Dark Matter searches with AMS02

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SEARCH FOR DARK MATTER with AMS02

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Abstract: The Alpha Magnetic Spectrometer (AMS), to be placed on ISS, will provide data on cosmic radiations in a large range of energy from 0.5 GeV to 1 TeV. The main physics goals in the astroparticle domain are the anti-matter and the dark matter searches. The e^+, $\bar{p}$ and γ channels will contribute to the dark matter indirect detection studies since they are expected to be produced in the annihilation of the $\tilde{\chi}_1^0$, one good Cold Dark Matter candidate predicted in the supersymmetry theory. The expected flux sensitivities in 3 year exposure for gamma rays, the e^+/e^- ratio and $\overline{p}$ yields as a function of energy are presented and compared to other direct and indirect searches.

Introduction

Cold dark matter (CDM) makes up 23 $\%$ of the energy of the universe, as deduced from the WMAP [1] measurements of the temperature anisotropies in the Cosmic Microwave Background, in combination with data on the Hubble expansion and the density fluctuations in the universe. One WIMPs (Weakly Interacting Massive Particles) candidate may be majorana neutralinos ($\tilde{\chi}_1^0$) proposed in the Supersymmetric Models in which case pair annihilations can occur to produce neutrinos, gamma rays, electrons, positrons, protons or antiprotons. Kaluza-Klein (KK) excitation of Standard Model fields (for example the B^1 particle, the first KK excitation of the B boson) which appear in models of universal extra dimensions are also good candidate for dark matter. From these the electrons and protons are drown in the many particles in the universe, but the others may be detectable above the background from nuclear interactions, especially because of much harder spectra expected from neutralino annihilation. AMS will measure precisely $\overline{p}$,γ, e^+ and $\bar{D}$'s spectrum from the GeV to the TeV. The identification of the particles will be a key issue to obtain a rejection against the proton background of, e.g, at least 10^4 at 200 GeV.

The detector

Compare to the AMS-01 detector which operated successfully during 10 days in June 1998 on the Shuttle Discovery, a significant upgrade of the detector AMS-02 has been planned. A complete description of the full detector, as well as the experimental performance can been found in references [2] and [3]. The major elements of the AMS-02 detector consist of a superconducting magnet (MG), a gaseous transition radiation detector (TRD), a silicon tracker (TR), Time of Flight hodoscopes (ToF), a ring imaging Cerenkov detector (RICH) [4]-[5], an electromagnetic calorimeter (EMC), a star tracker system (AST) and anti-coincidence veto counters (ACC). The momentum and sign of the charge Q is measured by the tracker, while the absolute value of the charge is measured in dependently by the tracker, RICH and ToF. The velocity of the particle is measured by the TOF, TRD and RICH, thus allowing for redundant particle identification, once the charge and the momentum are known. Gamma ray are detected either by the calorimeter or by the pair conversion outside the tracker. The large acceptance of the detector ($\sim 0.4m^2sr$) combined with rigidity measurements of charged particles up to the multi-TeV range and redundant and performing particle identification will allow for a good understanding of the cosmic rays in our galaxy.

Indirect searches

AMS, through the precise spectrum measurements of the positron, anti-proton, gamma and anti deuteron will perform indirect searches of DM; Those searches will be sensitive to both the local (positrons) and the galactic (anti proton and gamma) or extragalactic (gamma) Dark Matter. The search sensitivity will depend on different model assumptions related to the nature and the density of the Dark Matter candidate, his annihilation rate and on the the cosmic rays propagation in the galaxy for the charged annihilation products. A new spectrum generator (for positron ,anti-proton, gamma, anti-deuton and neutrinos) has been used and developed, interfacing MicrOMEGAS [6], which estimates the relic density for different models, with PYTHIA [7] for the decay and the hadronisation of the DM annihilation products. Charged particles are propagated with a semi analytical model, using the positron or anti-proton propagator with cylindrical conditions [8]- [10]. In addition different Halo profile models are assumed like the Navarro, Frenk and White (NFW) [9] halo profile in which the DM density is distributed following an isothermal spherical symmetric profile. Finally some substructure models naturally providing high boost factors (1000) exits without specific fine tuning [11]. In what follows, these so called IMBH models have been used to estimate the boost factor, necessary to fit excess seen in the HEAT data [12].

Positron Flux

AMS-02 will be able to measure the positron flux in the energy range 1 to 400 GeV, with an energy resolution of about 2%, statistical uncertainty of 1 $\%$ at 50 GeV and high average background rejection for e^+/e^- and $e+/p$.

To identify positrons among the large physical background coming from the protons flux, one should be able to separate positrons from protons at a level better than 10^6. In AMS-02, this is obtained by combining information provided by several sub-detectors: the Transition Radiation detector, the Tracker and the Calorimeter. The AMS-02 acceptance for positrons has been estimated to be on average $0.045\,\mathrm{m}^2.\mathrm{sr}$ in the range 2 to 500 GeV [13] while the effective rejection power defined as the inverse of proton acceptance is greater than 3.10^8 for energies above 10 GeV.

The sensibility to detect a positron signal in AMS-02 from a primary source such as the annihilation of neutralinos is illustrated in the figure 1 for a neutralino mass of 150 GeV, decaying mostly into bbar pair, where the signal is originally amplified as mentioned above. The e^+ interstellar flux has been calculated by means of a standard diffusion model [14] to fit the HEAT data [12]. Some class of 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 [15]. The figure 2 shows the signal expected in AMS-02 for the signal amplified to fit the HEAT data; compared to a MSSM scenario, the energy spectrum is quit different; this measurement will be a key point to distinguish the two theoretical hypotheses and learn more about the nature of the DM candidate.

Antiproton flux

Antiprotons are identified by their negative charge in the tracker and a hadronic signature in the TRD. The main background originating from proton interactions outside the sensitive volume is removed by severe quality cuts. Acceptance for antiprotons is 0.160 $m^2.sr$ in the range 1 to 16 geV and 0.033 $m^2.sr$ up to 300 GeV [16]. At energy below few GeVs, different uncertainties spoil the knowledge of the $\bar{p}$ spectrum of the secondary $\bar{p}$ components. AMS-02 will measure accurately the $\bar{p}$ spectrum up to hundred GeV with a few percent energy resolution and an irreducible background (coming from e^- and p) to signal ratio below a few percent level as illustrated in Figures 1 and 2. The simulation of secondary $\bar{p}$ spectrum detected by AMS-02 in three years is shown in Figures 1 and 2 together with previous measurements for both scenarios (MSSM or Extra dimension). The different spectra shape reflects the difference mass assumptions made in each case.

Gamma flux

The AMS potential for the DM detection in the channels with γ in final state has been performed including two detection modes presented previously, the ”conversion mode ” [17] and the ”single photon” [18]. In the conversion mode, gamma are converted in the .25 radiation lengths of the TRD and are identified but 2 opposite charged tracks with low invariant mass. In the calorimeter, photons shower directly with no other activity in the detector. These methods have complementary acceptances, the first one being efficient down to 2 GeV with a maximum acceptance of 0.06 $m^2.sr$ at 30 GeV while the second one is efficient to high energy with a maximum 0f 0.097 $m^2.sr$ at 200 GeV. Both methods have a similar time integrated sensitivity to the galactic Center.

Gamma rays might be a possible signature of dark matter processes through annihilation like and $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to \gamma\gamma$, and $\tilde{\chi}_1^0\tilde{\chi}_1^0 \to \gamma\gamma$ the continuum photon flux mainly through the π_0 mesons produced in jets from annihilation products, a typical spectrum including all the gamma sources is given in figures 1- 2. Different extragalactic sources based on the IMBH models [11], but at different distance (2 or 20 kpc), have been considered in Figure 1 (top) for neutralino mass of 150 GeV (left) or for Kaluza-Klein photon of 50 GeV(right), after three years of data taking.

Conclusions

AMS has a unique opportunity to measure simultaneously the gamma, antiprotons ans positrons spectra, increasing its sensitivity to Dark Matter search or leading to better constraints on the models. The combination of the precise energy spectrum measurements of the 3 channels will rend possible (in few optimistic cases of hints) the determination of the nature of dark matter and why not his decay modes.

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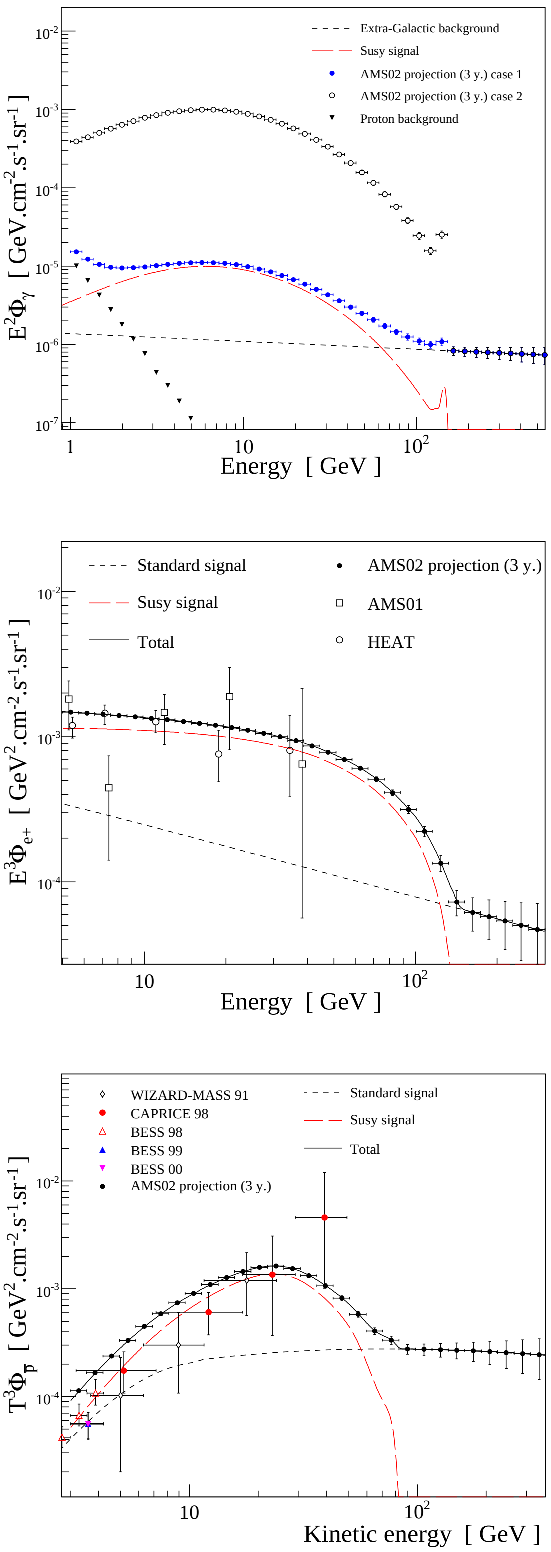

Figure 1: *Indirect searches assuming a 150 GeV $\tilde{\chi}_1^0$ mass in respectively the gamma (top), the positon (medium) and the anti-protons (bottom) after 3 years of data taking in AMS*

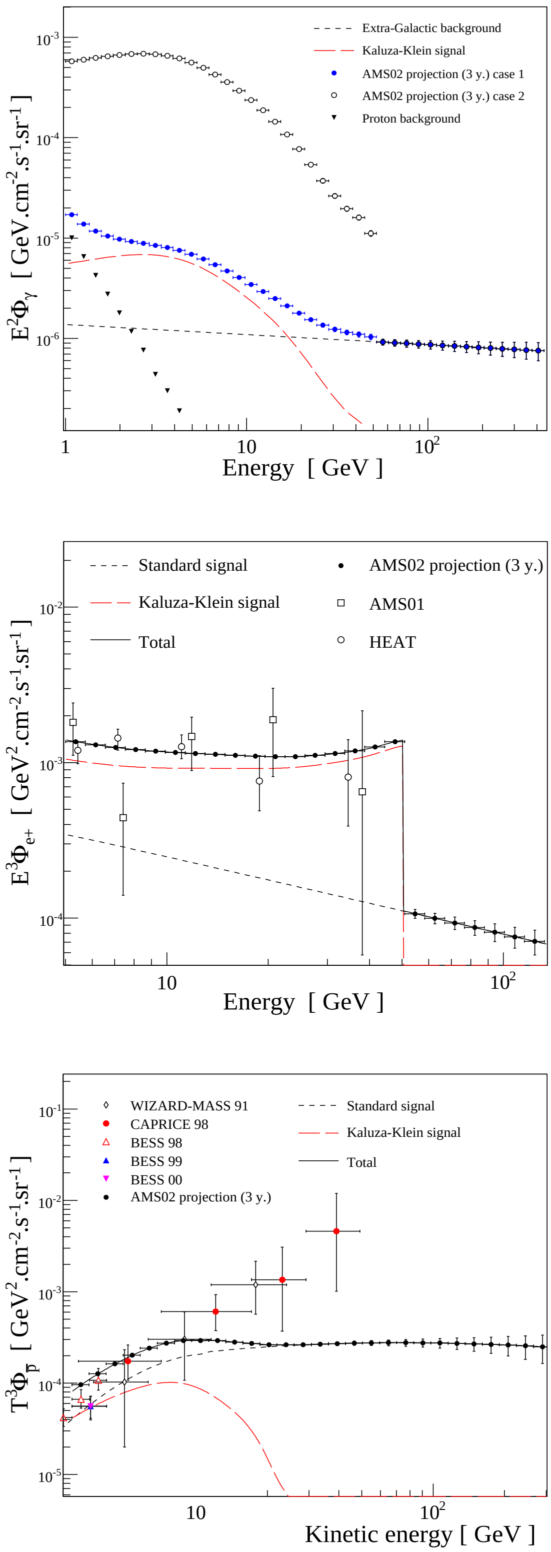

Figure 2: *Indirect searches assuming a 50 GeV KK boson mass in respectively the gamma (top), the positon (medium) and the anti-protons (bottom) after 3 years of data taking in AMS*