AMS

W.J. Burger
INFN Perugia

- Introduction
  - Constraints / Environment
  - AMS-01
- AMS-02 Detector
- *Preparativi* and launch dates

INFN-Spazio
Frascati, Italia
16 febbraio 2005

Alpha Magnetic Spectrometer (AMS)

- The AMS is a large acceptance (~0.5 m^2sr) detector designed to operate on the International Space Station(ISS), version AMS-02, for a long duration (3y) measurement of the cosmic-ray spectra (~500 MeV to several TeV).
- The spectrometer will provide precise measurements of the cosmic-ray composition up to Z~26, including light isotope separation, and is intended to provide a unprecedented sensitive search for antimatter and dark matter.
- A first version of the device (AMS-01) was operated successfully on a 10-day shuttle flight in June, 1998.

Constraints

- Vibrations and shock loads during launch
- The space vacuum
- The radiation environment (thermal and ionizing)
- Payload mass
- Payload power
- Bandwidth for data transmission

Space Environment

Cosmic Ray Composition:

~90 % hydrogen nuclei

~9 % helium nuclei

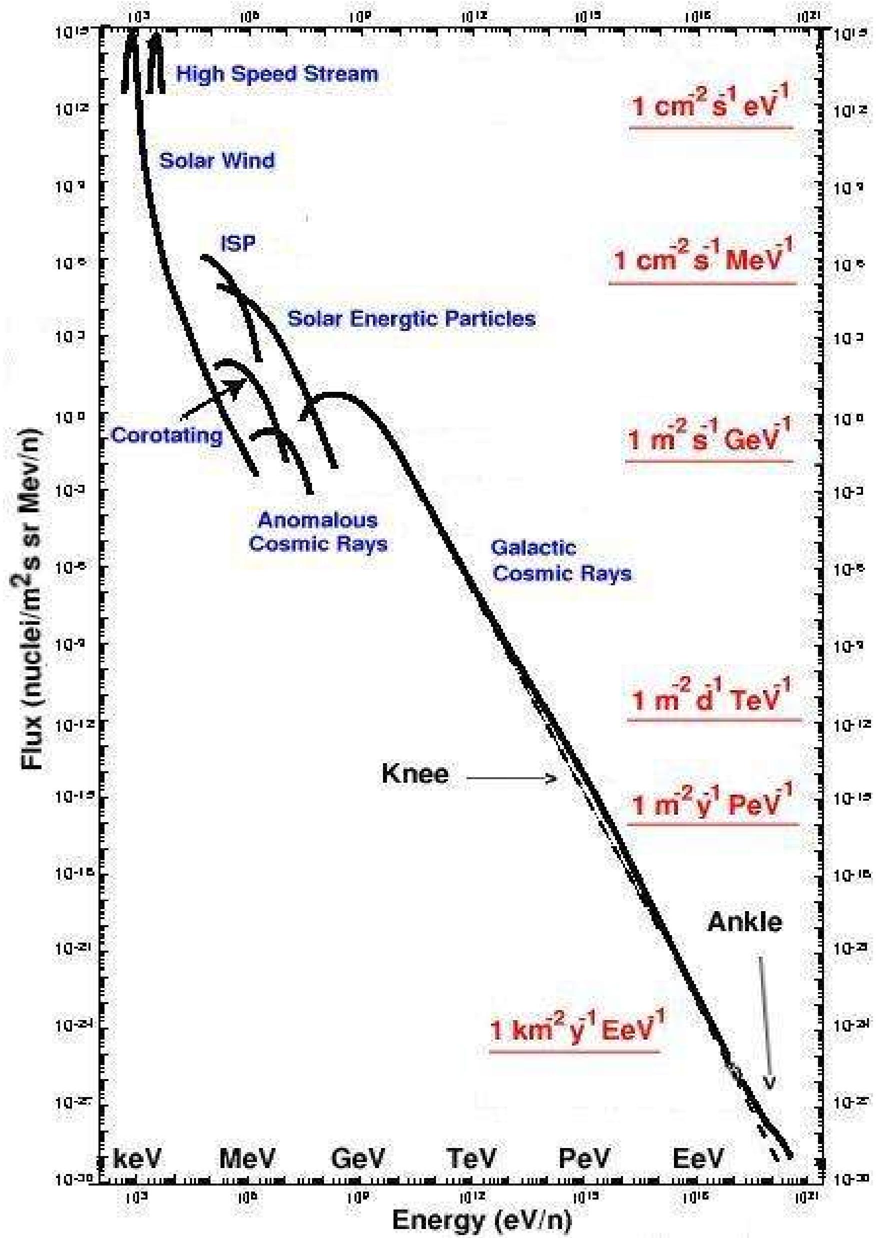
~1 % heavier nuclei

< 1 % electrons

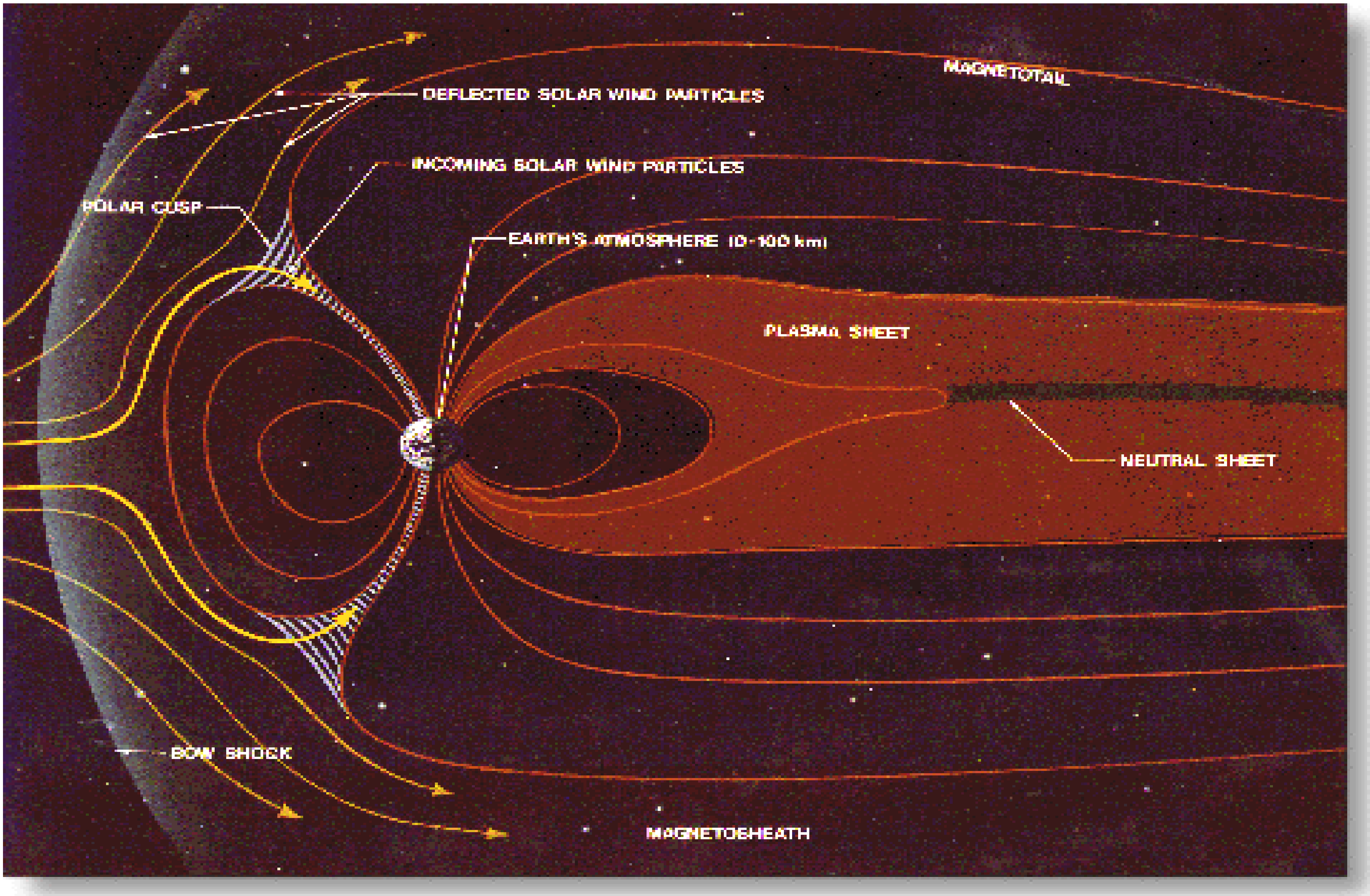
~0.1 % positrons

< 0.1 % gamma rays

< 10^{-4} antiprotons

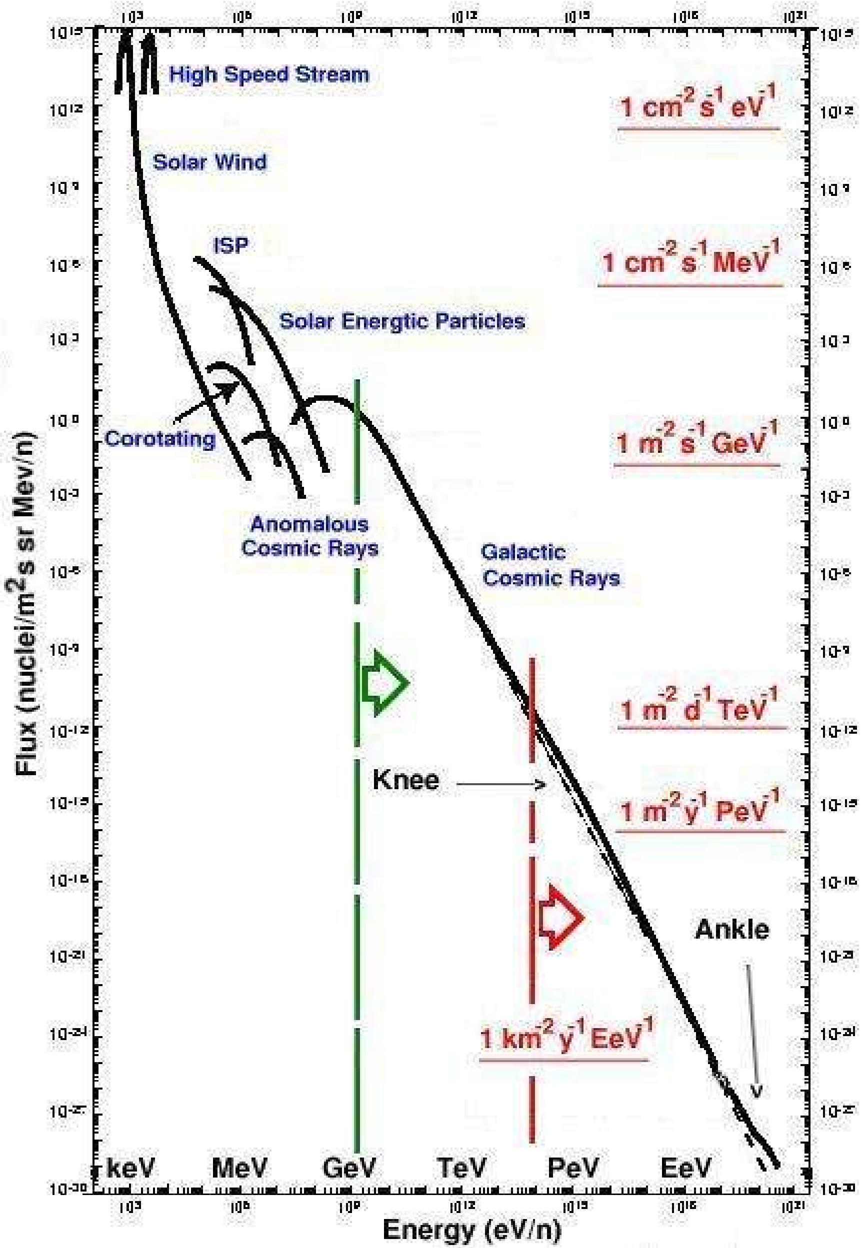


Space Environment



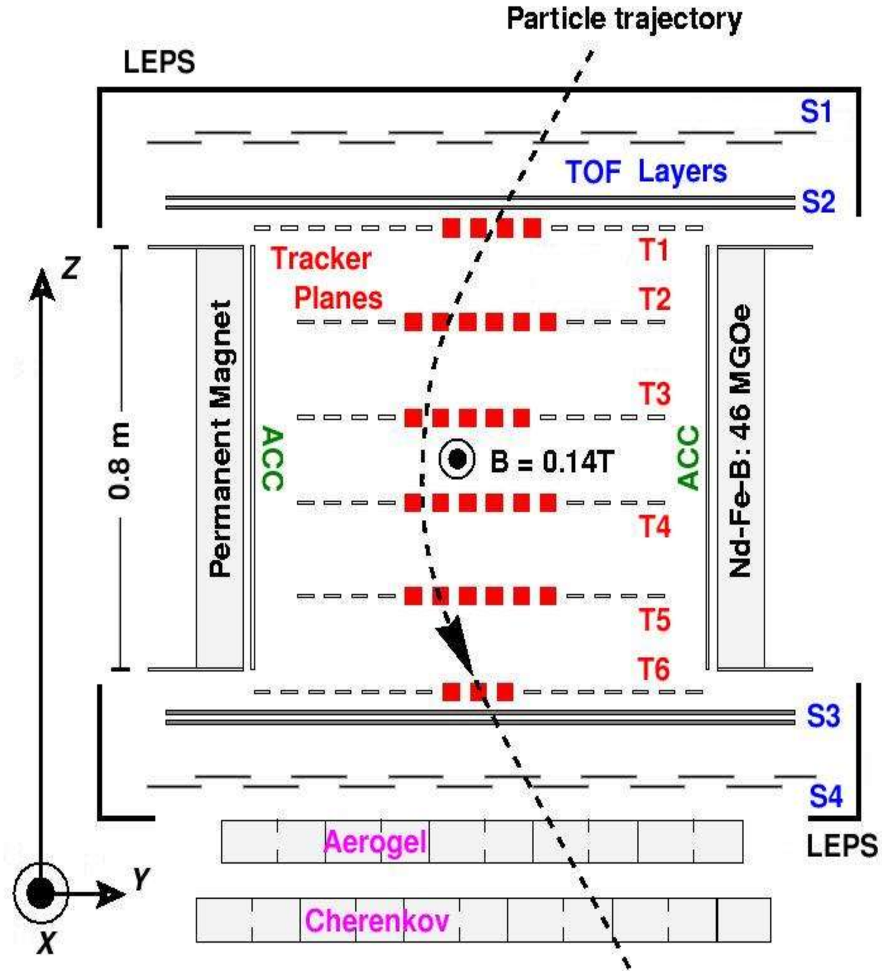
Cosmic Ray Detection in Space

- At relativistic energies, above ~1 GeV/n the detection techniques such as dE/dx-E or time-of-flight are inoperative or impractical
- A magnetic spectrometer provides an alternative, and allows a determination of the sign of the particle charge.
- Balloon-borne magnetic spectrometers are used to study cosmic rays, limited by fight times (currently 10-20 days)
- A fundamental constraint for a space-borne device is the small fluxes at highest energies (above ~1 PeV).



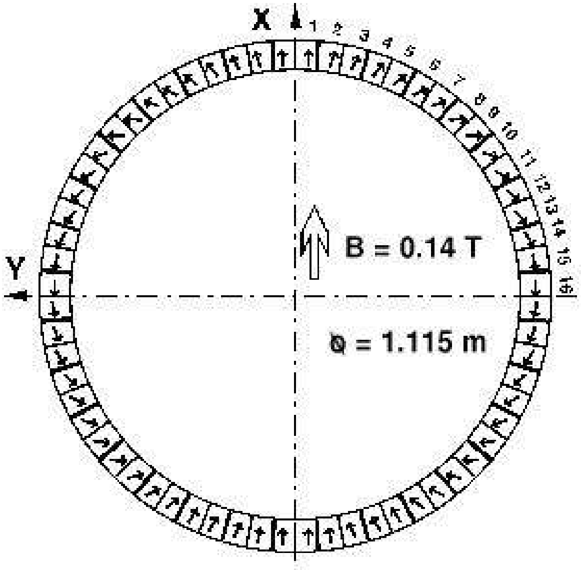
AMS-01

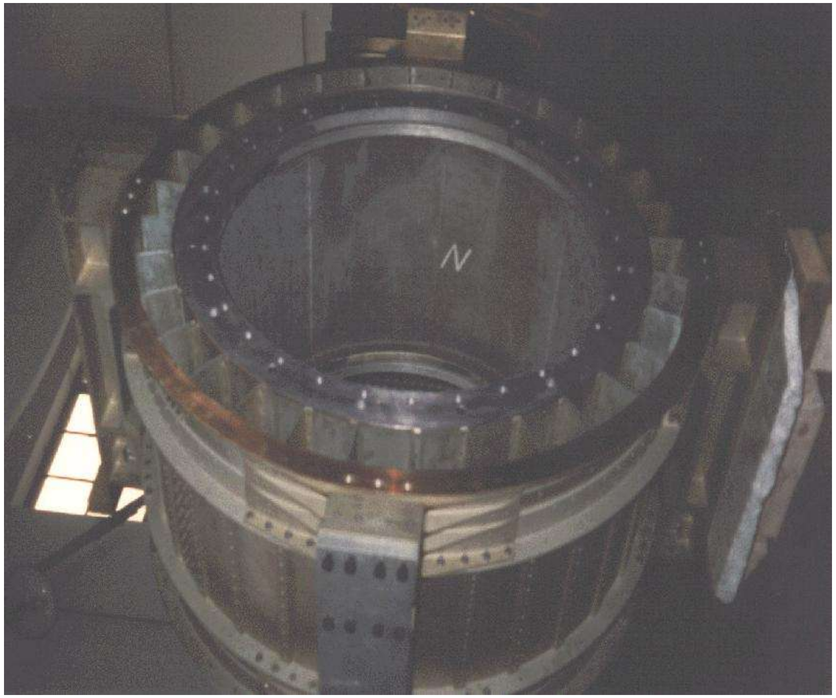
- TOF layers S1-S4 provided the velocity and dE/dx
- The tracker planes T1-T6 yielded the rigidity, dE/dx, and the sign of the charge
- Cherenkov counter discriminated between positrons (electrons) and protons (antiprotons) below 3.5 GeV/c
- The anti-coincidence counter ACC was used as a veto
- LEPS, low energy (< 5 MeV) particle shield



AMS-01 Permanent Magnet

- Cylindrical form to optimize acceptance/weight
- Composed of 640, 2”x2”x1” high grade NdFeB blocks
- Dimensions:
  inner dia. 1.115 m
  outer dia. 1.298 m
  length 0.80 m
- Weight: 2.2 t
- 0.14 T field at center
- Negligible dipole field,
  B < 3 G at 2 m from center

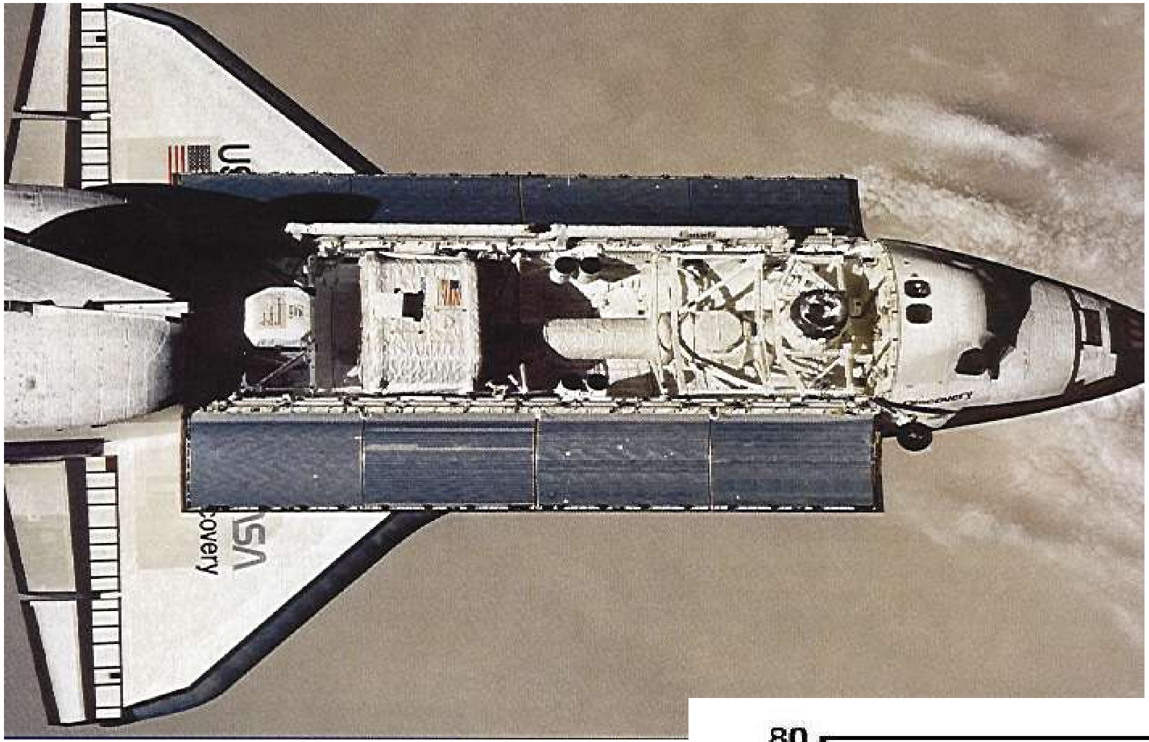




AMS-01 Silicon Tracker

- Tracker (T1-T6) composed of 4.136 x 7.205 x 0.03 cm^3 double-sided, silicon micron-strip sensors
- implantation/readout strip pitch
  p-side: 27.5/110 microns (y)
  n-side: 26.0/208 microns (x)
- Point measurement resolutions
  ~10 and ~30 microns
- 57 ladders (2.1 m^2 of silicon),
  geometric acceptance ~0.3 m^2sr
- 58,368 analog channels read out with a low-noise, low-power (0.7 mW/ch), high dynamic range (75 mips) front-end chip

AMS-01 Shuttle Flight STS-91



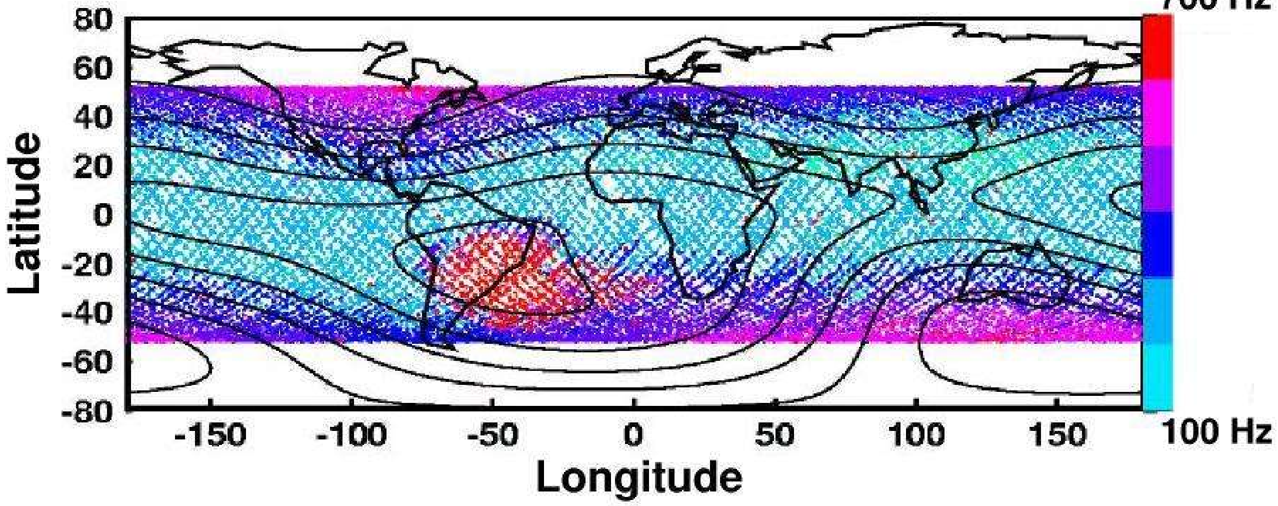
10-day flight in June, 1998

51.7° orbit at altitudes between 320-390 km

Last rendez-vous with Mir

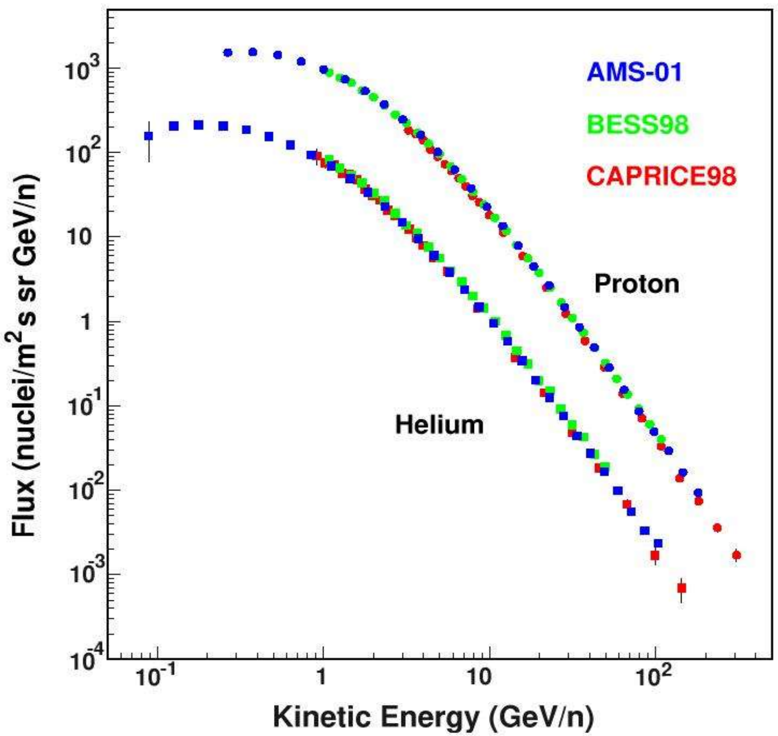
10^8 events recorded

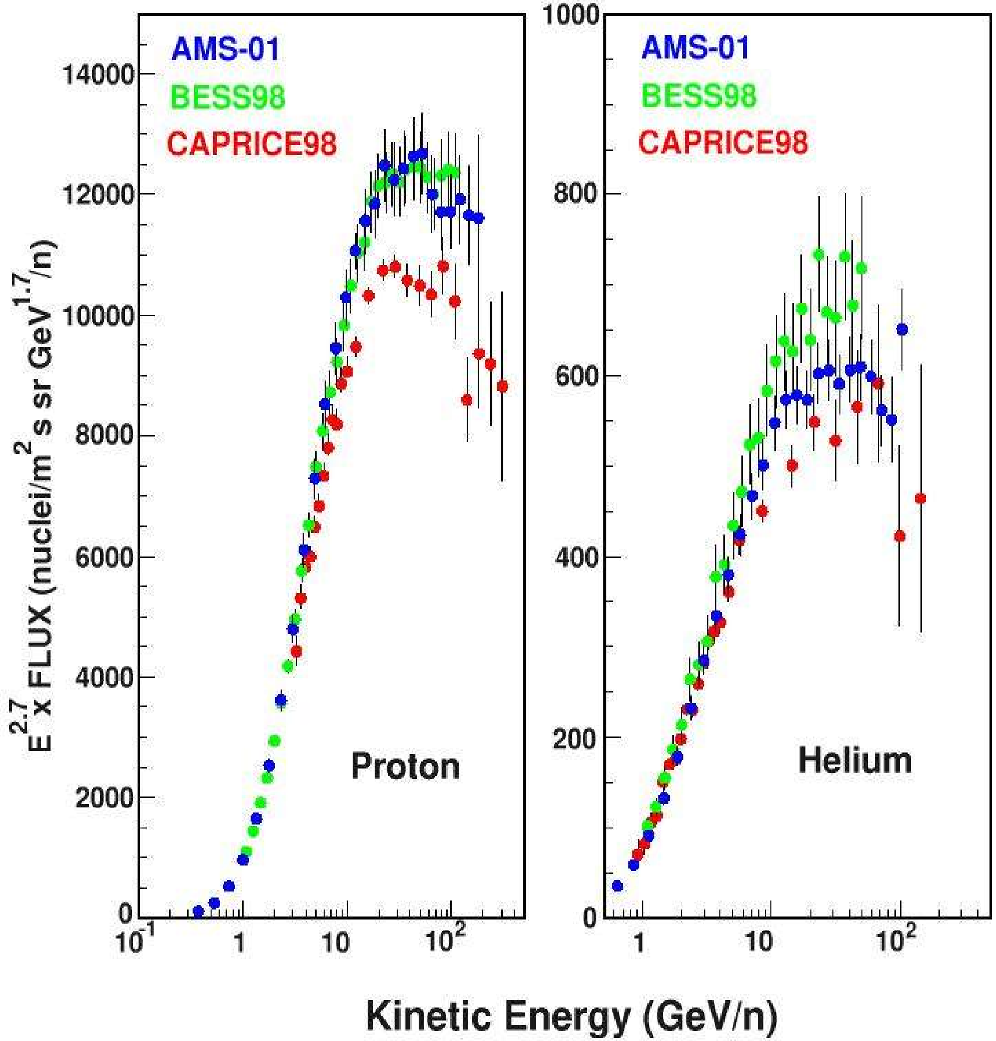
Event rates



AMS-01 Results

Cosmic-Ray Fluxes (p, He)

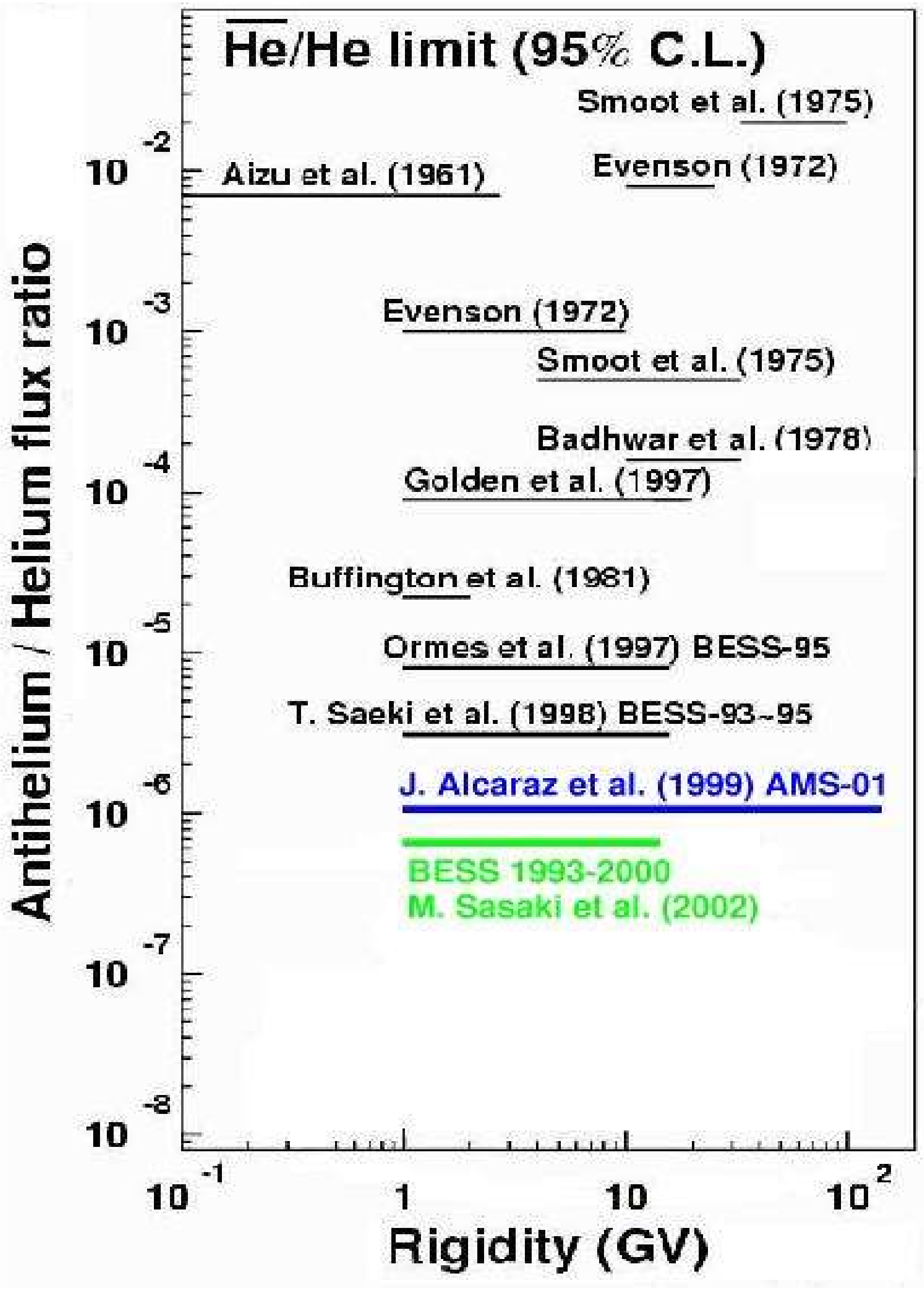




CAPRICE: May 1998
34.5° N, 110° W (4.3 GV)

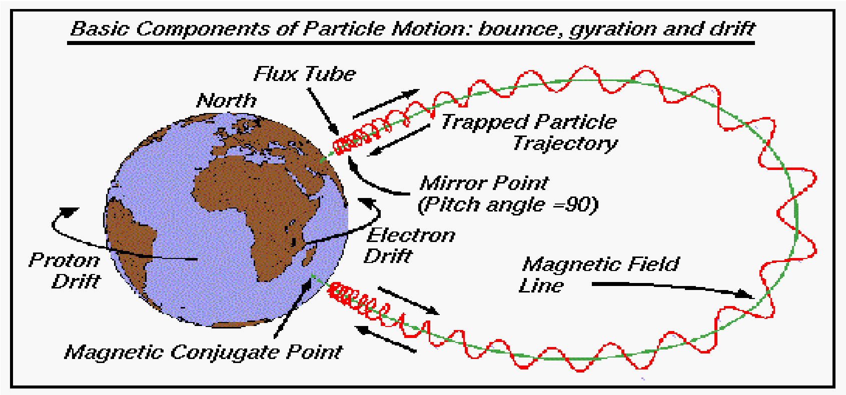
BESS: July 1998
57° N, 101° W (0.5 GV)

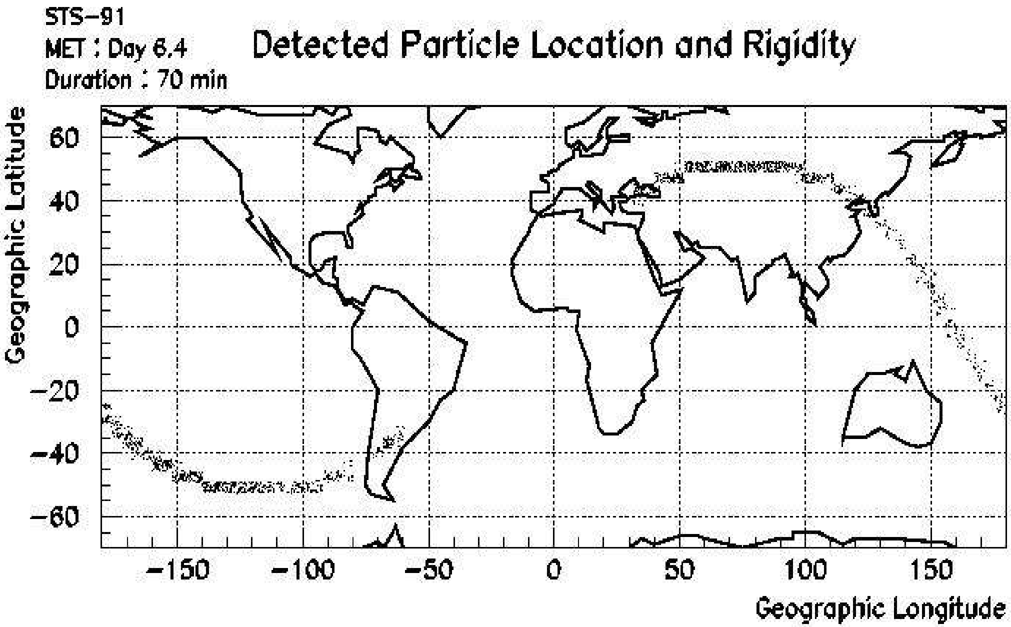
AMS-01 Results
Antihelium Search

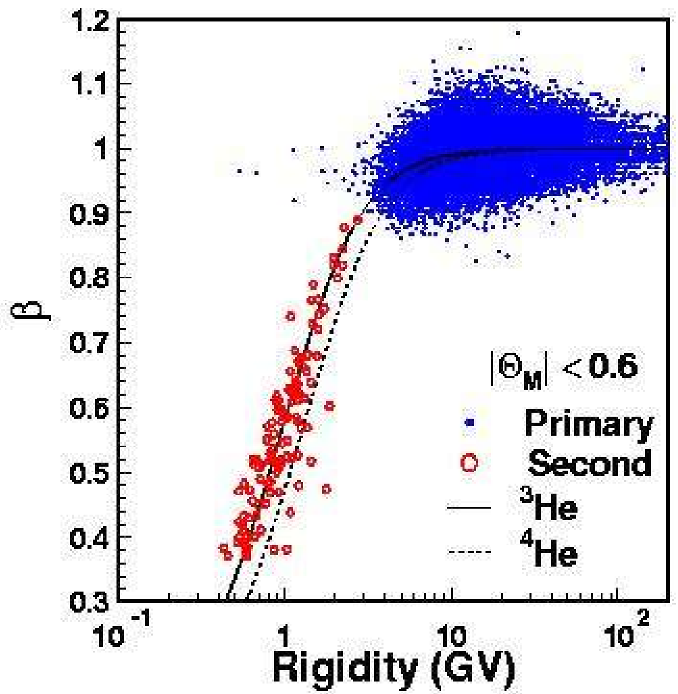


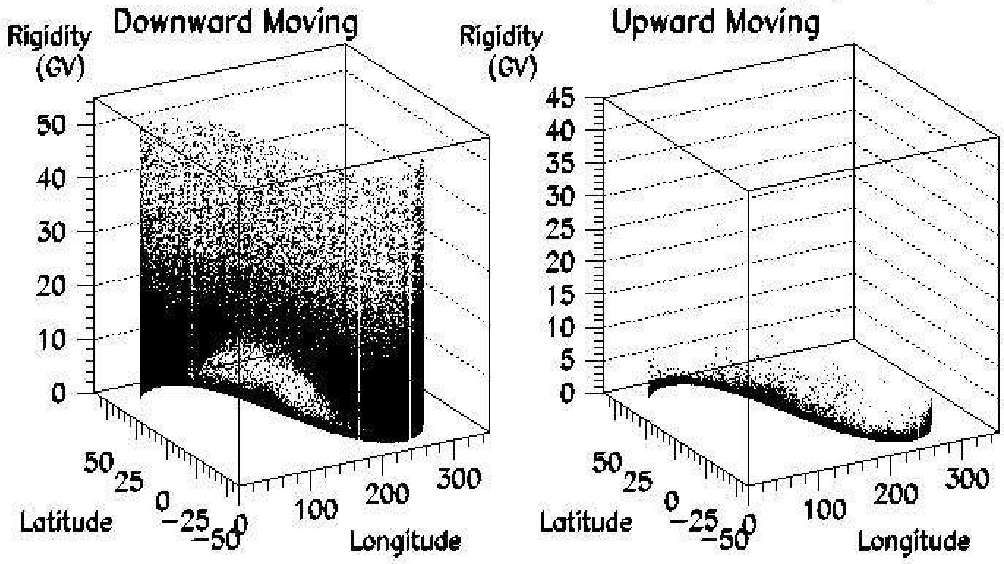
AMS-01 Results

Undercutoff Particle Populations ($p, e^-, e^+, {}^3He$)









AMS-02

w.r.t AMS-01

Modified:

- magnet
- tracker
- TOF
- ACC

Replaced:

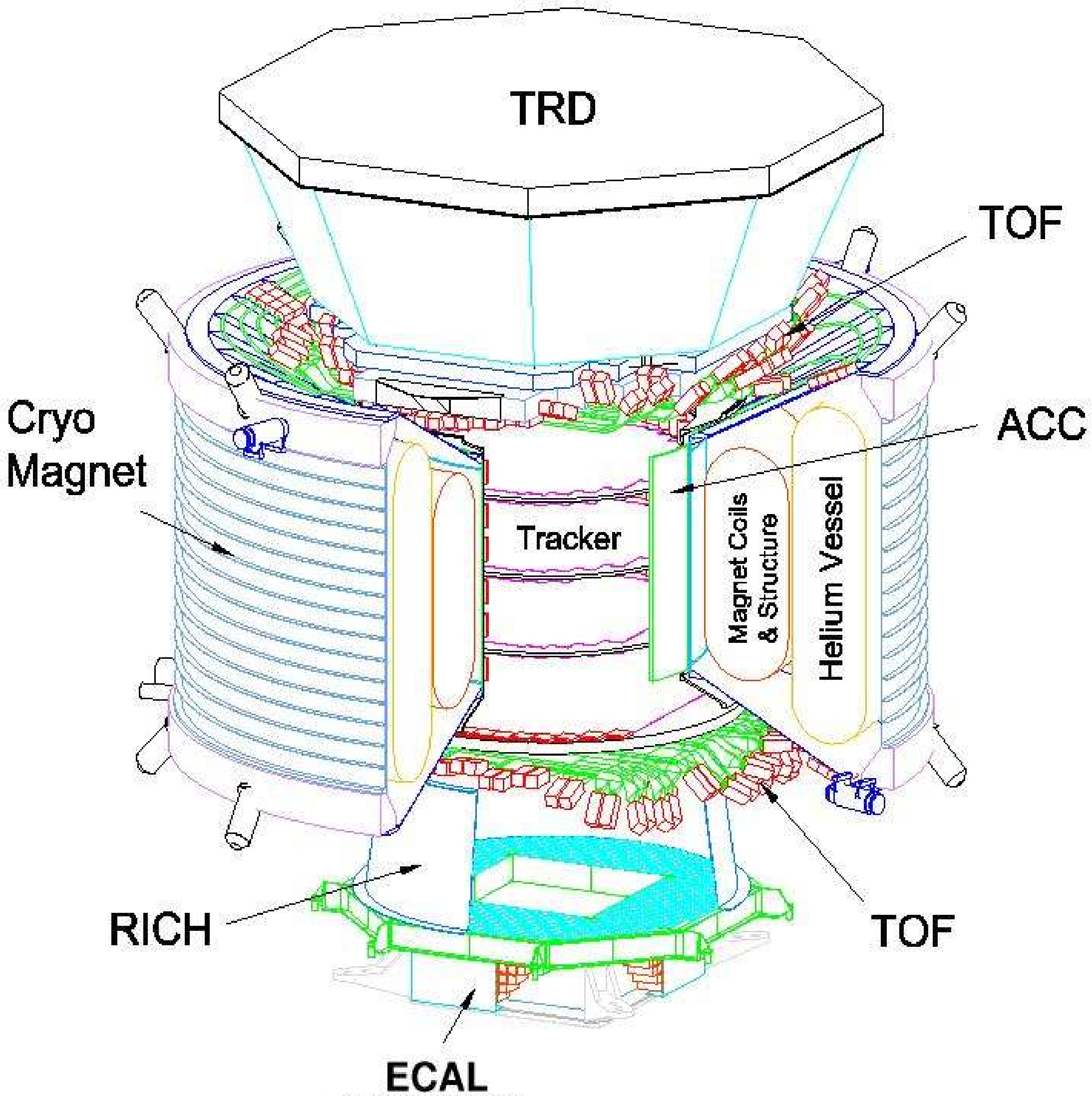
- Cherenkov ⇒ RICH

Added:

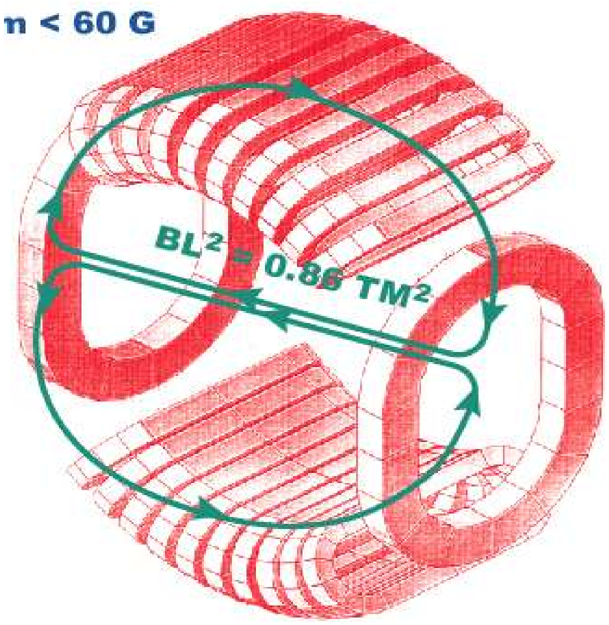
- TRD
- ECAL

Resources:

- mass 3.2 ⟶ 7.0 t
- power 1.0 ⟶ 2.0 kW
- 2 Mbit/s downlink

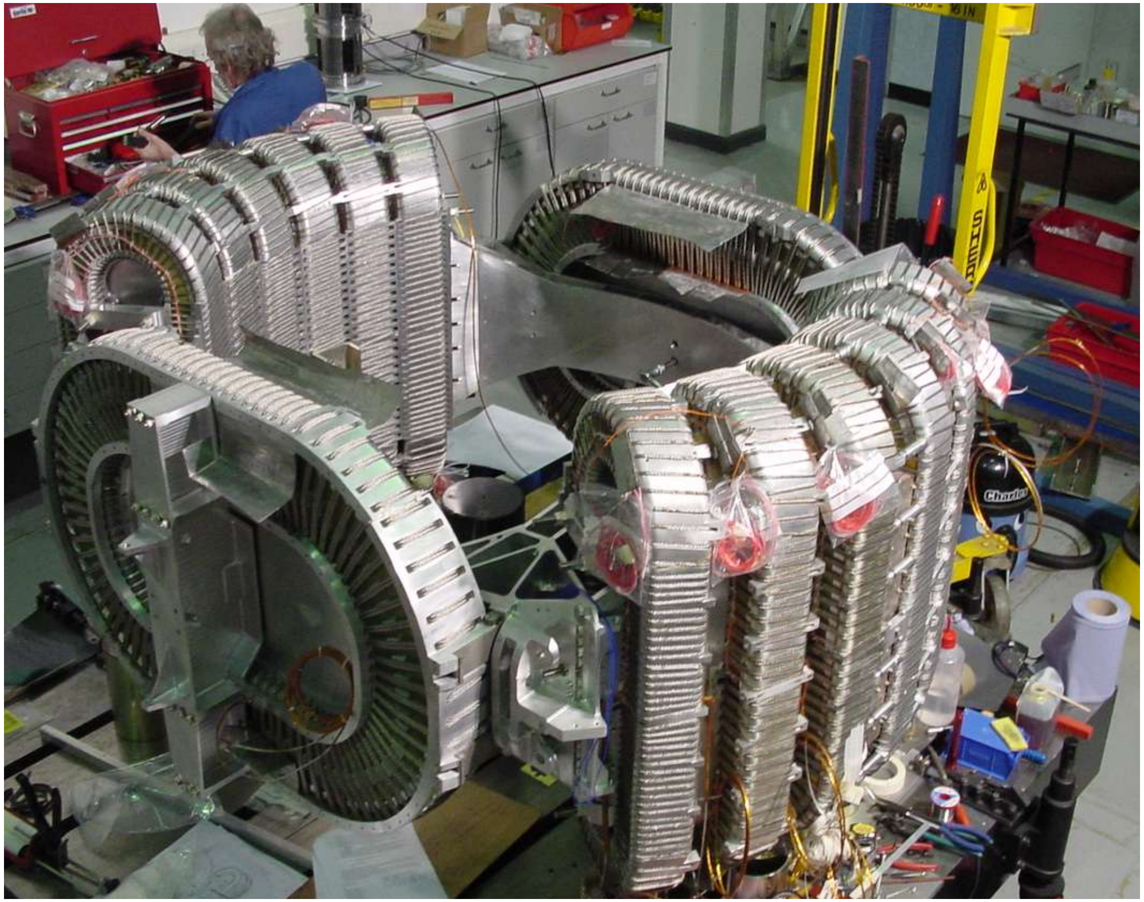


AMS-02 Superconducting Magnet



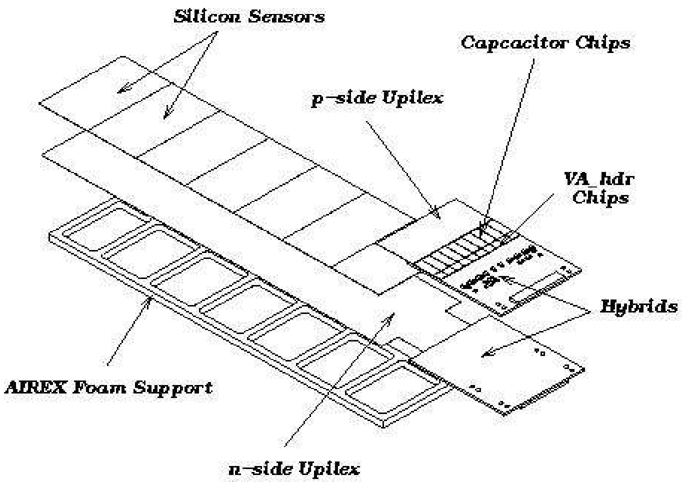
AMS-02 Coil Characteristics

Parameter	Helmholtz	Racetrack
Height [mm]	**1081**	**826**
Width [mm]	**681**	**306**
no. of turns	**3360**	**1457**
cross section [mm]	**88 × 146**	**54 × 103**



$BL^2 = 0.8\ Tm^2$

AMS-02 Silicon Tracker

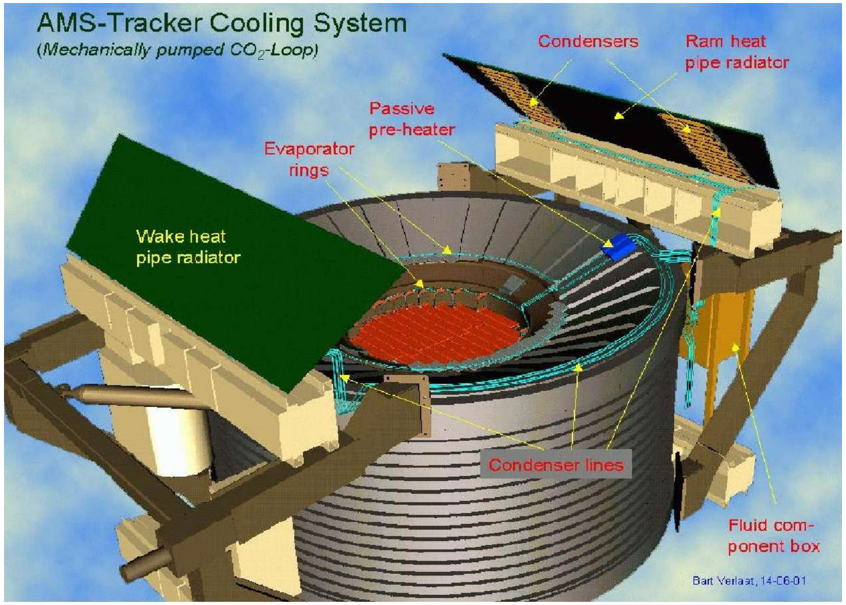


Ladder: implantation strip pitch n-side 26 → 104 microns

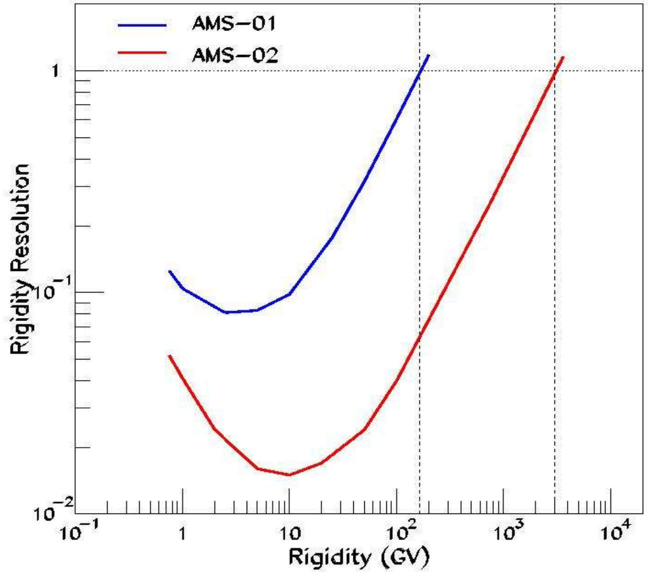
Plane: 6 → 5, layers of silicon 6 → 8

Tracker Thermal Control System (TTCS)

Liquid CO_2 used to remove heat generated by the front-end electronics in the interior of the magnet.

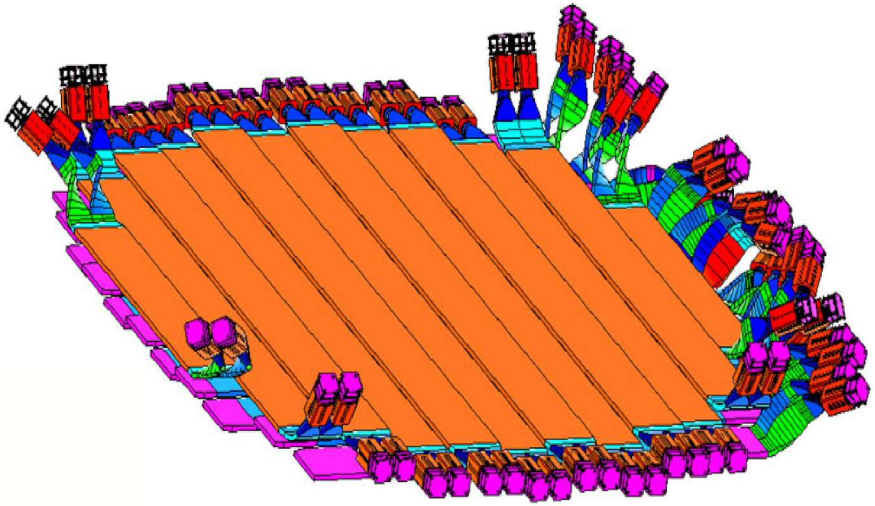


MDR ~2 TV

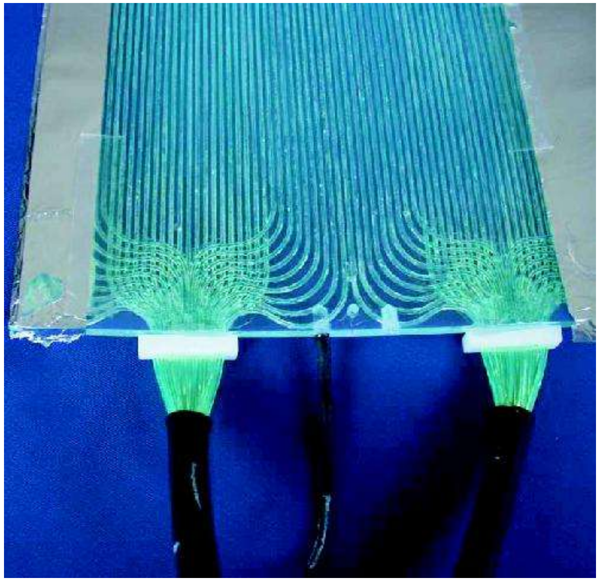


AMS-02 Subsystems

- TOF:
  - Curved light guides and fine mesh PMs.
  - Time resolution ~140 ps.
  - Segmentation reduced to 8, 8, 10, and 8 paddles per plan.

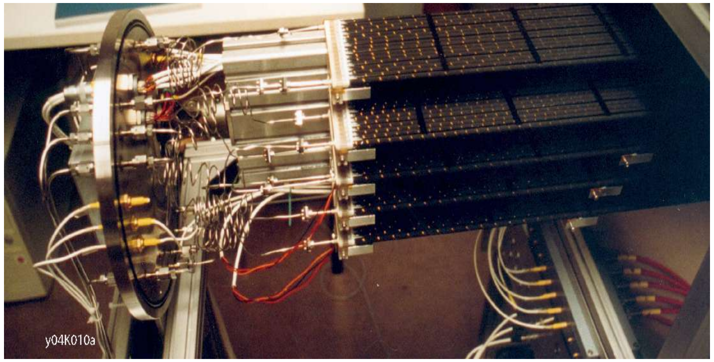


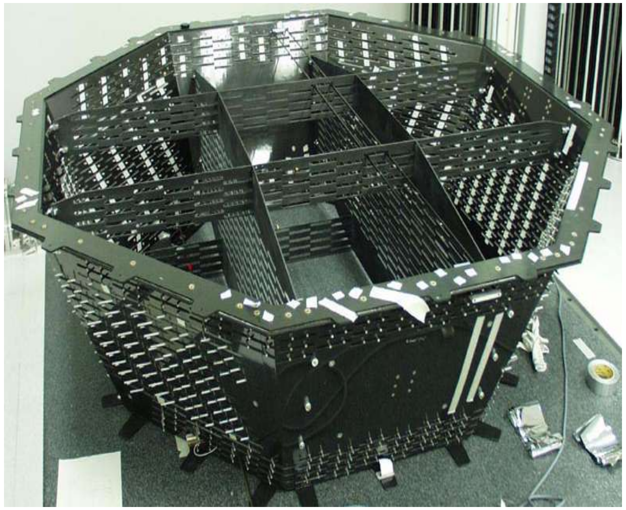
- ACC:
  - Sixteen 22 x 83 cm^3 scintillator paddles, thickness reduced from 10 to 8 mm.
  - The number of PMs is reduced from 32 to 16
  - Light collection with scintillating fibers



AMS-02 Subsystems

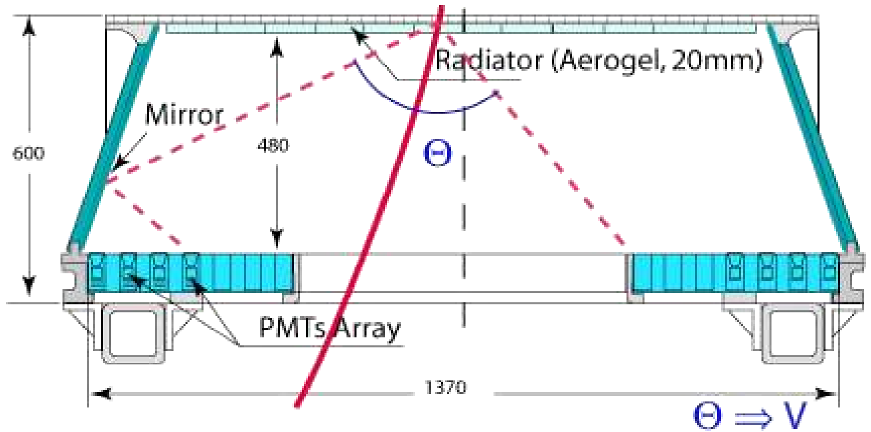
- TRD:
  - 20 layers of 21 mm thick polyethylene/polypropylene fleece radiator alternating with 6 mm dia. gas-filled straw tubes (80% Xe, 20% CO_2 @ 1 bar; 50 kg of gas embarked for 3 y operation (p rejection 10^2-10^3 in range 20 to 250 GeV with 90% $e^{\pm}$ detection efficiency)
  - Straw tubes grouped in 16-tube modules, 328 modules are arranged in a conically-shaped octagonal structure.
  - Layers are oriented orthogonally to provide 3-dimensional track reconstruction.





AMS-02 Subsystems

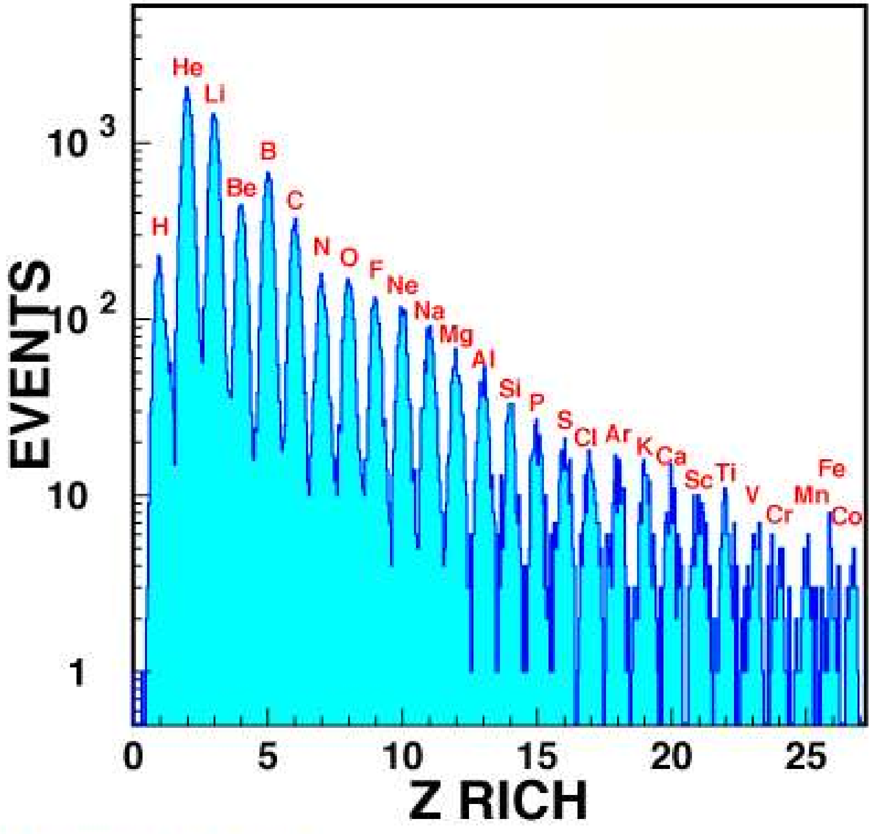
- Ring-Imaging Cherenkov (RICH):
  - 3 cm thick radiator consisting of 1.13 x 1.13 x 1 cm^3 silica aerogel tiles (n ~ 1.03-1.05) is mounted on support panel of last TOF plane
  - Cherenkov photons detected in an array of 680, 25 mm^2 multi-node (4 x 4) PMs @ 800 V, located 45 cm from the radiator; a 64.3 x 63.8 cm^2 aperture in front of the ECAL limits the geometric factor to ~ 0.4 m^2sr



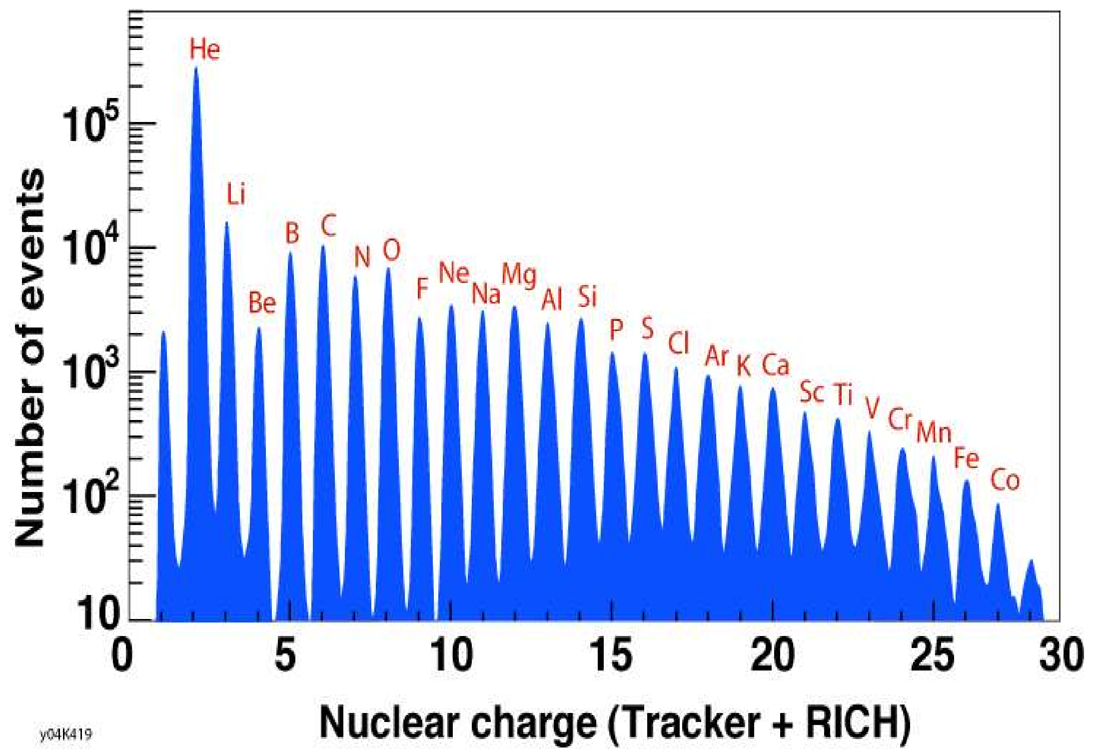
  - velocity measurement resolution ~0.1%, light isotope separation between 2 to 10 GeV/n, charge identification up to Z~26

Test Beam Results – Particle Charge

with RICH

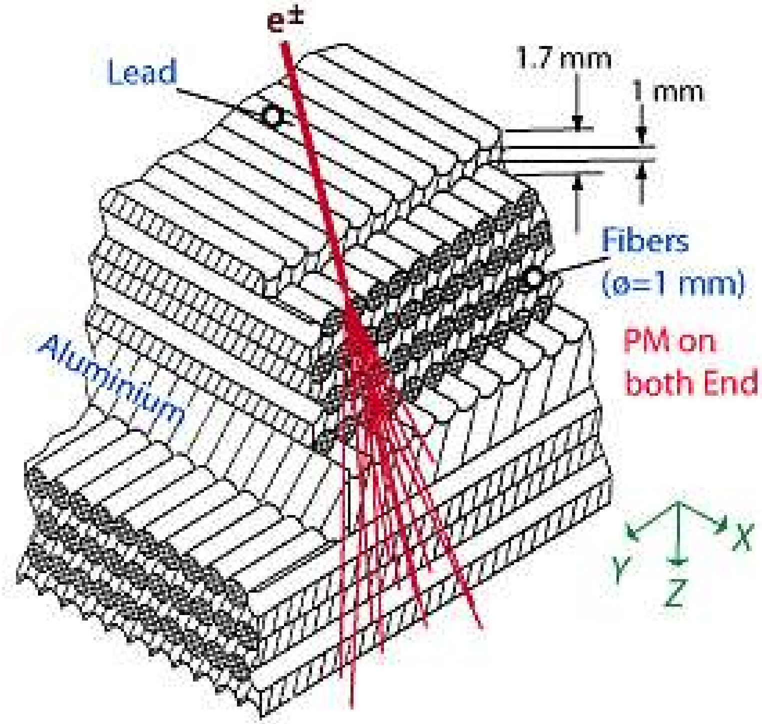


with RICH and Tracker



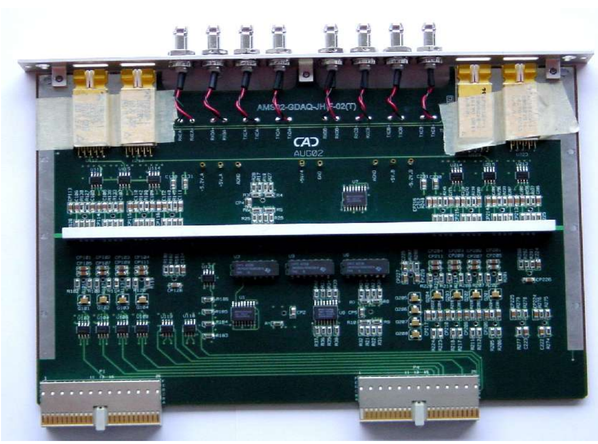
AMS-02 Subsystems

- ECAL, a Pb-scintillating fiber sampling calorimeter:
  - The 65.8 cm^2 is divided in 9, 1.85 cm thick “superlayers” , each “superlayer” consists of 11, 1 mm thick grooved Pb foils interleaved with layers of 1 mm dia. scintillating fiber.
  - Each “superlayer” is read out by 36 multi-anode PMs @ 650 V with a 0.9 x 0.9 mm^2 pixel size.
  - Radiation length of 9.6 mm
    $\Rightarrow$ calorimeter thickness 17.3 X_O
  - E_{TOT} from a few GeV to 1 TeV
    with an energy resolution of
    11.9% / $E^{1/2}$(GeV) + 2.8%

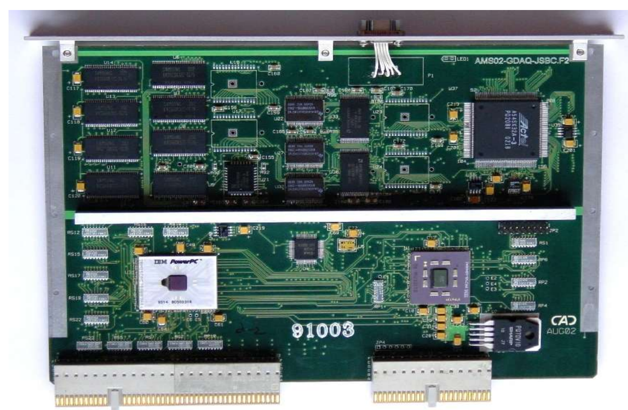


AMS-02 Subsystems

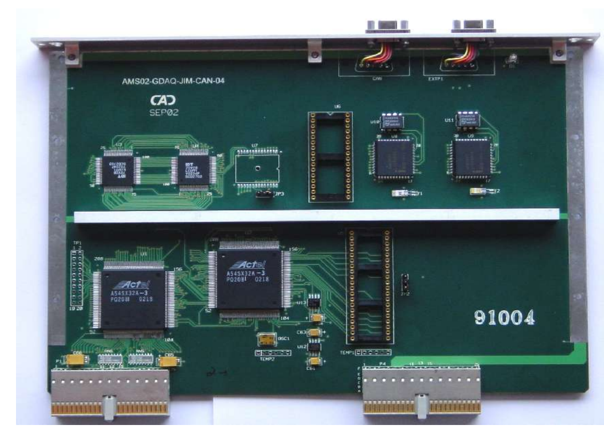
- DAQ:
  - ~227,300 channels (196,608 for the tracker), 16 bits/channel with event rates up to 2 kHz represent a raw data rate of 7.0 Gb/s
  - DAQ electronics must reduce to allocated 2 Mb/s downlink rate.



JHIF

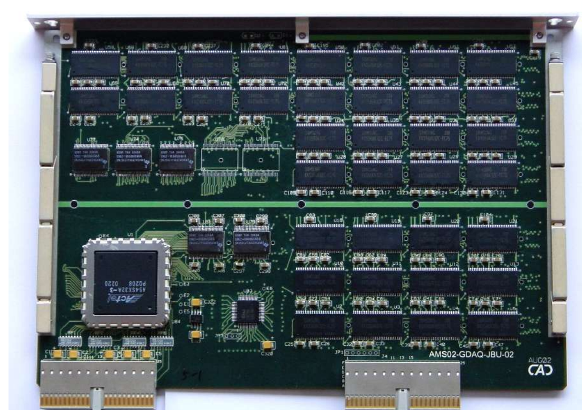


JSBC

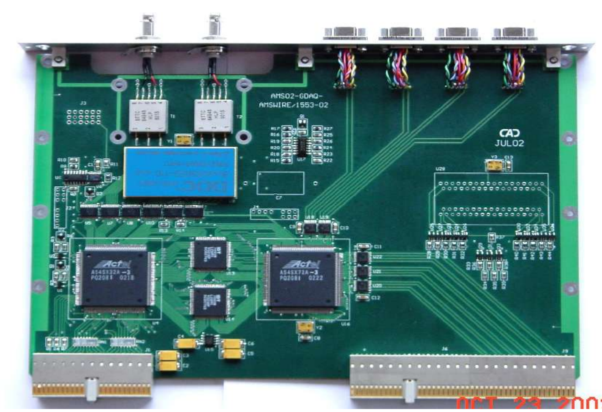


JIM-CAN

JIM-HRDL



JBU



JIM-AMSW&1553

Activities Prior to Launch

- Complete subsystems
- Thermal vacuum and vibration tests of key detector elements
- EM testing
- Final detector integration (CERN)
  present estimate exceeds 430 d
- Test beam (?)
- Delivery to NASA 6 months before launch date

Launch Dates *(at present)*

- Projected date for resumption of shuttle flights

  June 2005

- Projected data for AMS-02 launch

  second half of 2007

AMS-02 on the ISS