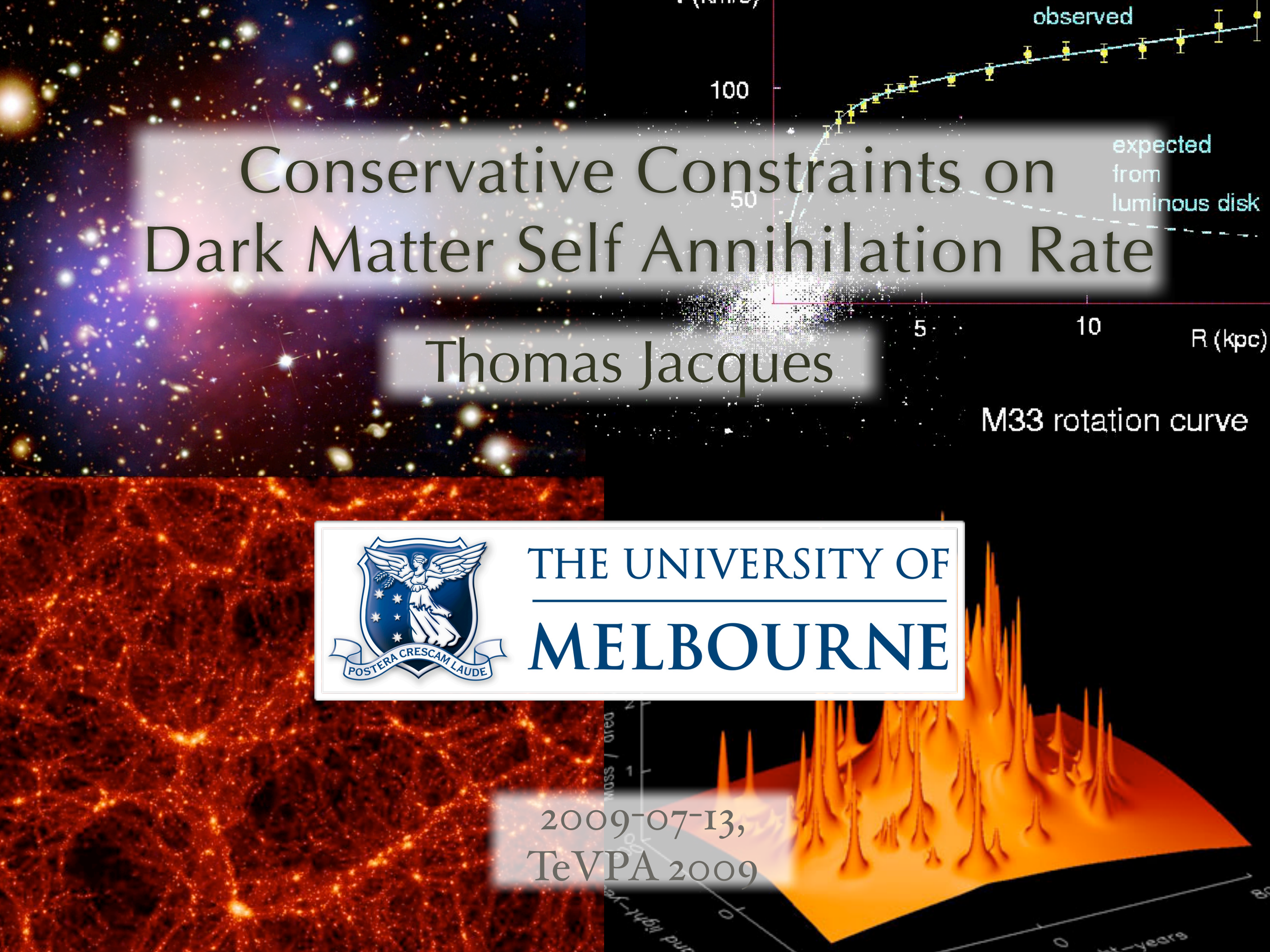
Conservative Constraints on Dark Matter Self Annihilation Rate

Thomas Jacques

THE UNIVERSITY OF MELBOURNE

2009-07-13,
TeVPA 2009



Indirect Detection

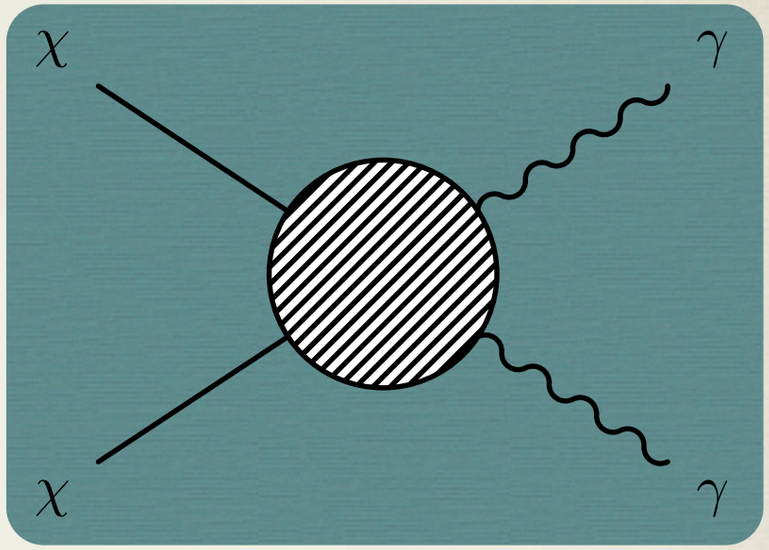
- Indirect detection often focuses on choosing a model, and comparing predicted flux to observed flux
- Great for testing a model, not so great for finding the nature of DM

Indirect Detection

- Indirect detection often focuses on choosing a model, and comparing predicted flux to observed flux
- Great for testing a model, not so great for finding the nature of DM

- So, what can we deduce about DM, ***in a model independent way***, from it's annihilation flux?
- Great progress in recent years; A number of bounds on annihilation cross section/decay width
- We expand and strengthen these limits, focusing on two final states, $\gamma\gamma$ and e^+e^-
- We can be confident that these upper limits are robust

$\gamma\gamma$



- Photon line
- 'Smoking Gun'
- Common final state, even if small branching ratio
- Don't know branching ratio:
  We constrain this channel only

from Mack, Jacques, Beacom, Bell, Yuksel; Phys.Rev.D78:063542 (2008)

Annihilation Flux

- Annihilation flux from a nearby source:

$$\frac{d\Phi_\gamma}{dE} = \frac{1}{2}\langle\sigma_A v\rangle \mathrm{Br}(\gamma\gamma) \int_0^R \frac{\rho(s)^2}{4\pi m_\chi^2} d\ell \frac{dN_\gamma}{dE}$$

Annihilation Flux

- Annihilation flux from a nearby source:

$$\frac{d\Phi_\gamma}{dE} = \frac{1}{2}\langle\sigma_A v\rangle \mathrm{Br}(\gamma\gamma) \int_0^R \frac{\rho(s)^2}{4\pi m_\chi^2} d\ell \frac{dN_\gamma}{dE}$$

Flux in some direction depends on:

Annihilation Flux

- Annihilation flux from a nearby source:

$$\frac{d\Phi_\gamma}{dE} = \frac{1}{2}\langle\sigma_A v\rangle \mathrm{Br}(\gamma\gamma) \int_0^R \frac{\rho(s)^2}{4\pi m_\chi^2} d\ell \frac{dN_\gamma}{dE}$$

Flux in some direction depends on:

Cross section,

Annihilation Flux

- Annihilation flux from a nearby source:

$$\frac{d\Phi_\gamma}{dE} = \frac{1}{2}\langle\sigma_A v\rangle \mathrm{Br}(\gamma\gamma) \int_0^R \frac{\rho(s)^2}{4\pi m_\chi^2} d\ell \frac{dN_\gamma}{dE}$$

Flux in some direction depends on:

Cross section,

Integral along the line of sight of the DM density squared,

Annihilation Flux

- Annihilation flux from a nearby source:

$$\frac{d\Phi_\gamma}{dE} = \frac{1}{2}\langle\sigma_A v\rangle \mathrm{Br}(\gamma\gamma) \int_0^R \frac{\rho(s)^2}{4\pi m_\chi^2} d\ell \frac{dN_\gamma}{dE}$$

Flux in some direction depends on:

Cross section,

Integral along the line of sight of the DM density squared,

The γ-ray spectrum per annihilation (Dirac delta)

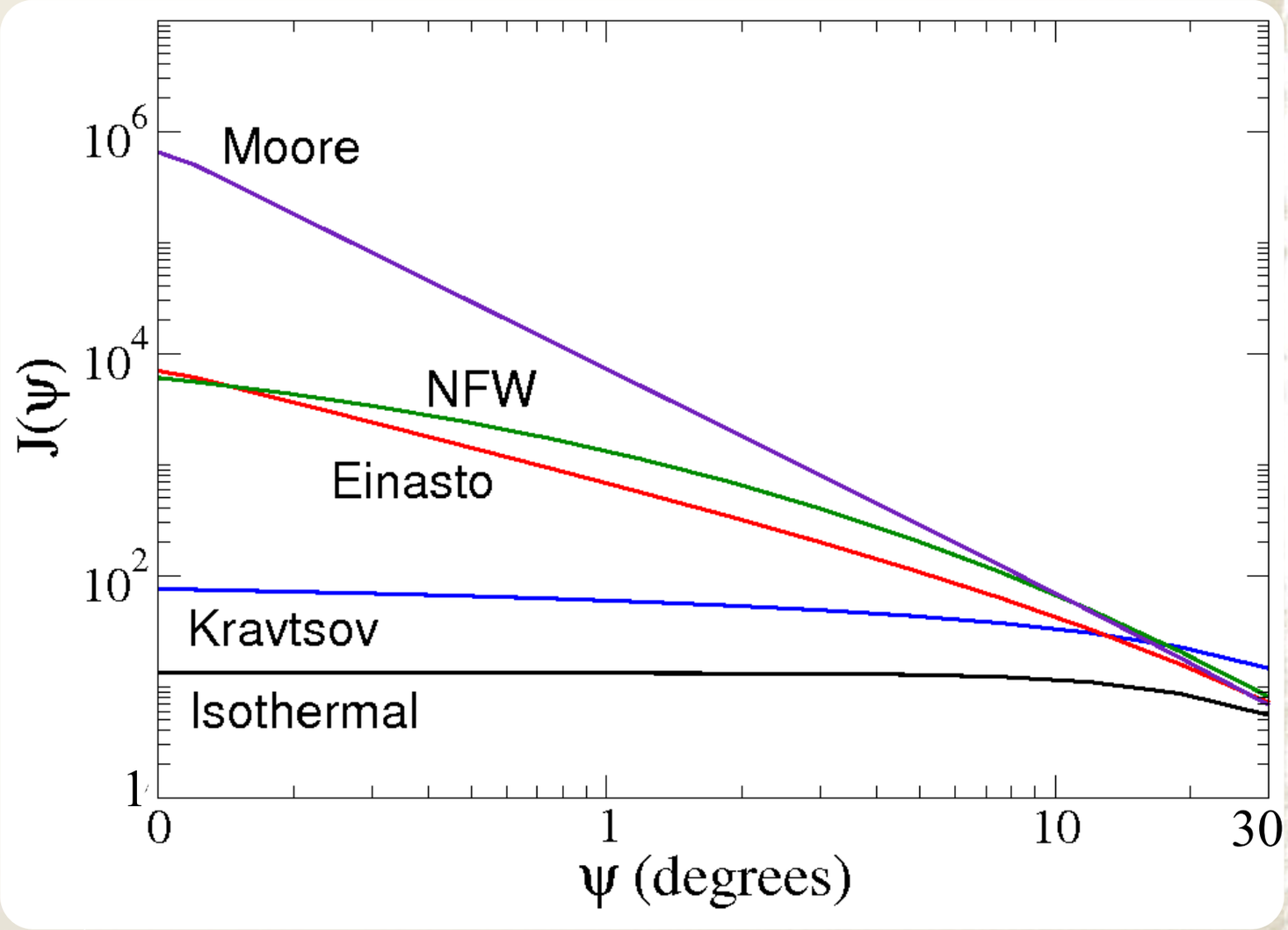
Annihilation Flux

- Annihilation flux from a nearby source:

$$\frac{d\Phi_\gamma}{dE} = \frac{\langle \sigma_A v \rangle_{\gamma\gamma}}{2} \frac{\mathcal{J}_{\Delta\Omega}}{\mathrm{J}_0} \frac{1}{4\pi m_\chi^2} \frac{dN_\gamma}{dE}$$

Density profiles

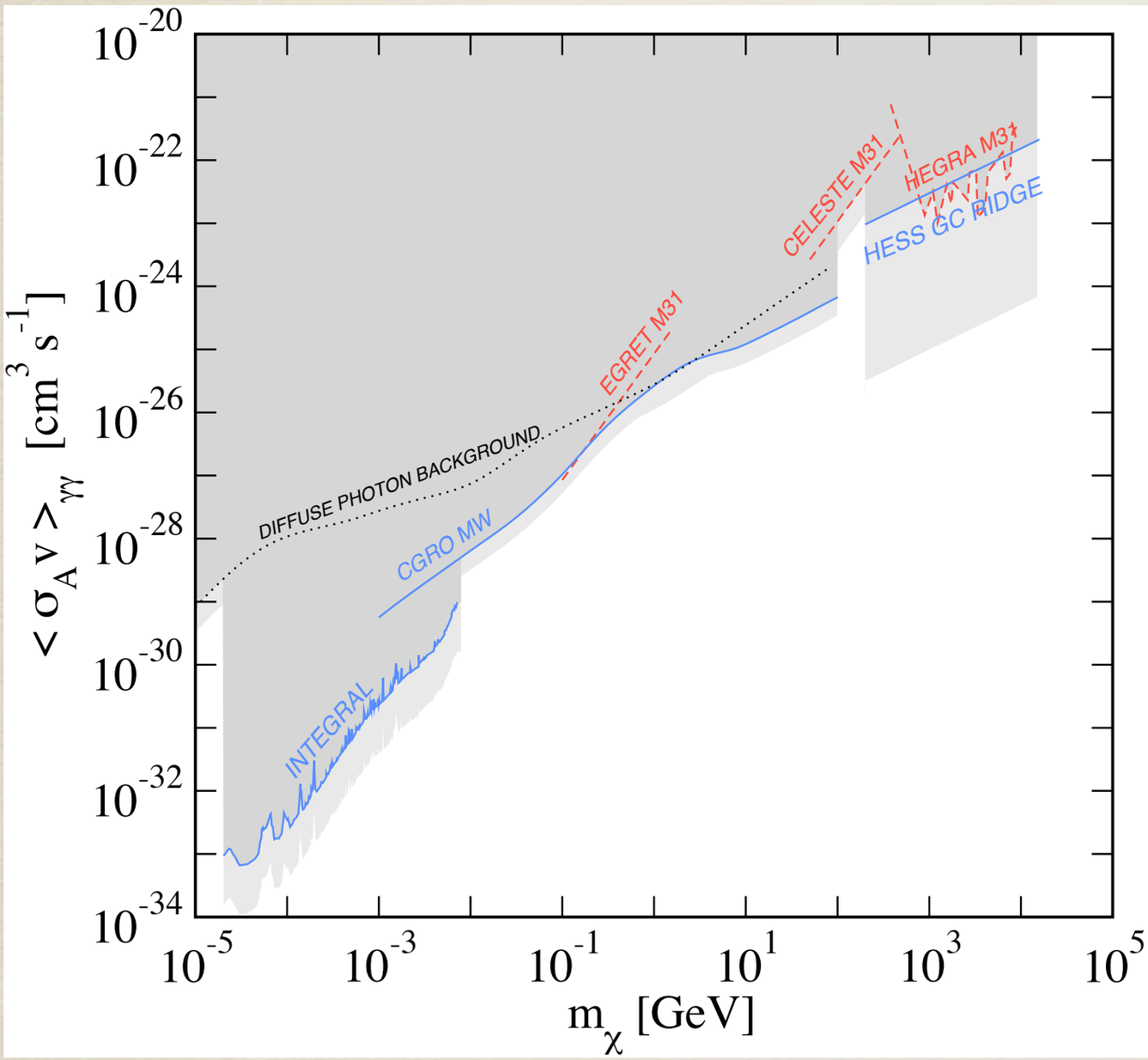
- Minimize uncertainty by looking at large angular regions
- Focus on conservative Kravtsov profile, but show results for other profiles



Observation Regions

- Galactic Center
  - Our main flux source; lots of data
- M31 (Andromeda)
  - Relatively weak upper limits on $\langle \sigma_A v \rangle$
  - Analysis very similar to GC case
- Cosmic Annihilation
  - Diffuse photon flux from extragalactic DM annihilation
  - Analysis includes integral over redshift, photon attenuation, DM clumping factor
- Use data from INTEGRAL, COMPTEL, EGRET, HEGRA, CELESTE, HESS, SMM
- Cover broad range of energies: ~10^{-5} to ~10^{4} GeV

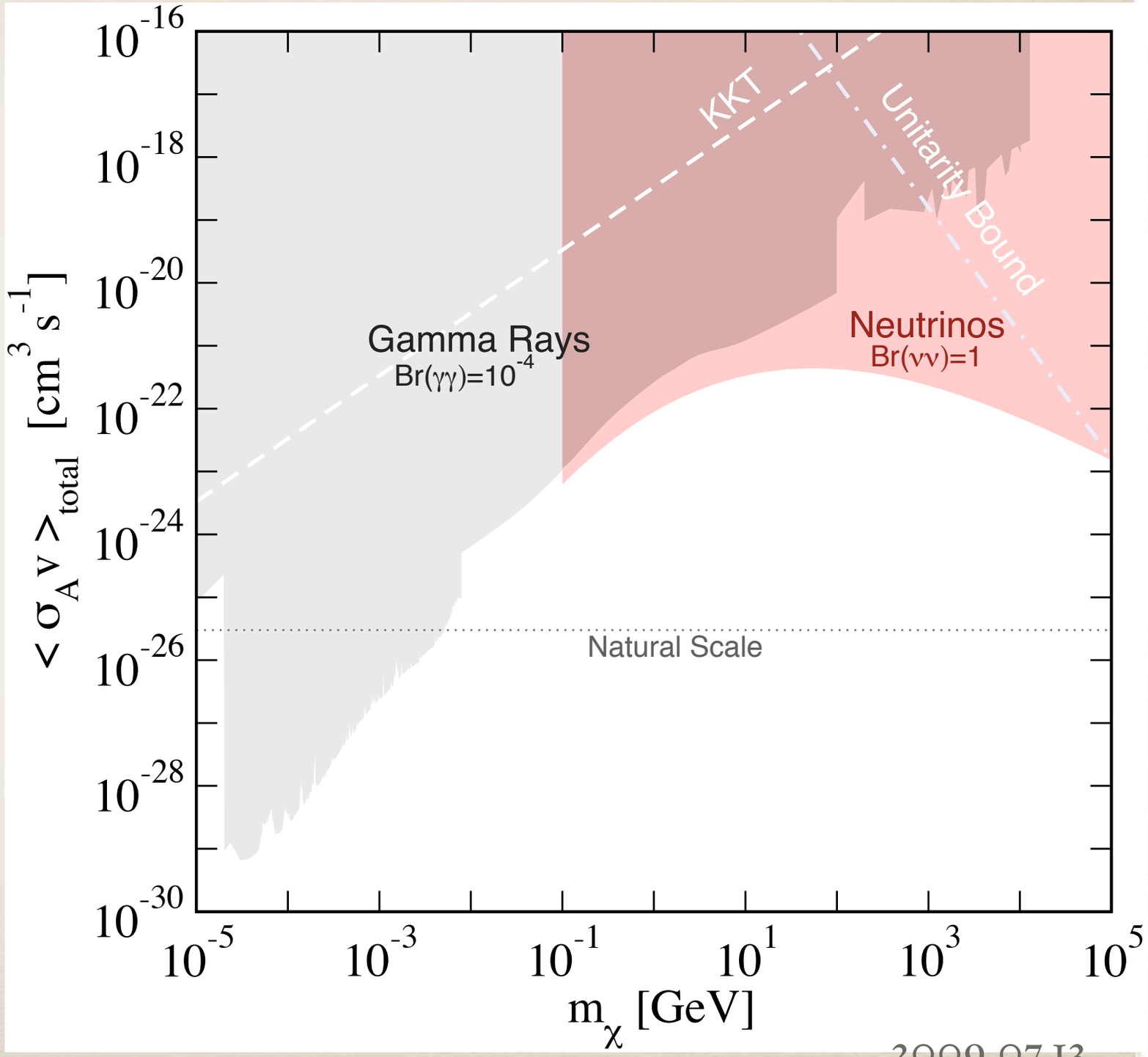
Results



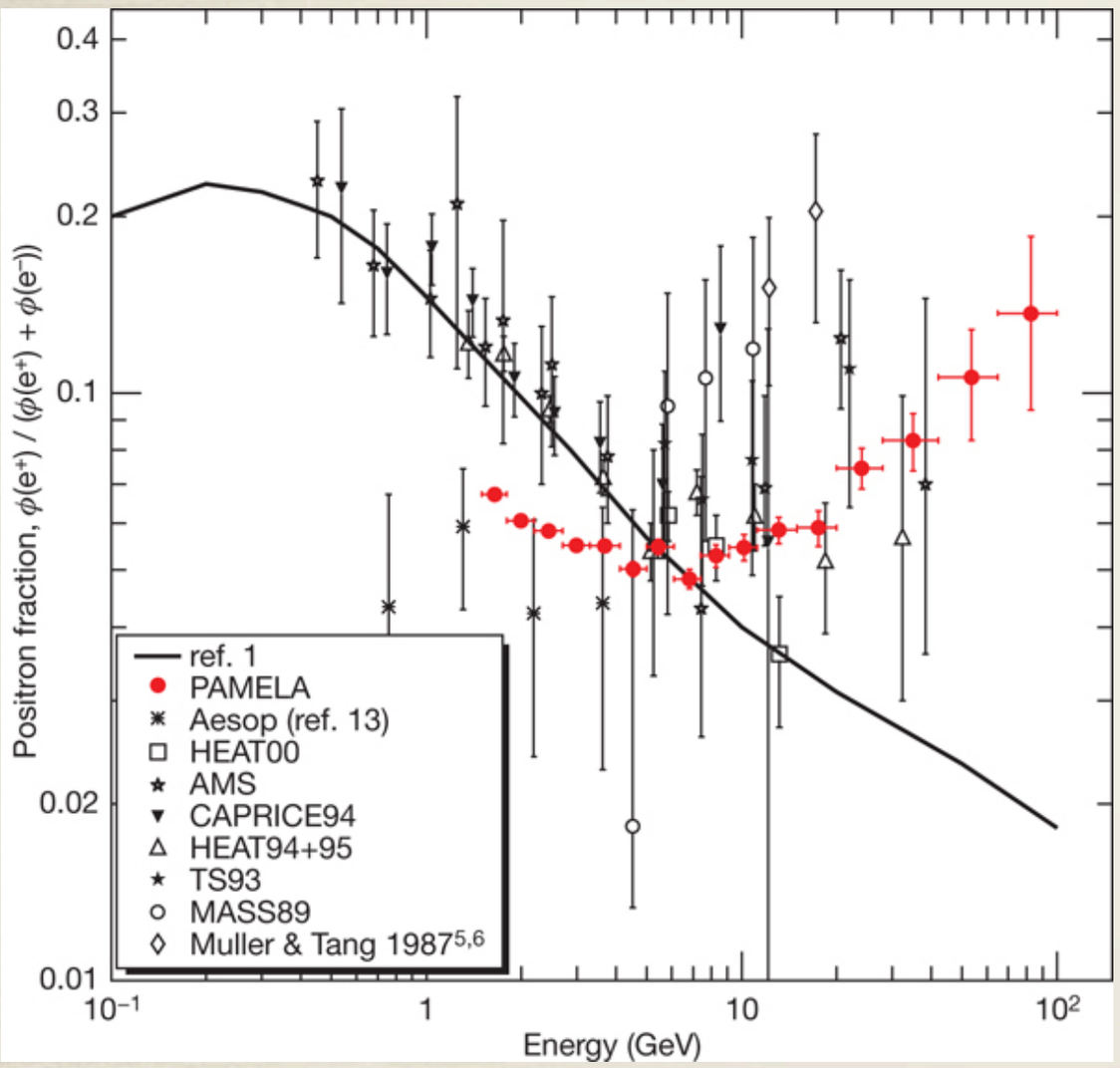
- Very conservative analysis
- Results more general than they appear: We integrate the signal over a large energy bin, so results are valid for an annihilation spectrum as wide as our analysis bin (0.4 in $\log_{10}$ E)
- At worst, our limit would be increased by a factor of several for a broad annihilation spectrum (except for INTEGRAL/HEGRA)

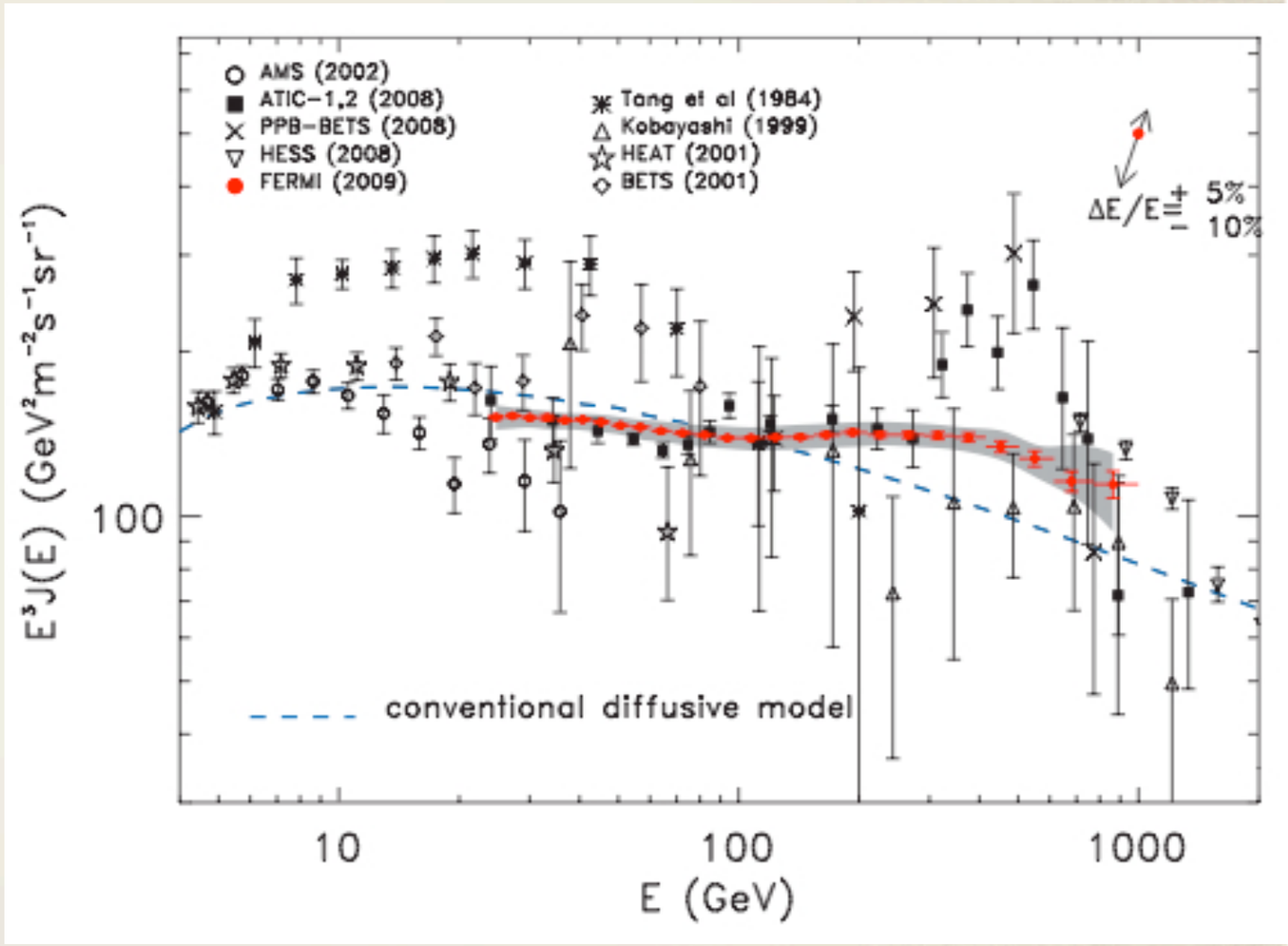
Results

- Using $Br(\gamma\gamma) = 10^{-4}$, find a limit on the total cross section



Positron Excess

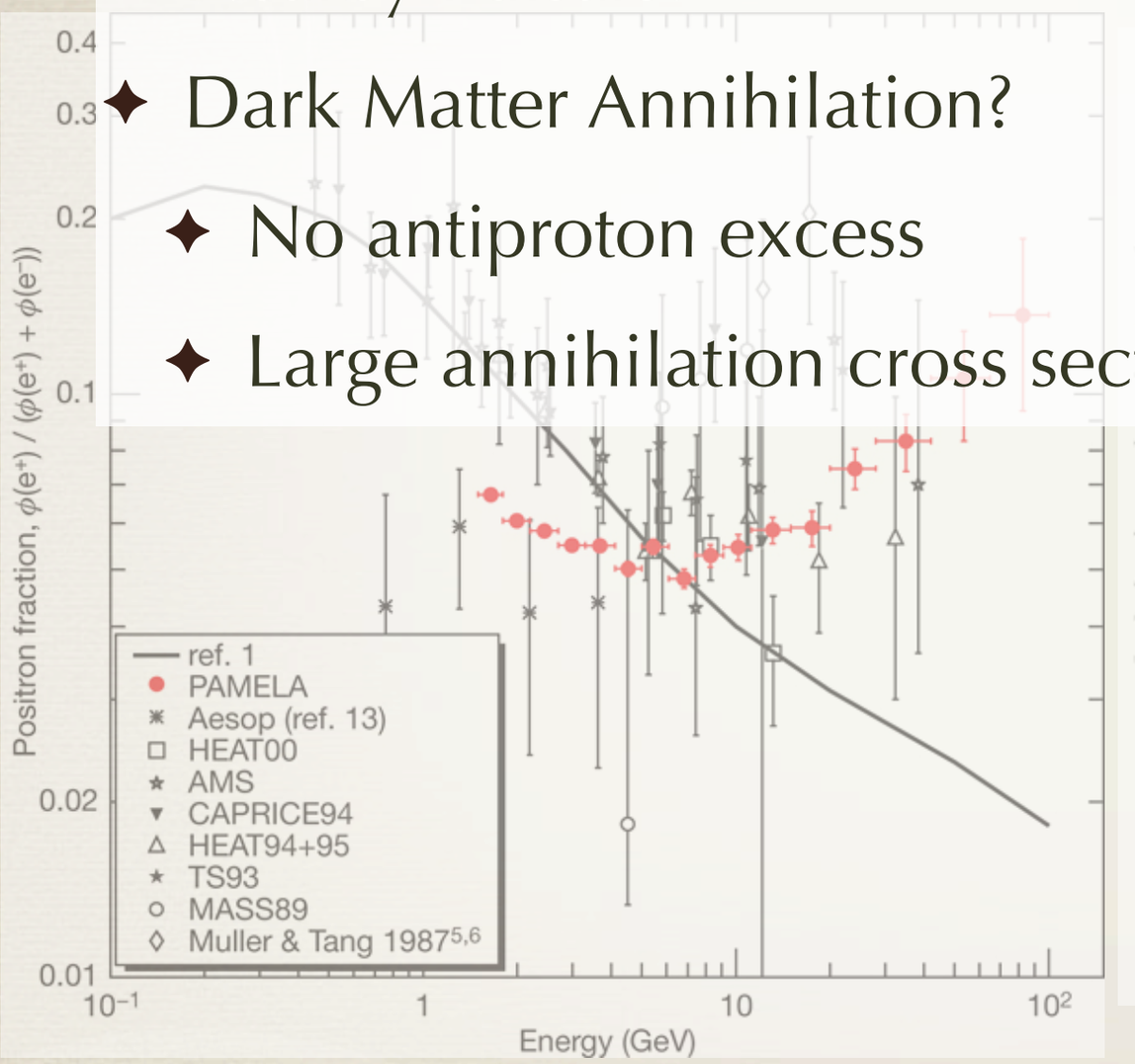


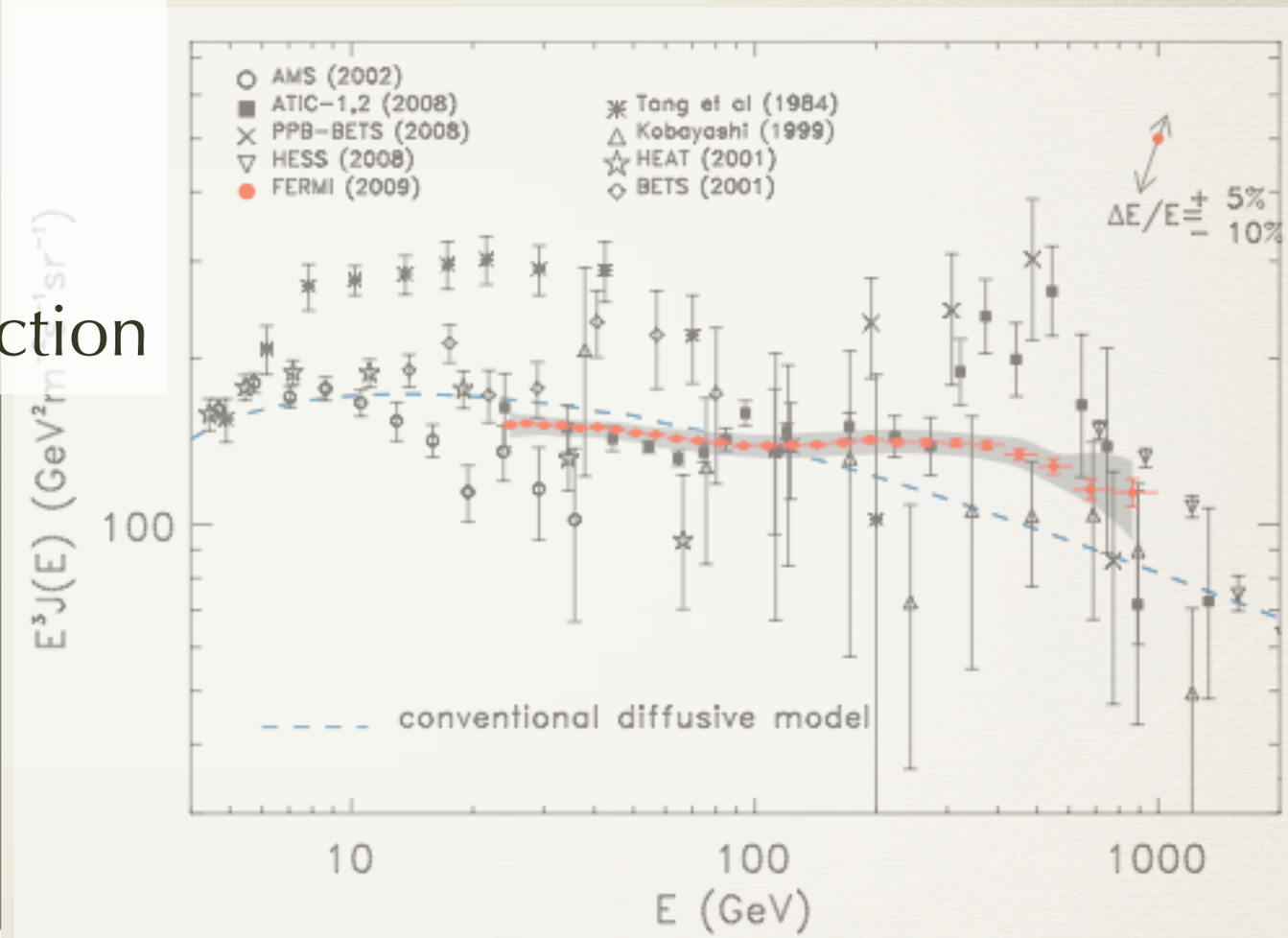


from N. Bell & T. Jacques; Phys.Rev.D79:043507 (2008)

Positron Excess

- Nearby Pulsars?
- Dark Matter Annihilation?
  - No antiproton excess
  - Large annihilation cross section

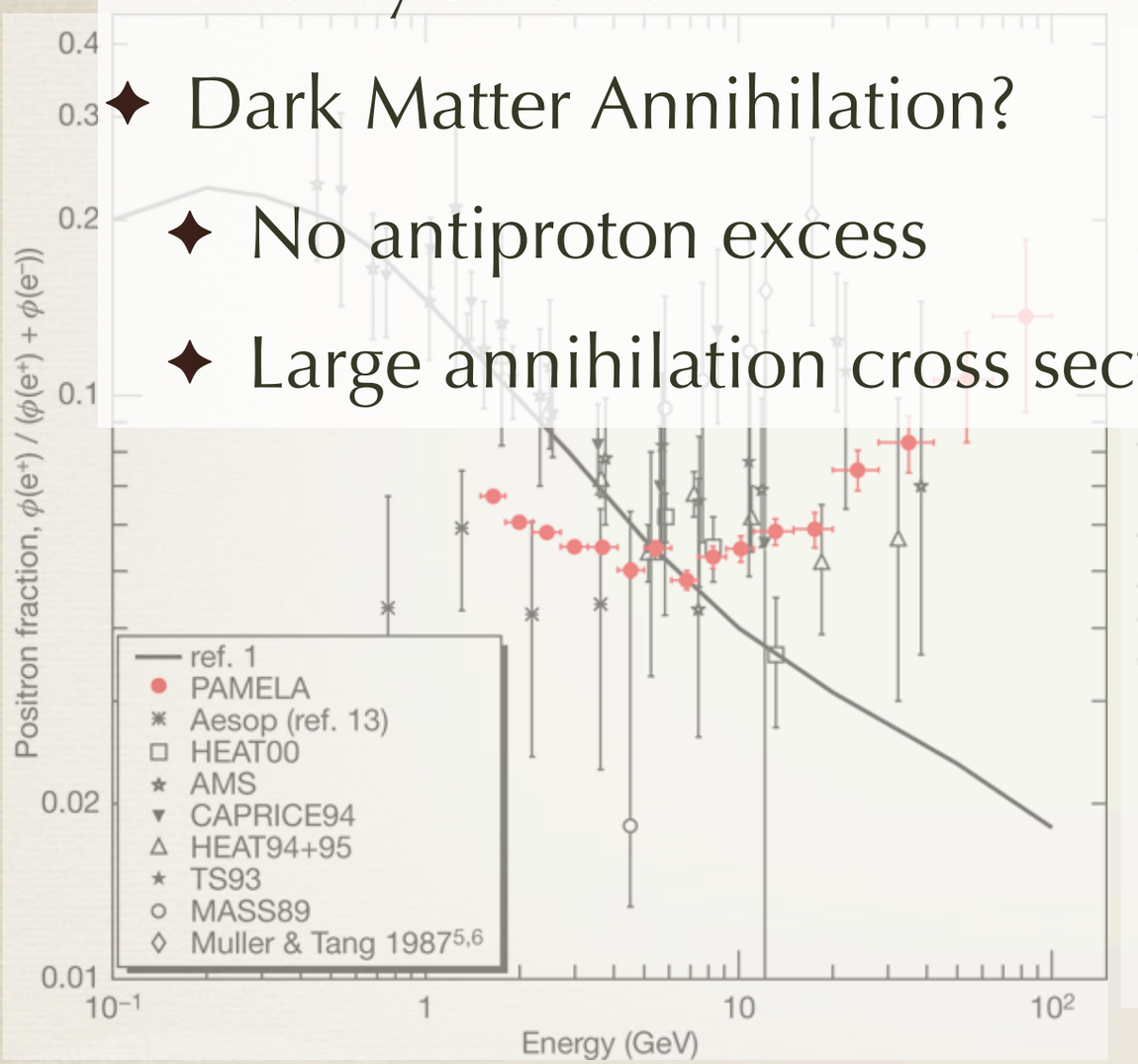




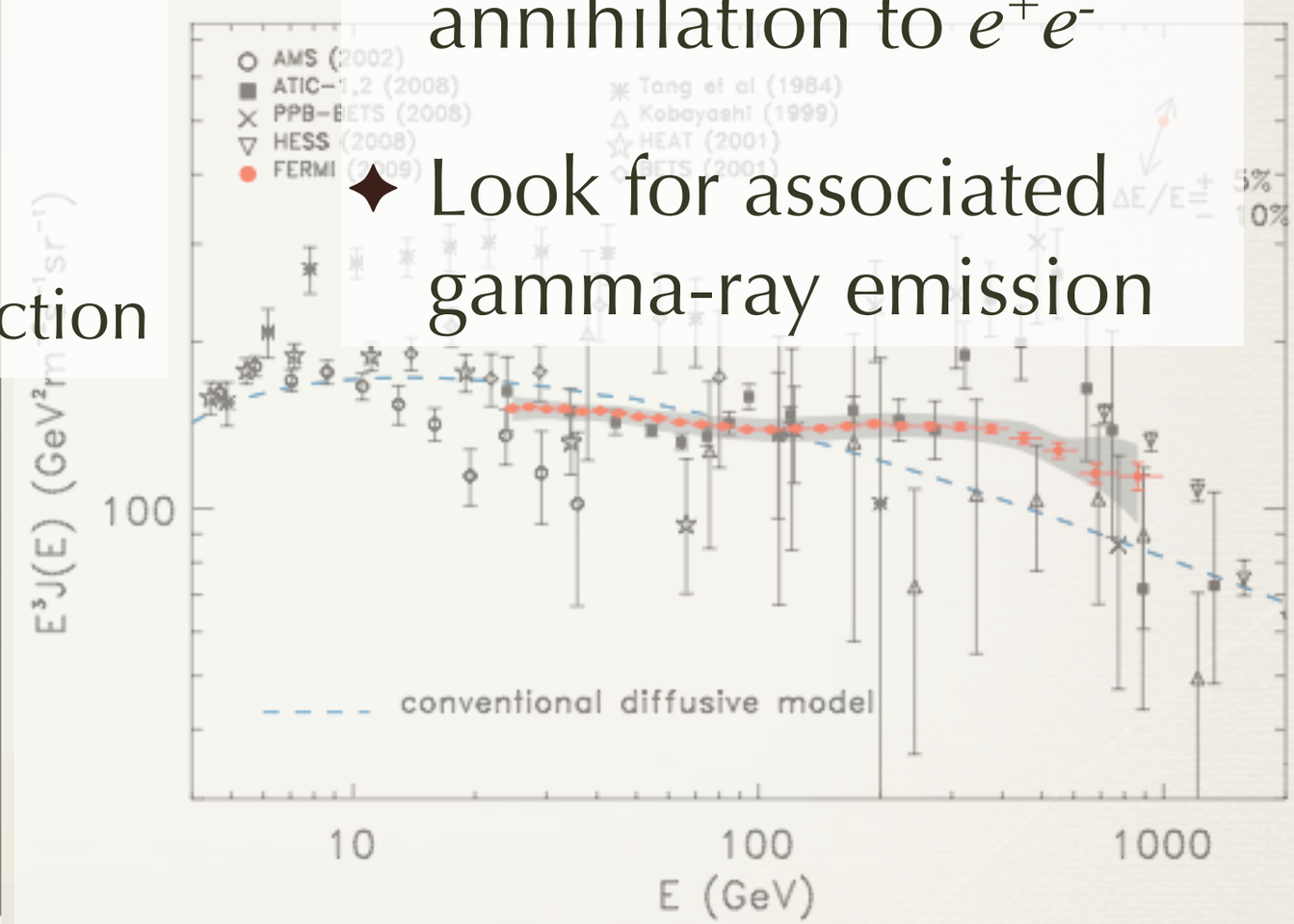
from N. Bell & T. Jacques; Phys.Rev.D79:043507 (2008)

Positron Excess

- Nearby Pulsars?
- Dark Matter Annihilation?
  - No antiproton excess
  - Large annihilation cross section



- Want to constrain annihilation to e^+e^-
- Look for associated gamma-ray emission

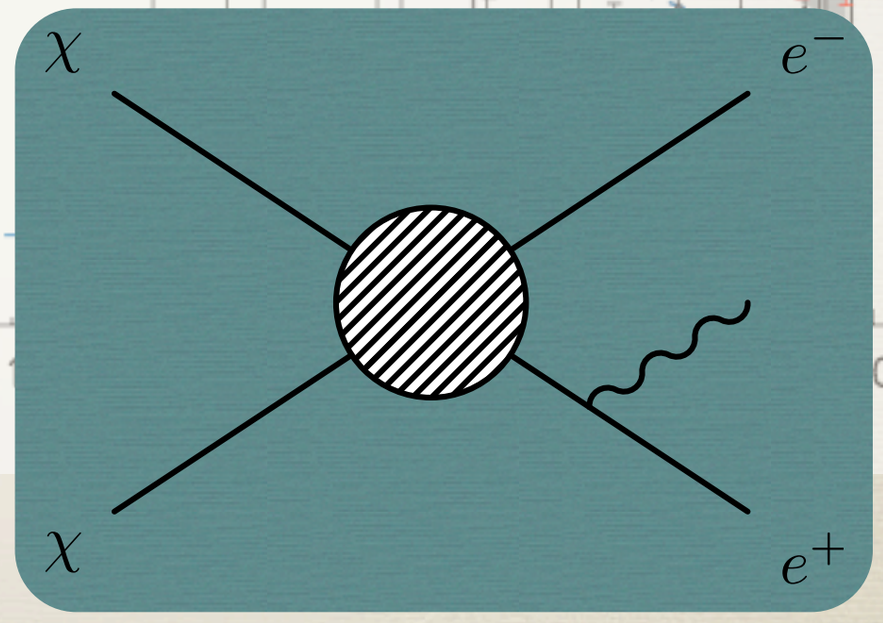


from N. Bell & T. Jacques; Phys.Rev.D79:043507 (2008)

Positron Excess

- Nearby Pulsars?
- Dark Matter Annihilation?
  - No antiproton excess
  - Large annihilation cross section
- **Internal Bremsstrahlung**
  - No dependence on Magnetic field, ISRF, Diffusion
  - Hard gamma rays near the endpoint, and background decreases with energy

- Want to constrain annihilation to e^+e^-
- Look for associated gamma-ray emission



from N. Bell & T. Jacques; Phys.Rev.D79:043507 (2008)

Internal Brem Spectrum

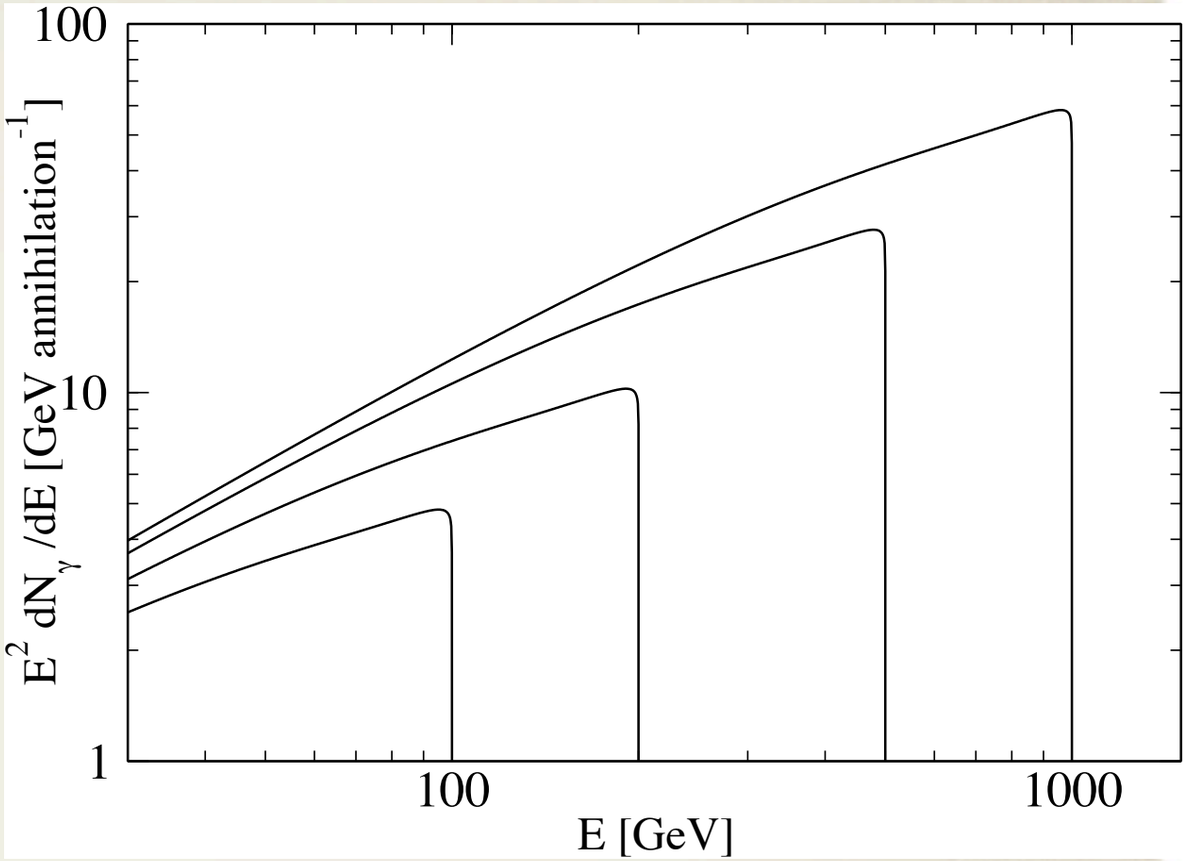
- Similar to analysis for gamma-gamma case
- Different spectrum

$$\frac{d\Phi_\gamma}{dE} = \frac{\langle \sigma_A v \rangle}{2} \frac{\mathcal{J}_{\Delta\Omega}}{\mathrm{J}_0} \frac{1}{4\pi m_\chi^2} \frac{dN_\gamma}{dE}$$

$$\frac{dN_\gamma}{dE} = \frac{1}{\sigma_{\mathrm{tot}}} \frac{d\sigma_{\mathrm{IB}}}{dE_\gamma}$$

$s=4m_\chi^2$

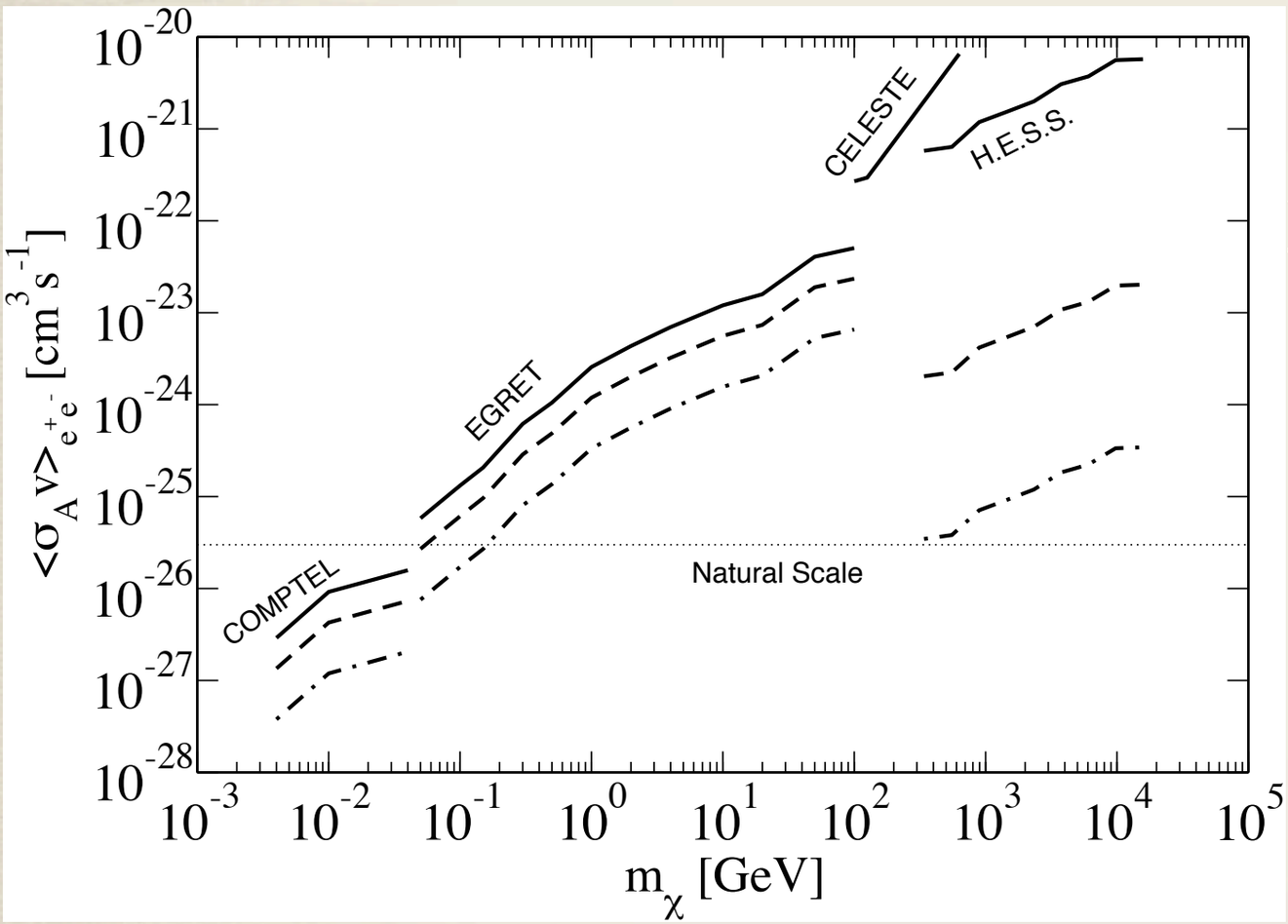
$s'=4m_\chi(m_\chi-E)$

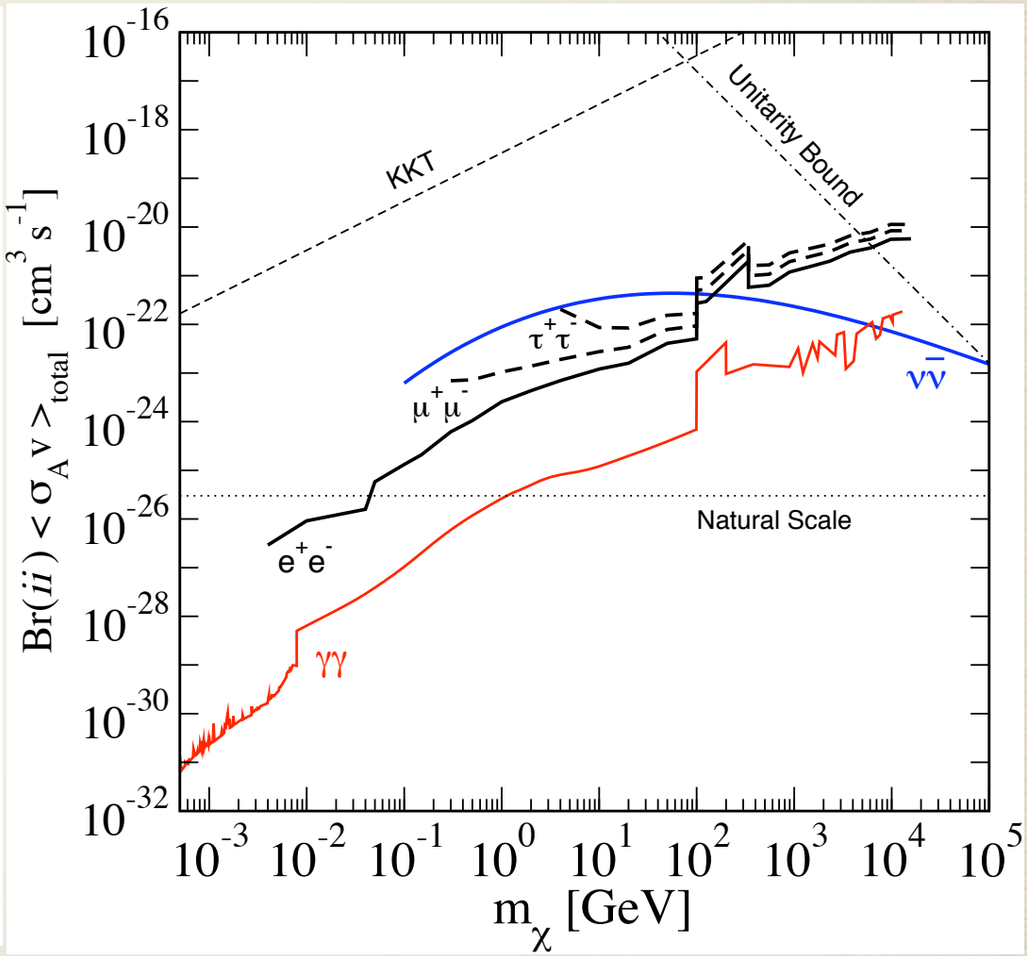


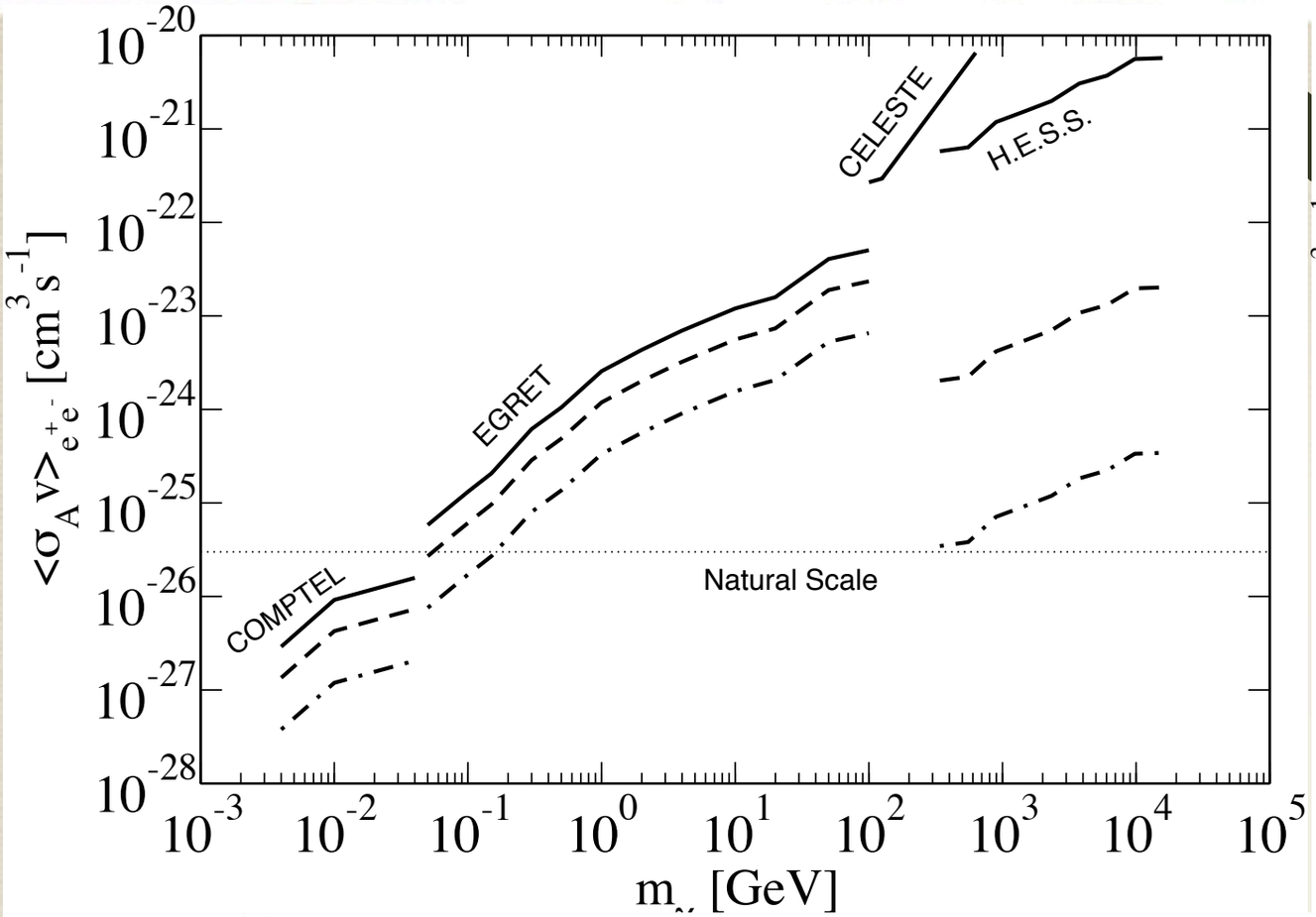
$$\frac{d\sigma_{\mathrm{IB}}}{dE} = \sigma_{\mathrm{tot}} \times \frac{\alpha}{E\pi}\left[\ln\left(\frac{s'}{m_e^2}\right) - 1\right]\left[1 + \left(\frac{s'}{s}\right)^2\right]$$

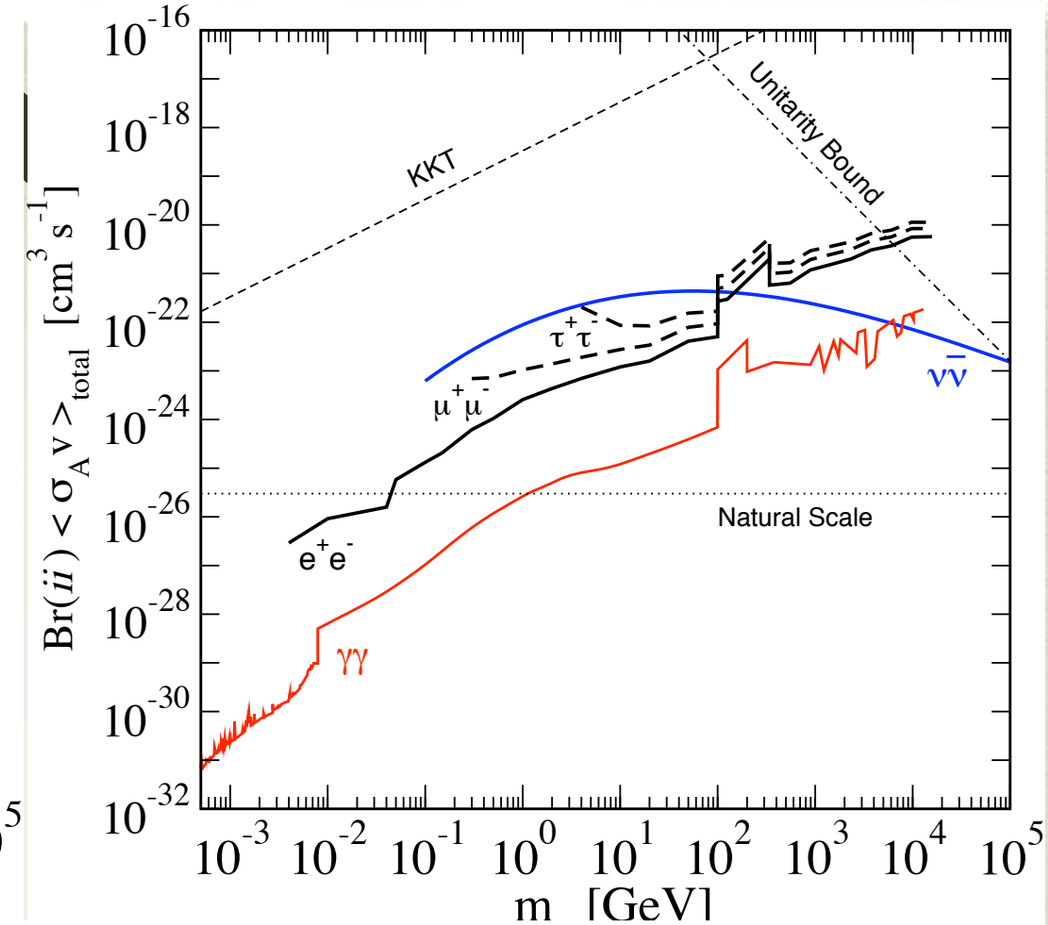
Beacom, Bell, Bertone, Phys.Rev.Lett.94:171301 (2005)

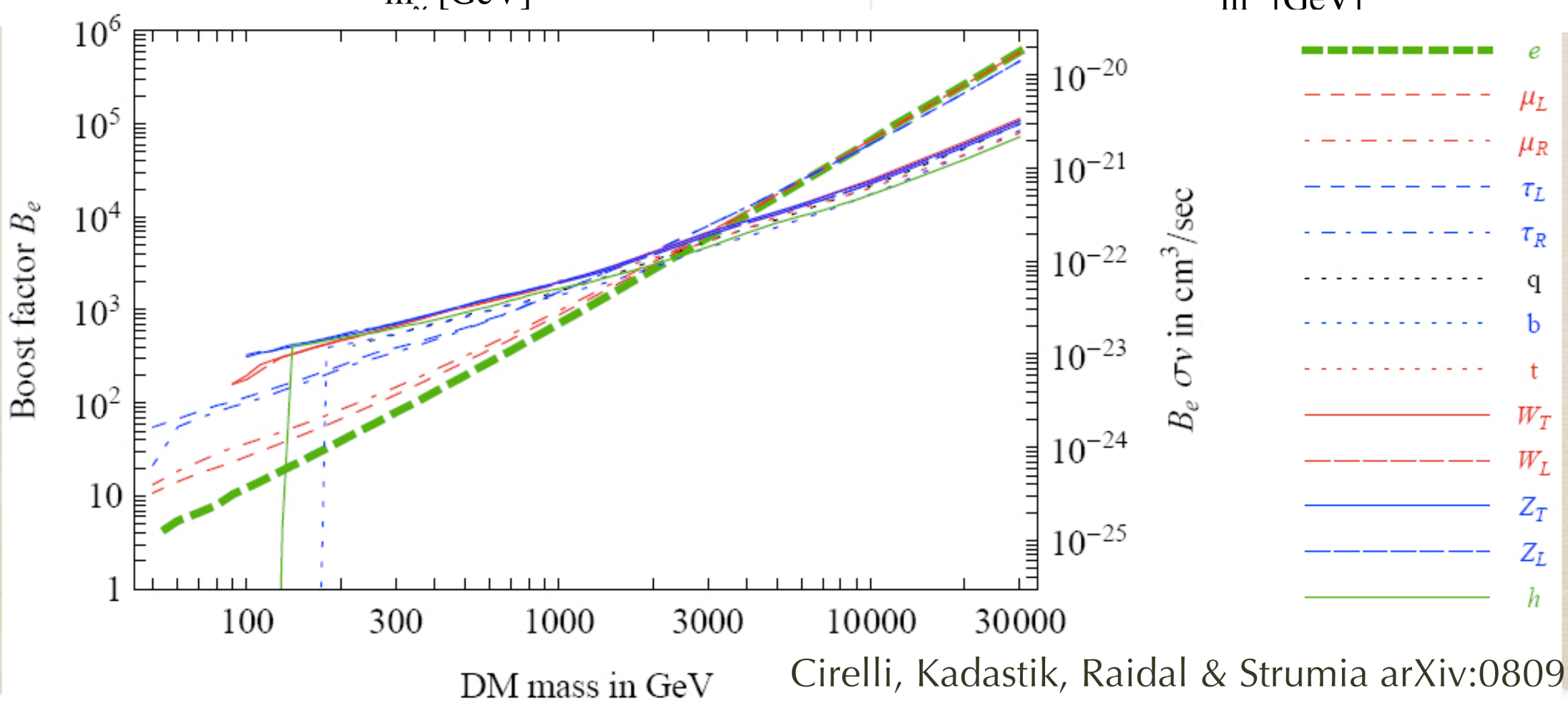
Constraints











Cirelli, Kadastik, Raidal & Strumia arXiv:0809.2409