The Alpha Magnetic Spectrometer on the International Space Station

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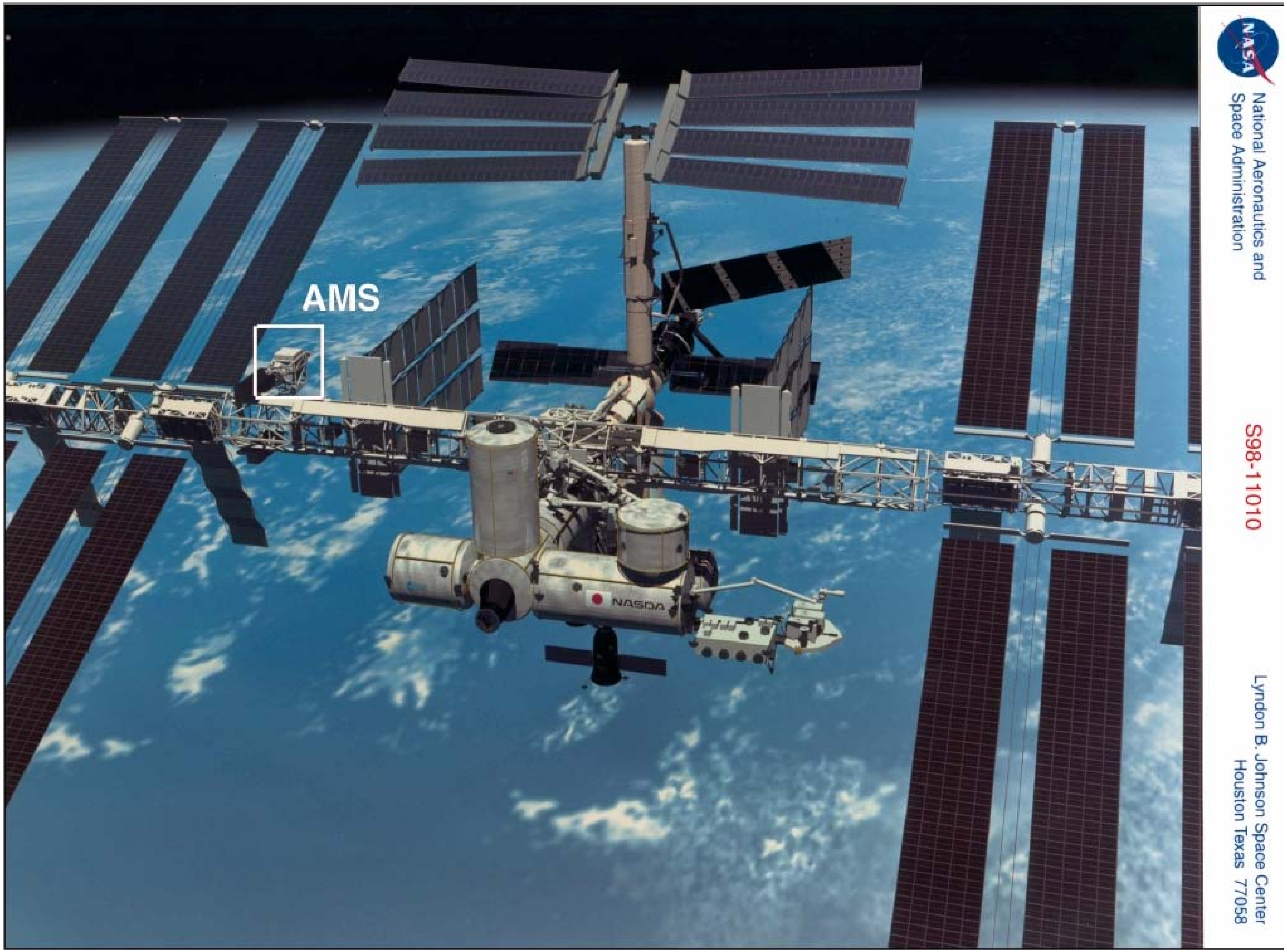
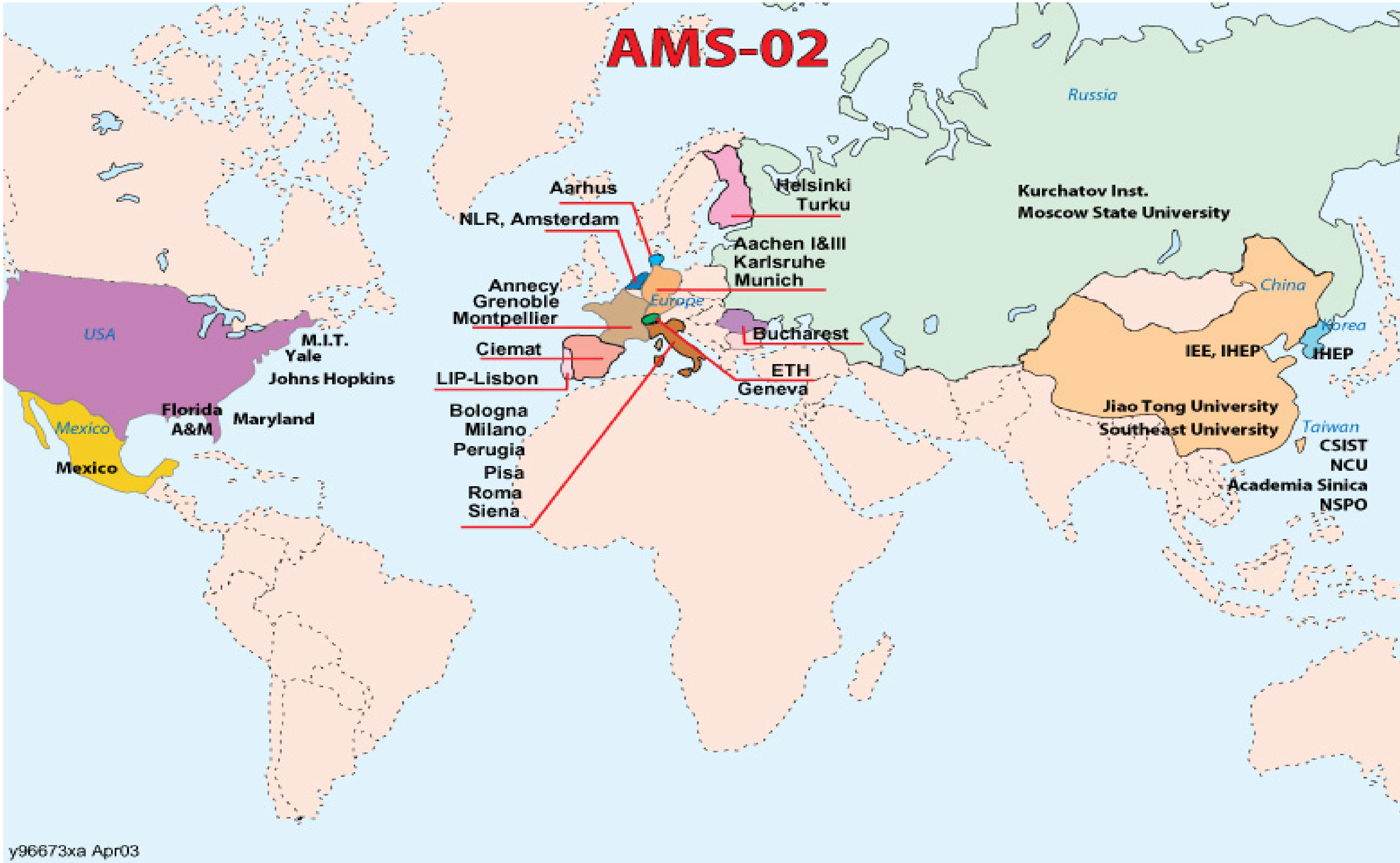
ICRC03, Tsukuba, Japan


AMS
NASDA
National Aeronautics and
Space Administration
S98-11010
Lyndon B. Johnson Space Center
Houston Texas 77058


AMS-02
Russia
Aarhus
Helsinki
Turku
Kurchatov Inst.
Moscow State University
NLR, Amsterdam
Aachen I&III
Karlsruhe
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China
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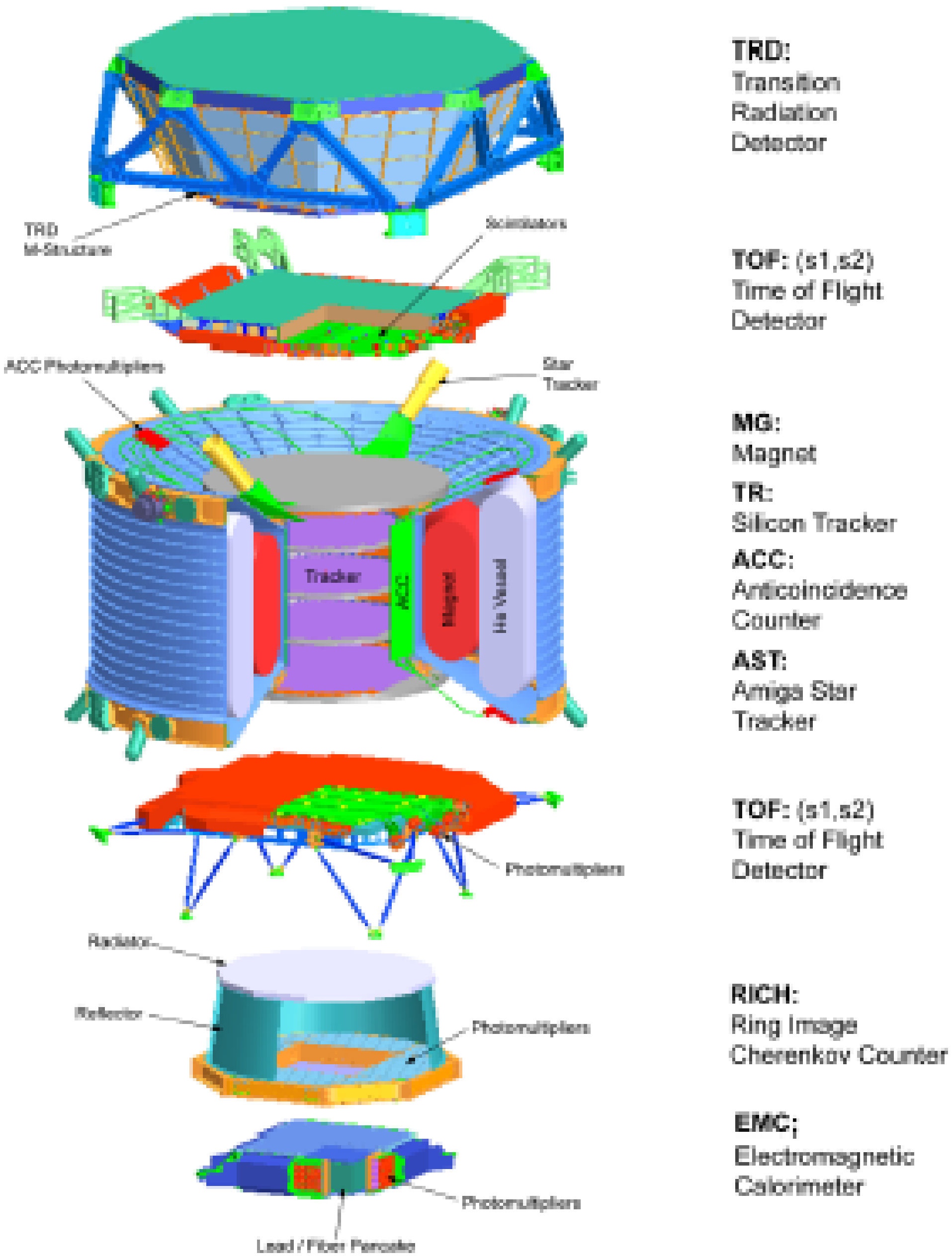
Jiao Tong University
Southeast University
Taiwan
CSIST
NCU
Academia Sinica
NSPO
Mexico
Mexico
y96673xa Apr03

International Collaboration

~200 scientists + dozens of contractors

U. of Aarhus (DK); Academia Sinica (Taiwan); U. of Bucharest (RO); Chinese Academy of Sciences, Inst. of High Energy Physics IHEP (Beijing); Chinese Academy of Sciences, Inst. of Electrical Engineering IEE (Beijing); Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas CIEMAT (Madrid, ES); Chung Shan Inst. of Science and Technology CSIST (Taiwan); EHWA Women's University (Seoul, KR) ETH Zurich (CH); Florida A&M U. (Tallahassee, FL); U. of Geneva (CH); Helsinki U. of Technology (FI); INFN Bologna & U. Bologna (IT); INFN Milano (IT); INFN Perugia, (IT); & U. Perugia (IT); INFN Pisa & U. Pisa (IT); INFN Roma & U. Roma (IT); INFN Siena & U Siena (IT); Inst. Superior Technico (Lisbon, PT); Inst. di Ricerca sulle Onde Elettromagnetiche IROE (Florence, IT); Inst. des Sciences Nucleaires de Grenoble ISN (FR); Inst. for Theoretical and Experimental Physics ITEP (Moscow, RU), Jiao Tong U. (Shanghai); Johns Hopkins U. (Baltimore, US); U. of Karlsruhe (DE); Kurchatov Institute (Moscow, RU); Kyungpook National University CHEP (Taegu, KR); Laboratoire d'Annecy-le-Vieux de Physique des Particules LAPP (FR); Laboratório de Instrumentaço e Física Experimental de Partículas LIP (Lisbon, PT); U. Maryland (College Park, US); Max Planck Inst. (Garching, DE) ; Massachusetts Inst. of Technology MIT (Cambridge, US); U. Montpellier (FR); Moscow State University (RU), Nat'l Aerospace Laboratory NRL (Amsterdam, NL); U. Nacional Autonoma de Mexico (MX); Nat'l Space Program Office (Taiwan); Nat'l Central University NCU (Taiwan); Nat'l Inst. for Nuclear Physics and High Energy Physics NIKHEF (Amsterdam, NL) I. Physikalisches Inst., RWTH Aachen (DE); III. Physikalisches Inst., RWTH Aachen (DE); Southeast U. (Nanjing); U. of Turku (FI); Yale U. (New Haven, US); Lockheed Martin, USA; Space Cryomagnetics LTD, UK; Arde, Inc., USA; CAEN Aerospace, IT; Carlo Gavazzi Space SpA, IT; ISATECH Engineering GmbH, DE; OHB GmbH, DE; Linde;

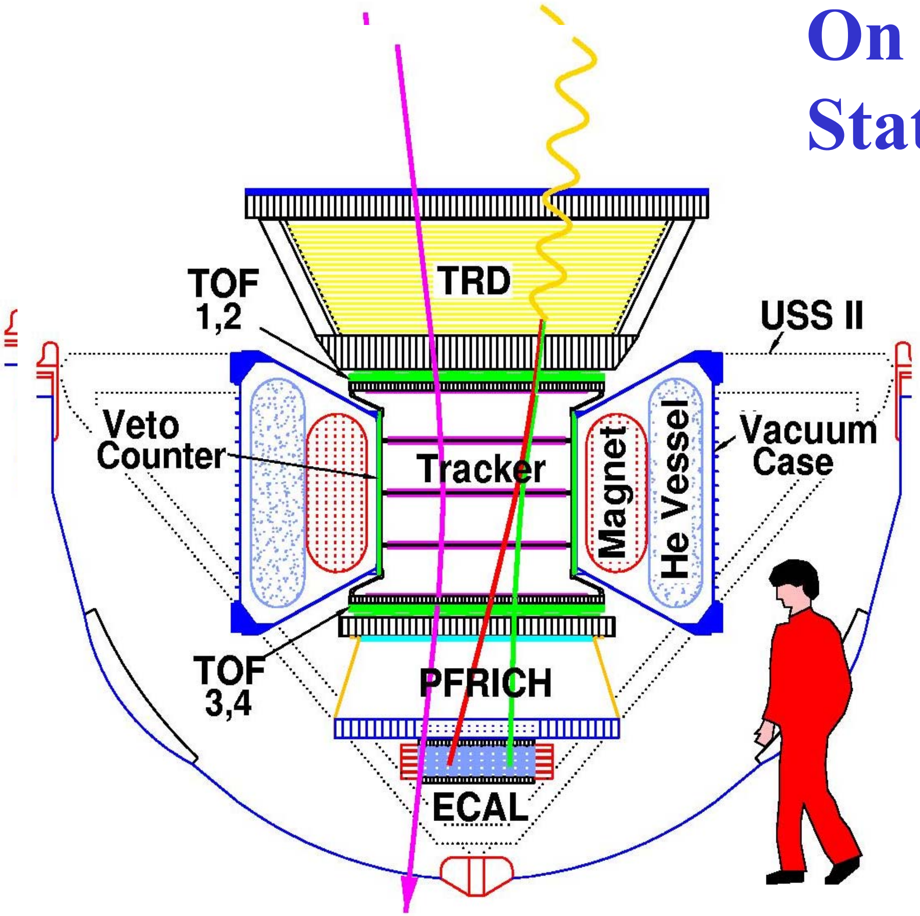
NASA



- Transition Radiation Detector
- Time of Flight scintillator counters
- 8 layers of Si strip tracker planes in superconducting magnet
- Rich Imaging Cerenkov detector
- Electromagnetic calorimeter

Japan.

The Alpha Magnetic Spectrometer



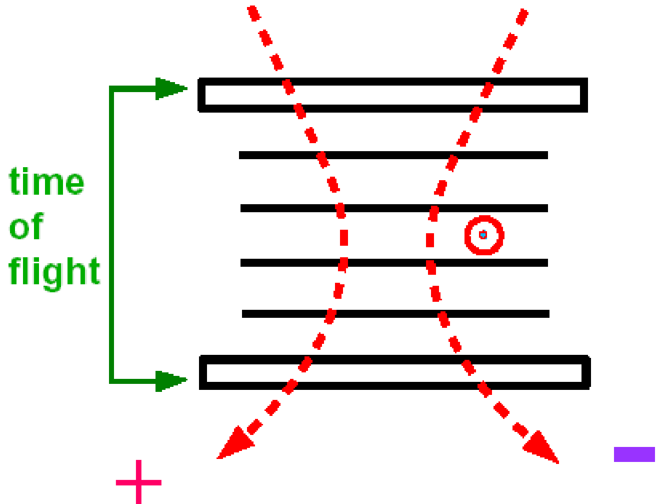
On International Space Station from October 2006

- Study of charged particles and nuclei with rigidity 0.5 GV– few TV
- Direct search for antimatter (antihelium)
- Indirect search for Dark Matter

How to detect antimatter in space?

Basic idea: magnetic spectrometer

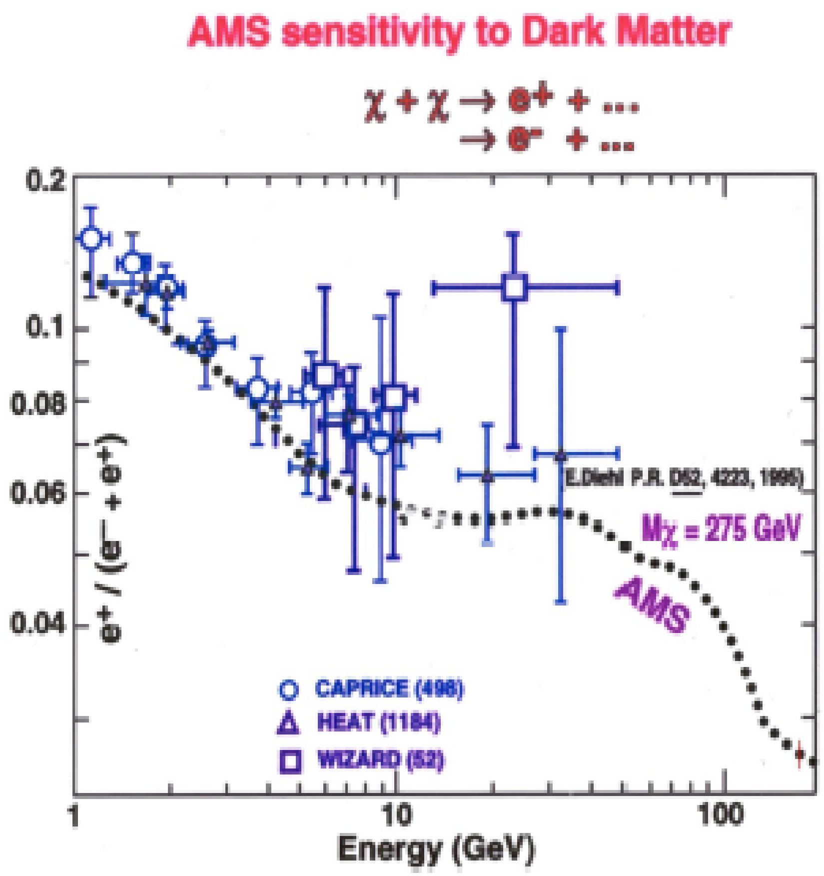
- magnet
- tracker
- time of flight



- $p = \gamma mv$ from curvature
- v from time of flight
- q magnitude from energy loss
- q sign from direction of curvature

m,q identifies particle

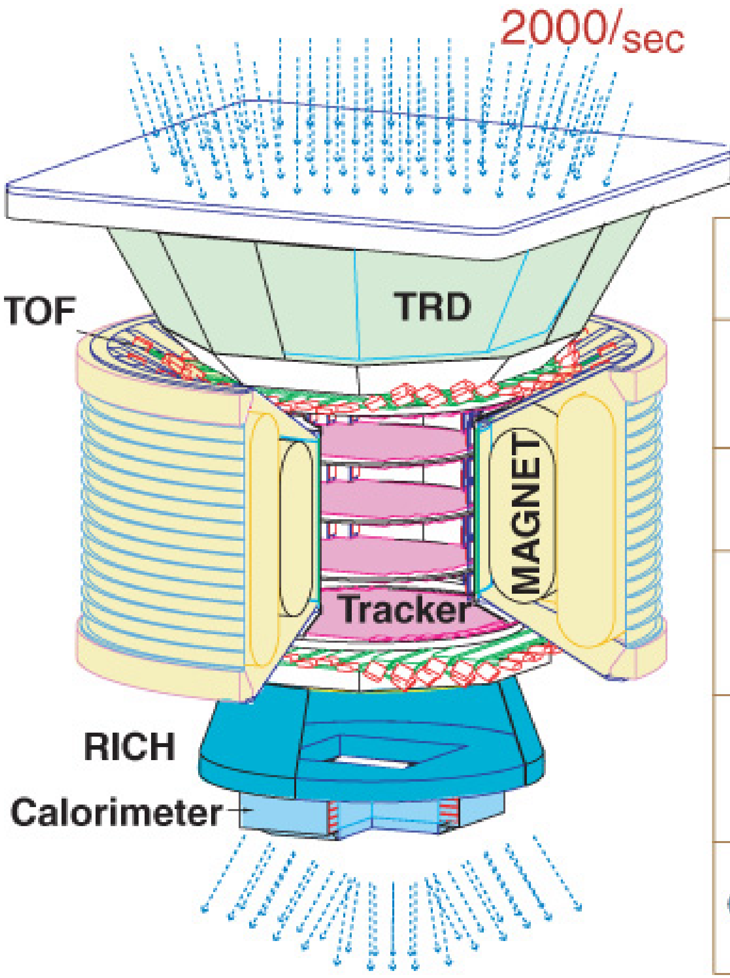
Cosmic ray sensitivity for dark matter search

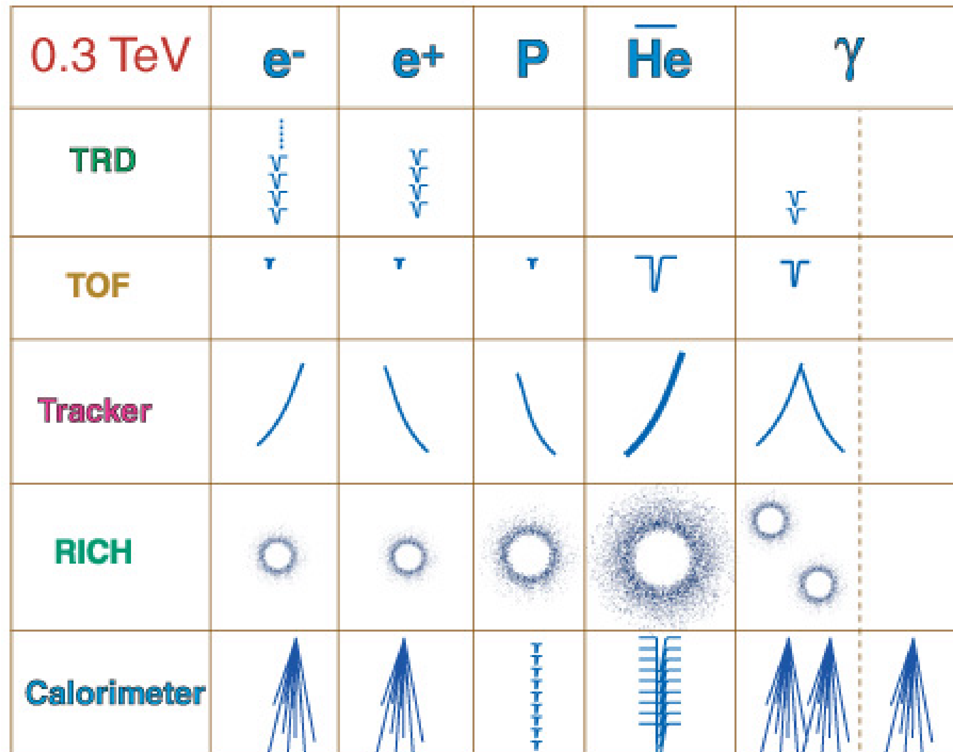


Cosmic-ray spectroscopy with high precision in particle identification:

p^+ Rejection > 10^6
e^+ Efficiency > 90%

AMS: A TeV Magnetic Spectrometer in Space





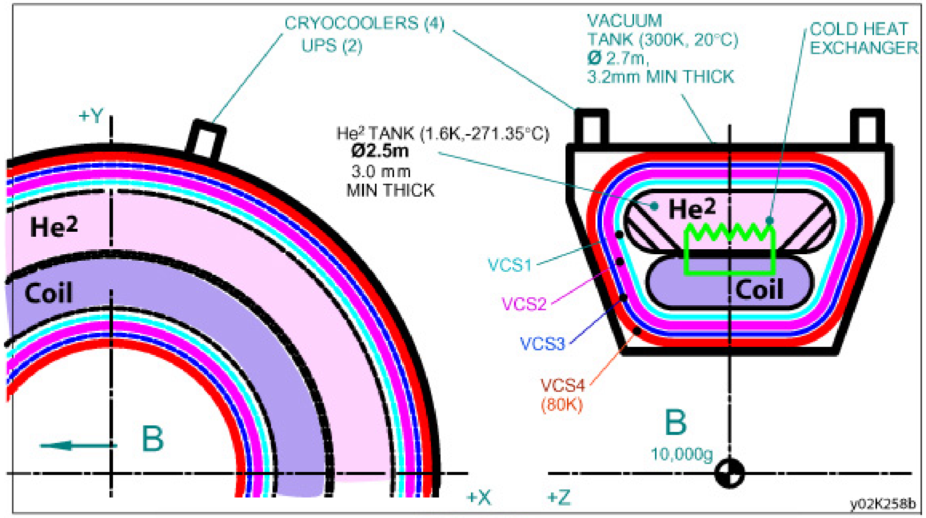
y2K025 _5 Gamma

AMS02 on International SpaceStation

- High Statistics (10^{10} ev) + Good Discrimination
- Space:
  - Thermal Environment (day/night: $\Delta T \sim 100^{\circ}C$)
  - Vibration (6.8 G RMS) and G-Forces (17G)
  - Limitation : Weight (14 809 lb) and Power (2000 W)
  - Vacuum: $< 10^{-10}$ Torr
  - Reliable for more than 3 years – Redundancy
  - Radiation: Ionizing Flux $\sim 1000\ cm^{-2}s^{-1}$
  - Orbital Debris and Micrometeorites
  - Must operate without services and human Intervention

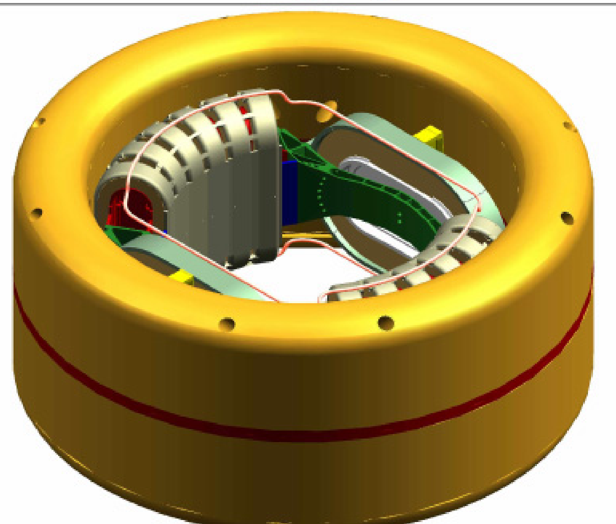
Superconducting Magnet

Superfluid helium vessel



Analyzing power

$$BL^2 = 0.8\ Tm^2$$



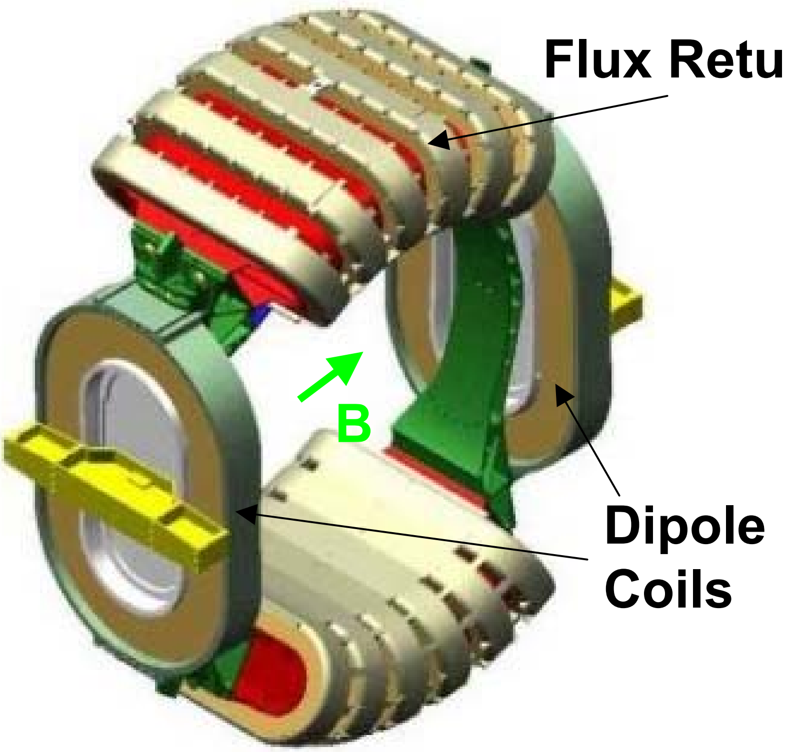
A puncture in the tank would result in expanding the volume from 2500 litres to 1.9 x 10^6 litres (six times the volume of the shuttle cargo bay) with extremely serious consequences.

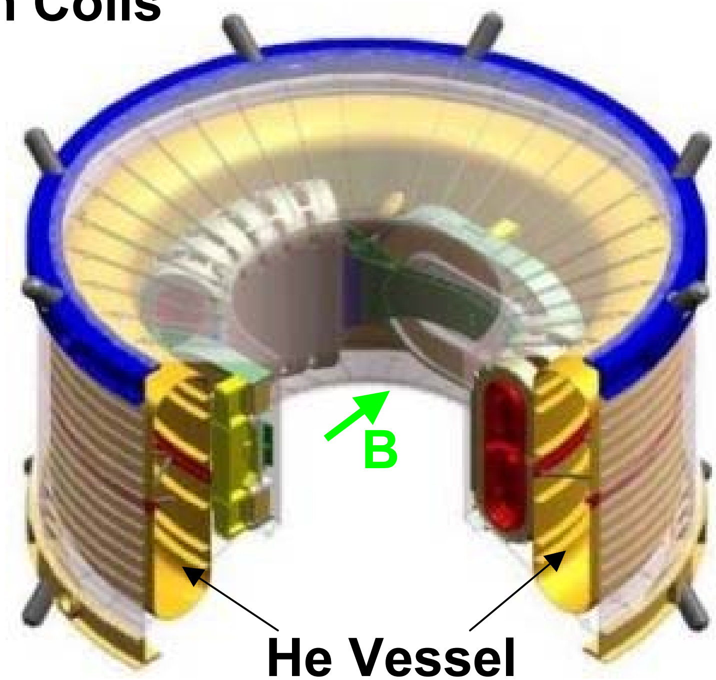
y02K121gHarrison

B.Blau
Talk 12
OG.1.5

Japan.

Superconducting Magnet





2500 Liters Superfluid He

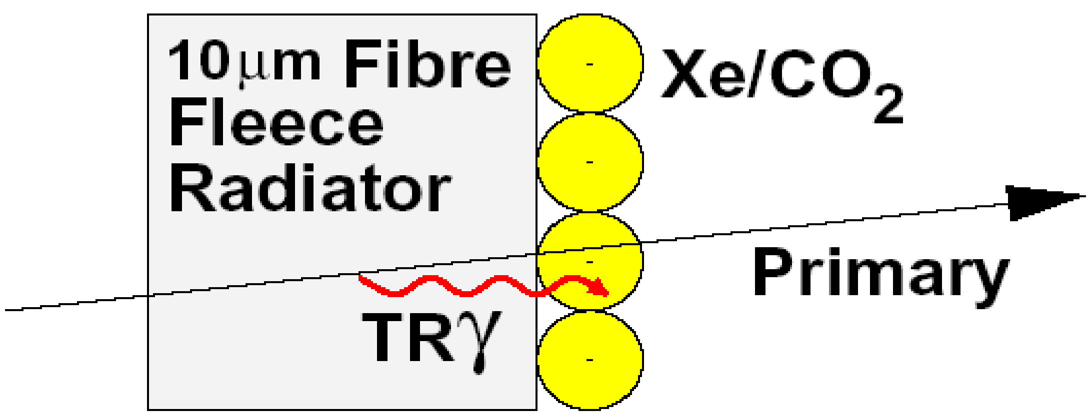
AMS-02 Transition Radiation Detector

S.Gentile
Talk 14
OG.1.5,
1-P-109

Transition radiation is produced when particles cross boundaries between materials with different dielectric properties

Significant for relativistic γ =E/m >~ 1000

At >~ GeV energies, electrons produce TR x-rays; protons do not: 3 –300GeV



20 layers of Xe/CO_2 filled straw tubes for dE/dx, TR x-ray detection

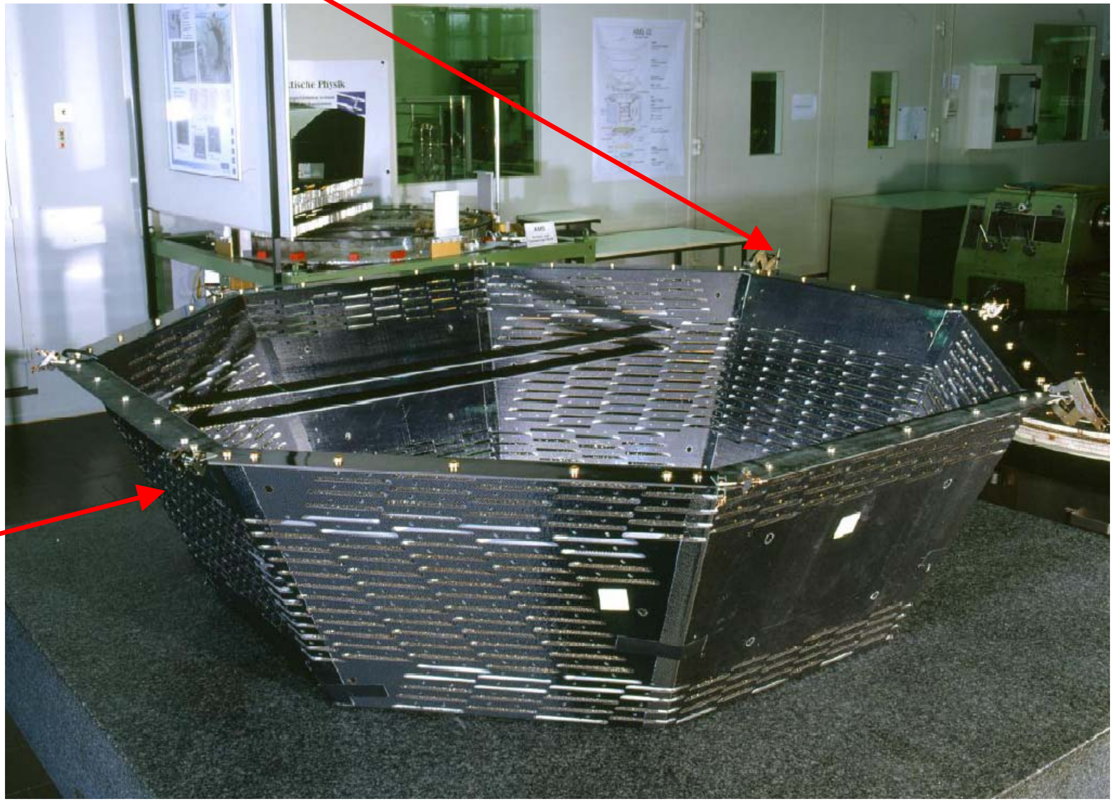
- e+/p rejection 10^2 –10^3 in 1.5 – 300 GeV
- with ECAL e+/p rejection >10^6

TRD Support Structure

Mechanical Accuracy <100μm

328 chambers = 5248 tubes

Modules

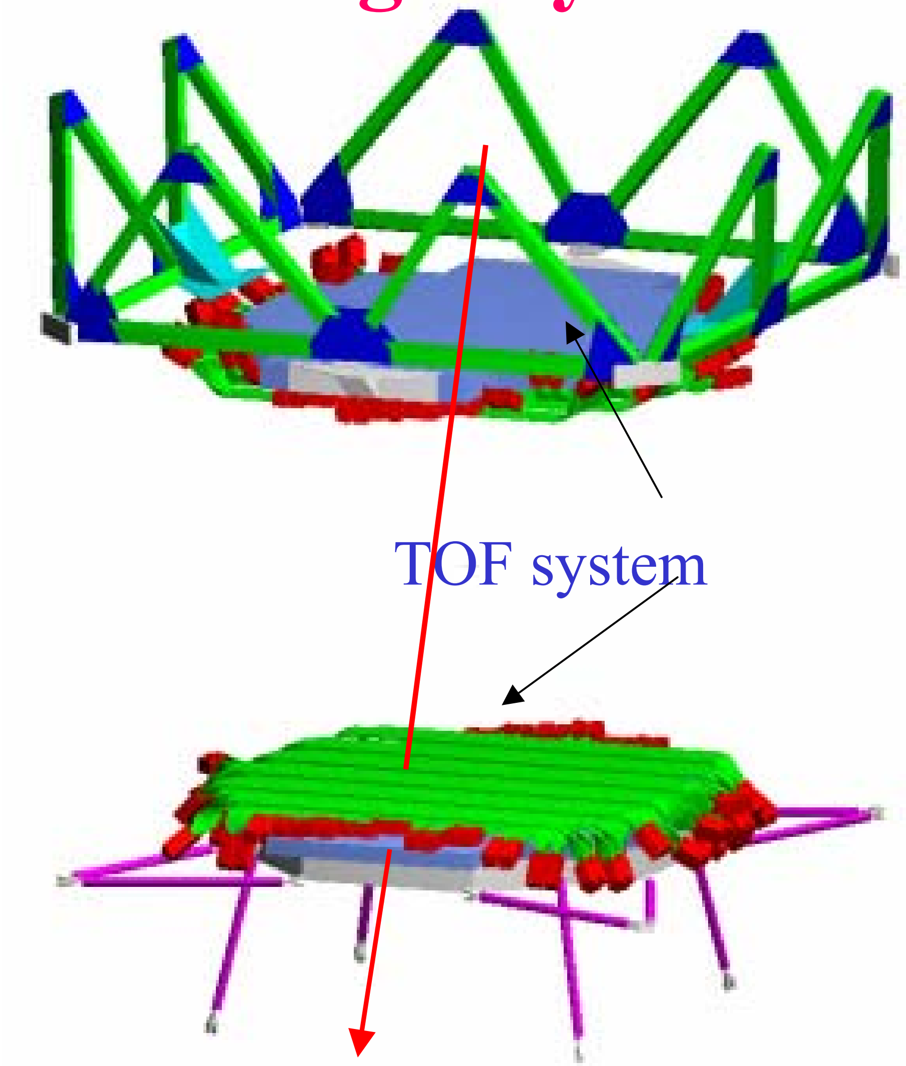


Honeycomb

Support Panels

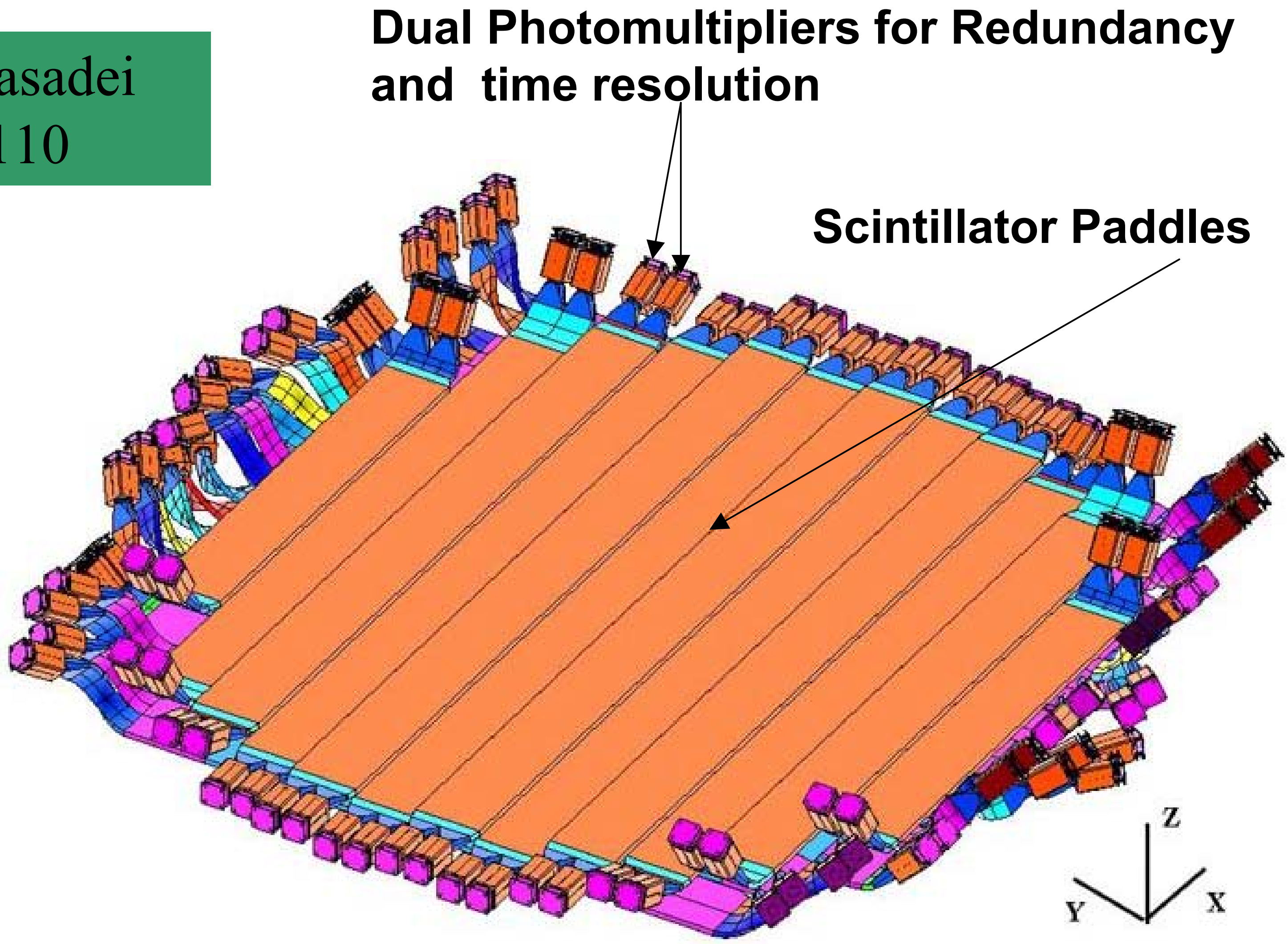
Time-of-flight system

- Trigger
- Time-of-flight (velocity).
- Up/Down Separation
- |Charge| Determination (dE/dx)
- 120 ps Time Resolution



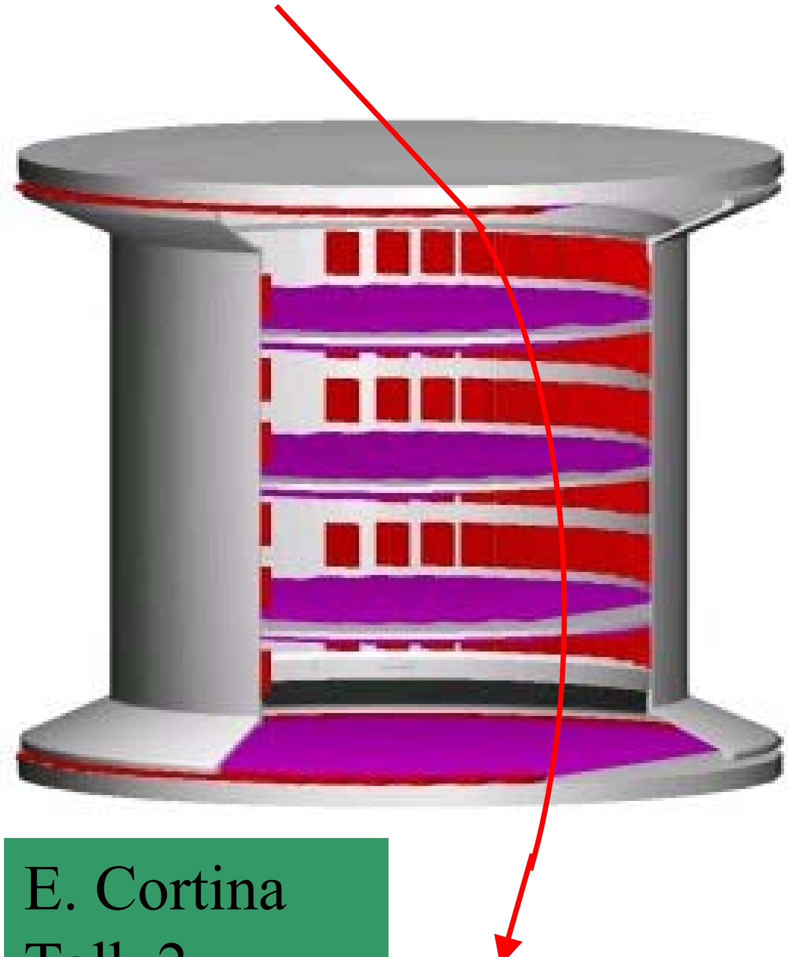
- 8 m^2 Total Area
- 4 Planes (2 upper,2 lower)

D.Casadei
1-P-110



Scintillator Paddles With Phototubes at Both Ends

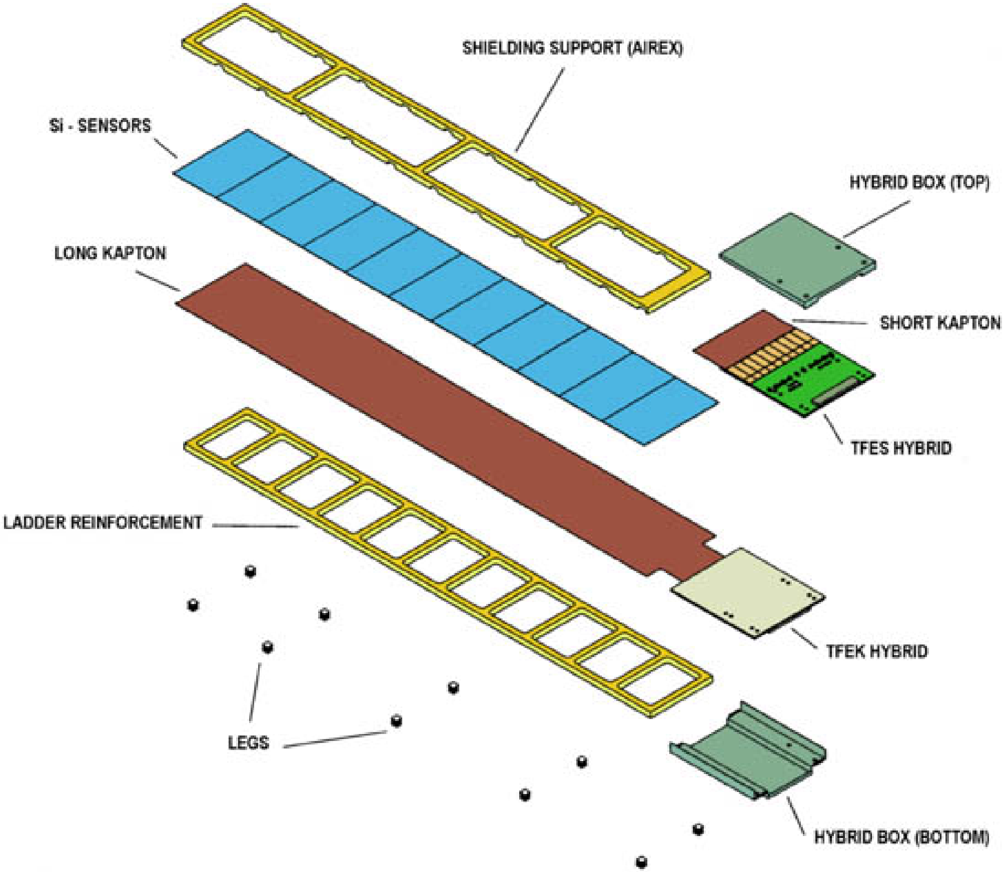
Silicon Tracker

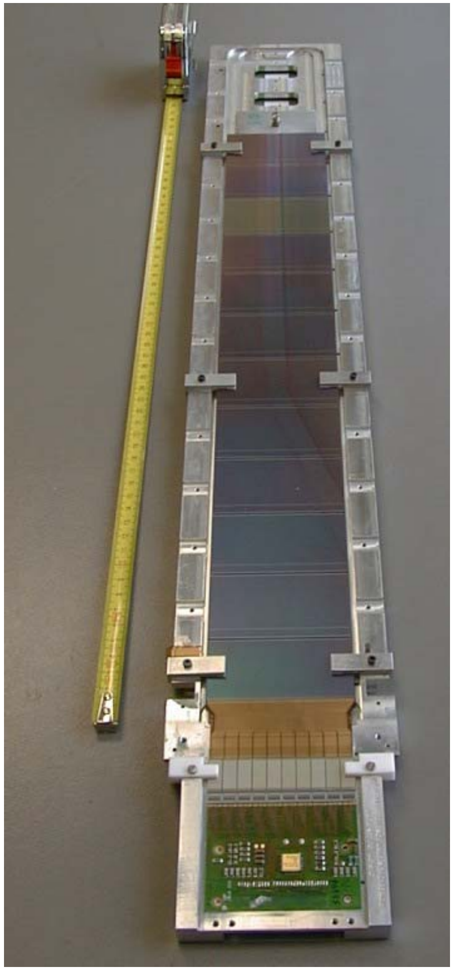


- Rigidity ($\Delta R/R \approx 2\%$ for 1 GeV Protons) with Magnet
- Signed Charge (*dE/dx*)
- 8 Planes, ~6m^2
- Pitch (Bending): 110 μm (coord. res. 10 μm)
- Pitch (Non-Bending): 208μm (coord. res. 30 μm)

E. Cortina
Talk 2
HE 3.4,
2-P-297

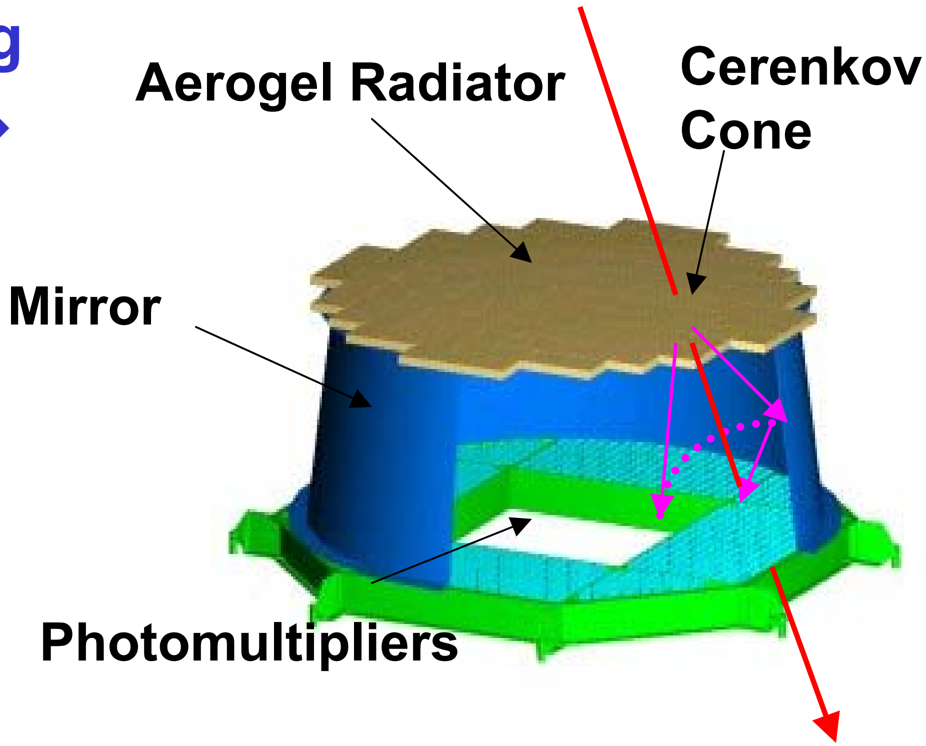
Silicon Tracker Ladder





Ring Imaging Cerenkov Counter

- Accurate Velocity Measurements via Opening Angle of Cerenkov Cone → Isotopic Separation.
- |Q| measurements
- $\Delta\beta/\beta \sim 0.1\%$
- Cosmic Ray Propagation.
- Additional Particle Identification capability

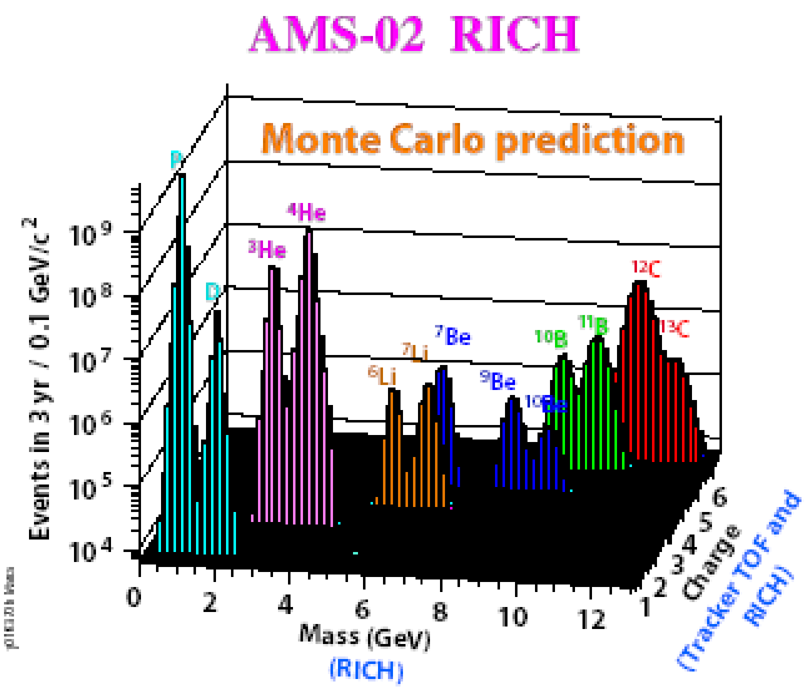


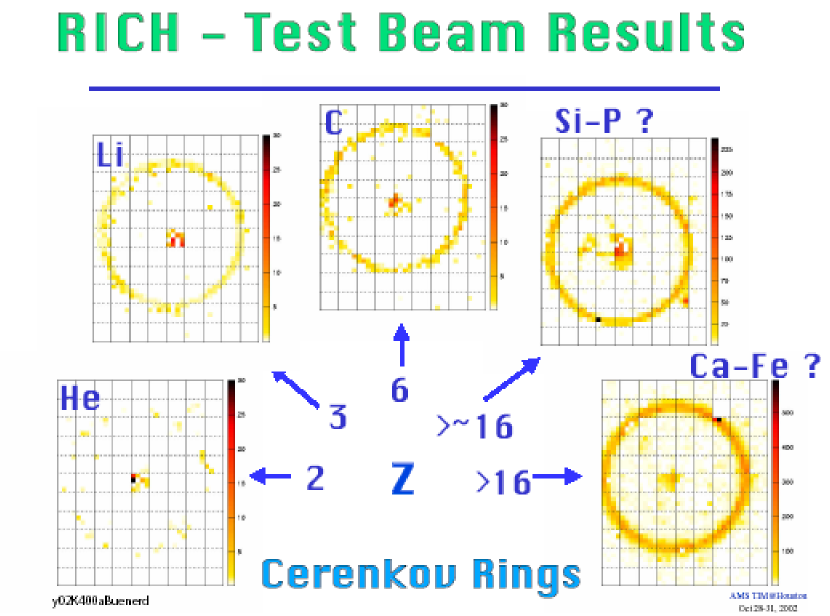
M.Buenerd
Talk 13 OG.1.5

AMS II - RICH

y03K054

Japan.


AMS-02 RICH
Monte Carlo prediction
Events in 3 yr / 0.1 GeV/c²
Mass (GeV)
(RICH)
Charge
(Tracker TOF and RICH)
p
D
³He
⁴He
⁶Li
⁷Li
⁷Be
⁹Be
¹⁰Be
¹⁰B
¹¹B
¹²C
¹³C

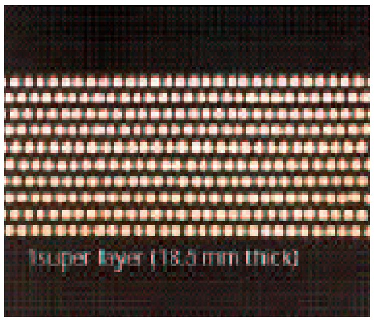

RICH – Test Beam Results
Li
C
Si-P ?
He
Ca-Fe ?
3
6
>~16
2
Z
>16
Cerenkov Rings

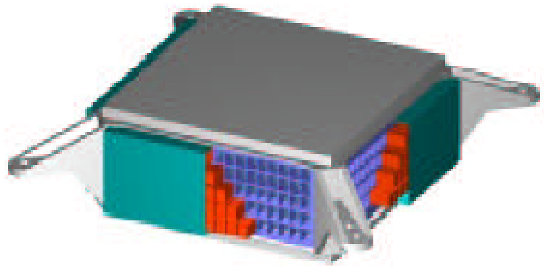
Electromagnetic Calorimeter

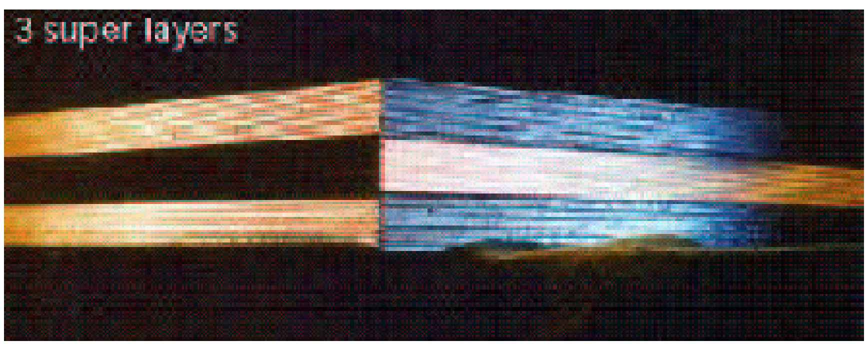
3D sampling calorimeter

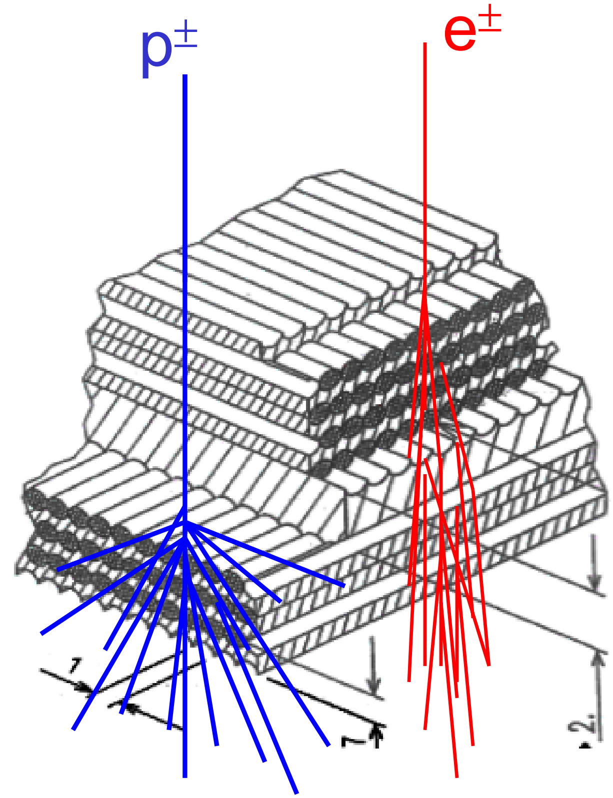
•9 superlayers of 10 fiber/lead planes each alternate in x and y scintillating fibers viewed by PMT
• 16.4 X_0 radiation length
• Measure energy and (angle) of γ, e^+,e^-
•Distinguish e, p better than 10^3 in the range
1 GeV-1 TeV.

Electromagnetic Calorimeter



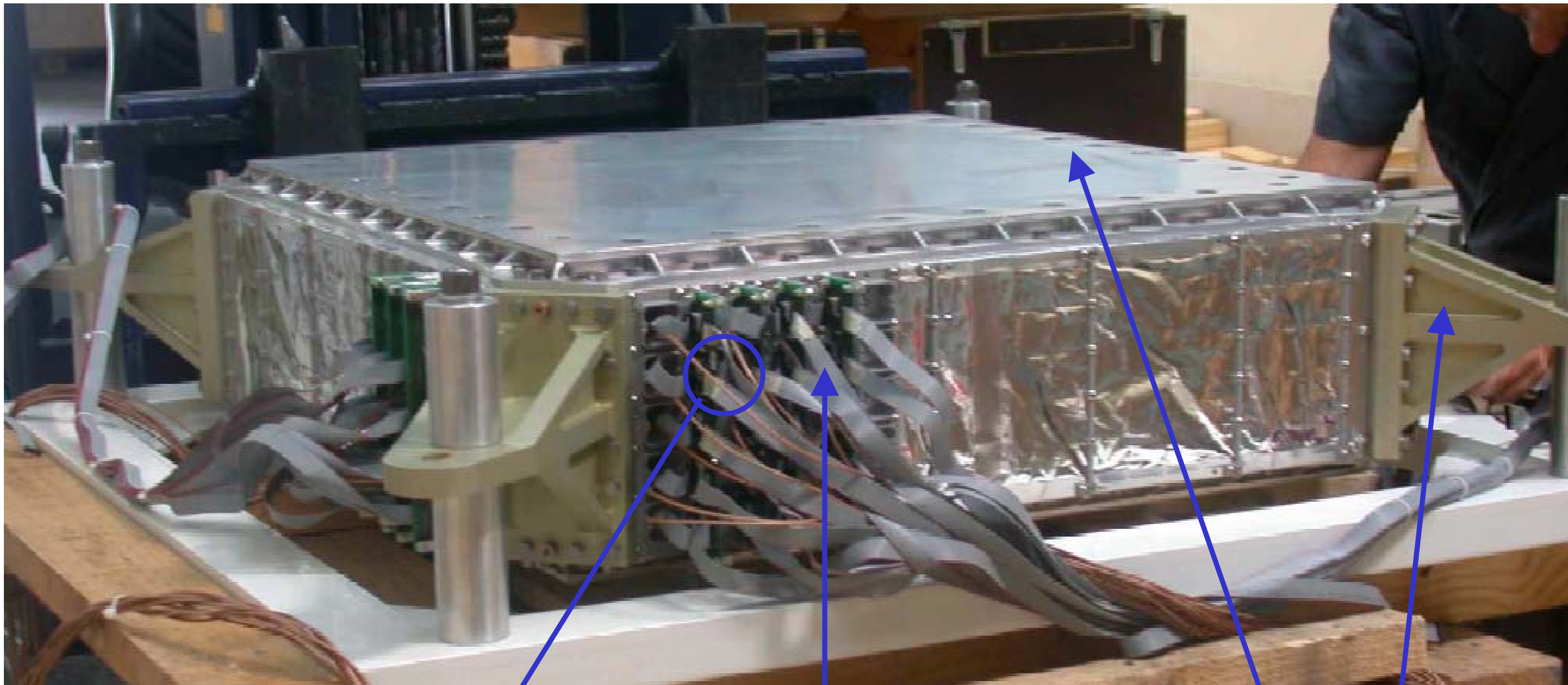


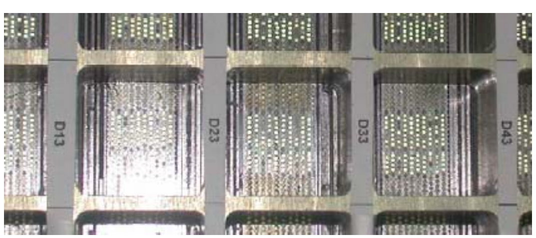




10^{-3} $p^{\pm}$ Rejection at 95% $e^{\pm}$ Efficiency Via Shower Profile

ECAL Prototype After Testbeam



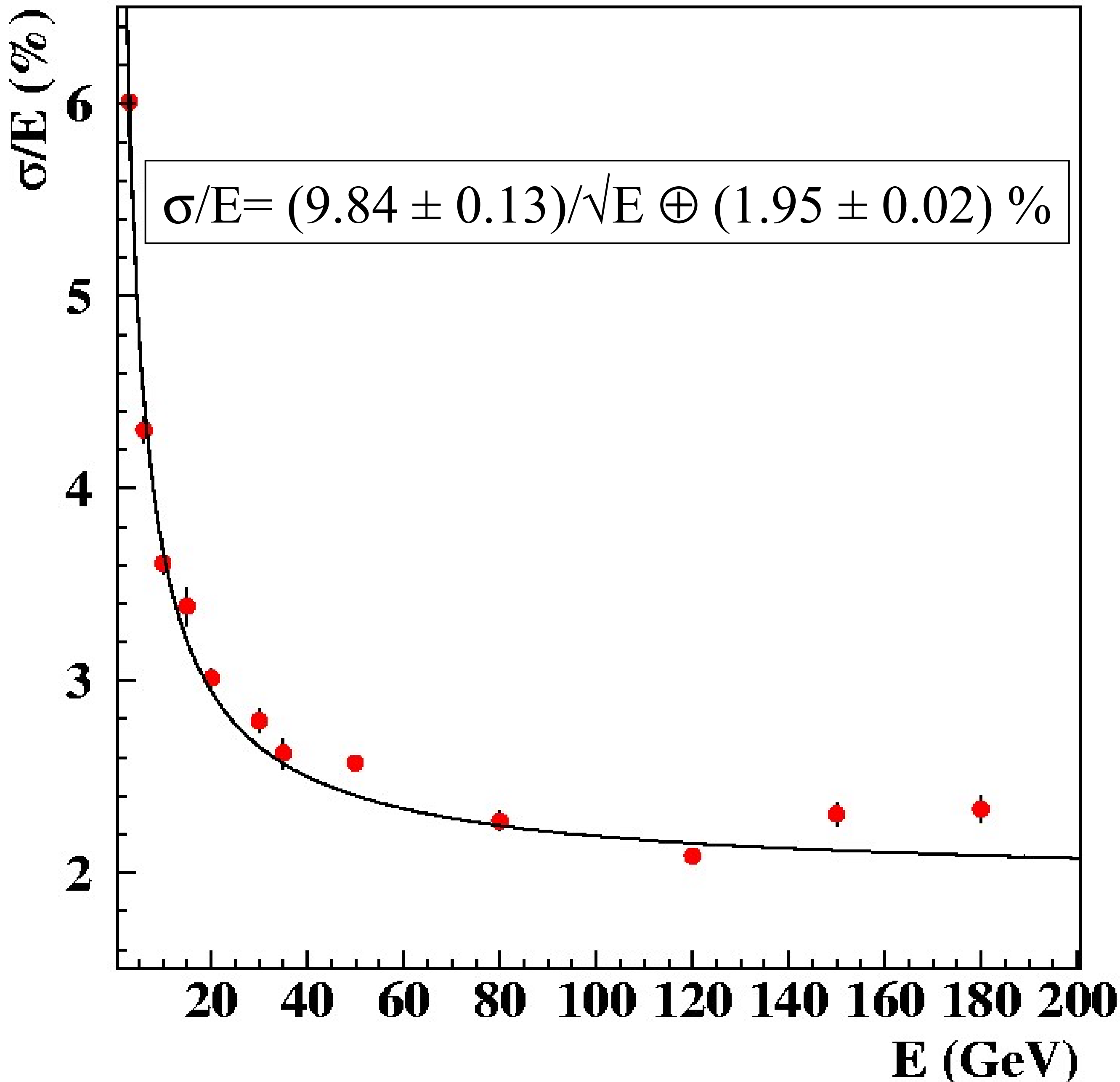


PMT's + Readout

PMT + Readout Housing

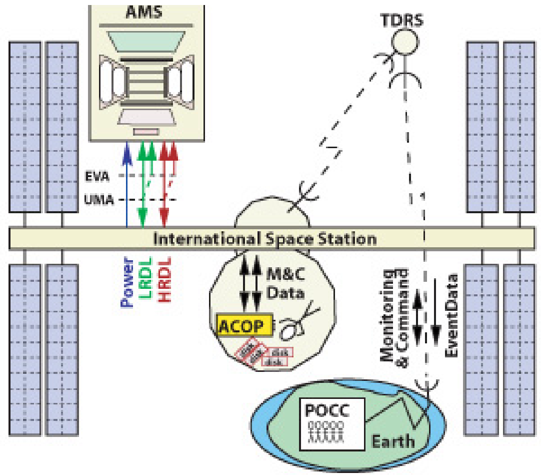
Al Support Structure

Energy resolution

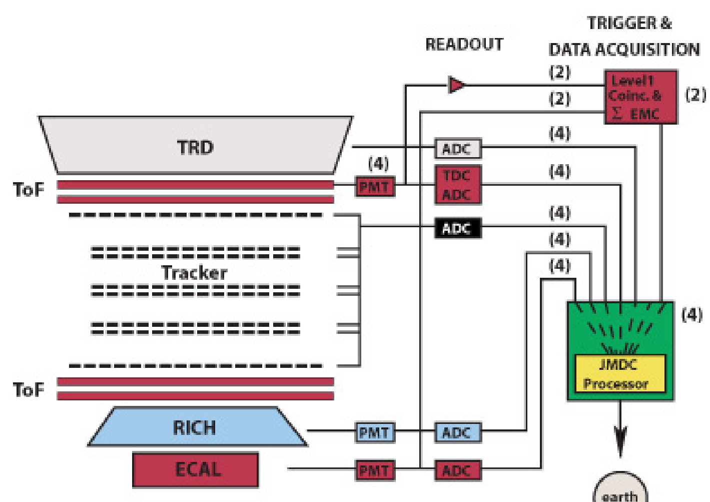


AMS-02 Electronics

A.S., CIEMAT, CSIST, ETH, Geneva, INFN (Perugia), LAPP, MIT, NCKU, NSPO, RWTH-1, SJTU,..



The AMS electronics is based on accelerator physics technologies.
It is ~ 10 times faster than commercial space electronics.



The level of redundancy is shown in parenthesis.

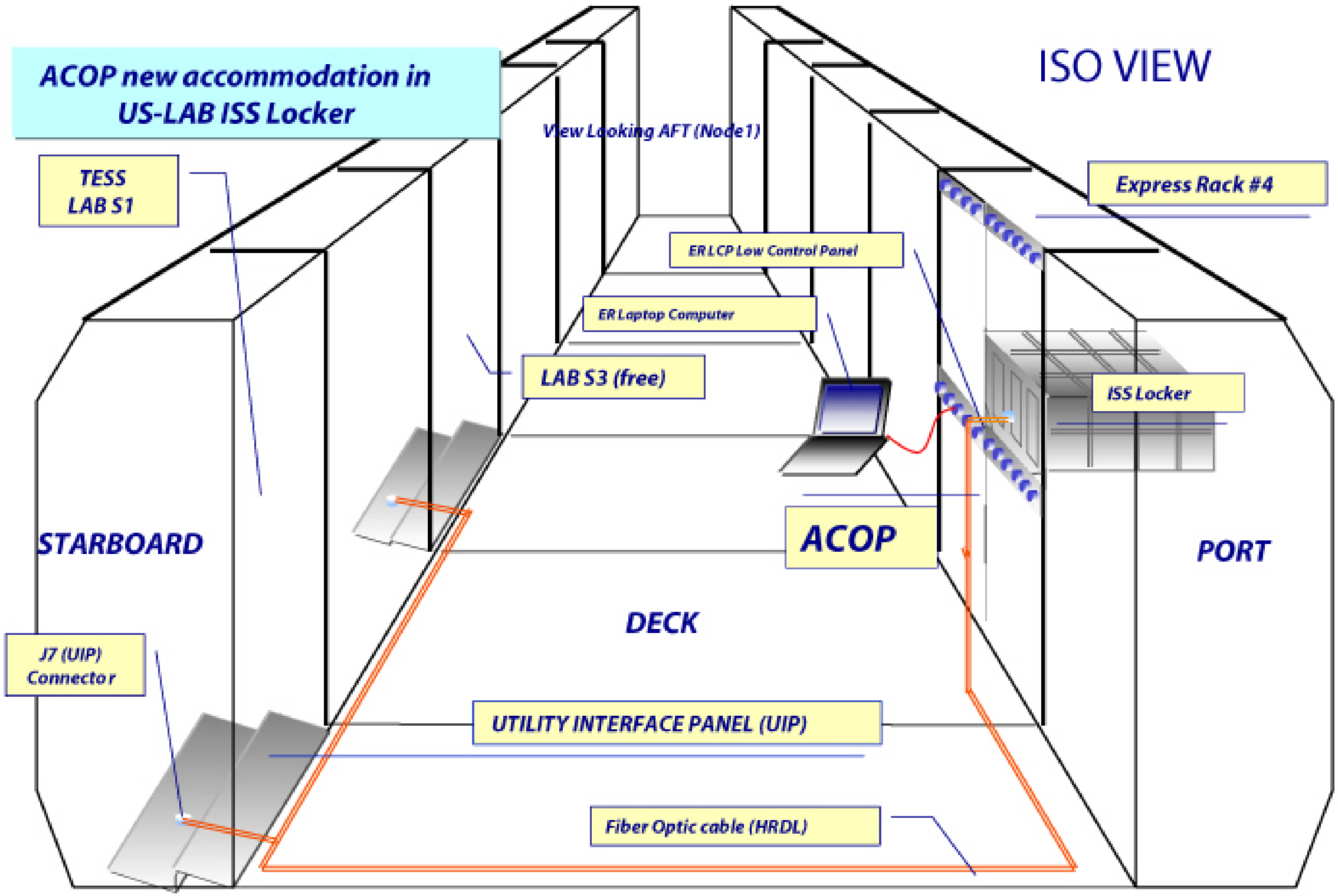
650 microprocessors

Most are made in CSIST, Taiwan

y01K074id / 316fa

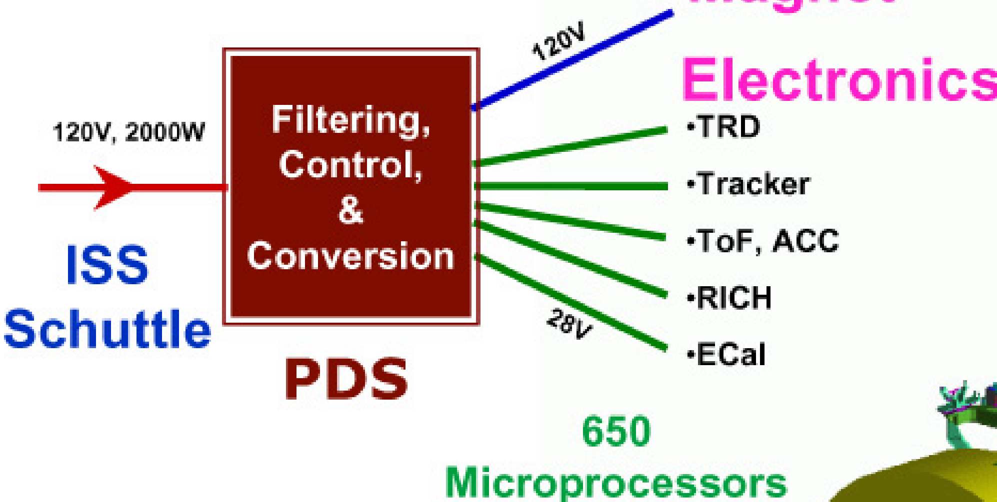
E.Cortina
Talk 15 OG.1.5

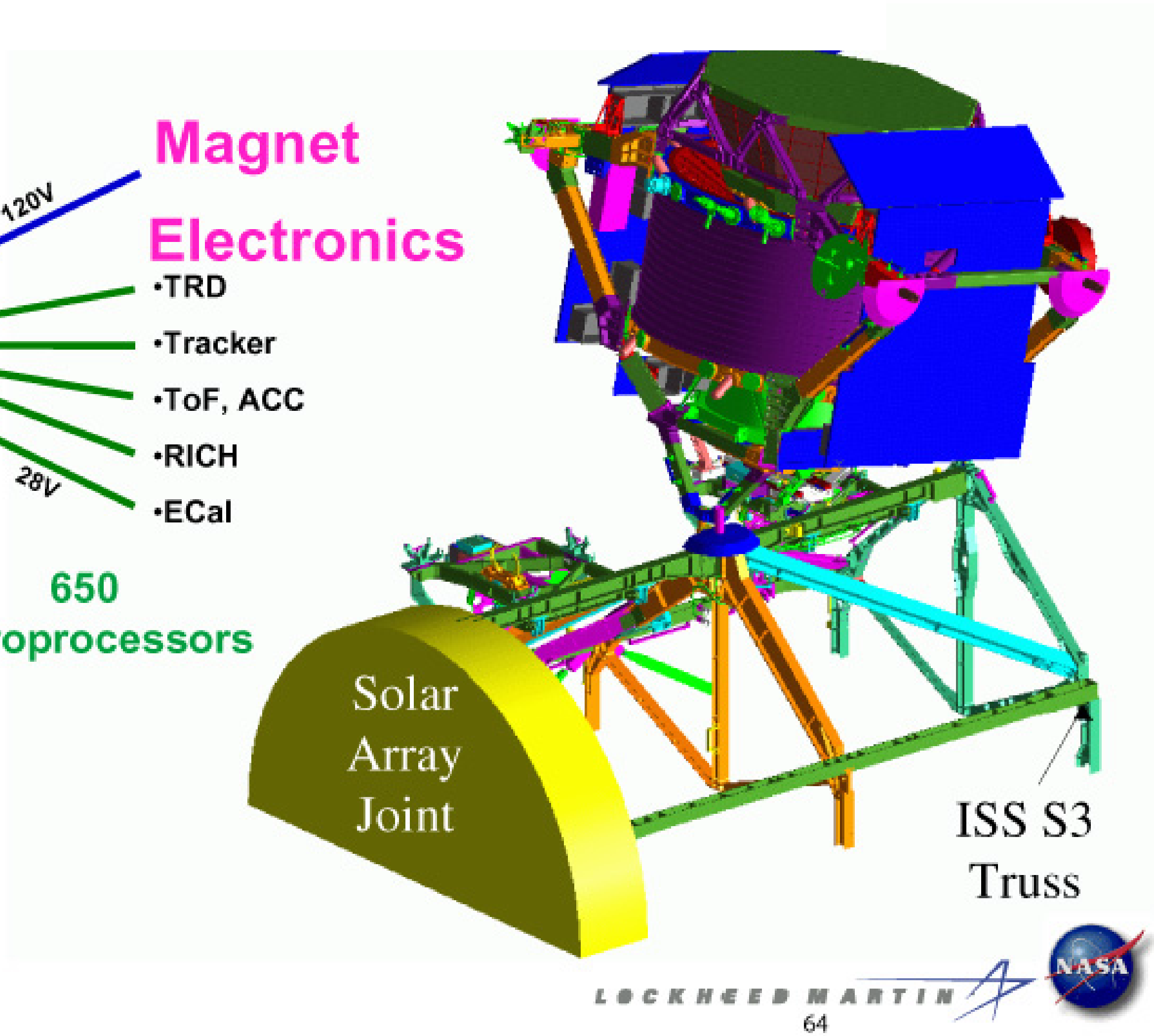
ACOP: AMS Computer facility



A on board backup is forseen once a month by austronauts

AMS-02 Power Distribution System (PDS)



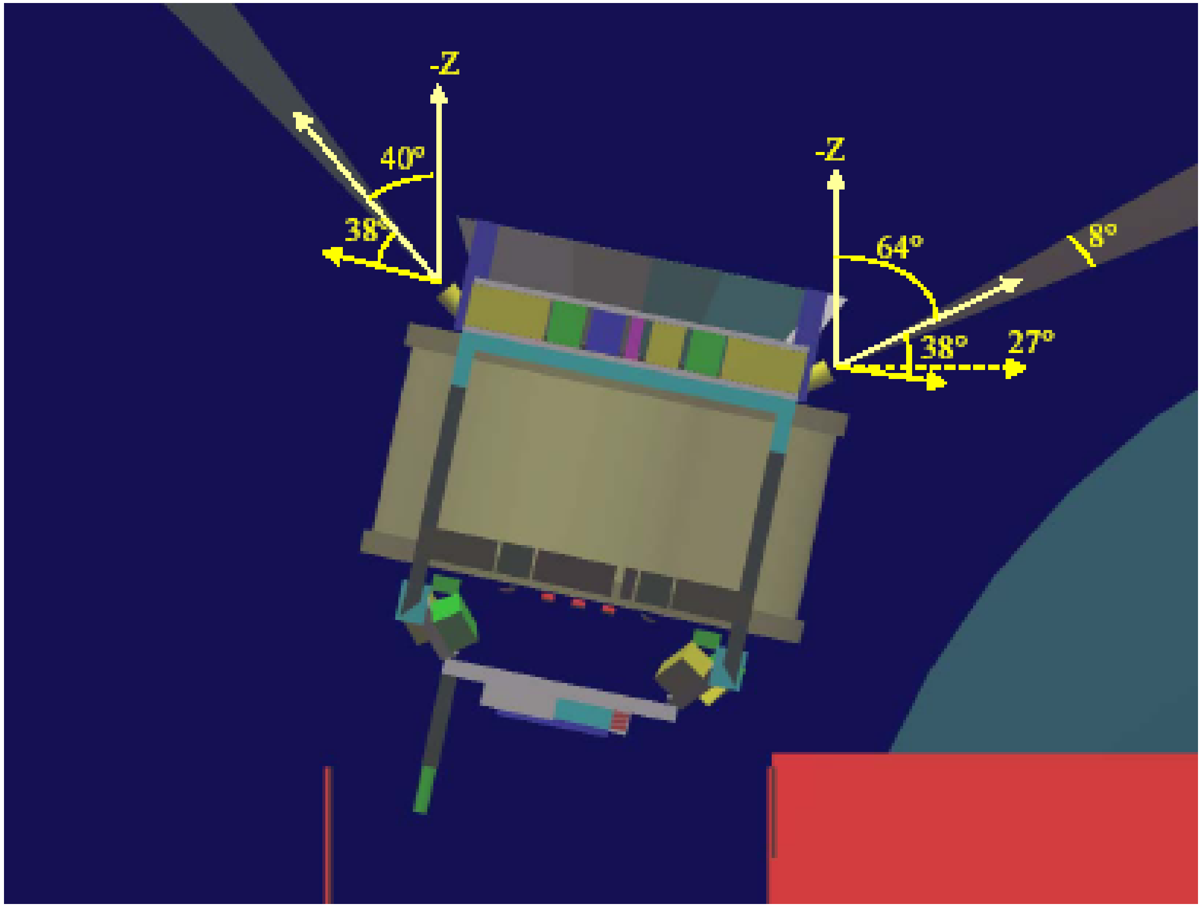


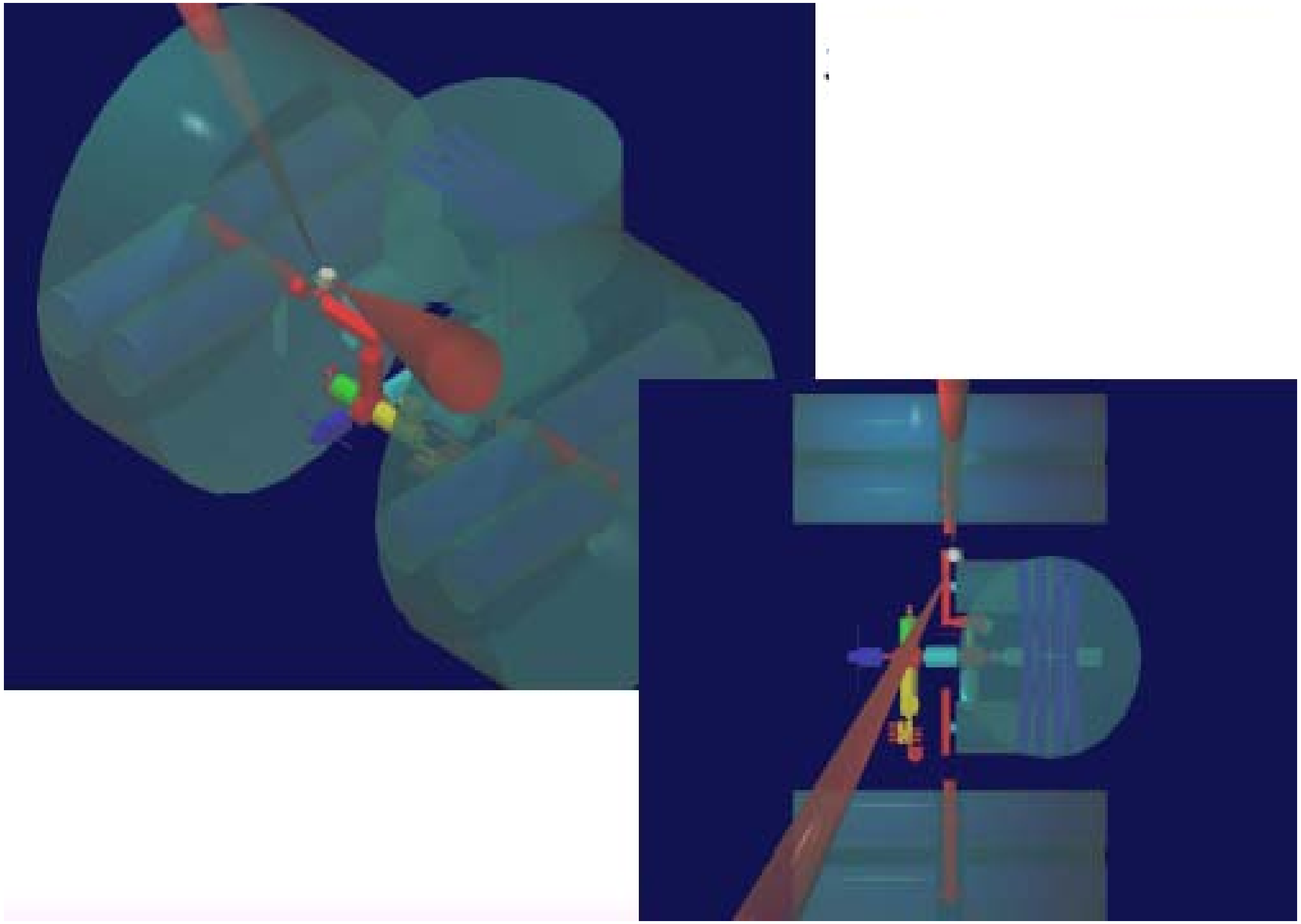
Max Power 2000W

Star Tracker

Angular resolution

30 arcsec





- **|Q| measured from Tracker, RICH, TOF.**
- **$\pm$ Q measured from tracker.**
- **Velocity β measured from TOF, TRD, RICH.**
- **Hadron Rejection TRD, ECAL.**

Main design characteristics:

- **Minimum X_o (up to ECAL)**
- **Many independent measurement of β**
- **Acceptance 0.5 m^2 anti-He search**
- **Hadron/positron $\Delta\beta/\beta = 0.1$ % to distinguish ^{9}Be,^{10}Be, ^{3}He,^{4}He isotopes.**
- **Rigidity R= pc/|Z| e GV resolution 20% at 0.5 TV and Helium resolution of 20% at 1TV.**

Conclusions

AMS02 will measure charged cosmic rays up to few TeV rigidity for 3 to 5 year on International Space station from October 2006.

To search for:

- **Antimatter**
- **Dark Matter**
- **Cosmic Ray Fluxes and propagation**
- **Search for isotopes**
- **High Energy γ**

Many channels are measured simultaneously, which will give a strong constrain on models and increase the potential of discovery.