Indirect Signals from Light Neutralinos

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Main results in:

Bottino, FD, Fornengo, Scopel

PRD 2004 (hep-ph/0401186)

The neutralino: an ideal CDM candidate

$$\chi \equiv a_1\widetilde{B} + a_2\widetilde{W}^{(3)} + a_1\widetilde{H}_1^0 + a_1\widetilde{H}_2^0$$

- **Neutral** & **colourless**
- **Weakly** interacting (WIMP)
- **Stable** if R-parity is conserved
- Non-relativistic at decoupling $\Rightarrow$ **CDM**
- Relic density $\Omega_\chi h^2$ in the WMAP range $(0.095 \leq \Omega_\chi h^2 \leq 0.131)$

LEP lower bounds in GUT frame: $m_\chi \sim 50$ GeV

SIGNALS from RELIC NEUTRALINOS

Supersymmetric particles are searched at ***accelerators***

But we cannot say anything about DM candidates

⬇

Direct detection via coupling to ordinary matter

Deep underground experiments

Indirect detection via pair annihilation products

Rare components cosmic & γ rays

Bottino, FD, Fornengo, Scopel

PRD 59(1999)095003 & 095004; PRD 62(2000)056006; PRD 63(2001)125003

NEUTRALINO INDIRECT SIGNALS

Annihilation inside celestial bodies:

- ν *(as up-going muons)*

$$\Phi_\mu^{(\mathrm{Earth,Sun})} \propto <\sigma_{\mathrm{ann}} v> \frac{\rho_\chi}{m_\chi}$$

Annihilation in the galactic halo:

- γ*-rays*
- e^+, $\bar{\mathrm{p}}$, $\bar{D}$

$$\Phi^{(\bar{p},\bar{D},e^+,\gamma)} \propto <\sigma_{\mathrm{ann}} v> \left(\frac{\rho_\chi}{m_\chi}\right)^2$$

LIGHT NEUTRALINOS and CRs

Bottino, Fornengo, Scopel PRD 2003
Bottino, FD, Fornengo, Scopel PRD 2003; 2004

- Relaxing relationship $M_1 \sim 0.5 M_2$
LEP lower bound $m_\chi \sim 50$ GeV does not apply

- The limit on m_χ can be derived from
$\Omega_\chi h^2 \leq (\Omega_{CDM} h^2)_{max}$

$\Downarrow$

$m_\chi \geq 7$ GeV

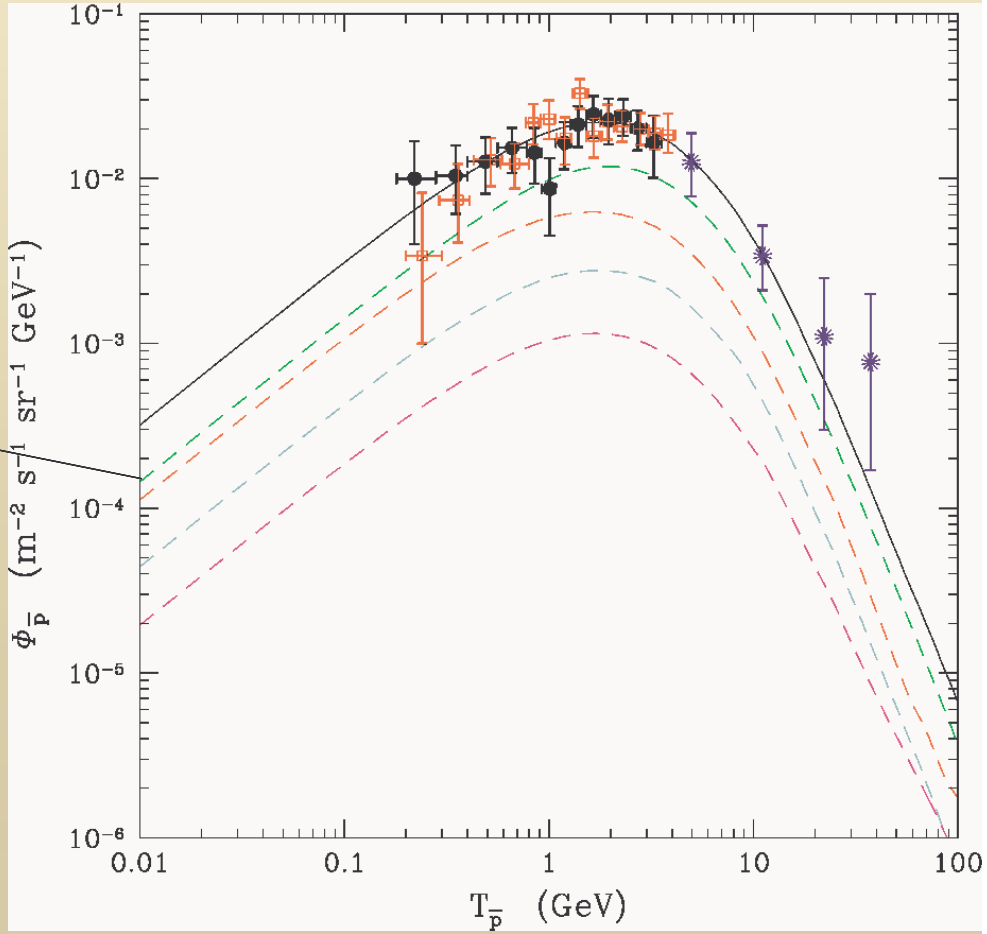
Interesting rates for direct and indirect detection!!!

ANTIPROTONS IN COSMIC RAYS

FD et al., ApJ (2001);Bergström et al.ApJ (1999);
Bieber et al. PRL (1999); Moskalenko et al., ApJ (2002)

SECONDARIES: $p(He)_{CR} + H(He)_{ISM}$

CR	– target
p	- H
p	- He
He	- H
He	- He



Very good agreement with data!!!

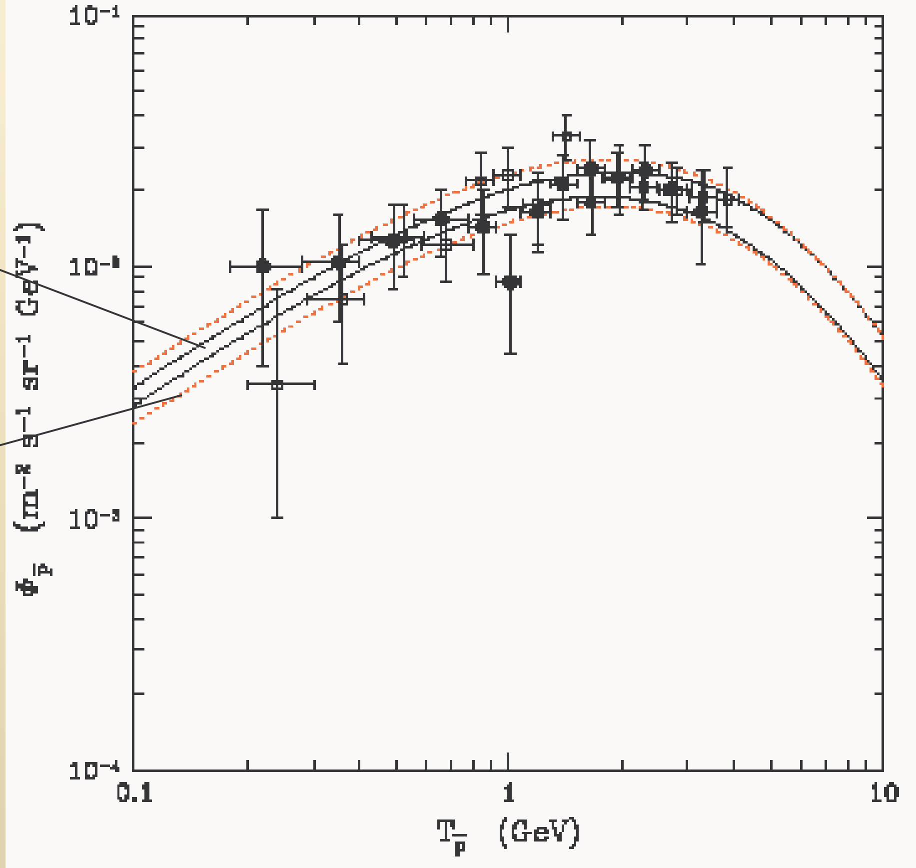
UNCERTAINTIES:

Astrophysic:
B/C Constraints

10-25%

Nuclear cross
Sections:

~ 20 - 25%



	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

ANTIPROTONS from RELIC NEUTRALINOS

FD, Fornengo,Maurin,Salati,Taillet, PRD (2004)

Bergström, Edsjö, Ullio ApJ (1999)

Bottino, FD, Fornengo, Salati PRD (1998)

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

χ ***density***

Annihilation cross section ***Production spectrum*** χ ***mass***

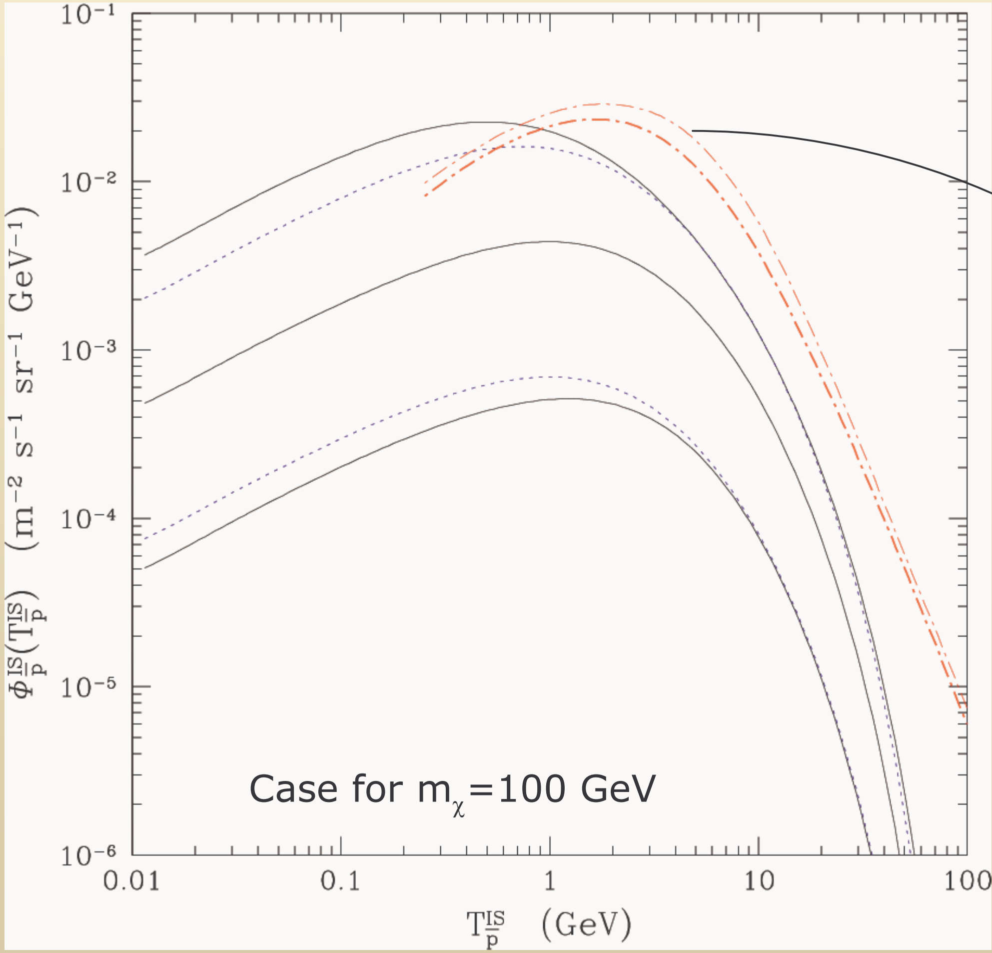
Production takes place everywhere in the halo!!

Solutions different from secondaries: May we look for new physics?!

PRIMARY FLUXES and UNCERTAINTIES

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

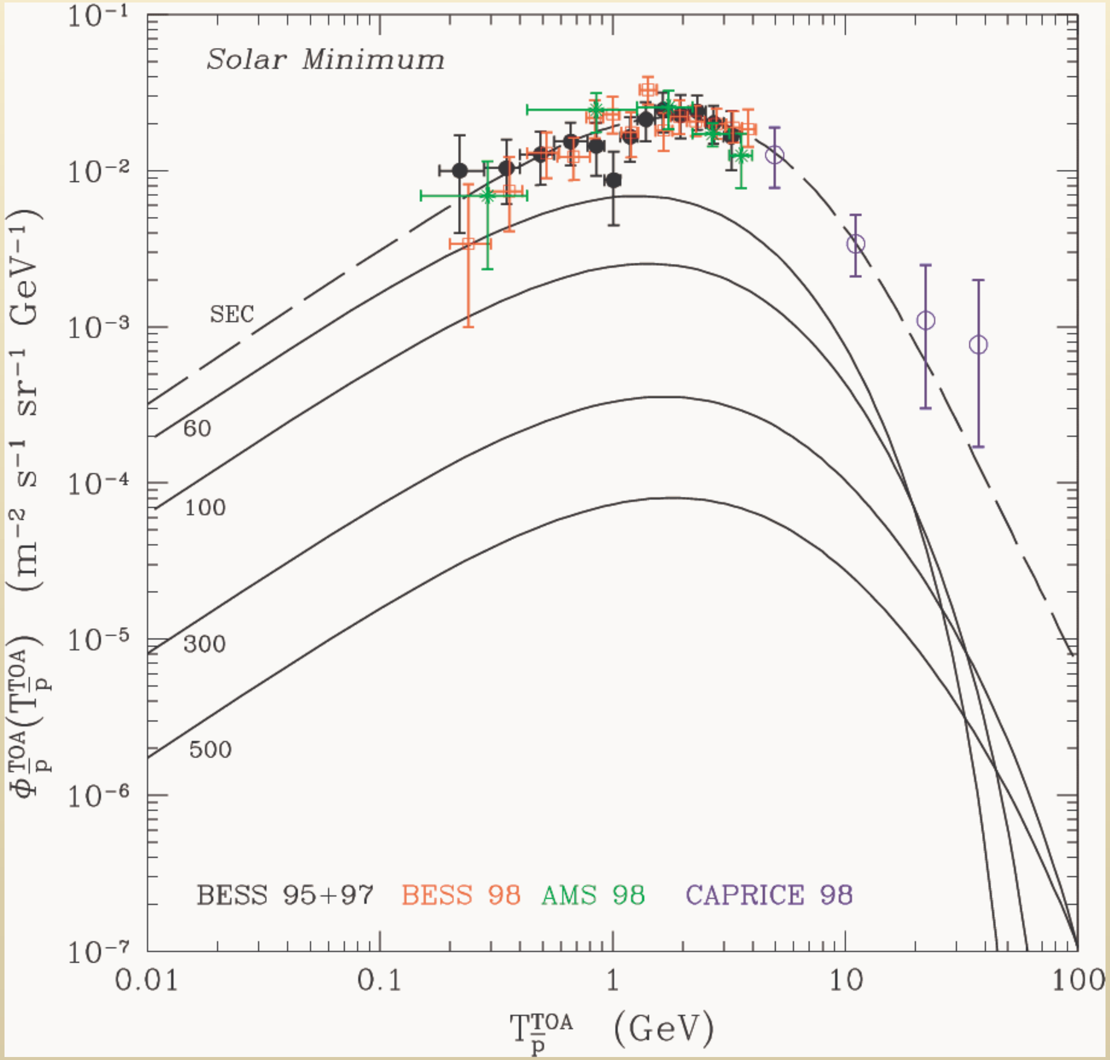
Dotted: $\chi^2_{B/C}<30$
(22 DF)



Secondary flux

Huge astrophysical uncertainty for primaries!!

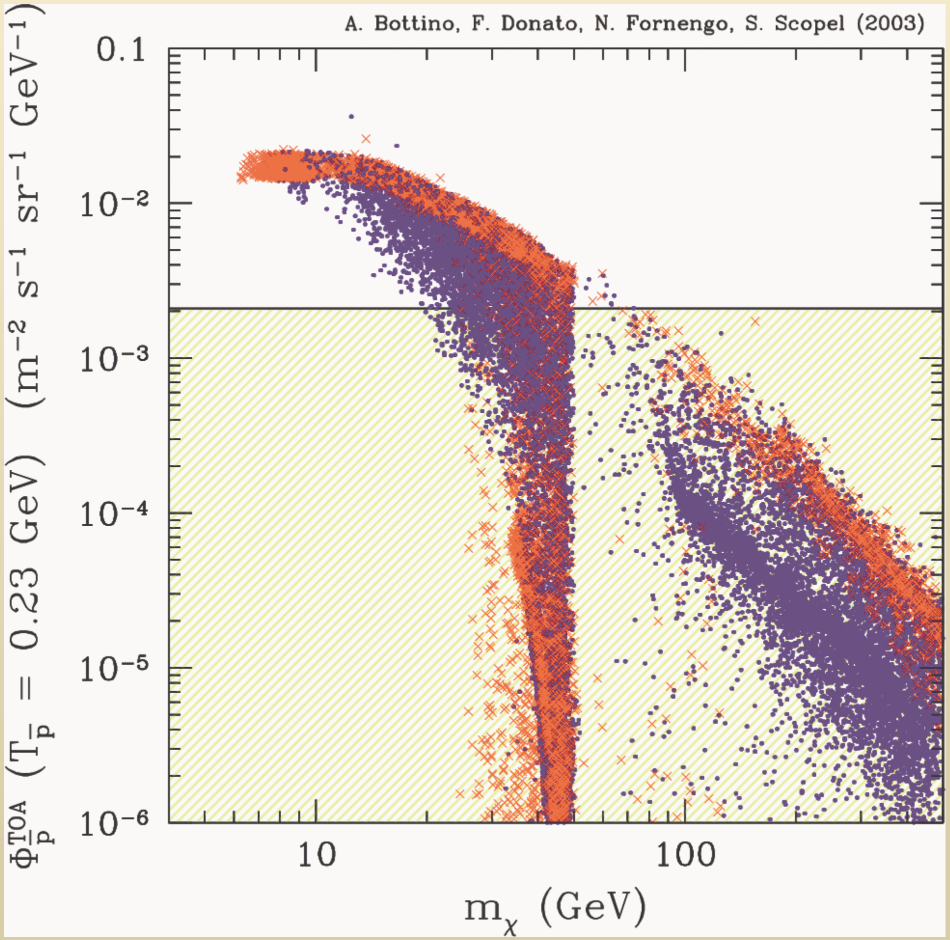
PRIMARY, SECONDARY & DATA



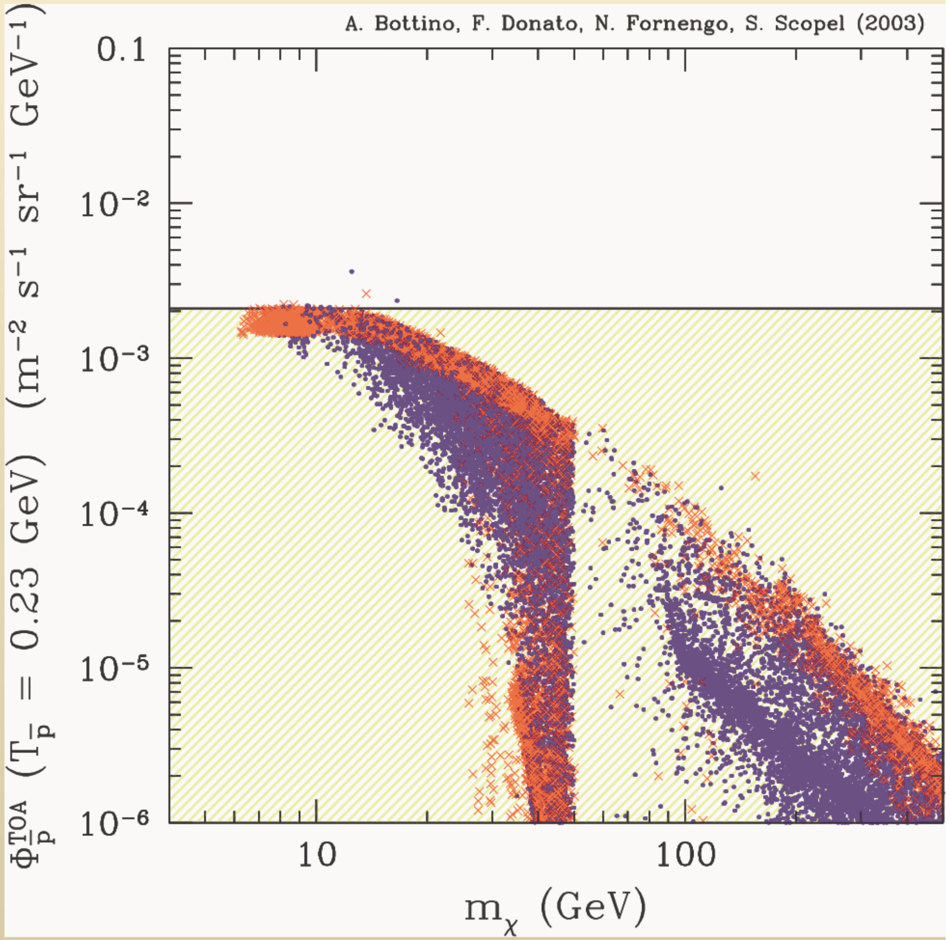
Constraints from data??

(Bottino, FD, Fornengo, Scopel PRD 2004)

Propagation: best fit



Propagation: very conservative



Crosses: $\Omega_\chi h^2 > (\Omega_{CDM} h^2)_{min}$ **Dots: $\Omega_\chi h^2 > (\Omega_{CDM} h^2)_{min}$**

$(\Omega_{CDM} h^2)_{min} = 0.095$ (WMAP)

Possible enhancements of the flux

If the dark halo is clumpy :

$$\Phi \rightarrow \Phi \cdot \eta^2$$

$\eta^2 \sim 10$ *(Berezinsky et al. PRD 2003)*

The local DM density :

$\rho_0 : 0.2\text{~}0.7\ GeV/cm^3 \quad \rightarrow \quad \Phi \sim \rho_0^{\ 2}$

Best fit for ↓	$(\Phi_{IS,2.5} - \Phi_{IS,3.5})/\ \Phi_{IS,3.5}$	$(\Phi_{NFW} - \Phi_{IS})/\ \Phi_{IS}$
L=1 kpc (min)	< 1%	0%
L=15 kpc (max)	-70%	+20%

Antiprotons are the best means to look

for low-mass (<50 GeV) neutralinos

BUT

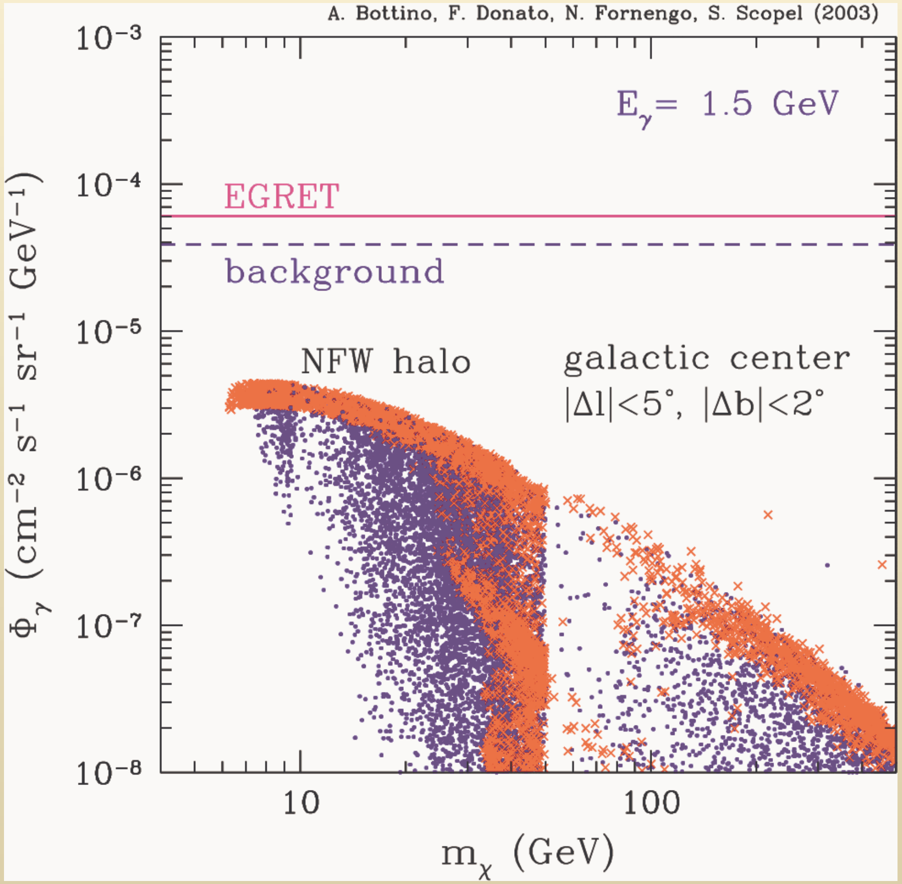
WE NEED BETTER DETERMINATION OF

PROPAGATION PARAMETERS

↓

Astrophysics of Galactic Cosmic Rays

γ-RAYS from LIGHT NEUTRALINOS



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Looking at the GC:

Great uncertainty in the background evaluation

Hunter et al. ApJ 1997, Mori ApJ 1997, Strong et al. ApJ 2000, Aharonian & Atonyan A&A 2000, Busching et al. A&A 2001, Erlykin & Wolfendale JPG 2002, ……

Difficult interpretation of EGRET measured flux

DM distribution at the GC:
Cored? Cuspy (NFW, Moore, …)?

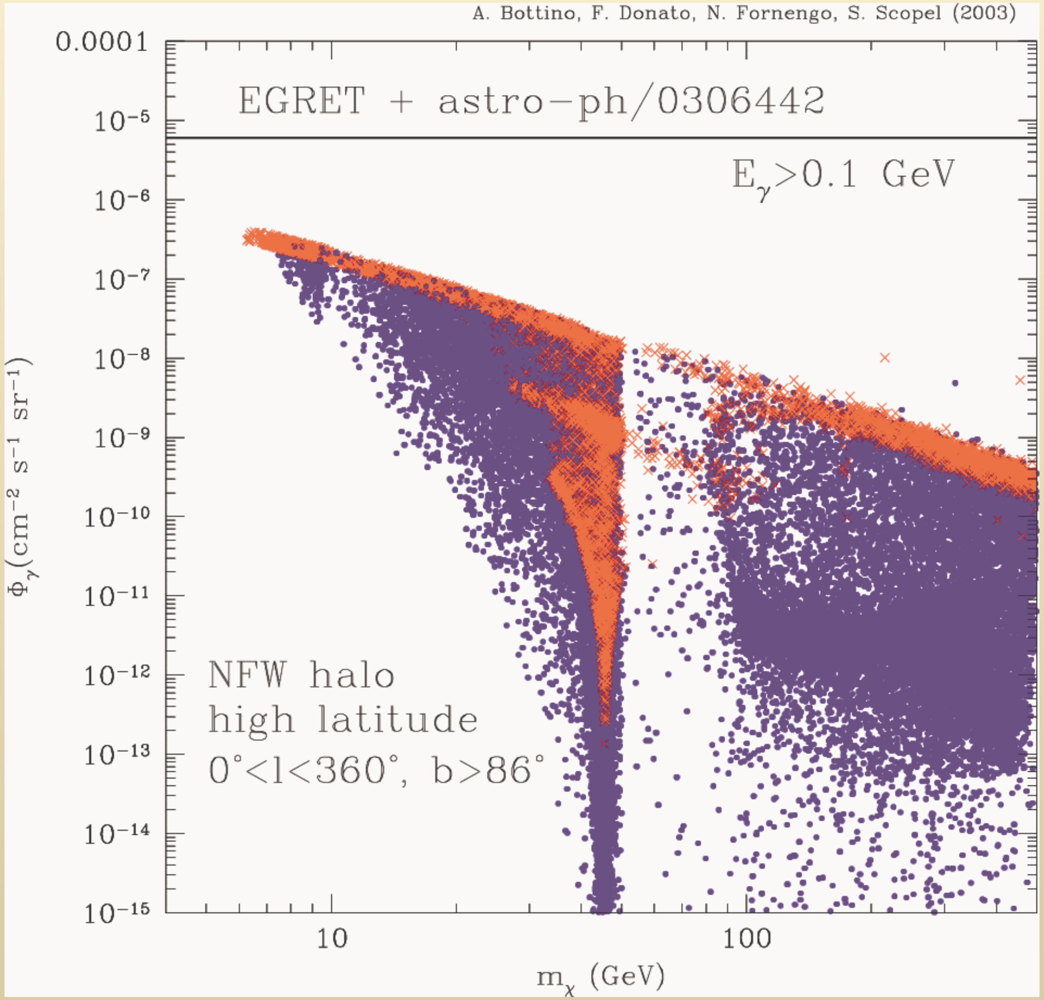
(Donato, Gentile, Salucci, MNRAS 2004)

If we adopt the law in Navarro et al., MNRAS 2004:

$$\beta_\alpha(r) = -d\ln\rho/d\ln r = 2(r/r_{-2})^\alpha \qquad (\alpha = 0.17)$$

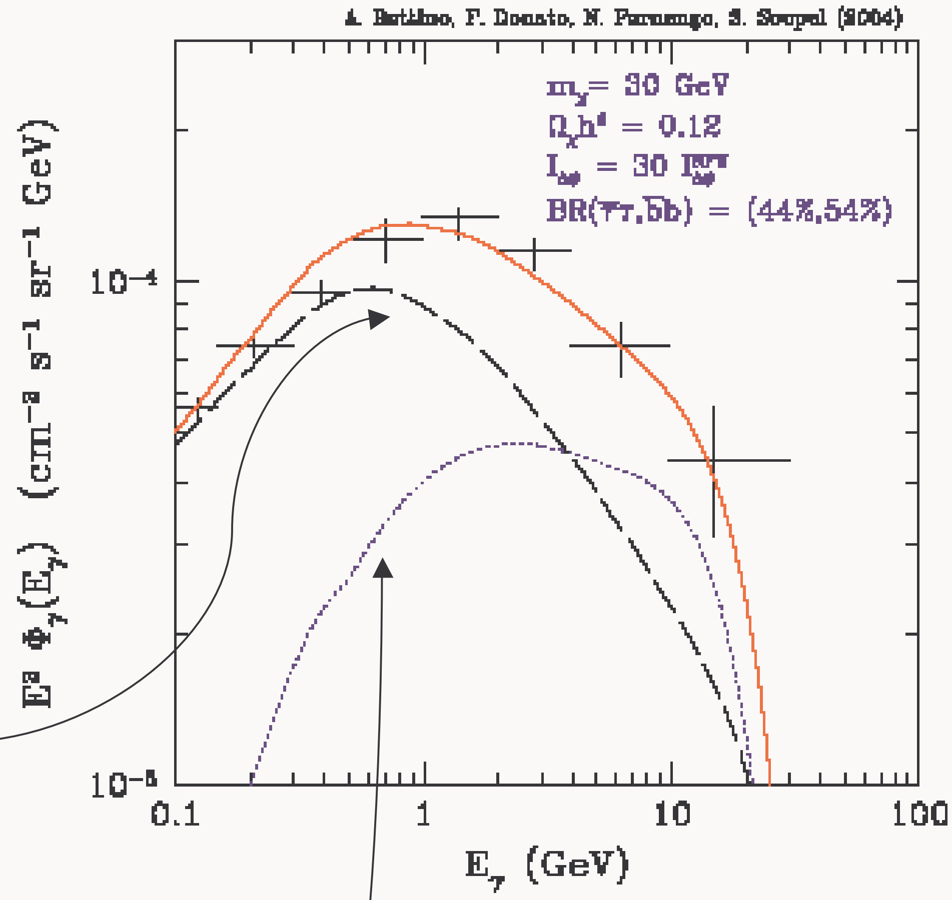
the geometric factor in the flux increased up to ~ 5 (NFW)

LOOKING AT THE GALACTIC POLES



Insensitive to the DM distribution function

Fitting data: just an example



EGRET DATA

background

30 GeV neutralino

Conclusions & Perspectives:

- Neutralino below LEP limit could be explored in indirect searches
- The best means are antiprotons
- γ-rays might improve fits
- Neutrino fluxes are much under present sensitivities
- Strong limits come from the background knowledge
- Data from Pamela, Ams, Glast, Agile, ecc.
- Antideuterons ….