On the IGMF strength and filling factor

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in collaboration with K. Dolag, M. Kachelriess, and R. Tomas

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- new: limits on IGMF from non-observation of GeV γ-rays from TeV blazars (Neronov & Vovk 2010; Tavecchio et al. 2010)

Limits on IGMF from GeV-TeV observations of blazars

- limits on the strength of IGMF from GeV-silent TeV blazars (Neronov & Vovk 2010; Tavecchio et al. 2010)
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- $\Rightarrow$ allows to get limits on the IGMF strength: $B \gtrsim 10^{-15}$ G
- open questions:
  - potential source variability?
  - impact of IGMF spacial structure

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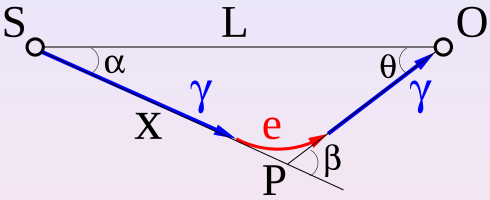
- highly efficient: $\sim 10^3$ cascades/s over cosmological distances

Angular deflections in magnetic fields

- simple for 2-step process: $\gamma \rightarrow e^{\pm} \rightarrow \gamma$



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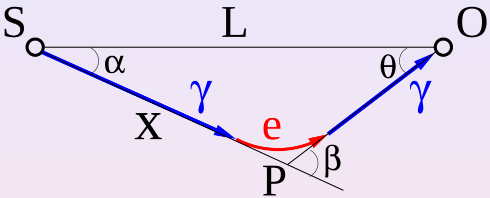

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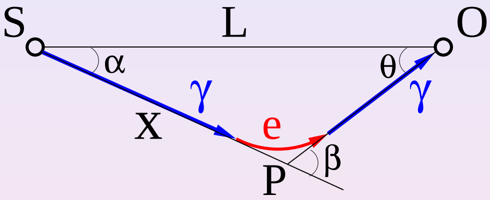

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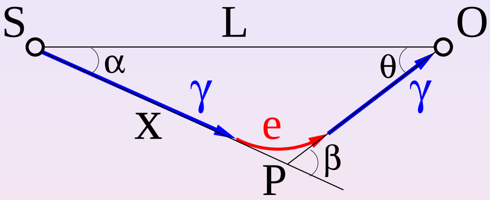

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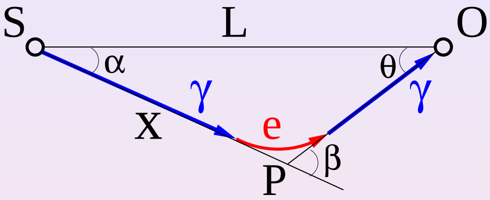

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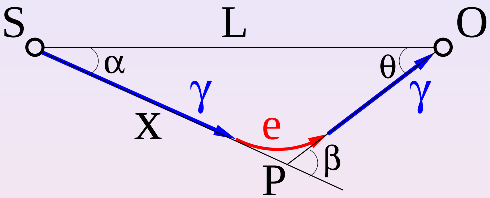

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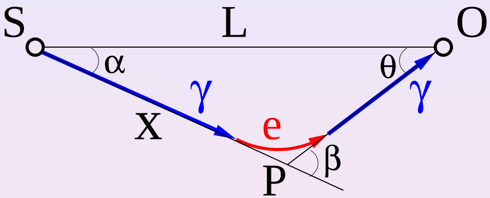

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  - additionally: fluctuations of Δx_e ($\langle \Delta x_e \rangle = l_{\rm cool}$)

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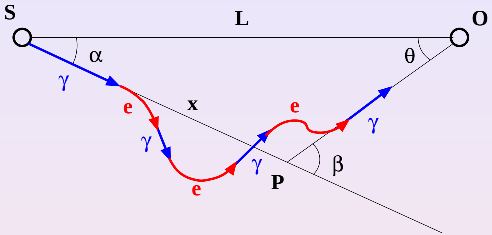

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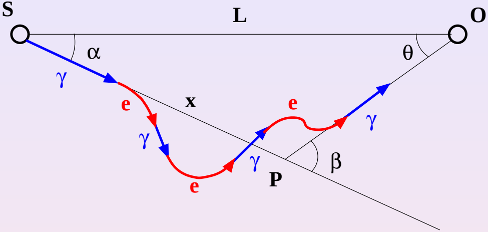

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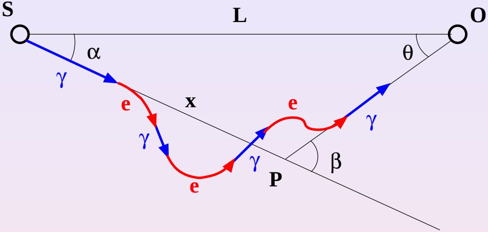

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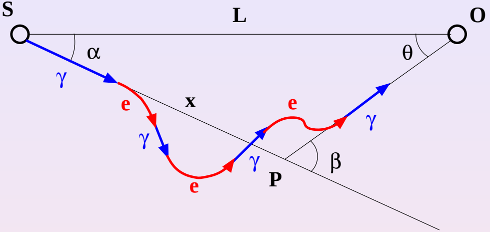

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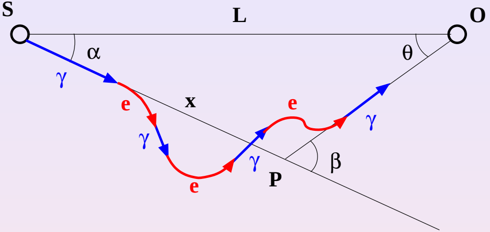

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- same assumptions on the source as in Tavecchio et al. 2010
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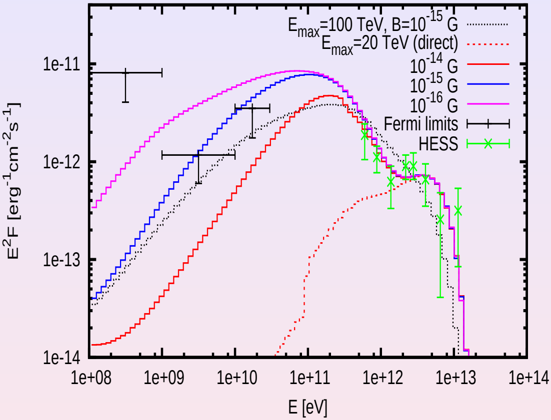

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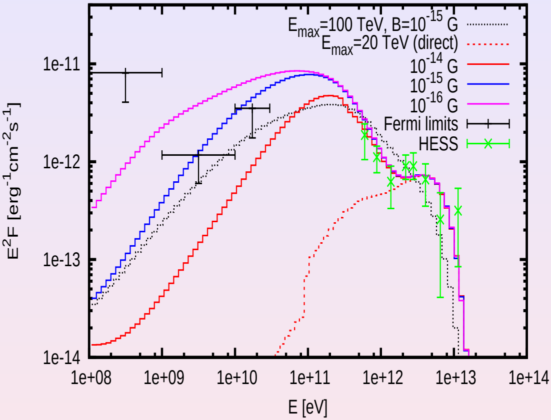

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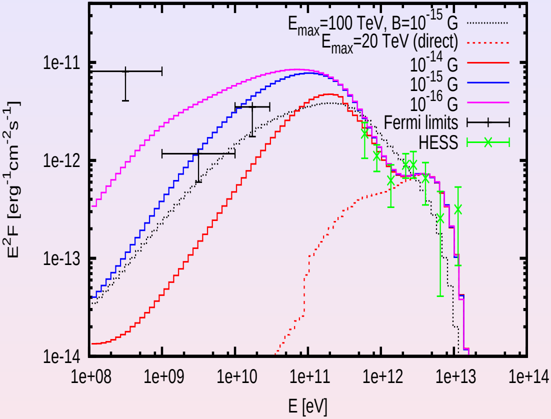

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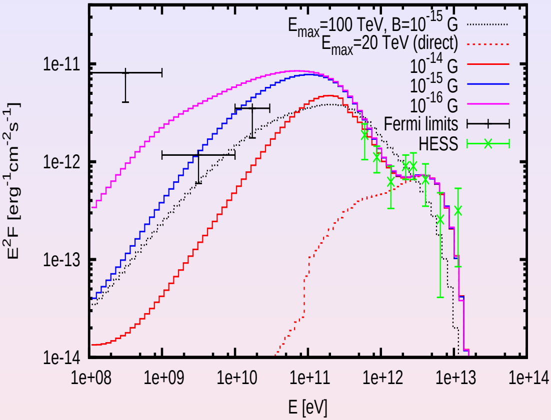

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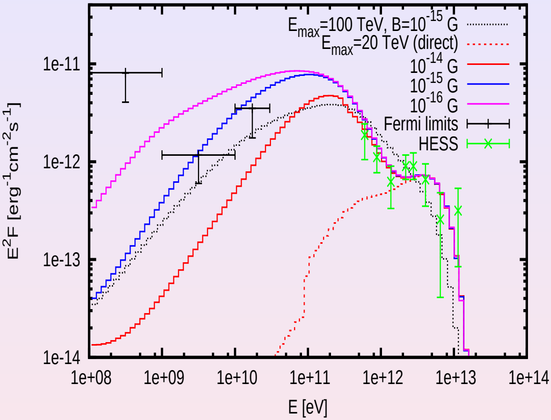

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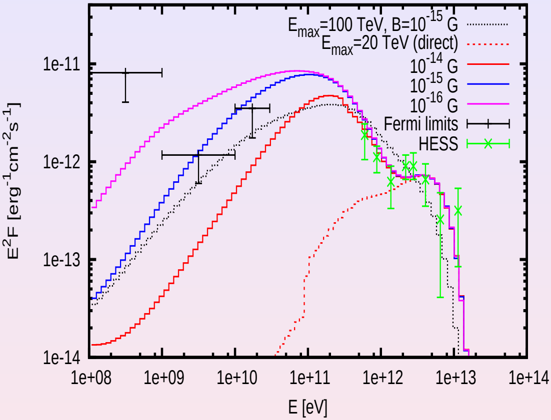

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- different spectral shape
  - e.g. spectral 'shoulder' in the TeV range for $E_{\rm max} = 20$ TeV

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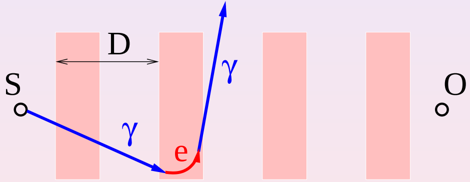

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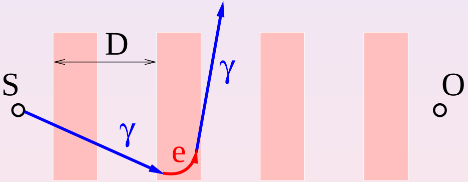

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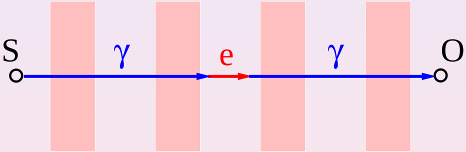

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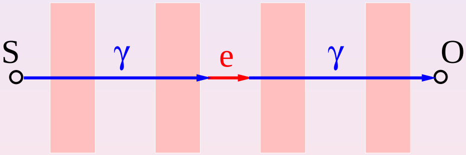

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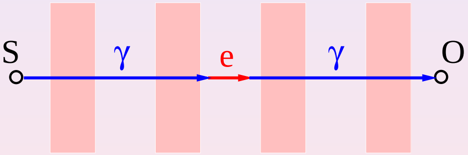

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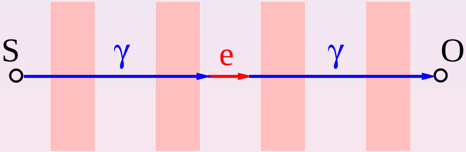

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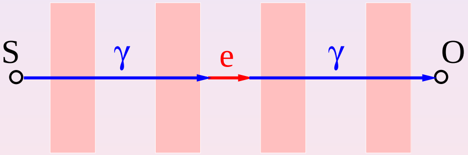

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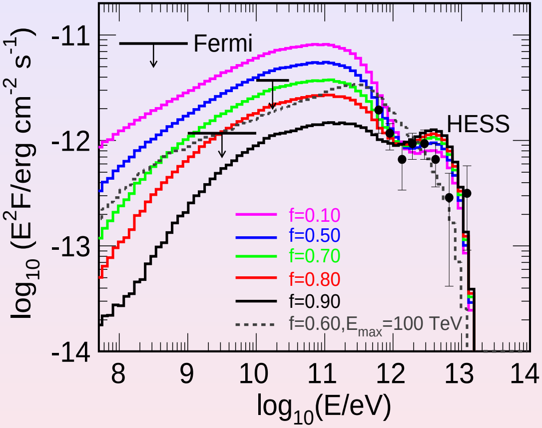
γ-rays from 1ES 0229+200: "filling factor" dependence



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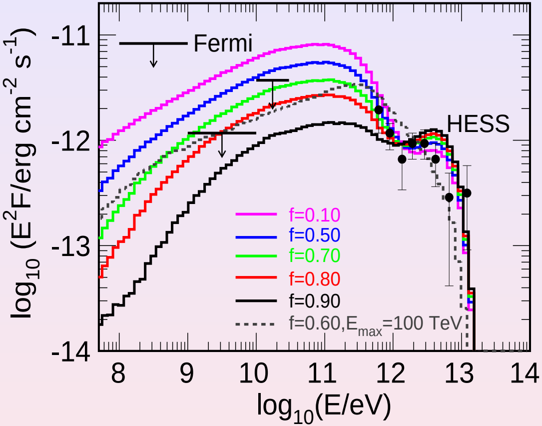

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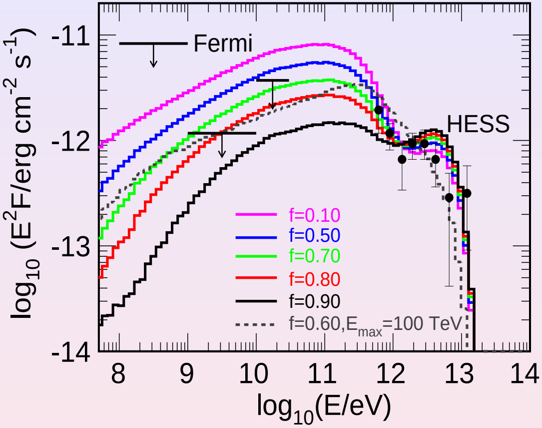

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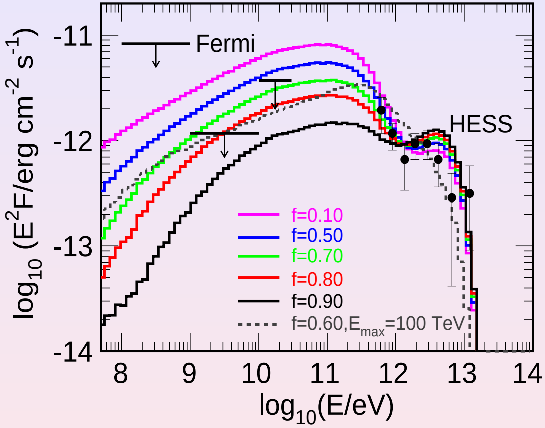

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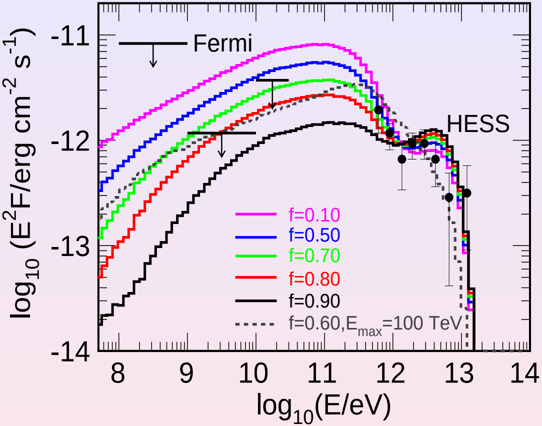

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- similar results when using realistic B-profiles from cosmological MHD simulations (Dolag et al., arXive:1009.1782)

Effect of time delays

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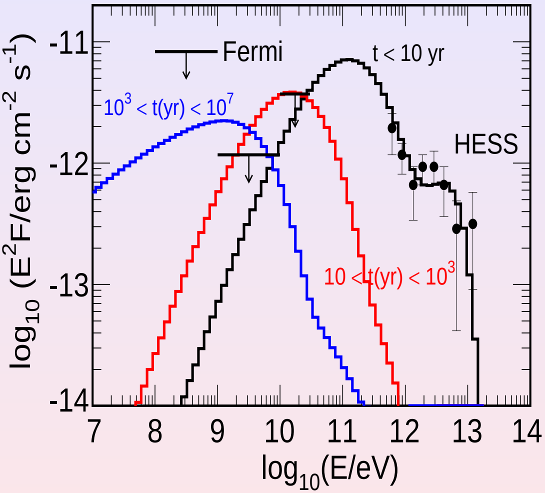

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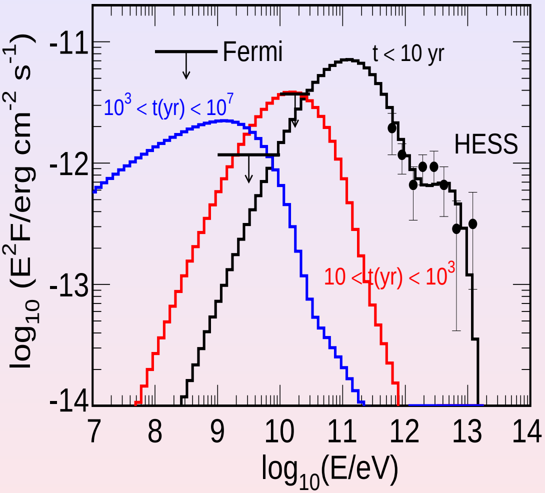

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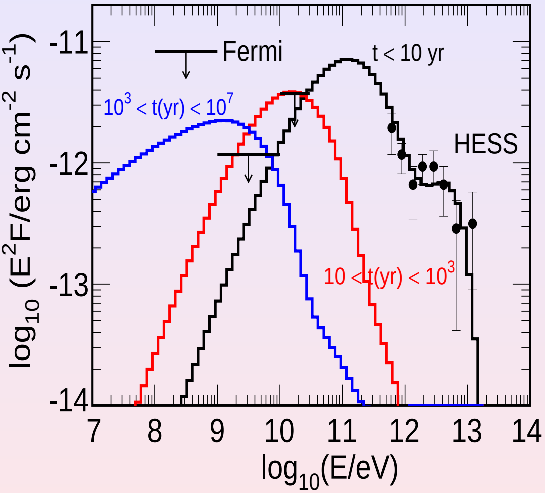

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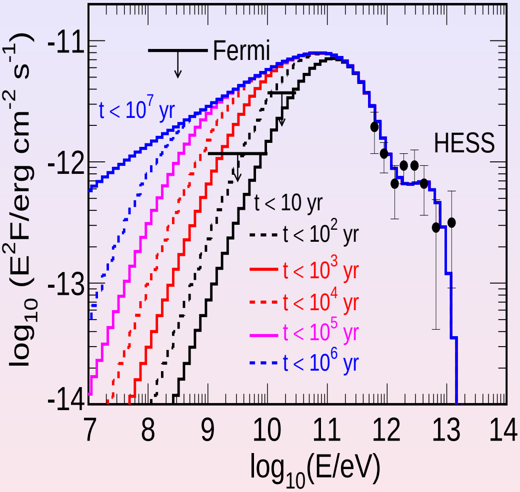

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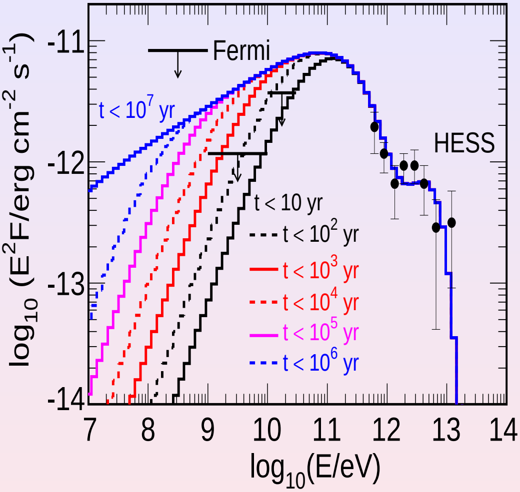

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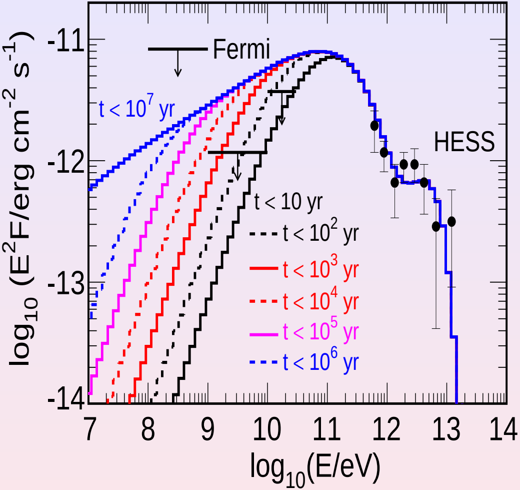

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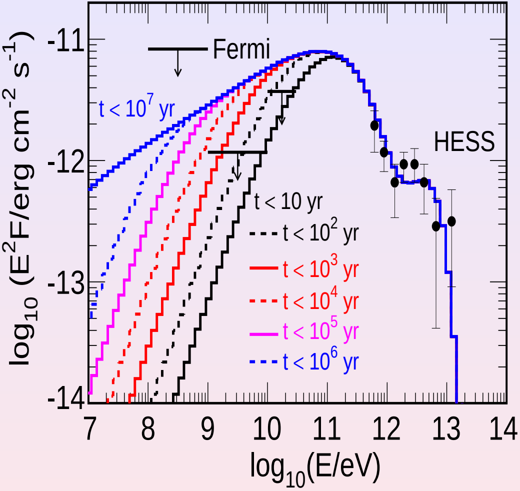

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- similar results obtained by Taylor et al. 2011

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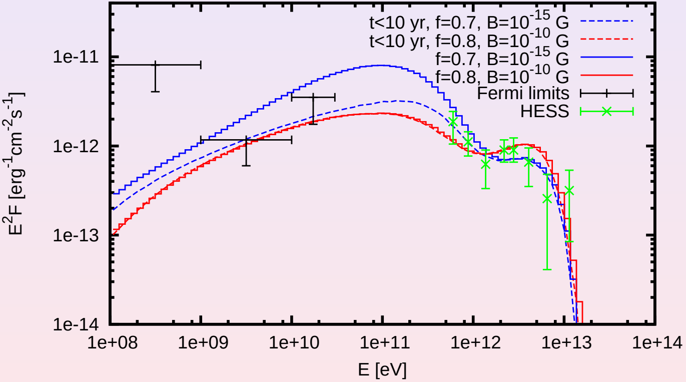

- variability of the source impacts the limits on the IGMF strength, not on the IGMF spacial distribution

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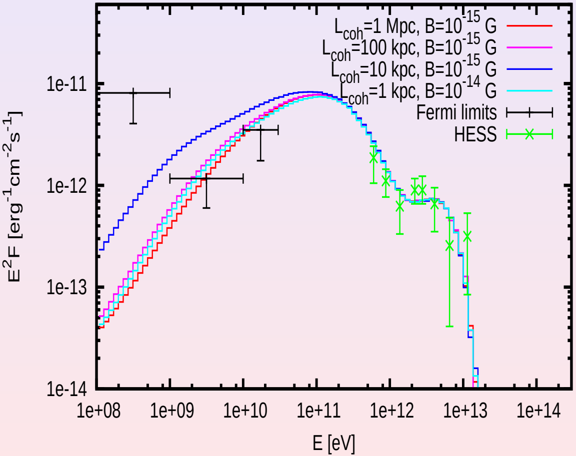

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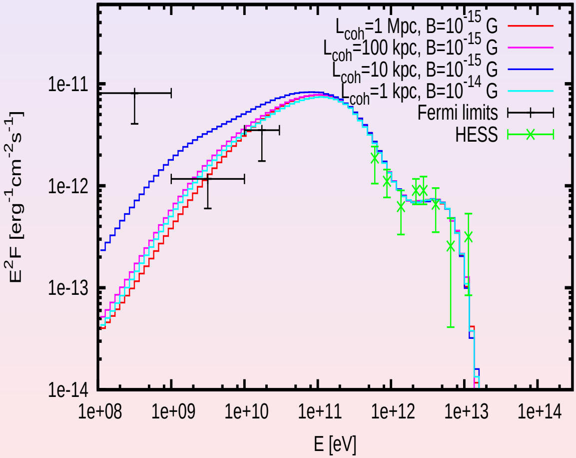

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- mean travel distance $\langle \Delta x_e \rangle$ of a parent $e^{\pm}$
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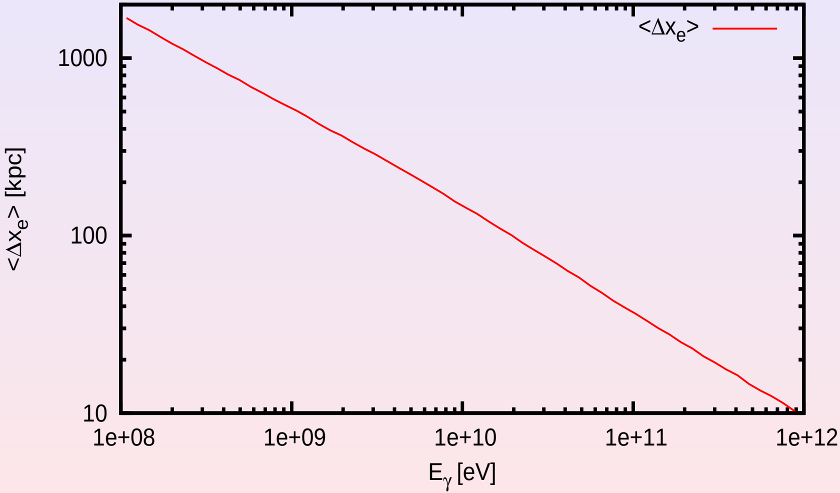

- however, the distribution of Δx_e
  has pronounced tails towards $\Delta x_e \sim 1$ kpc