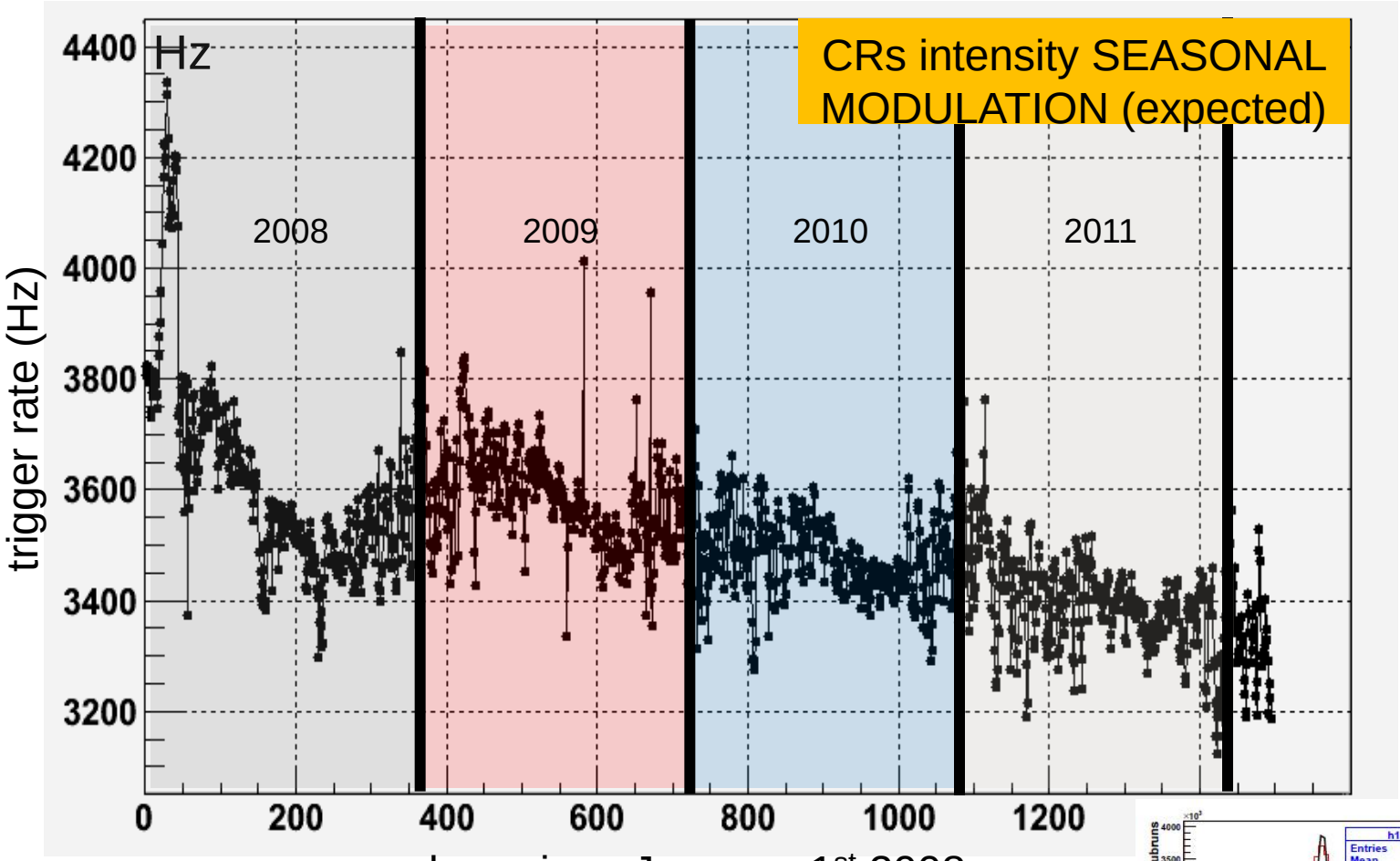


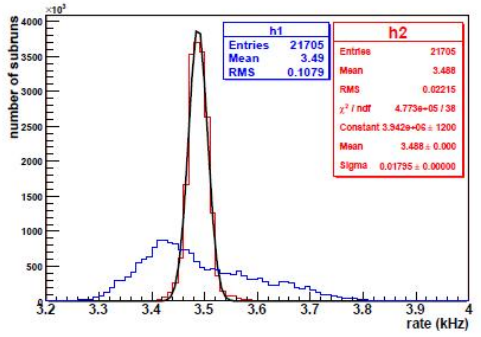




Most of deviations from the average are test runs.

Performance of the ARGO-YBJ experiment

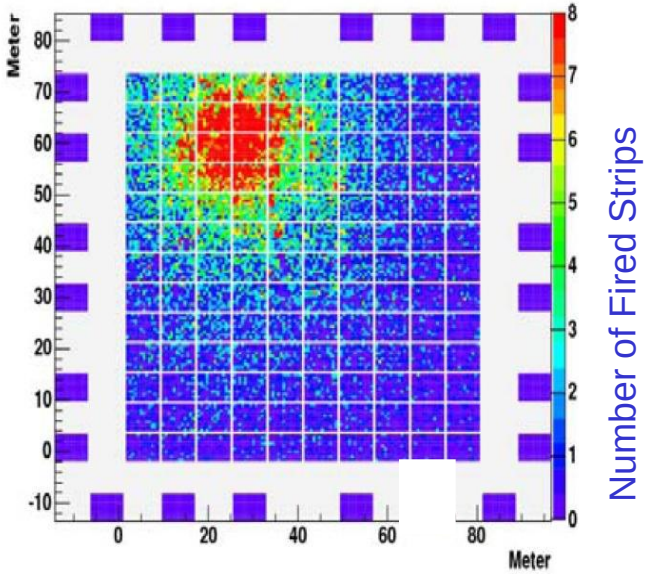


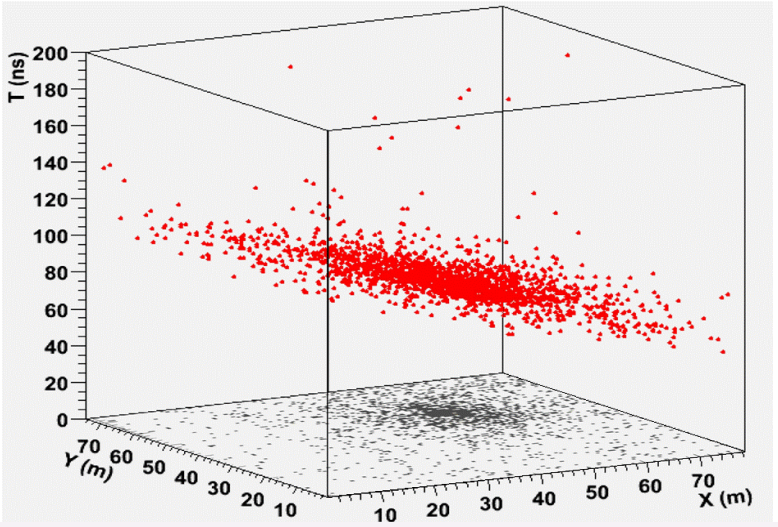


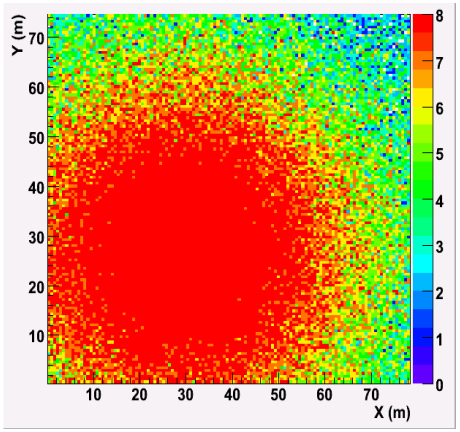
Intrinsic trigger rate stability 0.5%

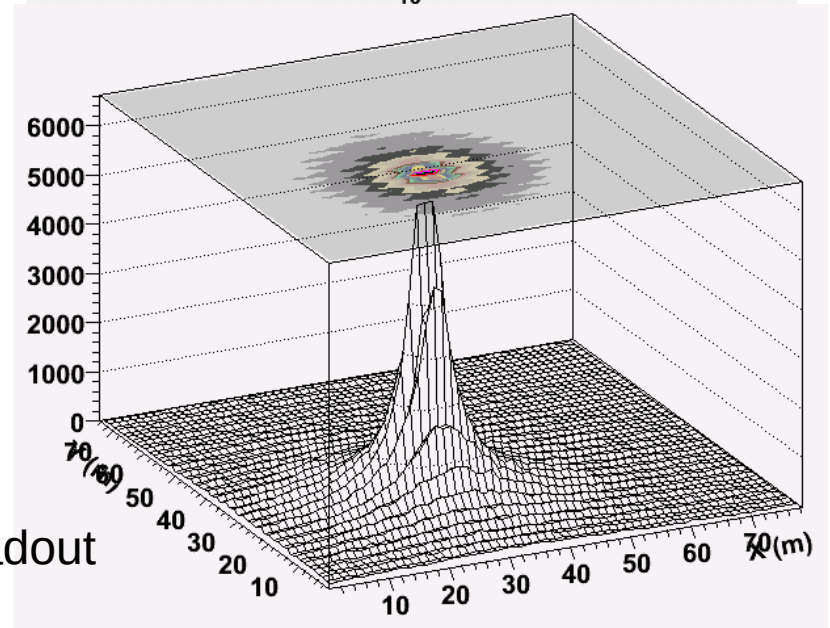
(i.e. after corrections for the T/p effect in the atmosphere)

Unprecedented detail in shower imaging.









Digital readout saturation → analog readout

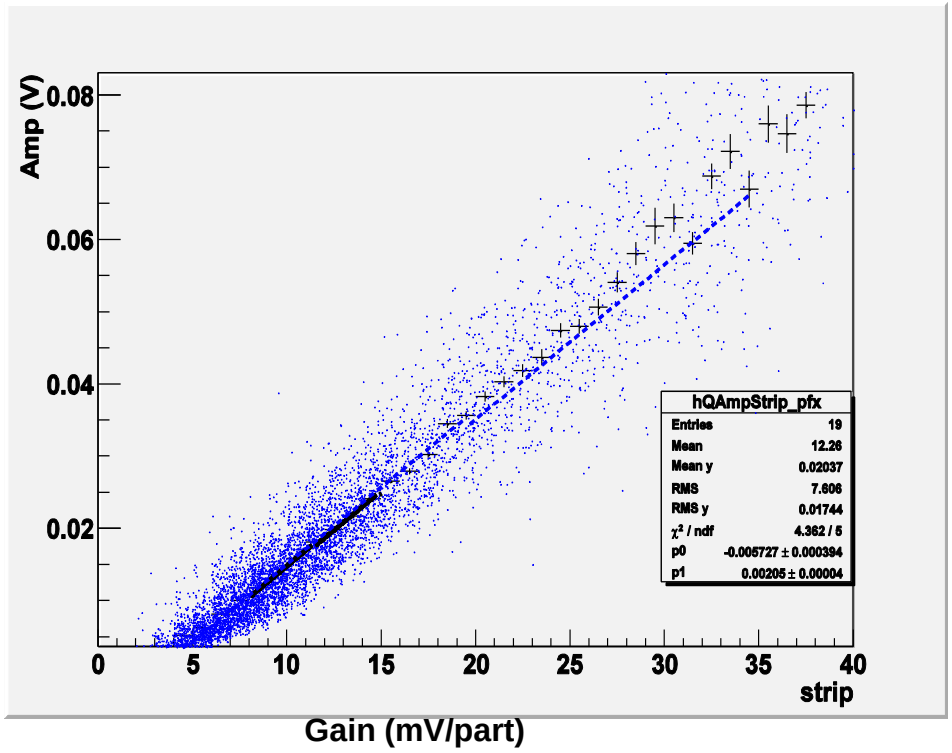
Calibration and stability of the analog readout

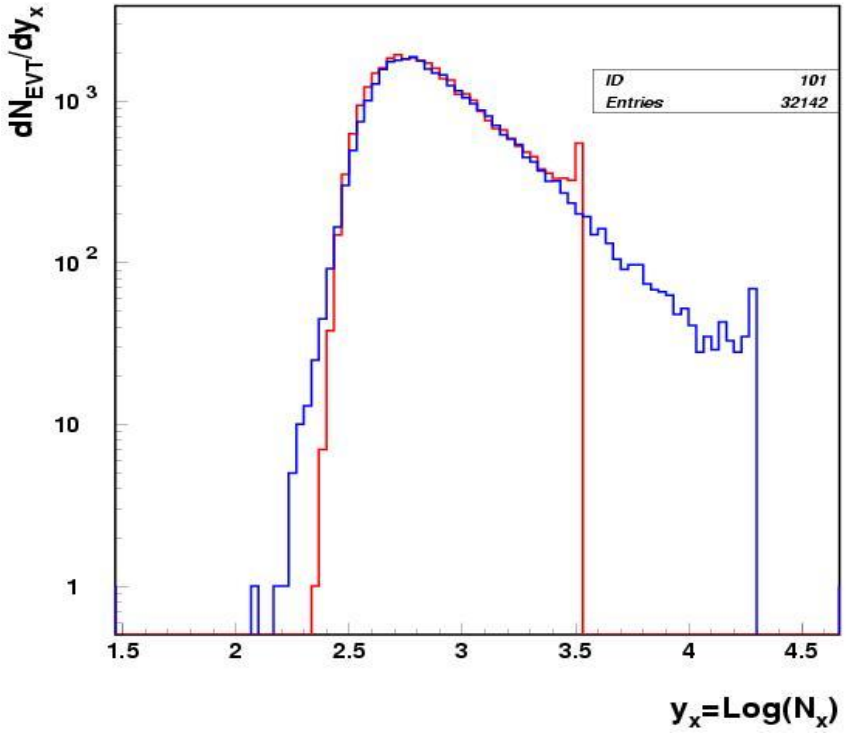
Analog readout system

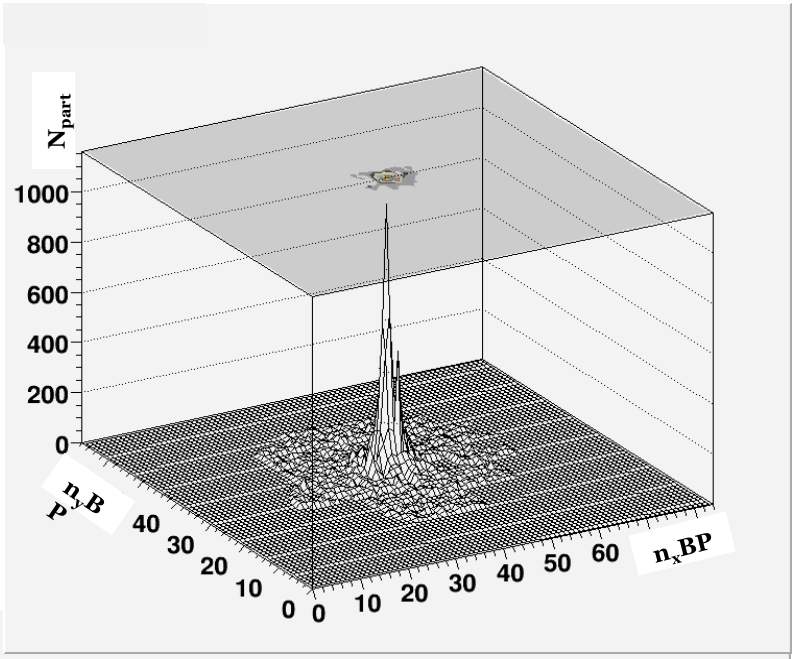
The system can be operated with different full scale (f.s) namely 0.33, 0.66, 1.3, 2.5, 5, 10, 20 and 40 V. The higher the scale, the higher the energy threshold. ***Operated since December 2009.***

The smallest f.s. can be used to calibrate the ADC gain with the digital readout system

Spectrum of the particle number of a cluster obtained by using both digital and analog info at the low scale.





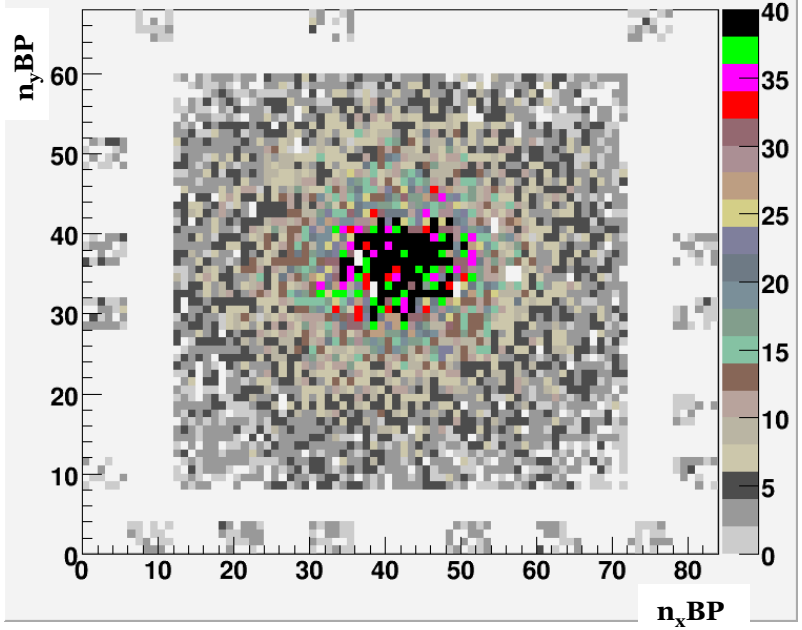


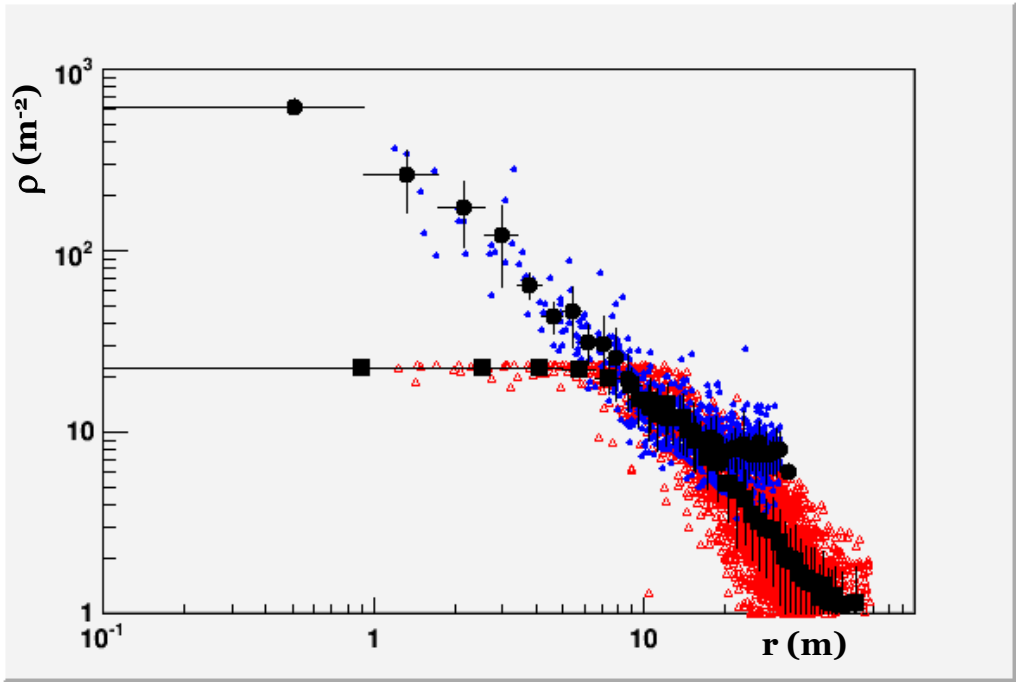
Digital-analog readout calibration within the same event.

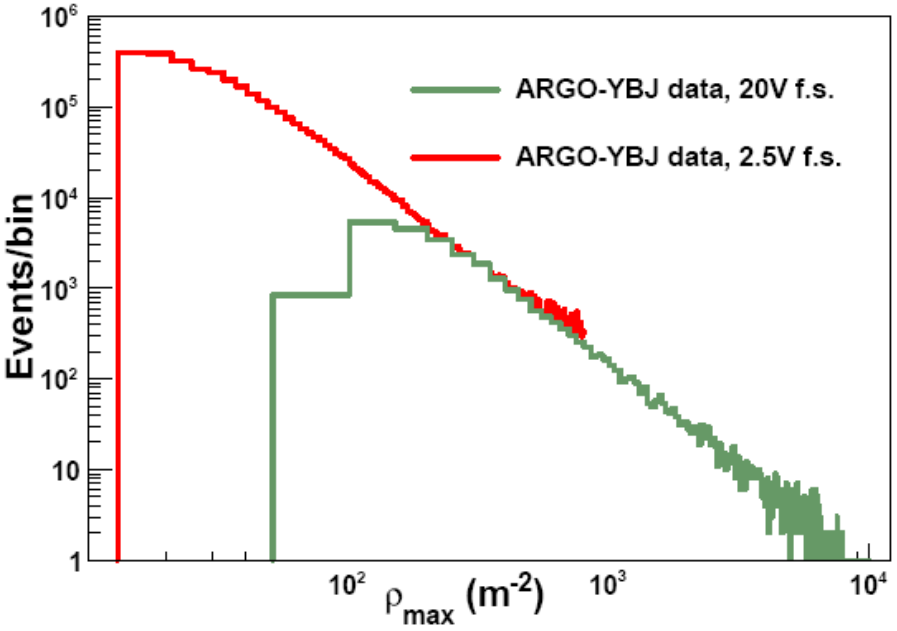
Digital readout saturation:
8 strip /1 pad=22 part/m^2

Analog readout 2.5 V fs:
1250 part / 1 bpad=750 part/m^2

RUN_95724_ev_51_PMax_1052







ρ_{max} = 300m^{-2} normalization point
Slopes: 2.23+/-0.01 (2.5 V) and 2.23+/-0.02 (20V).

Gain calibration between different f.s. scales

Spectrum of the maximum particle density measured on a big pad. Reciprocal normalization at 300 part/m^2

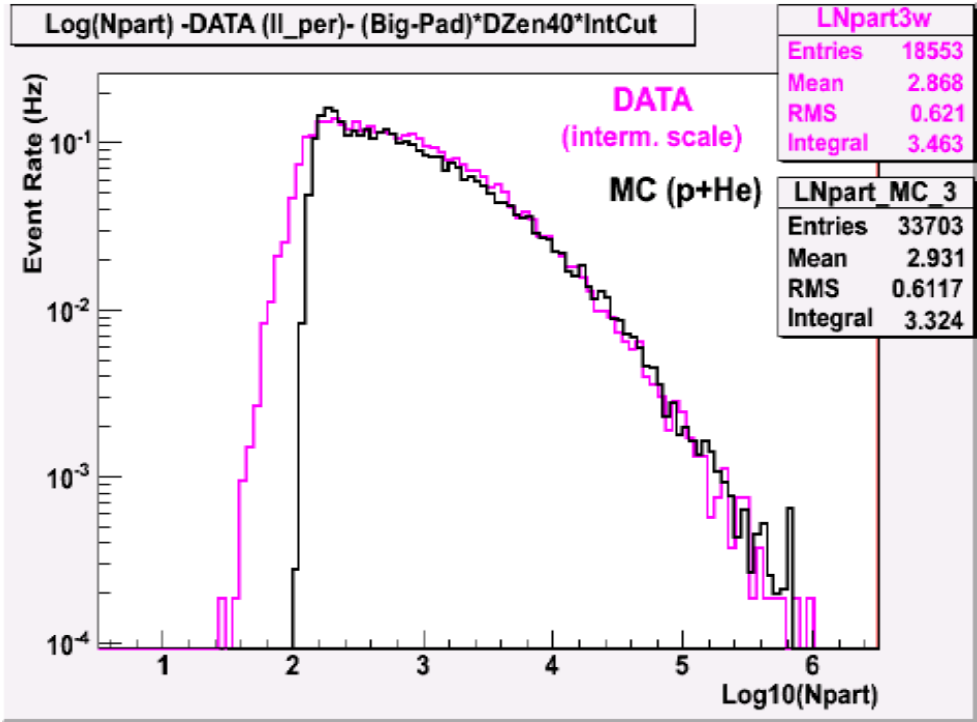
Accuracy: 0.9%.

Data-MC absolute comparison

Only internal events selected (64X64m^2)

Reconstructed arrival zenith angle: <40°

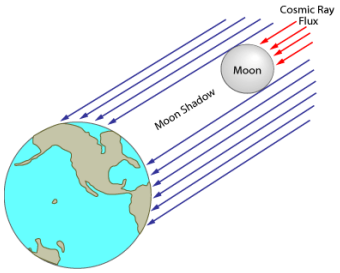
MC: p+He

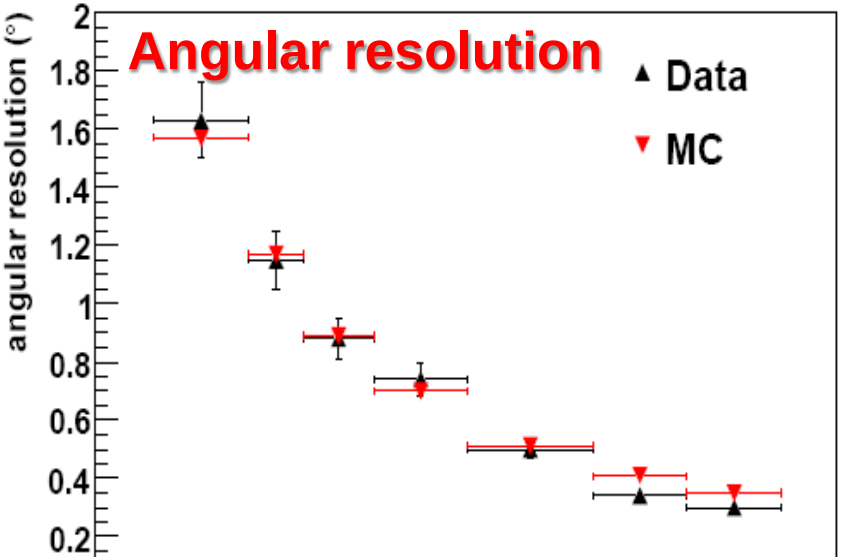


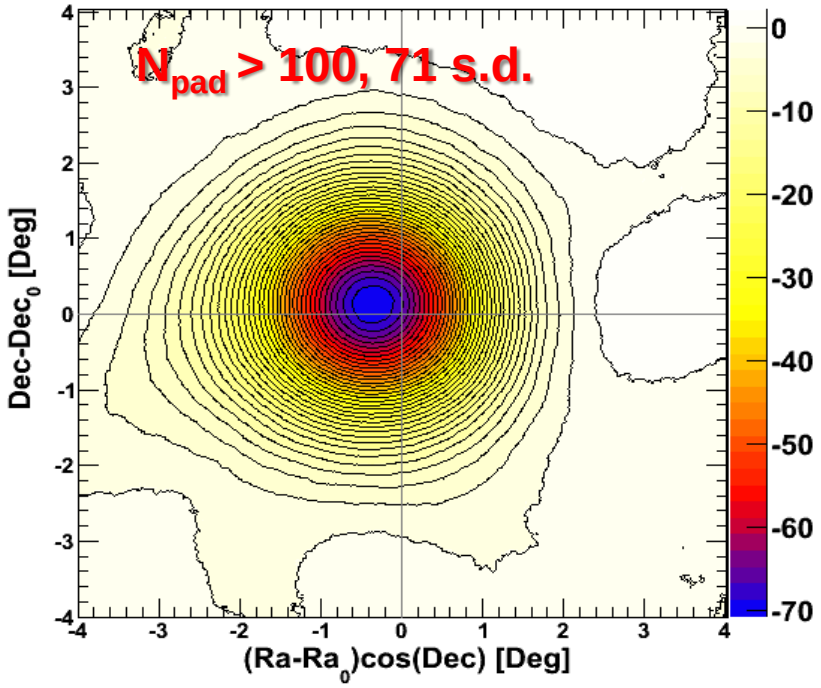
Moon shadow

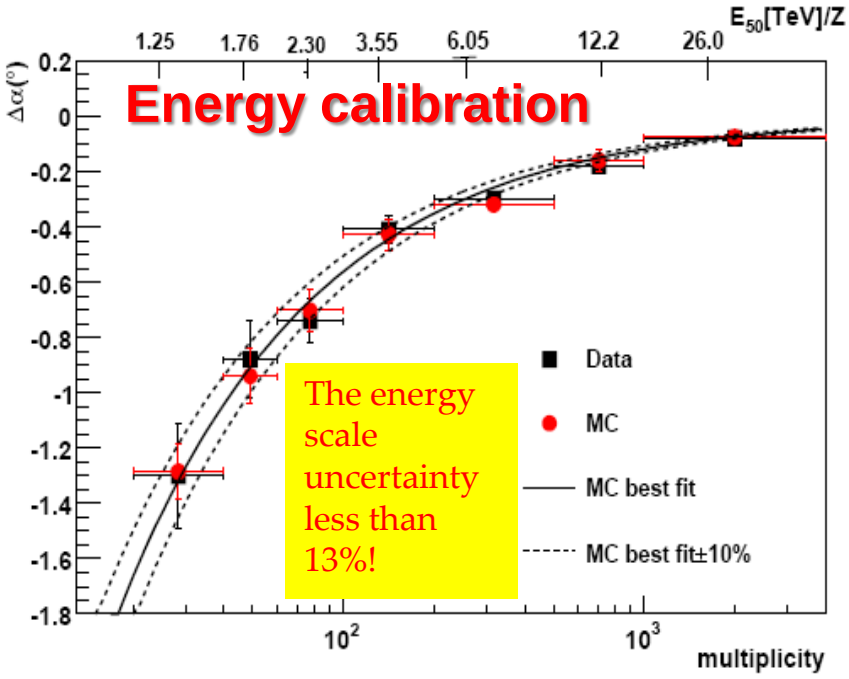
A natural tool
to evaluate
the performance
of the detector

- Pointing accuracy,
- Angular resolution,
- Absolute energy calibration.



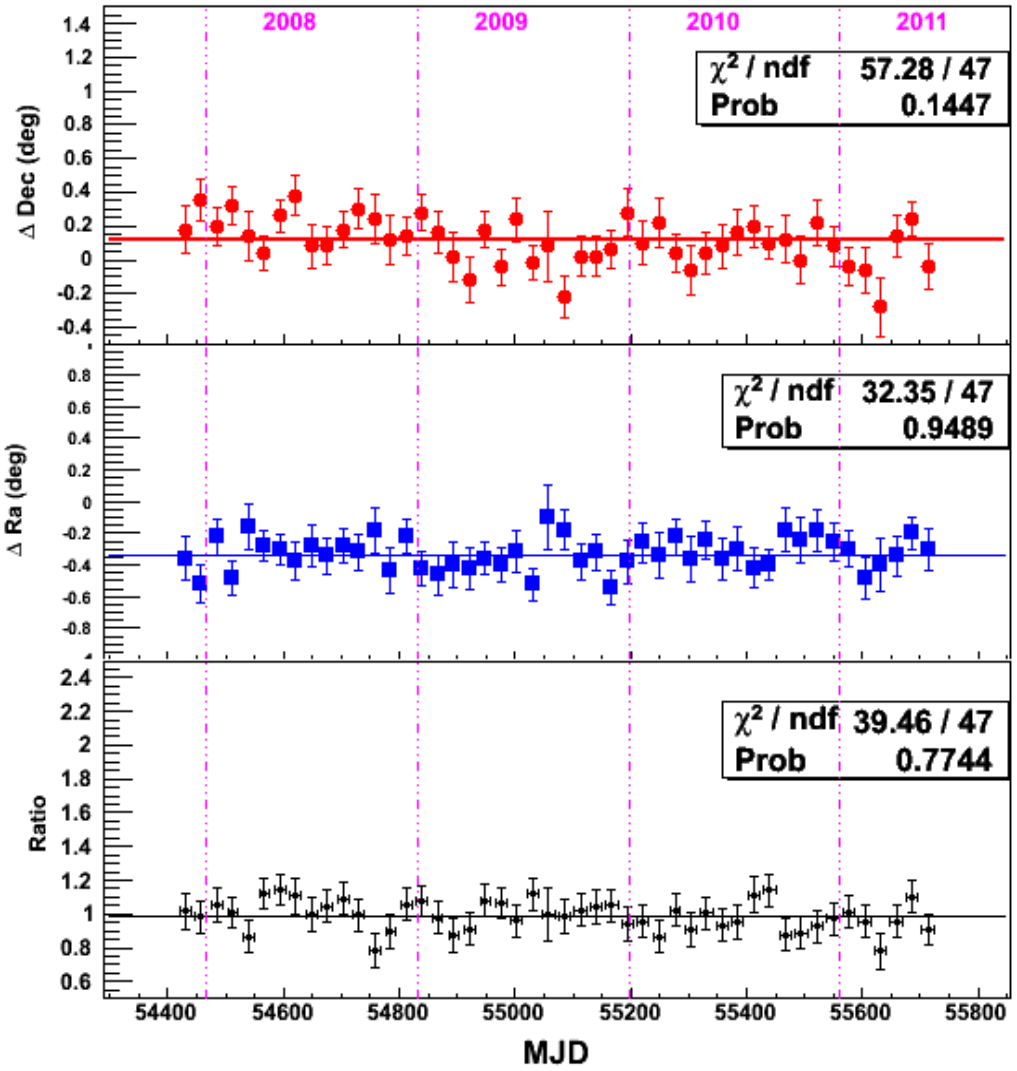






Moon shadow: detector stability

- N_{pad}>100: 10 s.d./month
- A tool to monitor the stability of the data and reconstruction
- Figures on the right: one point per month !
- Position stable at a level of 0.1°
- Angular resolution stable at a level of 10%

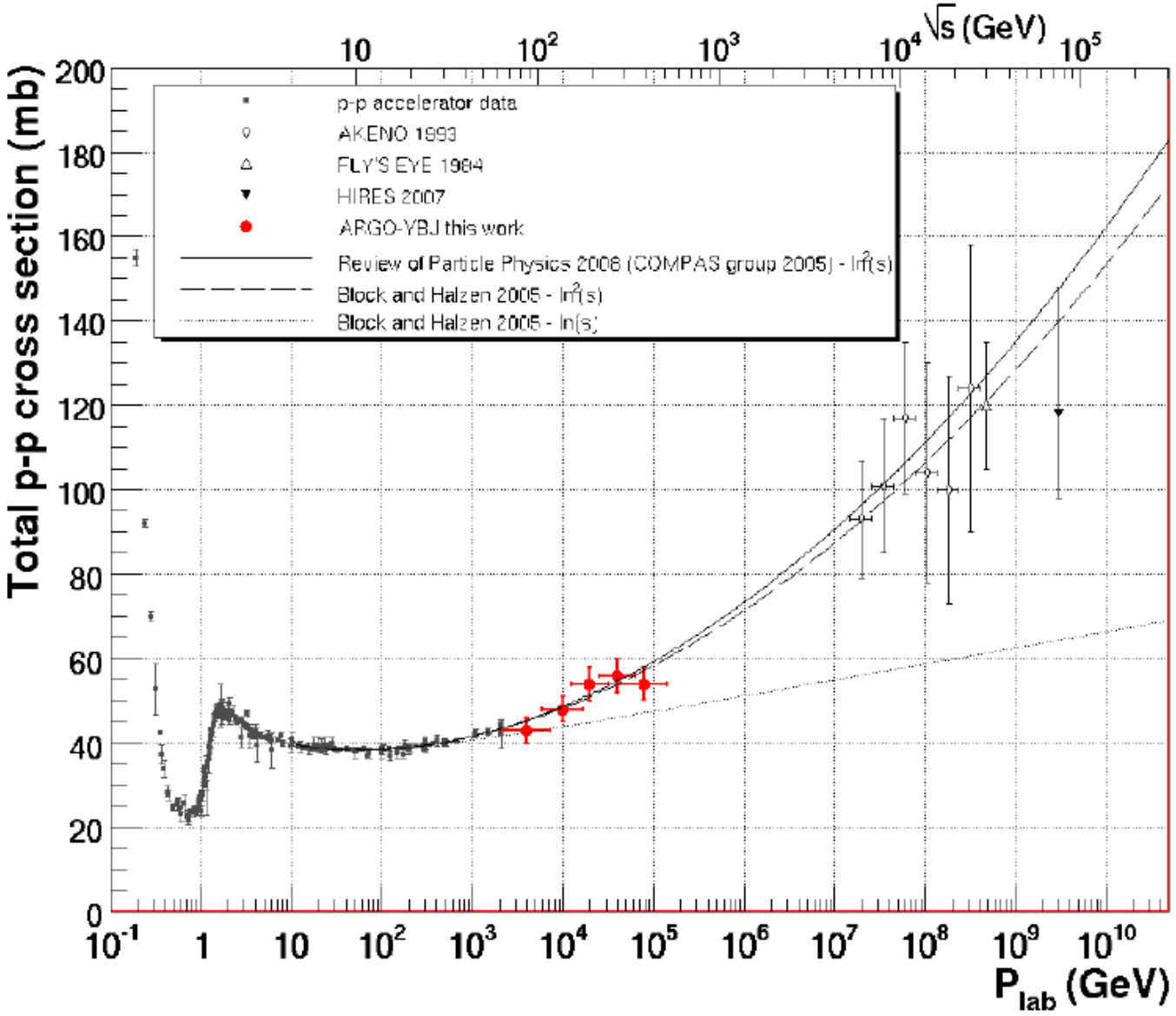


ARGO-YBJ Physics results

- **Measurement of the cosmic ray antiproton/proton flux ratio at TeV energies with the ARGO-YBJ detector.** Physical Review D 85, 022002 (2012)
- **Observation of TeV Gamma Rays from the Cygnus region with the ARGO-YBJ experiment.** Astrophysical Journal Letters 745 (2012) L22.
- **Early warning for VHE gamma-ray flares with the ARGO-YBJ detector.** Nucl. Instr. Meth. A 659 (2011) 428.
- **Observation of the cosmic ray moon shadowing effect with the ARGO-YBJ experiment.** Physical Review D 84 (2011) 022003.
- **Long-term monitor of Mrk 421 TeV emission using ARGO-YBJ experiment.** Astrophysical Journal 734 (2011) 110.
- **Mean Interplanetary Magnetic Field Measurement Using the ARGO-YBJ Experiment.** Astrophysical Journal 729 (2011) 113.
- **Gamma-Ray Flares from Mrk421 in 2008 observed with the ARGO-YBJ detector.** Astrophysical Journal Letters 714 (2010) L208.
- **Proton-air cross section measurement with the ARGO-YBJ cosmic ray experiment.** Phys. Rev. D 80 (2009) 092004.
- **ARGO-YBJ constraints on very high energy emission from GRBs.** Astroparticle Physics 32 (2009) 47.

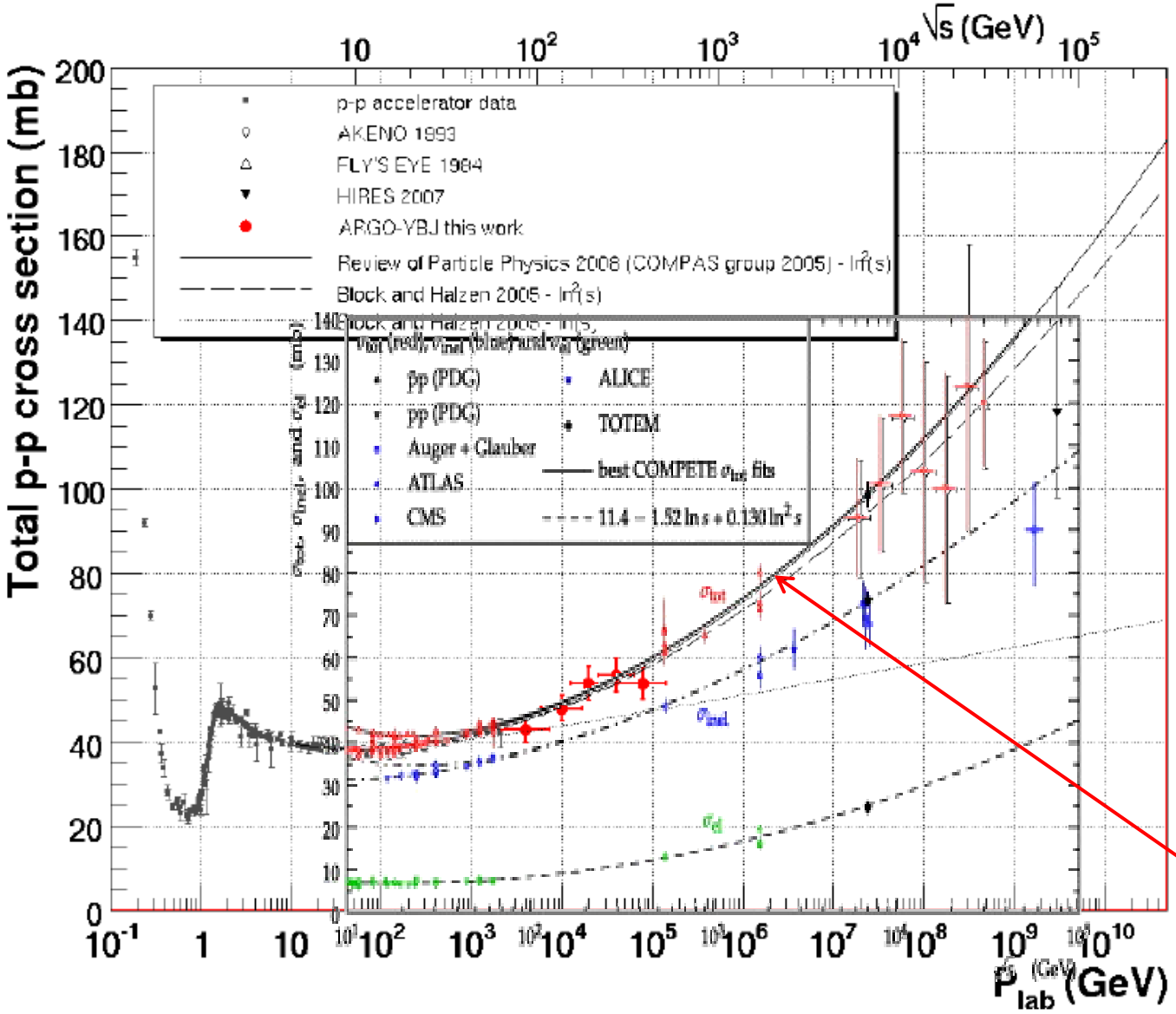
+ detector, method and techniques papers and 5 Physics papers more (rev. Ref.)

p-p total cross section



Measurement from ARGO-YBJ exploiting data collected in shower mode **(2009)**

p-p total cross section

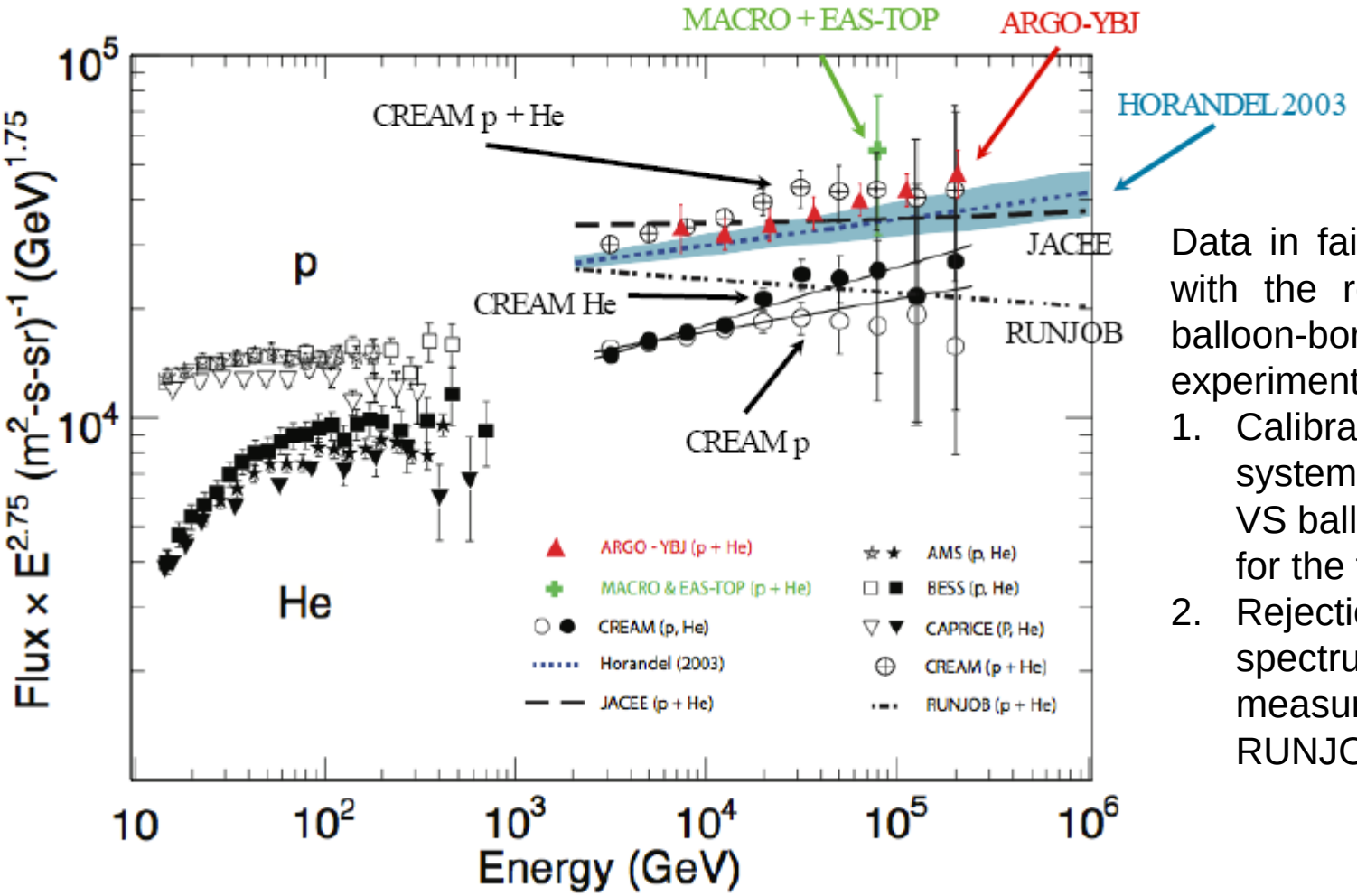


Measurement from ARGO-YBJ exploiting data collected in shower mode **(2009)**

Exploiting new data from experiments at accelerators, the systematic uncertainty related to the mass composition maybe hugely lowered. Work in progress for a measurement at $P_{lab}=2\ 10^{15}$eV with data from the analog readout.

Light component spectrum

First high-precision result of a ground based detector in the balloon energy range.



Data in fair agreement with the result of the balloon-borne experiment CREAM:

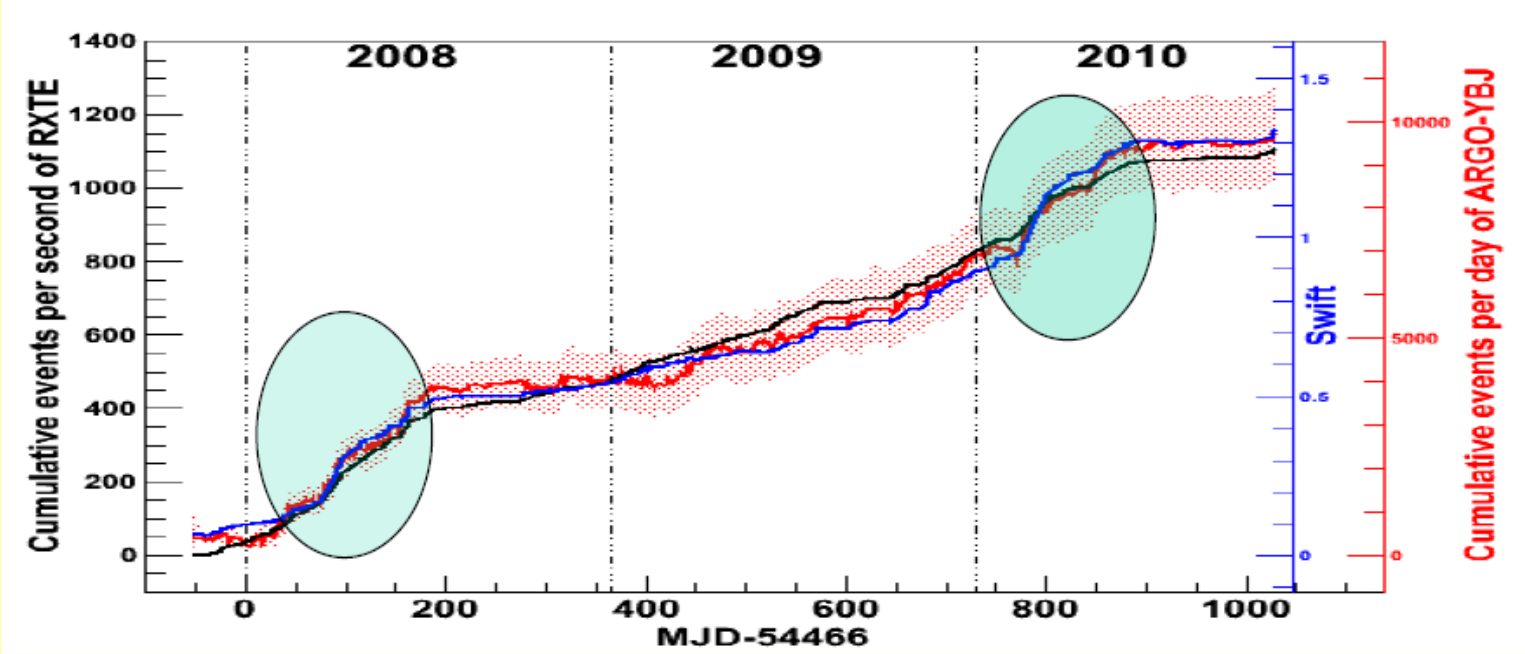
1. Calibration of systematics (g.b. VS ball.) possible for the first time.
2. Rejection of the He spectrum measured by RUNJOB.

Results obtained with the unfolding Bayesian technique.

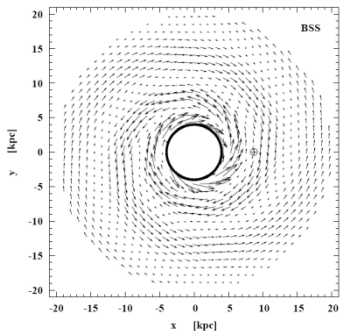
Mrk421 long-term monitoring (Bartoli et al. ApJ 734 (2011) 110)

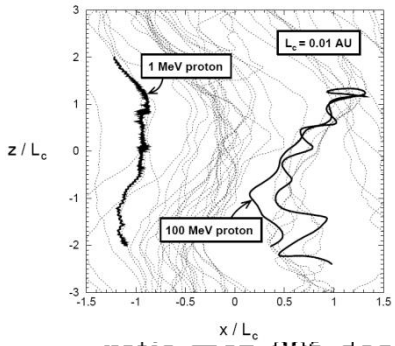
- ARGO-YBJ cumulative light curve (>TeV) compared with Swift and Rossi/RXTE data.
- Good correlation between TeV/X-ray data.
- Active and quiet periods are observed.

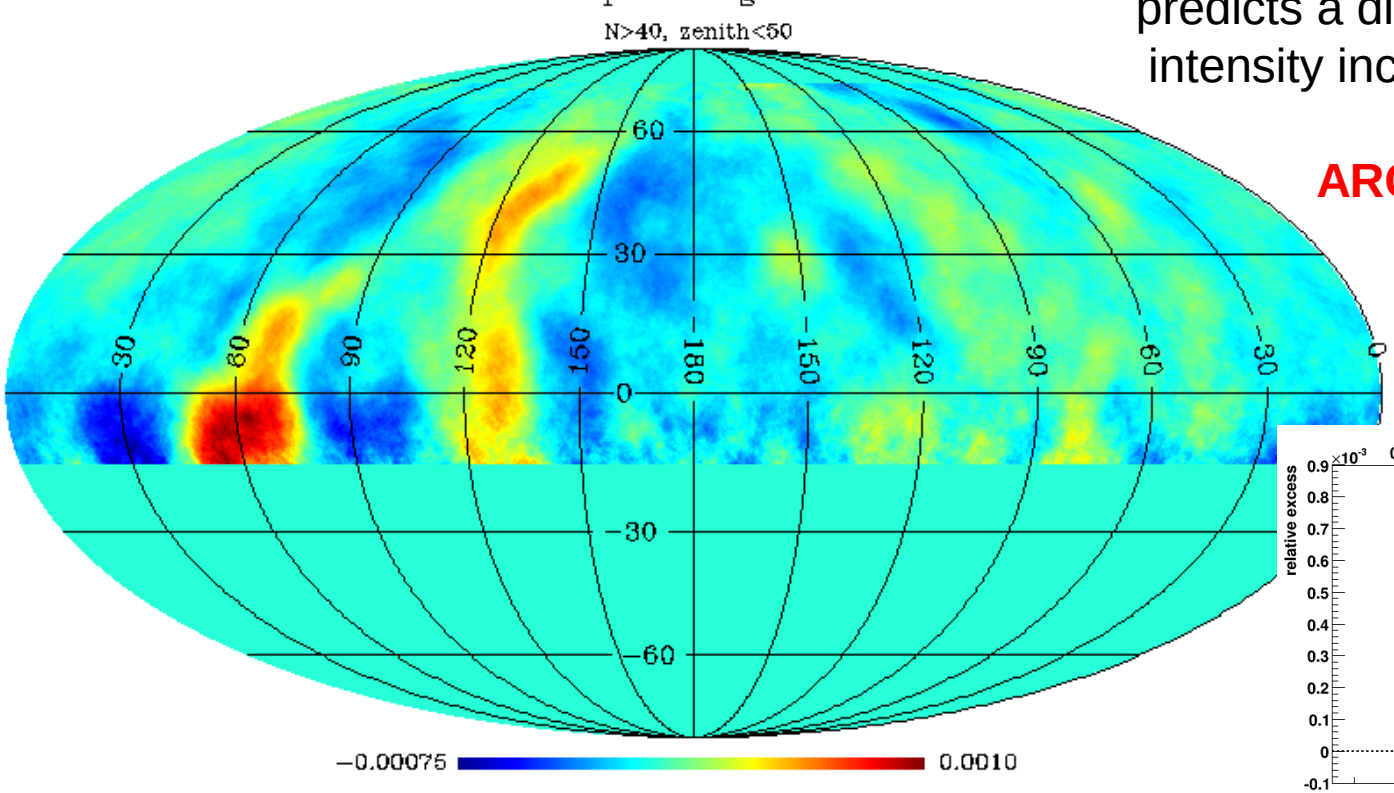
RXTE/ASM 2-12 keV
Swift/BAT 15-50 keV
ARGO-YBJ TeV



Intermediate scale anisotropy



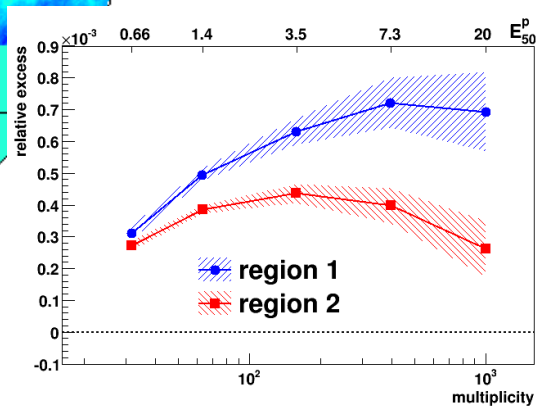




The galactic magnetic field is thought to be the superposition of a “regular” and a “chaotic” component (with intensities B_{reg}~2 μG and B_{ch}~0.5÷5 μG respectively).

The standard model of cosmic rays predicts a dipole anisotropy with intensity increasing with the CR energy.

ARGO-YBJ structures are too small and have peaked spectrum



Conclusions

- The ARGO-YBJ experiment started collecting data in shower mode since November 2007.
- The analog signal readout is operated since December 2009.
- ***More than 3 10^{11}*** events were recorded so far.
- The operating conditions of the RPC carpet are continuously monitored by the DCS. The angular resolution and the efficiency keep being monitored with a test telescope realized on purpose. Important numbers:
  - Running time >90%
  - Duty cycle >86% (dead time <4%)
  - Intrisic trigger rate variations: 0.5%
  - Time resolution 1.5-2.0 ns
  - Efficiency always >97%

  All that in Tibet, *without permanent scientific staff* in situ.
- Many scientific results were obtained in particle and CR physics, as well as in TeV gamma-ray astronomy.
- Data acquisition is planned to stop by the end of 2012. Future plans are under discussion.