cosmogenic neutrinos with GRAND

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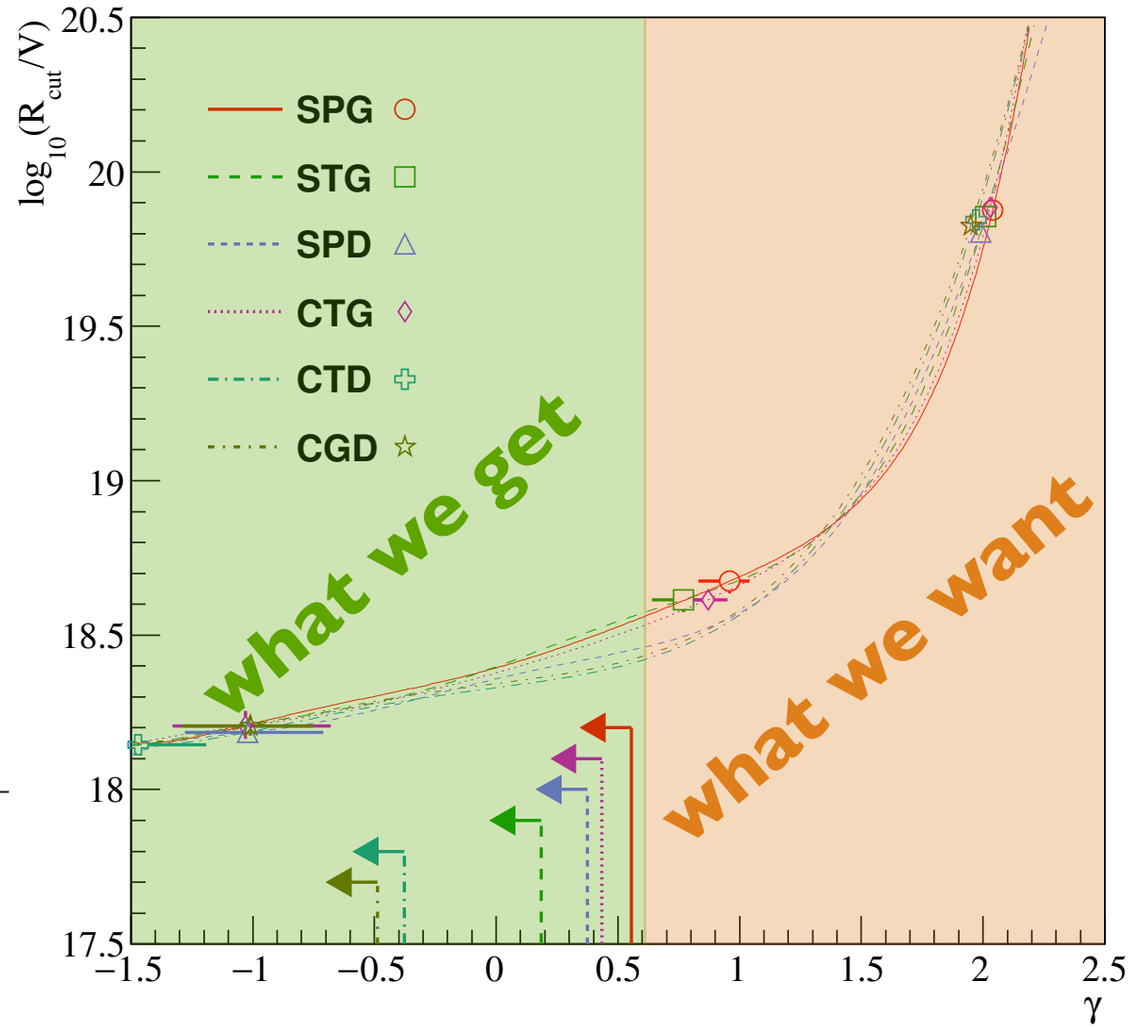
fitting the UHECR spectrum and composition

- spectral indices are very hard, incompatible with most acceleration models
- low spectral indices decrease the flux of neutrinos
- source evolution was not accounted for in the fit (how important is it?)

Pierre Auger Collaboration. JCAP 04 (2017) 038.



model	γ	$\log_{10}(R_{\rm cut}/{\rm V})$	D	$D(J)$	$D(X_{\rm max})$
SPG	$+0.96^{+0.08}_{-0.13}$	$18.68^{+0.02}_{-0.04}$	174.3	13.2	161.1
STG	$+0.77^{+0.07}_{-0.13}$	$18.62^{+0.02}_{-0.04}$	175.9	18.8	157.1
SPD	$-1.02^{+0.31}_{-0.26}$	$18.19^{+0.04}_{-0.03}$	187.0	8.4	178.6
CTG	$-1.03^{+0.35}_{-0.30}$	$18.21^{+0.05}_{-0.04}$	189.7	8.3	181.4
	$+0.87^{+0.08}_{-0.06}$	18.62 ± 0.02	191.9	29.2	162.7
CTD	$-1.47^{+0.28}_{*}$	$18.15^{+0.03}_{-0.01}$	187.3	8.8	178.5
CGD	$-1.01^{+0.26}_{-0.28}$	18.21 ± 0.03	179.5	7.9	171.6

*This interval extends all the way down to -1.5, the lowest value of γ we considered.

Table 8. Best-fit parameters and 68% uncertainties for the various propagation models we used (see table 7). For the CTG model we report the two main local minima, whose total deviances differ by 2.2.

fitting the Auger spectrum and composition

R. Alves Batista, R. M. de Almeida, B. Lago, K. Kotera. arXiv:1806.10879

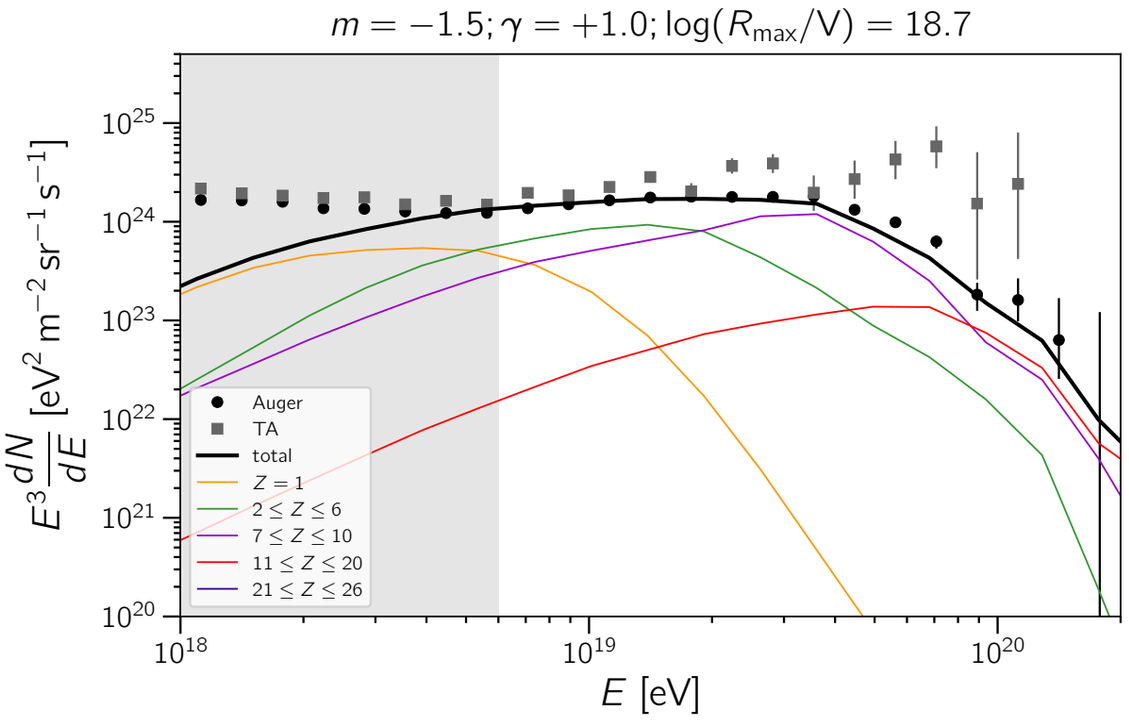
- single power-law spectrum (index α)
- cutoff at $E_{max}=ZR_{max}$
- five injected species at source (p, He, N, Si, Fe)
- source evolution models: $(1+z)^m$, SFR, AGN, GRB
- EBL model: Gilmore et al. 2012

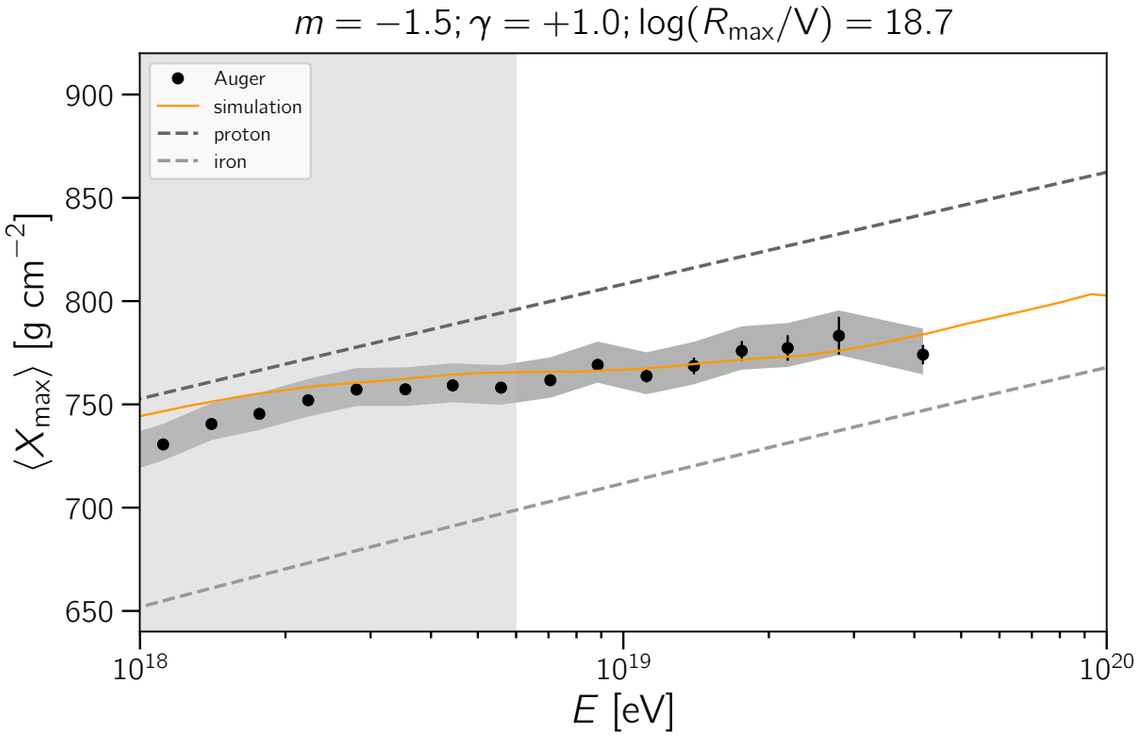
Table 1. Best-fit parameters for specific spectral indices.

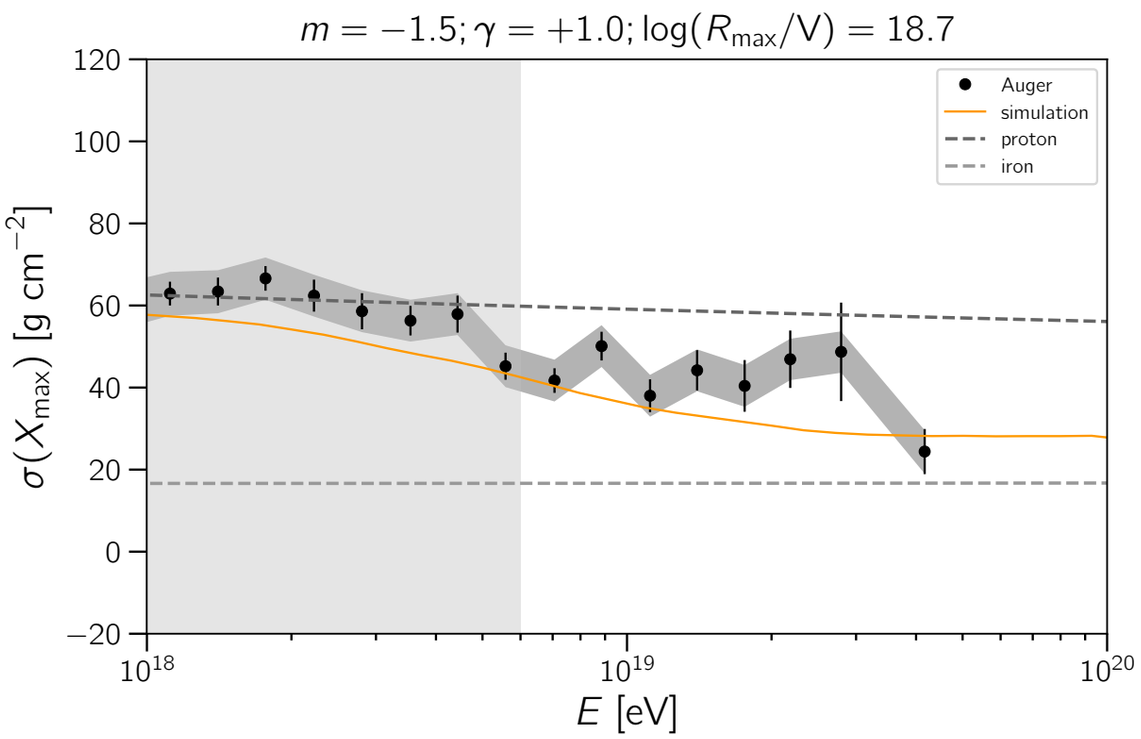
m	α	$\log(R_{\rm max}/{\rm V})$	$f_{\rm p}$	$f_{\rm He}$	$f_{\rm N}$	$f_{\rm Si}$	$f_{\rm Fe}$	D
-1.5	+1.00	18.7	0.0003	0.0002	0.8867	0.1128	0.0000	1.46
SFR	+0.80	18.6	0.0764	0.1802	0.6652	0.0781	0.0001	1.63
AGN	+0.80	18.6	0.1687	0.1488	0.6116	0.0709	0.0000	1.59
GRB	+0.80	18.6	0.1362	0.1842	0.6059	0.0738	0.0000	1.60

fitting the Auger data (+ source evolution)

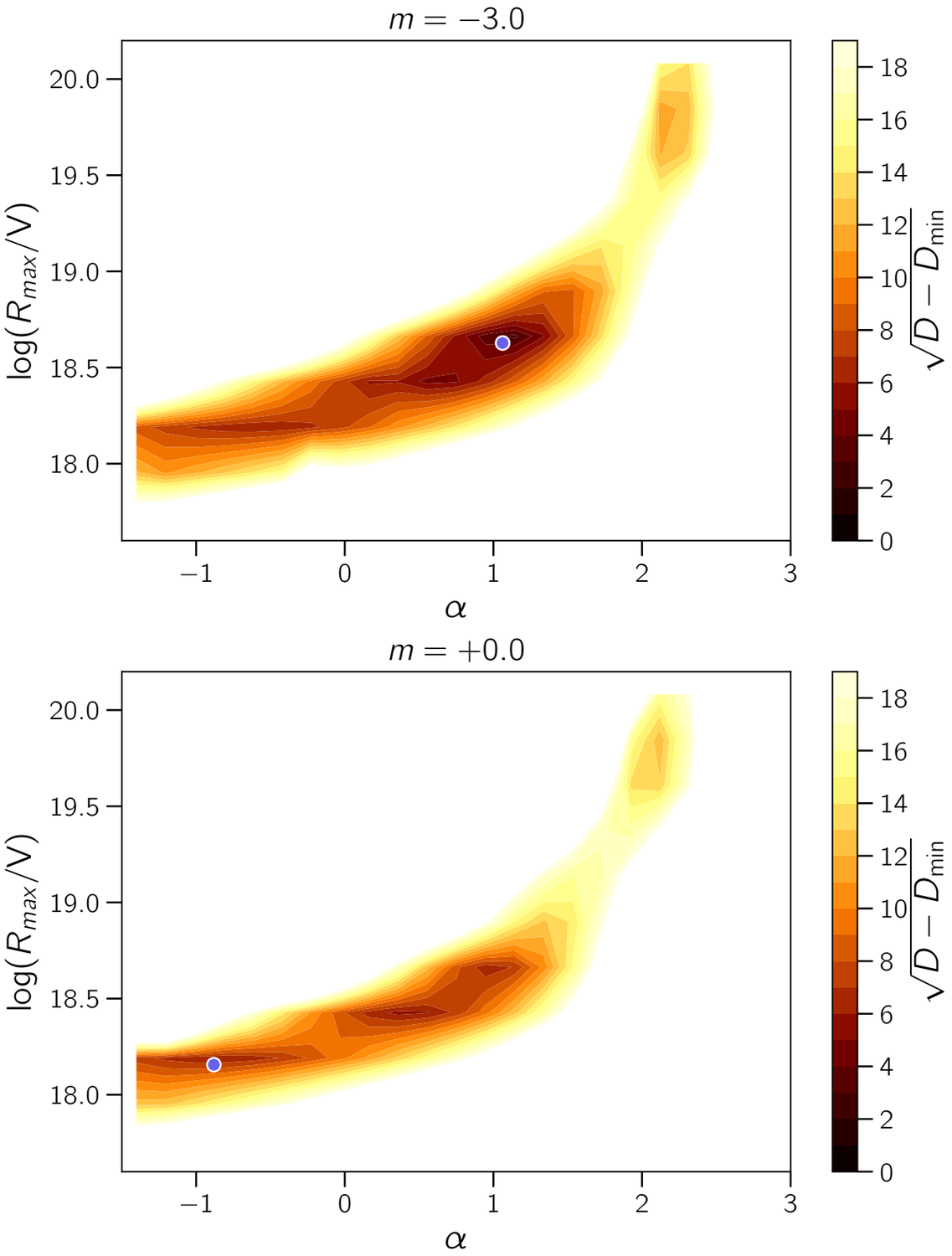
R. Alves Batista, R. M. de Almeida, B. Lago, K. Kotera. arXiv:1806.10879

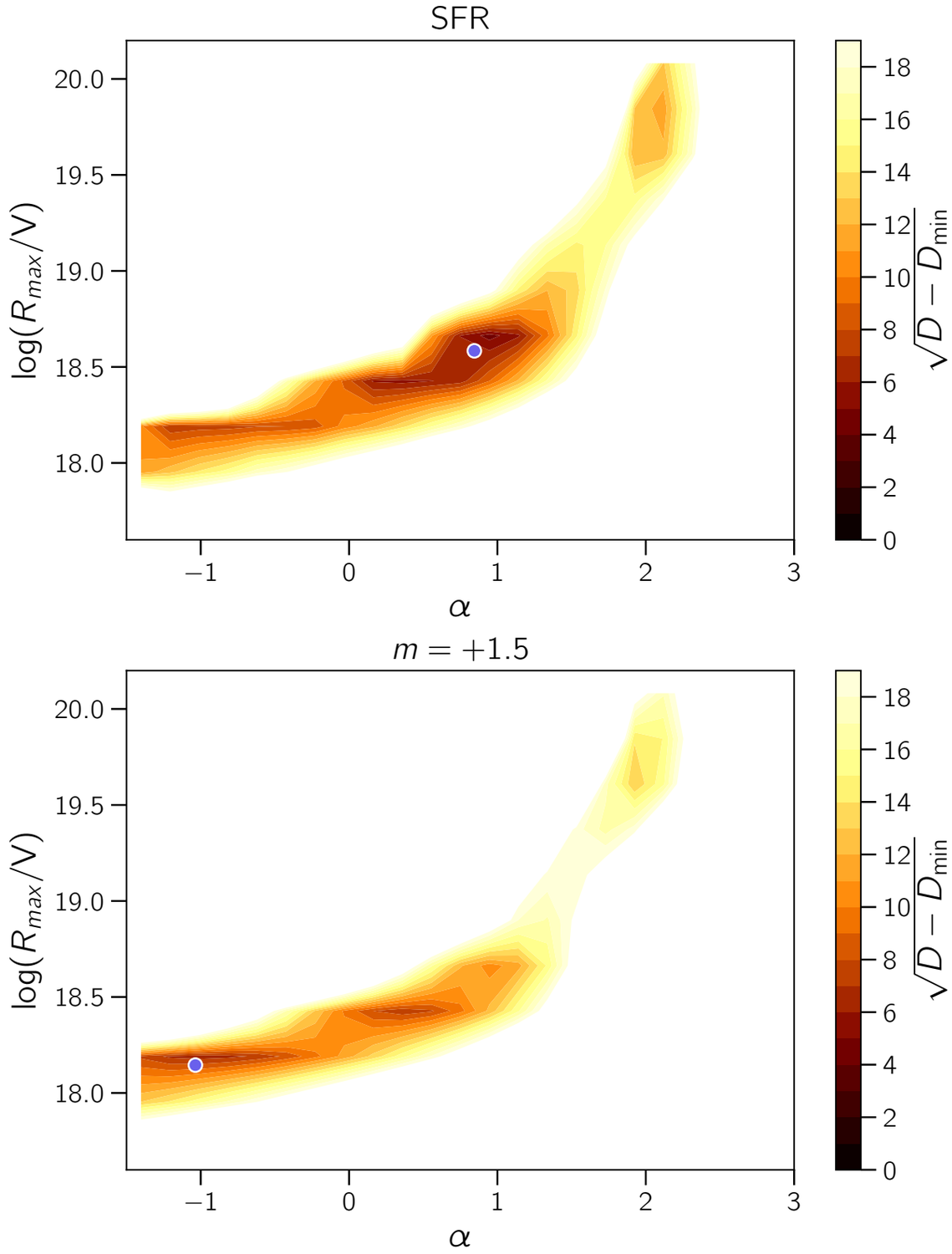






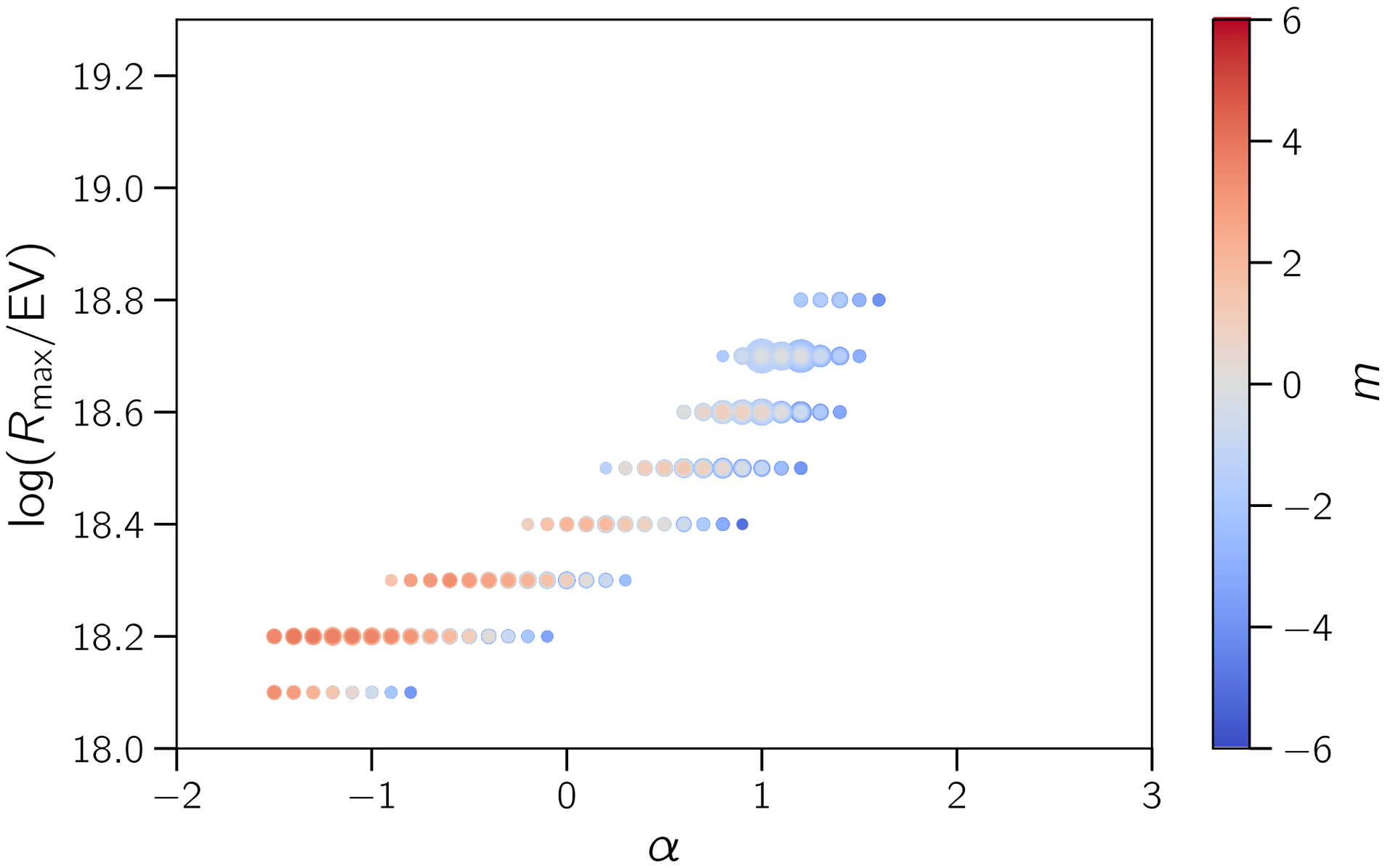
fitting the Auger spectrum and composition





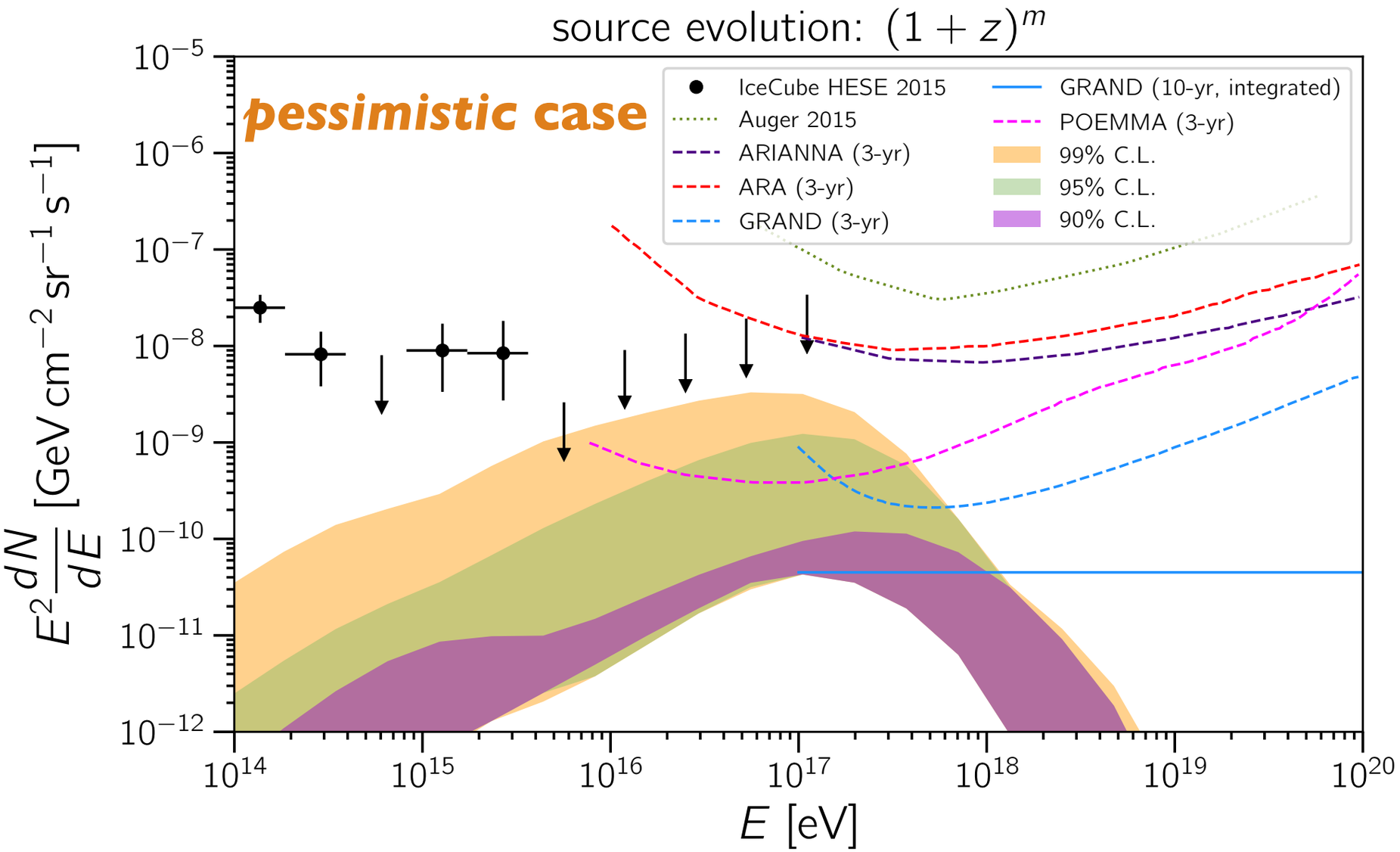
fitting the Auger data: negative source evolution?

R. Alves Batista, R. M. de Almeida, B. Lago, K. Kotera. arXiv:1806.10879



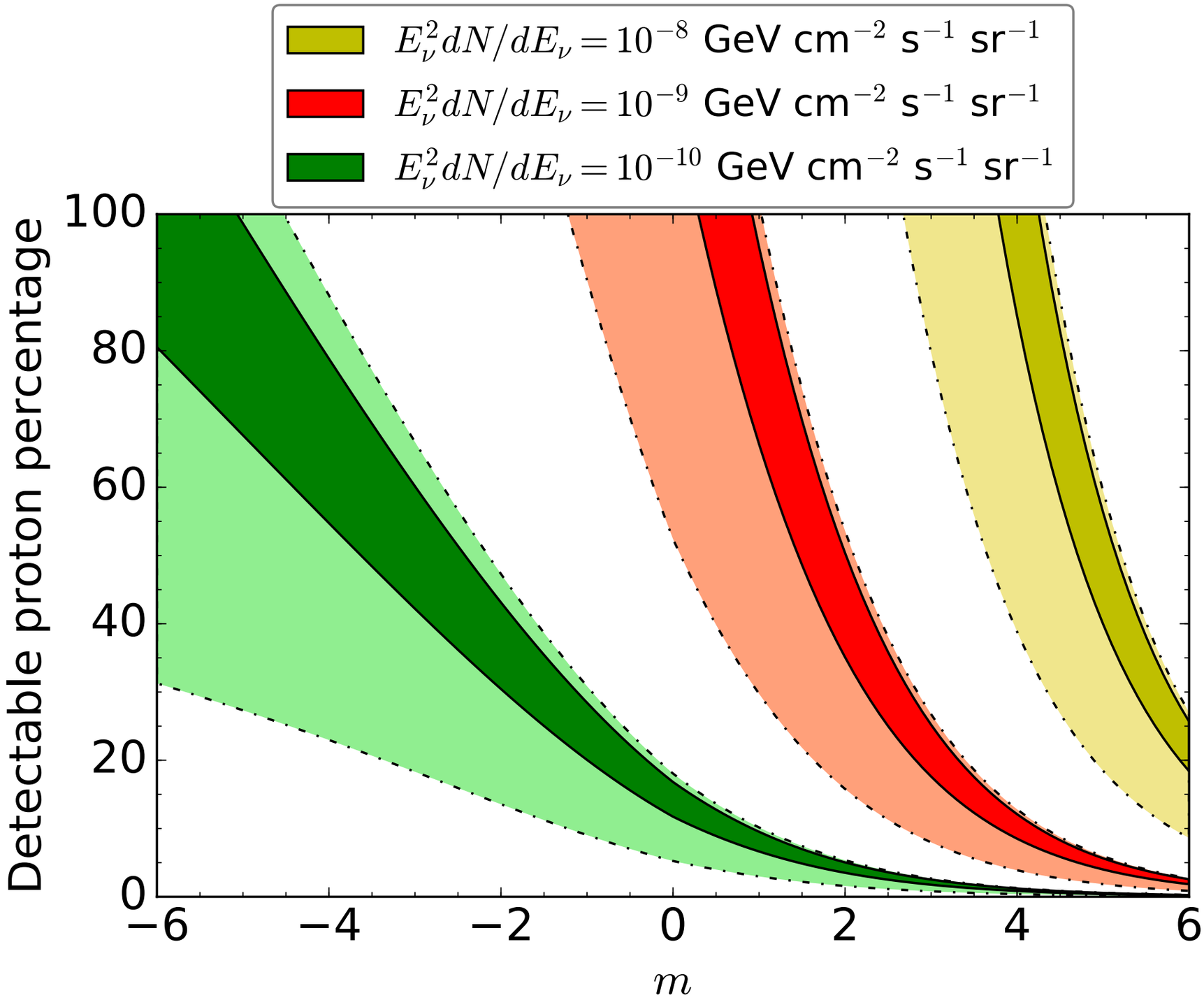
cosmogenic neutrino flux

R. Alves Batista, R. M. de Almeida, B. Lago, K. Kotera. arXiv:1806.10879



proton fraction at 1 EeV

A. van Vliet, R. Alves Batista, J. Hörandel. In preparation.



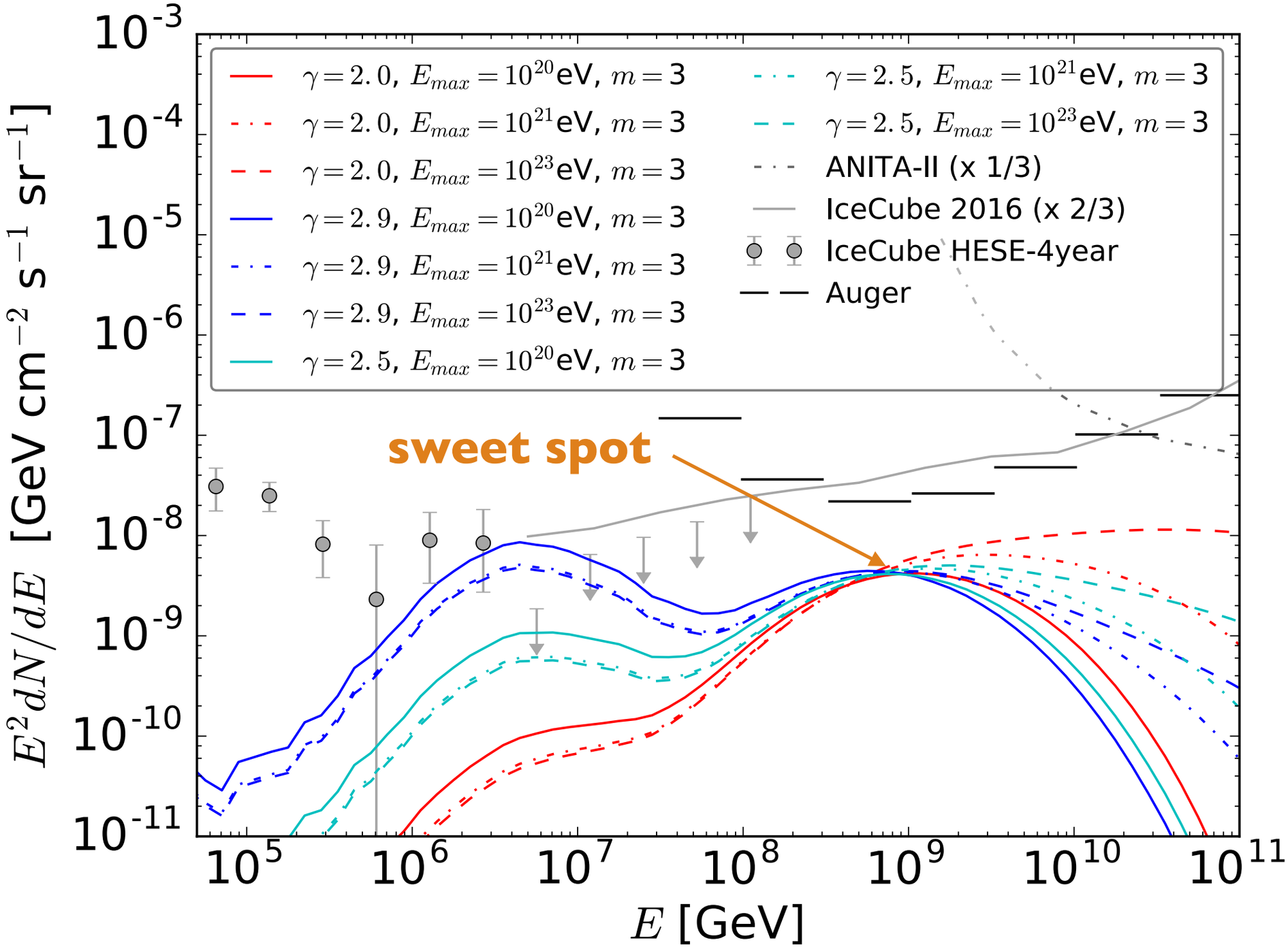
outlook

- Auger fit redone including source evolution
- in the limit of no evolution, we retrieve Auger's best-fit (agreement better than 1%)
- the fits suggest a negative source evolution for UHECR sources
- low spectral index vs. low source evolution degeneracy, which one dominates?
- the most pessimistic Auger-compatible cases are a factor 3 below GRAND 200k projected sensitivity for **6 years**
- GRAND may be able to reach the required level of sensitivity with ~10 years of data
- GRAND will have enough sensitivity to set limits on the fraction of UHE protons even in pessimistic scenarios with negative source evolution.

backup

proton fraction at 1 EeV

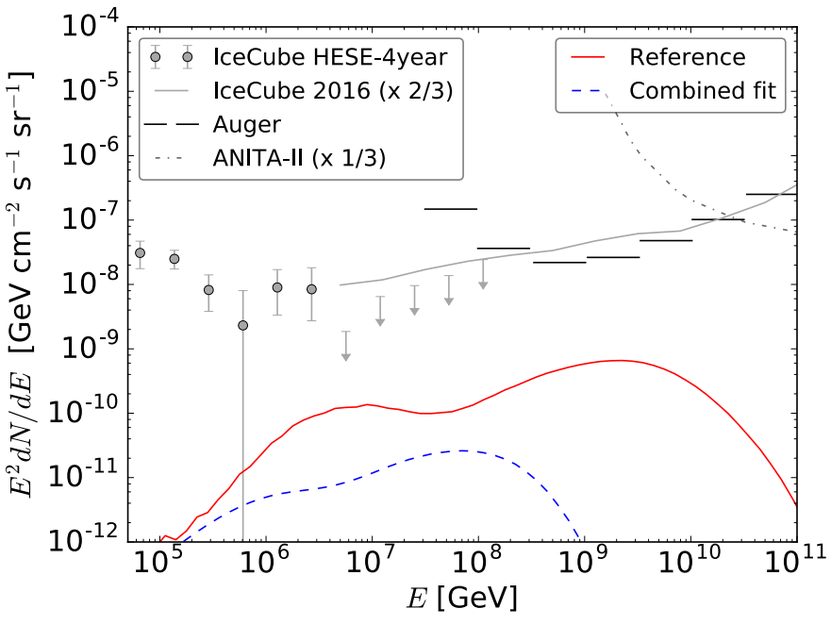
A. van Vliet, R. Alves Batista, J. Hörandel. In preparation.



interlude: what does the neutrino spectrum depend on?

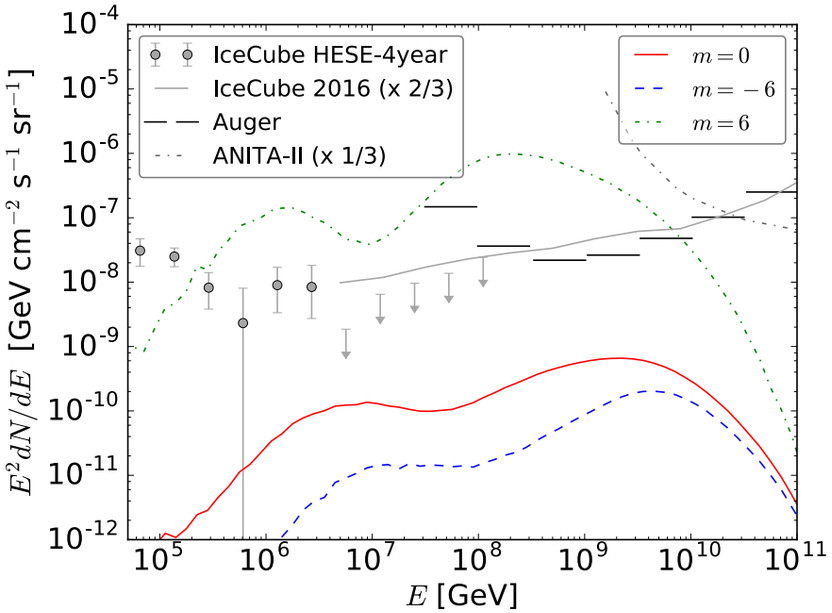
A. van Vliet, J. Hörandel, R. Alves Batista. PoS (ICRC2017) 562. arXiv:1707.04511

Auger best fit

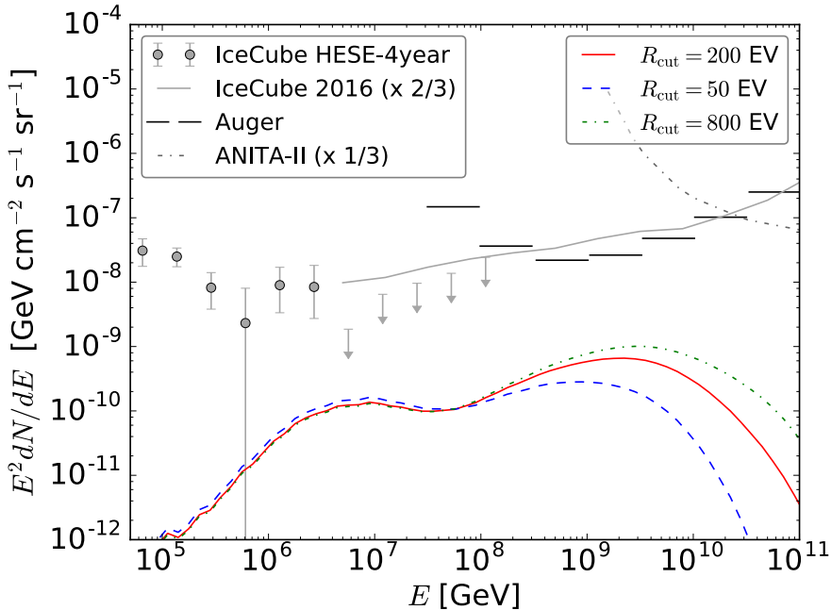


- what parameters are more relevant to compute the cosmogenic neutrino spectrum?
- let's adopt a reference scenario to get an idea: R_{cut}=200 EV, m=0, α=2.5
- we vary one parameter at a time

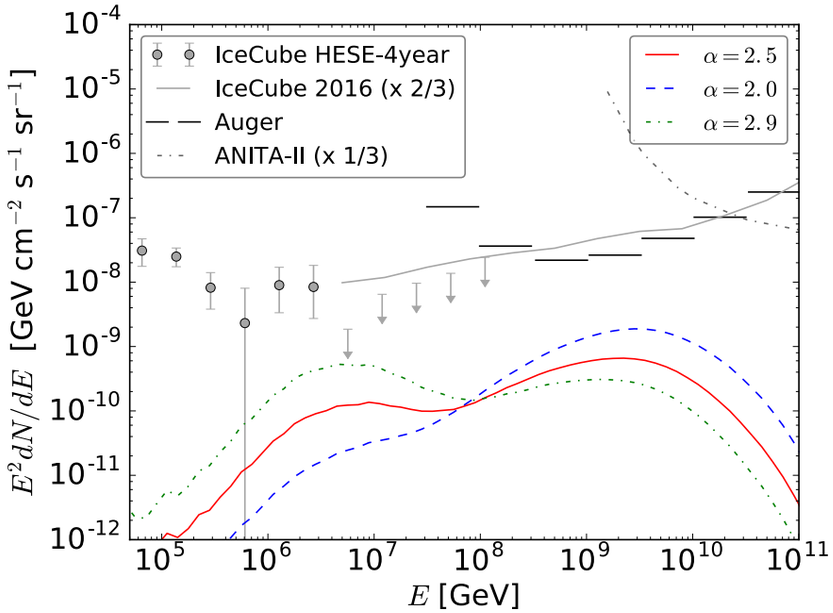
source evolution



maximum rigidity



spectral index



sources of uncertainties on neutrino fluxes

preliminary

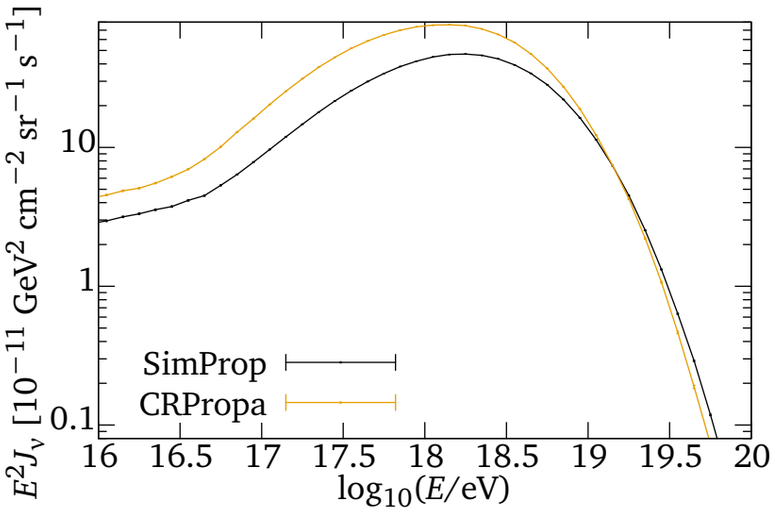
R. Alves Batista, D. Boncioli, A. di Matteo, A. van Vliet. In preparation

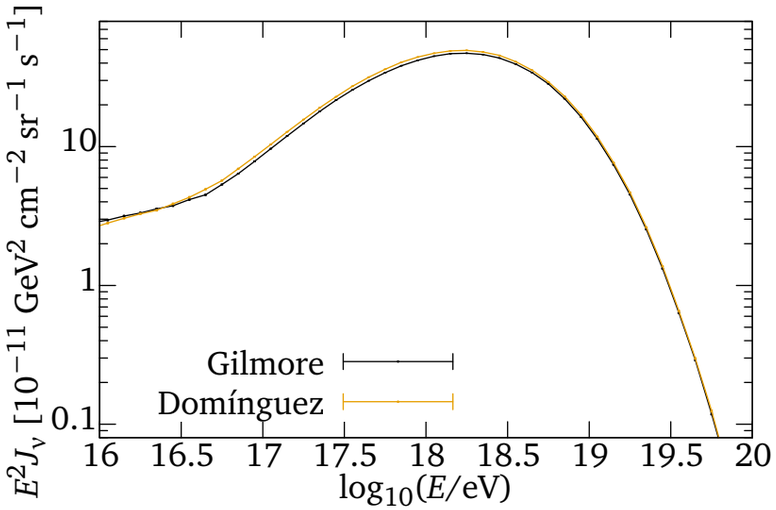
simulation codes

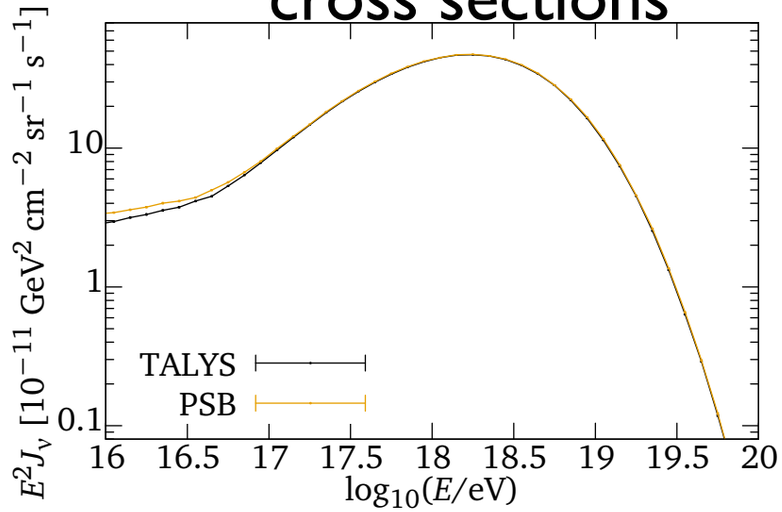
EBL models

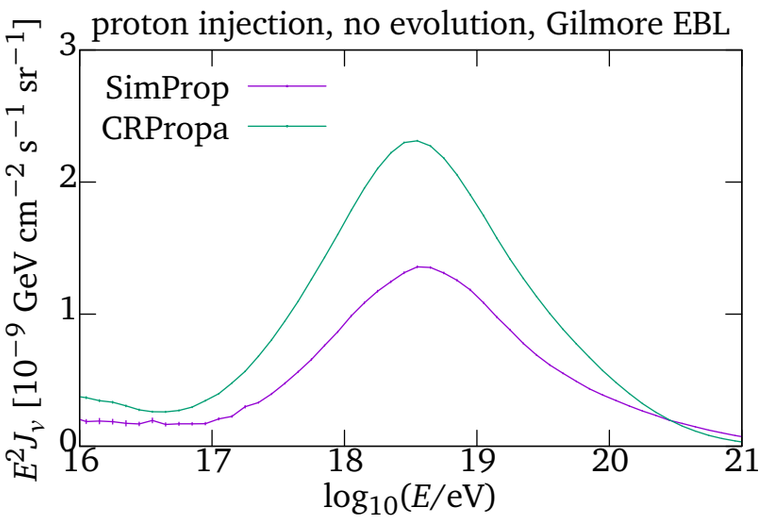
photodisintegration cross sections

nitrogen (hard)









- EBL models don't affect the neutrino spectrum significantly
- photodisintegration cross sections have a small impact on the neutrino spectrum at E~10 PeV
- different simulation codes give different results for the neutrino fluxes.
- CRPropa's treatment is more complete and uses fewer simplications in the treatment of interactions