# CONSTRAINING POSITRON EMISSION FROM PULSAR POPULATIONS WITH AMS-02 DATA

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**International Cosmic Ray Conference 2021**

Berlin,12/07/2021

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# 1. Pulsar as sources of electron-positron pairs

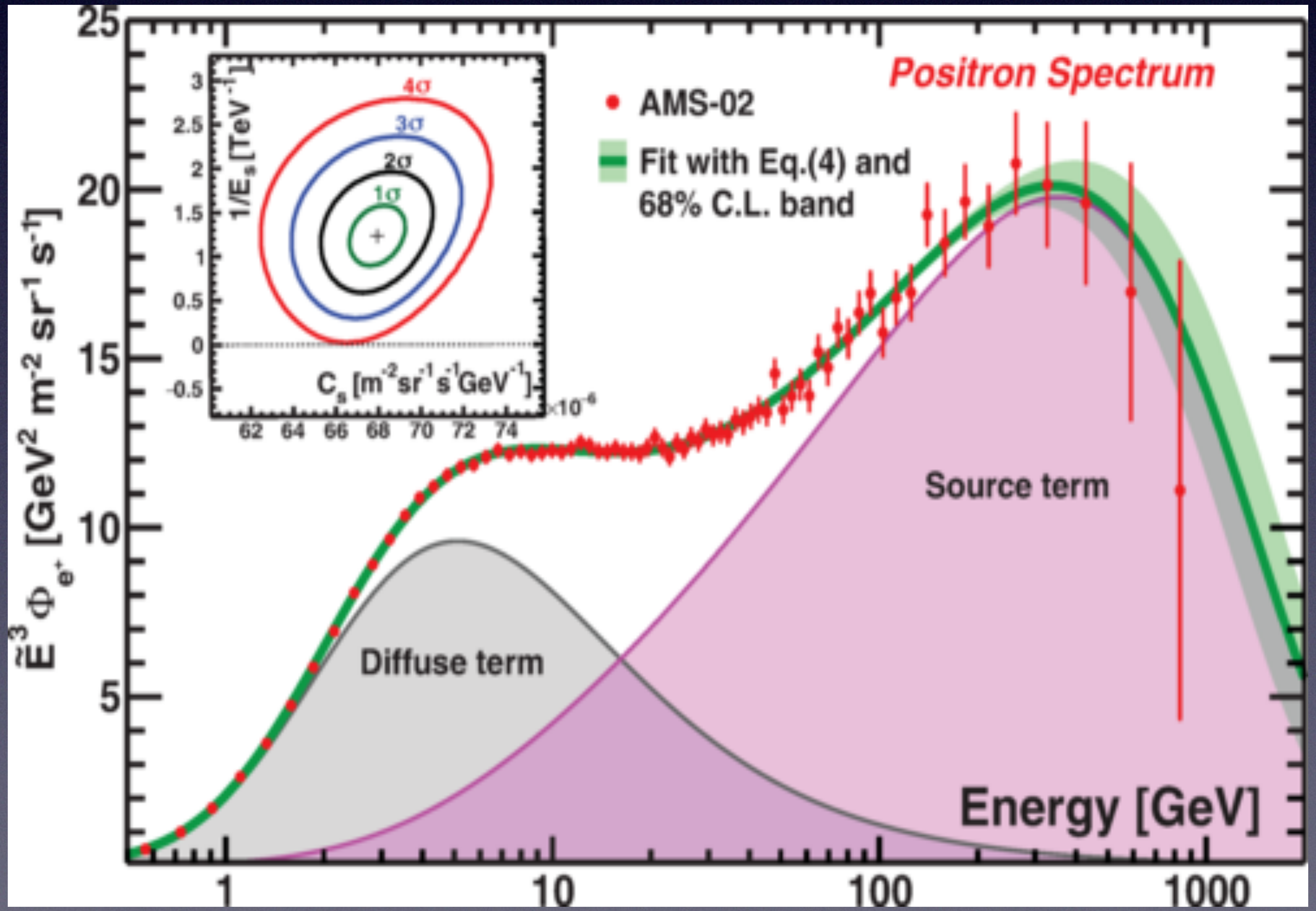
- AMS-02 positron flux measures → secondary + primary contribution.

- Pulsars as sources of cosmic-ray electrons and positrons($e^{\pm}$)

- Simulations of pulsar populations from models calibrated on observations.

- Injection spectrum $Q(E,t)$ of $e^{\pm}$ from pulsars:

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




AMS-02 Collab, PRL122(2019)

Total number of sources for each simulation: $N_{\rm PSR} = t_{max}\dot{N}_{PSR}$, $t_{max} = 10^8$ yr and $\dot{N}_{PSR} = 0.01$ yr$^{-1}$ [Keane et al.,2008].

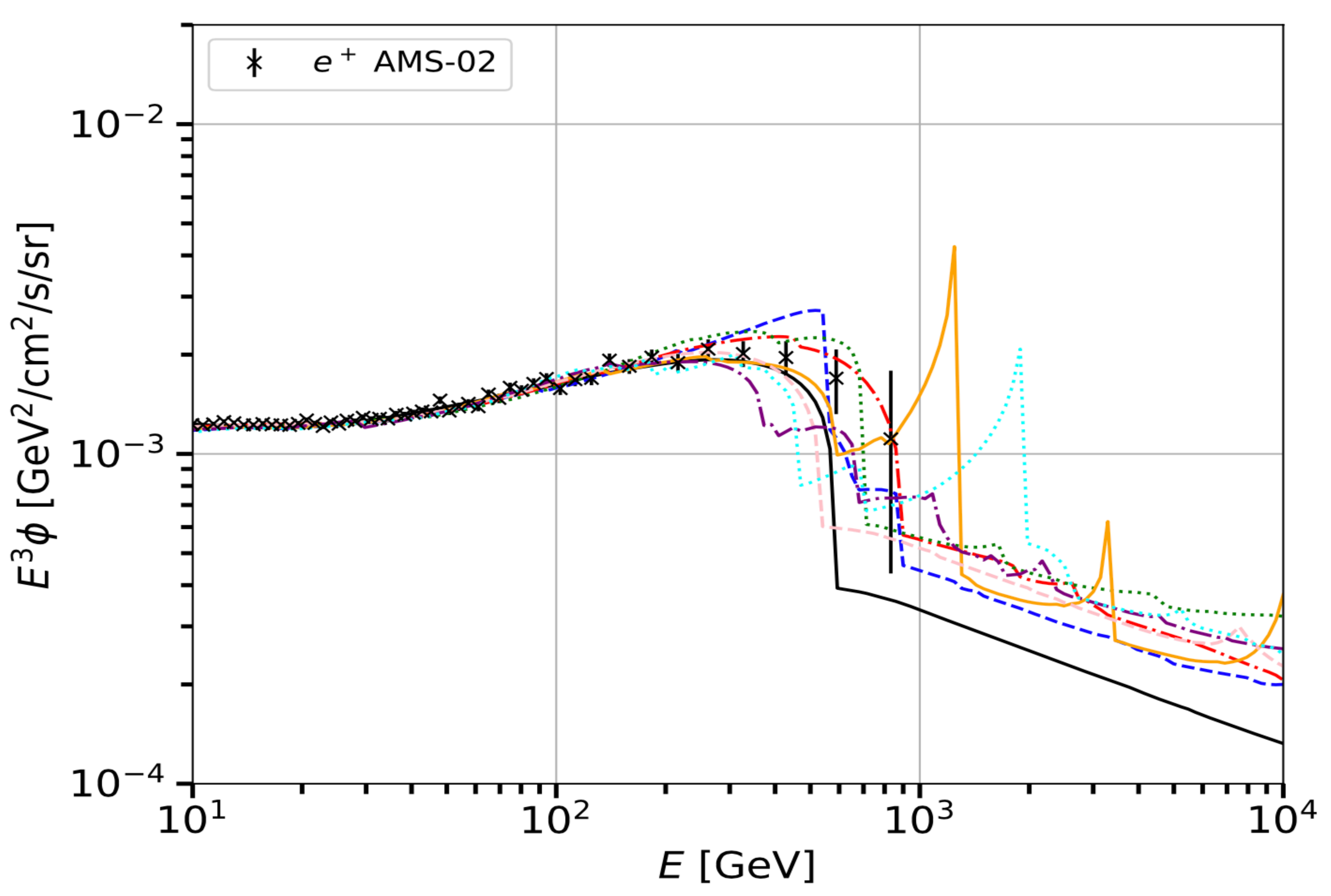
- **ModA**(Benchmark). Spin-down and pulsar evolution properties → **CB20**[Chakraborty et al., 2020]; radial surface density of sources → $\rho_L(r)$ [Lorimer, 2004]; propagation in the Galaxy → *Benchmark prop* [Di Mauro-Winkler, 2021].
- **ModB** (radial distribution effect): radial surface density of sources → $\rho_F(r)$ [Faucher-Giguère et al.,2006]
- **ModC** (spin-down properties effect): Spin-down and pulsar evolution properties → **FK06** [Faucher-Giguère et al.,2006] .
- **ModD**(propagation effect): propagation in the Galaxy → *SLIM-MED* [Génolini et al., 2021].

| PSR property | Simulated quantity | Benchmark | Variations |
|---|---|---|---|
| Age | $T$ | Uniform $[0, t_{max}]$ | - |
| Spin-down | | CB20 | FK06 |
| | $P_0$ | Gaussian [0.3s; 0.15s] | - |
| | $\log_{10}(B)$ | Gaussian [12.85G; 0.55G] | Gaussian [12.65G; 0.55G] |
| | n | Uniform [2.5-3] | Constant [3] |
| | $\cos\alpha$ | Uniform [0-1] | Constant [0] |
| $e^{\pm}$ injection | $\gamma_e$ | Uniform [1.4-2.2] | - |
| | $\eta$ | Uniform [0.01-0.1] | - |
| Radial distribution | **r** | $\rho_L(r)$ | $\rho_F(r)$ |

Fit to the AMS-02 data above 10 GeV:

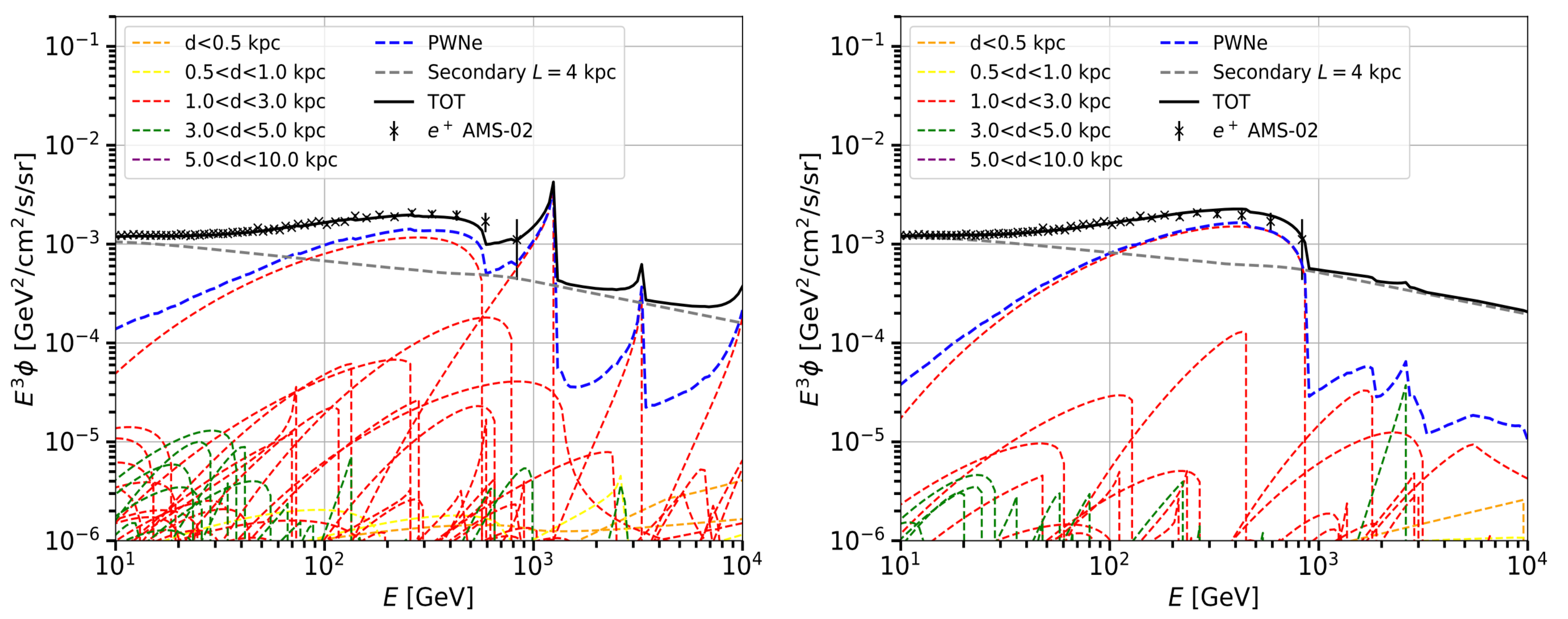
- Secondary component: free normalization factor $A_S$.
- Contribution of pulsars: overall normalization factor $A_P$.

| | $\chi^2_{\rm red} < 2$ | $\chi^2_{\rm red} < 1.5$ | $\chi^2_{\rm red} < 1$ |
|---|---|---|---|
| ModA | 1.5% | 0.8% | 0.4% |
| ModB | 3.0% | 1.9% | 0.6% |
| ModC | 1.5% | 1.0% | 0.3% |
| ModD | 4.2% | 2.5% | 1% |



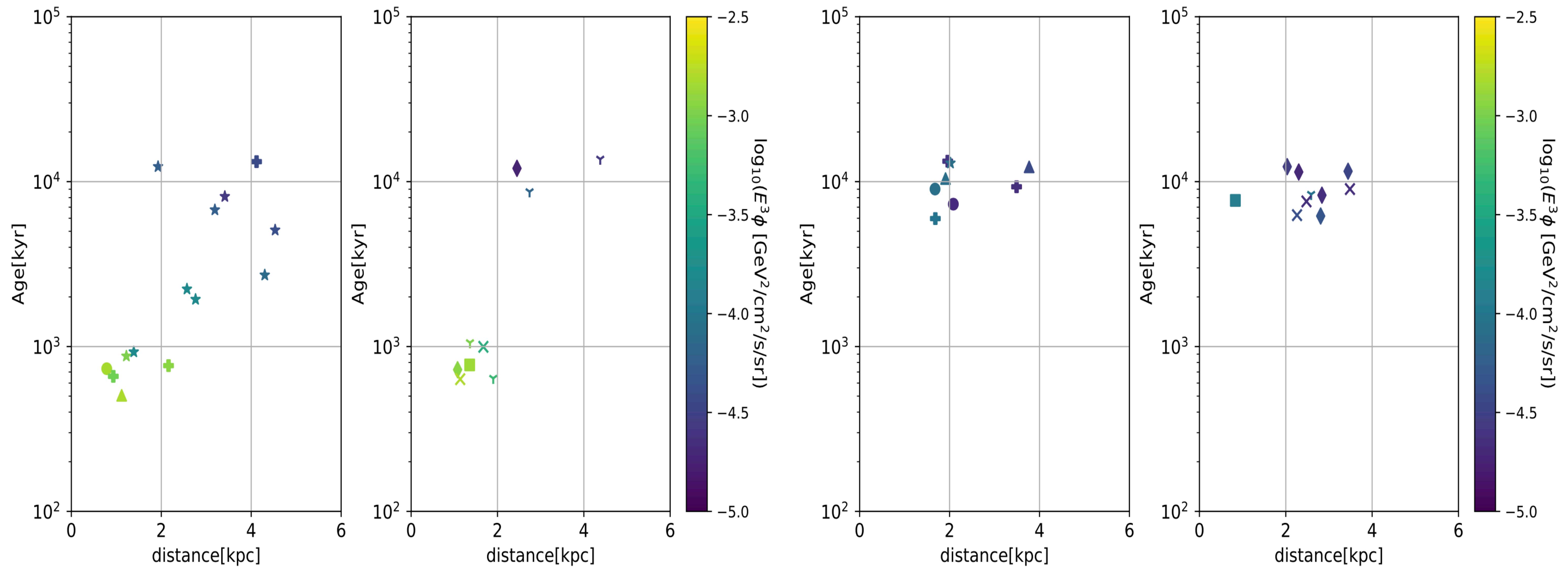

- For $A_P$ we find on average values slightly smaller than one.
- **ModD** promotes a higher number of simulations to be compatible with the data.

- The contribution from pulsars is significant for energies above 100 GeV.
- For energies lower than 200 GeV we do not find significant differences among the realizations.
- Above 300 GeV the peculiarities of each galaxy show up.



AMS-02 errors criteria to estimate the number of sources that are responsible for the most significant contribution of the pulsar $e^+$ emission:
"*we count all the pulsars that for at least one energy bin of AMS-02 produce a flux higher than the error of the flux in that bin*"

| | AMS-02 errors |
|---|---|
| ModA | 2.9 |
| ModB | 3.5 |
| ModC | 3.9 |
| ModD | 5.4 |




(a) ModA, $\chi^2_{red} < 1.5$

(b) ModA, worst $\chi^2_{red}$

- Only a few sources with a large flux are required to produce a good fit to the data.
- 1/2 sources with large maximum fluxes, ages between 400 and 2000 kyr and distances < 3 kpc.

## 6. Conclusions

- AMS-02 data can be used to constrain the characteristics of pulsars responsible for the $e^+$ emission.
- The smooth trend of the AMS-02 data disfavors scenarios with a huge number of bright sources.
- We do not find significant differences between the simulation setups, except for a few scenarios obtained with **ModD** → importance of the diffusion model.
- Our simulation setups are based on models calibrated on observations and are not based on ad hoc simulated parameters.