Constraining Dark Matter Properties From A Gamma-Ray Detection

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Constraining DM properties

- With gamma-rays

  S. Dodelson, D. Hooper and P. D. Serpico, *Phys. Rev. D77:063512, 2008*
  T. E. Jeltema and S. Profumo, *JCAP 0811:003, 2008*
  SPR and J. Siegal-Gaskins, *arXiv:1003.1142*
  N. Bernal and SPR, arXiv:1006.0477

- With neutrinos from the Sun

  J. Edsjo and P. Gondolo, *Phys. Lett. B357:595, 1995*
  M. Cirelli *et al.*, *Nucl. Phys. B727:99, 2005*
  O. Mena, SPR and S. Pascoli, *Phys. Lett. B664:92, 2008*

- With direct detection

  A. M. Green, *JCAP 0708:022, 2007*
  G. Bertone, D. G. Cerdeño, J. I. Collar and B. C. Odom, *Phys. Rev. Lett. 99:151301, 2007*
  M. Drees, C.-L. Shan, *JCAP 0806:012, 2008*
  A. M. Green, *JCAP 0807:005, 2008*
  C.-L. Shan, *New J. Phys. 11:105013, 2009*
  Y.-T. Chou and C.-L. Shan, *arXiv:1003.5277*

- With colliders

  E. A. Baltz, M. Battaglia, M. E. Peskin and T. Wizansky, *Phys. Rev. D74:103521, 2006*
  W. S. Cho, K. Choi, Y. G. Kim and C. B. Park, *Phys. Rev. Lett.100:171801, 2008*
  W. S. Cho, K. Choi, Y. G. Kim and C. B. Park, *Phys. Rev. D79:031701, 2009*

- With a combination

  N. Bernal, A. Goudelis, Y. Mambrini and C.Muñoz, *JCAP 0901:046, 2009*
  G. Bertone, D. G. Cerdeño, M. Fornasa, R. R. Austri and R. Trotta, *arXiv:1005.4280*

Indirect Detection in γ-Rays

- Extragalatic structures

  Bergstrom, Edsjo, Ullio, Lacey, Pieri, Branchini, Belikov, Hooper, Profumo, Jeltema, Pohl, Eichler, Abazajian, Agrawal, Chacko, Kilic...

- Galactic Center

  Berezinsky, Gurevich, Zybin, Bottino, Mignola, Bergstrom, Ullio, Buckley, Cesarini, Fucito, Lionetto, Morselli, Baltz, MAGIC Collaboration, HESS Collaboration...

- Milky Way Halo

  Baltz, Calcaneo-Roldan, Moore, Stoher, White, Springel, Tormen, Yoshida, Springel, Pieri, Lavalle, Bertone, Branchini, Fermi-LAT Collaboration...

- Milky Way subhalos

  Baltz, Pieri, Lavalle, Bertone, Branchini, Tasitsiomi, Olinto, Koushiappas, Zentner, Walker, Hoffmann, Diemand, Kuhlen, Madau...

- Dwarf Galaxies

  Baltz, Briot, Salati, Taillet, Silk, Tyler, Tasitsiomi, Siegal-Gaskins, Olinto, Bergstrom, Hooper, Strigari, Koushiappas, Bullock, Kaplinghat, Bringmann, Doro, Fornasa, Pieri, Pizella, Corsini, Bonatá, Bertola, Martínez, Trotta, Scott, Conrad, Edsjo, Farnier, Akrani, Evans, Ferrer, Sarkar, Simon, Geha, Willman, Essig, Sehgal, MAGIC Collaboration, HESS Collaboration, VERITAS Collaboration, Fermi-LAT Collaboration...

Overview of the analysis

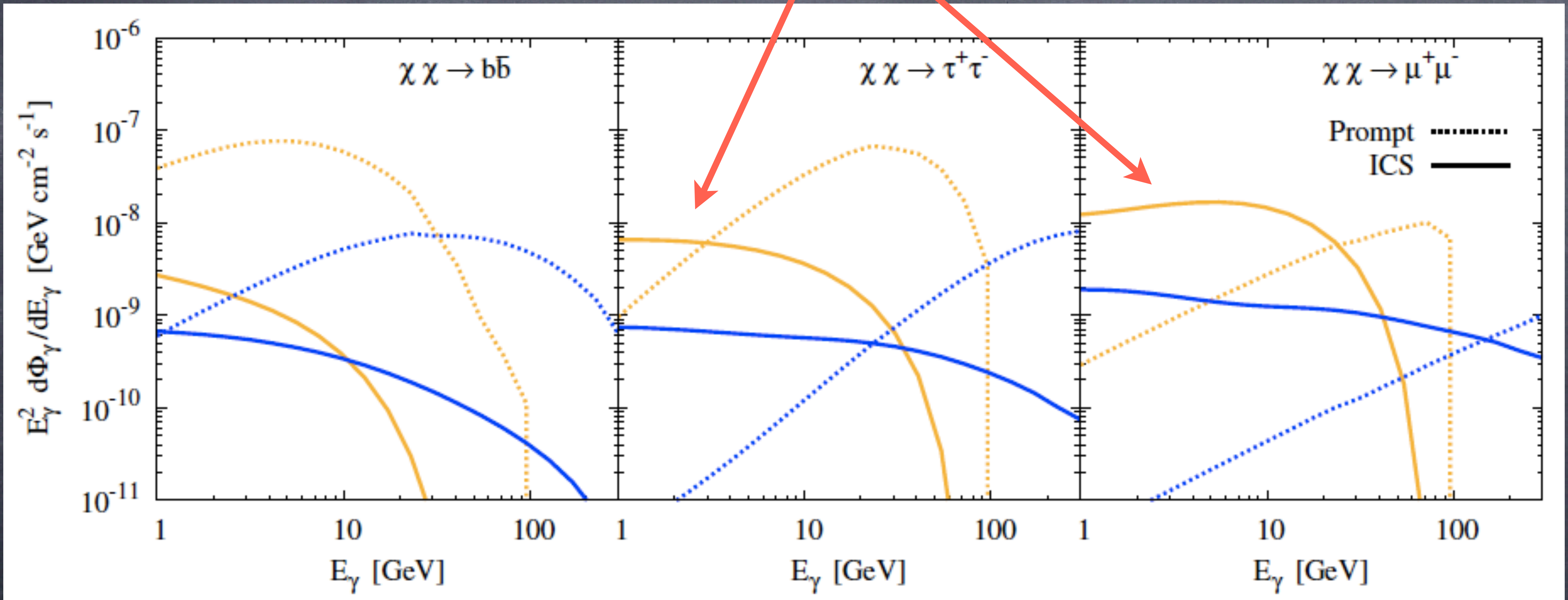
- We consider the energy range (1-300) GeV
- We select an optimal angular window: 10° around GC

P. D. Serpico and G. Zaharijas, *Astropart. Phys. 29:380, 2008*

- We add the ICS contribution to the DM-induced γ-ray spectrum: crucial for some cases
- We evaluate Fermi abilities to constrain DM properties: annihilation cross section, mass and dominant annihilation channels

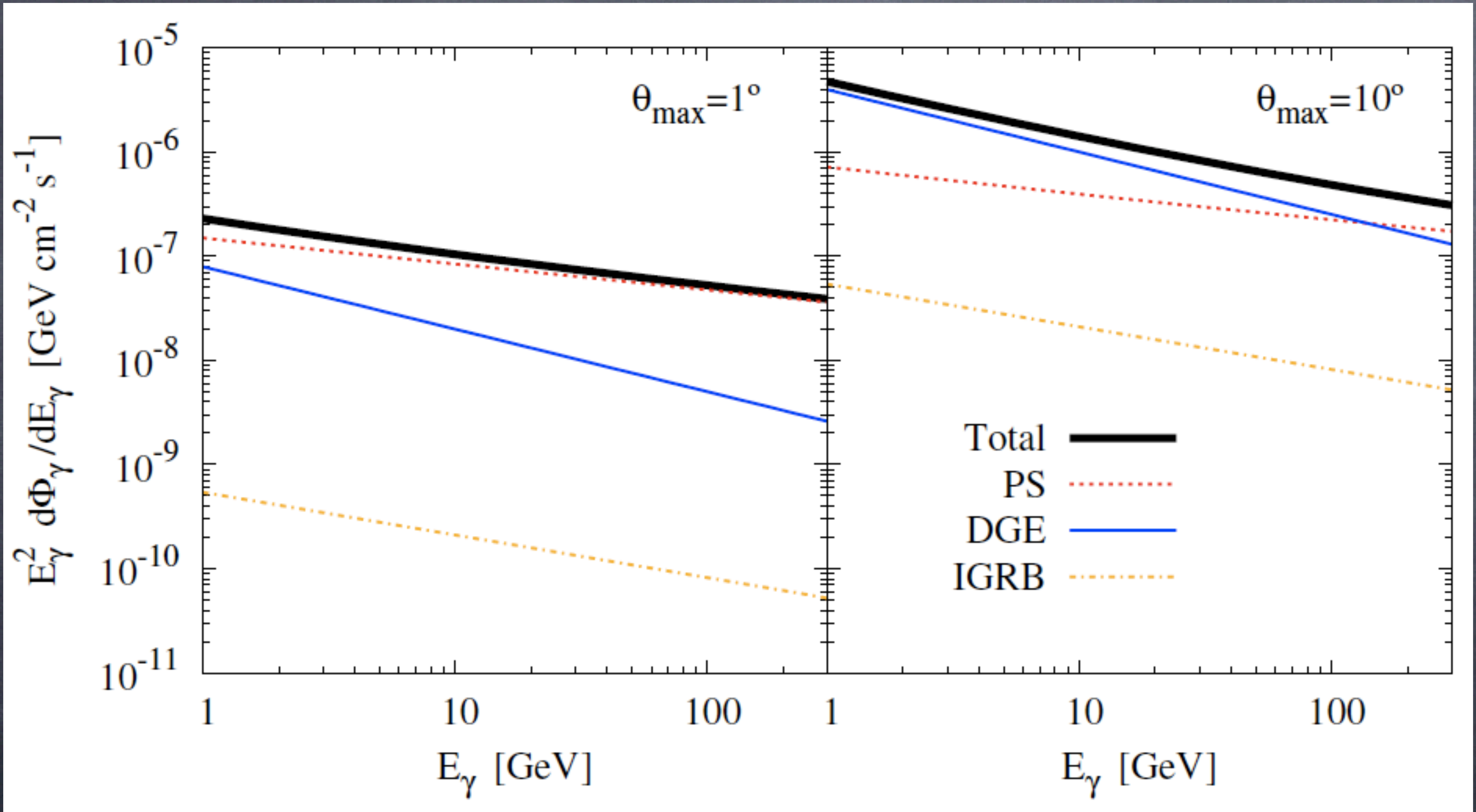
γ-Ray Spectra from DM annihilations

Important contribution from ICS at low energies



N. Bernal and SPR, arXiv:1006.0477

Galactic Foregrounds



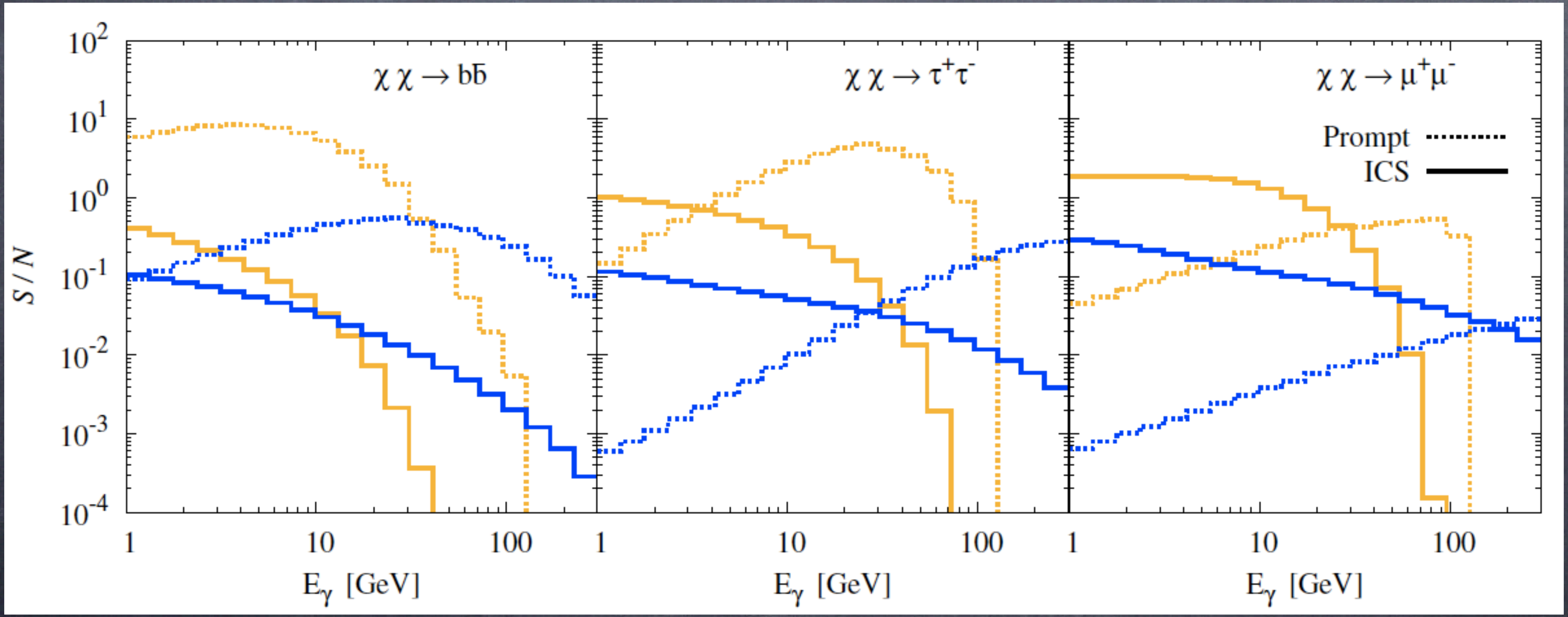
N. Bernal and SPR, arXiv:1006.0477

Significance of the Signal: S/N

Prompt: dominant

ICS: dominant at low energies
Prompt: dominant overall

ICS: dominant



N. Bernal and SPR, arXiv:1006.0477

Our Default Setup: 5 years

$\theta_{\max} = 10^o$ "Data" : $\tau^+\tau^-$ Simulated : $\tau^+\tau^- / bb$

DM Profile : NFW $\sigma_{bkg} = 0$ Propagation Model : MED

$\langle\sigma v\rangle = 3\times 10^{-26}\, cm^3 s^{-1}$

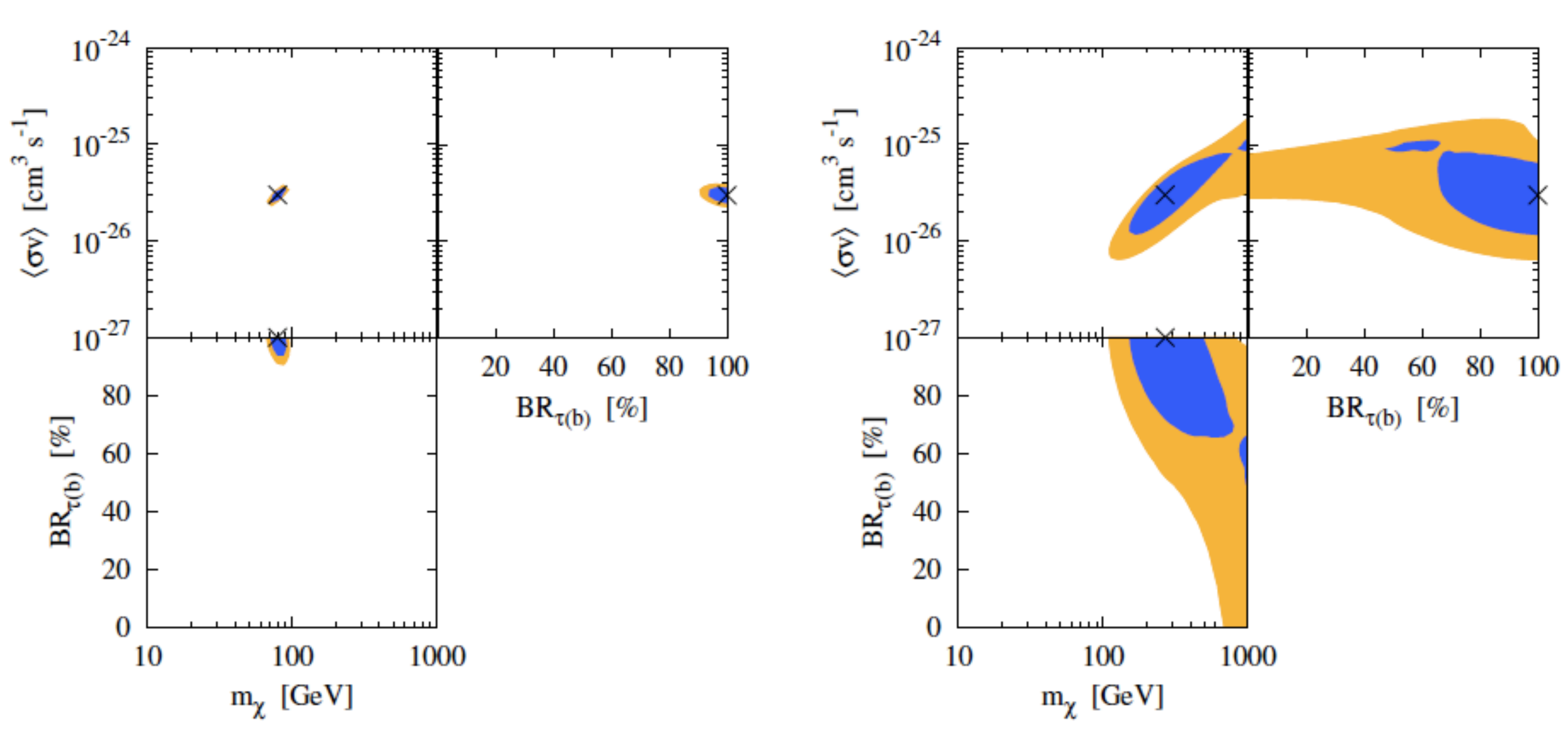
Other parameters we use

$\theta_{\max} = 1^o$ "Data" : $b\bar{b}$ or $\mu^+\mu^-$ Simulated : $\mu^+\mu^- / b\bar{b}$

DM Profile : Einasto $\sigma_{bkg} = 20\%$ Propagation Model : MIN/MAX

Default setup

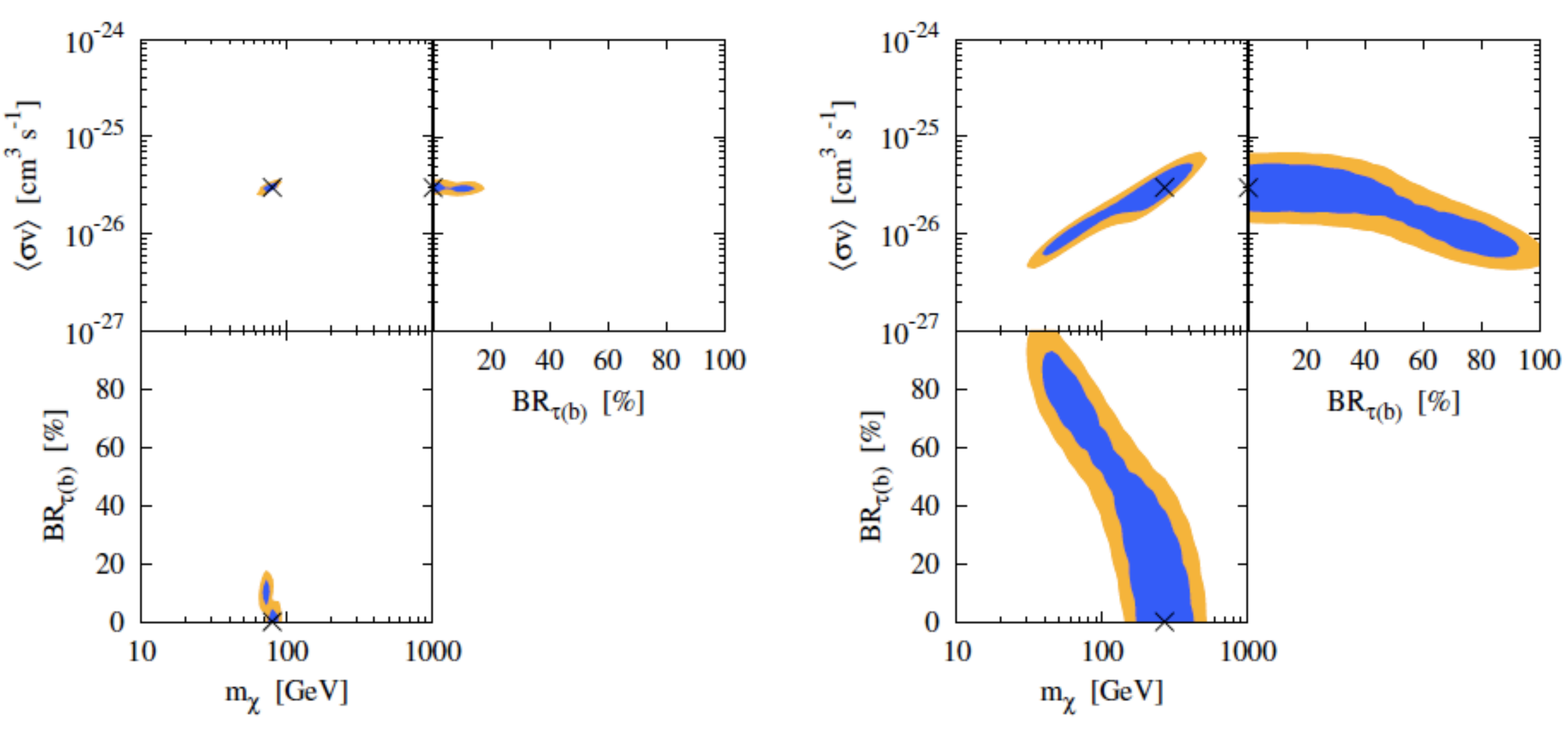
m=80 GeV   m=270 GeV



N. Bernal and SPR, arXiv:1006.0477

"Data": $b\bar{b}$

m=80 GeV **m=270 GeV**

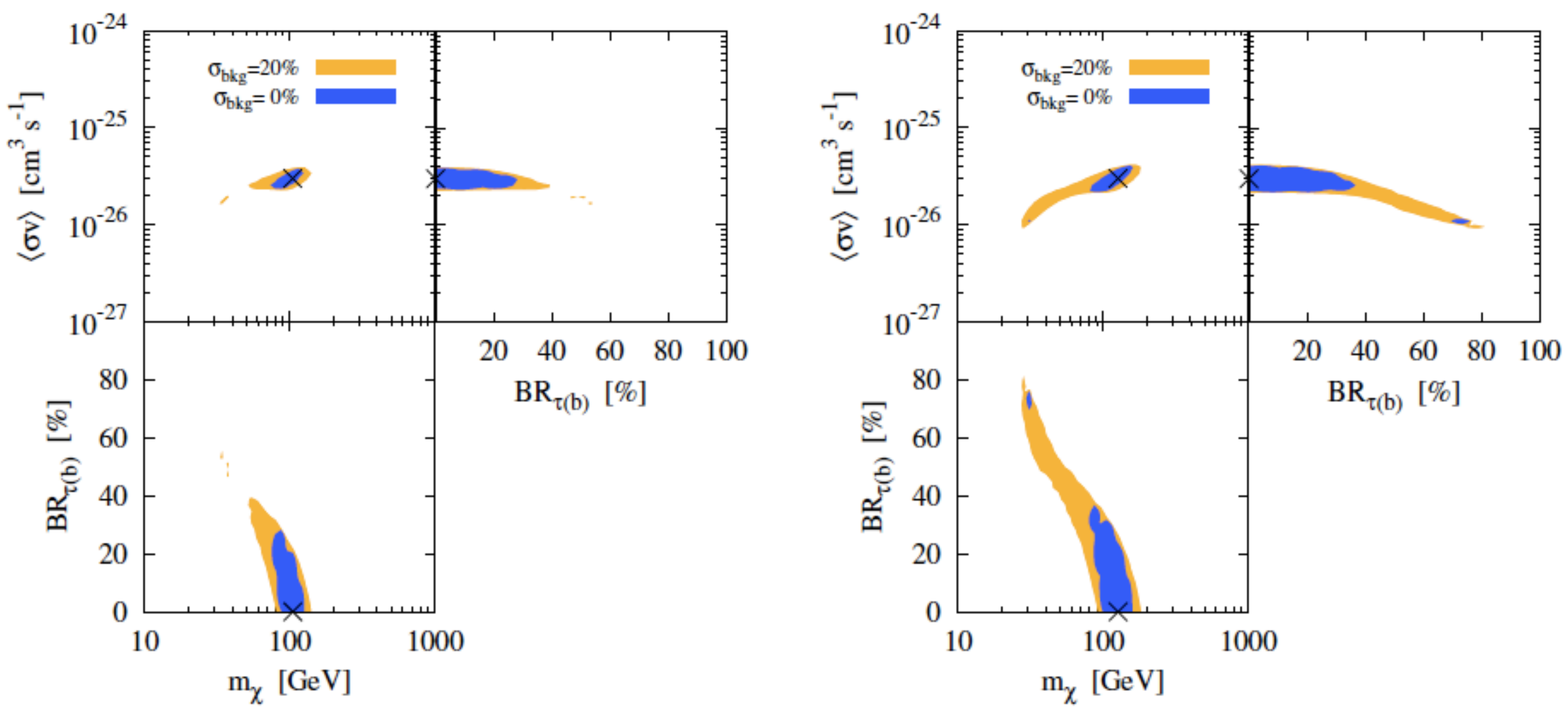


N. Bernal and SPR, arXiv:1006.0477

Dependence on systematic errors

"Data": $b\bar{b}$ $\sigma_{bkg} = 20\%$

m=105 GeV **m=125 GeV**



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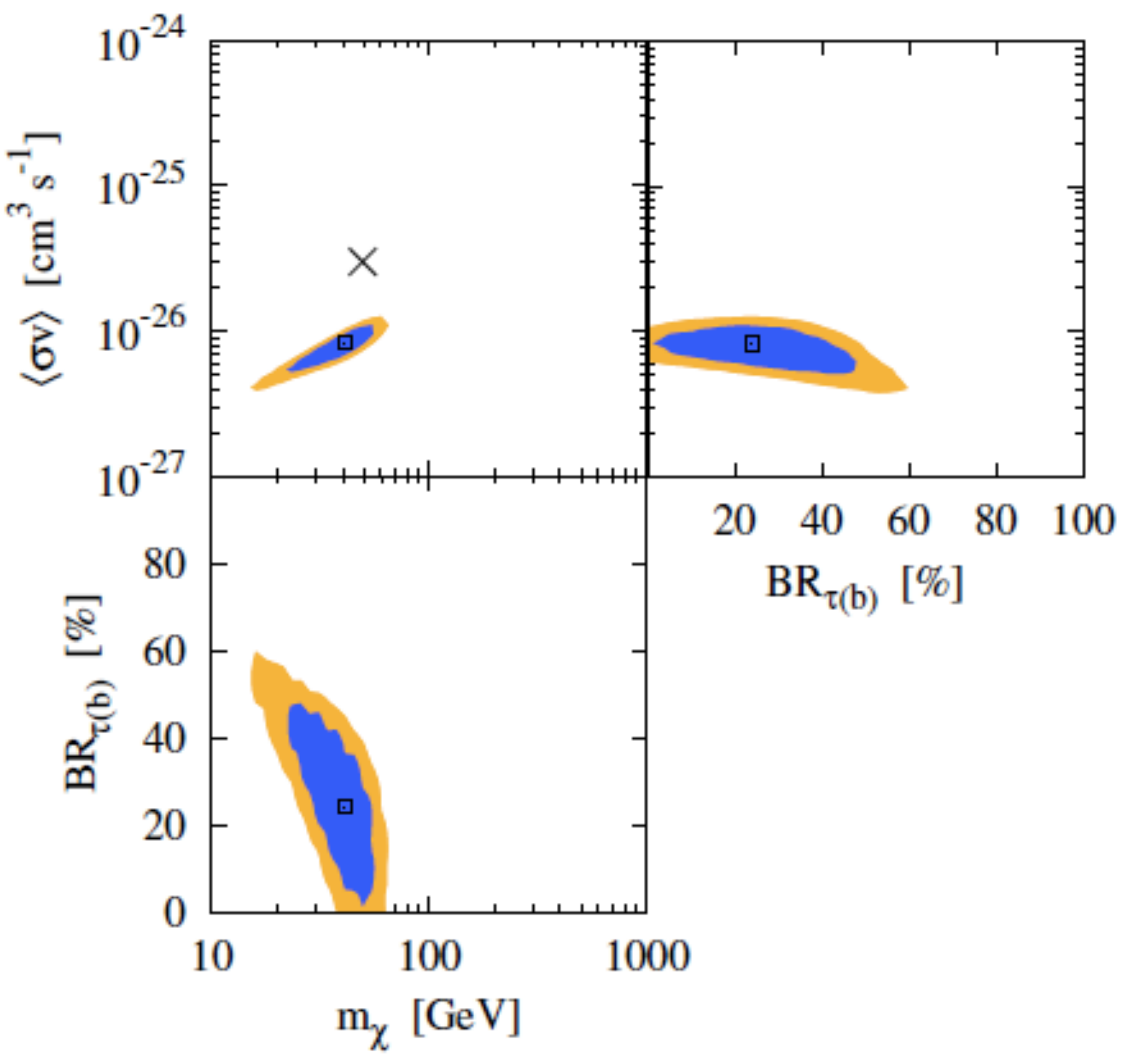
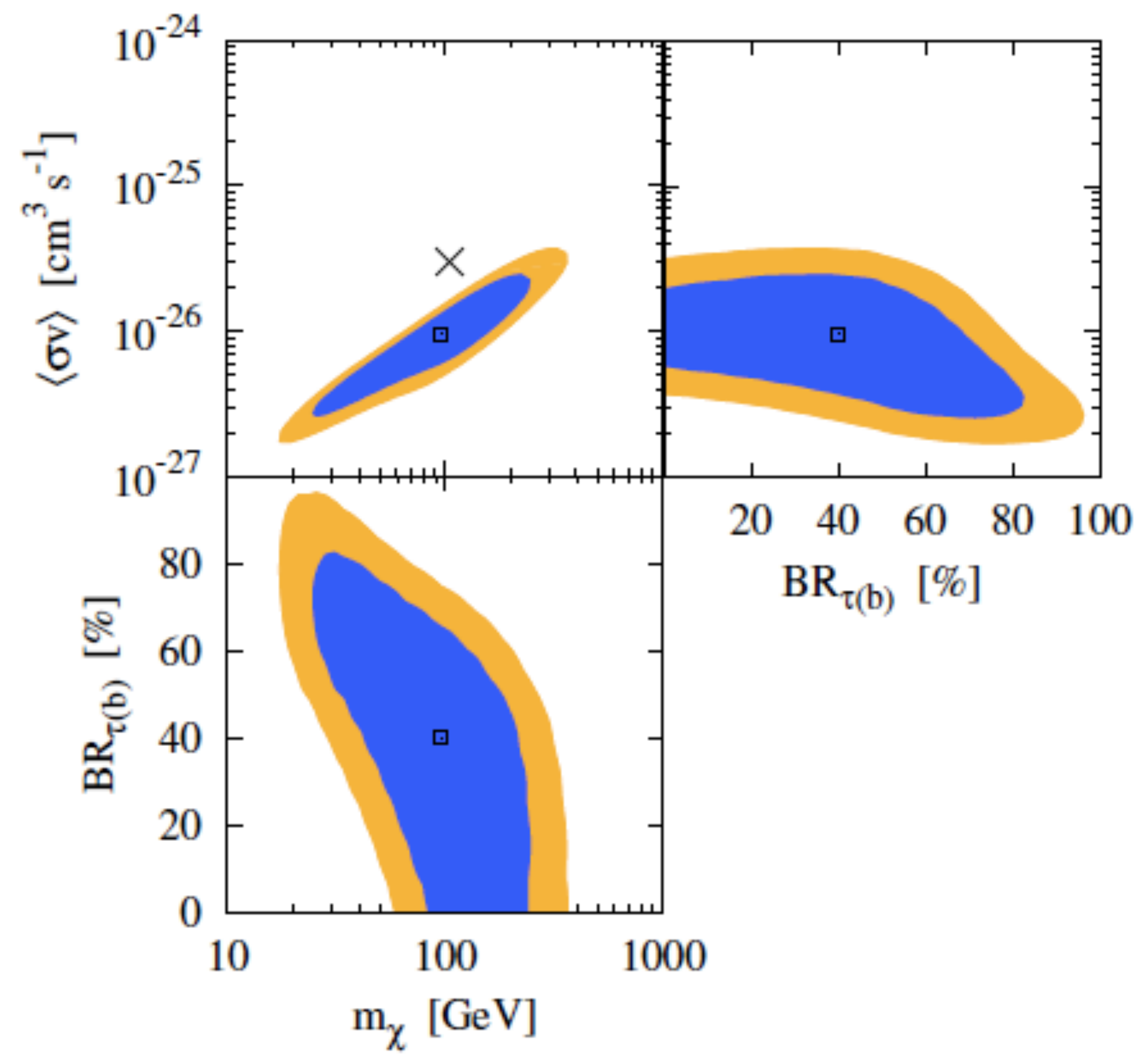
Importance of the ICS contribution

"Data": $\mu^+\mu^-$

m=50 GeV **m=105 GeV**



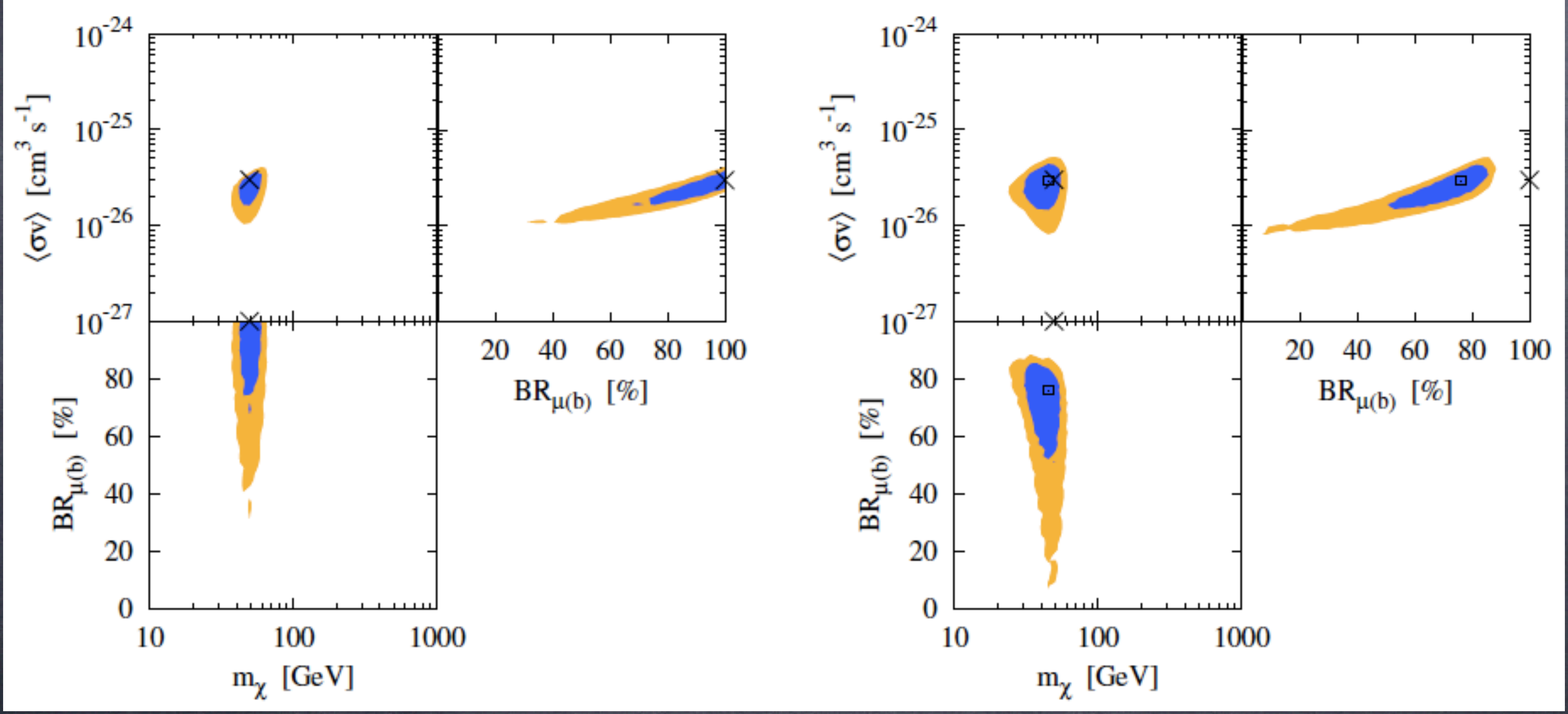


N. Bernal and SPR, arXiv:1006.0477

"Data": $\mu^+\mu^-$ Simulated: $\mu^+\mu^-$ / $b\bar{b}$

m = 50 GeV

with ICS **without ICS**



N. Bernal and SPR, arXiv:1006.0477

However... in case of a γ-ray signal...

Could annihilation and/or decay be identified as the origin of the signal?

SPR and J. M. Siegal-Gaskins, arXiv:1003.1142

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Not with only the energy spectrum
Endpoint = M (annihilations) vs. M/2 (decays)

SPR and J. M. Siegal-Gaskins, arXiv:1003.1142

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Could annihilation and/or decay be identified as the origin of the signal?

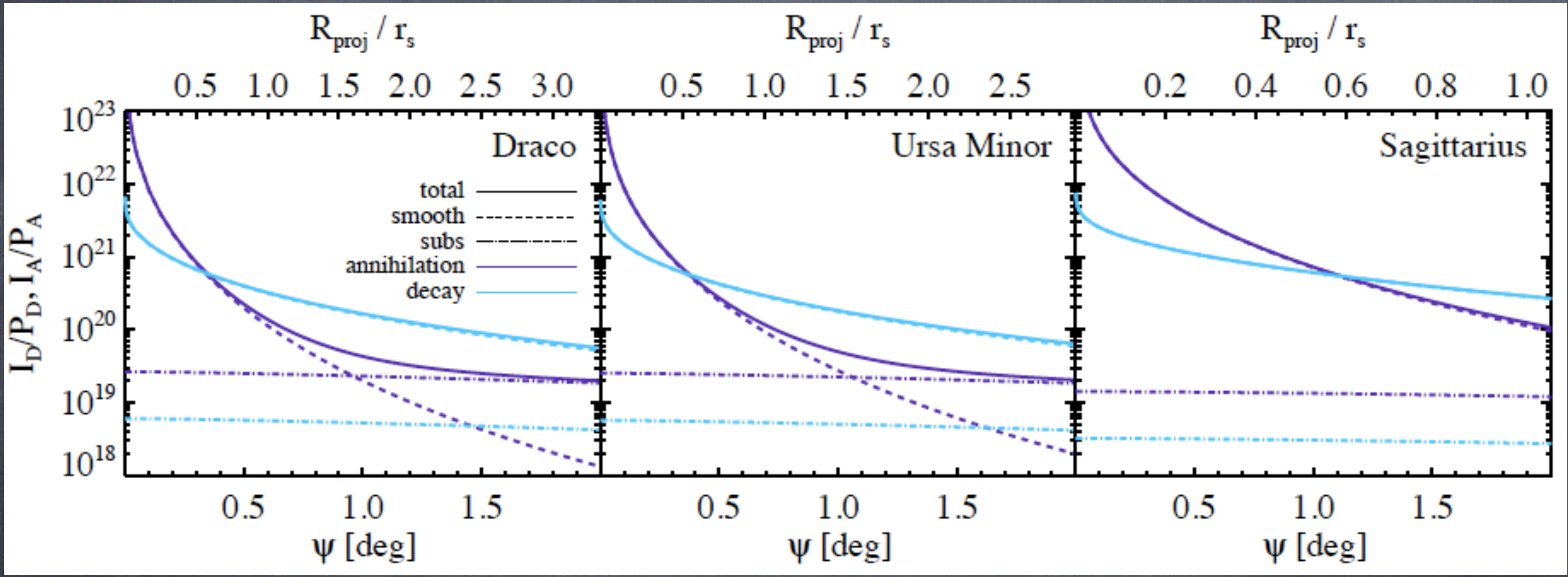
Not with only the energy spectrum
Endpoint = M (annihilations) vs. M/2 (decays)

- If dark matter is unstable and produces an observable signal from decay, an annihilation signal might also be present
- There is a range of parameters for which this would occur
- We propose to use gamma-ray observations of Milky Way dwarf galaxies with current or future experiments

SPR and J. M. Siegal-Gaskins, arXiv:1003.1142

Annihilation or Decay or ...?

Substructure?



SPR and J. M. Siegal-Gaskins, arXiv:1003.1142

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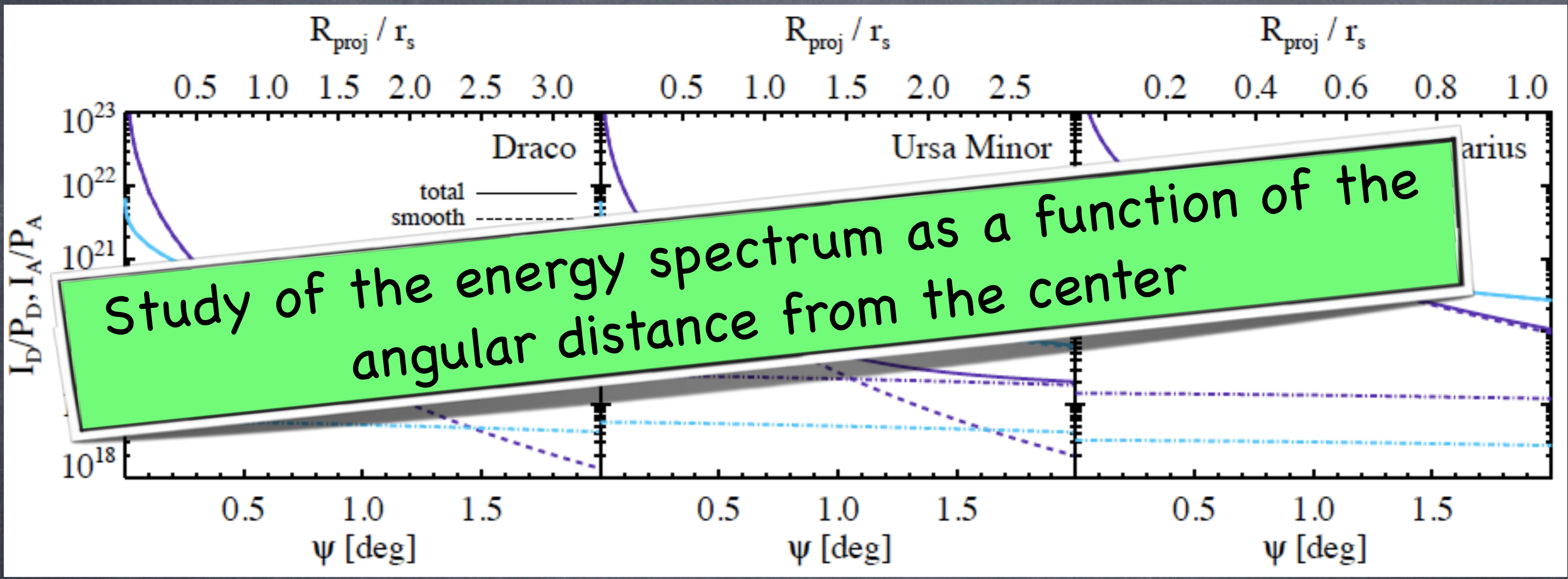
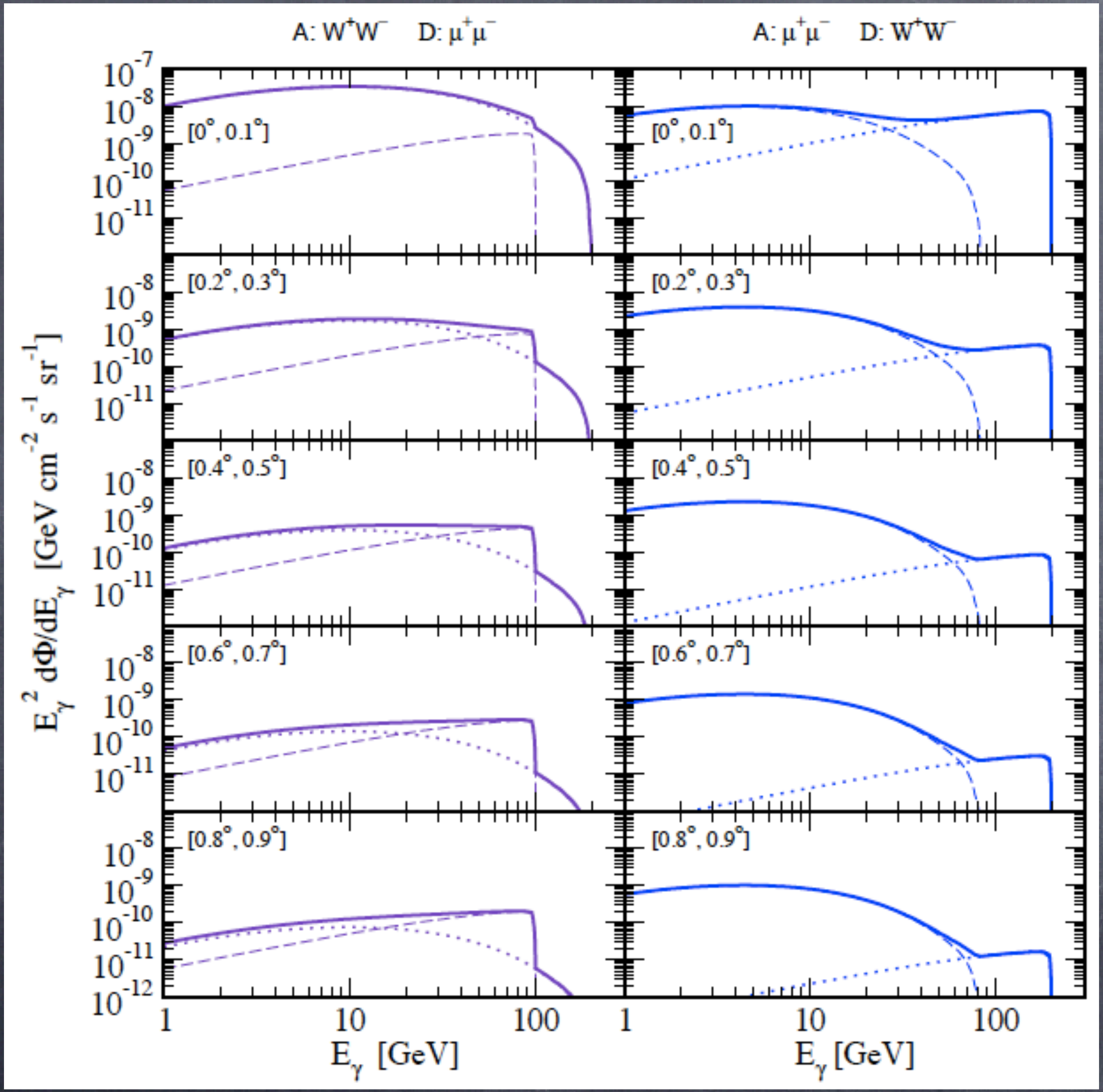


Study of the energy spectrum as a function of the angular distance from the center

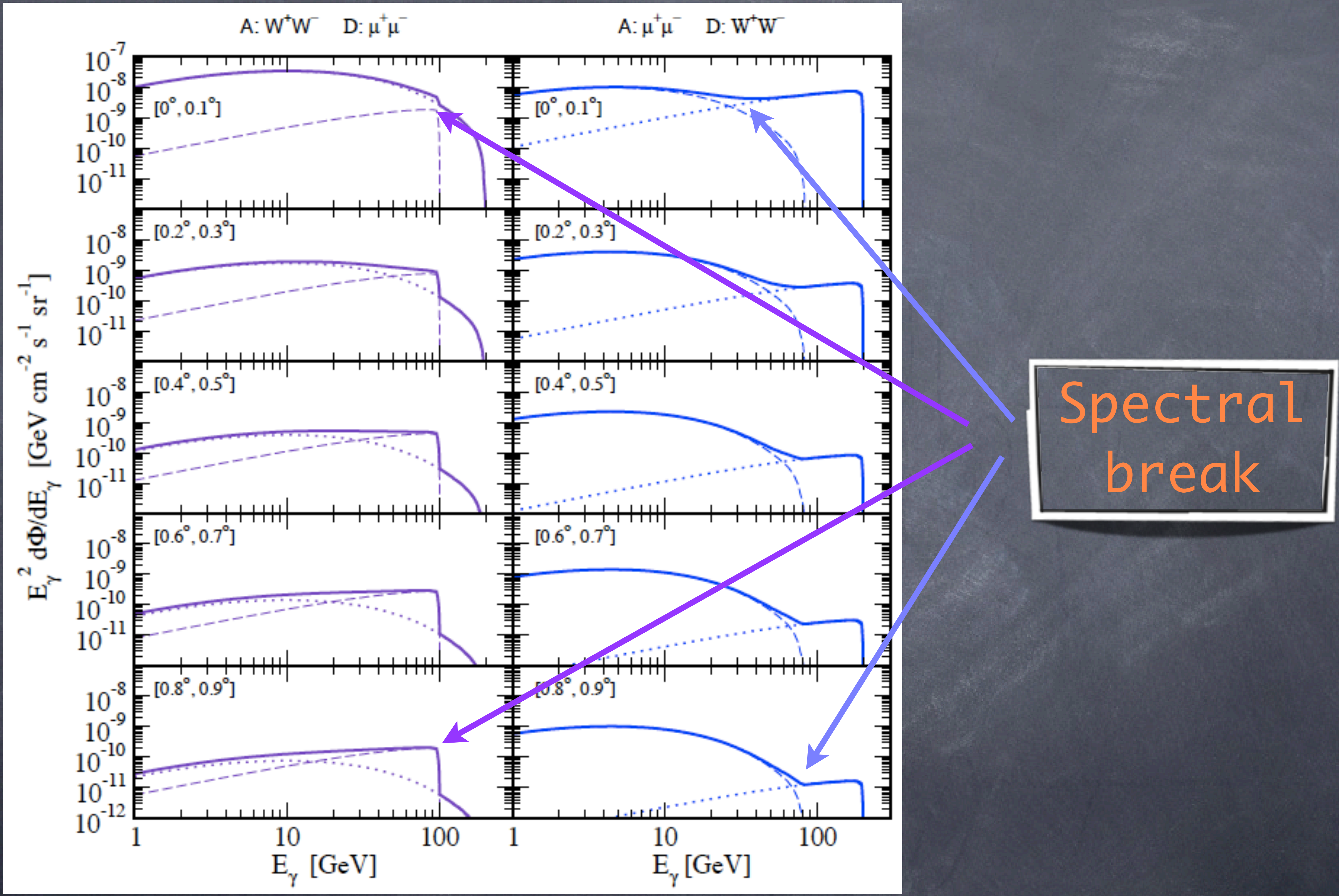
SPR and J. M. Siegal-Gaskins, arXiv:1003.1142

Soft-Hard   Hard-Soft



SPR and J. M. Siegal-Gaskins, arXiv:1003.1142

Soft-Hard Hard-Soft



SPR and J. M. Siegal-Gaskins, arXiv:1003.1142

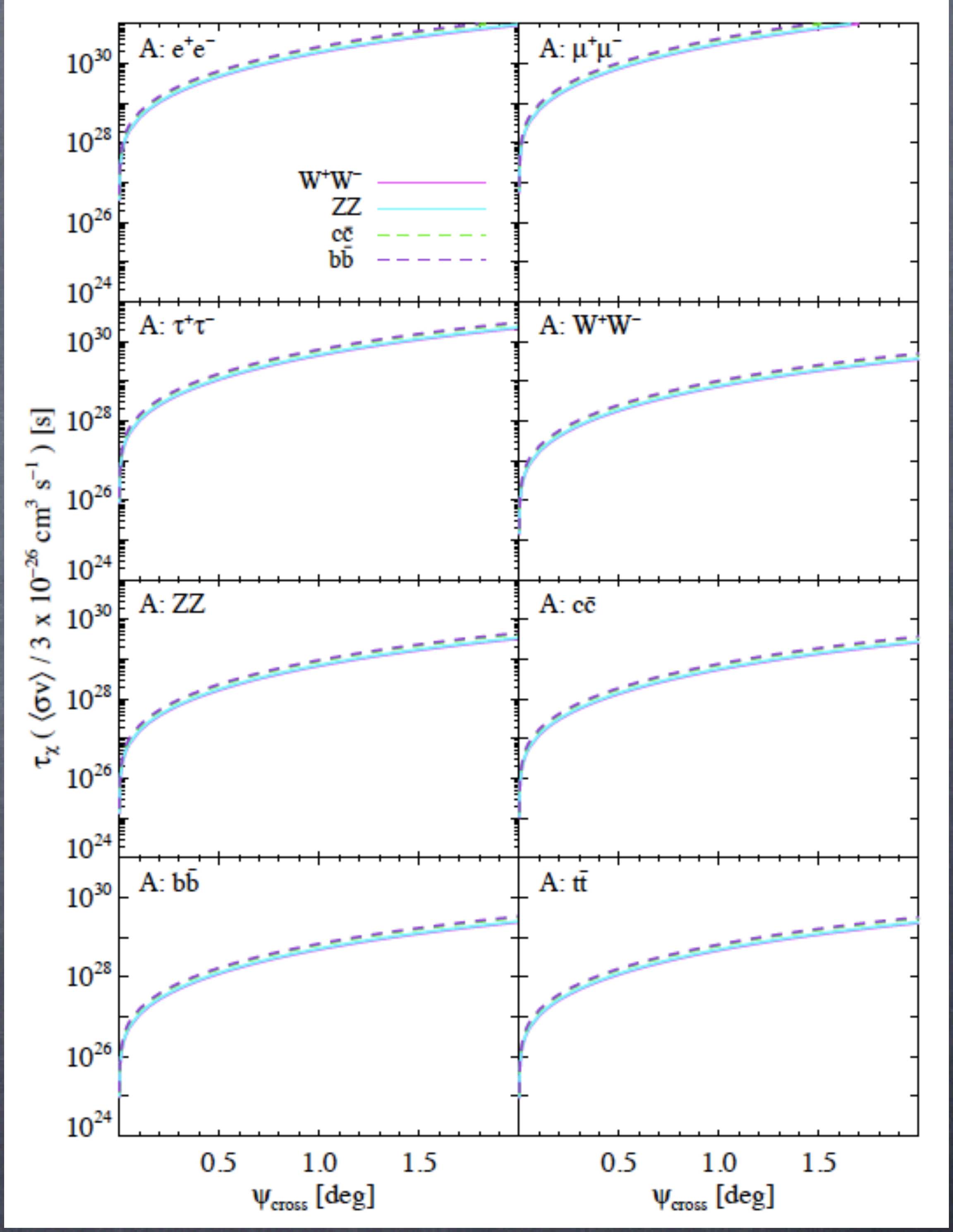
Range of interesting parameters

Here: m=200 GeV and energy threshold=1 GeV

The normalization depends on the relative photon yields from annihilation and decay: for a given lifetime, the transition occurs further from the center when the ratio from annihilation to decay is larger.

In order for the transition to occur within 1-2 degrees:

$$\tau_\chi \sim (10^{25} - 10^{31}\ \mathrm{s})\ (3 \times 10^{-26}\ \mathrm{cm}^3\ \mathrm{s}^{-1}/\langle\sigma v\rangle)$$



SPR and J. M. Siegal-Gaskins, arXiv:1003.1142

Conclusions

- We have studied the abilities of Fermi-LAT, by using gamma-rays from the GC, to constrain some DM properties: as annihilation cross section, mass and branching ratio into dominant annihilation channels
- We have included the ICS contribution to the signal spectra, which for some cases turns out to be crucial to get the correct results
- We have also studied the dependence on different uncertainties and assumptions
- However, we note that the spectral information alone is insufficient to identify the process that might produce the signal
- The key: examining the dependence of the intensity and energy spectrum on the angular distribution of the emission
- We have outlined the case of the detection of an indirect signal from gamma-ray observations of dwarf galaxies