Cosmic Rays measured at the ISS

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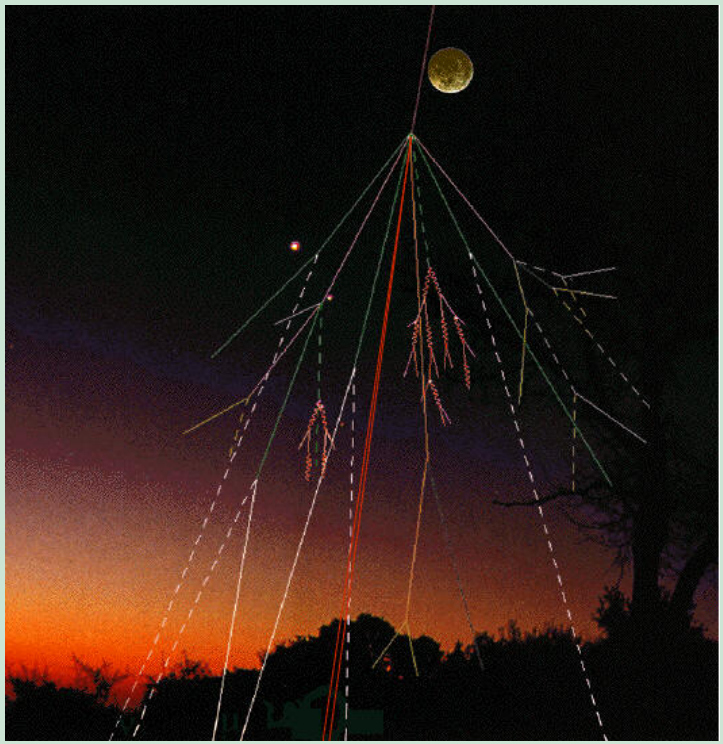
Introduction

- Space instruments, primordial particles created in the early Universe – background free environment
- Cosmology: baryon asymmetry, mass density composition
- Understanding of Dark Matter, Antimatter, the origin of CR etc.
- Strong demand for precision measurements of cosmic rays: large deviation of the $e^+/(e^+ + e^-)$ ratio predicted by our model (with ordinary cosmic ray collisions)
- International Space Station (ISS) – AMS launched 16 May 2011



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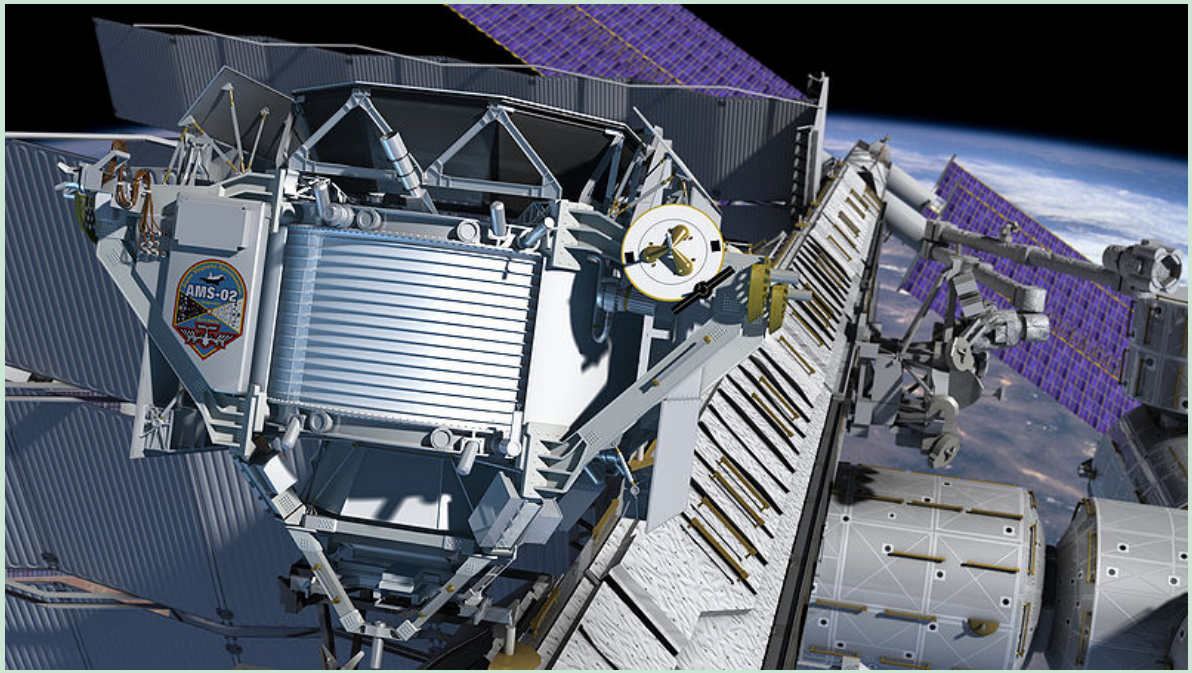
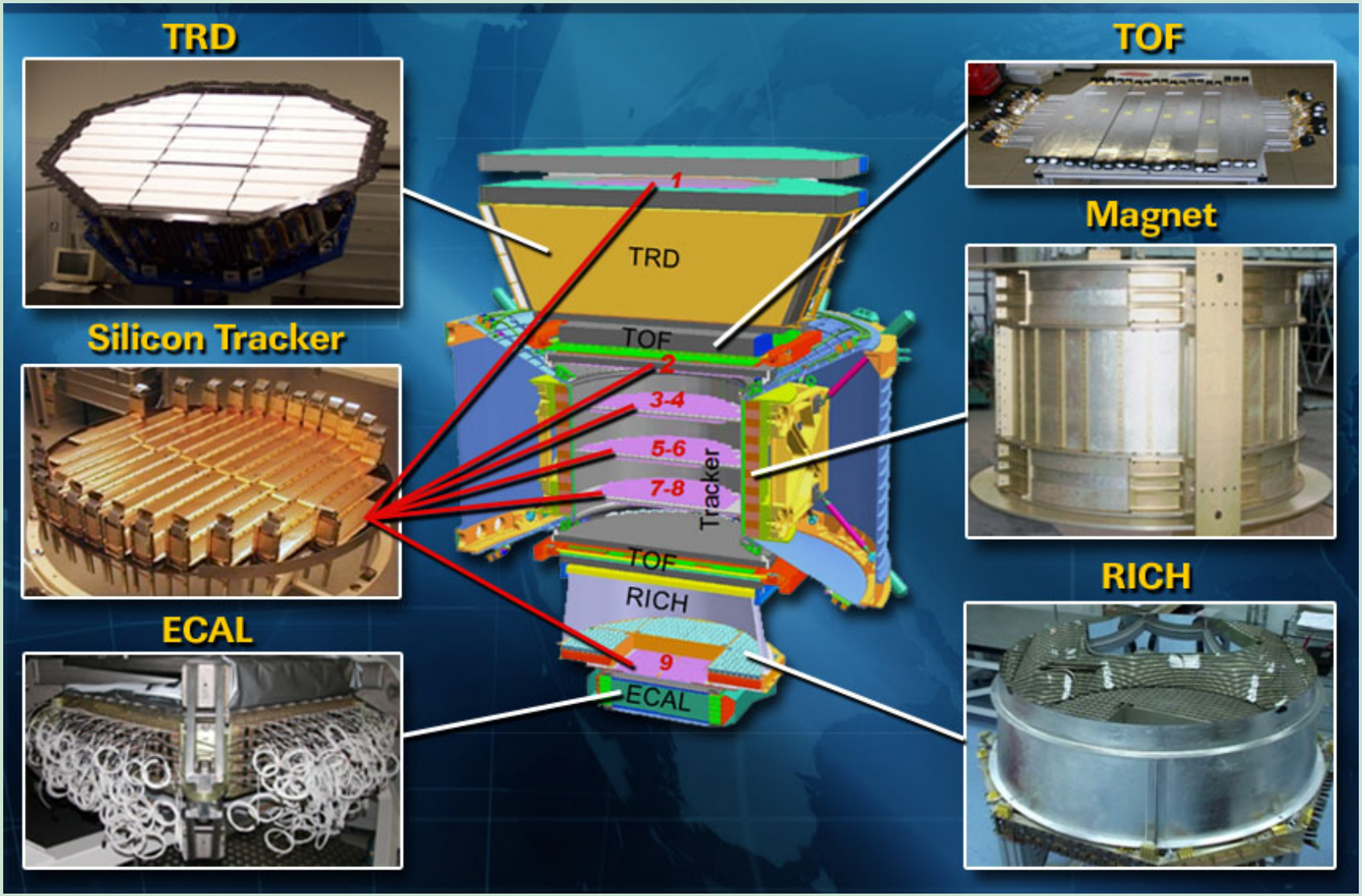
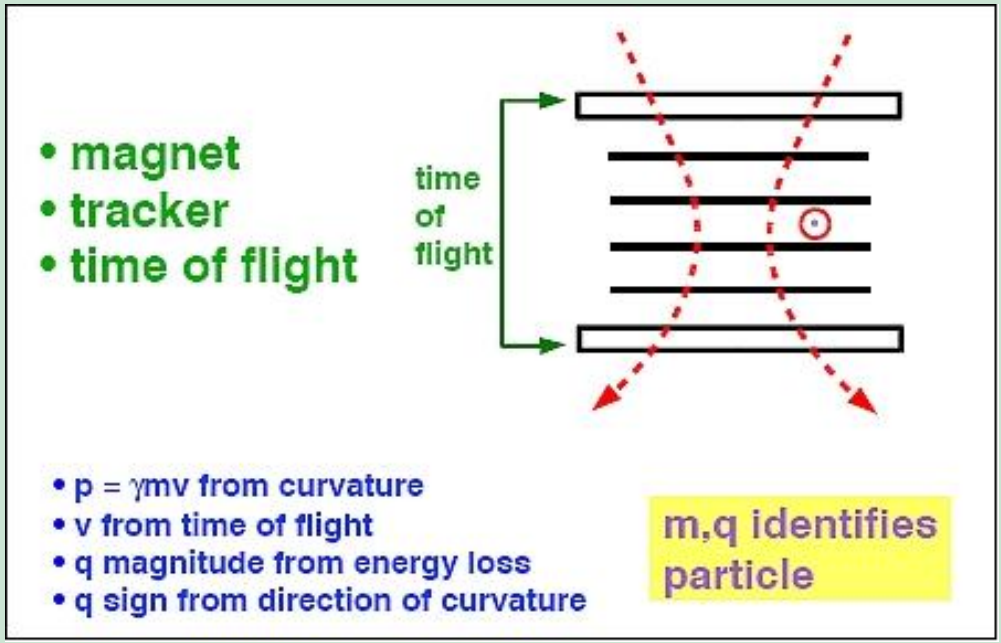
  - and all the rest

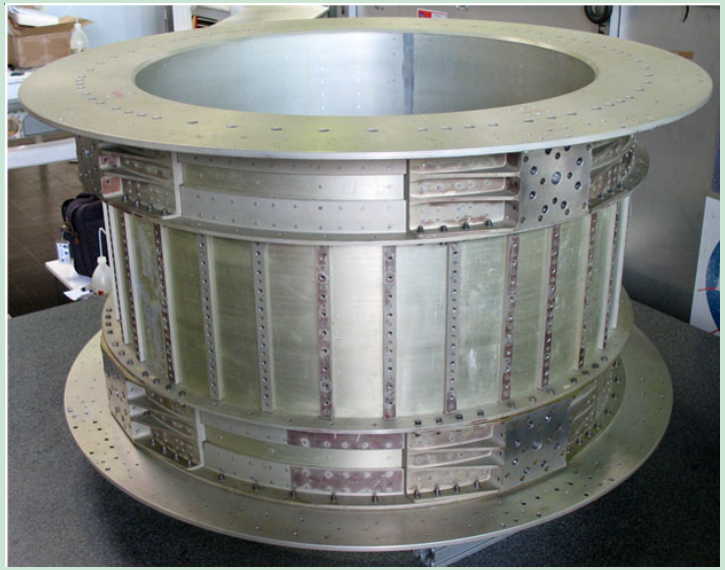


PART 1. Overview of the AMS



PM – Permanent Magnet



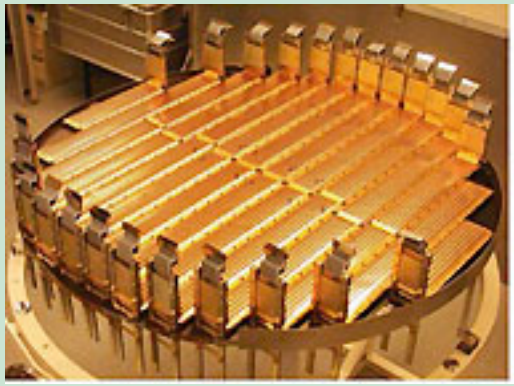


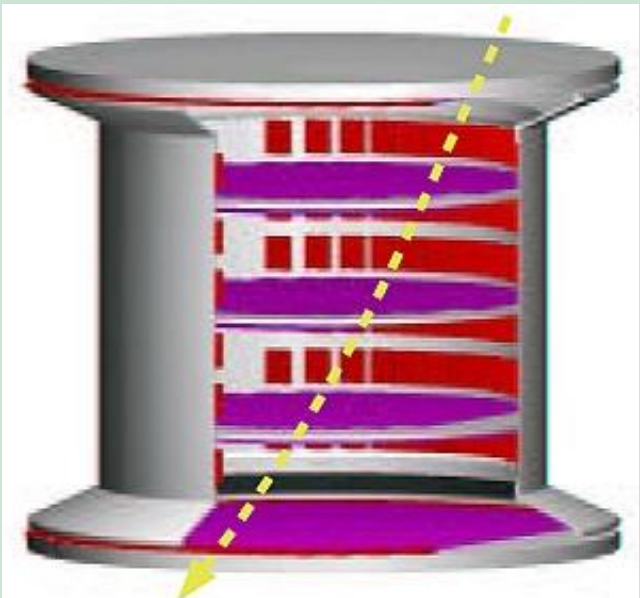
Charged particles in magnetic field: Lorentz force

- made of matter: curve one way
- made of antimatter (opposite charge): the opposite way

- $\mathbf{B} = 1.4$ kG

Silicon Tracker





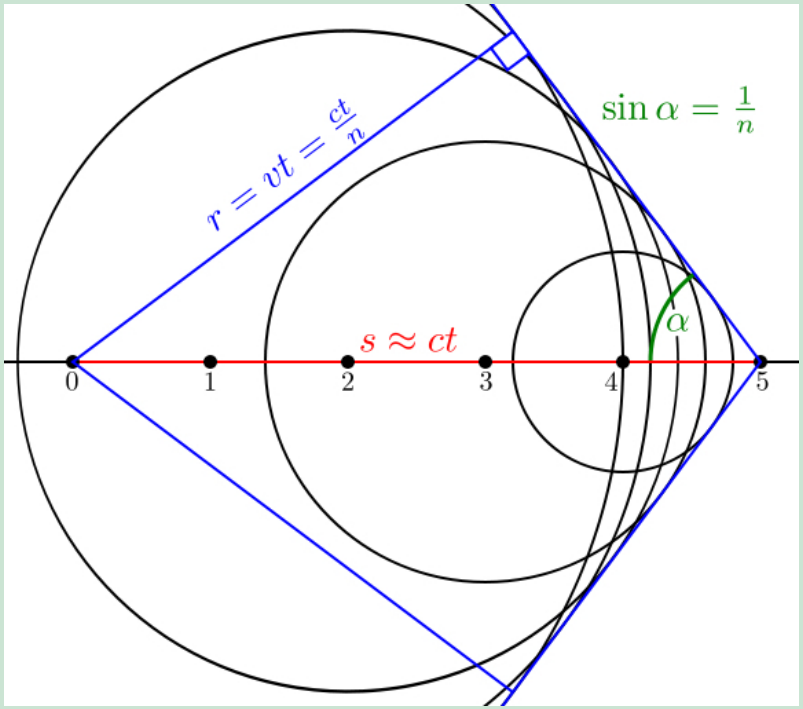
- detects the trajectory of the incoming particles
- identifies:
  - magnitude
  - polarity

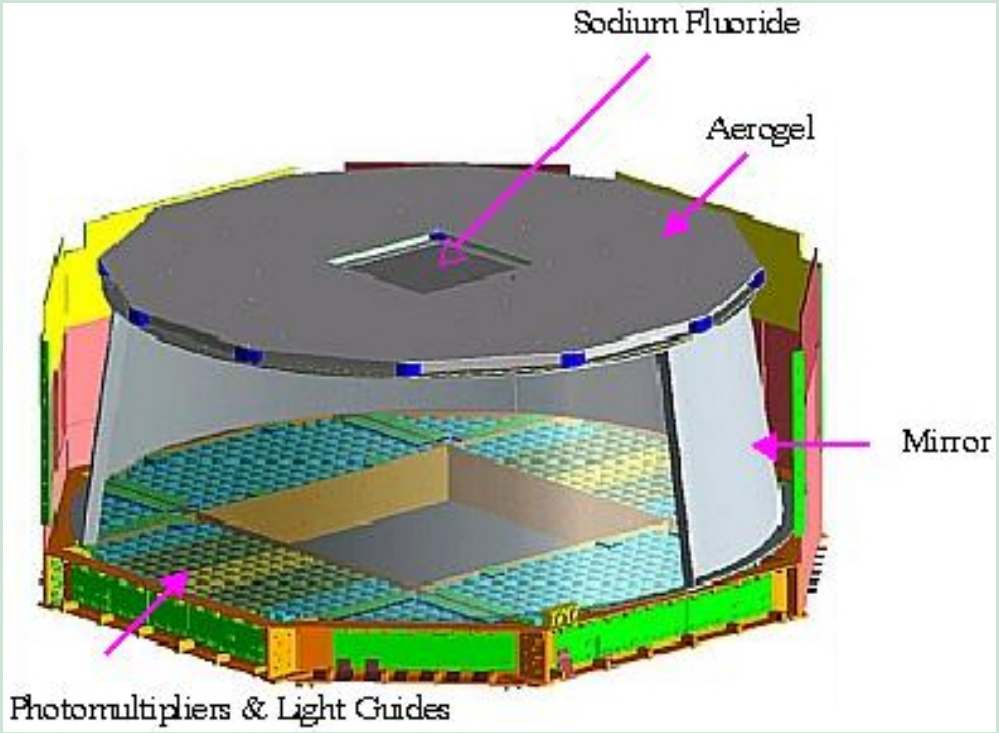
  of particles' electrical charge
- the higher the particle's momentum, the straighter the arc
- Accuracy: 10 μm
- $\sim$ 200000 readout channels
- charge separation of nuclei up to $Z = 26$
- anticoincidence counter

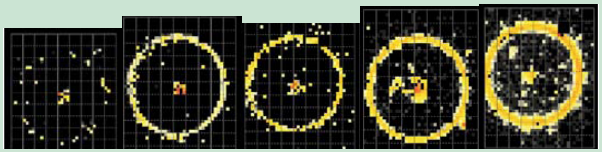
TOF – Time of Flight Counters

- distinguish between upward and downward traveling particles
- scintillator: flashes of light when struck by particles or photons
- measures the transit time of particles between two layers

RICH – Ring Imaging Cherenkov detector





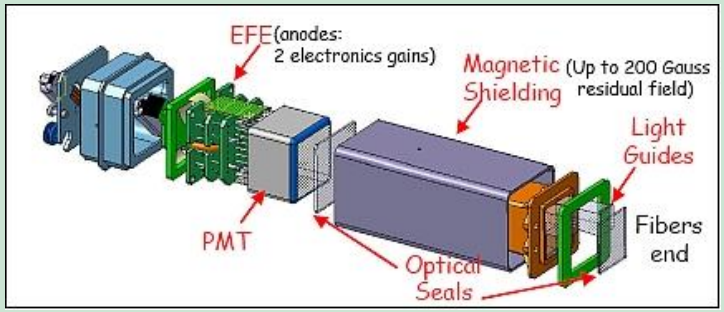


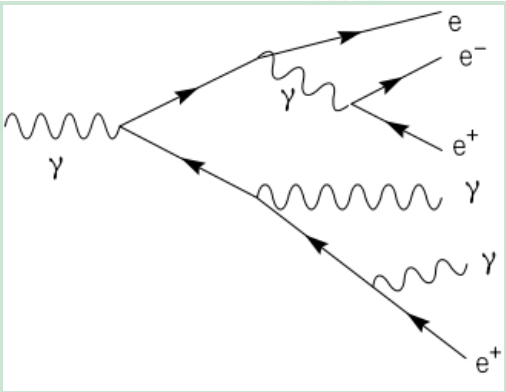
He Li C O Ca

- velocity of the charged cosmic particles
- by measuring vertex angle of the cone of Cherenkov light

- particle passes through a tile of silica aerogel (n=1.05) or NaF (n=1.33)
- photomultiplier tubes

ECAL – Electromagnetic Calorimeter





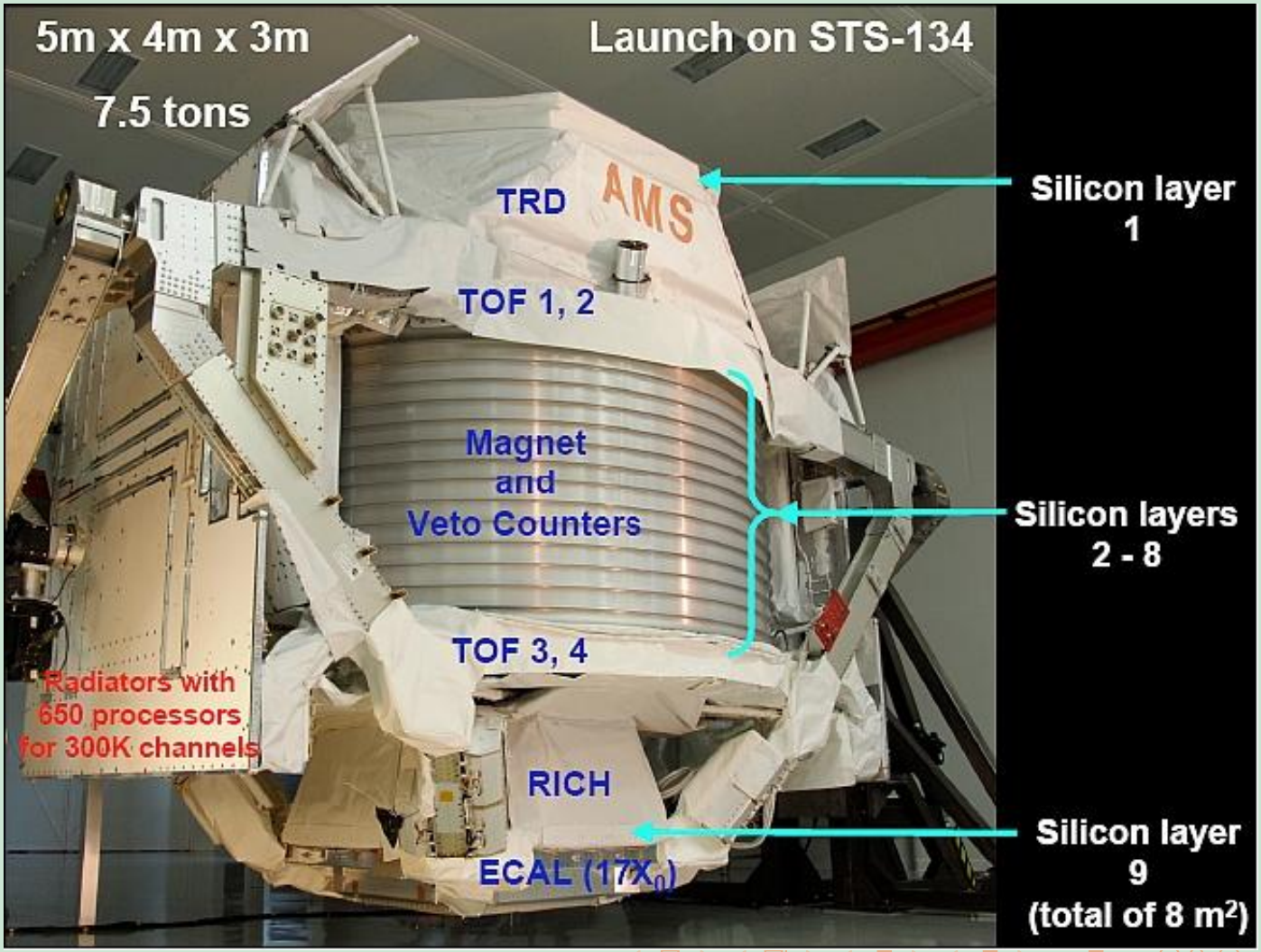
- electromagnetic particle identification:
  - electrons, positrons, and gamma rays
  - up to 1 TeV
  - angular resolution around 1°
  - e/p separation: $\sim 10^4 > 200$ GeV
- 9 modules made of layers of lead and scintillating fibers
  - function: completely stop particles $\rightarrow$ measuring energy
- electromagnetic showers
  - lead scintillating fiber sandwich
  - reading out: 4 PMTs

TRD – Transition Radiation Detector

- Transition radiation:
  - soft X-rays emitted by charged particles traverse the boundary between two media with different dielectric constants
  - electrons and positrons: higher probability of emitting TR photons than heavy particles
- used in conjunction with ECAL → distinguish between light and heavy particles of equal charge and momentum (positron, proton)
- Xenon/CO_2 gas mixture:
  - Xe captures the TR
  - leak rate: 6 μg/s → 24 ys in space

Conclusion of Part 1.

- AMS can measure simultaneously:
  - photon
  - electrons
  - protons
  - nuclei
  - + anti

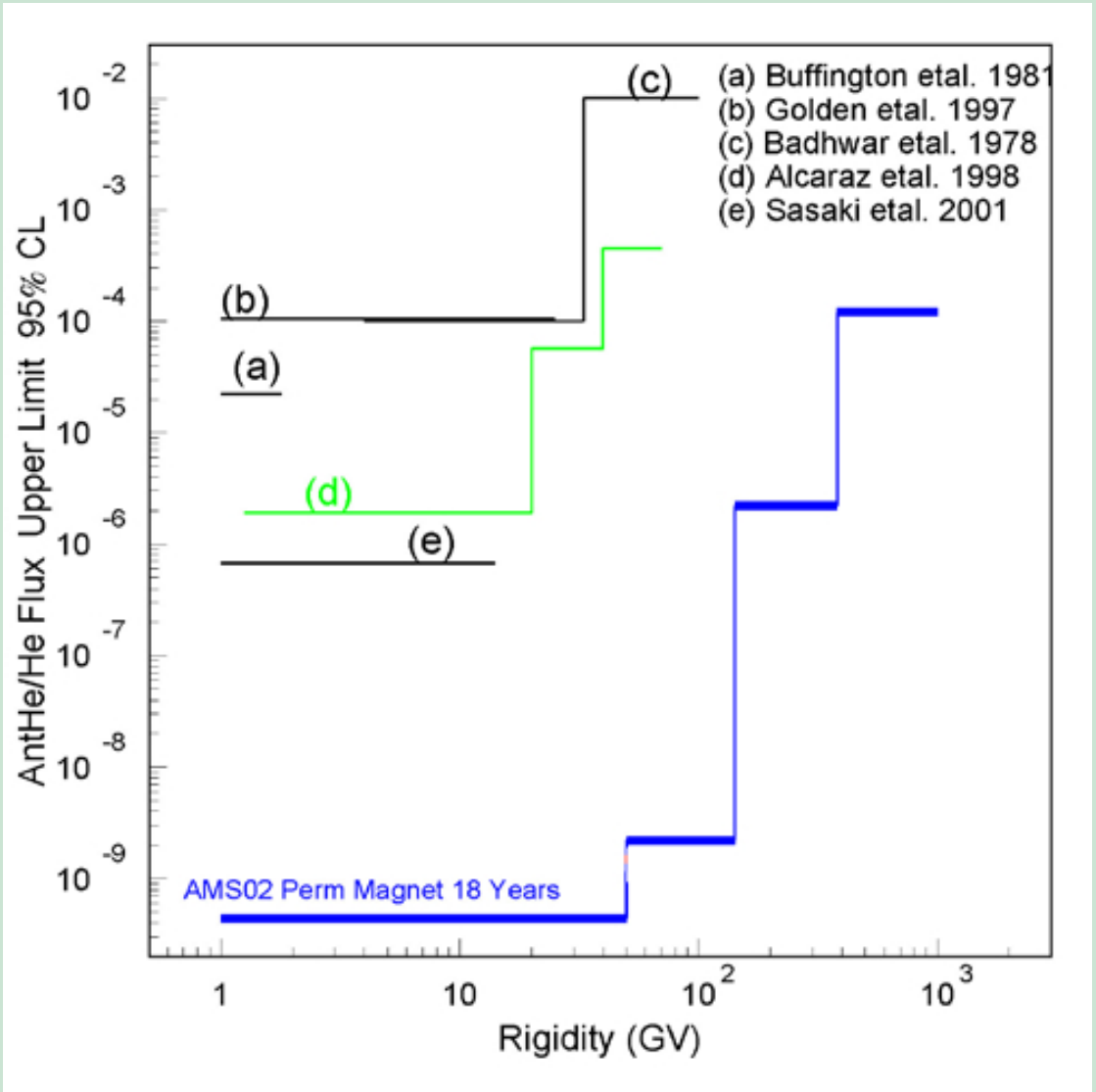


PART 2. AMS Physics Potencial – Anti-Matter I.

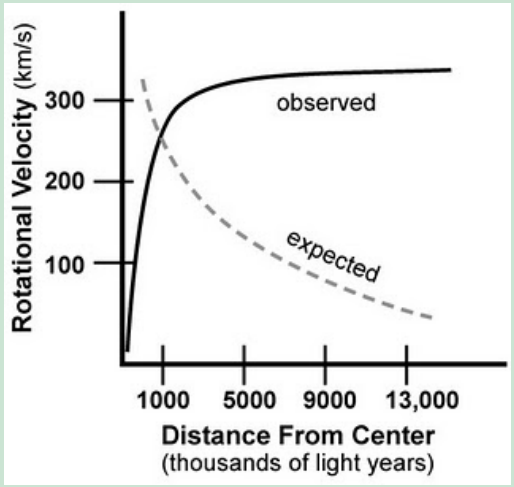
- Experimental evidence: our galaxy is made of matter. BUT:
  - more than 100 hundred million galaxies in the universe
  - theories trying to explain matter-antimatter asymmetry: not compatible with measurements
  - → fundamental question in modern astroparticle physics and cosmology
  - just one antihelium nucleus!
- AMS-02: sensitivity of 10^9
  - 3 orders of magnitude better than AMS-01 in 1998
  - extending the volume of the Universe tested for the existence of primordial antimatter

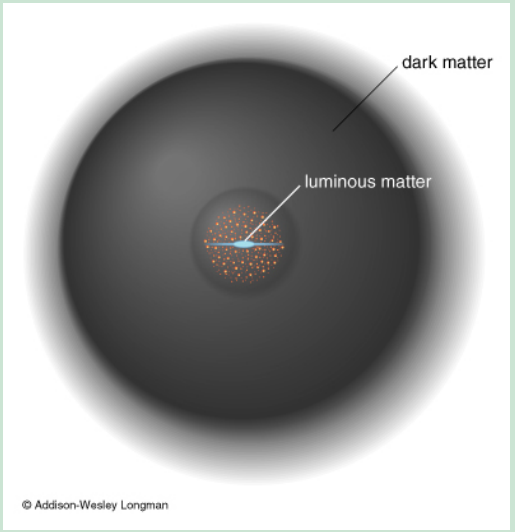
Anti-Matter II.

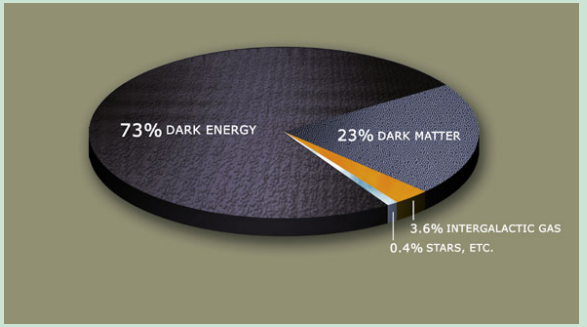
Sensitivity of AMS with the permanent magnet on ISS for 18 years compared with the other earlier measurements.



Dark Matter I.



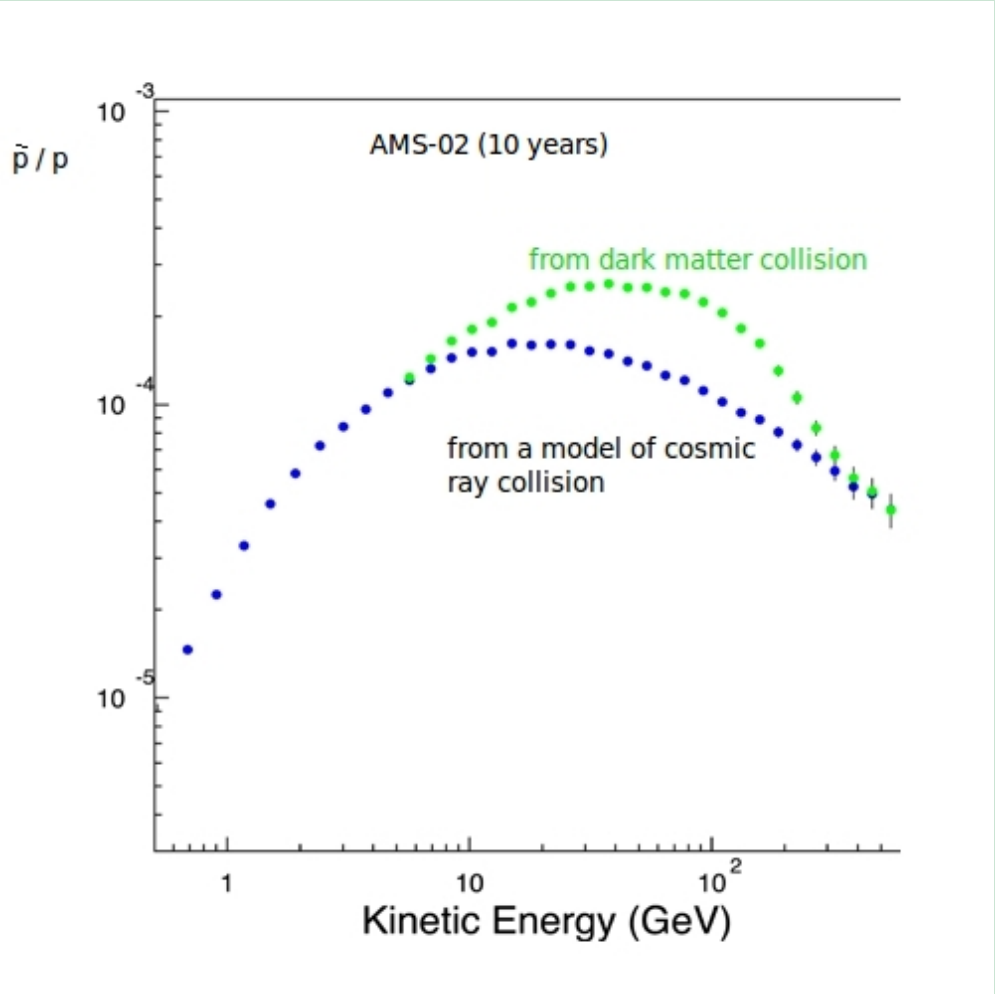




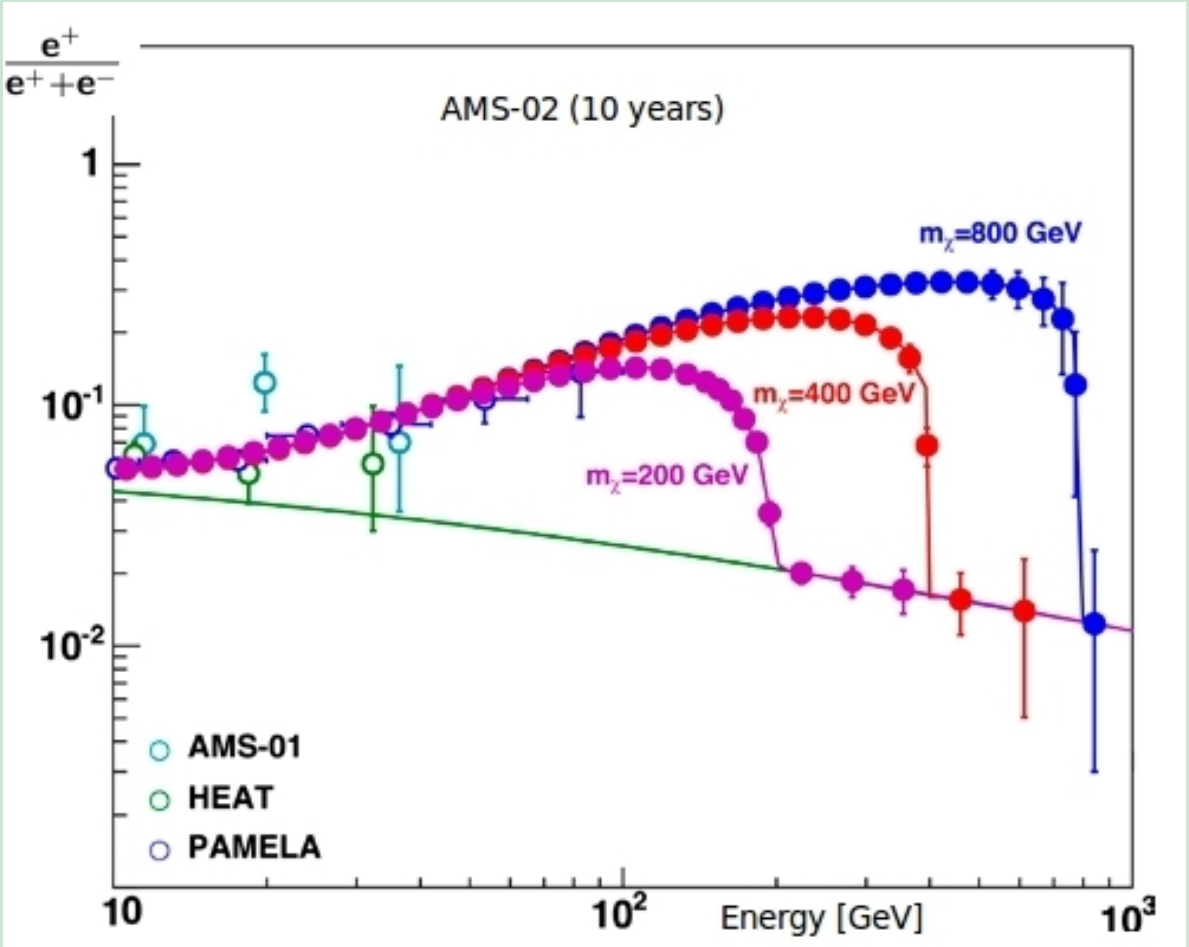
- neither emits nor scatters light or other electromagnetic radiation → cannot be directly seen with telescopes
  - postulated by Fritz Zwicky in 1933
  - observations of the rotational speeds of galaxies
  - believed to be composed of a new type of subatomic particle
- AMS: spectra for nuclei in the energy range [0.5 GeV/nucl ; 2 TeV/nucl]
  - with 1% accuracy
  - it can prove or disprove our theories

Dark Matter II.

- Candidate: neutralino
  - generic ingredient of SUSY models
  - supersymmetric
  - AMS: neutralino annihilation based on final state particles
- Picture: Accuracy of AMS-02 measurements
  - $\bar{p}/p$ spectrum
  - 10 years on ISS with the permanent magnet



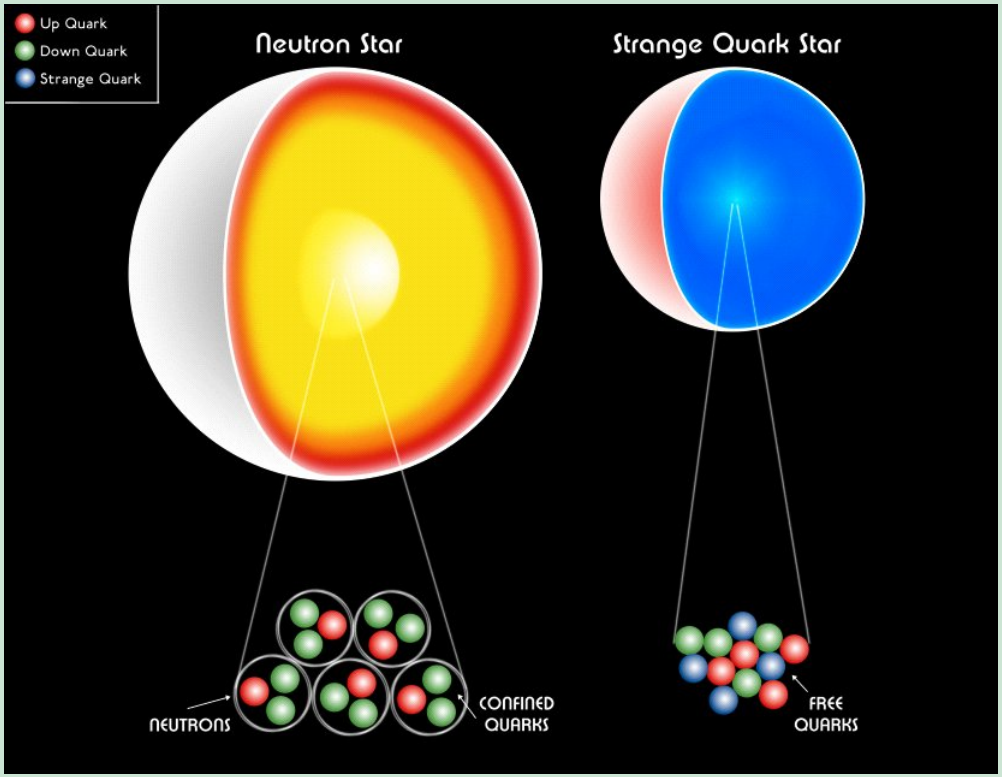
Dark Matter III.



- Dependence of the measured positron spectrum shape on the neutralino mass.

Strangelets (?)

- fragmet of "strange matter": up, down, strange quarks
- dark matter candidate
- higher size: more stable
- "quark star" (strange nucleus interacting with neutronstar)
- early Universe or cosmic-ray collisions
- heavy-ion colliders: we don't see them...



Discussion

- Alpha Magnetic Spectrometer 02 (AMS-02) is a particle physics detector on board of the ISS
- We had overviewed the instrument and the measuring basics.
- AMS-02 uses the unique environment of space to advance knowledge of the universe and lead to the understanding of the universe's origin by searching for antimatter, dark matter and measuring cosmic rays.
- "The most sophisticated particle detector ever sent into space."

References

- A.Kounine, 2010, XVI International Symposium on Very High Energy Cosmic Ray Interactions ISVHECRI 2010
- Diego Casadei, 2004, Talk given at Lake Louise Winter Institute
- http://www.ams02.org/ams-and-iss/
- Wikipedia
- http://events.eoportal.org/presentations/10001154/10002501.html

Thank you for your attention!