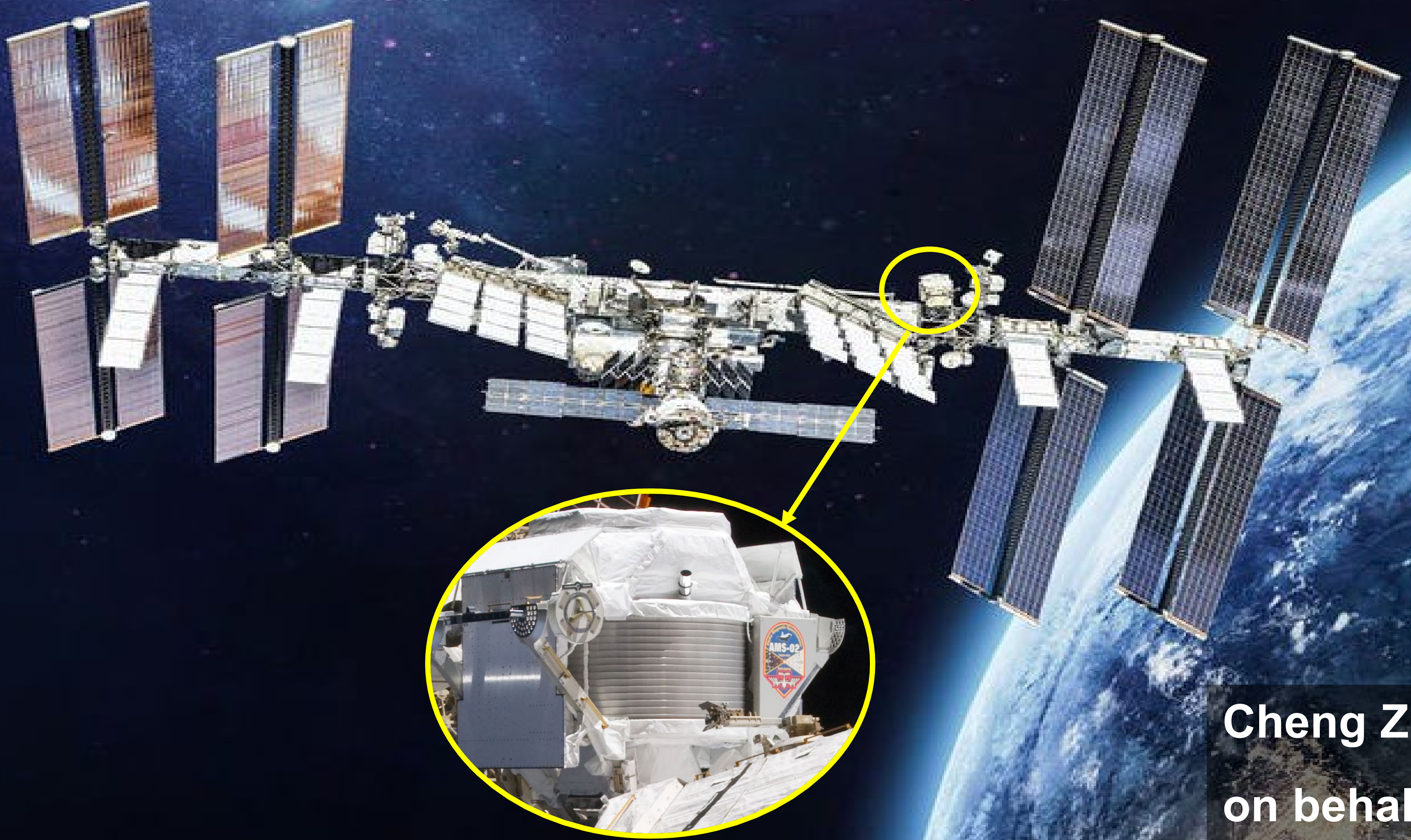
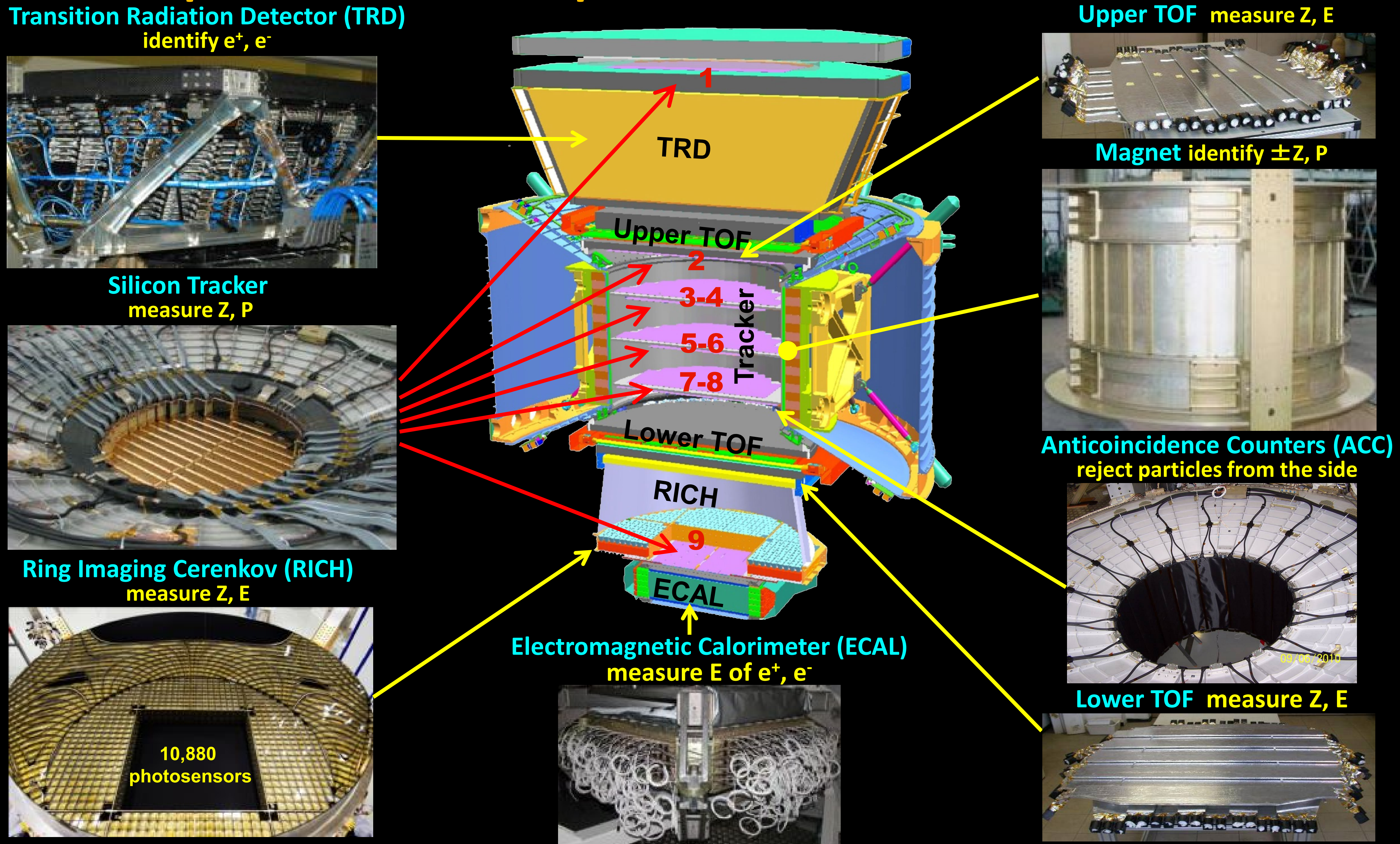
Understanding the Origins of Cosmic-Ray Positrons



Cheng Zhang/ IHEP

on behalf of AMS collaboration

AMS is a space version of a precision detector used in accelerators



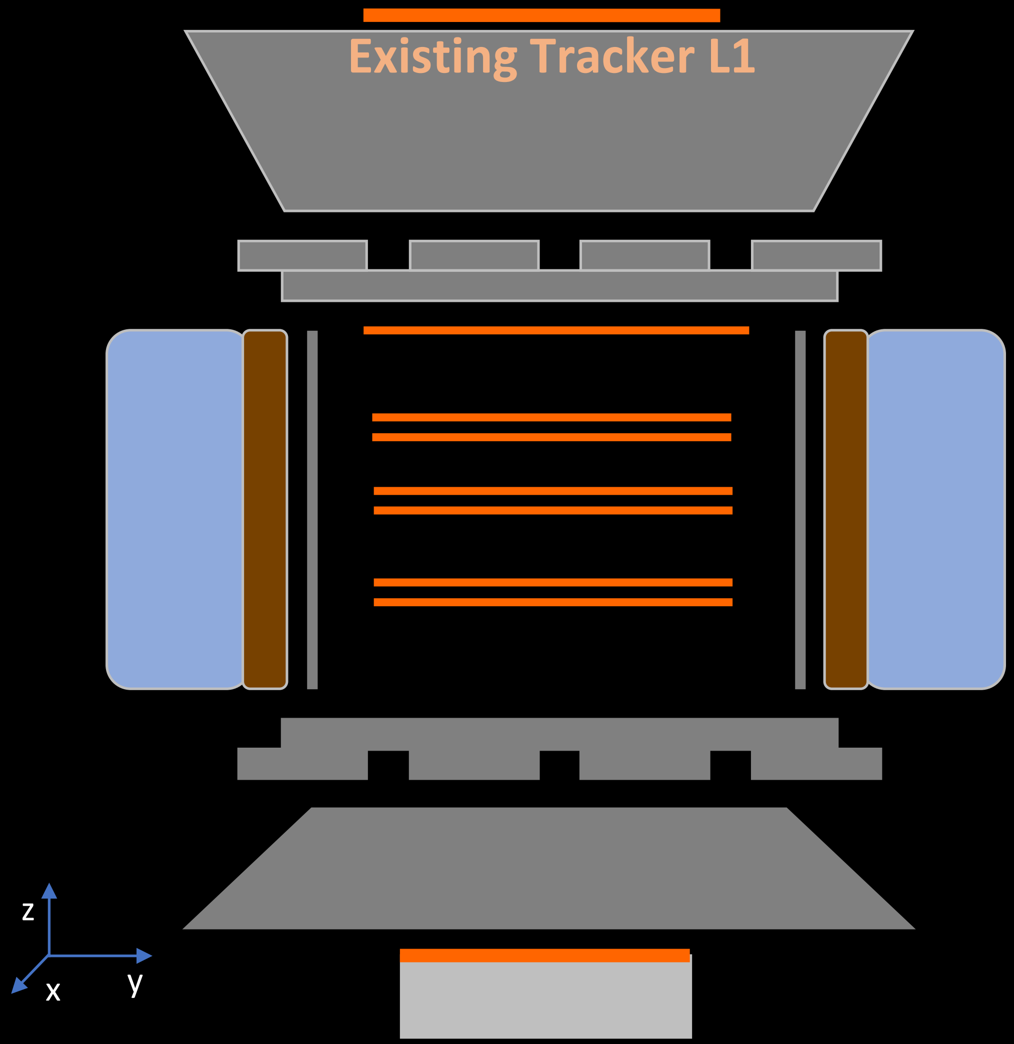
AMS on ISS

AMS 2011-2027

Continuous data-taking

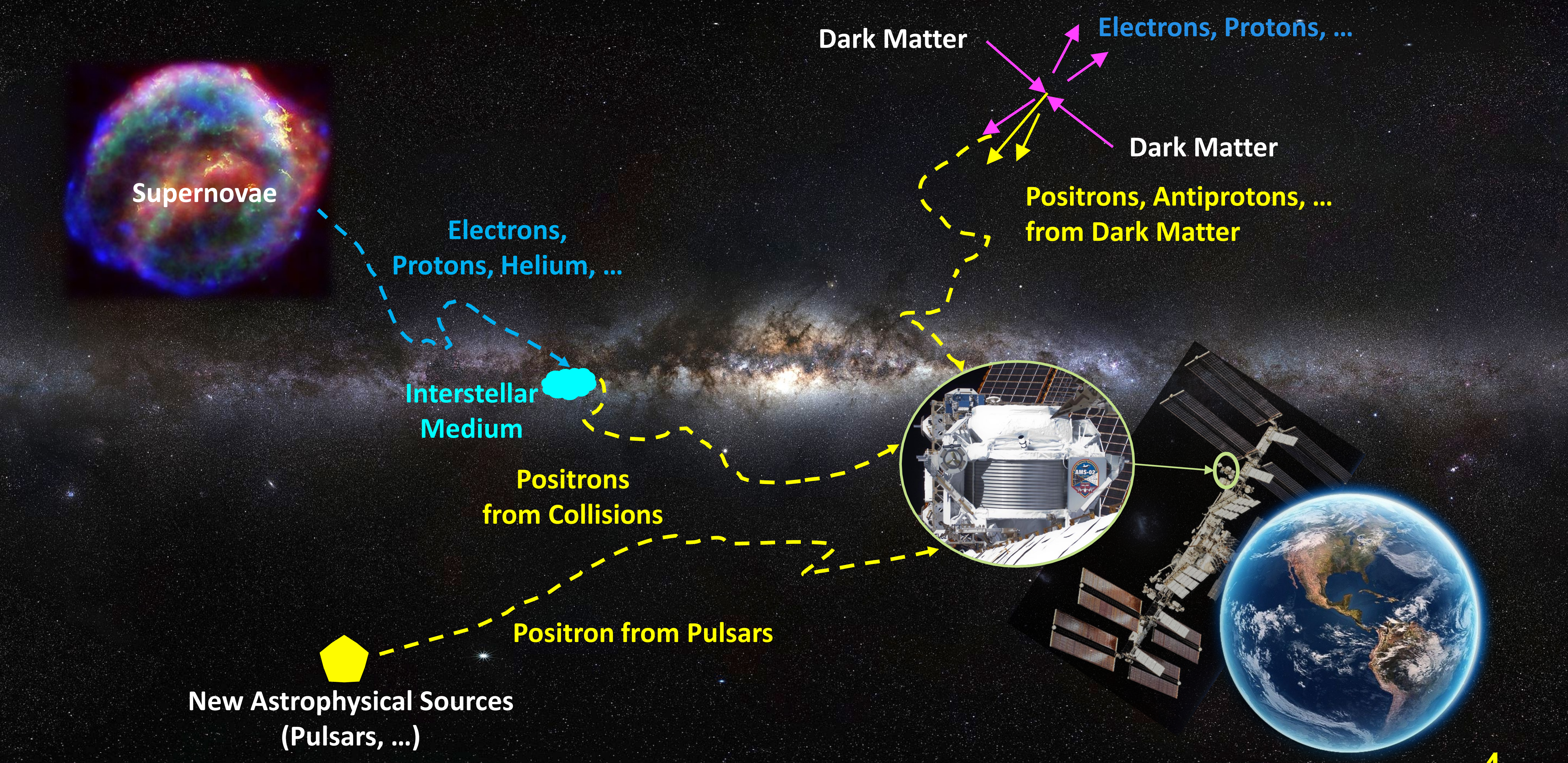
AMS 2027-2030+

New 4+4m^2 Silicon Tracker Planes
Acceptance increased to 300%

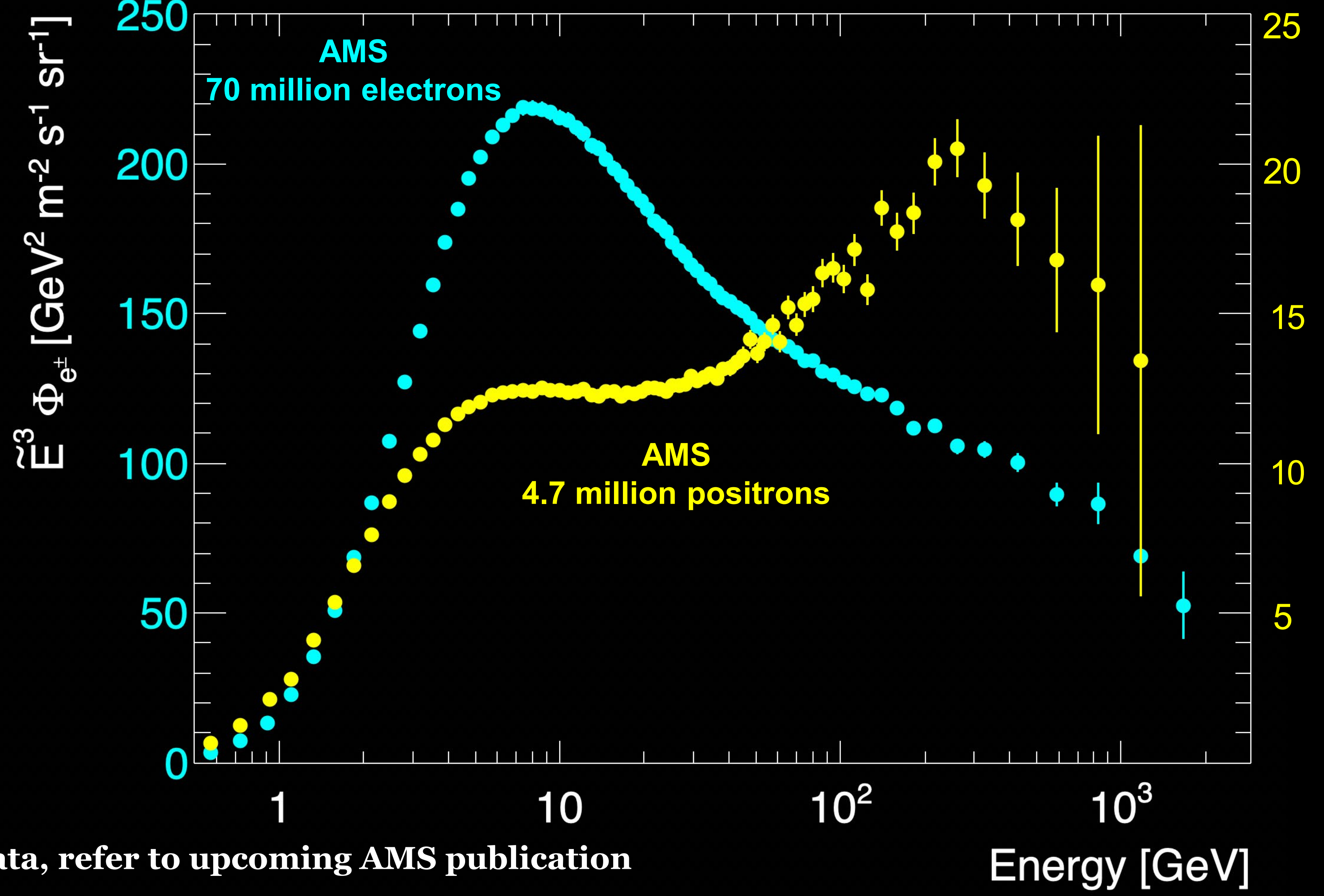


and Projections to 2030+

The origins of cosmic positrons, electrons

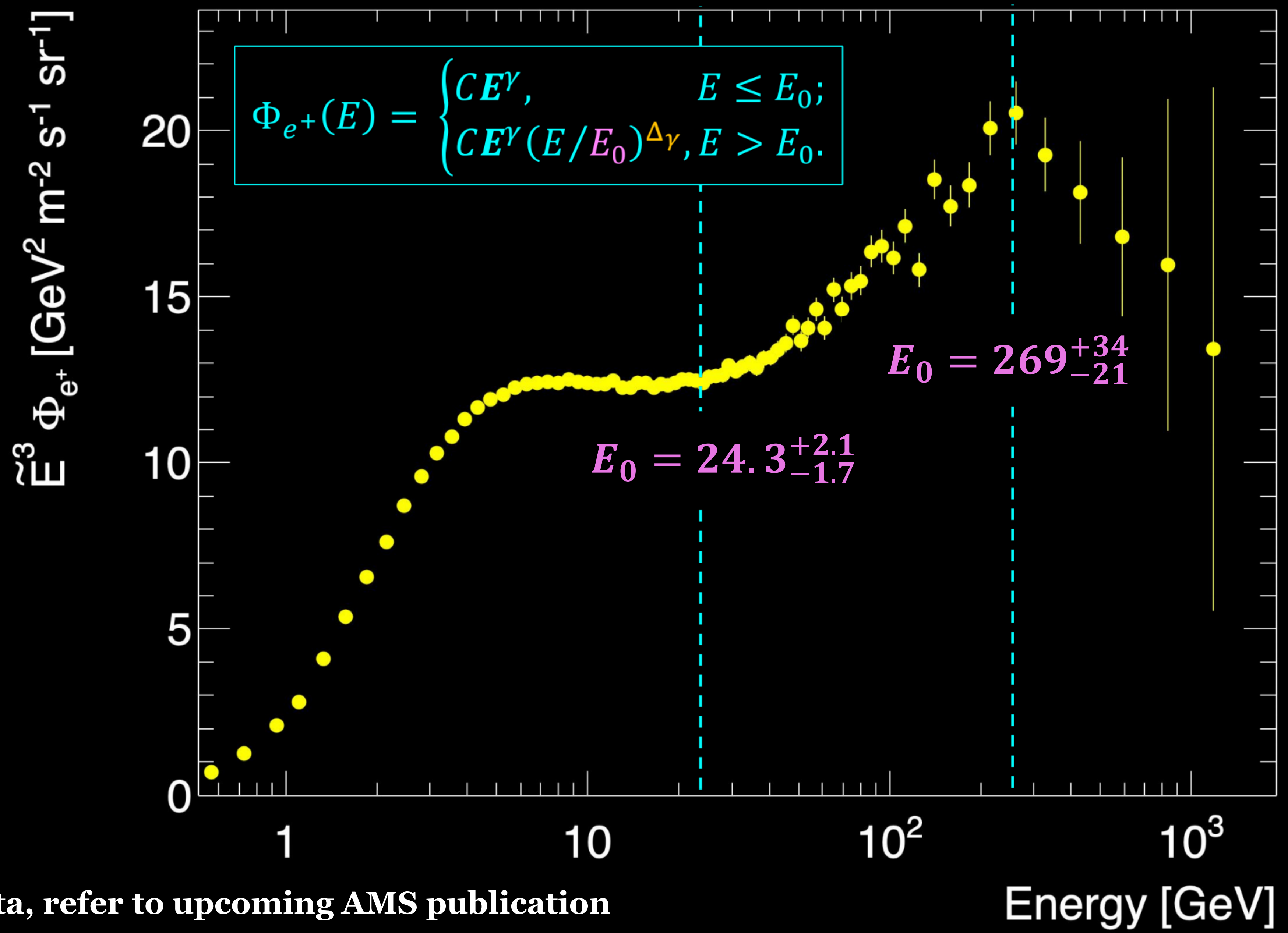


Latest Physics Results from AMS



Preliminary data, refer to upcoming AMS publication

Latest Physics Results from AMS: Positrons

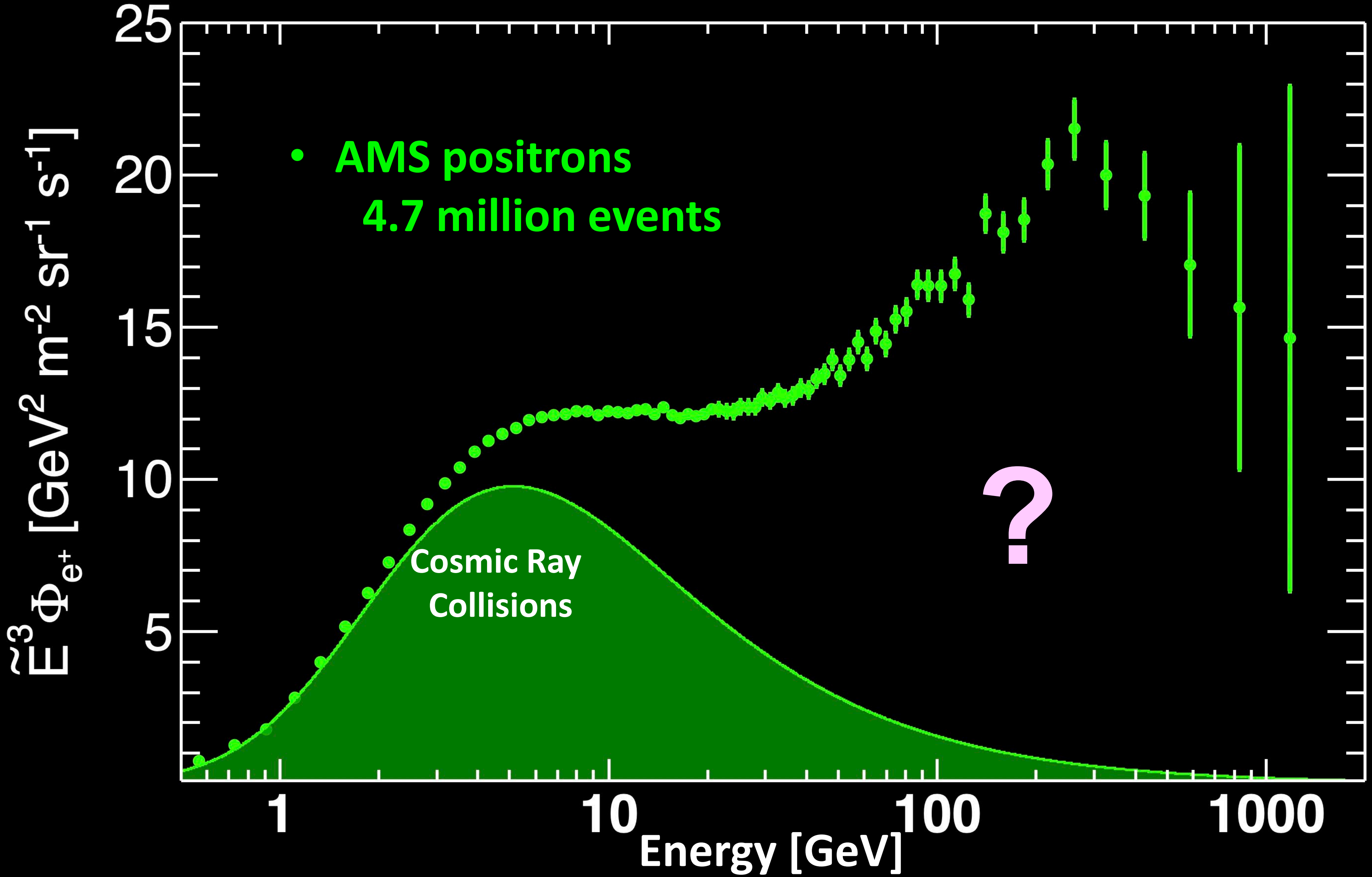


Preliminary data, refer to upcoming AMS publication

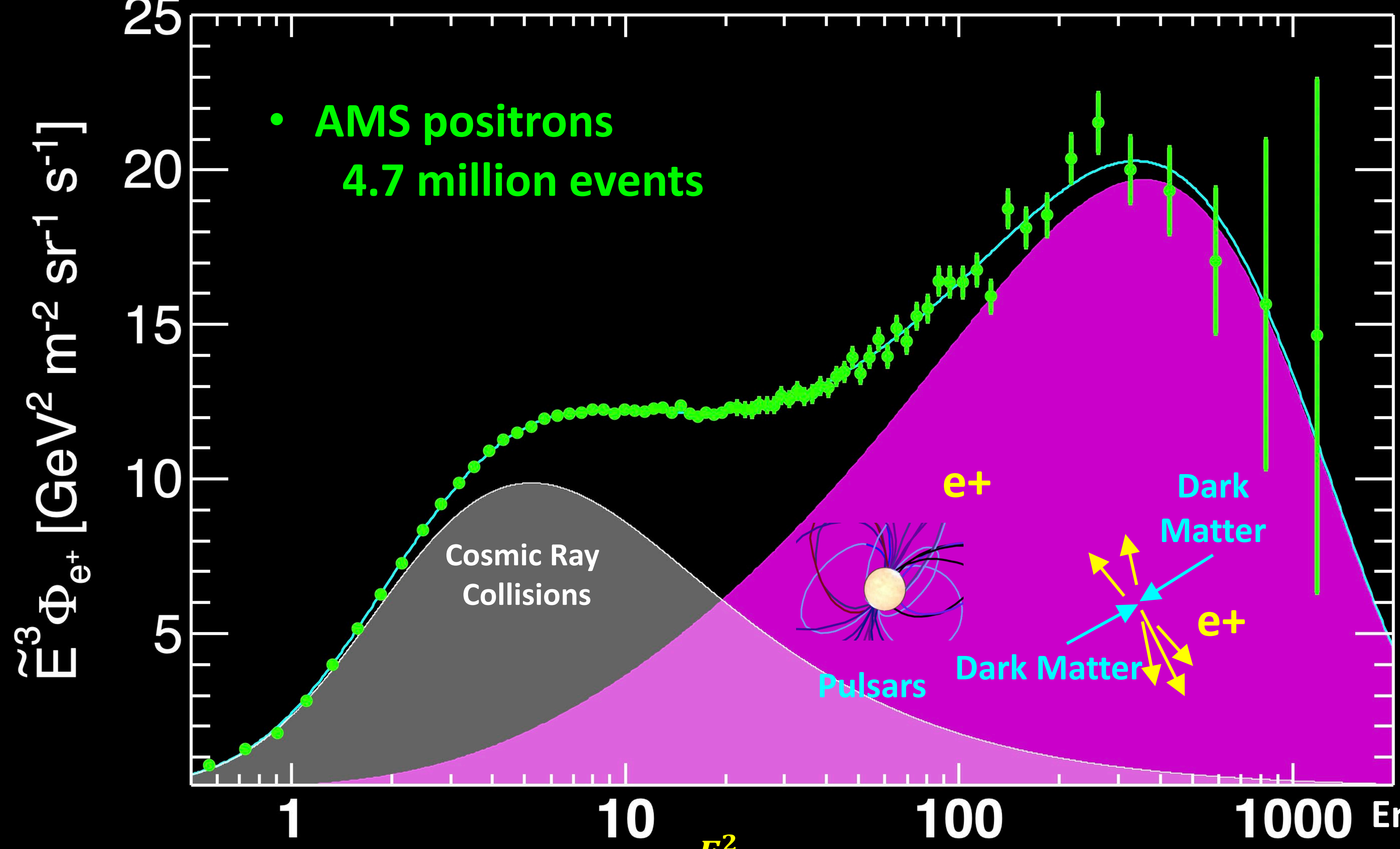
Latest Physics Results from AMS: Positrons

Low-energy positrons come from cosmic ray collisions

High-energy positrons must come from a new source



The positron flux is the sum of low-energy part from cosmic ray collisions plus a high-energy part from pulsars or dark matter with a cutoff energy



Existence of Cutoff

2026: 5-σ

2030: >6-σ

Empirical model:

χ^2/dof = 36/66

$$\Phi_{e^+}(E) = \frac{E^2}{\hat{E}^2}\left[C_d(\hat{E}/E_1)^{\gamma_d} + C_s(\hat{E}/E_2)^{\gamma_s}\exp(-\hat{E}/E_s)\right]$$

Solar Collisions Pulsars or Dark Matter

A sample of recent theoretical models explaining AMS positron and electron data (overall >3000 citations)

Dark Matter

1) I. Krommydas, I. Cholis, Phys. Rev. D 107 (2023) 2, 023003
2) I. John, T. Linden, JCAP 12 (2021) 007
3) H. Motz, H. Okada, Y. Asaoka, and K. Kohri, Phys.Rev. D102 (2020) 8, 083019
4) Z.Q. Huang, R.Y. Liu, J.C. Joshi, X.Y. Wang, Astrophys.J. 895 (2020) 1, 53
5) R. Diesing and D. Caprioli, Phys.Rev. D101 (2020) 10
6) A. Das, B. Dasgupta, and A. Ray, Phys.Rev. D101 (2020) 6
7) F. S. Queiroz and C. Siqueira, Phys.Rev. D101 (2020) 7, 075007
8) Z.L. Han, R. Ding, S.J. Lin, and B. Zhu, Eur.Phys.J. C79 (2019) 12, 1007
9) C.Q. Geng, D. Huang, and L. Yin, Nucl.Phys. B959 (2020) 115153
10) S. Profumo, F. Queiroz, C. Siqueira, J.Phys.G 48 (2020) 1, 015006

and many other excellent papers …

Astrophysical sources

1) O. M. Bitter, D. Hooper, JCAP 10 (2022) 081
2) T.P. Tang, Z.Q. Xia, Z.Q. Shen, et al., Phys. Lett. B 825 (2022) 136884
3) P. Mertsch, A. Vittino, and S. Sarkar, Phys.Rev. D 104 (2021) 103029
4) P. Zhang et al., JCAP 05 (2021) 012
5) C. Evoli, E. Amato, P. Blasi, and R. Aloisio, Phys.Rev. D103 (2021) 8, 083010
6) K. Fang, X.J. Bi, S.J. Lin, and Q. Yuan, Chin.Phys.Lett. 38 (2021) 3, 039801
7) C. Evoli, P. Blasi, E. Amato, and R. Aloisio, Phys.Rev.Lett. 125 (2020) 5, 051101
8) O. Fornieri, D. Gaggero, and D. Grasso, JCAP 02 (2020) 009
9) P. Cristofari and P. Blasi, Mon.Not.Roy.Astron.Soc. 489 (2019) 1, 108
10) S. Recchia, S. Gabici, F.A. Aharonian, and J. Vink, Phys.Rev. D99 (2019) 10, 103022

and many other excellent papers …

Propagation

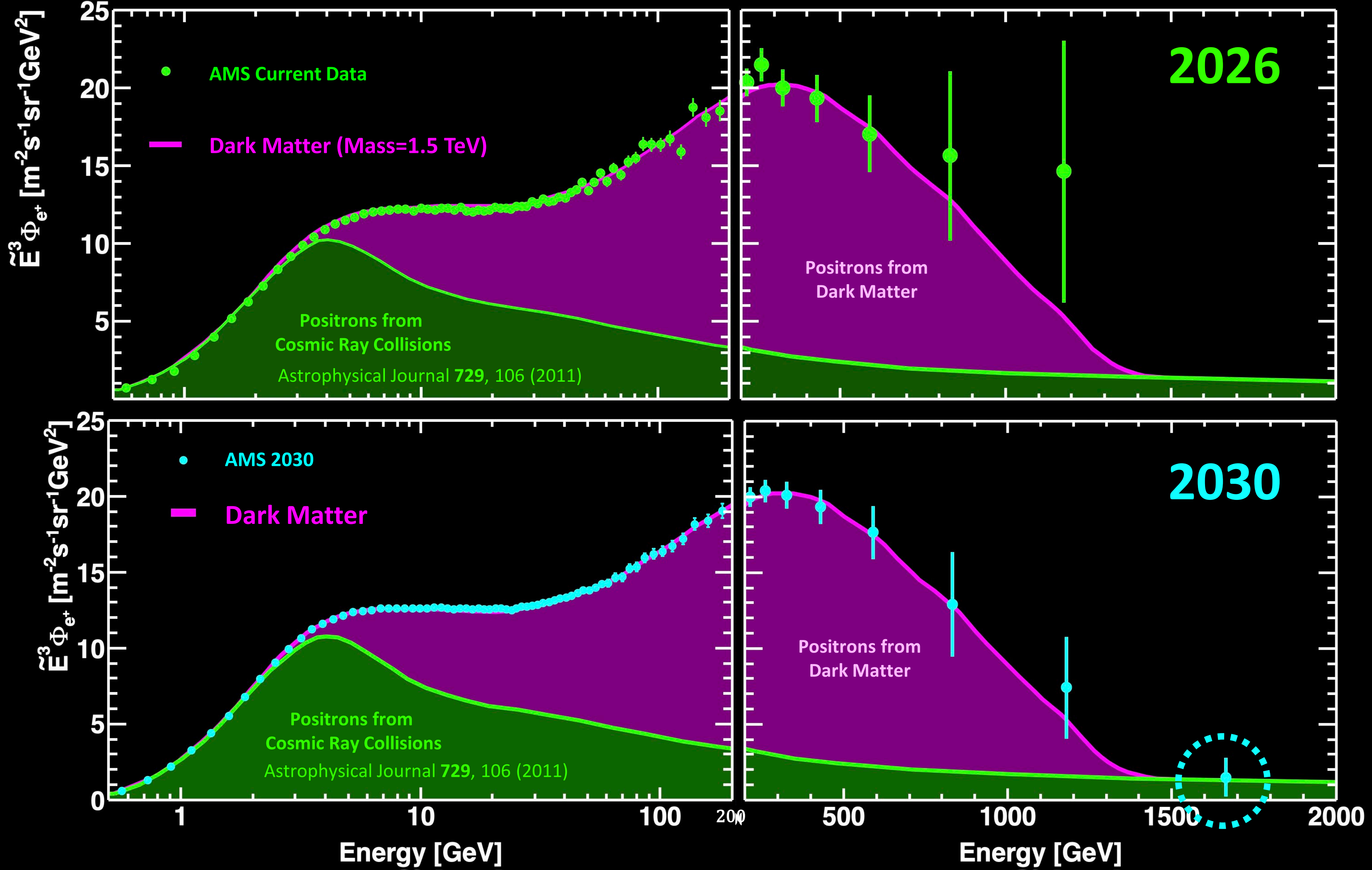
1) E. Silver, E. Orlando, Astrophys. J. 963 (2024) 2, 111
2) M. Di Mauro, F. Donato, M. Korsmeier, et al., Phys. Rev. D 108 (2023) 6, 063024
3) E. Amato and S. Casanova, J.Plasma Phys. 87 (2021) 1, 845870101
4) Z. Tian et al., Chin.Phys. C44 (2020) 8, 085102
5) W. Zhu, P. Liu, J. Ruan, and F. Wang, Astrophys.J. 889 (2020) 127
6) P. Liu and J. Ruan, Int.J.Mod.Phys. E28 (2019) 09, 1950073
7) R. Diesing and D. Caprioli, Phys.Rev.Lett. 123 (2019) 7, 071101
8) W. Zhu, J. S. Lan and J. H. Ruan, Int. J. Mod. Phys. E27 (2018) 1850073

and many other excellent papers …

AMS Publications on electrons and positrons

1) M. Aguilar *et. al.*, Phys. Rev. Lett. 110 (2013) 141102.
   APS Highlight of the Year 2013
   10-year Retrospective of Editors' Suggestions
2) L. Accardo *et al.*, Phys. Rev. Lett. 113 (2014) 121101.
   Editor's Suggestion
3) M. Aguilar *et. al.*, Phys. Rev. Lett. 113 (2014) 121102.
   Editor's Suggestion
4) M. Aguilar *et. al.*, Phys. Rev. Lett. 113 (2014) 221102.
5) M. Aguilar *et. al.*, Phys. Rev. Lett. 122 (2019) 041102.
   Editor's Suggestion
6) M. Aguilar *et. al.*, Phys. Rev. Lett, 122 (2019) 101101.
7) M. Aguilar et. al., Physics Reports, 894 (2021) 1.

AMS Positron Spectrum and Dark Matter

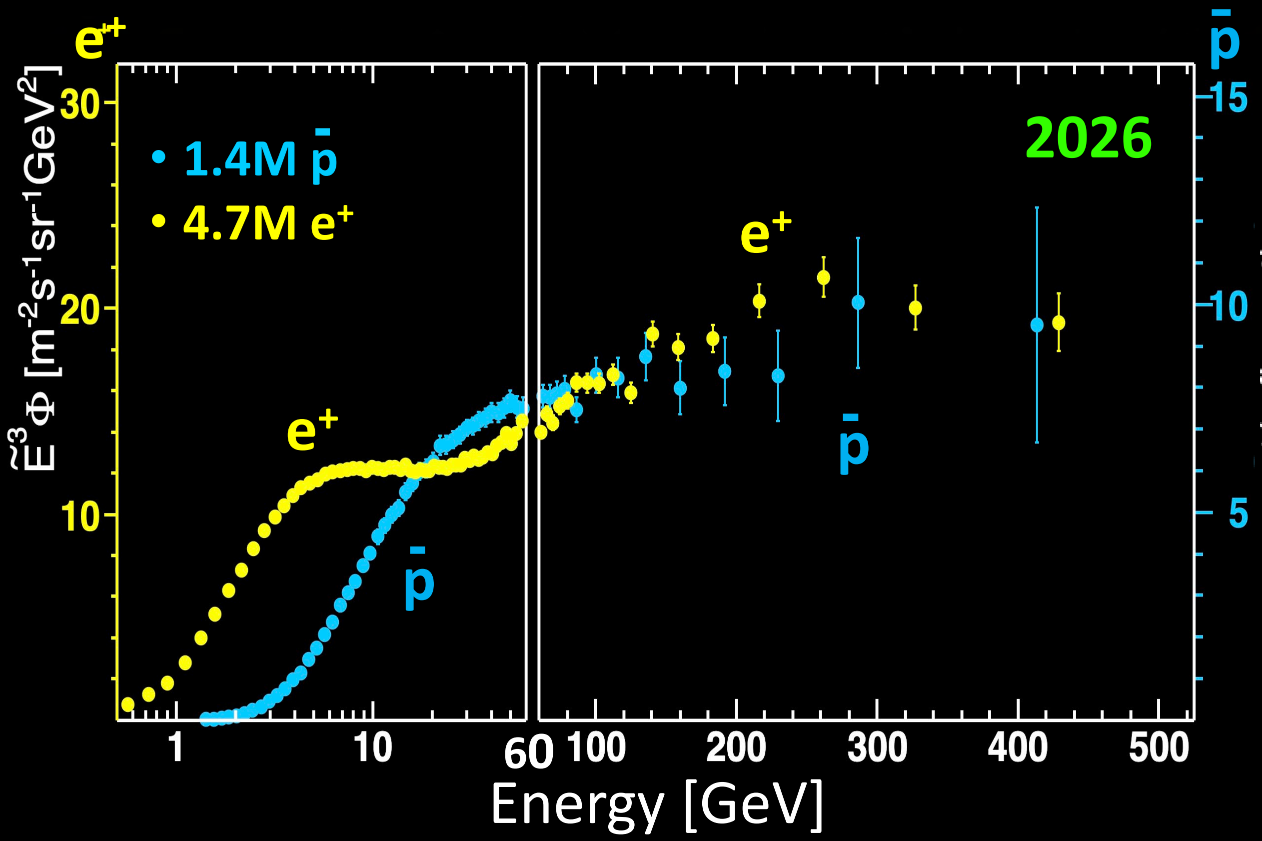


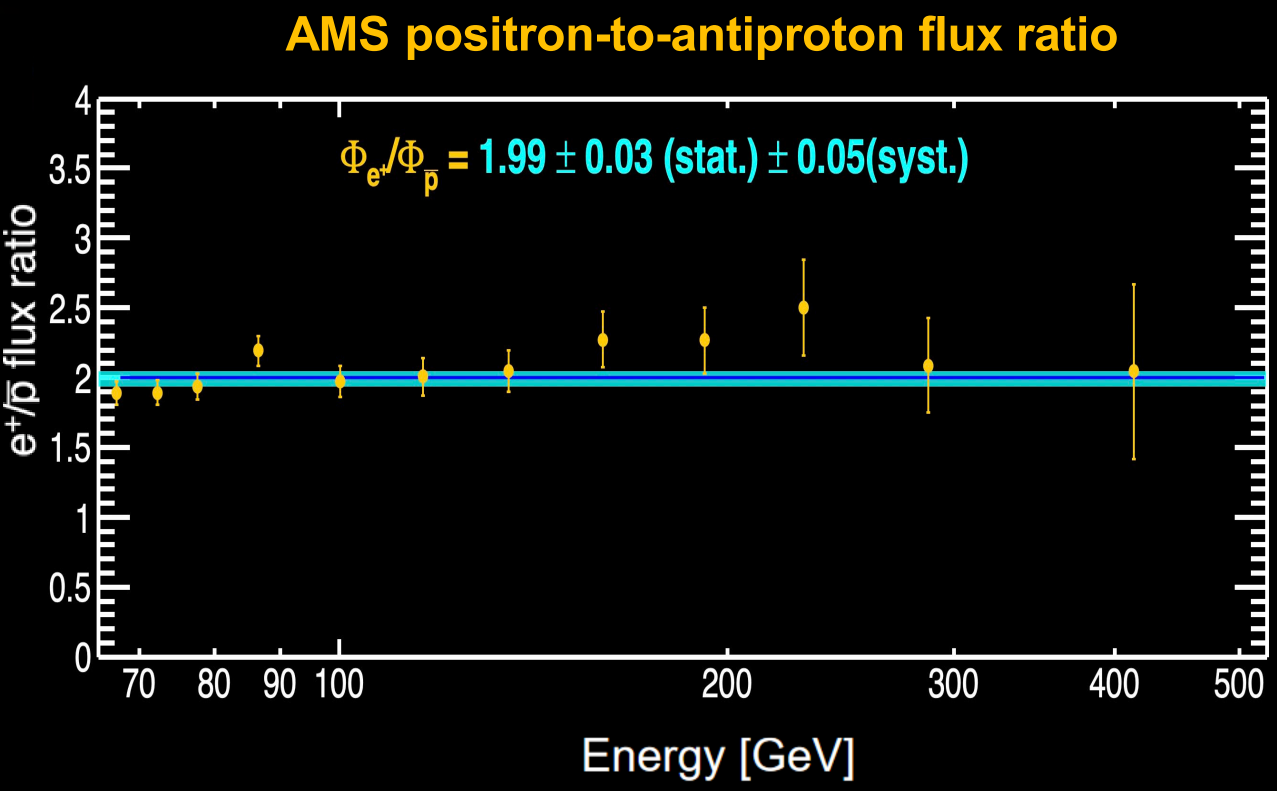
By 2030, AMS will ensure that the high energy positron spectrum drops off quickly in the 0.2-2TeV region and the highest energy positrons only come from cosmic ray collisions as predicted for dark matter model.

Unique Observation from AMS:

Positron and Antiproton have identical energy dependence above 60 GeV.

The positron-to-antiproton flux ratio is independent of energy.

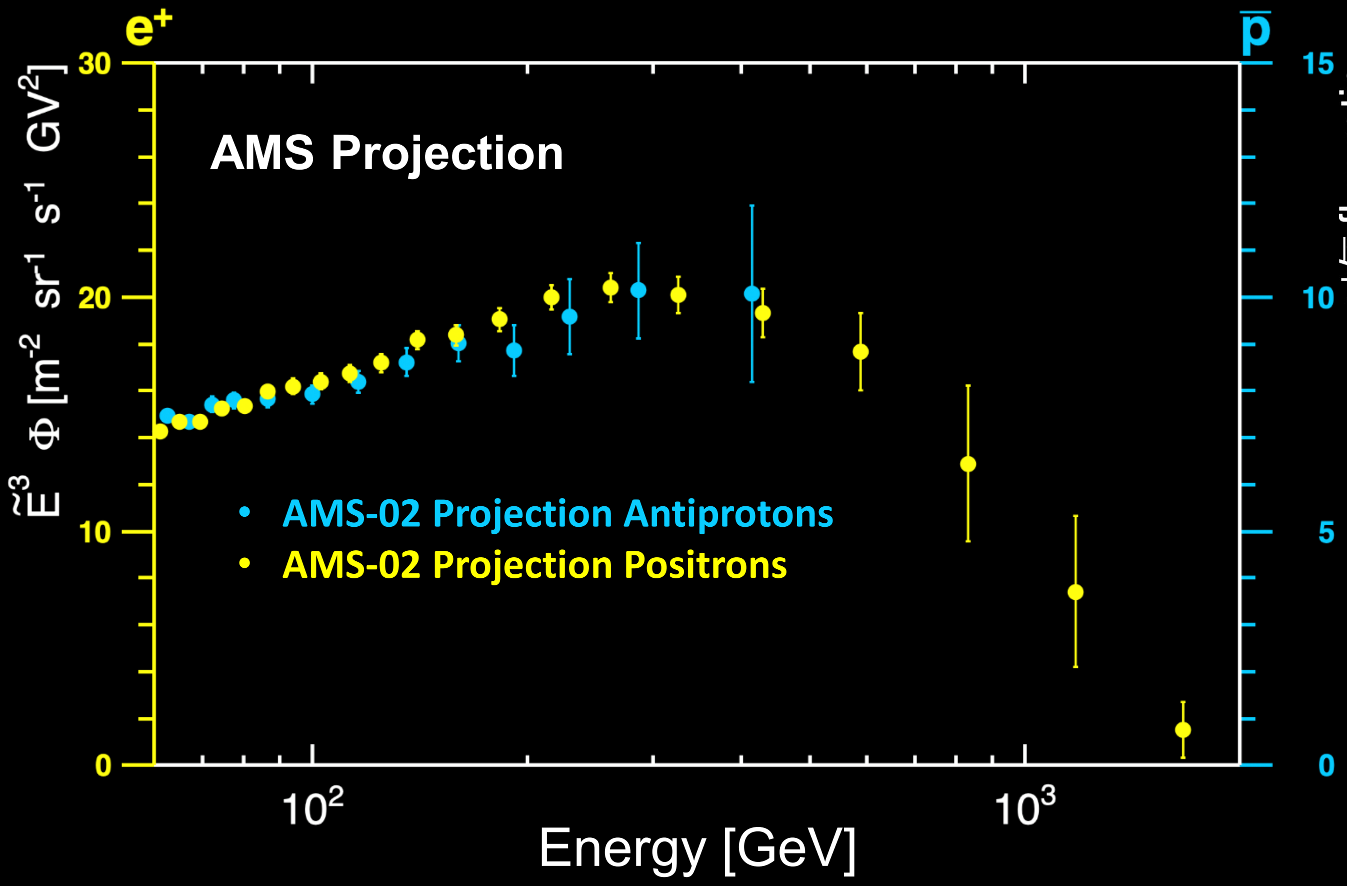


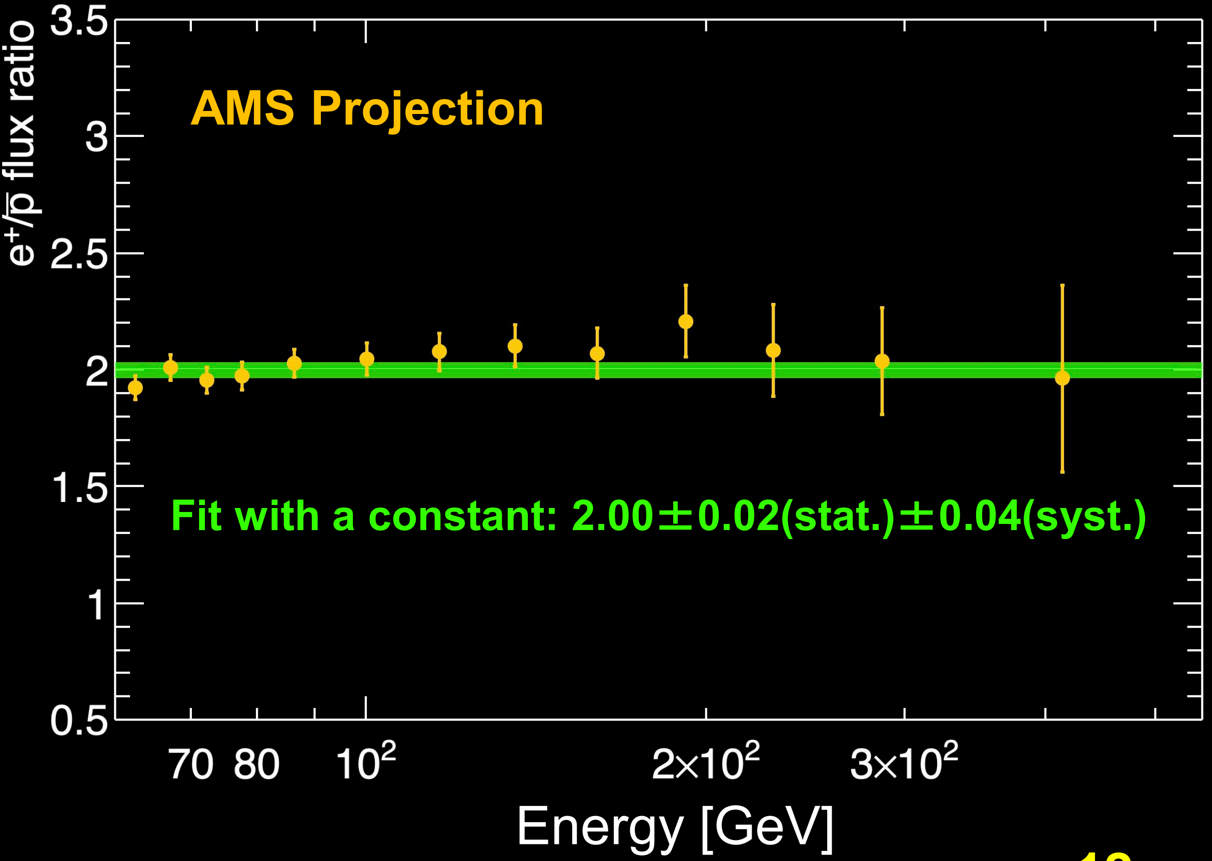


Antiprotons cannot come from pulsars.

By 2030, AMS will greatly improve the accuracy of the antiproton spectra

The identical behaviour of positrons and antiprotons excludes the pulsar origin of positrons





AMS is providing cosmic ray information with ~1% accuracy with energies up to multi-TeV. The accuracy and characteristics of the data require the development of a new comprehensive models.

AMS will continue to collect data to 2030 with the upgraded detector.