ARGO-YBJ Experiment: detector stability and performance

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1. Detector stability and barometric coefficient

Since November 2007 the ARGO-YBJ detector [1] is in stable data taking with an inclusive multiplicity trigger N$_{pad}$ $\geq$20 and a duty cycle $\geq$ 85%: the shower event rate is about 3.5 kHz on average. Indeed, as known, the atmospheric pressure affects the axtensive shower developmet and consequently the measured trigger rate (blue distribution in Fig. 1). The event rate also depends on the detector status: in our case, for instance, on the number of dead and reduced efficiency single pads or groups of pads which contribute to the trigger [9]. Thus the dependence of event rate from these factors can be expressed as:

$$R = R_o e^{-\alpha(1-\epsilon)} e^{-\beta(p-p_o)}$$

where R is the measured event rate, α a coefficient expressing the dependence of the rate on the global detector triggering efficiency ϵ, p the pressure and R_0 the rate at the pressure p_0. Thus, the parameter β takes into account the dependence of the measured event rate on the atmospheric pressure and is called *barometric coefficient*.

The investigation of the trigger rate variations with time, once correlated to the detector and environmental conditions, allowed to "correct" the event rate (i.e. to recover the reference one, R_0, Fig. 1), then to extract the dependence on the atmospheric pressure, through the barometric coefficient β. After the correction for the detector parameters, we obtained: $\beta = (0.672 \pm 0.089)\%\ mbar^{-1}$. This work has been entirely carried out by the Lecce group.

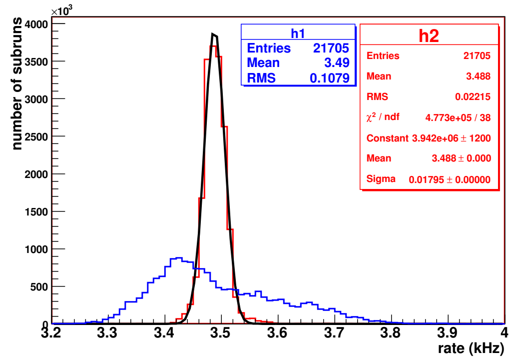

Figure 1. The measured event rate (blue) and the "corrected" one (red), i.e. that obtained after correcting for the variation induced by the detector efficiency and environmental conditions.

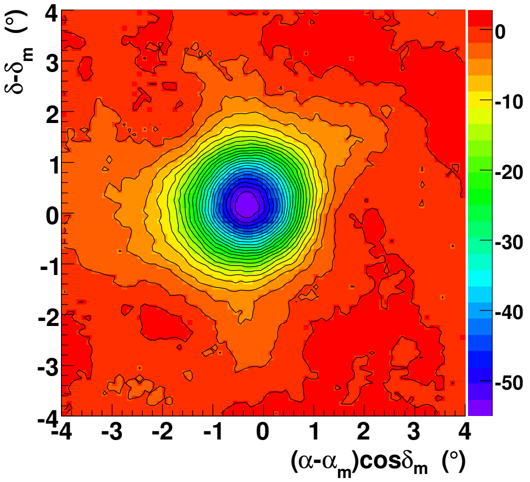

Figure 2. Moon shadow significance map for events with $N_{pad} \geq 100$ fired pads. The colour scale gives the significance.

2. Moon shadow and detector performance

The performance and the operation stability of the detector are continuously monitored by observing the Moon shadow, i.e. the deficit of cosmic rays (CR) caused by the Moon absorption. Indeed, the size of the deficit allows the measurement of the angular resolution while its position allows the evaluation of the absolute pointing accuracy of the detector. In addition, positively charged particles are deflected towards East due to the geomagnetic field by an angle depending on energy: $\Delta\theta \sim 1.6° Z/E[TeV]$. Therefore, the observation of the displacement of the Moon provides a direct calibration of the relation between shower size and primary energy.

Fig. 2 shows the significance map of the Moon

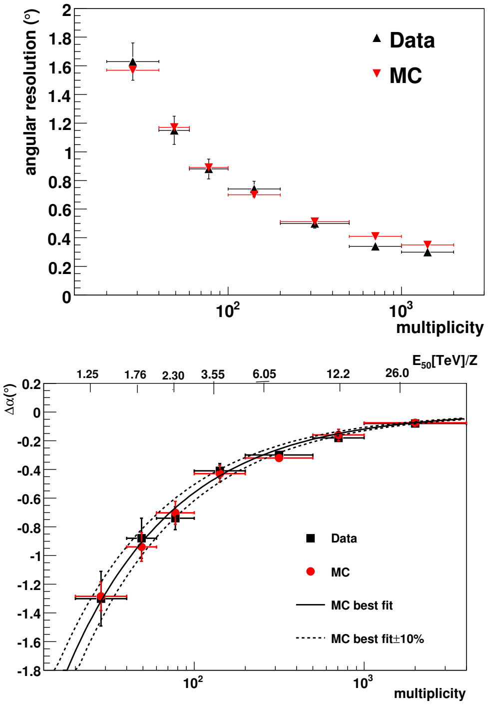

Figure 3. Moon shadow (data and simulation). Top: Angular resolution as a function of the hit multiplicity. Bottom: Westward shift of the Moon shadow due to the geomagnetic field as a function of hit multiplicity (the scale of the median energy over Z is also shown).

region with the detected deficit. With all data from July 2006 to December 2009 (about 3200 hours on-source in total) we observed the CR Moon shadowing effect with a significance of about 55 standard deviations (s.d.). The amount and shape of the CR deficit is the convolution of the point spread function of the detector and the widespread Moon disc. The measured angular resolution depends on the hit multiplicity, thus on the shower energy (3): it is better than 0.5° for showers of energies $E > 5\ TeV$. In Fig. 3 the West-shift is also shown versus hit multiplicity, in agreement with MonteCarlo simulation. Fig. 4 reports the stability of the shadow measurement and the residual pointing systematics ($\sim 0.2°$ North). The accuracy of the energy scale determination is estimated to be less than 18% in the energy range $1 - 30 TeV/Z$.

3. Observation of the Sun shadow

In a similar way, the Sun also causes a shadowing effect on cosmic rays coming from its direction, clearly shown in Fig. 5 as a result of the analysis of ARGO-YBJ data collected since July 2006 up to December 2009 [10].

In this case, an important role is also played by the magnetic field along the path from the Sun to the Earth, which deflects the primary charged particles from straight trajectories, producing a shift of the shadow from the true Sun position. Thus, in principle, the study of the Sun shadow and its variations could permit to measure and monitor in time the Interplanetary Magnetic Field (IMF). Nevertheless, the deficit significance and position are strongly correlated to the solar activity, so that IMF is better studied in quiet phases of the Sun. The ARGO-YBJ observation reported in Fig. 5 refers just in such a particularly good time window when solar activity stays at its minimum since 2006. In particular, the detected North-South displacement of the shadow from the Sun position is mostly related to the effect of IMF action.

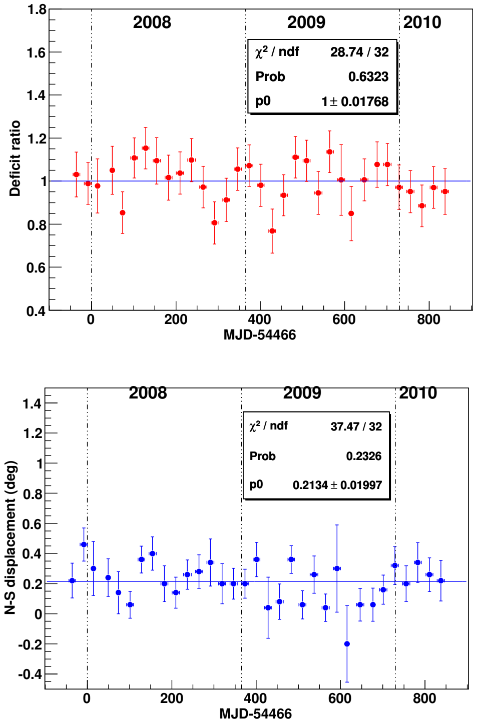

Figure 4. Moon shadow (data). Top: Ratio between expected and measured deficit versus time. Bottom: Systematic North offset of the Moon shadow versus time.

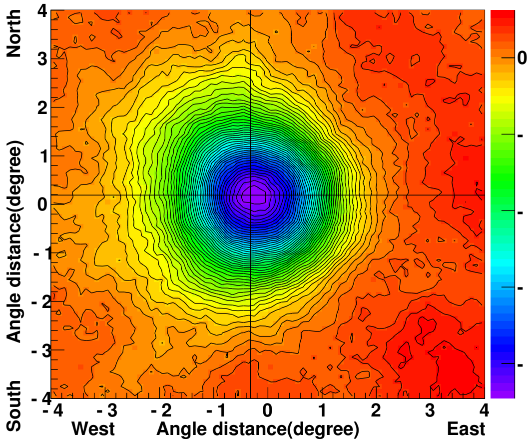

Figure 5. Sun shadow significance map for events with $N_{pad} \geq 100$ fired pads.

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