Cosmic positrons from catalogued pulsars

In collaboration with
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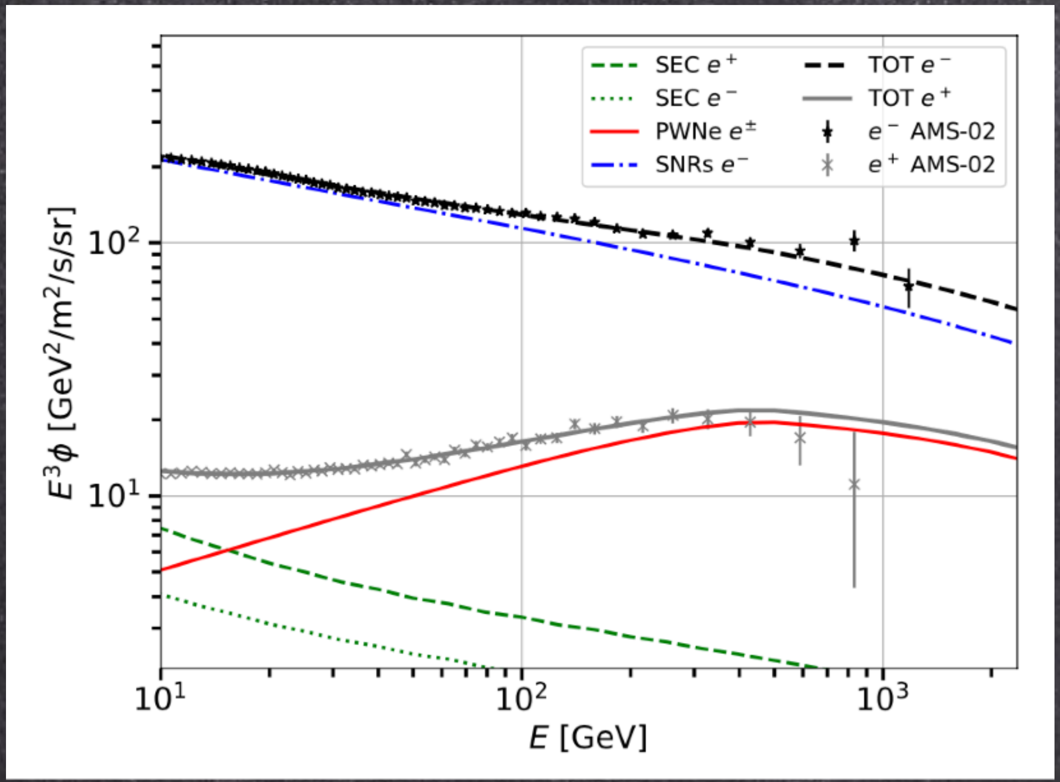
e+ & e- spectra, a natural explanation

e+ and e- AMS-02 spectra fitted with a multi-component model: secondary production, e- from SNR, e+ from PWN

Di Mauro, FD, Manconi PRD 2021

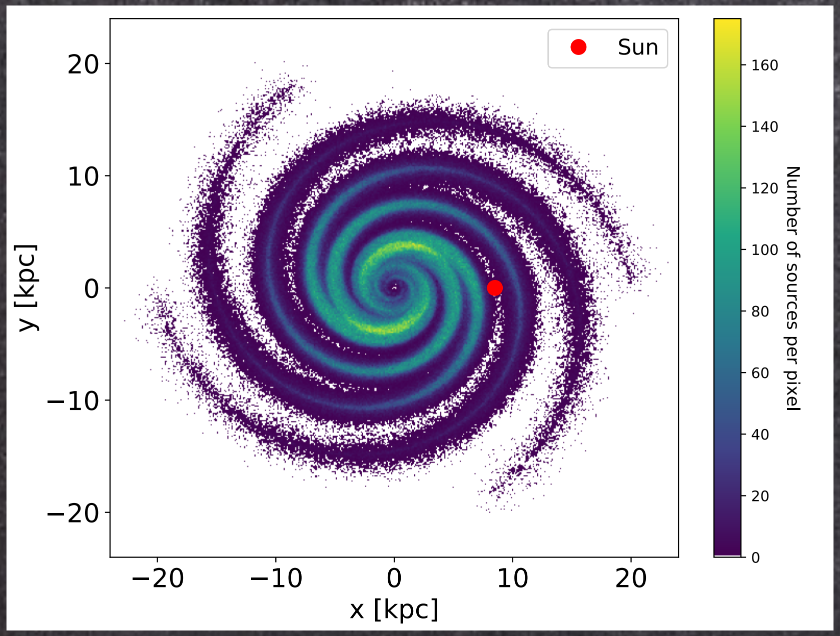


The break at 42 GeV in e- is explained by interplay between SNR and PWN

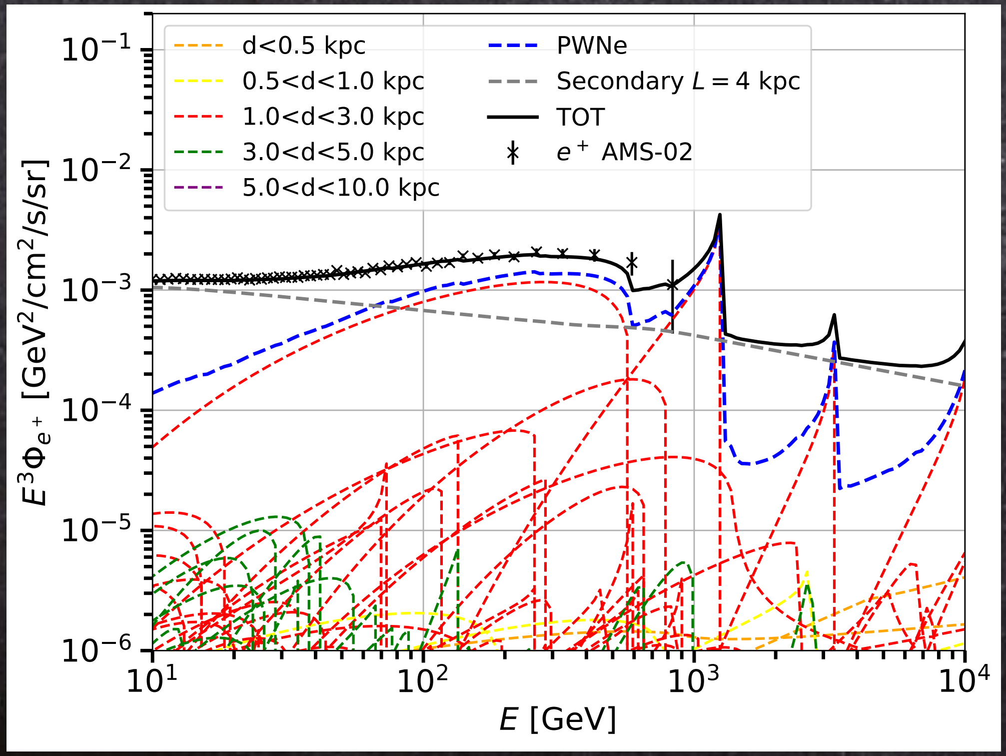
See also Fang+ 2007. 15601, Evoli+PRD 2021, Cuoco+ PRD2020

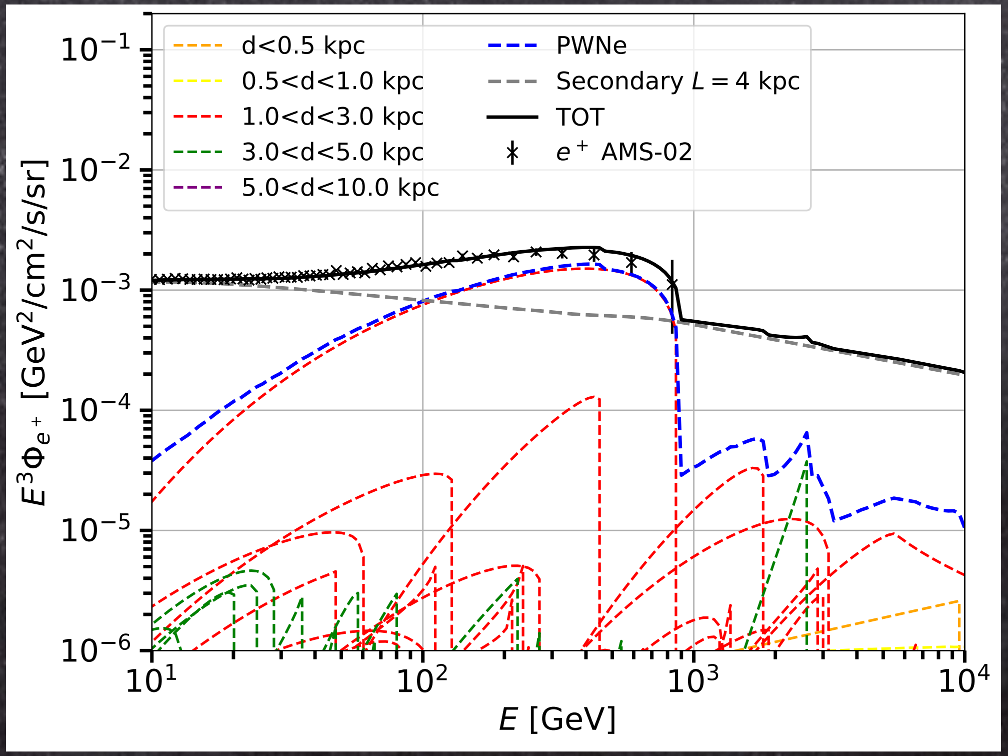
Simulation of Galactic pulsar populations: a fit to AMS-02 e+ data

L. Orusa, S. Manconi, M. Di Mauro, FD JCAP 2021



- Simulation of space distribution and pulsar properties
- The contribution of pulsars to e+ is dominant above 100 GeV
- May have different features
- E>1 TeV: unconstrained by data
- Secondaries forbid evidence of sharp cut-off
- No need for Dark matter, indeed

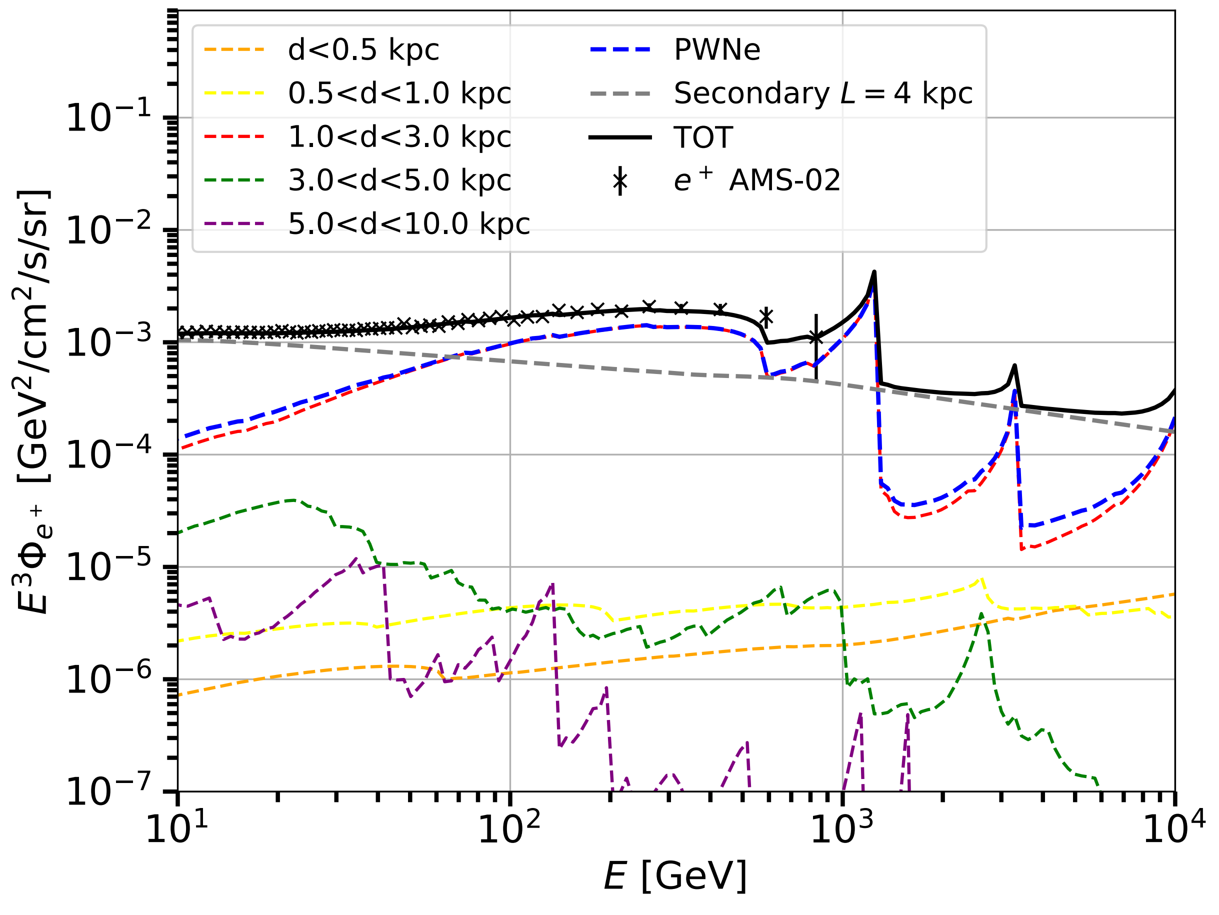


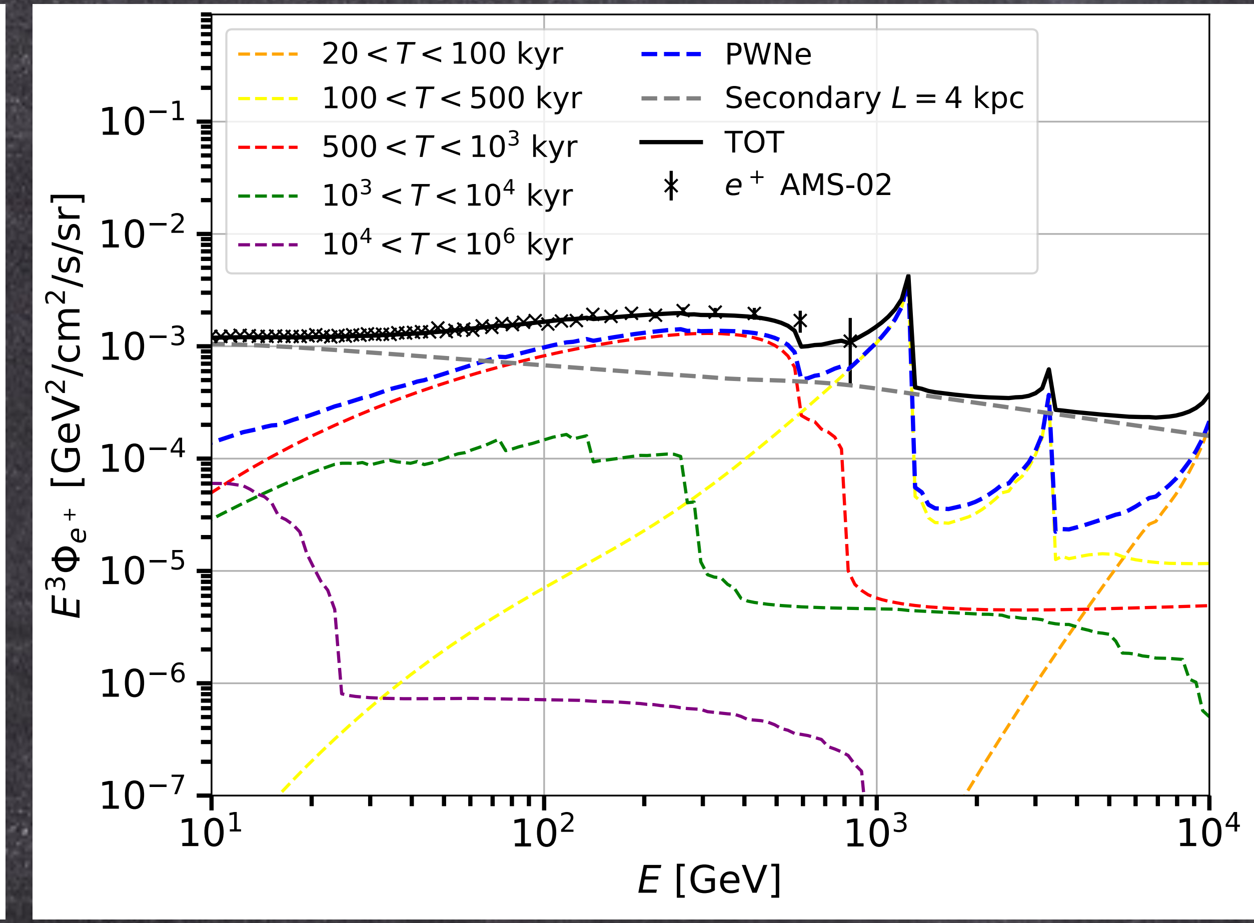


Simulations: effect of age and distance

on mock galaxies as selected by e+ AMS-02 data

L. Orusa, S. Manconi, M. Di Mauro, FD JCAP 2021





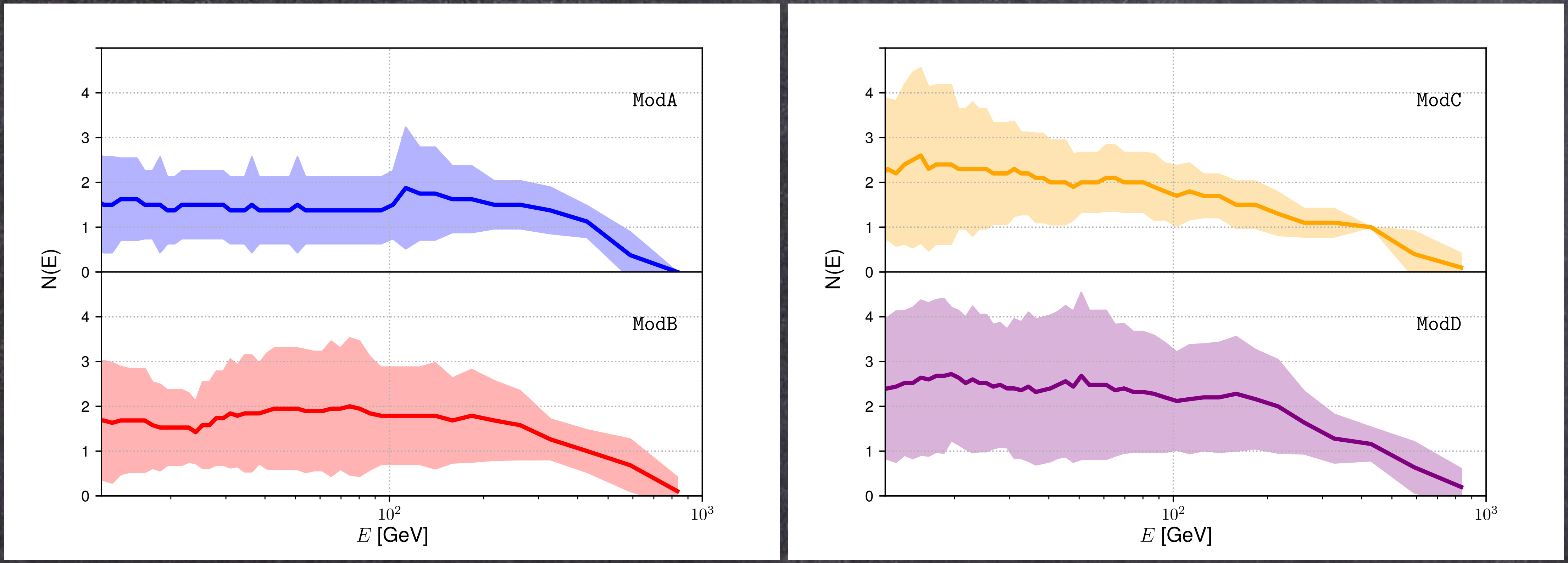
1-3 kpc ring is the most fruitful in terms of e+

Interplay between spiral arms and propagation length

Few pulsars suffice to fit AMS data

Very few ones, indeed

L. Orusa, S. Manconi, M. Di Mauro, FD JCAP 2021



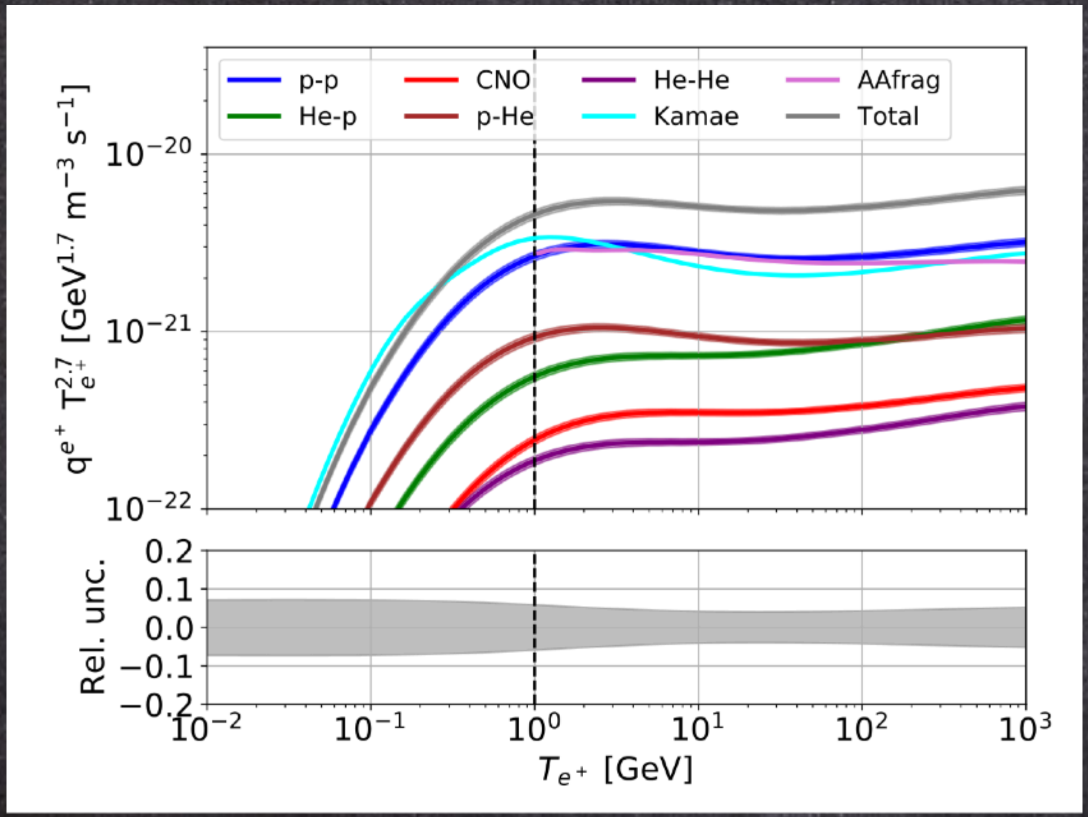
N(E) is the mean number of PWNe that produce a flux higher than the experimental flux error in at least one energy between above 10 GeV.

Typically 2-3 sources explain most of the measured flux (+ secs)

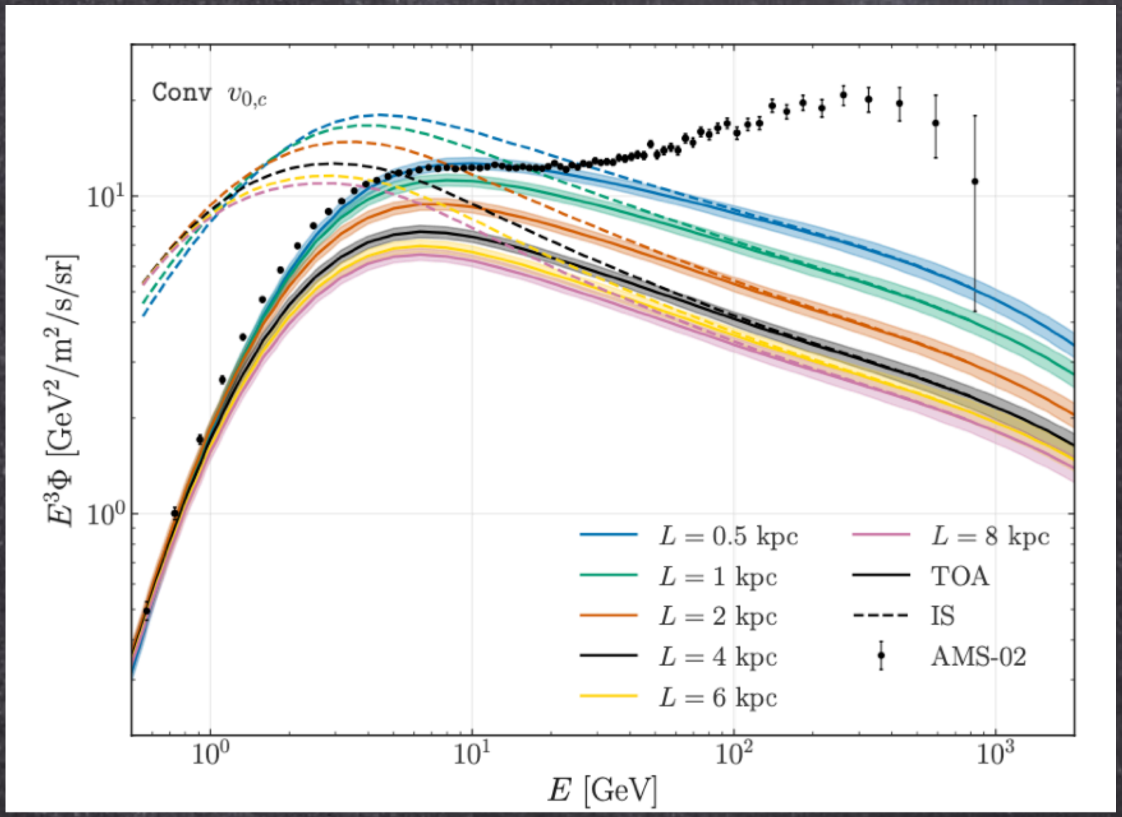
Secondary positrons: the role of cross sections

Secondaries rely on a new determination of productions cross section

Orusa, Di Mauro, Korsmeier, FD PRD 2023



Di MAuro, FD, Korsmeier, Manconi, Orusa PRD2023



New determination of cross sections: uncertainties about 5% (<8%).

New secondary e+: depend strongly on L, deficit above ~ 1 GeV

e± pair emission from pulsars

We assume continuous injection :

$$Q(E,t) = L(t)\left(\frac{E}{E_0}\right)^{-\gamma_e}\exp\left(-\frac{E}{E_c}\right) \qquad L(t) = \frac{L_0}{\left(1+\frac{t}{\tau_0}\right)^{\frac{n+1}{n-1}}}$$

Normalized to:

$$E_{tot} = \eta W_0 = \int_0^T dt \int_{E_1}^{\infty} dE\, E\, Q(E,t)$$

Having:

$$\dot{E} = \frac{dE_{\rm rot}}{dt} = I\Omega\dot{\Omega} = -4\pi^2 I \frac{\dot{P}}{P^3}\,.$$

We can derive a relation for:

$$\tau_0 = \frac{P_0}{(n-1)\dot{P}_0}.$$

Positrons form catalogued pulsars

L. Orusa, M. Di Mauro, FD, S. Manconi 2024, in preparation

We pick pulsars from the ATNF catalog: position, age, dE/dt

The other pulsar parameters are simulated (see Orusa, Manconi, Di Mauro, FD JCAP 2021)

Propagation in the Galaxy treated according to latest nuclei results

(see Di Mauro, FD, Korsmeier, Manconi, Orusa PRD 2023)

ModA: T_0 distribution

ModB: T_0 fixed

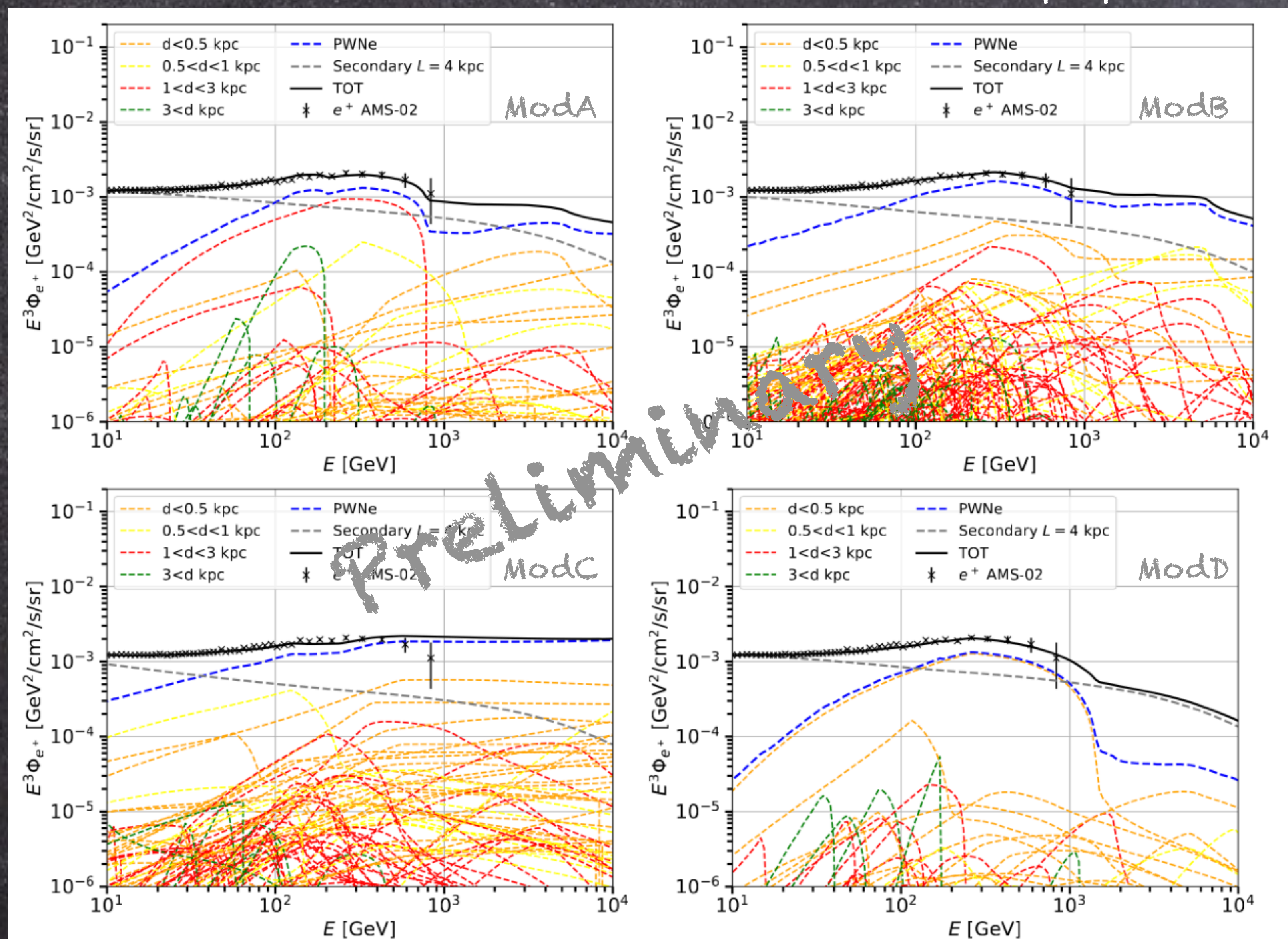
ModC: delayed emission

ModD: two-zone diffusion

Pulsar property	Simulated quantity	Benchmark	Variations
Spin-down		CB20[36]	$\tau_0 = 10$ kyr
	P_0	Gaussian [0.3s; 0.15s]	-
	$\log_{10}(B)$	Gaussian [12.85G; 0.55G]	-
	n	Uniform [2.5-3]	-
	$\cos\alpha$	Uniform [0-1]	-
$e^{\pm}$ injection	γ_L	Uniform [1.0-2.0]	-
	γ_H	Uniform [2.0-2.8]	-
	E_b	Uniform [300-600] GeV	-
	η	Uniform [0.01-0.1]	-
Kick velocity	v_k	-	FK06VB [57]

Catalogued pulsars: a fit to e+ data

L. Orusa, M. Di Mauro, FD, S. Manconi 2024, in preparation



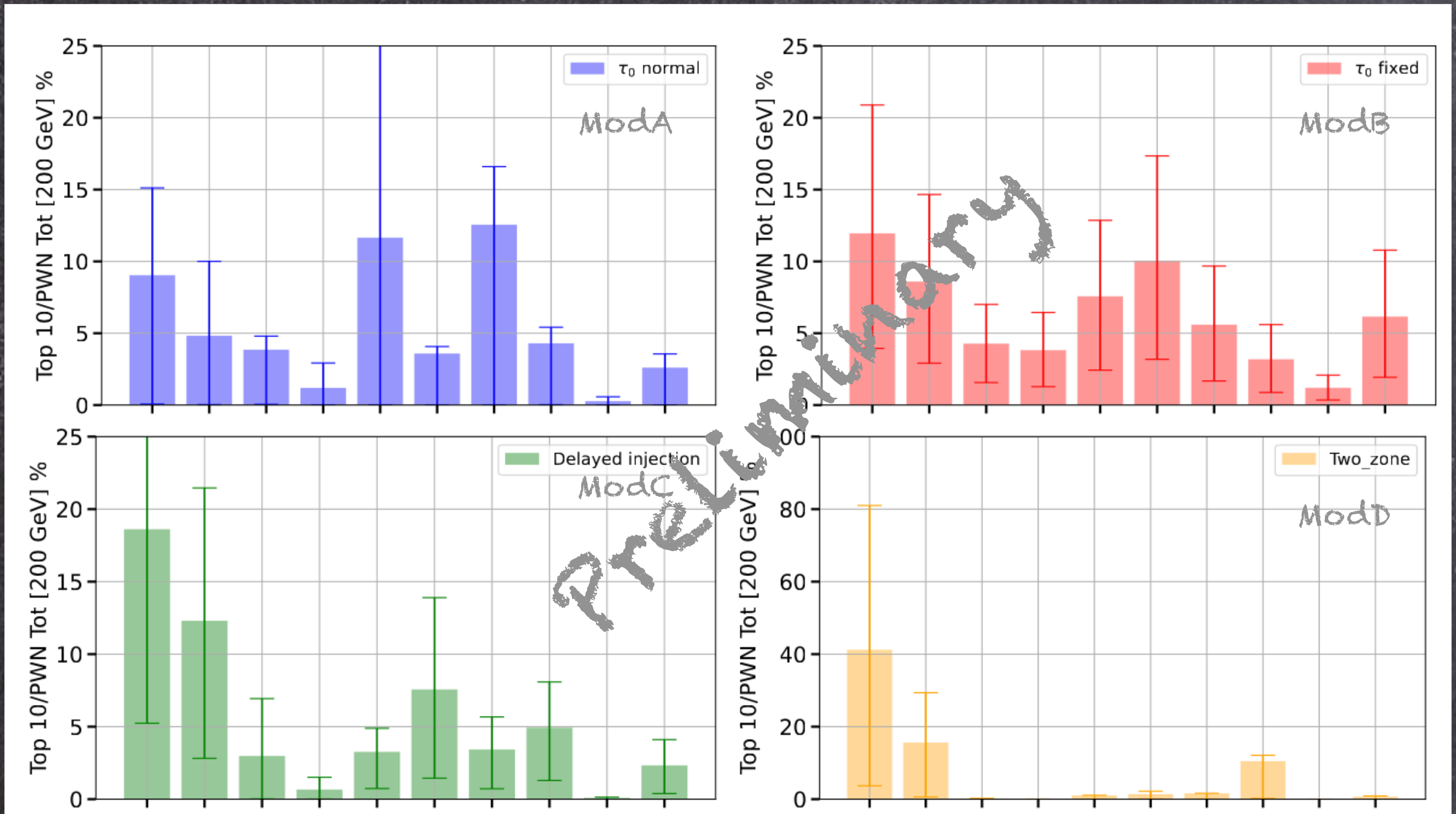
Exemplary best fits in ModA-B-C-D

Catalogue pulsars & secondaries explain well the data.

Fixed T_0 (ModB) prevents scenarios with one dominant pulsar

% contribution of 10 most relevant ATNF pulsars

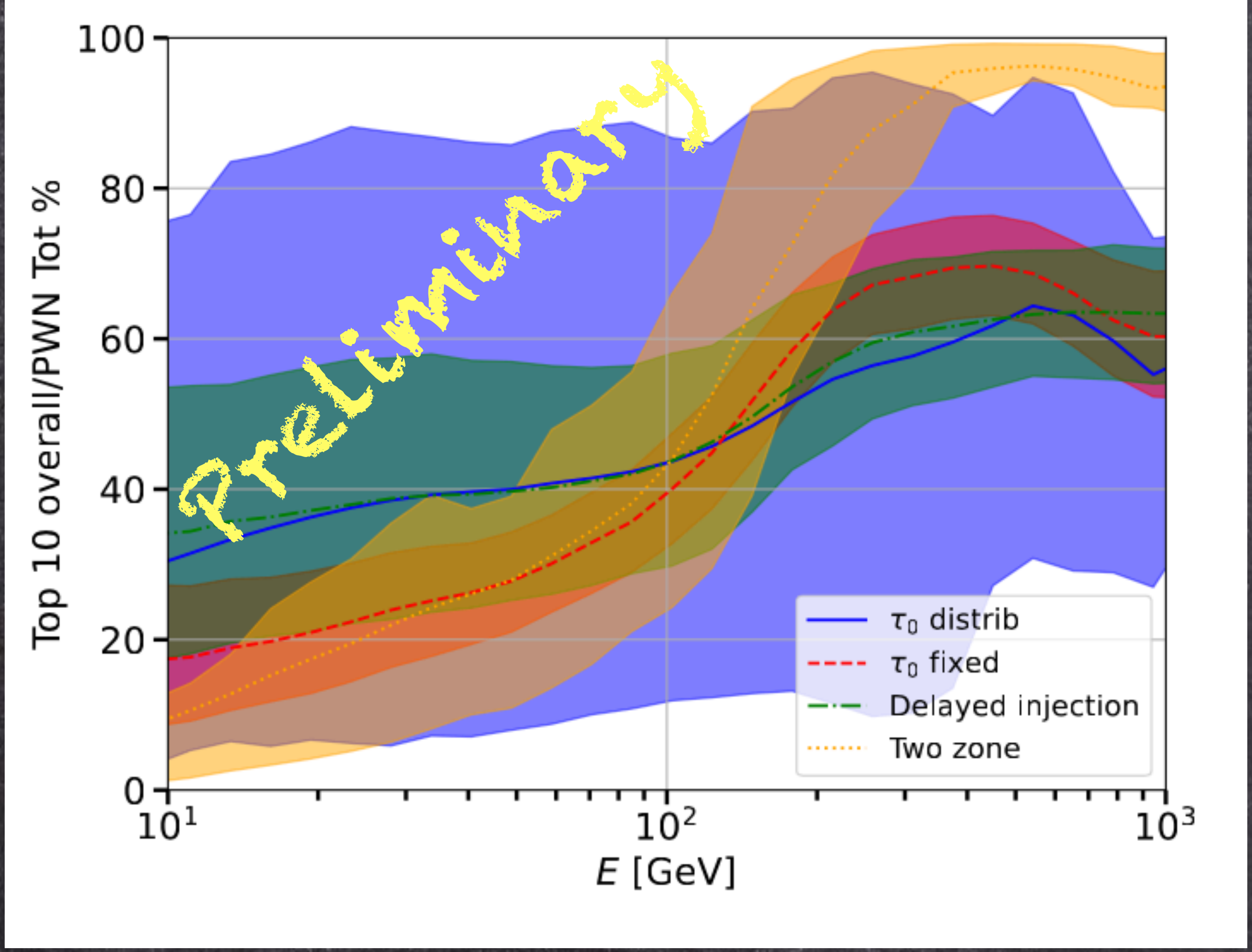
L. Orusa, M. Di Mauro, FD, S. Manconi 2024, in preparation



Flux intensity ratio of a PWN within the 10 most relevant ATNF pulsars averaged on all the simulation&fit.

% to total PWNe flux of 10 most powerful pulsars vs energy

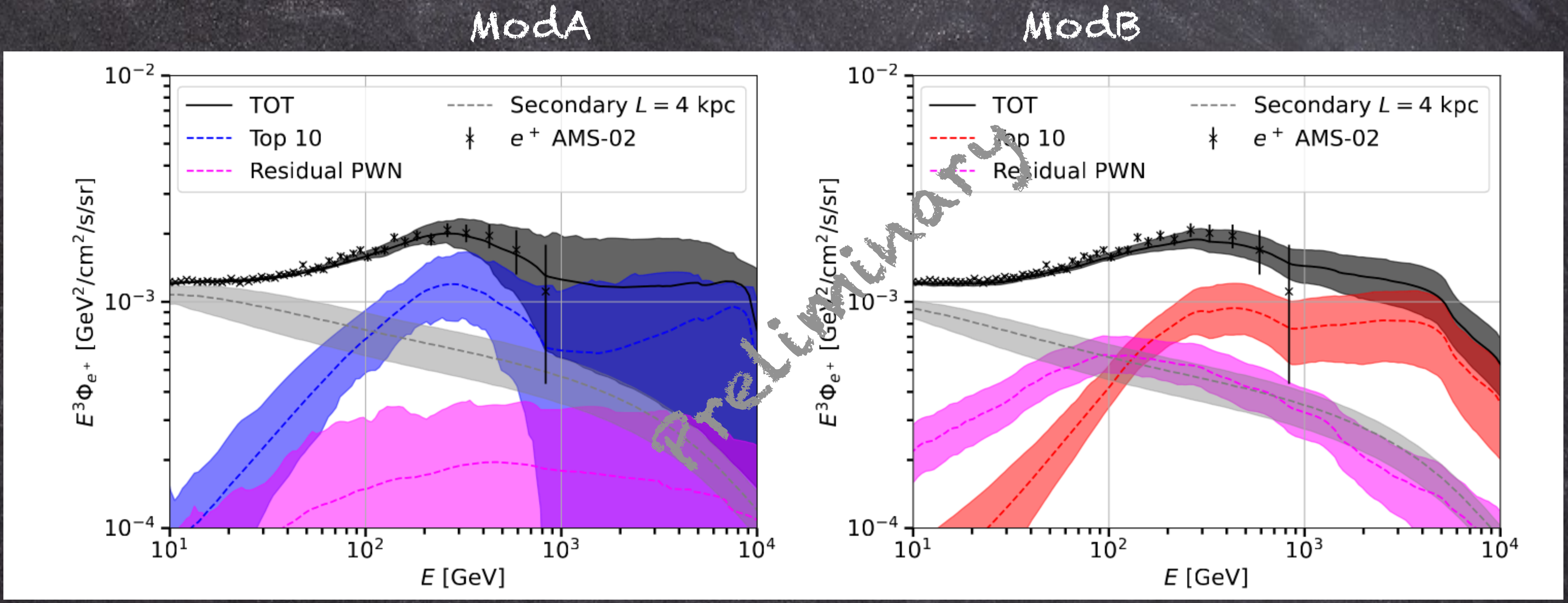
L. Orusa, M. Di Mauro, FD, S. Manconi 2024, in preparation



As previous histograms, but as a function of energy. ModA, with τ_0 in a distribution, allows high freedom to sources to readjust their contribution wrt AMS data

Fluxes from ATNF pulsars - two examples

L. Orusa, M. Di Mauro, FD, S. Manconi 2024, in preparation



Emission models and parameters are very relevant.
Some models are predictive also above TeV.
Secondaries are allowed with a free normalization
(always found < 1.5, typically around 1)

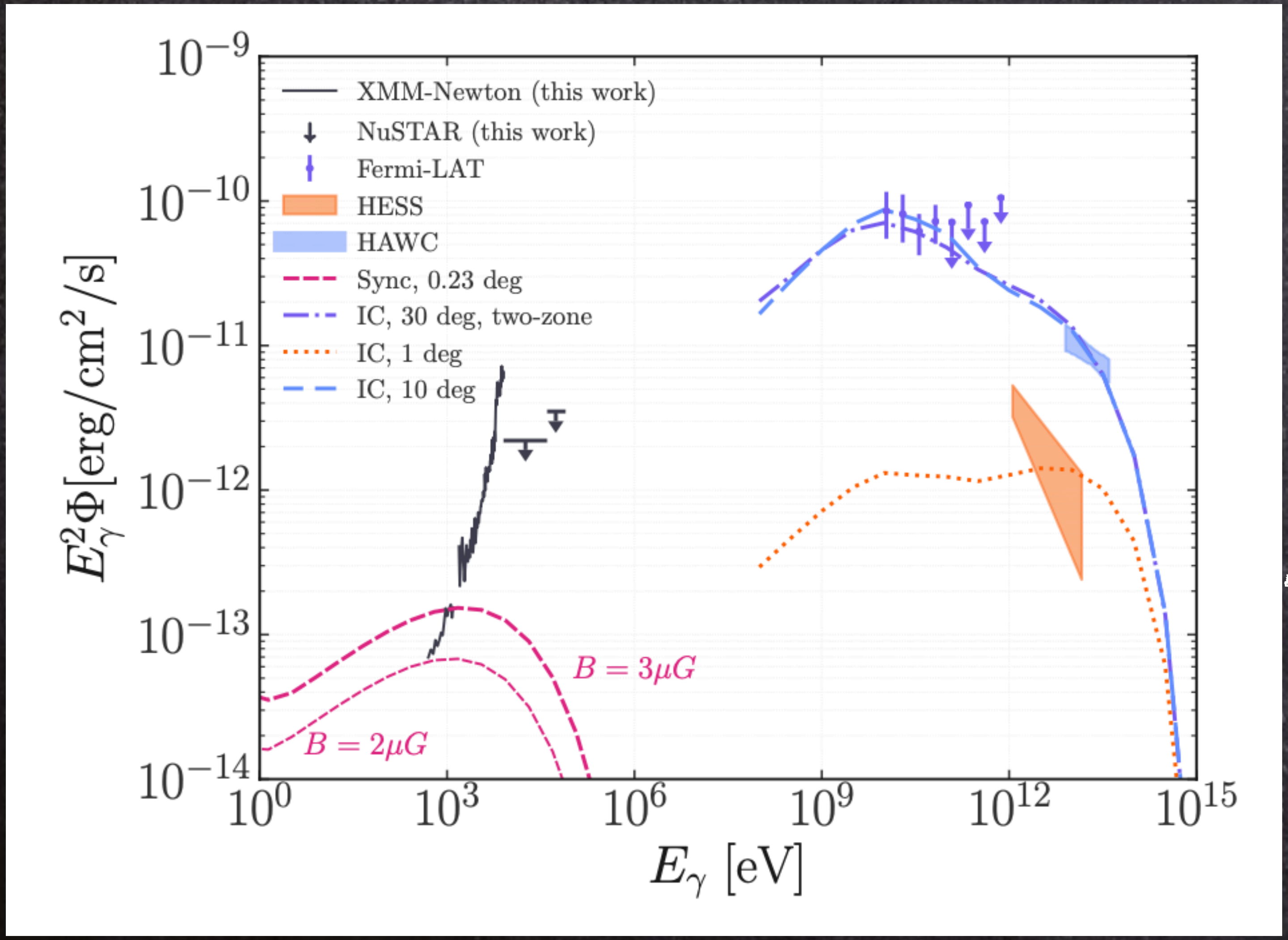
Multi-wavelength analysis of sources

Geminga's pulsar halo: an X-ray view

S. Manconi,FD+ A&A2024

A γ-ray halo has been observed in HAWC and Fermi-LAT data.
Interpreted as e± cooling by inverse-Compton scattering.

The same e± emit synchrotron radiation and for a similar X-ray halo



We use archival data in XMM Newton and NUSTAR. No X-ray halo is detected.

An upper bound on the magnetic field around the pulsar is set to 2 μG

Conclusions

We built a consistent frame - sources, emission, propagation models - for the flux of e+ reaching Earth

Secondaries from nuclear reactions have been updated

Pulsars are from ATNF catalog: position, age, E_dot. Other emission parameters are simulated

Secondaries + catalog pulsars give an excellent fit to AMS-02, with few recurring pulsars dominating the spectrum

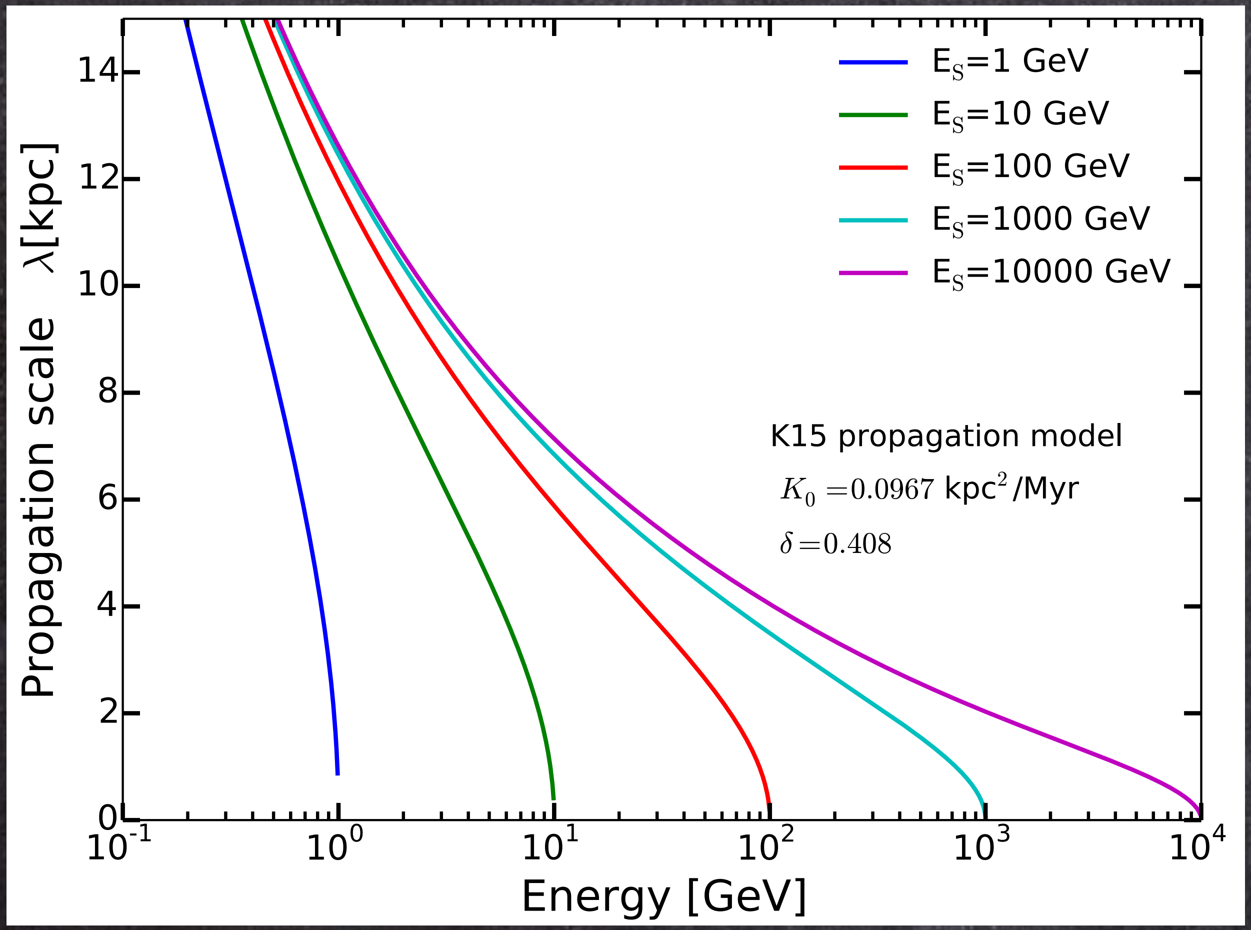
The emission model is very relevant for intensity and shape of the flux

Detected e+ and e- are local

$$\lambda^2(E, E_S) = 4 \int_E^{E_S} dE' \frac{D(E')}{b_{\text{loss}}(E')}$$

Typical propagation length in the Galaxy

Manconi, Di Mauro, FD JCAP 2017



Sources of e+ & e- in the Galaxy

- Inelastic hadronic collisions (asymm.)
- Pulsar wind nebulae (PWN) (symm.)
- Supernova remnants (SNR) (only e-)
- Particle Dark Matter annihilation (e+,e-)?

e-, e+ suffer strong radiative cooling and arrive at Earth if produced within few kpc around it.

Local sources very likely leave their imprints in the spectra