AMS-02 on the International Space Station

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Abstract. 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 motivations for the experiment and capabilities of the instrument.

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, including a transition radiator detector, a ring-imaging Cherenkov detector and an electromagnetic calorimeter, provide additional and redundant information to improve characterization of the fluxes of the different charged particles species.

PHYSICS MOTIVATIONS

There are several pmotivations for studying the composition and spectra of cosmic rays above the atmosphere:

- **Search for primordial antimatter:** The apparent asymmetry between matter and antimatter is a long-standing mystery of cosmology. A possible solution to the puzzle is a universe which does in fact contain distant domains of antimatter. Even for an asymmetric universe, small nearby pockets of antimatter created by an early phase transition are not ruled out. A smoking-gun signature of primordial antimatter would be antinuclei such as $\overline{\mathrm{He}}$ (or heavier elements) observed above the atmosphere.
- **Indirect search for SUSY dark matter:** Another long-standing puzzle is the nature of the dark matter of the universe. Some sort of non-baryonic dark matter is now thought to make up to $\sim$25% of the critical density of the universe. Neutralinos (χ), heavy, stable, neutral particles predicted by supersymmetric theories, are prime candidates for the dark matter. If neutralinos comprise the our galaxy's dark halo, they may annihilate, with antimatter ($\bar{p}$, e^+ or $\bar{d}$) among the direct or indi-

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rect 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 GeV/c could be the signature of $\chi\bar{\chi}$ annihilation. Gamma-rays may also be among the annihilation products.

- **Cosmic Ray Propagation:** A precision, high-statistics measurement of the ^{10}Be to ^{9}Be ratio in the cosmic ray flux, and its energy dependence, would be a powerful method of distinguishing between Galactic cosmic ray propagation models. These isotopes are "clocks" which measure the confinement time of charged cosmic rays in the galaxy.
- **Exotic Particles:** Exotic matter such as "strangelets" (a possibly stable state of matter consisting of *u*, *d*, and *s* quarks) or fractionally charged particles may manifest itself as particles with anomalous charge-to-mass ratio in a spectrometer[2].
- **The Unexpected?** Finally, since high-statistics cosmic ray measurements of this type have never been made before above the atmosphere, one can never rule out the possibility of surprising new observations.

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. In particular the limit on the $\overline{\mathrm{He}}/\mathrm{He}$ ratio was pushed down to nearly 10^{-6} for rigidities up to 20 GV[3]. No $|Z| > 2$ nuclei were found. Unprecedented high-statistics measurements of protons[4, 5], leptons[6, 7], and helium isotopes[8] were made. A full reporting of physics results from AMS-01 can be found in Reference [9].

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[10]. The acceptance of the tracker will be about 0.5 m^{2}sr. A few notes on the major AMS-02 sub-detectors are given below.

- **Silicon tracker**[11]: there will be eight layers of Si strip tracking planes, with a total of 196,000 channels covering 6.45 m^2. 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**[12]: four layers of scintillator counters provide time of flight (~140 picoseconds) and dE/dx information. The TOF also provides

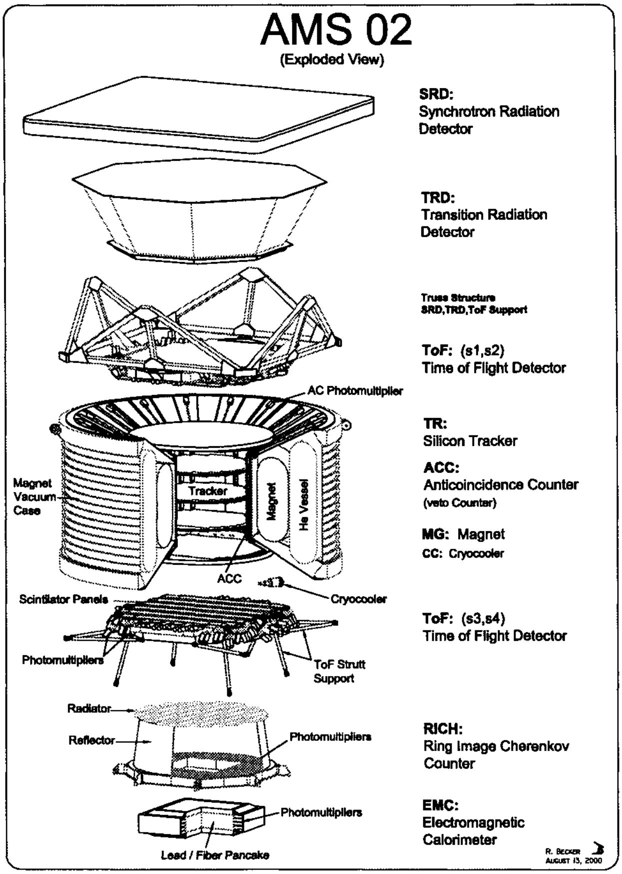

FIGURE 1. View of AMS-02 showing the subdetector components.

the fast trigger for the detector.

- **Transition radiation detector**[13]: there will be 20 layers of polypropylene radiator interspersed with Xe/CO_2 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 relativistic 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**[14]: 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 $\sim$10 GeV/n for isotopes up to approximately carbon.
- **Electromagnetic calorimeter**[15]: the 3D sampling ECAL, comprising 9 superlayers of lead and scintillating fibers, can measure energies and improve p/e^+ sep-

aration up to TeV energies, with a proton rejection factor of $\sim 10^3$. The combined rejections of the ECAL and TRD are essential for the measurement of positron spectral properties, because in the regime of interest for dark matter at around 10-100 GeV, protons outnumber positrons by a factor of $\sim 10^4$ to 1.

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.

AMS-02 will be able to study e^+, e^-, p, $\bar{p}$, d, t, ^{3}He and ^{4}He with statistics three or four orders of magnitude greater than previous measurements. It can search for anti-ions, such as $\overline{\mathrm{He}}$ and $\overline{\mathrm{C}}$; in particular the $\overline{\mathrm{He}}$/He sensitivity will be 1 in 10^9, giving limits some orders of magnitude beyond current ones.

In addition, AMS-02 may have some γ-ray sensitivity[16, 17] 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.

SUMMARY

In summary, the AMS-02 experiment will measure cosmic rays with momenta between 300 MeV/c and 3 TeV/c with unprecented statistics and precision over a three-year period starting in 2006. This will allow an antihelium search with $\overline{\mathrm{He}}$/He sensitivity of 10^{-9}, a SUSY dark matter annihilation product search, tests of cosmic ray propagation models, exotic matter searches and more.

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