PROCEEDINGS OF SCIENCE

Dark Matter Searches with AMS-02

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The Alpha Magnetic Spectrometer (AMS), to be installed on the International Space Station, will provide data on cosmic radiation 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 indicate that the Universe may include a large amount of unknown Dark Matter. It should be composed of non-baryonic Weakly Interacting Massive Particles (WIMPs), a good WIMP candidate being the lightest supersymmetric 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: positrons, antiprotons and gamma rays. The supersymmetric theory frame is considered together with alternative scenarios (extra-dimensions). The expected flux sensitivities in 3 year exposure for the e+/e- ratio, antiproton and gamma yields as a function of energy are presented.

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1. Dark matter in the universe

During the past decade, new data collected from independent cosmology experiments (see for instance, [1] for a recent review on the subject) point to a unified picture of the composition of the Universe consisting in 'dark energy'($\sim$ 73%) and non-baryonic 'dark matter' ($\sim$ 23%) as its primary components. The non-baryonic, 'cold' nature of dark matter is also supported by several observations and models which rule out other candidates such as neutrinos or massive bodies as being the major mass contributors. Cosmologists and particle theorists have a strong favorite in the so-called Weakly Interacting Massive Particles (WIMPs), particularly the lightest supersymmetric particle in R-parity conserving models and the lightest Kaluza-Klein particle of certain extra-dimensions models [2]. The neutralino constitutes a viable candidate of the former group as it is predicted to be stable, massive, neutral and weakly-interacting, as required by astrophysical and cosmological observations.

If any of these theories were proven true, a certain density of these WIMPs should be present in galactic halos as relics of their decoupling at early times. The random encounters between them lead to annihilations which add an extra cosmic ray component detectable as an anomaly in the expected spectrum of certain particle species.

2. AMS02

The Alpha Magnetic Spectrometer (AMS) [3] is a cosmic ray detector which will be attached to the International Space Station (ISS) for three years, being launch ready in late 2007. It is a major collaboration of European, Asian and American institutions, together with NASA. The main purpose of AMS measurements is to determine the characteristics of the incident particle such as its momentum, charge, velocity and mass, to the highest possible precision, to ensure its identification.

It will consist of five sub-detectors, a superconducting magnet and an anti-coincidence counter. In particular, the Transition Radiation Detector (TRD) will provide excellent lepton/hadron separation ($\gtrsim$ 100:1) up to 300 GeV. The silicon tracker will identify the particle's charge and measure its rigidity with a $\lesssim$ 2% uncertainty for rigidities below 20 GV and maximum detectable rigidity around 1 TV. An electromagnetic calorimeter (ECAL) provides further ($3.5 \cdot 10^3$:1) lepton discrimination power and an energy resolution better than 3% above 10 GeV.

In general, AMS will be able to identify cosmic rays up to Z$\simeq$26. The energies covered range from 0.5 GeV to 3 TeV. Its major scientific goals include dark matter, and anti-matter searches, cosmic ray related astrophysics [4] and gamma ray astronomy [5].

3. Search channels.

Positrons. Positrons in AMS will be measured in a wide energy range ($1 - 300$ GeV) with a mean acceptance of 0.045 m^2sr and a rejection factor of $\sim 10^5$ against protons, thanks to the TRD and ECAL lepton/hadron separation power.

Several neutralino annihilation modes lead to W^+W^- or ZZ pairs which decay into positrons, among other products. It is a very interesting channel, especially in the light of the yet-unconfirmed claim by the HEAT collaboration [6] in the range of $\sim$ 10 GeV, where an excess has been detected in the positron fraction measurement (defined as the flux of positrons over the combined flux of positrons and electrons).

In Fig. 1 we show the precision expected for the measurement of this positron excess, for a certain neutralino model (mSUGRA model) and assuming a 'boost' factor that would fit the normalization hinted by the HEAT data. This factor may be provided by the largely unknown and inhomogeneous local dark matter density. Predictions for another model in the more generic MSSM framework are shown in Fig. 2.

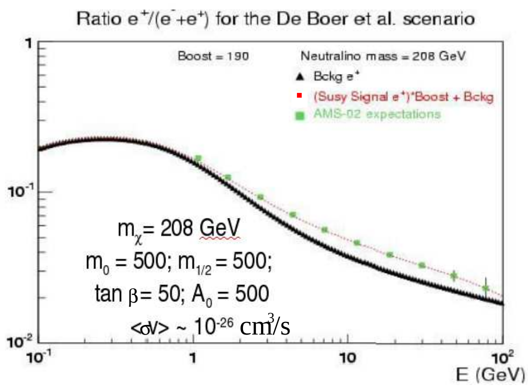

Figure 1: Positron fraction as a function of positron energy. The expected background from standard secondary production (darker curve), and the background plus signal spectrum (lighter curve) is shown for a 208 GeV neutralino, for a mSUGRA model with $m_0 = 500$ GeV, $m_{1/2} = 500$ GeV, $tan\beta = 50$, $\mu > 0$ and A_0=500. From [7][8].

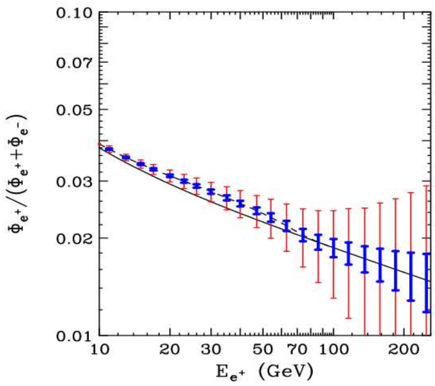

Figure 2: Positron fraction as a function of positron energy. In this case we consider a 100 GeV neutralino with a annihilation cross-section of 10^{-26} cm^3/s, obtained from a MSSM parameter scan of values compatible with WMAP results. The smaller error bars correspond to AMS after a three-year operation period (larger ones are for PAMELA). From [9].

Gamma rays. Photons in AMS will be detected via two modes, either through conversion in the upper layers of the detector and measurement of the resulting e^+e^- pair in the silicon tracker; or through direct measurement in the ECAL with no associated charged track activity.

A continuum signal could come from the decay of hadronization products, following the dark matter annihilation. A detailed study has been carried out [10] for this signal. For a given cuspy model of the Galactic halo, the results are shown in Fig. 3. These indicate that AMS would be sensitive to Kaluza-Klein models and SUSY Anomaly Mediated Symmetry Breaking models up to ~ 1 TeV, as well as to many high $\tan\beta$ models within a minimal supergravity (mSUGRA) scenario.

Antiprotons. Antiprotons will be measured in the $0.5 - 200$ GeV range. The mean acceptance has been determined to be 0.03 m^{2}sr through detailed Montecarlo simulations. The expected rejection factor is of the order of $\sim 10^6$ against protons.

Their flux seems to be consistent with secondary production by interaction of other cosmic ray components with the interstellar medium. However, data are still dominated by large errors above 10 GeV and below 1 GeV. The expected precision of the antiproton measurement, in case of standard production through cosmic ray spallation, is shown in Fig. 4. The model used for the prediction of such spectrum is given by [11] and it depends very strongly on other measured

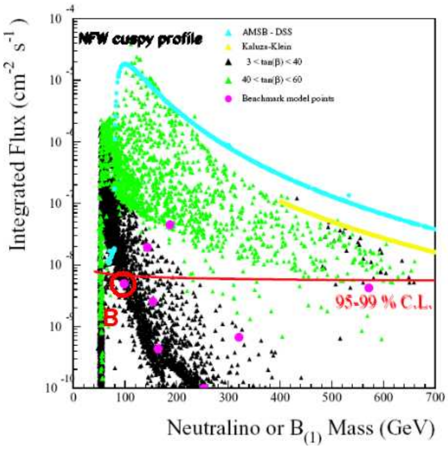

Figure 3: Integrated gamma ray flux from the Galactic Center as a function of the WIMP mass for a NFW dark matter halo profi le.From [10].

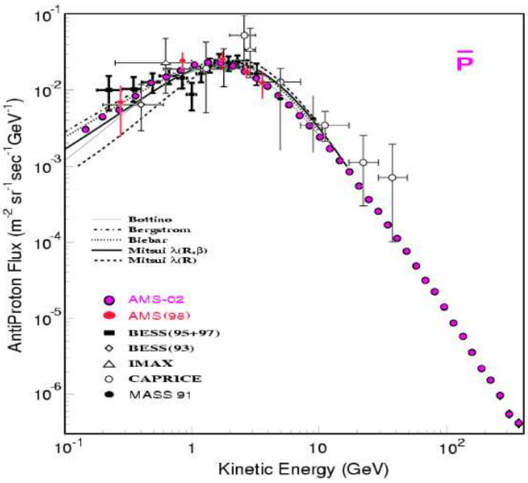

Figure 4: Antiproton spectrum predictions for AMS and results from past experiments, including AMS01 prototype. The background is computed in the GALPROP framework, as detailed in [11].

quantities, such as the Boron to Carbon ratio in cosmic rays. These will also be measured in AMS as detailed in [4].

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