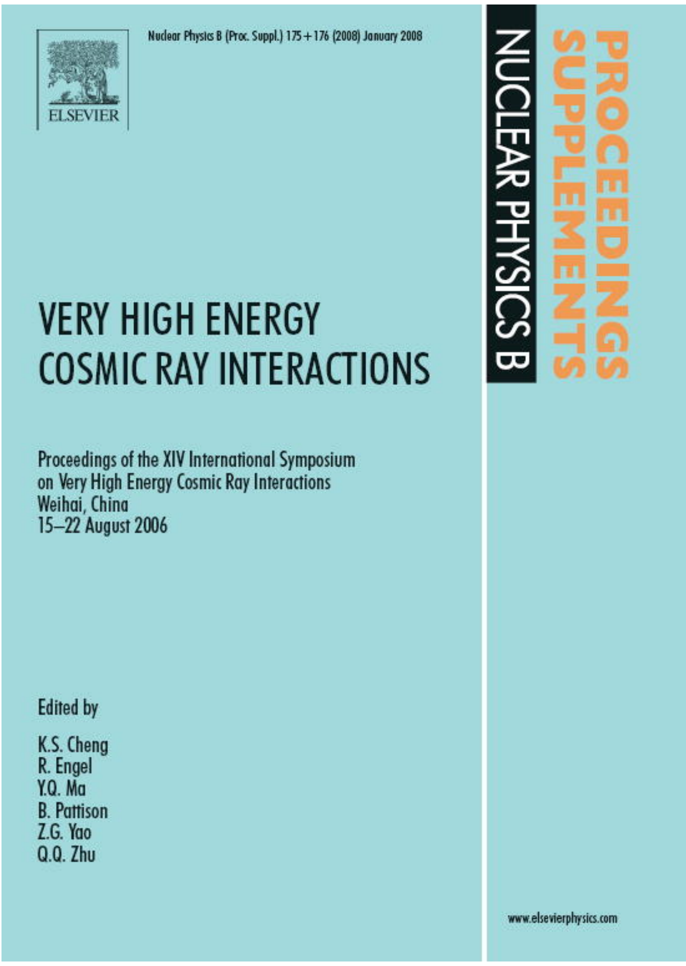
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Simulation of the ARGO-YBJ experiment operated in Scaler Mode

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The ARGO-YBJ experiment is a large area full coverage detector operating at high mountain altitude (4300 m a.s.l., Tibet, China, ∼6700 m^2 active surface). In scaler mode, the particle rate is recorded at fixed time intervals (0.5 s), allowing the achievement of an energy threshold as low as $E_{th} \sim 1$ GeV for the photons.

This result, together with the estimate of the effective area as a function of the primary energy, has been obtained using the simulation code CORSIKA6201 for the shower development in the atmosphere and a dedicated and detailed detector simulation, ARGOG, based on GEANT3.21.

With this simulation chain, and using the known primary proton and helium spectra, we obtained counting rates consistent with the measured ones, making us confident in the expectation of the detector performance as far as the photon shower detection is concerned, which is of crucial importance to determine the capability of the ARGO-YBJ experiment to detect gamma-ray bursts (GRBs).

1. Introduction

GRBs, discovered in 1969, still leave many problems unanswered in high energy astrophysics. In the GeV energy range, numerous models predict strong emission to hundreds of GeV and beyond, so far there have been detected an 18 GeV GRB by satellite, and no convincing evidence from ground-based instruments probably due to their higher threshold energy. The ARGO-YBJ experiment[1], a large sensitive area full coverage RPC array illustrated in Figure 1, operates at an altitude of 4300m a.s.l, recording the secondary particles induced in the atmosphere by primary cosmic rays, has a high duty cycle (∼90%) operated in scaler mode and a wide field of view, limited only by the atmospheric absorption and geometric acceptance($\sim 2.5sr$). For its lower threshold, especially running in scaler mode, the ARGO-YBJ experiment has advantages of searching for ∼GeV GRBs[2], solar high energetic particles and so on.

2. Detector

The whole array is divided into a central area and a guard ring with the central area consisting of 13×10 Clusters, and the guard ring which

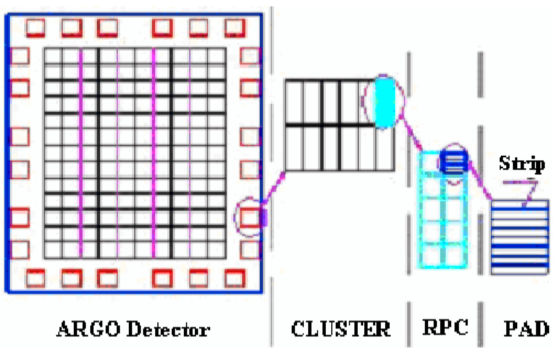

Figure 1. ARGO detector

consists of 4×6 Clusters is used mainly to discriminate the inner events from outer ones. Each Cluster is the combination of 12 RPCs which is made up of 10 detector unit, so called Pad. Eight unilateral read-out strips on each Pad provide the information of the number of particles. Each Cluster is connected in two different observation mode, shower mode and scaler mode. In the shower mode the arrival time and spatial information are recorded for each event to reconstruct the event, whilst in the scaler mode only the counting rate of each Cluster is measured every 0.5s, with no information of the arrival direction and spatial distribution of the detected particles. For each

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Cluster, 4 scalers are used to record the ≥ 1, ≥ 2, ≥ 3, ≥ 4 rates, with the coincidences defined in a narrow time window of 150ns and counting rates ~41KHz, ~2KHz, ~300Hz, ~120Hz. The counting rates for a given multiplicity are then obtained using the relation: $n_i = n_{\geq i} - n_{\geq i+1}$(i=1,2,3).

3. Monte Carlo Simulation

3.1. Cosmic ray background

A Monte Carlo simulation is performed with the CORSIKA 6.2010 code[6] and ARGOG code based on GEANT3.21. The primary particles energy proton 3.9-20000GeV and helium 8.3-80000GeV are considered.The energy spectrum of lower energy 3.9-13GeV(proton) and 8.3-27.7GeV(helium) are from the AMS experiment[7,8], while in the higher energy domain 13.0-20000GeV(proton) and 27.7-80000GeV(helium) the energy spectrum adopted are -2.7, -2.68, separately, accounting for the primary spectrum from the other experiments[9]. The simulation is valid for the altitude and magnetic field values of Yangbajing,Tibet (vertical effective cutoff rigidity ~13.85GV[10]). The zenith angle of primary direction is sampled randomly in the range of 0-70° and azimuth angle in the range of 0-360°. Simulated primary showers are observed with the detector configuration as the 42 Clusters(1900m^2) taking data in the ARGO-YBJ experiment. It has to be pointed out that sampling area needs to be large enough to collect the secondary particles induced from primary showers. In simulation, sampling area was progressively increased until the effective area reached the asymptotic level as illustrated in Figure 2. With the sampling area of 12000m×12000m , a sample data covering the energy range and sky field of cosmic rays background was accessible according to the distributions of energy and zenith for primary showers shown in Figure 3. This occurred at approximately 8000×8000m^2. In addition, when a particle hits the border area of one PAD, with more than one strip fired,which may belong to its neighborhood PADs, more than one PAD could be fired with multi-hit generated, so called hybrid effect[11]. Based on this the possibility for a particle hitting a RPC and generating one hit, two, three, and four are listed: 92.03%, 2.136%, 0.044%, 0.0044%. The Figure 4. shows that the effective areas of proton and helium for ≥ 1, ≥ 2, ≥ 3, ≥ 4 rates channels. Together with the primary spectrum, the counting rates,statistical error and mode energy from background cosmic rays are also obtained in Table1.

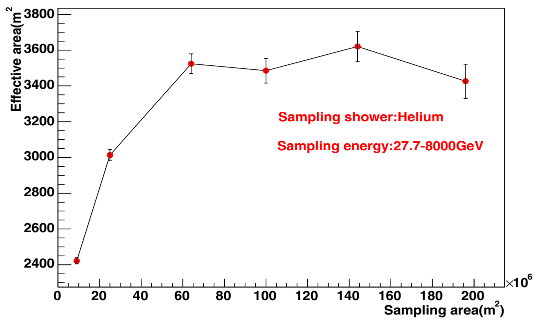

Figure 2. Relation between the calculated effective area of channel n≥1 of ARGO-YBJ operated in scaler mode and the sampling area for the primary helium with the energy 27.7-8000GeV

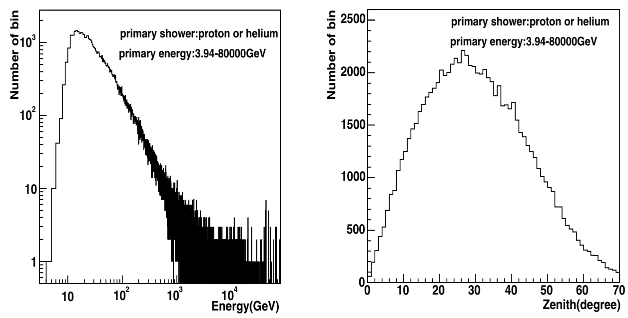

Figure 3. the event energy and zenith distribution for background cosmic rays when sampling area 12000m×12000m

3.2. Comparison of Monte Carlo simulations with the experimental data

The counts of 4 channels mainly consist of the counts from background cosmic rays without corrected by hybrid effect, hybrid effect, and accident coincidence, are also affected by many other factors, such as threshold voltage of front end electronics, components of mixture gas, high power supply, temperature, atmospheric pres-

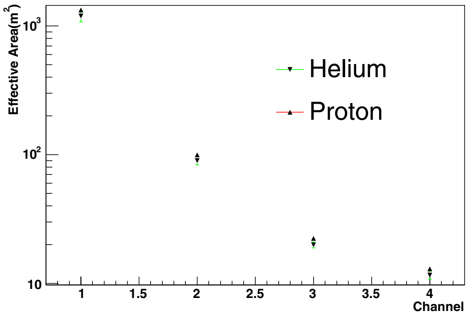

Figure 4. effective area for ch1(≥1),ch2(≥2),ch3(≥3),ch4(≥4) of the ARGO-YBJ experiment operated in scaler mode

Table1:**counting rates,statistical error and mode energy**

	cosmic rays background		
	rates (particles/s)	error	mode energy (GeV)
ch1(≥ 1)	1.64×10^4	41.2	13
ch2(≥ 2)	1.2×10^3	18.0	17
ch3(≥ 3)	255.8	8.34	117
ch4(≥ 4)	143.3	6.9	378

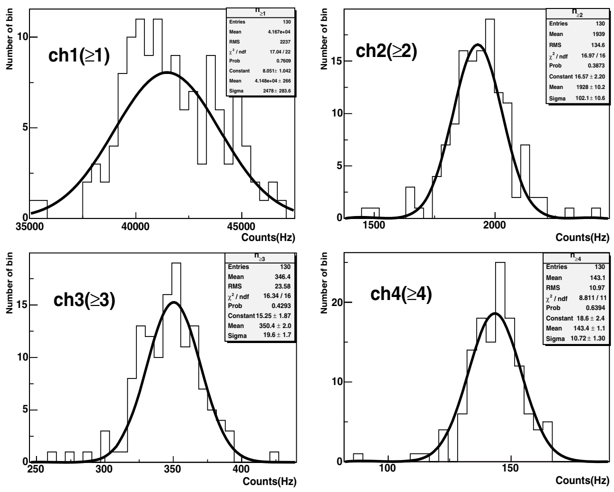

Figure 5. The distribution of counting rates for 4 channels ≥ 1,≥ 2,≥ 3,≥ 4

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Table2:the total counting rates

	ch2(≥ 2)		ch3(≥ 3)		ch4(≥ 4)	
	count	error	count	error	count	error
cosmic rays	828.6	42.3	222.5	9.8	122.1	6.6
coincidence	221	0	25	0	0	0
hybrid effect	958	16.3	126.4	19.5	29.5	1
total	1997	45.4	373.9	21.8	151.6	6.7

sure, solar activity, ground radiation, and so on. Figure 5. shows counting rates distribution of 130 running Clusters from the experimental data. For channel 1, supposing that the counting rates 16.1kHz induced by primary background cosmic rays are calculated correctly, the other part 25.2KHz is the noise from the electronics due to high voltage supplied of RPCs. The signals that originate from cosmic rays and electronics can not be distinguished by trigger system, thus, have the same effect on the multiplicity channel n=2, 3 and 4, and supposing the counting rates of channel n=1 is 40000Hz, the counts from the edge effect of 3 channels can be figured out. The rates from accidental coincidence can also be calculated in the coincidence time window of 150ns. The total counts are listed in Table 2. By comparison, the result of simulation is consist with the experimental data.

4. Gamma rays simulation

Searching for Gamma ray bursts is one of goals of ARGO-YBJ experiment operated in scaler mode.Photons of fixed energy with the energy range from 1GeV to 100GeV were simulated with large enough sampling area and many enough primary showers.

The effective area for 130 clusters of multiplicity channel =1, =2, =3, ≥ 4 are shown in Figure 6., and mode energy is 2GeV, 4.5GeV, 22GeV, >100GeV(spectrum index is -2.0). Using the experimental counting rates and a GRB spectrum model, assuming a power law spectrum up to 100GeV with differential spectral index $\alpha = -2.0$, zenith angle θ=20°, time duration

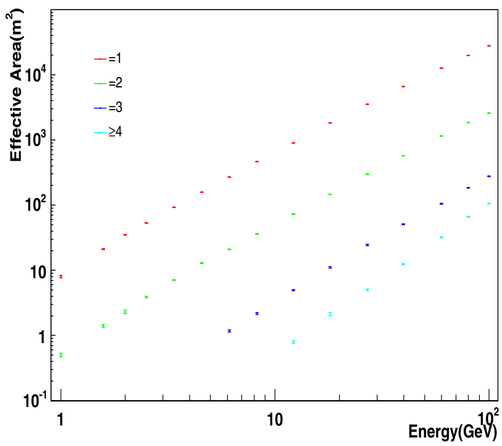

Figure 6. Effective area Vs. energy of 4 multiplicity channels =1,=2,=3,≥ 4

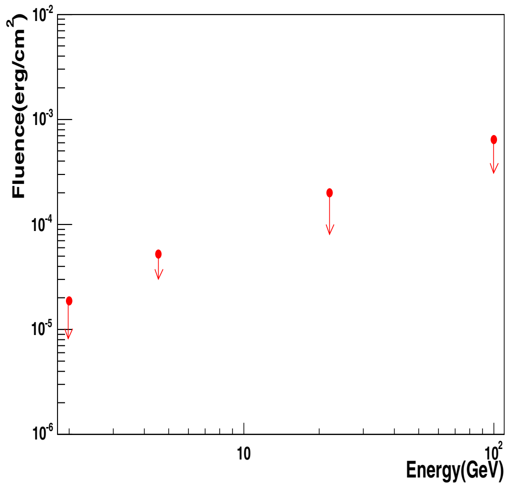

Figure 7. Typical fluence up limits of 4 multiplicity channels =1,=2,=3,≥ 4

$\Delta = 10s$ and statistical significance k=5, the fluence upper limits are obtained for the 4 multiplicity channels(Figure 7.).

5. Summary and Discussion

The simulation of the background cosmic rays, with the corresponding effective areas and mode energies, results in counting rates consistent with the experimental data, therefore we are confident in our future studies on cosmic ray flux variations. The simulation of the effective areas for photons, which result larger than those of satellites, combined with the reliable and stable operation of the detector, shows that the ARGO-YBJ experiment has a high sensitivity in observing ∼GeV GRBs

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