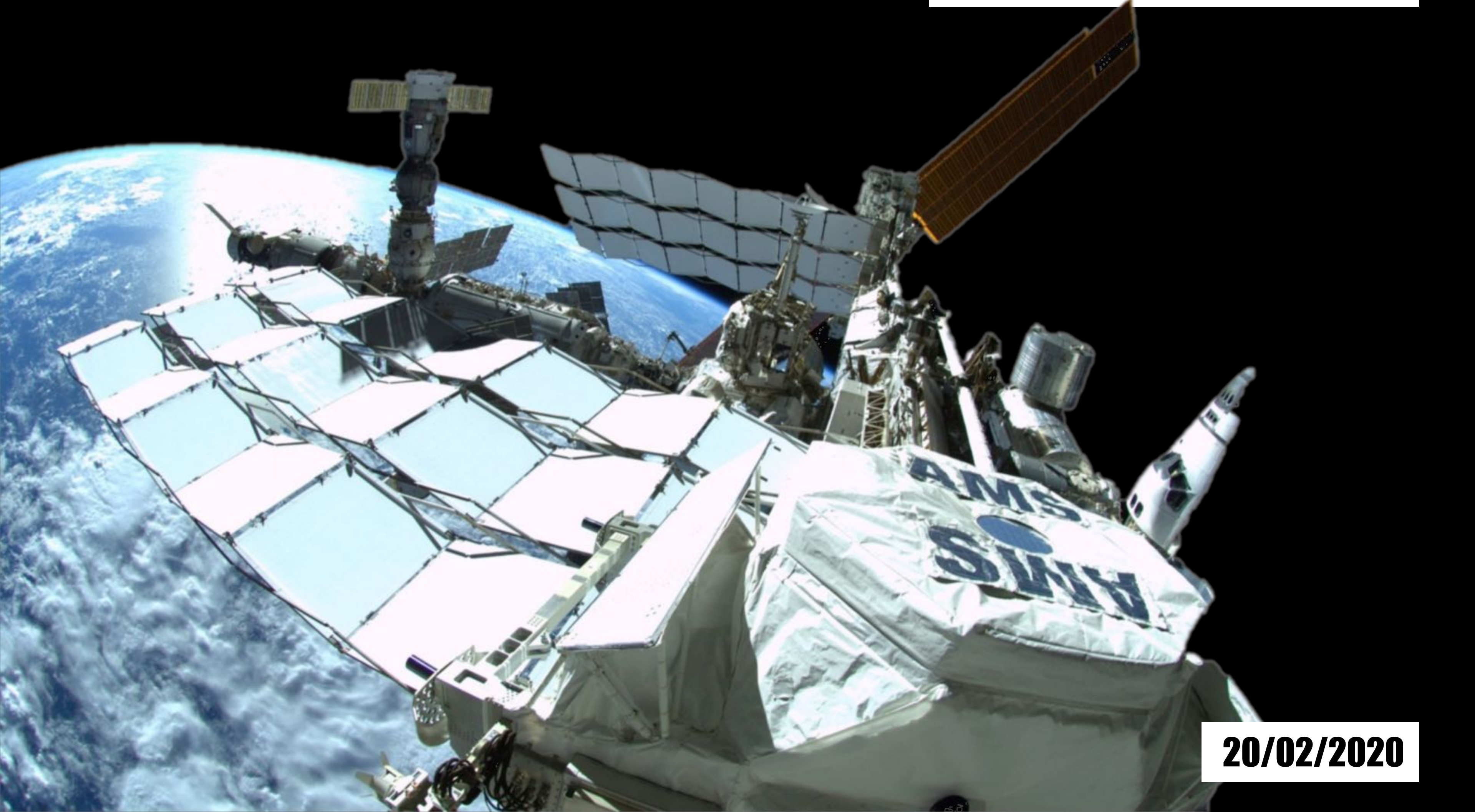
Latest News and Physics Results of the Alpha Magnetic Spectrometer on the International Space Station

A. Oliva for the AMS-02 Bologna Group

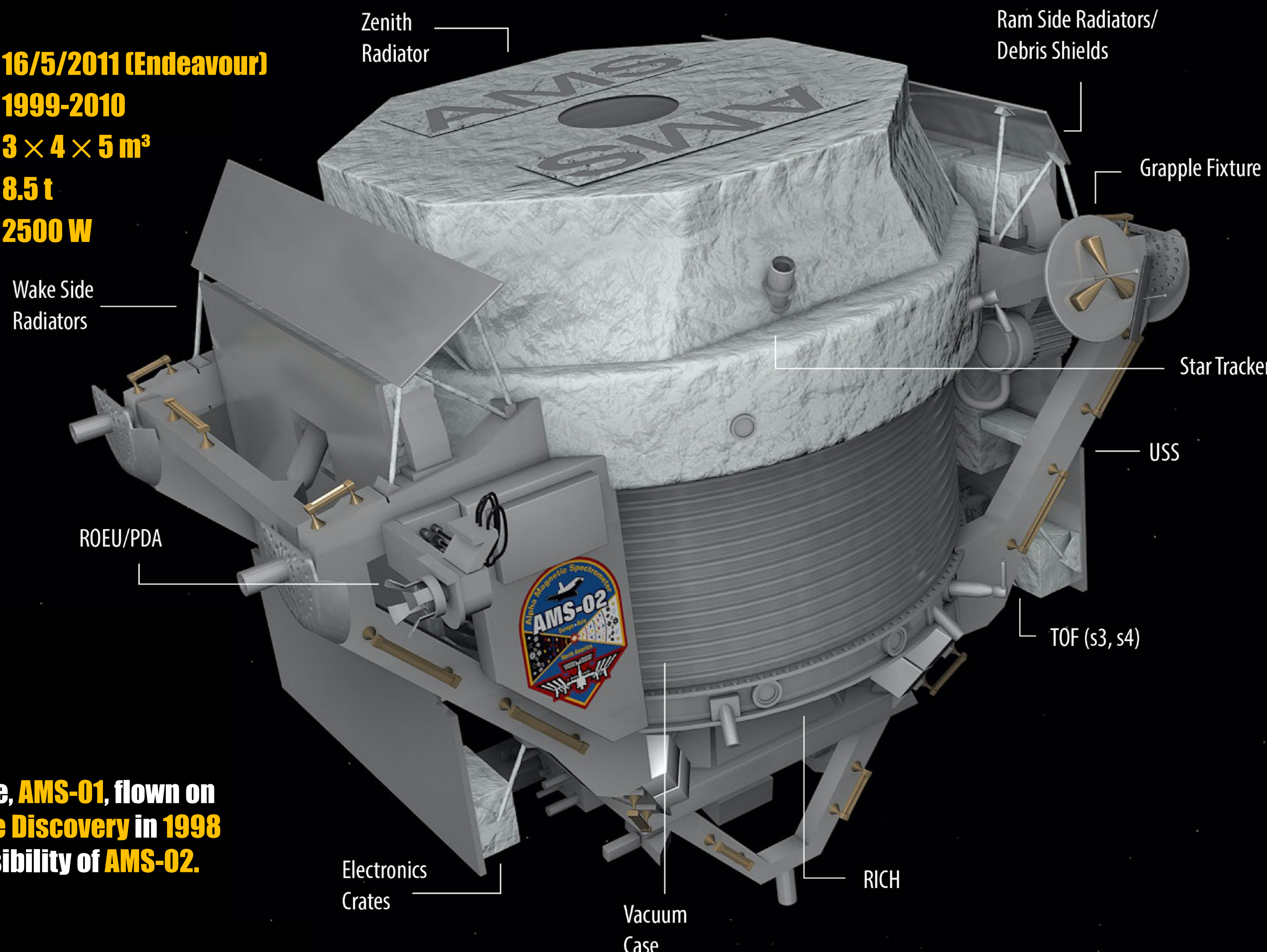
INFN Bo, Assemblea di Sezione



20/02/2020

AMS-02: Alpha Magnetic Spectrometer

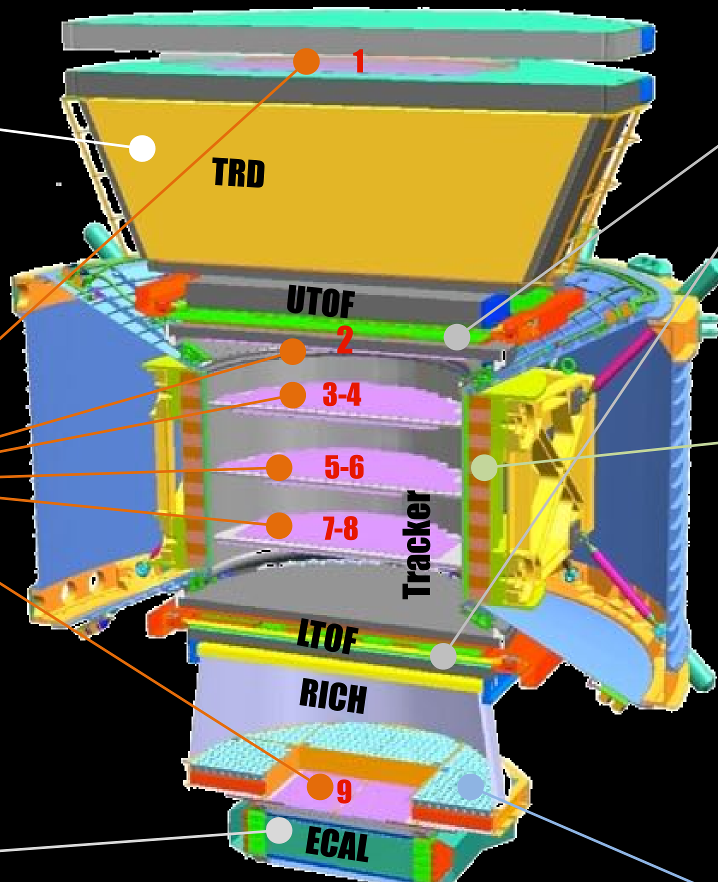
Launch	**16/5/2011 (Endeavour)**
Construction	**1999-2010**
Volume	**3 × 4 × 5 m³**
Weight	**8.5 t**
Power	**2500 W**

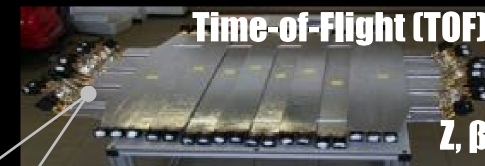


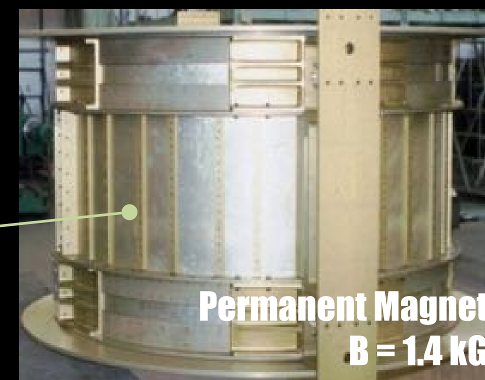
The prototype, AMS-01, flown on space shuttle Discovery in 1998 showing feasibility of AMS-02.

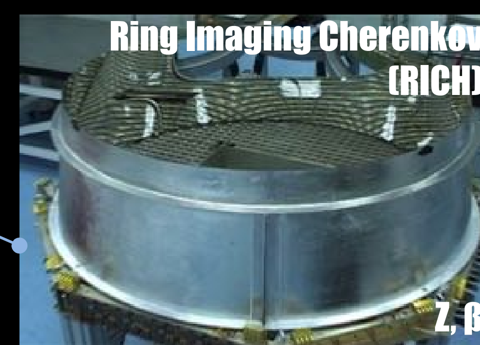
AMS-02: A TeV Multi-Purpose Spectrometer

AMS-02 separates hadrons from leptons, matter from anti-matter, chemical and isotopic composition from fraction of GeV to multi-TeV.









Multiple and Independent Measurement of Charge (Z), Energy (β, p, E) and Charge Sign (±).

AMS-02: A TeV Multi-Purpose Spectrometer

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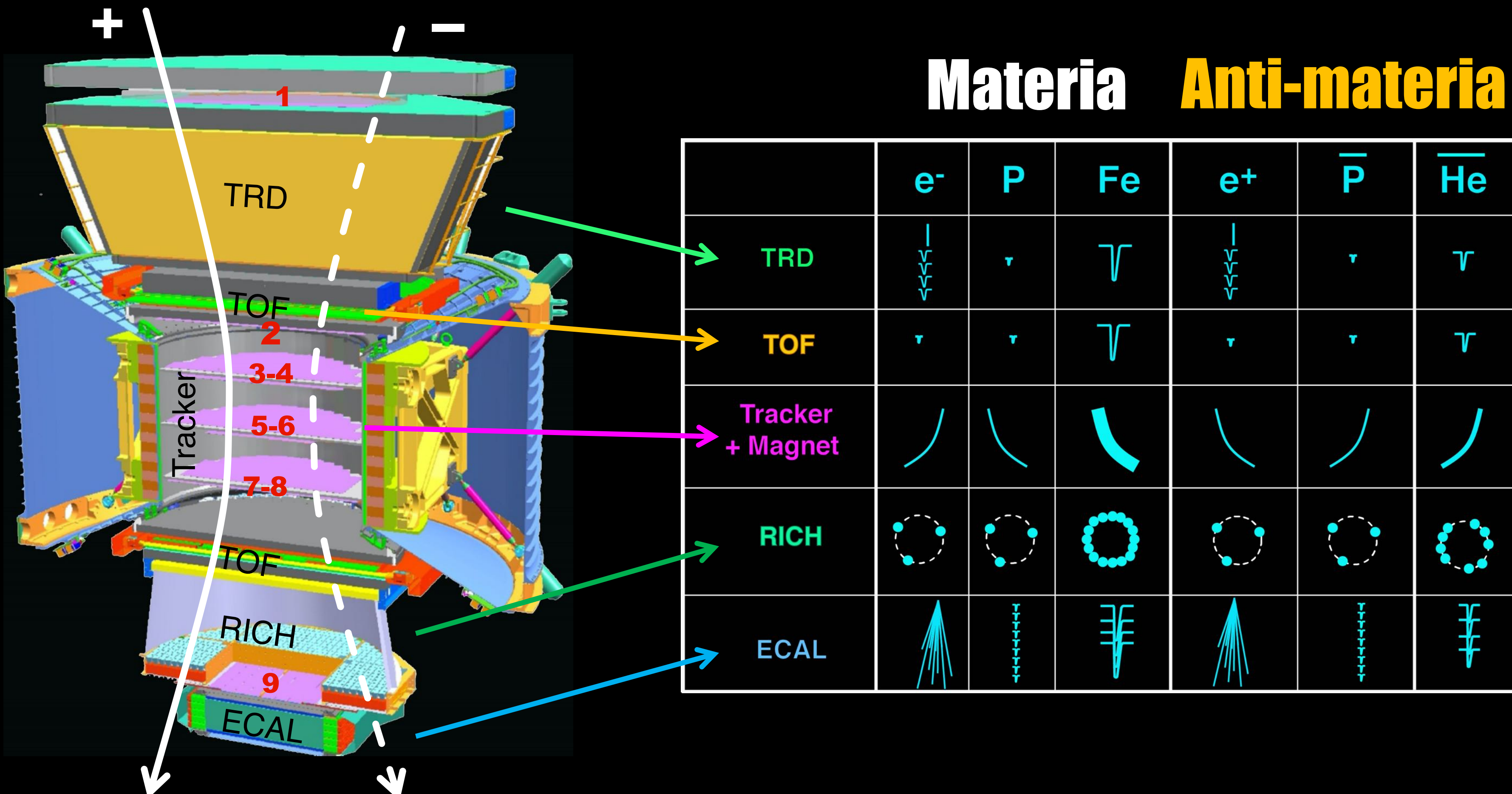
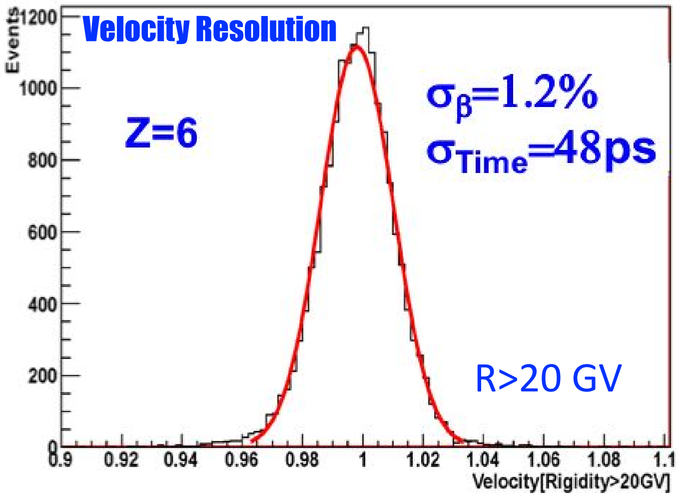
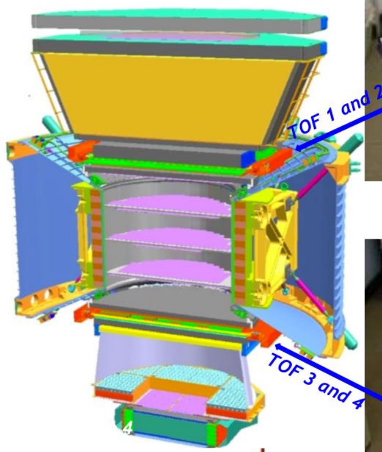


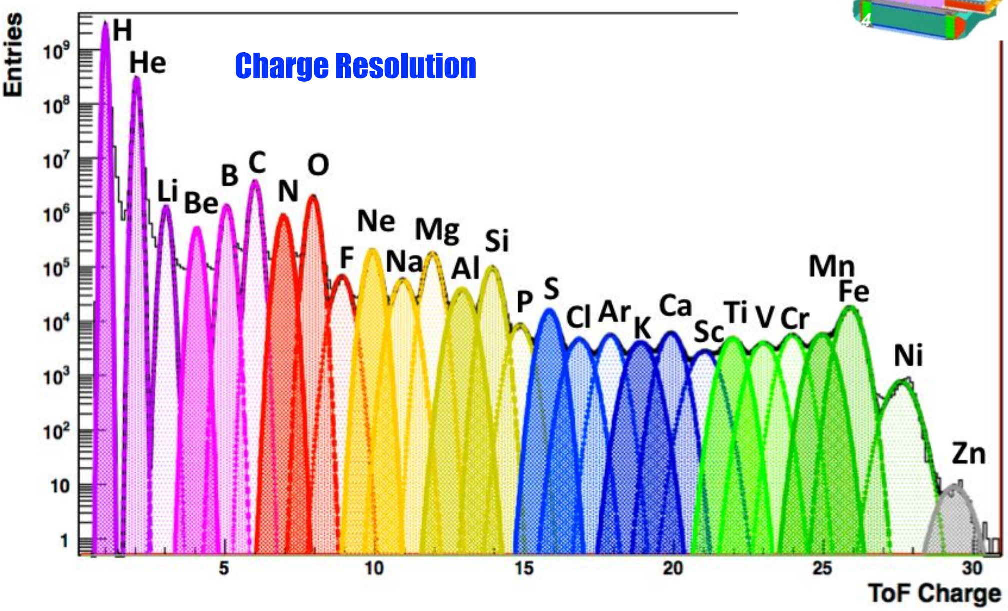
AMS is able to identify 1 positron from 10^6 protons, unambiguously separate positrons from electrons up to a TeV.

AMS-02: Time-of-Flight

Built in Bologna. Bologna has full responsibility of the TOF (operations, calibrations).







Other activities in Bologna:

→ AMS-02 data analysis (nuclei fluxes, …)

→ Phenomenology of cosmic rays

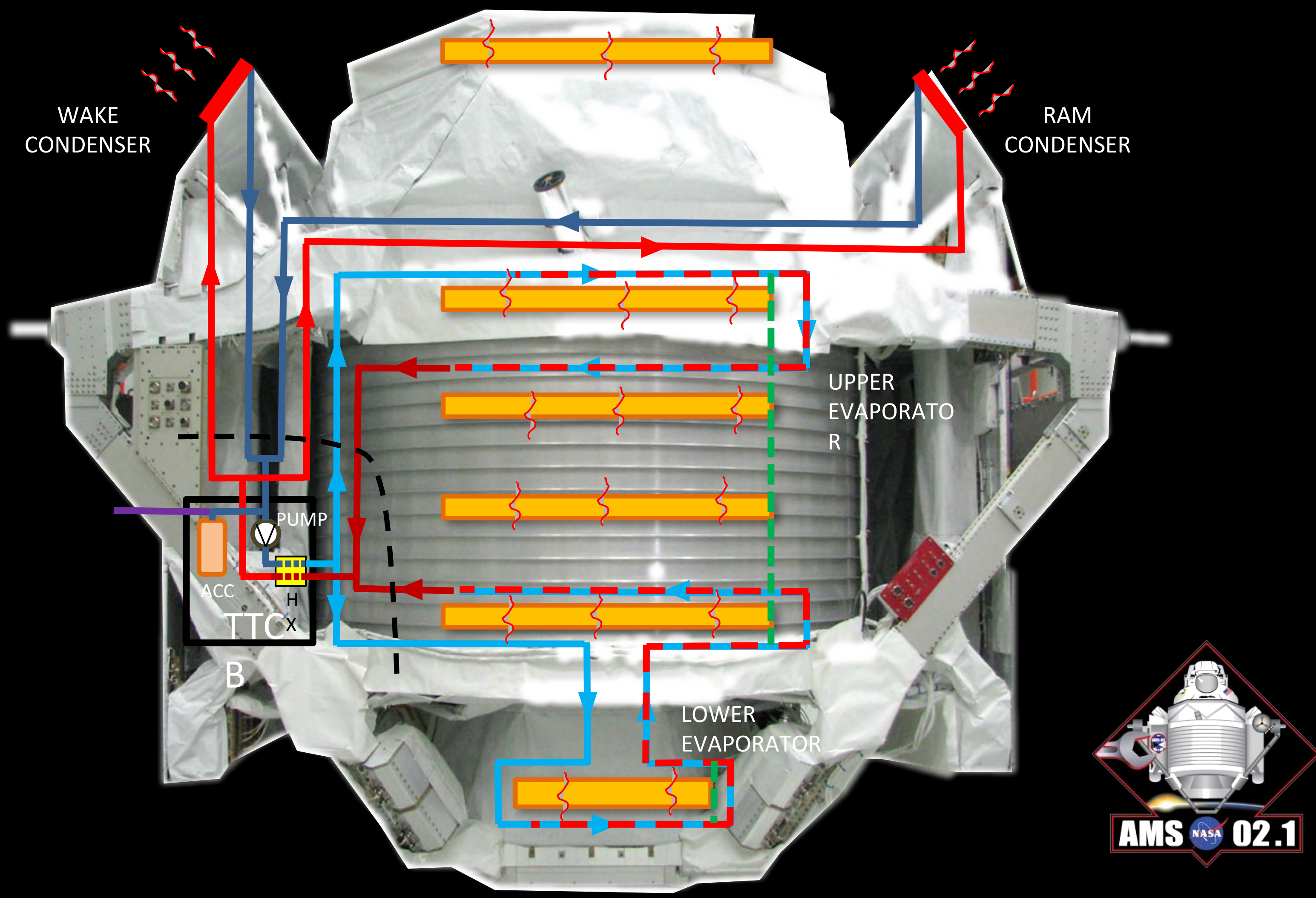
AMS on the International Space Station

From May 19th 2011 active on ISS, operating continuously since then.
AMS has collected > 150 billion cosmic rays up to today.
With such a statistics the most rare components of the cosmic rays are visible.

Altitude	~ 400 km
Inclination	~ 51°
Period	~ 93 min
Construction	1998-...
Dimension	73 × 109 m^2
Weight	420 t

The Tracker Thermal Control System (TTCS)

A mechanically pumped double phase CO_2 cooling system

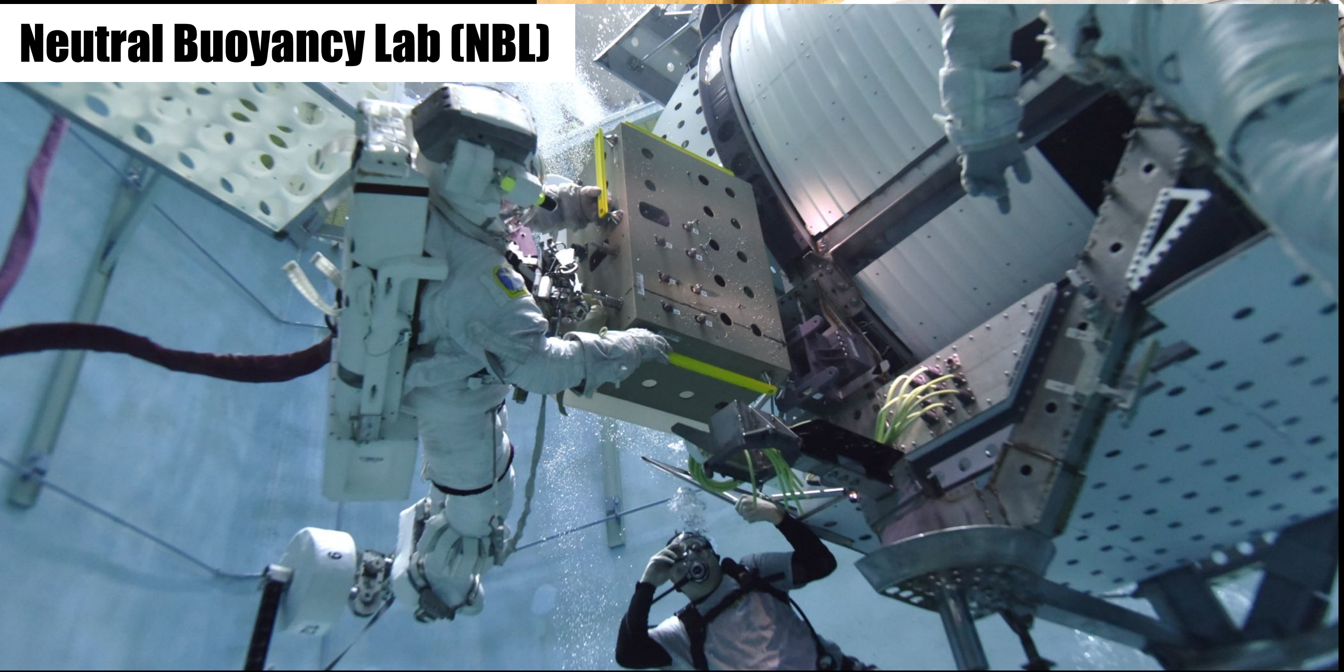


Problems with pumps since 2014. To extend AMS lifetime, in the last 5 years, we designed and realized a new pump block (UTTPS). NASA developed tools and procedures to install it.

EVAs Preparation: Astronauts Training

Active Response Gravity Offload System (ARGOS)

Neutral Buoyancy Lab (NBL)



95 simulations (ARGOS + NBL), more than 7 astronauts involved.

EVAs Preparation: Shipping to the ISS

Astronauts:
Luca Parmitano,
Drew Morgan,
Alexander Skvortsov

EVA Tools

UTTPS

Soyuz 59S
20/07/'19

Baikonur

SpX-18
25/07/'19

Cape Canaveral

HTV-8
24/09/'19

Tanegashima

NG-12
02/11/'19

Wallops Flight Facility

EVA #1: Gaining Access

15/11/'19

L. Parmitano dismounting the *debris shield*

EVA #2: Tube cutting

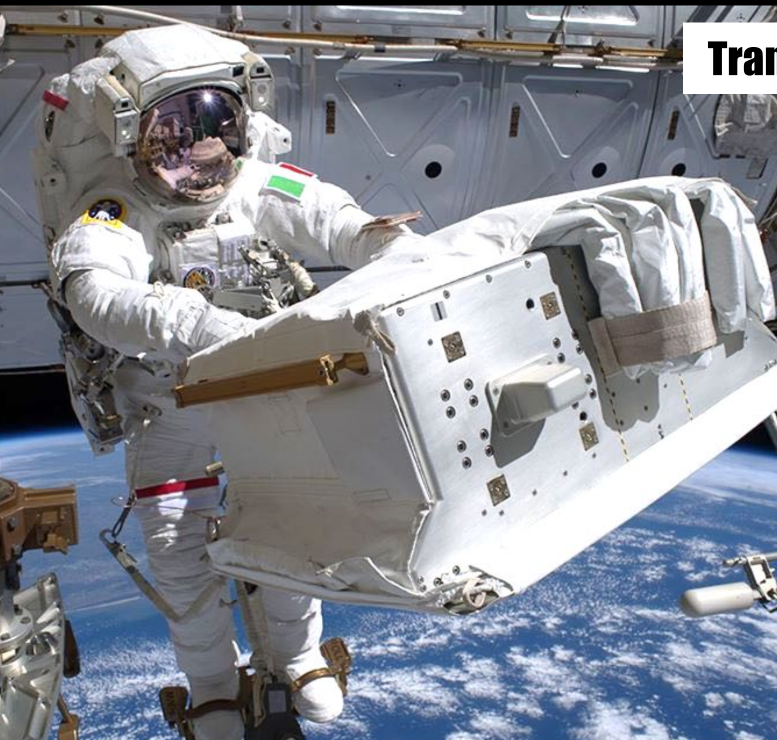

Tube cutting


Caps installation


22/11/'19

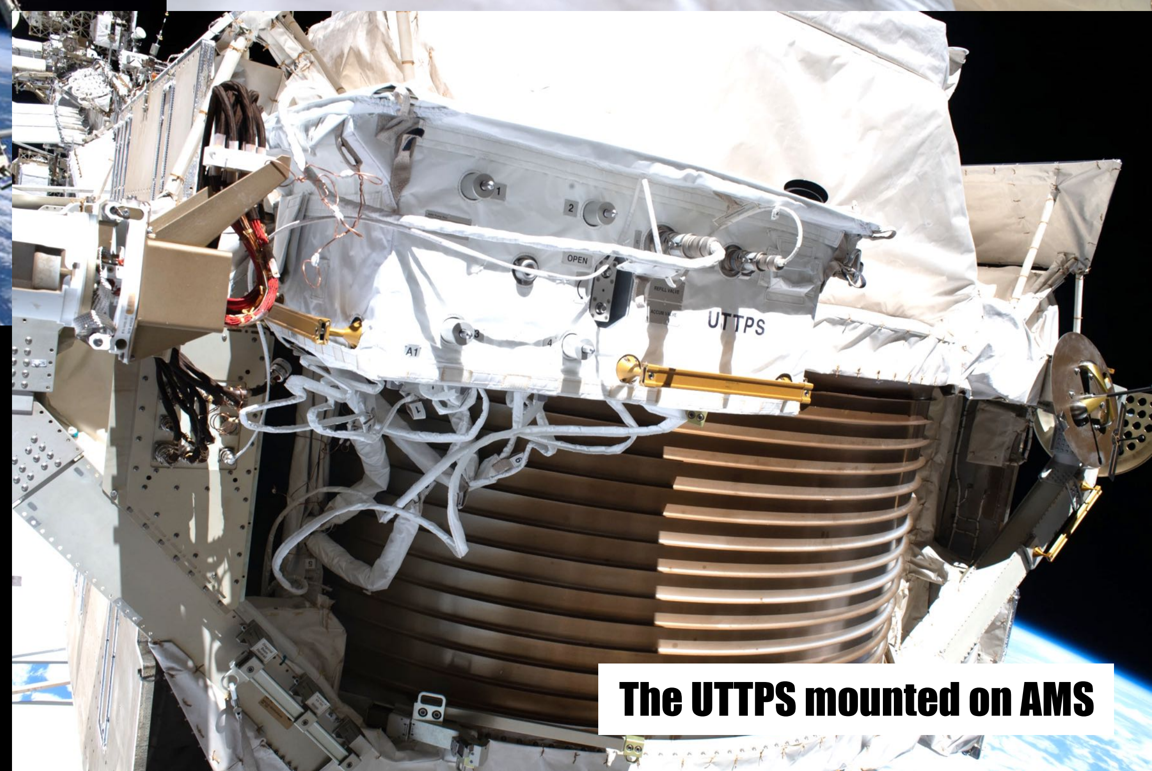
AMS 02.1

EVA #3: UTTPS Installation



Transport

Reconnecting fluid lines



The UTTPS mounted on AMS

AMS NASA 02.1

02/12/'19

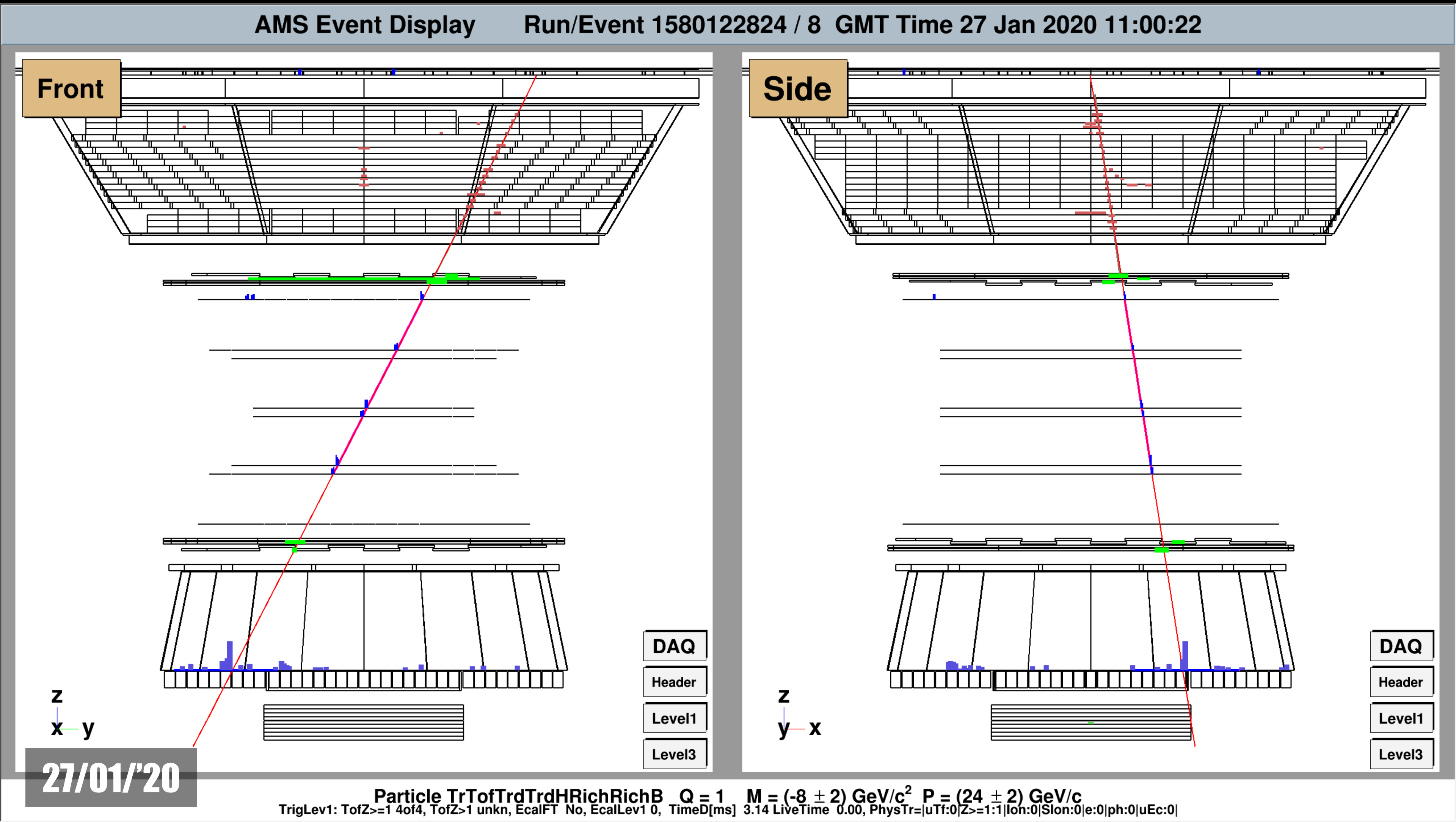
EVA #4: Leak Check

25/01/'20

AMS 02.1

AMS Activation

"AMS is fully operational as of a few moments ago. This is the first run after the UTTPS installation in EVA-4. From now on, we will continue to collect data for the lifetime of the ISS." (S.C.C. Ting, AMS-02 P.I.)

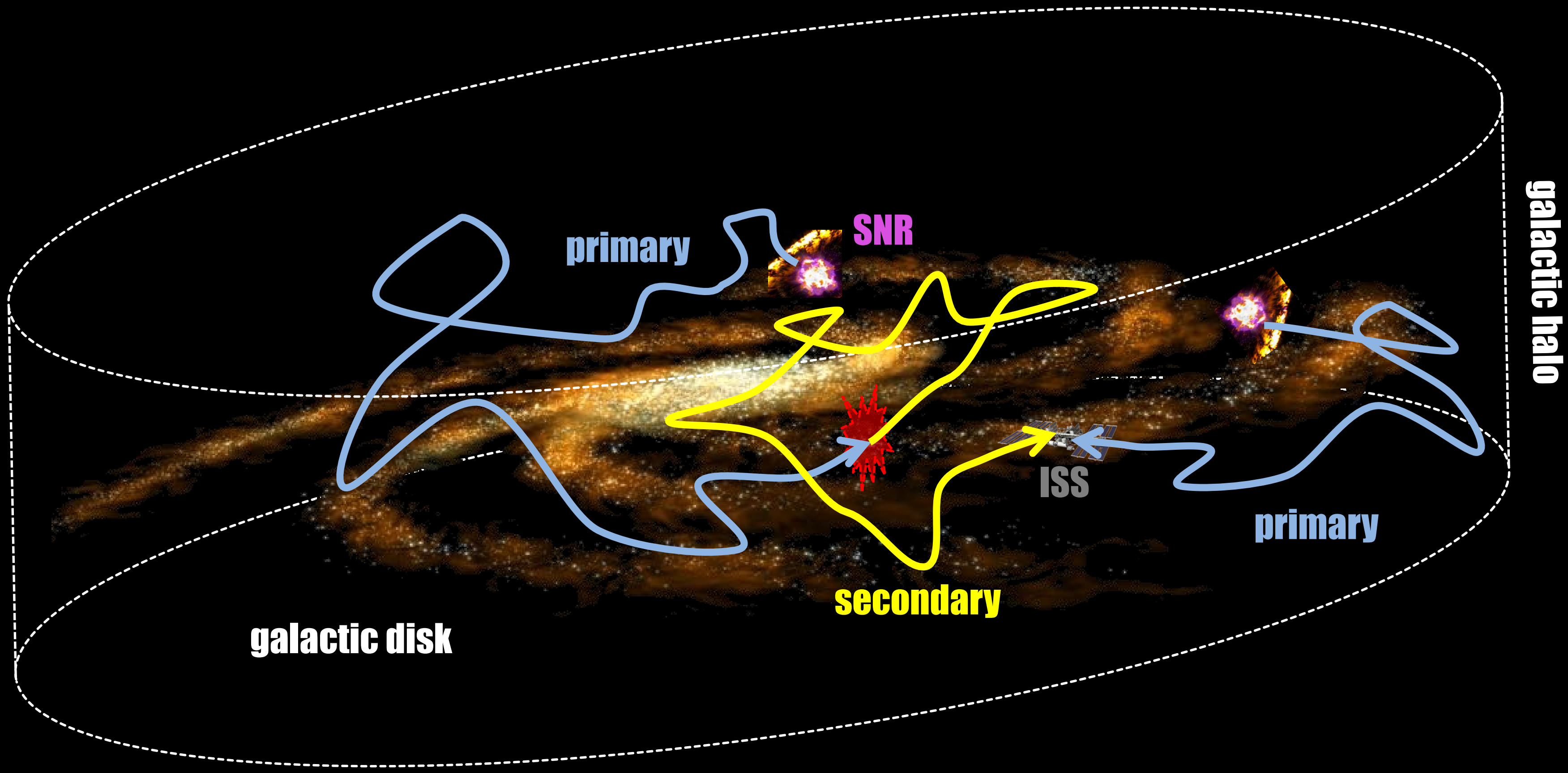


AMS-02 Reloaded
In occasione del rientro di Luca Parmitano [ESA] dalla Stazione Spaziale Internazionale, discuteremo in un seminario divulgativo e in una diretta in videoconferenza lo stato di AMS-02 dopo le 4 passeggiate spaziali di riparazione
Giovedì 6 Febbraio
Ore 14:00 – 15:30
Aula Magna del Dipartimento di Fisica e Astronomia, Via Irnerio 46, Bologna
INFN
Istituto Nazionale di Fisica Nucleare
BICOCCA

06/02/'20

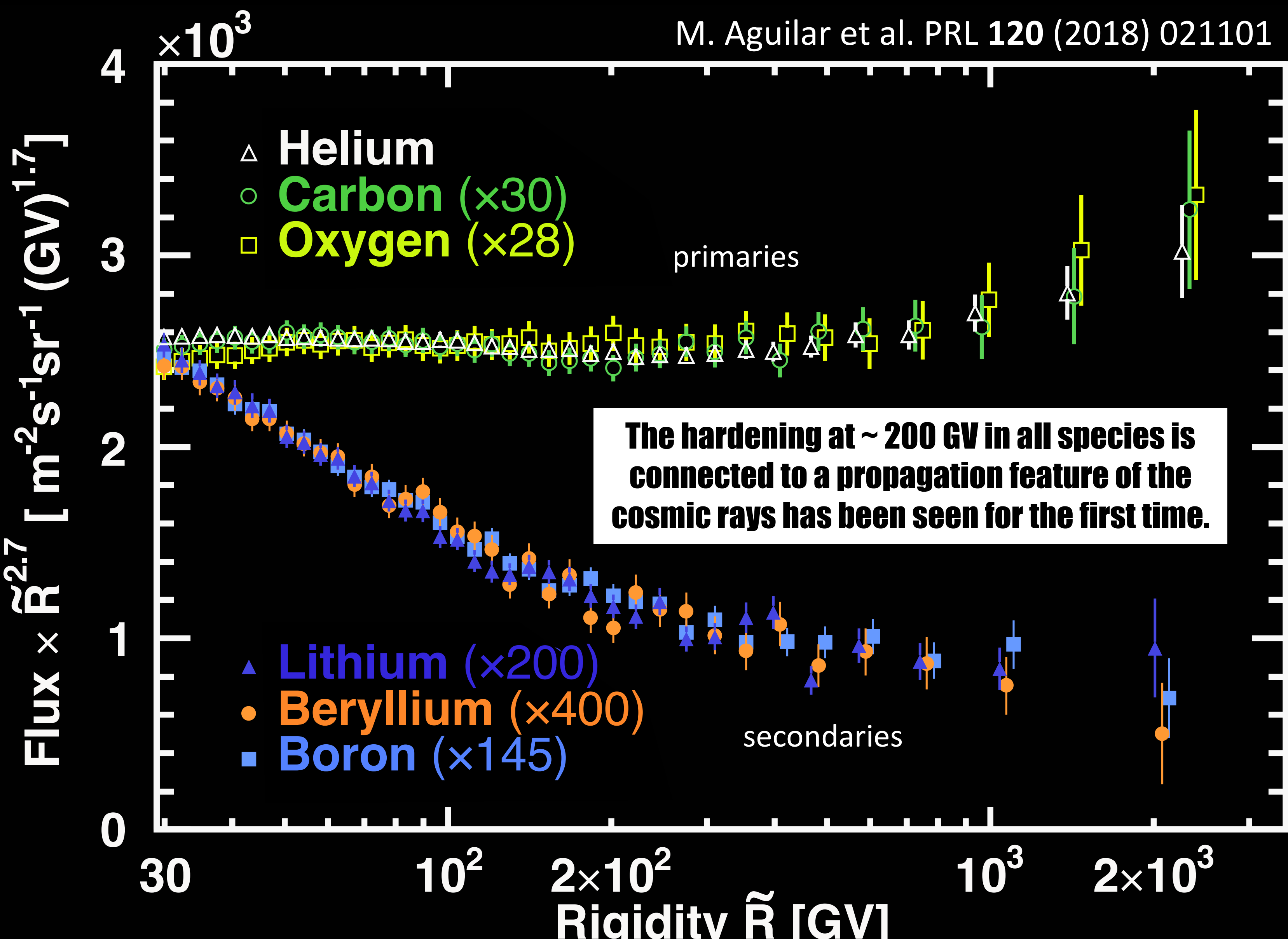
Primary and Secondary Cosmic Rays

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.



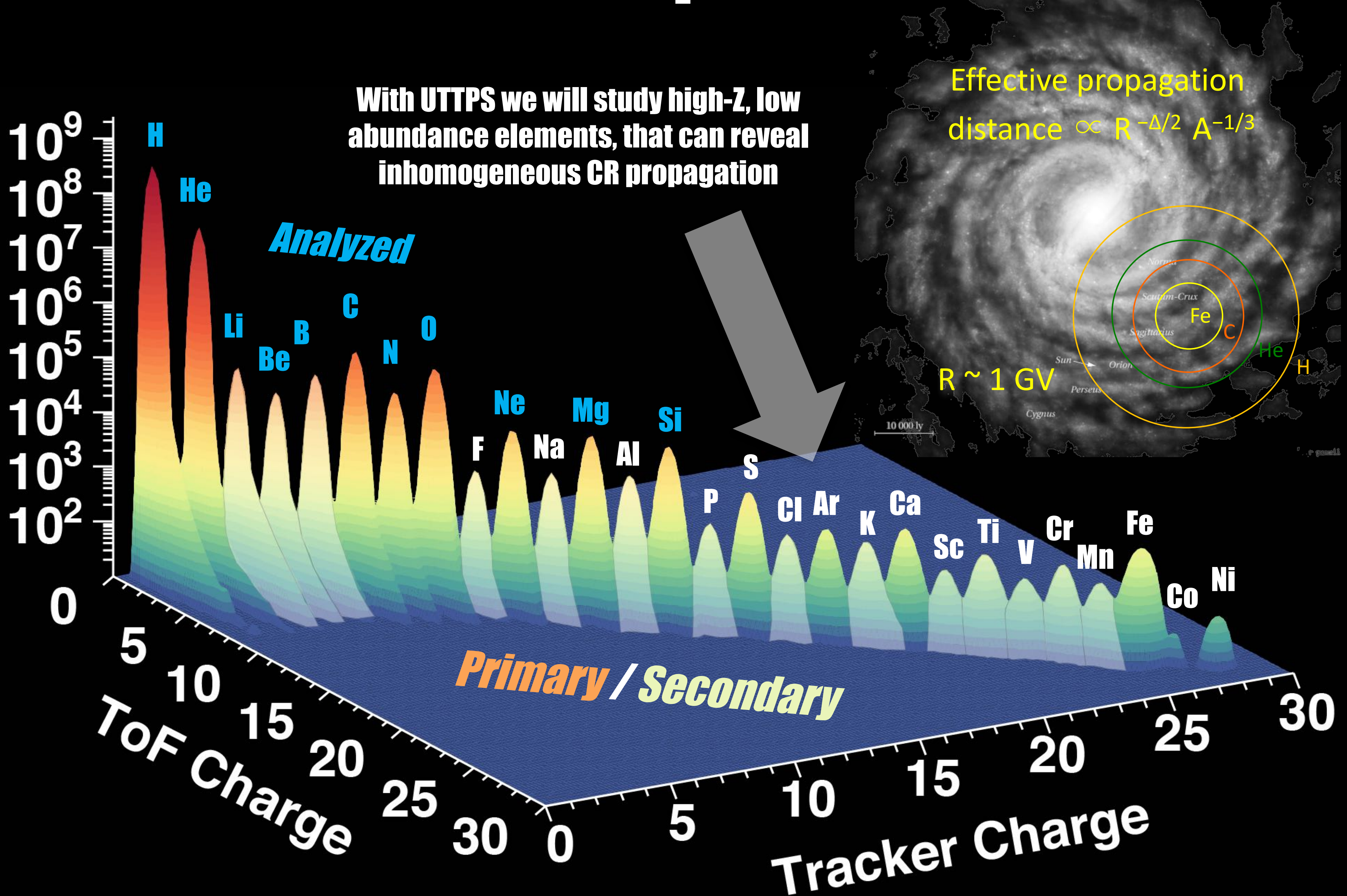
Cosmic rays are commonly modeled as a relativistic gas diffusing into a magnetized plasma.
Diffusion models based on different assumptions predict a Sec/Pri ratio asymptotically proportional to $\mathbf{R^{\delta}}$.
With Kolmogorov turbulence model a $\boldsymbol{\delta = -1/3}$ is expected, while Kraichnan theory leads to $\boldsymbol{\delta = -1/2}$.

AMS Primary and Secondary Fluxes

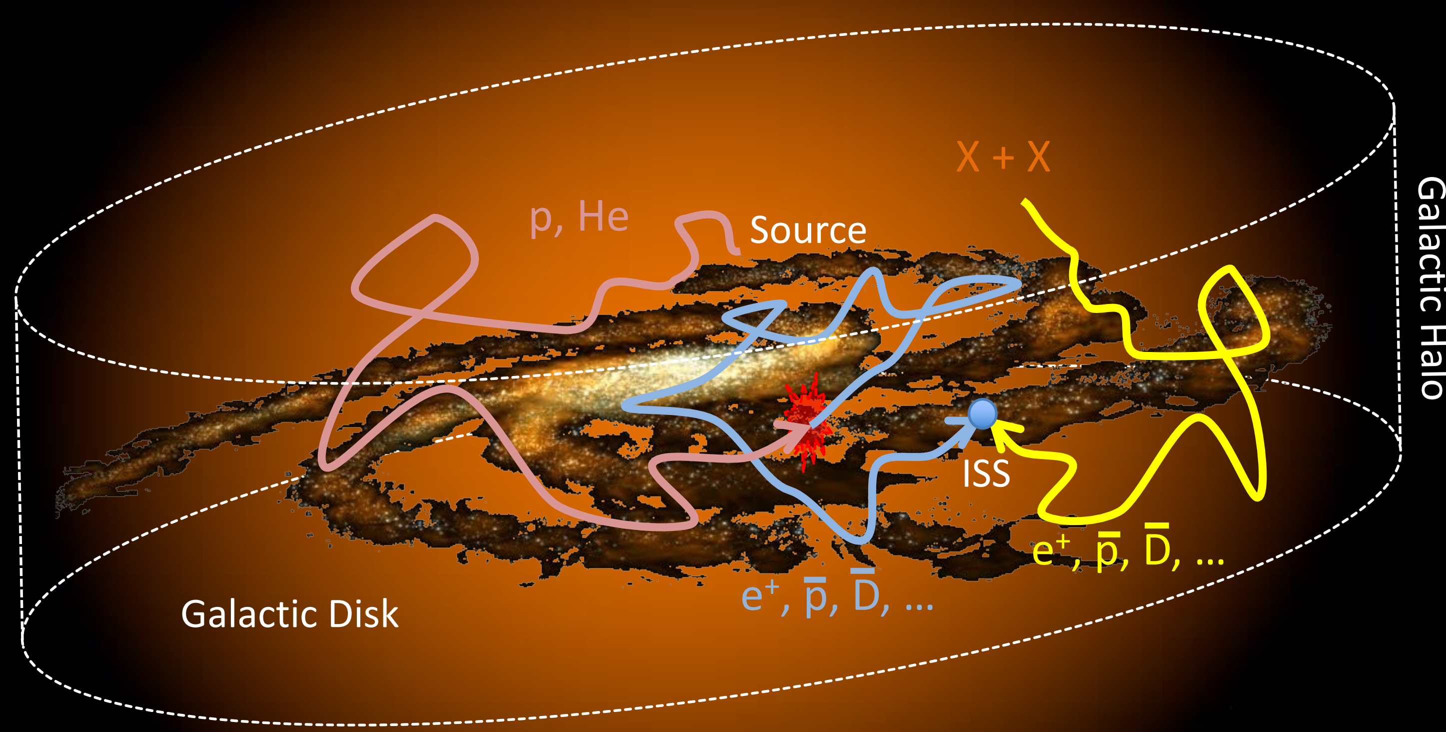


CR Chemical Composition with AMS

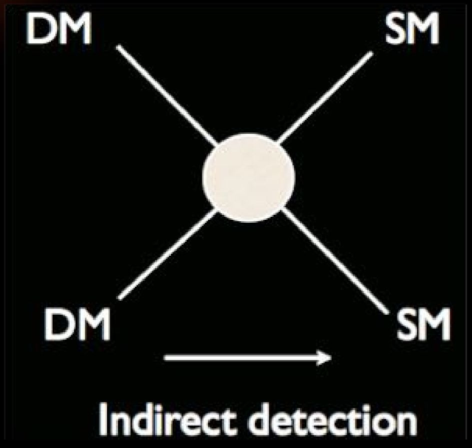
With UTTPS we will study high-Z, low abundance elements, that can reveal inhomogeneous CR propagation



Indirect Search of Dark Matter with CR Anti-Matter

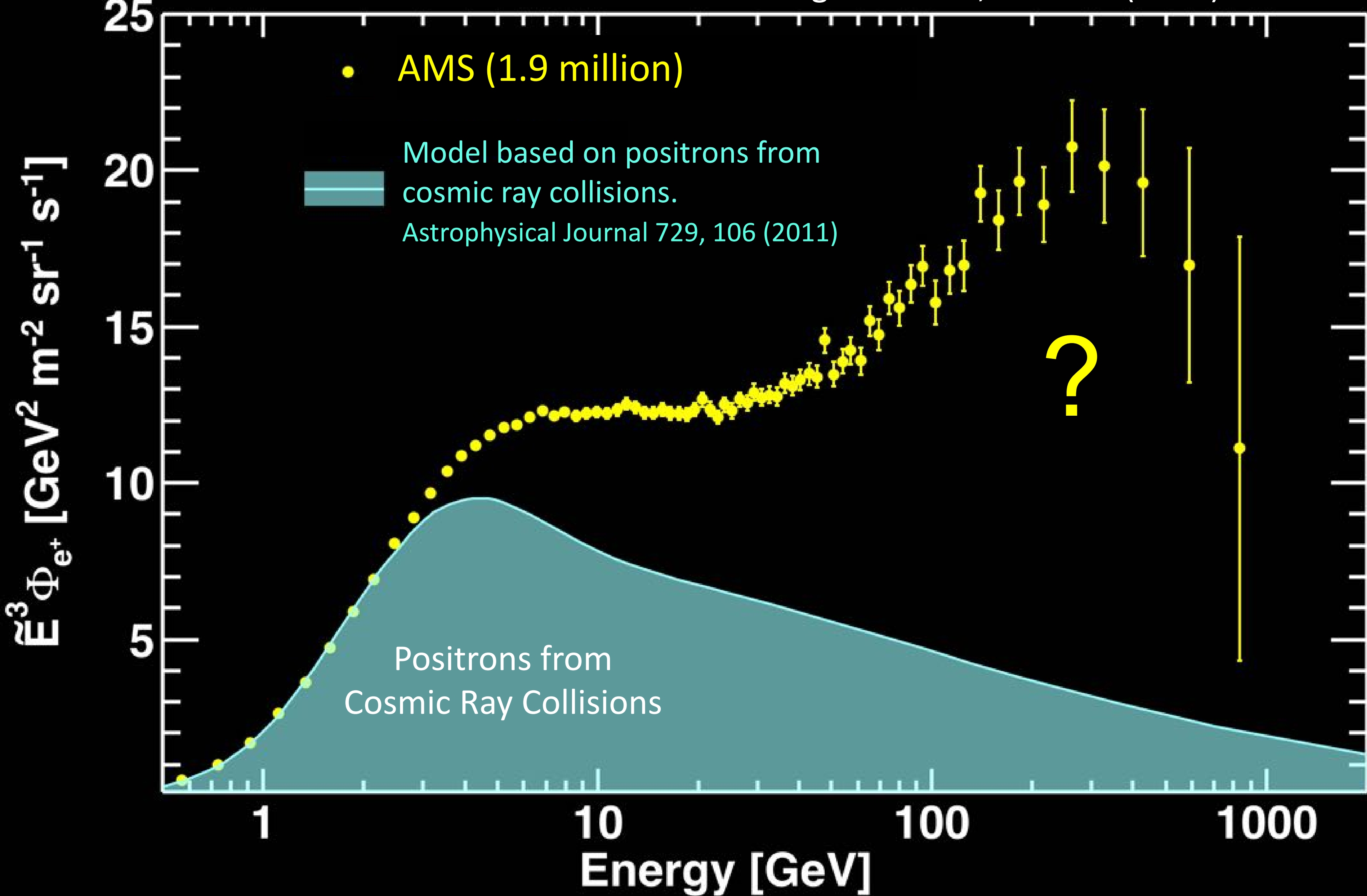


Collisions of dark matter particles (ex. neutralinos)
may produce a signal of e^+, $\bar{p}$, $\bar{D}$, … that
can be detected above the background from the
collisions of primary CRs on interstellar medium

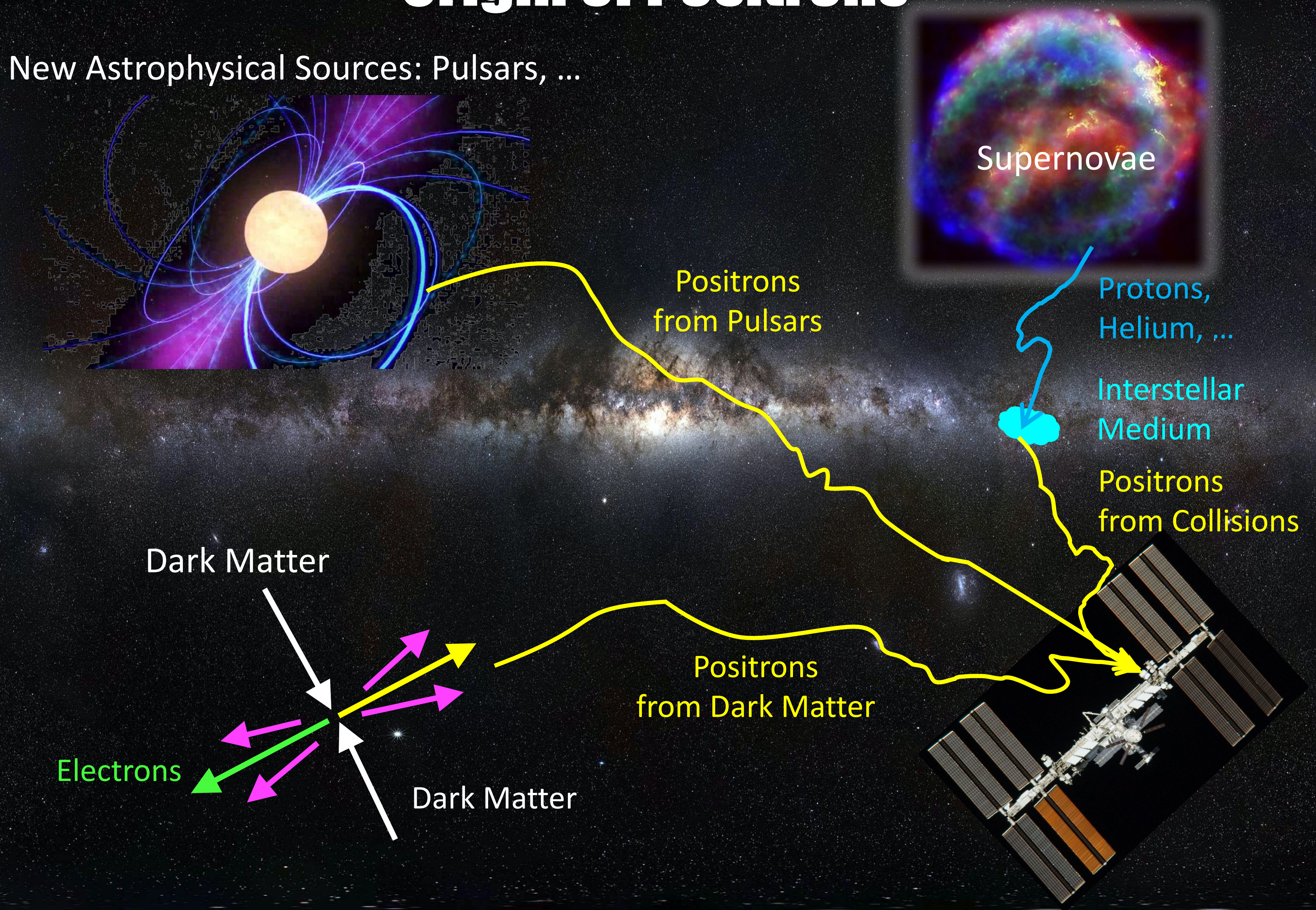


AMS Positron Flux

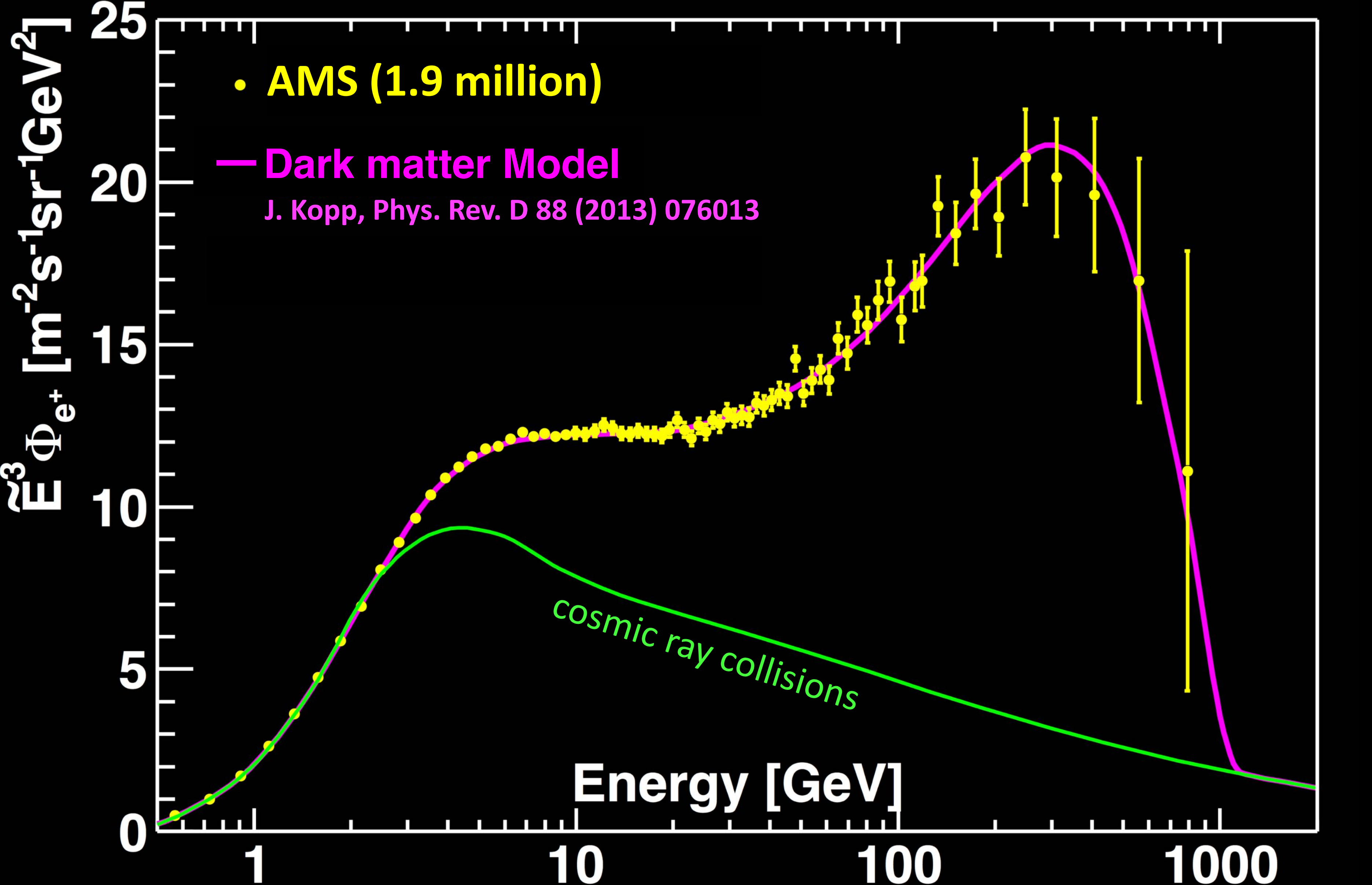
M. Aguilar et al., PRL **122** (2019) 0411012



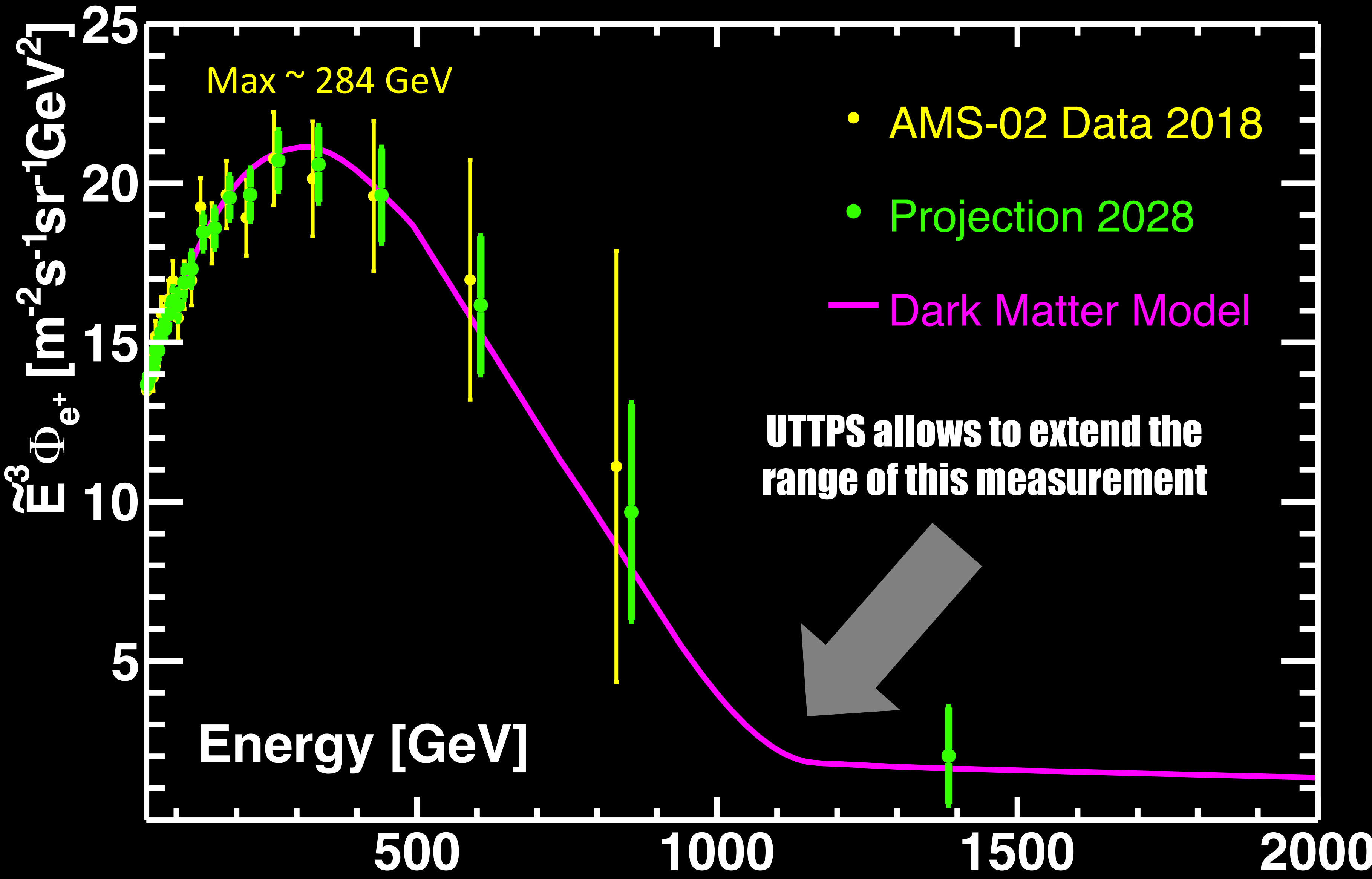
Origin of Positrons



Positron Excess from Dark Matter

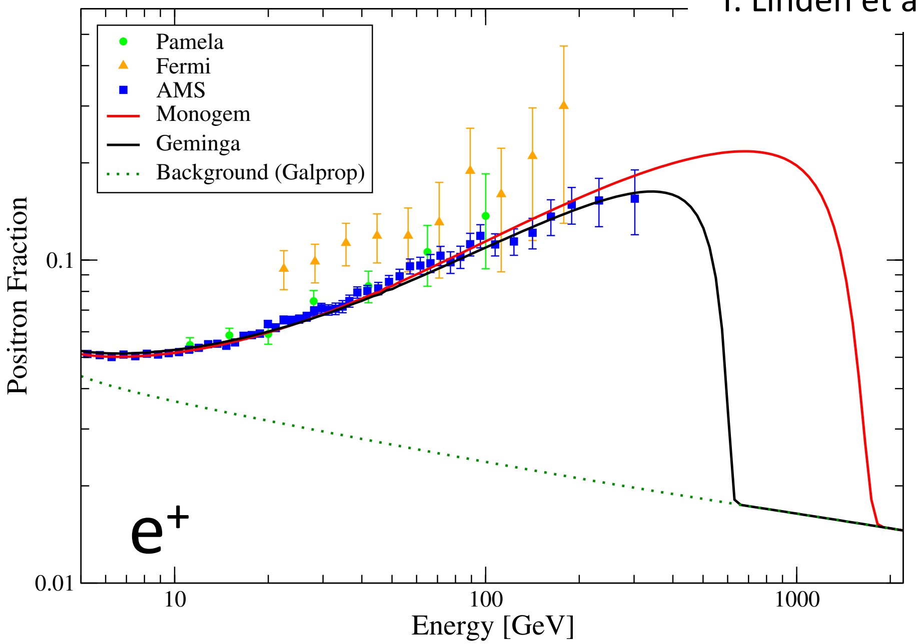


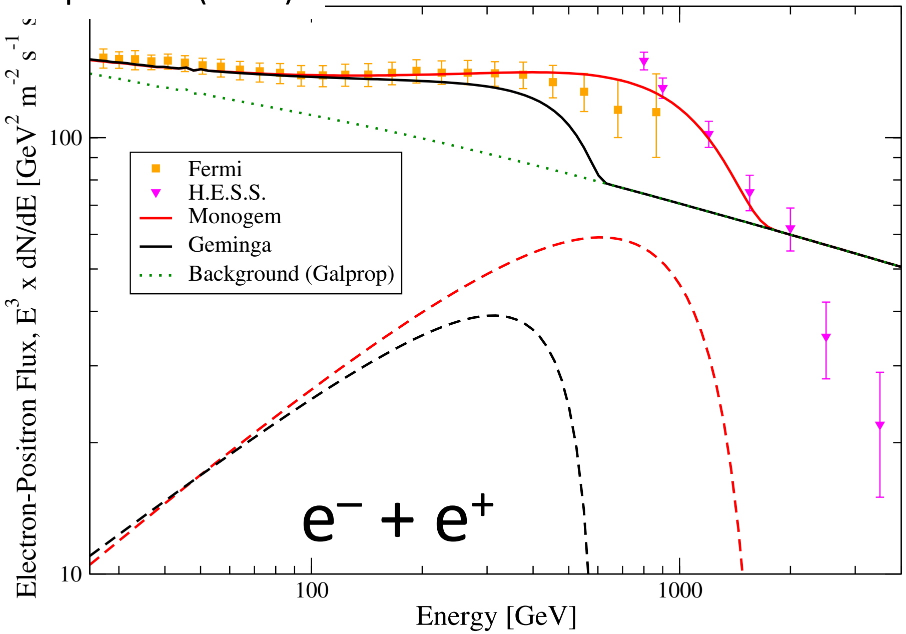
Projection of Positron Excess to 2028



Positron Excess from Pulsars

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

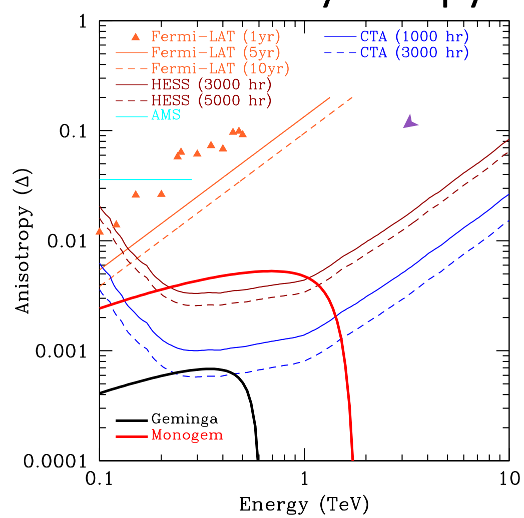


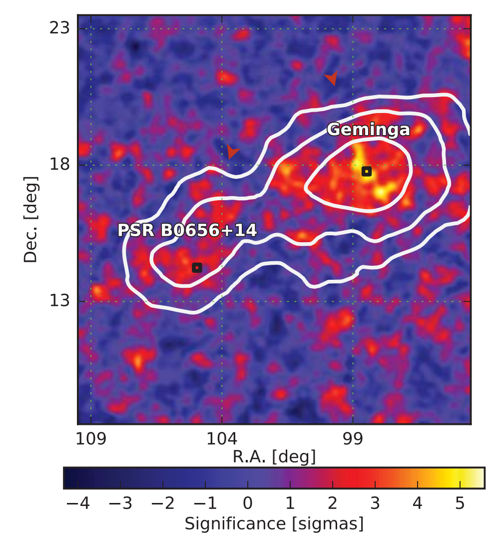


Pulsars spinning produce EM radiation and cosmic rays (pair production).
To distinguish from DM models:

→ **spectral features** of e^+ and of $(e^+ + e^-)$
→ **anisotropy** of e^+ and of $(e^+ + e^-)$
→ **no anti-proton** production

e⁻ + e⁺ anysotropy



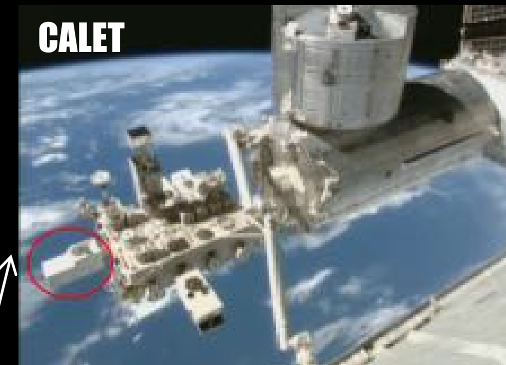


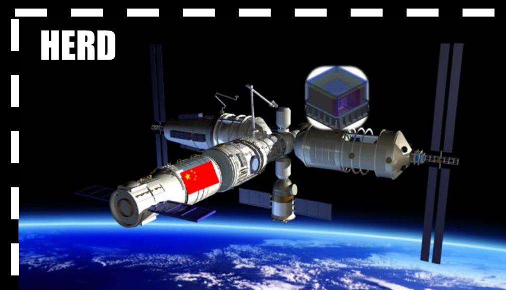
$e^+ + e^-$ Flux

Spectrometer
& EM Calorimeter

EM Calorimeter

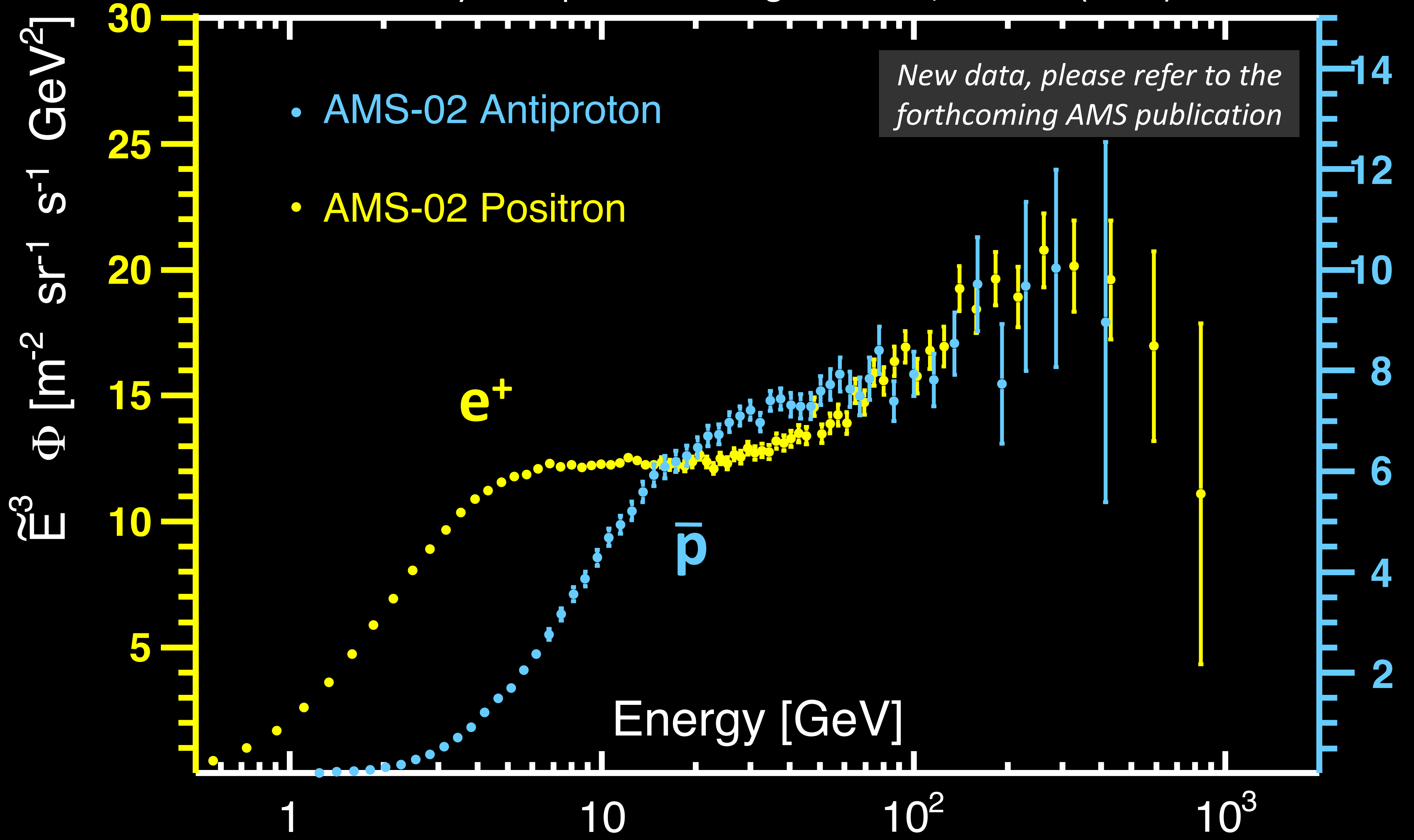
Cherenkov Telescope





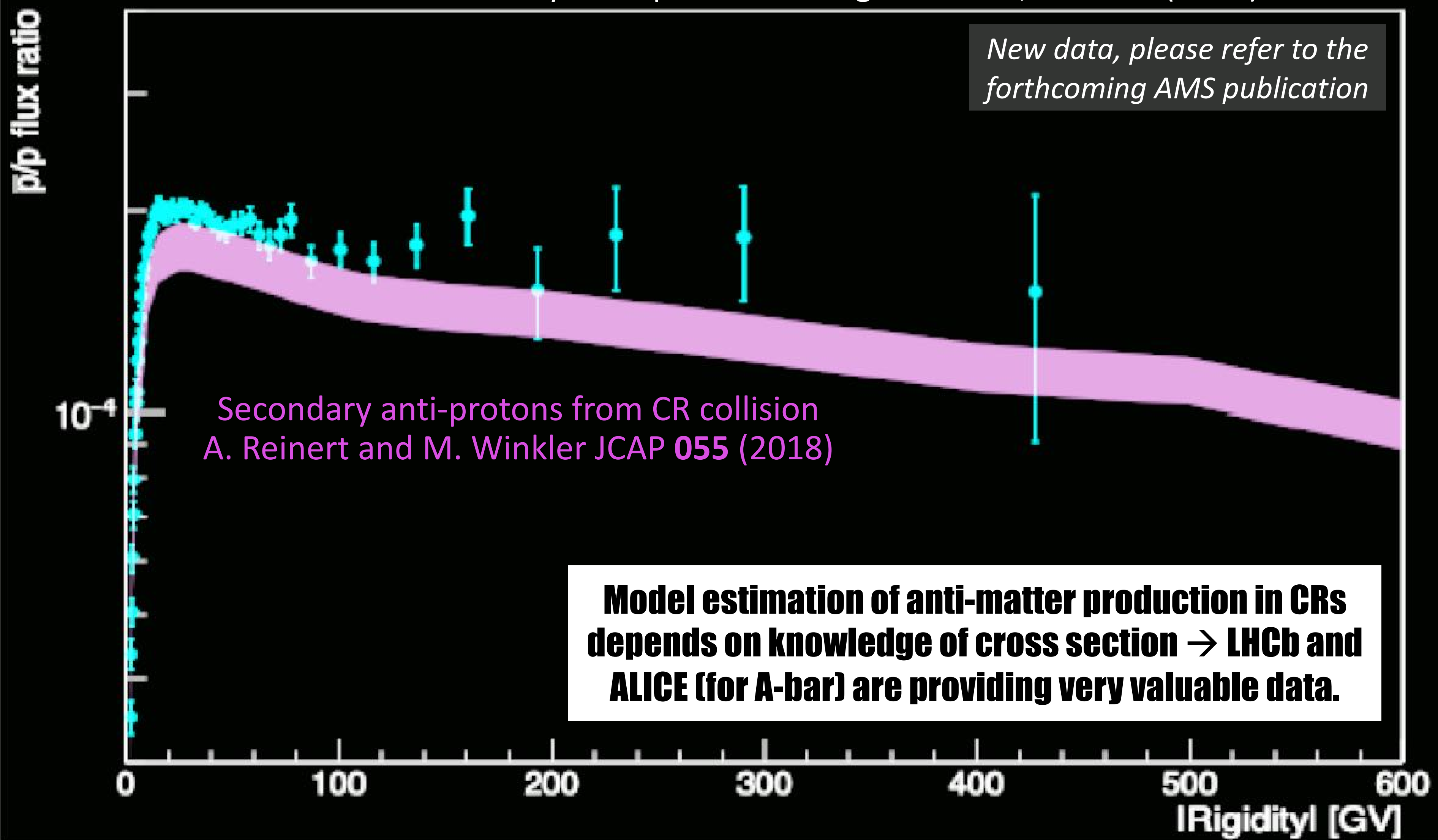
AMS Anti-Proton Flux

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



AMS Anti-Proton Flux

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

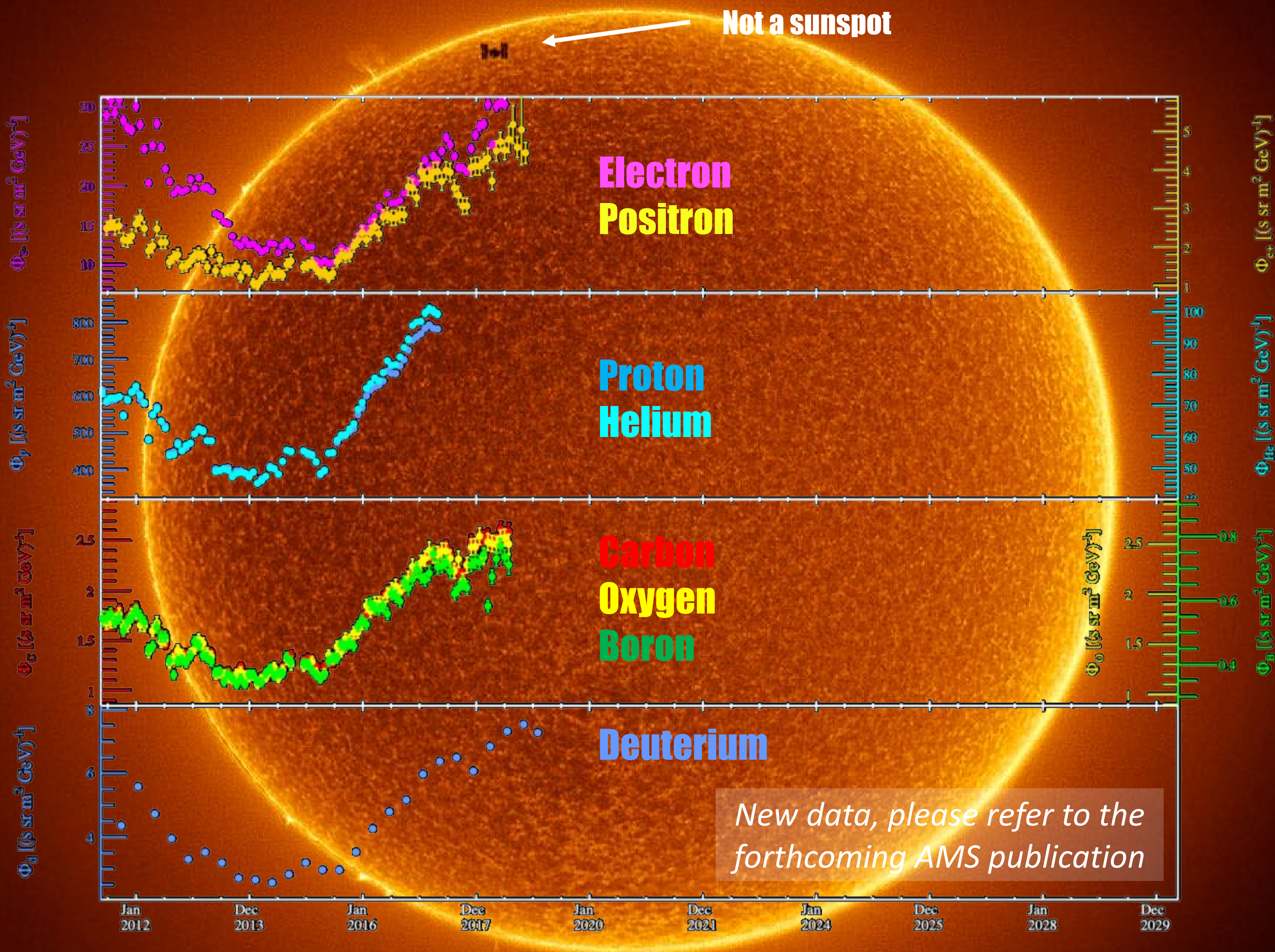


New data, please refer to the forthcoming AMS publication

Secondary anti-protons from CR collision
A. Reinert and M. Winkler JCAP **055** (2018)

Model estimation of anti-matter production in CRs depends on knowledge of cross section → LHCb and ALICE (for A-bar) are providing very valuable data.

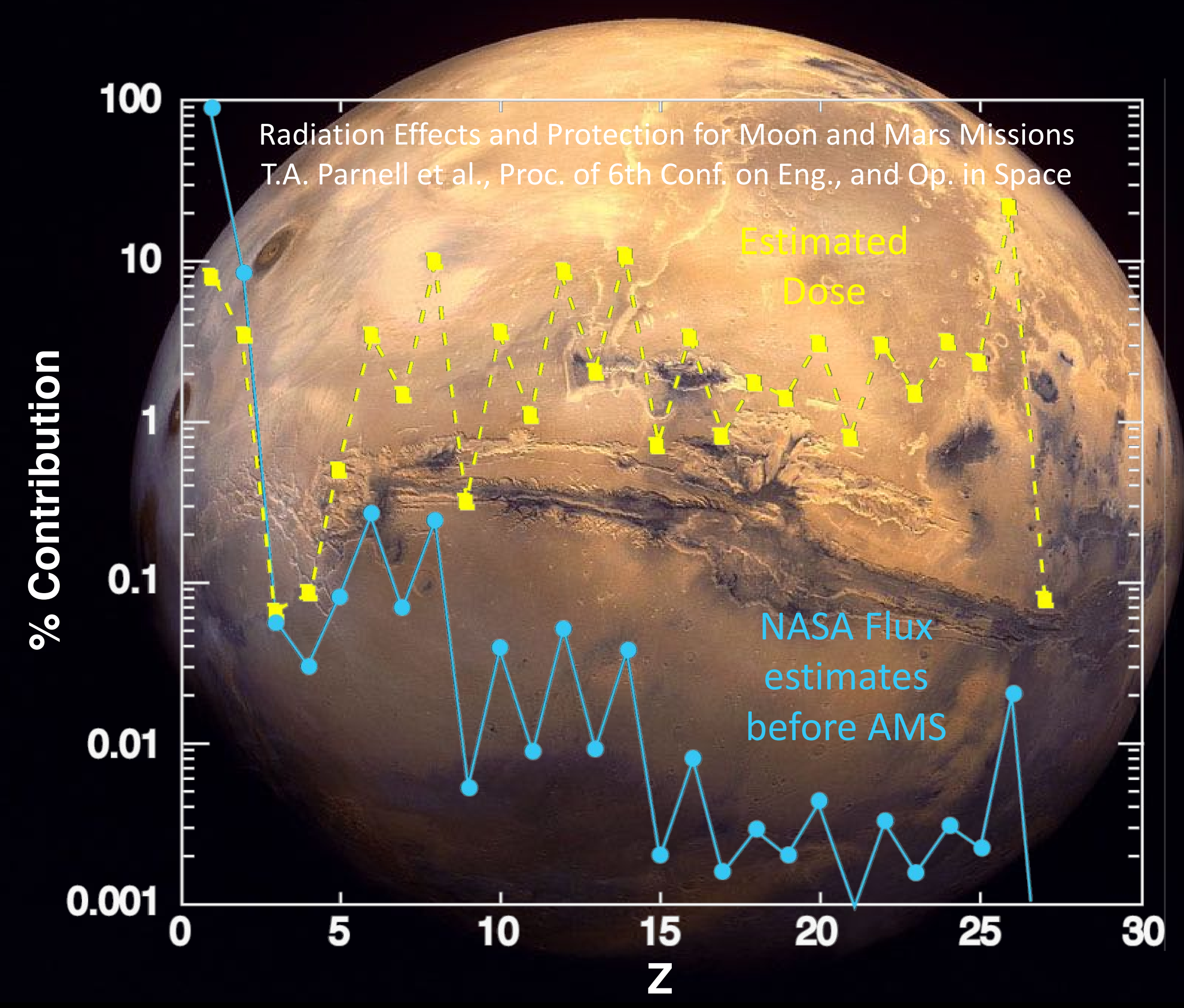
Solar Physics with AMS-02



New data, please refer to the forthcoming AMS publication

Image Credits: APOD 15 July 2019

Space Radiation with AMS-02



Space travel needs cosmic rays high-Z flux measurements, as a function of time and energy.

AMS has been operating in the Space Station since May 2011 performing **precision measurements of cosmic rays** and revealing new details about origin and propagation of all CRs species.

A new pump system have been installed extending AMS lifetime of to the ISS lifetime.

With its unprecedented statistics and accuracy, AMS has an unique capability to detect **antimatter in cosmic rays** and study its properties.

AMS is the **only operating spectrometer in space**, and will continue to collect and analyze data for the lifetime of the Space Station.