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Cosmic ray physics with AMS

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Abstract. The AMS-02 experiment is the first large acceptance magnetic spectrometer to perform high statistics studies of cosmic rays in space. It will operate on the International Space Station for more than three years and precisely measure the cosmic ray fluxes of individual elements in the rigidity range from $\sim$ 1GV to $\sim$ 1TV. It will test propagation models through the precise measurement of secondary to primary ratios as $^3He/^4He$ in the range from a few hundreds of MeV to tens of GeV, and B/C up to 1TV.

1 Introduction

AMS-02 is a large acceptance magnetic spectrometer which will extend high statistics measurements of cosmic ray (CR) properties to high rigidities. In 2006 it will be mounted on the International Space Station (ISS) for a three year mission. It was preceeded by AMS-01 in a precursor flight on space shuttle mission STS91 in 1998. Originally conceived as a technical checkout, this flight also brought physics results and six publications [1-6] on $e^{\pm}$, p, $\overline{p}$, D, He, and $\overline{He}$. The AMS experiment is constructed largely in Europe by European laboratories and universities.

The AMS-02 detector is described elsewhere [7]. It contains a transition radiation detector, time of flight hodoscopes, a large superconducting magnet with a silicon tracker, a ring imaging Cherenkov counter, and an electromagnetic calorimeter. It has a large acceptance, $(0.5m^2sr)$.

2 Nuclei in space

^{10}Be is the lightest β-radioactive CR secondary nucleus having a half-life comparable with the confinement time of cosmic rays in the galaxy ($\sim 2\times10^6$ yr). AMS-02 will be able to separate ^{10}Be from stable ^9Be in the range $0.15 < E < 10$ GeV/n. AMS-02 will collect 10^5 ^{10}Be in three years (Fig. 1).

AMS-02 will collect 10^4 B and 10^5 of its parent C with energies above 100 GeV/n and thus precisely measure their ratio up to 1 TeV/n. The expected B/C sensitivity after six months of data taking is shown in Fig. 2.

As regards the stable light isotope measurements, AMS-02 will be able to distinguish ^2H from ^1H and ^3He from $4He$ in the energy range $0.1 \leq E \leq 10$ GeV/n. After

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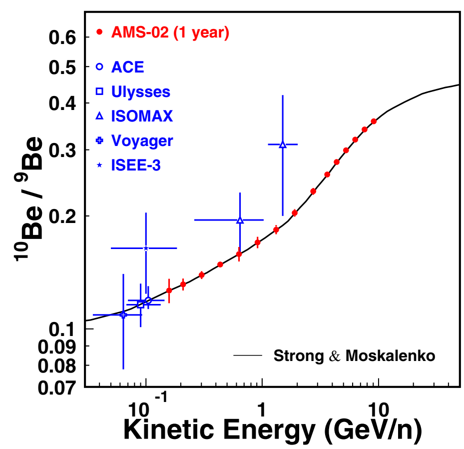

Fig. 1. AMS-02 expected performance on $^{10}Be/^9Be$ ratio after 1 year of data taking vs. recent measurements [8]. Ratio simulated according to the propagation model described in [9]

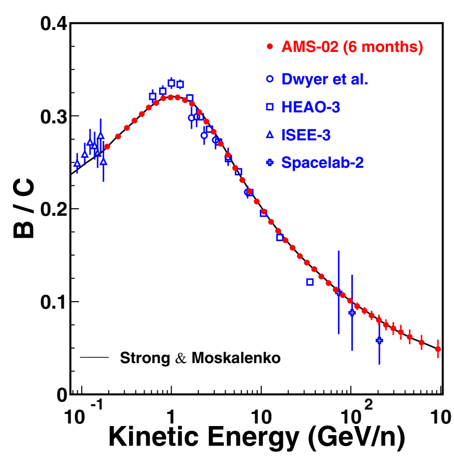

Fig. 2. AMS-02 expected performance on B/C ratio after 6 months of data taking vs. recent measurements [10]. Ratio simulated according to the propagation model described in [9]

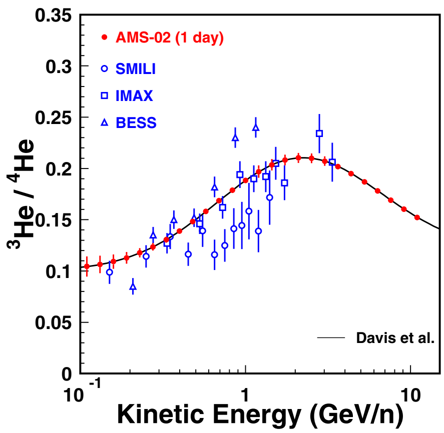

Fig. 3. AMS-02 expected performance on $^3He/^4He$ ratio after 1 day of data taking vs. recent measurements [11]. Ratio simulated according to the propagation model described in [12]

three years, AMS-02 will identify 10^8 ^2H and ^3He. The sensitivity to $^3He/^4He$ after one day is shown in Fig. 3.

3 Search for antimatter

A major objective in the physics program of AMS is to search for cosmic ray antinuclei.

On the 10 day precursor flight identified 2.86×10^6 He nuclei but not a single $\overline{He}$. On AMS-02, the expected upper limit after three years of data taking is $\overline{He}/He < 10^{-9}$. The AMS-02 expectation vs. results from AMS-01 and other experiments is shown in Fig. 4.

4 Indirect search for supersymmetric dark matter

There are indications of large amounts of dark matter in the universe, which could be composed of non-baryonic Weakly Interacting Massive Particles (WIMPs), such as the lightest supersymmetric particle in R-parity conserving SUSY models. AMS can study SUSY dark matter in several decay channels from neutralino annihilation:

Positron Flux:
Recently [14] e^+ production by annihilating neutralinos χ_1^0 in the galactic halo has been simulated according to several models, varying seven free parrameters of the MSSM, with e^+ interstellar flux calculated by means of a standard diffusion model. Models assuming m_χ 336 GeV and 130.3 GeV respectively were investigated by means of DARKSUSY[13]. The e^+ signal from χ annihilation was boosted by factors of 11.7 and 54.6 to fit the HEAT data, and simulated primary positron fluxes added to the Moskalenko and Strong secondary positron spectrum. The results of the simulation of the positron fraction expected to be measured by AMS-02 in one year are shown in Fig. 5. Details can be found in [13,15].

Antiproton Flux:
Several attempts at interpreting existing measurements of CR $\overline{p}$ indicate that an exotic origin such as neutralino annihilation cannot be excluded[16]. For high m_χ a high-energy excess of $\overline{p}$ is measurable. AMS-02 will measure accurately the $\overline{p}$ spectrum up to hundreds of GeV with a few percent energy resolution as shown in Fig. 6.

5 Other exotic matter

Strangelets:
Theorists have proposed the existence of strangelets [17], stable mixtures of u,d,s quarks with many different quarks in the lowest energy state. The signature would be an anomalous ratio Z/A ($Z \approx 0.3A^{2/3}$, while Z/A = 0.33-0.67 for normal nuclei). In 5 years, AMS-02 would be sensitive to strangelet fluxes on the order of $10^{-10} - 10^{-11}$ $(cm^2 s \cdot sr)^{-1}$. In preparation, we have searched for doubly charged anomalously heavy nuclei in the data from AMS-01 [18]. Over 4×10^6 He events were collected. After tight quality cuts on measured rigidity and velocity, one candidate event was found, with $Z/A \sim 0.114$, corresponding to a flux of $5 \times 10^{-5}(m^2 \cdot sr \cdot sec)^{-1}$. We estimated the background from ordinary nuclei to be $< 10^{-3}$ events.

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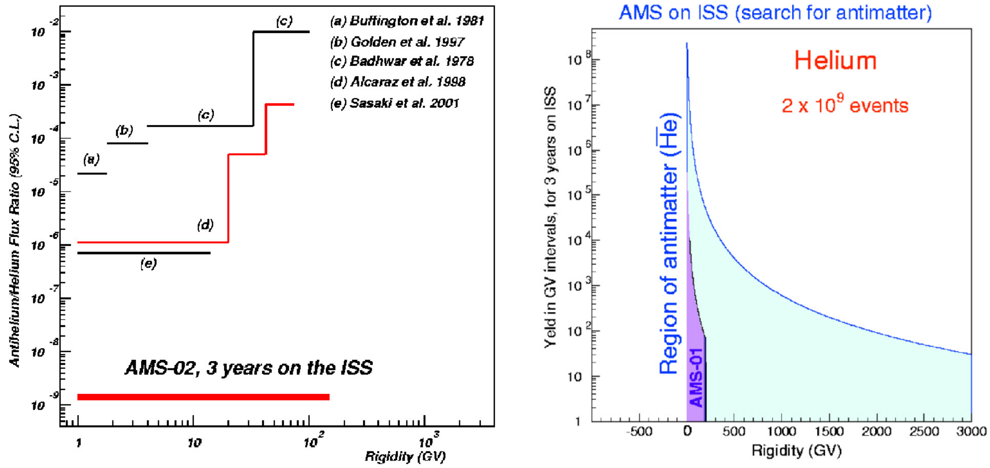

Fig. 4. AMS-02 expectation for $\overline{He}$ vs. results from AMS-01 [1] and other experiments [11]

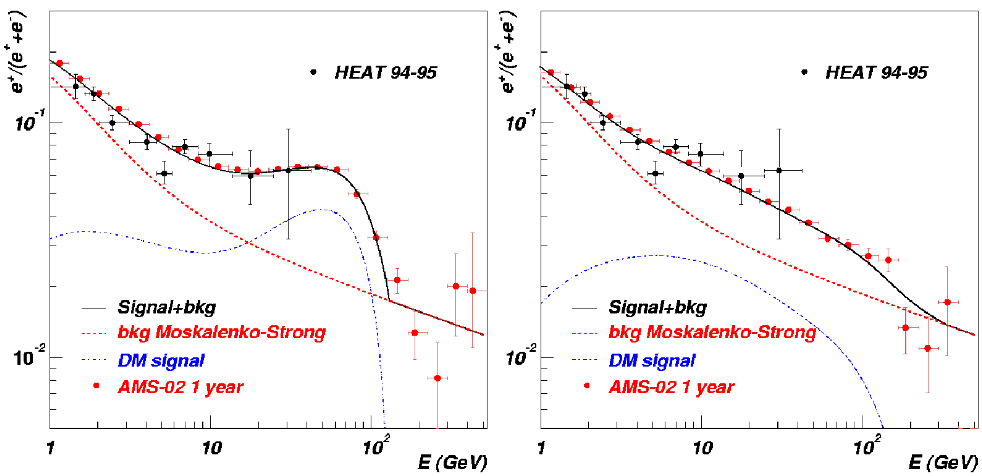

Fig. 5. AMS-02 e^+ fraction in the case of a primary e^+ from annihilating χ

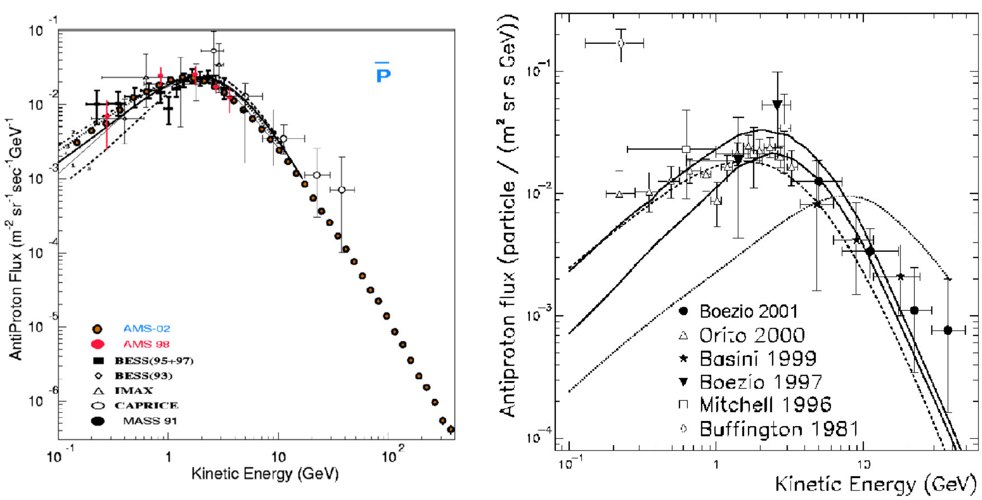

Fig. 6. **a** AMS-02 3 years secondary (*pbar*) flux. **b** Example of distortion due to χ signal