Internal Bremsstrhalung in neutralino annihilation: revised impact on indirect detection by γ-rays

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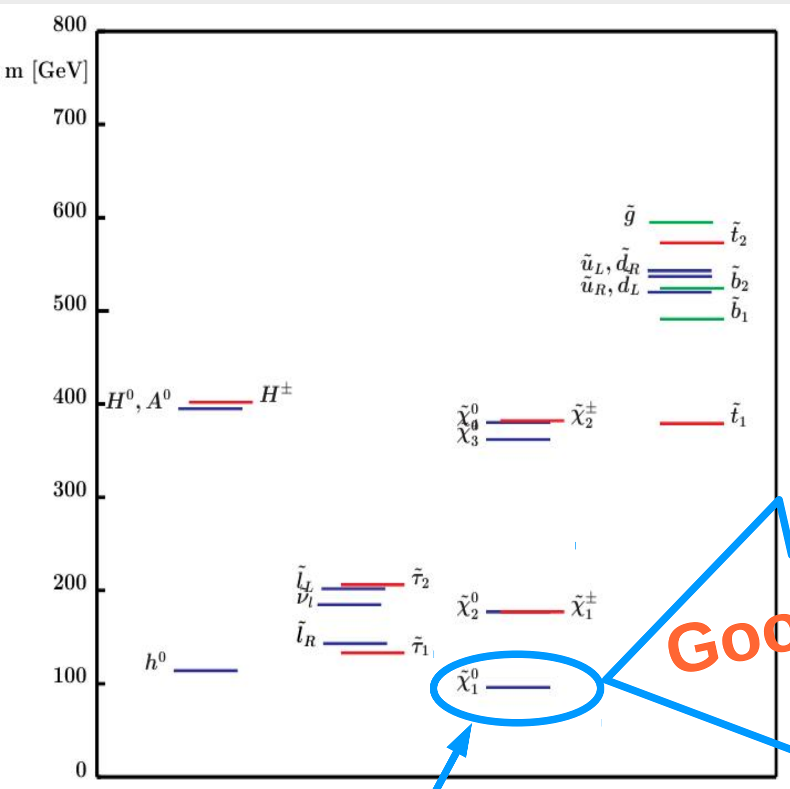
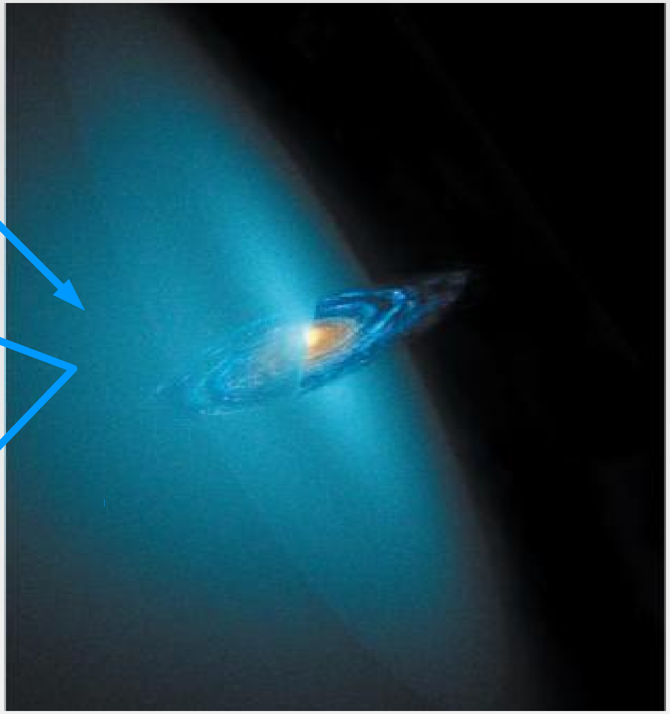
Based on:
M.C., M. E. Gomez, M.A. Sanchez-Conde, F. Prada, O. Panella
***PRD81, 107303 (2010)* arXiv:1003.5164**

Supersymmetry (SUSY) and Dark Matter (DM)



Cosmology and Astrophysics require a Dark Matter halo to sorround the galaxies composed by Weakly Interacting Particles (WIMP)



Good WIMP candidate!

In R-parity conserving models the lightest Neutralino is stable. Interactions can be “weak” enough to explain the relic density value inferred by WMAP

Indirect detection: look for photons, positrons, anti-protons produced by neutralinos interactions in the halo

γ rays from $\chi\chi$ annihilation

Uncomplete list of original referenes….

Secondary photons

J. Gunn et al, AJ 233 (1978)

F. W. Stecker, AJ 233 (1978)

Y. B. Zeldovich et al., Yad. Fiz 31 (1980)

j. Silk, M. Srednicki, PRL 53 (1984)

Internal Bremsstrahlung(IB)

L. Bergstrom, PLB 225 (1989)

R. Flores, K.OLive, S. Rudaz PLB 232 (1989)

L. Bergstrom et al, PRL 95 (2005)

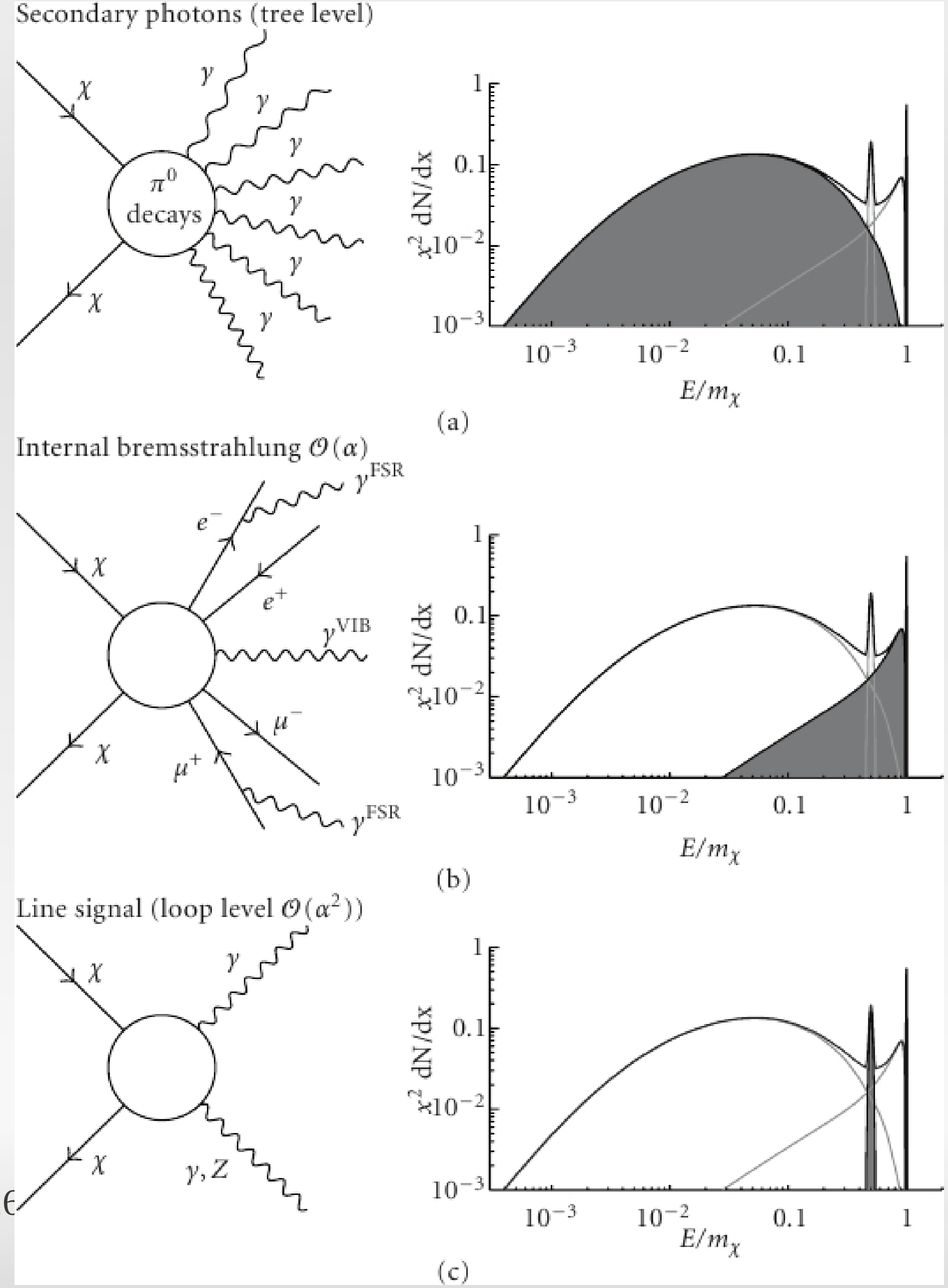
T. Bringmann et al, JHEP 01 (2008)

Lines

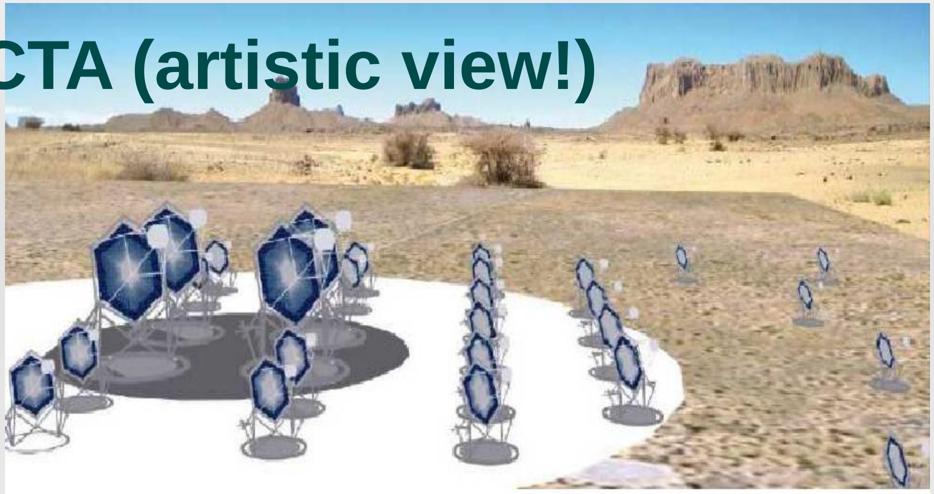
L. Bergstrom, PLB 225 (1989)

L. Bergstrom, P. Ullio, NPB 504 (1997), PRD57 (1998)

Z. Bern et al, PLB 411 (1997)



γ detectors: Imaging Atmospheric Cherenkov Telescopes (IACT)



M. Doro,arXiv:0908.1410

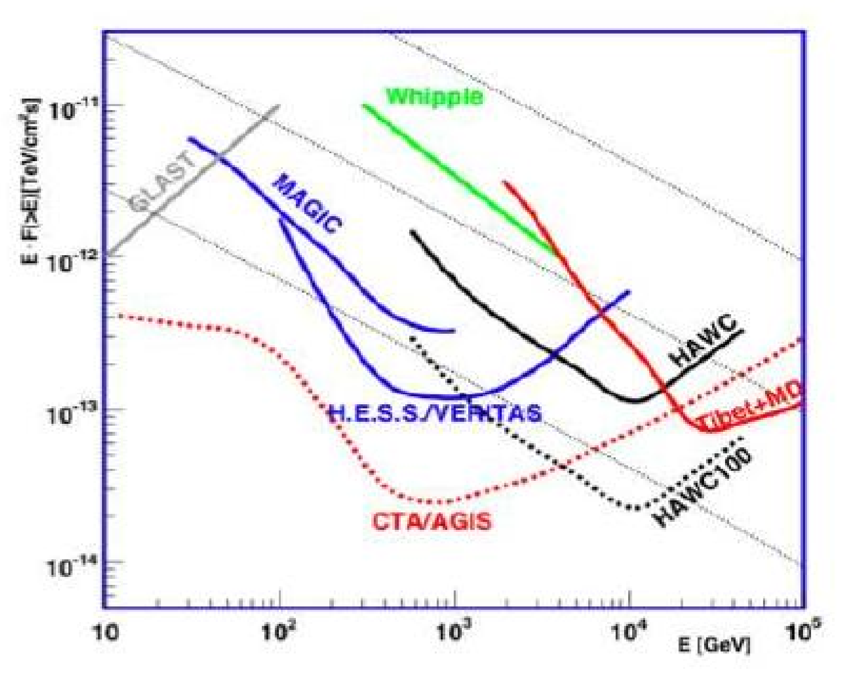


Figure 2: Integral sensitivity for a Crab-like spectrum for several current IACT and expected for CTA/AGIS (5σ, 50 h) and Fermi/GLAST (5σ, 1 yr).

- Typical **energy threshold** of IACT: **100 GeV**
- We use **simulated sensitivity curves for MAGIC II and CTA with 50 hours of observation and 5σ detection limit**

Astrophysical target: DRACO dwarf spheroidal galaxy (1)

Dwarf spheroidal galaxies (dSph) satellites of the Milky Way (Draco, Segue, Willman 1 etc.) are optimal targets. In particular DRACO dSph:

- Near: located at 80 kpc
- High matter to light ratio (high concentration of DM!)
- Many observational constraints help to model the DM halo
- Already observed in gamma rays with null results by:

MAGIC I (E>140 GeV)	**AJ679 (2008)**
Fermi-Lat (0.1 GeV< E< 300 GeV)	**AJ 712 (2010)**
VERITAS (E>200 GeV)	**arXiv:1006.5955**

Astrophysical Target: DRACO dwarf spheroidal galaxy (2)

Some previous studies of the signal from Draco:

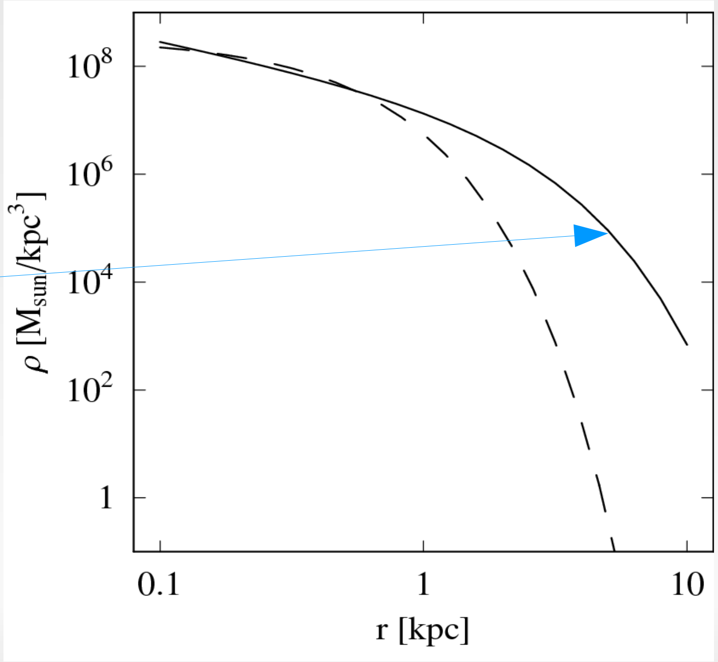
N. W. Evans, F. Ferrer, S. Sarkar, PRD69 (2004)
L. Bergstrom, D. Hooper PRD 73 (2006)
S. Profumo, M. Kamionkowski, JCAP 0603(2006)
S. Colafrancesco, S. Profumo, P.Ullio,PRD75(2007)
T. Bringmann, M. Doro, M. Fornasa JCAP0901(2009)

$$\rho_{DM}^{Draco}(r) = C r^{-\alpha} \exp\left(-\frac{r}{r_b}\right)$$

$\alpha = 1 \rightarrow$ cuspy profile
$C = 3.1 \times 10^7 M_\odot / kpc^2$
$r_b = 1.189$ kpc

We use the cuspy halo profile from:

M. A. Sanchez-Conde, F. Prada, E.L.Lokas, M. E. Gomez, R. Wojtak, M.Moles, PRD 76 (2007)



Obtained with a fit stellar kinematics observations.

Expected γ Flux: astrophysical factor (AF)

$$F(E_\gamma > E_{\rm th}) = f_{SUSY}(E_\gamma > E_{\rm th}) \cdot J(\Psi)$$

$$J(\Psi) = \frac{1}{4\pi}\int d\Omega \int d\lambda\, \rho^2[r(\lambda)]\, B_{\sigma_t}(\Omega)$$

$$r = \sqrt{\lambda^2 + D^2 - 2\lambda D \cos\Psi}$$

Ψ: direction of observation in the sky

λ: distance along the line of sight determined by Ψ

r : intergalactic distance

D: distance of the halo center from us

B: beam smearing function of the IACT

We use the total AF integrated over the full angular extension of the galaxy

WARNING: In literature uncertainties by a factor 2-3, depending on the halo model: not crucial for our analysis. Example, FERMI analysis use a J 2.6 times bigger (NFW halo profile)

$$\overline{J} = \frac{1}{4\pi D^2}\int_V \rho^2_{DM}(r)\, dV = 3.7 \times 10^{17} GeV^2 cm^{-5}$$

Espected γ Flux: particle physics factor

$$F(E_\gamma > E_{\rm th}) = f_{SUSY}(E_\gamma > E_{\rm th}) \cdot J(\Psi)$$

$$f_{susy} = f_{cont} + f_{lines}$$

$$f_{cont} = \left(\sum_f \int_{E_{th}}^{m_\chi} \frac{dN_\gamma^f}{dE_\gamma} dE_\gamma \right) \frac{\langle \sigma_{\chi\chi} v \rangle}{2 m_\chi^2} = f_{sec} + f_{IB}$$

Number of continuos photons
with energy
greater than the threshold

$$f_{lines} = 2 \frac{\langle \sigma_{\gamma\gamma} v \rangle}{2 m_\chi^2} + \frac{\langle \sigma_{Z\gamma} v \rangle}{2 m_\chi^2}$$

Experimental constraints

- WMAP relic density interval: $0.09<\Omega h^2<0.13$ (3σ)
- LEP bounds on Higgs mass: $m_h>114$ GeV
- Chargino mass bound: $m_c >103.5$ GeV
- $b \rightarrow s\gamma$
- Accelerator bounds on sparticle masses
- We use **DarkSUSY 5.05** where IB is fully included

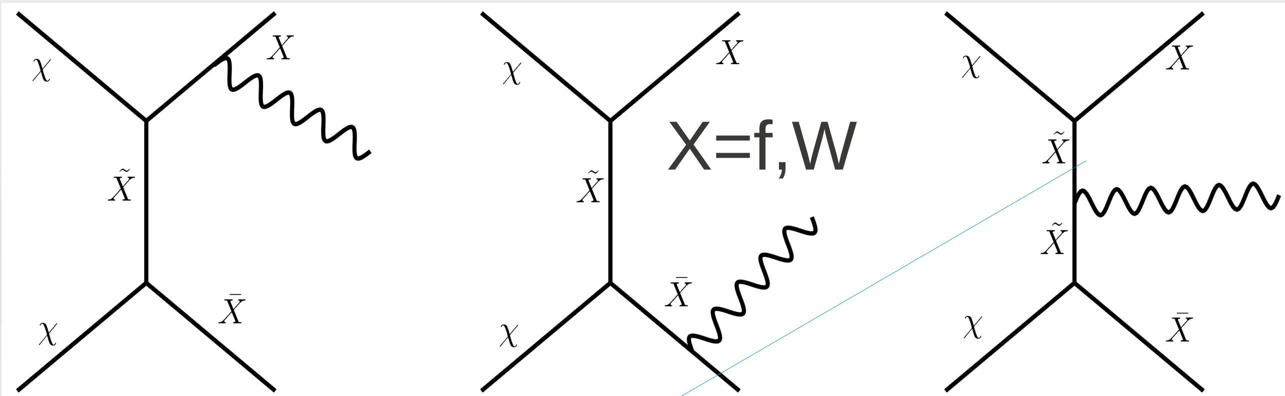
Warning:
the following mSUGRA results are from ISAJET 7.78; different results are obtained in some points of the parameter space with other codes (SOFTSUSY, SUSPECT)

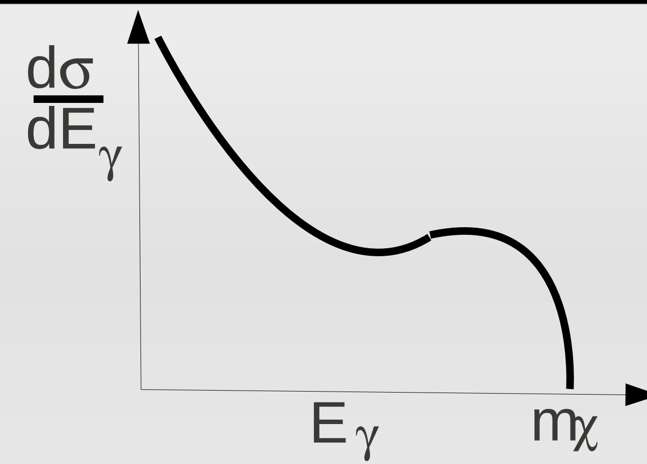
P. Gondolo, J. Edsjö, P. Ullio, L. Bergstöm, M. Schelke and E.A. Baltz, JCAP 07 (2004) 008

http://www.physto.se/~edsjo/darksusy

Now included also in micrOMEGAs 2.4 arXiv: 1004.1092

IB: $f\bar{f}\gamma$ final state



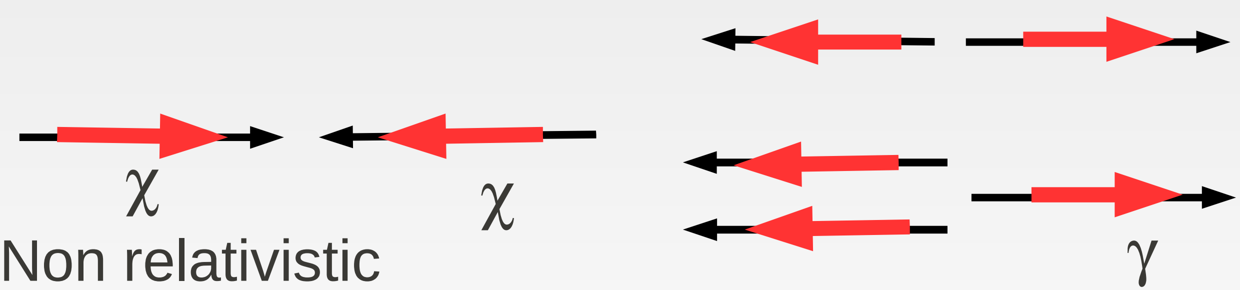


$$m_\chi \gg m_X$$

$$\frac{1}{(m_\chi^2 - m_{\tilde{X}}^2) - 2 m_\chi E_X}$$

- $m_\chi \sim m_{\tilde{X}}$
- E_X small, E_γ large

→ Large cross section



m_f^2 Suppressed due to "wrong" fermion helicity

Non relativistic
Identical fermions

$S_z=0$

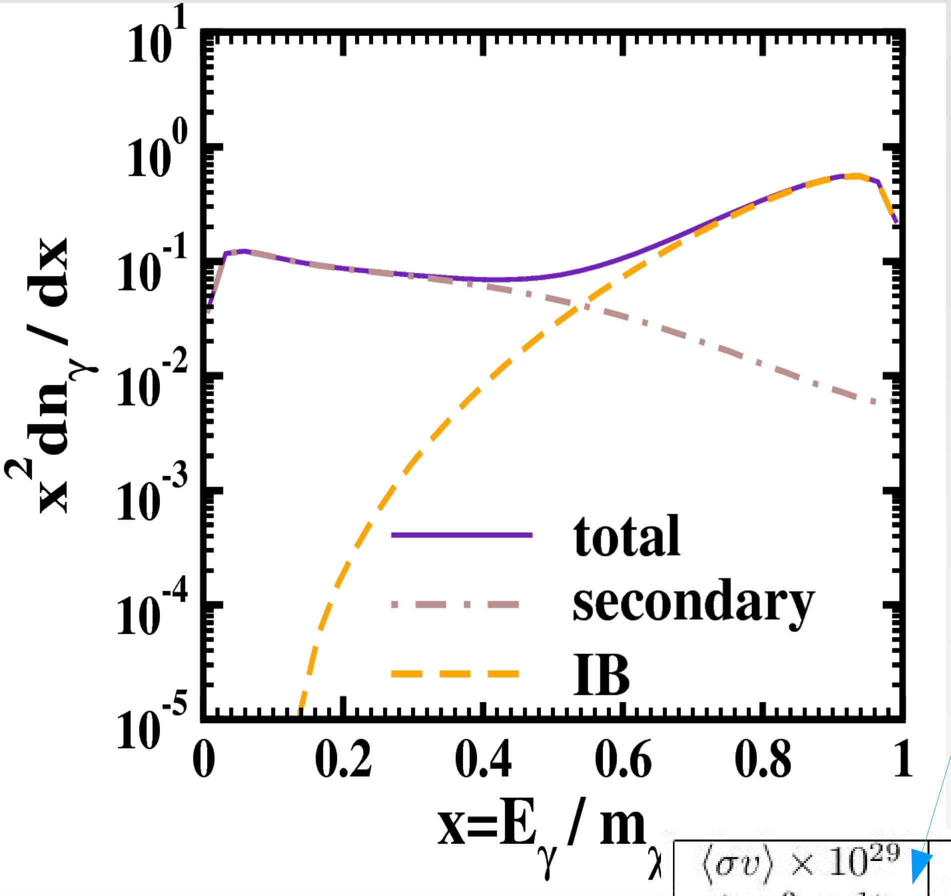
z

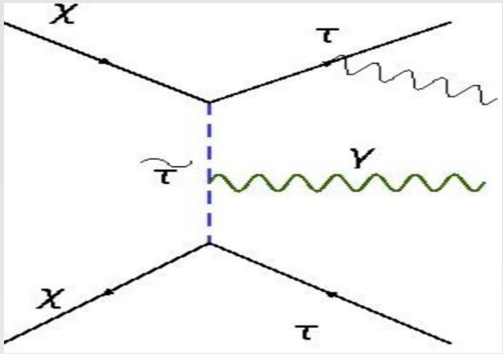
No helicity suppression favored configuration with γ energy near χ mass

CMSSM: stau co-annihilation region

$\tan\beta$	m_0 (GeV)	$m_{1/2}$ (GeV)	A_0 (GeV)	$m_{\tilde{\chi}}$ (GeV)	$m_{\tilde{\tau}}$ (GeV)
18	127	459	−135	187.6	195

$$m_{\tilde{\tau}} \gtrsim m_\chi$$





$$\sigma \simeq \sigma(\chi\chi \to \tau\tau) + \sigma(\chi\chi \to b\bar{b})$$

f_{IB} bigger contribution

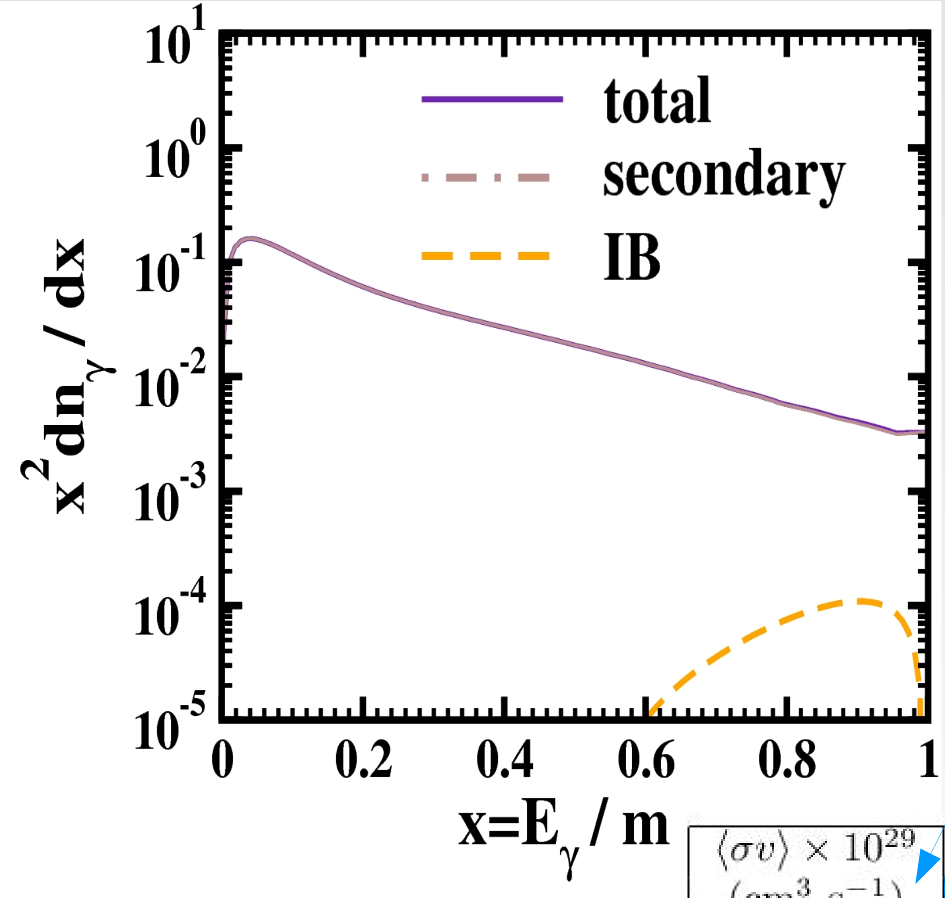
f_{lines} dominate over secondaries

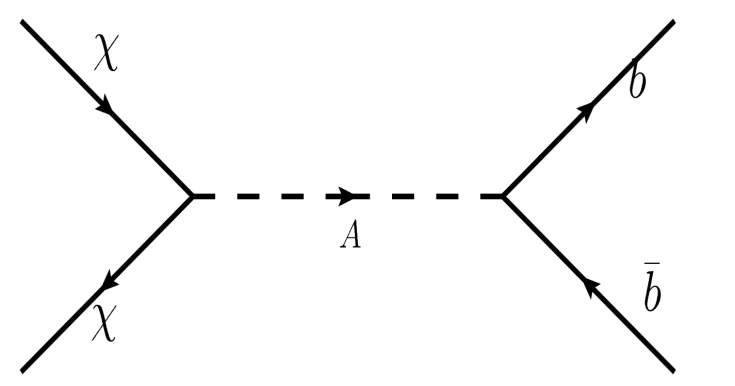
$\langle\sigma v\rangle \times 10^{29}$ ($cm^3\ s^{-1}$)	$f_{sec} \times 10^{32}$		$f_{lines} \times 10^{32}$ ($GeV^{-2}\ cm^3\ s^{-1}$)		$f_{IB} \times 10^{32}$	$f_{SUSY} \times 10^{32}$
29	0.008	<	0.018	<	0.079	0.1

CMSSM: funnel region

$\tan\beta$	m_0 (GeV)	$m_{1/2}$ (GeV)	A_0 (GeV)	$m_{\tilde\chi}$ (GeV)	m_A (GeV)
52	982	1377	725	598	1211

$$m_A \simeq 2m_\chi$$





$$\sigma \simeq \sigma(\chi\chi \to b\bar{b})$$

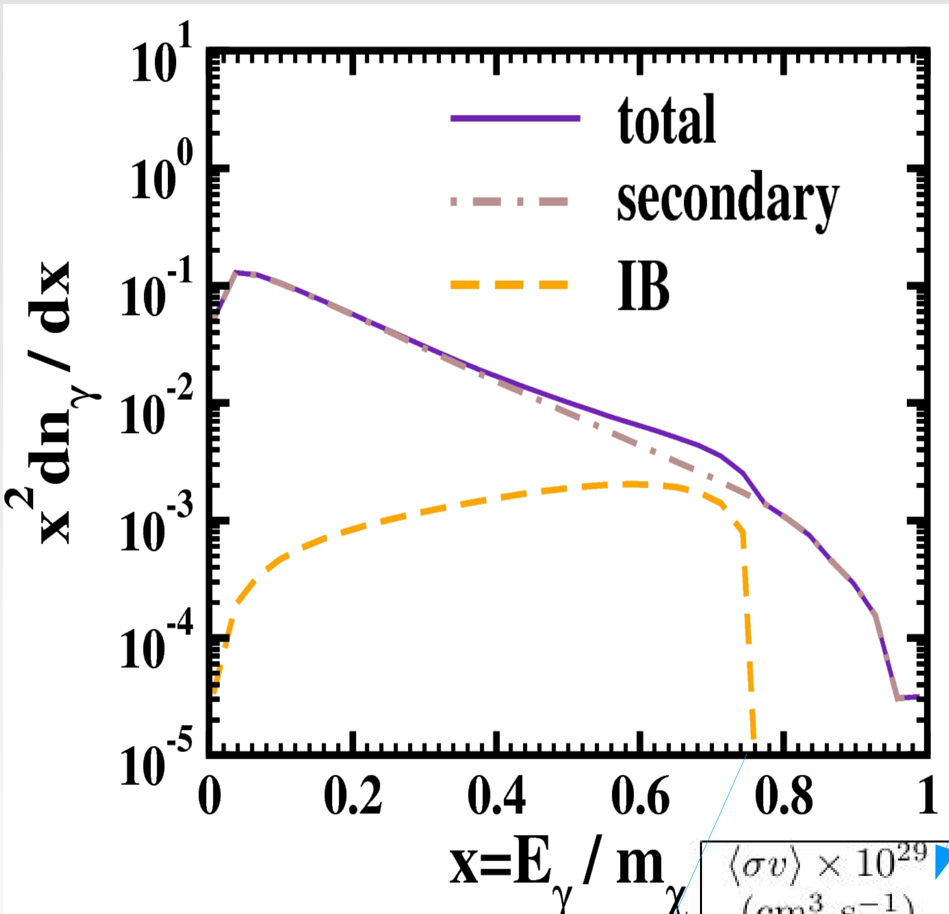
f_{lines} and f_{IB} negligible

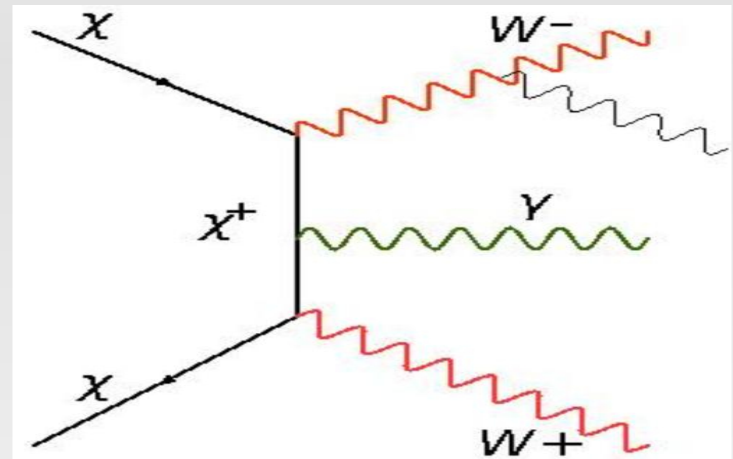
$\langle\sigma v\rangle \times 10^{29}$ ($cm^3\ s^{-1}$)	$f_{sec} \times 10^{32}$	$f_{lines} \times 10^{32}$ ($GeV^{-2}\ cm^3\ s^{-1}$)	$f_{IB} \times 10^{32}$	$f_{SUSY} \times 10^{32}$
2600	0.72	10^{-5}	10^{-5}	0.72

CMSSM: focus point region (1)

$\tan\beta$	m_0 (GeV)	$m_{1/2}$ (GeV)	A_0 (GeV)	$m_{\tilde{\chi}}$ (GeV)	$m_{\chi_1^+}$ (GeV)
17	2200	430	805	163	212

$$m_{\chi_1^+} \gtrsim m_\chi \gtrsim m_W$$





$$\sigma \simeq \sigma(\chi\chi \to W^+W^-)$$

The 3 contributions are of the same order

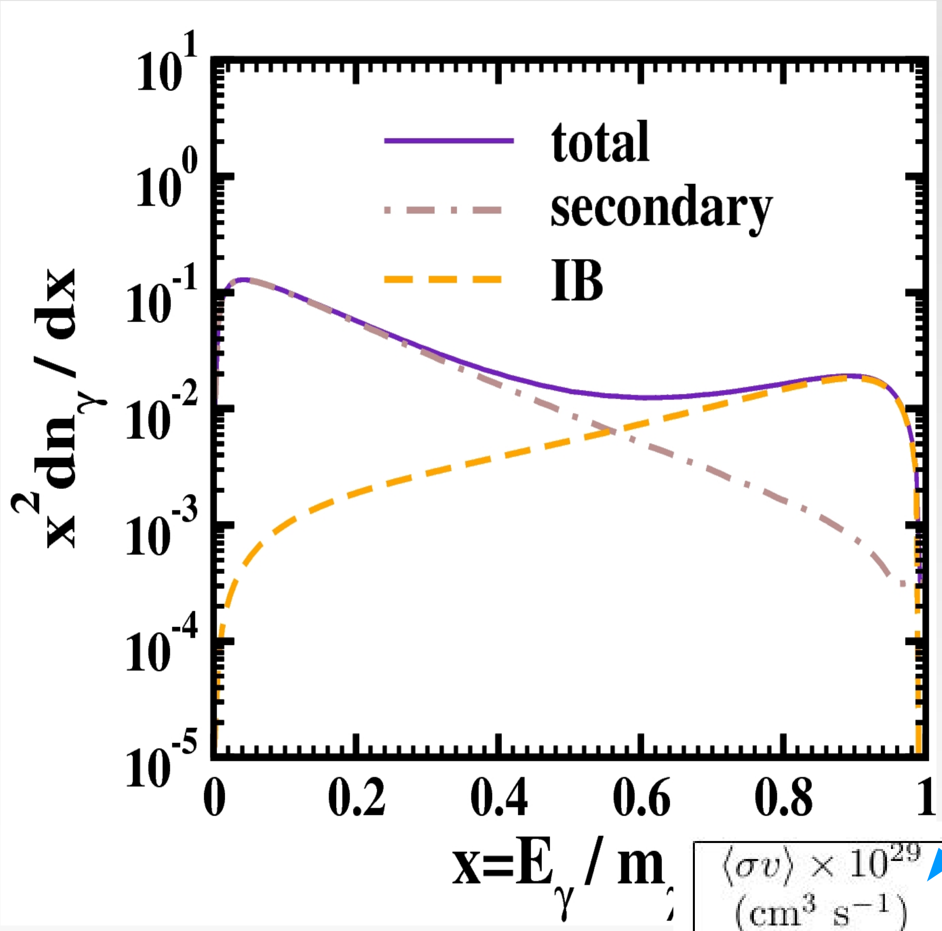
$\langle\sigma v\rangle \times 10^{29}$ (cm^3 s^{-1})	$f_{sec} \times 10^{32}$	$f_{lines} \times 10^{32}$ (GeV^{-2} cm^3 s^{-1})	$f_{IB} \times 10^{32}$	$f_{SUSY} \times 10^{32}$
2225	0.04	0.06	0.02	0.12

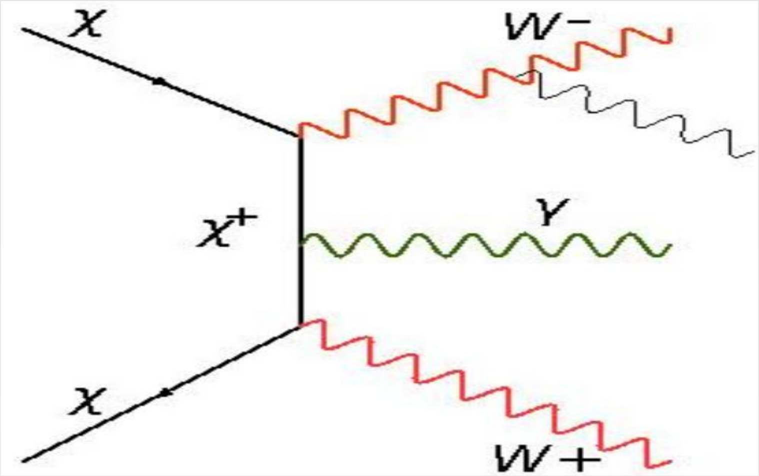
$$1 - \frac{M_W^2}{m_\chi^2} = 0.75$$

CMSSM: focus point region (2)

$\tan\beta$	m_0 (GeV)	$m_{1/2}$ (GeV)	A_0 (GeV)	$m_{\tilde{\chi}}$ (GeV)	$m_{\chi_1^+}$ (GeV)
51	8940	2218	−4221	918	954

$$m_{\chi_1^+} \gtrsim m_\chi \gg m_W$$



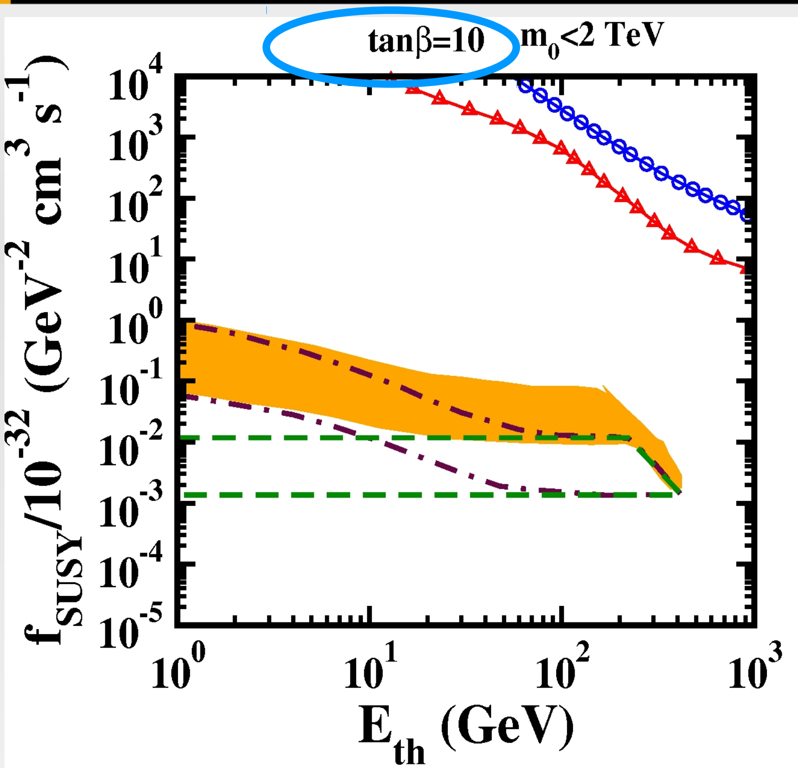


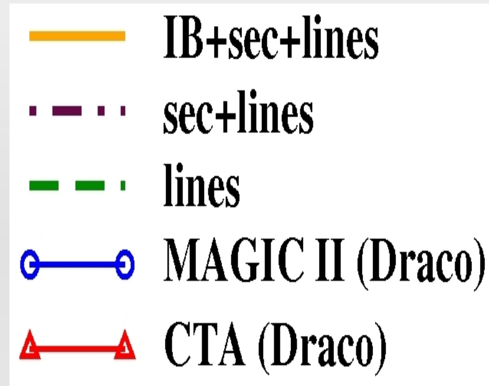
$$\sigma \simeq \sigma(\chi\chi \to W^+W^-, ZZ, t\bar{t})$$

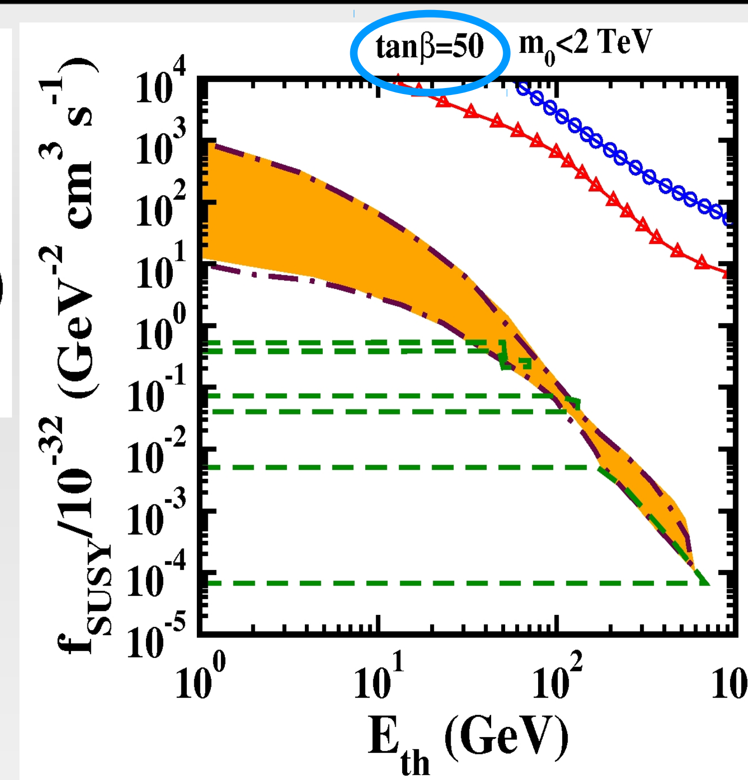
f_{IB} a factor 5 greater than lines,
Secondaries dominate

$\langle\sigma v\rangle \times 10^{29}$ (cm^3 s^{-1})	f_{sec} $\times 10^{32}$	$f_{lines} \times 10^{32}$ (GeV^{-2} cm^3 s^{-1})	$f_{IB} \times 10^{32}$	$f_{SUSY} \times 10^{32}$
1203	0.3	0.003	0.017	0.32

f_{SUSY} vs E_{th}: $A_0 = 0$, $m_0 < 2$ TeV, $\mu > 0$







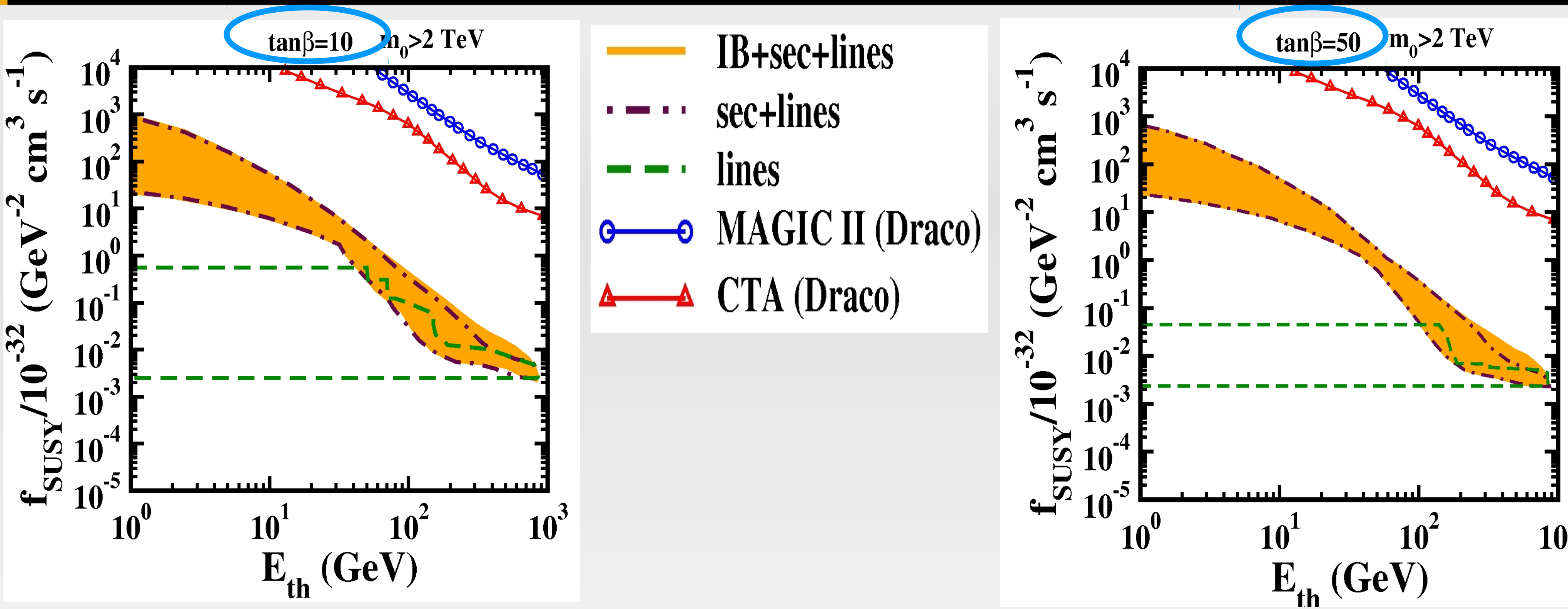
(m_0, $m_{1/2}$) are such that the CMSSM points satisfy the experimental constraints

Stau cohannihilation: up to an order of magnitude effect on expected flux above 100 GeV

Higgs funnel: no effect

For Draco dSph even including IB the expected flux is too small for IACT

f_{SUSY} vs E_{th}: $A_0 = 0$, $m_0 > 2$ TeV, $\mu>0$

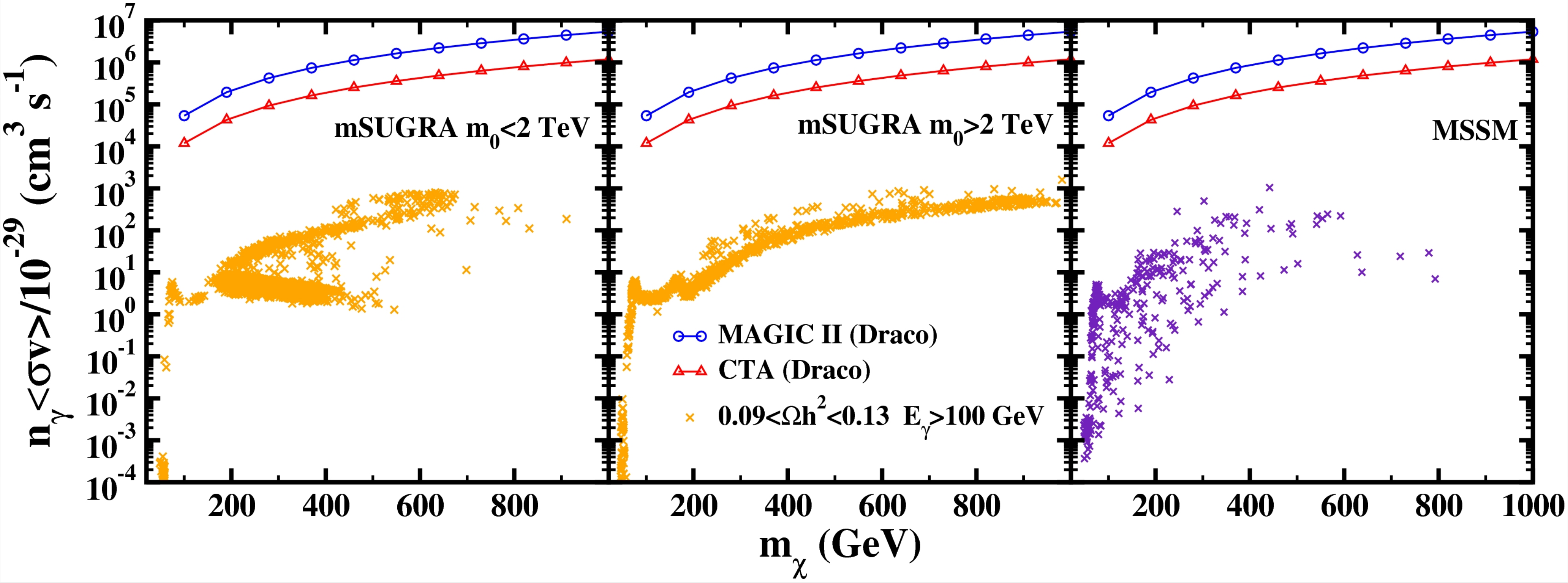


Here points are in the focus point and funnel regions: small IB effect at high energy

For Draco dSph even including IB the expected flux is too small for IACT

General CMSSM and MSSM

$N_\gamma(E_\gamma>100$ GeV$)$ x $<\sigma v>$ VS m_χ



$$\begin{aligned} 3 < & \tan\beta < 60, \\ 50 \text{ GeV} < & m_{1/2} < 2300 \text{ GeV}, \\ -3\, m_0 < & A_0 < 3\, m_0, \\ 50 \text{ GeV} < & m_0 < 10 \text{ TeV} \end{aligned}$$

$$\begin{aligned} 10 < & \mu < 10000\text{GeV}, \\ 5 < & \tan\beta < 60, \\ 50 \text{ GeV} < & M_i < 3000 \text{ GeV}, \\ 50 \text{ GeV} < & m_{\tilde f} < 10 \text{ TeV}, \\ -3\, m_{\tilde f} < & A_{\tilde f} < 3\, m_{\tilde f}, \\ 100 \text{ GeV} < & m_A < 1000 \text{ GeV}. \end{aligned}$$

2-3orders of magnitude below sensitivity limits

Conclusions

1) IB contribution is relevant only in models and at energies where the lines contribution is dominant over the secondary photons.

The most optimistic particle physics scenarios for DM detection (which typically correspond to those where most of the flux is given by secondary photons) will not change substantially.

3) Being typically the IB yield at most an order of magnitude greater than the lines yield, the net increase on absolute flux is of the same order.

4) DM detection prospects of the Draco dSph for the MAGIC and CTA IACT: the predicted fluxes are still at least three orders of magnitude below the sensitivity of the instruments both in CMSSM scenario and in the general MSSM.

5) Need an increase in sensitivity of IACT....keep on looking!