XIV Seminar on Software for Nuclear, Subnuclear and Applied Physics

from Sunday, 4 June 2017 at **08:00** to Friday, 9 June 2017 at **22:30** (Europe/Rome)

Dark Matter searches with Space Experiments

Bruna Bertucci
University and INFN Perugia

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DM searches in space:

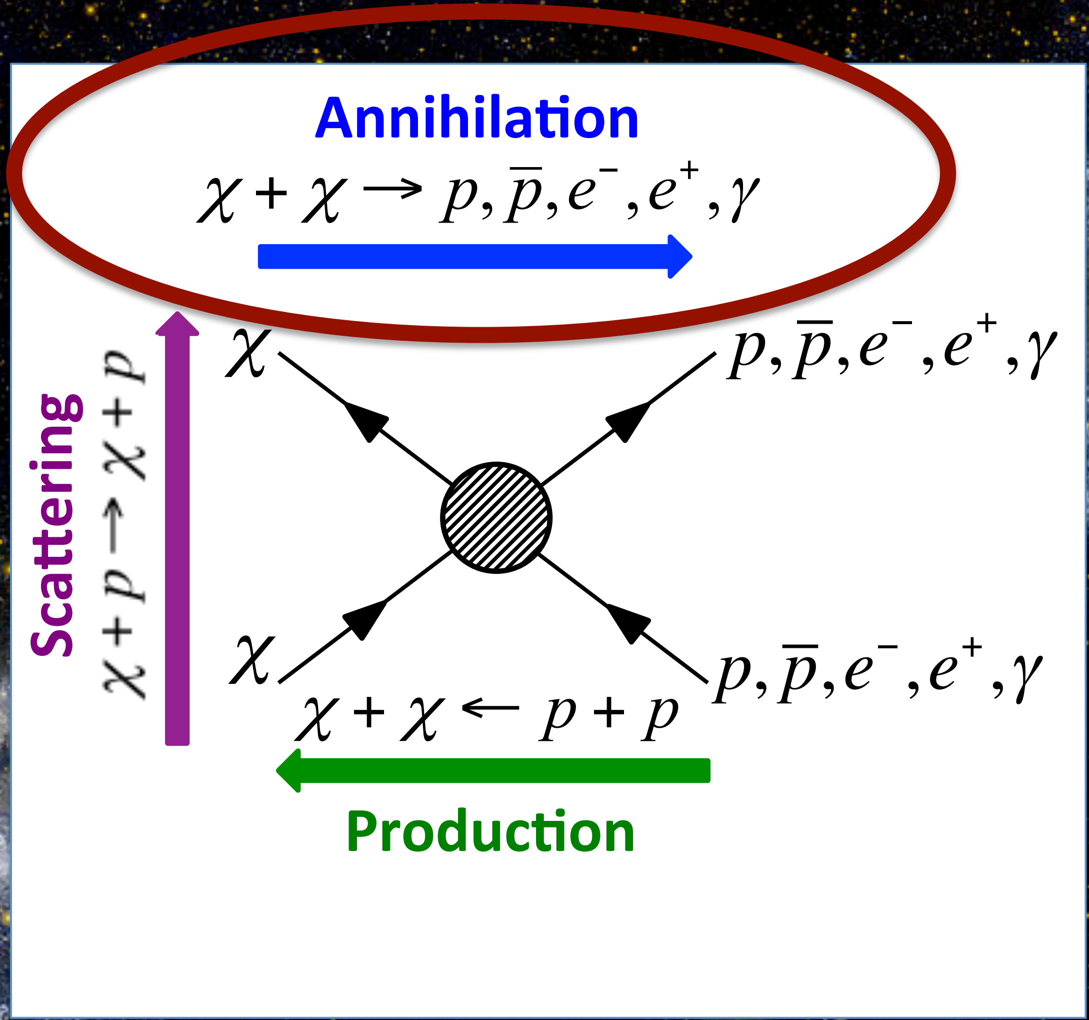
→ Cosmic Rays & Dark Matter searches

→ The experimental program

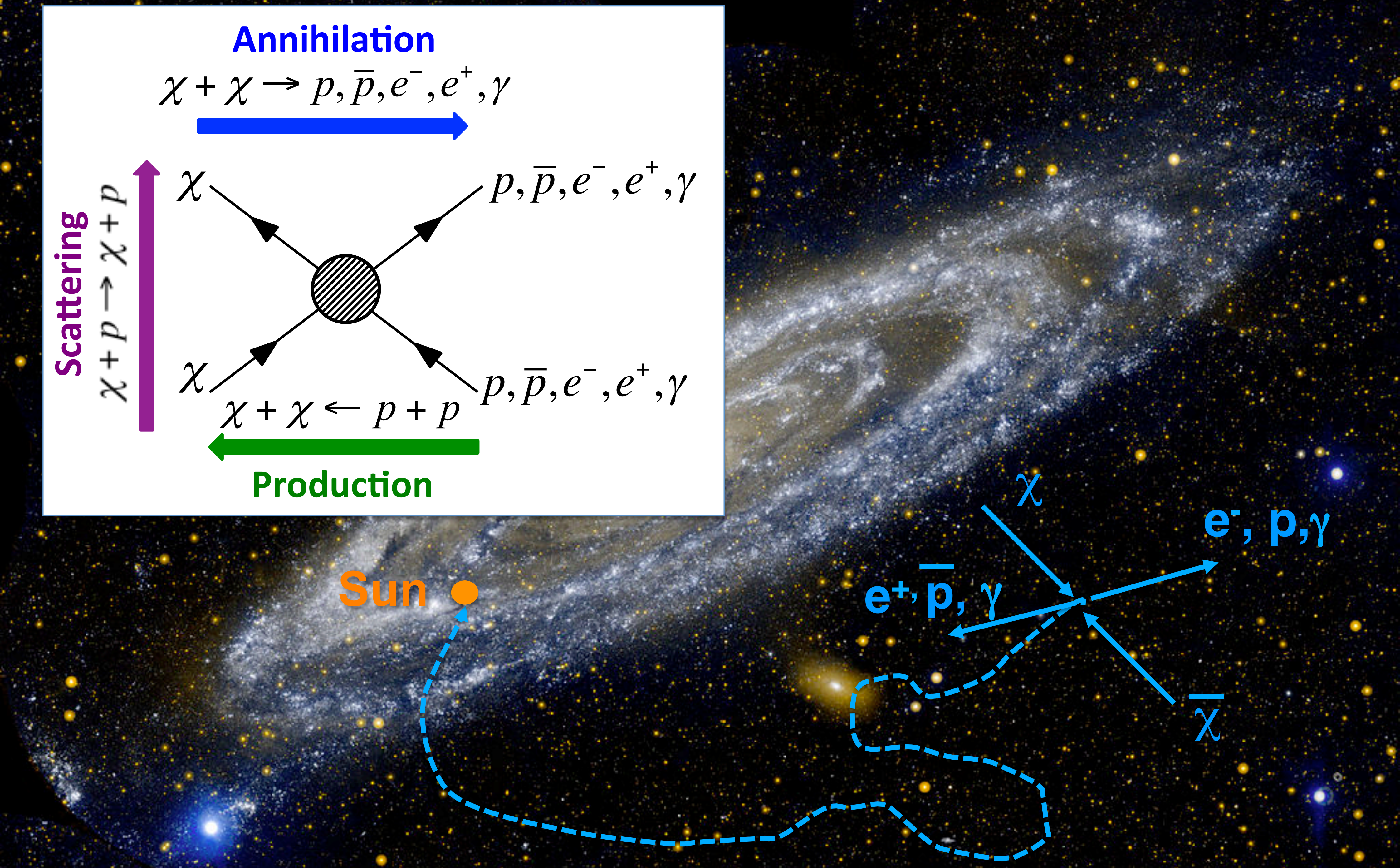
→ Challenges in SW

→ Summary

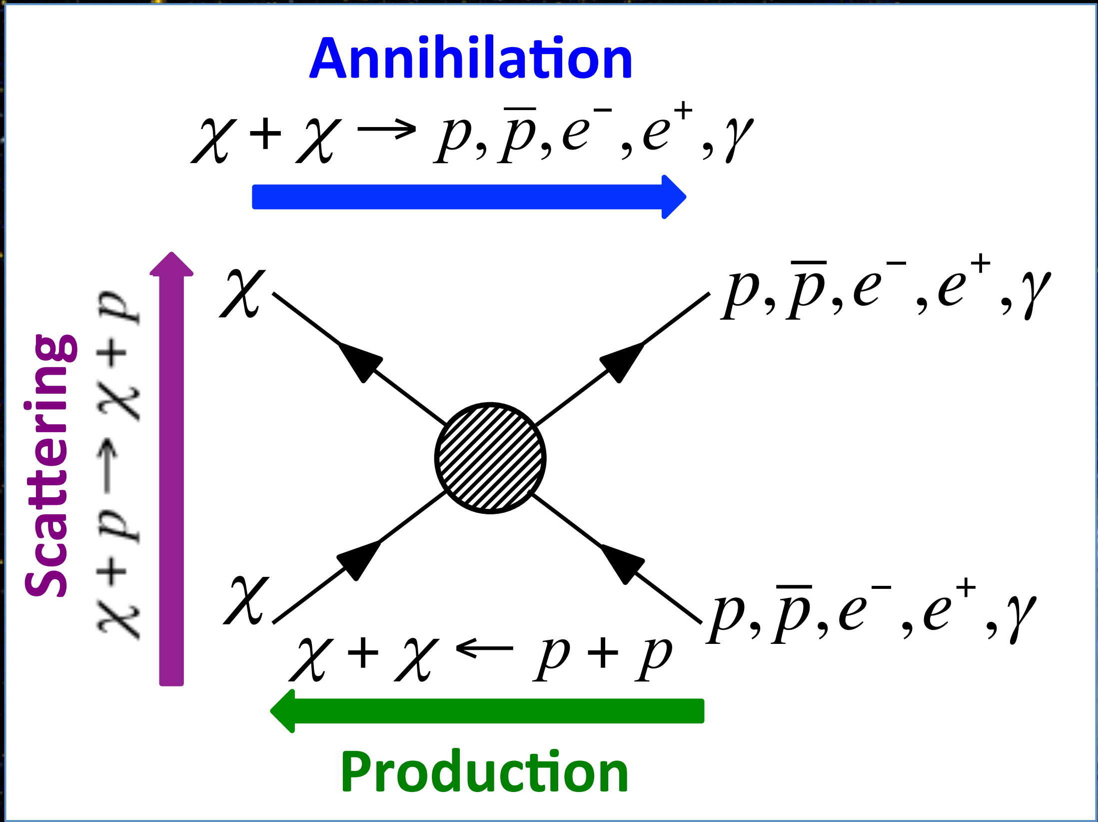
The quest for Dark Matter

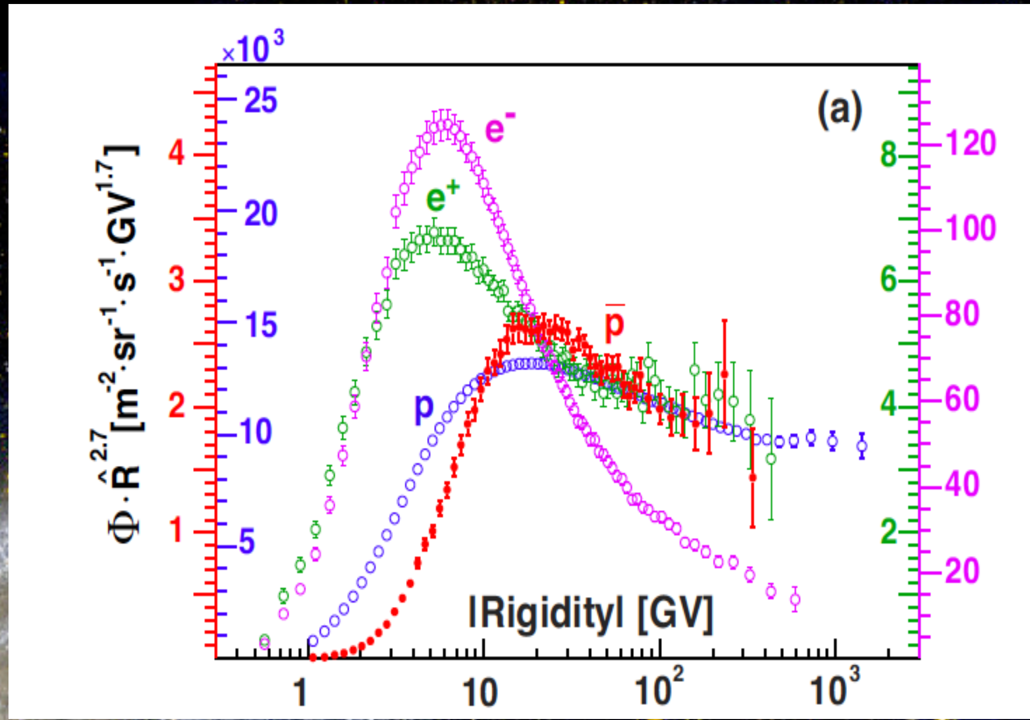


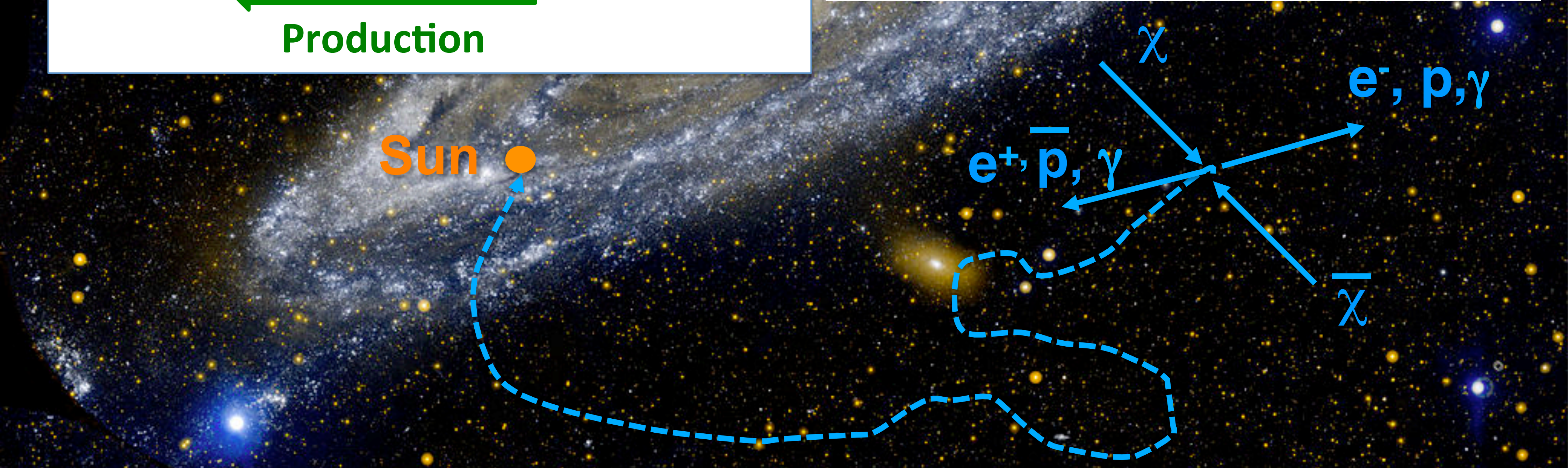
The quest for Dark Matter



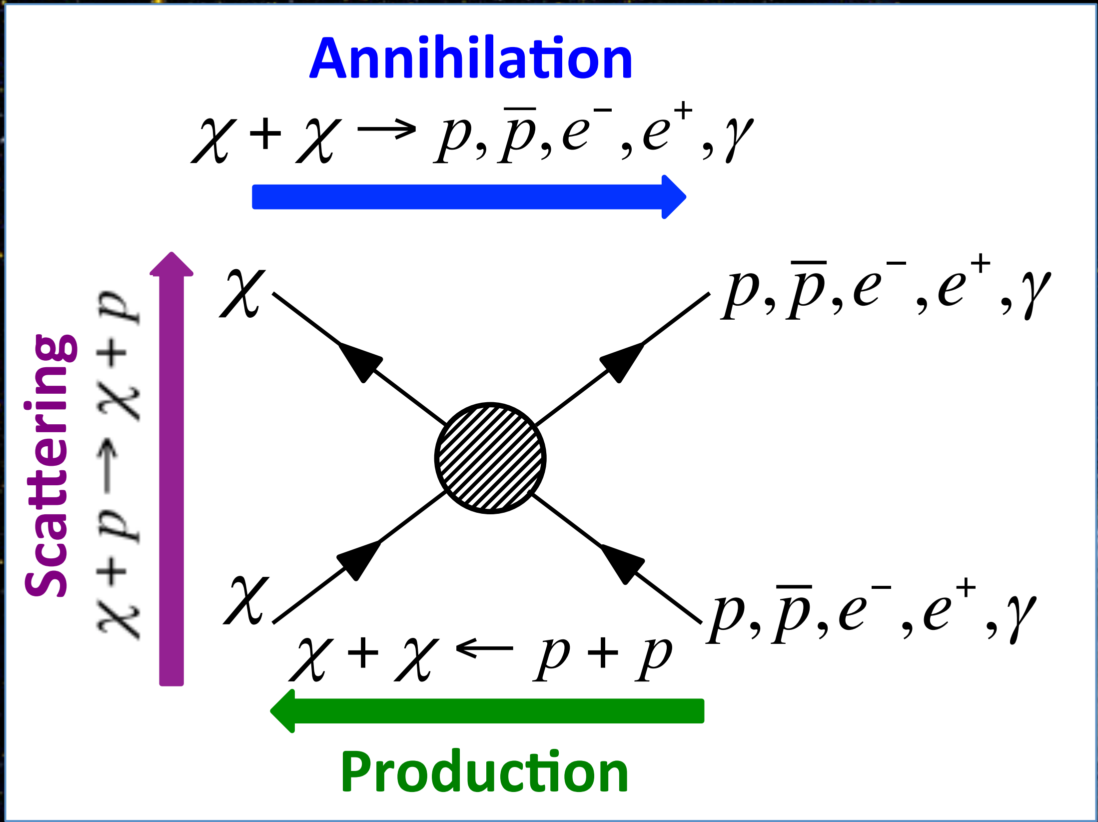
The quest for Dark Matter

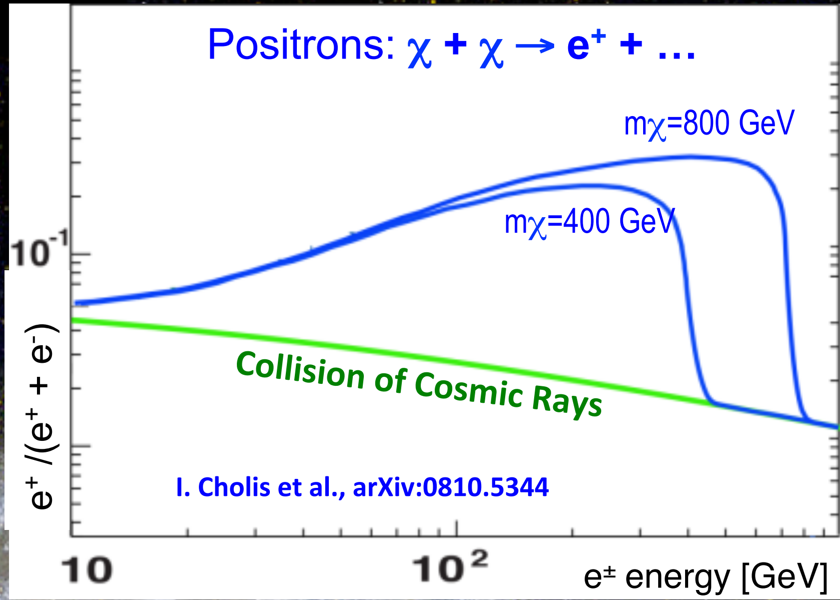


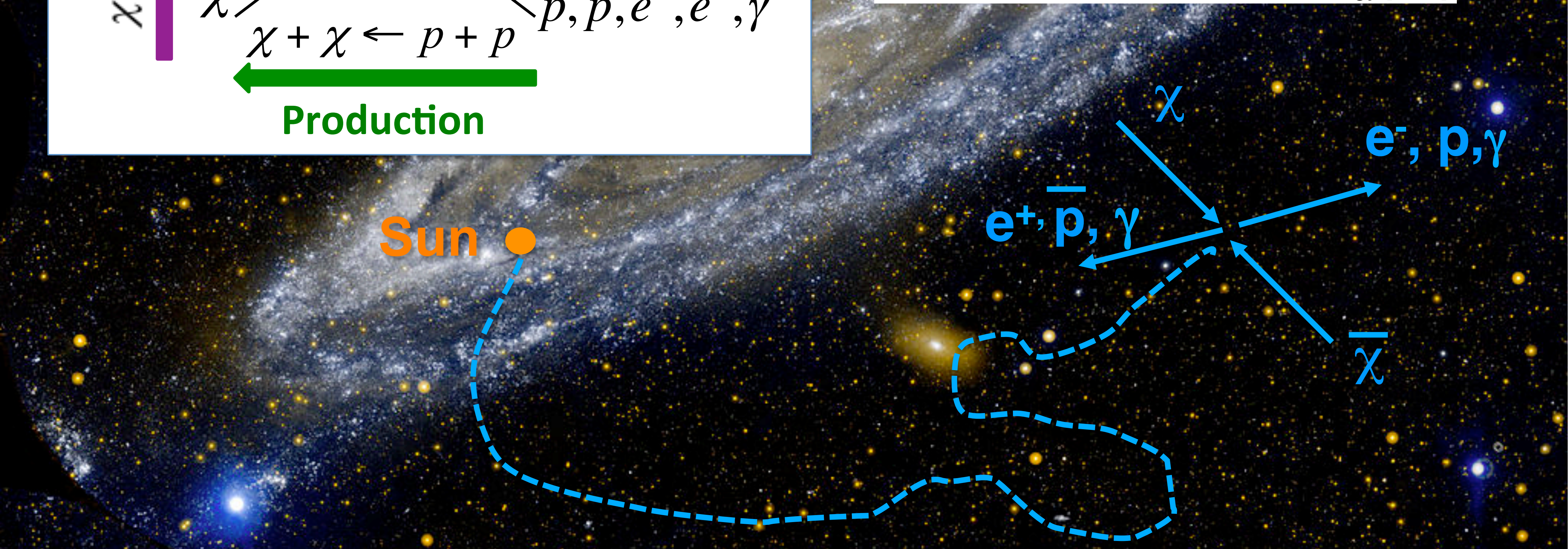




The quest for Dark Matter

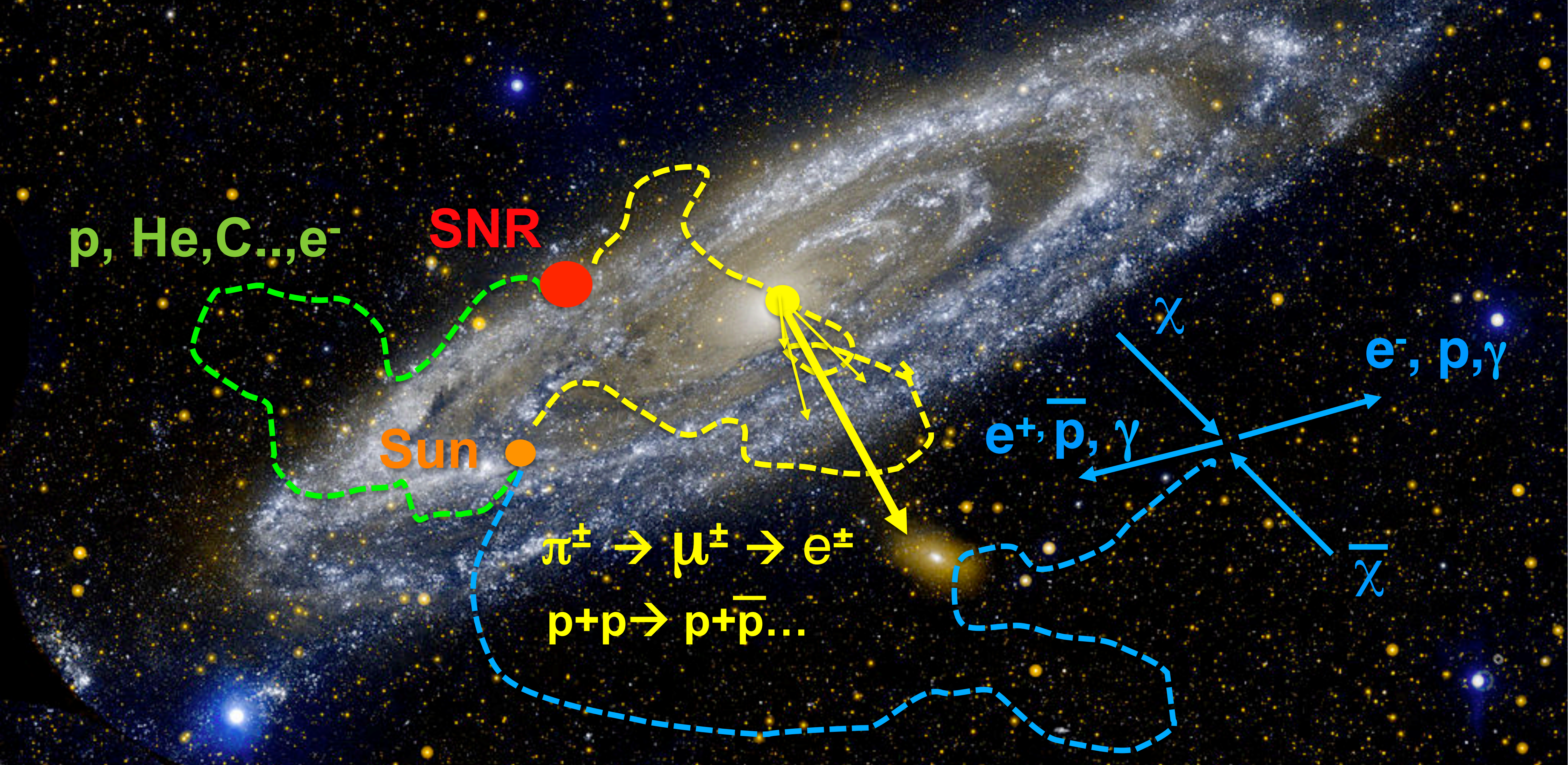






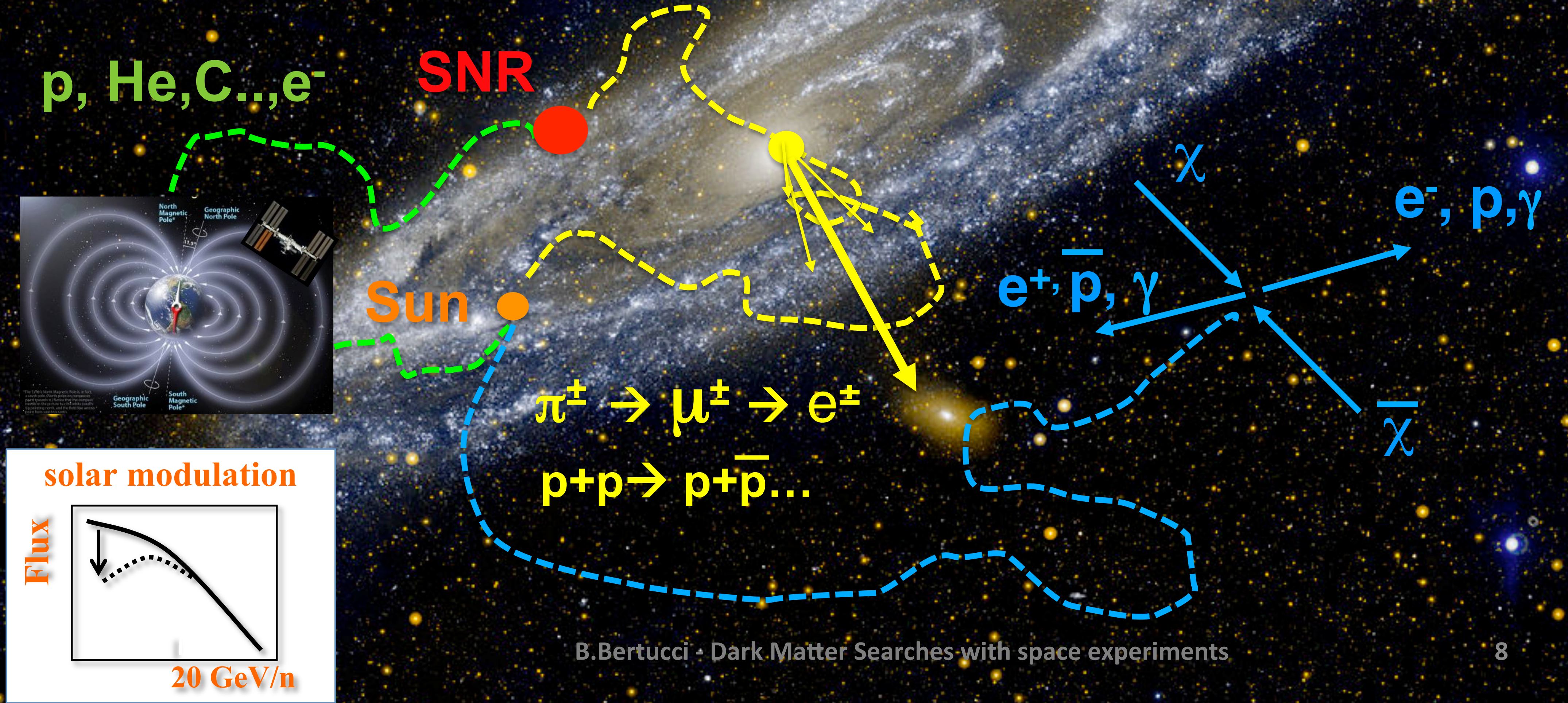
The Astrophysical Background:

Origin, propagation and production of CRs and their secondaries in the galaxy



The Astrophysical Background:

Origin, propagation and production of CRs and their secondaries in the galaxy
+ heliospheric / magnetospheric effects…



Indirect Dark Matter search

BUT

Direct CR Measurements !

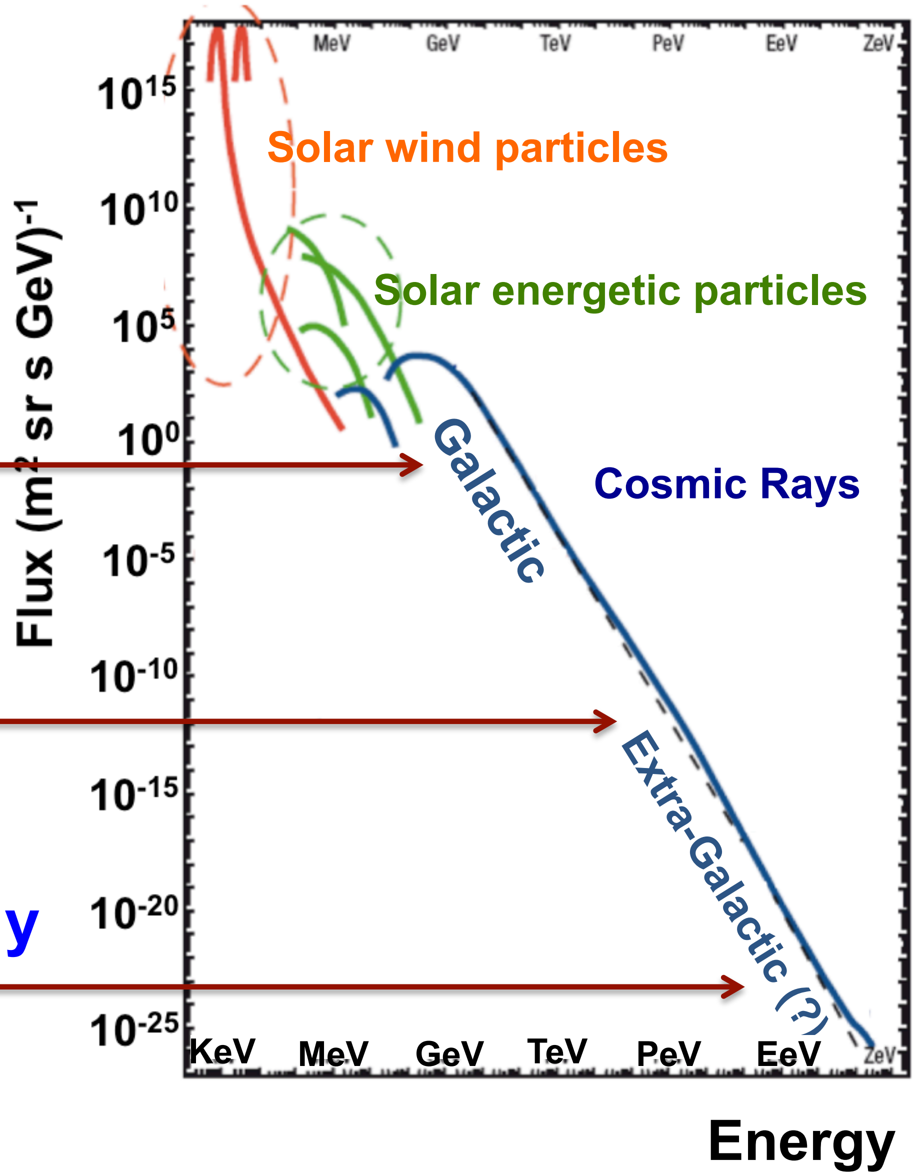
The Cosmic Ray Flux

$\Phi(E) \approx E^{-\gamma}$

@ 100 GeV ≈ 1 particle / m^2 s

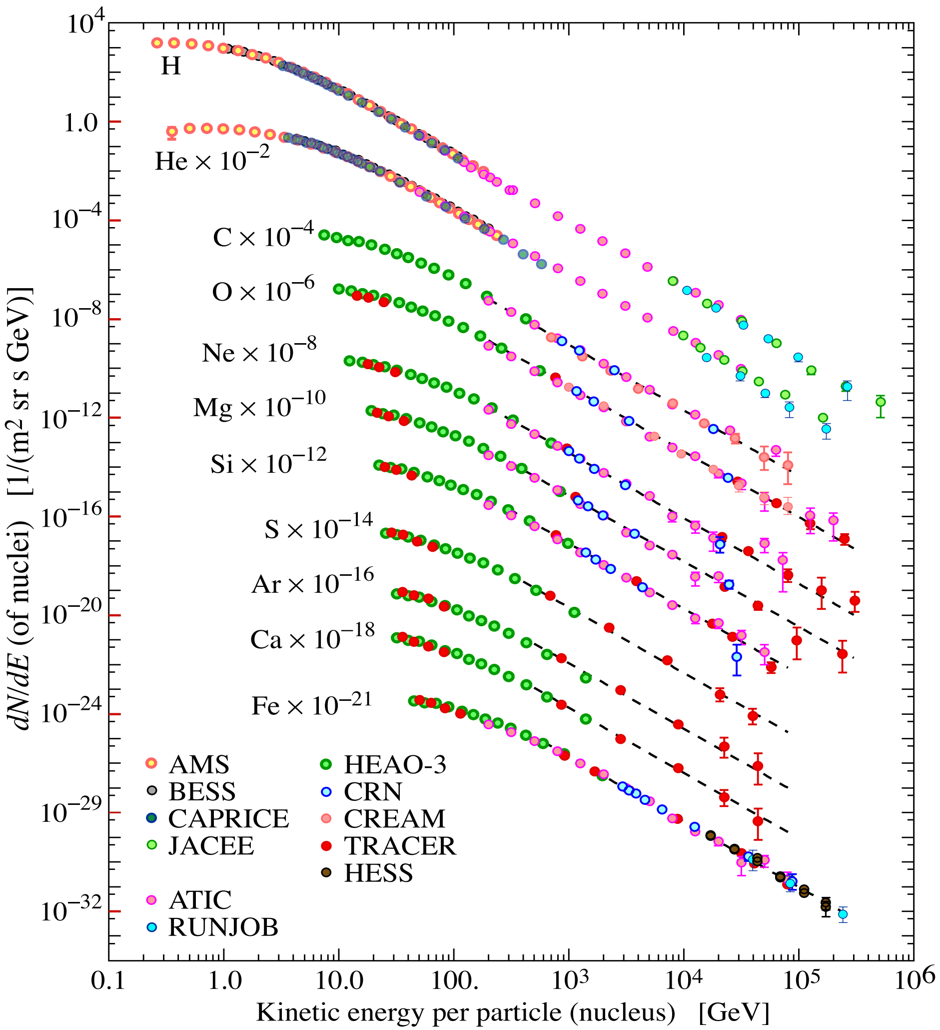
@ 10^{15} eV ≈ 1 particle / m^2 y

@ 10^{19} eV ≈ 1 particle / km^2 y



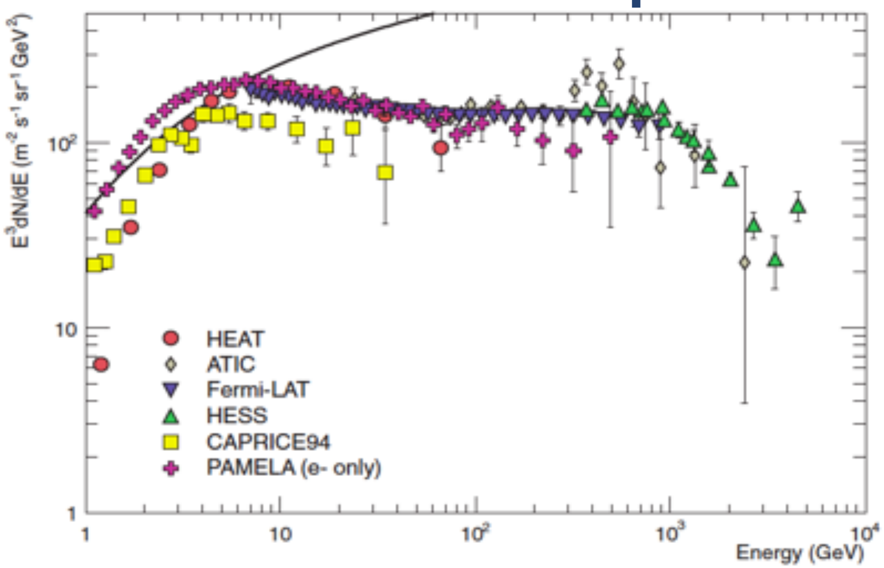
$\Delta N/\Delta E = \Phi(E) \times \Delta T \times A(E)$

Different channels to explore for different (and complementary) objectives : from CR origin in the galaxy to new exotic sources….

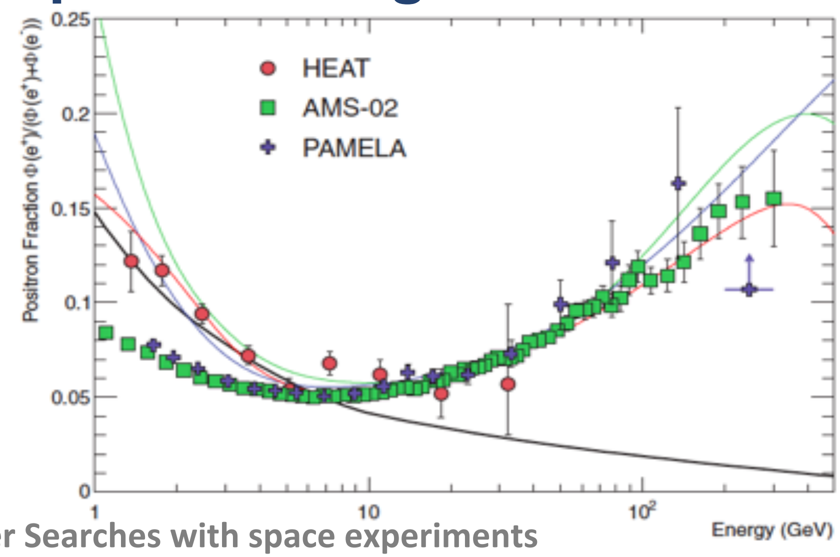


Chemical composition energy spectra of primary (and secondary)

The e± component



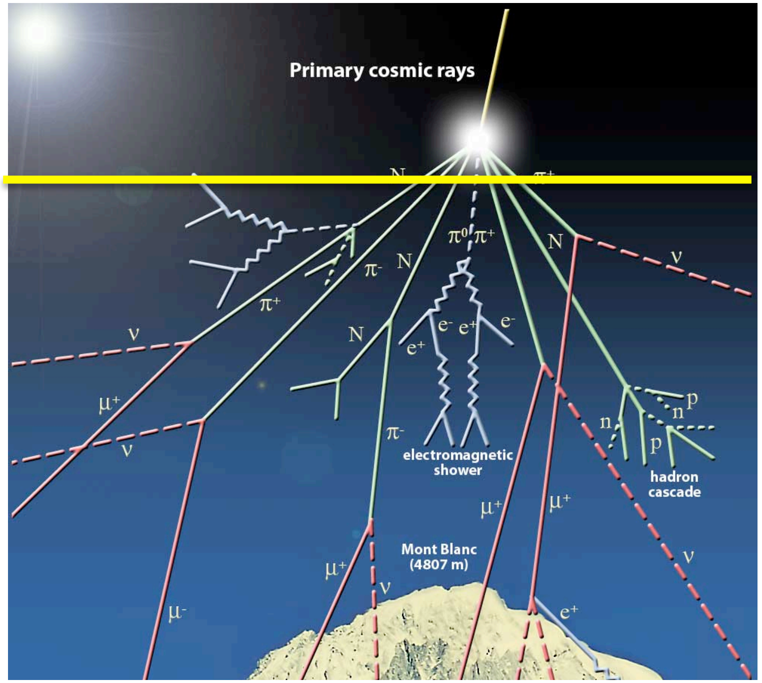
Anti-particles: e.g. the $e^+/e^+ + e^-$ fraction

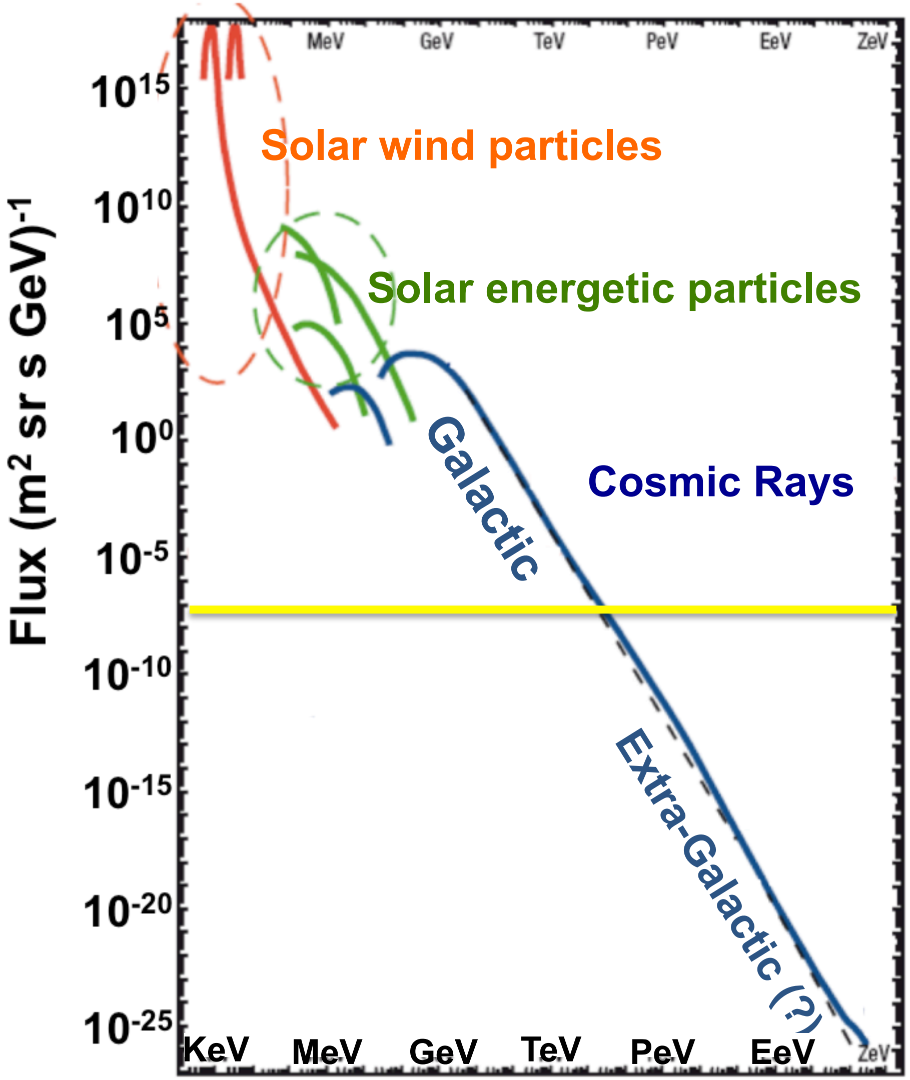


The Cosmic Ray Flux

Direct CR measurements :

- ✓ **Particle identification**
- ✓ **Energy measurement**
- ✓ **Charge sign (anti-particles)**



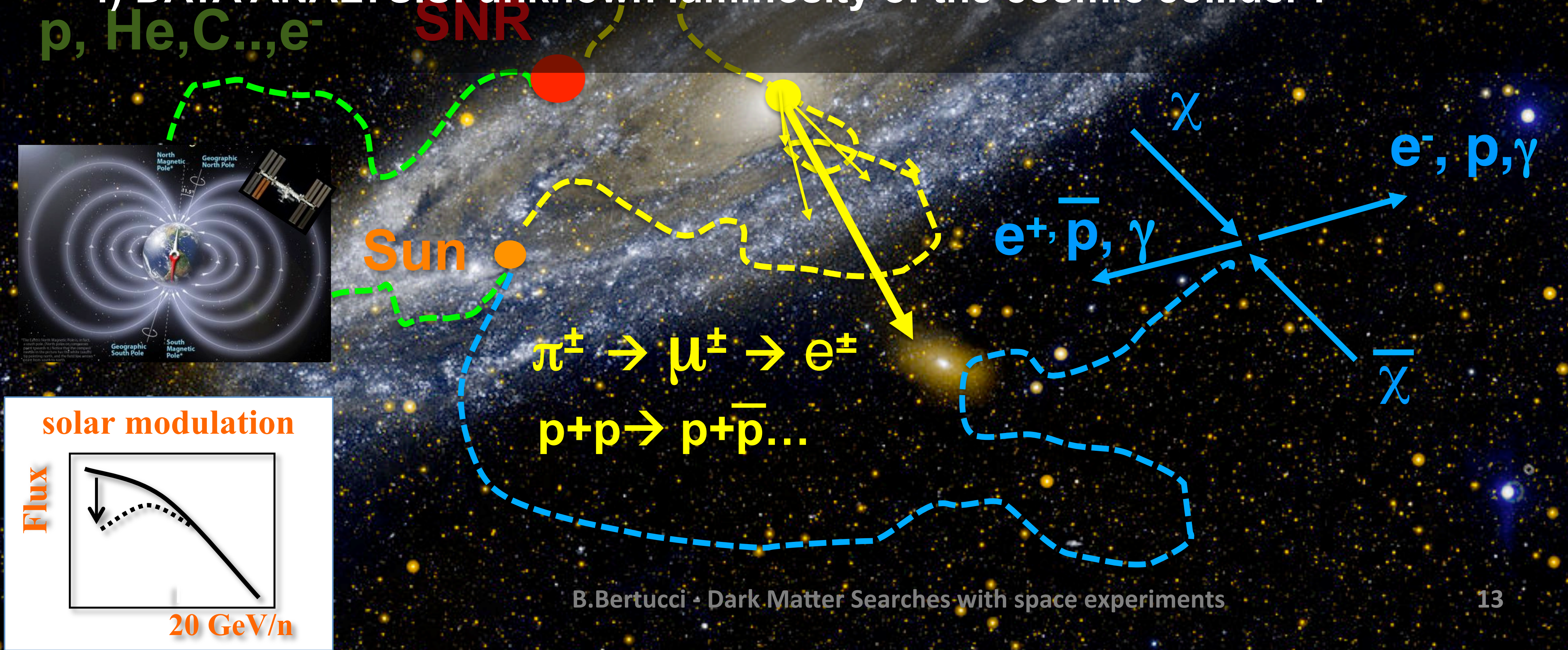


$$\Delta N/\Delta E = \Phi(E) \times \Delta T \times A(E)$$

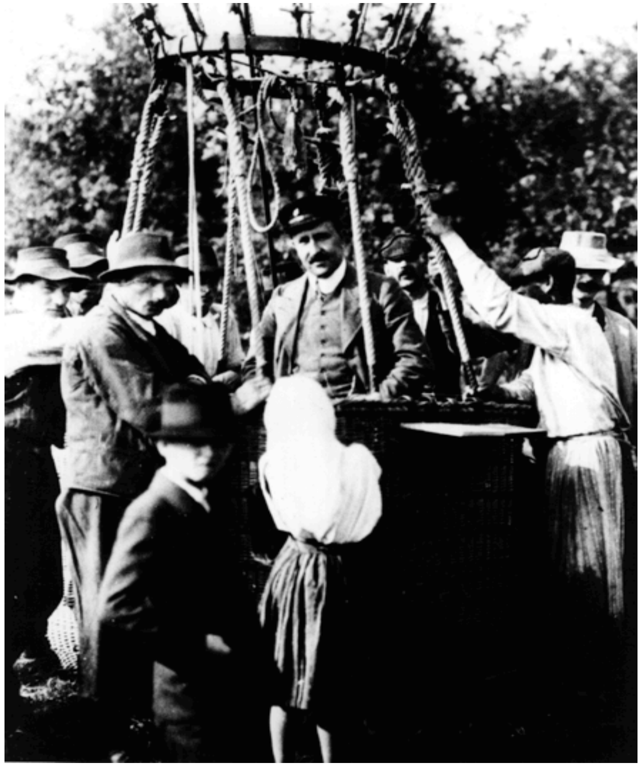
The experimental challenge

Hunt rare signals and provide accurate flux measurements of the CR components to constraint astrophysical models

1) DESIGN : state of the art detectors providing redundant particle measurements
2) TEST: test and calibration on ground
3) OPERATION in Space: monitoring and calibration
4) DATA ANALYSIS: unknown luminosity of the cosmic collider !



Direct CR measurements :
(some of) the experimental challenges



Requirement:
No atmosphere ⇒ **- Stratospheric Balloons**
- Space

The neverending fight against Weight/Size

Stratospheric Balloons: from few hrs to months

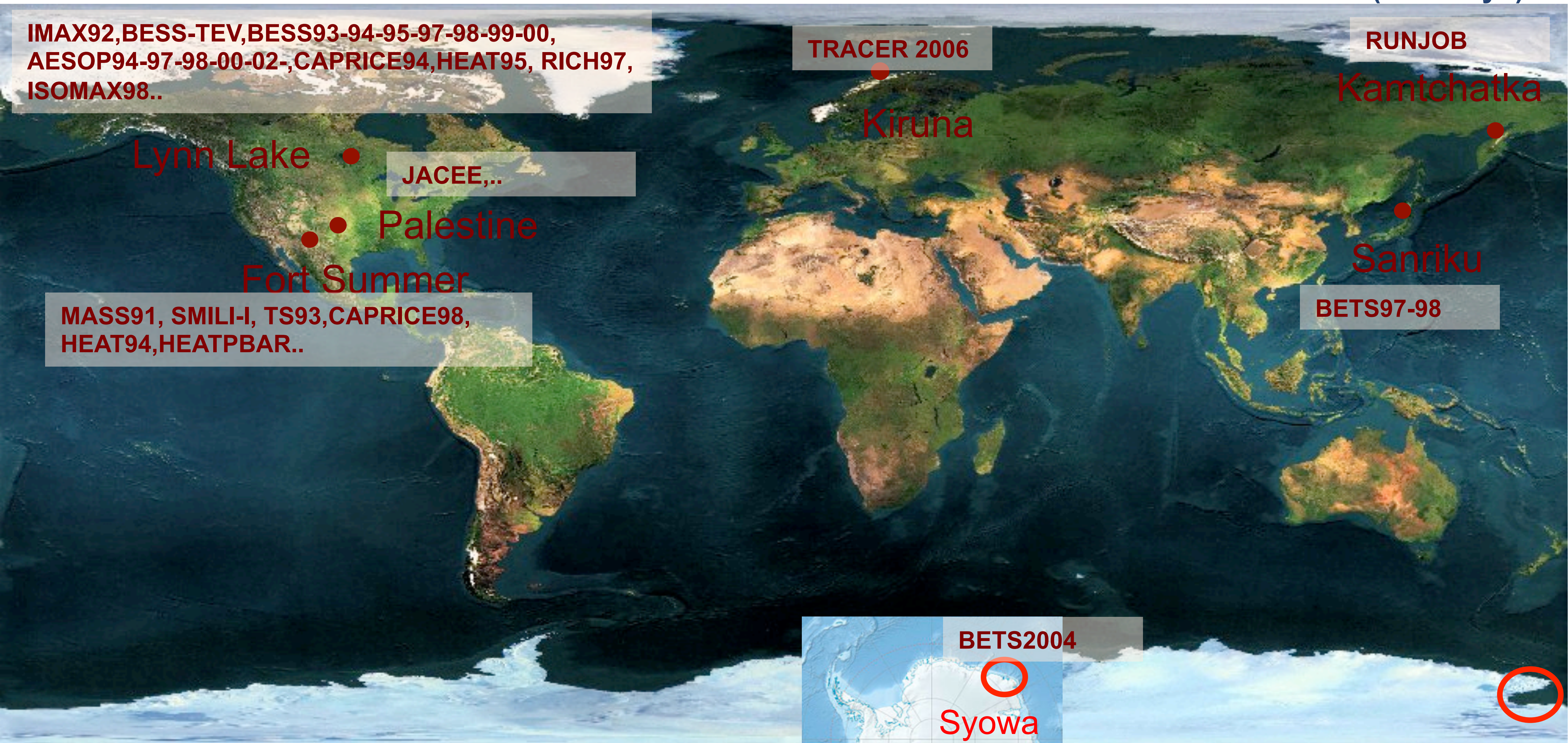
Magnetic Spectrometers

...

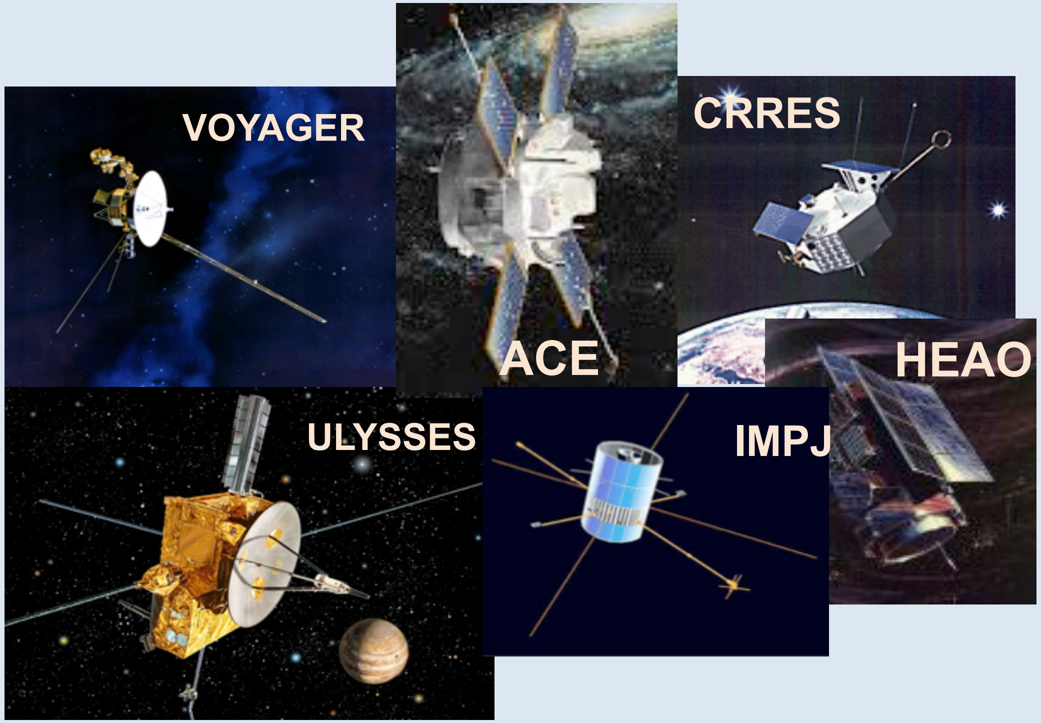
BESS/POLAR/TEV (9 Flights)
WIZARD (6,Flights)
HEAT/PBAR (4,Flights)

Calorimetry, TRD +..

RUNJOB (62 day, 10 Flights)
TRACER (18 days, 3 Flights)
CREAM (161 days,6 Flights)
ATIC (53 days, 3 Flights)
TIGER/S-TIGER (2/55 days)



Space:



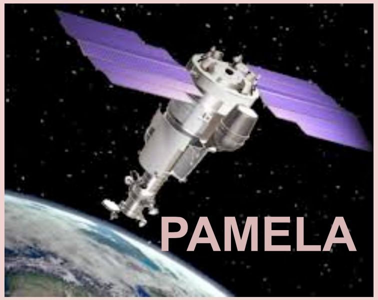
Long missions (years)
Small payloads
Low energies..

IMP series < GeV/n
ACE-CRIS/SIS Ekin < GeV/n
VOYAGER-HET/CRS < 100 MeV/n
ULYSSES-HET (nuclei) < 100 MeV/n
ULYSSES-KET (electrons) < 10 GeV
CRRES/ONR < (nuclei) 600 MeV/n
HEAO3-C2 (nuclei) < 40 GeV/n

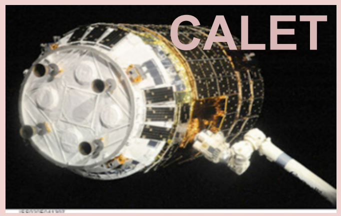
Short missions (days)/ Larger payloads

CRN on Challenger
(3.5 days 1985)

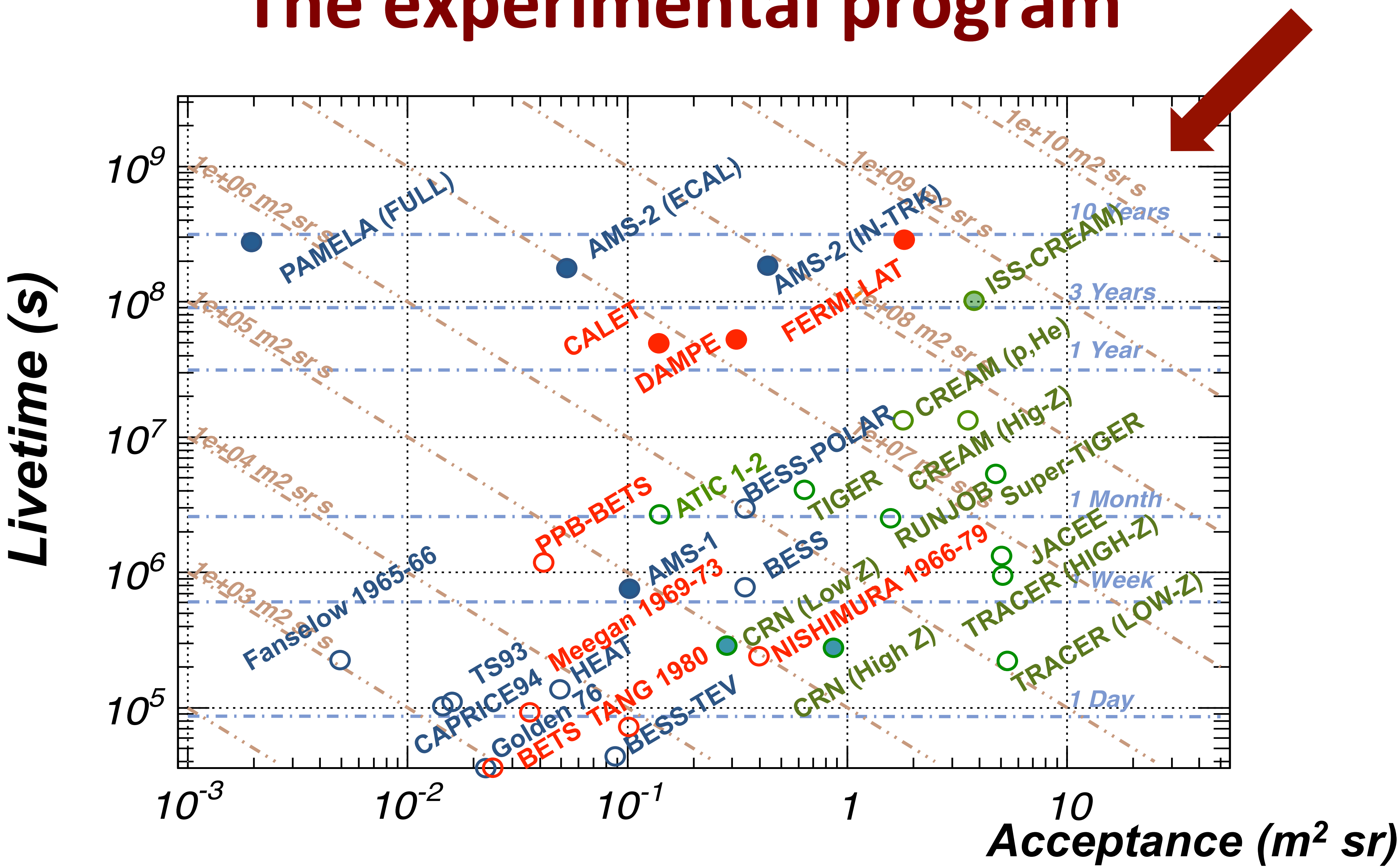
AMS-01 on Discovery
(8 days, 1998)



Long missions
Large payloads



The experimental program



○ No B field, different techniques with main focus on Z
○ No B field, different techniques with main focus on e,γ
○ Magnetic spectrometers

○ Balloon
● Space
● Space (planned)

Calorimetric detectors

Now on orbit:

→ AGILE (2006): γ-rays up to few Gevs
→ FERMI (2007): γ-rays up to 300 GeV, **electrons**
→ CALET (2015) : **electrons,** nuclei
→ **DAMPE** (2015): **electrons,** nuclei, photons

Ready to launch:
→ ISS-CREAM (2017 !!) : nuclei

Magnetic spectrometers

→PAMELA (2006-2016) : **anti-particles**, p, He, light nuclei

Now on orbit:
→ **AMS-02** (2011): **anti-particles**, p, He ...nuclei (up to Fe..)

The experimental challenge

No atmosphere: Stratospheric Balloons
Space

Limits on size / weight / time

- Detector design focused on specific measurements

p,He,e^-,anti-particles

Primary spectra, Nuclei, $e^{\pm}$

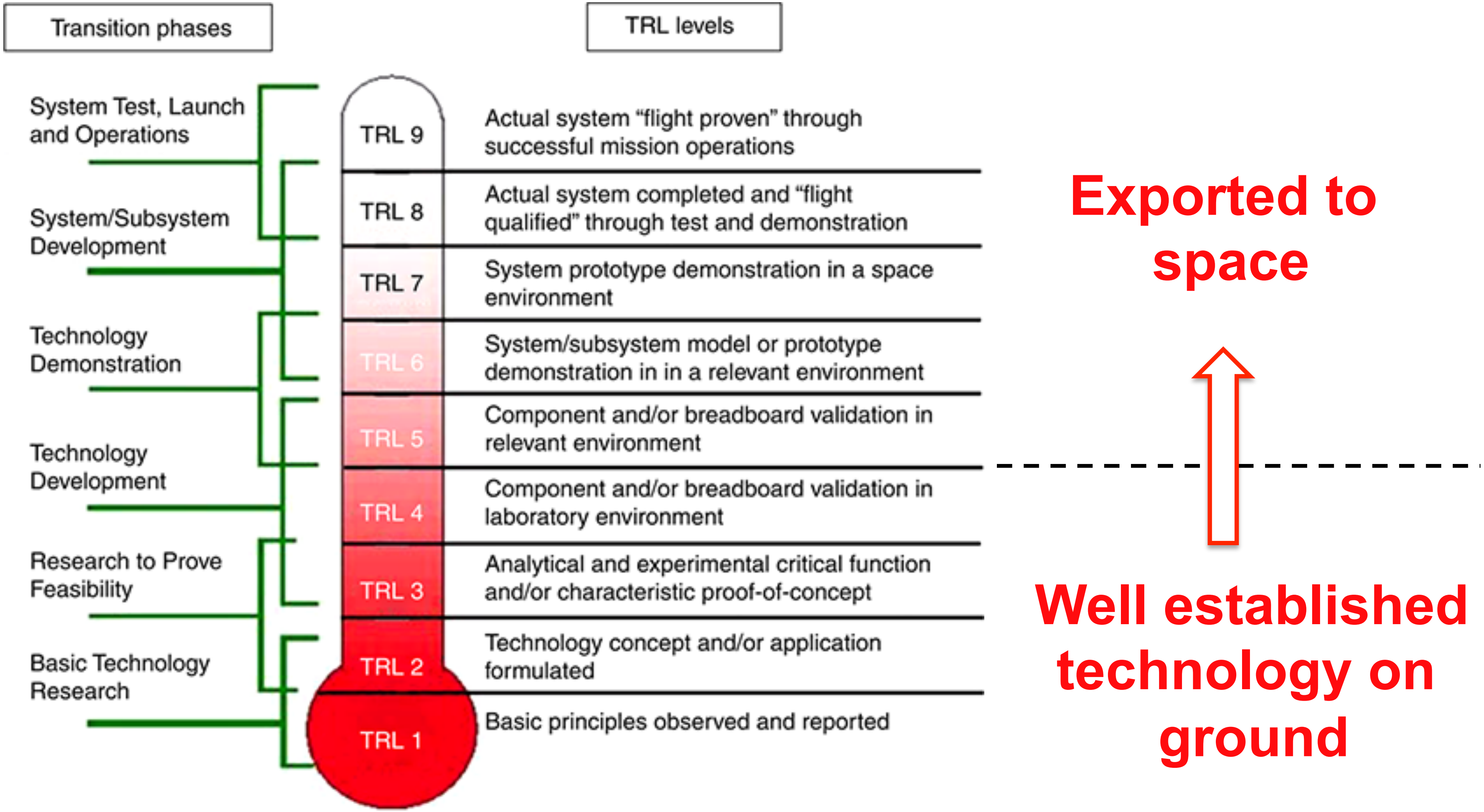
Magnetic spectrometers
Energy reach on anti-particles limited by Maximum Detectable Rigidity

Calorimeters
Energy reach limited by statistics

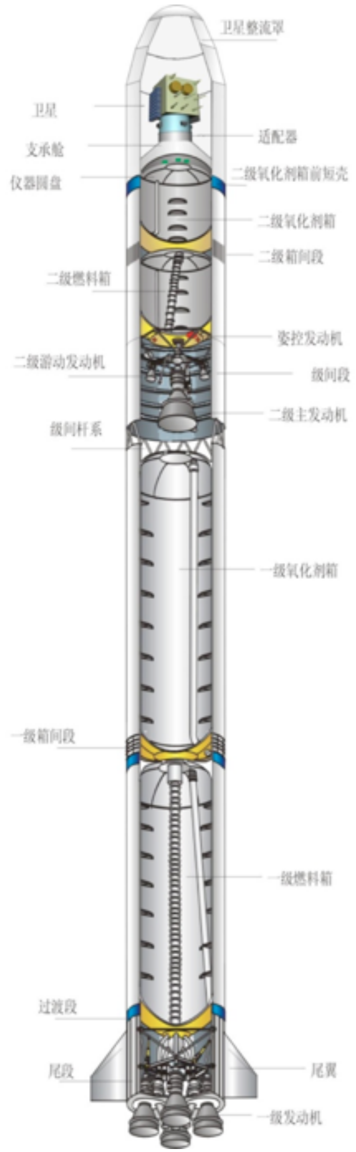
→ HEP detectors adapted to space !

From Ground to Space…..

Technology Readiness Level



Source: Adapted from NASA and Mankins (1995)



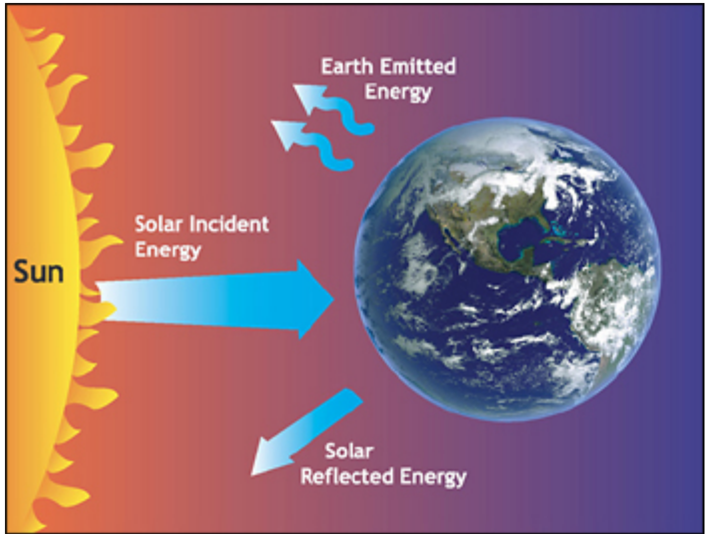
HEP detectors in Space

Mechanical stress at launch:

- Static acceleration
- Random vibration
- Sinusoidal vibration
- Pyroshock

Life in space:

- **Thermal stresses due to Sun-light (seasonal / day-night effects)**
- **Vacuum**



Careful Design, Model validation and Qualification are needed to ensure *highest possible reliability*

As a space payload: qualification tests before and after assembly

Full space qualification sequence before launch:

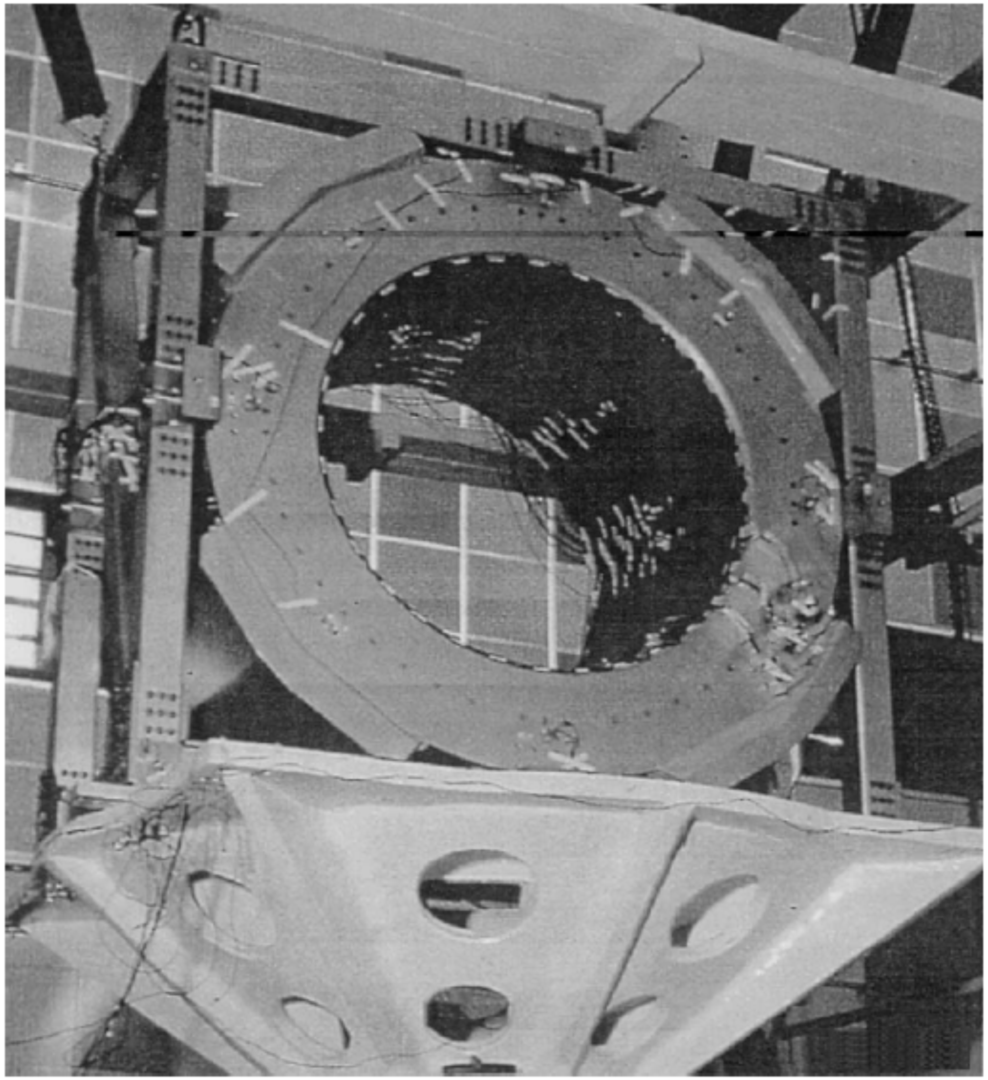
- Operational tests after stress
- Verification of dynamical behaviour
- Verification of thermal model

Thermal Stress → Functional check → Mechanical Stress → Functional check →

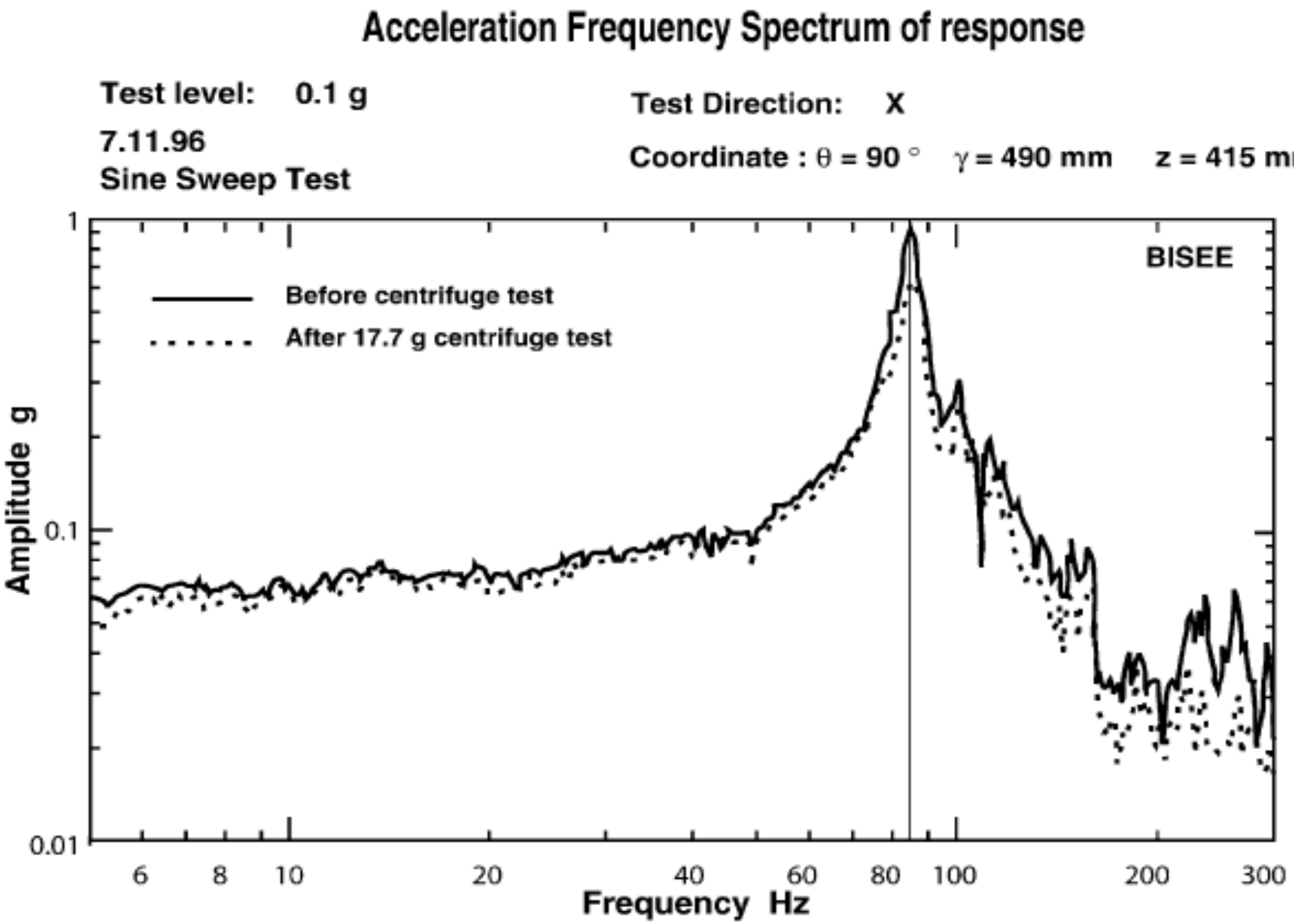
Thermal cycles in Vacuum → Functional check

EMC

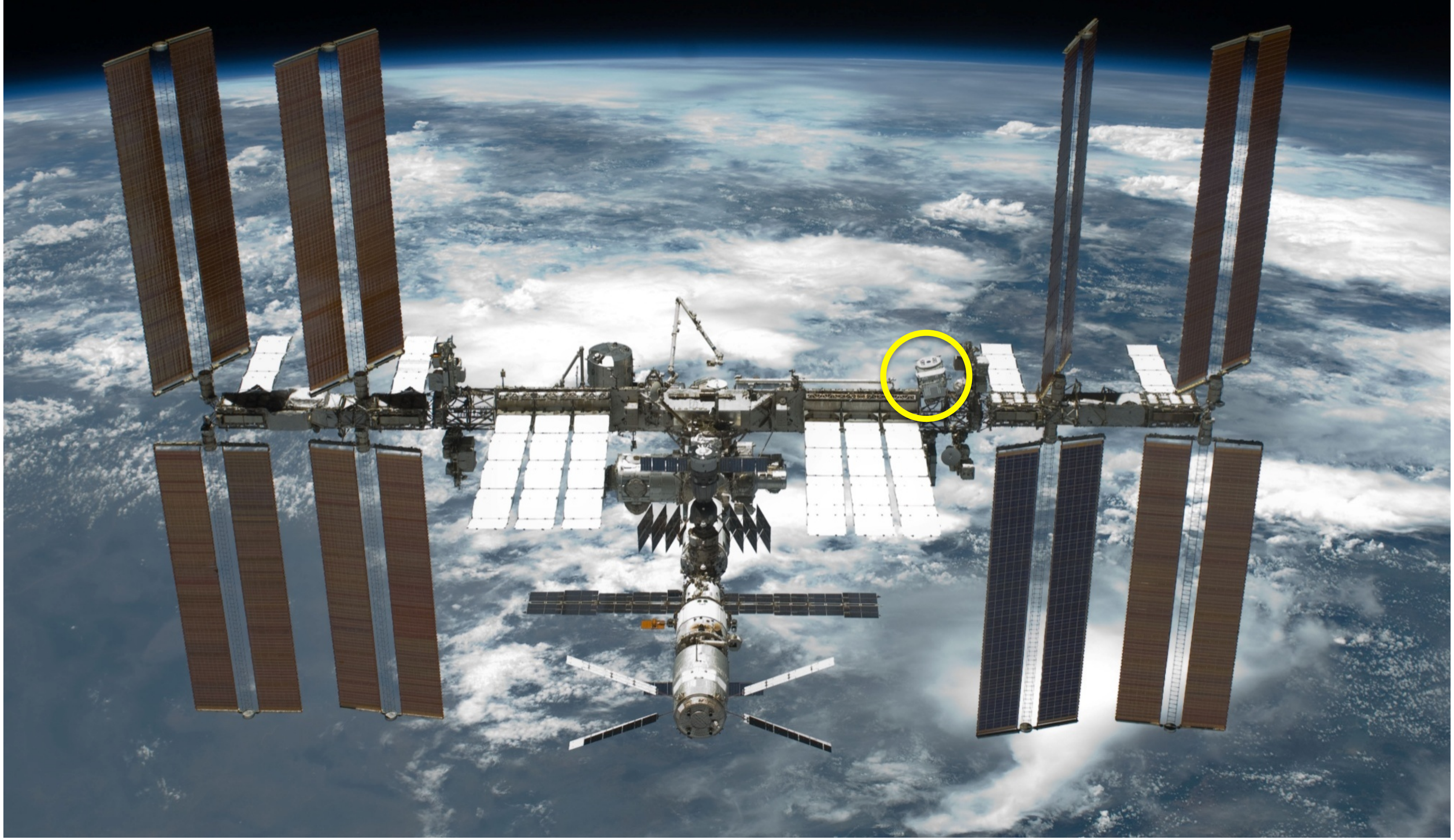
The AMS magnet before going to space.....



The AMS magnet before going to space.....

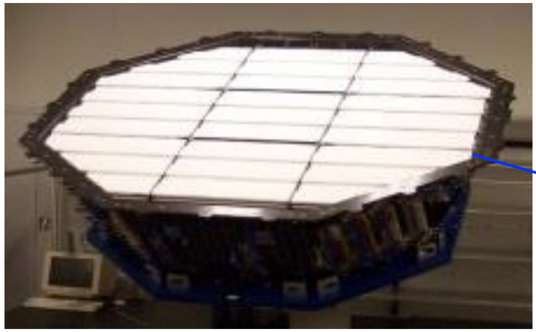


A closer look to the Alpha Magnetic Spectrometer



AMS-02: A TeV precision, multipurpose spectrometer

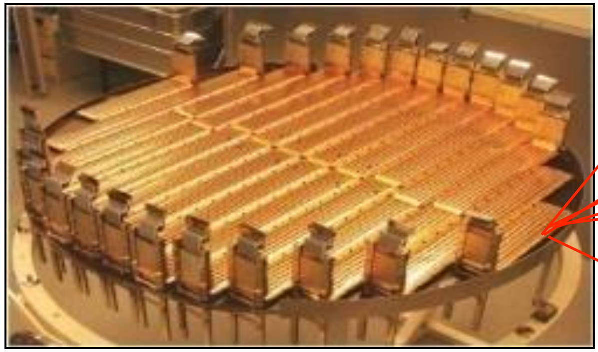
Transition Radiation Detector (TRD)
Identify e^+, e^-

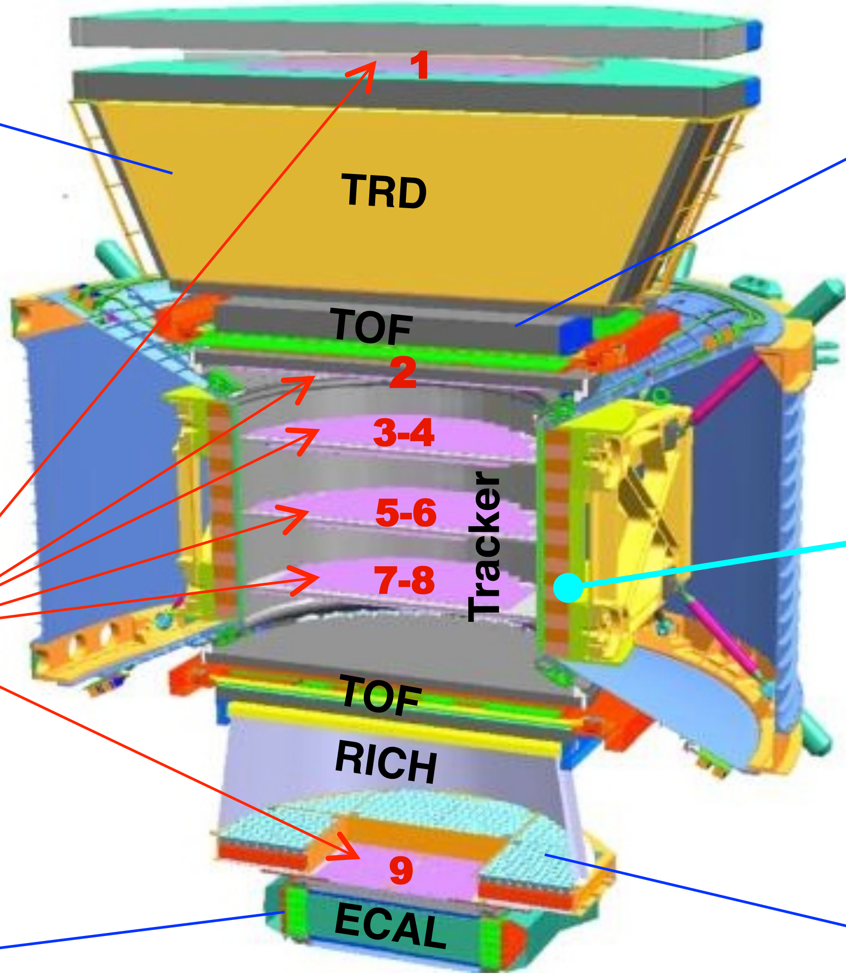


Particles and nuclei are defined by their charge (Z) and energy (E)

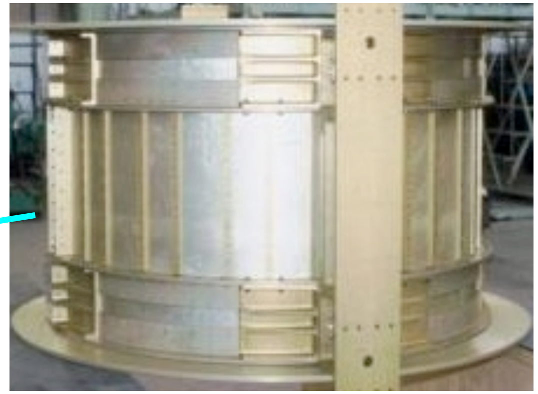
Time of Flight (TOF)
Z, E

Silicon Tracker
Z, P





Magnet (0.15 T)
±Z

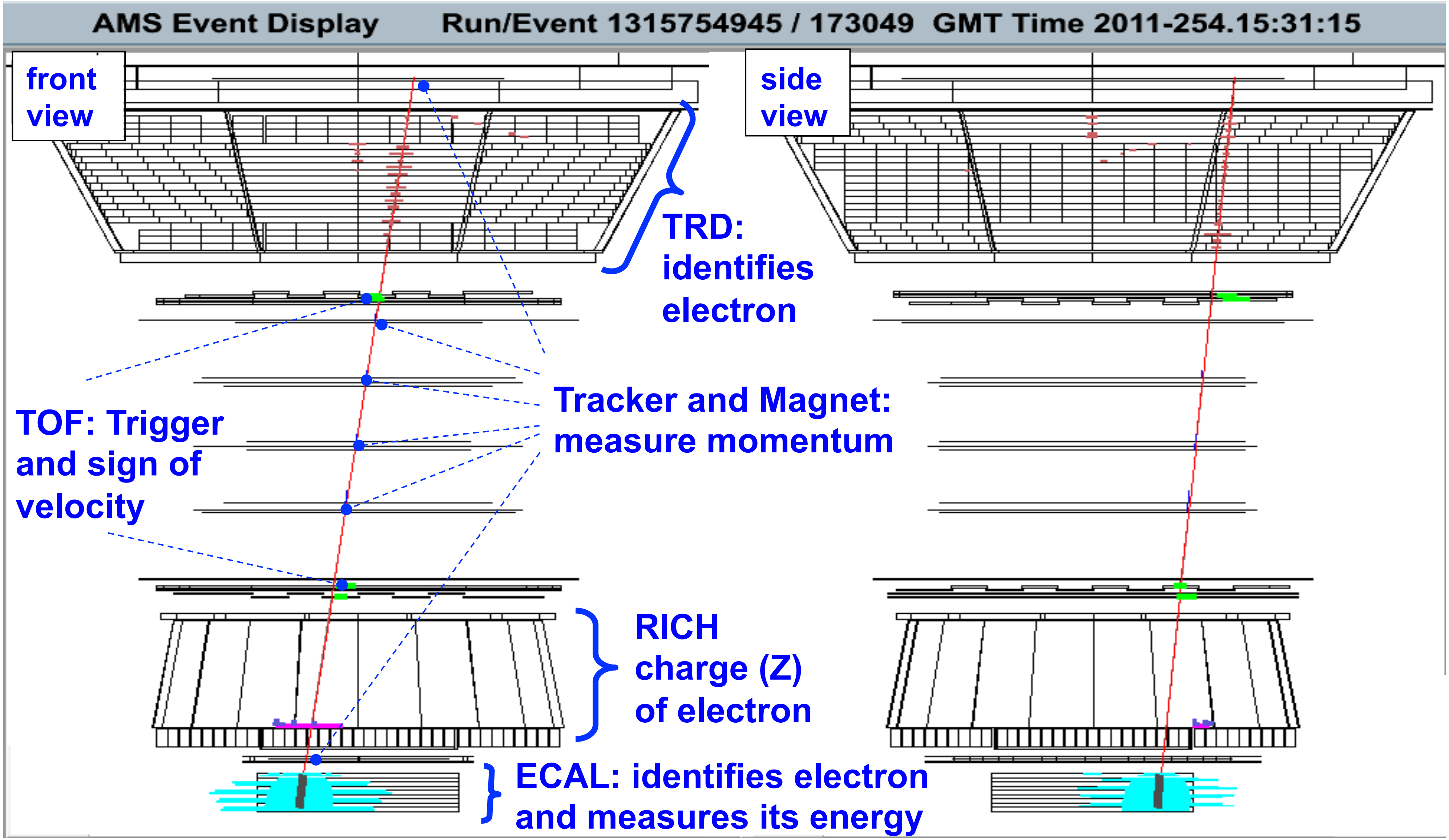


Ring Imaging Cherenkov (RICH)
Z, E

Electromagnetic Calorimeter (ECAL)
E of e^+, e^-, γ

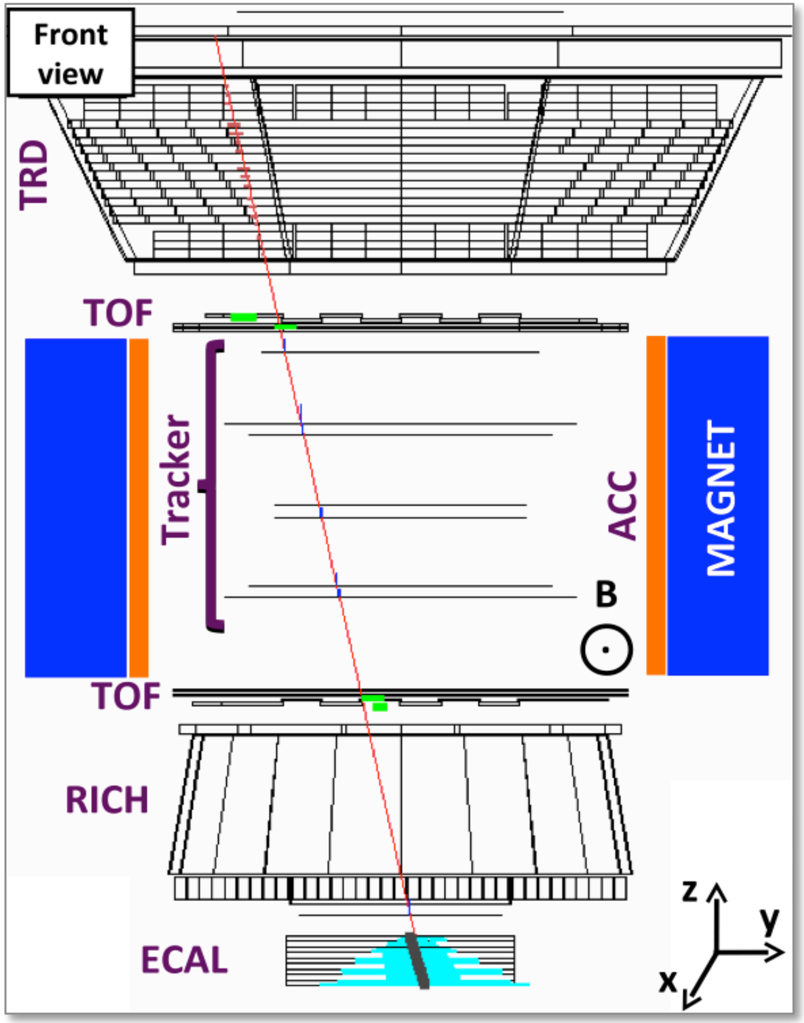
Z, E, R, β
are measured independently by the Tracker, RICH, TOF and ECAL for the same CR

AMS data on ISS: 1.03 TeV electron



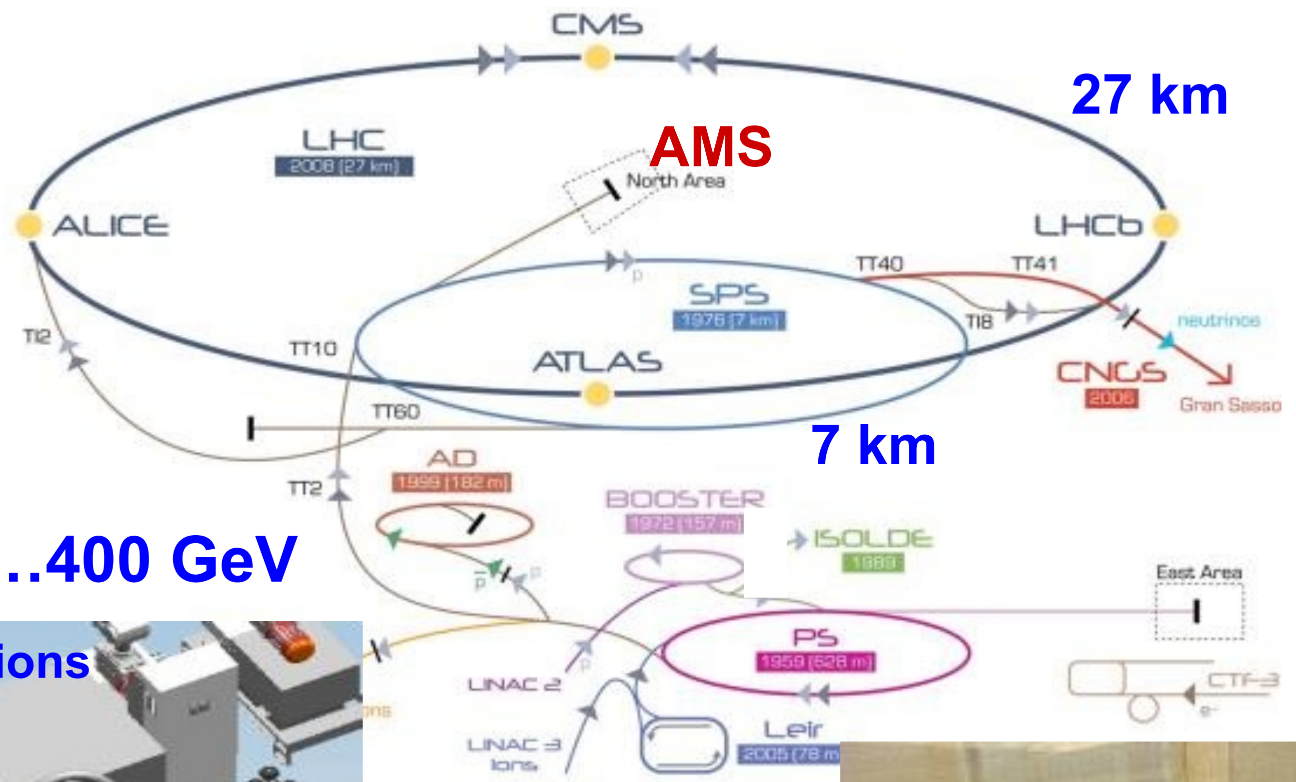
Full coverage of anti-matter & CR physics

600 GeV electron

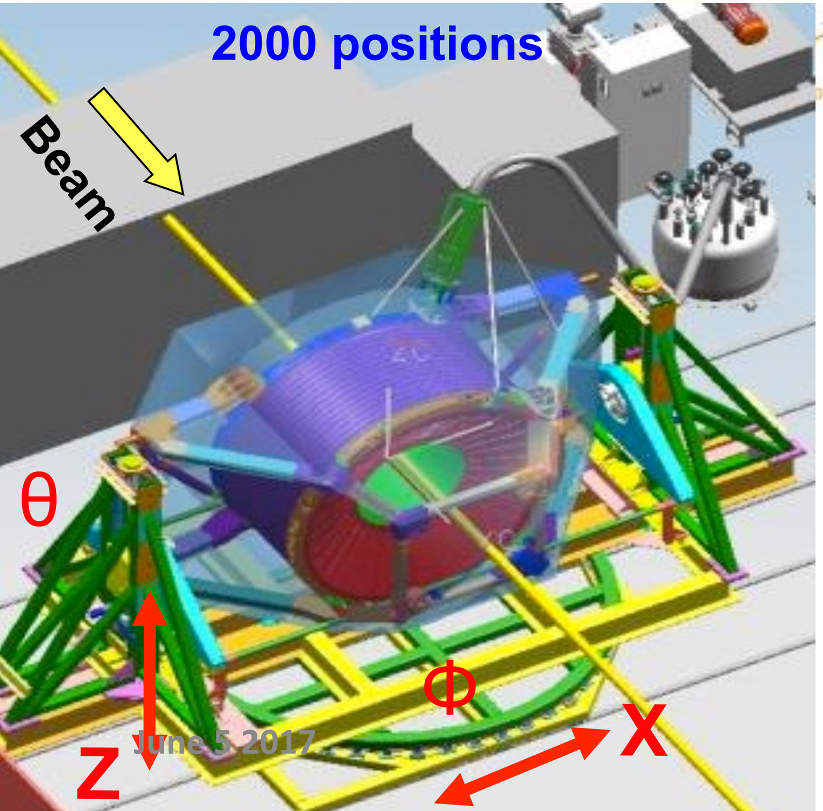


	e^+	e^-	p	$\bar{p}$	He	$\overline{He}$	
TRD 20 layers							e/p separation charge (|Z|)
TOF 4 layers							trigger velocity (β) charge (|Z|)
TRK 9 layers							momentum (p) sign (±Q) charge (|Z|)
RICH							velocity (β) charge (|Z|)
ECAL 18 layers							$e^{\pm}$ energy e/h separation γ trigger

As any HEP experiment: beam test calibration @ CERN



p, e^+, e^-, π 20…400 GeV

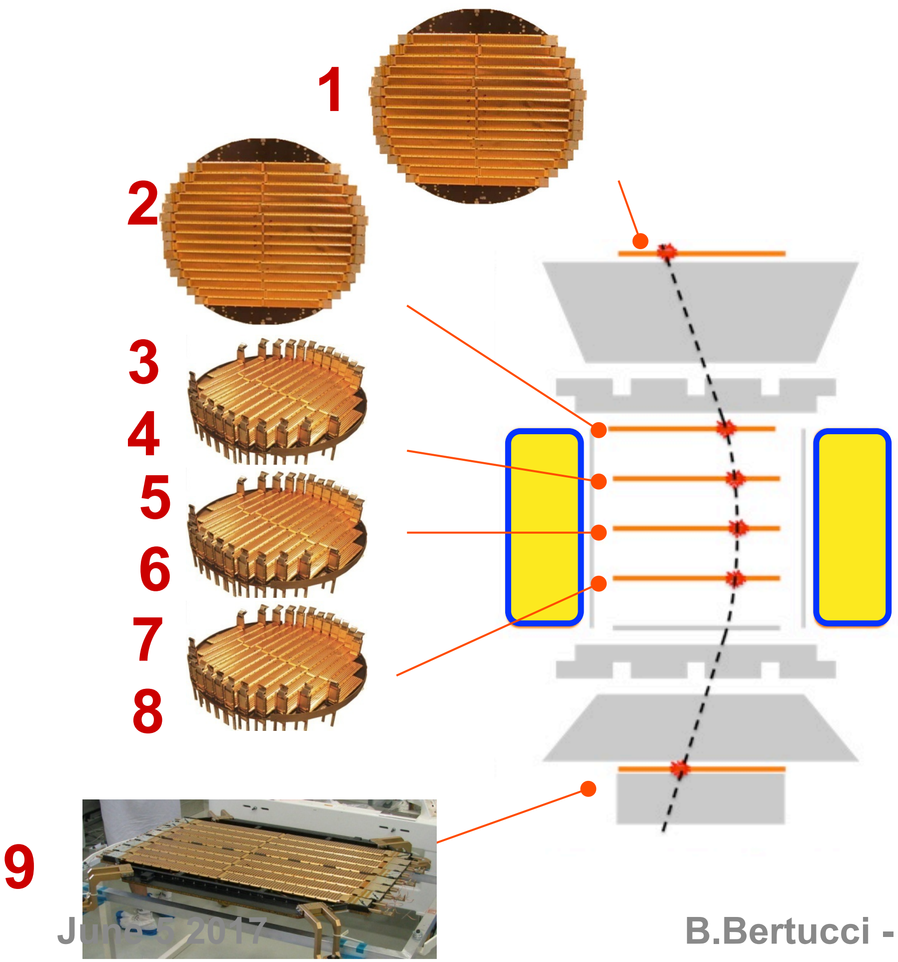


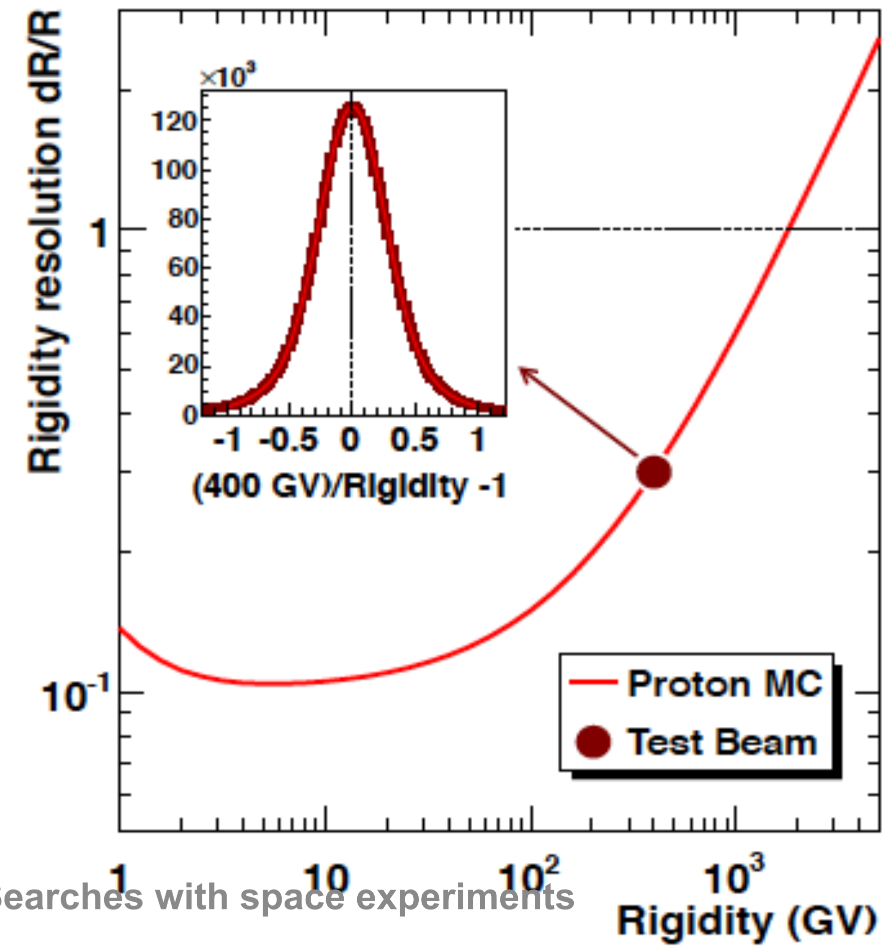
Tracker: ≈2600 Si sensors, 192 ladders, 200 kchannels

9 layers of double sided silicon microstrip detectors to reconstruct the particle trajectory with 10 μ resolution in the bending plane

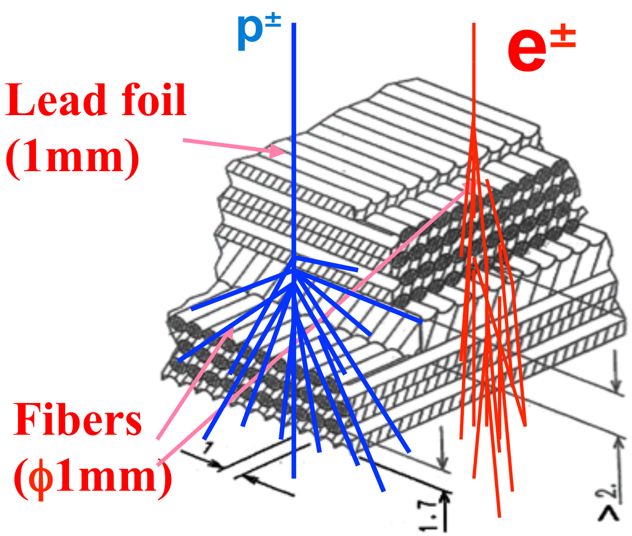
→ 20 –UV Lasers to monitor inner tracker alignment

→ Cosmic rays to monitor outer tracker alignment

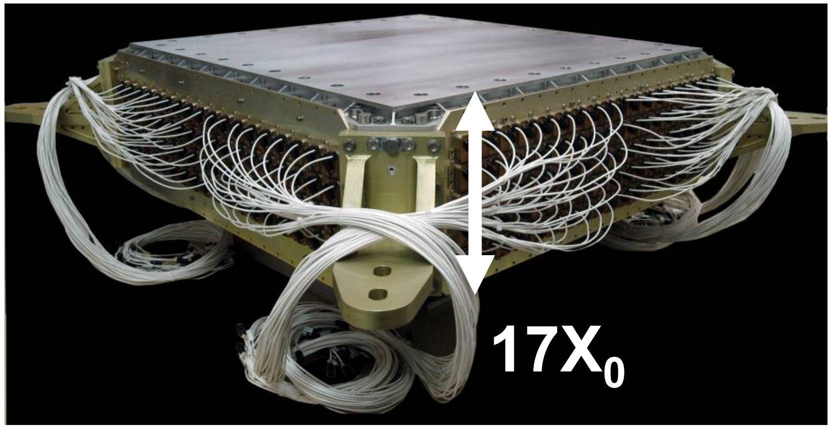


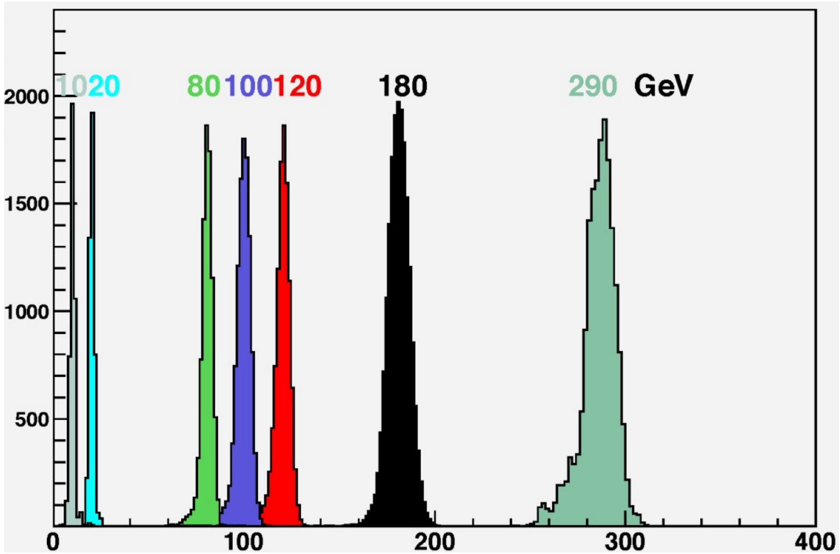


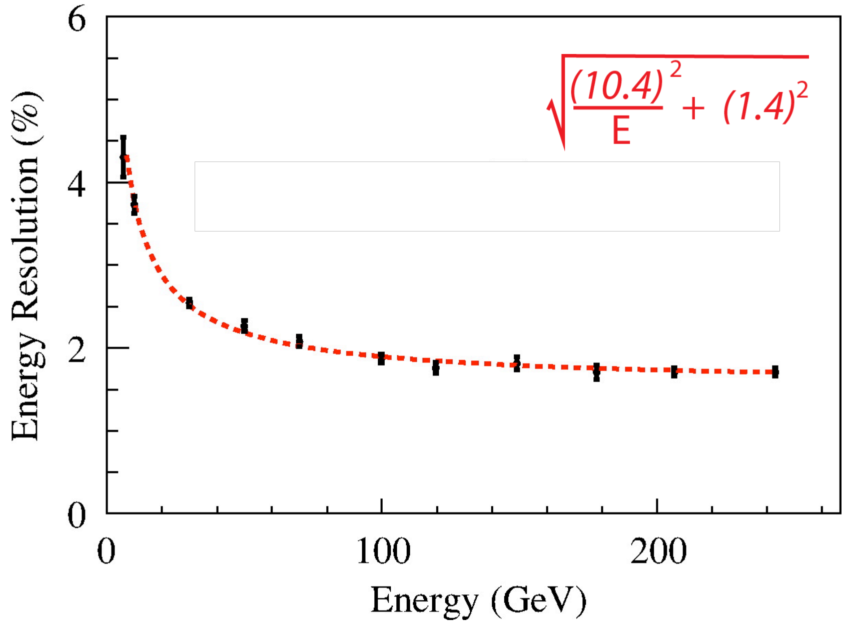
Electromagnetic calorimeter



50,000 fibers, φ = 1 mm
distributed uniformly Inside 600 kg of lead



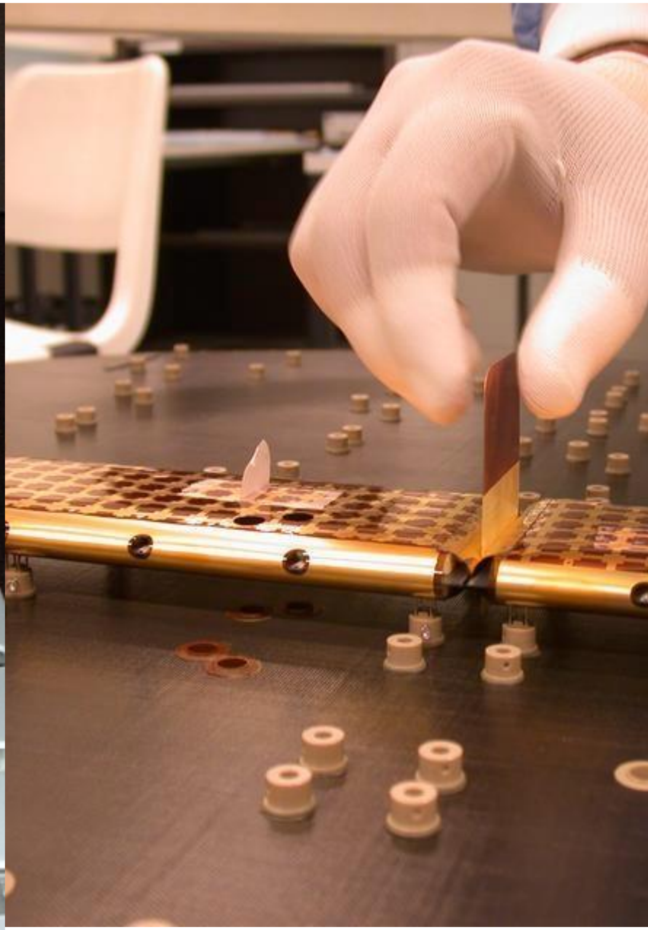




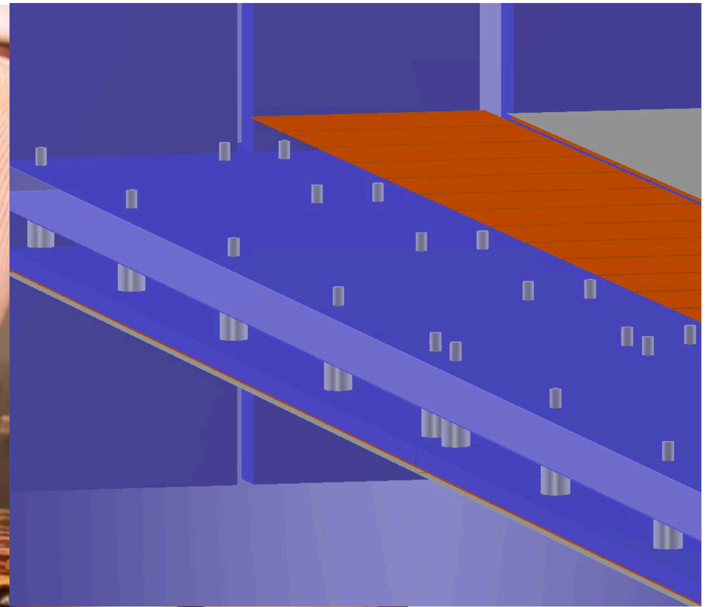
As an HEP experiment : GEANT4 to describe materials/interactions e.g. Tracker fixation details..

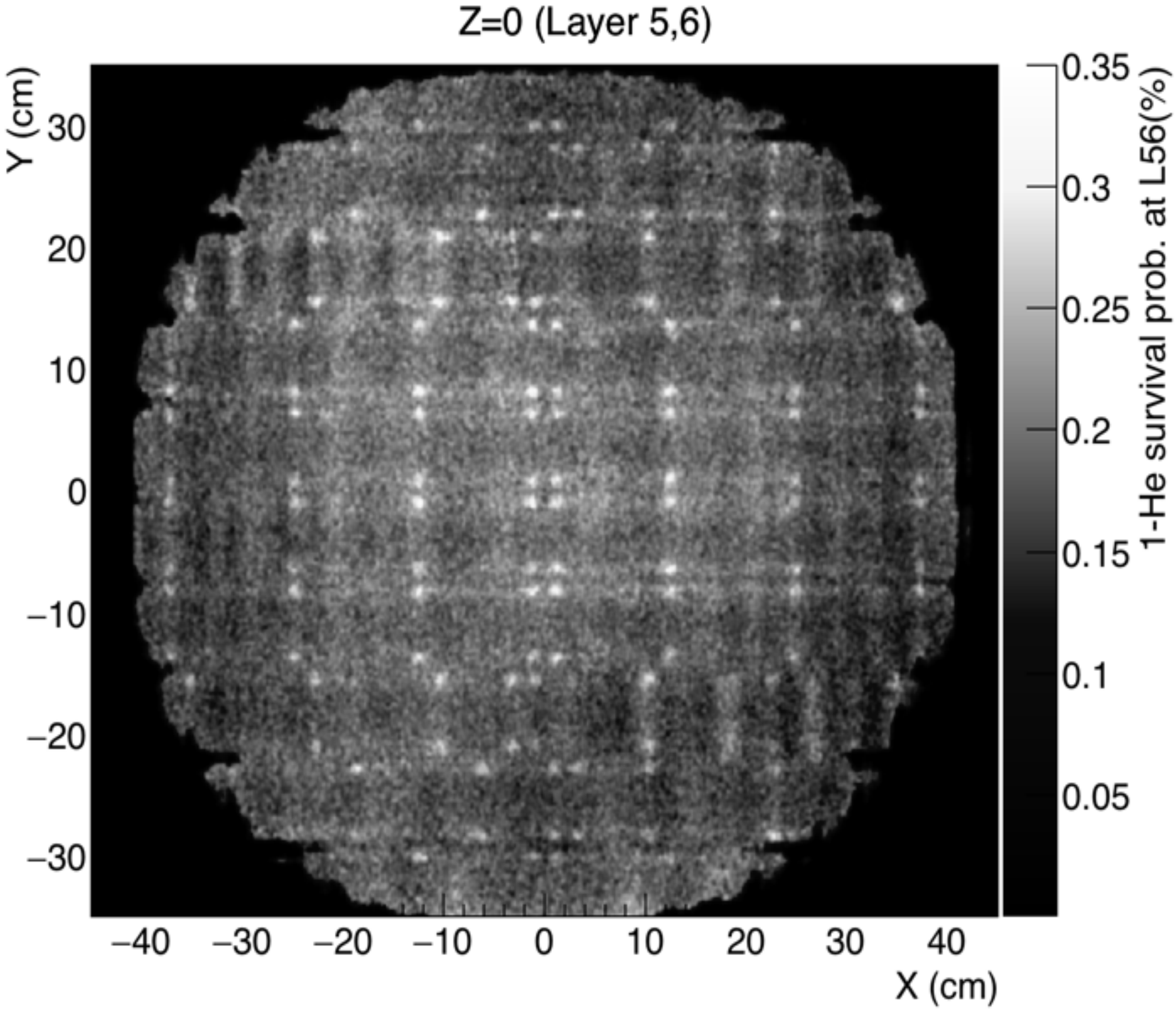
Feet glued to a ladder

Example of Ladder fixation

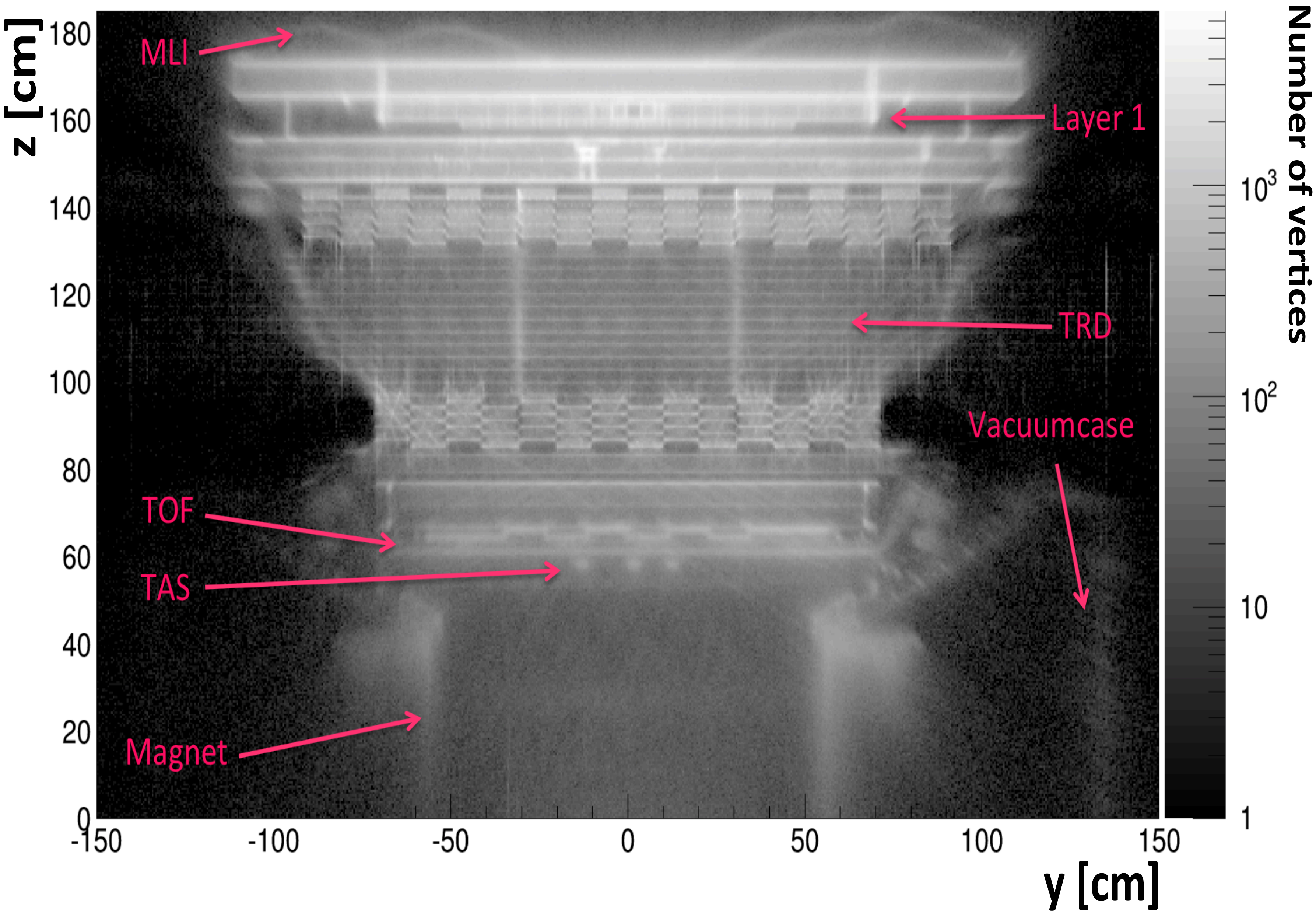


MC implementation

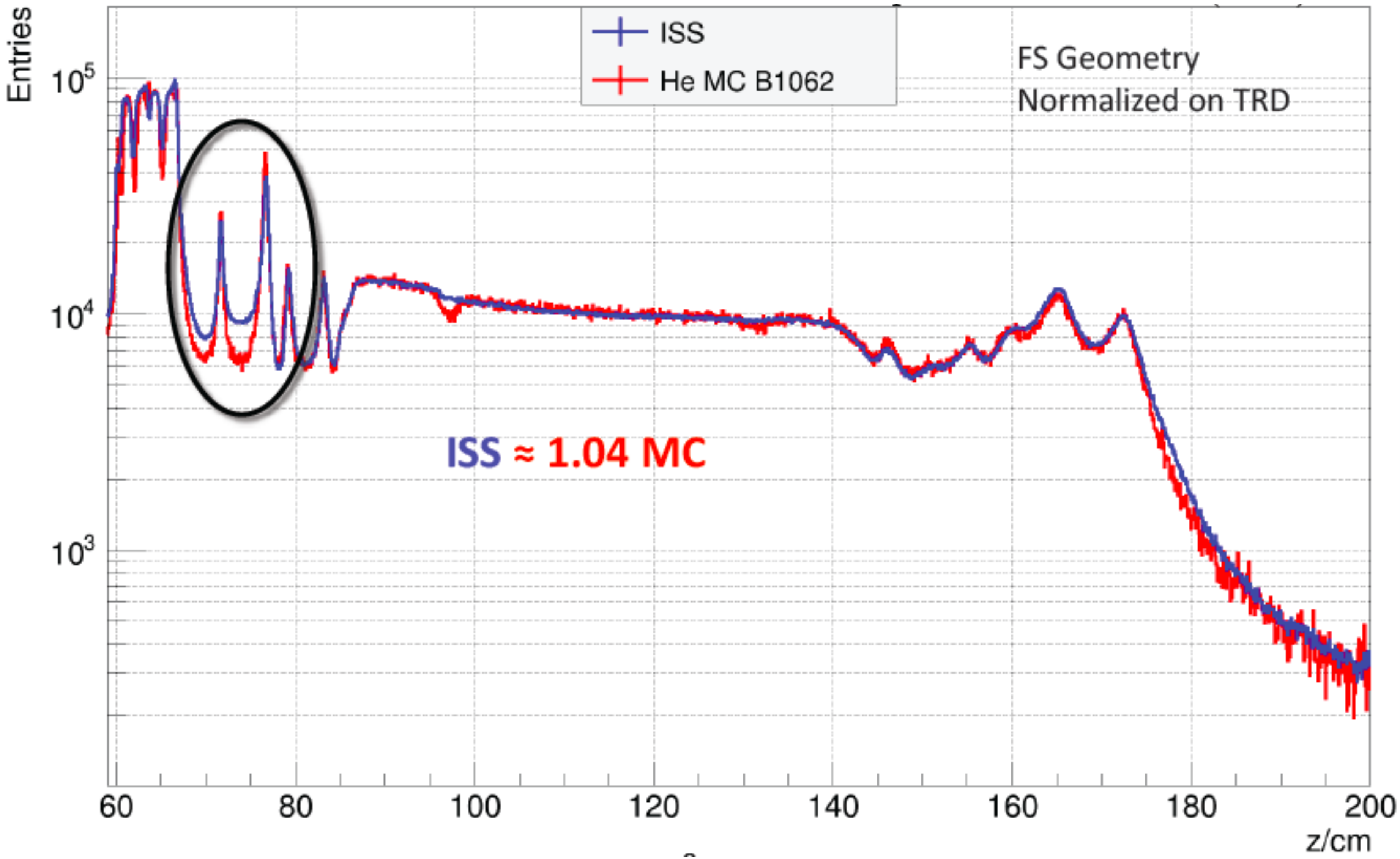



Z=0 (Layer 5,6)
Y (cm)
30
20
10
0
−10
−20
−30
−40
−30
−20
−10
0
10
20
30
40
X (cm)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
1-He survival prob. at L56(%)

In space: tomography of detector materials by means of CR interactions

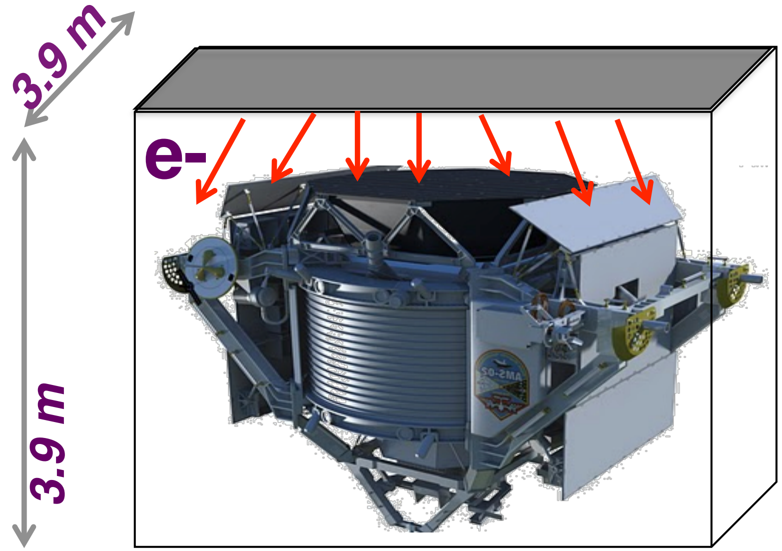


As an HEP experiment : GEANT4 to describe materials/interactions



Acceptance → Geant4

- Estimated with MC (Geant 4)



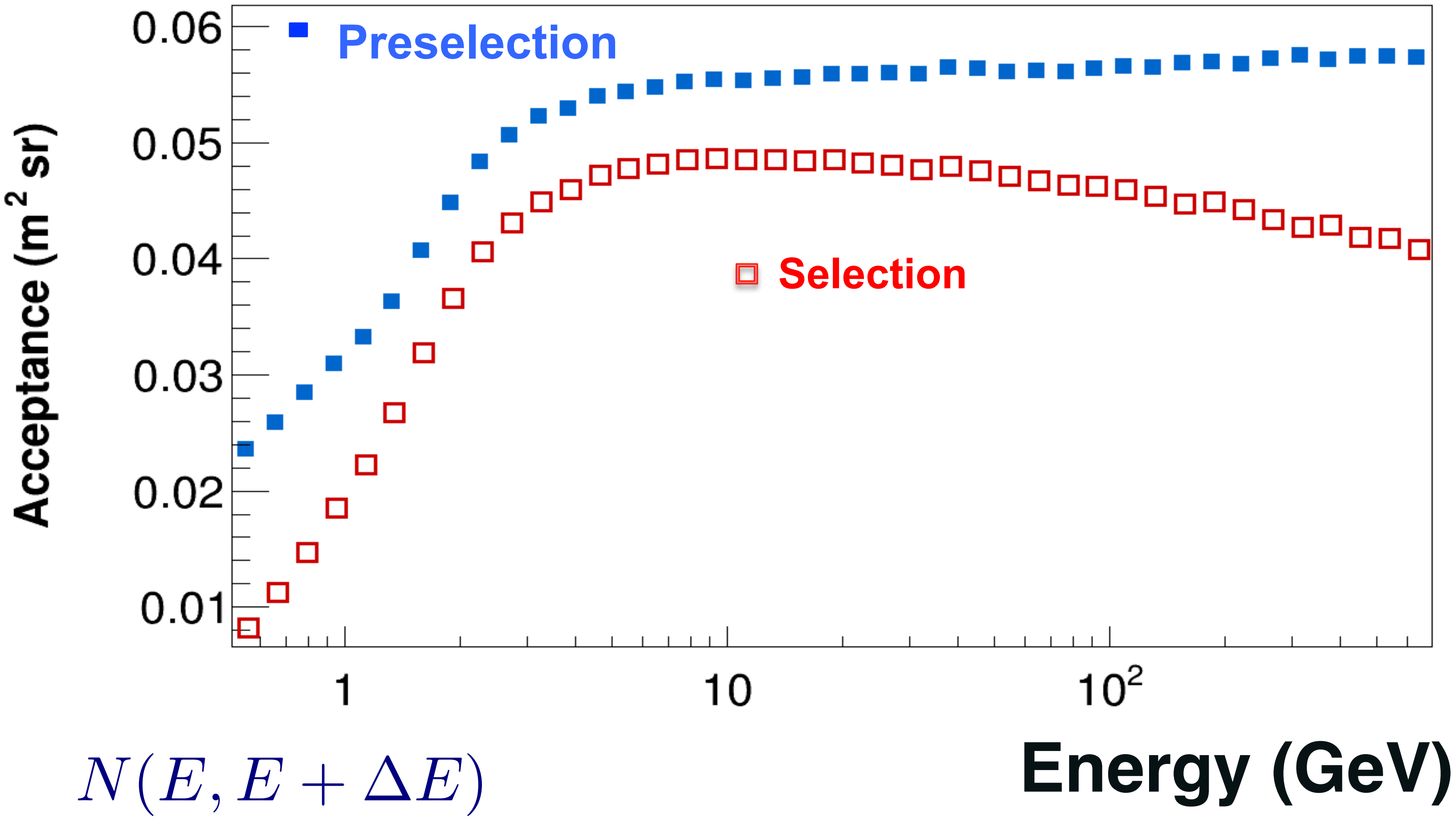
$$A_{eff.}(E) = A_{generated} \times \frac{N_{selected}(E)}{N_{generated}(E)}$$

- $A_{generated}$ = acceptance of the generation surface
- $N_{selected}$ = events passing the selection criteria

During the analysis chain, efficiencies for different requests on the event will appear as multiplicative factors.

For each selection request the efficiency measured in data is compared with that on MC

The acceptance

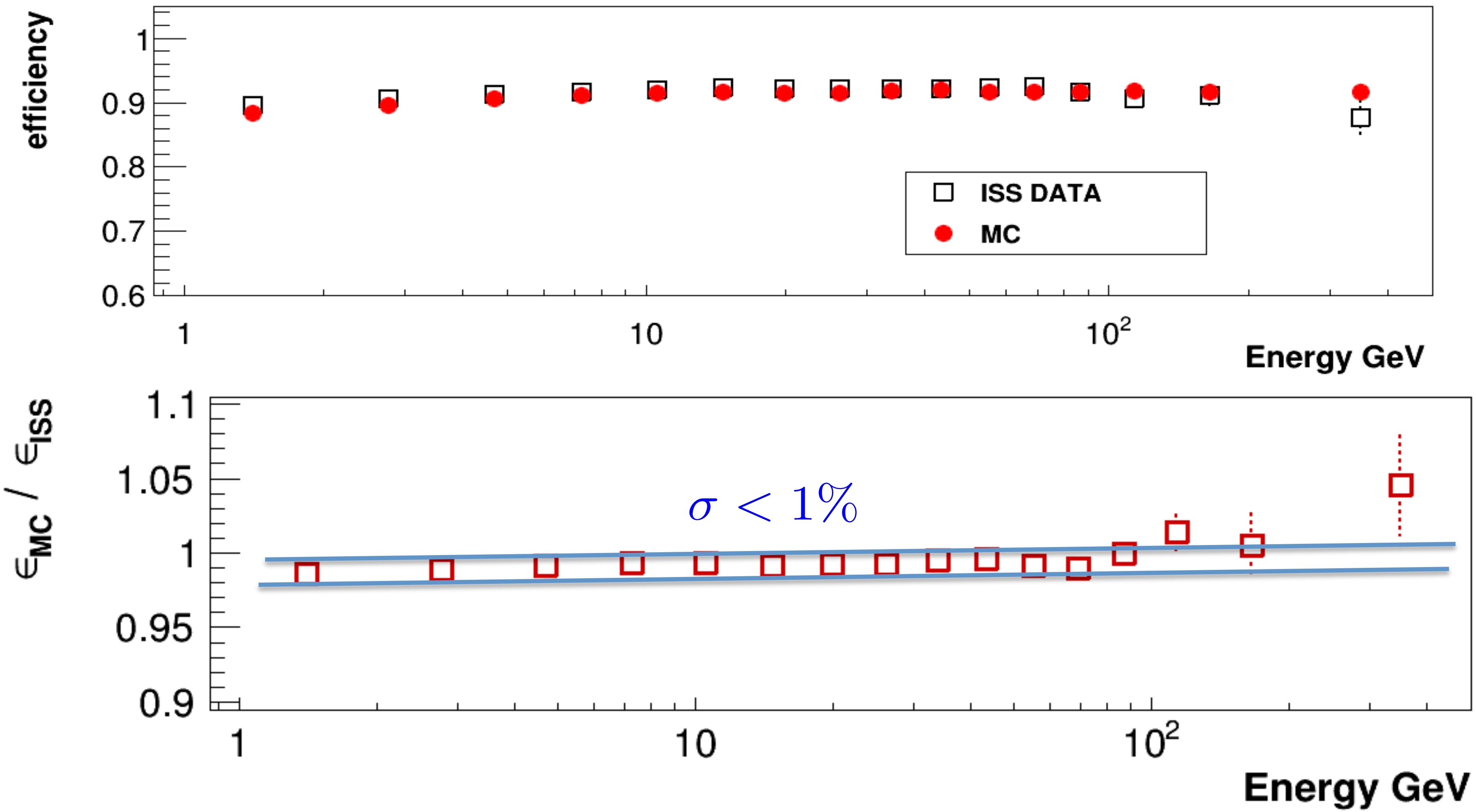


$$\Phi(E) = \frac{N(E, E+\Delta E)}{\Delta E \Delta T_{\rm exp} A_{\rm eff} \varepsilon_{\rm trig}}$$

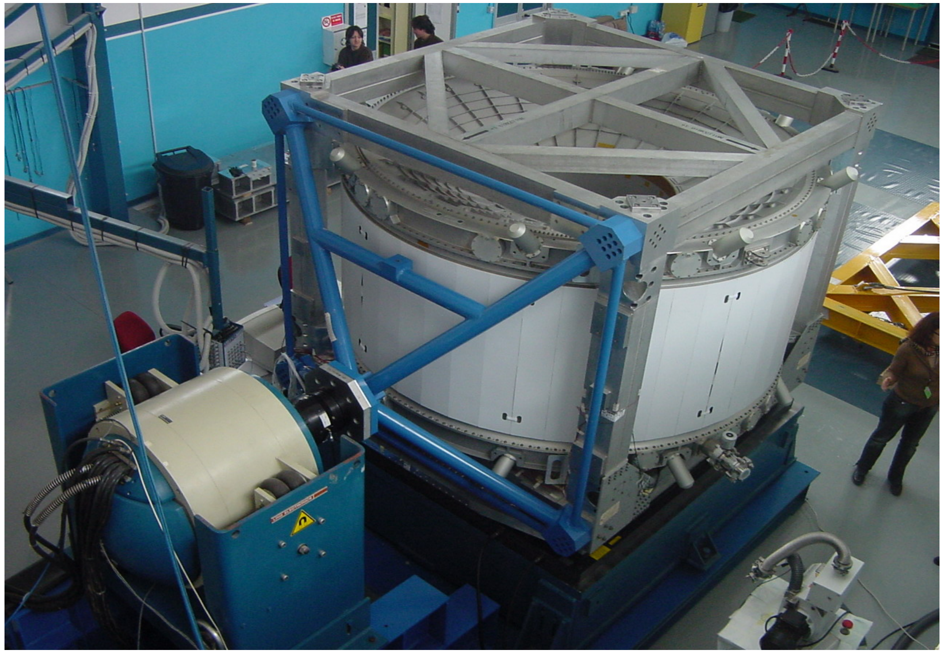
Φ = Absolute differential flux (m^{-2} sr^{-1} GeV^{-1})
N = Number of observed events
ΔT_{exp} = Exposure time (s)
A_{eff} = effective acceptance ($m^2 sr$)
ε_{trig} = trigger efficiency

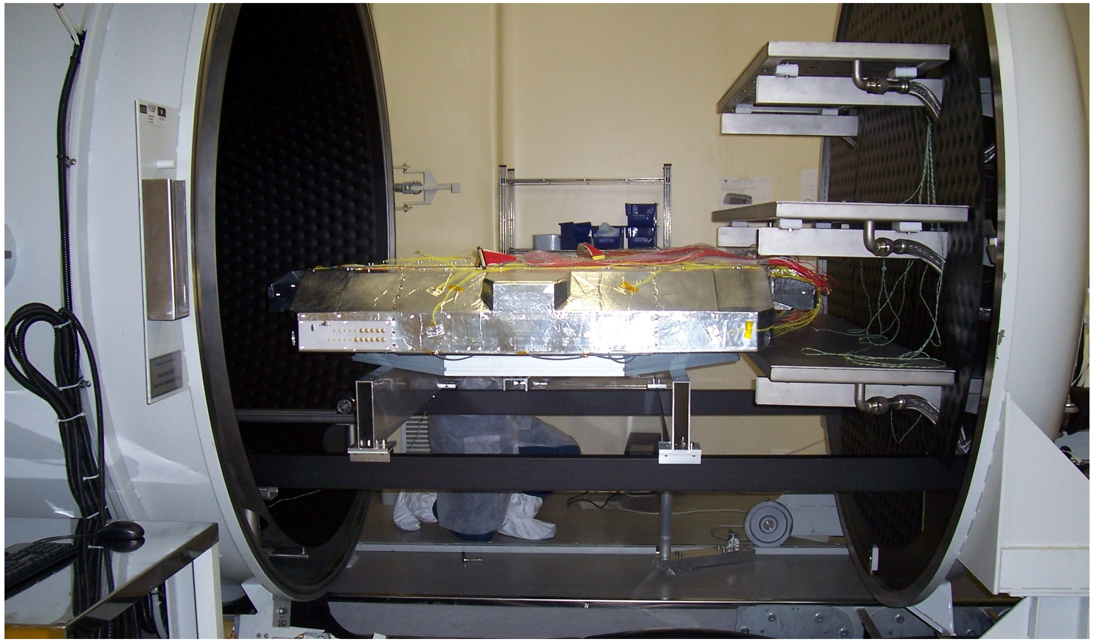
e.g. tracker efficiency

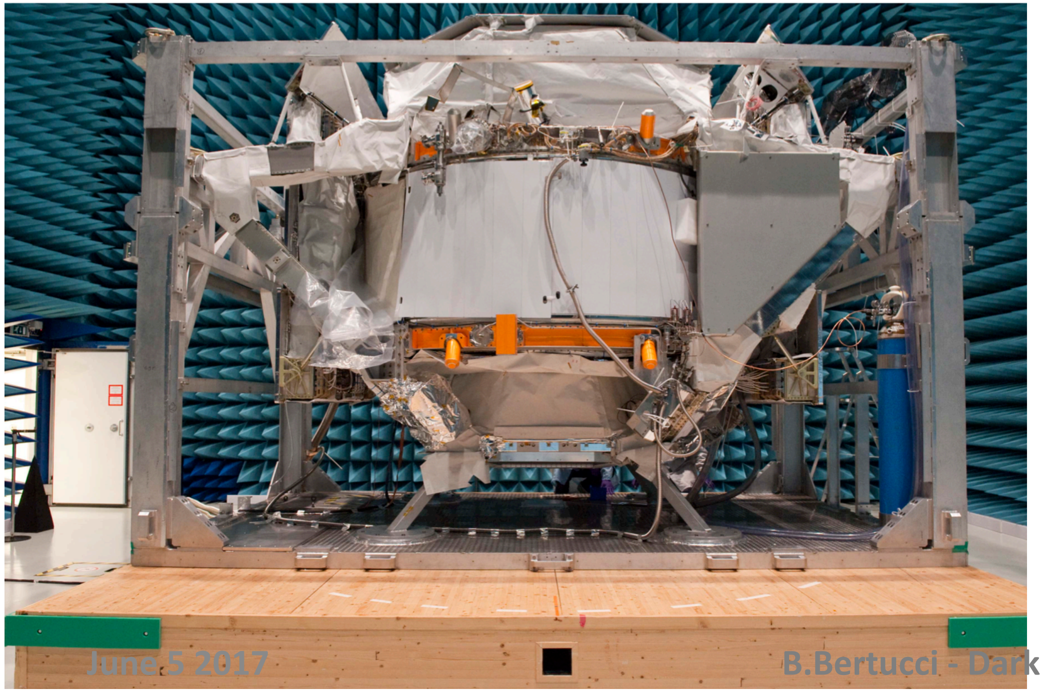
Track reconstruction: $\dfrac{\text{\# of electrons with a track}}{\text{\# of electrons passing through TRK acceptance}}$

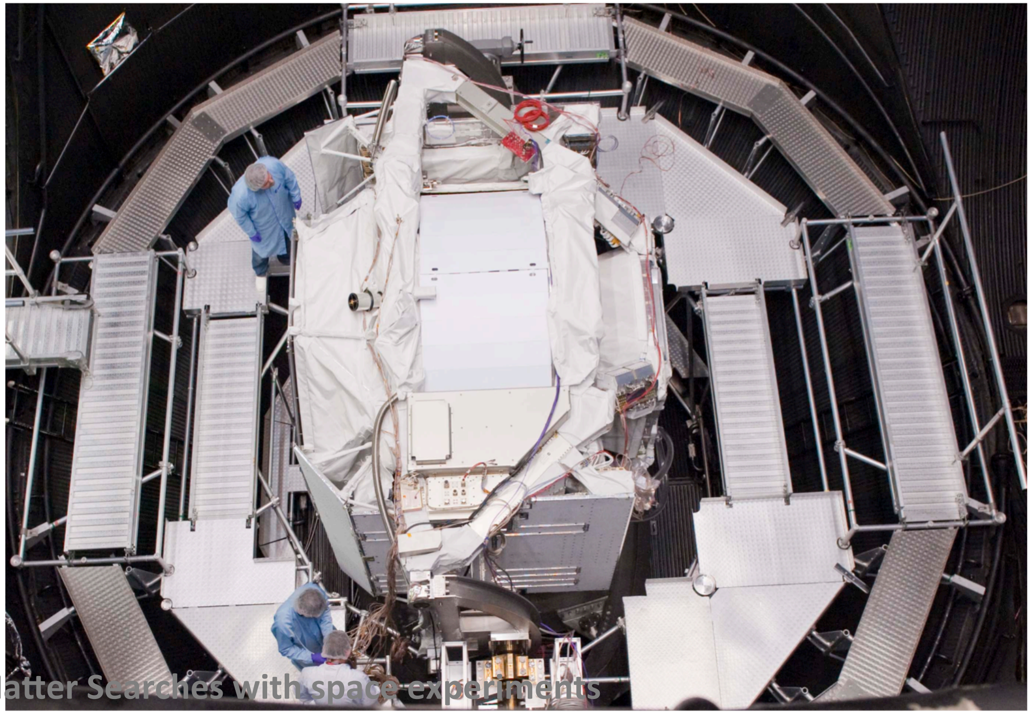


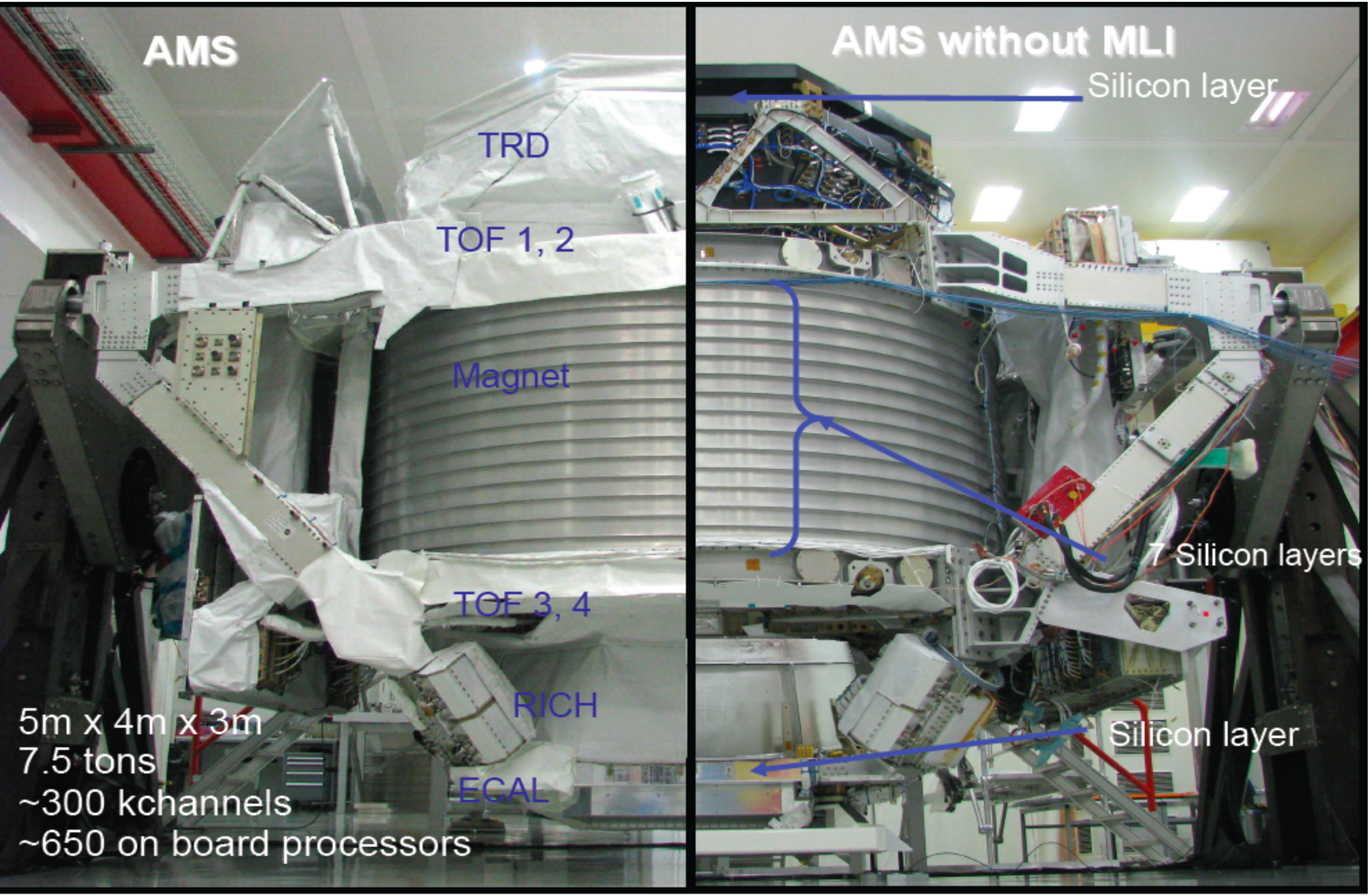
As a space payload:
qualification tests before and after assembly







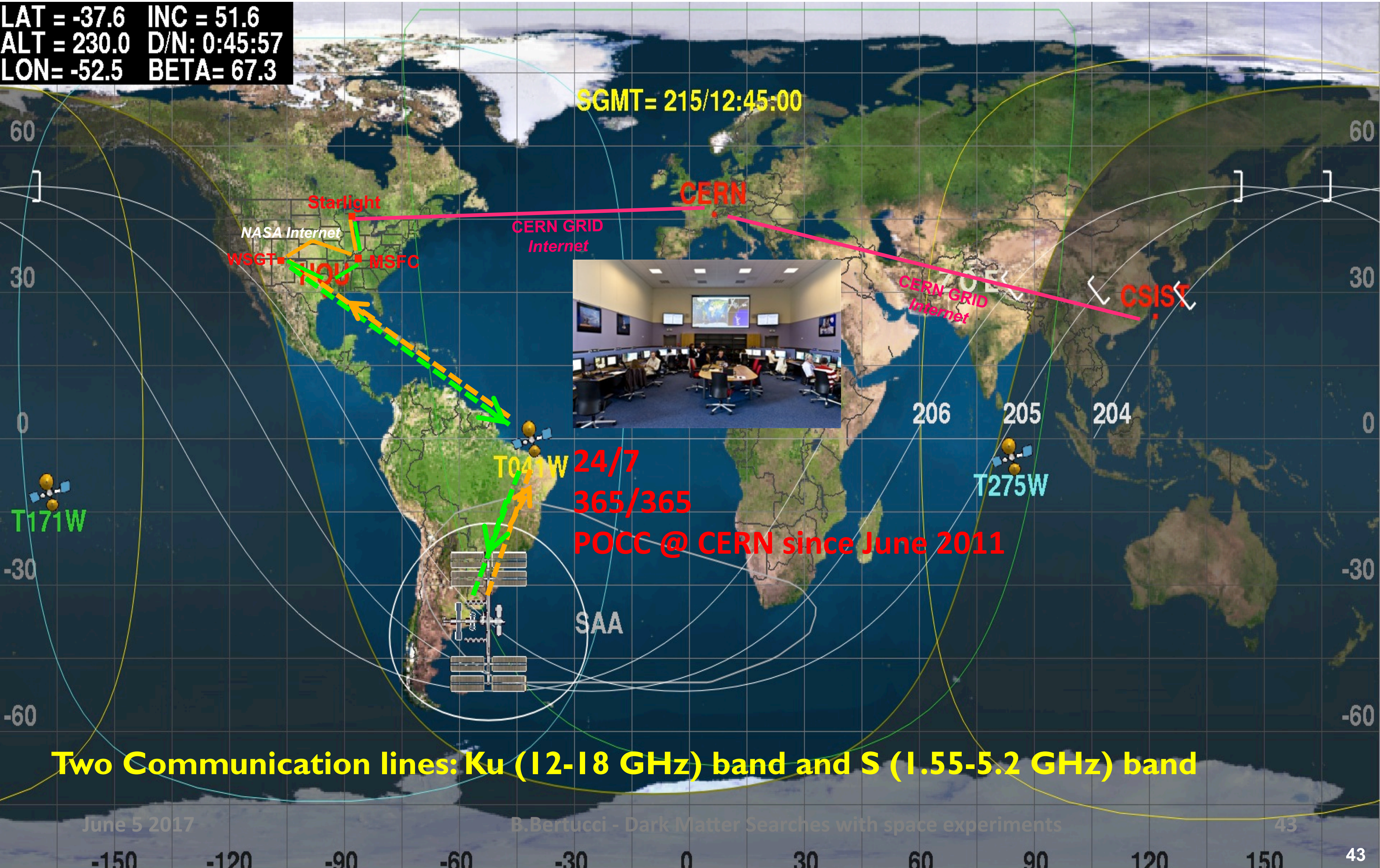



AMS
TRD
TOF 1, 2
Magnet
TOF 3, 4
RICH
ECAL
5m x 4m x 3m
7.5 tons
~300 kchannels
~650 on board processors
AMS without MLI
Silicon layer
7 Silicon layers
Silicon layer

Launch of AMS
May 16, 2011

AMS on ISS
May 19, 2011

Operation in Orbit : 24h/day 365d/year 35 TB/year



AMS Data Structure

- **Requirements:** compliant to standard communication protocols used by NASA to communicate with ISS
- Basic unit are "**frames**" of fixed size whose format is defined by the Consultative Committee for Space Data System (**CCSDS**). Uniquely identified by a triplet (**APID, Time, Seqno**)
- AMS detectors produces **AMSBlocks split in** one-minute **frames** to be transferred via NASA communication systems and copied locally (ISS) on a dedicated laptop
- @ CERN **frames** are **merged to rebuild the AMSBlocks**: check on the stream integrity and missing frames are eventually recovered from the laptop playback
- **Raw data** are obtained from the merging of **AMSBlocks** collected along a **run** (1/4 of ISS orbit / ≈ 23 minutes).
- **Root files** are produced from Raw data for calibration and physics analysis.

AMS Data Structure

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- **Raw data** are obtained from the merging of **AMSBlocks** collected along a **run** (1/4 of ISS orbit / ≈ 23 minutes).

Specific for each space experiment !!!

- **Root files** are produced from Raw data for calibration and physics analysis.

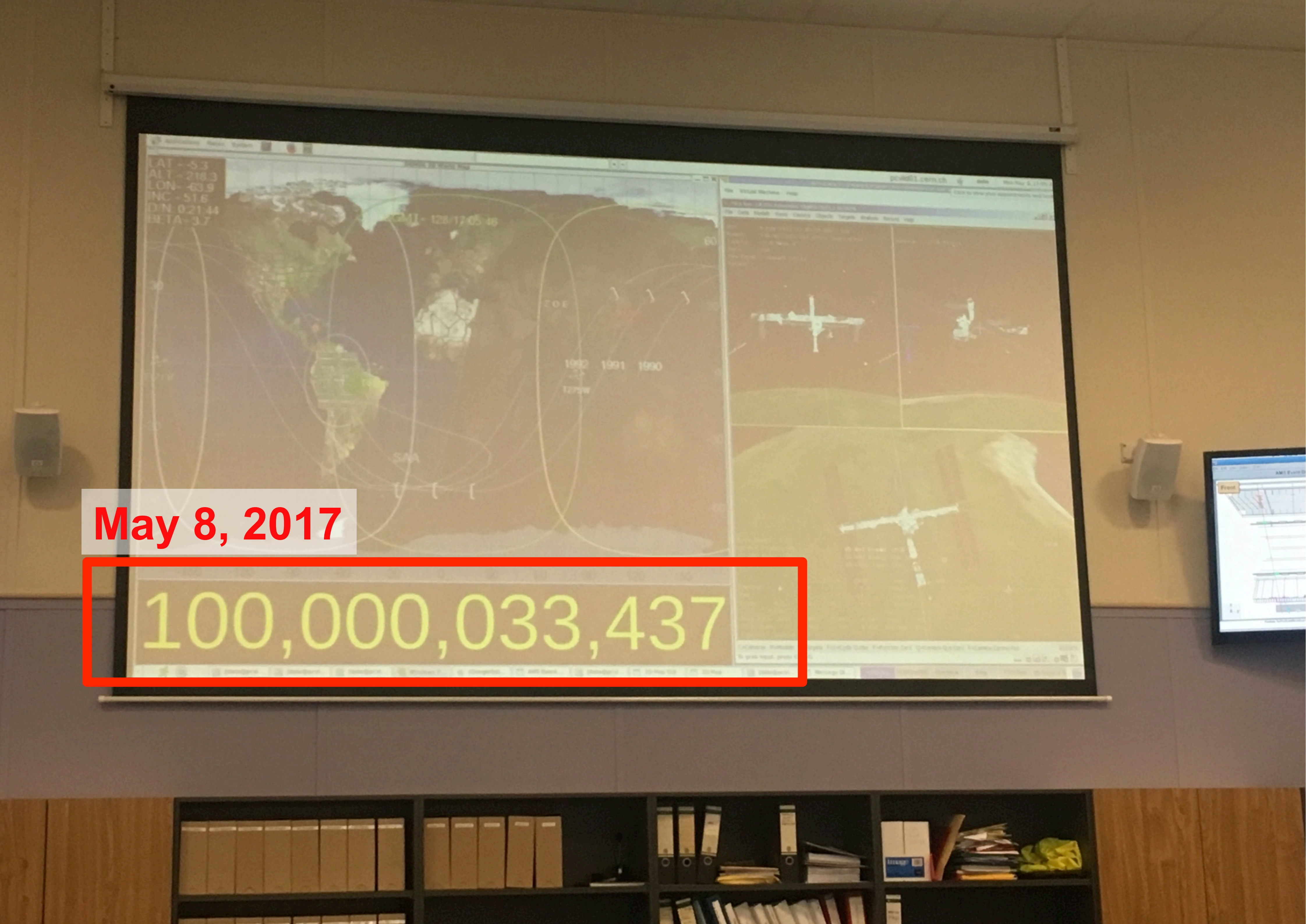
As in any HEP experiment !

AMS Data Structure

- Two independent data productions on board
  - ✓ House Keeping Data (HK), ~ 20 Kb/s →
  - ✓ Science Data (SCI) ~ 6-24 Mb/s
- Two external interfaces
  - ✓ HRDL (High Rate Data Link)
  - ✓ LRDL (Low Rate Data Link) →
- HK Data always goes on both interfaces
- SCI data has two possibilities
  - ✓ go out immediately after being produced
  - ✓ enqueued into a memory buffer

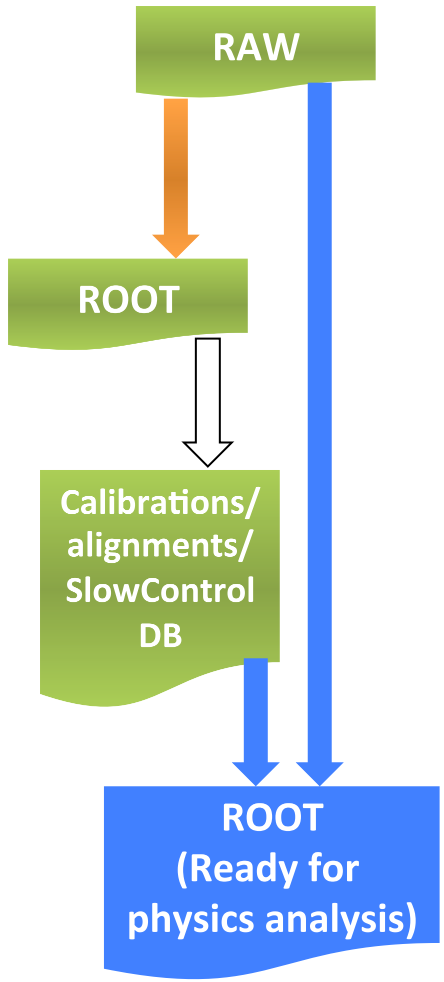
Driven by operation in space !

On line Monitoring


May 8, 2017
100,000,033,437

Data Reconstruction

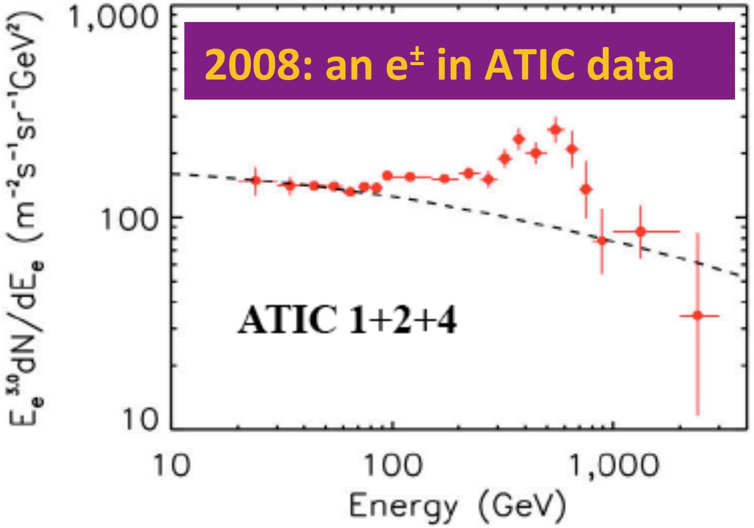
- **First Production (a.k.a. “std”)**
  - Runs 365dx24h on freshly arrived data
  - Initial data validation and indexing
  - Usually available < 2 hours after flight data arriving
  - Used to produce calibrations for the second production as well as quick performance evaluation (“one-minute ROOT files”, prescaled)
  - Used for non-critical on-line monitoring in the POCC
  - 100 cores (@ CERN) to keep up with the acquisition
- **Second Production (a.k.a. “pass*N*”)**
  - Every 6 months, incremental
  - Full reconstruction in case of major software update
  - Uses all the available calibrations, alignments, ancillary data…
  - 100 core-years per year of data



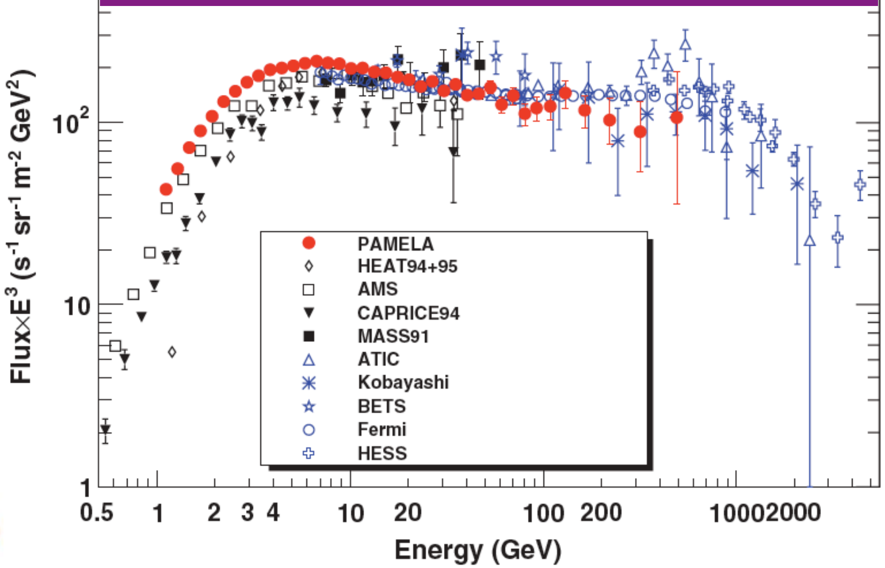
AMS & Dark Matter search

The electron/positron puzzle

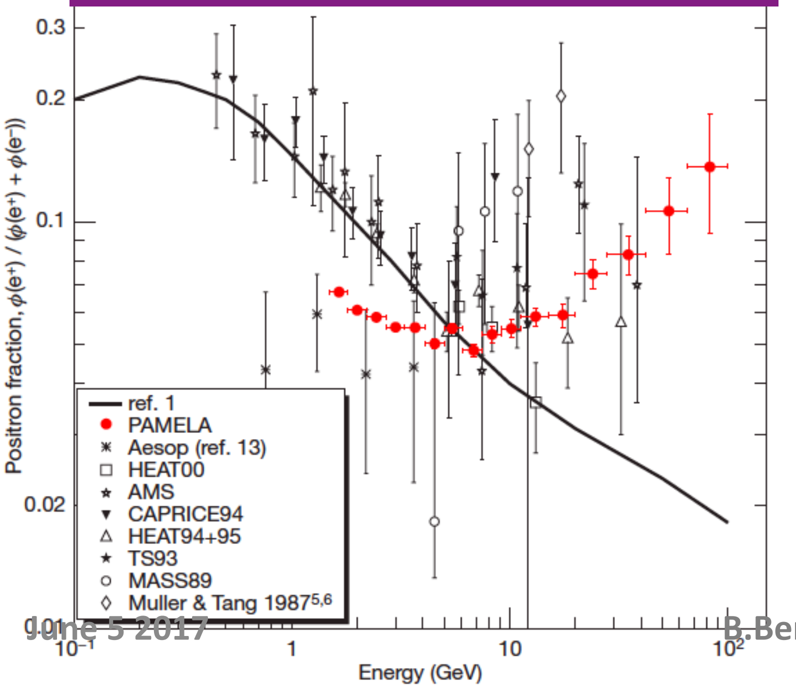
2008: an e± in ATIC data



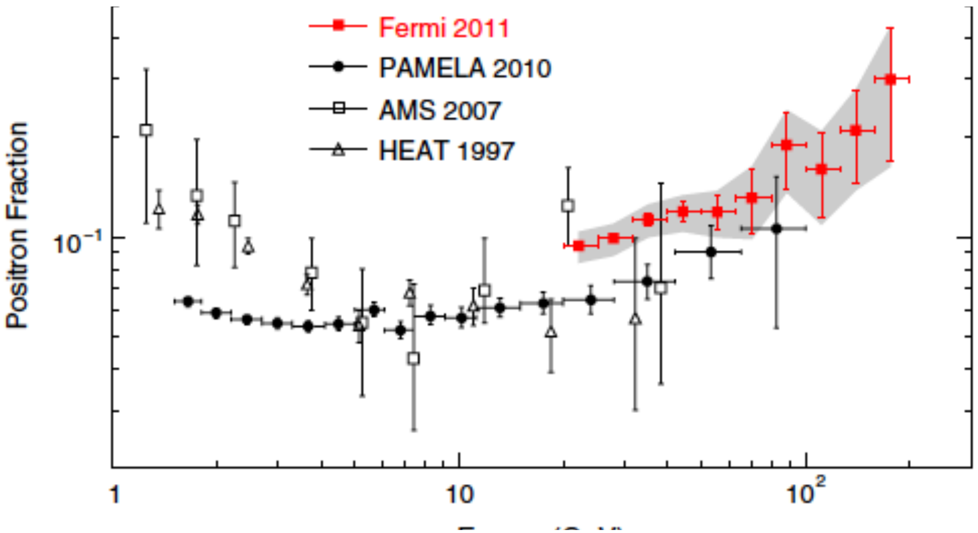
2009: No excess in Fermi e±
2011: No excess in e- from PAMELA



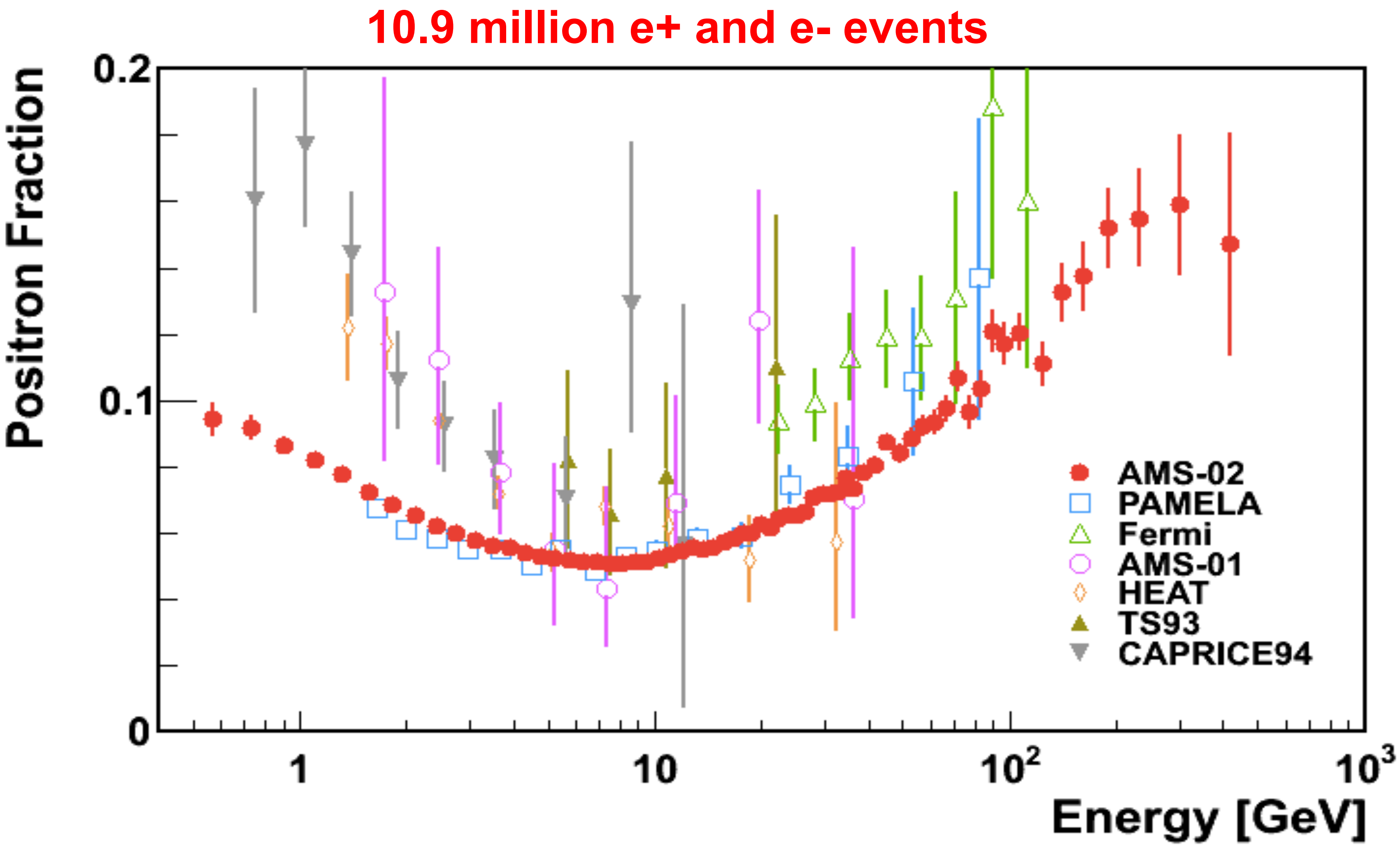
2008: e+ excess in PAMELA data



2009: Confirmed by Fermi

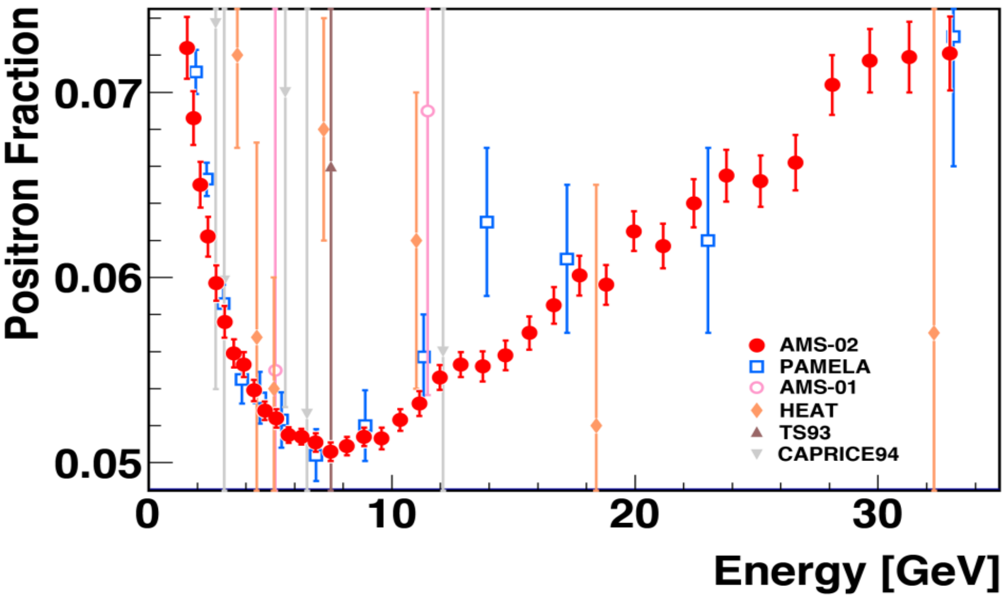


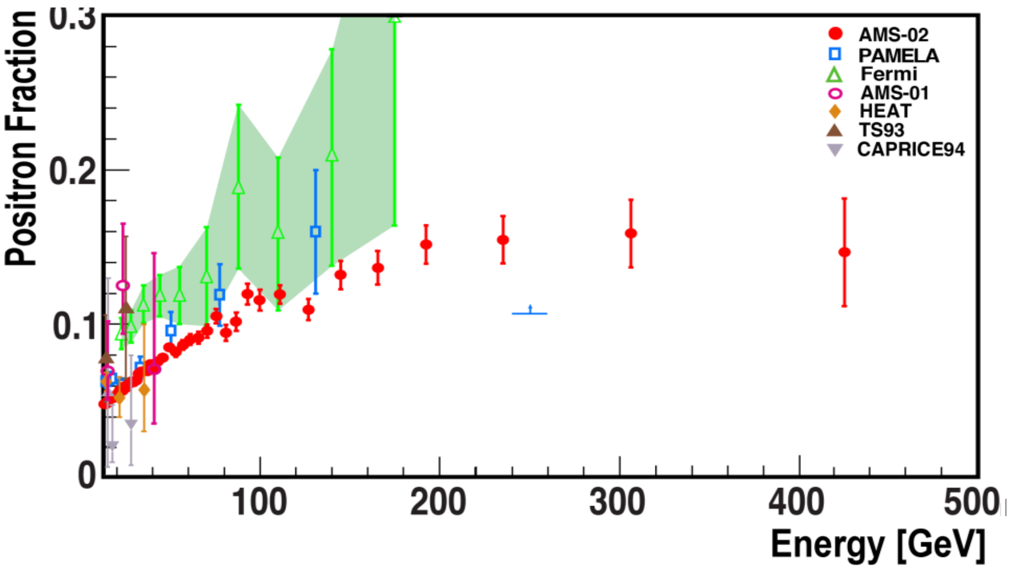
Positron fraction with 2.5 years of AMS data

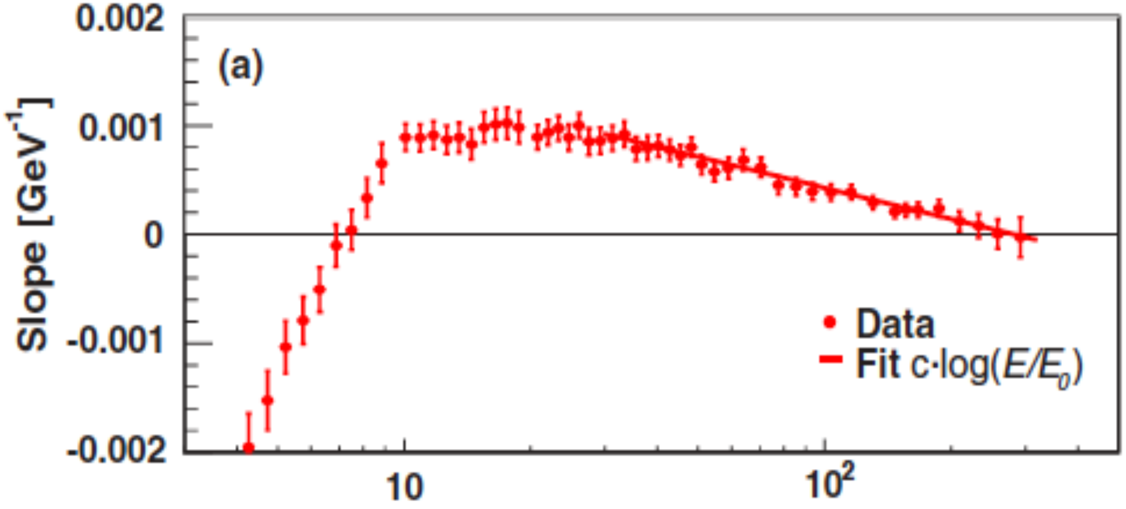


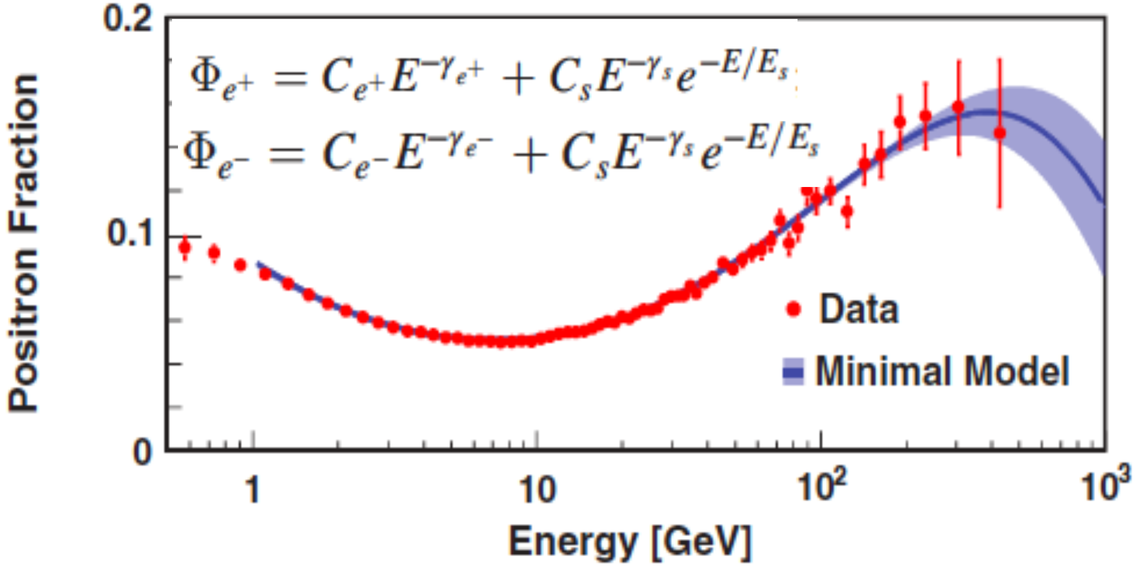
Positron fraction with 2.5 years of AMS data

- ✓ No sharp structures
- ✓ Steady increase of the positron content up to ≈ 275 GeV
- ✓ Well described by an empirical model with a common source term for e^+/e^-



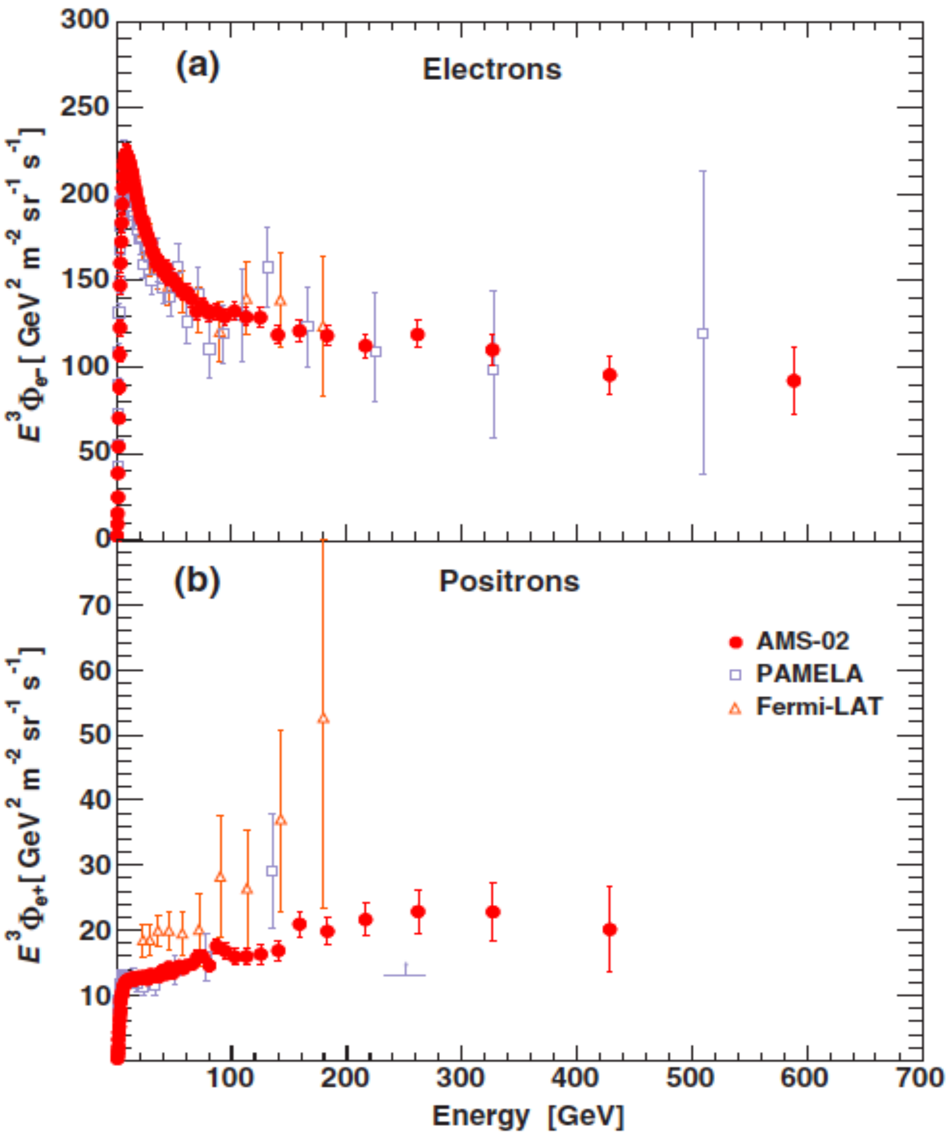


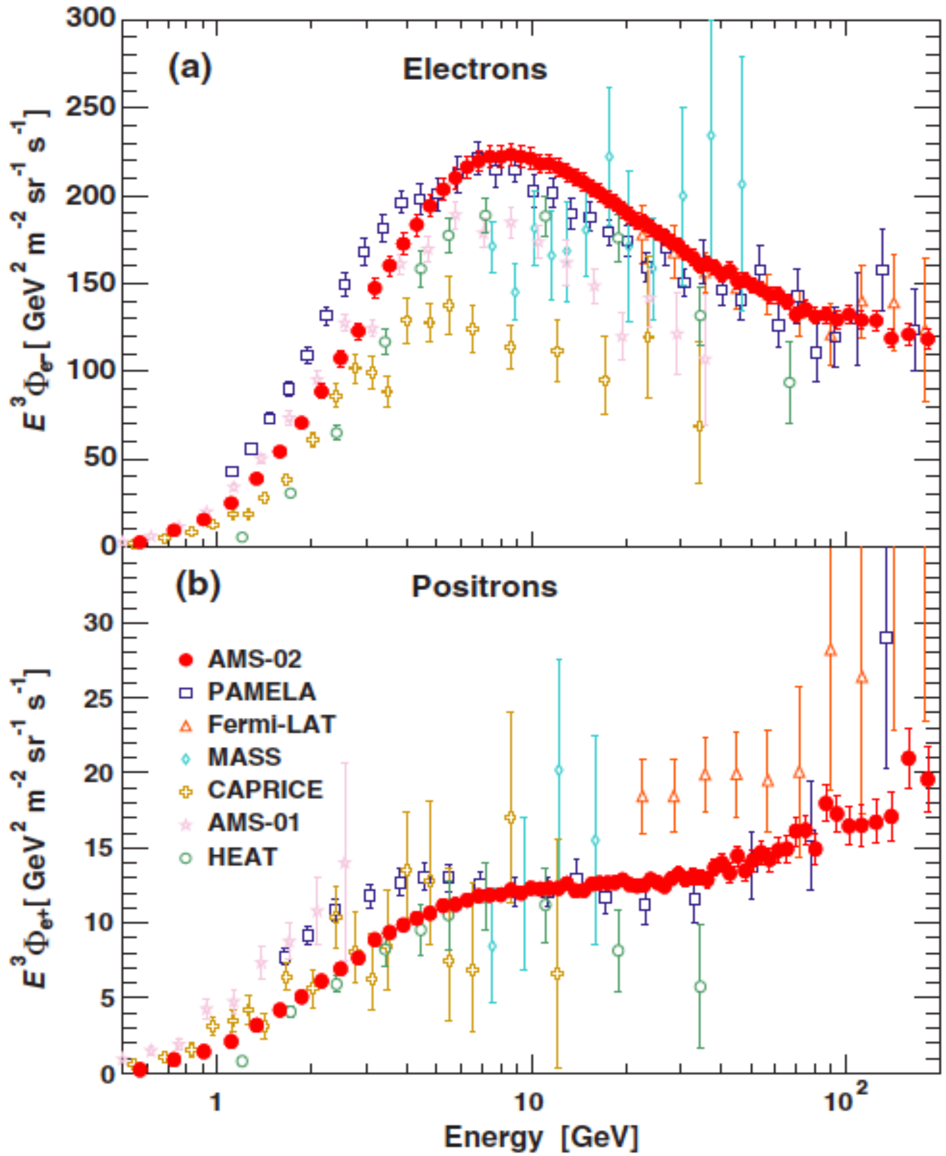




Electron/Positron fluxes with 2.5 years of AMS data

No sharp structures

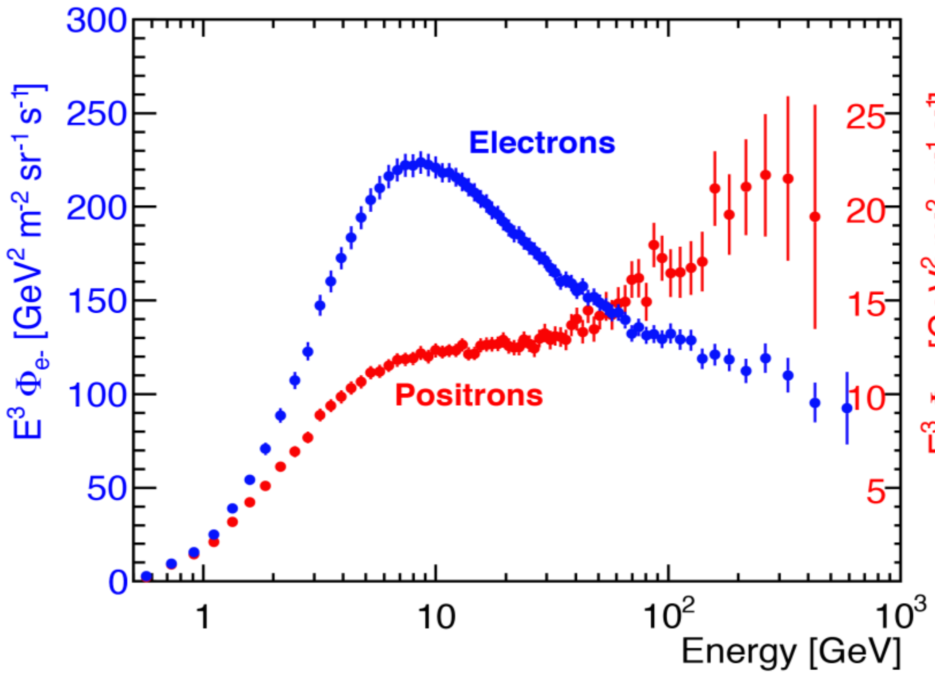


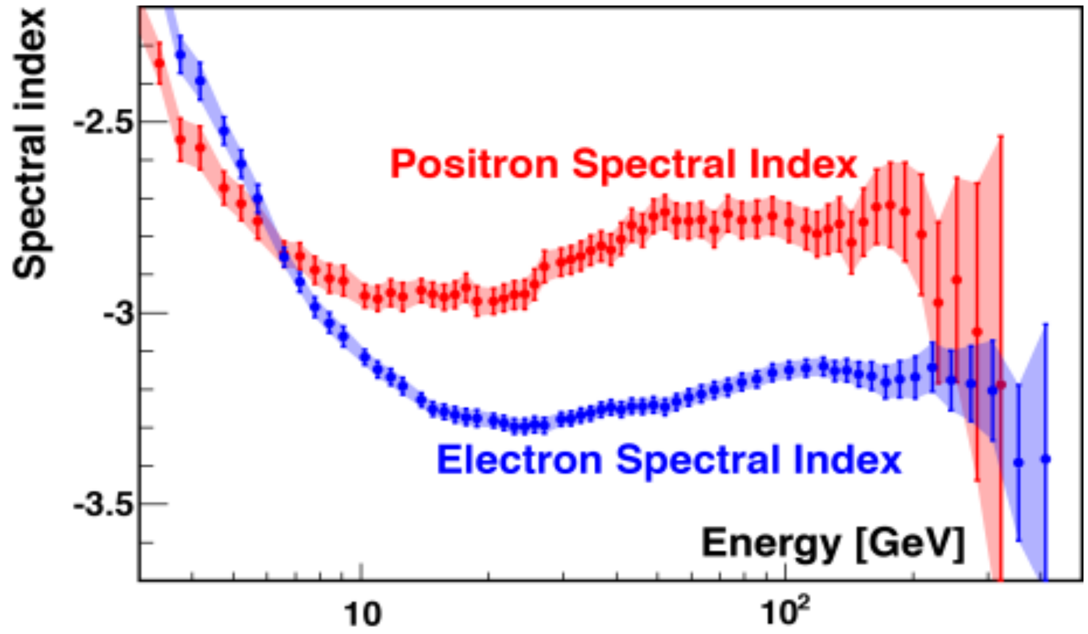


Electron/Positron fluxes with 2.5 years of AMS data:

For the first time a detailed study of the spectral index variation with energy :

$$\gamma_{e^\pm} = d[\log(\Phi_{e^\pm})]/d[\log(E)]$$



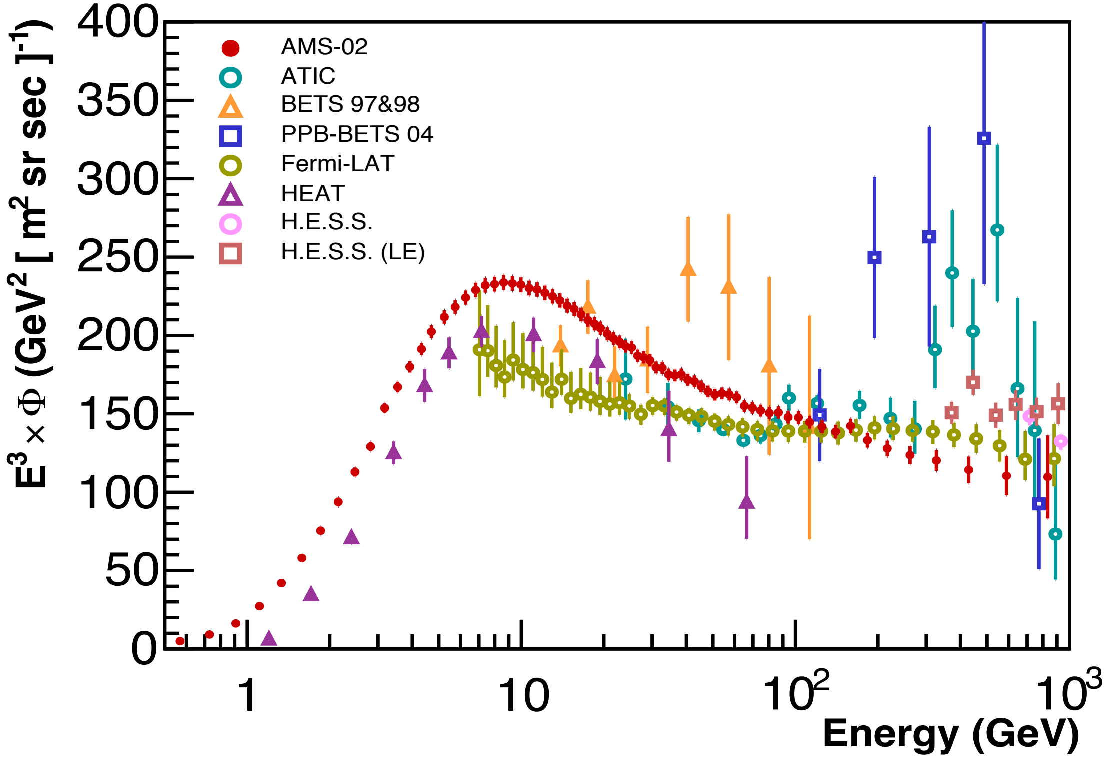


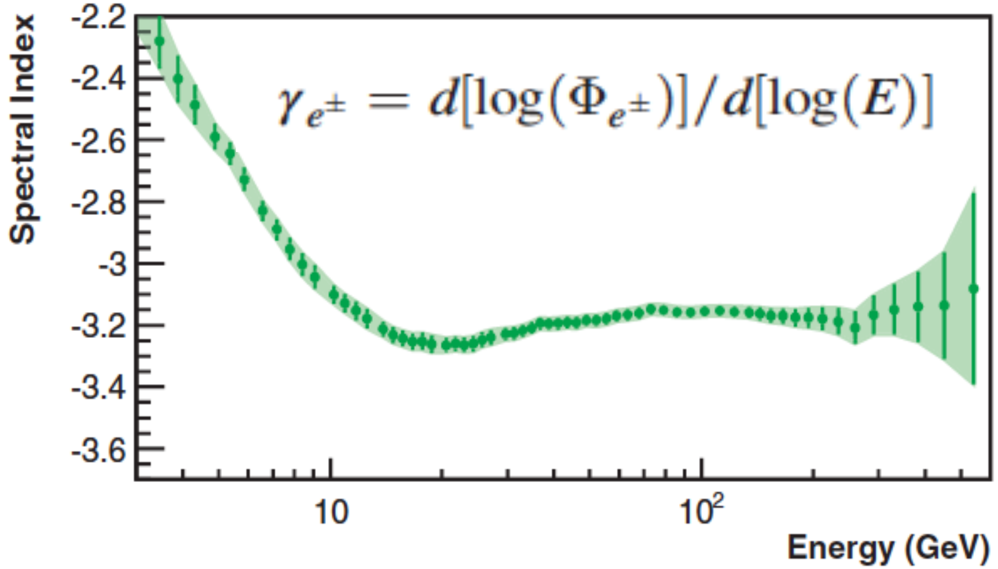
Hardening of the positron spectrum is at the origin of the positron fraction increase…

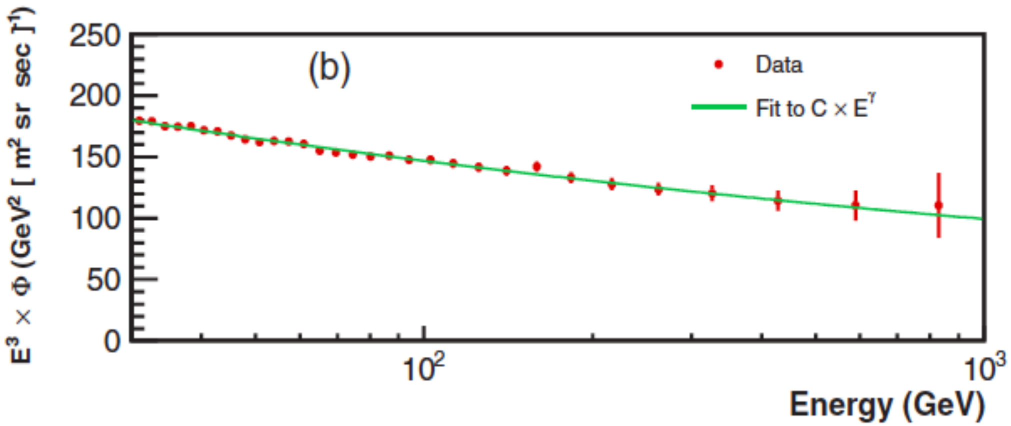
Electron + Positron flux with 2.5 years of AMS data:

Charge insensitive measurement →
higher energy, directly comparable with previous experiments

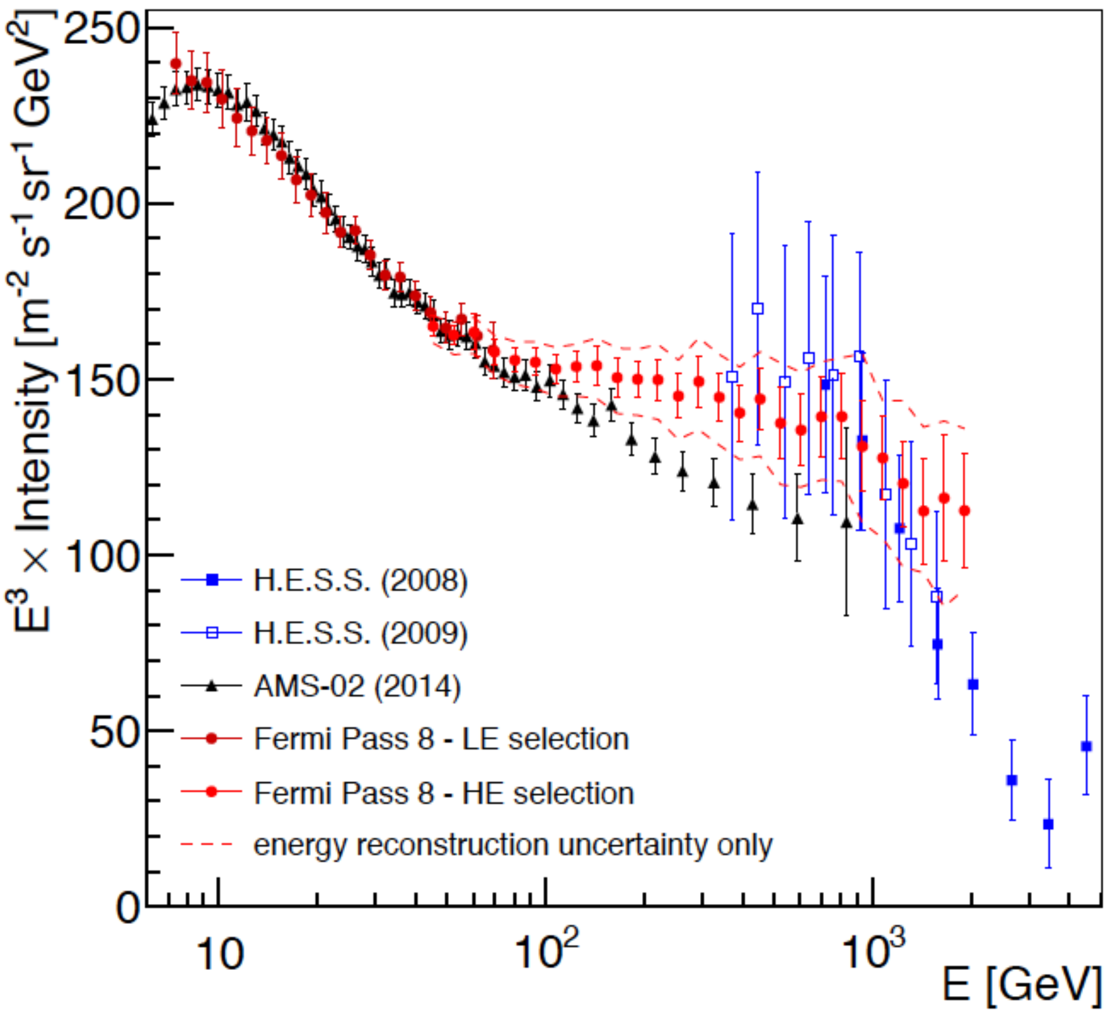
- ✓ **No sharp structures**
- ✓ **A single power low describes the spectrum after 30 GeV**







Electron + Positron flux: Fermi 2017



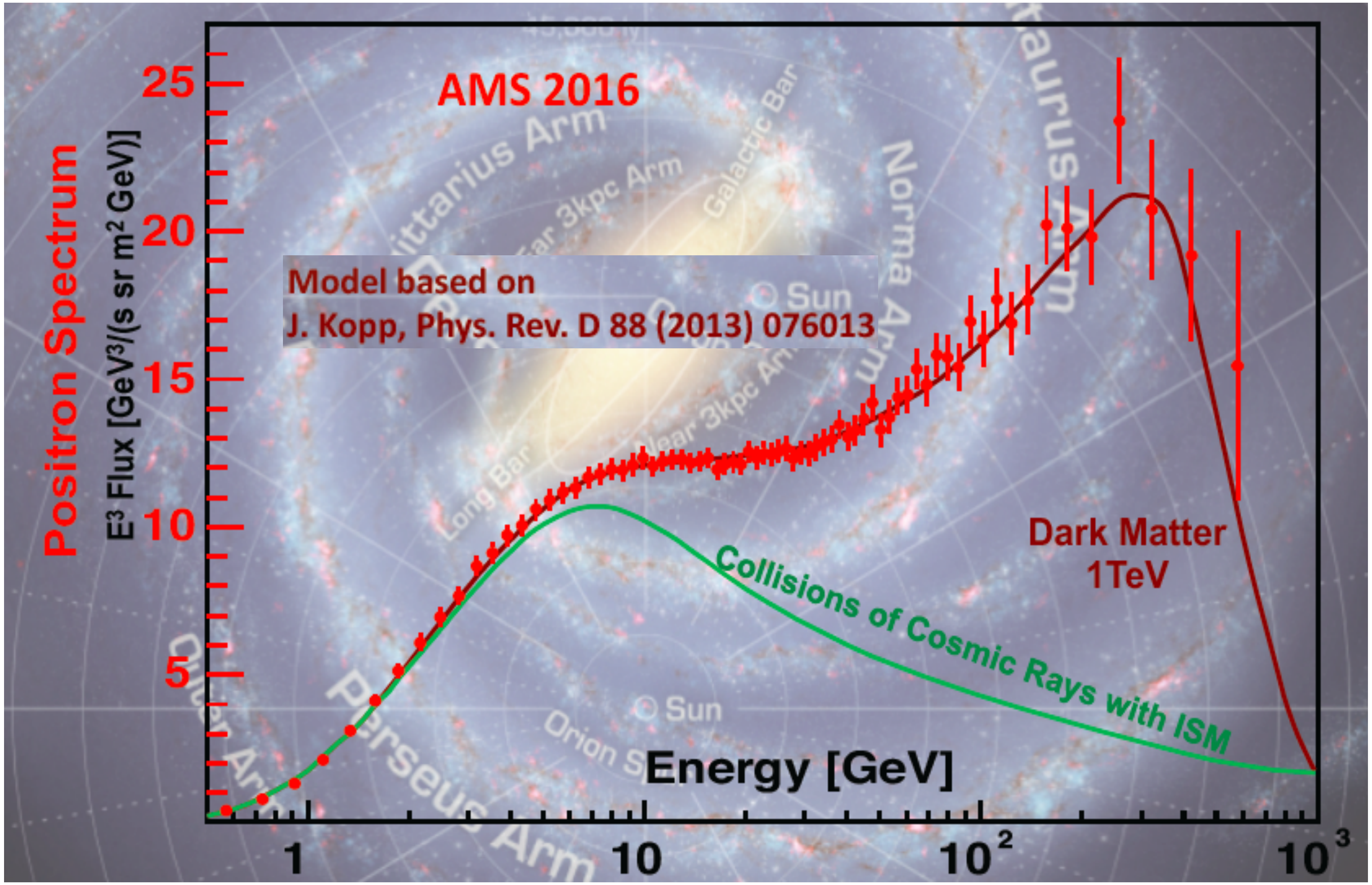
New measurement:

→ agreement with AMS up to ≈ 100 GeV

→ different (smooth) spectrum above

What is AMS observing?

Something **"different"** with respect "conventional" models of e^+ production by collisions of CR hadrons with the interstellar matter



- Points in the plot still preliminary: not to be quoted before publication!

What is AMS observing?

From Dark Matter

1) J. Kopp, Phys. Rev. D 88, 076013 (2013);
2) L. Feng, R.Z. Yang, H.N. He, T.K. Dong, Y.Z. Fan and J. Chang Phys.Lett. B728 (2014) 250
3) M. Cirelli, M. Kadastik, M. Raidal and A. Strumia ,Nucl.Phys. B873 (2013) 530
4) M. Ibe, S. Iwamoto, T. Moroi and N. Yokozaki, JHEP 1308 (2013) 029
5) Y. Kajiyama and H. Okada, Eur.Phys.J. C74 (2014) 2722
6) K.R. Dienes and J. Kumar, Phys.Rev. D88 (2013) 10, 103509
7) L. Bergstrom, T. Bringmann, I. Cholis, D. Hooper and C. Weniger, PRL 111 (2013) 171101
8) K. Kohri and N. Sahu, Phys.Rev. D88 (2013) 10, 103001
9) P. S. Bhupal Dev, D. Kumar Ghosh, N. Okada and I. Saha, Phys.Rev. D89 (2014) 095001
10) A. Ibarra, A.S. Lamperstorfer and J. Silk, Phys.Rev. D89 (2014) 063539
11) Y. Zhao and K.M. Zurek, JHEP 1407 (2014) 017
12) C. H. Chen, C. W. Chiang, and T. Nomura, Phys. Lett. B 747, 495 (2015)
13) H. B. Jin, Y. L. Wu, and Y.-F. Zhou, Phys.Rev. D92, 055027 (2015)
14) M-Y. Cui, Q. Yuan, Y-L.S. Tsai and Y-Z. Fan, arXiv:1610.03840 (2016)
15) A. Cuoco, M. Krämer and M. Korsmeier, arXiv:1610.03071 (2016)

From Astrophysical Sources

1) T. Linden and S. Profumo, Astrophys.J. 772 (2013) 18
2) P. Mertsch and S. Sarkar, Phys.Rev. D 90 (2014) 061301
3) I. Cholis and D. Hooper, Phys.Rev. D88 (2013) 023013
4) A. Erlykin and A.W. Wolfendale, Astropart.Phys. 49 (2013) 23
5) P.F. Yin, Z.H. Yu, Q. Yuan and X.J. Bi, Phys.Rev. D88 (2013) 2, 023001
6) A.D. Erlykin and A.W. Wolfendale, Astropart.Phys. 50-52 (2013) 47
7) E. Amato, Int.J.Mod.Phys.Conf.Ser. 28 (2014) 1460160
8) P. Blasi, Braz.J.Phys. 44 (2014) 426
9) D. Gaggero, D. Grasso, L. Maccione, G. DiBernardo and C Evoli, Phys.Rev. D89 (2014) 083007
10) M. DiMauro, F. Donato, N. Fornengo, R. Lineros and A. Vittino, JCAP 1404 (2014) 006
11) K. Kohri, K. Ioka, Y. Fujita, and R. Yamazaki, Prog. Theor. Exp. Phys. 2016, 021E01 (2016)

From Secondary Production

1) R.Cowsik, B.Burch, and T.Madziwa-Nussinov, Ap.J. 786 (2014) 124
2) K. Blum, B. Katz and E. Waxman, Phys.Rev.Lett. 111 (2013) 211101
3) R. Kappl and M. W. Winkler, J. Cosmol. Astropart. Phys. 09 (2014) 051
4) G.Giesen, M.Boudaud, Y.Gènolini, V.Poulin, M.Cirelli, P.Salati and P.D.Serpico, JCAP09 (2015) 023;
5) C.Evoli, D.Gaggero and D.Grasso, JCAP 12 (2015) 039.
6) R.Kappl, A.Reinertand, and M.W.Winkler, arXiv:1506.04145 (2015)

What is AMS observing?

Something **"different"** with respect "conventional" models of e^+ production by collisions of CR hadrons with the interstellar matter (ISM):

Astrophysical Sources:

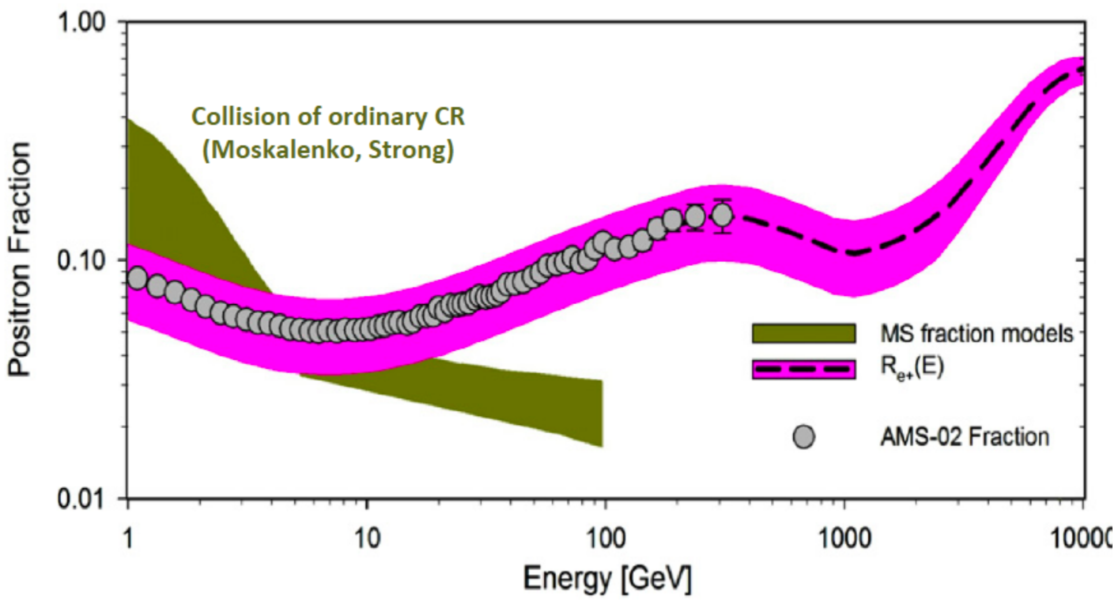
- Local sources as pulsars (slow fall at high energies, anisotropy..)
- Interactions of CR hadrons in old SNR (but this should affect also other secondary species as anti-protons, B/C)
- purely secondary production in non-conventional models

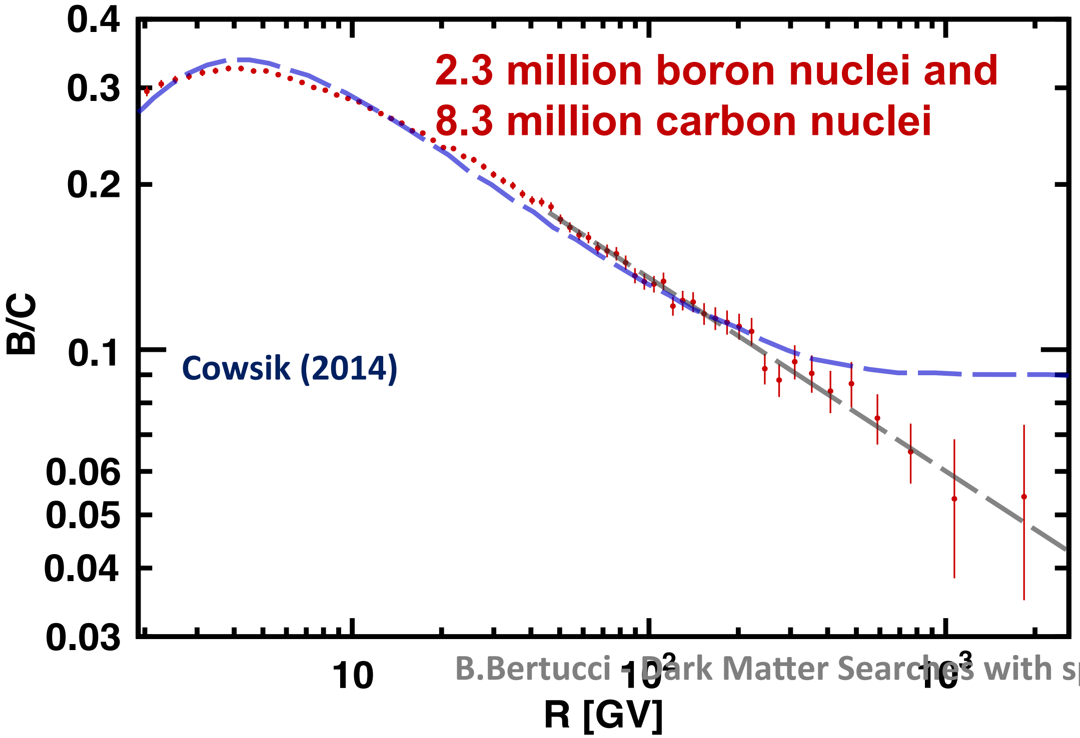
Dark matter:

- The mass of the DM particle could give a sharp cutoff with energy
- Isotropic distribution
- Effects also on anti-p

Secondary production:

R. Cowsik, B. Burch, and T. Madziwa-Nussinov, Ap. J. 786 (2014) 124

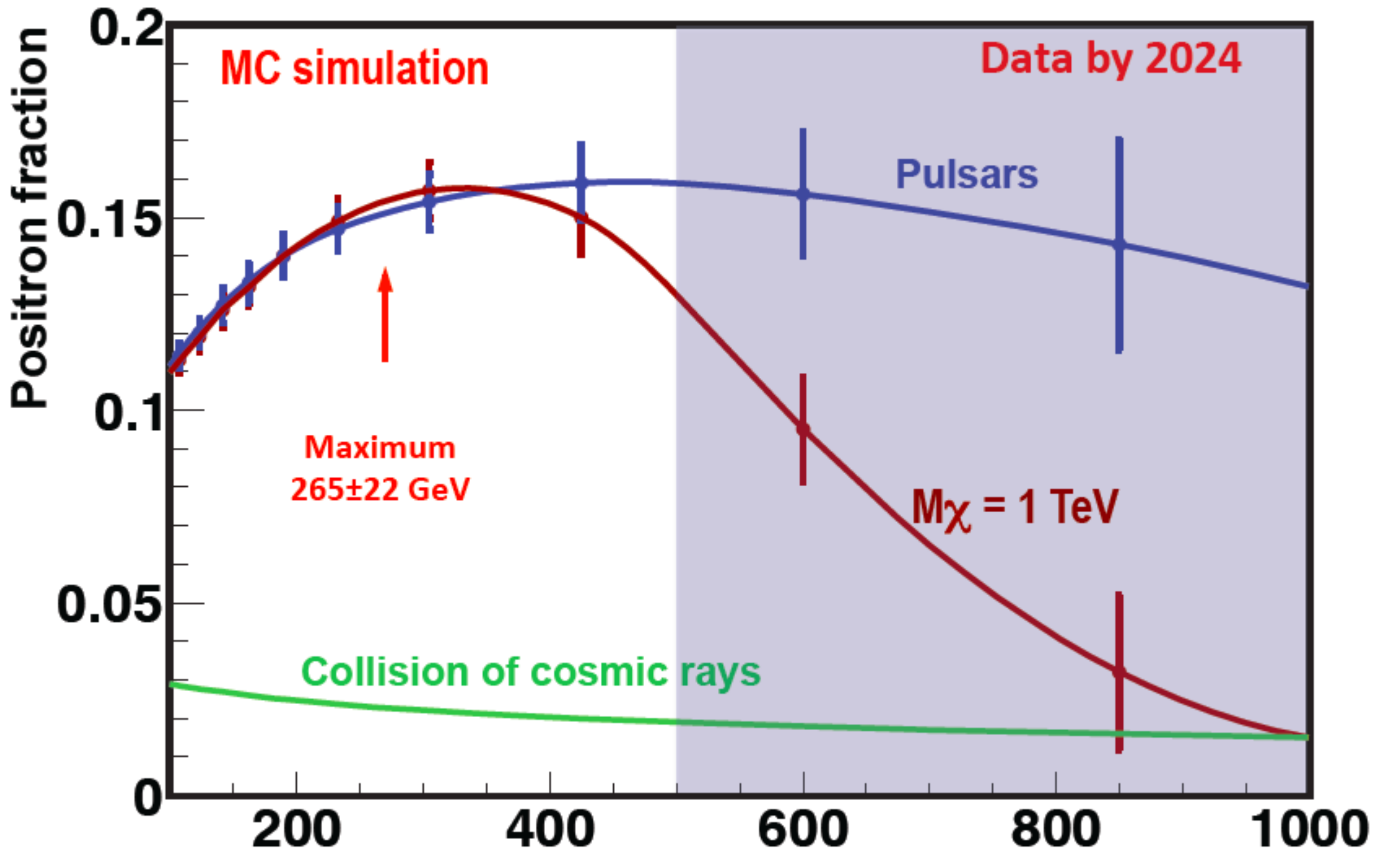




ok
for positron fraction

fails in other channels !

We have to wait….



I. Cholis and D. Hooper, Phys.Rev. D88 (2013) 023013
J. Kopp, Phys. Rev. D 88 (2013) 076013

- ✓ **Increase statistics & energy range**
- ✓ **Better understanding of astrophysical background from other measurements (nuclei)**
- ✓ **Study other anti-particle channels….**

Anti-proton/proton in the past millennium..

the early times (1984)

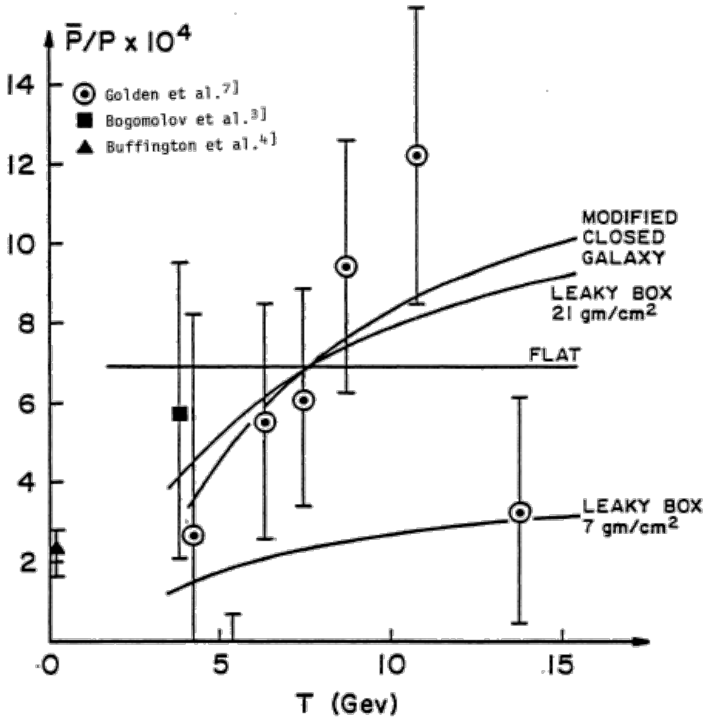
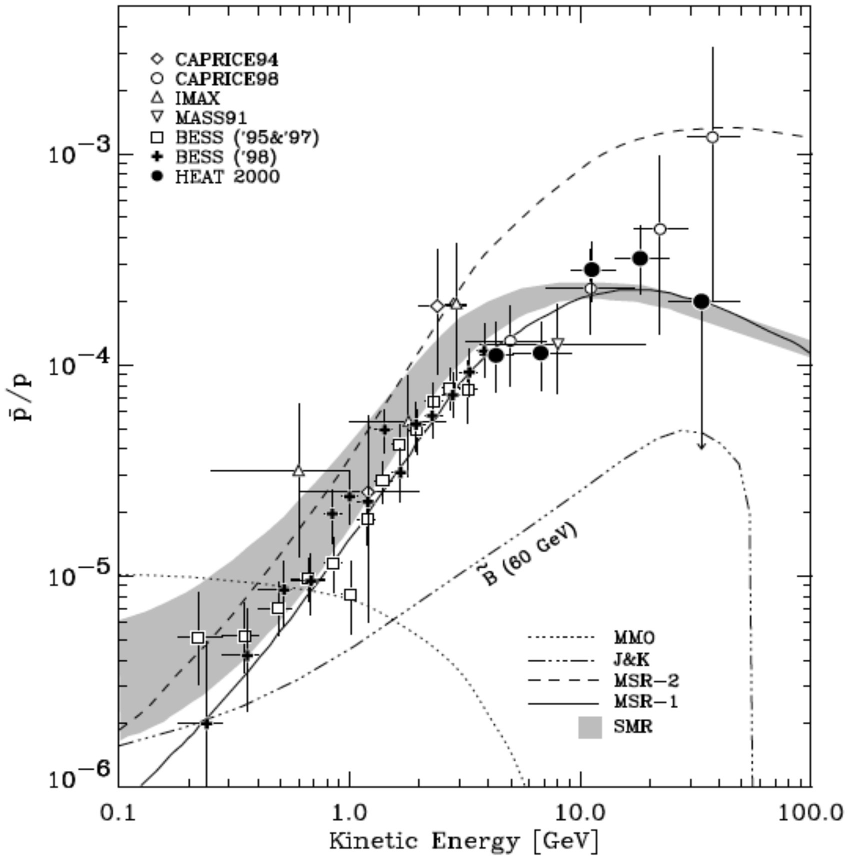


Figure 1. Antiproton Observations and Predictions

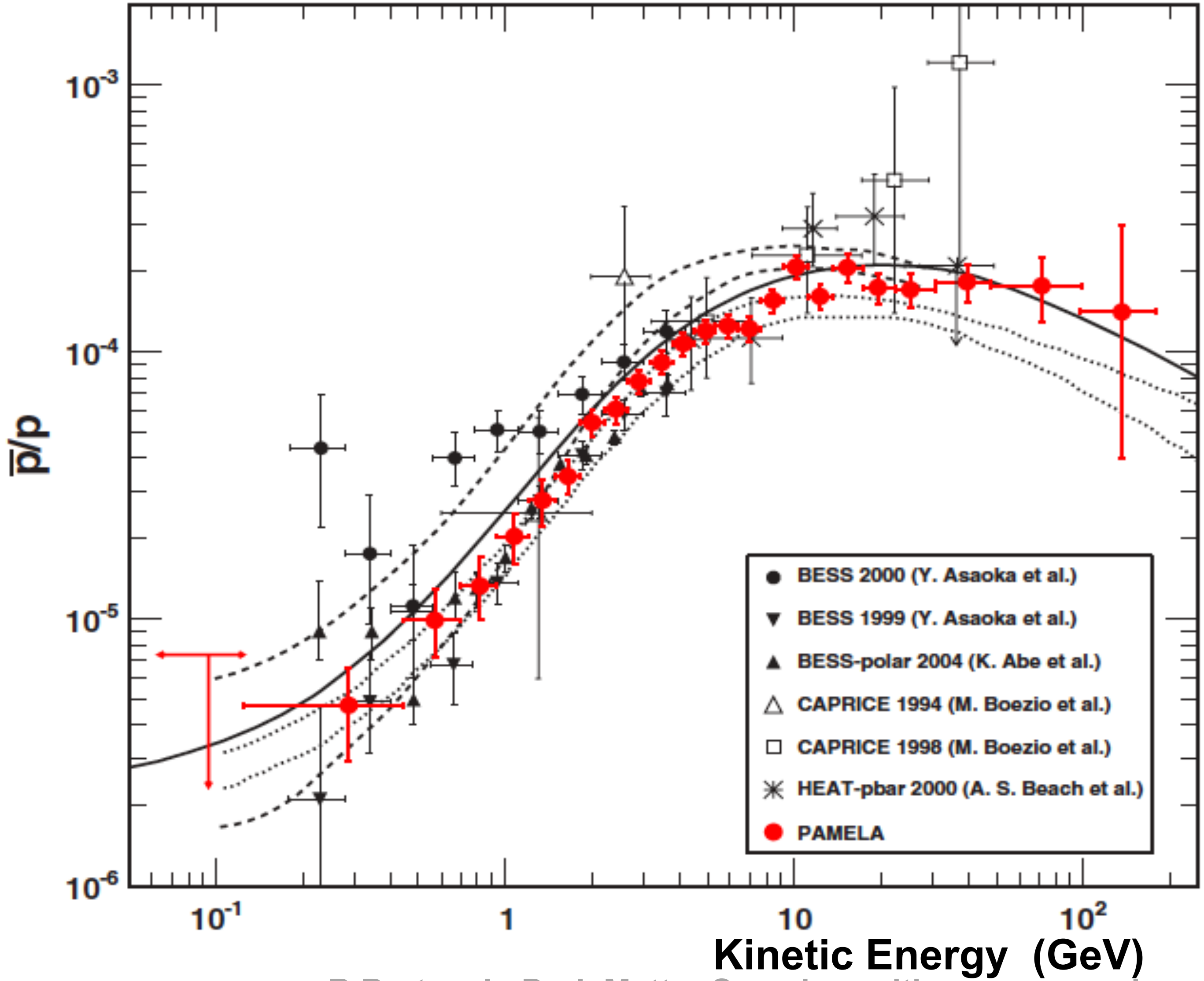
...around 2000



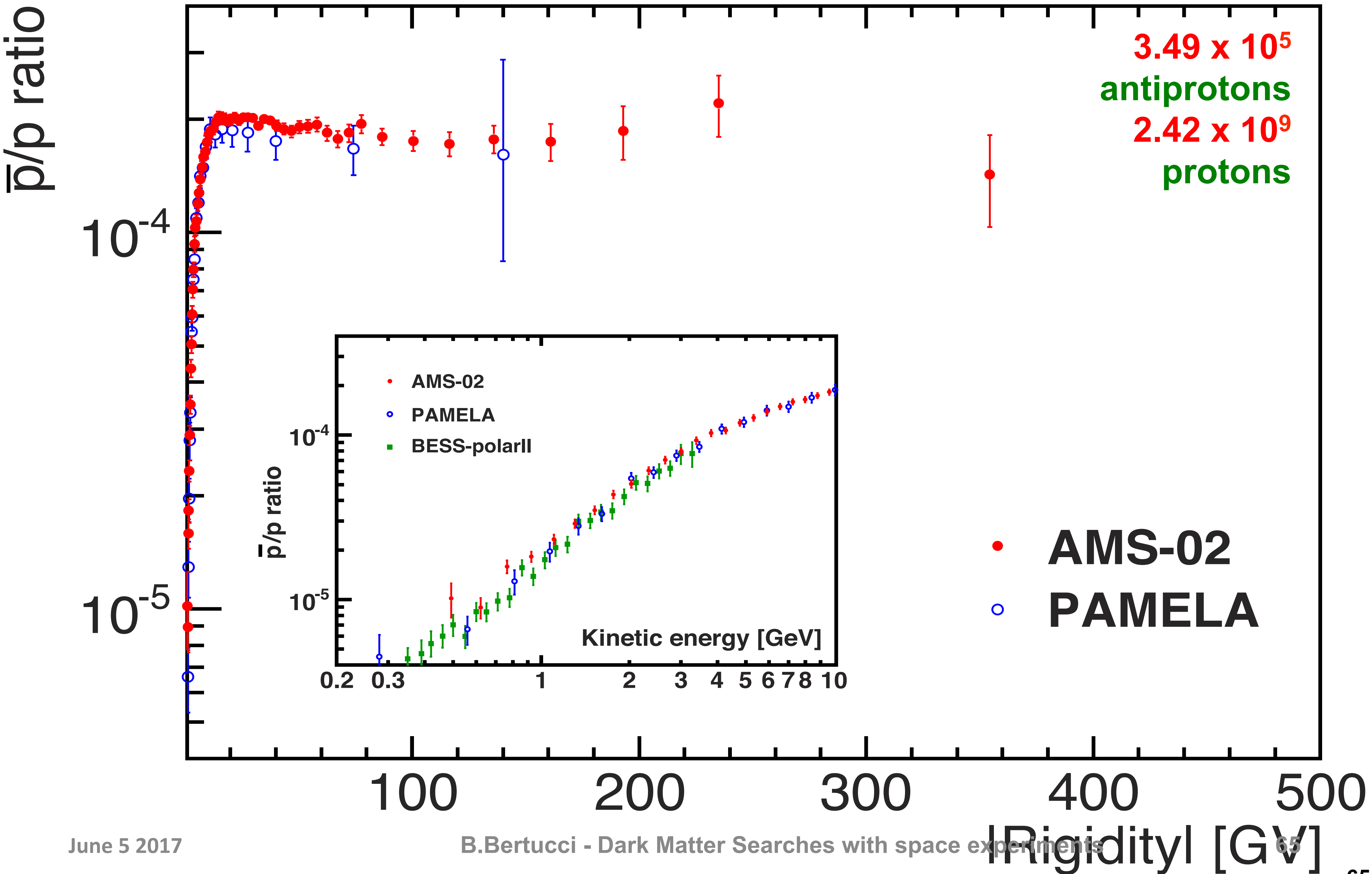
HEAT ≈ 70 events
CAPRICE ≈ 31 events

Anti-proton/proton : 2010

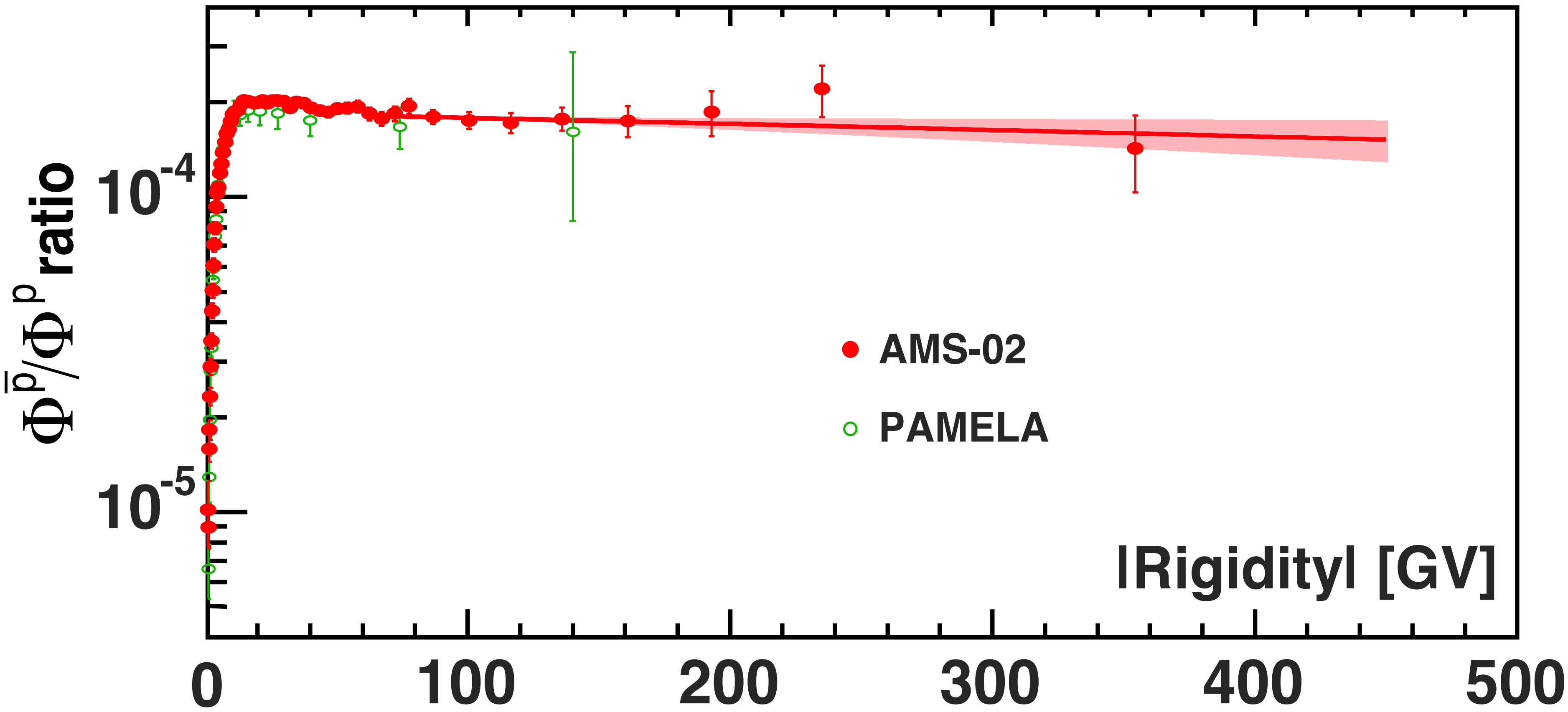
BESS-POLAR (2004) ≈ 1520 events < 4.2 GeV
PAMELA (2006-2009) ≈ 1500 events



AMS results on the $\overline{p}/p$ flux ratio

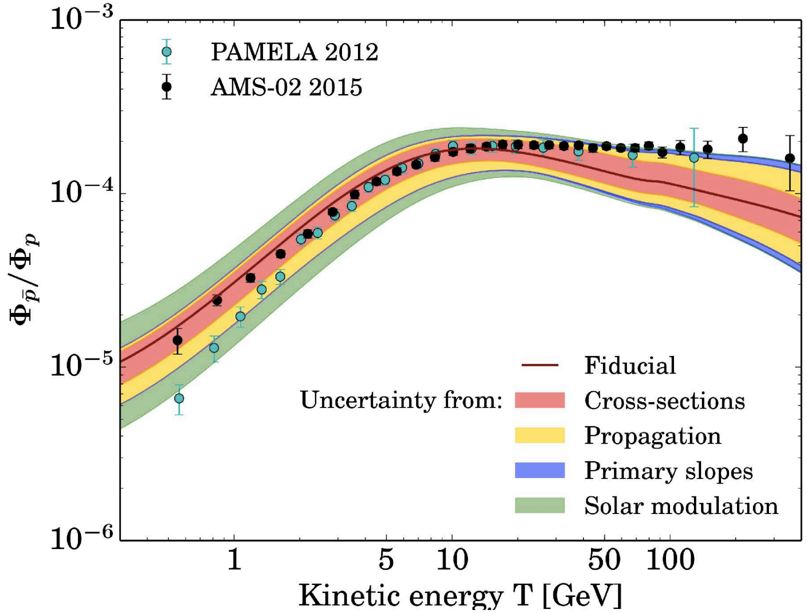


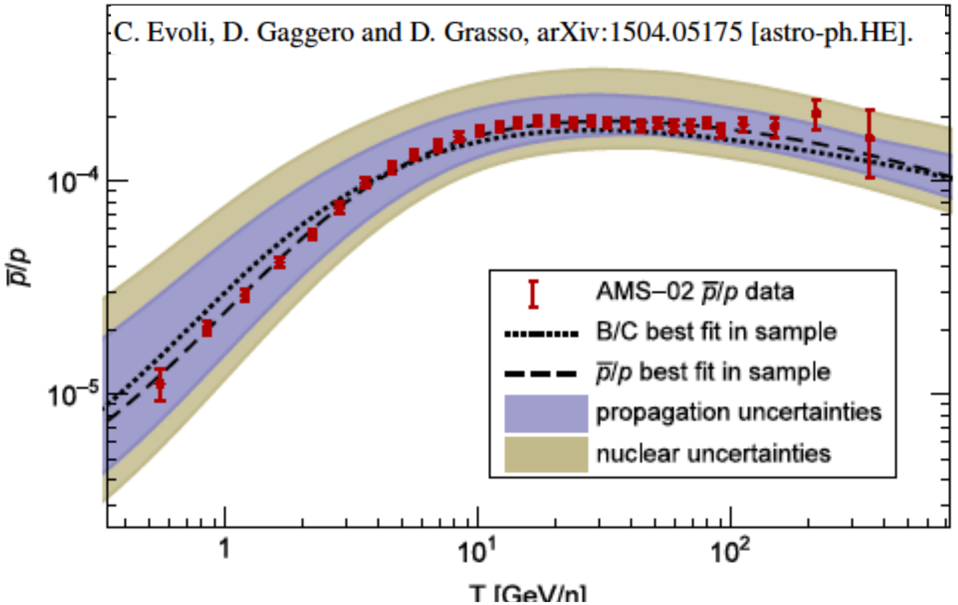
The pbar/p ratio flattens above 60 GeV..

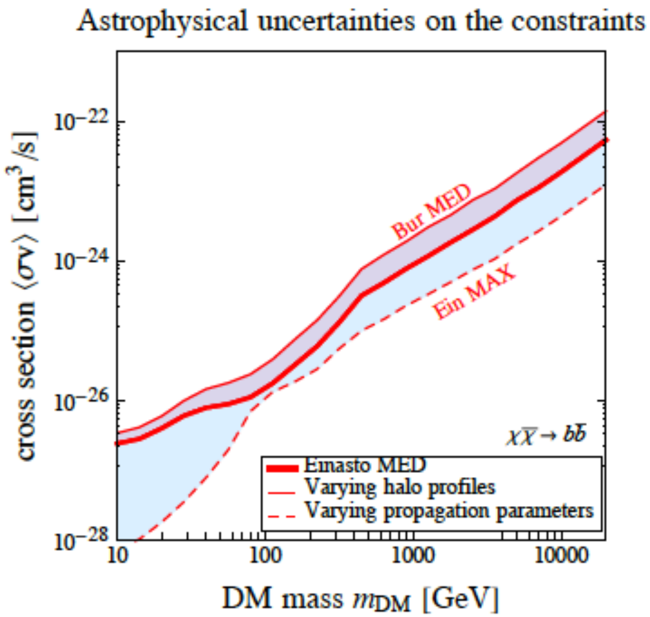


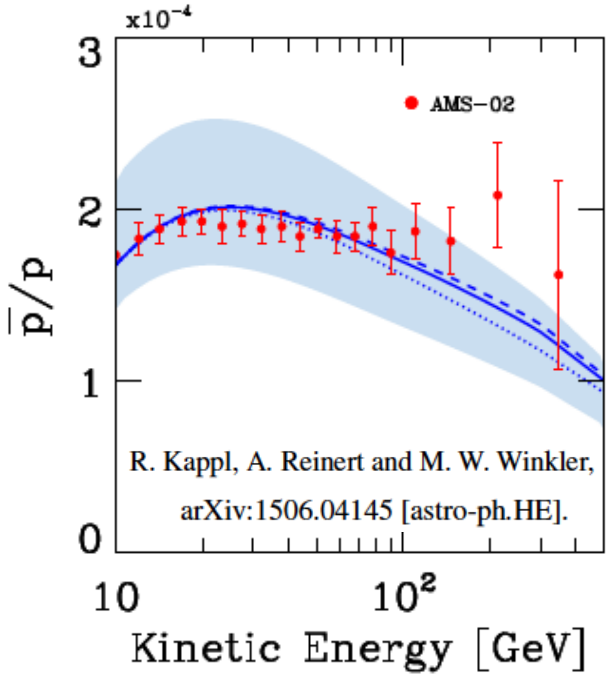
What is AMS observing?

The accuracy of the AMS measurement challenges current knowledge of cosmic background !









XSCRC2017: Cross sections for Cosmic Rays @ CERN

29 Mar 2017, 14:00 → 31 Mar 2017, 19:00 Europe/Zurich

503-1-001 - Council Chamber (CERN)

Description New space borne experiments are ushering us into the era of precision direct measurements in cosmic ray physics. However, a poor knowledge of several particle physics and nuclear physics inputs - such as antiproton production or spallation cross sections - can seriously limit the relevant astroparticle physics information that can actually be extracted from these data, for instance for Galactic propagation parameters or indirect dark matter searches. The goal of the workshop, bringing together different communities, is to review theoretical motivations for the measurements of key processes, current galactic models and recent advances in cosmic ray observations that crucially depend on some of these inputs. The workshop also strongly aims at presenting current efforts and discussing forthcoming perspectives for particle/nuclear measurement campaigns.

Duration: The workshop will start Wednesday, March 29 in the late morning, and will end Friday, March 31 at about 4pm.

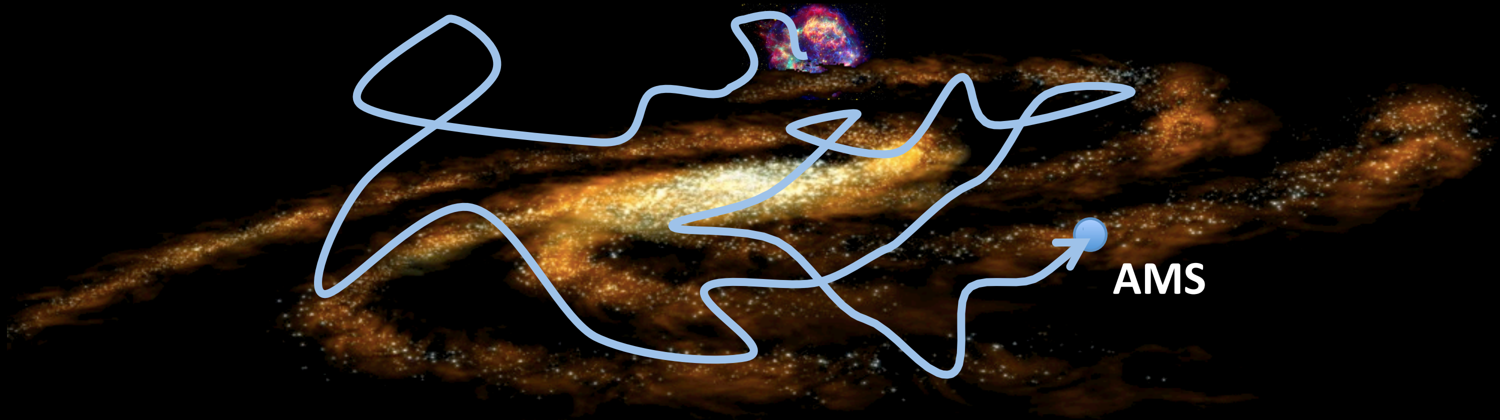
Organizing Committee: Bruna Bertucci (Perugia University), F. Donato (Torino University, chair), G. Giudice (CERN), Giovanni Passaleva (INFN, Florence), P. D. Serpico (LAPTH, Annecy, co-chair)

Scientific Advisory Committee: Oscar Adriani (Univ. and INFN, Firenze), Luca Latronico (INFN, Torino), Julie McEnery (Goddard NASA), Nadia Pastrone (INFN, Torino), Pierre Salati (LAPTH, Annecy), Andy Strong (MPE, Munich), Samuel C.C. Ting (MIT, Cern), Guy Wilkinson (Oxford Univ)

Invited Speakers: AMS Collaboration, Compass Collaboration, LHCb Collaboration, Alfredo Ferrari, Nicolao Fornengo, Guðlaugur Jóhannesson, Vladimir Ivanchenko, Tune Kamae, David Maurin, Nicola Mazziotta, Igor Moskalenko

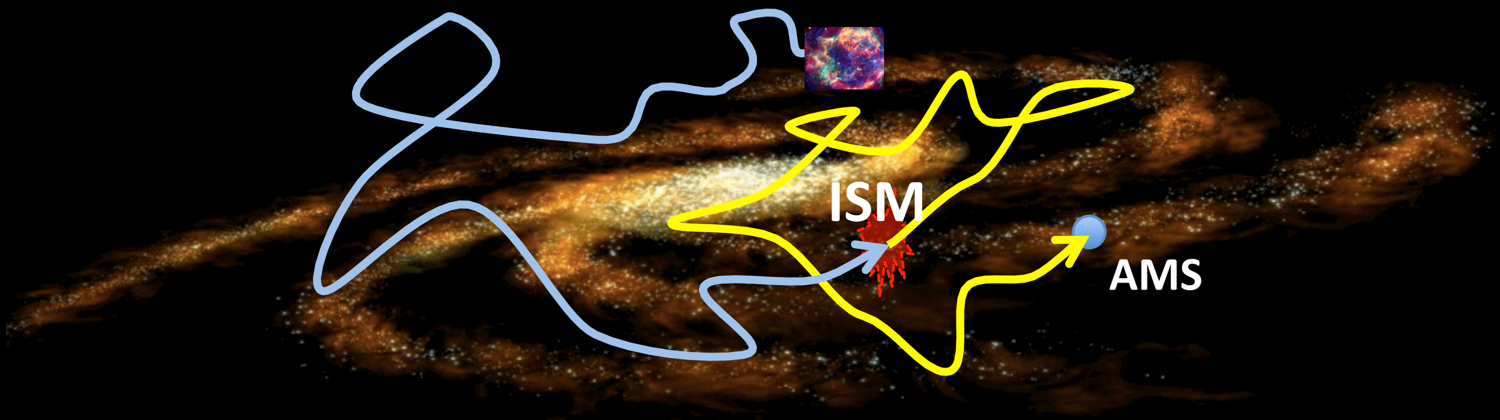
Registration *This event is open to new participants.* Register

A comprehensive set of measurements is needed to constrain astrophysical background:



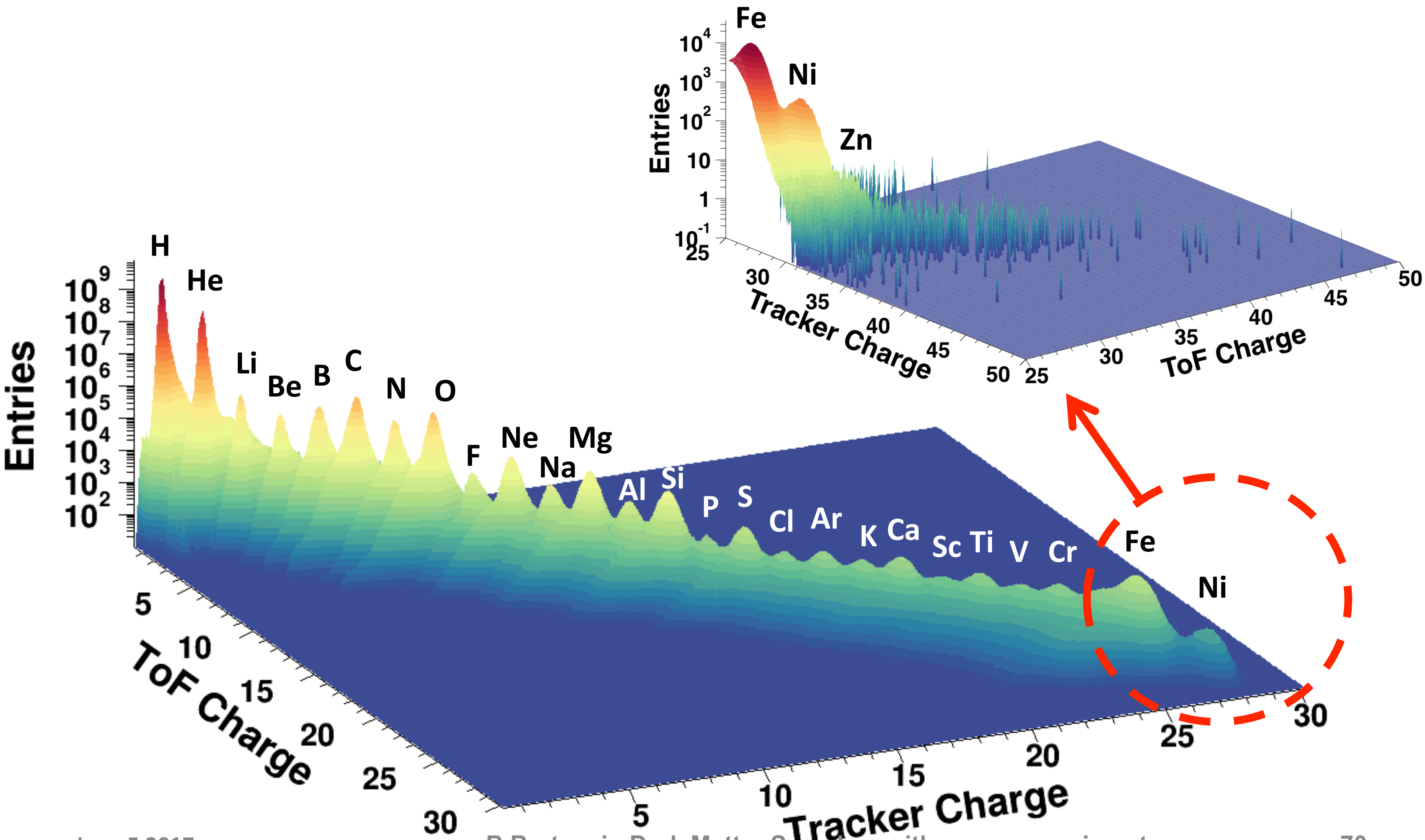
Primary Cosmic Rays (p, He, C, O, …)

C, O, …, Fe + ISM → Li, Be, B + X



Secondary Cosmic Rays (Li, Be, B, …)

Cosmic ray composition with AMS



What next?

- **AMS-02** will continue its mission up to 2024 or whenever the ISS will be operated….
- **CALET / DAMPE** experiments will soon start release their first data ….calorimetric measurements of electrons and nuclei (…more news on e^{+}+e^{-})
- **ISS-CREAM** will start its mission this summer calorimetric measurements of nuclei

- **GAPS** a balloon borne experiment to search for low energy anti-deuterons

NEW MISSIONS TOWARDS DM SEARCHES ?

China’s Space Station Program

2022

Phase -III

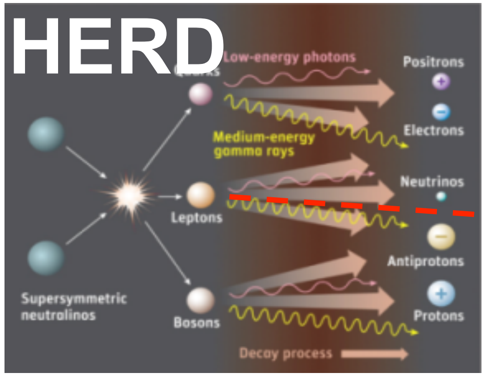
2018

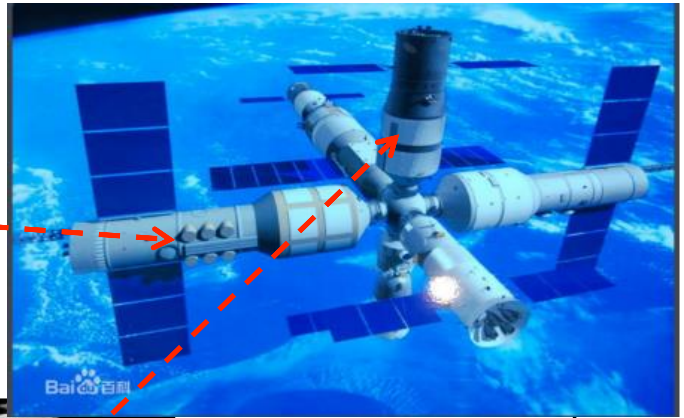
Phase -II

2011

Phase -I

2003



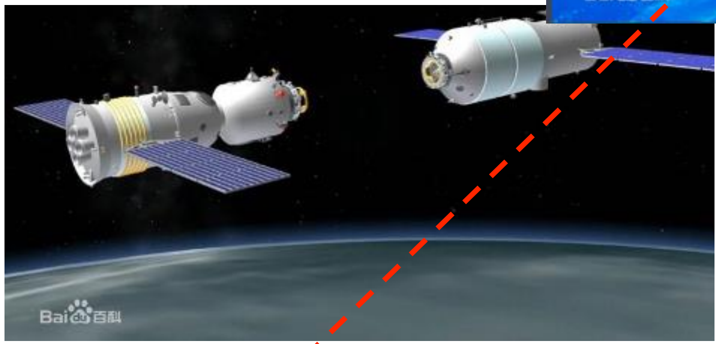


Space Station

3 large modules

+ 2 m telescope

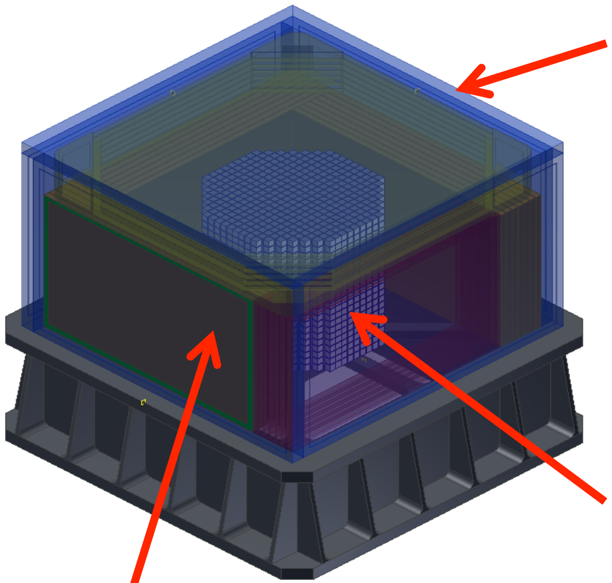
~10-year lifetime



Space lab: no living cabin

10 astronauts in 5 flights → space walk

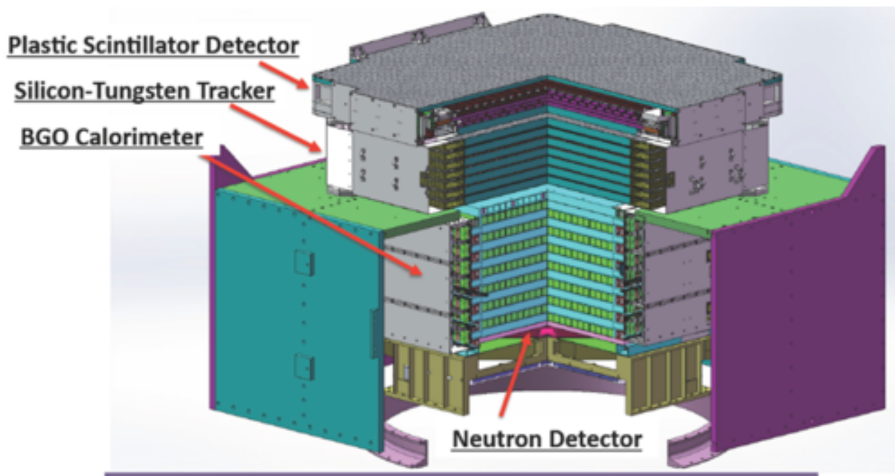
HERD: High Energy Cosmic Ray Detector



PSD, five sides
low energy Gamma Id
Charge

3D CALO
e/γ/CR energy
e/p discrimination

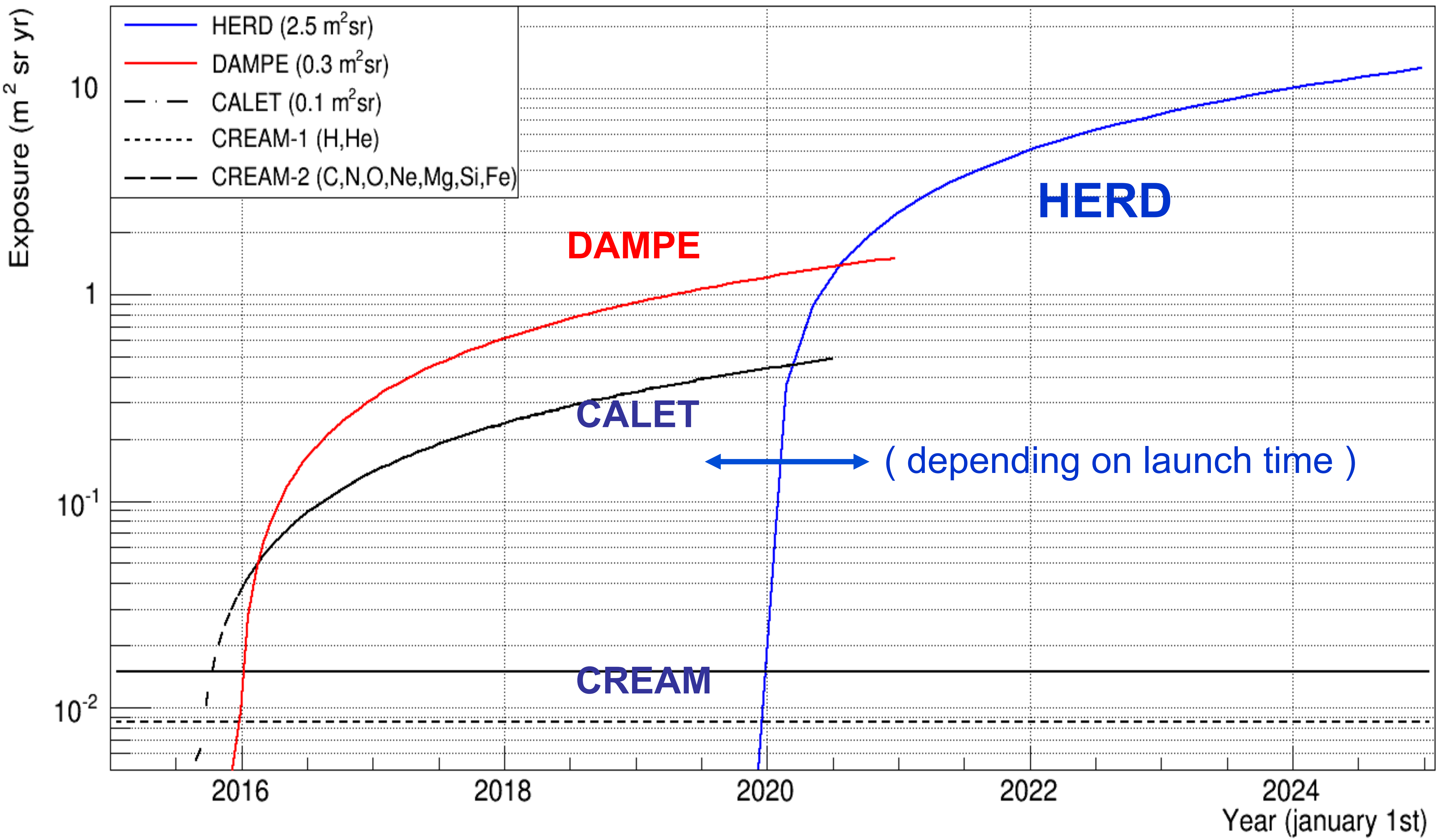
STK(SSD+W),five sides
Charge
Trajectory
Gamma tracking



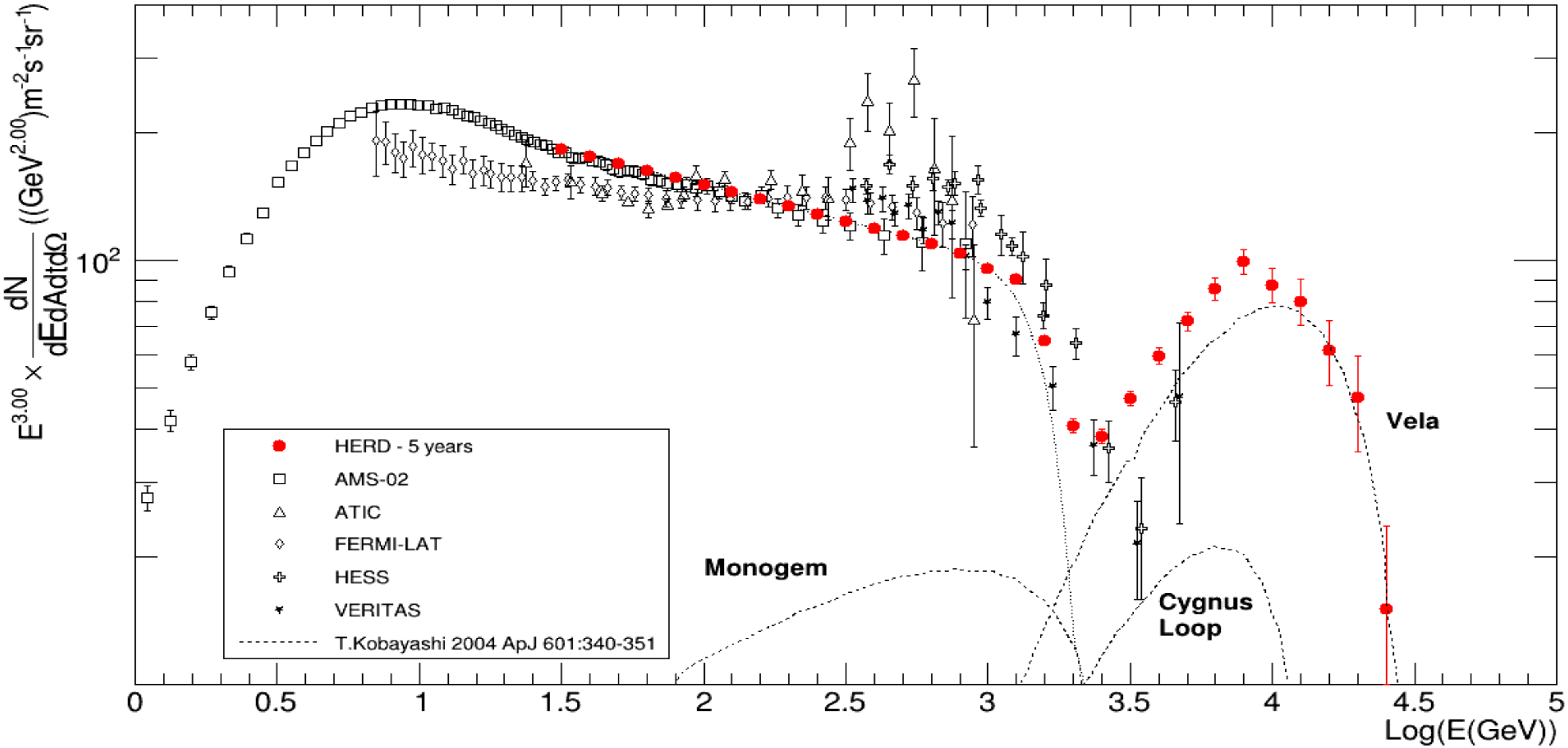
W converter + thick calorimeter (total 33 X_0) + precise tracking + charge measurement ➡ high energy γ-ray, electron and CR telescope

Working mode
- Normal trigger mode
  - PMT trigger (E_{dep}>30 GeV)
  - PMT trigger (E_{dep} >0.5GeV) + PSD veto
- Calibration mode
  - PMT trigger (1.2 GeV>E_{dep}>0.6 GeV)

Exposure (assuming GF=2.5m²sr)



Expected HERD Spectra for electrons



Conclusions & Perspectives

- ✓ Stratospheric balloon program is still relevant for specific measurements (GAPS for anti-d ?..)
- ✓ Space is giving an important contribution to direct CR measurements & DM searches
  - ✓ PAMELA did a great job…
  - ✓ AMS-02 is starting to release impressive results..and more will come in the next future
  - ✓ CALET and DAMPE just launched…
- ✓ in 10 years large acceptance space based calorimetric experiments insuring good overlap with ground based (indirect) measurements (HERD?)

For a real advance in DM searches: Anti-matters matters

A long term plan (with R&D development) is needed for a new antimatter large acceptance detector in orbit ..