Status of AMS-TRD-Straw Modules

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Abstract

The AMS02 experiment will be installed on the International Space Station ISS for a data taking period of 3 years. The TRD consists of 20 layers of straw modules and fleece radiator with a total of 328 modules (16 straws each). The housing consists of a conically shaped octagon structure made out of CFC-Al-honeycomb material and is closed by a lower and upper honeycomb plate. The gas is a 80:20 Xe/CO2 mixture. The straw modules will be operated in proportional mode at a gasgain of 3000. The signals are readout by VA chips. The detector is under construction at RWTH Aachen, the gas system will be built at MIT, slow-control at INFN Rome and DAQ at TH Karlsruhe. In the presentation special emphasis will be dedicated to the space qualification aspects and the status of the straw module production.

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1 Introduction

The AMS-02 experiment is a large acceptance particle spectrometer (0.5 m^2sr) designed to operate in space and measure cosmic ray fluxes on the International Space Station ISS for a time period of three years. The main goals of the experiment include antimatter and dark matter search and cosmic ray physics in the energy range from few GeV up to 1 TeV. The AMS-02 experiment will allow indirect searches of dark matter candidates with high statistics measurements of e^+ from neutralino annihilation (1). To reach the required precision in e^+-spectroscopy the dominating proton background has to be reduced by a factor 10^6. This will be achieved with the AMS-02 electromagnetic calorimeter delivering 3-4 orders of magnitude and the TRD with proton rejections between 100 and 1000.

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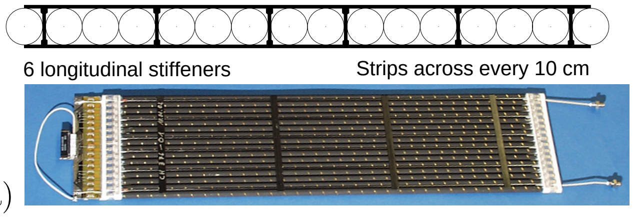
2 The AMS-02 TRD Straw Modules

The design of AMS-02 TRD is based on R&D work for ground based experiments (2; 3). The challenge is to build such a detector to operate safely and reliably for three years in space (4; 5; 6).
Fleece material[1] is used as radiator and the TR photons are detected in proportional mode straw tubes, filled with a Xe/CO_2 (80%/20%) gas mixture. The TRD consists of 20 layers, each with 20 mm fleece and modules of 16 straw tubes with 6 mm diameter made from a double layer kapton-aluminium foil of 72 μm wall thickness. The modules (Fig. 1) are closed with polycarbonate endpieces which serve as gas manifolds and centre the Cu-Te-crimp plugs to hold a 30 μm goldplated tungsten wire tensioned with 1 N. The straw modules are mechanically stabilized by longitudinal and vertical carbon fibre stiffeners. In total 328 modules of lengths up to 2 m are supported by two bulkheads in a conically shaped octagon structure. The upper and lower four layers run parallel to the magnetic field, the others perpendicular to provide 3D tracking. The octagon is made of a carbon fibre and aluminium honeycomb machined to 100 μm precision keeping gasgain variations below 2 %.



a)

Fig. 1. AMS-02 TRD module with 16 straw tubes.

The circulating gas system has 41 loops at 1 l/h each serving 8 modules connected in series. The total volume of the straw modules is 230 l and the total length is 500 m. The gas tightness of the straw modules is the most critical design issue. 46 kg (8100 l at 1 atm) of Xe and 4 kg (2000 l at 1 atm) of CO_2 will have to last for three years of operation (safety factor 1). The measured leakrate for one straw of $0.3 \cdot 10^{-6}$ l mbar/s/m is dominated by diffusion through the straw walls (Fig. 2a). Assuming pure diffusion leaks this would correspond to a loss of 50 l Xe (safety factor 160) and 170 l CO_2 (safety factor 12). Additional gas losses are caused by diffusion through the polycarbonate endpieces. Therefore the aim is to produce straw modules with a CO_2 leakrate of $1.2 \cdot 10^{-5}$ l mbar/s/m (safety factor 4). This can only be achieved by testing each of the 5248 straws individually before producing a module. A single straw teststand (Fig. 3) has been developed where Helium is used to achieve fast and accurate measurements. A Helium leakrate of $10 \cdot 10^{-5}$ l mbar/s/m corresponds to a safety factor of 4 for CO_2 (Fig. 2b). The single straw is glued gastight at one end using a brass plug. A steel tube is glued to

[1] LRP-375 BK manufactured by Freudenberg Vliesstoffe KG, Germany

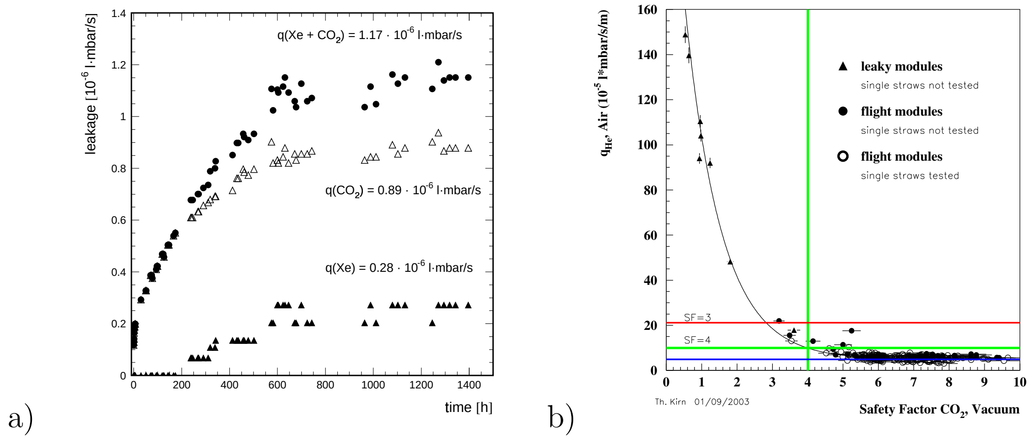


Fig. 2. a) Xe/CO_2 leakrate measured with a mass spectrometer with three 1.3 m long straws. b) Correlation between measured He- and CO_2-leakrates.

the other end serving as gas inlet. The straw is placed inside an external volume which is closed gastight by a lid and an O-ring. This volume is connected to a reference volume via a valve and a differential pressure sensor. The volumes are in thermal contact and the temperature is monitored. After the straw installation, the valve is opened shortly to ensure that the pressure in both volumes is the same. Then Helium is filled into the straw with a pressure of 2.8 bar. The gas leaks into the external volume due to diffusion through the straw walls or due to leaks. The differential pressure increase is measured and the leakrate can be determined after a period of 5 minutes (Fig. 3).

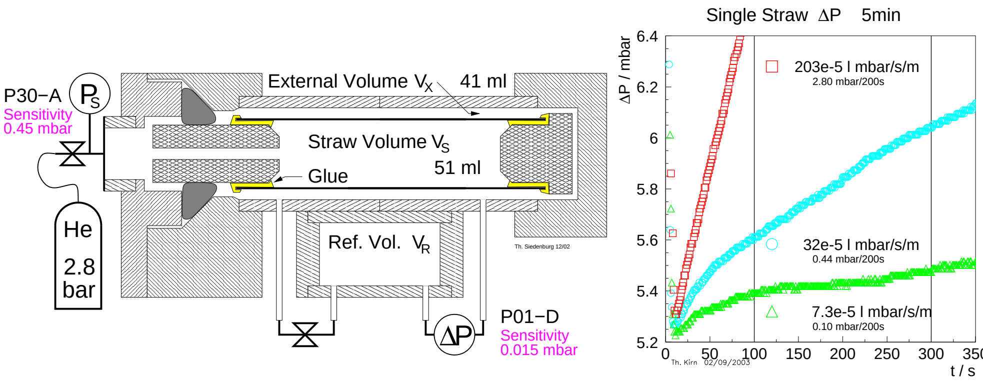
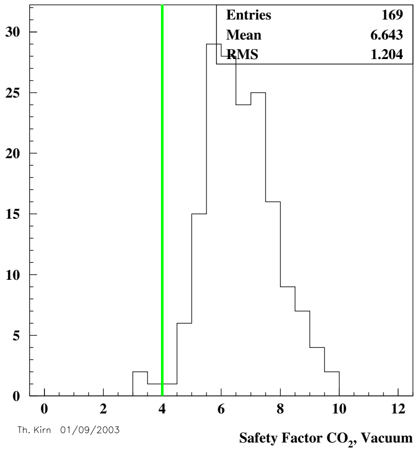


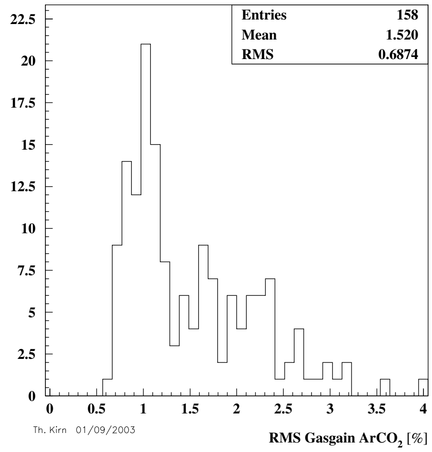
Fig. 3. AMS-02 TRD Single Straw Teststand. Leakrate measurement of 3 straws, one acceptable, two above the limit $10 \cdot 10^{-5}$ l/mbar/s/m.

A detailed description of the straw module production can be found in (4). During the production all straw modules undergo the following tests:
Pressure drop test (Fig. 4a): The CO_2-leakrate of each straw module is measured by a pressure drop test at 1.7 bar in a vacuum vessel. After 169 produced flight modules the average safety factor is ~ 6.7 (20 years operation on ISS).
Dark currents: The straws operate without any significant (< 1 nA) dark cur-

rent at a high voltage of 1500 V with Ar/CO_2 (80/20).
Fe^{55}-gasgain homogenity (Fig. 4b): A calibration of the straw modules is done by a measurement of the gasgain as a function of position along the straws and for each straw of the module on a precision granite block. The straw signals are caused by converted 5.9 keV photons of an Fe^{55}-source. The mean homogenity of all measured gasgains is 1.5 %.



a)



b)

Fig. 4. Straw Module Production Status: a) Safety Factor CO_2, b) Gasgain homogenity using Ar/CO_2 (80/20) at the nominal gasgain of 3000.

Space qualification tests have been carried out for eight 0.7 m long straw modules. The modules underwent vibration tests (a 0.5 g sine sweep followed by a 6.8 grms random test followed again by a 0.5 g sine sweep), 8 cycle thermovacuum tests (between $-40°$ C and $+60°$ C) followed again by vibration tests. No significant changes in gastightness, gasgain or eigenfrequencies were observed.

3 Conclusions

A single straw teststand has been successfully developed to reach the limit of the CO_2-leakrate of $1.2 \cdot 10^{-5}$ l mbar/s/m. The AMS-02 TRD flight straw modules are under construction and so far within specifications and schedule. The straw modules fulfill the space qualification requirements like eigenfrequencies, material stresses, outgassing and gastightness.

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