The AMS-02 TRD for the International Space Station

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Abstract

The Alpha Magnetic Spectrometer (AMS-02) is an experiment which will be mounted on the International Space Station (ISS) to measure primary cosmic ray spectra in space. A key element is a Transition Radiation Detector (TRD) to distinguish an e^+ or p^- signal reducing the p^+ or e^- background by a rejection factor $10^{-3} - 10^{-2}$ in an energy range from 10-300 GeV. This will be used in conjunction with an electromagnetic calorimeter to provide overall p^+ rejection of 10^{-6} at 90% e^+ efficiency.
The detector consists of 20 layers of 6 mm diameter straw tubes alternating with 20 mm layers of polyethylene/polypropylene fleece radiator. The tubes are filled with a 80%:20% mixture of $Xe : CO_2$ at 1.0 bar absolute from a recirculating gas system designed to operate >3 years in space. The layers are mounted to 0.1 mm precision in a stable carbon fiber composite/aluminum honeycomb octagonal mechanical support. The upper and lower four layers of tubes run in the x direction and the central layers run in the perpendicular y direction, to provide tracking in the bending and non-bending directions of the 0.8 T superconducting magnet as well as particle identification. The construction of the detector will be presented.

1. Introduction

The Alpha Magnetic Spectrometer is an experiment which will be mounted on the International Space Station (ISS) to measure primary cosmic ray spectra in space [1]. Its uppermost element is a Transition Radiation Detector (TRD) (Fig. 1). Transition radiation (TR) consists of soft X-rays which are emitted when charged particles traverse the boundary between two media with different dielectric constants. In the momentum range of 10-300 GeV/c, light particles such as electrons and positrons have much higher probability of emitting TR photons than heavy particles such as protons and antiprotons. At a single boundary, the probability of emission is still very small, on the order of 10^{-2}, but this is enhanced by using a fleece as a radiator. This, in turn is divided into twenty

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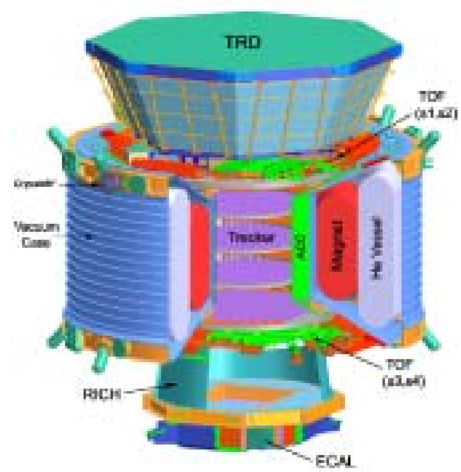

Fig. 1. The TRD in AMS-02

20 mm thick layers, with layers of 6 mm diameter straw tubes, filled with an 80%:20% $Xe : CO_2$ gas mixture, in between to detect the photons. In this way a rejection factor of $10^{-3} - 10^{-2}$ for p^+ and e^- can be achieved against e^+ and $\overline{p}$ in the aforementioned momentum range. Combining the TRD rejection power with that of an electromagnetic calorimeter (Ecal in Fig. 1) located at the bottom of AMS-02 increases the p^+ rejection to the order of 10^6 at 90% e^+ efficiency.

2. Mechanical Structure

The conical octagon structure (width from 1.5 m at bottom to 2.2 m at top) is built of a carbon fiber and aluminum honeycomb sandwich material, both for the sidewalls, with slots machined with a precision of 100 μm, and the top and bottom covers. The dimensions are verified on a precision optical measuring machine. The octagon is supported from the magnet vacuum case and the Universal Support Structure (USS) which holds AMS-02 in the shuttle and on the ISS by an aluminun M-structure. Detailed finite element calculations have been performed to verify that the large TRD octagon structure and support satisfies all dimensional and safety requirements. The straw tubes are built as modules of 16 tubes. The 20 layers of modules are arranged in the conical octagon structure. The top and bottom 4 layers are oriented parallel to the AMS-02 x axis, which is the direction of the field in the magnet. The middle 12 layers are oriented along the perpendicular y direction. Thus the tubes provide tracking both in the bending and non-bending directions of the magnet as well as particle identification.
The length of the straw modules varies from 0.8 m to 2.0 m. In all, there are 328 modules, for a total of 5248 straws. The wall material of the straws is a 72 μm Kapton foil, whose structure is shown in Fig. 2. The sense wires are 30 μm gold

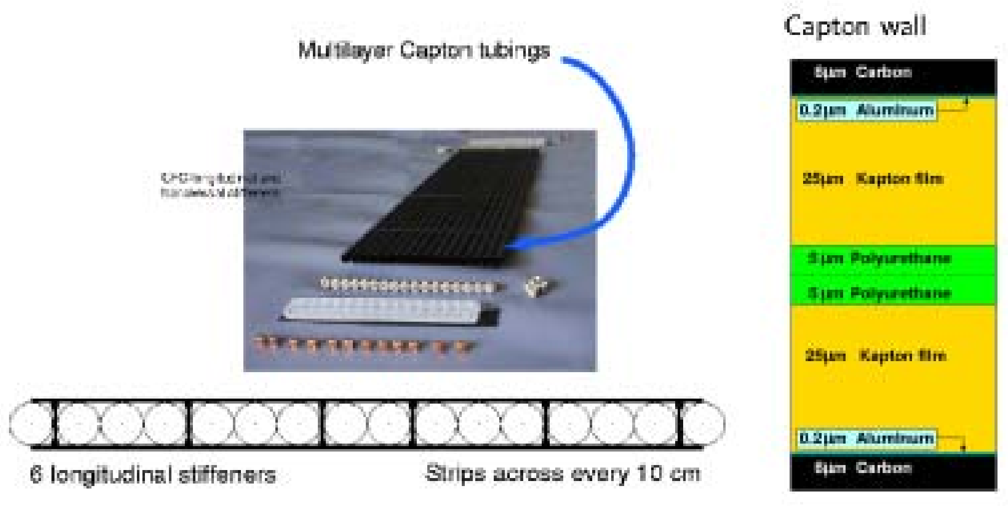

Fig. 2. Straw Tube Module: 16 6 mm tubes with 30 μm W-Au wire

plated tungsten. The wires are held in the polycarbonate end pieces by crimping in Cu-Te blocks. The radiator is a fleece of 10 μm polyethylene/polypropylene fibers. The fiber sheets have a density of 0.06 g/cm^3 and are 5mm thick. Before use, the material is cleaned with CH_2Cl_2. Measurements have shown that this is sufficient to attain the outgassing limit of 10^{-12} g/s/cm^2 required by NASA.

3. Electronics and DAQ System

The Data Acquisition (DAQ) system of the TRD is divided in two parts: The front end electronics which are mounted on the walls of the detector, and the first level of data acquisition which is hosted in two identical crates. The digitization of the signals from the straw tubes is done in the front end electronics. The crates hold the power supplies, the boards which collect and compress the data and the control of the whole TRD DAQ system.

4. Module Production

Each straw is pretested and accepted only with a He leakrate below 10^{-5} l mbar/s/m. Straw module production continues with gluing of 16 straws with their stiffeners. Then the endpieces are glued to the straws. After curing the glue, the wires are inserted, tensioned, and crimped into the CuTe blocks in a special machine. The wire tension is measured, then a preview test of the signal noise spectrum is made with HV and an Ar/CO_2 gas mixture. After these tests are passed, the final glue potting of the endpieces is done and the HV boards are mounted. This is followed by a serial test of gas tightness, dark current and corona, and the gas gain is measured as a function of high voltage with an Fe^{55} source and the Ar/CO_2 gas mixture. An X-ray measurement of the wire position is made on a subsample of the modules, as well as a long term test in vacuum of the gas gain.

5. Gas System

The TRD contains Xe/CO_2 mixed 4:1 in volume. The gas has to be stored, mixed, and distributed through the TRD modules. The gas system to do this is divided into three parts. Box S stores the Xe and CO_2 in separate vessels, which will contain 46 kg of Xe and 4 kg of CO_2, 50 kg in total. The gases are transferred in controlled amounts (by measuring partial pressures) to a mixing vessel, from which the mixture is released to box C. Box C contains redundant pumps to circulate gas through the TRD to ensure uniform gas properties. It also contains a CO_2 analyzer and monitor tubes for measuring gas gain with an Fe^{55} source. Gas tightness is crucial for the operation of the TRD detector in space. The 60 flight modules produced so far all show a leak rate below 10^{-4} l mbar/s/m, which is sufficient for operating the TRD up to 10 years. Nonetheless, the volume of the TRD is divided into 41 separate gas circuits, each consisting of eight modules connected in series. Pressure sensors and valves located in the so-called manifolds can detect leaks and isolate a leaky segment.

6. Monitoring and Control

The monitoring and control crate for the gas system contains two redundant Universal Slow Control Modules (USCMs) which contain the monitor program which tests the status of the gas system against pre-conditions and executes commands, which are stored in the form of decision tables. The USCMs are connected to the main Monitor and Control Computer of AMS via CAN-Bus, and to the gas system control electronics via a dedicated control bus. The gas control electronics consists of separate redundant Box S, Box C, and manifold control cards in the crate, and cards mounted on the manifolds for the pressure sensors. The cards monitor pressures, temperatures, gas composition and gain, and control the opening and closing of the valves for safety and gas mixing operations.

We want to thank the many organizations and individuals listed in the acknowledgements of ref. [1].

7. References

1. S. Gentile, “The Alpha Magnetic Specrometer on the International Space Station”, these proceedings.