THE AMS-02 TRANSITION RADIATION DETECTOR FOR THE INTERNATIONAL SPACE STATION

A. BARTOLONI
I.N.F.N. Sezione di Roma.
Ple Aldo Moro 2,
00185, Roma, Italy
E-mail: alessandro.bartoloni@roma1.infn.it

On behalf of the AMS-02 TRD group:
I Phys. Inst. RWTH, Aachen, Germany
Massuchusetts Institute of Technology, Cambridge, USA
IEKP University of Karlsruhe, Germany
INFN Roma, Italy
Kyungpook National University, Taegu, Korea

The Alpha Magnetic Spectrometer (AMS-02) is a large experiment in the International Space Station (ISS) intended to measure primary cosmic ray spectra in space. It sits outside of the station, looking out into space. High-energy particles pass through it, interacting with different detectors on the way. The Transition Radiation Detector (TRD) contributes to distinguish an e^+ or p^- signal reducing the p or e^- background by a rejection factor 10^2 to 10^3 in the energy range from 10 to 300 GeV. This detector will be used in conjunction with an electromagnetic calorimeter to provide an overall p rejection of 10^6 with 90% efficiency for positrons. AMS-02 TRD consists of 20 layers of straw proportional tubes alternating with layer of fiber fleece radiator. The layers are mounted in a stable and light carbon fiber composite/aluminum honeycomb octagonal support, fixed by an M-structure to the AMS-02 magnet flange. A space qualified redundant electronic subsystem processes signals coming from the 5248 straw tubes providing front-end readout, first level DAQ and interface to the AMS-02 trigger/DAQ system. The straw tubes are filled with a Xe:CO_2 gas mixture provided by a gas circulating system capable to operate more than 3 years in space. The gas control system of the TRD is also an essential item for its performance. To obtain the required discriminating power, a stringent control of gas parameters is necessary. The construction of the detector is 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]. A key element for dark matter search using AMS-02 is the capability to detect positron where the expected flux ratio p/e^+ is order 10^4. The Transition Radiation Detector (TRD) used in conjunction to an electromagnetic calorimeter allows distinguishing positrons over protons with a rejection factor $R_{p/e+} < 10^6$ at 90% e^+ efficiency. Transition Radiation (TR), consisting of soft X-rays emitted by a charged particle when crosses the boundary between two media with different dielectric constant, is proportional to the Lorentz factor of the particle. In the momentum range of 10 to 300 GeV light particles (electrons and positrons) have much higher probability of emitting TR photons than heavy particles (protons or antiprotons) allowing the required positron identification capability. At a single boundary the probability of emission is very small (10^{-2}) but it is enhanced by using of multilayered dielectric boundary spaced in vacuum.

TR photons are then detected using straw tubes filled with Xe:CO_2 gas mixture. The requirements for the AMS-02 TRD is $R_{p/e+} < 10^2 – 10^3$ and is reached using 20 layers of 22 mm polypropylene/polyester fleece radiator, each coupled with 6 mm diameter straw tubes filled with an 80%:20% Xe:CO_2 gas mixture.(fig.1).

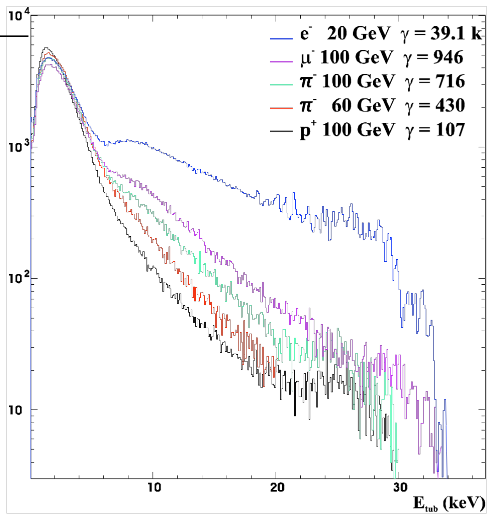

Figure 1. p/e^+ rejection.

2. Mechanical Structure

The straw tubes are built as modules of 16 tubes. The 20 layers of modules are arranged in a conical octagon structure. The top and bottom 4 layers are oriented parallel to the direction of the magnetic field while the 12 middle layers are oriented perpendicular to the field. Such way the tubes provide tracking both in the bending and non bending directions of the magnet as well as particle identification.

The entire TRD is composed by 328 modules, ranging in length from 1.5 meters up to 2.2, for a total of 5248 straw tubes. The tube wall is composed of a 72 μm thick foil and the sense wires are 30 μm gold plated tungsten. The wires are held by the polycarbonate end pieces crimped in Copper-Tellurium blocks. The radiator is a fleece of 10 μm polyethylene/polypropylene fibers cleaned with CH_2CL_2 to attain the outgassing limit of 10^{-2} g/s/cm2 required by NASA. A conical octagon support structure, of carbon fiber and aluminum honeycomb sandwich material, mounts all the straw modules. The dimensions (1.5 meters at the bottom and 2.2 meters at top) are verified by a precision optical measuring machine. The octagon, see figure 2, 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 aluminum M-structure. Detailed finite element calculation were performed to verify that the large TRD octagon structure and support satisfies all dimensional and safety requirements.

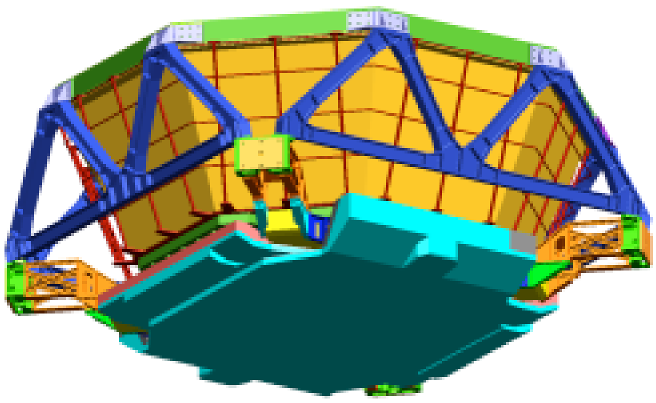

Figure 2. Transition Radiation Detector: mechanical structure.

3. Electronics and DAQ system

The Data Acquisition (DAQ) system of the TRD is divided in two parts: the readout front-end electronics which are mounted on the walls of the detector, and the first level of data acquisition which is hosted in four crates. Front-end electronics digitizes signals from the straw tubes. Crates are mounted on the

AMS-02 radiators, two of them host all the DC-DC converters needed to generate the different power supply voltages starting from the 28 VDC generated from the AMS-02 Power Distribution Box (PDB). The other two crates hold the boards which collect and compress the data. These boards produce high voltage (about 1400 VDC) necessary to the straw tube anode and the control of the whole TRD DAQ system.

4. Module Production

Each straw is tested and accepted only with a He leak rate below 10^{-5} liter mbar/s/m. Sixteen straws are glued with their stiffeners; end-pieces are glued to the straws. After curing the glue, the wires are inserted, tensioned and crimped into the Cu-Te blocks by a special machine. The wire tension is measured, and then a preview test of the signal noise spectrum is made using an Ar:CO_2 gas mixture. After these tests are passed, the final glue potting of the end-pieces is done and the high voltage distribution boards are mounted. This step is followed by a serial test of gas tightness, dark current and corona, and the gas gain is measured as a function of the high voltage with 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 of the gas gain in vacuum [2].

5. Gas System

The TRD, mixed in the ratio 80/20. contains Xe/CO_2 in volume. The gas has to be stored, mixed and distributed to the TRD modules. The gas system is divided into three parts: *box S*, *box C* and *manifolds*. Box-S stores the Xe and CO_2 in separate vessels, which will contain 46 Kg of Xe and 4 Kg of CO_2. The gases are transferred in controlled amounts, to a mixing vessel from which the mixture is released to box-C. Box-C contains a pair of pumps to circulate gas through the TRD. It also contains a CO_2 analyzer and monitor tubes for measuring gas gain with a Fe^{55} source. Gas tightness is crucial for the operation of the TRD detector in space. The volume of the TRD is divided in 41 separate gas circuits, each consisting of 8 modules connected in series. Pressure sensor and valves, located in the so-called manifolds, can detect leak and isolate a leaky segment.

6. Monitoring and Control

Electromechanical devices contained inside the gas system are monitored and controlled by the TRD gas system control electronics which consists of two different subsystem named UG crate and UGPD.

UG crate (TRD Gas System Control Crate): in this crate all the electronics boards are located. This electronics is in charge to receive commands from the main monitoring and control computer of AMS-02 experiment, named JMDC. The computer runs the gas mixture programs, the monitor program which tests the status of the system sensors and execute the commands activating all the devices (pumps, valves, sensors, etc.) present in the gas system.

The Gas Control System is composed by eleven boards (6U-height, VME-like format) of five different types and a backplane board.

UGPD (Gas Power Distribution Box): in this box all the filter and control electronics are located, included DC-DC converters necessary to provide power supply to the Gas System starting from the 28 VDC produced by the AMS Power Distribution Box. DC-DC converters are needed for 120, 24, 12, 5, 3.3 VDC.

Since the above electronics has to operate in space environment for three years without maintenance, it will be designed using redundancy criteria to cope with failure of one element at the time. To implement this feature, for every board in operation, or hot board, a standby unit, cold board, will be provided.

7. Conclusions

A Transition Radiation Detector to be used in the AMS-02 experiment is in construction. Test beam measurements demonstrated that the required proton rejection of order of 10^2-10^3 is reached. Quality of the design is demonstrated through calculations and space qualification tests in thermo-vacuum chamber and vibration table.

References

[1]. S.Gentile, “The Alpha Magnetic Spectrometer on the International Space Station”, *Proceedings of 28th International Cosmic Ray Conference* ,(2003).

[2]. T.Kirn, “Status of AMS-TRD Straw Modules”, *Radiation Detectors for Accelerators and Space Applications*