

Rare Components in Cosmic Rays with AMS-02

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Abstract. The Alpha Magnetic Spectrometer 02 (AMS-02), like the AMS-01 experiment flown in 1998 on board the Space Shuttle, offers a unique opportunity for exploration of cosmic rays. AMS-02 will be installed to the International Space Station (ISS) providing precise data on cosmic radiation spectra in a wide energy range for at least three years. Although the major part of cosmic ray particles is of astrophysical origin, a small component may originate from interaction of dark matter particles. Redundant detection in several sub-detectors with accurate particle identification allows precision measurements and identification of up to now concealed or undetected deviation from Standard Model prediction. After an introduction to detector design, an overview of physics goals of AMS-02 is given.

1. Introduction

The Alpha Magnetic Spectrometer 02 (AMS-02) is a large acceptance spectrometer for high energy charged particles and gamma rays in cosmic radiation. It is designed for maintenance-free operation on board the International Space Station (ISS) for at least three years, comprising the biggest super-conducting magnet in space.

In June 1998 the prototype version AMS-01 has successfully flown for ten days on board the Space Shuttle Discovery. This precursor flight has provided essential information about detector operation and performance under space-conditions and interesting physics data, which results are summarized in [1]. About 1000-times higher statistics of AMS-02 data will widely improve our knowledge about propagation and sources of cosmic rays. AMS-02 also will allow searches for heavy antimatter nuclei, dark matter signatures, which profits from improved proton rejection in the order of 10^6 , or even exotic new types of matter [2].

2. AMS-02 Detector Design

Accurate particle identification in cosmic rays requires measurement of energy, rigidity, velocity and electric charge. To gain precision AMS-02 performs a redundant measurement of a particle's properties in different sub-detectors. Core of the experiment is a large super-conducting magnet with a large area silicon strip detector. Figure 1 shows an artist model view of the detector with Transition Radiation Detector (TRD), Time of Flight (ToF), Anti-coincidence Counter (ACC), Ring Image Cherenkov Detector (RICH) and Electromagnetic Calorimeter (ECAL) sub-detectors. The assembled detector has a weight of about 7 tons with an acceptance of $0.5 \text{ m}^2\text{sr}$.

Space qualified electronics running with 650 microprocessors control and read out 300,000 physics channels, GPS, Startracker Camera and heat control systems. At an expected trigger rate of up to 2000Hz data is reduced by fast DAQ electronics to a rate of about 2 MBit/s.

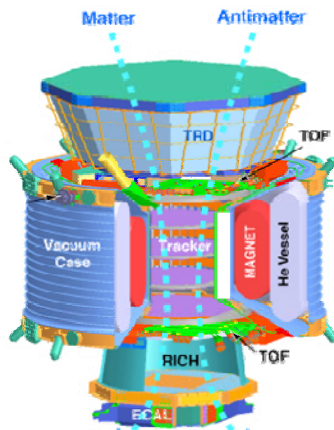


Figure 1

counter tubes in 20 layers and contribute to dE/dx measurement.

- The ToF is designed as a fast primary trigger with a time resolution of 130 ps and velocity measurement of $d\beta/\beta < 3\%$. The 2×2 scintillator planes are attached to upper and lower side of the tracker. The 16 cylindrical shell paddles of the ACC surrounding the Tracker operate as veto.
- The RICH detector performs velocity measurement of charged particles up to 20 GeV/n and accurate determination of a particle's charge up to $Z=26$. It consist of combined NaF and Aerogel radiators and PMT array to detect Cherenkov photons.
- The ECAL is located on bottom of the experiment, where the particle crashes into 18 planes of lead with scintillator fiber inserts. Its thickness corresponds to $16X_0$ ($.5\lambda_h$) and contributes to energy measurement with $dE/E < 5\%$ up to TeV and to proton/positron suppression with a factor of >1000 . For gamma ray detection ECAL acts as an independently triggered photon detector with angular resolution of $< 1^\circ$.

3. Cosmic Ray Astrophysics with AMS-02

Three major physics goals will be presented in the next subsections, keeping in mind that AMS-02 is a multipurpose instrument providing relevant data for various fields of cosmology and particle physics. AMS-02 is a long-duration cosmic radiation monitor.

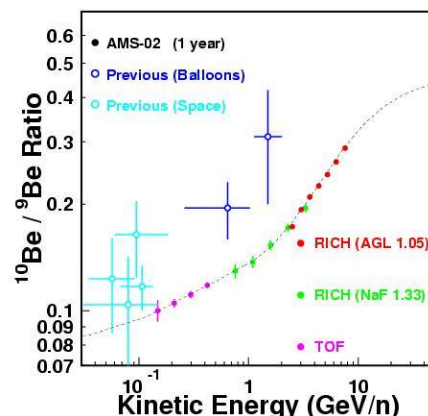
3.1. Cosmic Ray Physics

A precise measurement of galactic cosmic ray spectra is the basis to investigate origins and to improve parameters of current acceleration and propagation models of cosmic ray particles. AMS-02 is capable to determine chemical composition and abundance of cosmic ray nuclei from Helium to Cobalt with 1% accuracy. Furthermore different Isotopes can be distinguished. Measuring different Helium isotopes already AMS-01 found that spectra are unexpectedly separated in space.

AMS-02 will collect about 10^5 Berillium-10 isotopes in three years and measure isotope ratio shown in figure 2. Since half-life is in the order of confinement time of cosmic ray particles, an exact measurement will improve propagation model parameters like resident time and galactic halo size.

AMS-02 will measure the ratio of Carbon to its spallation secondary Boron up to 1 TeV/n, which gives information about the amount of matter traversed by cosmic ray particles and diffusion processes to understand and fix free parameters of propagation models.

Figure 2



The two complementary modes for gamma detection, either by ECAL or by e^+e^- detection in tracker after conversion, turn AMS-02 also into telescope for high energetic gamma rays from 1 to a few hundreds GeV, complementary to measurement of charged particles with the same instrument. Combined this allows to study cosmic rays interaction with gas as the main source of gamma rays, but also accelerating processes of cosmic rays in 'standard' astrophysics.

3.2. Indirect Search for Dark Matter

The major subject of today's astrophysics certainly is to clarify nature of cold dark matter. Leading idea is some kind of not-yet-seen particle like the Neutralino WIMP candidate as lightest SUSY particle in R-conserving model. Indirect searches are based on quark pair production in annihilation, whose decay then is well known from accelerator experiments. AMS-02 at the same time will measure Antiproton and Positron spectra, which may contain an antimatter excess from annihilating dark matter particles. Furthermore it was shown that one could tune cosmic models from excess in gamma ray flux by fitting a dark matter signal [3].

In standard physics antideuterons in cosmic rays are produced with high energies, whereas antideuterons from Neutralino annihilation can be found below 1 GeV. Since this excess would be orders of magnitudes, extraction of SUSY signal could be much easier than from antiprotons. A large acceptance spectrometer like AMS-02 is required to measure these still extremely low fluxes.

Low scale quantum gravity predicts bosons with mass, allowing direct annihilation into e^+e^- pairs in a dominant channel. This would result in steep features in the spectrum which is different from Neutralino annihilation signal and could be discovered for boson mass of about 300 GeV [4].

3.3. Direct Search for Heavy Antimatter

One of the original goals of AMS-02 is to determine the primordial antimatter content of the Universe, which still is unknown and its existence can not be excluded by standard model on cosmological scale. Up to today no antimatter annihilation signal was found from within our cluster. If there is no heavy antimatter particle found by AMS-02, this would prove there is no antimatter in the Universe, on the other hand a single anticarbon would mean there are antimatter stars.

AMS-02 is designed as a multipurpose instrument and so looking for even new types of matter like stable quark strange matter first proposed in [5]. These Strangelets event signature would simply be an anomalous $Z/A < 0.12$, of which already one candidate was reported by AMS-01.

4. Conclusions

AMS-02 will be a unique and challenging experiment on board the ISS and will be able to extend our understanding of the nature of the Universe. AMS-02 perfectly complements current big experiments on ground and in space in exploring new physics.

Individual detector sub-systems are built, successfully tested and passed space qualification procedure. Full detector assembly started in summer 2007 at CERN facilities in cooperation with NASA. Final AMS-02 test for space qualification will be performed in the Large Space Simulator at ESTEC, before shipment to Kennedy Space Center in Florida for launch preparation in 2009.

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References

- [1] M. Aguilar et al., Physics Reports, vol. 366/6 (Aug.2002), pp.331-404
- [2] The AMS collaboration, Design Report, to be published, preprint available at <http://ams.cern.ch/AMS/AMS.pdf>
- [3] W.de Boer, C.Sander, V.Zhukov, A.Gladyshev, D.Kazakov, astro-ph/0508617, 444 (2005) 51
- [4] H.C.Cheng, J.L.Feng and K.T.Matchev, Phys.Rev.Lett V89, N21 (2002) 211301-1
- [5] E. Witten, Phys. Rev. D, 272-285 (1984)