

# Dark-matter production of anti-helium cosmic rays

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PRL 126 (2021) with Tim Linden



***News from the Dark 2021***

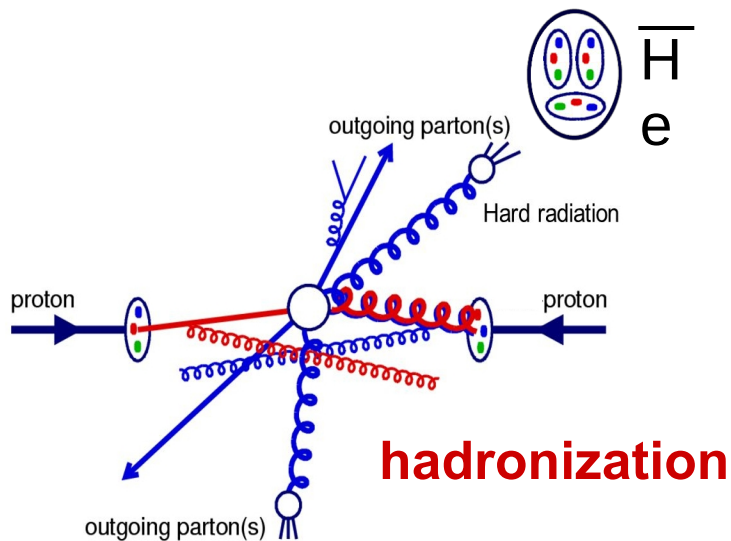
*November 22, 2021*



# Antinuclei in Cosmic Rays

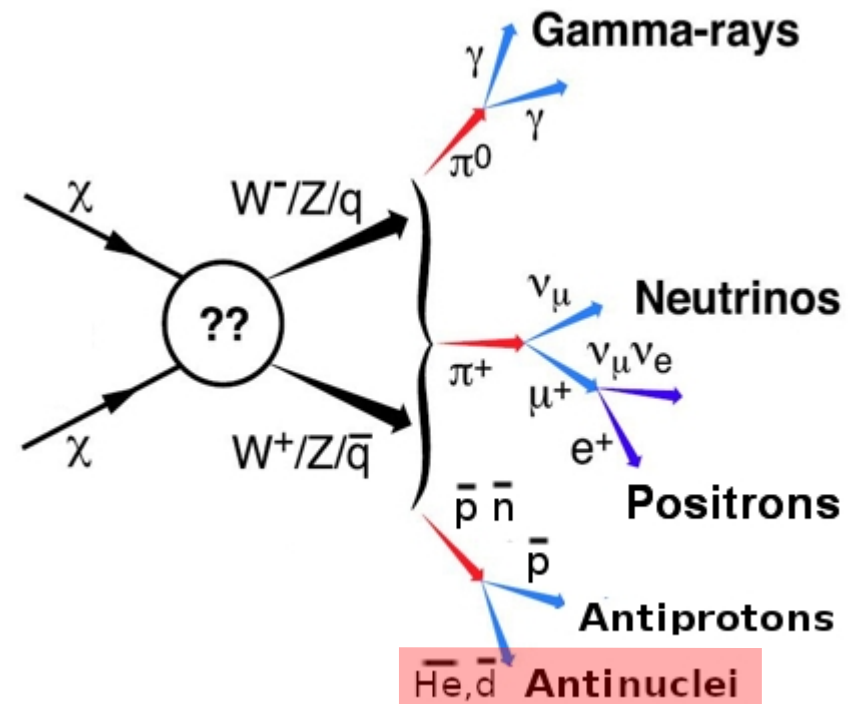
## secondary background

- primary cosmic rays (p,He) scatter on interstellar matter



## primary antinuclei

- dark matter annihilation

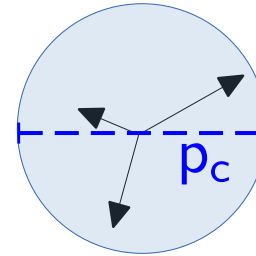


# Coalescence Model

- (anti)nucleons with low relative momentum merge into nucleus

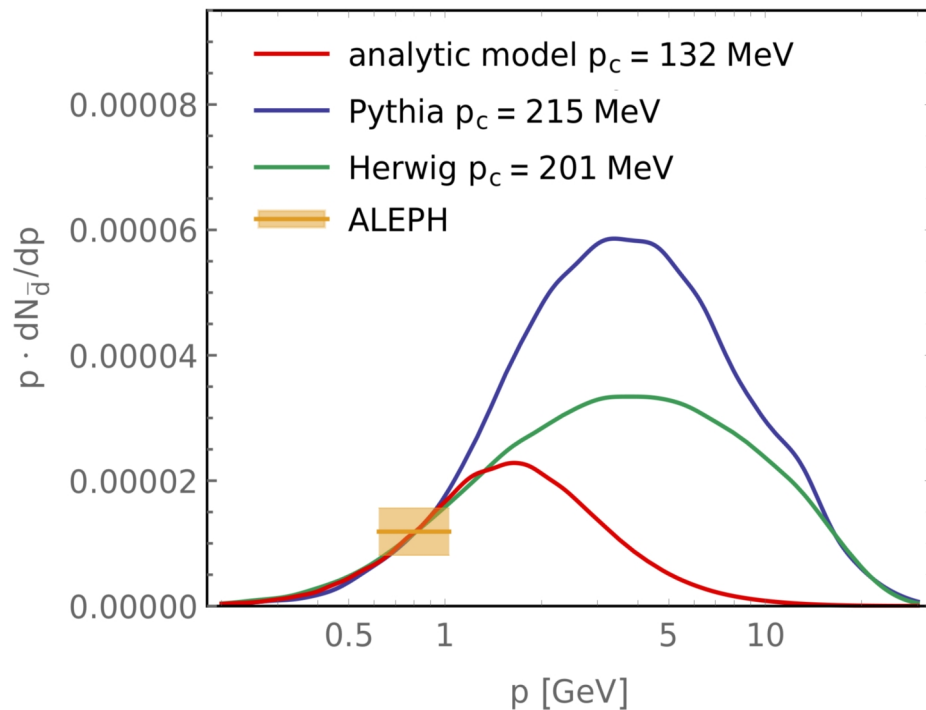
Schwarzschild, Zupancic, Phys. Rev. 129 (1963)

$$|\Delta\mathbf{p}| < p_c \quad \text{antideuteron}$$

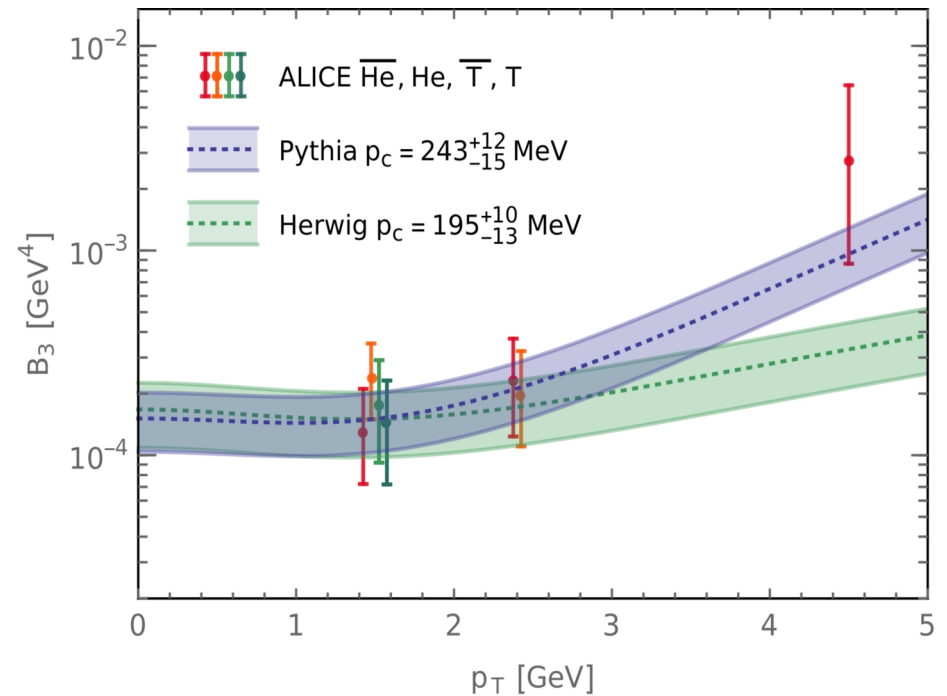


antihelium

$$e^+e^- \rightarrow Z \rightarrow \bar{d} \quad (\text{ALEPH})$$

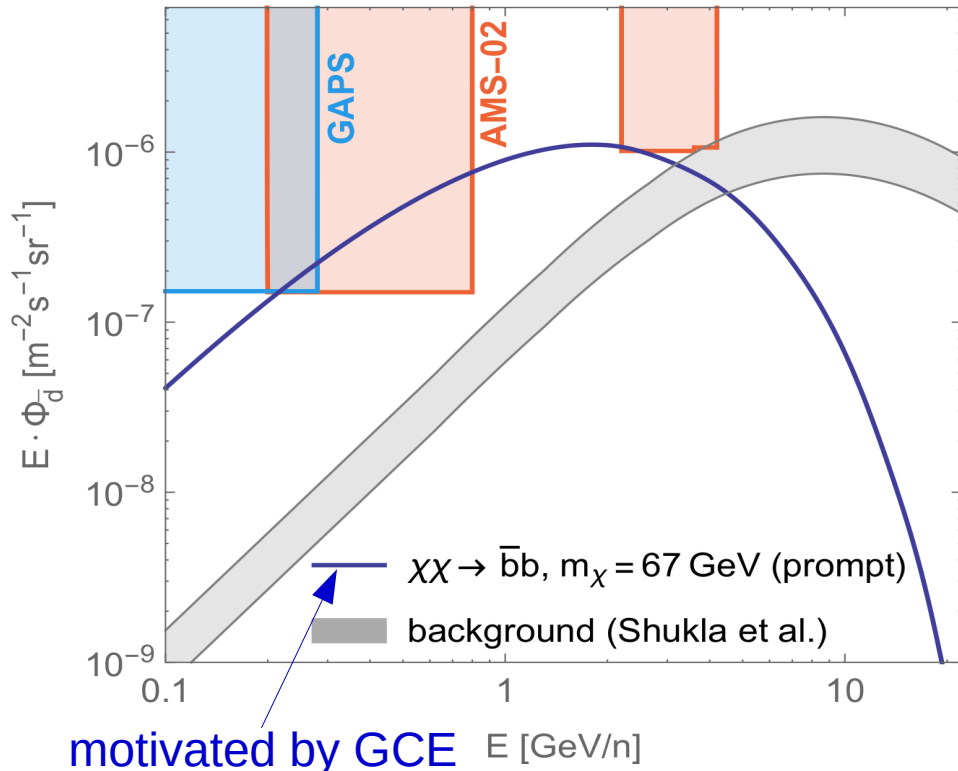


$$pp \rightarrow \bar{\text{He}} \quad (\text{ALICE})$$



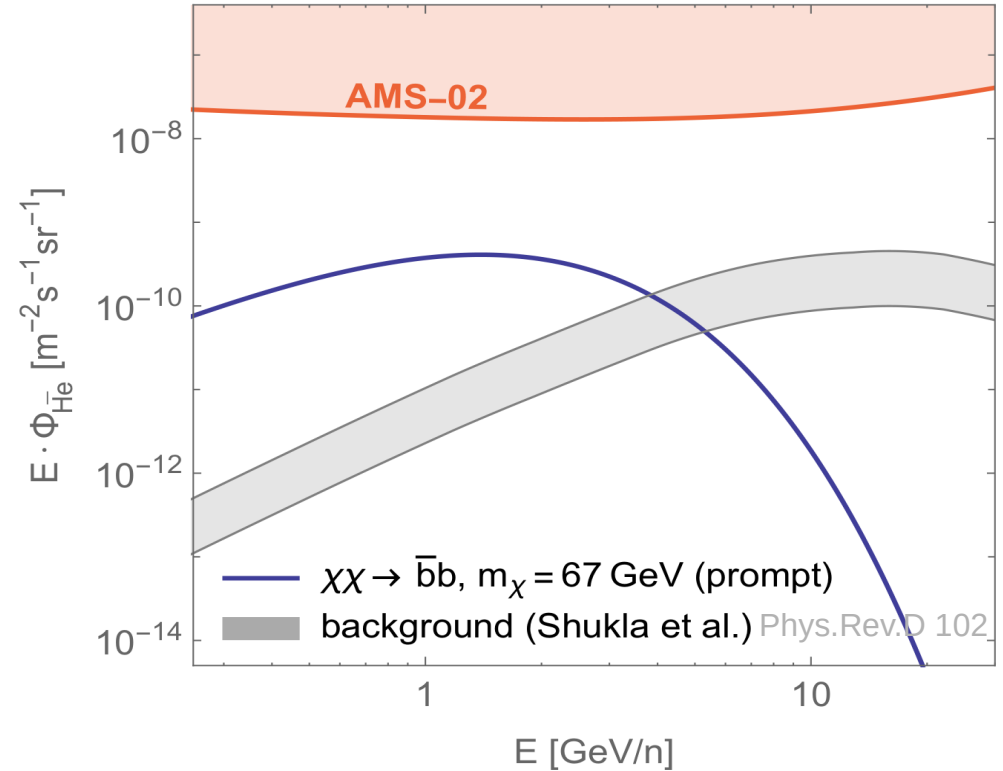
# Antinuclei Fluxes (Status 2020)

## Antideuteron



"smoking gun"

## Antihelium



hopeless?

**BUT: tentative detection of  $\sim 10 \bar{\text{He}}$  events at AMS-02**

S.Ting, CERN Colloquium 2016, Science Magazine 2017

# Exotic Antihelium Sources

- **Antimatter Clouds or Anti-Stars**

Poulin et al., Phys. Rev. D 99 (2019)

- **Peculiar Dark Sectors**

Heeck, Rajaraman, J. Phys. G47 (2020)

- **Alfvén reacceleration**

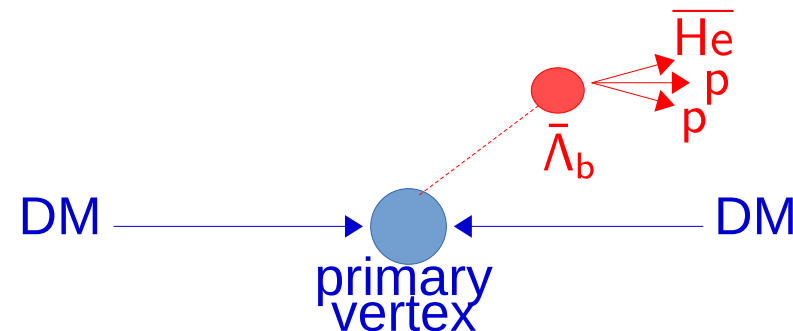
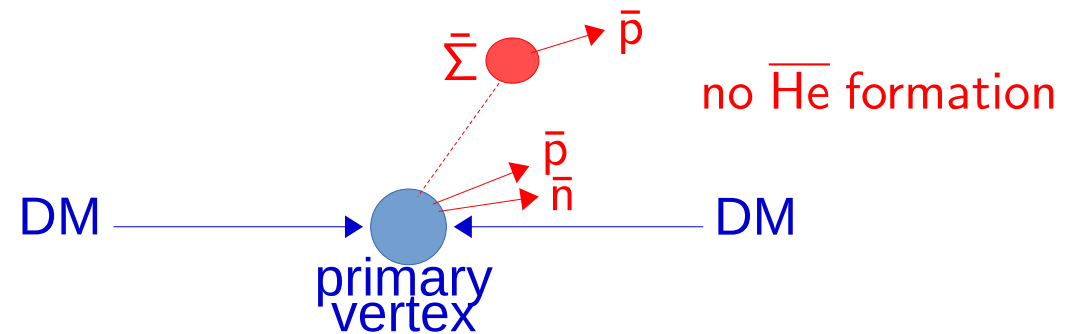
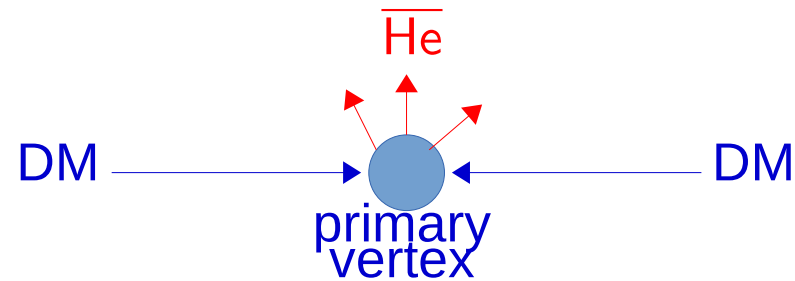
Alfvén reacceleration, Phys. Rev. D 102 (2020)

- **Pushing Uncertainties in Coalescence Model**

Blum et al., Phys. Rev. D 96, (2017), Coogan, Profumo, Phys. Rev. D96 (2017)

# Displaced Antihelium from Dark Matter

- previous analyses derived  $\overline{\text{He}}$  emission by prompt antinucleons
- Idea: prompt antinucleons cannot merge with displaced antinucleons
- potentially **dominant**  $\overline{\text{He}}$  production mode has been missed



# $\bar{\Lambda}_b$ : The Perfect $\bar{\text{He}}$ -Catalyst

- DM annihilation yields large number of  $\bar{\Lambda}_b$

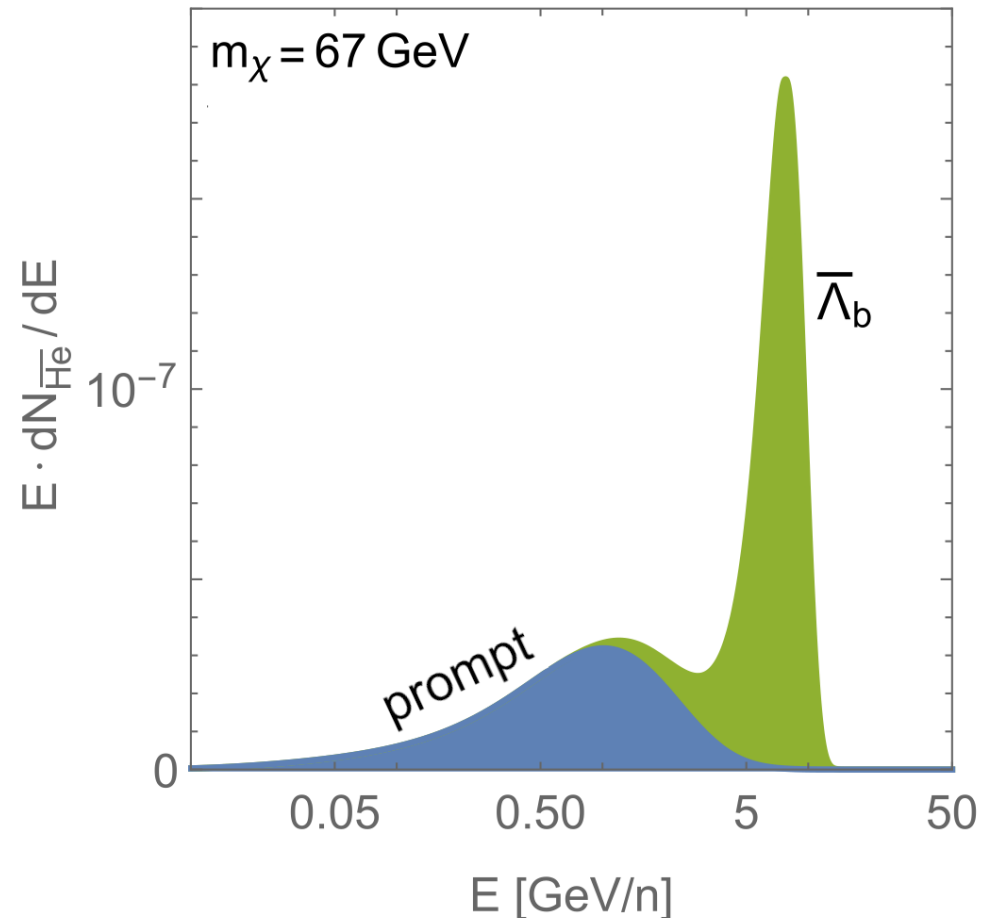
$$f(\bar{b} \rightarrow \bar{\Lambda}_b) \sim 0.1$$

- carry antibaryon number
- antinucleons produced with low relative momentum

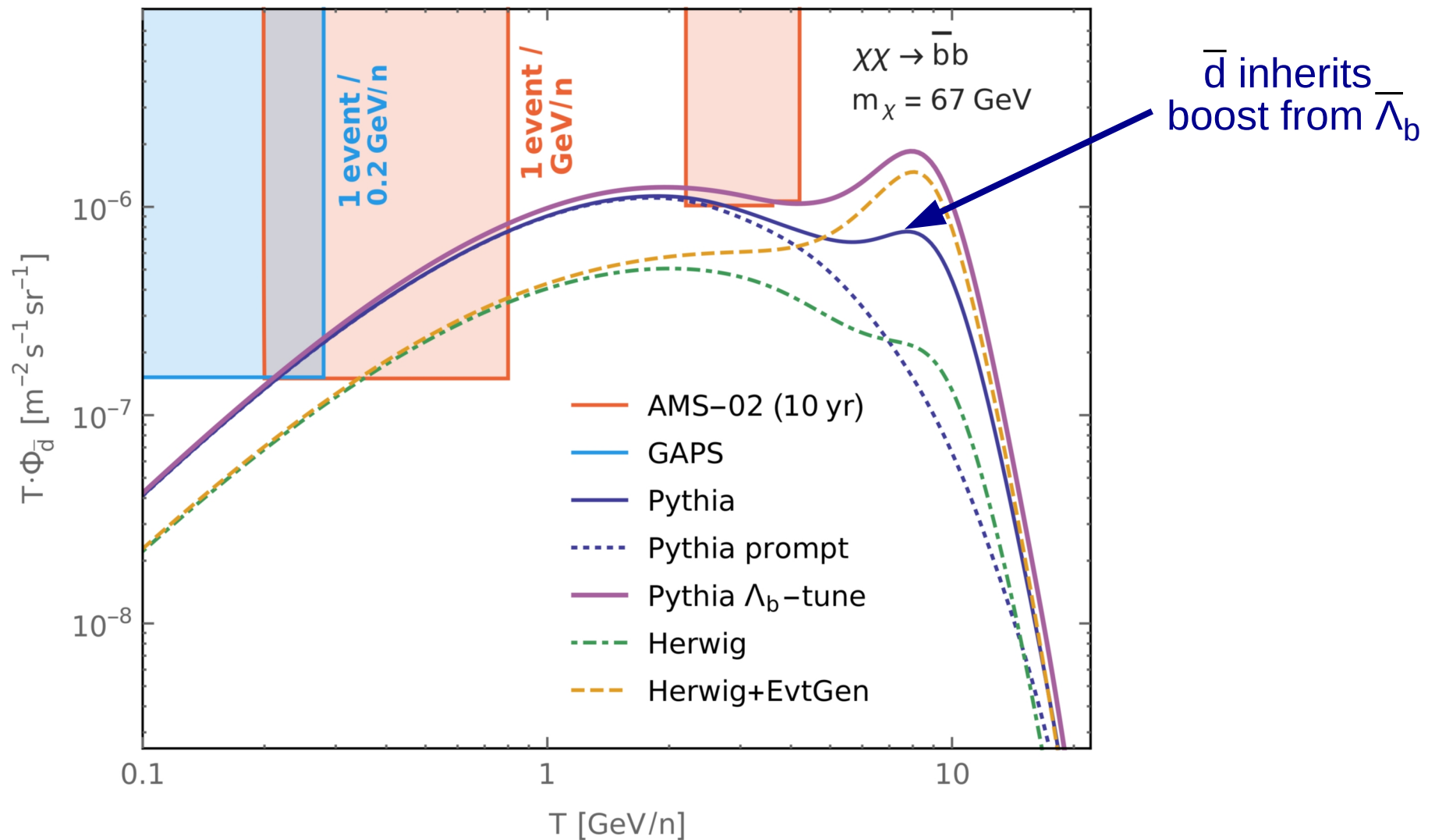
$$m_{\bar{\Lambda}_b} - 5m_n \simeq 1 \text{ GeV}$$

$$\text{Br}(\bar{\Lambda}_b \rightarrow \bar{\text{He}}) \sim 10^{-6}$$

- $\bar{\text{He}}$  from  $\bar{\Lambda}_b$  contributes to the high-energy flux



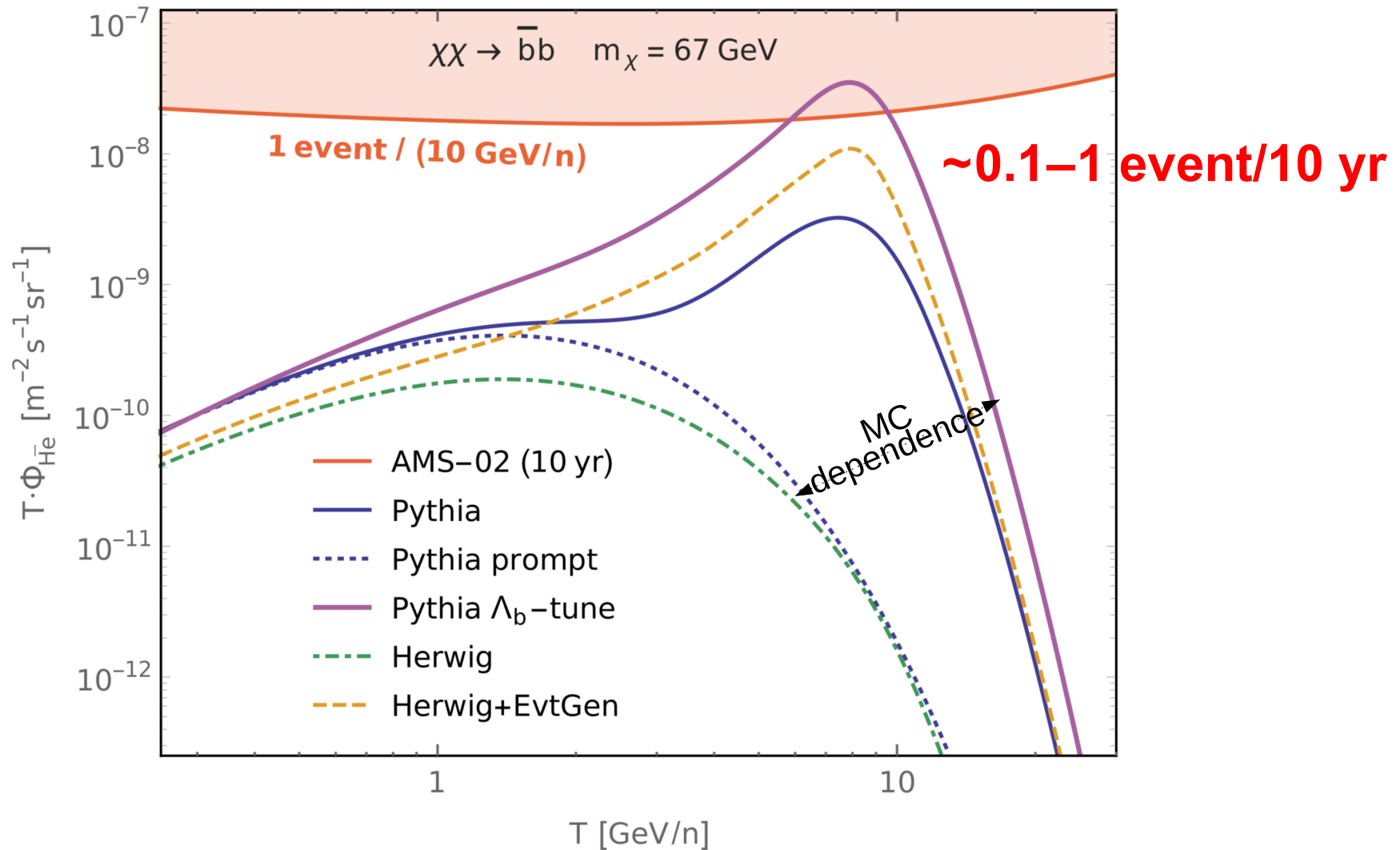
# Impact on Antideuteron Flux



- promising new high-energy signature in antideuteron flux

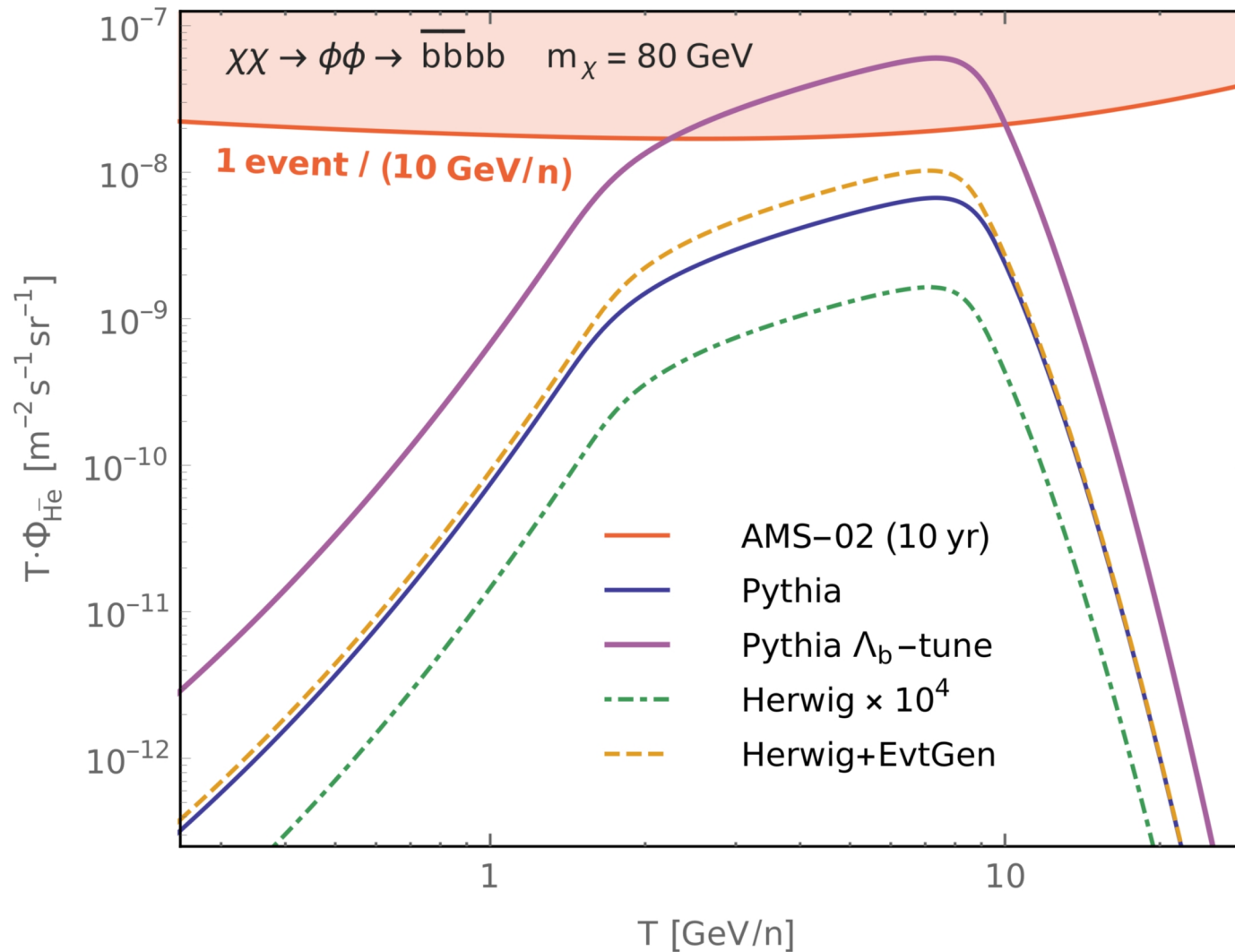


# Impact on Antihelium Flux



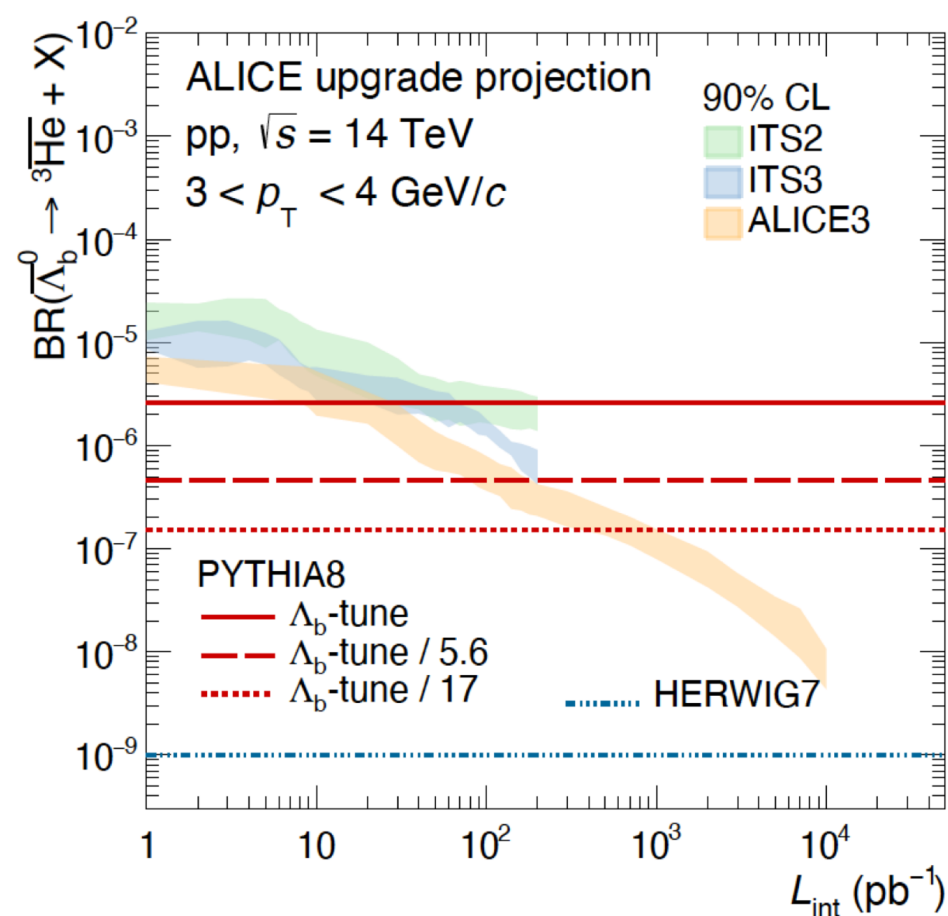
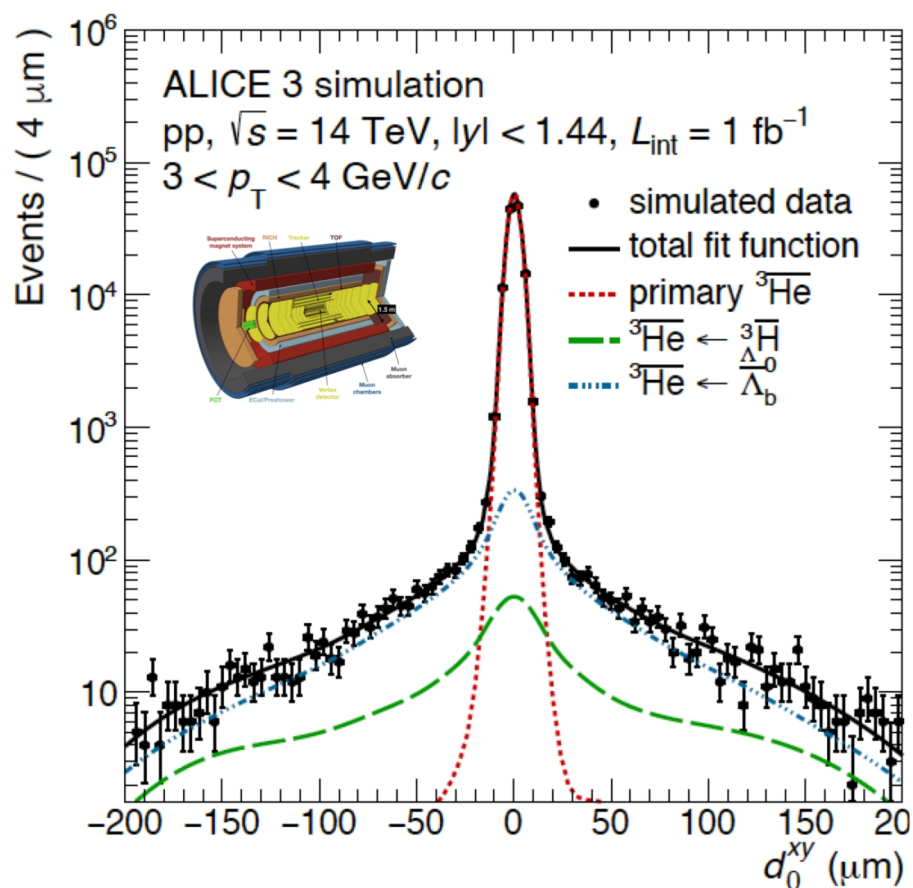
- antihelium events enhanced by up to  $O(100)$  due to  $\bar{\Lambda}_b$

# Light Mediator Model



- further increase of antihelium flux e.g. in mediator-models

# Experimental Prospects



A. Kalweit, CERN ALICE 3 Workshop, CERN 2021

- ALICE has implemented our results into their detector simulation and will measure  $\text{BR}(\bar{\Lambda}_b \rightarrow \bar{\text{He}})$  in Run 3.

# Conclusion and Outlook

- $\bar{\Lambda}_b$  decays can dramatically enhance the cosmic ray  $\bar{\text{He}}$ -flux
- $\bar{\text{He}}$  signal at AMS-02 possible for well-motivated DM candidates
- Key observable  $\text{BR}(\bar{\Lambda}_b \rightarrow \bar{\text{He}})$  to be measured at the LHC