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The first flight of ATIC: Preliminary results on Li, Be, B nuclei

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Abstract. The ATIC balloon experiment had its first, test flight that lasted for 16 days around Antarctica. The ATIC spectrometer consists of a fully active BGO calorimeter, scintillator hodoscopes and a silicon matrix. The silicon matrix consisted of 4480 pixels was used as a charge detector in the experiment. We discuss a possibility of the ATIC to measure individual energy spectra of Li, Be and B.

1 Introduction

The light nuclei Li, Be and B are not present in the primary cosmic ray sources. They appear in the interstellar medium as a result of fragmentation of heavier nuclei. The energy dependence of the secondary to primary ratio is traditionally used to study energy dependence of the cosmic ray escape length in the Galaxy. At present, it is known that the escape length λ for primary nuclei of $Z \geq 6$ depends on magnetic regidity R as $\lambda \sim R^{-\alpha}$ with $\alpha \approx 0.6$ (Engelmann, 1990). This dependence is valid at $R > 5GV$. But this dependence should not be fundamental, because its extrapolation up to energy $\approx 10^5 GeV$ should lead to the cosmic ray anisotropy higher than observed one. The most probable dependence should be $\alpha = 1/3$ (Shibata, 1995). Such dependence is expected for the Kolmogorov type spectrum of turbulence in the interstellar medium. This dependence is preferred because it should not lead to the contradiction with the observed anisotropy. The new experimental data are required to clarify the situation.

2 The ATIC experiment

The ATIC spectrometer consists of three main parts: charge module, carbon target interleaved with scintillators and fully active BGO calorimeter (fig.1).

The calorimeter consists of 320 BGO crystals of $2.5cm \times 2.5cm \times 25cm$. The target module consists of three layers of carbon of 10 cm thick each ($0.6 \times \lambda_p$ in total). In the experiment, events are selected in which primary particles pass through charge module, interact in the target and generate electron-hadron cascade in the calorimeter. There are three scintillator detectors located above, inside and below the carbon target. Each detector consists of two x-y layers of scintillator strips.(Isbert, 2001) At the top of the ATIC instrument is located a silicon matrix, the main detector for charge measurements. The silicon matrix consists of 4480 individual silicon pixels of $1.5cm \times 2cm$ to avoid distortion of charge measuring because of albedo (Adams, 2001). The ATIC spectrometer was flown from December 28, 2000 to January 13, 2001 at the altitude of 37 km in the Antarctic flight. (Wefel, 2001). Above 26 million events were detected during the flight.

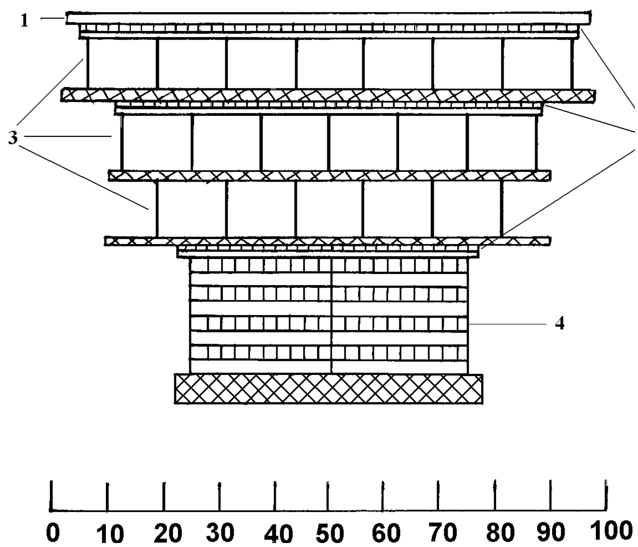

Fig. 1. Schematic view of the ATIC spectrometer: 1-silicon matrix, 2-scintillators, 3-carbon target, 4-BGO calorimeter

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3 Statistics of light nuclei expected for the ATIC flight

To estimate expected statistics we used the data of the HEAO-3-2c experiment (Engelmann, 1990). In this experiment spectra of nuclei beginning from Be were measured. Therefore we estimated the expected statistics for Be and B only. As trigger efficiency for the ATIC experiment is $< 100\%$ at energy deposit $< 10GeV$ we took for the estimation the intensity at $1.6GeV/nucleon$ as it is measured by the HEAO-3-2c:

$$i_{Be+B} = 0.52m^{-2}s^{-1}ster^{-1}(GeV/nucleon)^{-1}$$

The integral intensity of these nuclei is

$$I_{Be+B}(> E) = i(E) \times E/\gamma = 0.36m^{-2}s^{-1}ster^{-1}$$

where $E = 1.6GeV/nucleon$ and $\gamma = 2.3$.The data collecting time for the ATIC flight was about $360hours = 1.3 \times 10^6 s$. The ATIC geometry factor is $0.21m^2ster$. Therefore,

$$N_{Be+B} = 0.36 \times 0.21 \times 1.3 \times 10^6 \approx 10^5$$

for the ATIC flight.

4 Admixture of light nuclei from the residual atmosphere

The mean depth of residual atmosphere in the ATIC flight was $x \approx 4.4g/cm^2$. Therefore we are to estimate an admixture of secondary light nuclei generated in the residual atmosphere. The admixture of secondaries in L-group is

$$N_L^{atm}/N_L^{prim} = (N_{>L}^{prim}/N_L^{prim}) \times (x/\lambda) \times P_{Z\to L}$$

where x is mean depth of residual atmosphere, λ_{int} is interaction length, $P_{Z\to L}$ is probability of fragmentation of heavier nuclei to the L group. The ratio $N_{>L}/N_L$ for primaries according to HEAO data is ≈ 6.88 for $E = 1.6GeV/nucleon$. Assuming for rough estimation $\lambda = 20g/cm^2$, and $P_{Z\to L} = 0.25$, we get $N_L^{atm}/N_L^{prim} = 0.38$. Therefore the admixture of secondaries from the atmosphere should be accurately estimated in the final results.

5 Charge measurement

The silicon matrix of the ATIC spectrometer is designed to resolve individual elements from proton to iron. To provide this resolution careful calibration of each pixel of the silicon matrix is required. Firstly, for each electronic channel of the matrix the pedestal value was subtracted taking into account its drift during the flight. The muon calibration made before the flight was used then to convert electric signals (in ADC channel number) to energy deposit in each pixel (Ahn, 2001).

Up to now we made preliminary analysis of the experimental data obtained for approximately two hours of the flight, that is $< 1\%$ of total statistics. The simplest algorithm was used to determine a value of primary particle charge. We accepted that primary nucleus passed through the silicon pixel in which the maximal signal E_d^{max} is measured in this event. This algorithm assumed that a nucleus heavier than proton always generated signal higher than albedo or noise signals. The trajectory was fitted using coordinates of the silicon pixel with E_d^{max} and coordinates of energy deposit weight centers in BGO layers. Taking into account thickness of silicon passed by the particle we calculated

$$Z = \sqrt{E_d^{max} \times cos(\theta)/0.143}$$

where 0.143 MeV is a value of MIP accepted during the muon calibration. To deal with only relativistic particles we selected events with energy deposit in BGO calorimeter higher than $10GeV$, energy deposit in each layer of the calorimeter being $> 100MeV$. The charge distribution for all 4480 pixels of the silicon matrix is shown in fig.2. The peaks of He, C and O are clearly seen in the figure, but the resolution for the moment is worse than expected. The gain correction for each electronic channel, improvement of calibration and improvement of algorithm of charge determination are requied to improve the results. We suppose to use the flight data to improve calibration. The idea is to use a position of He peak for additional calibration in each pixel or in each daughter board consisted of four pixels made on one silicon wafer. In these cases we avoid dispersion connected with difference of thickness of silicon wafers. The charge distribution in one daughter board is shown in fig.3 for two hours of flight. To increase accuracy of He peak position, increasing of accumulation time of statistics is required.

6 Conclusion

Up to now only a small part of statistics obtained in the first flight of the ATIC instrument is processed for the purpose of this paper. We hope to present significantly more full data during the conference.

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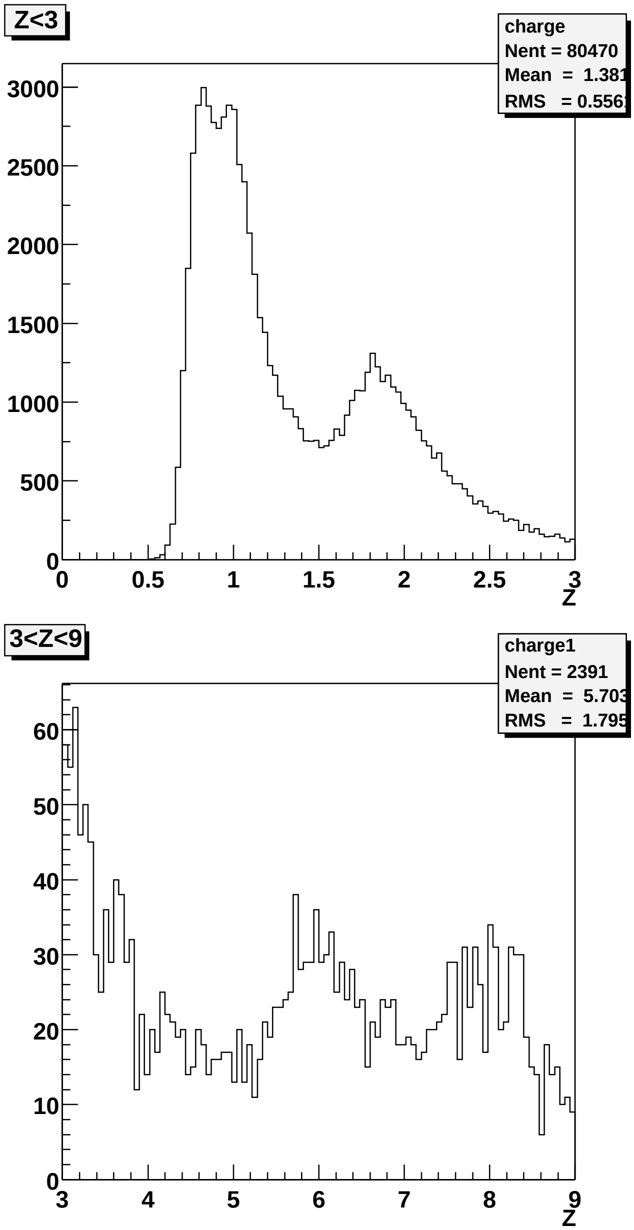

Fig. 2. Charge distribution for the entire silicon matrix

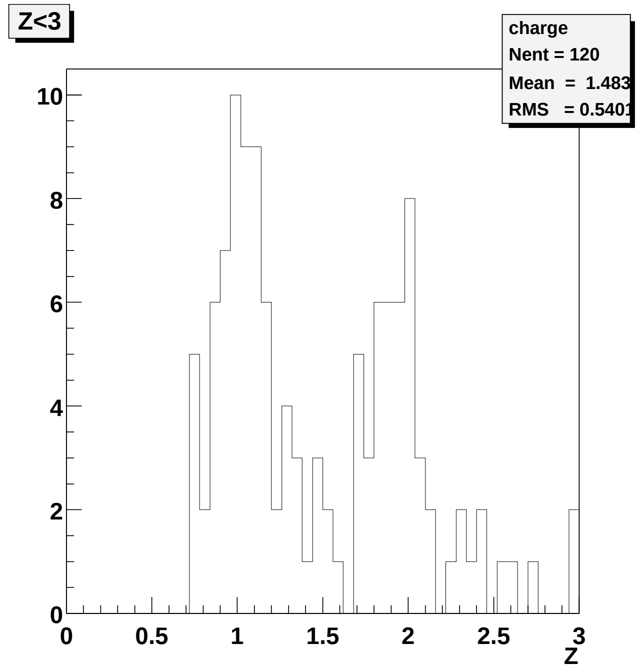

Fig. 3. Charge distribution for one daughter board