

Precision measurement of the lithium flux in cosmic rays with the AMS-02 detector

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Summary. — The Alpha Magnetic Spectrometer (AMS-02) is a magnetic spectrometer designed for the precision study of cosmic ray (CR) composition and energy spectrum from GeV to TeV. It was installed on May 2011 on the International Space Station and is continuously taking data since then. Using the high acceptance ($0.45 \text{ m}^2 \text{ sr}$) and long exposure time, AMS-02 is able to measure the flux of numerous CR species and to study their spectral index variation as a function of energy. In particular, lithium nuclei in cosmic rays are produced by the spallation of heavier ions that collide with interstellar nuclei. For this reason, the abundance of lithium in CRs is a useful tool to model the propagation of CRs in the Galaxy. In this contribution the precision measurement of the lithium flux from 1.9 GV to 3 TV, based on 1.9 million events collected by AMS-02 detector in five years is discussed.

1. – Introduction

Cosmic rays (CRs) are charged and neutral particles with galactic or extra-galactic origin reaching the Earth atmosphere from all directions and spanning a wide energy range (from few MeV up to 10^{20} eV). CR elements such as helium, carbon and oxygen are mostly of primary origin, *i.e.* accelerated at the CRs production site. Lithium, as beryllium and boron, is produced from the spallation of primary cosmic rays during their propagation in the interstellar medium. As a secondary element or even tertiary (since it can also be produced by the spallation of secondary species) the abundance of lithium is sensitive to the propagation history of cosmic rays and can be used to constrain the parameters describing the diffusion, convection or reacceleration of cosmic rays in the Galaxy [1].

2. – Detector

The AMS-02 detector [2] is composed by a permanent magnet, a silicon tracker, four planes of time of flight (TOF) scintillation counters, and an array of anticoincidence counters (ACC). AMS also features a transition radiation detector (TRD), a ring imaging

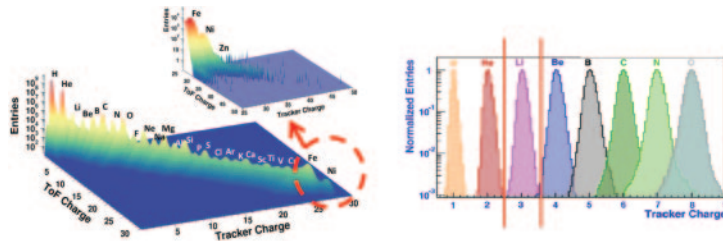


Fig. 1. – Left: charge measurement provided by the Inner tracker and TOF; AMS-02 is able to perform precise measurement of the hadronic component in CRs for nuclei up to Fe. Right: inner tracker charge measurement; vertical red lines show the charge cut applied to select the lithium sample.

Cerenkov detector (RICH), and an electromagnetic calorimeter (ECAL). Nine double-sided silicon microstrip detectors form the tracking system, the first (L1) at the top of the detector, the second (L2) just above the magnet, six (L3 to L8) within the core of the magnet, and the last (L9) just above the ECAL. L2 to L8 constitute the inner tracker (IT). The tracker accurately measures the curvature of particles in the magnetic field with resolution better than $6 \mu\text{m}$ in the bending direction for $Z = 3$, and it allows to derive the rigidity ($R = pc/Ze$) of charged cosmic rays. The resulting maximum detectable rigidity (MDR) is 3 TV over the 3 m lever arm from L1 to L9 and 0.88 TV over the lever arm from L1 to L8. Each layer of the tracker provides also an independent measurement of the charge Z with a resolution of $\Delta Z/Z = 6\%$. Overall, the inner tracker has a resolution of $\Delta Z/Z = 3\%$ (see fig. 1).

3. – Event selection

The AMS-02 detector, with its large acceptance and long exposure time, is able to perform a precise measurement of the hadronic component in CRs for nuclei up to Fe. In the first 5 years (May 19th, 2011 to May 26th, 2016) AMS-02 has collected $8.5 \cdot 10^{10}$ cosmic ray events. The collection time used in this analysis includes only those seconds during which the detector was in normal operating conditions, AMS-02 was pointing within 40° of the local zenith, and the ISS was outside the South Atlantic Anomaly. The measured rigidity is also required to be greater than 1.2 times the maximum geomagnetic cutoff within the AMS field of view. The cutoff was calculated by backtracing [3] particles from the top of AMS out to 50 Earth's radii using the most recent IGRF geomagnetic model [4]. The identification of lithium ions is achieved by requiring a charge compatible with $Z = 3$ on the tracker L1, inner tracker, upper TOF and, for rigidity > 0.88 TV, tracker L9. Due to the multiple independent measurements of the absolute charge, the contamination from $Z < 3$ particles is negligible after the tracker and the TOF selection. The residual background to lithium events resulting from the fragmentation of heavier nuclei in the upper part of AMS-02 (TRD and upper TOF) is evaluated by fitting the charge distribution of tracker L1 with charge distribution templates of Li, Be, B, C, N and O (see fig. 2). The templates are obtained following the same procedure described in [5]. This residual background is $\leq 0.1\%$. The background from the fragmentation with the materials above L1 has been estimated from the simulation, using MC samples generated according to AMS flux measurements. This background is 5% at 2 GV and decreases to 2% at 2.5 TV.

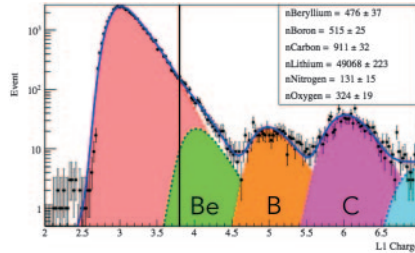


Fig. 2. – Charge distributions measured by the tracker L1 for lithium events selected by the inner tracker in the rigidity range between 16 GV and 18 GV (black points). The solid blue line shows the fit of the sum of the charge distribution templates Li, Be, B, C, N, O (obtained with the procedure in [5]) to the data. The charge selections applied on tracker L1 is shown as a vertical solid line.

4. – Data analysis

The isotropic lithium flux Φ_i in the i -th rigidity bin ($R_i, R_i + \Delta R_i$) is given by

$$(1) \quad \Phi_i = \frac{N_i}{A_i \epsilon_i T_i \Delta R_i},$$

where N_i is the number of lithium events corrected for bin-to-bin migrations, A_i is the effective acceptance, ϵ_i is the trigger efficiency, and T_i is the collection time. The trigger efficiency (described in detail in [6]) for lithium was measured to be $> 98\%$ over the entire rigidity range. The acceptance of AMS-02 has been evaluated using a Monte Carlo simulation (MC) of the entire detector. The simulation is validated comparing the reconstruction and selection efficiencies estimated from flight data with those obtained from the simulation itself: any difference between the two evaluations of each efficiency is used to correct the estimated acceptance and to assess the systematic uncertainty on the measurement. The effect of the finite resolution in the rigidity measurement (that would result in a bin-to-bin migration of events in the flux measurement) is taken into account and corrected using different unfolding methods [6]). Extensive studies were made of the systematic errors. These errors include the uncertainties in the two background estimations, the trigger efficiency, the geomagnetic cutoff factor, the acceptance calculation, the rigidity resolution function and the absolute rigidity scale. The lithium flux, as measured by the AMS-02 detector and shown at this conference, exhibits a spectral feature that can be described with a double power law with the position of the hardening compatible with the one found for proton [6] and helium [7].

5. – Conclusions

The precise knowledge of the lithium flux is important in understanding the origin, acceleration, and propagation of cosmic rays. The precise measurement of the lithium flux from 1.9 GV to 3 TV provided by AMS-02 has been discussed. The lithium flux presented in this conference deviates from a single power law and the spectral index progressively hardens at high rigidities. The rigidity position of the hardening is found to be compatible with the ones determined from the proton and helium fluxes measured by AMS-02.

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