

## The AMS-02 Tracker

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The central part of the AMS detector is occupied by the silicon tracker. It is built out of 2264 double-sided silicon microstrips sensors,  $51.36 \times 72.05 \times 0.30 \text{ mm}^3$  each, with a total surface of  $6.7 \text{ m}^2$ . The sensors are combined into ladders of 7 to 15 sensors and the ladders disposed onto eight layers installed inside a superconducting magnet with bending power of  $0.8 \text{ Tm}^2$ . To evacuate the heat generated by the tracker electronics in the vicinity of the superconducting magnet cryostat, a two-phase mechanically pumped loop system with carbon dioxide ( $\text{CO}_2$ ) has been developed. A detailed description of the whole tracker system will be presented.

### 1. Introduction

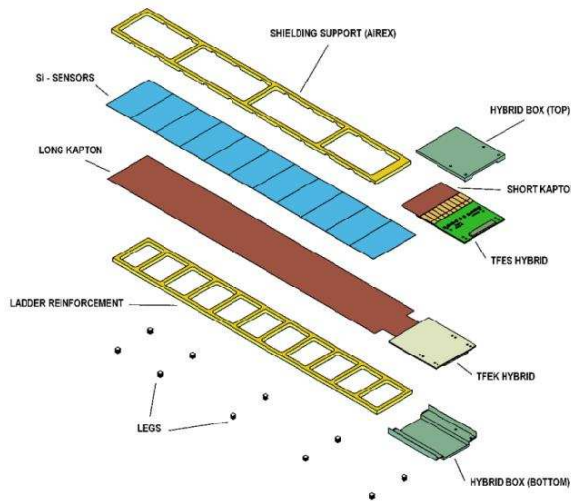
AMS is a magnetic spectrometer designed to study charged and neutral radiation in space [1]. The precursor flight of AMS-01 in 1998 [2] has validated the choice of a silicon microstrip detector as a performing tracker device, adapted to operate in space environment. In the final AMS-02 detector, the tracker design has been optimized covering a larger area ( $6.7 \text{ m}^2$ ) with more performant silicon and new electronics designed to take full advantage of the new superconducting magnet with six times larger magnetic field [3]. A new thermal control system has been conceived to evacuate the heat generated by the electronics. A Star Tracker will also be installed. The tracker performance is presented in Reference [4].

### 2. Silicon sensors

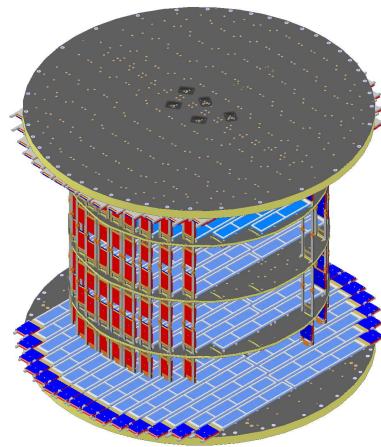
The AMS-02 silicon detectors are made of high resistivity ( $\geq 6 \text{ k}\Omega\cdot\text{cm}$ ) n-doped silicon wafers covered with longitudinal heavily  $p^+$ -doped silicon strips on one side (p-side) and with  $n^+$  strips orthogonal to the  $p^+$  strips on the other side (n-side). In this way it is possible to measure space coordinates with a single detector, reducing thus the material budget (0.3% of a radiation length). The implantation (readout) strip pitches are  $27.5(110) \mu\text{m}$  for the p-side and  $104(208) \mu\text{m}$  for the n-side. The finer pitch p-side strips are used to measure the bending coordinate. Table 1 summarizes the silicon sensors characteristics. The microstrip detector,  $300 \mu\text{m}$  thick, is operated at full depletion: when a charged cosmic ray passes through the depleted detector, electron-hole pairs created along the particle trajectory induce an electric signal at the nearest  $p^+$  and  $n^+$  strips. The signals are amplified and stored by the front-end electronics and then sent to a digitalizing and processing electronics (TDR, Tracker Data Reduction board).

All sensors were tested twice, once at the foundry and a second time at INFN-Perugia and at an Italian industrial facility to ensure that electrical parameters and performance meet the space qualification requirements. Over  $2 \times 10^7$  electrical measurements have been performed and the results stored in a database.

The modules are assembled in a clean room to avoid contamination and mechanical defects due to dust particles, since high sensitivity silicon detectors are sensitive objects. All along the construction, assembly and integration, complete series of electrical tests are performed to ensure that quality does not degrade. All results are kept in a central data base to ensure complete traceability.



**Figure 1.** Exploded view of a ladder.



**Figure 2.** Lay-out of the tracker showing the two outer planes equipped with ladders on one side and the three inner planes equipped on both sides, as well as the *thermal bars* and front electronics.

**Table 1.** AMS-02 silicon sensors characteristics

Dimensions	7.2 cm × 4.1 cm
Thickness	300 μm
Active width p-side	70.5 mm
Strip pitch p-side	27.5 mm
Number of p-strips	2568
Readout pitch p-side	110 μm
Number of p-side read-out strips	640
Active width n-side	39.8 mm
Strip pitch n-side	104 μm
Number of n-strips	384
Readout pitch n-side	208 μm
Number of n-side read-out strips	192

### 3. Ladders

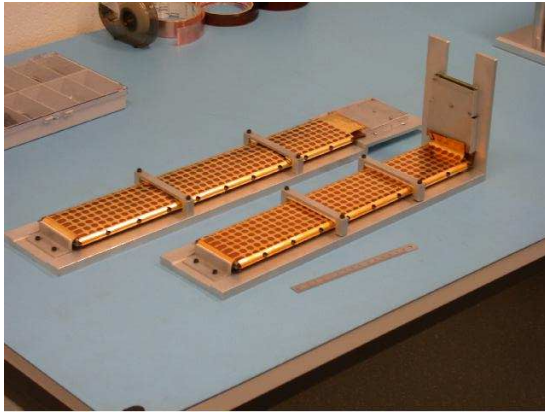
The principal goal of the ladder fabrication is to guarantee the required precision for the relative alignment of the silicon sensors and to minimize the degradation of the electrical performance due to handling and ultrasonic bonding.

The silicon sensors are organized into 192 ladders (requiring 2264 double sided sensors). A ladder is made of a variable number of silicon sensors (from 7 to 15). The strips are daisy chained to increase the detection surface while using a limited number of readout channels. An exploded view of a ladder is shown in Fig. 1. For the p-strips, the daisy chain is provided through direct bonding from sensor to sensor, while for the transversal n-strips a metalized Upilex film (long kapton cable) is used. The front electronics are located on two separate PCB. The n-strips are connected to it using the long Upilex cable, while a short cable is used for the p-side.

Aluminium fixation feet are glued on carbon fiber/foam reinforcements. Finally a kapton foil coated with Cu/Au pattern is wrapped around the ladder to provide electromagnetic shielding. Fig. 3 shows two ladders ready to be mounted on a supporting plane.

#### 4. Tracker support structure

The ladders are organized in eight layers of  $\sim 1 \text{ m}^2$  each on five ultra-light supporting planes. The three inner planes have silicon ladders on both sides, the outer planes only on one side as shown in Fig. 2. Front end electronics is fixed on heat conducting bars (*thermal bars*) used also to evacuate the heat generated locally. Fig. 4 shows one of the inner planes completely equipped. The three inner planes are supported by a carbon fiber cylindrical shell. The two outer planes are fixed to the inner cylinder by two carbon fiber conical flanges not shown on Fig. 2.



**Figure 3.** Two AMS-02 ladders ready to be mounted on a support plane.

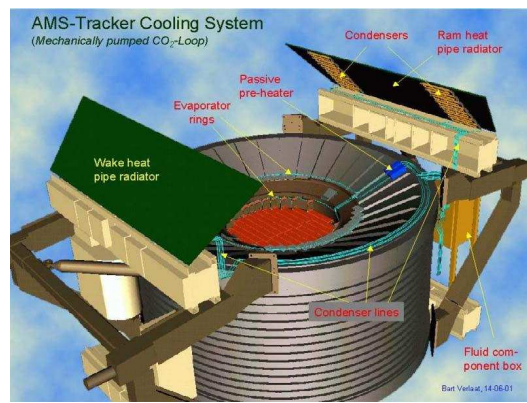


**Figure 4.** One of the inner plane equipped with ladders.

An alignment system developed by RWTH-Aachen using infrared Laser beams mimics straight tracks through the 8 layers of the silicon tracker. It has been shown with AMS-01 that these artificial straight tracks allow the tracing of changes of the tracker geometry with a position accuracy of better than  $5 \mu\text{m}$  [5]. The system uses the same silicon sensors for both particle detection and control of the alignment. It serves to generate position control data within seconds at regular time intervals.

#### 5. Tracker Thermal Cooling System

The Tracker Thermal Control System (TTCS), as illustrated in Fig.5, is a two-phase, mechanically pumped loop system. The cooling liquid,  $\text{CO}_2$  at 23 to 50 bar, is circulated by a pump. It enters into the tracker volume at a temperature just below the boiling point and passes close to the *thermal bars* on the outer and outermost inner planes, where the heat from the front-end hybrids is collected. The tracker volume is then isothermally cooled and the cooling hardware located inside the tracker acceptance is minimized. Outside the tracker volume, the outgoing fluid is directed to condensers on the tracker thermal radiator panels facing deep space. There, the vapor/fluid mixture is cooled to below the boiling point, and then returns to the pump input, closing the circuit. This system removes 150 W of tracker power.



**Figure 5.** Locations of the principal elements of the Tracker Thermal Control System.

## 6. Conclusion

The ladder production is completed: a total of 216 ladders have been built and tested, including  $\approx 12\%$  spare units. The installation of the ladders on planes is ongoing: four out of eight tracker layers have been equipped. All planes should be finished by December 2005.

## 7. Acknowledgements

We wish to thank the many organisations and individuals listed in the acknowledgements of Reference [1].

## References

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