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AMS-02 and the TOF detector: performance and physical perspectives

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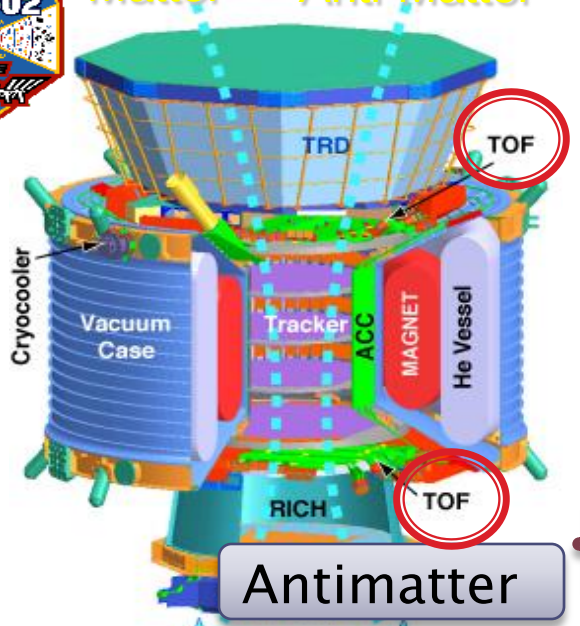
Main tasks



An Improved Version of AMS-01

Value	AMS-01	AMS-02
Mission lenght	10 days	10 years
MDR	150 GV	2.14 TV
He Statistics	2.86×10^6	$> 10^9$
$E_{max}\ (e^-)$	~ 30 GeV	1.4 TeV
$E_{max}\ (e^+)$	~ 3 GeV	350 GeV
$E_{max}\ (\bar{p})$	~ 3 GeV	450 GeV

Antimatter

Astrophysics, Dark Matter

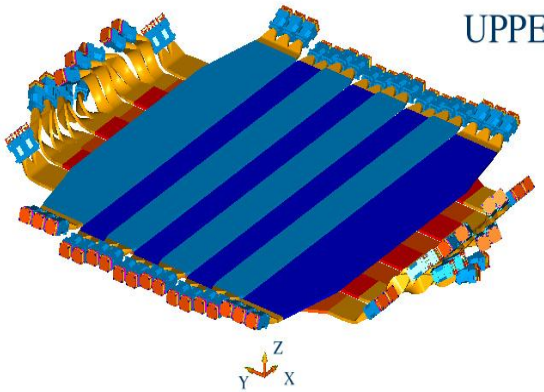
Strangelets

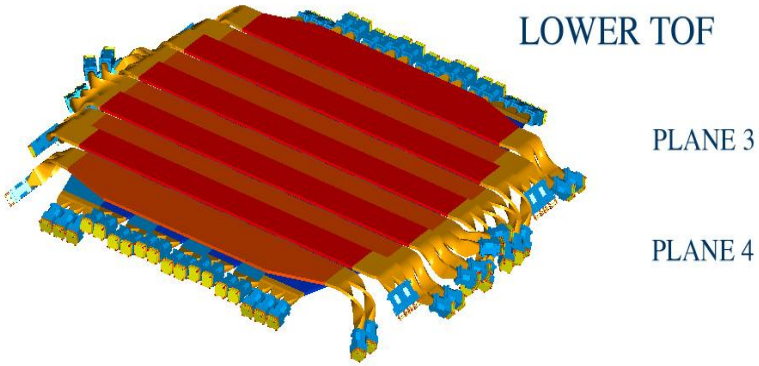
$$\frac{\overline{He}}{He} < 1.1 \times 10^{-6}$$

The TOF system provides:

- the **fast trigger** to the whole AMS and the selector of the events through the LT, HT and SH;
- the measurement of the time of flight (**Δt** – better than 180 ps), for the determination of the particle velocity (**β**), with a resolution of few %;
- the measurement of the **absolute particle charge** up to Z =15;
- the **distinction** from upward and downward going particles at a level of 10^{-9} necessary to distinguish between **matter and antimatter**;.

The AMS-02 TOF



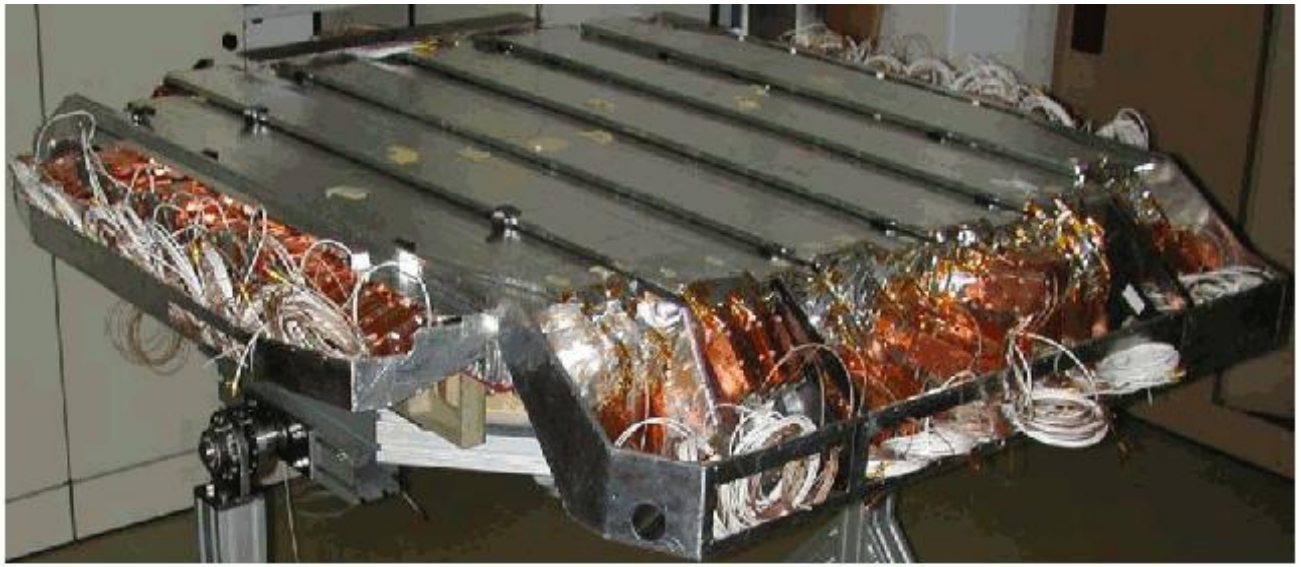


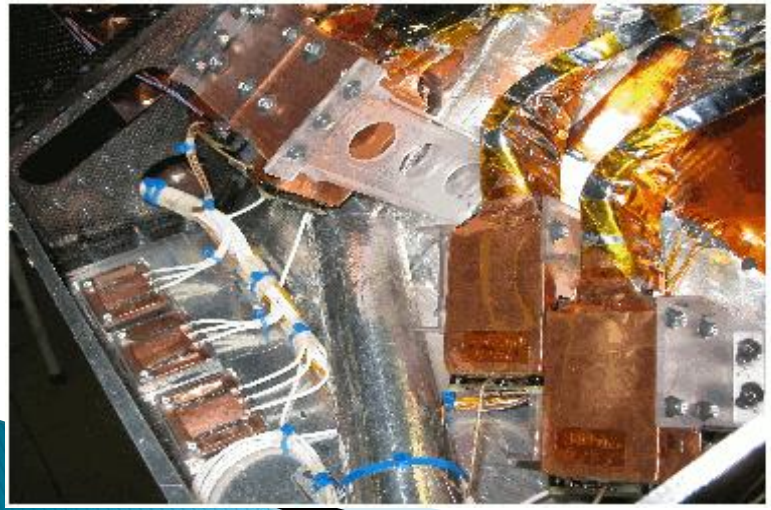
Hamamatsu fine-mesh R5946

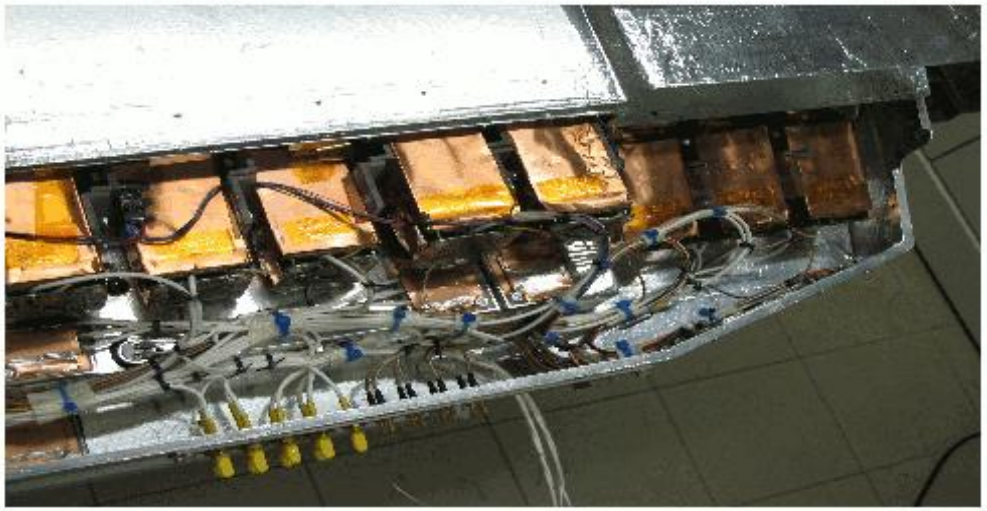
TOF consists of 4 plastic scintillator planes, 2 above and 2 below the magnet.
The counters of adjacent planes are orthogonal.
The number of counters per plane has been reduced to 8, 8, 10, 8 counters to reduce the weight (34 scintillators).

Each TOF counter is composed by:
- **a plastic scintillator** 1 cm thick and around 120 cm long (Eljen-Technology type: Ej-200),
- **read at both ends by 2 independently powered photomultiplier tubes** (fine-mesh Hamamatsu R5946 with max spectral response at 420 nm),
- **connected with transparent light guides**.

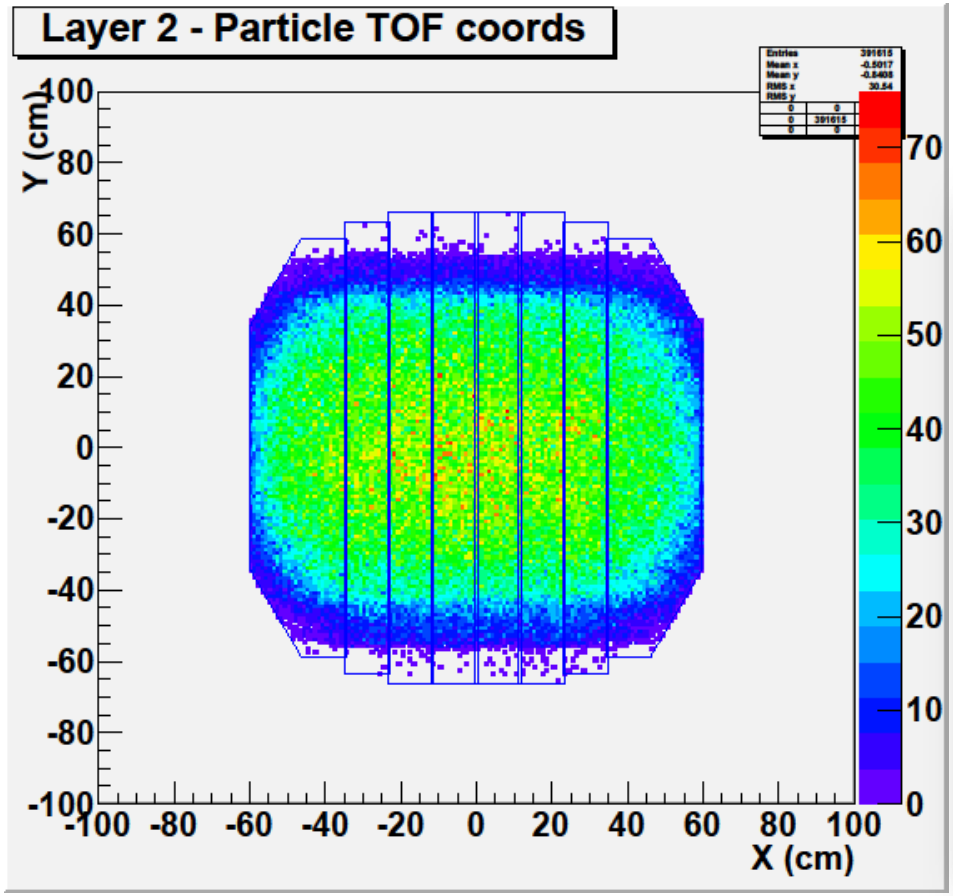
The AMS-02 TOF



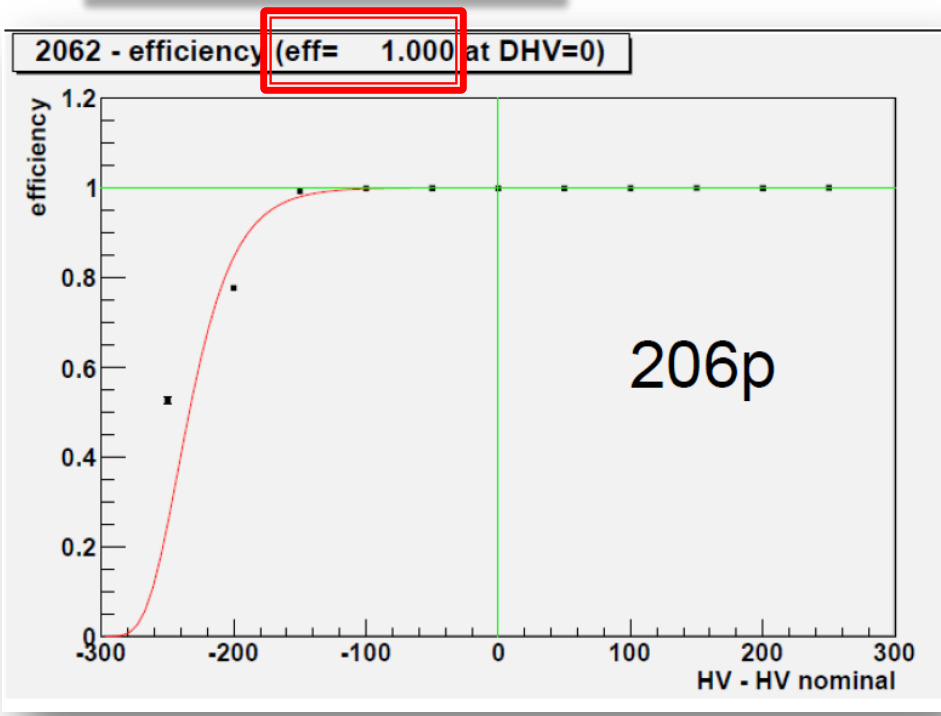




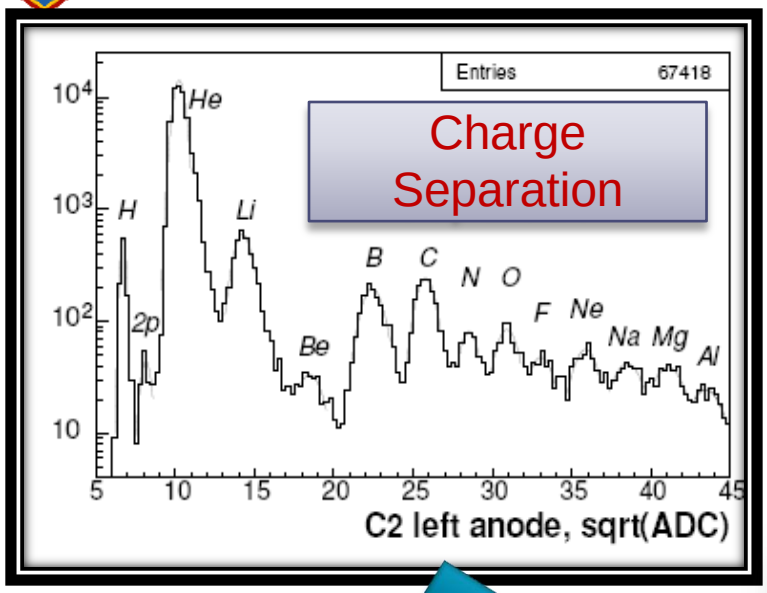
The AMS-02 TOF



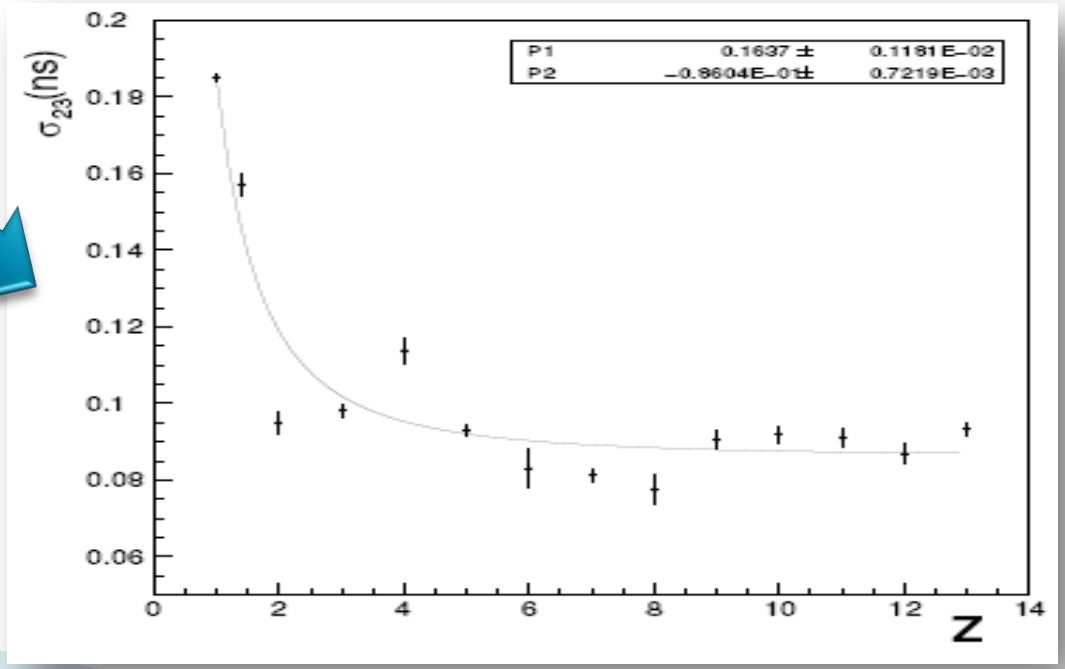
On the ISS



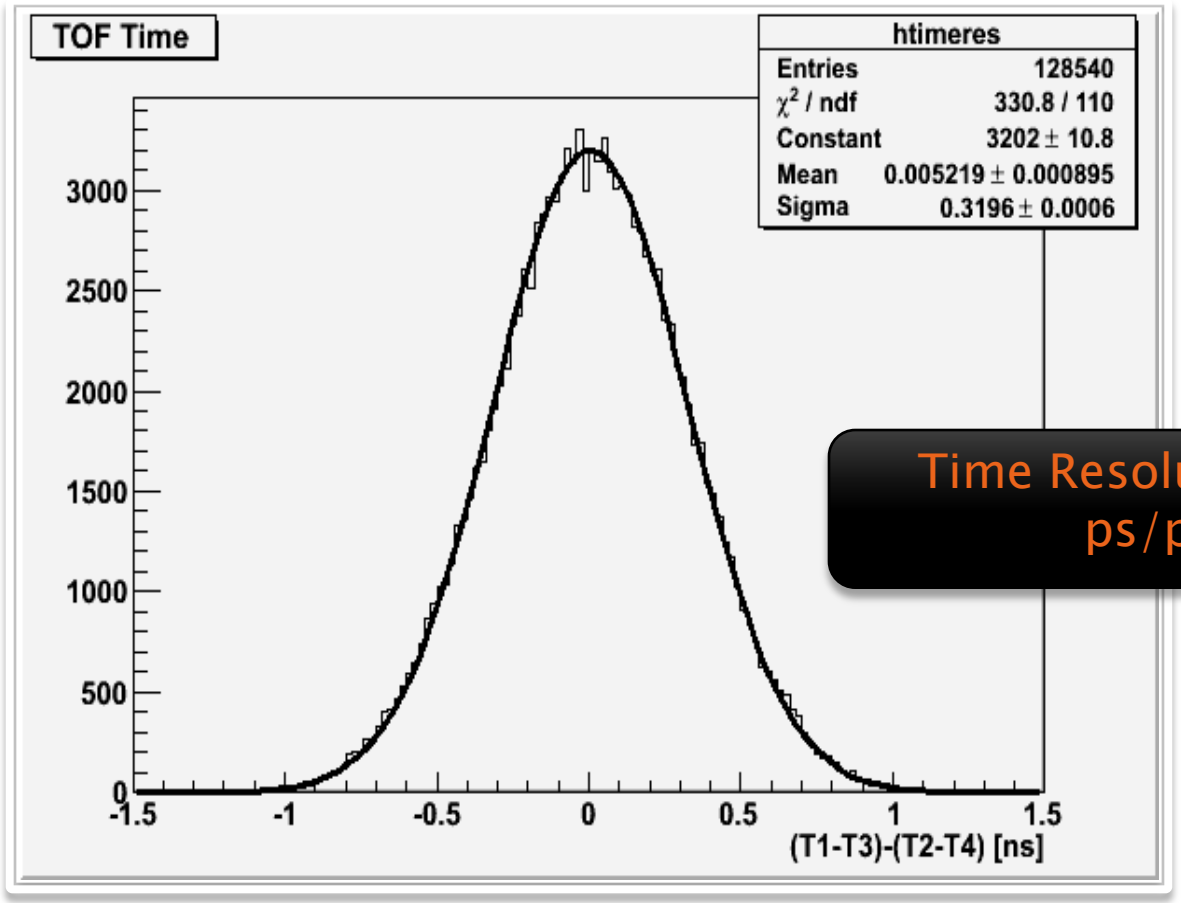
Performance - Charge



Time Resolution



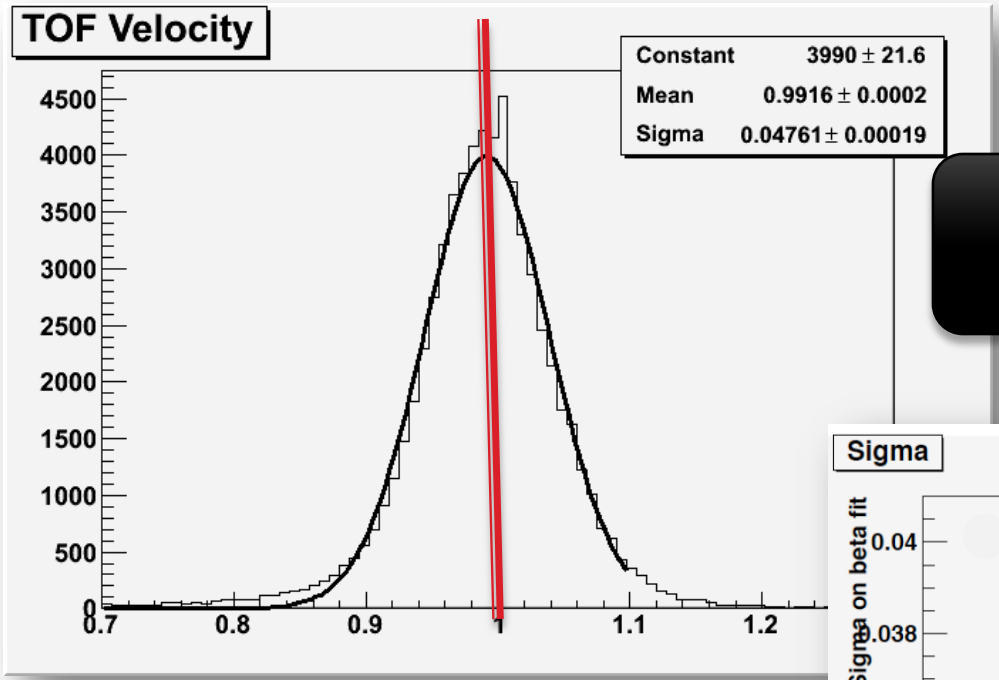
Performance - Time



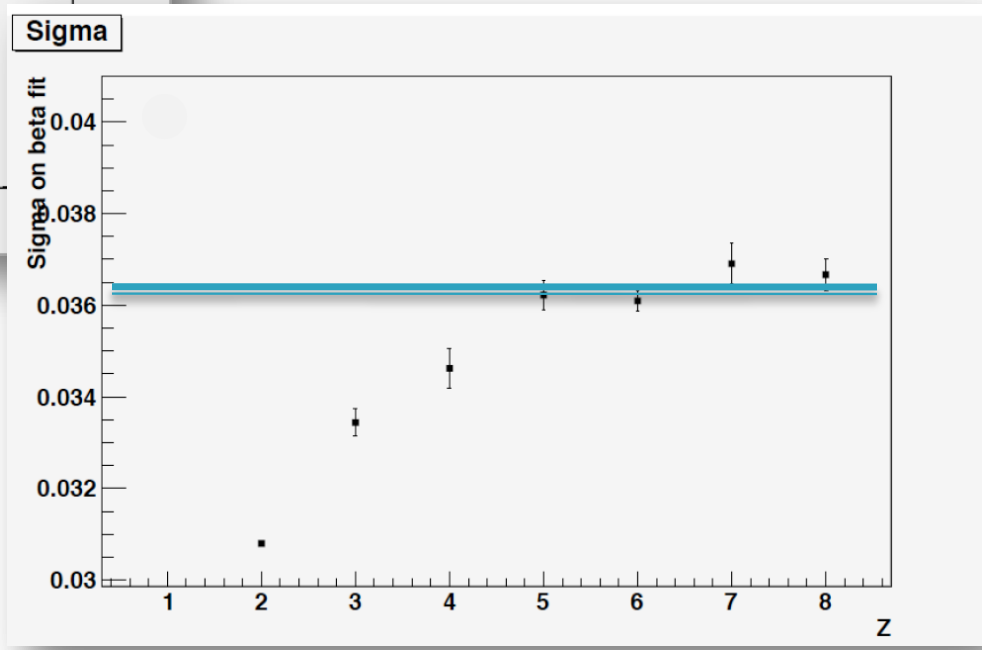
p

Time Resolution: 160 ps/pad

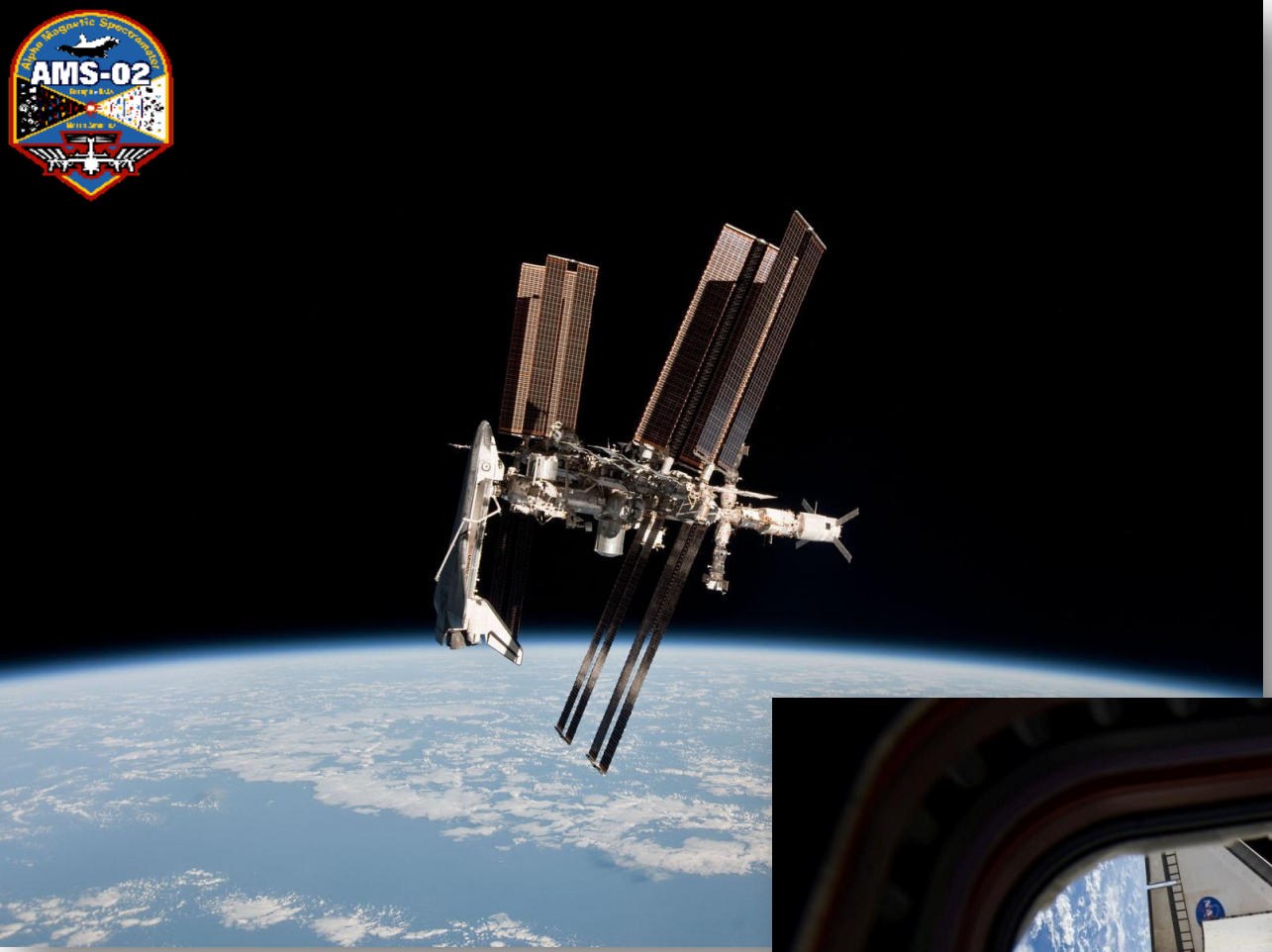
TOF response to Z=1 particles in space - Velocity

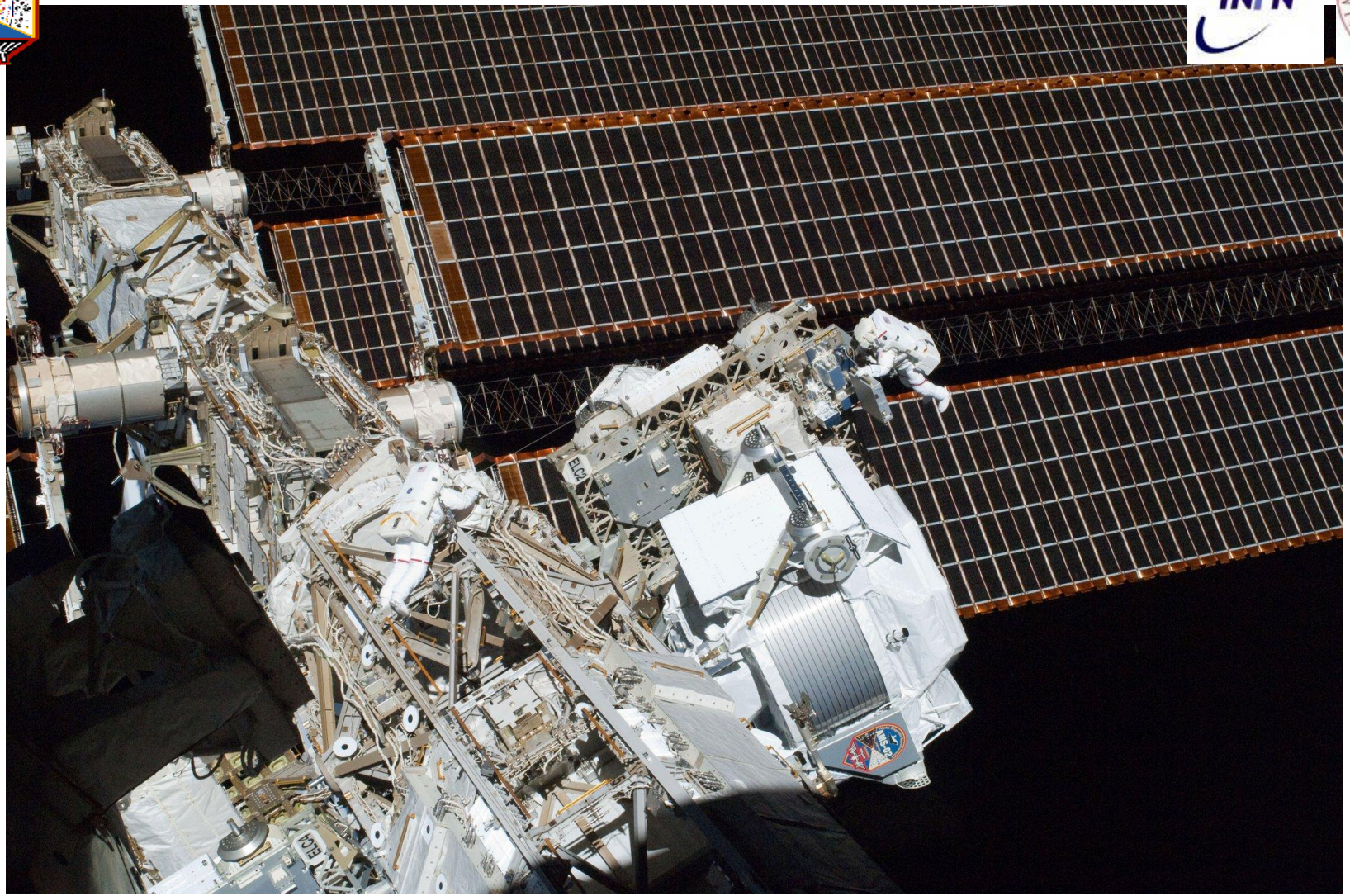


β Resolution:
>4.8%



Go baby go!




ELC2
ELC4

And physics begins

AMS-02 and the Antiworld
Island of Antimatter?

The CPT theorem assures that any particle species there exists the antiparticle with exactly the same mass and decay width and eventually opposite charges.
This striking symmetry would naturally lead us to conclude that the Universe contains particles and antiparticles in equal number densities.

The observed Universe is drastically different.

- 100 MeV γ flux excludes wide antimatter regions up 100 Mpc
- Sakharov's 3 Principles of Baryogenesis .....

  ... but alternative models predict distant antimatter local domains
- A single anti-He CR nucleus represents a strong evidence for Antimatter Domains in our Universe

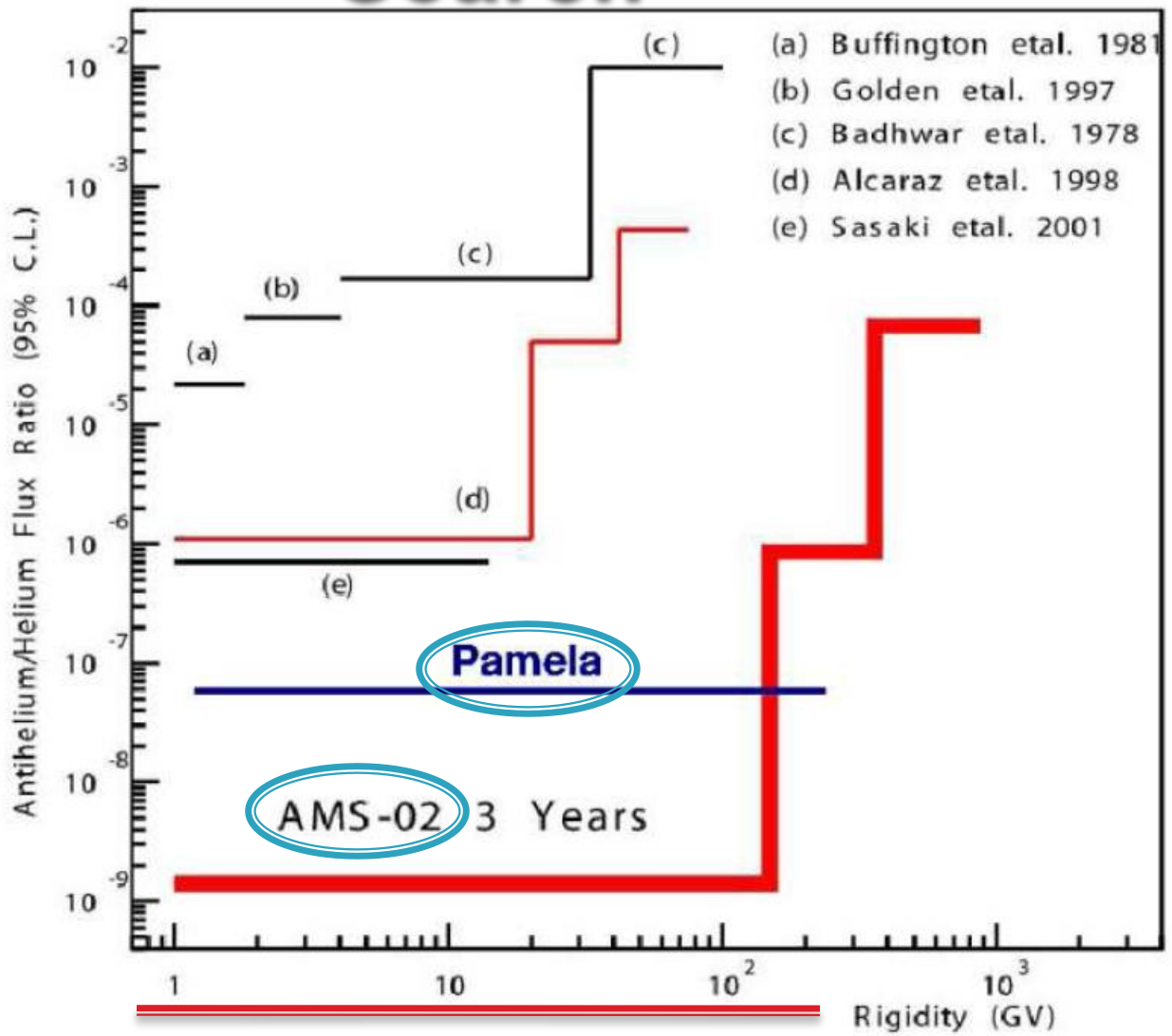
Expected Goal for Antinuclei Search

Expected number of detected cosmic ray particles above a given energy threshold in three years of data

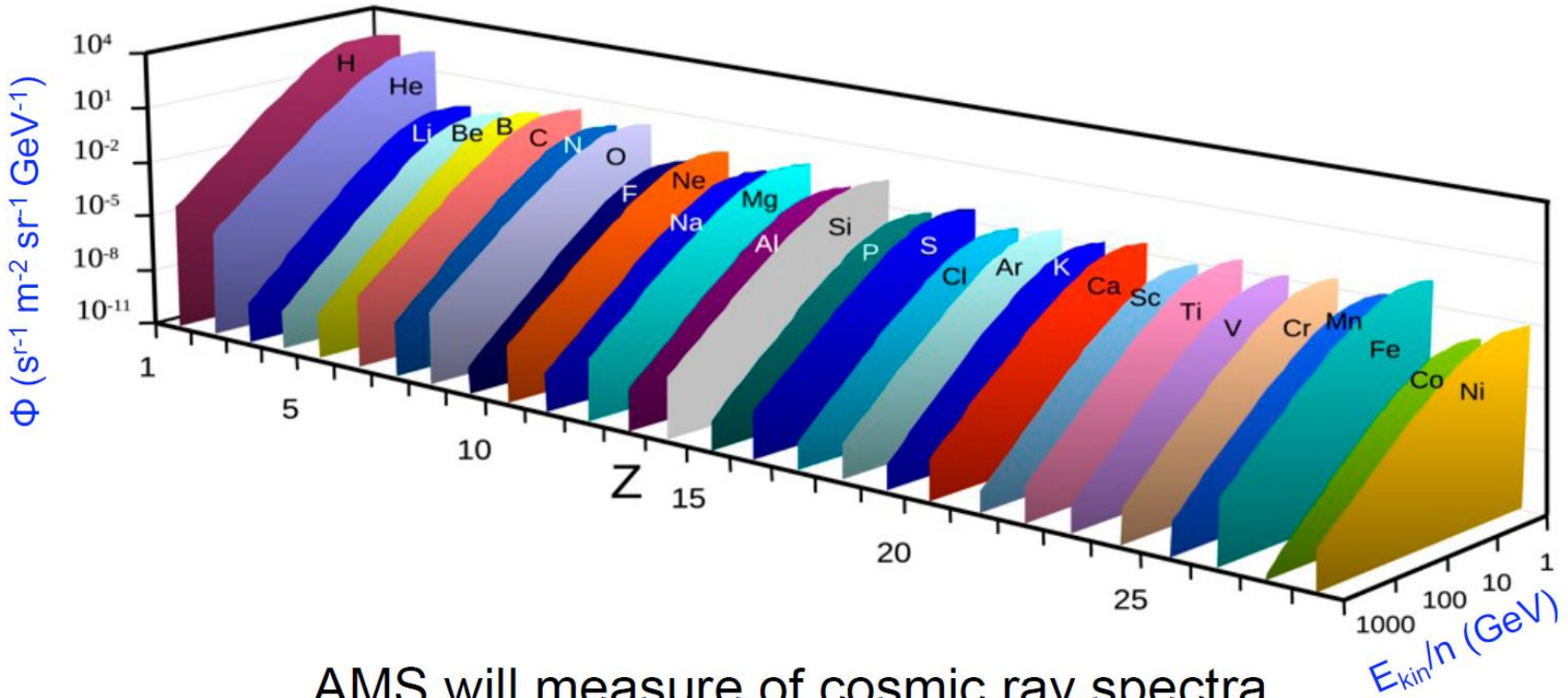
	$> 1\,\mathrm{GeV/c}$	$> 10\,\mathrm{GeV/c}$	$> 10^2\,\mathrm{GeV/c}$	$> 1\,\mathrm{TeV/c}$
p		6.1×10^9	1.5×10^8	2.5×10^6
	^{8}	6.8×10^6	7.2×10^4	4.4×10^2
		3×10^5	1.6×10^3	6
	^{8}	6.8×10^6	7.2×10^4	4.4×10^2
He	6.4×10^8	2.1×10^8	7.3×10^6	1.7×10^5

Antihelium/Helium Flux

Expected Goal for Antinuclei Search



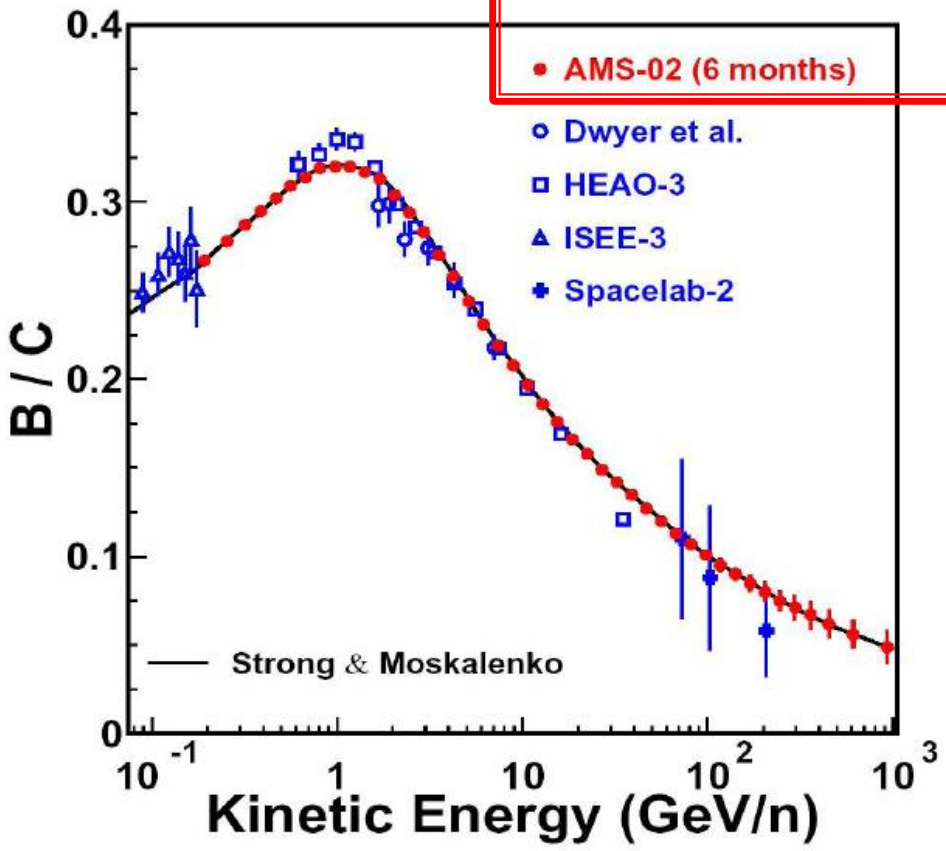
Cosmic Rays

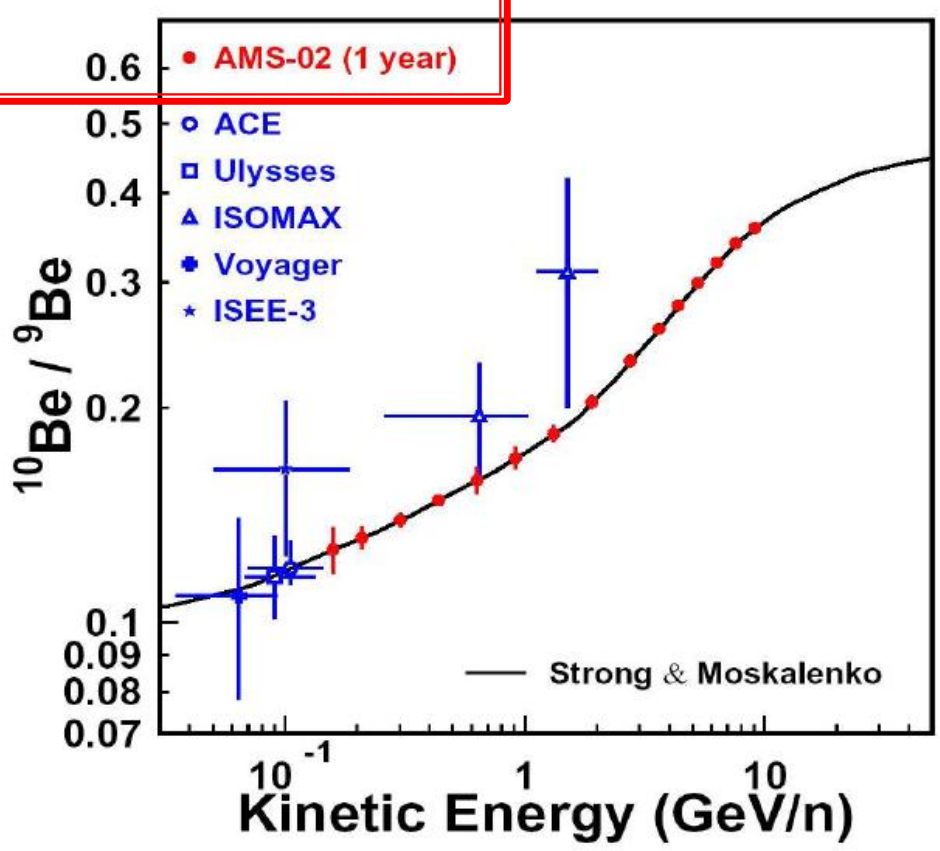


AMS will measure of cosmic ray spectra
for nuclei, for energies from 100 MeV to 2 TeV
with 1% accuracy continuously over the solar cycle.

The isotopic composition of the CR is correlated with their propagation mechanisms

CR Propagation Constraint





Light nuclei ratios to fix the propagation parameters and improve the accuracy of GALPROP

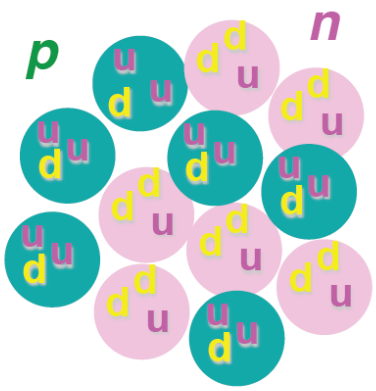
New Physics: Strangelets

There are six types of Quarks found in accelerators (u, d, s, c, b, t).

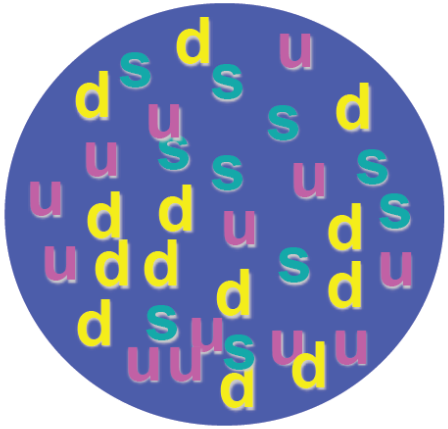
All matter on Earth is made out of only two types (u, d) of quarks.

"Strangelets" are new types of matter composed of three types of quarks (u, d, s) which should exist in the cosmos.

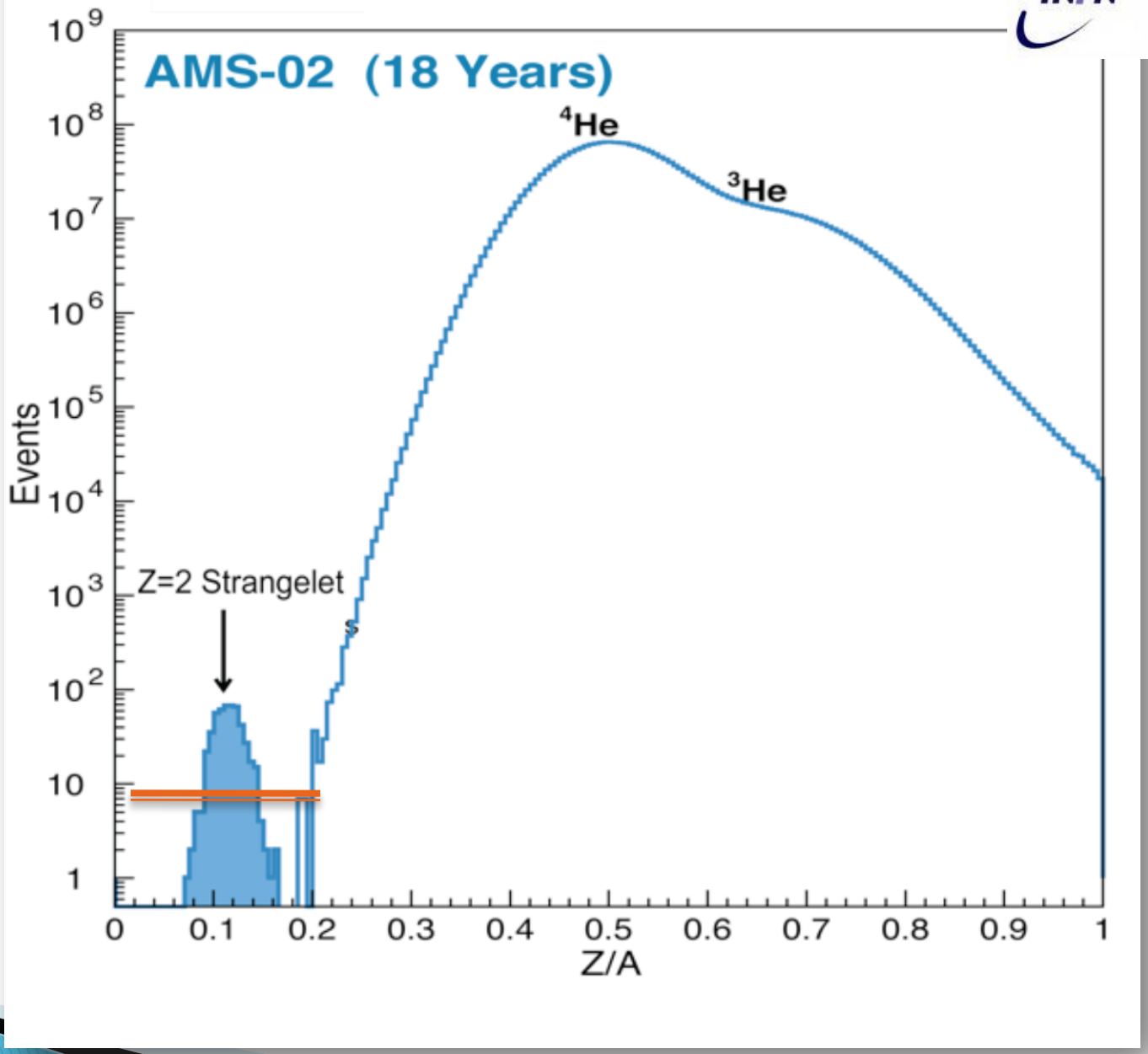
Carbon Nucleus
Z/A ~ 0.5



Strangelet
Z/A ~ 0.1

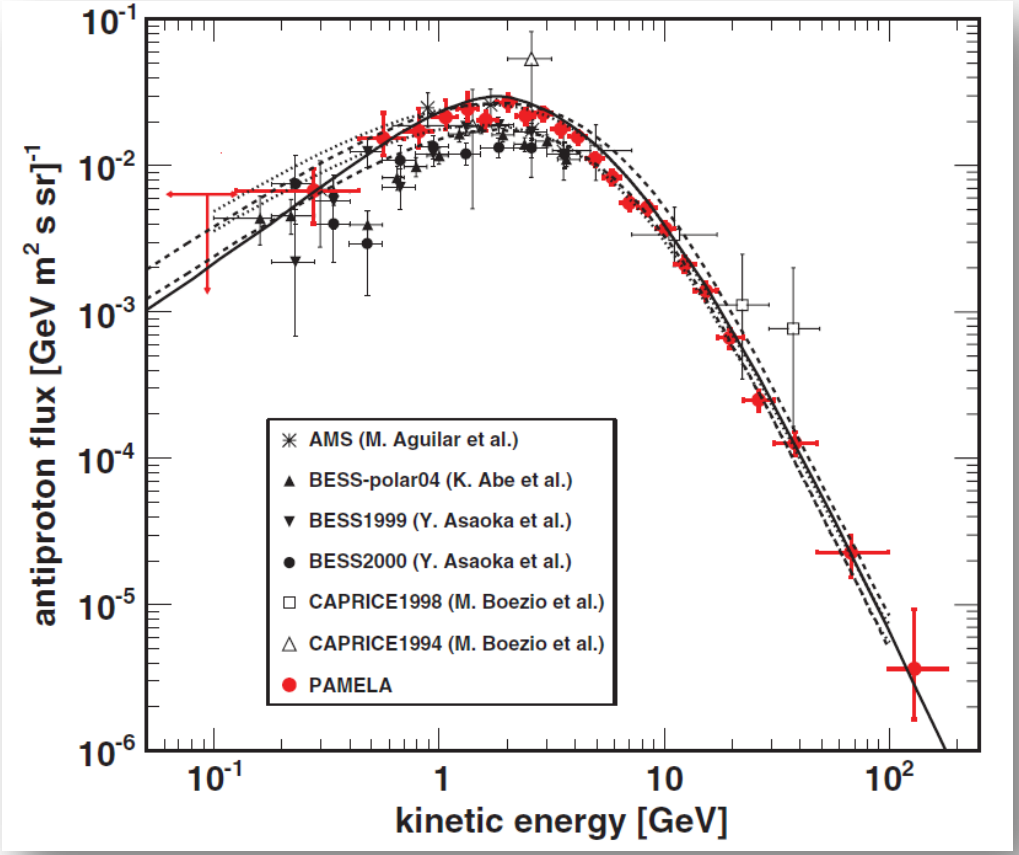


$\Phi_{strangelets} = 5x10^{-10}(cm^2 s\ sr)^{-1}$



Dark Matter Program (TOF Group)

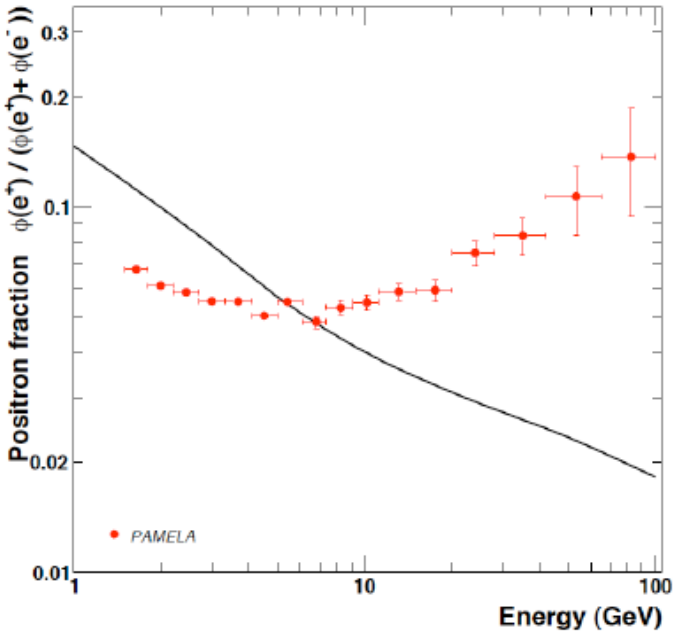
Indirect detection via annihilation/decay chain products: antiproton, positron, gamma, antideuteron



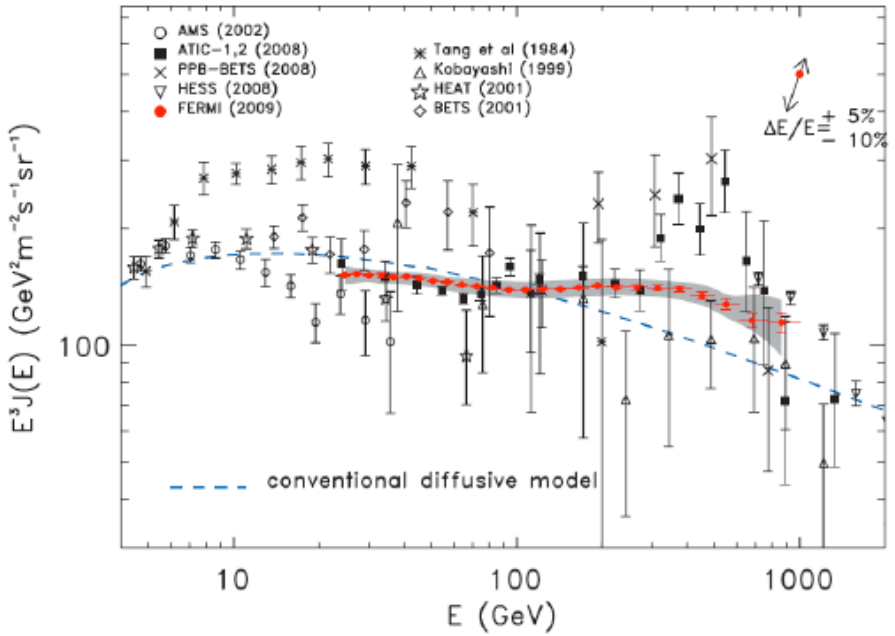
PAMELA results on the Cosmic-Ray Antiproton Flux

No Dark Matter Signal!

Are we seeing dark matter?

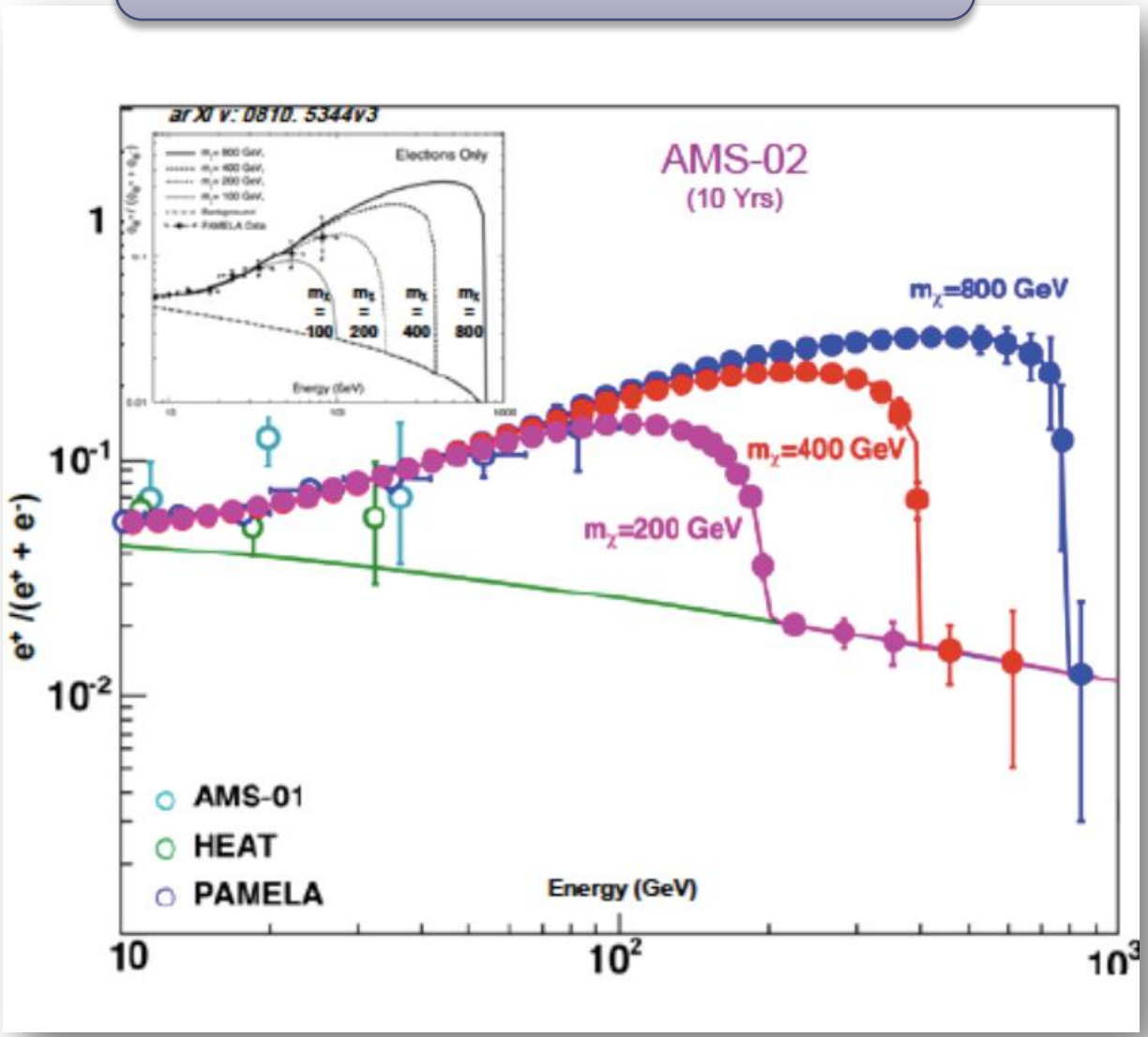


PAMELA requires:
leptons but no antiprotons.



Fermi and Hess set the mass:
$M_{\rm DM} \simeq 2 - 3$ TeV

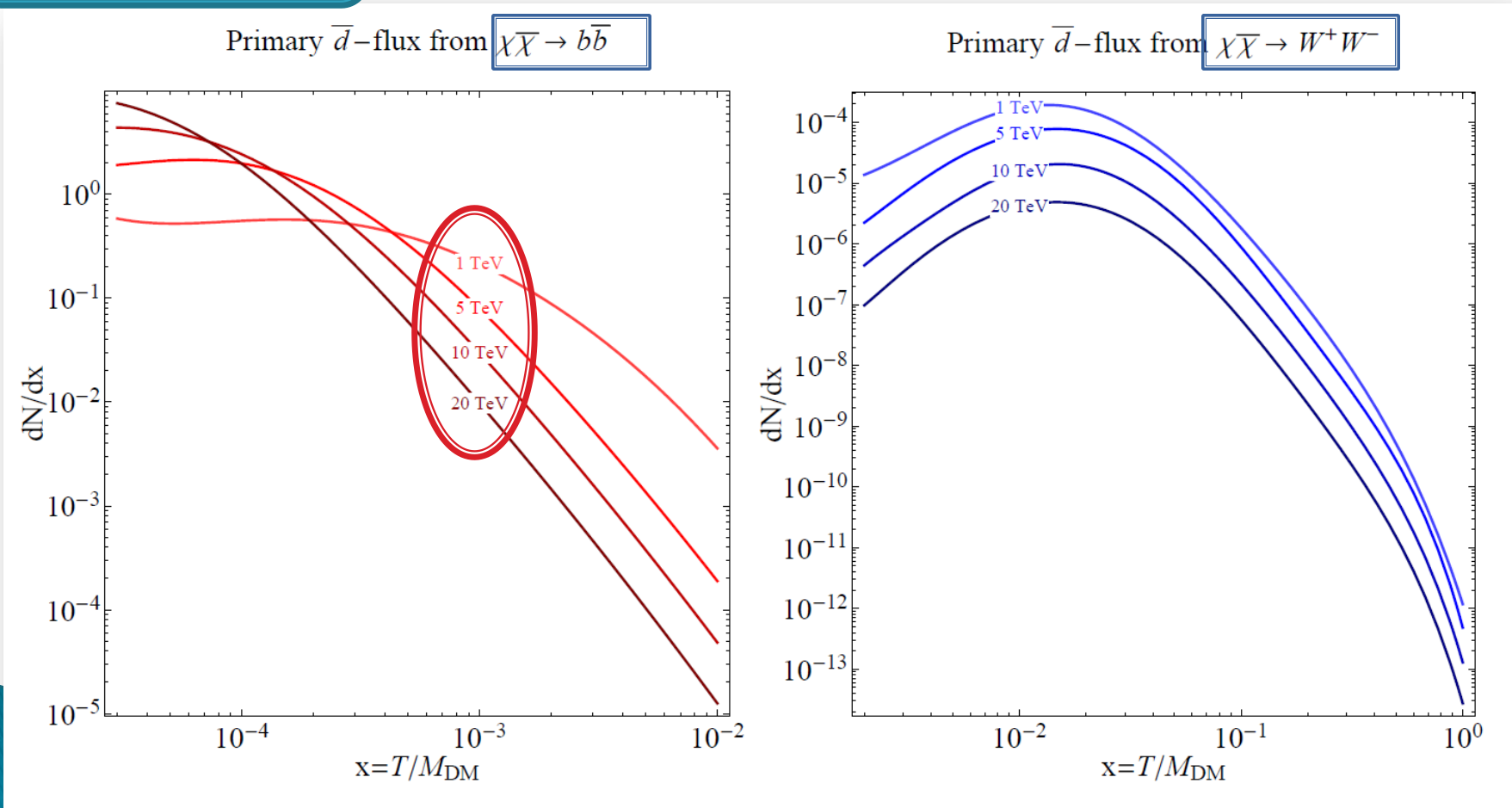
Primary CR Positron from Dark Matter



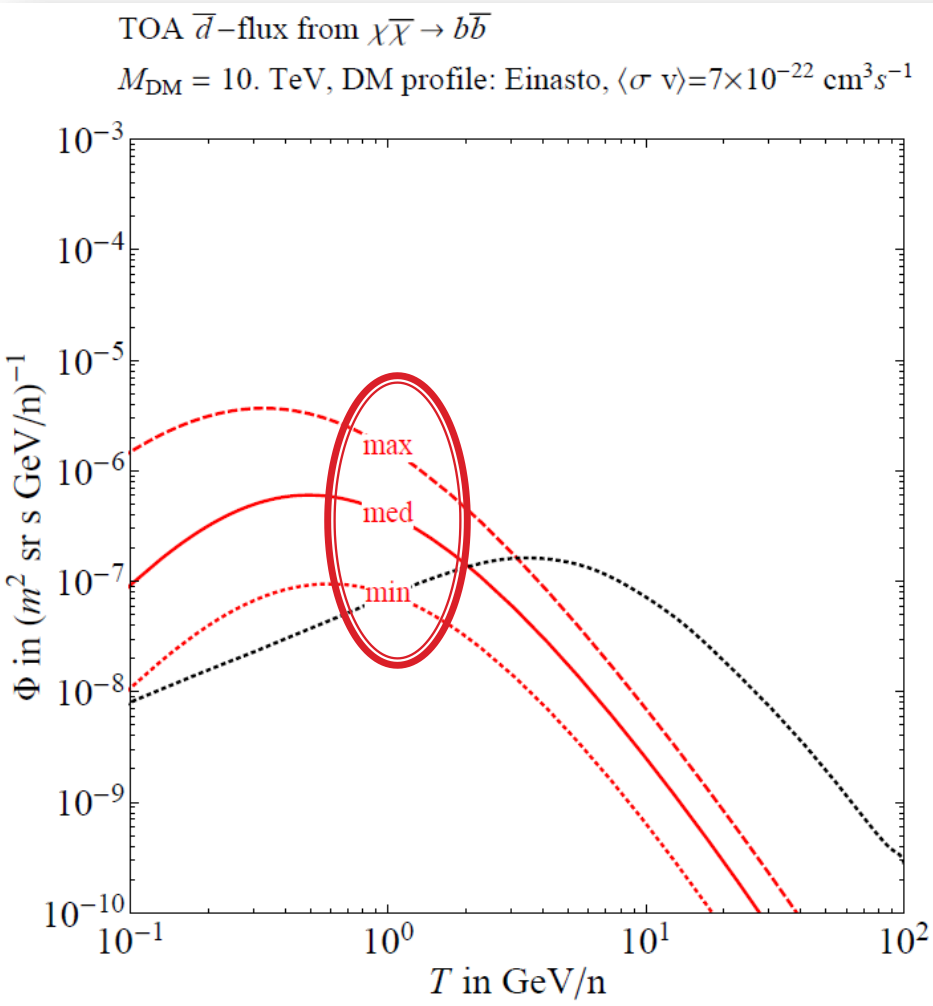
Antideuteron Flux and Uncertainties comparison

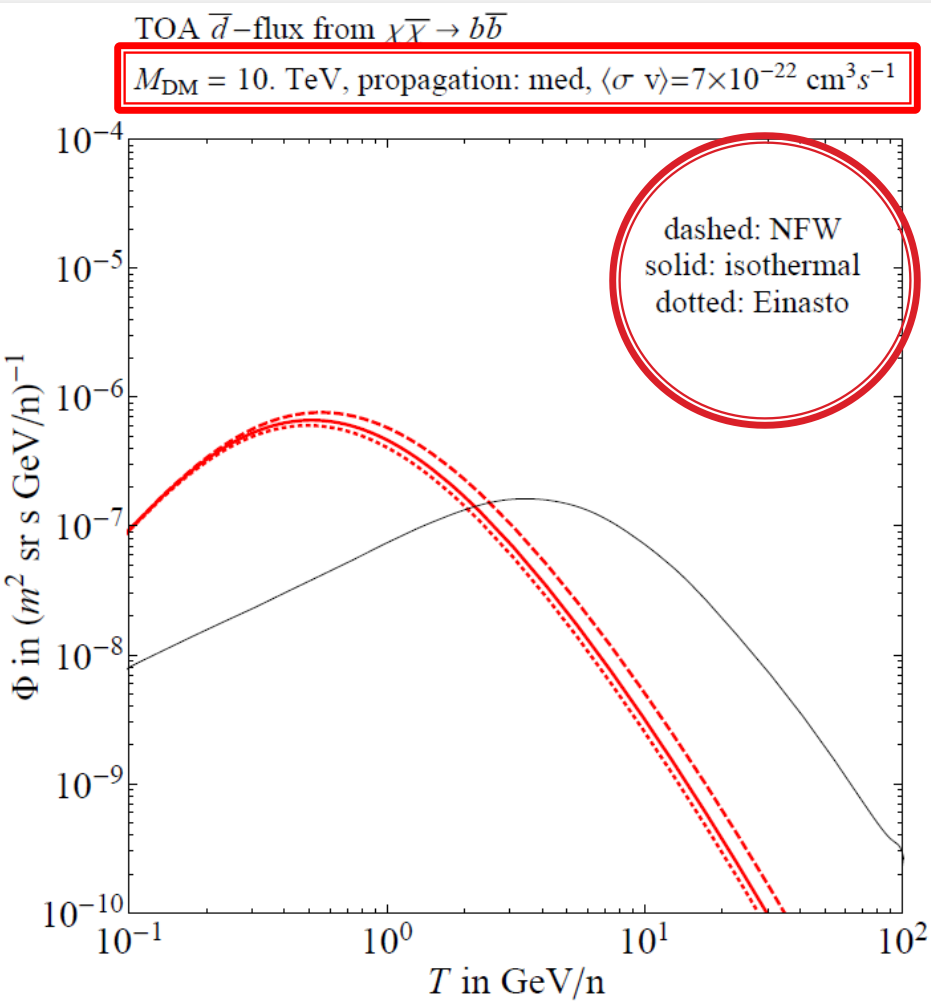
Mass and Decay Channel

For heavy hadrophilic high cross section WIMP



Propagation Model and dark Matter Halo

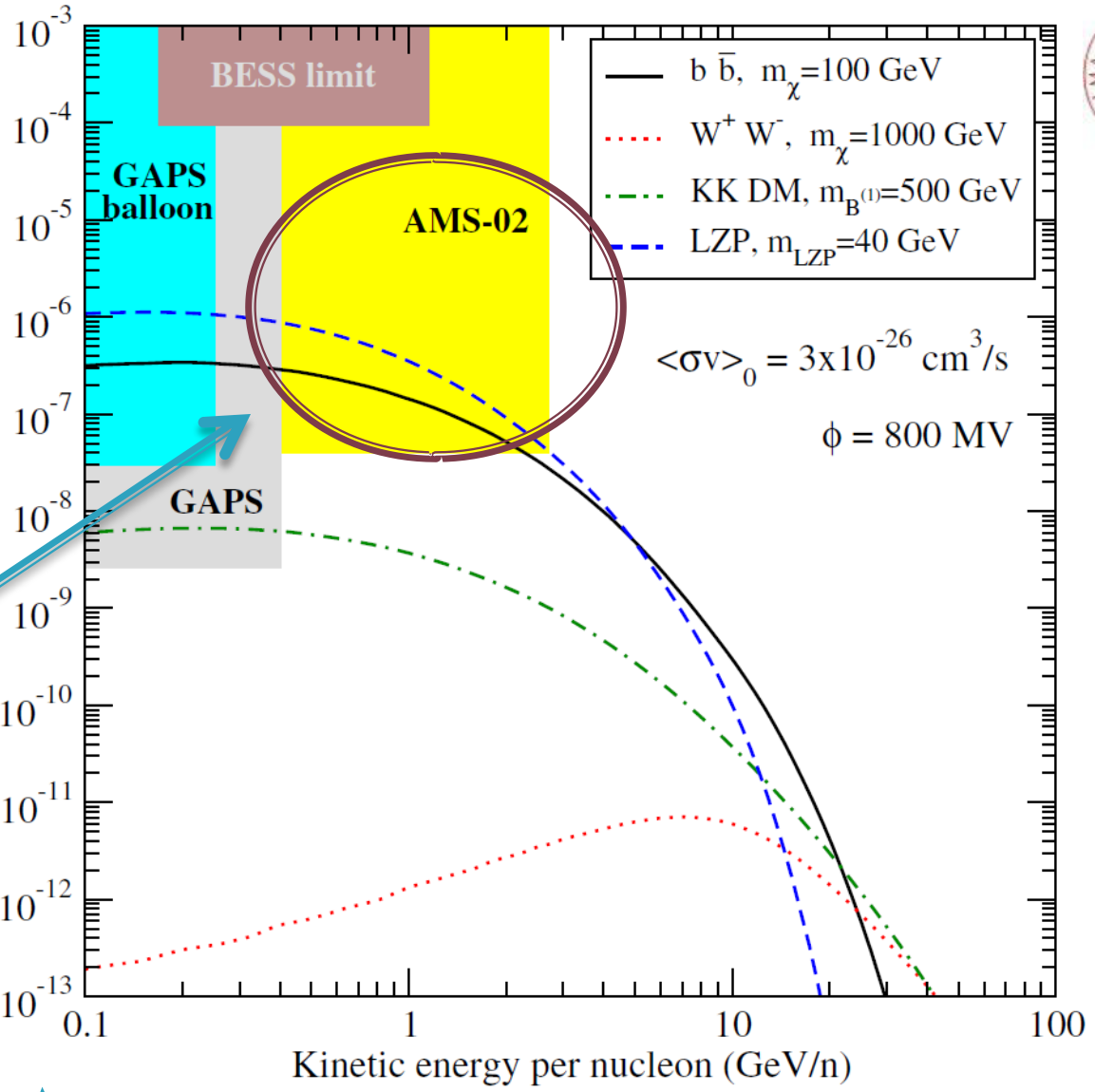




An example: Antideuteron flux from neutralino, KK Photon and right-handed neutrino LZP

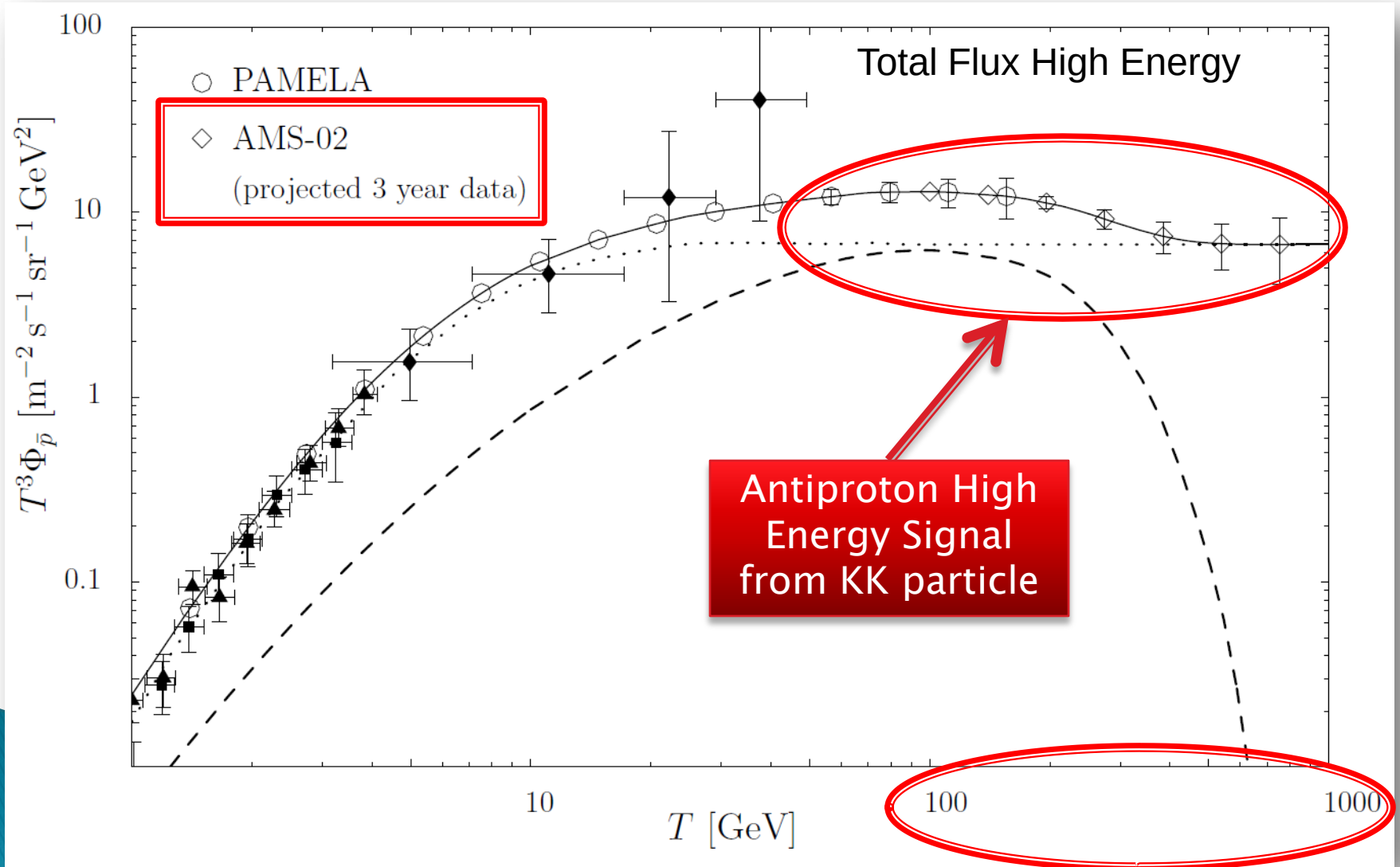
Light LZP provides measurable fluxes for AMS-02

With e+ and **low energy** antideuteron we can probe



SUSY Wino, Little Higgs, KK Theory, PBH, Singlet Scalar, Minimal DM, Technicolor…

And also… High Energy Hadrons



Antiproton & Antideuteron HE Search with AMS-02 :

Dark Matter Parameters Space for a non-leptophilic candidate:

$$M_{DM} \geq 2\,TeV$$

$$\langle \sigma v \rangle \sim 10^{-(26 \div 22)} cm^3 s^{-1}$$

$$High\ Energy\ \bar{p}, \bar{d}\ Fluxes\ of\ 10^{-(5 \div 6)} [GeV\, m^2\, s\, sr]^{-1}$$

$$for\ Kinetic\ Energy\ of\ 70 \div 500\ GeV/n$$

A lot of new stuff!
Stay tuned….