Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 4 (HE part 1), pages 821–824

30TH INTERNATIONAL COSMIC RAY CONFERENCE

ICRC'07 Mérida, México

The Alpha Magnetic Spectrometer on the International Space Station

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Abstract: The Alpha Magnetic Spectrometer (AMS) is a particle physics detector designed to measure charged cosmic ray spectra up to TV region, with high energy photon detection capability up to few hundred GeV. With the large acceptance, the long duration (3 years) and the state of the art particle identification techniques, AMS will provide the most sensitive search for the existence of anti matter nuclei and for the origin of dark matter. The detector is being constructed with an eight layers Silicon Tracker inside a large superconducting magnet, providing a ≈ 0.8 Tm^2 bending power and an acceptance of ≈ 0.5 m^{2}sr. A Transition Radiation Detector and a 3D Electromagnetic Calorimeter allow for electron, positron and photon identification, while independent velocity measurements are performed by a Time of Flight scintillating system and a Ring Image Cerenkov detector. This contribution will describe the current status of the overall detector construction and its expected performances.

Introduction

The Alpha Magnetic Spectrometer (AMS) is an extremely high profile space-based particle physics experiment that is led by Nobel laureate Samuel Ting of the Massachusetts Institute of Technology (MIT). The AMS experiment is a high energy particle detector aimed at making a high precision measurement of Cosmic Ray (CR) and gamma fluxes at low Earth orbit from few hundred MeV/n up to few TeV/n.

The scaled version of AMS, AMS-01, flew in space in June of 1998 aboard the Space Shuttle Discovery (NASA, STS-91 flight) for ten days in June 1998. The detector had been operational for about 180 hours collecting more than one hundred million cosmic ray events which led to significant results [1], [2], [3], [4], [5], [6]. The AMS-02 design has been improved in order to fulfil the requirements of large acceptance (0.5 m^{2}sr), wide energy range, very long exposure time and excellent particle identification. These qualities make AMS-02 unique in the search for cosmic antimatter nuclei, dark matter indirect signatures and in refining the current CRs knowledge.

AMS-02, 7 tons and 4 meter high shuttle payload (shown in the figure 1), will be ready at the end of 2008 and it is currently scheduled to fly on the International Space Station (ISS), where it will operate for at least three years.

The AMS experiment is designed and constructed by an international team of over 450 physicists and engineers from over 50 institutions and companies in 16 countries. The technical challenges to build such a detector for use in space have been surmounted through the close collaboration of the AMS scientists and industries around the world whose efforts have resulted in the development of new technologies and higher standards of precision. AMS is built in accordance with strict space qualification standards and safety parameters required by NASA. Along with the international support of the experiment, the project represents a major joint effort by the U.S. Department of Energy and NASA.

The AMS-02 detector

This detector, AMS-02, is based on a spectrometer with a super-conducting magnet. Its main components are shown in figure 2 and shortly described below.

The Super Conducting Magnet (SCM) has a inner diameter of 1.1 m. It consists of two dipoles and

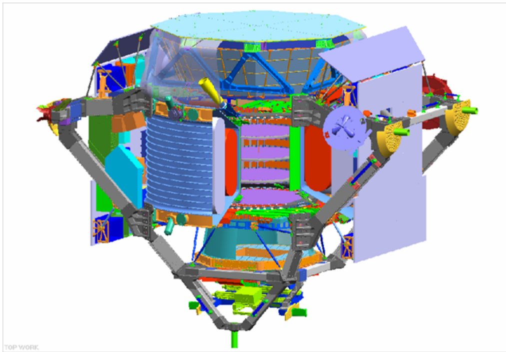

Figure 1: The full view of the Alpha Magnetic Spectrometer shuttle payload.

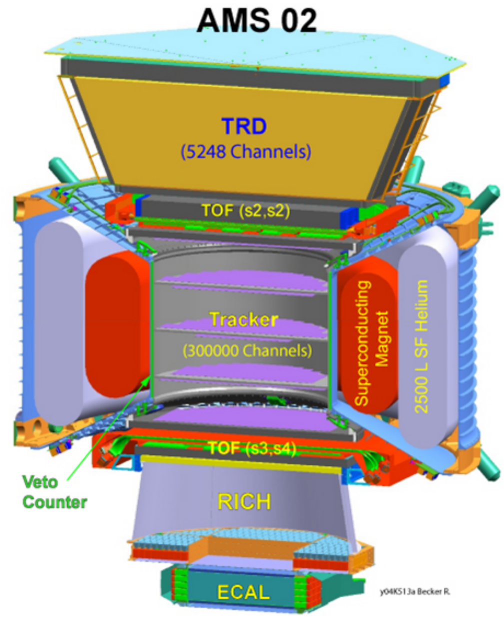

Figure 2: The AMS-02 Spectrometer. The detector components are: Transition Radiation Detector (TRD), Time Of Flight detector (TOF), silicont Tracker (Tracker), Ring Imaging CHerenkov detector (RICH), Electromagnetic CALorimeter (ECAL), AntiCoincidence Counters (ACC) and finally the magnet.

two sets of smaller racetrack coils to ensure an intense magnetic field ≈ 0.9 T and a null magnetic dipole moment outside the SCM. The magnet has a bending power of ≈ 0.8 Tm^2. It will be cooled to 1.8 K by 2500 liters of superfluid helium [7]. The already assembled fight module of the magnet is shown in figure 3.

The AMS-02 Tracker consists of eight layers of double side silicon microstrip detectors mounted on 5 carbon fiber planes for a total active area of about 6.4 m^2. In each layer, simultaneous measurements of position and energy loss in silicon are performed along the particle trajectory. With its high spatial resolution, 10 μm for singly charged particles ($\approx$ 6μm for Z$>$ 1), the silicon tracker will allow the determination of the rigidity (R) and the charge sign of particles up to several TVs, with a resolution $\sigma R/R \approx 2.5\%$ up to $O(100)$ GV. The low noise and wide dynamic range of the silicon readout electronics allow to exploit the energy loss measurements to determine the particle absolute charge for nuclei up to Fe [8].

The Transition Radiation Detector (TRD) is designed to separate e^+/e from p^+/p^- up to 300 GeV. TRD consists of 20 layers of straw tubes, filled with a mixture of Xe/CO_2 , alternating with fleece radiators [9].

The Ring Imaging CHerenkov detector (RICH) will provide Z measurement up to iron and a precision velocity measurement with $\Delta\beta/\beta \approx 0.1/Z\%$ allowing for isotope separation in the kinetic energy range from 0.5 GeV/n to 10 GeV/n for $A = 10$ [10], [11].

The Time of Flight detector (ToF) consists of four planes of plastic scintillators placed at both ends of the superconducting magnet. It provides a fast trigger to the experiment, velocity with a $\Delta\beta/\beta \approx 3\%$ for protons and a charge identification up to $Z = 20$ [12].

The Anti Coincidence Counter (ACC) will ensure that only particles passing the magnet aperture and not being scattered in the tracker will be accepted. The ACC system is composed by 16 plastic scintillator paddles, displaced in order to form a cylinder of an inner diameter of 109.1 cm.

The Electromagnetic CALorimeter detector (ECAL) consists of 9 superlayers of lead foils with glued scintillating fibers resulting into a total radiation depth of 16 X_0 for shower development. ECAL is designed to assure precise e^-, e^+ and γ

spectra from 1 GeV to 1 TeV with $dE/E < 5\%$ and good e^+/p discrimination (below 500 GeV). For gamma ray studies, ECAL acts as an independent photon detector with an angular resolution of $\approx 1^\circ$ [13]. In figure 4 is shown the flight module of the ECAL subdetector, actually located inside the clean room in the CERN laboratories to be installed on the AMS mechanical structure.

The design of AMS-02 sub-detectors meets a set of specific constraints imposed by NASA policy and space conditions. All the detectors and related electronics are built with redundant philosophy.

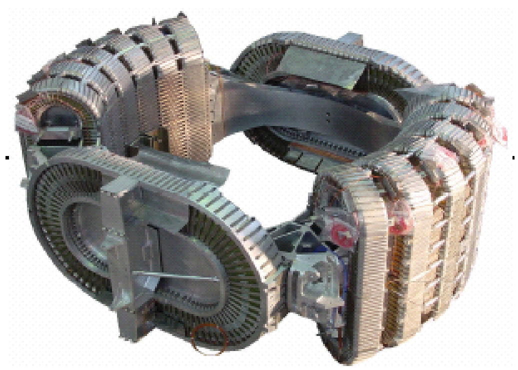

Figure 3: The flight module of the supeconducting magnet.

The AMS-02 goals and capabilities

The AMS-02 has interesting and ambitious targets during the three years of mission. The most important are briefly summarized below and better explained in other papers presented at this conference.

- AMS-02 will improve the actual knowledge of the cosmic ray spectra and chemical composition up to TeV region energy range [13]. It can perform high statistics secondary-to-primary ratios measurements, for example d/p, He^3/He^4 and B/C, all useful quantities to distinguish between different cosmic ray propagation and confinement models.

- AMS-02 will improve by three orders of magnitude the actual knowledge of primordial anti-matter by direct detection of anti-nuclei, for example of a cosmic anti-helium. This represents a crucial improvement in our knowledge of the Universe.

- Finally AMS-02, thanks to its unprecedented particle identification capability will explore the indirect detection of dark matter combining searches in several different channels as anti-deuterium, anti-protons, positrons spectra and gamma rays [14], [15], [16].

Conclusions

The AMS experiment is a high energy particle detector that will performe high precision measurement of Cosmic Ray (CR) and gamma fluxes at low Earth orbit from few hundred MeV/n up to few TeV/n. It will be installed on the Internation Space Station where it will operate for at least three years.

The AMS-02 detector integration will start in September 2007 in a dedicated clean assembly area at CERN. After integration, the whole apparatus will undergo ElectroMagnetic Interference (EMI) compatibility test and thermal test in vacuum chamber at the ESA ESTEC facility. In fall 2008 a beam test is foreseen at CERN, in order to verify the performance of the apparatus and to calibrate the spectrometer. The delivery of the AMS-02 at the NASA KSC is scheduled in December 2008.

Acknowledgements

The construction of AMS-02 is an undertaking of many individuals and organizations. The support of NASA and the U.S. Dept. of Energy has been vital in the inception, development and fabrication of the experiment. The interest and support of NASA, the Federal Agency for Atomic Energy, Russia, the Ministry of Science and Technology, China, and the European Space Agency is gratefully acknowledged. The support of the space agencies from Germany (DLR), Italy (ASI), France (CNES), Spain (CDTI) and China and the support of CSIST, Taiwan, have made the construction possible. The support of GSI-Darmstadt to test

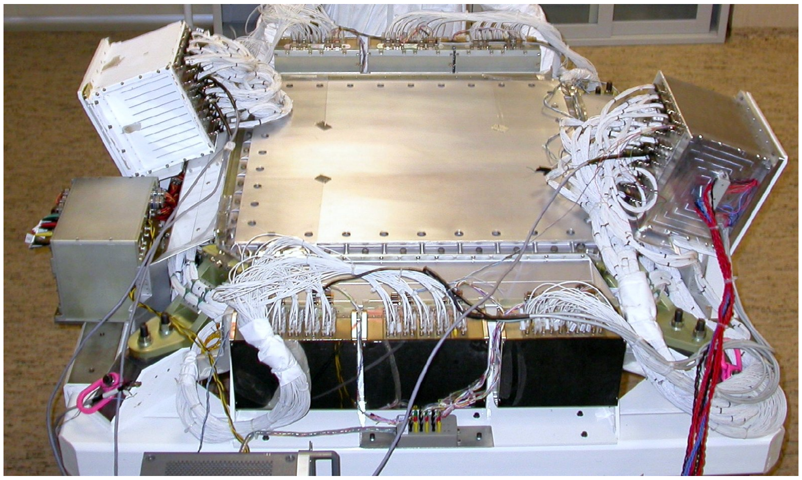

Figure 4: The flight module of the Elettomagnetic CALorimeter, actually inside the clean room at CERN and ready to be assembled in the AMS mechanical structure.

electronics components for radiation effects. The support of ESA will enable the overall thermal vacuum test of ESTEC. The support of INFN, Italy, IN2P3, Region Rhône-Alpes and Haute Savoie, France, CIEMAT and CICYT, Spain, LIP, Portugal, CHEP, Korea, the Chinese Academy of Sciences, the National Natural Science Foundation and the Ministry of Science and technology of China, Academia Sinica, Taiwan, the U.S. NSF, M.I.T., ETH-Zürich, the University of Geneva, National Central University, National Space Program Office, National Chaio Tung University and National Cheng Kung University, Taiwan, Moscow State University, Southeast University, Nanjing, Shanghai Jiao Tong University, Sun Yat-sen University, Guangzhou, Shandong University, Jinan, RWTH-Aachen, the University of Turku and the University of Technology of Helsinki, is gratefully acknowledged. We are grateful for the strong support and interest shown from the private sector, including Linde, ILK, CGS, CAEN, CRISA, G&A Engineering, ISATEC and Bieri Engineering.

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