Comparison of Measured and Simulated Albedo Signals in the ATIC Experiment

V.I.Zatsepin,[1] J.H.Adams,[2] H.S.Ahn,[3] G.L.Bashindzhagyan,[1] K.E.Batkov,[1] J.Chang,[6] M.Christl,[2] A.R.Fazely,[5] O.Ganel,[3] R.M.Gunasingha,[5] T.G.Guzik,[4] J.Isbert,[4] K.C.Kim,[3] E.N.Kouznetsov,[1] M.I.Panasyuk,[1] A.D.Panov,[1] W.K.H.Schmidt,[6] E.S.Seo,[3] N.V.Sokolskaya,[1] J.Z.Wang,[3] J.P.Wefel,[4] J.Wu[3]

(1) Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow, Russia
(2) Marshall Space Flight Center, Huntsville, AL, USA
(3) University of Maryland, College Park, MD, USA
(4) Louisiana State University, Baton Rouge, LA, USA
(5) Southern University, Baton Rouge, LA, USA
(6) Max Plank Institute fur Aeronomie, Lindau, Germany

Abstract

Albedo, radiation backscattered from an interaction and from the subsequent shower development, provides a 'background' for calorimeter experiments. In ATIC (Advanced Thin Ionization Calorimeter), a balloon borne instrument to measure cosmic ray composition and energy spectra for elements from hydrogen to iron from 30 GeV to near 100 TeV, a fully active BGO calorimeter follows a carbon interaction target and scintillator hodoscopes. The first detector is a silicon matrix constructed of 4480 individual silicon pixels, each 2 cm $\times$ 1.5 cm, that provide a measurement of the charge of the primary particle in the presence of albedo. ATIC had two successful balloon flights in Antarctica: from 28 Dec 2000 to 13 Jan 2001 (ATIC-1) and from 29 Dec 2002 to 18 Jan 2003 (ATIC-2). We compare the albedo signals measured in the silicon matrix during the ATIC-1 flight with simulations performed using the GEANT 3.21 code and the QGSM event generator for nucleus-nucleus interactions.

1. Experimental data

The description of ATIC instrument and of its silicon matrix may be found in [1,2]. To identify the pixel with the signal from the primary particle, the centroid of the cascade in the calorimeter was used. A trajectory was reconstructed using weighted centers of energy deposits in BGO layers. The point of intersection of this trajectory with Si-matrix and its rms was determined. The pixel with maximal pulse amplitude A in the error corridor $\pm 3\sigma$ is taken as the primary particle. The primary particle charge is estimated as $Z = \sqrt{A/A_{mip} \times \cos\theta}$, where

pp. 1861–1864

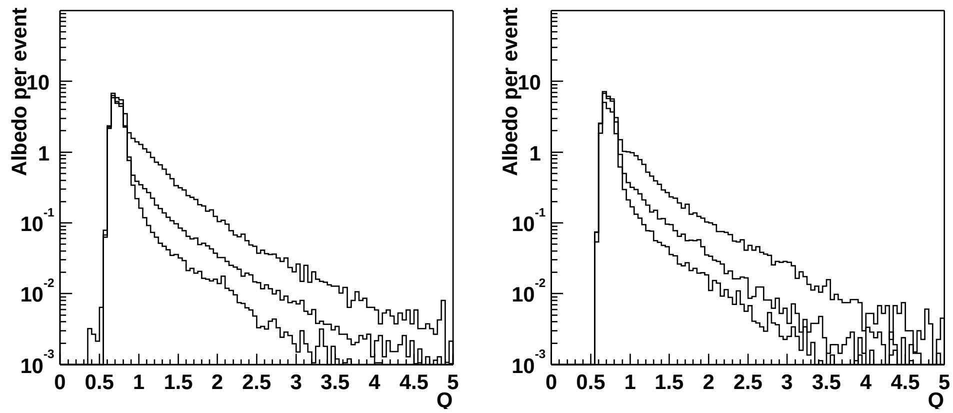

Fig. 1. Number of albedo signals in the entire matrix; left panel: all particles, $E_d > 1000$ GeV, > 100 GeV and > 10 GeV from top to bottom; right panel: $E_d > 100$ GeV, for nuclei of $Z > 5$, helium nuclei and protons from top to bottom

A_{mip} is mean pulse amplitude for a minimum ionizing particle and θ is zenith angle of the trajectory. Signals in all other pixels not overlapped with the one containing the primary are produced by backscatter or noise. The distribution of these other signals denoted by the value of Equivalent Charge, $Q = \sqrt{A/A_{mip}}$ is shown in Fig.1. In the left panel there are 7000 events for $E_d > 10$ GeV and $E_d >$ 100 GeV, and about 1600 events for $E_d > 1$ TeV (E_d denotes energy deposited in the BGO calorimeter). In the region of $Q < 1$, noise signals dominate and these do not depend upon energy. On average there are about 20 of these per event. The main contribution at $Q > 1$ comes from albedo particles. The number of albedo signals decreases with Q almost exponentially. Note that for our algorithm of primary particle charge measurement, only albedo signals with Q higher than the charge of primary particle Z may cause misidentification. Albedo could be dangerous for proton, helium and light nuclei groups. It can shift protons to helium and both protons and helium to light nuclei.

2. Simulation

The estimation of the albedo effect on proton and helium charge measurements in the error corridor was performed by simulations with GEANT 3.21 code. The FLUKA generator was used for hadron-hadron interactions and QGSM generator [3] was used for nuclei-nuclei interactions.

The primary nuclei with a power-law spectrum for three regions of kinetic energy ($E_{kin} > 10$,> 100 and > 1000 GeV) were incident on the Si matrix plane isotropically over the ATIC-1 aperture. The events with $E_d > 10$, > 100 and > 1000 GeV correspondingly were selected for analisys. The simulated statistics

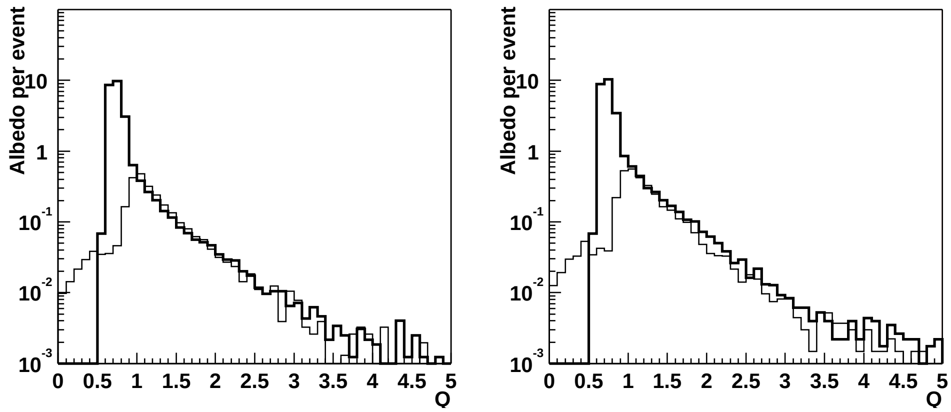

Fig. 2. Number of albedo signals in the entire matrix; left panel: protons, right panel: helium. $Ed > 100$ GeV; thin lines are for simulation

were 1000 - 1500 events in each energy group for protons and helium nuclei. The comparison of simulated and experimental distributions of albedo are shown in Fig.2, and one can see that the simulation describes experiment adequately in the region of $Q > 1$, where noise signals contribute minimally to the albedo distribution. Now using the data of simulation we can calculate probability of albedo signals in different lateral regions around incident point of primary particle. The mean values of σ in reconstructed position of primary particle in the matrix depend on cascade energy. The tracking algorithm applied for processing of the experimental data provide these values to be 12.2 cm, 4.7 cm and 3.5 cm at $E_d > 10$, > 100 and > 1000 GeV correspondingly. Taking an error corridor for searching primary particle as 3σ, we obtain estimations for the albedo's influence on charge determination shown in Table1 as a relative change of the number of events assigned as protons and helium.

Table 1. Distortion of proton and helium fluxes due to albedo

	$E_d > 10$ GeV	$E_d > 100$ GeV	$E_d > 1000$ GeV
area of search	37 cm	14 cm	10 cm
protons	-0.053	-0.030	-0.039
helium	+0.11	+0.038	+0.048

Events with $Z < 1.7$ were considered as protons, while events with $1.7 < Z < 2.5$ were considered as helium nuclei. For this estimation it was taken into account that number of proton cascades are about 2.5 times higher than number of helium cascades at the same E_d. Except at the lowest energies, we find only a small influence of albedo on the spectra of protons and helium.

The experimental charge resolution for protons and helium nuclei is shown in Fig.3. To avoid influence of particles outside the aperture, events were selected in which restored trajectories intercept the silicon matrix at distance more than $3\times\sigma$ from the edge. Fig.3 demonstrates that protons and helium are well resolved over the entire energy region.

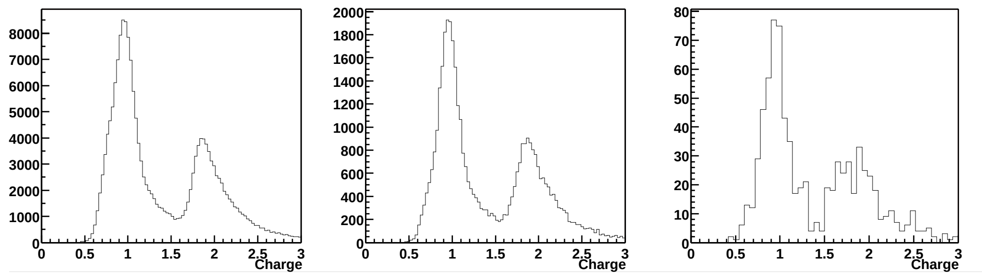

Fig. 3. Charge resolution for protons and helium: left panel: $E_d > 30$ GeV, middle panel: $E_d > 100$ GeV, right panel: $E_d > 1000$ GeV

3. Conclusions

In the ATIC-1 experiment, the probability of misidentification for protons and helium nuclei due to albedo is small and should have little effect on determining the energy spectra.

4. Acknowledgements

This work was supported with NASA grants to LSU, MSFC, UMD and SU. In Russia the work is supported by Russian Foundation for Basic Research, grant 02-02-16545.

5. References

1. Adams J.H. et al 2001, Proc. 27^{th} ICRC, Hamburg, v.6, p.2127
2. Guzik T.G. et al 1999, Proc. 26^{th} ICRC, Salt Lake City, v.5, p.9
3. Rappoport I.D., Turundaevsky A.N., Shestoperov V.Ya. 2002, Physics of Atomic Nuclei, 65, 170; Amelin N.S. et al 1990, Sov.J.Nucl.Phys, 51,327