The AMS-02 Tracker

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Abstract

After the successful test flight in 1998, the AMS experiment has been redesigned to improve its performances for future operation on the ISS. In particular, the use of a novel superconducting magnet will allow the AMS-02 spectrometer to reach a bending power of ∼0.8 Tm^2. The tracking detector has been also optimized to take full advantage of the increased magnetic field strength and a new thermal control system has been conceived to minimize the heat transfer from the tracker electronics to the cooling system of the magnet. The tracker is made of ∼6.4 m^2 of double sided microstrip silicon detectors arranged in eight planes, with a single point resolution of 10(30) microns in the bending (non bending) coordinate. The description of the tracker system will be presented.

1. Introduction

Thanks to its large acceptance ($\sim 0.5\ m^2sr$) and long observation time AMS-02 will be traversed by a large sample of high energy particles, up to few TeV per nucleon, and will provide the possibility to study fundamental questions, like the apparent disappearance of nuclear antimatter and the existence of dark matter, with very high sensitivity. A detailed description of the AMS-02 experiment can be found in [1]. In the present paper the construction of the Silicon Tracker will be described stressing in particular assembly method, electrical tests and mechanical measurements of the basic components of the detector.

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2. The AMS-02 Silicon Tracker

The Silicon Tracker (Figure 1. (left)), which measures with high precision the position of the particles for their momentum determination, consists of 8 layers of double sided silicon microstrip detectors for a total silicon area of $6.4m^2$. The design of the Silicon Tracker was guided by the strict conditions of space, such as mechanical stress during the launch, large temperature range, limited electrical power available and weight. The total weight of the detector is about 186 Kg and the power consumption is 734 W. In order to remove the heat dissipation generated inside the magnet by the front-end electronics a mechanically pumped two-phased loop with CO_2 has been built.

3. The assembly procedure

In order to achieve a high spatial resolution the construction of the Silicon Tracker is based on a very precise assembly procedure. The basic component of the Silicon Tracker of the AMS-02 detector is the "ladder". The ladder is made

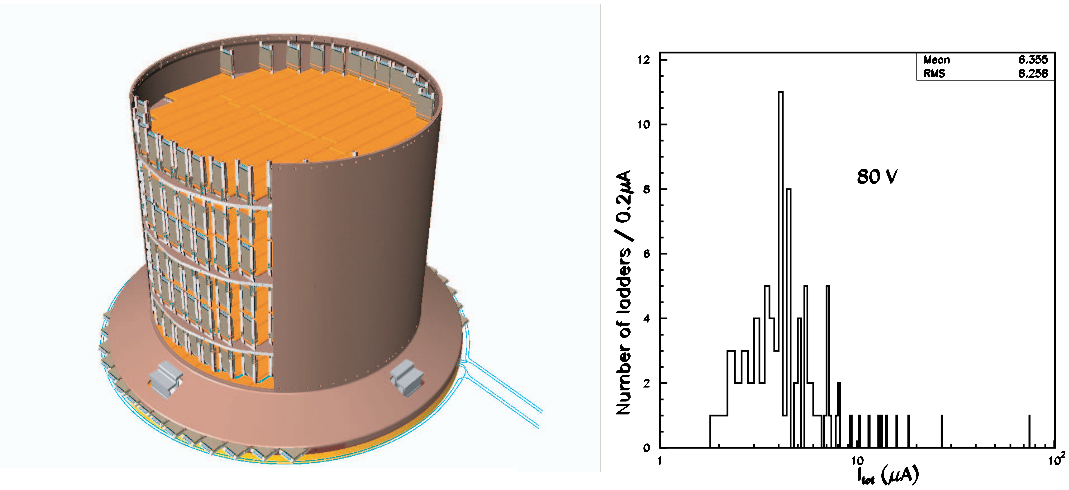

Figure 1. View of the Silicon Tracker, the top plane is missing (left). Total leakage current for all the measured ladders at 80V (right).

of a variable number of silicon sensors (from 7 to 15) aligned and glued together. The silicon strips on the two sides of the sensors, p-side and n-side, are parallel and perpendicular to the longitudinal dimension of the ladder, respectively. On the n-side a upilex fanout is glued in order to reroute the strip signals to the readout electronics, placed at one end of the ladder. A foam reinforcement is glued to the upilex fanout. The ladders are then mounted on aluminum-carbon planes. The number of ladders needed to complete the tracker is 192, subdivided in the different layers as follows:
30(L1), 24(L2), 22(L3), 20(L4), 20(L5), 22(L6), 24(L7), 30(L8)

In order to obtain a high quality detector, two important aspects have to be especially considered: requirements on the quality of single components and the mechanical precision of the assembly procedure. Stringent requirements have been applied on all components of the ladders, in particular on the two critical elements, the silicon sensors and the electronic readout. The AMS sensors are high resistivity ($\geq 6\ K\Omega \cdot cm$) n-doped, double sided silicon wafers. They have a thickness of $300 \pm 15\ \mu m$, 2560 strips ($27.5\ \mu m$) on the p-side and 768 ($104\ \mu m$) on the n-side, respectively. The acceptance criteria for the silicon sensors can be summarised as follows:

1. the depletion voltage V_{dep} must satisfy $V_{working} = 1.5 \times V_{dep} \leq 80V$
2. the total leakage current of each sensor has to be less than $2\ \mu A$
3. the leakage current of the single strip has to be less than $2\ nA$ (p-side) and less than $10\ nA$ (n-side), otherwise the strip is flagged as hot. The number of hot strips has to be less than 6 on p-side, and less than 4 on n-side

Only 0.4% of the sensors fails criterium 2, while 1.9% (3.8%) fails criterium 3 for p (n) side. The percentage of sensors which pass all the criteria is 96.1%. The performance of the Silicon Tracker, in terms of momentum resolution, are related to the precision in the alignment of the sensors in the ladder. The alignment relies on a very precise cut of the wafers. The distance between the precision marks on the wafers and the edge of the sensors is measured and a precision of the order of $4\ \mu m$ rms is found. The silicon sensors in the ladder are daisy chained for biasing and readout. The readout electronic is based on a VA-hdr9a chip designed to meet the requirements of the experiment in terms of optimization of the noise performance, low power consumption ($\sim$ 0.7 mW/channel) and large dynamic range ($\pm$ 70 MIPs). The strips of the silicon sensors are AC-coupled to the VA via 700 pF capacitor chips. For the final acceptance, each front-end hybrid must have less than 1% defective channels. The total production of front-end hybrids has been delivered and the average of the defective channels has been found to be of the order of 0.5%.

4. Results

The construction of the AMS-02 Silicon Tracker started in January 2001 in three assembly centers, Perugia, Geneva and an Italian company G&A [2]. Due to the relatively large scale of the construction, an industrial approach has been chosen and a large effort has been put in the technology transfer to the industry. A total of 107 (out of 192) ladders have been assembled, and the second phase of the assembly, which consists in the integration of the ladders on the support planes just started. The ladders have been measured in terms of mechanical precision and have been electrically tested. In Figure 1. (right) the total leakage current for the measured ladders is shown. It can be seen that in most of the cases the total leakage current is less than 10 μA. In Figure 2. (left) the noise

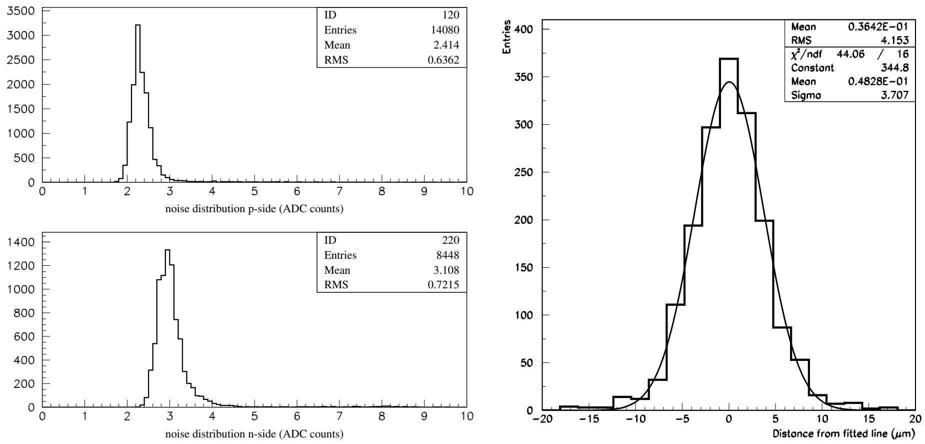

Figure 2. Left: measured noise on p-side (top) and n-side (bottom). Right: results of the metrology for the measured ladders.

distribution on the n-side and on the p-side, measured for a sub-sample of the produced ladders, is shown; typical values of 2-3 ADC counts are found, to be compared with ~ 30 ADC counts for a MIP signal. The results of the metrology of the ladders are shown in Figure 2. (right). For 73 measured ladders the residuals of the measured positions of sensors with respect to their nominal position are plotted, and a sigma better than 4μm is found.

5. Conclusions

The AMS-02 Silicon Tracker is made of 192 ladders, for a total of $6.4m^2$ of double sided silicon microstrip detectors. Much experience has been gained during the assembly and a good quality detector, in terms of mechanical precision and electrical performance, is being assembled. More than half of the total ladders have been produced. The end of the assembly is foreseen for December 2003.

We want to thank the many organizations and individuals, listed in the acknowledgments of reference [1].

6. References

1. S. Gentile 2003, ICRC03, Conf. Proc.

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