



ELSEVIER

Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

Nuclear Physics B (Proc. Suppl.) 138 (2005) 35–37

NUCLEAR PHYSICS B
PROCEEDINGS
SUPPLEMENTS

www.elsevierphysics.com

Indirect dark matter searches with AMS-02

K. Scholberg^a

^aDepartment of Physics, Massachusetts Institute of Technology, Cambridge, MA, 02139.

AMS-02 is the main phase of the Alpha Magnetic Spectrometer experiment and is to be installed on the International Space Station for a three-year exposure. I will review the experiment, focusing on indirect dark matter detection capabilities.

1. INTRODUCTION

The Alpha Magnetic Spectrometer (AMS) is a charged particle in space, with a main goal of studying cosmic rays with energies up to TeV. The basic idea is simple: a high dipole magnetic field provided by a superconducting magnet allows momentum and charge sign measurements in a precision silicon tracker. Combining tracking information with dE/dx and velocity measurement, one can identify masses and charges of particles traversing the detector. Several other sub-detectors (TRD, RICH, ECAL), provide additional and redundant information to improve characterization of the fluxes of the different charged particles species.

The original motivation for studying cosmic rays above the atmosphere was the search for primordial antimatter, such as $\overline{\text{He}}$; however currently the potential for indirect detection of dark matter has become very exciting. Other motivations include precision, high statistics measurements of light isotopes, as well as searches for exotic particles such as strangelets.

2. DARK MATTER SEARCHES

Some sort of non-baryonic dark matter is now thought to make up $\sim 25\%$ of the critical density of the universe. Neutralinos (χ), heavy, stable, neutral particles predicted by supersymmetric theories, are prime candidates for the dark matter. If neutralinos comprise our galaxy's dark halo, they may annihilate each other, with antimatter (\bar{p} , e^+ or \bar{d}) among the direct or indirect

annihilation products [1]. Such “primary” χ annihilation antimatter could be distinguished from “secondary” antimatter produced in cosmic ray collisions by an anomalous energy spectrum. For instance, a bump in the observed e^+ spectrum at around 10-100 GeV/c could be the signature of $\chi\chi$ annihilation. Gamma rays may also be among the annihilation products. Non-SUSY dark matter models (e.g. [2]) may also provide charged cosmic ray signatures.

3. THE AMS-01 PRECURSOR MISSION

The AMS-01 precursor experiment flew on Space Shuttle Discovery in June of 1998 for a period of 10 days, recording 100 hours of data and 10^8 particles. The orbit was 51.7° , and the altitude 320-390 km. The precursor mission employed a permanent Nd-Fe-B magnet with a 0.15 T field, in addition to six planes of silicon tracker, time-of-flight scintillator counters, and a threshold Cherenkov counter. This successful flight produced a number of new results. A full reporting of physics results from AMS-01 can be found in reference [3].

4. THE AMS-02 EXPERIMENT

The AMS-02 experiment is to be installed on ISS in 2006 for a three-year exposure. A significant upgrade with respect to AMS-01 is the superconducting magnet with a field of 0.87 T, allowing spectral measurement up to TeV energies [4]. The acceptance of the tracker will be about $0.5 \text{ m}^2\text{sr}$. A few notes on the major AMS-02 sub-

detectors are given below.

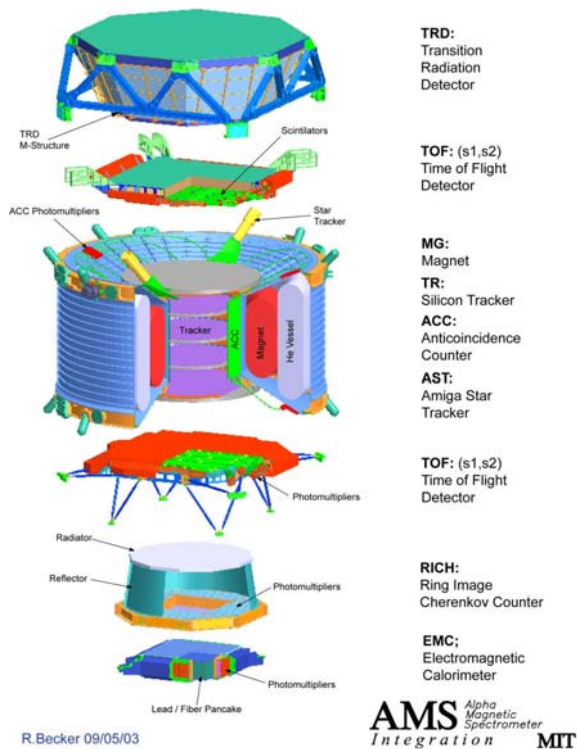


Figure 1. View of AMS-02 showing the subdetector components.

- **Silicon tracker** [5]: there will be eight layers of Si strip tracking planes, with a total of 196,000 channels covering 6.45 m². The maximum detectable rigidity is approximately 1 TV. The silicon tracker provides dE/dx information as well as a rigidity measurement.
- **Time of flight scintillator counters** [6]: four layers of scintillator counters provide time of flight (~ 140 picoseconds) and dE/dx information. The TOF also provides the fast trigger for the detector.
- **Transition radiation detector** [7]: there will be 20 layers of polypropylene radiator interspersed with Xe/CO₂ drift tubes to detect the transition radiation resulting from charged particles traversing the interfaces between materials of differing refractive index. Since transition radiation depends on the Lorentz γ of the charged particle, the TRD improves p/e^+ separation with a proton rejection factor of $\sim 10^2 - 10^3$, up to about 300 GeV/c.
- **Ring-imaging Cherenkov detector** [8]: the RICH consists of a layer of aerogel (and possible some NaF) radiator, a conical reflector, and a layer of photomultiplier tubes, is sensitive to charge and velocity, via the intensity and angle, respectively, of the Cherenkov ring produced. The RICH will provide nuclear isotope identification up to ~ 10 GeV/n for isotopes up to approximately carbon.
- **Electromagnetic calorimeter** [9]: the 3D sampling ECAL, comprising 9 superlayers of lead and scintillating fibers, can measure energies and improve p/e^+ separation up to TeV energies, with a proton rejection factor of $\sim 10^3$.

The requirements for building a detector for space are extremely challenging. The detector has a strict weight limit of 14809 lb, and must have a power consumption of less than 2 kW. It must withstand temperature variations between -180° and 50°C , and of course it must work in vacuum. It must survive accelerations up to 9 G during shuttle launch. The data rate is limited to 2 Mbits per second, which constrains trigger configurations. Finally, the detector must function without intervention for three years.

5. CAPABILITIES FOR INDIRECT DARK MATTER DETECTION

Probably the cleanest signature of dark matter annihilation in AMS-02 will be for the positron channel, for which AMS-02 will have good resolution and excellent statistics up to about

300 GeV/c. Figure 2 shows the expected capabilities for one year of running on ISS.

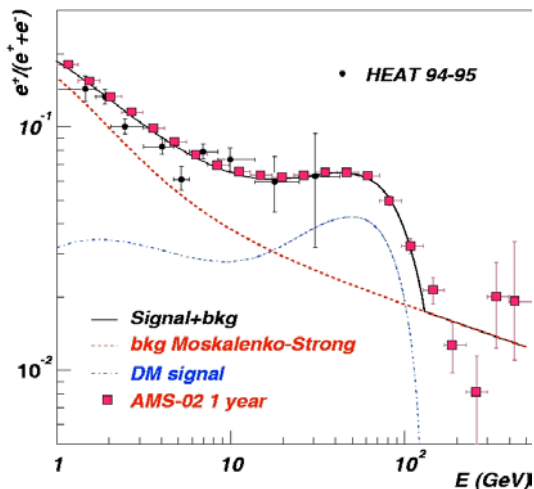


Figure 2. Expected AMS-02 positron fraction for one year on ISS for one particular SUSY model superimposed on background, following references [10,11]. Also shown is the HEAT measurement [12], which shows a hint of an anomalous positron spectrum.

Because protons dominate positrons in the cosmic ray flux in the interesting signal region (tens to hundreds of GeV) by several orders of magnitude, the misidentification rate must be less than about one in 10^5 . Therefore the TRD and ECAL detectors, which each can achieve a proton rejection of about 10^3 , are key for this measurement.

There is some chance for AMS-02 to measure an anomalous antiproton spectrum (*e.g.* [13]), too, although background from secondaries becomes more challenging in the relevant energy regime. More promising, perhaps, are the prospects for detection of antideuterons [14]. In this case, although signal from neutralino annihilation is suppressed, background from secondaries may be yet more kinematically suppressed at low energy (below a few GeV per nucleon).

In addition, AMS-02 may have some γ -ray sensitivity [15,16] in the ~ 10 -100 GeV range, via pair conversions in the upper layers of the detector, and shower production in the ECAL. This capability will permit studies of GRBs, blazars and other sources, as well as SUSY dark matter annihilation γ 's for some parameters.

6. SUMMARY

In summary, the AMS-02 experiment will measure cosmic rays with momenta between 300 MeV/c and 3 TeV/c with unprecedented statistics and precision over a three-year period starting in 2006. This will allow high sensitivity to indirect dark matter searches in e^+ , \bar{p} , \bar{d} and γ channels.

REFERENCES

1. K. Griest *et al.*, Phys. Rept. 333 (2000) 167.
2. H.C. Cheng *et al.*, Phys. Rev. Lett. 89 (2002) 211301.
3. J. Alcaraz *et al.*, Phys. Lett. B 366 (1999) 331.
4. B. Blau *et al.*, Nucl. Phys. Proc. Suppl. 113 (2002) 125.
5. W. J. Burger *et al.*, Nucl. Phys. Proc. Suppl. 113 (2002) 139.
6. D. Casadei *et al.*, Nucl. Phys. Proc. Suppl. 113 (2002) 133.
7. T. Siedenbueg *et al.*, Nucl. Phys. Proc. Suppl. 113 (2002) 154.
8. J. Casaus *et al.*, Nucl. Phys. Proc. Suppl. 113 (2002) 147.
9. F. Cadoux *et al.*, Nucl. Phys. Proc. Suppl. 113 (2002) 159.
10. E.A. Baltz *et al.*, Phys. Rev. D 65 (2002) 063511.
11. P. Maestro, Ph.D. thesis, U. of Siena, 2003.
12. S. Coutu, ICRC Proceedings (2001).
13. L. Bergström *et al.*, astro-ph/9902012.
14. F. Donato *et al.*, Phys. Rev. D 62 (2000) 043003.
15. R. Battiston, Astropart. Phys. 13 (2000) 51.
16. M. Pohl, Int. J. Mod. Phys. A17 (2002) 1809.