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Results from AMS-02 on the ISS after 6 years in space

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Summary. — AMS-02 is a cosmic-ray detector which has been operating on the International Space Station since May 2011 to conduct a unique mission of fundamental research in space. More than 100 billion cosmic rays have been collected by AMS-02 after 6 years of operations, providing a detailed insight into the features of different species of cosmic rays. This contribution reviews the recent AMS-02 results based on 6 years of operations in space and their contribution to the advances in the understanding of cosmic-ray origin, acceleration and propagation physics.

1. – The AMS-02 mission

The Alpha Magnetic Spectrometer [1] (AMS-02) is the high-energy spectrometer which has been operating onboard the ISS since May 2011 to measure cosmic-ray (CR) composition and spectra up to the TeV energy scale. AMS-02, in orbit for more than 6 years of successful continuous operations, has collected more than 100×10^9 CRs.

The detector core is the magnetic spectrometer, composed of a 0.14 T dipole permanent magnet and 9 layers of double-sided Si microstrip tracker detectors. The particle rigidity R is measured over a lever arm up to 3 m, the maximum detectable rigidity is 2 TV for $|Z| = 1$ particles and 3.2 TV for $|Z| > 1$ particles. The direction of the curvature inside the magnetic field identifies the sign of the charge and consequently separates matter from the rare antimatter CR component. The charge resolution of the inner tracker amounts to $\Delta Z/Z = 3.5\,\%$ for He and improves up to 1.5% for O nuclei. Four time-of-flight (TOF) planes trigger the readout of the detector and measure the particle flight direction and velocity. The 17 X_0 ECAL imaging calorimeter provides the measurement of the $e^{\pm}$ energy (E), and the topology of the shower is used to separate $e^{\pm}$ from hadrons. The energy deposits in the 20 layers of the TRD are used to further differentiate between $e^{\pm}$ and p. The analysis of the radiation in the Ring Imaging Cherenkov detector (RICH) provides accurate information on nuclei charges and velocity.

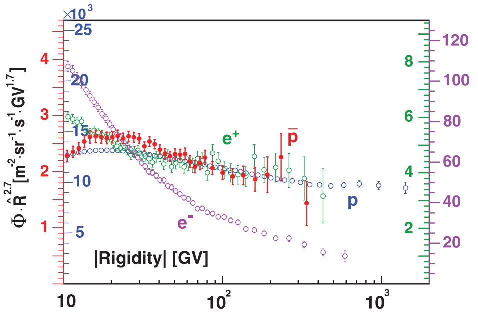

Fig. 1. – Fluxes of protons, antiprotons, electrons and positrons measured by AMS-02 [2].

2. – Antimatter components of cosmic rays

AMS-02 measurements of the rare antimatter components of CRs have provided major advances for understanding the origin of CRs. AMS-02 has observed evidence that the shapes of the e^- and e^+ fluxes measured up to 700 GeV are significantly different [3]. The analysis of the excess observed in the positron fraction (PF, $e^+/(e^+ + e^-)$) with respect to the abundance expected by pure secondary production of e^+ provides strict constraints on the nature of primary $e^\pm$ sources that could explain the data [4]. Moreover, the $\overline{p}/p$ ratio measured by AMS-02 results flat from $\sim$ 60 GeV up to $\sim$ 450 GeV, differently from expectations of pure secondary $\overline{p}$ production that predict a $\overline{p}/p$ with power law index between -0.1 and -0.3 [5]. As shown in fig. 1, the $\overline{p}$ spectrum above 60 GeV is similar to that of e^+ and p and different from that of e^-. These results confirm that the antimatter spectra are not compatible with a dominant secondary production of e^+ and $\overline{p}$ and require an additional primary source. Future AMS-02 measurements of heavier antimatter, like $\overline{^2\mathrm{H}}$ or $\overline{\mathrm{He}}$, will provide further insights to understand the origin of the observed antimatter excess in CRs.

3. – Primary and secondary nuclear components of cosmic rays

The sensitivity to disentangle between different hypotheses for the e^+ excess and of the possible $\overline{p}$ excess is limited by the uncertainties on the predictions of secondary CR

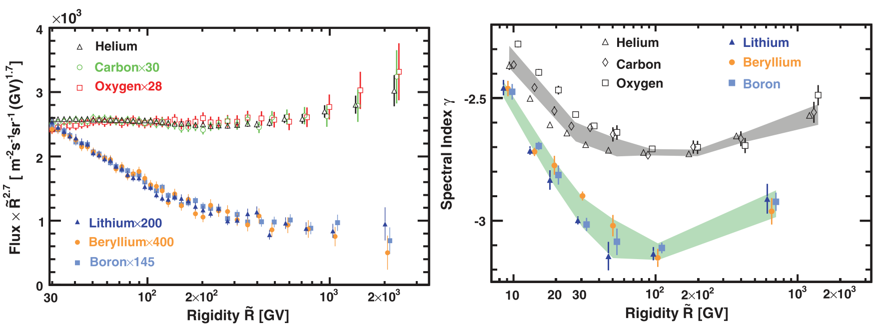

Fig. 2. – Fluxes and spectral indices for primary (helium, carbon, oxygen) and secondary (lithium, beryllium, boron) nuclei cosmic rays measured by AMS-02 [6, 7].

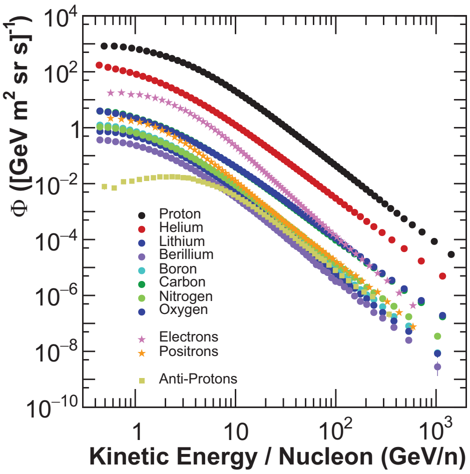

Fig. 3. – Measurements of cosmic-ray fluxes by AMS-02 as of 2017.

abundances, dominated by the finite knowledge of the nuclear interaction cross-sections at high energies and of the propagation mechanisms. Complementary measurements of the CR nuclear components by AMS-02 can be used to improve the current understanding of CR propagation physics. The sampling of the nuclear charge at different depths of the detector allows to measure directly the heavy-nuclei fragmentation probabilities to consequently improve the charge identification capabilities. AMS-02 has measured the spectra of heavy nuclei (helium to oxygen) with unprecedented accuracy up to ~ 2 TV [6,7]. The fluxes and the rigidity dependence of the spectral indices are shown in fig. 2. For the first time, the evidence of a common hardening at approximately 200 GV has emerged from the measurements. Primary CRs (He, C, O) and secondary CRs (Li, Be, B) all deviate from single power laws but, despite the common hardening, the rigidity dependence of primary CRs differs from that of the softer secondary CRs. These results are consistent with models in which the hardening of CR fluxes is due to the propagation properties in the Galaxy.

4. – Outlook and prospects

A collection of the most relevant measurements of CR fluxes by AMS-02 after 6 years of operations is shown in fig. 3. AMS-02 will collect data at least until 2024. The new data will increase the accuracy of the current results and will open the possibility for new measurements of rare components of CRs as well as measurements of CR properties like anisotropies, time dependences or isotopic abundances, all of which will provide further insights towards a more comprehensive understanding of the origin and propagation of CRs.

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