Antiprotons et anti-deuterons : mesures et interprétations

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“La physique d'AMS : enjeux et perspectives scientifiques“

LAPP, Annecy-le-Vieux 10.03.2010

2-zone Semi-analytic Diffusive Model

Maurin, Donato, Taillet, Salati ApJ 2001; Maurin, Taillet, Donato A&A 2002

TALKS BY D.MAURIN & A.PUTZE

+All the effects included ($V_A \neq 0$ & $V_C \neq 0$)

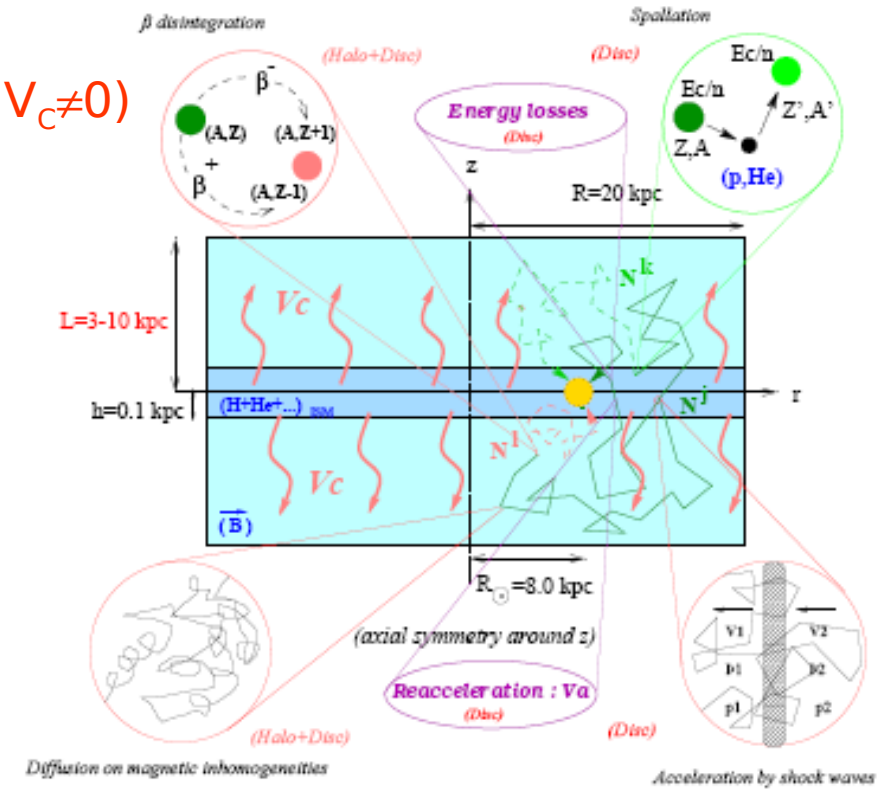
+2D semi-analytic

+ Local Bubble for radioactives

- ISM constant

-V_C constant througout the halo

- V_A in the disk



- Diffusion coefficient $K(R)=K_0 \beta R^{\delta}$
- Convective velocity V_c
- Alfven velocity V_A
- Diffusive halo thickness L
- Acceleration spectrum $Q(E)=p^{\alpha}$

K_0, δ, V_c, V_A, L, (α)

Systematic scan
of parameter space
Evaluation of uncertainties

ANTIPROTONS IN COSMIC RAYS

Donato, Maurin, Salati, Barrau, Boudoul, Taillet, et al, ApJ 2002
. ApJ (2001); Bergström, Edsjö, Ullio, ApJ (1999);
Bieber et al. PRL (1999); Moskalenko et al., ApJ (2002); Donato, Maurin, Brun, Delahaye, Salati PRL2009

Measured fluxes

$P_{CR} + H_{ISM}$

$P_{CR} + He_{ISM}$

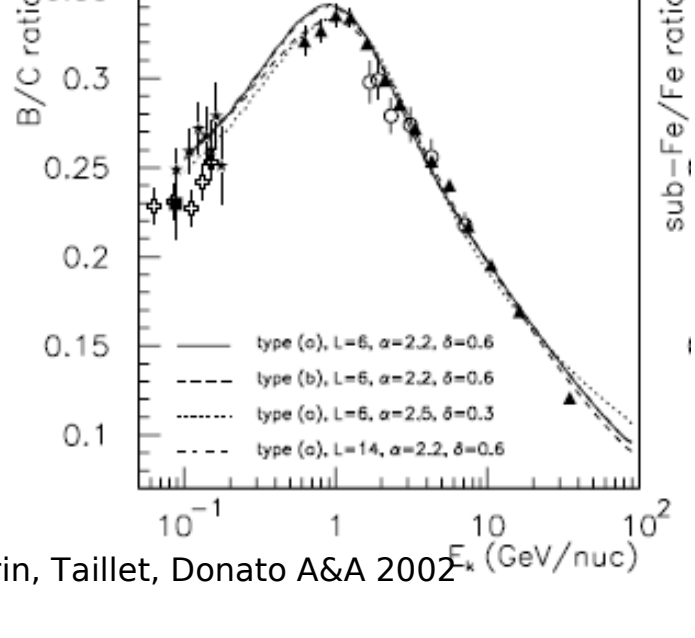
$\alpha_{CR} + H_{ISM}$

$\alpha_{CR} + He_{ISM}$

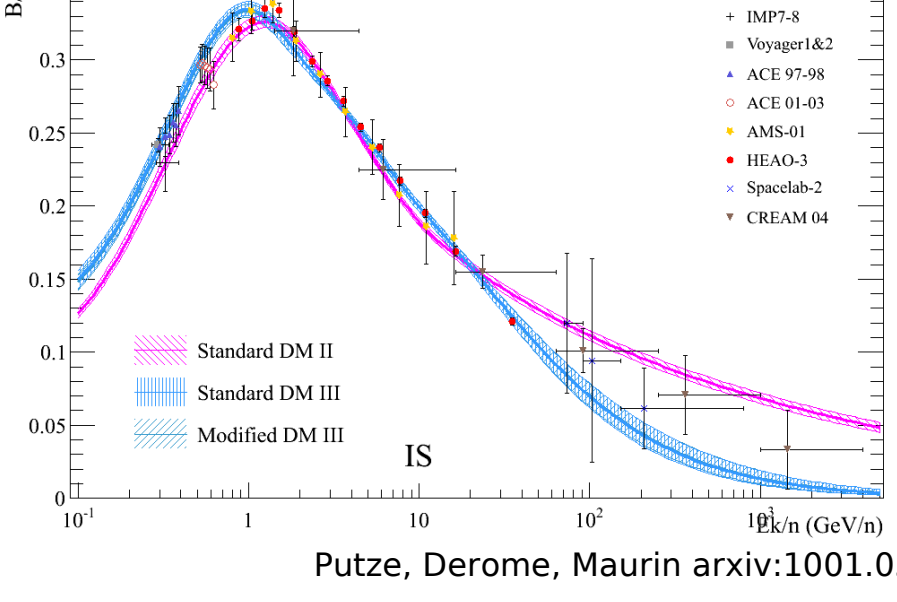
⇒ p- + X → Diffusion

Nuclear cross sections

Diffusion model tested on B/C



Maurin, Taillet, Donato A&A 2002



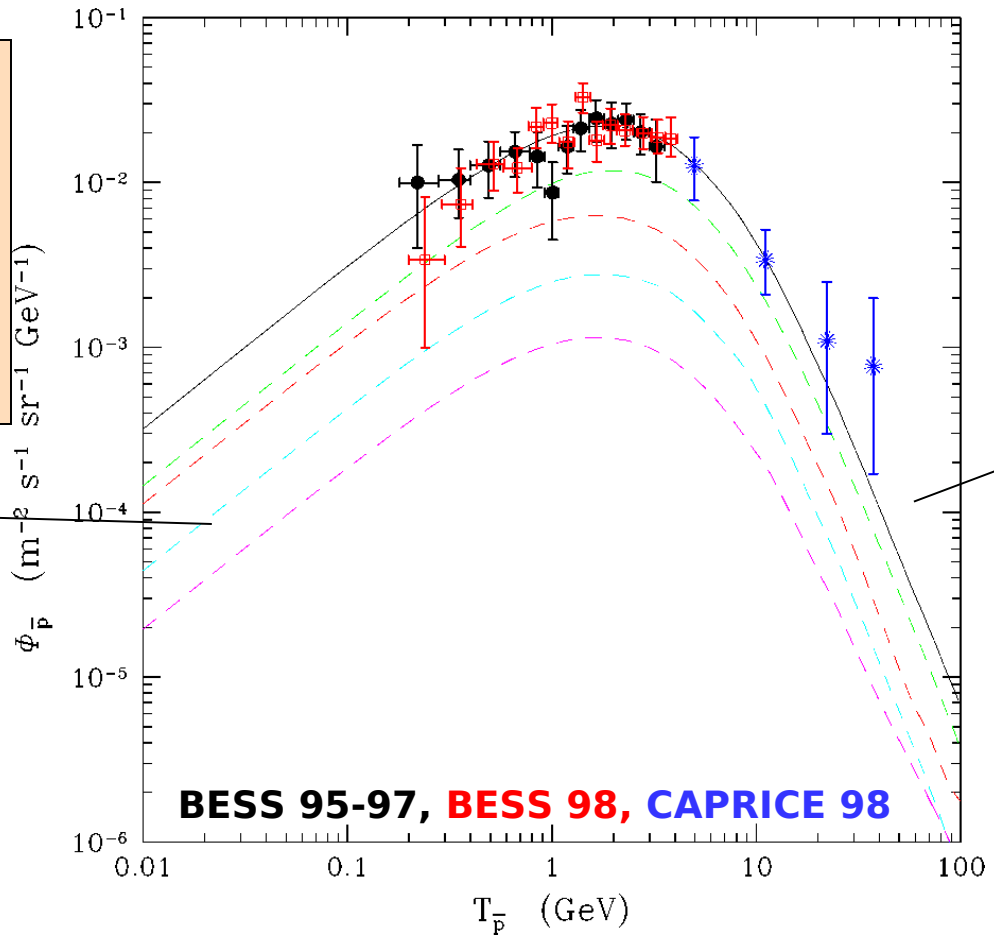
Putze, Derome, Maurin arxiv:1001.0551

SECONDARY ANTIPROTON FLUX and DATA

Donato, Maurin, Salati, Barrau, Boudoul, Taillet, et al, ApJ 2002

CR – target

p - H
p - He
He - H
He - He

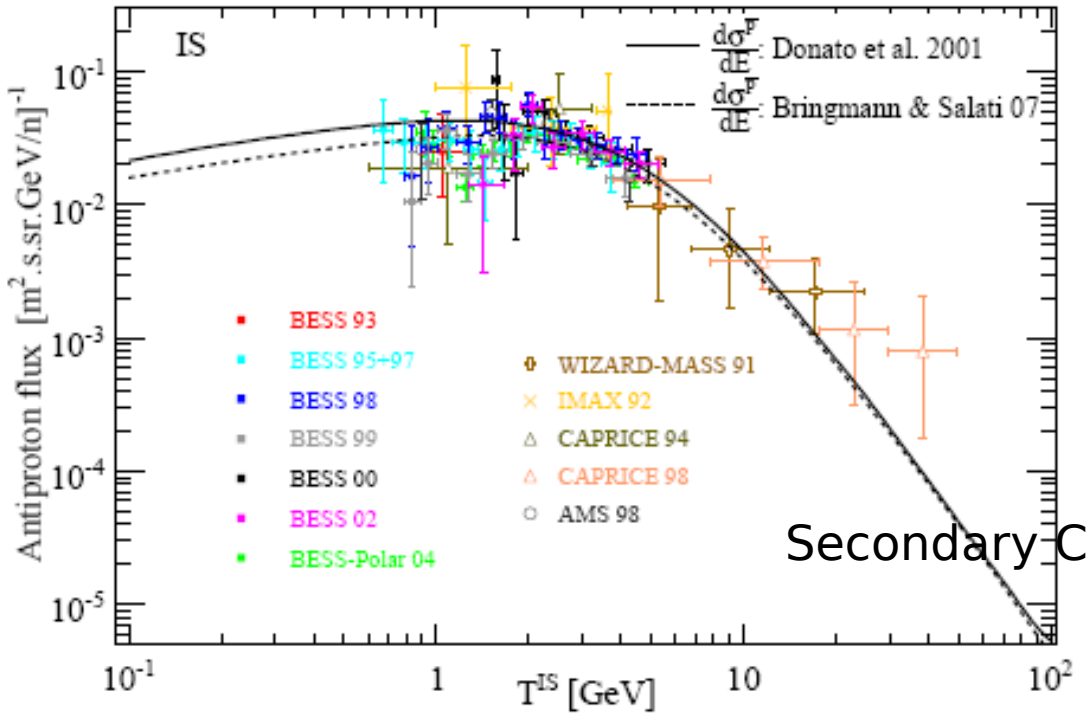


Total flux

N.B. Propagation parameters: B/C best fit

Antiprotons data

Donato, Maurin, Brun, Delahaye, Salati PRL 2009



Secondary CR production

Demodulated data cover ~ 0.7 ÷40 GeV

All experiments from **ballons** (residual atmosphere) except **AMS98**

Pamela: preliminary data 3-10 GeV, and expected in 0.08 ÷ 190 GeV

Antiprotons From Relic Dark Matter particles

Donato, Fornengo,Maurin,Salati,Taillet, PRD (2004), Bottino, Donato, Fornengo, Salati PRD (1998)
Bergström, Edsjö, Ullio ApJ (1999)

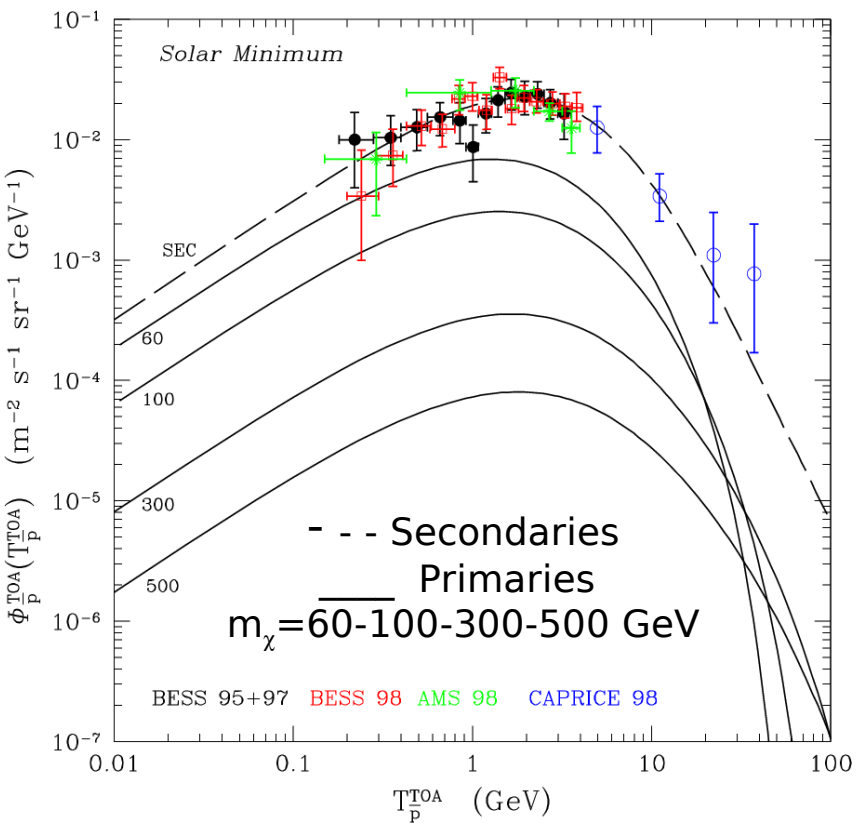
Source:

$$q_{\bar{p}}^{susy}(E_{\bar{p}}) = < \sigma_{ann} v > g(E_{\bar{p}}) \left\{ \frac{\rho_\chi(r,z)}{m_\chi} \right\}^2$$

Annihilation cross section

Production spectrum

χNumber density



Production takes place everywhere in the halo!!

Solutions (still analytical in the 2D model) different from secondaries

Antiproton/proton: data, models, exotic tips

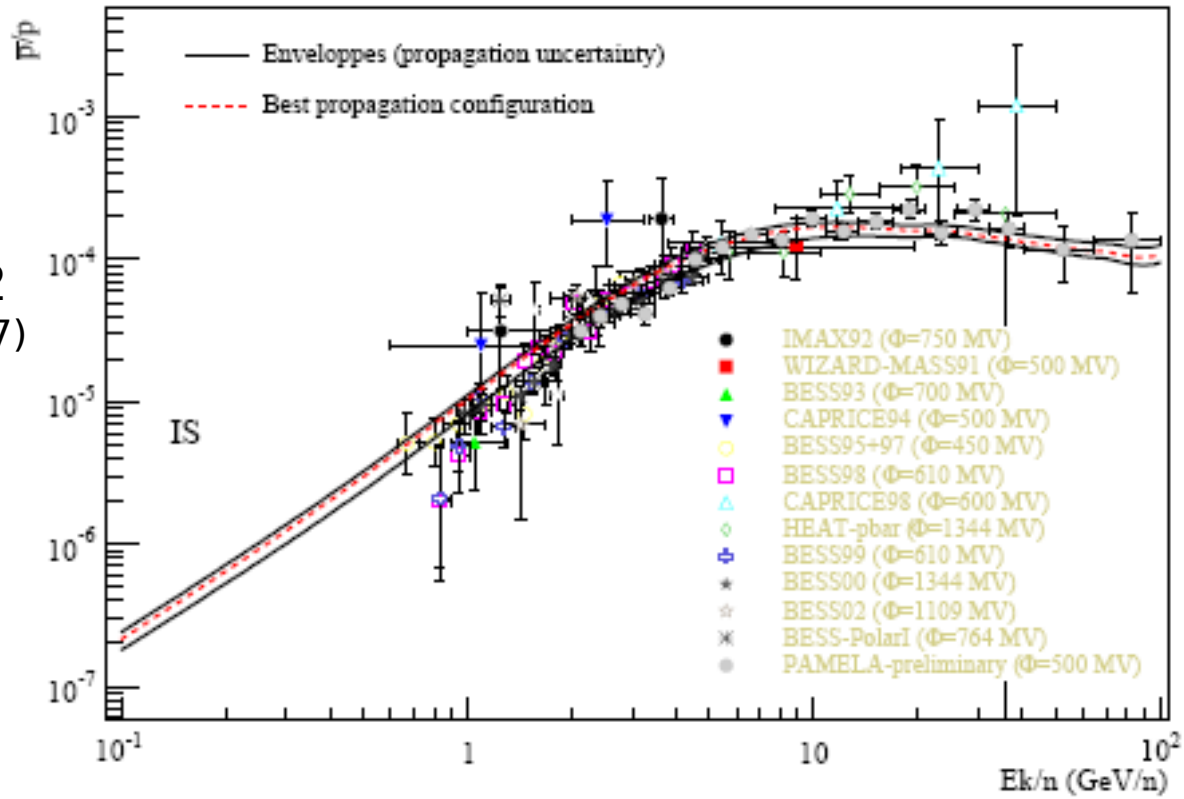
Theoretical calculations with the semi-analytical DM, compatible with stable and radioactive nuclei

Donato, Maurin, Brun, Delahaye, Salati PRL 2009

PROTON flux:
$\Phi = A\beta^{-P1}R^{-P2}$

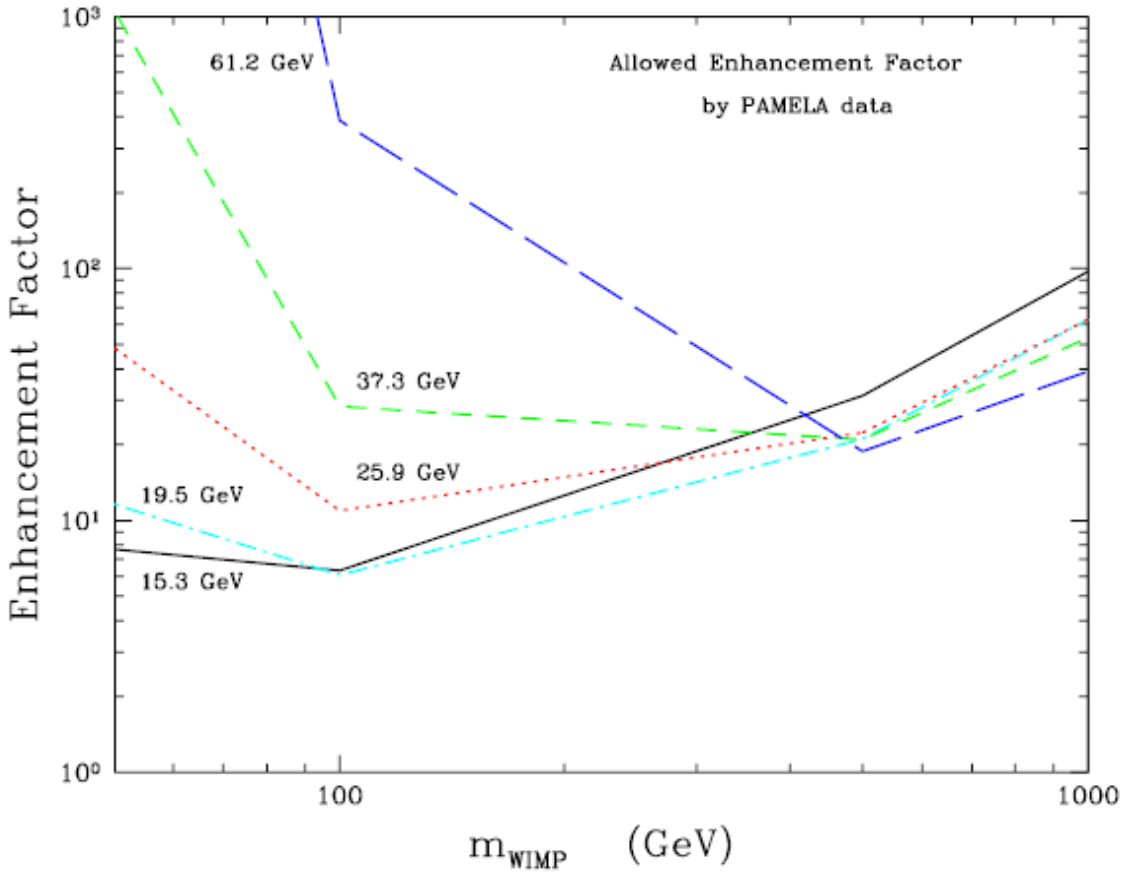
•T<20 GeV: Bess 1997-2002
(Shikaze et al. Astropart. Phys. 2007)

•T>20 GeV, our fit (Bess98, BessTeV&AMS):
{24132; 0; **2.84**}



NO need for new phenomena (astrophysical / particle physics)

Allowed Enhancement factors from pbar data



Limits obtained for:

- $\langle\sigma v\rangle = 3\cdot 10^{-26}$ cm^3/s
- MED prop parameters
- Cored Isoth DM
- $\rho = 0.3$ GeV/cm^3
- 2σ error bars, T>10 GeV

Boost < 6-20-40 for m=0.1-0.5-1 TeV

Limits get weaker for increasing masses

Antideuteron Flux From Astrophysical Processes

- Proton and helium cosmic fluxes; antiproton calculated fluxes
- Production and non-ann (tertiary) cross sections
- Nuclear fusion: coalescence model, one parameter P_{coal} = 79 MeV
  the flux depends on $(P_{coal})^3$
- Propagation in the MW from source to the Earth:
  2-zones semi-analytic diffusion model
- Solar modulation: force field approximation
  ϕ= 0.5 MV for solar minimum

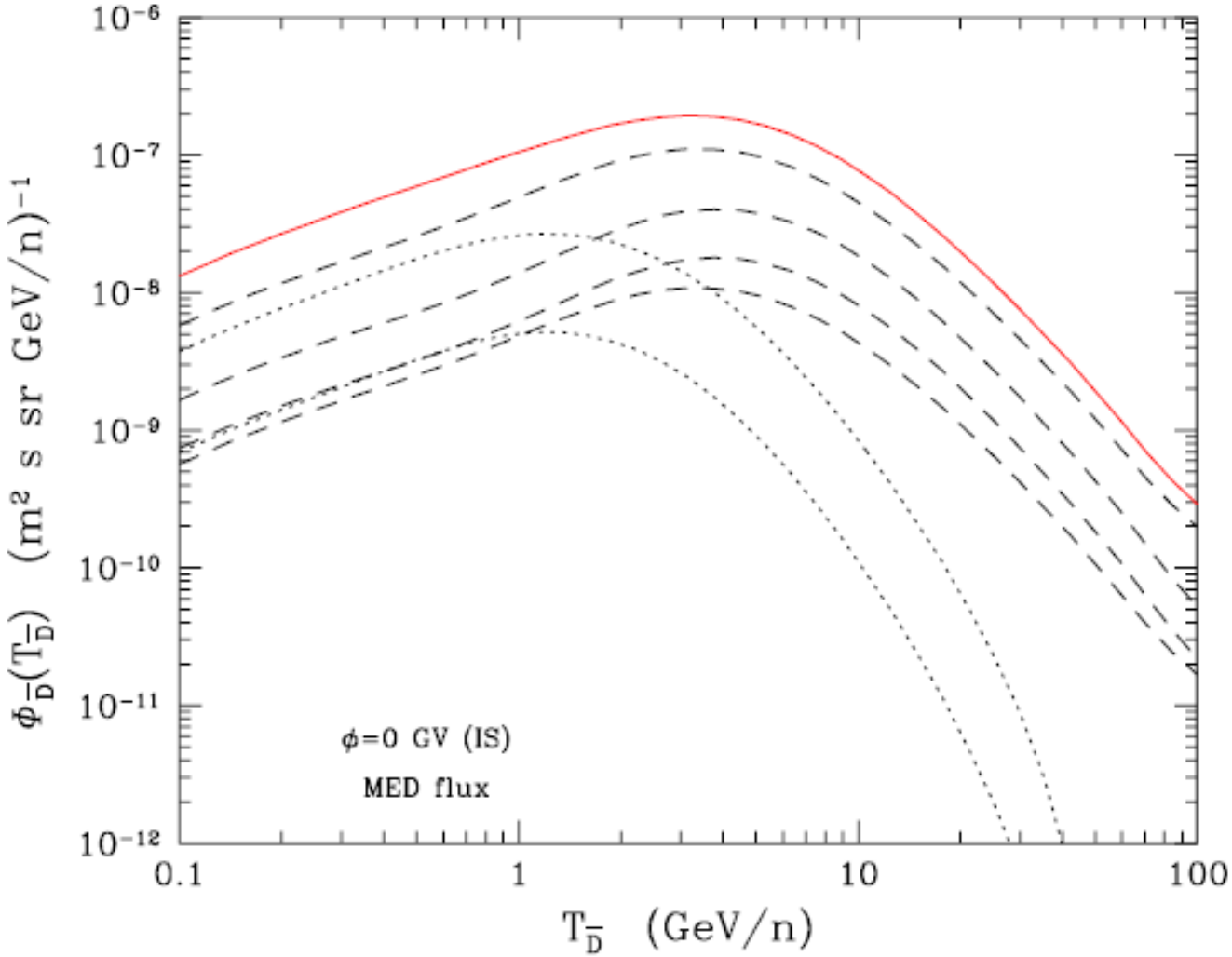
Secondary antideuterons

Donato, Fornengo, Maurin arXiv:0803.2460, PRD in press

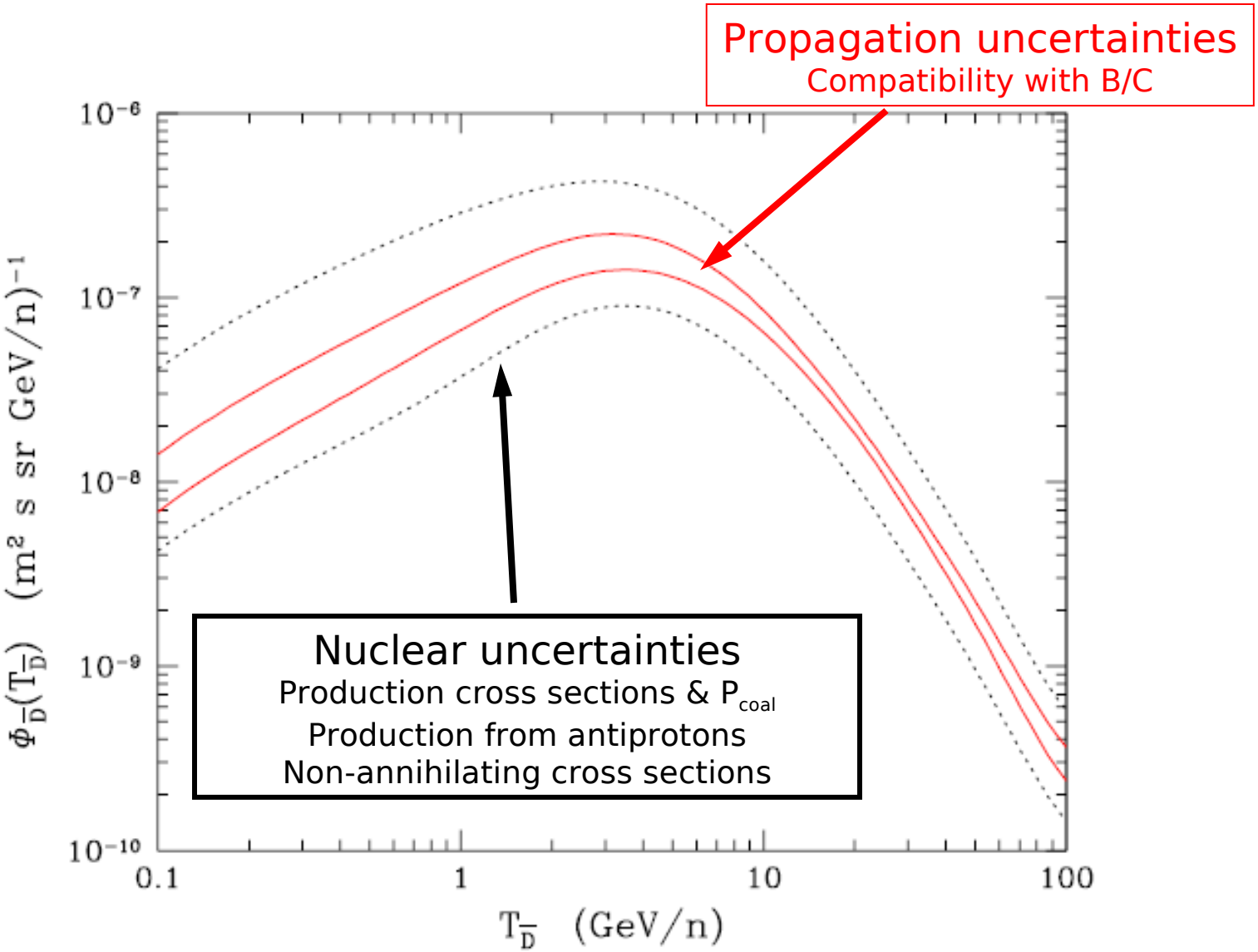
Contributions to Secondaries

p-p
p-He
He-H
He-He

$\bar{p}$ -H
$\bar{p}$- He

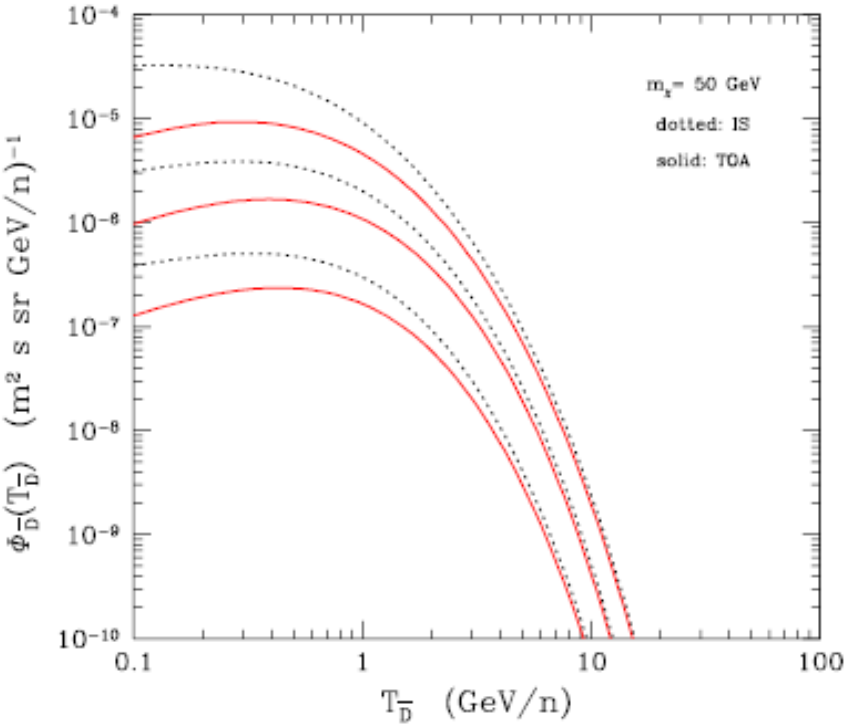


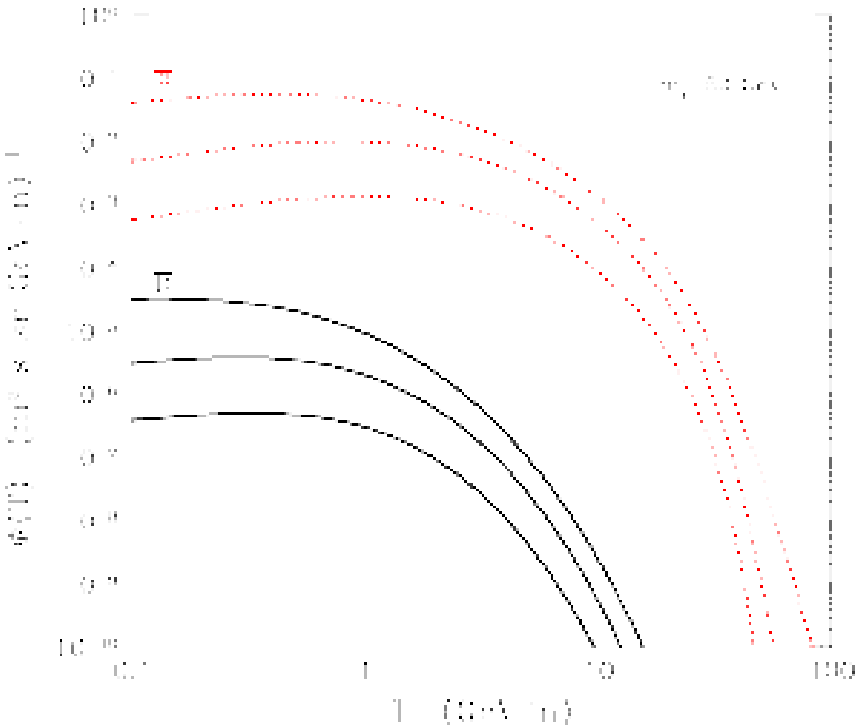
Secondary Antideuterons



Antideuterons from DM Annihilations

Donato, Fornengo, Maurin PRD 2008; Donato, Fornengo, Salati PRD 2000



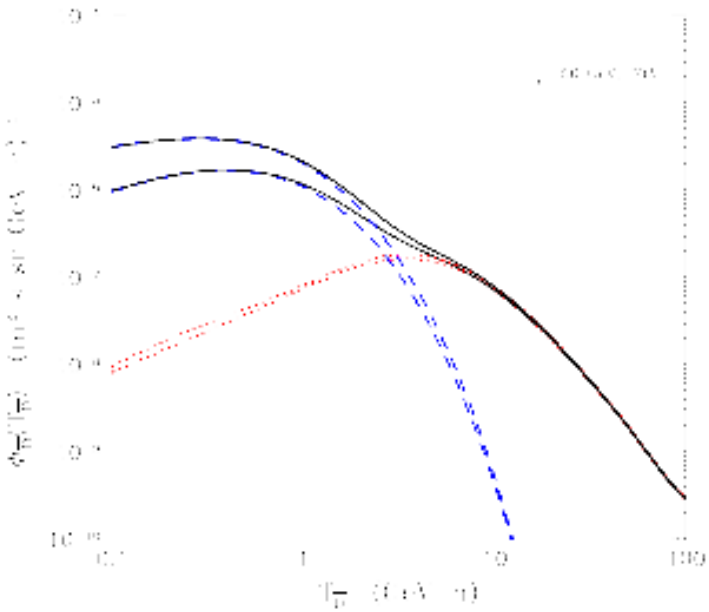


Propagation uncertainties driven by L
At lower energies, also effect from V_C

Antiprotons & Antideuterons
Propagation Uncertainties

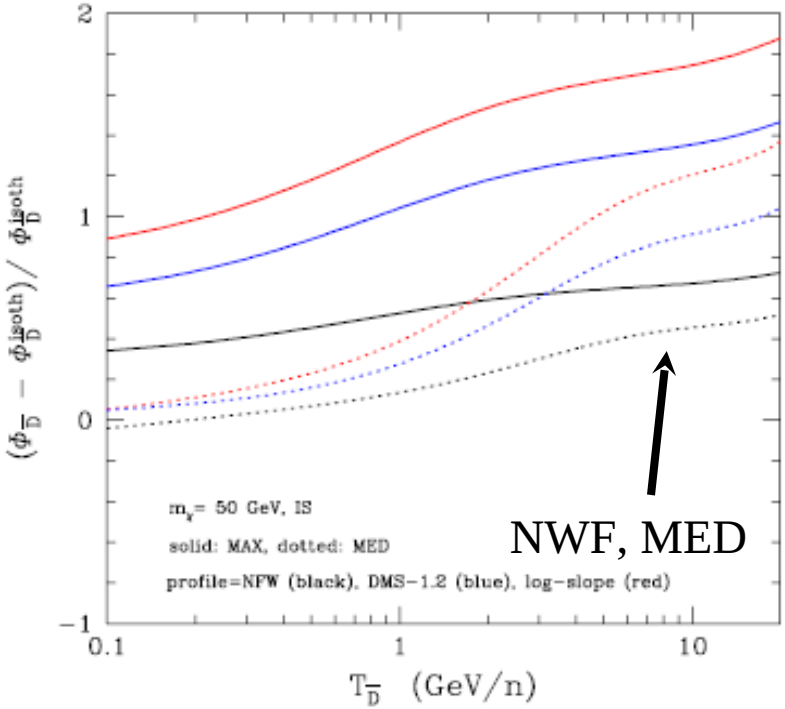
PRIMARY & SECONDARY ANTIDEUTERONS in a 2-zones diffusion model

(Donato, Fornengo, Maurin, arXiv:0308.2460)



Secondary Primary Total

B/C best fit (L=4 kpc)
InterStellar (upper) &
solar minimum



Effect of different DM distribution functions

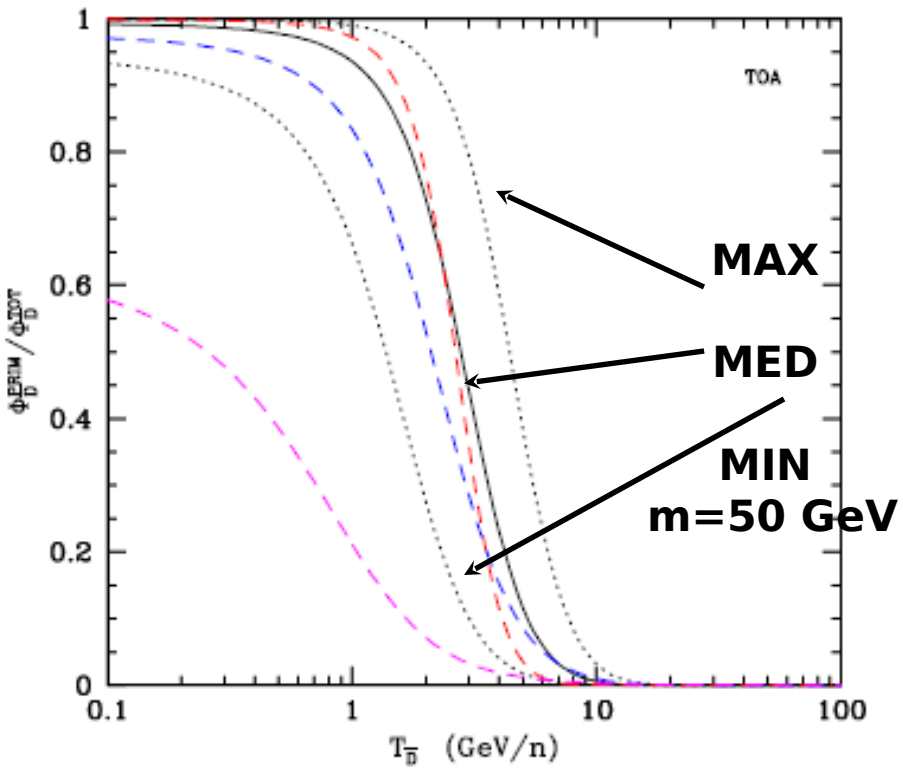
Antideuteron Signal-to-Background

Dashed: MED

m=10

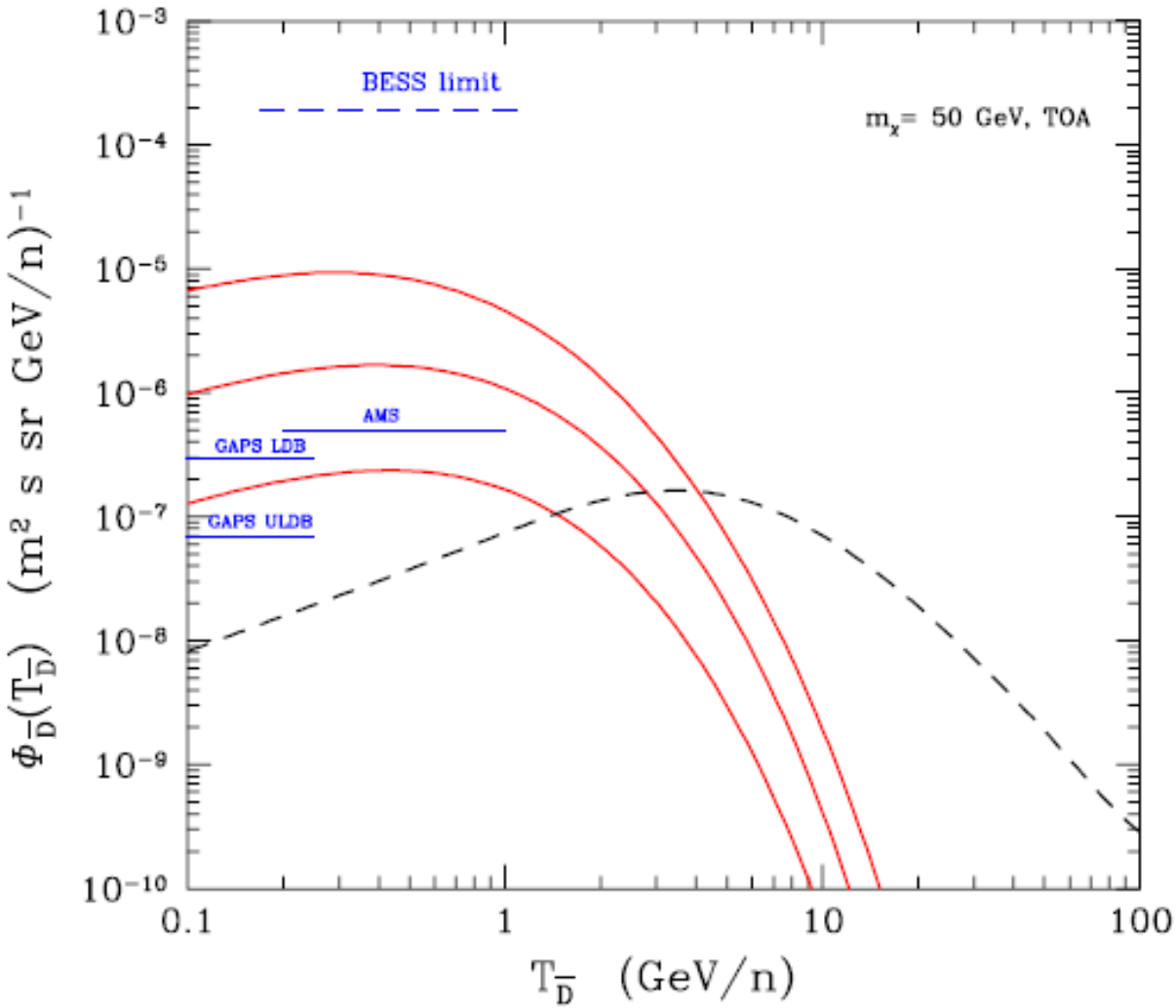
m=100

m=500



Low energy antideuterons have a high discrimination power

ANTIDEUTERONS & future experiments



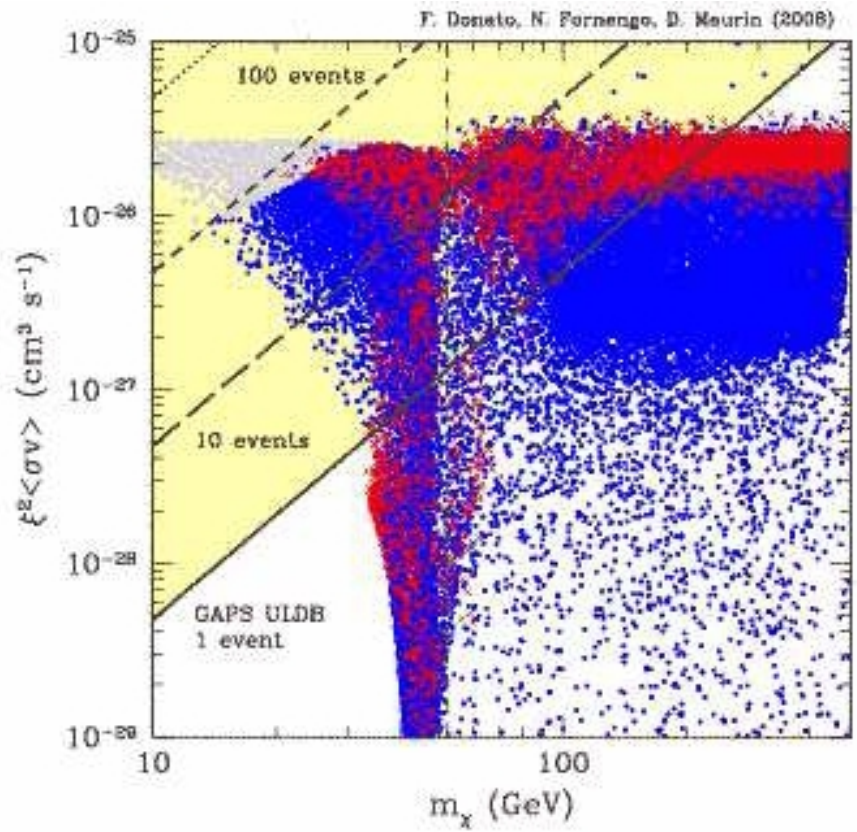
effMSSM neutralino dark matter can be detected by means of next generation space instruments measuring

MSSM Inspections with Antideuterons

GAPS ULDB reach

Median propagation Parameters

Red: dominant neutralinos
Blue: sub-dominant neutralinos



What do we expect/need from AMS-02?

- Energy (i.e light nuclei from tens of MeV/n up to 0.5 TeV/n)

- Variety
  - Absolute fluxes for p, He, CNO; LiBeB…
  - Radioactive isotopes energy *spectrum*
  - B/C, Be/C from 0.1 GeV/n up to 3-400 GeV/n
  - Lepton absolute fluxes

- Precision i.e. small uncertainties also at ~ 100 GeV/n

- Originality antideuteron discovery!