

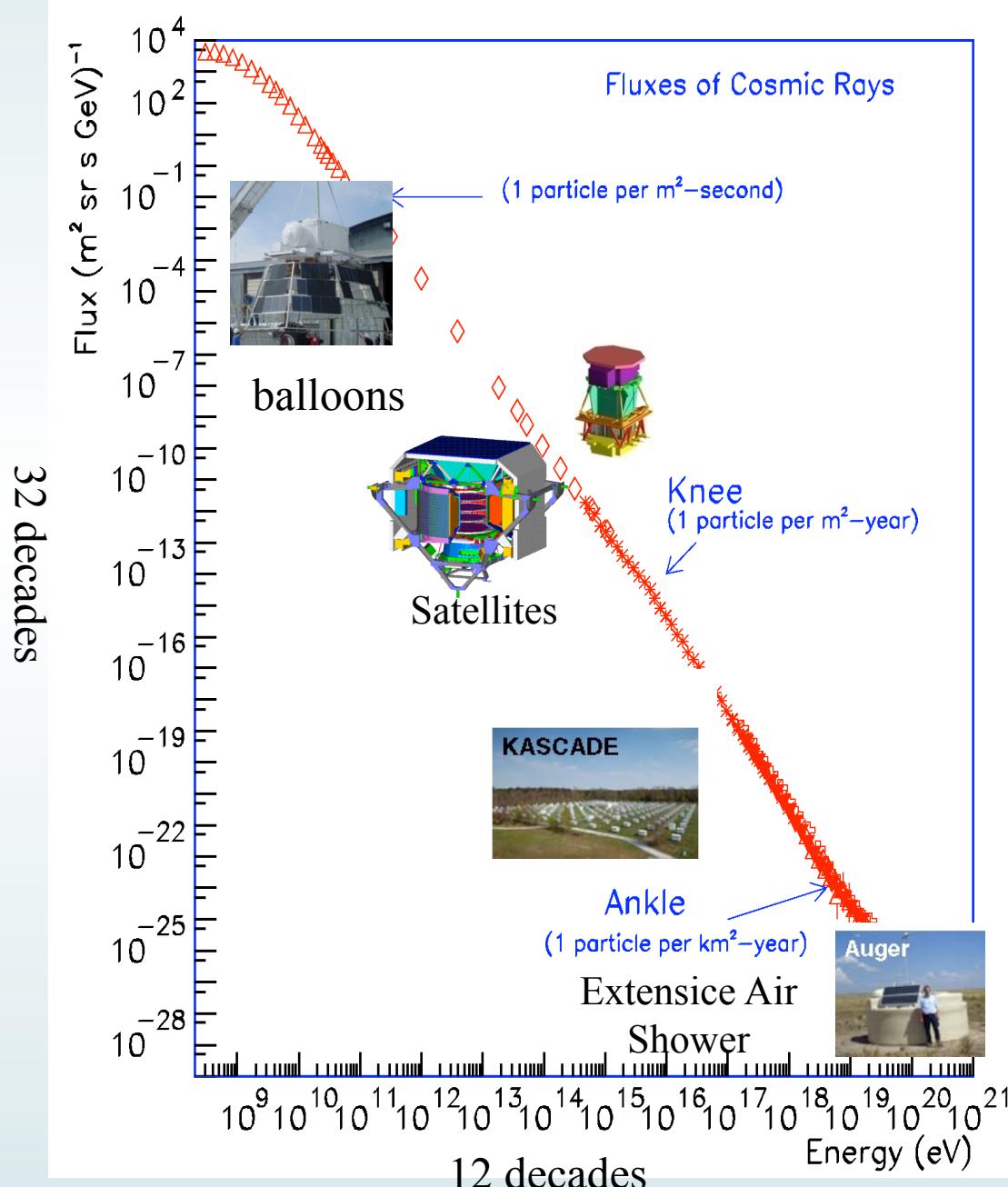
Experimental status

- ▷ Introduction
- ▷ Charged Cosmic rays
 - ▷ Nuclei
 - ▷ Anti matter
 - ▷ Electrons, Positrons
- ▷ Gamma rays

Sylvie Rosier Lees – LAPP IN2P3/CNRS

AMS Workshop – Annecy, March 2010.

Cosmic Ray fluxes measurements

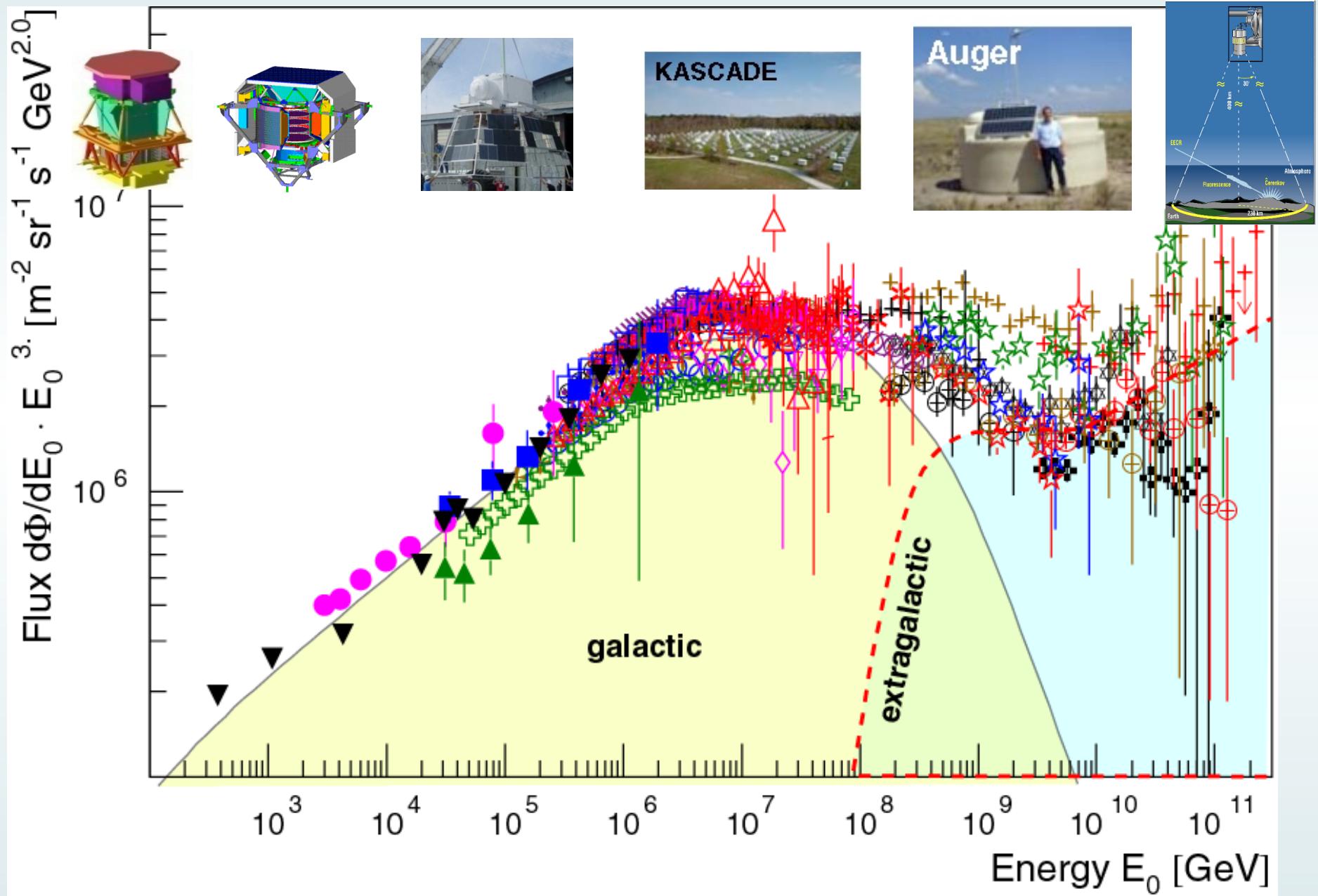


$$\frac{dN}{dE_0} \propto E_0^{-3}$$

Different energy ranges and Acceptance

- ▷ Nature of CR
- ▷ Origine of CR (sources)
- ▷ Propagation in different medium, galactic or extra galactic CR

Cosmic Rays spectrum



Cosmic Ray flux, a first estimation

$$\gamma = \alpha + \delta \approx 2.7$$

$E^{-\gamma}$
Measured
CR density

$$\frac{N_{\text{cr}}}{T} = Q_{\text{cr}}$$

$E^{-\alpha}$
Source spectrum

$$\alpha = 2.0 \dots 2.4$$

$E^{-\delta}$
Diffusion/confinement
time

$$\delta = 0.3 \dots 0.7$$

- ▷ Measured spectrum index (γ) results from :
 - ▷ Production/acceleration mechanism (α)
 - ▷ Diffusion term (δ)

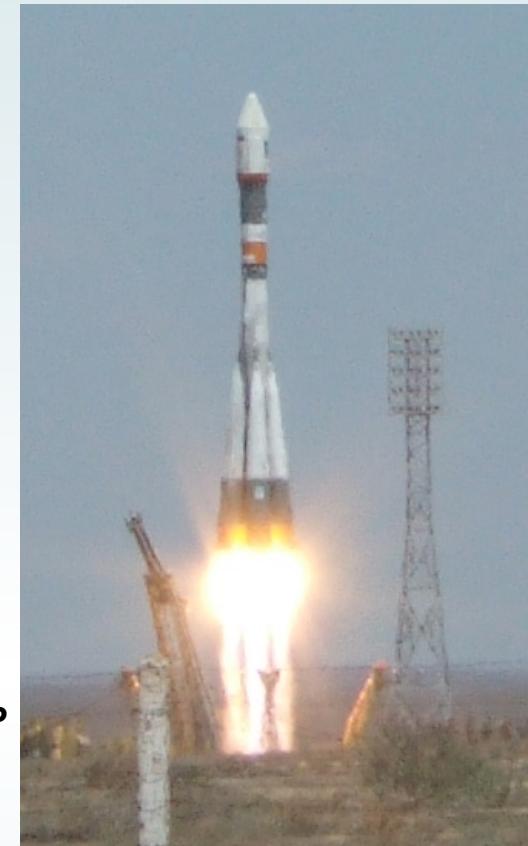
Nuclei from few GeV to 10^{4-5} GeV

- ▷ Experimental devices
 - ▷ Balloons
 - ▷ Satellites
- ▷ Measurements
 - ▷ Composition
 - ▷ Diffusion parameters in the Galaxy:
 - ▶ Energy dependence
 - ▶ path length
 - ▶ Diffusion time
- ▷ Propagation models could be constrained/tuned from measurements
- ▷ Necessary for any new physics searches

PAMELA

Launch
15/06/06

*16 Gigabytes
transmitted daily to
Ground*

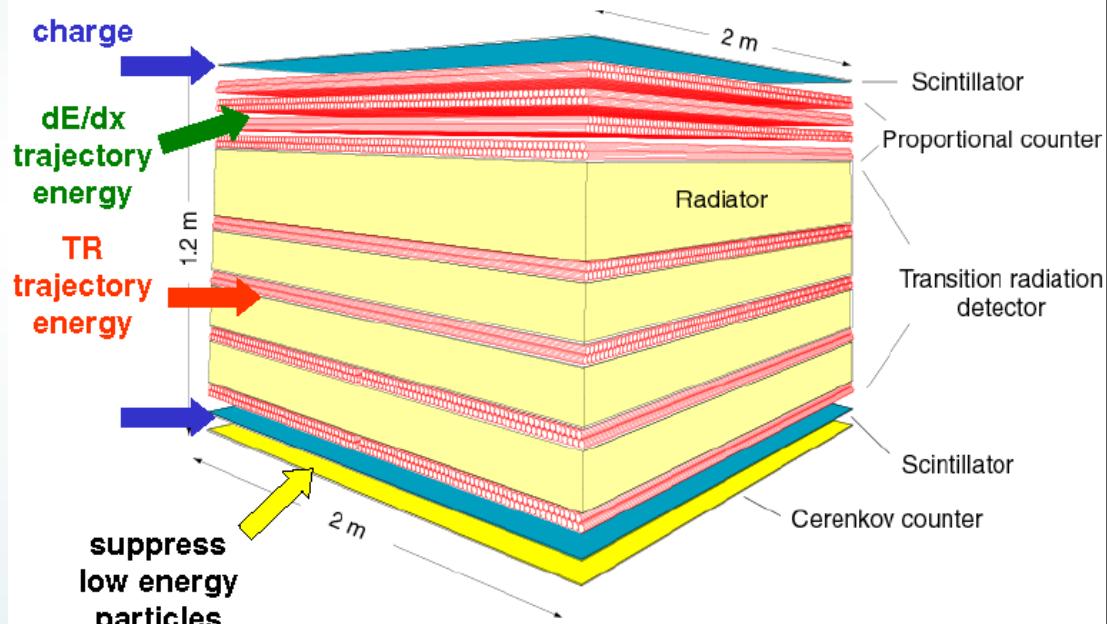


Balloons : Tracer



Direct measurement of the composition of cosmic rays from 0.5 to 10,000 GeV/amu with single elemental resolution

Transition Radiation Array for Cosmic Energetic Rays



Specific Ionization in gas:

10 – 1000 GeV/amu

TRD:

400 – several 10,000 GeV/amu

Cherenkov:

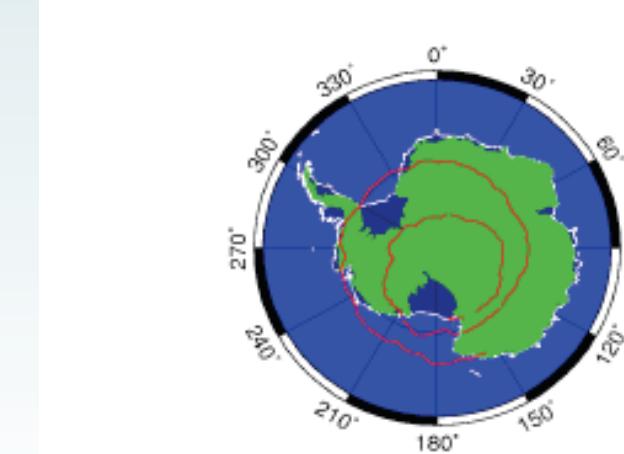
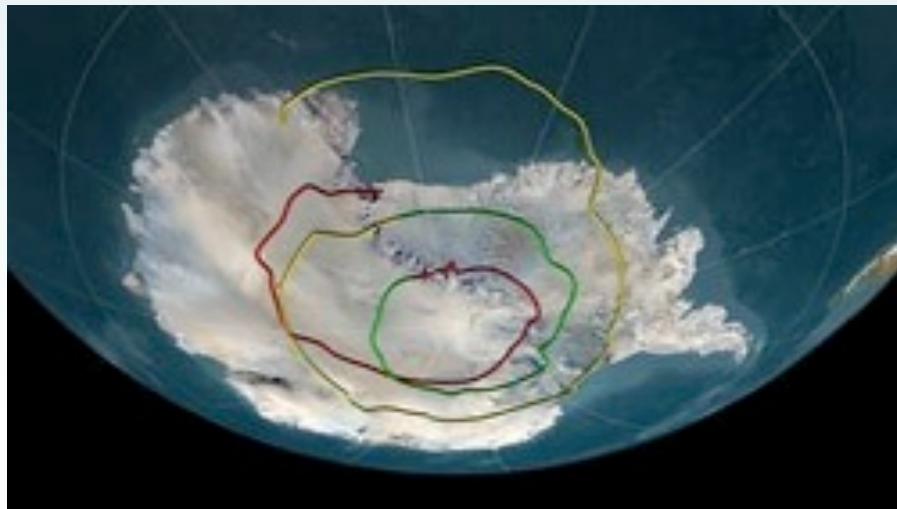
0.5 – 10 GeV/amu
($n=1.49$)

▷ Principle

- ▷ Energy measurement over a large energy range
- ▷ Charge identification

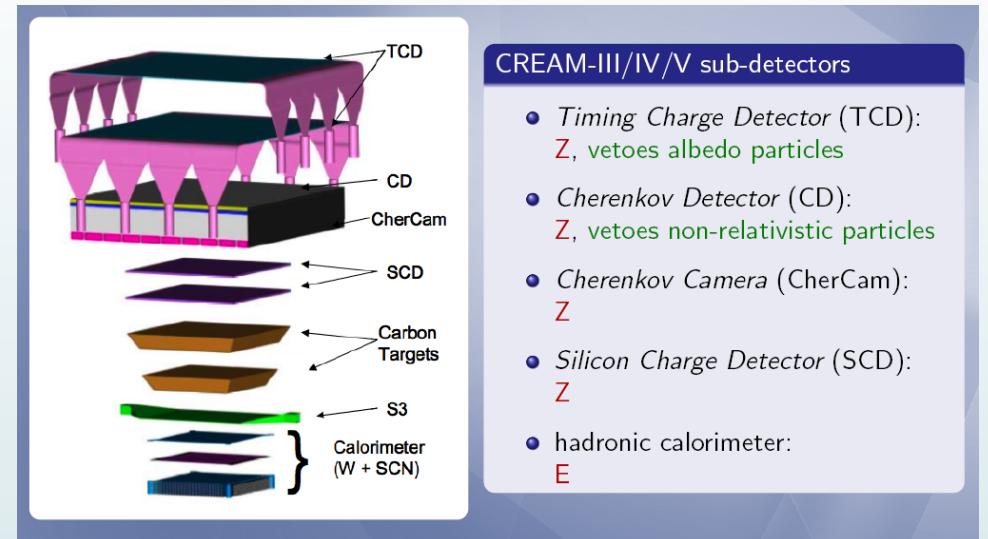
Cosmic Ray Energetic and Mass - CREAM

1st CREAM flight
from 16/12/04 to 26/01/05
(42 days in the 2004 campaign)



GMD 2009 Jan 09 00:01:35 L03_Antarctica_2008-2009_CREAM
CREAM IV trajectory: 21 days flight

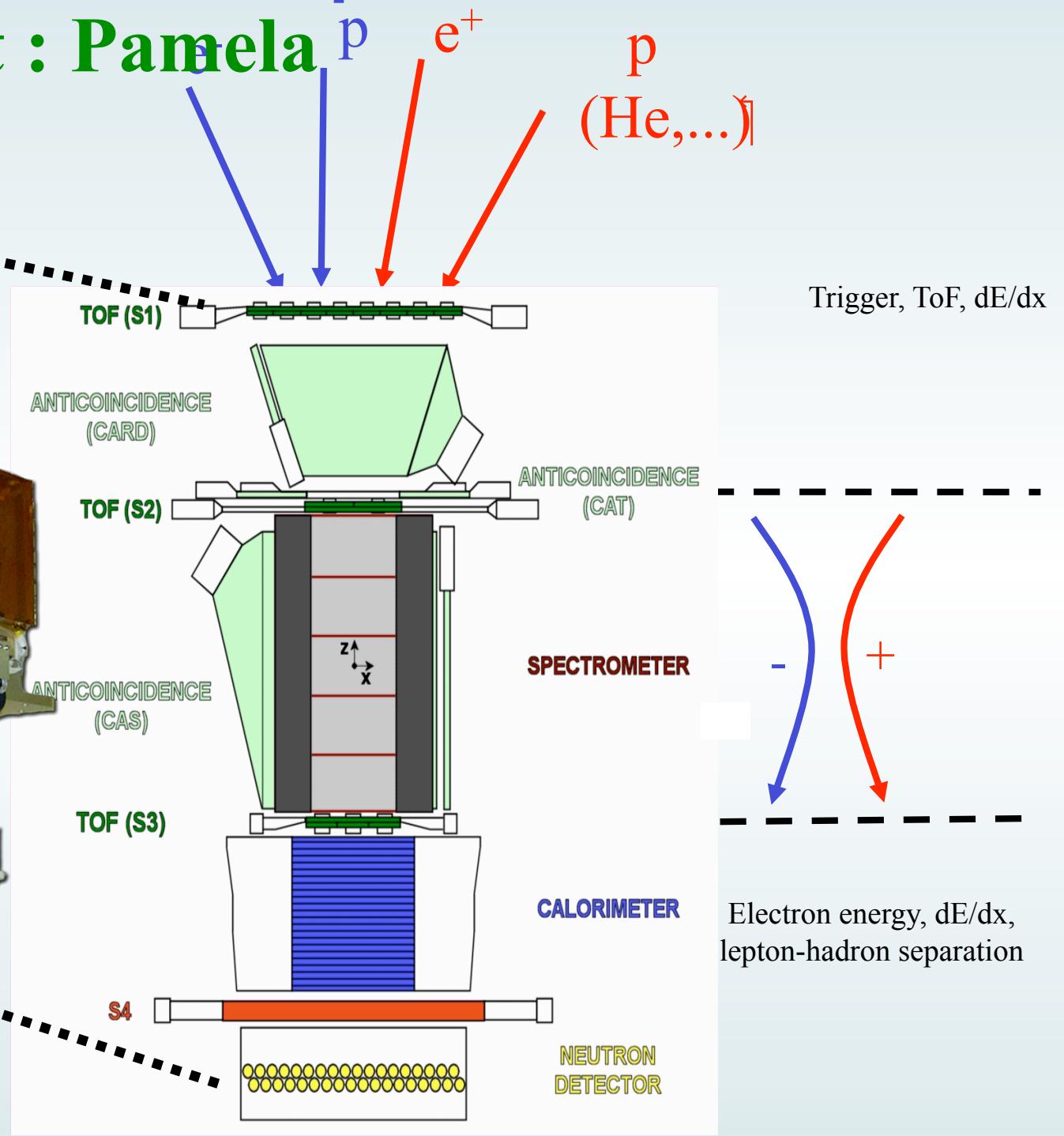
-TRD gas lost < 10 % (100 days ok)
-Mean altitude 37 km, 4g/cm²



Spacecraft : Pamela

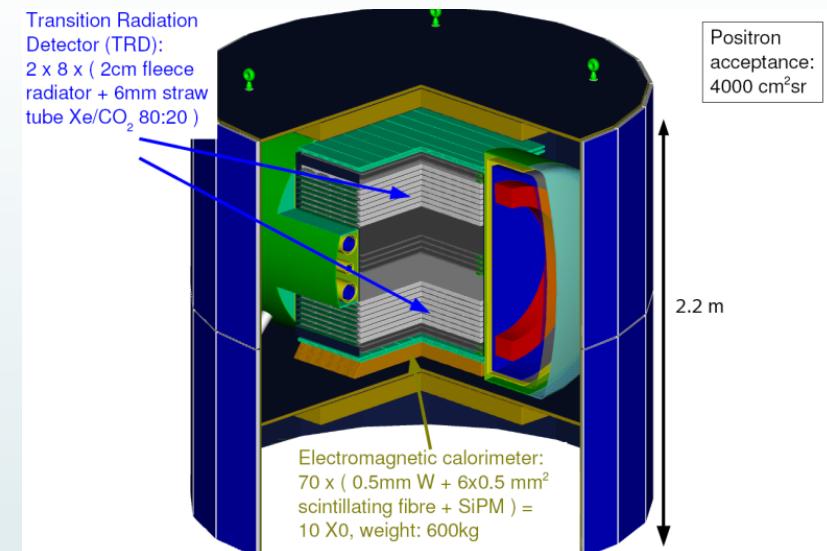
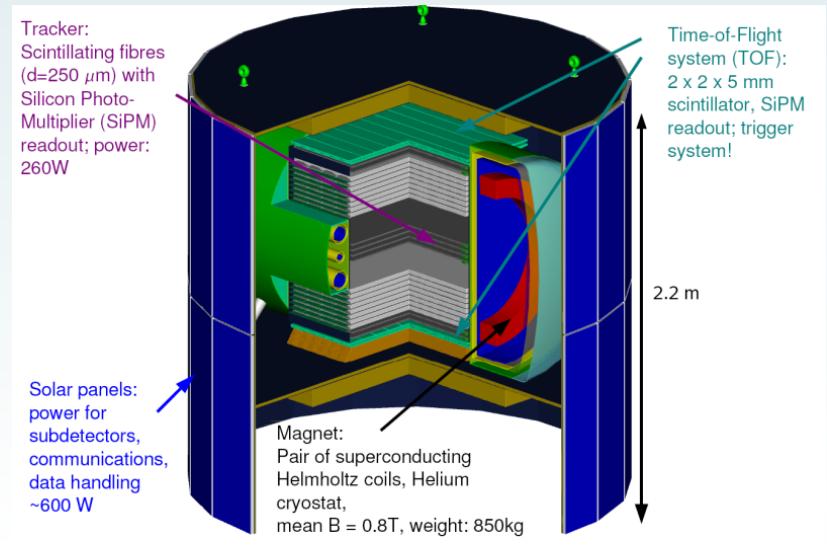
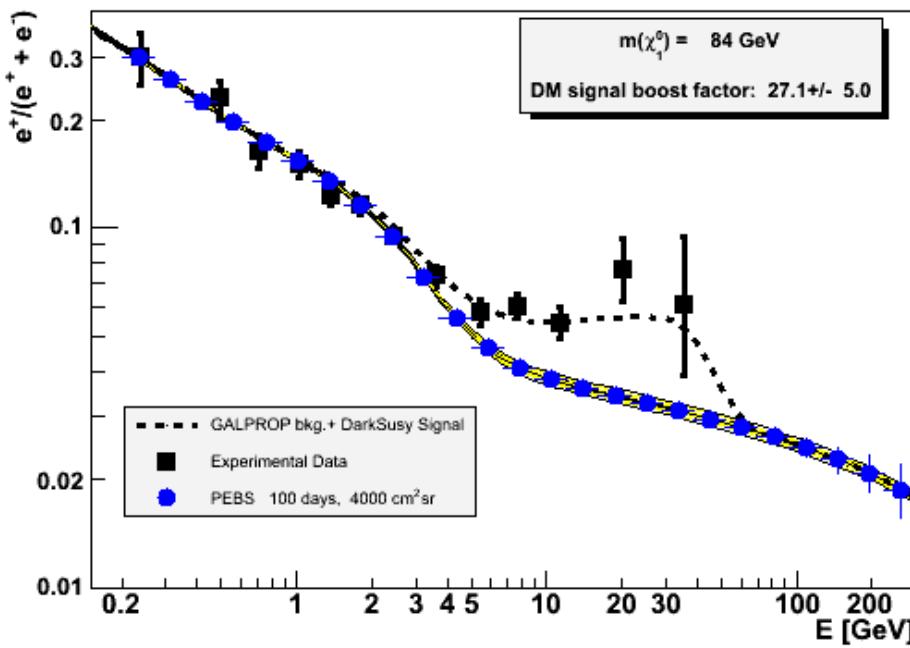


GF $\sim 21.5 \text{ cm}^2 \text{sr}$
Mass: 470 kg Size:
130x70x70 cm³



PEBS :Positron Electron Balloon Spectrometer

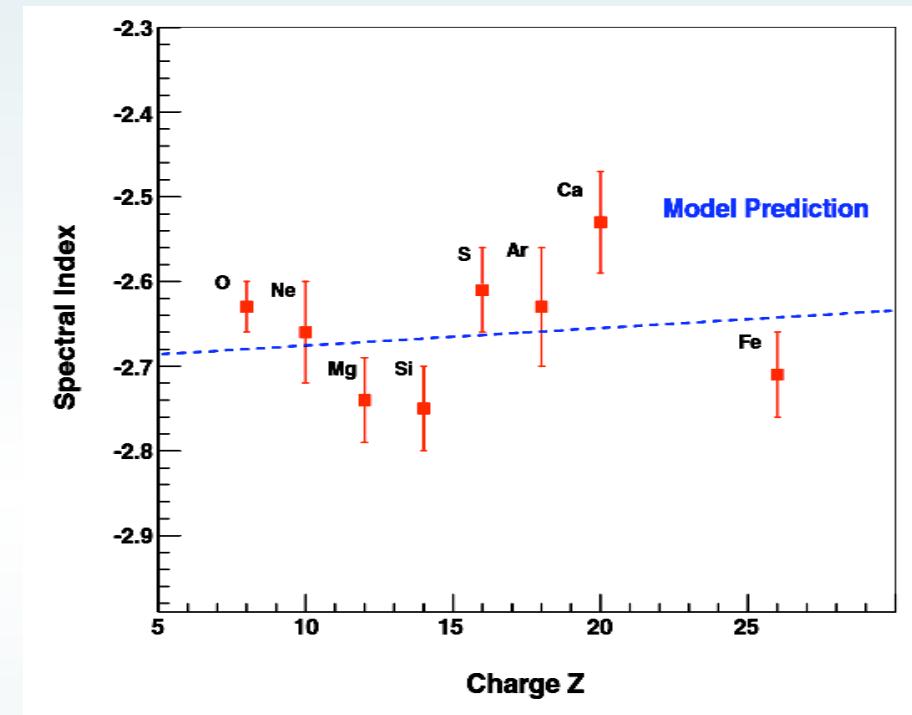
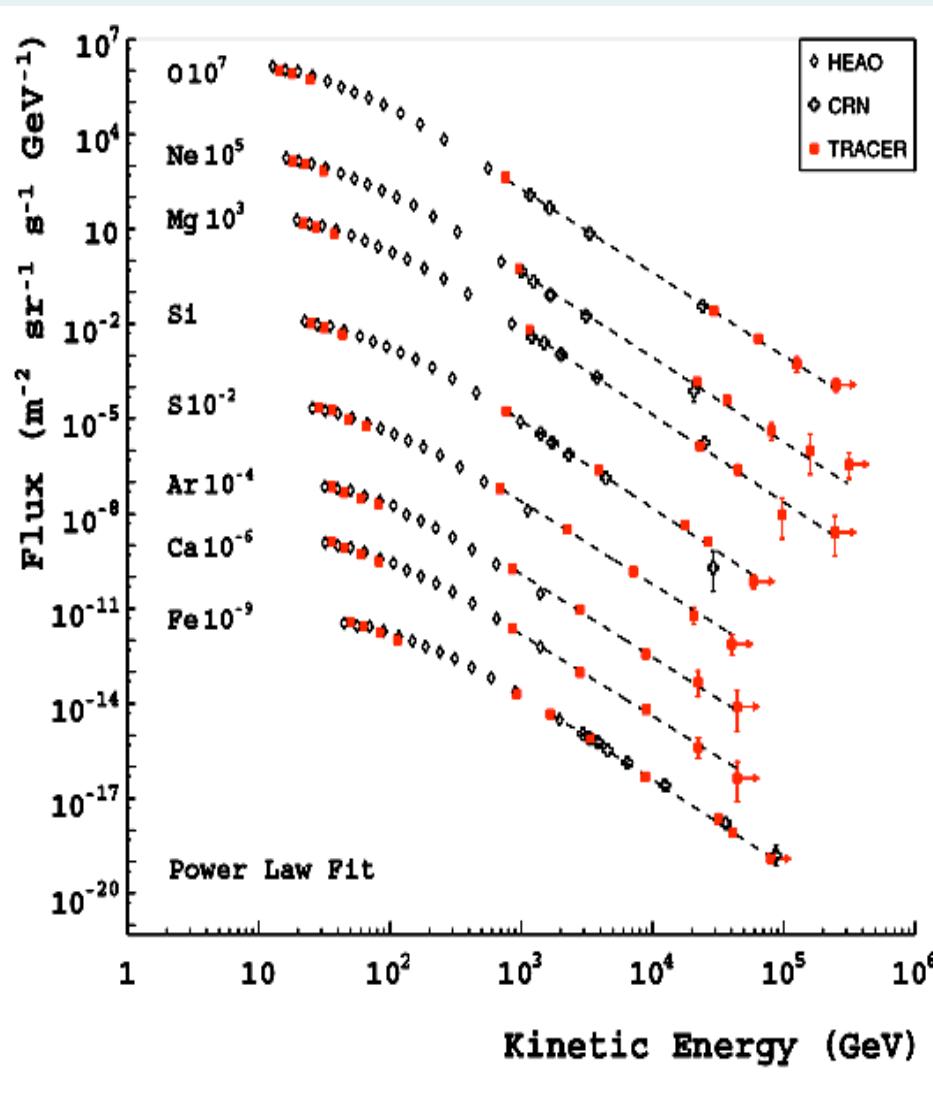
- ▷ Alternate or complement to AMS
- ▷ Balloon - Flight > 2010
- ▷ ~ 100 days on 3 years:
 - ▷ Acc : 2500-4000 cm².sr
 - ▷ Comparable AMS e⁺



GCR - AMS vs. BESS/PAMELA

	BESS-Polar	PAMELA	AMS-02
Acceptance	0.3	0.002	0.5
MDR (GV)	150	740	2500
Flight duration (days)	10+20	1000	1000
Flight Altitude (km)	36	690	350
Residual air (g/cm ²)	5	-	-
Weight (tons)	1.5	0.38	~7
Power consumption (W)	600	345	< 3000
Magnetic field (Tesla)	0.8-1	0.4	0.87
Flight latitude (deg.)	80	±70	±52
Energy region (GeV)	> 0.1	> 0.1	~ > 0.5
Flight vehicle	Balloon	Satellite	ISS
# of events for:			
protons (range in GeV/n)	$3 \cdot 10^9$ (0.2-200)	$3 \cdot 10^8$ (0.08-700)	$2 \cdot 10^{10}$ (0.5-2500)
antiprotons	$3 \cdot 10^4$ (0.2-4)	$3 \cdot 10^4$ (0.08-190)	$3 \cdot 10^6$ (0.08-700)
e-	-	$6 \cdot 10^6$ (0.05-2000)	$6 \cdot 10^8$ (0.5-5000)
e+	-	$3 \cdot 10^5$ (0.05-270)	$3 \cdot 10^7$ (1-400)
Anti-He/He	$3 \cdot 10^{-8}$	$7 \cdot 10^{-8}$	$1 \cdot 10^{-9}$
Anti-D/D	$5 \cdot 10^{-6}$	-	$3 \cdot 10^{-7}$

Nuclei abundance and γ index measurements



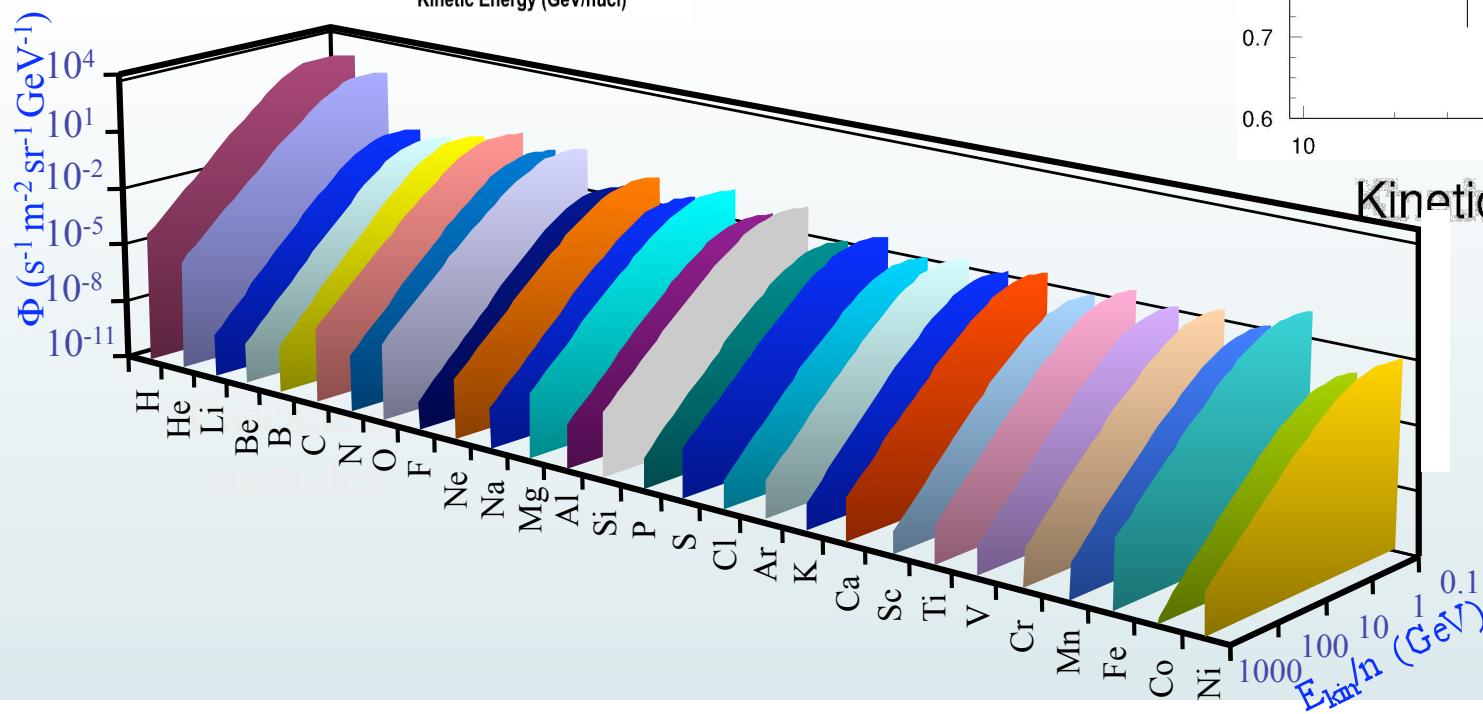
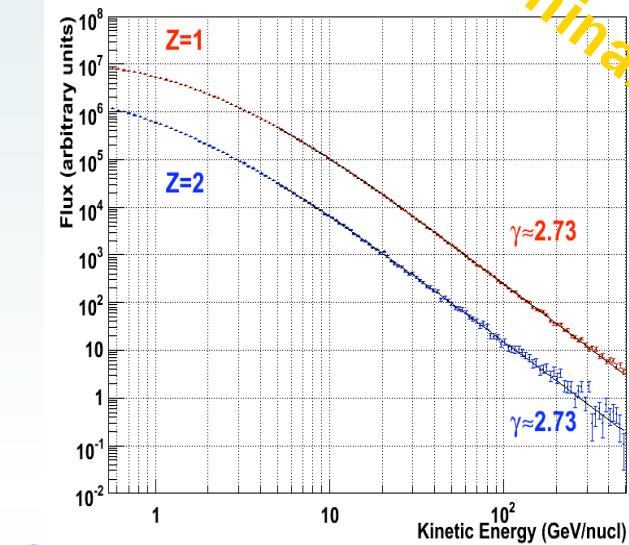
$$\gamma = \alpha + \delta \approx 2.7$$

Independent of Z ?

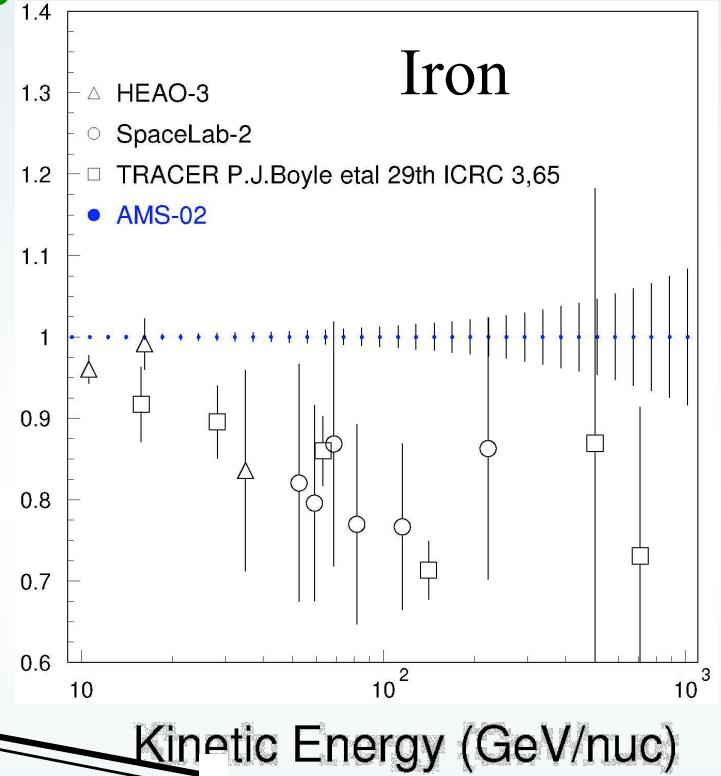
γ index measurements- spacecraft experiments

Pamela

Preliminary !!!



Relative Fe Fluxes

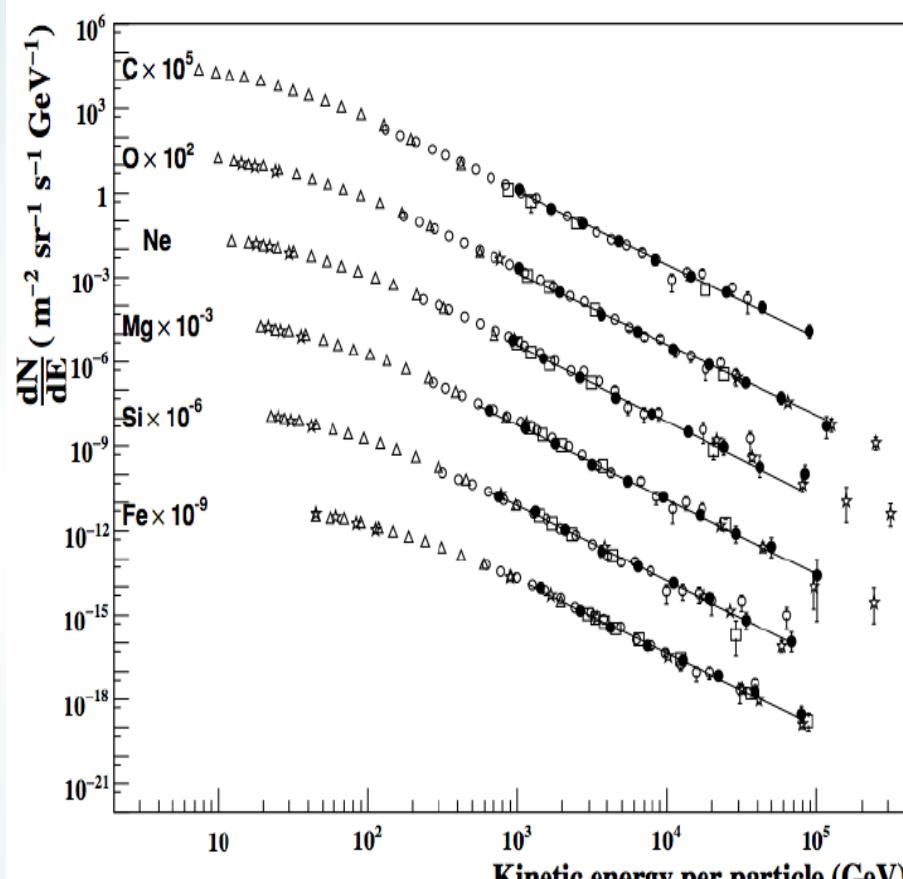


Iron

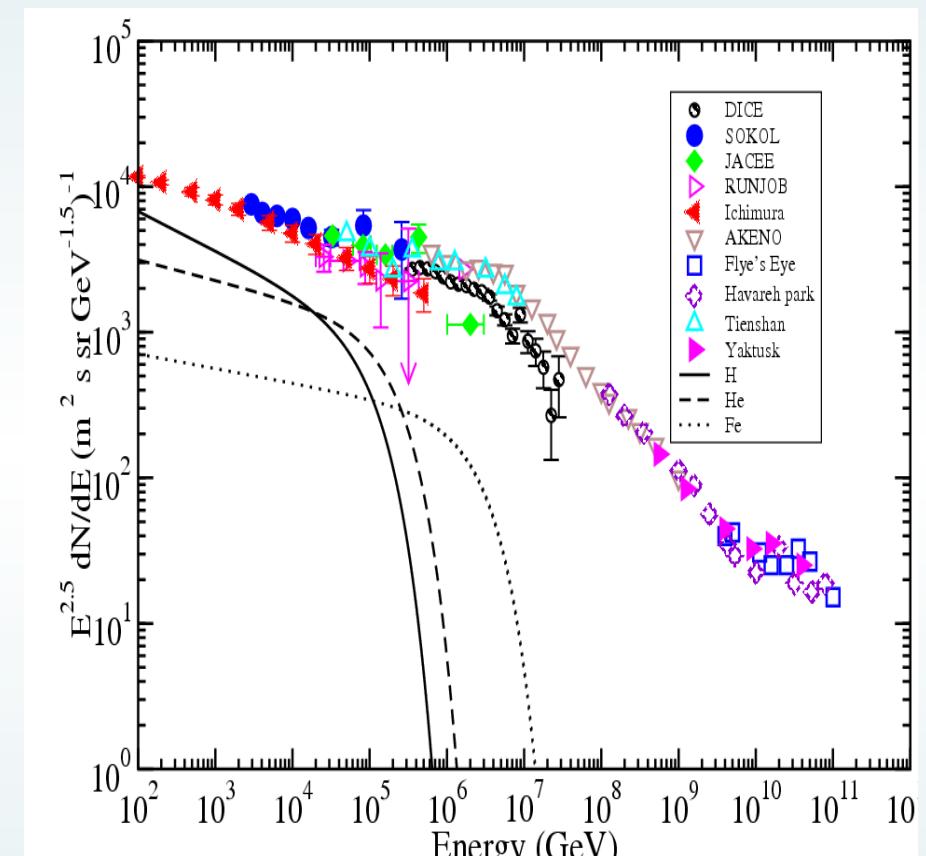
AMS 02
projection

Nuclei abundance and γ index measurements

Does the energy cutoff
depends on the CR composition ?



[H. S. Ahn et al., *Astrophys. J.* 707:593-603, 2009]

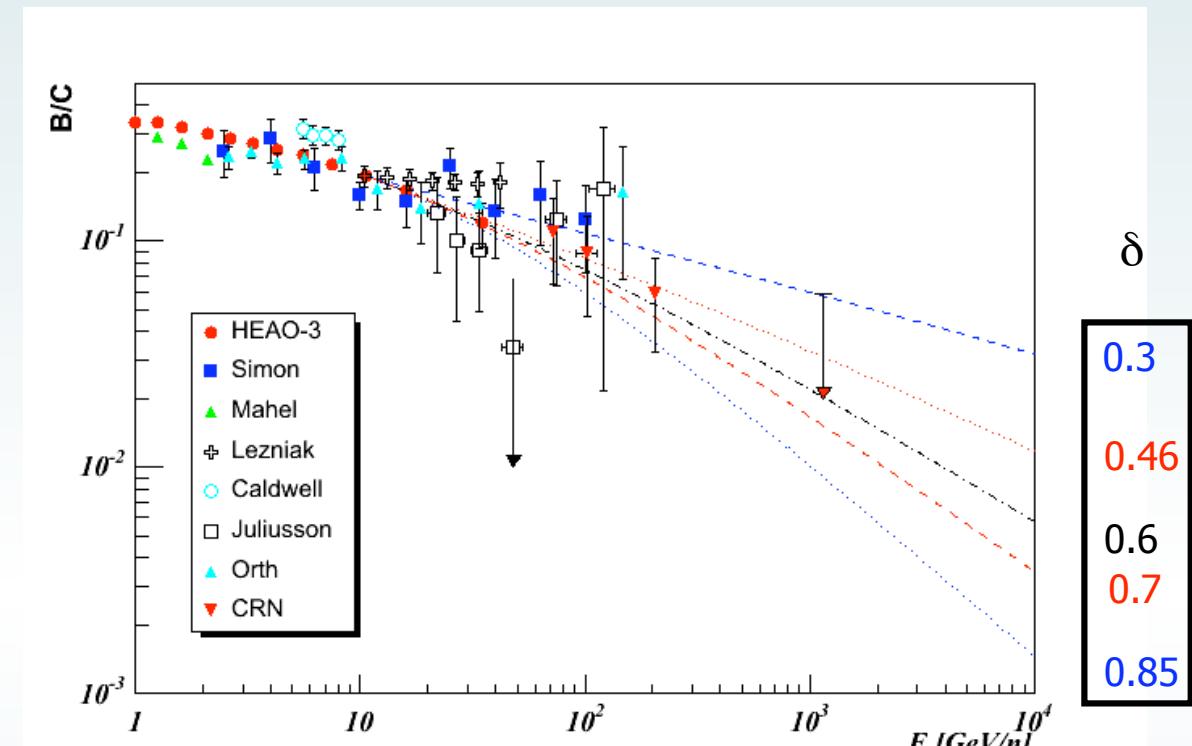


Knee puzzle: from balloon to ground detectors extrapolation or/and Xcalibration ?

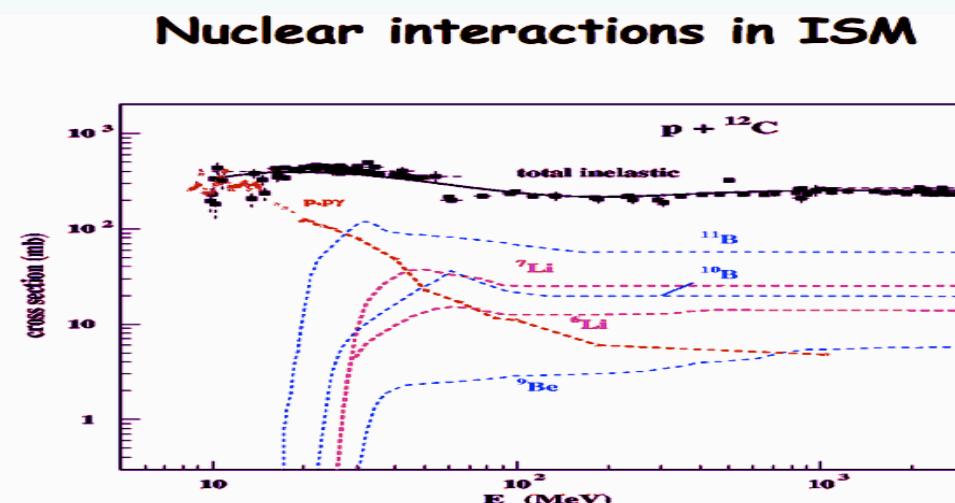
δ index measurements

secondary /primary
Diffusion dominating at
 $E/n > 100 \text{ GeV}$

- ▷ $N_B = \sigma_{\text{spall}} * N_C / E^\delta$
- ▷ $N_{\text{Sec}} / N_{\text{Prim}} \sim E^{-\delta}$

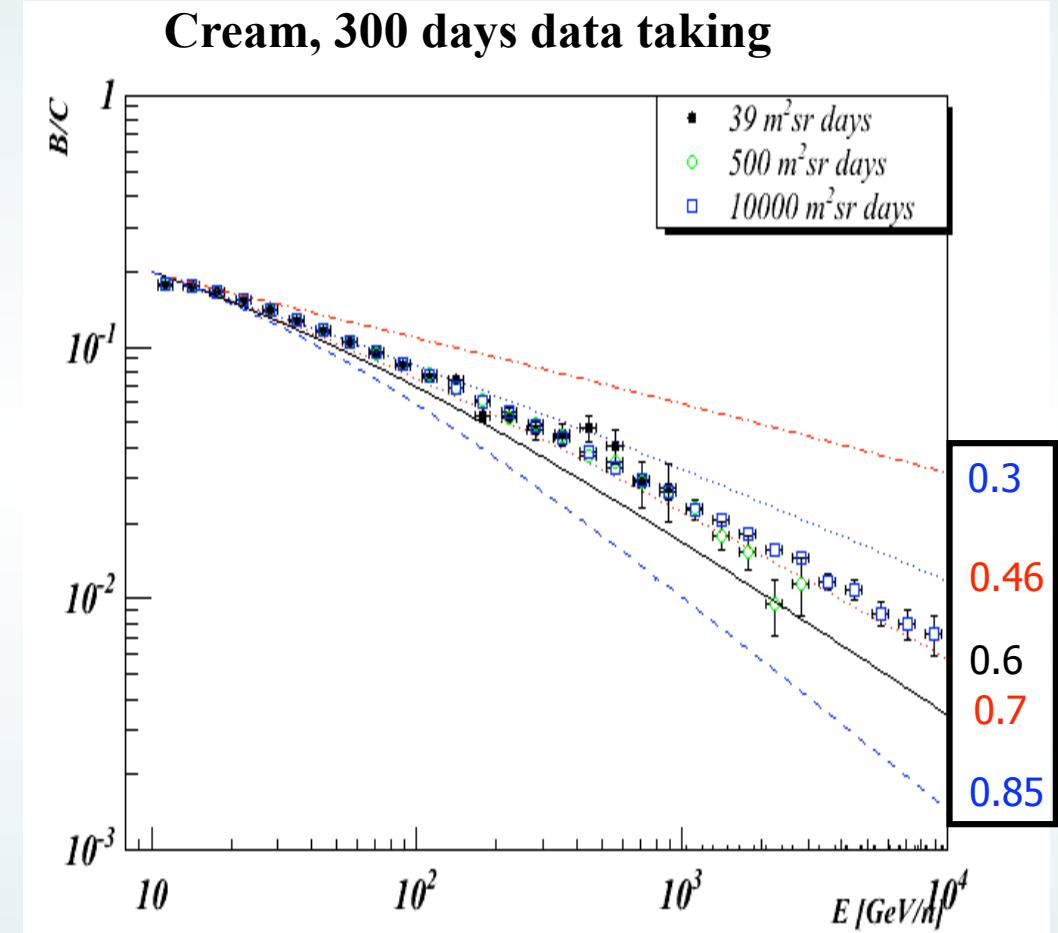
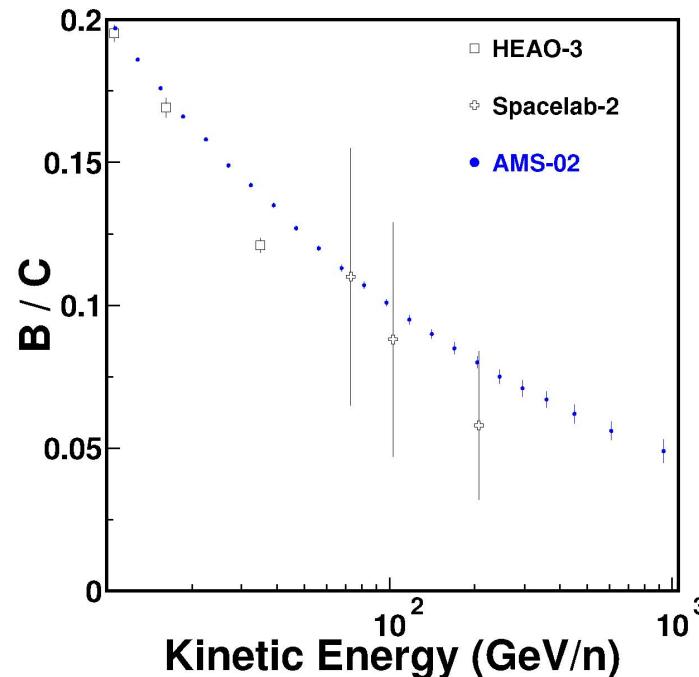
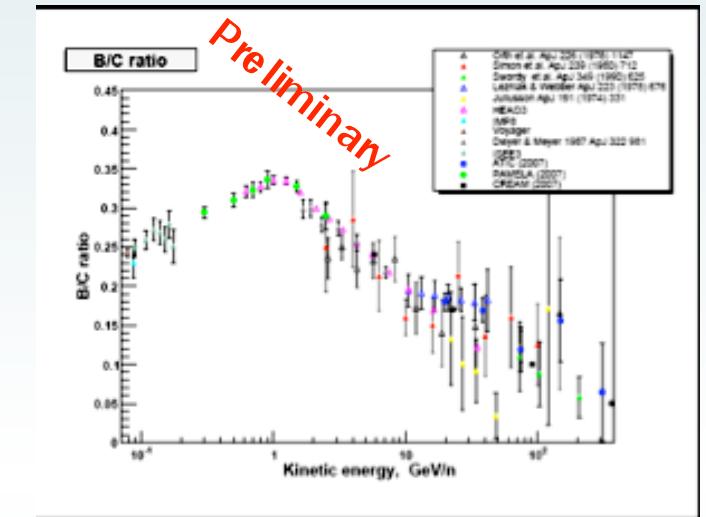


σ_{spall}



δ index prospects

Last Measurements, including Pamela,
From Picozza, Blois 2008



- ▷ δ Accuracy $\sim 10\%$
- ▷ Constraints on propagation of another nuclei
(anti-protons, anti deuton ...), path length

Time confinement in the galaxy

Radioactive isotopes

$^{12}\text{C} + \text{H} \rightarrow ^9\text{Be}$ **stable secondary nucleus**

$^{12}\text{C} + \text{H} \rightarrow ^{10}\text{Be}$ **unstable secondary nucleus**
($t_{\text{lifetime}} \sim 4 \text{ Myr}$)

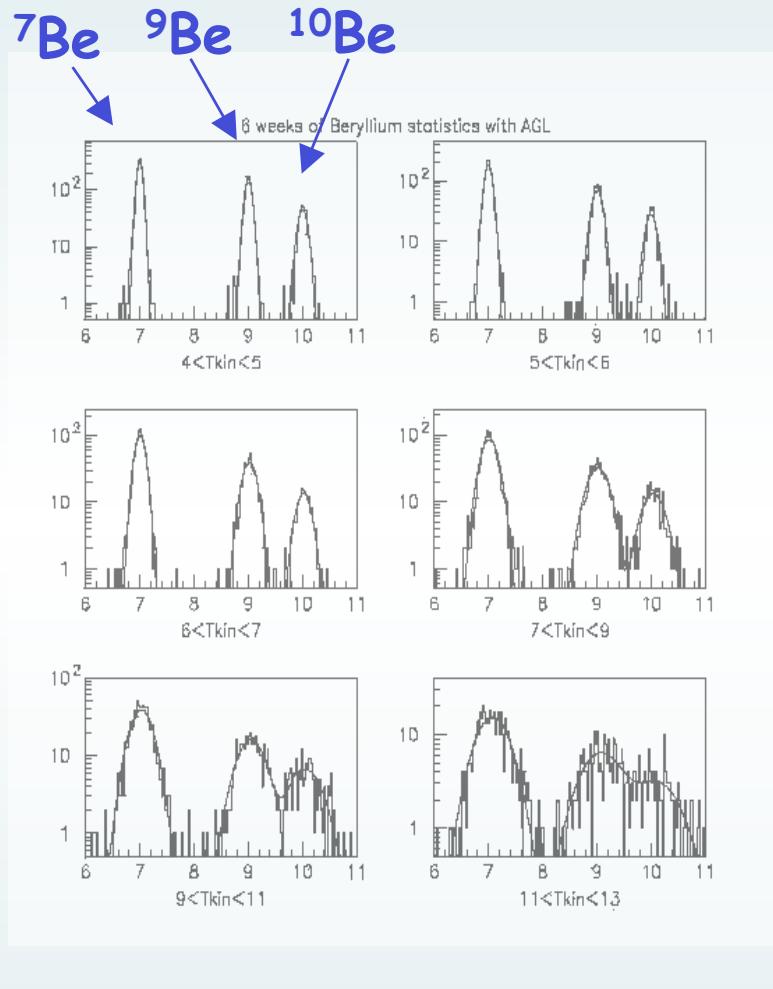
Needs of :

- ▷ Charge identification
- ▷ Precise mass measurement on the wide energy range ($\Delta m = 1$)
 - ▷ Rigidity + Z -> momentum
 - ▷ Velocity
 - ▷ $\Delta m/m = \Delta p/p + \gamma^2 \Delta \beta/\beta$

$^{10}\text{Be}/^9\text{Be}$ will tell us about the time spent in the galaxy for nuclei

It allows to break the degeneracy between diffusion strength (D_0) and diffusion halo size

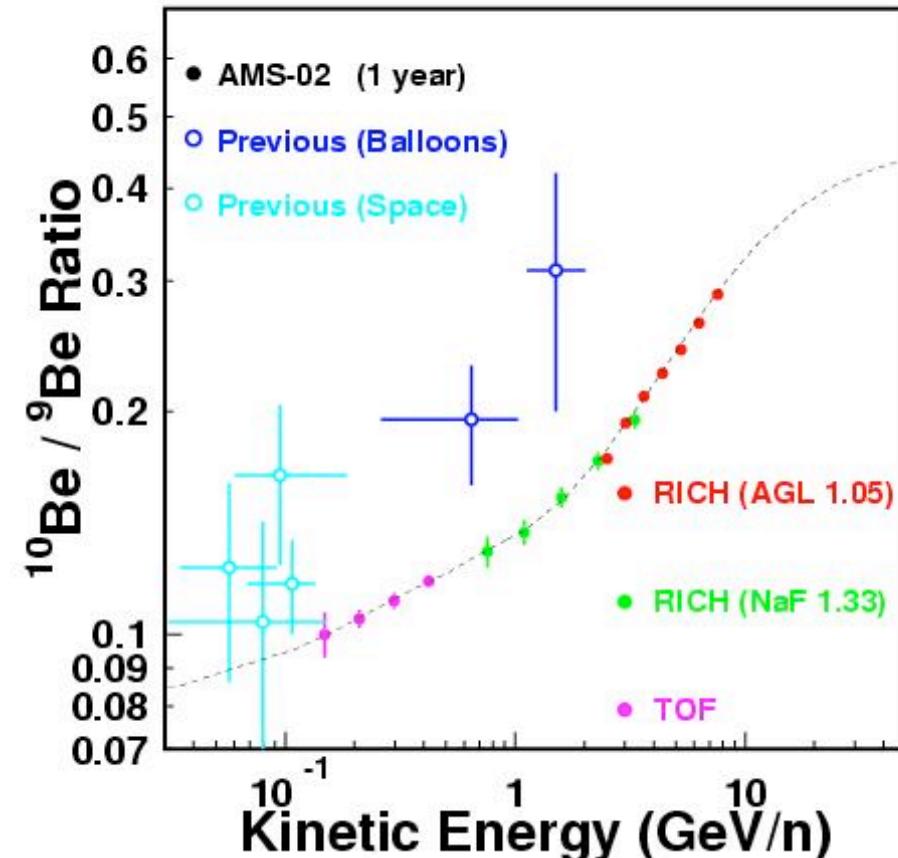
Cosmic Ray Clocks



After 6 weeks ~ 200000 events

-

▷ $\tau_{\text{conf-escp}} \sim 20 \text{ Myr} @ 1\text{GeV/n}$



Characteristics of AMS

$\Delta t = 100 \text{ ps}$, $\Delta x = 10 \mu\text{m}$, $\Delta v/v = 0.001$

	e^-	P	He,Li,Be,..Fe	γ	e^+	\bar{P}, \bar{D}	\bar{He}, \bar{C}
TRD							
TOF							
Tracker							
RICH							
ECAL							
Physics example	Cosmic Ray Physics				Dark matter		Antimatter

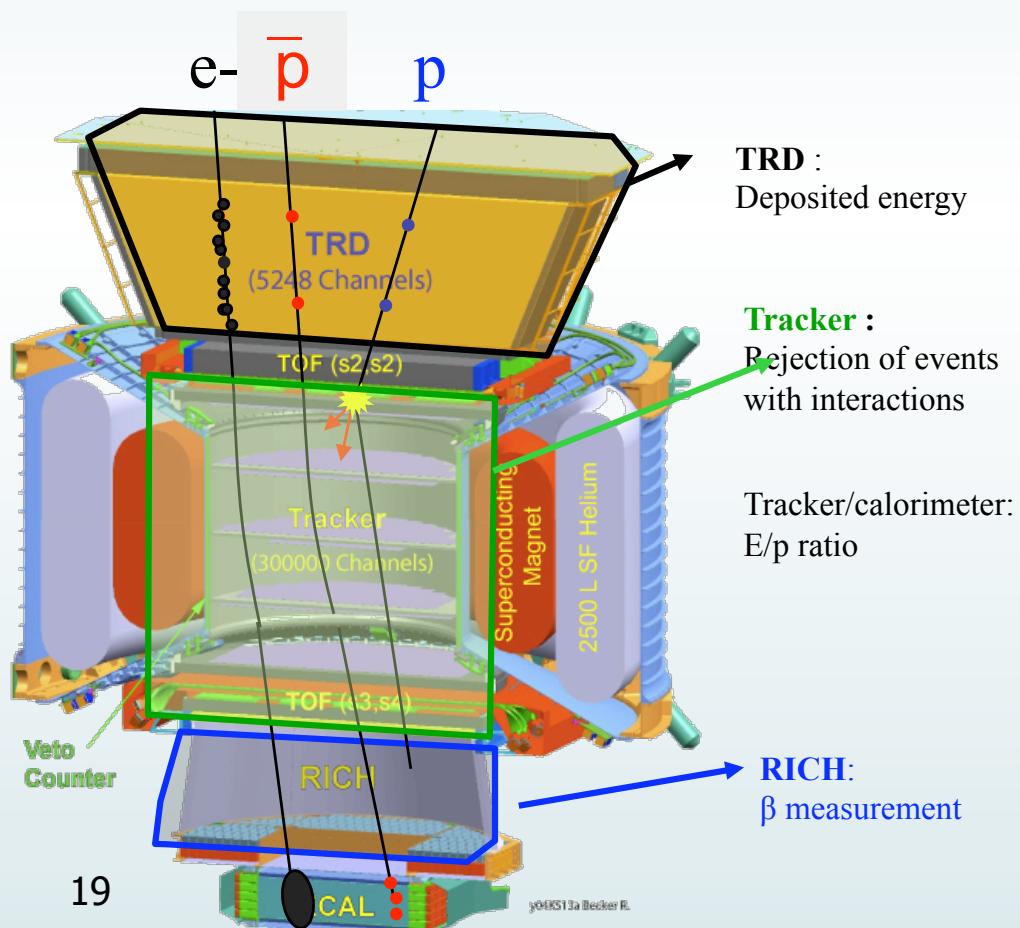
Anti protons

\bar{p}

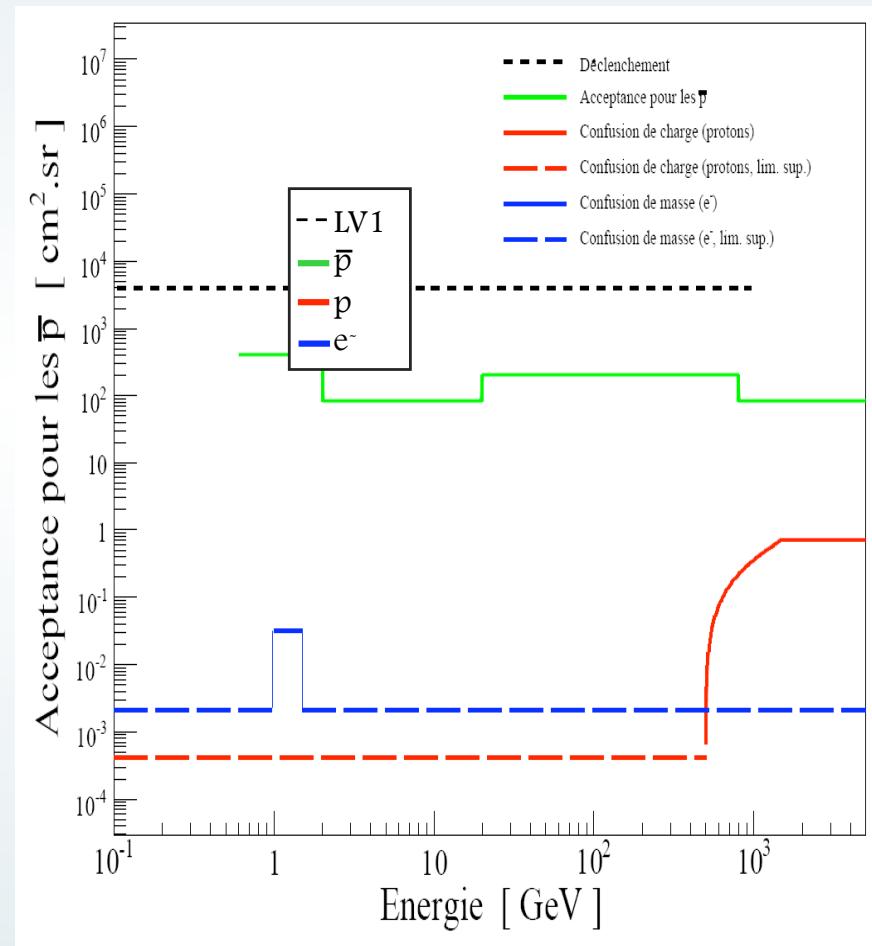
▷ Background

► protons $\Phi_p \sim 10^{4-5} * \Phi_{\bar{p}}$

► electrons $\Phi_{e^-} \sim 10^3 * \Phi_{\bar{p}}$

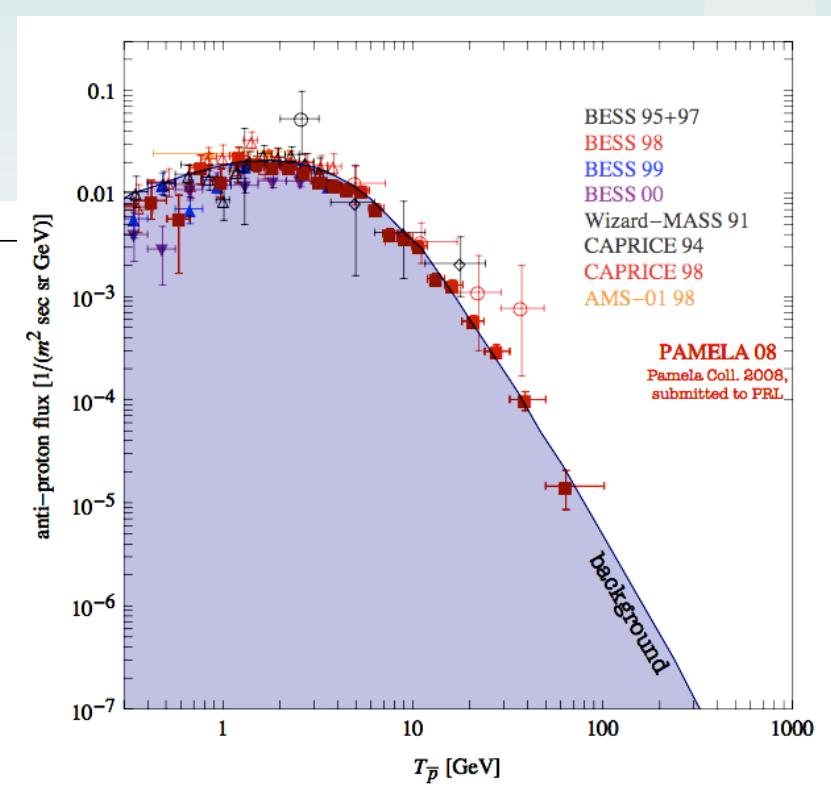
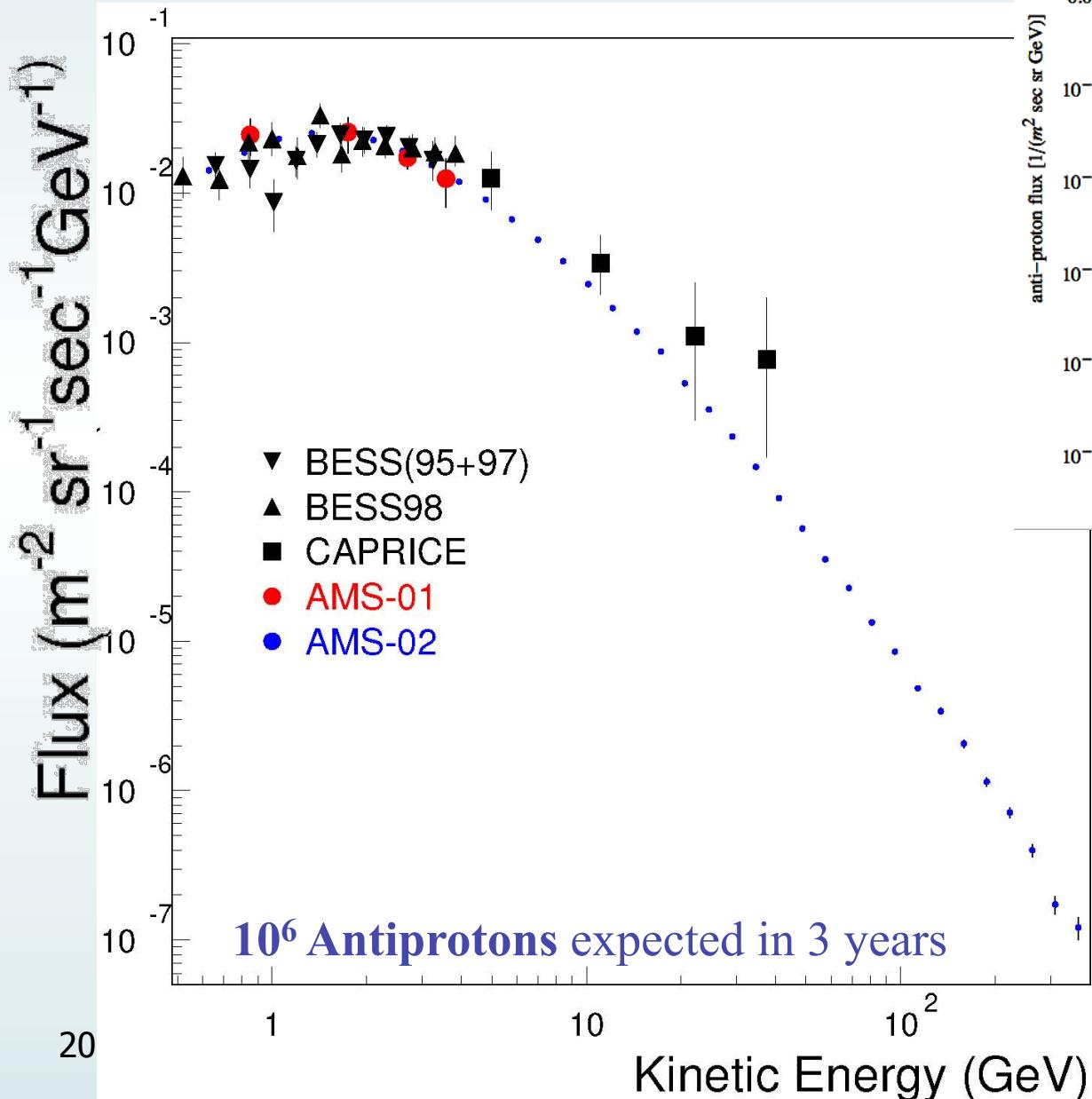


$$A_p / A_{\bar{p}} \sim 10^6$$



Range : 0.8 GeV ~ 600 GeV

Anti protons

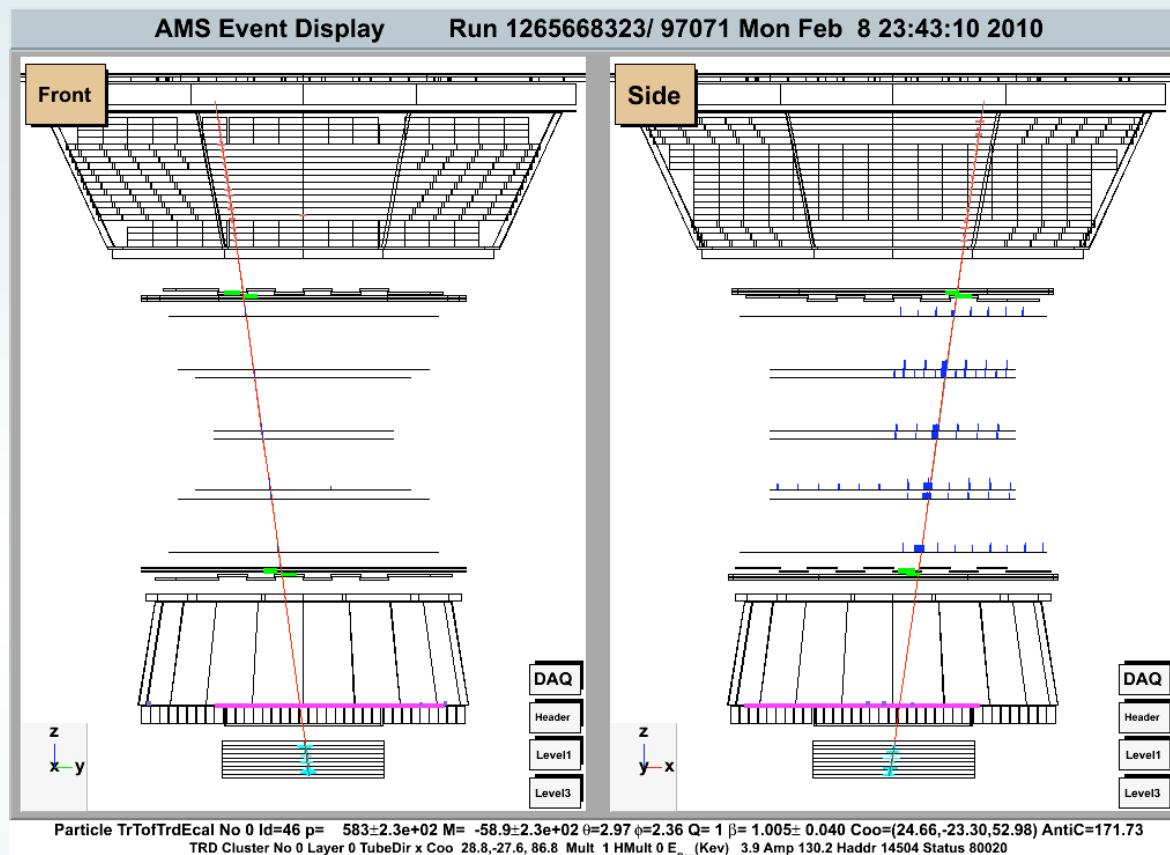


**About 1000 anti p,
collected,
No excess**

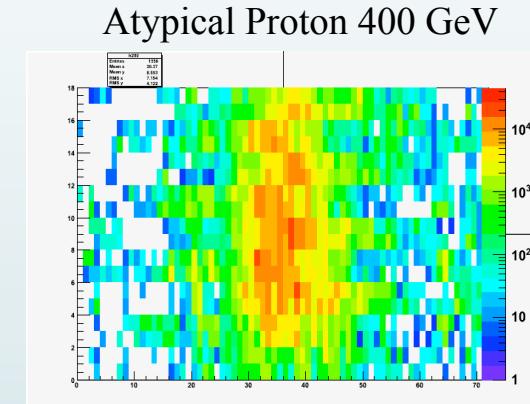
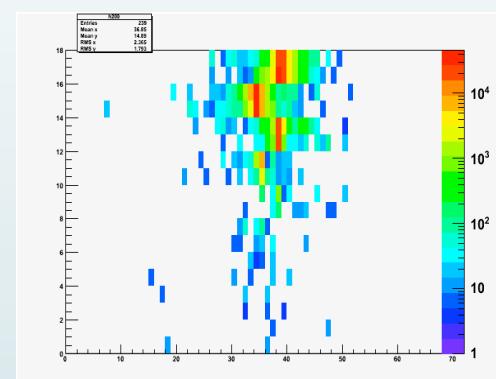
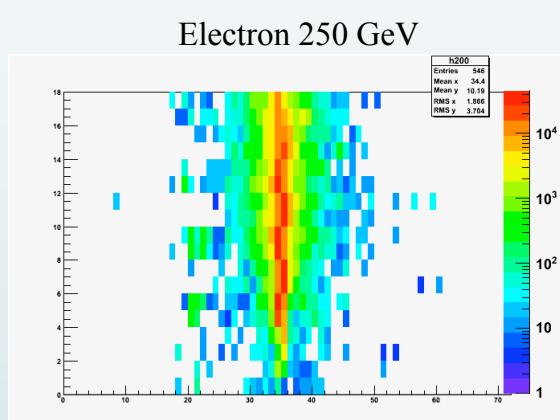
Anti deuterium
The signal similar in shape as p
spectrum,
almost background free

-> GAPS: General Anti-Particle System – test balloon 2010 ?

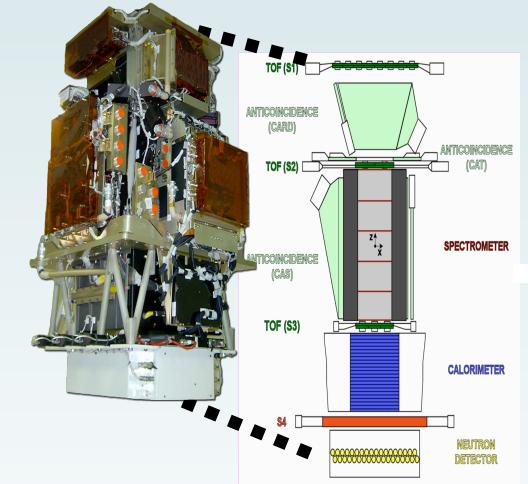
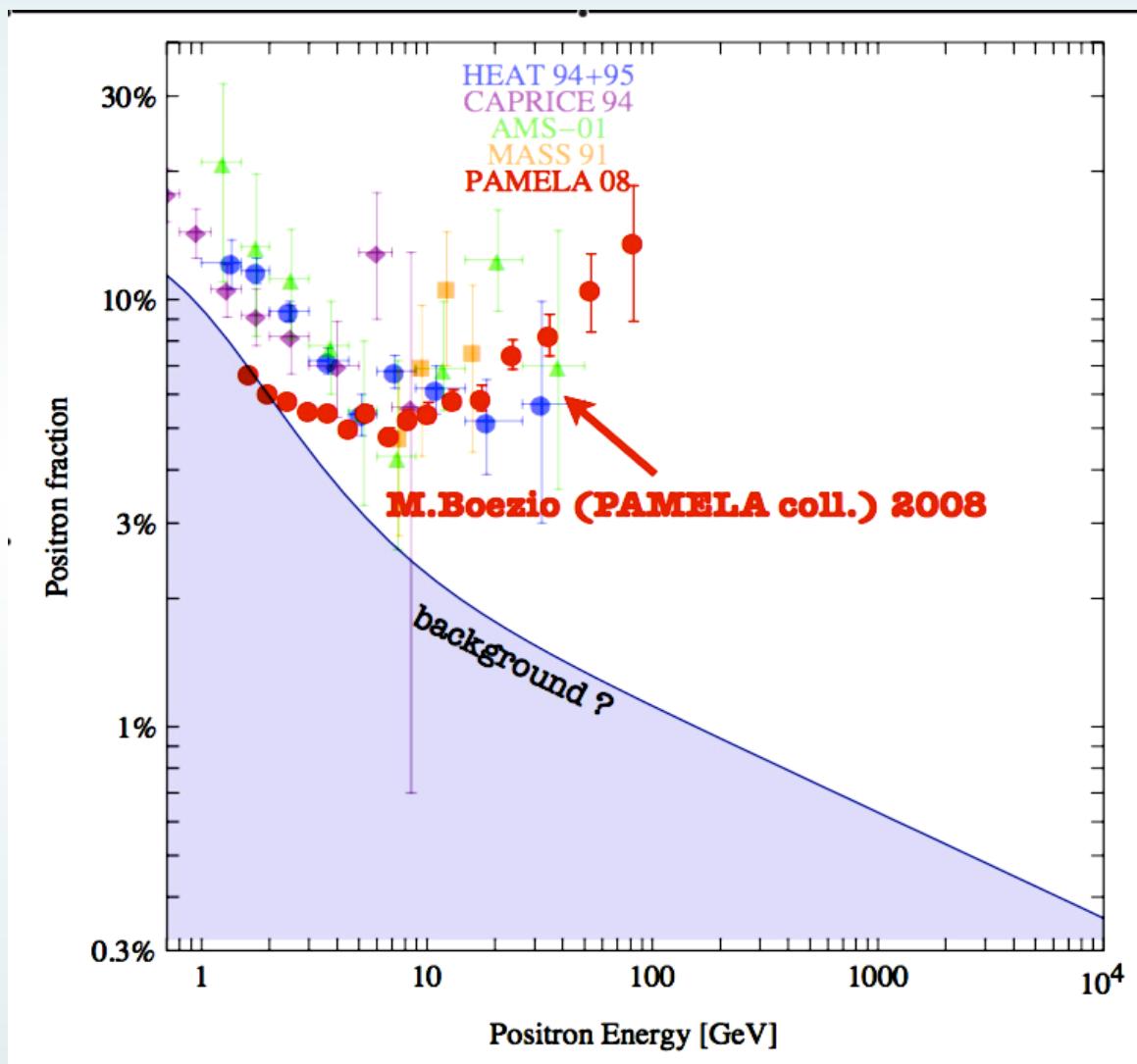
Positrons and electrons



Test beam CERN,
Février 5-9 2010



positrons or electrons

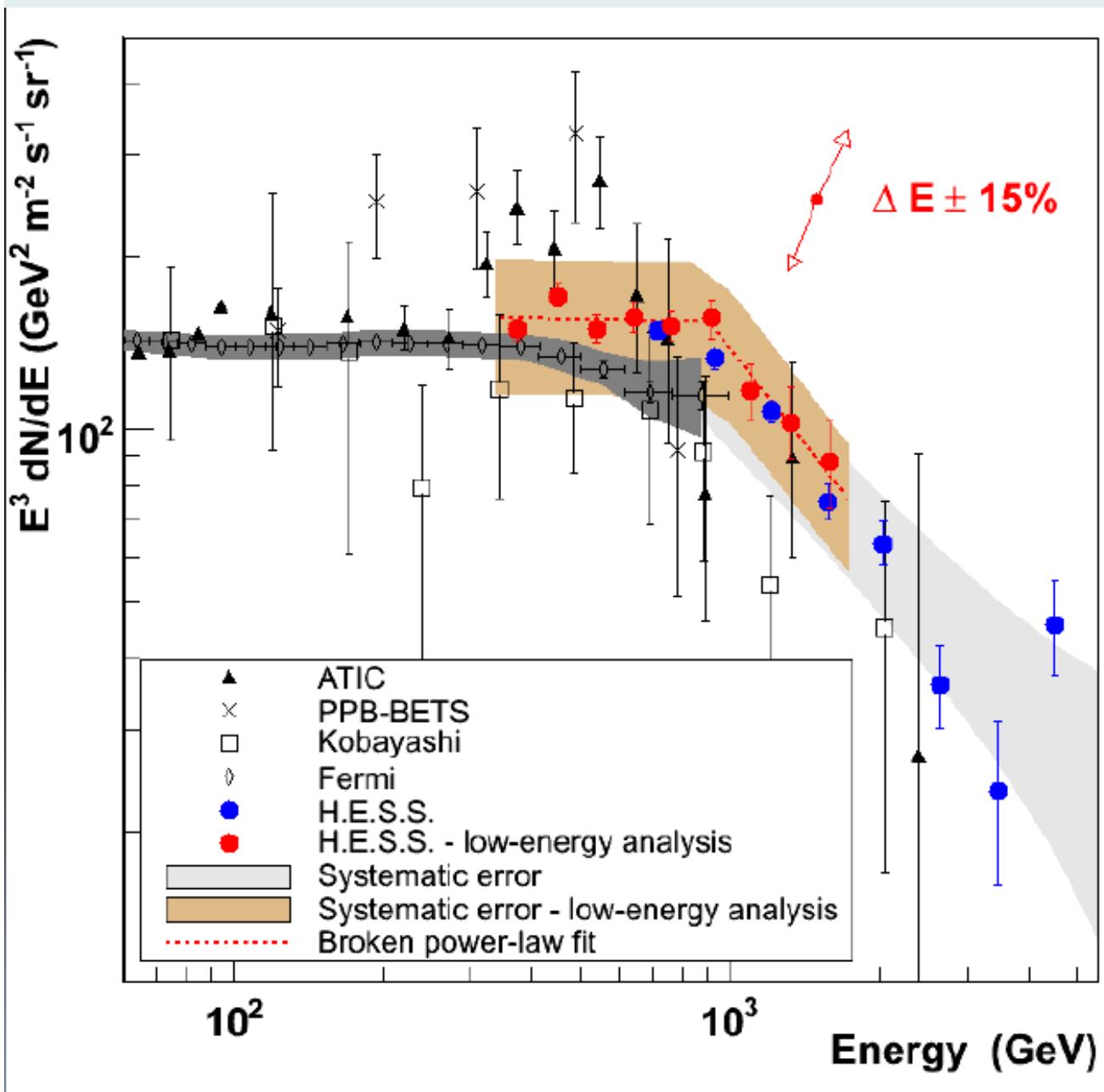


Deviation from the standard model prediction, assuming no primary source of positrons

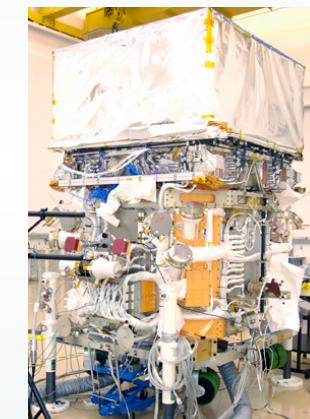
Separate spectrum measurement for both e+ and e- needed

electrons and positrons (elecposi)

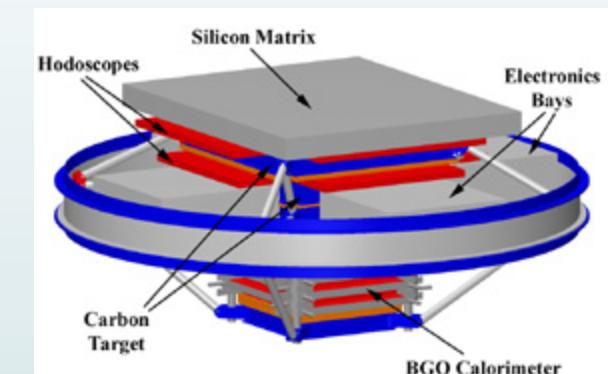
HESS



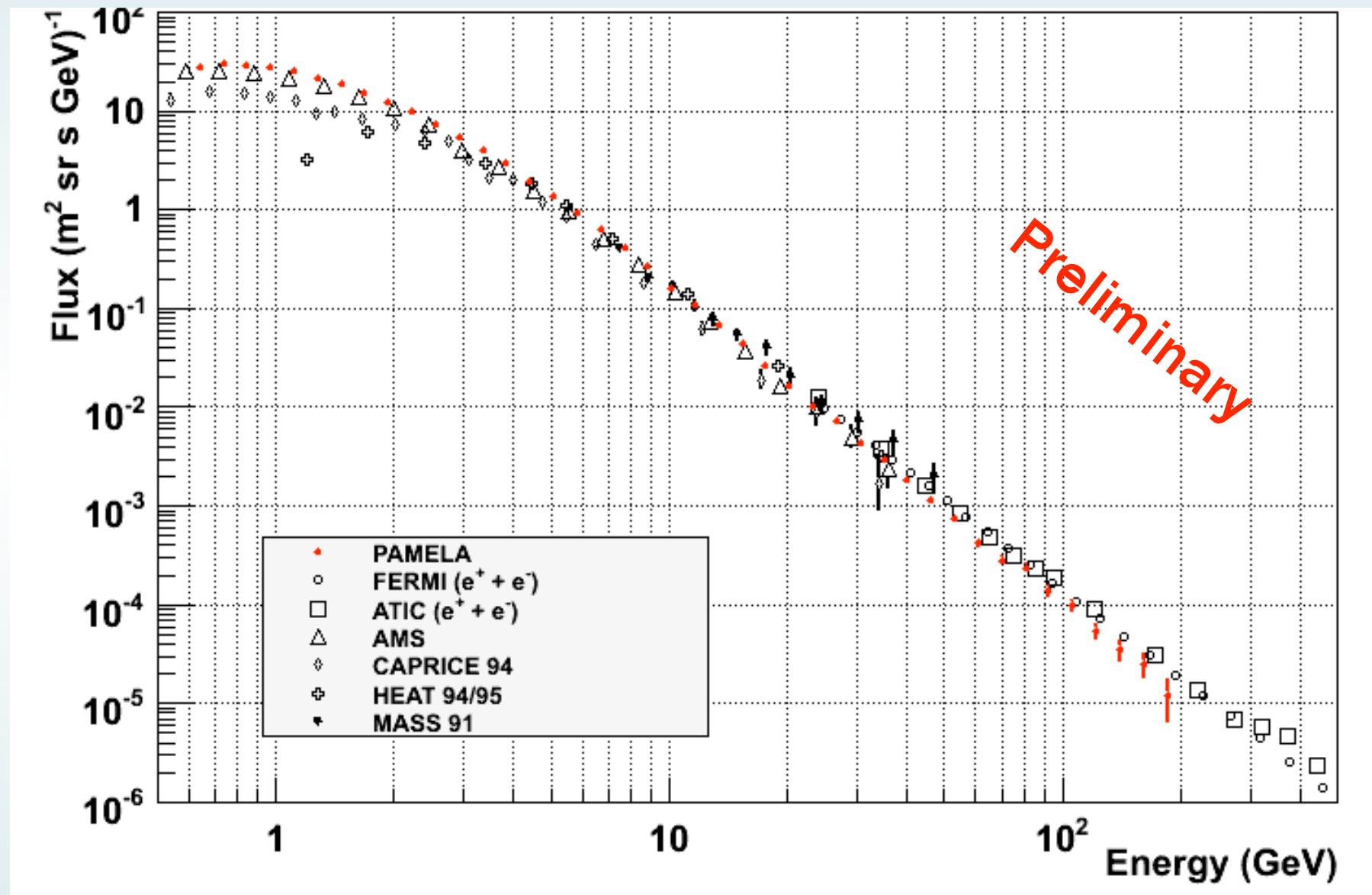
FERMI



ATIC – Long Duration Balloon flight



electrons and positrons (elecposi) and electrons from Pamela



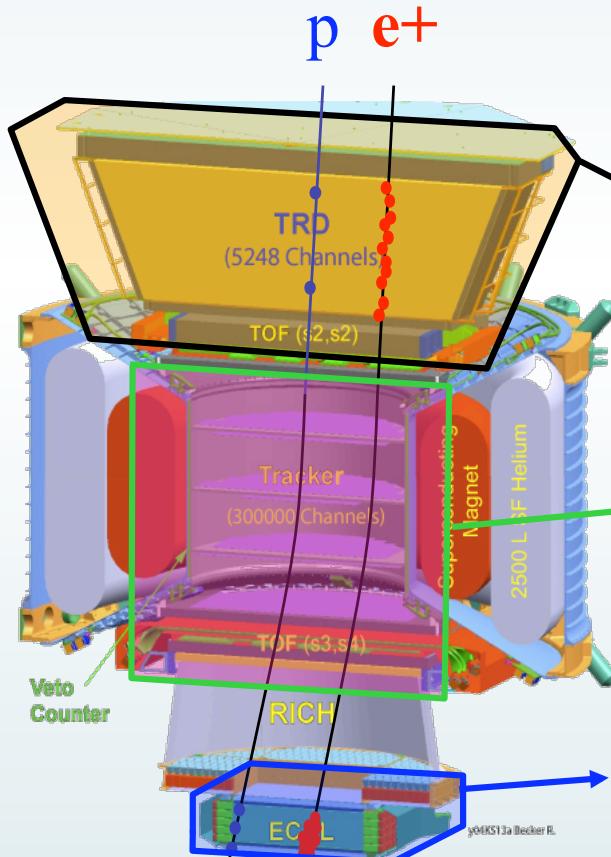
Different systematic uncertainties: proton rejection and Energy measurements

e^+

Positron

► Background

- protons : $\Phi_p \sim 10^{3-4} * \Phi_{e^+}$
- electrons : $\Phi_{e^-} \sim 10 * \Phi_{e^+}$

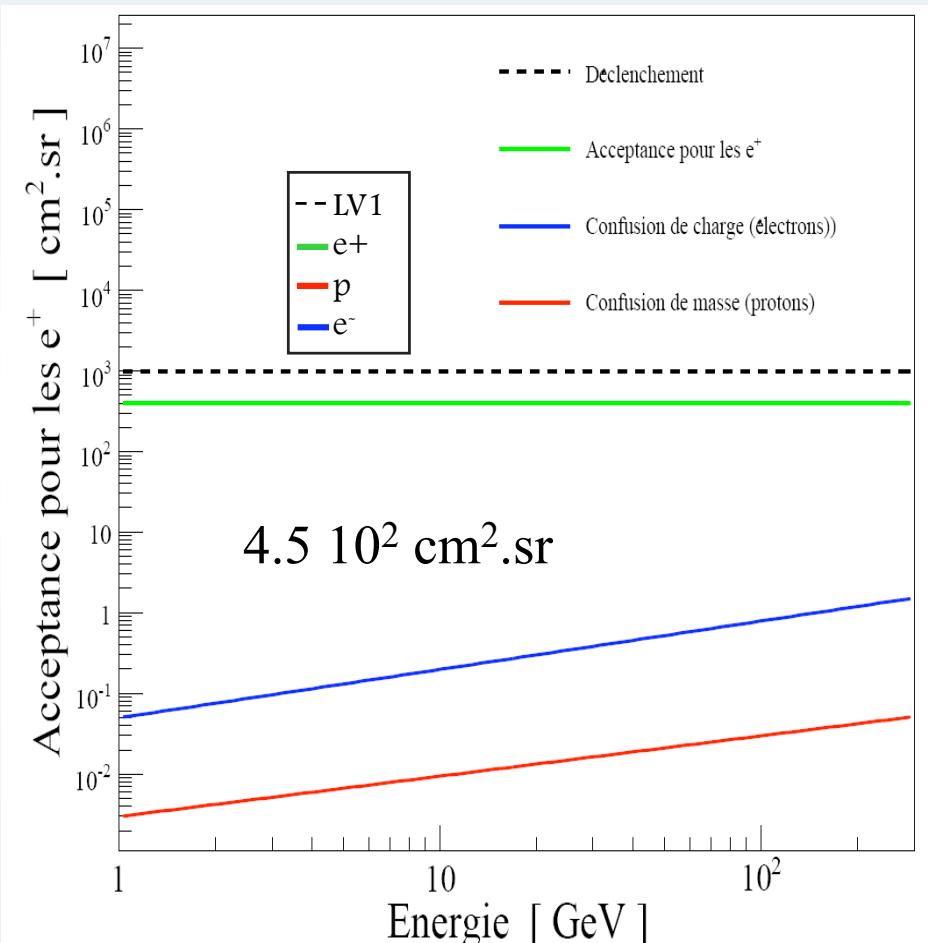


TRD :
Deposited energy

Tracker /
calorimeter:
E/p ratio

Calorimeter :
Electromagnetic
shower properties

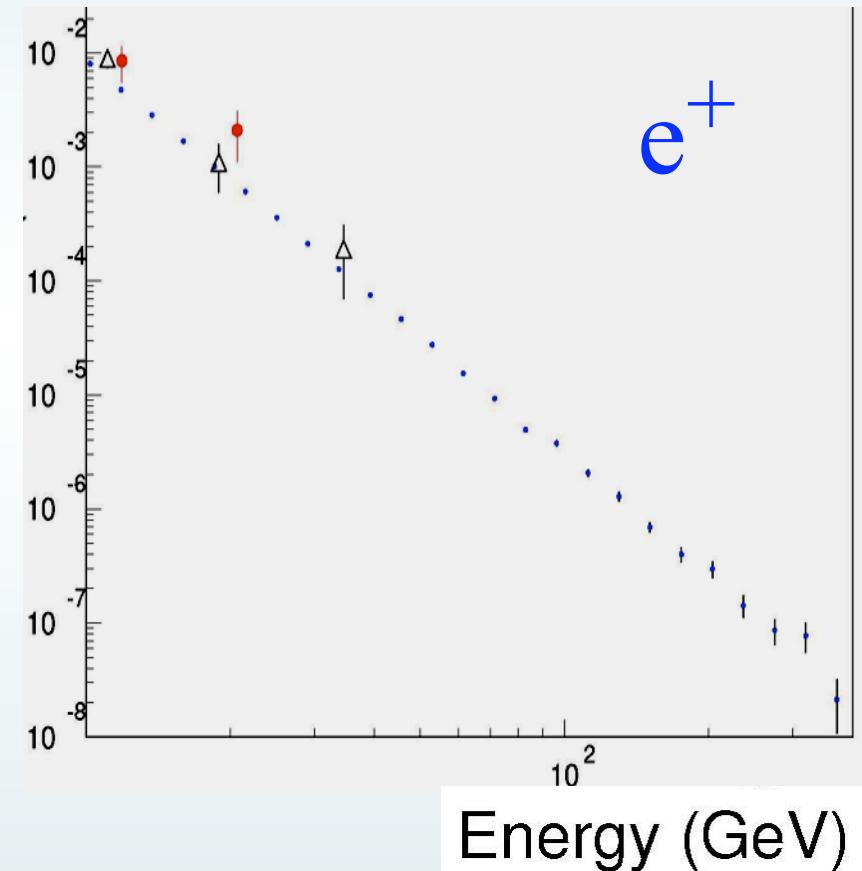
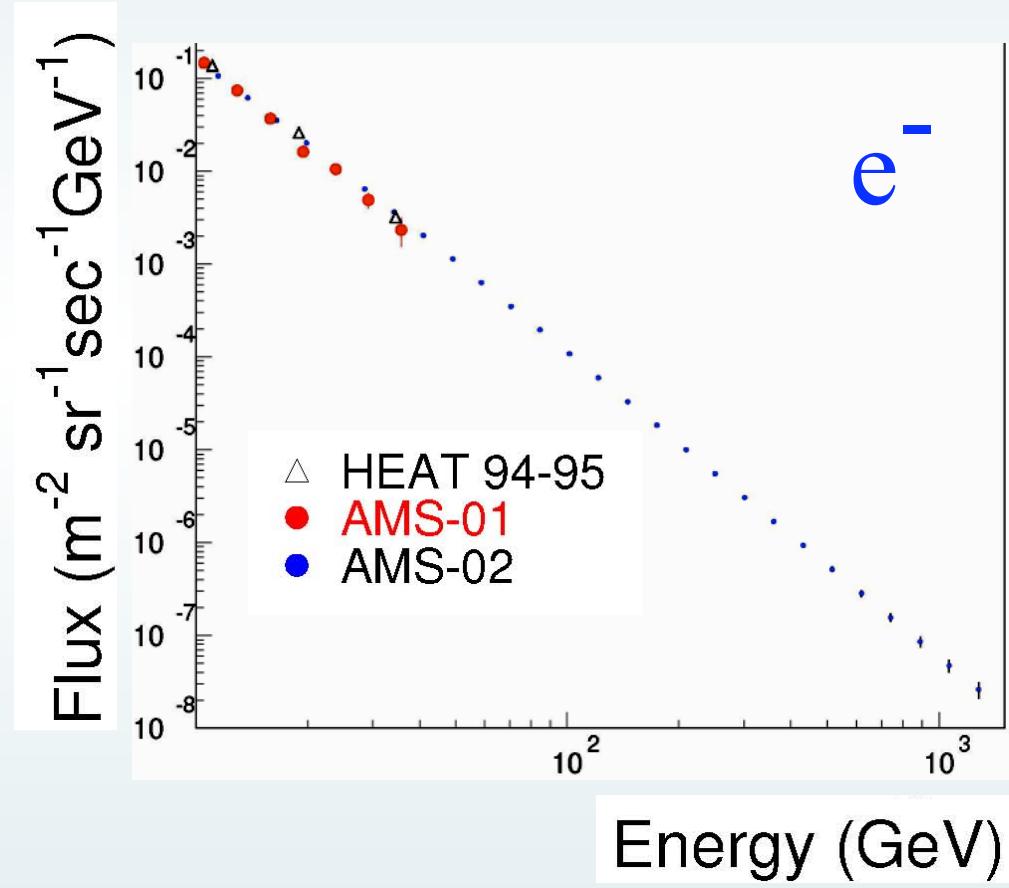
$$A_{e^+} / A_p \sim 10^5$$



$$e^+ : 1 \text{ GeV} \sim 300 \text{ GeV}$$

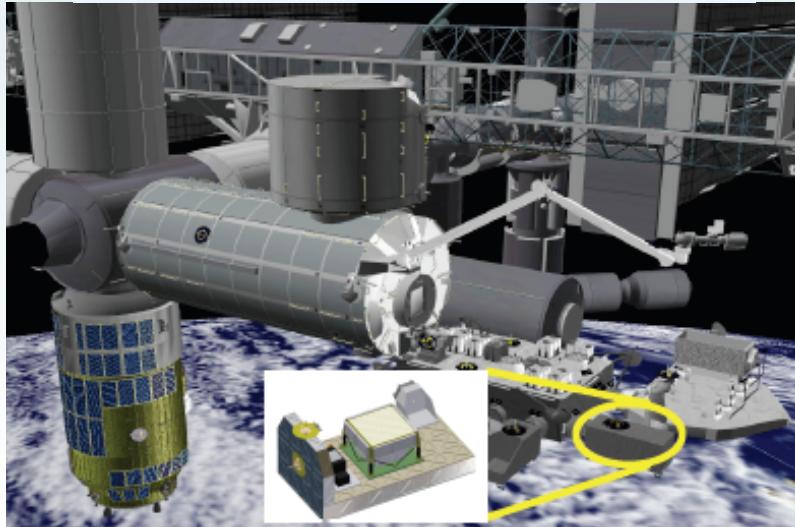
Positron or electrons

AMS 3 years



CALET: CALorimetric Electron Telescope

Japan/USA/Italie/China (PPB-BETS coll.)

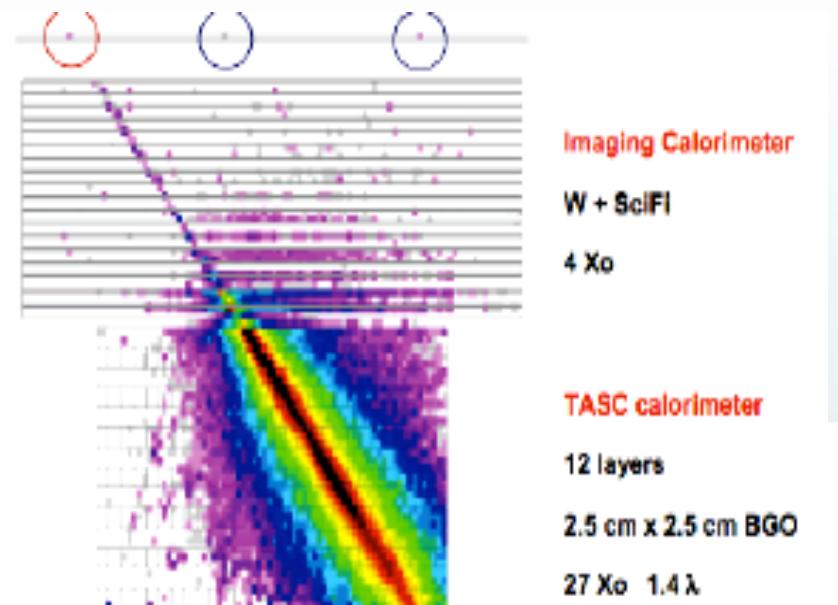


CALET Payload:

- ▷ 1 GeV - 10 TeV for “elecposi” ($e^+ + e^-$)
- ▷ 20 MeV – TeV for gamma rays
- ▷ Z^2 measurement
- ▷ **Acceptance 1 m²sr**

CALET Mission:

- ▷ Launch HTV: HIIA Transfer Vehicle
- ▷ Attach point on the ISS: exposed Facility of Japanese Experiment Module (JEM-EF)
- ▷ **Lifetime > 3 years**
- ▷ **Mission Status Launch around 2013**



CALET and bCALET : e+ e-

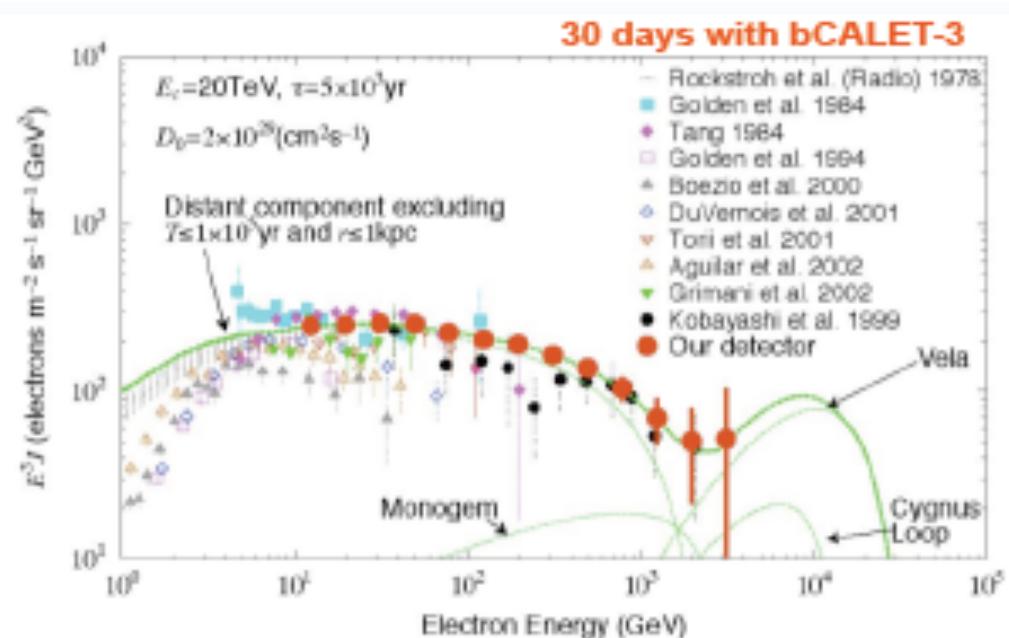
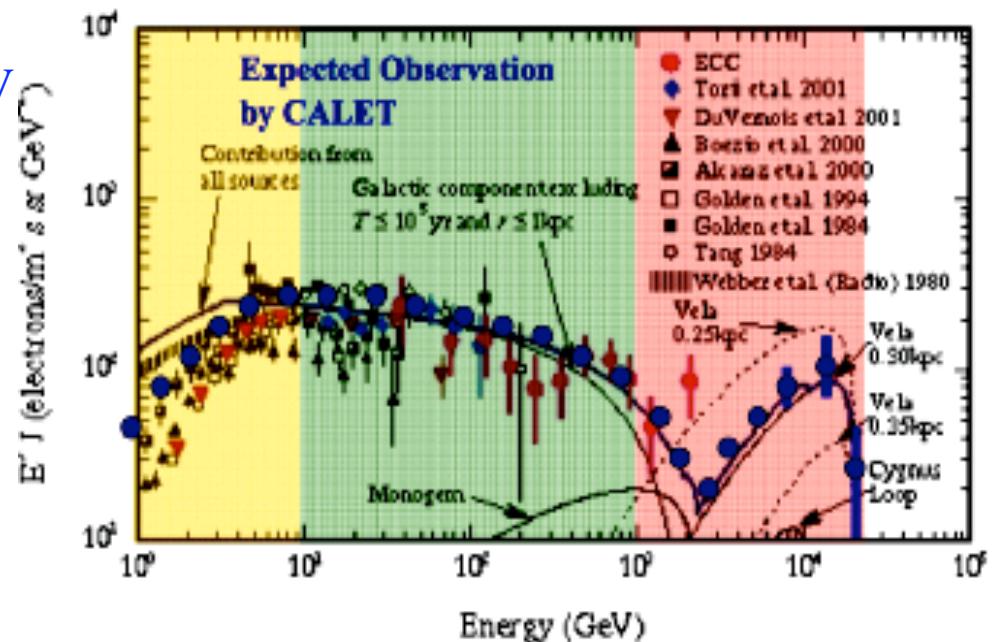
e+ & e-

- ▷ Precise flux from the GeV to 20 TeV
- ▷ Above 1 TeV sensitive probe of nearby source
- ▷ Sensitive Anisotropy >15 %

bCALET 1(1/64) 2006

bCALET 2(1/32) in preparation

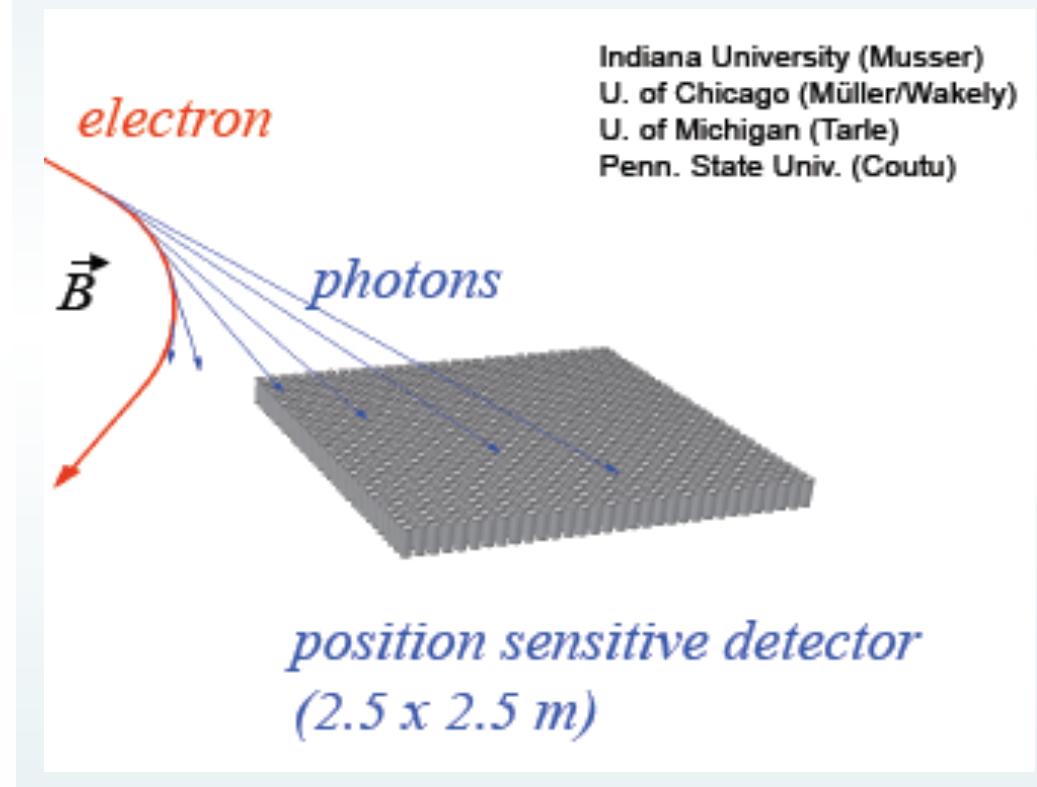
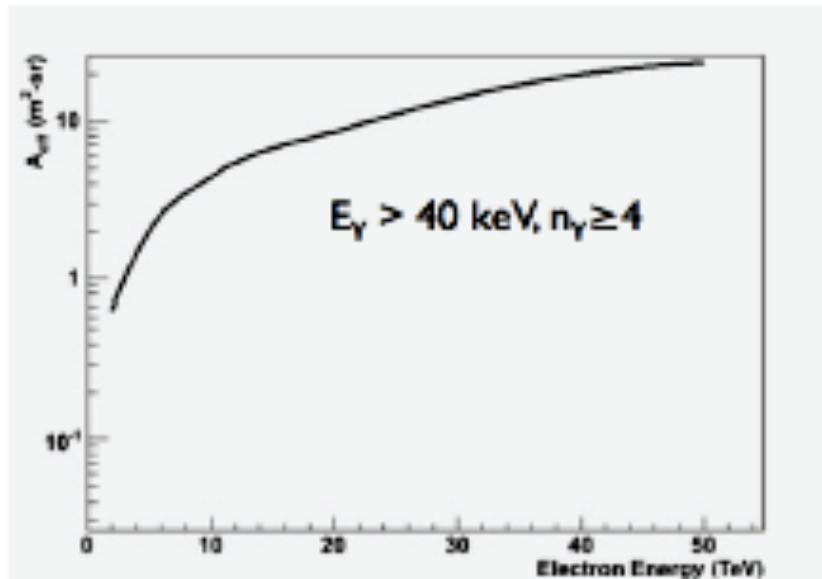
bCALET-3 Long duration flight



CREST : e+ & e- Cosmic Ray Synchrotron Radiation Telescope

e+ & e-: X-ray synchrotron radiation
in earth's magnetic field

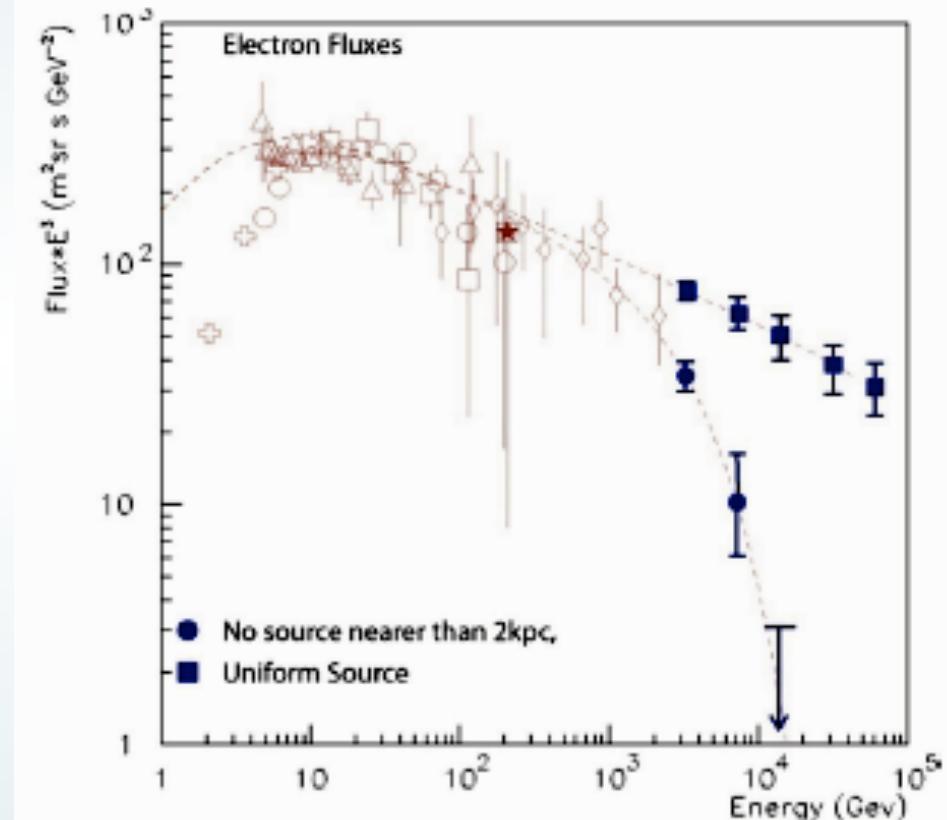
- ▷ Effective acceptance > Physical detector size
- ▷ **1024 BaF₂ crystals read by PMT**



CREST : e+ & e- Cosmic Ray Synchrotron Radiation Telescope

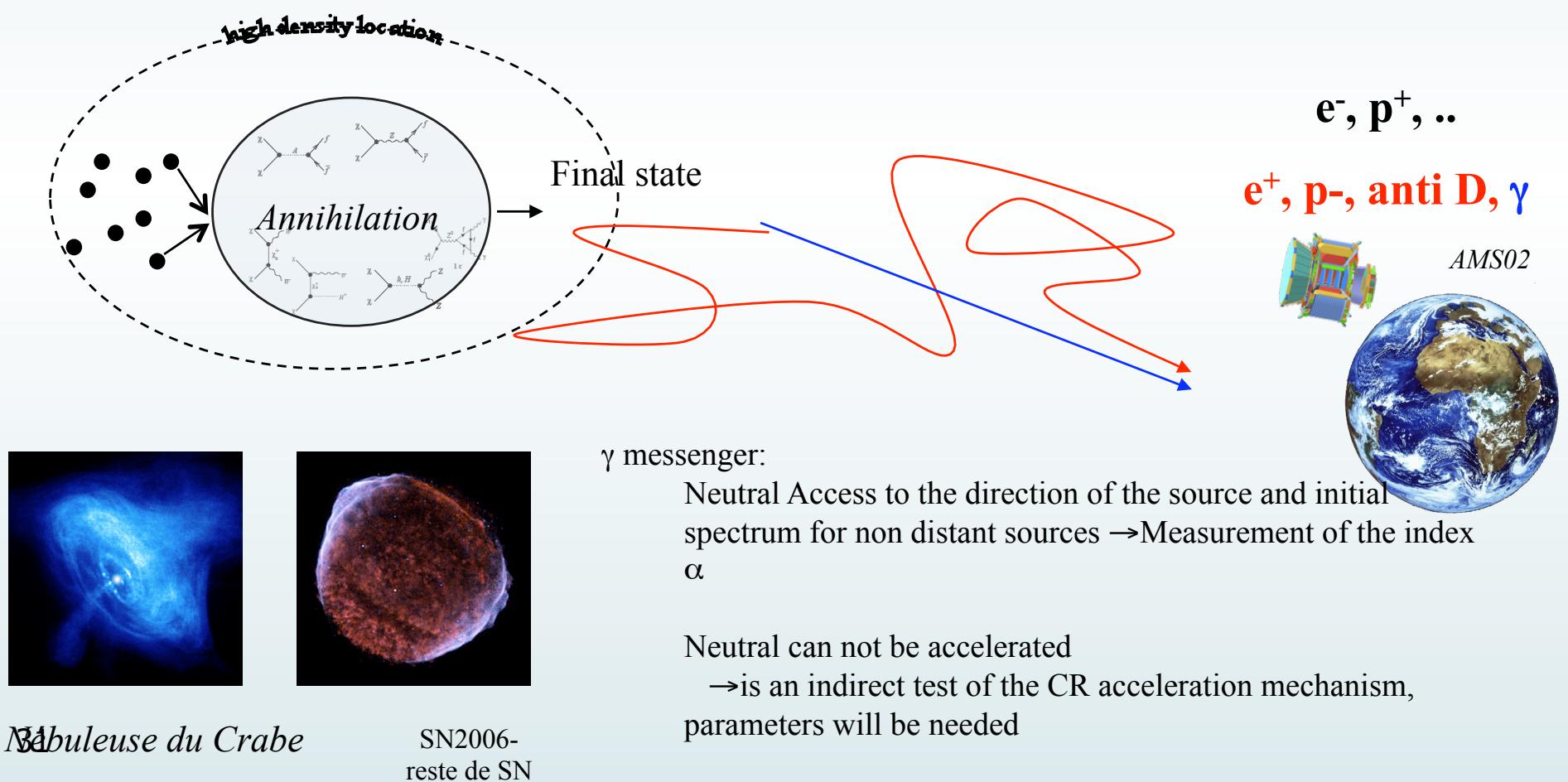
- ▷ First Crest test flight done last summer
- ▷ Long and very long flight foreseen in the coming years
- ▷ Long term: a CREST in space, with all the advantages (longer exposure, no atmosphere, lower x-ray threshold)

Expected result: 100-day CREST exposure for two extremes: no local source, and for a uniform source distribution



Dark Matter: positrons, anti protons and Gamma rays

- ▷ Astrophysics and Source study : Fermi and Cerenkov telescopes
- ▷ One DM channel could be combined with other searches



Non-thermal Radiation

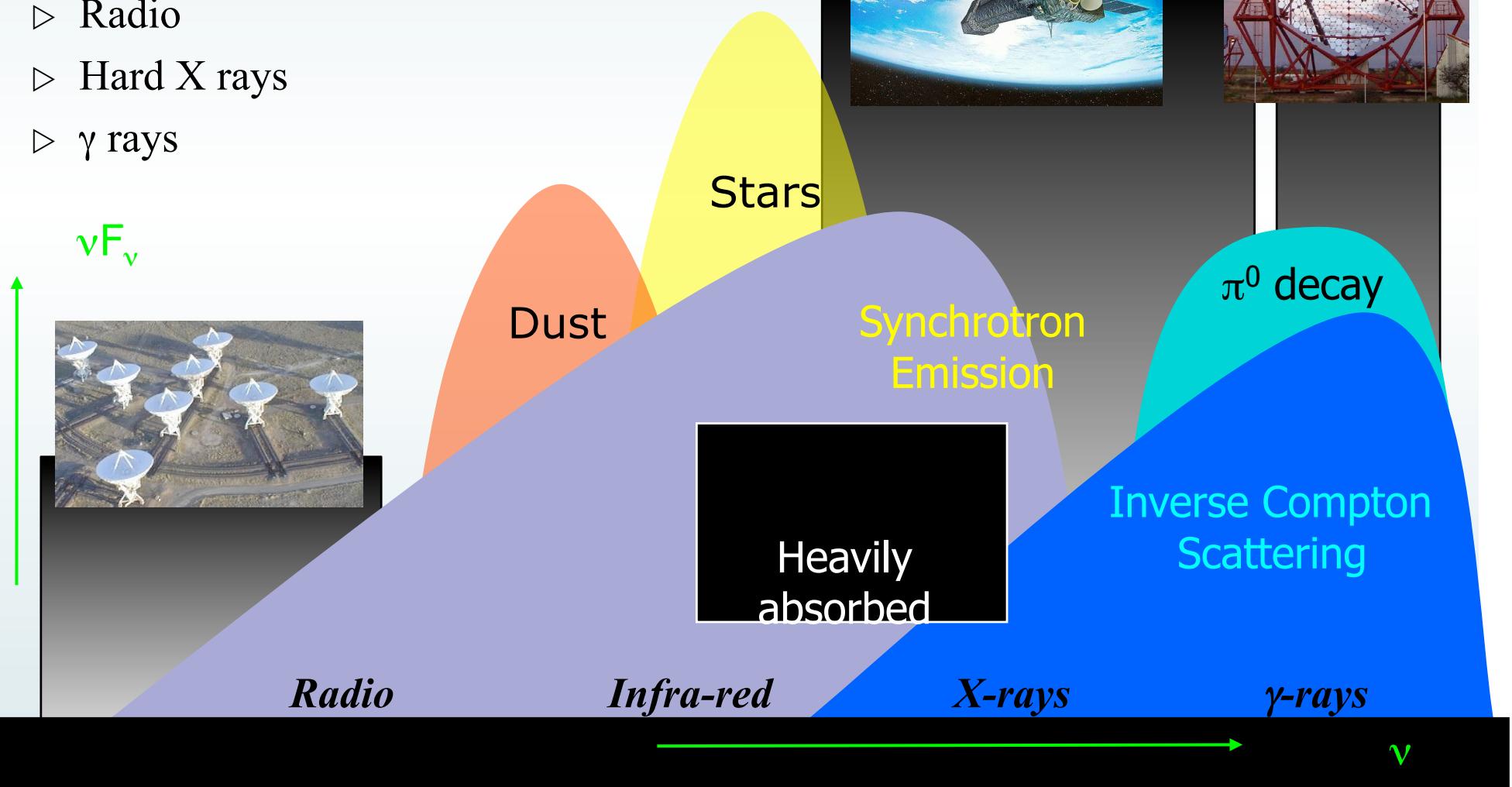
- ▷ Tracers for relativistic electrons and hadrons

- ▷ Radio
- ▷ Hard X rays
- ▷ γ rays

X/ γ -ray Satellites

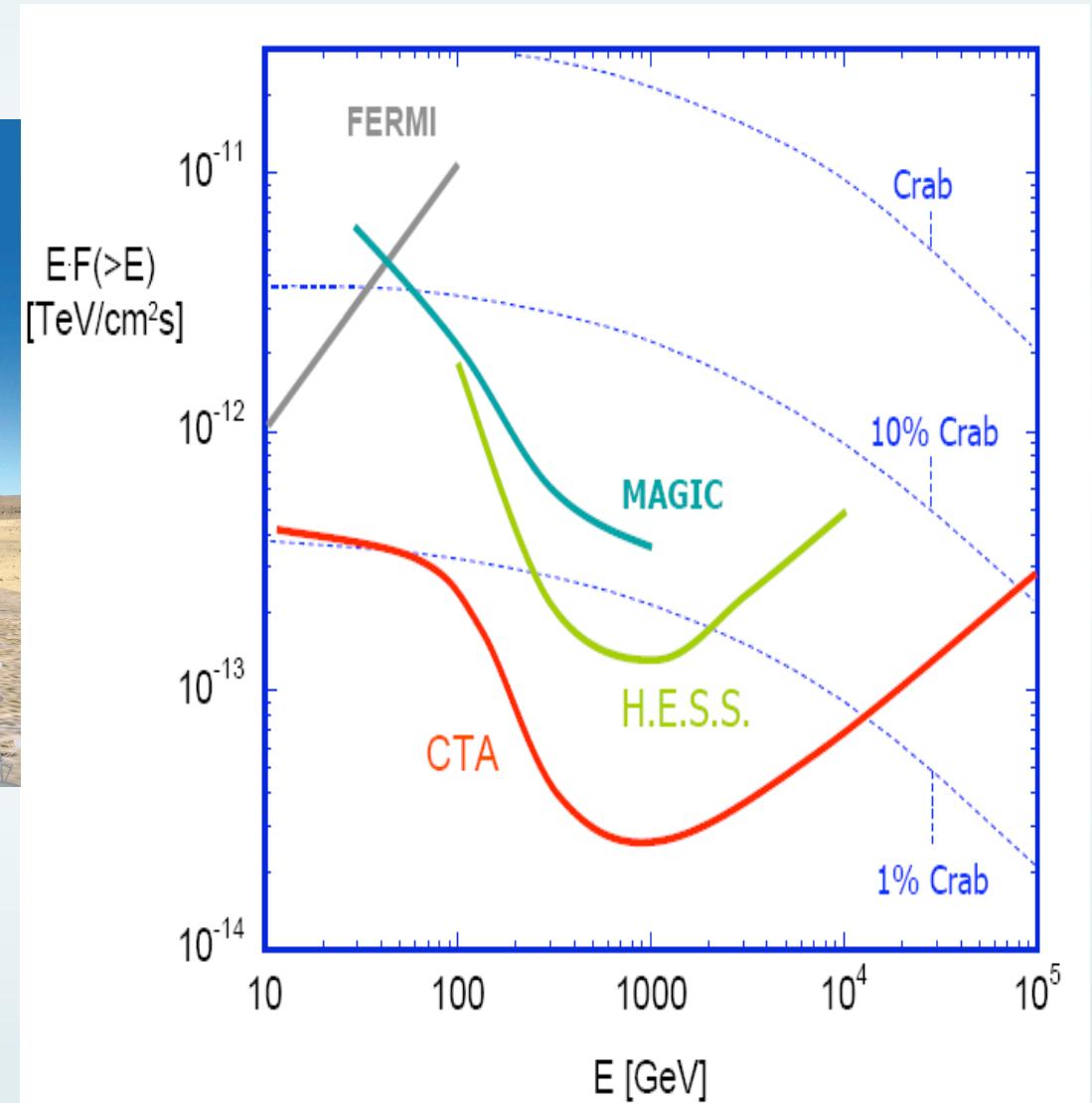
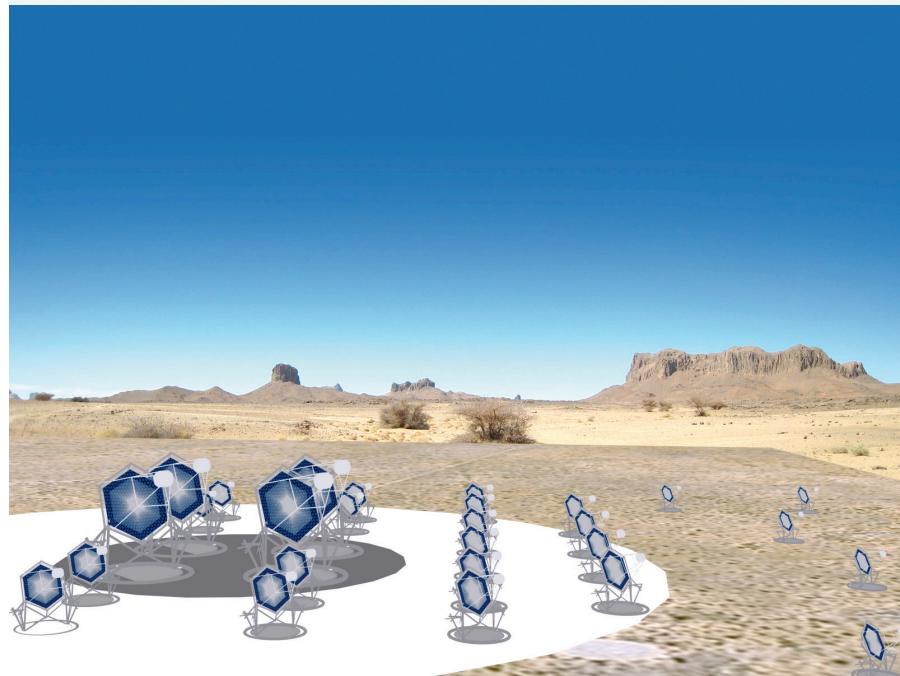


Cherenkov Telescopes

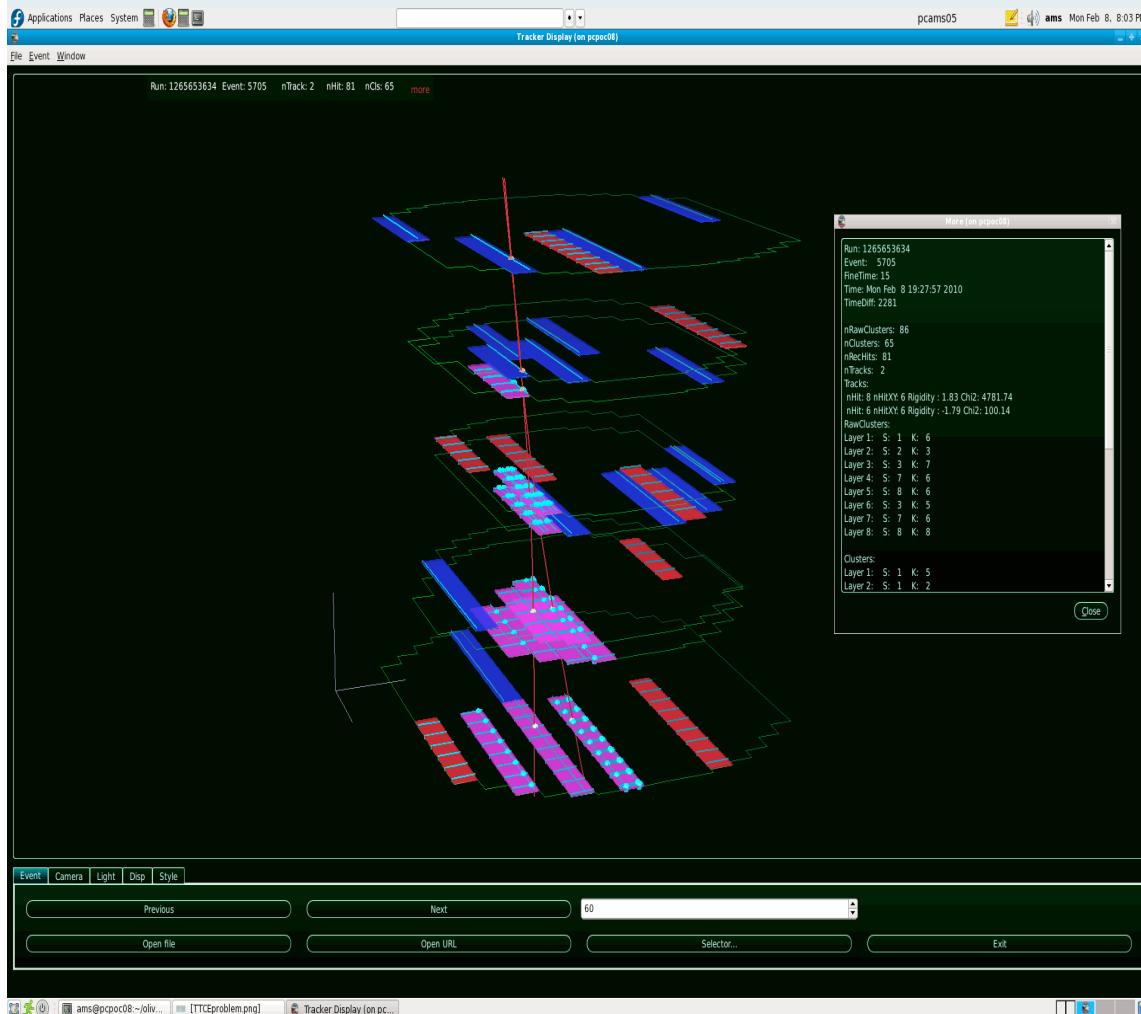


Near Future: CTA

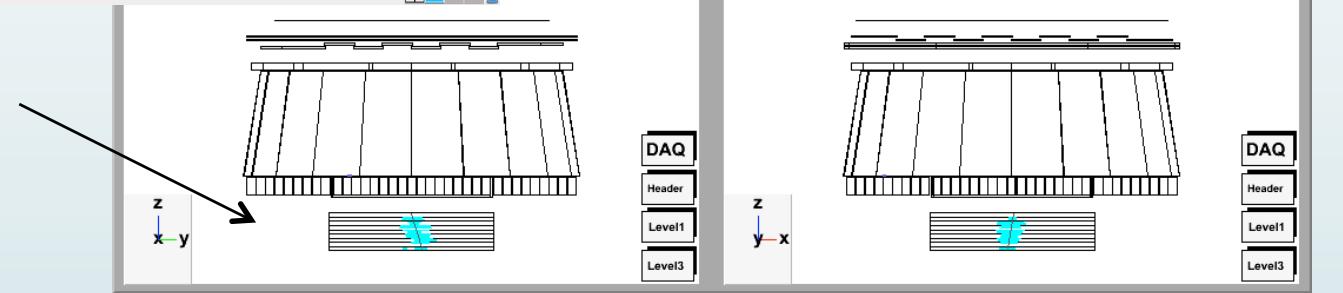
[10-100 TeV]



Conversion in the Tracker



Gamma in the calorimeter



Gamma rays



Tests Faisceaux CERN,
Février 5-9 2010

Run 1265653634/ 5707 Mon Feb 8 19:27:57 2010

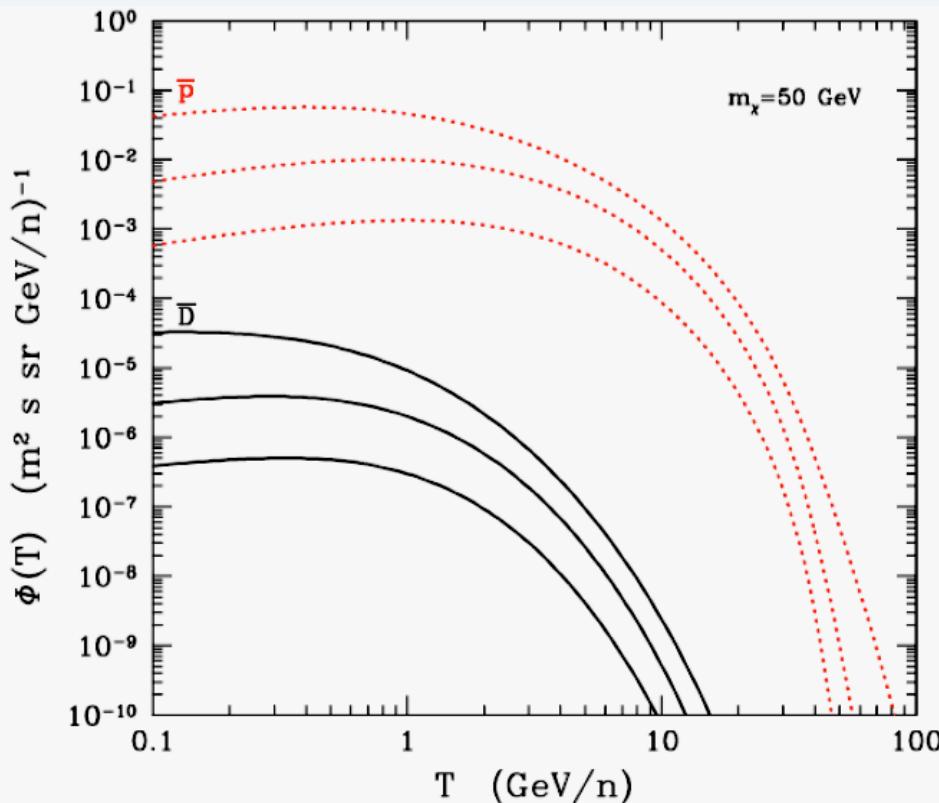
Conclusion

- ▷ A lot of pressure/projects everywhere, in particularly from the balloon side, where 100 day long flights will be possible soon
 - ▷ Ultra Long Duration Balloon flight
 - ▷ **0.6 million m³ balloon able to carry a one-ton instrument for 100 days**
- ▷ The multipurpose AMS experiment has to take data urgently

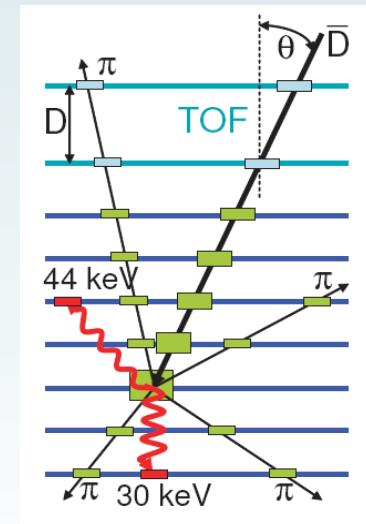
Anti Deuterium

GAPS: General Anti-Particle System

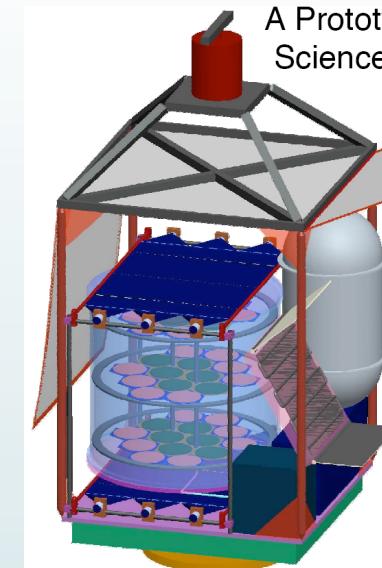
The signal similar in shape as p spectrum,
almost background free



15 evts per year and GeV/n in AMS ($\varepsilon = 100\%$)



Antiparticle capture : formation of a
“protonium” in excited state
Characteristic Xrays of de-excitation
Charged particles when annihilation



NaI Crystal to detect
X rays around target