

THE AMS INFRARED TRACKER ALIGNMENT SYSTEM - FROM STS91 TO ISS

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We report on AMS tracker alignment control in space using artificial laser produced straight tracks (flight data AMS-01, laboratory tests AMS-02) as well as precisely measured high momentum cosmic tracks.

1 AMS experiment

1.1 AMS-01

The large acceptance Antimatter Spectrometer (AMS) experiment ^{1 2} has been operated successfully on the NASA STS91 shuttle flight (02-June-98 - 12-June-98, AMS-01). It will be redeployed, including major upgrades, for a 1000 day data taking mission (AMS-02) on the International Space Station late in 2004; see talk by R. Battiston at this conference.

1.2 AMS Si-tracker Tracker Alignment System TAS

AMS particle tracking is based on 8/6 (AMS-02/01) planes of double-sided Si detectors providing a maximum detectable rigidity (MDR) of 3000(500) GV by measuring the sagitta of the tracks in a 0.9 T superconducting (0.12 T permanent NdFeB) magnet. The sagitta can be determined with an accuracy of 22(25) μm . In AMS the position stability of the tracking elements is controlled using nearly straight tracks. Fig. 1a shows the laser beams and their measured profiles (recorded in space and transmitted to ground on June 4th 1998) in the AMS-01 configuration. From an analysis of the residuals for > 4 GV tracks individual ladder displacements have been derived ^{3 4} (for principle see fig. 1b, results fig. 4).

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AMS Laser & Cosmics alignment

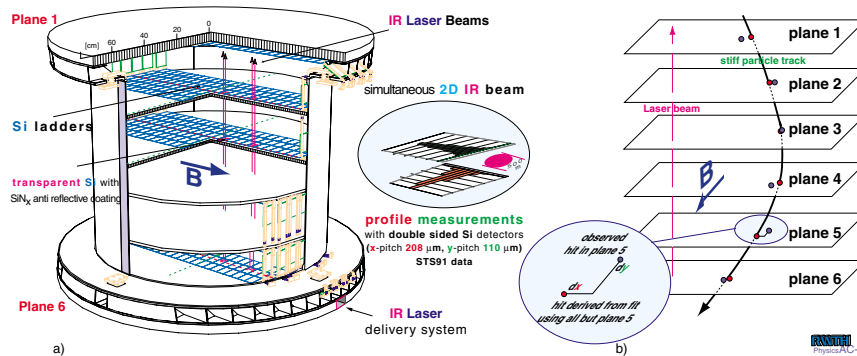


Figure 1. a) AMS 01 Si tracker and the Tracker Alignment System. The insert shows laser profiles observed while AMS was in orbit. b) ladder displacement measurement with cosmic tracks (curvature greatly exaggerated, 10 GV sagitta 0.5/3 mm for AMS-01/02).

1.3 TAS technical aspects

Artificial tracks are produced by 1082 nm Laser radiation. Si is highly transparent at 1082 nm, provided the natural reflectivity ($n_{Si} = 3.3$) can be reduced and shadowing by the metallization of the readout strips can be kept small. AMS alignment sensors are antireflective coated and use 10 μm wide readout strips in the Laser impact areas. Thus single layer transparency can be as high as 50%. It has been shown (AMS-01) that a Laser ray can be recorded in 6 Si layers in sequence⁴. The AMS-02 tracker (8 planes Si, SC magnet) will be equipped with 2 sets of 10 laser rays each, that traverse the Si in 2 opposite directions (fig. 2b) and do overlap in the central planes.

These rays are detected by generating electron hole pairs in the fully depleted Si particle detectors^{4 6}. Signals from the alignment rays are recorded exactly like the charged particle tracks. 1082 nm Laser radiation is generated with high efficiency in DBR-Laser diodes coupled to monomode optical fibres that deliver - via miniature projection optics - low divergence circular rays into the tracker (fig. 2a). At the photon intensities readily available from Laser diodes ($> 10^8$ / pulse) signals exceeding that of 1000 mips can be produced in the Si layer (thickness 300 μm) close to the projection optics. At adequate Laser intensities this approach allows high precision ($< 2 \mu\text{m}$) tracker stability tests in very short time (< 1 s). The fully operational system (20 beams) weighs less than 5 kg.

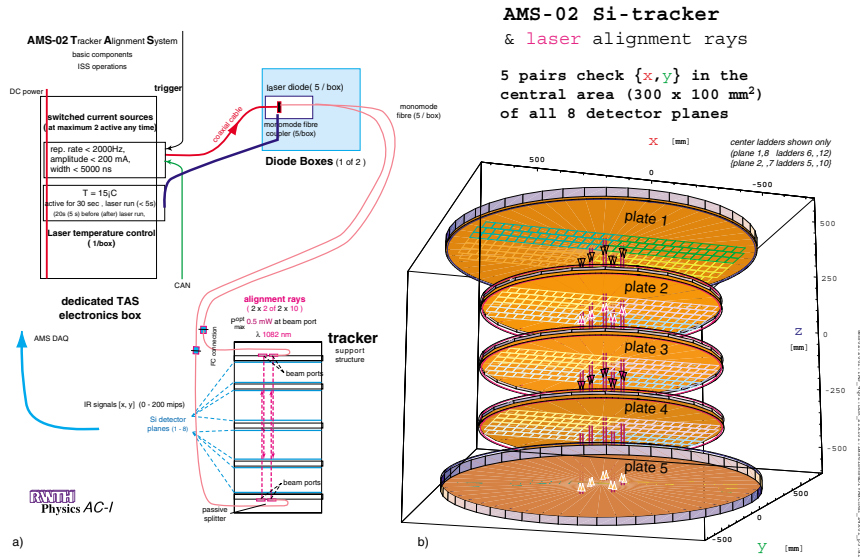


Figure 2. AMS 02 Tracker Alignment System. a) laser radiation generation, b) basic configuration of 2 x 5 laser ray pairs.

2 TAS and AMS tracker stability

2.1 STS91 flight

Overall the AMS-01 tracker ⁷ has been extraordinarily stable. Over the whole flight - including lift-off and landing - all tracking elements were found at their expected positions within $\pm 15 \mu\text{m}$. Laser measurements (once per 3 orbits (on manual command)) were confirmed by observation with stiff (almost straight) tracks comparing extrapolated tracker hits with actually measured ones (fig. 4). Correcting for the time evolution of the small but finite displacements results in an approximately 20 corrections are important only for the high rigidity tail of the cosmic ray spectra observable by AMS ($p > 80 \text{ GV}$).

The excursions observed are probably due thermal effects because they correlate with changes in flight attitude hence heating by the sun.

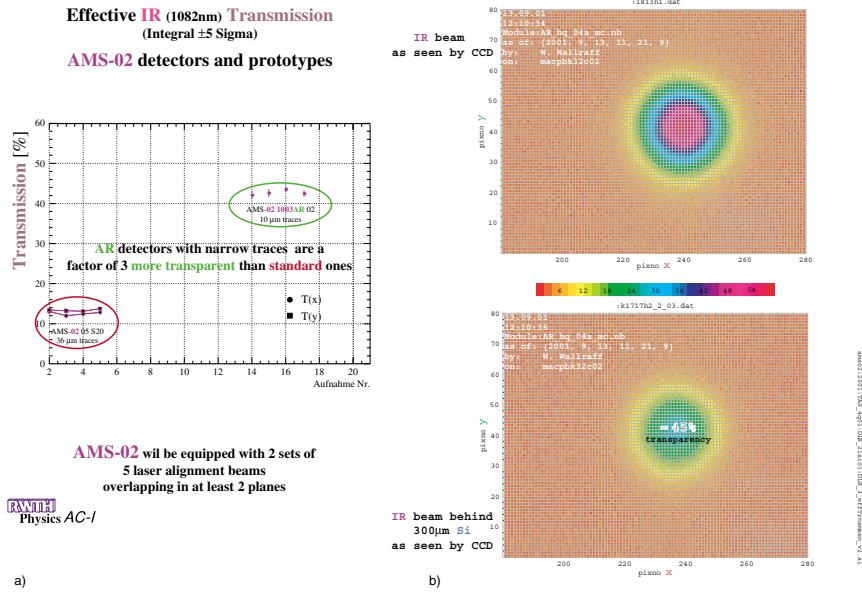


Figure 3. a) AMS-02 Si sensor transparency, standard and with antireflective coating. b) high quality coatings eliminate front back interferences and distortions of the laser beam while passing through a sensor.

2.2 prospects

Based on AMS-01 experience a tracker stability verification along 10 lines and with better than 4 μ m accuracy can be expected from short (< 10 s) runs 4 times per orbit. This measurement over an area of 300 x 100 mm² in the center of the acceptance is complemented by minimizing for high rigidity tracks over the full acceptance the pulls in the redundant trackfit with 8 points through the rather smooth and very stable AMS-02 B-field.

The method of position control of Si trackers with artificial laser generated straight tracks has not only applications for space experiments. A similar system has recently been studied for implementation in the large area Si tracker of the CMS experiment⁵ to be installed at LHC.

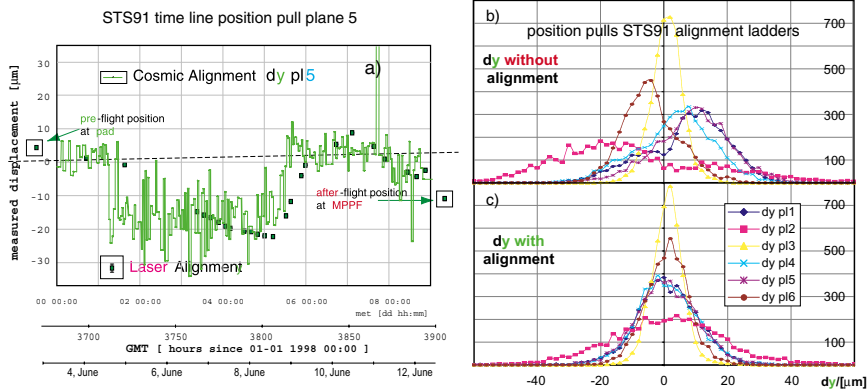


Figure 4. AMS 01 tracker stability during the STS 91 space flight; a) time line of y displacements ($\perp B$), from stiff cosmic tracks; squares indicate Laser data. Frequency distributions of observed displacements in the AMS-01 (Laser) alignment ladders before b) and after correction c) observed for high momentum cosmic rays during the STS91 spaceflight; details are given in the references 3 and 4.

Acknowledgments

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The meeting at Villa Olmo has proven again to be highly useful, many thanks to the organizers.

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