Search for Antiparticles in Cosmic Rays in the Earth's Atmosphere and in Space

Philip von Doetinchem
I. Phys. Inst. B, RWTH Aachen University

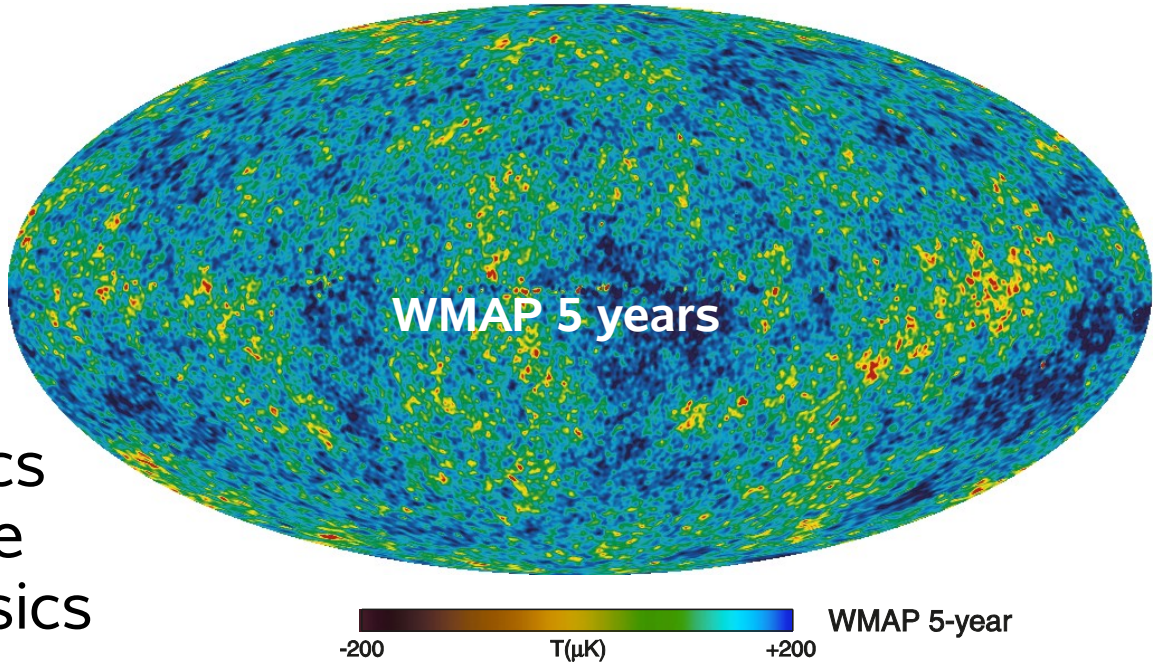
Graduiertenkolleg, Bad Honnef – 4th of September 2008

Overview

- cosmic ray physics in the GeV-TeV range
- the **AMS-02 detector** for the ISS in **Space**:
  - anticoincidence counter
  - search for anthelium
- the **PEBS detector** in **Earth's atmosphere**:
  - simulation of cosmic ray measurements at the Southpole in the Earth atmosphere
  - prospects for PEBS

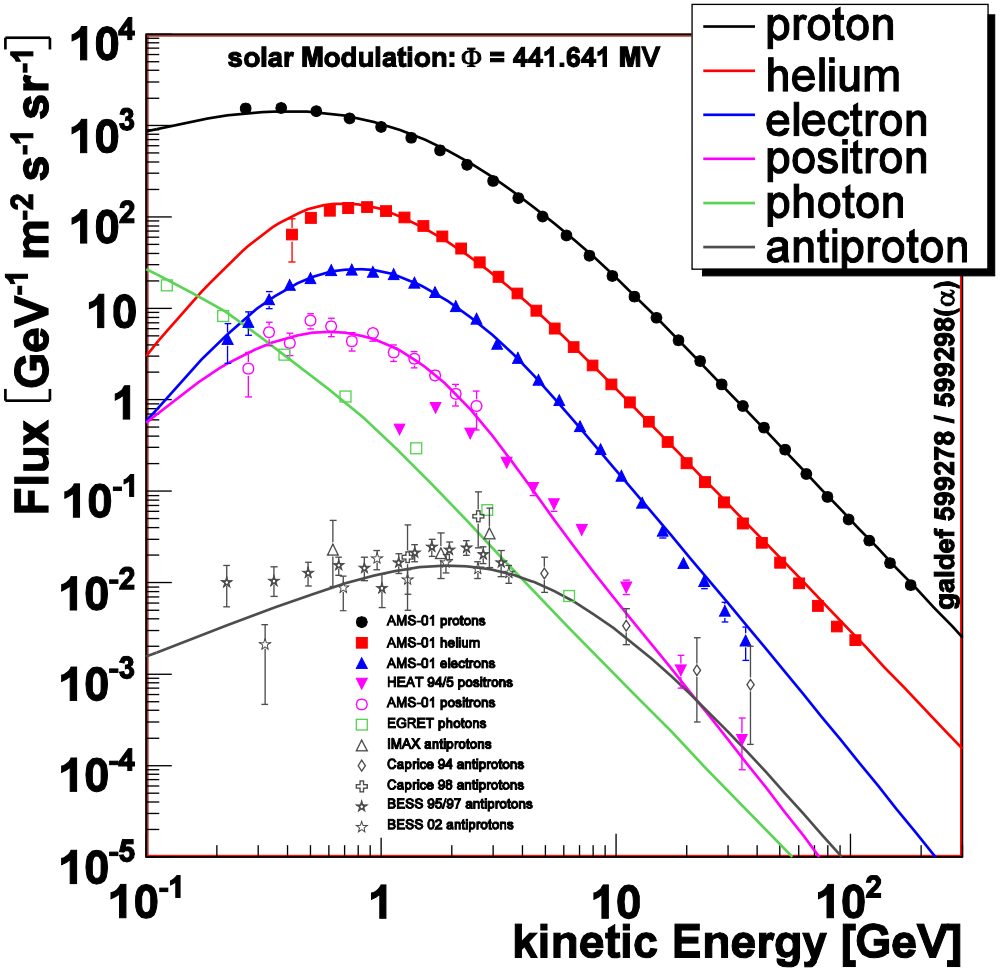
Particle & Astro Physics

- particle physics & astrophysics are merging
- use particle physics methods in astrophysics and get input to particle physics from astrophysics



- **important observations cry for explanations:**
  - Dark matter exists! What is the nature? Supersymmetry, Kaluza-Klein, …
  - Where does the asymmetry between matter and antimatter in the universe come from?
  - …

Cosmic Rays in the Gev-TeV Range



- learn about sources, acceleration, propagation, age, grammage of matter, halo size,…
- good agreement of models in the GeV-TeV range for particles, some unexplained features in antiparticle/photon spectra
- no primary sources for positrons and antiprotons are known
- sensitive to new physics: dark matter annihilations e.g. from new particles in supersymmetric or Kaluza-Klein Theories

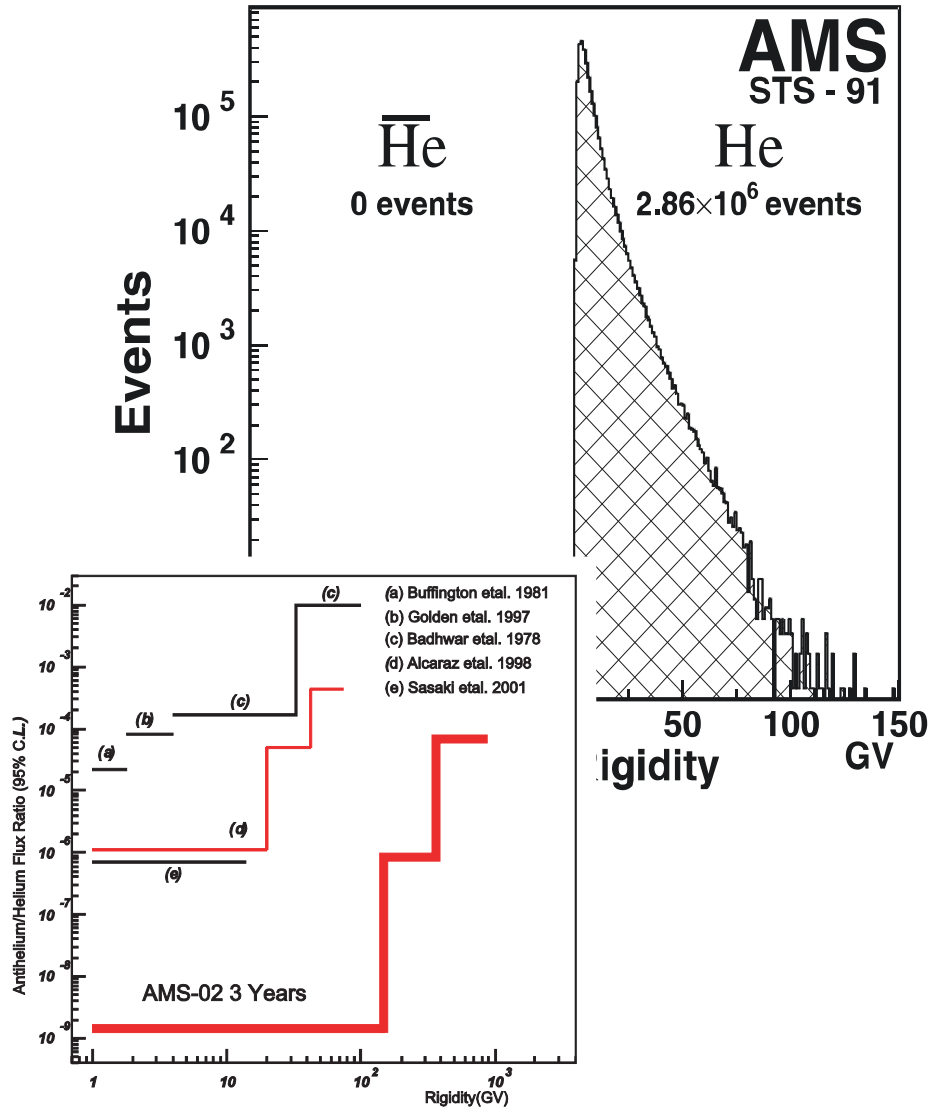
Antihelium

approach for the explanation of the baryon asymmetry:

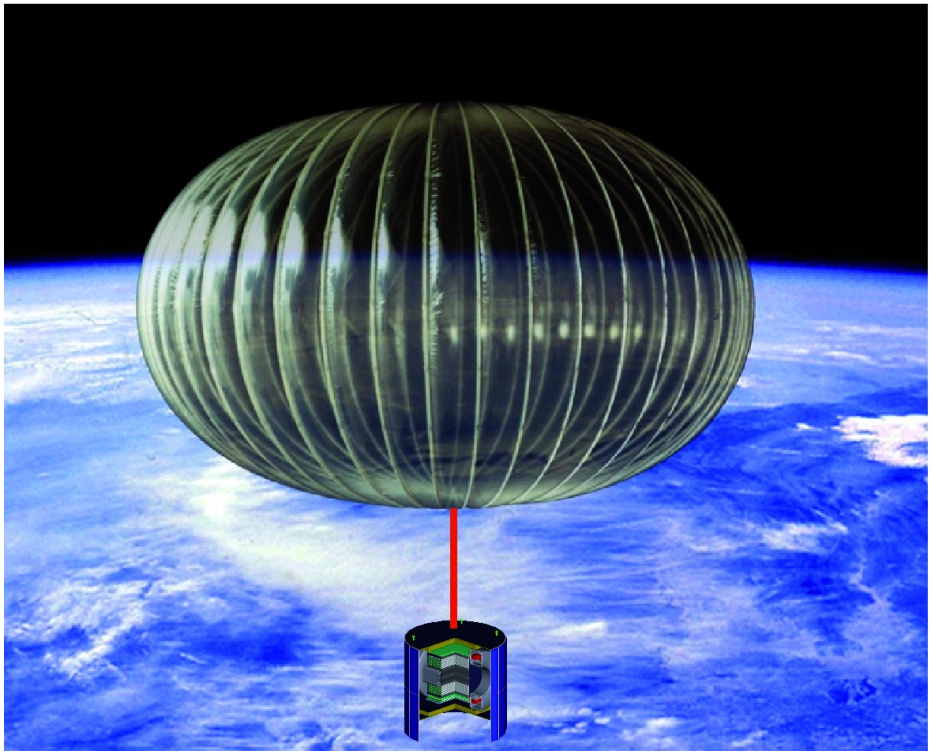
- initial asymmetry
- separation of matter and antimatter in the early universe
- large CP violation is needed

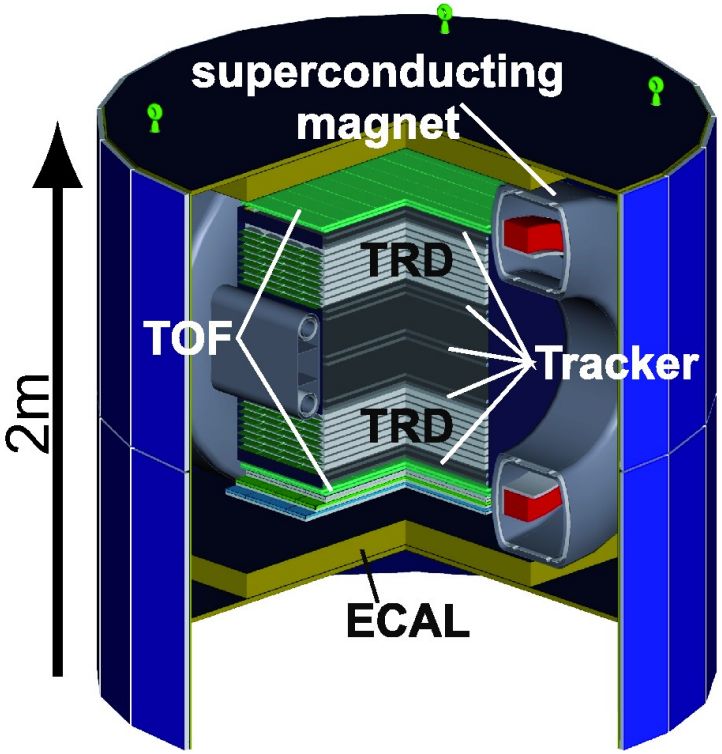
measurement:

- bound on antihelium gives constraint for the distance between galaxies and antigalaxies
  (NO(!) production of antihelium in the matter universe possible)



PEBS – Cosmic Rays in the Atmosphere





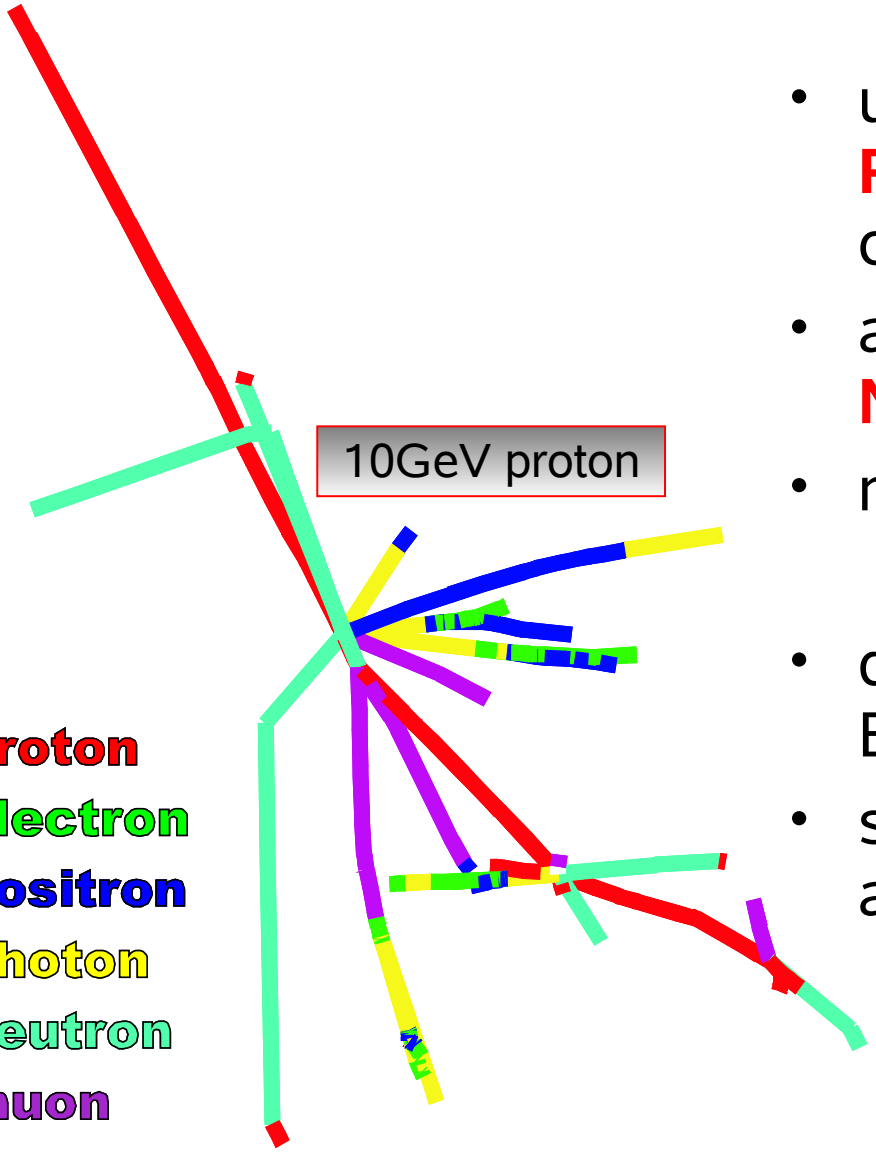
detector proposal:

- cosmic ray measurements @ North Pole or South Pole
- balloon at 40km altitude in the atmosphere and magnetic field

detector properties:

- flight time: 100days (total)
- acceptance: 0.4m^{2}sr
- magnetic field: 1T
- weight: < 2t

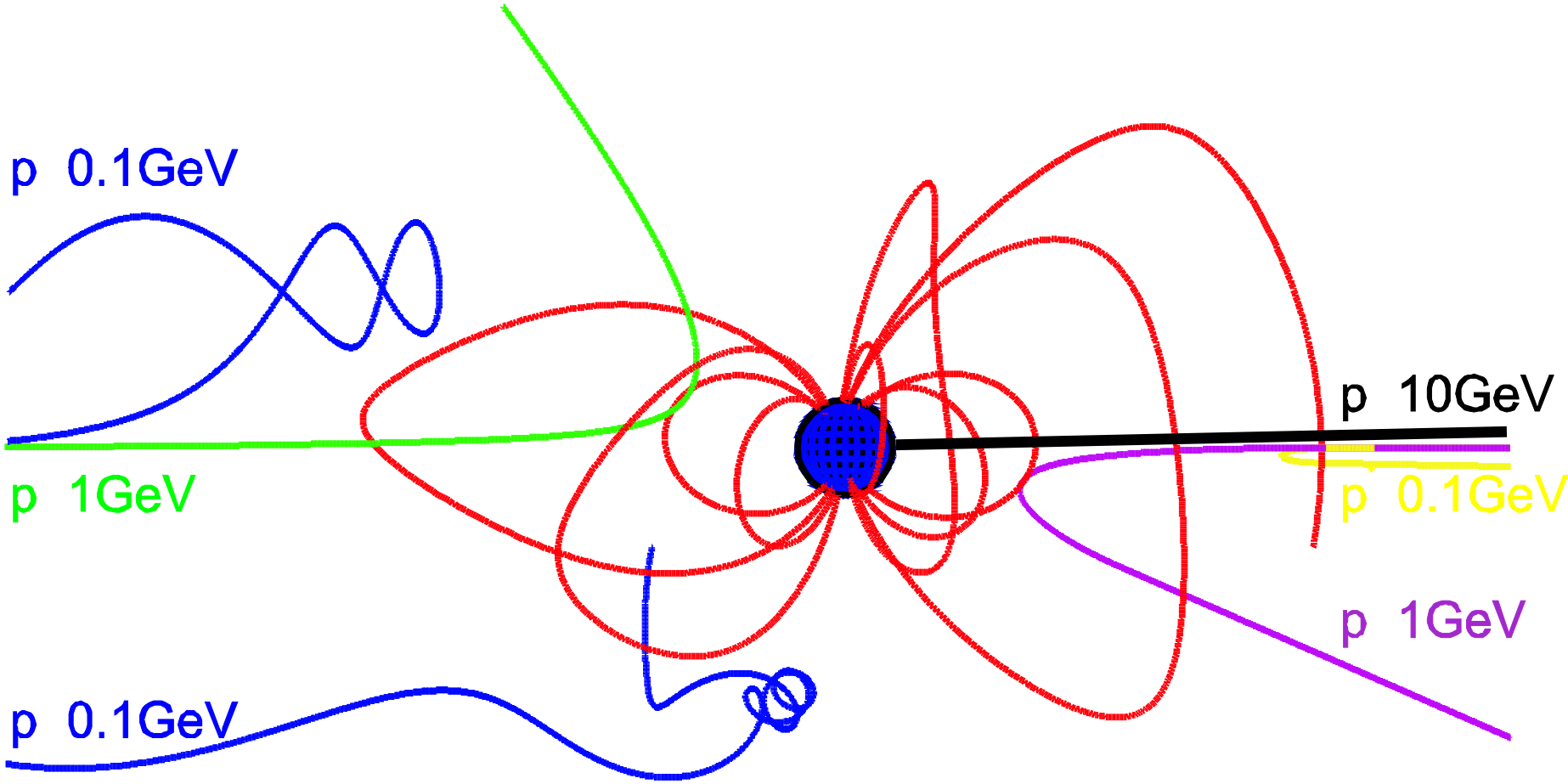
Air Shower



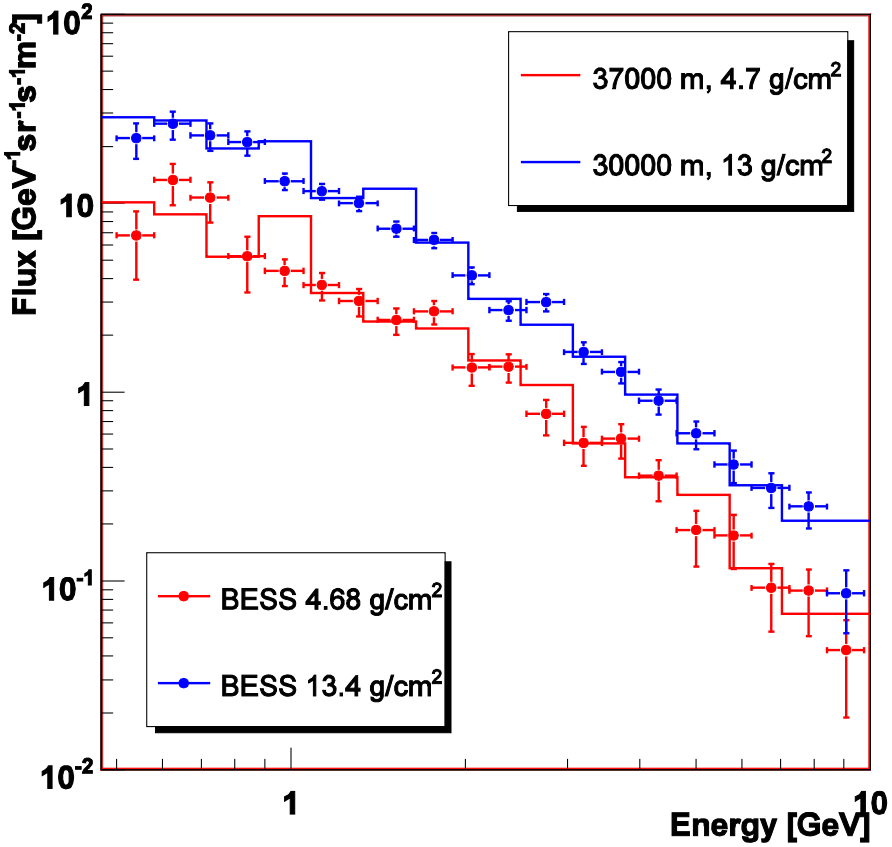
- use of program package: **PLANETOCOSMICS** based on GEANT4
- atmospheric model: **NRLMSISE00**
- magnetic field: **IGRF 2005**

- detection planes around the Earth
- start particles at 500km altitude

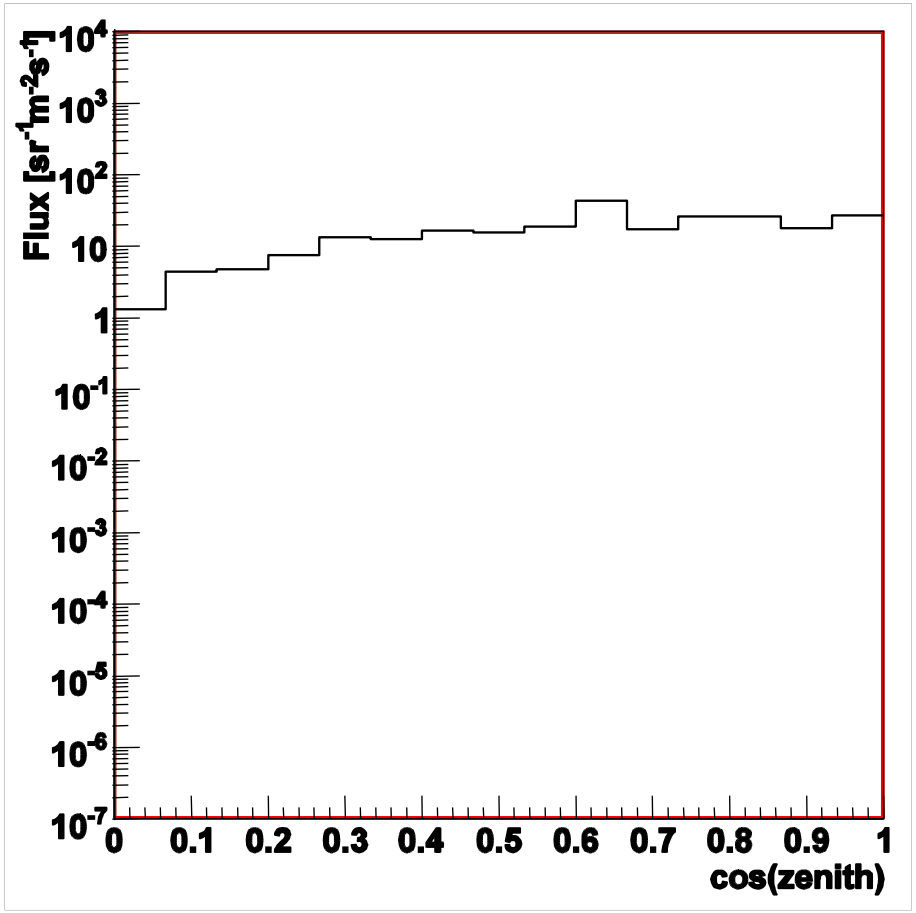
Magnetic Field



BESS Muon Data in New Mexico



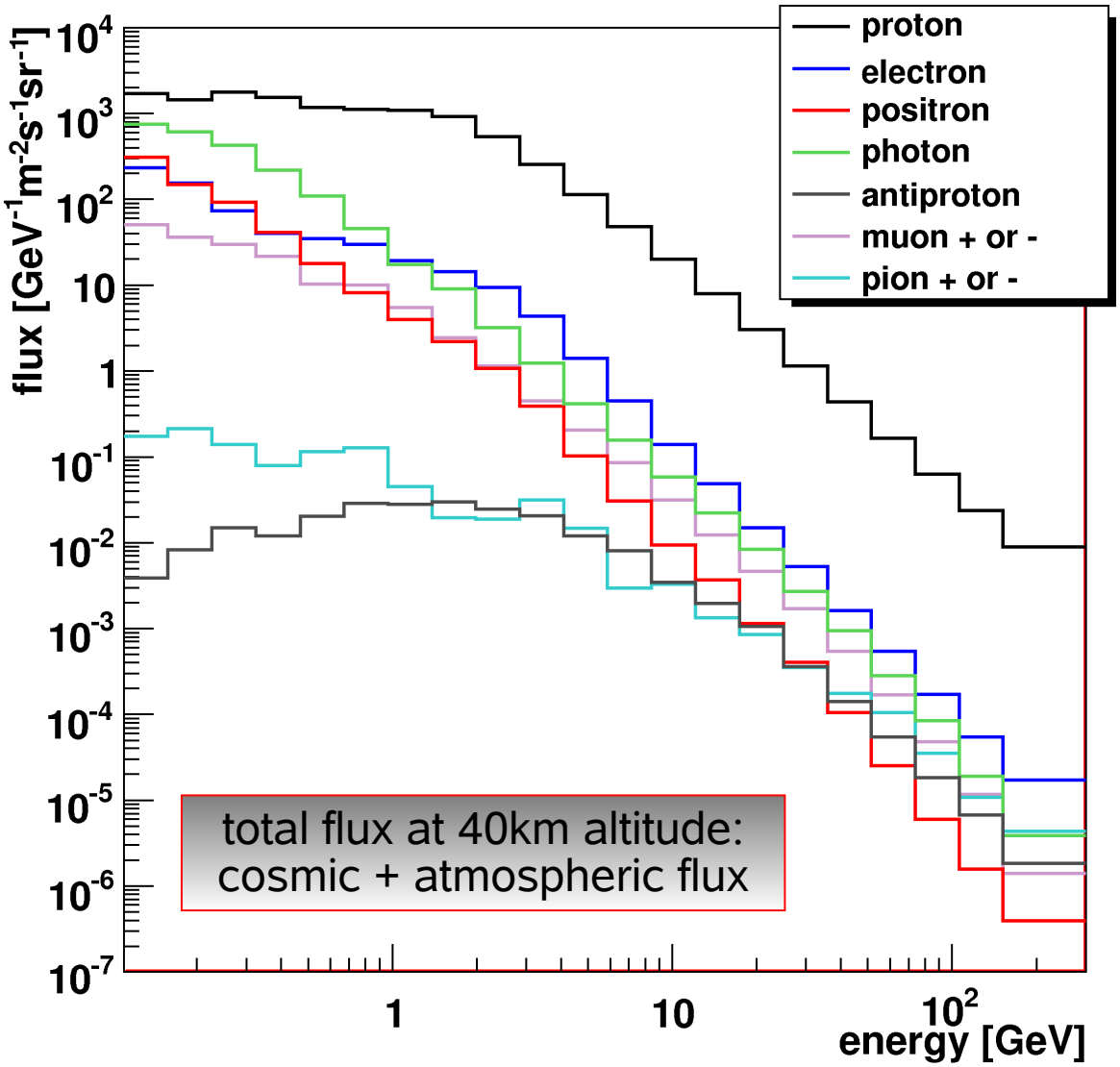
good agreement of simulated secondary muons with BESS data at Ft. Sumner, NM



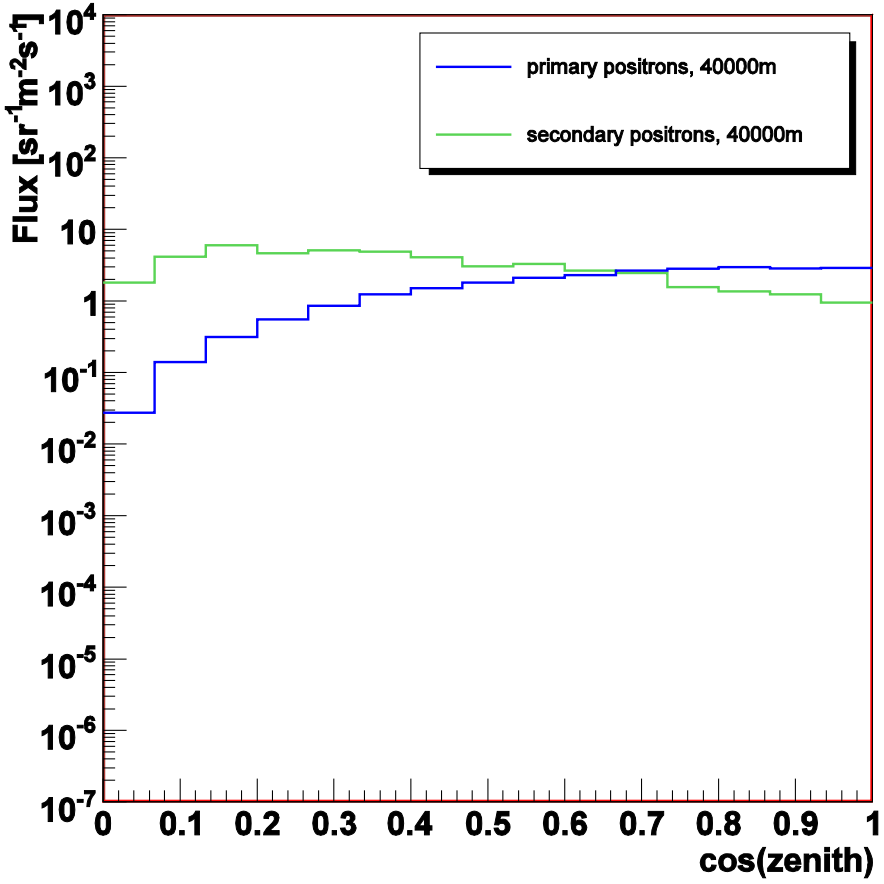
simulated angular distribution for muons at 37km altitude

Simulation works, now South Pole

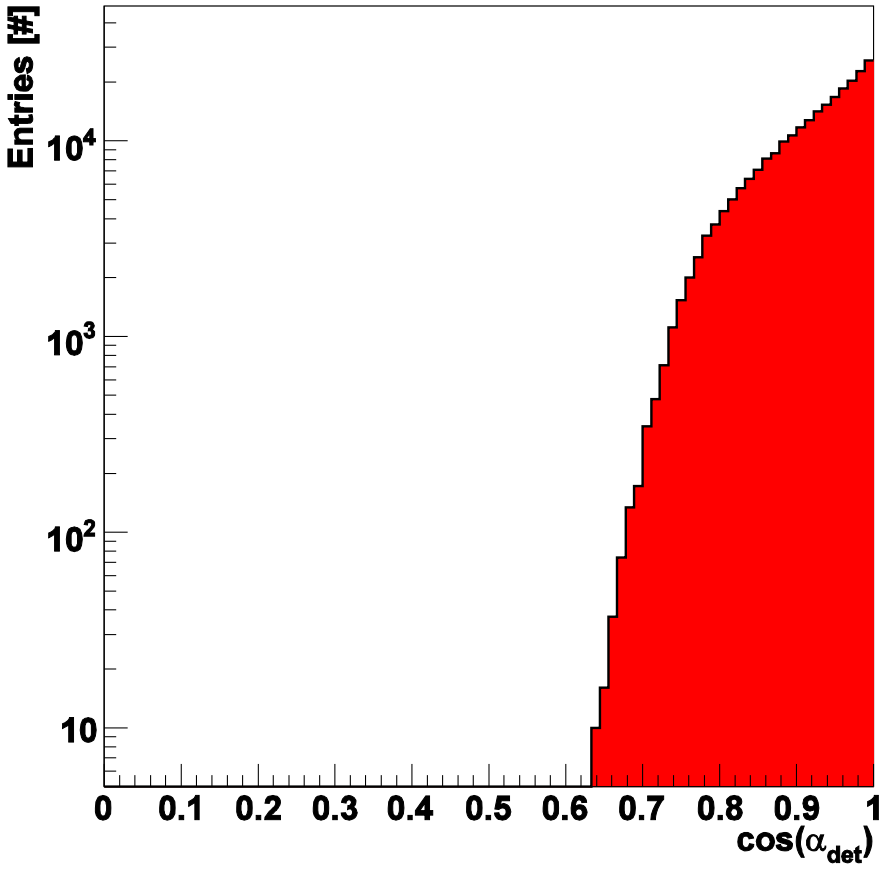
Particle Flux at South Pole



Detector Acceptance

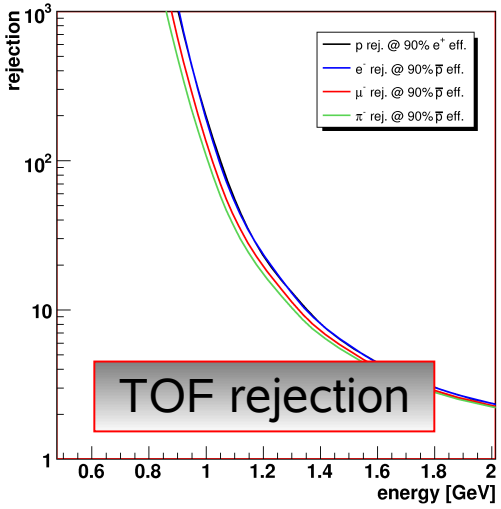


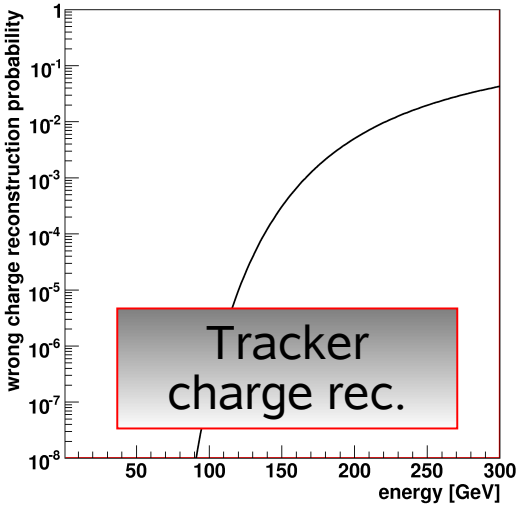
angular distribution of secondary and primary positrons

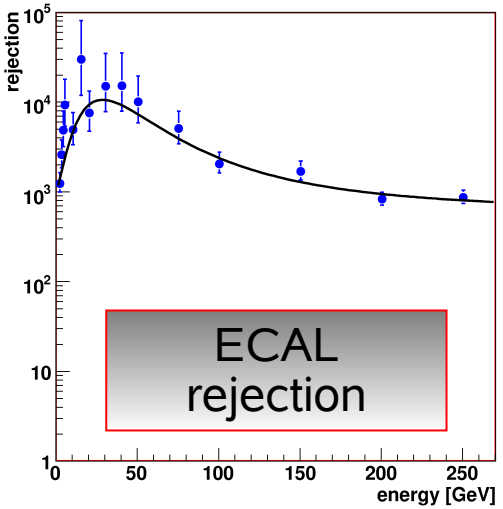


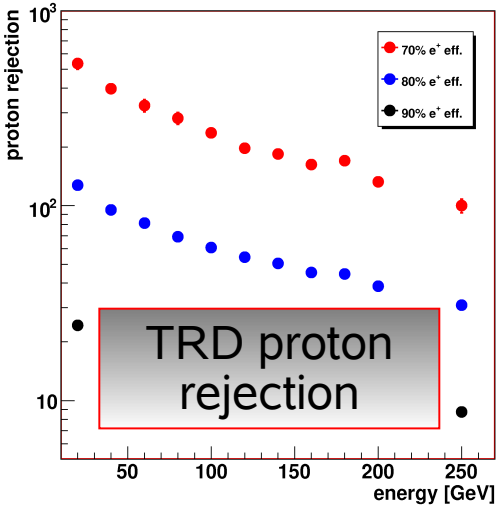
angular acceptance of PEBS works as filter on secondaries

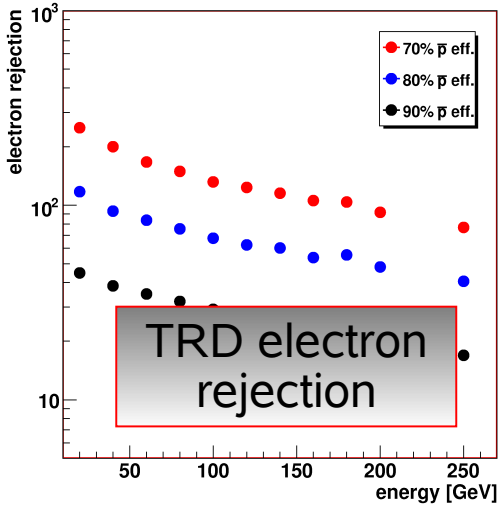
Detector Properties

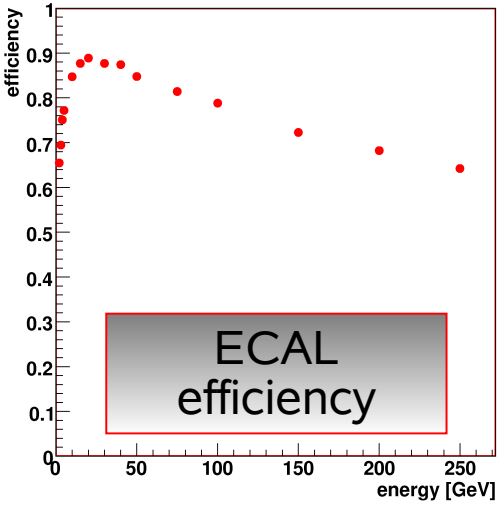




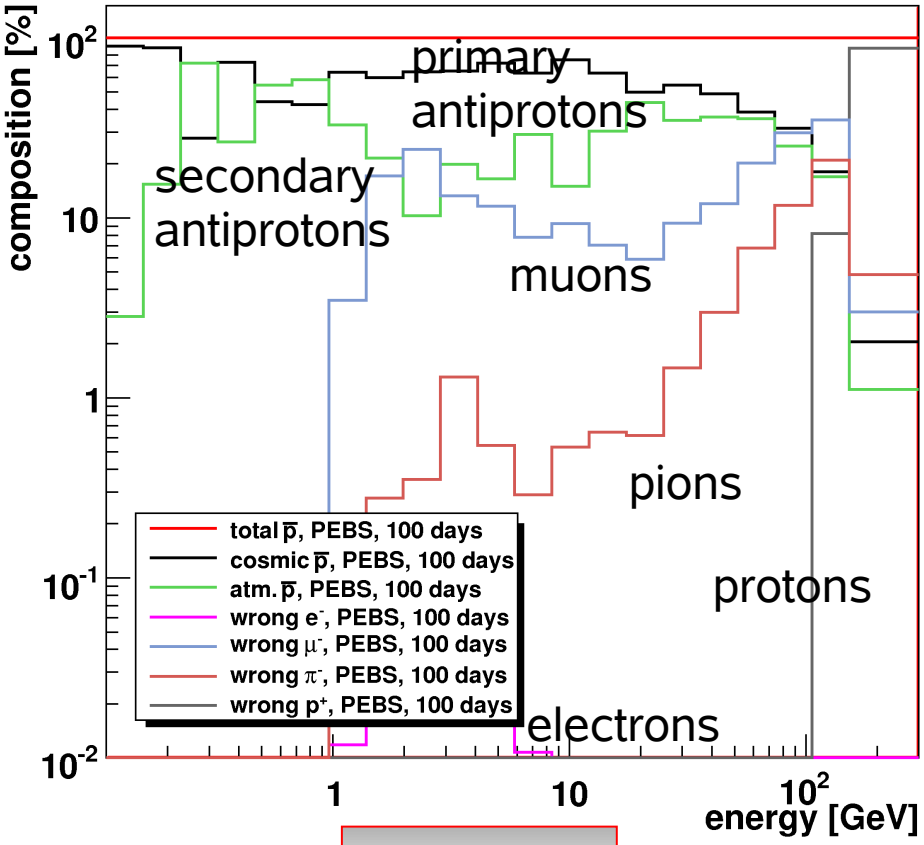




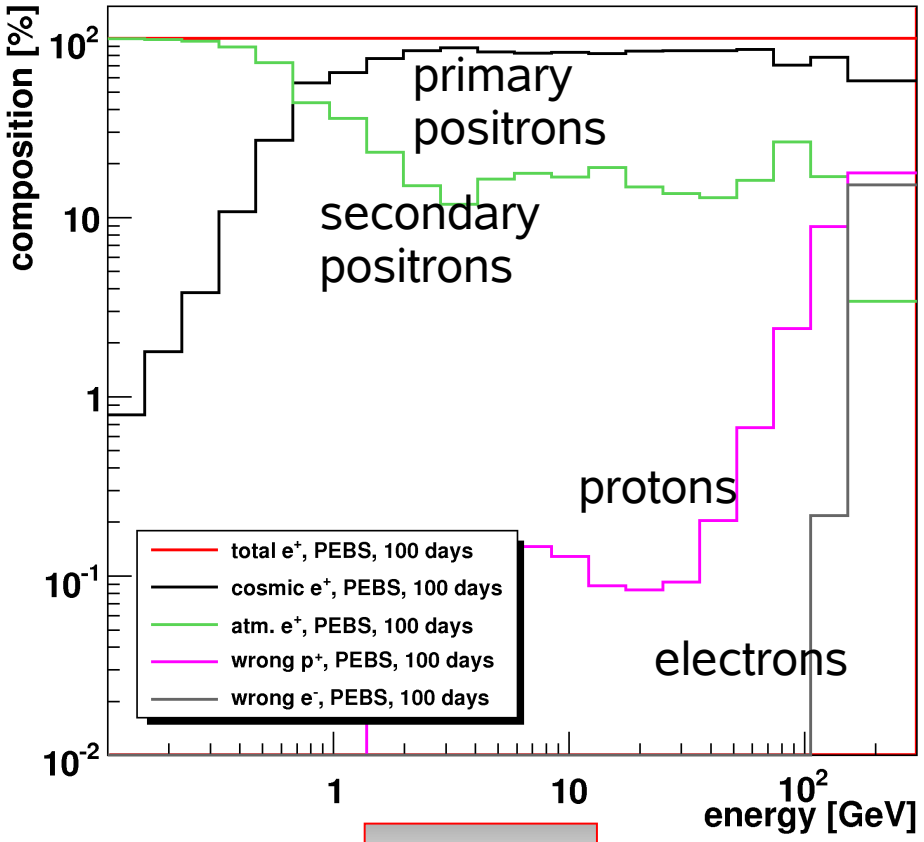




Composition



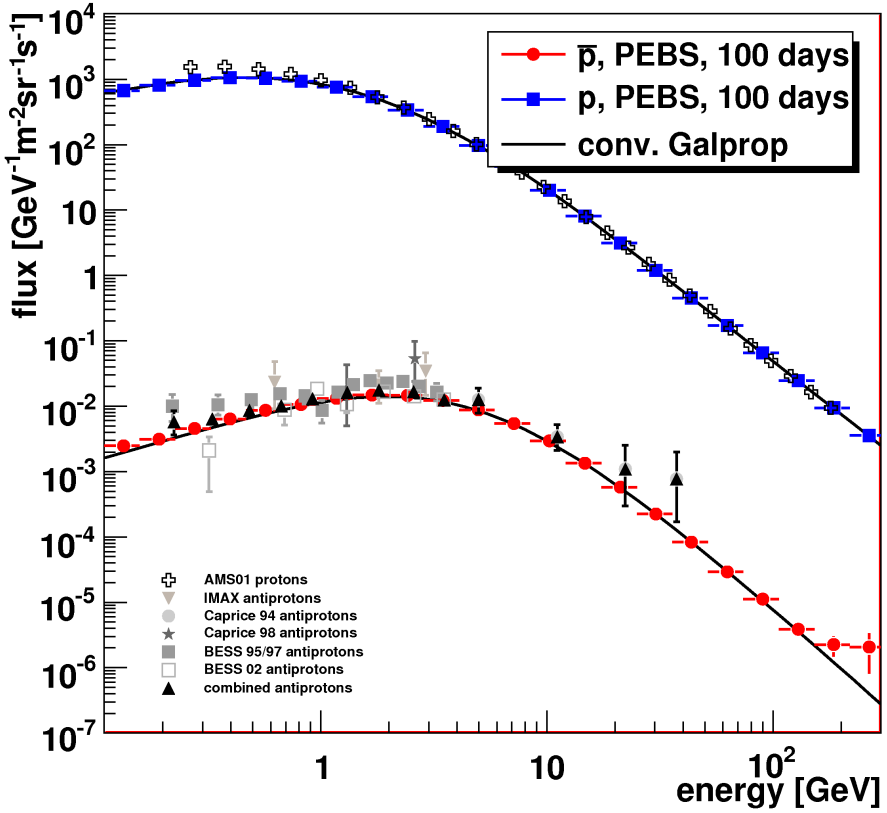
antiprotons



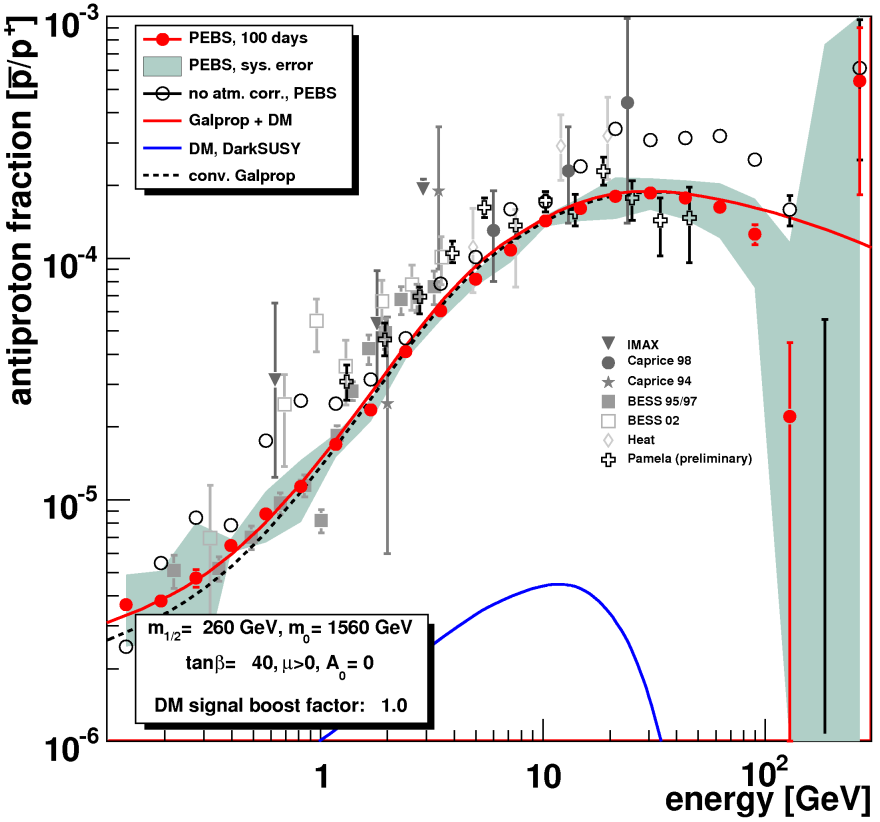
positrons

using the according rejections and efficiencies for each type

Antiprotons



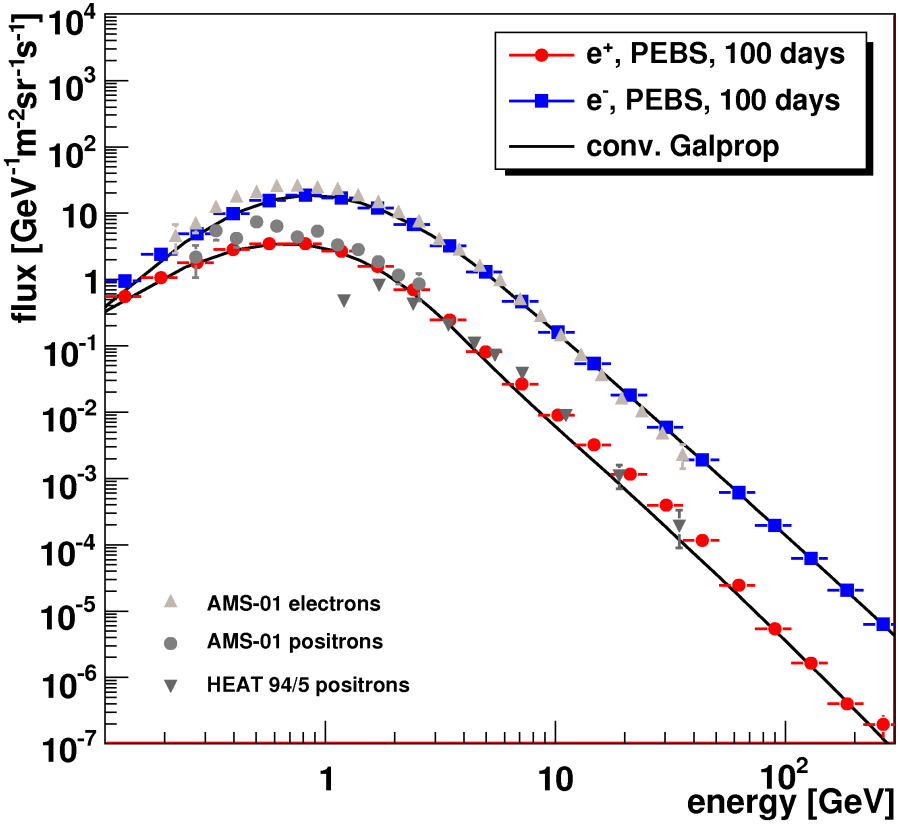
fluxes



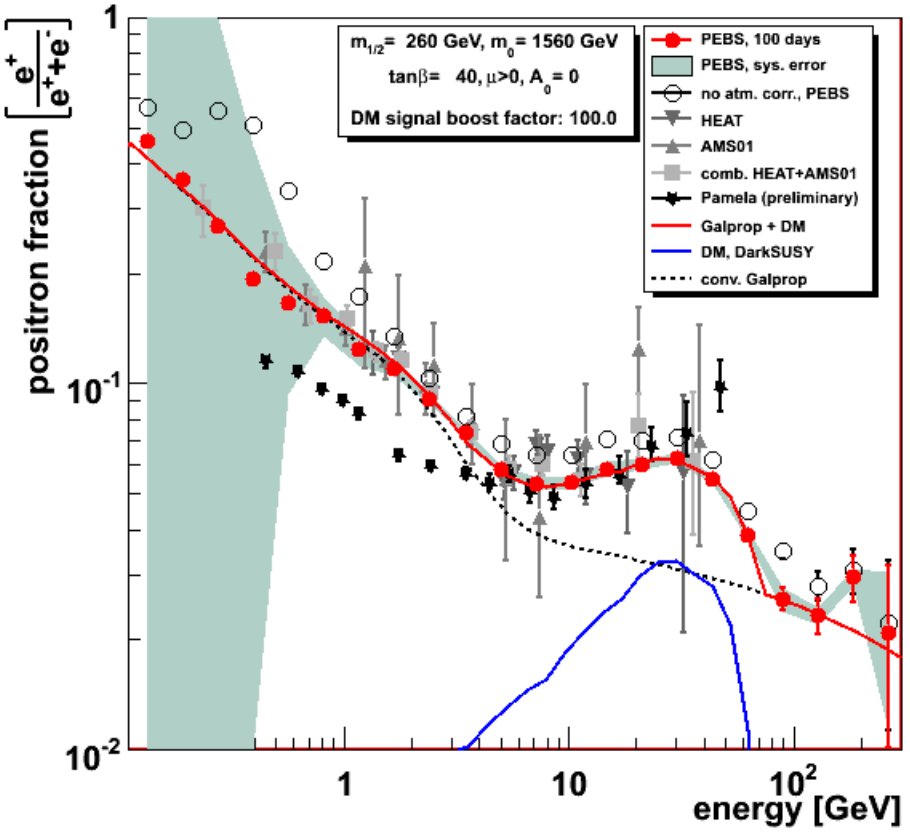
fraction

using the according rejections and efficiencies for each type
with systematic errors for detectors of 10% and 15% for the atmosphere

Positrons



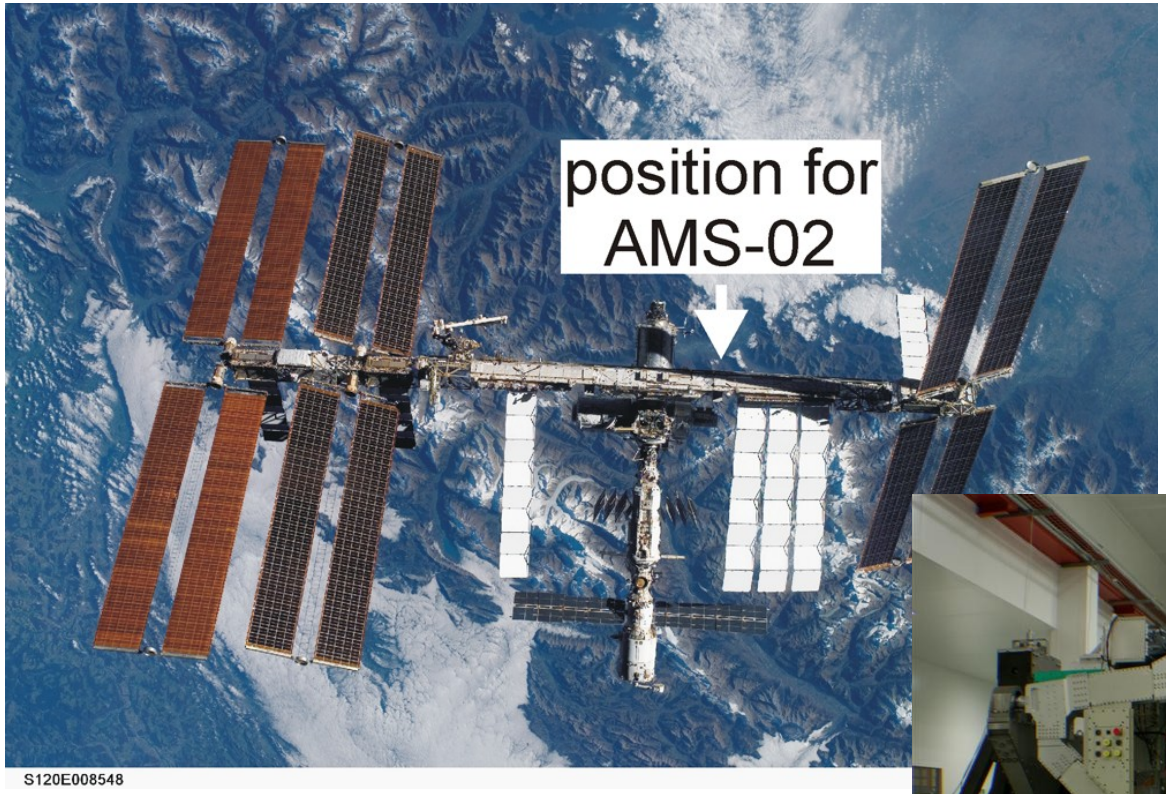
fluxes



fraction

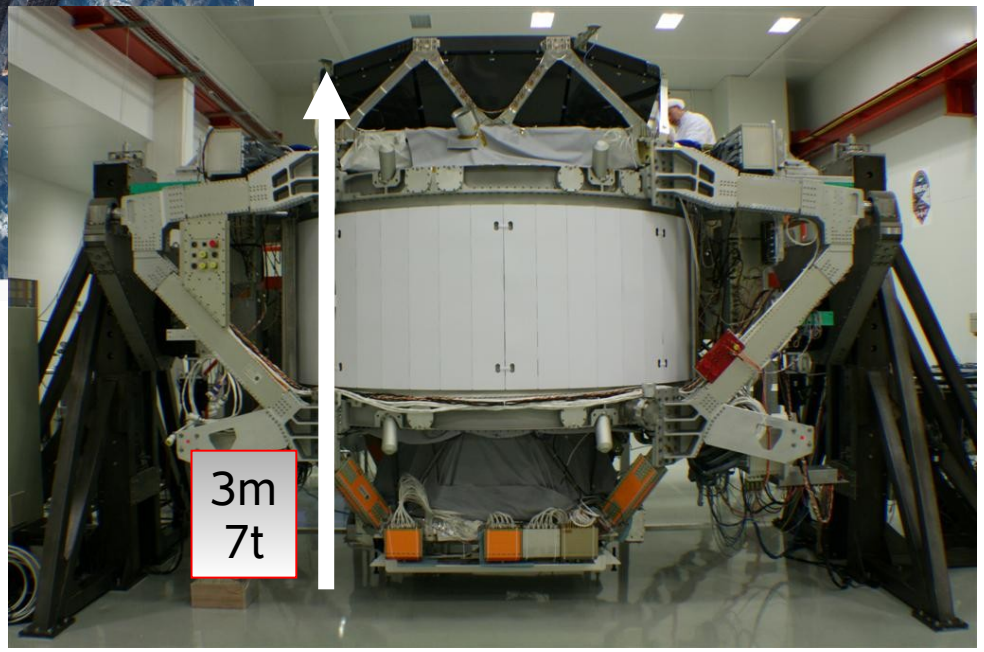
using the according rejections and efficiencies for each type
with systematic errors for detectors of 10% and 15% for the atmosphere

The AMS-02 Detector

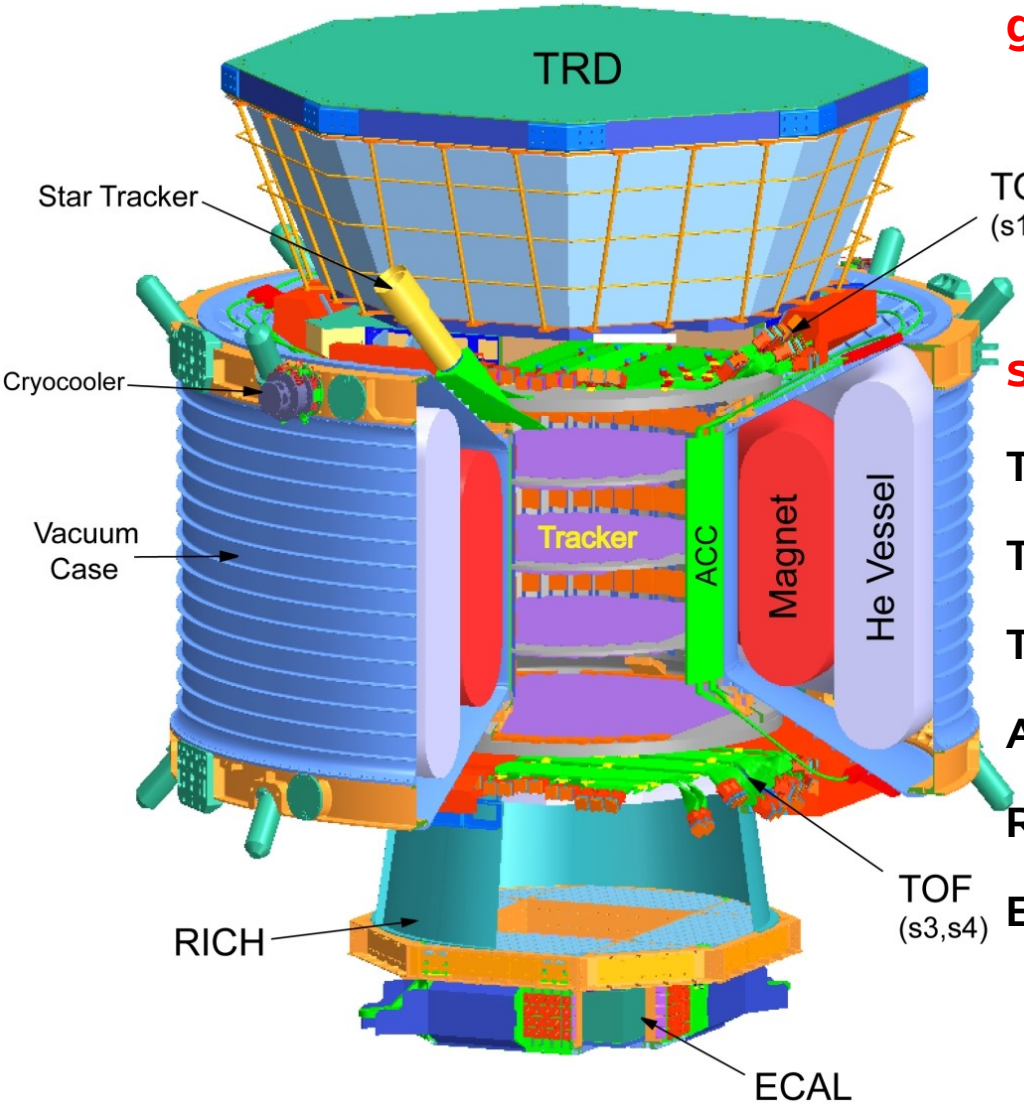


artist view of AMS-02
on the International Space Station
> 2010

AMS-02
in the clean room @ CERN



AMS-02 Overview



goals of AMS-02:

- precise spectroscopy of cosmic rays without interactions in the atmosphere on the ISS
- measurement/bounds on antimatter
- indirect dark matter search

subdetectors:

Transition Radiation Detector (TRD)
- classify particles by γ=E/m

Time of Flight (ToF)
- trigger, velocity, dE/dx

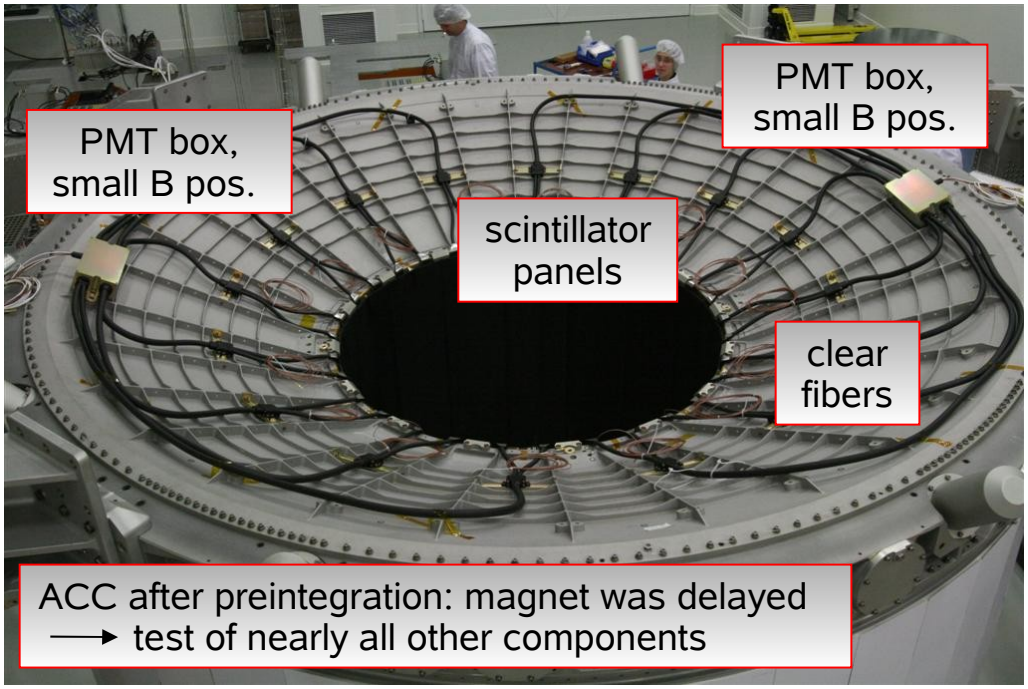
Tracker + superconducting Magnet (1T)
- track reconstruction, momentum, dE/dx

Anti-Coincidence Counter (ACC)
- event selection ⟶ next slide

Ring Image Cherenkov Detector (RICH)
- precise velocity mesaurement

Electromagnetic Calorimeter (ECal)
- shower shape and energy determination

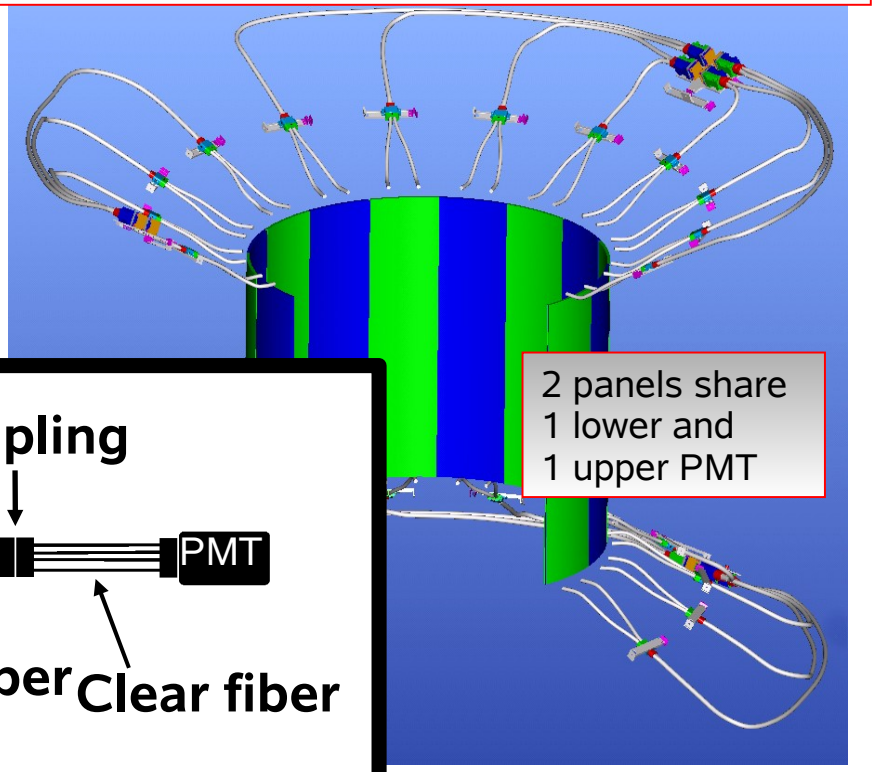
ACC System

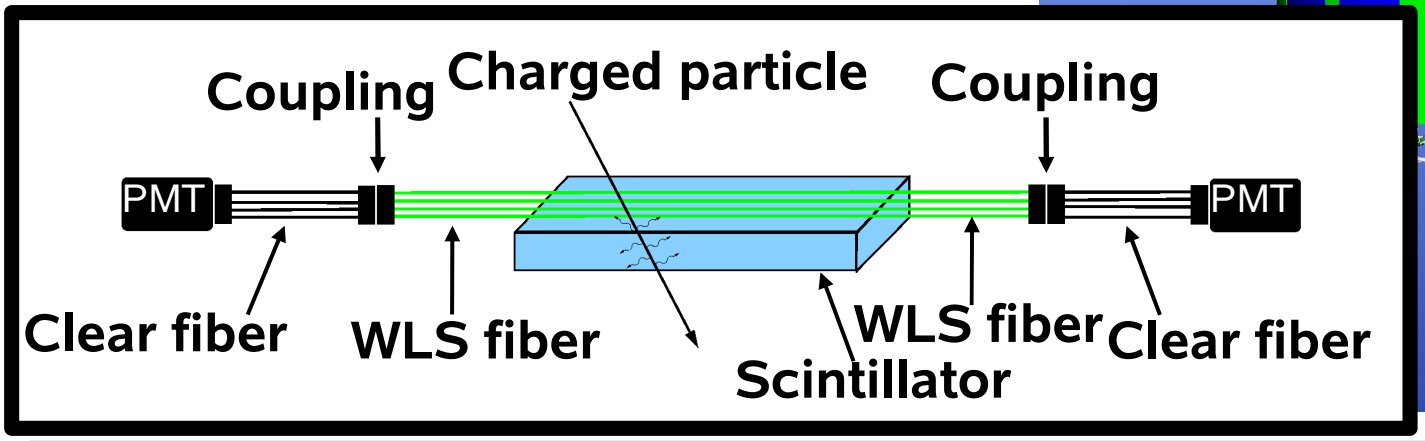


ACC after preintegration: magnet was delayed
⟶ test of nearly all other components

- small ACC inefficiency needed ($<10^{-4}$)

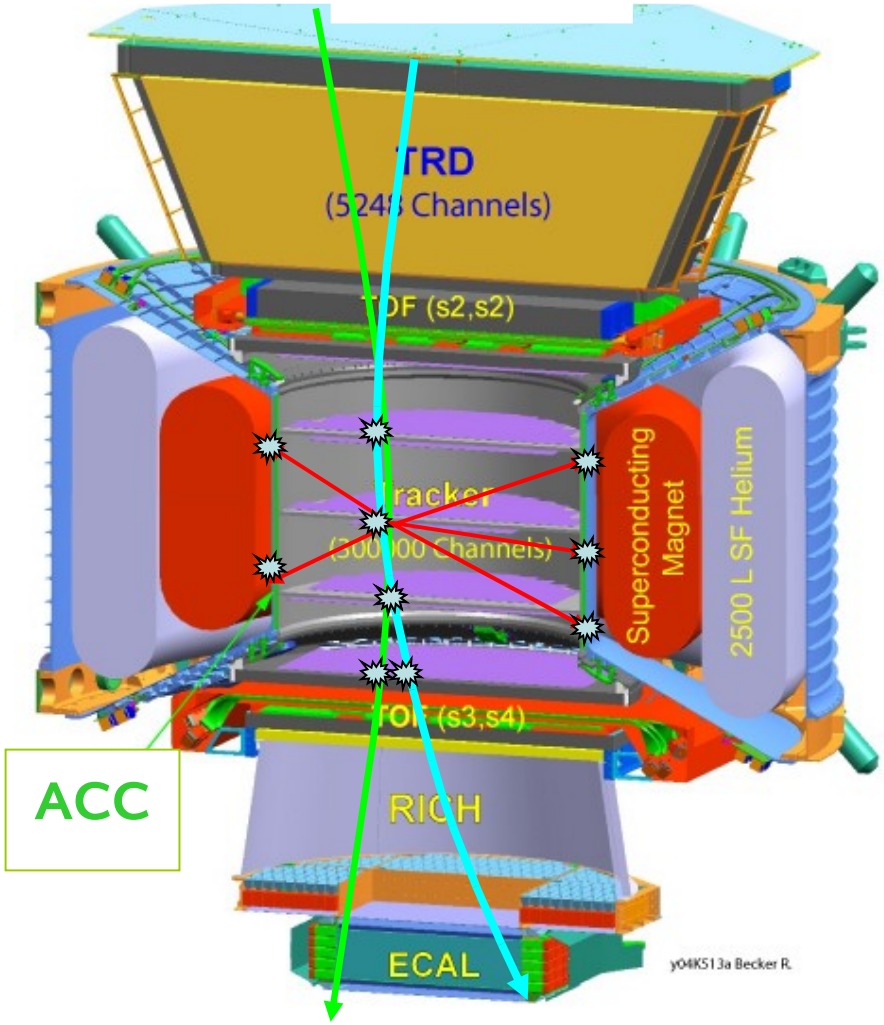
  for measurement of antimatter with very clean single tracks
- reduce trigger rate, fast detector (ns): e.g. South Atlantic Anomaly



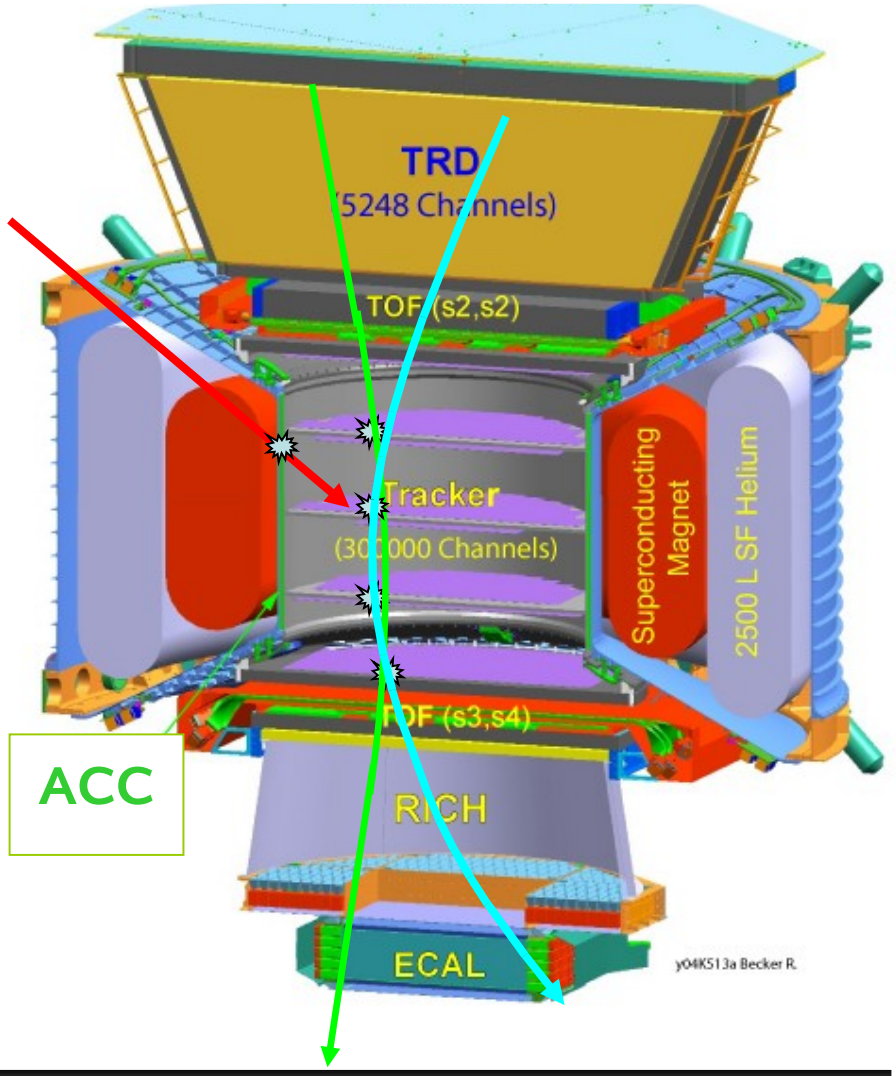


Important Events for the ACC

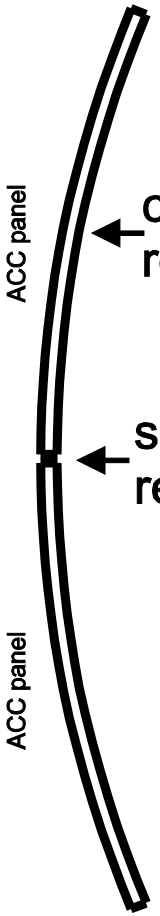
rejection of internal interactions

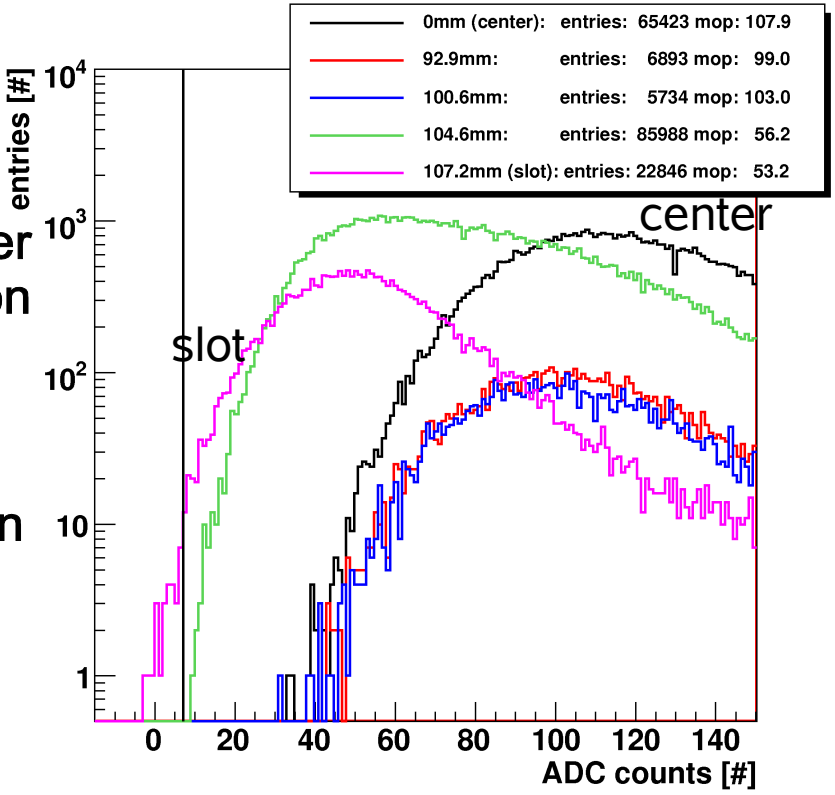


rejection of external particles

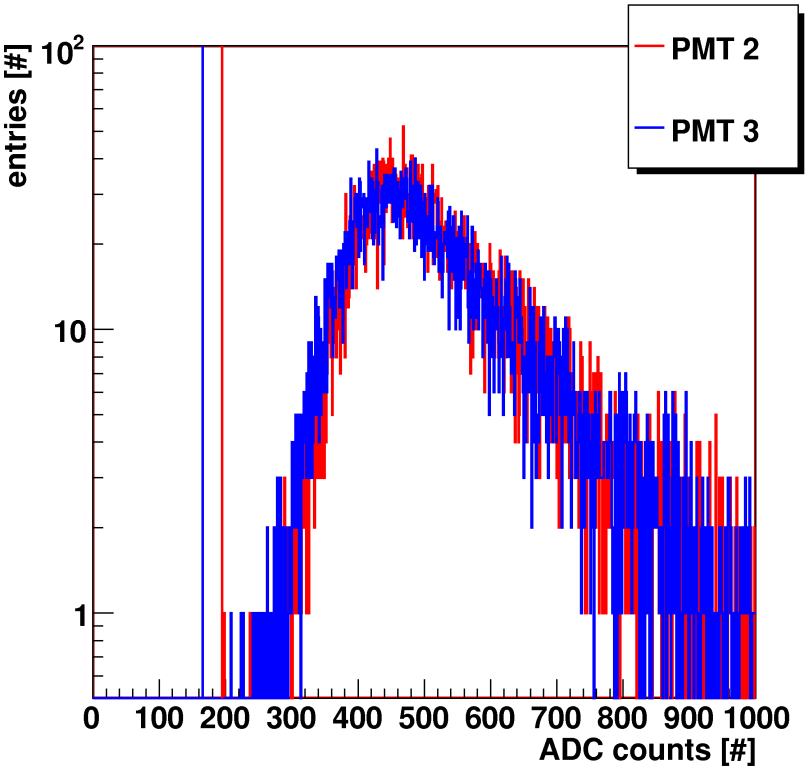


Testbeam & Flight Electronics



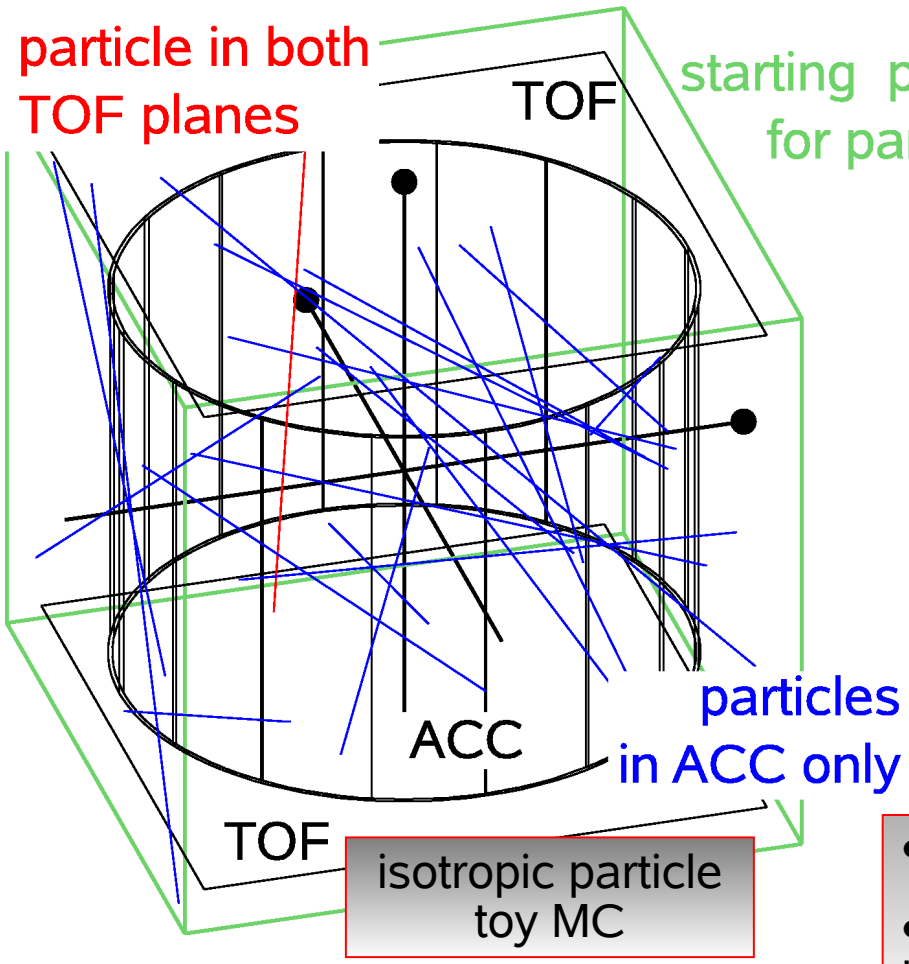


testbeam measurements across panel width with lab electronics

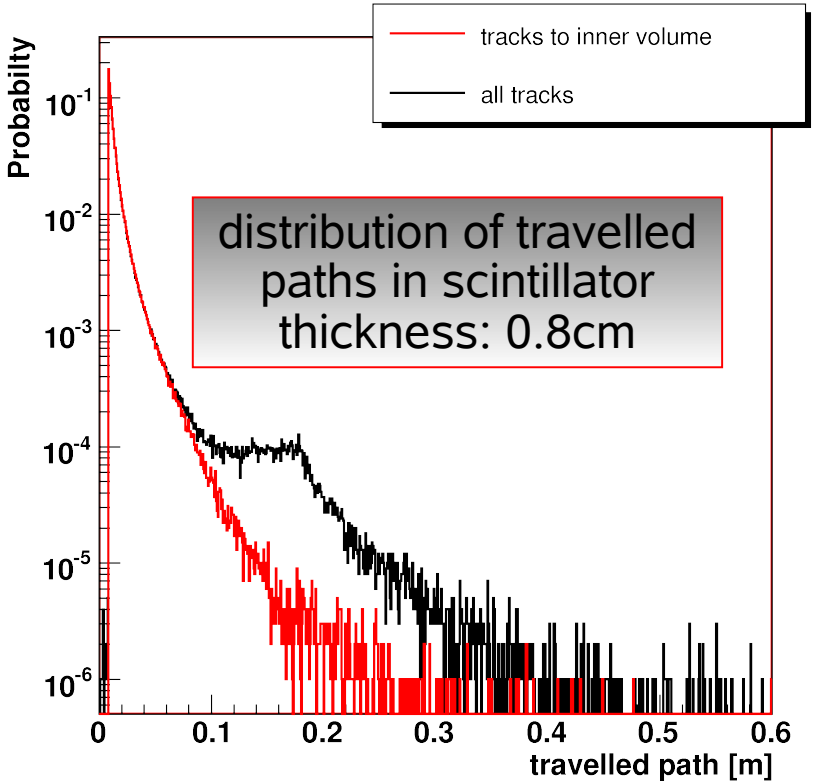


measurements with final electronics in central region
0 missed events out out 8000

Isotropic Particle Distribution



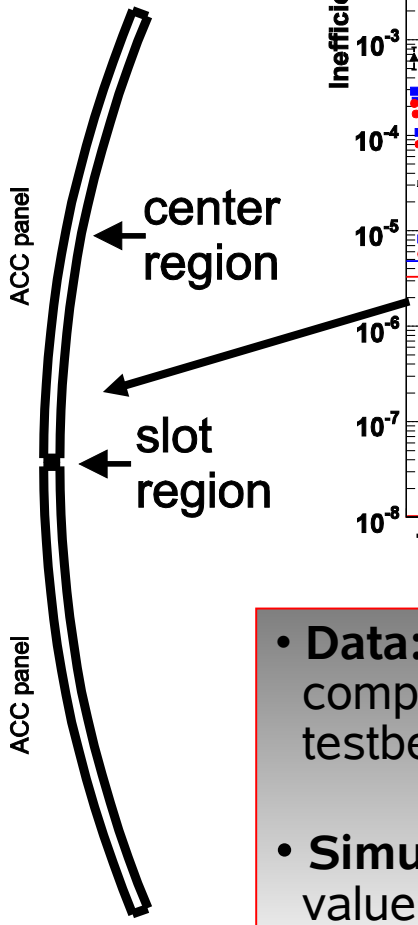
isotropic particle toy MC

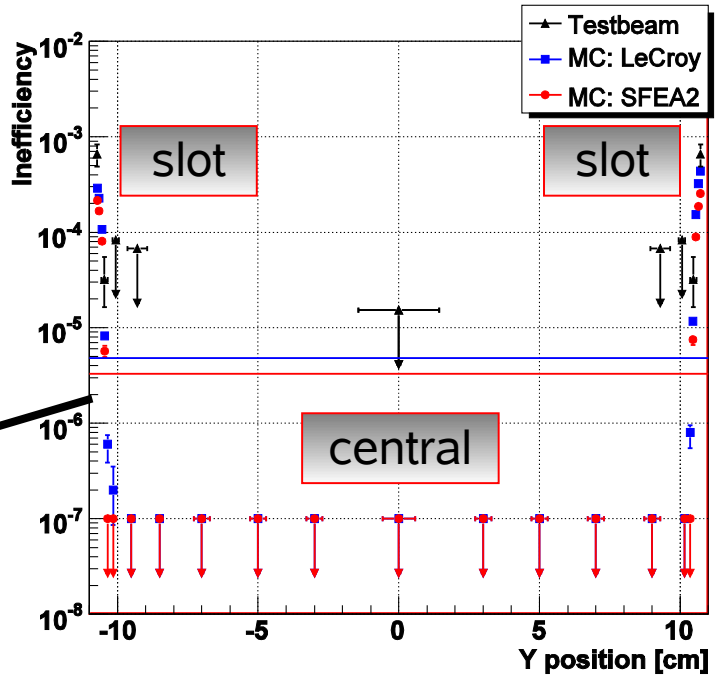


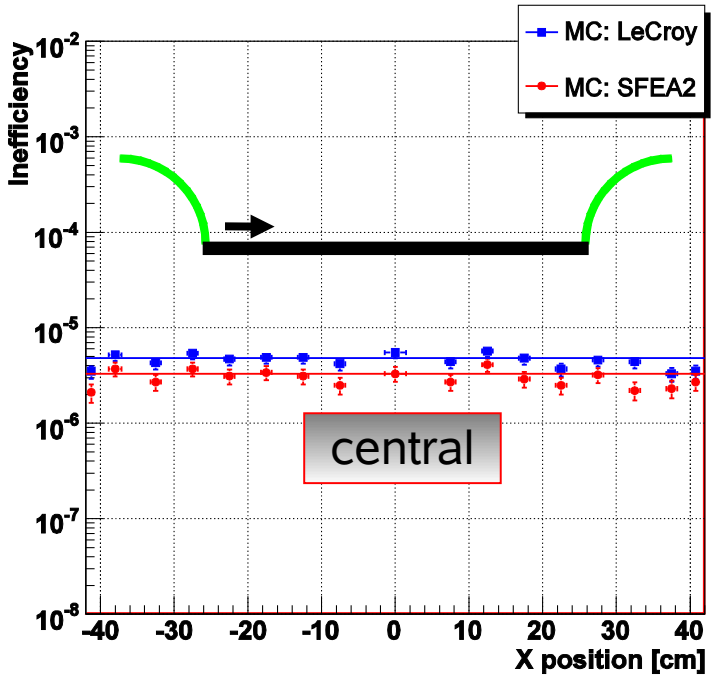
distribution of travelled paths in scintillator thickness: 0.8cm

- **beamtest**: straight infall to panel
- **space**: isotropic particle distribution leads to **longer** path lengths in scinitillator

Inefficiency Model

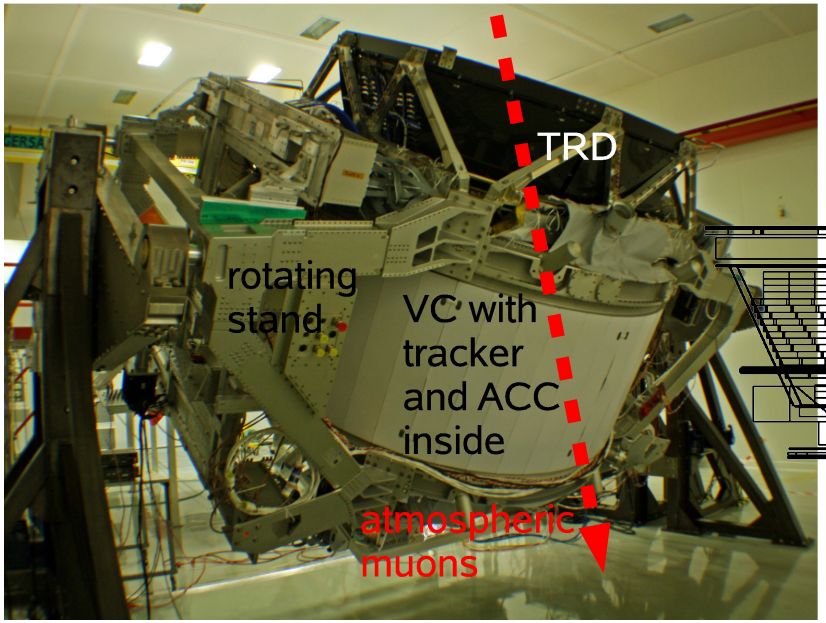




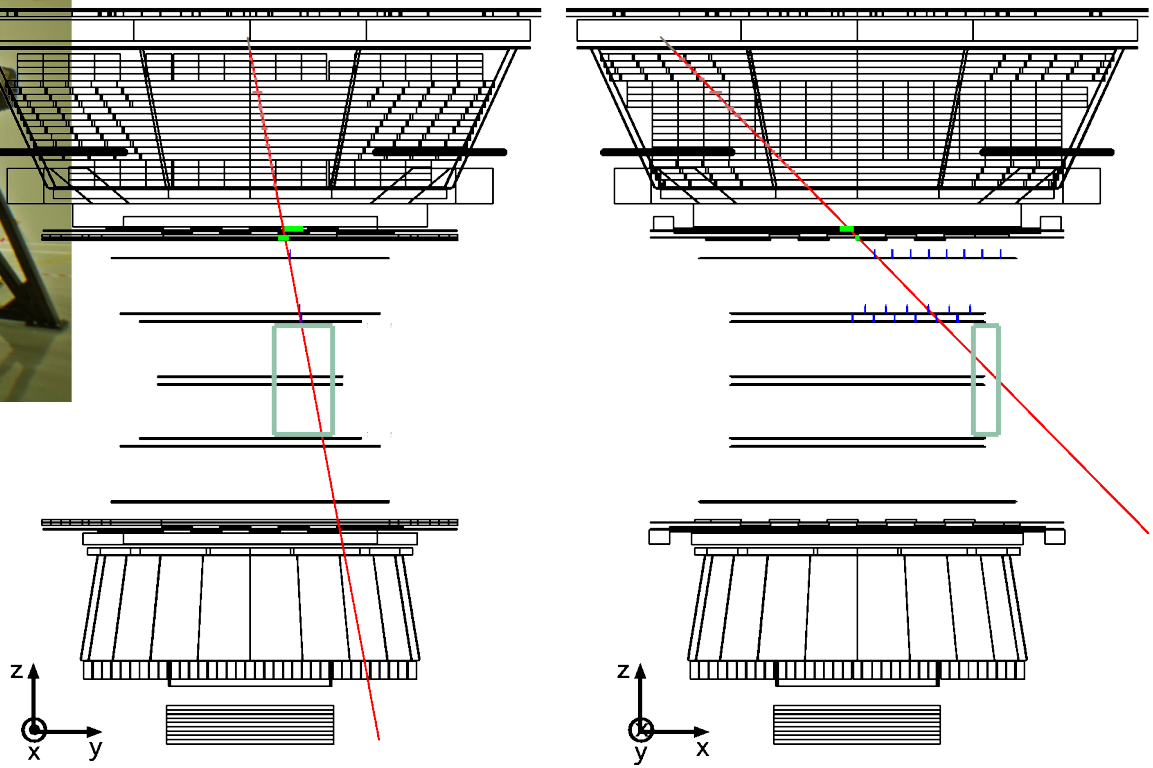


- **Data:** Mean inefficiency for **one complete ACC panel** with complete system test results and isotropic particle distribution and testbeam electronics: $5 \cdot 10^{-5}$
- **Simulation:** use of testbeam spectra with extrapolation to small values, system test, flight electronics, position measurements, isotropic particle distribution, smearing of signal values: $3 \cdot 10^{-6}$

AMS-02 Cosmics

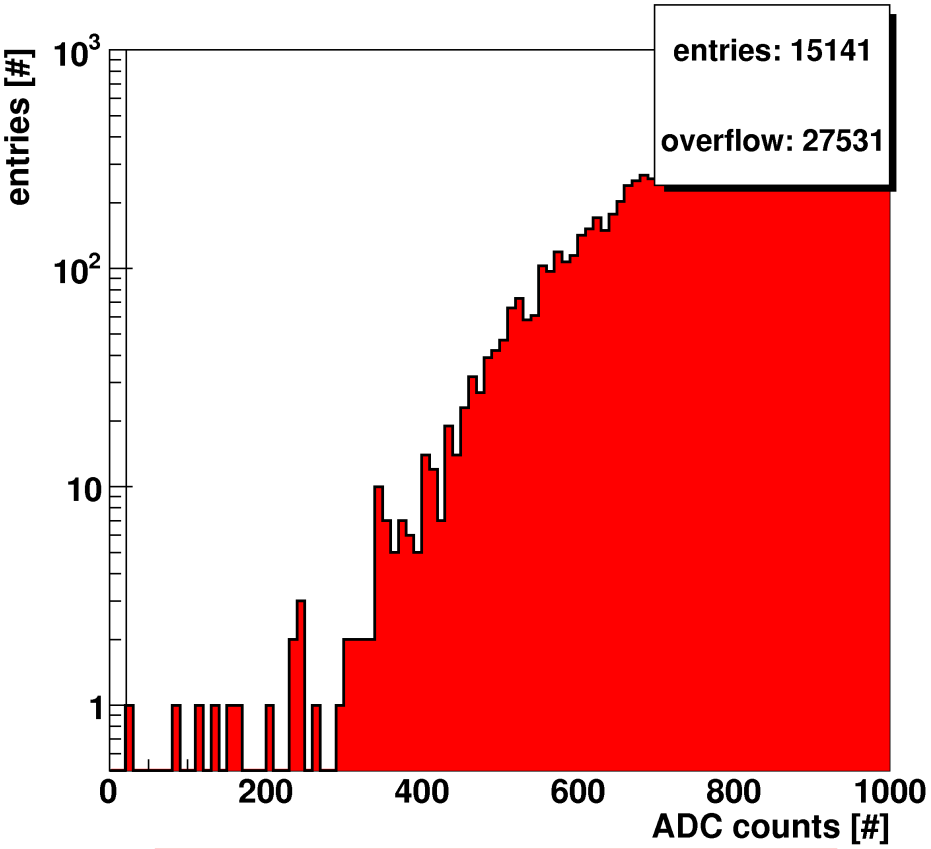


AMS-02 taking data after preintegration
(all components, but magnet)

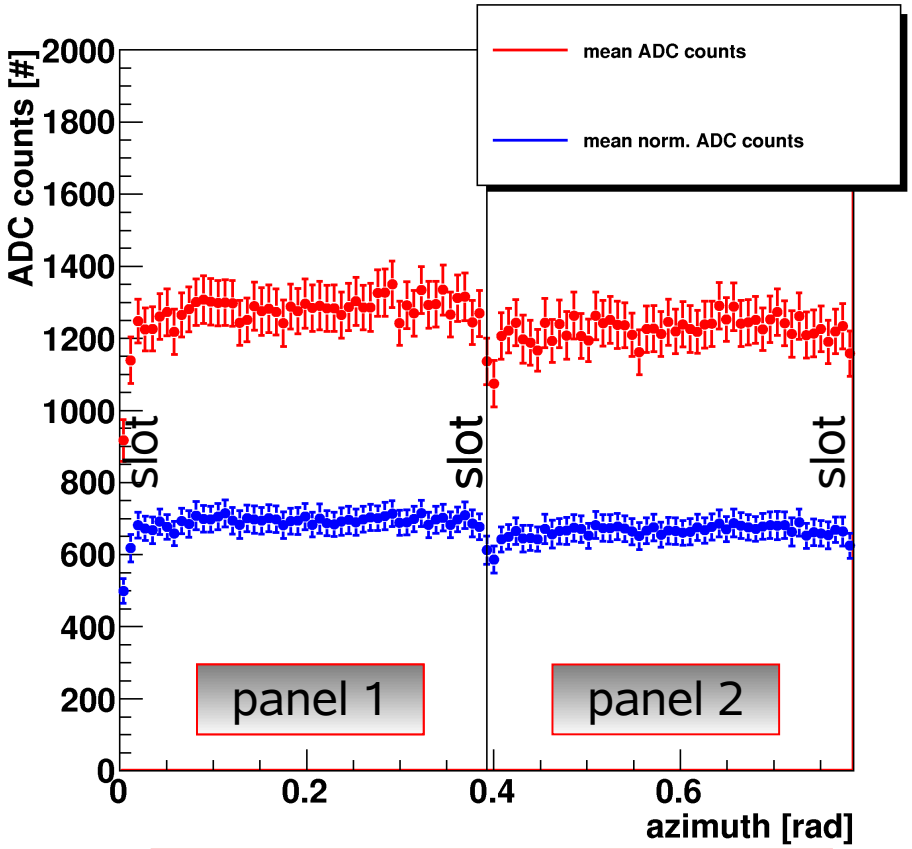


inefficiency study of ACC with TRD and tracker tracks

AMS-02 Cosmics

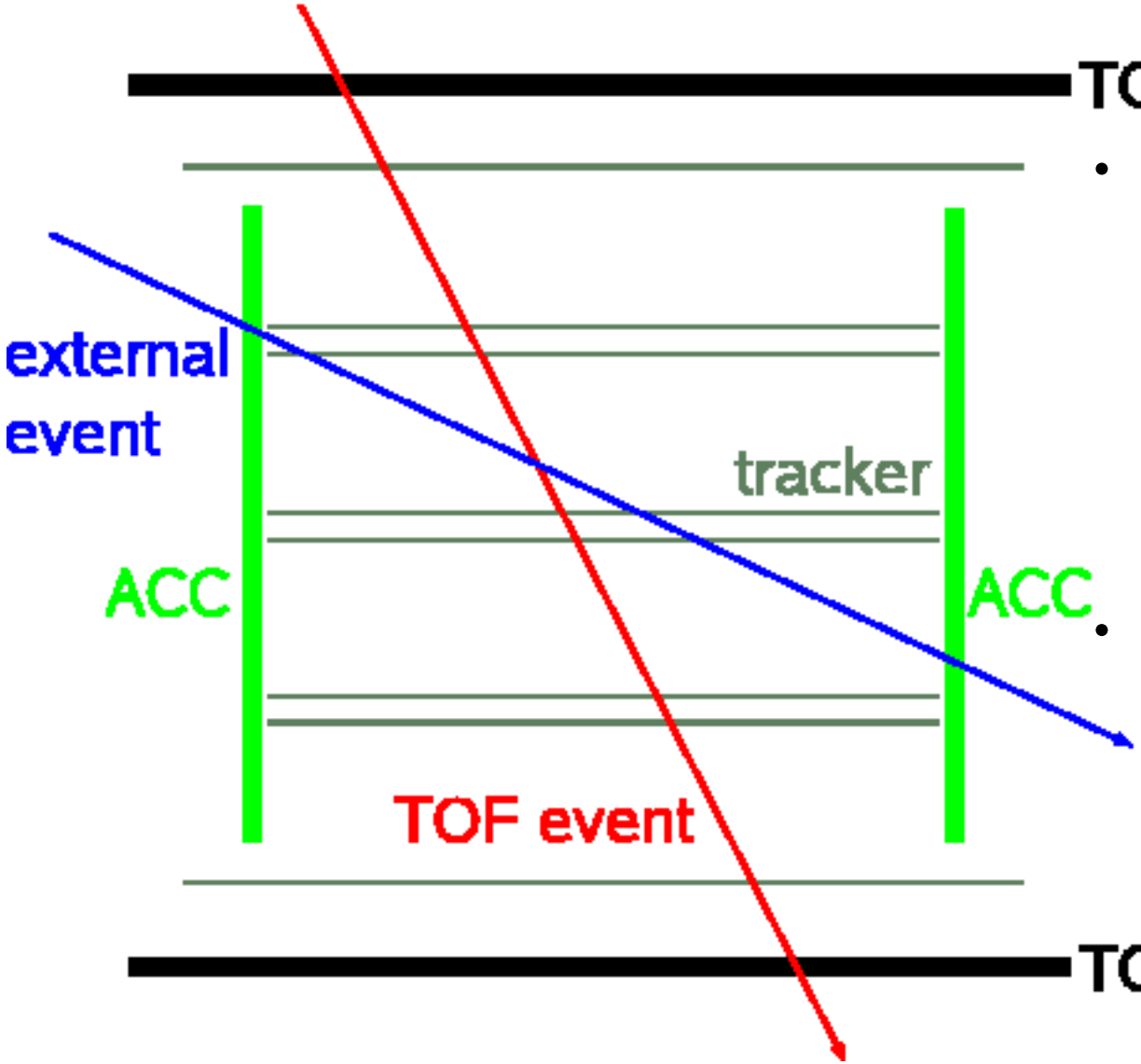


- use of very clean tracks in TRD and tracker
- **inefficiency < $2 \cdot 10^{-5}$**



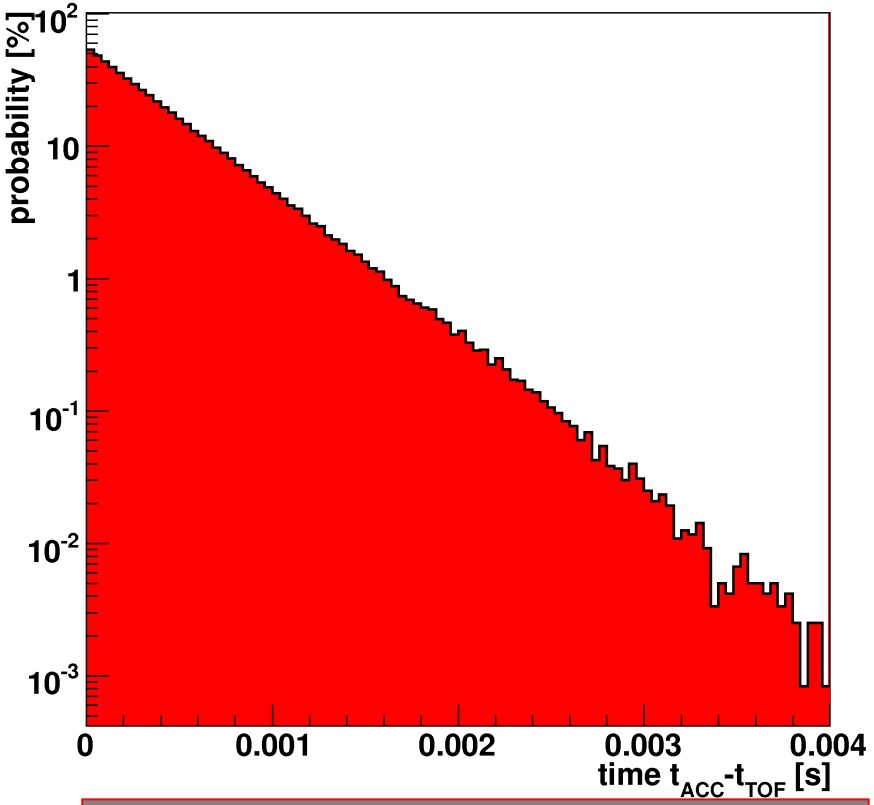
- average signal height across a sector of two ACC panels

Antihelium with AMS-02

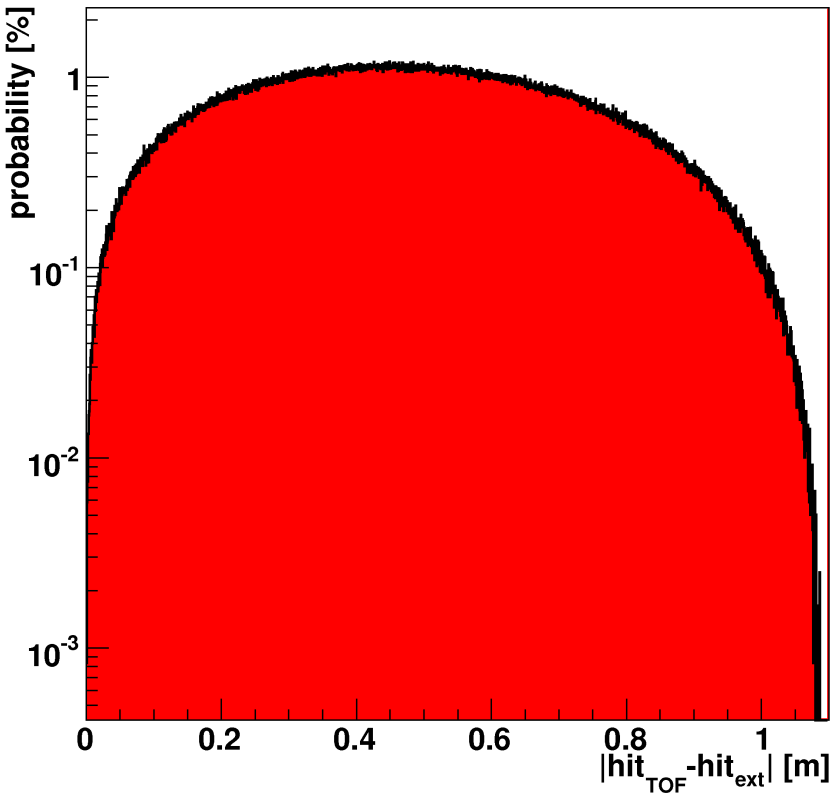


- check for the ability to measure particles between triggers with the ACC which could **spoil the charge determination**
- **toy MC with TOF, Tracker and ACC** with isotropic particle distribution and without magnetic field

Antihelium with AMS-02



probability for the distance in time between external and TOF trigger events with hits in the tracker normalized to TOF triggers



probability for the distance between external and TOF trigger events in the tracker

external events traversing the ACC can be excluded < $5 \cdot 10^{-15}$ to spoil measurement

Conclusion

- **PEBS prospects are promising!**
  - atmospheric and magnetic simulations work fine
  - good capabilities to measure positrons and antiprotons and South Pole or North Pole

- **ACC system for AMS-02 works!**
  - fabrication and preintegration successfully done!
  - cosmic test of AMS-02 successful
  - good inefficiency for antimatter search