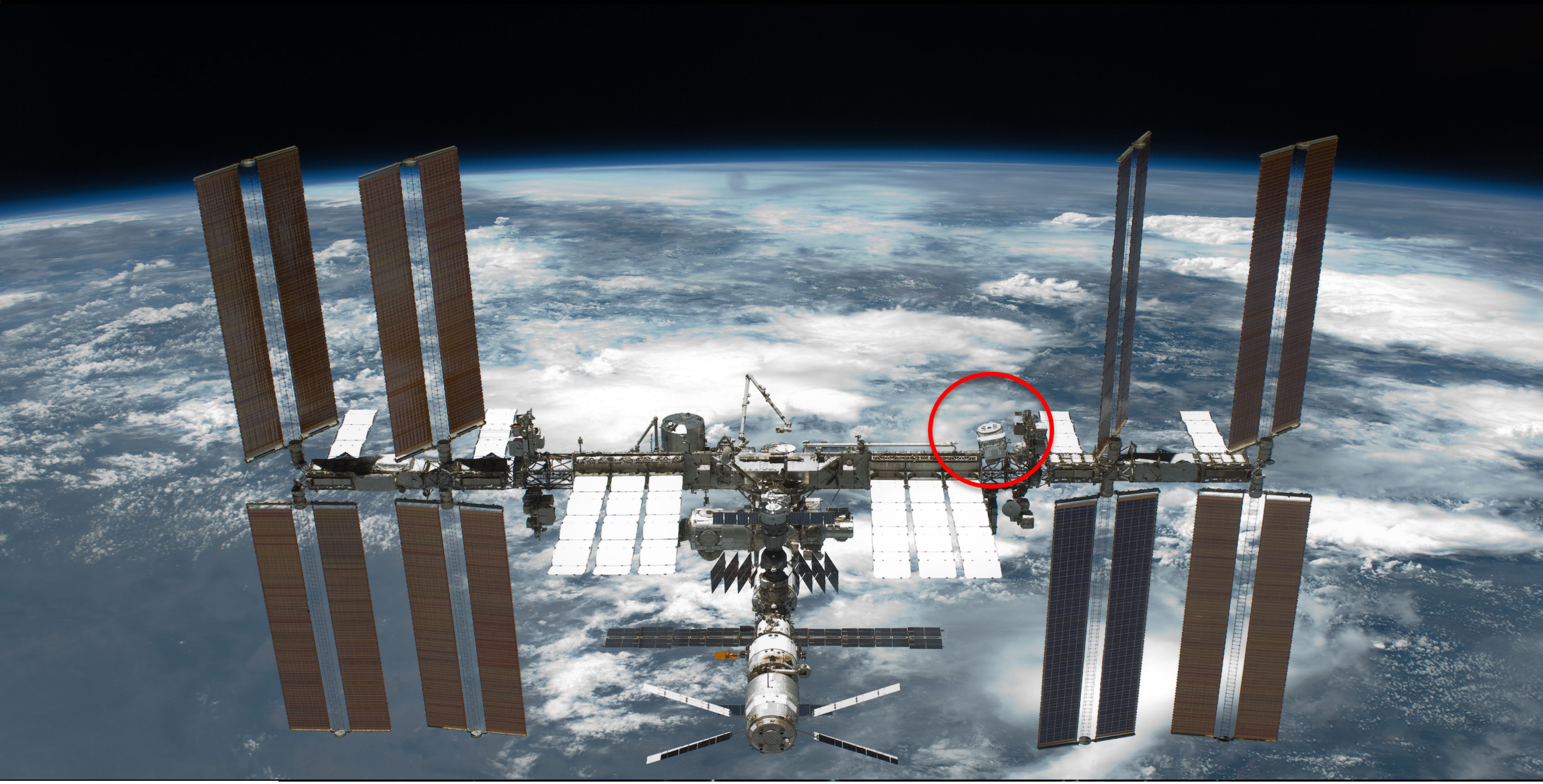
The AMS latest results and the impact on the design of future Cosmic Ray Space Experiments

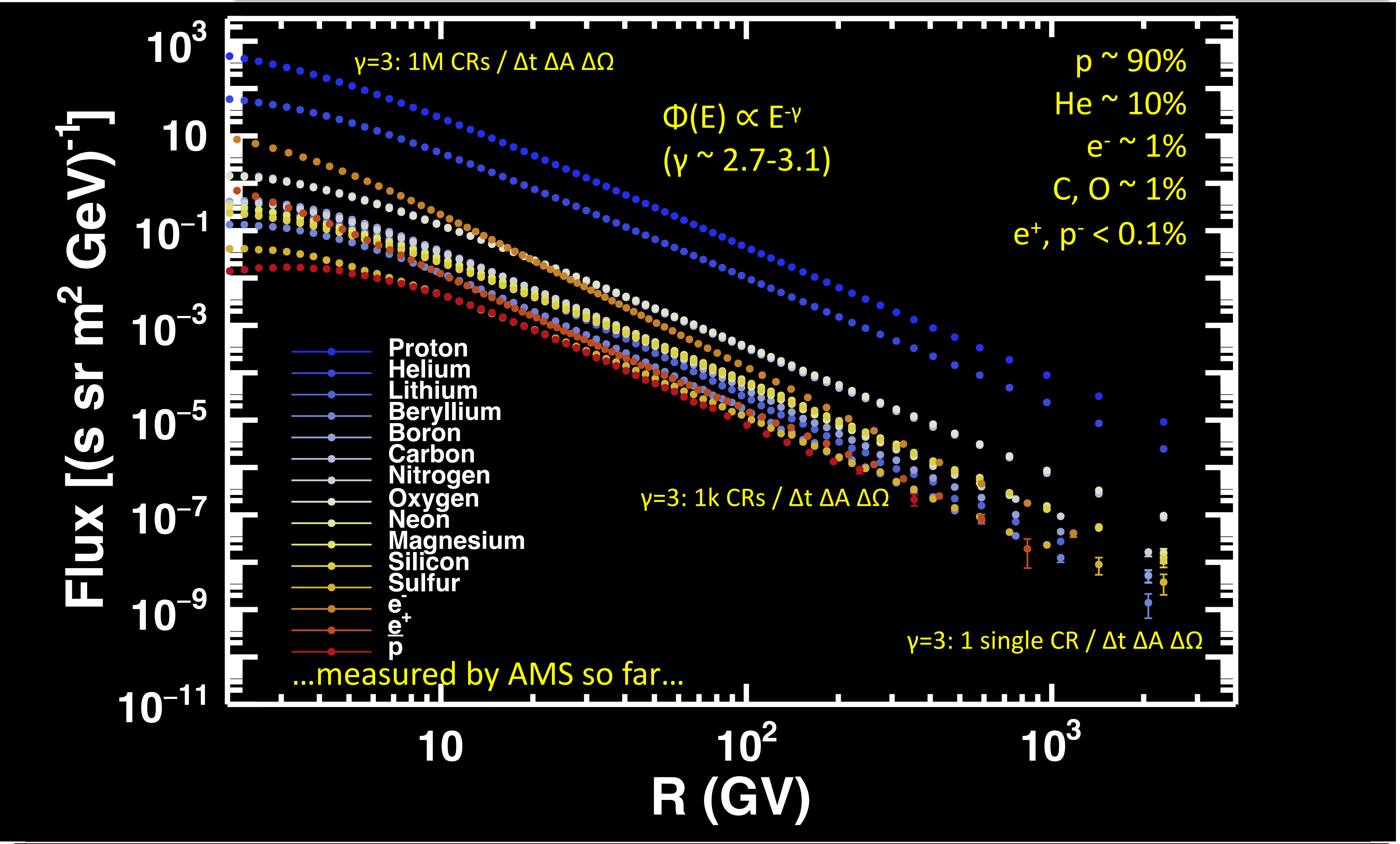


Matteo Duranti

Istituto Nazionale Fisica Nucleare – Sezione di Perugia

Charged Cosmic Rays in Space

Charged cosmic rays

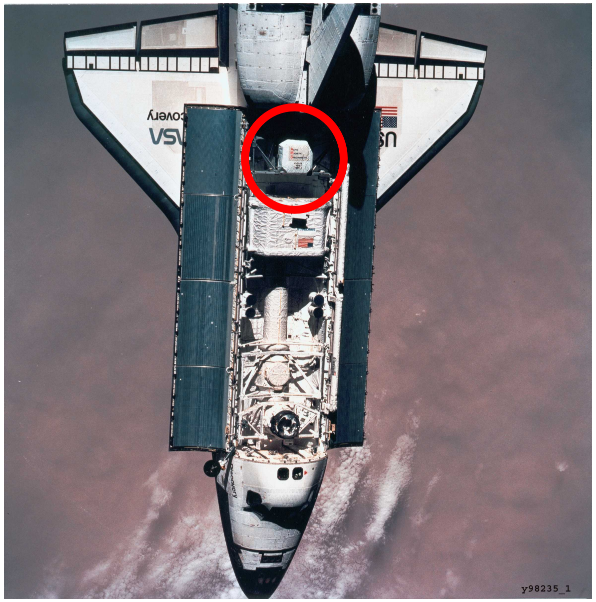


Outline

- Current and past experiments – key concepts/detectors
- Latest AMS results
- Future/proposed 4π experiments
  - HERD
  - ALADInO
  - AMS-100

Current and past experiments – key concepts/detectors

Past experiments – PAMELA, AMS-01



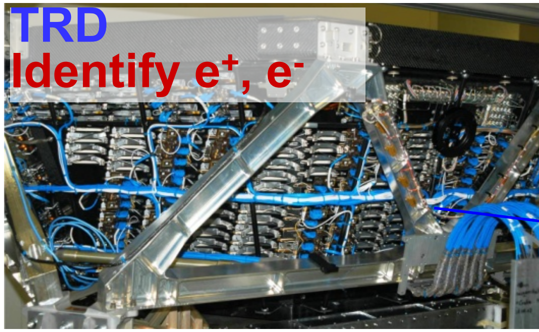
Alpha Magnetic Spectrometer - 01 (AMS-01)

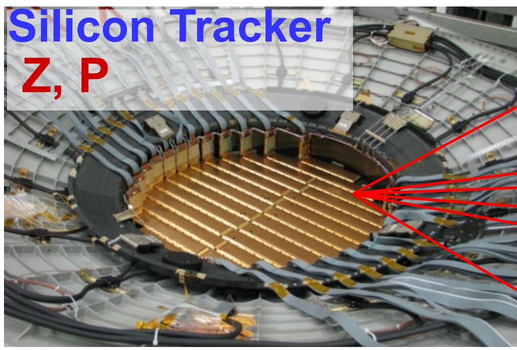
- ~ 2 tons
- Same orbit of the ISS and of AMS-02
- 10 days of mission on board the Space Shuttle Discovery mission STS-91, June 1998

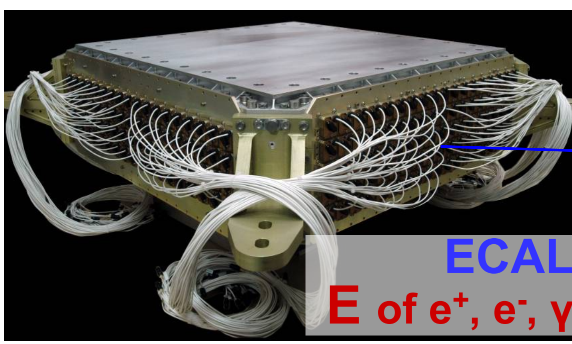
Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA)

- 470 Kg
- On board Resurs-DK1 satellite
- 15 June 2006 – 7 February 2016

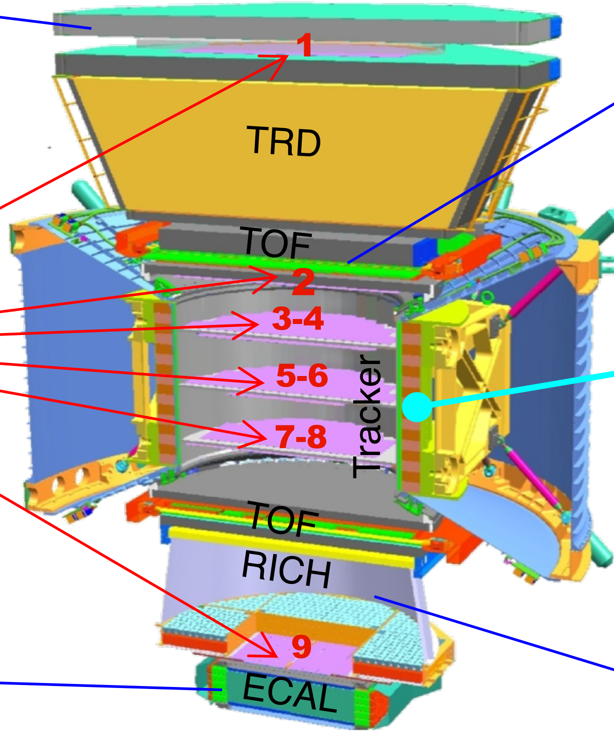
Current operating experiments – AMS-02



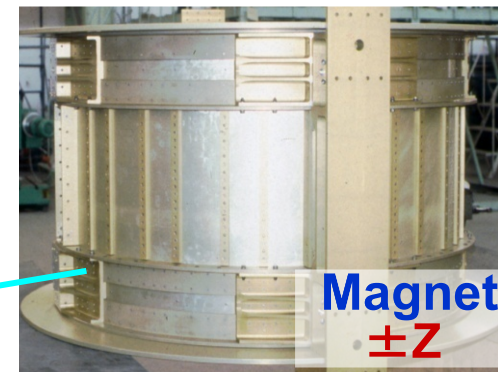


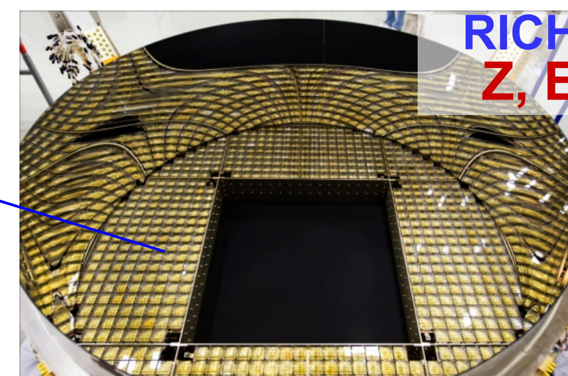


***Z, P** independently measured by*
Tracker, RICH, TOF and ECAL



On ISS since 16 May 2011



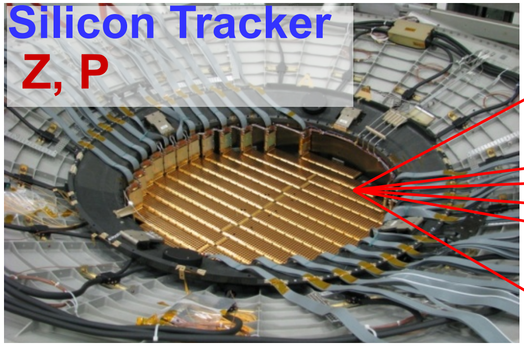


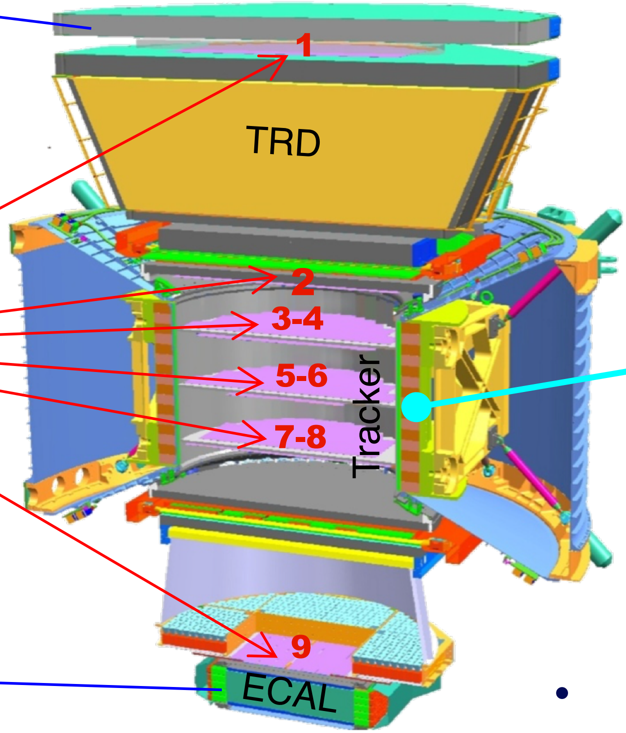
Key concepts/detectors

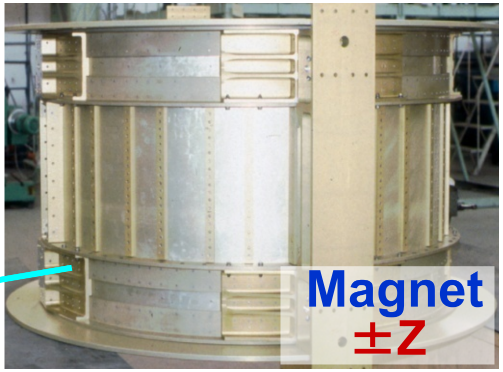
Techniques:

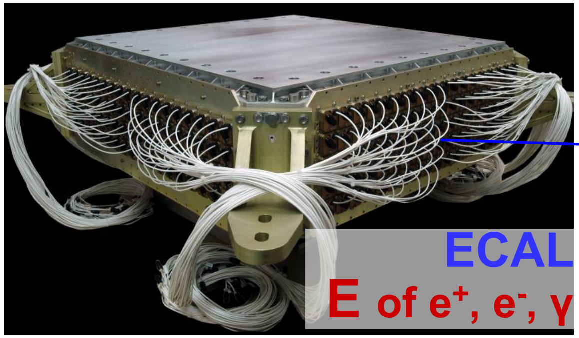
- Transition Radiation
- Shower development topology

- Energy/Momentum (E/p) match
- neutrons produced in the hadronic shower







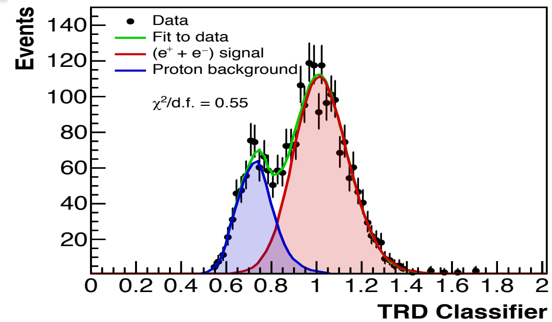


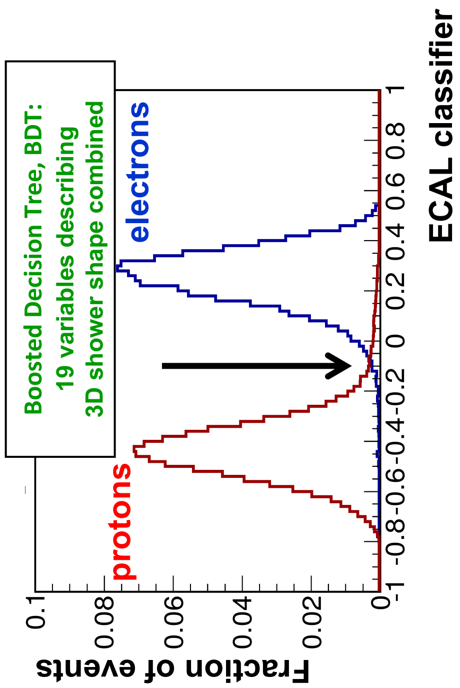
Electron/proton separation:

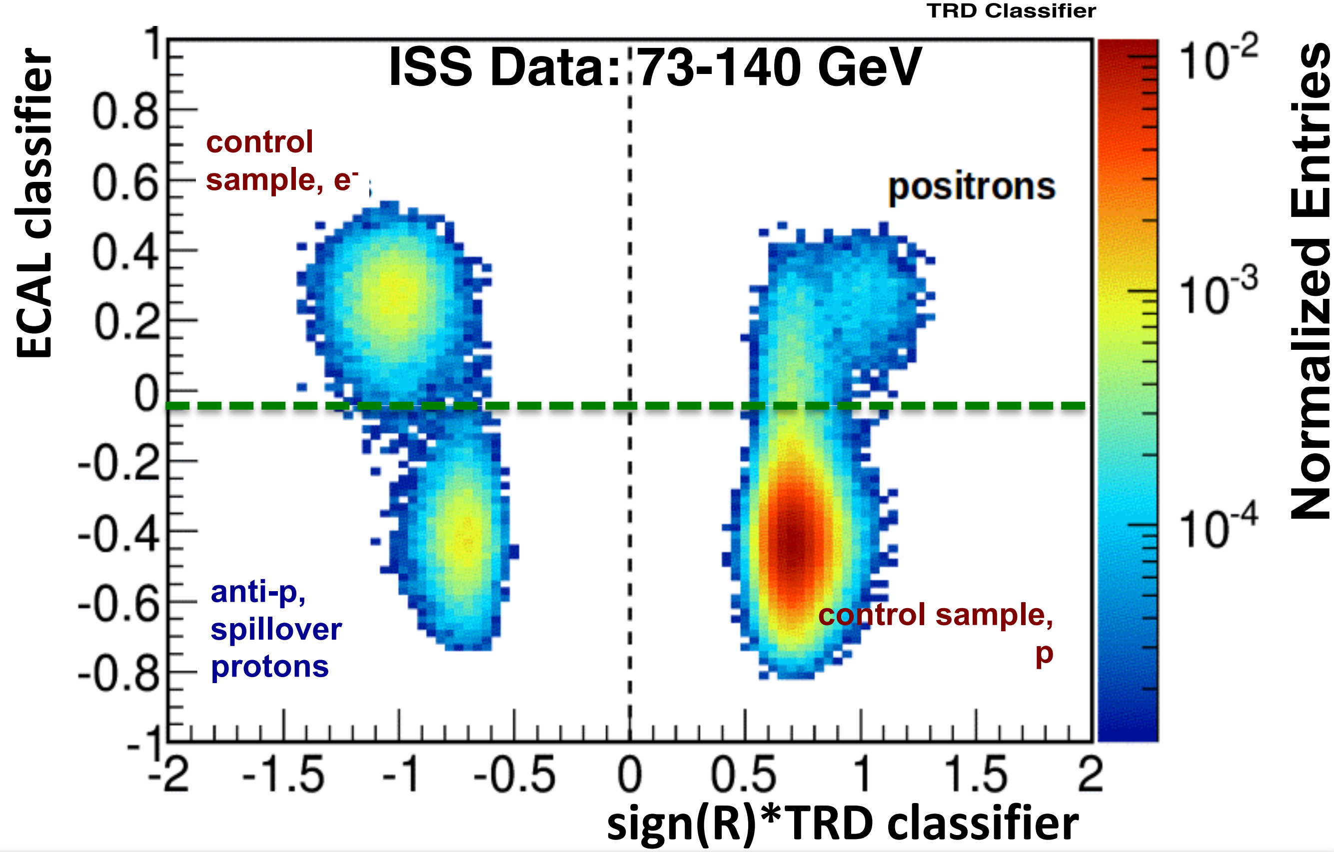
- e^- wrt the p background
- e^+ wrt to the p background
- anti-p wrt to the e^- background
- γ's wrt the p background

Key concepts/detectors

One important lesson from the AMS experiment is the importance of the redundancy: use one detector to create control sample for another one.

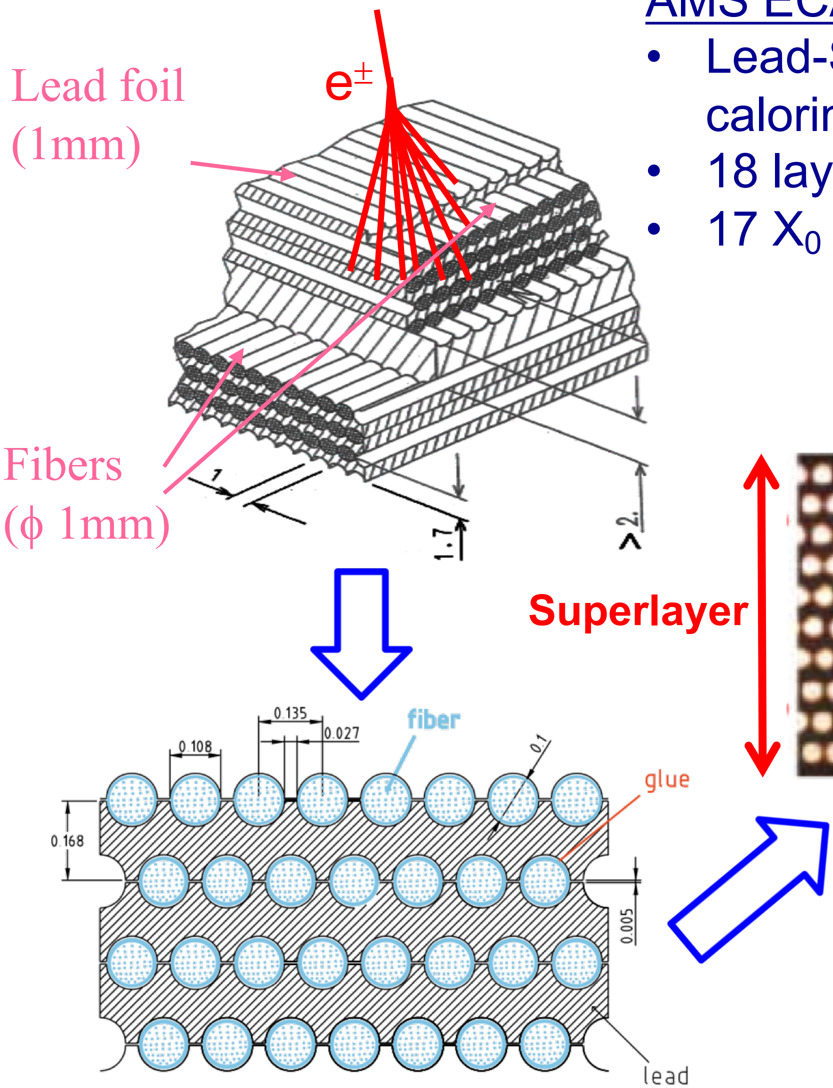




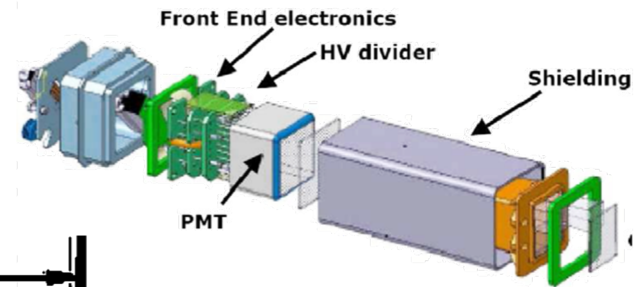


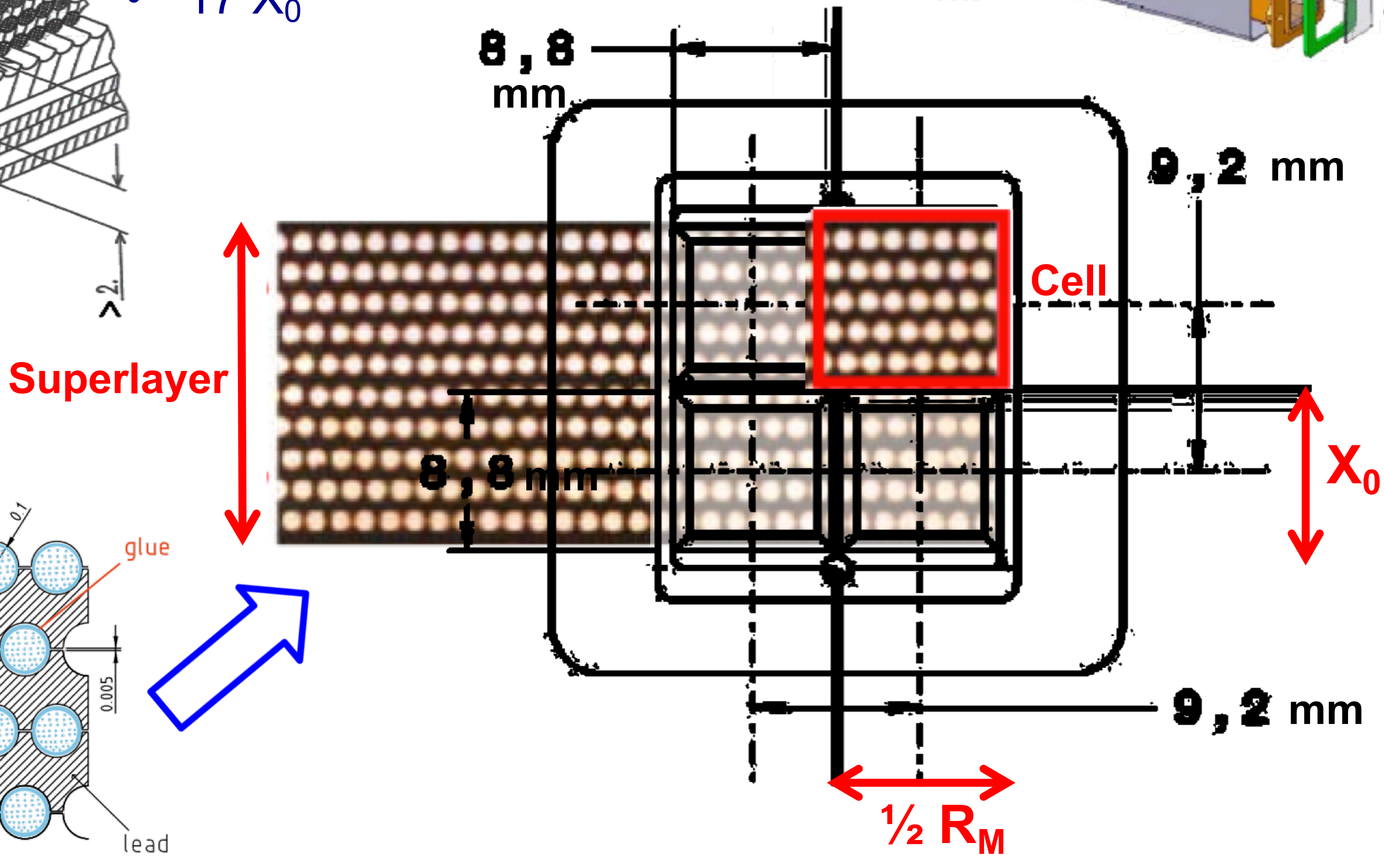
INFN PERUGIA

Shower development topology: segmentation



AMS ECAL:
- Lead-SciFi sampling calorimeter
- 18 layers (9 super-layers)
- 17 X_0

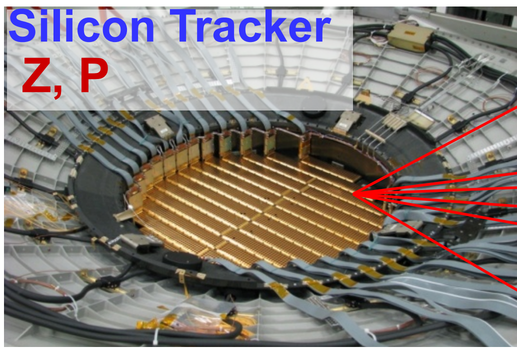


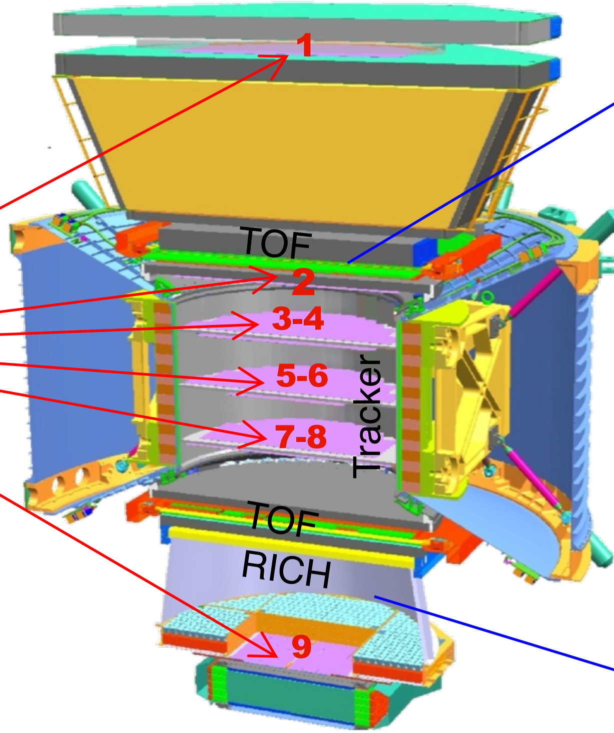


Key concepts/detectors

Techniques:

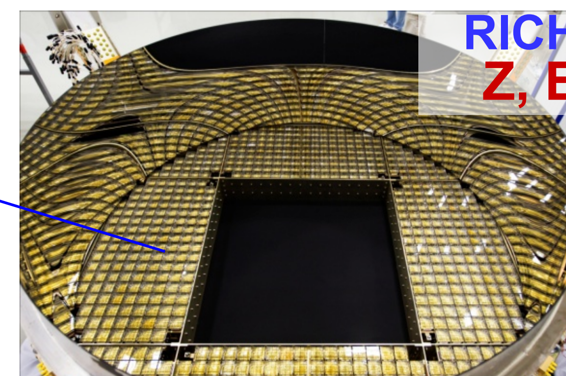
- dE/dx
- number of photons in the Cherenkov radiation



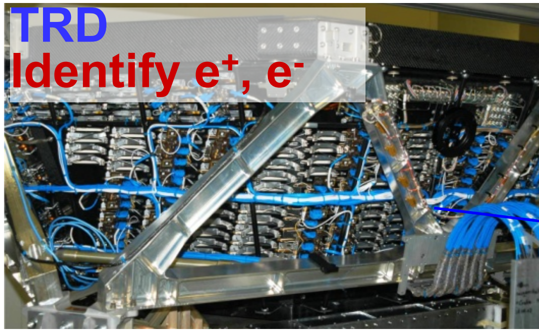


Charge measurement:

- identify the different nuclear species
- control the fragmentations (if multiple measurements along the detector)



Key concepts/detectors



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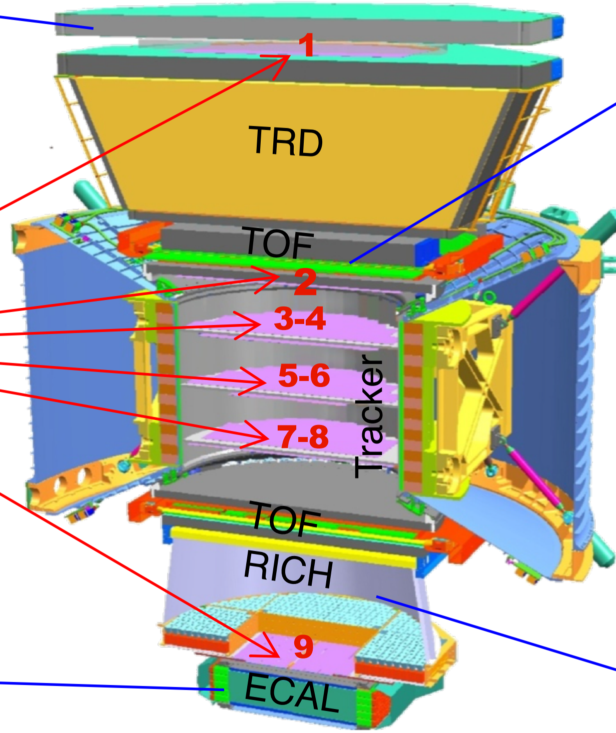

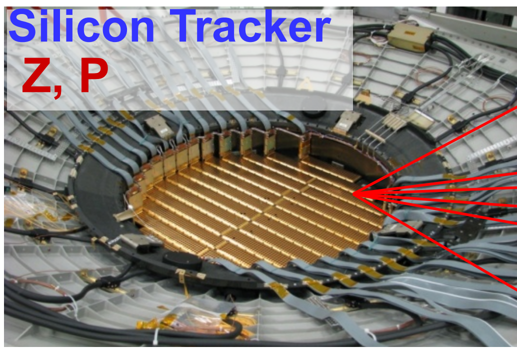

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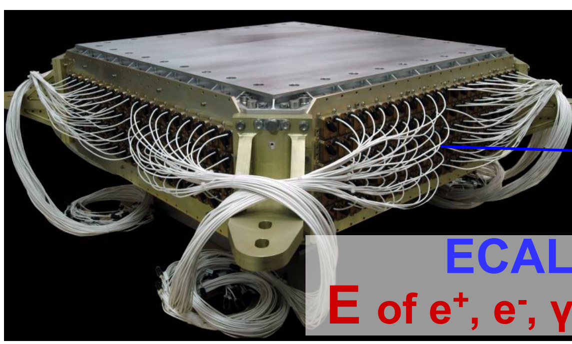
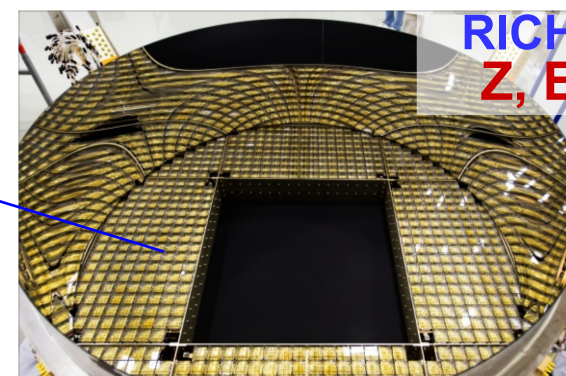
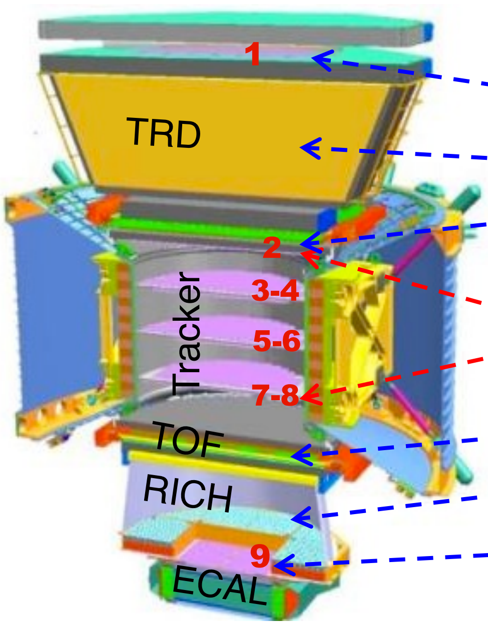


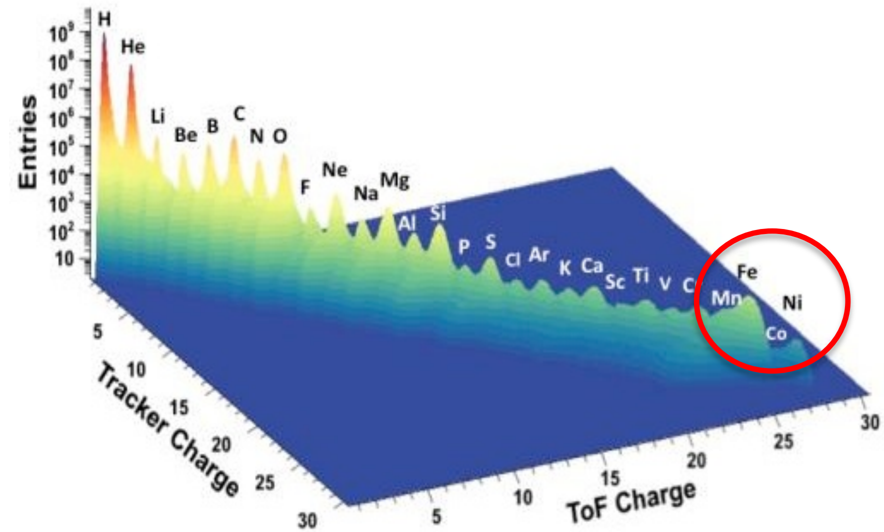


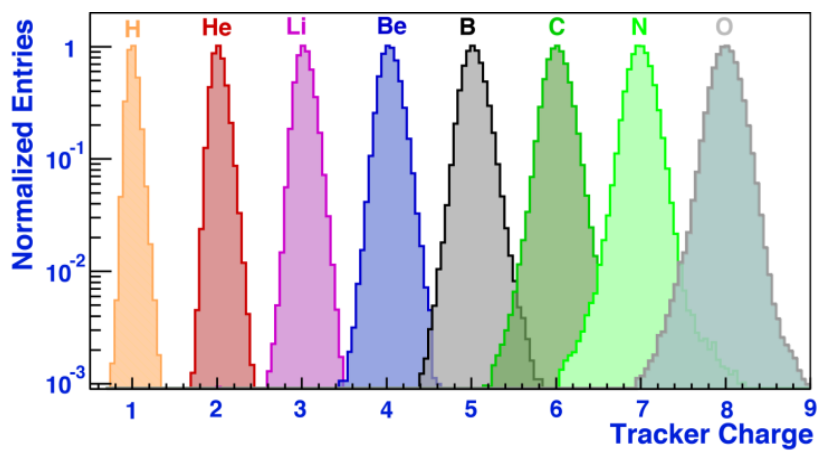
Key concepts/detectors



Charge Resolution (Z=6)

Detector	Resolution
Tracker Plane 1	0.30
TRD	0.33
Upper TOF	0.16
Inner Tracker 2-8	0.12
Lower TOF	0.16
RICH	0.32
Tracker Plane 9	0.30

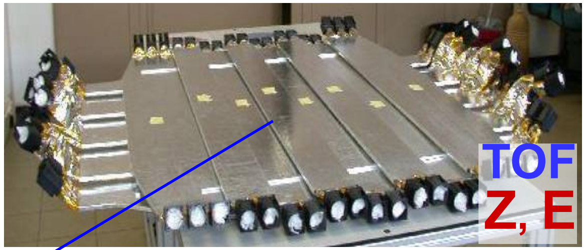


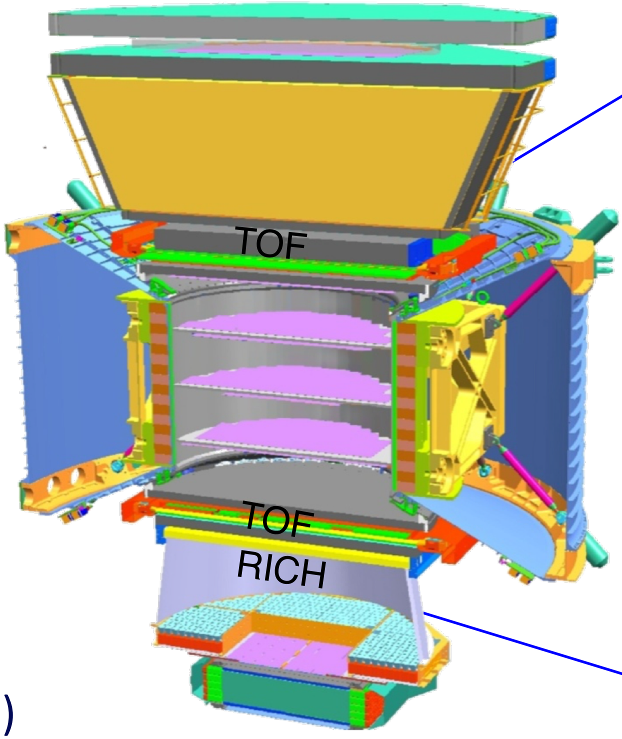


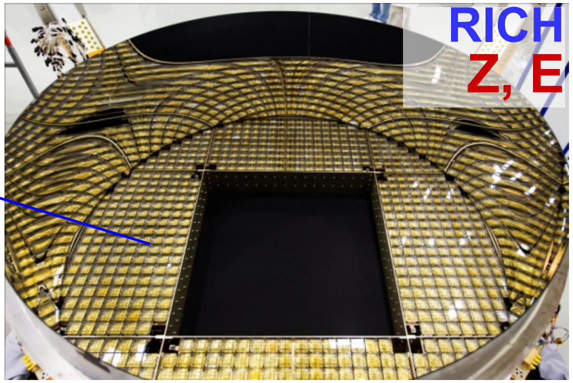
Key concepts/detectors

β measurement:

- identify the different isotopes (d/p, $^3He/^4He$, $^7Li/^6Li$, $^{10}Be/^9Be$, $^{27}Al/^{26}Al$, …)
- control the quality of the momemtum/energy measurement (check on the mass)





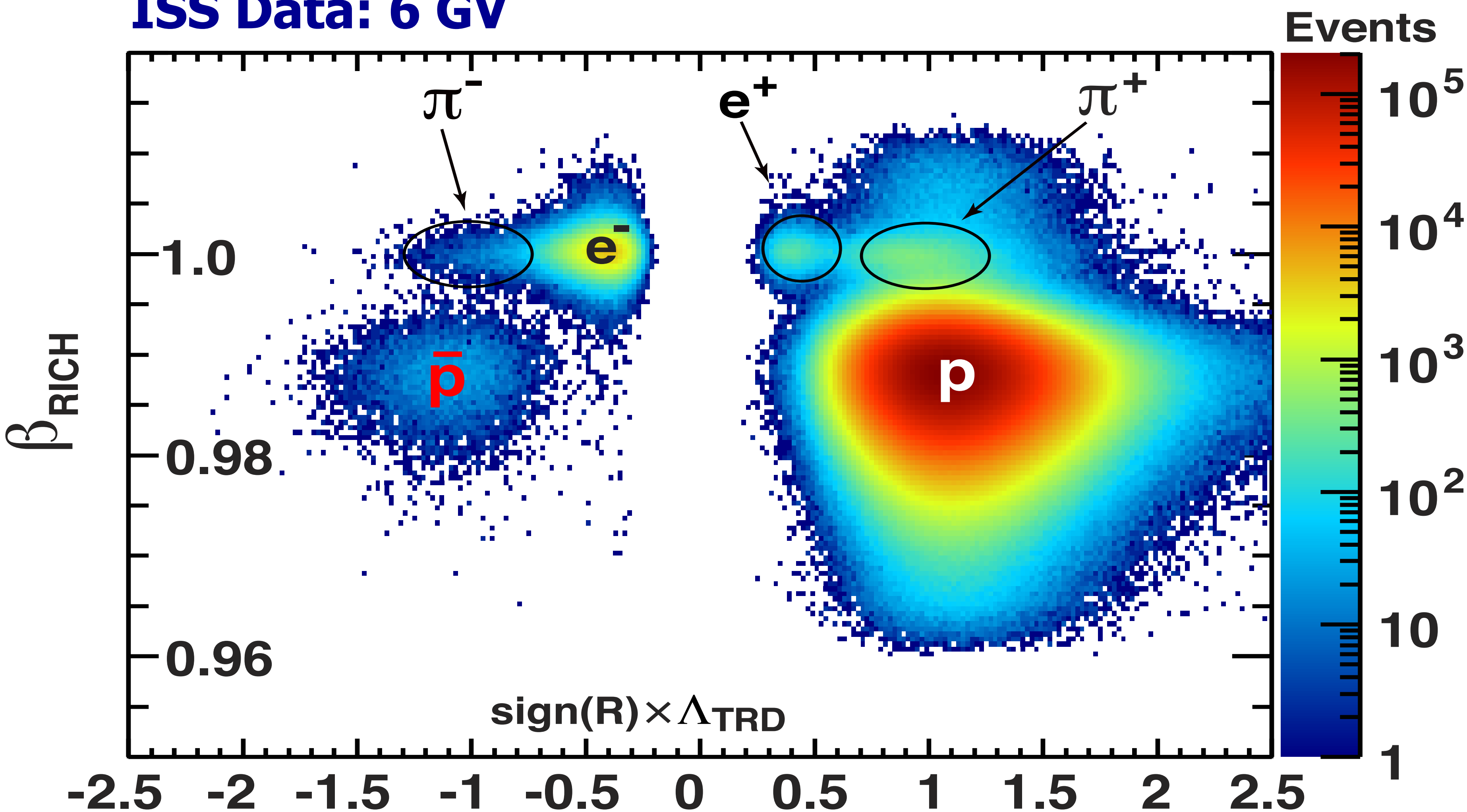


Techniques:

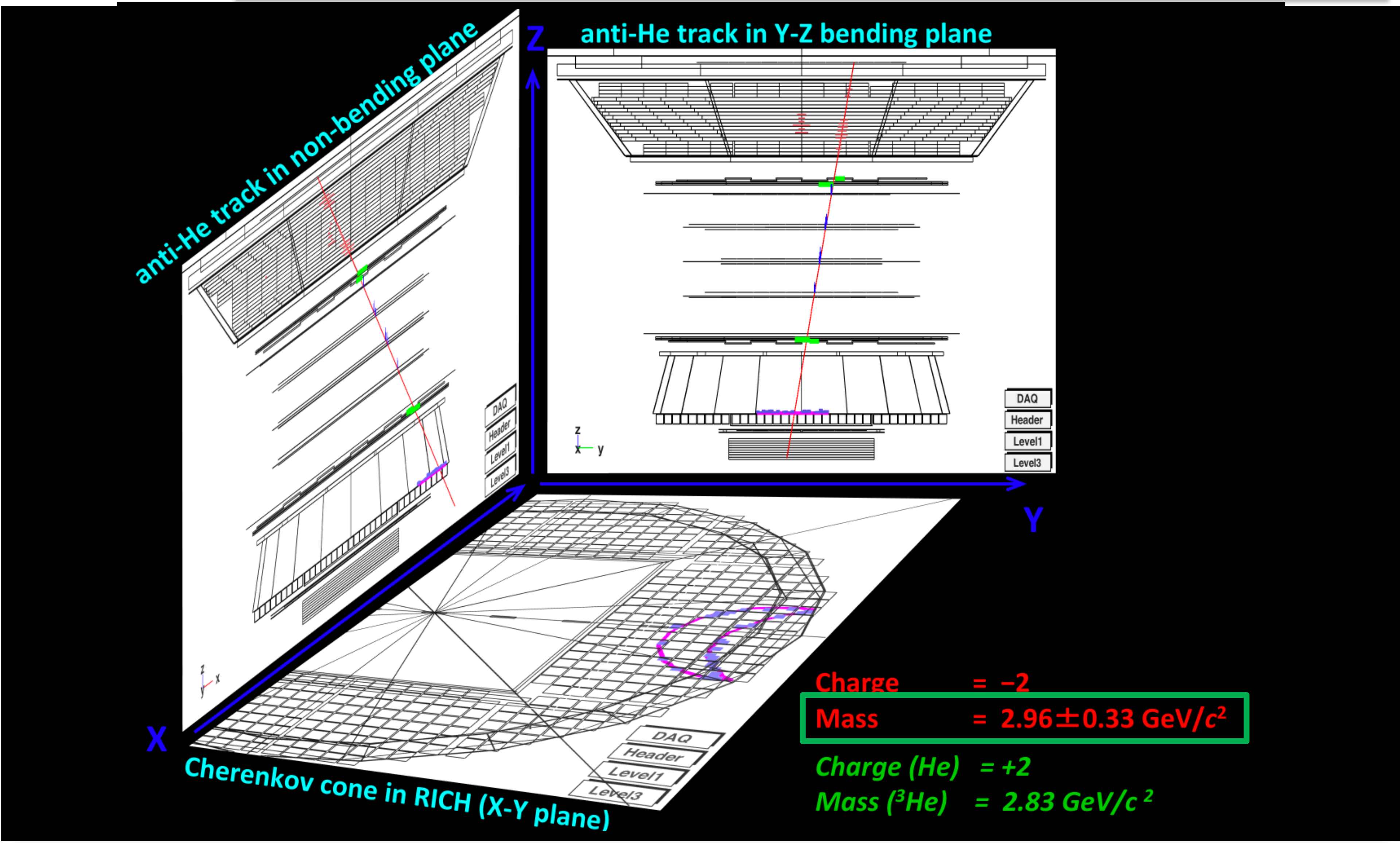
- Time of Flight (ToF)
- Cherenkov (ring or threshold)
- Transition Radiation (measuring γ)

Key concepts/detectors

ISS Data: 6 GV



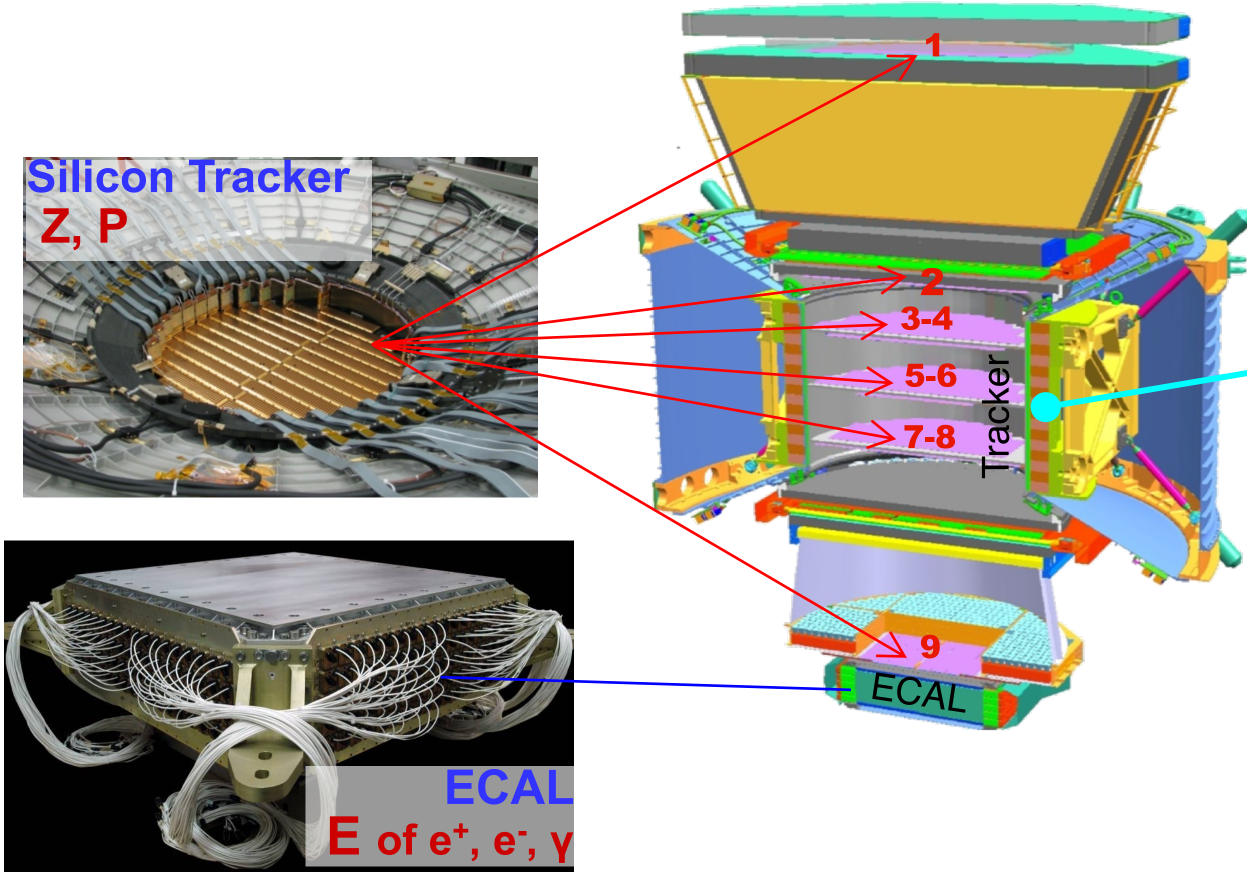
Key concepts/detectors

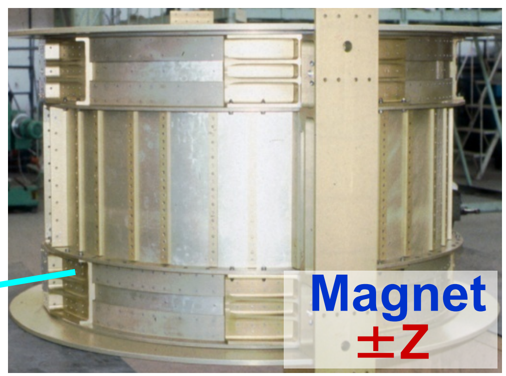


Key concepts/detectors

Energy/momentum measurement:

- search for spectral features





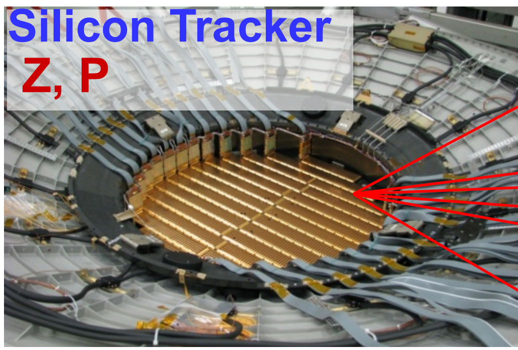
Techniques:

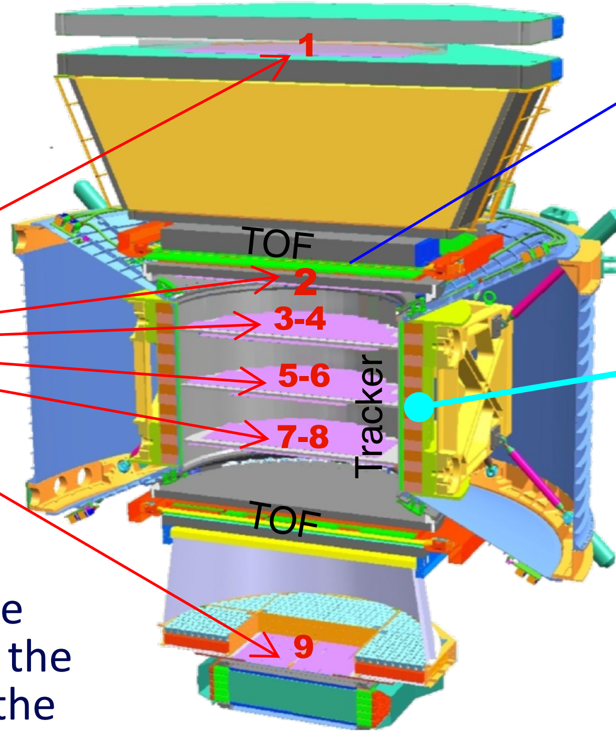
- Spectrometry
- Calorimetry
- Transition Radiation (measuring γ)

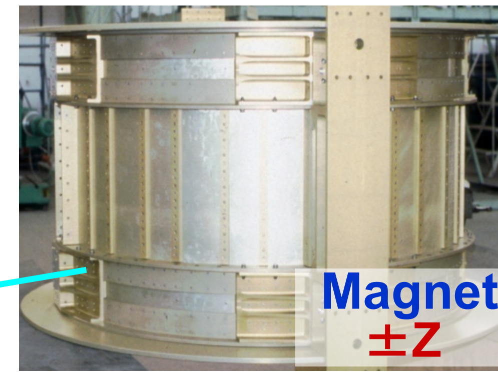
Key concepts/detectors

Charge sign measurement:

- matter/anti-matter







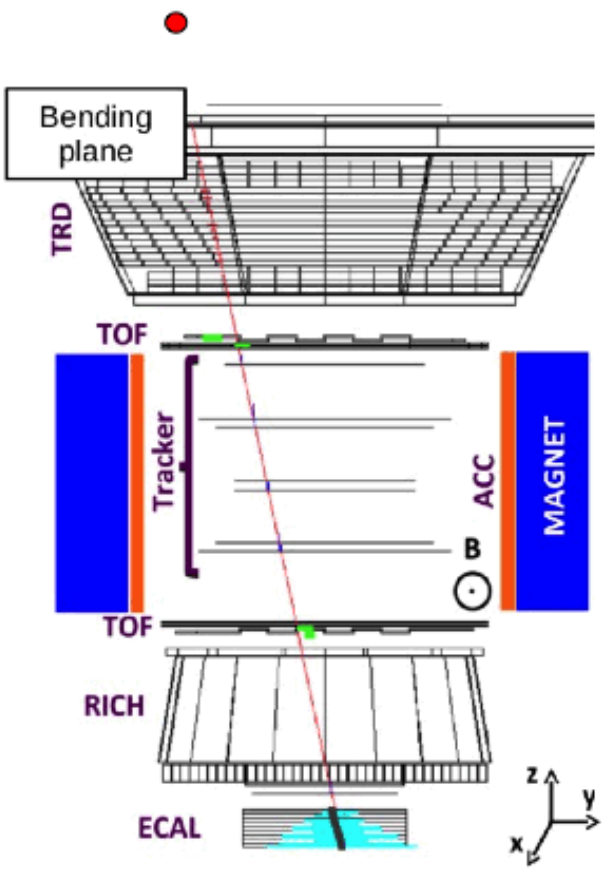
The intensity of the magnetic field (B), the lever arm (L) and the spatial resolution (σ_x) determine the momentum resolution (δp) and the detector Maximum Detectable Rigidity, MDR ($\delta p/p=1$):

$$MDR \propto B L^2 / \sigma_x$$

Techniques:

- Spectrometry + ToF

Redundancy and complementarity

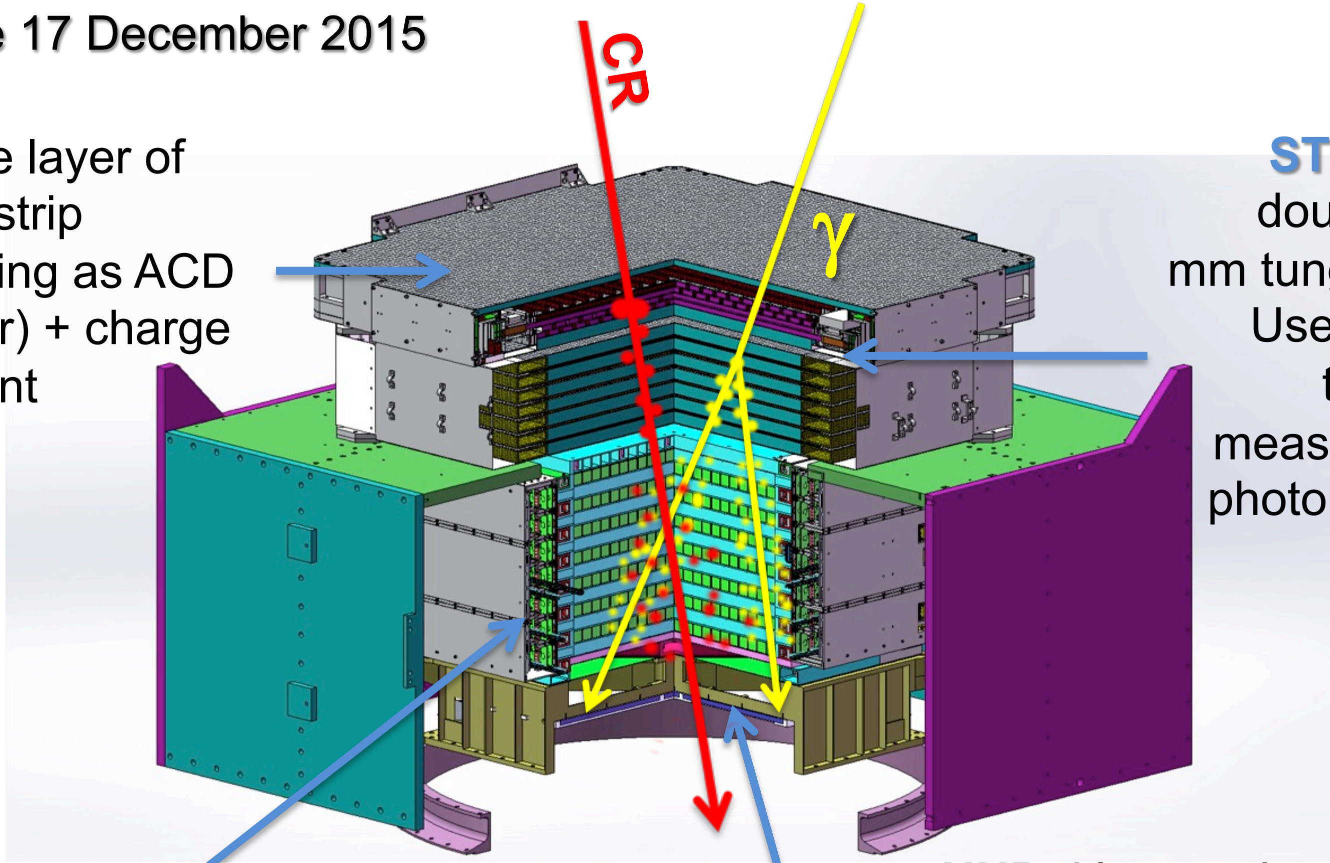


	e⁻	p	He
TRD 20 layers			
TOF 4 layers			
TRK 9 layers			
RICH			
ECAL 20 layers			

Current operating experiments - DAMPE

In orbit since 17 December 2015

PSD: double layer of scintillating strip detector acting as ACD (anti-counter) + charge measurement



STK: 6 tracking double layer + 3 mm tungsten plates. Used for particle track, charge measurement and photon conversion (~ 2 X_0)

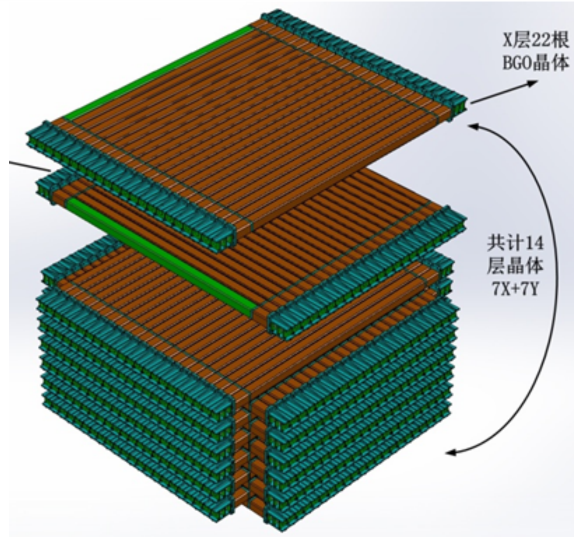
BGO: the calorimeter is made of 308 BGO bars in hodoscopic arrangement (~31 X_0). Performs energy measurements, hadron/lepton identification (*e/p rejection*), and trigger

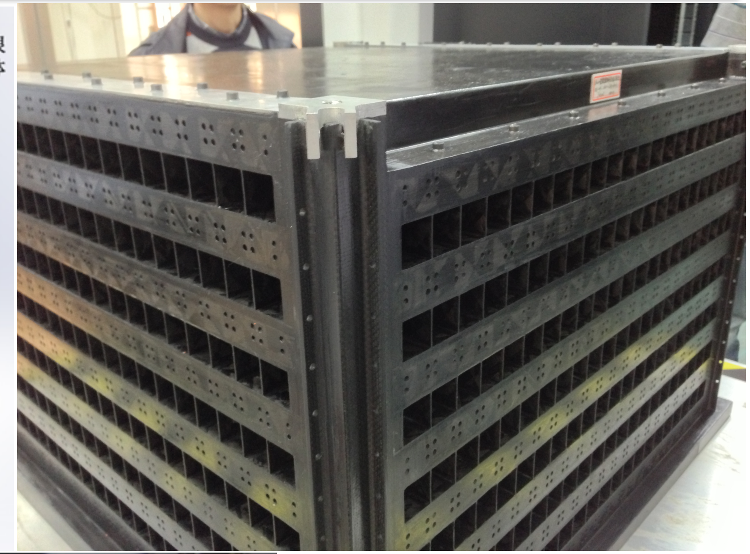
NUD: it's complementary to the BGO e/p rejection, by measuring the thermal neutron shower activity. Made up of boron-doped plastic scintillator

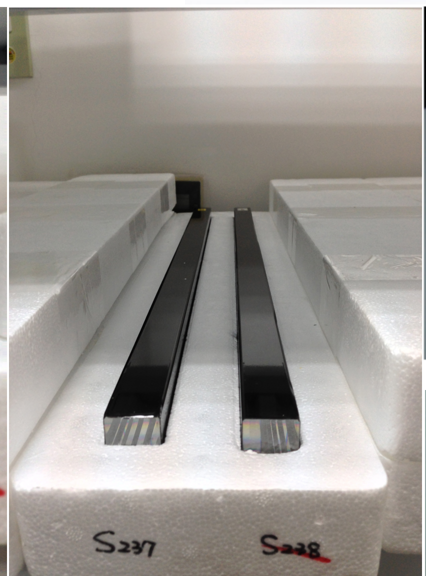
Shower development topology: segmentation

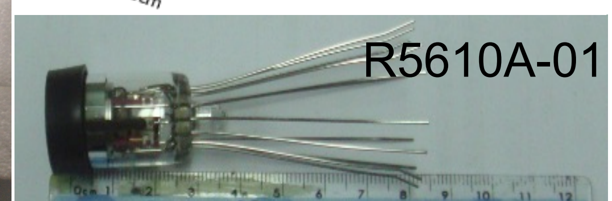
<u>DAMPE BGO:</u>

- homogeneous calorimeter
- ~ 31 X_0
- 14 layers (~ $2X_0$ per layer)



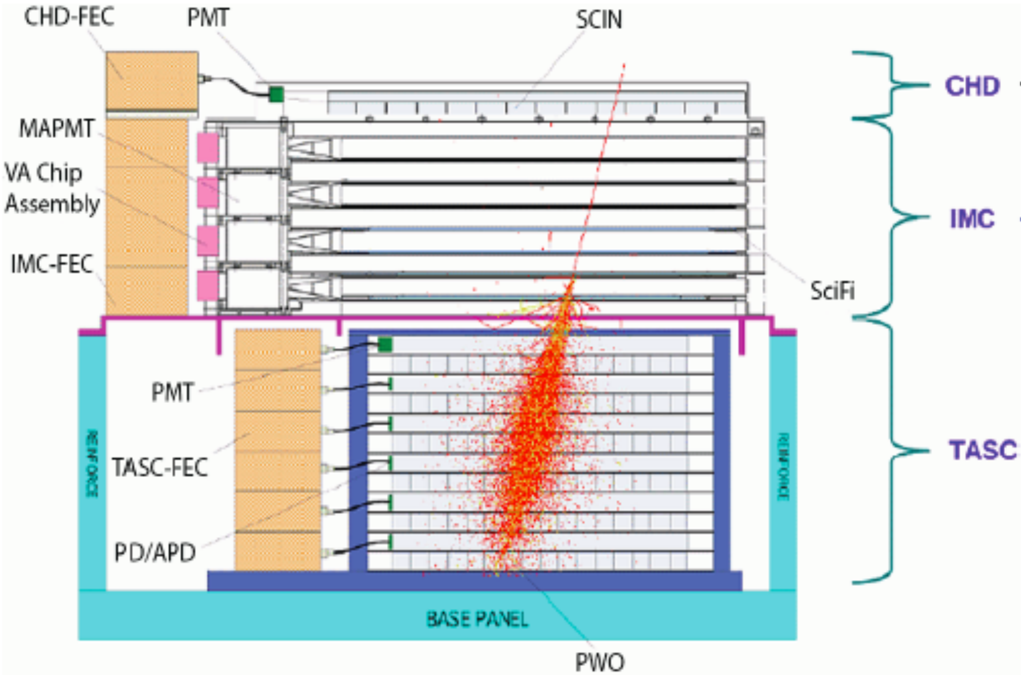






308 bars
616 PMTs

Current operating experiments - CALET



In orbit since 19 August 2015

CHD - **CHarge Detector (CHD)**
(Charge Measurement Z=1-40)

IMC - **Imaging Calorimeter (IMC)**
(Particle ID, Direction)

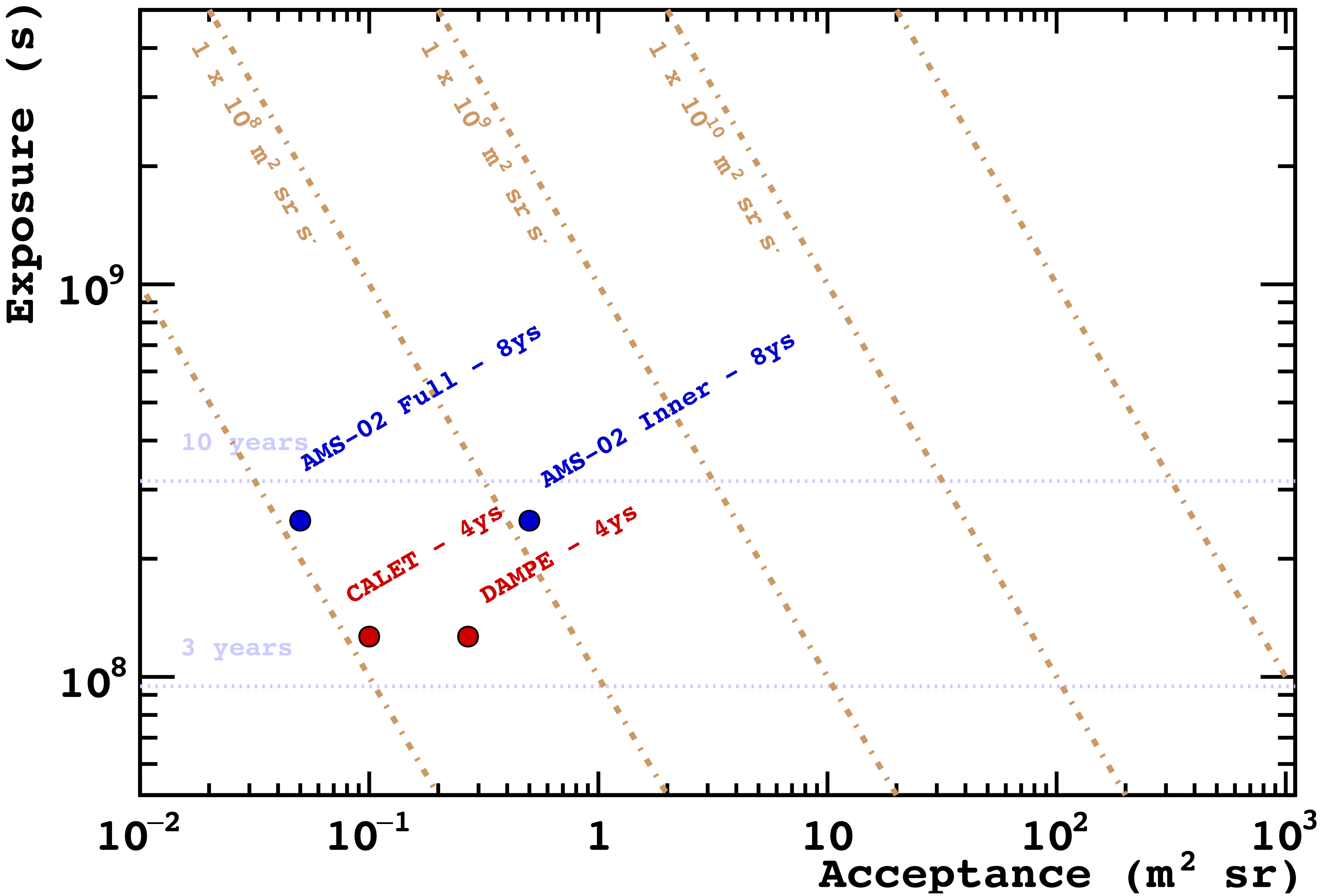
Total Thickness of Tungsten (W): $3\ X_0$, $0.1\ \lambda_I$
Layer Number of Scifi Belts: 8 Layers × 2(X,Y)

TASC - **Total Absorption Calorimeter (TASC)**
(Energy Measurement, Particle ID)

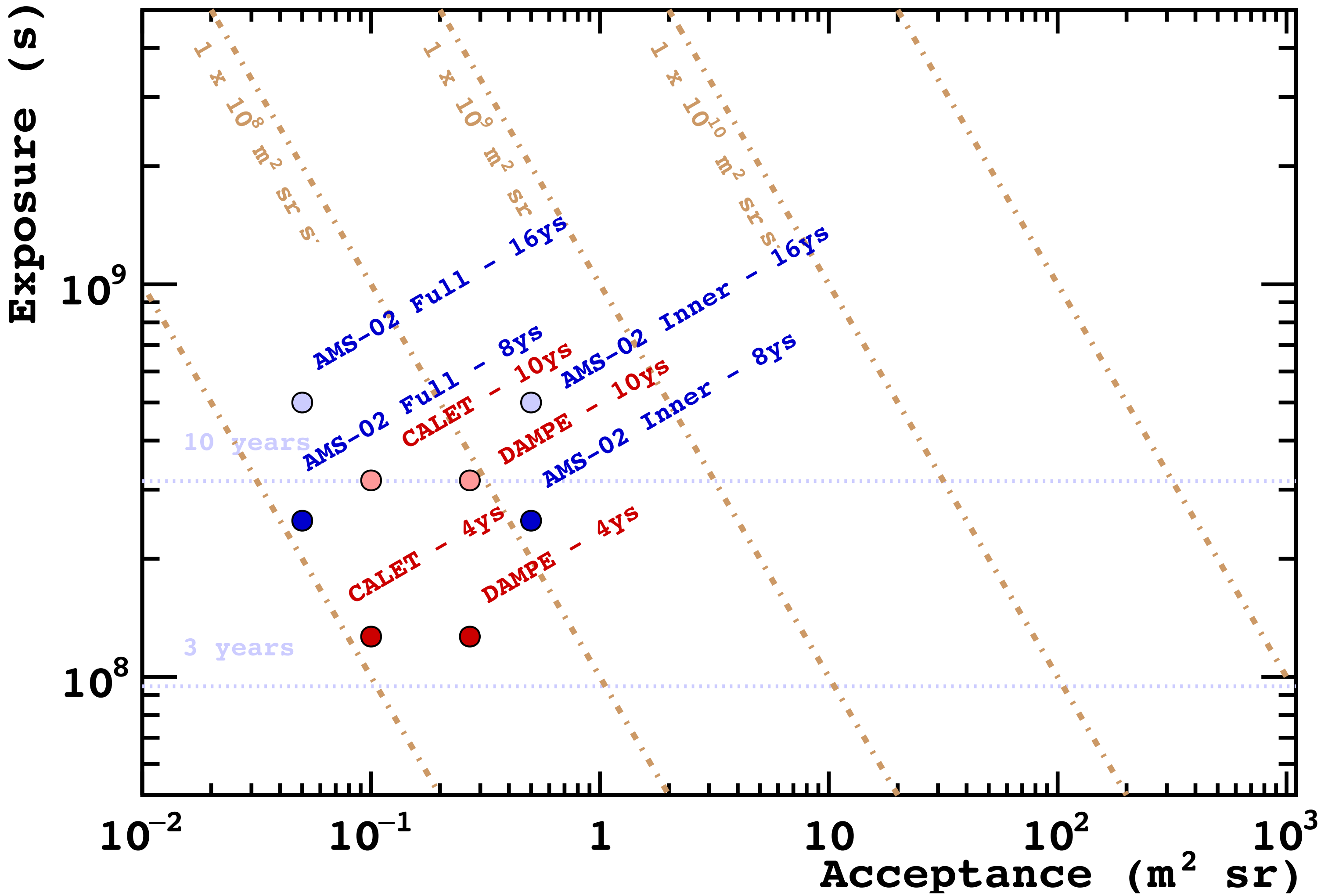
PWO 20mm x 20mm x 320mm
Total Depth of PWO: $27\ X_0$ (24 cm) , $1.2\ \lambda_I$

	CHD (Charge Detector)	IMC (Imaging Calorimeter)	TASC (Total Absorption Calorimeter)
Function	Charge Measurement (Z = 1 - 40)	Arrival Direction, Particle ID	Energy Measurement, Particle ID
Sensor (+ Absorber)	Plastic Scintillator : 2 layers Unit Size: 32mm x 10mm x 450mm	SciFi : 16 layers Unit size: 1mm² x 448 mm Total thickness of Tungsten: $3\ X_0$	PWO log: 12 layers Unit size: 19mm x 20mm x 326mm Total Thickness of PWO: 27 X_0
Readout	PMT+CSA	64 -anode PMT+ ASIC	APD/PD+CSA PMT+CSA (for Trigger)

Current operating experiments

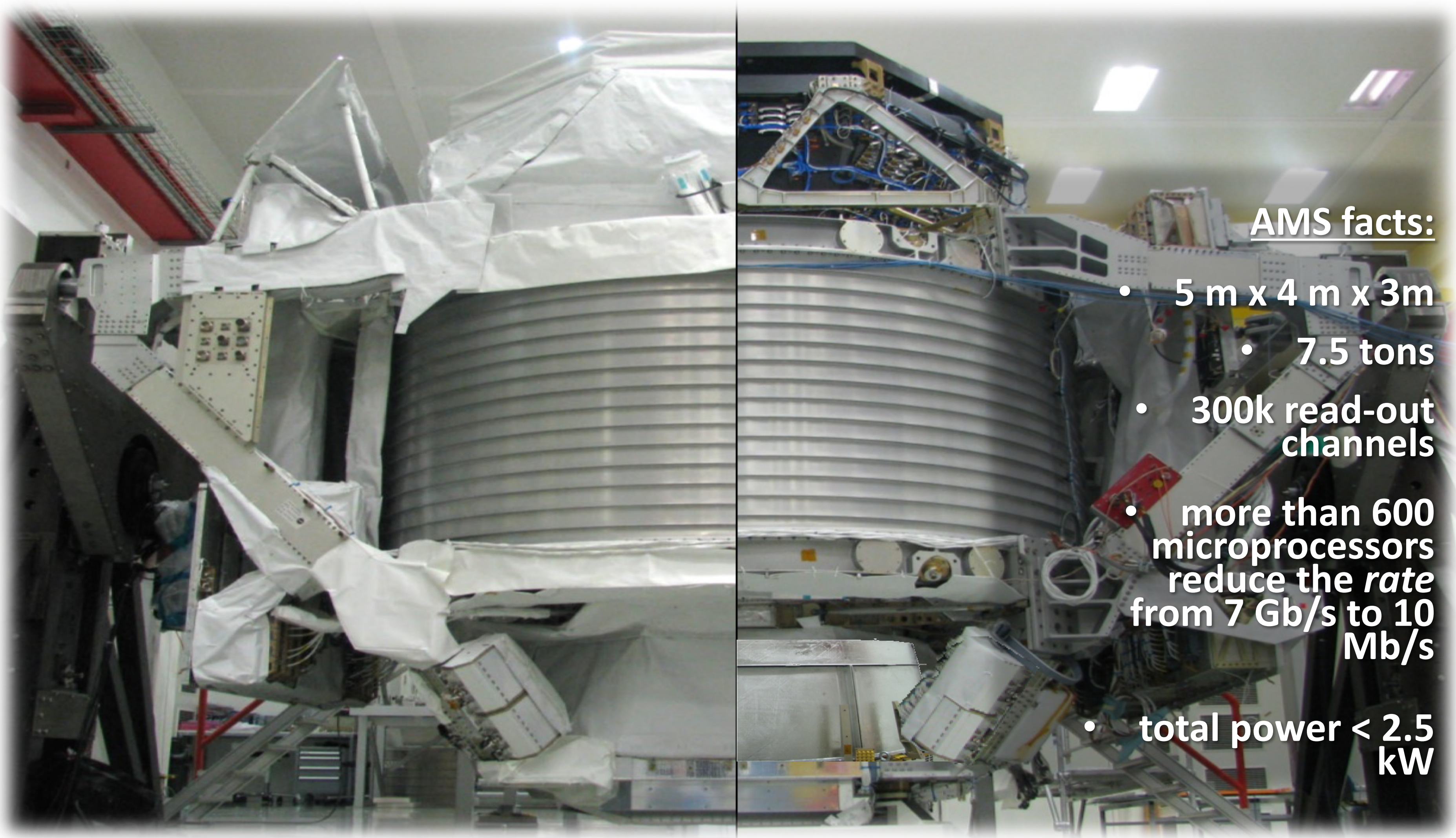


Current operating experiments @2027



Latest AMS results

2010: AMS-02 assembled



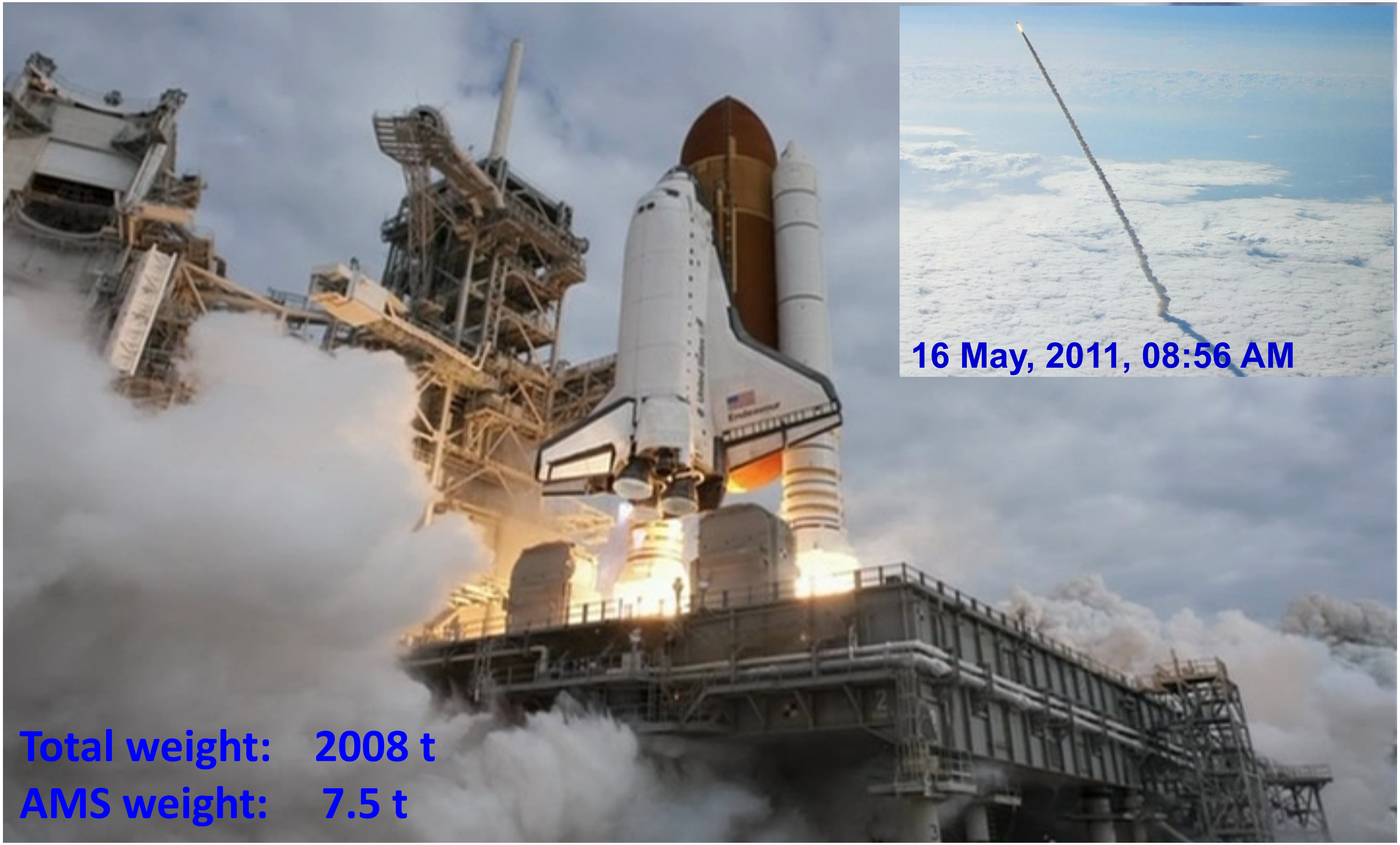
<u>AMS facts:</u>

- 5 m x 4 m x 3m
- 7.5 tons
- 300k read-out channels
- more than 600 microprocessors reduce the *rate* from 7 Gb/s to 10 Mb/s
- total power < 2.5 kW

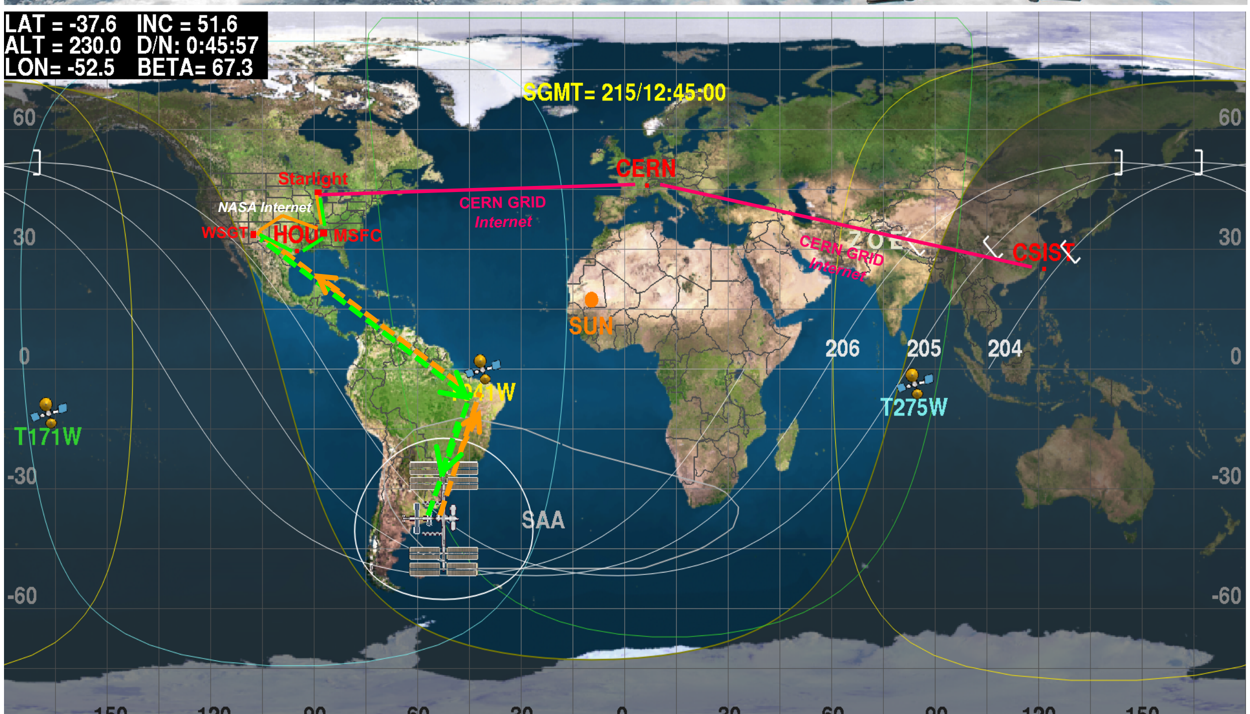
2011: AMS launch - @ JSC, Texas

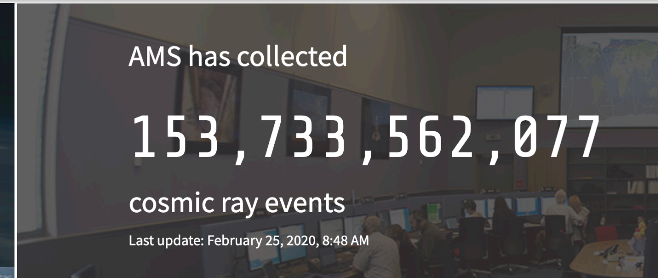
Houston, JSC – 16 May, 2011@ 07:56 AM

2011: AMS launch - @ KSC, Florida

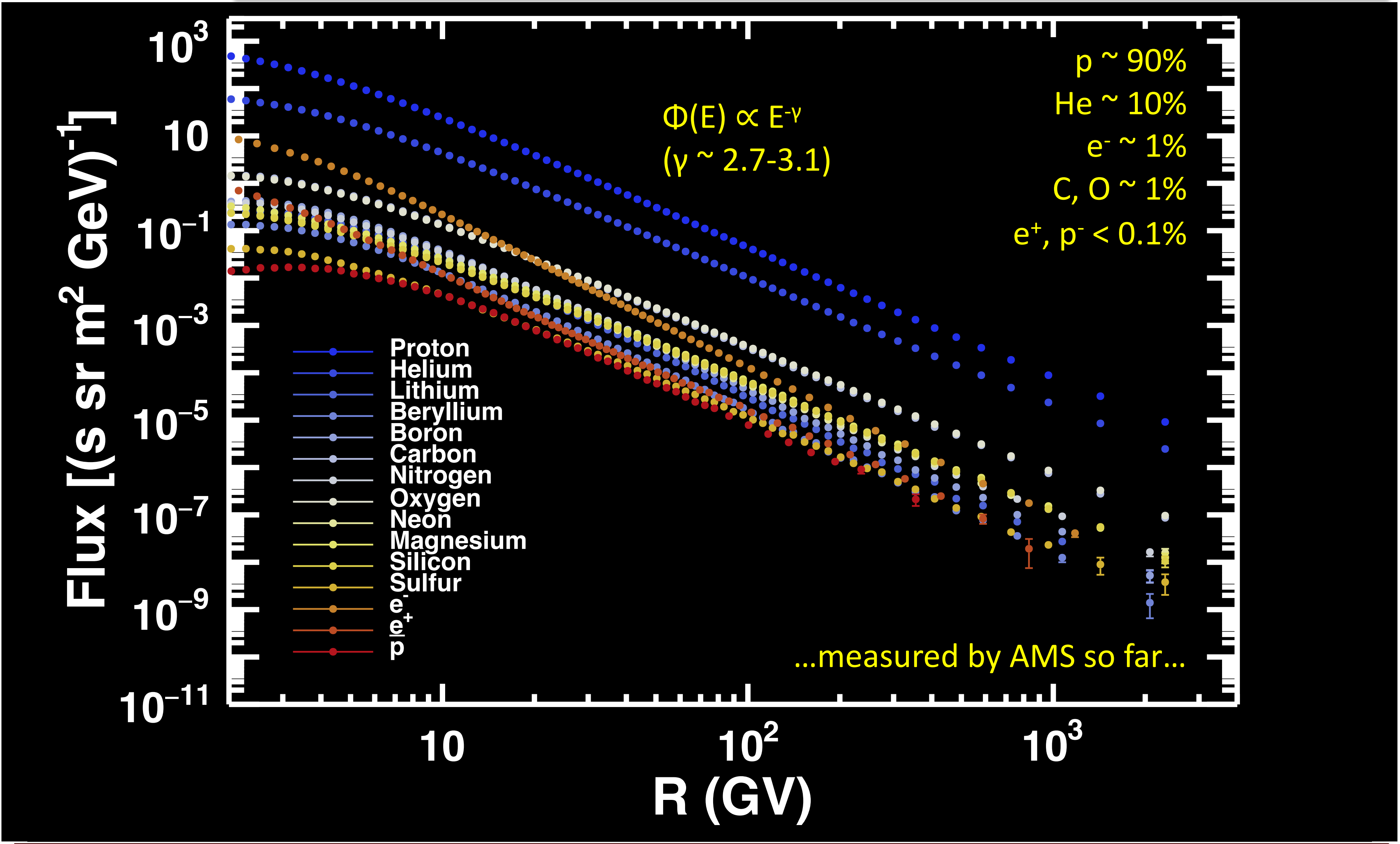


A particle physics experiment on ISS

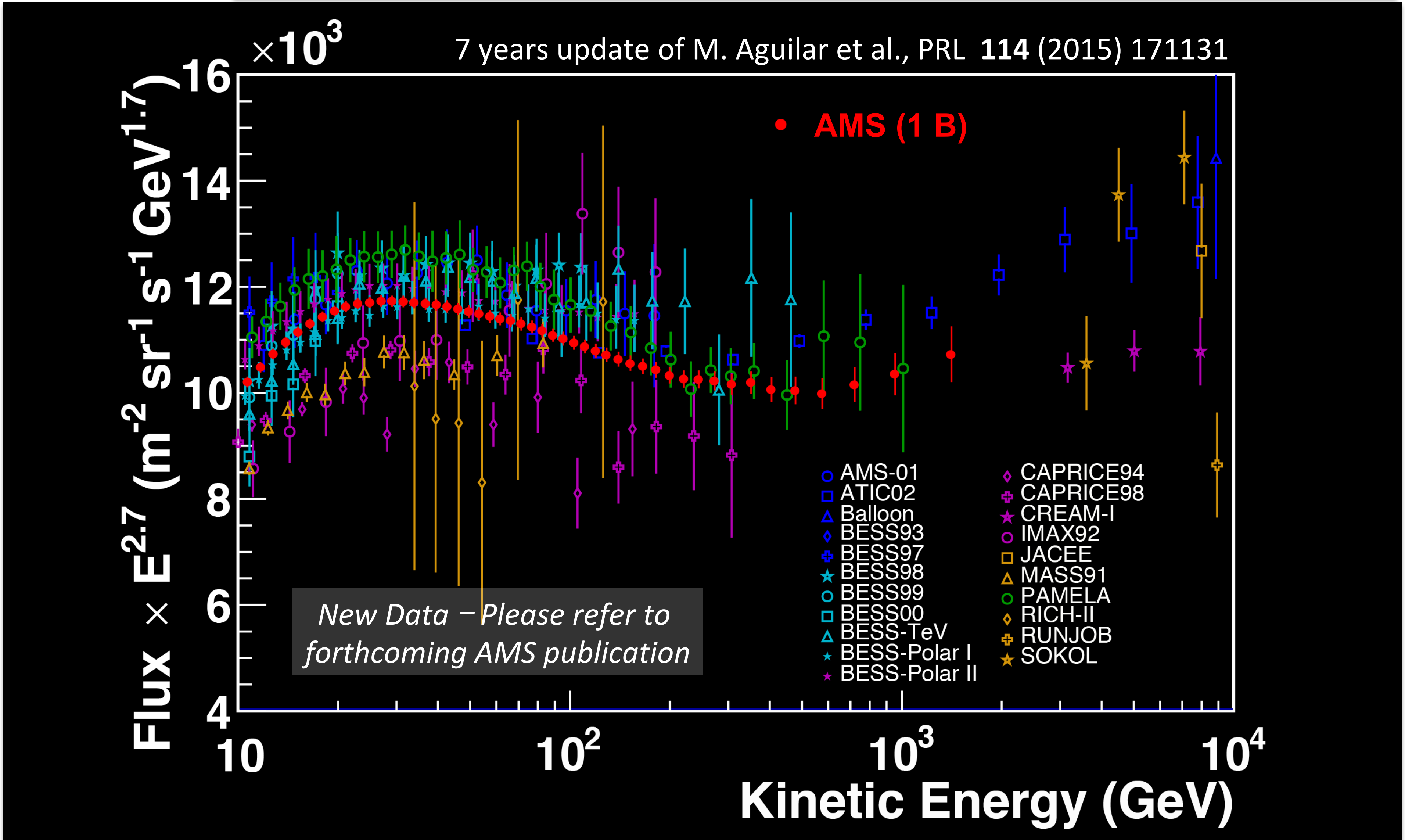




Goal: to measure all the CR fluxes

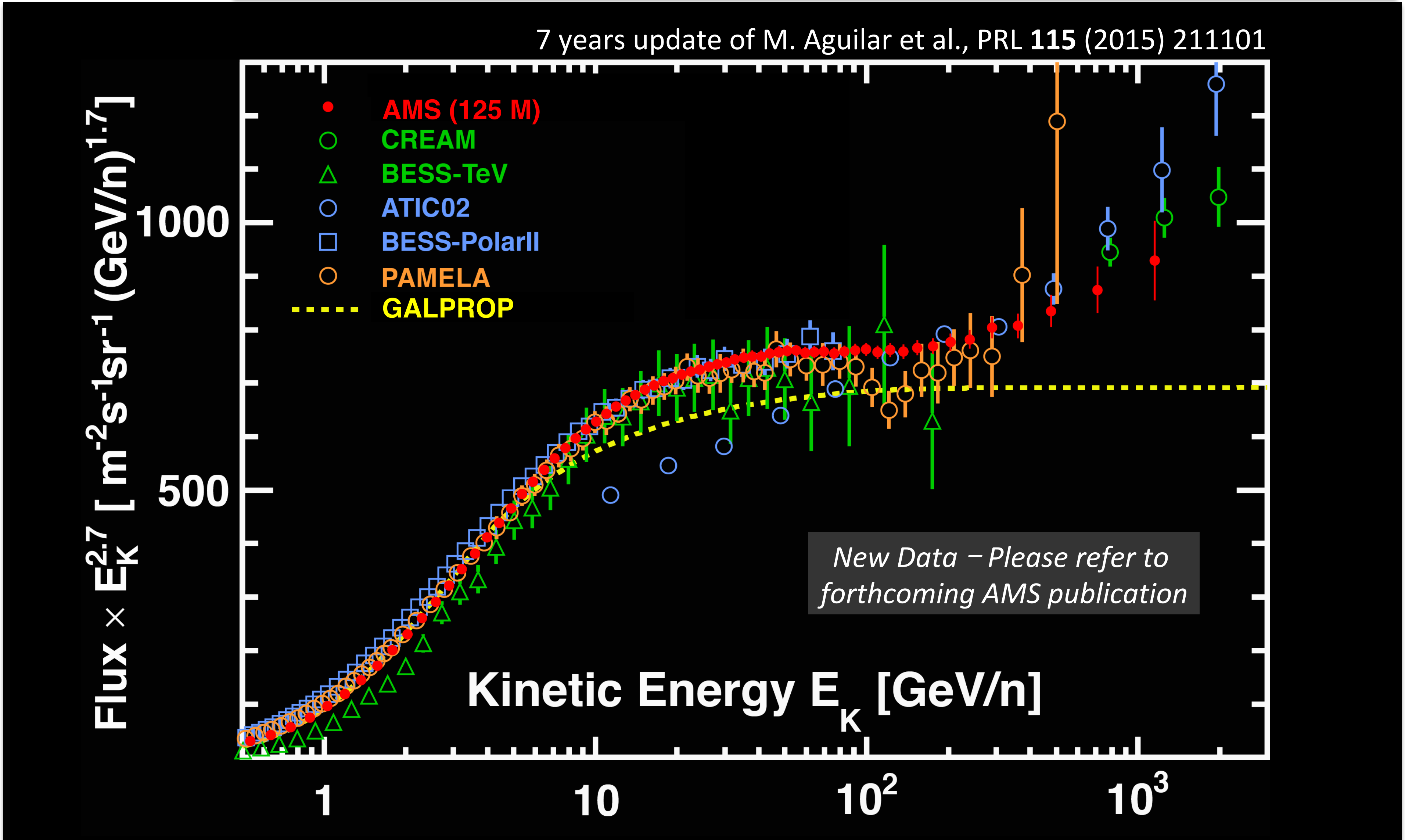


Proton Flux



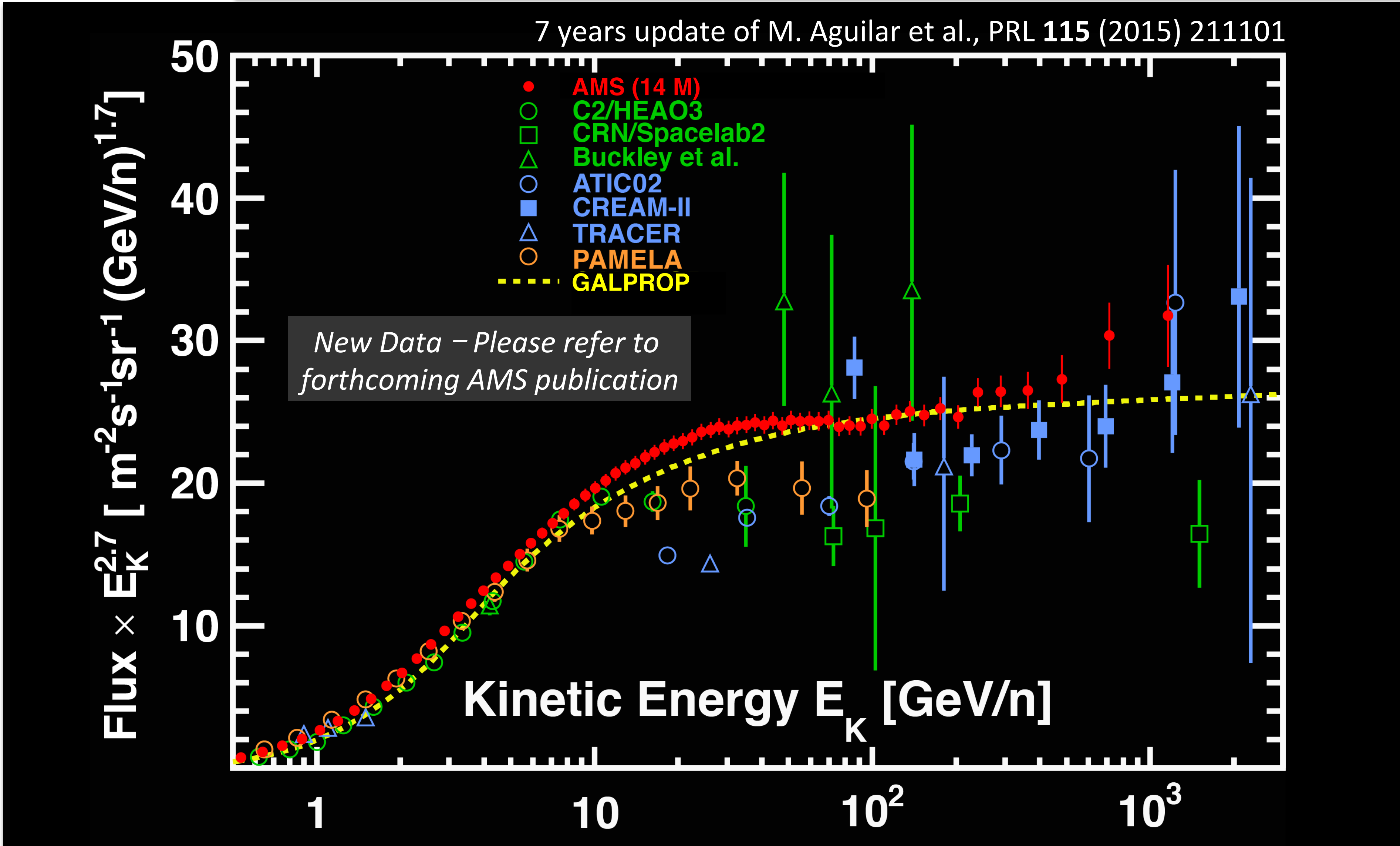
7 years update of M. Aguilar et al., PRL **114** (2015) 171131
AMS (1 B)
Flux × E^2.7 (m^-2 sr^-1 s^-1 GeV^1.7)
×10^3
16
14
12
10
8
6
4
10
10^2
10^3
10^4
Kinetic Energy (GeV)
AMS-01
ATIC02
Balloon
BESS93
BESS97
BESS98
BESS99
BESS00
BESS-TeV
BESS-Polar I
BESS-Polar II
CAPRICE94
CAPRICE98
CREAM-I
IMAX92
JACEE
MASS91
PAMELA
RICH-II
RUNJOB
SOKOL
New Data – Please refer to forthcoming AMS publication

Helium Flux



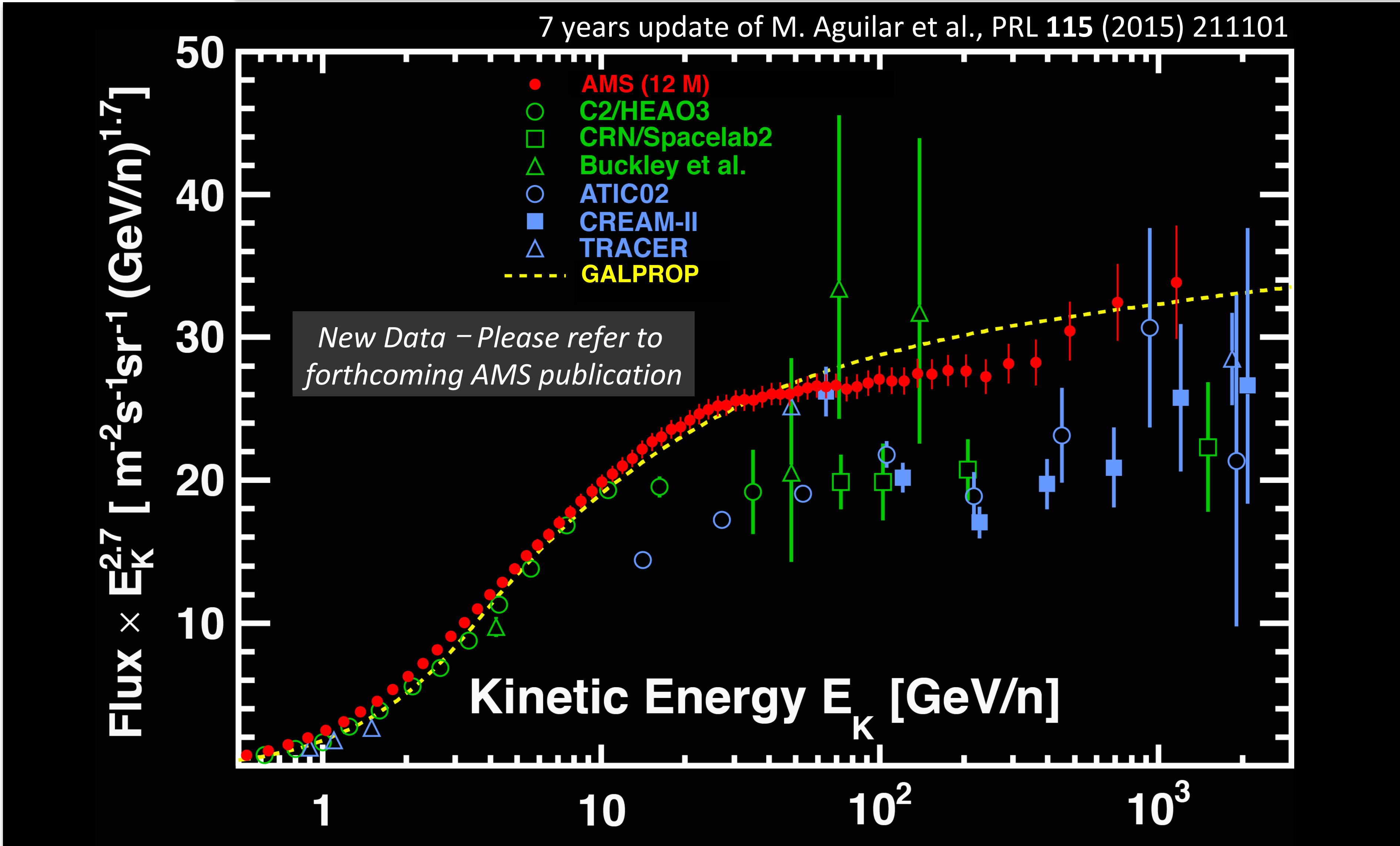
7 years update of M. Aguilar et al., PRL **115** (2015) 211101
AMS (125 M)
CREAM
BESS-TeV
ATIC02
BESS-PolarII
PAMELA
GALPROP
Flux × $E_K^{2.7}$ [$m^{-2}s^{-1}sr^{-1}$ (GeV/n)$^{1.7}$]
1000
500
Kinetic Energy E_K [GeV/n]
1
10
10^2
10^3
New Data – Please refer to forthcoming AMS publication

Carbon Flux



7 years update of M. Aguilar et al., PRL 115 (2015) 211101
AMS (14 M)
C2/HEAO3
CRN/Spacelab2
Buckley et al.
ATIC02
CREAM-II
TRACER
PAMELA
GALPROP
New Data – Please refer to forthcoming AMS publication
Flux × $E_K^{2.7}$ [$m^{-2}s^{-1}sr^{-1}$ $(GeV/n)^{1.7}$]
Kinetic Energy E_K [GeV/n]
50
40
30
20
10
1
10
10^2
10^3

Oxygen Flux



7 years update of M. Aguilar et al., PRL 115 (2015) 211101
AMS (12 M)
C2/HEAO3
CRN/Spacelab2
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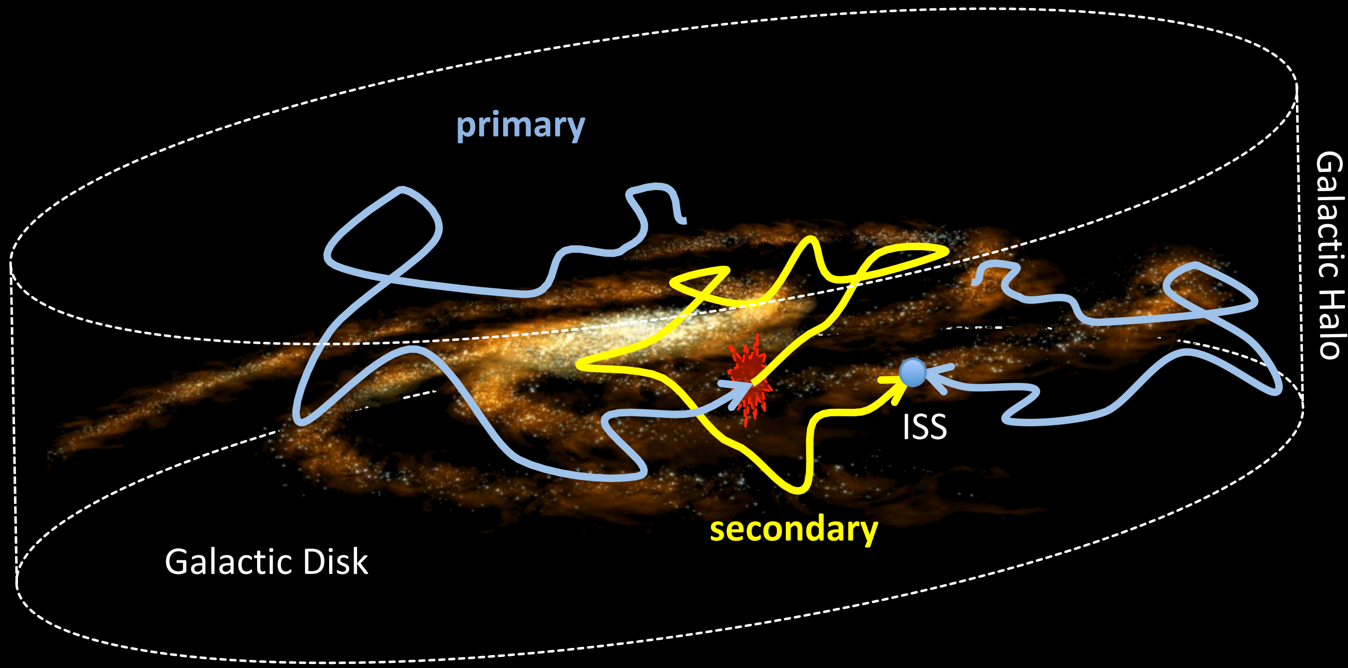
Kinetic Energy E_K [GeV/n]
50
40
30
20
10
1
10
10^2
10^3

Secondary Cosmic Rays

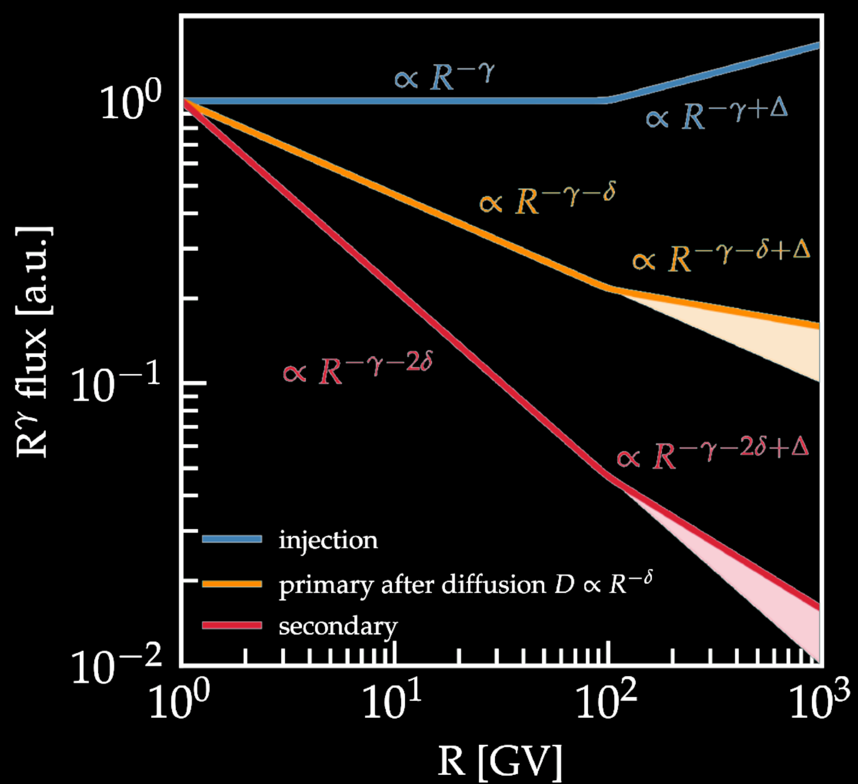
Cosmic rays **primaries** are mostly produced at astrophysical sources (ex. e^-, p, He, C, O, …),
secondaries (ex. Li, Be, B, …) are mostly produced by the collision of cosmic rays with the ISM.



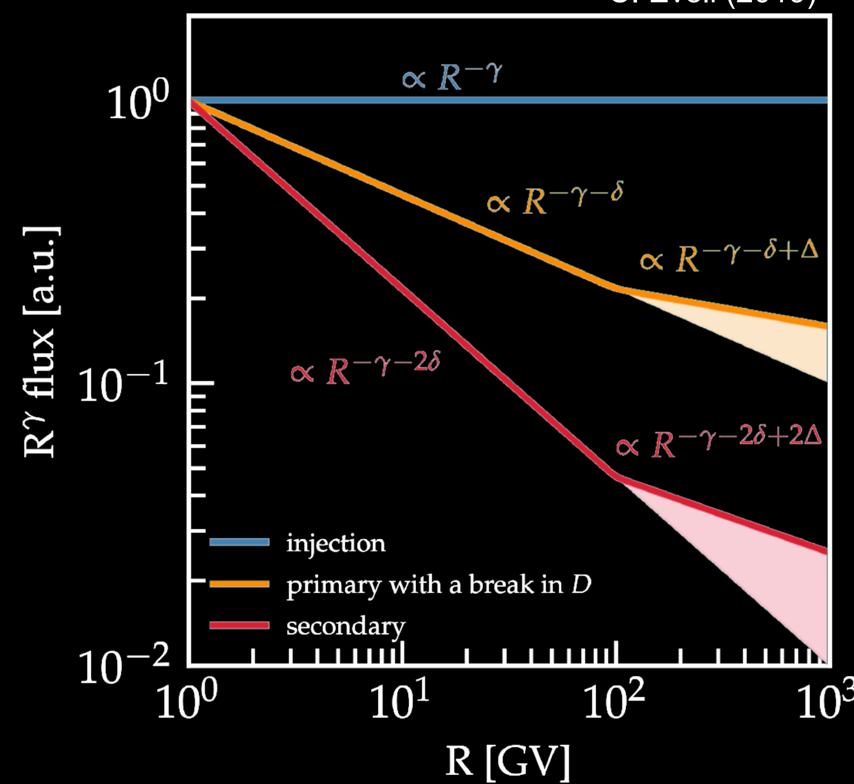
The understanding of primary and secondary cosmic rays nuclei reveal details of sources and propagation of all CRs species, specially for the secondary production of e^+, $\bar{p}$, $\bar{D}$, ...

- The cosmic ray fluxes of their "parents" (p, He)
- Behaviour of their propagation in the Milky Way (B/C, Be/B, …)

Cosmic Ray Propagation



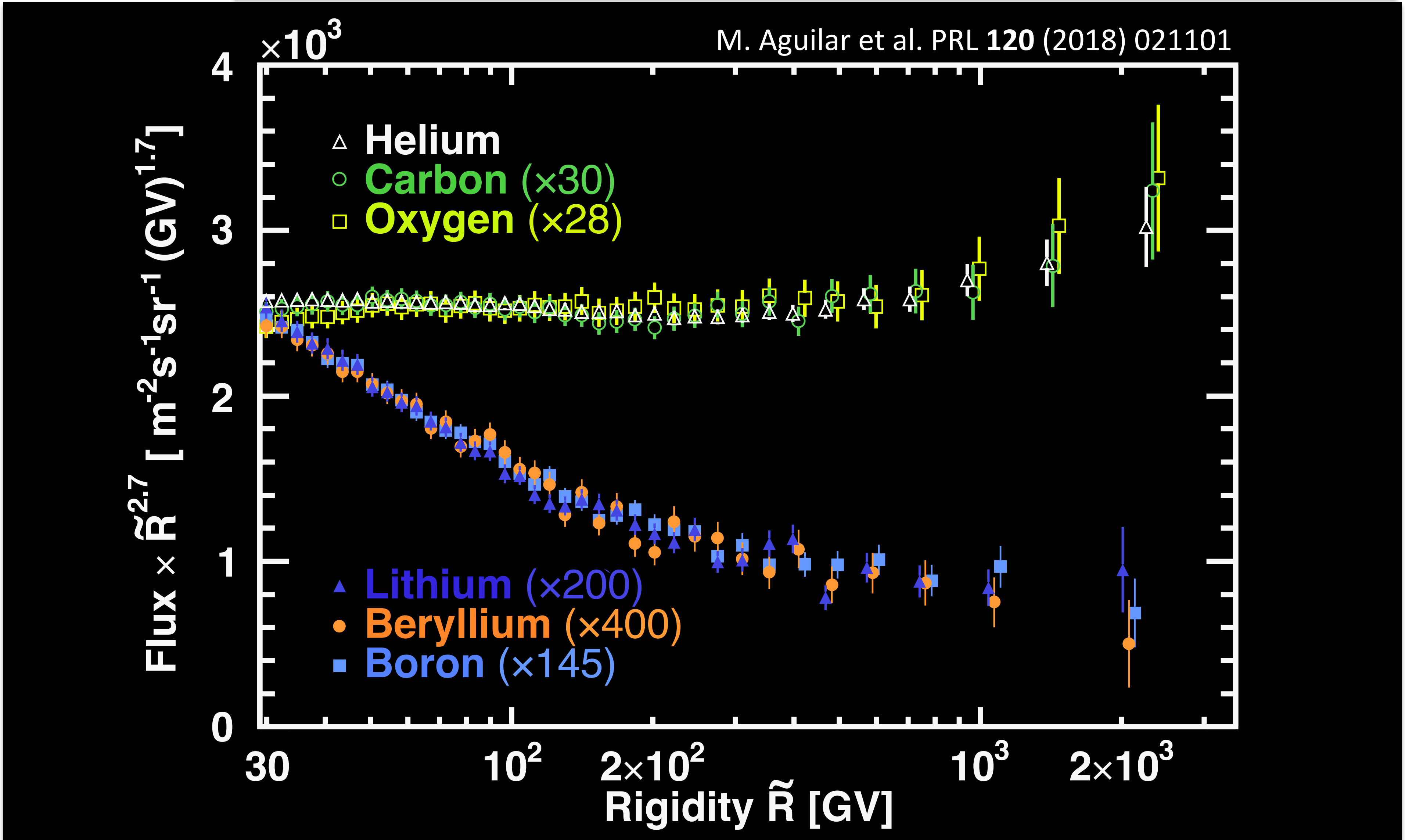
C. Evoli (2019)



If the hardening in CRs is related to the **injected spectra** at their source, then **similar hardening** is expected both for **secondary** and **primary** cosmic rays.

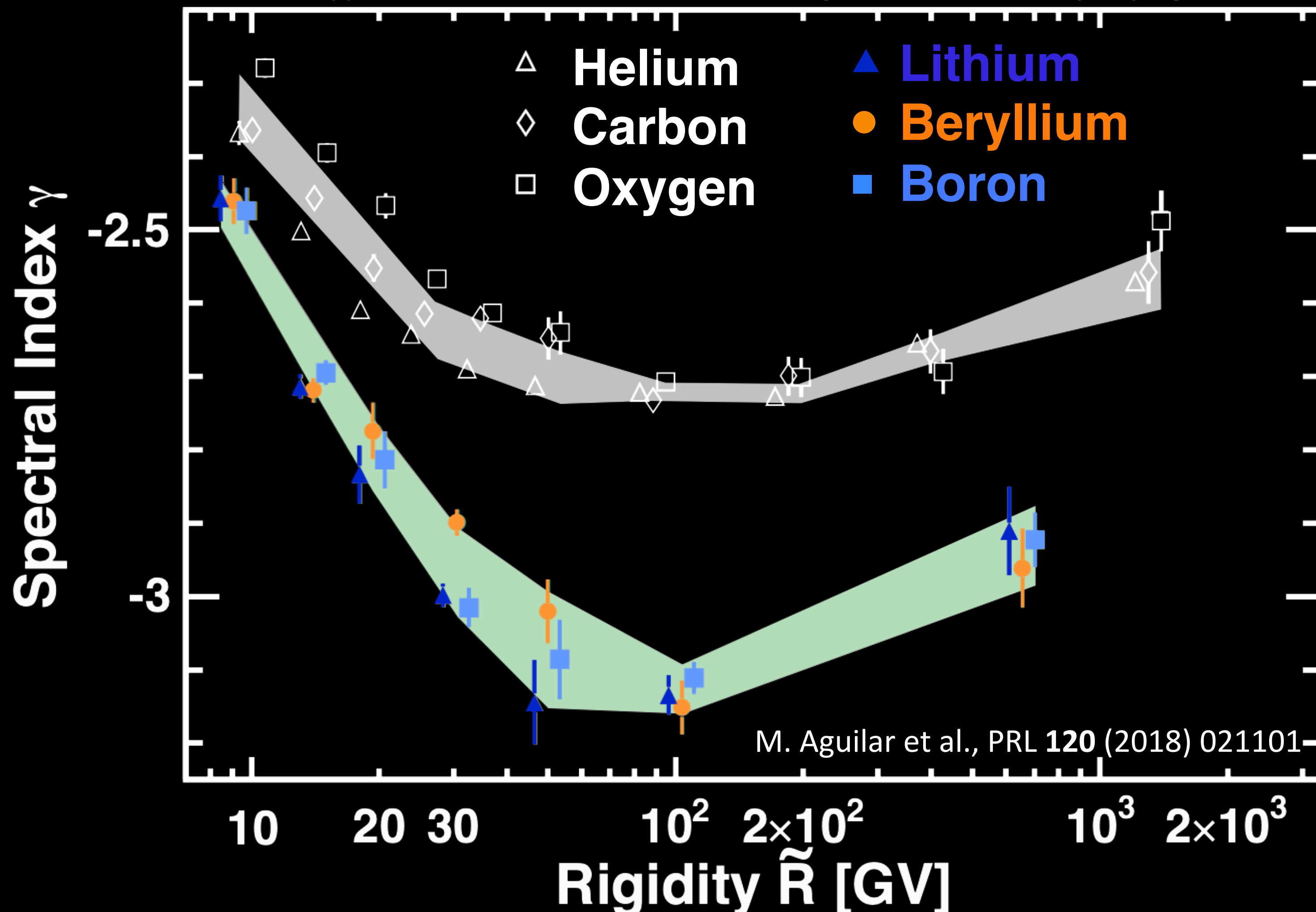
If the hardening is related to **propagation properties** in the Galaxy then a **stronger hardening** is expected for the **secondary** with respect to the **primary** cosmic rays.

Primary and Secondary Nuclei Fluxes

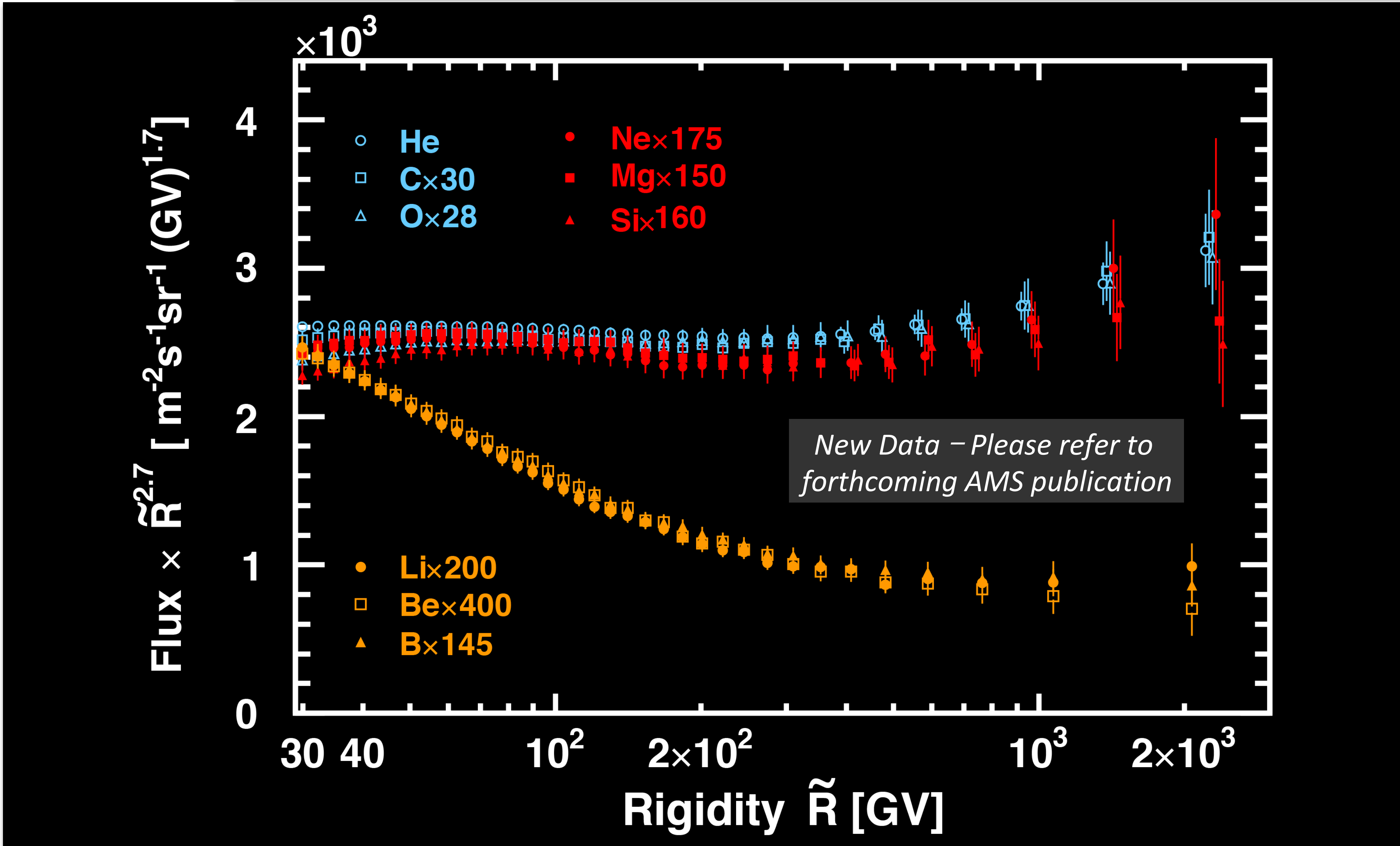


Primary and Secondary Nuclei Spectral Indices

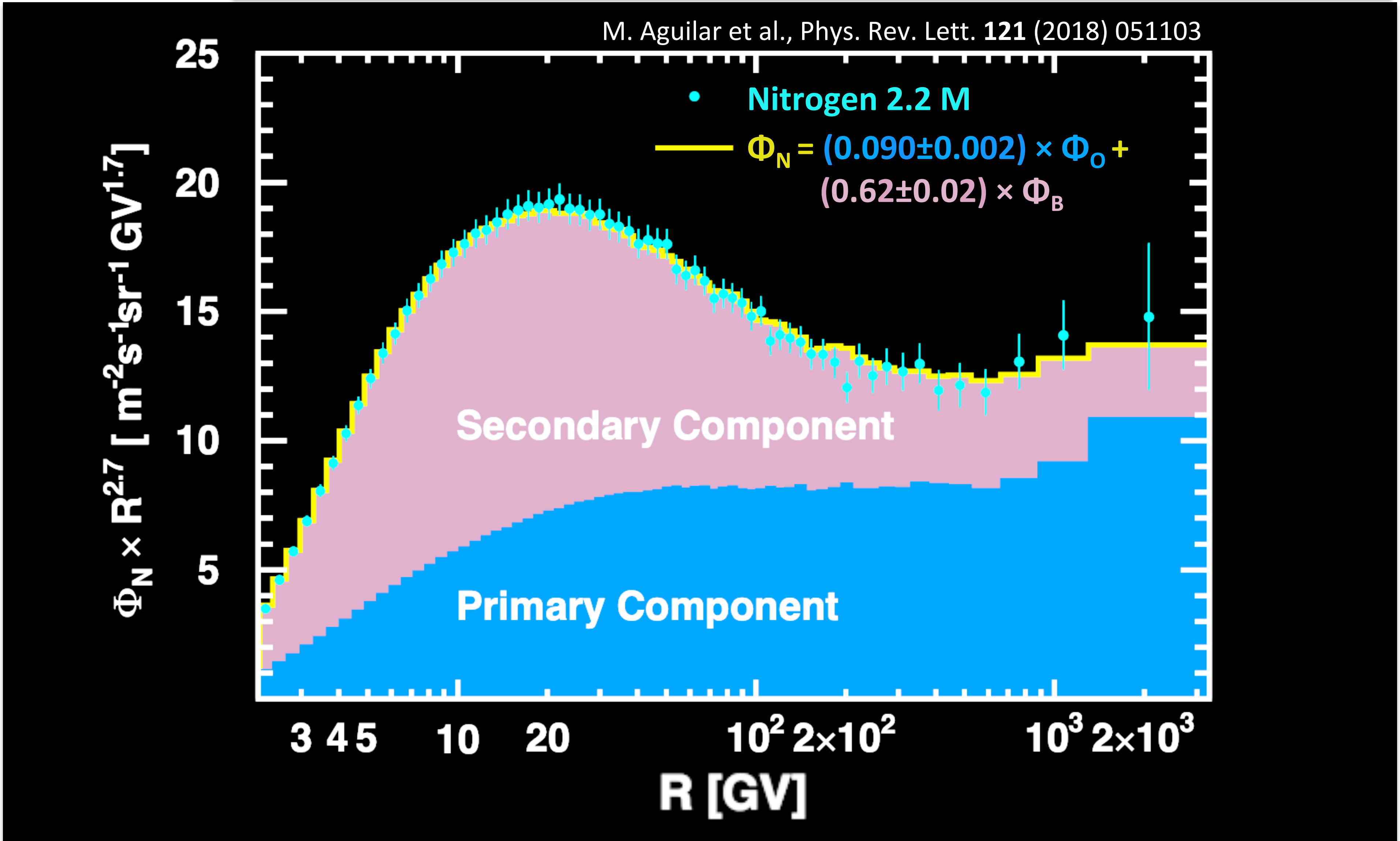
Deviate from single power law above 200 GV. Secondary hardening is stronger
AMS favors the hypothesis that the flux hardening is an **universal propagation effect**.



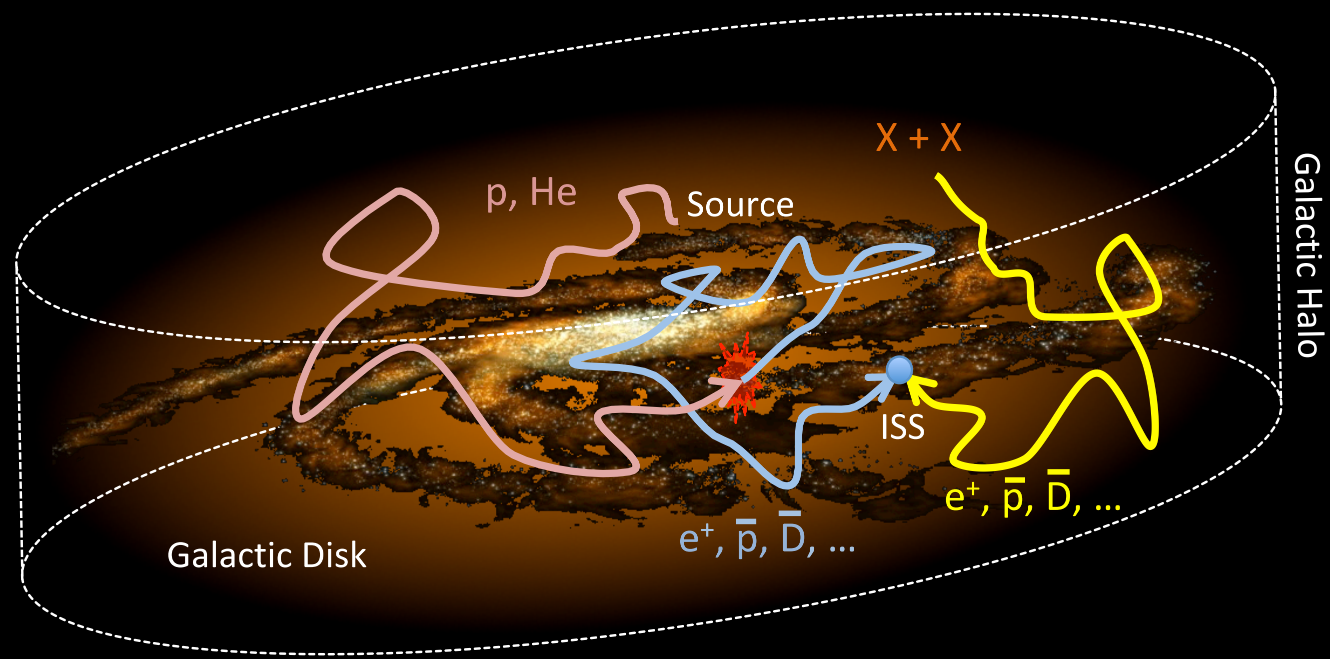
Extending Nuclei Fluxes Towards High-Z



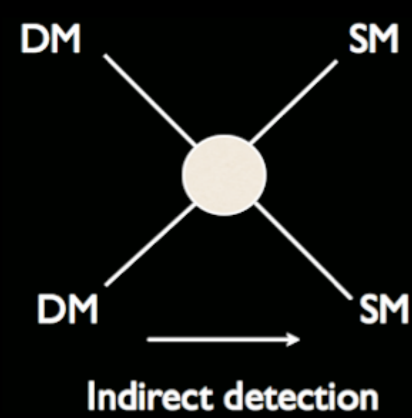
Nitrogen Flux



Indirect Search of Dark Matter with CR Anti-Matter



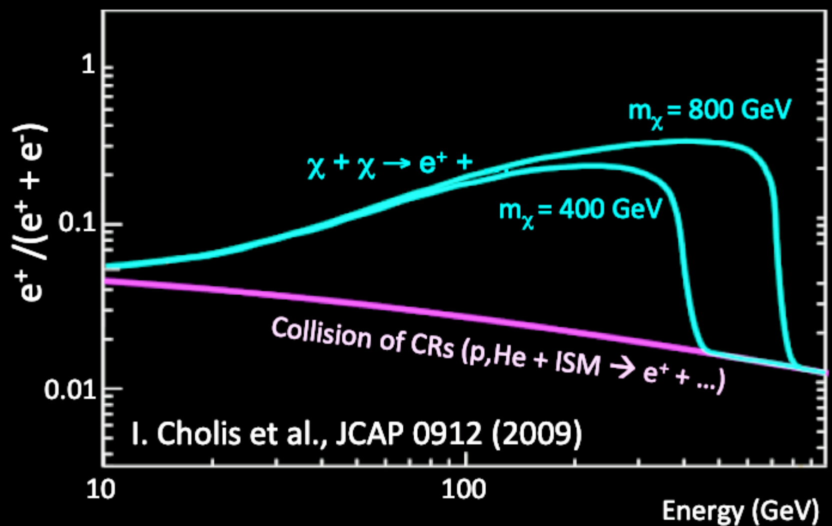
Collisions of dark matter particles (ex. neutralinos)
may produce a signal of e^+, $\bar{p}$, $\bar{D}$, … that
can be detected above the background from the
collisions of primary CRs on interstellar medium



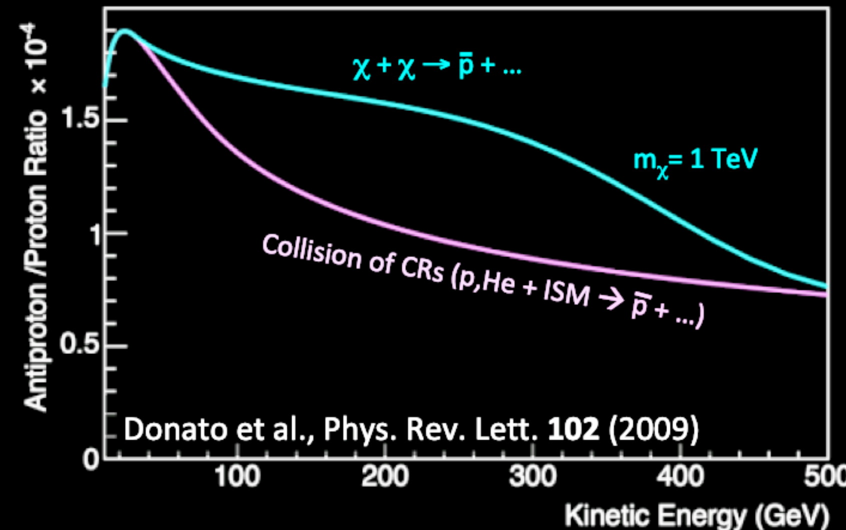
Indirect Search of Dark Matter with CR Anti-Matter

Collisions of Dark Matter particles (ex. neutralinos) may produce a signal of e^+, $\bar{p}$, $\bar{D}$ ...
detected above the background from the collisions of CRs on interstellar medium (ISM)

positron fraction



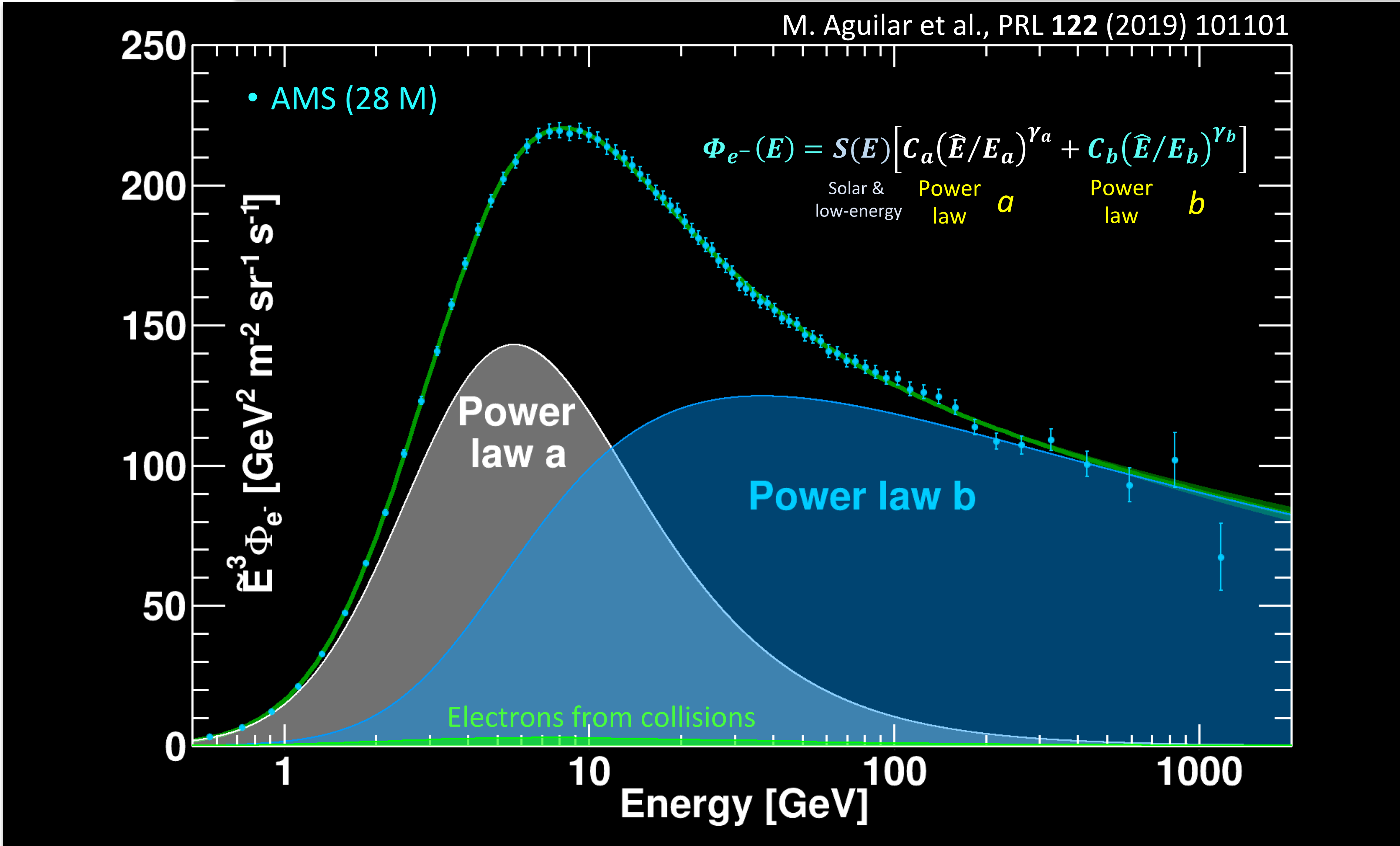
$\bar{p}$/p flux ratio



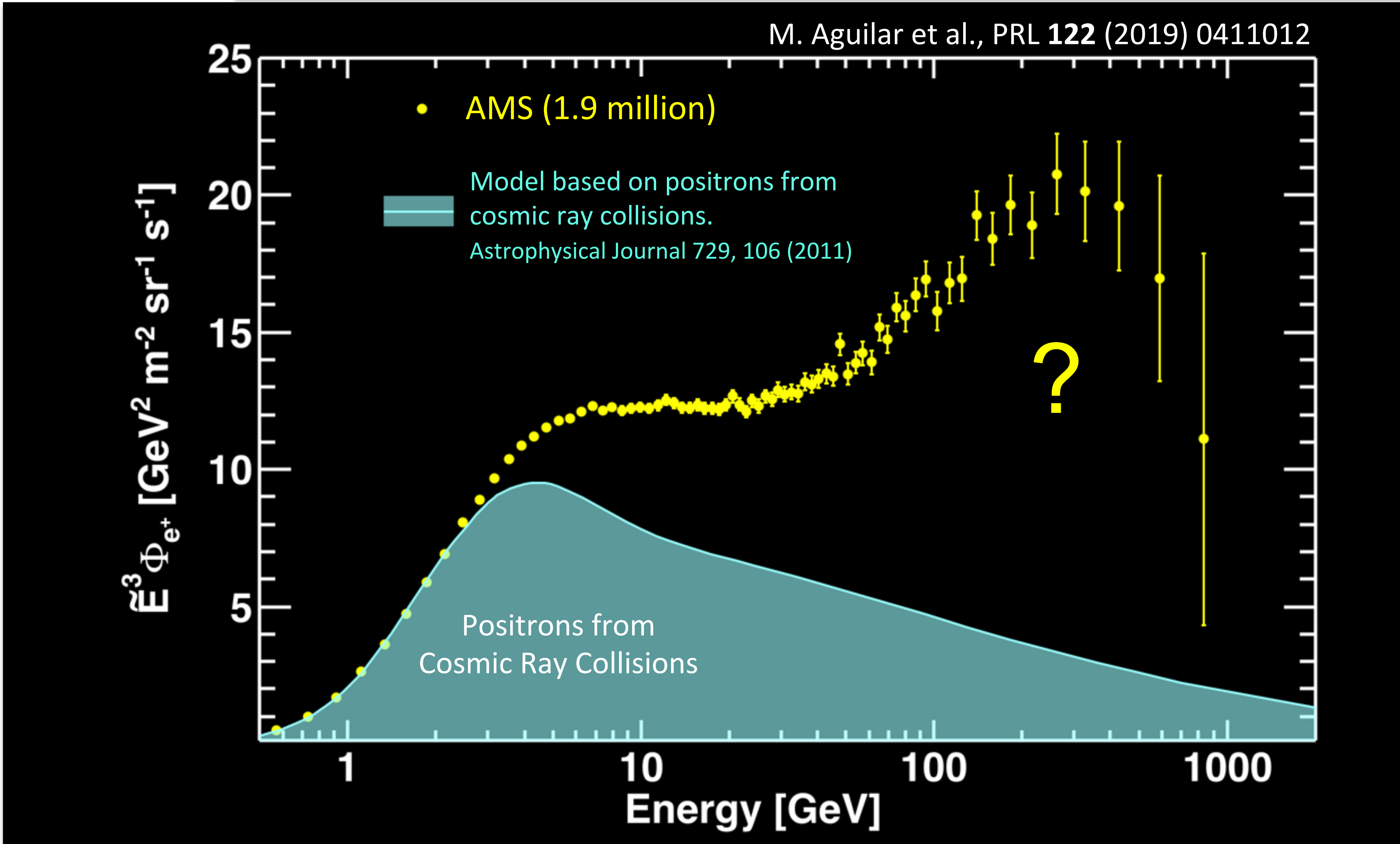
To calculate the secondary production of e^+ and p-bar we need

- The cosmic ray fluxes of their "parents" (p, He)
- Production cross-section (p → p + p + p + ...)
- Behaviour of their propagation in the Milky Way (B/C, Be/B, ...)

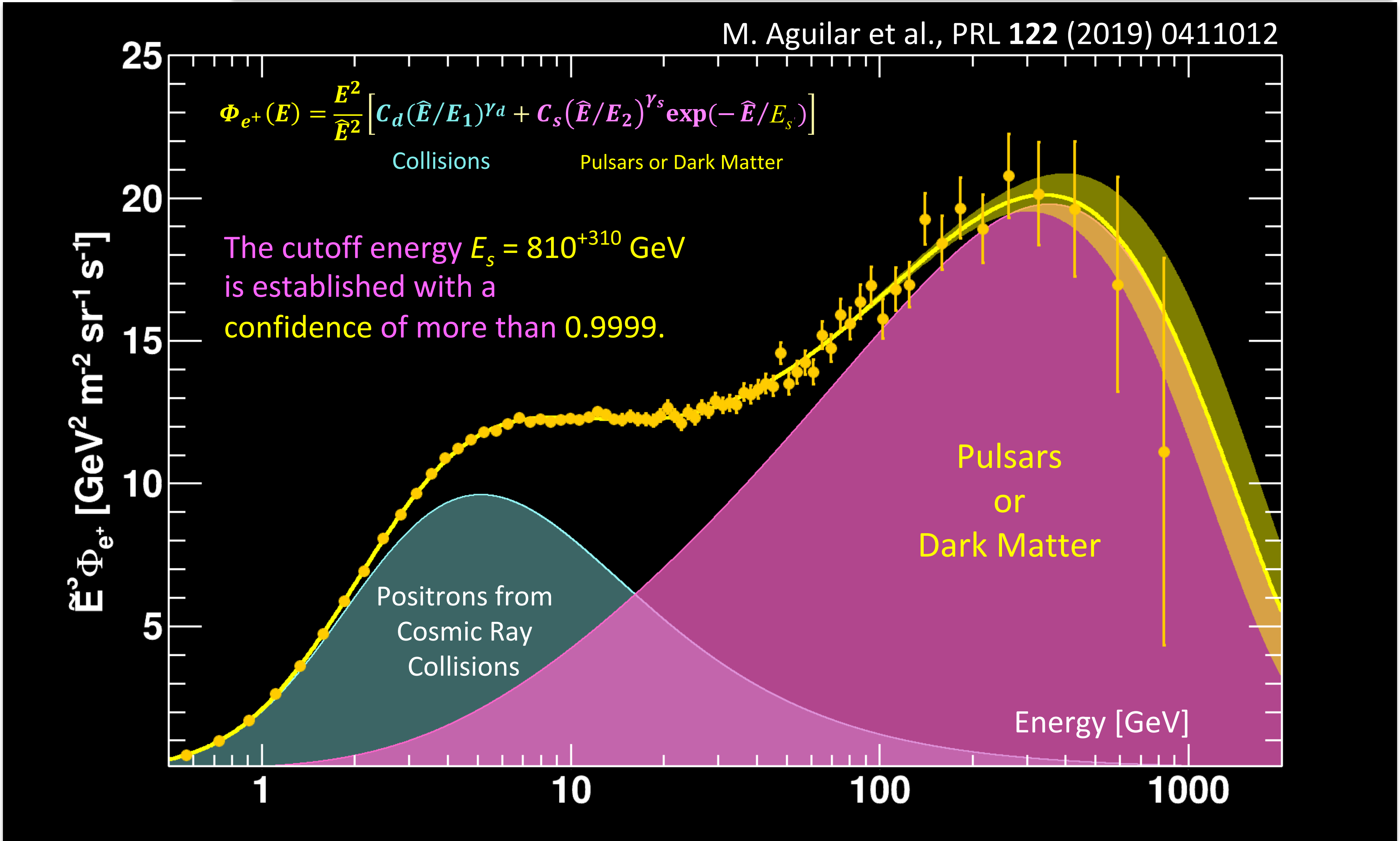
Electron Flux



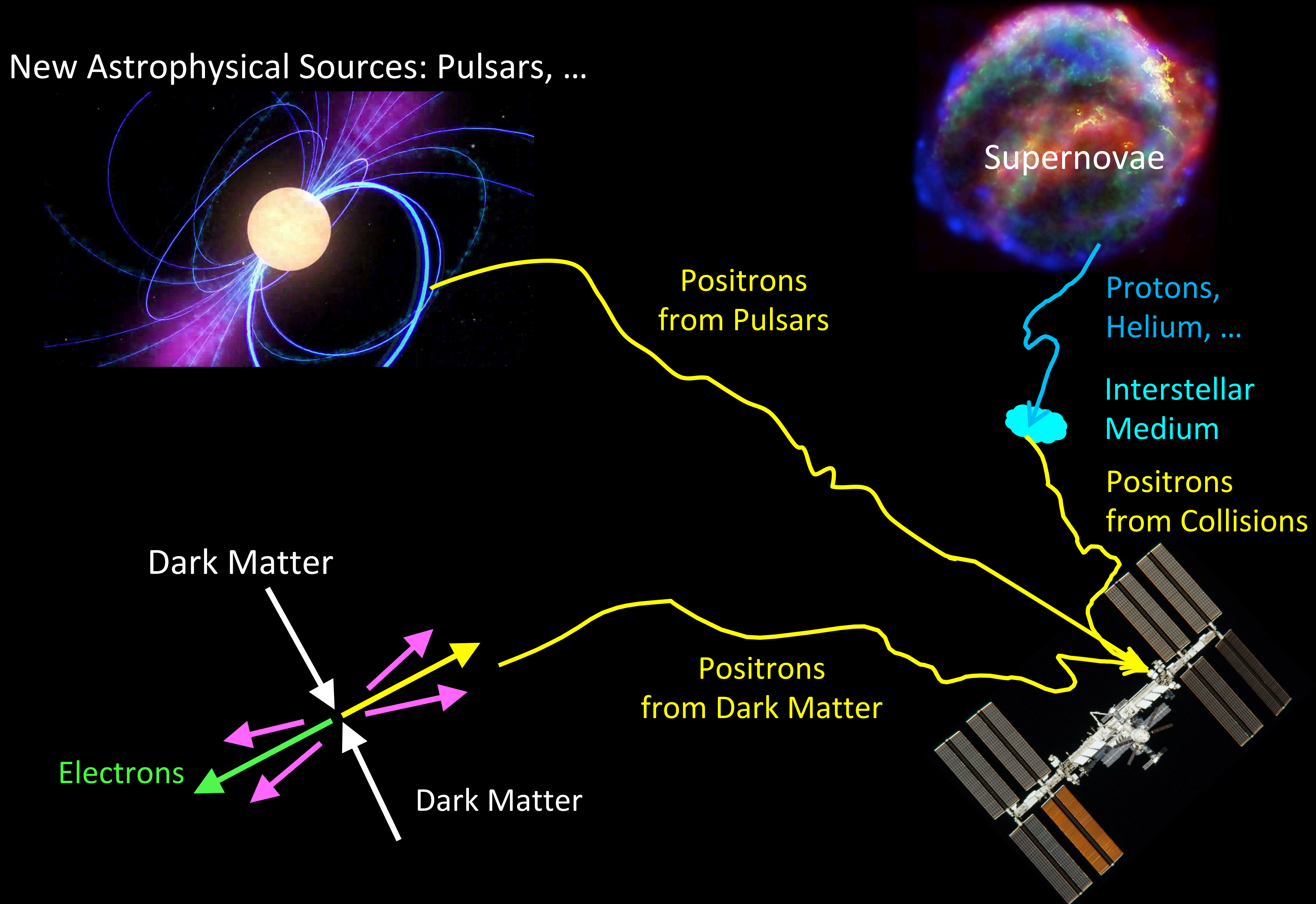
Positron Flux



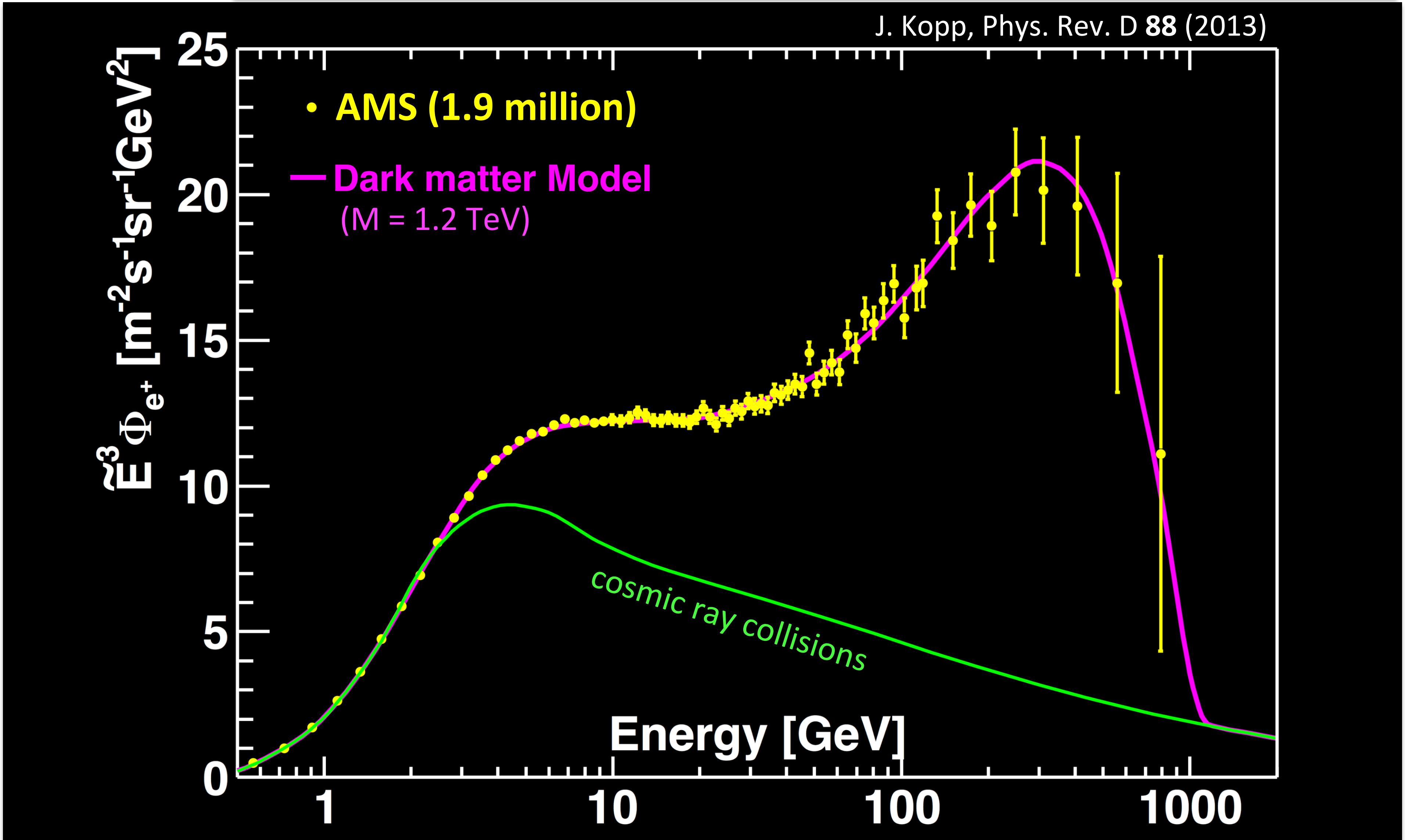
Positron Flux



Origin of Positrons

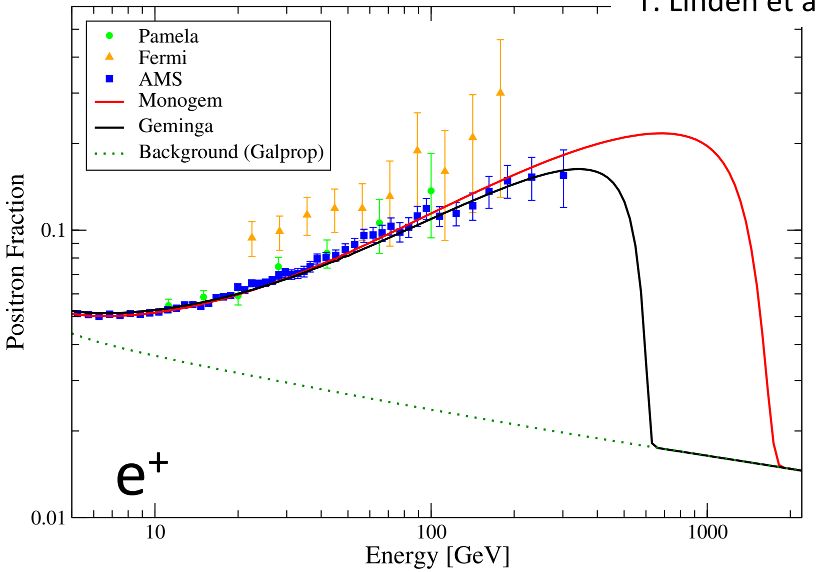


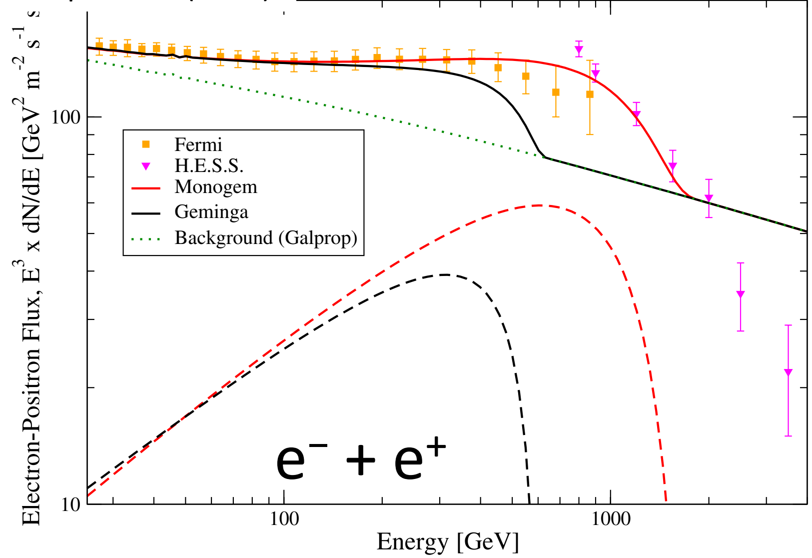
Positrons & Dark Matter



Positrons from Pulsar

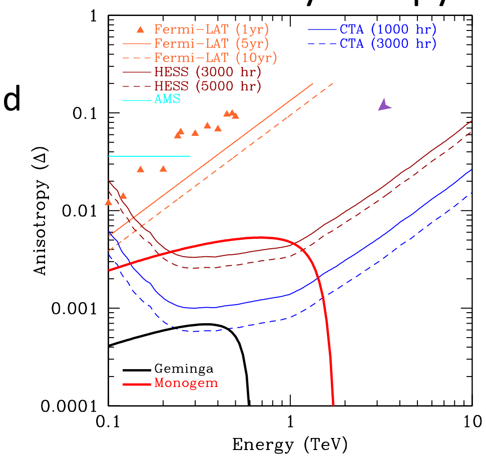
T. Linden et al., Astrop. J. **772** (2013)

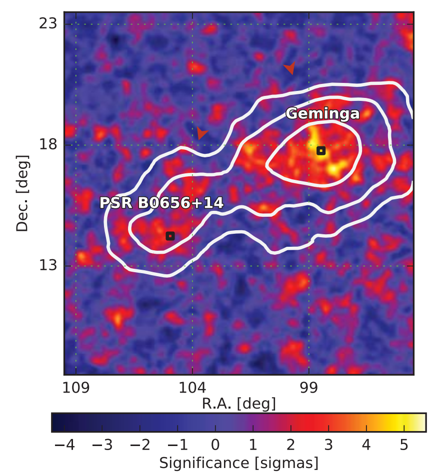




Pulsars spinning produce EM radiation and cosmic rays (pair production).
To distinguish from DM models:
→ **spectral features** of e^+ and of ($e^+ + e^-$)
→ **anisotropy** of e^+ and of ($e^+ + e^-$)
→ **no anti-proton** production

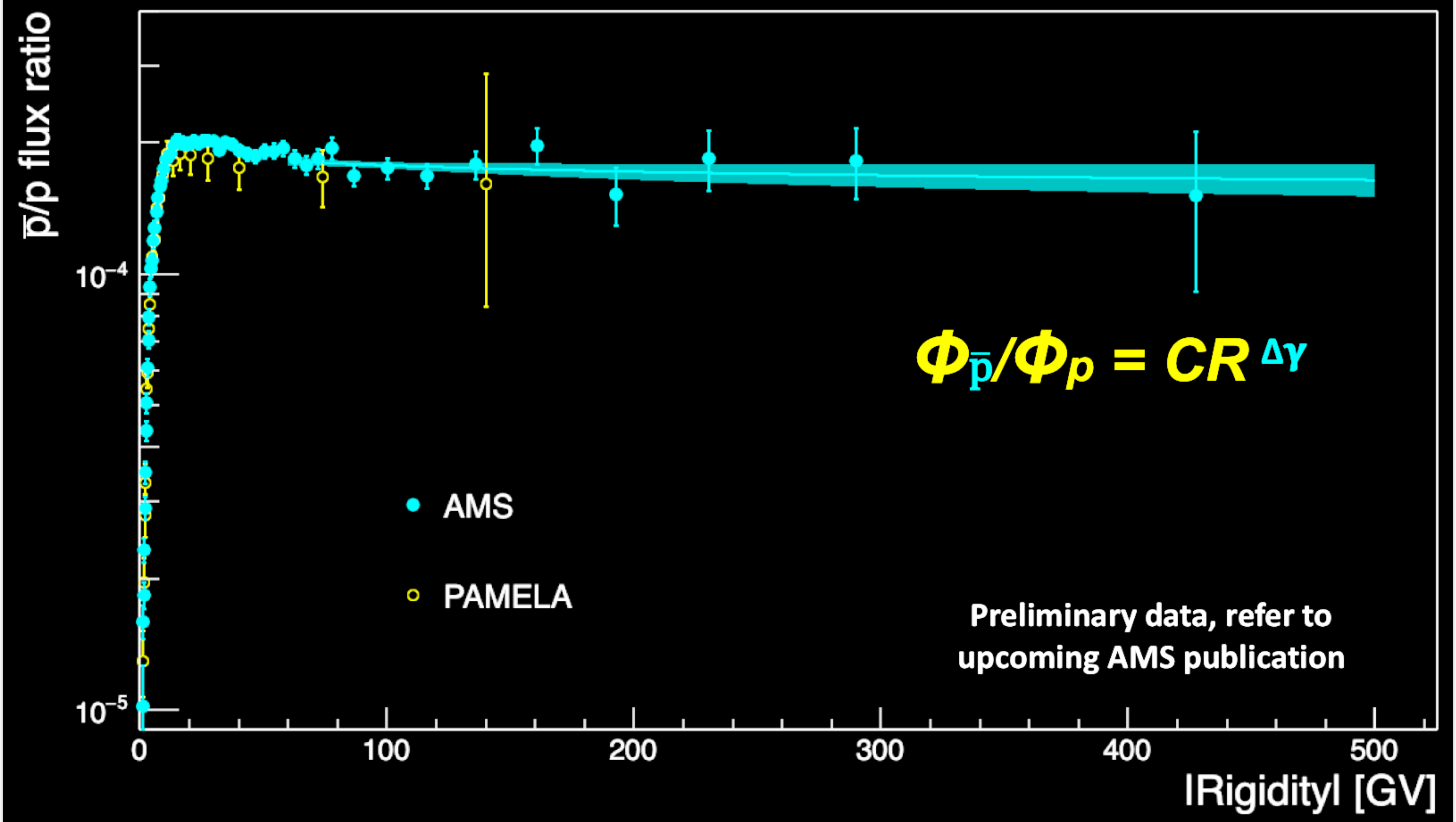
$e^- + e^+$ anysotropy





Anti-Proton / Proton Ratio

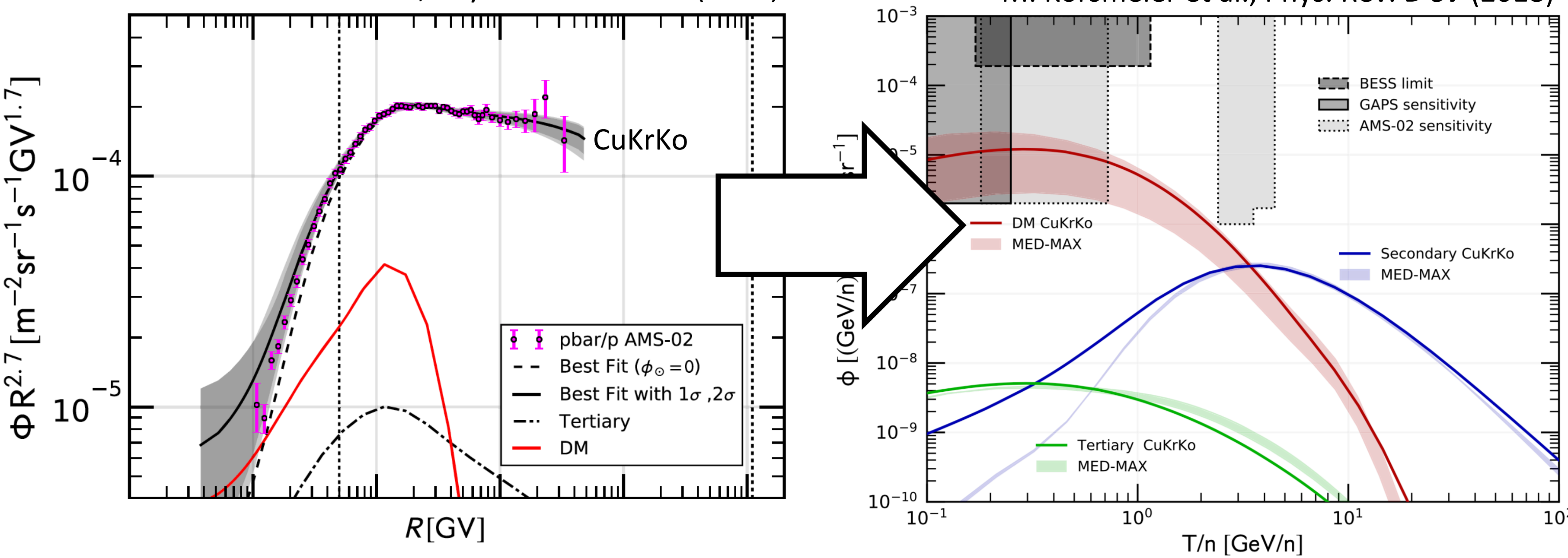
7 years update of M. Aguilar et al., PRL **117** (2016) 0911003



Low energy Anti-Proton and Anti-Deuteron

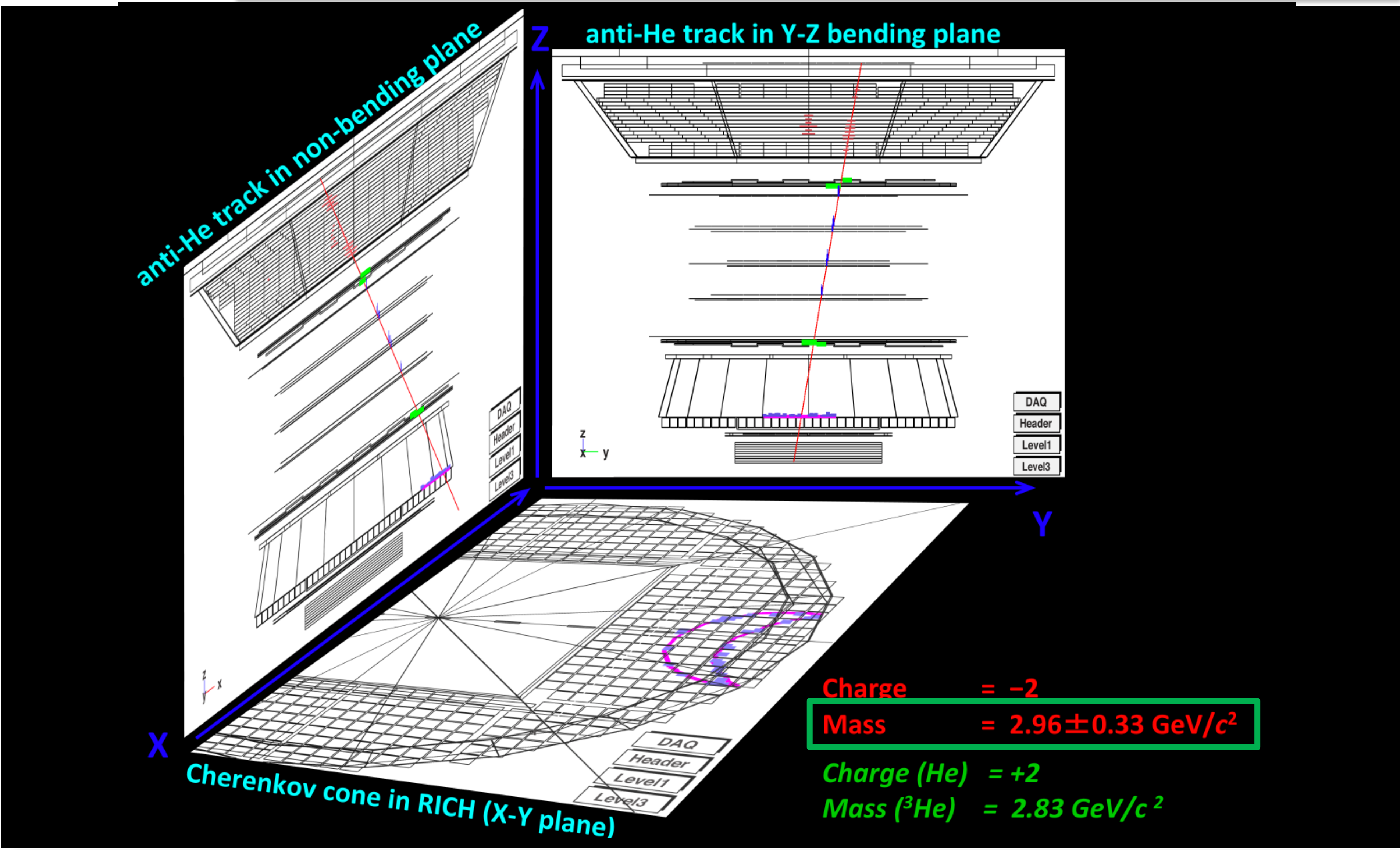
A. Cuoco et al., Phys. Rev. Lett. **118** (2017)

M. Korsmeier et al., Phys. Rev. D **97** (2018)



Several authors reported an allowed **anti-proton** excess at low energy, with different significances, at 10 GV that can be explained a dark matter signal. This signal can give a detectable **anti-deuteron** signal.

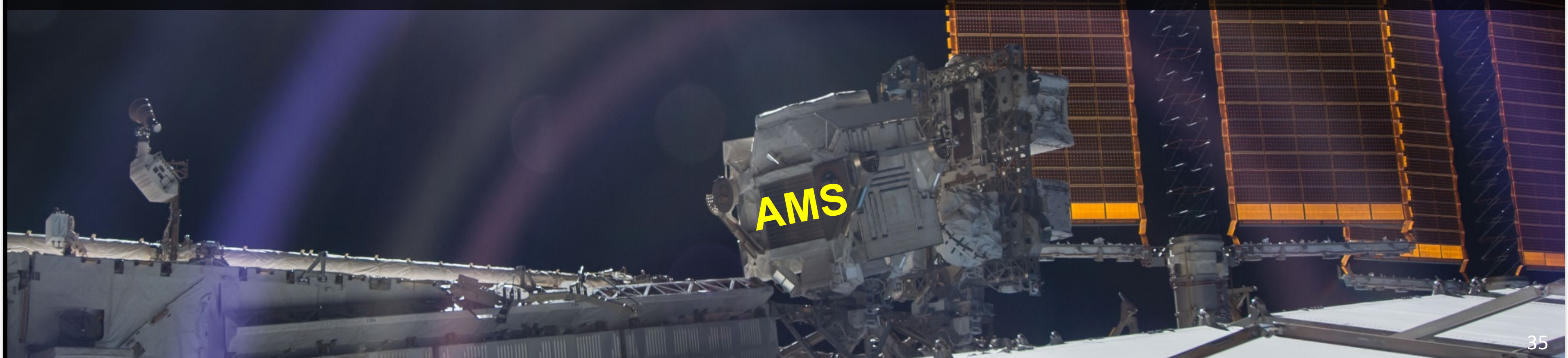
Key concepts/detectors



Currently, AMS observed 8 anti-helium candidates (mass region from 0-10 GeV/c^2) with rigidity <50 GV with respect to a sample of 700 million helium events selected.

The rate in AMS of antihelium candidates is less than 1 in 100 million helium.

At this extremely low rate, more data (through the lifetime of the ISS) is required to further check the origin of these events.

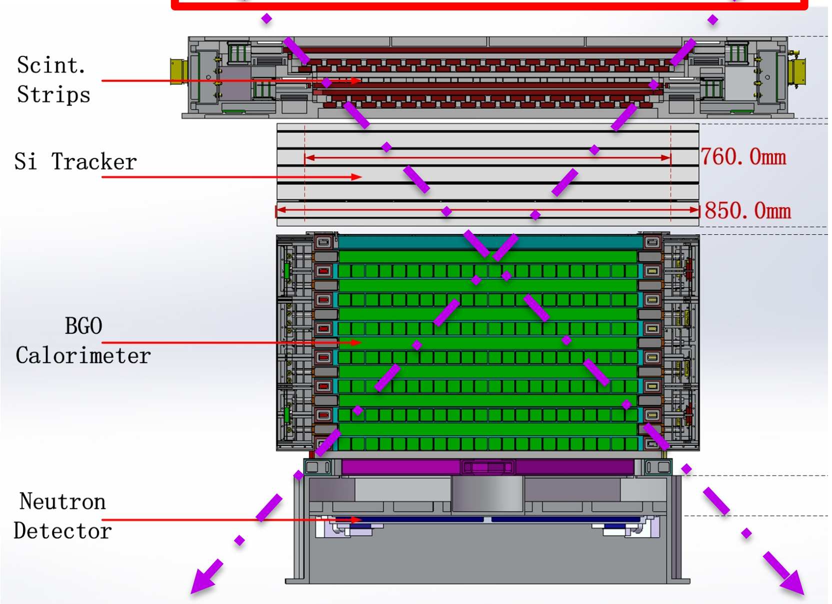


Future/proposed 4π experiments

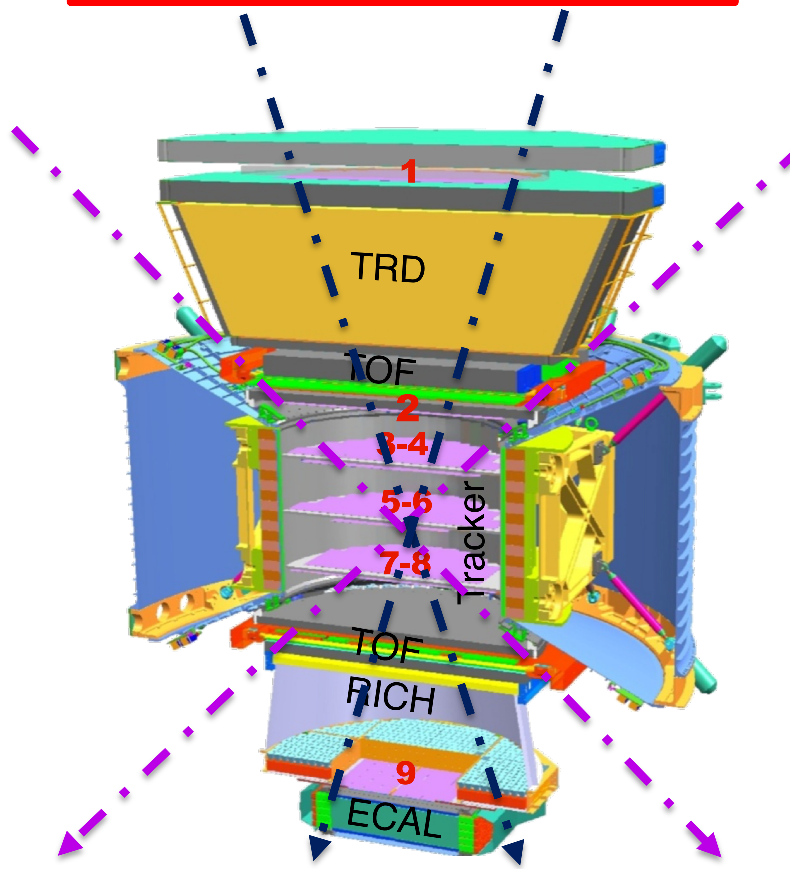
– HERD
– ALADInO
– AMS-100

Current operating experiments - DAMPE

DAMPE Field of View ~ 1 sr
→ Acc ~ 0.3 m² sr



AMS Inner ~ 0.5 m² sr
AMS Full Span ~ 0.05 m² sr



All the current and past detectors are designed as 'telescopes': they're sensitive only to particles impinging from "the top"

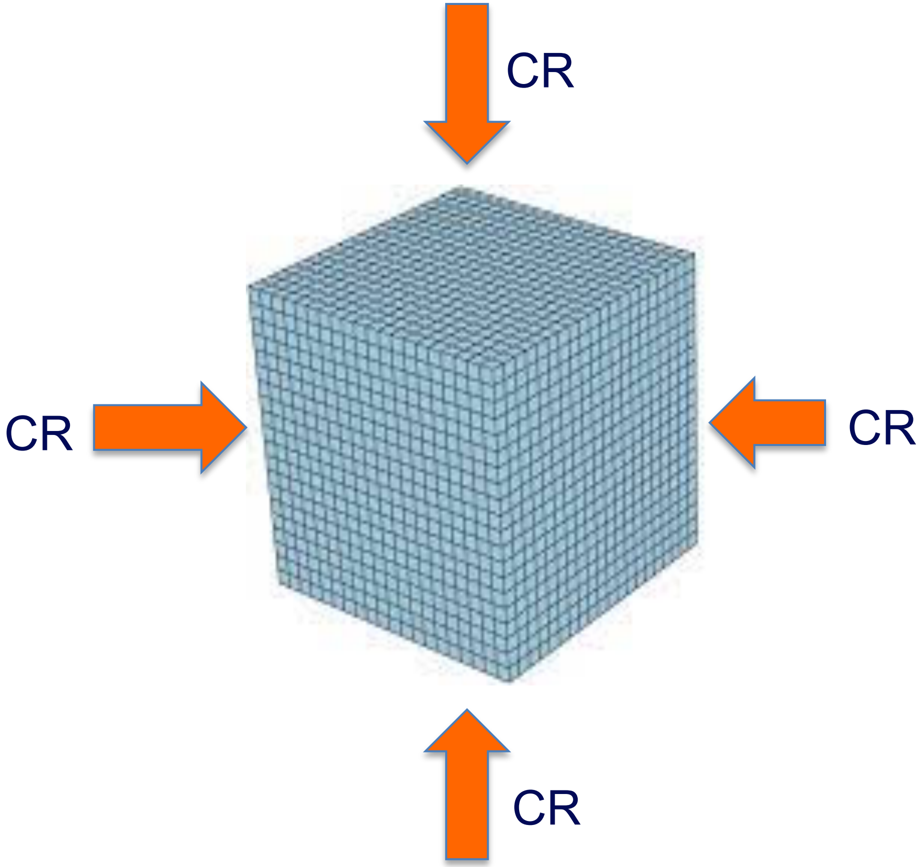
limited FoV → small acceptance

New paradigma - CaloCube

- Exploit the CR "isotropy" to maximize the effective geometrical factor, by using all the surface of the detector (aiming to reach $\Omega = 4\pi$)

- The calorimeter should be highly isotropic and homogeneous:
  - the needed depth of the calorimeter must be guaranteed for all the sides (i.e. cube, sphere, …)
  - the segmentation of the calorimeter should be isotropic

→ this is in general doable just with an homogeneous calorimeter

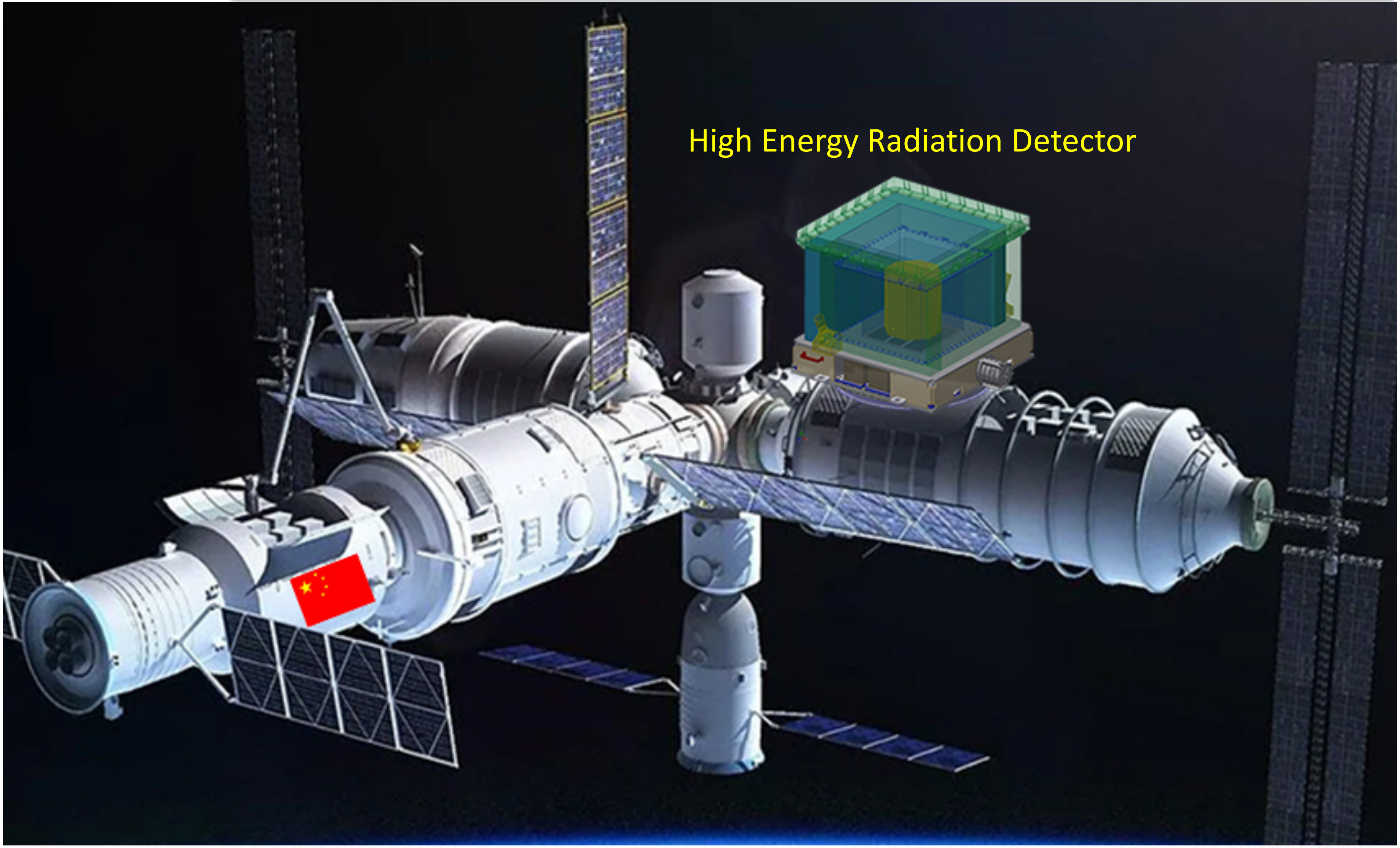


CaloCube is an INFN R&D initiated in Florence (Adriani et al.), almost always inspiring the next generation of large space cosmic rays detectors

4π experiments

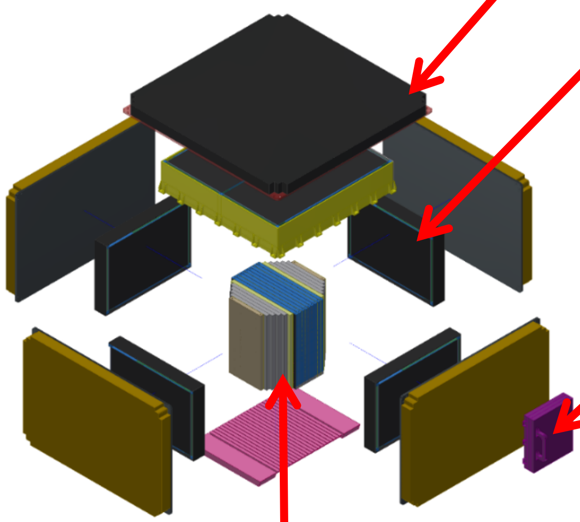
- HERD on the Chinese Space Station (CSS)
- ALADInO (in L2)
- AMS-100 (in L2)

HERD on the CSS



HERD detector

~ 300k readout channels



PSD, 6 sides
γ identification
Charge

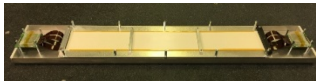
Tracker, 5 sides
Charge
CR trajectory
γ conversion & tracking

TRD
TeV CR calibration

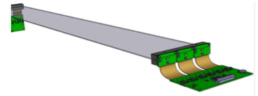
CALO: 3-D
Energy
e/p separation

~7500 LYSO crystals (55 X_0, 3 λ_I)
Trigger sub-system
Dual readout with IsCMOS & PD/SiPM

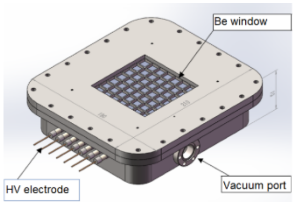
@INFN Bari & IHEP



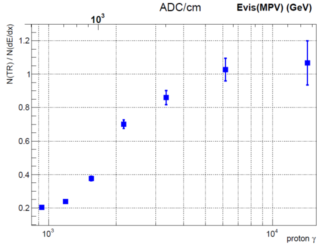
Silicon Track
@INFN Perugia

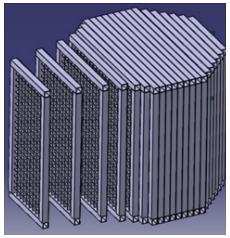


Fiber Tracker
@Univ. of Geneva

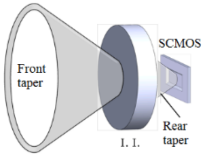


@Guangxi Univ.





@IHEP



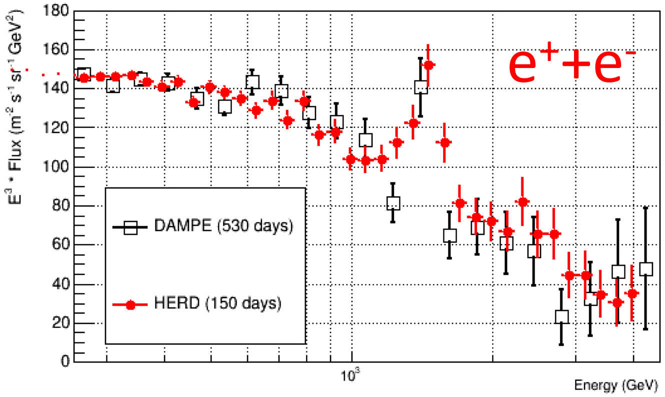
@XIOPM

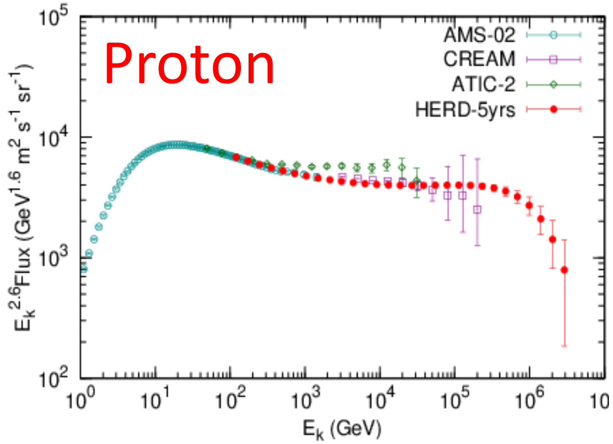
@INFN Florence

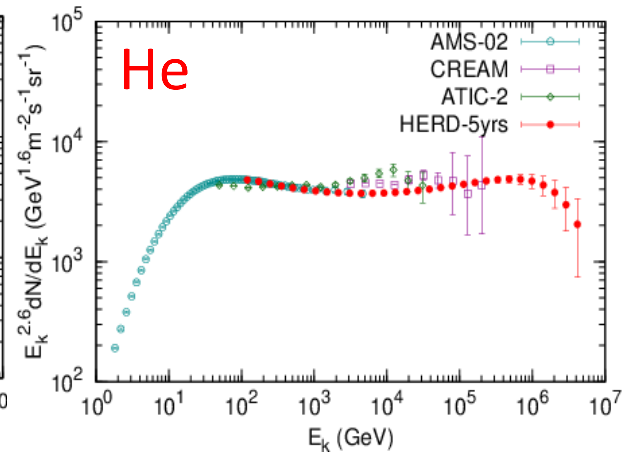
HERD performances

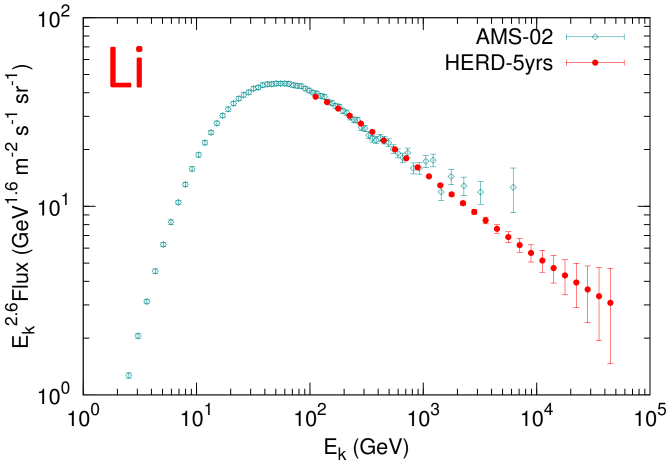
Item	Value
Energy range (e/γ)	10 GeV - 100 TeV (e); 0.5 GeV-100 TeV (γ)
Energy range (nuclei)	30 GeV - 3 PeV
Angle resolution	0.1 deg.@10 GeV
Charge resolution	0.1-0.15 c.u
Energy resolution (e)	1-1.5%@200 GeV
Energy resolution (p)	20-30%@100 GeV - PeV
e/p separation	~10^{-6}
G.F. (e)	>3 m^2sr@200 GeV
G.F. (p)	>2 m^2sr@100 TeV
Field of View	~ 6 sr
Envelope (L*W*H)	~ 2300*2300*2000 mm^3
Weight	~ 4000 kg
Power Consumption	~ 1400 W

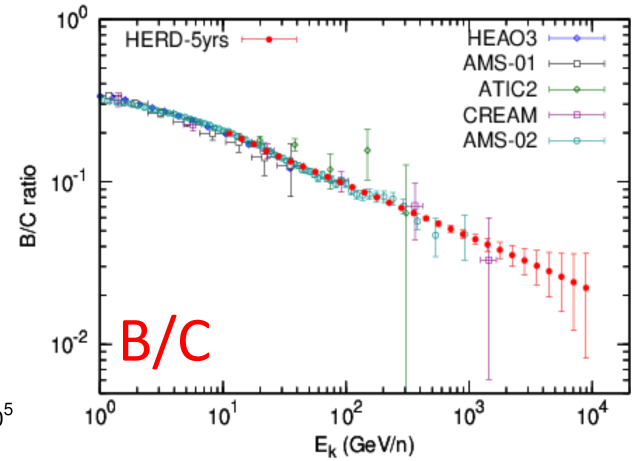
HERD capabilities

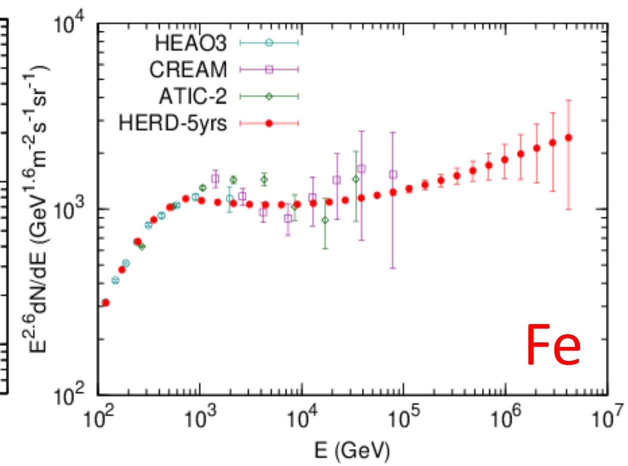










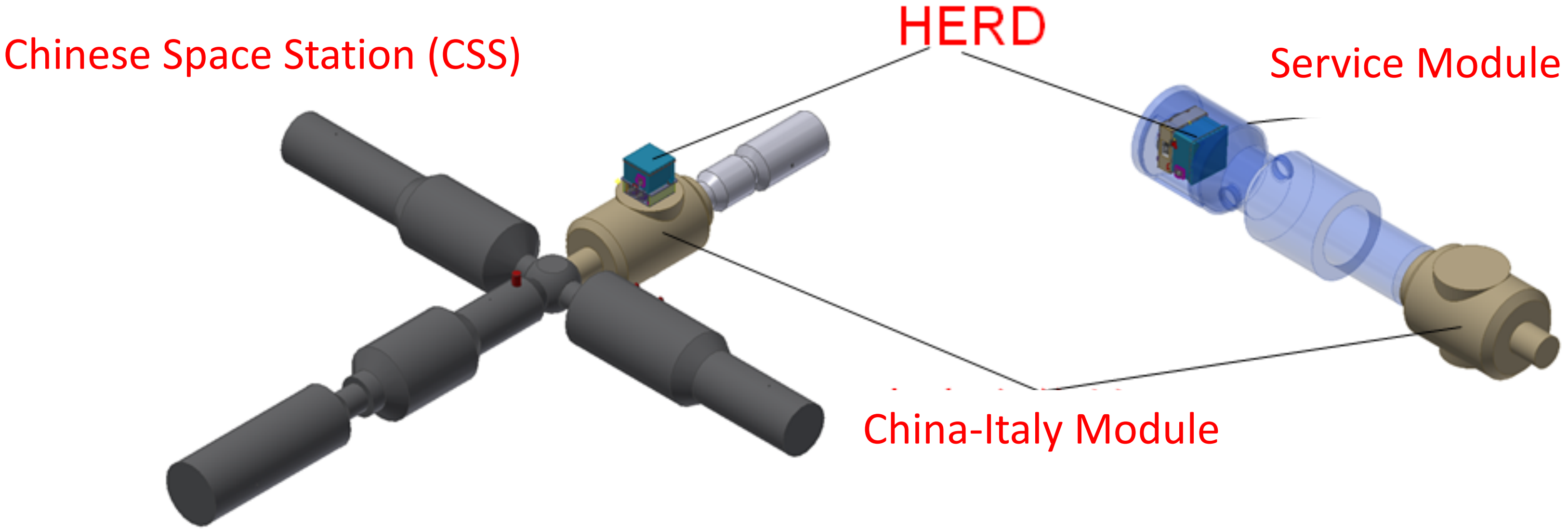


HERD consortium

- The HERD consortium includes 130+ scientists from China, Italy, Switzerland, Spain, Germany, Denmark, Sweden, Russia, ... (new collaborators are welcome!)
  - most of the members have been collaborating on previous high energy experiments, both on hardware development and data analysis
- 7 HERD international workshops have been organized in China and Europe since 2012. Last one in China in December 2019.
- 3 CERN beam tests on HERD prototypes have been successfully implemented by Chinese and European colleagues.

HERD mission

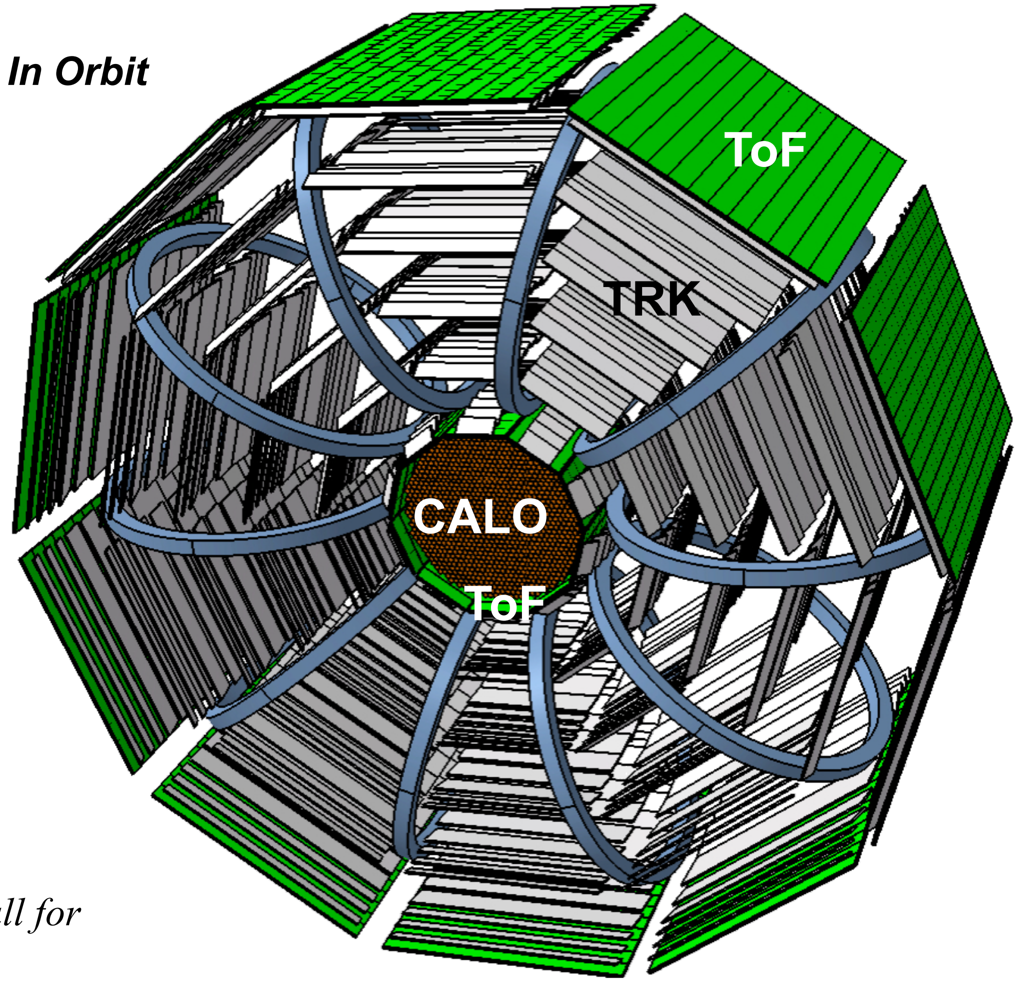
- Mission concept
  - Launched with the China-Italy Module and installed on the Module.
  - Periodic calibration is performed every 3-6 months.
  - Several devices are replaced or upgraded every 3-4 years.
  - Telemetry is achieved with the help of relay satellites.
- The HERD proposal was reviewed positively in May 2018 at ASI.
- HERD is written into the joint declaration between China & Italy during the visit of President XI Jinping in March 2019.



ALADInO (in L2)

High Precision Particle Astrophysics as a New Window on the Universe

with an Antimatter Large Acceptance Detector In Orbit (ALADInO)



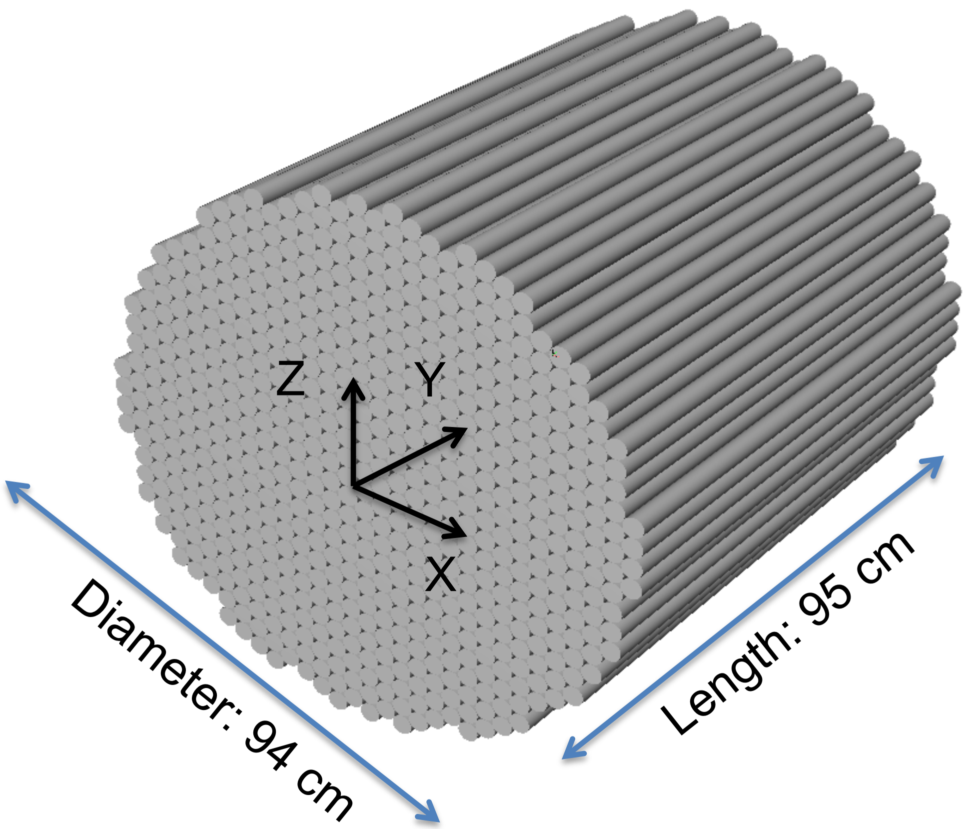
A White Paper submitted in response to ESA's Call for the VOYAGE 2050 long-term plan

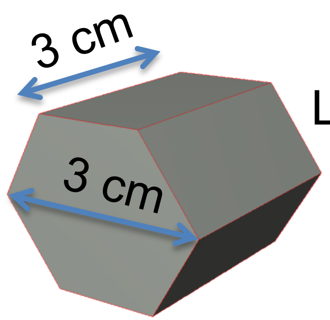
https://www.cosmos.esa.int/web/voyage-2050/white-papers

https://www.cosmos.esa.int/documents/1866264/3219248/BattistonR_ALADINO_PROPOSAL_20190805_v1.pdf

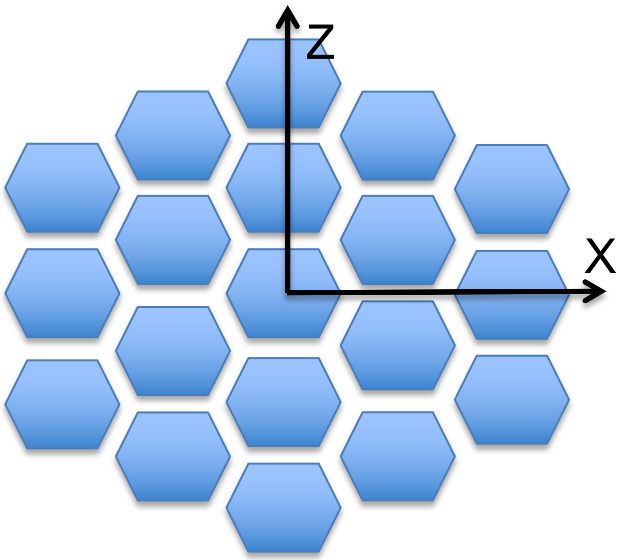
ALADInO calorimeter

Weight~(2300+300) kg
N. crystals: ~20.000



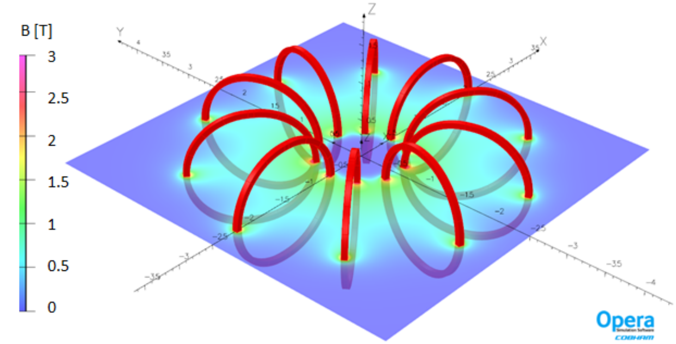


Basic crystal: hexagonal base prisma

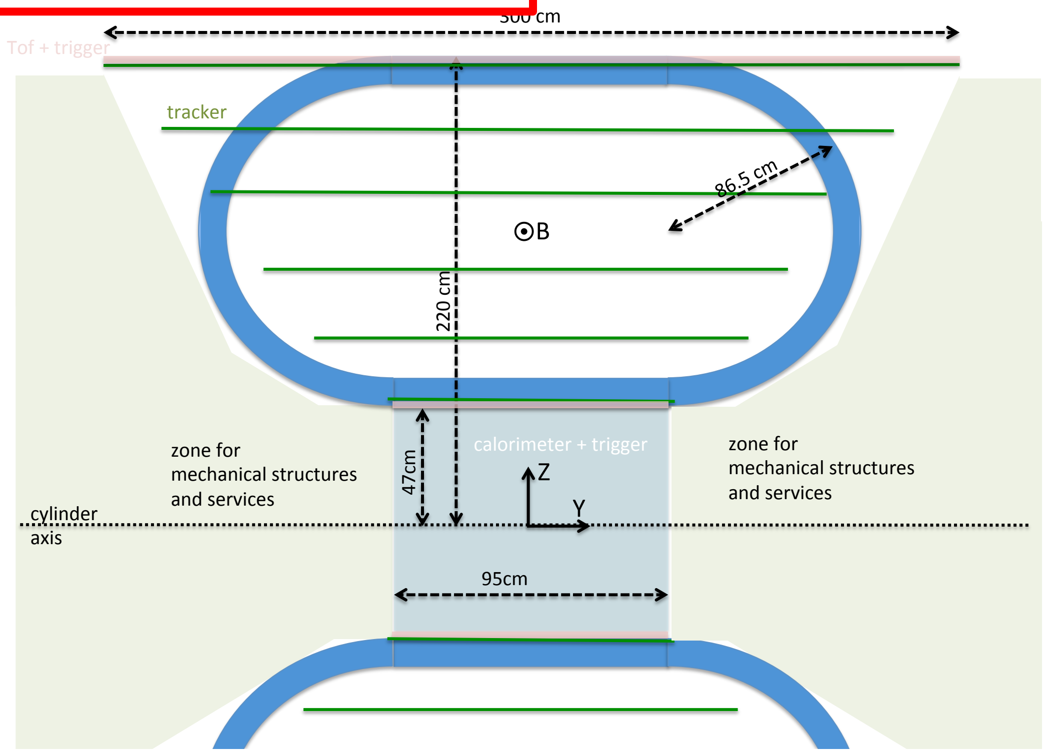


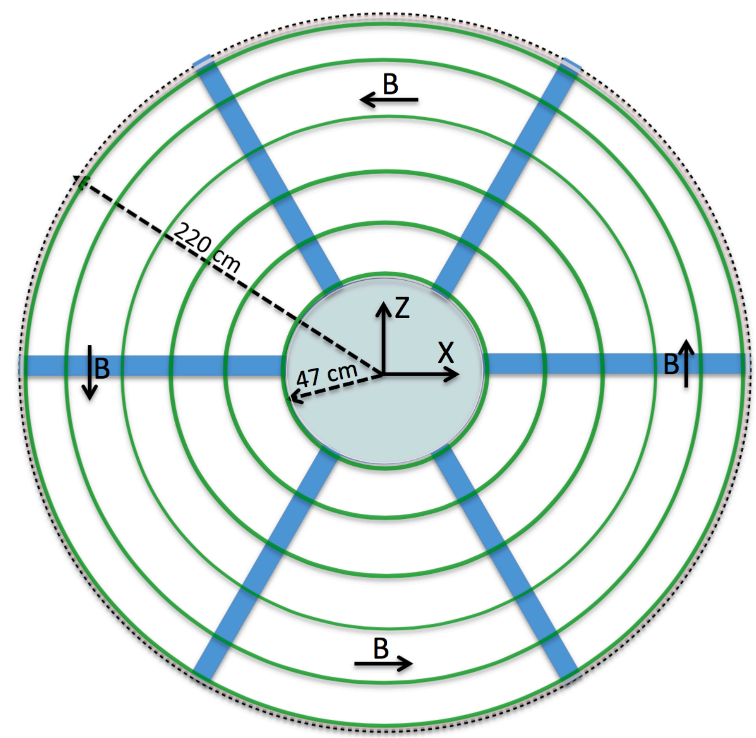
ALADInO magnet

Benefit from the R&D of high temperature superconducting magnets (MgB_2, YBCO and in particular REBCO) for space applications (T ≈ 15÷40° K)

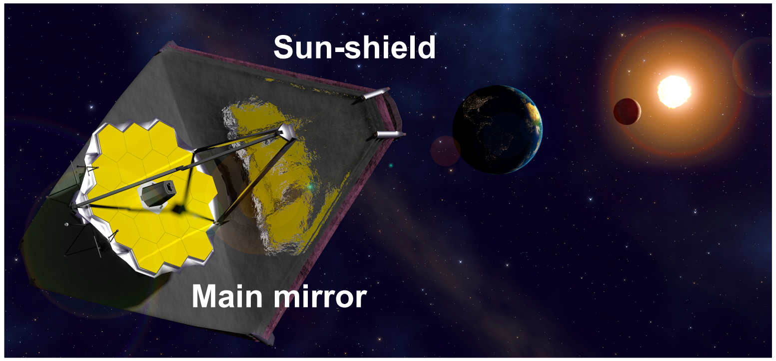


Field 0.8 T
Bending power > 1.1 T m
Weight ~ 1000 Kg

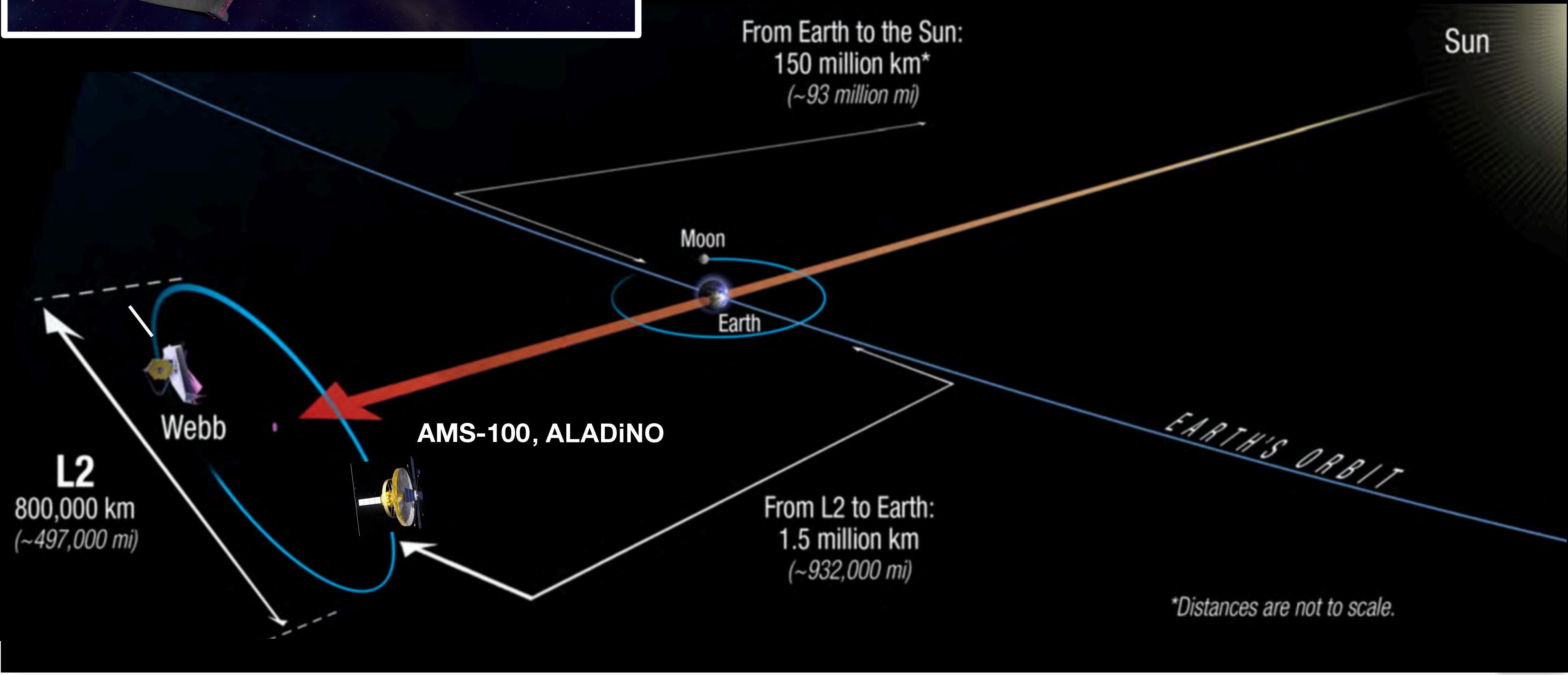




James Webb Telescope - L2



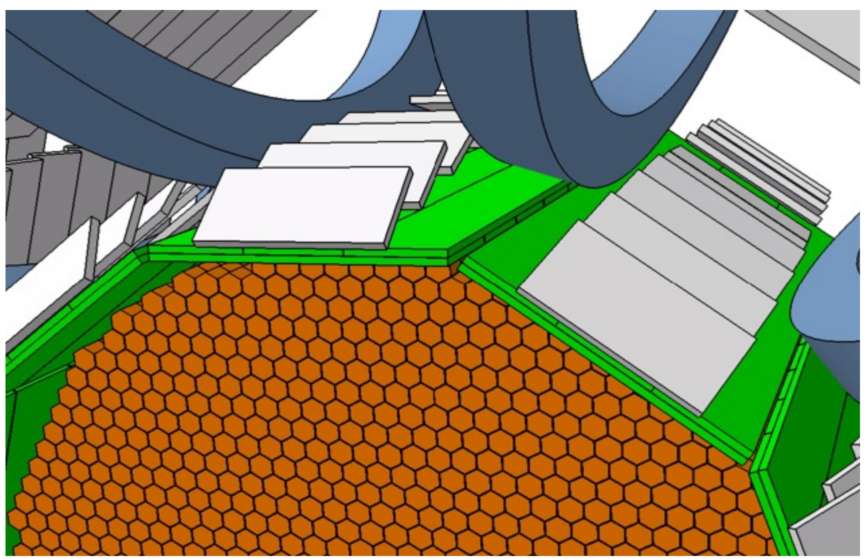
The best place where to operate a cryogenic superconducting magnet is the Lagrange Point 2, like the Webb space telescope

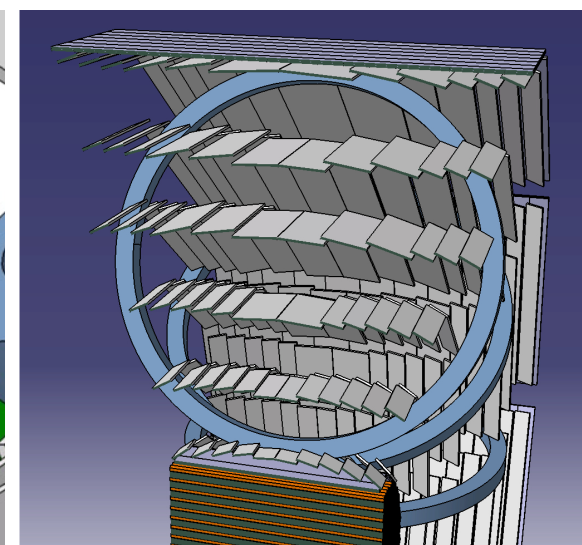


ALADInO performances

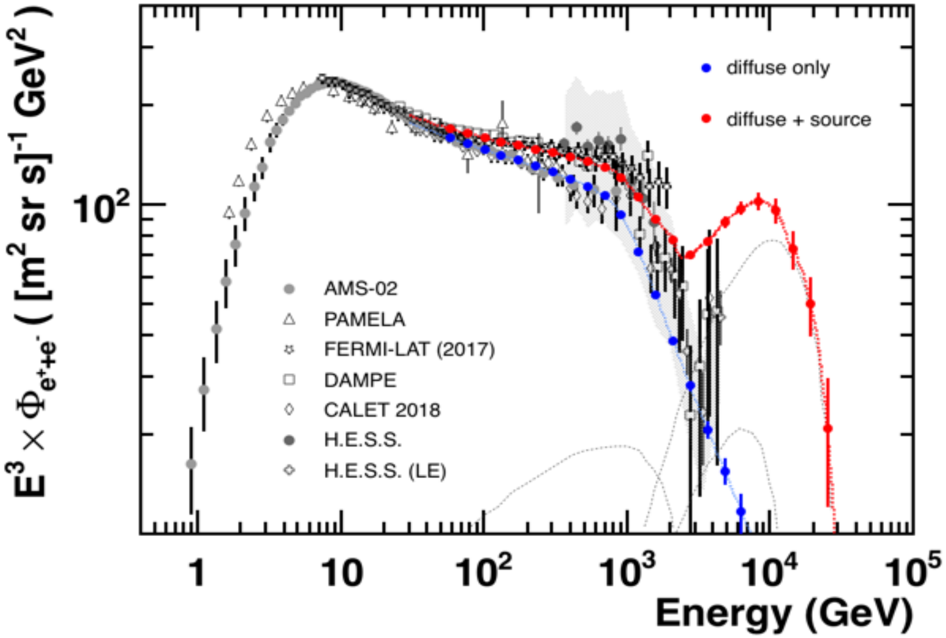
Calorimeter acceptance	~ 9 m^2 sr
Spectrometer acceptance	>10 m^2 sr (~ 3 m^2 sr w/i CALO)
Spectrometer Maximum Detectable Rigidity (MDR)	> 20 TV
Calorimeter depth	61 X_0, 3.5 λ_I
Calorimeter energy resolution	25% ÷ 35% (for nuclei) 2% (for electrons and positrons)
Calorimeter e/p rejection power	> 10^5
Time of Flight measurement resolution	~100 ps
High energy γ-ray acceptance (Calorimeter)	~ 9 m^2 sr
Low energy γ-ray acceptance (Tracker)	~ 0.5 m^2 sr
γ-ray Point Spread Function	< 0.5 deg

Weight: ~ 6 Tons
Power: ~ 4 kW
channels: 2.5 M





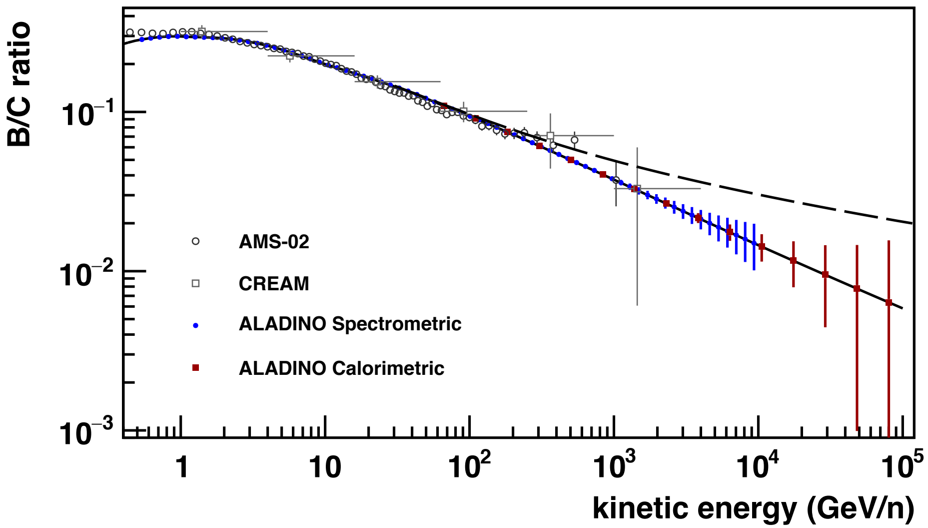
ALADInO capabilities



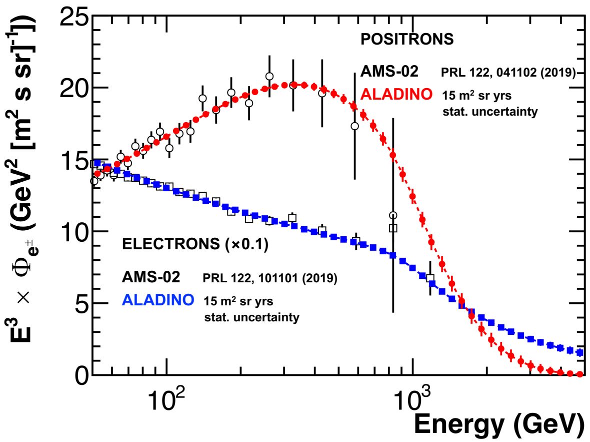
The calorimeter is slightly bigger than the HERD one but is very similar:

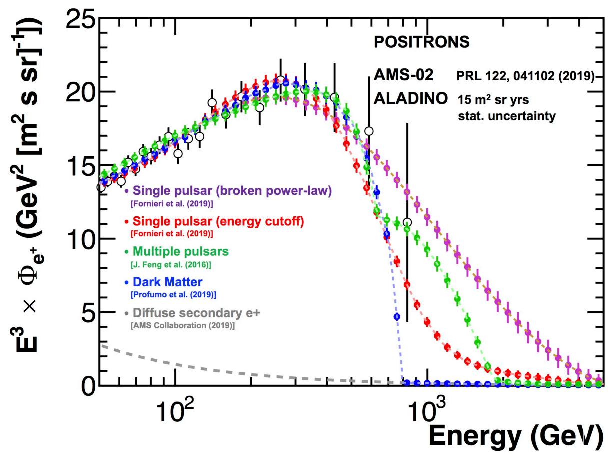
- similar statistical errors similar energy reach
- similar energy resolution, both for electromagnetic particles and nuclei

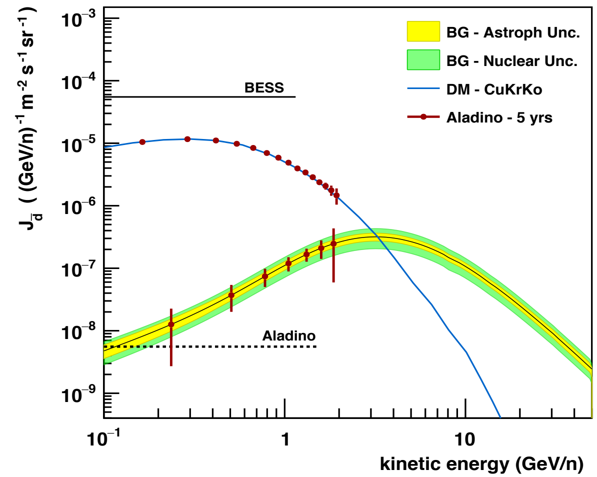
The possibility to crosscheck the Energy in the Calorimeter with the Rigidity (i.e. Momentum) in the Spectrometer will permit lower systematics

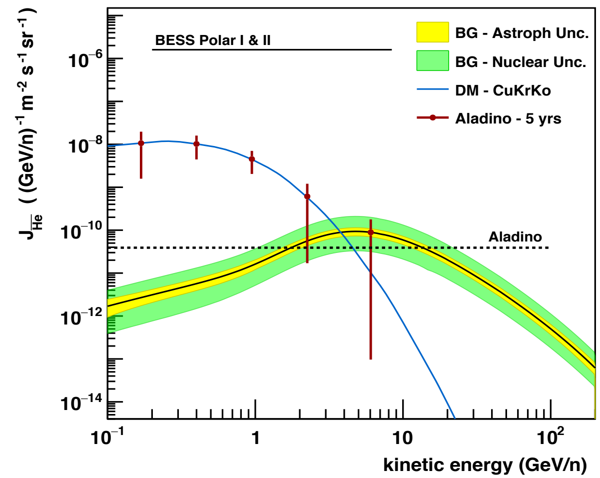


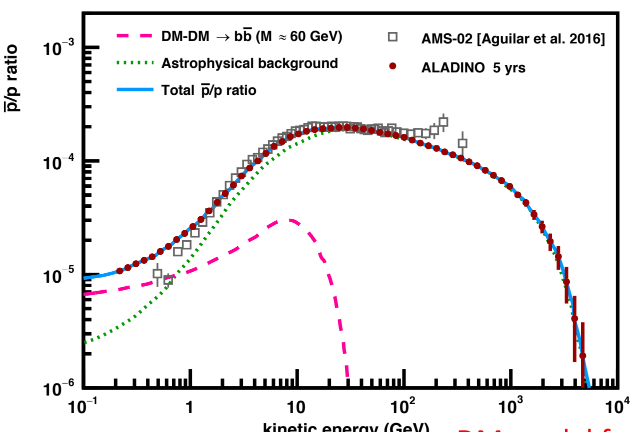
ALADInO capabilities

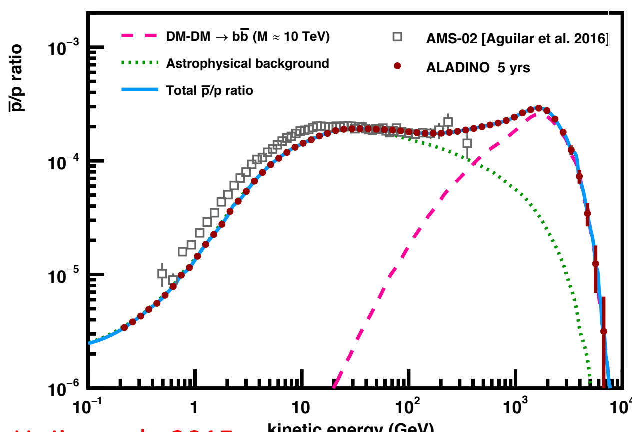










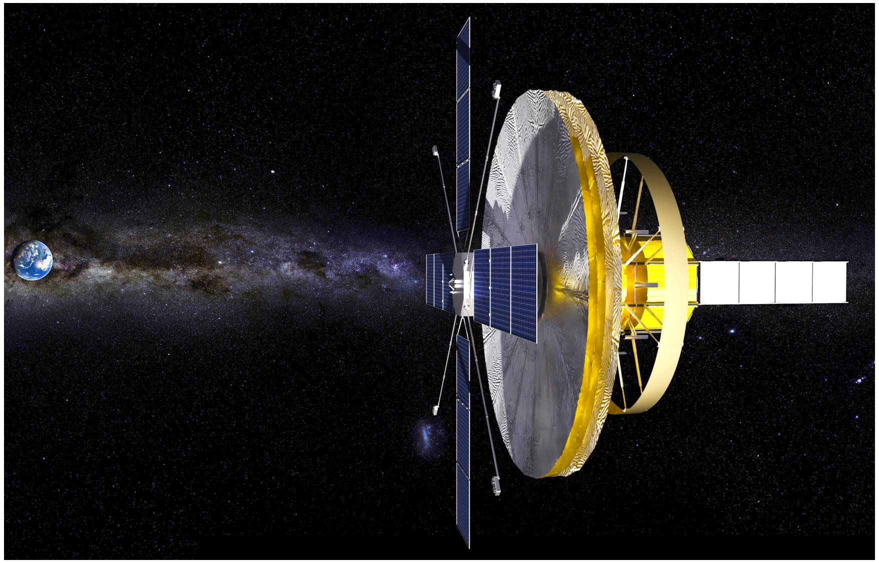


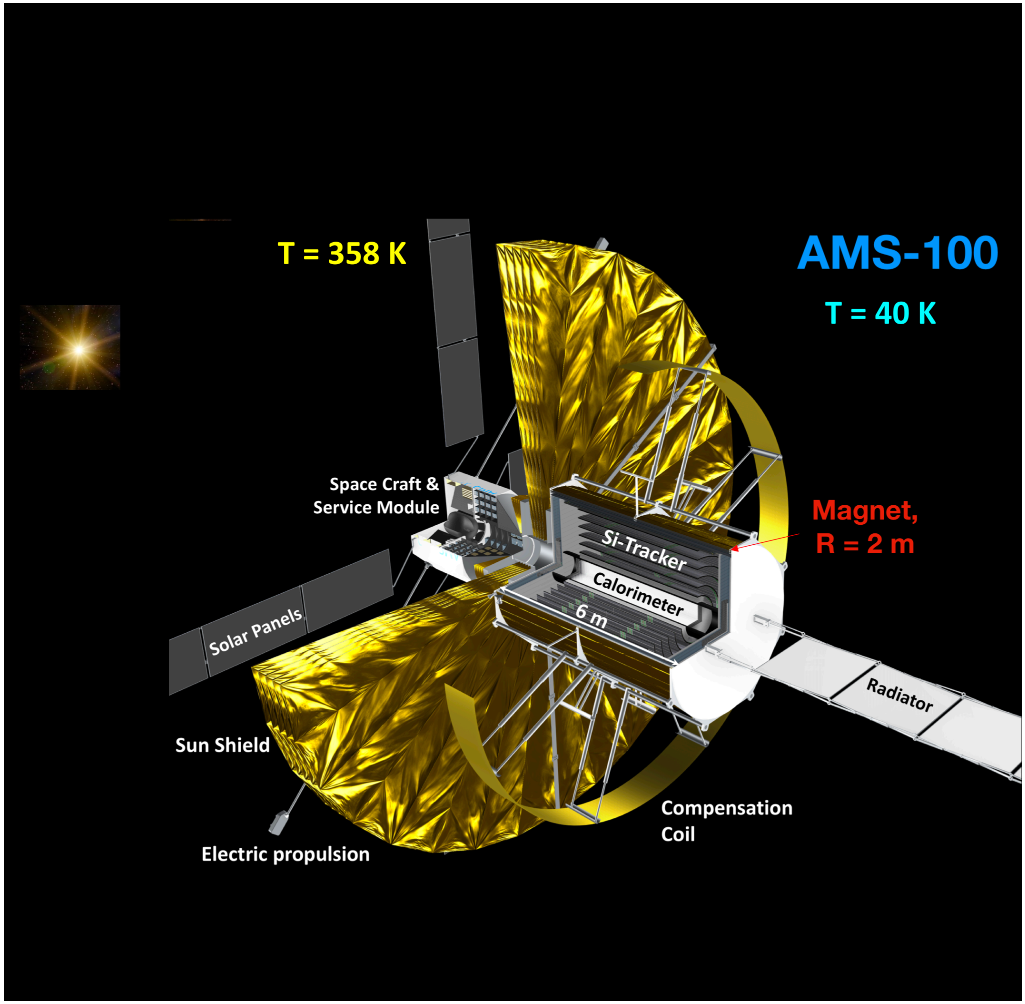
DM model from H. Jin et al., 2015, Phys. Rev. D 92, no. 5, 055027

DM model from A. Cuoco et al. 2017, Phys. Rev. Lett. 118, 191102, M. Korsmeier et al., 2018, Phys. Rev. D 97 n.10, 103011
BKG model from N. Tomassetti and A. Oliva, 2017, ApJ Lett. 844

AMS-100 (in L2)

AMS-100
The Next Generation Magnetic Spectrometer in Space –
An International Science Platform for Physics and Astrophysics at
Lagrange Point 2

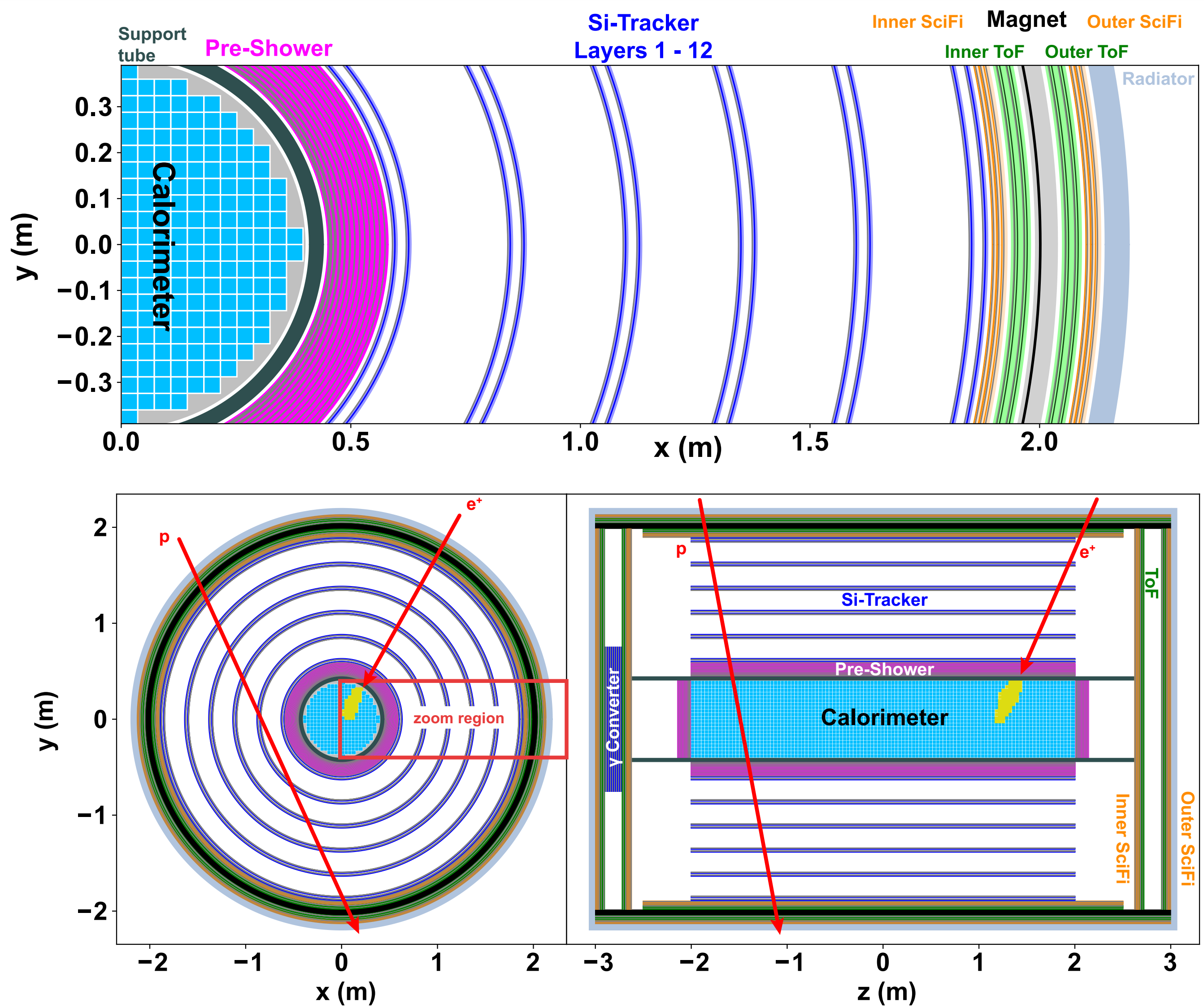




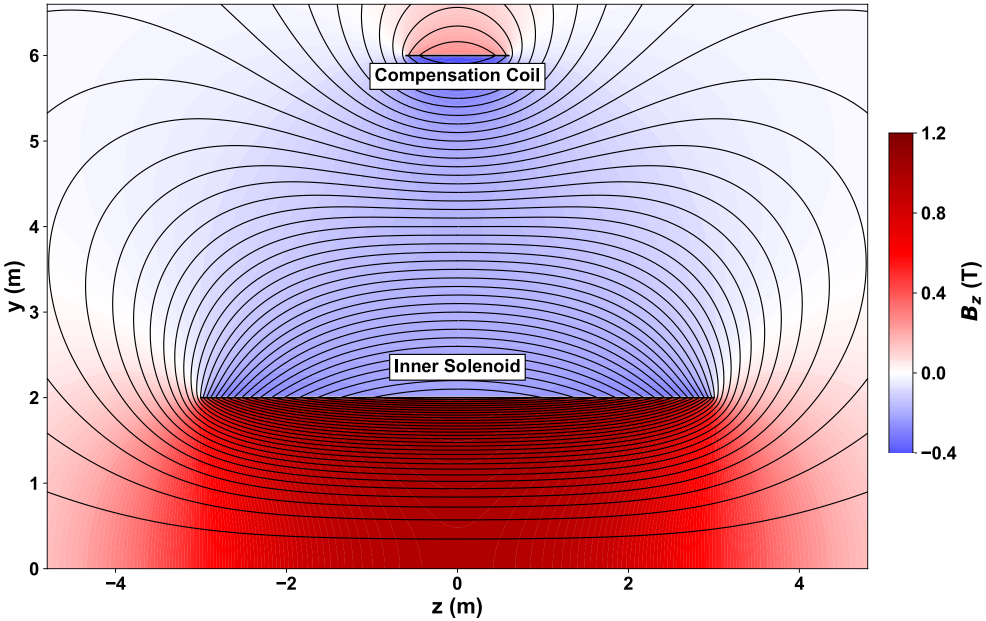
https://www.cosmos.esa.int/web/voyage-2050/white-papers
https://www.cosmos.esa.int/documents/1866264/3219248/SchaelS_AMS100_Voyage2050.pdf
arXiv:1907.04168v1 [astro-ph.IM] 9 Jul 2019

AMS-100 detector

- The Calorimeter is essentially based on the HERD design
- A Pre-Shower (silicon detectors + tungsten) is foreseen to provide an angular resolution for γ-rays similar to the Fermi-LAT one
- An additional external γ-ray converter on the end-cap is foreseen to increase the γ-ray acceptance



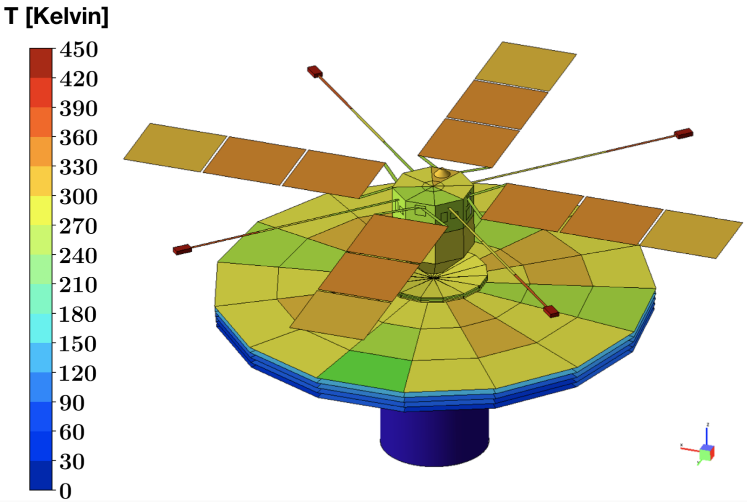
AMS-100 magnet and thermal system

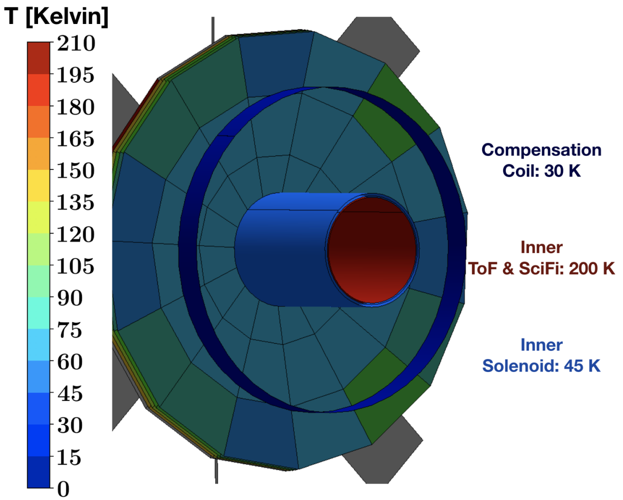


An (expandable) compensation coil balances the magnetic moment of the solenoid and allows the attitude control of the instrument within the heliospheric magnetic field

The High Temperature Superconducting magnetic system is based on REBCO tapes operated at 50-60° K

The sunshield is a key component of AMS-100, allowing the HTS magnet to operate without cryogens. It has a radius of 9 m and is designed similar to the concept developed for the James Webb Space Telescope

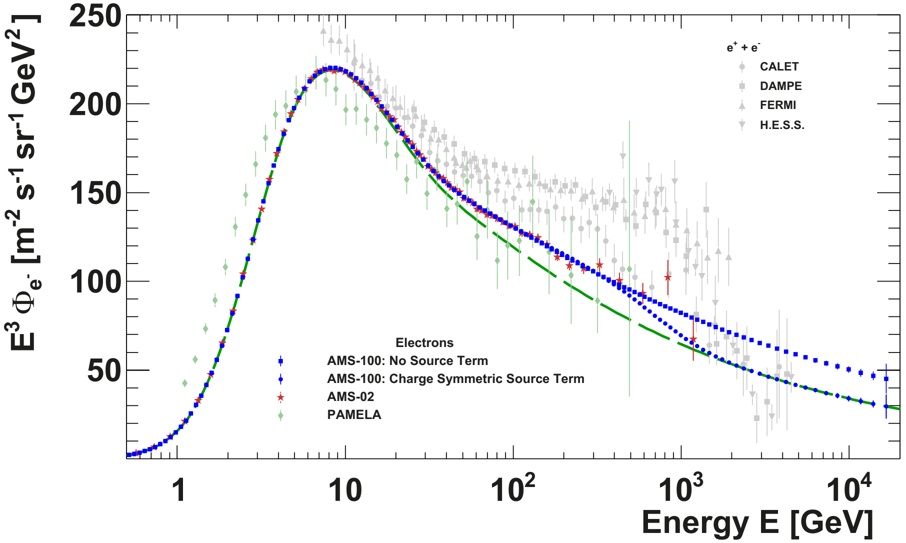


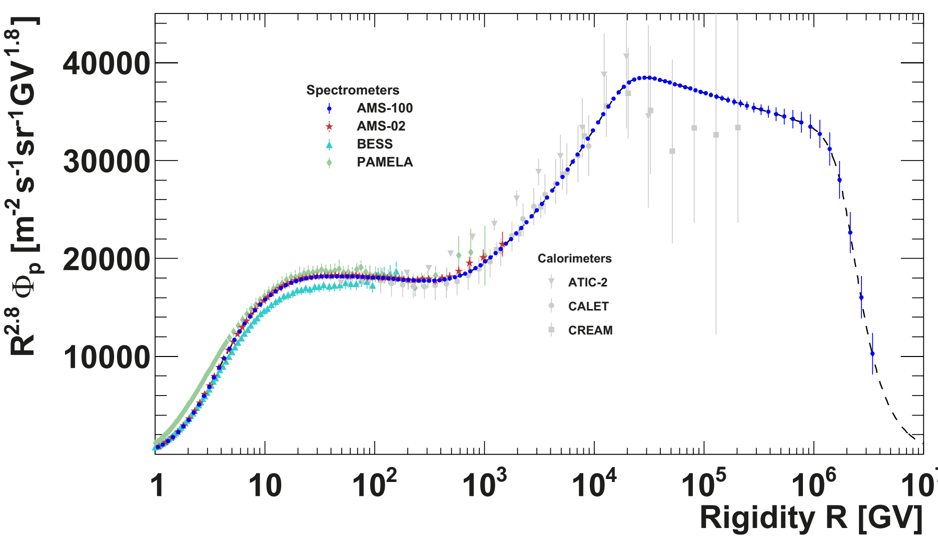


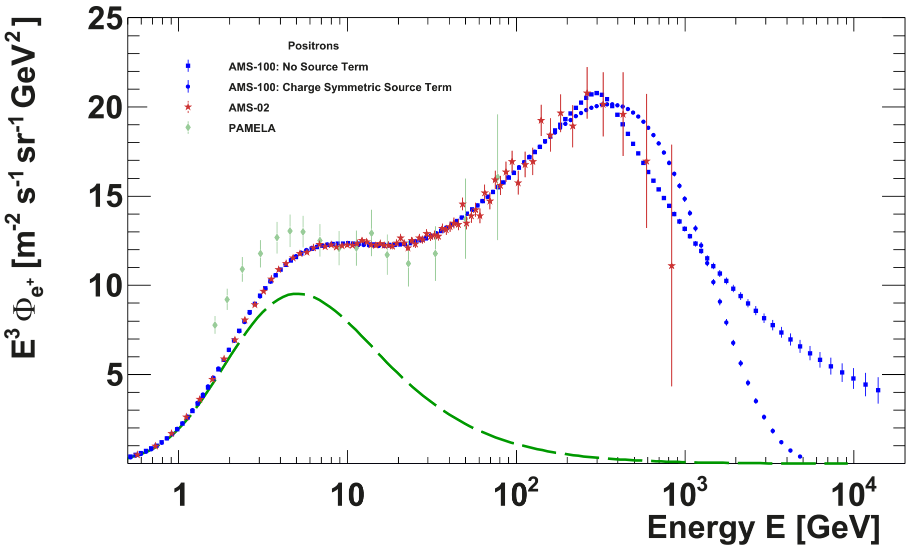
AMS-100 performances

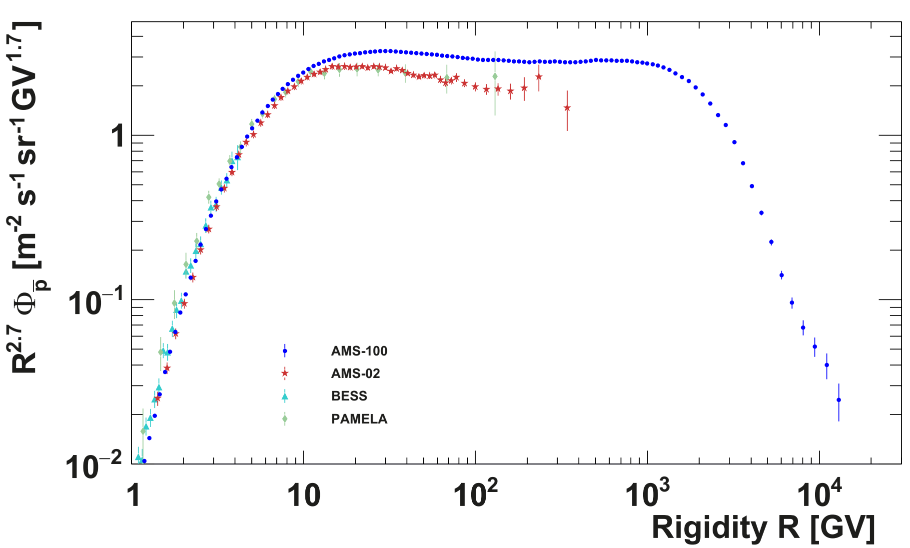
Quantity	Value	
Acceptance	$100\,\mathrm{m}^2\,\mathrm{sr}$	
MDR	100 TV	for $\|Z\| = 1$
Material budget	$0.12\,X_0$	
of main solenoid	$0.012\,\lambda_I$	
Calorimeter depth	$70\,X_0,\ 4\,\lambda_I$	
Energy reach	10^{16} eV	for nucleons
	10 TeV	for e^+, $\bar{p}$
	8 GeV/n	for $\bar{D}$
Angular resolution	4″	for photons at 1 TeV
	0″.4	for photons at 10 TeV
Spatial resolution (SciFi)	40 µm	
Spatial resoultion (Si-Tracker)	5 µm	
Time resolution of single ToF bar	20 ps	
Incoming particle rate	2 MHz	
High-level trigger rate	few kHz	
Downlink data rate	∼28 Mbps	
Instrument weight	43 t	
Number of readout channels	8 million	
Power consumption	15 kW	
Mission flight time	10 years	

AMS-100 capabilities

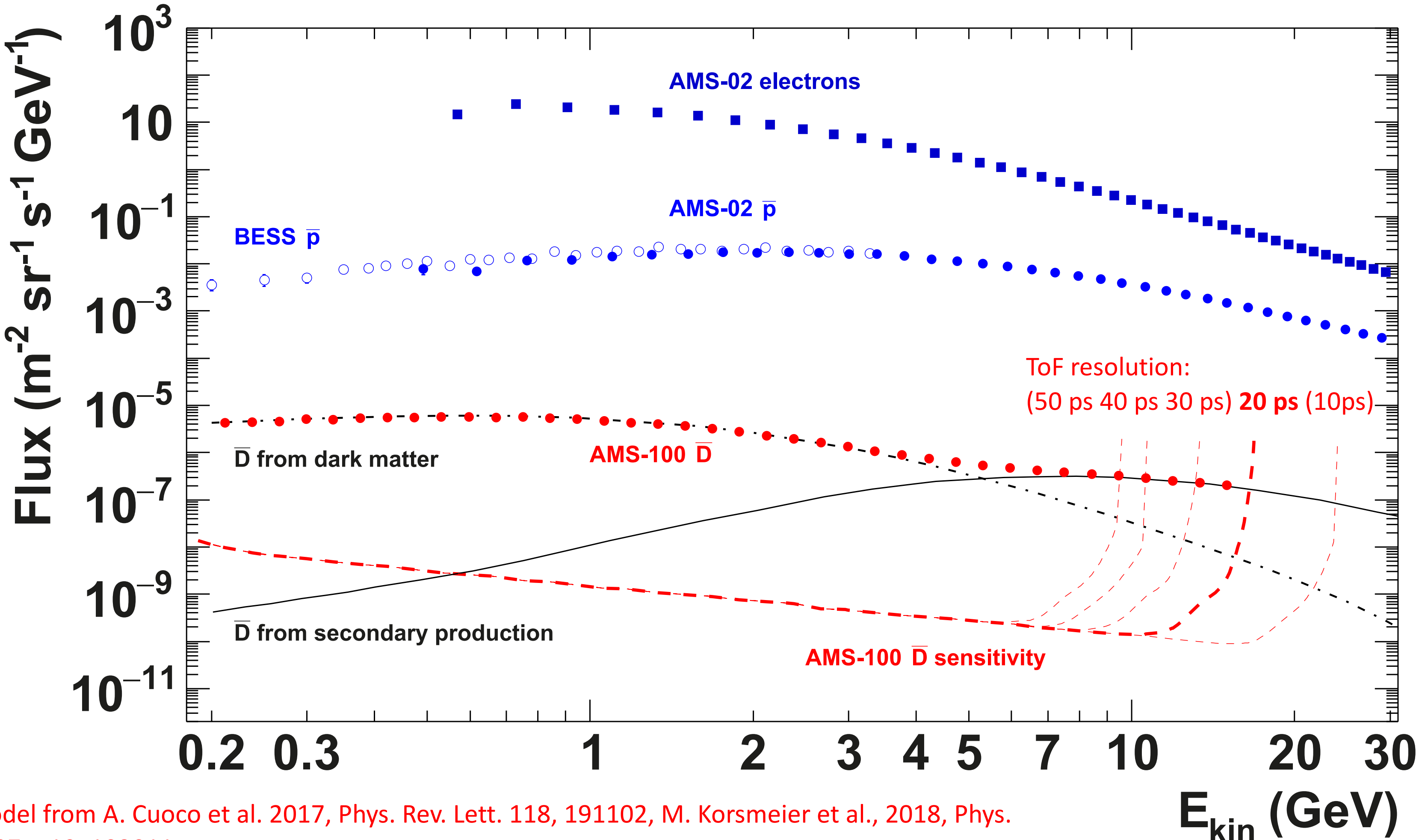








AMS-100 capabilities



DM model from A. Cuoco et al. 2017, Phys. Rev. Lett. 118, 191102, M. Korsmeier et al., 2018, Phys. Rev. D 97 n.10, 103011

BKG model from S.-J. Lin, X.-J. Bi, and P.-F. Yin, arXiv e-prints (2018). arXiv:1801.00997.

For anti-He the expected sensitivity is ~ 10^{-11}

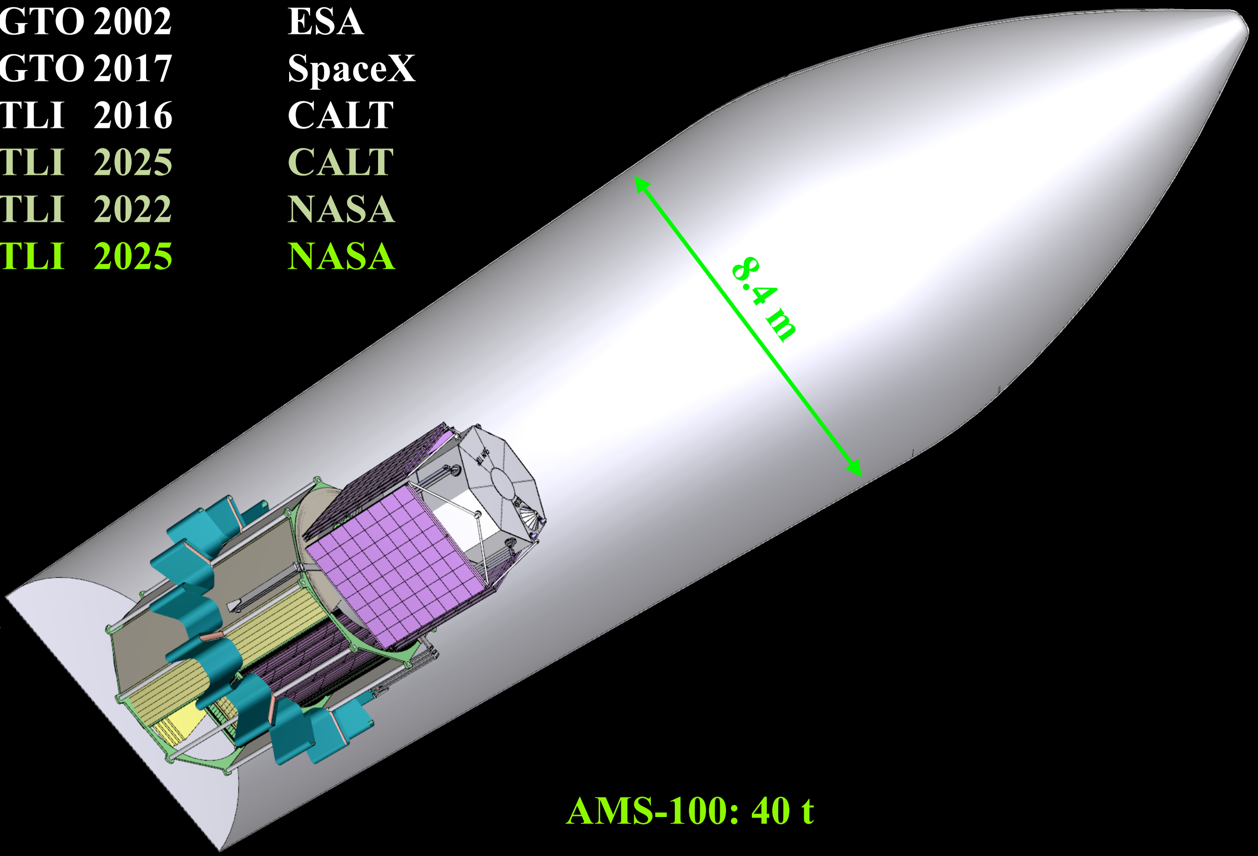
AMS-100 launcher

Current and upcoming rockets

Name	LEO [kg]	other [kg]	First flight	
Ariane 5	21,000	10,730 GTO	2002	ESA
Falcon Heavy	63,800	26,700 GTO	2017	SpaceX
Long March 5	25,000	8,000 TLI	2016	CALT
Long March 9	130,000	50,000 TLI	2025	CALT
SLS Block 1B	105,000	39,100 TLI	2022	NASA
SLS Block 2	130,000	45,000 TLI	2025	NASA

Operational
Under development

LEO: Low Earth orbit
GTO: Geostationary transfer orbit
TLI: Trans-lunar injection

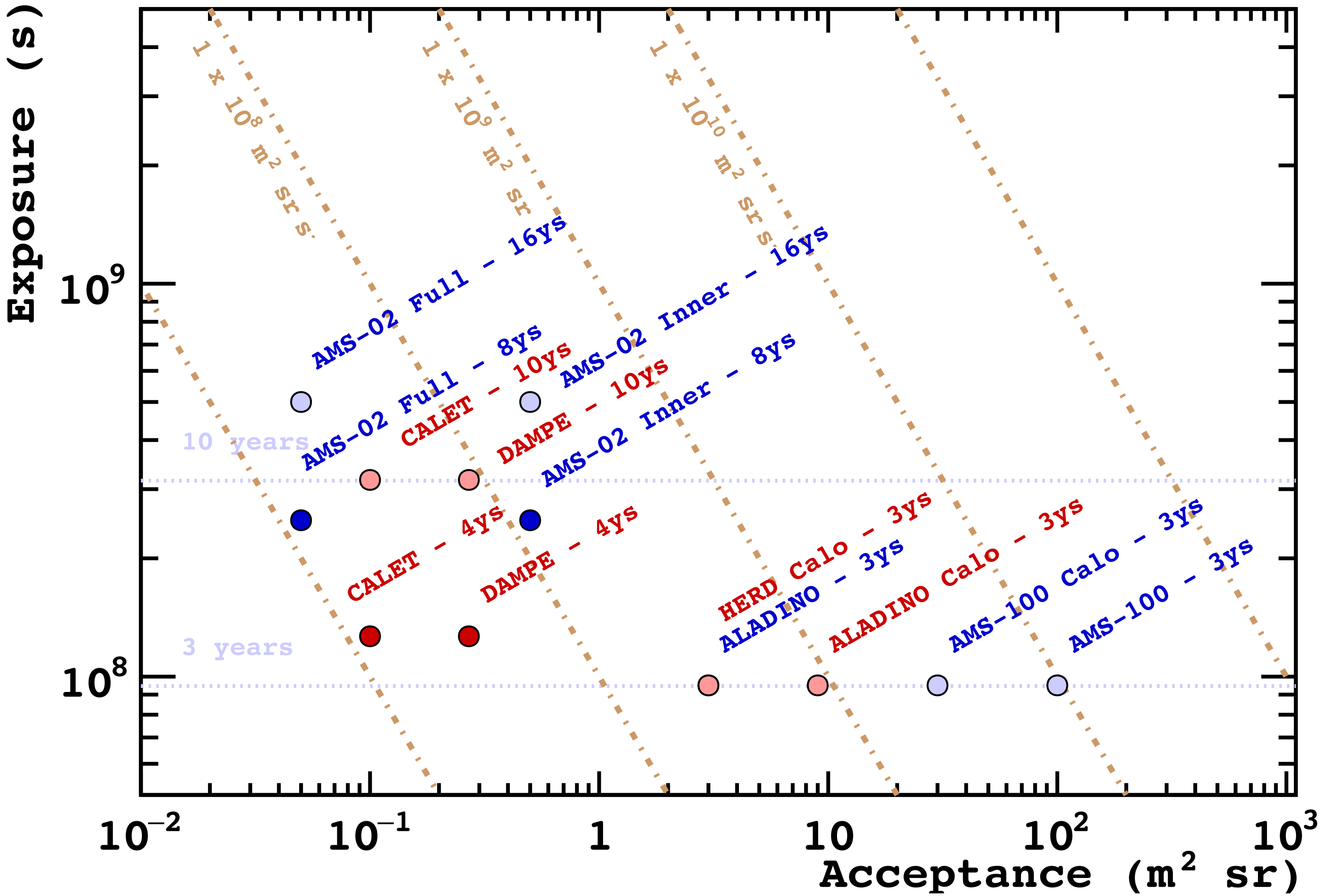


AMS-100: 40 t

Instrument performances

Item	HERD	ALADINO	AMS-100
Electromagnetic calorimeter depth	55 X_0	61 X_0	70 X_0
Hadronic calorimeter depth	3 λ_I	3.5 λ_I	4 λ_I
MDR	-	20 TV	100 TV
Acceptance (spectrometer)	-	~ 10 m^2 sr	~ 100 m^2 sr
Acceptance (spectrometer + calorimeter	-	~ 3 m^2 sr	~ 30 m^2 sr
Acceptance (calorimeter)	~ 3 m^2 sr	~ 9 m^2 sr	~ 30 m^2 sr
# of channels	300 k	2.5 M	8 M
Weight	~ 4000 kg	~ 6000 kg	~ 40000 kg
Power Consumption	~ 1400 W	~ 4000 W	~ 15000 W

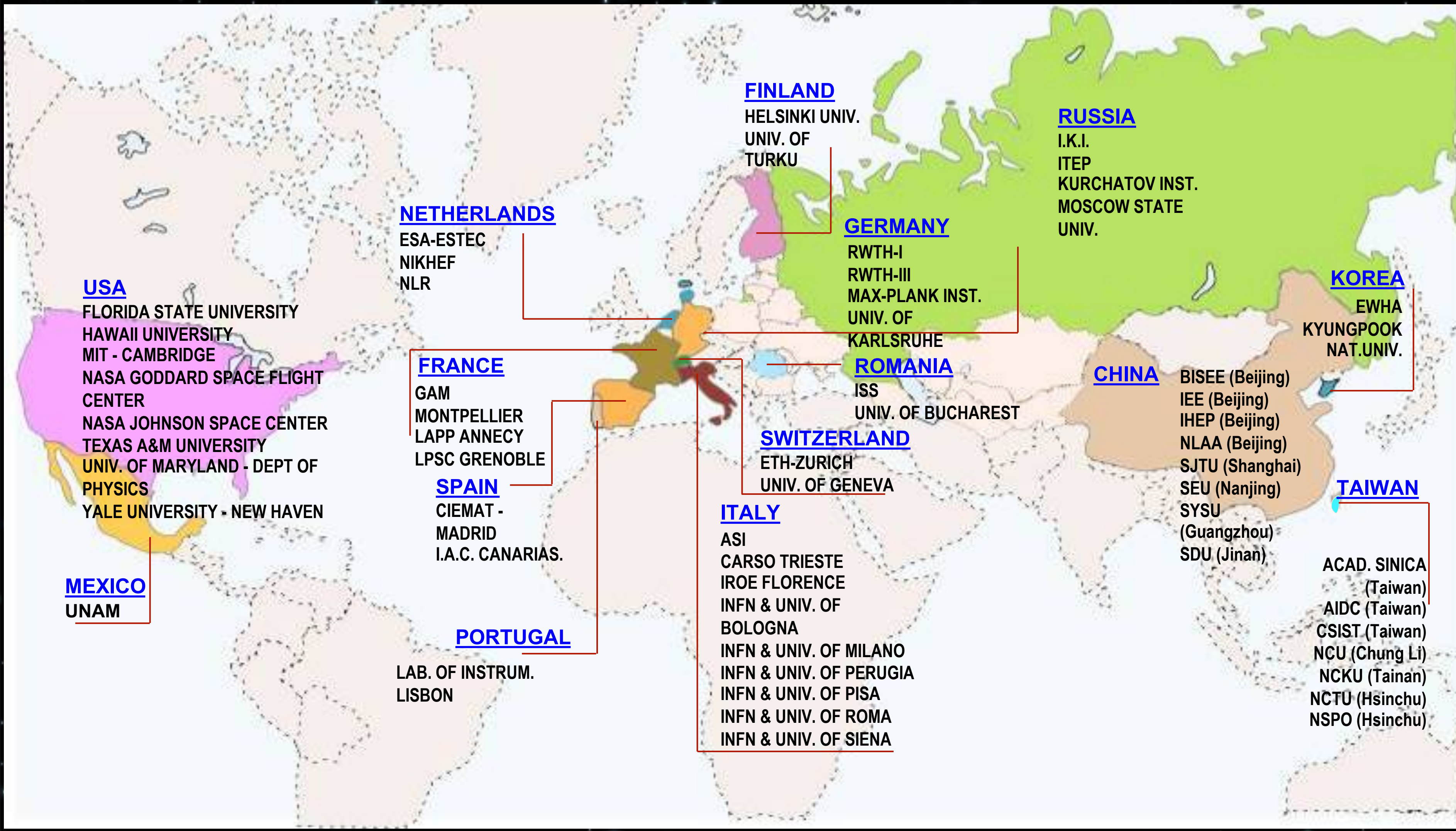
Current operating and future/possibile experiments



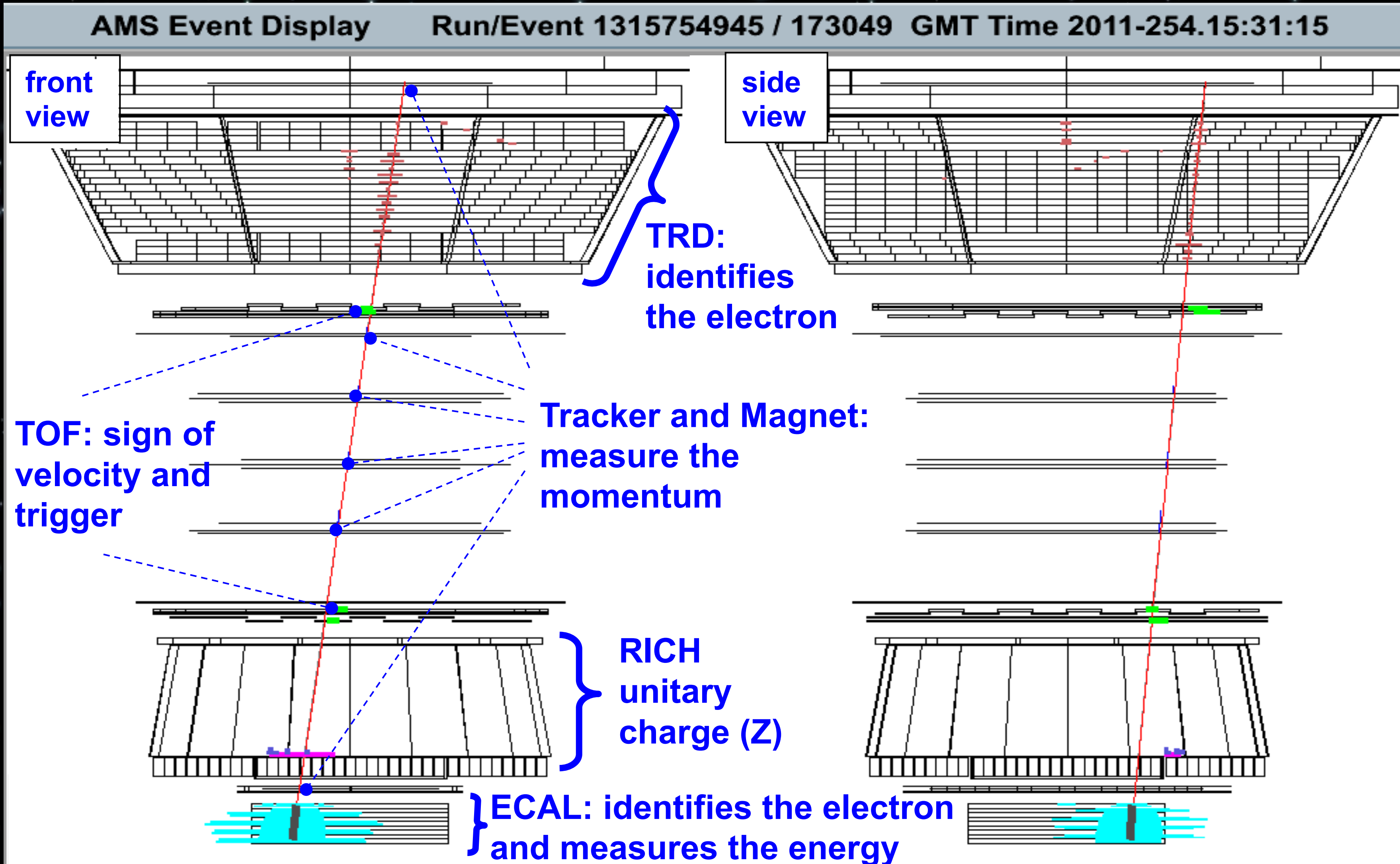
Stay tuned...

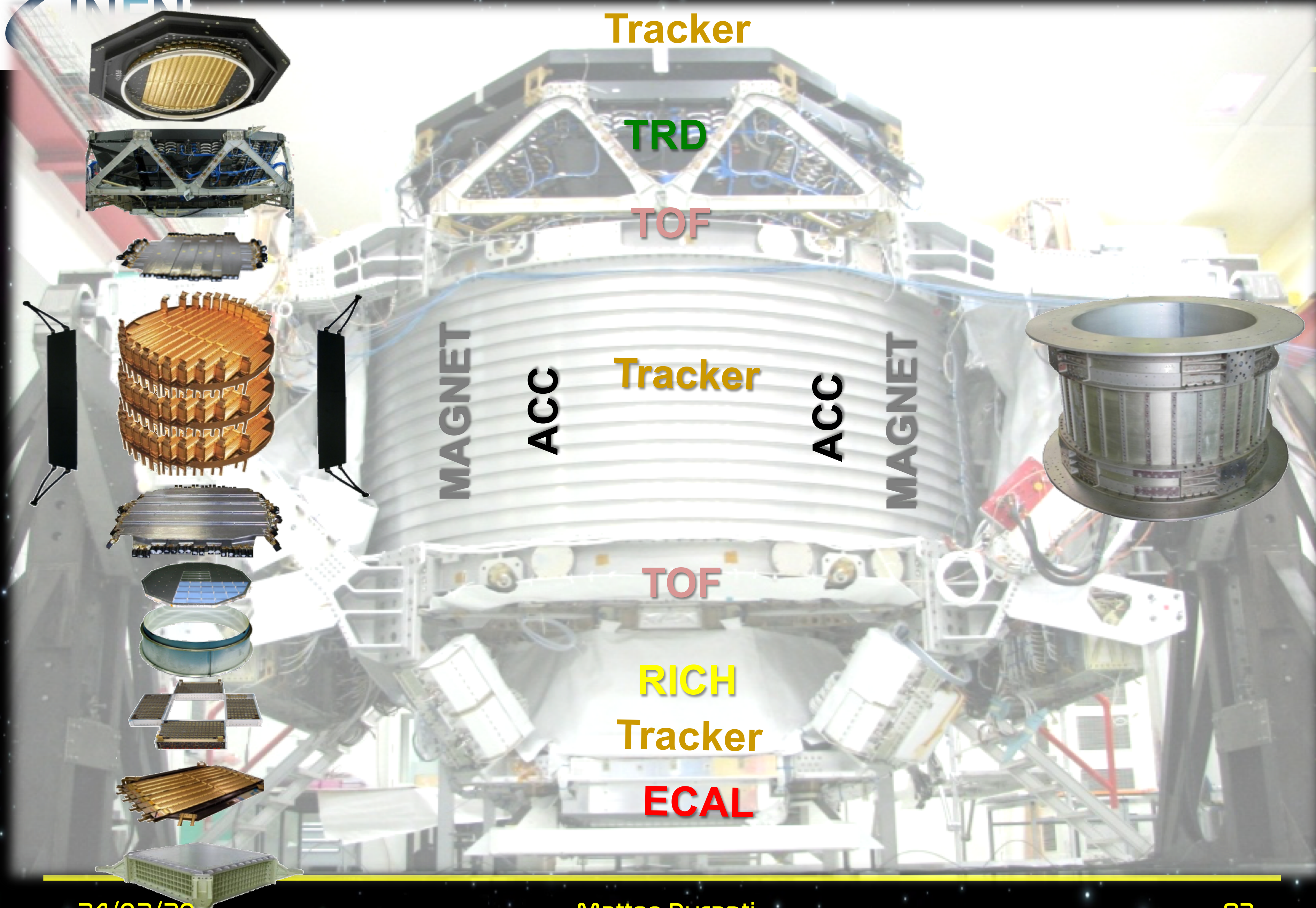
Backup

16 Nations, 60 Institutes e 600 Researchers

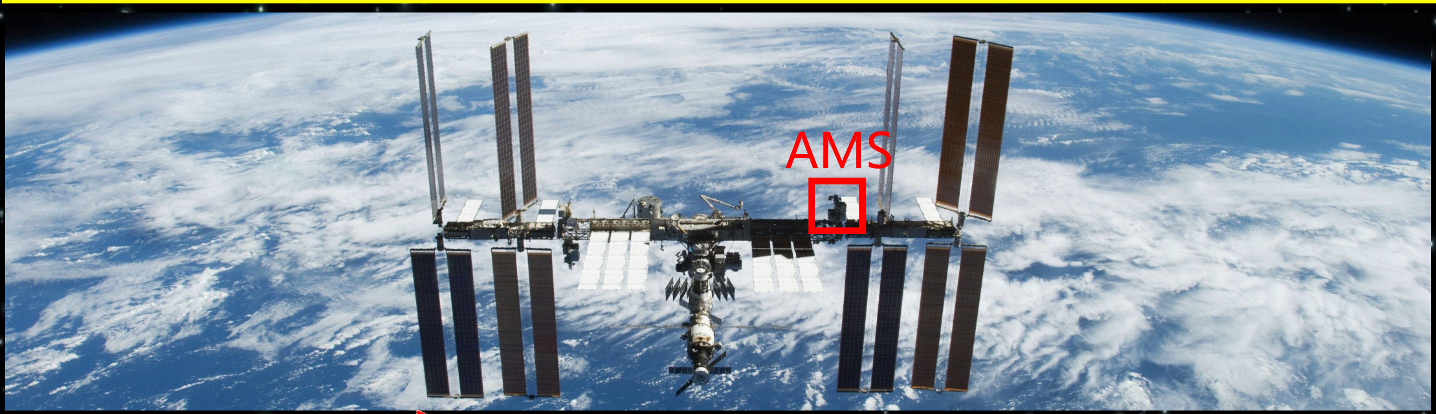


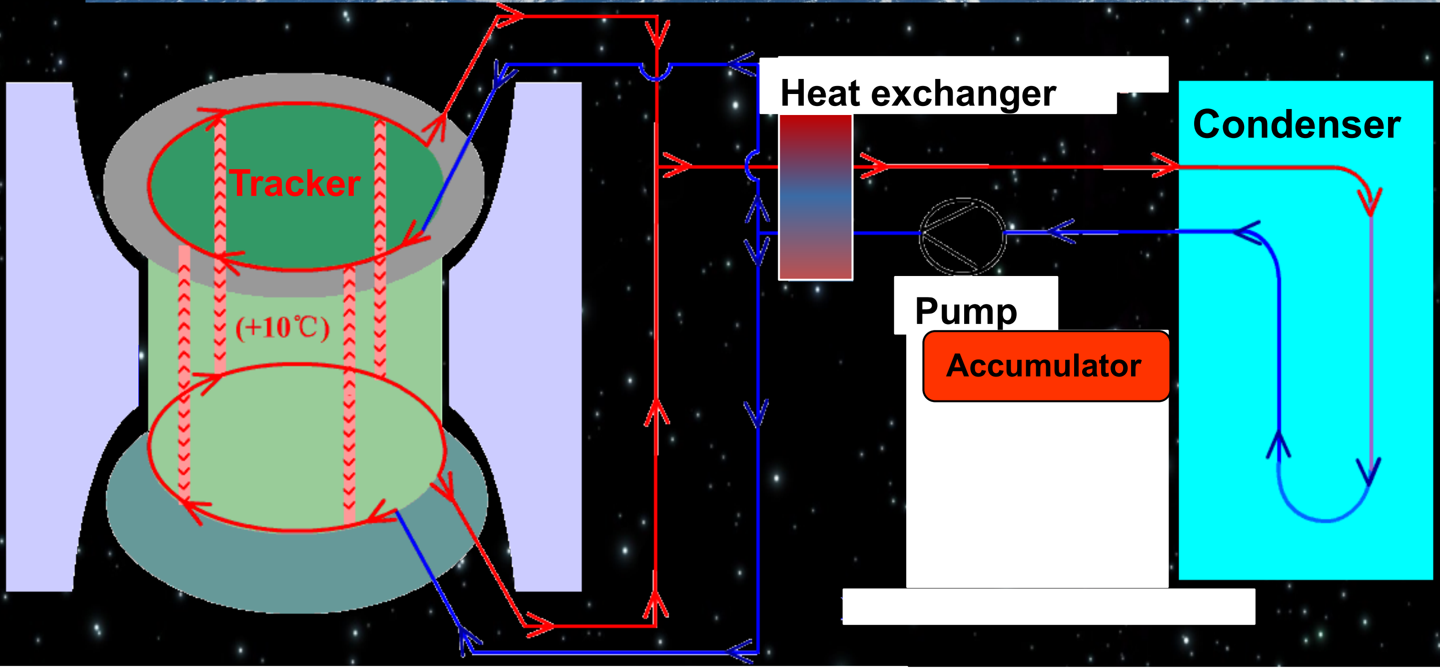
ISS Data – 1.03 TeV Electrons




Tracker
TRD
TOF
MAGNET
ACC
Tracker
ACC
MAGNET
TOF
RICH
Tracker
ECAL

Thermal Control of the AMS-02 Silicon Tracker



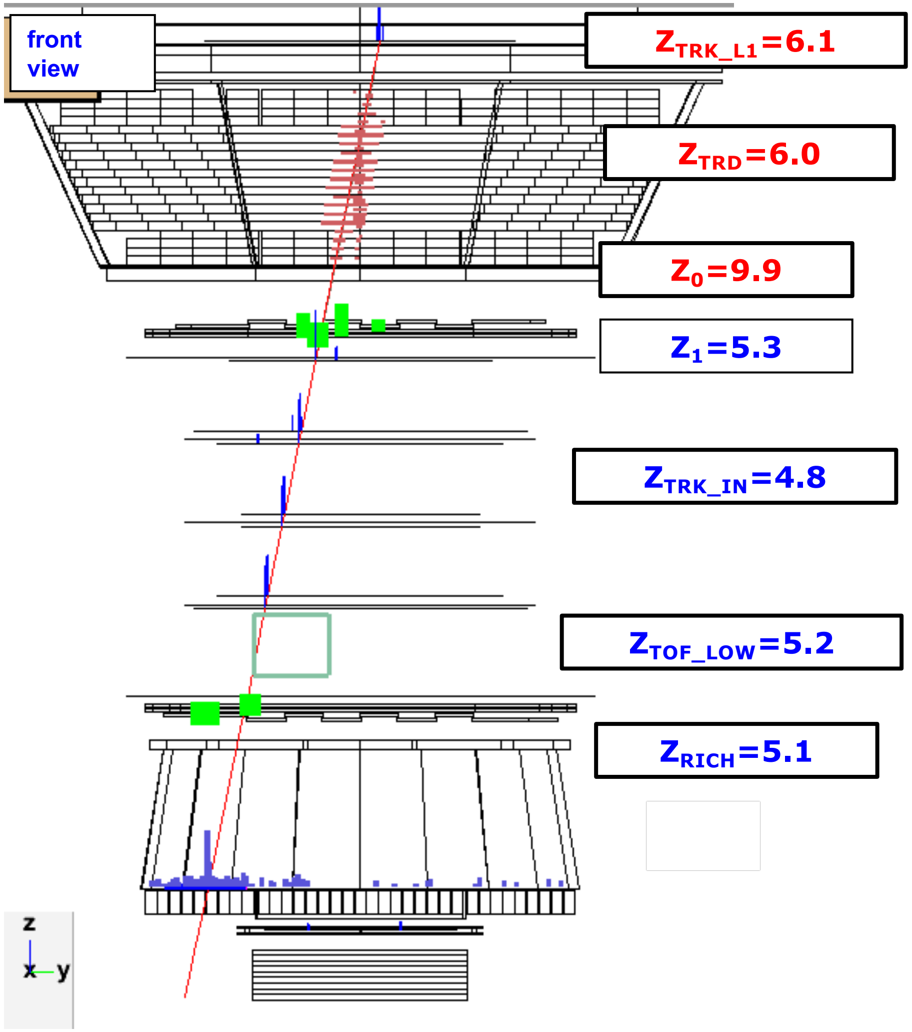


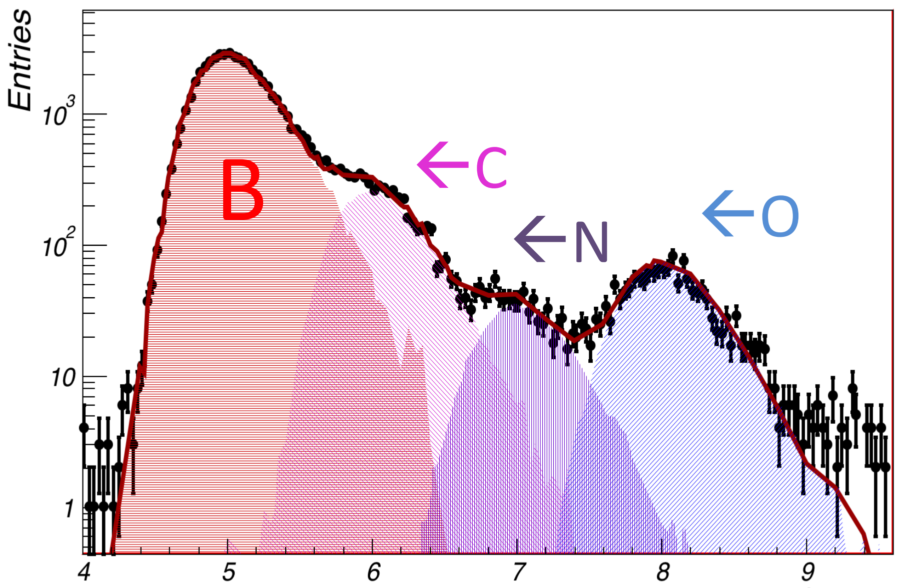
Red line: CO_2 gas/liquid two phase Blue line: CO_2 liquid phase

#SpacewalkforAMS

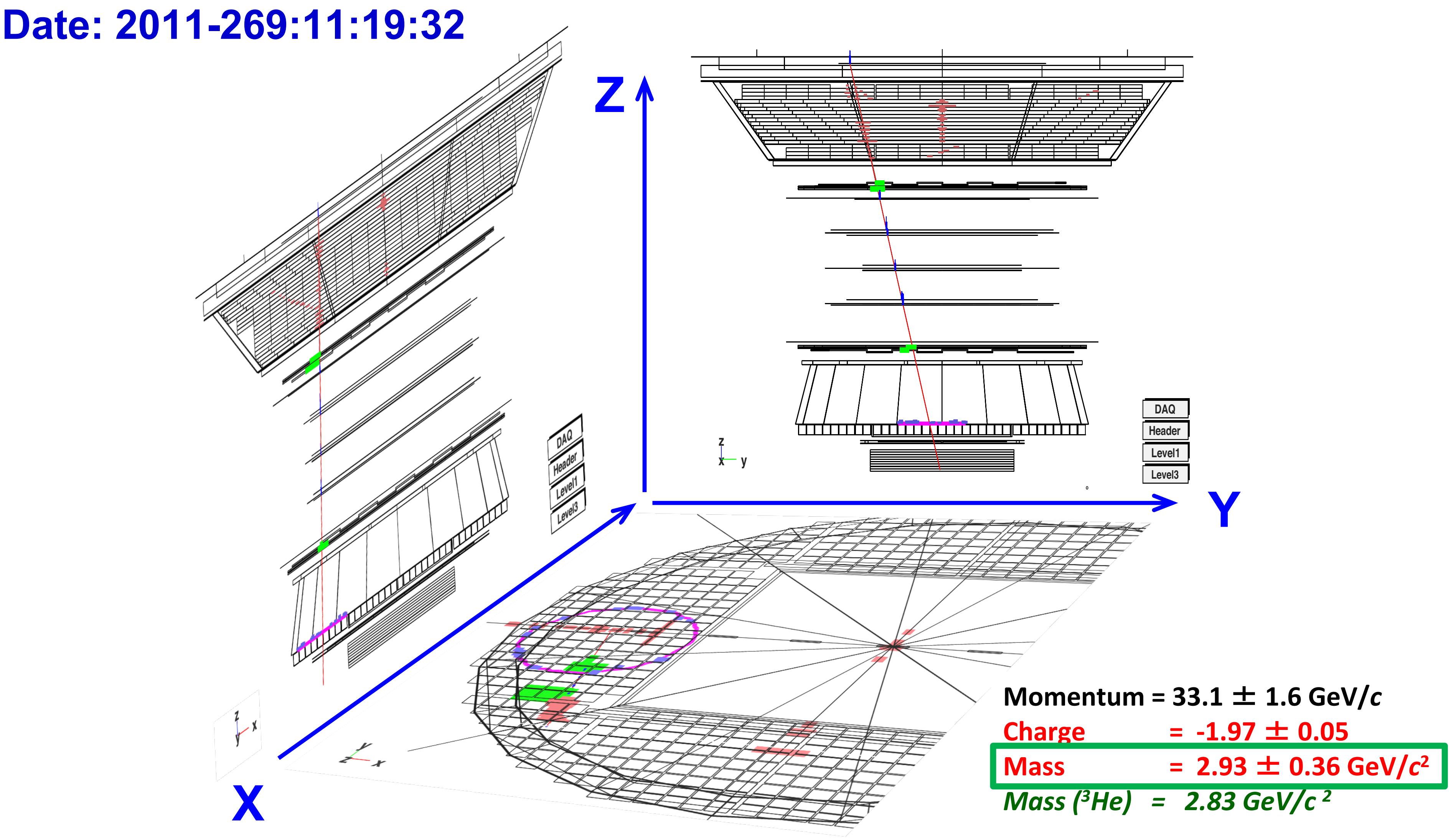
15 November 2019

Control of fragmentation inside the detector

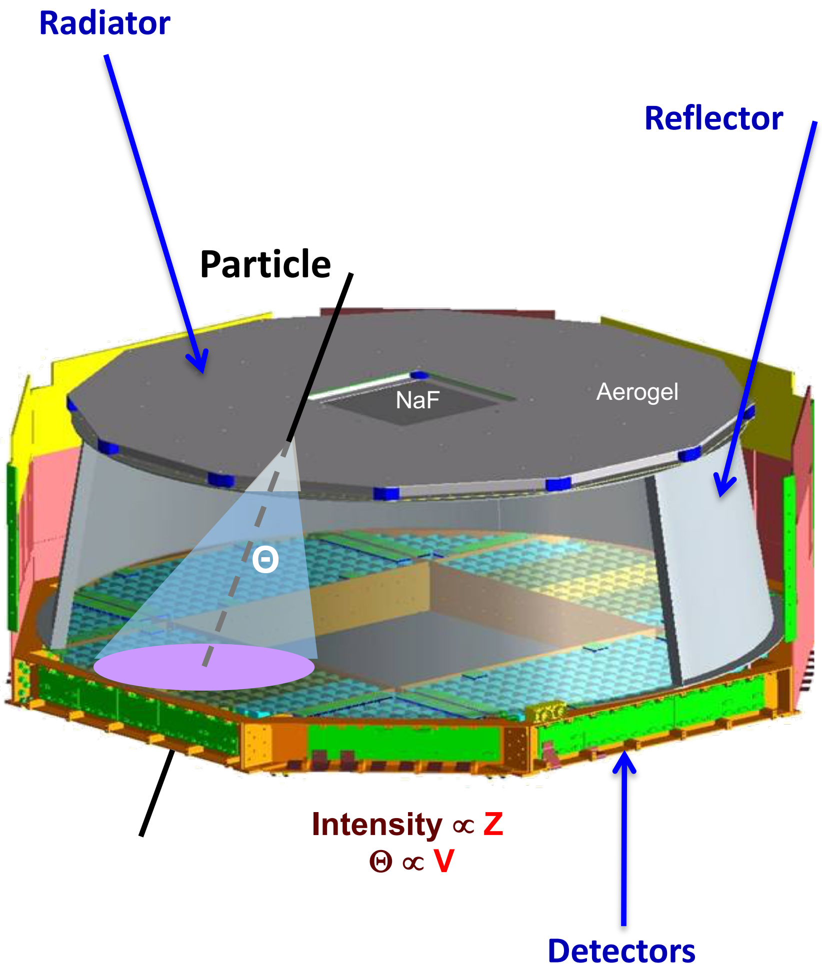


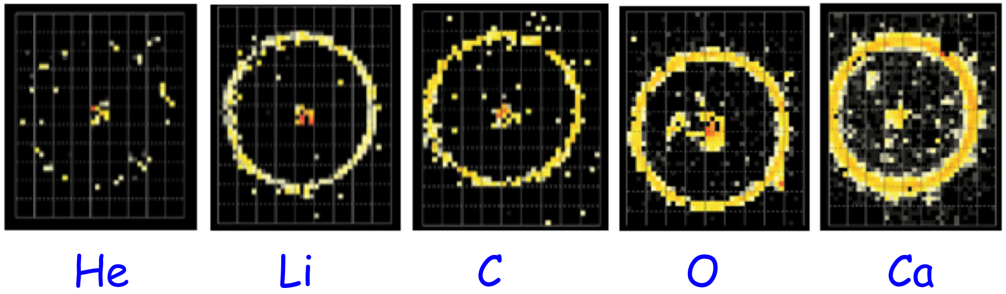


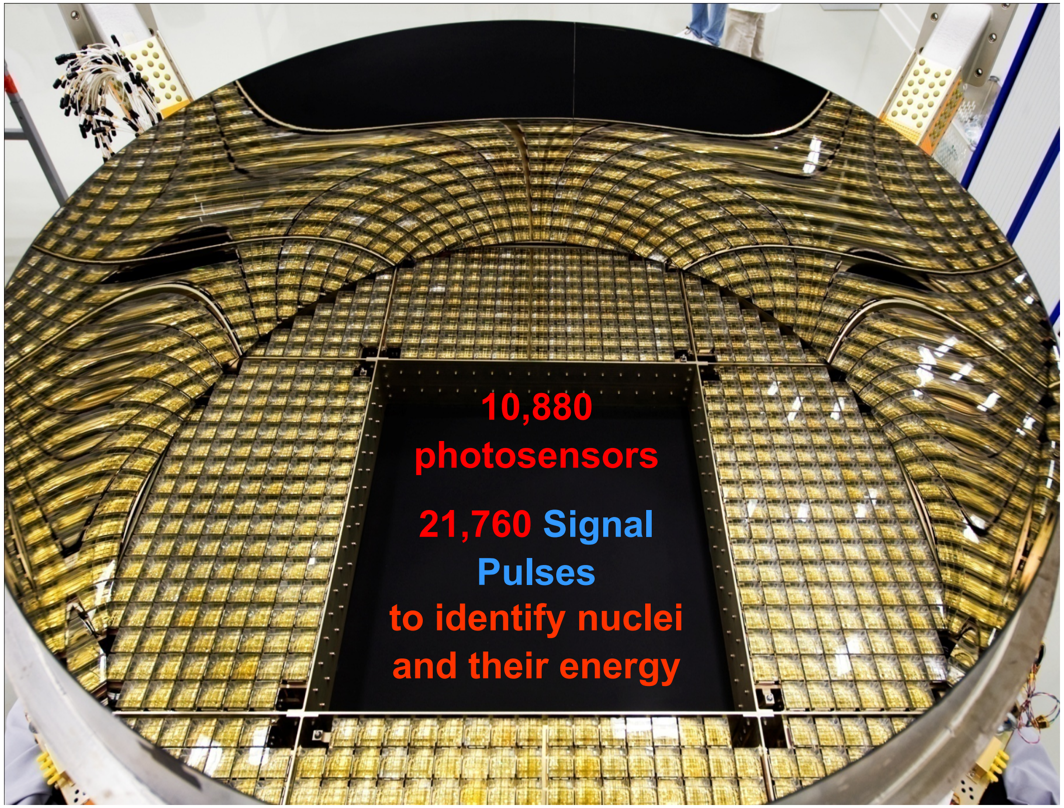
Key concepts/detectors



AMS-02 Ring Imaging CHerenkov

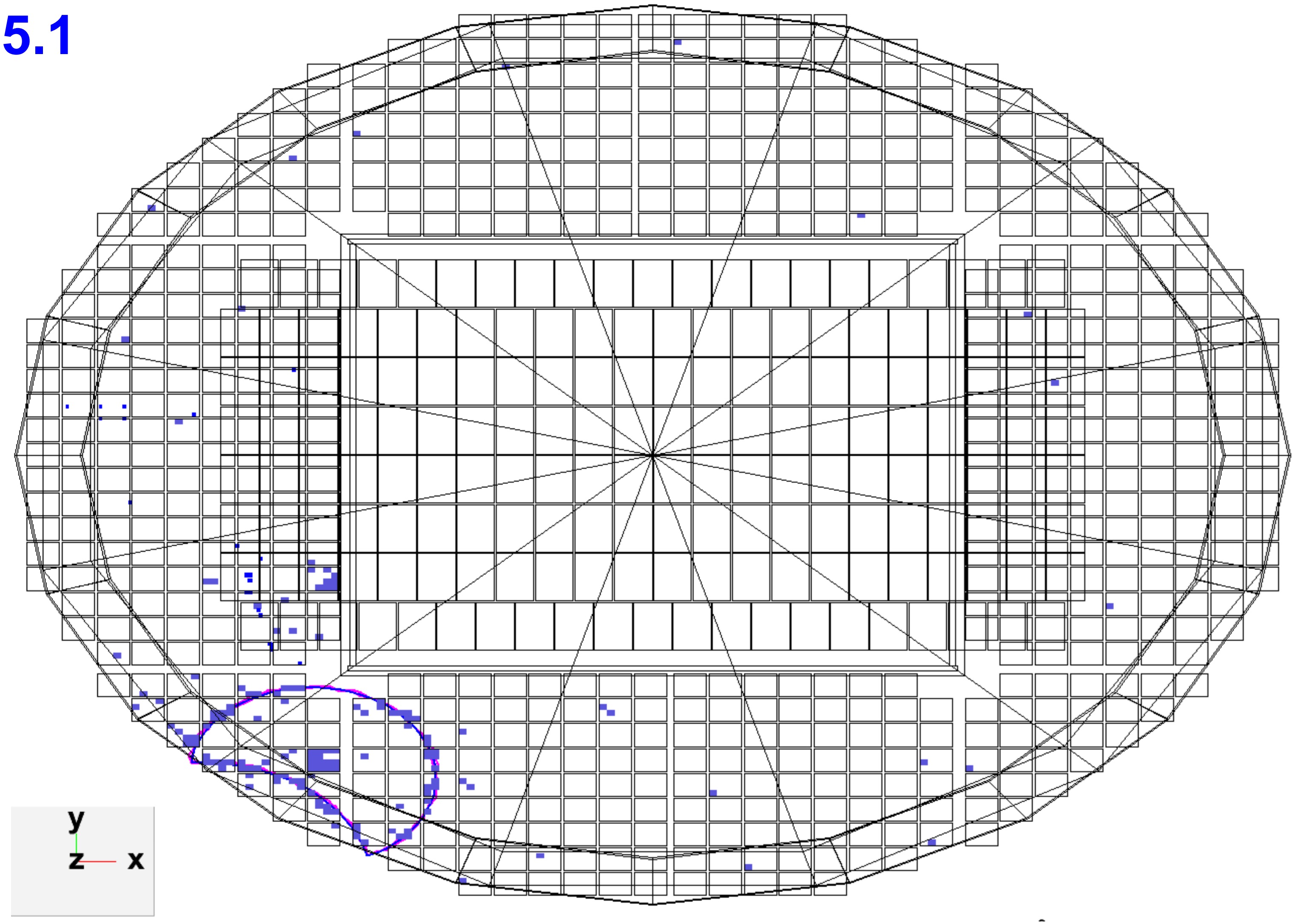




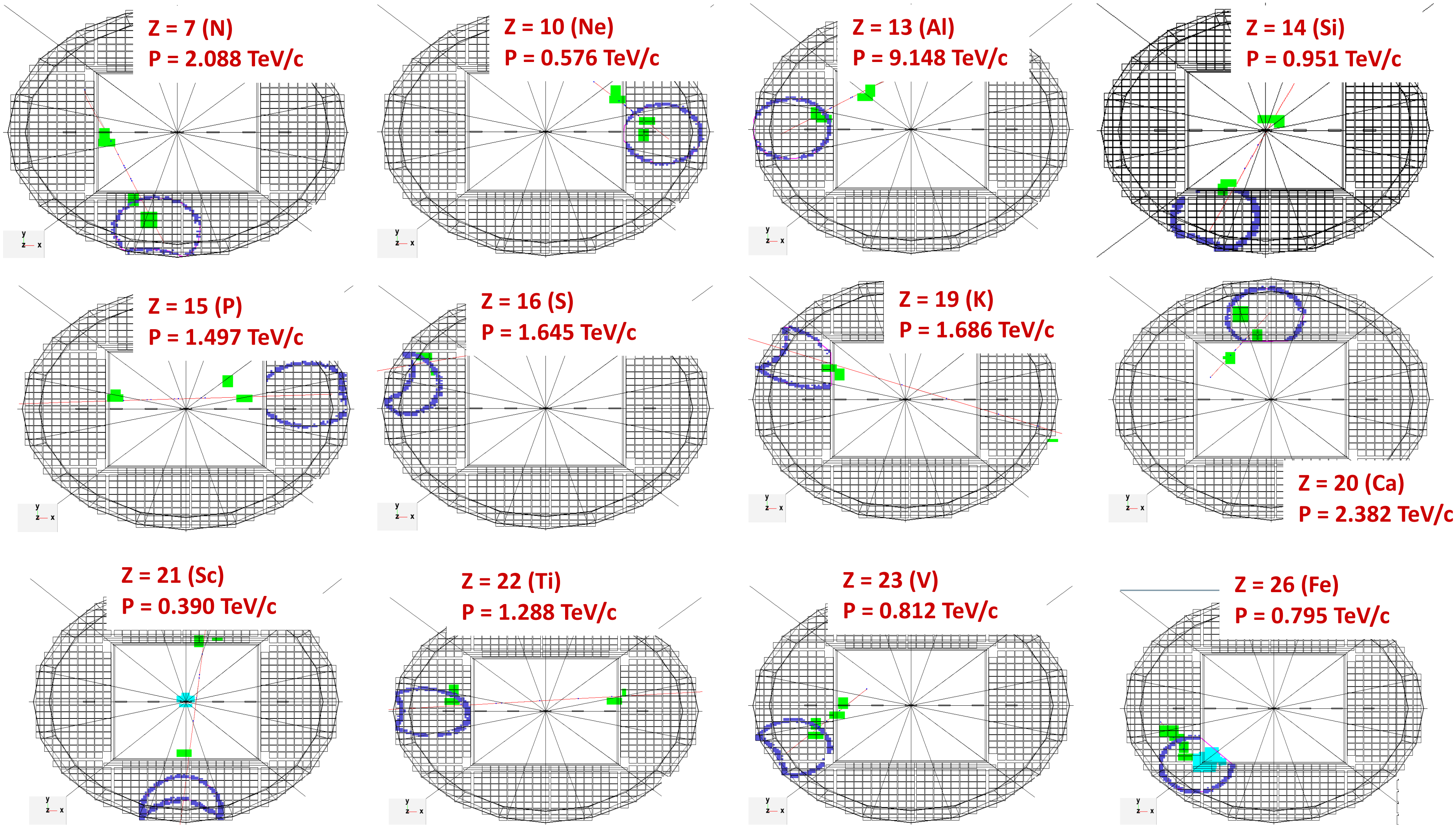


An AMS-02 RICH ion ring

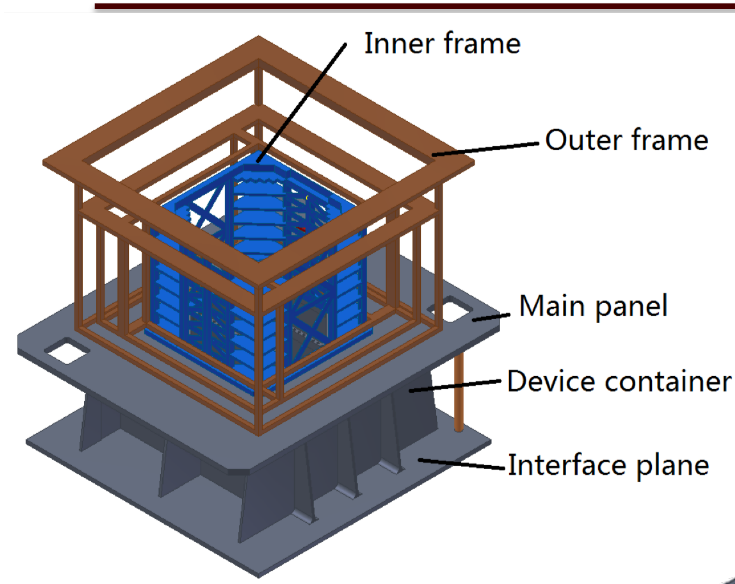
Z_{RICH}= 5.1

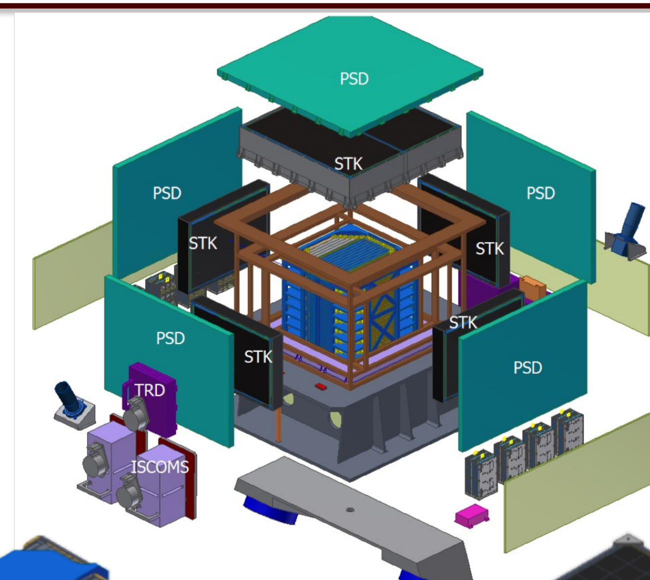


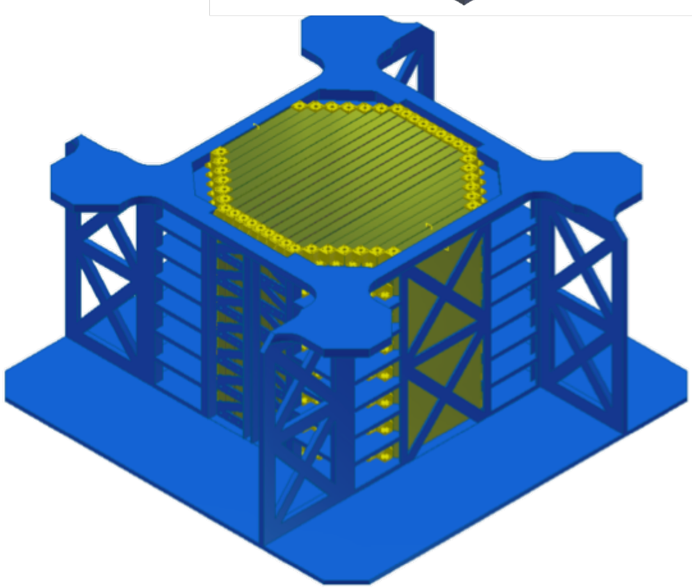
Up to iron...

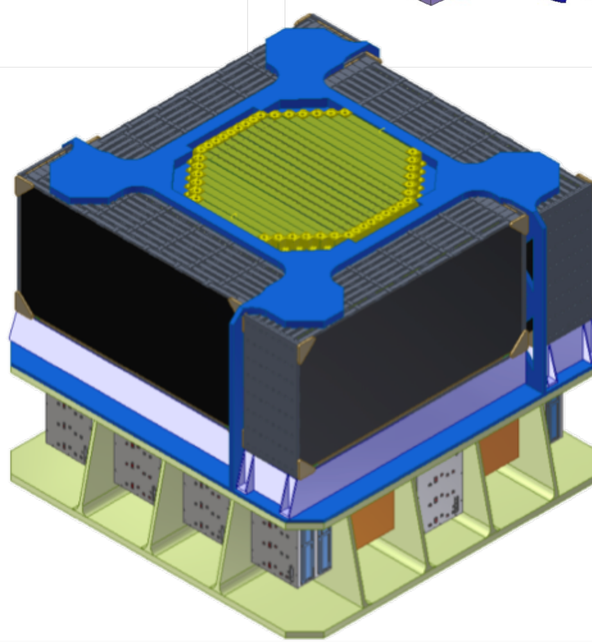

Z = 7 (N)
P = 2.088 TeV/c
Z = 10 (Ne)
P = 0.576 TeV/c
Z = 13 (Al)
P = 9.148 TeV/c
Z = 14 (Si)
P = 0.951 TeV/c
Z = 15 (P)
P = 1.497 TeV/c
Z = 16 (S)
P = 1.645 TeV/c
Z = 19 (K)
P = 1.686 TeV/c
Z = 20 (Ca)
P = 2.382 TeV/c
Z = 21 (Sc)
P = 0.390 TeV/c
Z = 22 (Ti)
P = 1.288 TeV/c
Z = 23 (V)
P = 0.812 TeV/c
Z = 26 (Fe)
P = 0.795 TeV/c

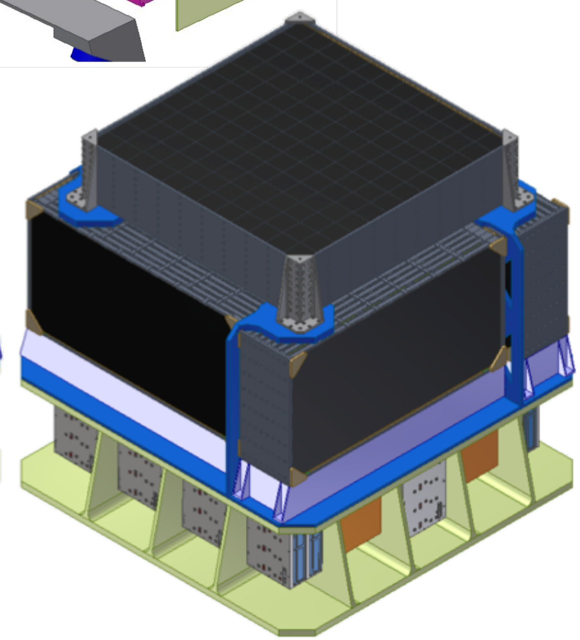
HERD detector











ALADInO magnet

Benefit from the R&D of high temperature superconducting magnets (MgB_2, YBCO and in particular REBCO) for space applications (T ≈ 15÷40° K)

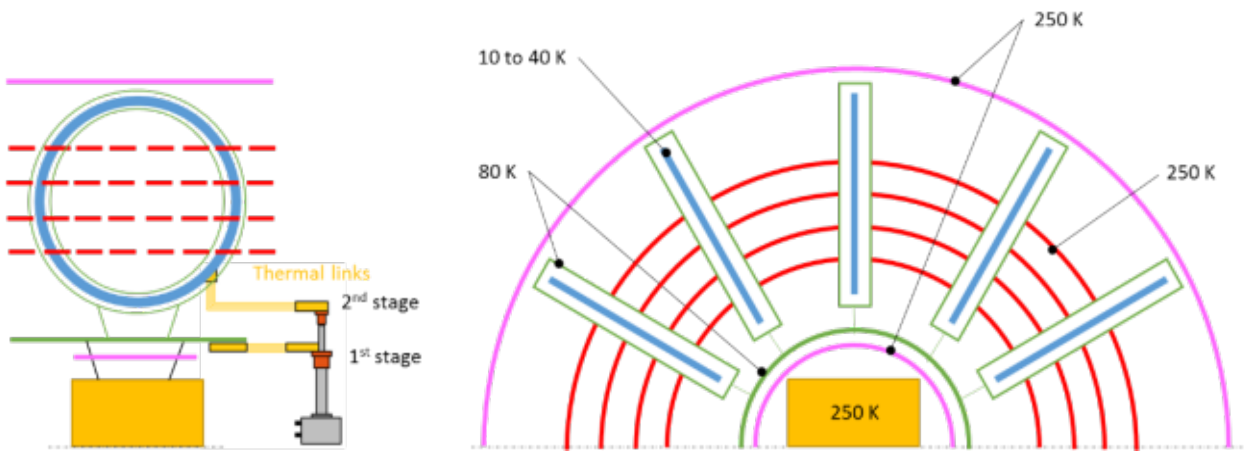
Field 0.8 T
Bending power > 1.1 T m
Weight ~ 1000 Kg

The natural place for this kind of detector is the L2 Lagrangian point.

Most of the heat flux from the Sun is passively intercepted by an umbrella-type shield made of V-groove layers (inspired by the one of the J.Webb telescope).
The temperature on the dark side of the sunshield can be estimated ~ 60 K.

Side cross-sectional view

Top cross-sectional view

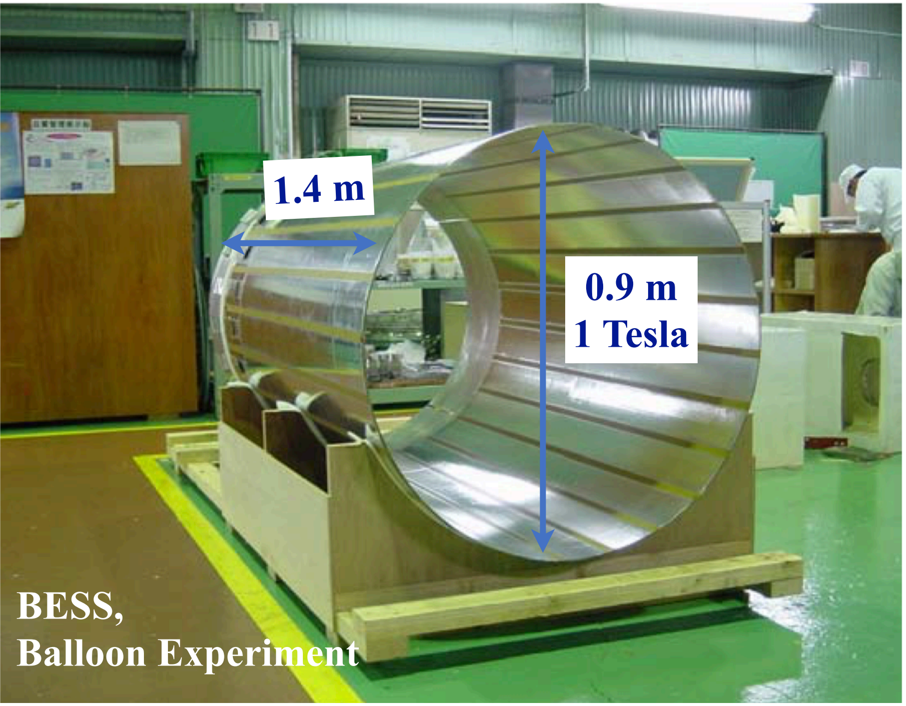


ToF + trigger Superconducting coil Tracker Cryogenic shield + thermal link Cryocooler
Mechanical support Calorimeter + trigger

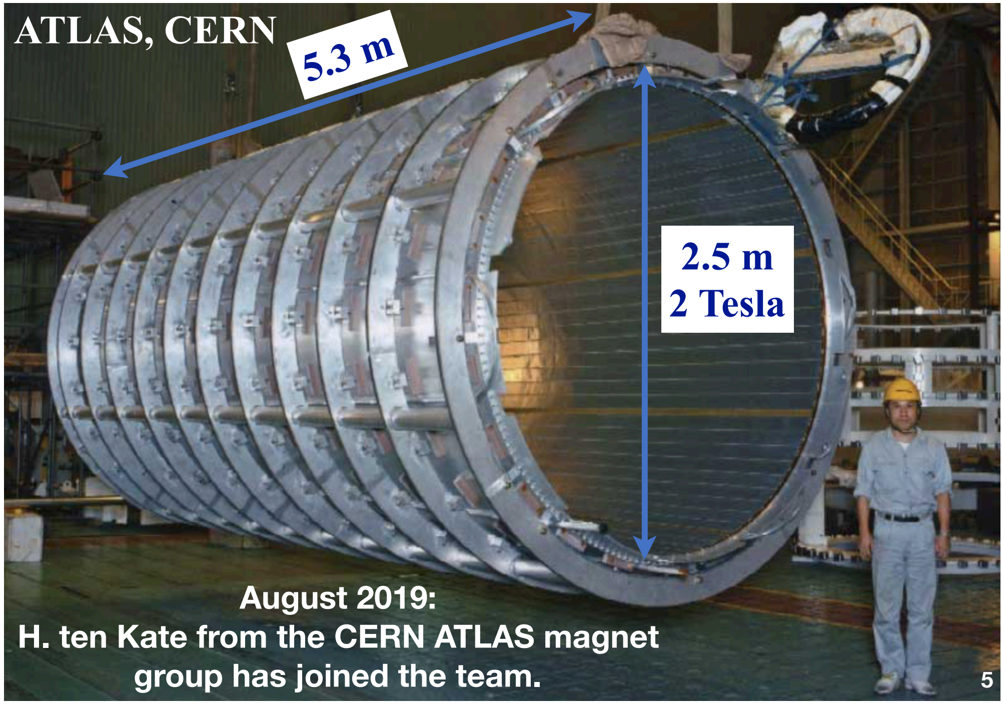
AMS-100 magnet

Example of Thin Solenoids
using Low Temperature Superconductors (Nb-Ti) at T = 4 Kelvin

The coil weights 43 kg and has a radial thickness of 3.4 mm and was build at KEK, Japan.

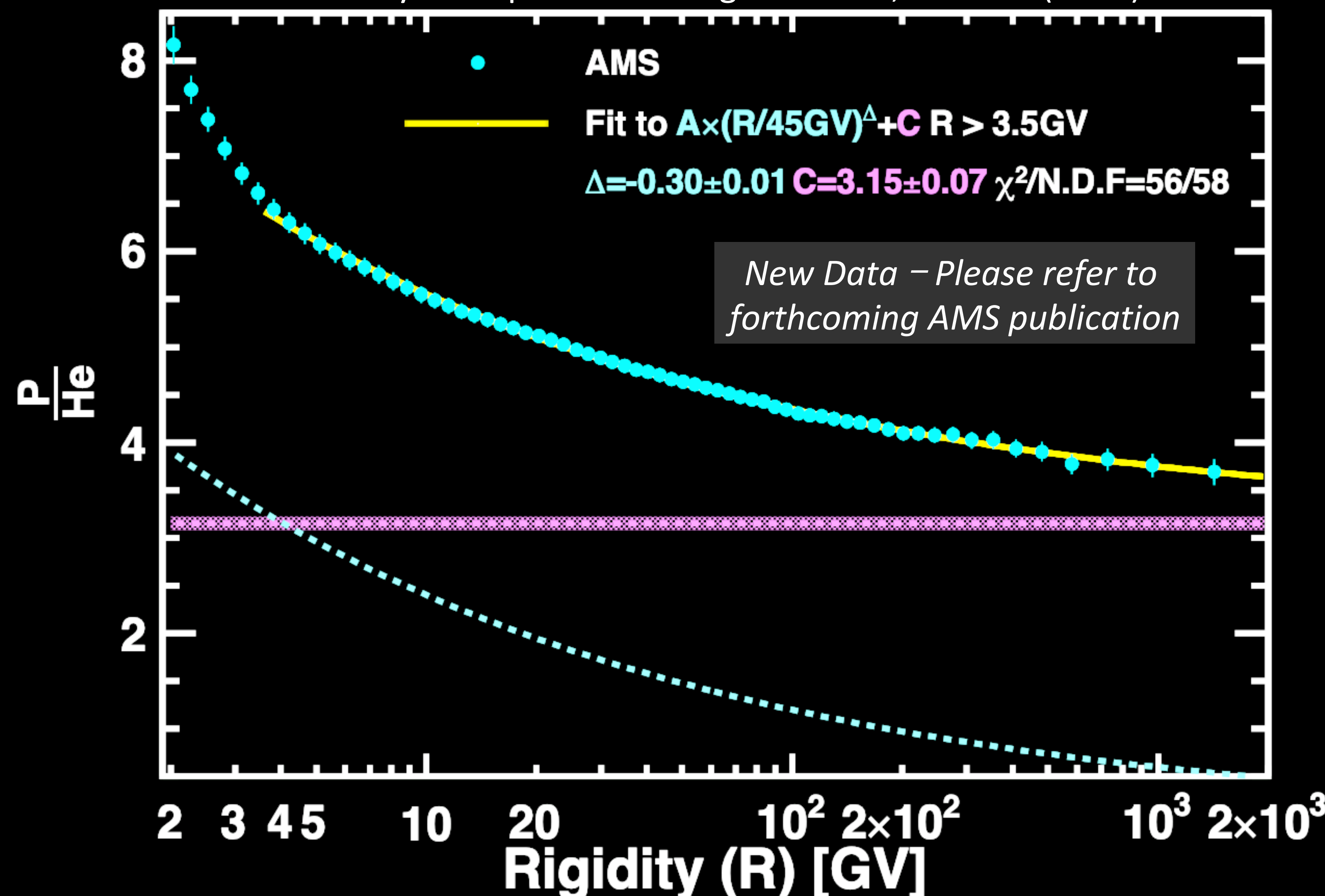


The coil weights 5.5 tons and has a radial thickness of 4.5 cm and was build at Toshiba, Japan.

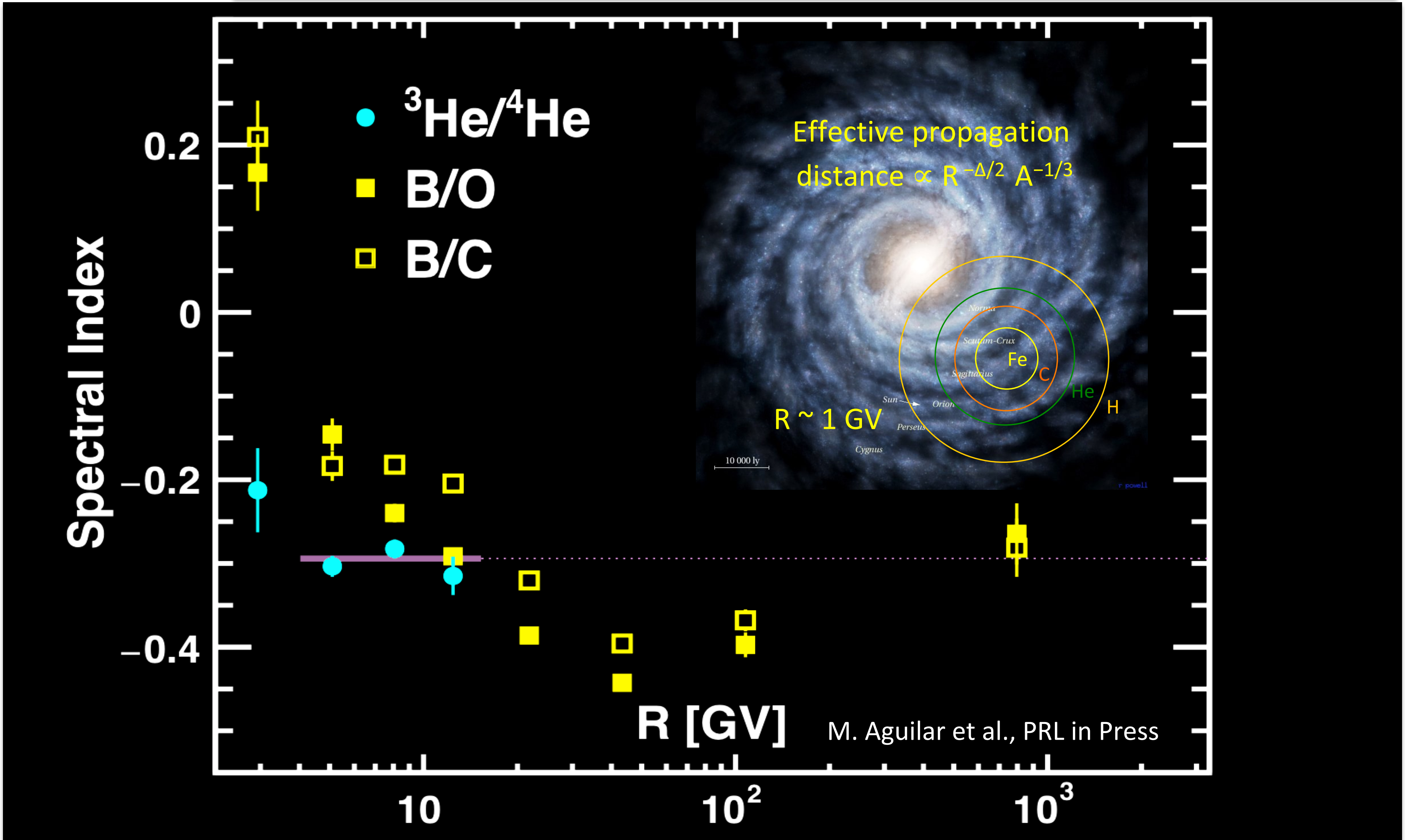


p/He Flux Ratio

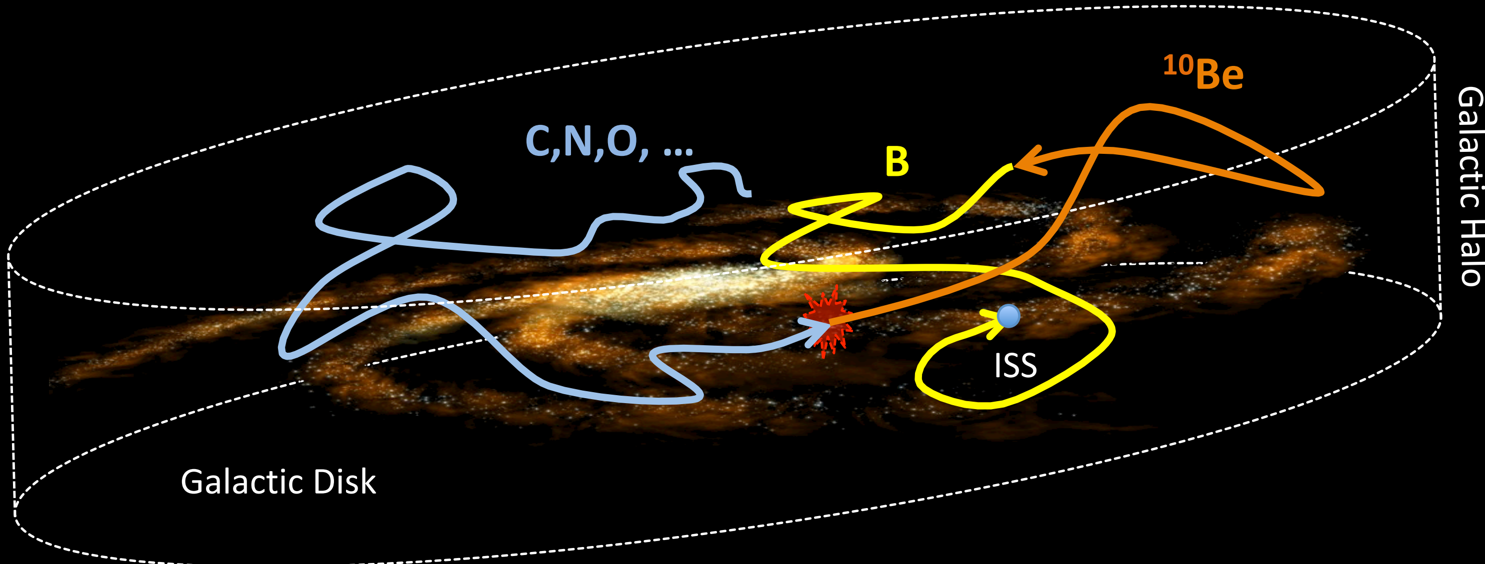
7 years update of M. Aguilar et al., PRL **115** (2015) 211101



Probing Non-Homogeneous Diffusion: AMS $^3He/^4He$ Ratio



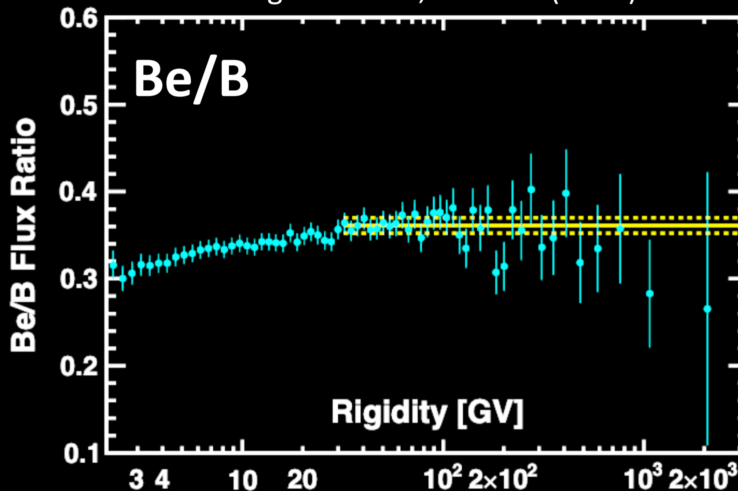
Cosmic Ray Clock: AMS Be/B Flux Ratio



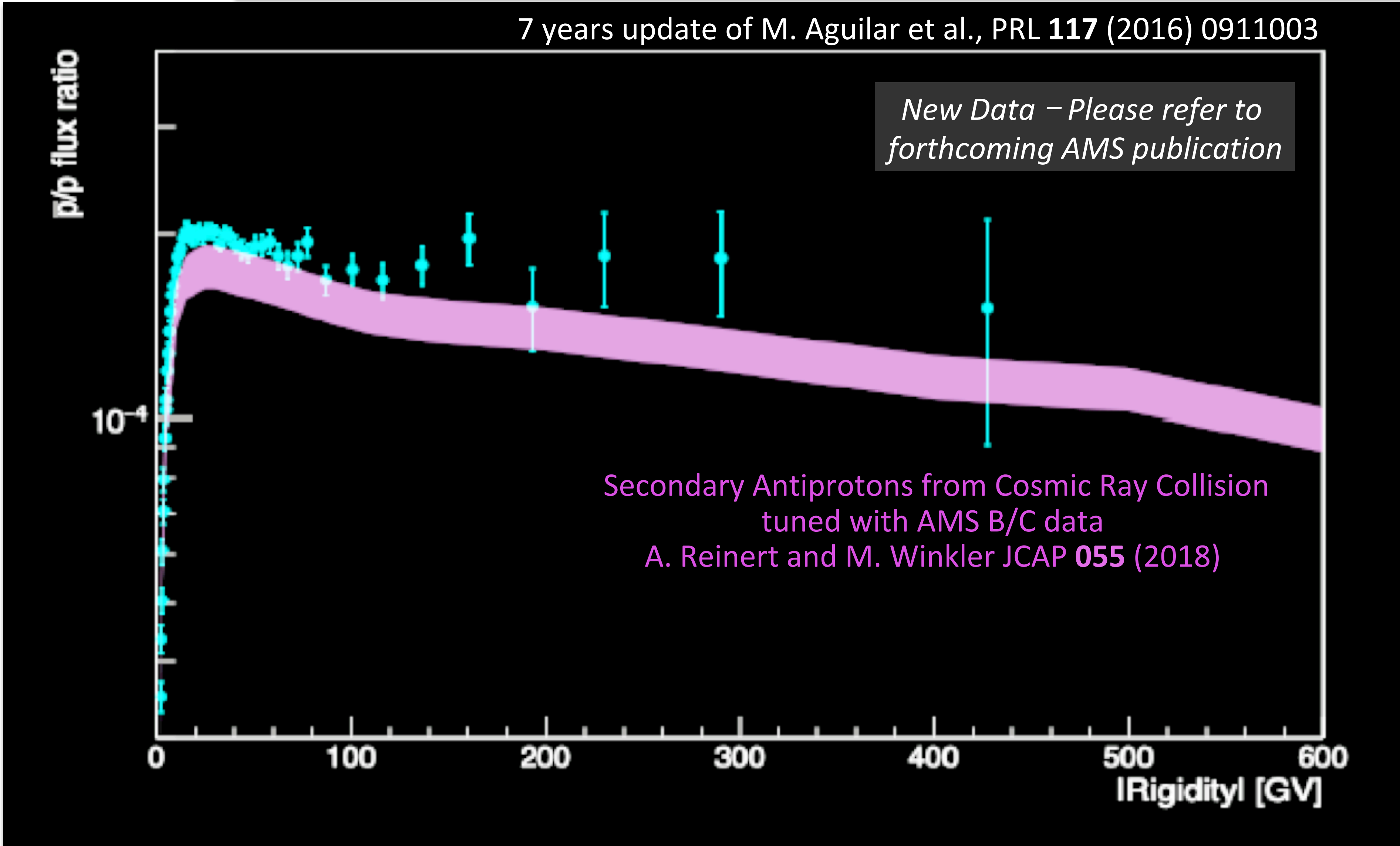
The secondary ^{10}Be beta-decays with $t_{1/2}$ = 1.4 My through $^{10}Be \rightarrow {}^{10}B + e^- + \bar{\nu}$.

The Be/B ratio rigidity dependence is related to the **cosmic rays confinement time** (or the galactic halo size in diffusion models).

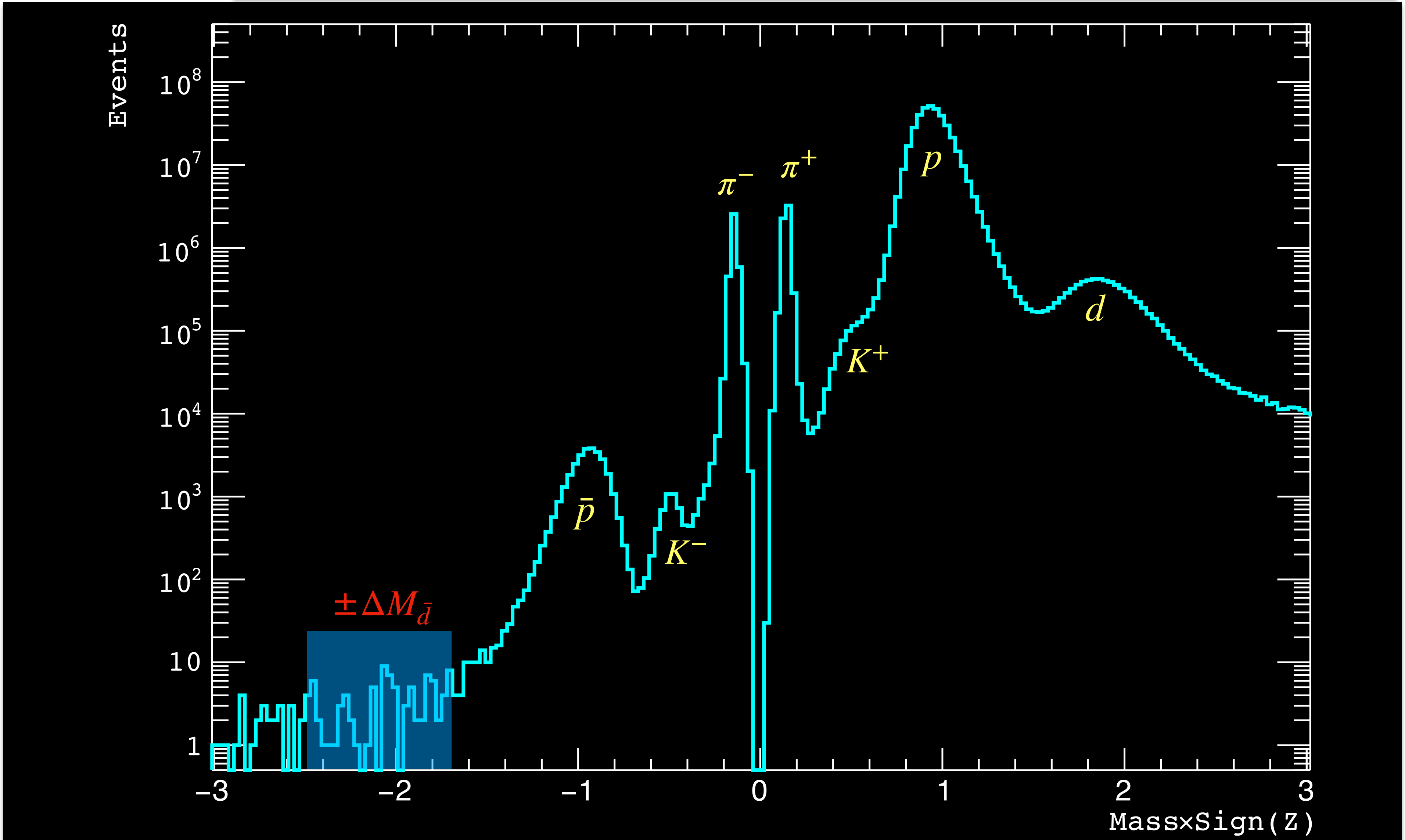
M. Aguilar et al., PRL **120** (2018) 021101



Anti-Proton / Proton Ratio



Antideuteron Search



Timing in an astro-particle tracker

Including the timing into the Tracker of an astro-particle detector permits to:

- substitute (or provide full redundancy to) any other **ToF detector** (i.e. planes of scintillators) in measuring β → isotopic composition for nuclear species (combined with *E* or *p* measurement);

$$M = \frac{E}{\gamma} = \sqrt{1-\beta^2}E \qquad \frac{\delta M}{M} = \frac{\delta E}{E} \oplus \beta^2\gamma^2\frac{\delta\beta}{\beta}$$

With 20% energy resolution (doable @5-10 GeV for protons?) the mass resolution cannot be never below 20%

→ d/p doable maybe…

→ ^{3}He/^{4}He already ruled out…

With δβ/β = 2% (i.e. 60 ps @ 1 m) the velocity uncertainty term dominates if γ^2>O(10) → γ>O(3) → E_p>3 GeV