The AMS Silicon Tracker for Cosmic Ray Physics

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On behalf of the AMS Tracker Collaboration

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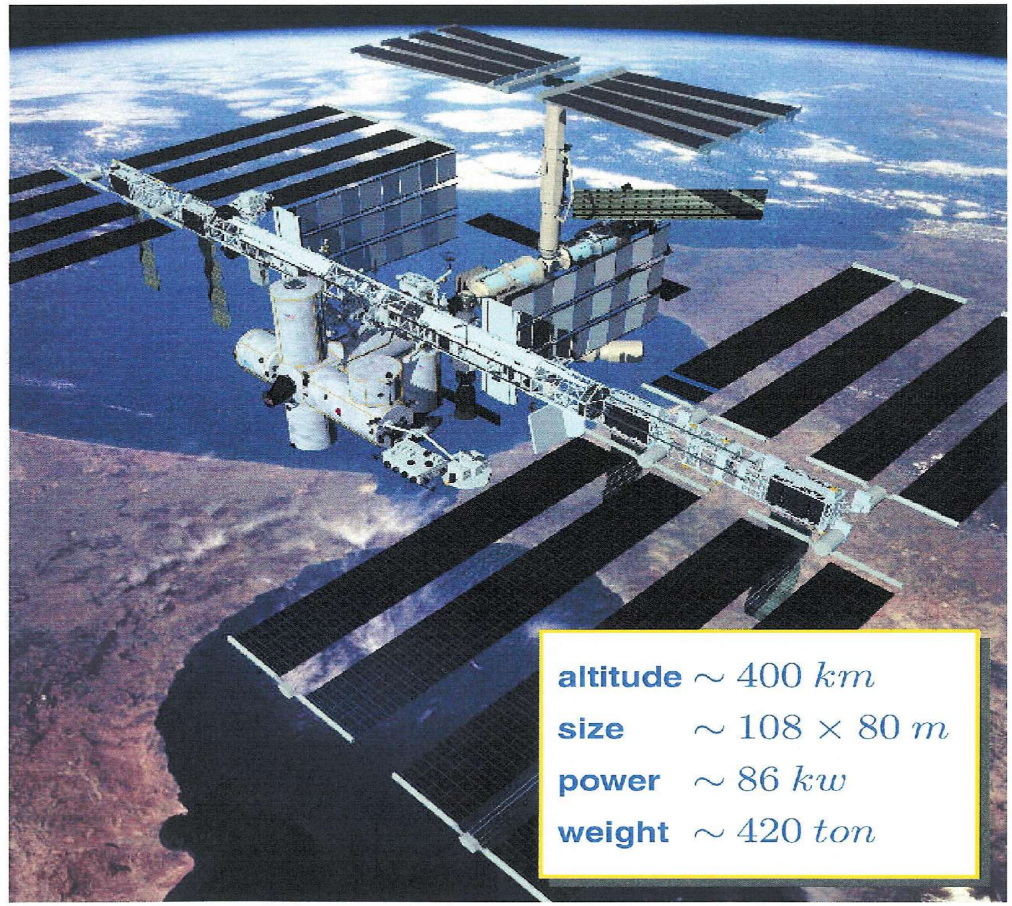
AMS on the International Space Station

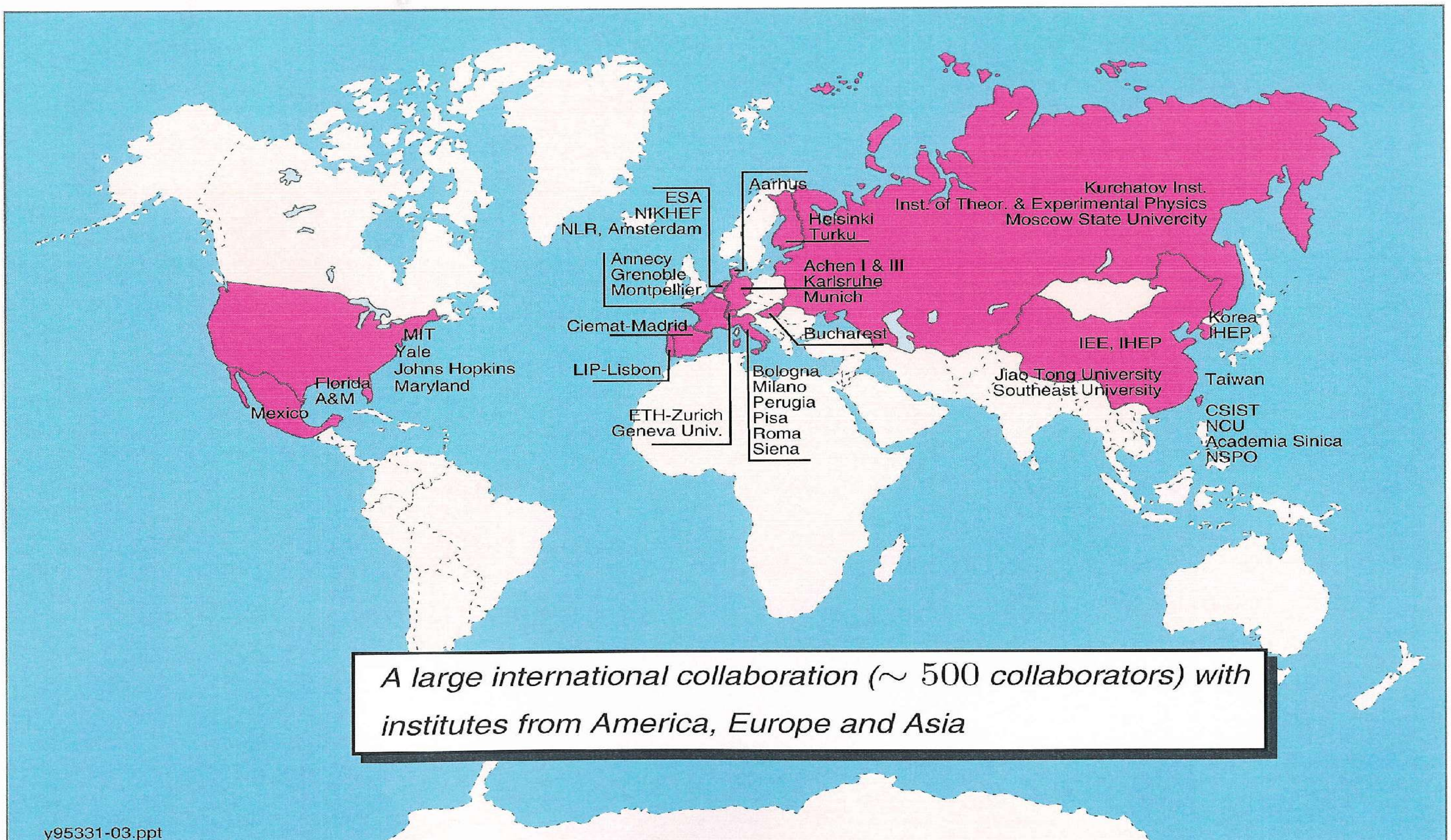
AMS is a precision magnetic spectrometer scheduled to be installed in the International Space Station (ISS) by 2007, for three years.

physics issues

- ▷ Search for Cosmic *Anti-matter*
- ▷ Search for *Dark Matter*
- ▷ Precision measurements on the relative abundance of different *nuclei* and *isotopes* of primary cosmic rays
- ▷ *gamma ray* astrophysics

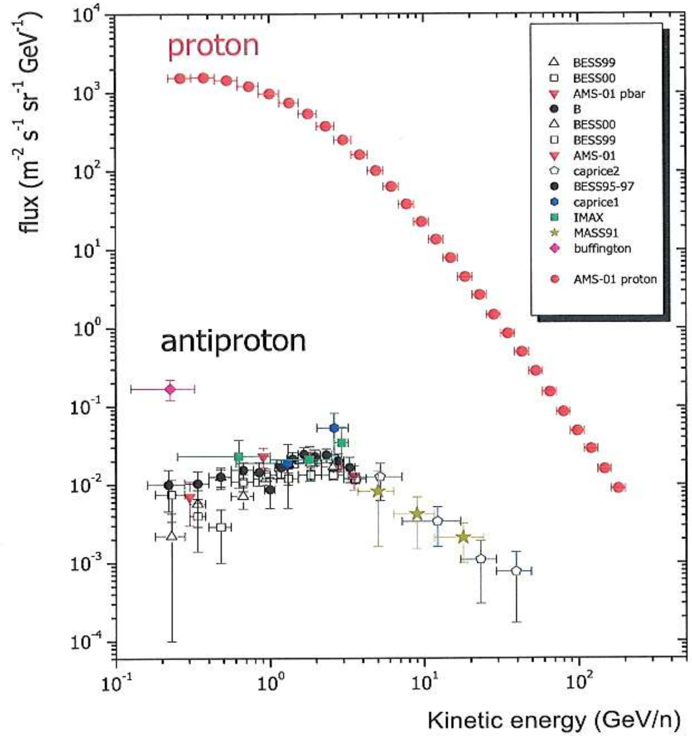


AMS Collaboration



Antimatter Quest

- At the Big Bang equal amounts of matter and antimatter produced
- What is nowadays observed ?
  - **low antiparticle fluxes**
    essentially explained by secondary production
  - **baryon-photon ratio** $\frac{N_B}{N_\gamma} \sim 10^{-10}$
    BBN prediction : $\frac{N_B}{N_\gamma} \sim 10^{-19}$ *!*



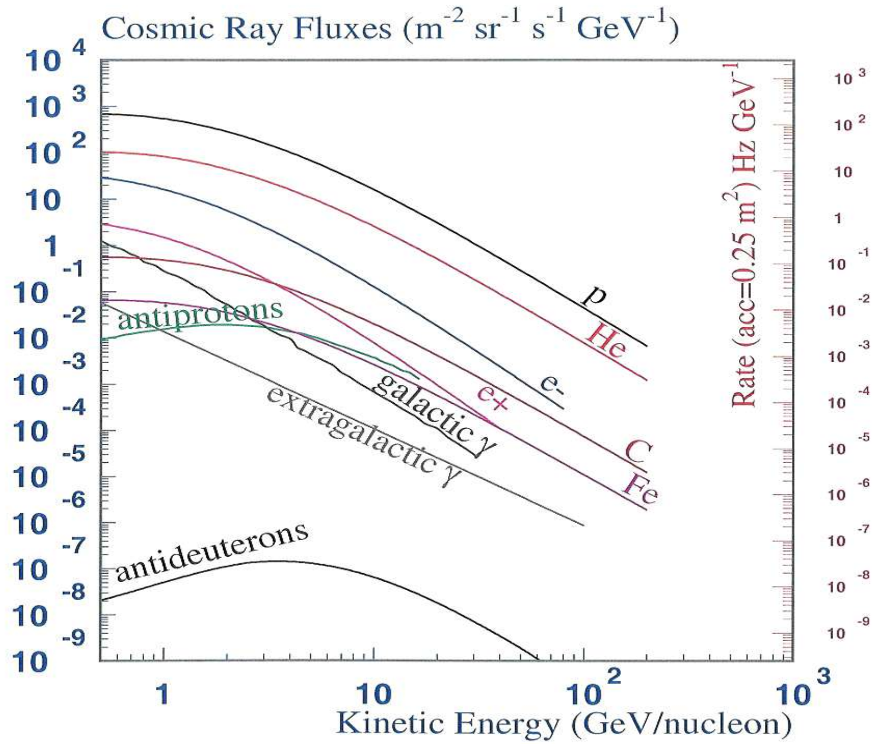
$$\frac{\Phi_{\bar{p}}}{\Phi_p} \sim 10^{-4} - 10^{-5}$$

Baryogenesis mechanism ? ? ?
CP Violation
Baryon number violation

Cosmic Rays Fluxes

- ▷ Spectra modulated at low energy
  solar wind effect
- ▷ Event rates depend on the geo-magnetic lattitude
  geomagnetic cutoff effect
- ▷ AMS maximal rate expected
  $\sim 2\ KHz$

protons	~ 1
heliums	$\sim 10^{-1}$
electrons	$\sim 10^{-2}$
positrons	$\sim 10^{-3}$
carbon	$\sim 10^{-4}$
iron	$\sim 10^{-5}$



Detector Requirements

Antimatter	DarkMatter	Astrophysics
antinuclei production from matter collisions is strongly suppressed $(p + ISM \rightarrow \bar{N} + \ldots)$ $\frac{\bar{N}}{\bar{p}} \propto \exp\left(-\frac{M_N - m_p}{80\ MeV}\right)$	**signals : $\bar{p}$, e^+, γ, $\bar{d}$**	**detection of a large range of nuclei (Z)** **ability to identify different isotopes**
detection of antinuclei would be a clear signal of existence of antimatter	• e^+ and $\bar{p}$ produced in $p + ISM$ collisions • physics background : $p/e^+ \sim 10^3$ $e^-/\bar{p} \sim 10^2$	**detection of gamma rays**
	a good e,p separation is needed $B/S \sim 1\% \Downarrow$ Rejection Factor $\sim 10^5$	

- charge identification
- rigidity measurement
- velocity measurement
- e.m energy measurement
- e/p separation
- albedo rejection
- strong system redundancy

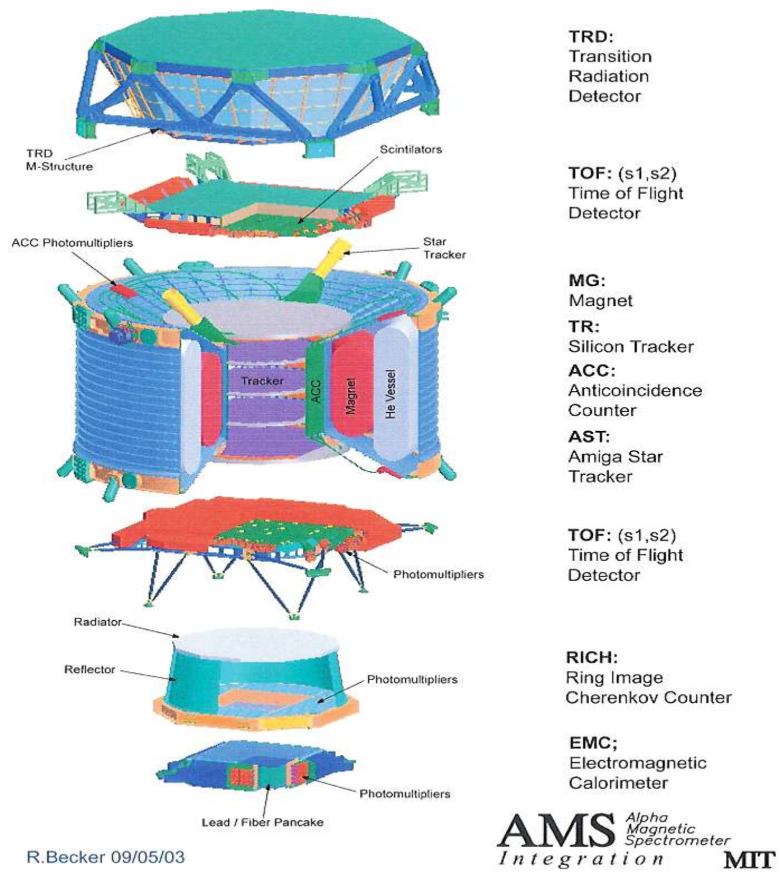
From AMS-01 on Shuttle to AMS-02 on ISS

Improved capabilities

- ▷ larger acceptance
  $\sim 0.5\ m^2.sr$
- ▷ Superconducting magnet
  a magnetic field ~ 8 times larger
- ▷ larger silicon Tracker
  8 double-sided layers
  $\sim 6.5\ m^2$ silicon surface
- ▷ a momentum resolution improved by a factor ~ 10

New Detector systems

- ▷ New Cerenkov Detector (RICH)
- ▷ Electromagnetic Calorimeter (ECAL)
- ▷ Transition Radiation Detector (TRD)



Advantages of a Silicon Tracker for AMS

Large surface to cover large acceptance of spectrometer (0.5 m^2 sr)

>> High statistics measurement (rare anti-nuclei if any, exponentially decreasing CR spectrum)

Excellent spatial resolution in magnetic field (10 µm/plane in 0.8 T)

>> High rejection power against nuclei in anti-nuclei search

>> Good identification of light isotopes

>> Good double-track reconstruction for converted photons

Advantages of a Silicon Tracker for AMS

Large number of planes:

>> reduces background due to nuclear interactions (several indep. measurements.)

Choice of double-sided sensors increases transparency of the detector (~3 % of a radiation length)

>> Reduces large angle scattering of nuclei which could simulate the curvature of anti-nuclei.

Well adapted to space environment:

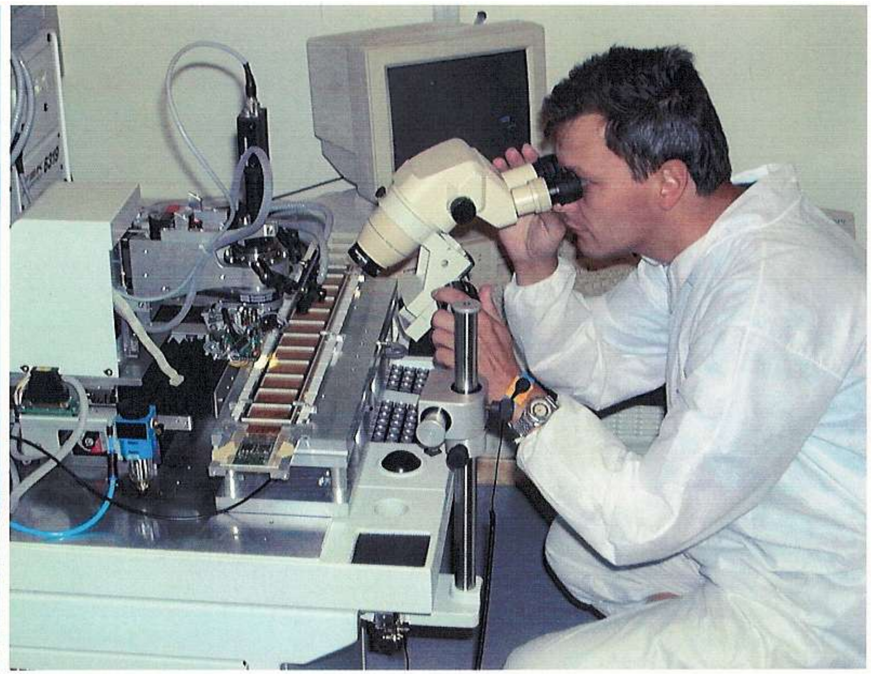
Absence of gas system and wires, light weight, limited power, can survive vibrations and accelerations, works in vacuum, limited data transfer, temperature can be controlled.

Advantage of a Silicon Tracker for AMS

Measurement of high energy converted photons

- Together with Star Tracker and GPS
- E.g. study of Gamma Ray Burst energy and time distributions

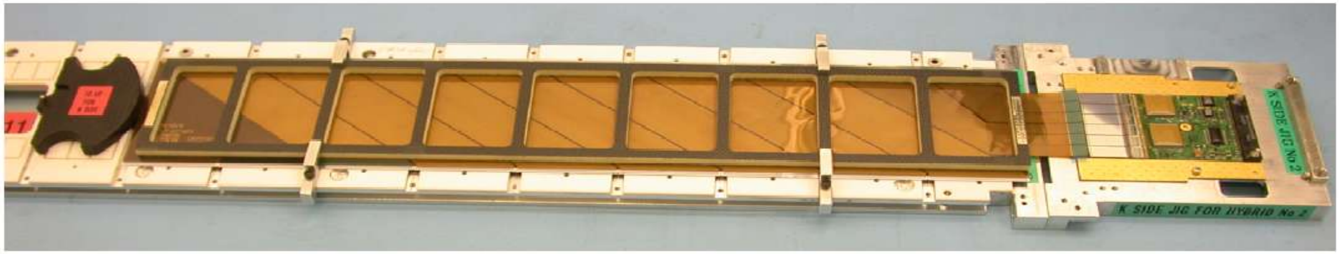
AMS-02 Tracker Construction



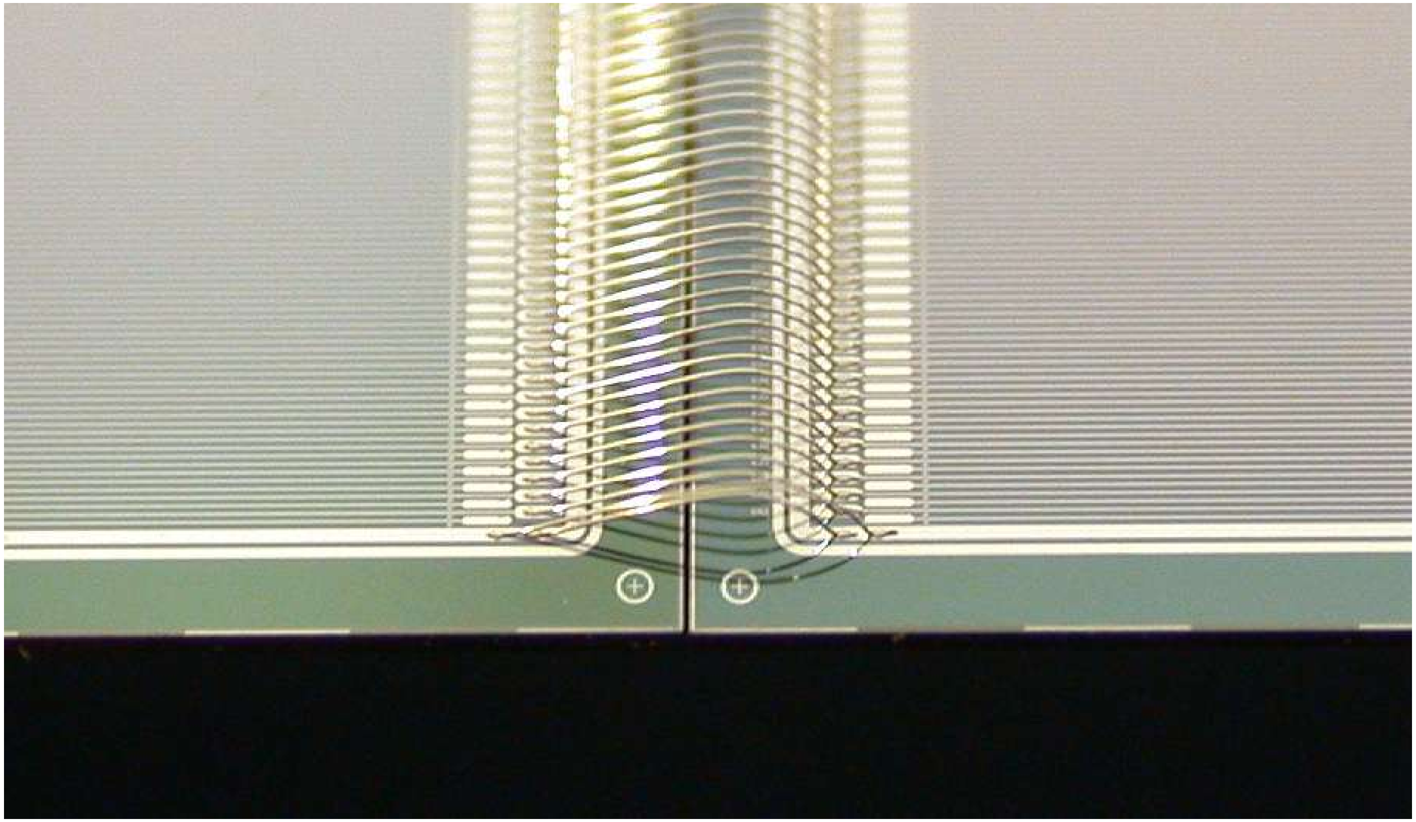
Positioning to a few μm accuracy.

Collaboration with ETH Zurich bonding facility at CERN.

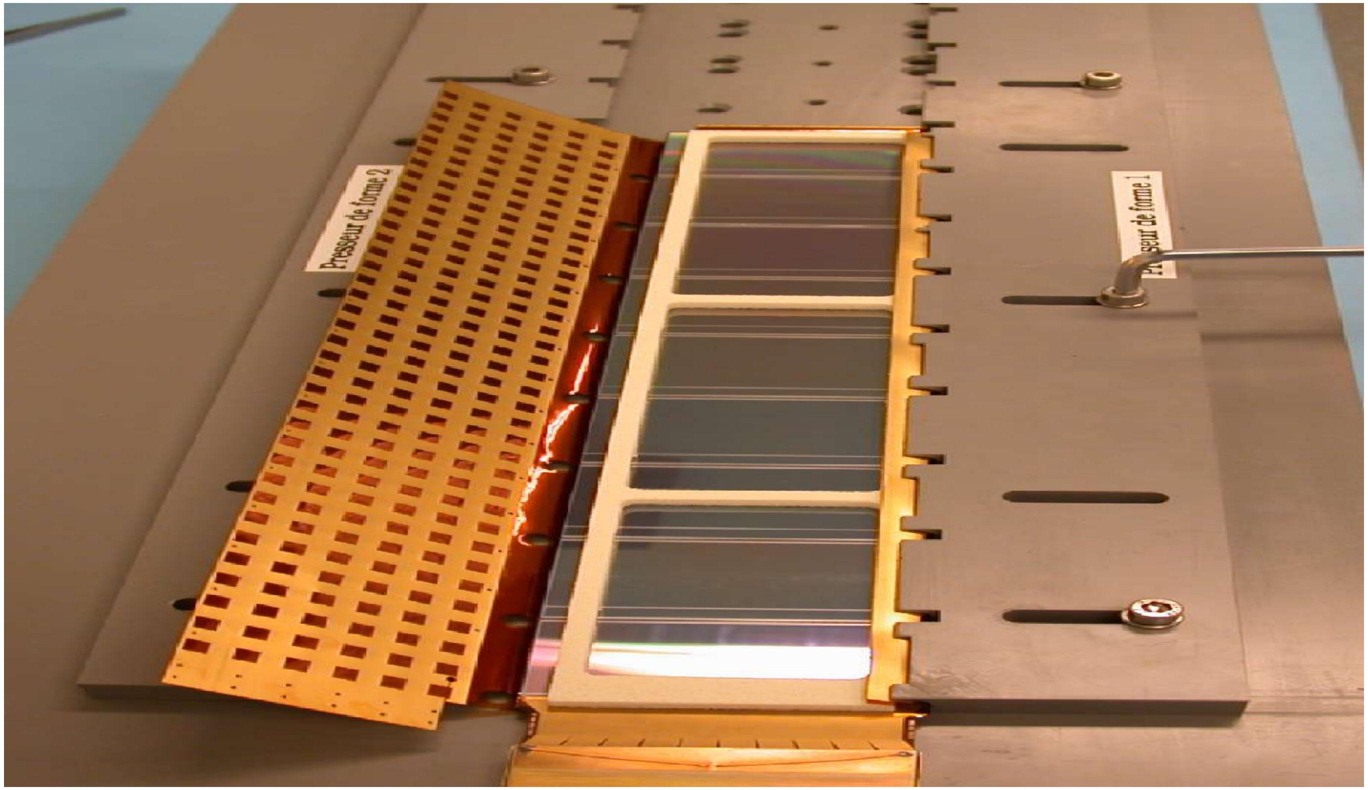
N-side bonding jig



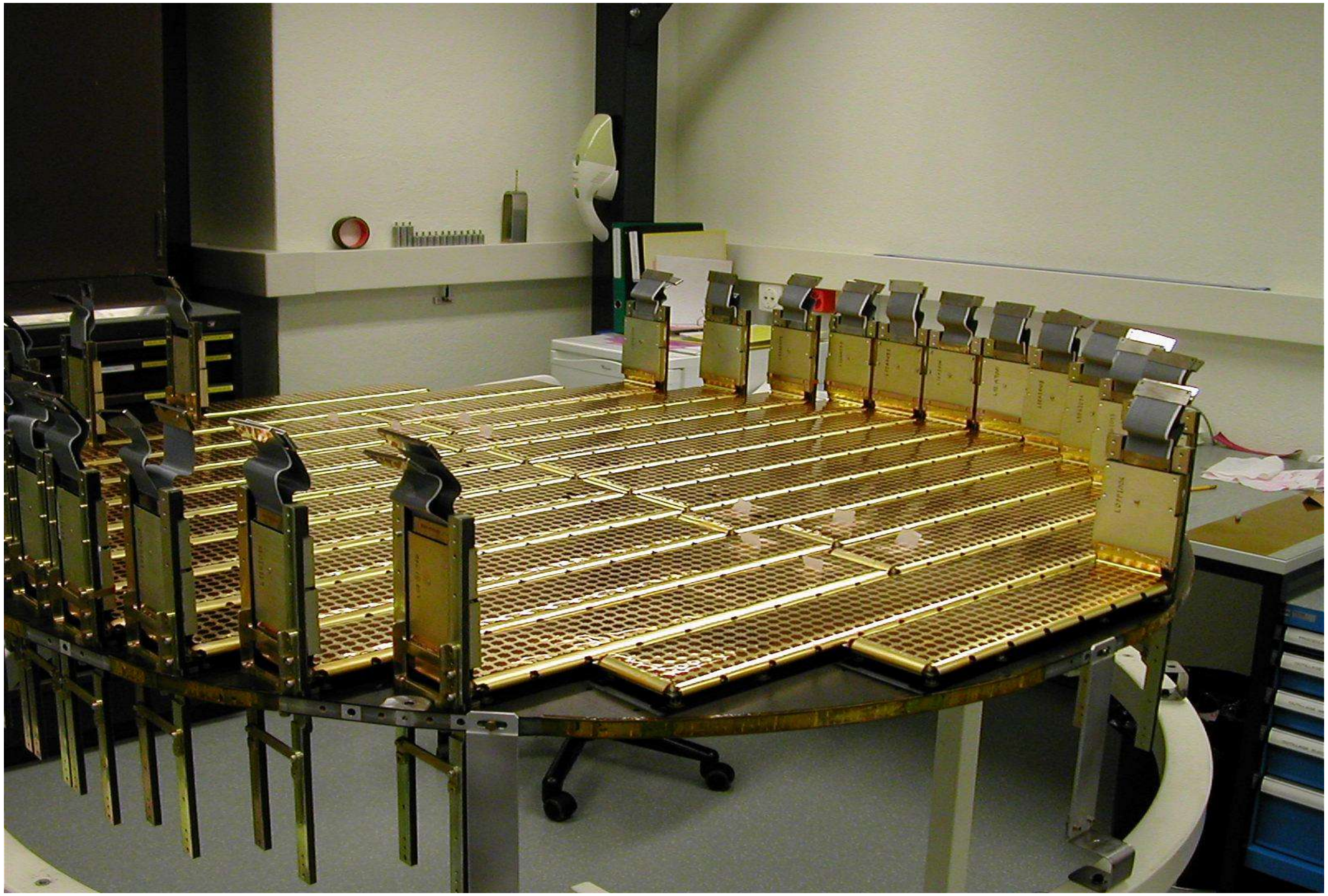
Wire bonds



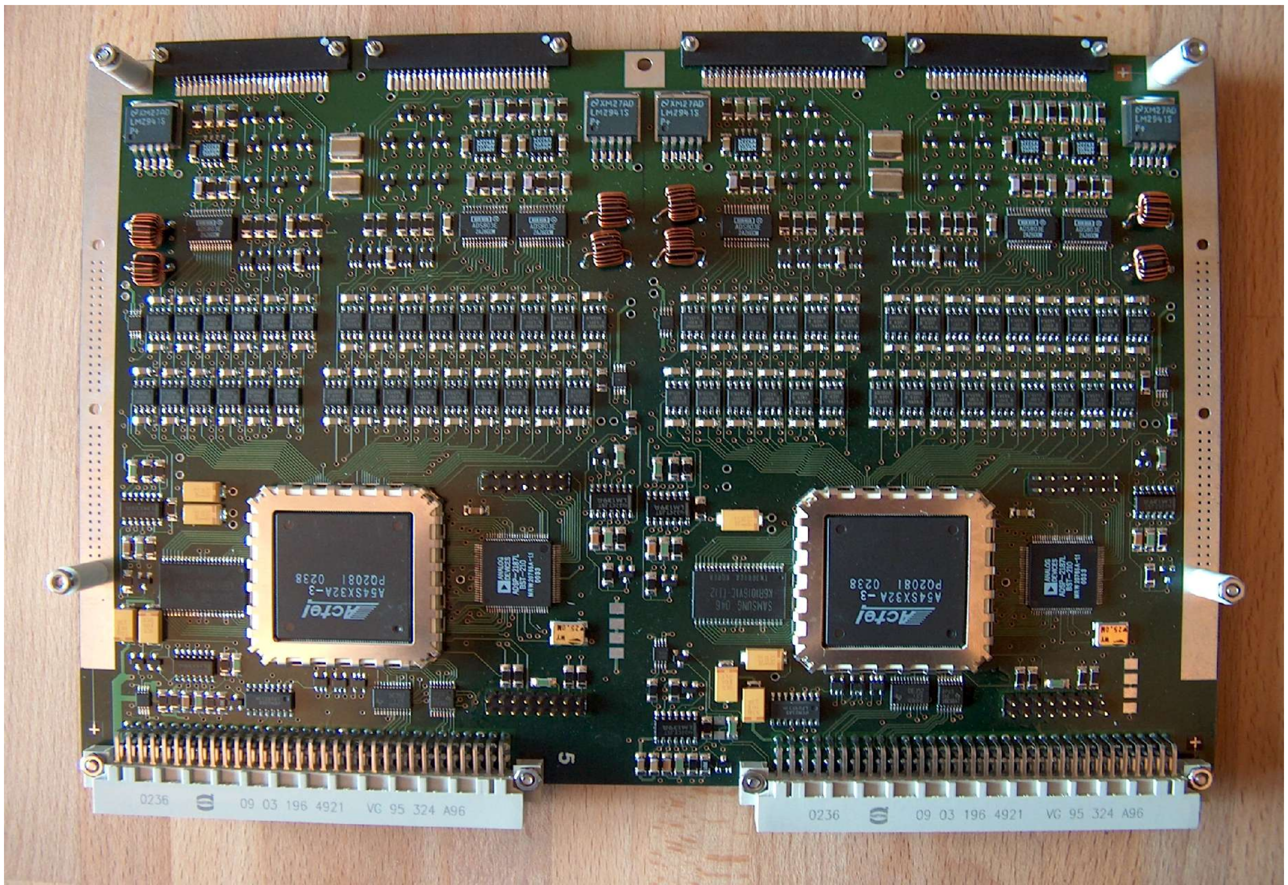
Shielding wrapping



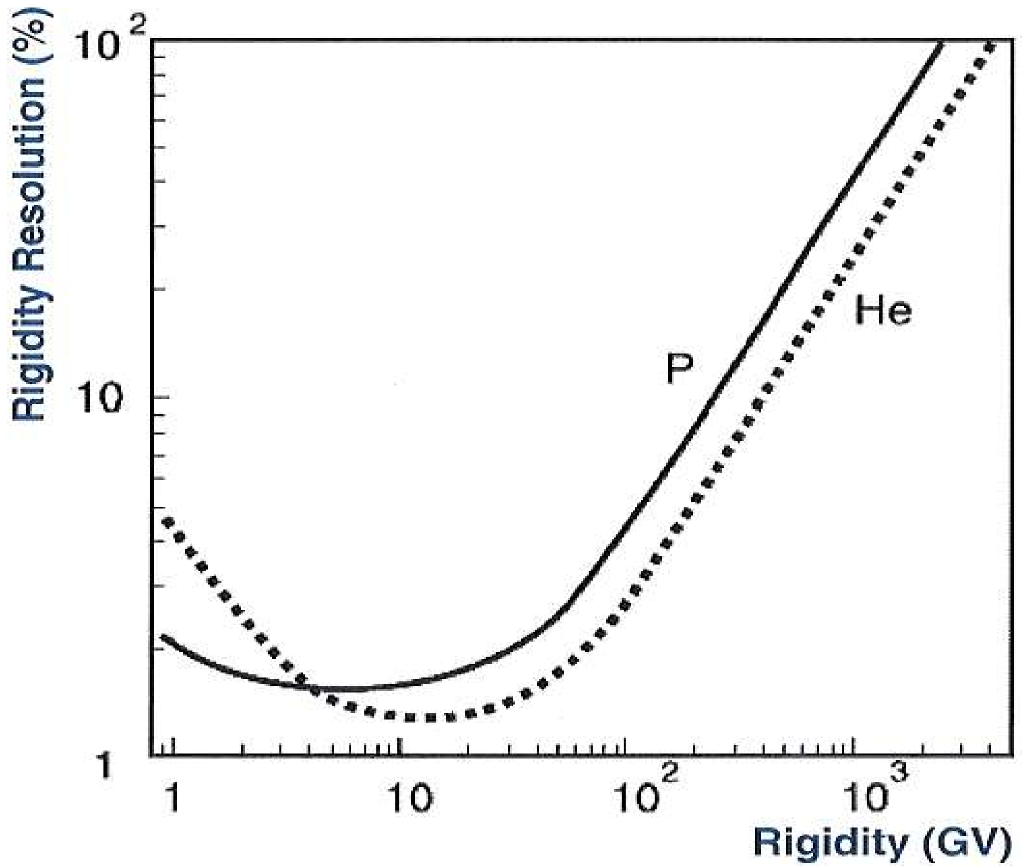
AMS-02 Tracker Plane



Tracker Reduction Board

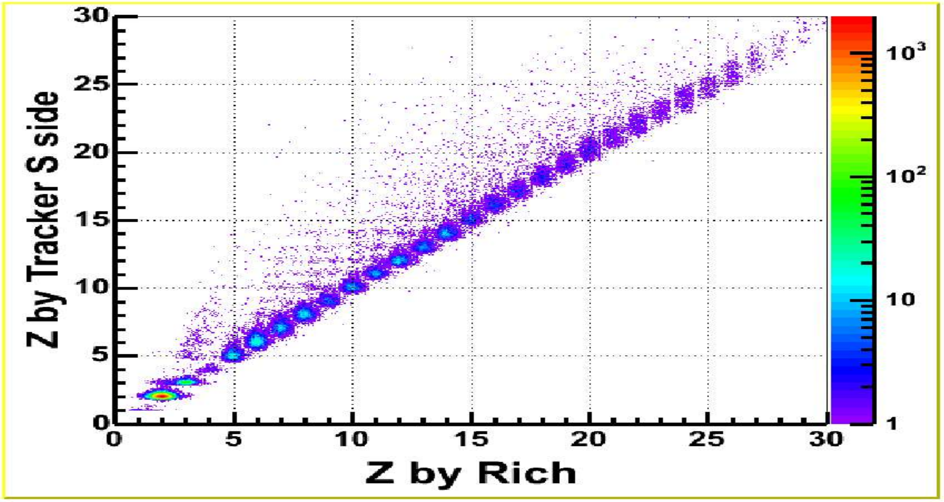


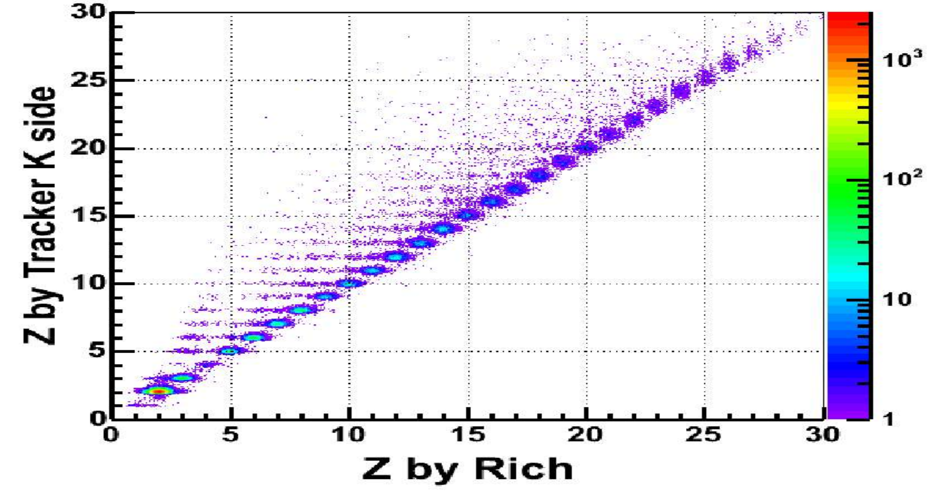
Tracker Rigidity Resolution



Tracker charge resolution

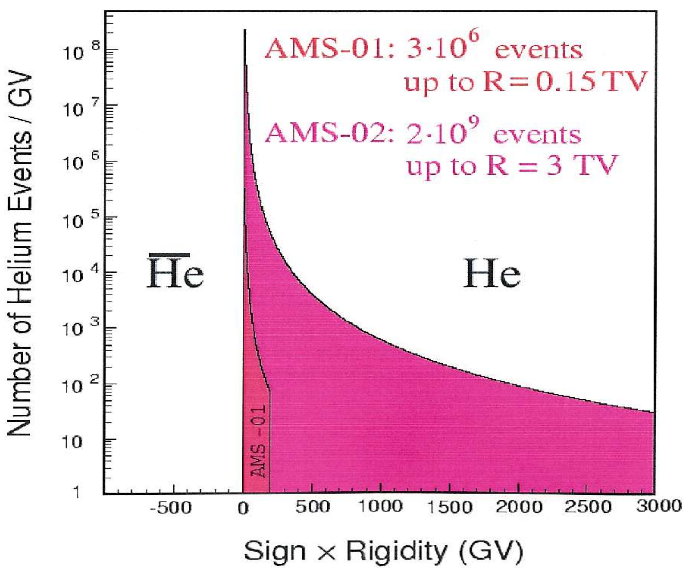
- Correlation of p-side and n-side measurements with a prototype RICH detector



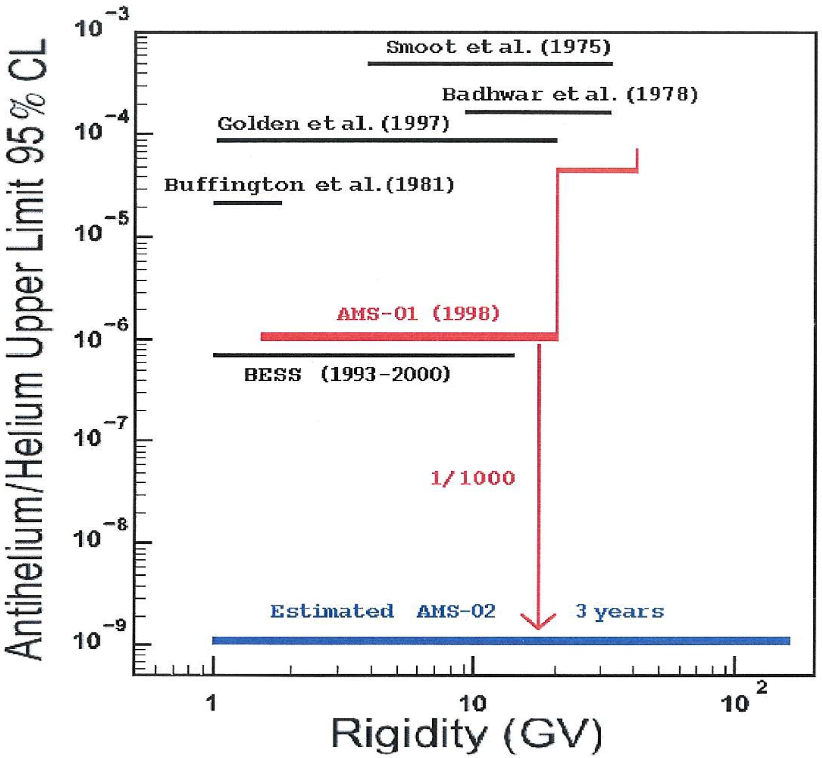


Antimatter Search with AMS-02 antihelium

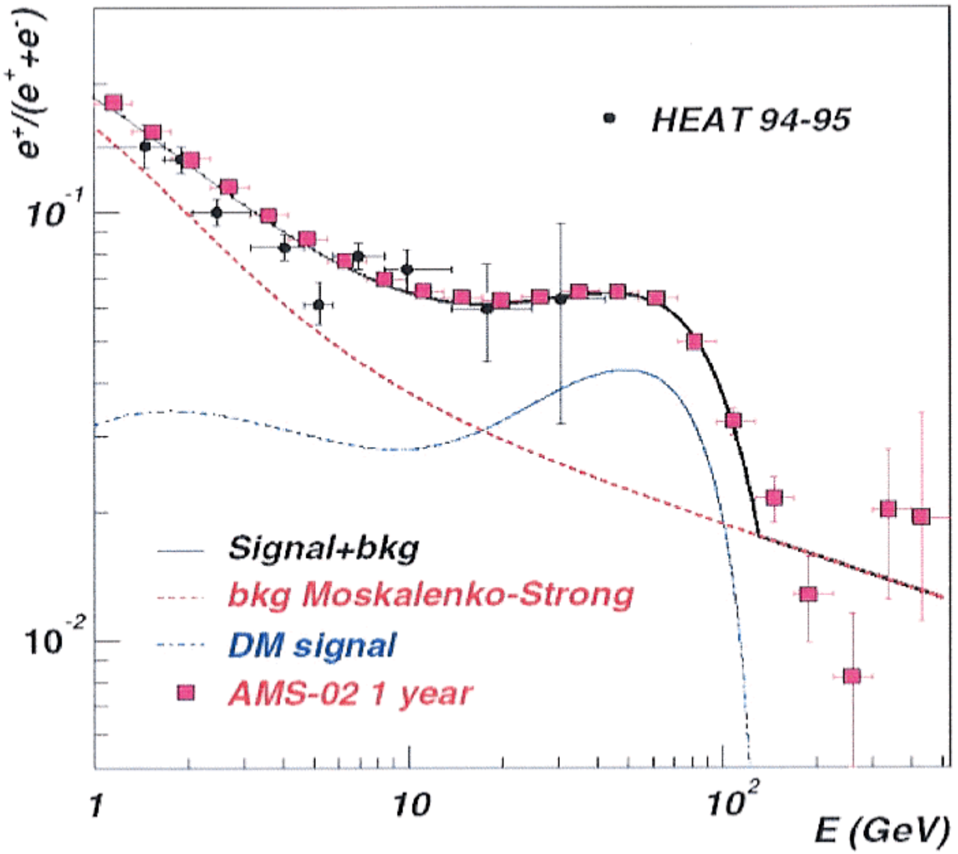
- an expected efective statistics of more than 10^9 events
- a rigidity sensitivity improved $\sim$ 8 times



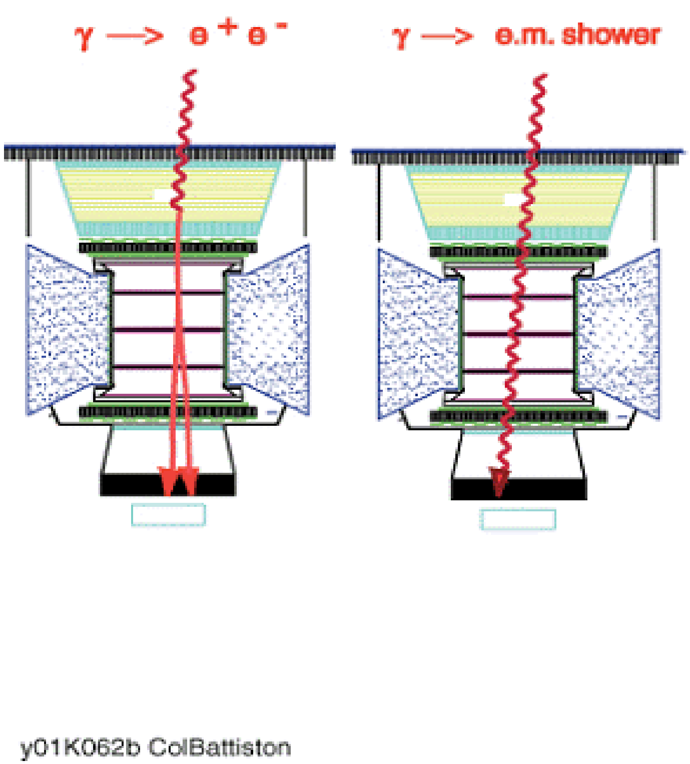
AMS expected limit with 3years data

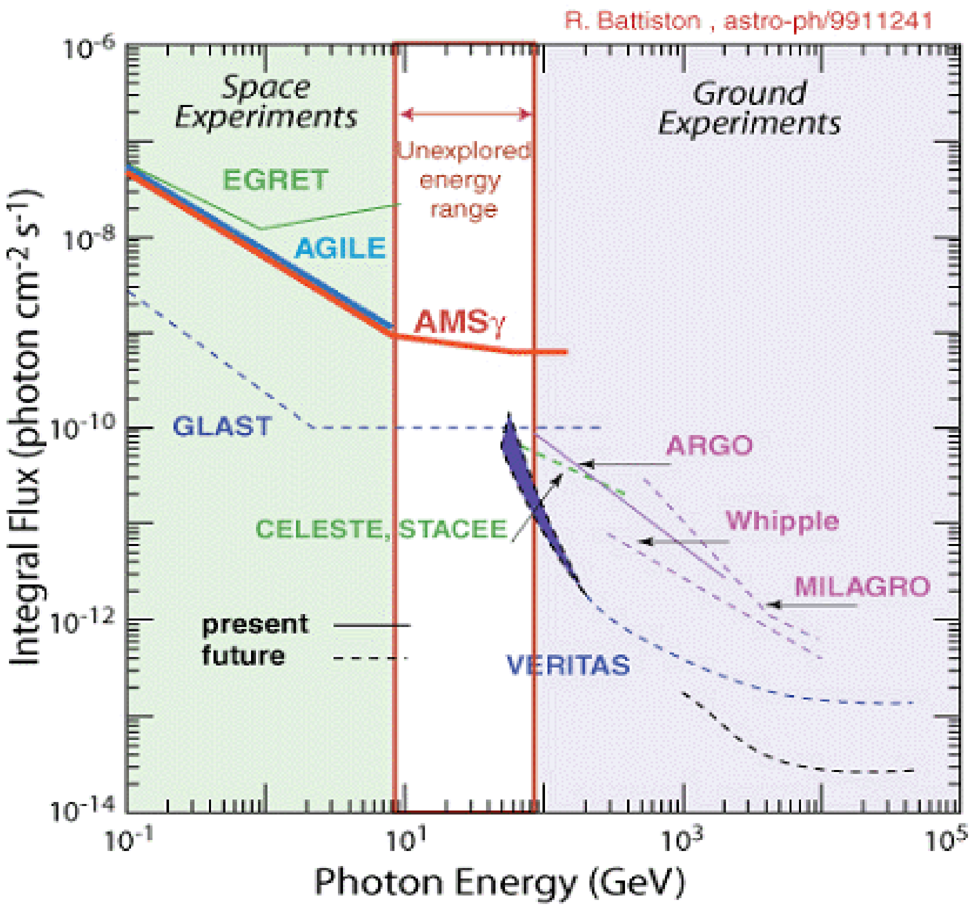


Darkmatter Search with AMS-02 positrons

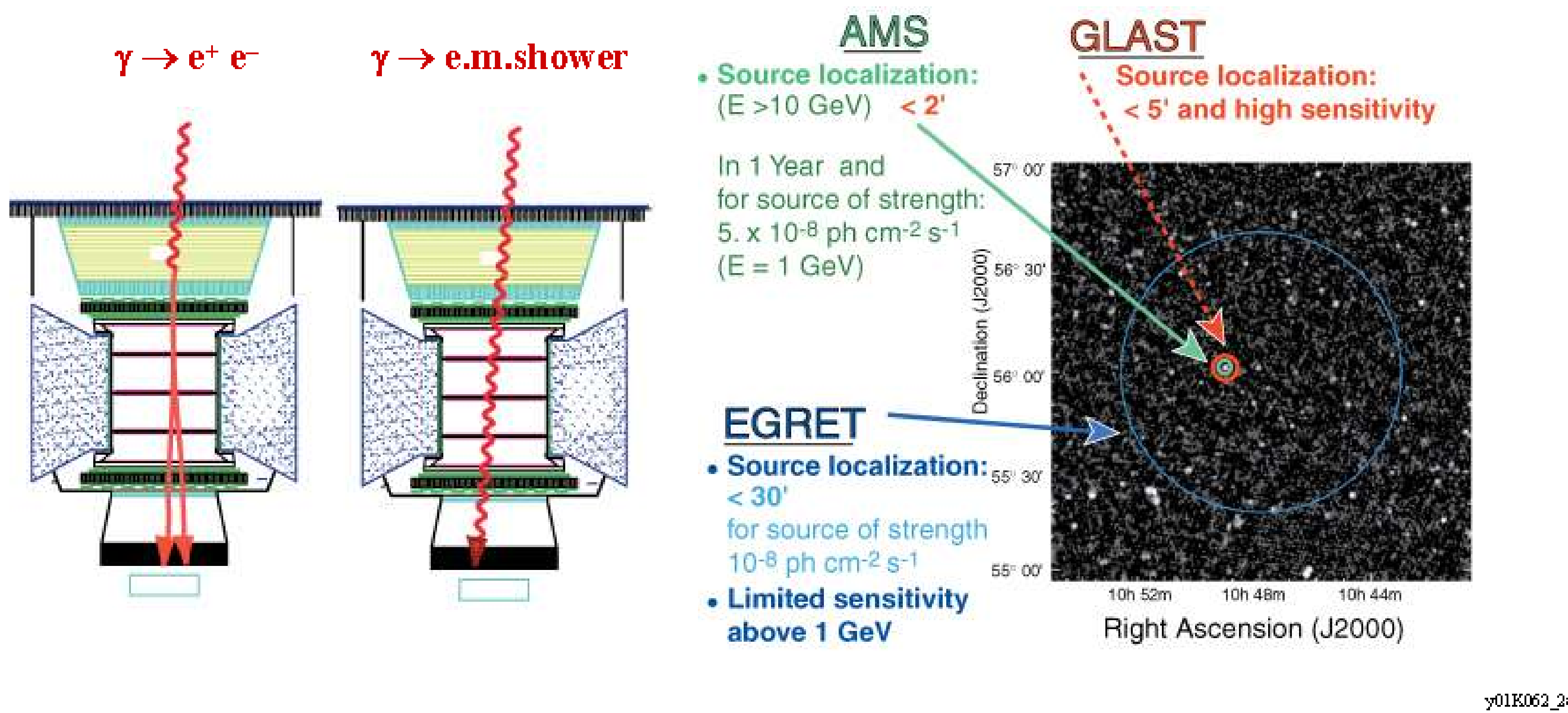


Space born and ground based high energy γ ray detectors





Unidentified Sources with AMS



Conclusions

- The AMS detector will be installed on the ISS on 2007 for 3 years.
- Fundamental physics issues will be adressed
  - Antimatter sensitivity of the order 10^{-9}
  - Dark matter searches through different signatures (e^+, $\bar{p}$, γ, ···)
  - Astrophysics measurements

- Charged particle tracking is done with a silicon microstrip detector, well adapted to work in the high field superconducting magnet

It meets the scientific goals with

Measurement of rigidity over large range (1 GeV to 2 TeV)

Detection of large range of nuclei (Z = 1 to 26)

Measurement of converted high energy photons

Good performance in space environnement with no human intervention

DarkMatter Quest

Evidence for the existence of a large quantity of non-baryonic darkmatter

- ▷ Rotation galactic curves indicate the presence of non-luminous galactic halos
- ▷ Universe matter content is $\sim 5\times$ larger than the baryonic matter BBN prediction
  $\Omega_m \sim 0.3 \quad (BBN: \quad \Omega_b \sim 0.05)$

- ▷ Weakly Interacting Massive Particles (WIMP's)
- ▷ SUSY has a good candidate
  Lightest Supersimmetric Particle (LSP) - neutralino (χ)
  $\chi\chi \to f\bar{f},\ W^-W^+,\ ZZ,\ Z\gamma,\ \gamma\gamma$
- ▷ physics signatures
  anomalies on $e^+,\ \bar{p},\ \gamma, \bar{d}$ spectra

Astrophysics motivations

▷ *Secondary nuclei*

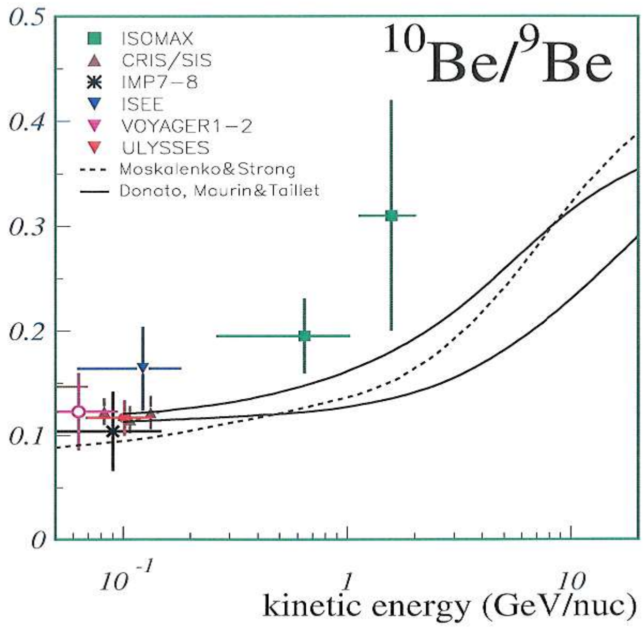
CNO spallation $\rightarrow$ Li, Be, B

information about propagation of cosmic-rays in the galaxy

▷ *Cosmic Rays Clocks*

radioactive secondary nuclei produced ($^{10}Be_{T1/2} \sim 1.5 \times 10^6\ yrs$)

$^{10}Be/^9Be$ provides information about confinement of cosmic rays



Improvement of current isotopic measurements needed!

- done at relatively low energies
- based on low event statistics