Dark Matter Searches with AMS-02

J. Pochon for the AMS02 Collaboration
Presenter: J. Pochon (jonathan.pochon@lapp.in2p3.fr), fra-pochon-J-abs1-he23-oral

The Alpha Magnetic Spectrometer (AMS), to be installed on ISS, will provide data on cosmic radiations in a large range of energy from 0.5 GeV to 3 TeV. The main physics goals in the astroparticle domain are the anti-matter and the dark matter searches. Observations and cosmology indicate that the Universe may include a large amount of unknown Dark Matter. It should be composed of non baryonic Weakly Interactive Massive Particles (WIMP). A good WIMP candidate being the Lightest Susy Particle in R-Parity conserving models. AMS offers a unique opportunity to study simultaneously SUSY dark matter in three decay channels from the neutralino annihilation: e^+, antiproton and gamma. The supersymmetric theory frame is considered together with alternative scenarii (extra dimensions). The expected flux sensitivities in three years exposure for the $e+/(e^+ + e^-)$ ratio, antiproton and gamma yields as a function of energy are presented.

1. Introduction

Cold dark matter (CDM) makes up 23 % of the energy of the universe. Supersymmetry or extra-dimensions models provide viable candidates to Dark Matter. Dark Matter annihilations can occur in the galactic halo and produce an exotic source of positrons, antiprotons and gamma rays. The AMS-02 spectrometer is a multi-purpose detector described in detail in [1]. Its key features relevant to indirect dark matter searches are a 0.5 m^2.sr geometrical acceptance, a very good energy resolution in the GeV to TeV range and redundant particle identification.

2. Positron flux measurements

AMS-02 will be able to measure the positron energy spectrum from 1 to 400 GeV, with an energy resolution of 3% above 10 GeV. The AMS-02 acceptance for positrons has been estimated to be on average 0.045 m^2.sr in the energy range 2 to 500 GeV [2], [3], [4], while the effective rejection power defined as the inverse of the proton acceptance is larger than 3.10^8 for energies above 10 GeV.

The sensitivity to detect a positron signal in AMS-02 from a primary source such as the annihilation of neutralinos is illustrated in Figure 1 for two models chosen within the m-Sugra scenario. The signal is obtained from the DarkSusy [5] code interfaced with the Suspect [6] code, while the background is derived from the parametrisation given in [7]. For both cases, the boost factor is adjusted to fit the HEAT data [8].

The m-Sugra framework assumes universality of the gaugino masses at the GUT scale. By breaking this universality, models phenomenologically more favorable for the positron channel can be obtained. For instance, by taking the gluino mass M_3 as half the gaugino mass, boost factors on average one thousand times smaller are needed. This is illustrated in Figure 2: for each point of the $(m_{1/2}, m_0)$ plane, boost factors are adjusted so that the positron signal is at the limit of visibility (95 % C.L) in AMS-02.

Some models with extra dimensions provide a particle candidate to Dark Matter. The chosen example is extracted from Universal Extra Dimensions models, where the stable particle can be a Kaluza-Klein photon [9]. The decay and hadronisation of the annihilation products are performed using PYTHIA [10] and positrons are propagated by an independent code [11]. Figure 3 shows the signal expected in AMS-02 after amplification to fit the HEAT data or to be at the limit of visibility (95 % C.L) in AMS-02. A similar simulation was performed in [12], obtaining however substantially lower boost factors.
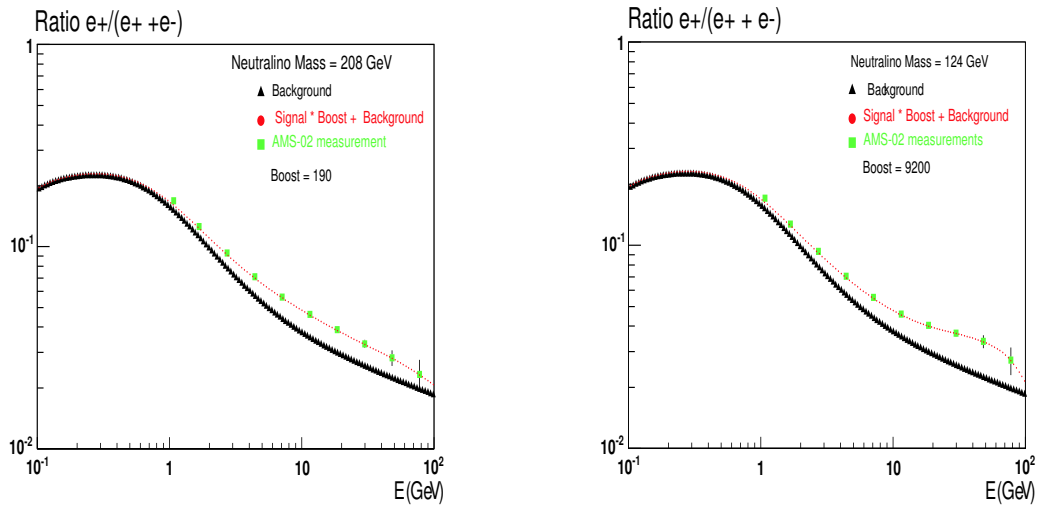
Figure 1. Ratio of the positron over the positron plus electron flux as a function of positron energy for the secondary positron production (triangle/full curve) and an additional primary flux (square and dotted line) originated from a m-Sugra model. The signal amplification is adjusted to fit the HEAT data and is given in the legend. Left: $m_0 = 500\,\text{GeV}$, $m_{1/2} = 500\,\text{GeV}$, $\tan\beta = 50$, $\mu > 0$ and $A_0 = 500$ adapted from [15]. Right: $m_0 = 1530\,\text{GeV}$, $m_{1/2} = 300\,\text{GeV}$, $\tan\beta = 10$, $\mu > 0$ and $A_0 = 0$ [16]
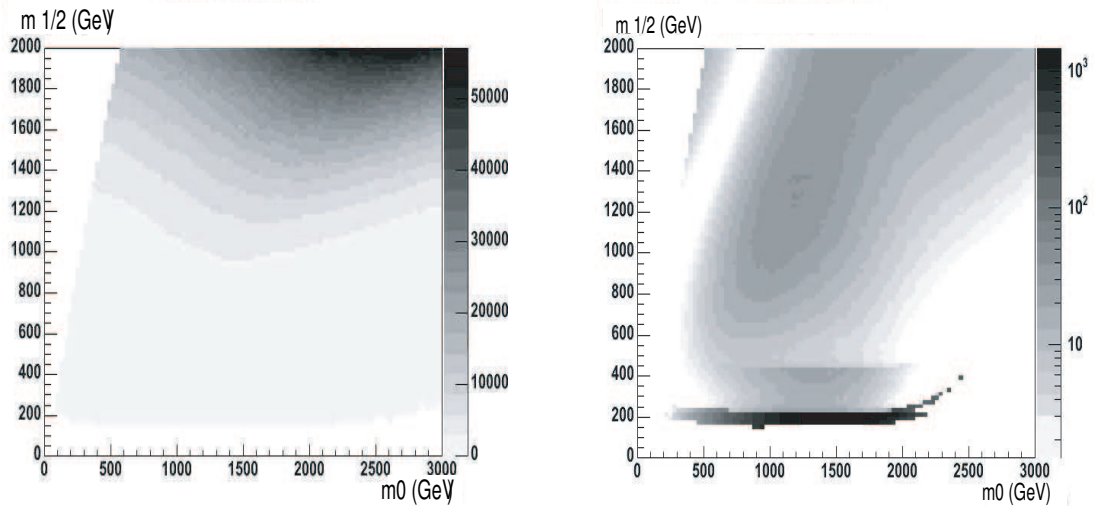

Figure 2. Smallest boost factor (right grey scale) needed to see the signal in three years of operation of AMS-02, in the $(m_0, m_{1/2})$ plane in (left) m-Sugra models and (right) relaxing the gaugino mass universality constraint so that $M_3 = 0.5 m_{1/2}$
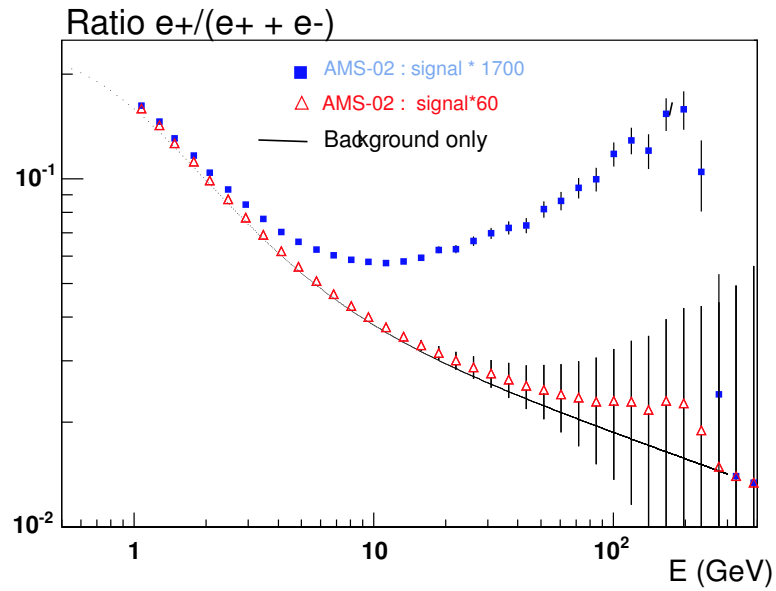
Figure 3. Ratio of the positron over the positron plus electron flux as a function of positron energy for the secondary positron production (line) and an additional primary flux coming from a Kaluza-Klein model as explained in the text. The signal is boosted to fit the HEAT data (square) or is amplified to be at the limit of visibility (95 % C.L) in AMS-02 (triangle).

3. Antiproton flux measurements

Measurements of the antiproton flux are scarce at high energy and not precise. However a neutralino with a high mass [13] could enhance significantly the $\bar{p}$ fluxes at high energy. The expected statistical accuracy on the antiproton spectrum measured with AMS-02 in 3 years is presented in Figure 4.

4. Gamma flux measurements

Gamma rays might be a possible signature of dark matter through the golden processes $\chi\chi \rightarrow \gamma\gamma$, and $\chi\chi \rightarrow Z_0\gamma$ or through the γ continuum coming from π^0 mesons, produced by the other decay channels during hadronisation.

The observed γ-ray flux depends on the annihilation rate into gammas which is related to SUSY models and on the neutralino density along the line of sight to the Galactic Center given by the dark matter halo profile [14]. The AMS potential for the Dark Matter detection with γ has been performed using two methods: the "conversion mode " and the "single photon" as described in detail in References [17] and [18]. The expected γ spectrum in the direction of the Galactic Center, measured by the "single photon" method after one year of data taking is given in Figure 4. A SUSY signal [16] is superimposed to the expected diffuse galactic gamma spectrum.

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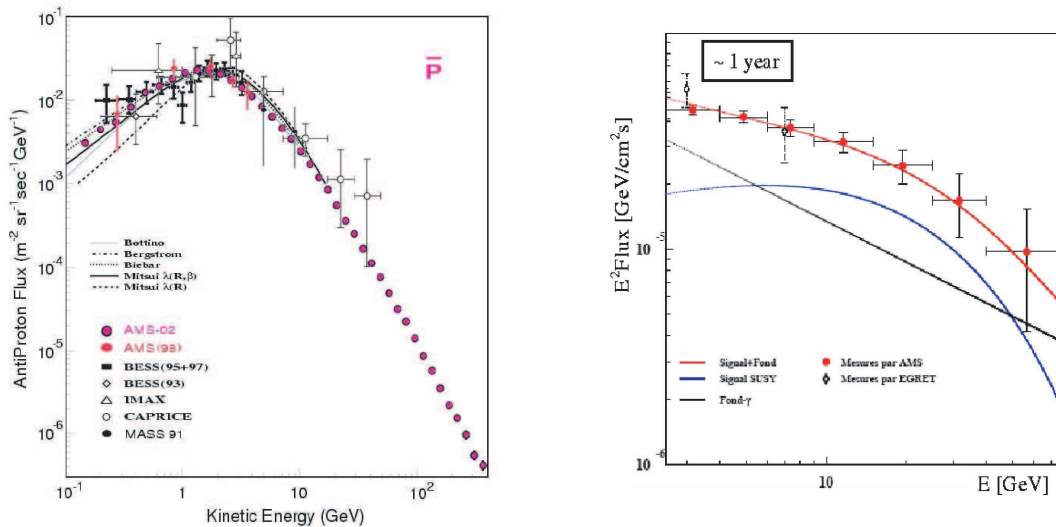
Figure 4. Left: Expected measurements with statistical errors of the antiproton spectrum with AMS-02 in 3 years. Right: γ flux expected from the Galactic Center for a chosen Susy model after one year of data taking with AMS-02.

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