

AMS-02 / DAMPE / HERD

CHIPP Roadmap Workshop 2024

Andrii Tykhonov

AMS-02, DAMPE, HERD @ Switzerland

AMS-02

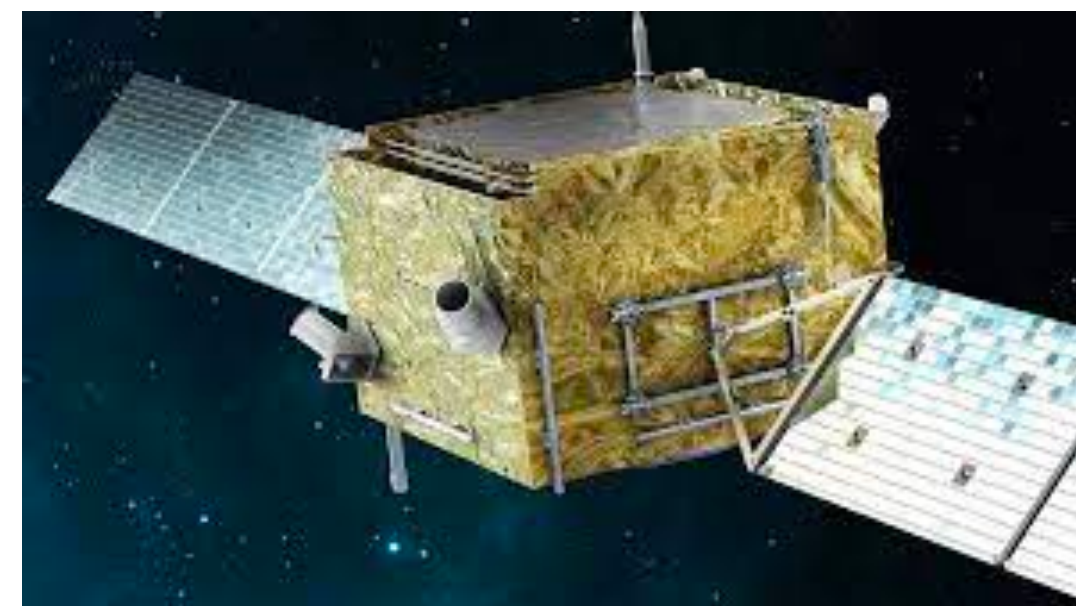
- The largest magnetic spectrometer in space, installed on ISS since 2011
- Currently the most precise cosmic ray space detector in rigidity range 0.5 GV to 3 TV
- Will continue its operation for the entire lifetime of ISS through 2030

DAMPE

- The largest calorimeter-based space mission, launched in 2015
- Since then in excellent working condition
- About 3-times the acceptance of AMS-02
- First direct detection of spectral break in e^+e^- at 1 TeV
- Currently most precise measurements of cosmic rays up to 100 TeV
- Excellent hardware status and the important science return
- Operation will certainly continue for 5-10 more years.

HERD

- Next generation calorimeter-based astroparticle mission
- Unprecedented acceptance (10 times higher than DAMPE) and precision:
 - Direct measurements of cosmic rays beyond PeV.
 - Excellent gamma-ray imager from 100 MeV to 100 TeV
- China-Europe mission
- Currently in the final selection phase
- If adopted, will be installed on China Space Station around 2028.



AMS-02, DAMPE, HERD @ CH

Involved PI(s):

Xin Wu (UNIGE), Andrii Tykhonov (UNIGE), Chiara Perrina (EPFL), Mercedes Paniccia (UNIGE)

Swiss participant Institutions and investment level:

AMS (UNIGE)

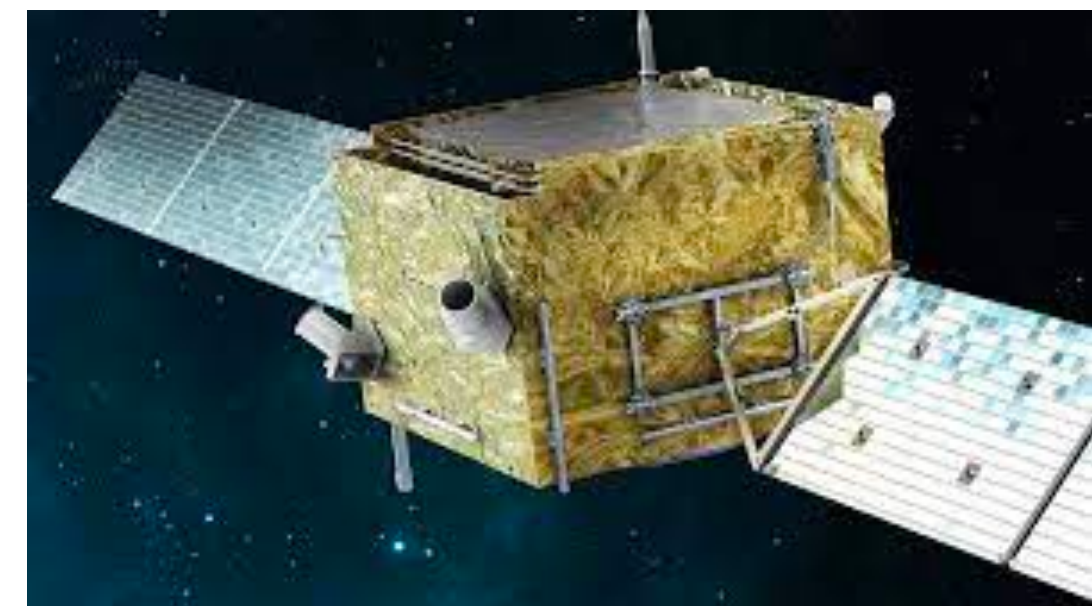
- Major hardware, software, and operation contributions:
 - Construction of the AMS silicon tracker
 - Silicon tracker charge calibration, detector monitoring and operation, ML
- Major contributions to data analysis and publications: nuclei and isotopes spectra

DAMPE (UNIGE, EPFL)

- Major hardware, software and operation contributions:
 - Proposer and project leader of the DAMPE silicon tracker (STK)
 - DAMPE software framework, STK simulation, reconstruction and tracking software
 - ML algorithms for tracking, particle ID and energy correction
 - STK monitoring, calibration, alignment, European MC production
- Major contributions to data analysis and publications

HERD (UNIGE, EPFL)

- Major hardware and software contributions
 - Proposer and project leader of scintillating fibre tracker (FIT)
 - FIT reconstruction software
 - ML algorithms, hadronic model tuning
 - MC studies to estimate the HERD sensitivity to a gamma-ray flux from dark-matter annihilation



Funding from SNSF, Swiss Space Office, ERC, Boninchi

AMS-02, DAMPE, HERD @ CH

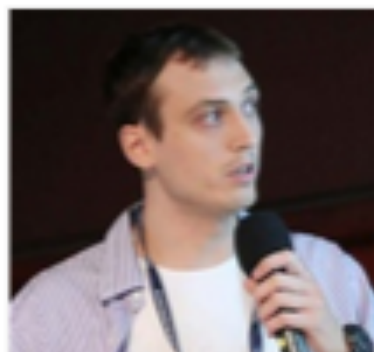


**UNIVERSITÉ
DE GENÈVE**



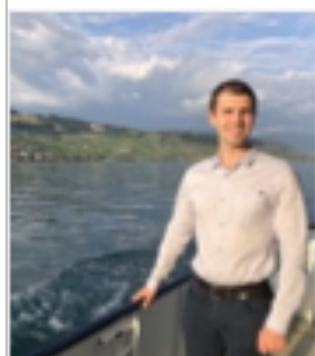
Prof. Xin WU
Professeur ordinaire - Head of the group

[MORE INFORMATION >>](#)



Prof. Andrii TYKHONOV
Professeur Assistant - ERC PeVSPACE (DAM
HERD)

[MORE INFORMATION >>](#)



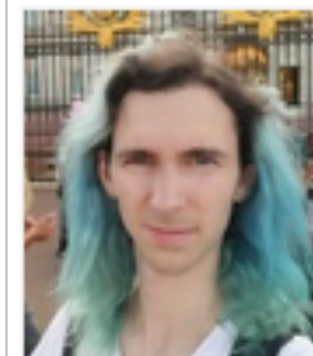
M Daniil SUKHONOS
Postdoctorant - groupe DAMPE/HERD/PAN

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M. Paul COPPIN
Assistant postdoctorant - Group

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Mr Enzo PUTTI-GARCIA
PhD Student - DAMPE

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Mme Manbing LI
PhD student - AMS-02

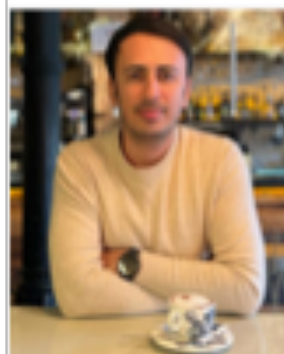
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Dr Mercedes PANICCIA
Collaboratrice scientifique II - AMS & PAN



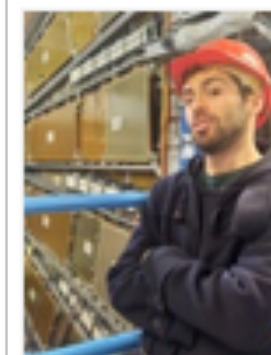
Dr Philipp AZZARELLO
Collaborateur Scientifique II - PAN, DAMPE



Mr Shahid KHAN
Postdoc - AMS-02



Mr Dimitrios KYRATZIS
Postdoc - DAMPE and HERD



Mr Andrea SERPOLLA
PhD student - DAMPE



Mr Andrii KOTENKO
PhD Student - ERC PeVSPAC

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Chiara Perrina



Scientist - Ambizione fellow (DAMPE, HERD)

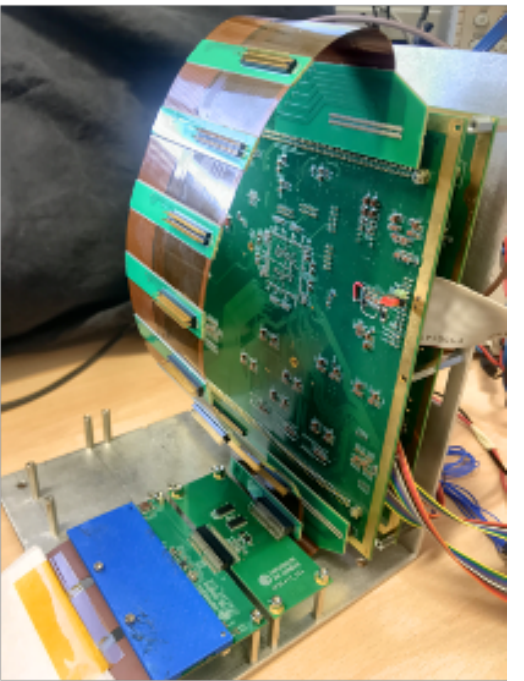
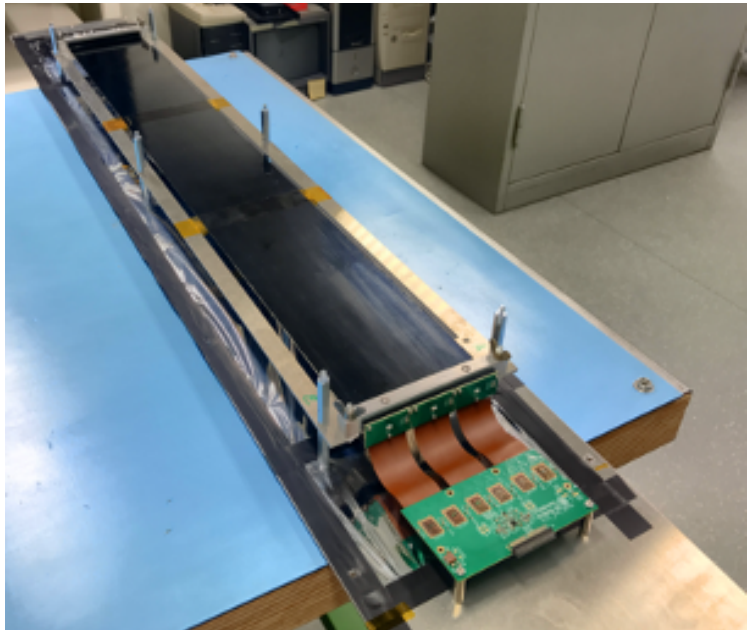
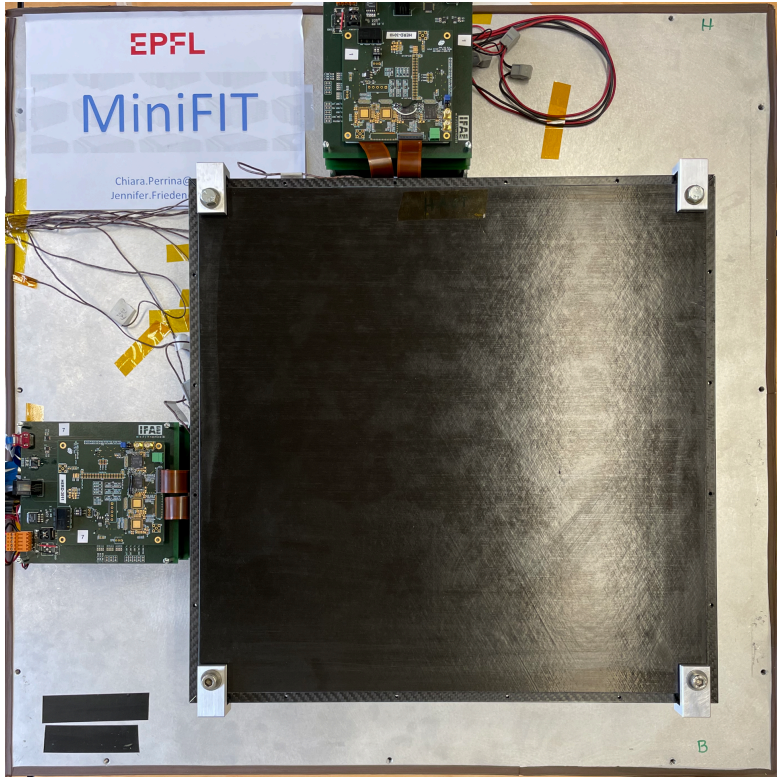
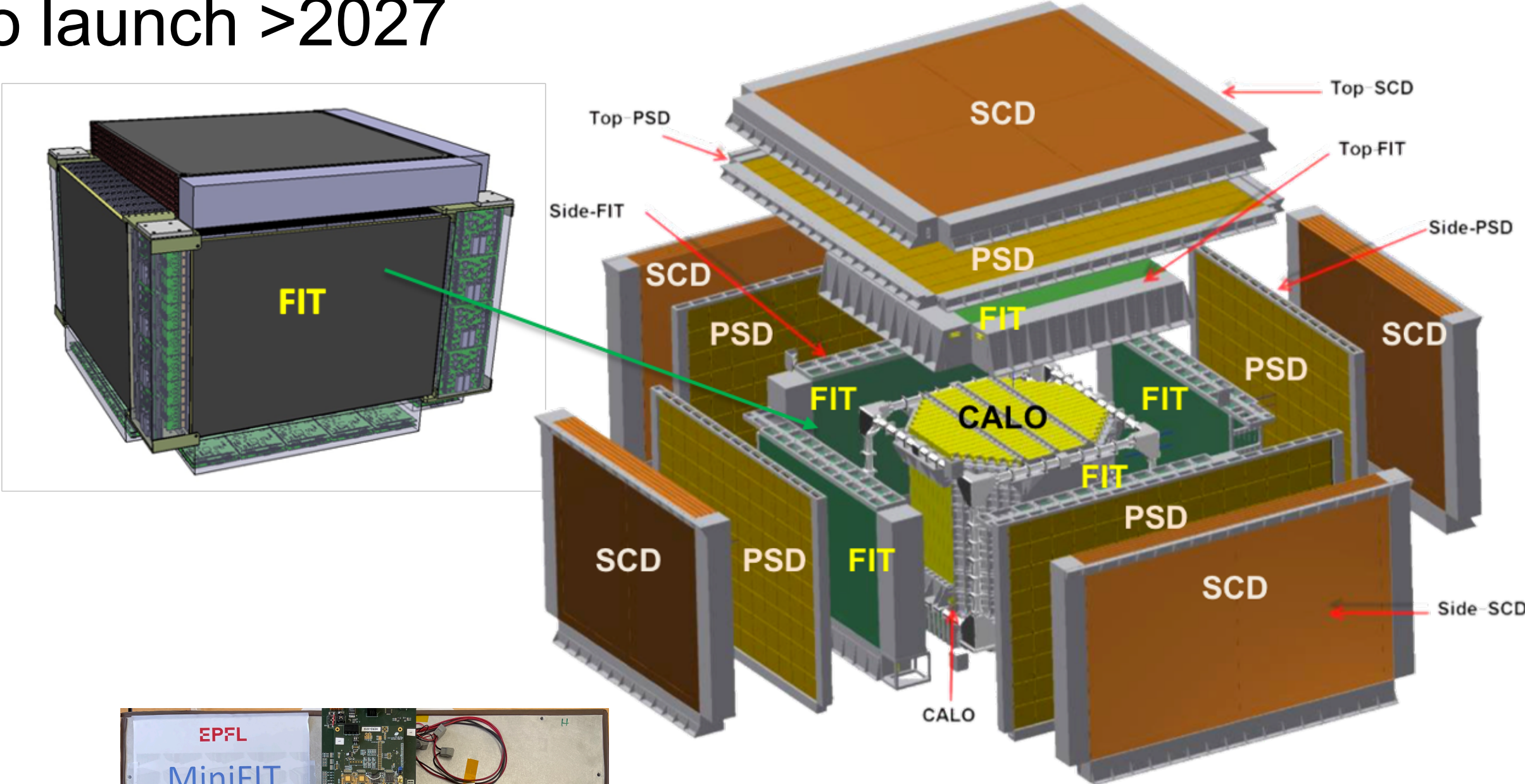
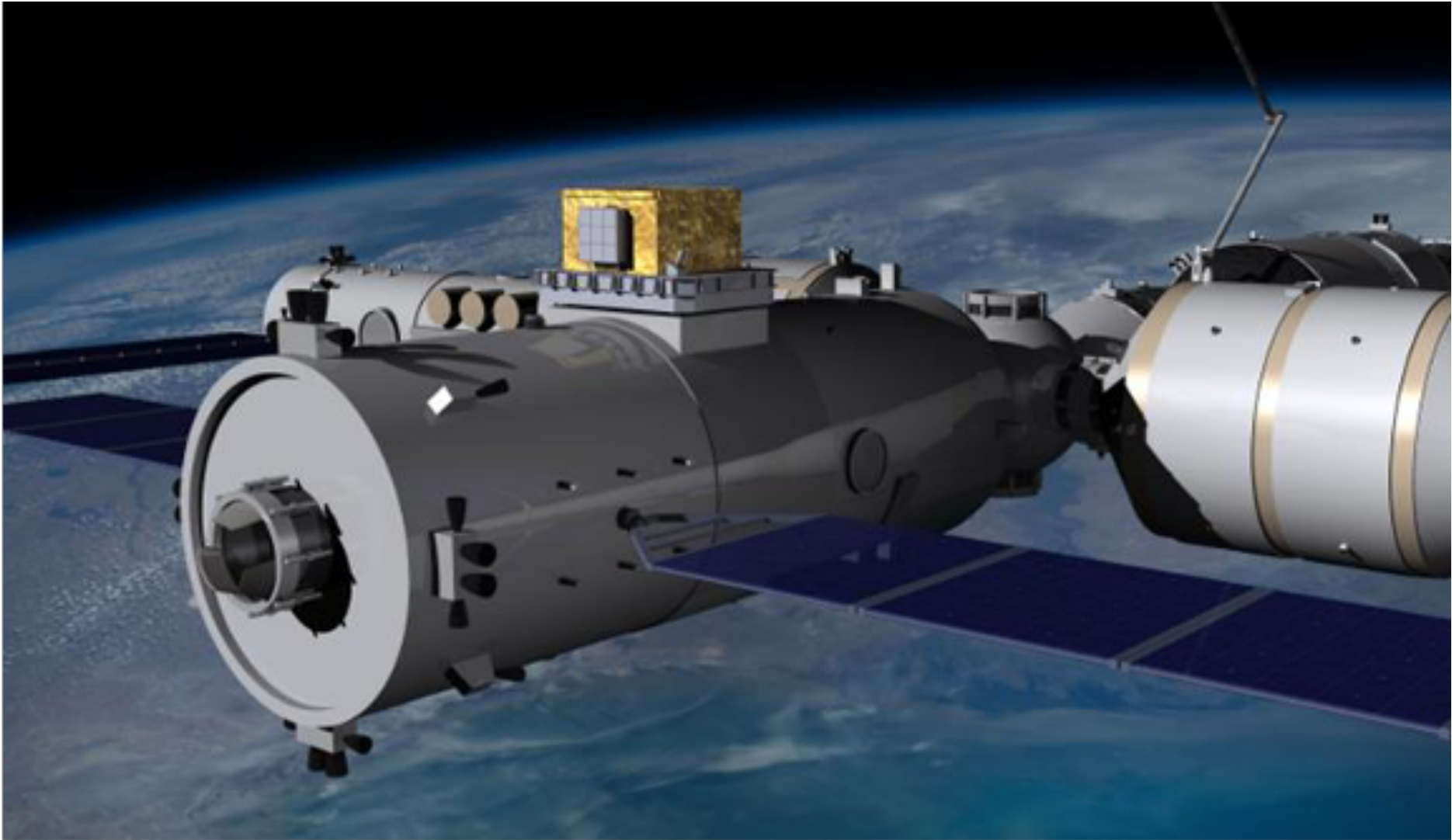
Jennifer Maria Frieden



PhD student (DAMPE, HERD)

Direct detection of PeV cosmic rays: HERD (CERN RE since 2023)

- China-Europe collaboration since 2012, expected to launch >2027



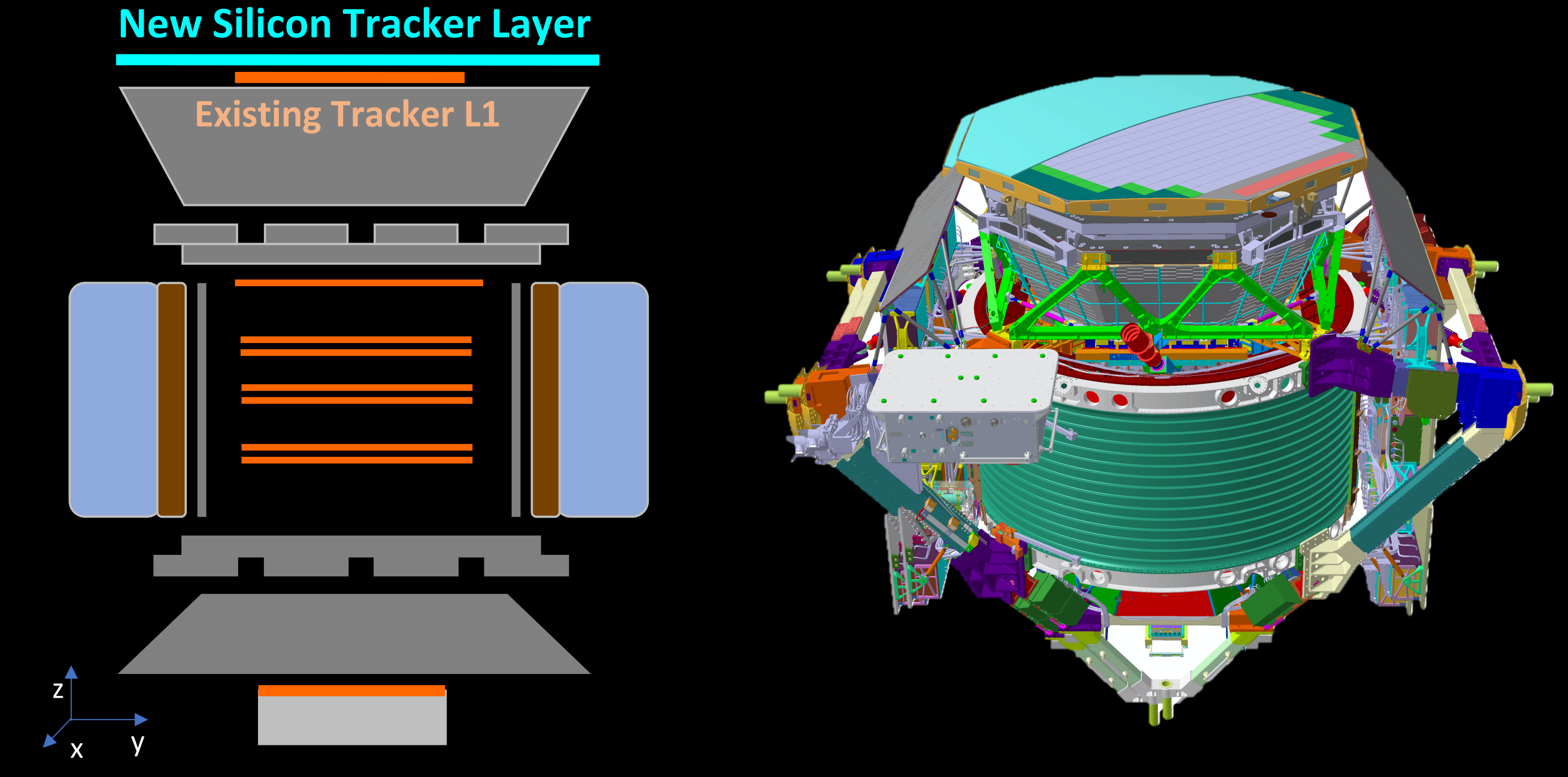
- UNIGE and EPFL in charge of the Fiber Tracker (FIT)
 - Chiara, Jennifer, Philippe, Daniil, Dimitrios, Andrii
 - Phase B R&D completed
 - Test beam activities on-going (with IFAE and U. Barcelona)
 - Update of FEB with new ASIC (BETA from U. Barcelona)
 - Monte-Carlo simulation studies ongoing

Upgrade with new Silicon Tracker Layer

Acceptance increased to 300%

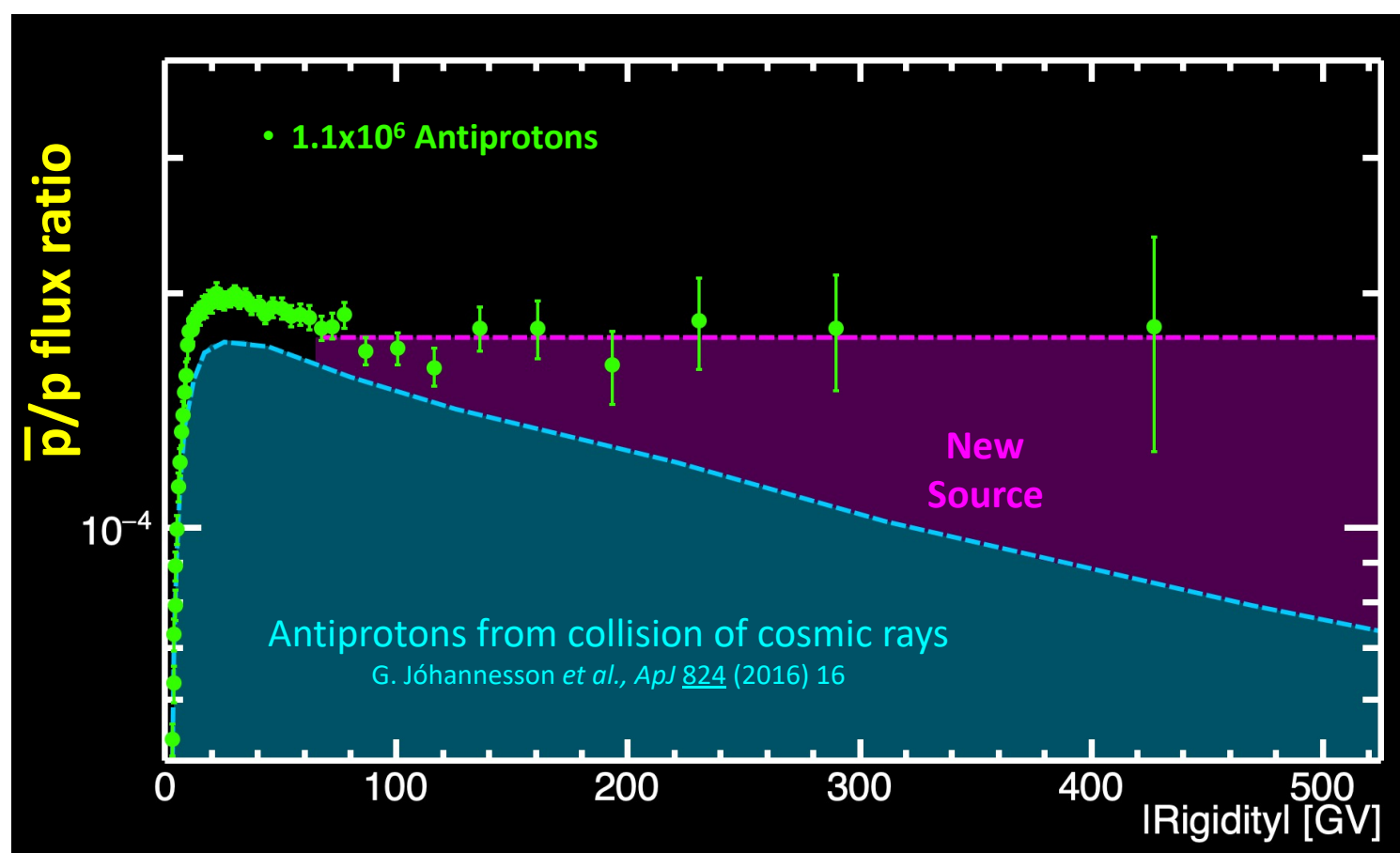
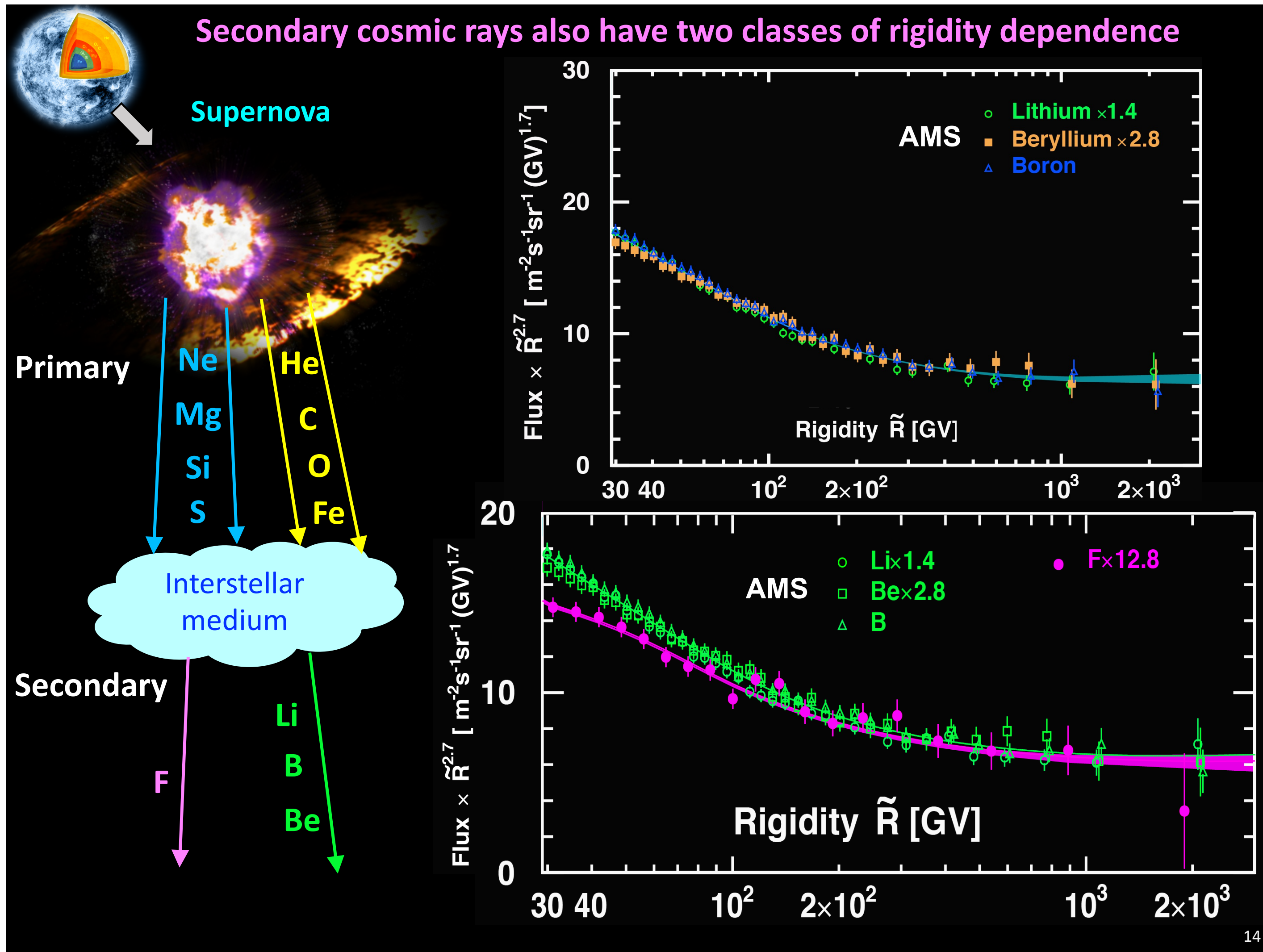
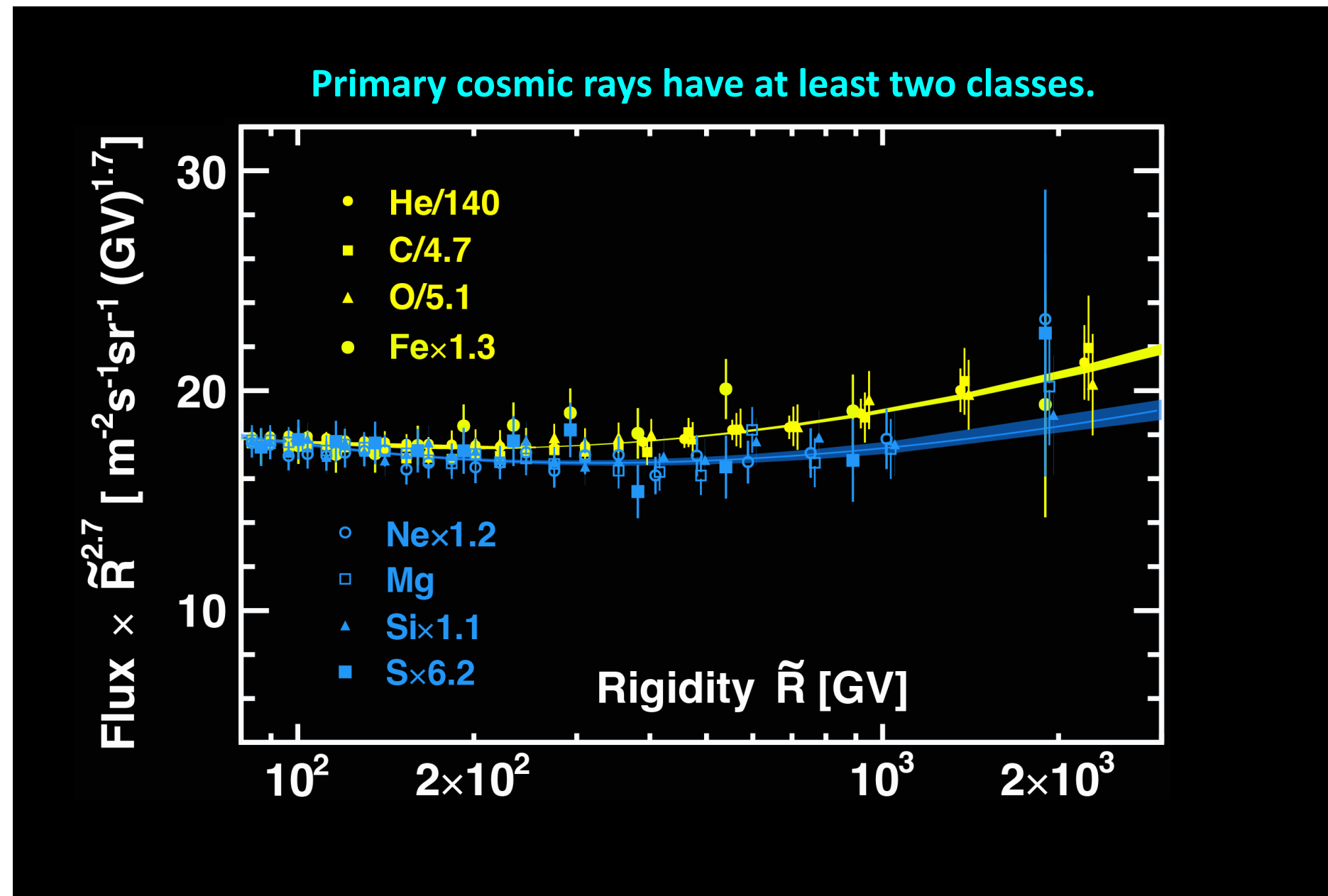
Currently 2025-2030 = 5 years

With upgrade = 15 years



* Slides credit: ICRC2023 highlight talk

AMS-02 comprehensive look at cosmic rays at GeV – TeV scale



* Slides credit: ICRC2023 highlight talk

Dr Mercedes Paniccia (Team Leader), Dr Shahid Khan (joined July 2023)

Phd students: Mr. Erwan Robyn (graduated in Aug. 2023), Ms. Manbing Li

External collaborators from the Shandong Institute of Advanced Technology: Dr, Yao Chen, Dr Jiahui Wei

Detector Operations at the AMS-POCC at CERN:

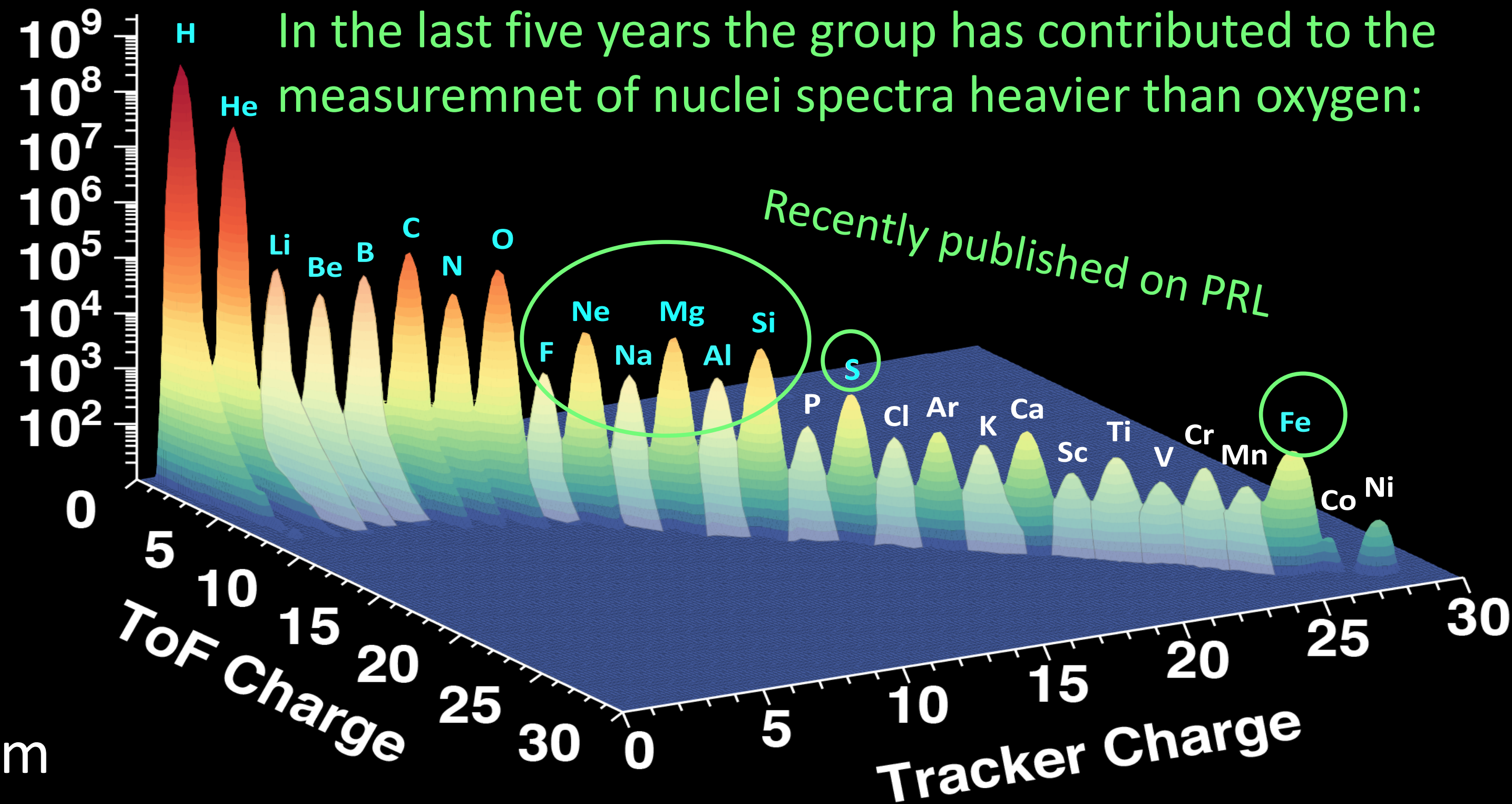
- Monitoring of Tracker & TRD detectors

Data Analysis:

- Cosmic-ray nuclei fluxes
- Isotopic composition of light nuclei

These provide crucial information on:

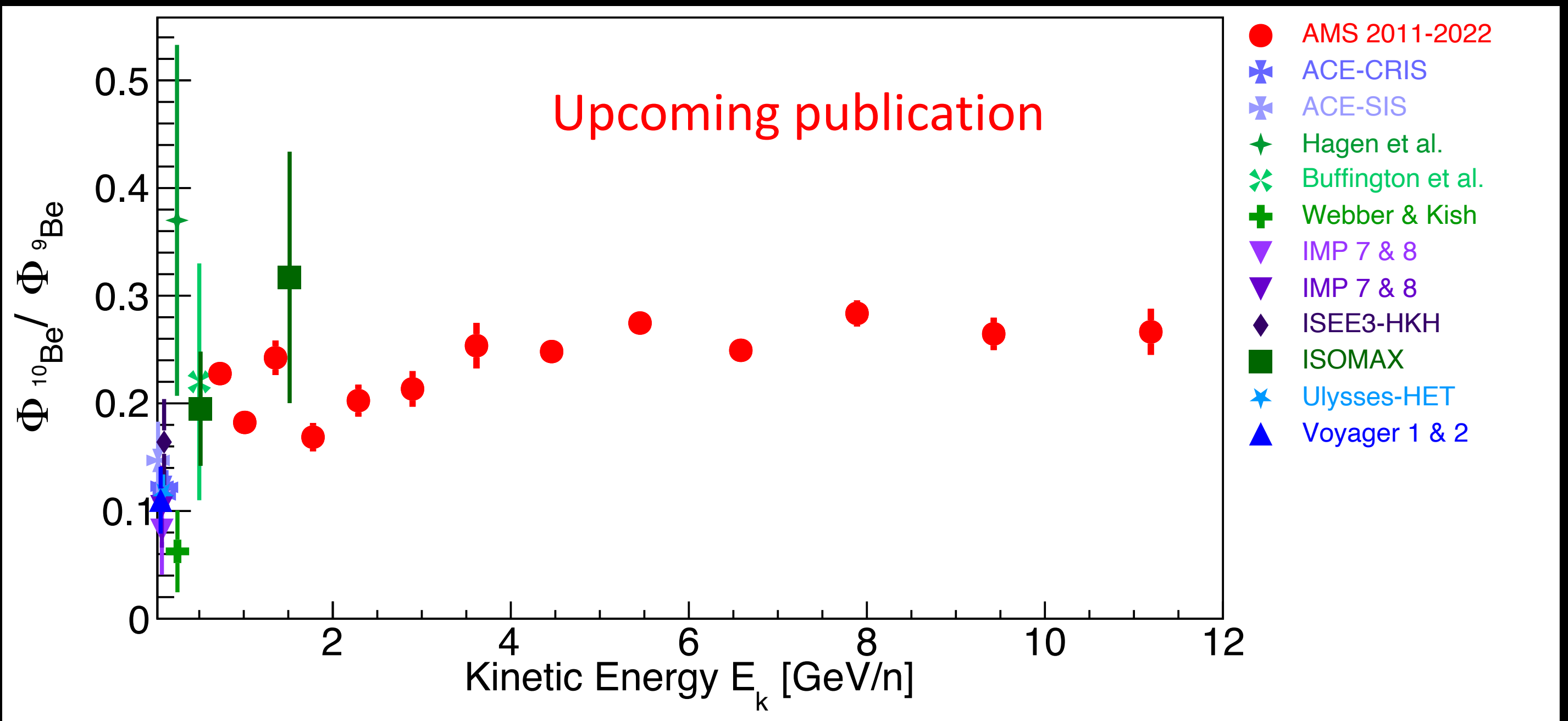
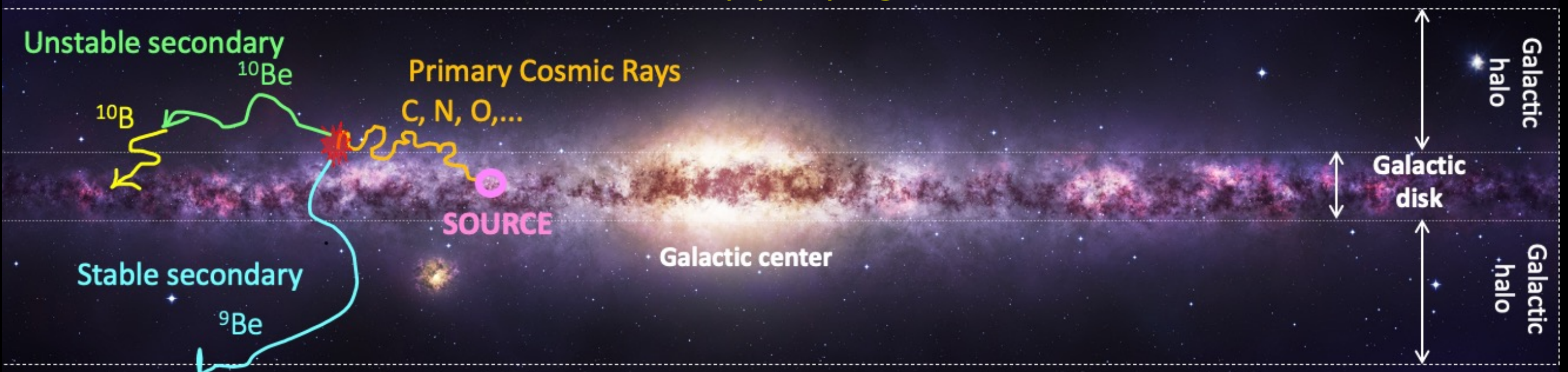
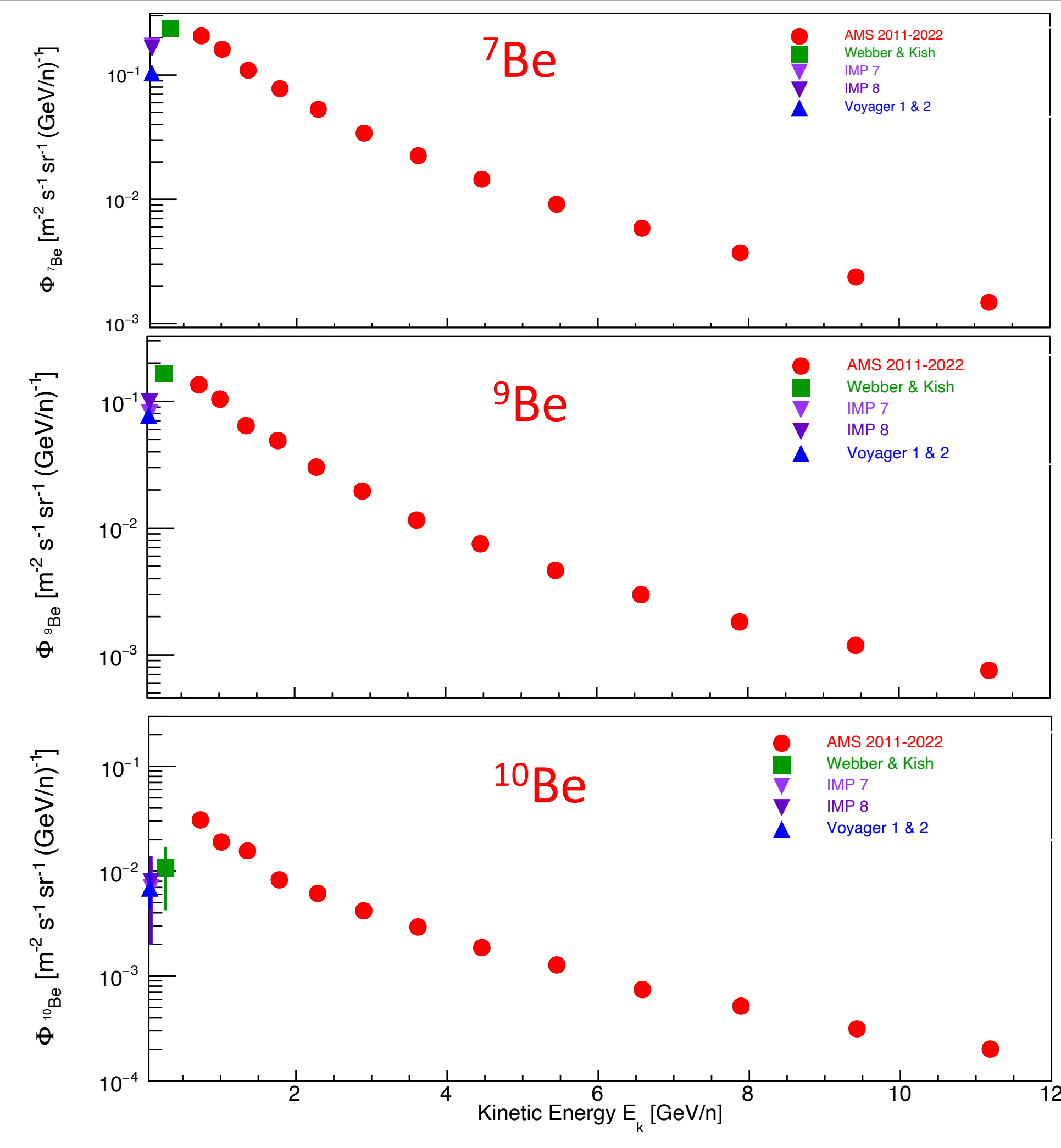
1. Sources of cosmic rays
2. Cosmic-ray acceleration and propagation mechanisms
3. Properties of the interstellar medium



Spectra of beryllium isotopes ${}^7\text{Be}$, ${}^9\text{Be}$ and ${}^{10}\text{Be}$

Manbing Li's PhD thesis

The ratio of unstable-to-stable secondary cosmic rays ${}^{10}\text{Be}/{}^9\text{Be}$ measures the size of the cosmic-ray propagation volume.

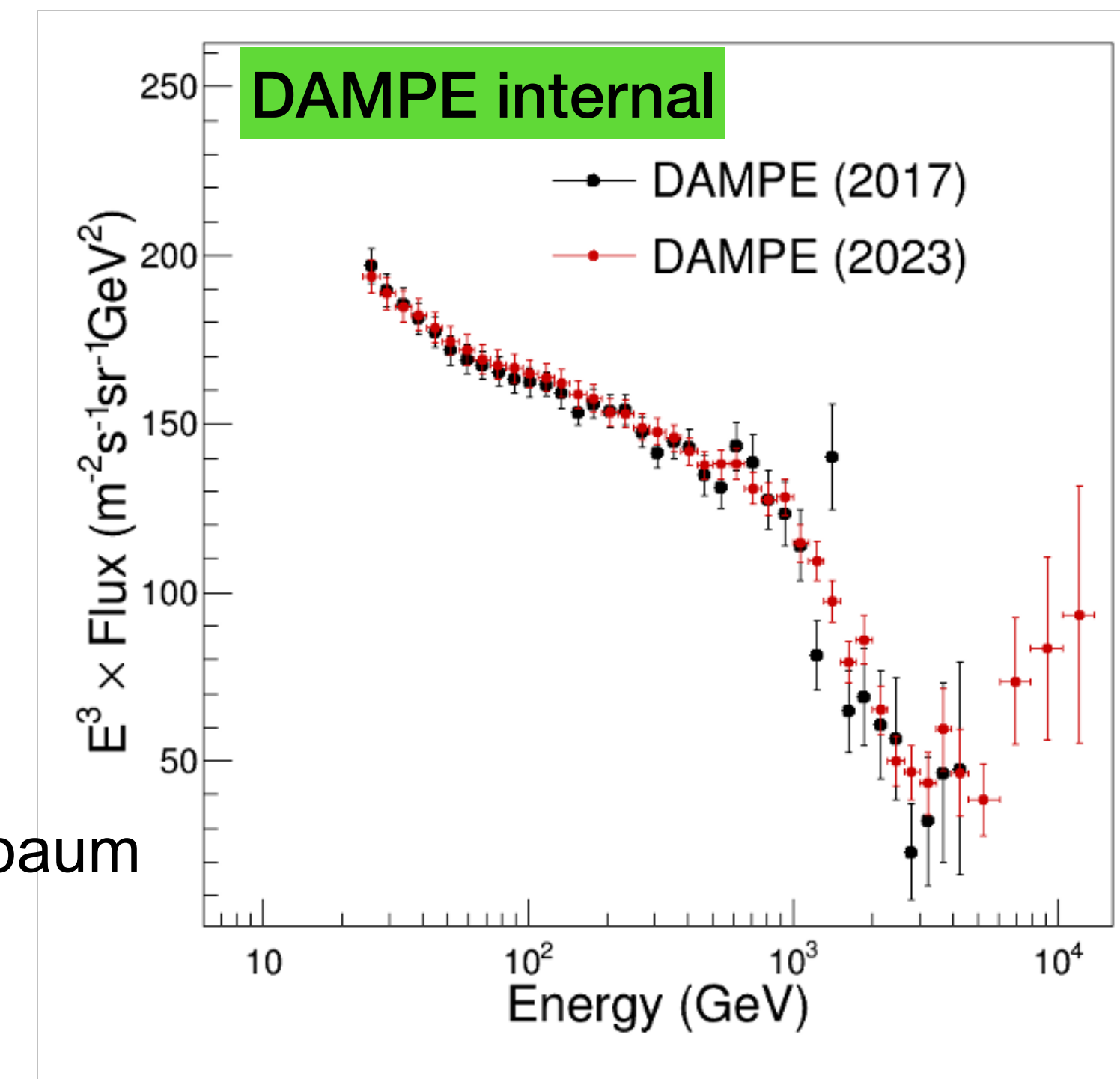
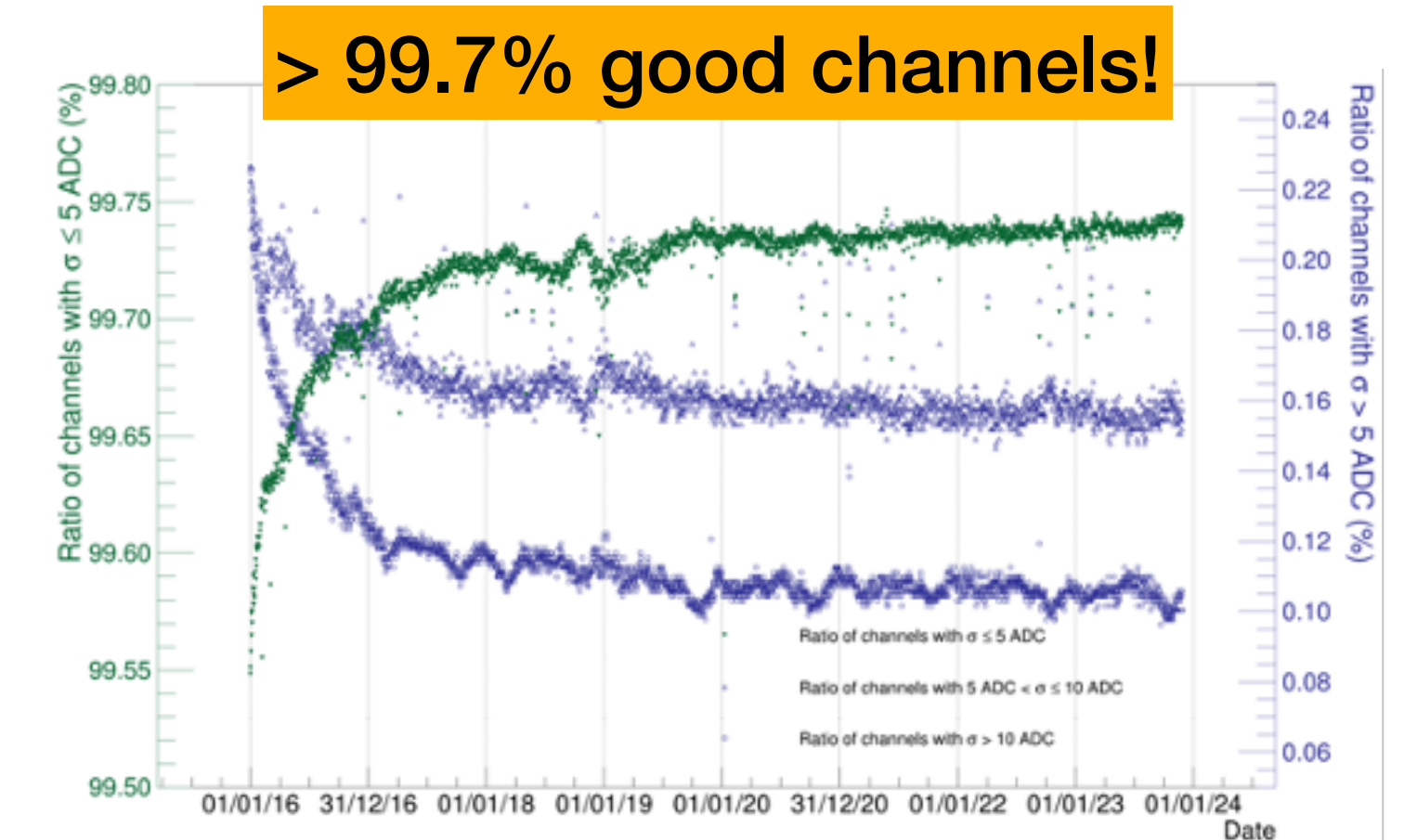


DAMPE in 2023

- **STK (built at DPNC) in excellent condition after 8 years in space!**
 - UNIGE & EPFL — calibration, alignment



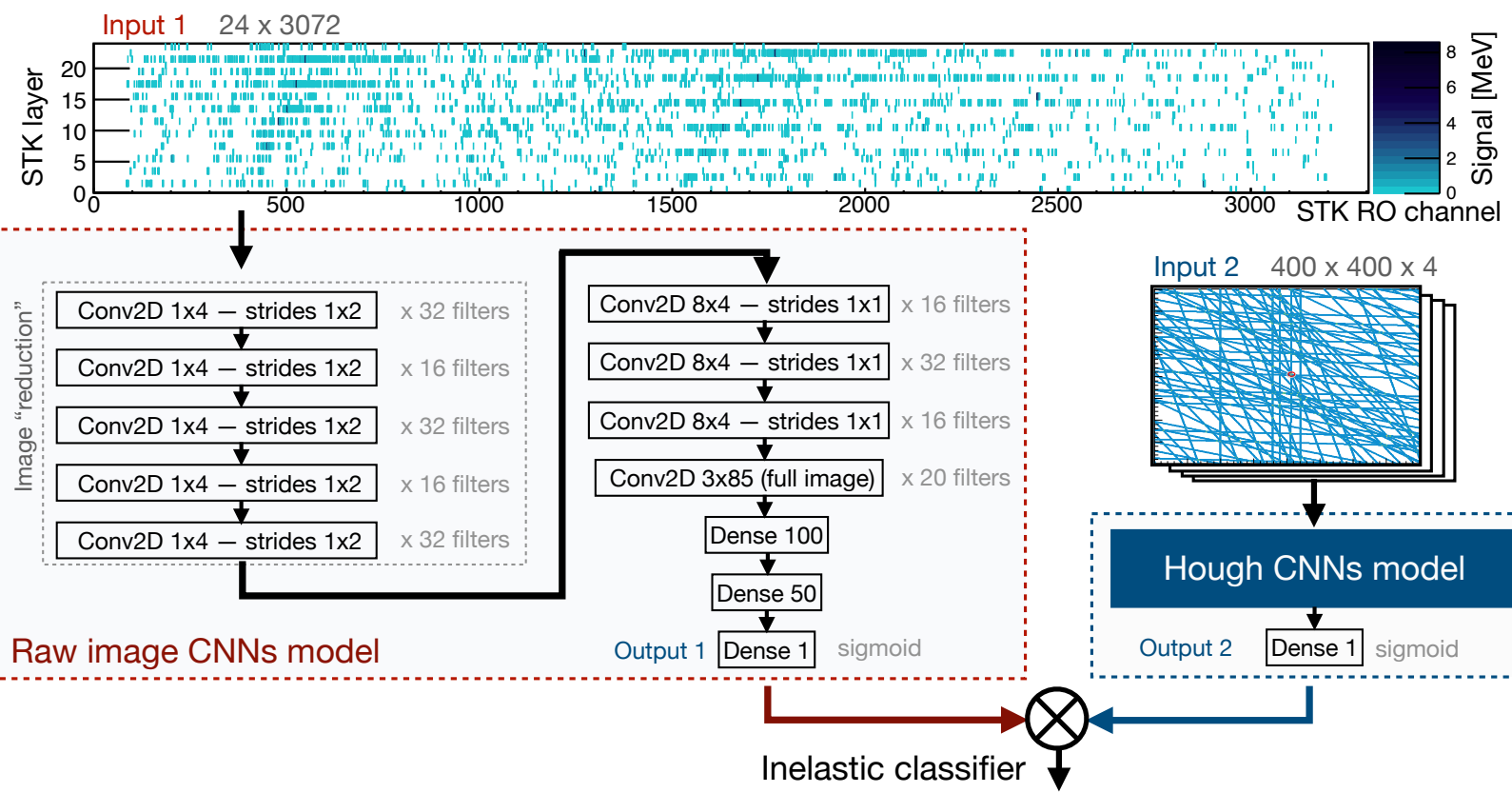
- **A. Ruina graduated in June**
 - He flux extended to 200 TeV with 7 years of data
 - Analysis continued by A. Tykhonov, P. Coppin, A. Kotenko, A. Serpolla
 - Proton flux update to ~PeV
- **M. Stolpovskiy (left in Oct.), D. Kyratzis, A. Serpolla**
 - Carbon and Oxygen flux being finalized, publication in preparation
 - Next steps: measurement of Li, Be, B (secondary nuclei) fluxes
- **D. Droz (left in March), E. Putti, A. Tykhonov**
 - Electron flux up to 14 TeV, possible new hardening at ~3 TeV (~3 σ) -Nearby pulsar?
 - Continue with larger statistics and extended fiducial region
- **All profited from ML methods developed in house: tracking, particle ID, energy corrections**
 - A. Tykhonov, D. Droz, M. Stolpovskiy, E. Putti, EPFL master students: L. Niggli, P. Nussbaum
- **Several papers/proceedings published**
- **Several talks/posters at ICRC 2023**



DAMPE: Deep Learning methods on the rise, gamma rays

Tykhonov et al. Astropart. Phys. 146 (2023)
arxiv.org/abs/2206.04532

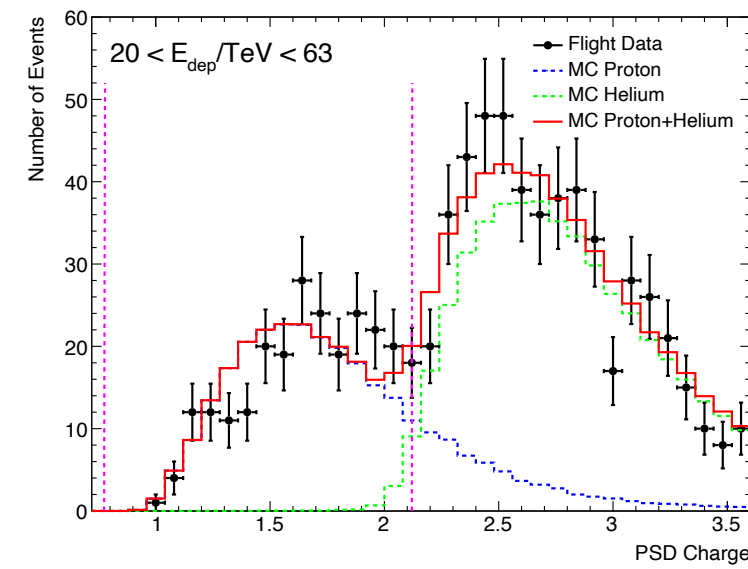
Stolpovskiy et al. JINST 17 (06) (2022).
doi.org/10.1088/1748-0221/17/06/P06031



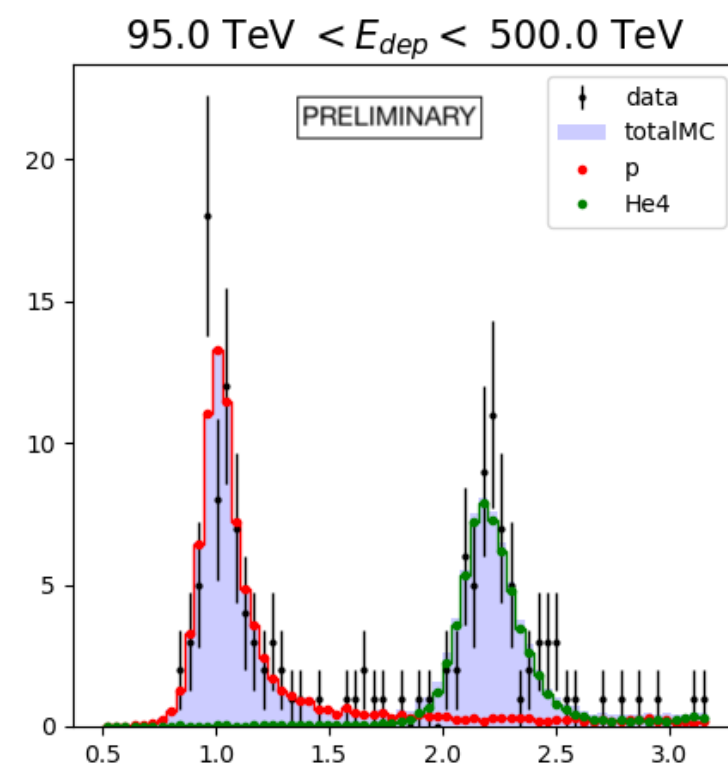
Before (no ML)

Now! (With ML)

arxiv.org/abs/1909.12860 (2019)

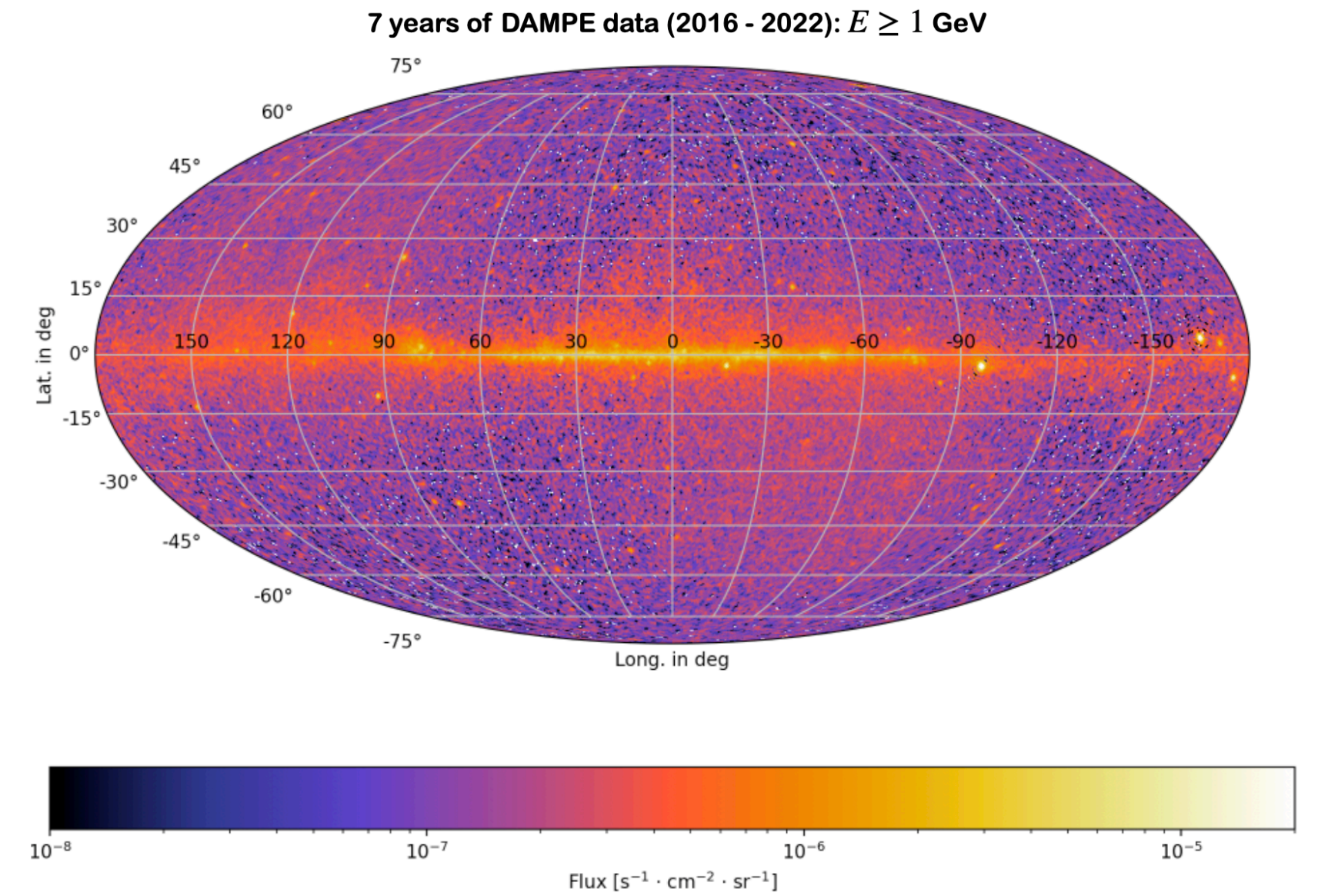


A. Ruina, A. Kotenko et al. (2023) pos.sissa.it/444/170/



J. Frieden, C. Perrina (EPFL)

- Gamma-ray spectrum extended to 1 TeV
- Sky map updated
- Search for gamma-ray lines in the Galaxy ongoing



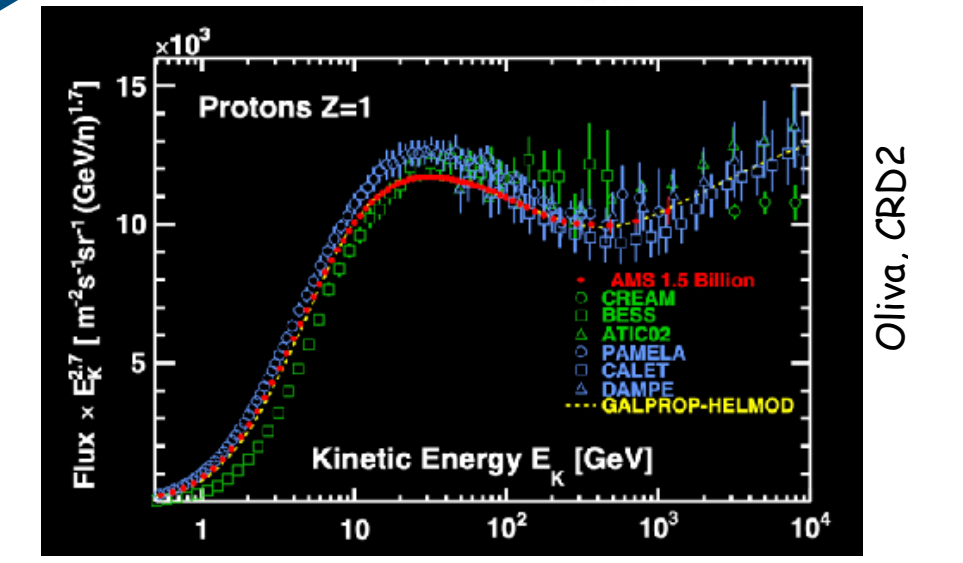
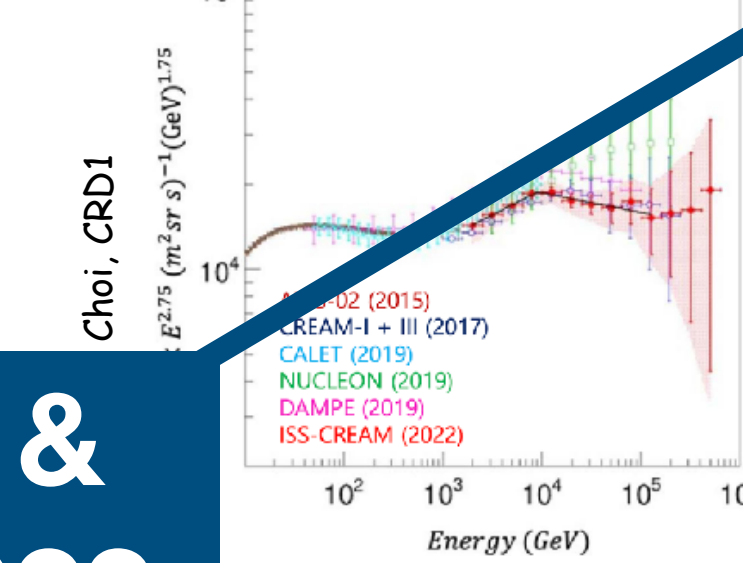
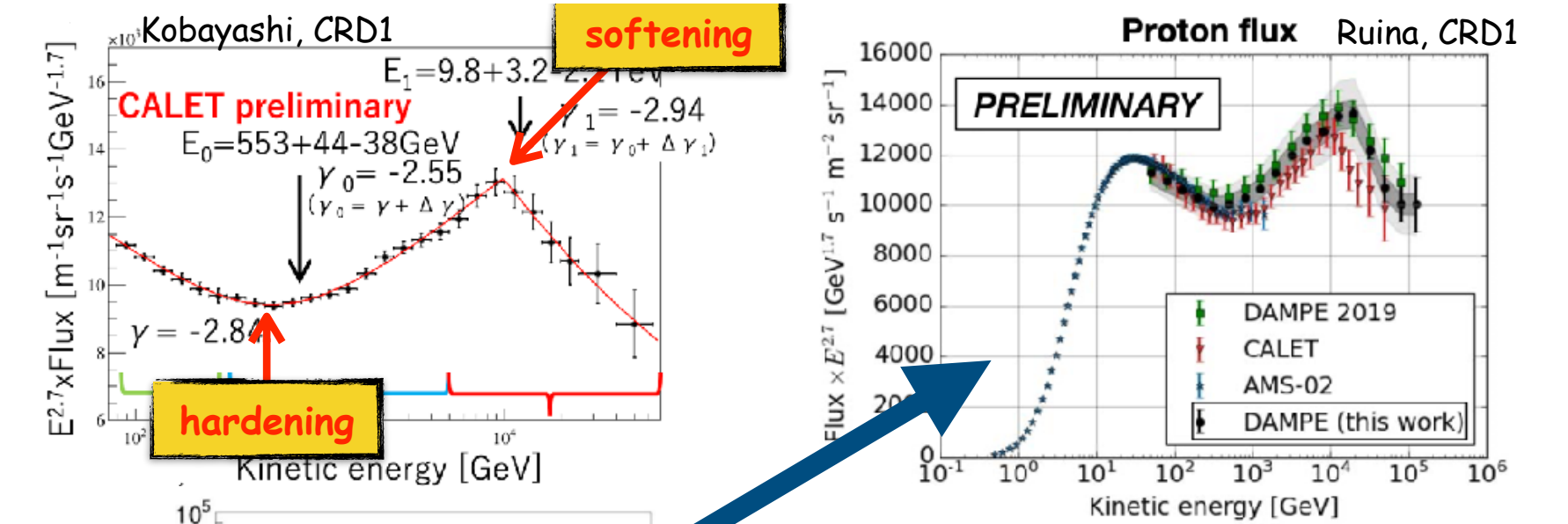
DAMPE results in spotlight of ICRC2023: cosmic rays at multi-TeV

New insights in cosmic ray acceleration & propagation at multi-TeV

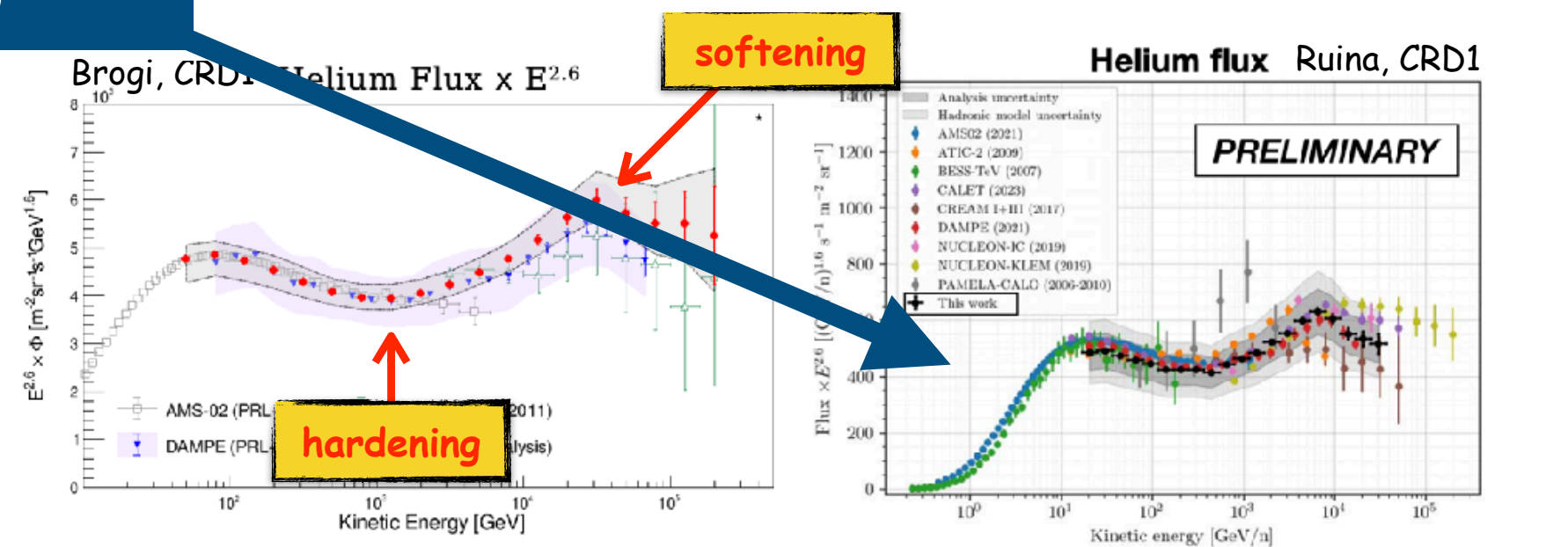
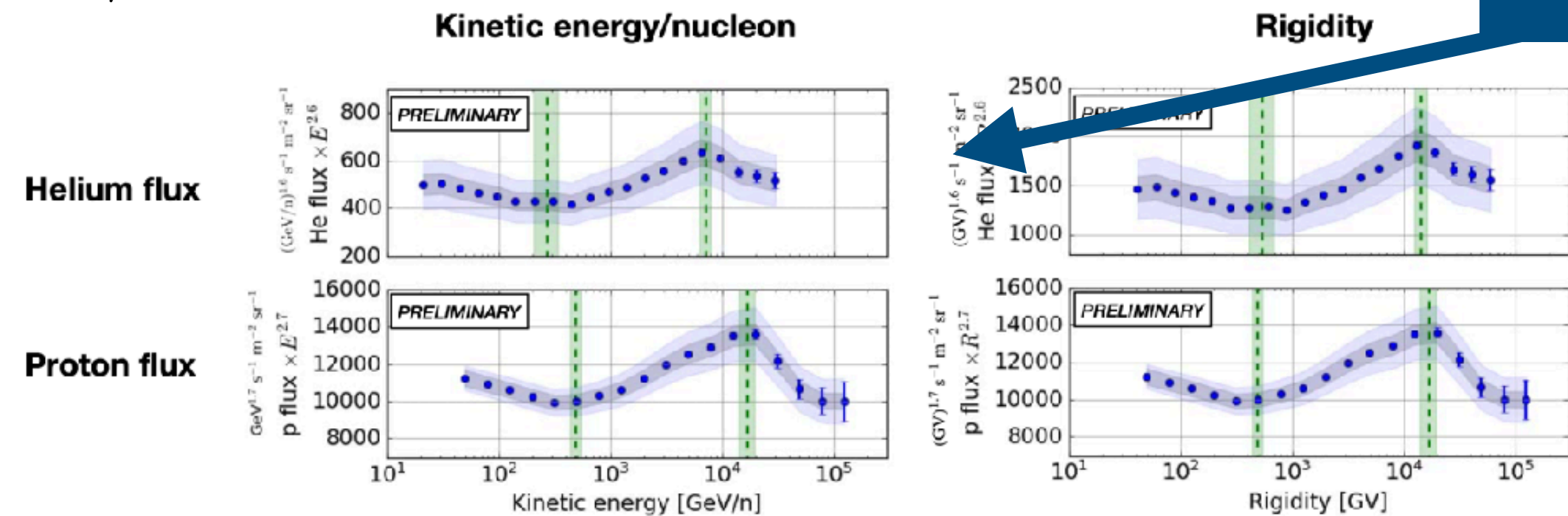
Energy per nucleon or rigidity?
That is the question



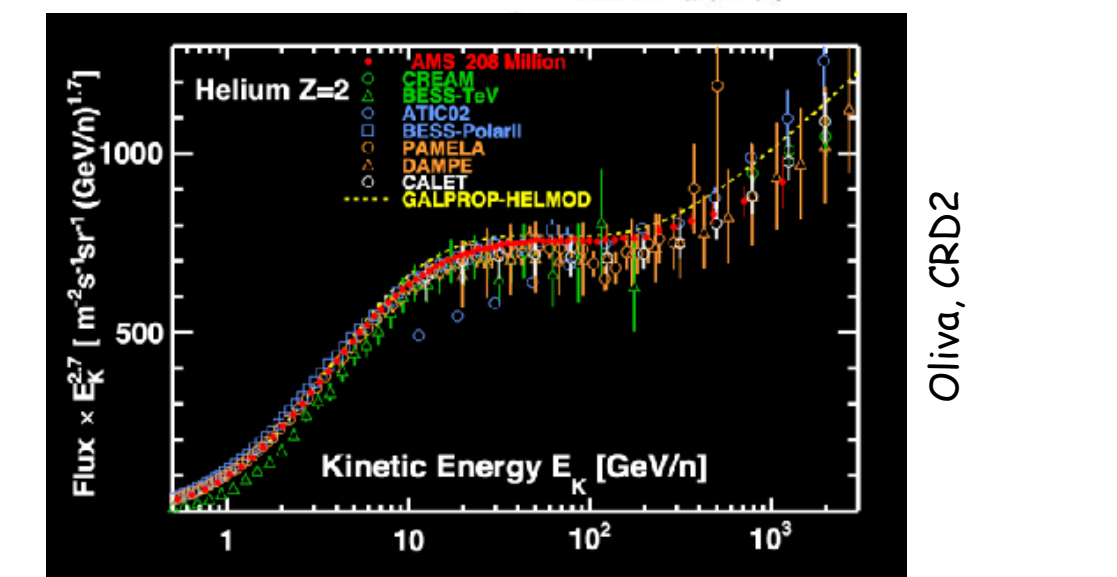
DAMPE proton & helium fluxes 2023 (ML methods)



Ruina, CRD1



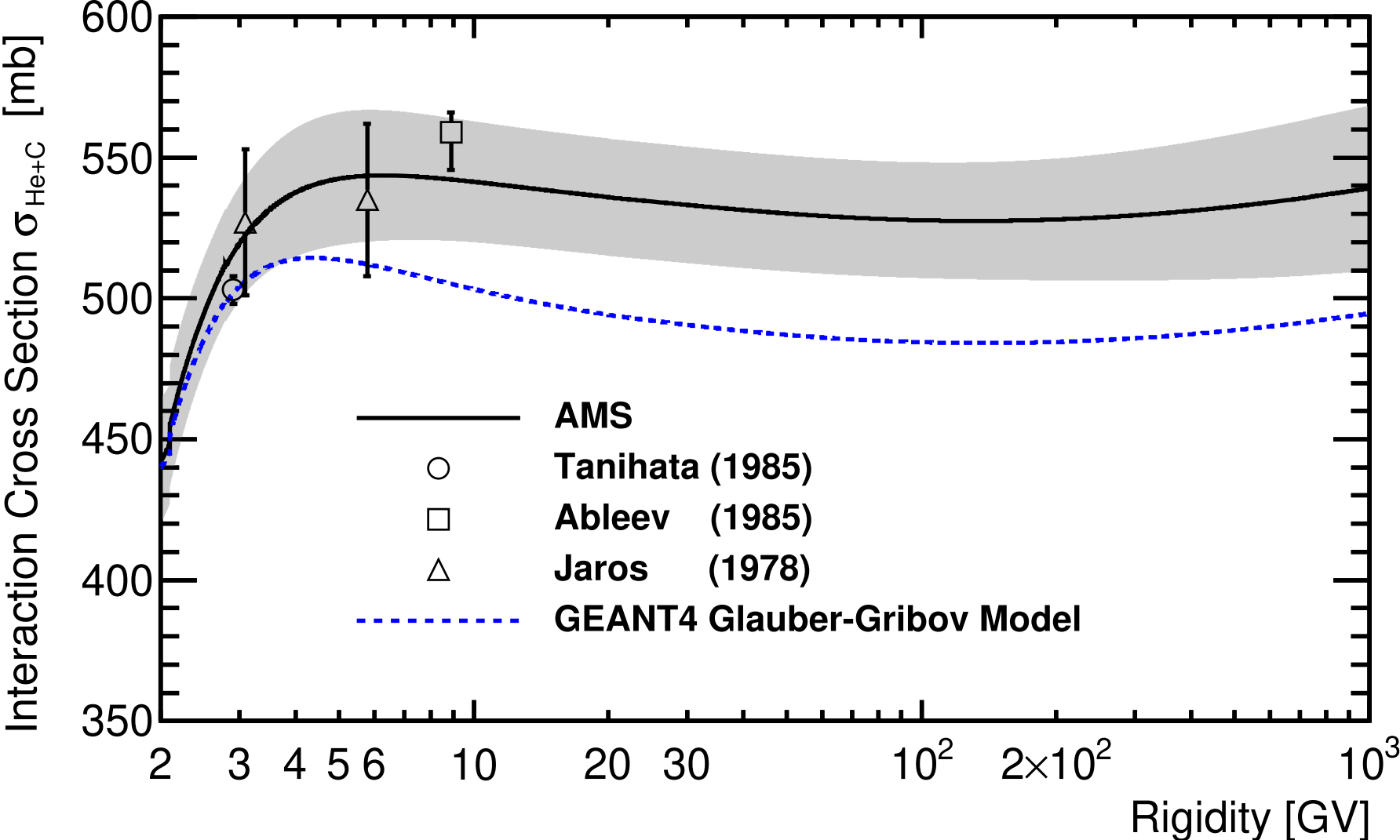
He spectrum follows the same pattern as the proton one



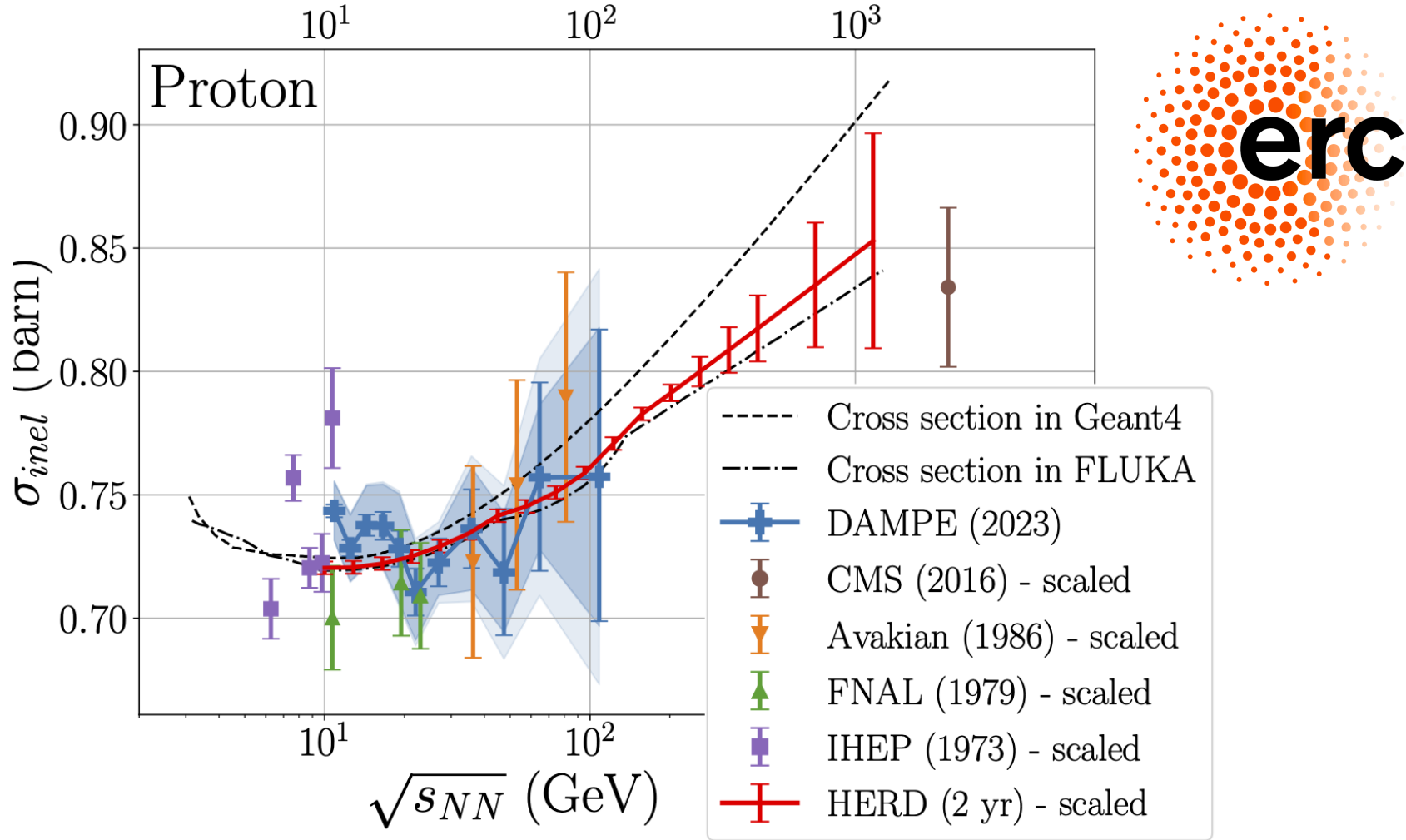
* Slides from ICRC 2023 Rapporteur talk (S. Gabici, Aug 3, 2023) 12

Hadronic physics at GeV–PeV: AMS-02, DAMPE, HERD

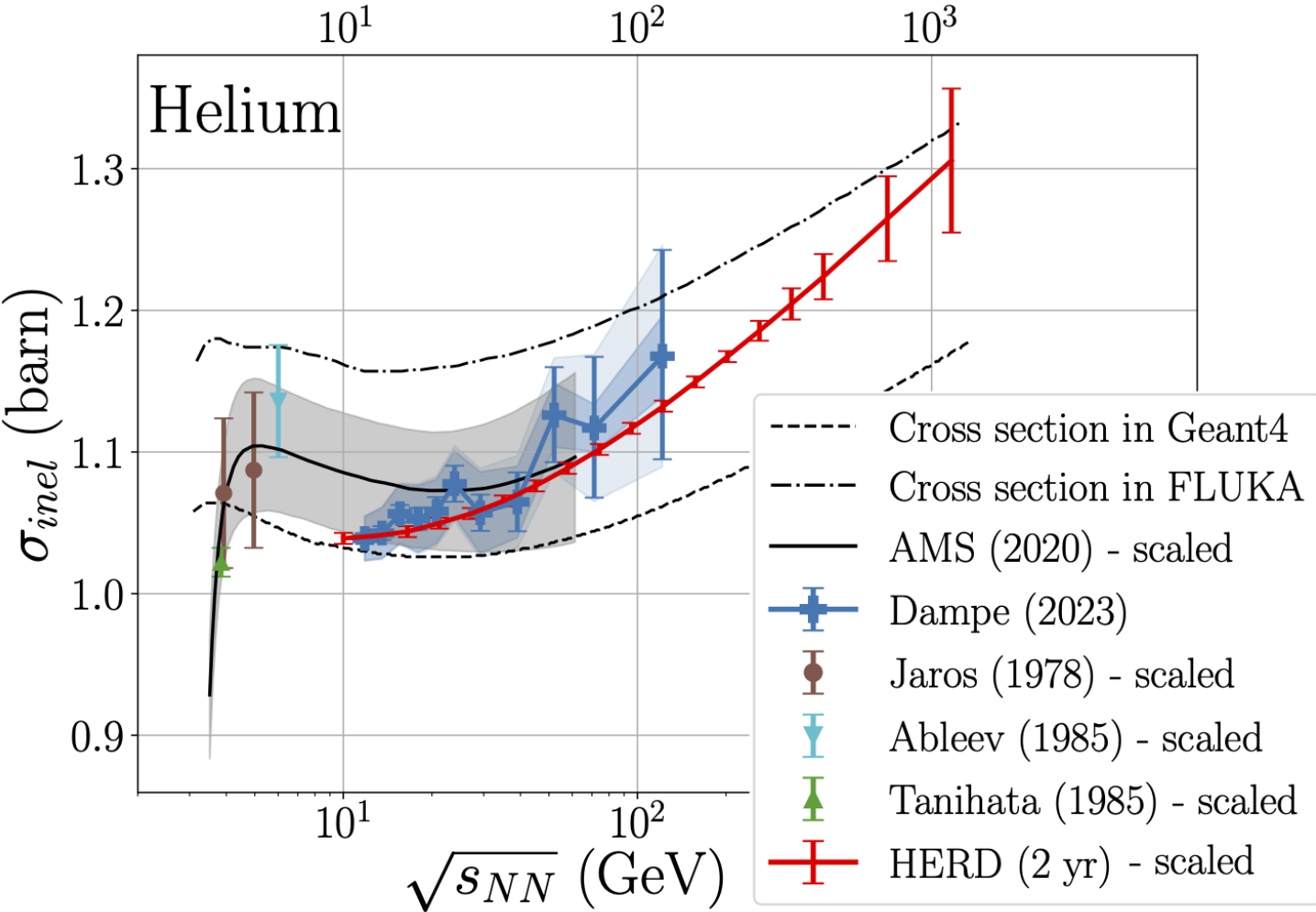
Inelastic cross section:
helium–iron (AMS)



Inelastic cross section: Proton
– BGO (DAMPE, HERD)



Inelastic cross section: Helium
– BGO (DAMPE, HERD)



Coppin et al. (2023) pos.sissa.it/444/142/

* data of previous proton and helium cross section scaled to proton-BGO or helium–BGO assuming $A^{2/3}$ and nuclear-radius dependencies

Q. Yan, M. Paniccia et al. Nuclear Physics A 996 (2020) 121712,
AMS Collaboration, PRL 126, 041104 (2021)

“Test beam” in space: hadronic physics + reducing systematics + cross sections

POLAR-2

People:

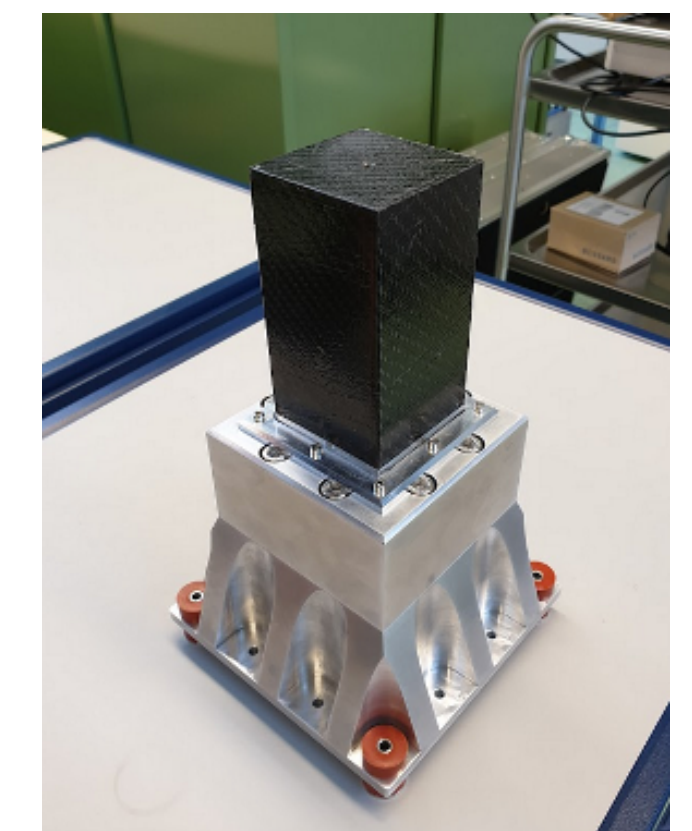
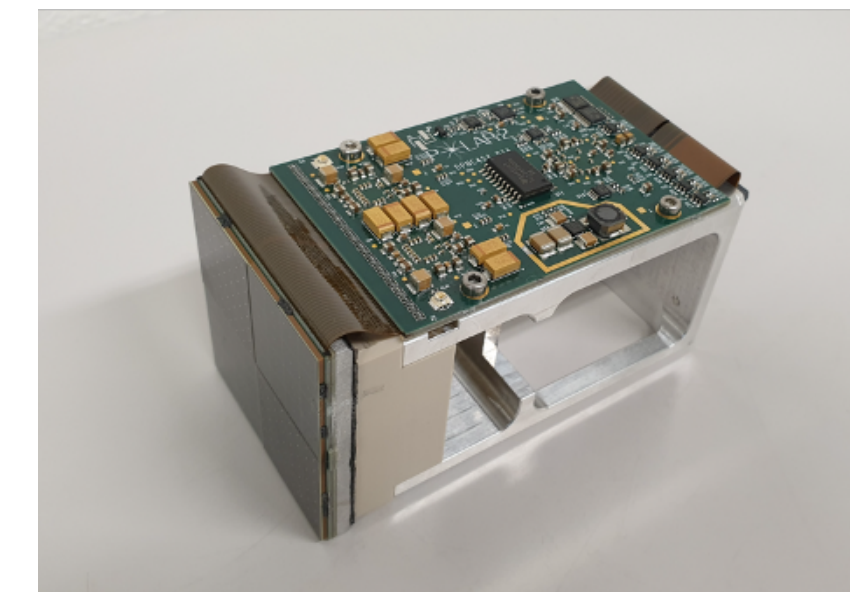
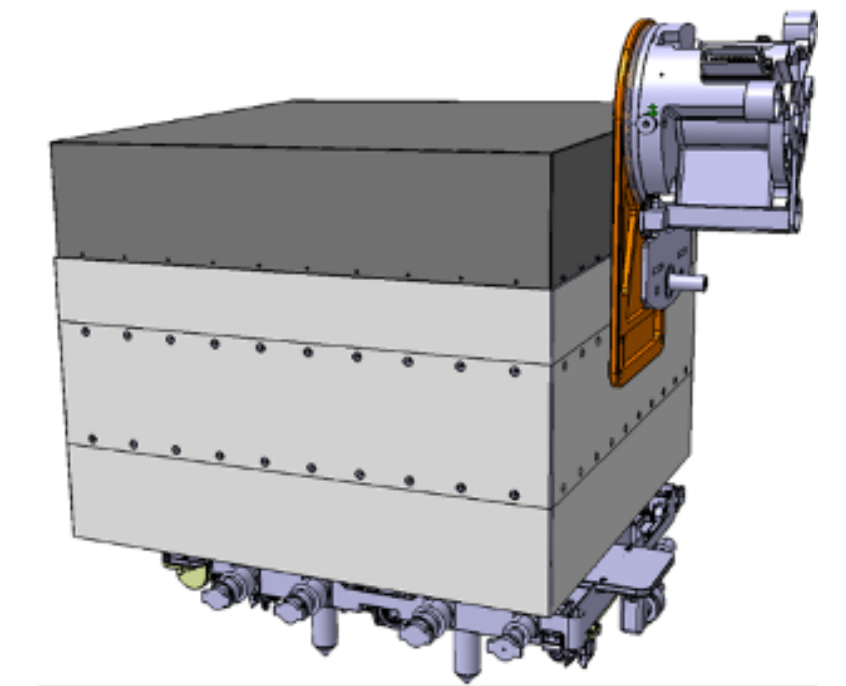
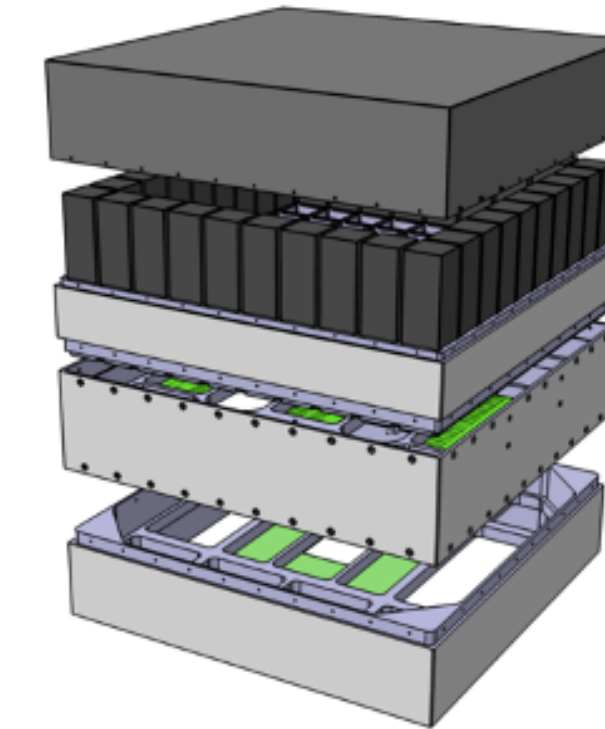
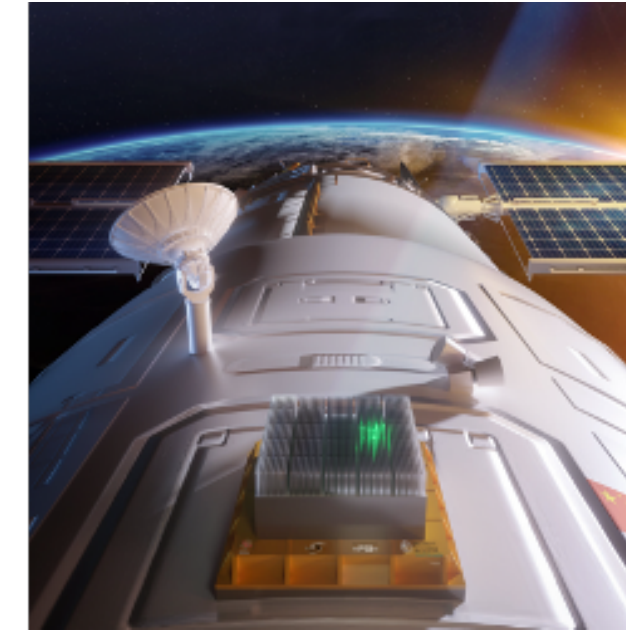
M. Kole, N. Produit, J. Hulsman

- Prototype tested at ESRF in April 2023
- Final FEE produced, FW being finalized
- Final module design review in November
- **Detailed document produced**
- Final mechanical designed ready
- Interface to backend and to CSS being finalized

Ready to move to the production phase, launch ~2027

- N. De Angelis Ph.D defense in December 2023
- G. Koziol Master defense in June 2023
- International Science Workshop in October 2023
 - organized by M. Kole, funded by SNF
- Several technical papers published
- POLAR data analysis ongoing, papers being published

High
sensitivity GRB
polarimeter



Backup

Recommendations and findings

The simultaneous observation of high energy sources with data from cosmic rays, photons, neutrinos, and gravitational waves in as large an energy range as feasible promises new insights of both astrophysical and particle physics phenomena. The major existing projects with Swiss participation, MAGIC, **AMS-02**, **DAMPE** and EUCLID, in addition to scientific goals of their own right, provide a testing ground for the multi-messenger approach. In view of this, it is desirable to establish multi-messenger data repository in Switzerland. In the mid-term future, major projects such as CTA, JEM-EUSO, **HERD** as well as large underground facilities, will have to include the multi-messenger aspect in their planning and provide wider access to their data.

Updated paragraph from the old roadmap

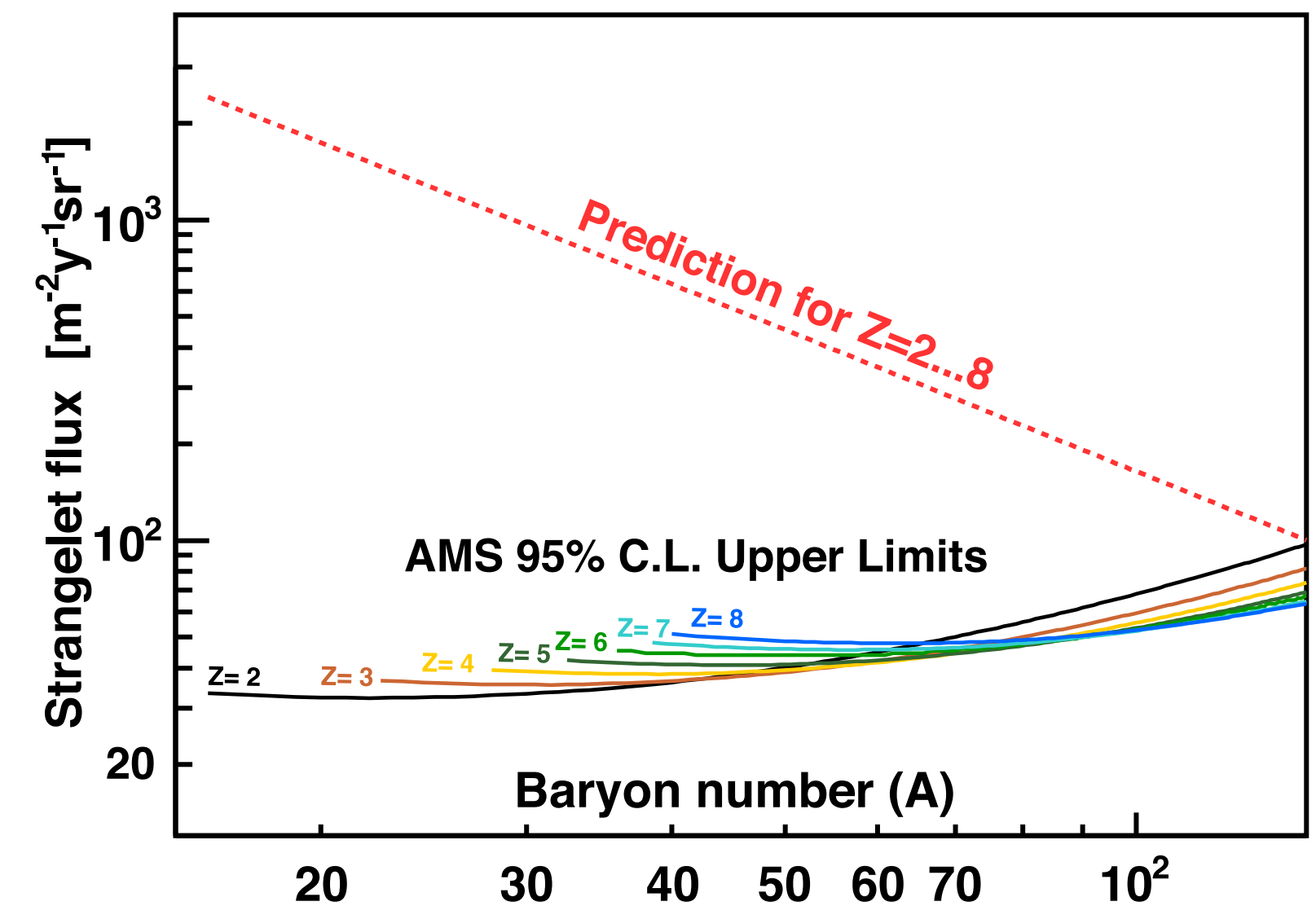
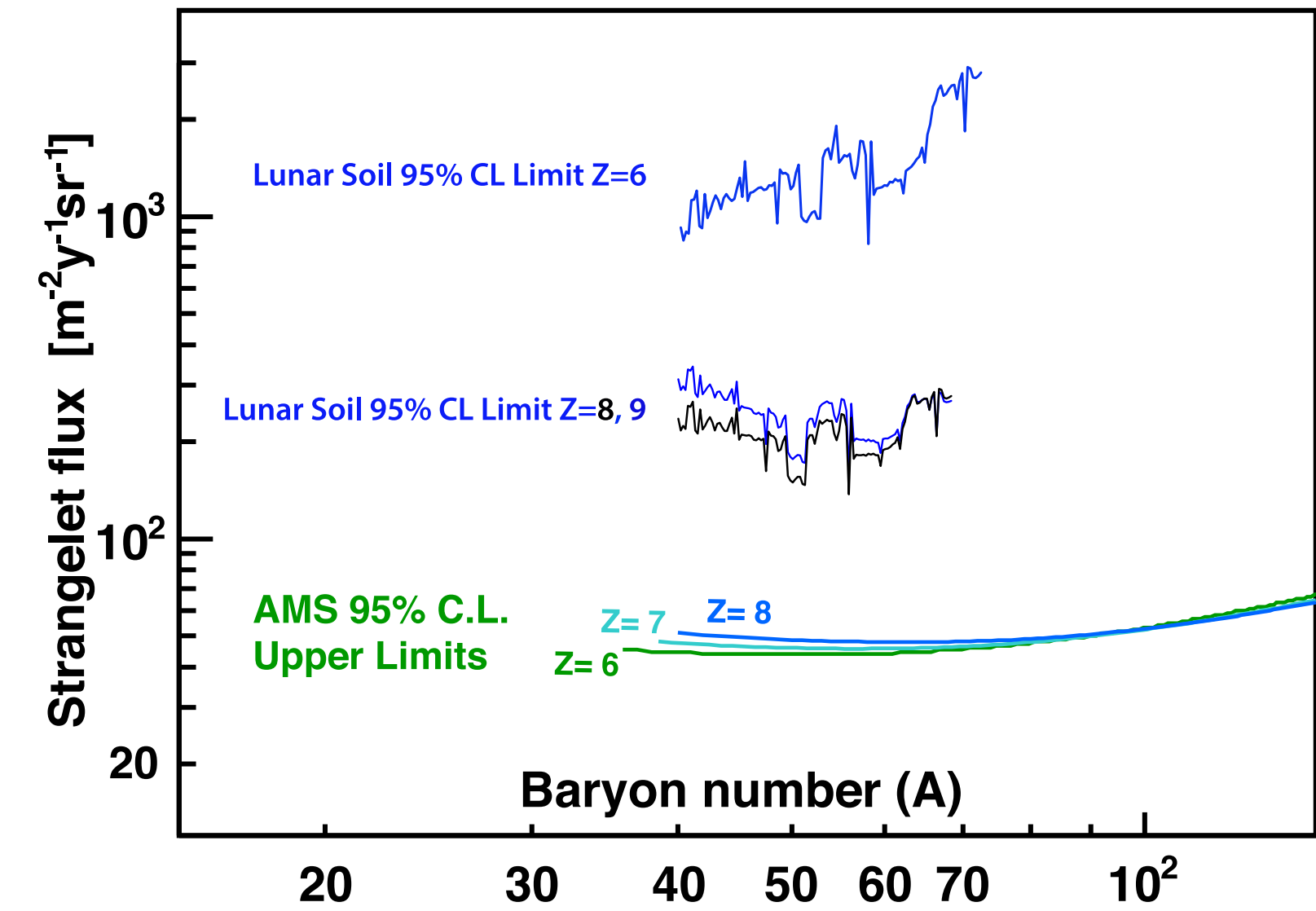
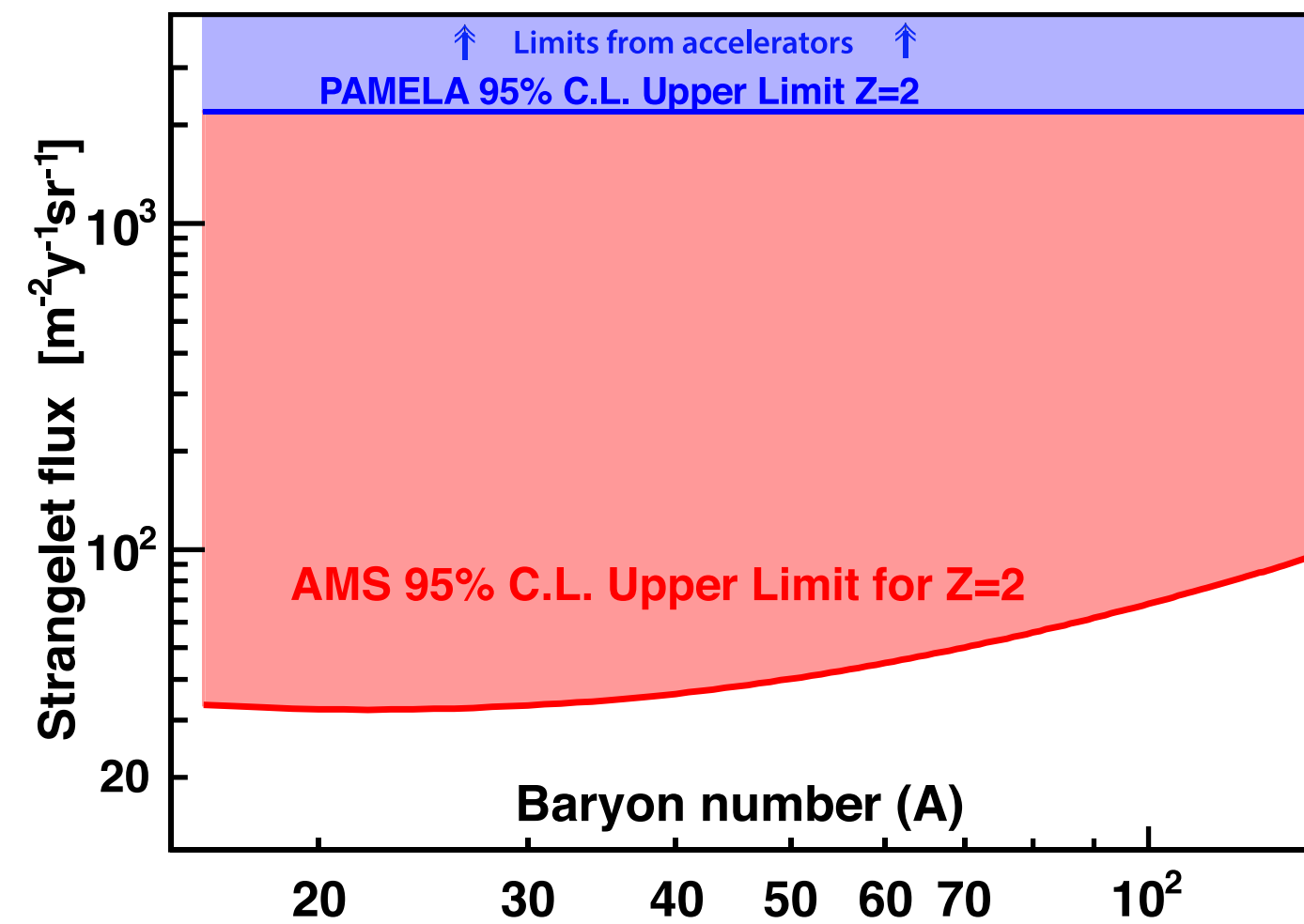
Ancillary notes:

POLAR-2 launch date have to be updated in the new roadmap: **2027** (not 2024)

AMS-02 & Flavour: Stranglets

Strangelets — "bags" containing free up, down and strange quarks

- Distinguished from ordinary nuclei by Z/A
 - Expected to be ~ 0.1 (ordinary nuclei ~ 0.5)
- Measured by instruments able to distinguish isotopes (AMS)
- PAMELA, and AMS have published upper limits
 - search of strangelets of charge $Z \leq 8$ *
- AMS continuing updating search with increased statistics.



* <https://doi.org/10.1016/j.physrep.2020.09.003>

Rigidity spectra of heavy Primary Cosmic Rays: Sulfur, Argon and Calcium nuclei

Erwan Robyn's PhD thesis defended in August 2023

Unige Thesis Sc. 5759 <https://archive-ouverte.unige.ch/unige:171532>

Sulfur spectrum published in Physical Review Letters
[Phys. Rev. Lett. 130, 211002 \(2023\)](#)

