

Status of cosmic-ray antinuclei searches

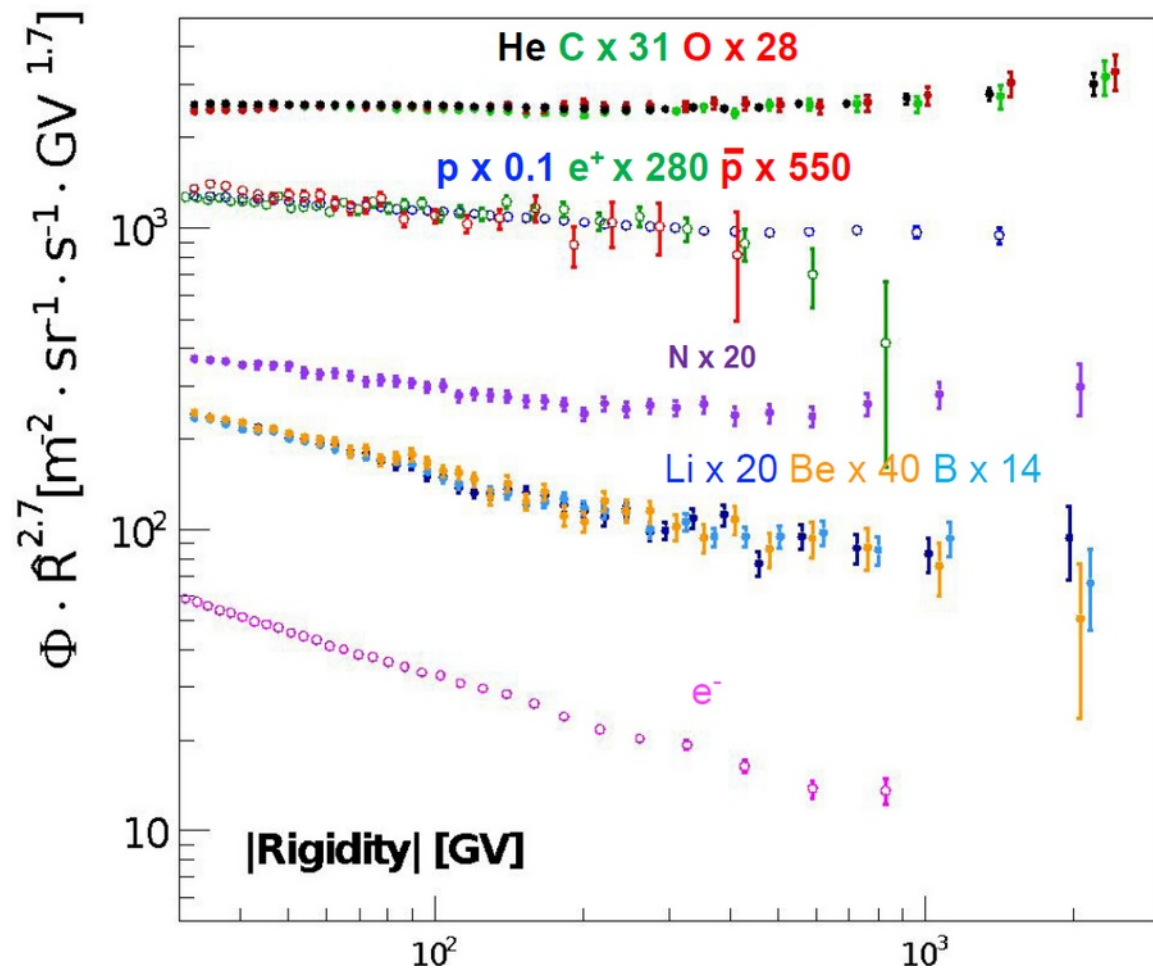
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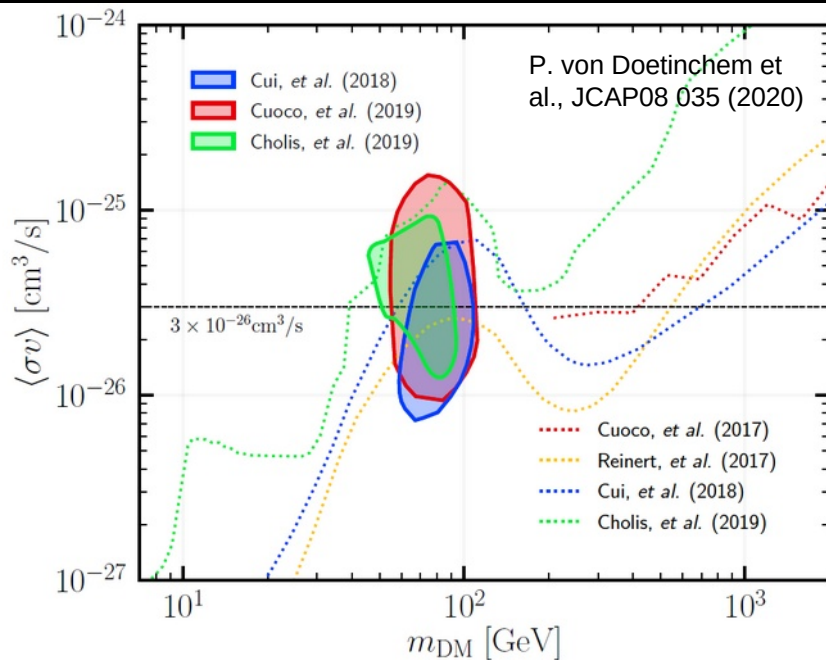
Snapshot of cosmic-ray status



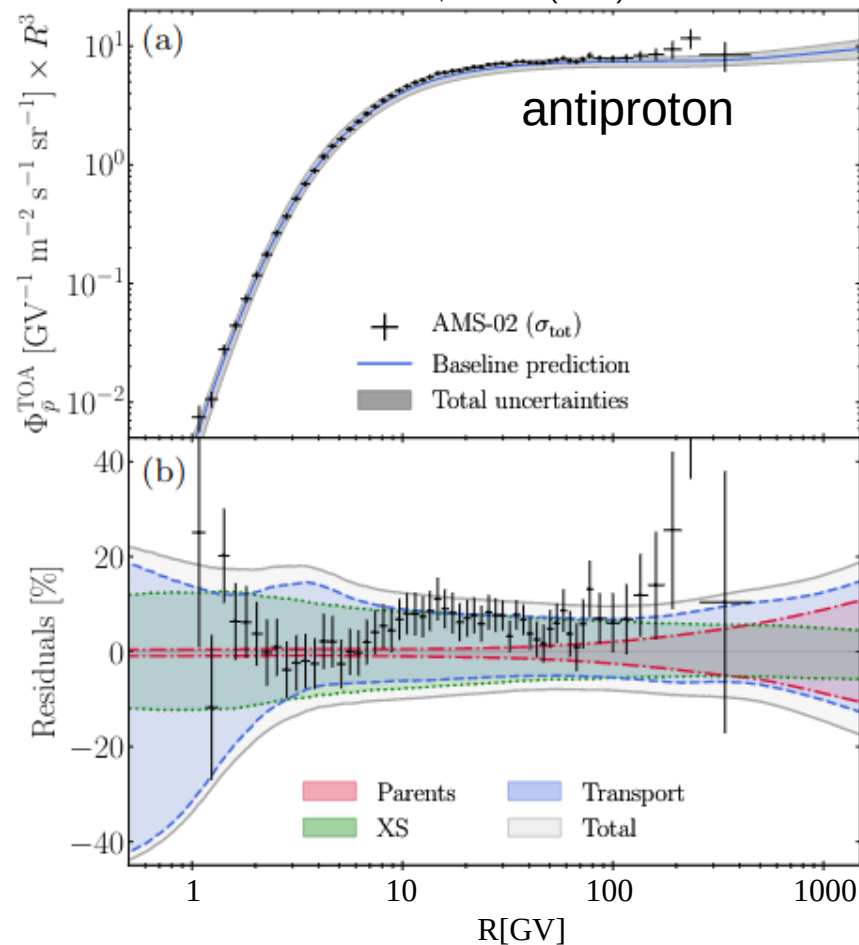
- AMS-02 started new precision era of direct cosmic-ray measurements
- Lots of interesting new findings for cosmic-ray physics concerning sources, acceleration, transport, interstellar medium
- Also available: helium isotopes, Neon, Magnesium, Silicon, Sulfur Iron, Deuterium
- Focus of this talk: **antinuclei**

Unexplained features in cosmic antiprotons?

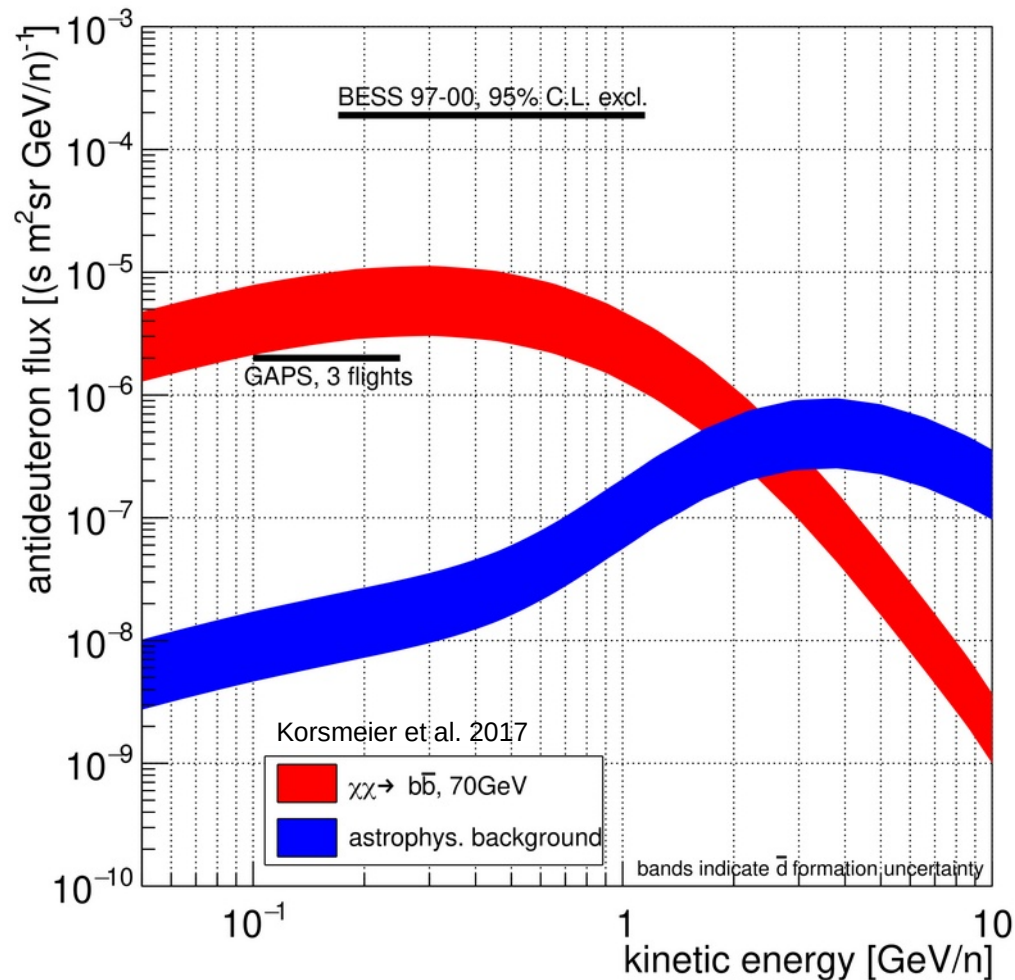
M. Boudaud et al., Phys. Rev. Research 2, 023022 (2020)



- combined fit with antiproton and diffuse gamma-rays from the Galactic Center \rightarrow 70-80GeV DM particle?
- understanding astrophysics background is a challenge**
 \rightarrow better constraints on cosmic-ray propagation and production needed



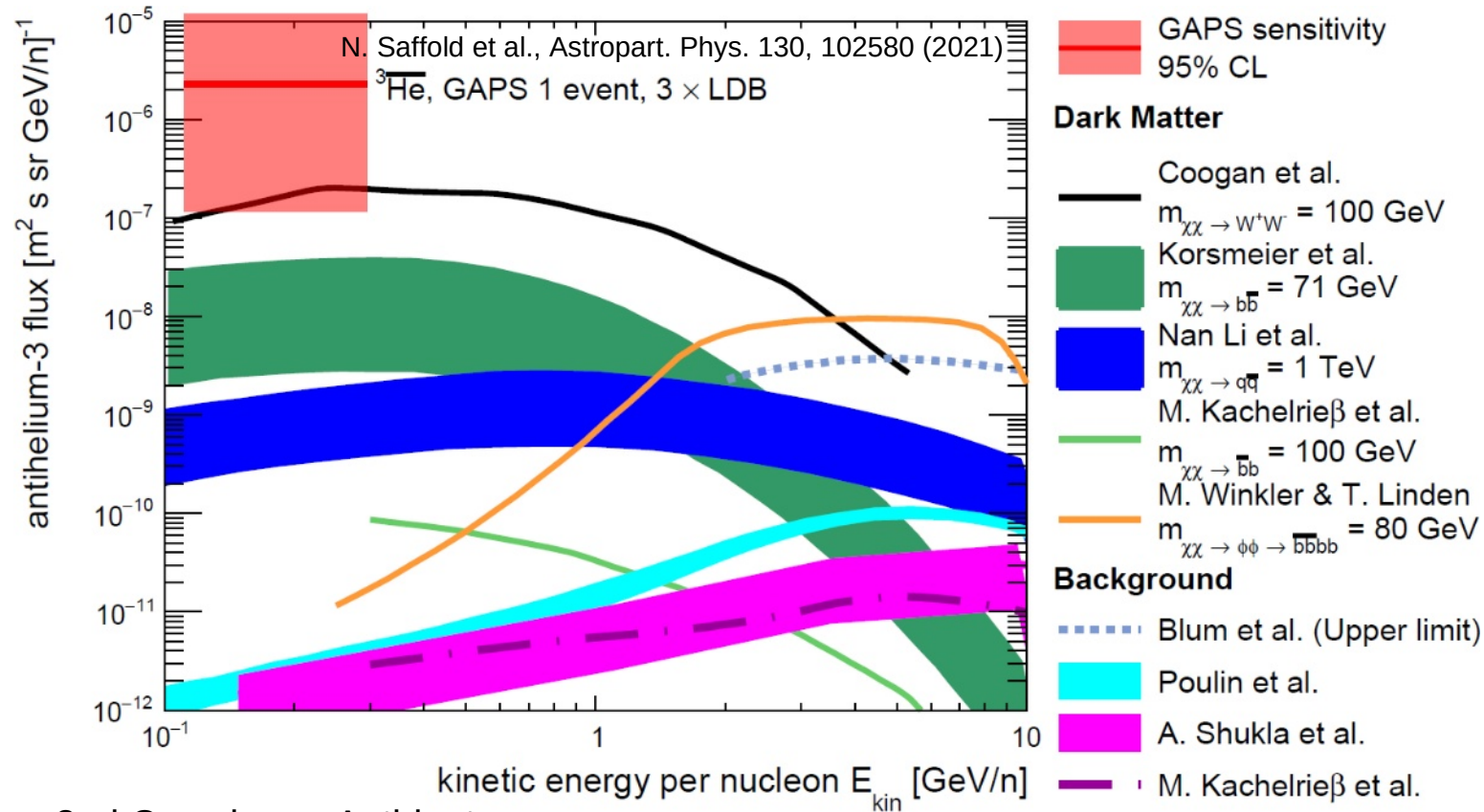
Antideuteron as a probe of dark matter



- Low-energy antideuteron from dark matter annihilation or decay can be orders of magnitude above the astrophysical background.
- Antideuterons are an important dark matter search technique that needs to be explored much more!

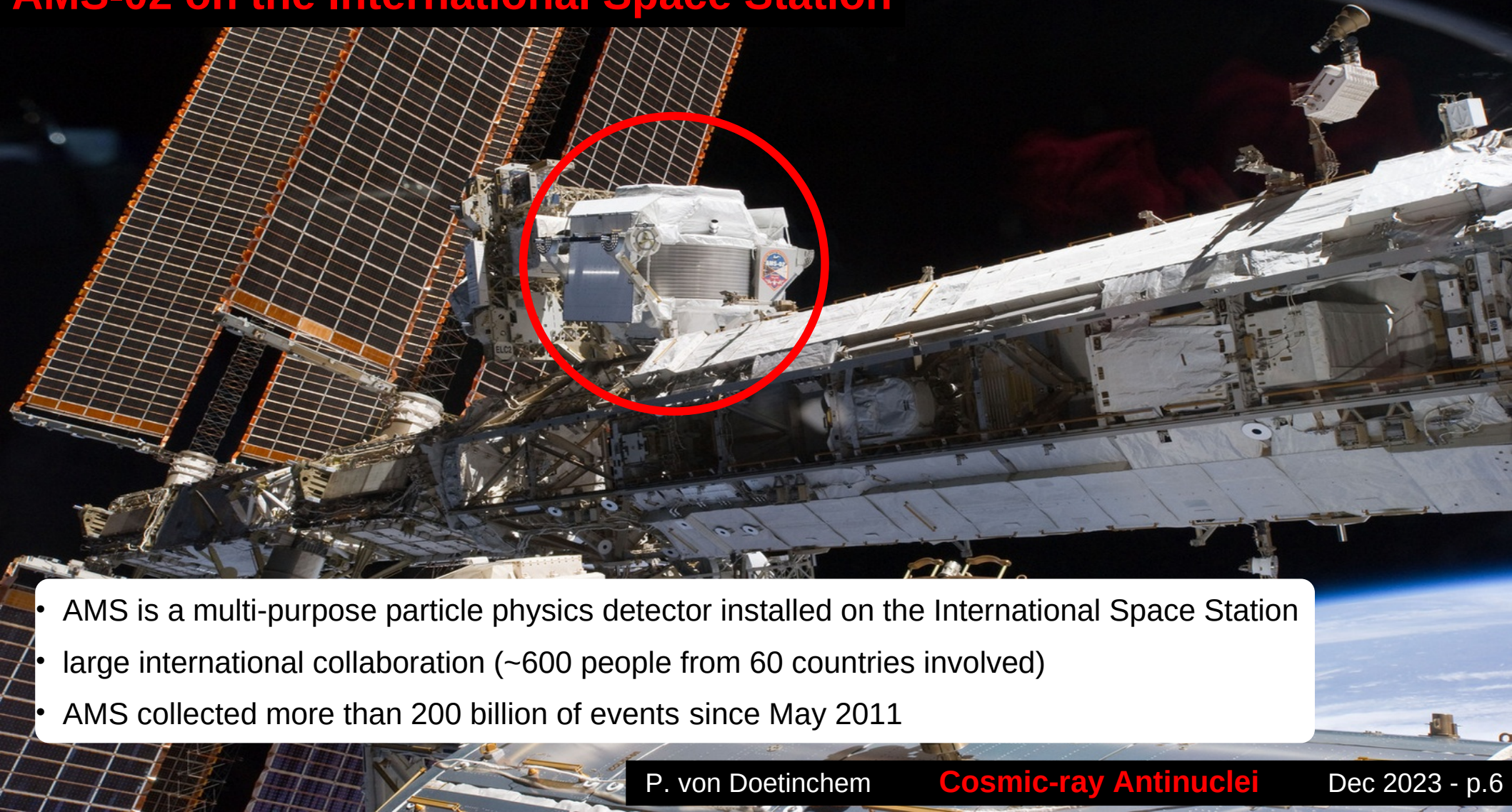
Cosmic antihelium-3

Finding low-energy antihelium would be truly revolutionary new physics



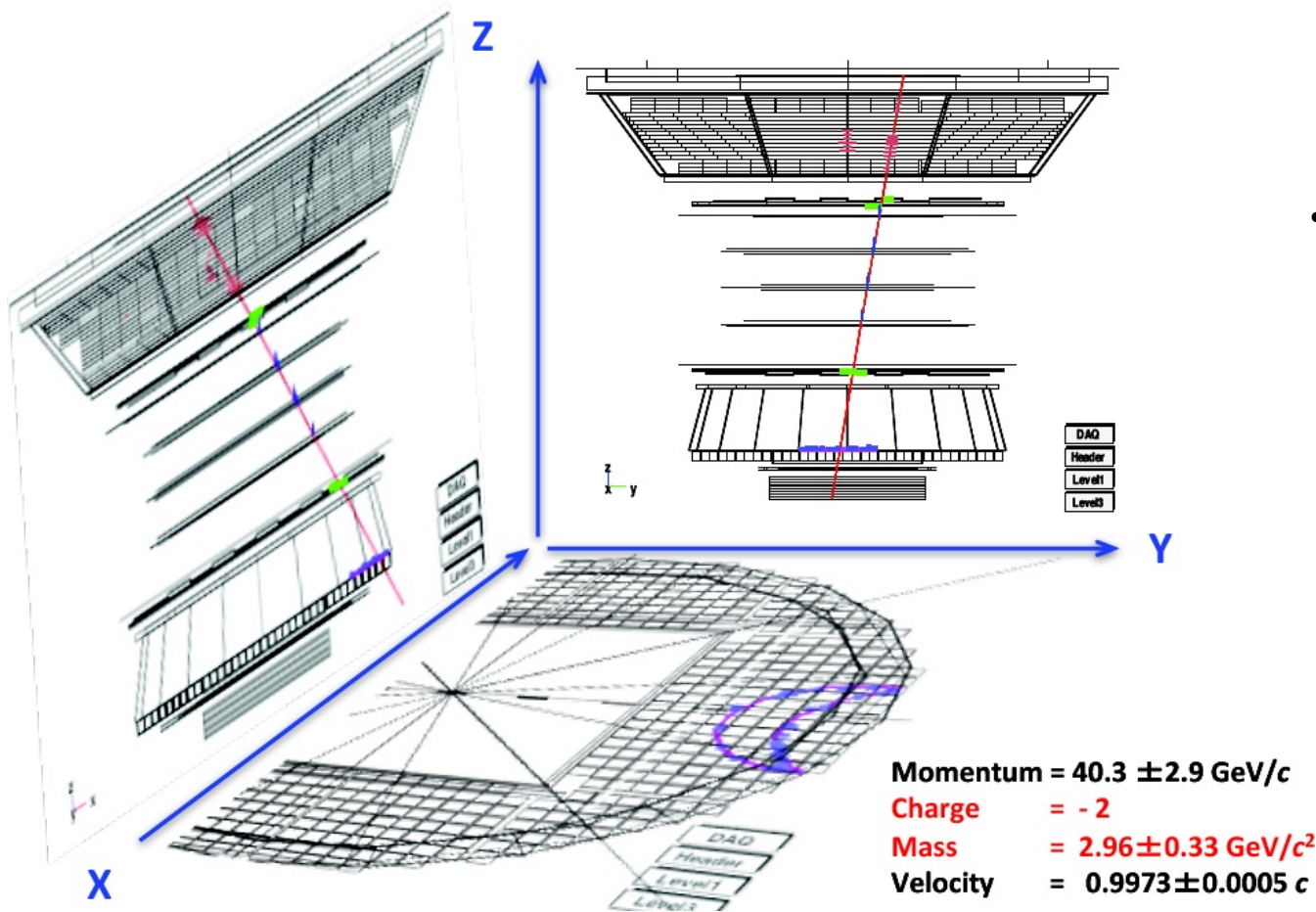
Review based on 2nd Cosmic-ray Antideuteron
Workshop: JCAP08(2020)035,
arXiv:2002.04163

AMS-02 on the International Space Station



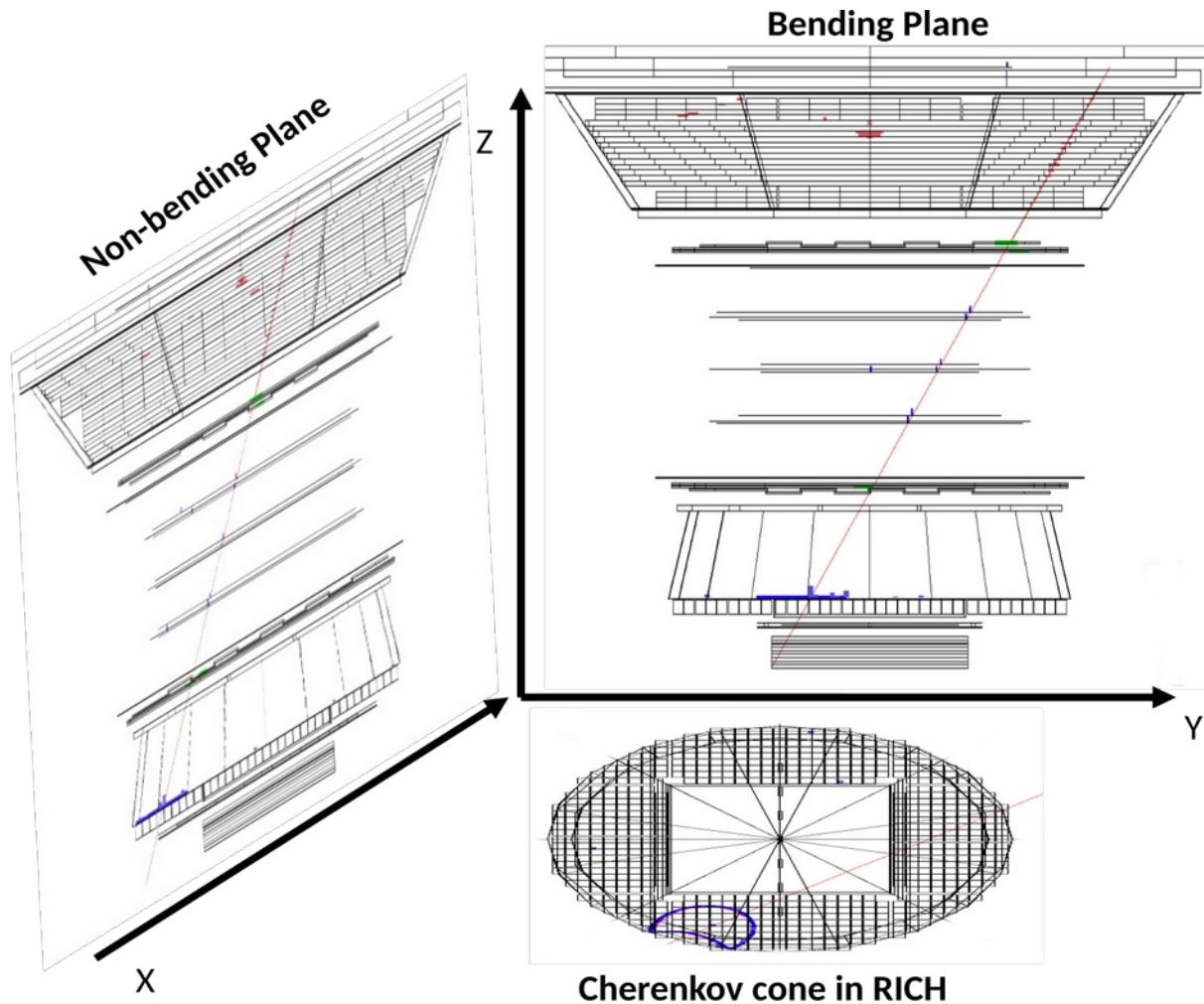
- AMS is a multi-purpose particle physics detector installed on the International Space Station
- large international collaboration (~600 people from 60 countries involved)
- AMS collected more than 200 billion of events since May 2011

AMS-02 antihelium candidate



- AMS-02 reported that **several $\overline{\text{He}}$ candidate events have been observed**
→ interpretations are actively ongoing
- Possible antihelium candidate explanations include:**
 - Secondary astrophysical background
 - Dark matter annihilation or decay
 - Nearby antistar: at distance of $\sim 1\text{pc}$

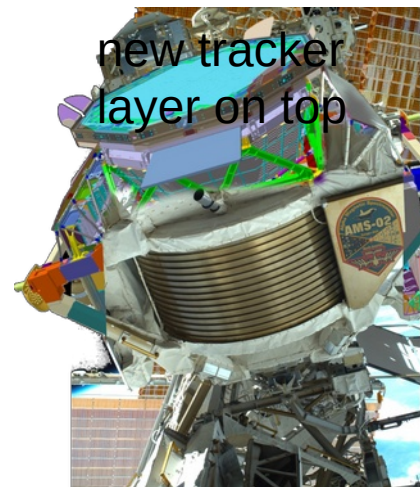
AMS-02 antideuteron candidate



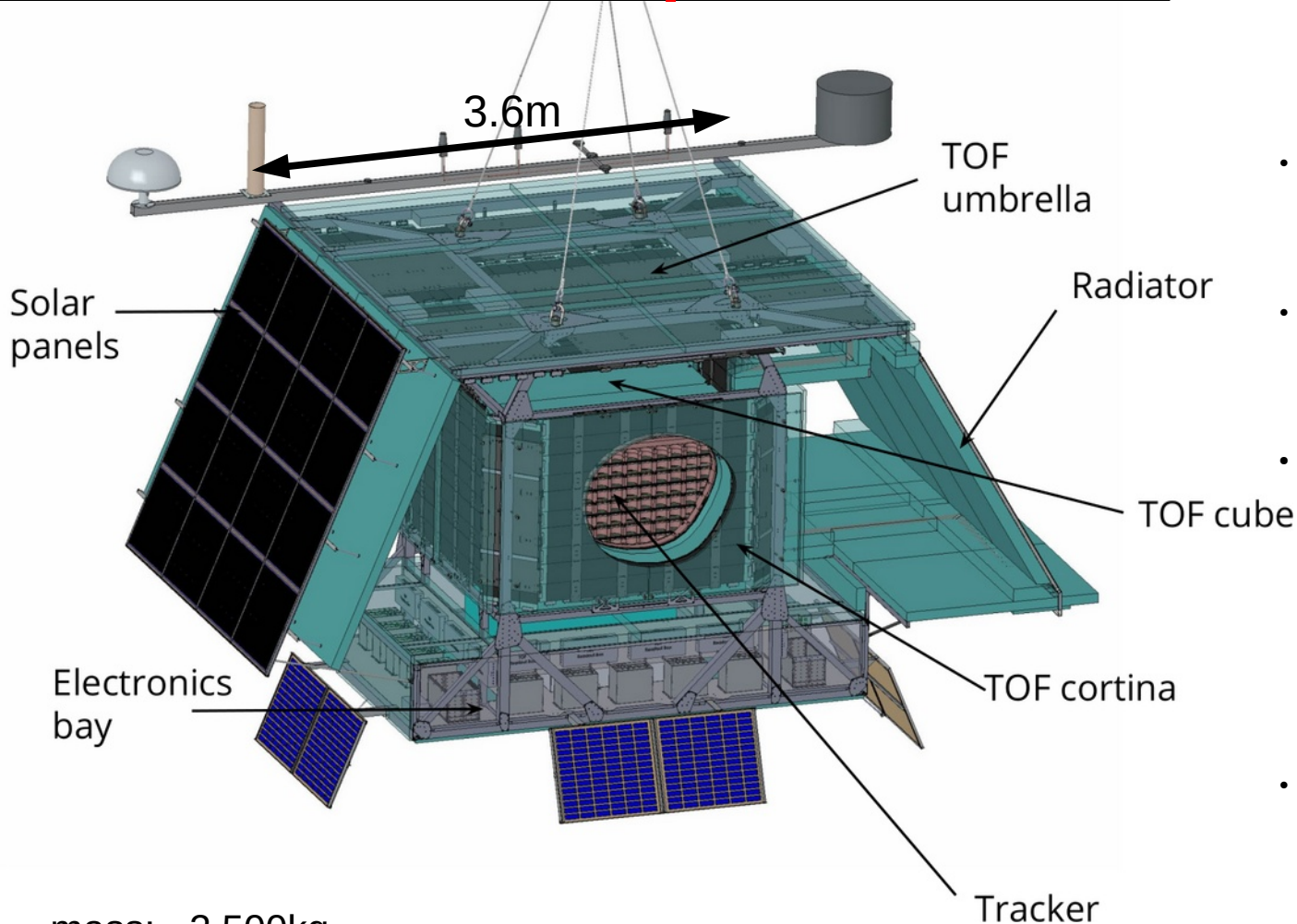
Anti-deuteron Candidate

Charge = -1.02 ± 0.05

Mass = $1.9 \pm 0.1 \text{ GeV}/c^2$

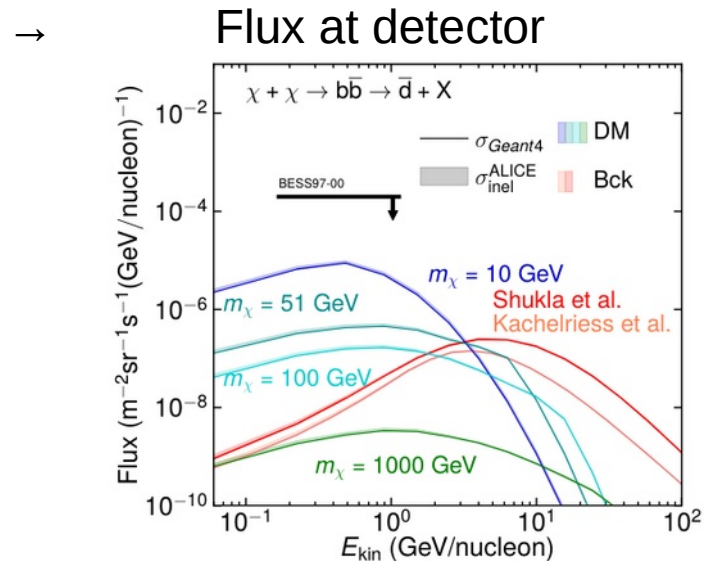
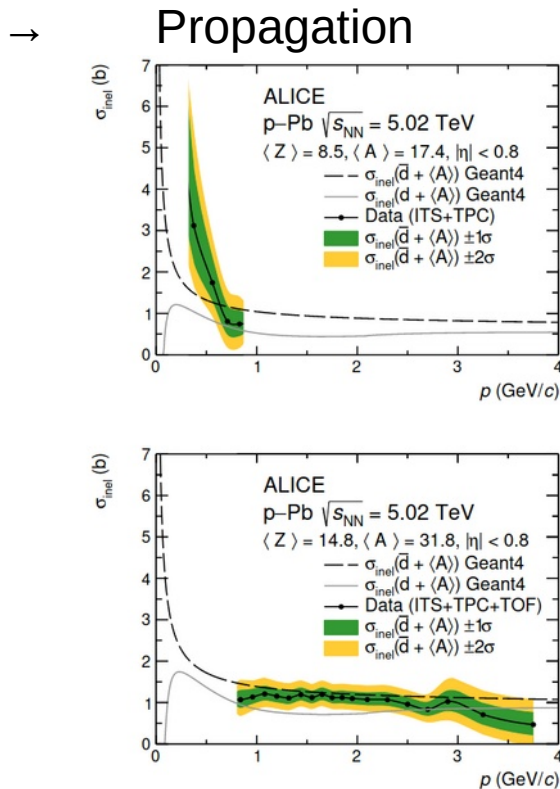
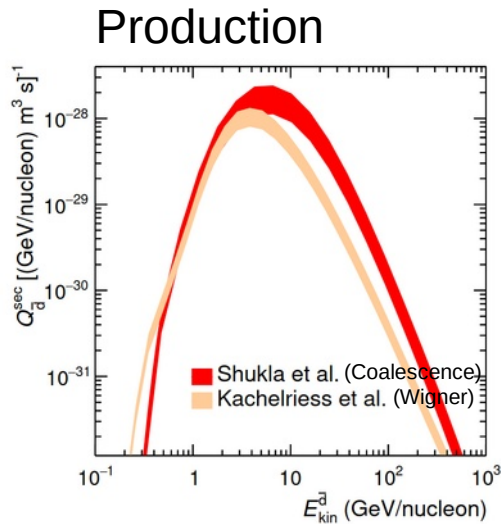


The GAPS experiment



mass: ~2,500kg
power: 1.3kW

- The **General AntiParticle Spectrometer** is the first experiment dedicated and optimized for low-energy cosmic-ray antinuclei search
- Requirements: long flight time, large acceptance, large identification power, flight at low-geomagnetic cutoff location
- **GAPS will deliver:**
 - a precision antiproton measurement in an unexplored energy range <0.25 GeV/n
 - antideuteron sensitivity 2 orders of magnitude below the current best limits, probing a variety of DM models across a wide mass range
 - leading sensitivity to low-energy cosmic antihelium nuclei
- **GAPS is under construction, preparing for first Antarctic Long Duration Balloon flight in December 2024**



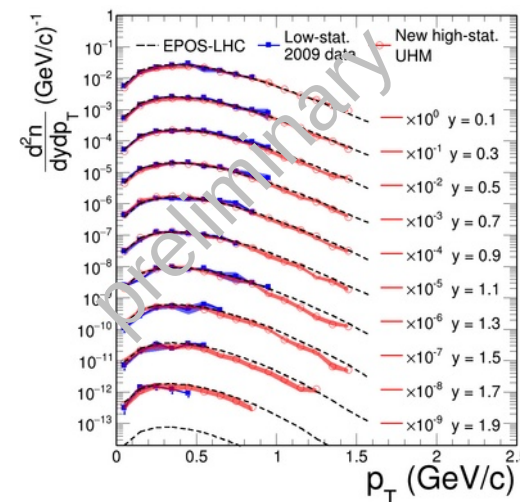
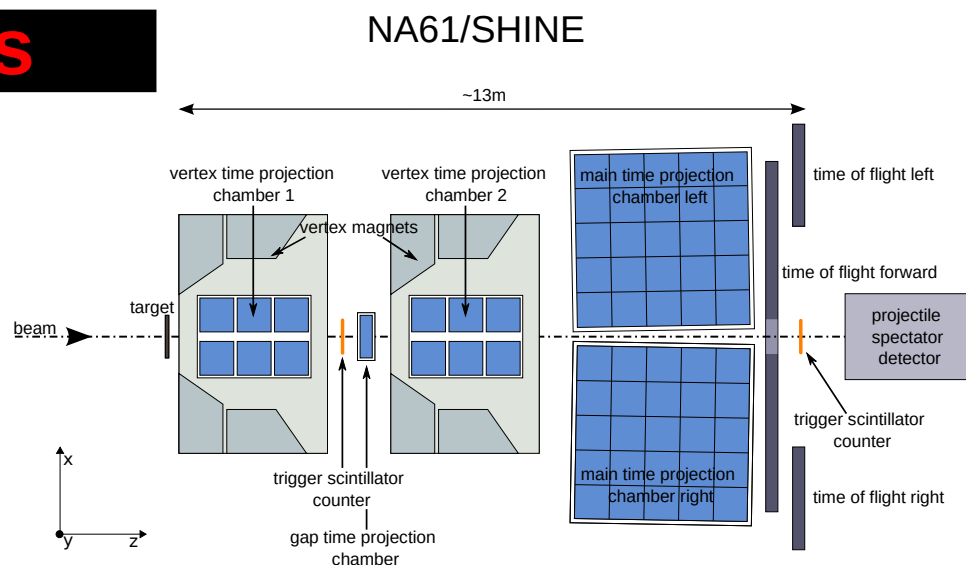
Antideuteron flux at the top of the atmosphere

- Significant uncertainties for antinuclei production exist
- Significant uncertainties for propagation in Galaxy exist

→ Measurements of relevant primary cosmic ray and interstellar medium cross sections are important

Accelerator measurements

- NA61/SHINE at CERN SPS:
 - Fixed target experiment
 - High statistics \bar{p} studies
 - C-p fragmentation cross section measurements
 - Deuteron production cross section, d/p ratio
 - Antiparticle correlation studies
- LHCb at LHC:
 - Antideuteron production in heavy hadron decays and in fixed-target collisions
 - Antihelium-3 from antilambda-b decays
- ALICE at LHC
 - Antinuclei production
 - Antinuclei inelastic cross sections
- AMBER at CERN SPS (upgraded COMPASS):
 - Fixed target experiment
 - High-statistics antiproton production cross section measurements



Conclusion & Outlook

- Cosmic-ray antinuclei are important means to the study new physics
- Uncertainties need to be reduced:
 - Antideuteron and antihelium formation are not well understood
 - Cross section measurements need to be conducted for interpretation
- AMS-02 continues collecting data and will be upgraded
- GAPS will have first flight in 2024
- Accelerator experiment data is crucial for interpretation