Constraints from antiproton data

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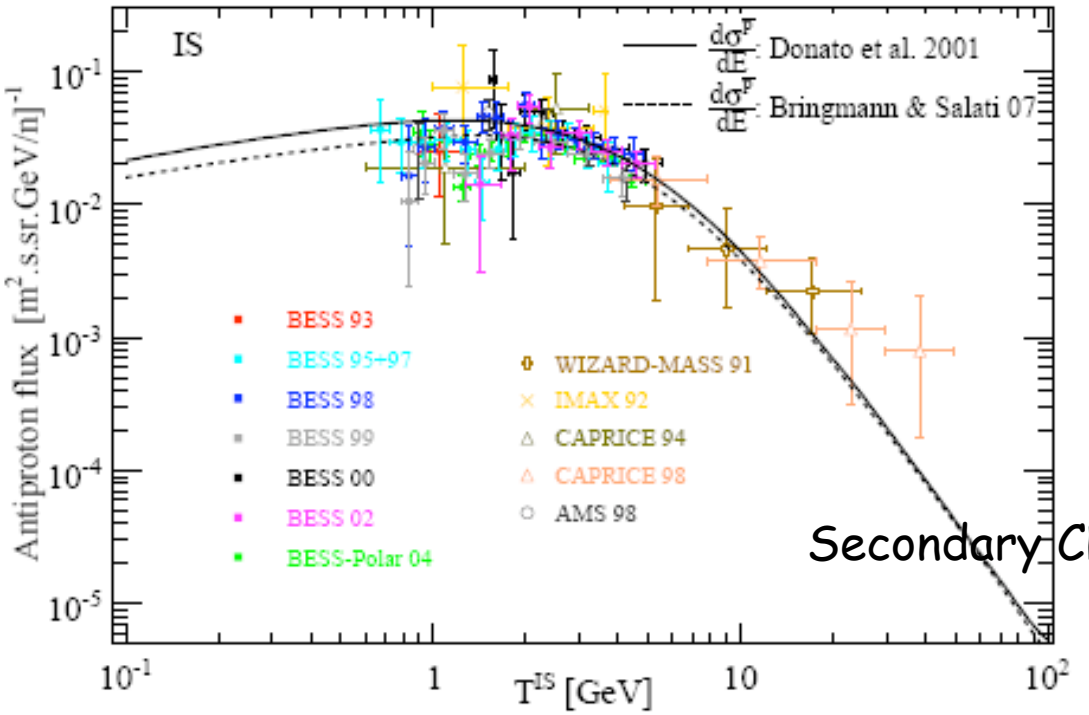
TANGO in Paris 6.05.2009

Antiprotons data

FD, 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

2-zone Semi-analytic Diffusive Model

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

& talk by David Maurin @ TANGO

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

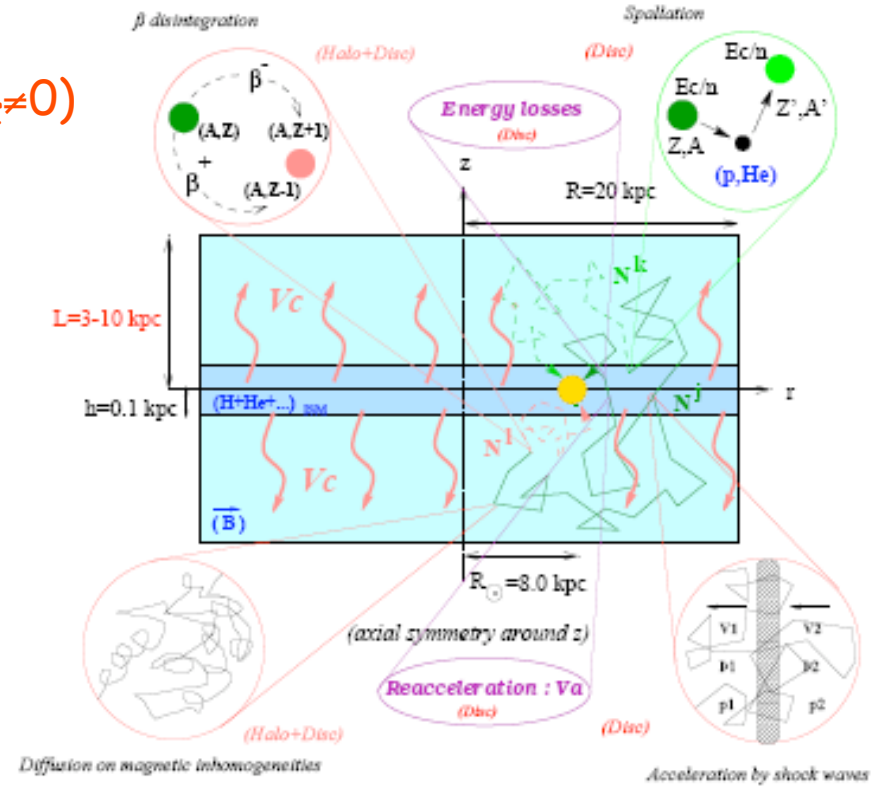
+2D semi-analytic

+ 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)

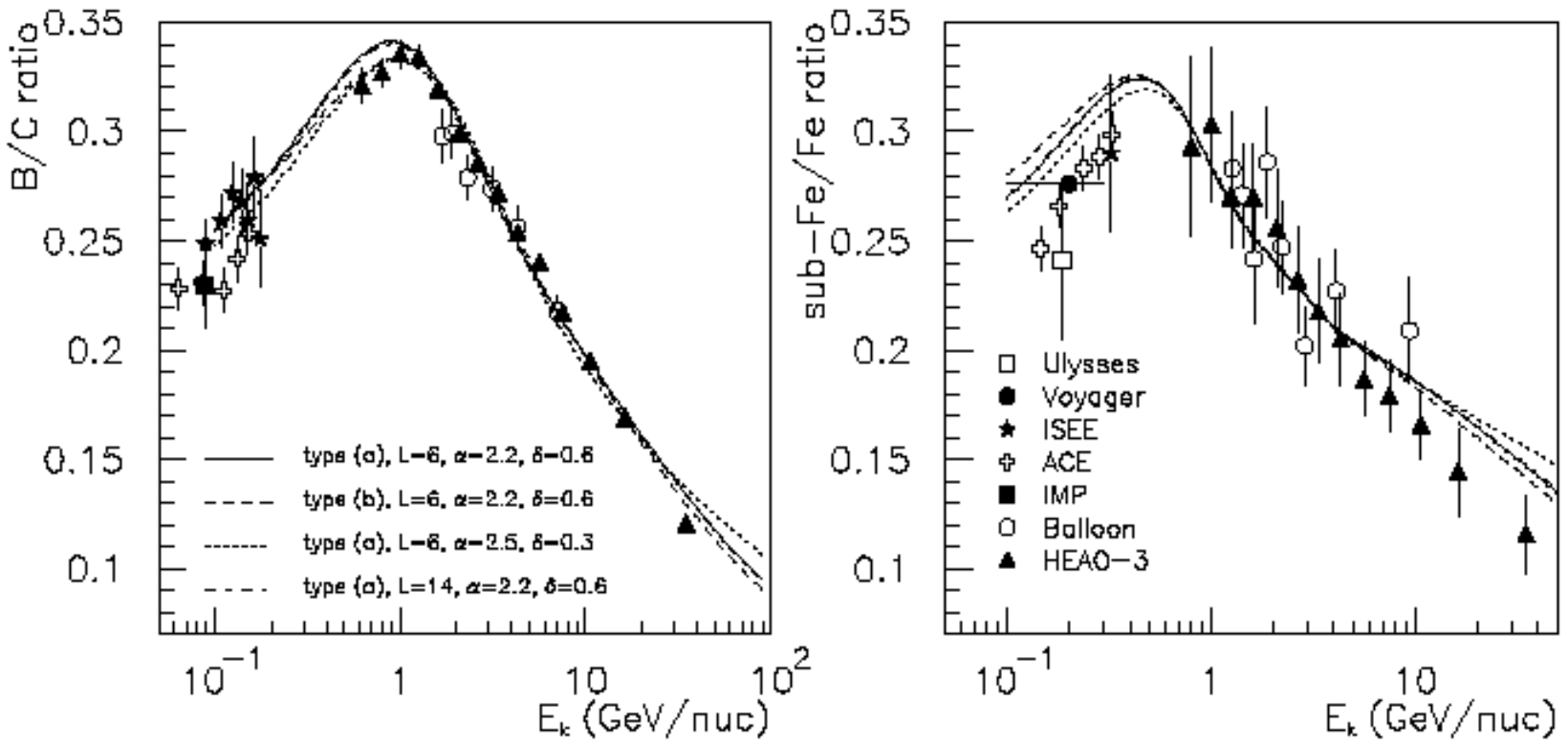
Systematic scan
of parameter space
Evaluation of uncertainties

RESULTS ON OBSERVED PRIM/SEC

Maurin, FD, Taillet, Salati, ApJ (2001) Maurin, Taillet, FD A&A (2002)

Systematic scan of the parameter space!

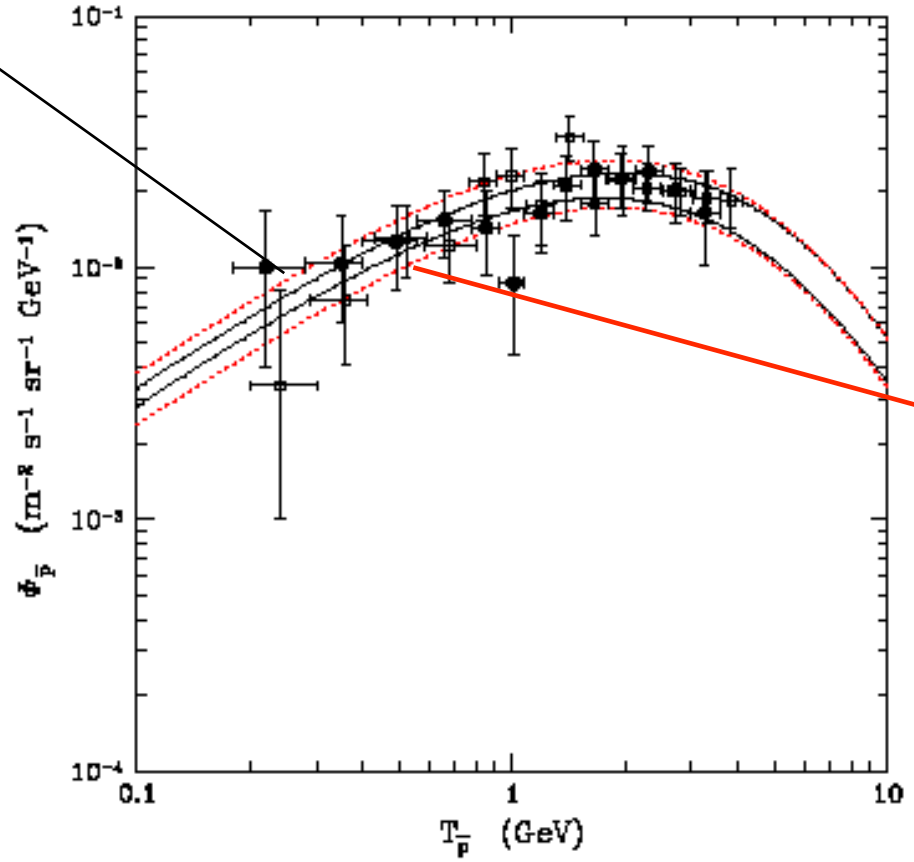
6 free parameters: diffusion (K_0, δ), convection (V_C), acceleration(α), reacceleration (V_A), diffusive halo (L)



Uncertainties on the Secondary Antiproton Flux

Donato, Maurin, Salati, Barrau, Boudou, Taillet Ap J 2001

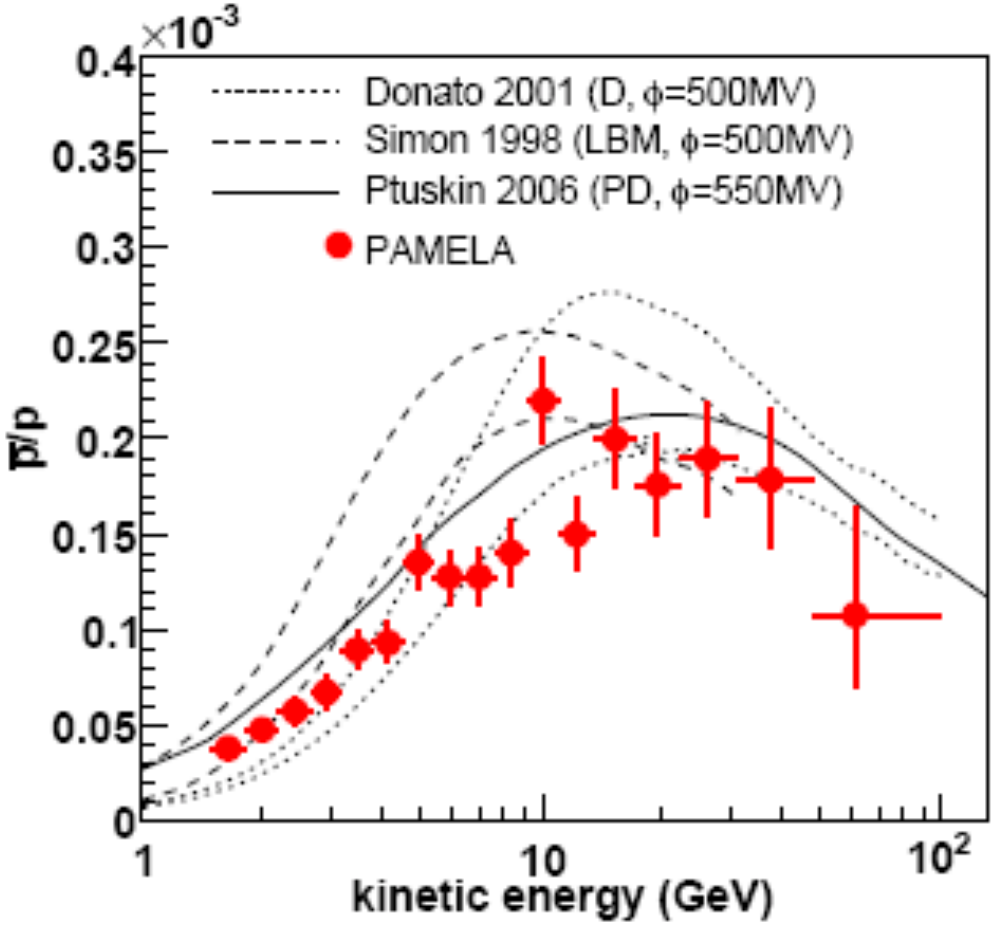
Astrophysic: B/C constraints



Nuclear cross sections (MC)

Pbar/p data by PAMELA

Adriani et al. PRL 2009



No rising trend at high energy

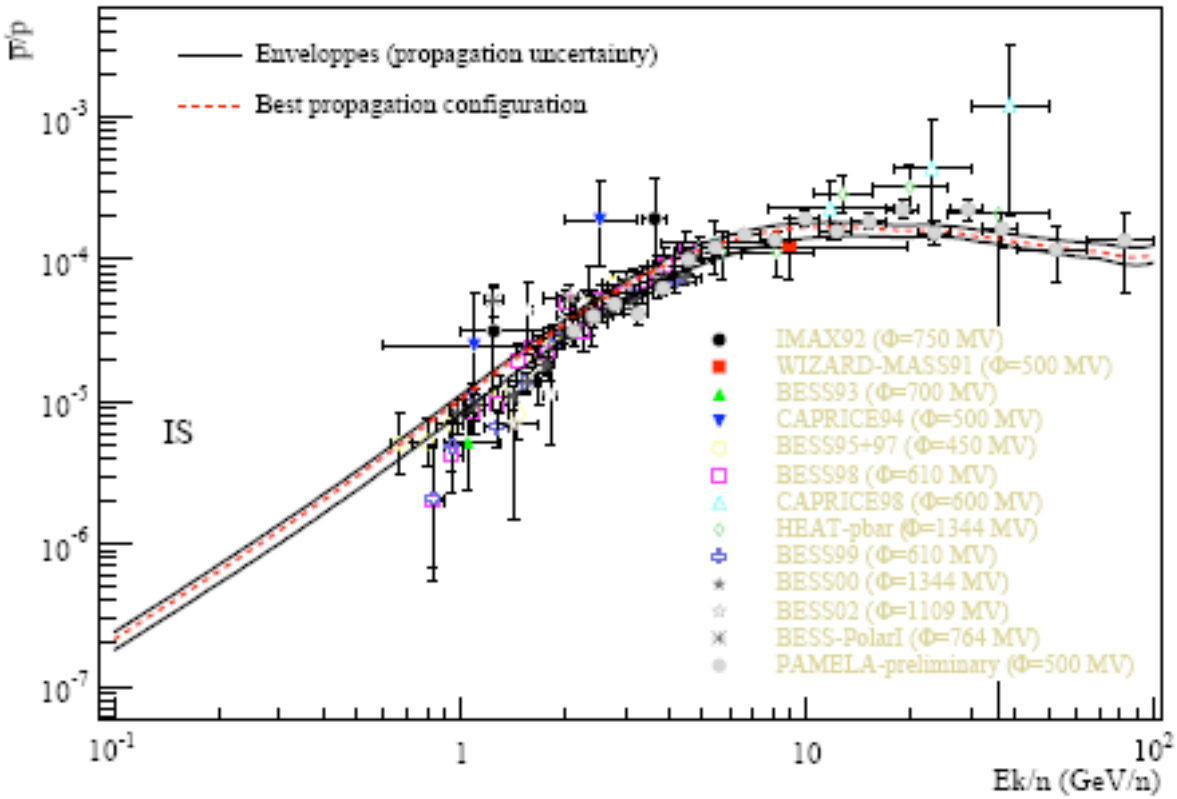
Antiproton/proton: data and models

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

Donato et al. PRL 2009

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

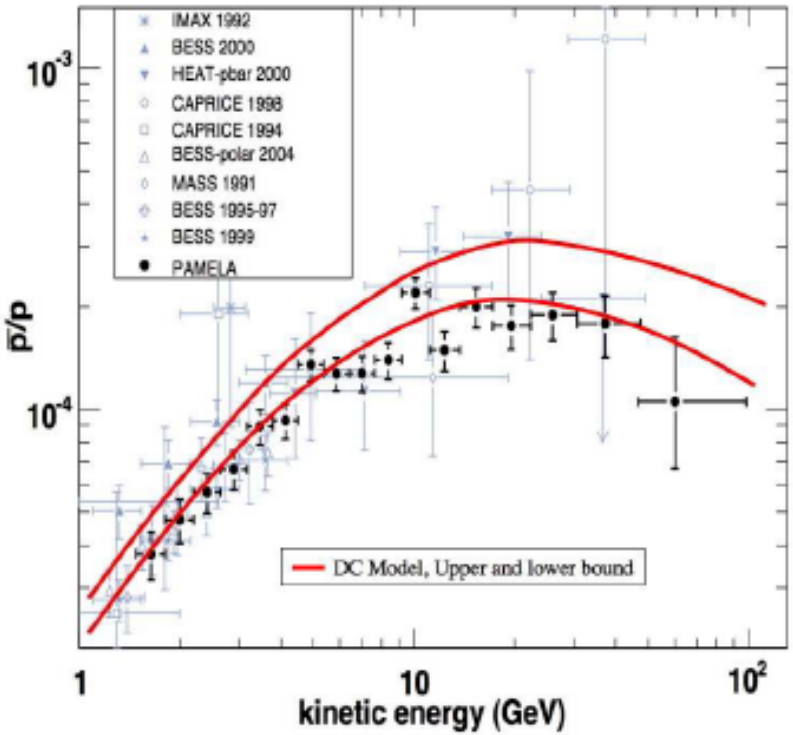
- T<20 GeV: Bess 1997-2002 (Shikaze et al. Astropart. Phys. 2007)
- T>20 GeV, our fit (Bess98, BessTeV&AMS):
  {24132; 0; **2.84**}



NO need for new phenomena (astrophysical / particle physics)

Compatibility with data – more (Galprop)

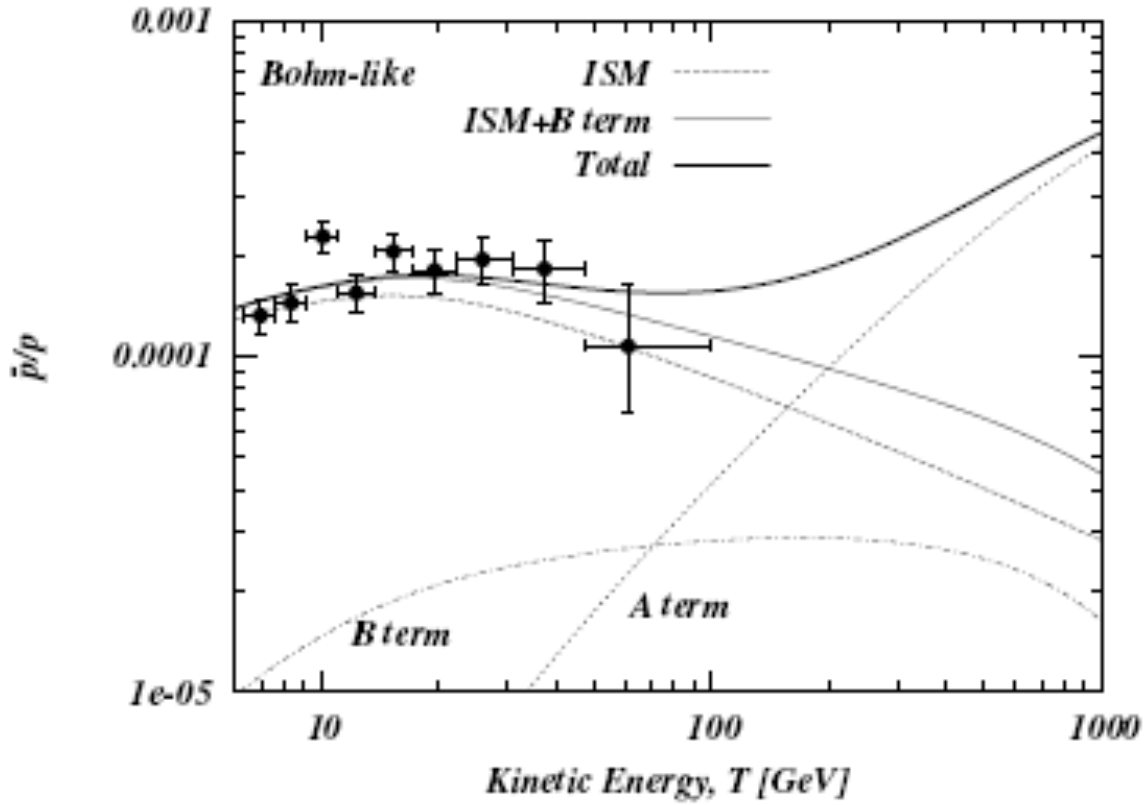
Morselli & Moskalenko, arxiv:0811.3526



Band: approximate range expected for secondary production with Galprop

More astrophysical clues with antiprotons

Blasi & Serpico arxiv:0904.0871



Re-acceleration in mature SNRs

Antiprotons as a tool to test our understanding of the Galaxy

Antiprotons From Relic Neutralinos

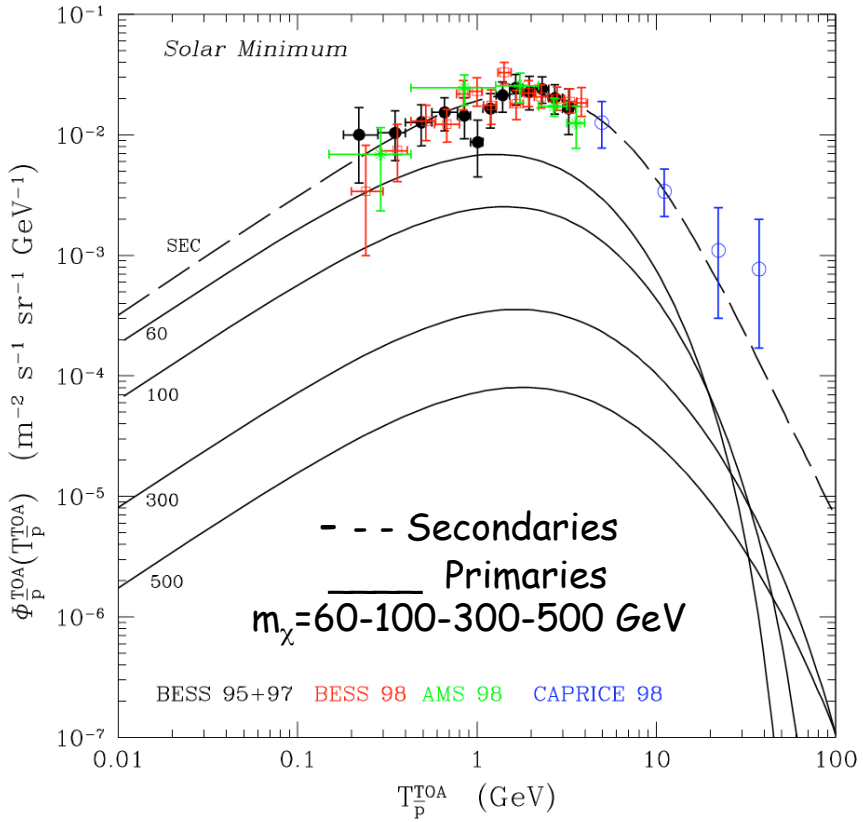
FD, Fornengo,Maurin,Salati,Taillet, PRD (2004), Bottino, FD, Fornengo, Salati PRD (1998)
BergstrÖm, EdsjÖ, Ullio ApJ (1999)

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!!

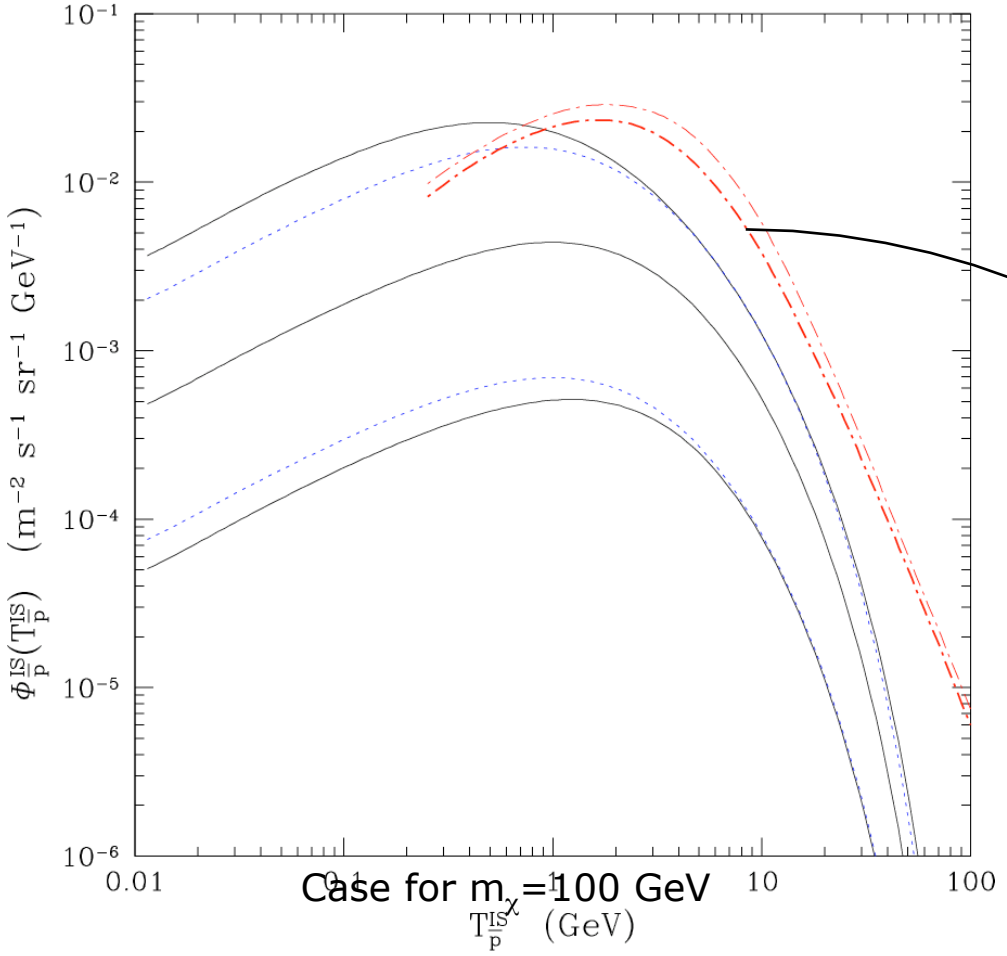
Solutions (still analytical in the 2D model) different from secondaries

PRIMARY FLUXES and UNCERTAINTIES

Solid: $\chi^2_{B/C}<40$

Dotted: $\chi^2_{B/C}<30$

(22 DF)

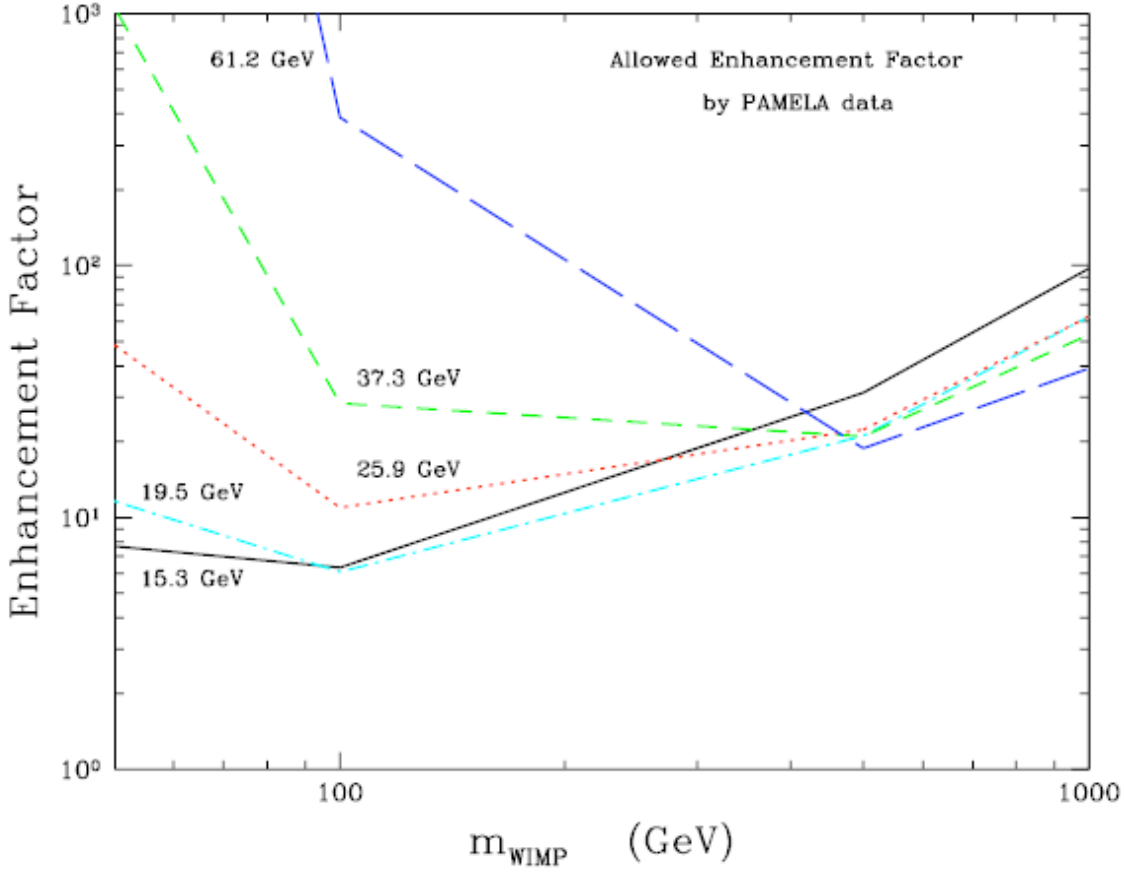


Secondary flux

Case for m_χ=100 GeV

CASE	δ	K_0 (kpc²/Myr)	L (kpc)	V_c (km/sec)	V_A (km/sec)	$\chi^2_{B/C}$ (22 DF)
MAX	0.46	0.077	15	5	118	39.98
MED	0.70	0.011	4	12	53	25.68
MIN	0.85	0.002	1	13.5	22	39.02

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

Enhancement of the antiproton flux?

- Clumpiness in the DM distribution in the Milky Way: energy dependent (Lavalle, Yaun, Maurin, Bi A&A 2008)

  → boost factors may be different for positrons, antiprotons, gamma rays, ..

  (Lavalle, Pochon, Salati, Taillet A&A 2006)

  → a low boost factor (for gamma rays) emerges from most recent N-body simulations (Diemand et al. 2008; Springel et. MNRAS 2008)

  → talk by J. Lavalle

- Enhancement of the annihilation cross section

  (Bergstrom PLB 1989; Hisano et al. PRL 2004)

  → depends on the mass (> TeV)

  → talk by J. Hisano

Compatibility with positron data?

Positron flux: data and predictions

see talk by N. Fornengo

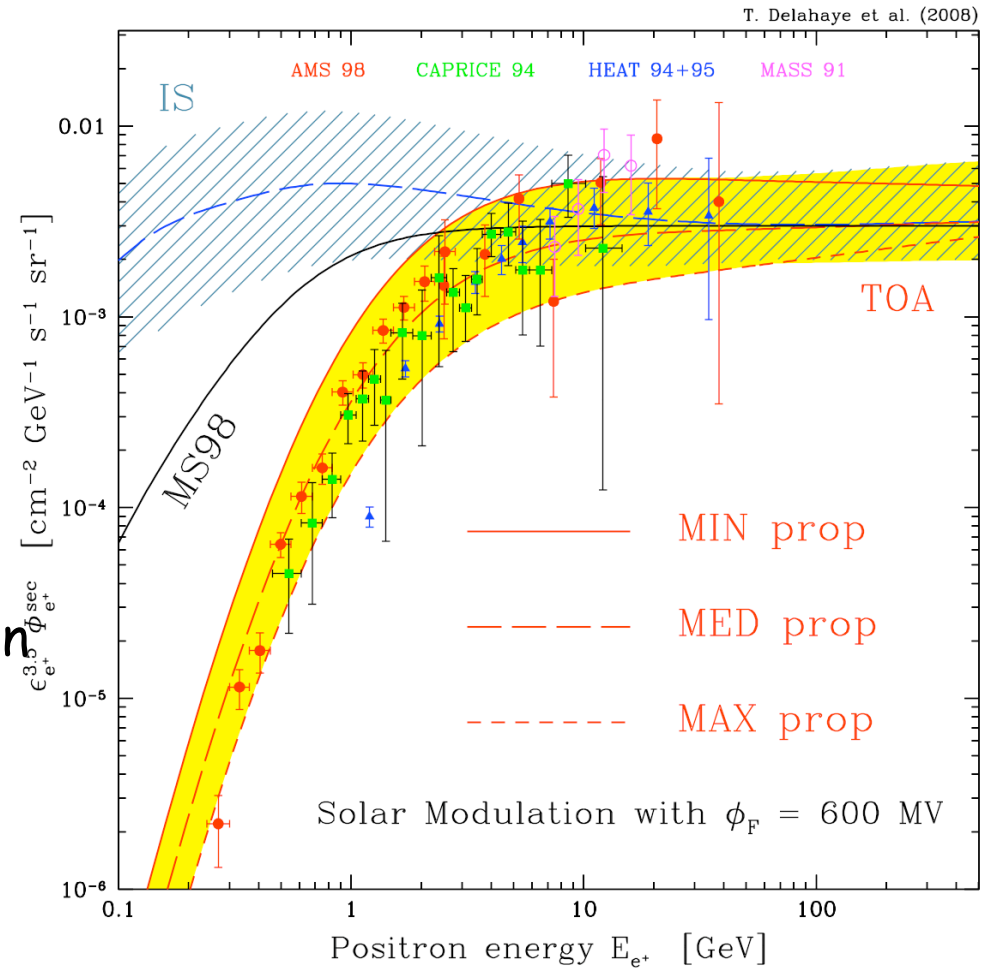
Delahaye et al. A&A 2009

<u>Same propagation models:</u>

Positrons as secondary CRs

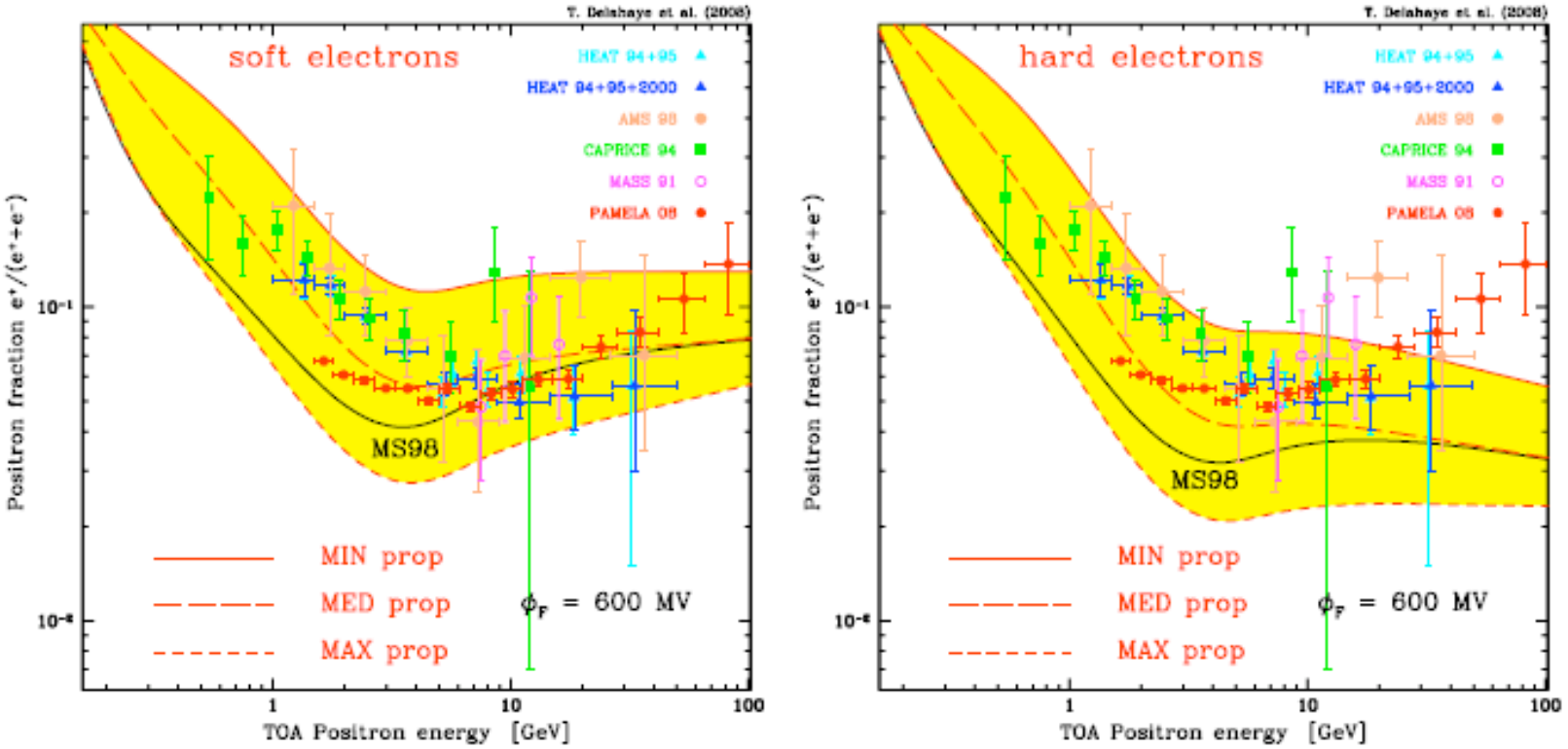
are well fit by predictions

Uncertainties due to propagation and to cross sections



Positron/electron: data and predictions

Delahaye et al. A&A 2009, in press



Yellow band: secondary positrons & propagation uncertainties

Hard electrons: γ=3.34

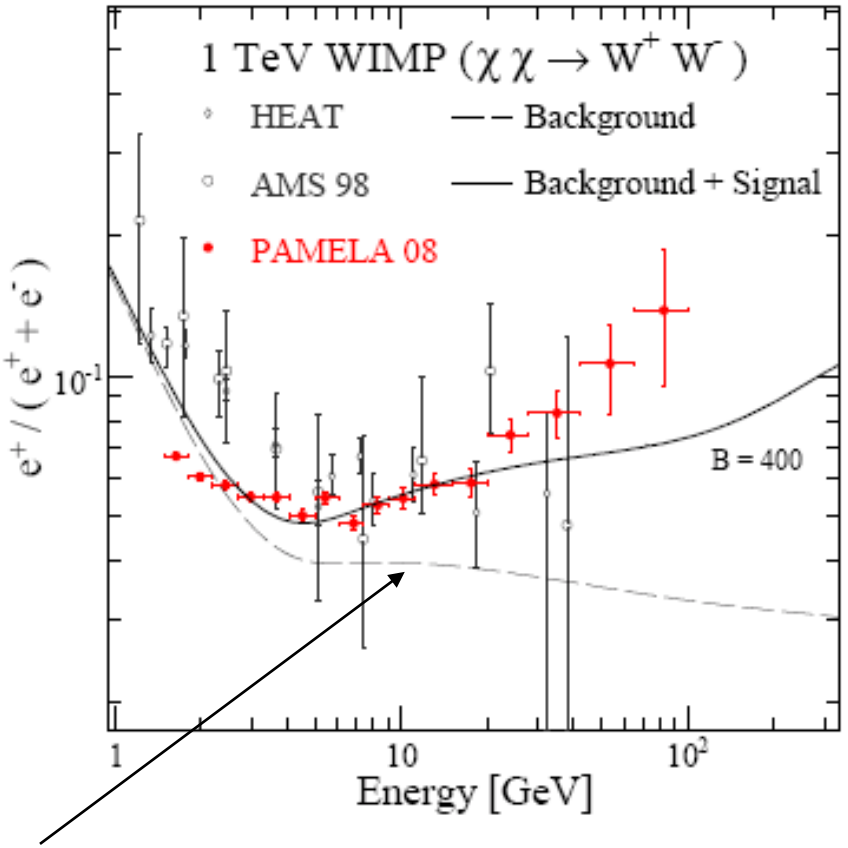
There is no "standard" flux – dashed is B/C best fit

Constraints from positron/electron data

Donato et al. PRL 2009

Example: m=1 TeV, WW
fit improves, but highest points
in E not explained

High boost factor required ☹



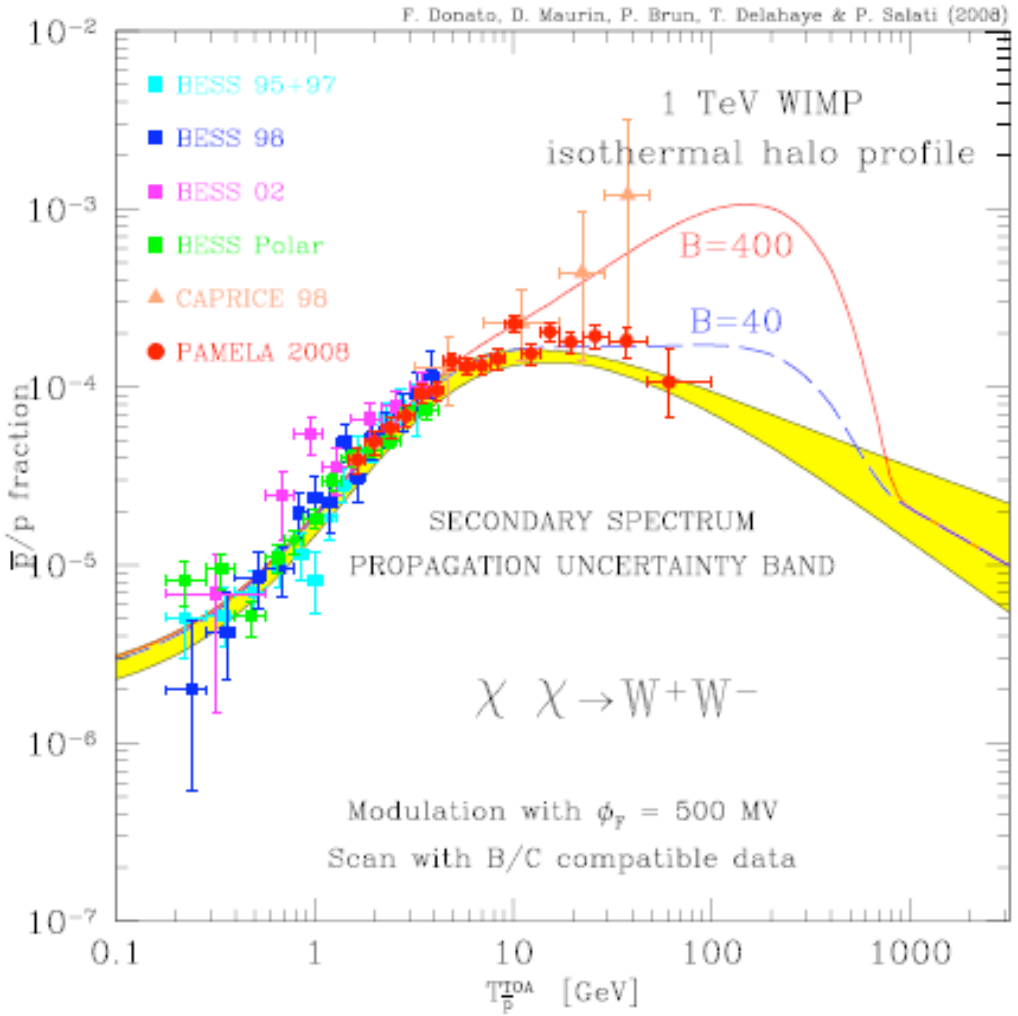
Secondary positrons
Best fit propagation parameters

Effect on antiprotons

The same example: 1 TeV DM candidate

B=400 largely excluded by Pamela!

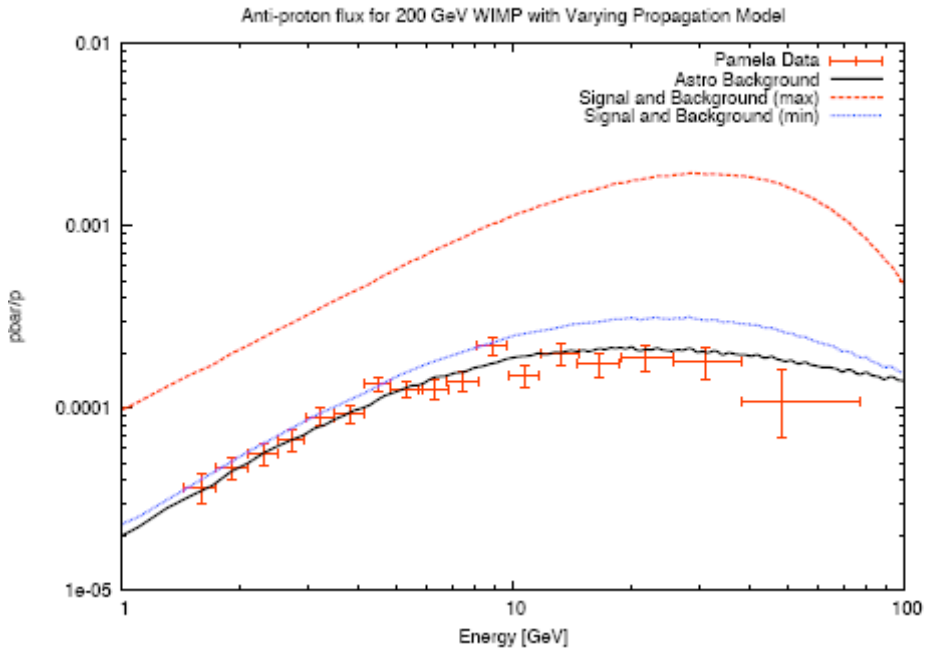
B=40 marginally allowed

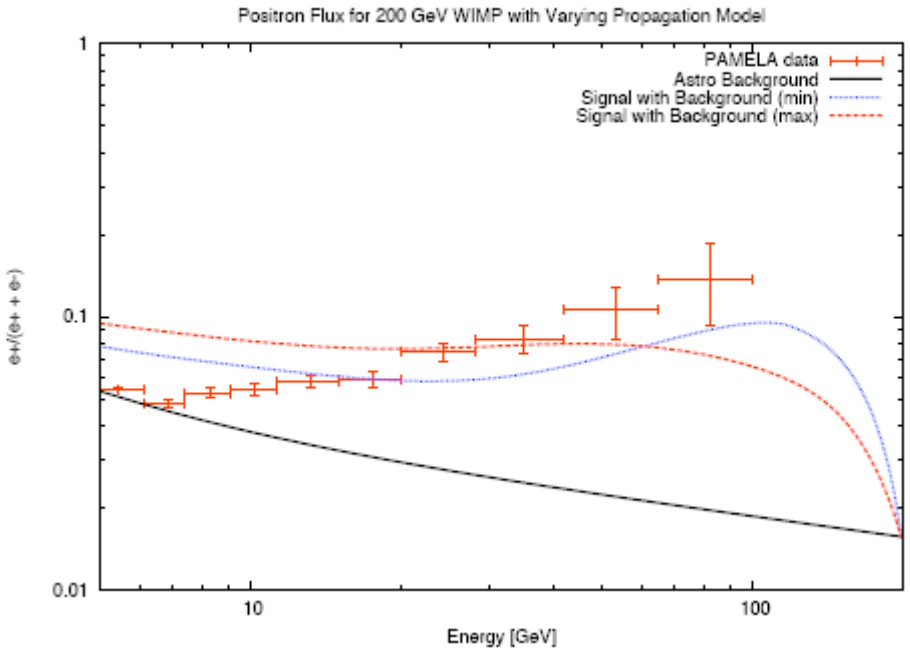


Constraints on antiproton – 200 GeV Wino

(Grajek et al. Arxiv:0812.4555)

Positron fraction: playing also with huge energy losses

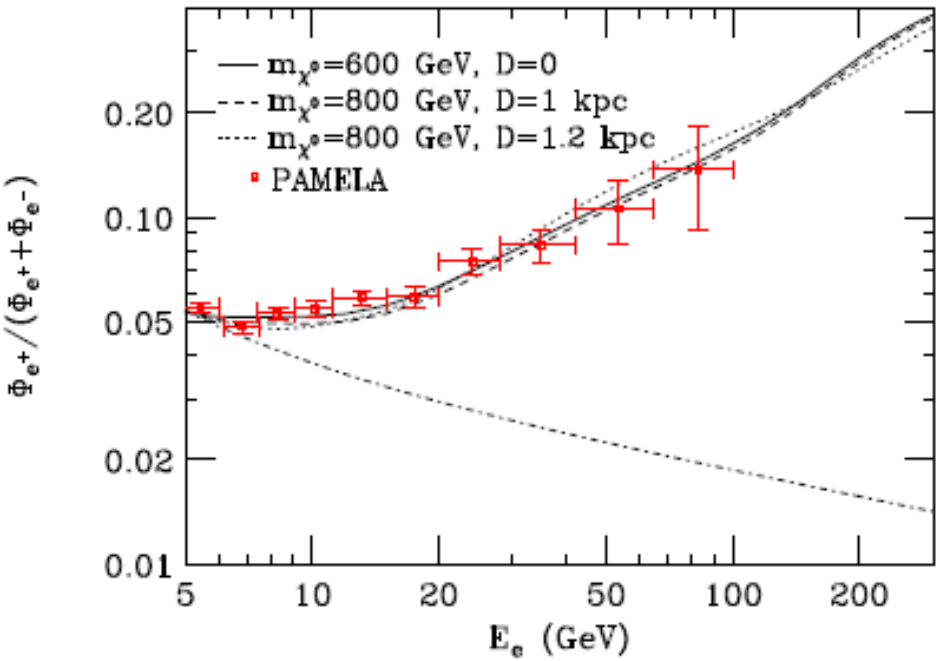




Too many antiprotons …

Efforts to reconcile data

Hooper, Stebbins, Zurek arxiv:0812:3202



Very dense and close clump,
with different effect for antiprotons,
at minimum of propagation …

Lavalle et al. PRD 2008; Lavalle, Yaun, Maurin, Bi *A&A* 2008

N-body simulations → antiproton and positrons
Local contributions: O(10)
@ high energies for e+
@ low energy for pbar

Cooking with uncertainties and with the unknown!

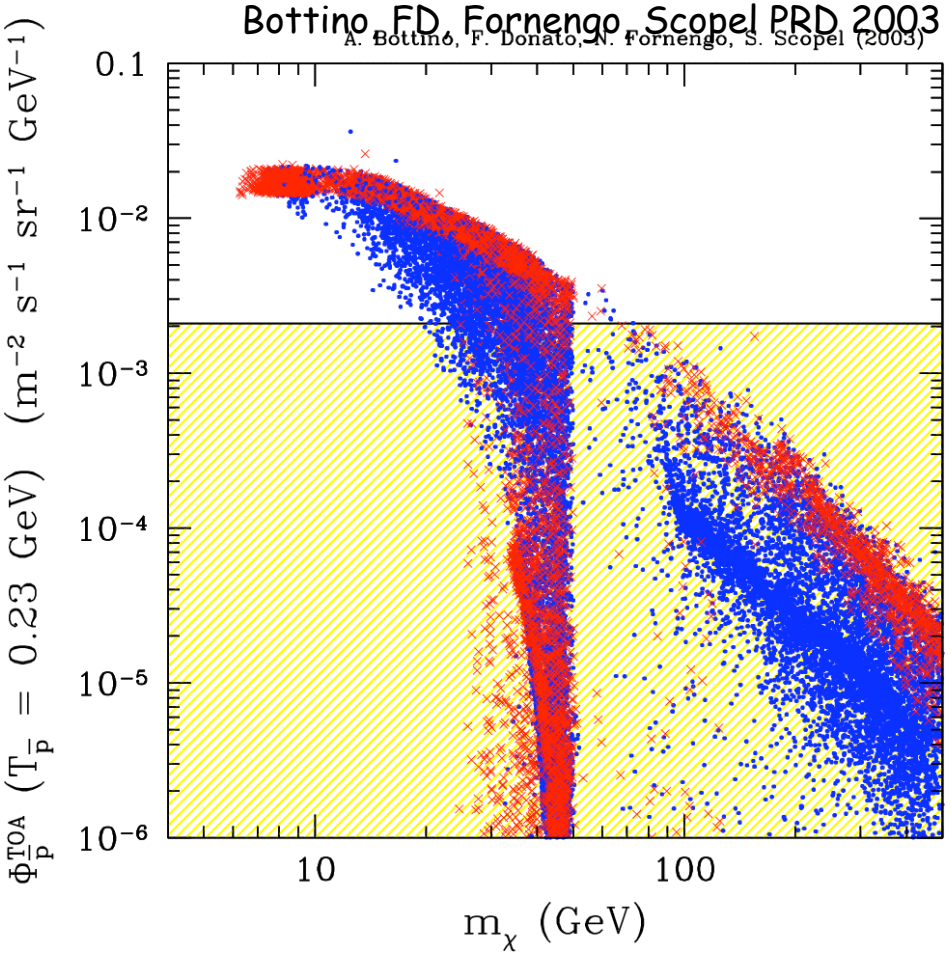
We can cook positrons
from big fishes,
with a little bit of clumps,
some Sommerfeld…
and bake antiprotons with
a little less clumps…

Try propagation at mimimum,
allow more pepper to both species

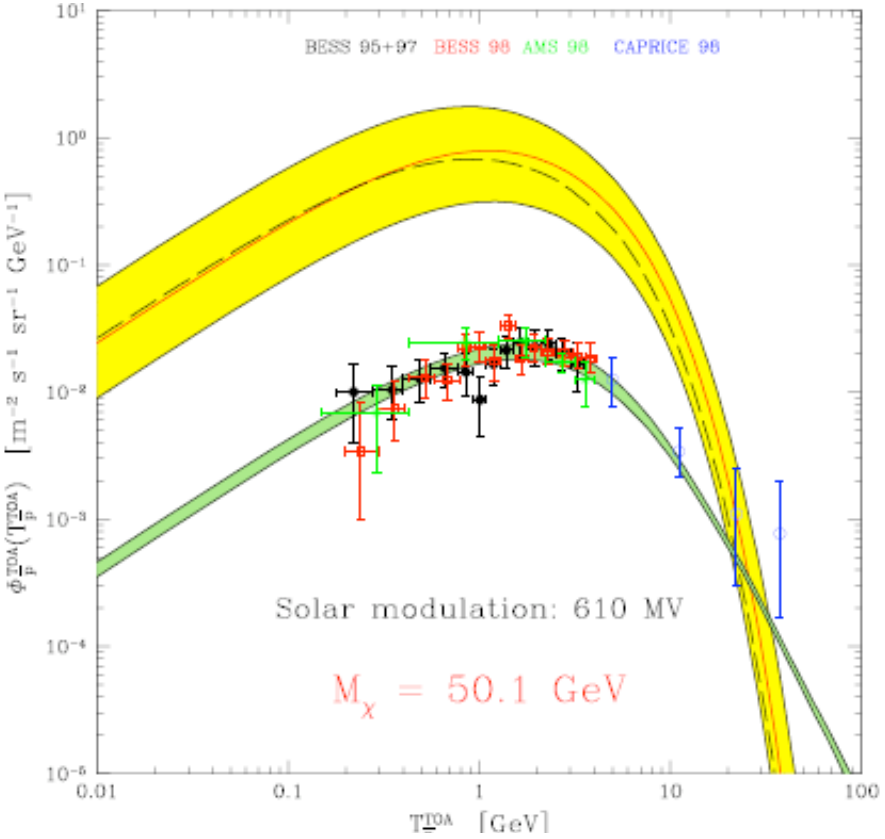
Any of you is leptophylic?
Baked positrons, forget antiprotons

Low energy antiprotons as constraints …..

Bottino, FD, Fornengo, Scopel PRD 2003



Bergström, Edsjo, Gustafsson, Salati JCAP 2006

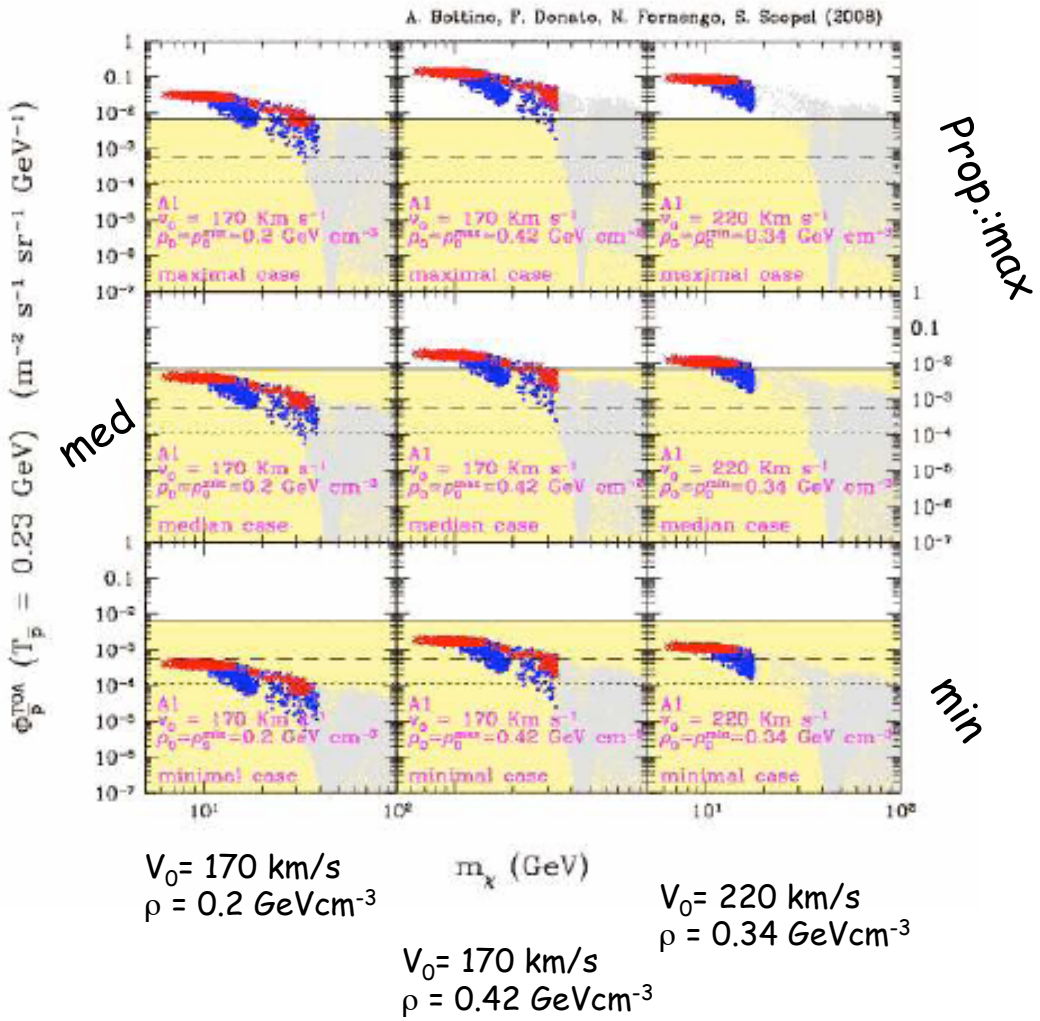


Light masses in effMSSM & Bess DATA
Medium prop. parameters

With models from
De Boer et al. A&A2005

Antiprotons in cosmic rays as a **tool** for constraining supersymmetric models (Bottino, FD, Fornengo, Scopel PRD 2008)

Antiproton flux in effMSSM @ 240 MeV & Dama allowed region



V_0= 170 km/s
ρ = 0.2 GeVcm^{-3}

V_0= 170 km/s
ρ = 0.42 GeVcm^{-3}

V_0= 220 km/s
ρ = 0.34 GeVcm^{-3}

red: WMAP
blue: subdominant, rescaled

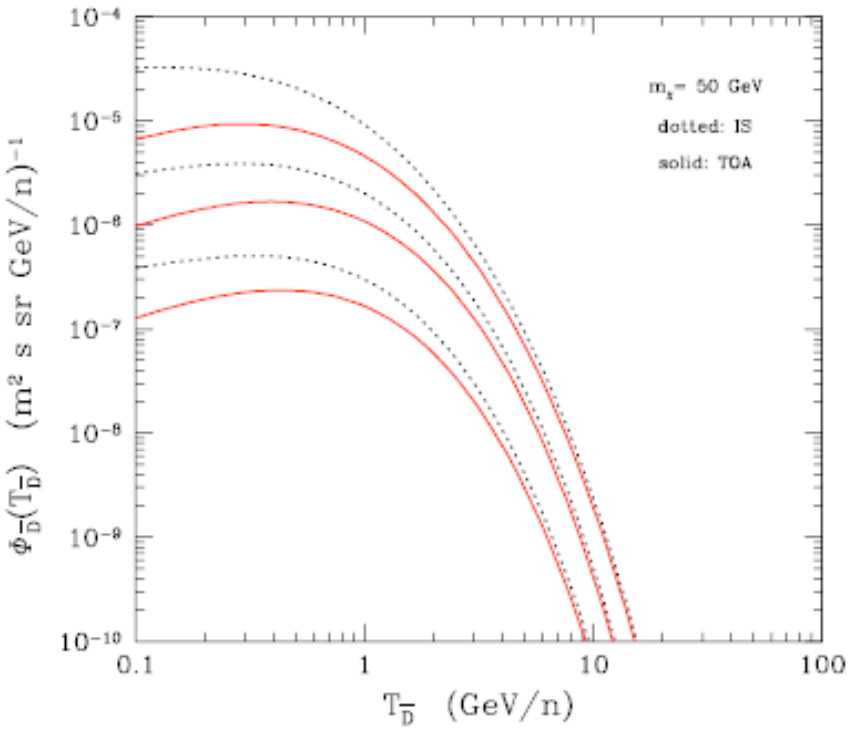
Yellow band: compatible with Antiproton data (Bess exp.)

Many configurations are compatible with Dama & Bess

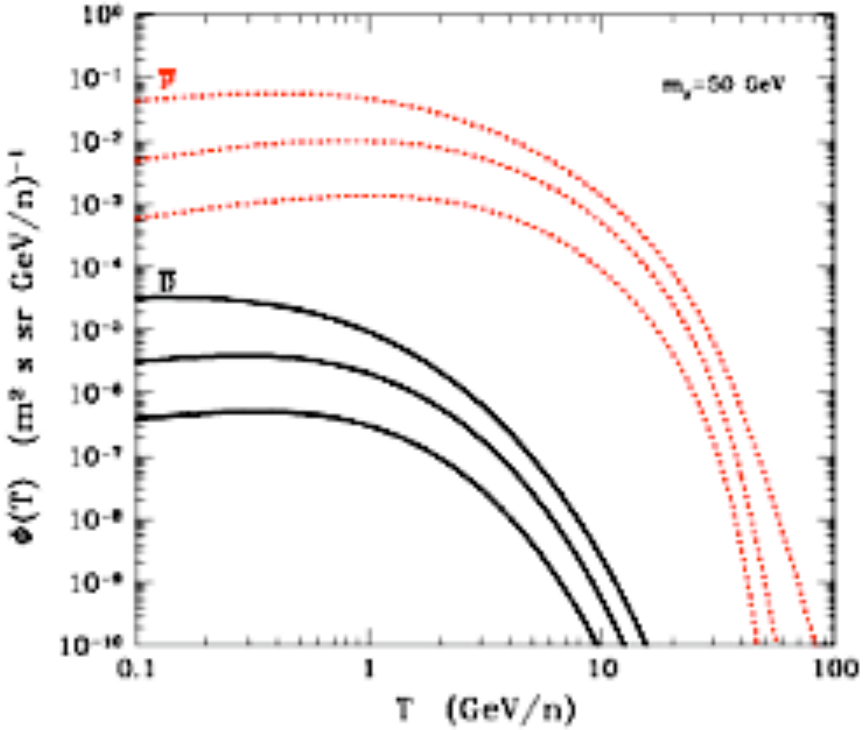
Exclusion of effMSSM parameters depends on propagation models.....

Antideuterons from DM Annihilations

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

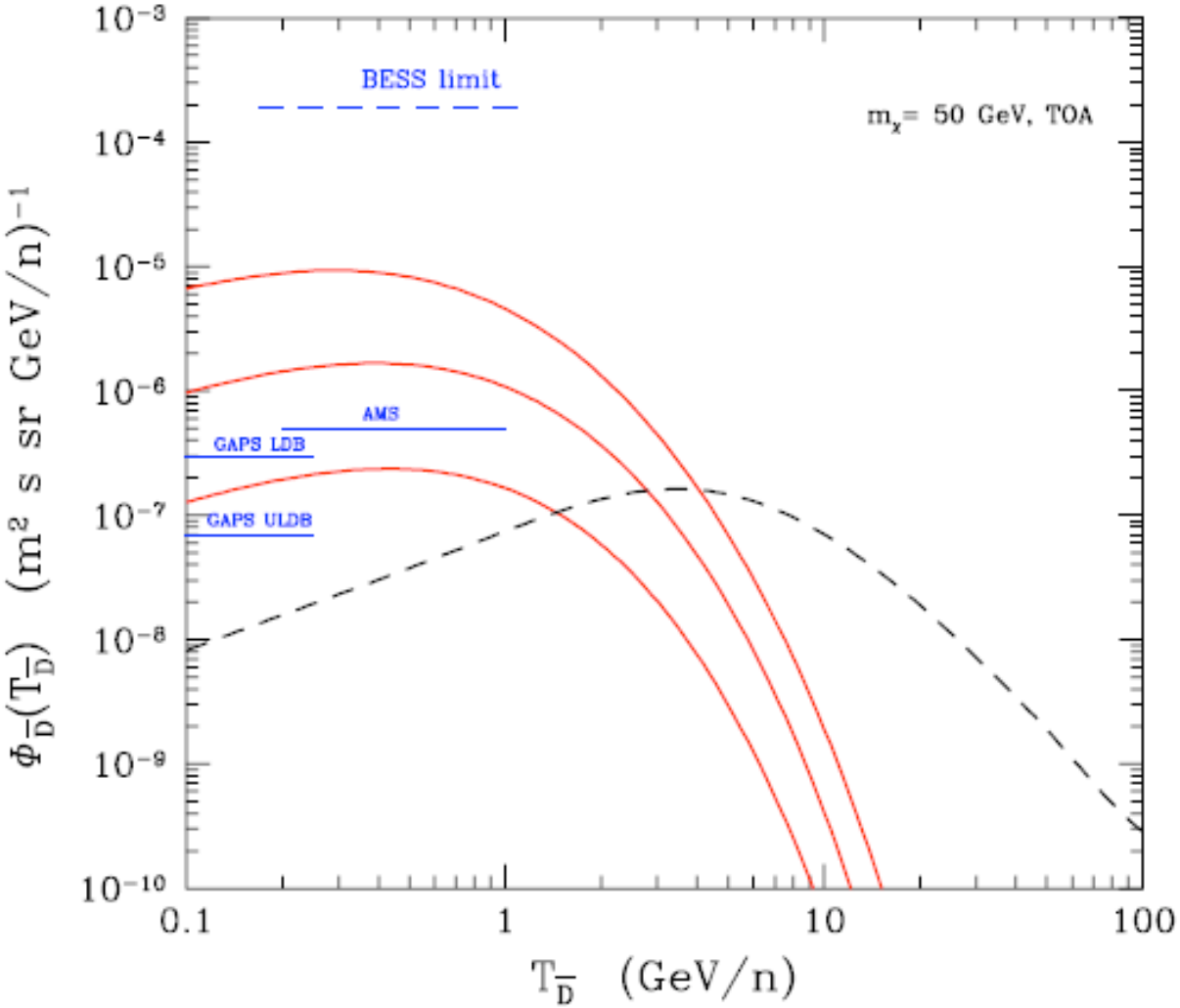


Propagation uncertainties driven by L
At lower energies, also effect from V_C



Antiprotons & Antideuterons
Propagation Uncertainties

ANTIDEUTERONS & future experiments



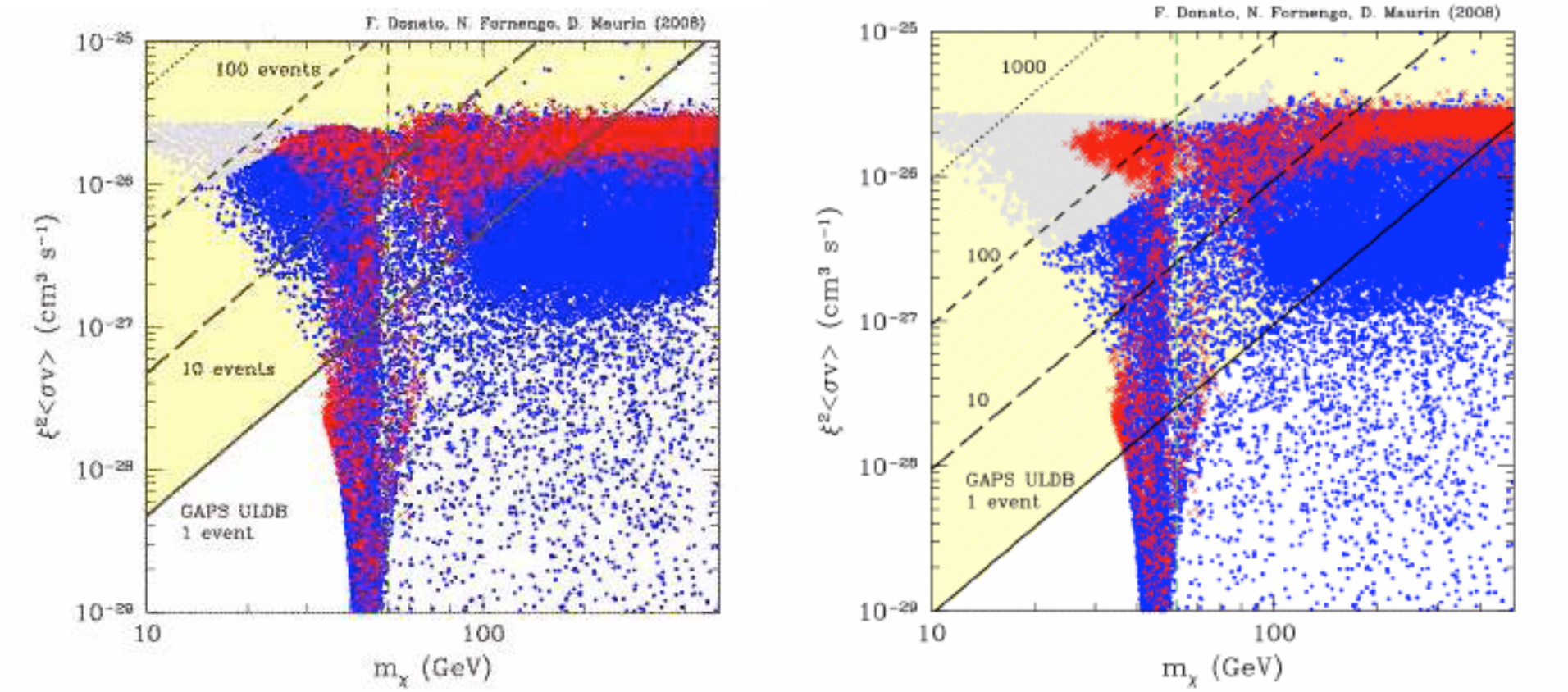
effMSSM neutralino dark matter can be detected by means of next generation space instruments measuring antideuterons in CRs

MSSM Inspections with Antideuterons

Median propagation Parameters

GAPS ULDB reach

Maximal propagation Parameters



Red: dominant neutralinos Blue: sub-dominant neutralinos

Grey: constraints from antiprotons

Antiproton data are very well reproduced by standard secondary CRs
Theoretical prediction have small uncertainties

No feature for DM presence in antiproton → only constraints

Present pbar/p data exclude sizeable contribution from DM annihilation
Compatibility with positrons requires some tuning

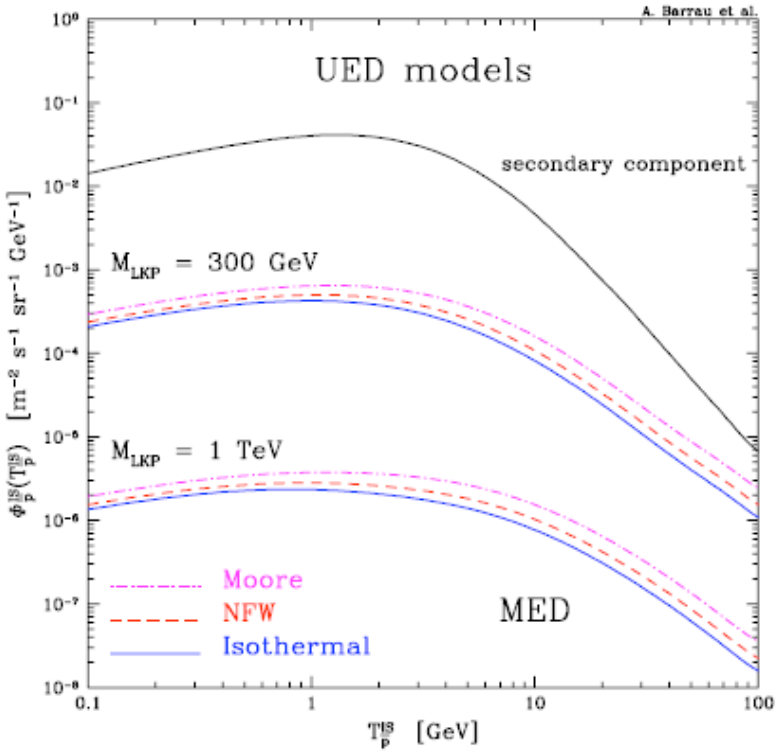
Better constraints possible only with better measurements
(and study:-) of primary and secondary "standard" cosmic rays

Predictions for KK antiprotons

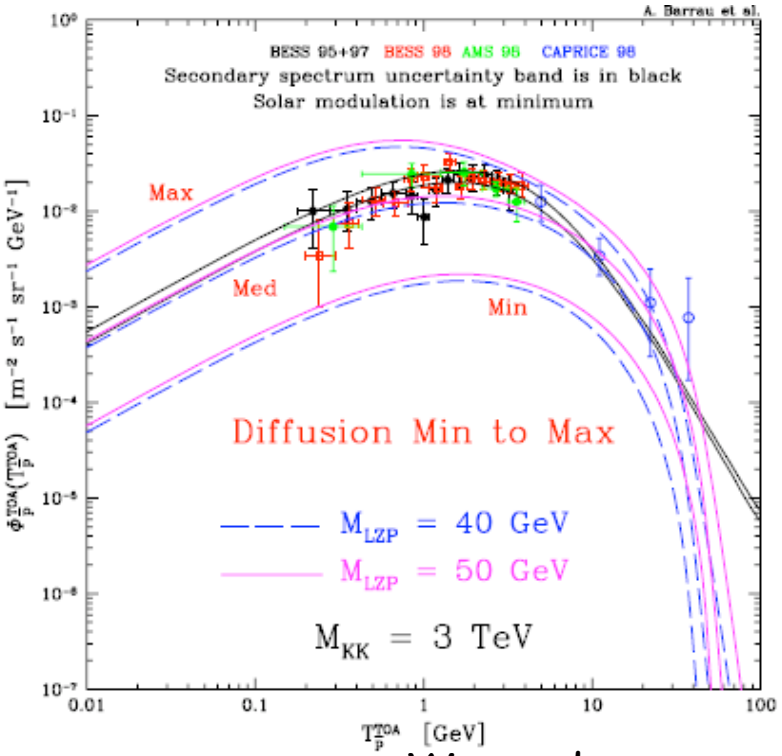
(Barrau et al. PRD 2005)

✓ Universal Extra Dimensions → LKP: 300-1000 GeV

✓ Warped geometries (Randall-Sundrum) →LZP: GeV-TeV



Median propagation parameters:
LKP are well below secondaries
(and data)



Warped geometry

Light masses ↔ Detectable fluxes