The AMS-02 Experiment on ISS:

Search for Antimatter, Dark Matter and High Energy Gamma Rays Observation

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Abstract

The Alpha Magnetic Spectrometer (AMS) will analyze cosmic radiation of galactic and extragalactic origin at an altitude of about $400km$ above Earth. A precursor flight on NASA Space Shuttle mission STS-91 took place in June 1998, using the prototype detector AMS-01. The experiment took data during 10 days resulting in about 100 million triggers. This wealth of data already allowed a broad spectrum of physics analysis both concerning cosmic rays and the Earth's radiation belts. Based on experience gathered during this first mission, a more ambitious detector, AMS-02, is being built.

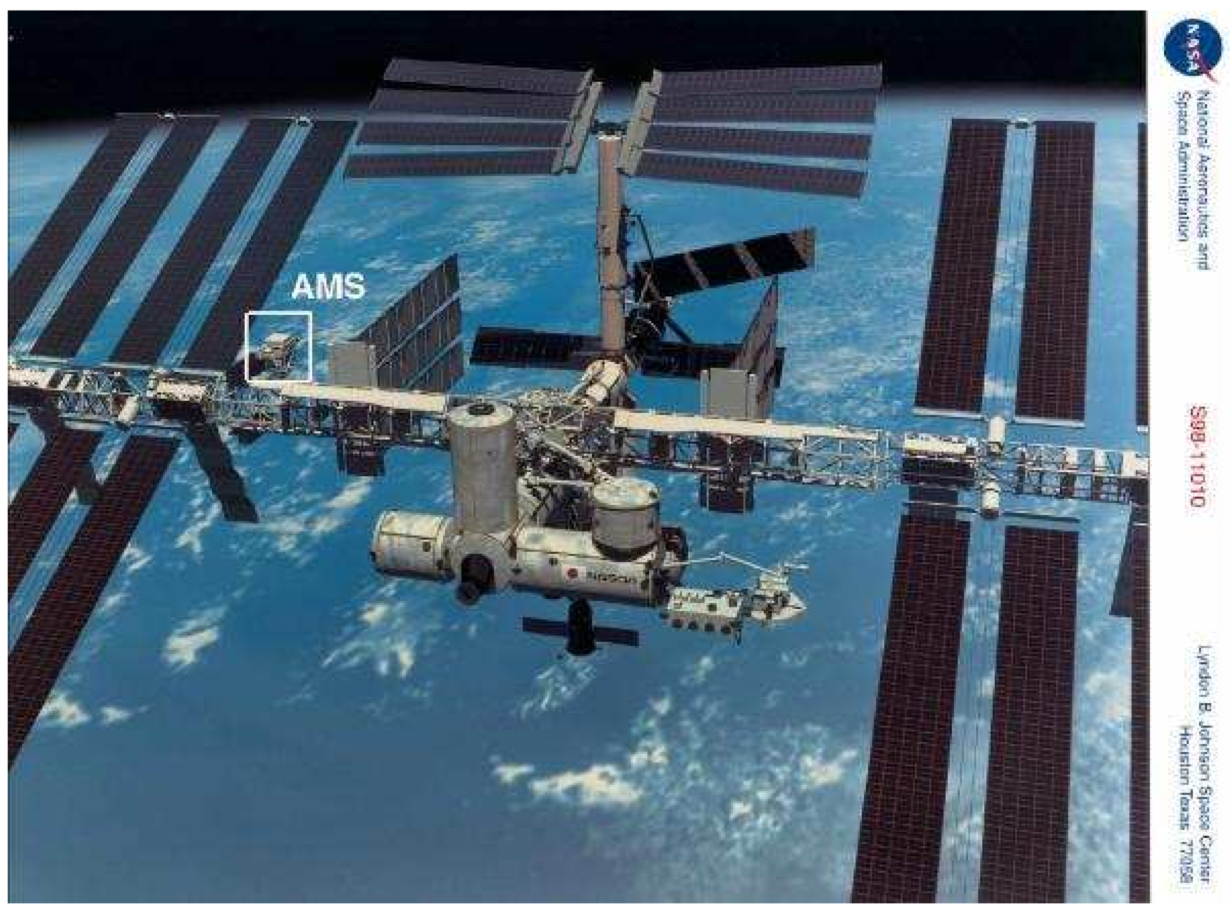


Figure 1: AMS-02 detector on International Space Station (ISS)

The detector is currently foreseen to be installed on the International Space Station (ISS) during October 2006.

1 The AMS-02 Detector

The layout of AMS-02 detector is shown in Figure 2.

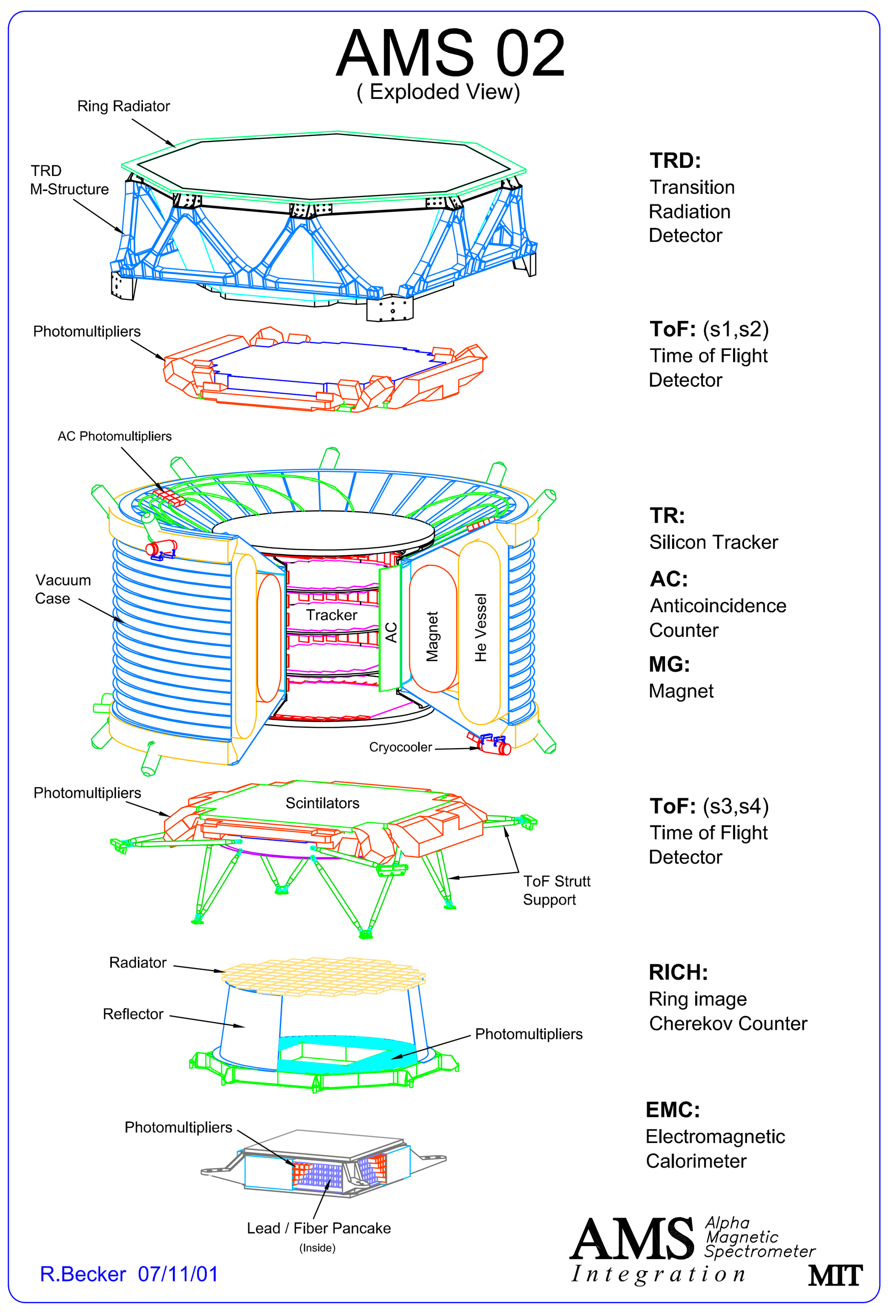


Figure 2: Exploited view of AMS-02 detector

The new detector design aims to extend the energy range of the spectrometer into the TeV region and improve on its particle identifications capabilities. It is built around a spectrometer with a superconducting magnet, supplemented with particle identification devices like a time-of-flight system, a ring imaging Cerenkov detector, and an electromagnetic calorimeter.

2 Physics Goals

The abundance of matter and the apparent absence of antimatter nuclei (anti-helium, anti-carbon etc.) in the Universe is one of the great puzzles in particle physics and cosmology. Theories which predict either the existence of antimatter in segregated domains or the total absence of antimatter require speculative new physics ingredients and lack experimental data to be confronted with. The overwhelming majority of the mass in the Universe is invisible in the form of dark matter of unknown origin. Moreover, a novel form of energy, called dark energy, appears to be accelerating the universe expansion. The more one thus learns about the physics of the universe, the less one appears to understand in terms of the Standard Models of particle physics and cosmology.

The direct observation of comic rays by balloon and satellite experiments is traditionally limited less by energy reach than by rate. Since the primary rate falls by almost three orders of magnitude for every decade in energy, simultaneous direct measurements of composition and spectrum of cosmic rays have so far not been possible beyond a few tens of GeV. The AMS project aims at improving this situation by providing a large area, high resolution spectrometer to be exposed to cosmic rays over a long observation period.

2.1 Dark Matter

More than 90% of the Universe is made of dark matter. Theory suggests that Supersymmetric particles like the neutralino $\tilde{\chi}^0$ could be an important contributor to this dominant component of the Universe. Annihilation of these particles in the galactic halo might produce a visible contribution to the anti-particle and photon spectra via

$$\begin{aligned}\tilde{\chi}^0\tilde{\chi}^0 &\rightarrow \bar{\mathrm{p}} + \cdots\\ &\rightarrow \mathrm{e}^+ + \cdots\\ &\rightarrow \gamma + \cdots\end{aligned}$$

2.2 Antimatter

The strong evidence supporting the Big Bang origin of the Universe requires matter and antimatter to be equally abundant at the very hot beginning. The absence of sharp annihilation photon peaks excludes the presence of large quantities of antimatter within our cluster of galaxies. Theories which predict either the existence of antimatter in segregated domains or the total absence of antimatter at the present time are highly speculative. The resolution of this important problem requires further data: from the current generation of particle colliders and the B factories at SLAC and KEK to improve our current understanding of CP-violation; from Tevatron and LHC to provide clues on the correct extension of the Standard Model; from proton decay experiments in Japan and Italy to improve our understanding of baryon stability; and from AMS to improve the observational basis of the matter-antimatter balance in the Universe.

2.3 Cosmic Rays

AMS-02 will collect of the order of 10^9 nuclei of D, He, Li, Be, B and C. An accurate determination of isotope abundances over a wide range of energies provides crucial information regarding the propagation of cosmic rays in the galaxy.

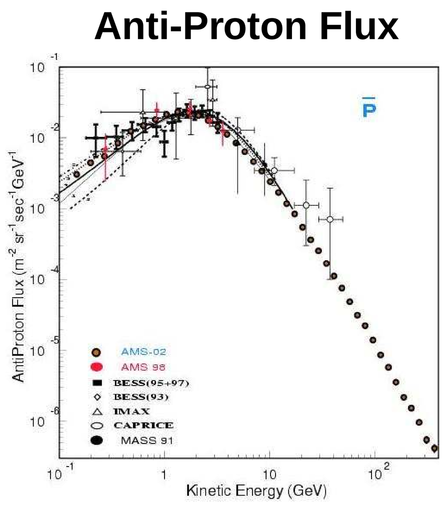
2.4 High Energy Photons

AMS-02 will constantly monitor the gamma ray sky, with rather good acceptance and resolution, both using conversion in the tracker and the electromagnetic calorimeter. Measurements of high energy gamma ray emission from galactic sources like pulsars and extragalactic sources like active galactic nuclei will complement the observations in other frequency bands to gain a better understanding of astrophysical particle acceleration mechanisms.

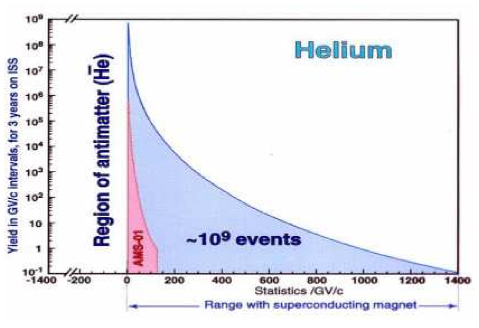
3 AMS-01 Results and AMS-02 Predictions

Search for Antimatter

Anti-Proton Flux

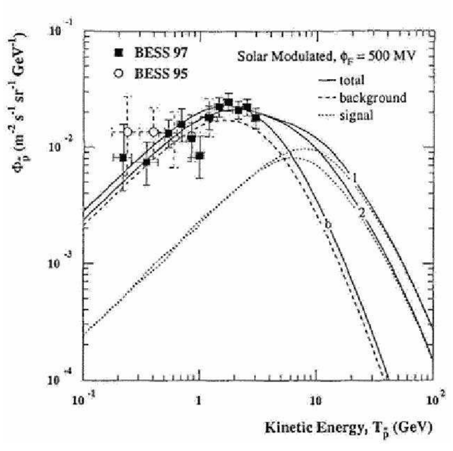


Anti-helium Capabilities

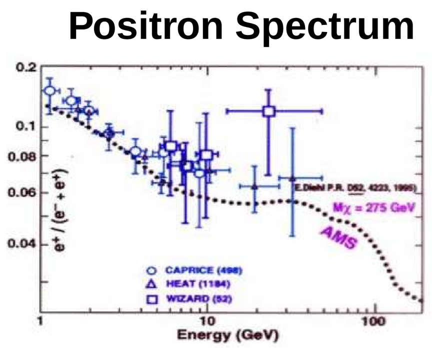


Search for Dark Matter

Anti-proton Spectrum

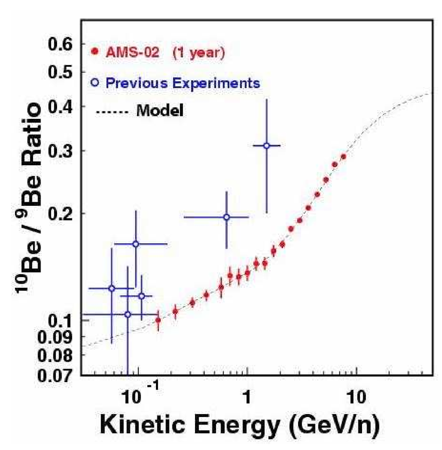


Positron Spectrum



Cosmic Rays

- The determination of isotope abundances provides information on the propagation of Cosmic Rays in the galaxy.

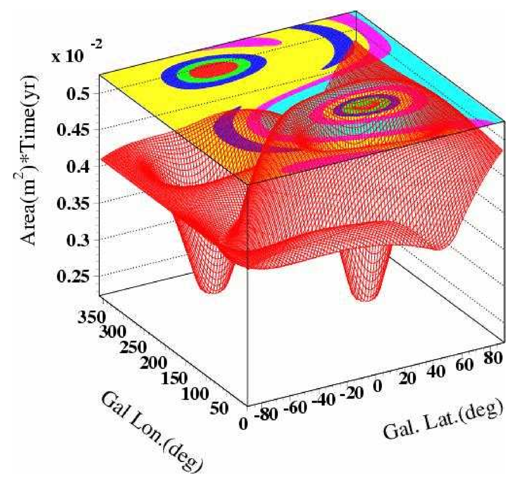


- $^{10}Be/^{9}Be$ ratio ($^{10}Be \sim 1.6{\cdot}10\ yrs$) gives information on:
  - Cosmic Rays confinement time in the galaxy
  - Mean density of interstellar material traversed
- AMS-02 will collect of the order of 10^9 of:

- Proton: dominant component
- He: 5 % of p flux at 10 GeV
- D, Li, Be, B and C
- Anti-proton: $\sim 10^{-3}$ % of p flux

High Energy γ-Rays Exposure

Tracker



Calorimeter