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Results from the ARGO-YBJ experiment

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on behalf of ARGO-YBJ Coll.

The ARGO-YBJ detector at the YangBaJing Cosmic Ray Observatory (4300 m a.s.l., Tibet, P.R. China) has been put into operation in the full configration since November 2007. It is the first EAS detector combining a very high mountain altitude with a full coverage detection surface. The high time-space granularity combined with the full coverage make ARGO-YBJ a unique device to study the EAS characteristics. In this paper we report a few selected results in Gamma-Ray Astronomy and Cosmic Ray Physics

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1. The ARGO-YBJ detector

ARGO-YBJ is located in Tibet (China) near the YangBaJing village at 4300 $a.s.l.$ It is an air shower array optimized for the study of the cosmic radiation with an energy threshold of few hundreds of GeV.

The detector consists of a full coverage array made of a single layer of RPCs of dimension $78 \times 74\ m^2$ operated in streamer mode. This central carpet is surrounded by a sampling ring with other 1000 m^2 equipped with RPCs[1].

Since November 2007 the full detector has been in stable data taking with a duty cycle of about 95% with a trigger rate of about 3.6 kHz.

2. Measurement of the proton-air cross section

The data collect since November 2007 are used to study the proton-air cross section in the energy range 1-100TeV. This analysis is based on the flux attenuation for different atmospheric depths (i.e. zenith angles θ) and exploits the detector capabilities of selecting the shower development stage by means of hit multiplicity, density and lateral profile measurements at ground.

The flux attenuation $I(\theta)$ can be parametrized as $I(\theta) = I(0)exp(-x_0(sec\theta - 1)/\Lambda_{obs})$, where x_0 is the vertical atmospheric depth at the detector location and Λ_{obs} is the observed attenuation length of air showers related to the mean free path λ_{int} of the primary particle through the parameter $K = \Lambda_{obs}/\lambda_{int}$ [2]. This parameter, which takes into account the fluctuations both in the shower development and in the shower sampling, is calculated via MC simulation. The measured p-air cross section values are reported in figure 1 (left panel) as a function of the primary proton energy.

The measurements found by other experiments and the expectations given by some hadronic interaction models are also shown.

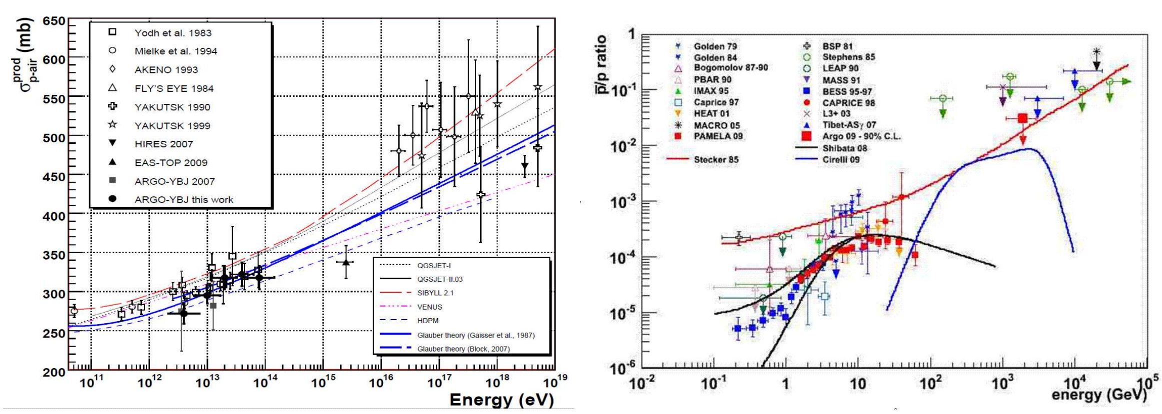

Figure 1: Left Panel:Proton-air cross section measured by ARGO-YBJ and by other CR experiments. The values given by several hadronic interaction model are also reported. Right Panel:$\overline{p}/p$ ARGO-YBJ upper limit toghether with the results of other CR experiments. Some teoretical predictions are also reported.

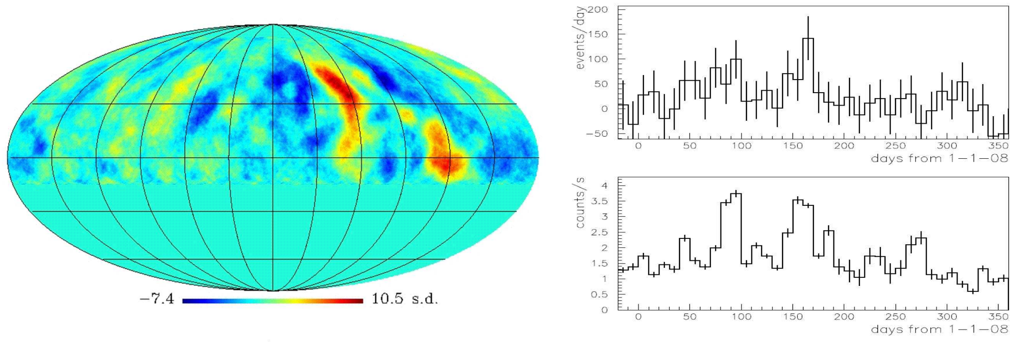

Figure 2: Left panel:ARGO-YBJ all-sky map. An anysotropy in the cosmic rays flux is well evident. Right upper panel: excess event rate detected by ARGO-YBJ as a function of time. Right lower panel: X-ray counting rate detected by RXTE/ASM.

3. Measurement of the antiproton/proton ratio

In order to measure the $\overline{p}/p$ ratio at TeV energies we exploit the Earth-Moon system as an ion spectrometer. Due to the geomagnetic field, positively charged particles are deflected towards East by an angle of about $1.6°/E(TeV)$, where E is the particle energy. Therefore, if protons are deflected towards East, antiprotons are deflected towards West.

Since the Moon has an angular radius of about $0.25°$, it must cast a shadow in the cosmic ray flux. If the energy is low enough and the angular resolution small we can distinguish, in principle, between two shadows, one shifted towards West due to protons and the other shifted towards East due to antiprotons. If no event deficit is observed on the antimatter side an upper limit on the antiproton content can be calculated [3].

The upper limit on the $\overline{p}$ flux obtained is reported in figure 1 (right panel). The obtained results is already comparable with other CR experiments while the data used in the current analysis is only a fraction of the data that ARGO-YBJ can collect in 3 years of operation.

4. Gamma astronomy

The Crab Nebula is the most luminous TeV γ-ray source in the Northern hemisphere and is used as a standard candle for VHE gamma-ray astronomy in order to check the detector sensitivity and the analysis procedure. The Crab Nebula has been observed by ARGO-YBJ detector since 2007 November to 2009 March, for a total of 424 onsource days.

The average number of gamma rays detected per day in the observational window centered on the source position is 155 ± 25 for $N_{pad} > 40$. The data can be fitted by the power law spectrum:

$$dN/dE = (3.7 \pm 0.8) \times 10^{-11} E^{-2.67 \pm 0.25} \; \gamma rays \; cm^{-2} s^{-1} TeV^{-1}$$

in fair agreement with other observations.

A first all−sky map obtained using the data collected in the same period is reported in figure 2 (left panel). An anysotropy in the cosmic ray flux is well evident. This anysotropy is in agreement with similar results obtained by Milagro [4] and Ice-Cube [5].

After the remove of the anysotropy the two more intense sources visible in the sky are the Crab Nebula and Markarian 421.

Markarian 421 is the blazar closest to our Galaxy and the first extragalactic source observed in the TeV energy range. It is extremely variable at any wavelength. The X-ray and TeV fluxes are often correlated, and in many occasions the latter becomes several times larger than the Crab Nebula one. We analyze the Markarian 421 region from 2008 February 11 to September 5, where the X-ray flux showed the most intense flares.

Figure 2 right pannel shows the rate of events observed by ARGO-YBJ from May 30 to June 16, averaged over 3 days, compared with the X-ray flux measured by RXTE/ASM. The source has been detected with a statistical significance of 3.2 standard deviations during the interval 11-13 June, when the maximum of the second flare occurred.

To compare the ARGO-YBJ measurements with the theoretical expectations, we integrate our data from June 11 to 13, where the X-rays flux reaches the maximum intensity. The observed event rate (in 16.8 hours of measurement) is in good agreement with the rate expected from a source spectrum given by the theoretical prediction [6].

A dedicated analysis of the observation of Markarian 421 is reported in [7].

5. Conclusion

The ARGO-YBJ experiment has been completely installed since November 2007 is taking data with a duty cycle 95%. The detection of the Moon shadow, and the observation of gamma rays from Crab Nebula and Mrk421 show that the detector is properly working, with good angular resolution and sensitivity. The p-air cross section has been measured in the range 1 - 100 TeV and the corresponding p-p cross section inferred. A preliminary upper limit of the $\overline{p}/p$ ratio at TeV energies has been put.

References

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