# The Primary Importance of Secondaries

## MeV Dark Matter in Y-rays

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With: Daniele Gaggero & Christoph Weniger

GRAPPA
GRavitation AstroParticle Physics Amsterdam
UNIVERSITY OF AMSTERDAM

*6th APS meeting*
*29-31 August 2016*
*Château de la Tour, Gouvieux, France*

# Introduction

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or: the title explained

## **Why MeV Dark Matter?**

- Fermi-LAT has done great for indirect DM searches in the GeV regime
- *"MeV Gap"*

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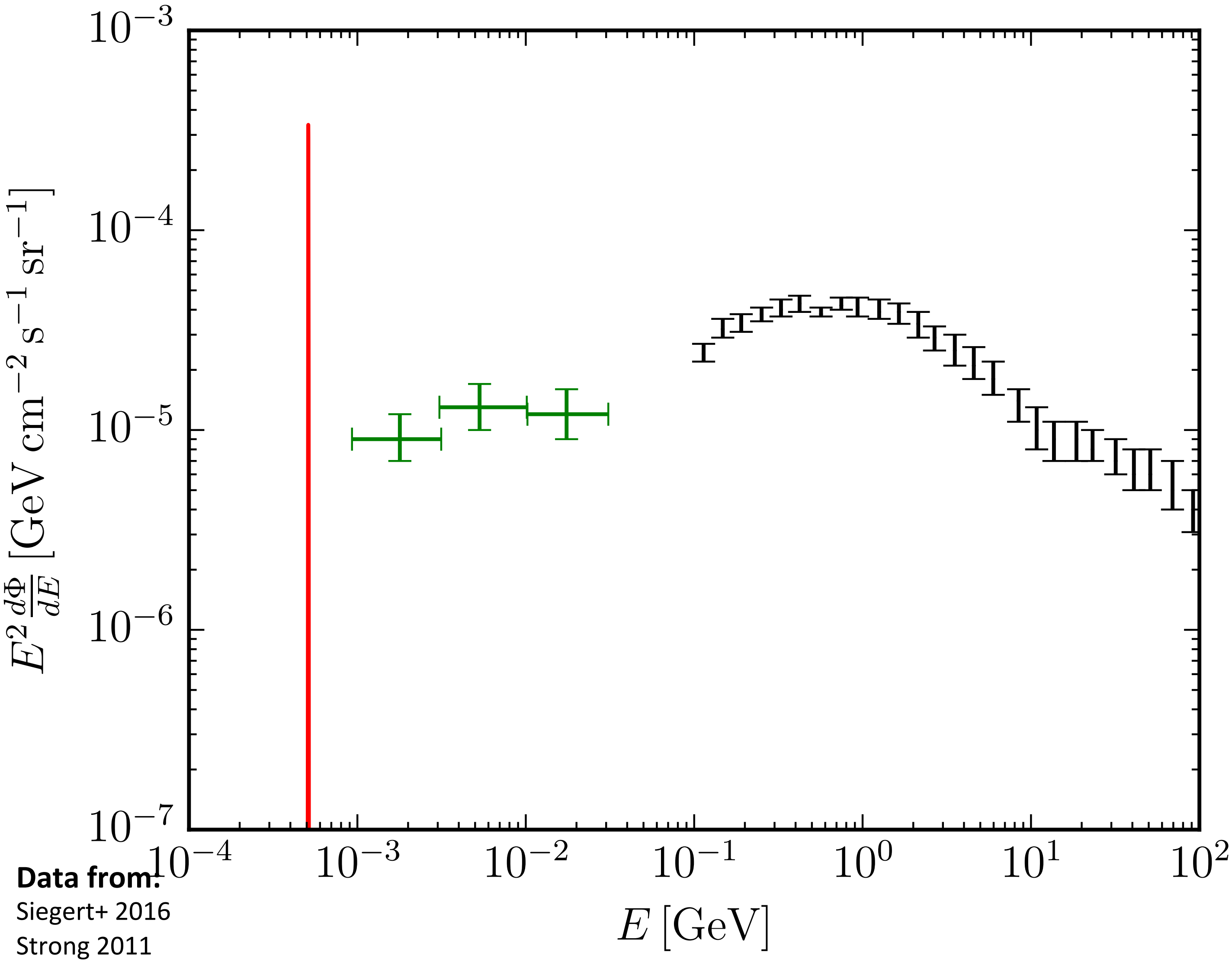
- *“MeV Gap”*

## Why Secondaries?

- Because they provide the dominant signal!

# The *MeV Gap*




**Data from:**
Siegert+ 2016
Strong 2011

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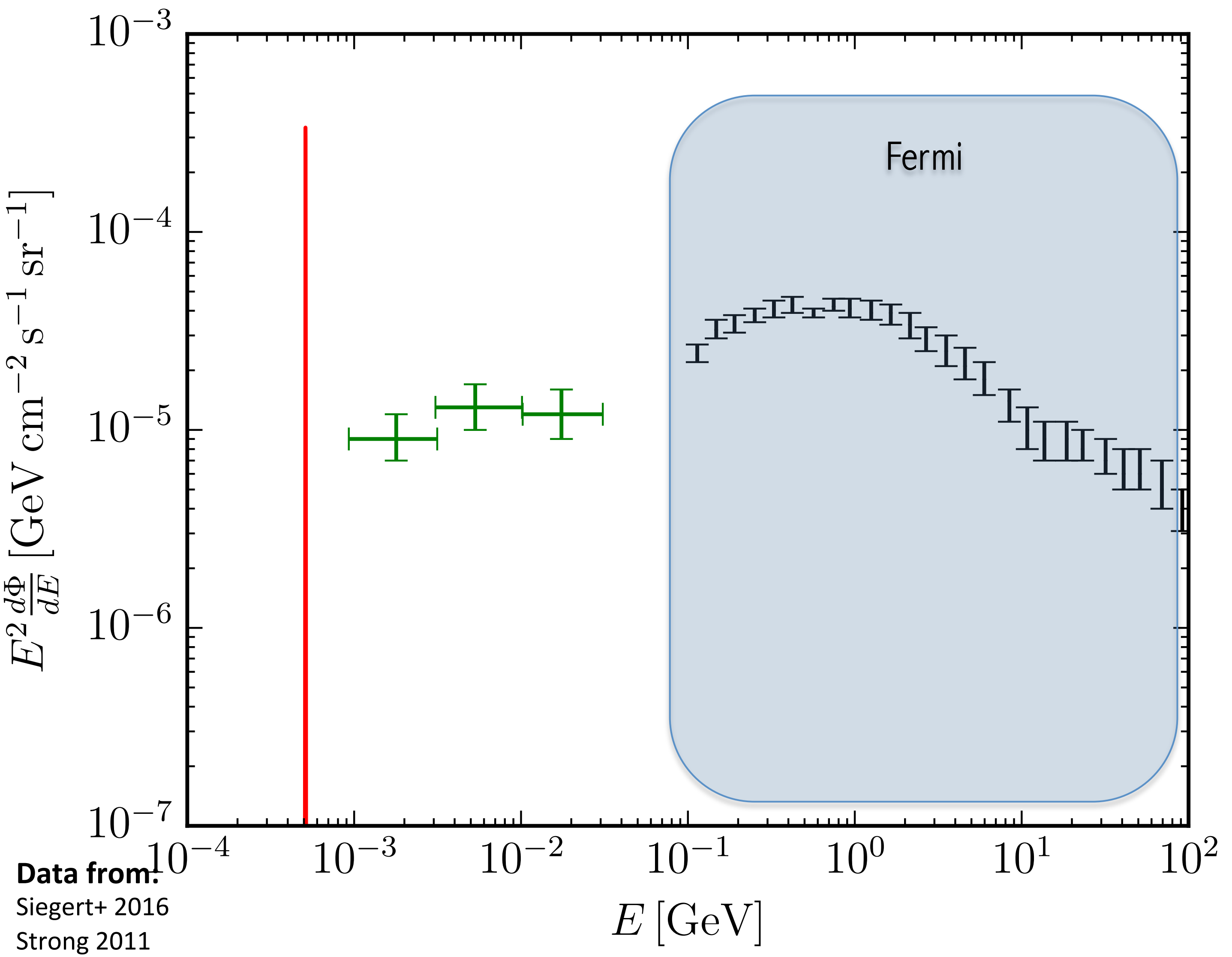


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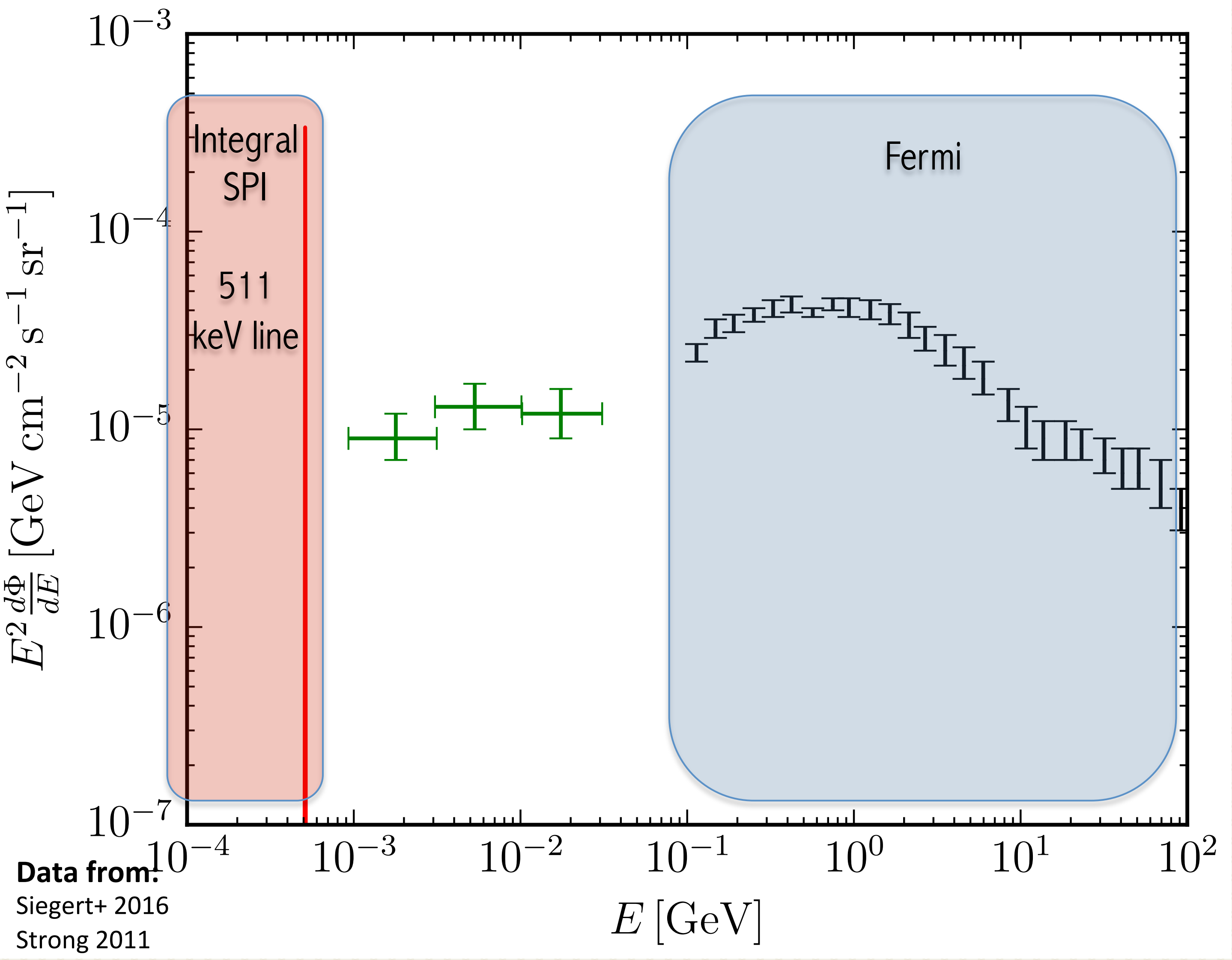


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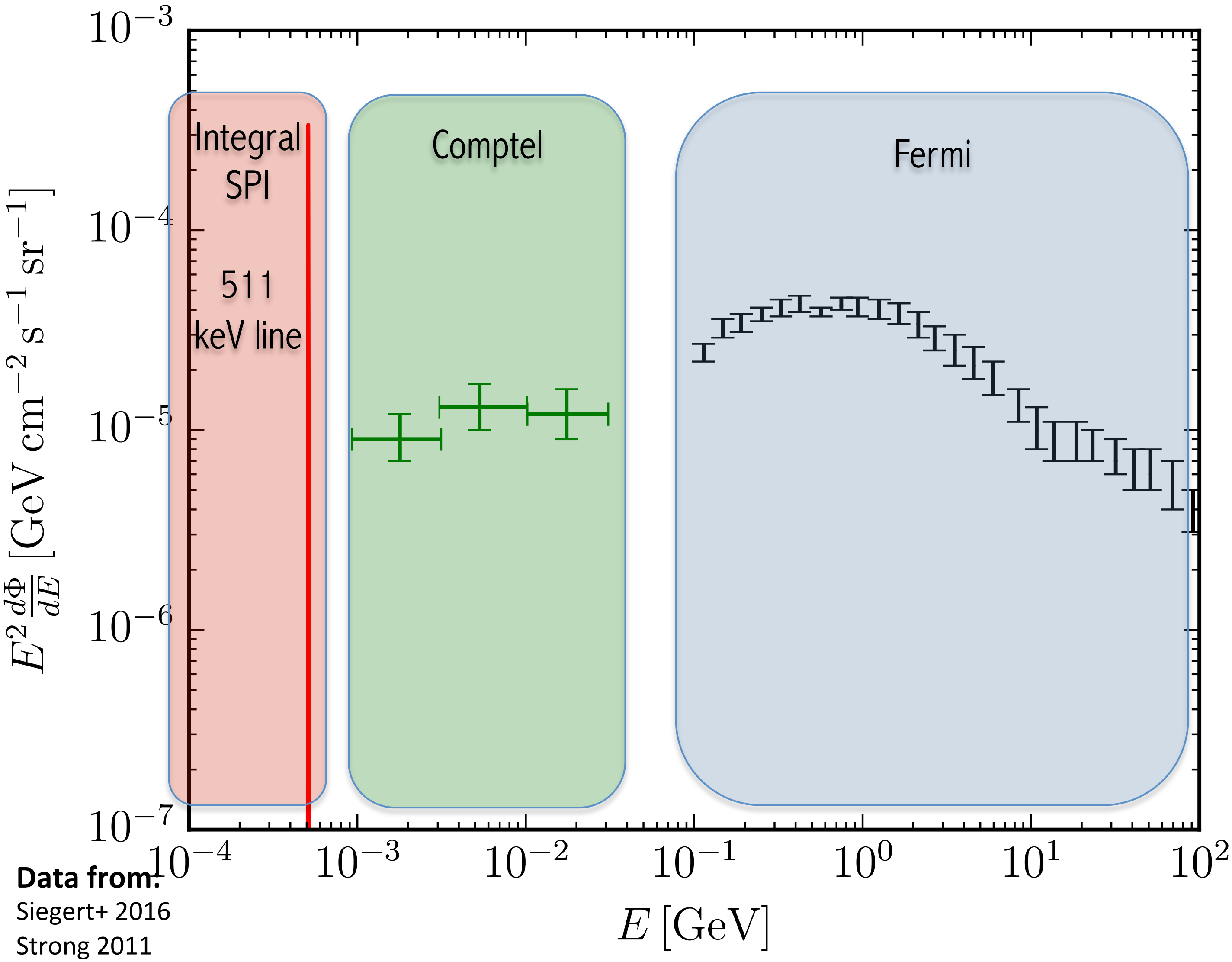


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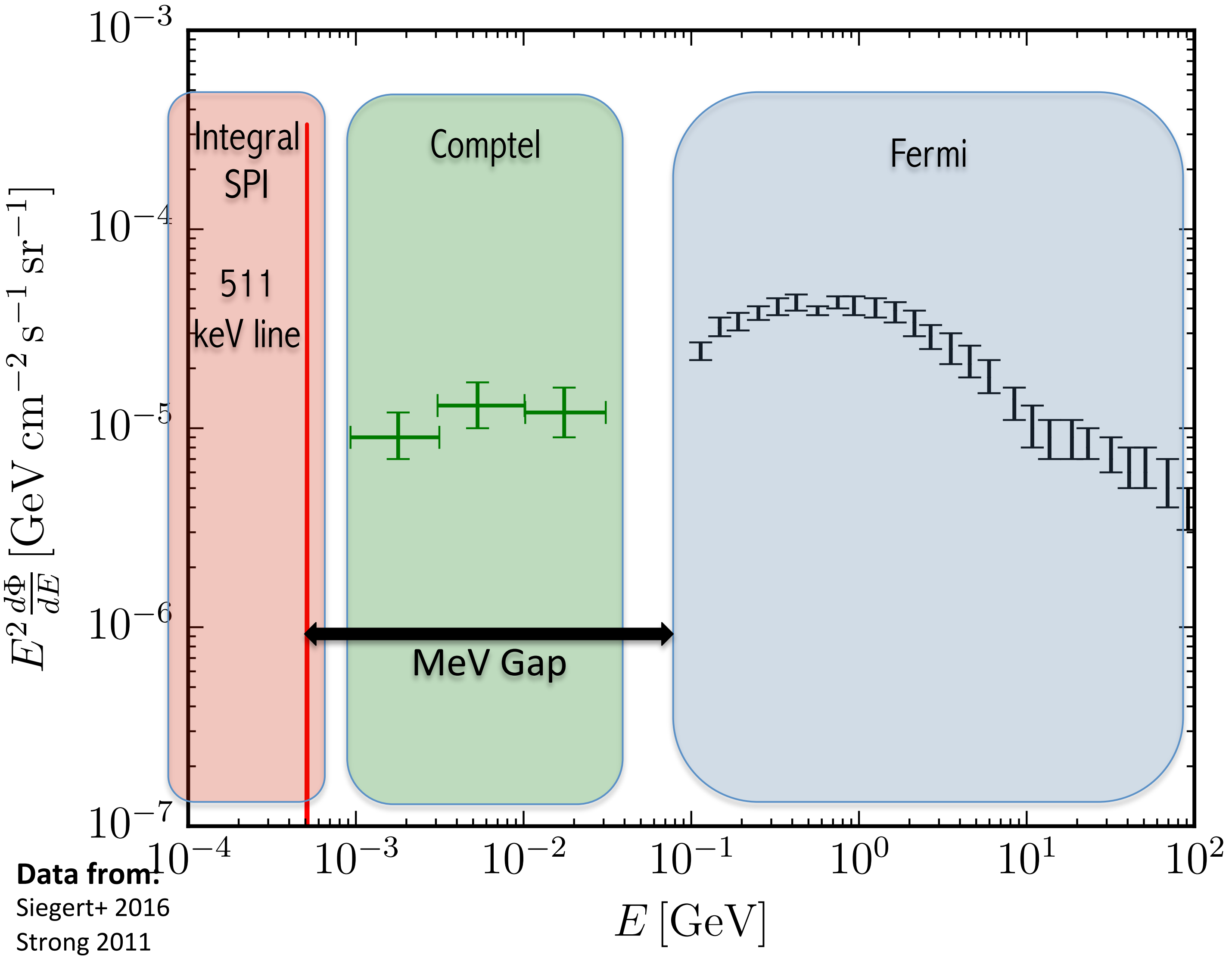


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# Next generation instruments

E.g.:

- E-ASTROGAM (http://astrogam.iaps.inaf.it/)
- ComPair (*arXiv:1508.0734*)

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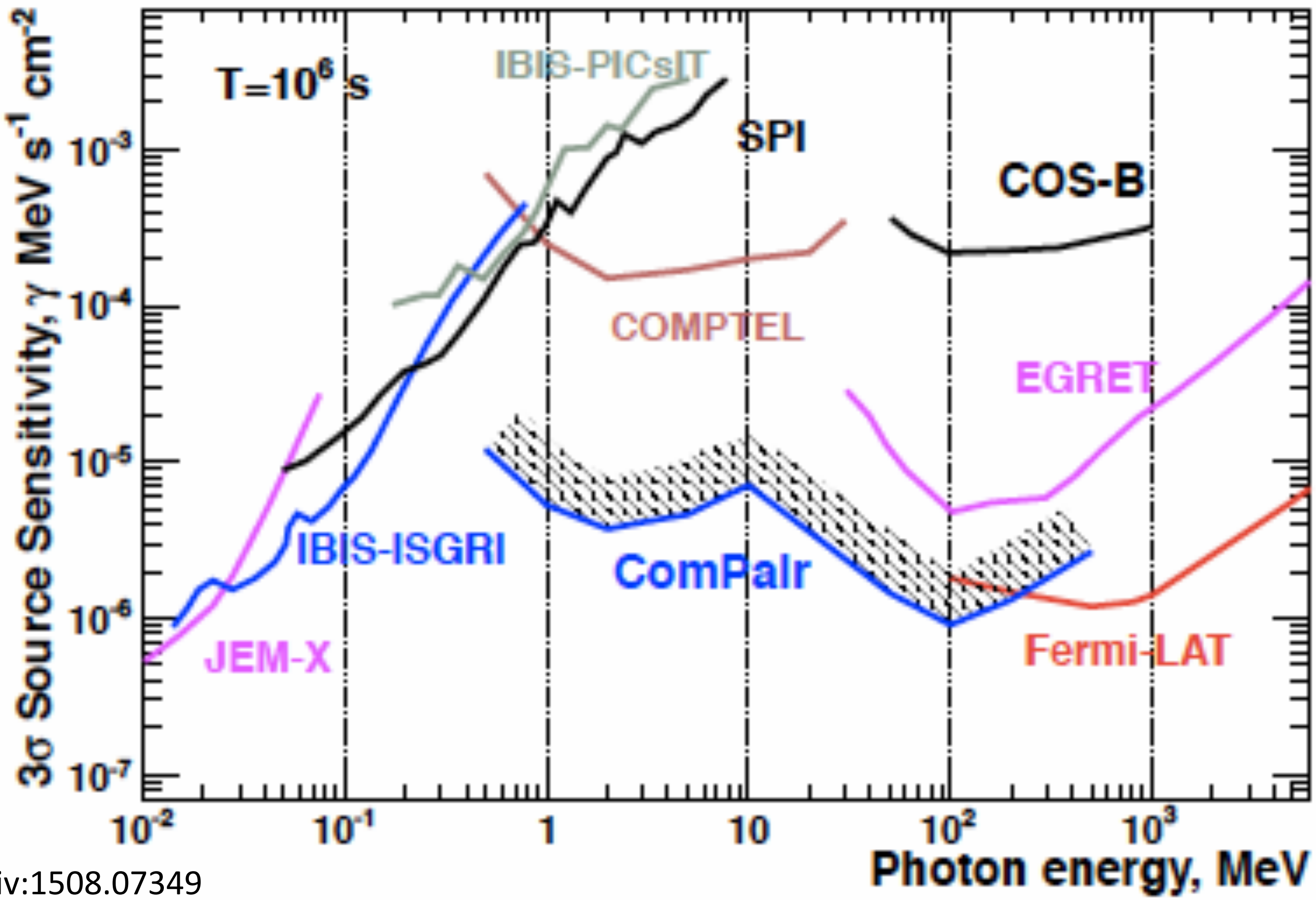


arXiv:1508.07349

# MeV Dark Matter Models

Not many channels kinematically available

- Photons
- Pions (>140 MeV) *(Boddy & Kumar, 2015)*
- Neutrinos
- Muons (>105 MeV)
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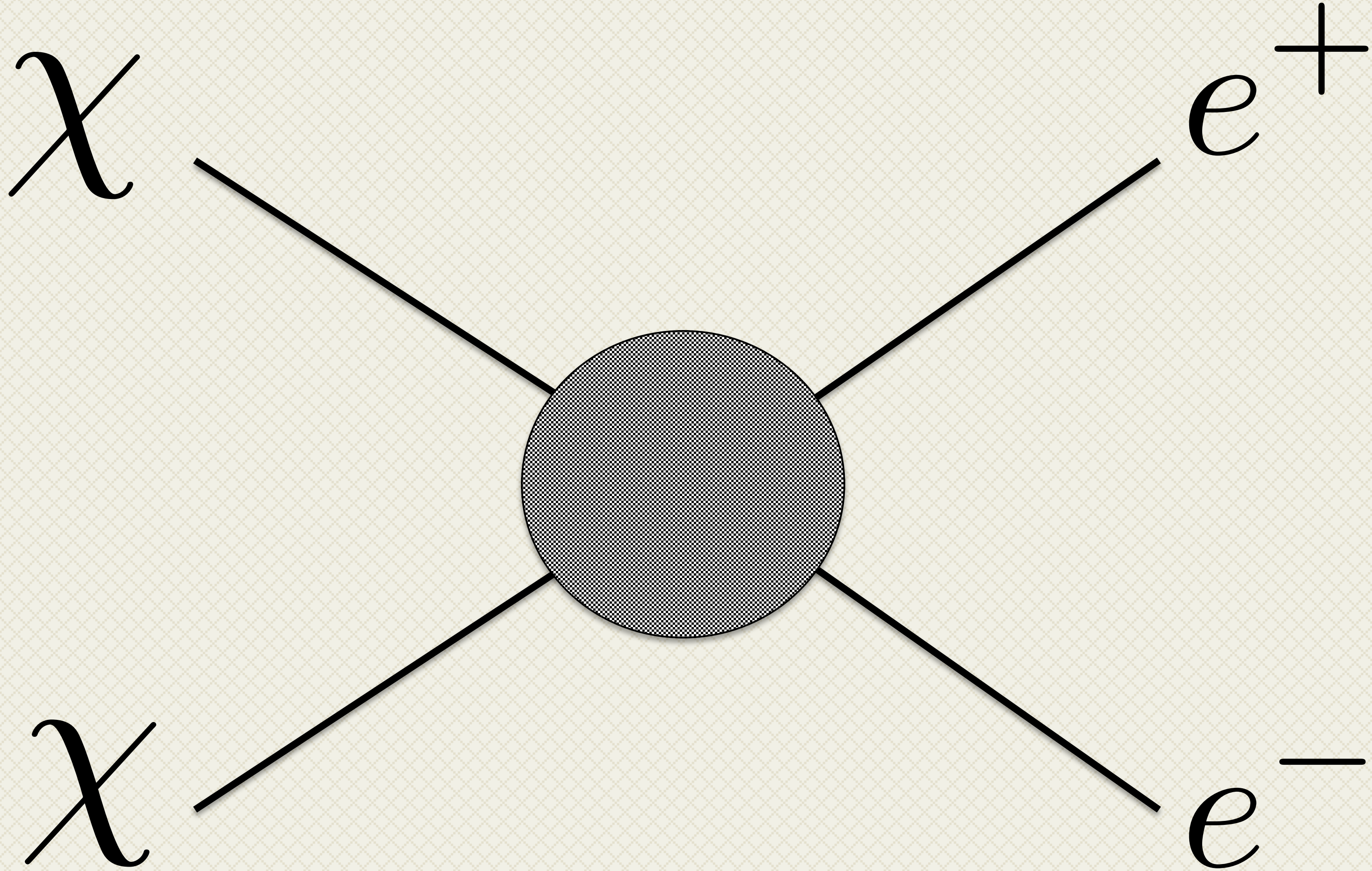

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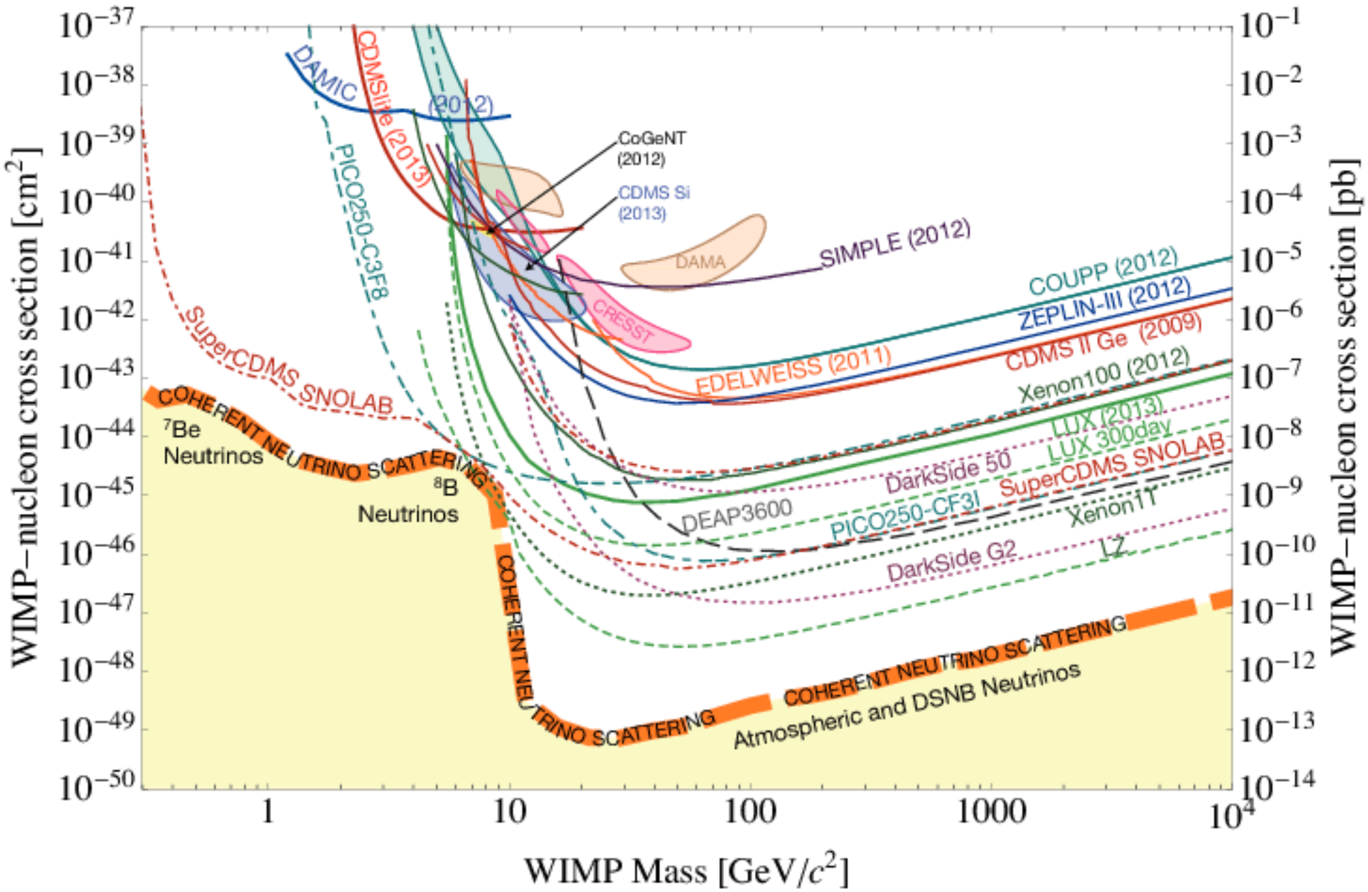


*Cooley (2014)*

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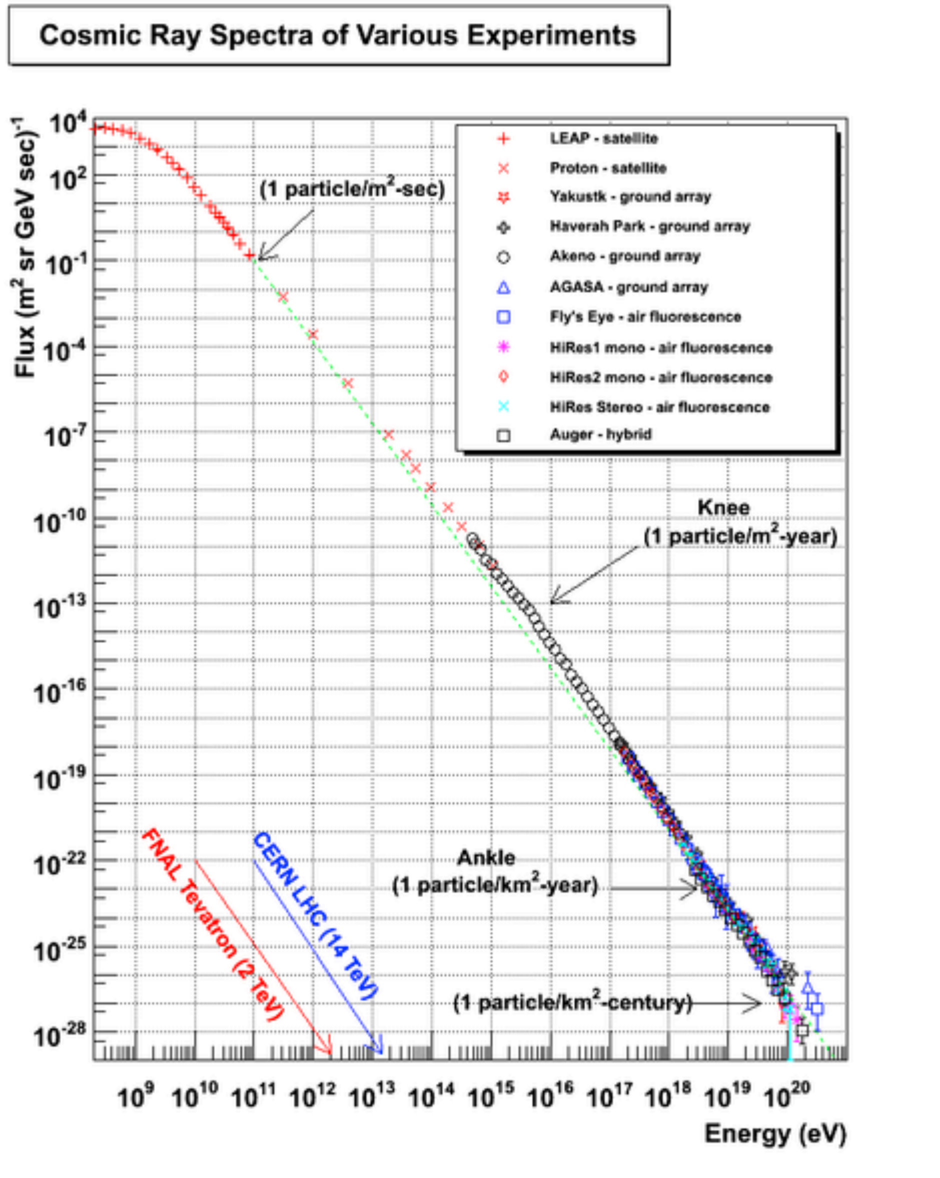


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2. Solar w… …ion" of electro…

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1. MeV dark matter is difficult to detect in direct detection experiments
2. Solar wind prevents "direct detection" of electrons & positrons
3. How far can we go with gamma-rays??

# A bit of history: DM & the 511 keV line

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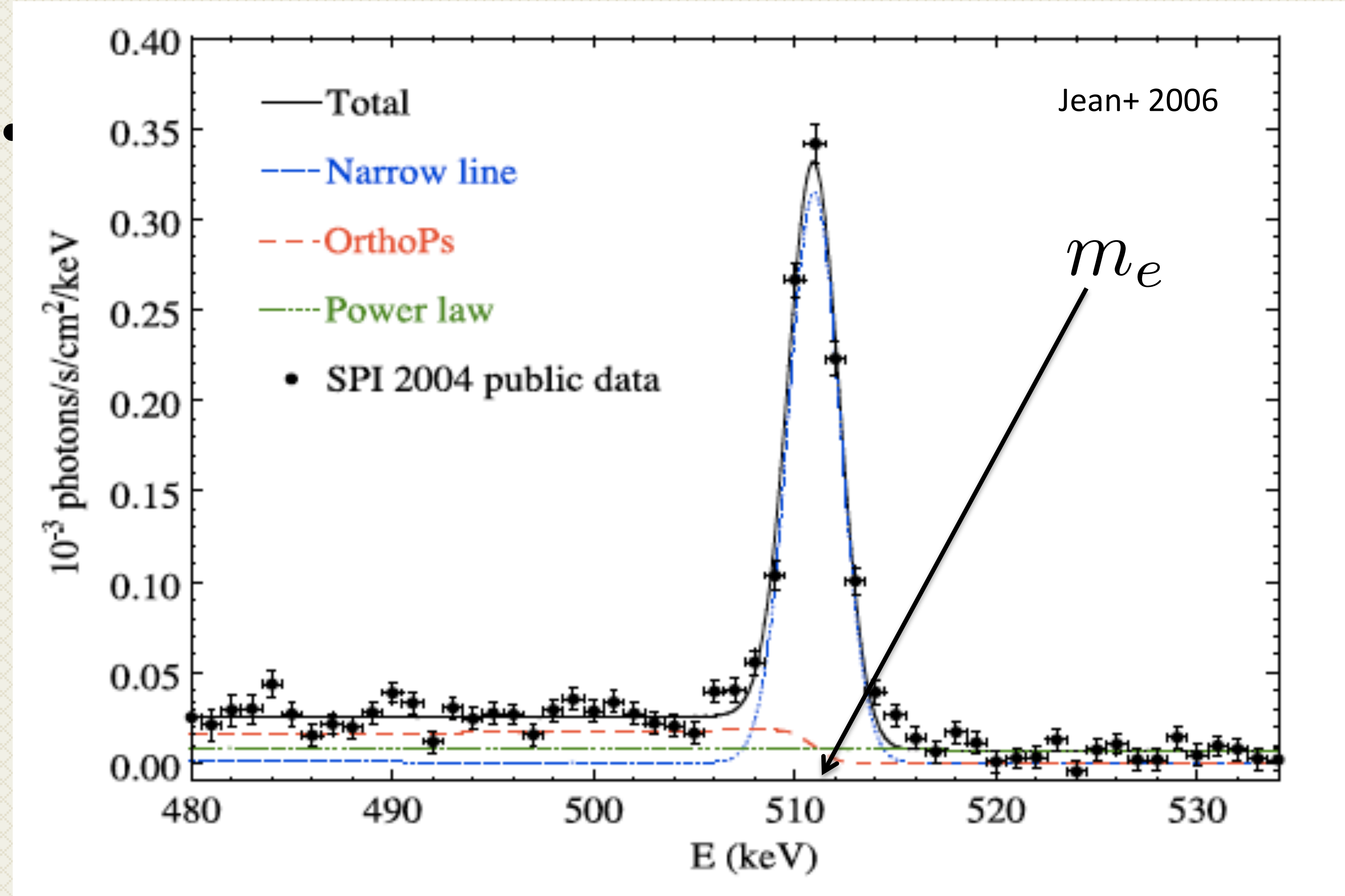

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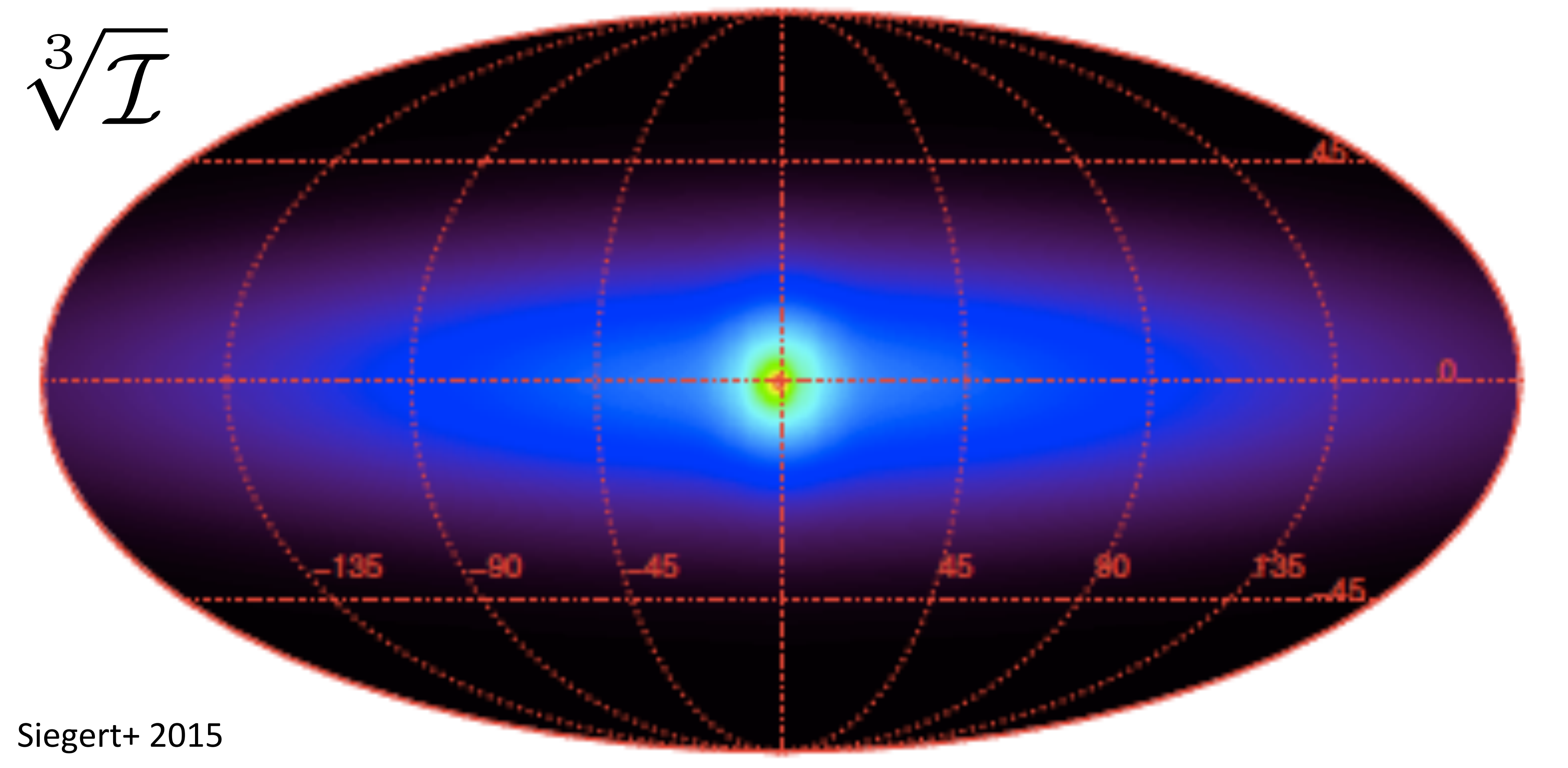


Siegert+ 2015

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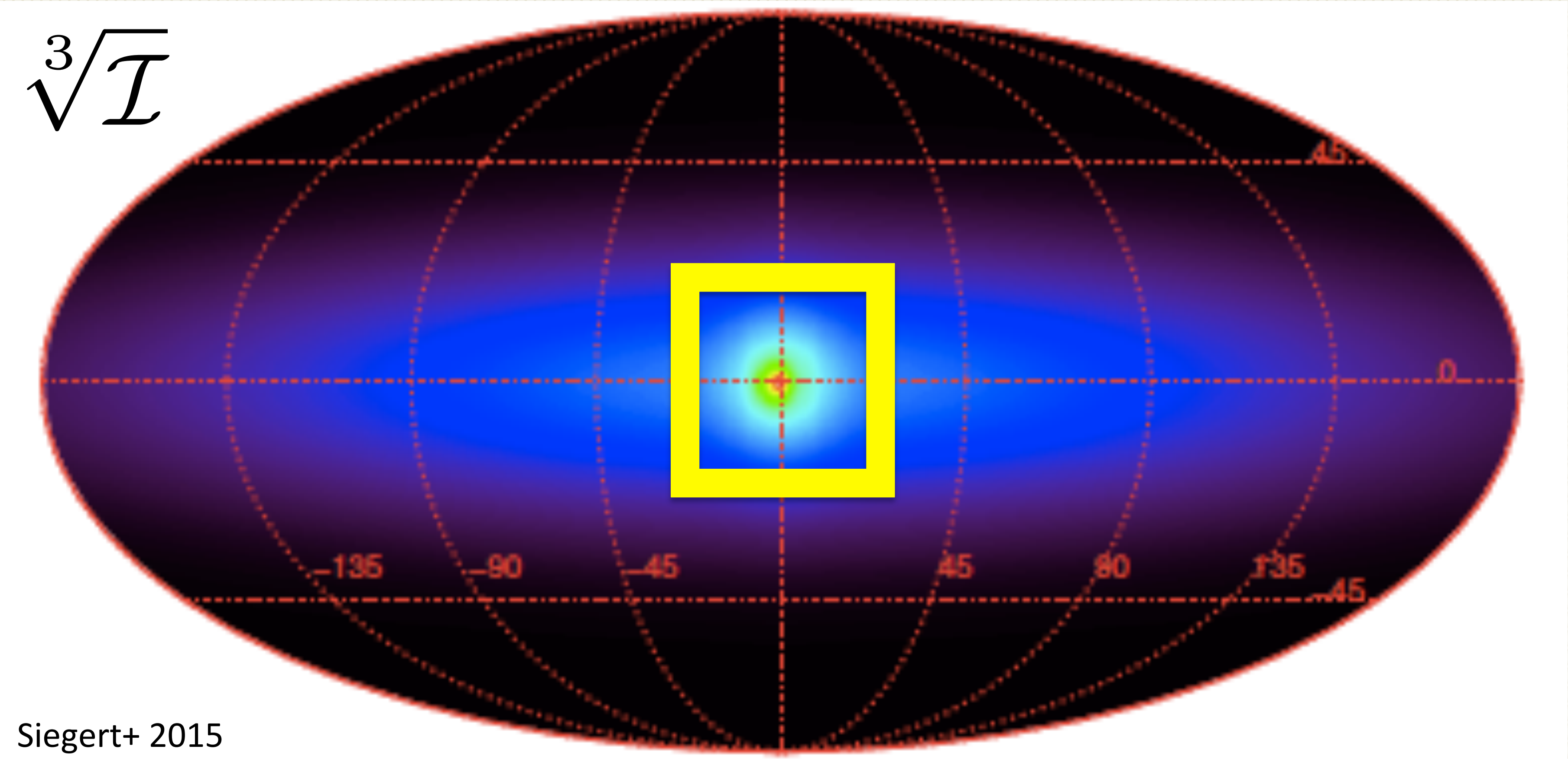


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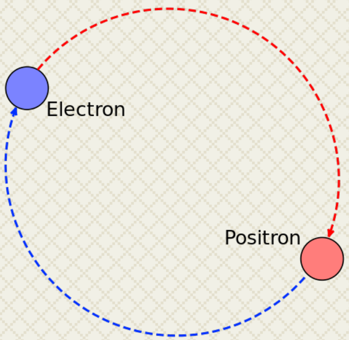
- Strong Bulge component → DM?

# A bit on positron decay

1. At low energies $(E_k \sim 100\,\mathrm{eV})$
   *Positronium formation*
   - *Para-positronium:* $\mathrm{p\text{–}Ps} \to \gamma\gamma$
   - *Ortho-positronium:* $\mathrm{o\text{–}Ps} \to \gamma\gamma\gamma$

   Line: all p-PS



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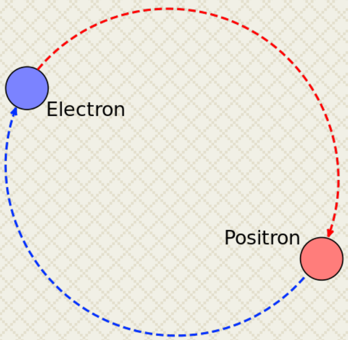


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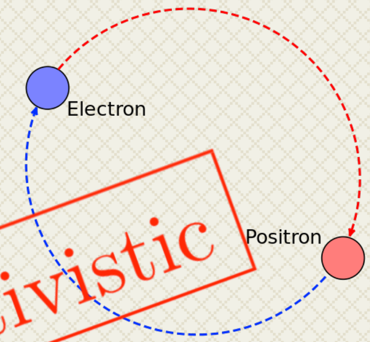


$e^+$ are non-relativistic

2. Direct or *In-flight* Annihilation (IfA)

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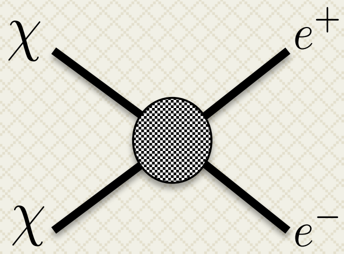
# This constrains the injection energy

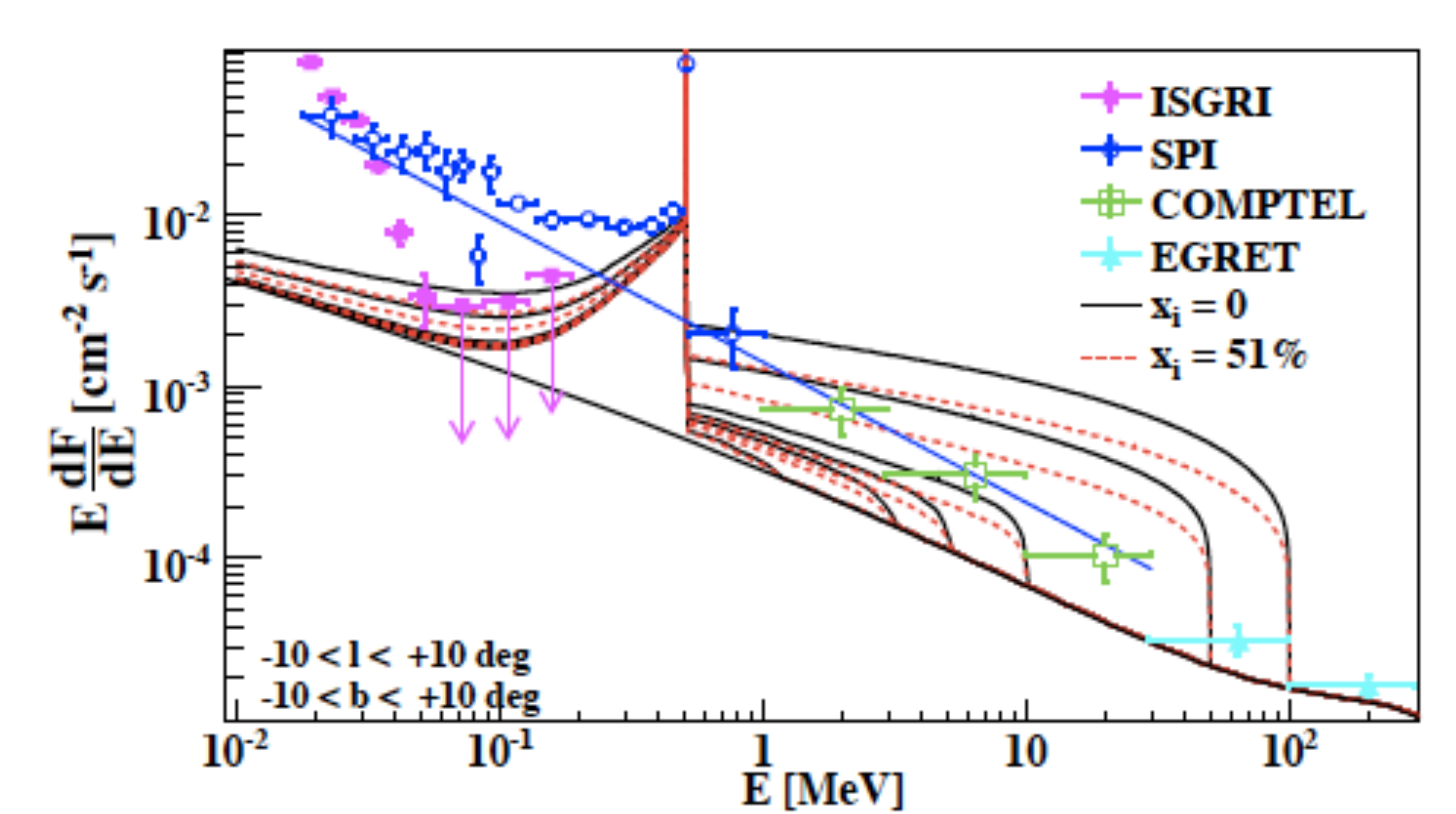
- *Beacom & Yüksel (2005)* and *Sizun+ (2006):*

  if all bulge 511-keV emission comes from




then, $M_\chi \lesssim 10\,\mathrm{MeV}$

# This constrains the injection energy




Sizun+ 2006

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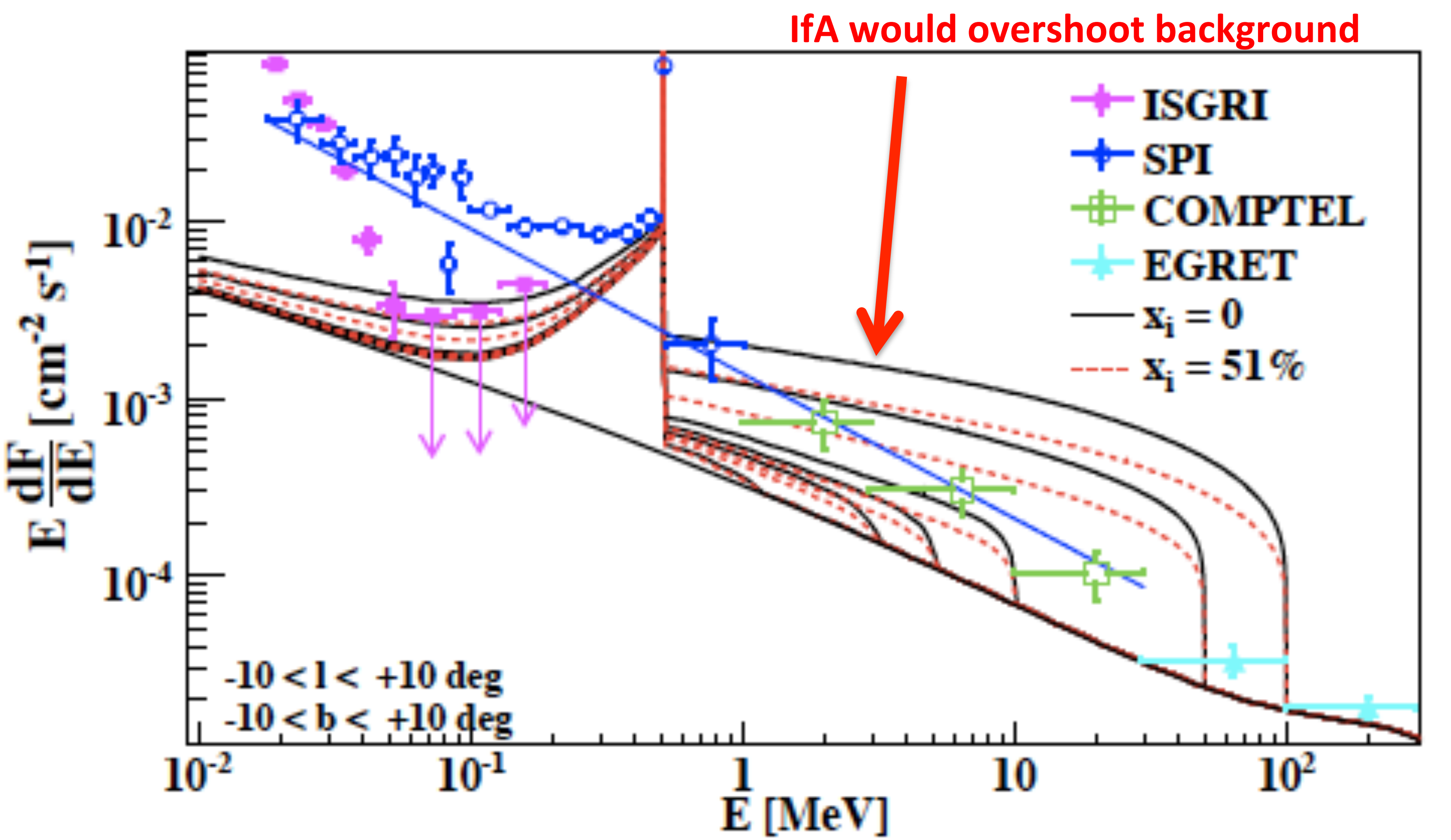


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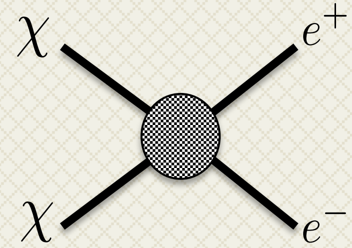
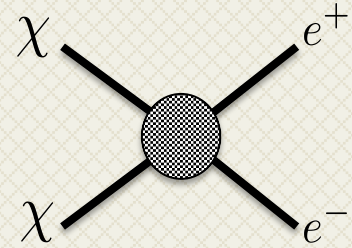
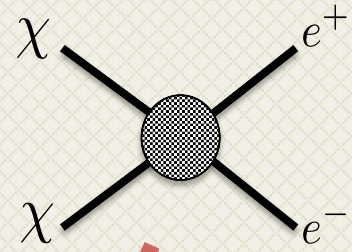
2. Other sources (probably a few contribute substantially):
   - Radioactive isotopes (present in the disk)
   - Microquasars (Siegert+ 2016)
   - Etc…

# So, how to detect:  ?

# So, how to detect:  ?



1. $e^+e^-$ injection: secondary emission
   – Can this have distinctive spectral features, e.g. like from IfA??

# So, how to detect:  ?



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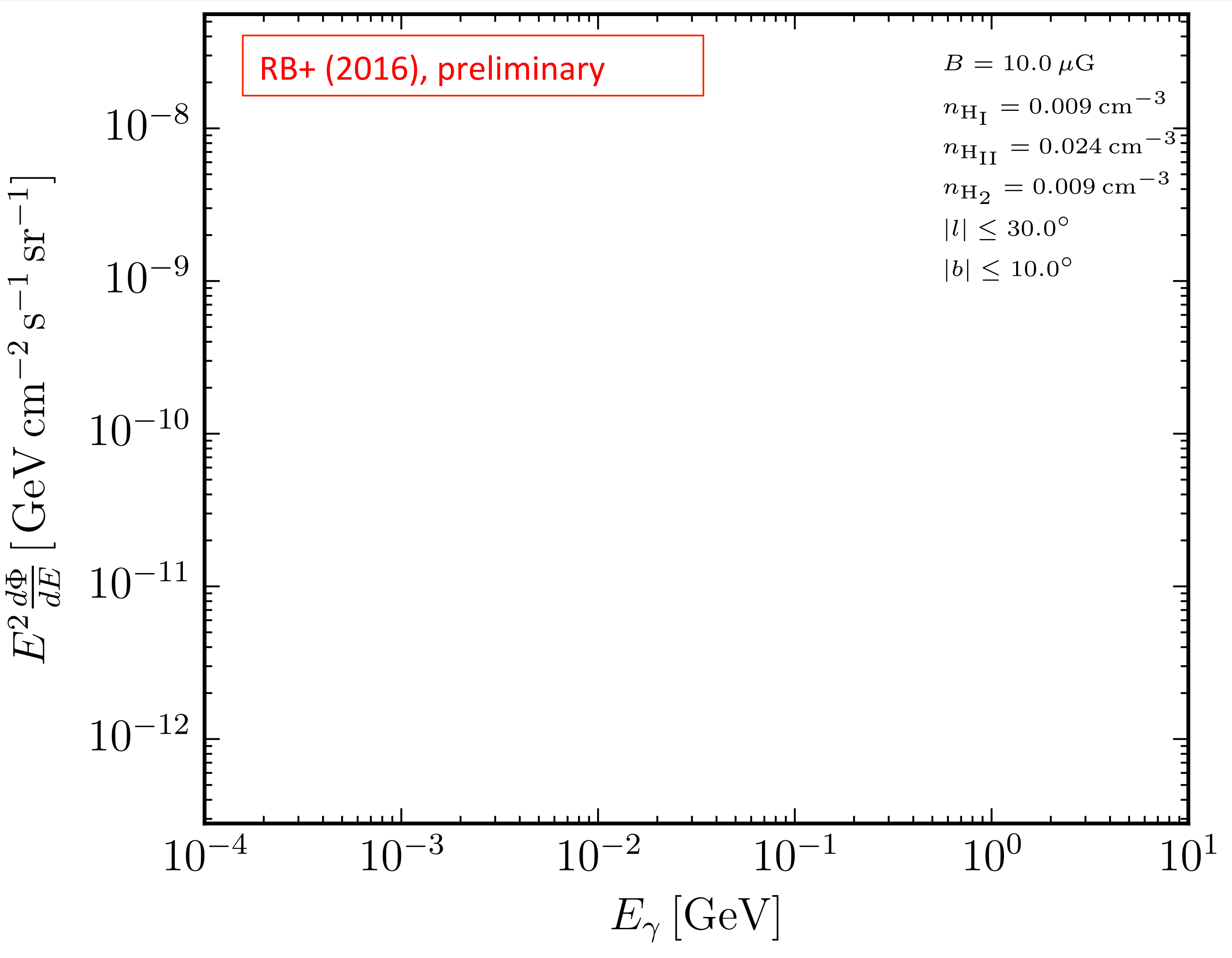
   – Can this have distinctive spectral features??

and some other models ☺

# Example: $M_\chi = 100\,\mathrm{MeV}$.



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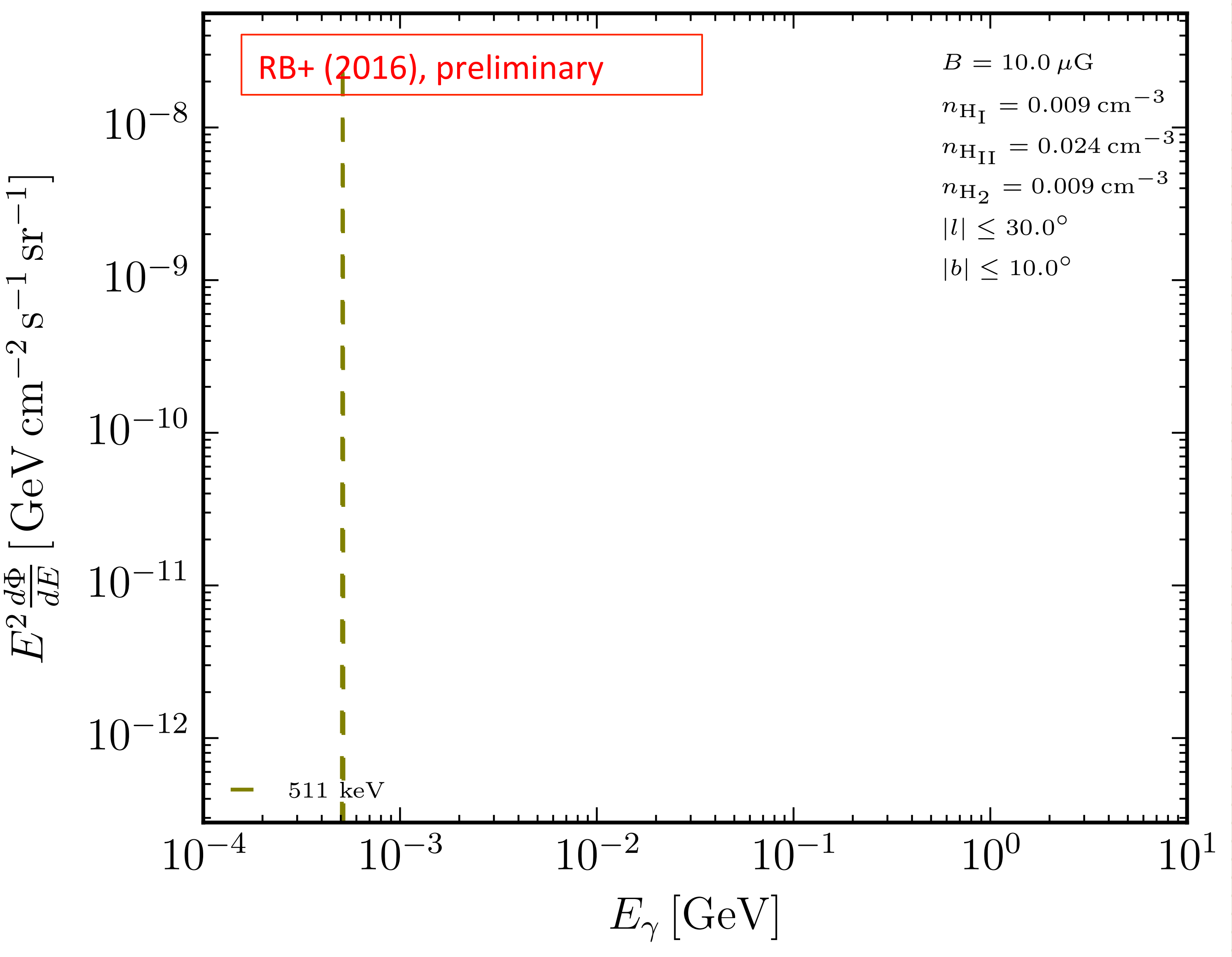

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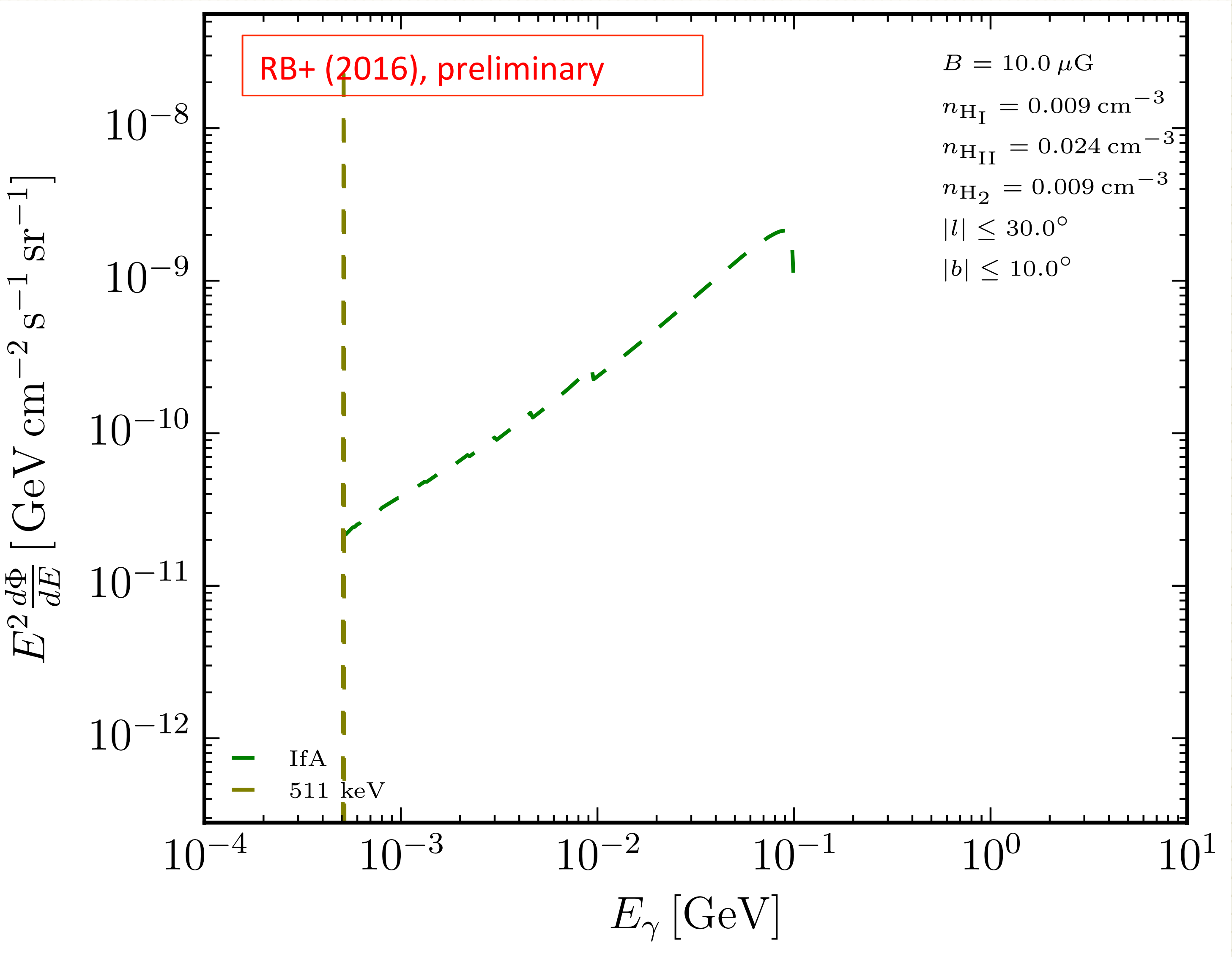

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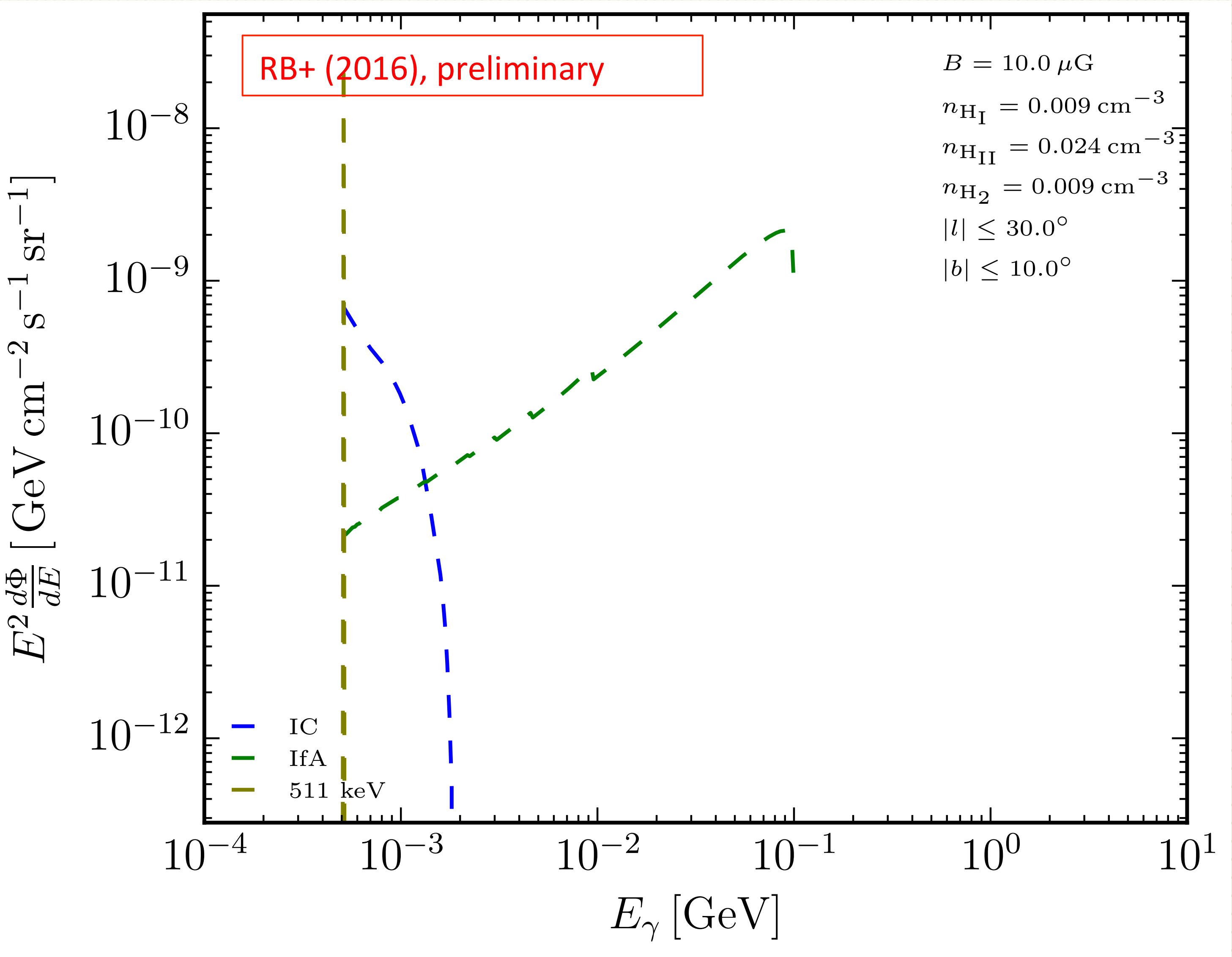

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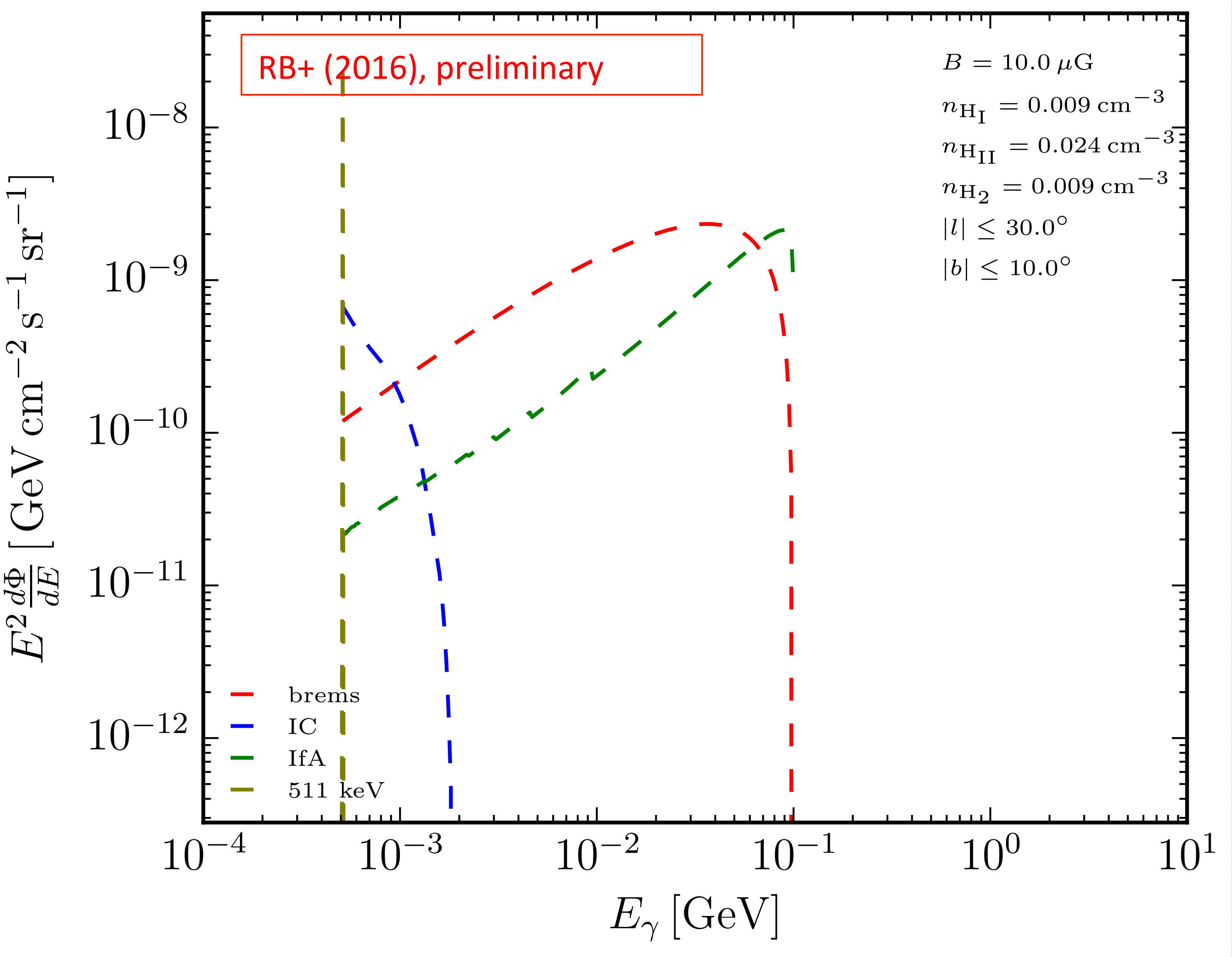

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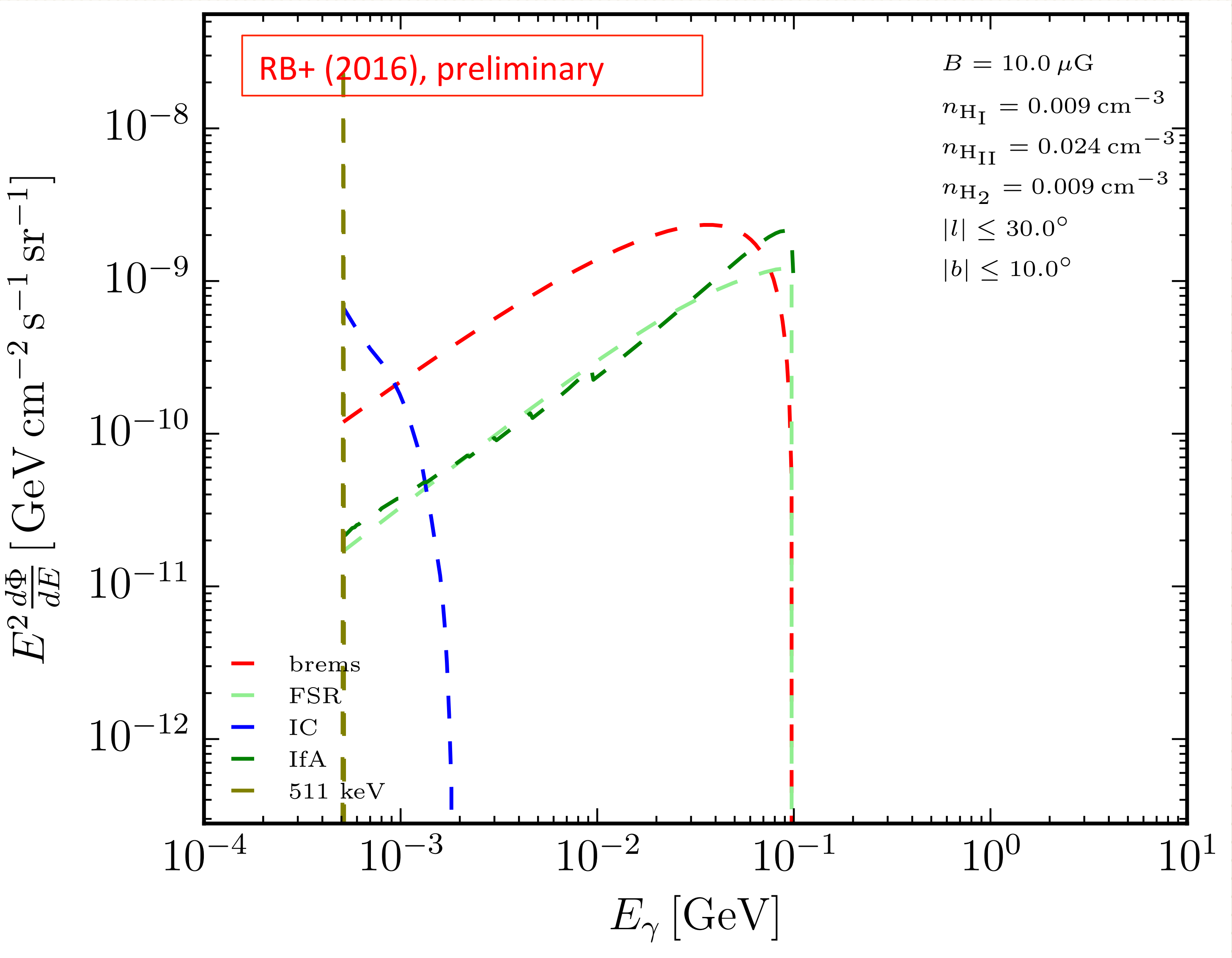

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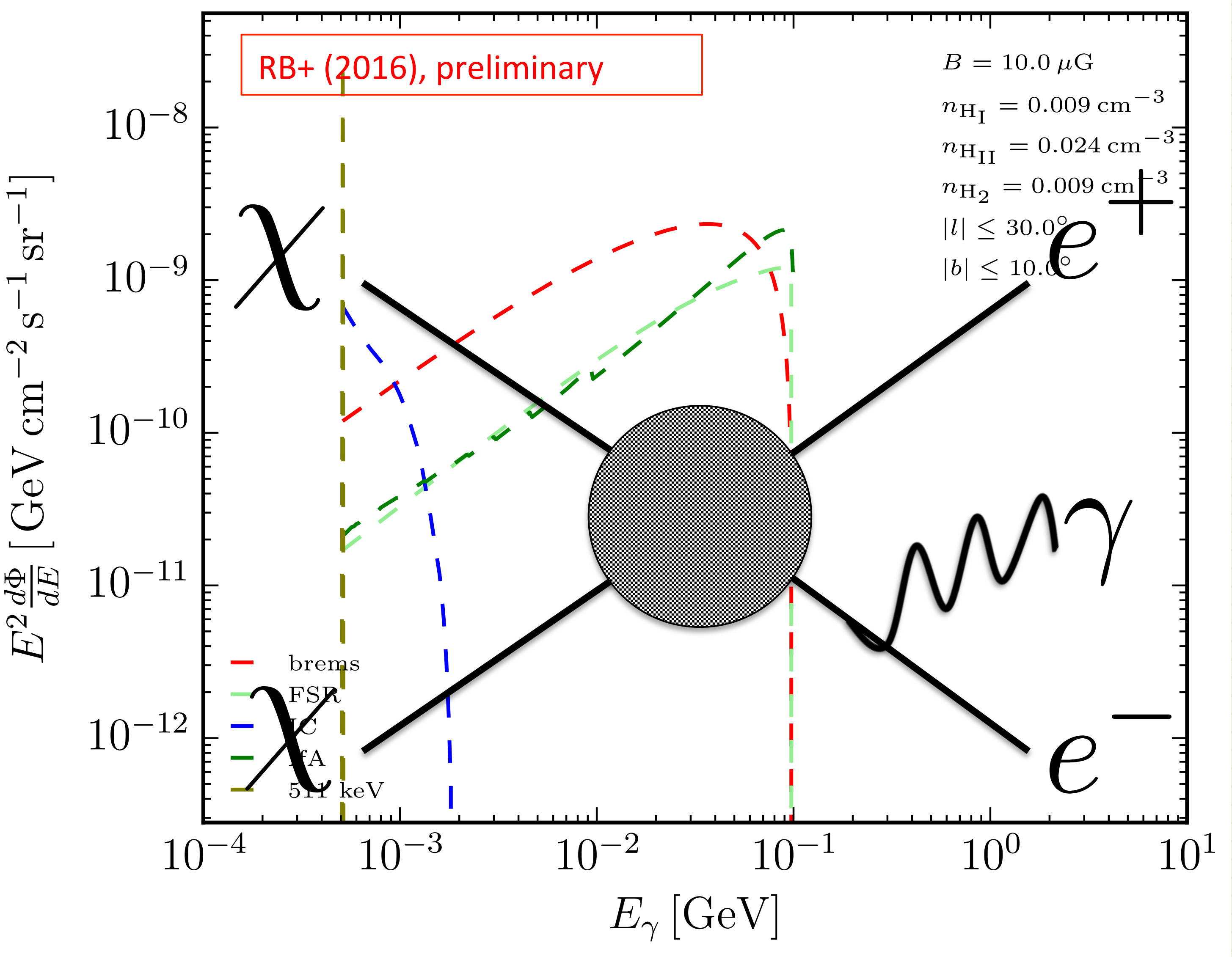

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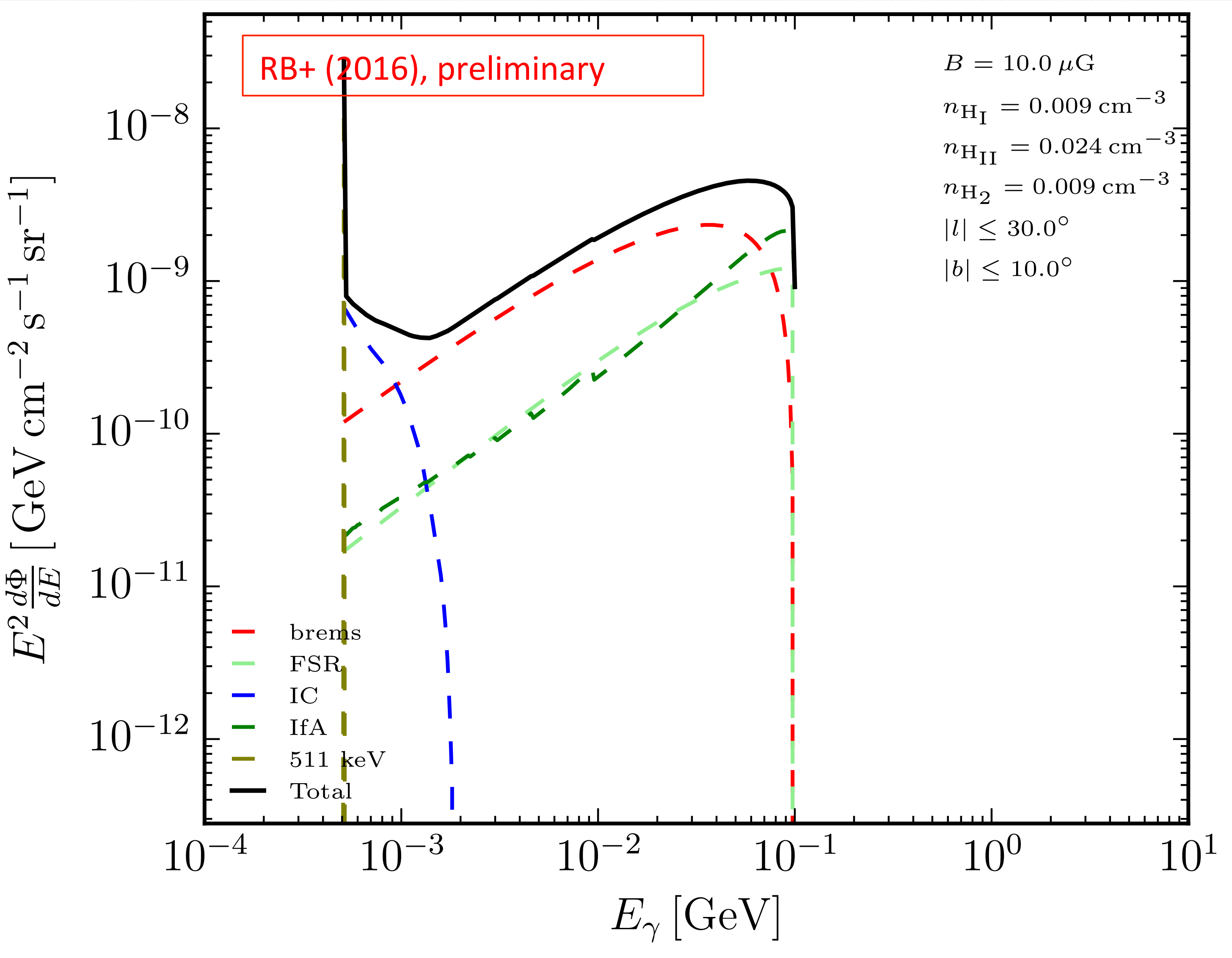

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- In-flight annihilation
- Bremsstrahlung (Also see *Cirelli+ 2013)*
- Final-State Radiation

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} 

- Contribute at roughly similar levels
- Similar spectra

# The Future

- How well can an E-ASTROGAM/ComPair experiment do?

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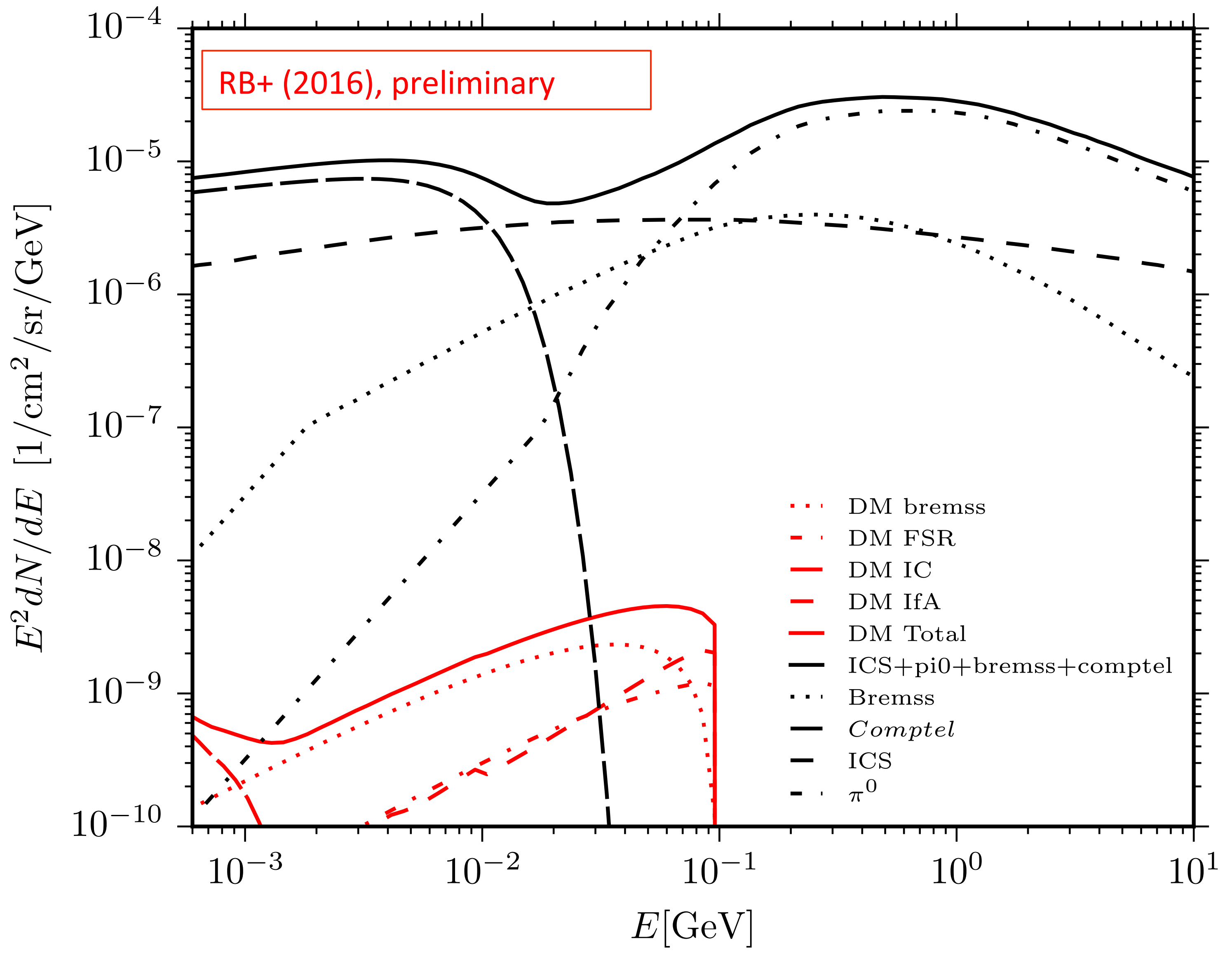
<u>We assume</u>

- Effective area: $\sim \text{few} \times 100\,\text{cm}^2\,\text{s}$
- Energy resolution: $\Delta E/E = 0.3$

# Spectral analysis



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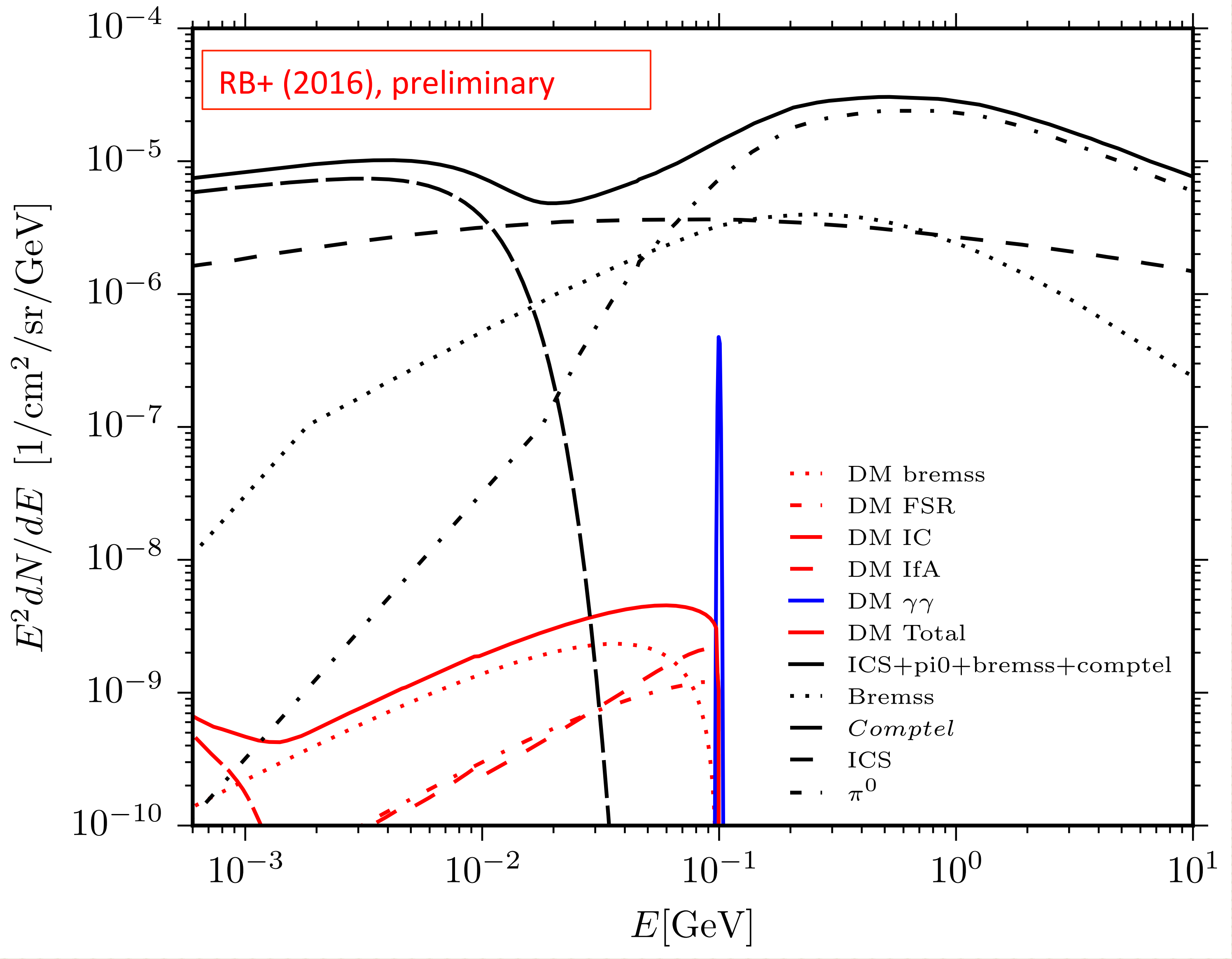

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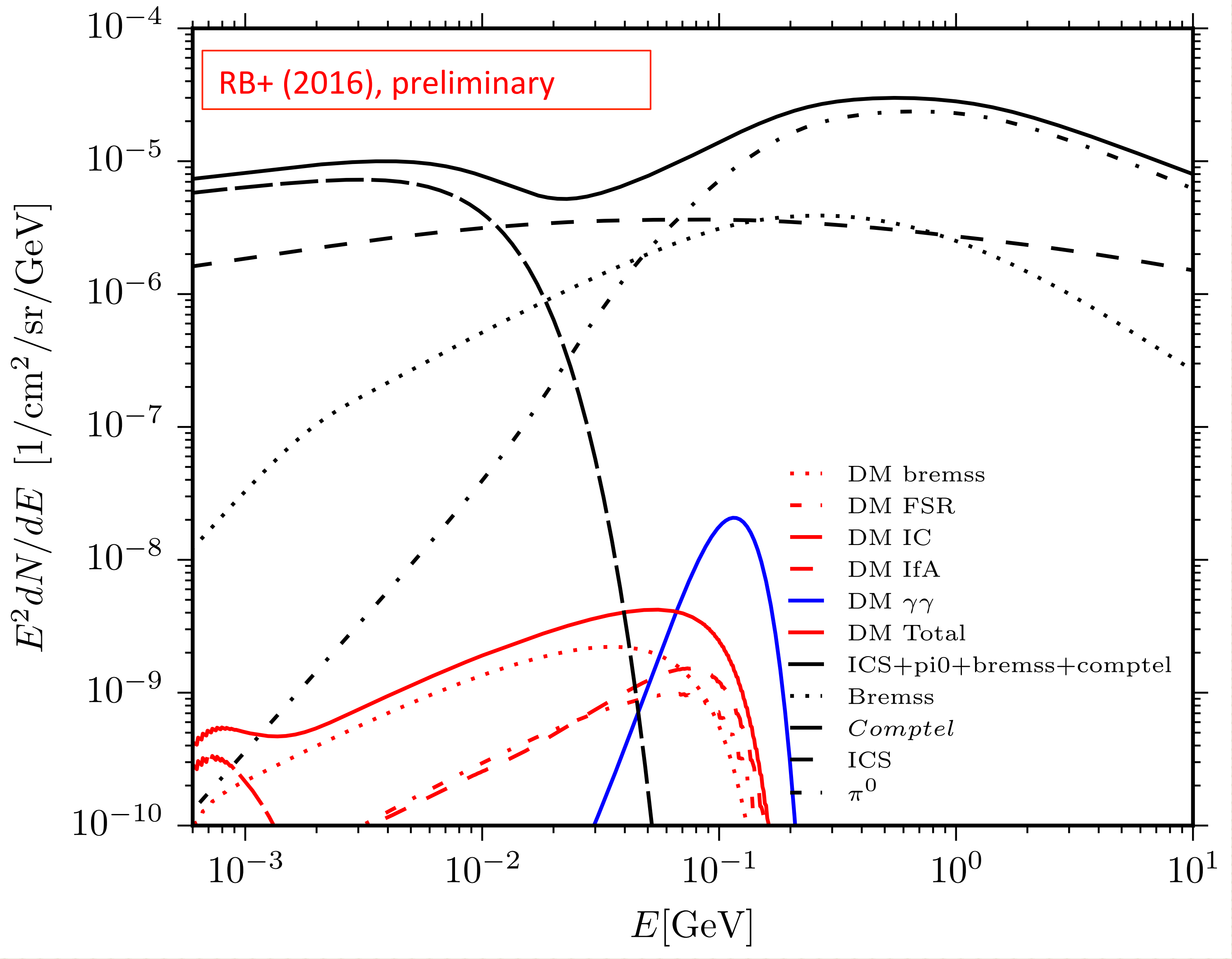
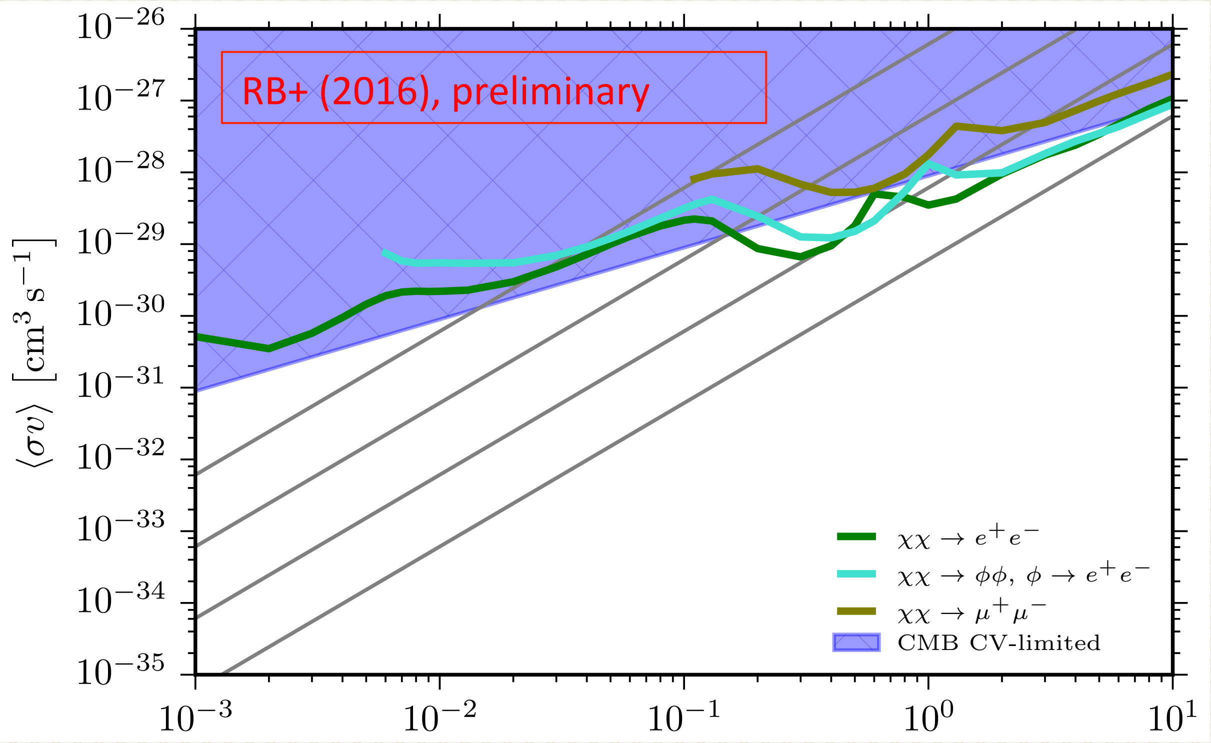


# Projected limits



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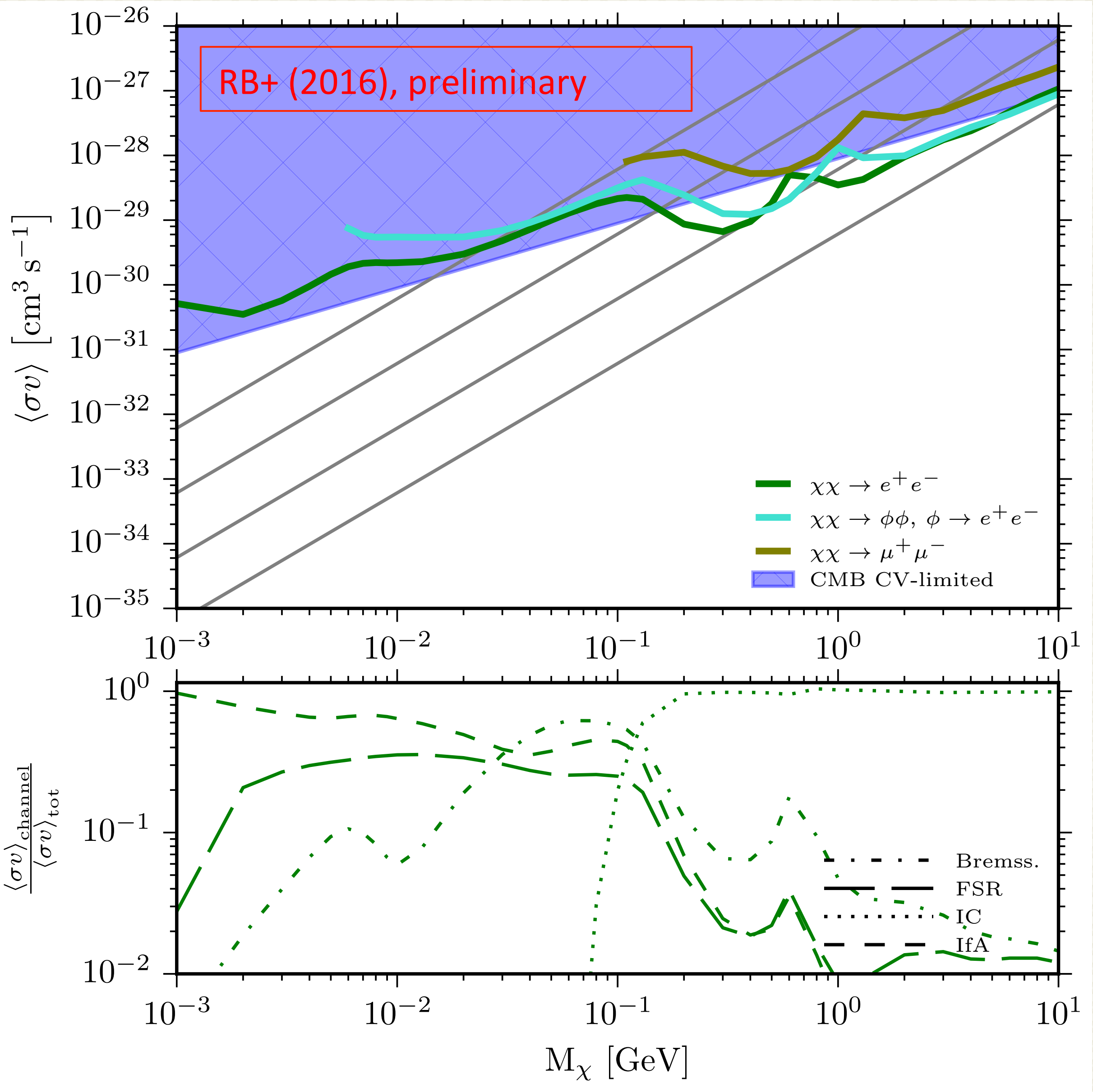

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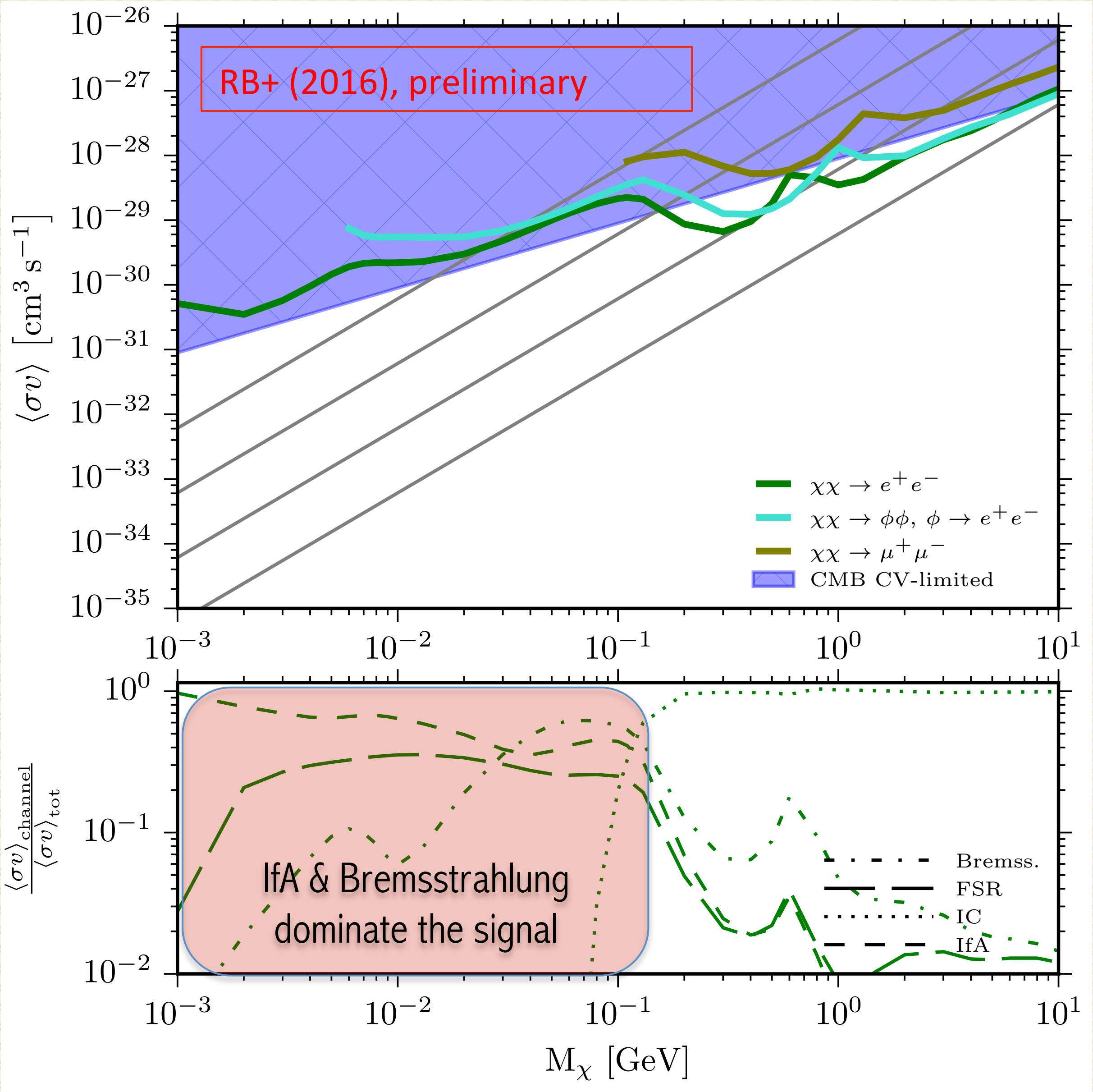

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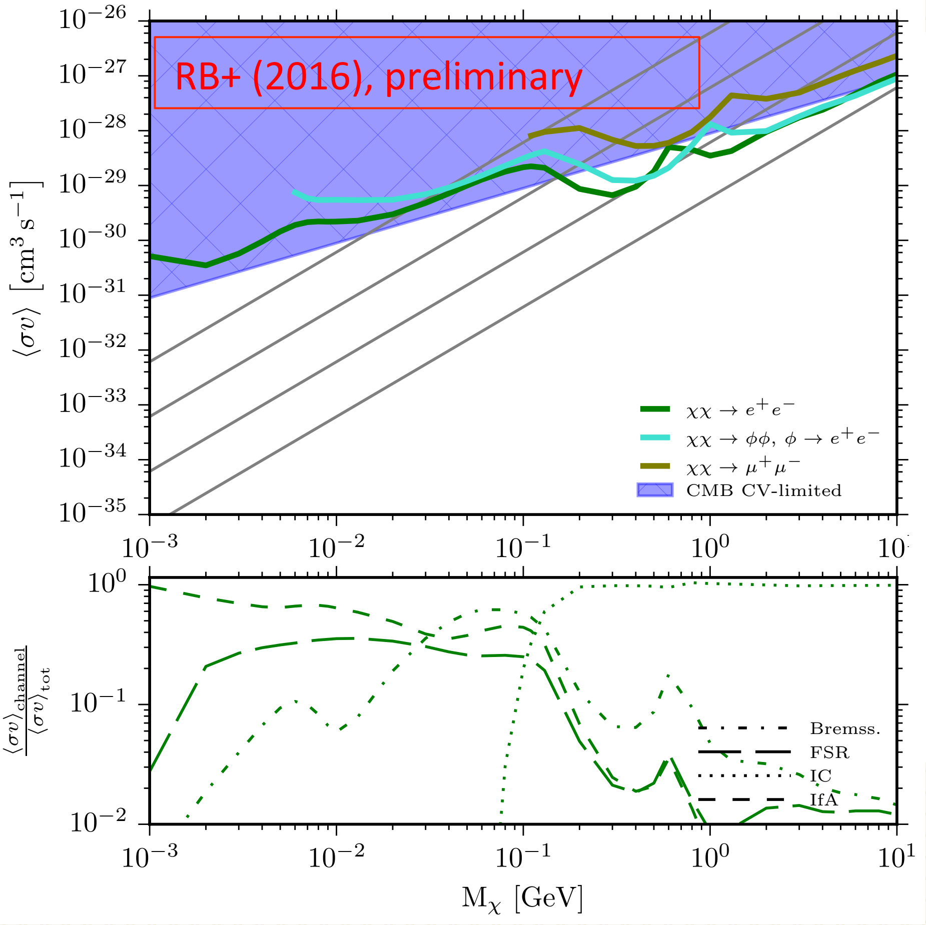
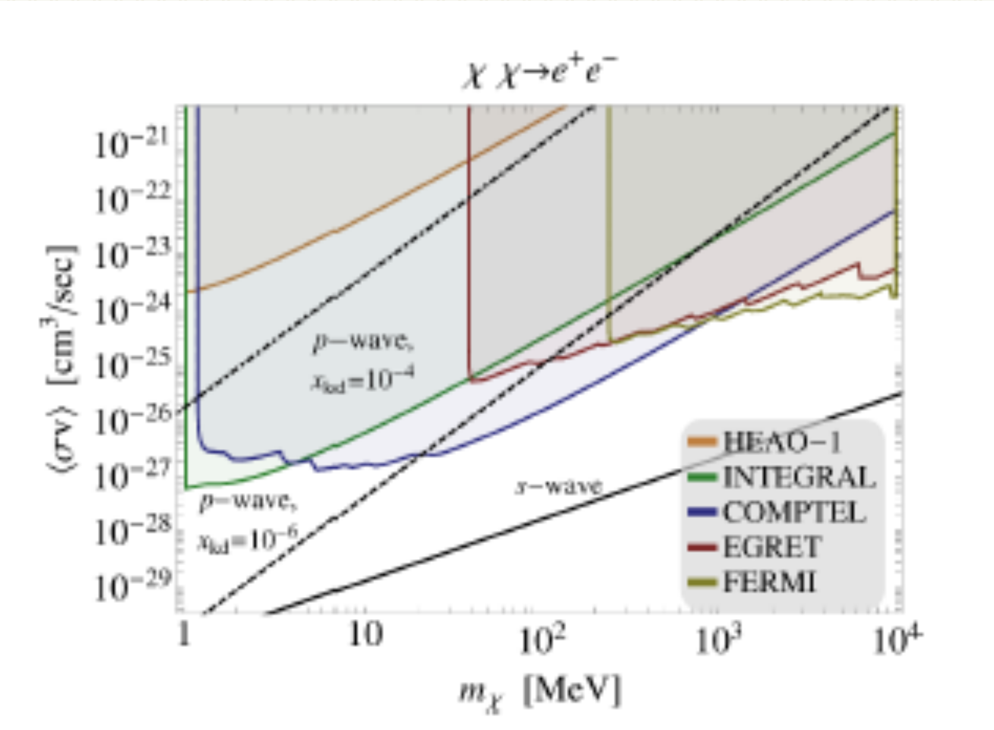



Compare with Essig+ (2013) who consider Final State radiation only:



# Projected limits: model with line

$$\mathcal{L} \supset \frac{\mathcal{C}_U F_A}{2m_U^2}\bar{\chi}\gamma_\mu\gamma_5\chi\bar{\psi}_e\gamma^\mu\gamma_5\psi_e$$ [*Pullen+ 2006*]

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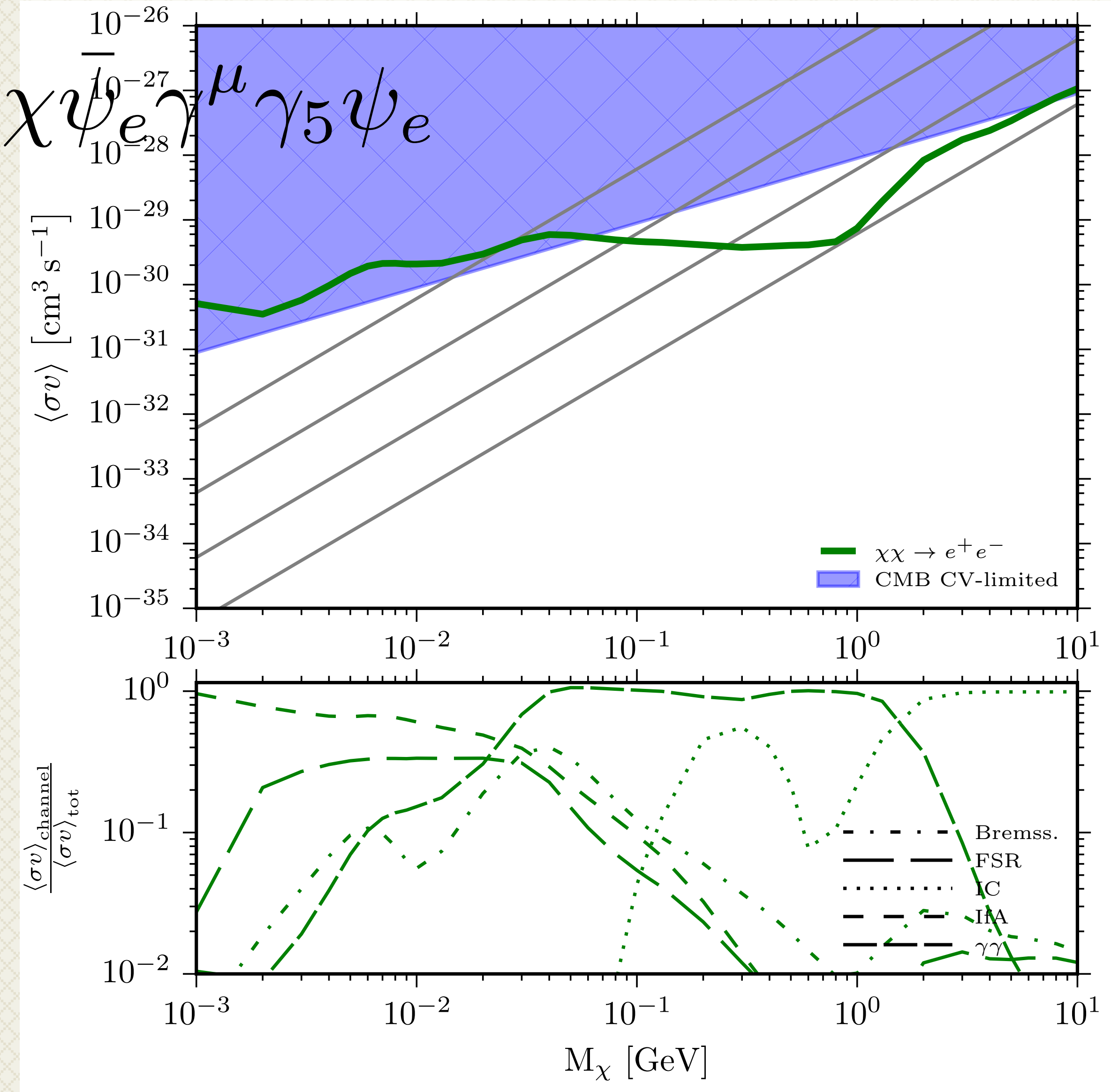

# Dragon implementation

- Account for variations in gas, ISRF and B-field
- Study the impact of diffusion on the results
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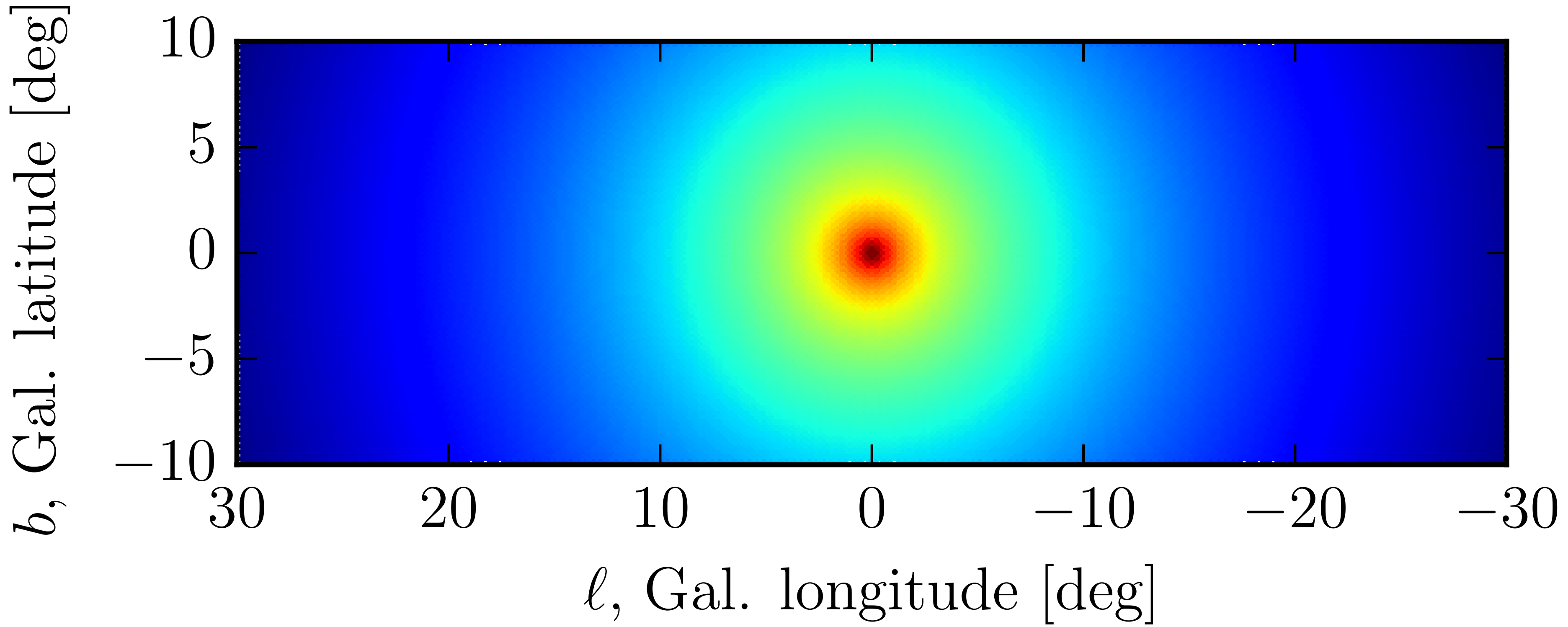
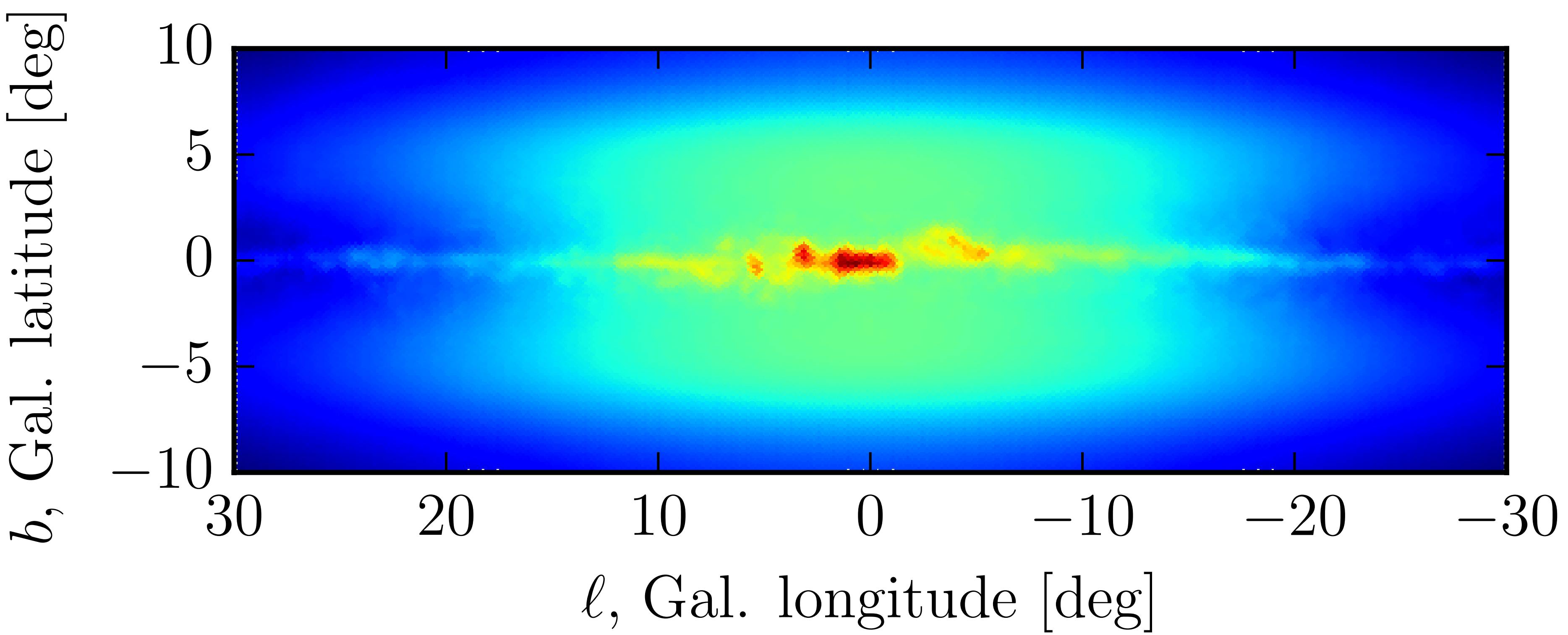
Results @ TeVPA 2016

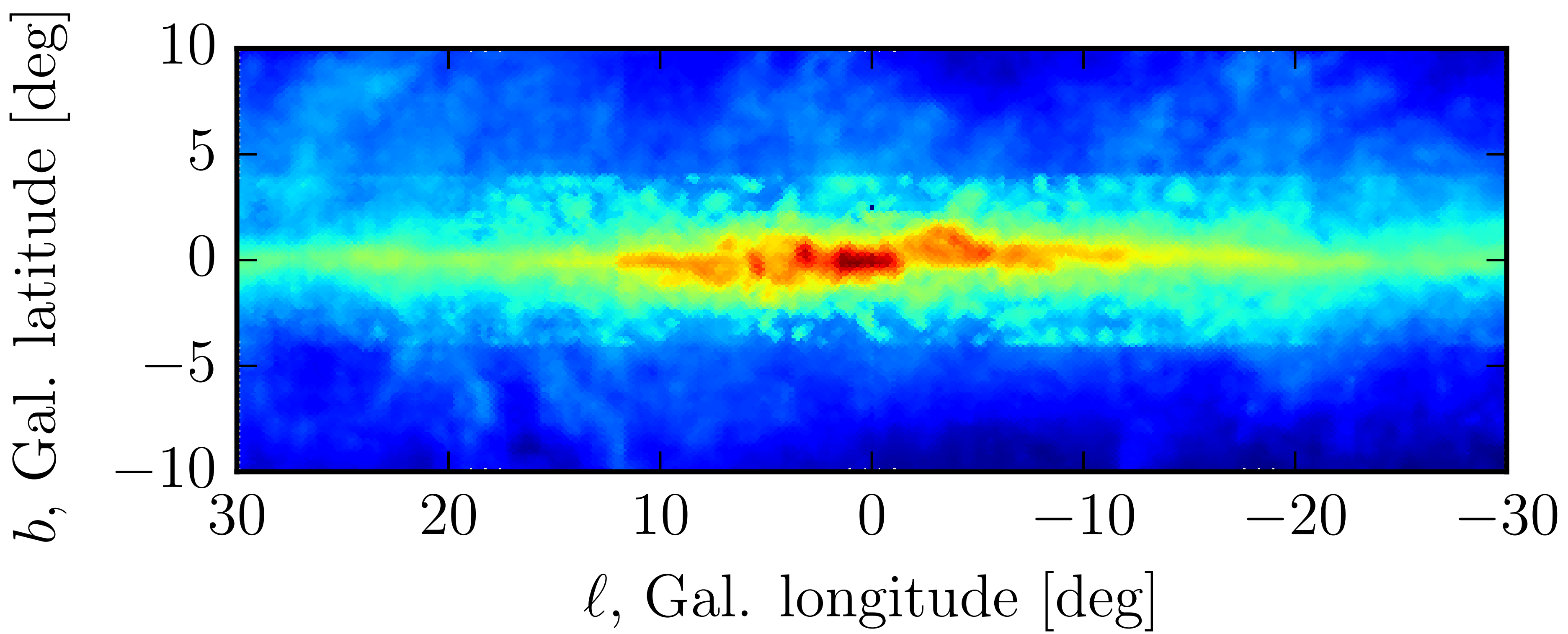
# Morphology: FSR



# Morphology: IfA



# Morphology: Bremss.



# Conclusion

- Future gamma-ray experiments can look for spectral features from MeV dark matter

- Secondaries dominate the spectrum below $\sim 100\,\mathrm{MeV}$

Thank you ☺