Cosmic Ray Measurements with the AMS Experiment in Space

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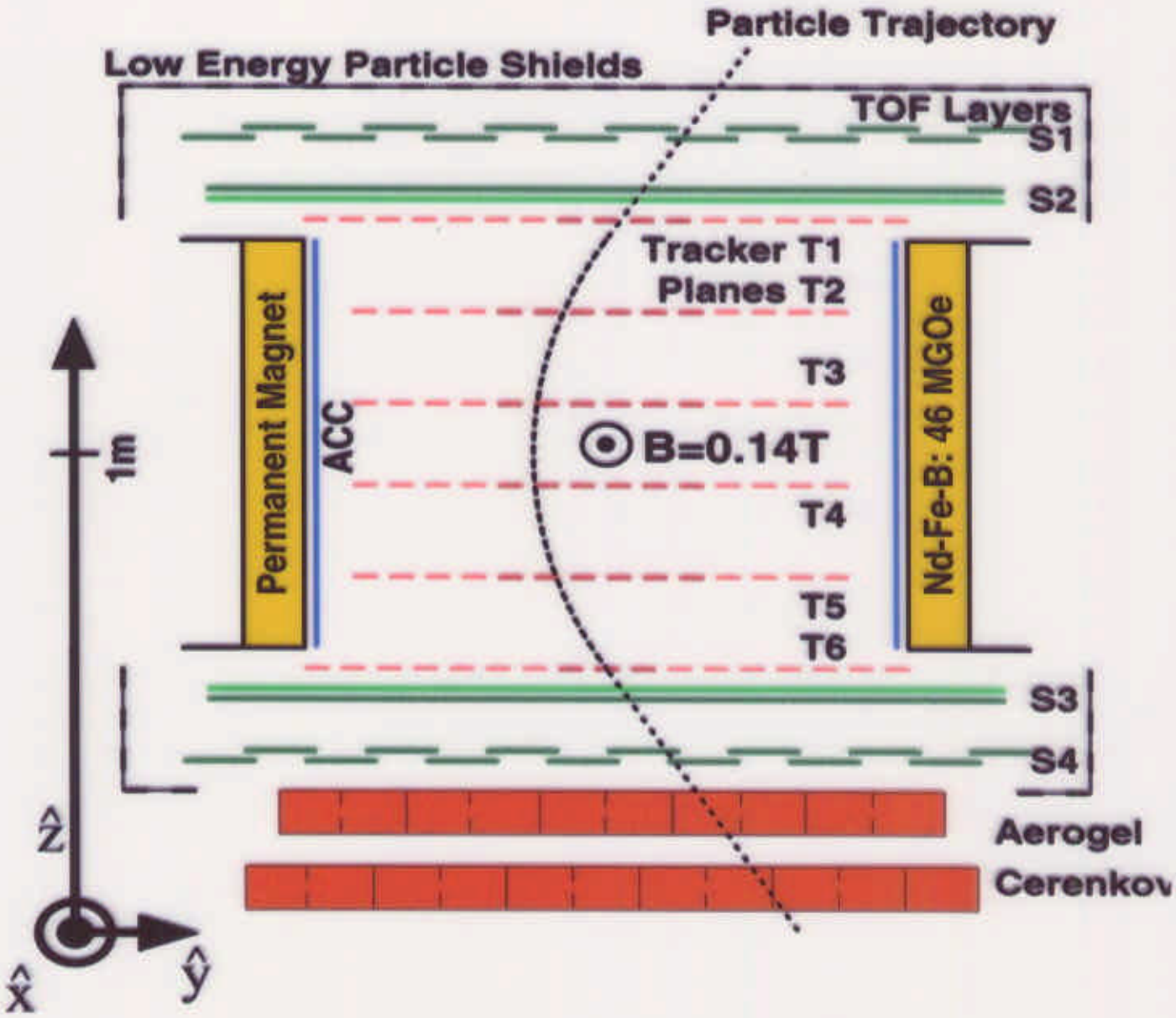
The AMS Experiment is a particle spectrometer, scheduled to operate for three years in space on board of the International Space Station.

The AMS has the following main physics goals:

- Search for the antimatter in the Universe on the level less than 10^{-8};
- Search for the dark matter via the $\bar{H}$ nuclei and $e^{\pm}$ spectra measurements;
- Make high statistics measurements of light isotops and $e^{\pm}$spectra over a broad energy range.

The preliminary version of the AMS detector had a 100 hours engineering flight on board the space shuttle Discovery in 1998.

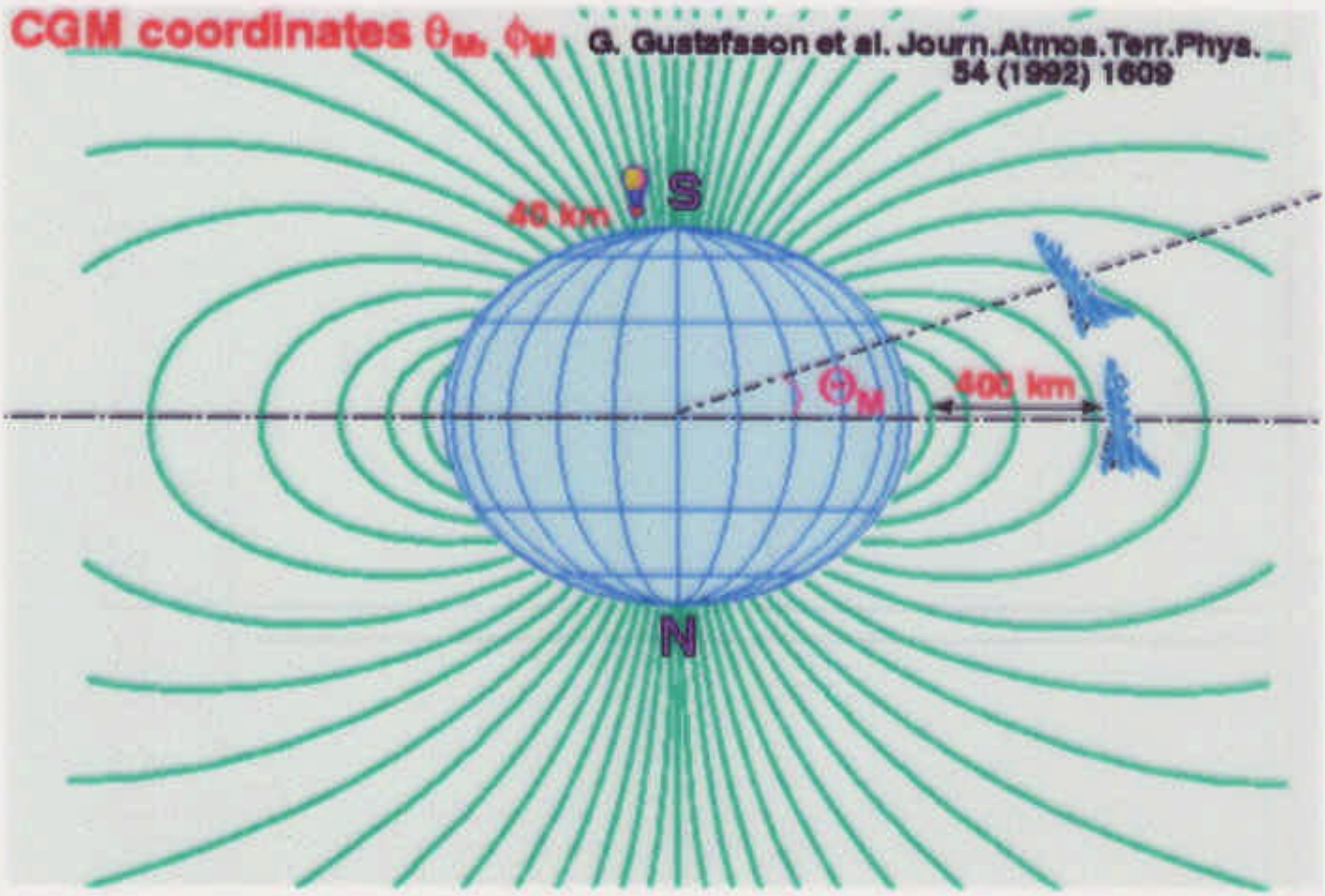
AMS Detector



- Permanent Magnet: Magnetic Field 0.14 T;
- ToF Hodoscope: Trigger, Velocity and Charge Magnitude;
- Silicon Tracker: Rigidity and Charge Magnitude;
- Aerogel Threshold Cerenkov: Velocity Measurements;
- Anticounters: Rejection of Multi Particle Events.

04

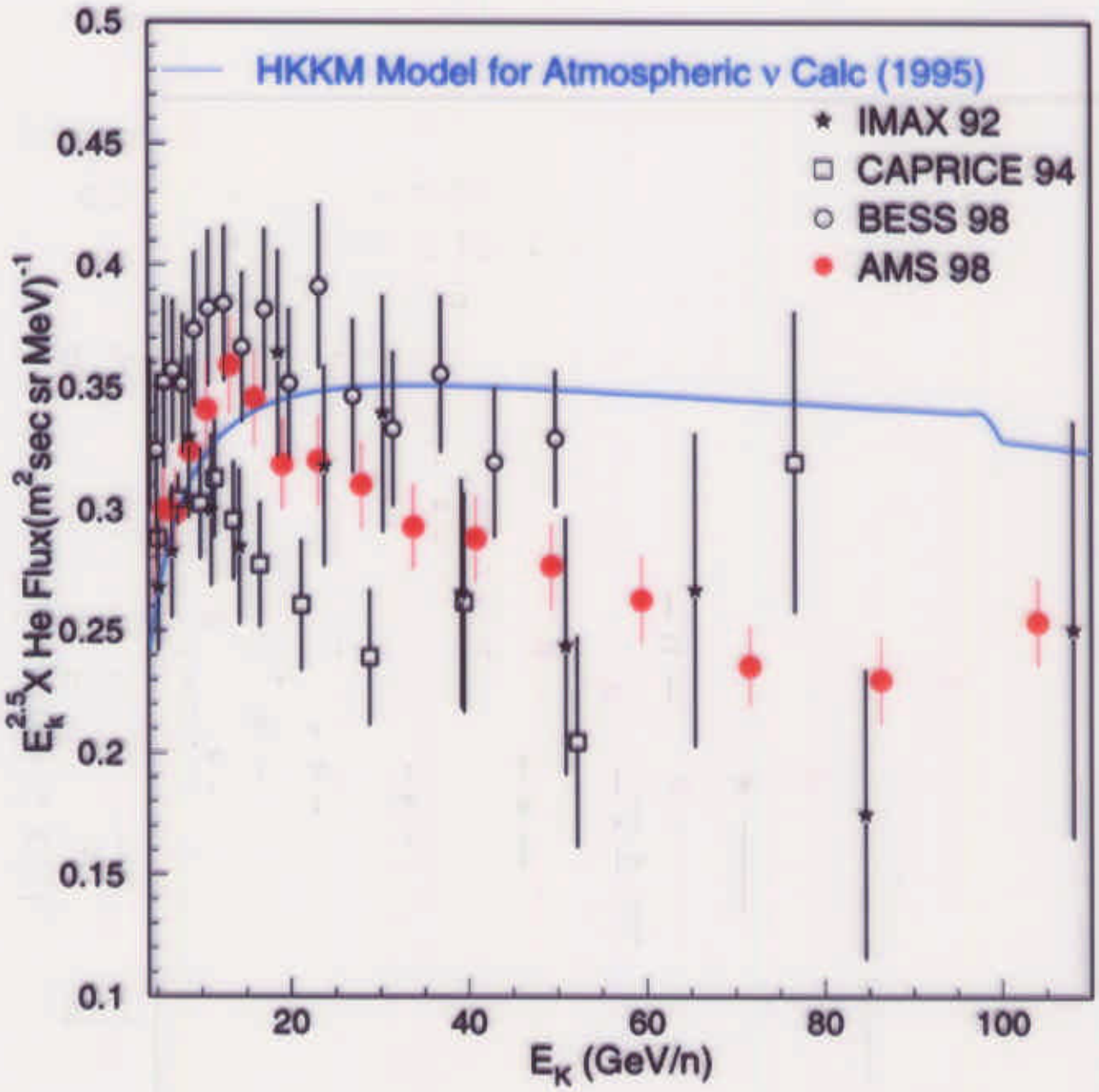
Test Flight Environment



Cosmic rays measured by AMS in near Earth orbit:

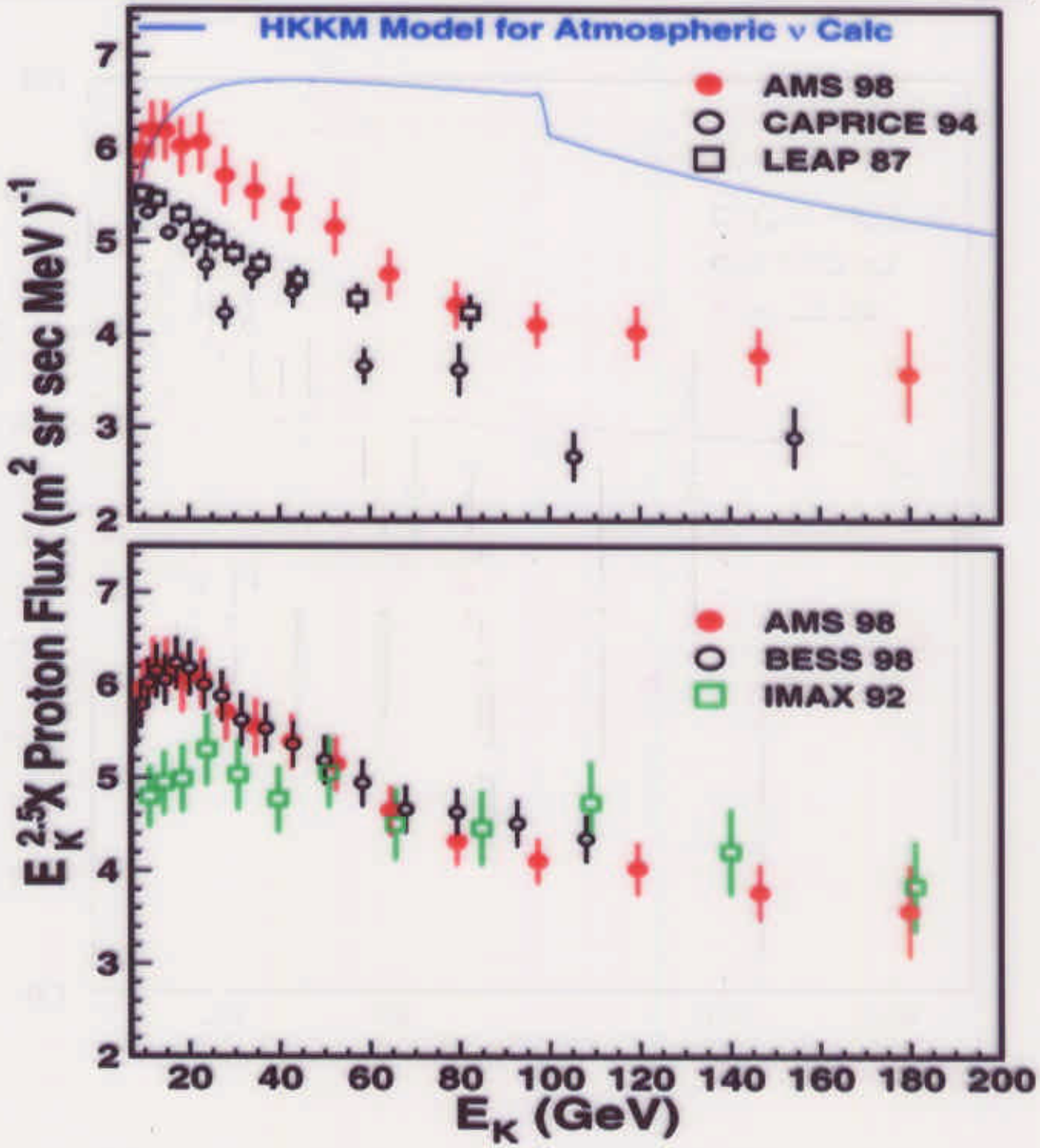
- Originate from supernova explosions in our galaxy or produced in particle interactions with the interstellar media;
- Follow rigidity power law, with low energy part modified by solar wind;
- Low energy CR are deflected by geomagnetic field, with *Geomagnetic Rigidity Cutoff* varies with Θ_M from 60 to 0.4 GV;
- Interact with atmosphere and produce "secondaries", which may be trapped in geomagnetic field for some time.

6 Primary Helium Spectrum (High Energy)



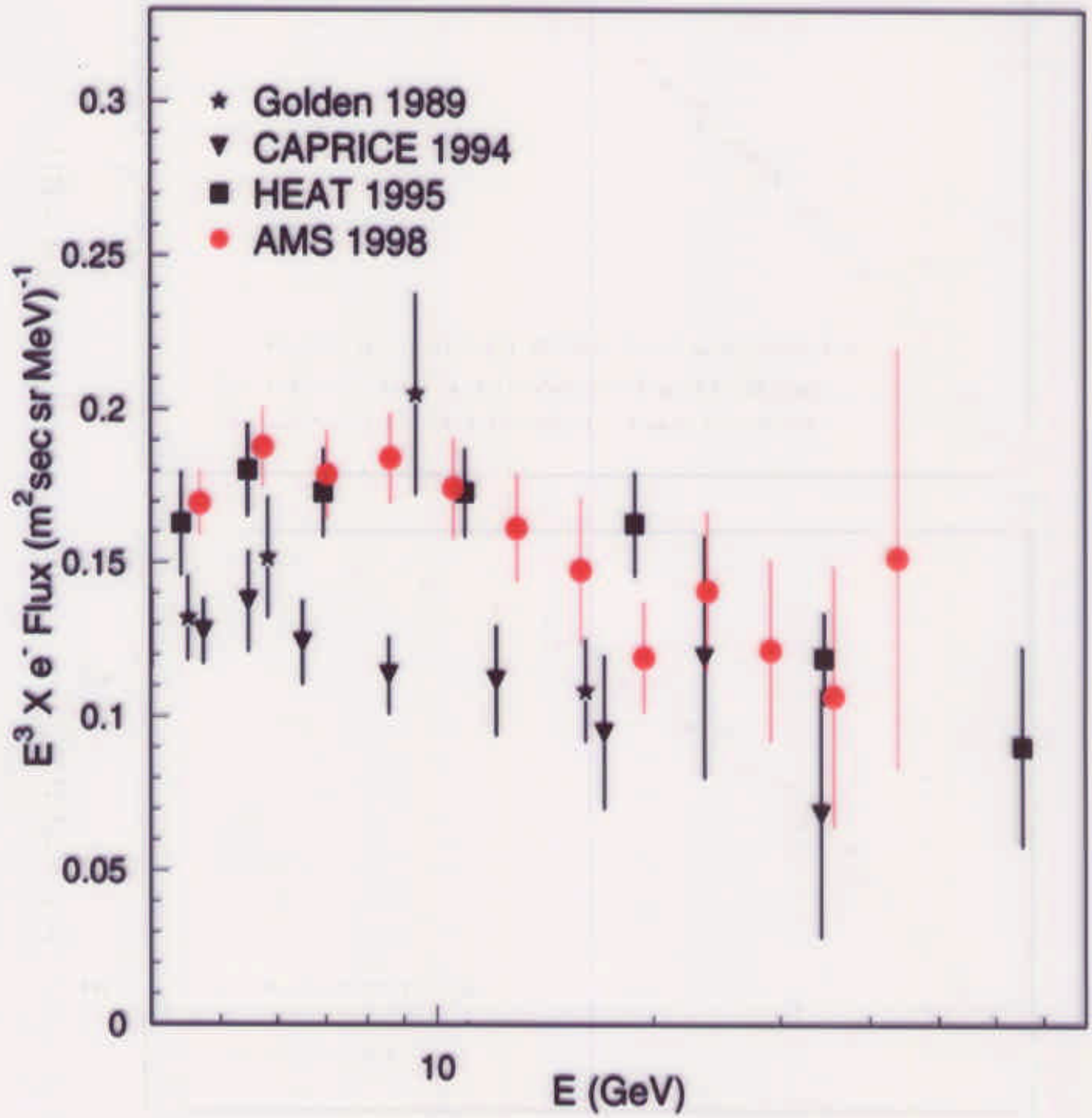
- High Statistics Measurement (about 10^6 Events);
- Power law fit: $\gamma_{He} = 2.74 \pm 0.02$;

5 Primary Proton Spectrum (High Energy)

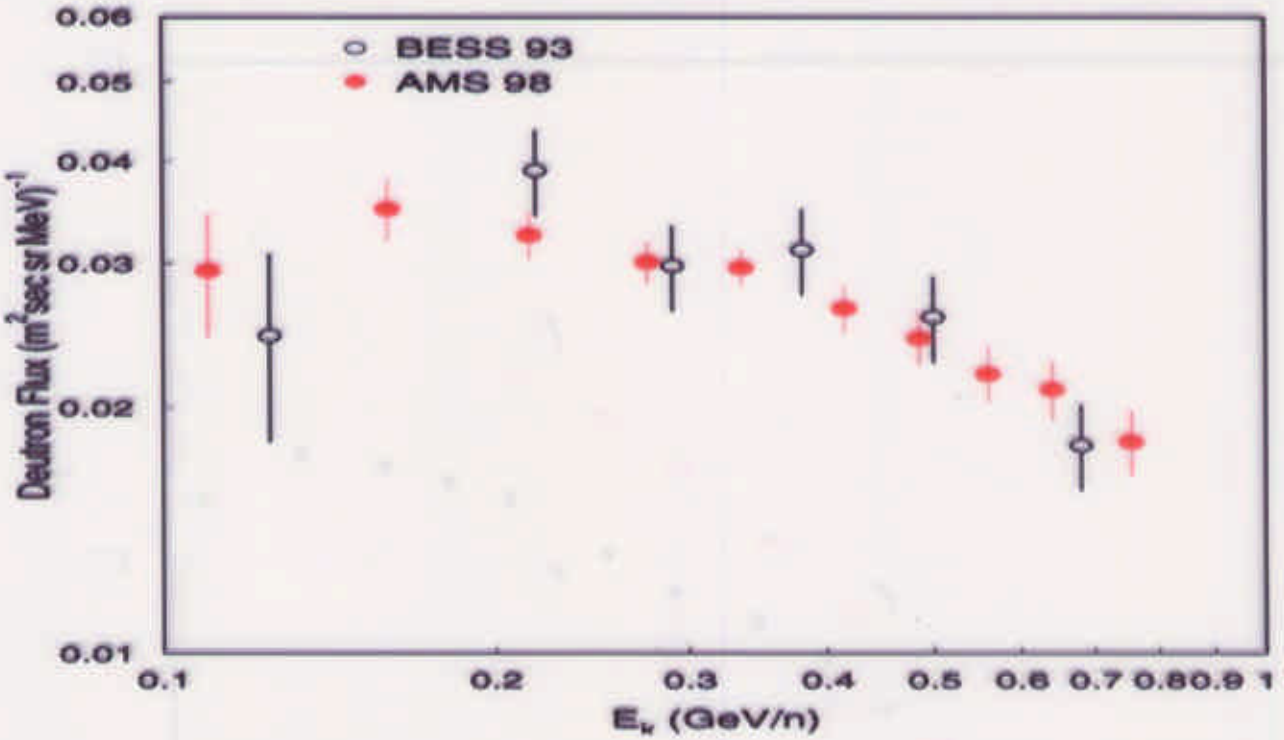


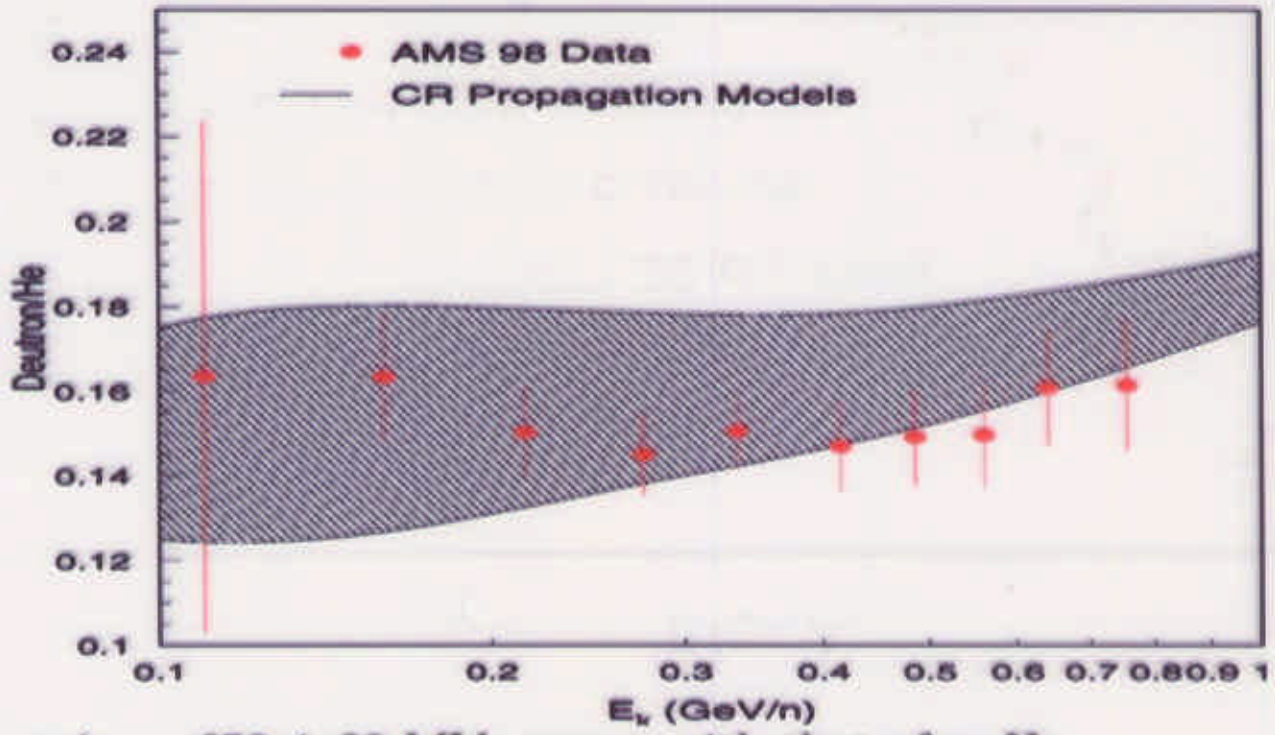
- High Statistics Measurement ($> 6 \cdot 10^6$ Events);
- Power law fit: $\gamma_p = 2.78 \pm 0.025$;

7 Primary Electron Spectrum (High Energy)



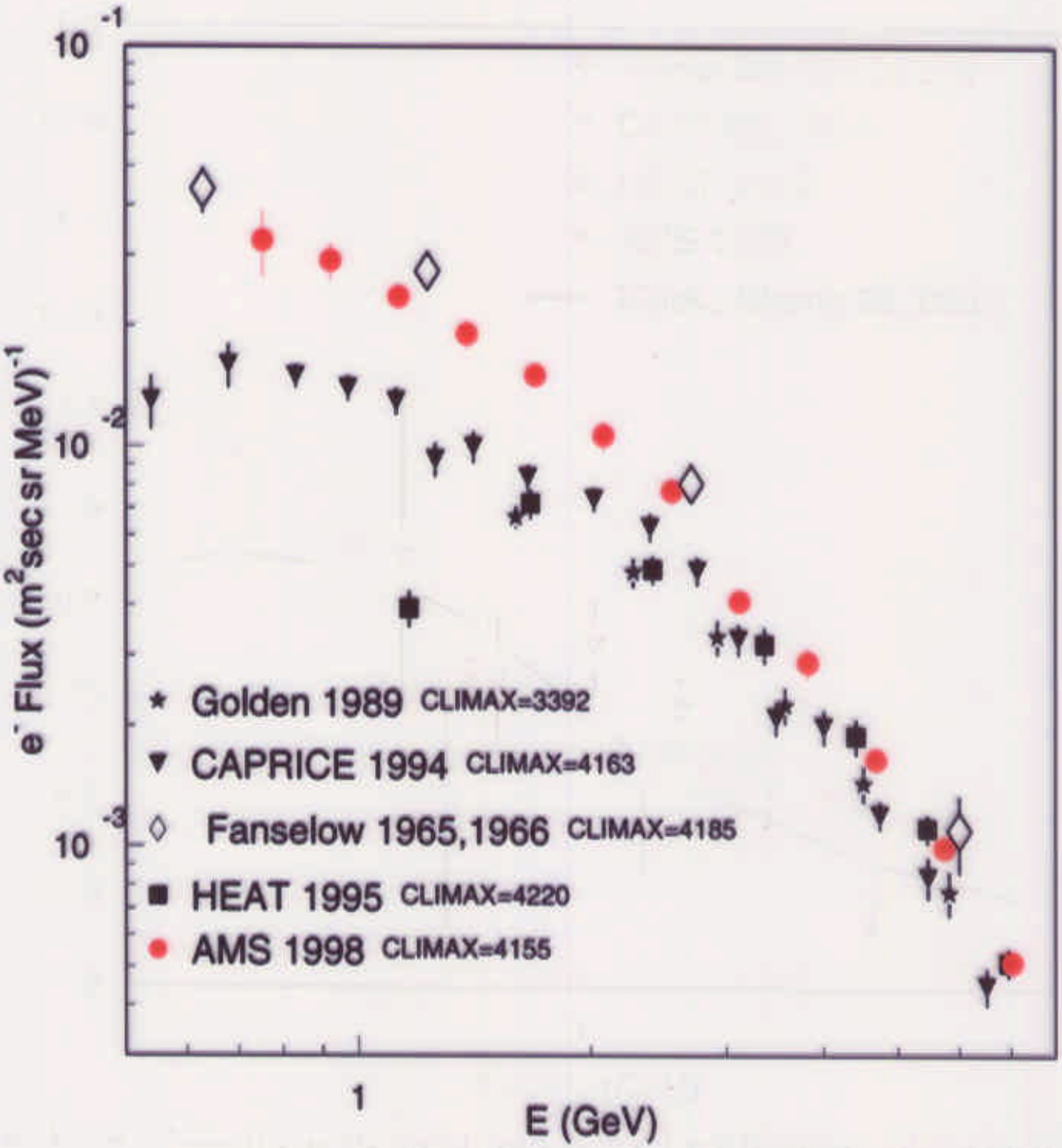
Cosmic Deuteron Spectrum





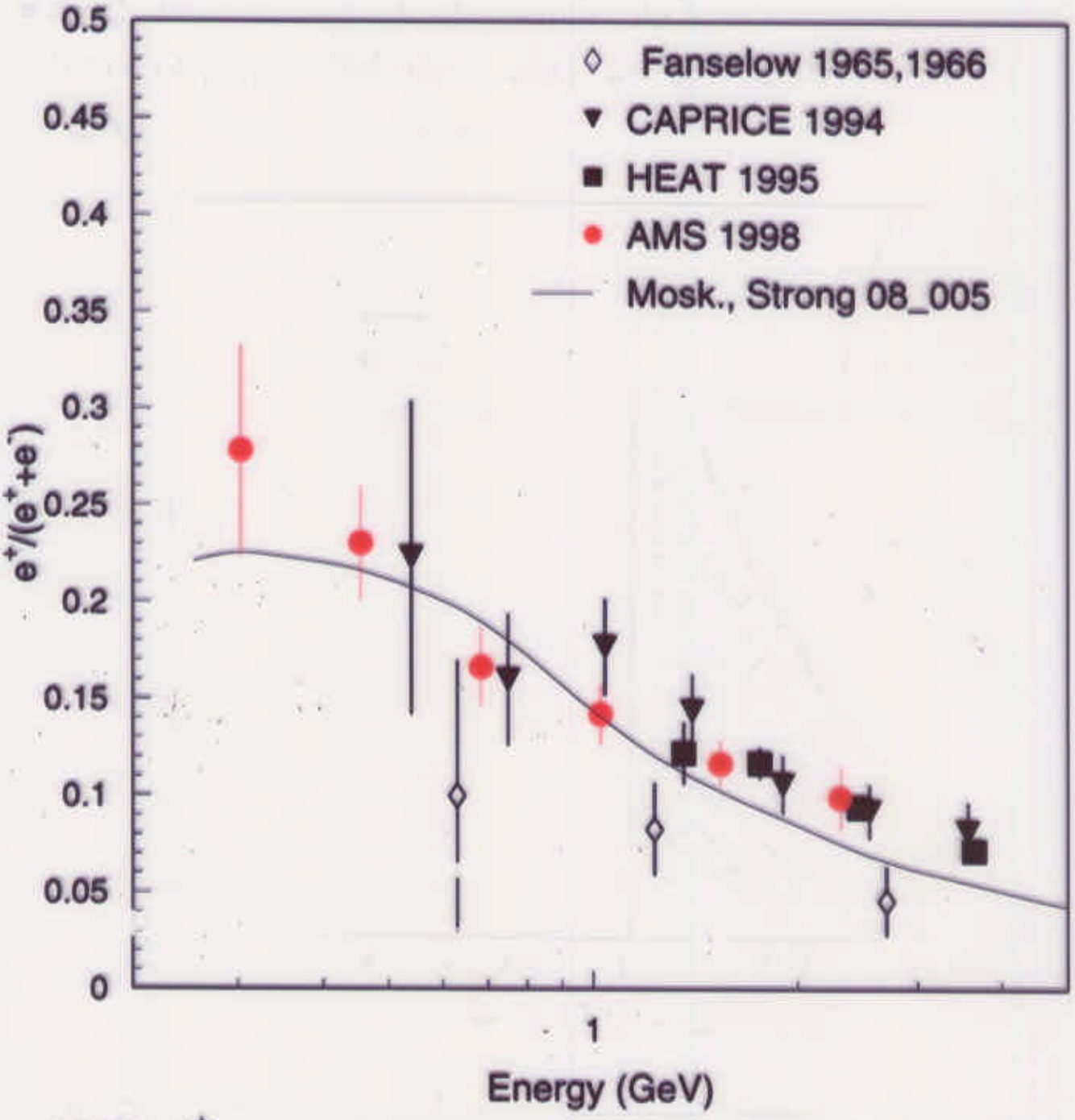
- $\phi_D = 650 \pm 20$ MV, agrees with that of p, He.
- $\frac{\mathrm{D}}{\mathrm{He}}$ is compatible with CR models predictions.

Primary Electron Spectrum (Low Energy)



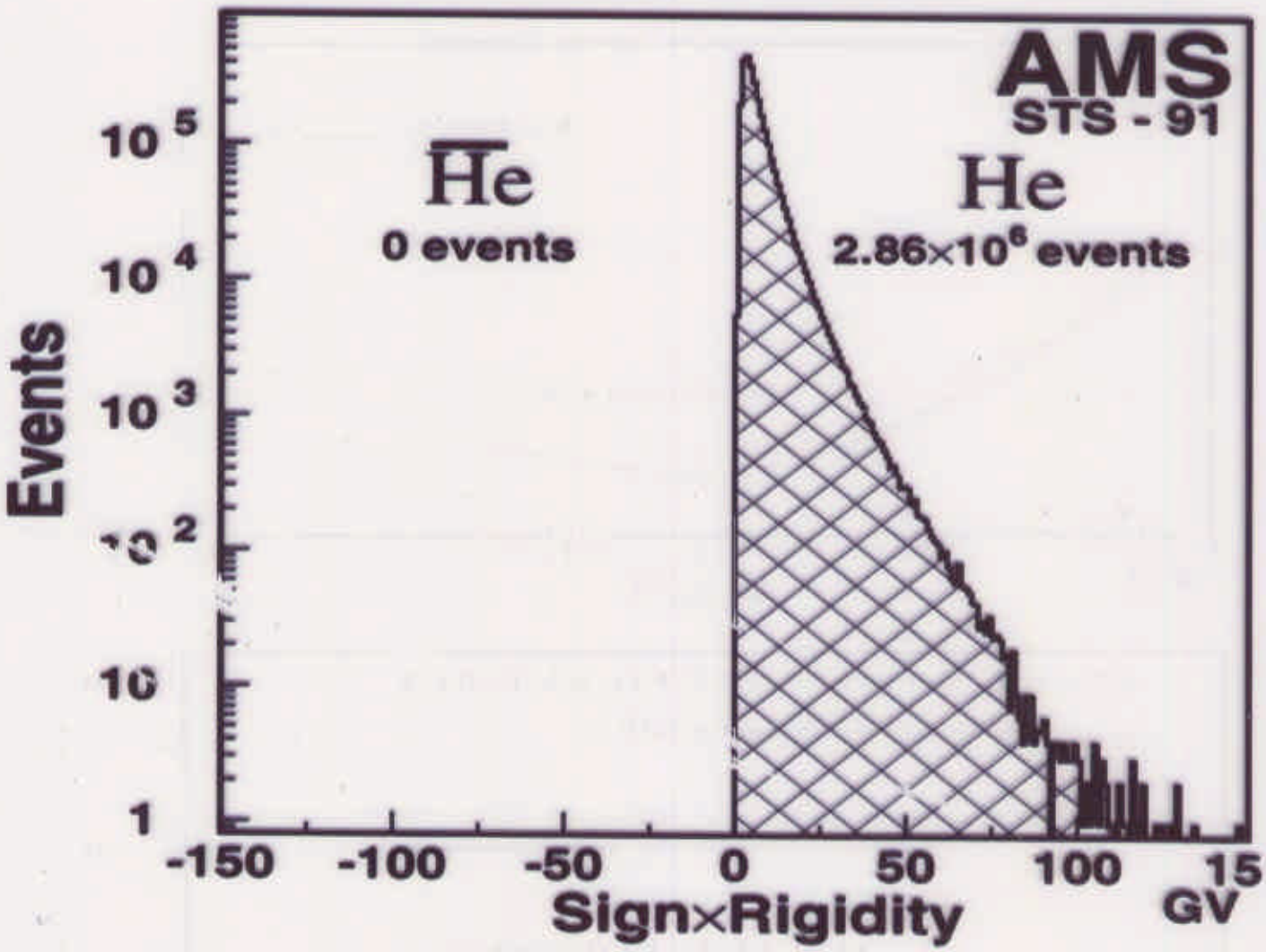
- AMS data: $\phi_e = 400 \pm 30$ MV.

Cosmic Electron to Positron Ratio



- AMS $\frac{e^+}{e^++e^-}$ measurement agrees well with same solar cycle earlier measurements.

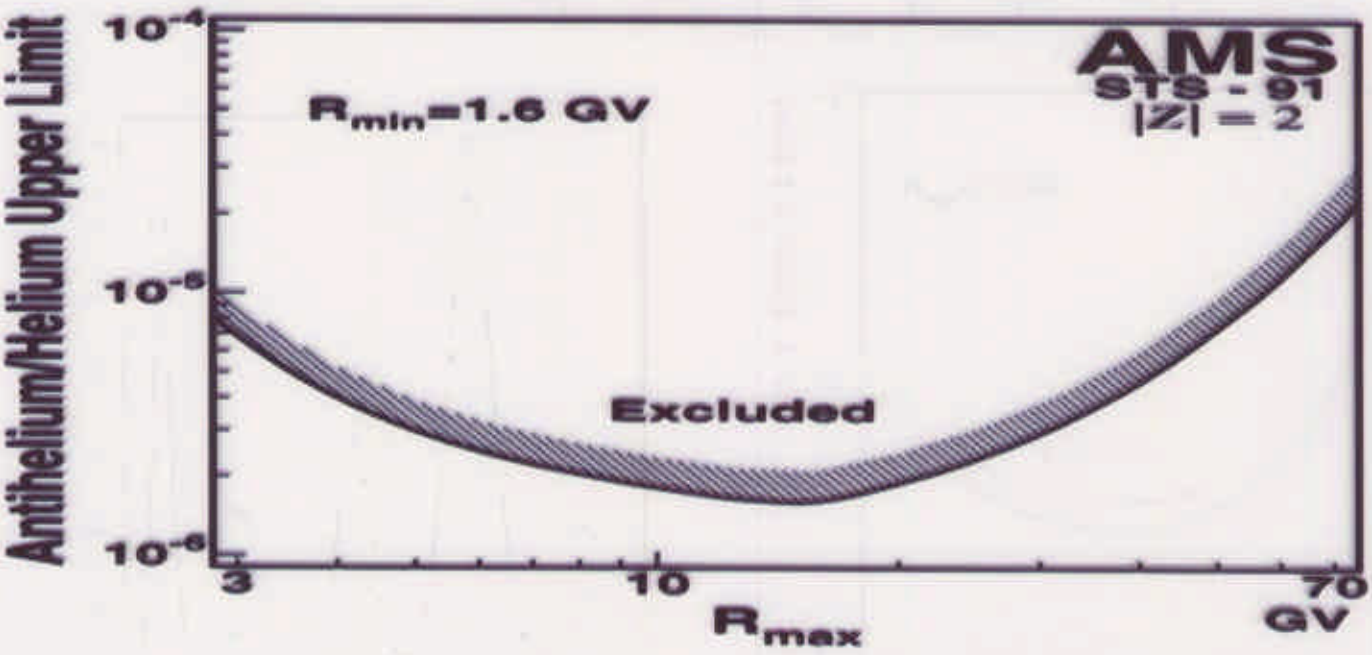
- Z=2 ($\bar{\text{He}}$) - discovery of a single nucleus - evidence of existence of primordial antimatter, as $\frac{\bar{\text{He}}_{\text{sec}}}{\text{He}} < 10^{-12}$;
  - No candidates so far;

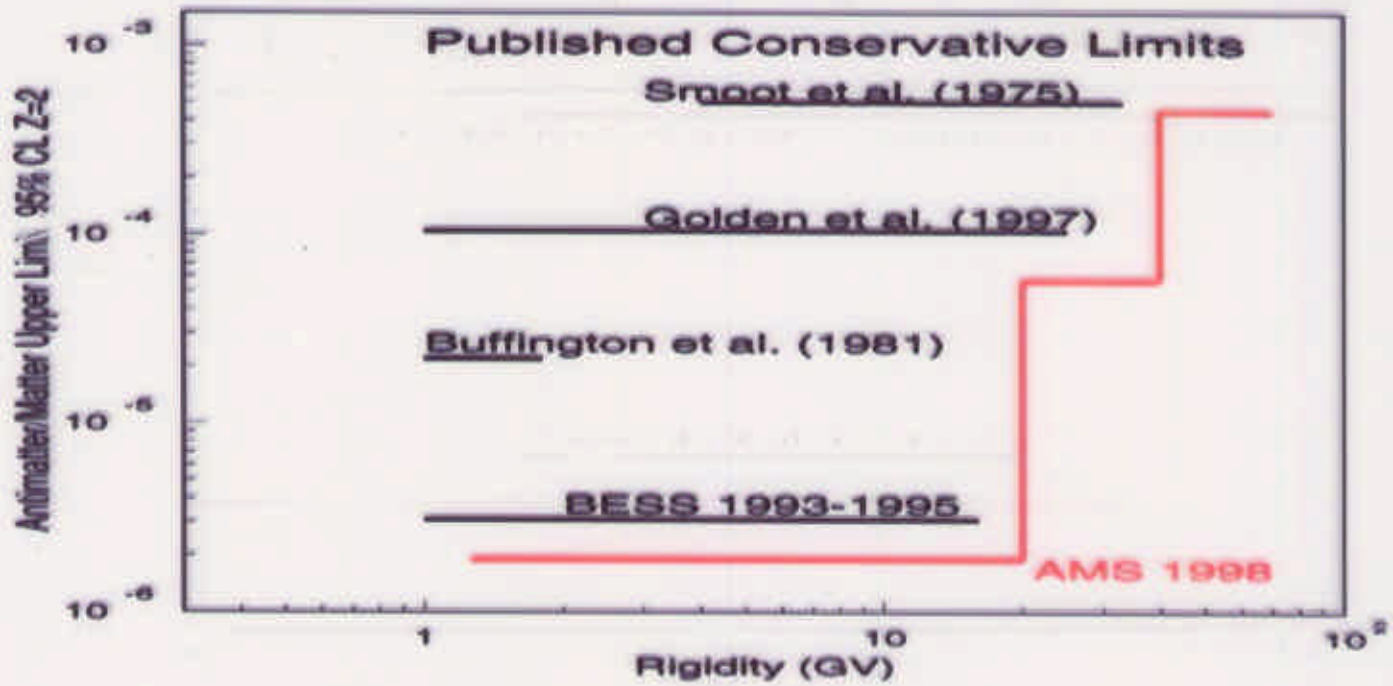


  - "Same Spectrum" Limit: $\frac{3}{\int_{R_{min}}^{R_{max}} \text{Flux}(R)\cdot\epsilon_{\bar{\text{He}}}(R)dR}$.
  - AMS 98: $\frac{\bar{\text{He}}}{\text{He}} < 1.1\cdot10^{-6}$; Rigidity < 100 GV
  - BESS 93-98: $\frac{\bar{\text{He}}}{\text{He}} < 1.0\cdot10^{-6}$; Rigidity < 16 GV

Search For AntiMatter

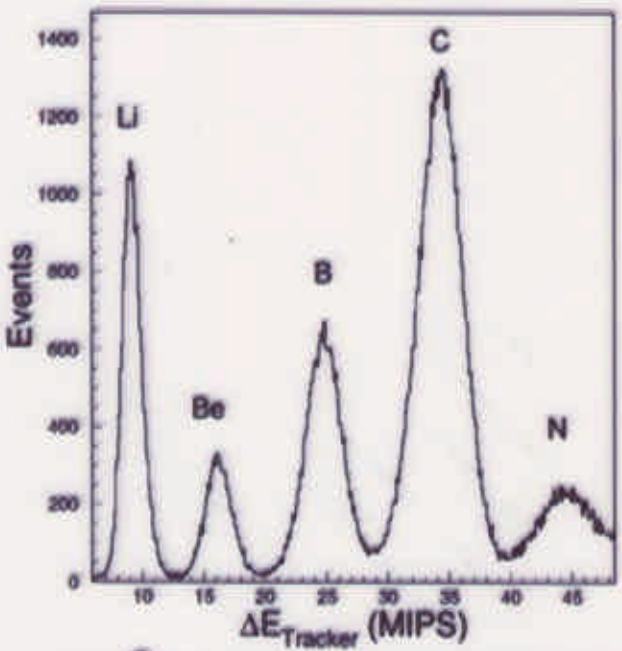
– Conservative Limit: $\dfrac{3}{\text{Acceptance}_{min}[R_{min}\cdots R_{max}]\cdot\int_{R_{min}}^{R_{max}}\text{Flux}(R)dR}$.

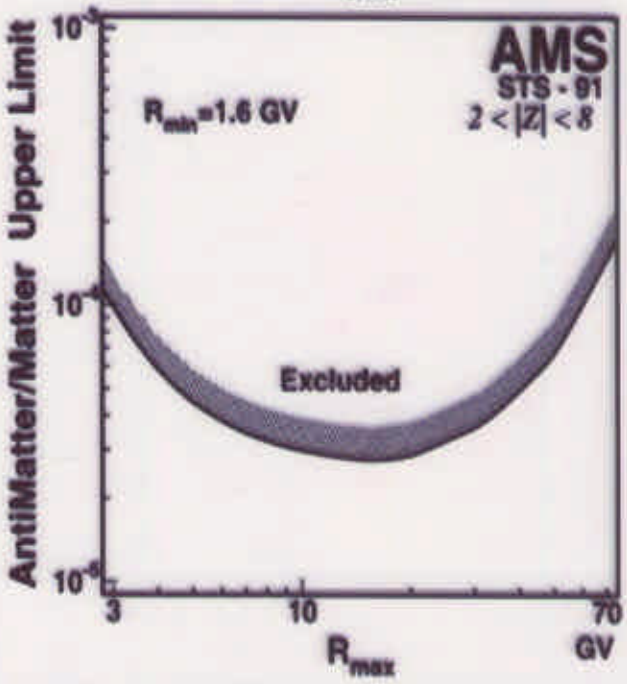


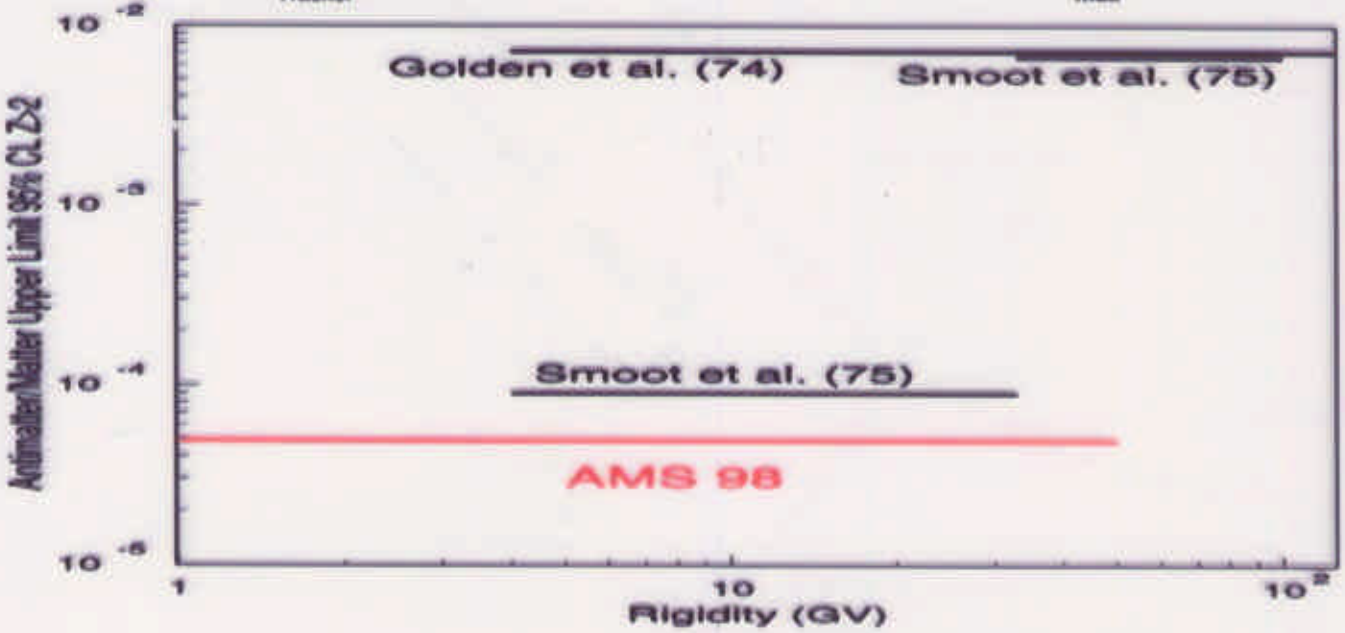


Search For AntiMatter

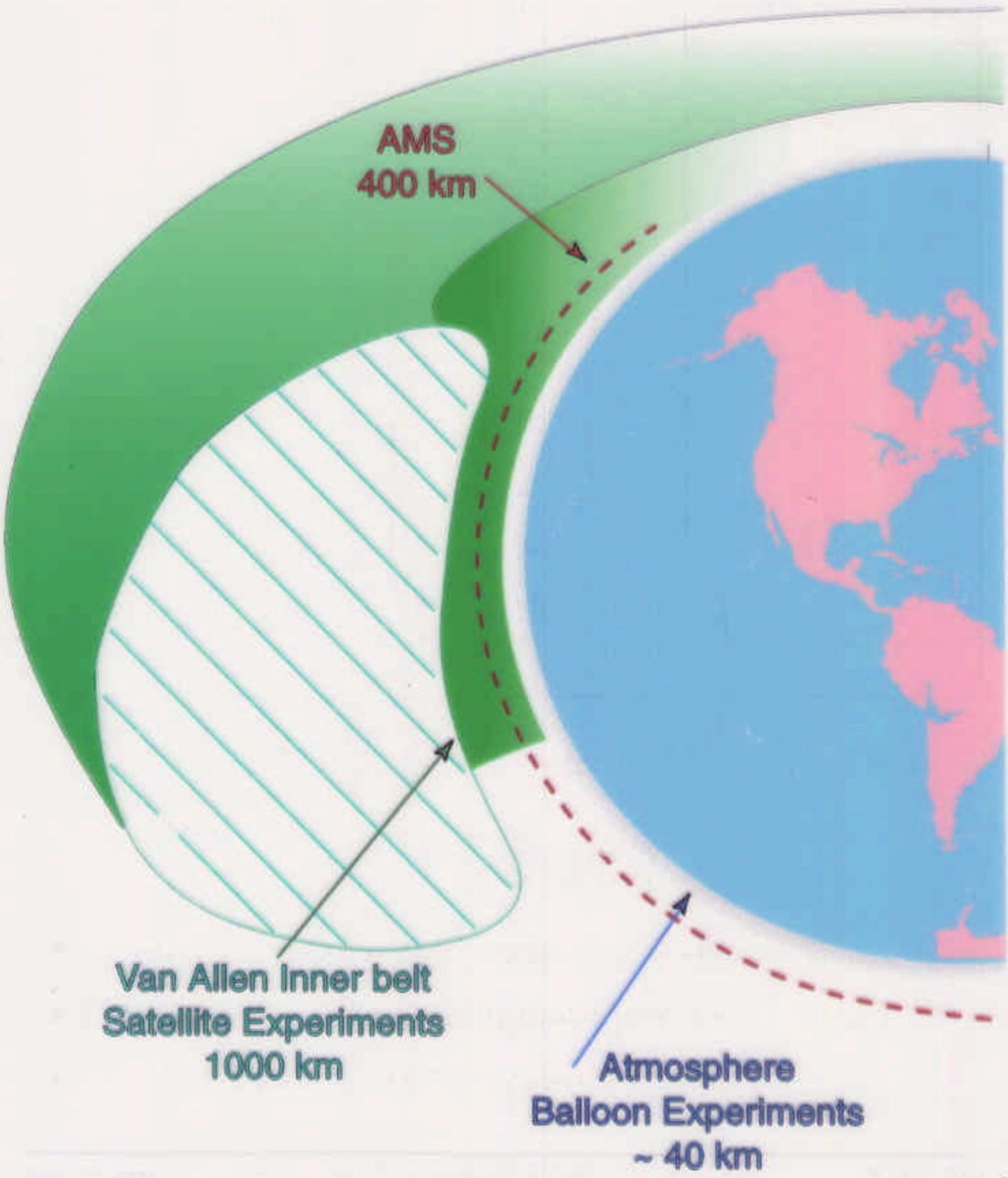
- Z>2 - discovery of a single nucleus would be an evidence of existence of antistars.
  - No candidates so far;
  - Limit Definition: $$\frac{3}{\text{Acceptance}_{min}[R_{min}...R_{max},Z]\cdot\sum_Z \int_{R_{min}}^{R_{max}} \text{Flux}(R)dR}.$$





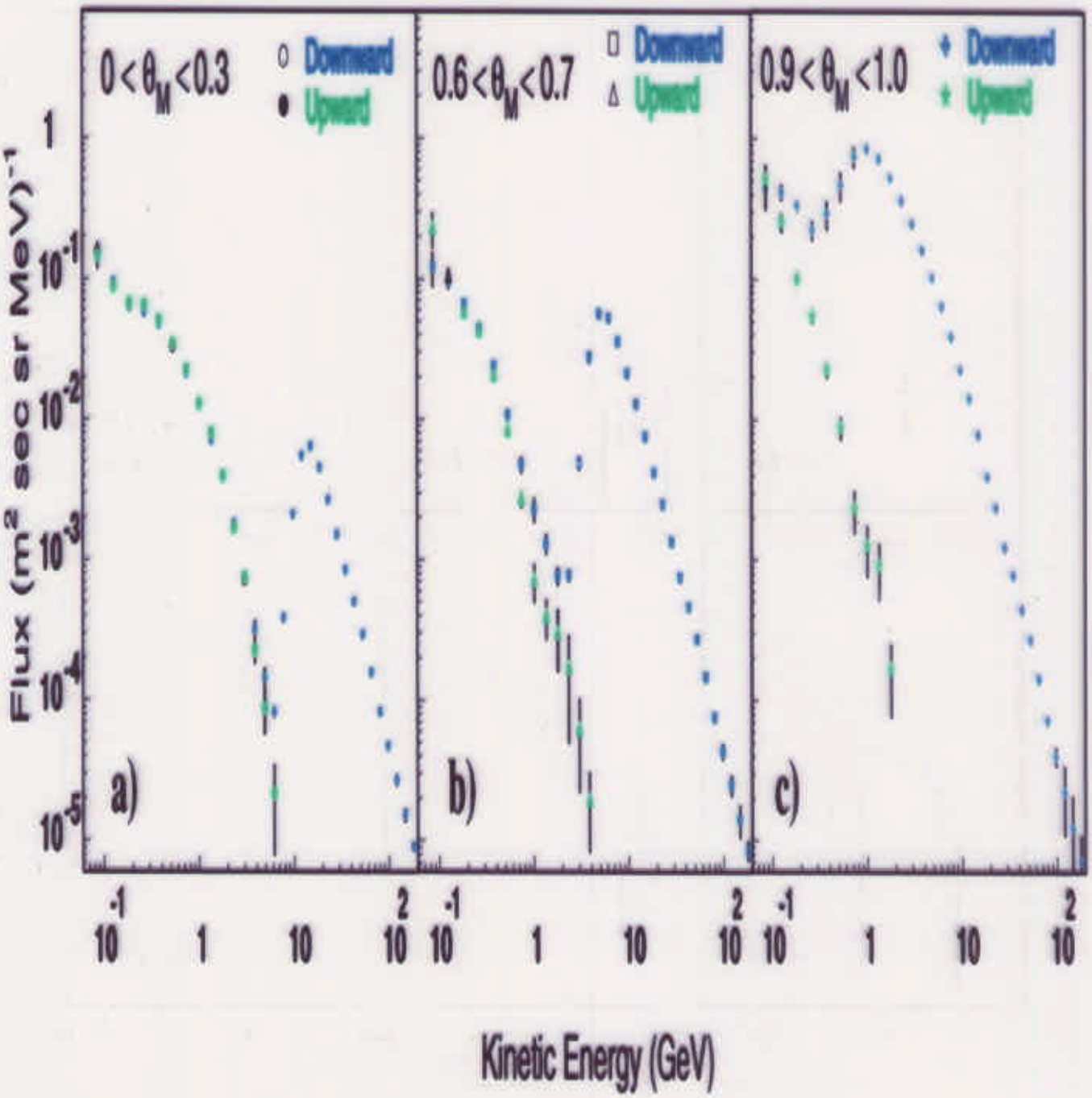


On the origin of elementary particles and nuclei in the magnetosphere



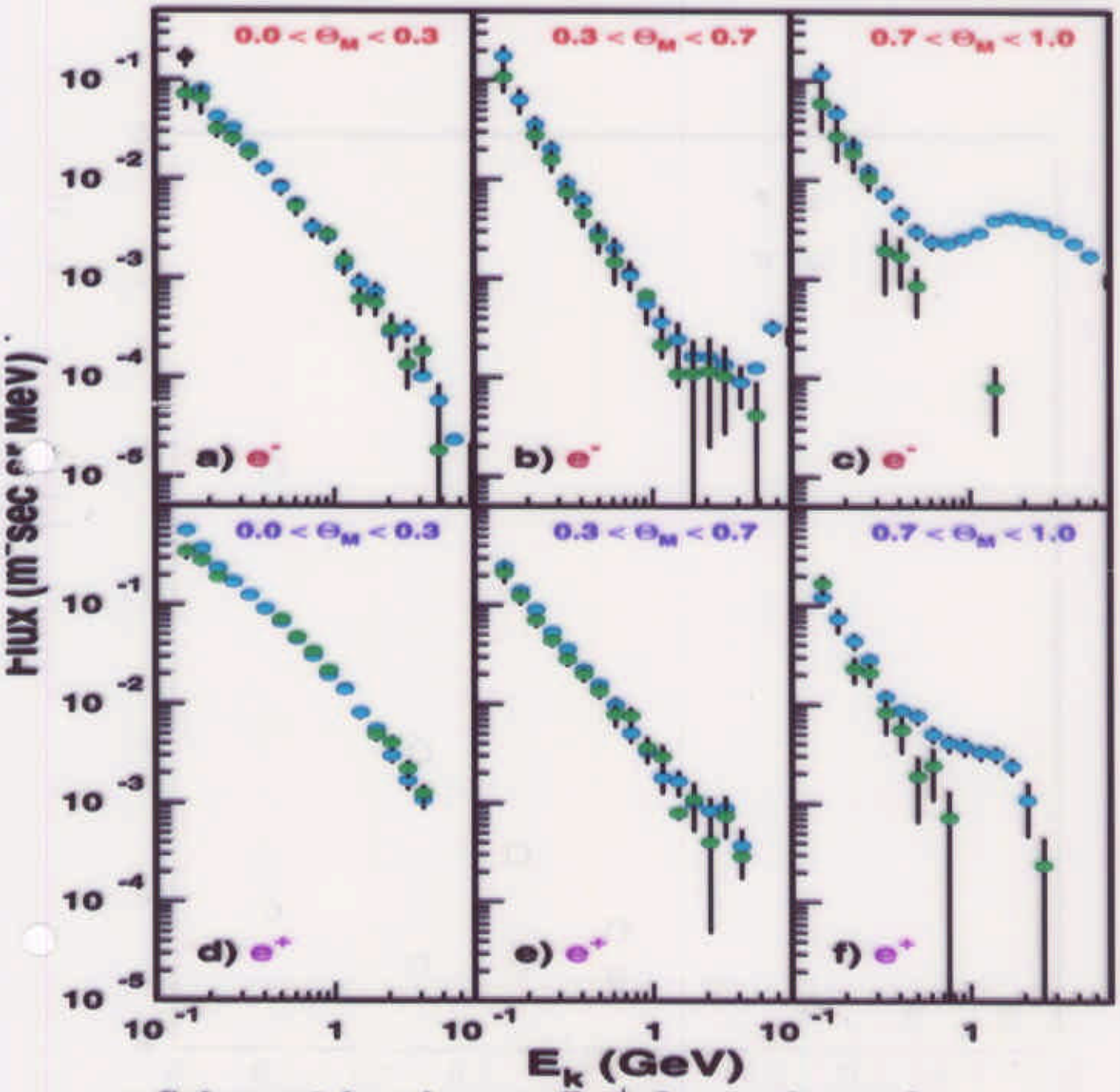
y99415_3d Fig.1

Second Spectrum: Protons



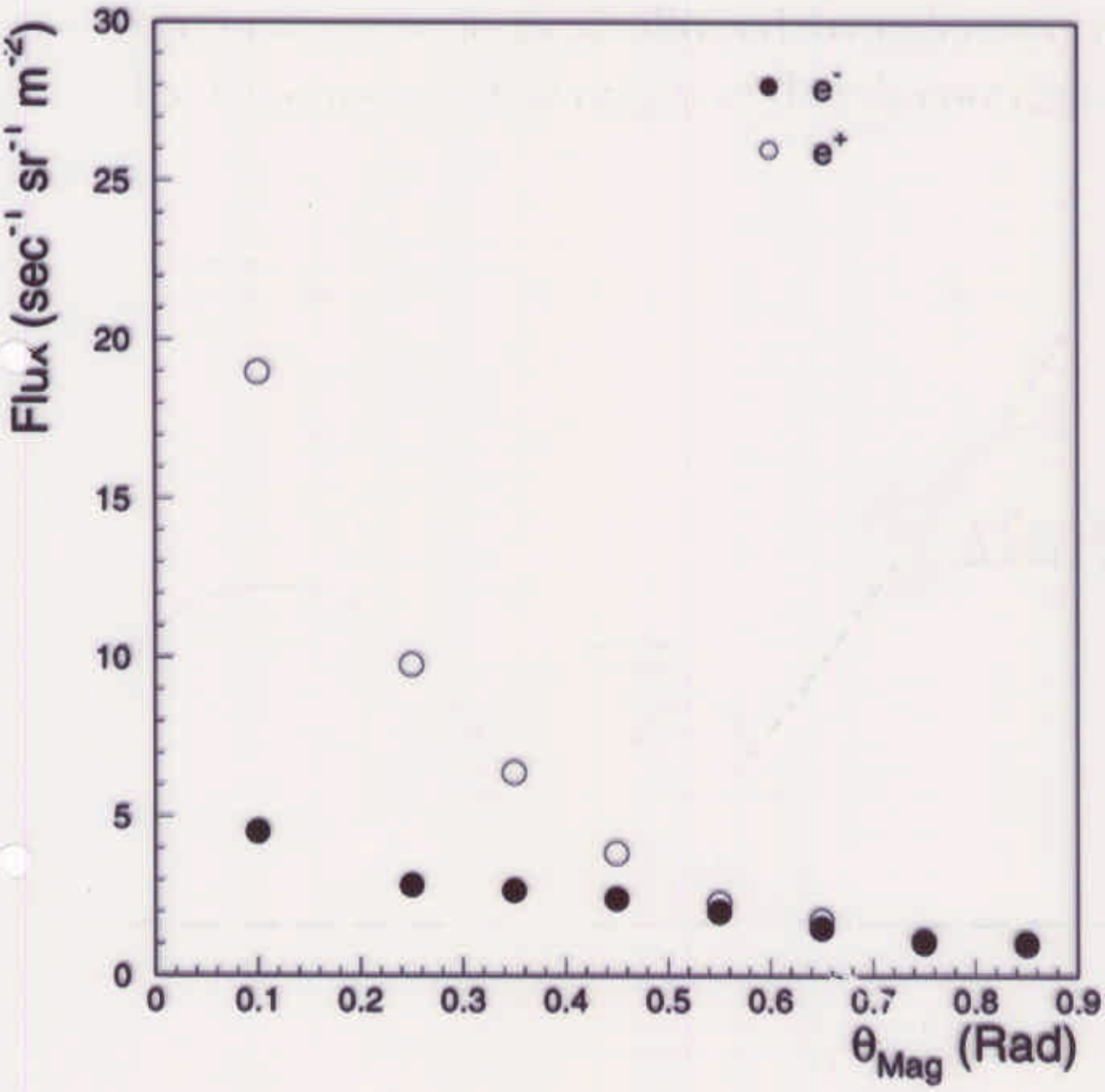
- Substantial under cutoff proton flux is observed;
- Fluxes for downward and upward protons are equal;
- Equatorial increase of the undercutoff flux is seen.

17 Second Spectrum: Electrons and Positrons



- Substantial under cutoff $e^{\pm}$ flux is observed;
- Fluxes for downward and upward $e^{\pm}$ are equal;
- Equatorial increase of the undercutoff flux is seen,

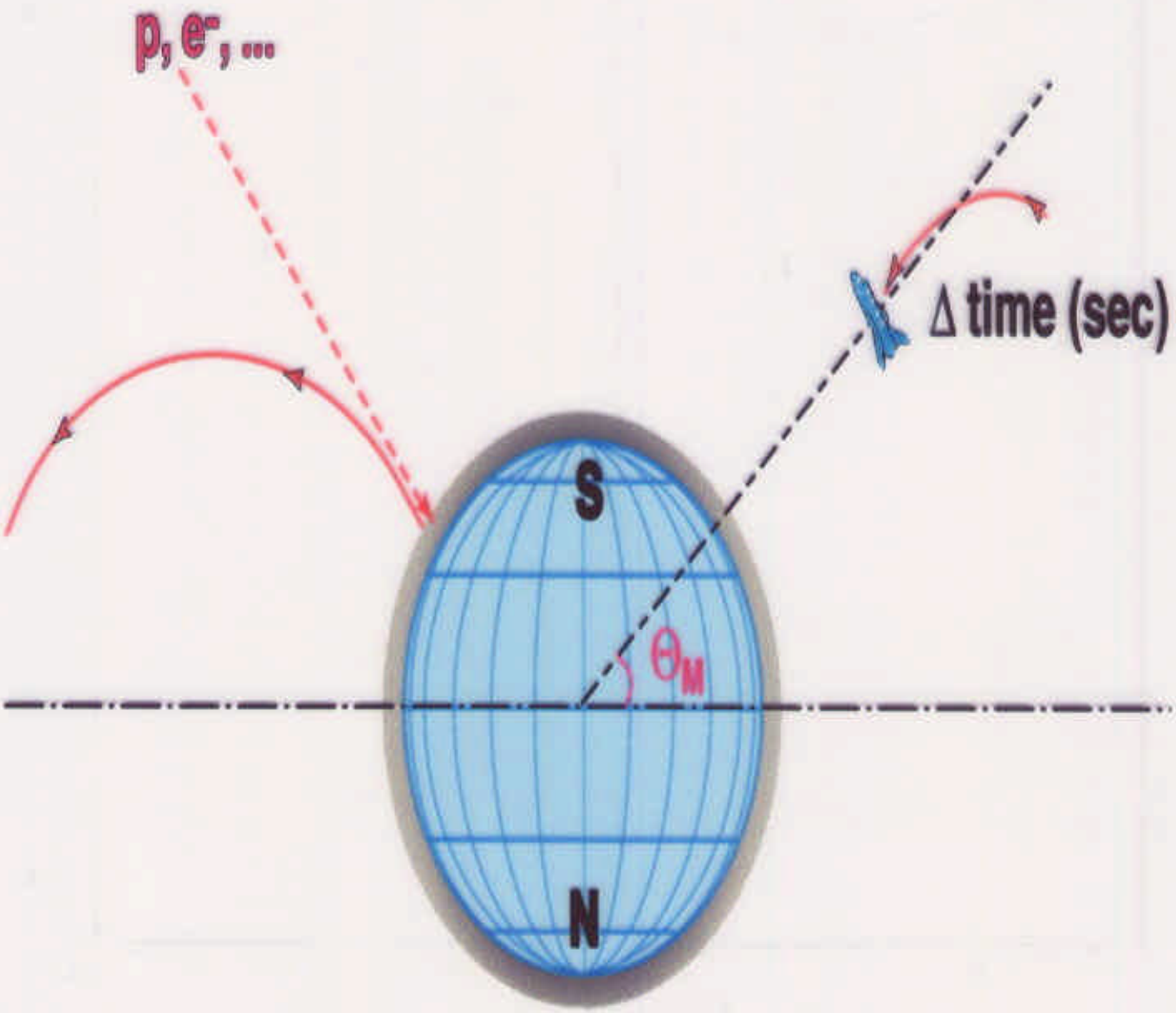
18 Second Spectrum: Electrons and Positrons



- $\frac{e^+}{e^-}$fluxes ratio varies between 1(pole) to 4(equator).

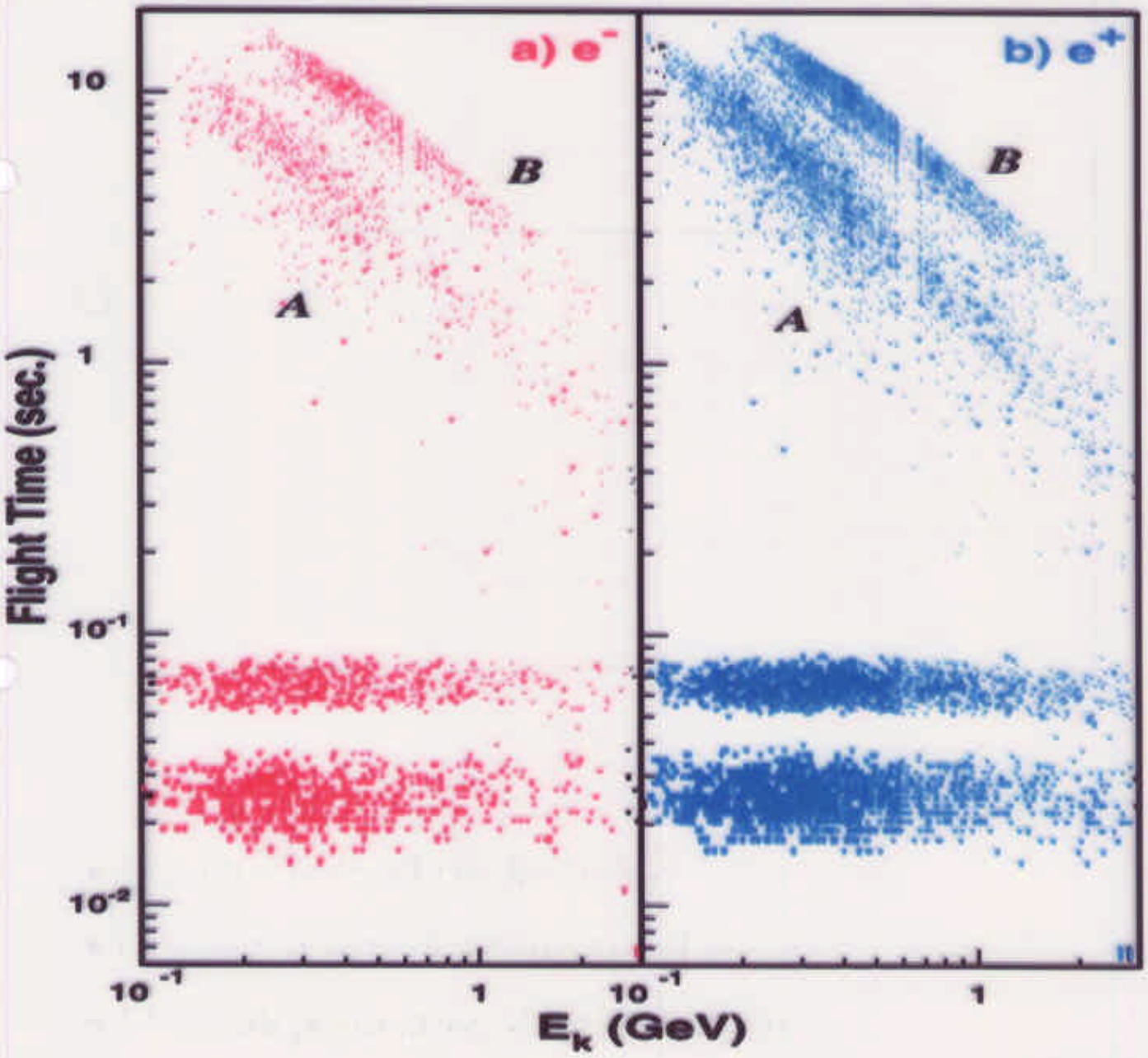
17 Second Spectrum: Understanding the Origin

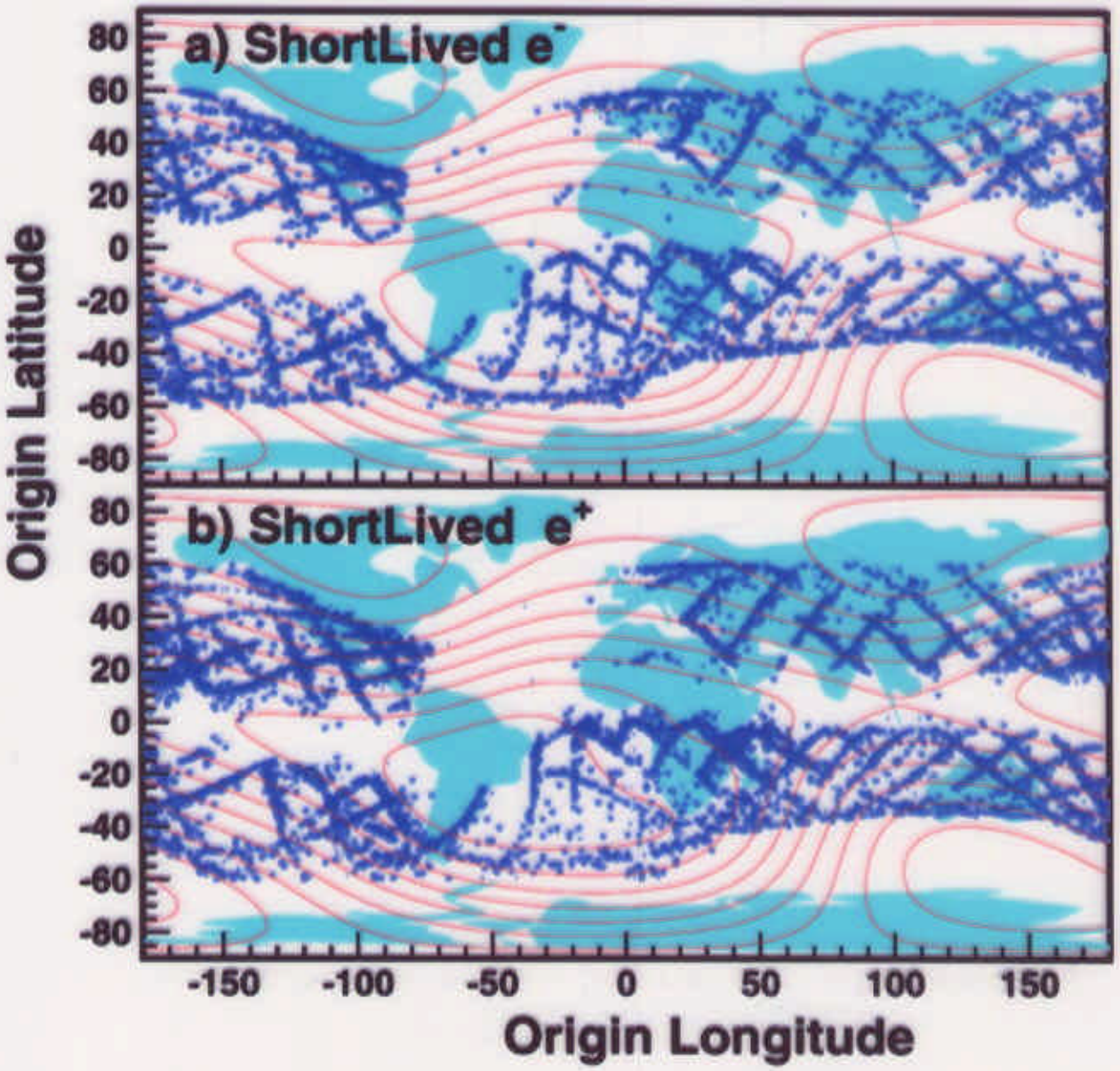
- Tracing particles trajectories back and forth in the geomagnetic field allowed to calculate their life time as well the origin and sink coordinates;



18 Second Spectrum: Understanding the Origin

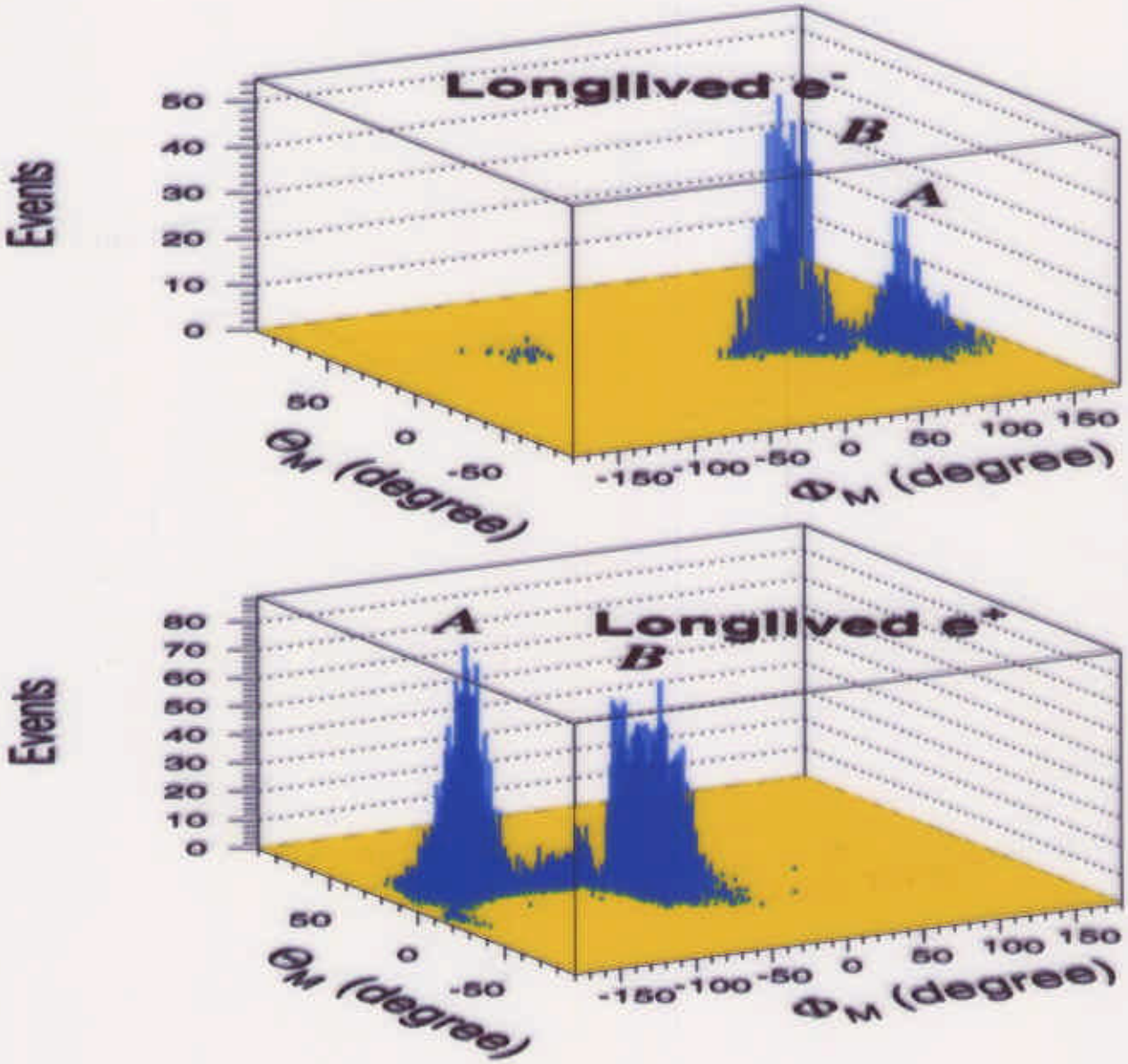
- Two distinct component were observed: "Short" (< 200 ms life time) and "long" (> 200 ms life time) lived electrons and positrons(protons), the majority of the particle being "long" lived ones.





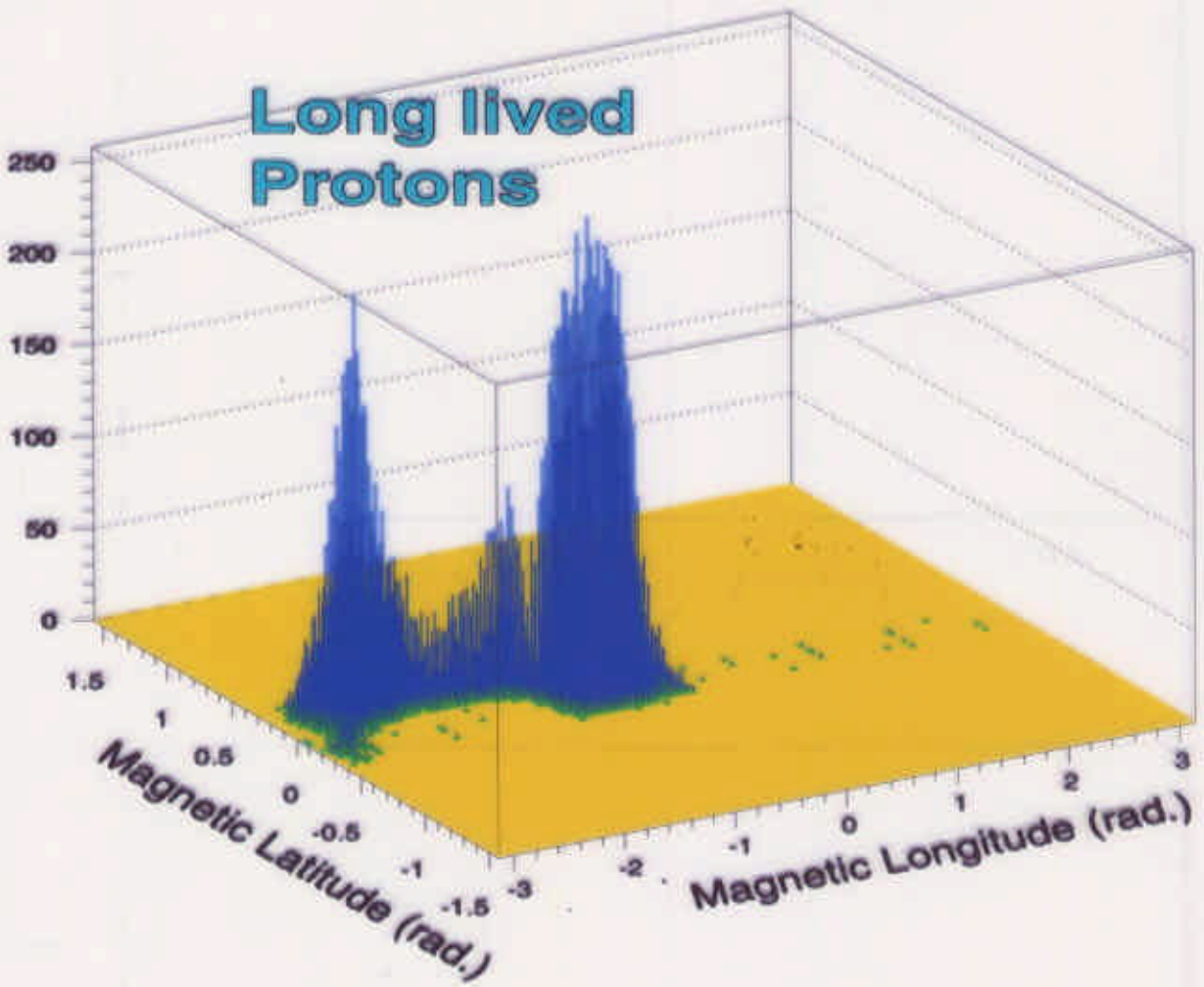
- Detected over all the latitudes;
- Originated outside of equatorial region;
- Flux independent on shuttle attitude.

Second Spectrum: Understanding the Origin

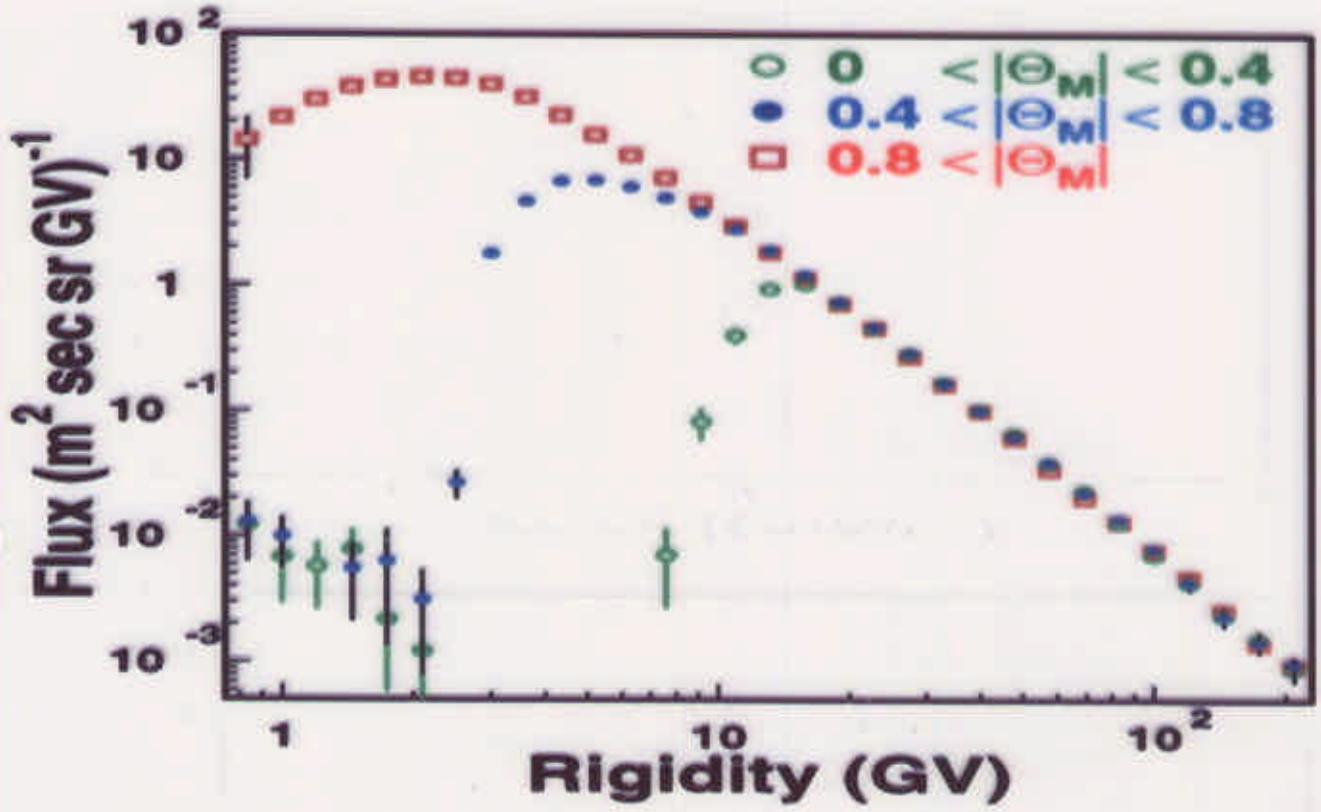


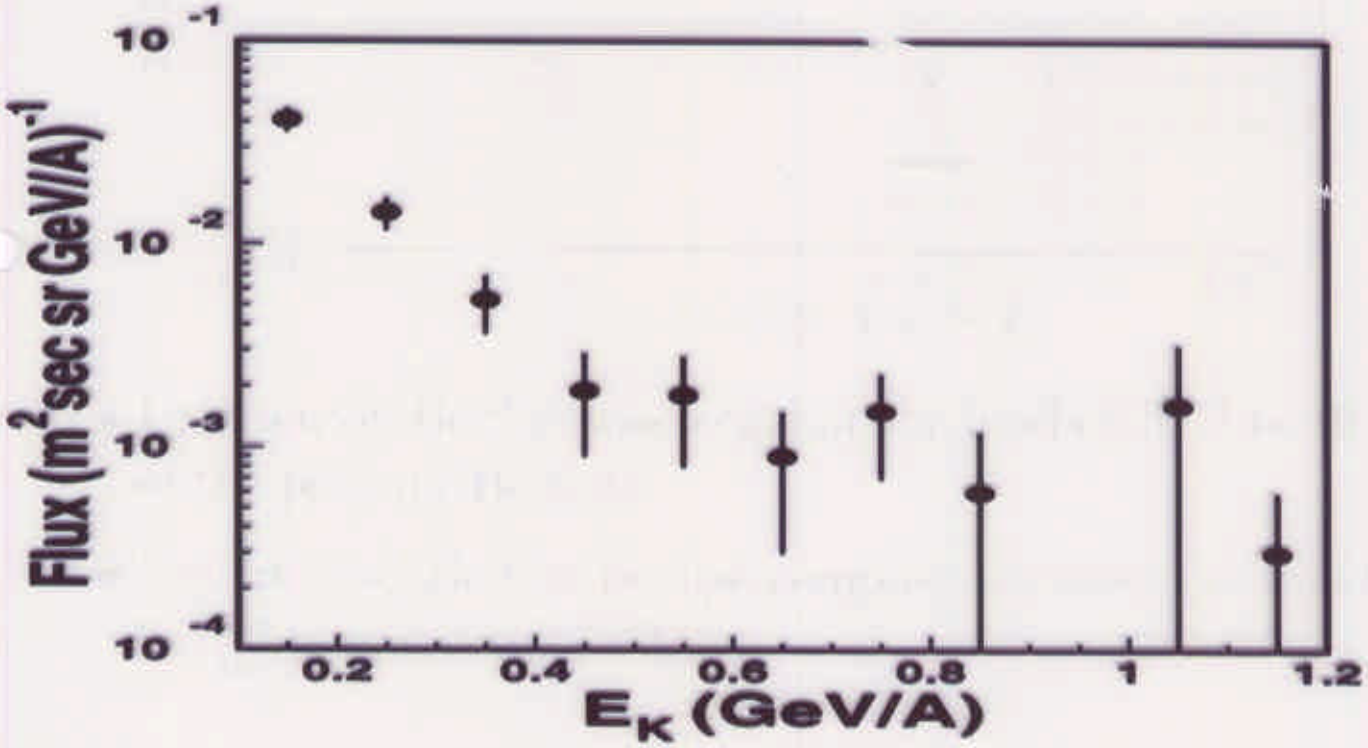
- Detected essentially at $\Theta_M < 0.3$;
- Originated in definite regions;
- Flux dependent on shuttle attitude.

21 Second Spectrum: Understanding the Origin

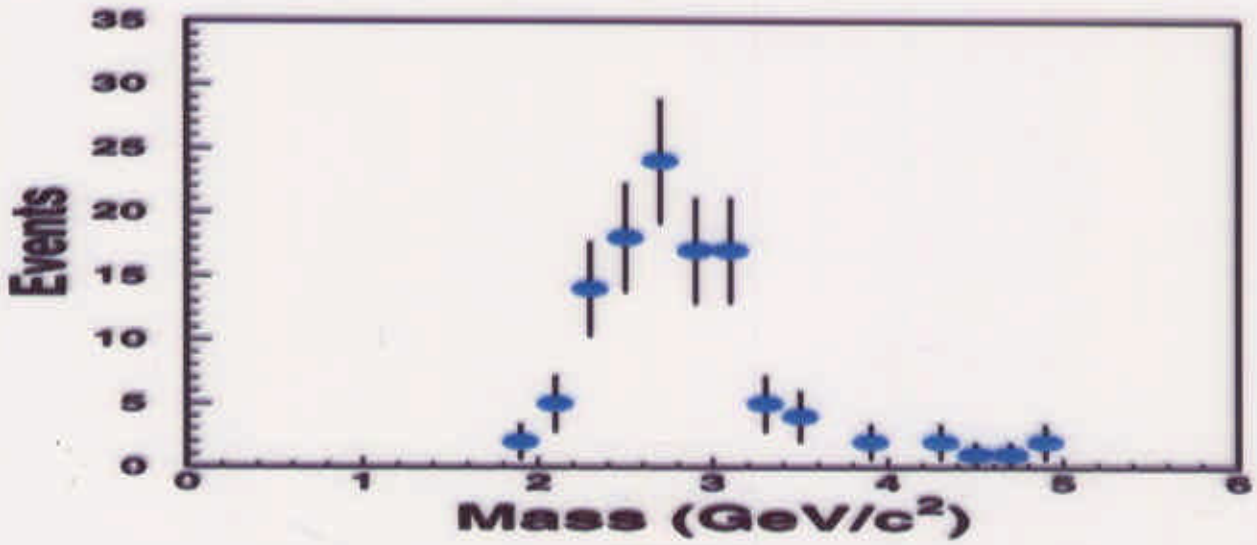


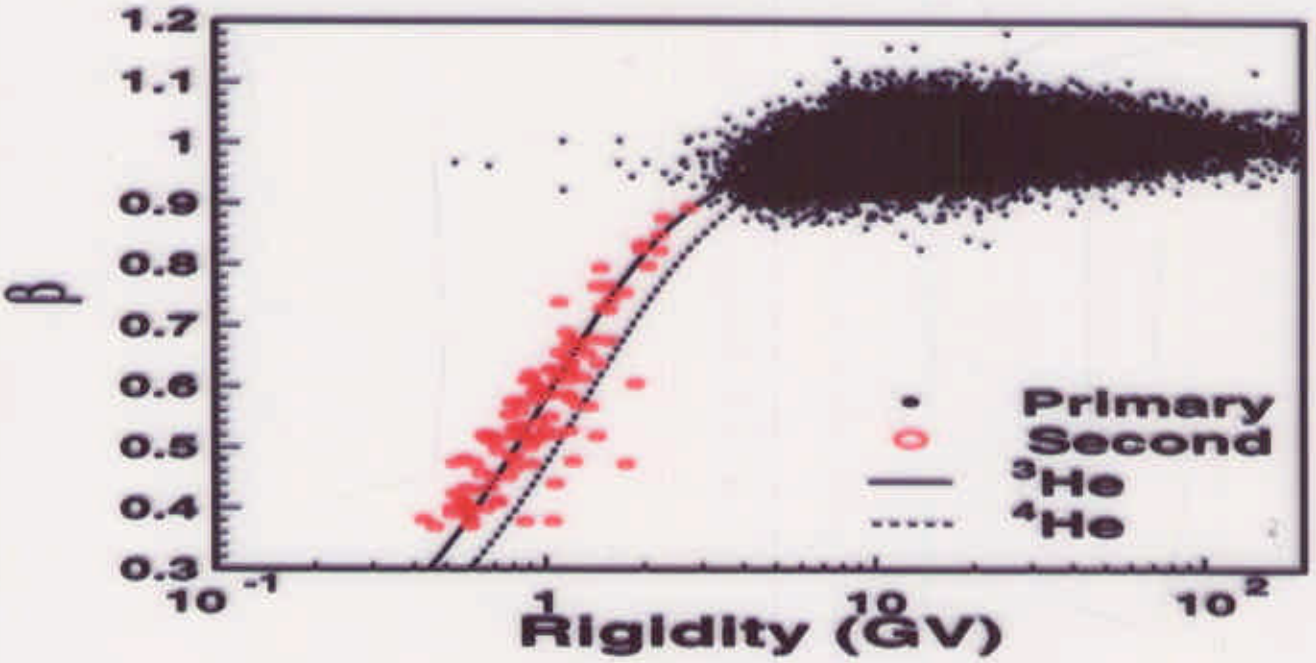
Second Spectrum: Helium





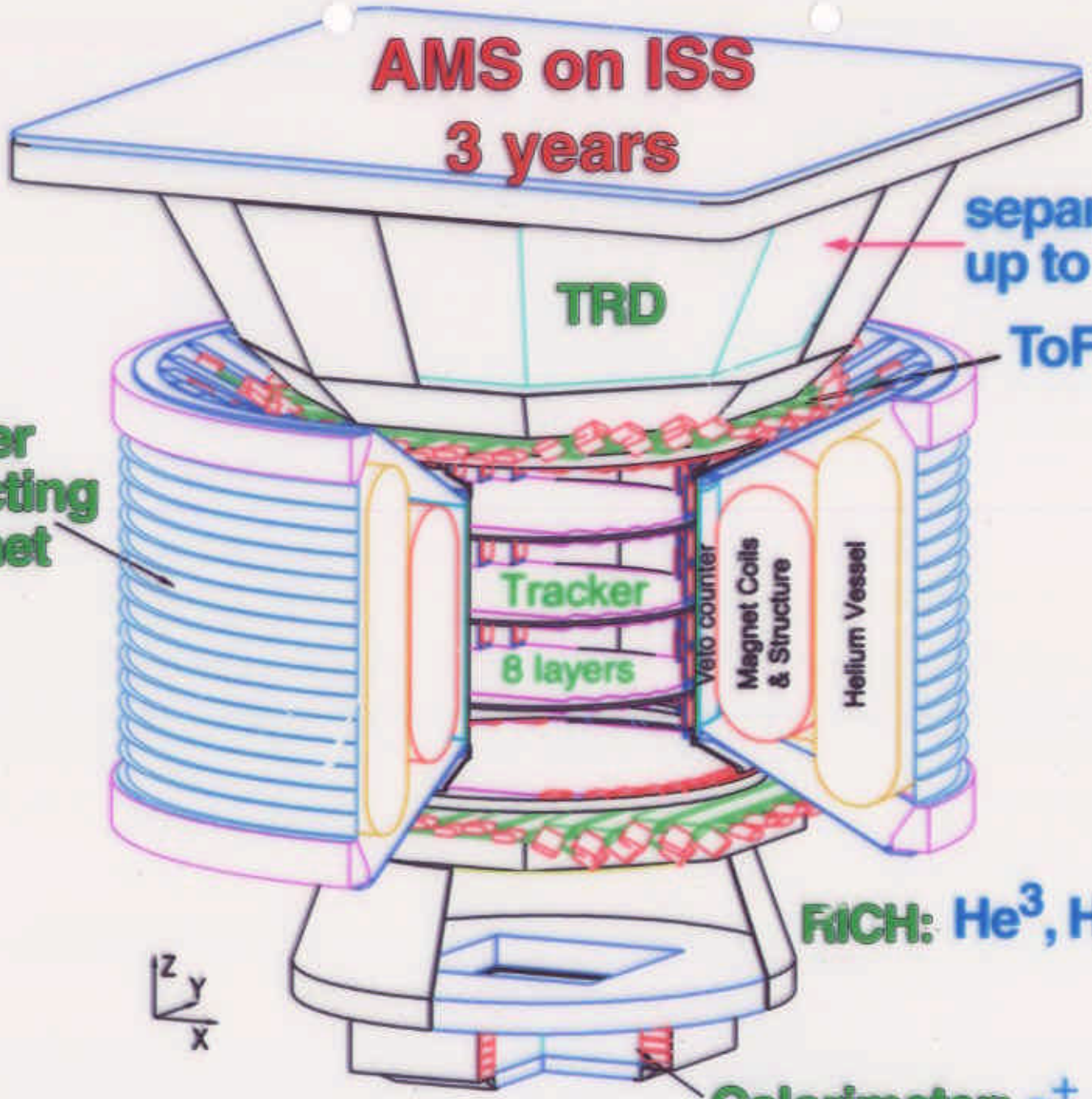
Second Spectrum: Helium





- Undercutoff He flux was found at the level of 10^{-4} to 10^{-3} of the primary He flux;
- UnderCutoff He flux isotope composition was measured to be $\frac{He^3}{He} > 0.9$ at 90 % CL.

AMS on ISS
3 years



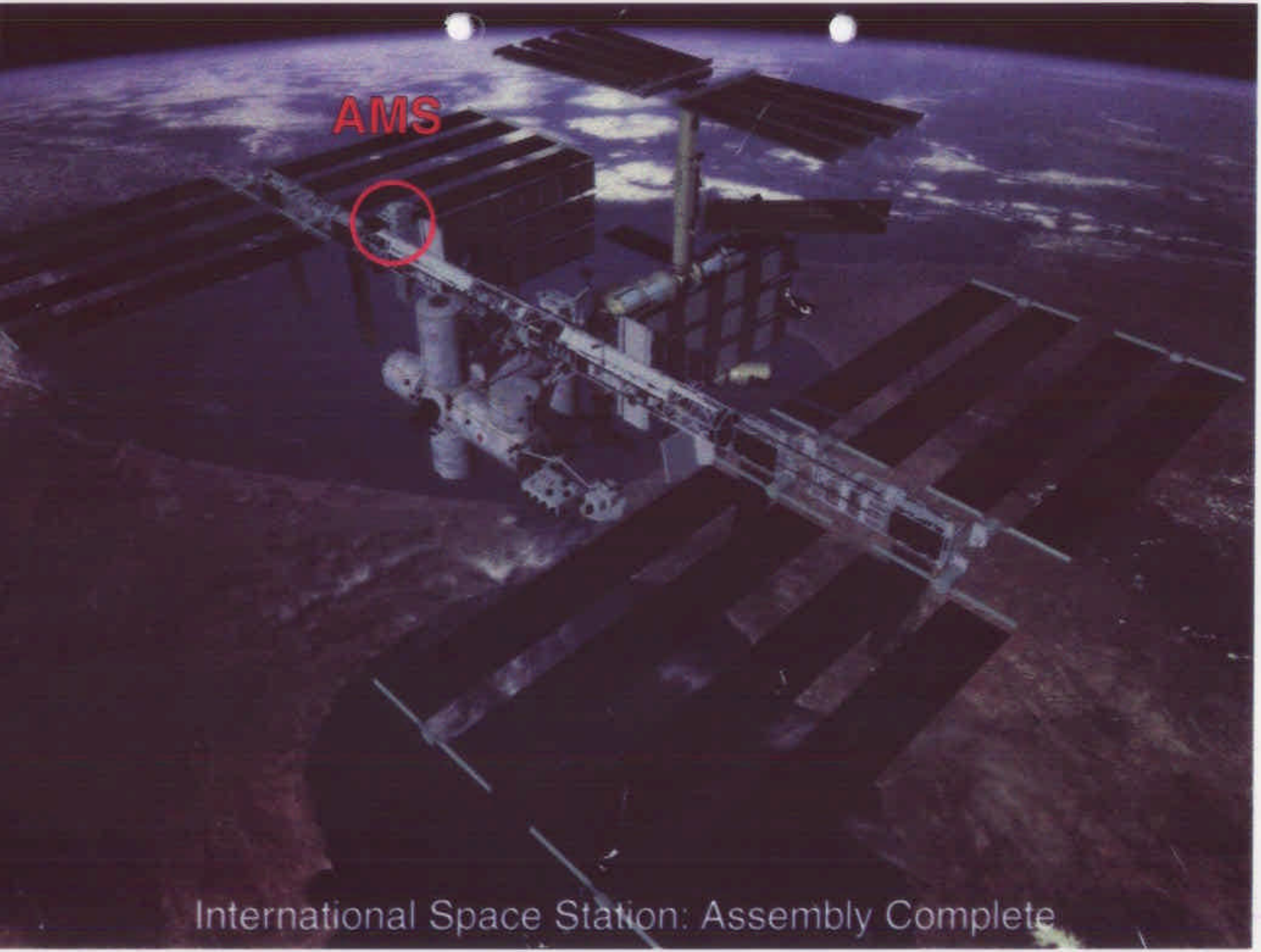
separate $e^{\pm}$ from $\bar{p}$, p up to 300 GeV

ToF

Super conducting Magnet

RICH: He^3, He^4, B, C, . . .

Calorimeter: $e^{\pm}$, γ to 1000 GeV



International Space Station: Assembly Complete