Status of Cosmic-ray Antinuclei Searches

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Philip von Doetinchem - philipvd@hawaii.edu
Department of Physics & Astronomy - University of Hawaii at Manoa

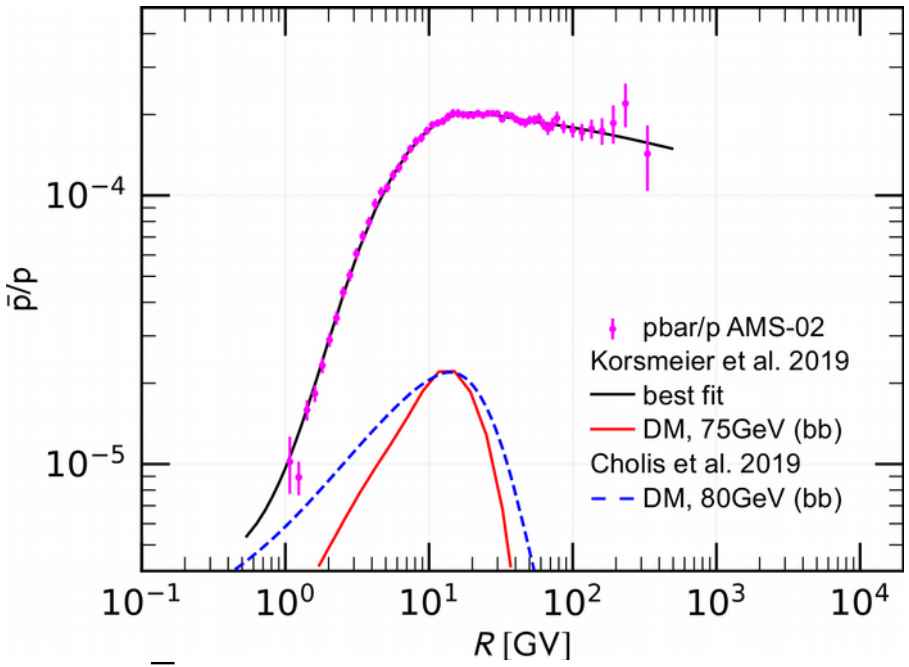
Cosmic-ray Antinuclei Searches

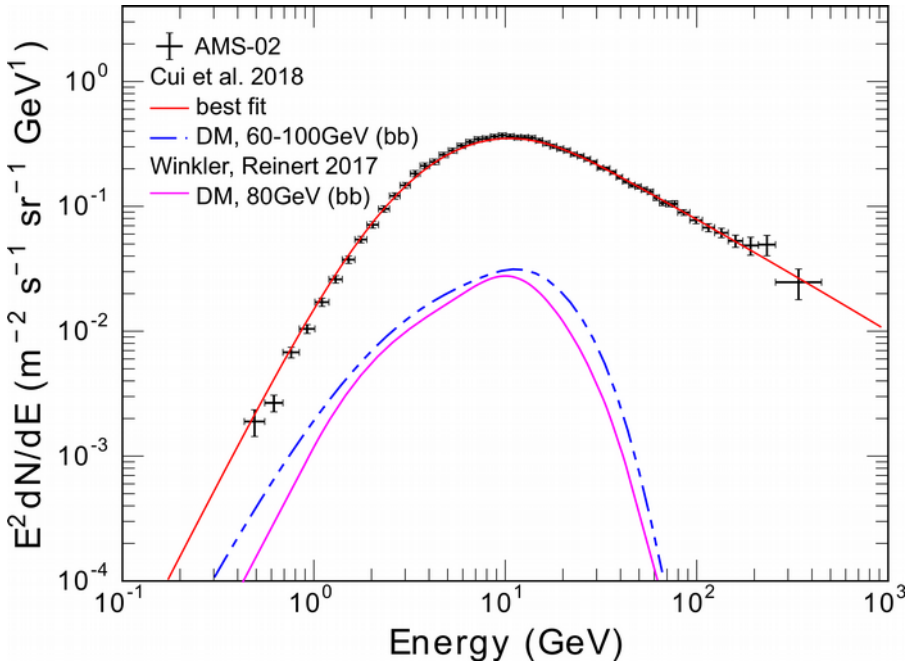
- This talk is a review of some key results of the:
  2nd Cosmic-ray Antideuteron Workshop
  (UCLA, March 27-29, 2019, 45 participants)
  https://indico.phys.hawaii.edu/e/dbar19
  (organizers: Rene Ong, Mirko Boezio, Kerstin Perez, PvD)

- Measurement of cosmic-ray antinuclei (antiproton, antideuteron, antihelium) is an exciting way to search for new physical phenomena:

  - experimental cosmic-ray search updates
  - potential primary sources of antinuclei
  - uncertainties of production and propagation in our Galaxy
  - path forward

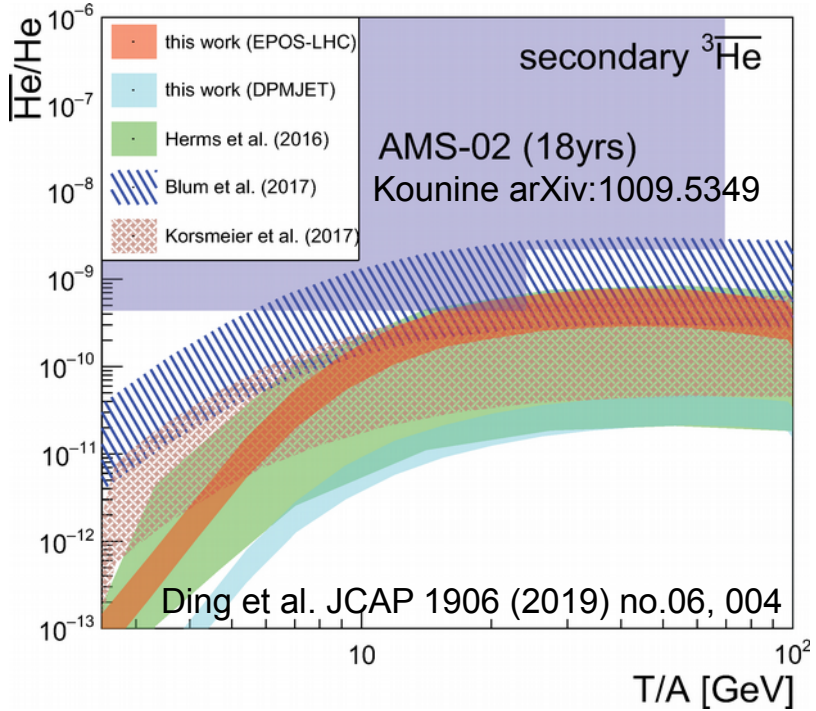
Low-energy Antiproton Excess

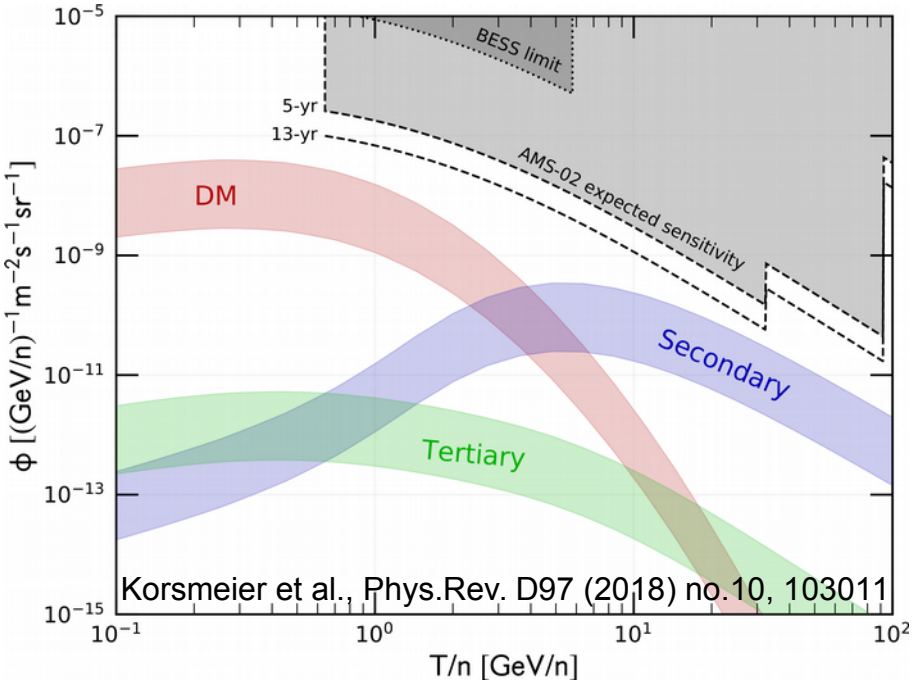




- A small $\bar{p}$ excess in AMS-02 data (Bertucci, 7/27, 11:30am; Tang, 7/25, 1:30pm) above secondary background predictions at R~10 GV was found in various studies (e.g., Hooper, 7/31, 6pm)
  → significance level unclear, but defines interesting target for $\bar{d}$ searches
- This excess is in agreement with explaining the γ-ray excess at the Galactic Center with a signal from dark matter annihilation
- New analysis (Boudaud, 7/25, 1:45pm) with different technique for errror correlation matrix does not need additional contribution

Antihelium



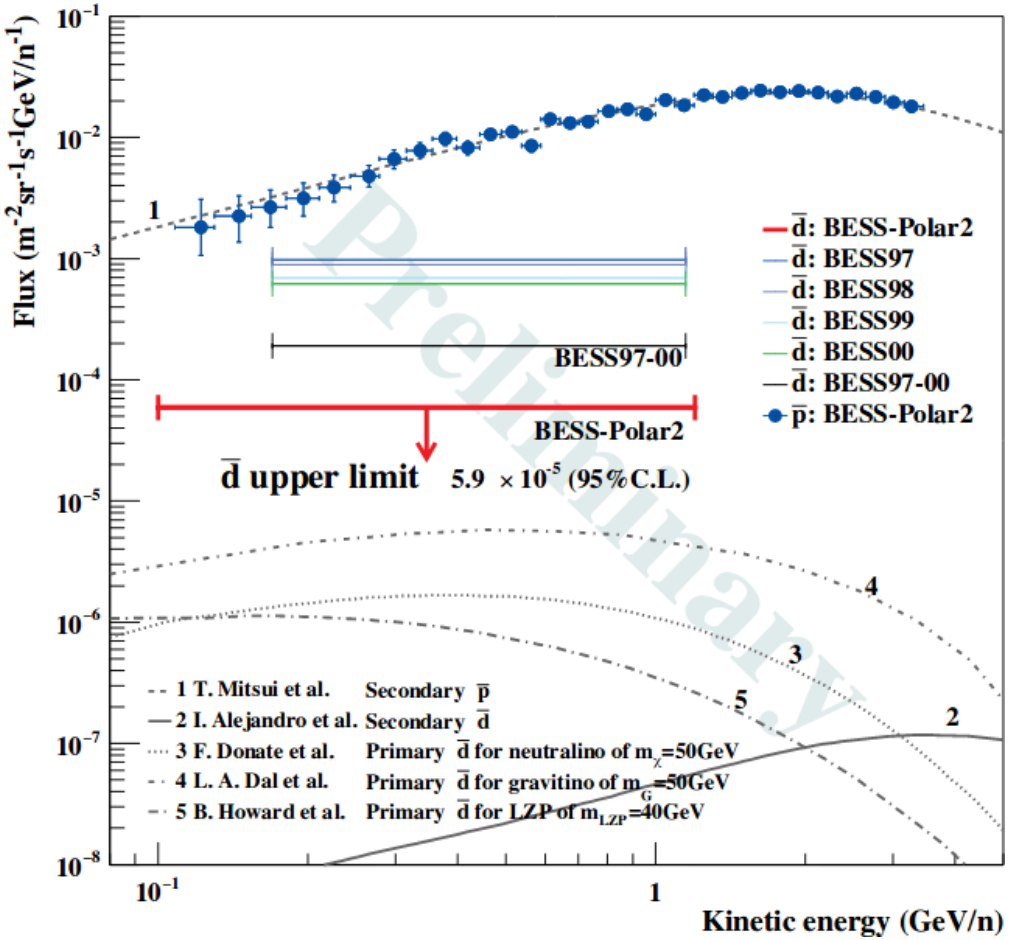


- AMS-02 reported that antihelium candidate events have been observed (Ting, CERN Colloquium, 5/24/18) → interpretations are ongoing
- key constraints: no explanation should overproduce antiprotons and antideuterons?
  - **Secondary astrophysical background:** uncertainties in antihelium formation models leave room to explain higher energy antihelium events
  - **Dark matter:** difficult to contruct a model that does not overproduce antiprotons
  - **Nearby antistar:** at distance of ~1pc, prfound impact on Big Bang Nucleosynthesis (Poulin et al., Phys.Rev. D99 (2019) no.2, 023016)

New BESS Antideuteron Results

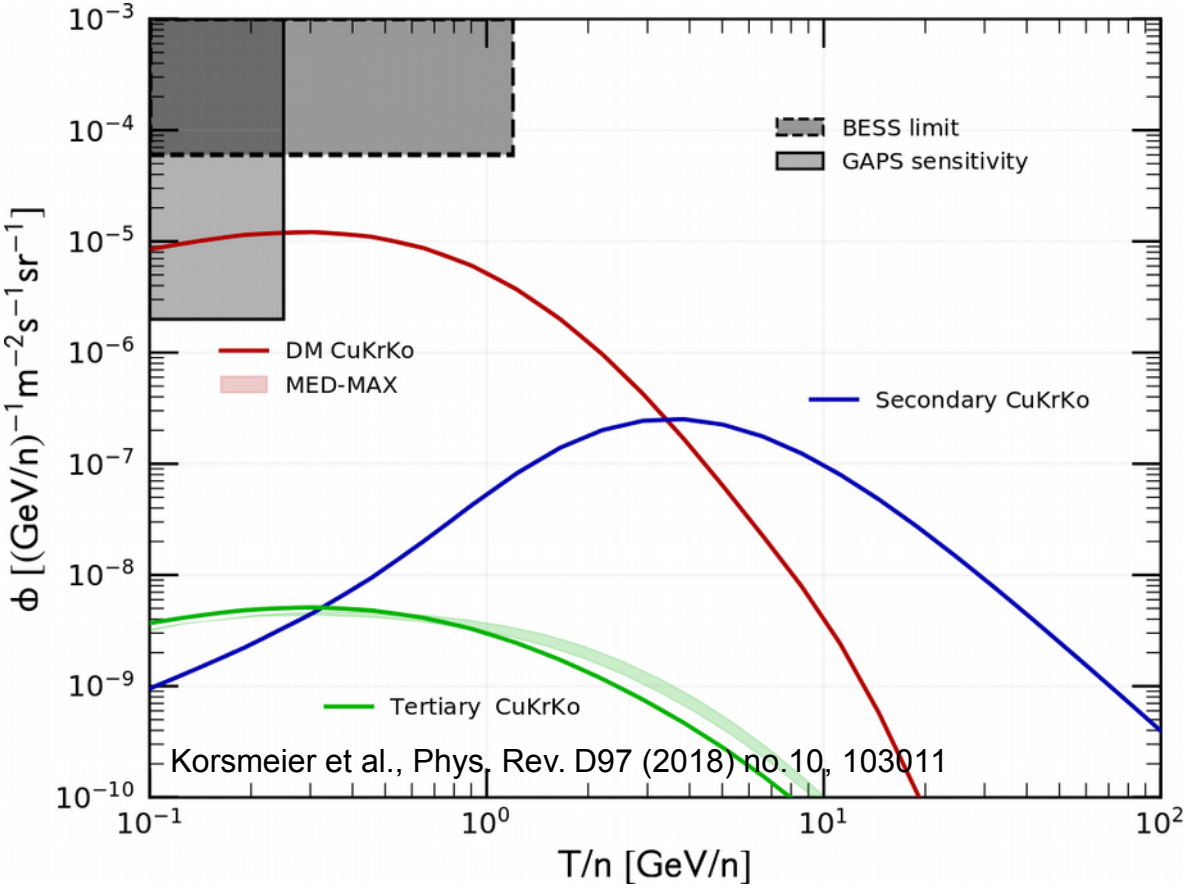
- Antiproton, antideuteron, antihelium need to be explained in one coherent picture:
  - Antiproton and antihelium both constrain antideuterons

- New analysis from BESS-Polar II flight (2007, 24.5 days):
  - Extended to low-energy range for antiprotons
  - New antideuteron limit (analysis is ongoing)
  - Details: Sakai, 7/25, 2:15pm



Antideuterons from Dark Matter

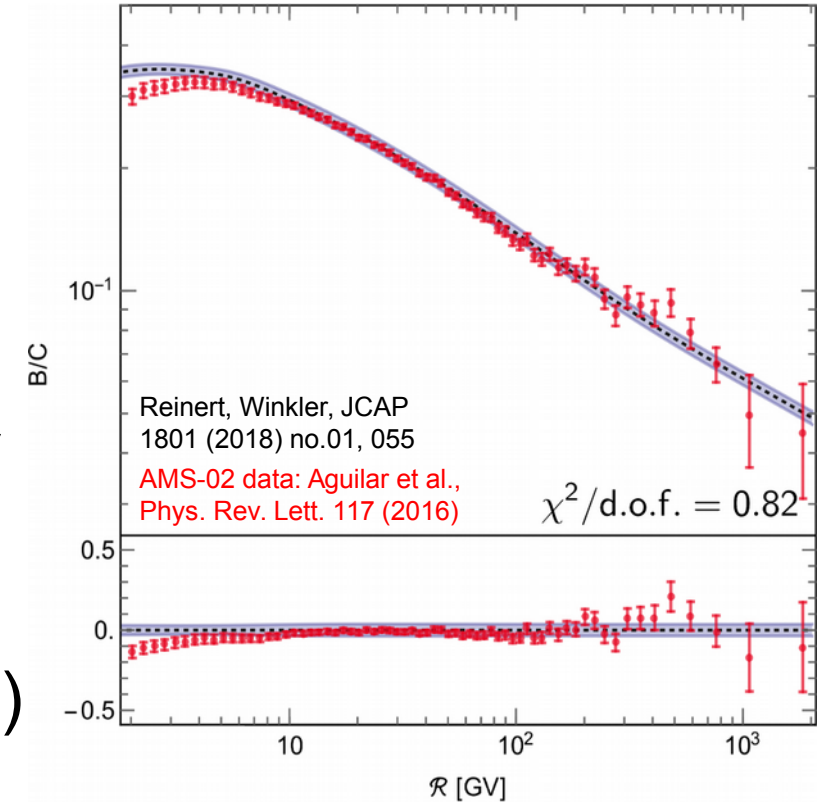
- γ-rays from Galactic center and antiproton excess fitted with DM → use the same parameters to make prediction for antideuterons:
  - Coalescence momentum from ALICE data
  - Flux propagation with GALPROP
- Dark matter hint from cosmic-ray antiprotons can produce antideuteron signal within experimental reach



Propagation Uncertainties

- An important constraint for antinuclei flux from dark matter annihilations is the Galactic halo size, which directly scales the observable flux

- Fits of cosmic-ray nuclei data are very important to constrain cosmic-ray propagation models
(e.g., Li/C, Li/O, Be/C, Be/O, B/C, B/O)



- Measurement of relevent primary cosmic ray and interstellar medium cross sections is important

Antinuclei Formation

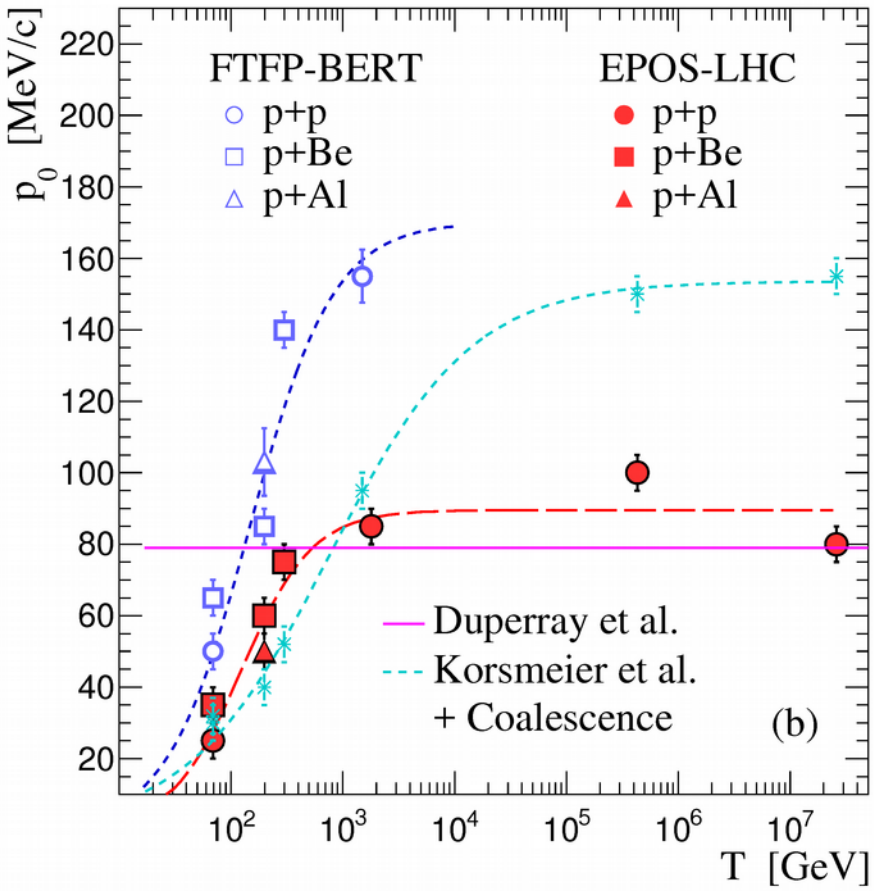
- **Antinuclei formation process breaks the degeneracy of antinuclei with antiprotons**

- **Coalescence:**
  - $\bar{d}$ can be formed by an $\bar{p}$-$\bar{n}$ pair if relative momentum is small compared to coalescence momentum p_0
  - Hadronic generators not really tuned for antiparticle production
  - hadronic generators do not model coalescence

- **Thermal model:**
  - Antinuclei directly formed at hadronization stage
  - tuned hadronic generator (Pierog (EPOS) 7/27, 2:45pm) can produce antideuterons directly from quarks

- **Quantum mechanical approach**
  - Enhanced antihelium formation due to interference of the wave functions of the constituents (Blum et al., Phys. Rev. D96 (2017) no.10, 103021)
  - Wigner function based coalescence model (Kachelriess et al., arXiv: 1905.01192)

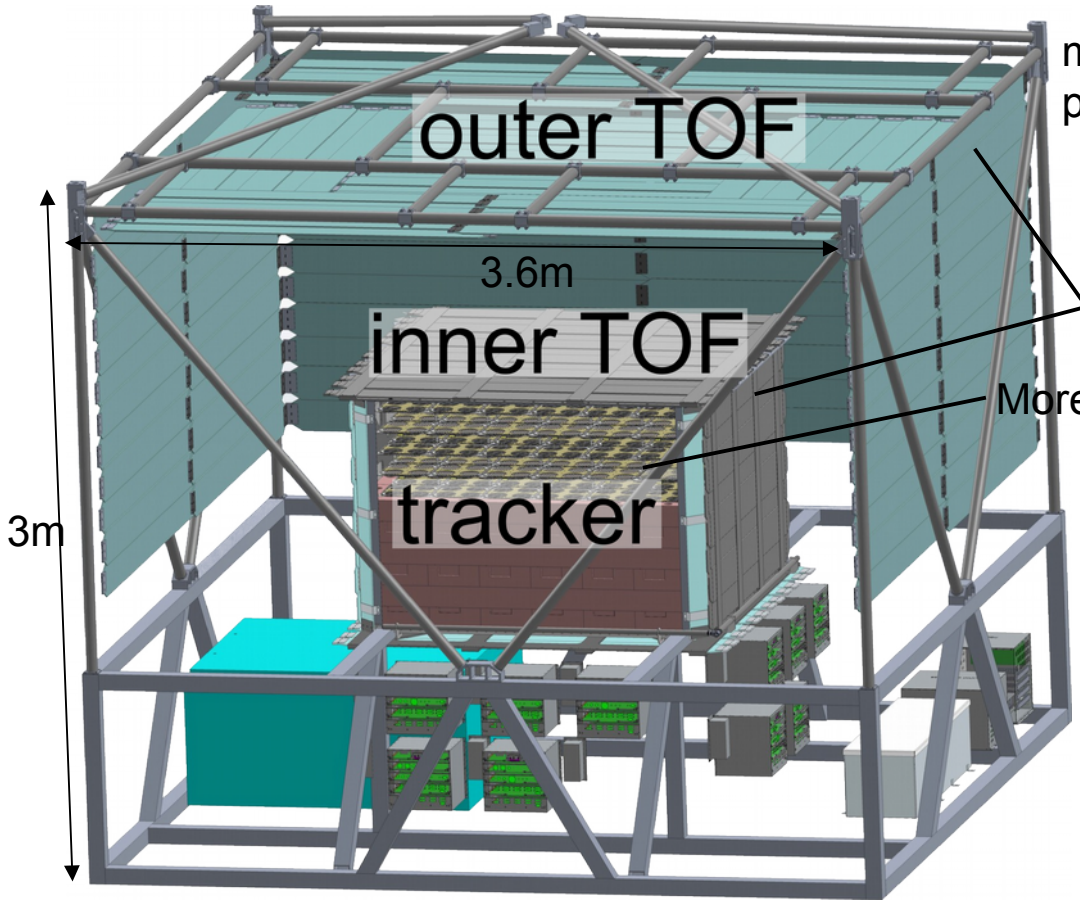
Gomez et. al, Phys. Rev. D 98, 023012 (2018)



- **more high statistics data needed to constrain antinuclei formation models**

GAPS Experiment

Columbia U, UCSD
UCLA, UCB,
U Hawaii, MIT

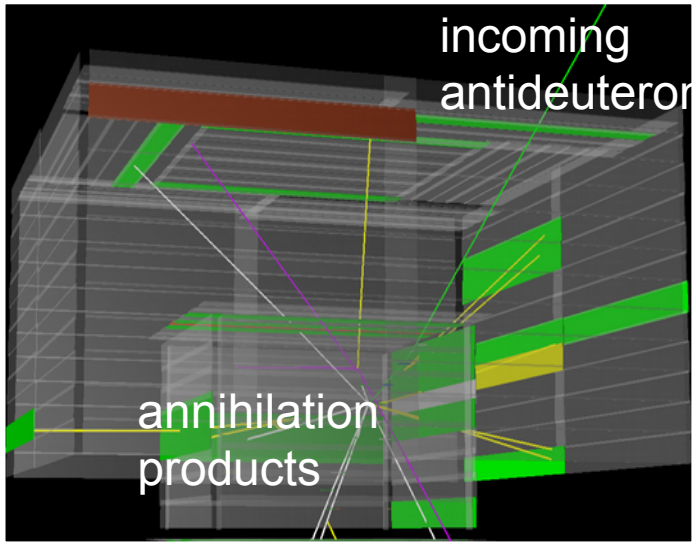


mass: ~2,500kg
power: ~1.5kW

TOF with SiPM readout

More than 1,000 Si(Li) wafers

Details: Bird, 7/25, 2:45pm
Posters: Munini, Quinn, Scotti



- the **G**eneral **A**nti**P**article **S**pectrometer is designed for low-energy antinuclei
- **GAPS is under construction → first Long Duration Balloon flights from Antarctica flight 2021**

Conclusion

- Cosmic-ray antideuteron workshop was in-fact a cosmic-ray antinuclei workshop
  → Antinuclei species need to be explained together

- Antideuteron and antihelium formation are not well understood

- Cross section measurements need to be conducted on for the interpretation

- Thanks a lot to all $\bar{d}$19 workshop participants
  → this review is not complete and a more detailed paper is coming up