$e^{+/-}$ transport and connection to Galactic γ-ray diffuse emission: Basic ingredients and phenomenology

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based on: T. Delahaye, JL, R. Lineros, F. Donato & N. Fornengo, in prep
$+$ P. Salati & R. Taillet

Diffuse γ-ray workshop
LAPTH-Annecy — Wednesday, May 27$^{\rm rd}$ 2009

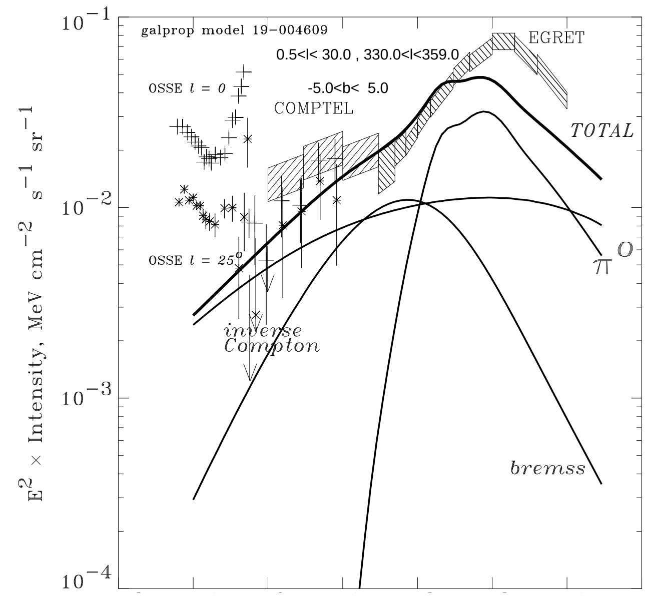
Reminder

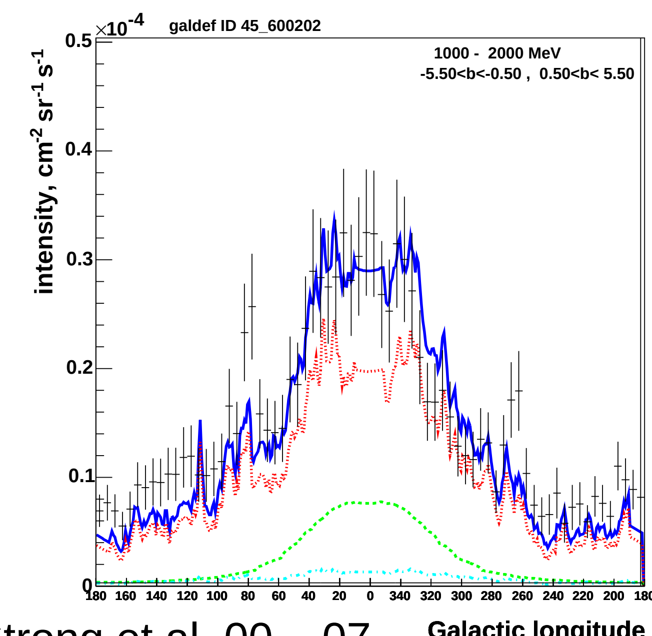
Inputs for diffuse emission from $e^{+/-}$

- **Sources**
- **Propagation** $\Rightarrow \frac{dn}{dE}(\vec{x})$
- **Material or radiation target at** $\vec{x}$
- **Line of sight integral from Earth**

$$\phi_\gamma(E) \propto \sum_i \int d\Omega dl \int dE_e \frac{d\phi}{dE_e} \frac{d\sigma_i(\rightarrow E)}{dE_e} n_i$$

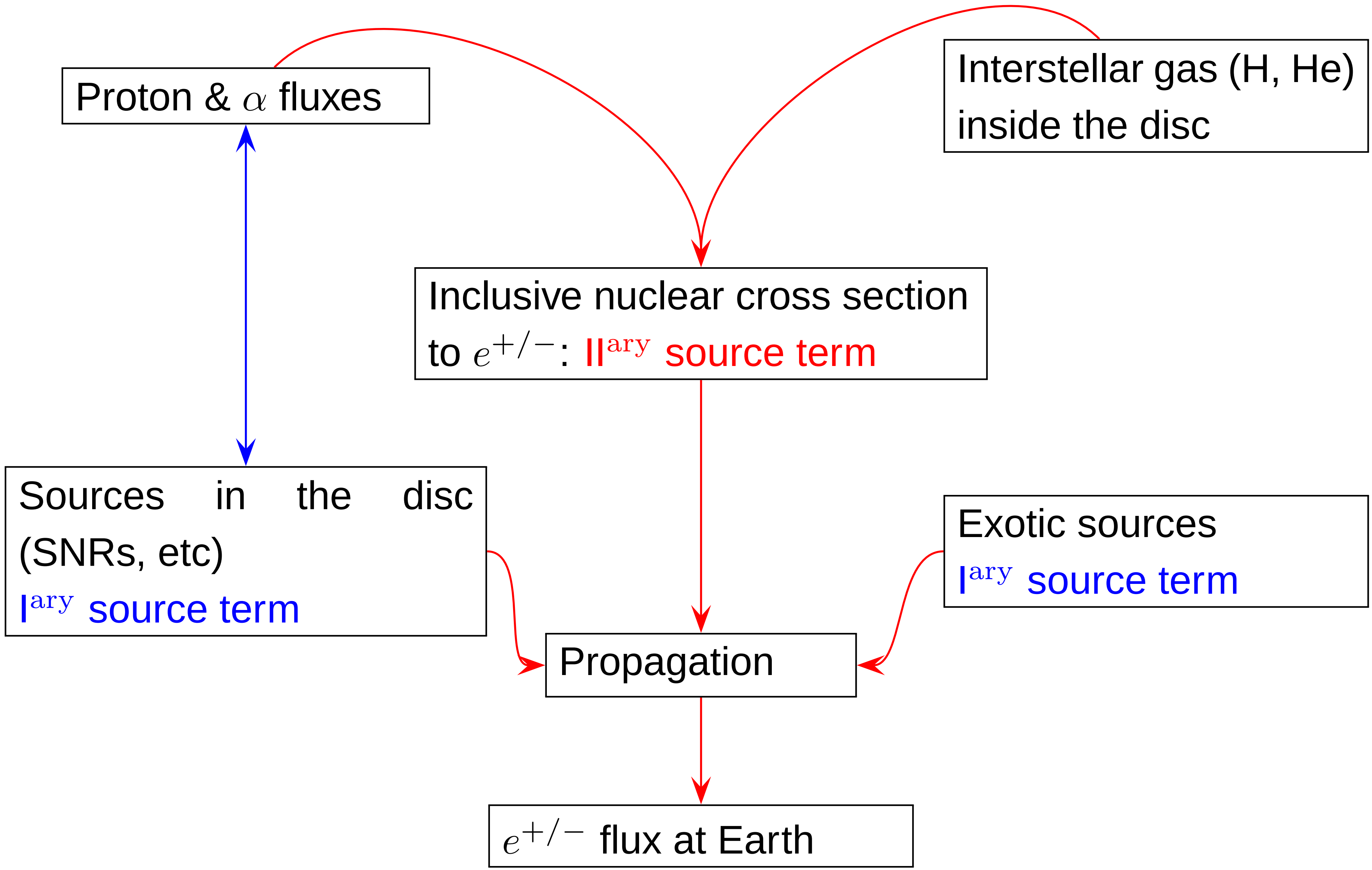
Biblio: Longair (!!!) + Russian School (Ginzburg et al, Bulanov et al, Berezinski et al) — Strong & Moskalenko



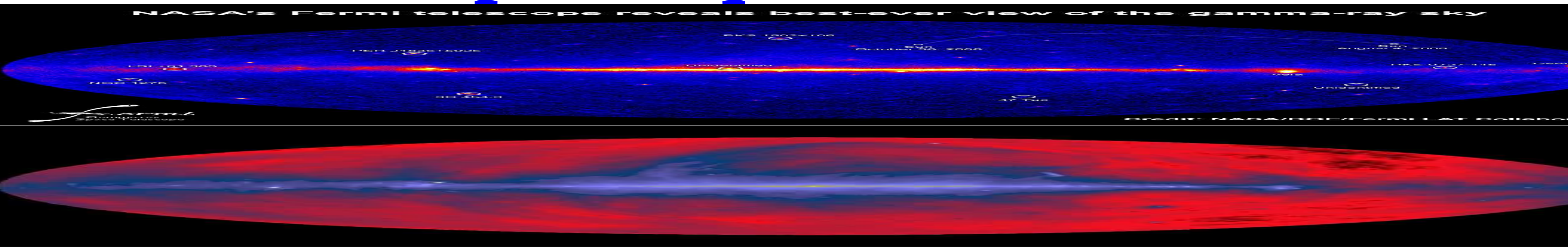


Strong et al, 00 – 07

Short recipe for $e^{+/-}$ flux at Earth



Transport equation for $e^{+/-}$



$$
\begin{aligned}
\partial_t \frac{dn}{dE} &= Q(E, \vec{x}, t) \\
&+ \left\{ \vec{\nabla}(K(E,\vec{x})\vec{\nabla} - \vec{V}_{\rm c}) \right\} \frac{dn}{dE} \\
&- \partial_E \left\{ \left(\frac{dE}{dt} - \partial_E E^2 K_{\rm pp} \partial_p E^{-2} \right) \frac{dn}{dE} \right\} \\
&- \left\{ \Gamma_{\rm spal} \right\} \frac{dn}{dE}
\end{aligned}
$$

source: injected spectrum

spatial current: diffusion and convection

$K(E) = K_0 \left(\frac{E}{E_0} \right)^{\alpha}$

$\vec{V}_{\rm c}(z) = sign(z) \times V_{\rm c}$

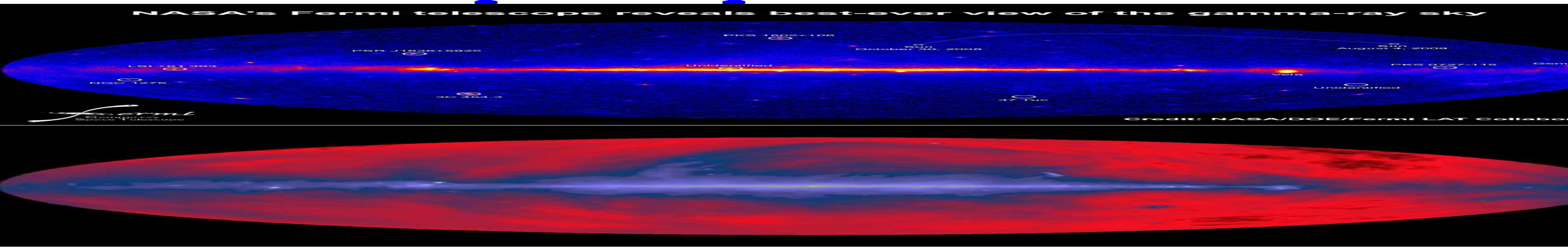
Energy losses and reacceleration

spallation (nuclei)

Uncertainties and degeneracies in parameters (Maurin et al 01)

(Complementary & full numerical: **Galprop**, Strong et al)

Transport equation for $e^{+/-}$



e.g. Bulanov & Dogel 73, Baltz & Edsjö 98, Lavalle et al 07, Delahaye et al 08

$$\begin{aligned} \partial_t \frac{dn}{dE} &= Q(E,\vec{x},t) \\ &+ \left\{ \vec{\nabla}(K(E,\vec{x})\vec{\nabla} \qquad) \right\} \frac{dn}{dE} \\ &- \partial_E \left\{ (\frac{dE}{dt} \qquad\qquad) \frac{dn}{dE} \right\} \end{aligned}$$

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$\gamma - e^{+/-}$ interactions & energy losses

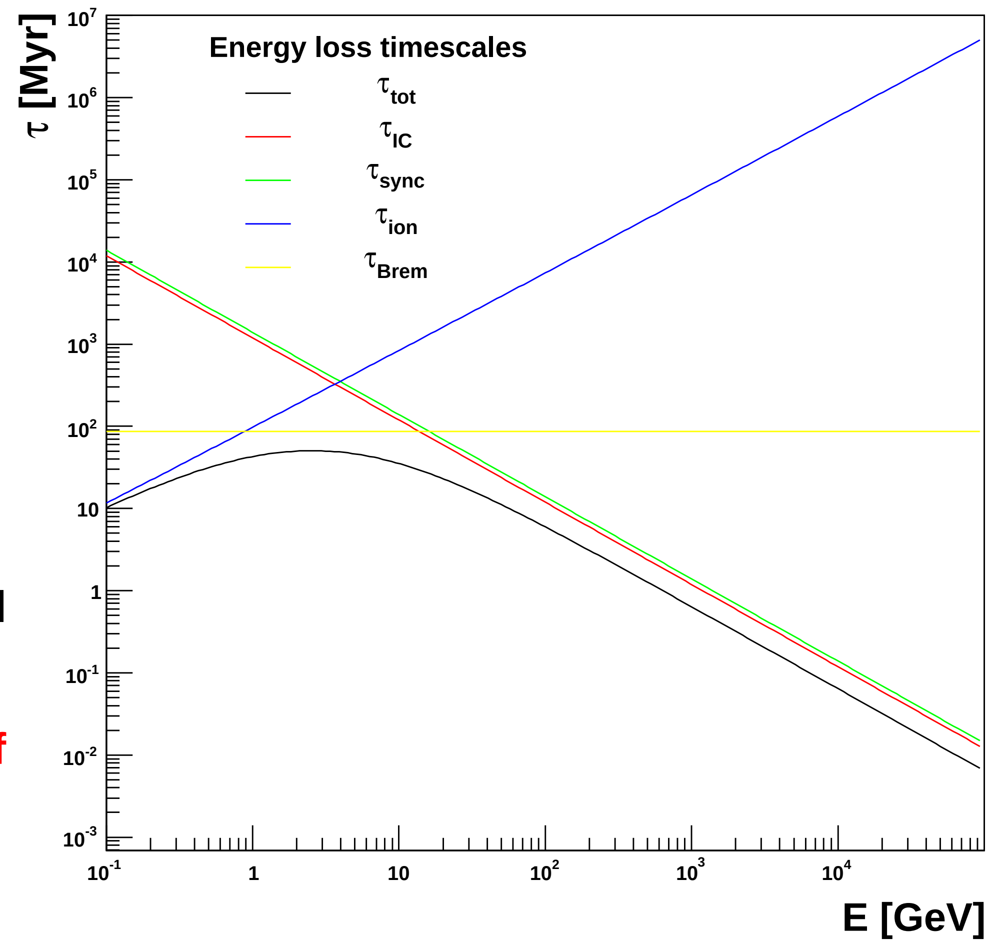
Photons from MIS+$e^{+/-}$: **Bremsstrahlung**

- electron - electron — $\propto E \ln(E)$
- electron - nuclei — $\propto E$

Photon **Comptonization** (IR, CMB, virtual)

- **Inverse Compton** (CMB, IR)
  $E \longrightarrow E' \propto \gamma^2 E$
  CMB $\sim 10^{-4}$ eV $\xrightarrow{1 \text{ TeV } e^-}$ 1 GeV
  IR $\sim 10^{-3}$ eV $\xrightarrow{1 \text{ TeV } e^-}$ 1 TeV
- **Synchrotron** off magnetic field (virtual photons) $E \rightarrow E' \propto \gamma^2 B^2 E$ — Sub-MeV

$\Rightarrow$ **Importance of the spatial distribution of gas and radiation fields**



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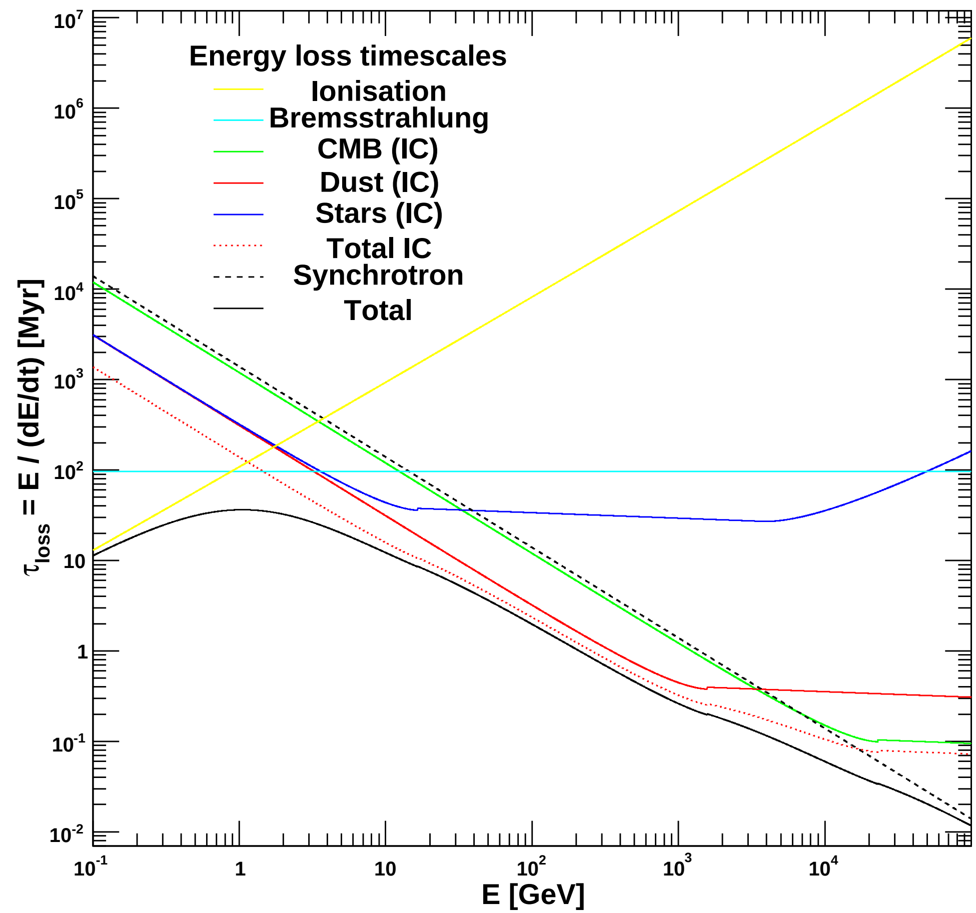


Spatial scales and typical spectra

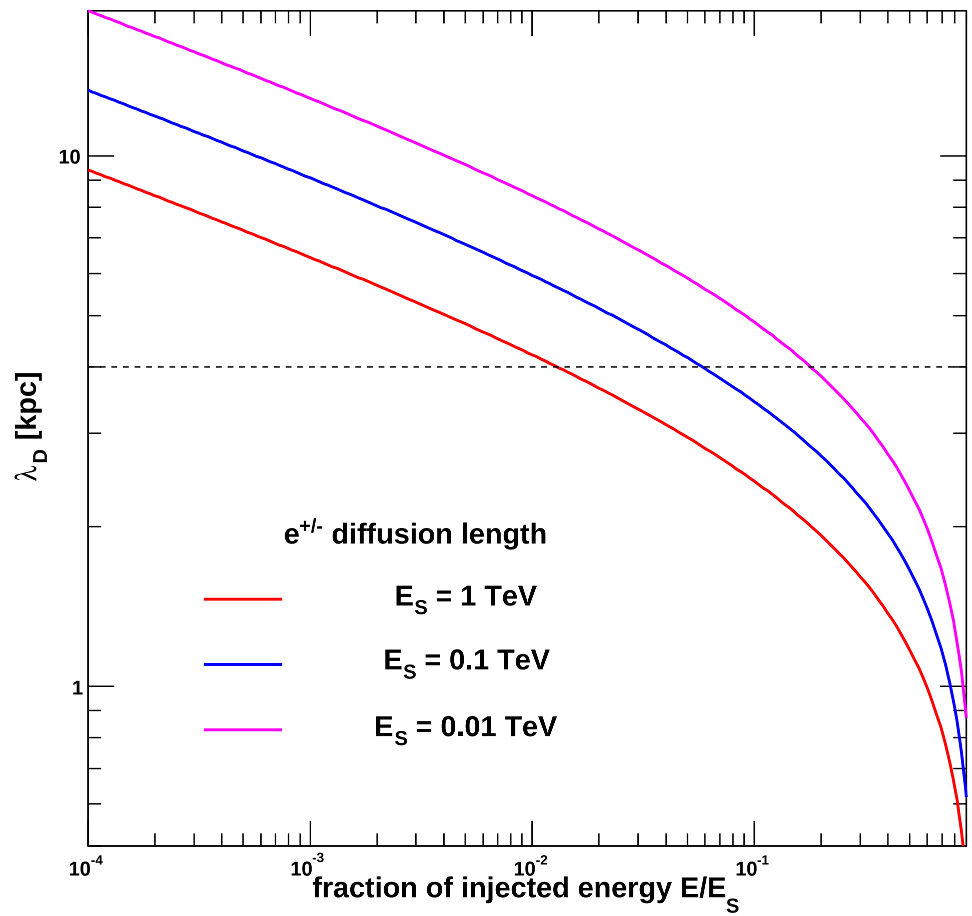
Spatial scales:

GeV-TeV range $\Rightarrow$ IC and synchrotron losses — $dE/dt = E^2/(E_0\tau)$, with $\tau \sim 300$ Myr.

Characteristic propagation scale:

$$\lambda_{\rm d}^2 \propto \int dt K(E) = \int dE \frac{K(E)}{dE/dt}$$

$$\Rightarrow \lambda_{e^-} \sim 1\ \text{kpc} \ll \lambda_{\rm CRs}$$



Typical spectra:

source term $Q(E,\vec{x}) \propto Q_0\,\delta(z)\,E^{-\gamma}$

$$\Rightarrow \phi(E) \propto E^{-\gamma-1-\frac{1}{2}(\delta-1)}$$

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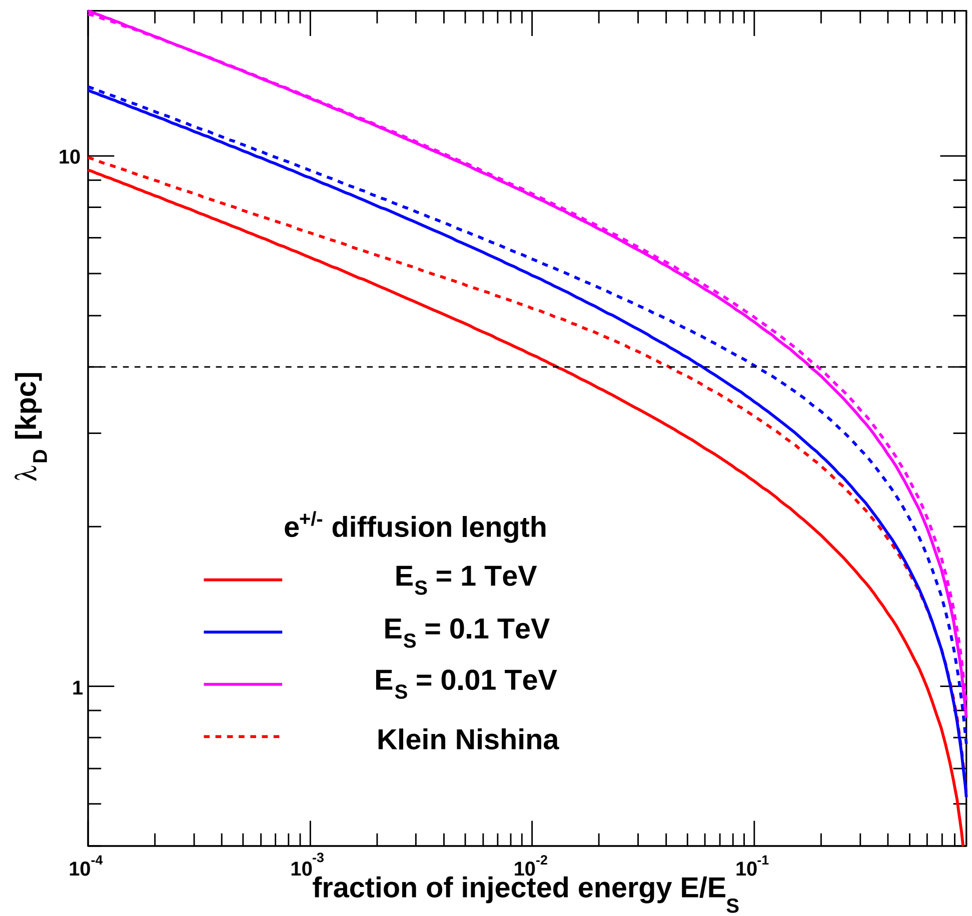

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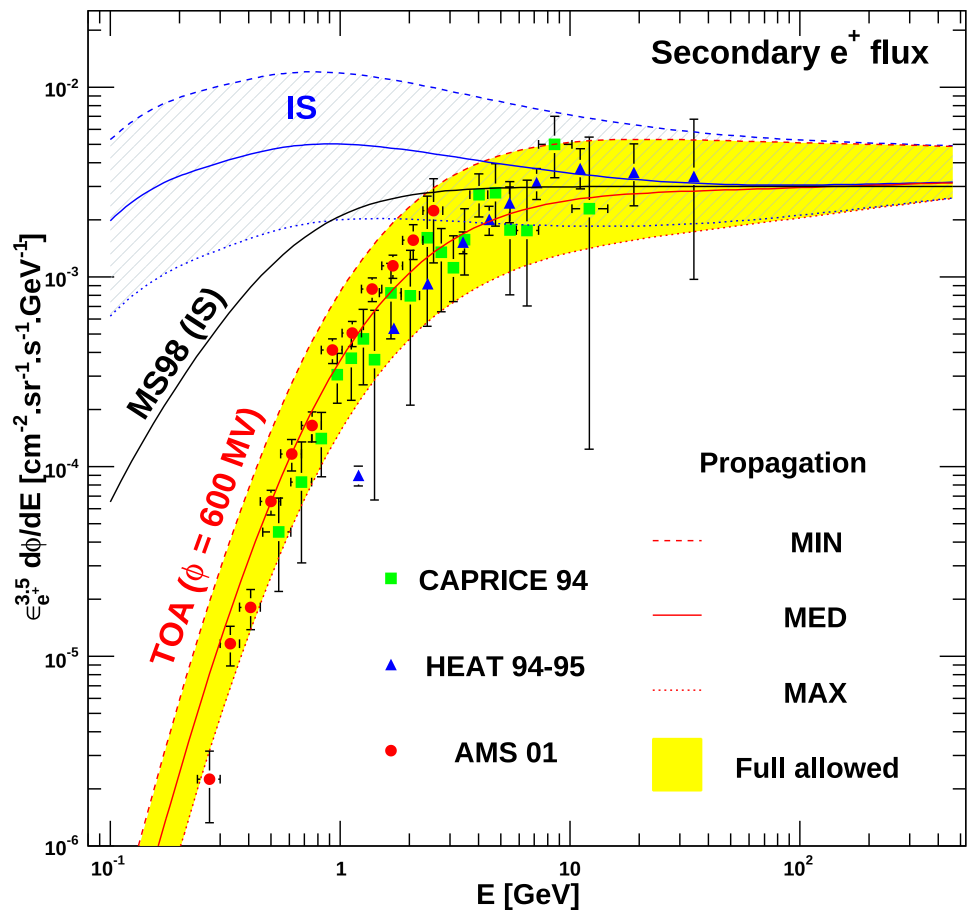

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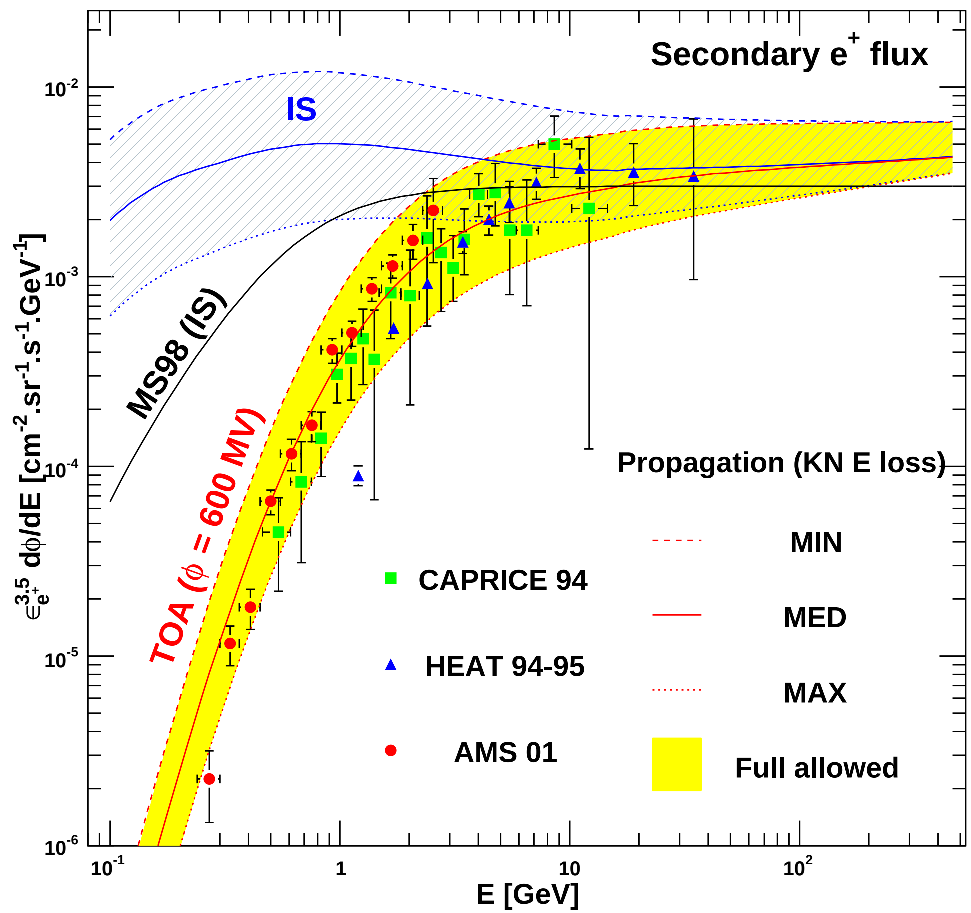

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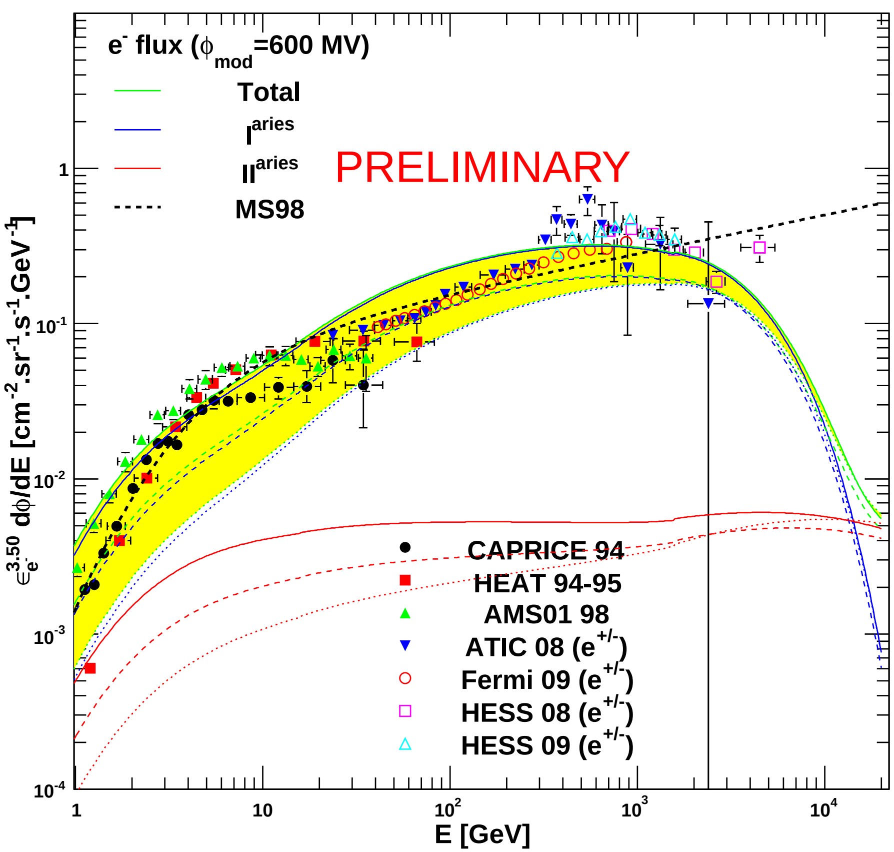
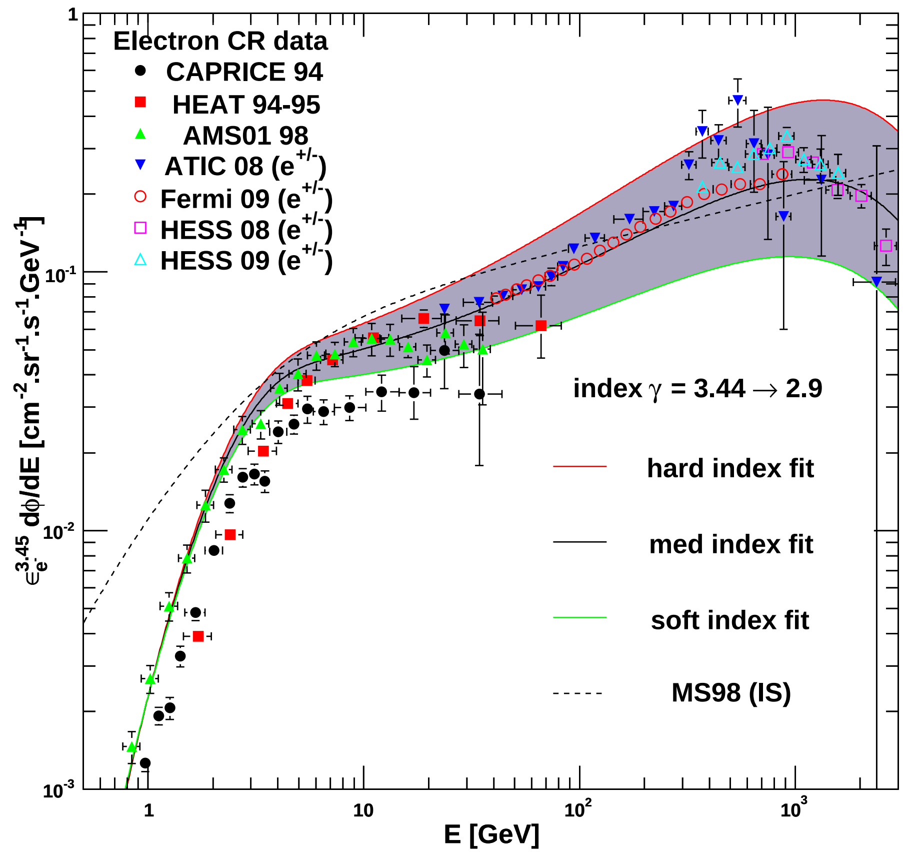
$e^{+/-}$ flux at Earth

Delahaye et al, in progress





Issues: injection spectrum ($\frac{\phi_p}{K(E)}$?), spatial distribution of sources, normalization.

Summary

- Electrons around 10 GeV come from few kpc: check spatial distribution of sources, template spectra, explosion rate.
- Above 100 GeV, the local environment within 1 kpc is very important: large fluctuations in space-time are expected (+ anisotropy ?).
- Contribution to the diffuse emission involves to average over the angular resolution along the line of sight: local fluctuations are slightly smoothed.
- Importance of spatial distributions of the gas and of the interstellar radiation field: 3D models + observations.
- **THEORETICAL UNCERTAINTIES !!!**