

DARK MATTER SEARCHES WITH COSMIC ANTIHELUM

NICOLAO FORNENGO

Department of Theoretical Physics, University of Torino
and Istituto Nazionale di Fisica Nucleare (INFN) – Torino
Italy



fornengo@to.infn.it
nicolao.fornengo@unito.it

www.to.infn.it/~fornengo
www.astroparticle.to.infn.it



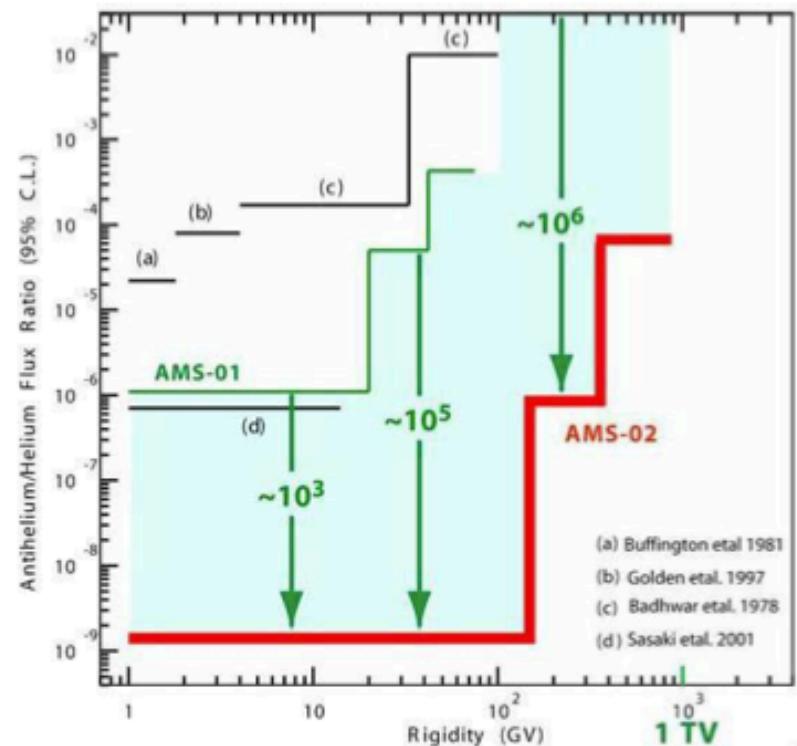
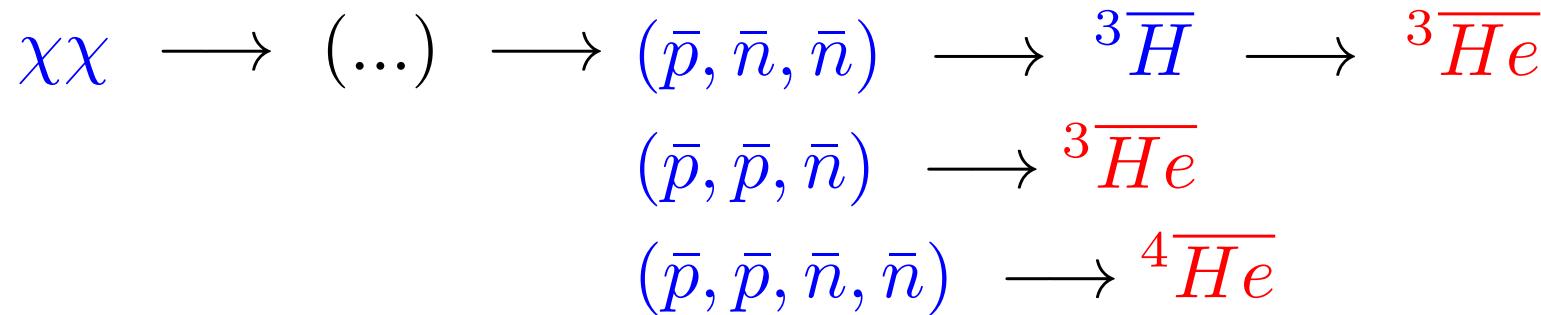
Antideuteron 2014
UCLA – 5.06.2014

- Cirelli, Fornengo, Taoso, Vittino
“*Anti-Helium from dark matter annihilation*”
arXiv:1401.4017

See also:

Carlson, Coogan, Linden, Profumo, Ibarra, Wild
“*Antihelium from dark matter*”
arXiv:1401.2461

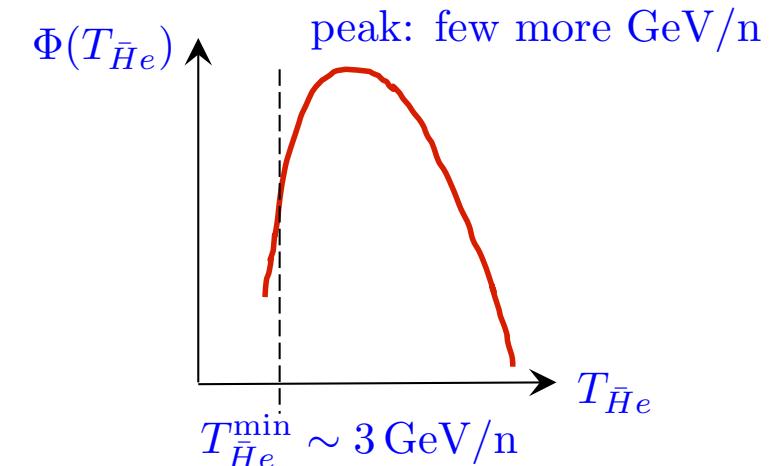
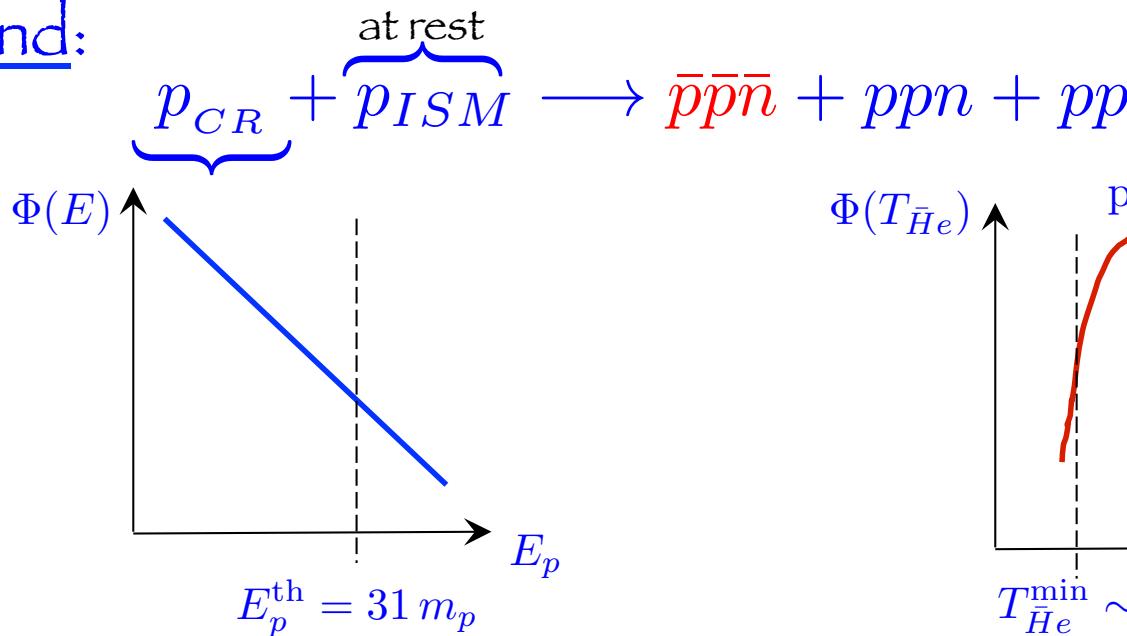
Anti ^3He



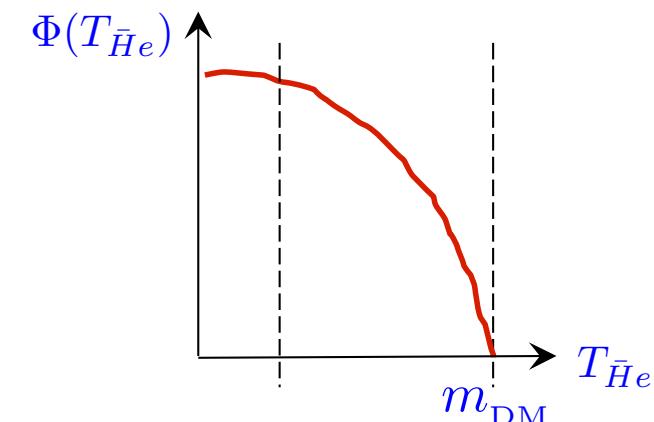
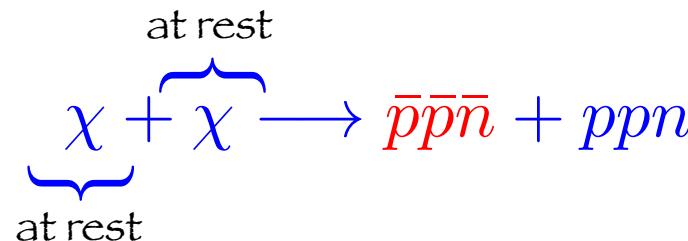
The low-energy window

The low-energy window is even more favorable than for antiD

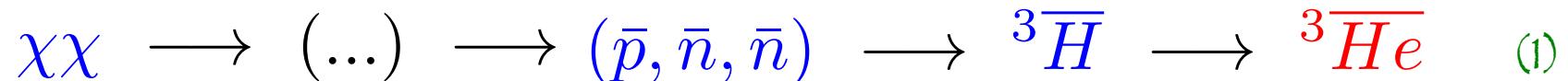
Background:



Signal:



Anti 3 Helium



(1) : Fast (half-life: 12 yr)

(2) : Suppressed by Coulomb repulsion of $\bar{p}\bar{p}$

(3) : For each additional nucleon : rate $\times O(10^{-4})$

$$\gamma_{\bar{A}} \frac{d^3 N_{\bar{A}}}{d^3 k_{\bar{A}}} = \left(\frac{4}{3} p_{\text{coal}}^3 \right)^{A-1} \left(\gamma_{\bar{p}} \frac{d^3 N_{\bar{p}}}{d^3 k_{\bar{p}}} \Big|_{k_{\bar{p}}=k_{\bar{A}}/A} \right)^A$$

Anti ${}^3\text{He}$



We consider only the Tritium channel

Conservative assumption: inclusion of the two additional channels
could increase the fluxes by at most a factor of 2

Coalescence process

- “MC model”: event-by-event coalescence

$$F_{(\bar{p}\bar{p}\bar{n})}(\sqrt{s}, \vec{k}_1, \vec{k}_2, \vec{k}_3) \longrightarrow F_{(\bar{p}\bar{p}\bar{n})}^{\text{MC}}(\sqrt{s}, \vec{k}_1, \vec{k}_2, \vec{k}_3)$$

$$\Delta_{ij} = |\vec{k}_i - \vec{k}_j| < p_0 \quad i, j = 1, 2, 3 \quad [i \neq j]$$

$$L_{ij} = |\vec{r}_i - \vec{r}_j| < R_\star \quad i, j = 1, 2, 3 \quad [i \neq j] \quad (*)$$

(*) : Too time consuming for the MC with such rare events:
equivalent to switch off the decays of long-lived particles

Tuning of the model

- Experimental data on the anti-He (or anti-tritium) production are extremely scarce
- They refer to proton-nucleus or heavy-ions collisions (dynamics different from DM annihilation)
- Adopted same coalescence momentum as for antiD

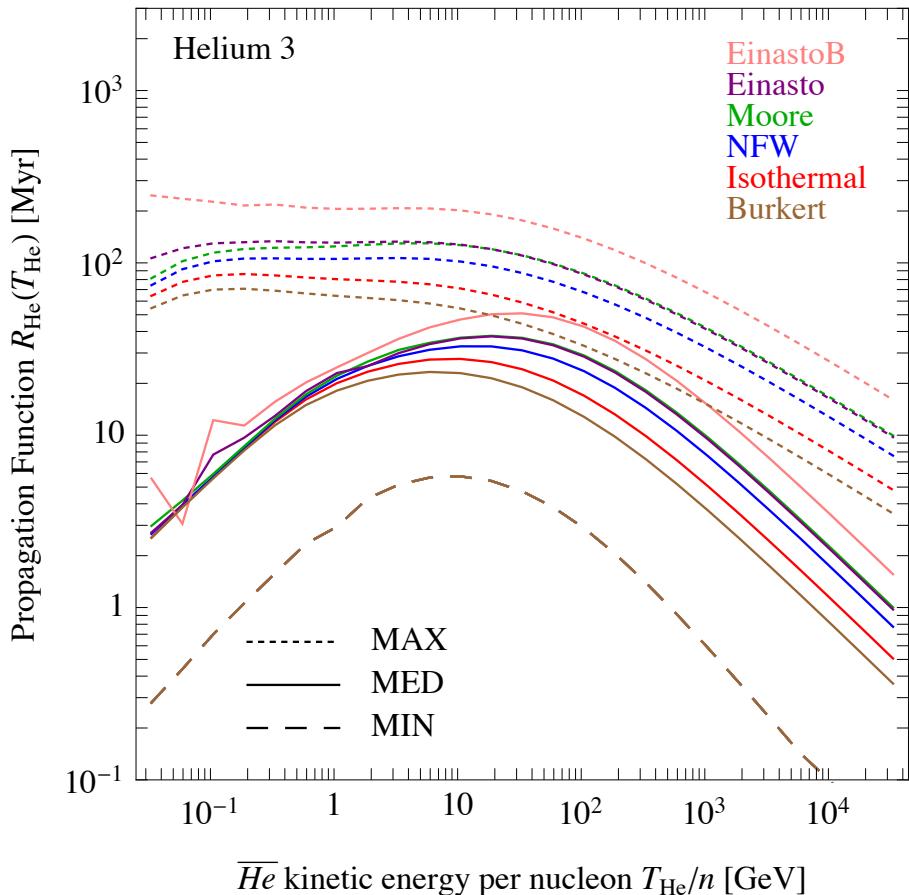
$$p_0 = 195 \text{ MeV}$$

Transport in the galactic medium



$$\Phi(E) = \frac{\beta}{4\pi} \left(\frac{\rho_\odot}{m_\chi} \right)^2 R(E) \frac{1}{2} \langle \sigma v \rangle \frac{dN}{dE}$$

| | δ | K_0 (kpc ² /Myr) | L (kpc) | V_c (km/s) |
|-----|----------|-------------------------------|-----------|--------------|
| MIN | 0.85 | 0.0016 | 1 | 13.5 |
| MED | 0.70 | 0.0112 | 4 | 12 |
| MAX | 0.46 | 0.0765 | 15 | 5 |



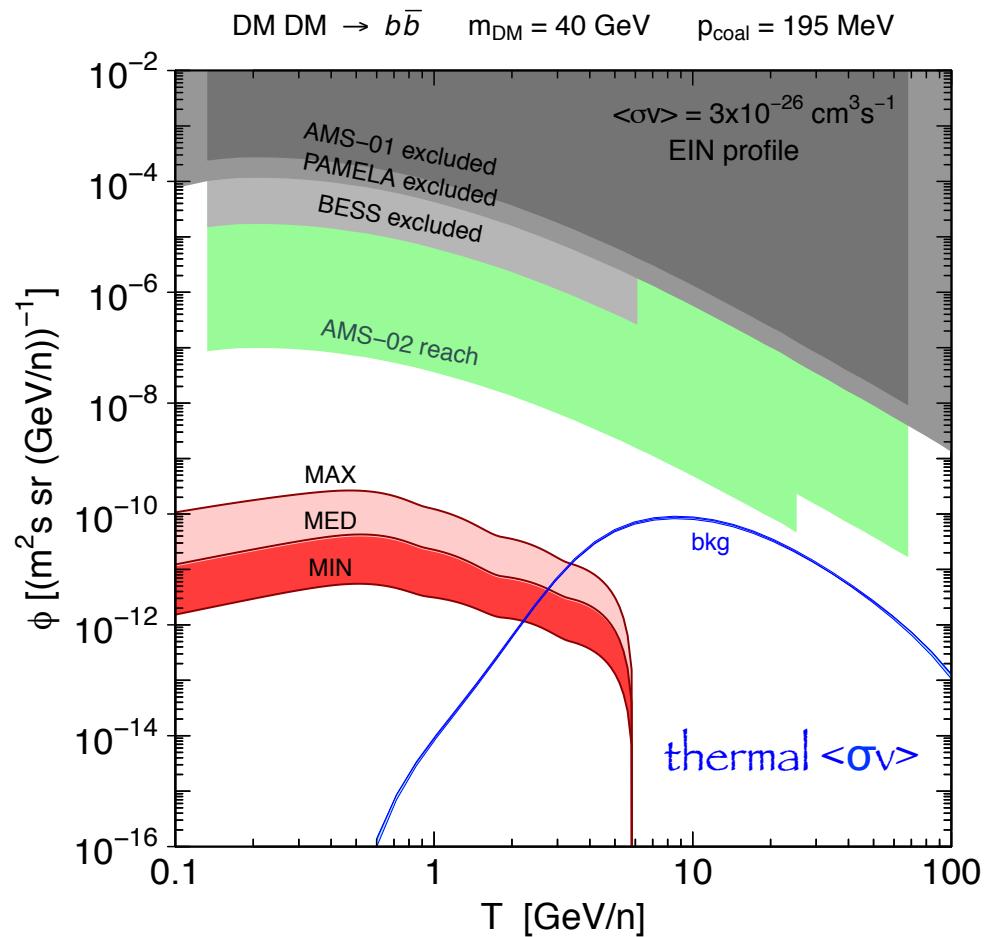
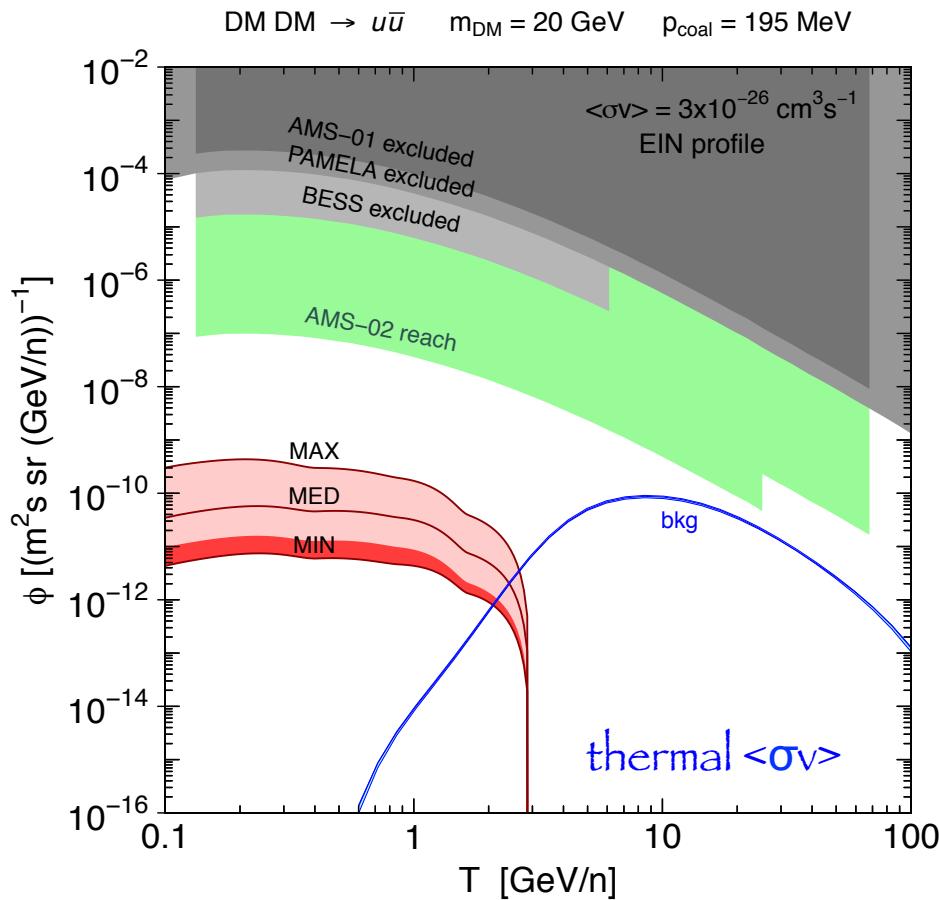
Transport in the heliosphere



CR transport in the heliosphere treated with a
“force-field” approximation

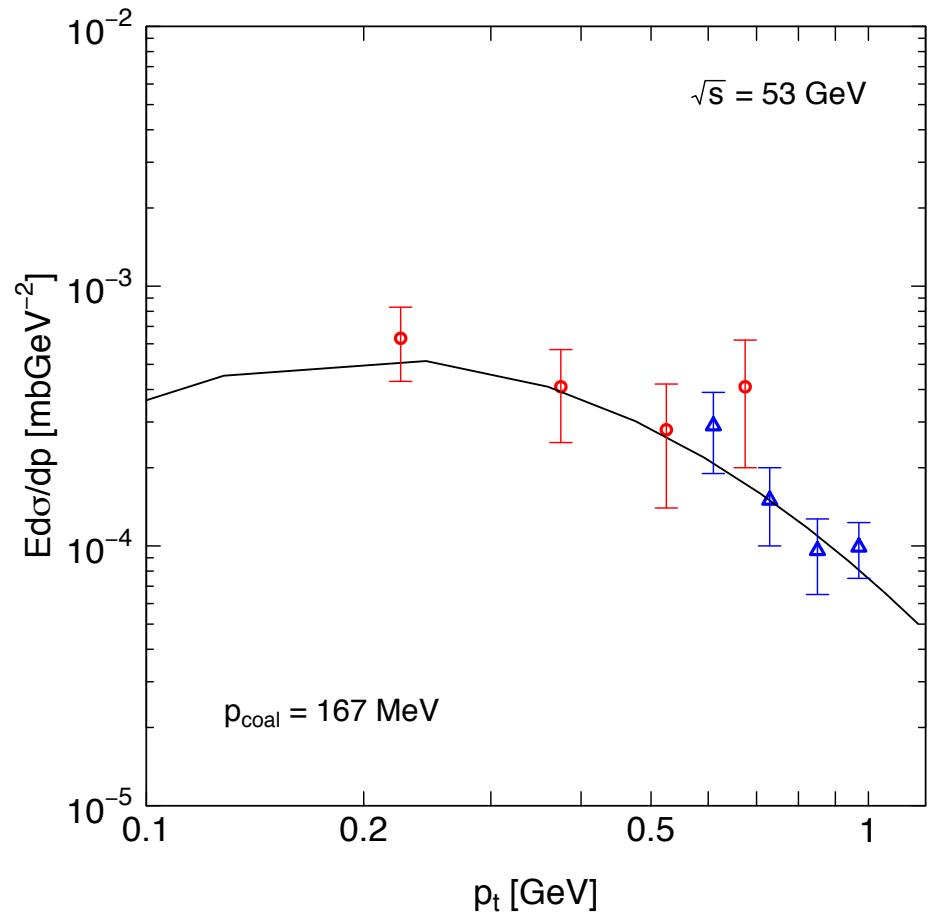
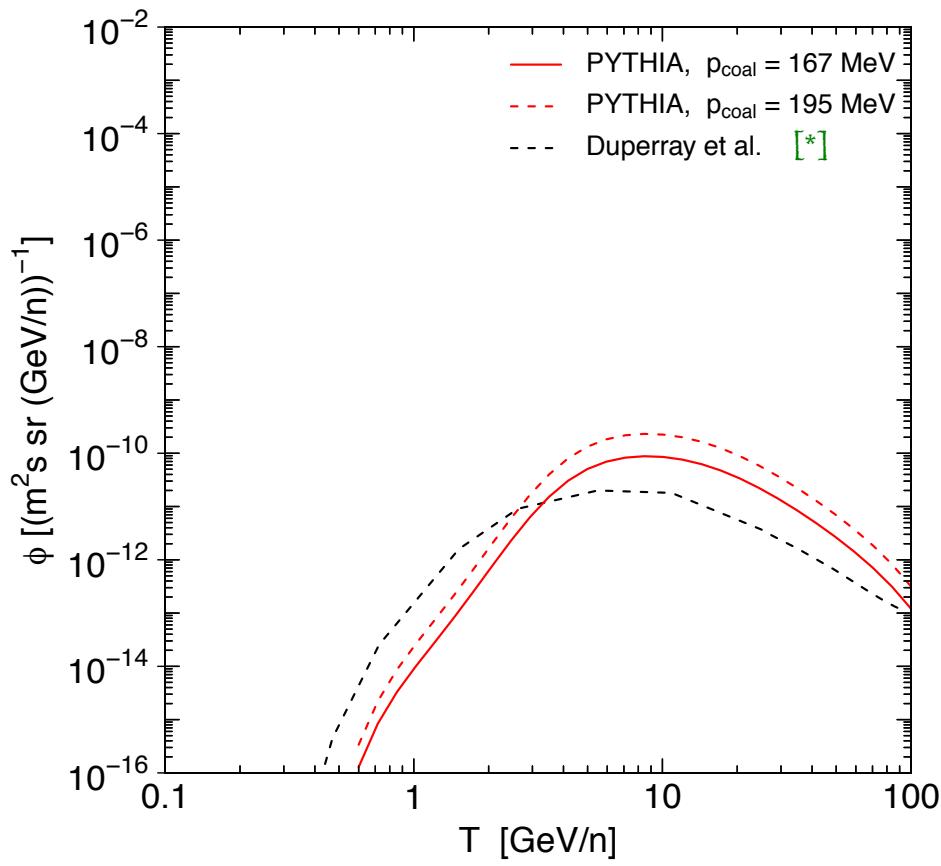
$$\frac{\Phi_{\bar{p}}(T_{\bar{p}})}{p_{\bar{p}}^2} = \frac{\Phi_{\bar{p}}(\hat{T}_{\bar{p}})}{\hat{p}_{\bar{p}}^2}$$
$$T_{\bar{p}} = \hat{T}_{\bar{p}} + \Delta$$
$$\Delta = 500 \text{ MV}$$

Anti ^3He



Light red: DM configurations disfavoured by antiproton bounds

Anti ^3He background

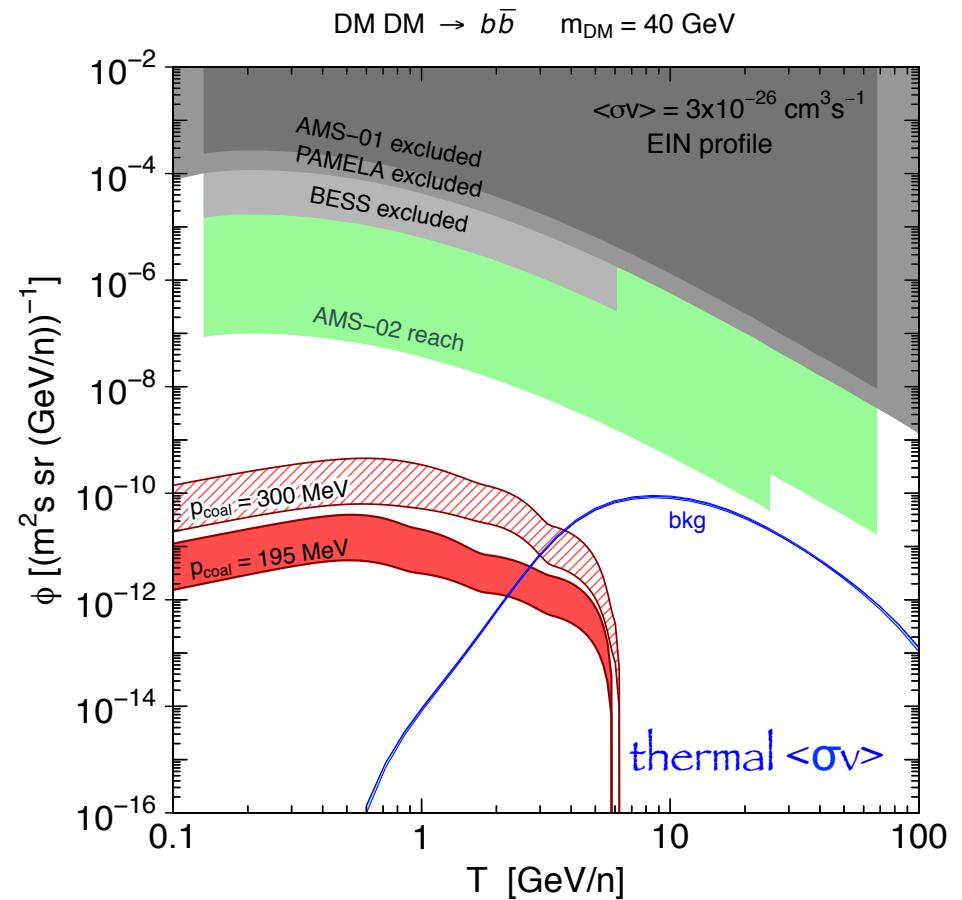
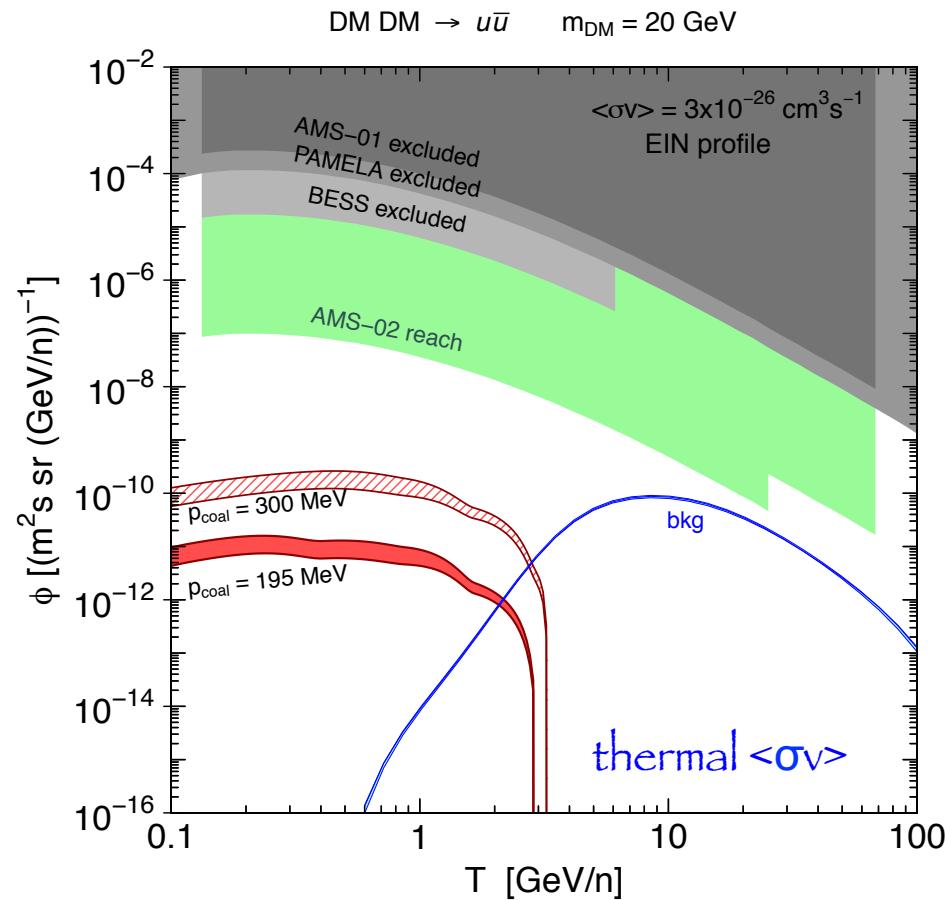


$p_0^{\text{back}} = 167 \text{ MeV}$ (from antiD analysis on ISR data)

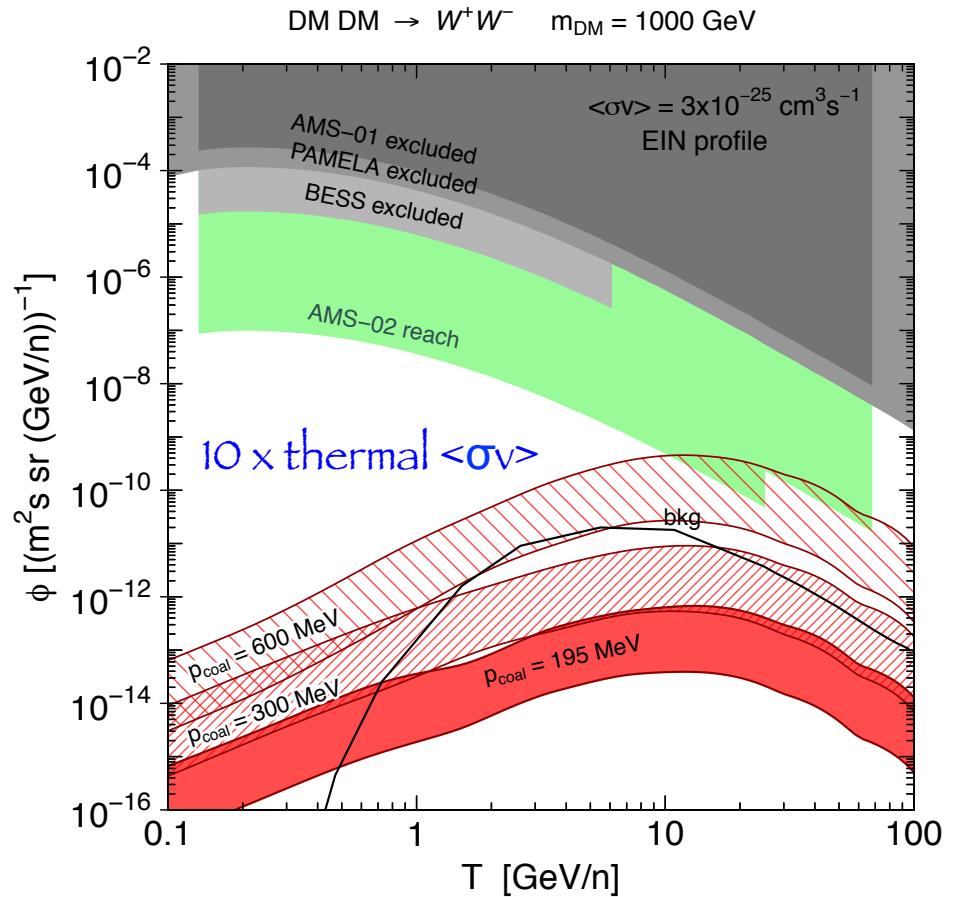
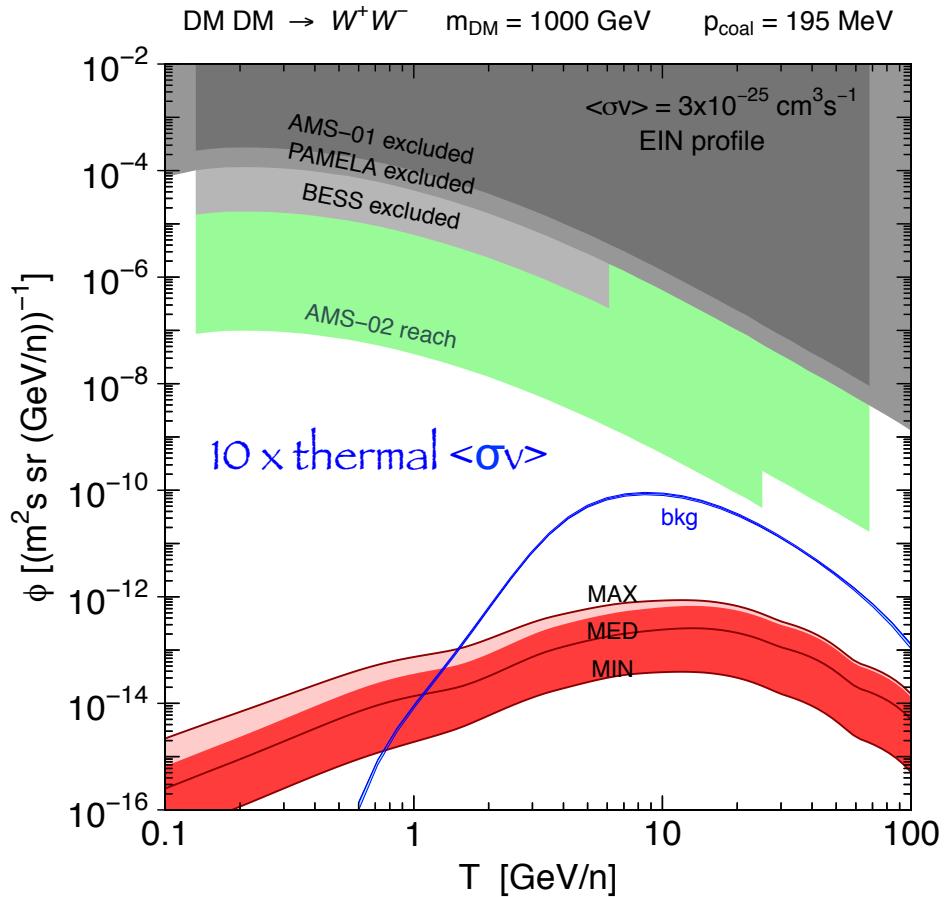
Cirelli, Fornengo, Taoso, Vittino, submitted for publication

[*] Duperray et al., PRD 71 (2005) 083013

Anti ^3He

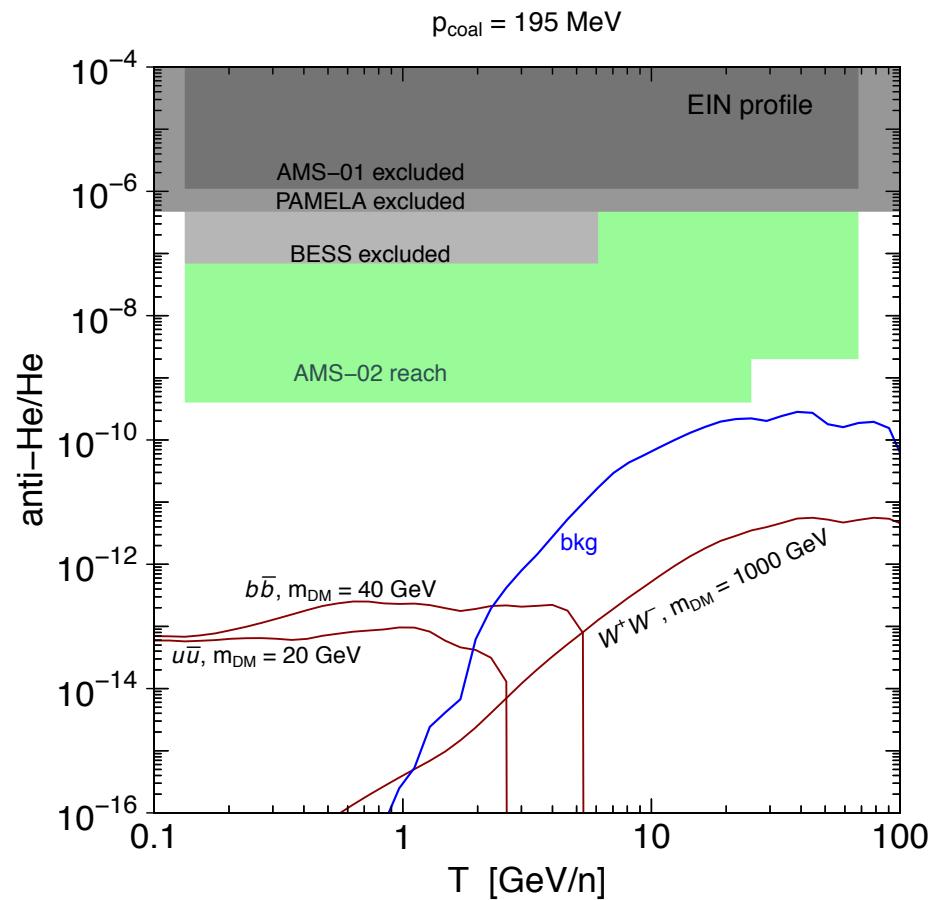


Anti ^3He

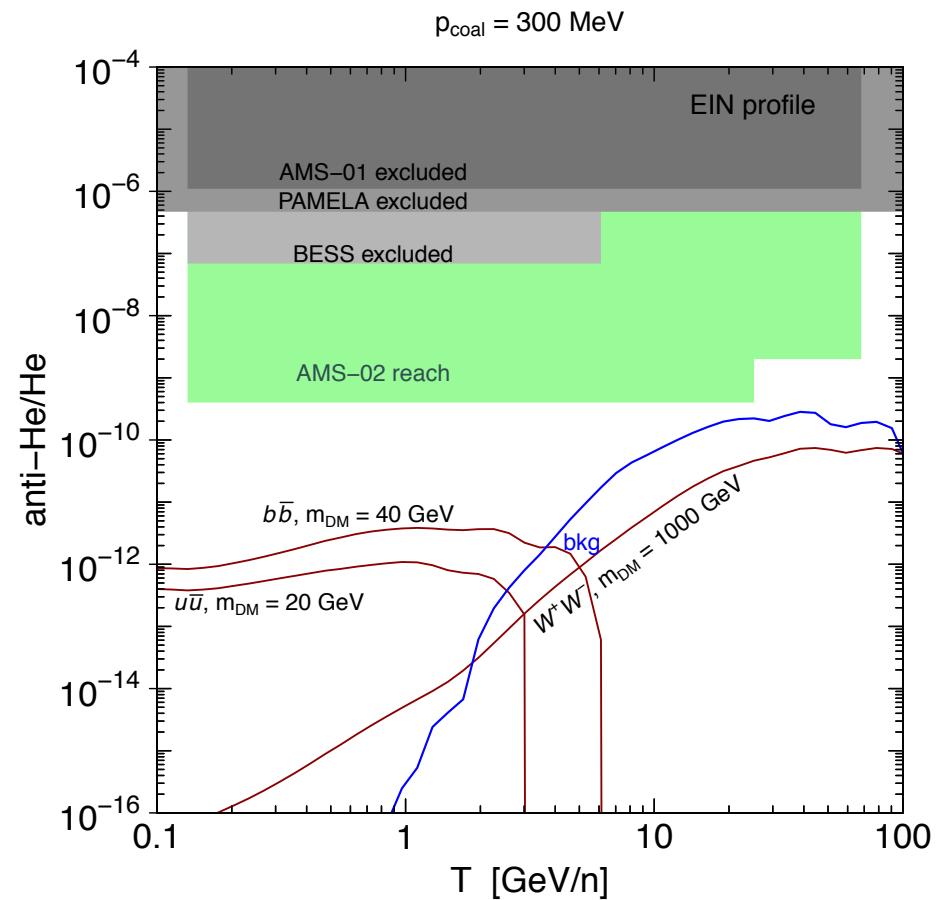


Light red: DM configurations disfavoured by antiproton bounds

Anti ^3He / ^3He ratios



$p_0 \approx 195 \text{ MeV}$



$p_0 \approx 300 \text{ MeV}$

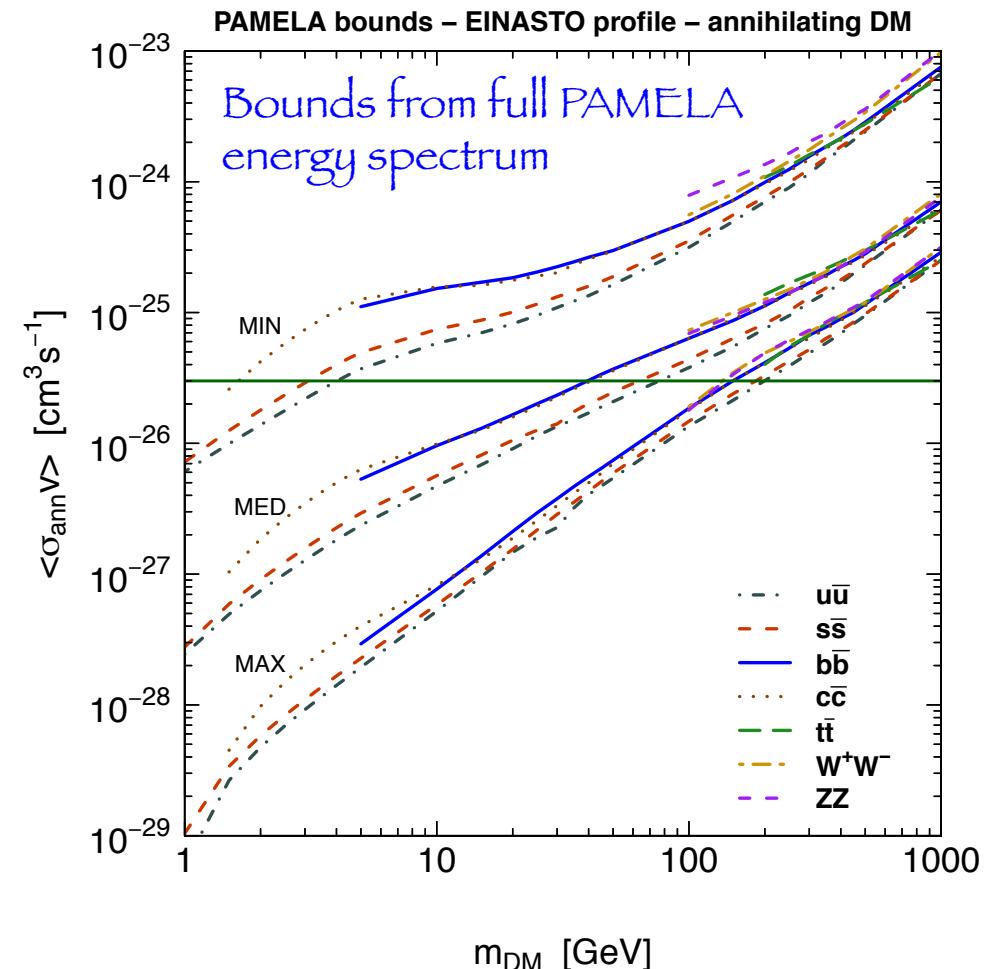
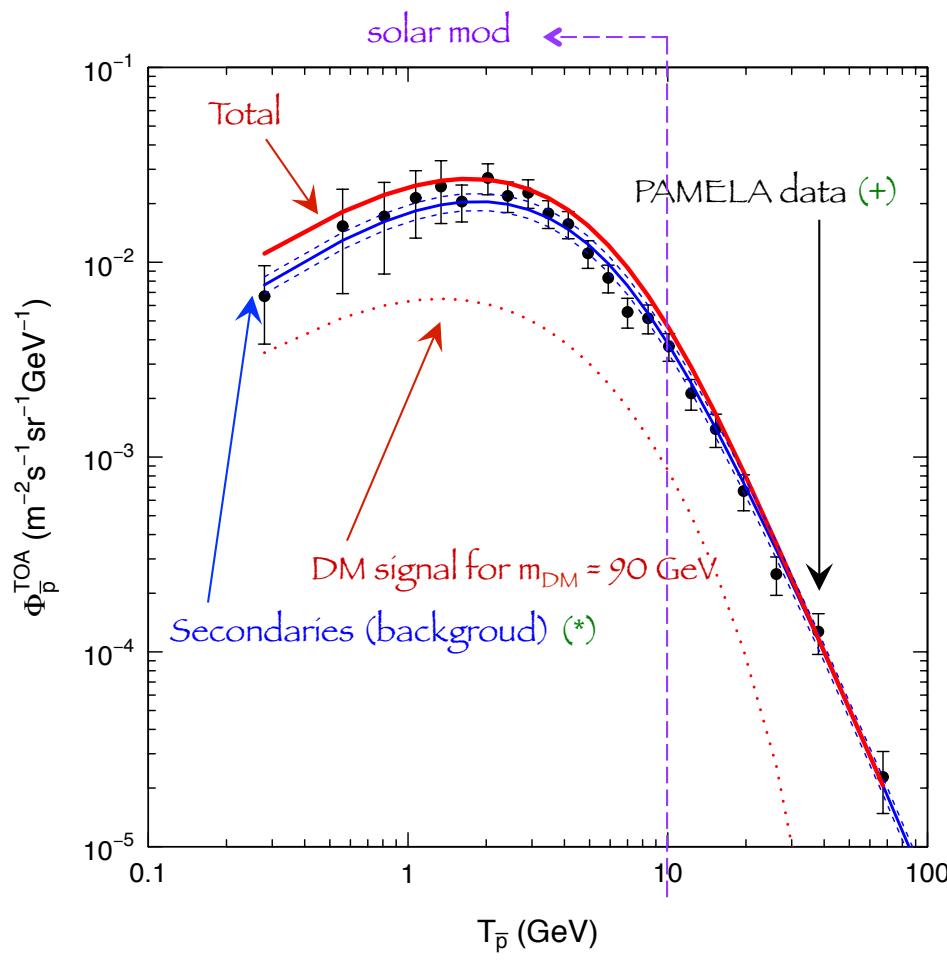
Conclusions

- AntiHelium

- At low kinetic energies the S/B ratio is even larger than antiD
 - Prospects for signal detection limited by extremely low statistic
 - If antiD are detected, antiHe might allow signal cross-verification, but only with improved detector sensitivities

Backup Slides

Antiprotons



(*) Donato, Maurin, Brun, Delahaye, Salati, PRL 102 (2009) 071301
 (+) Adriani et al. (PAMELA Collab.), PRL 105 (2010) 121101

Fornengo, Maccione, Vittino, JCAP 09 (2013) 031

Caveat: the bounds are reported (as is usual) under the hypothesis that the DM candidate is the dominant DM component, regardless of its thermal properties in the early Universe