Gamma and *Cosmic Rays* from Galactic Dark Matter Annihilation

Fiorenza Donato

A. von Humboldt fellow

MPI, Munich

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Plan of my talk

- Short introduction

- Antiprotons in cosmic rays (CRs)

- Gamma rays from the galactic center (GC) and poles

- Light neutralinos

The neutralino: an ideal CDM candidate

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

- **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 ($e^+, \bar{p}, \bar{D}$) & γ rays, ν

Bottino, FD, Fornengo, Scopel
PRD 59(1999)095003 & 095004; PRD 62(2000)056006; PRD 63(2001)125003

ANTIPROTONS IN COSMIC RAY

FD, Maurin, Salati, Barrau, Boudoul, Taillet, ApJ (2001)
BergstrÖm, EdsjÖ, Ullio, ApJ (1999) — Bieber et al. PRL (1999)
Moskalenko et al., ApJ (2002)

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

- p and He in CRs   *(AMS & BESS 1998)*

- Nuclear cross sections   *(Tan&Ng + DTUNUC)*

- Diffusion model   *(our DM&B/C)*

ANTIPROTONS from RELIC NEUTRALINOS

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

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

→ χ *density*

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

Production takes place everywhere in the halo!!

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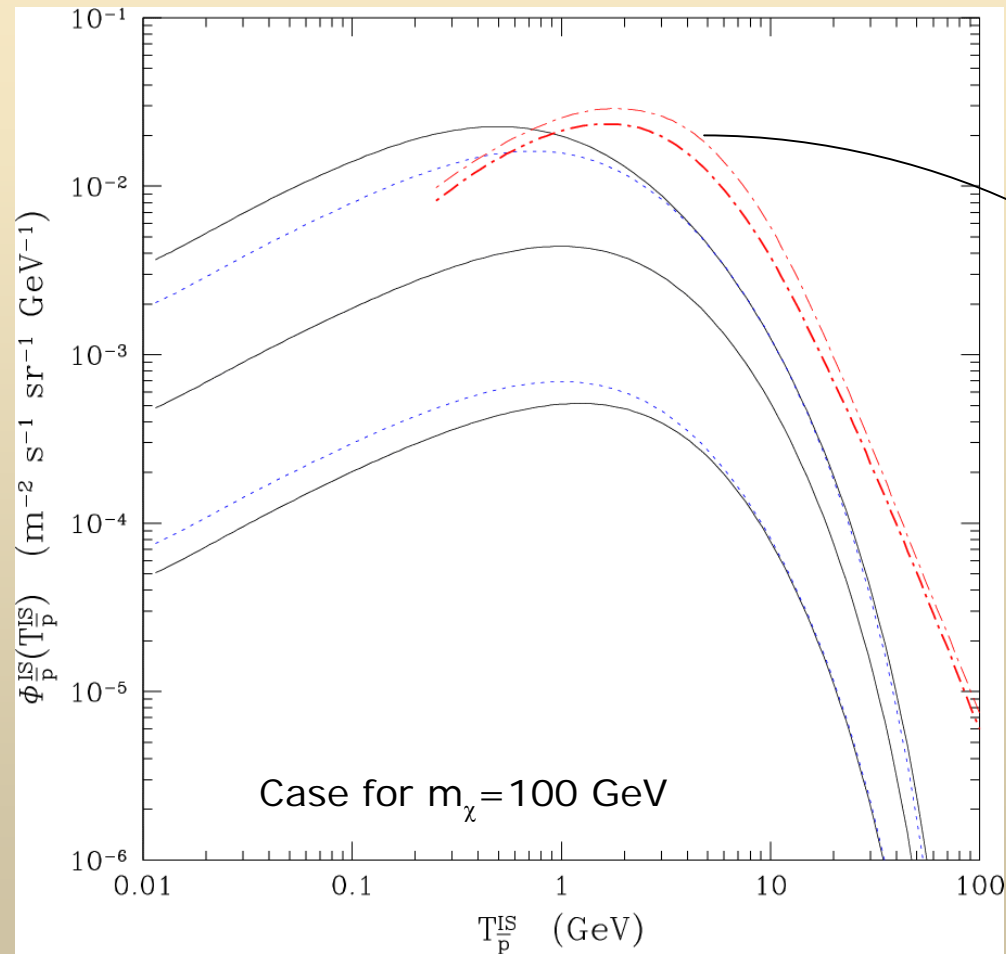May we look for new physics?!**

PRIMARY, SECONDARY & DATA
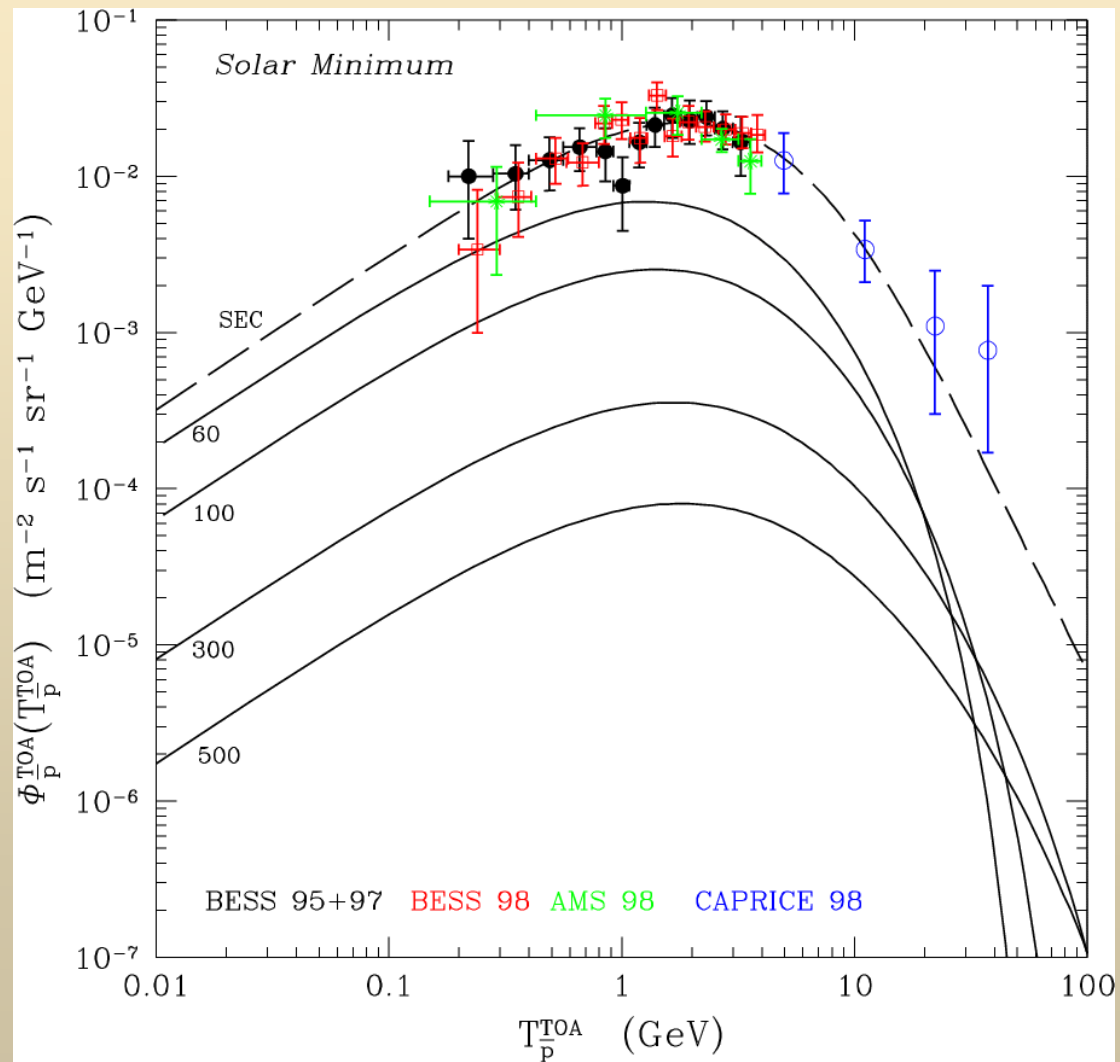
PRIMARY FLUXES and UNCERTAINTIES

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

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

Secondary flux

Case for $m_\chi = 100$ GeV

Plot axes: $\Phi^{IS}_{\bar{p}}(T^{IS}_{\bar{p}})$ (m^{-2} s^{-1} sr^{-1} GeV^{-1}) versus $T^{IS}_{\bar{p}}$ (GeV)

Huge astrophysical uncertainty for primaries!!

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
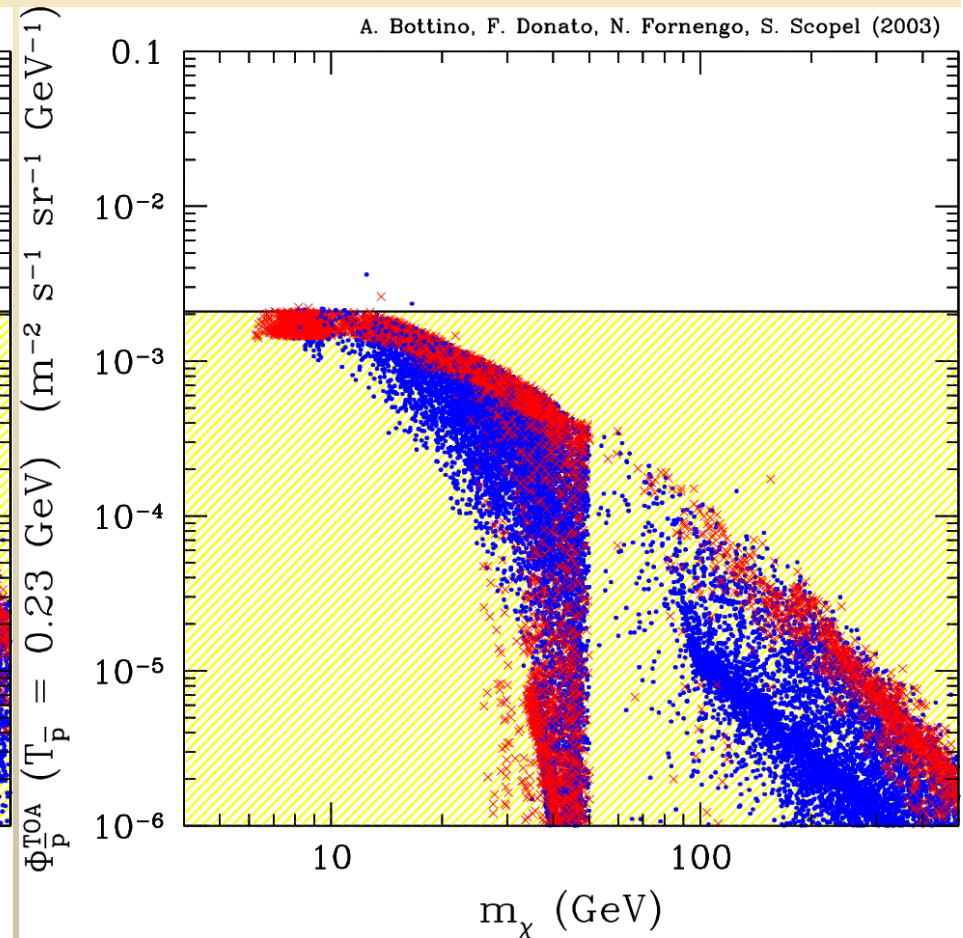$$\Omega_\chi h^2 \leq (\Omega_{CDM} h^2)_{max}$$

$$\Downarrow$$

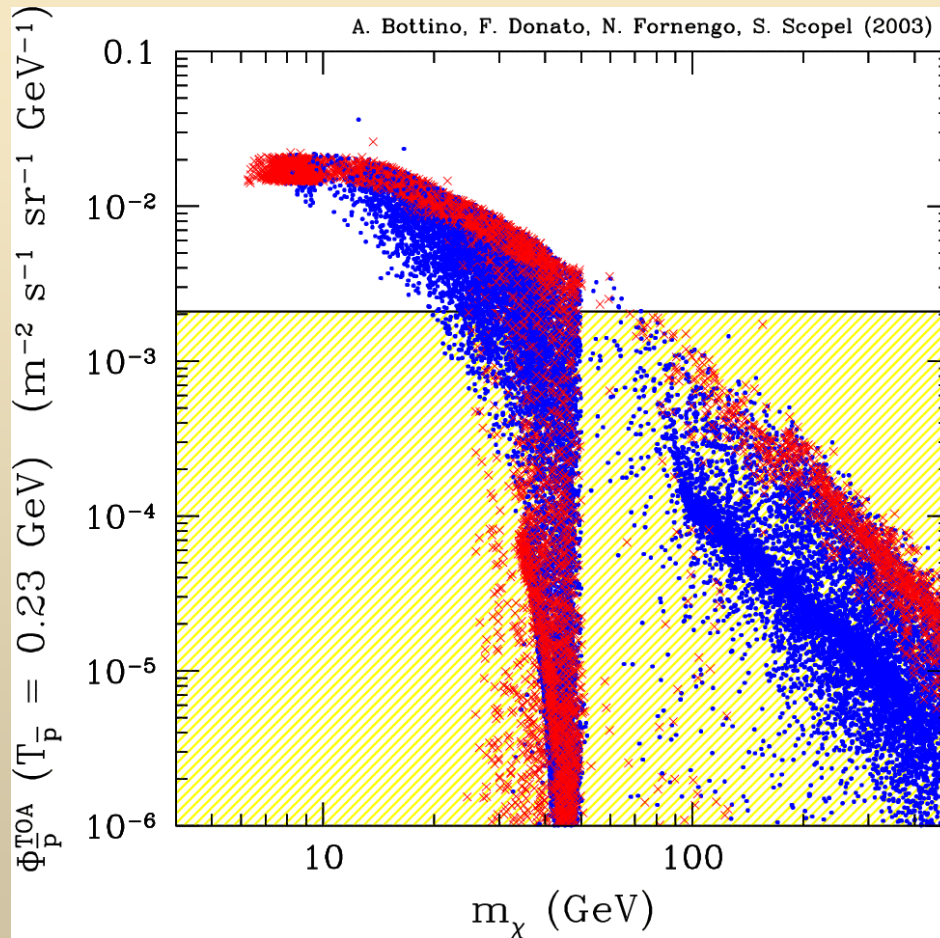$$m_\chi \geq 7 \text{ GeV}$$

Interesting rates for direct and indirect detection!!!

Constraints from Antiproton data??

(Bottino, FD, Fornengo, Scopel PRD 2004)

Propagation: best fit   Propagation: very conservative

$\Omega_\chi \, h^2 > 0.095$ $\Omega_\chi \, h^2 < 0.095$

Possible enhancements of the flux

If the dark halo is <u>clumpy</u> :

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

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

The local DM <u>density</u> :
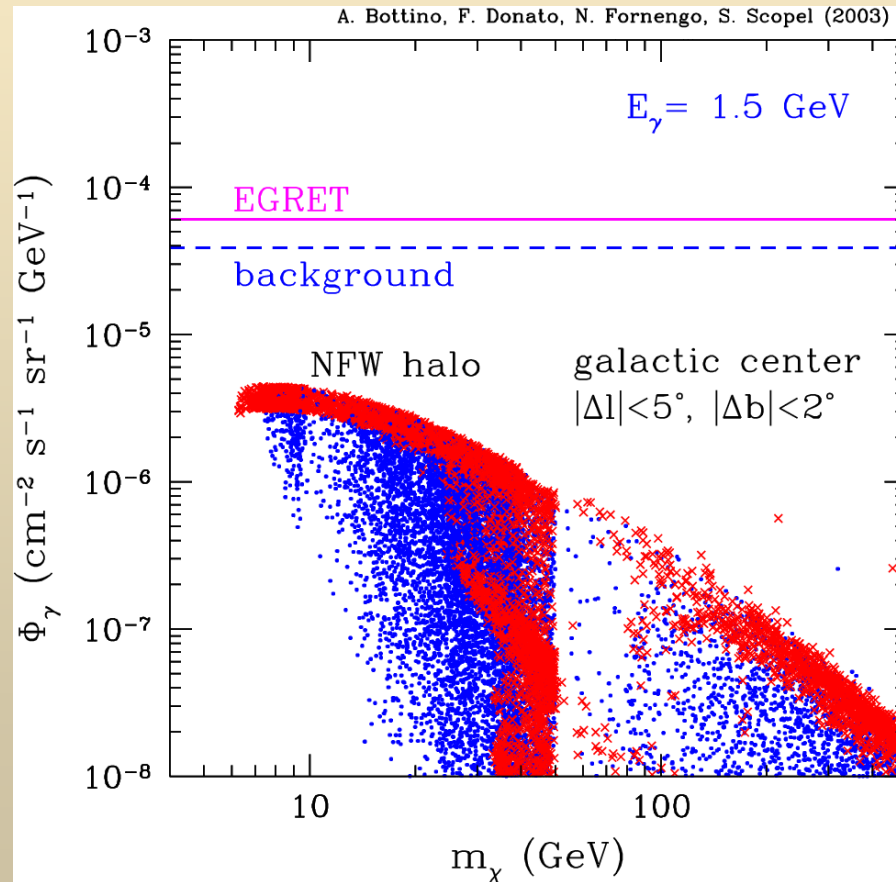
$$\rho_0 : 0.2 \sim 0.7 \ GeV/cm^3 \qquad \rightarrow \qquad \Phi \sim \rho_0^{\,2}$$

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%

γ-RAYS from LIGHT NEUTRALINOS

(Bottino, FD, Fornengo, Scopel PRD 2004)

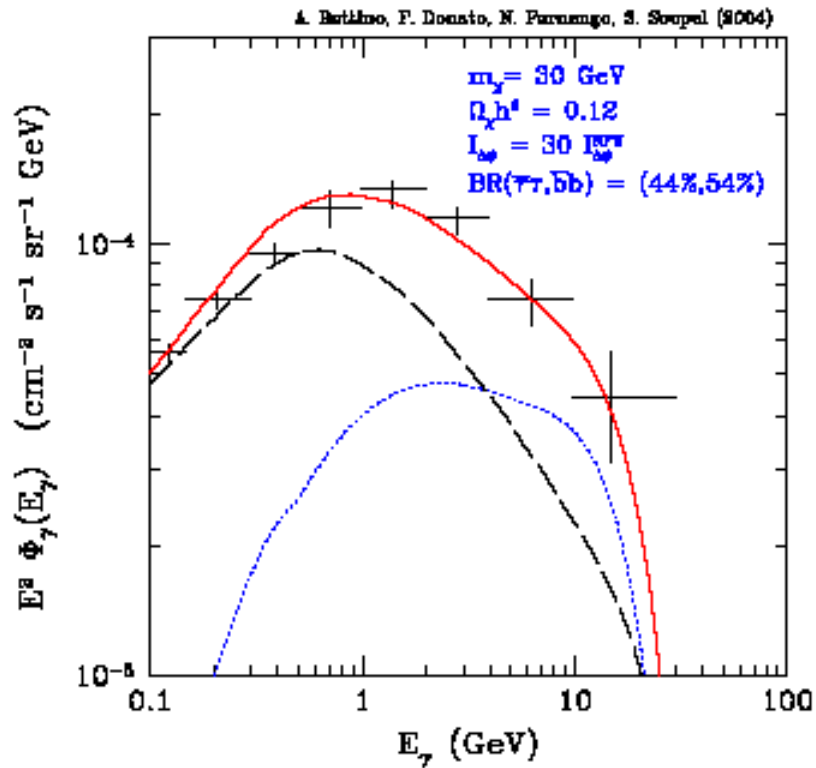## The Galactic Center is a Peculiar Site: Does it cluster DM?

A. Bottino, F. Donato, N. Fornengo, S. Scopel (2003)

H.E.: Cangaroo & Hess
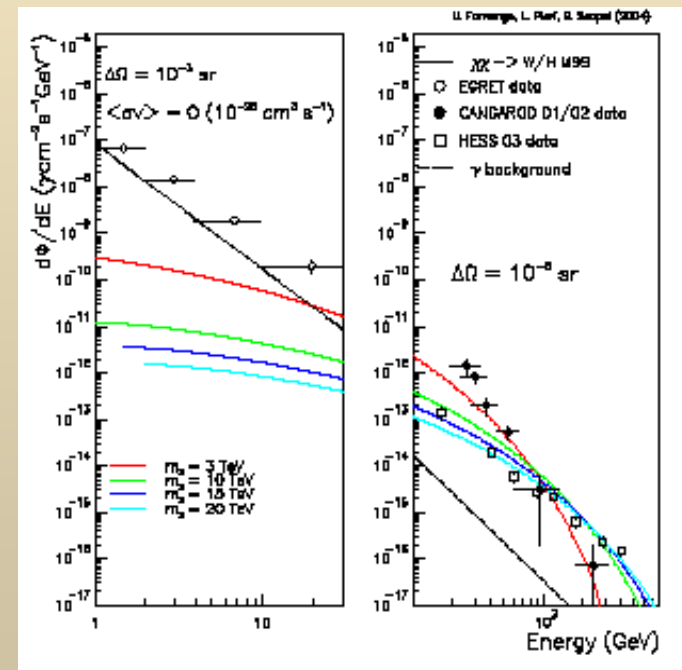
from Fornengo, Pieri, Scopel PRD 2004

$\Omega_\chi h^2 > 0.095$ $\Omega_\chi h^2 < 0.095$

SUSY + Backgroung & EGRET GC

GALACTIC POLES

Cuspy DM profile !
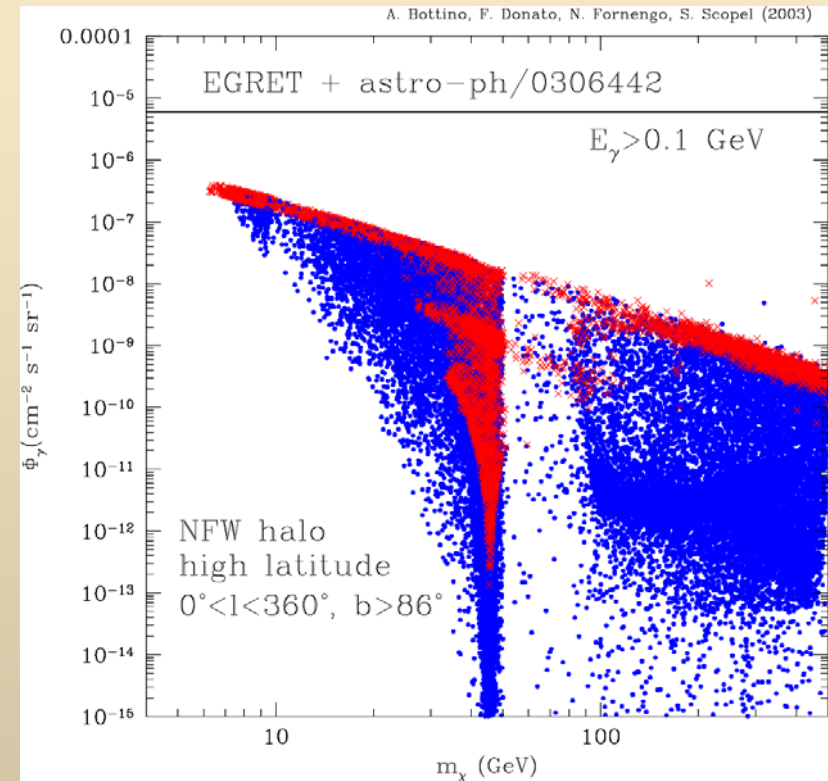
Insensitive to the DM distribution function

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)

Conclusions & Perspectives:

- *Neutralino below LEP limit could be explored in indirect searches, as well as in direct searches*

- *The best means are antiprotons*

- *γ-rays might improve fits*

- *Strong limits come from the background knowledge*

- *DM distribution at GC?*

- *Plenty of data from telescopes, balloon-borne and space-based detectors, satellites*

- *Eventually, wait for accelerators!*