Astroparticle Physics with AMS-02

Giovanni Lamanna
on behalf of the AMS-02 Collaboration
CERN European Organization for Nuclear Research,
CH-1211 Geneva 23, Switzerland

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 2005 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 these searches are presented.

1. Introduction

AMS 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 Shuttle flight, a significant upgrade of the experiment has been started. A description of the final AMS-02 configuration is given in[8].

2. Search for Anti-matter

The main direction in the theoretical studies of the baryon asymmetry of the Universe is the baryogenesis approach. Numerous baryogenesis theories expect no antimatter in our Universe. According to some alternative models some primordial antimatter could exist nowadays[7]. Until now, a consistent theory of baryogenesis has not been yet proposed as these models are not presently supported by particle physics experimental data. To date baryon non-conservation and large levels of CP-violation have not been observed. All last 20 years cosmic ray searches for antinuclei have given negative results. It is obvious that experimental input is of critical importance. A major objective of the physics program of the AMS experiment is to search for cosmic-ray antinuclei.

AMS measures the value of the particle's charge independently in the Tracker, RICH and ToF sub-detectors. The particle momentum is measured by the tracking system in the magnetic field of 0.8Tm^2. The velocity is measured by the ToF, TRD and RICH sub-detectors. The AMS detector has a large acceptance (0.5 m^2 sr) and the low material budget along the particle trajectory minimizes the probability for large angle nuclear scattering which could be confused with the signal of anti-nuclei. The AMS search for $\overline{He}$ on the ISS is illustrated in Fig.1.

pp. 1727–1730

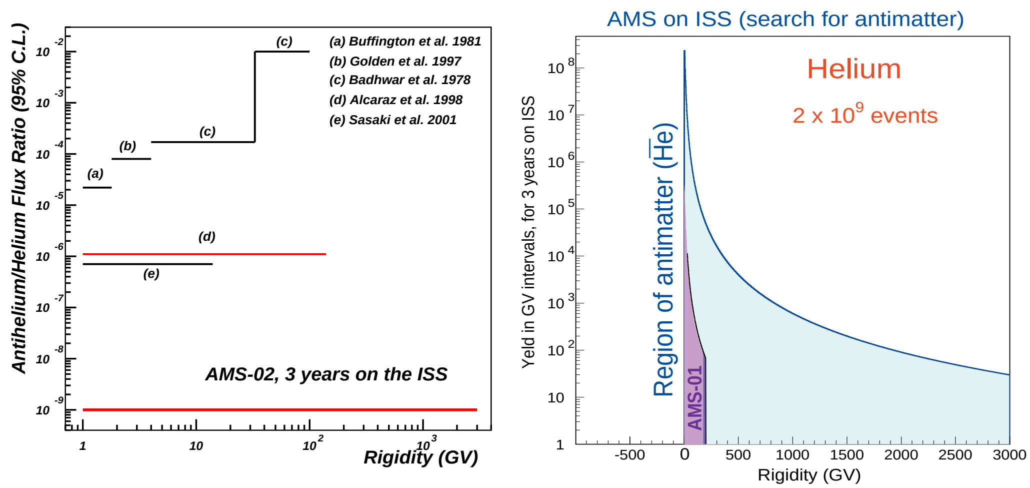

Fig. 1. AMS-02 expectation *vs* results from AMS-01 (d)[1] and other experiments[6].

The expected upper limit after 3 years of exposure is $\overline{He}/He < 10^{-9}$. By its rigidity range and acceptance, AMS-02 will provide the best sensitivity to these searches.

3. Indirect search for Supersymmetric Dark Matter

Observations and cosmology indicate that the Universe may include a large amount of unknown dark matter (DM). It should be composed of non-baryonic Weakly Interacting Massive Particles (WIMP). A good WIMP candidate being the Lightest Supersymmetric Particle in R-parity conserving SUSY models. AMS offers a unique opportunity to study simultaneously SUSY dark matter in three decay channels from the neutralino annihilation: e^+, $\bar{p}$ and γ.

Positron Flux: In recent works[2] 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[11]. 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 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.2. Details can be found in[11][5].

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[3]. For high m_χ a high-energy excess of $\bar{p}$ is measurable. AMS-02 will measure accurately the $\bar{p}$ spectrum up to hundreds GeV with a few percent energy resolution[4] as shown in Fig.3.

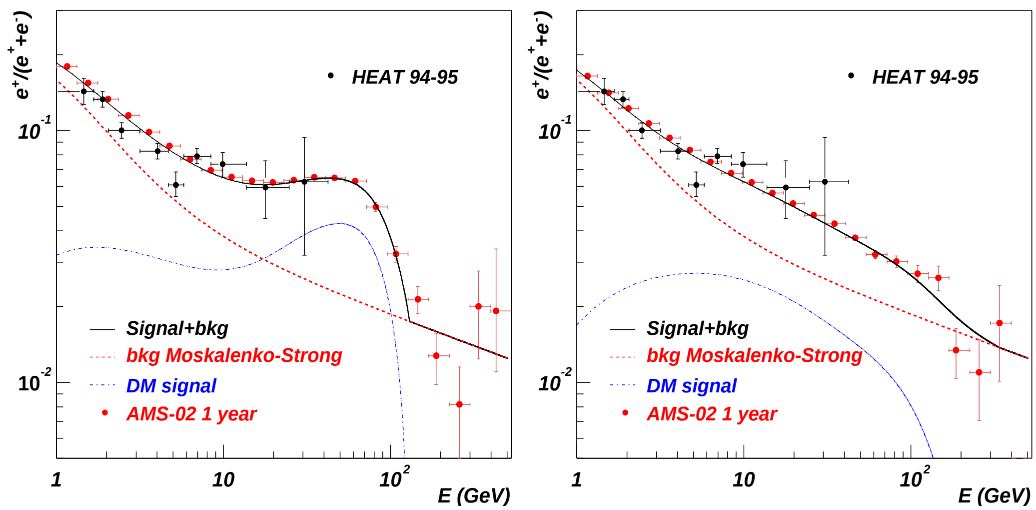

Fig. 2. AMS-02 e^+ fraction in the case of a primary e^+ from annihilating χ [11].

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[10]. The AMS potential for the DM detection in the channels with γ in final state was performed in mSUGRA models[9]. 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.4, the mSUGRA scan of the γ flux as a function of the m_χ is shown for two Navarro-Frenk-White parameterizations. 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

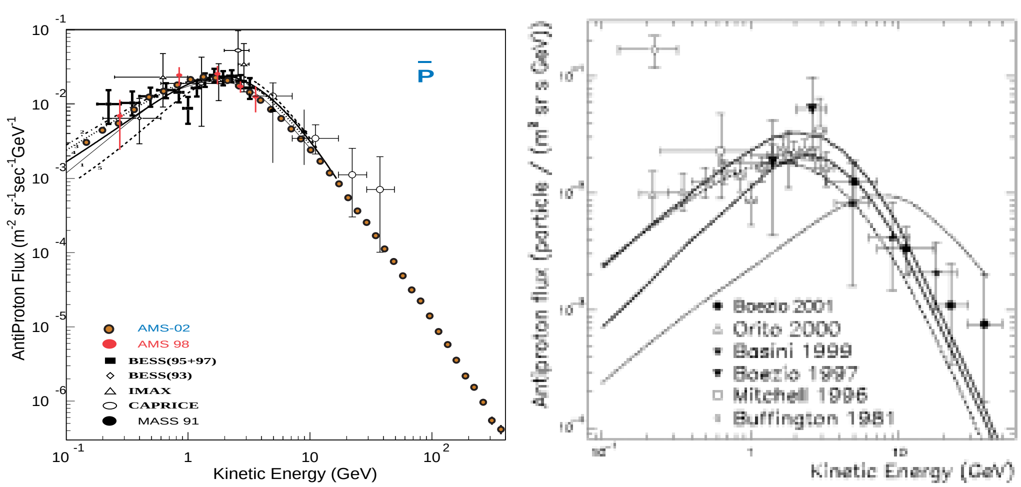

Fig. 3. a) AMS-02 3 years secondary $\bar{p}$ flux. b) Example of distortion due to χ signal.

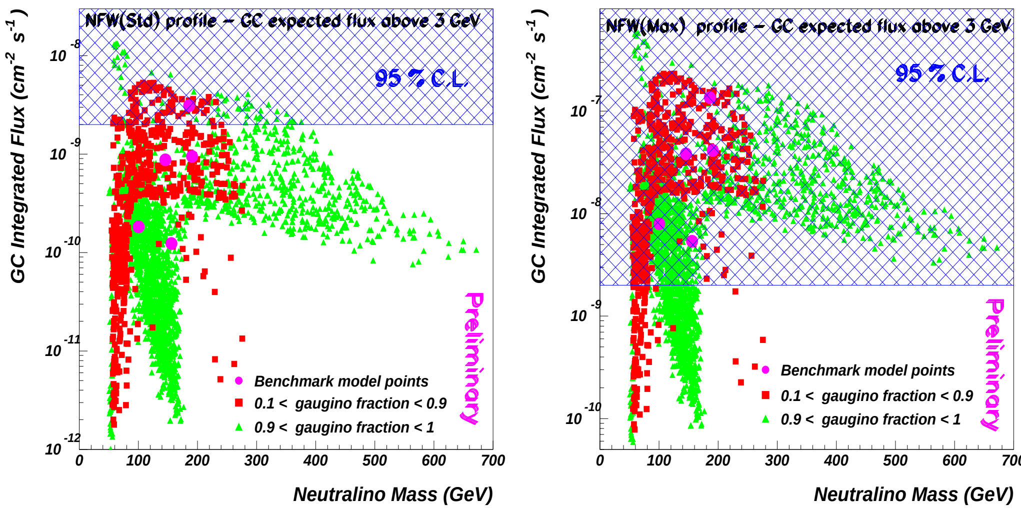

Fig. 4. The integrated γ flux from GC as a function of m_χ for mSUGRA, large m_0 scan as expected for 2 NFW DM halo profiles[9].

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

exclusion/discovery domain in the dark matter searches. We want to thank the many organizations and individuals, listed in the acknowledgments of ref. [8].

4. References

1. M. Aguilar et al. 2002, Phys. Rep. 366, 331
2. E.A. Baltz, J. Edsjo, K. Freese, P. Gondolo 2002 Phys. Rev. D65
3. L. Bergstrom, J. Edsjo, P. Ullio 1999 Astrop. Jour. 526, 215
4. V. Choutko 2002, Nucl. Phys. B (Proc. Suppl.) 113, 170
5. V. Choutko, G. Lamanna, A. Malinin 2002, Int. J. Mod. Phys. A, 17, 1817
6. M. Cristinziani 2002, Nucl. Phys. B (Proc. Suppl.) 113, 195
7. Y. Galaktionov 2002, Rep. Prog. Phys. 65, 1243
8. S. Gentile 2003, these proceedings
9. A. Jacholkowska, G. Lamanna, E. Nuss, M. Sapinski AMS-Note 2003-05-01
10. G. Lamanna 2002, Nucl. Phys. B (Proc. Suppl.) 113, 177
11. P. Maestro 2003, Ph.D. Thesis, University of Siena, AMS-Note 2003-01-01