Cosmic-ray Astrophysics with AMS–02

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Abstract

Precise knowledge of the hadronic component of cosmic rays is needed to describe the cosmic ray production, acceleration and propagation mechanisms in our galaxy. Present measurements suffer from limitations coming from short exposure time, intrinsic instrumental limitations and restricted energy range. The AMS–02 experiment is the first large acceptance magnetic spectrometer to perform high statistics studies of cosmic rays in space. The detector will operate on the International Space Station for more than 3 years. AMS–02 will precisely measure the cosmic ray fluxes of individual elements up to Z$\sim$26 in the rigidity range from $\sim$1GV to $\sim$1TV. AMS–02 will allow to test propagation models through the precise measurements of secondary-to-primary ratios as D/p, ^{3}He/^{4}He in the energy range from few hundreds MeV to tens of GeV, and B/C, sub-Fe/Fe up to $\sim$1TV. In particular, the accurate measurement of ^{10}Be/^{9}Be in a wide energy range will allow to understand the age of the cosmic-ray confinement in the galaxy and will constraint the size of the galactic halo.

1. Introduction

Cosmic rays (CR) are the only direct sample of extraterrestial matter arriving the Earth. Among its different components, hadrons represent the major contribution to the CR flux. Measurements of the hadronic CR element abundances compared to those of the Solar System have helped to understand qualitatively the source composition and propagation properties of galactic CR. However, only precise measurements of the elemental and isotopic spectra of hadronic CR can validate specific models for their origin and propagation. Moreover, the backgrounds for faint signal searches in CR must be understood on the basis of such models.

Most precise measurements can be only achieved on space-borne experiments, where the effects of the residual Earth's atmosphere are negligible. Present measurements regarding individual spectra have been obtained in a limited energy range, whereas isotopic separation has been only achieved for energies up to

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the GeV/nucleon range.

AMS–02 is the first large acceptance magnetic spectrometer to operate in space. AMS–02 will operate on the International Space Station for more than 3 years. Due to the detector unique capabilities for particle identification and energy measurement, AMS–02 will provide measurements for individual element fluxes and isotopic ratios with unprecedented accuracy.

2. The AMS–02 Spectrometer

The AMS–02 magnetic spectrometer is presented in detail somewhere else in this conference [1]. The detector provides a rigidity (p/Z) determination with a resolution of 1.5% at 10 GV based on the precise measurement of the particle trajectory in the magnetic field of the experiment using a silicon tracker system [2]. A velocity measurement with a resolution of a 3% is provided by the Time of Flight system, TOF [3]. A second, more precise velocity measurement (1 permil resolution) is obtained with a Ring Imaging Čerenkov Counter, RICH [4], for particles above its Čerenkov threshold. Finally, the simultaneous measurements of the particle energy deposition in the tracker and TOF planes and the amount of Čerenkov light detected by the RICH allow to determine the absolute value of the particle electric charge up to $Z \sim 26$. The large geometrical acceptance of the system (0.5 m^2sr) together with the long time exposure of the experiment (more than 3 years) will allow to collect a data sample orders of magnitude larger than present experiments.

3. Expected Performances

The expected performances of AMS–02 regarding measurements relevant for constraining models for galactic CR production, acceleration and propagation can be separated in three different categories. First, precise measurements of the fluxes of H, He and CR species which are believed to have a primary origin (CNO) in a wide energy range is related to the injection spectra and can constrain the primary acceleration mechanisms of CR. The fluxes of secondaries (absent at the CR sources) and, the ratio of these secondary species to the primaries which produce them through their path in the ISM, define the amount of material traversed by the CR since their acceleration. Finally, the ratio of unstable to stable secondary nuclei can be used to determine the cosmic ray confinement time in the galaxy and, in difussion models, the effective thickness of the galactic halo.

AMS–02 will precisely determine the fluxes of individual elements with electric charges $1 \leq Z \lesssim 26$ in the energy range 0.1 GeV/n $\lesssim E \lesssim$ 1 TeV/n. After 3 years of data taking AMS–02 will collect 10^8 H, 10^7 He and 10^5 C with energies above 100 GeV/n. In addition, AMS–02 will identify 10^4 B with energies above 100 GeV/n and thus precisely measure the ratio of boron to its primary carbon

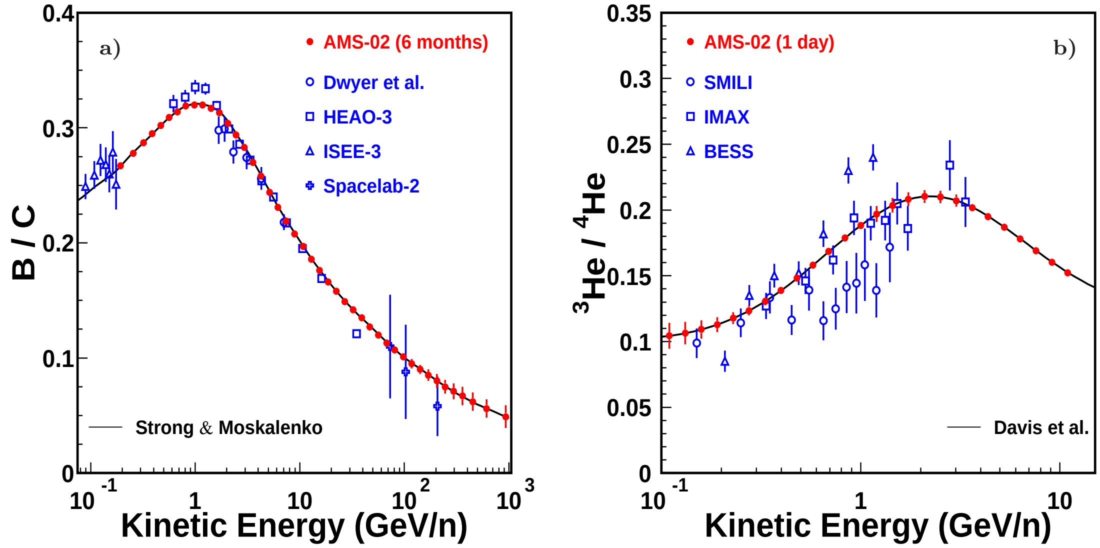

Fig. 1. AMS–02 expected performance on a) B/C ratio after 6 months of data taking and b) ^{3}He/^{4}He ratio after 1 day of data taking compared to recent measurements [5] and [7]. The ratios have been simulated following the models described in [6] and [8] respectively.

up to 1TeV/n. The expected B/C sensitivity after 6 months of data taking is shown in Fig. [1]a.

As regards the stable light isotope measurements, AMS–02 will be able to identify ^{2}H from ^{1}H and ^{3}He from ^{4}He in the energy range $0.1 \lesssim \mathrm{E} \lesssim 10$ GeV/n. After 3 years, AMS–02 will identify 10^8 ^{2}H and ^{3}He. The sensitivity on ^{3}He/^{4}He after 1-day exposure is shown if Fig. [1]b.

Among all β-radioactive secondary nuclei in cosmic rays, ^{10}Be is the lightest isotope having a half-life comparable with the confinement time of cosmic rays in the galaxy. AMS–02 will be able to separate ^{10}Be from the stable ^{9}Be in the range $0.15 \lesssim \mathrm{E} \lesssim 10$ GeV/n. After 3 years, AMS–02 will collect 10^5 ^{10}Be in this energy range. The expected sensitivity on ^{10}Be/^{9}Be after 1 year of data taking is shown in Fig. [2] and compared to recent measurements *.

4. Conclusions

The AMS–02 spectrometer is a fundamental physiscs experiment performed in space. The identification capabilities of the detector in a wide energy range and the large data sample collected after its 3–year exposure will provide the benchmark data to validate current models for galactic cosmic ray propagation.

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*An unconfirmed measurement [10], which would imply an anomalously high value for this ratio (^{10}Be/^{9}Be$\,>1$), is not included in the plot.

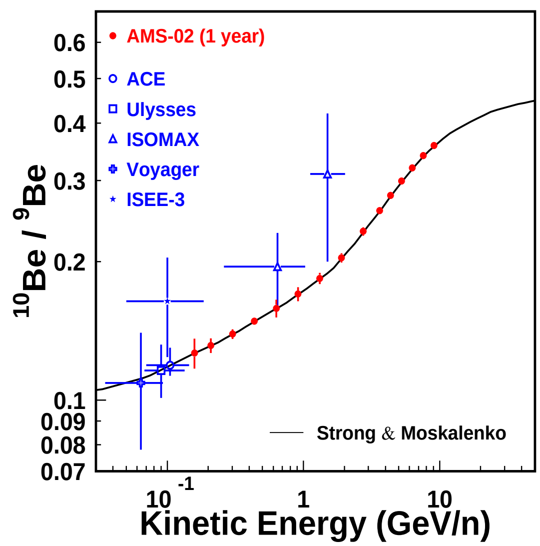

Fig. 2. AMS–02 expected performance on ^{10}Be/^{9}Be ratio after 1 year of data taking compared to recent measurements [9]. The ratio has been simulated according to the propagation model described in [6].

5. Acknowledgments

We want to thank the many organizations and individuals listed in the acknowledgments of [1].

6. References

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