AMS-02 on the International Space Station

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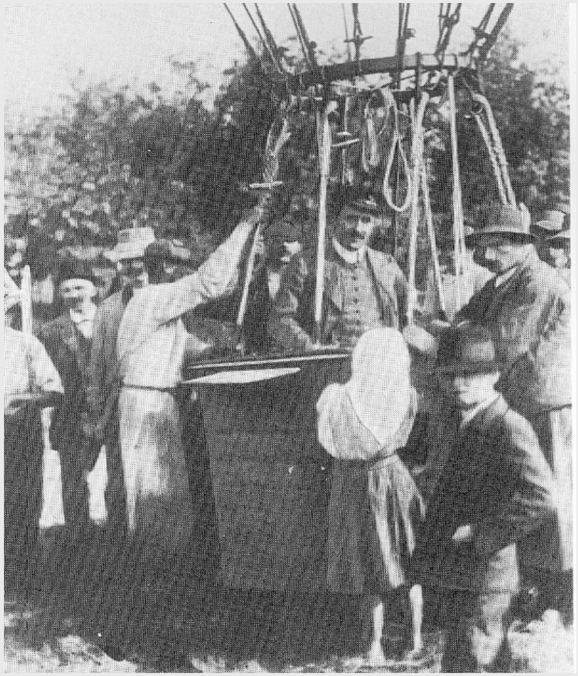
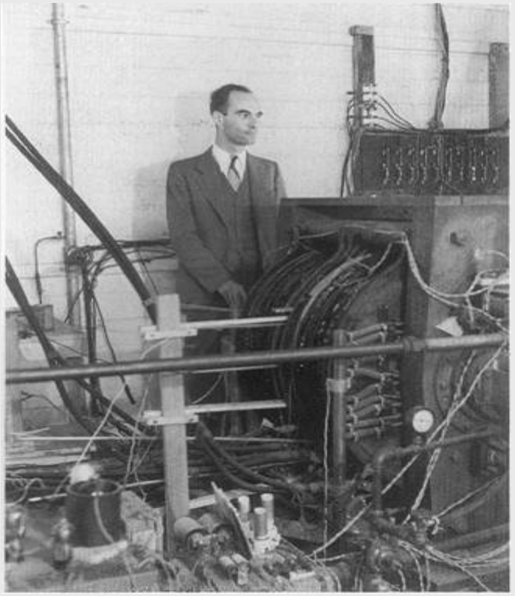
INFN Rome

for the AMS-02 Collaboration

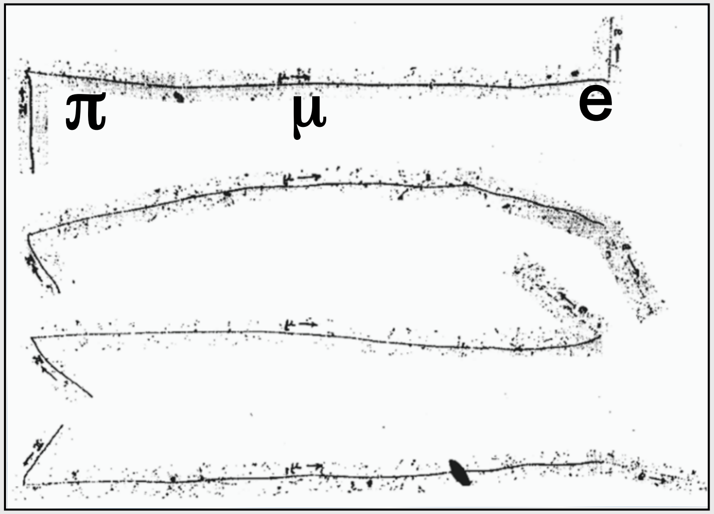
Fundamental discoveries from charged Cosmic Rays…



1912: Discovery of Cosmic Rays



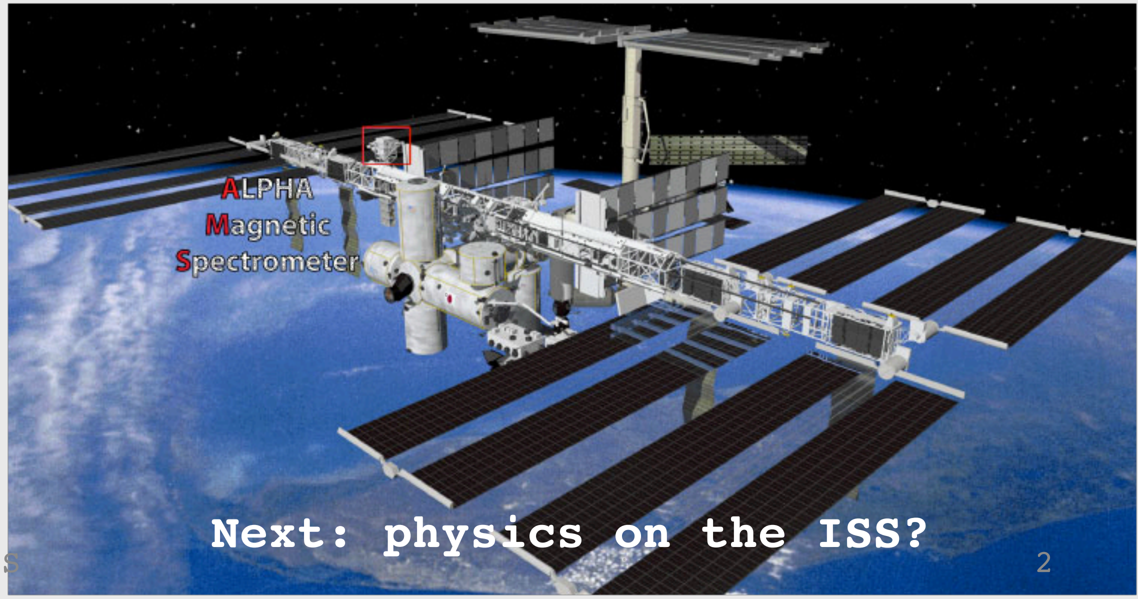
1932: Discovery of positron



1947: Discovery of pions

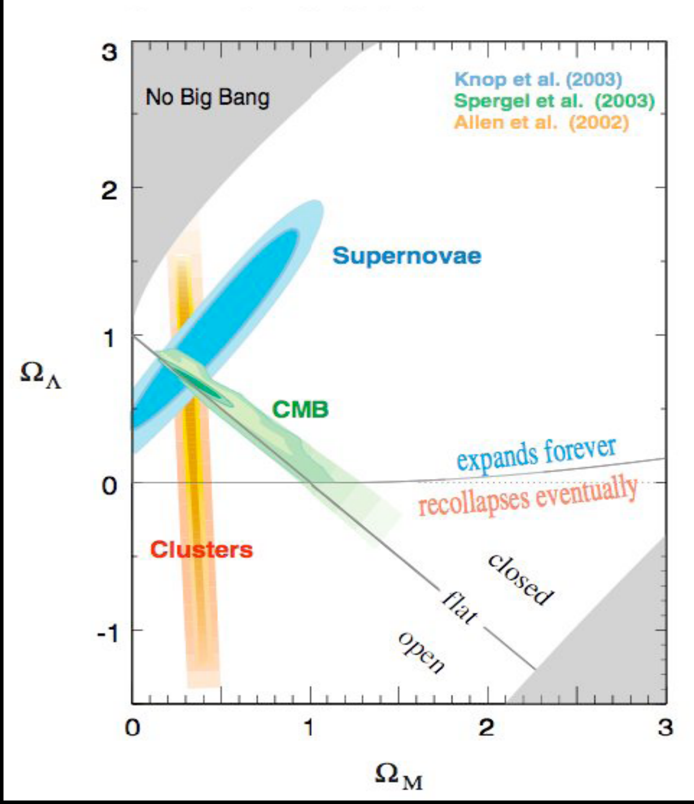
Discoveries of

- **1936: Muon (μ)**
- **1949: Kaon (K)**
- **1949: Lambda (Λ)**
- **1952: Xi (Ξ)**
- **1953: Sigma (Σ)**



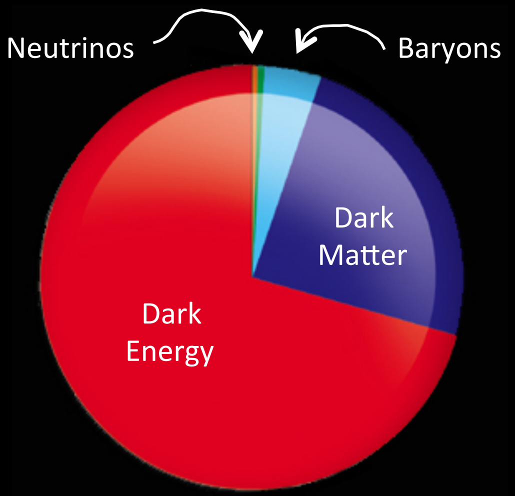
Next: physics on the ISS?

Precision cosmology…



The "Standard" cosmological model describes a Universe composed of

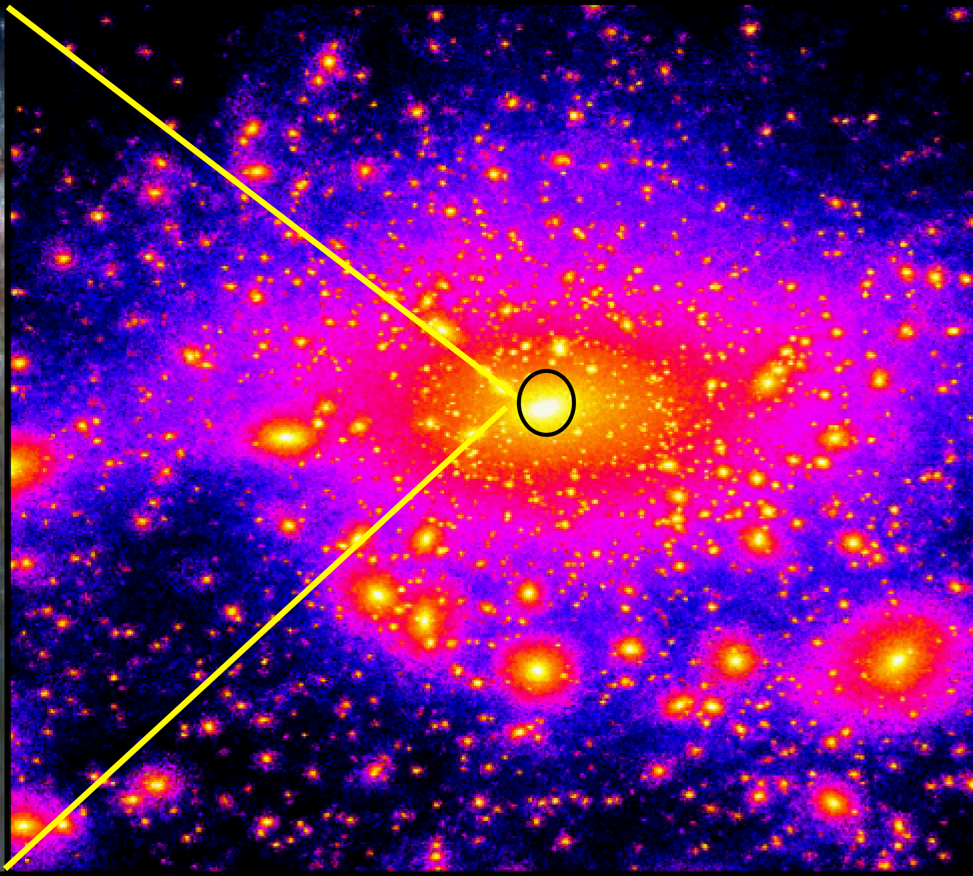
Ordinary matter and radiation	4 %
Cold Dark matter	23 %
Dark energy	73 %
Antimatter	$< 10^{-6}$ matter



Scientific goals of AMS: the origin of Dark Matter

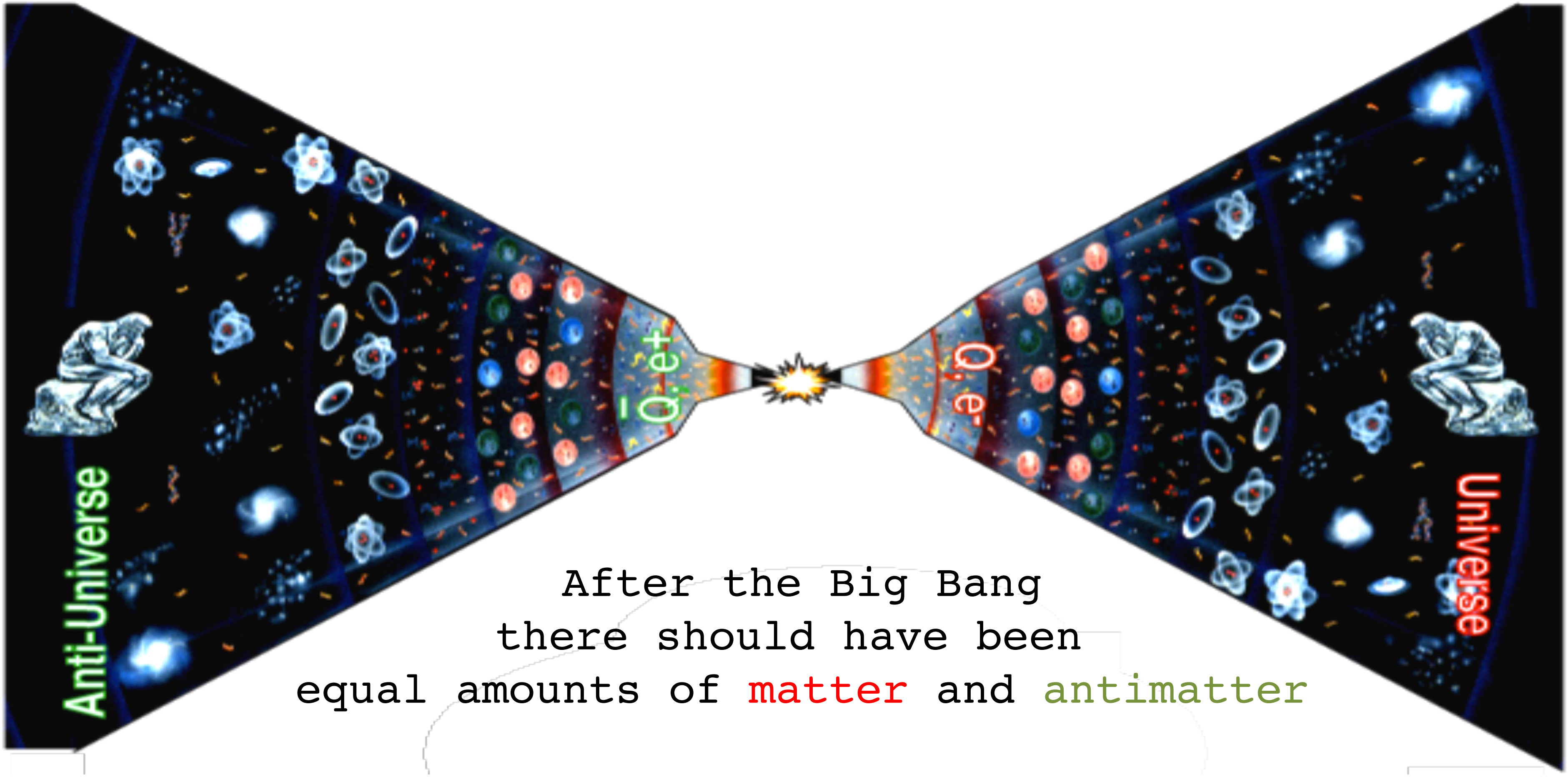
~ 90% of Matter in the Universe is not visible

A Galaxy as seen by telescope



If we could see Dark Matter in the Galaxy

Scientific goals of AMS: search for Cosmic Antimatter

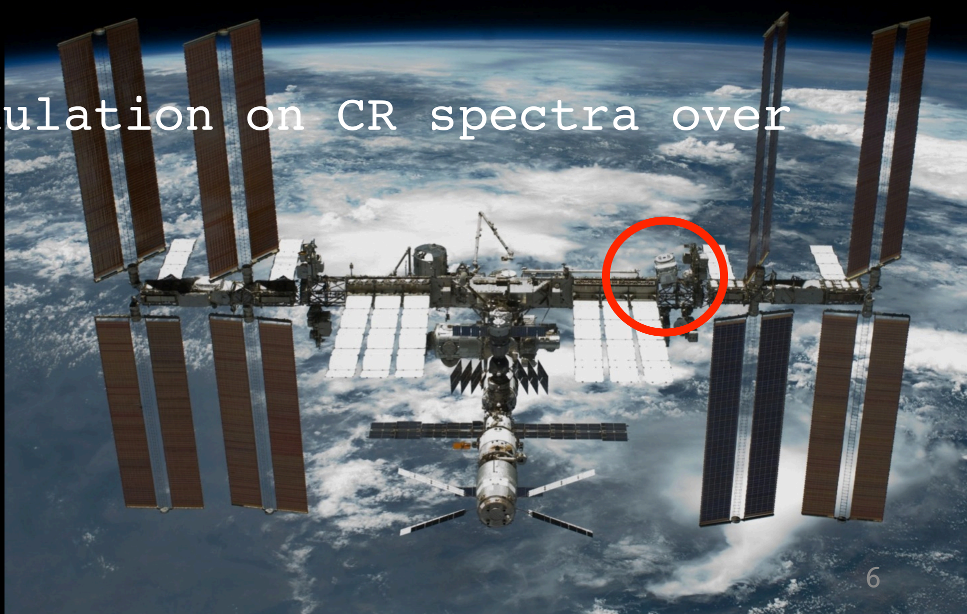


After the Big Bang
there should have been
equal amounts of matter and antimatter

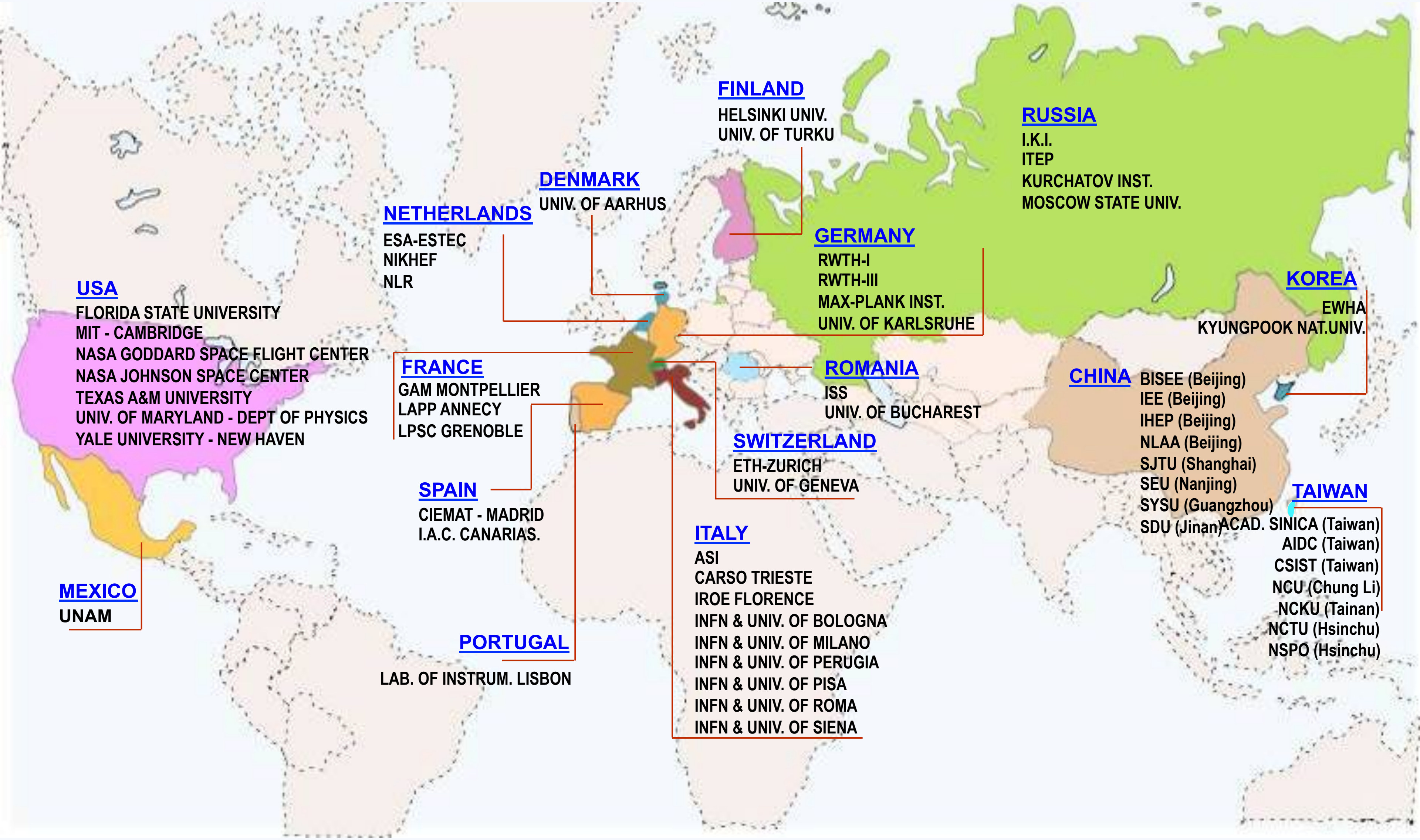
AMS on the Space Station for 10-20 years will search for the existence of antimatter to 1000 Mpc distance

Scientific goals of AMS on the International Space Station

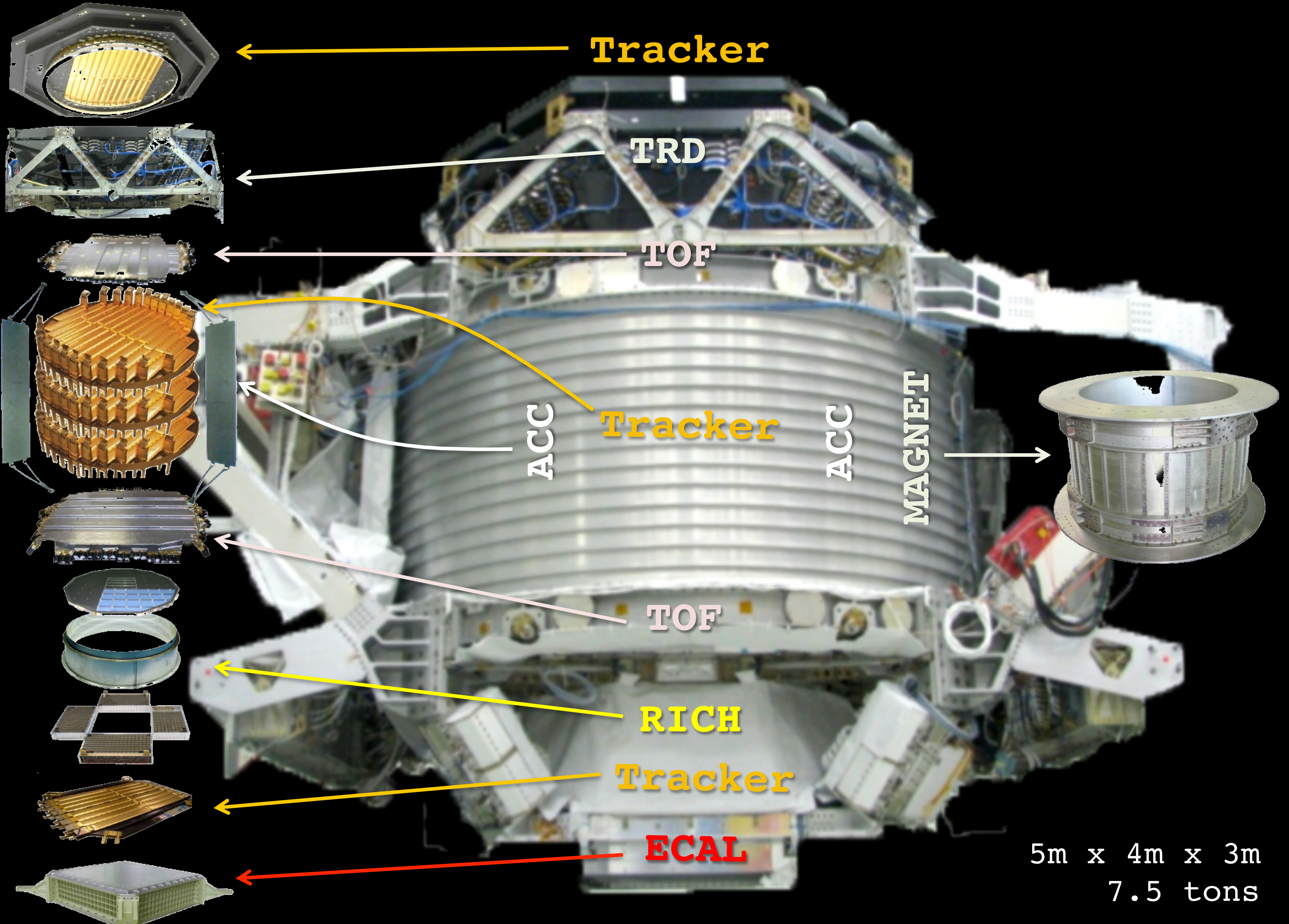
- Searches for primordial antimatter:
  - Anti-nuclei: $\overline{He}$, $\overline{C}$, …
- Dark Matter searches:
  - e^+ , $e^\pm$, $\bar{p}$, …
  - simultaneous observation of several signal channels
- Searches for new forms of matter:
  - strangelets, …
- Measuring CR spectra – refining propagation models;
- Identification of local sources of high energy photons (~TeV):
  - SNR, Pulsars, PBH, …
- Study effects of solar modulation on CR spectra over 11 year solar cycle
- …



AMS international collaboration
16 Countries, 60 Institutes and 600 Physicists, 17 years



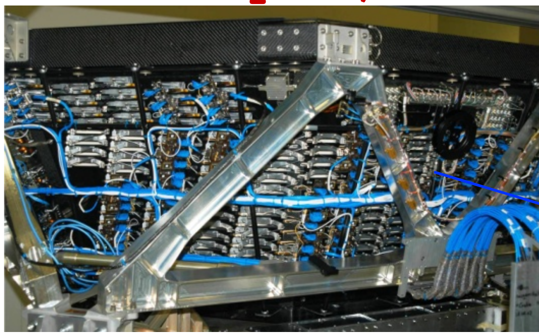
The detectors and electronics were built all over the world and assembled at CERN, Switzerland.



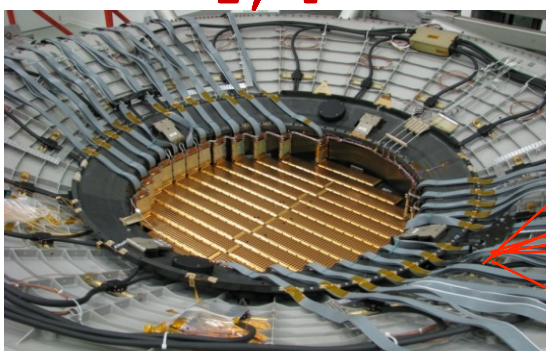
5m x 4m x 3m
7.5 tons

A TeV precision, multipurpose spectrometer

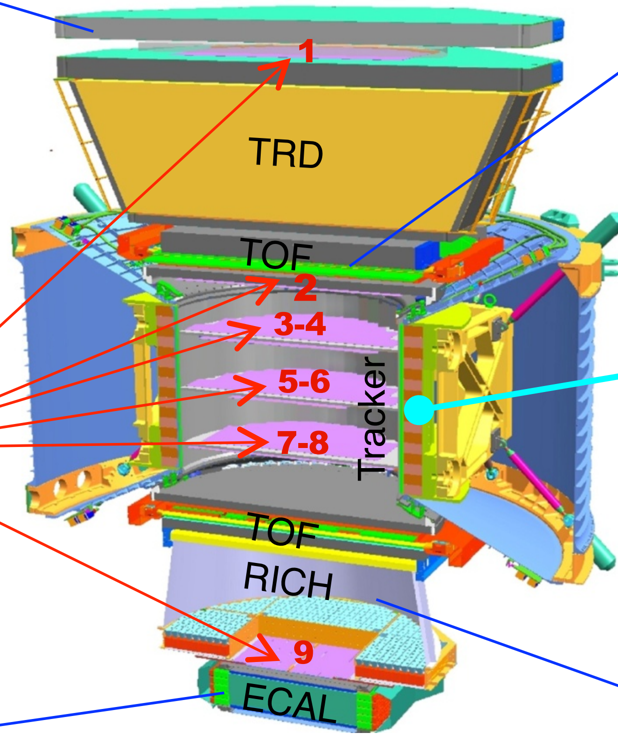
TRD
Identify e^+, e^-



Silicon Tracker
Z, P

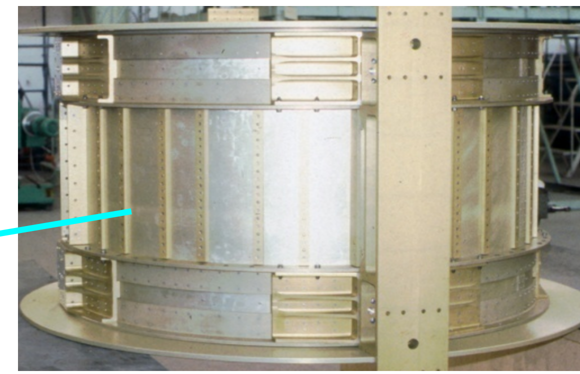


ECAL
E of e^+, e^-, γ

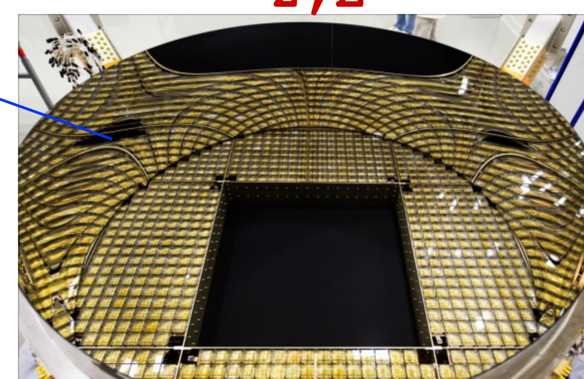


TOF
Z,E

Magnet
±Z



RICH
Z,E



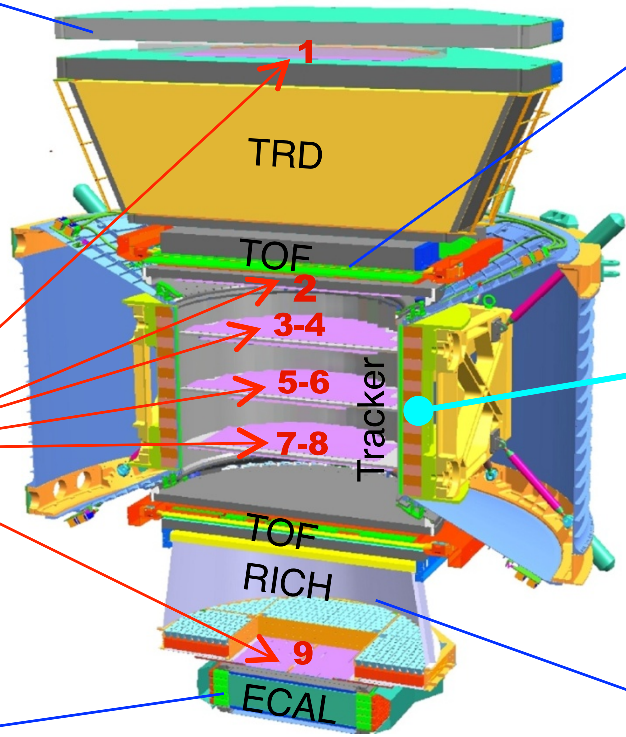
Z, P
are measured independently by Tracker, RICH, TOF and ECAL

A TeV precision, multipurpose spectrometer

TRD
Identify e^+, e^-
- 20 layer radiator/straw tubes
- Xe/CO_2 80%/20% gas
- 5284 channel

Silicon Tracker
Z, P
- 9 layer double sided detector
- 192000 high dyn. range readout channel
- low material budget

ECAL
E of e^+, e^-, γ
- 3D sampling calorimeter
- 17 X_0
- 9 superlayer lead/fibers
- 324 MAPMT
- 2916 channels



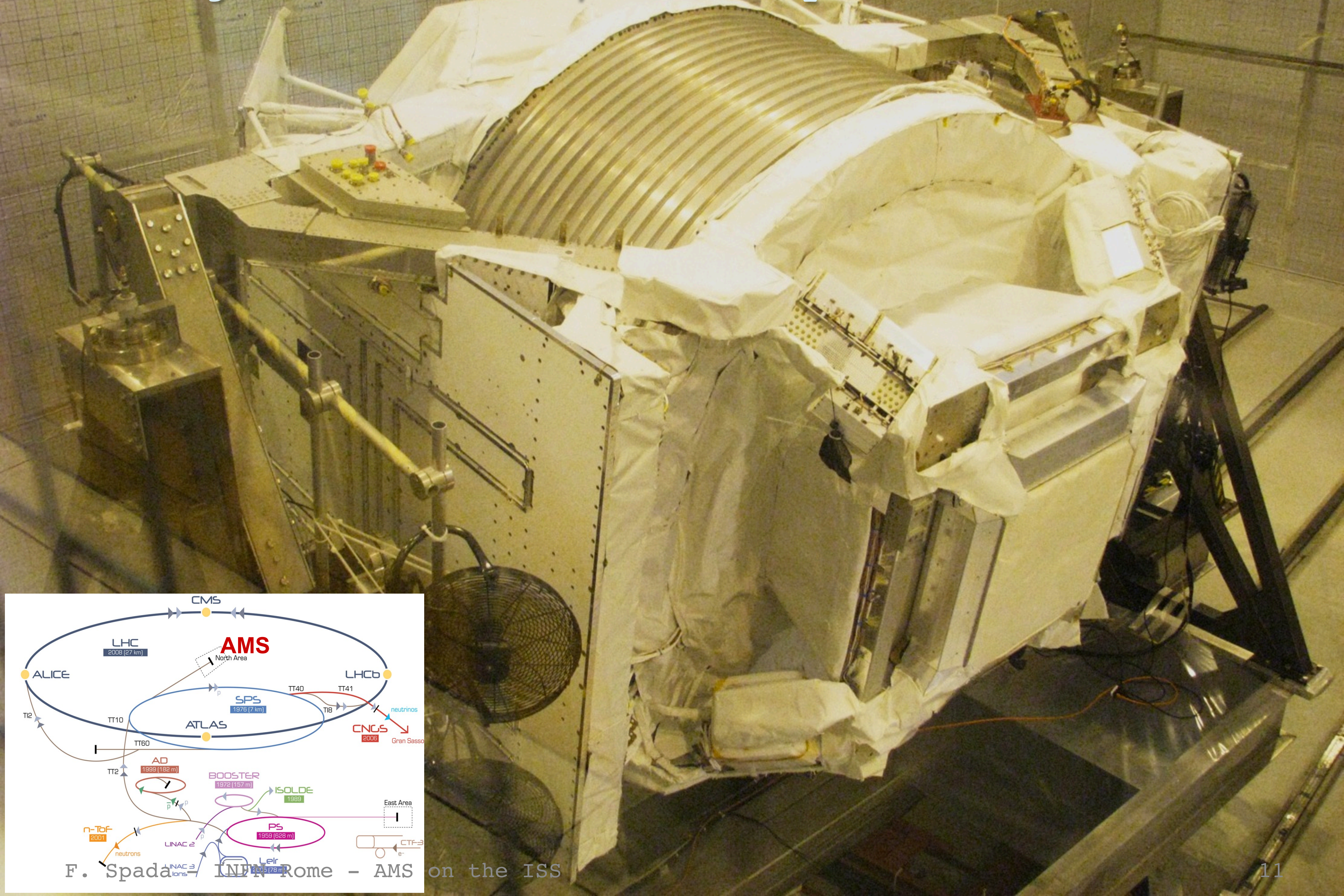
TOF
Z,E
- 4 layer scintillators
- 48 PM
- 1536 channels

Magnet
±Z
- B ~ 0.14 Tesla
- 4000 Nd-Fe-B blocks 1inx2inx1in
- 1900 Kg

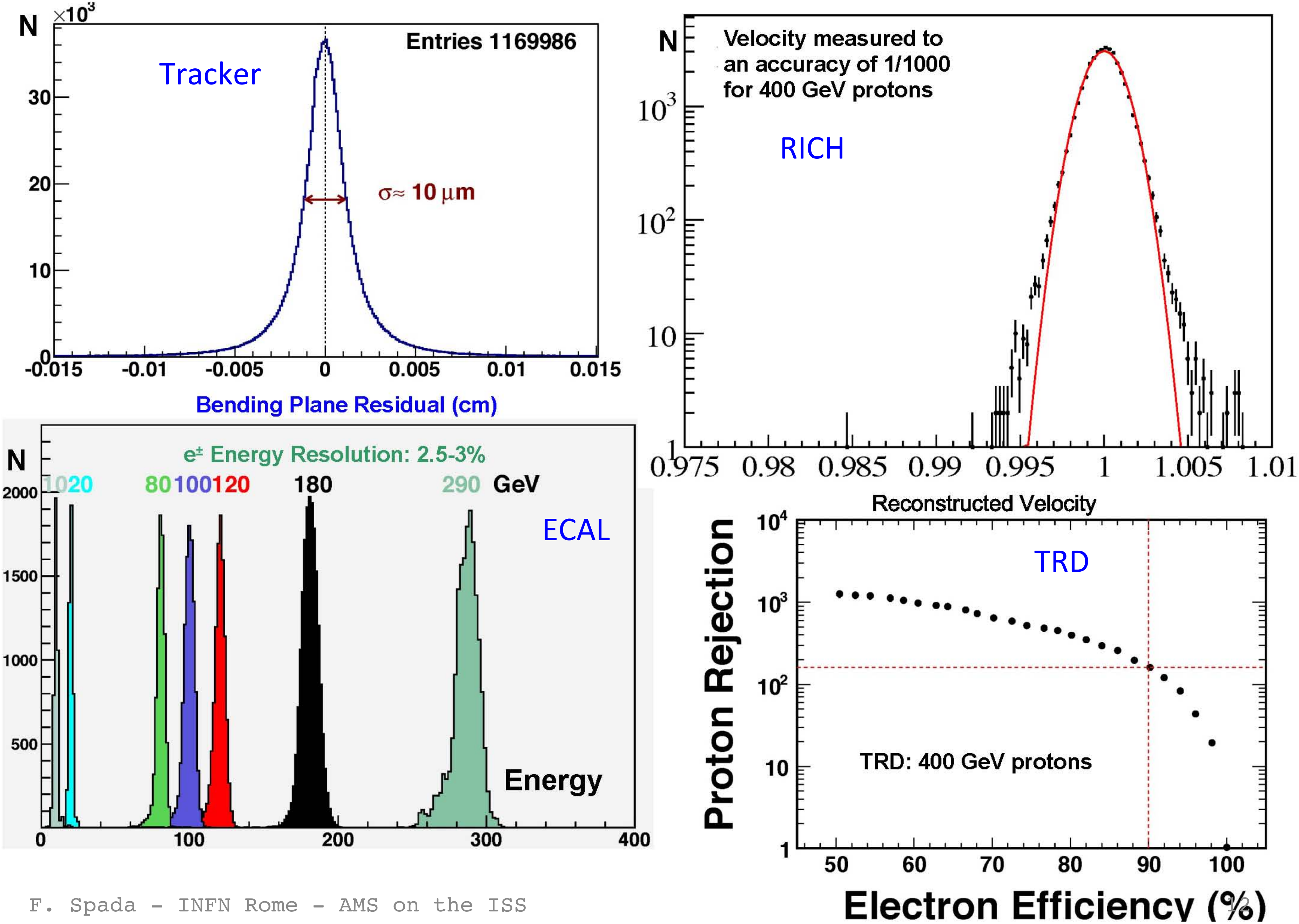
RICH
Z,E
- Areogel and NaF radiator
- 680 MAPMT
- 21726 channels

MDR = 2 TV
e/p separation > 10^6

AMS in Test Beam at CERN with permanent magnet 8–20 Aug 2010 with e^+, e^- and protons



Test Beam results with permanent magnet



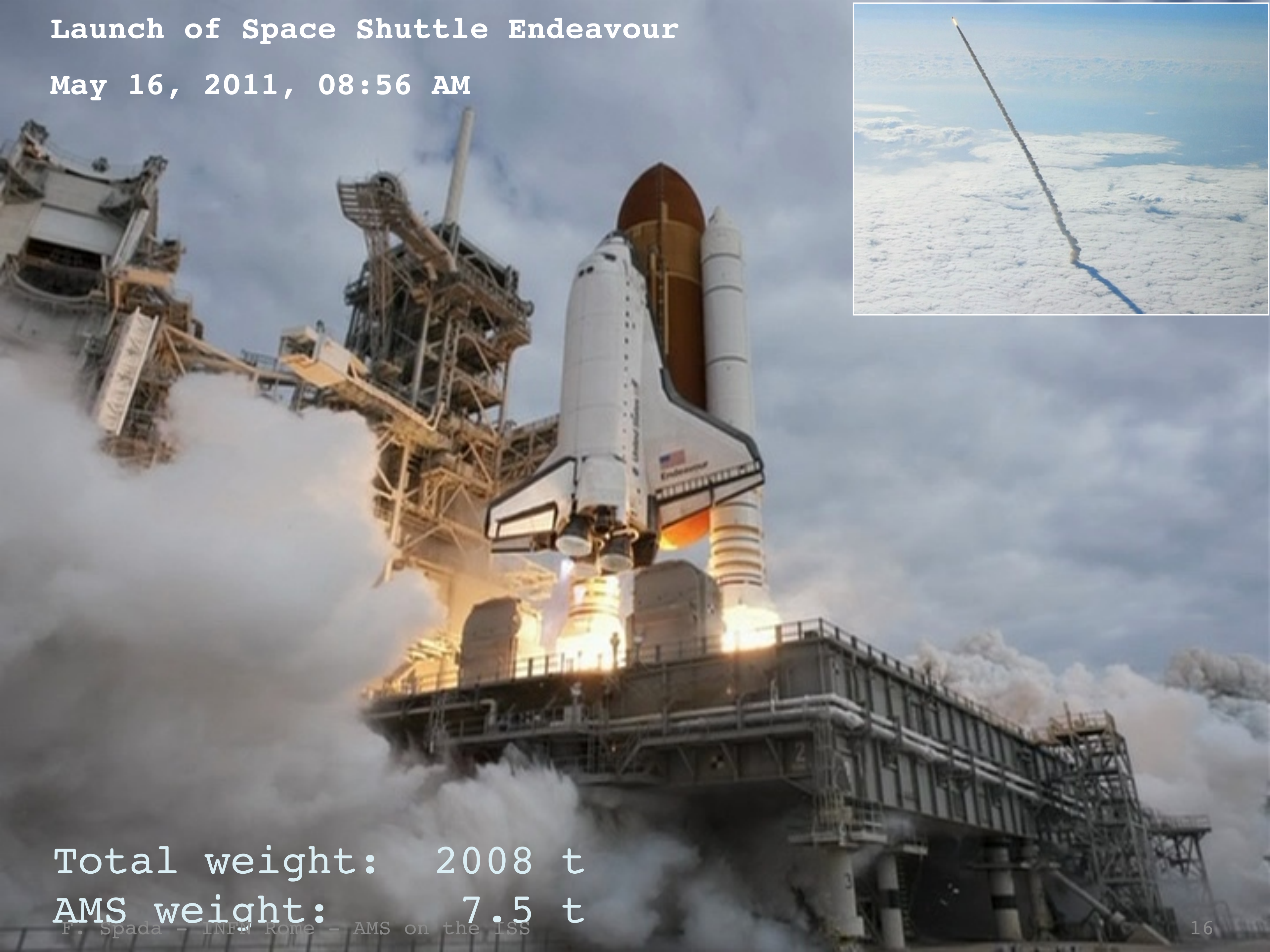
A US-AirForce C-5 Galaxy has been used for transport from Geneva to KSC - August 25th 2010


AMS

Closing Endeavour's Payload Bay Doors at the Launch Pad

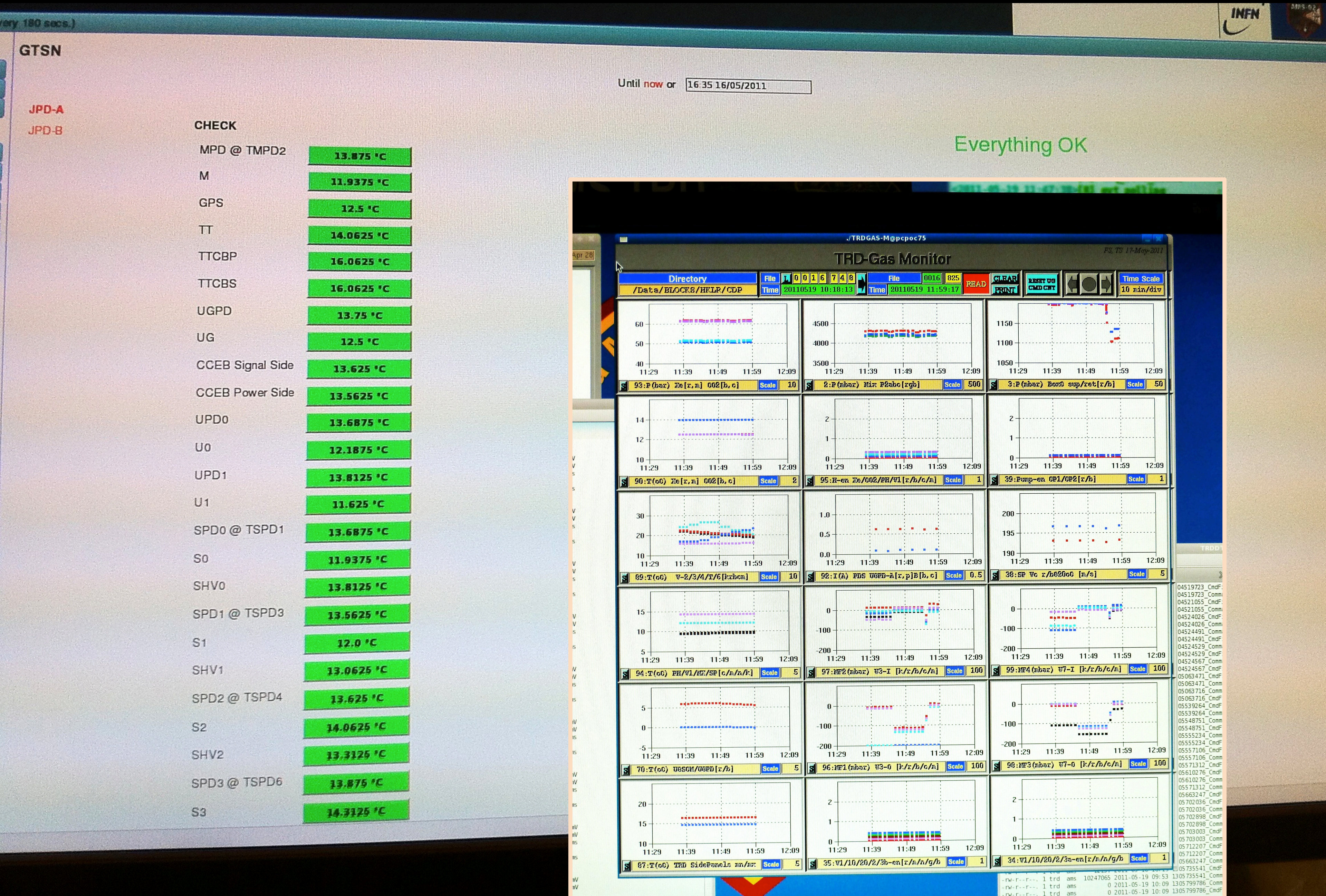
Launch of Space Shuttle Endeavour

May 16, 2011, 08:56 AM



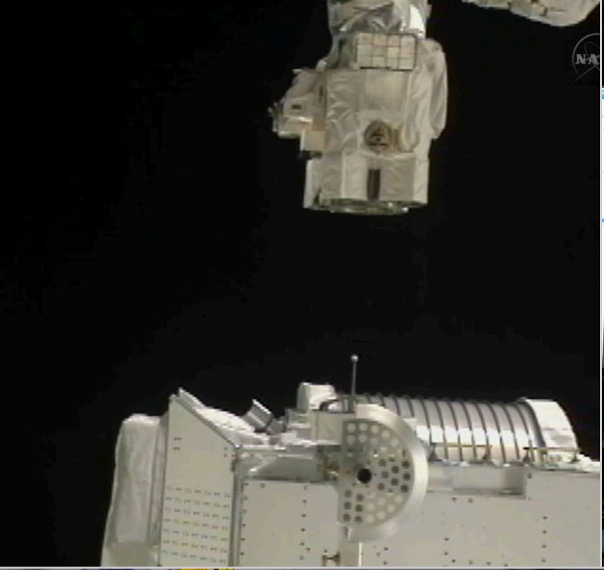
Total weight: 2008 t
AMS weight: 7.5 t

First SlowControl data 2.5 h after the launch



Endeavour approaches the International Space Station

From Shuttle to ISS



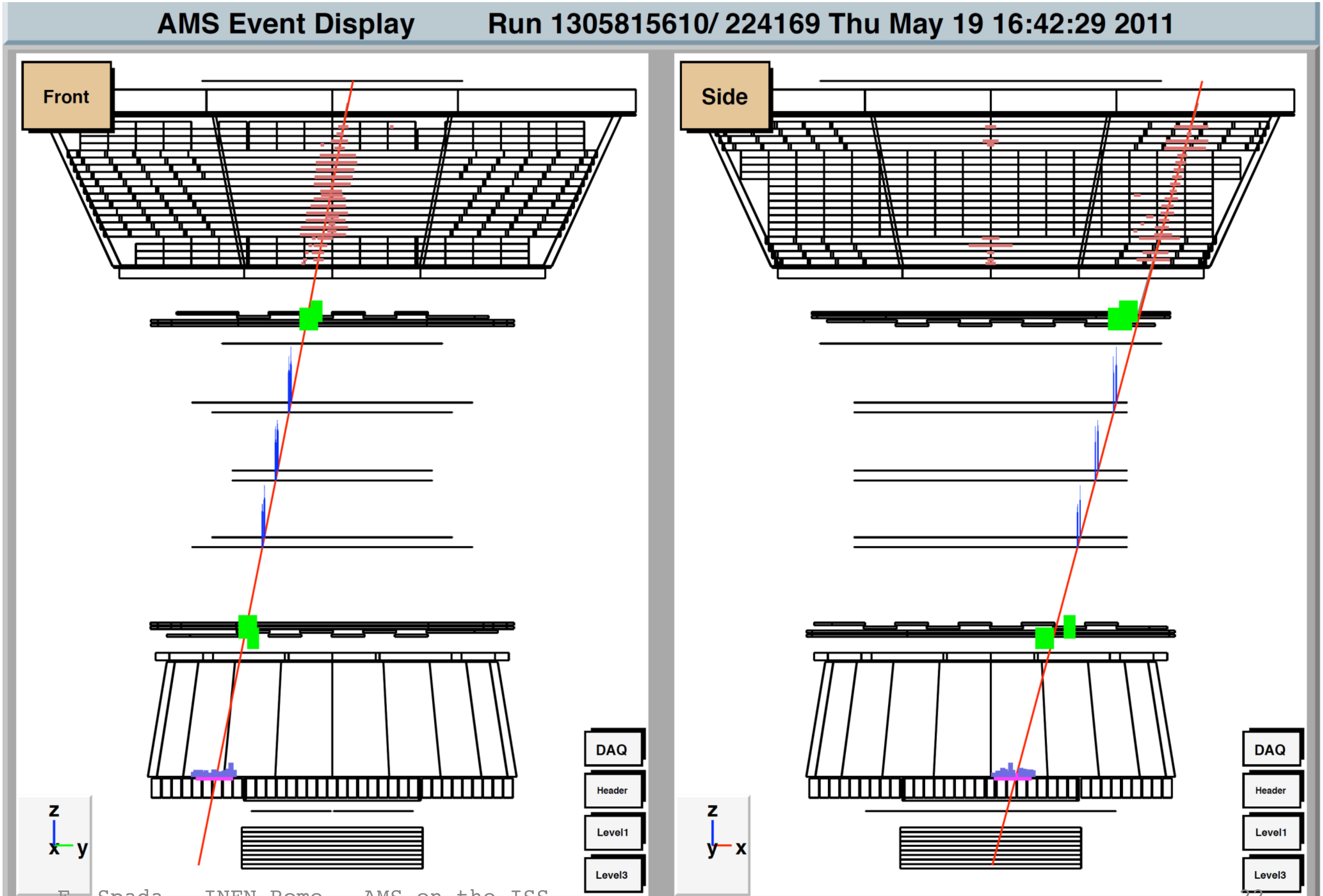

JAXA


AMS


AMS Liaison
AMS Thermal

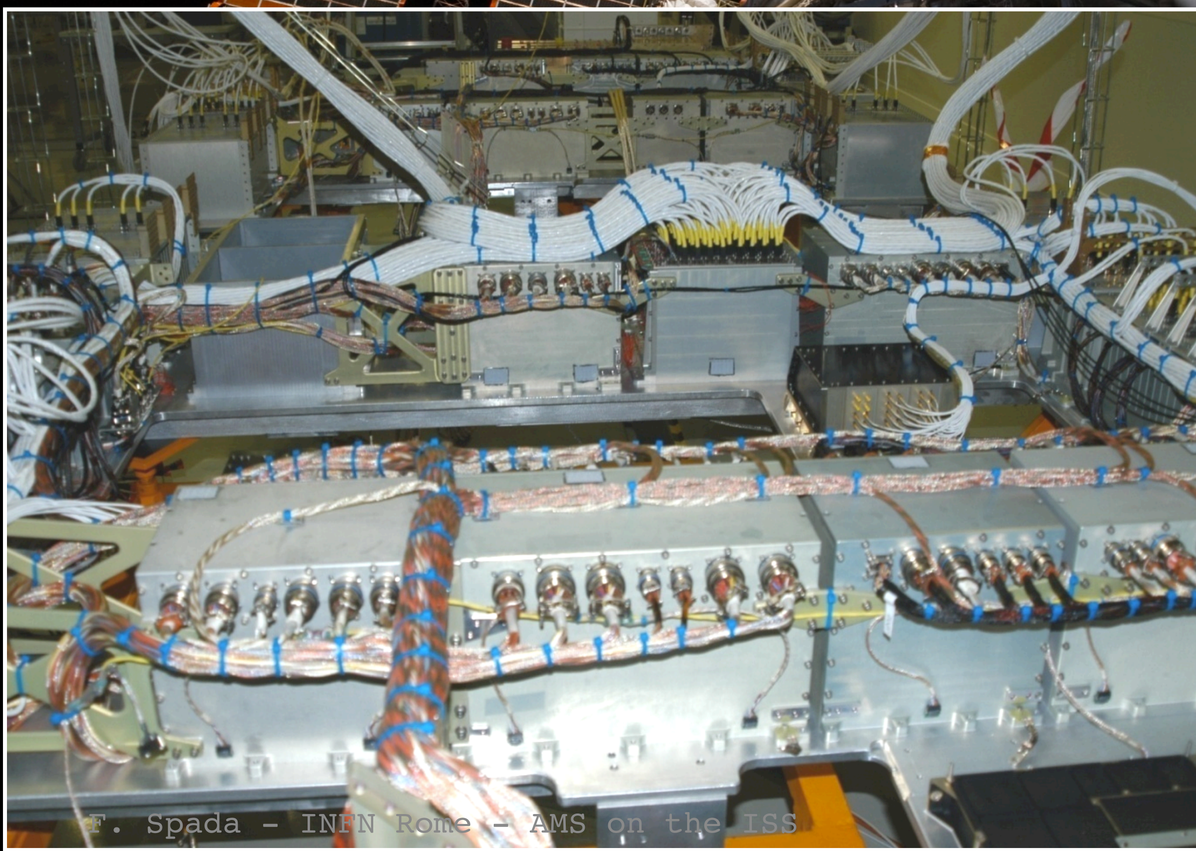
May 19: AMS installation completed at 5:15 AM
Data taking started at 9:35 AM

Data from the first few minutes – 42 GeV/c Carbon



Johnson Space Center, May 19th 2011

AMS electronics on the ISS



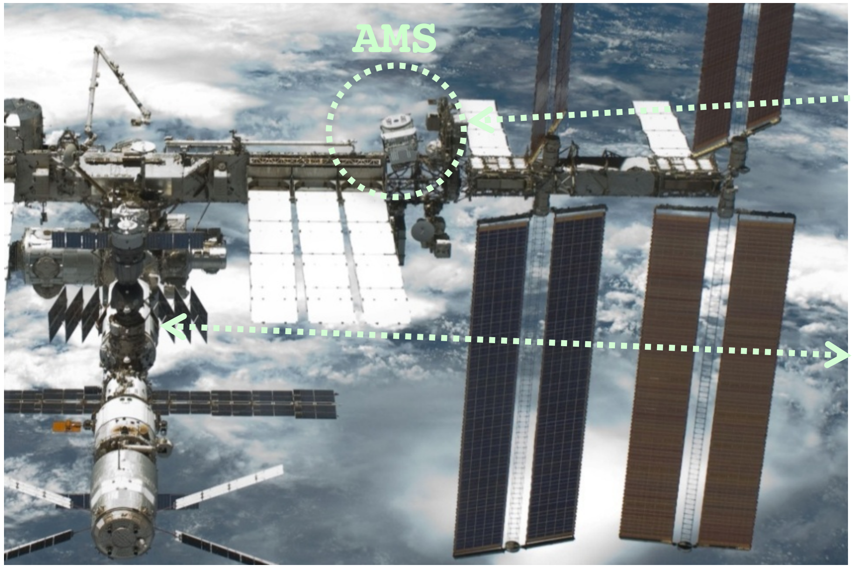
650 computers

300,000 channels

up to 400% redundancy

A ten year effort by 75 engineers

AMS Operations



Ku-Band
High Rate (down):
Events <10Mbit/s>

Flight Operations

Ground Operations

S-Band
Low Rate (up & down):
Commanding: 1 Kbit/s
Monitoring: 30 Kbit/s

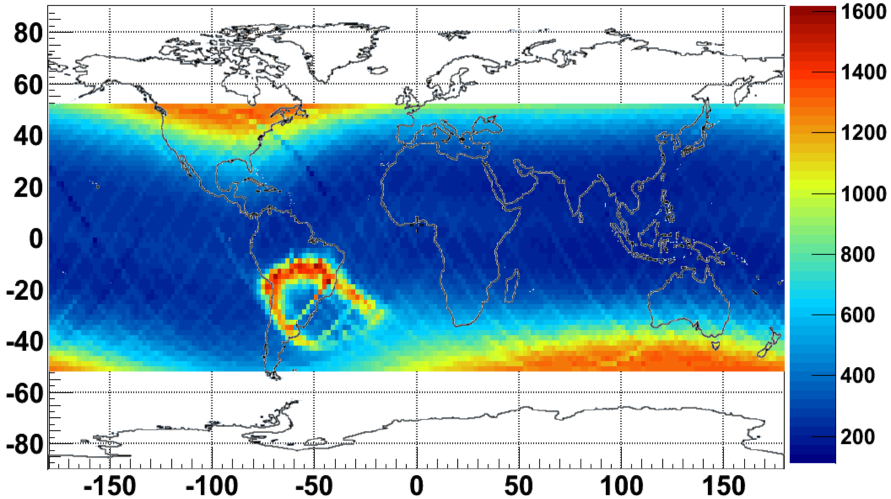
AMS Payload Operations Control (POCC) and Science Operations Centers (SOC) at CERN

AMS Computers at MSFC, AL

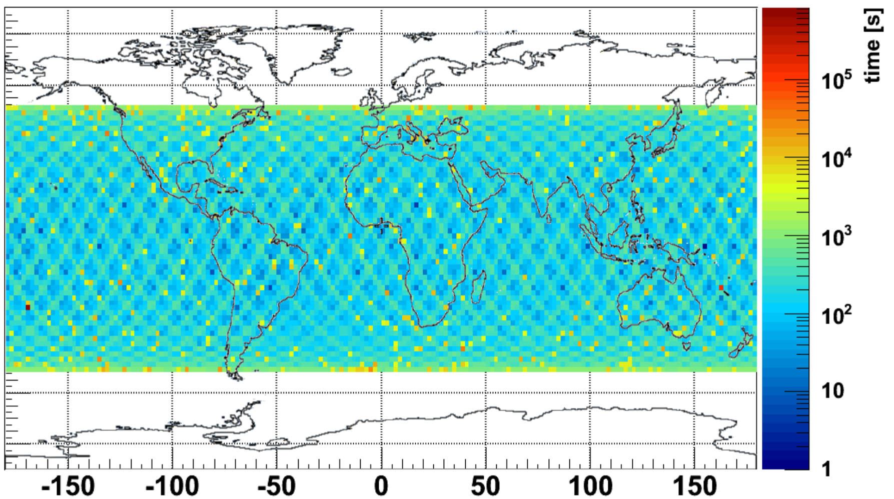
White Sands Ground Terminal, NM

Orbital DAQ parameters

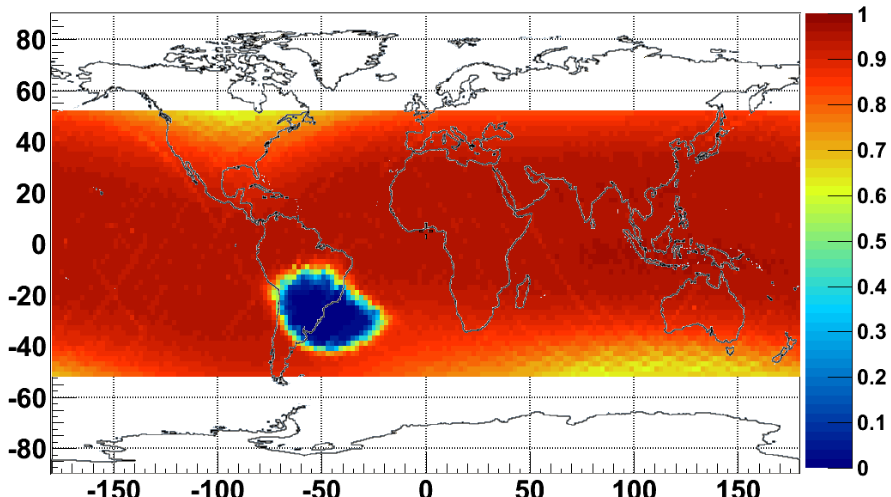
Acquisition rate [Hz]



Time at location [s]



DAQ efficiency



<u>Particle rates:</u>

from 200 to 2000 Hz per orbit

<u>On average:</u>

DAQ efficiency 85%

DAQ rate ~700Hz

<u>One year of data:</u>

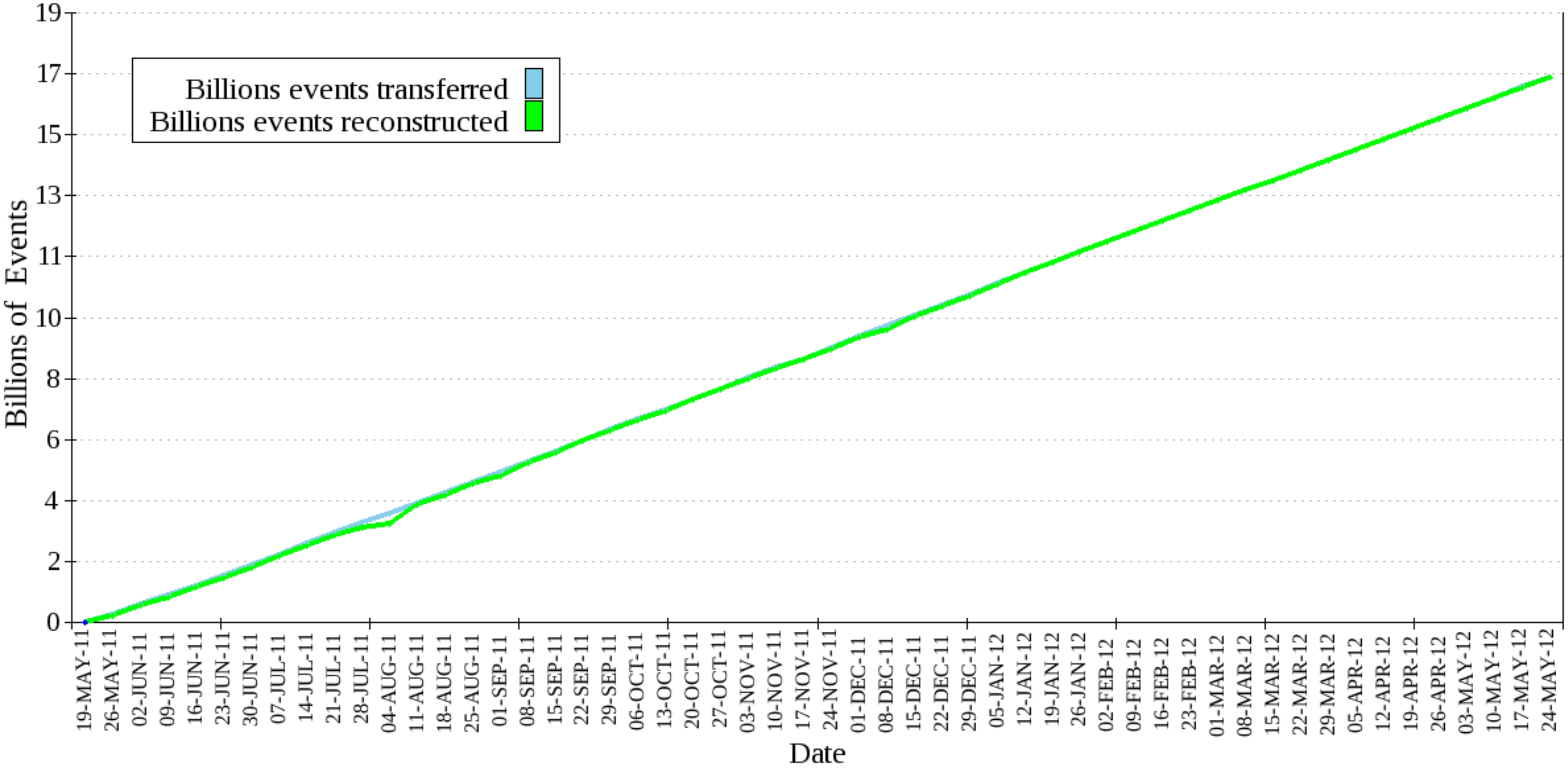
1.6 10^{10} events

35 TB raw events

The detectors function exactly as designed

AMS collected over 16 billion events over the first 12 months

Data taking has been continuously active except a few hours



Every year, we will collect $16*10^9$ events

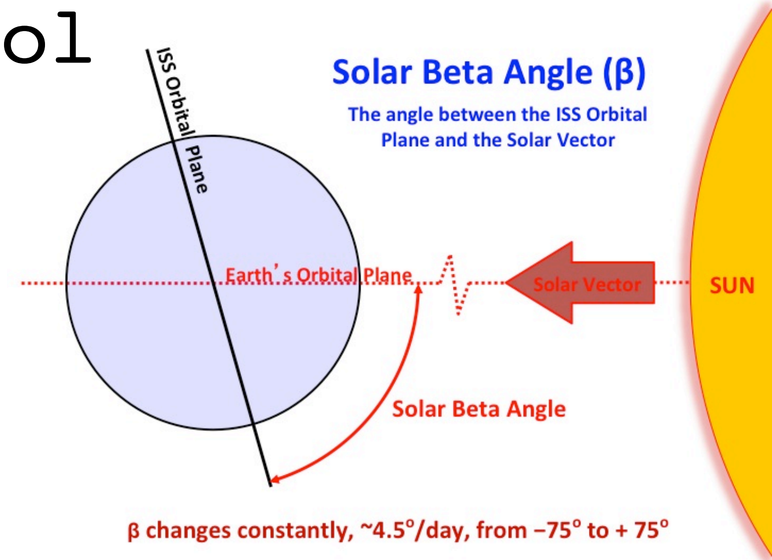
and in 10-20 years we will collect $160-320*10^9$ events

This will provide unprecedented sensitivity to search for new physics

On-orbit thermal control

The thermal environment on ISS is constantly changing due to:

- Solar Beta Angle (β)
- Position of the ISS Radiators and Solar Arrays
- ISS Attitude

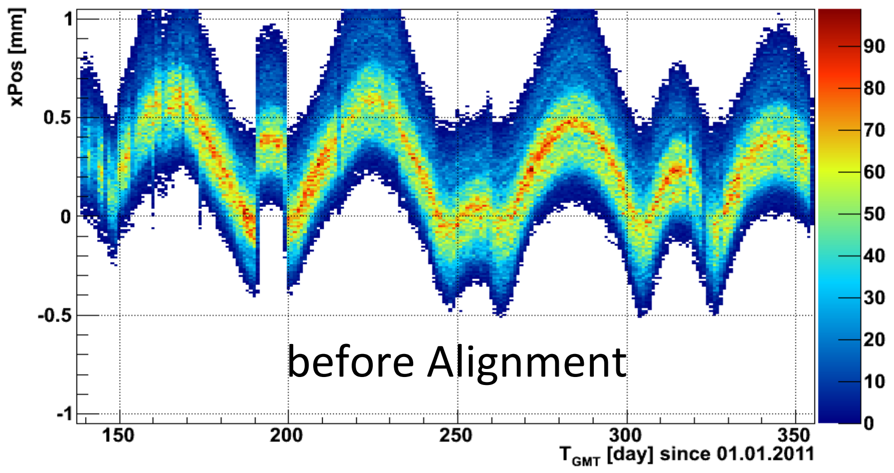


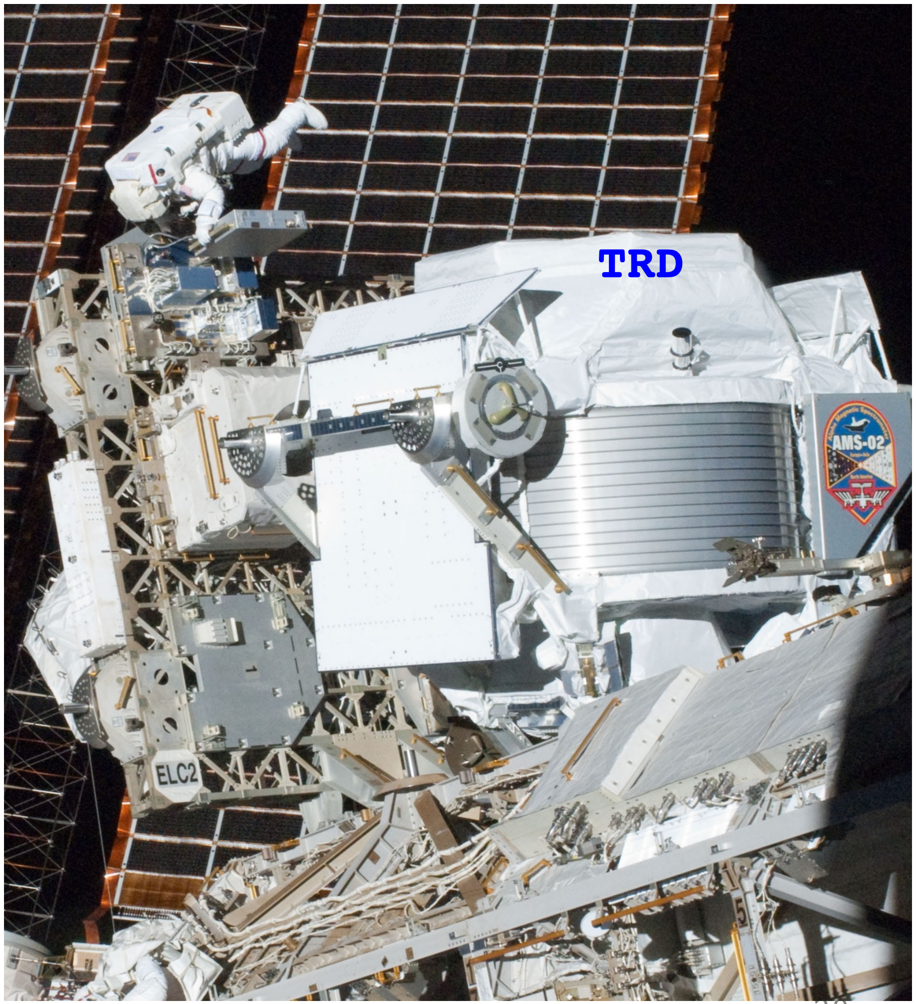
Over 1,100 temperature sensors and 298 heaters are monitored around the clock in the AMS POCC to assure components stay within thermal limits and avoid permanent damage

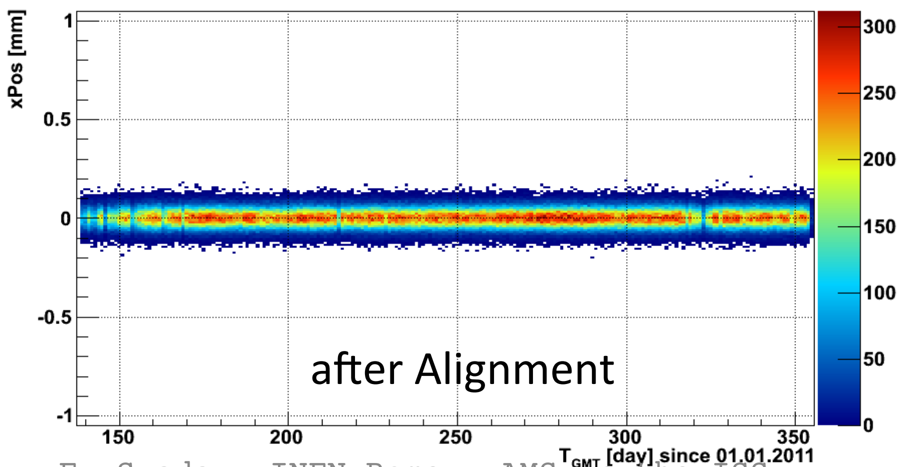
Flight operation: TRD performance

Due to temperature variations the TRD is moving on top of the inner tracker by up to 1 mm.

We can use protons for alignment to an accuracy of 0.04 mm for each straw module.



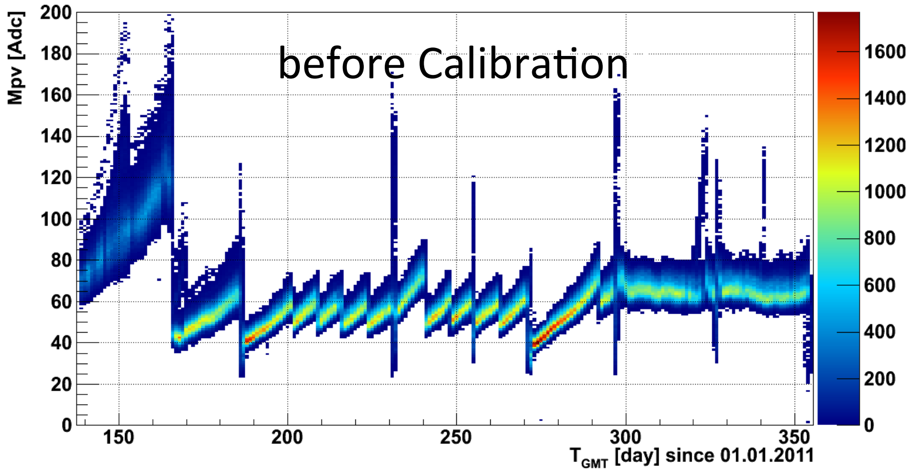


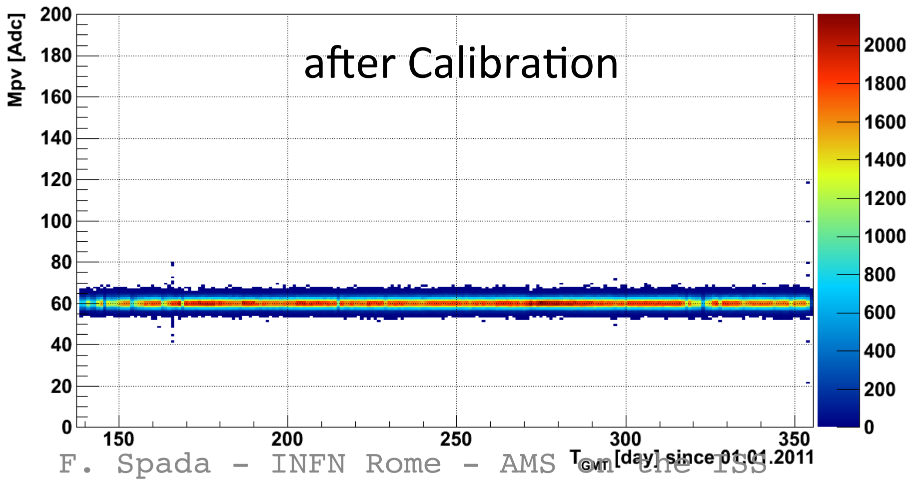


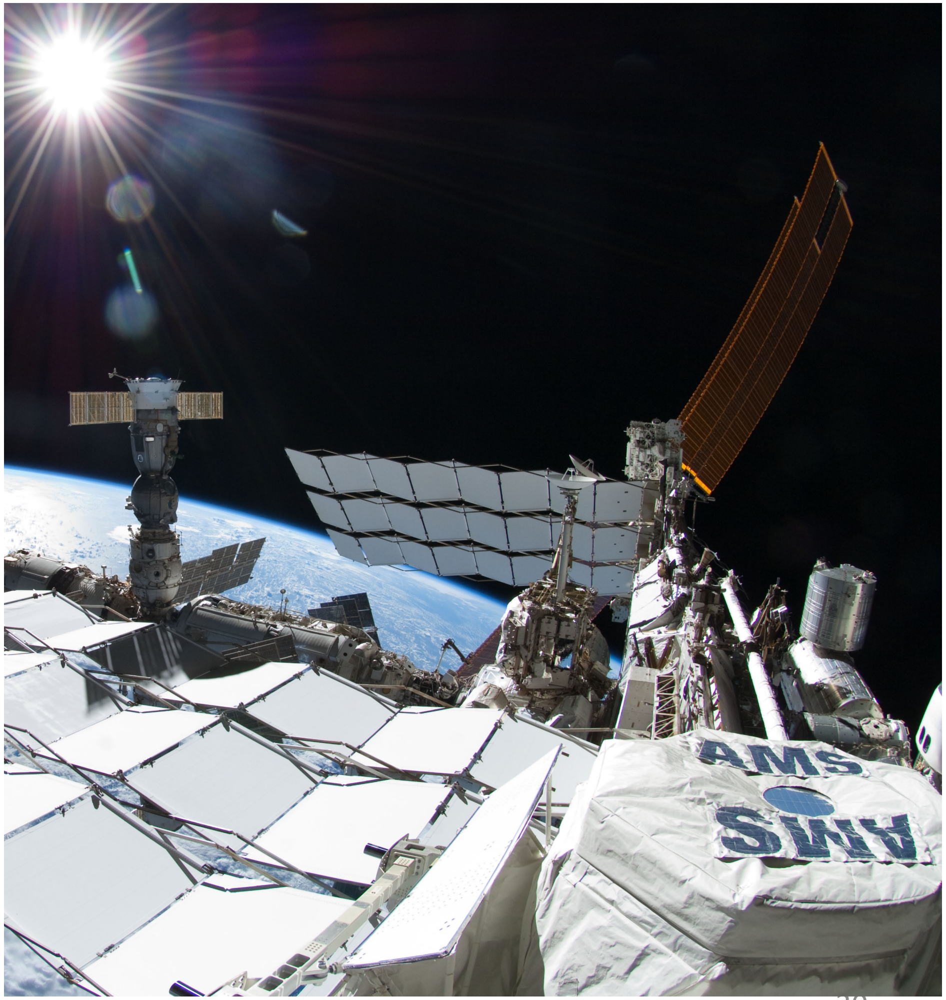
Flight operation: TRD performance

Due to temperatue, pressure, gas composition and HV changes the TRD detector response is changing

We can use cosmic ray protons to calibrate the detector response to 3% accuracy

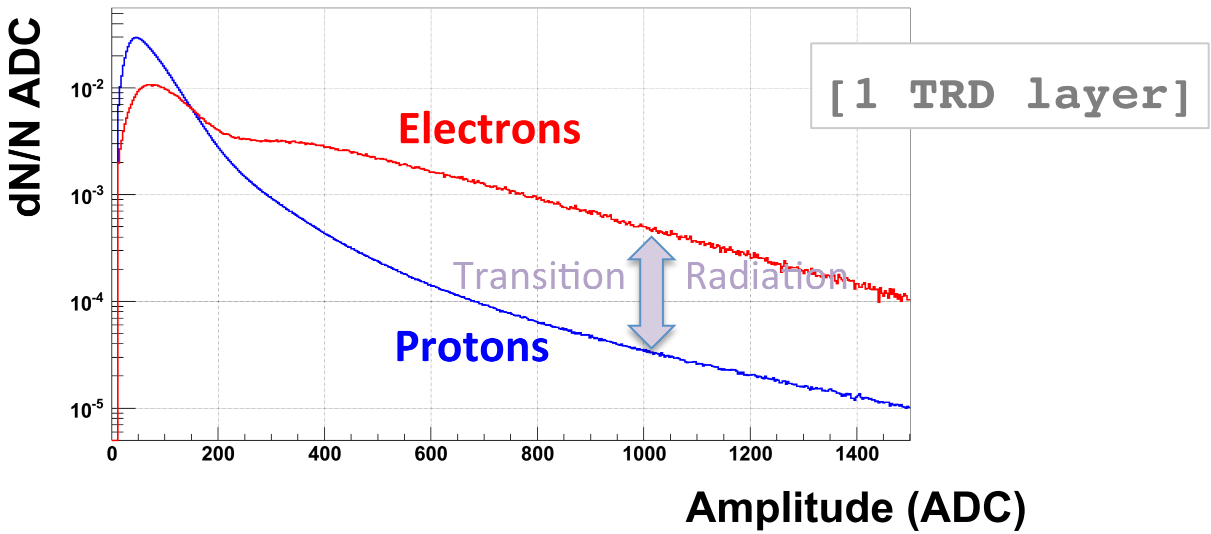


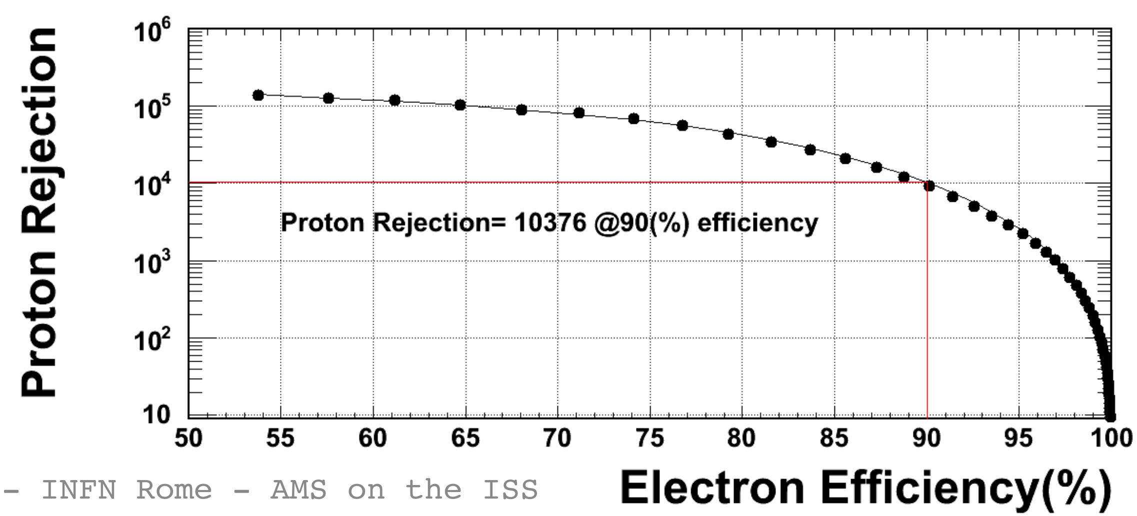




Flight operation: TRD performance

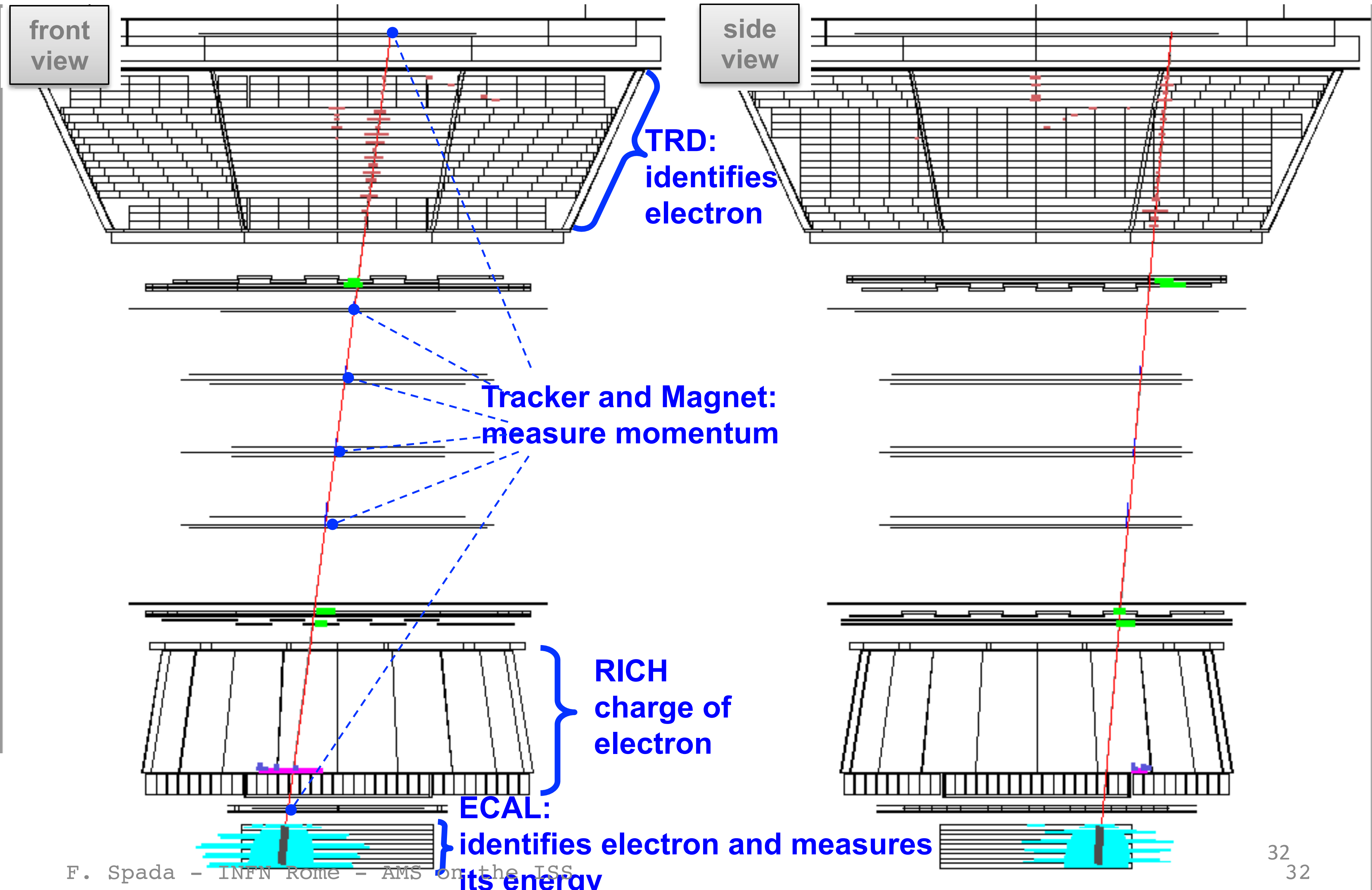
We can use the AMS Tracker and ECAL to define clean Electron and Proton samples and study the TRD response in Space and determine the particle identification power from space data directly!





AMS Flgiht data on high-energy $e^{\pm}$

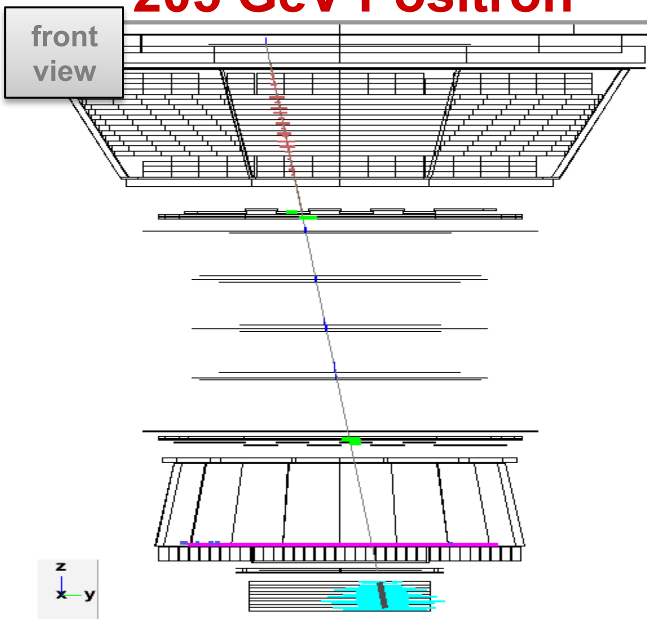
1.03 TeV electron



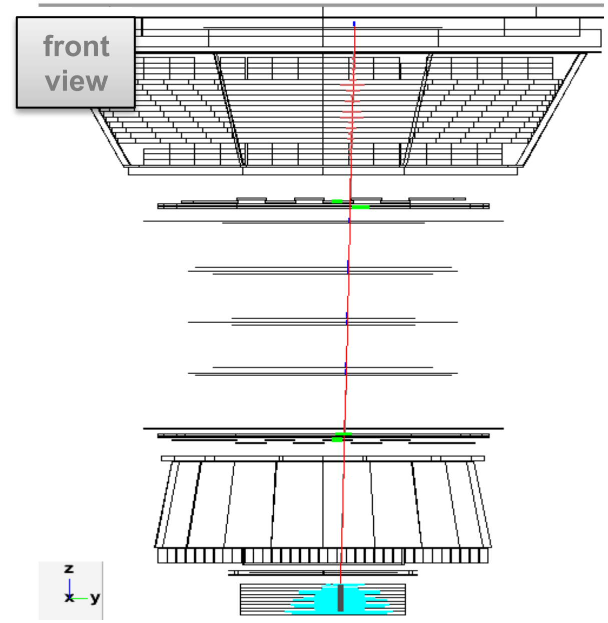
32

AMS Flight data on high-energy $e^{\pm}$

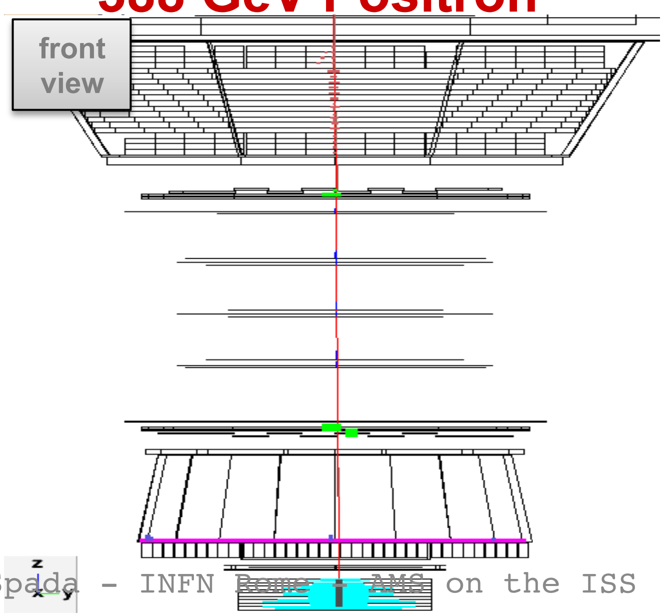
205 GeV Positron



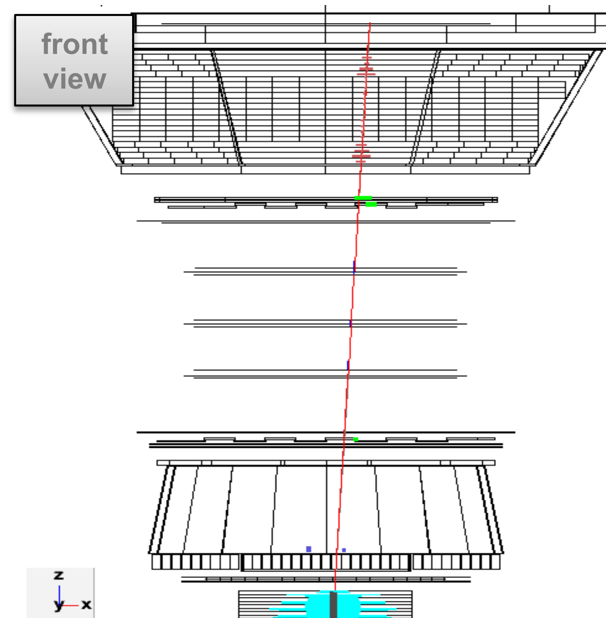
369 GeV Positron



388 GeV Positron

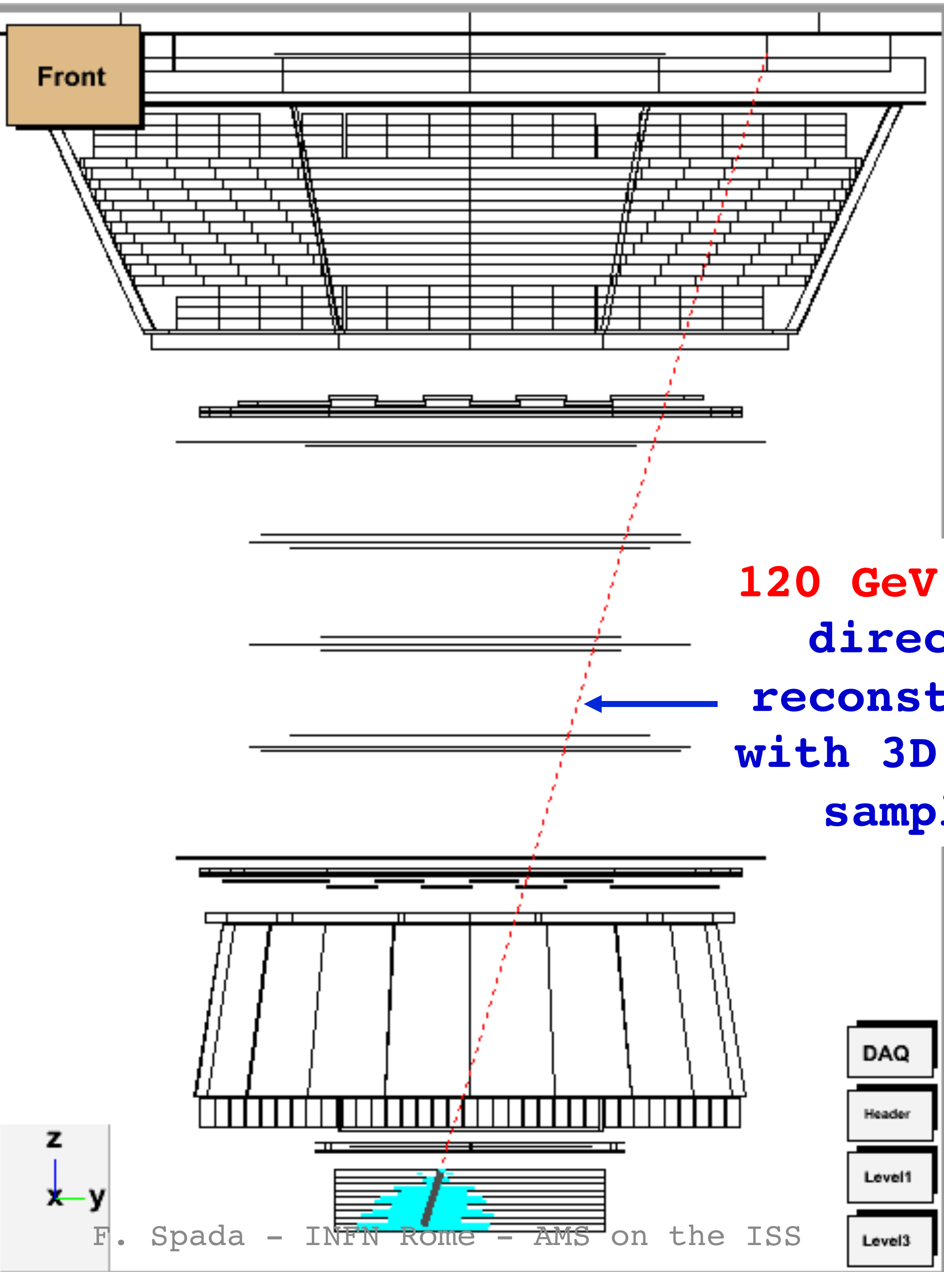


424 GeV Positron

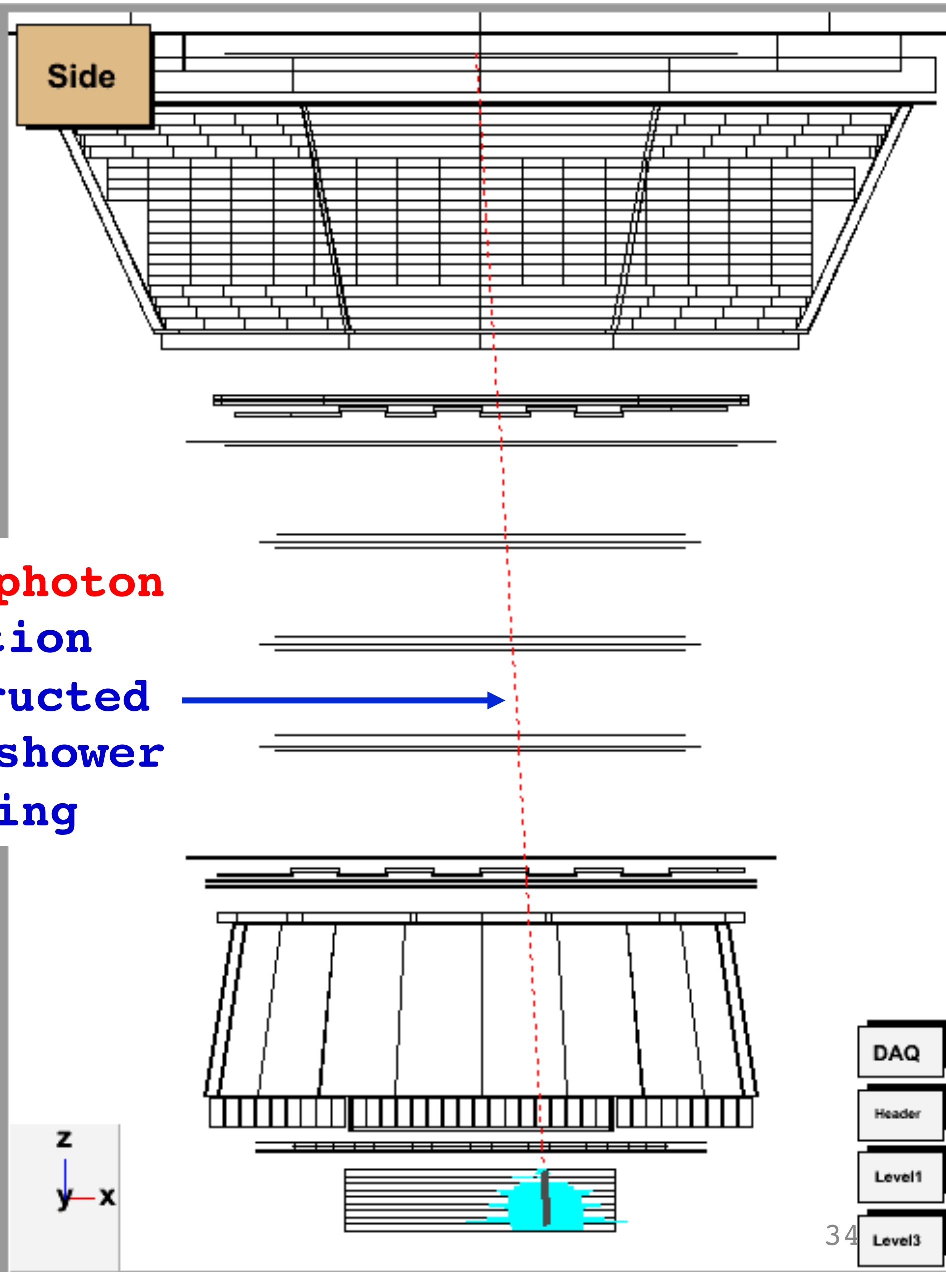


AMS Fligth data: 120 GeV Photon

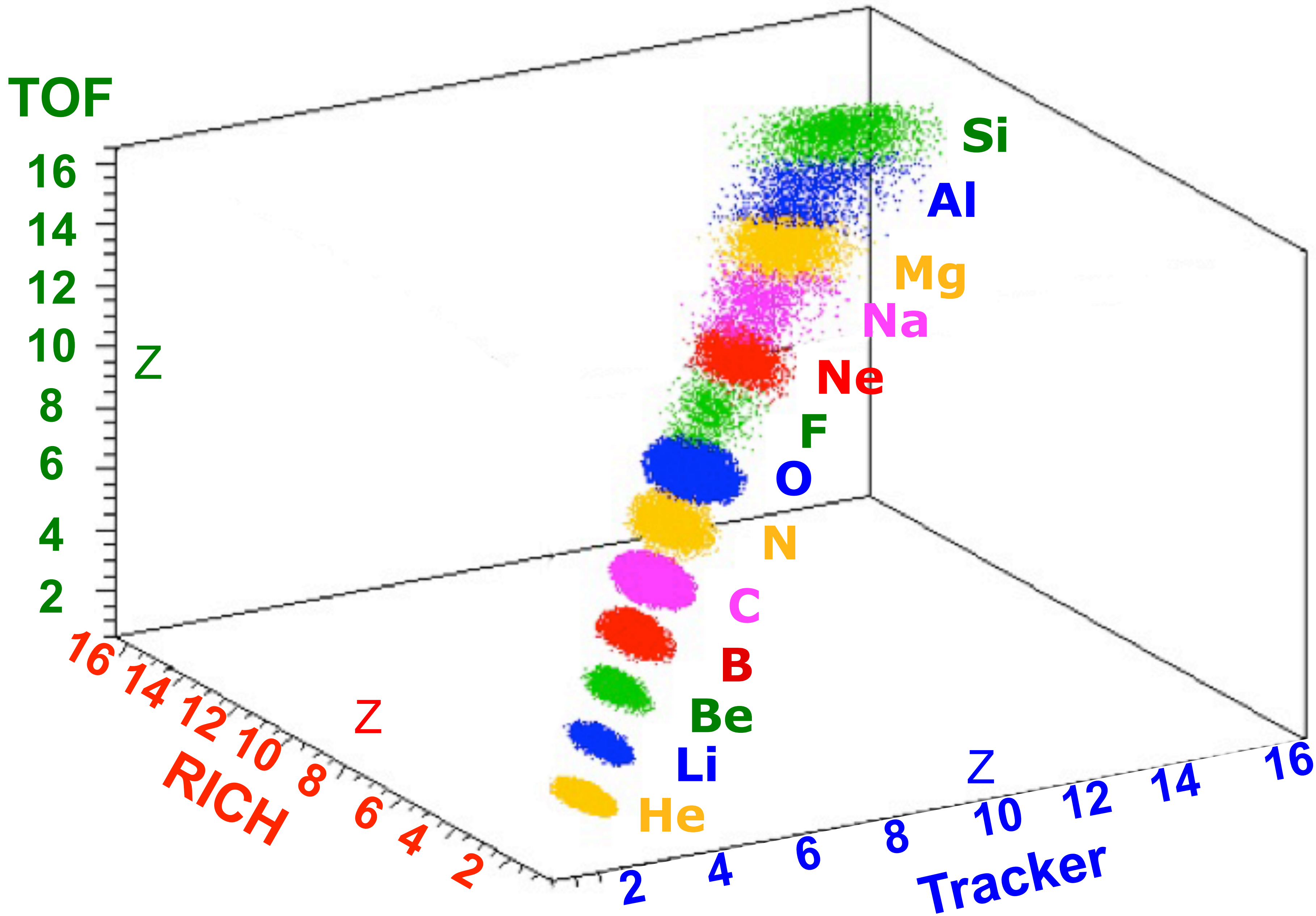
Unique Features: 17 X_0, 3D ECAL, measure γ to 1 TeV, time resolution 1μs



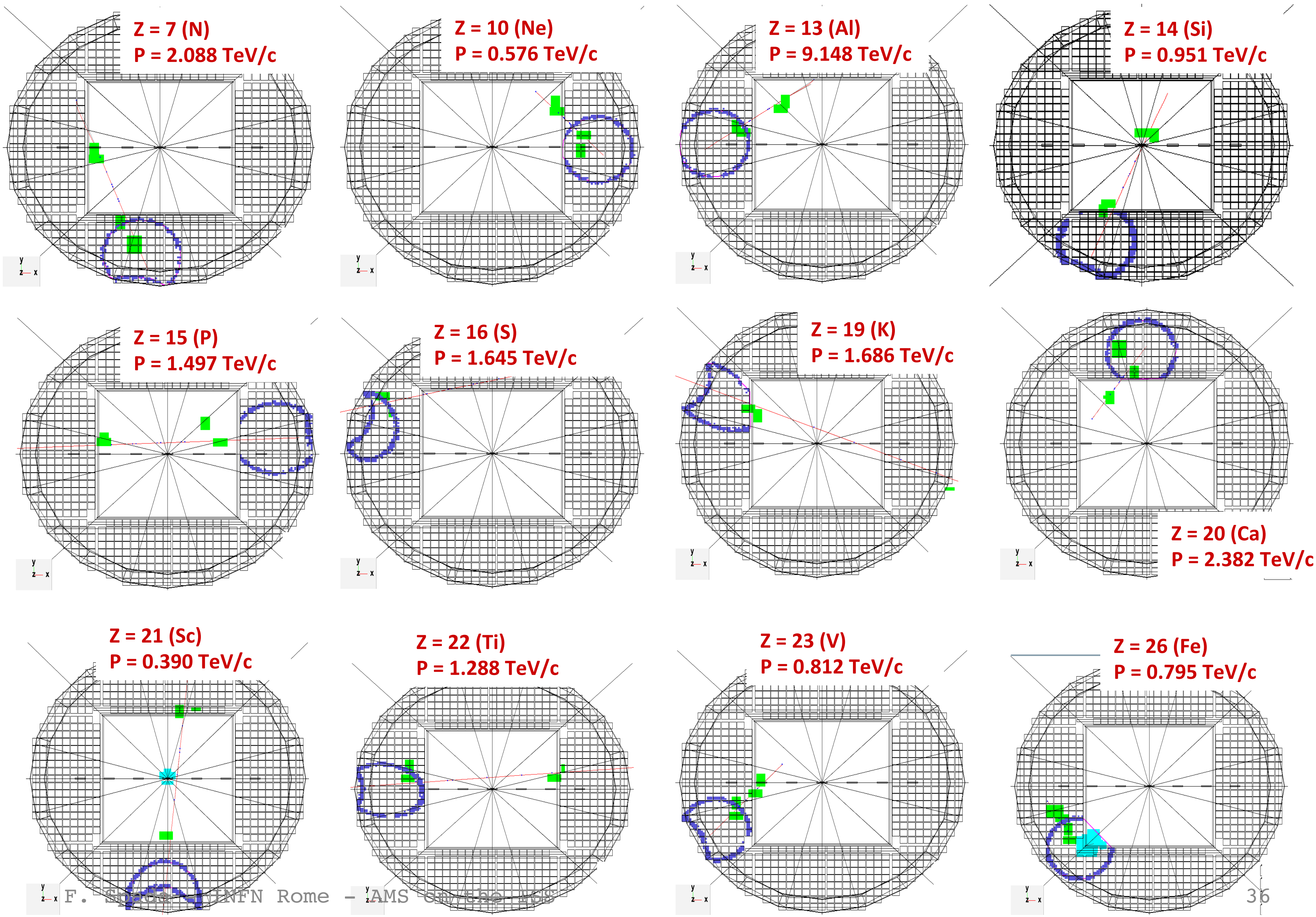
120 GeV photon direction reconstructed with 3D shower sampling



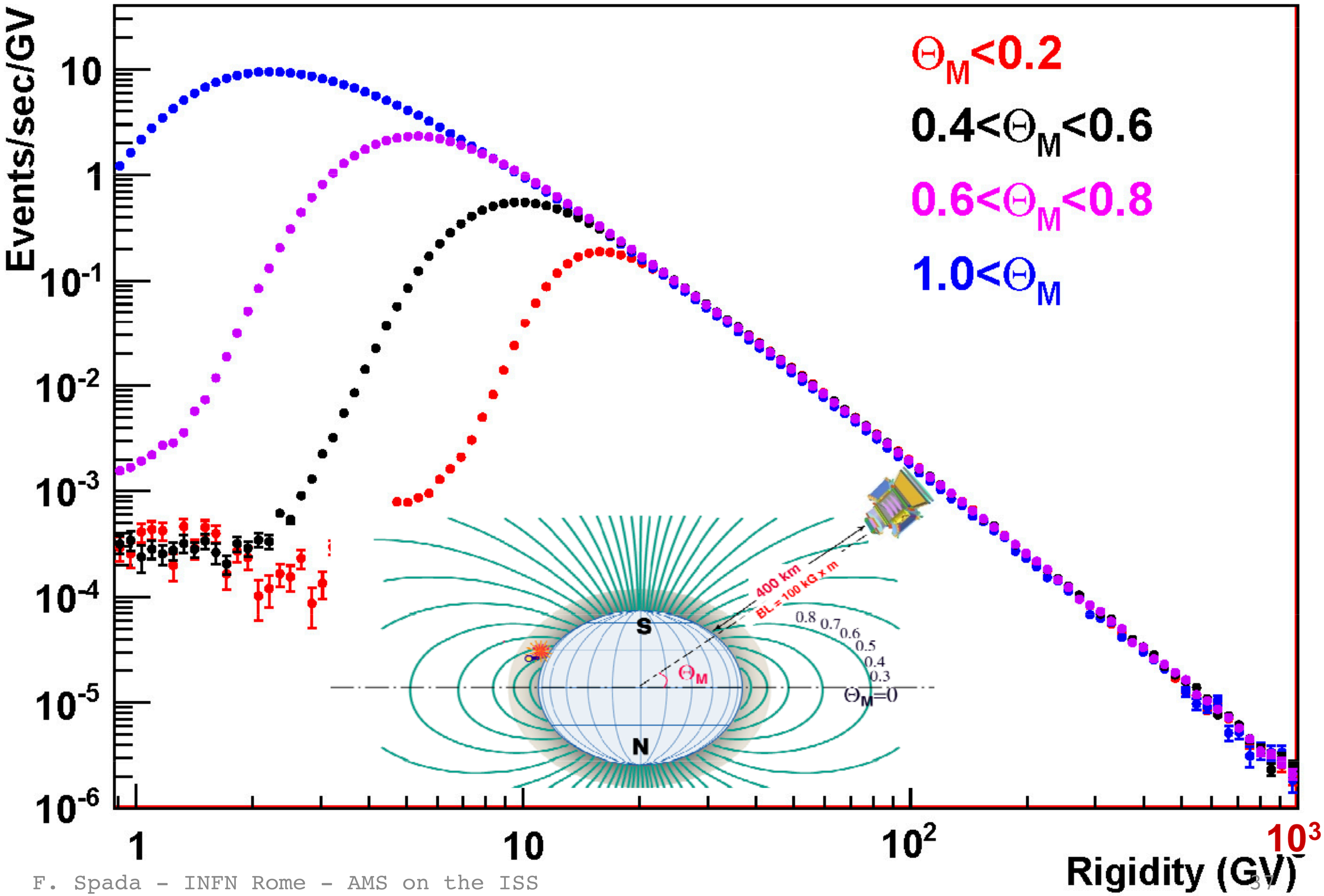
AMS Fligth data: cosmic nuclei



AMS data: Nuclei in the TeV range

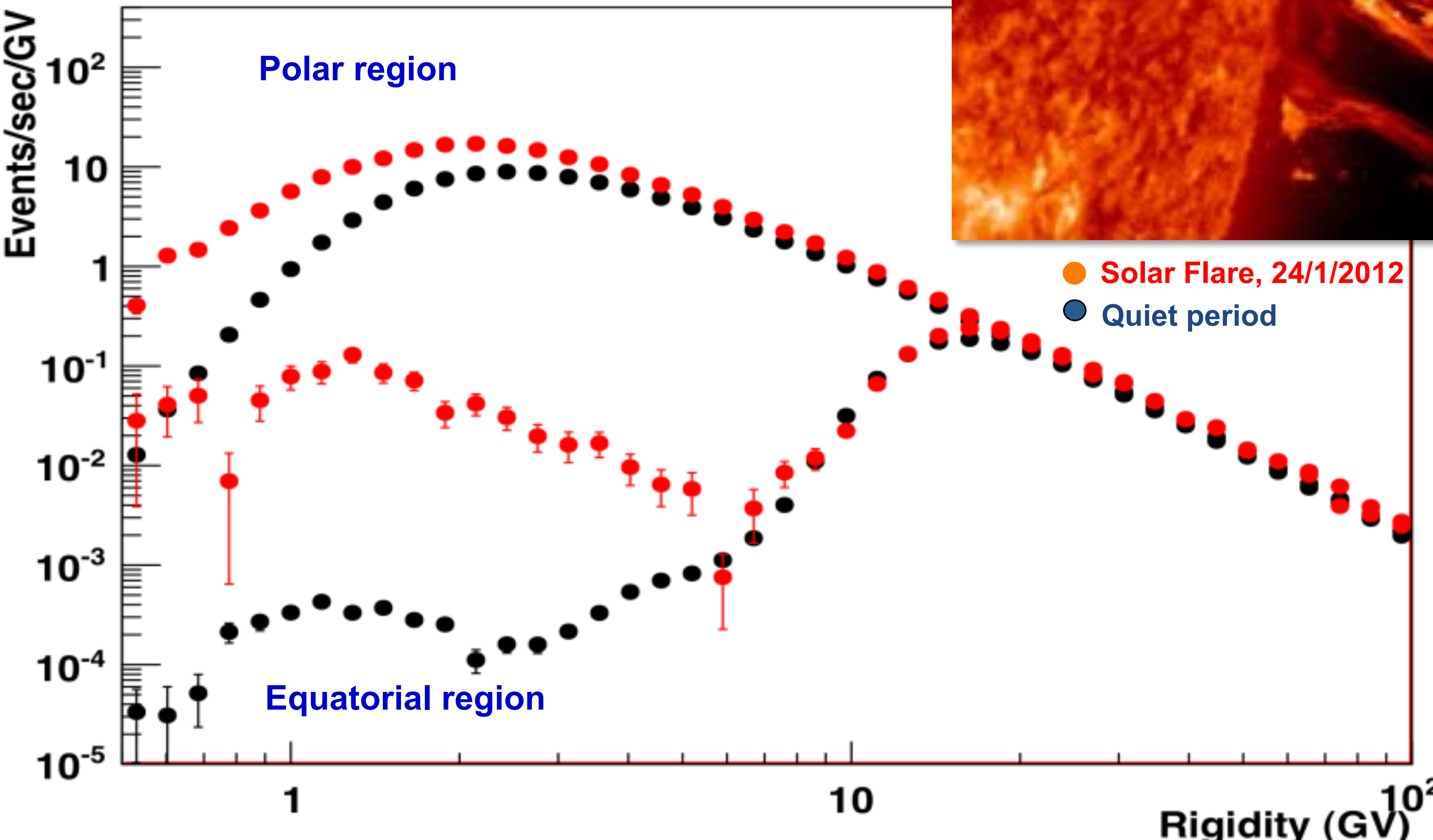


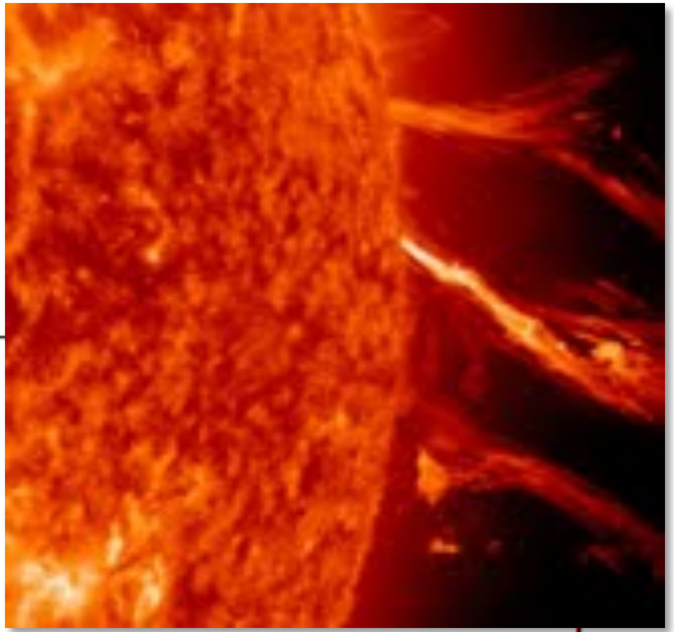
AMS Fligth data: Helium rate



AMS Fligth data:

He rate with solar flare





Conclusions

The Cosmos is the ultimate lab:

cosmic rays can be observed at energies higher than any accelerator

- AMS02 is in orbit since May 16th 2011
- All the detectors are properly functioning with DAQ in nominal conditions since May 19th 2011
- Ground operations (POCC and SOC) run smoothly
- Detector calibration (alignment, e/p rejection, charge id, etc.) are well advanced
- 10+ years on board the ISS at 1.6 10^{10} events/year: great discovery potential

Science coming soon!

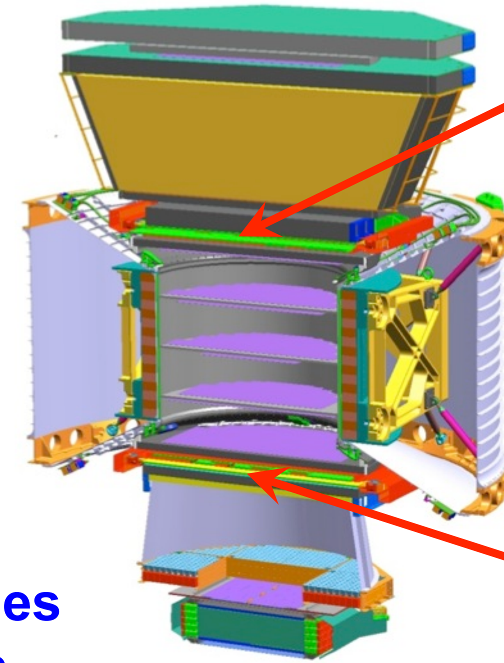
BACKUP

Time of Flight (TOF)

TOF

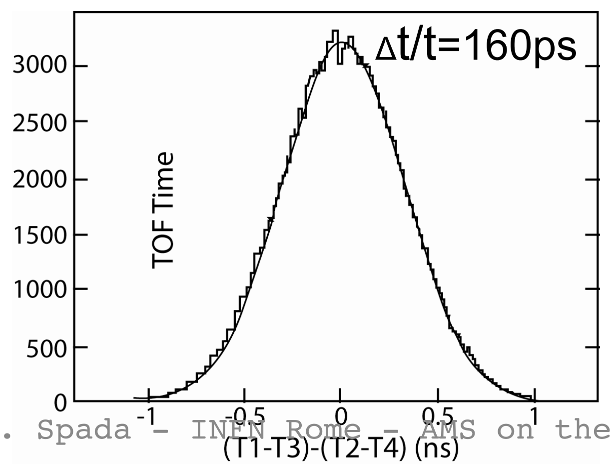
Provides trigger for charged particles

Trigger time is synchronized to UTC time to 1μs

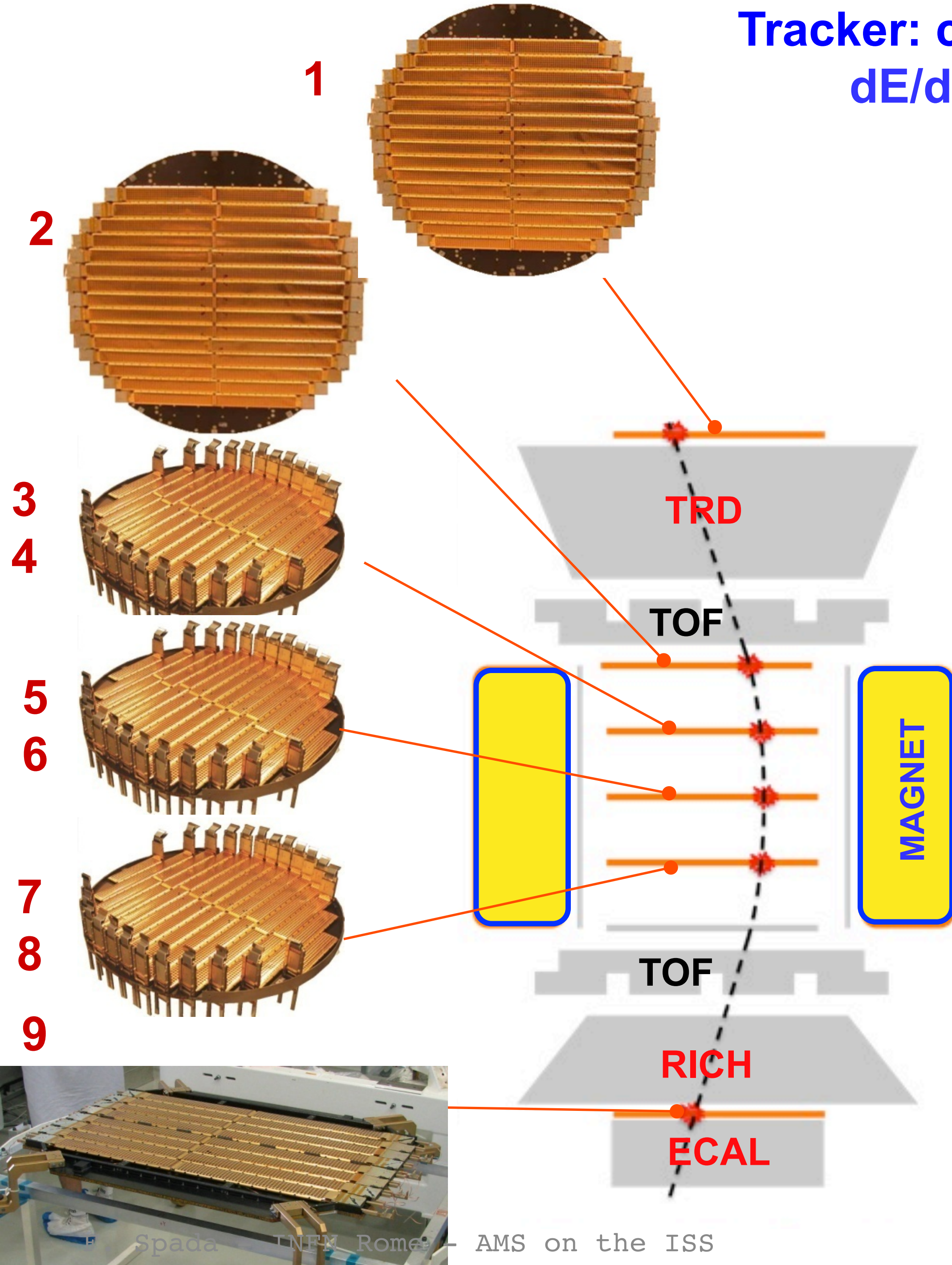


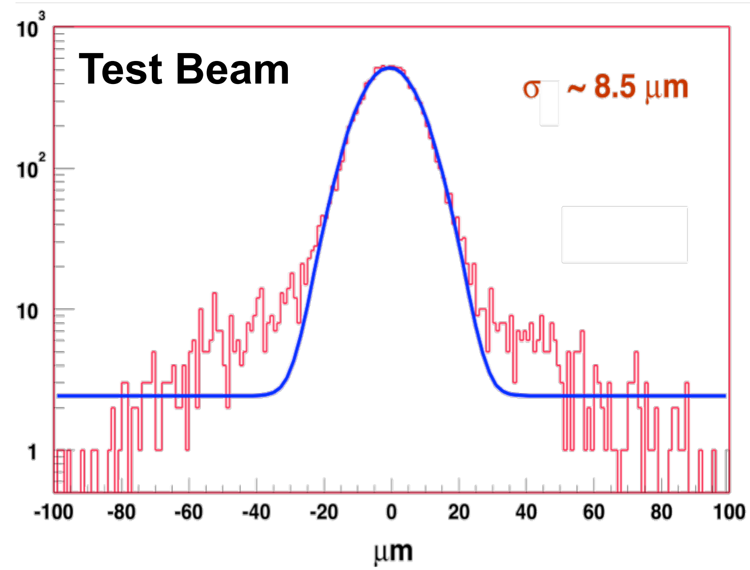
Measures the time of relativistic particles to 160 picoseconds

TOF

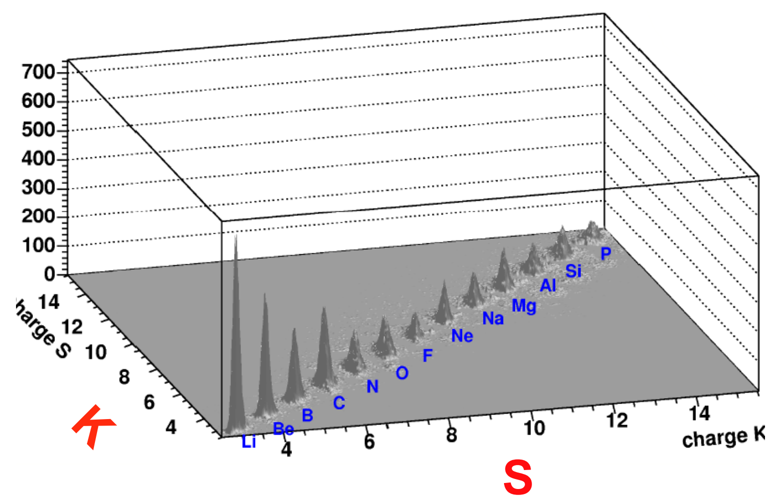


Tracker: coordinate resolution 0.010 μμ
dE/dX: identify nuclei



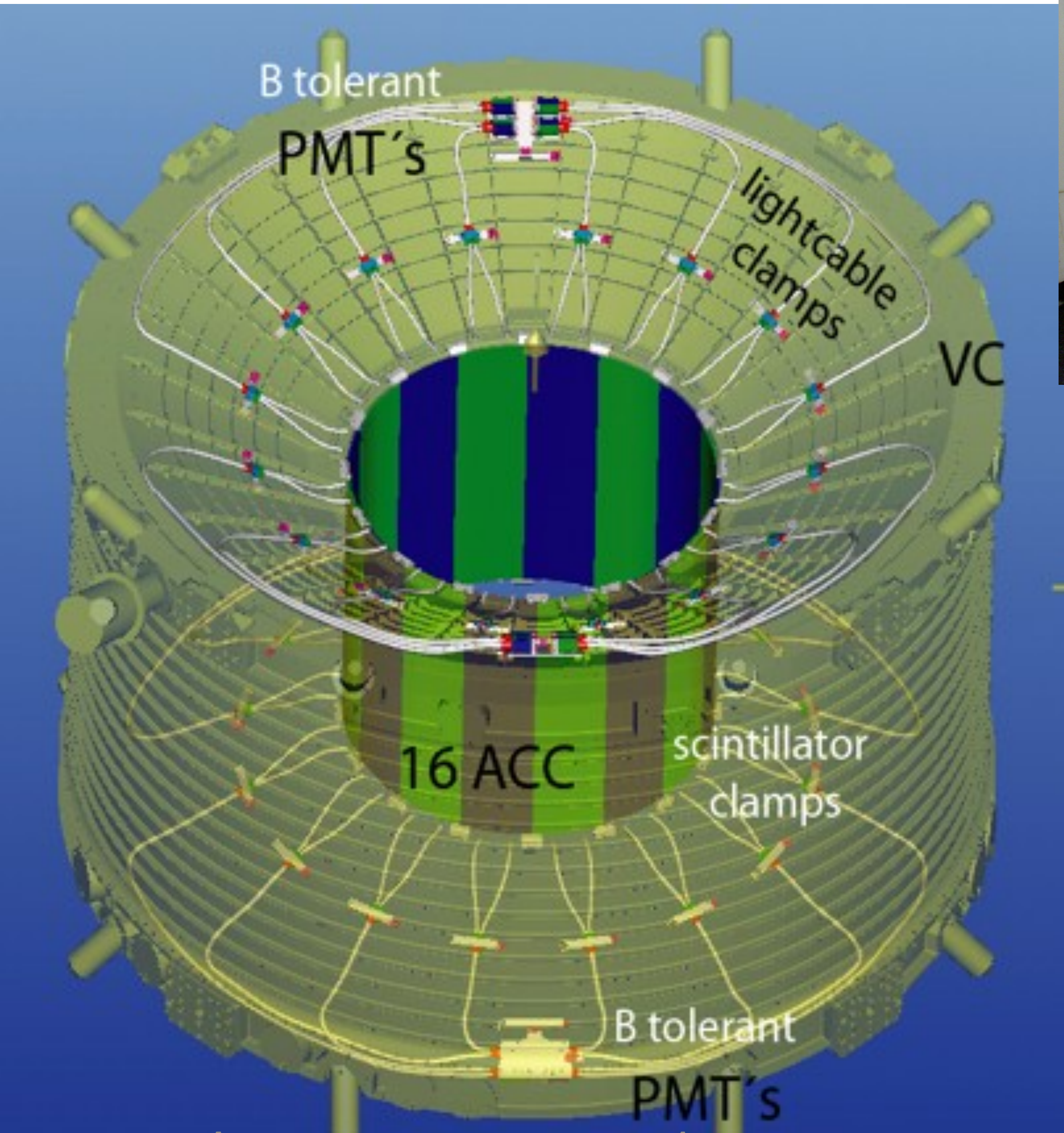


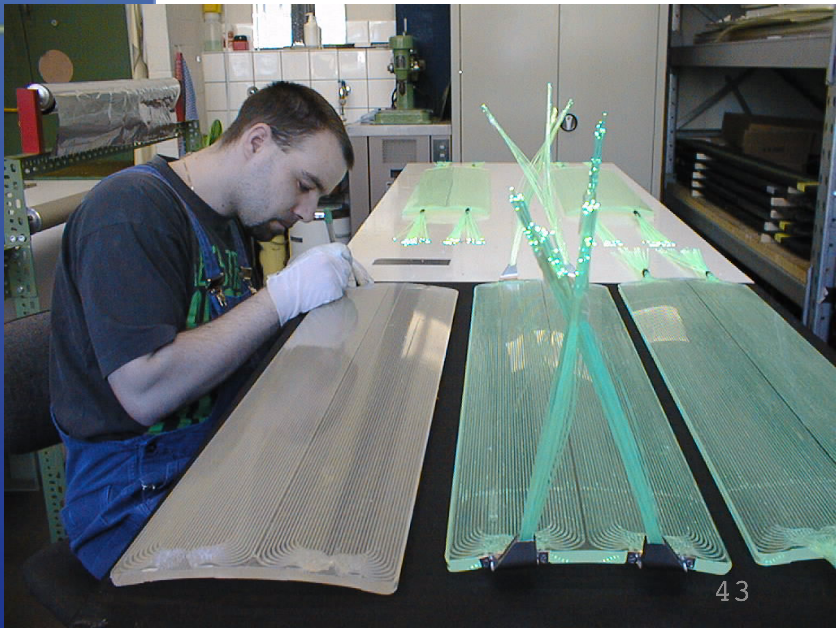
Test Beam



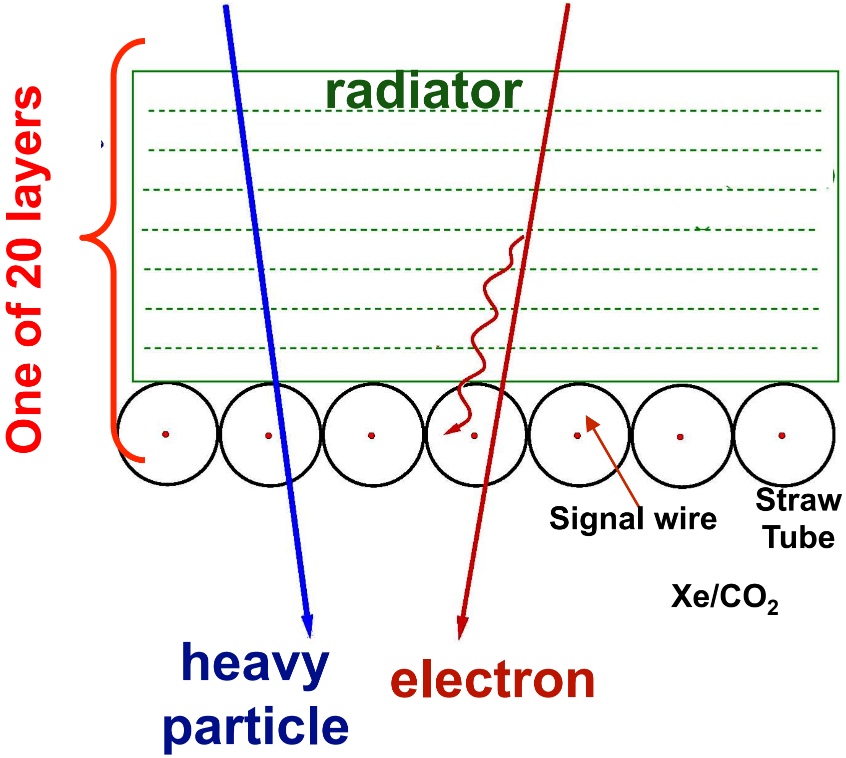
Anti-Coincidence Counter

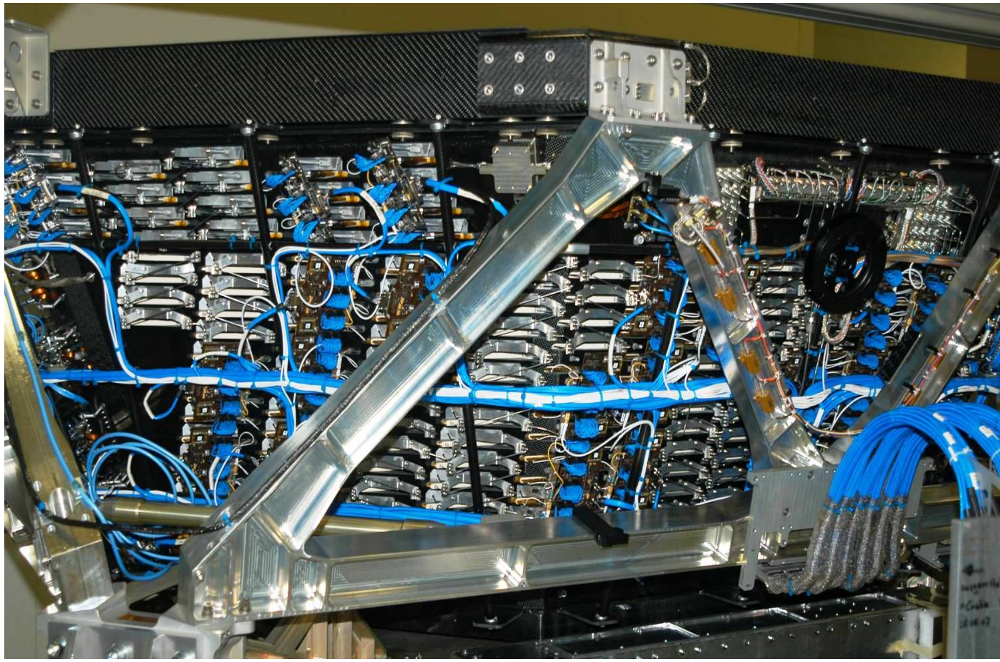
Efficieny >99.99%

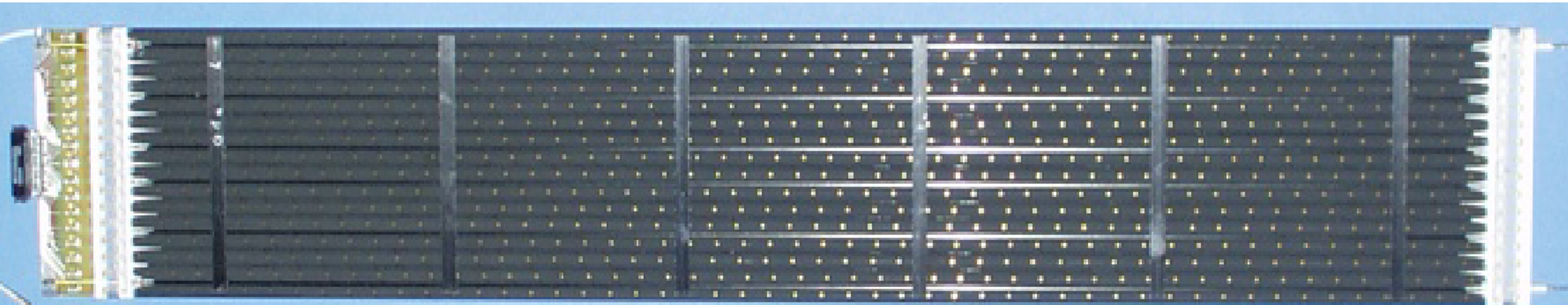




Transition Radiation Detector (TRD): identifies Positron and Electron



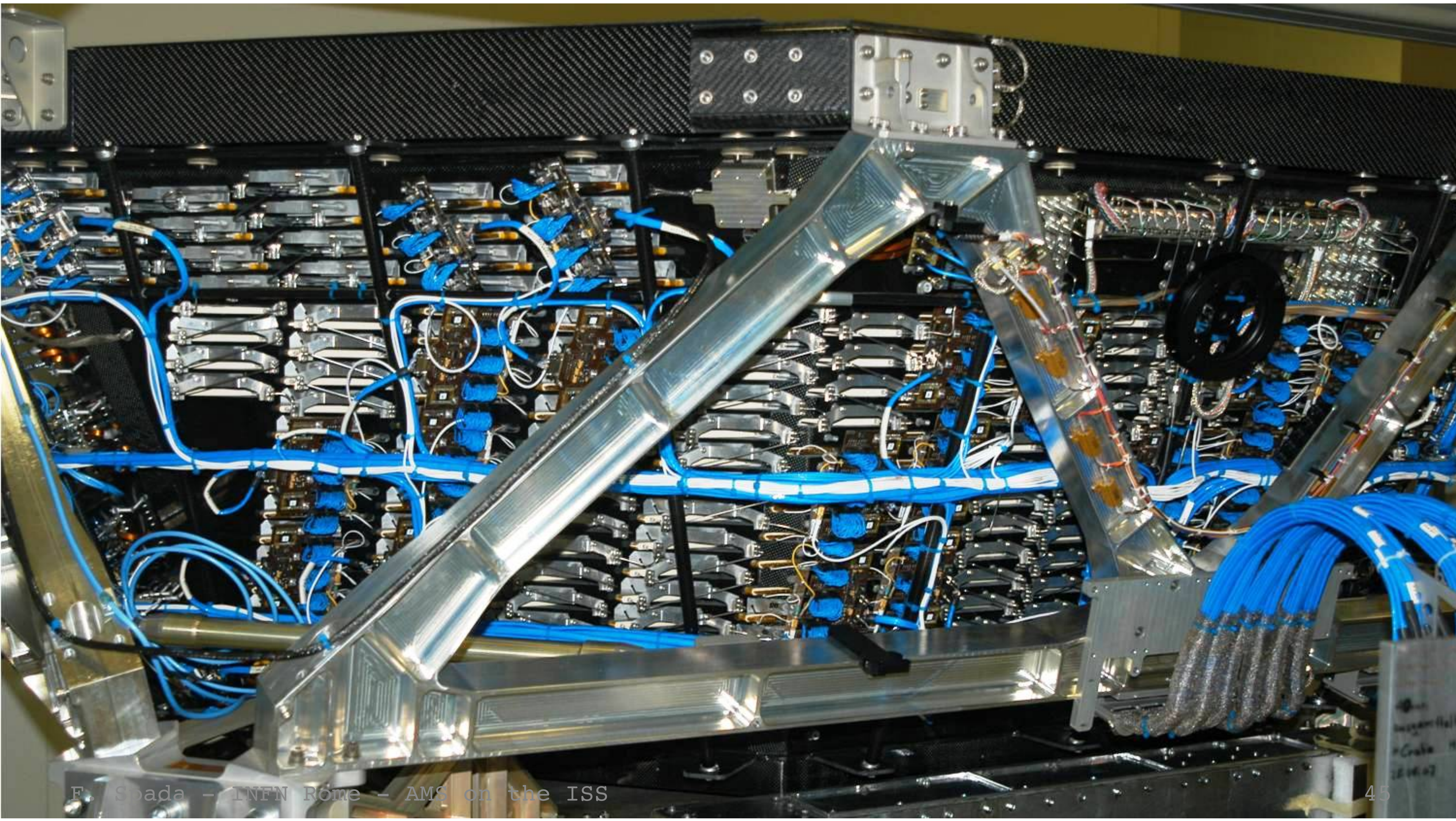




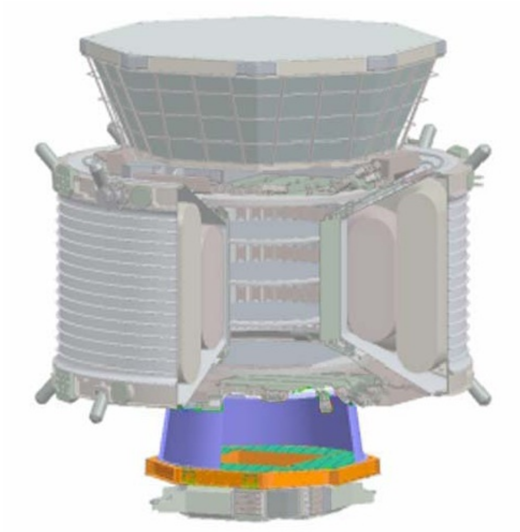
TRD: 5,248 Pulse Heights

Precision TRD Gas System: 482 Temperature Sensors, 24 Heaters 8 Pressure Sensors ensures pulse height stability

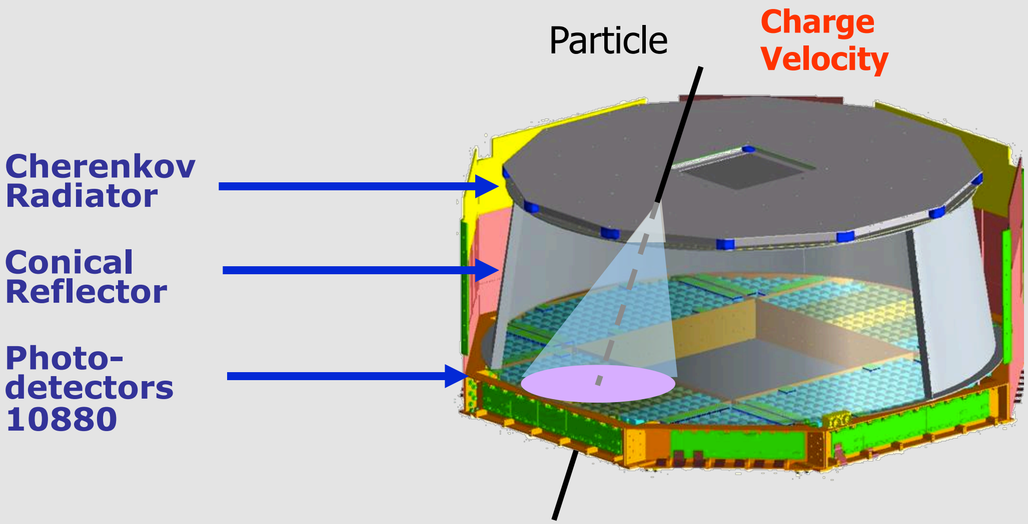
Onboard processing: 30 computers

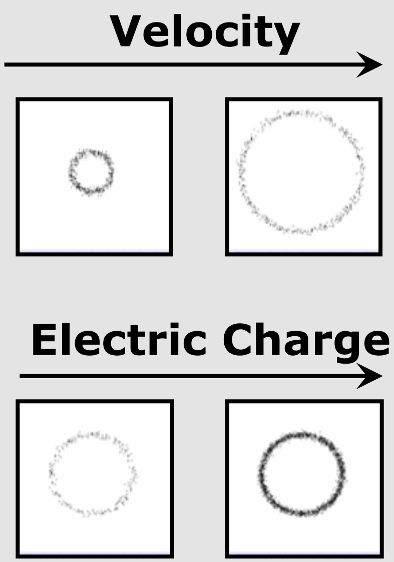


AMS Ring Imaging CHerenkov (RICH)

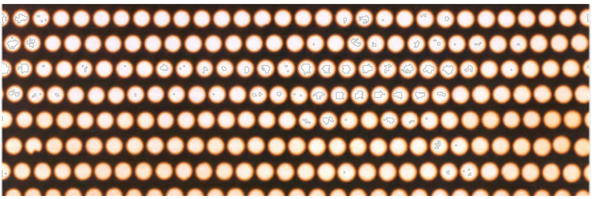


Cherenkov radiation

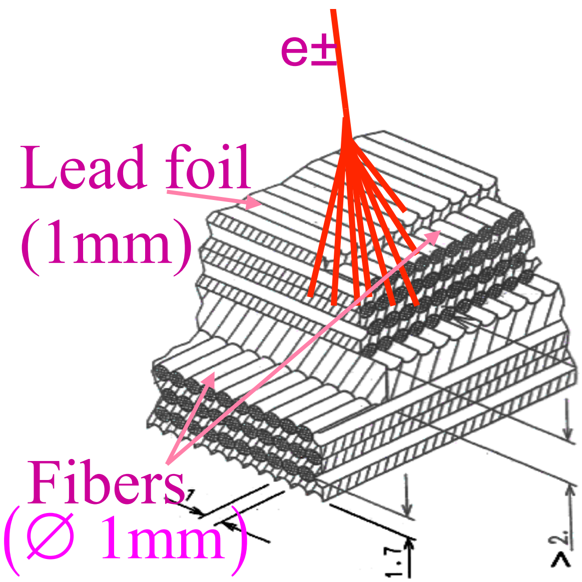


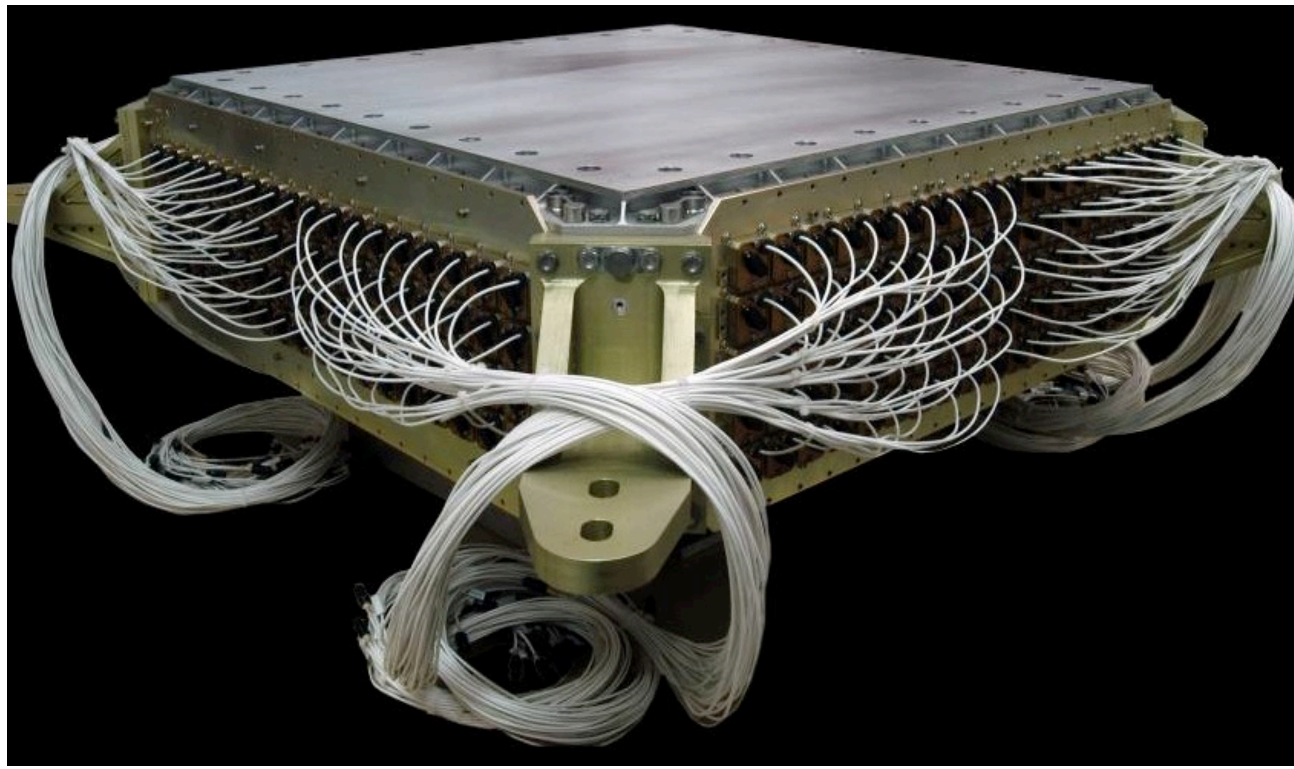


Electromagnetic Calorimeter (ECAL)



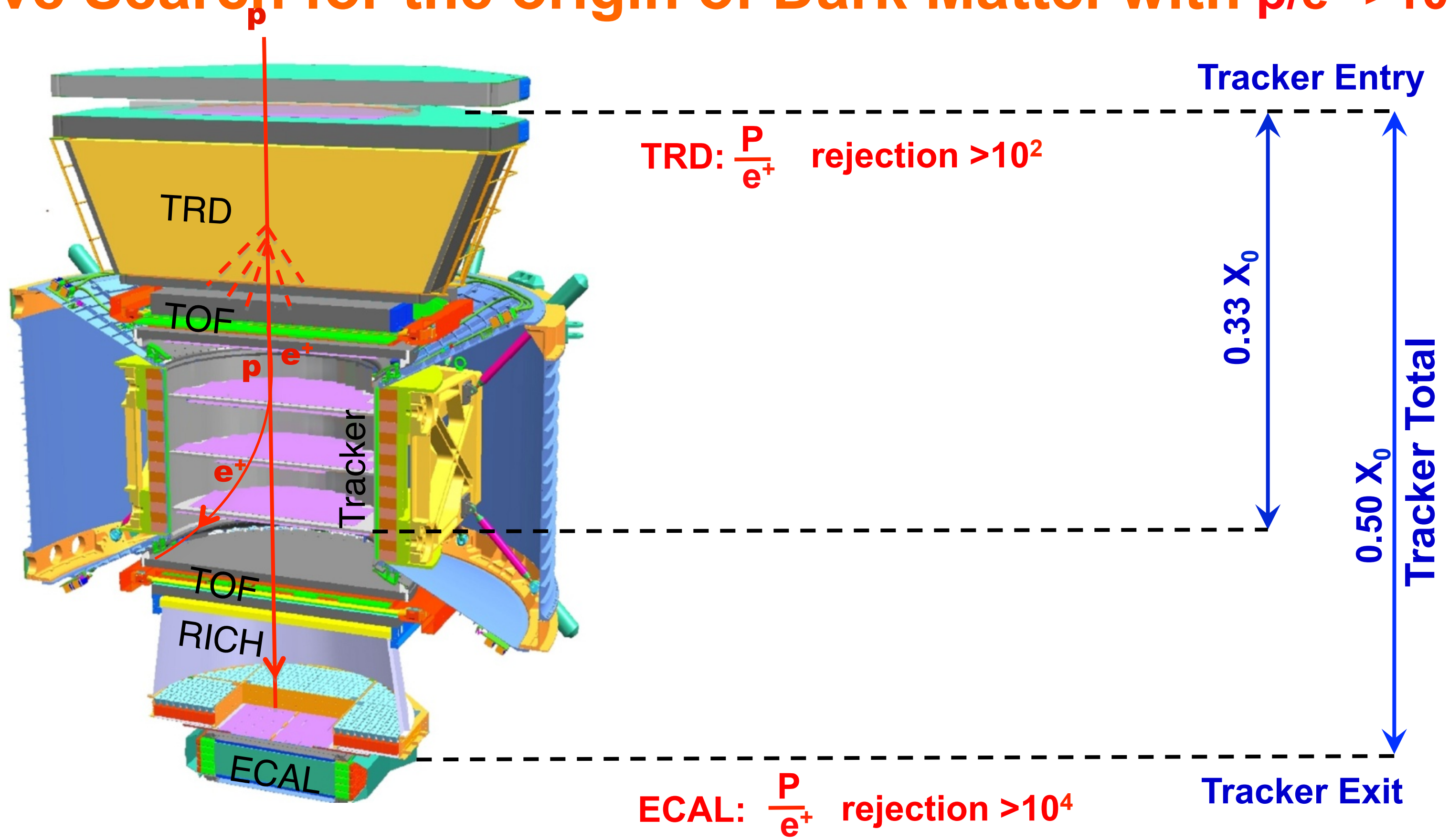
A precision 3-dimensional measurement of the directions and energies of light rays and electrons





50,000 fibers, d =1mm, distributed uniformly inside 1,200 lb of lead which provides a precision, 3-dimensional, $17X_0$ measurement of the directions and energies of light rays and electrons up to 1 TeV

Sensitive Search for the origin of Dark Matter with $p/e^+ > 10^6$

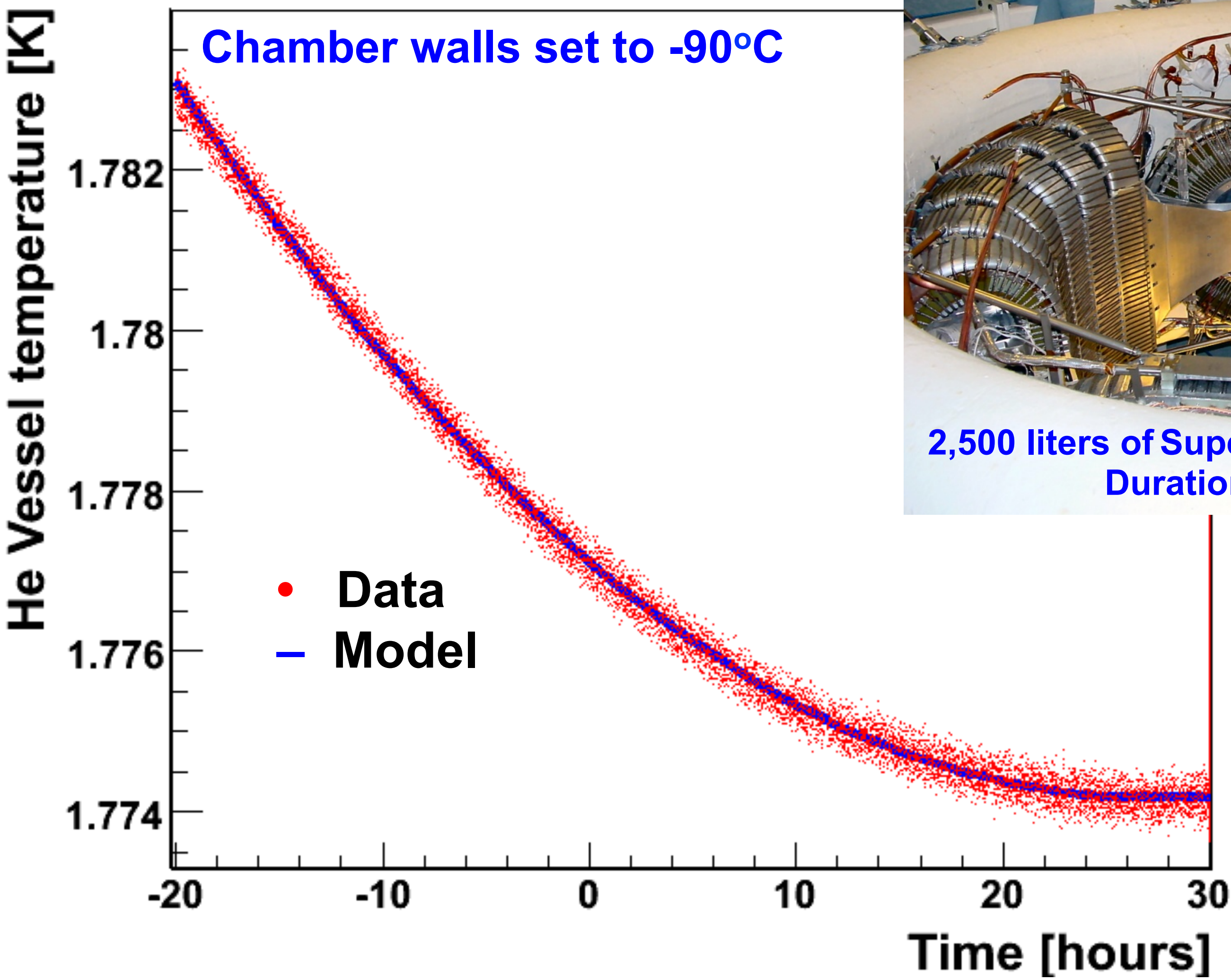


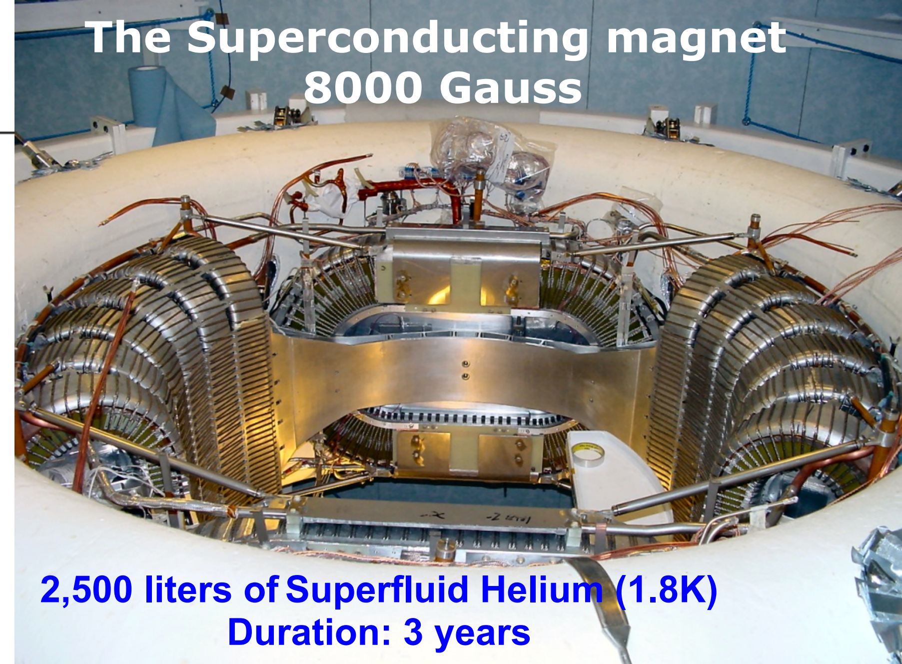
a) Minimal material in the TRD and TOF
So that the detector does not become a source of e^+.

b) A magnet separates TRD and ECAL so that e^+ produced in TRD will be swept away and not enter ECAL
In this way the rejection power of TRD and ECAL are independent

c) Matching momentum of 9 tracker planes with ECAL energy measurements

Stabilization of the He Vessel





Stability criteria:
dT/dt < 0.0001K/h

Expected life time of the AMS Cryostat on ISS: 28±6 months