



UNIVERSITY of
TURIN and INFN
Department of Physics

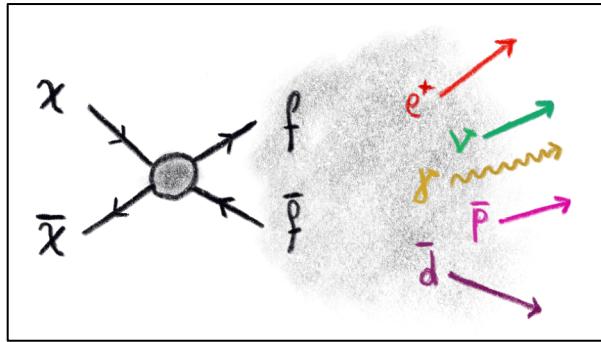


Prospects to find cosmic-ray antinuclei and the impact of cross section uncertainties

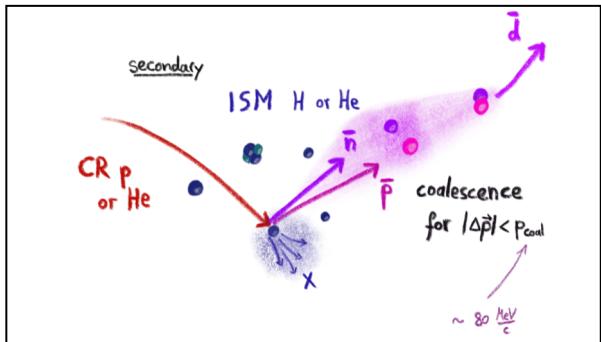
Michael Korsmeier

Based on: MK, Donto, Fornengo; arXiv:1711.08465

Outline

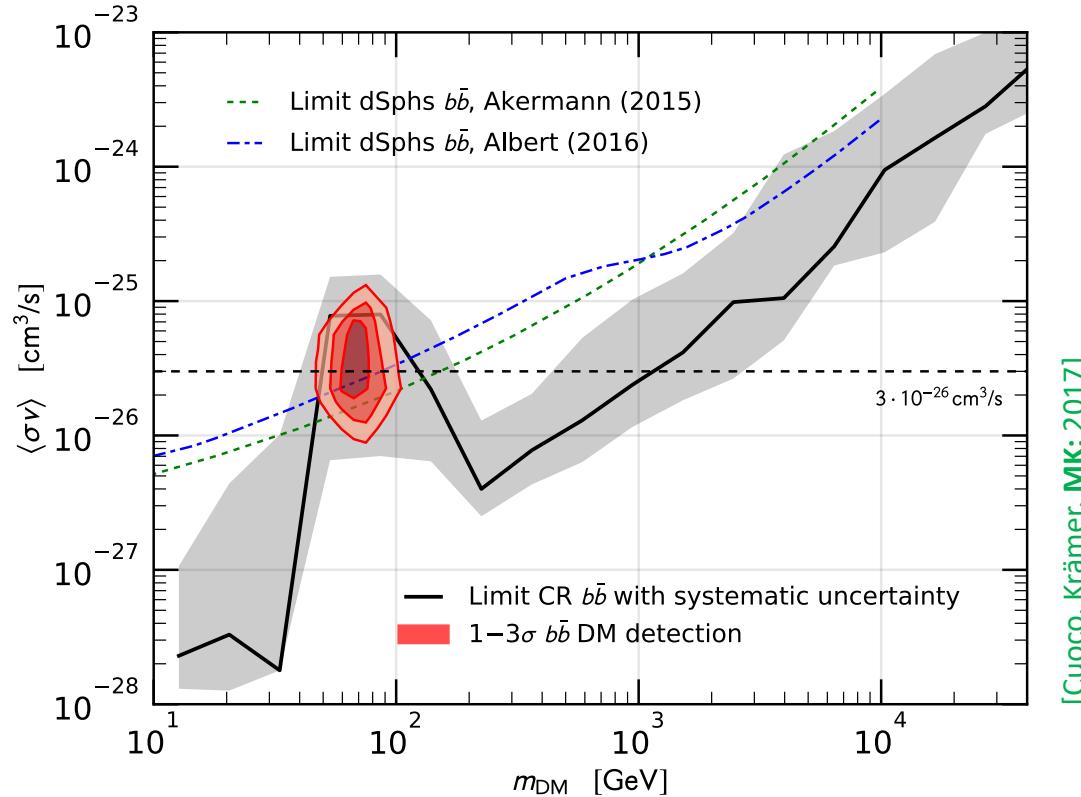


- Hint for DM annihilation and the prospects to observe a signature with GAPS



- Cross section uncertainties for cosmic-ray antideuteron

Hint for DM in cosmic-ray antiprotons

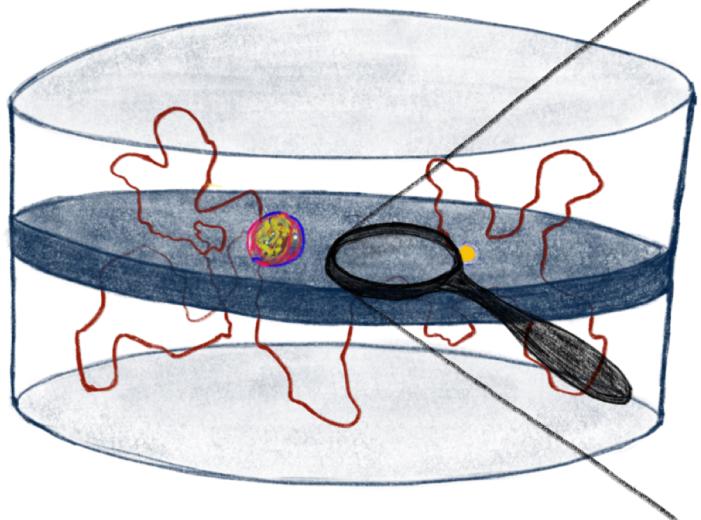


[Cuoco, Krämer, MK; 2017]

Is there an alternative way to test this DM hint?

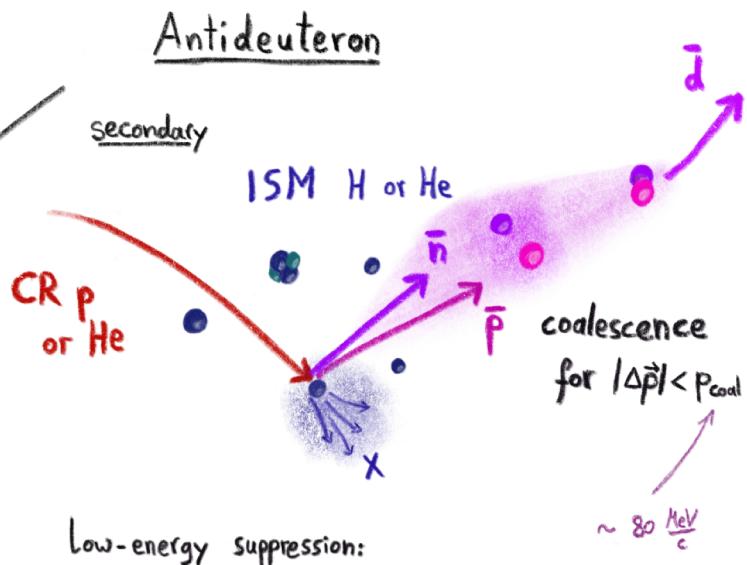
→ see also Martin Winkler, Dan Hooper, Mingynang Cui, Michael Korsmeier

Antideuterons in cosmic rays



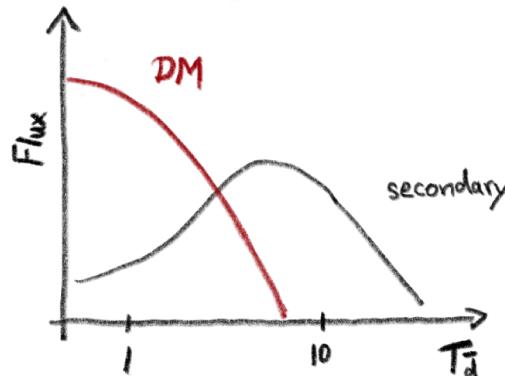
DM

- Production by coalescence
- No low-energy suppression
(annihilation at rest)



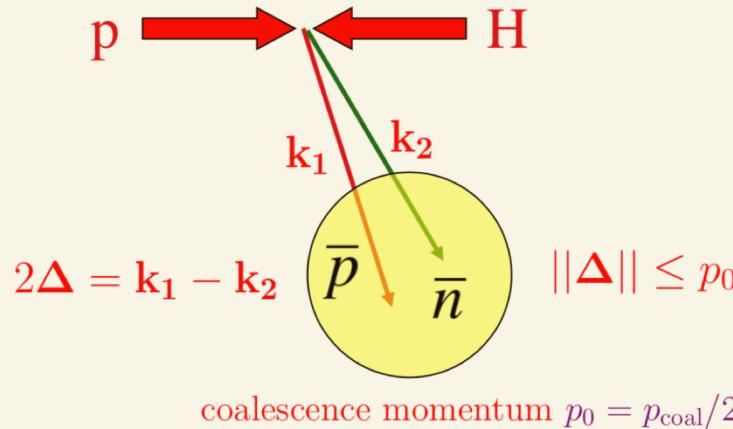
$$2E_p m_p + 2m_p^2 = \left[\left(\frac{E_p}{p_p} \right) + \left(\frac{m_p}{0} \right) \right]^2 = M_{\text{gg}}^2 \geq (4m_p + 2m_n)^2$$

$$\Leftrightarrow E_p \gtrsim 17 m_p$$



Antideuteron coalescence

coalescence \equiv fusion of \bar{p} & \bar{n} into \bar{d} , ${}^3\text{He}$ or ${}^4\text{He}$



$$d^3\mathcal{N}_{\bar{d}}(\mathbf{K}) = \int d^6\mathcal{N}_{\bar{p},\bar{n}} \{\mathbf{k}_1, \mathbf{k}_2\} \times \mathcal{C}(\Delta) \times \delta^3(\mathbf{K} - \mathbf{k}_1 - \mathbf{k}_2)$$

$$B_2 = \frac{E_{\bar{d}}}{E_{\bar{p}} E_{\bar{n}}} \int d^3\Delta \mathcal{C}(\Delta) \simeq \frac{m_{\bar{d}}}{m_{\bar{p}} m_{\bar{n}}} \left\{ \frac{4}{3} \pi p_0^3 \equiv \frac{\pi}{6} p_{\text{coal}}^3 \right\}$$

Coalescence factor B_2

$$\frac{E_{\bar{d}}}{\sigma_{\text{in}}} \frac{d^3\sigma_{\bar{d}}}{d^3\mathbf{K}} = B_2 \left\{ \frac{E_{\bar{p}}}{\sigma_{\text{in}}} \frac{d^3\sigma_{\bar{p}}}{d^3\mathbf{k}_1} \right\} \left\{ \frac{E_{\bar{n}}}{\sigma_{\text{in}}} \frac{d^3\sigma_{\bar{n}}}{d^3\mathbf{k}_2} \right\}$$

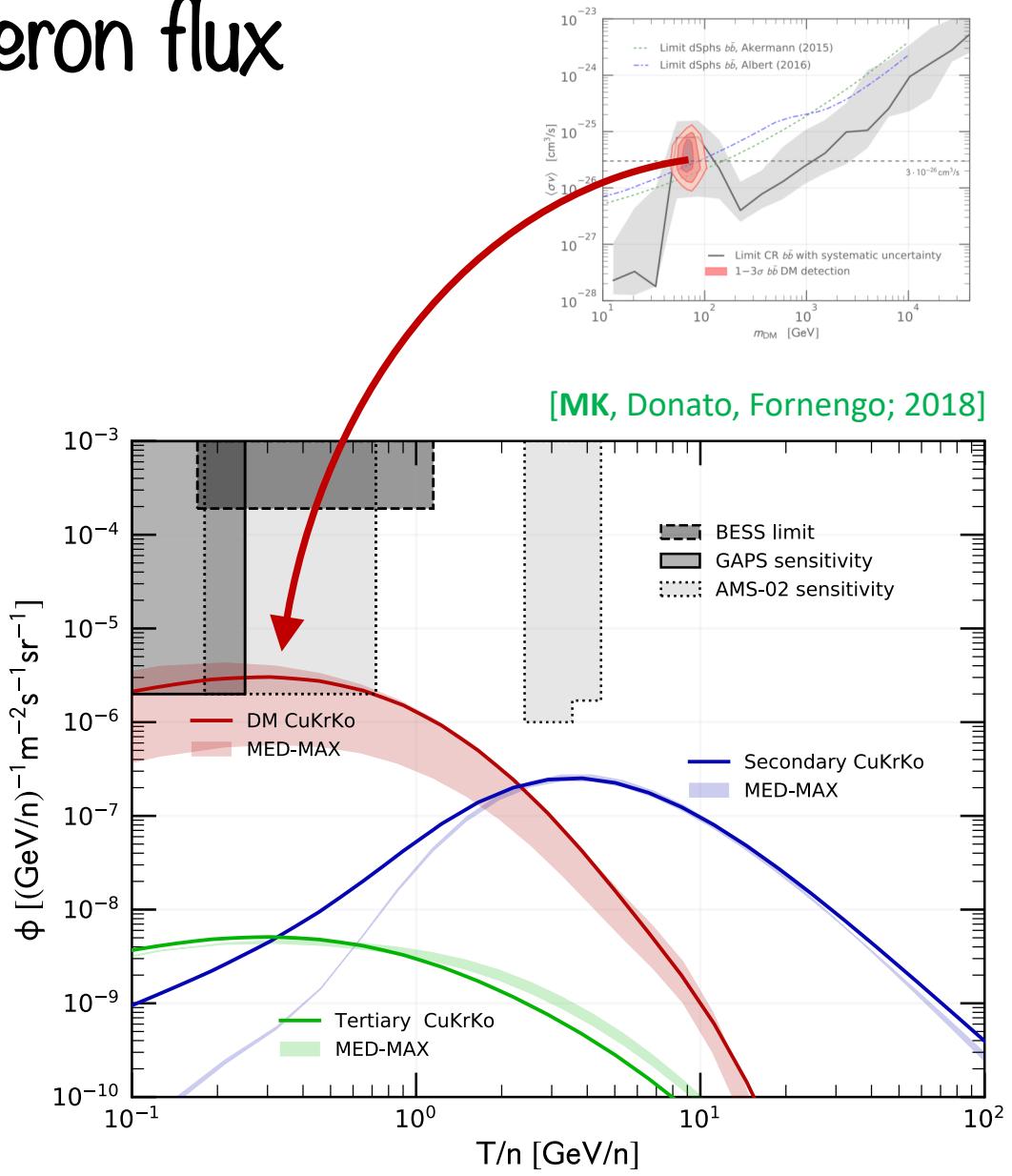
[Pierre Salati; dbar19 LA]

Expected antideuteron flux

Our standard setup:

- Analytic coalescence
- Coalescence momentum from ALEPH (Z decay)
- Flux propagation with GALPROP
- DM energy spectra from PPPC4DM

The DM hint from CR antiprotons is within the antideuteron sensitivity of GAPS and AMS-02!

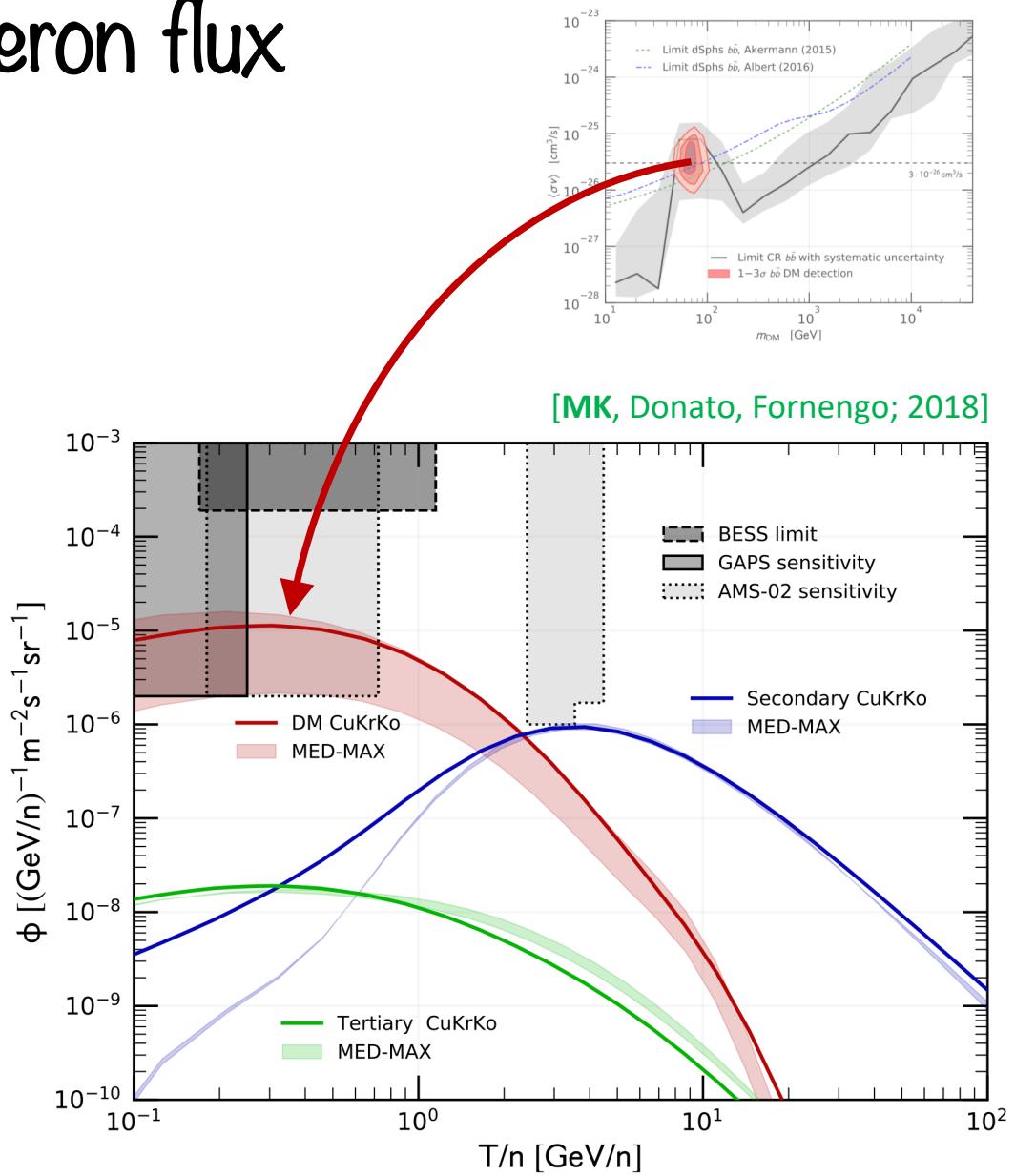


Expected antideuteron flux

Our optimistic setup:

- Analytic coalescence
- Coalescence momentum from ALICE (pp)
- Flux propagation with GALPROP
- DM energy spectra from PPPC4DM

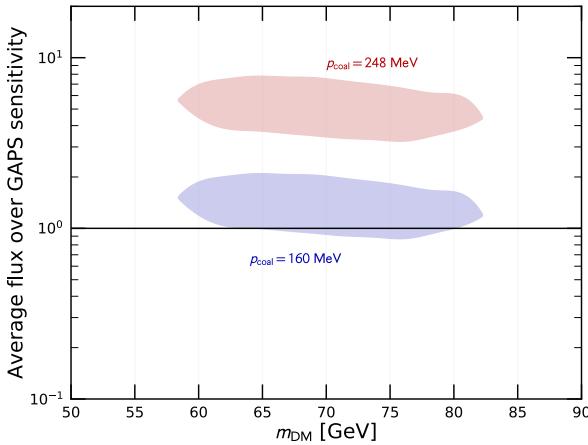
The DM hint from CR antiprotons is within the antideuteron sensitivity of GAPS and AMS-02!



Systematic uncertainties

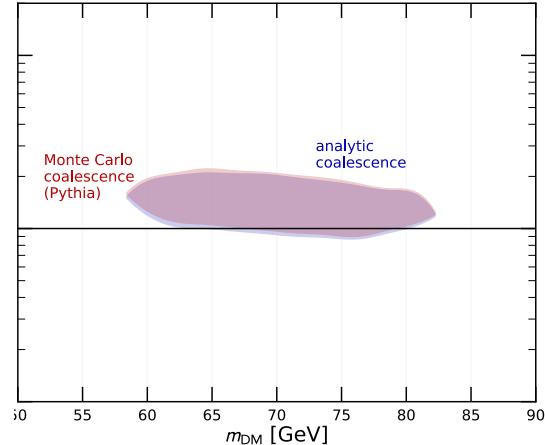
Coalescence momentum

- p_c suggested by recent ALICE measurements would increases signal by a factor of 4



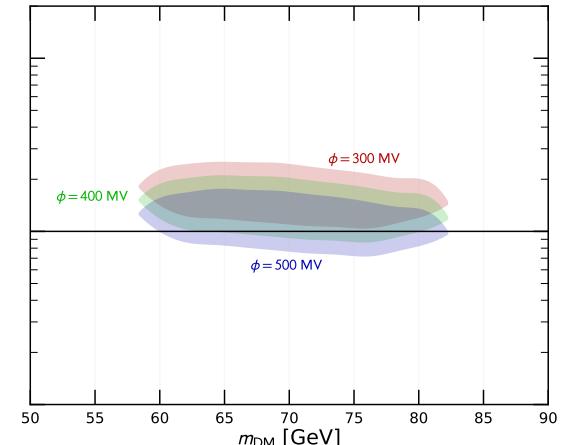
Coalescence approach

- Monte Carlo based coalescence and analytic approach agree in the GAPS energy range

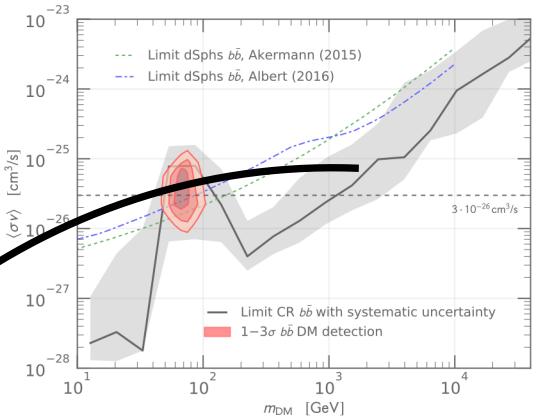
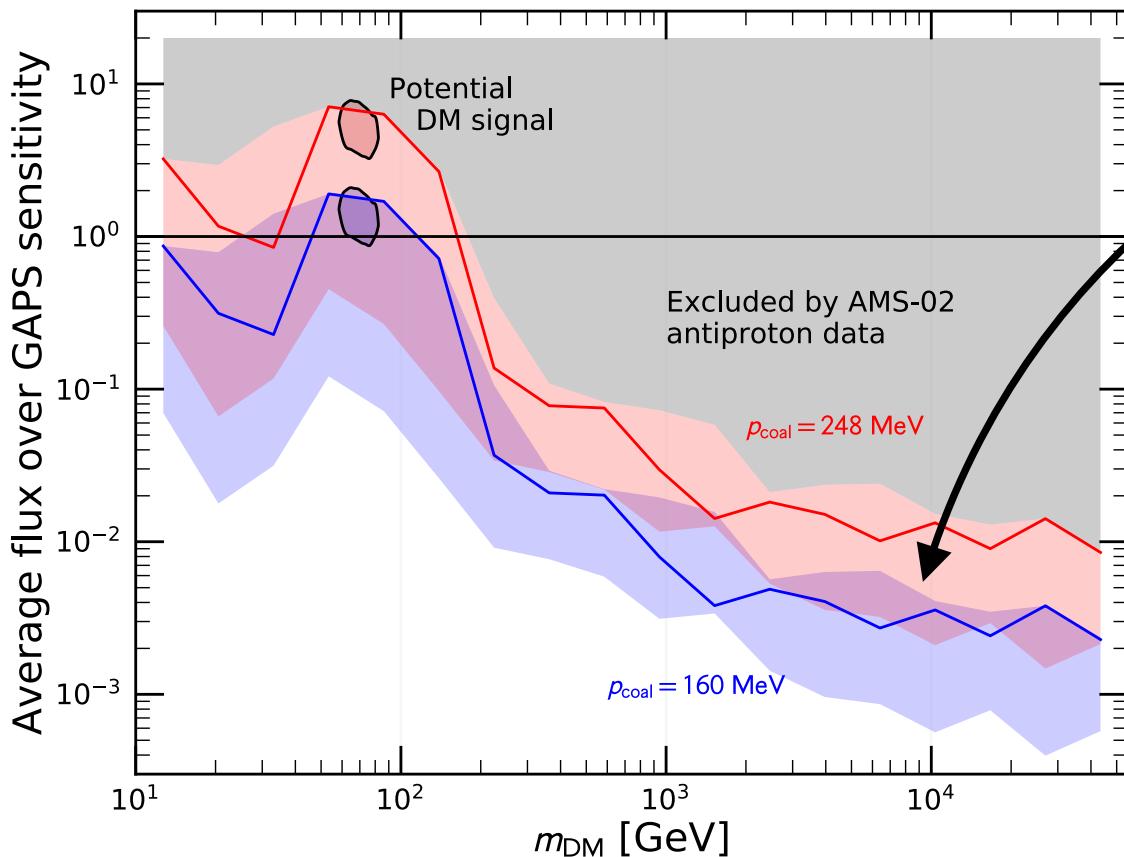


Solar modulation

- Has only a small impact

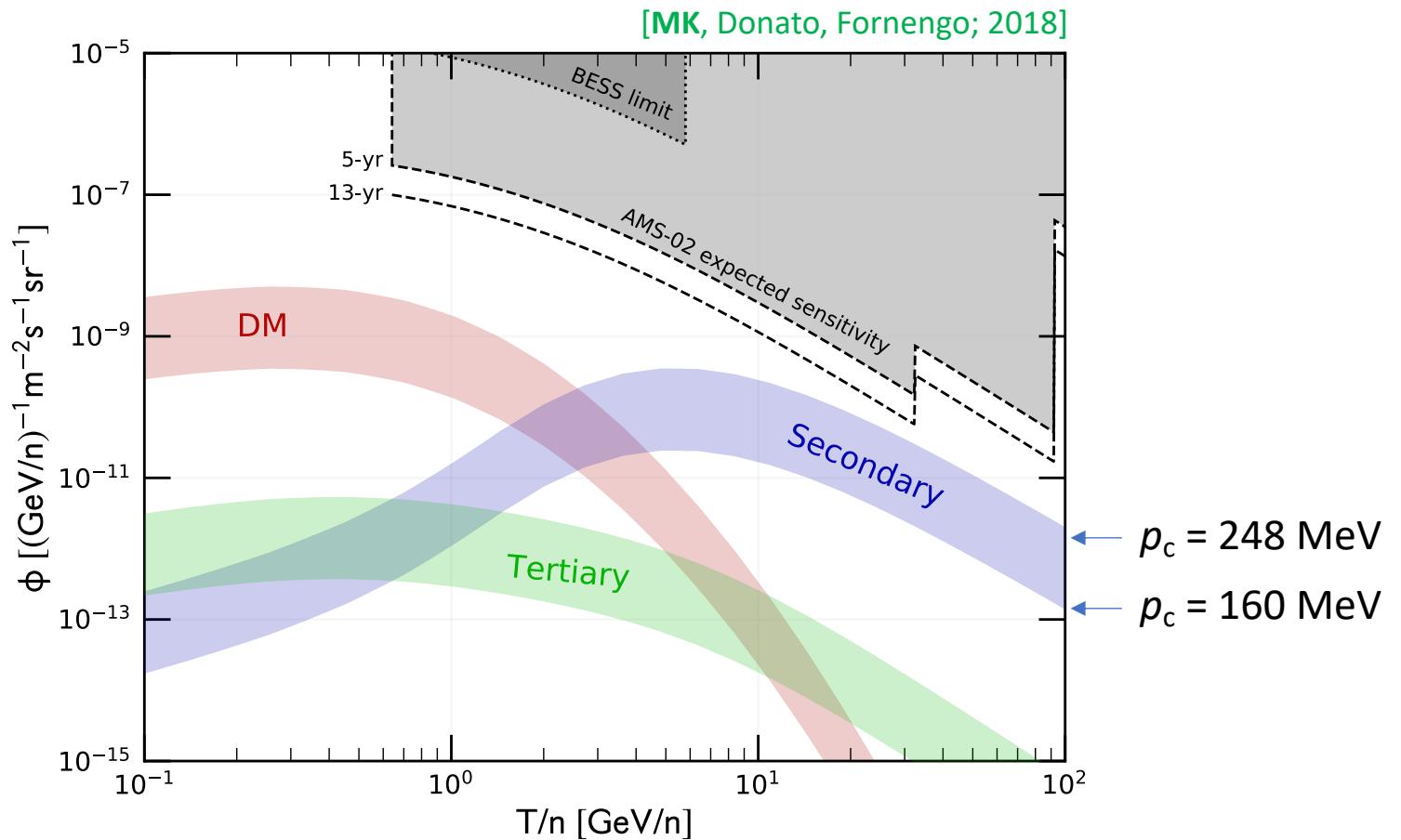


Conservative approach: DM limits



Large DM masses are already excluded by AMS-02 antiproton limits (in the $b\bar{b}$ channel)

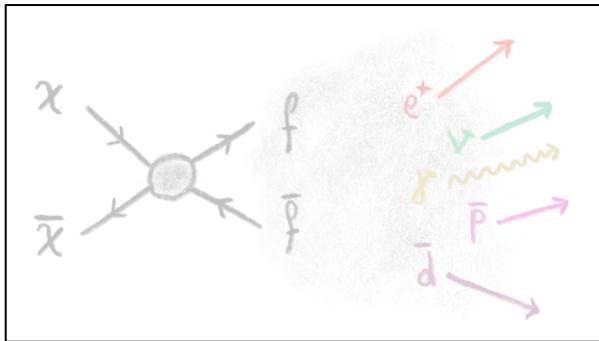
What about antihelium?



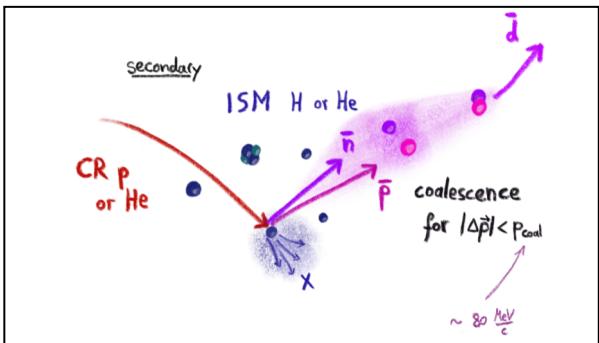
All the expected antihelium (${}^3\overline{\text{He}}$) fluxes are at below the expected sensitivity of AMS-02, even with optimistic assumptions on the coalescence momentum.

→ see Stefano Profumo, Kenny Chan Yu Ng, Pierre Salati, Vivian Poulin

Outline

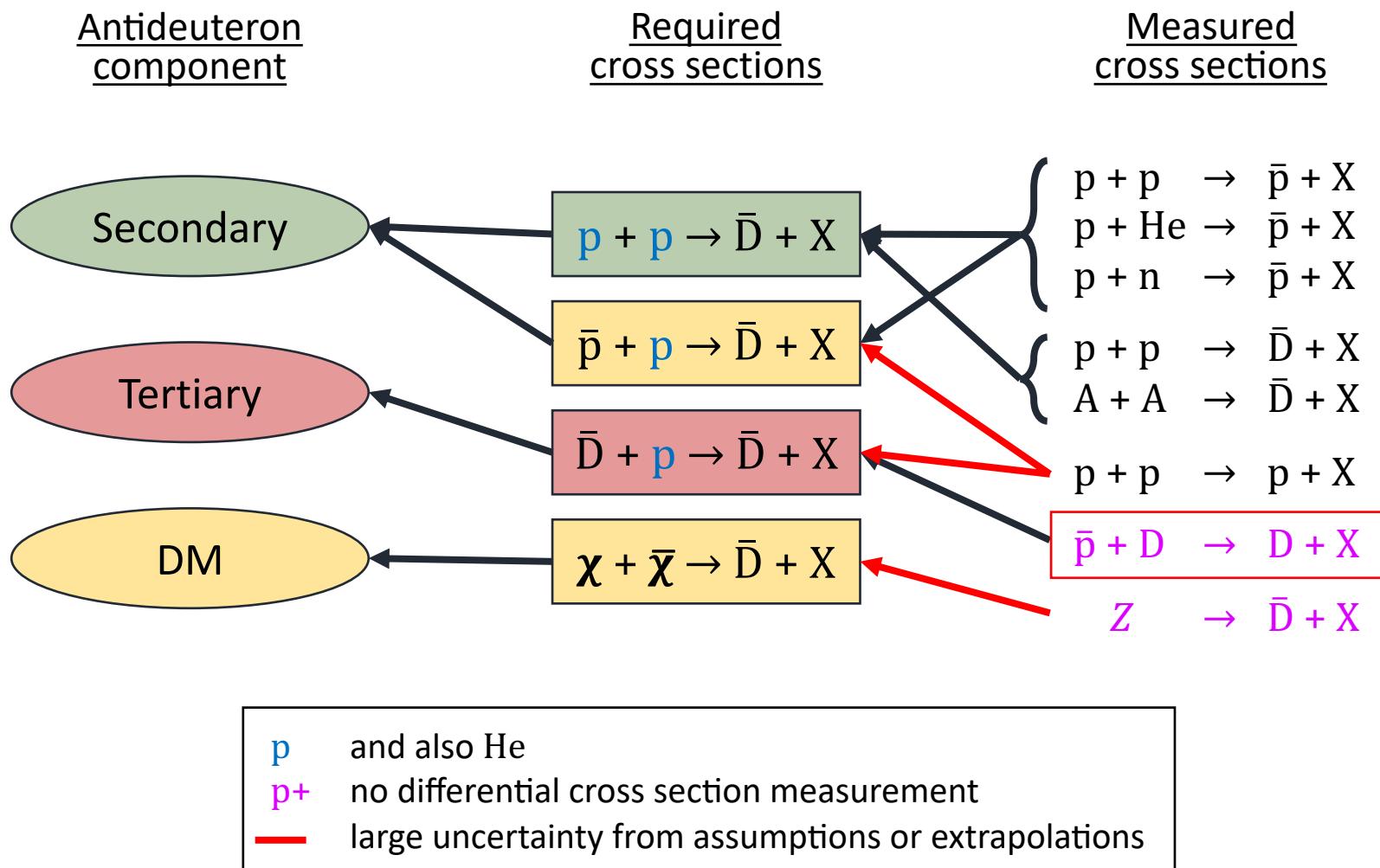


- Hint for DM annihilation and the prospects to observe a signature with GAPS



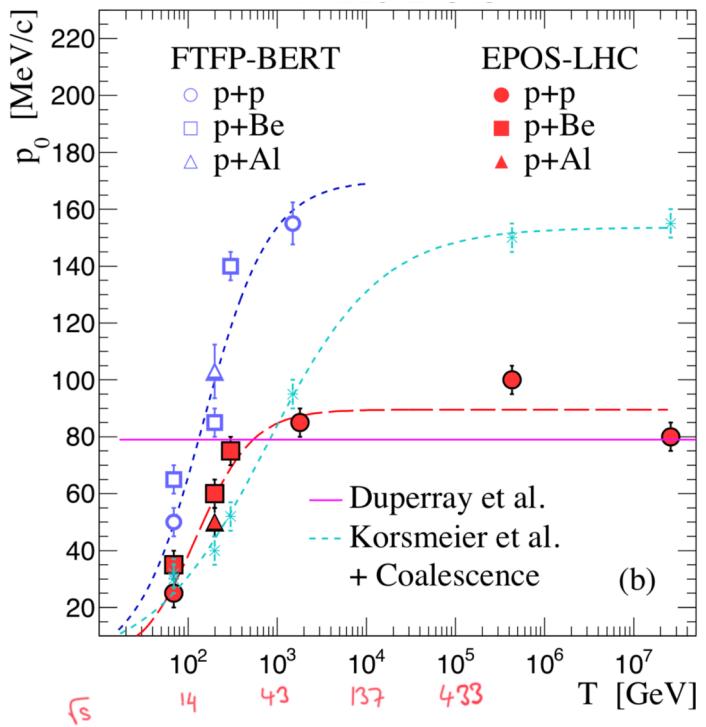
- Cross section uncertainties for cosmic-ray antideuteron

Cross section uncertainties for CR antideuteron

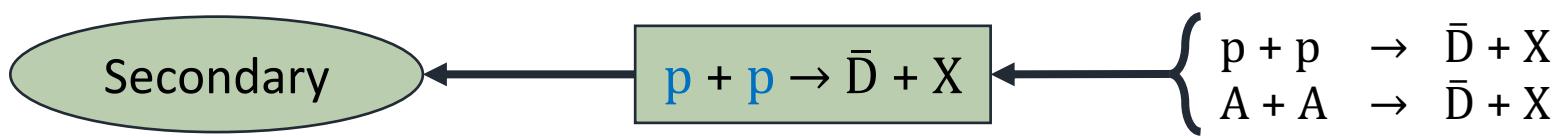
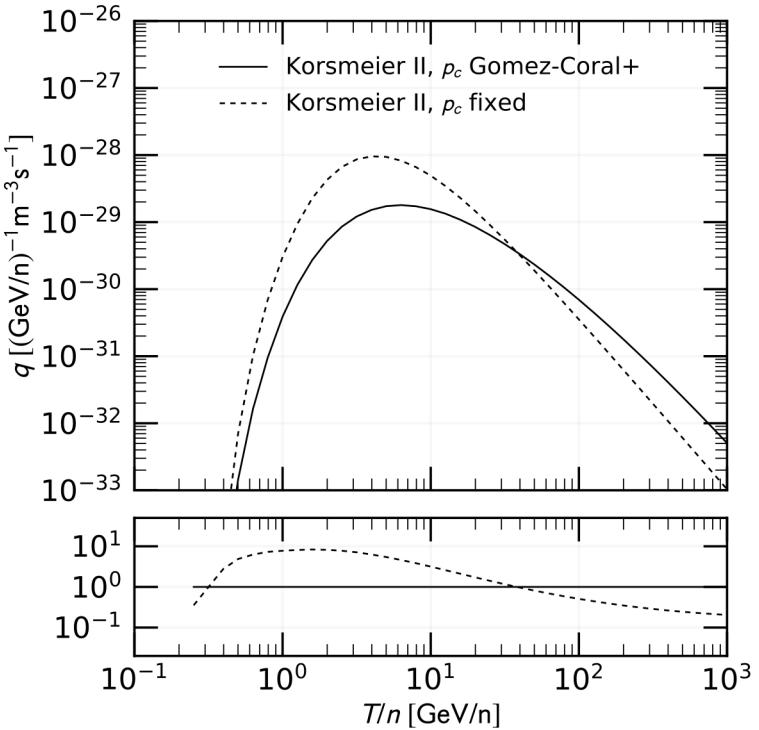


[Preliminary! From ongoing discussions with F. Donato, N. Fornengo]

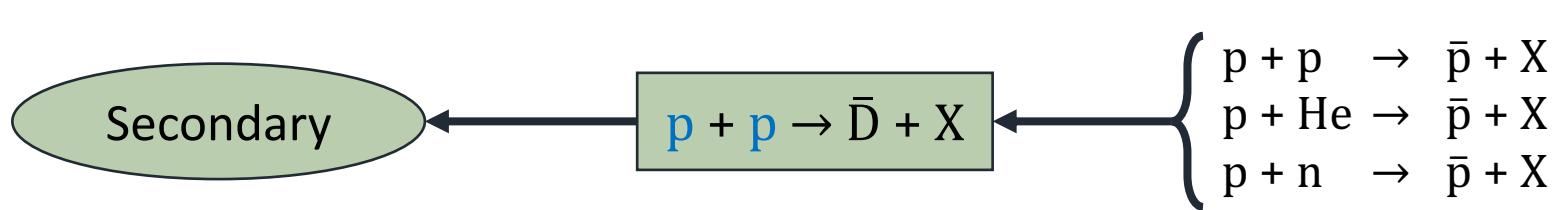
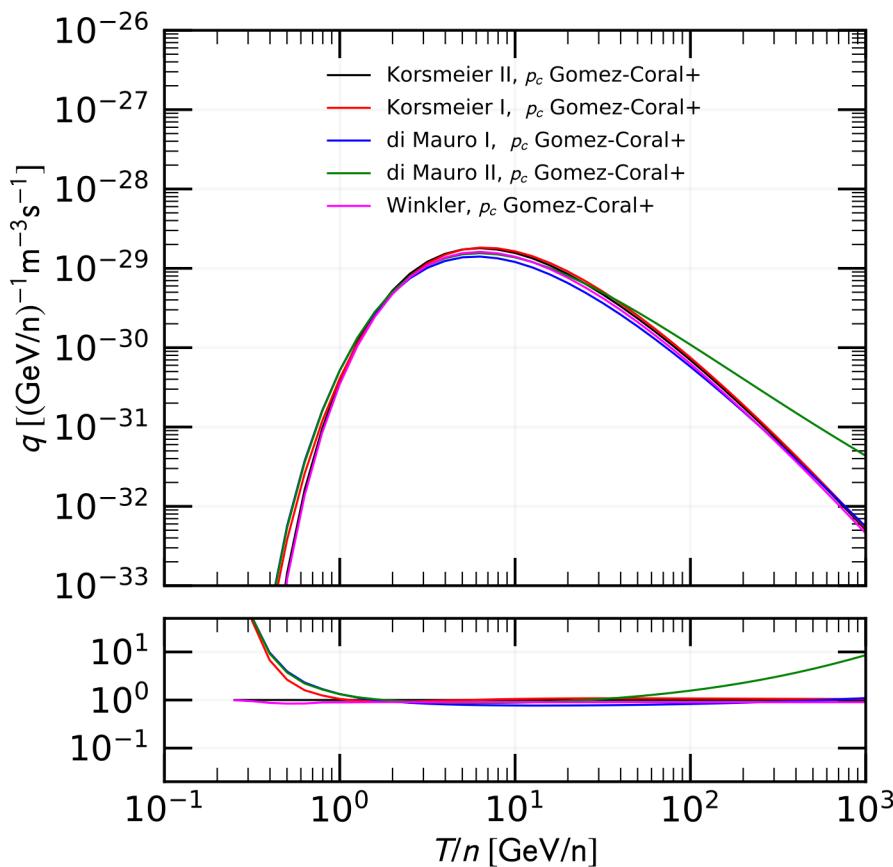
Cross section uncertainties for antideuteron



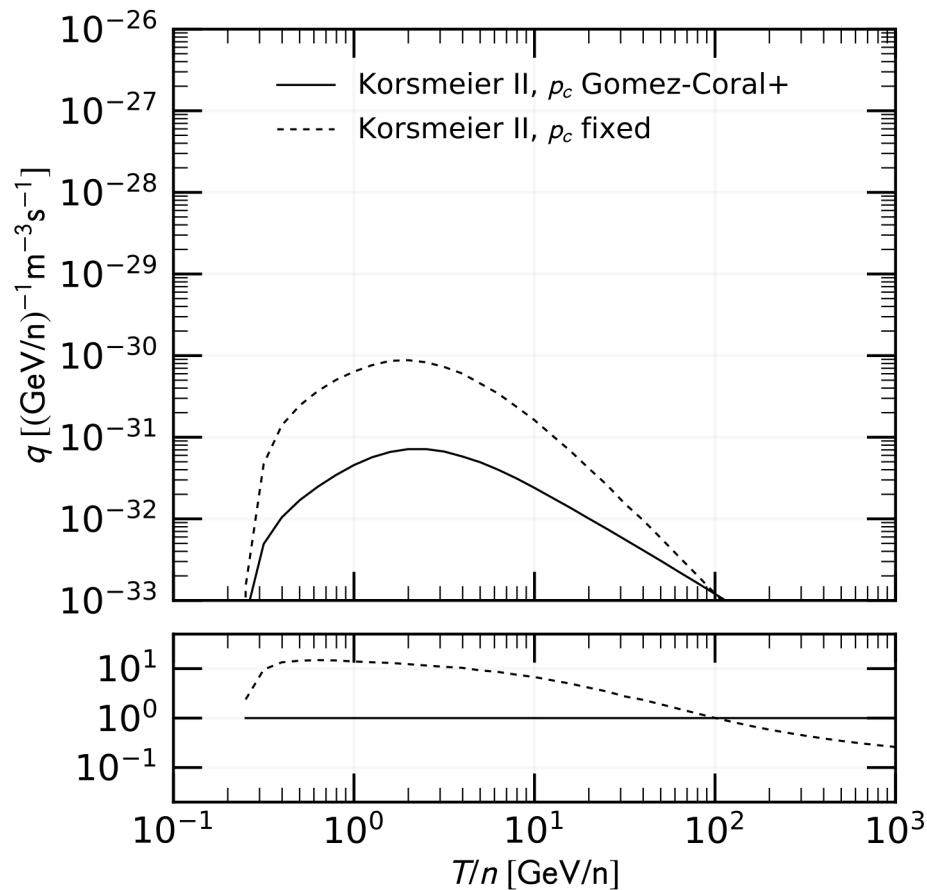
[Gomez-Coral, Rocha, Grabski, Datta,
von Doetinchem, Shukla; 2018]



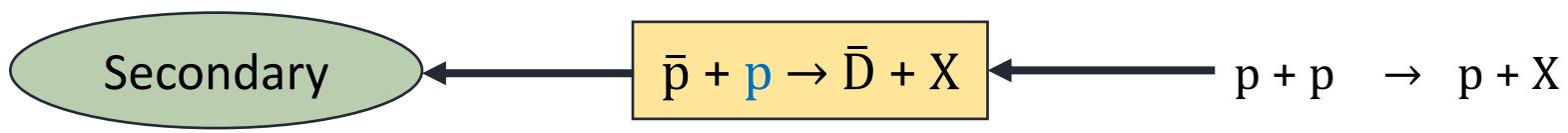
Cross section uncertainties for antideuteron



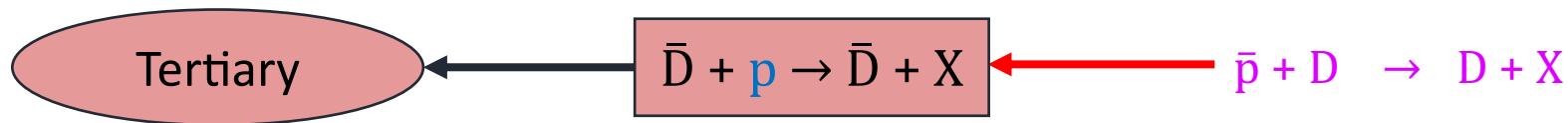
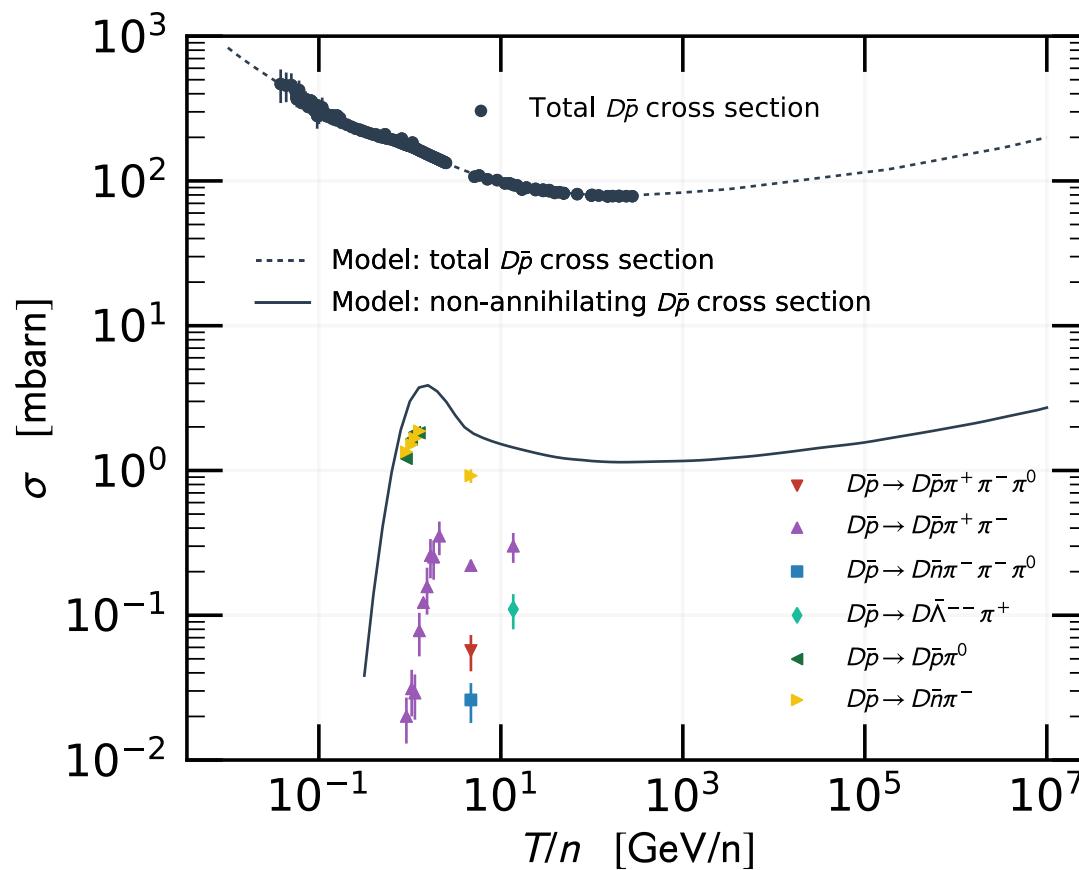
Cross section uncertainties for antideuteron



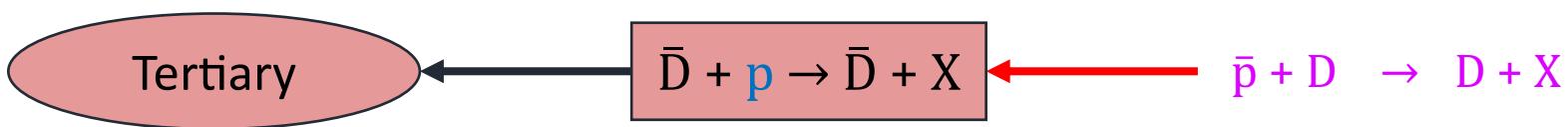
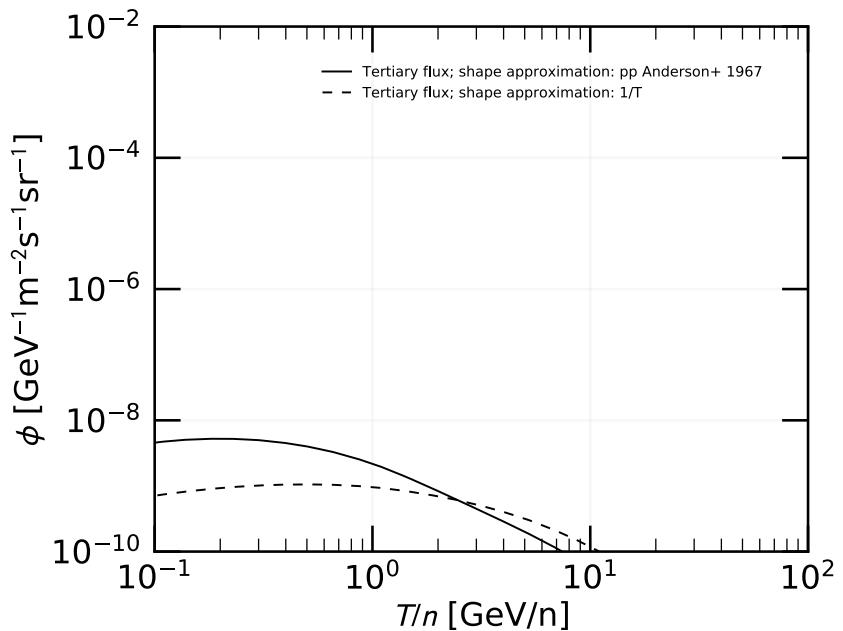
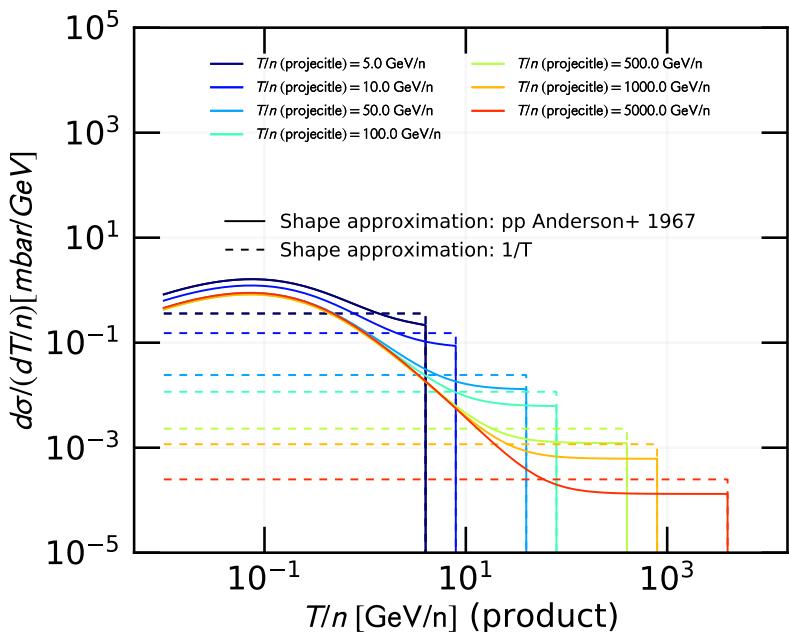
There is no direct measurement
of the cross section
→ It cannot be tuned to data



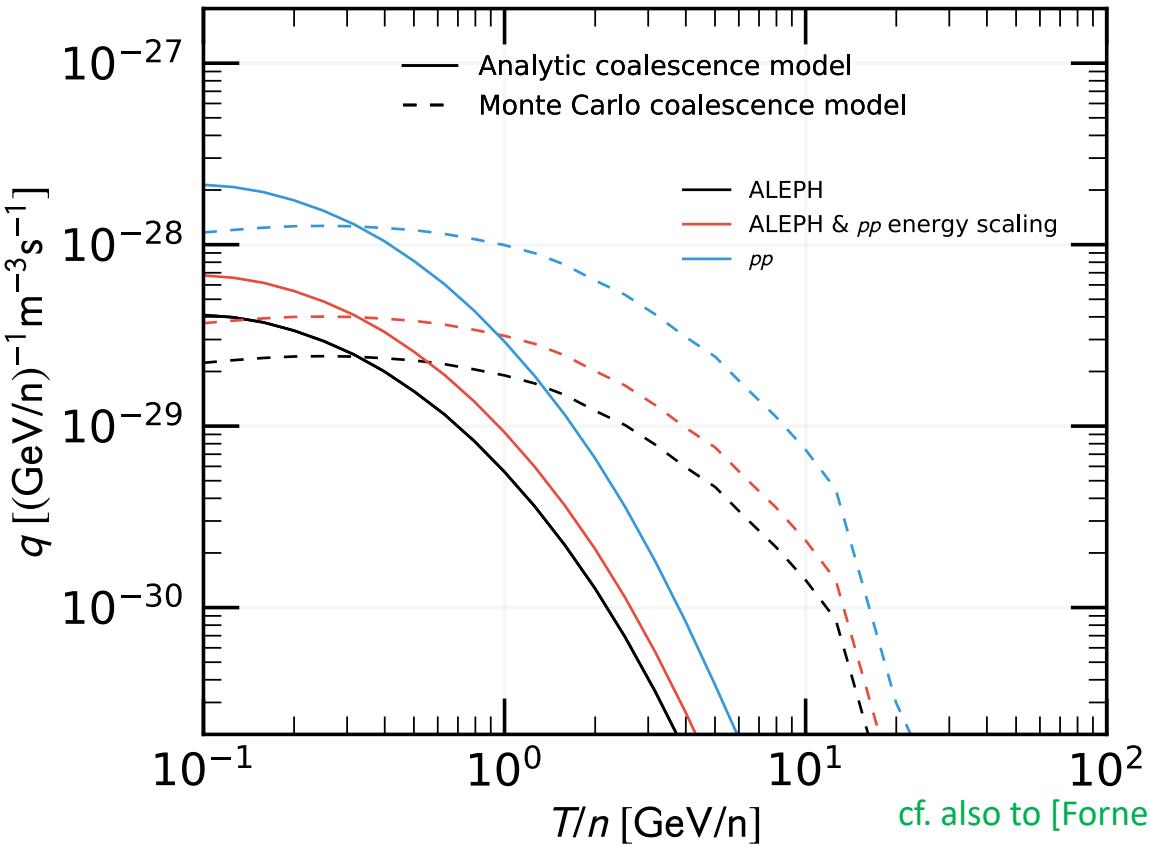
Cross section uncertainties for antideuteron



Cross section uncertainties for antideuteron

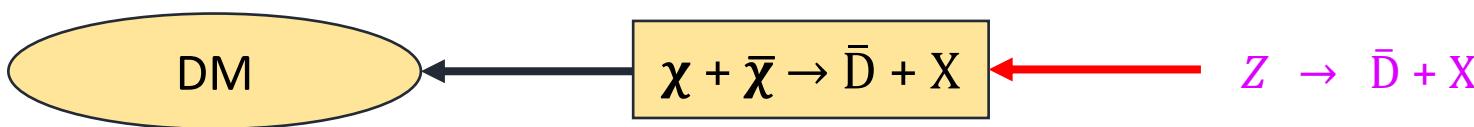


Coalescence uncertainties for DM antideuteron



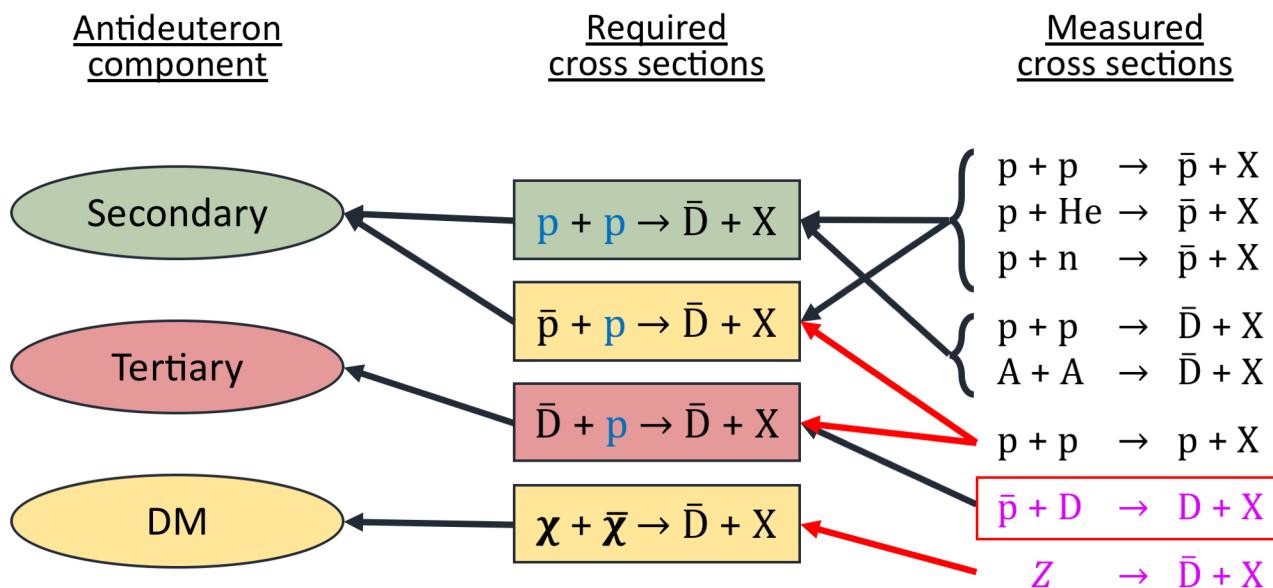
DM source term of a
• 100 GeV WIMP
• Thermal cross section
• $b\bar{b}$ final state
for different coalescence assumptions.

cf. also to [Fornengo, Macchione, Vittino; 2014]



Summary and conclusion

- Low-energy antideuterons are an important and complementary tool to search for DM in CRs
- Coalescence models are phenomenological and have uncertainties



Thank you for your attention!