Updated CMB constraints on DM annihilation cross-sections

Fabio Iocco

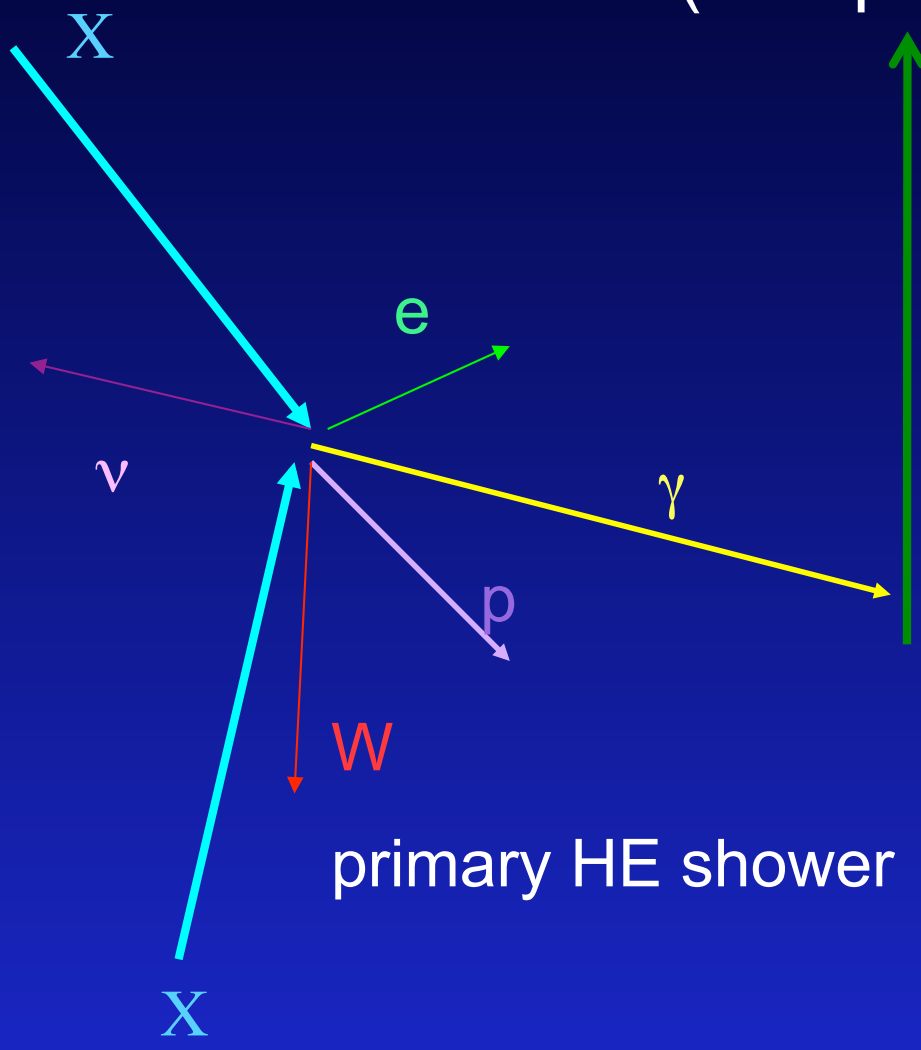
Marie Curie fellow at

Institut d'Astrophysique de Paris

In collaboration with: G. Bertone, S. Galli, A. Melchiorri

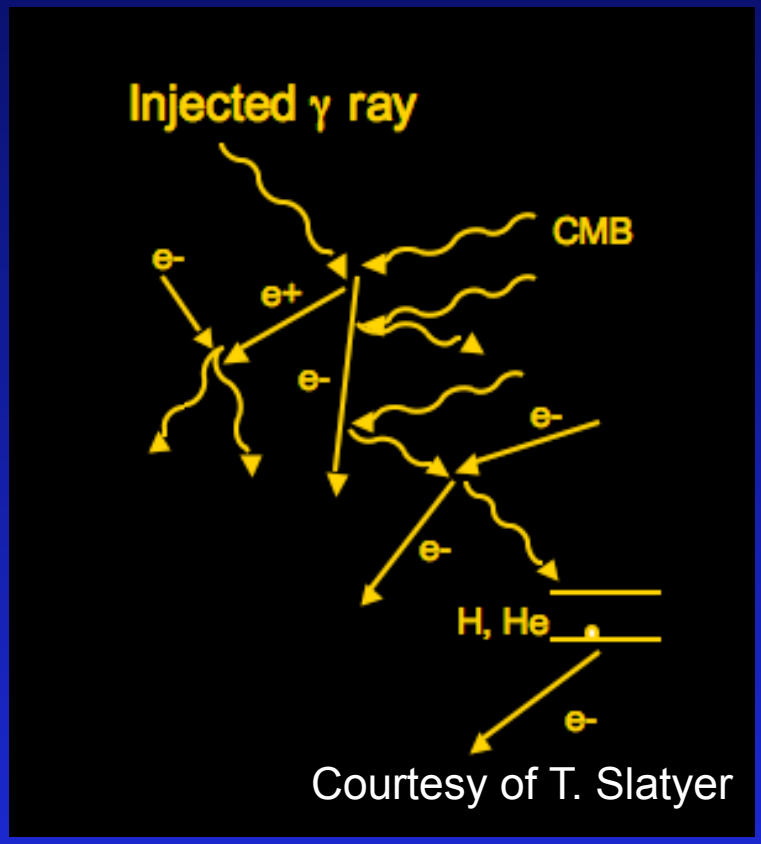
TeVPA 2011
Stockholm, 5/08/11

DM annihilation and the IGM
(and plenty of time)



primary HE shower

GeV -TeV scale



keV scale

heating and *ionization*

Isotropically averaged cosmological DM annihilation

Smooth component

$$A^{\rm sm}(z) = \frac{\langle \sigma v \rangle}{2\, m_\chi^2} \rho^2_{\rm DM,0} (1+z)^6$$

Structure component

$$A^{\rm struct}(z) = \frac{\langle \sigma v \rangle}{2\, m_\chi^2} \int \int dM \frac{dn}{dM}(z, M) (1+z)^3 4\pi r^2 \, \rho_i^2(r, M(z)) dr$$

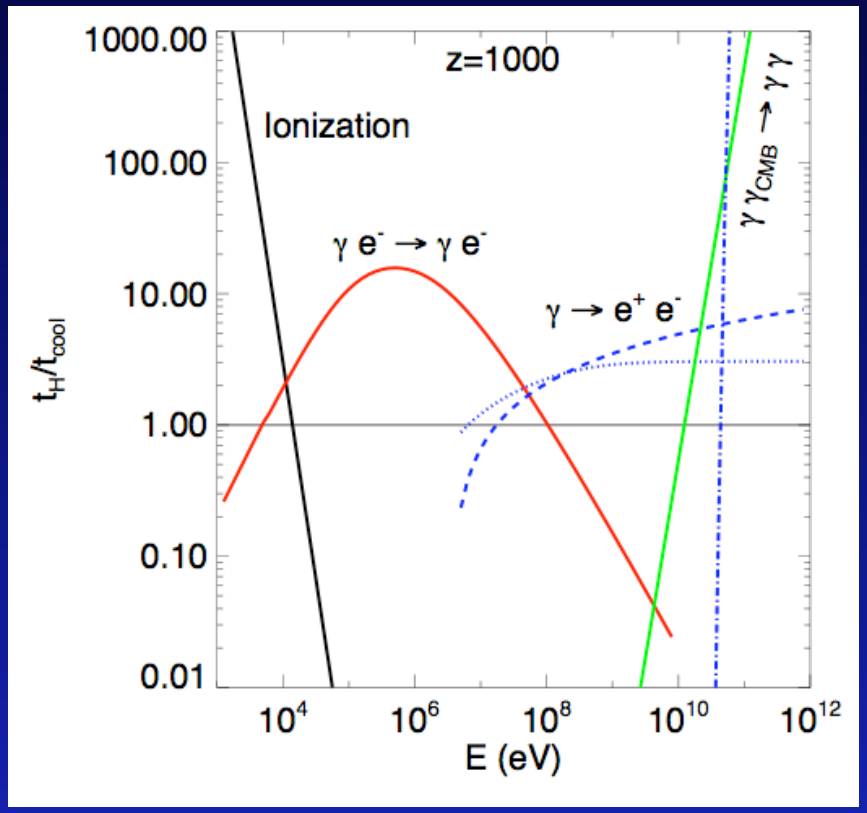
Structure formation history
(Press-Schechter / Sheth-Tormen)

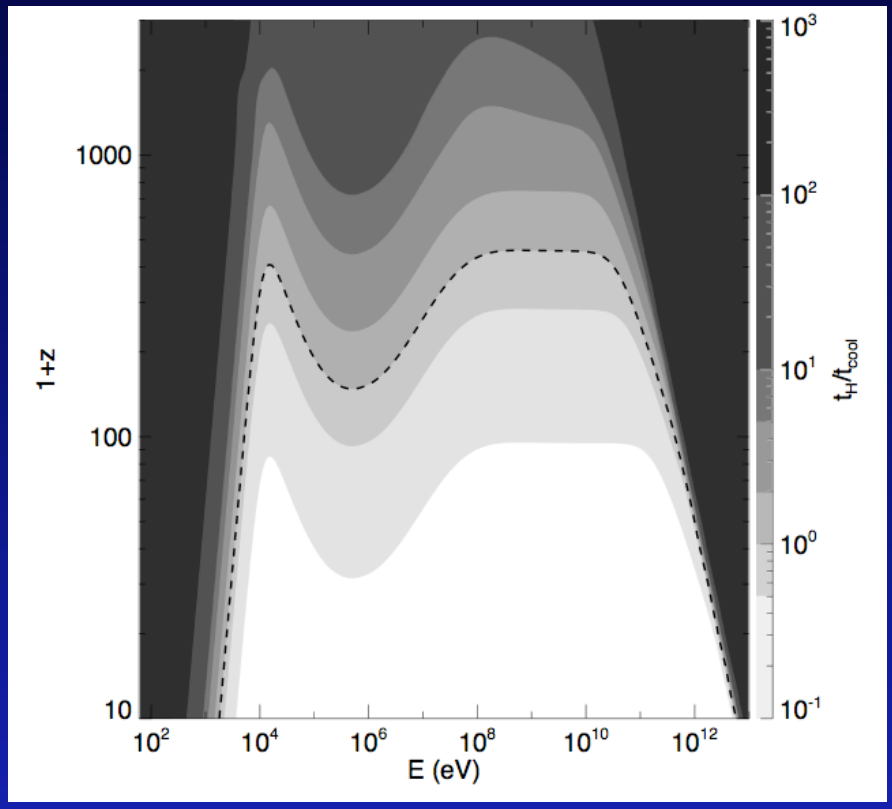
DM density halo profile
Burkert / Einasto / NFW

$$A(z) = \frac{\langle \sigma v \rangle}{2\, m_\chi^2} \rho^2_{\rm DM,0} (1+z)^6 \, (1 + \mathcal{B}_{\rm M}(z))$$

Only after structure formation $z \leq \approx 100$

…and its absorption by the surrounding gas
(coupling DM induced shower to IGM)





Photoionization, IC scattering,
pair production (on CMB γ and matter),
γγ scattering

"Opacity window"
of the Universe

[Slatyer et al. '09]

Electron optical depth τ

$$\tau = -\int n_e(z)\,\sigma_T\,\frac{dt}{dz}$$

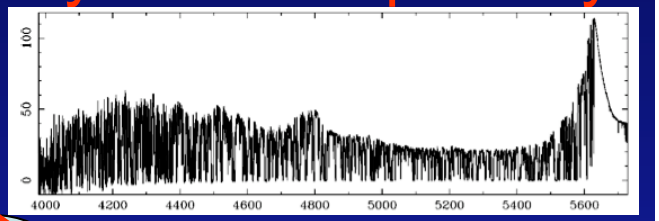
τ = 0.084 WMAP7 value

δ τ = 0.046

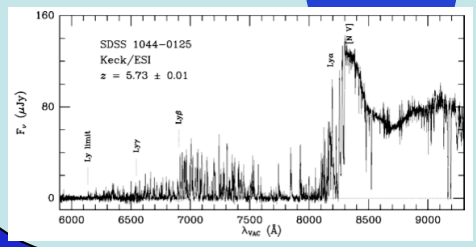
τ_o = 0.038

Neutral:
Ly-α absorber

Ionized:
Ly-α free to pass by



= neutral gas



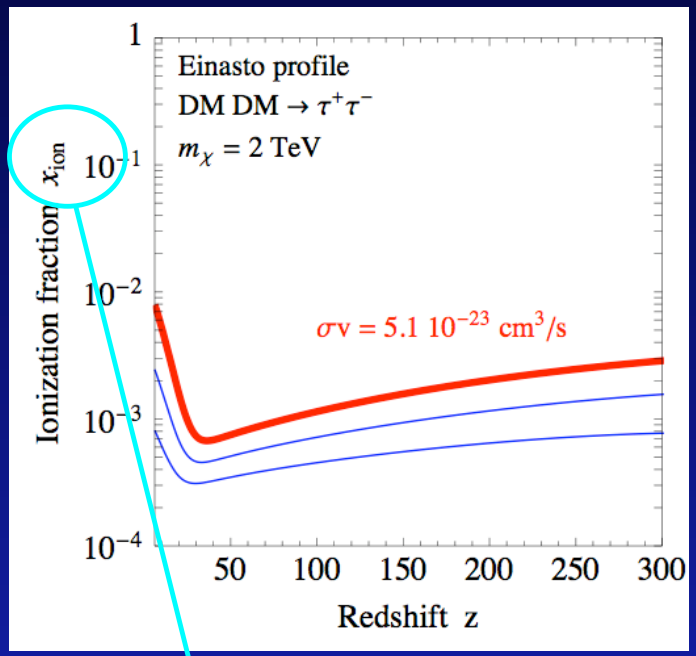
Completely ionized IGM

z ~ 6

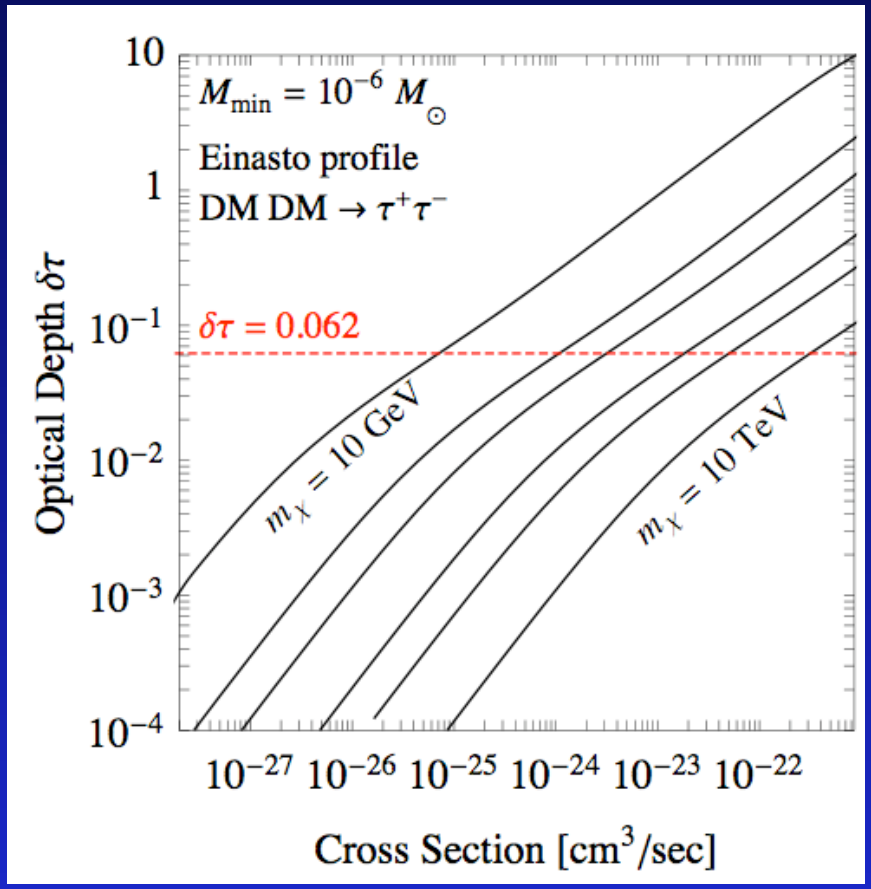
z

τ constraints

(DM annihilations can overproduce free e^-)



To be integrated!



In this models:

no astrophysical sources (z > 6)

Extra-conservative bounds!

[Cirelli, FI, Panci '09]

Isotropically averaged cosmological DM annihilation

Smooth component

$$A^{\rm sm}(z) = \frac{\langle \sigma v \rangle}{2\, m_\chi^2} \rho^2_{\rm DM,0} (1+z)^6$$

Structure component

$$A^{\rm struct}(z) = \frac{\langle \sigma v \rangle}{2\, m_\chi^2} \int \int dM \frac{dn}{dM}(z, M) (1+z)^3 4\pi r^2 \, \rho_i^2(r, M(z)) dr$$

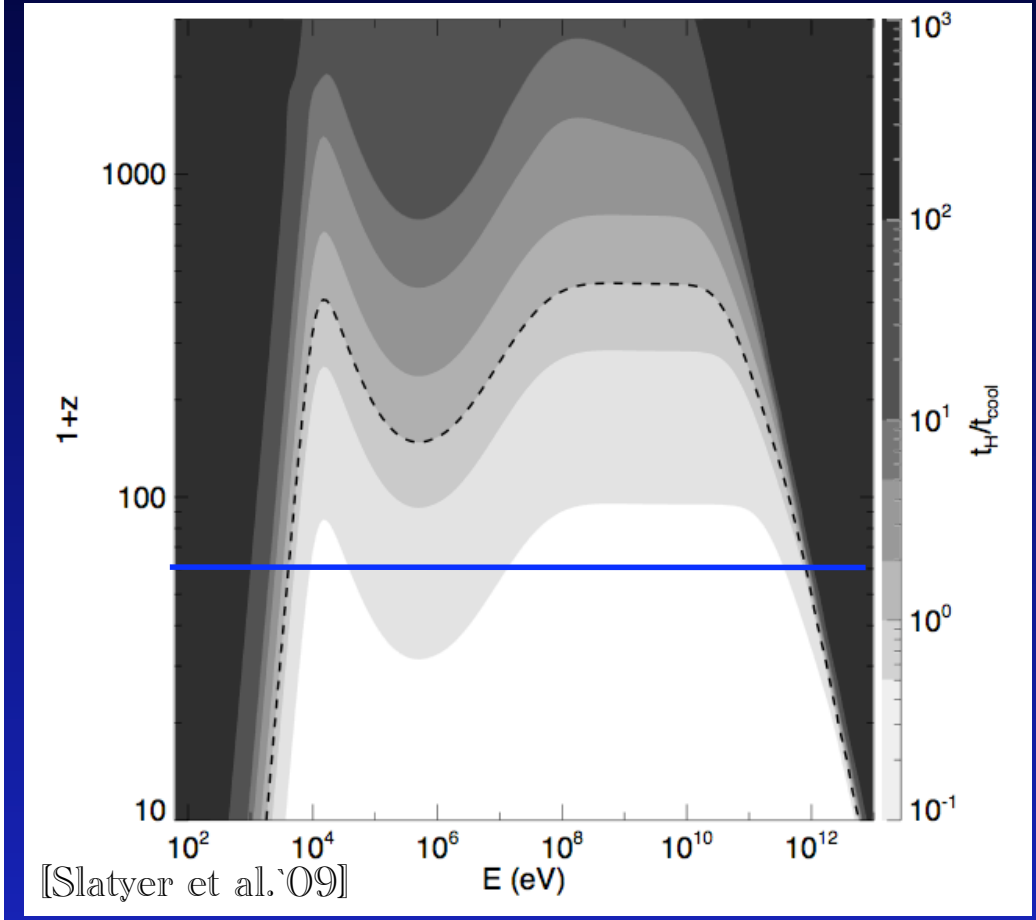
Structure formation history
(Press-Schechter / Sheth-Tormen)

DM density halo profile
Burkert / Einasto / NFW

$$A(z) = \frac{\langle \sigma v \rangle}{2\, m_\chi^2} \rho^2_{\rm DM,0} (1+z)^6 \, (1 + \mathcal{B}_{\rm M}(z))$$

Only after structure formation $z \leq \approx 100$

Transparency of the Universe & structure formation

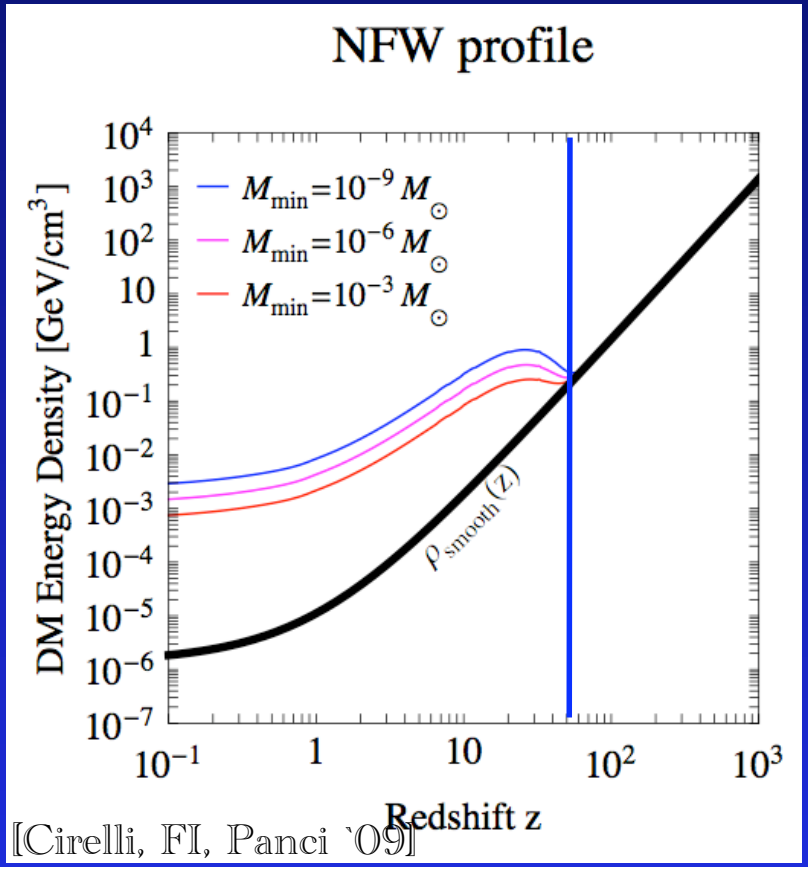


[Slatyer et al.`09]

HE shower gets efficiently absorbed

at high z

Structure formation takes place in a late Universe (z < 60)



[Cirelli, FI, Panci `09]

Self-annihilating DM and the IGM

The smooth DM component annihilates with a rate (per volume)
(easily re-writable for decaying DM)

$$\frac{dI}{dt}(z) = n_{DM}^2(z)\langle\sigma v\rangle m_\chi c^2$$

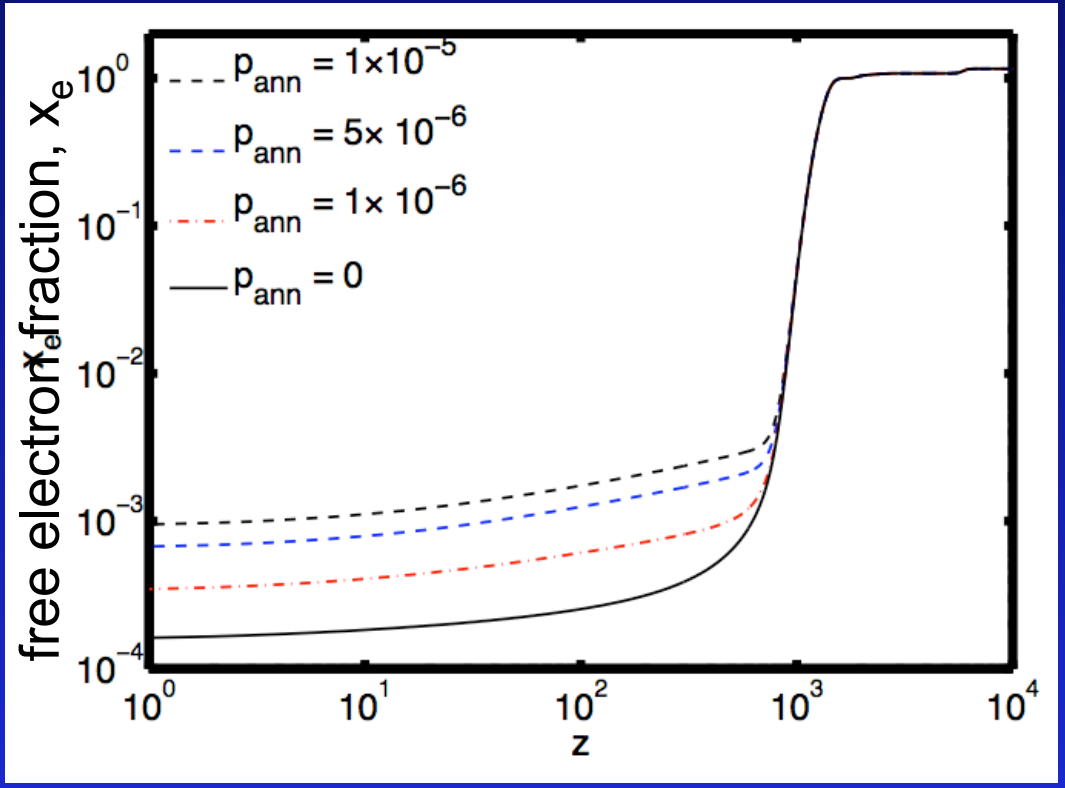
depositing energy in the gas (IGM) at a rate

$$\frac{dE}{dt}(z) = \rho_c^2 c^2 \Omega_{DM}^2 (1+z)^6 f \frac{\langle\sigma v\rangle}{m_\chi}$$

The only DM-related parameter is

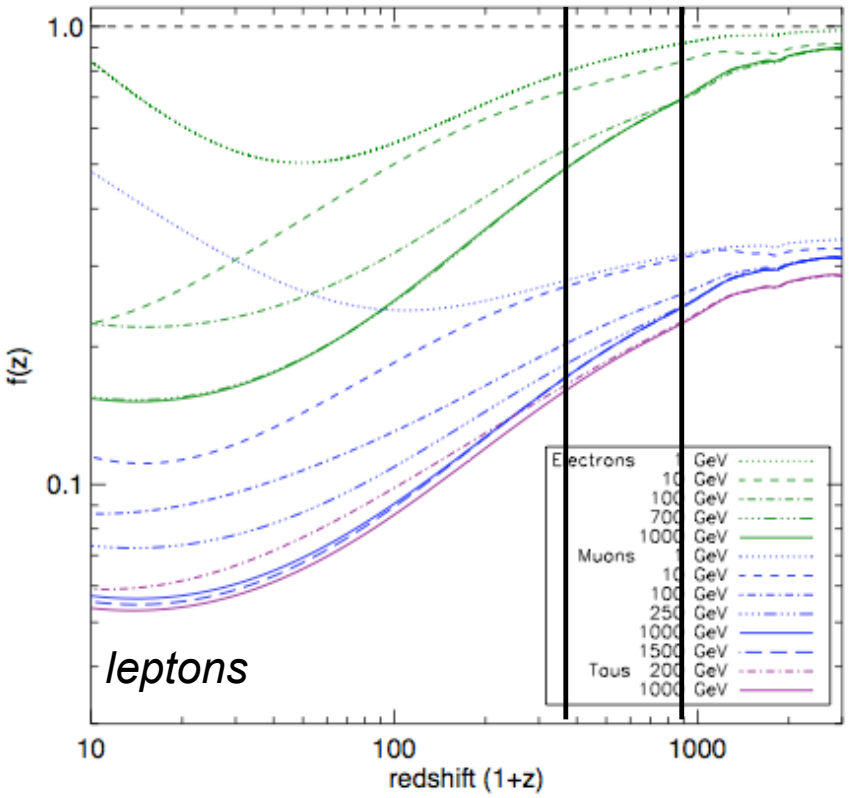
$$p_{\rm ann} \equiv f(z)\frac{\langle\sigma v\rangle}{m_\chi}$$

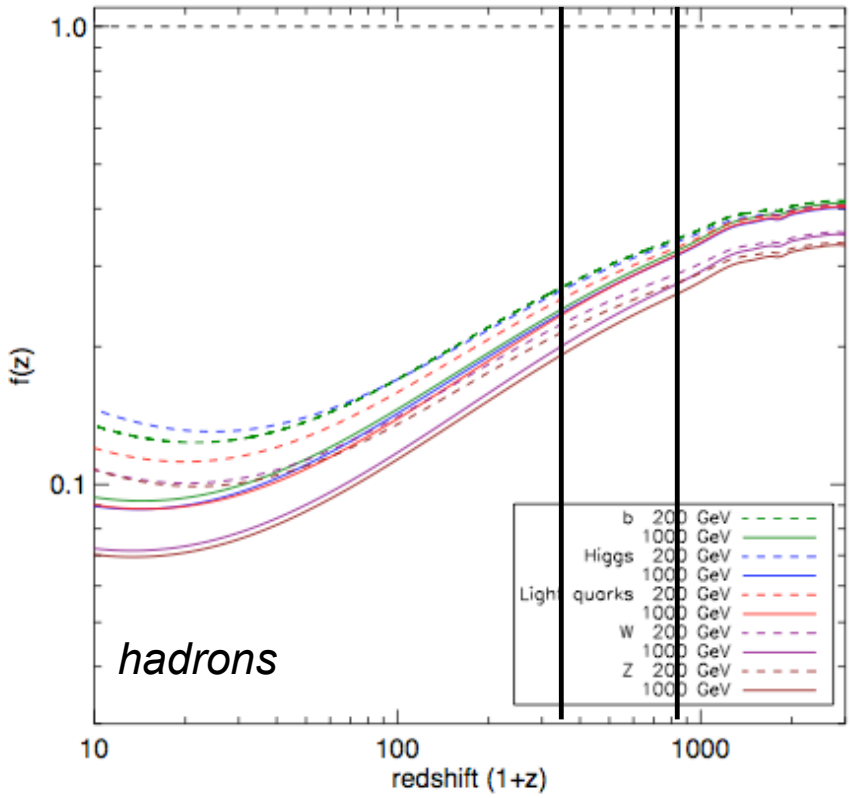
Main effect of injected energy: ionization of the IGM



[Galli, FI, Bertone, Melchiorri '09]

Evaluating “ $f(z)$ ”





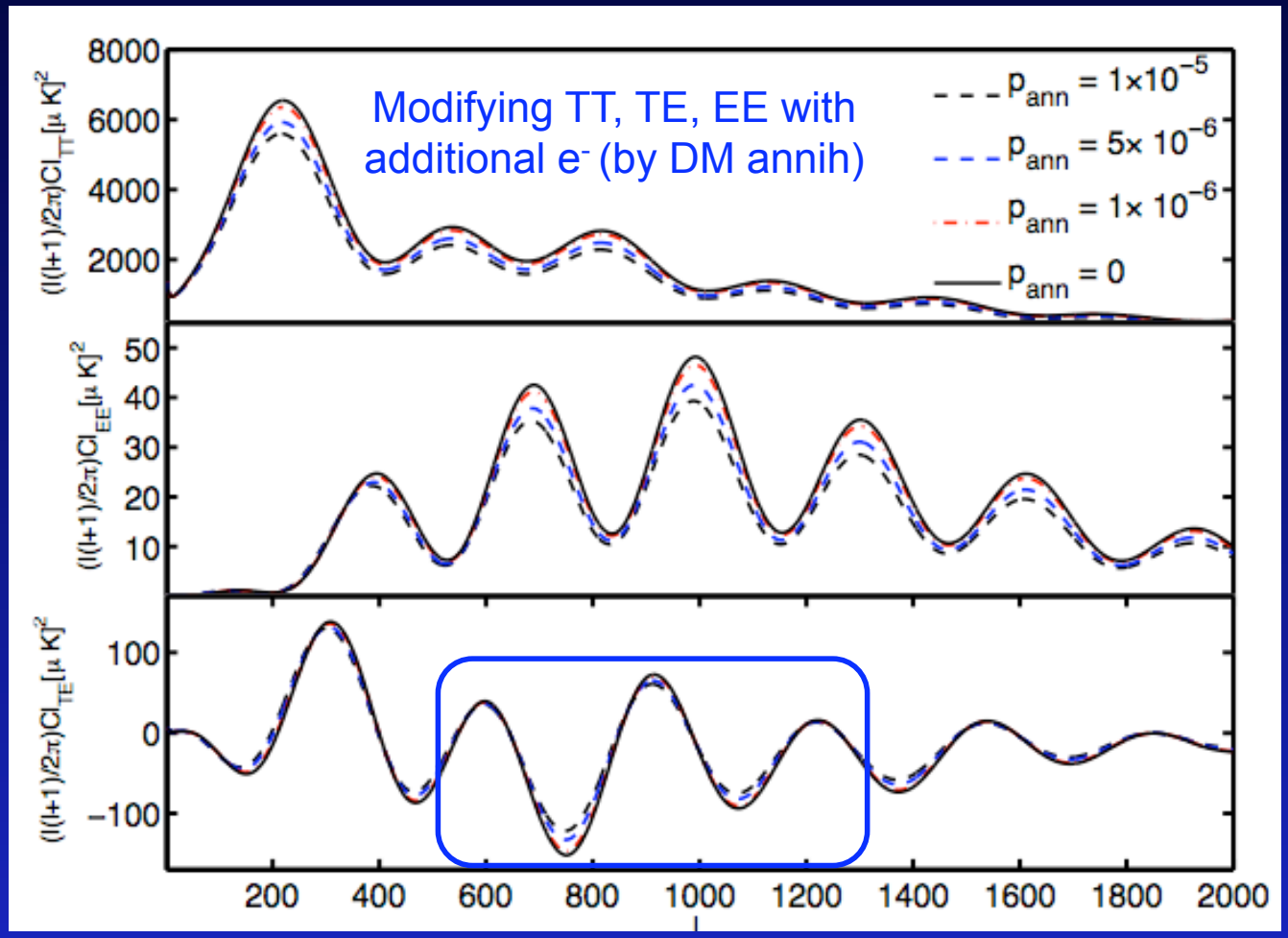
Previous analysis based on constant “ f “ ; not-so-bad! see *[Finkbeiner + ’11]* for PCA motivation of *f=f(600)*

All channels, all secondaries, redshift dependence

Branching ratio of DM annihilation crucial for determining absorption

[Slatyer et al. 09]

Self-annihilating DM and the CMB



@ z >1000 , many e^-
no effects
energy injection is small

Degeneracy of p_{ann} with cosmological parameters $(\omega_b, n_s, \omega_{dm})$

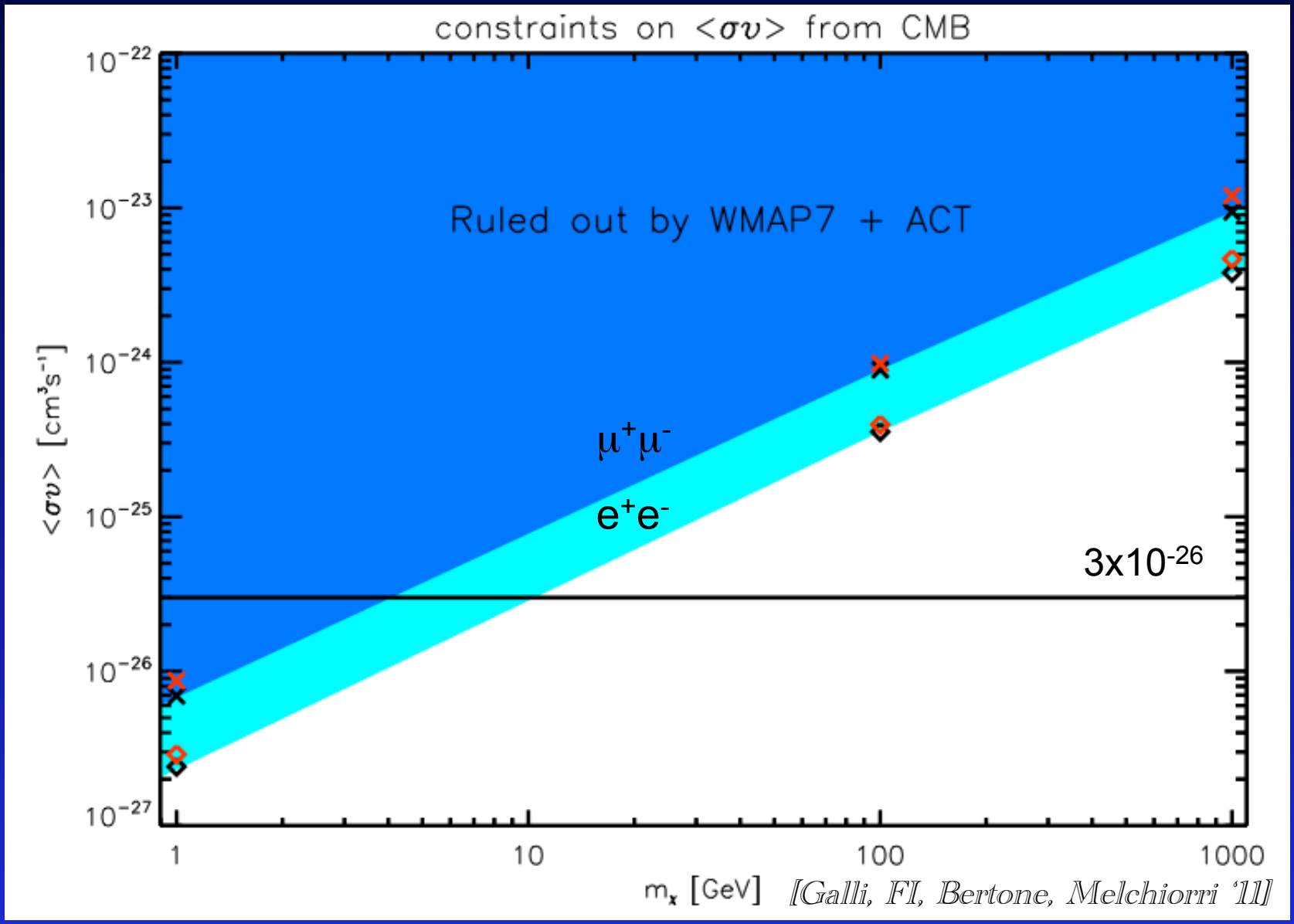
[Padmanabhan & Finkbeiner 05]

RUN OF COMPLETE Cosmomc analysis

[Galli, FI et al. '09]

Constraints from WMAP7+ACT

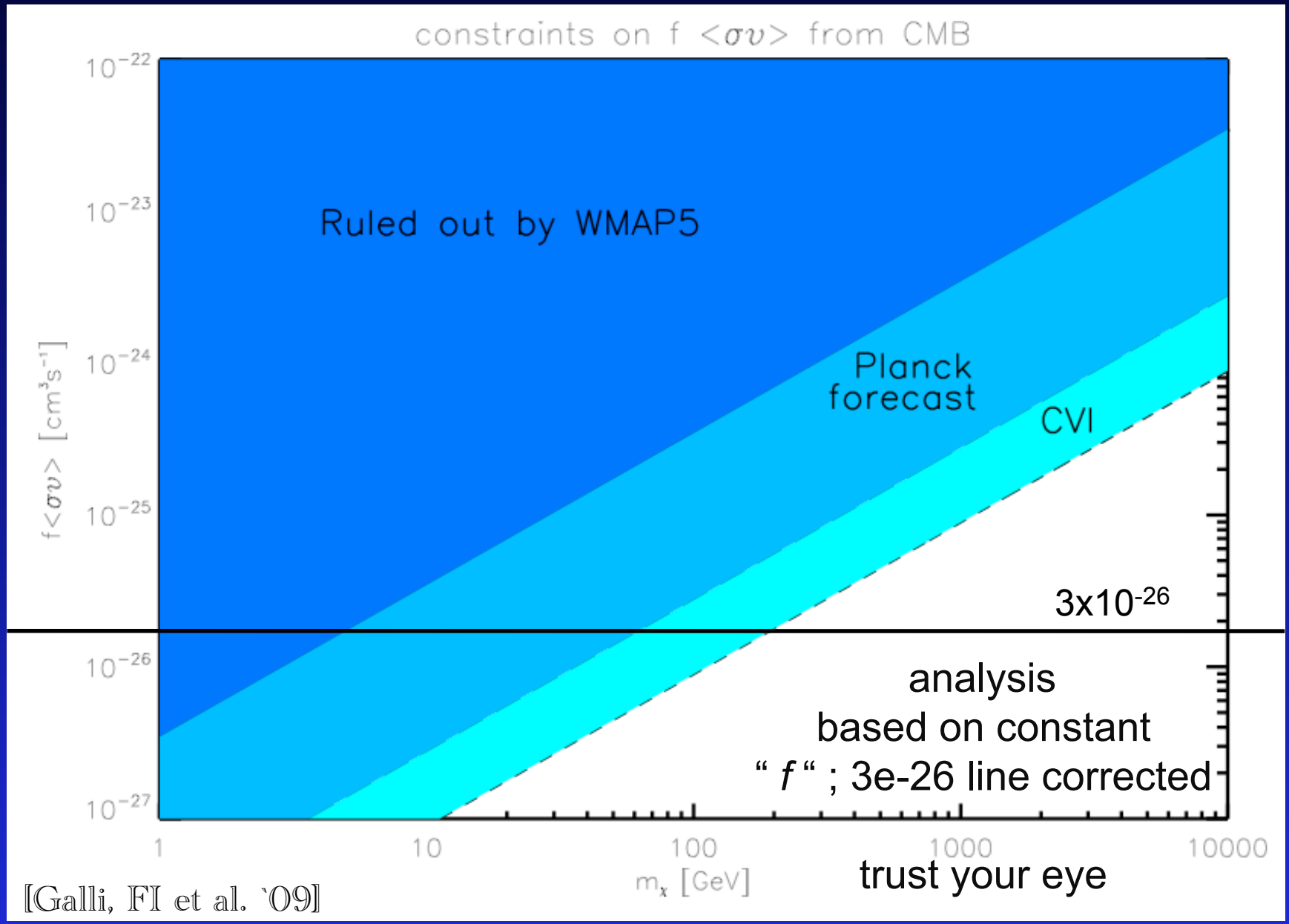
(l_{max}=3500)



[Galli, FI, Bertone, Melchiorri '11]

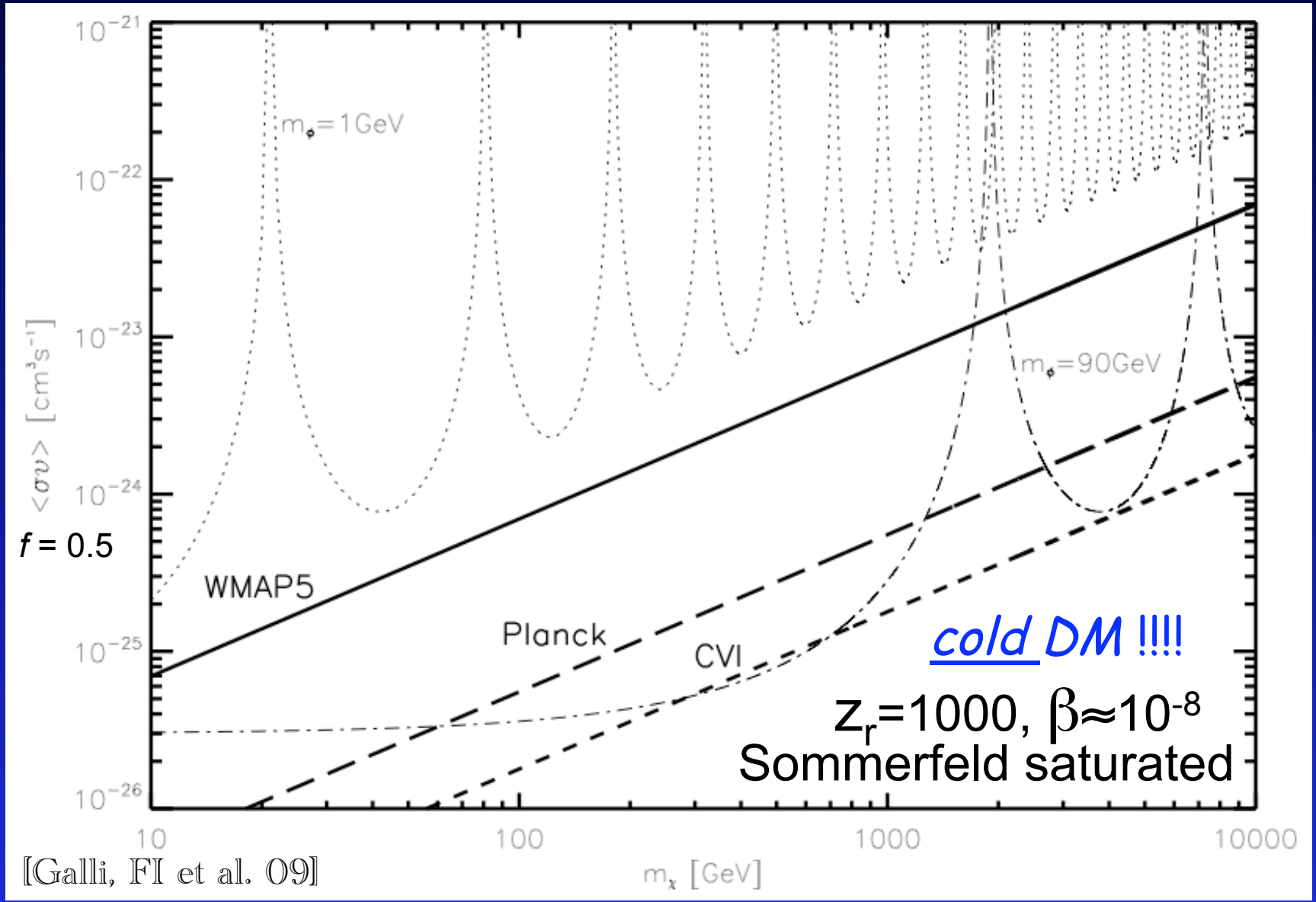
Similar analysis by [Hutsi et al '11], *no ACT data, different f(z)*

Forecasts for Planck



[Galli, FI et al. '09]

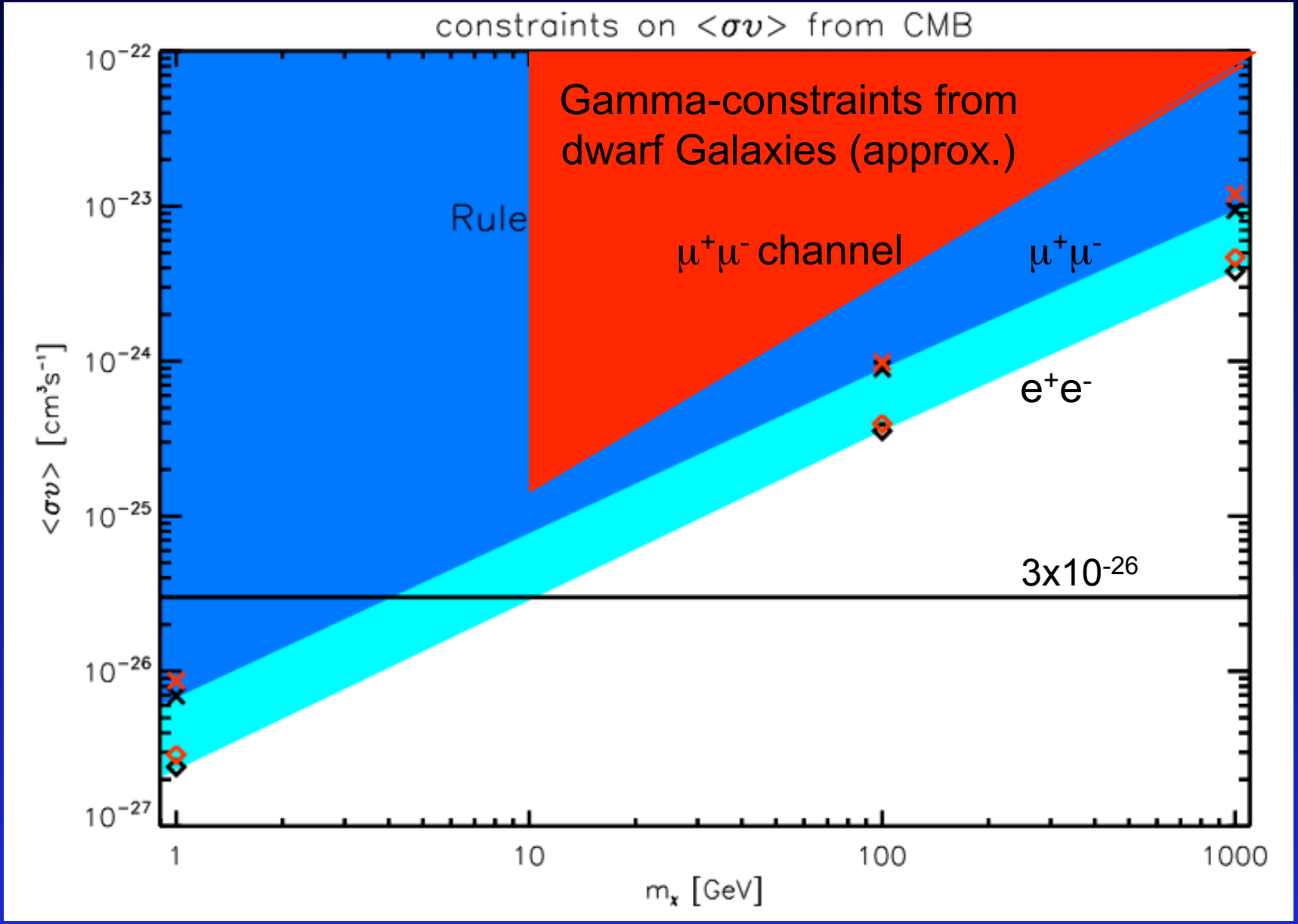
Constraining Sommerfeld Enh. with CMB



[Galli, FI et al. 09]

See also [Slatyer et al '11] for a discussion of this

Comparing constraints



Dwarf-Galaxies constraints on other channels vary, see talk by Maja Llena-Garde

Concluding

- CMB is a powerful tool to constrain DM annihilation properties

- Independent from "usual suspect" unknowns: halo profile, central slope, minimal mass, structure formation history. Cosmology only!

- Exquisite tool to test Sommerfeld enhancement

- If Planck sees something, refrain from rejoying: think first