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THE AMS-02 TRACKER

MERCEDES PANICCIA [a]

[a] *Département de Physique Nucléaire et Corpusculaire, Université de Genève, 24 quai Ernest-Ansermet, CH-1211 Genève, Suisse*

Abstract

The Silicon Tracker is the central detector of the AMS-02 magnetic spectrometer. Eight layers of double sided silicon microstrip sensors embedded in a magnetic field of $\sim 0.8\ T$ allow for an accurate 3D reconstruction of particle trajectories. The tracker is made of $\sim 6.4\ m^2$ of silicon with a single point resolution of 10 (30) μm in the bending (not bending) coordinate. In this paper, a detailed description of the tracker system is presented.

1 Introduction

After the successful test flight in 1998 [1], the AMS detector has been redesigned to improve its performances for future operation on the International Space Station. The AMS-02 detector is a large acceptance

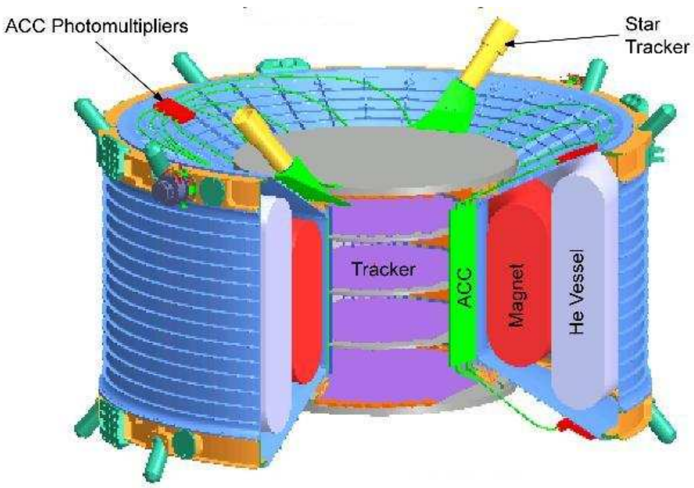

Figure 1: Layout of the AMS-02 Tracker inserted into the magnet system. Also visible are the magnet cooling system, the Anti-Coincidence Counter (ACC) and the Star Tracker.

($\sim 0.5\ m^2 sr$) and high sensitivity spectrometer. Its main components are a superconducting magnet and a silicon tracking device (Figure 1).

The superconducting magnet is cooled by evaporating liquid helium and has a reservoir for about three years operation without refill. Its dipolar field, normal to the aperture of the magnet, is based on a magic ring configuration of race track coils around a pair of Helmholtz coils. It amounts to $\sim 0.8\ T$ close to the center, six times the field strength of the AMS-01 permanent magnet, thus extending the rigidity range for charged particles up to few TV.

In order to remove the heat dissipation generated inside the magnet by the Tracker front-end electronics a dedicated thermal control system has been developed. It is based on a mechanically pumped two-phase loop with carbon dioxide as working fluid.

An Anti-Coincidence Counter (ACC) placed inside the inner bore of the magnet allows to reject particles entering the tracker laterally, outside the main acceptance.

A Star Tracker has been added to the AMS-02 set-up to ensure accurate knowledge about the instrument orientation, since the ISS attitude is rather variable.

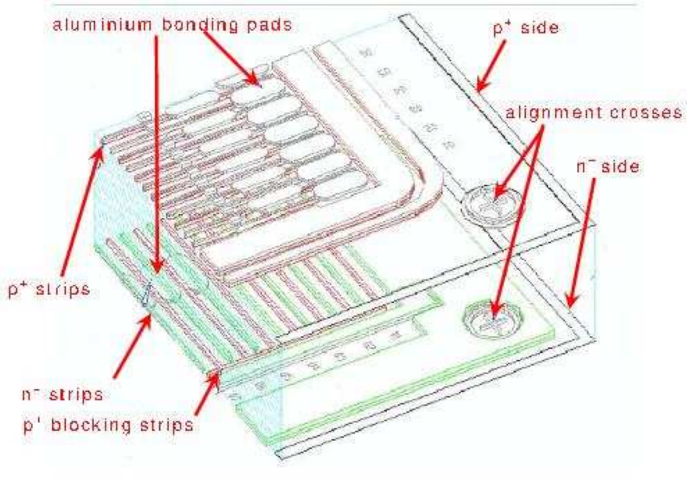

Figure 2: Layout of the AMS-02 double-sided silicon microstrip sensor.

2 The Silicon Tracker

The AMS-01 tracker was the first application in space of the high precision silicon technology developed for position measurements in accelerator experiments [2]. The high modularity, low voltage levels ($< 100\ V$), and gas-free operation of the device is well suited to operation in space. The 1998 shuttle test flight demonstrated both the successful adaptation of the technology to the space environment and the feasibility of large area detectors.

Silicon microstrip sensors were originally developed for vertex detectors in colliding beam experiments in order to provide a few high precision position measurements near the interaction point. The AMS application differs considerably. The tracking information is provided uniquely by the silicon sensors, which implies a large surface area and higher inter-strip capacitances. The major challenges were to maintain the required mechanical precision and low-noise performance in the large scale application, and to do so in outer space.

2.1 The AMS-02 silicon sensors

The AMS-02 Tracker is built with double-sided silicon microstrip sensors. The n-type, high resistivity ($> 6\ k\Omega$) sensors are biased with the punch-through technique and p$^+$ blocking strips, implanted on the n-side, are used to minimize the influence of surface charge on the position measurement

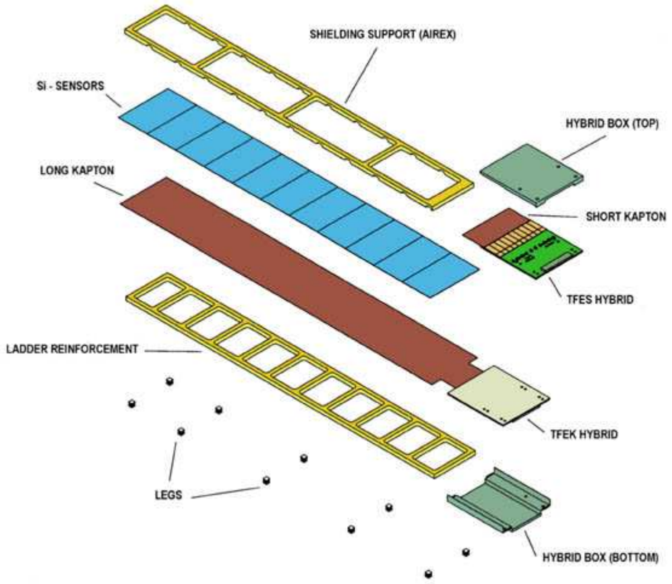

Figure 3: Exploded view of the silicon ladder.

obtained from the ohmic side [3]. The sensor design uses capacitive charge coupling [4] with implantation (readout) strip pitches of 27.5 (110) μm for the p-side and 52 (208) μm for the n-side. The finer pitch p-side strips are used to measure the bending coordinate and the orthogonal n-side strips measure the not bending coordinate. Furthermore the measurement of the specific energy loss, $dE/dx \propto Z^2$, in the silicon allows nuclei identification. Figure 2 shows the AMS-02 sensor layout.

The ionization loss of singly charged particles traversing the fully depleted, reverse-biased 300 ± 10 μm thick sensor is described by a Landau distribution [5]. The peak energy loss of a singly charged, minimum ionizing particle at normal incidence produces $22,000$ electron-hole pairs [6]. The opposite sign charge carriers drift rapidly $(10-25\ ns)$ in the electric field to the two surfaces (p/n) where the accumulated charge on metallized strips is fed to the front-end electronics. The position of the particle is determined by the relative signal levels observed at the readout strip positions. At the single sensor level, the position resolution depends on the sampling pitch and the signal-to-noise performance.

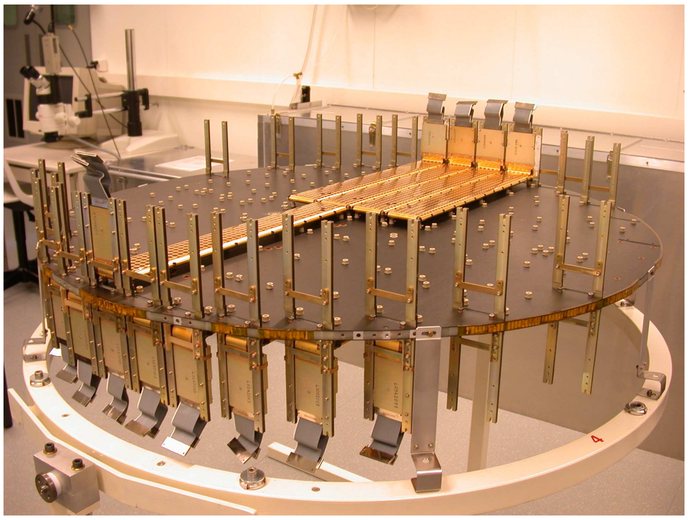

Figure 4: Plane number 3 being assembled.

2.2 The construction of the Silicon Tracker

The silicon sensors are arranged in 192 ladders, made of variable number of sensors (from 7 to 15) with daisy chained strips. Figure 3 shows the principal elements of the silicon ladder and the main components of the readout hybrids. A thin film, 50 μm, metalized upilex, glued directly to the silicon sensors, serves as routing cable to bring the n-side signals to the n-side front-end hybrid, which is located at the ladder end closest to the magnet wall. The flexible upilex film and a second short upilex film joining the p-side strips to the p-side front-end hybrid allow the two hybrids to be placed back-to-back, perpendicular to the detection plane, thus minimizing the material in the sensitive region of the Tracker. Finally an electromagnetic shield, in the form of a doubly-metalized upilex film, surrounds each ladder.

The silicon sensors of each ladder are supported by a 5 mm thick foam that is glued to the n-side upilex film. The exposed surface of the foam is covered with a 100 μm thick layer of carbon fiber. Small 5 mm^3 aluminum frames are glued to the carbon fiber surface (the exact number depends on the ladder length). The aluminum frames contain a screw fixation hole which is used to attach the ladder to the tracker plane.

During the production phase each ladder undergoes an extensive series of quality control tests (mechanical and electrical). Furthermore several tests with particles beams have been performed on selected ladders and other tests are foreseen to be performed before the end of the assembly of the tracker. Very good performances of the silicon ladders have been found both in spatial resolution and in nuclei identification [7, 8, 9].

The ladders are installed in 8 layers, on 5 planes of an ultra-light support structure composing the whole tracker. The tracker planes located inside (outside) the magnet are a composite structure with two 220 (700) μm thick layers of carbon fiber surrounding a 12 (40) mm thick, low density aluminum honeycomb interior, $\rho = 16.02$ (32.0) kg/m^2. The diameter of the inner (outer) planes is 1.0 (1.4) m. The three inner planes are equipped with ladders on both sides, while the outer planes are equipped with ladders only on one side.

3 Conclusions

The ladder production has been organized between University of Geneva, INFN-Perugia, ETH-Zurich, University of Bucarest, University of Turku, Skobeltsyen INP, Southeast University and an industrial firm in Italy (G&A Engineering). Until now 80% of ladders have been produced and three out of eight layers have been fully equipped with ladders at University of Geneva. Figure 4 shows the innermost plane of the Tracker during the assembly. The Tracker assembly will be completed by June 2005 and it will be integrated inside the magnet in June 2006.

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