The experiment AMS

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The AMS experiment goals are to perform a high statistics and high precision study of the primary cosmic rays spectrum. A prototype of the AMS detector, to be deployed in the ISS by the beginning of 2004, was flight in the space shuttle Discovery in 1998 for 200 hours. Its results are presented and the perspectives of the final mission are outlined.

Contents

1 What's AMS?

AMS is a particle physics detector in the space to perform a high statistics and high precision study of the primary charged cosmic ray energy spectrum, with isotopic and chemical identification power, and with photon detection capabilities:

It will allow us to (at least)

- Study the cosmic rays production and propagation.
- Probe the nature of (cold) dark matter.
- Probe the existence of primordial antimatter.

...in our galaxy.

1.1 Why are we looking at the sky?

The high energy scale of several astrophysical and cosmological phenomena make them a perfect arena to probe for physics beyond the standard model far away of any accelerator technology:

- The cosmological inflation scale is $\sim 10^{12} GeV$ as GUT scale.
- Ultra High Energy Cosmic Rays with $E_p > 10^{11} GeV$ and $E_\gamma > 1 TeV$ (HEGRA,AGASA) open a window to the possibility of Lorentz Invariance Violation or exotic particle existence probes.
- The path length of the cosmic rays allows to look for subtle effects amplified by large traveling times (QG).

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- Annihilation of stable SUSY particles in galaxy would produce low scale energy spectrum structures for most models.
- Cosmic rays contain particles of primordial origin.
- Maybe the only probe for the nature of Ω_Λ available.
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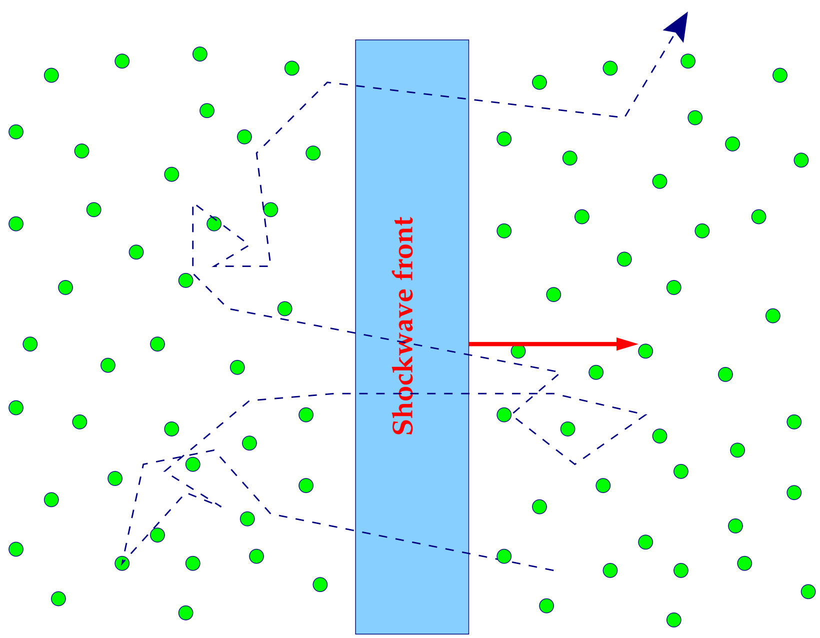
- $\bullet\bullet\bullet$

And this is far from being an exhaustive list...

1.2 A charged cosmic ray life...

Acceleration ⟶ *Propagation* ⟶ *Detection*

The only known energy sources able of provide the our local steady flux of $10^{41} erg/s$ are the supernova explosions (30 per year), with diffusive shockwave as the underlying acceleration mechanism.



- In each up/down cross

$$\frac{\Delta p}{p} = \frac{4}{3}\frac{\Delta\beta}{\beta}$$

- Output spectrum

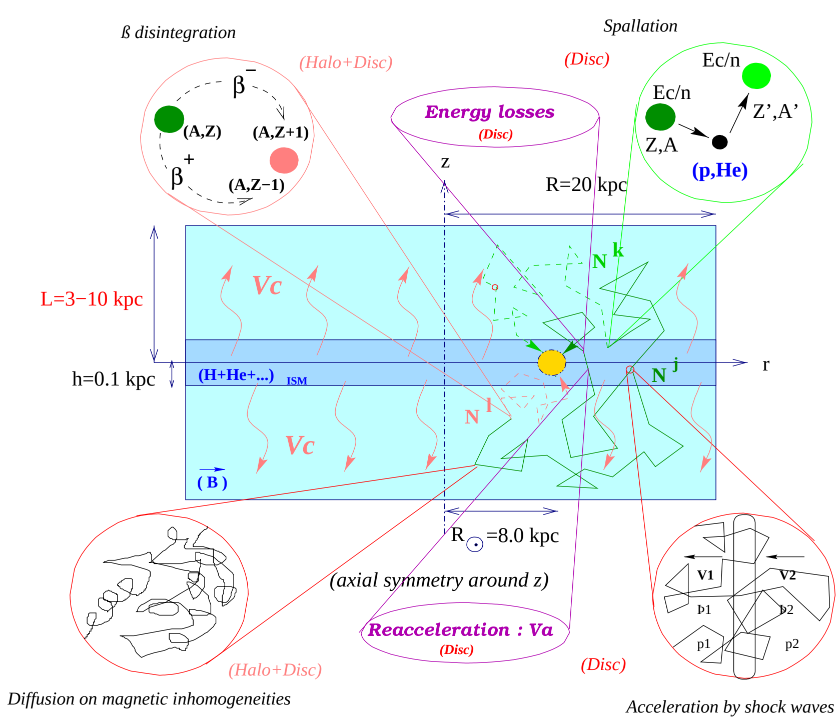
$$\Phi(E) \sim E^{-2.2}$$

up to $E \simeq 10^{14} eV$.

1.2 A charged cosmic ray life...

Acceleration ⟶ *Propagation* ⟶ *Detection*

Assumed to be diffusive due to turbulences on the galactic magnetic field ($1 \sim 12\ \mu G$). Spallation processes in the galactic disk and disintegration along the path (mainly spent in the Halo) change the initial composition.



- No origin information.
- $B/C \rightarrow$ disc size.
- $Be^{10}/Be^{9} \rightarrow$ galaxy size.

1.2 A charged cosmic ray life...

$\boxed{Acceleration} \longrightarrow \boxed{Propagation} \longrightarrow \boxed{Detection}$

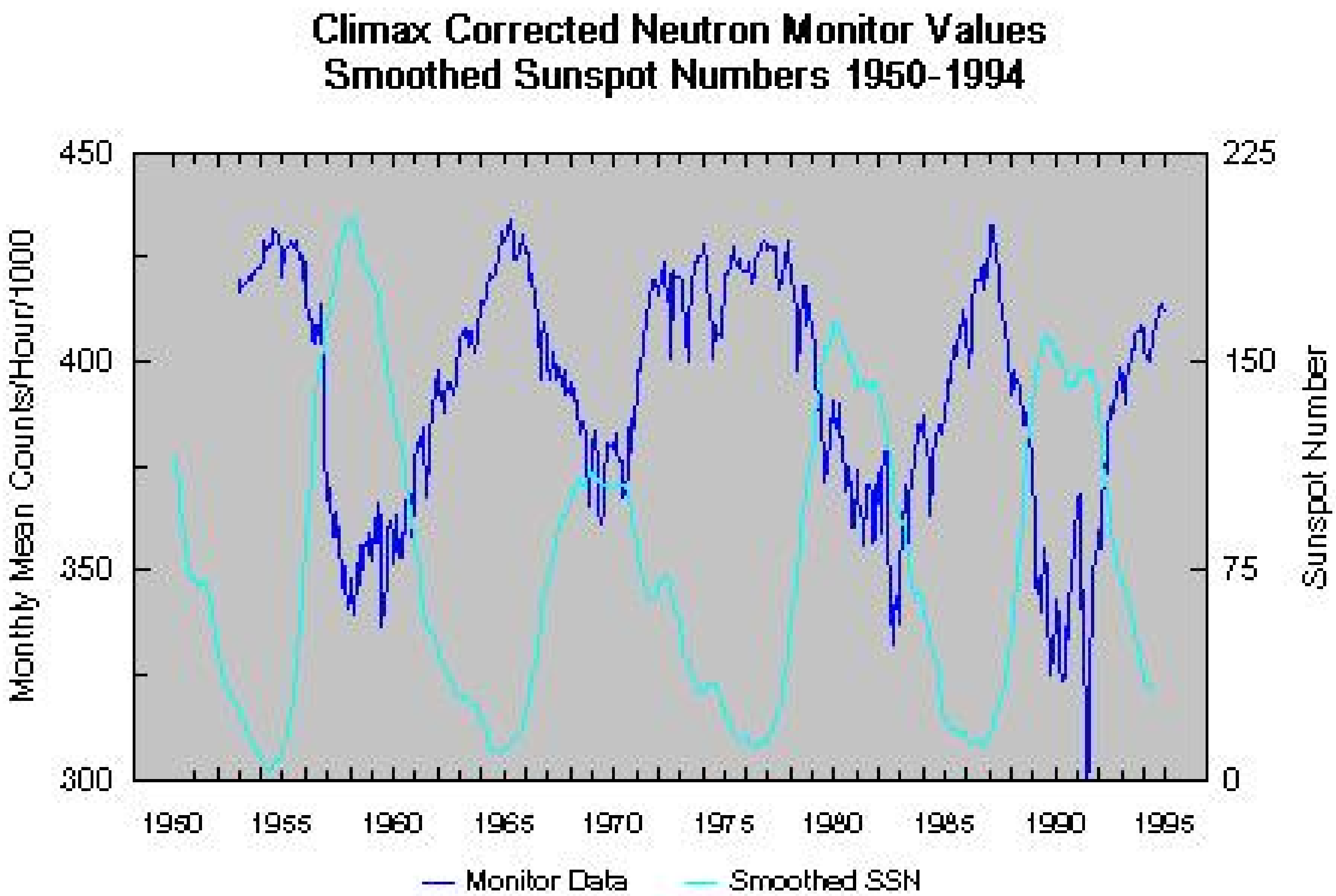
Within the solar system before reaching our detector, it suffers several processes...

- Modulation by the magnetic field carried away by the solar wind.
- Deflection due to the earth bipolar magnetic field.
- Interaction with the atmosphere...not really for as.

1.2 A charged cosmic ray life...

Acceleration ⟶ *Propagation* ⟶ *Detection*

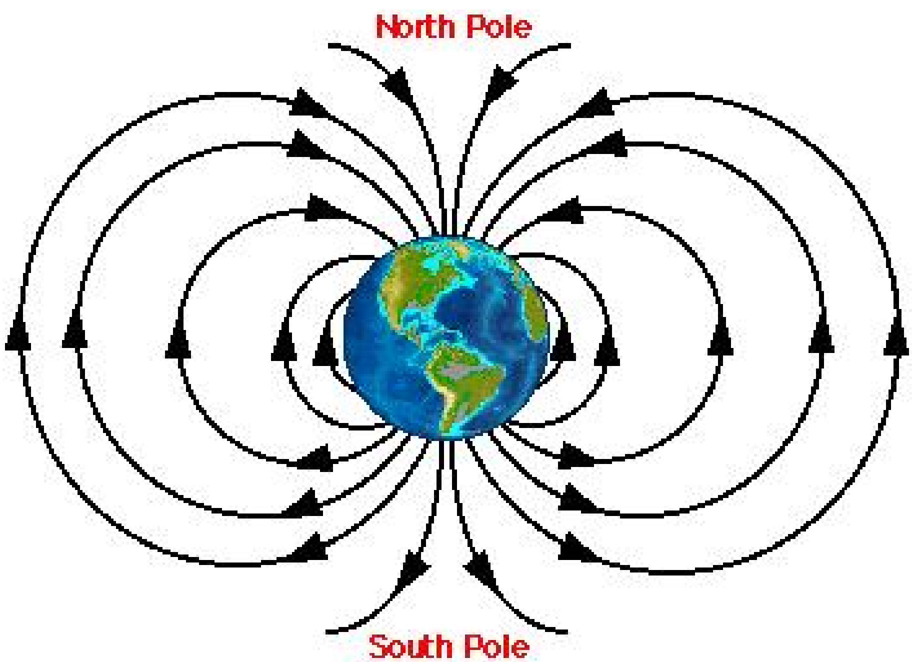
Solar modulation



1.2 A charged cosmic ray life...

Acceleration ⟶ *Propagation* ⟶ *Detection*

Earth magnetic shielding



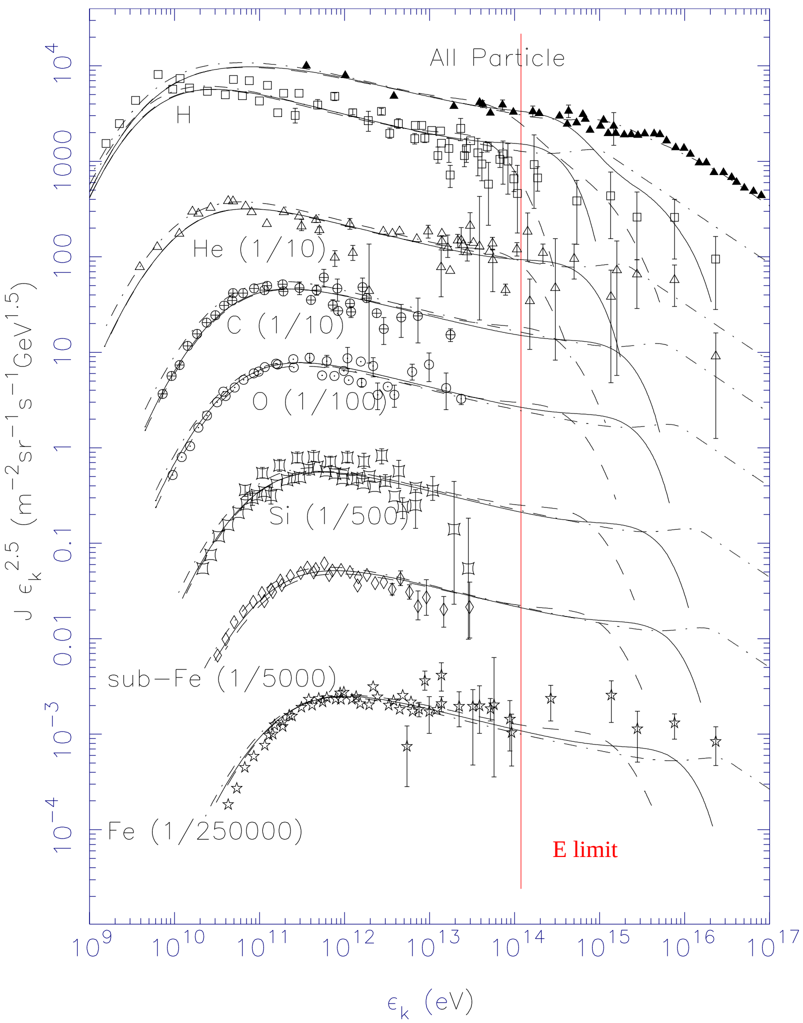
Field intensity: $\sim 0.5G$

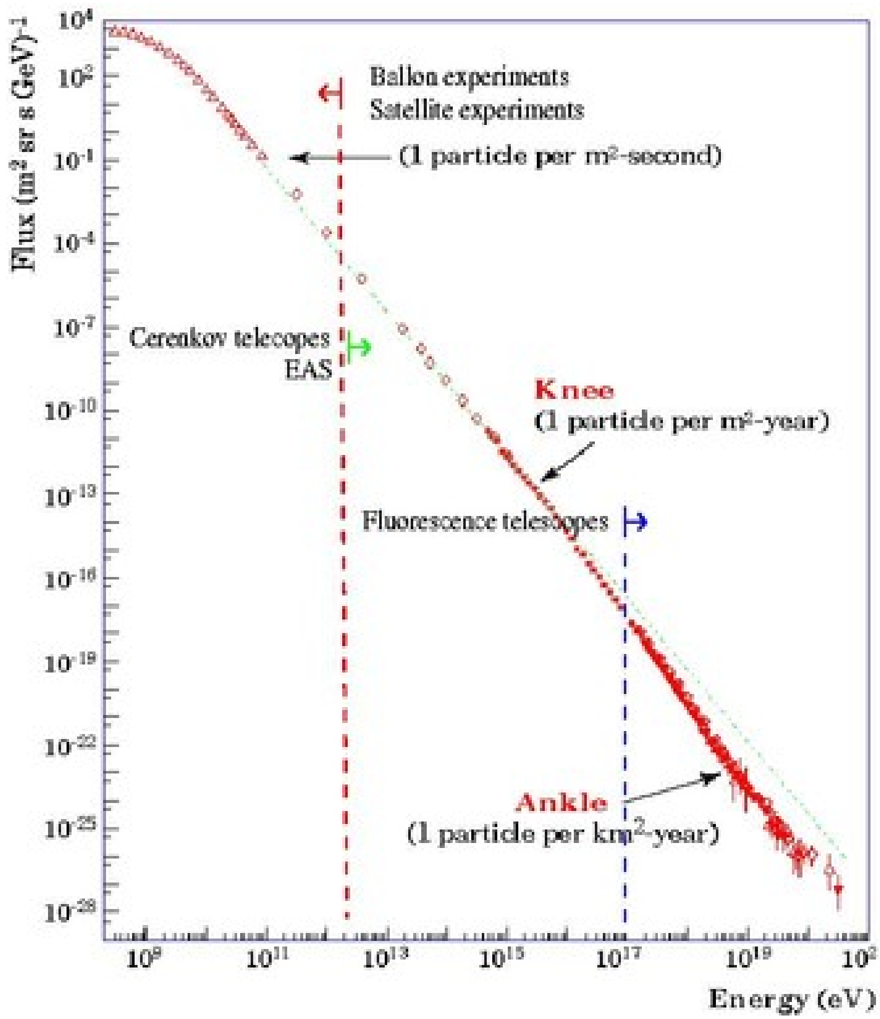
Latitude	Rigidity cutoff (p/Z)
0^O	$14.9GV$
40^O	$5.1GV$
60^O	$0.93GV$

1.2 A charged cosmic ray life...

Acceleration ⟶ *Propagation* ⟶ *Detection*

The result





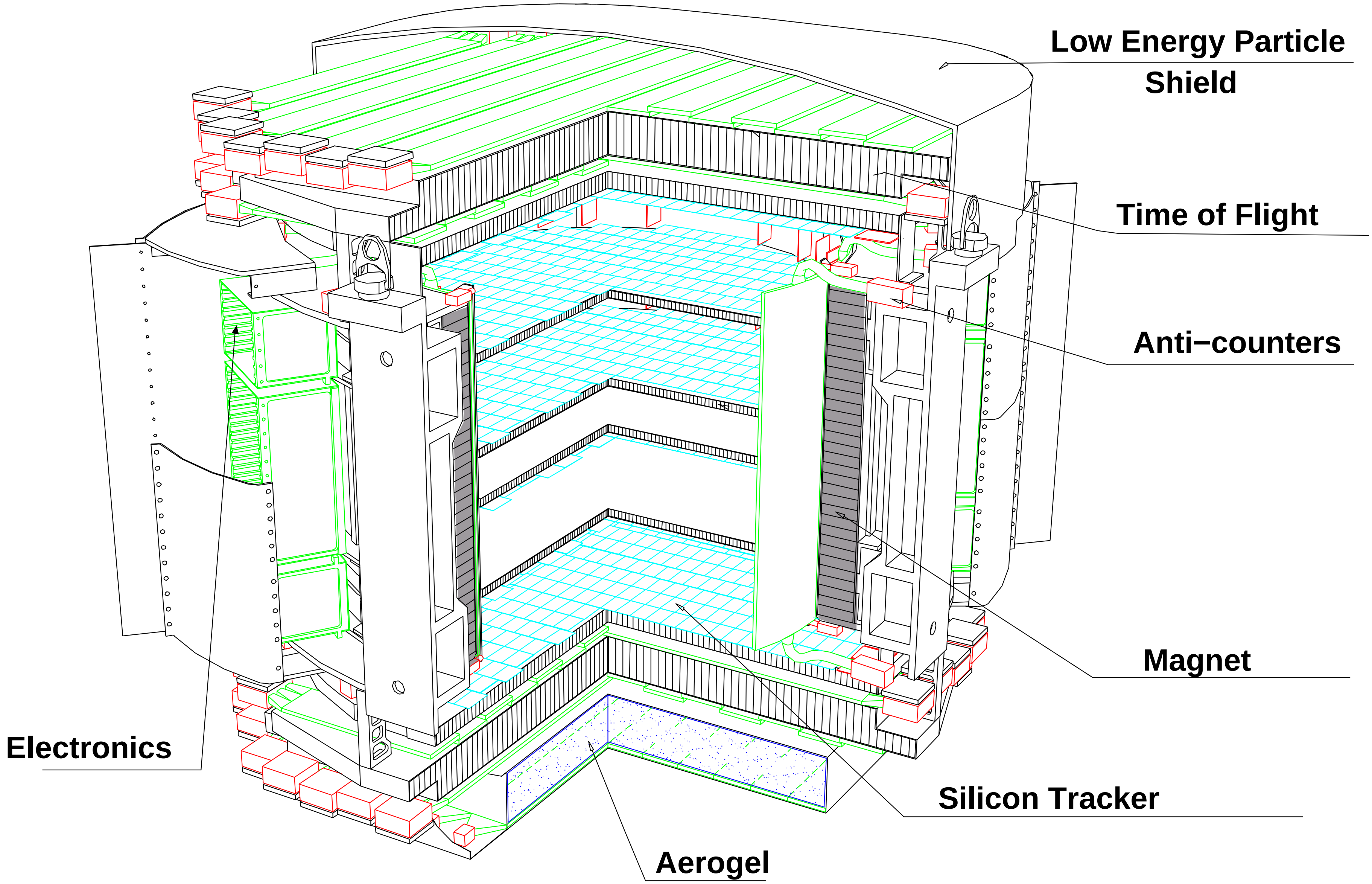
2 AMS 01

2.1 The first detector.

Test flight aboard space shuttle in 1998...

- Detector acceptance: $\sim 0.3 m^2 sr$
- Data taken: $\sim 10^8$ events in 90 hours
- Detector detection properties:
  - $\frac{\Delta\beta}{\beta} \sim 0.03$ from TOF
  - $\frac{\Delta R}{R} \sim 0.02$ for $10GV$ protons from TRACKER with $B \simeq 0.18T$

    $R = p/Z$
  - Charge measured by energy deposition in TOF and TRACKER
  - Threshold Čerenkov counter for e^+/p separation



Dimensions: $1.65 \times 1.65 \times 1.30m^3$

Weight: $3.1Tons$

Power consumption: $< 1.8kW$

2.2 Results.

Some preliminary notes

- The AMS01 acceptance is 5 times larger than the typical ballon spectrometers.
- The detector is far away from atmosphere top, usually considered at $\sim 40Km$ (height of ballon experiments)
- The detected events consist on a single particle traversing all the detector downwards or upwards.
- The data is trasmited to earth and stored in disks on board.
- The data is taken for all latitudes covered by the shuttle but for the South Athlantic Anomaly, where the radiation rate due to then Van Allen Belt makes neccesary to switch off the detector.

Antimatter search

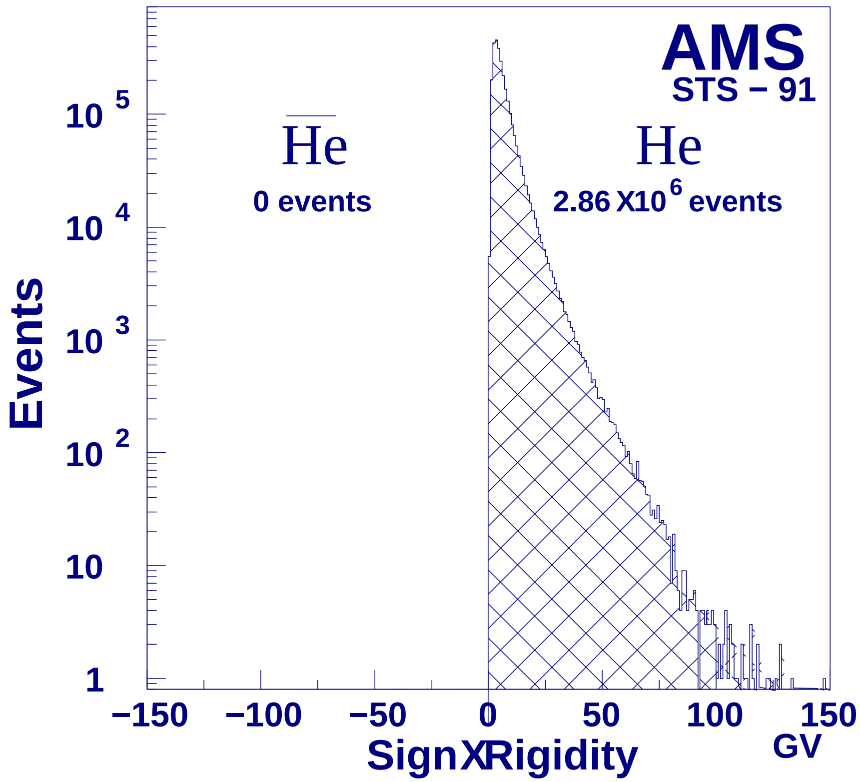
Proton spectrum

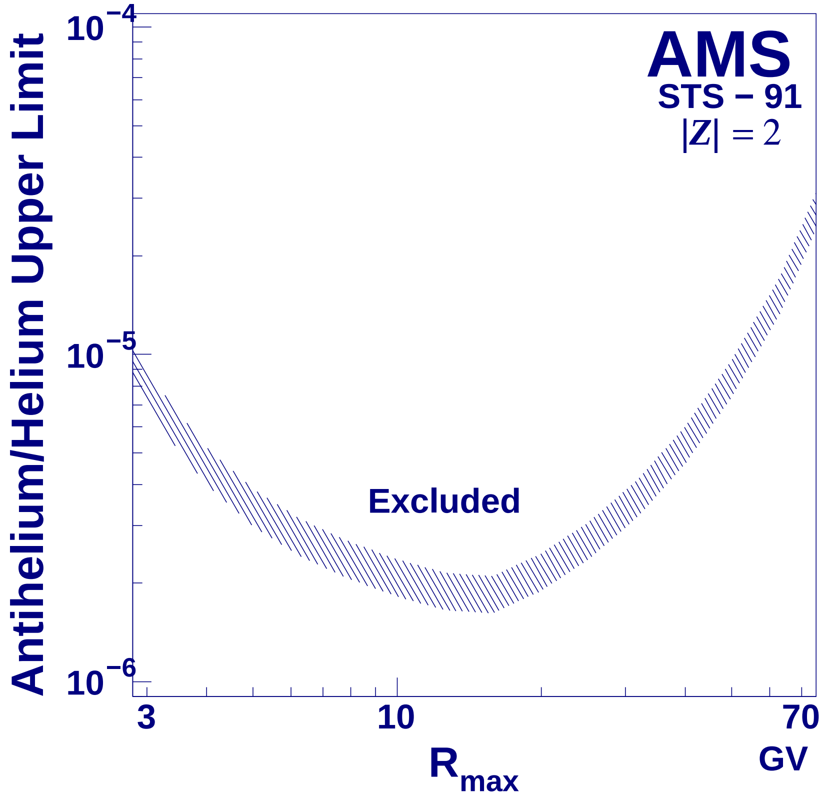
Helium spectrum

Leptons spectrum

Antimatter search | Proton spectrum | Helium spectrum | Leptons spectrum

Antihelium search

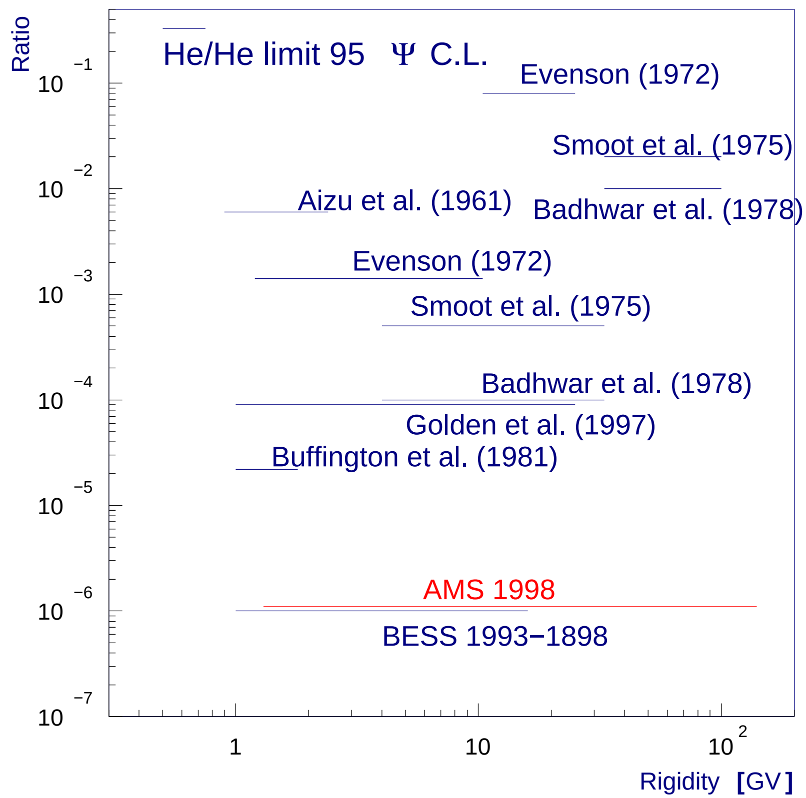


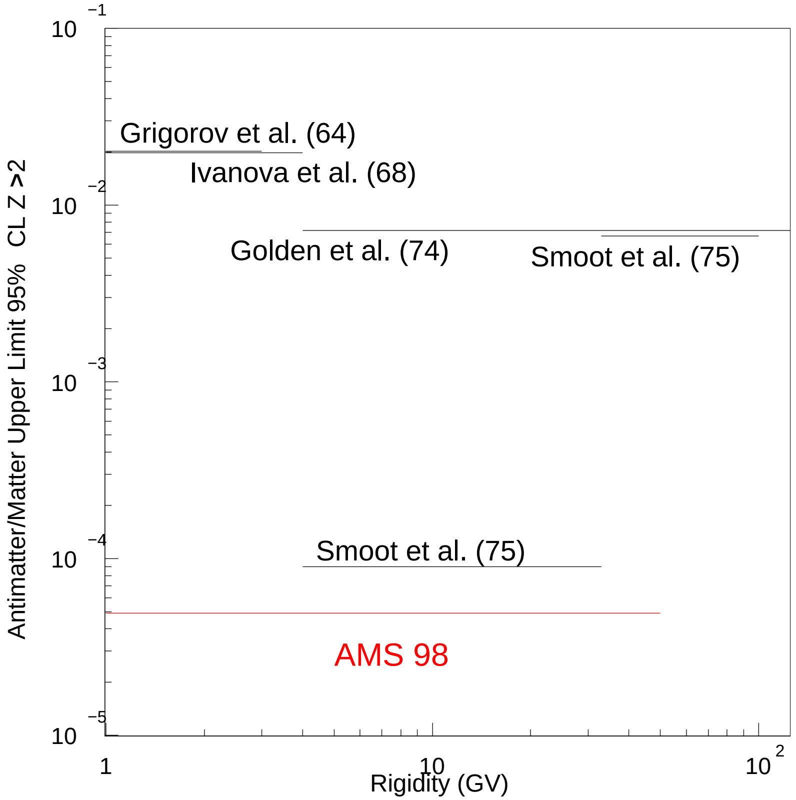


- No a single $\overline{He}$ found and 3×10^6 He put a limit similar to BESS98.
- Still far away from the 10^{-9} theoretical limit.

Antimatter search | Proton spectrum | Helium spectrum | Leptons spectrum

Current total antimatter limits



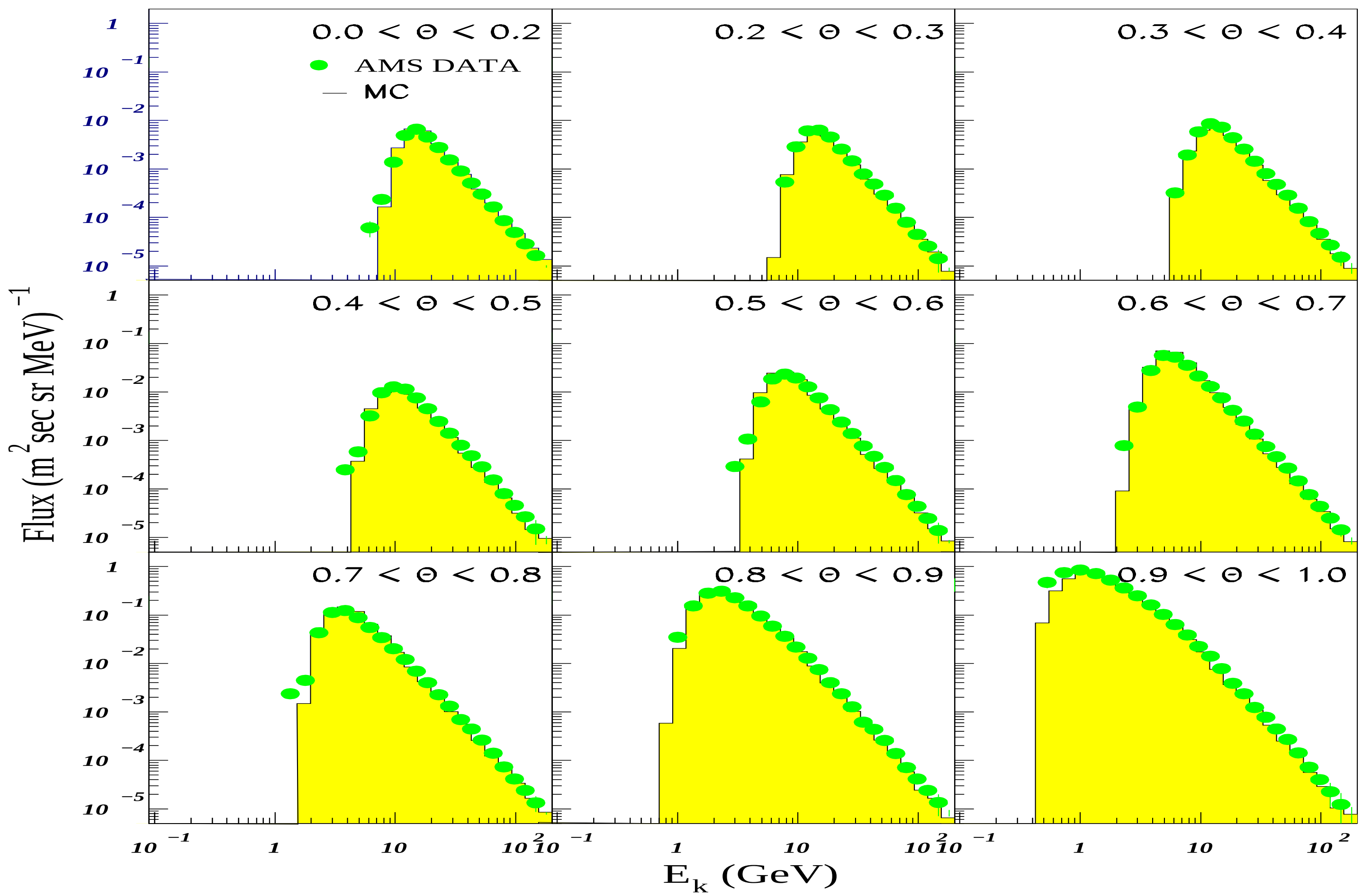


Assuming equal matter/antimatter spectrum

Antimatter search | Proton spectrum | Helium spectrum

Leptons spectrum

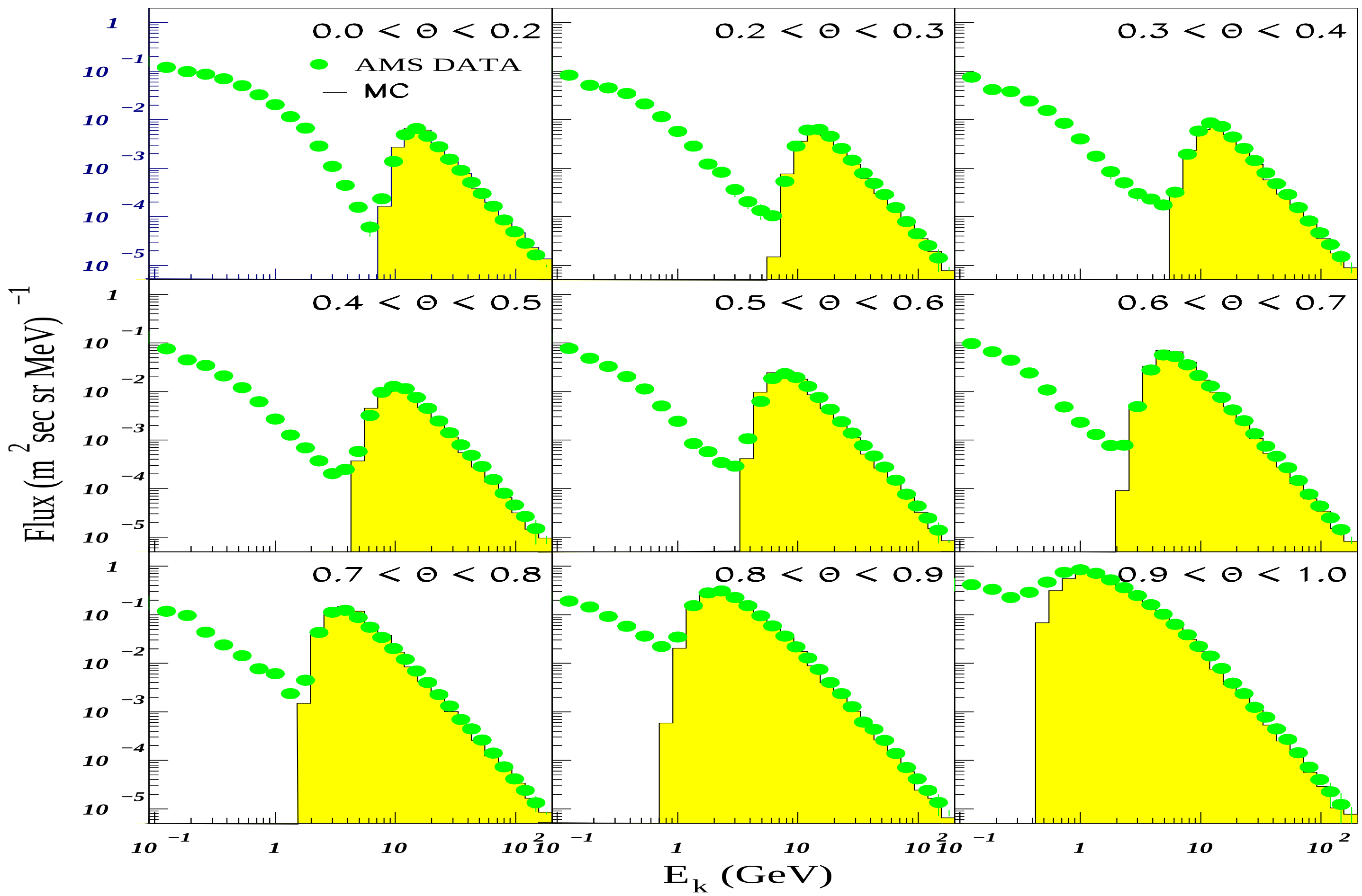
Primary downward proton spectrum



All the expected features were in the data but...

Antimatter search | Proton spectrum | Helium spectrum | Leptons spectrum

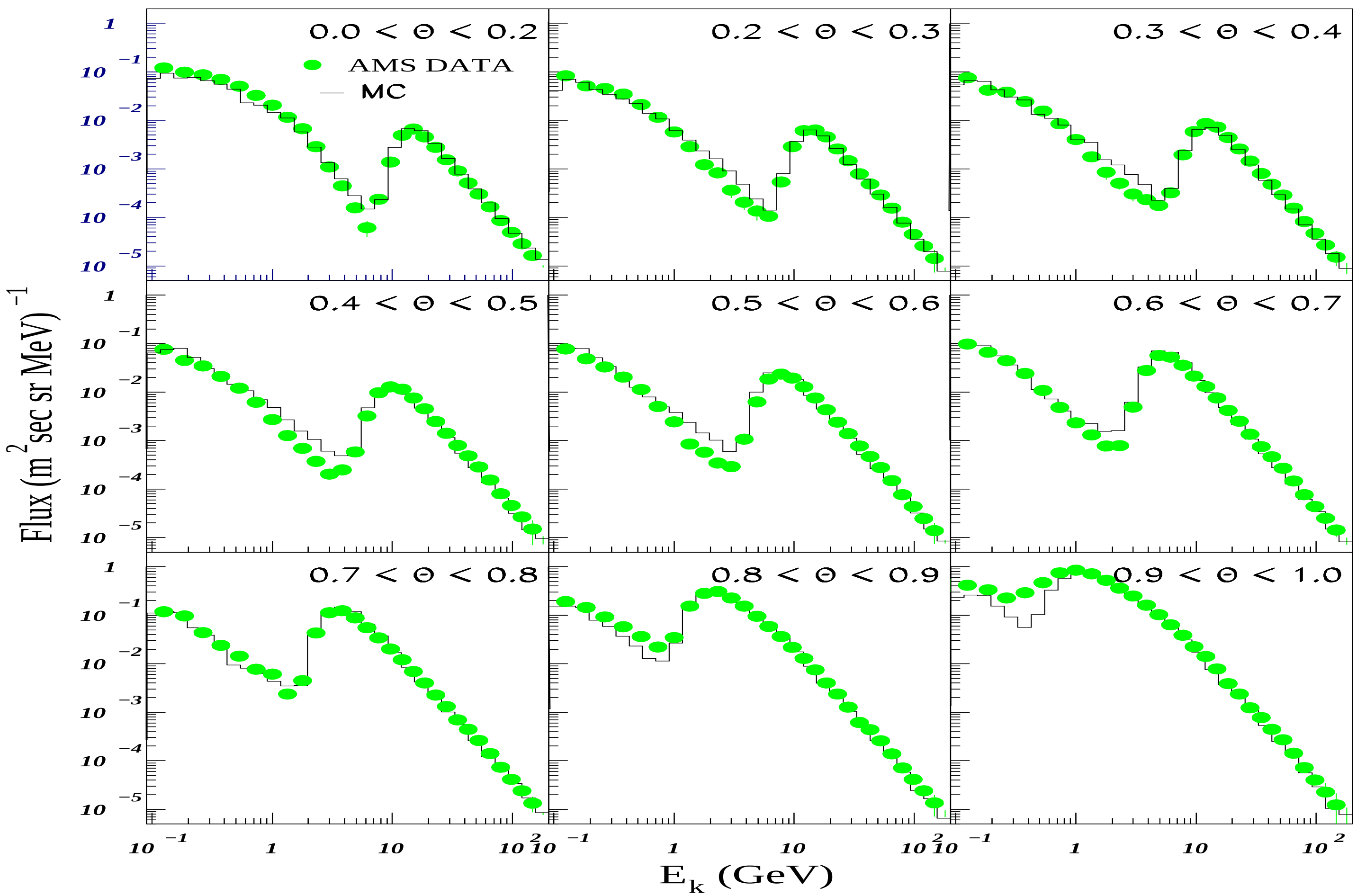
Primary downward proton spectrum



a secondary spectrum below the cutoff appeared.

Antimatter search | Proton spectrum | Helium spectrum | Leptons spectrum

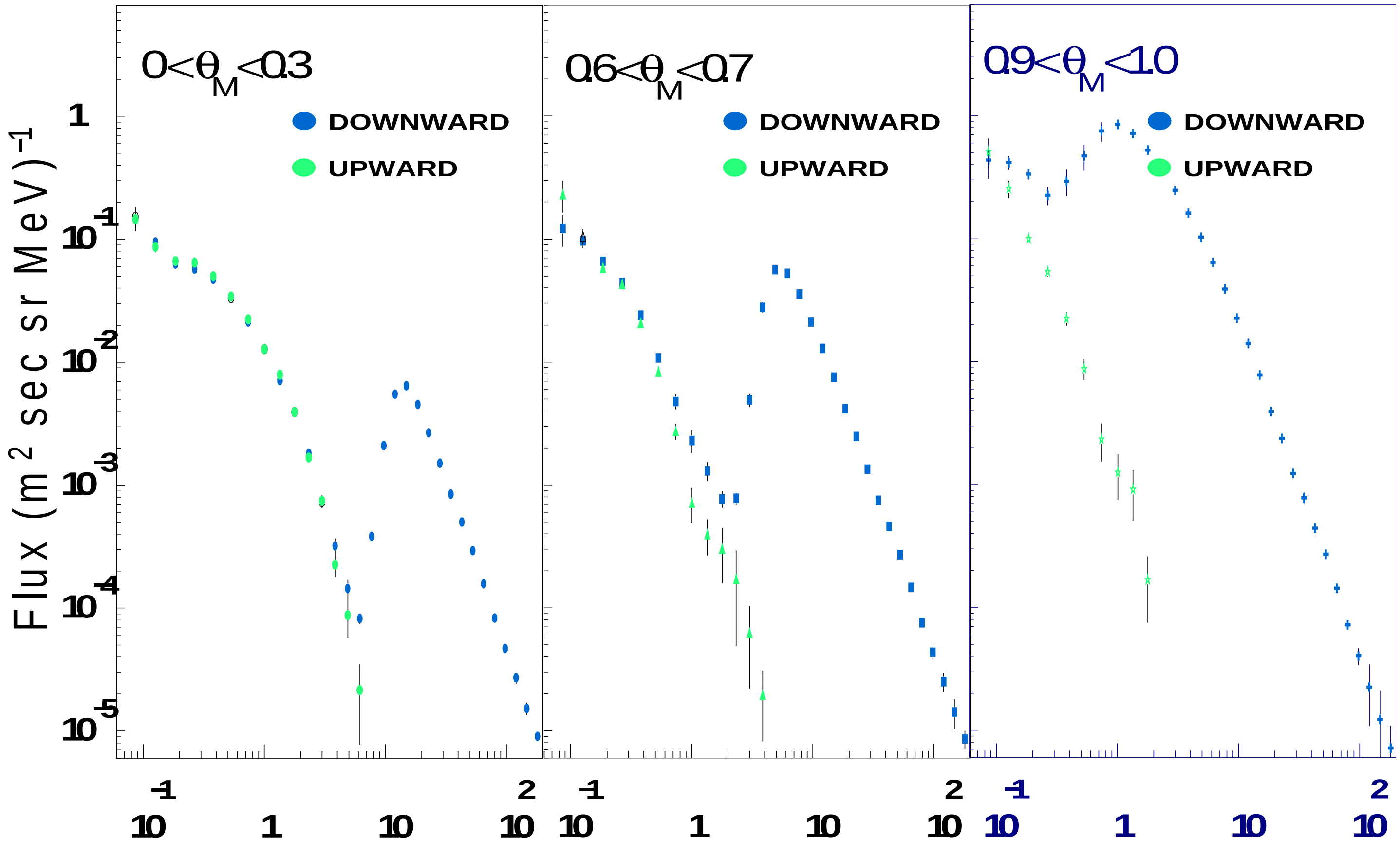
Primary downward proton spectrum



The forgotten ingredients: atmosphere and earth magnetic field

Antimatter search | Proton spectrum | Helium spectrum | Leptons spectrum

Secondary upward proton spectrum

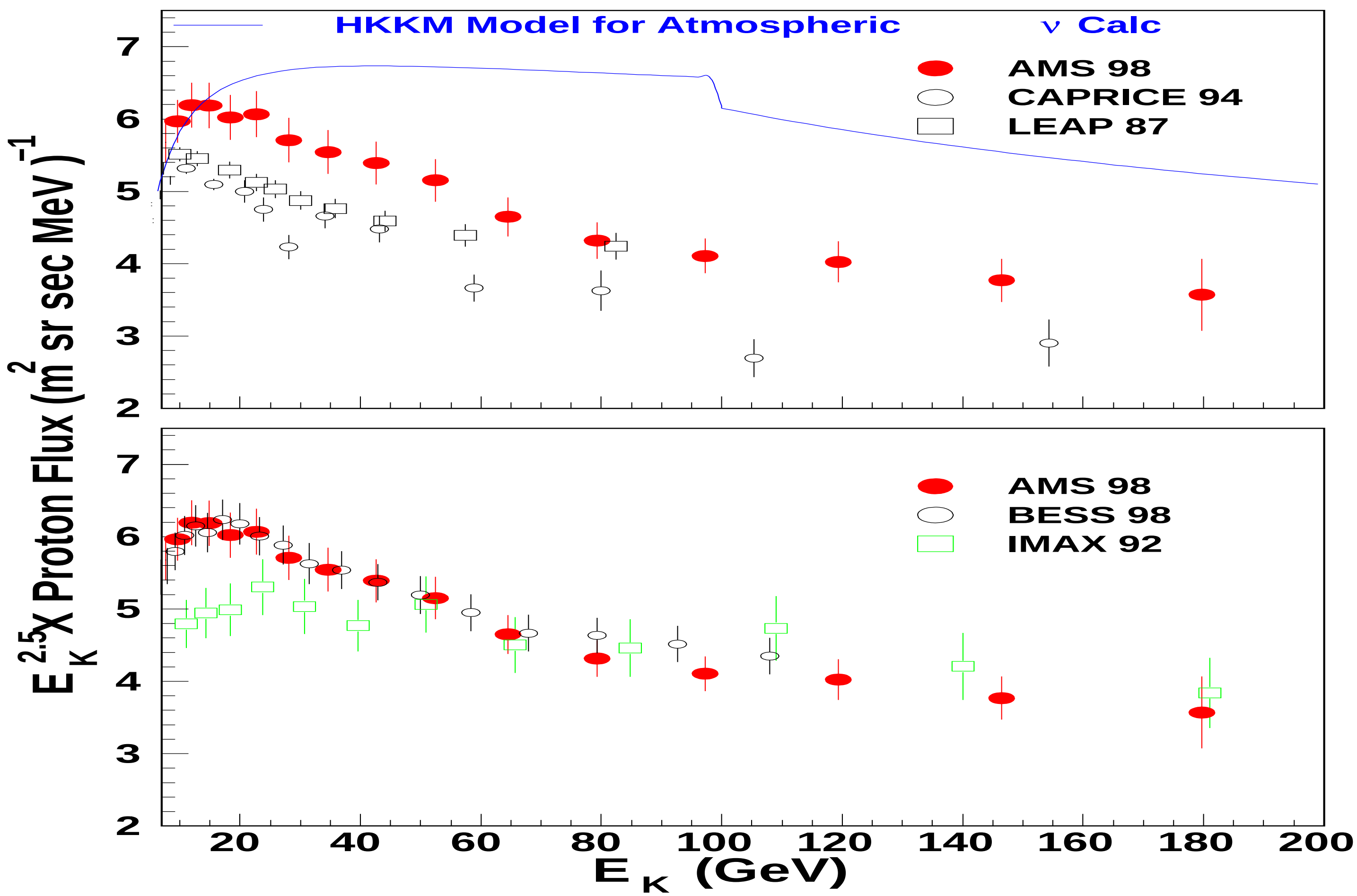


The secondaries protons trapped in the earth magnetic field pass through our detector in the upward and downward direction several times.

Antimatter search | Proton spectrum | Helium spectrum

Leptons spectrum

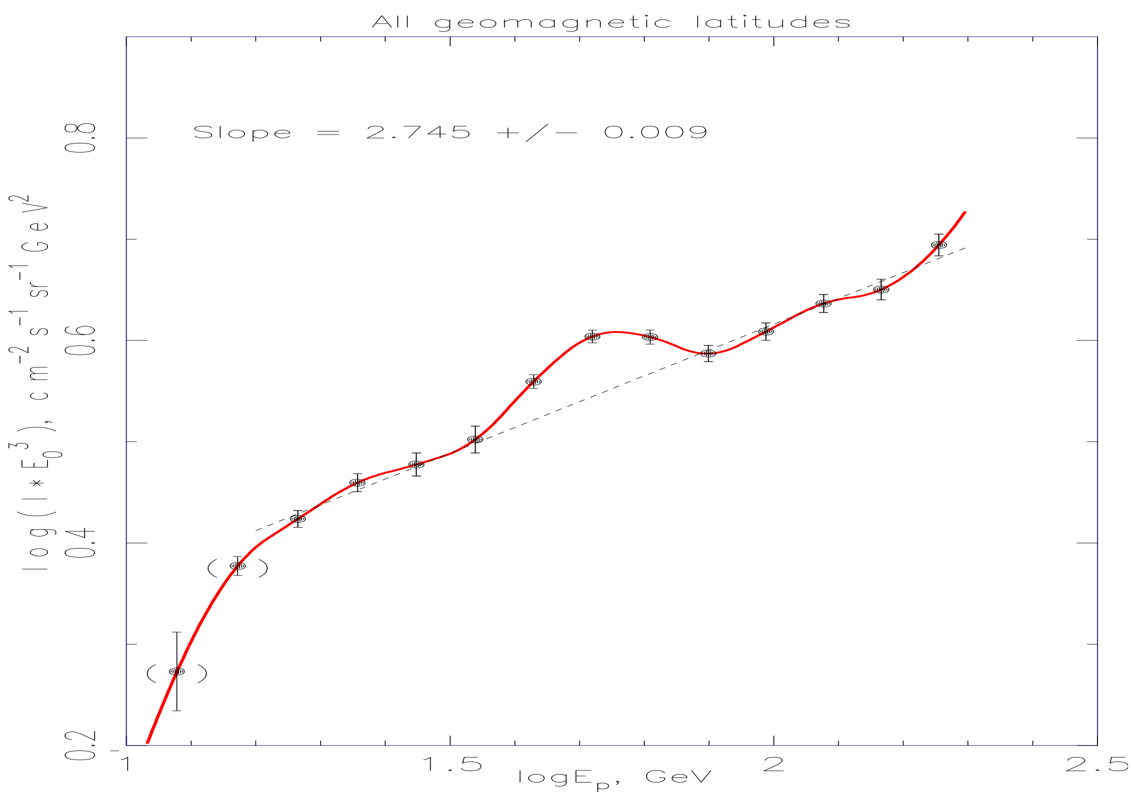
High energy primary spectrum



Antimatter search | Proton spectrum | Helium spectrum

Leptons spectrum

A surprise



However it is not an official AMS result...

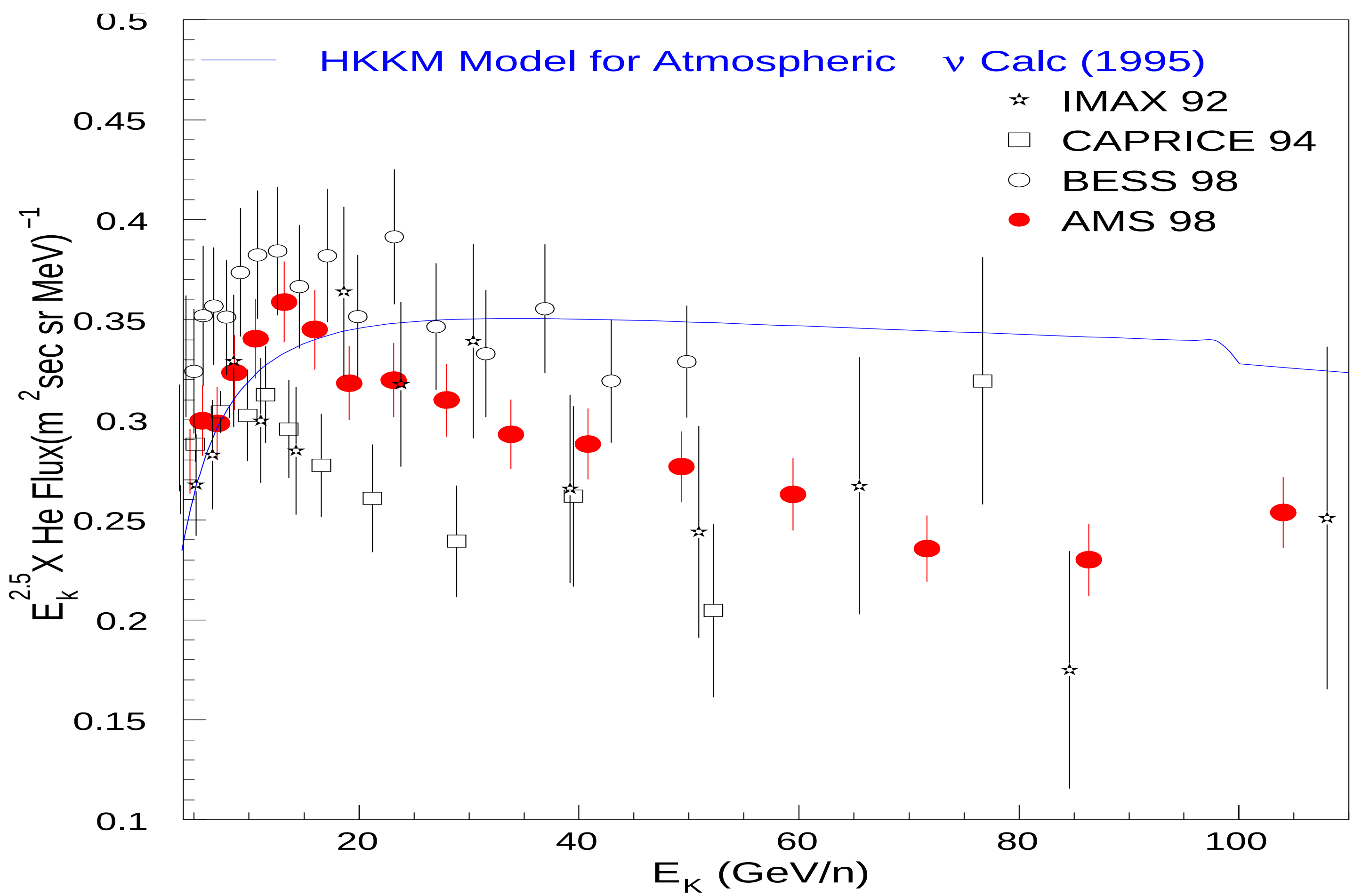
Antimatter search

Proton spectrum

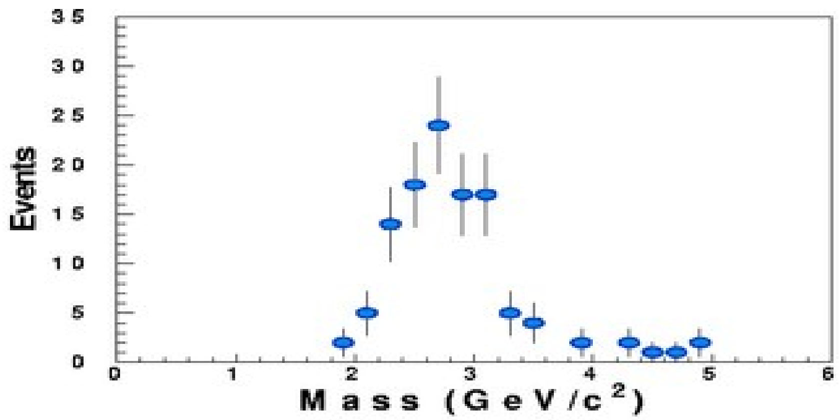
Helium spectrum

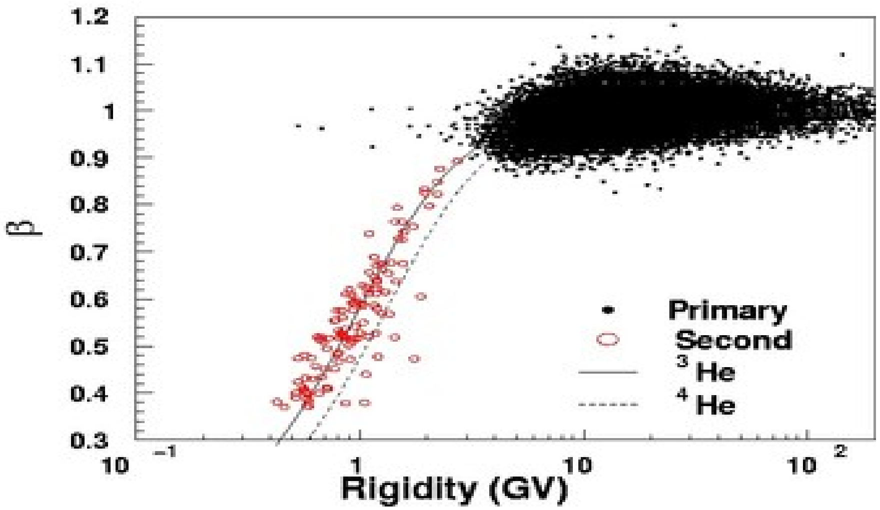
Leptons spectrum

High energy helium spectrum



Helium under cutoff spectrum properties



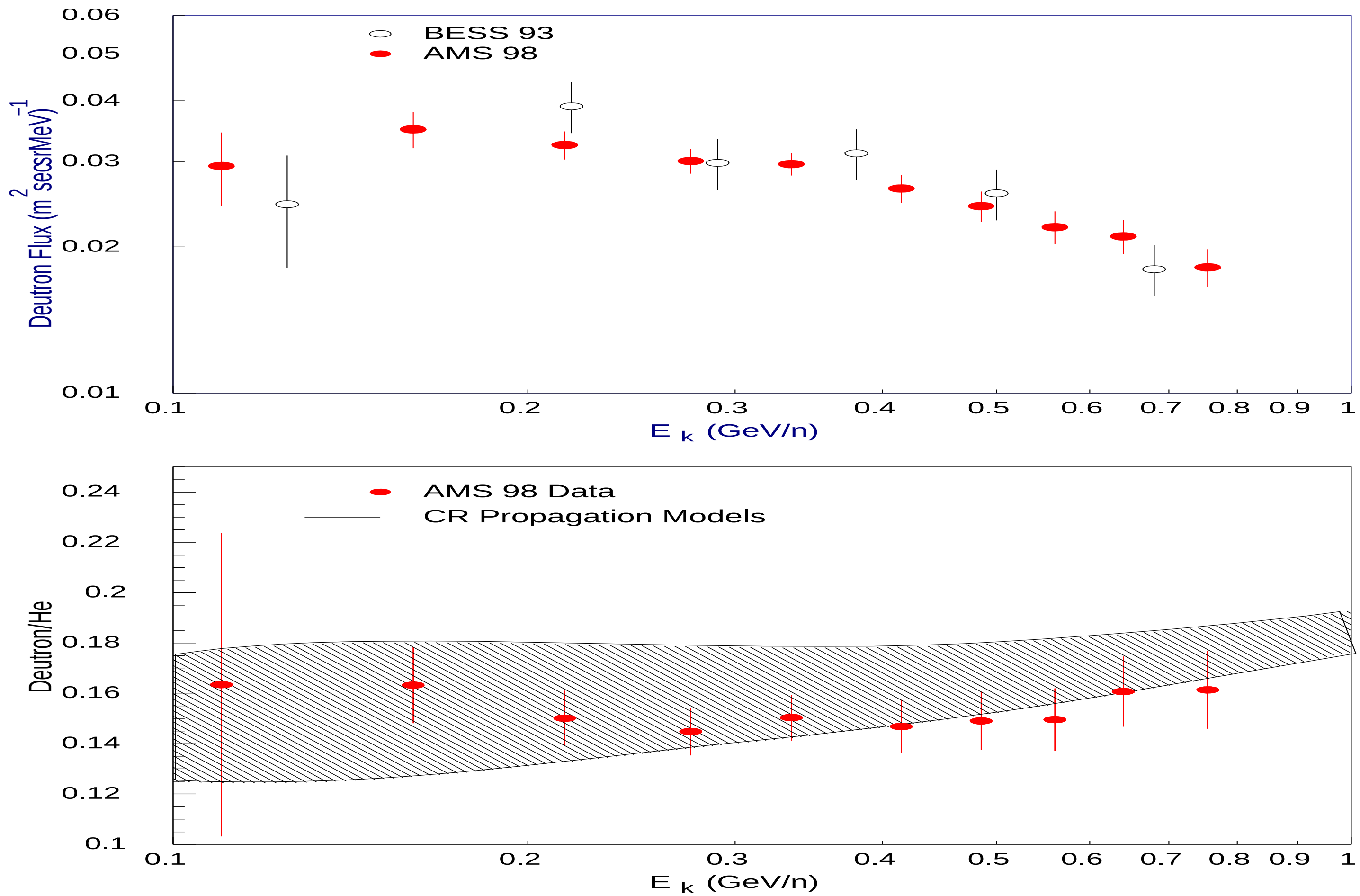


- At the level of $10^{-3} \sim 10^{-4}$ of primary flux.
- $\frac{^3He}{^4He} > 0.9$
- Same origin as the secondary proton spectrum presumed.

Antimatter search | Proton spectrum | Helium spectrum

Leptons spectrum

Cosmic deuterium

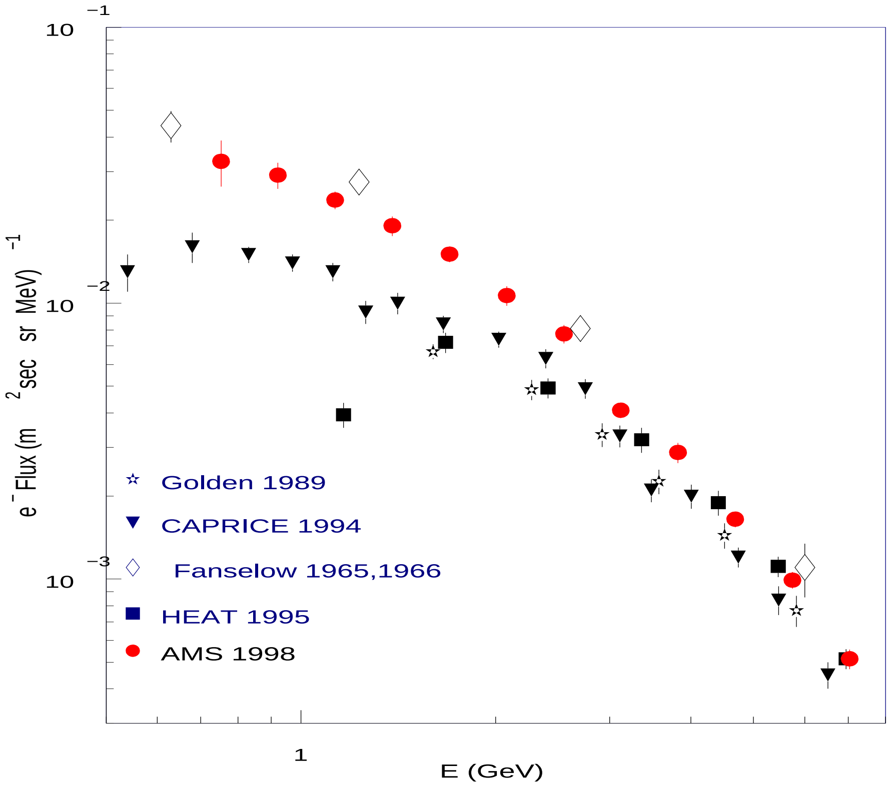


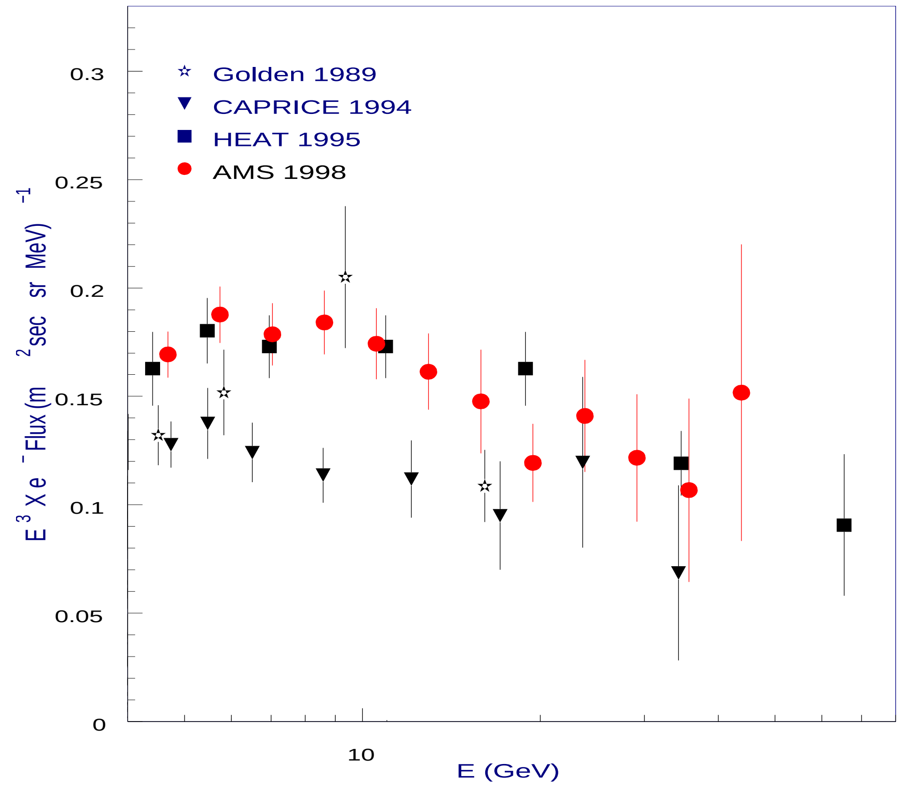
Good agreement with cosmic rays propagation models

Antimatter search | Proton spectrum | Helium spectrum

Leptons spectrum

Electrons primary spectrum



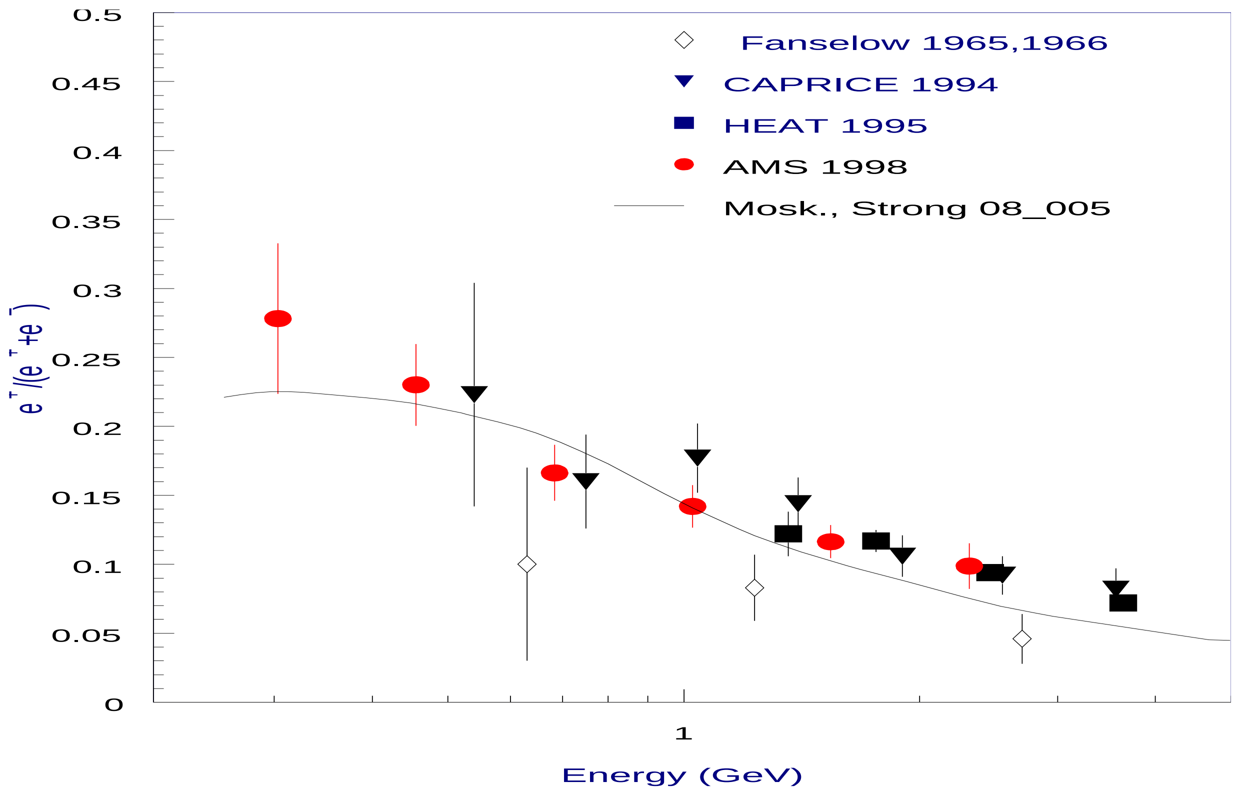


Differences at low energy not likely to be due to different solar modulation

Antimatter search | Proton spectrum | Helium spectrum

Leptons spectrum

Cosmic electron/positron ratio

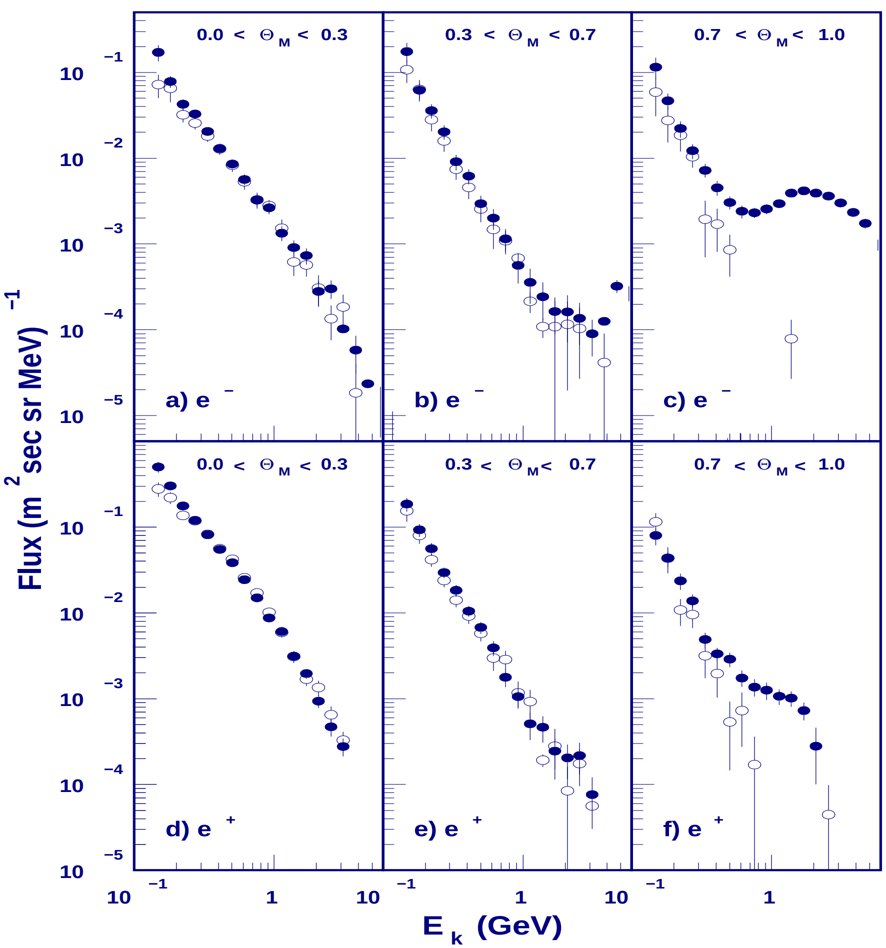


Good agreement with earlier measurements in the same solar cycle.

Antimatter search | Proton spectrum | Helium spectrum

Leptons spectrum

Secondary spectrum

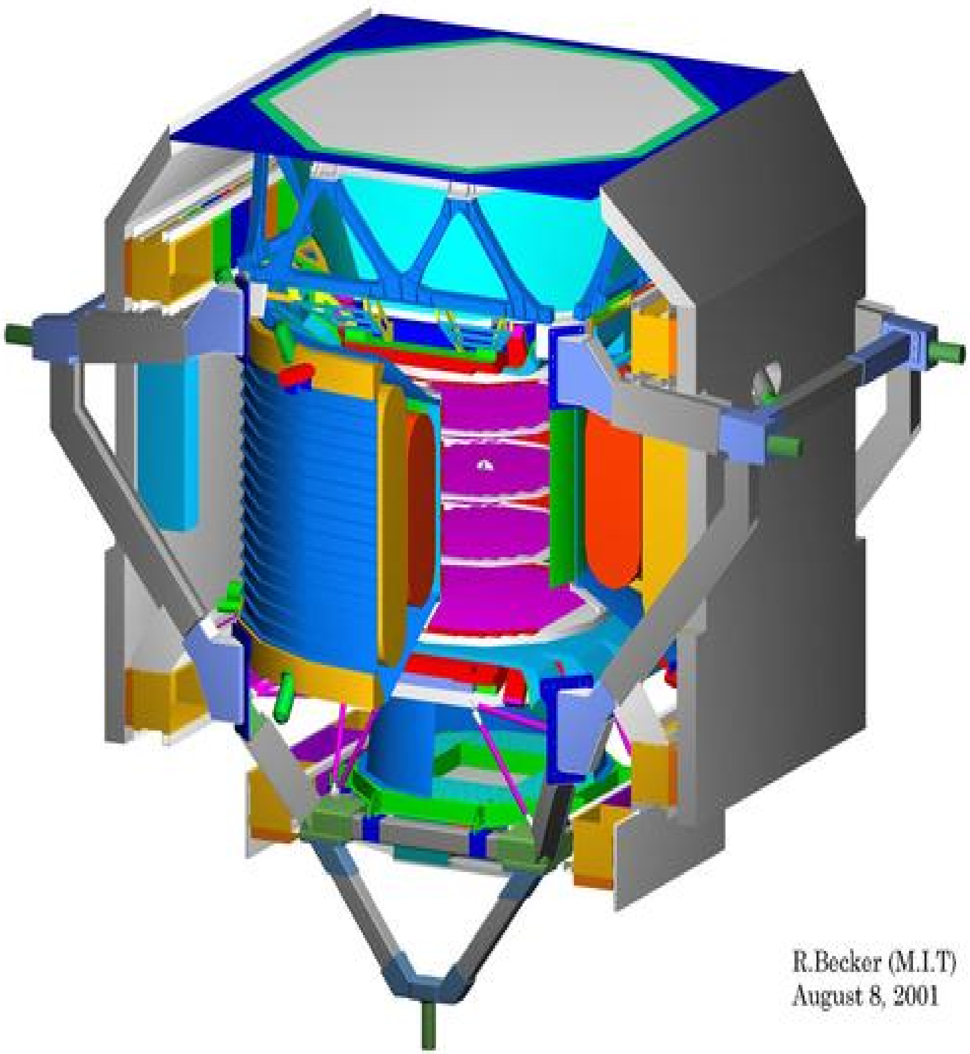


Two different poblations:

- Generated and absorbed in the atmosphere close to the detector
  Life time $< 200ms$
- Generated and absorbed far from the detector
  Life time $> 200ms$
  Quasi trapped in magnetic field
  Origin and sink positions well determined

3 AMS 02

3.1 The new detector.



- To be instaled in the ISS by the 2004 for 3 years.
- Very good complete PID
  TRD+ECAL
  ·h/e separation
  TRACKER+TOF+RICH
  ·mass and charge
- $T \simeq 1 \rightarrow 10^3 GeV/A$

G. Acceptance $\sim 0.5 m^2 sr$

3 AMS 02

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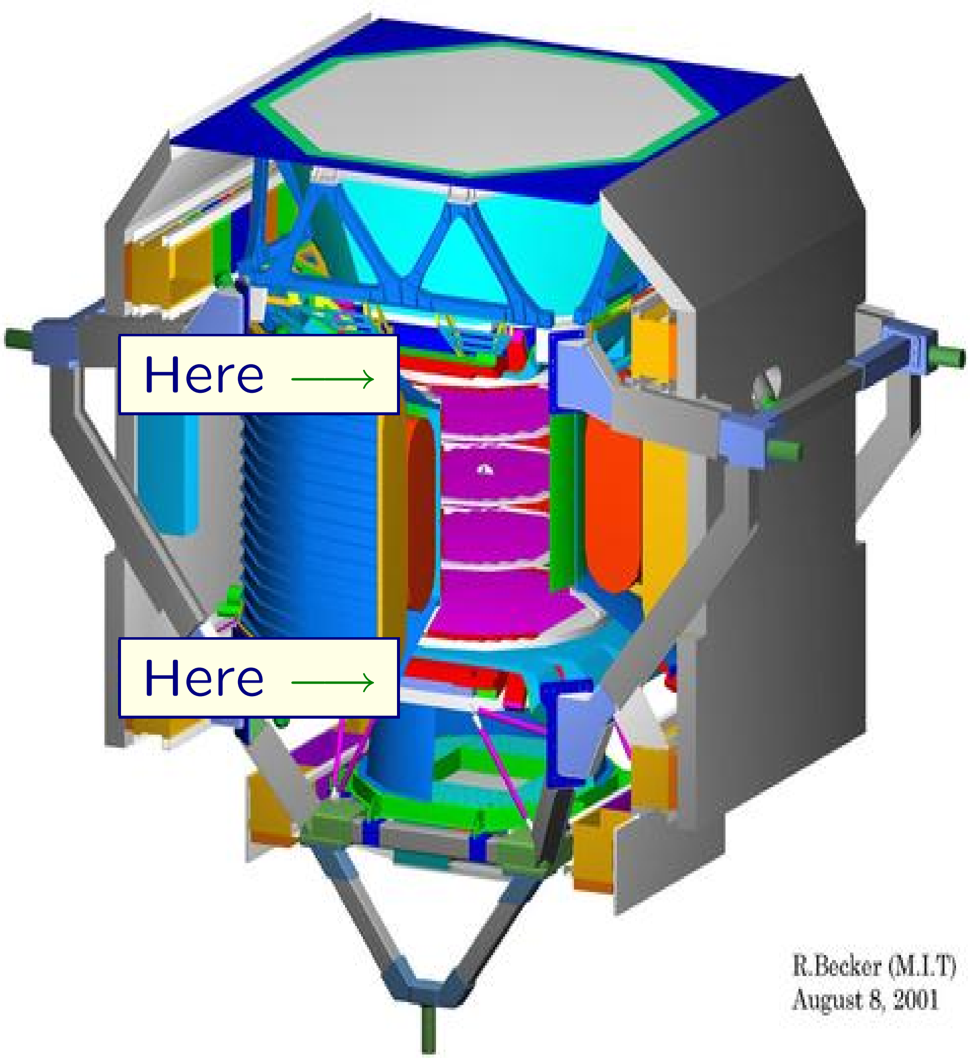

TOF

Time Of Flight

- 4 planes of 14 scintillator bars.
- Provides trigger and first β measurement.

$$\frac{\Delta\beta}{\beta} \sim 0.03$$

- 4 planes of 14 scintillator bars.
- Very similar to AMS01 one.

3 AMS 02

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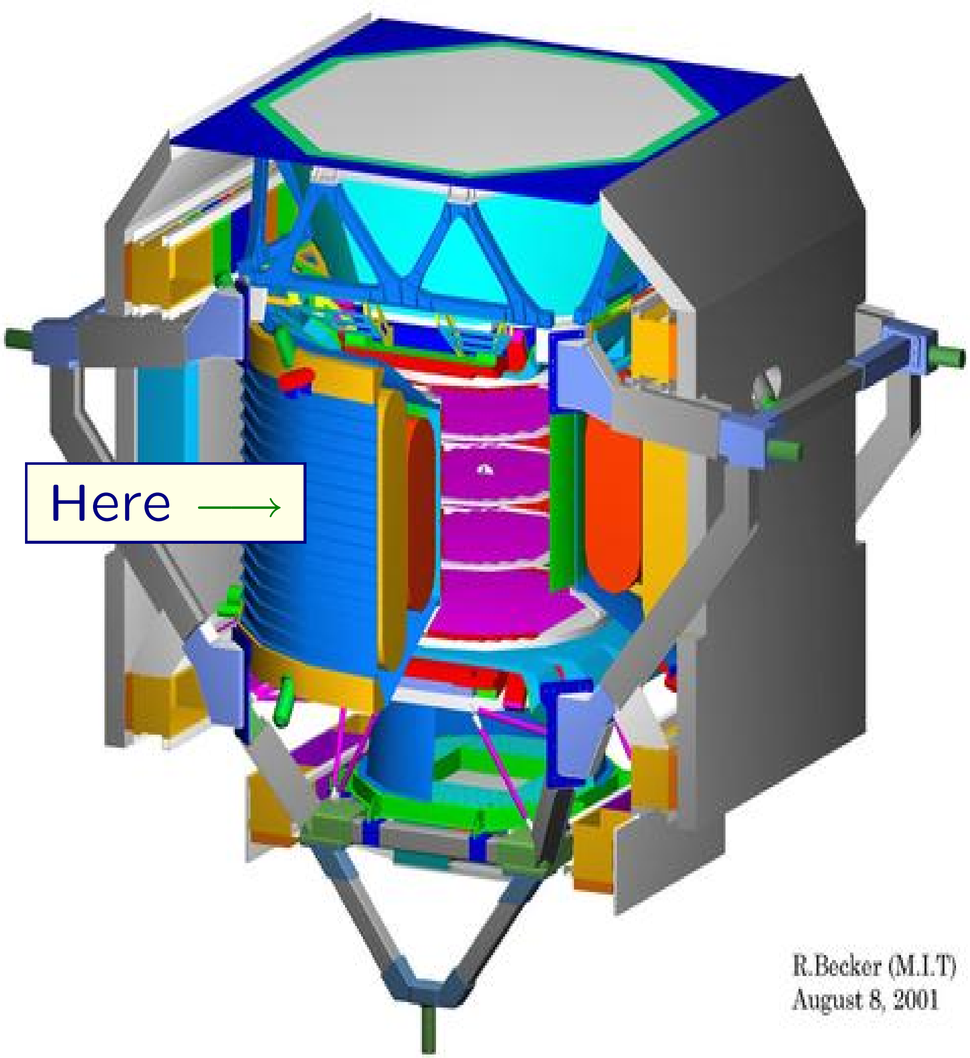
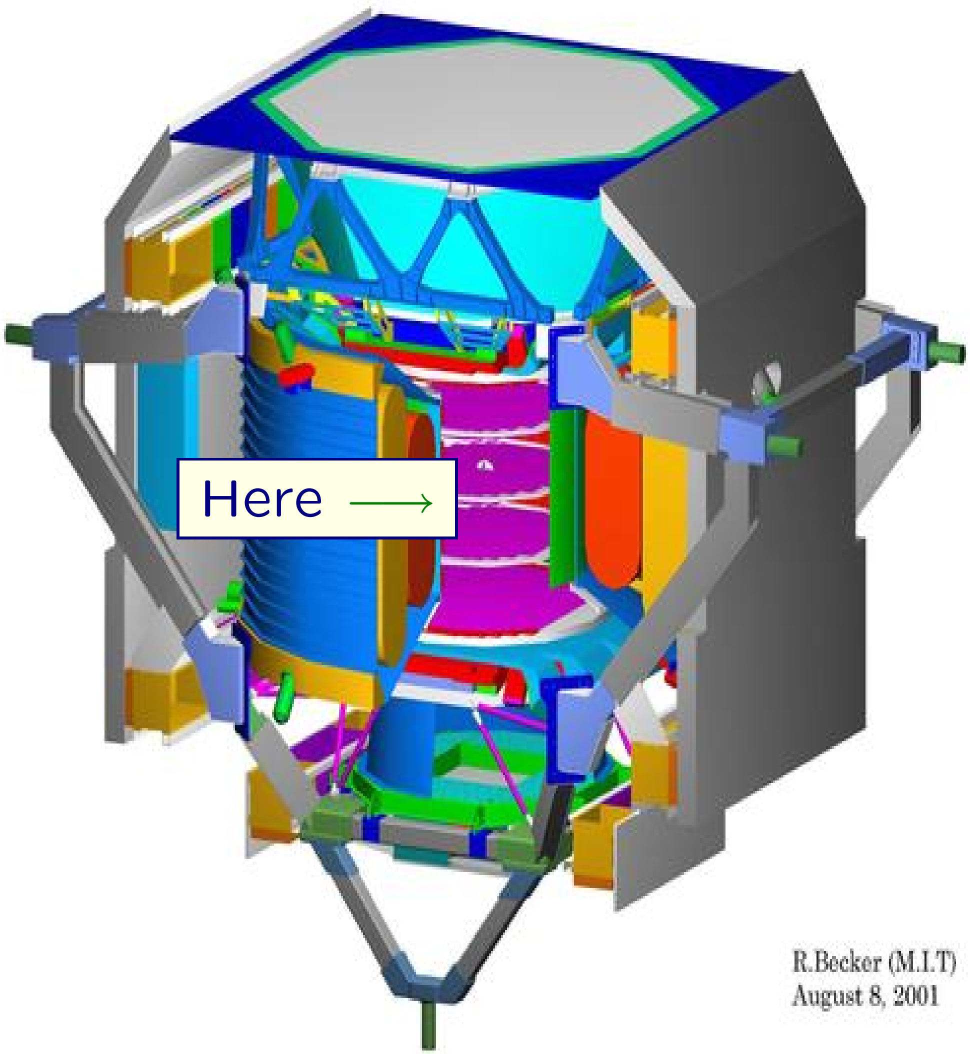


MAGNET

- First large size superconducting magnet in space.
- Dipolar field of $B \simeq 0.86T$ perpendicular to its axis.
- Stored energy $\sim 15MJ$
- Cooled to $1.4K$ by liquid nitrogen.

3 AMS 02

3.1 The new detector.



TRACKER

- 8 planes of doubled sided silicon microstrip detectors.

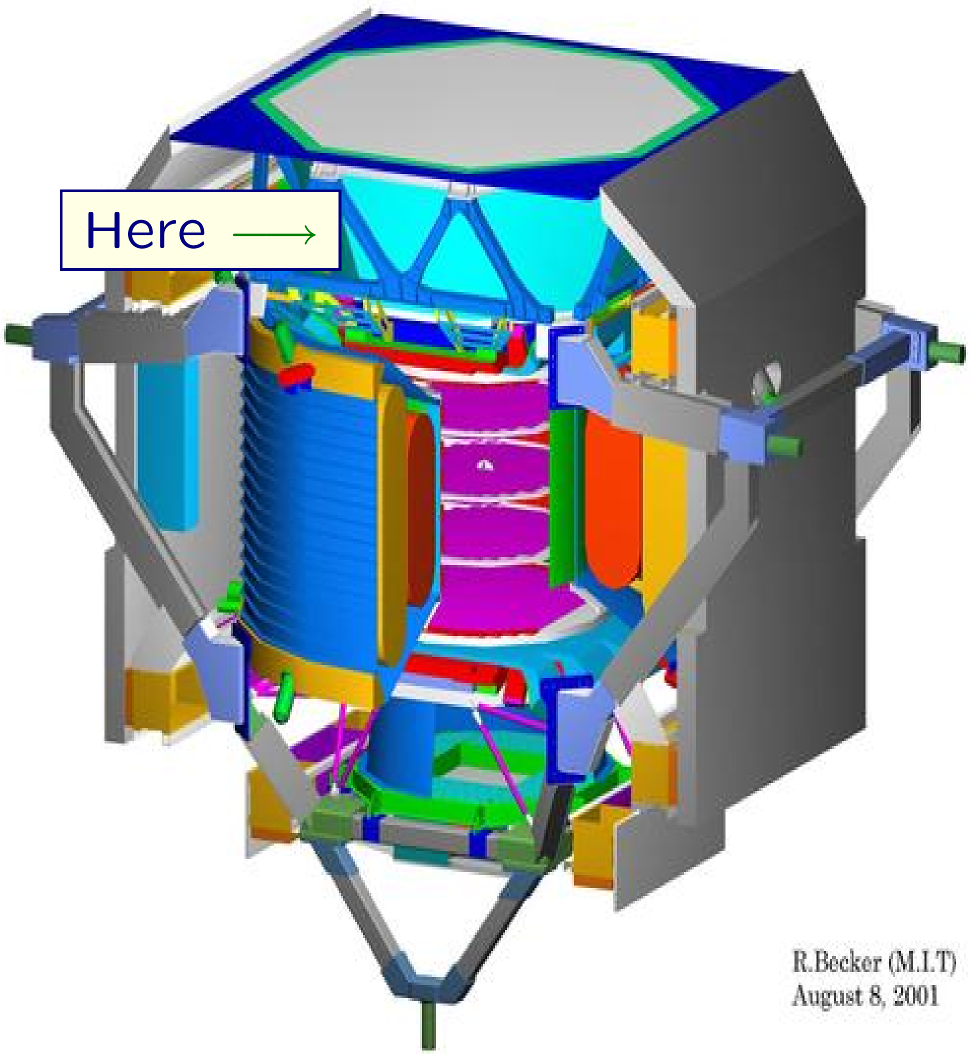
$$\Delta x \simeq \Delta y \simeq 10\mu m$$

$$\frac{\Delta R}{R} \simeq 0.02(10GeV/c\ p)$$

- Aligned on board by IR laser.
- AMS01 prototype extended.

3 AMS 02

3.1 The new detector.

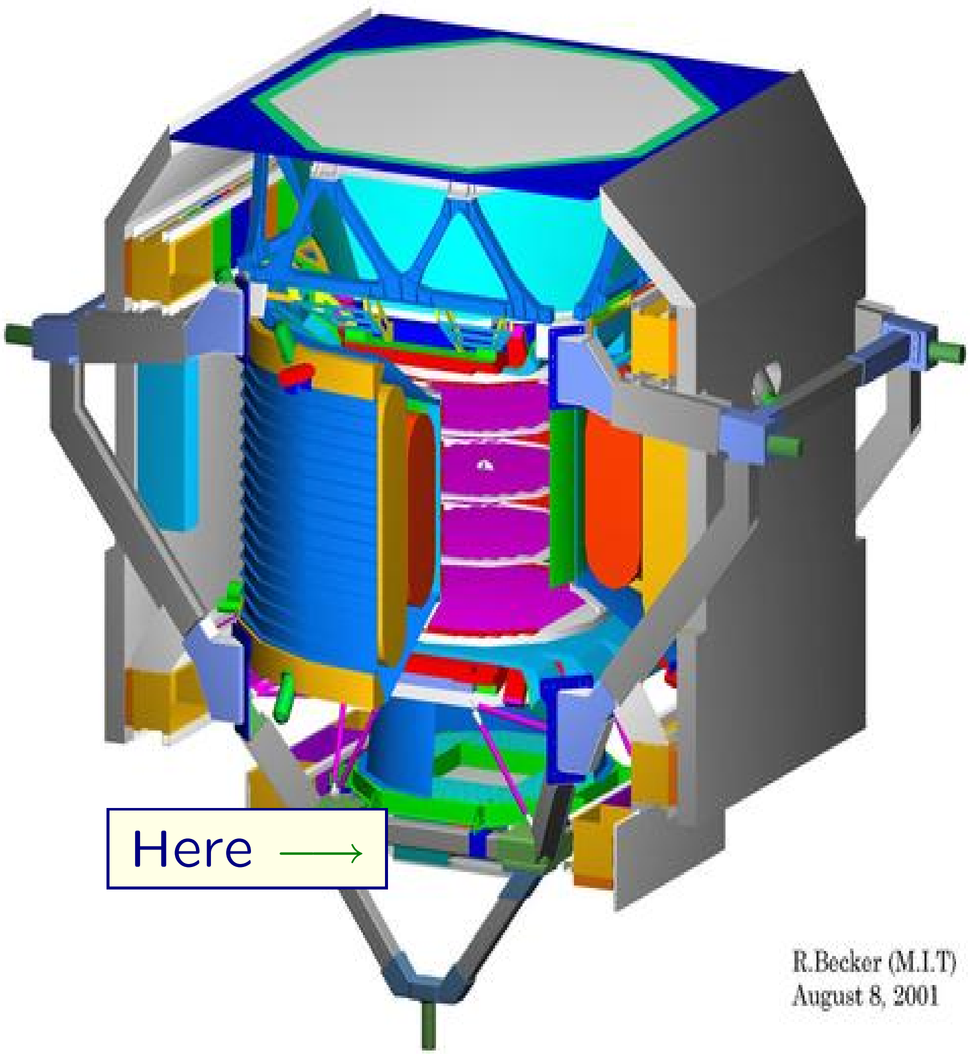


TRD

- 20 layers of foam separated by drift tubes.
- Hadron ID.
- e/h separation up to $100 GeV$
- Tracking capability.

3 AMS 02

3.1 The new detector.



ECAL

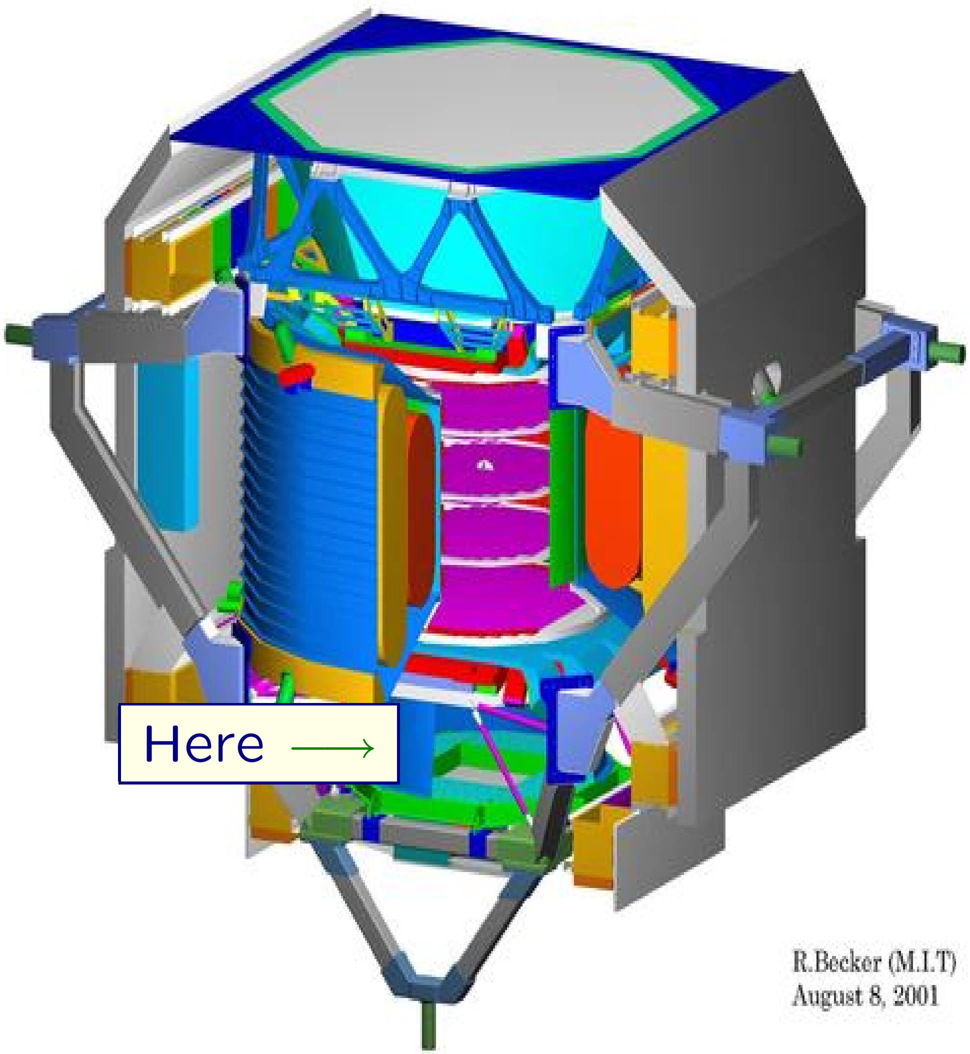
- 16.5 χ_0 in 10 superlayers of lead and scintillator.
- 3D sampling of shower:

$$\frac{\Delta E}{E} \simeq 0.015\ (100 GeV\ e)$$

- Provides
  · e/h separation at 10^{-4} level.
  · γ detection with direction reconstruction.

3 AMS 02

3.1 The new detector.



RICH

- Proximity focusing type with aerogel as radiator.
- Provides β and Z^2 measurements for $\beta > 0.95$

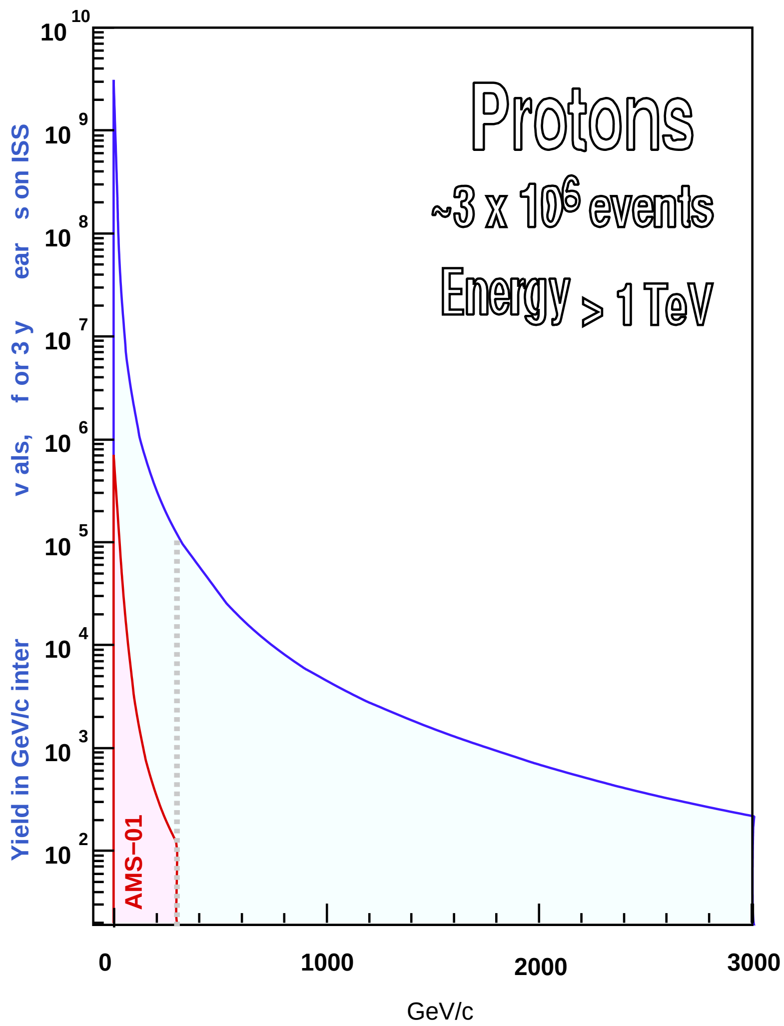
$$\frac{\Delta\beta}{\beta} \simeq 0.001(Z = 1)$$

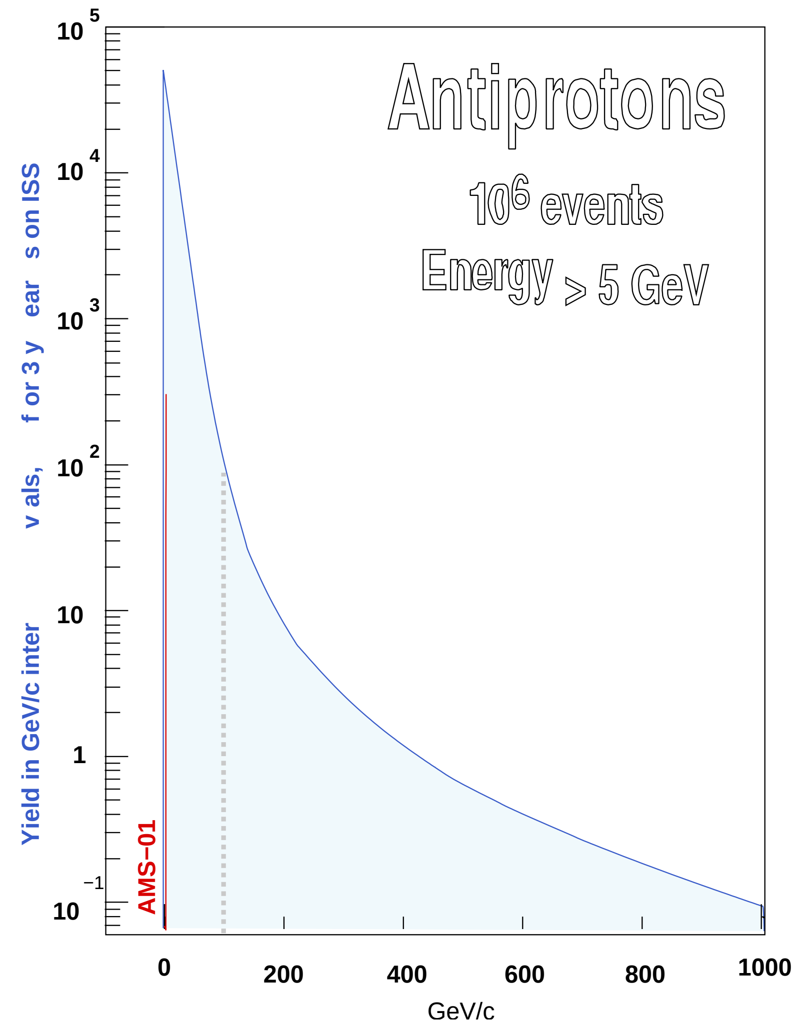
- Isotope and chemical PID up to $Z \simeq 26$ and $T \simeq 10GeV/A$:

$$\frac{\Delta m}{m} = \frac{\Delta p}{p} \oplus \gamma^2 \frac{\Delta\beta}{\beta}$$

3.2 Perspectives

The new configuration allows to cover a larger energy region, whereas the threen years of data taking allow us to have very large statistics.





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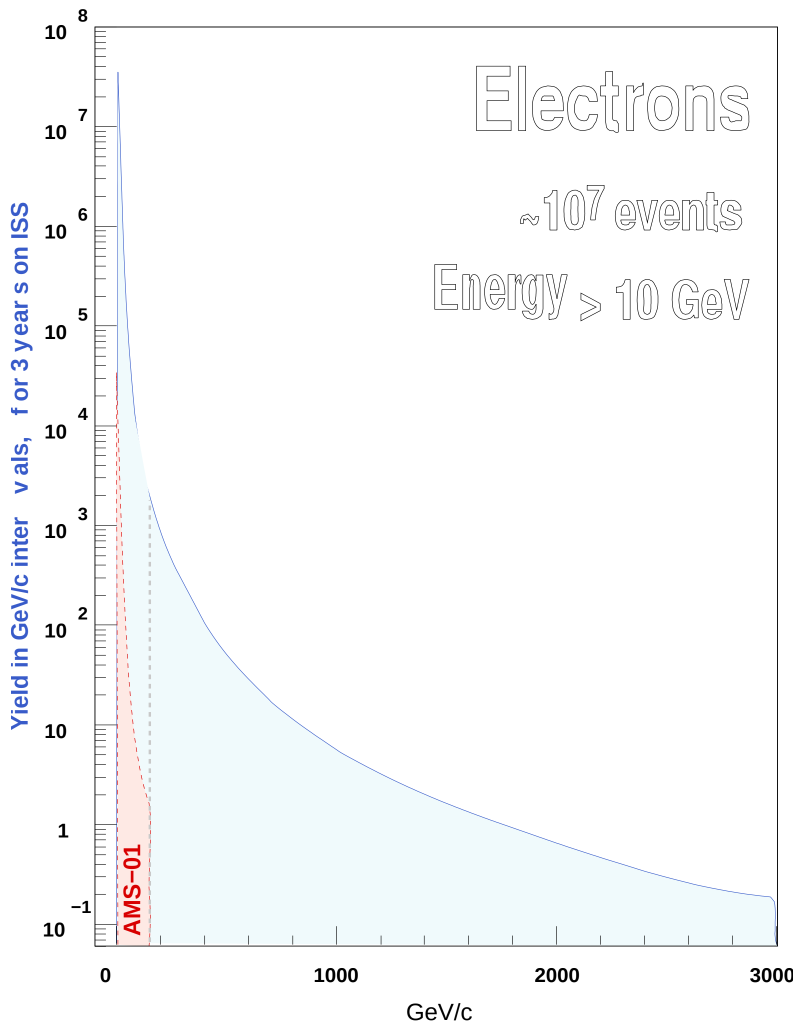

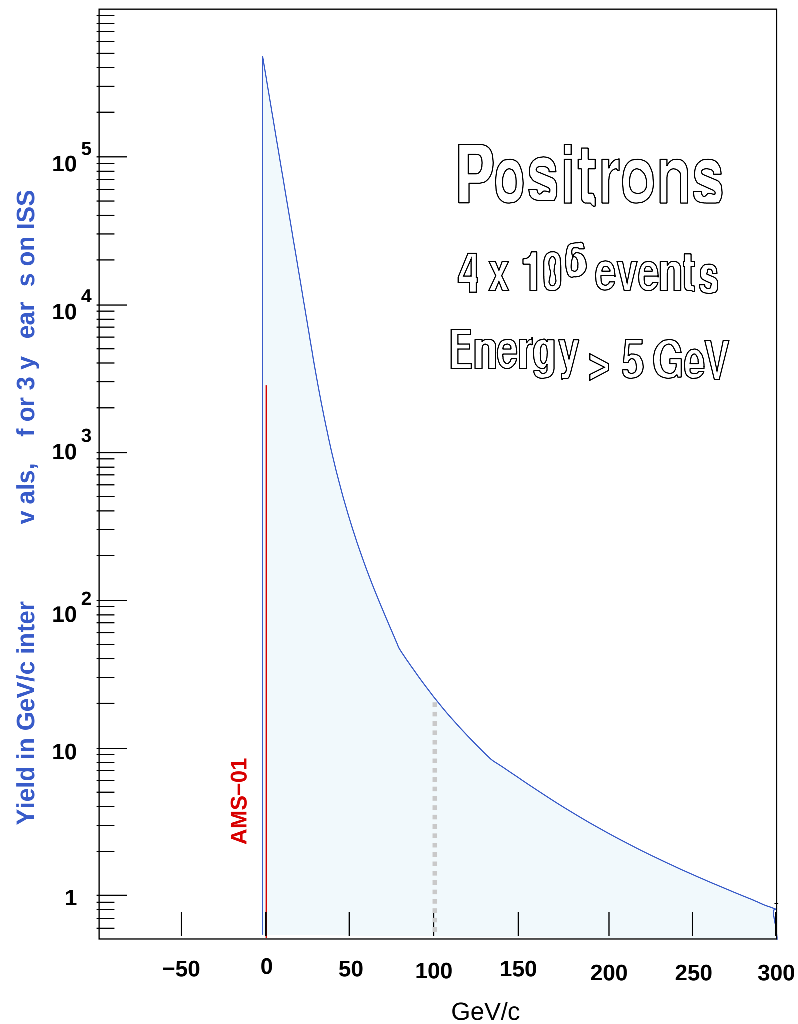

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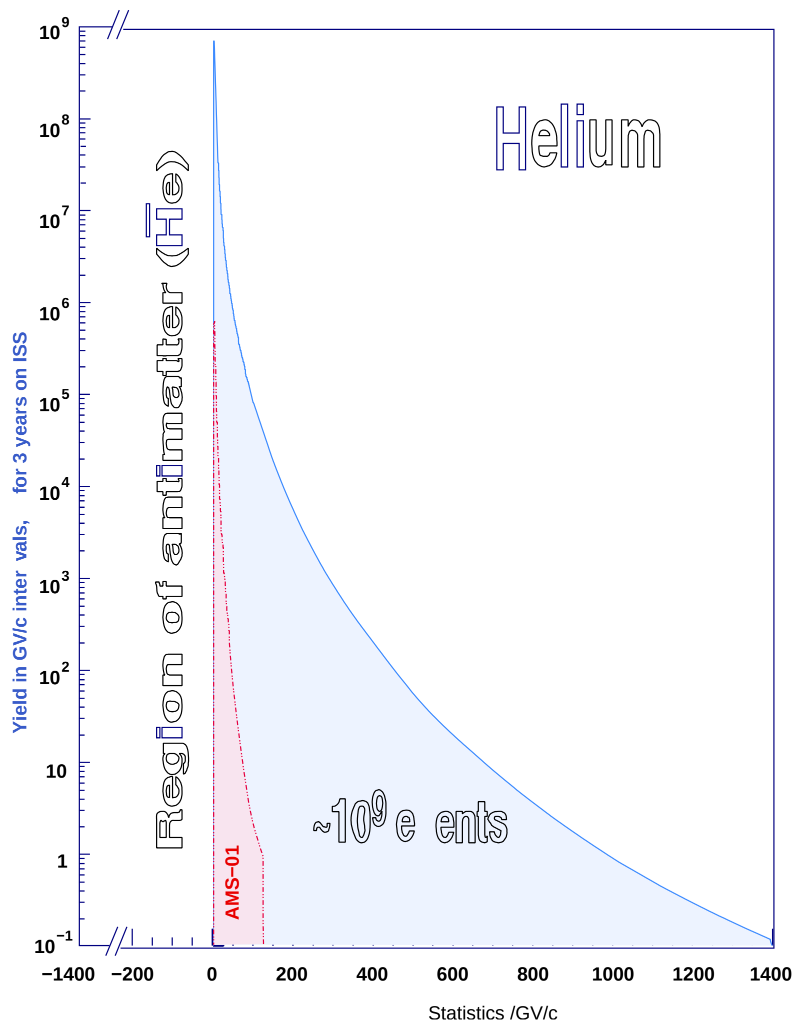
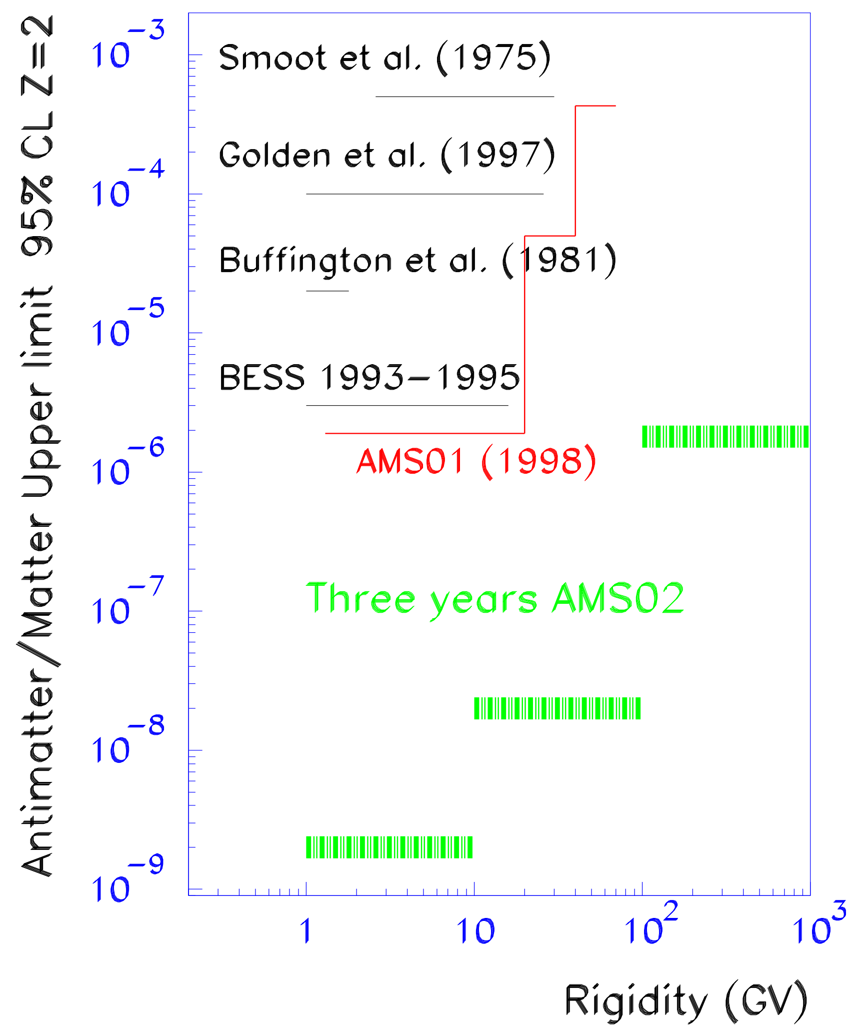
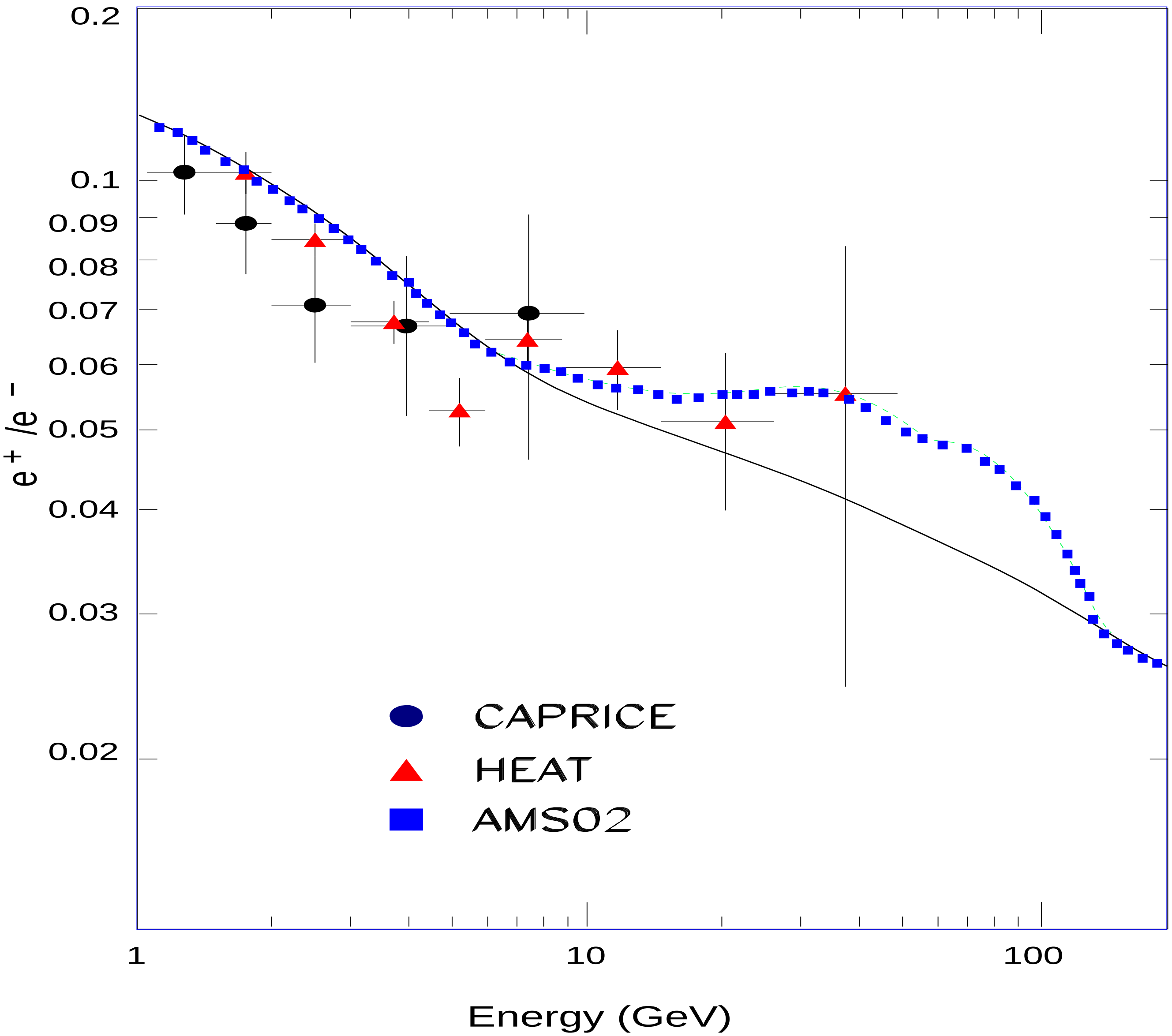




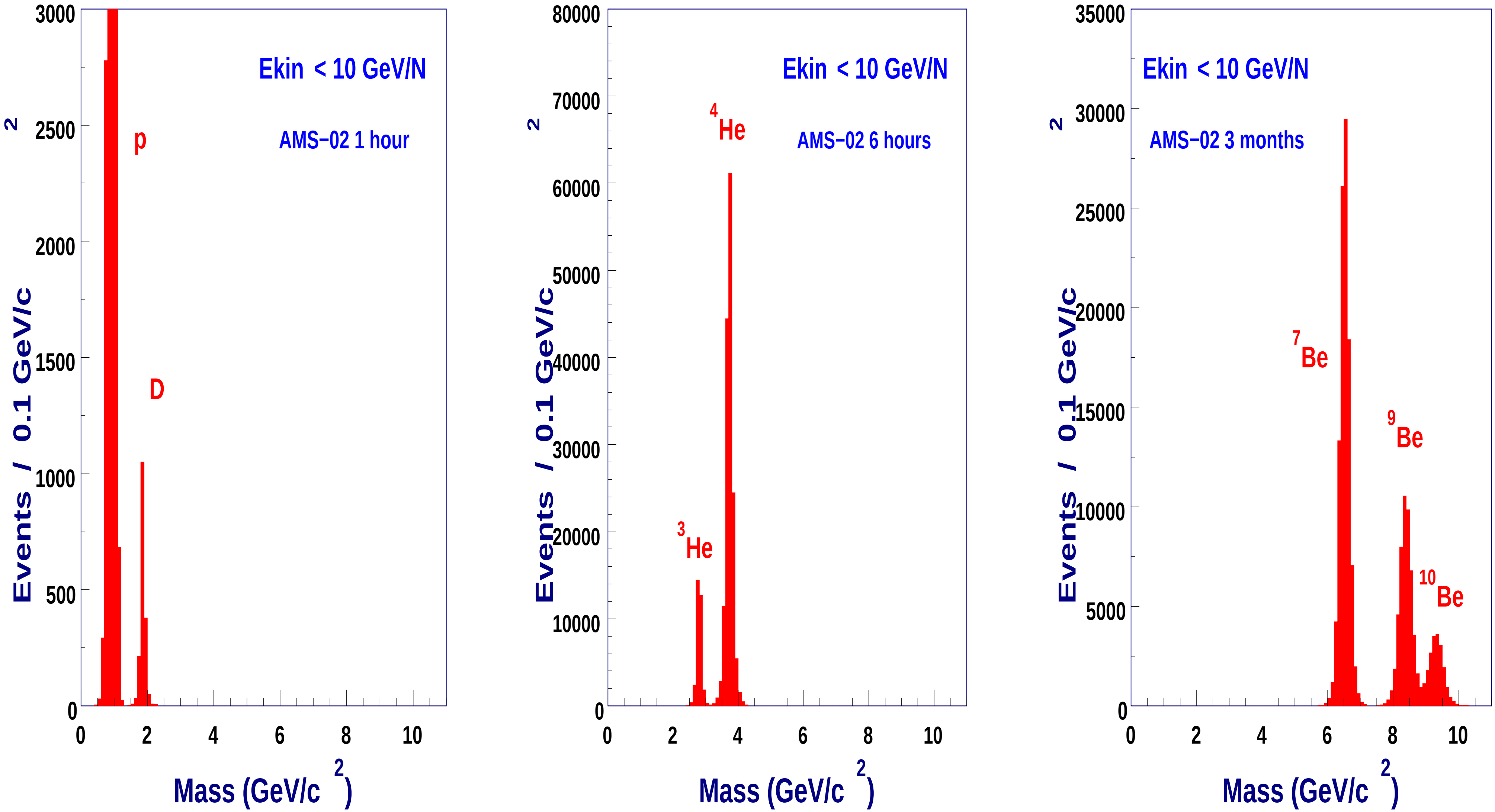
Neutralino search



Example for 275 GeV χ.

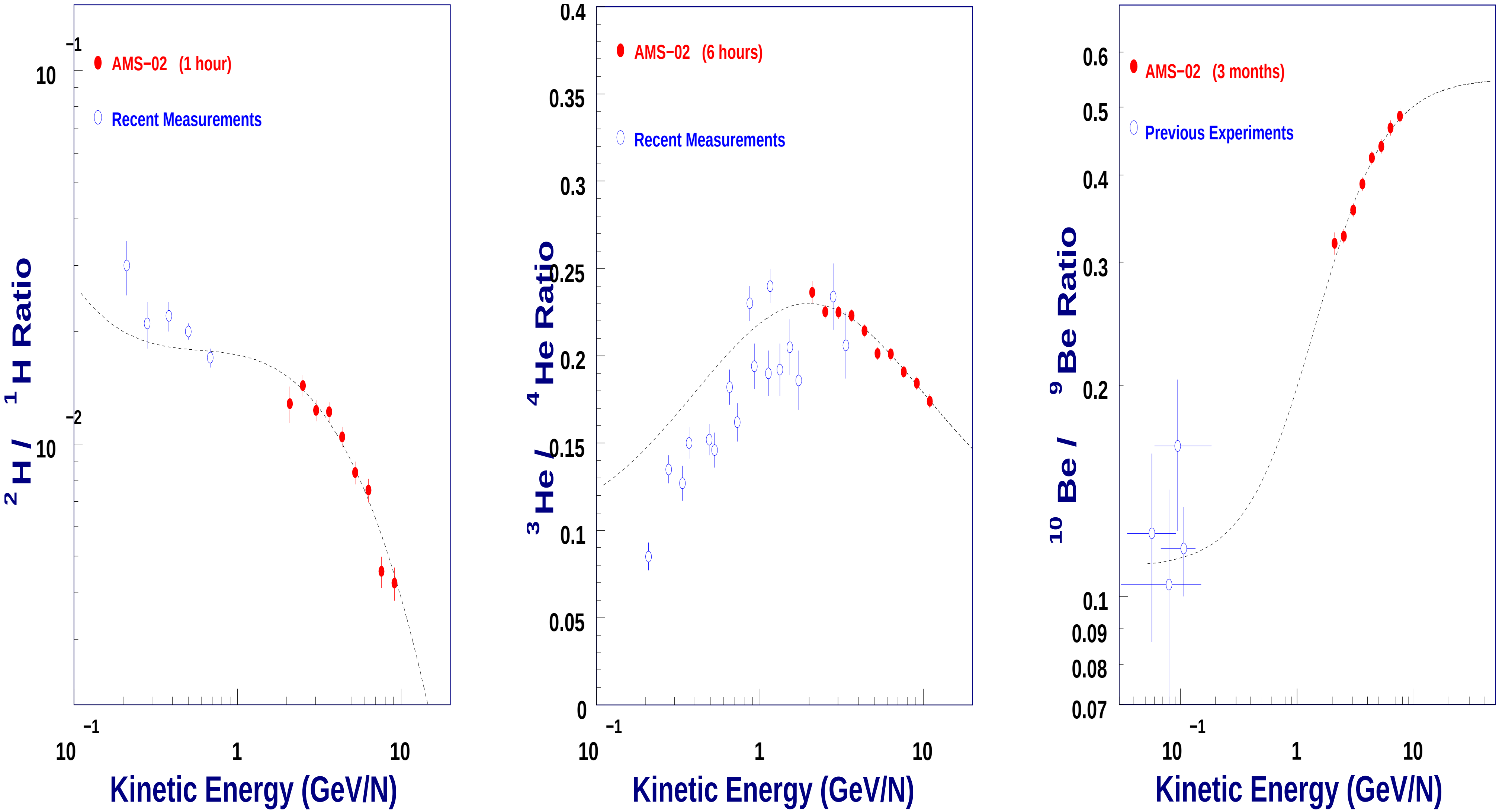
Channel also open to the (brand new) γ detection mode.

Beyond helium:RICH



First run of the prototype two week ago.

Beyond helium: RICH



It will allow to cover a completely unexplored region

Conclusions(?)

- AMS01: Results comparable, and usually better han any other experiment (or combination of them).
- AMS02: Promising... let's see soon.
- Astroparticle physics community growing and very interesting results expected in near future.

Hands and brains (still) welcomed to AMS