Performance of AMS-02 on the International Space Station

DESY Theory Workshop, 29.09.2011Hamburg
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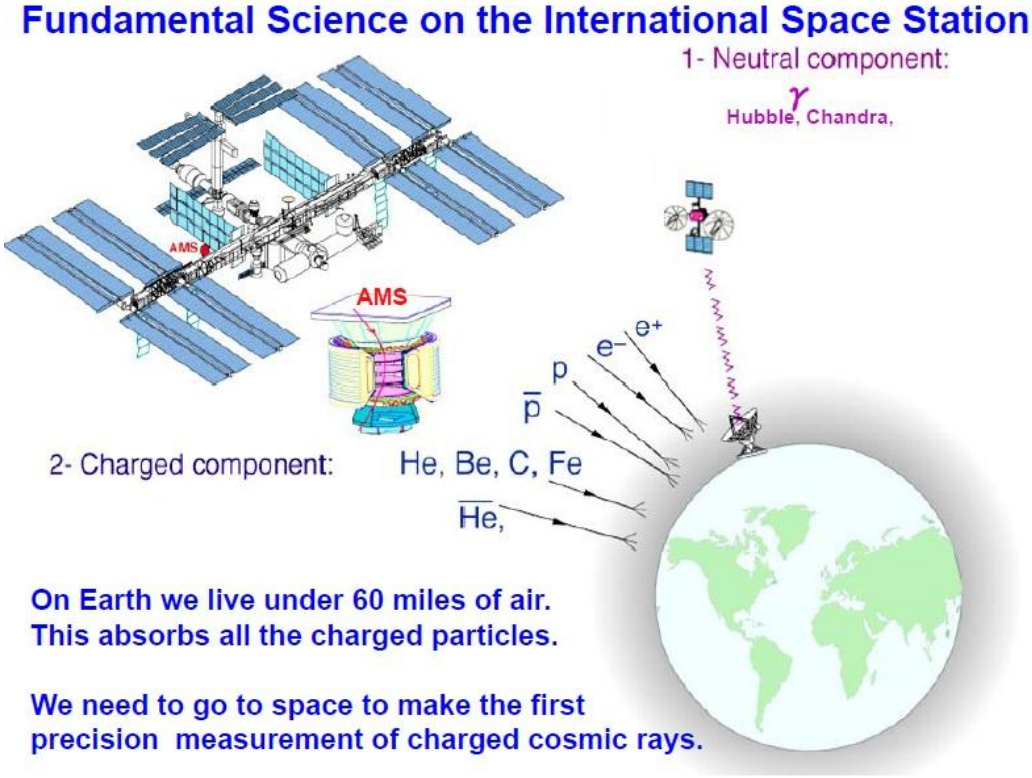
Overview

- The Alpha Magnetic Spectrometer
- The Physics
- The Detector
  - ➢ Particle identification
    - positron/proton separation with the Transition Radiation Detector (TRD)
    - Beam Test results
- The Journey
- Events / Data acquisition
- Calibration
    - Calibration of the TRD
- Summary

Alpha Magnetic Spectrometer

- ~600 Physicists from 60 institutes of 16 countries
- Spokesperson: Samuel C.C. Ting
- German contribution:
  TRD:
  RWTH Aachen
  Karlsruhe Institute of Technology



"THE MOST EXCITING OBJECTIVE OF AMS IS TO PROBE THE UNKNOWN; TO SEARCH FOR PHENOMENA WHICH EXIST IN NATURE THAT WE HAVE NOT YET IMAGINED NOR HAD THE TOOLS TO DISCOVER"

(S.C.C. Ting)

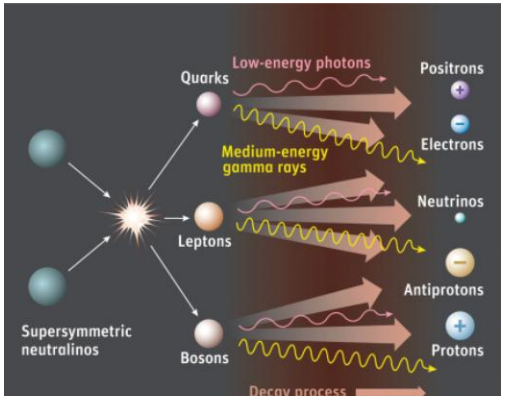
The Science

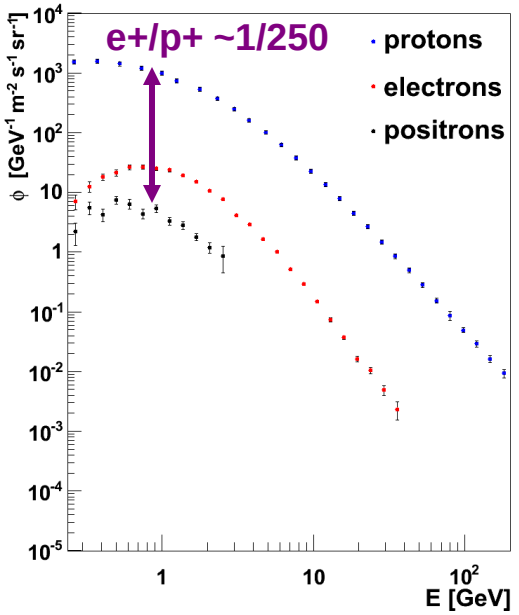
• Cosmic Rays:
AMS will measure the flux of all the different compounds in the cosmic rays with un-preceded precision

• Dark Matter Searches:
annihilation of two DM candidate particles (e.g. SUSY- neutralinos) in standard model particles
→ Search for DM Contribution (Signal) in Cosmic Ray Spectra (Background)
→ only Antimatter Spectra → need of good Positron/Proton and Electron/Antiproton separation

•Heavy Antimatter:
AMS will lower the limit of the Antihelium/Helium flux down to 10^{-9}

• New Physics...

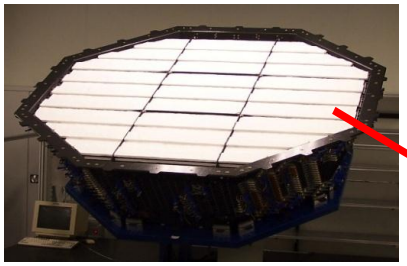




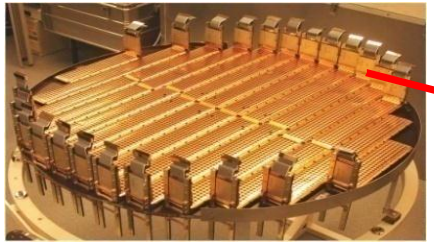
The Detector

mass (m), charge (Q) and energy (E = P)

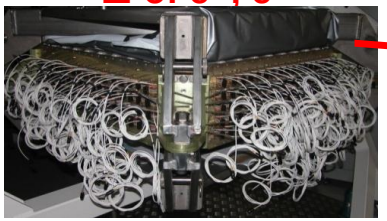
TRD
Identify e+, e-

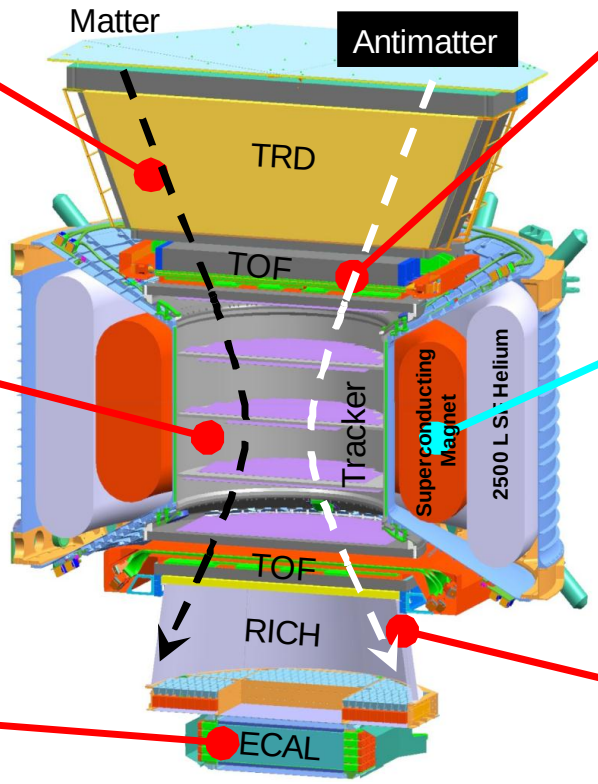


Silicon Tracker
m, Q, E



Electromagnetic CALorimeter
E of e+, e-

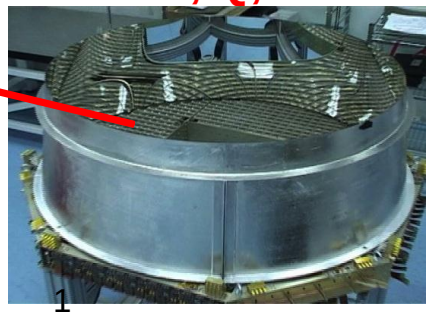




Time of Flight
m, Q, E

Magnet
± Q

Ring Imaging CHerenkov
m, Q, E

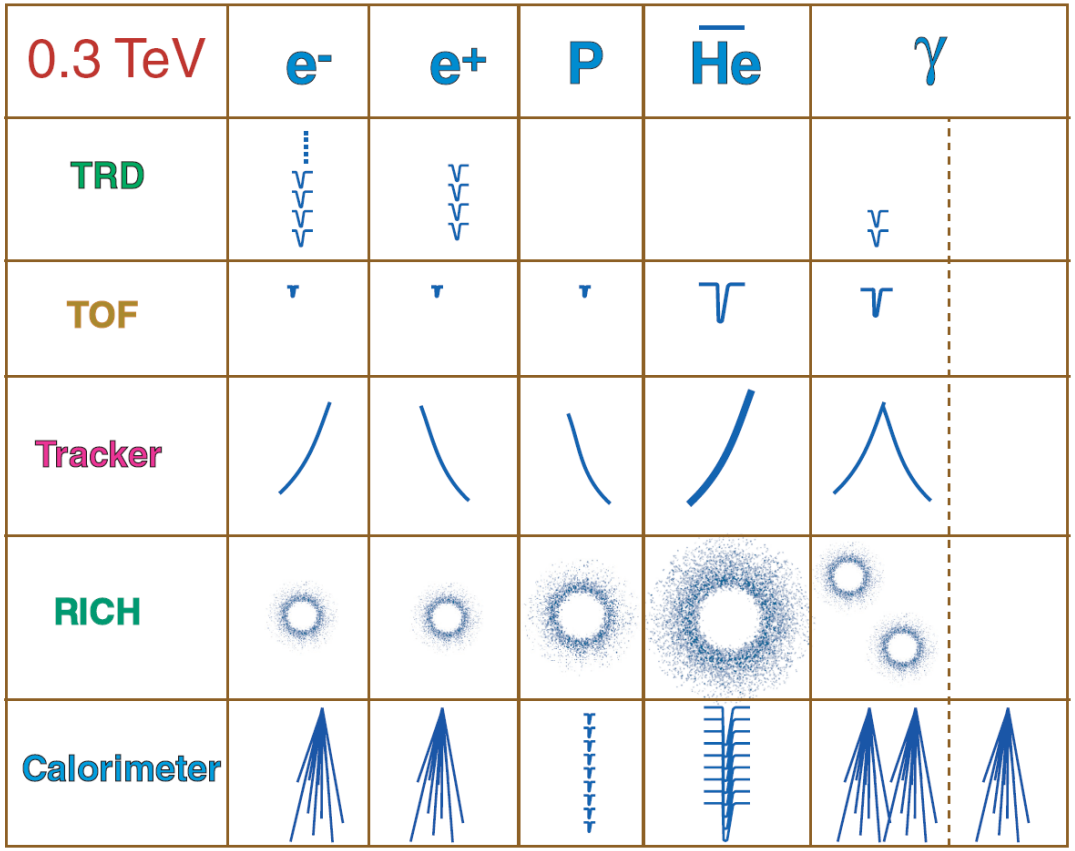


Particle Identification

Reconstructed particle attributes:

Charge: TRD, Tracker, RICH, ToF
Sign of Charge: Tracker
Energy: Ecal
Momentum: Tracker
Beta: ToF, RICH
Gamma: TRD

→ Positron/Proton Separation: Ecal + TRD



Particle Identification

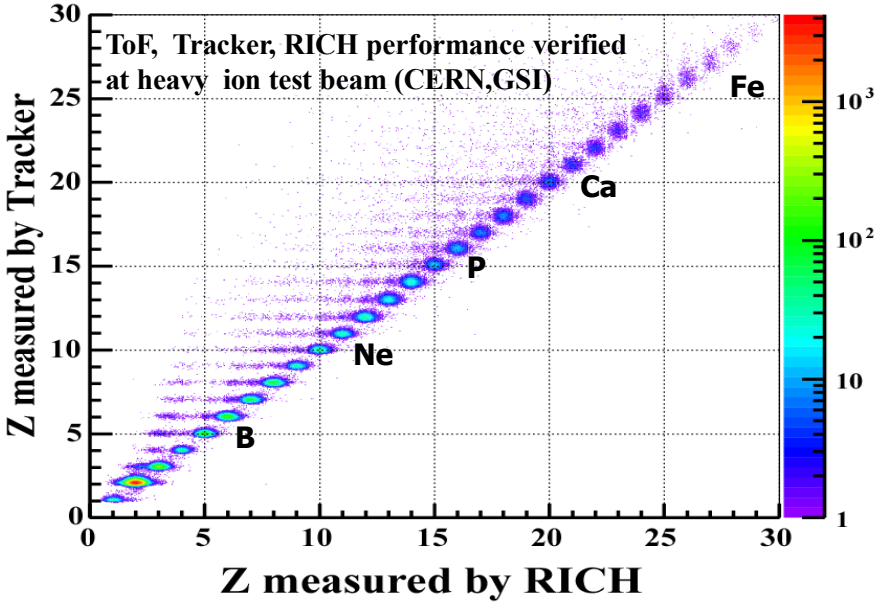
charge measurement:

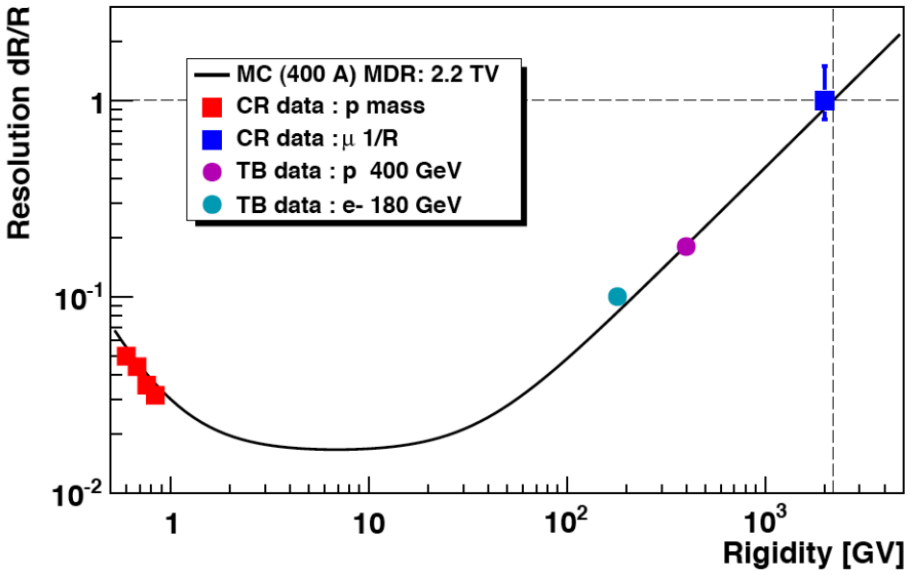
Tracker, ToF, RICH

(verified in Heavy Ion BeamTest 2007 @GSI)

rigidity measurement by Tracker:

Test Beam and cosmic ray on ground data

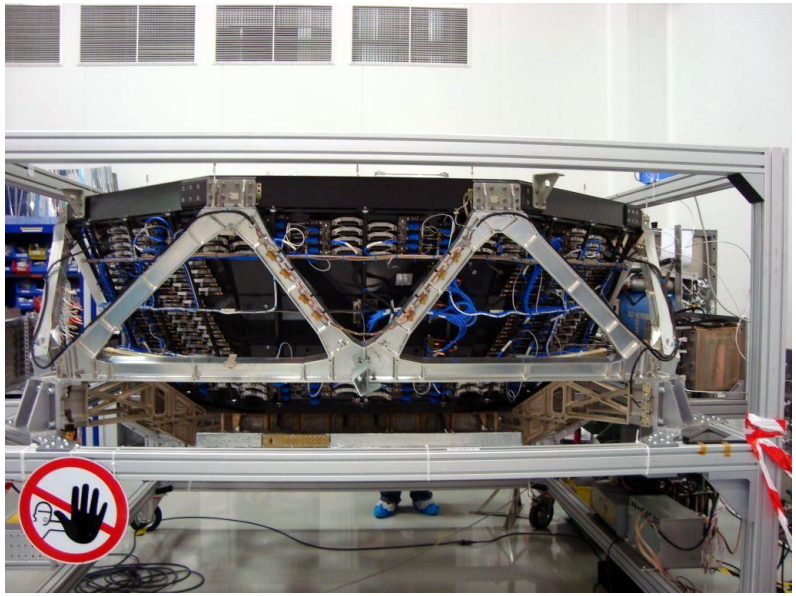


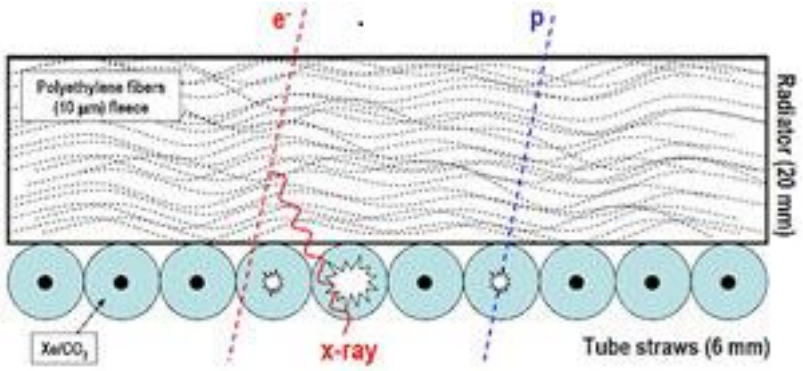


Transition Radiation Detector

Detector design:

- 5248 proportional chambers
- Filled with mixture of Xe/CO_2 (~80/20)
- Operated at ~1500 V
- 5 kg CO_2 , 49 kg Xe for refills on board (will last ~17 years)
- 10 separable gas circuits (á 4(5) Gas Units)





- 4 bottom and 4 top layers rotated 90° in respect to 12 middle layers

  -> 3D – track reconstruction

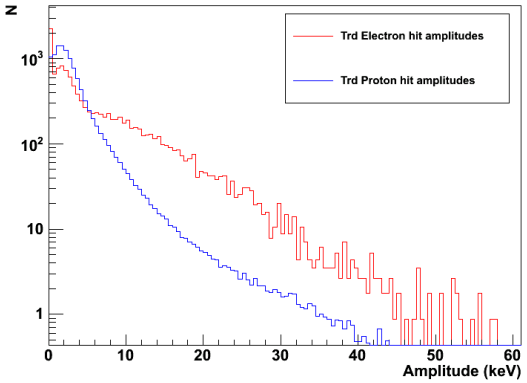
e+/p+ - separation with the TRD

- TRD separates particles based on their γ-factor
  - high γ-particles produce transition radiation which is detected in the proportional chambers
  - detected signal:
    - protons: ionization only
    - positions: ionization + transition radiation

      (electrons and positrons give the same signal

      -> electron data used for further calculations)
  - separation algorithm:
    - Create pdf of particle signal
    - Calculate likelihood of particle ID

TRD Signal



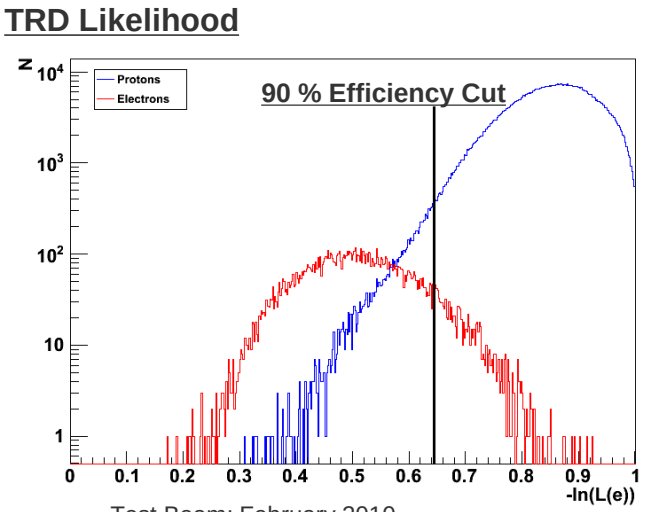
Test Beam: February 2010

Proton rejection

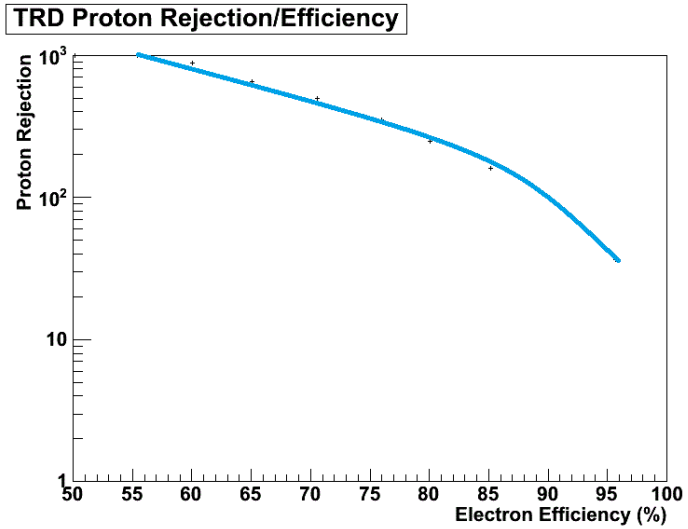
- Test Beam results:
  - 400 GeV protons
  - 180 GeV electrons

  For 90% electron efficiency:

  TRD proton rejection ~100



Test Beam: February 2010



Test Beam: February 2010

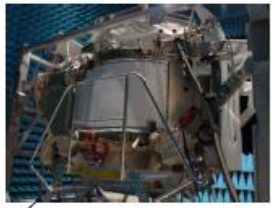
- combined rejection with ECal for 400 GeV protons:
  - Ecal and E/p : ~ 10^4 – 10^5
  - TRD, ECal and E/p:

    e+/p+ - rejection: > 10^6

The Journey

KSC – Cape Canaveral (USA)

ESTEC - Nordwijk (NL) – Large Space Simulator



AMS Electronics
Produced in Taiwan

JSC – Houston (USA)
Mission Control Center

CERN – Geneva (CH)
Assembly and Beam Test

Oct. 2009: first assembly @ CERN

Feb. 2010: BT @ CERN

Feb. 2010: EMI @ ESTEC

Apr. 2010: TVT @ ESTEC

Jul. 2010: reassembly @ CERN

Aug. 2010: BT @ CERN

Aug. 2010: transport to KSC

Apr. 2011: AMS to shuttle

16th May 2011: AMS to space

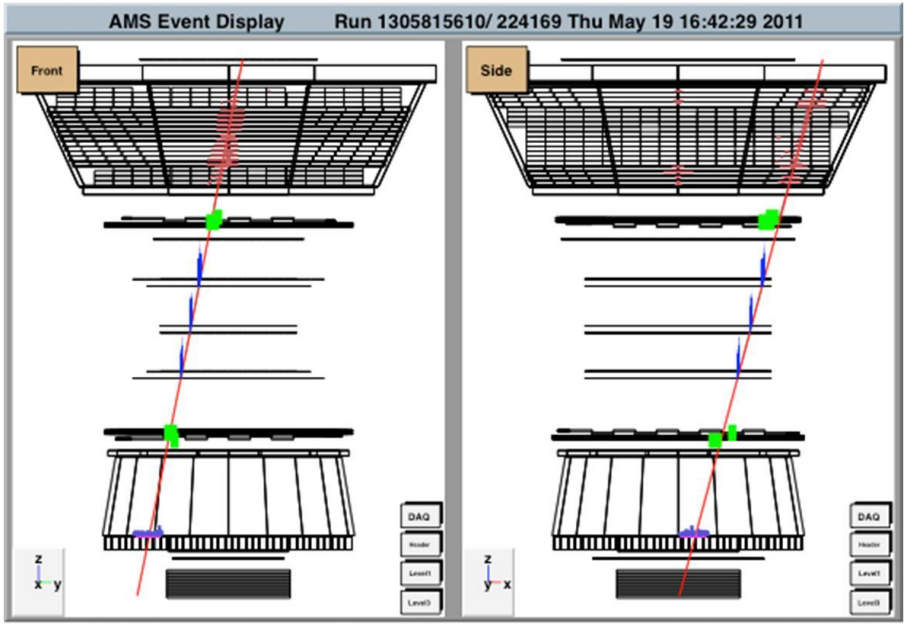
19th May 2011: AMS installed on ISS

The Journey II

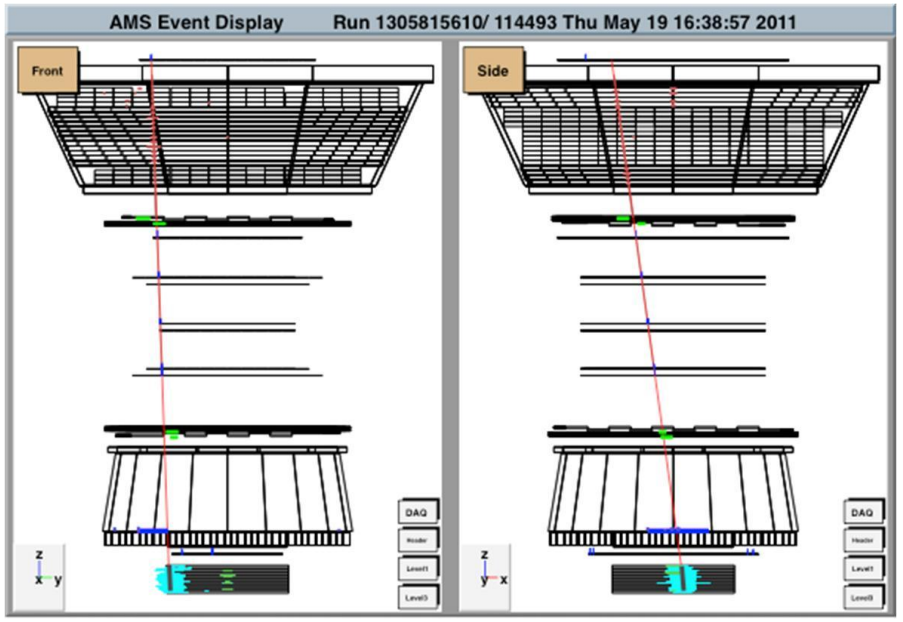
Events

- Average trigger rate: ~ 1400 Hz (PAMELA: ~ 23 Hz)
- Total collected events so far: ~ 6 billion (collected in one month as many events as PAMELA in it's lifetime of 5 years)

42 GeV Carbon nucleus

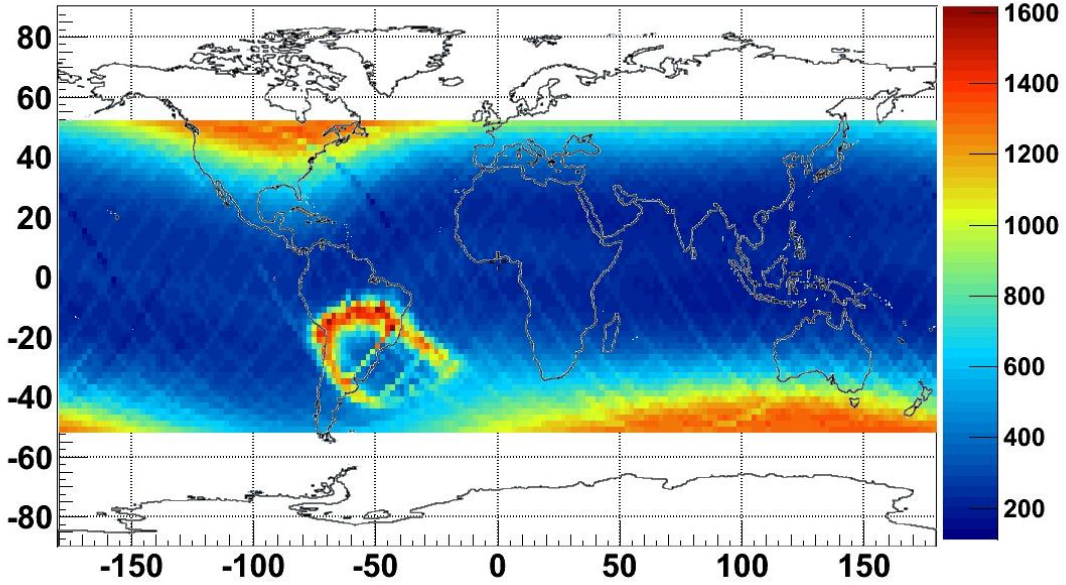


20 GeV electron

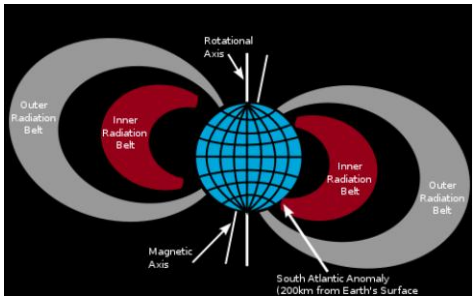


Data Acquisition

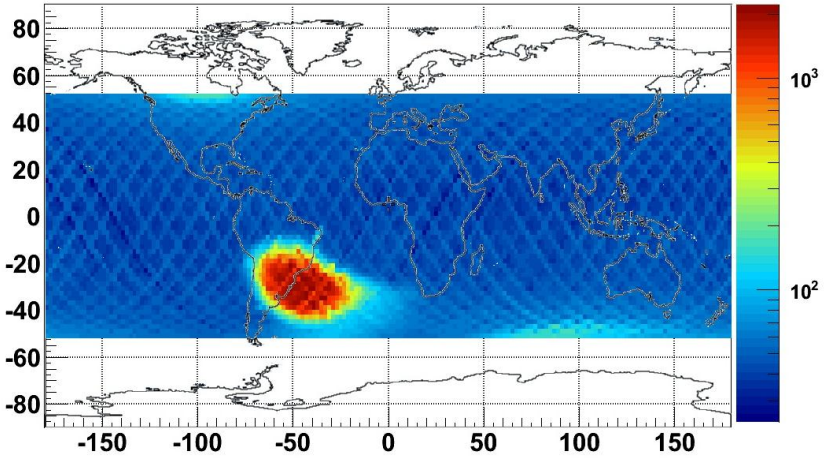
Trigger Rate (Hz)



- at the (magnetic) polar region low energy particles are not deflected by the earths magnetic field → higher particle flux



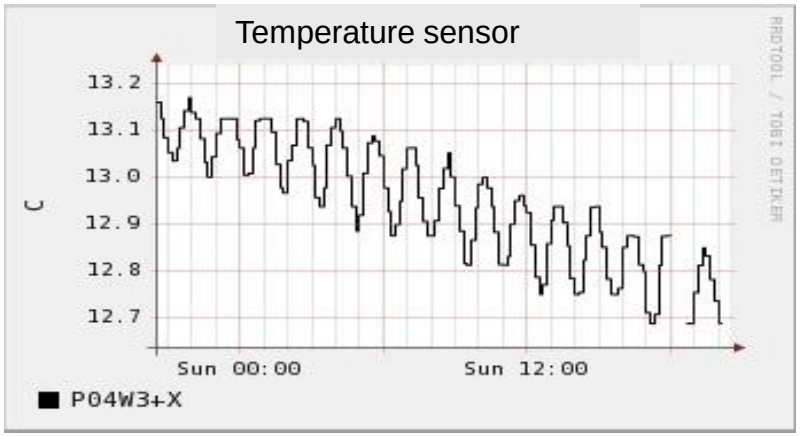
TRD Hits/Event



- the size and location of the TRD make it very sensitive to the particle flux → very many hits in the SAA (South Atlantic Anomaly)

AMS-02 Calibration

- AMS-02 needs to be calibrated again in space after shuttle launch according to:
  - Temperature variations (all detectors)



•Temperatur variation due to orbit (sun/shadow)

•Overall temeratur change due to ISS parameters (beta angle, radiator setup, orientation,…)

  - No gravitation (main issue: new Tracker alignment)
  - Vacuum (main issue: TRD gas diffusion)

TRD Calibration

Impact parameters on the gas gain:

-Gas composition

less CO_2 → higher signal

-Gas density

higher density → lower signal

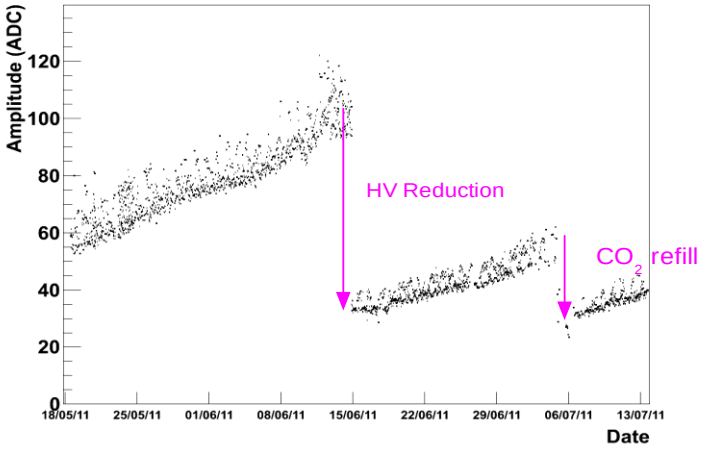
-High Voltage

higher voltage → higher signal

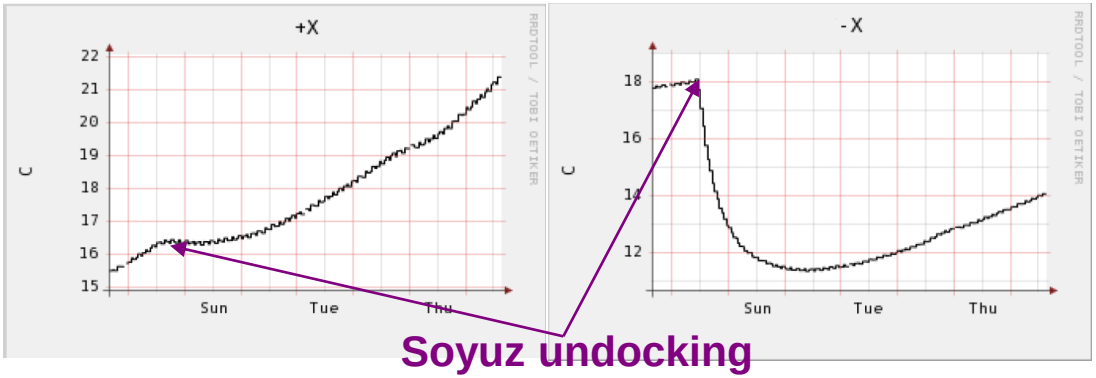
-Temperature

→ leading to different gas density

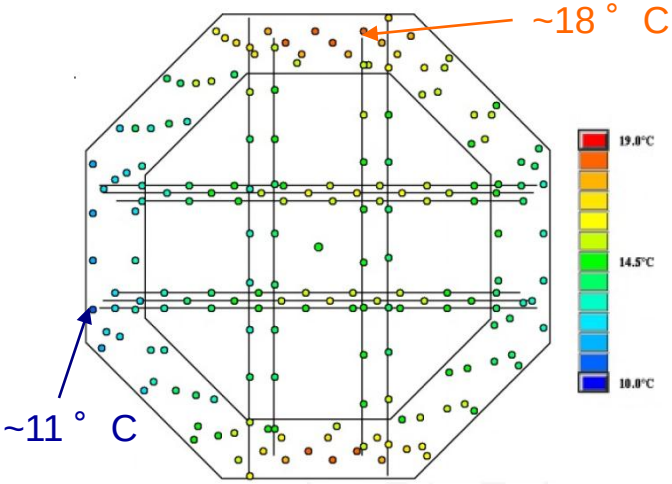
TRD signal vs. time



TRD temperatures vs. time



TRD temperature gradient



TRD Calibration II

!Gas composition changes due to diffusion of CO_2

!Gas density changes due to leakage → monthly refills

!Weekly HV adjustment

!Temperature changes due to ISS, heater actions and periodically with orbit

→ **Time dependent calibration needed**

+ different temperatures over the detector

→ Complicated calibration algorithm needed!

Find best time interval and geometrical unit which provide enough statistics for “on the go” calibration!

Summary

- Beam Test data shows proton rejection power > 10^6

  →sufficient for clean positron spectrum

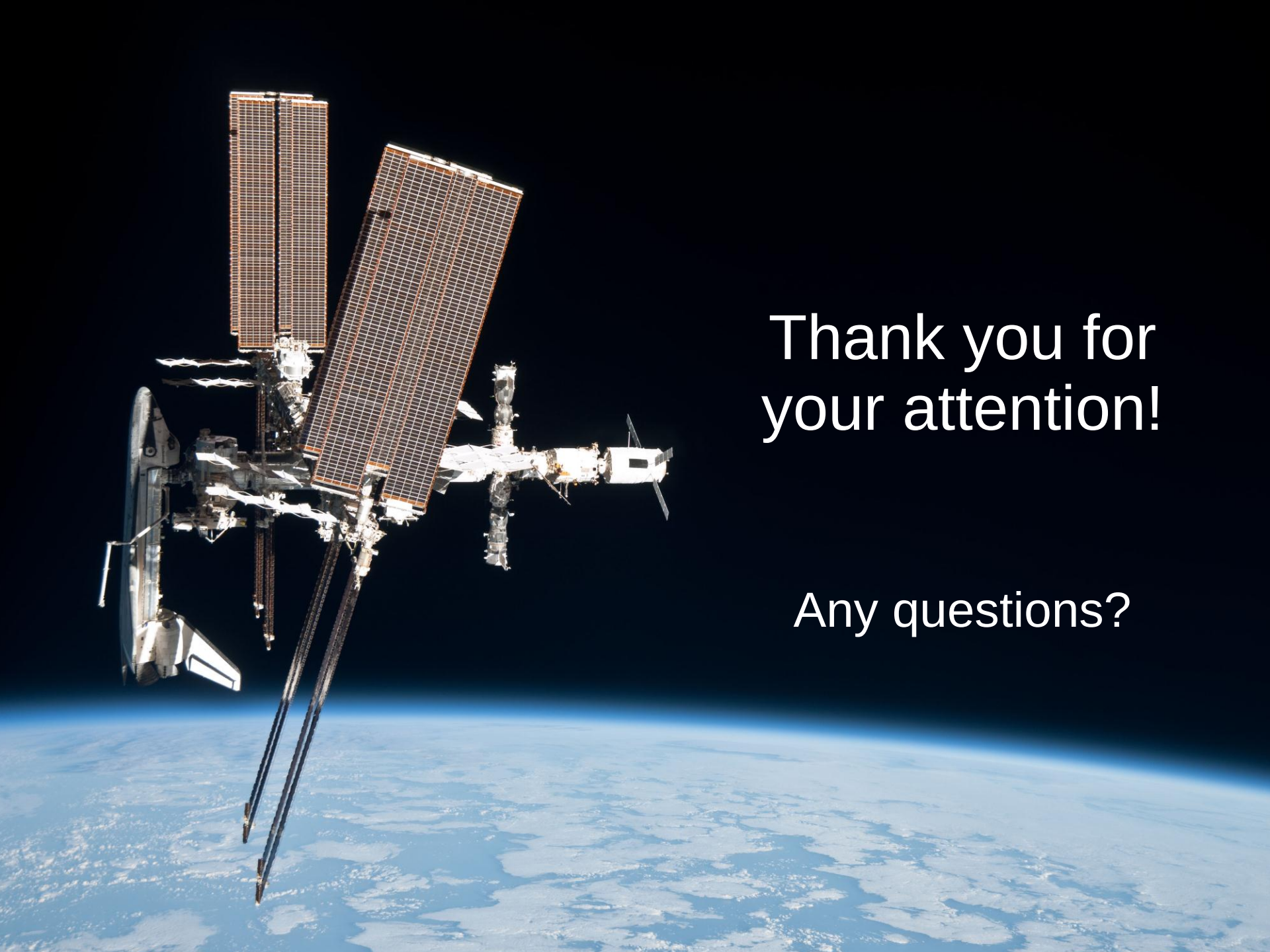
  First look at ISS data reproduces BT results!

- AMS-02 was launched on board Endeavour May 16th 2011
- AMS-02 started taking data on May 19th 2011

  All systems are working properly!

- Calibration of subdetectors is ongoing

- First results expected in 2012…



Thank you for your attention!

Any questions?