Cosmic-Rays Astrophysics with AMS-02

Alberto Oliva*
on the behalf of the AMS Collaboration
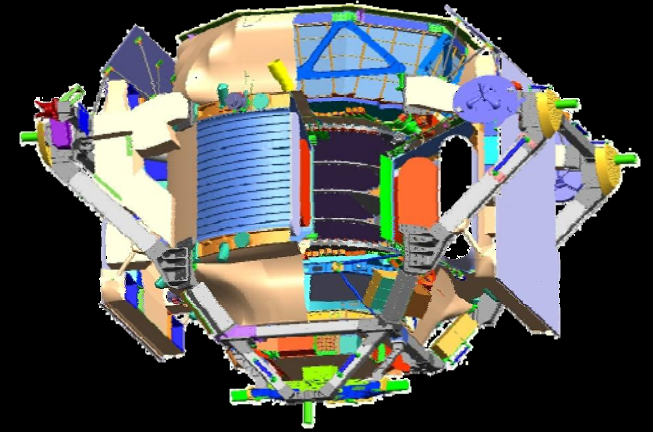
*University and INFN Perugia, Italy

Outline

- High Energy Astrophysics with AMS

- The AMS-02 Detector, and the Measurement Methods

- Expected Physics

AMS-02 experiment

High Energy Particle Physics in Space (ISS):

- Large Acceptance, Long Duration → High Statistics

- Charged Particles & Nuclei Spectra

- High Energy Gamma Rays

Physics goals:

- Search for Primordial Antimatter by Direct Detection of Antinuclei ($\overline{He}$/He<10^{-9})

- Dark Matter Signatures in $\bar{p}$, e^+, $\bar{d}$, γ spectra

- Production, Acceleration and Propagation of Cosmic-Rays

- Solar Modulation

AMS-02 experiment

High Energy Particle Physics in Space (ISS):

- Large Acceptance, Long Duration → High Statistics

- Charged Particles & Nuclei Spectra
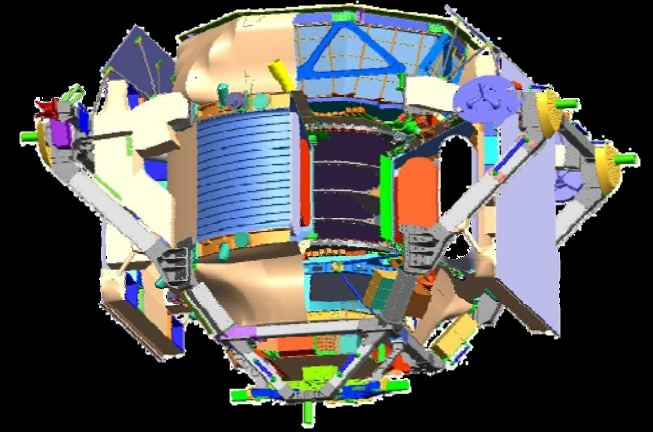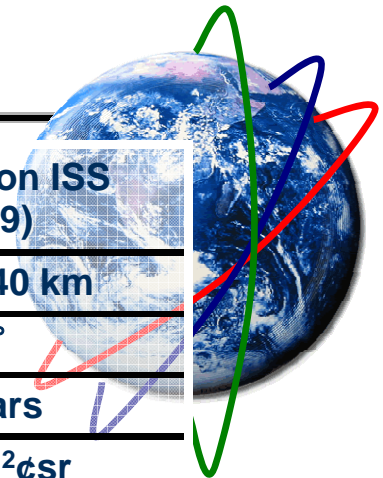
- High Energy Gamma Rays

Physics goals:

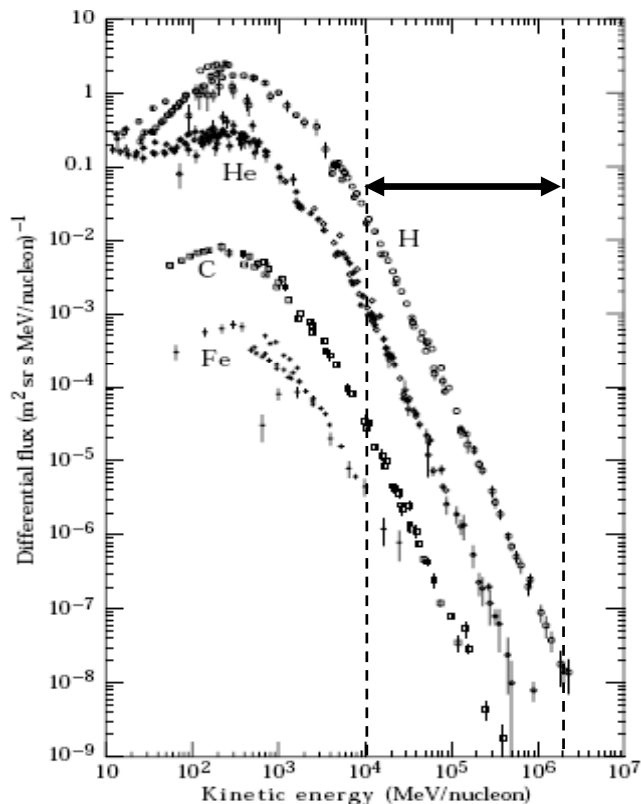- Search for Primordial Antimatter by Direct Detection of Antinuclei ($\overline{He}$/He<10^{-9})

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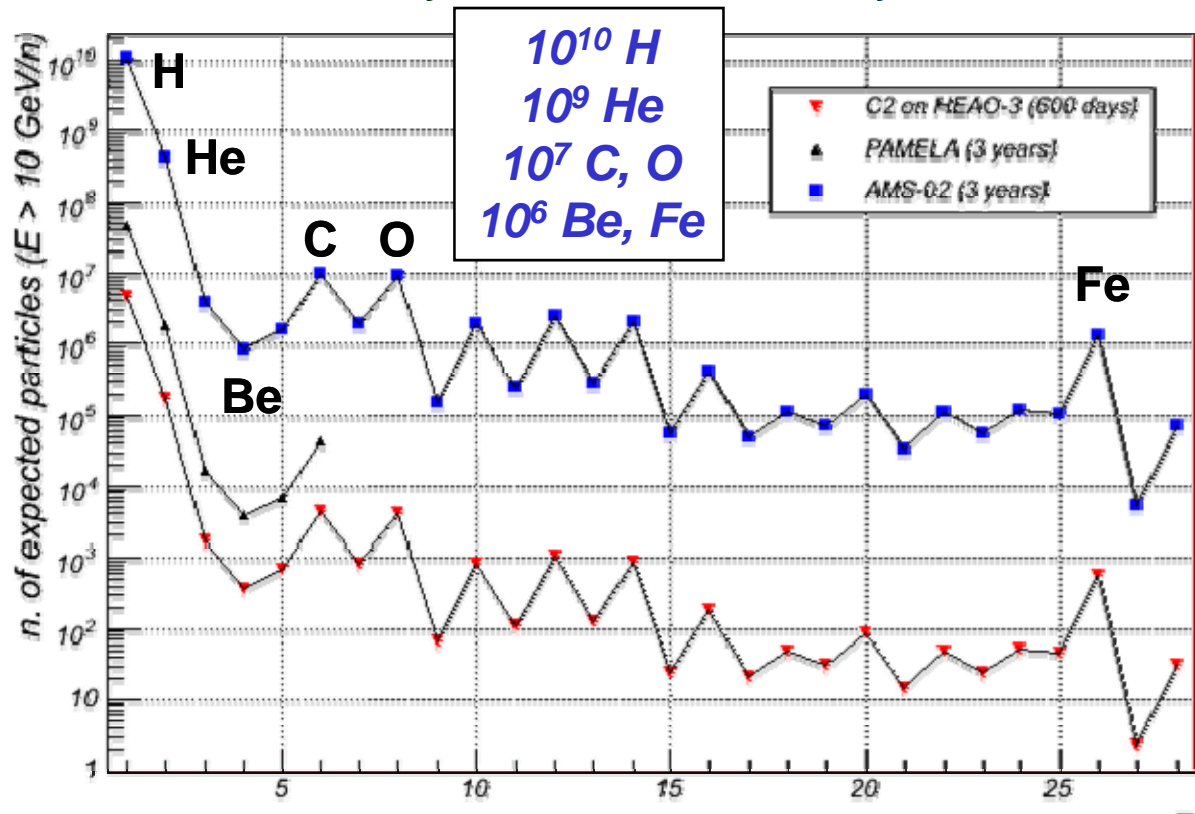- Production, Acceleration and Propagation of Cosmic-Rays

- Solar Modulation

CR spectrum and AMS-02 expectation

	C2 on HEAO-3 (1979)	PAMELA on DK1 (2006)	AMS-02 on ISS (2009)
Perigee £ Apogee	490 £ 510 km	350 £ 600 km	360 £ 440 km
Inclination	44°	70°	52°
Δt	600 days	3 years	3 years
Acceptance	4 cm²¢sr	21.5 cm²¢sr	0.45 m²¢sr
Energy	600 MeV/n – 35 GeV/n	100 MeV/n – 250 GeV/n	700 MeV/n – 1 TeV/n
Charge distinction	Z · 26	Z · 6	Z · 26
Mass reconstruction	no	yes	yes

10^{10} H
10^{9} He
10^{7} C, O
10^{6} Be, Fe

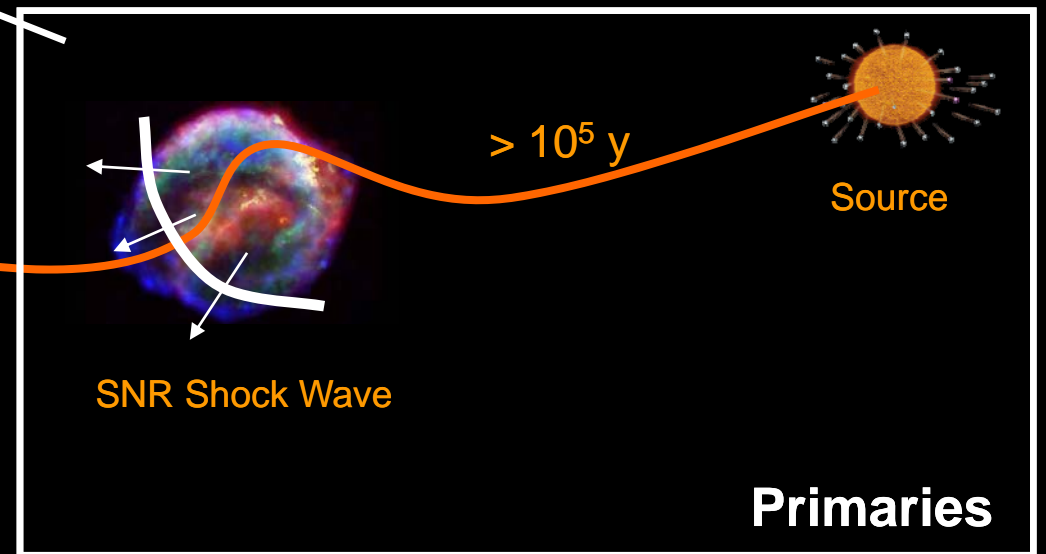Legend:
- C2 on HEAO-3 (600 days)
- PAMELA (3 years)
- AMS-02 (3 years)

1. J.A. Simpson, Ann. Rev. Nucl. and Part. Sci. 33, 323 (1983).

Cosmic Nuclei Astrophysics

	stable	β decay	K capture
primary CR	big bang and stellar nucleosynthesis	age of the origin material (U, Pu, Cm, …)	Delay between synthesis and acceleration (^{56}Ni, ^{57}Co)
secondary CR (dependent from ISM)	diffusion process (B/C, sub Fe/Fe)	galaxy confinement time (^{10}Be, ^{26}Al, ^{36}Cl, ^{54}Mn)	Energy changes (decelerations)

Secondaries

Our Galaxy

$> 10^5$ y

Source

SNR Shock Wave

10^7 y

Primaries

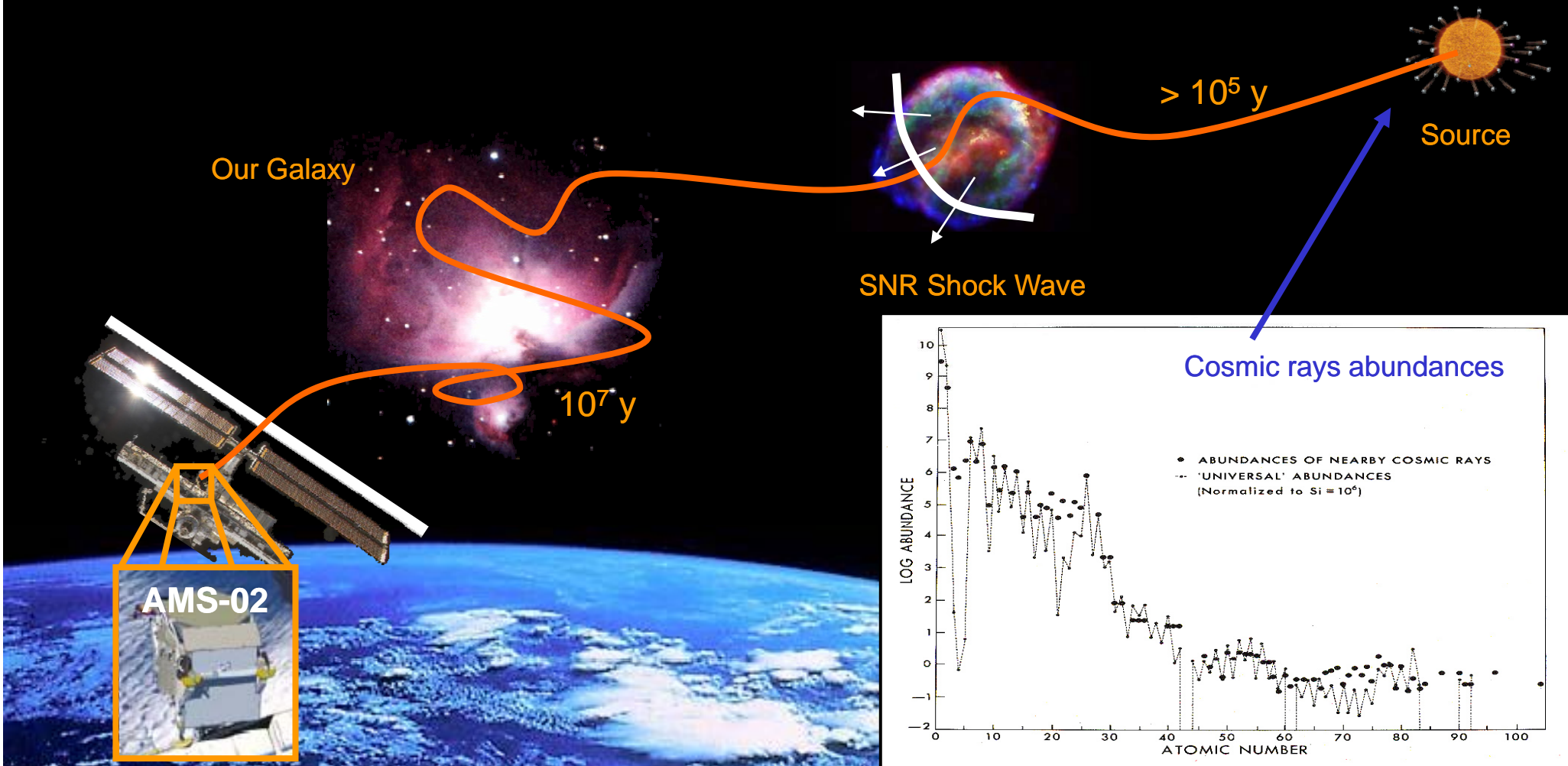**AMS-02**

Cosmic Nuclei Astrophysics

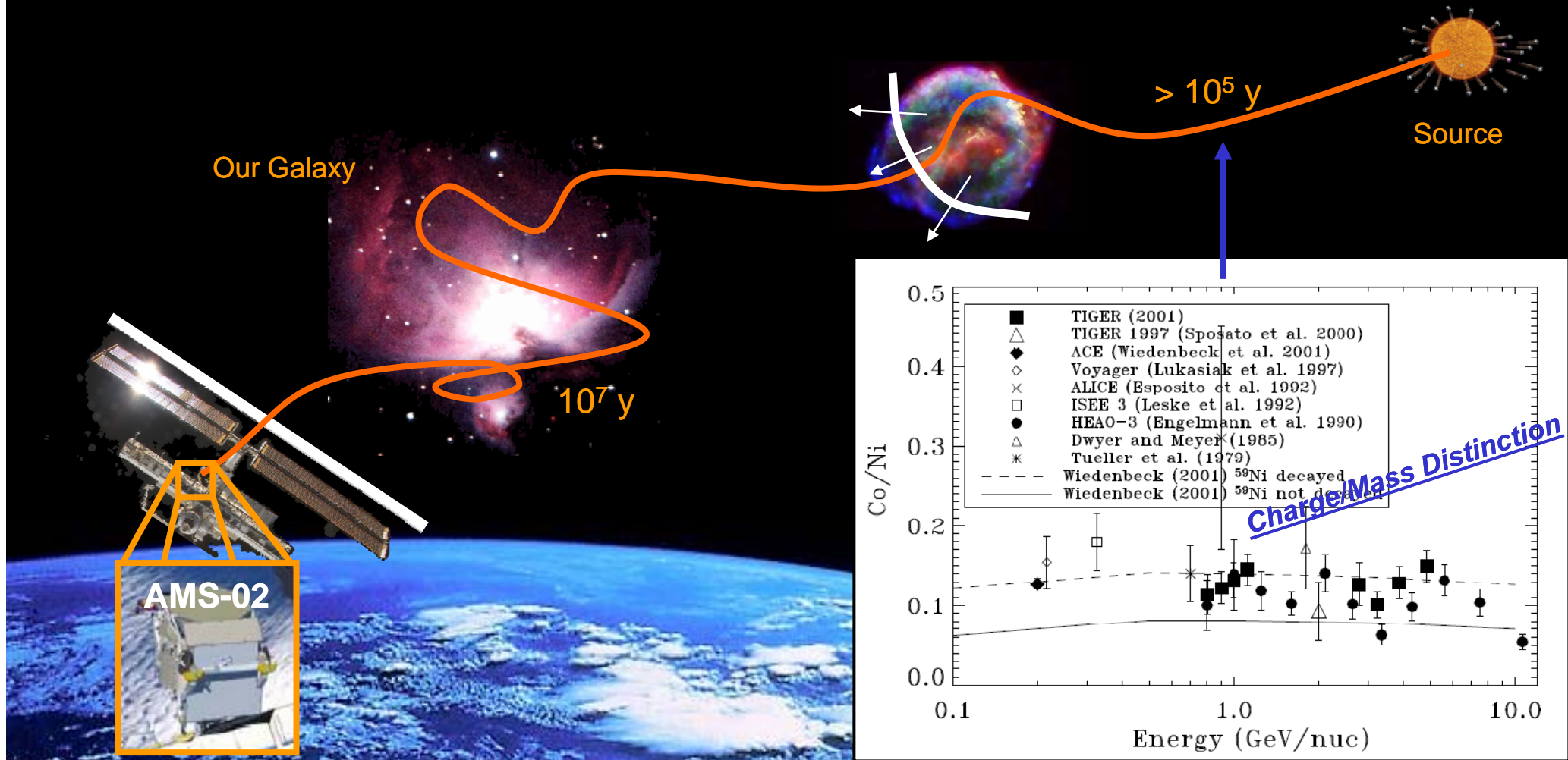|	stable	β decay	K capture
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SNR Shock Wave

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AMS-02

Cosmic rays abundances

ABUNDANCES OF NEARBY COSMIC RAYS
'UNIVERSAL' ABUNDANCES (Normalized to Si ≡ 10^6)

LOG ABUNDANCE

ATOMIC NUMBER

Cosmic Nuclei Astrophysics

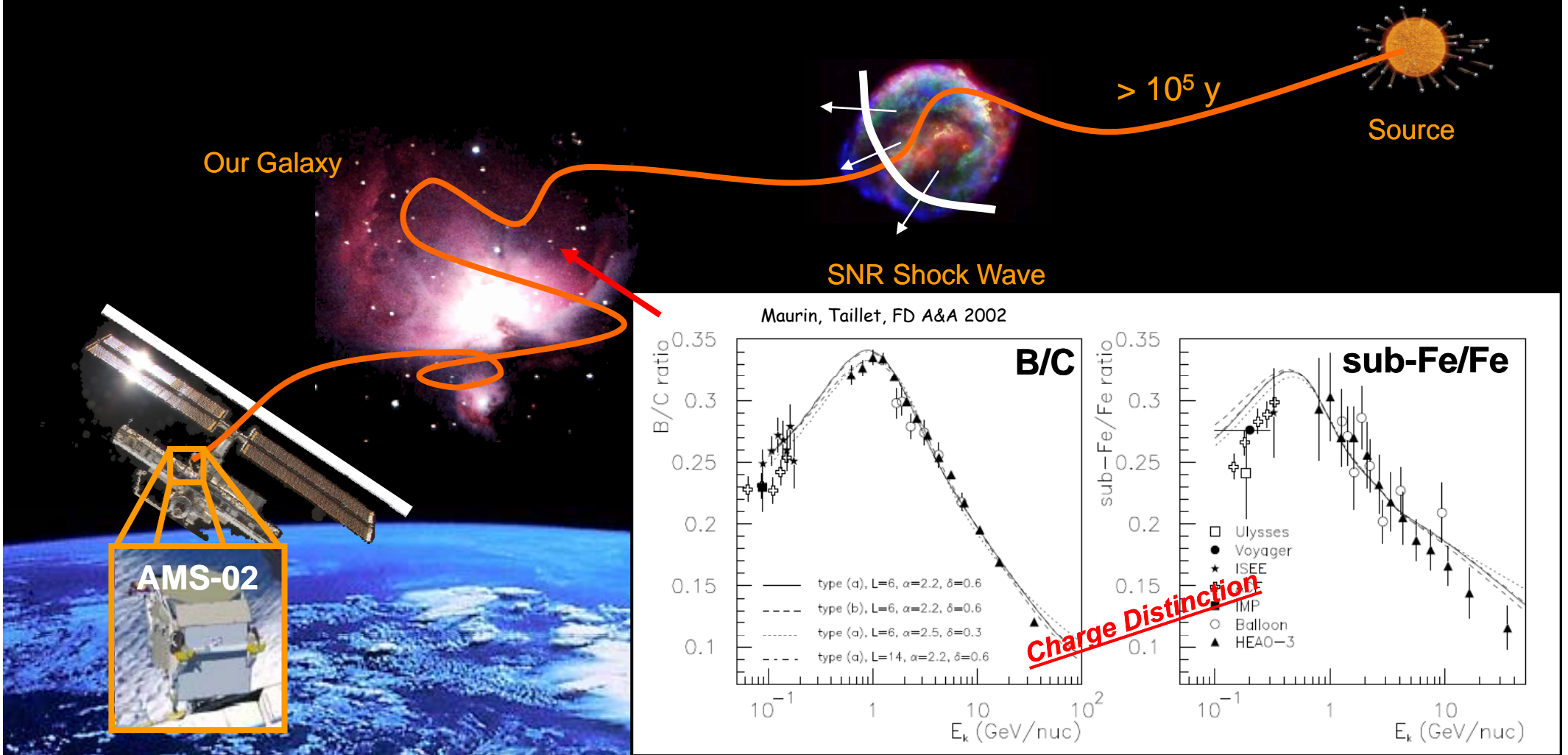|	stable	β decay	K capture
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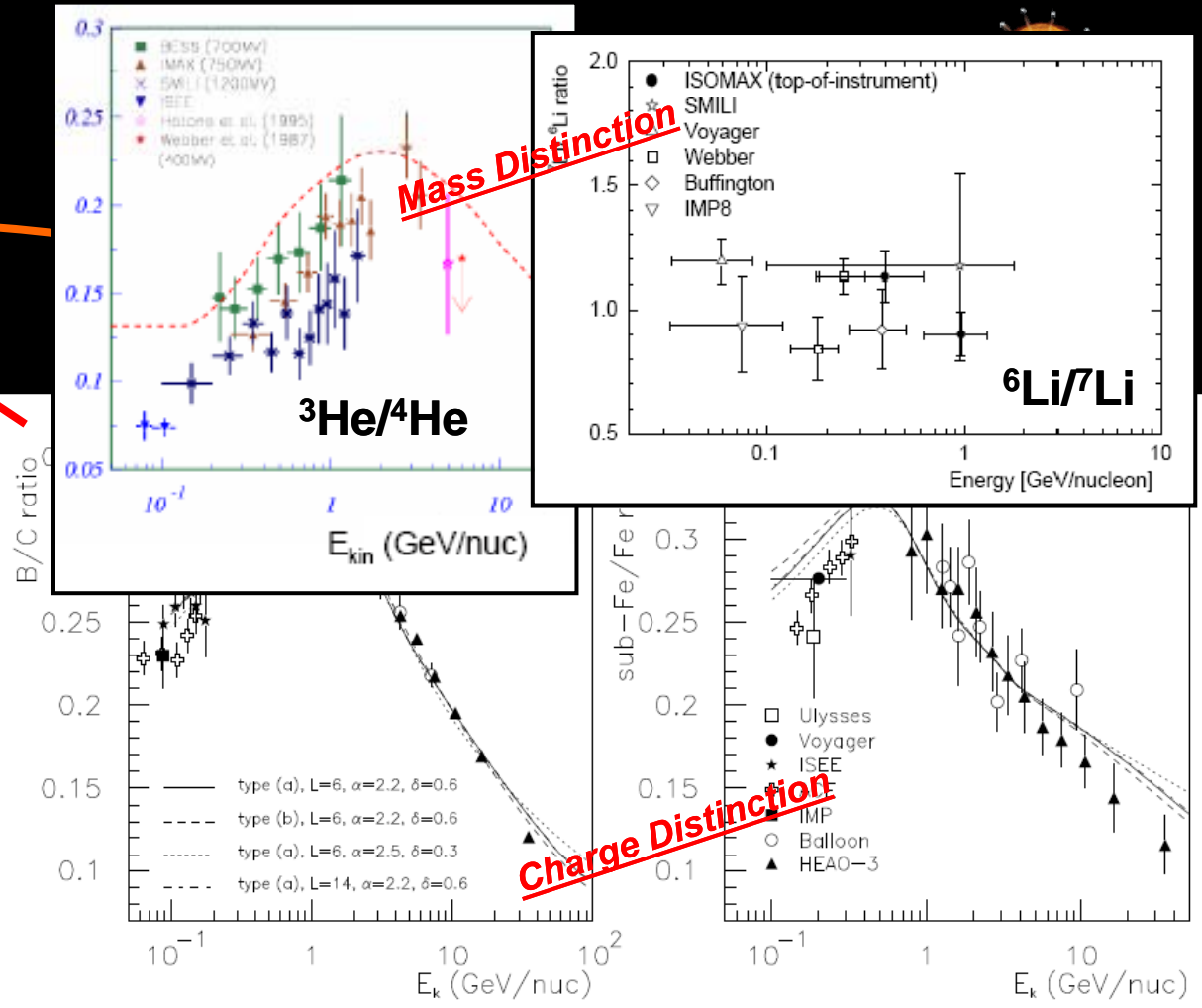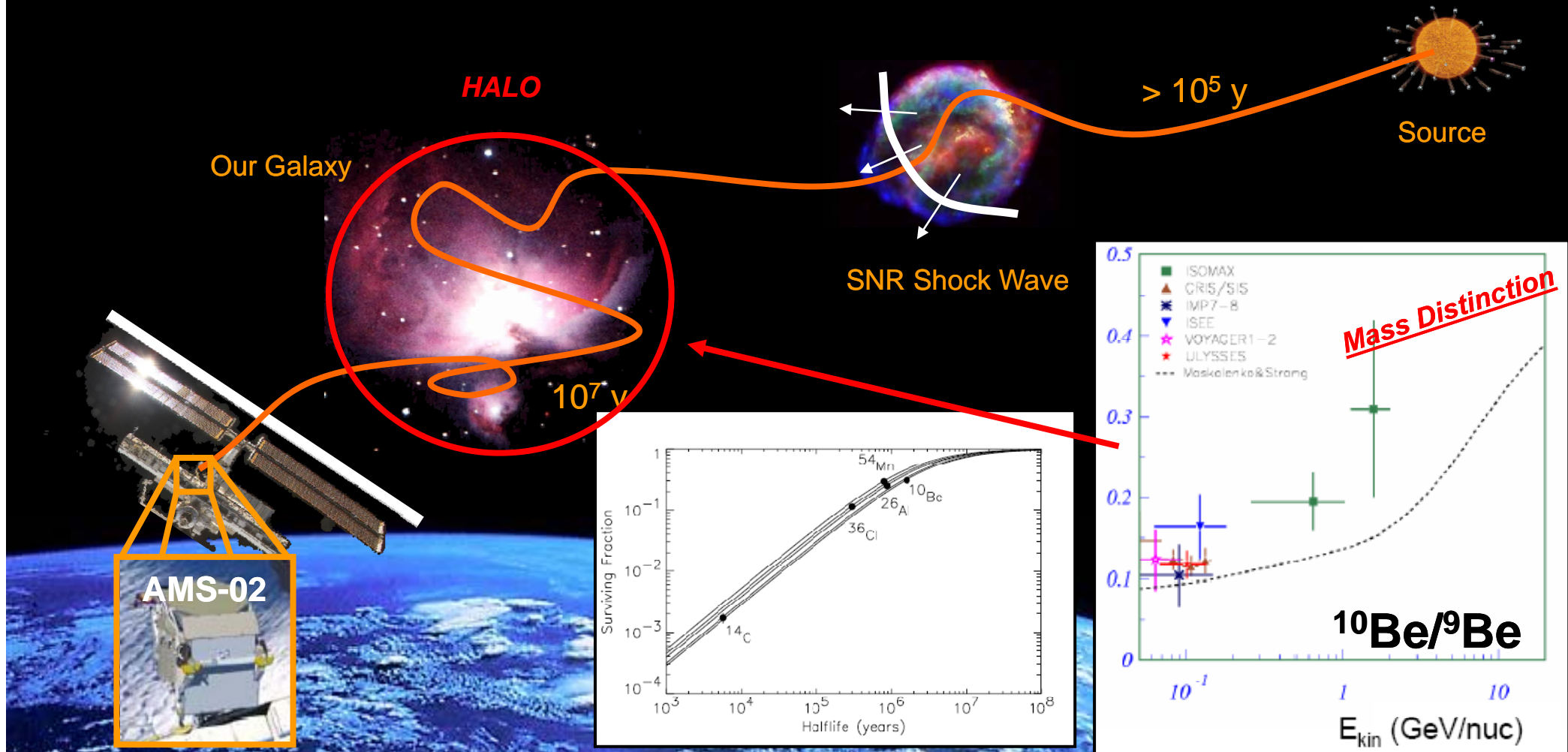|	stable	β decay	K capture
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> 10^5 y

Source

Our Galaxy

SNR Shock Wave

AMS-02

Maurin, Taillet, FD A&A 2002

B/C

sub-Fe/Fe

Charge Distinction

- type (a), L=6, α=2.2, δ=0.6
- type (b), L=6, α=2.2, δ=0.6
- type (a), L=6, α=2.5, δ=0.3
- type (a), L=14, α=2.2, δ=0.6

□ Ulysses
● Voyager
★ ISEE
✚ IMP
○ Balloon
▲ HEAO-3

B/C ratio — E_k (GeV/nuc)

sub-Fe/Fe ratio — E_k (GeV/nuc)

Cosmic Nuclei Astrophysics

|	stable	β decay	K capture
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AMS-02 Detector

- **Cryogenic Superconducting Magnet of 0.8 T**

- **TOF: 4 layers of scintillators (150 ps resolution)**

- **Tracker: 8 layers of Si detectors (10 (30) μm)**

- **RICH Detector ($\Delta\beta/\beta = 0.1/Z$ %)**

- **TRD Detector: p/e rejection in 10^3**

- **Pb/Sc EM Calorimeter: p/e rejection 10^4**

- Geometric acceptance of 0.45 m^2¢sr

- Z measurement up to Iron

- A global statistics above 10^{10} particles

- Detector redundancy (charge, velocity)

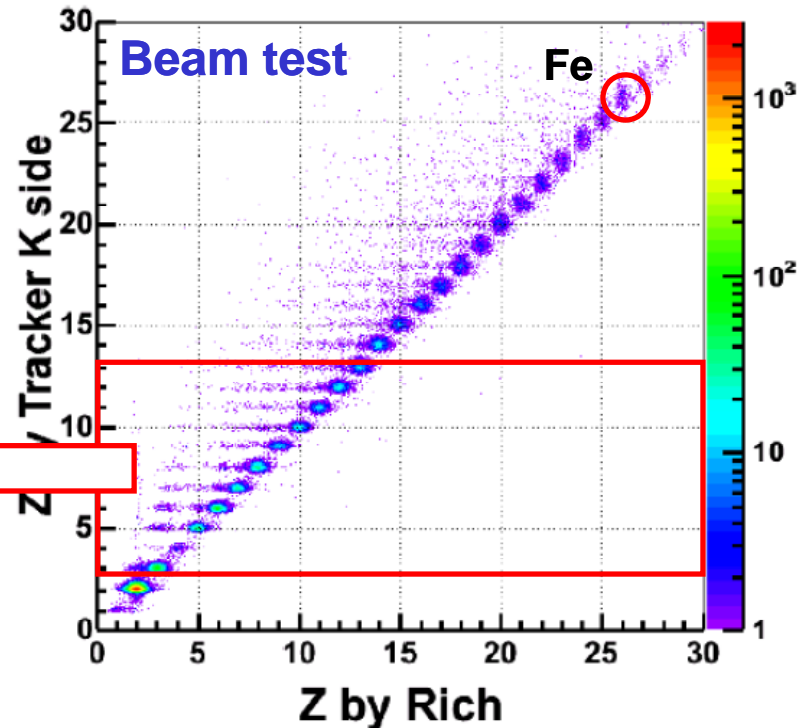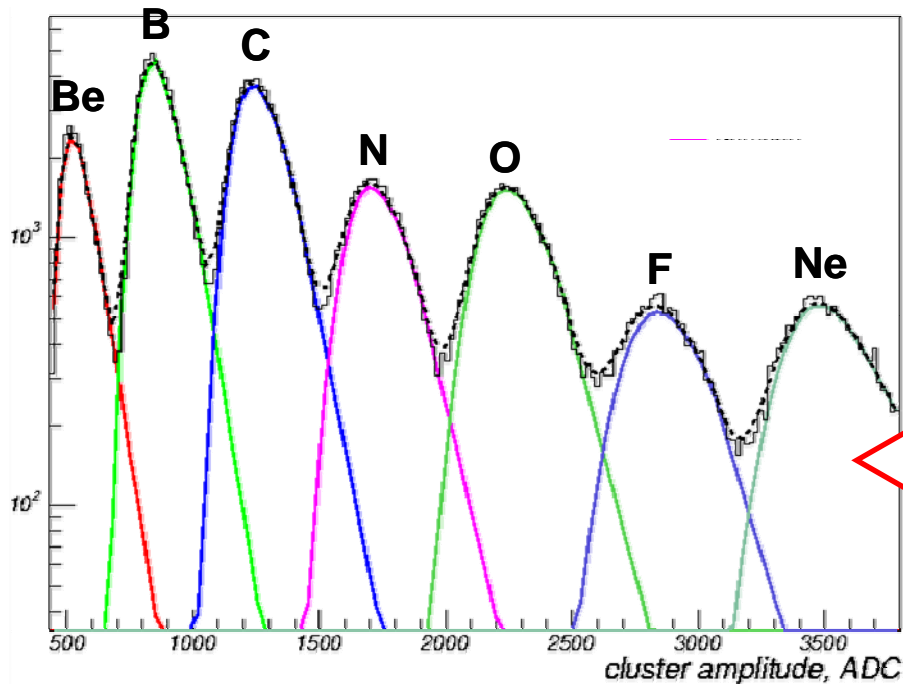- Trigger: TOF, ACC (no ACC for ions) or ECAL for γ
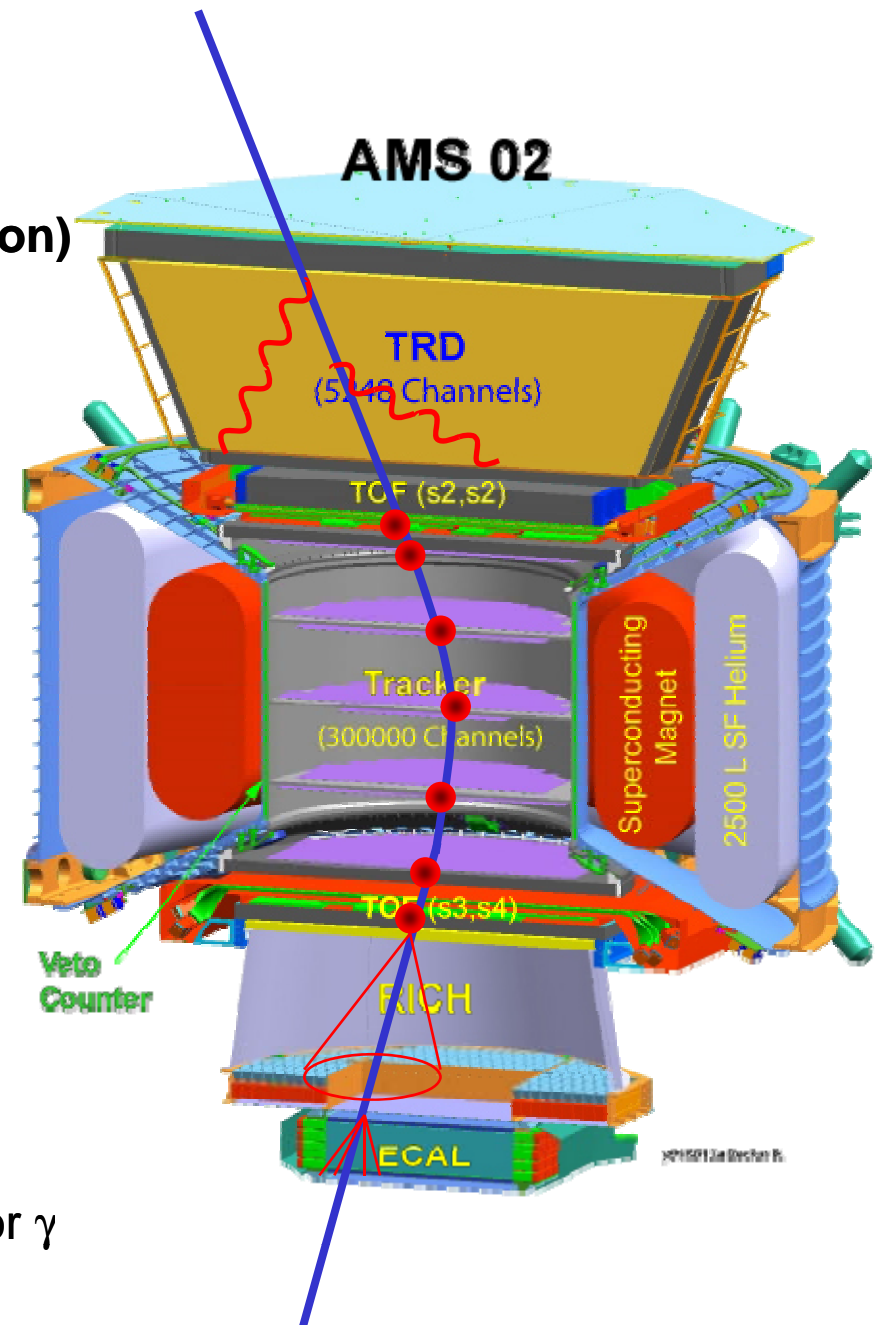
Charge measurement

The charge evaluation is redundant

- **Tracker**, TOF: energy deposition by ionization

- RICH: number of photons in the Cherenkov ring

$$\left(\frac{\mathrm{d}E}{\mathrm{d}X}\right)_{\text{bethe}} \propto Z^2$$

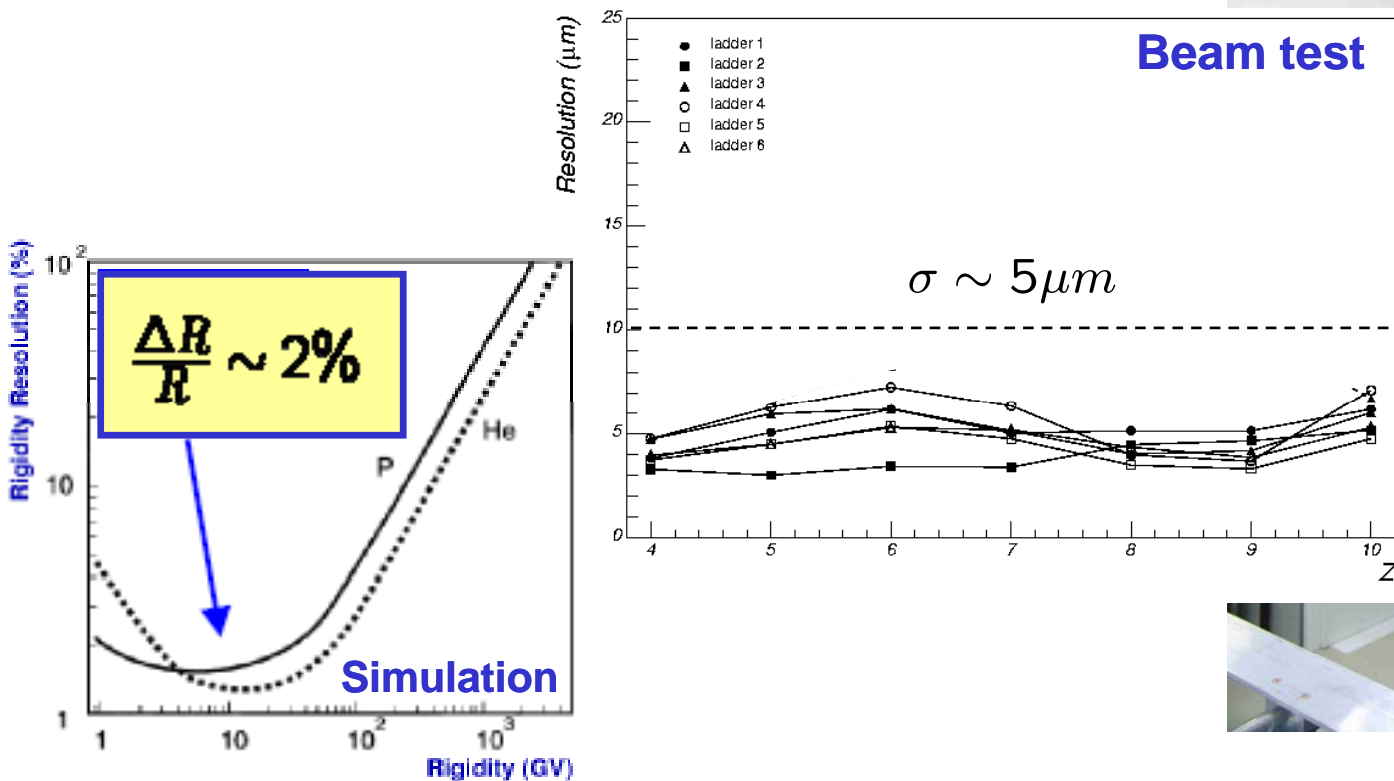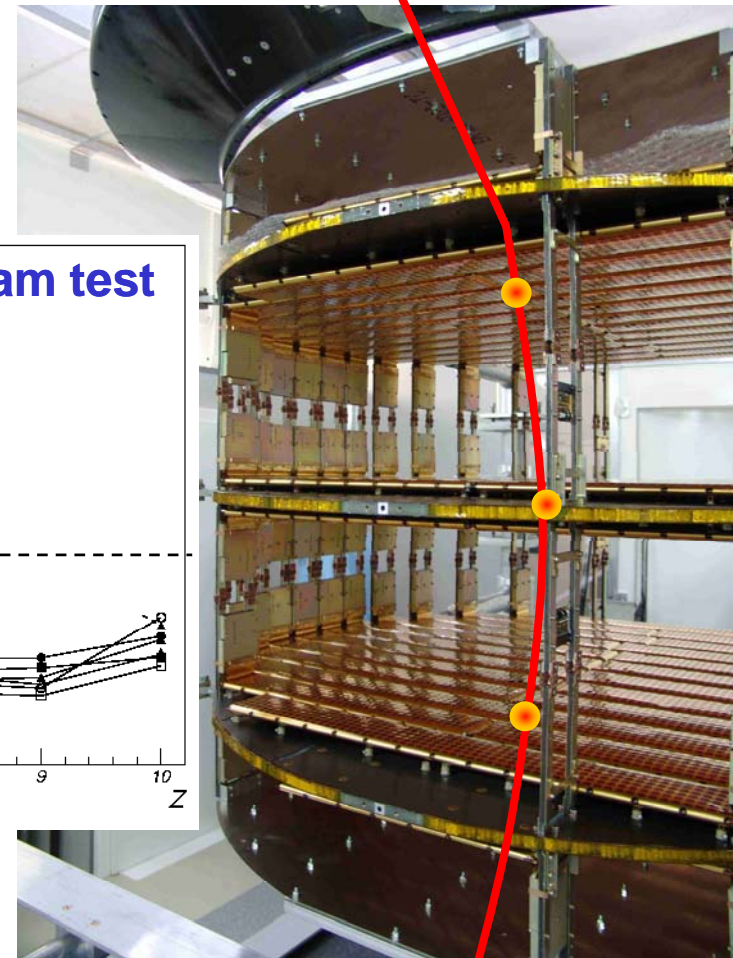$$N_\gamma \propto Z^2 \Delta L \left[1 - \frac{1}{\beta^2 n^2}\right]$$

Rigidity measurement

The AMS-02 Si Tracker:

- Silicon double-sided sensors

- 8 layers arranged in 5 planes

- Resolution < 10 μm in the bending direction

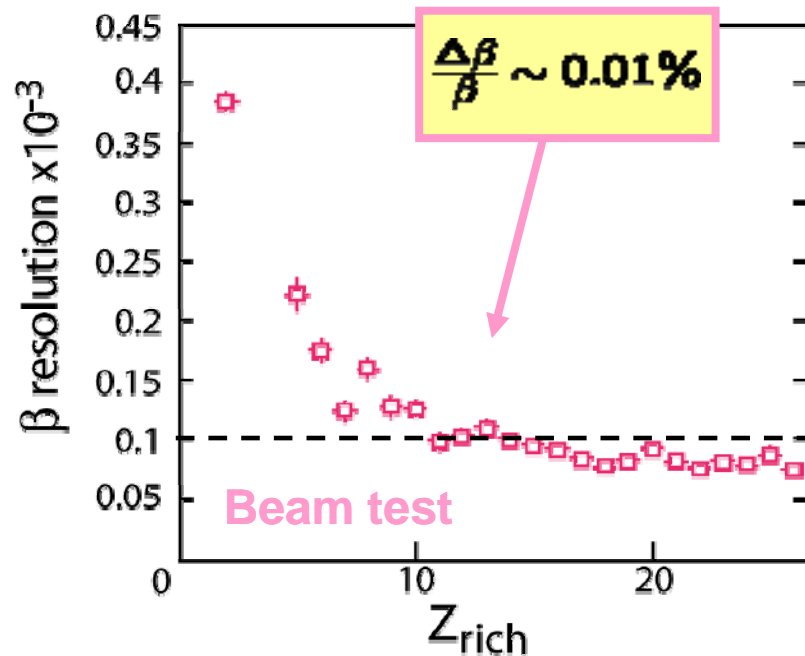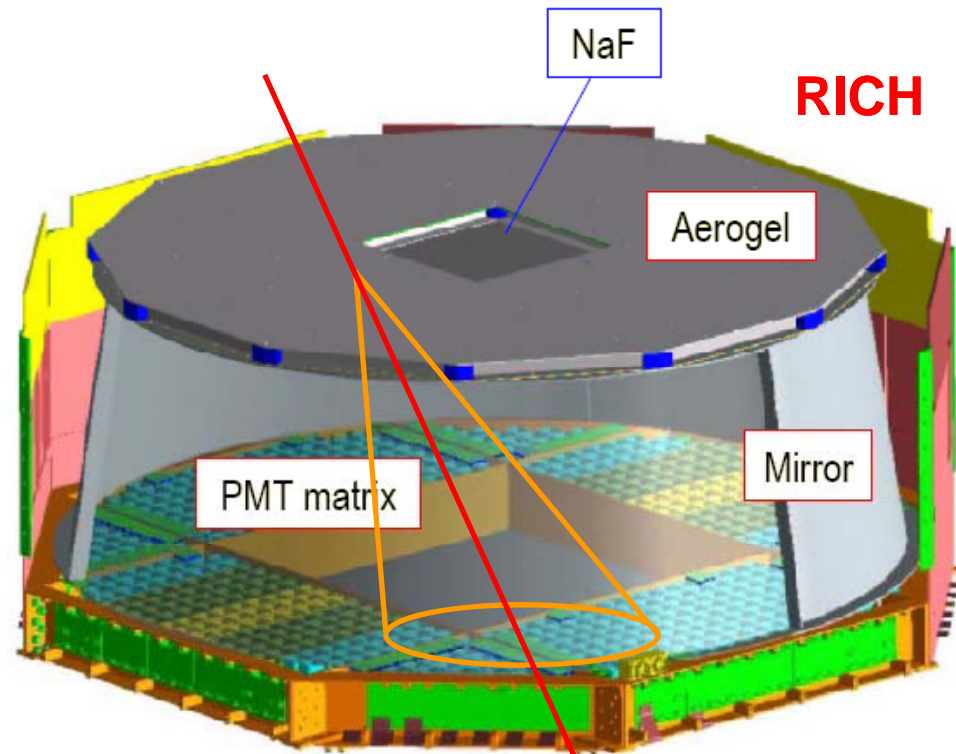- A rigidity determination of 2% at 10 GV
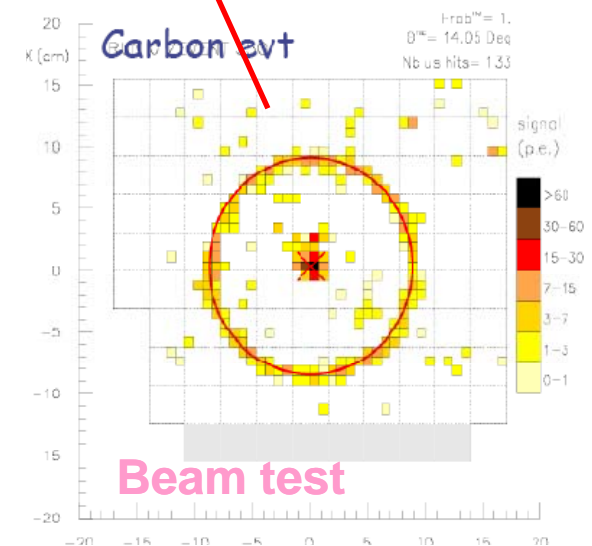
$$R = B\rho = \frac{p}{eZ}$$

$$\frac{\Delta R}{R} \sim 2\%$$

Simulation

Beam test

$$\sigma \sim 5\mu m$$

Velocity measurement

Redundant measurements

- TOF: $\beta = \Delta L / \Delta t$ with $\Delta\beta/\beta = 1\%$

- **RICH**: β with $\Delta\beta/\beta = 0.01\%$

RICH

NaF

Aerogel

Mirror

PMT matrix

$$\frac{\Delta\beta}{\beta} \sim 0.01\%$$

β resolution x10^{-3}

Beam test

Z_{rich}

$$\cos\theta_c = \frac{1}{\beta n}$$
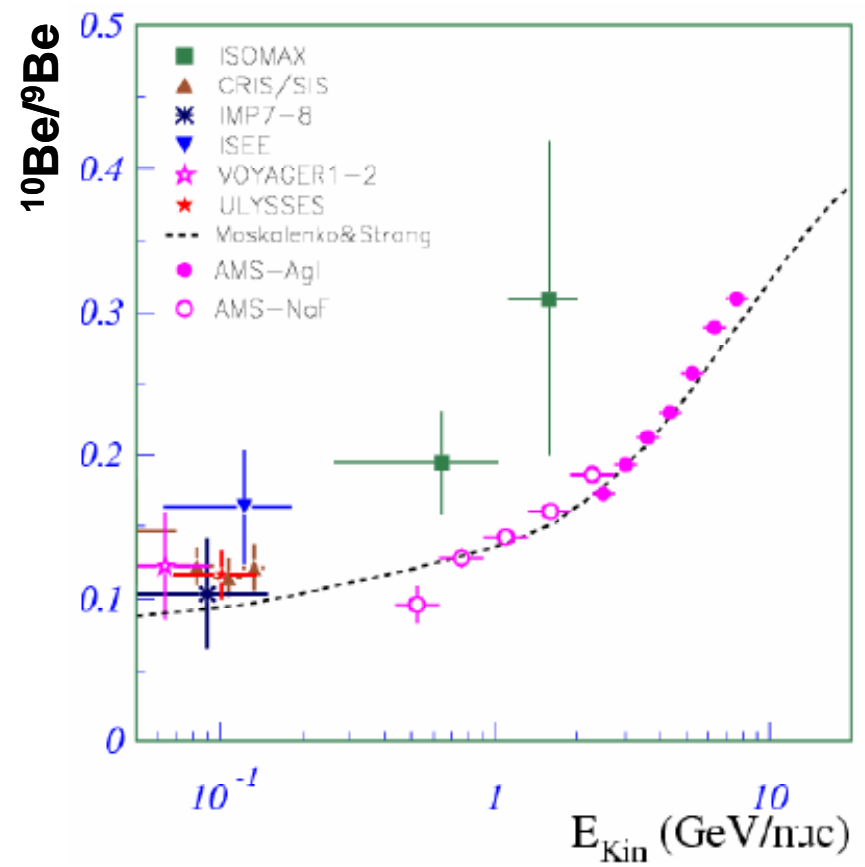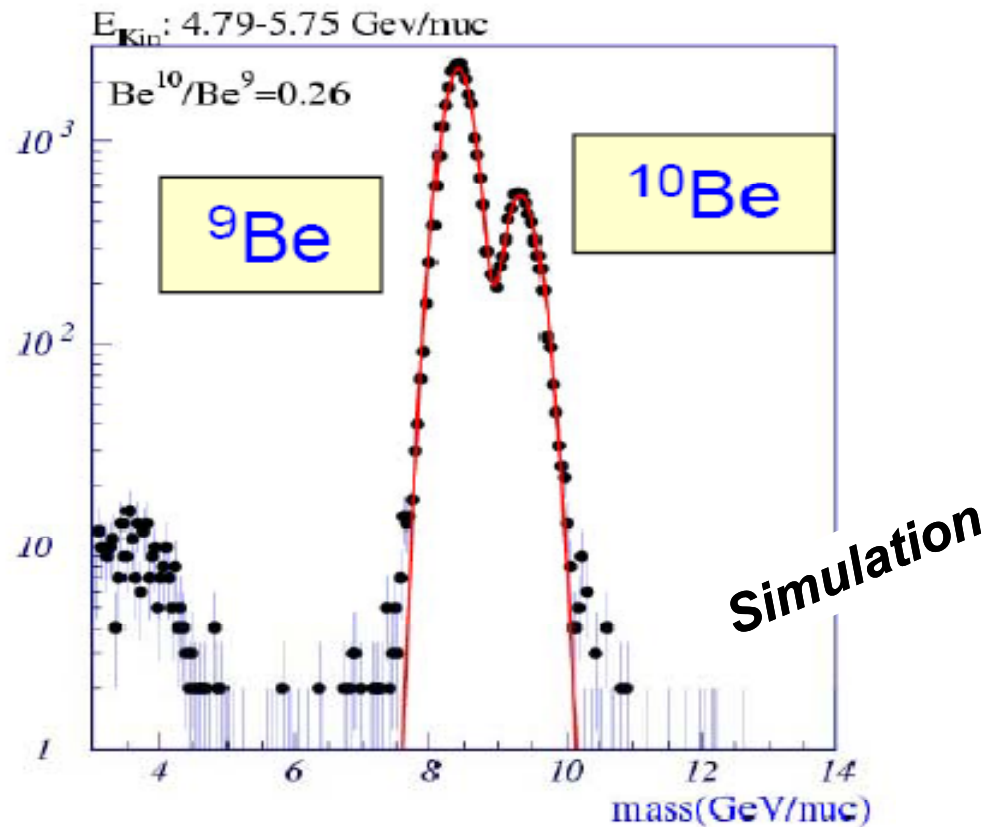
Carbon evt

Beam test

Mass measurement

The AMS-02 spectrometry

- Tracker for rigidity and charge

- RICH for velocity and charge

- Isotopic distinction up to 10 GeV/n

$$m = \frac{e}{c} \cdot \frac{RZ}{\beta\gamma}$$

$$\left(\frac{\Delta m}{m}\right)^2 = \left(\gamma^2 \frac{\Delta\beta}{\beta}\right)^2 + \left(\frac{\Delta R}{R}\right)^2$$

E_{Kin}: 4.79-5.75 Gev/nuc

$Be^{10}/Be^9 = 0.26$

^9Be

^{10}Be

Simulation

mass(GeV/nuc)

$^{10}Be/^9Be$

- ISOMAX
- CRIS/SIS
- IMP7-8
- ISEE
- VOYAGER1-2
- ULYSSES
- Moskalenko&Strong
- AMS-AgI
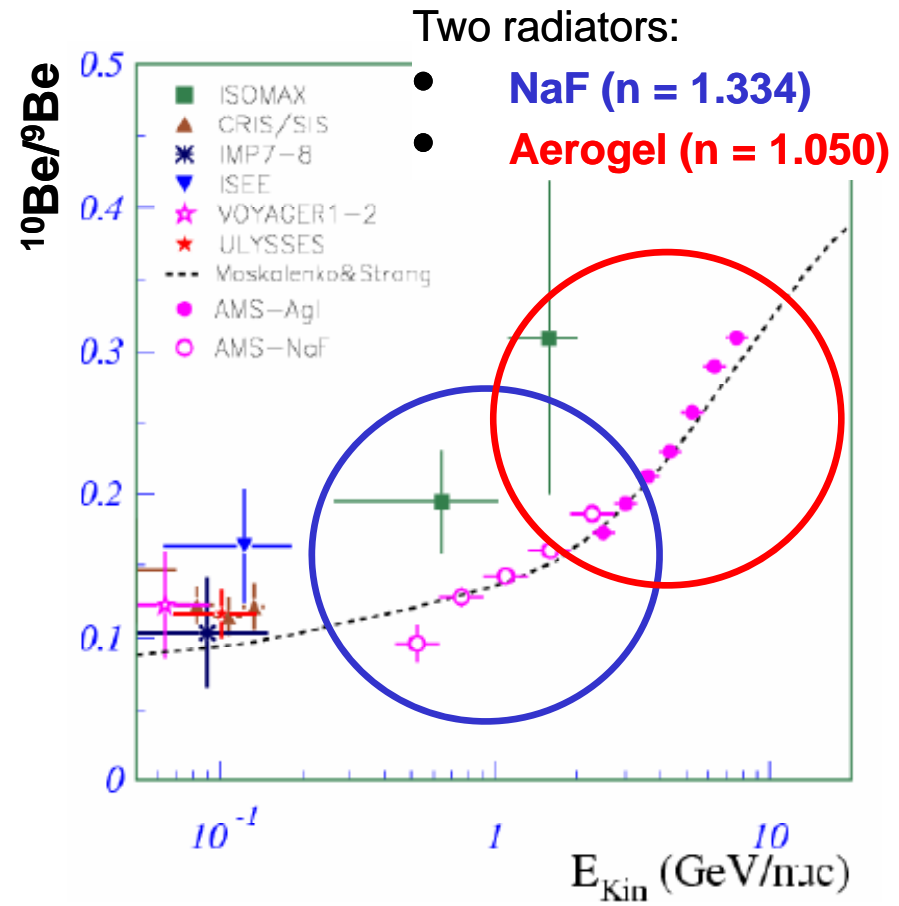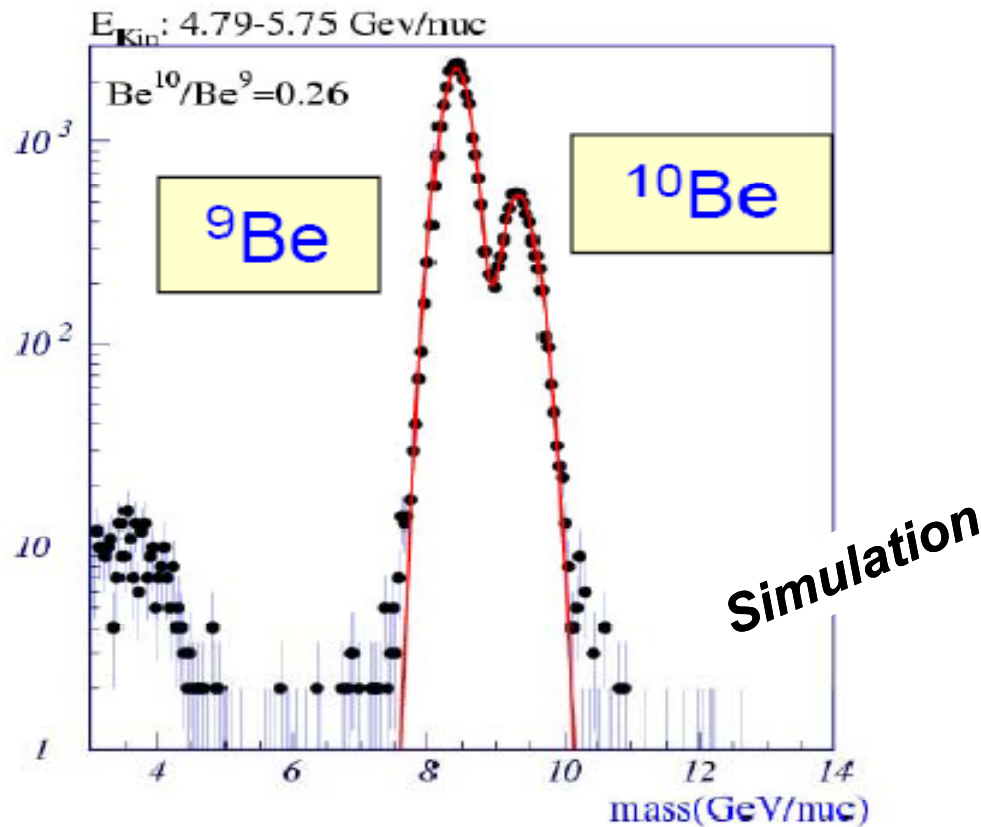- AMS-NaF

E_{Kin} (GeV/nuc)

Mass measurement

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- Tracker for rigidity and charge

- RICH for velocity and charge

- Isotopic distinction up to 10 GeV/n
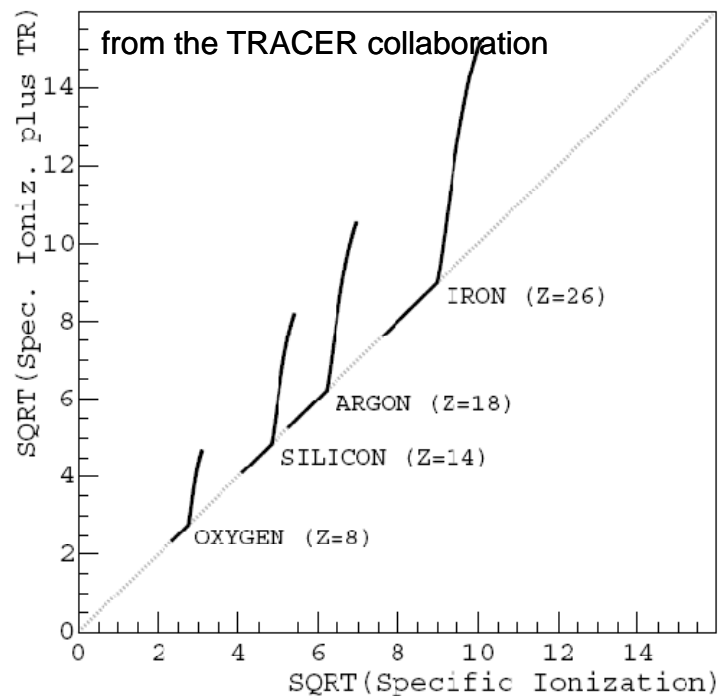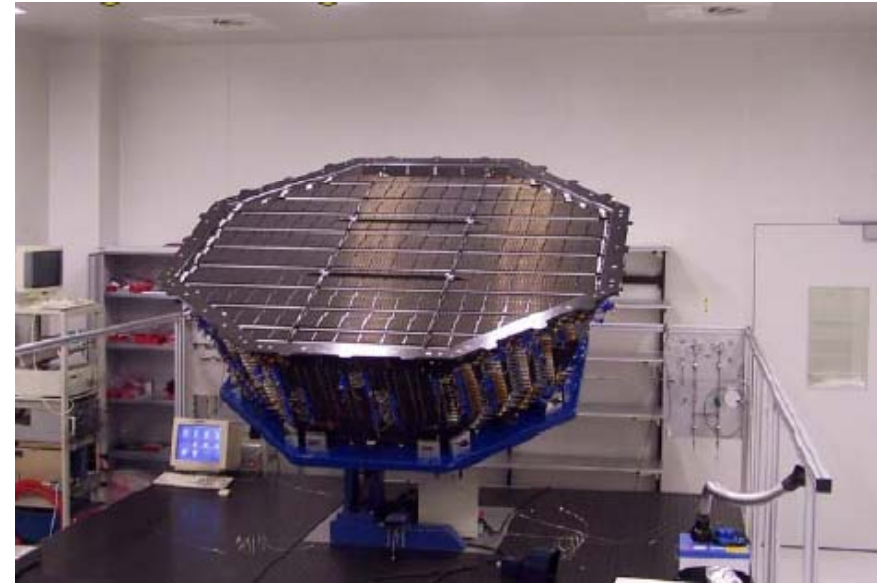
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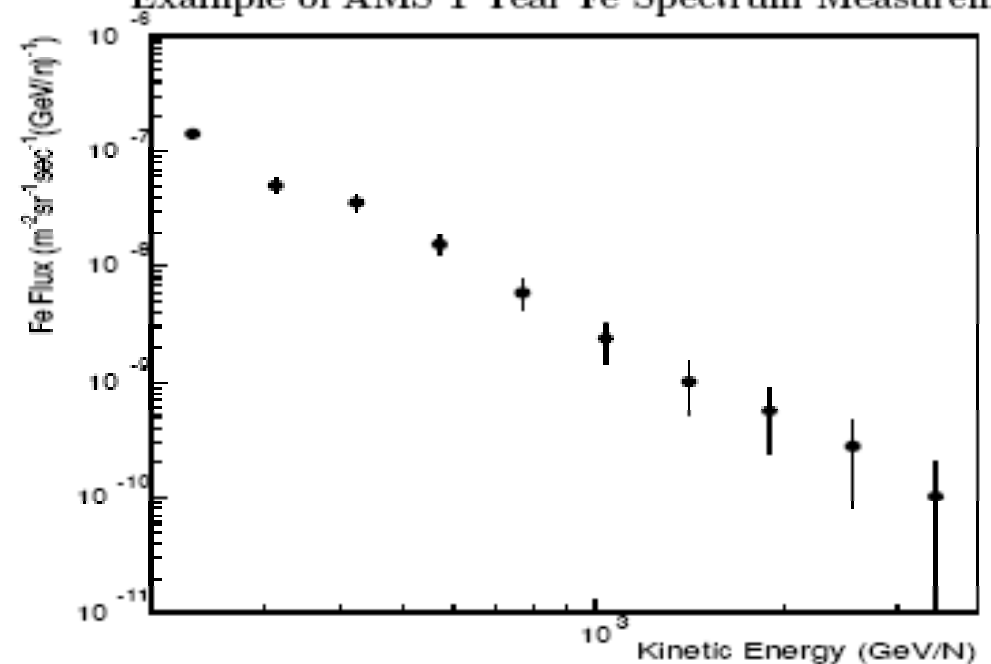

E_{Kin}: 4.79-5.75 Gev/nuc

$Be^{10}/Be^9 = 0.26$

^9Be ^{10}Be

Simulation

mass(GeV/nuc)

Two radiators:

- **NaF (n = 1.334)**
- **Aerogel (n = 1.050)**

$^{10}Be/^9Be$

- ISOMAX
- CRIS/SIS
- IMP7-8
- ISEE
- VOYAGER1-2
- ULYSSES
- Moskalenko&Strong
- AMS-AgI
- AMS-NaF

E_{Kin} (GeV/nuc)

Long term measurement
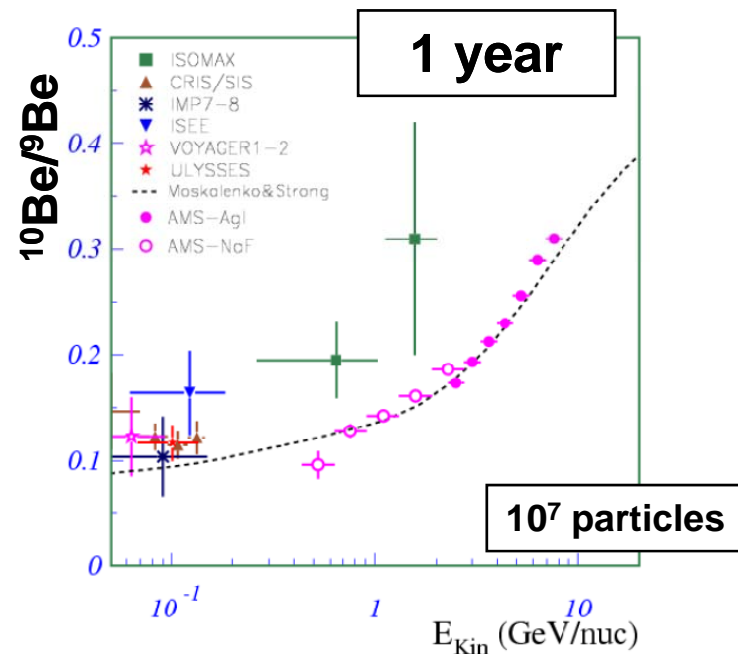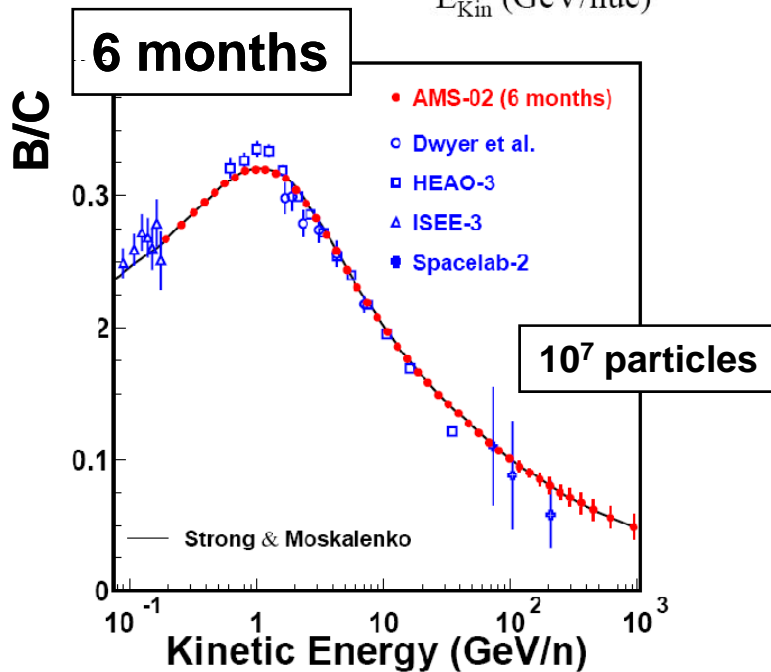
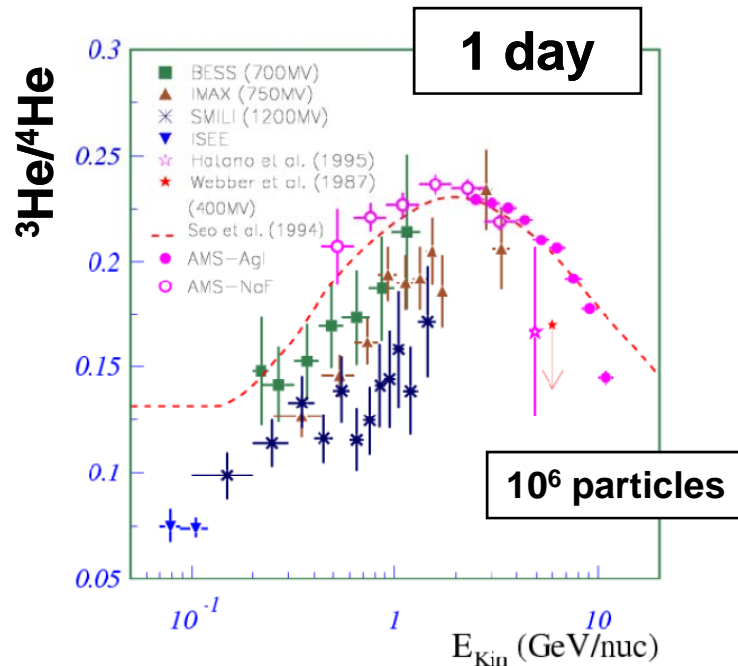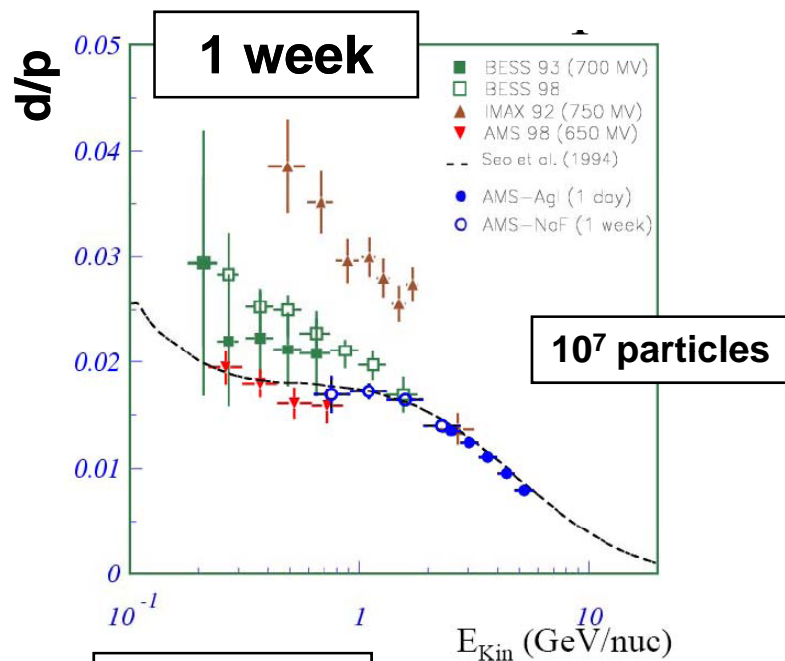After 3 years of "full" magnetic spectrometry:

- Lowering TRD gain by a factor 20

- Measure γ for charges up to Iron

- 10 – 30 % energy resolution

- From 200 to 4000 GeV/n

from the TRACER collaboration

IRON (Z=26)

ARGON (Z=18)

SILICON (Z=14)

OXYGEN (Z=8)

SQRT (Spec. Ioniz. plus TR)

SQRT (Specific Ionization)

Example of AMS 1 Year Fe Spectrum Measurement

Fe Flux (m^{-2}sr^{-1}sec^{-1}(GeV/n)$^{-1}$)

Kinetic Energy (GeV/N)

Expected Physics

Conclusions

- AMS-02 in the integration phase and will be installed on the ISS in 2009
- AMS-02 will perform high statistic measurement of all chemical species up to Iron in CR in a wide energy spectrum
- AMS-02 will play a key role in the CR Astrophysics studies

THANK YOU