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Indirect dark matter search with AMS-02

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Abstract. The Alpha Magnetic Spectrometer (AMS) is a high energy particle physics experiment in space to be placed on the International Space Station (ISS) in 2006 for a three years mission. The main physics goals in the astroparticle domain are the anti-matter and the dark matter searches. Some results of Monte Carlo feasibility study of the AMS detector sensitivity to indirect dark matter searches are presented.

PACS. 95.35.+d Dark matter (stellar, interstellar, galactic, and cosmological) – 98.70.Sa Cosmic rays (including sources, origin, acceleration, and interactions)

1 Introduction

AMS-02 is a large acceptance, superconducting magnetic spectrometer which will provide data on cosmic radiations in a large range of energy from 0.5 GeV to TeVs. After the AMS-01 precursor flight on Space Shuttle, which already brought interesting physics results [1], a significant upgrade of the experiment has been started. A description of the final AMS-02 configuration is given in [15].

The main physics goals of AMS-02 are the antimatter and dark matter (DM) searches. The detector will also perform observations in gamma-ray astronomy and will be able to investigate some exotic physics signatures like strangelets. It will also increase precision of standard measurements, eg. B/C ratio. Here we describe the potential of AMS-02 in supersymmetric dark matter search. Other subjects are covered in [16].

2 Dark matter

Observations and cosmology indicate that the Universe may include a large amount of unknown dark matter. The latest measurements of cosmic microwave background anisotropy [2] suggest that cold non-baryonic dark matter constitues about 83% of the total Universe matter budget. This result is in perfect agreement with the results from primordial nucleosynthesis and large scale structure information from Galaxy and cluster surveys [3]. It should be composed of Weakly Interacting Massive Particles (WIMP) forming DM-halos in galaxies. A good WIMP candidate is the Lightest Supersymmetric Particle (LSP) in R-parity conserving SUSY models. In mSUGRA models the LSP is usually the neutralino χ_1^0.

[a] on behalf of AMS-02 Collaboration

AMS offers a unique opportunity to study simultaneously SUSY dark matter in four decay channels from the neutralino annihilation: e^+, $\bar{p}$, $\bar{d}$ and γ. Each of the signals origin from various regions of DM halo (eg. 50% of the positron(antiproton) flux near Earth comes from distance of 4(6) kpc, while gamma flux comes almost exclusively from halo center [12]), giving possibility of complex investigation of the distribution of DM in halo.

3 Indirect search for supersymmetric dark matter

Positron Flux: In recent works [4] e^+ production by annihilating neutralinos χ_1^0 in the galactic halo has been simulated according to several models, varying 7 free parameters of the MSSM. In each model the e^+ interstellar flux has been calculated by means of a standard diffusion model. Two models assuming m_χ being 336 GeV and 130.3 GeV respectively have been investigated by means of DARKSUSY [19]. The e^+ signal from χ annihilation was boosted by factors 11.7 and 54.6 to fit the HEAT data, the simulated primary positron fluxes have been added to the Moskalenko & Strong [11] secondary positron spectrum. The results of the simulation of the positron fraction, as expected to be measured by AMS-02 in 1 year, are shown in Fig. 1. Details can be found in [13,19].
Antiproton Flux: Measurements of CR $\bar{p}$ flux are few and, at high energy, not very precise. Several attempts of interpreting these measurements have shown the difficulty of deducing $\bar{p}$ propagation properties since an exotic origin such as neutralino annihilation cannot be excluded [6]. Low energy $\bar{p}$ spectrum is compatible with recent simulations of CR propagarion in Galaxy [7], however uncertainities of the astrophysical parameters of the model are very large. In low energy bin signal would be difficult to extract

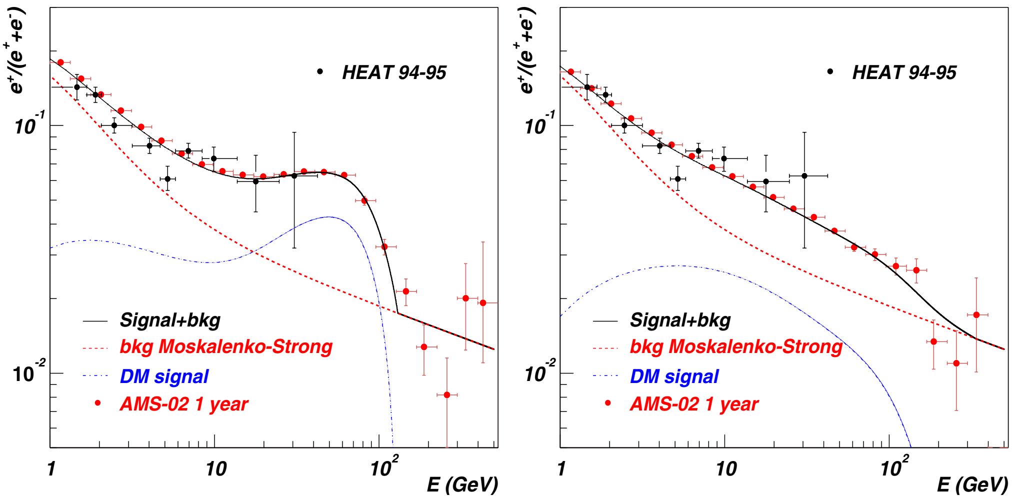

Fig. 1. AMS-02 e$^+$ fraction in the case of a primary e$^+$ from annihilating χ [11]

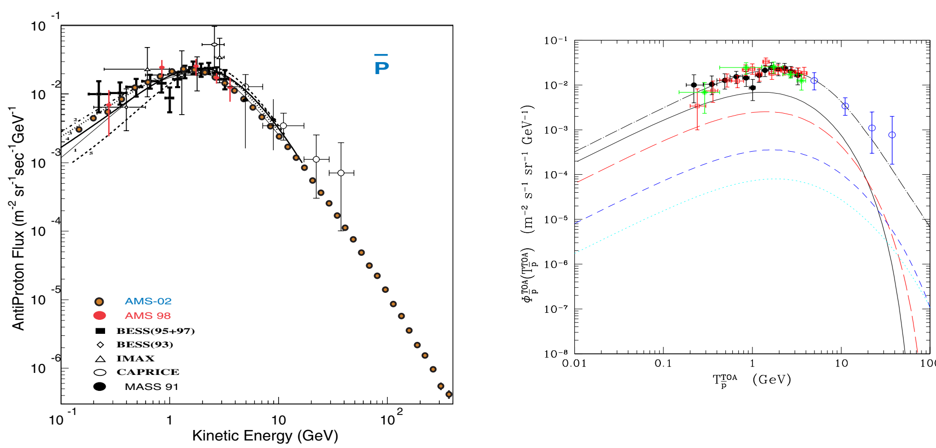

Fig. 2. On the left plot: AMS-02 secondary flux measurements after 3 years mission. Right plot: example of distortion of the primary antiproton flux at the top of the atmosphere (TOA) due to χ signal for $m_\chi = 60, 100, 300$ and 500 GeV (solid-black, red-dashed, blue-dashed and blue-dotted curves). The upper dot-dashed curve corresponds to the secondary flux [7]. Full circles show the BESS 1995-97 data [8]; open squares show BESS 1998 data [9]; the stars show AMS-01 data [1], and empty circles show the CAPRICE data [10]

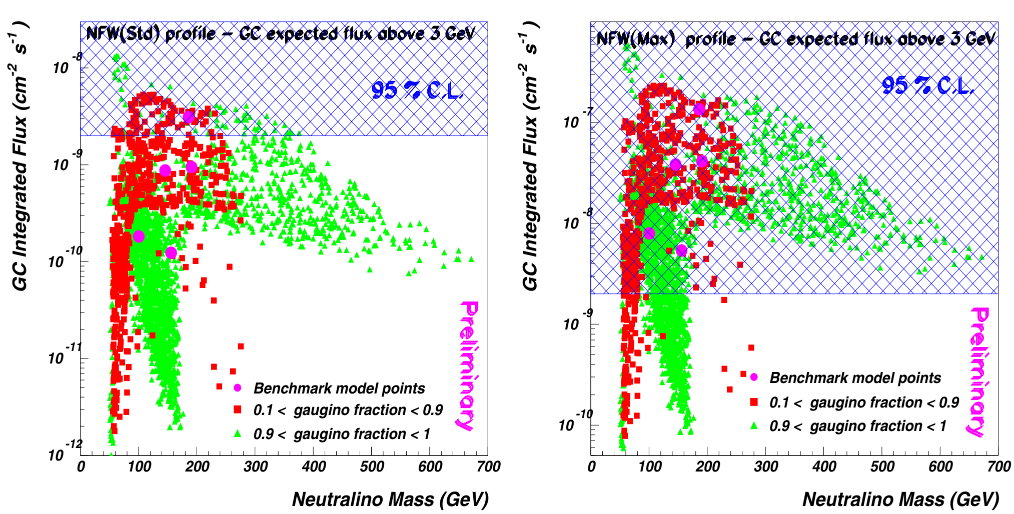

Fig. 3. The integrated γ-ray flux from GC as a function of m_χ for mSUGRA, large m_0 scan as expected for two Nawarro-Frenk-White DM halo profiles [17]. The AMS sensitivity in both cases are represented by shadded region

Table 1. Numbers of γ from the GC, for benchmark models, detected by AMS-02 in 3 years

model	N_γ-NFW (generic)	N_γ-NFW (max)	N_γ-Moore
B	1.5	83	156
C	0.1	6	18
G	0.6	45	111
I	3.6	258	525
L	15.0	597	1416

even with more precise model of CR propagation. In contrary, eventual signal in $\bar{p}$ channel depends very weakly on the dark matter distribution. For high values of neutralino mass an excess of $\bar{p}$ at high-energy is measurable. AMS-02 will determine accurately the $\bar{p}$ spectrum up to hundreds GeV with a few percent energy resolution[4] as shown in Fig. 2.

Antideuteron Flux: The usual stellar processes produce antideuterons with energies above 1 GeV/nucleon. Below this energy antideuterons can be produced in neutralino annihilation processes, so observation of a significant signal at a very low energy would indicate the existence of DM [5]. However the recent estimation of the non-annihilating rescattering process [14] show an increase of flux of low energy secondary antideuterons. AMS-02 will provide high-precision data with large statistics of $\bar{d}$.

Gamma-Ray Flux: AMS-02 will detect high-energy gamma rays (between few and few hundred GeV) by reconstruction of e^+e^- pairs in the Tracker and of single photon by ECAL detection [18].

The objects which are expected to emit a significant γ flux due to DM annihilation are central parts of halos and local clumps. One of the most promising object is the Galactic Center, which will be observed by AMS during about 400 hours per year.

The AMS potential for the DM detection in the channels with γ in final state was performed in mSUGRA models [17]. The benchmark model values of the expected number of γ in AMS-02 in 3 year exposure are shown in Table 1 for different parameterizations of the Galactic Center (GC) dark matter halo.

In Fig. 3, the mSUGRA scan of the γ flux as a function of the m_χ is shown for two Navarro-Frenk-White parameterizations of the DM halo density profile. The 95% CL was obtained by 3σ fluctuation of the diffuse gamma background spectrum as measured by EGRET. With 3 GeV energy threshold, AMS will reach the sensitivity of $(2.0 \pm 0.2)10^{-9} cm^{-2} s^{-1}$ in 3 years exposure.

In conclusion, with optimistic astrophysical conditions, AMS will open new exclusion/discovery domain in the dark matter searches. It will be the unique experiment performing these searches simultaneously in four neutralino decay channels.

References

1. M. Aguilar et al. (AMS Collaboration): Phys. Rept. **366**, 331 (2002); Erratum-ibid. **380**, 97 (2003)
2. C.L. Bennett et al.: arXiv:astro-ph/0302207; D.N.Spergel et al.: arXiv:astro-ph/0302209; H.V. Peiris et al.: arXiv:astro-ph/0302225
3. W. Percival et al.: Mon. Not. R. Astron. Soc. **327**, 1297 (2001) [arXiv:astro-ph/9906426]
4. E.A. Baltz, J. Edsjo, K. Freese, and P. Gondolo: Phys. Rev. D **65**, 063511 (2002) [arXiv:astro-ph/0109318]
5. F. Donato, N. Fornengo, and P. Salati: arXiv:hep-ph/9904481
6. L. Bergstrom, J. Edsjo, and P. Ullio: arXiv:astro-ph/9906034
7. F. Donato, N. Fornengo, D. Maurin, R. Taillet, and P. Salati: arXiv:astro-ph/0306312
8. S. Orito et al. (BESS Collaboration): Phys. Rev. Lett. **84**, 1078 (2000) [arXiv:astro-ph/9906426]
9. T. Maeno et al. (BESS Collaboration): Astropart. Phys. **16**, 121 (2001) [arXiv:astro-ph/0010381]
10. M. Boezio et al. (WiZard/CAPRICE Collaboration) Astrophys. J. **561**, 787 (2001) [arXiv:astro-ph/0103513]
11. I.V. Moskalenko and A.W. Strong: Phys. Rev. D **60**, 063003 (1999) [arXiv:astro-ph/9905283]
12. W. de Boer, M. Herold, C. Sander, and V. Zhukov: arXiv:hep-ph/0309029
13. V. Shoutko, G. Lamanna, and A. Malinin: Int. J. Mod. Phys. A **17**, 1817 (2002)
14. B. Baret et al.: arXiv:astro-ph/0306221
15. J. Burger: this proceedings
16. G. Lamanna: Mod. Phys. Lett. A **18**, 1951 (2003)
17. A. Jacholkowska, G. Lamanna, E. Nuss, and M. Sapinski: AMS-Note 2003-05-01
18. G. Lamanna: Nucl. Phys. Proc. Suppl. **113**, 177 (2002)
19. P. Maestro: Ph.D. Thesis (2003), University of Siena, AMS-Note 2003-01-01