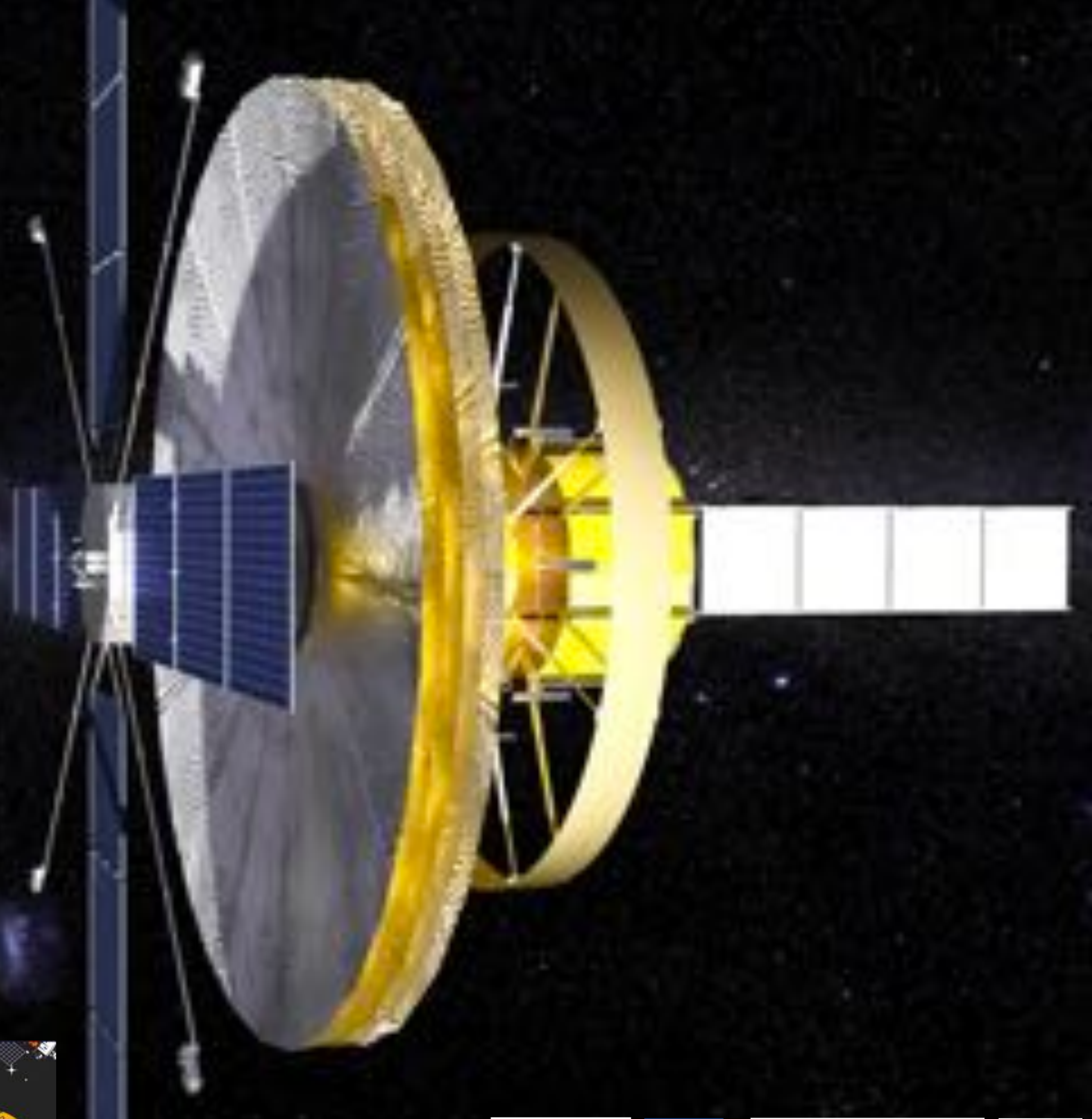
AMS-100

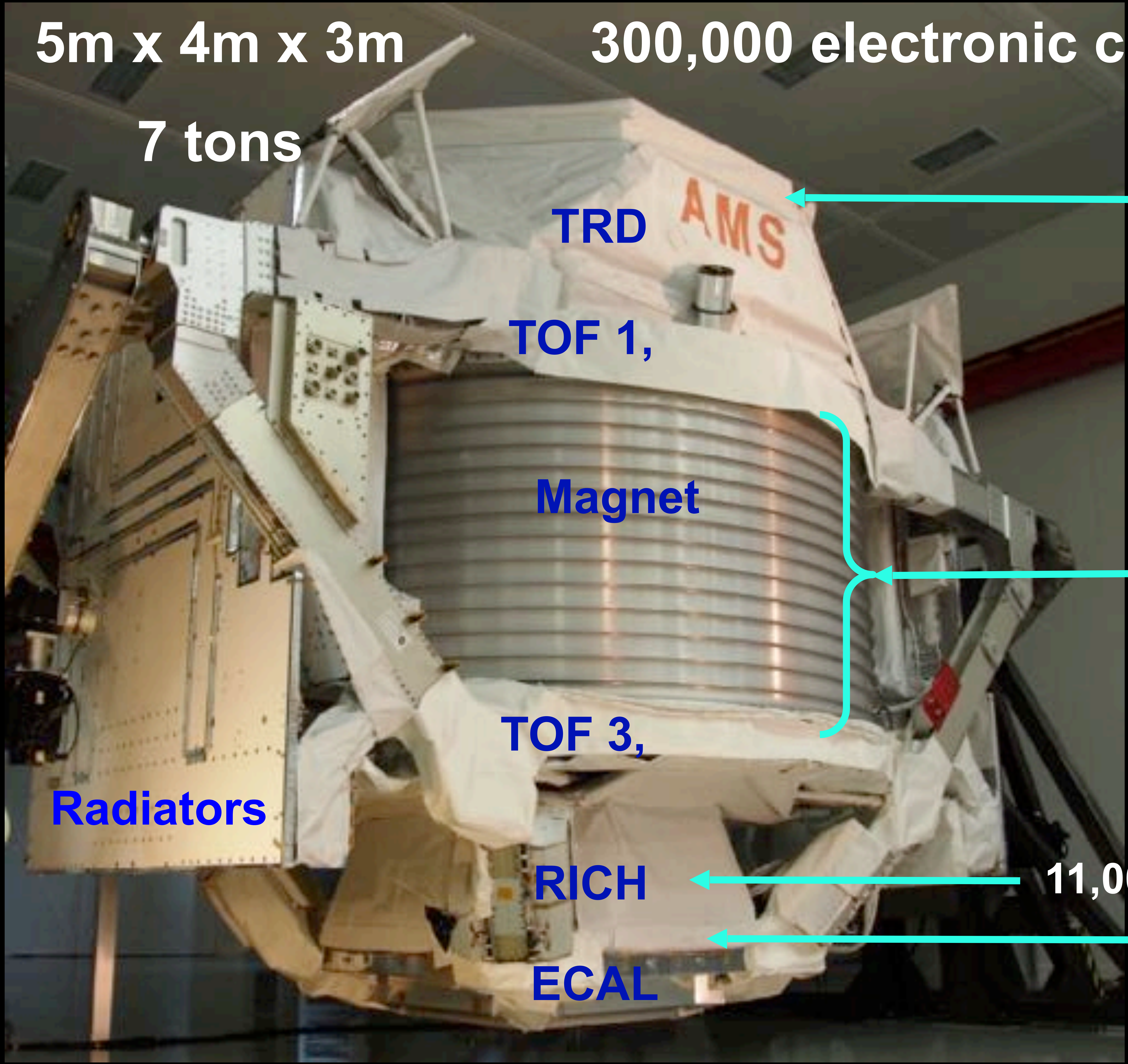
A Magnetic Spectrometer with an acceptance of 100 m^2 sr in Space

Nuclear Inst. and Methods in Physics Research, A 944 (2019) 162561

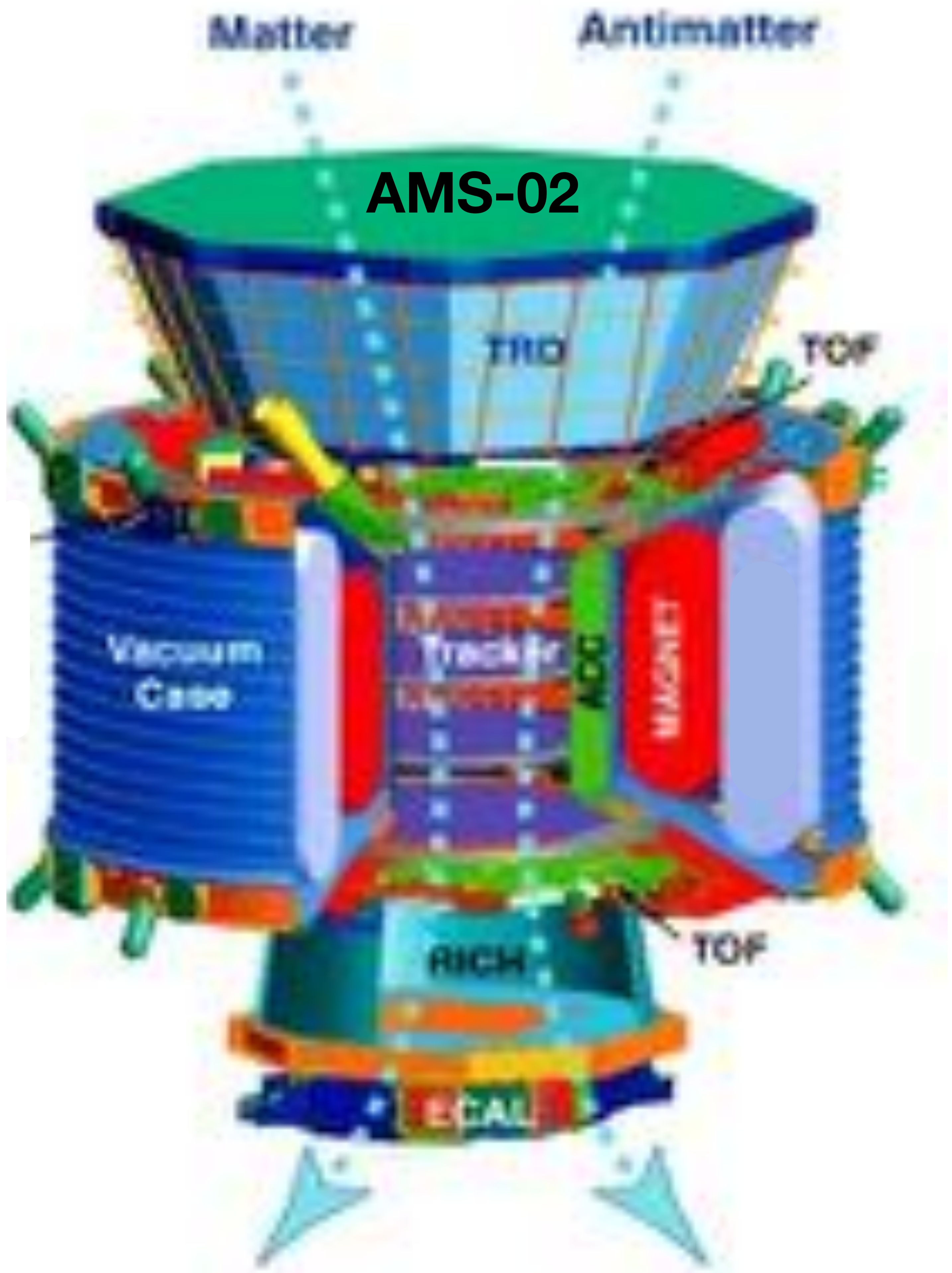


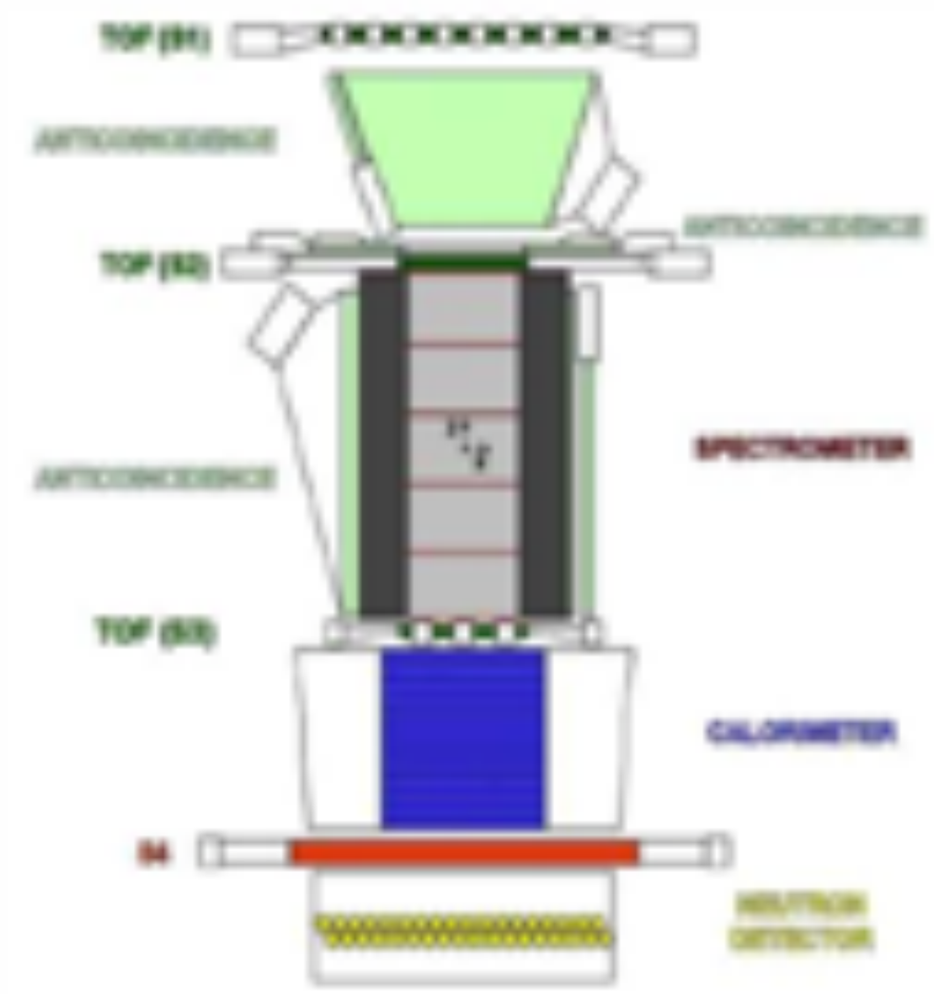
S. Schael, RWTH Aachen University

It took 600 Physicists and Engineers from 16 Countries and 60 Institutes 17 years to construct the Alpha Magnetic Spectrometer.



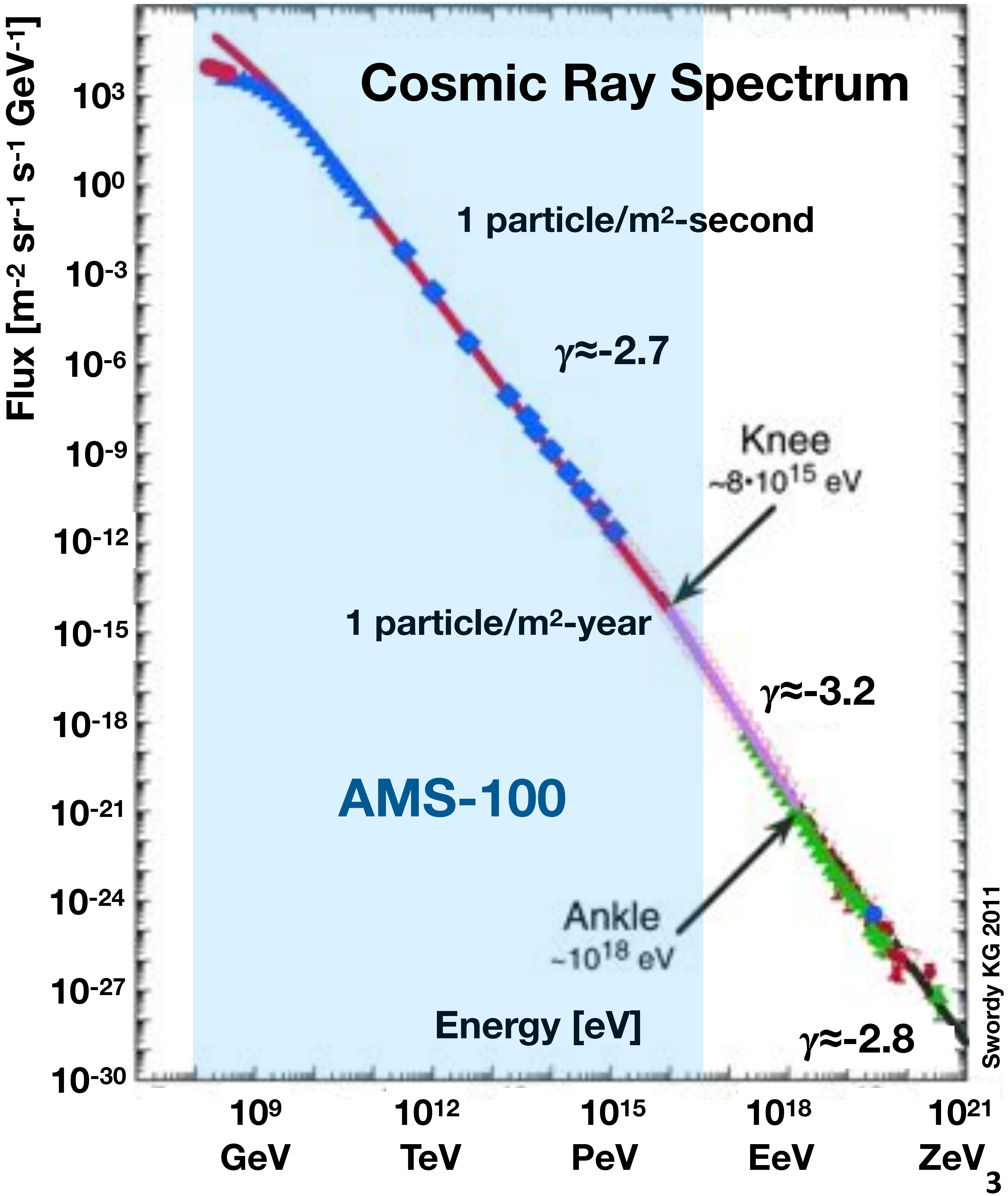
We have to start now to work on the next generation magnetic spectrometer in space !



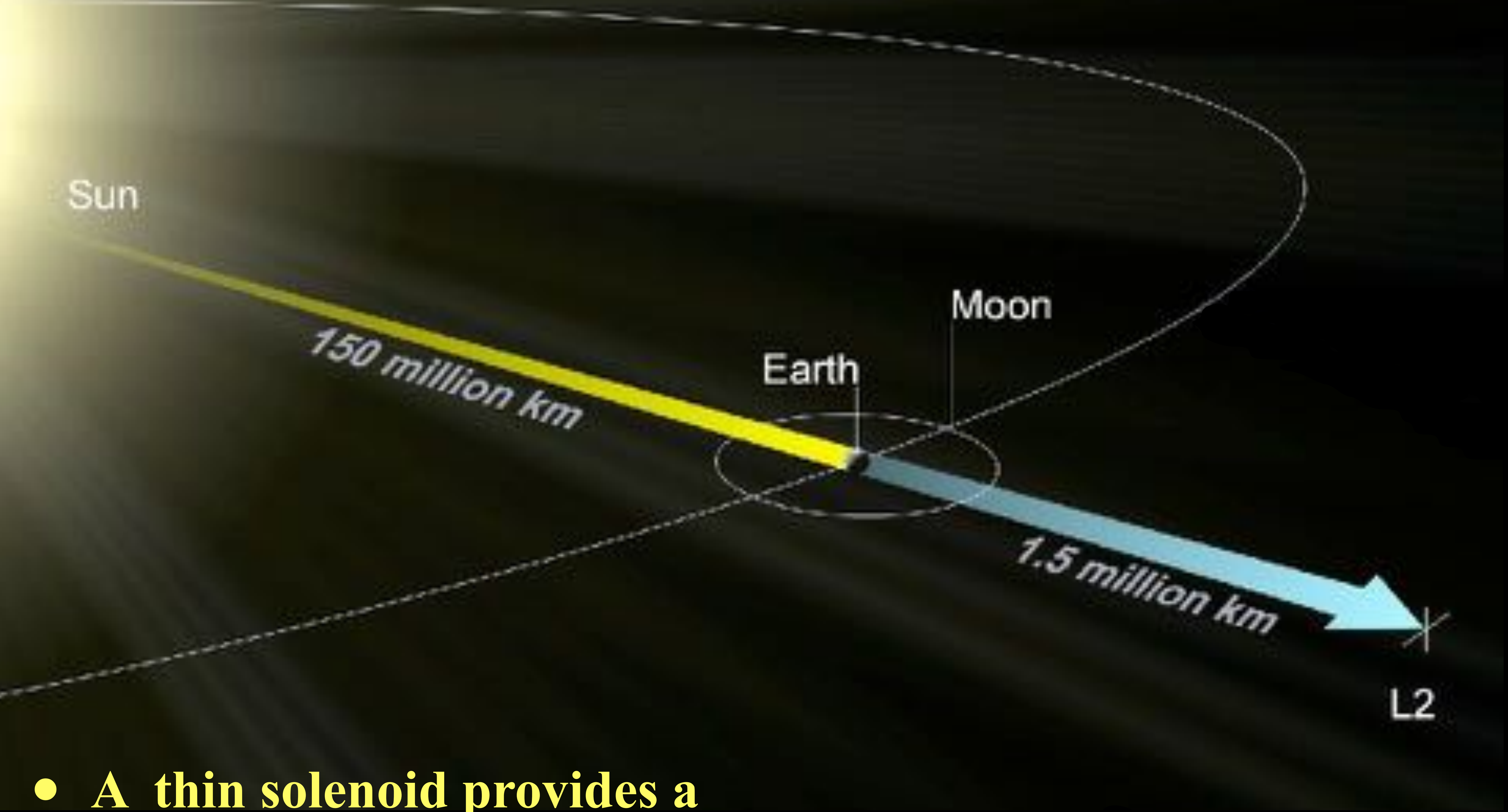


PAMELA

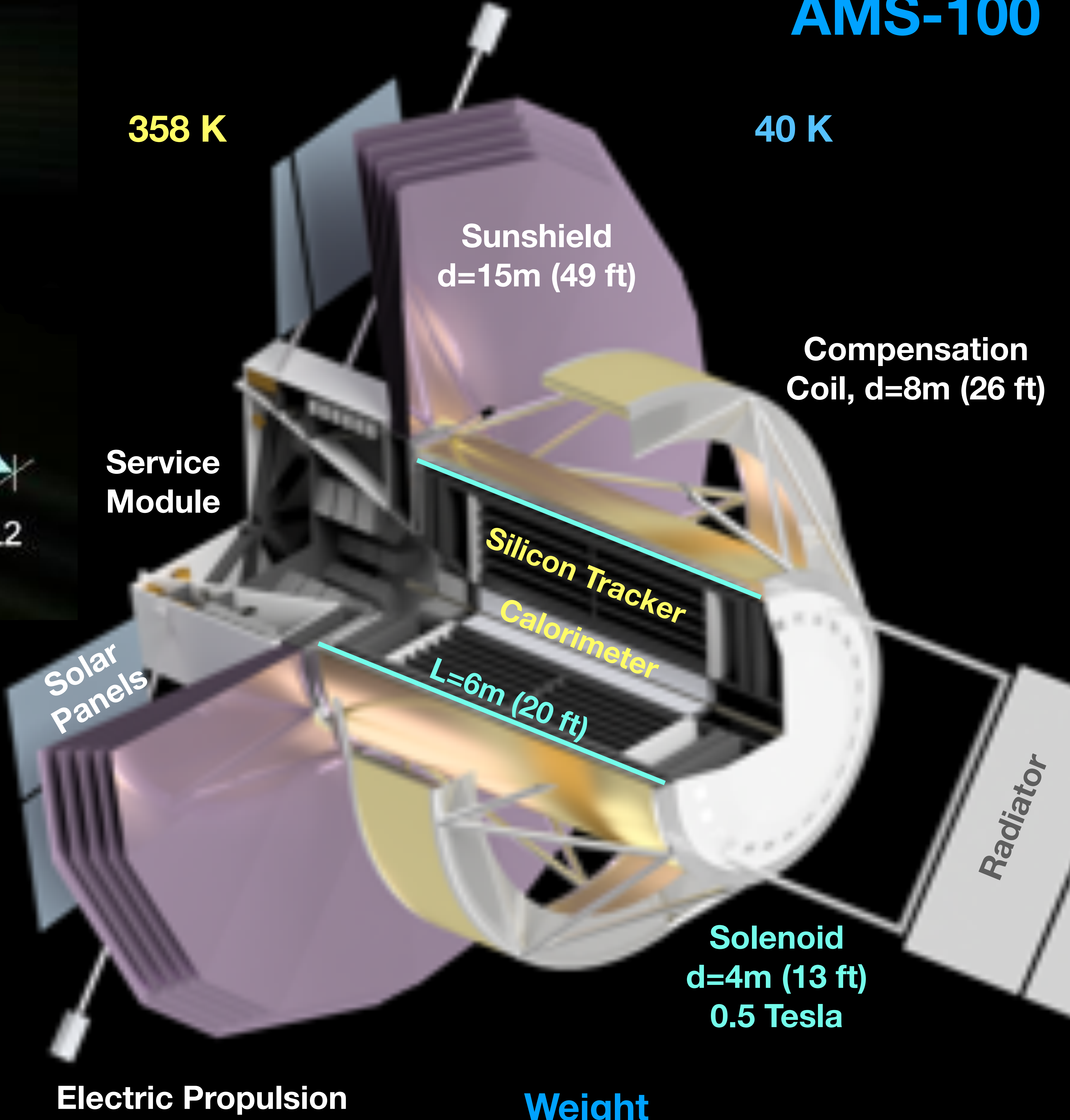
- The cosmic ray flux follows a power law $\Phi \approx C\ E^{-3}$
- An increase in energy by a factor 10 requires an increase in acceptance by 1000. AMS-02 weights 7 tons.
- Both PAMELA and AMS-02 have a telescope like geometry.
- Just scaling such a geometry does not allow to increase the energy reach by a factor 10 and simultaneously the acceptance by a factor 1000.



AMS-100



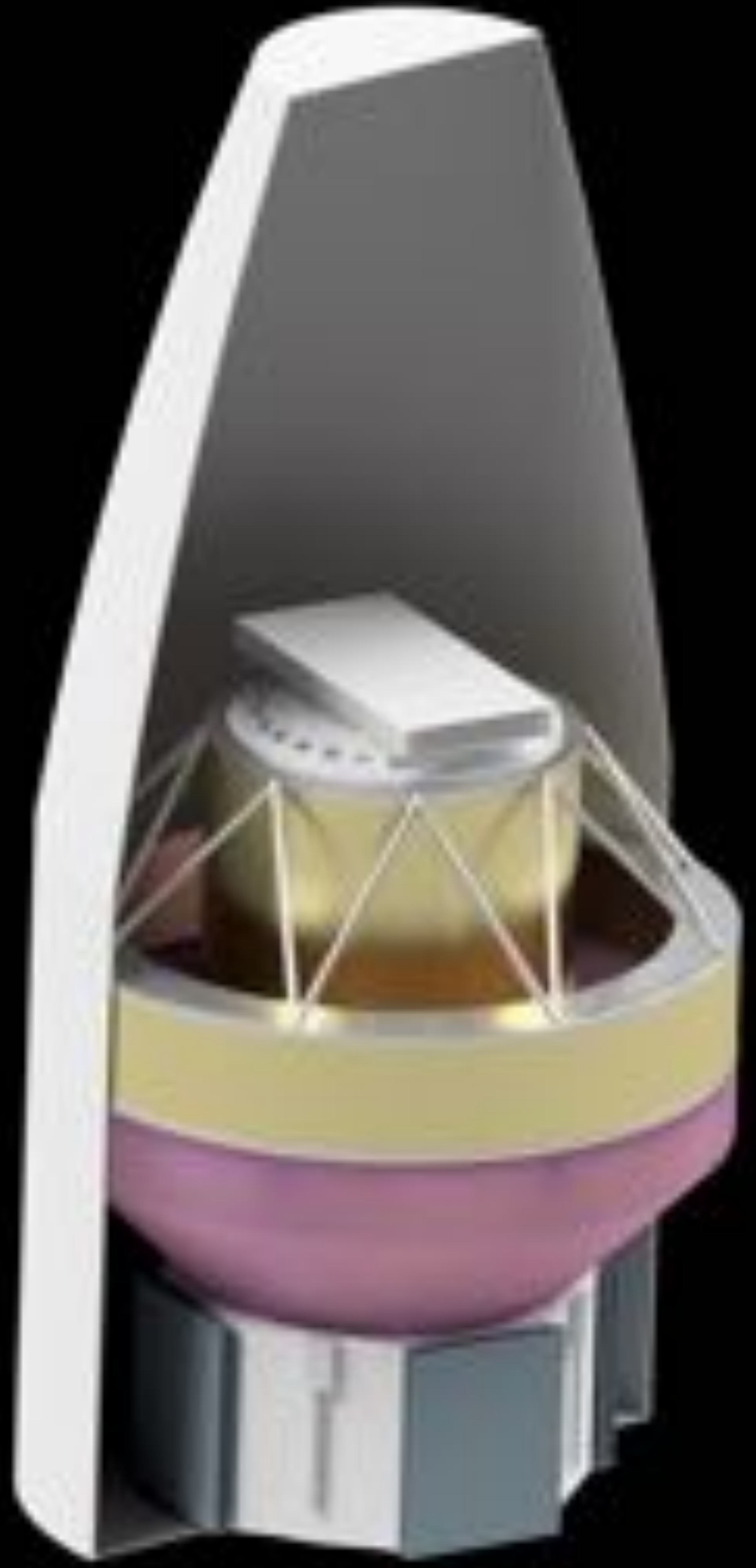
- A thin solenoid provides a magnetic field of 0.5 Tesla.
- The solenoid is operated at 60 K behind the sunshield in thermal equilibrium with the environment.
- A compensation coil balances the magnetic dipole moment of the solenoid.
- The solenoid is instrumented on the inside with a silicon tracker and a calorimeter system.



The Expedition to Lagrange Point 2

Vehicle and Launch:

- Target launch year: ~2035.
- Operational for 10+ years.
- Total estimated mass of AMS-100: 40 Tons
  - ~4 Tons for the magnet system,
  - ~16 Tons of detector equipment,
  - ~20 Tons of auxiliary equipment and cabling.
- Launched with SpaceX's Starship rocket.

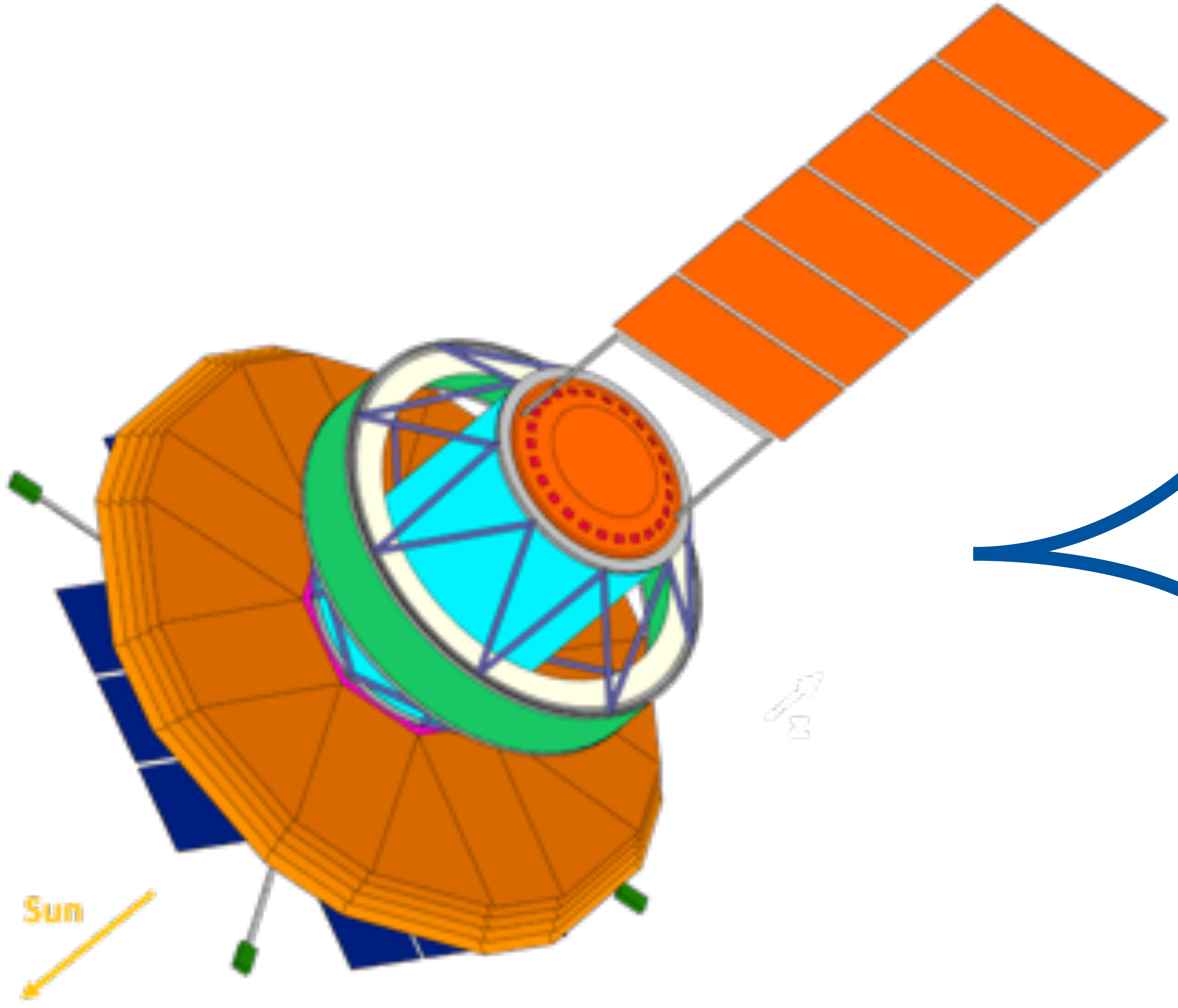


Starship's 8 m (26 ft) diameter payload dynamic envelope

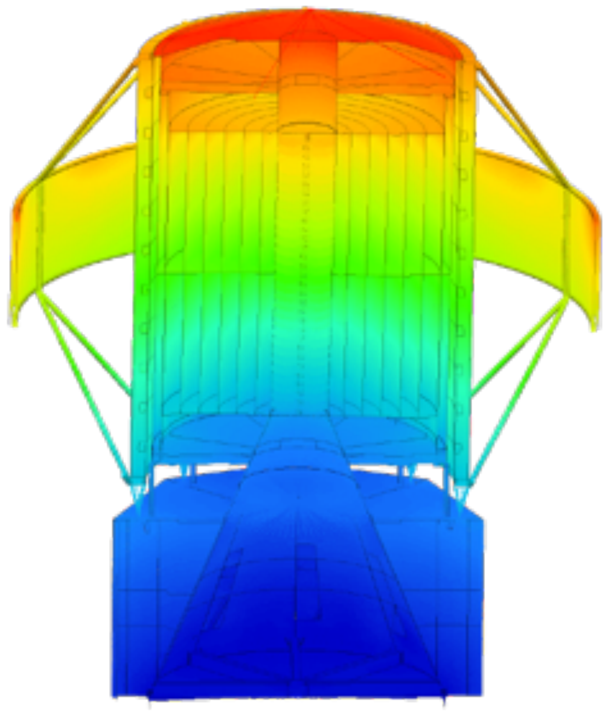
SpaceX

- In 2019, the cost per launch for Starship was estimated by SpaceX to be as low as US$2 million.
- Elon Musk has said in 2020 that, with a high flight rate, they could potentially go even lower, with a fully-burdened marginal cost on the order of US$10 per kilogram of payload launched to low Earth orbit.

ARCHITECTURE | MODELS

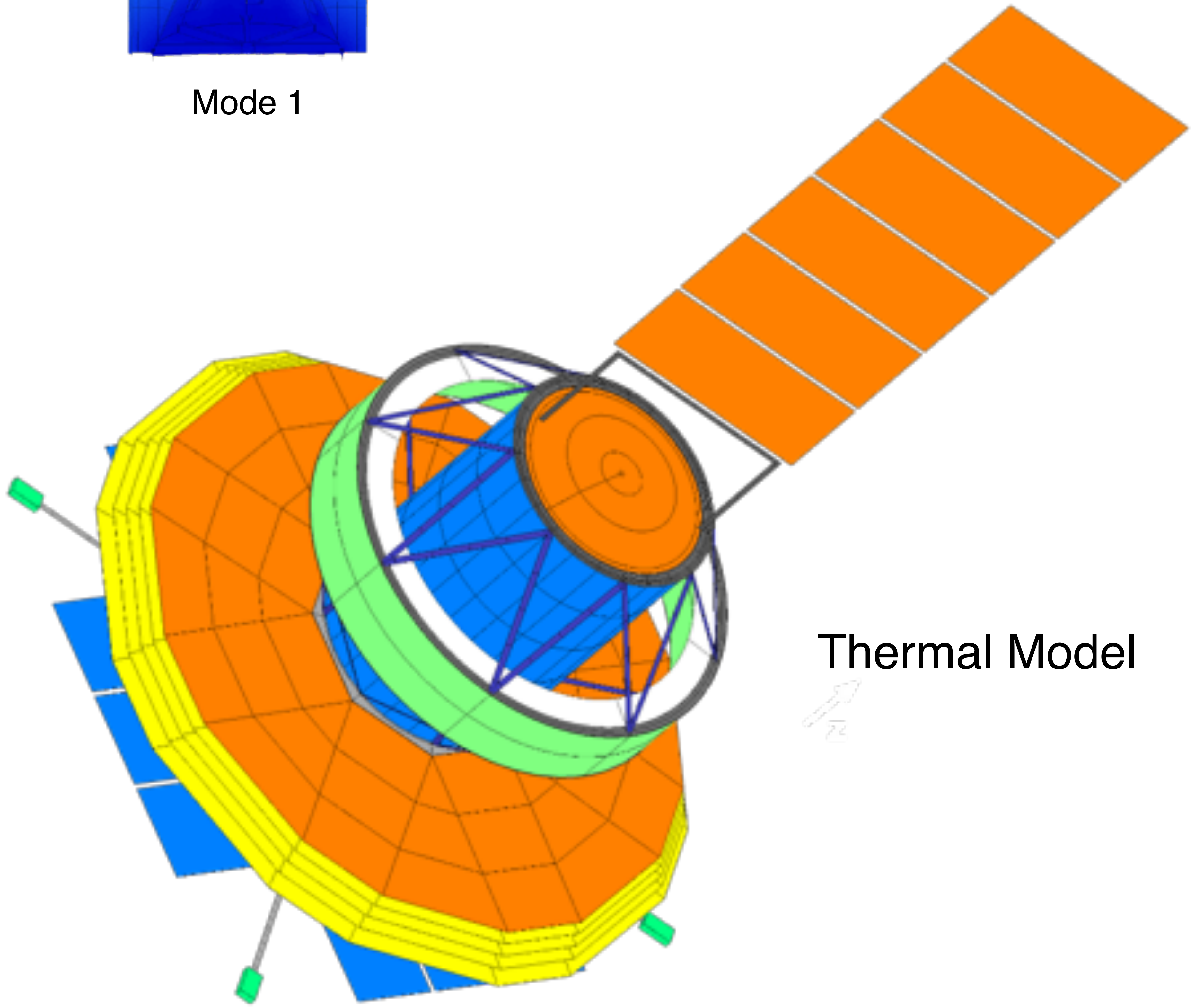


CAD Model



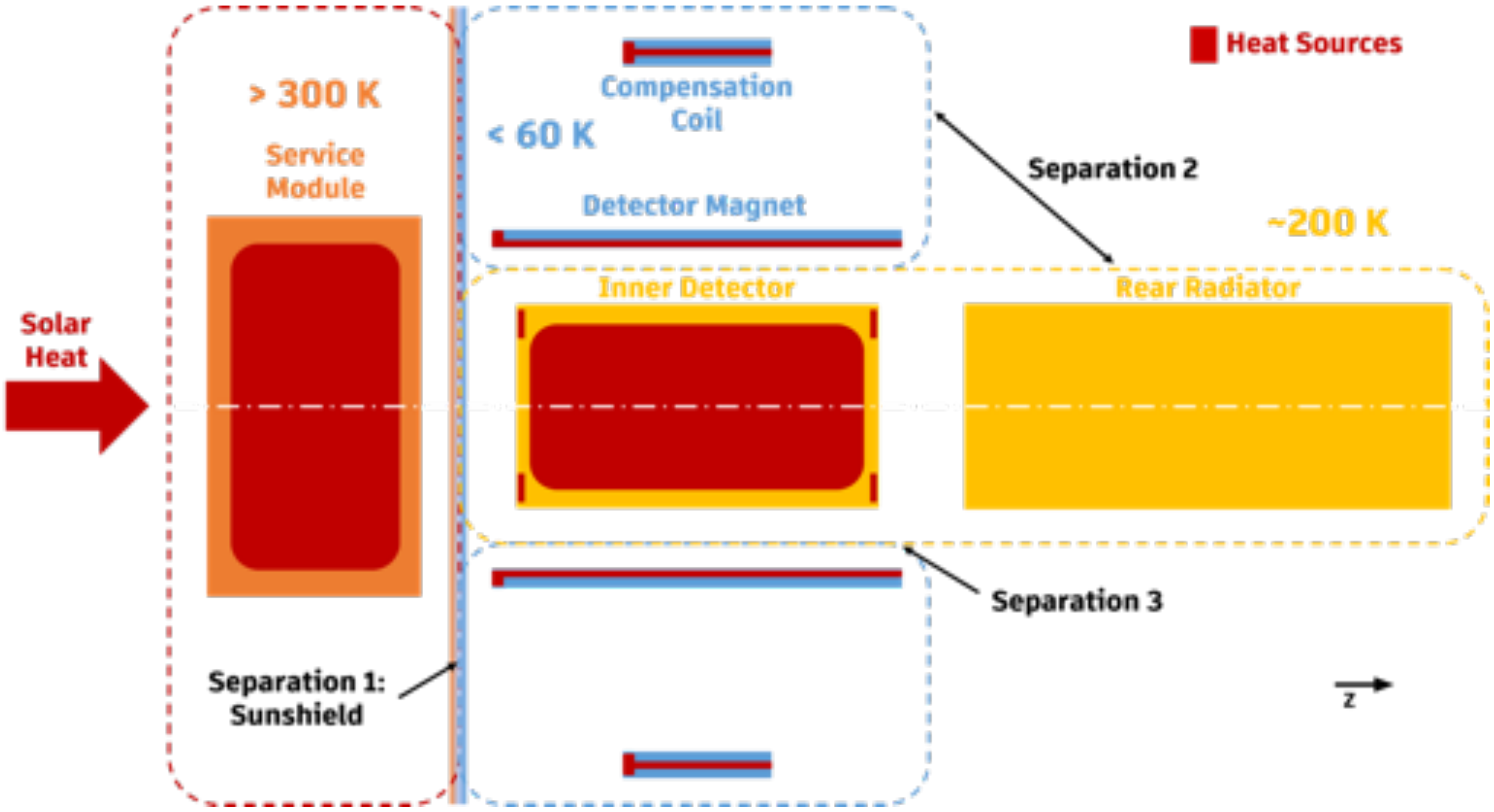
Mode 1

Structural Model



Thermal Model

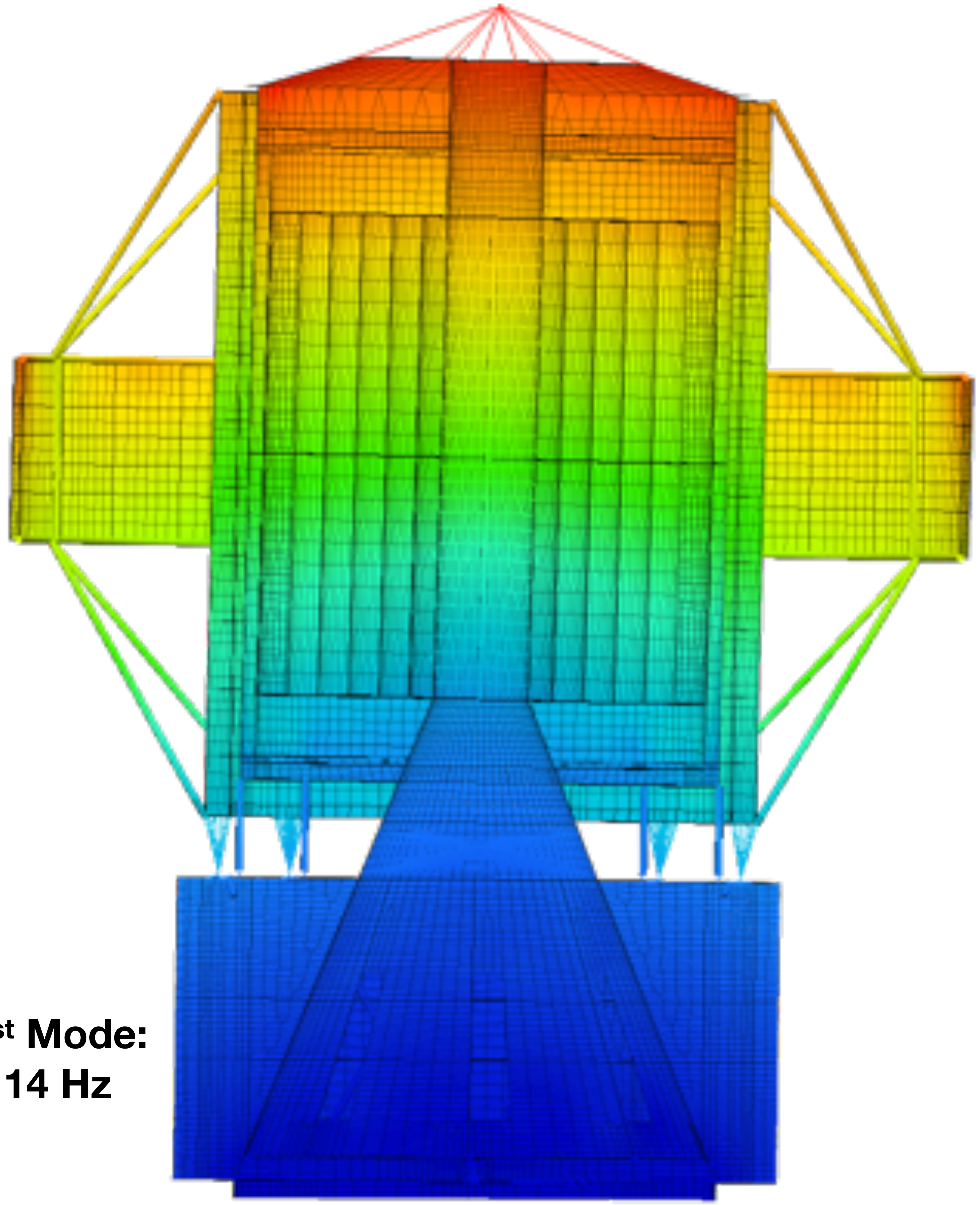
THERMAL DESIGN | HEAT SOURCES



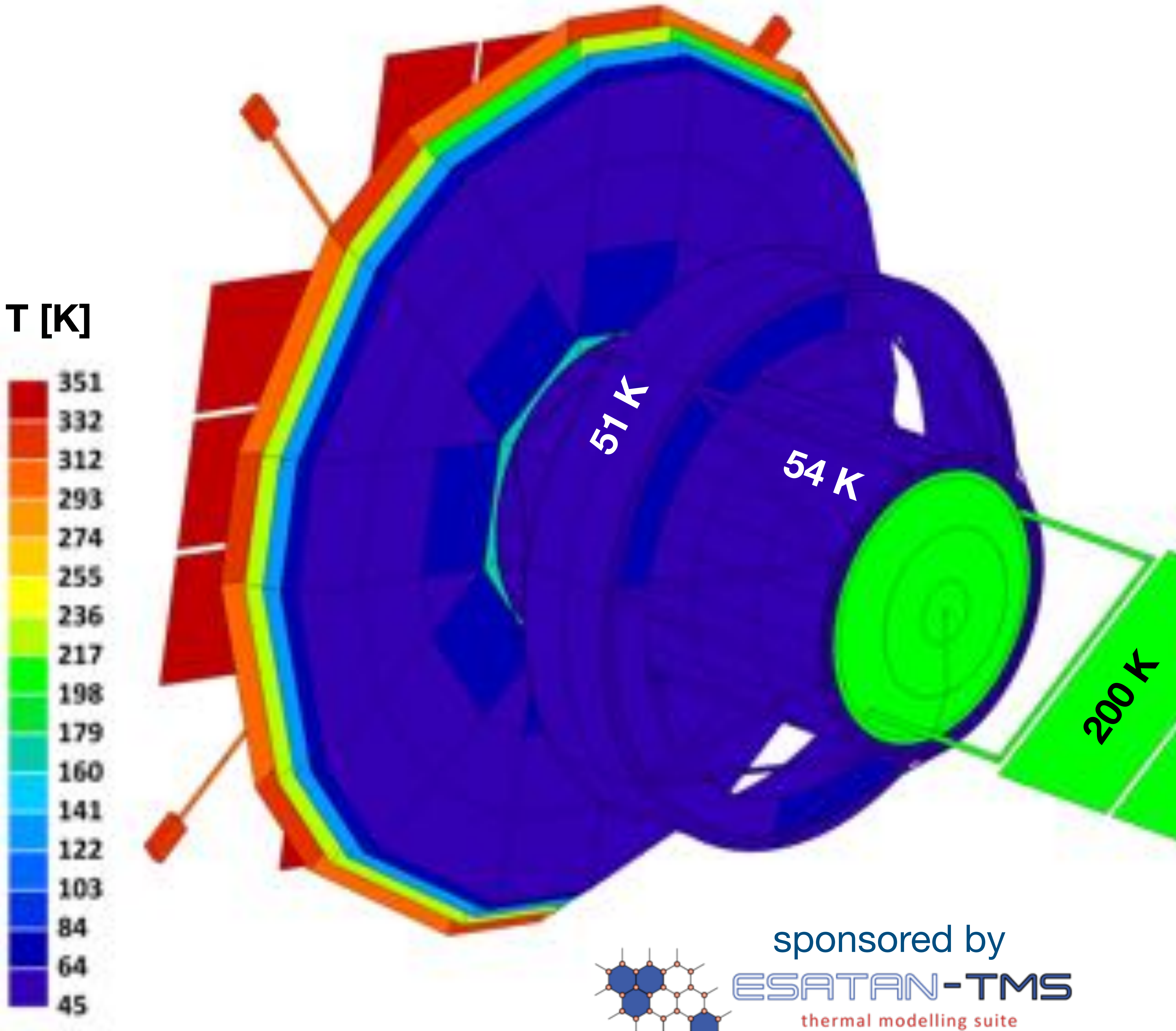
- Service module & payload data handling
  - ~8000 W
- Inner detector
  - ~8000 W
- Solenoids
  - ~15 W

AMS-100: Structural Model

AMS-100: Thermal Model

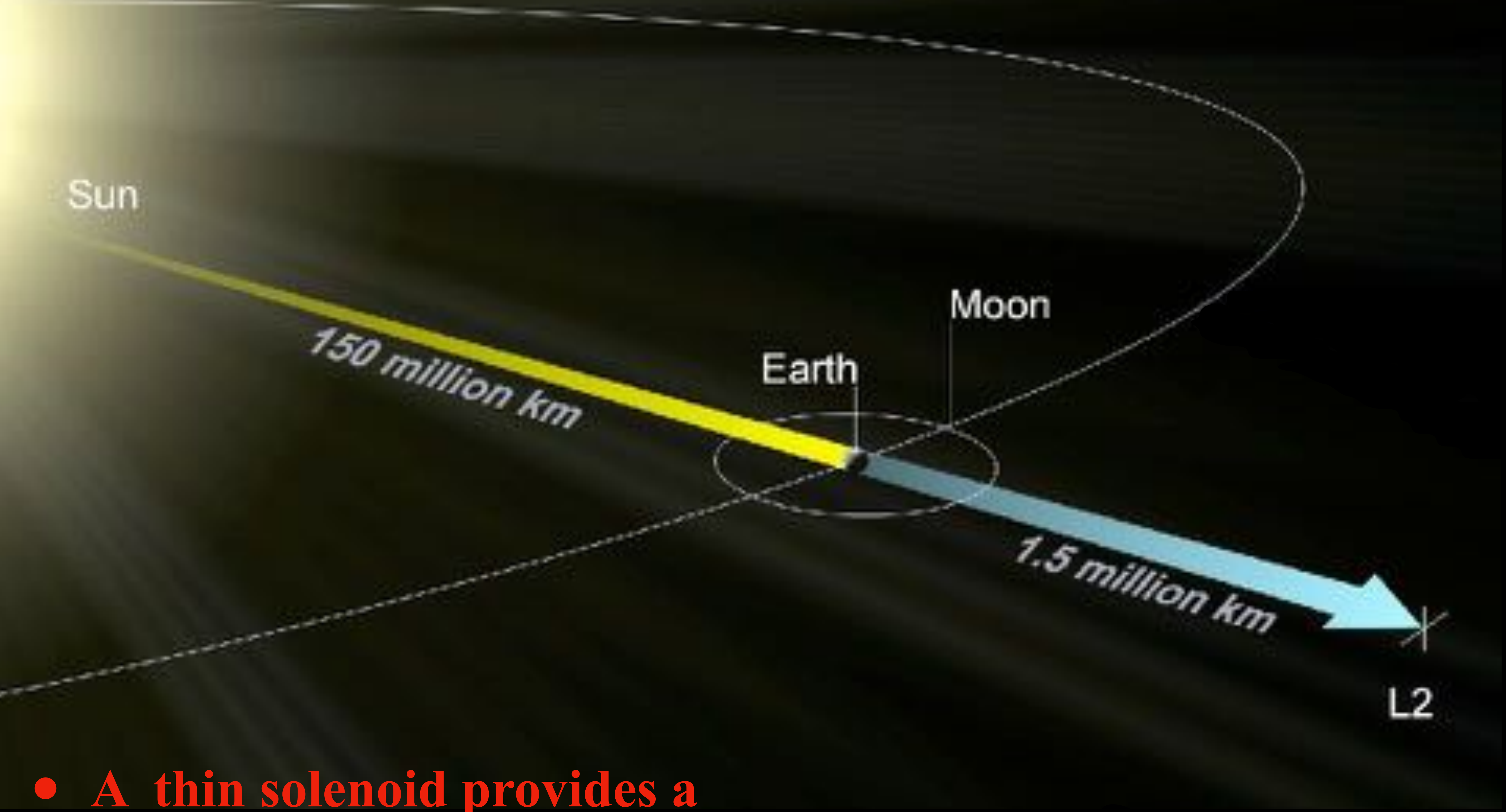


1st Mode:
14 Hz



sponsored by ESATAN-TMS thermal modelling suite

AMS-100



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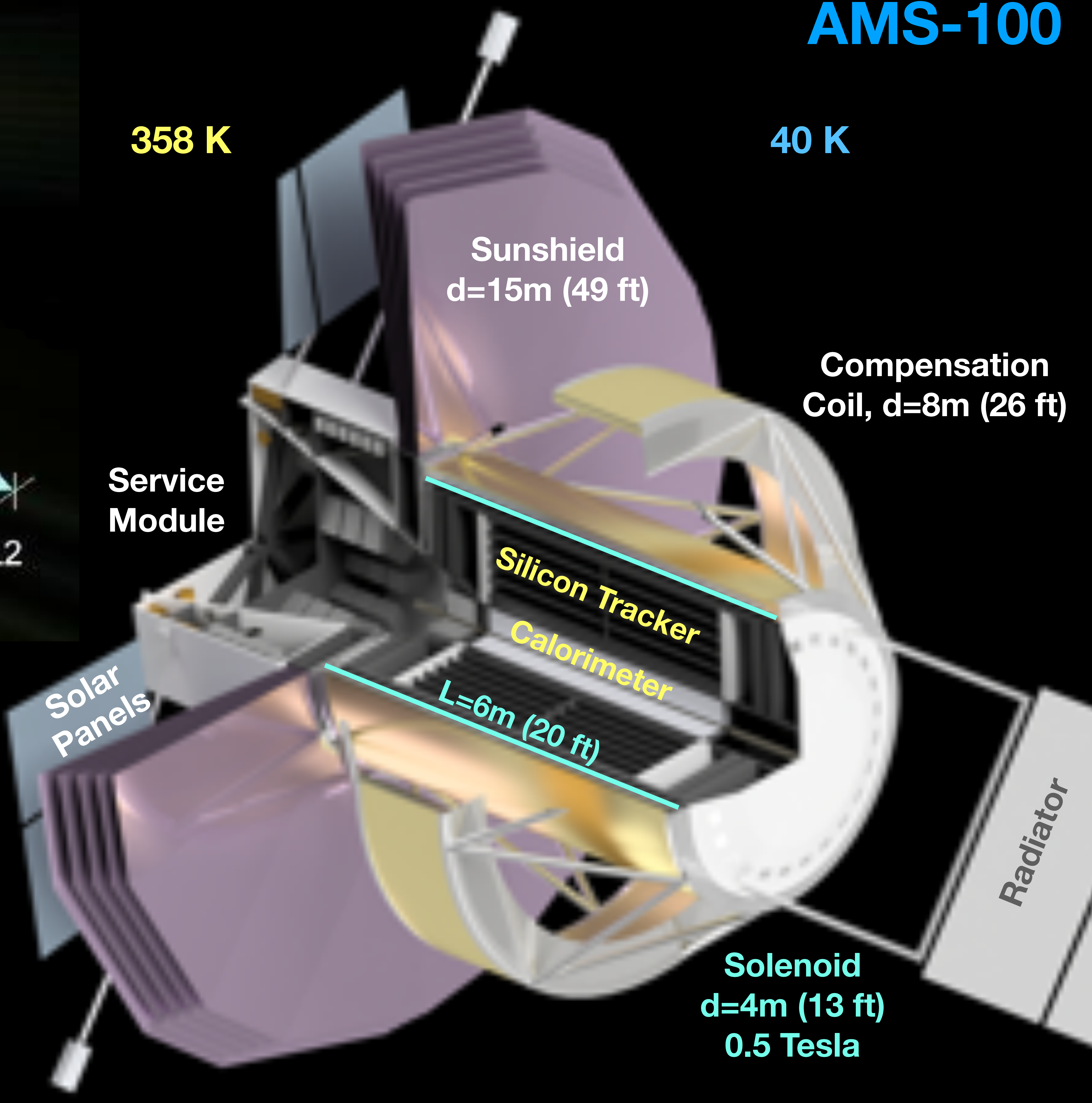
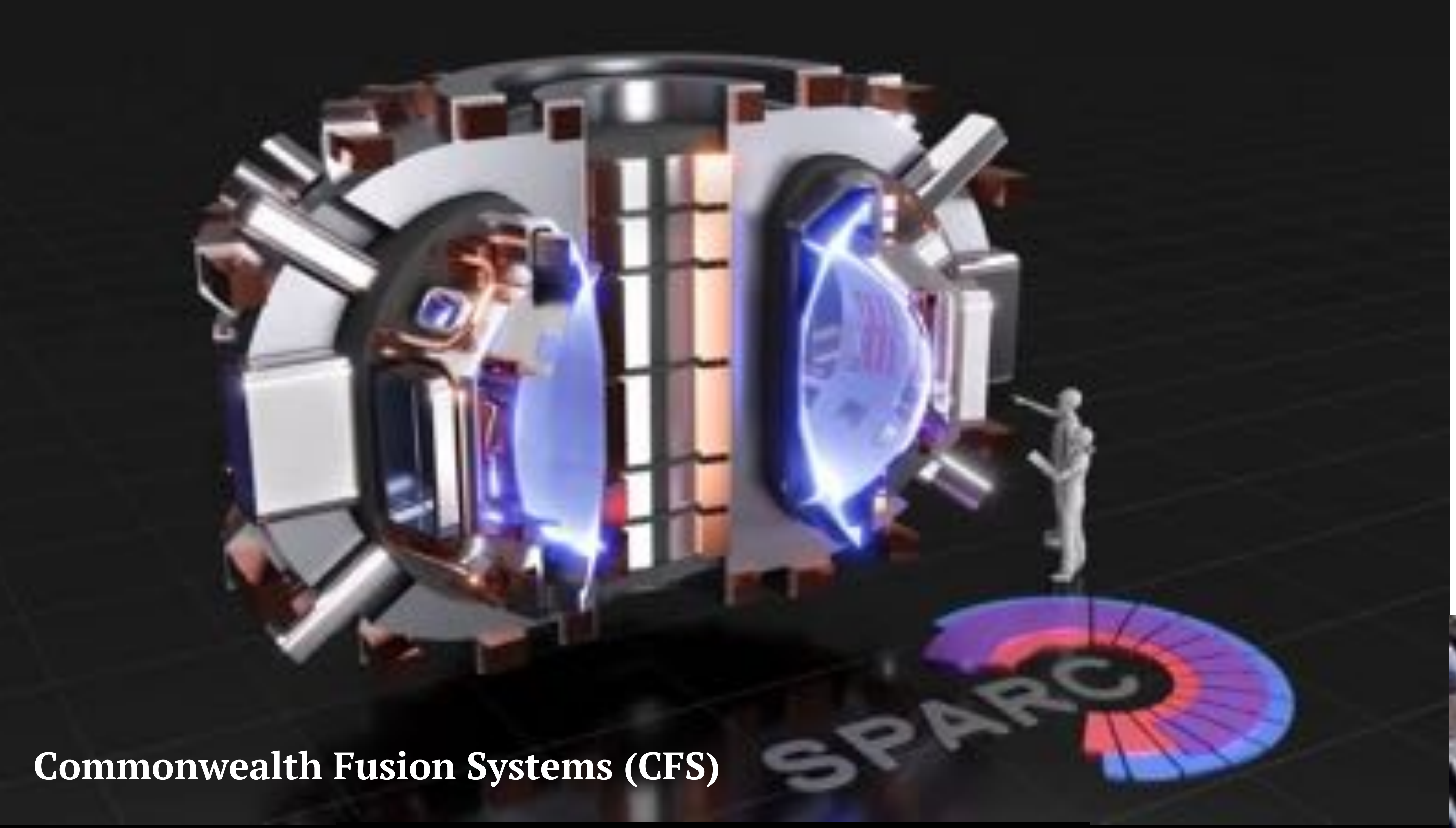




	SPARC	AMS-100
B-Field	20 Tesla	0.5 Tesla
Temperature	20 K	55 K
I_{op}	40 kA	10 kA
Stored Energy	110 MJ	14 MJ
HTS Length	270 km	85 km

16 HTS coils

AMS-100: A Magnetic Spectrometer

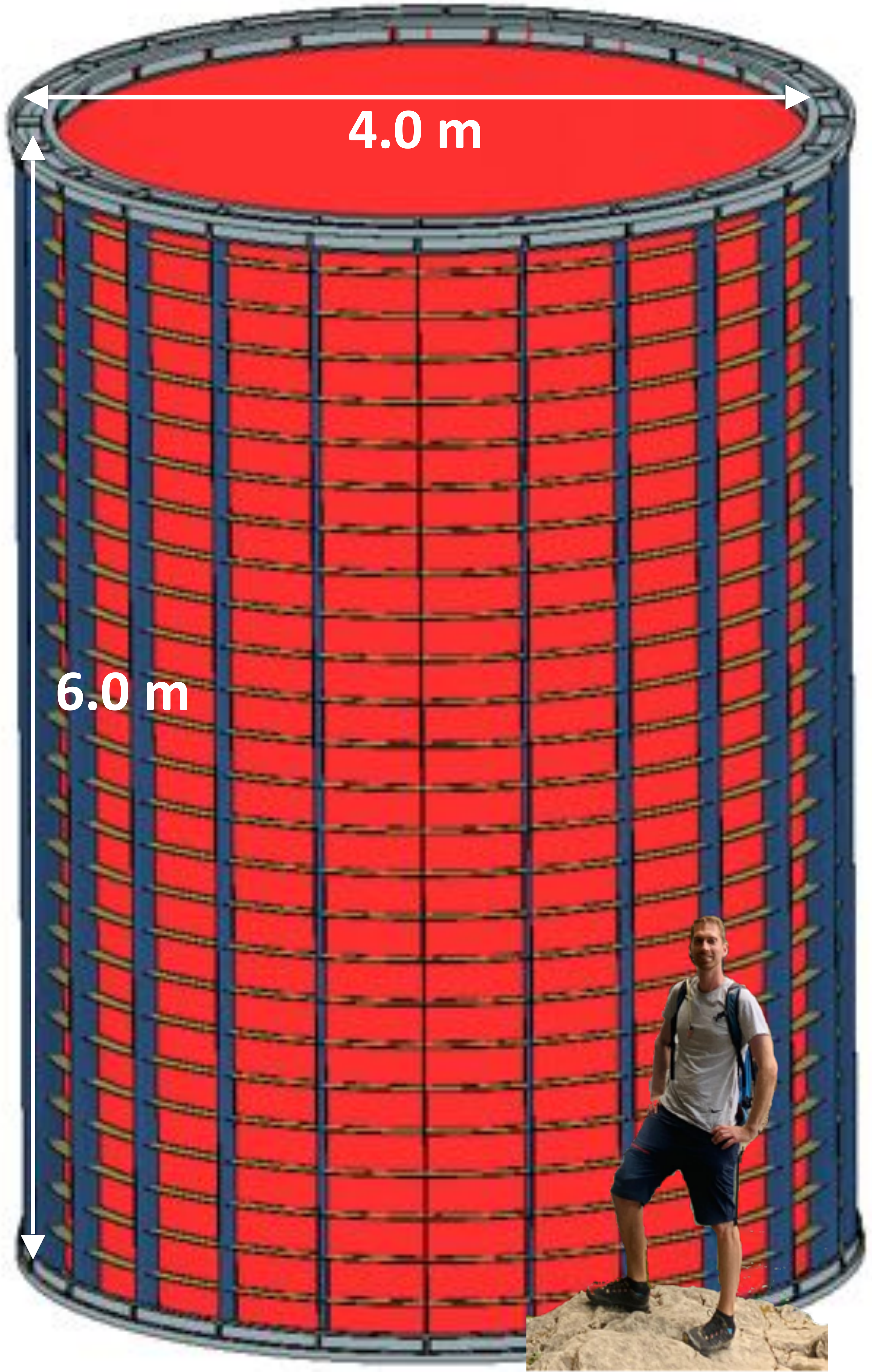


Table of properties for the AMS-100 main solenoid and compensation coil.

	Main	Compensation	Combined	Unit
Coil radius	2.0	4.0		m
Coil length	6.0	1.5		m
Tape width	12	12		mm
Stabilizer	Al-6063	Al-6063		
Cable thickness	2.85	2.85		mm
Cable width	16	16		mm
Layers	1	1		-
Turns	376	94		-
Inductance	286	114	287	mH
Number of tapes	18	18		-
Total tape length	85	43	128	km
Operating current	10.0	-10.0		kA
Cable mass	1090	545	1635	kg
Stored Energy	14.3	5.7	14.4	MJ
Energy Density*	14	11	9	kJ/kg

*Considering only the mass of the cable.

Design **B-field of 0.65 T** in the center, ~1 T on the conductor at the edge of the solenoid.

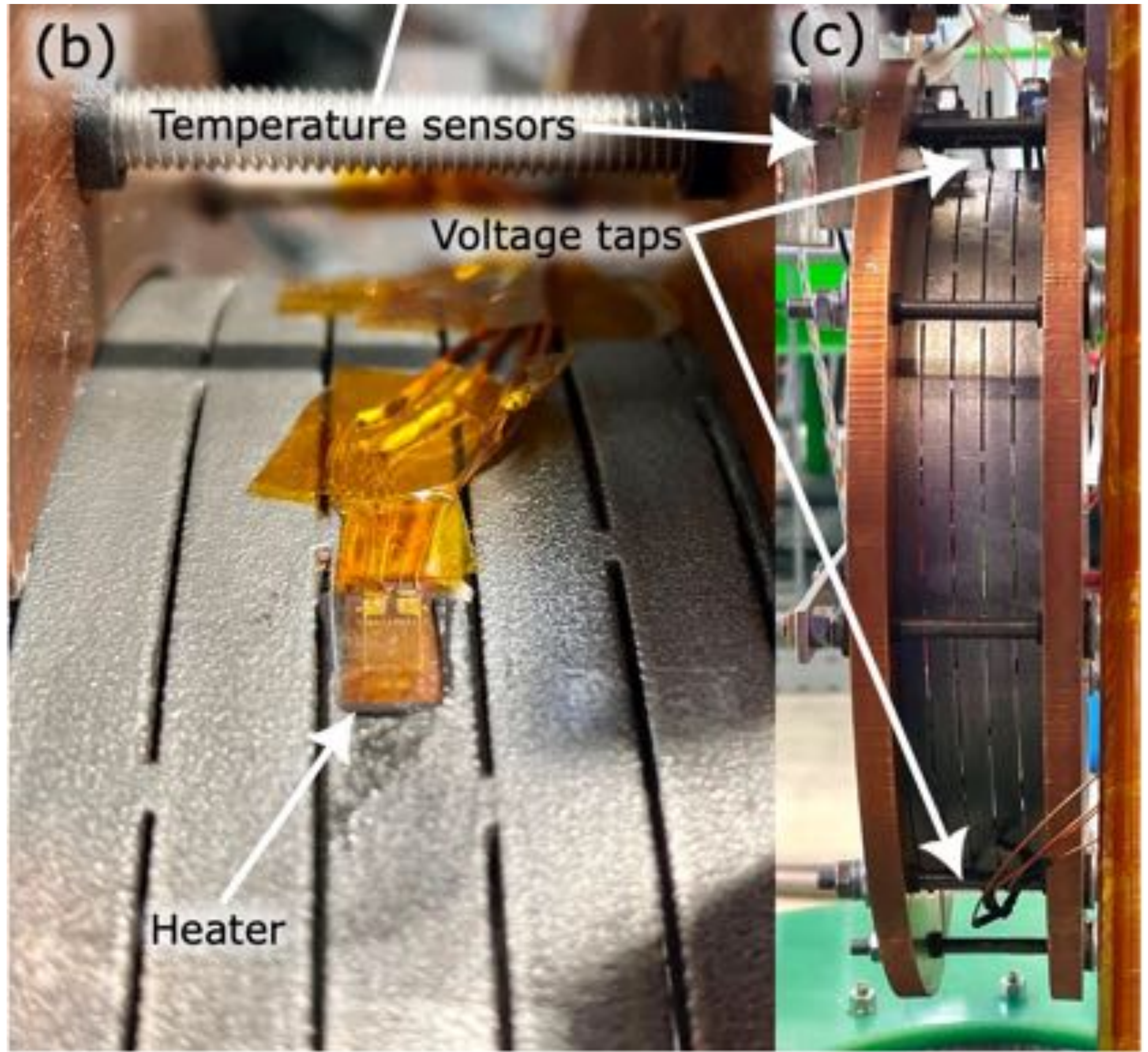
B-field of 0.5 T when the compensation coil is on.

Operating temperature range of 50 to 60 K:

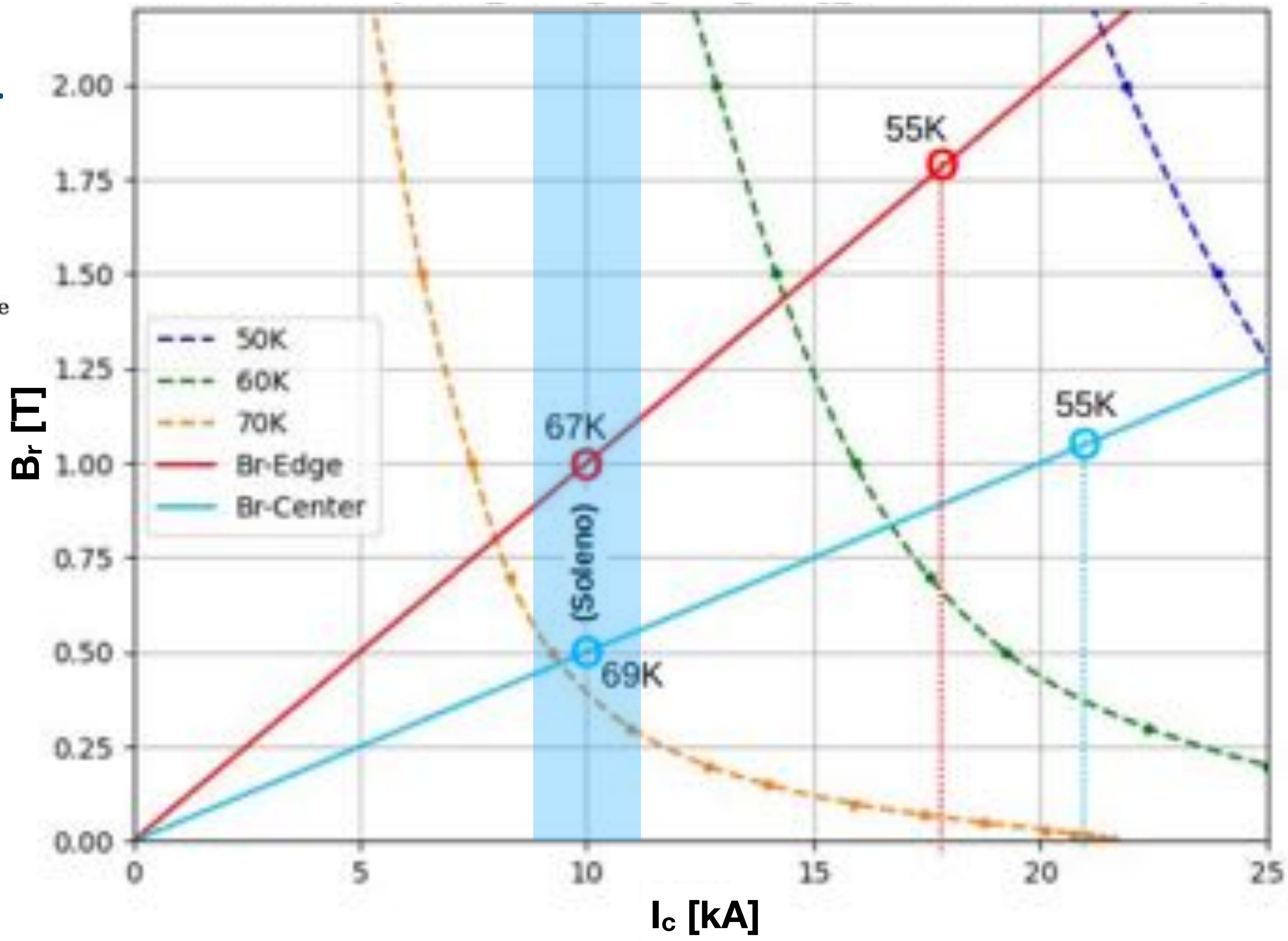
- ΔT of 12 K @ 55 K

Self-Protected High-Temperature Superconducting Demonstrator Magnet for Particle Detectors

Joep L. Van den Eijnden[1,2,*], Anna K. Vaskuri[1], Benoit Curé[1], Alexey Dudarev[1], and Matthias Mentink[1]
[1] CERN, 1211 Geneva 23, Switzerland
[2] Eindhoven University of Technology, Groene Loper 3, 5612 AE Eindhoven, The Netherlands



T. Siedenburg 06-2022



peak field on the conductor is 1.2 T

AMS-100

100 cm
Radiator & Debris shield: 0.5 mm Al 6110, 50 mm Al-Honeycomb, 0.5 mm Al 6110
outer-stringers, AL 6063
5 mm x 130 mm
h=8.6 cm
MLI
X0=1.8%
SciFi-Tracker: 0.5 mm CFRP - 10 mm Nomex
GFRP
Magnet
inner-stringers,
AL 6063
10 mm x 25 mm
h=7.5 cm
MLI
Magnet Interfaces
10 cm
MLI
Main Support Cylinder
1.0 mm CFRP - 30 mm Al-Honeycomb - 1.0 mm CFRP
X0=14.7%, NIL=2.8%
(without MLI)
Y
X
1mm =2 pt

Simulated Quench Behavior and Survival

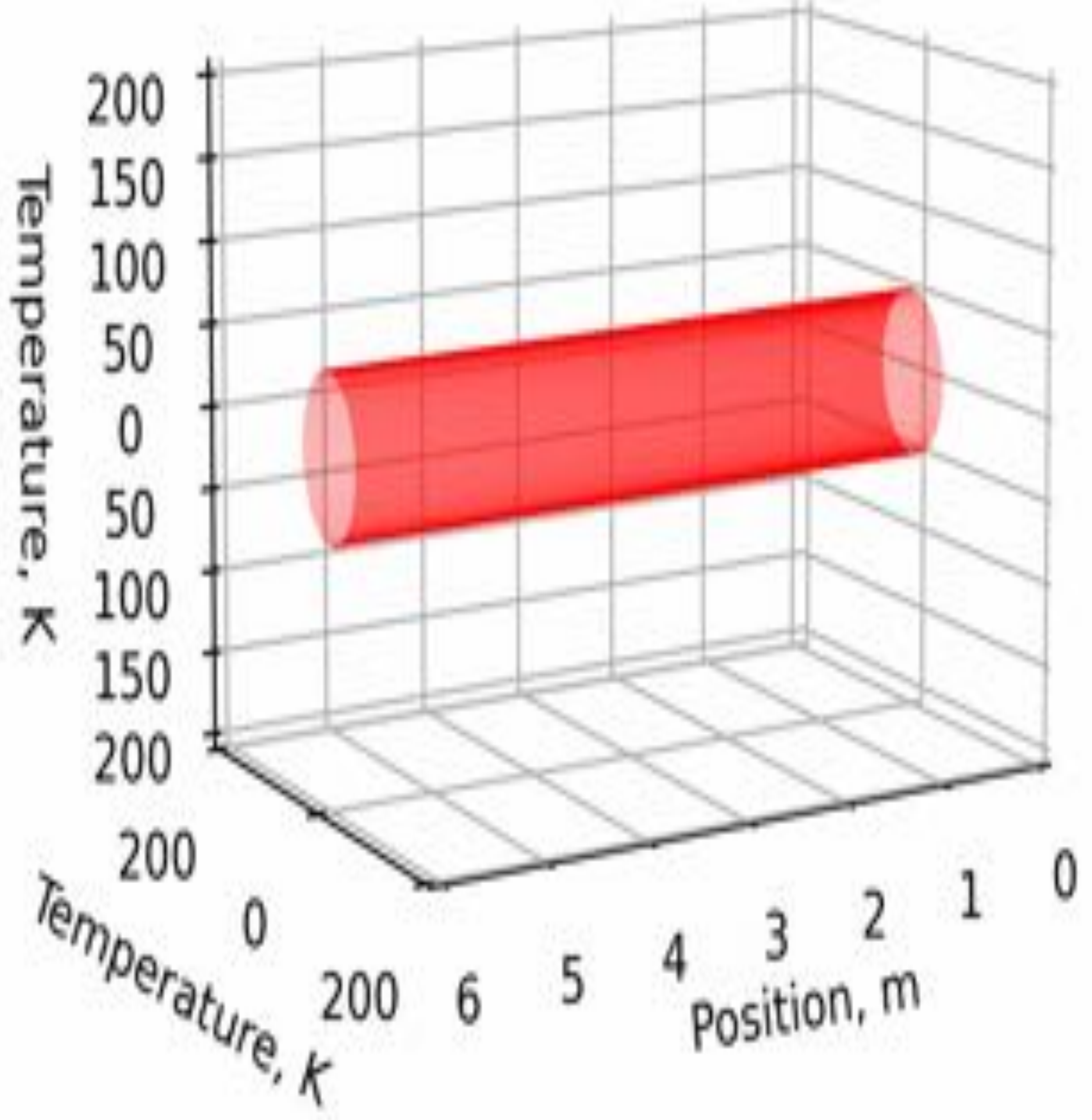
428 turn main solenoid, I_{op} = 13.5 kA, B = 1 T.

t = 0.2428 s

t = 0.2428 s

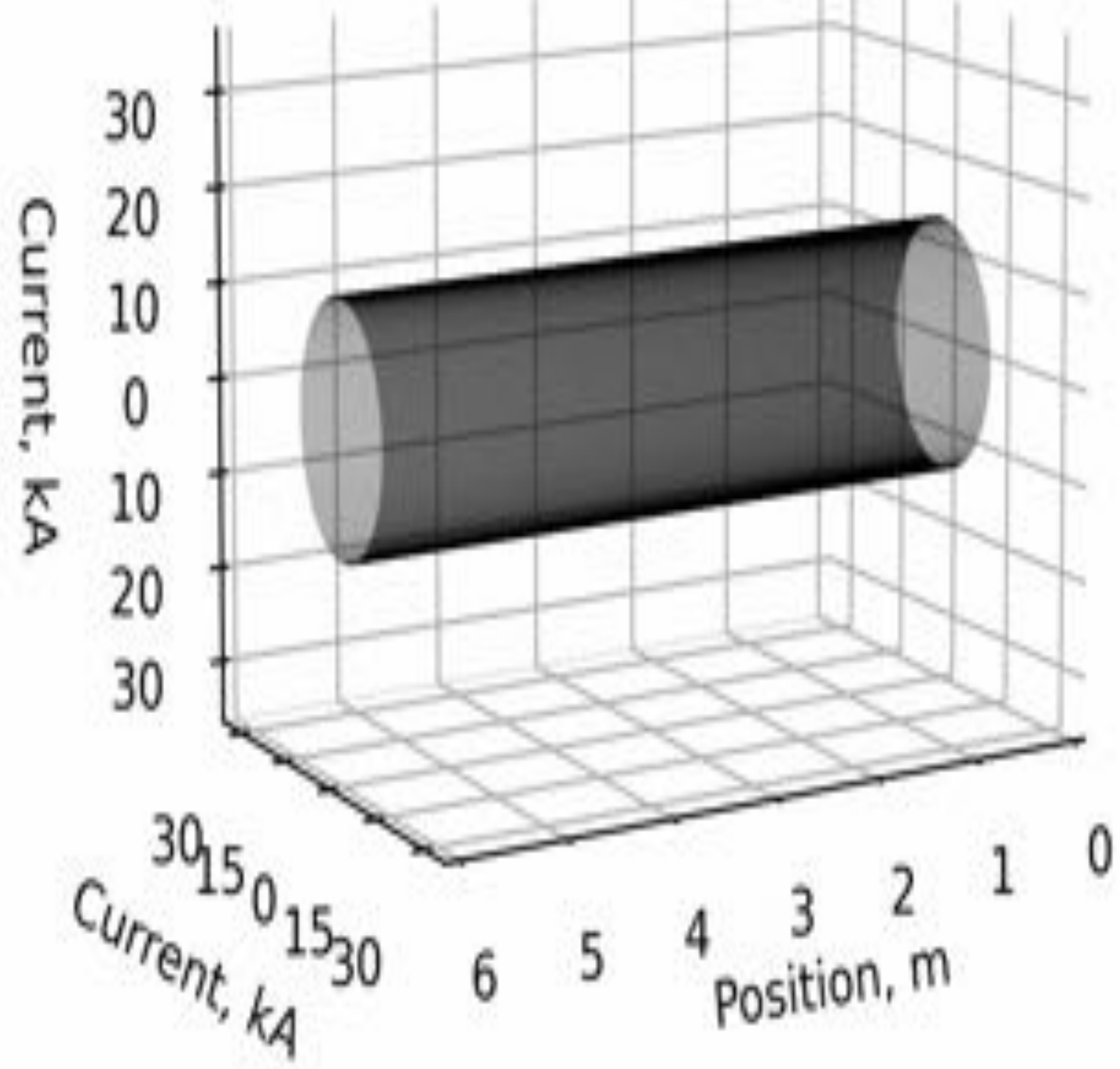
Simulations indicate that the main solenoid is thermally self-protected.

Peak hot-spot near extremities



Temperature

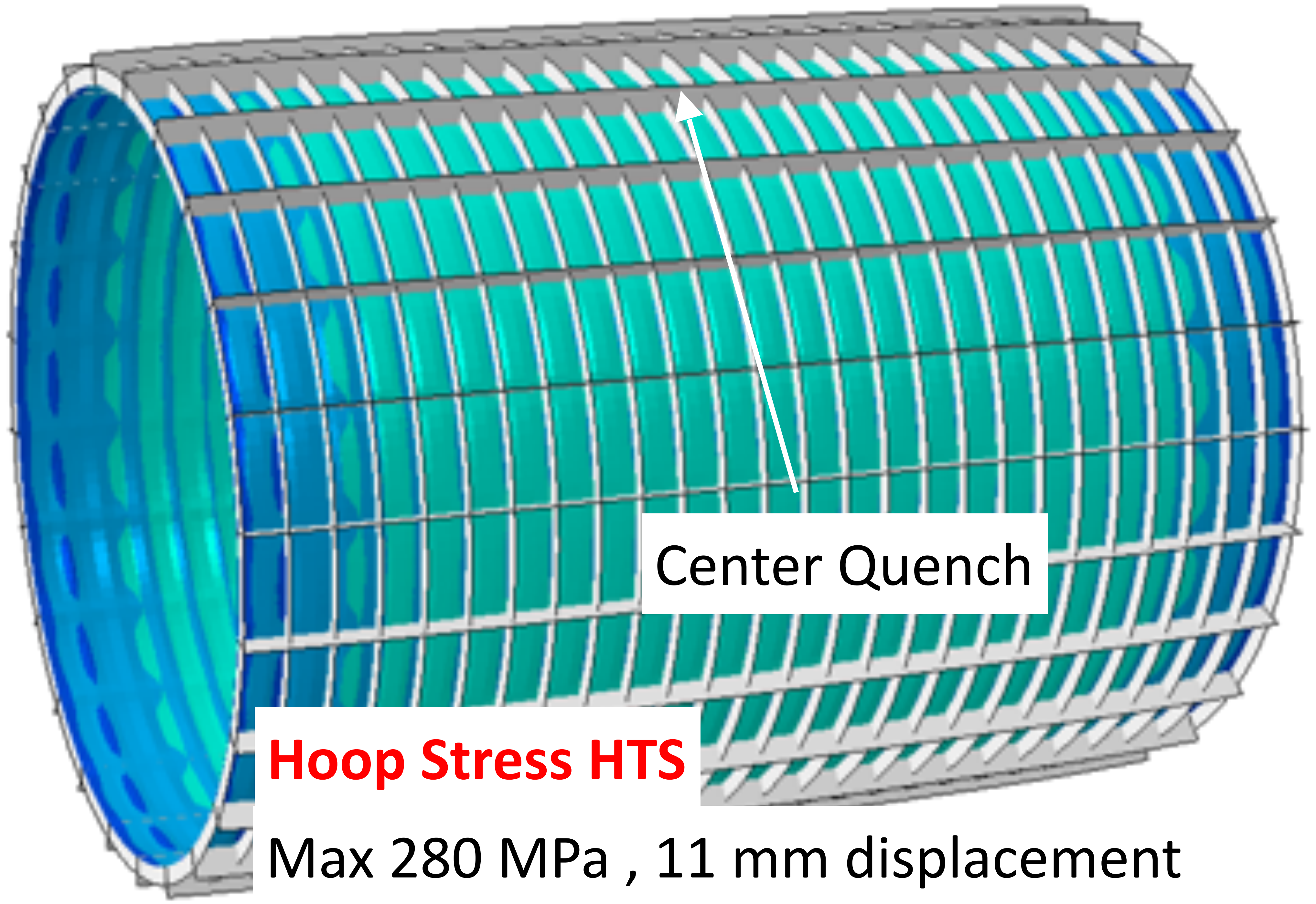
NZPV of ~ 4-8 m/s



Current

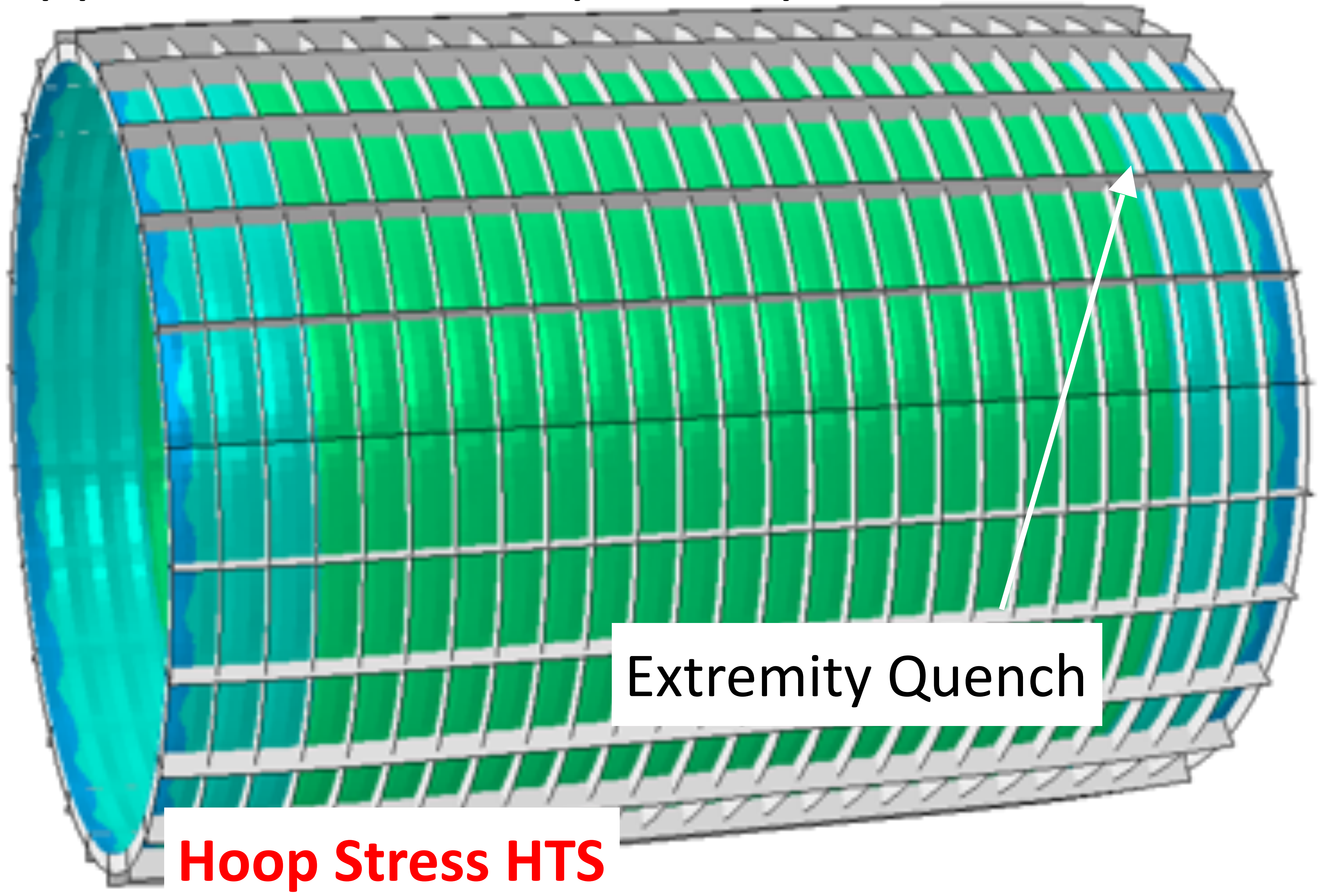
Mechanical Quench Analyses

- Shell model set-up in Abaqus to calculate stress in the HTS, Al-alloy conductor and structural components.
- Model includes the conductor, ribs and stringers.
- Stress in the conductor is almost tripled during a quench due to enormous induced current.
- Ribs locally reduce the stress in the conductor.
- Stress in the conductor due to thermal gradients not critical, strength of the epoxy to be validated experimentally.
- Peak stress (~300 MPa) caused by radial Lorentz force.
- Support structure requires optimization.



Hoop Stress HTS

Max 280 MPa , 11 mm displacement



Hoop Stress HTS

Max 240 MPa, 10 mm displacement

J. Zimmermann & D. Pridöhl, RWTH Aachen

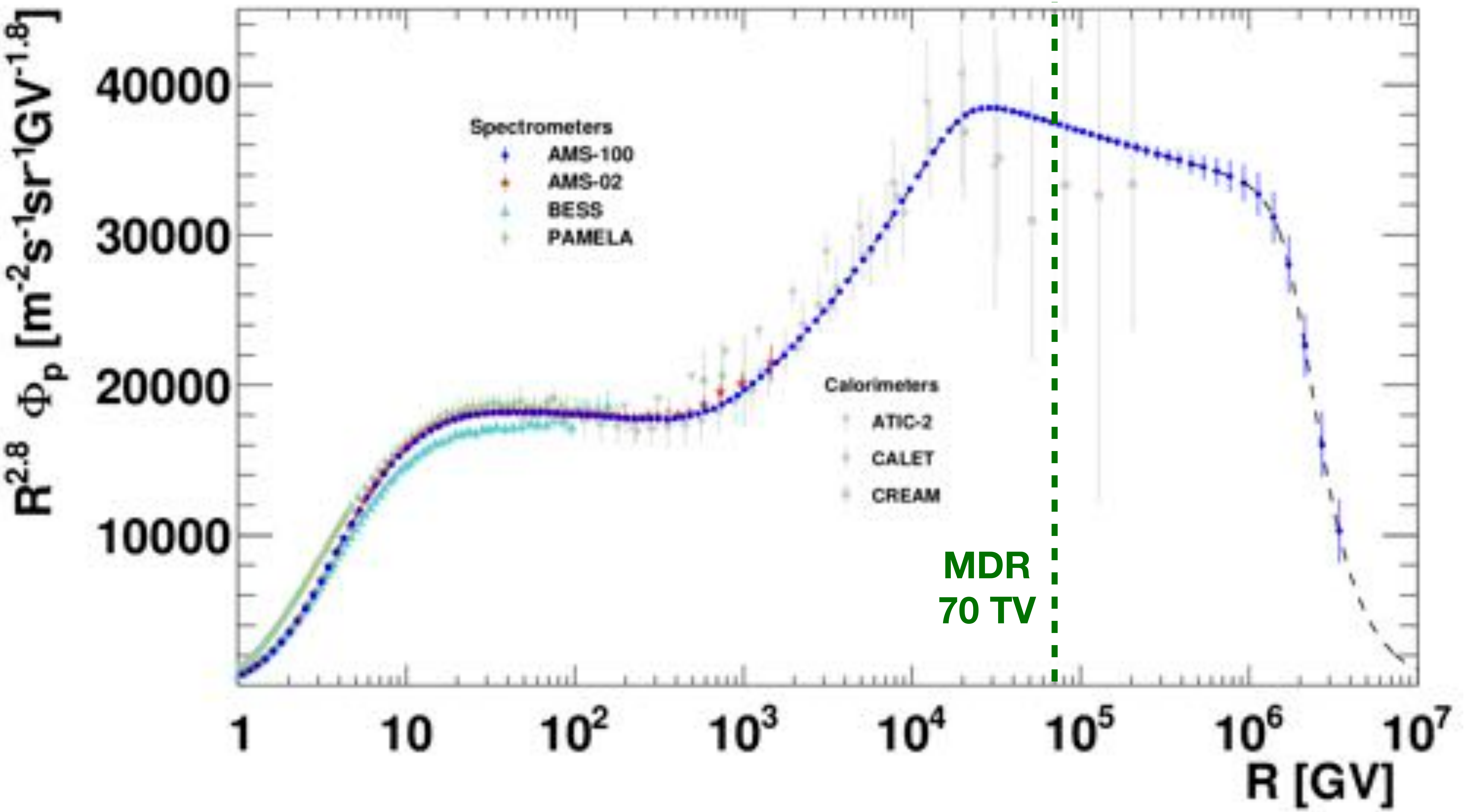
Boundary condition: outer rings fixed to circular shape, free thermal shrinkage

AMS-100

Weight: 40 t | Readout-Channels: 8 10^6 | Power: 15 kW | Measurement Time: 10 years
MDR: 70 TV | Acceptance: 100 m² sr | B-Field: 1 Tesla | Calorimeter: 70 X_0, 4λ

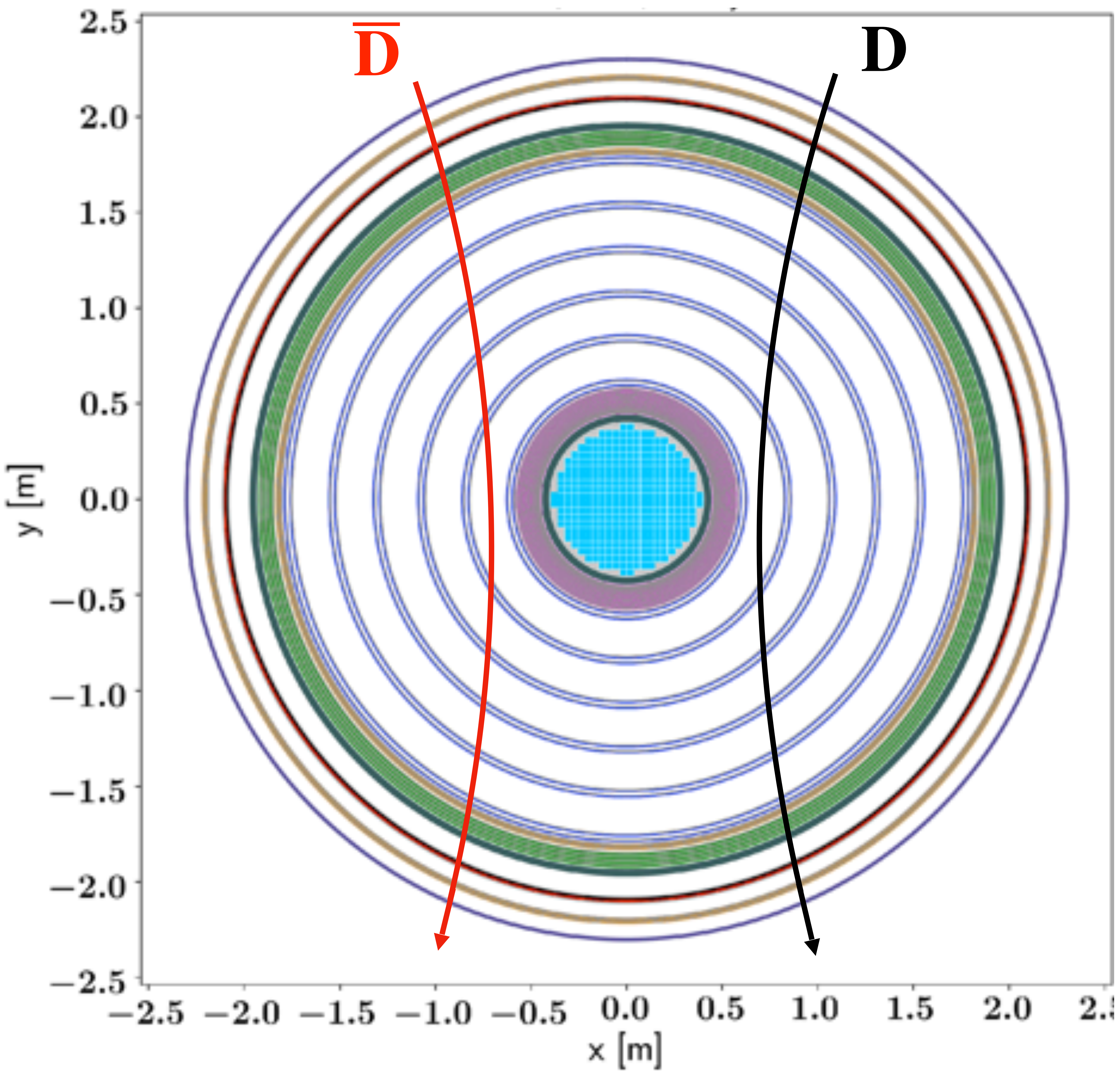
Th. Kirn, "The AMS-100 experiment: The next generation magnetic spectrometer in space", Nucl.Instrum.Meth.A 1040 (2022) 167215 • Proceedings of: VCI2022

AMS-100 will measure light Nuclei in Cosmic Rays up to the maximum energy that can be reached by cosmic ray accelerators in our galaxy.

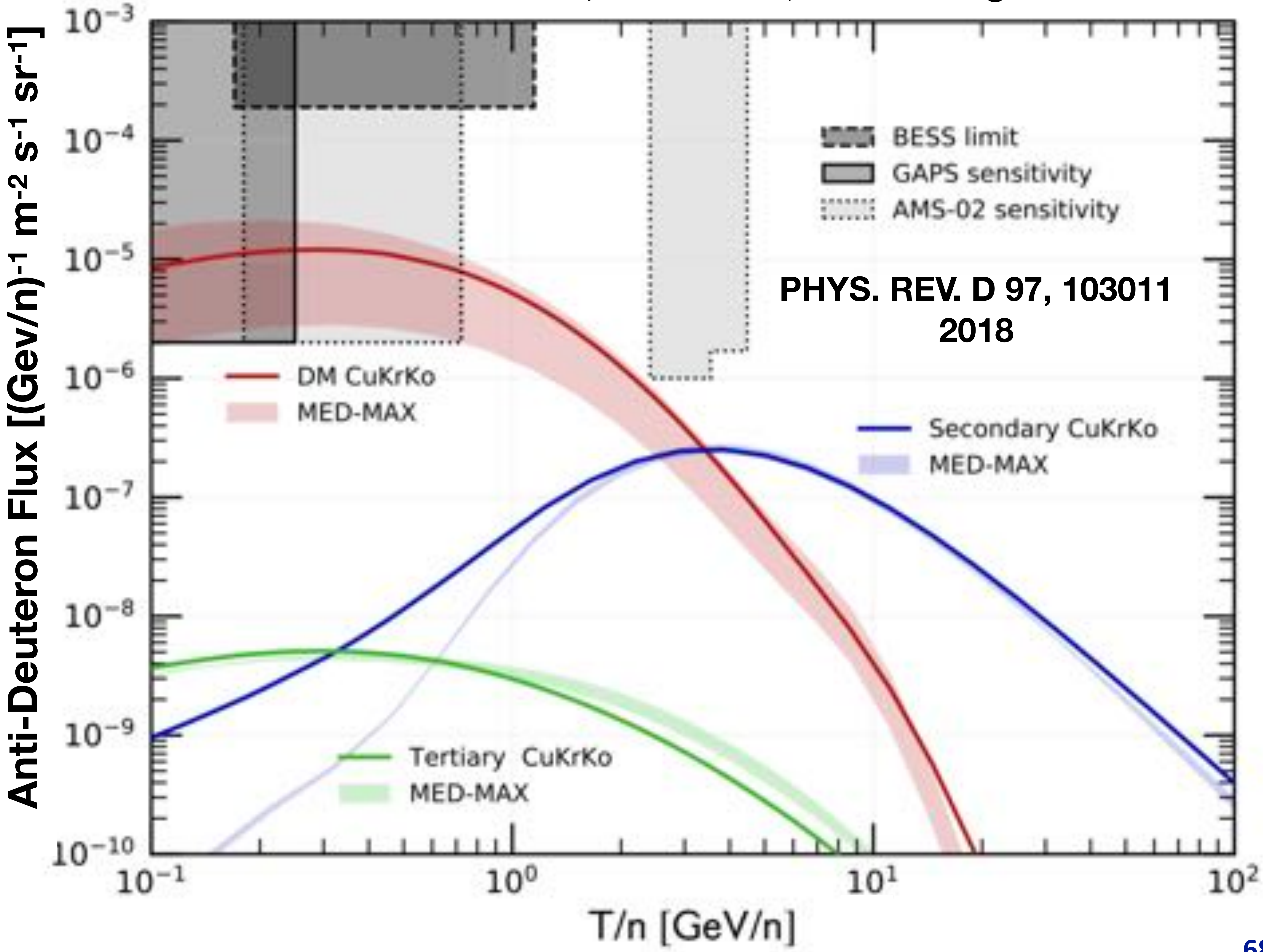


Anti-Deuterons are a very sensitive probe for New Physics in Cosmic Rays

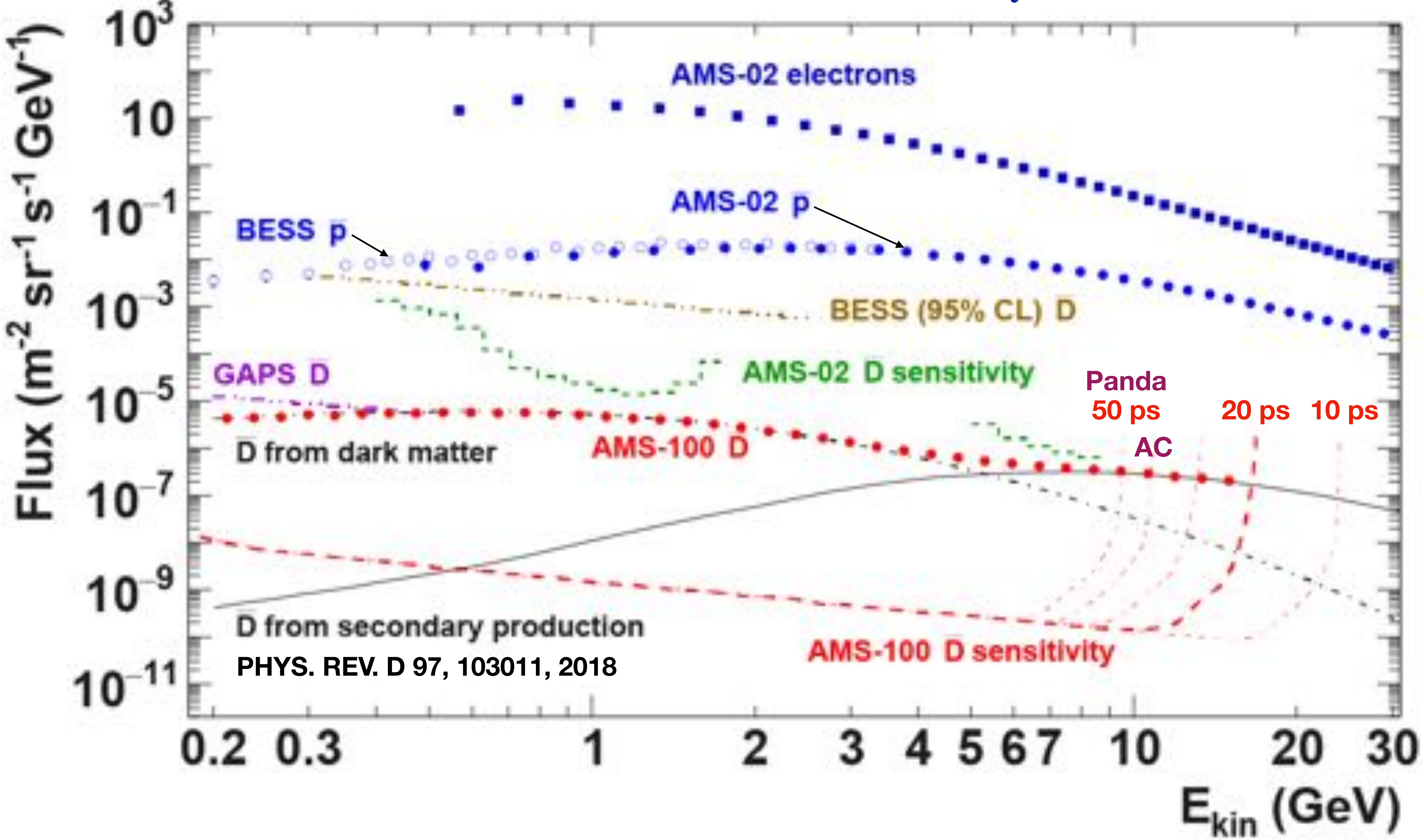
As a Magnetic Spectrometer AMS-100 can separate Anti-Matter from Matter.



M. Korsmeier, F. Donato, N.Fornengo

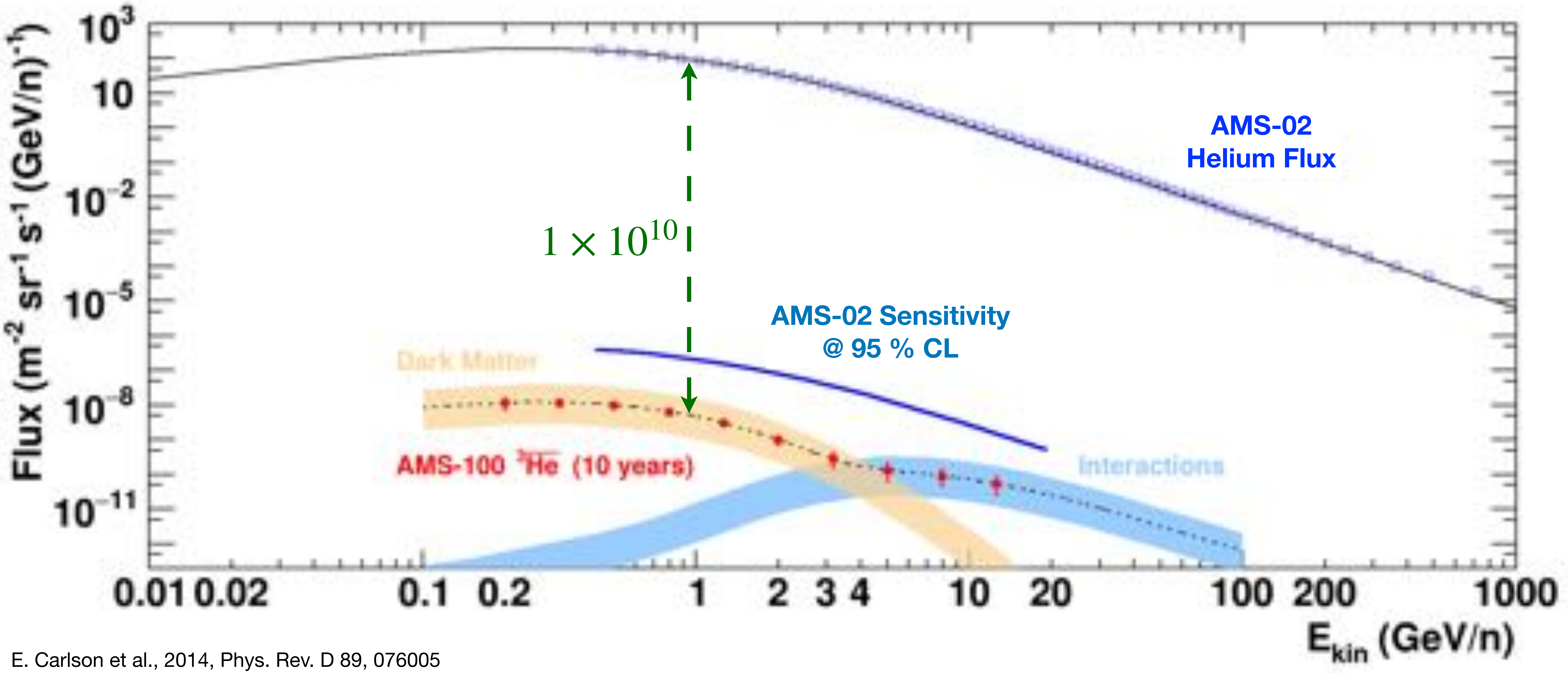


Z = – 1 Particles in Cosmic Rays



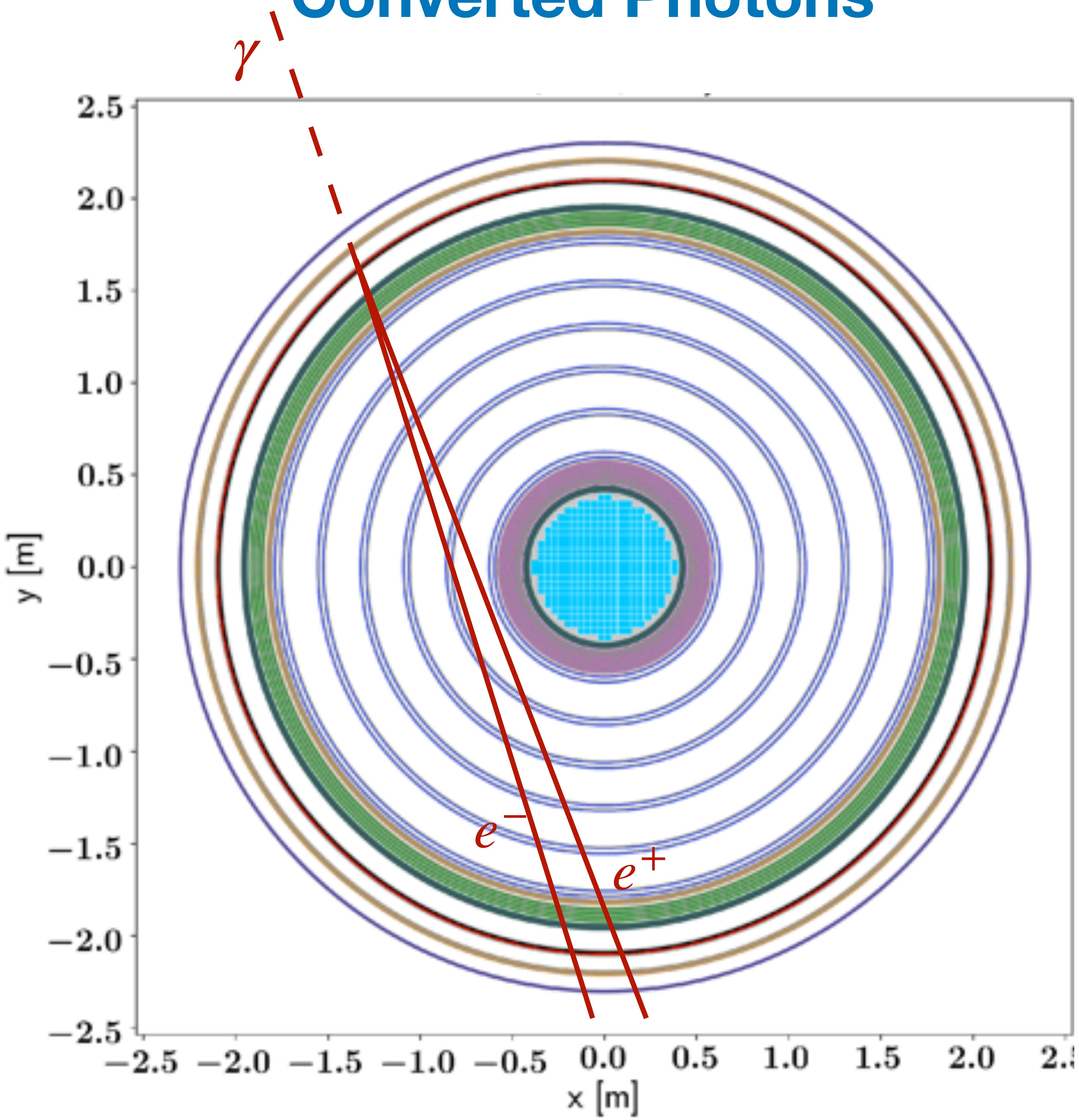
PHYS. REV. D 97, 103011, 2018

Anti-Helium in Cosmic Rays

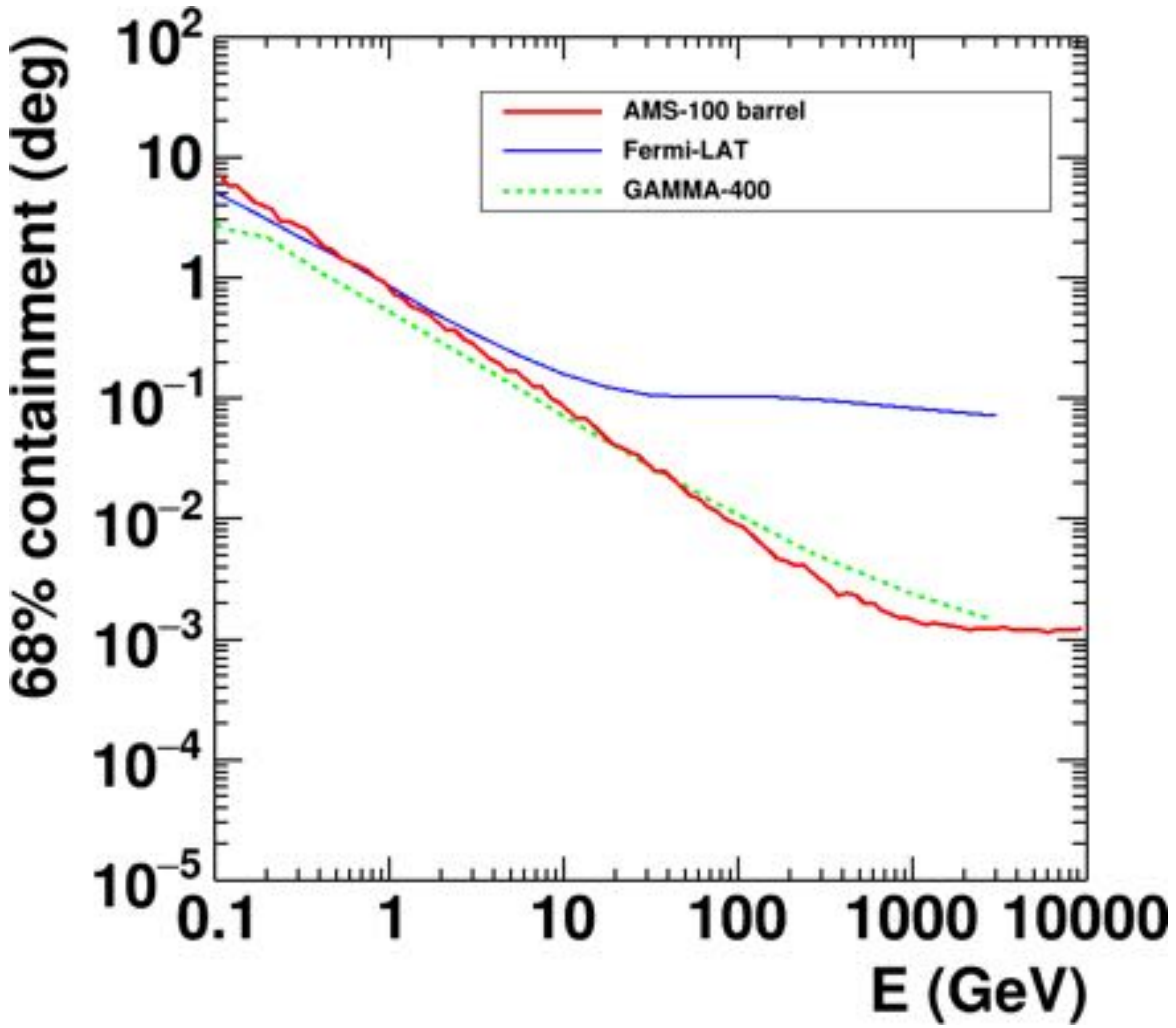


E. Carlson et al., 2014, Phys. Rev. D 89, 076005
M. Cirelli et al., 2014, JHEP 1408, 009
A. Coogan and S. Profumo, 2017, Phys. Rev. D 96, 083020

AMS-100
Converted Photons



Angular Resolution for Converted Photons



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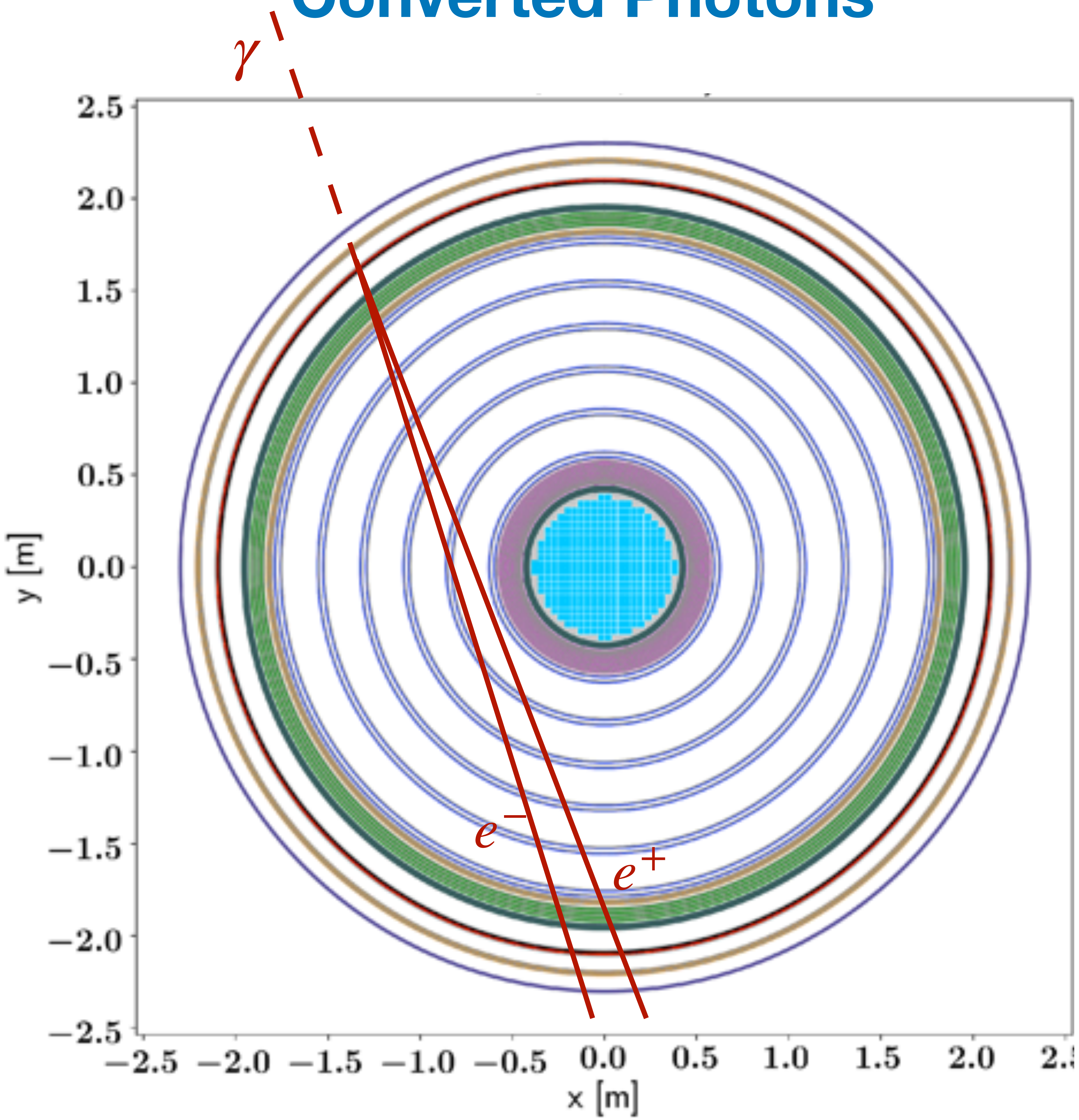
Converted Photons



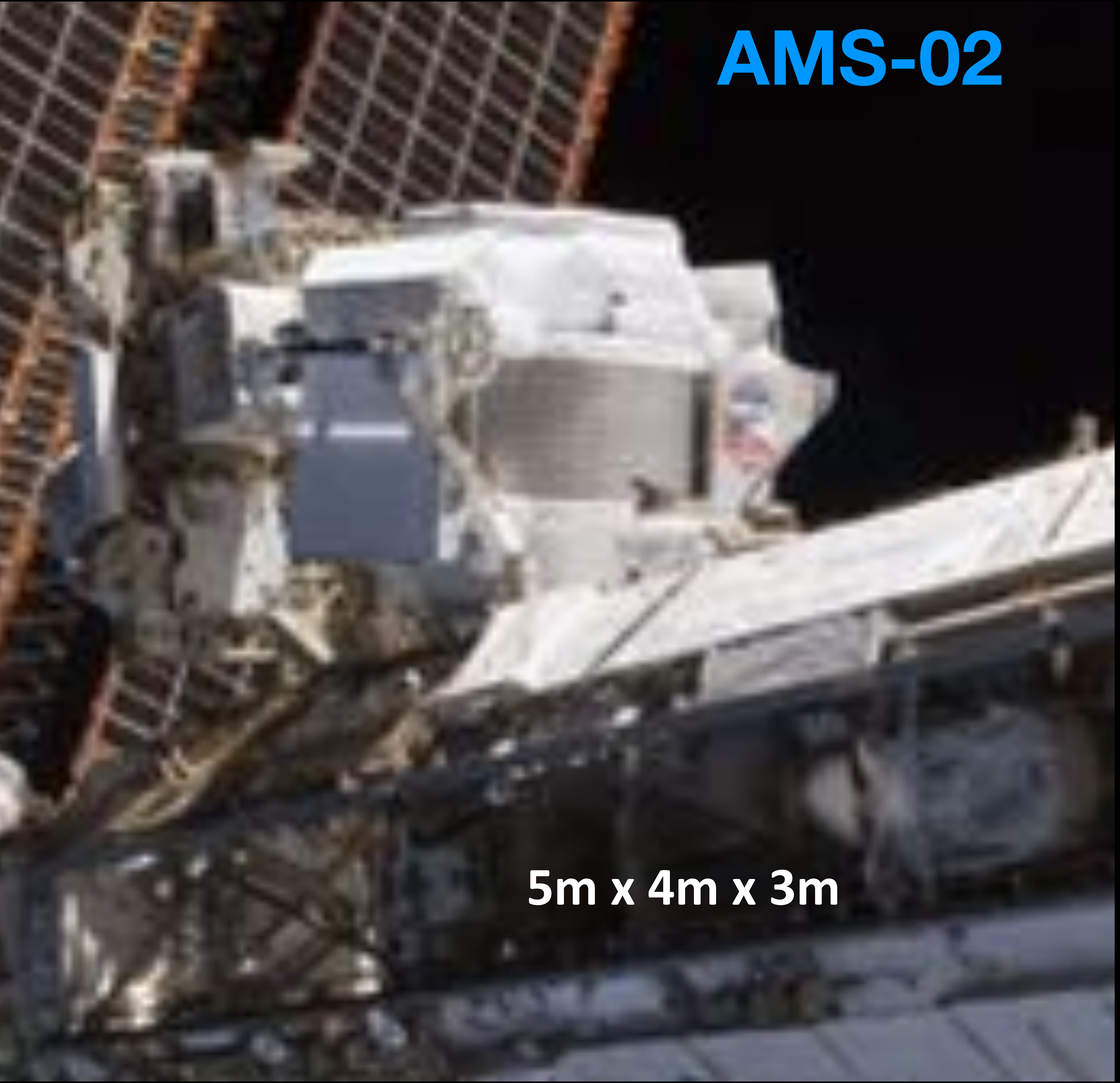
Crab Nebula with Chandra (blue and white), Hubble (purple), and Spitzer (pink) data.

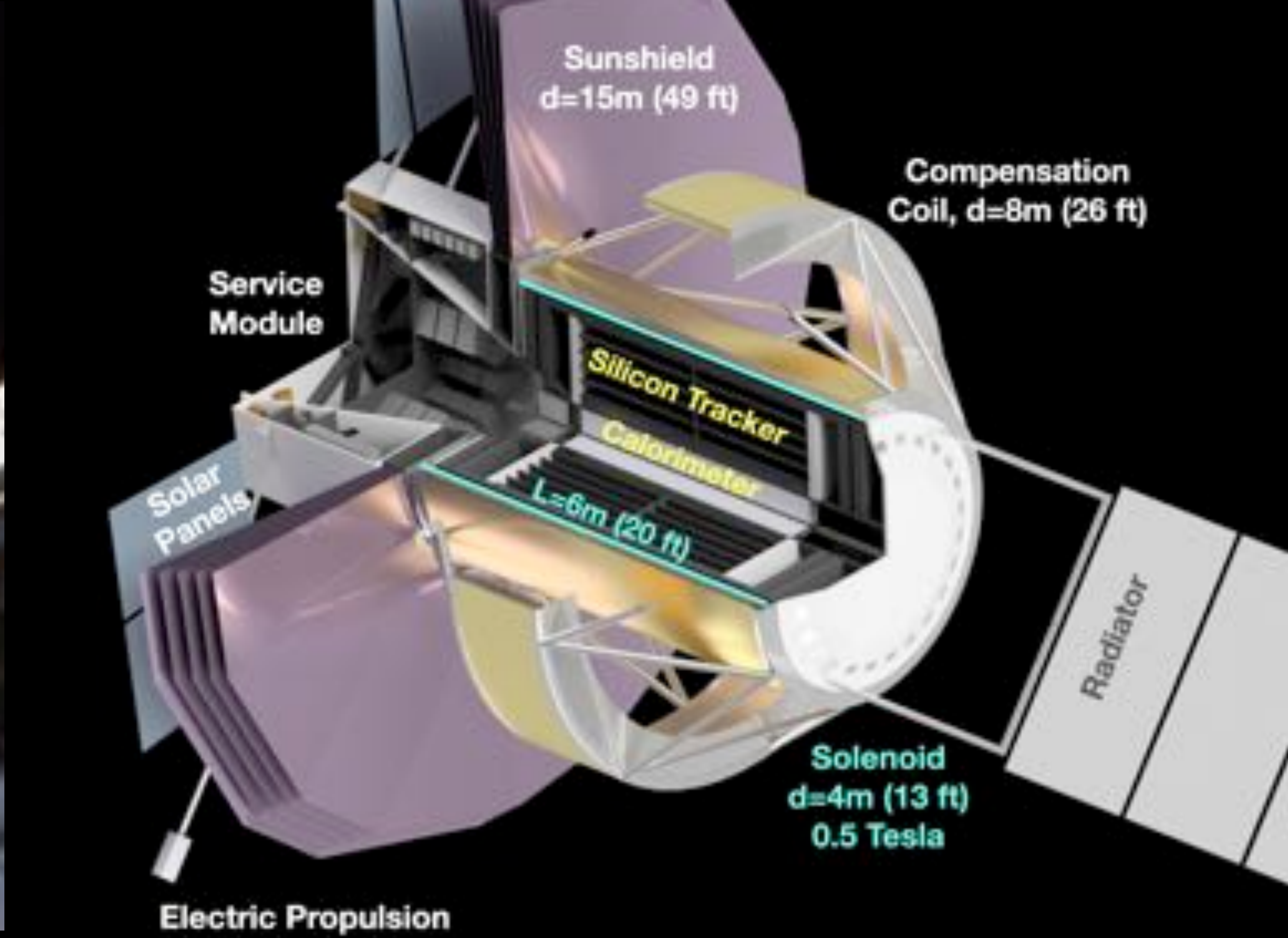
FERMI, CTA

AMS-100

CRAB Nebula TeV - Photons

AMS-02





- AMS-02 has collected more than 200 Billion cosmic rays since 2011 and will continue to take data for the lifetime of the ISS. It is a unique scientific instrument in Space.
- AMS-100 will improve the sensitivity of AMS-02 by a factor 1000 and will explore a completely new territory in precision cosmic ray physics.