Search for doubly charged anomalously heavy nuclei with AMS detector in space

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Abstract

The Alpha Magnetic Spectrometer (AMS-01) experiment was flown on the space shuttle Discovery during flight STS–91 (1998) in a 51.7° orbit at altitudes between 320 and 390 km. More than 4×10^6 He events were collected during the flight. We have searched for doubly charged anomalously heavy nuclei, and one candidate event, corresponding to the flux of $5 \cdot 10^{-5}$ $(\mathrm{m}^2\cdot\mathrm{sr}\cdot\mathrm{sec})^{-1}$, was found. The candidate has $\frac{Z}{A}$ of 0.114 ± 0.01 and kinetic energy of 2.1 GeV. The background from ordinary nuclei was estimated to be less than 10^{-3} events.

1. Introduction

Numerous searches for anomalously heavy nuclei in cosmic rays and Earth's atmosphere were conducted during the past years[4]. One of the motivations for such searches is the possible existence of strange quark matter in form of strangelets[6,8]. In the present paper we report on search for doubly charged anomalously heavy nuclei which was performed with more than four millions He events collected by AMS-01 detector[1,2]. The AMS-01 detector consisted of a permanent magnet, a tracker, time of flight scintillator counters, a Cerenkov counter and anticoincidence counters.

2. Event Selection

We have assumed that the only difference between anomalously heavy and ordinary He event signatures was the Z/A ratio, which we preferred to approximate by $\frac{\beta\cdot\gamma\cdot\mathrm{m_{proton}}}{\mathrm{Rigidity}}$. The selection strategy was therefore to select doubly charged events and impose tight quality cuts on measured rigidity and velocity. There were several identified backgrounds to the signal events:

- Events with the wrongly measured rigidity due to single or multiple scattering in the tracker materials. Main cuts to eliminate this background were on the consistency of the measurements of the rigidity over the particle trajectory and on the χ^2 value obtained in fitting the trajectory.
- Events with secondary particles produced inside the AMS detector. To remove these events the "isolation" cut was applied, i.e. no additional hits both in tracker and scintillator counters should be found in the vicinity of the reconstructed particle trajectory.

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- Events with the wrongly measured velocity. To remove this background, events which have less than four consistent time measurements and/or high χ^2 value obtained by velocity fitting were rejected. Finally, due to finite time measurement resolution only events with velocity<0.82 were accepted*.

3. Results

Fig. 1. shows the measured Z/A distribution for the survived events. There is one event with low Z/A=0.114 situated outside the distribution. Table 1. shows the main properties of that event. The *cutoff* parameter stands for geomagnetic rigidity cutoff and was calculated by backward tracing particles in the geomagnetic field[7,10] and verified by measuring rigidities of the selected He events recorded in the vicinity of the candidate event detection point.

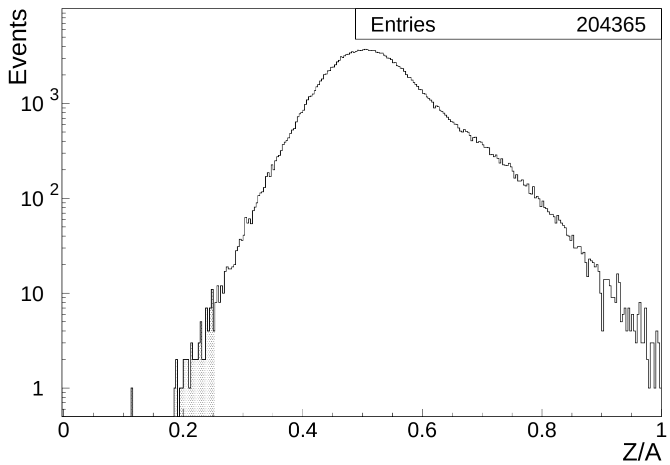

Fig. 1. The measured Z/A distribution for the survived events.

Table 1. Properties of the candidate event.

Lat	Long	Rigidity (GV)	β_{TOF}	β_{dE}	Z/A	Cutoff (GV)
-44.38°	23.70°	4.31±0.38	0.462±0.005	0.44±0.04	0.114	1.95±0.1

4. Discussion

Firstly we wanted to understand the nature of the background low Z/A events, shown by shaded area of Fig. 1. Fig. 2.(a) compares the quality of the rigidity reconstruction for these events with that of for normal He events and shows that most of the low Z/A events seems to have their rigidity incorrectly

*The value of this cut was determined by analyzing the events which had measured velocity greater than one.

measured, while Fig. 2.(b) shows that all the events but our candidate event are

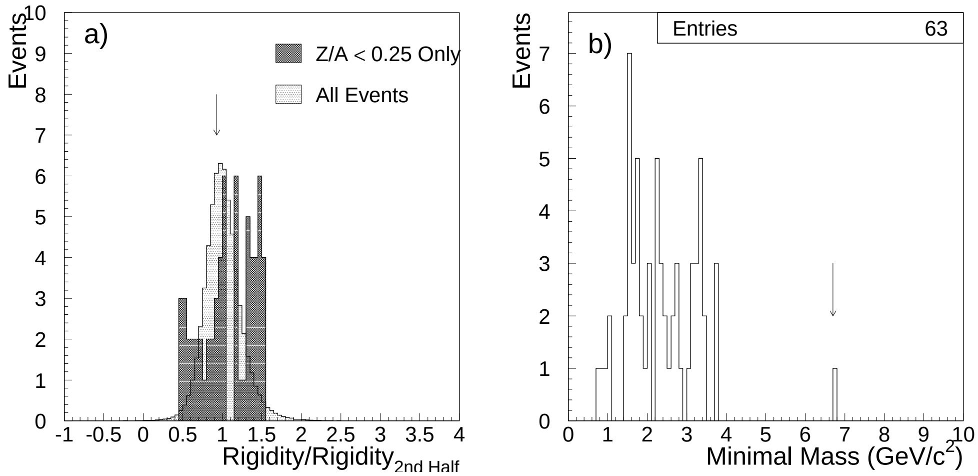

Fig. 2. a) Ratio of the measured rigidity to the one obtained by using half of the tracker measurements only for normal He and low Z/A events. This ratio expected to be around one for the good events.; b) Reconstructed masses for the low Z/A events (right panel) obtained by using geomagnetic rigidity cutoff as particle rigidity. Arrows indicate corresponding values for the candidate event.

compatible with He^4 overcutoff nuclei with mismeasured rigidity. The following possible origins of the candidate event have been then considered:

- Overcutoff He^4 nucleus with wrongly measured velocity and rigidity. Taking geomagnetic cutoff rigidity as the true one leads to minimal velocity value of 0.66 instead of 0.46. Fig. 3. shows the distributions of the ionization losses in scintillator counters as well as in tracker for the corresponding He event samples. One can see that candidate event ionization losses are largely incompatible with that of He events with velocity around 0.66.
- Overcutoff Li^7 nucleus with wrongly measured rigidity, charge and velocity. The Li^7 nucleus with rigidity around 2 GV and velocity around 0.68 would have the ionization losses compatible with that of the candidate event. We estimated probability of such an event to be $O(10^{-6})$, taking into account measured time of flight and tracker resolution and expected Li/He fluxes ratio.
- Undercutoff He^3 nucleus with wrongly measured rigidity. As was shown by AMS[2], there is an undercutoff He flux on the low Earth orbit composed mainly of He^3 nuclei. Taking into account the undercutoff to overcutoff He flux ratio, tracker energy resolution and He isotopes composition we have estimated the probability of such an event to be less than 10^{-3}.
- Doubly ionized oxygen nucleus[9]. This type of events cannot be seen by AMS-01, as nuclei with kinetic energy within the AMS energy range would be completely ionized at very top of the AMS[3,5].

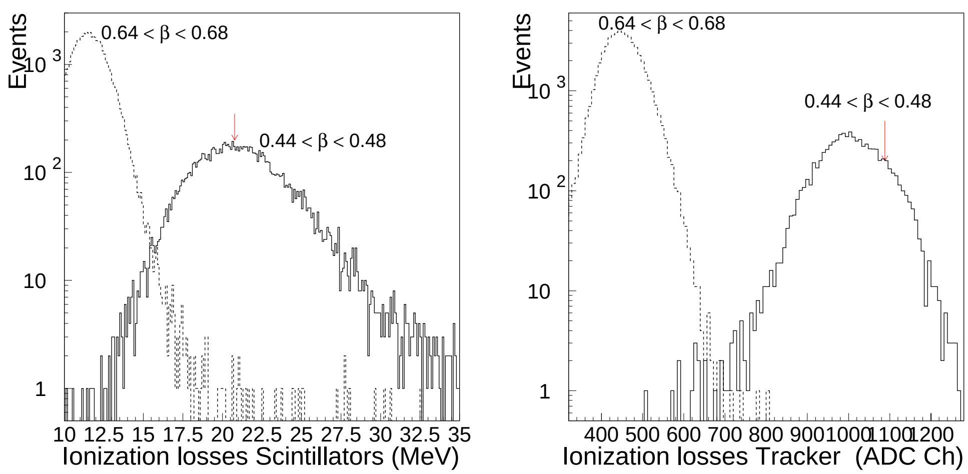

Fig. 3. The scintillator counters (left panel) and tracker (right panel) ionization losses for the He events samples with 0.46 and 0.66 average velocity. Arrows indicate the ionization losses for the candidate event.

We have concluded therefore that the presented event could not be easily explained by ordinary nuclei background.

5. Flux Estimation

Assuming the nuclear interaction length of the candidate event be similar to that of the ordinary nuclei, we have estimated the AMS-01 acceptance for such type of nuclei using dedicated MC simulation model[2]. The acceptance turned out to be $2 \cdot 10^4$ m^2·sr·sec in the kinetic energy interval of 1.5 to 10 GeV, corresponding to the flux of $5 \cdot 10^{-5}$ (m^2·sr·sec)$^{-1}$.

6. References

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