About cross sections relevant for UHECRs

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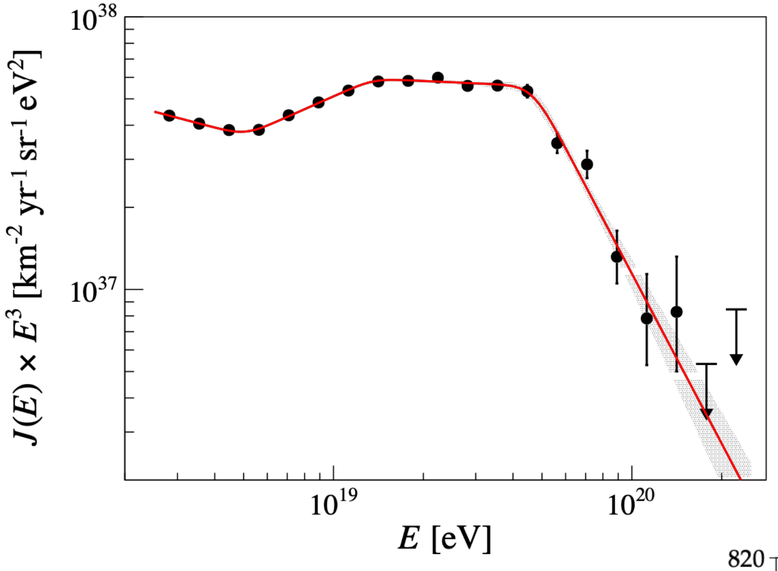
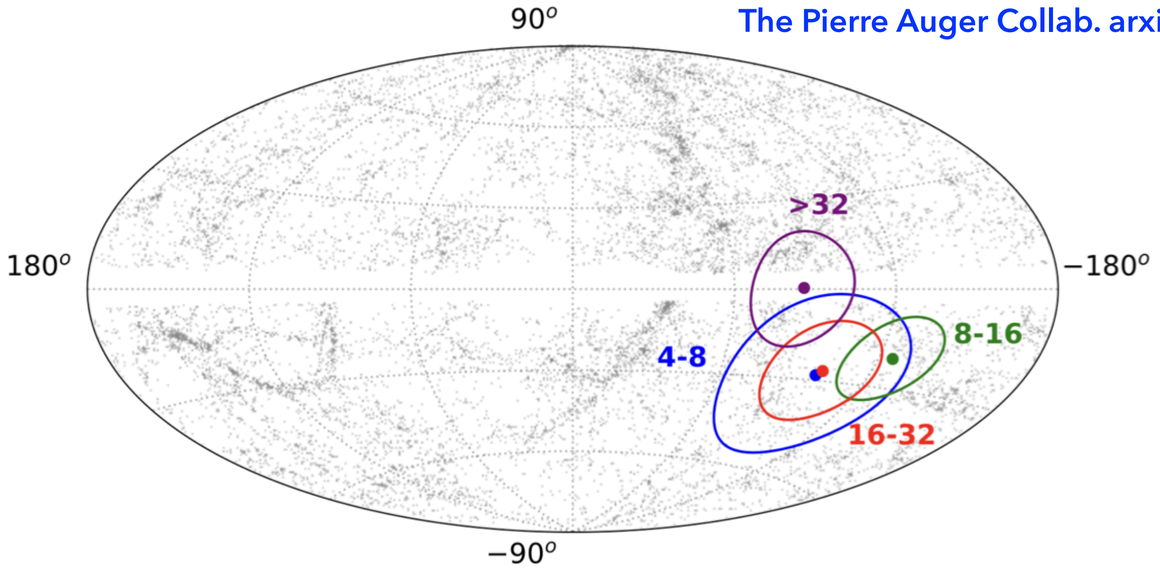
XSCRC24, 16-18 October 2024

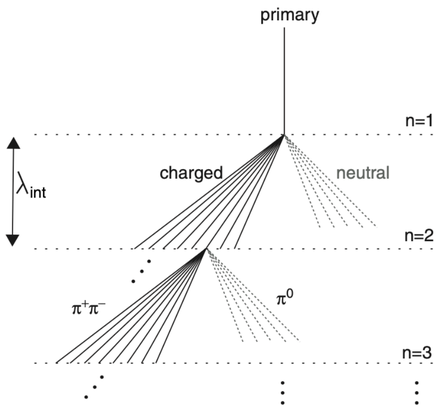
WHY ARE WE INTERESTED IN NUCLEAR REACTIONS IN THE CONTEXT OF UHECRS?

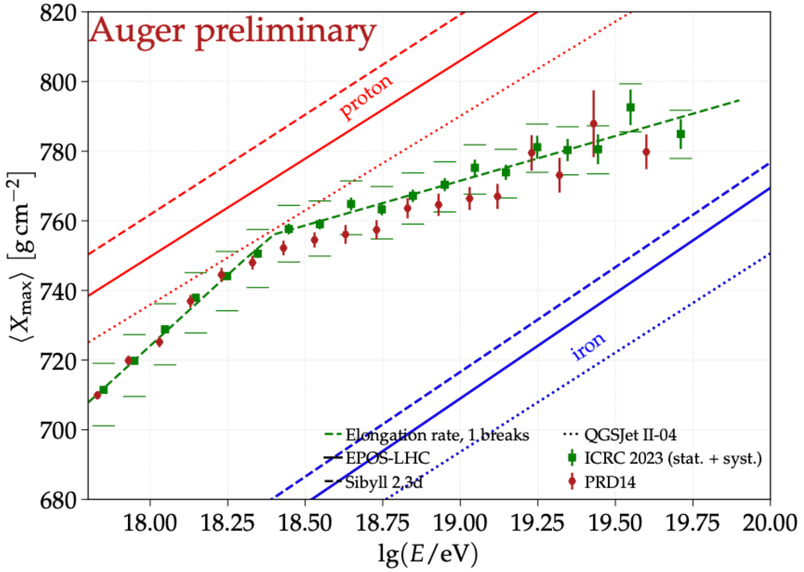
The Pierre Auger Collab. PRD&PRL 2020

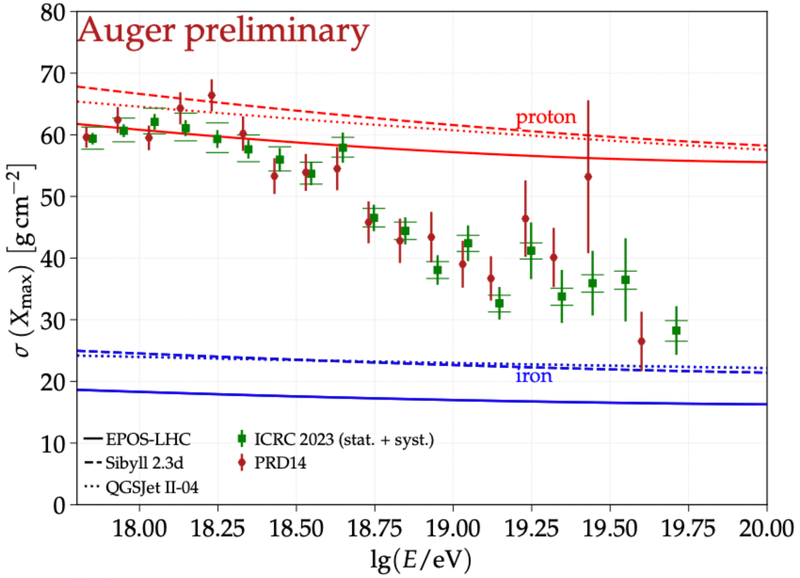


The Pierre Auger Collab. arxiv:2408.05292



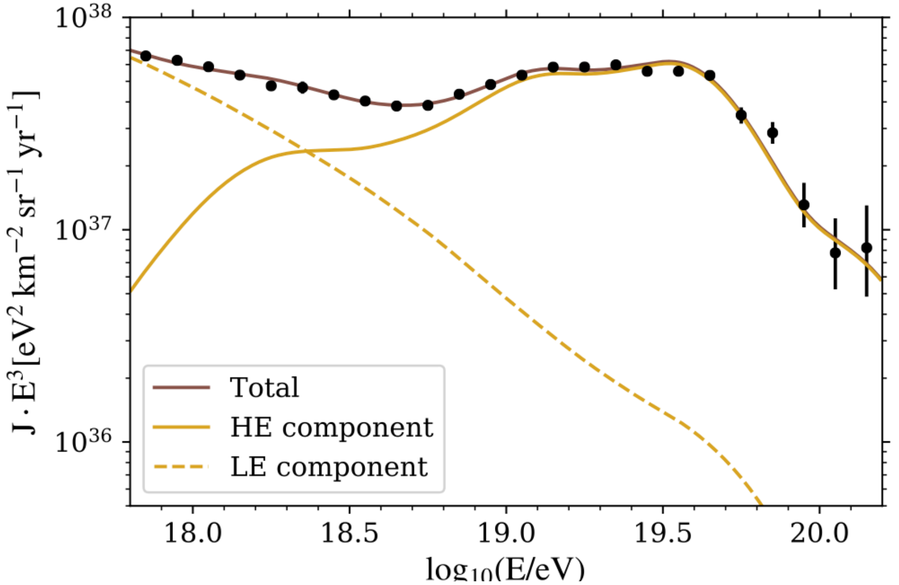


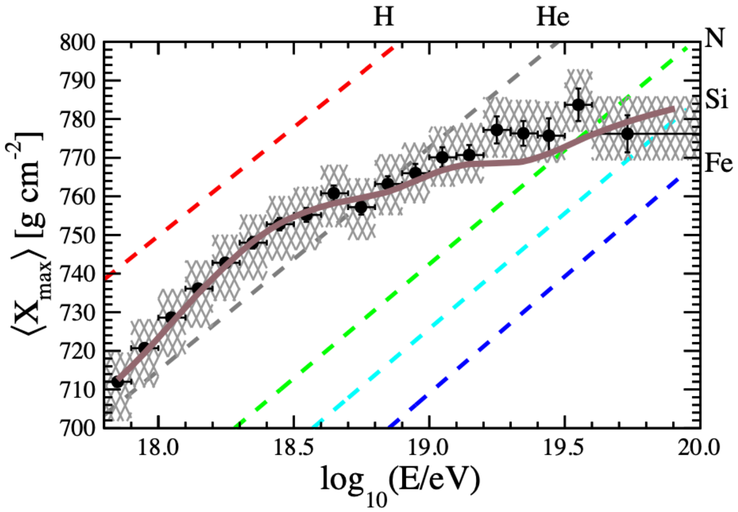


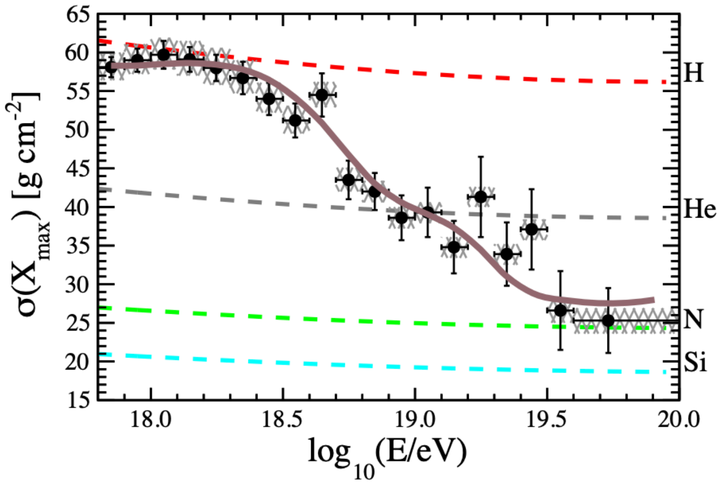


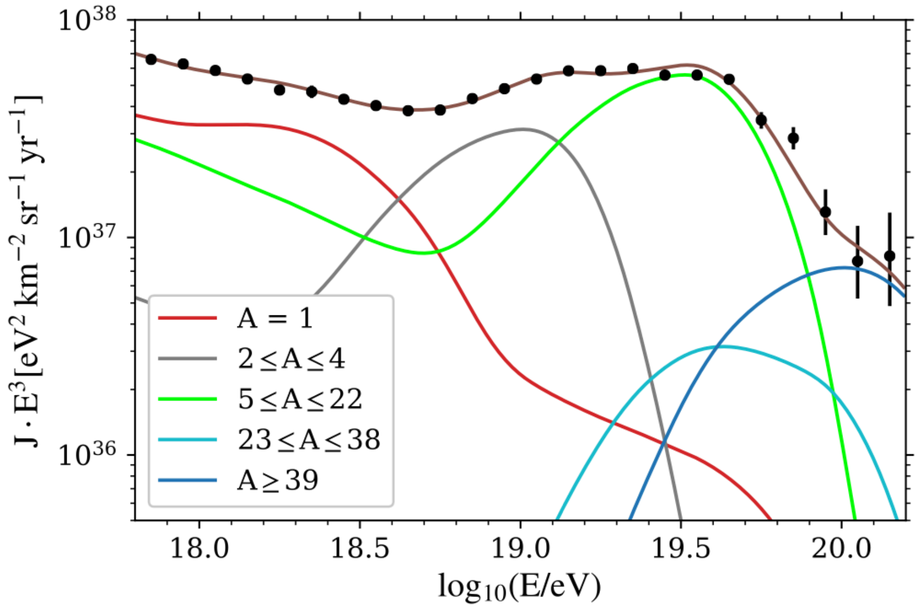
The Pierre Auger Collab. ICRC23

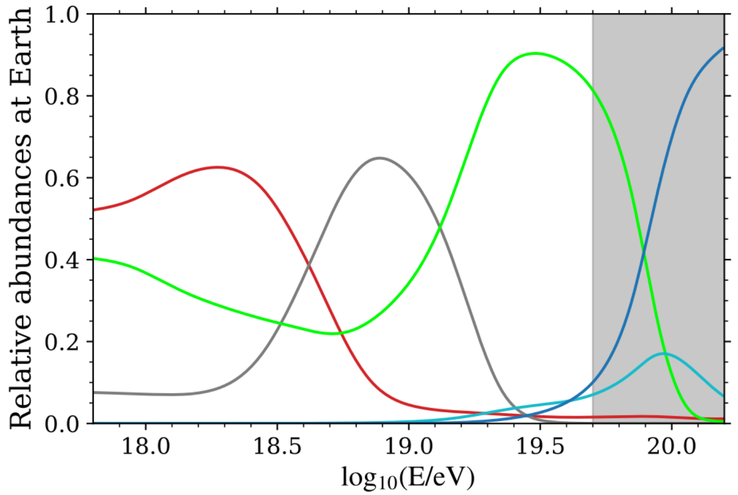
ASTROPHYSICAL SCENARIOS EXPLAINING UHECR DATA





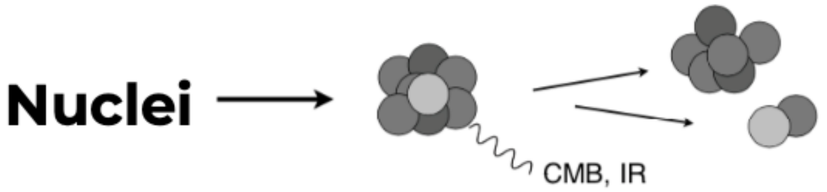


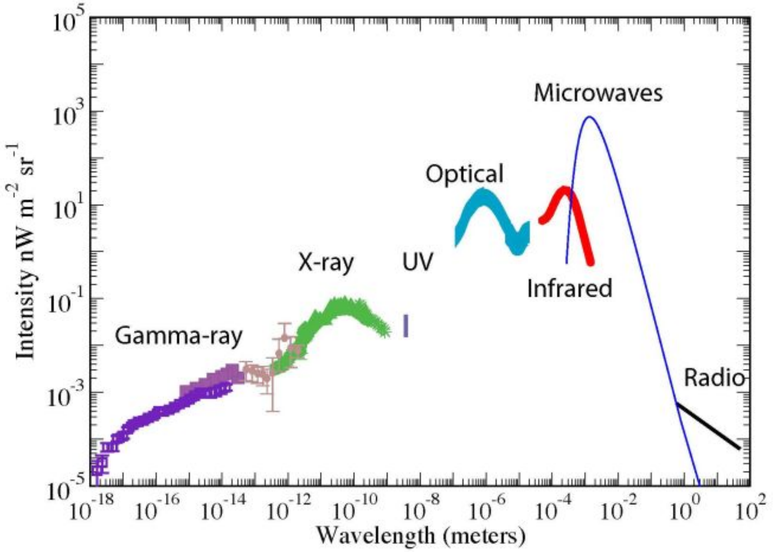




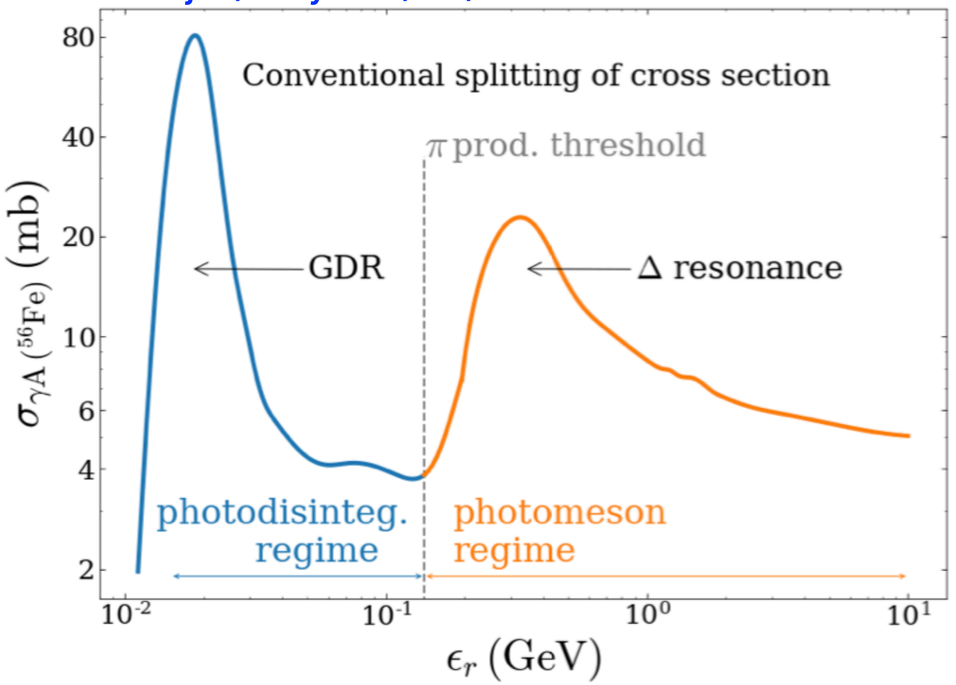
Aloisio, Berezinsky & Blasi JCAP 2014; Mollerach & Roulet PRD 2020; Das et al, Eur.Phys.J. 2021; Luce et al, ApJ 2022;**The Auger Collab. JCAP 2023**

PHOTO-DISINTEGRATION OF NUCLEI IN EXTRAGALACTIC SPACE





Morejon, Fedynitch, DB, Biehl & Winter JCAP 2019



- Regimes of photo-disintegration reactions
  - Giant Dipole Resonance (GDR): protons and neutrons can be considered as penetrating fluids; absorption of photons determines vibrations; ejection of one/ two nucleons is dominant
  - Quasi-Deuteron (QD), 20-150 MeV: the photon wavelength becomes comparable with the nuclear dimensions; photon interacts with nucleon pair; ejection of pair + possibly other nucleons
- Conservation of Lorentz factor

Photodisintegration implemented in several UHECR propagation codes, such as

CRPropa (Alves Batista et al, JCAP 2022), SimProp (Aloisio, DB, di Matteo, Grillo, Petrera, Salamida JCAP 2017), Prince (Fedynitch & Heinze)…

ASTROPHYSICAL SCENARIOS EXPLAINING UHECR DATA

- Uncertainties to be taken into account
  - UHECR measurements:
    - Energy scale: 14%
    - Xmax: 6-9 g/cm^2
  - Shower models
  - Propagation models (cross section models and extragalactic background light models)

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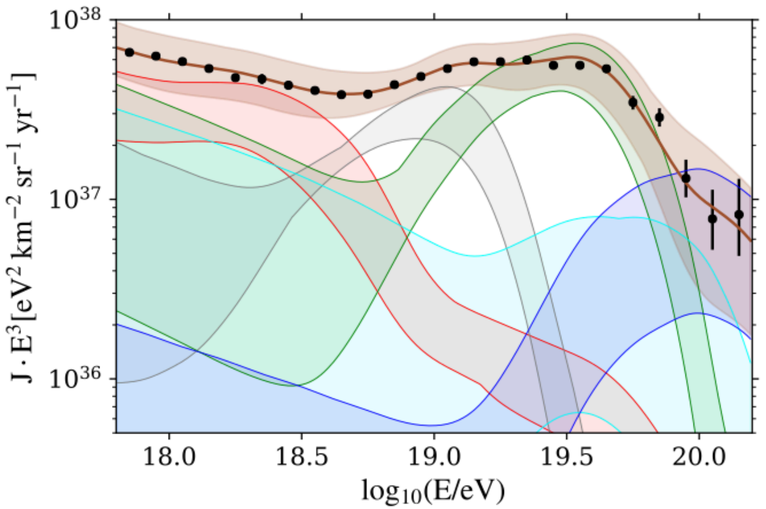
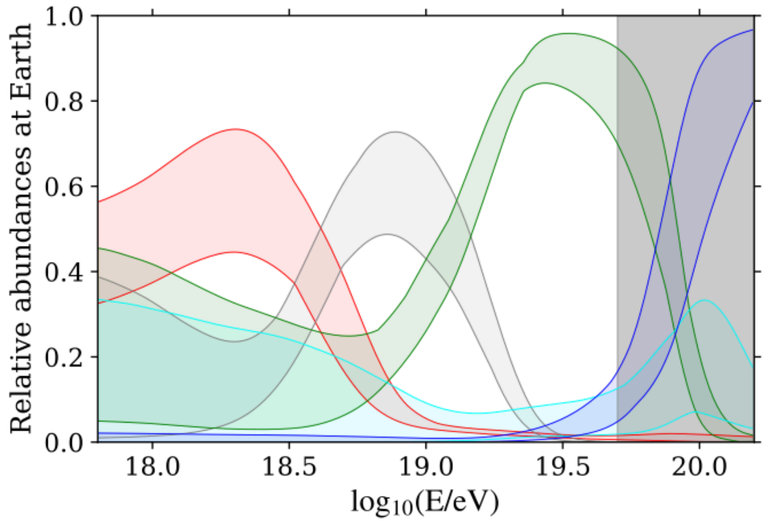
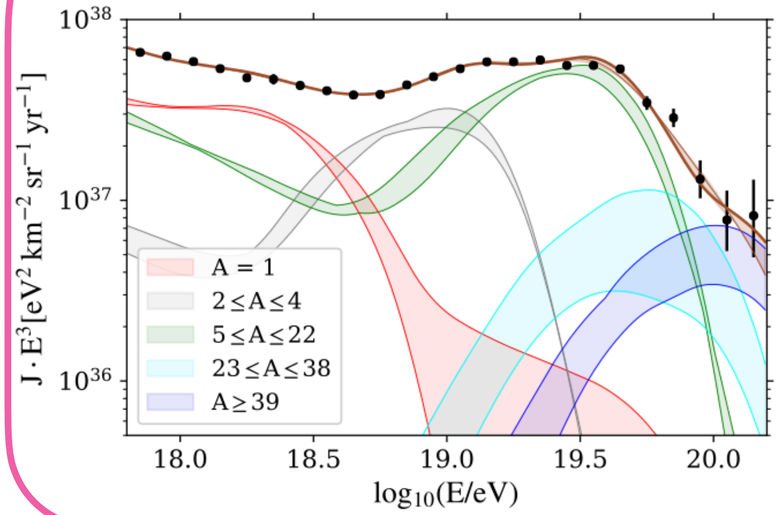
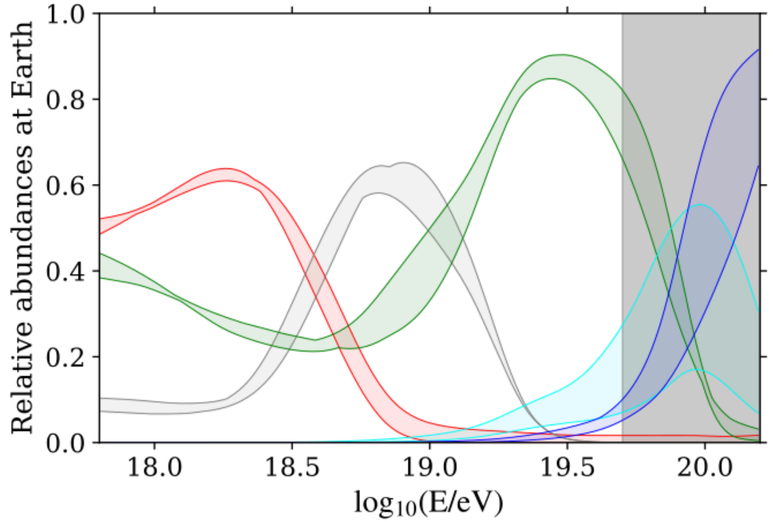




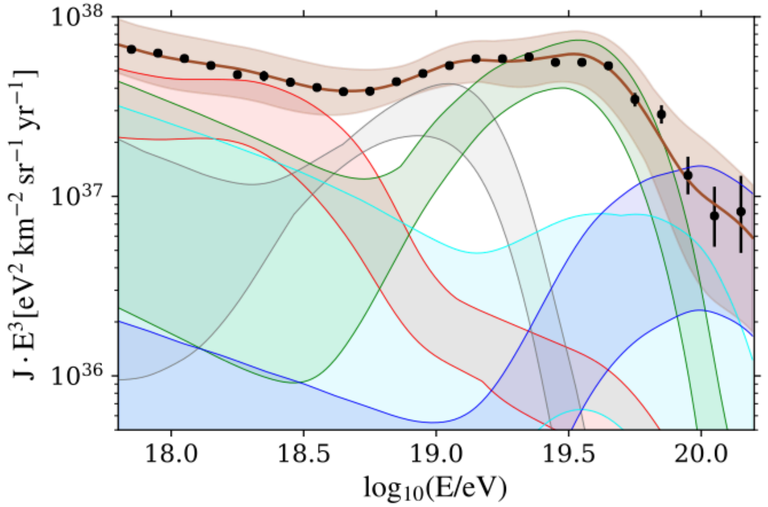
The Pierre Auger Collab. JCAP 2024

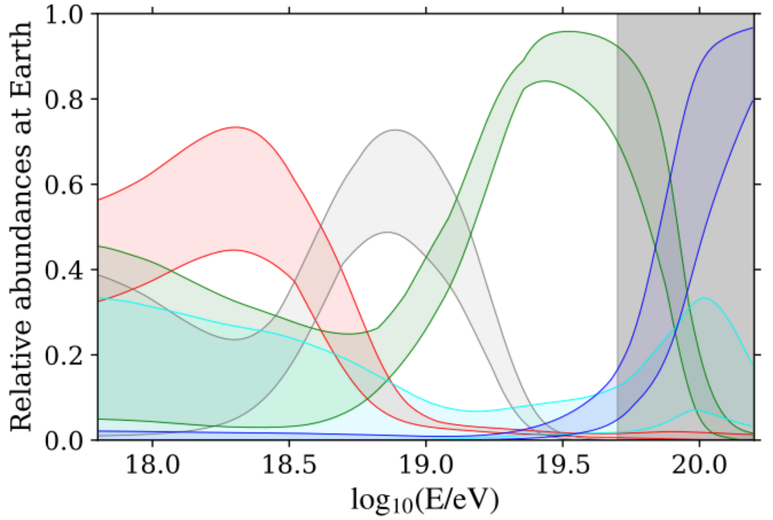
ASTROPHYSICAL SCENARIOS EXPLAINING UHECR DATA





	TALYS		PSB	
Gilmore EBL	LE	HE	LE	HE
$\mathcal{L}_0/(10^{44}\,\mathrm{erg\,Mpc^{-3}\,yr^{-1}})$ *	11.4	5.1	11.1	4.9
γ	3.52 ± 0.03	-1.99 ± 0.11	3.51 ± 0.03	-1.89 ± 0.18
$\log_{10}(R_{\rm cut}/{\rm V})$	>19.4	18.15 ± 0.01	> 19.5	18.16 ± 0.02
$I_{\rm H}$ (%)	48.7	0.0	49.1	0.2
$I_{\rm He}$ (%)	7.3	23.6	11.1	48.3
$I_{\rm N}$ (%)	44.0	72.1	39.8	41.5
$I_{\rm Si}$ (%)	0.0	1.3	0.0	8.5
$I_{\rm Fe}$ (%)	0.0	3.1	0.0	1.5
$\delta_{\rm HIM}$	1.0 (limit)		$0.96^{+0.04}_{-0.12}$	
D_J (N_J)	56.6 (24)		50.7 (24)	
$D_{X_{\rm max}}$ ($N_{X_{\rm max}}$)	516.5 (329)		529.0 (329)	
D (N)	573.1 (353)		579.7 (353)	





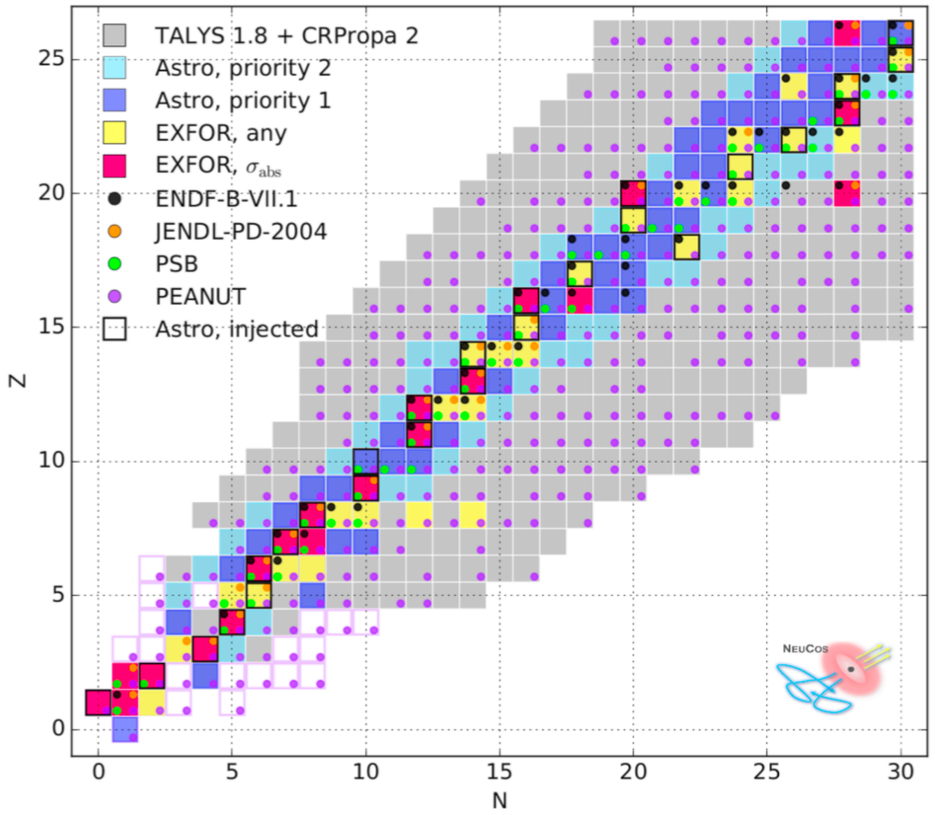
TALYS	EPOS-LHC		SIBYLL 2.3d	
Gilmore EBL	LE	HE	LE	HE
$\mathcal{L}_0/(10^{44}\,\mathrm{erg\,Mpc^{-3}\,yr^{-1}})$ *	11.4	5.1	10.8	4.9
γ	3.52 ± 0.03	-1.99 ± 0.11	3.40 ± 0.02	-1.30 ± 0.19
$\log_{10}(R_{\rm cut}/{\rm V})$	>19.4	18.15 ± 0.01	18.26 ± 0.05	18.19 ± 0.02
$I_{\rm H}$ (%)	48.7	0.0	15.6	0.0
$I_{\rm He}$ (%)	7.3	23.6	46.2	20.9
$I_{\rm N}$ (%)	44.0	72.1	38.2	70.7
$I_{\rm Si}$ (%)	0.0	1.3	0.0	5.4
$I_{\rm Fe}$ (%)	0.0	3.1	0.0	3.0
D_J (N_J)	56.6 (24)		42.7 (24)	
$D_{X_{\rm max}}$ ($N_{X_{\rm max}}$)	516.5 (329)		592.2 (329)	
D (N)	573.1 (353)		634.9 (353)	

The Pierre Auger Collab. JCAP 2024

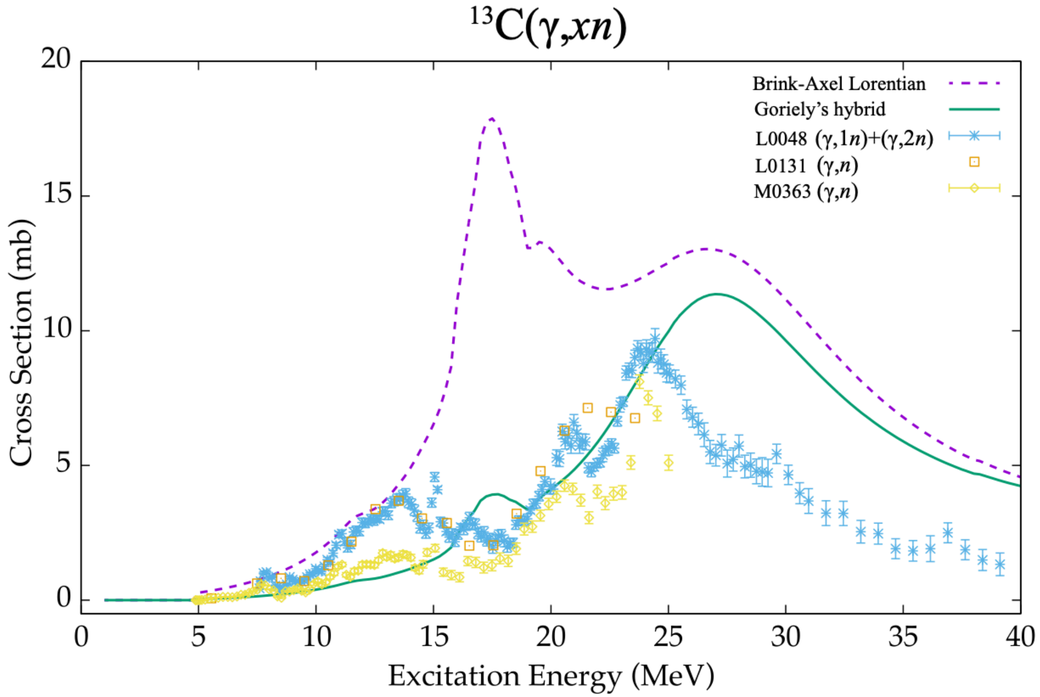
UNCERTAINTIES IN PHOTO-DISINTEGRATION

- Available measurements are sparse

DB, Fedynitch & Winter, Sci. Reports 2017



Tamii et al, PANDORA project, Eur.Phys.J. 2023

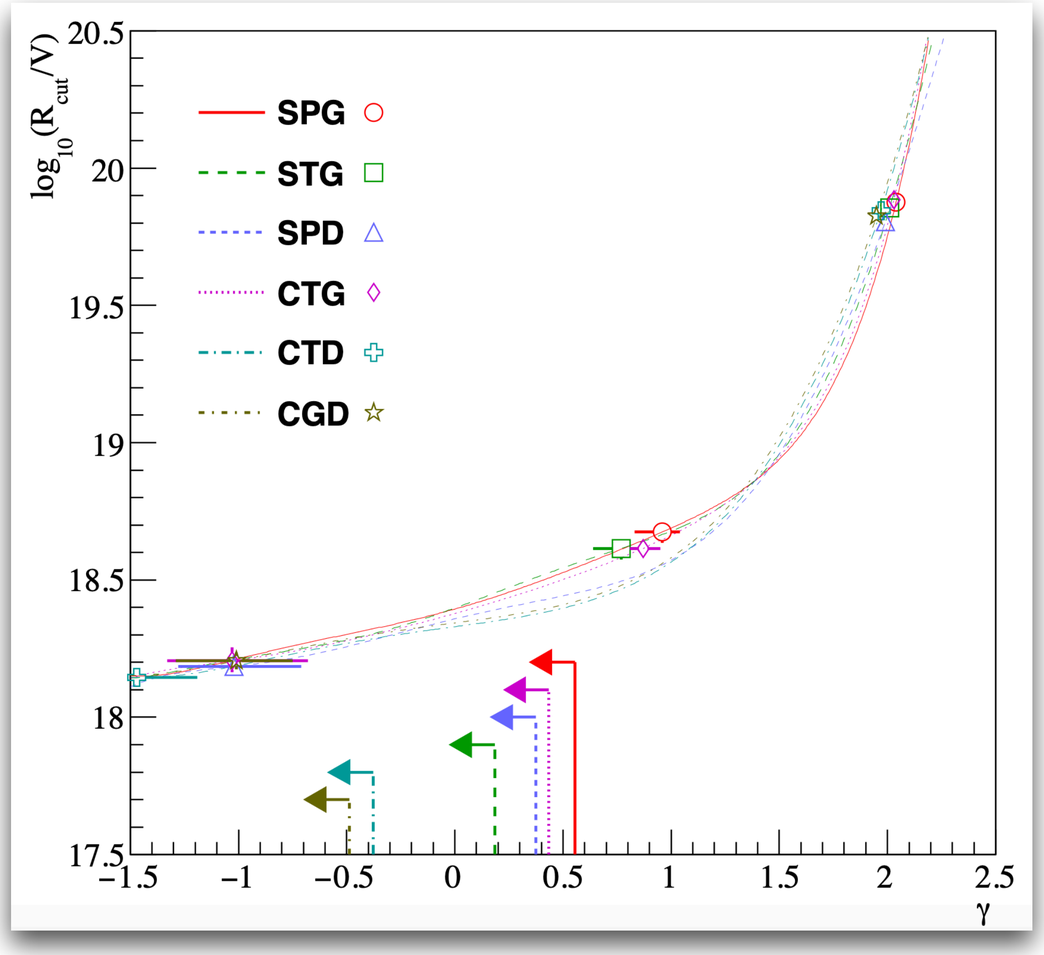


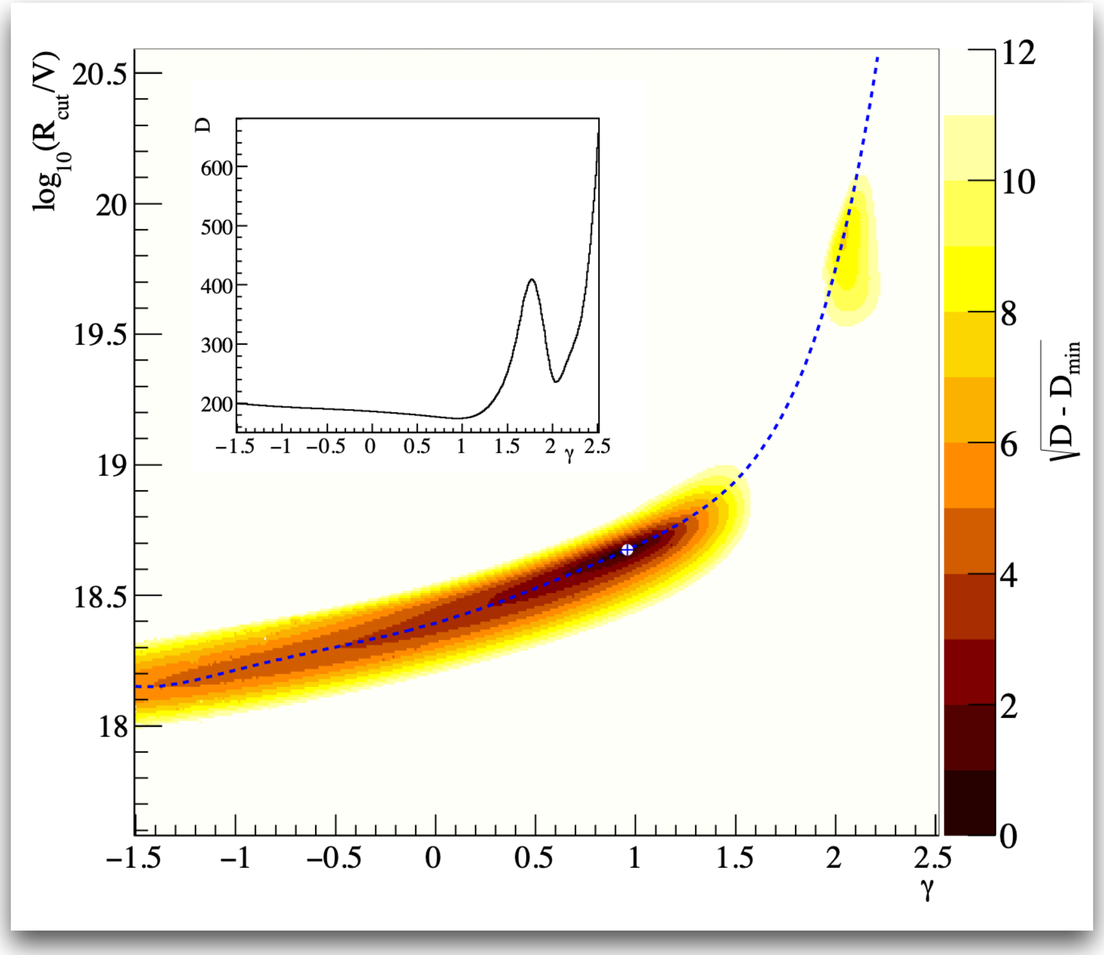
- Theoretical models do not always reproduce (available) data

- Studies of sensitivity of UHECR data to uncertainties in photo-disintegration: Khan et al Astropart.Phys. 2005; Allard et al JCAP 2006; Alves Batista, **DB**, di Matteo, van Viet & Walz JCAP2015; The Pierre Auger Collab. JCAP 2017; **DB**, Fedynitch & Winter, Sci.Report 2017; Alves Batista, **DB**, di Matteo & van Vliet JCAP2019; Heinze, Fedynitch, **DB** & Winter ApJ 2019;The Pierre Auger Collab. JCAP 2023; Kido et al. Astropart.Phys. 2023
- New measurements: The PANDORA project, Eur.Phys.J. 2023

BACKUP SLIDES

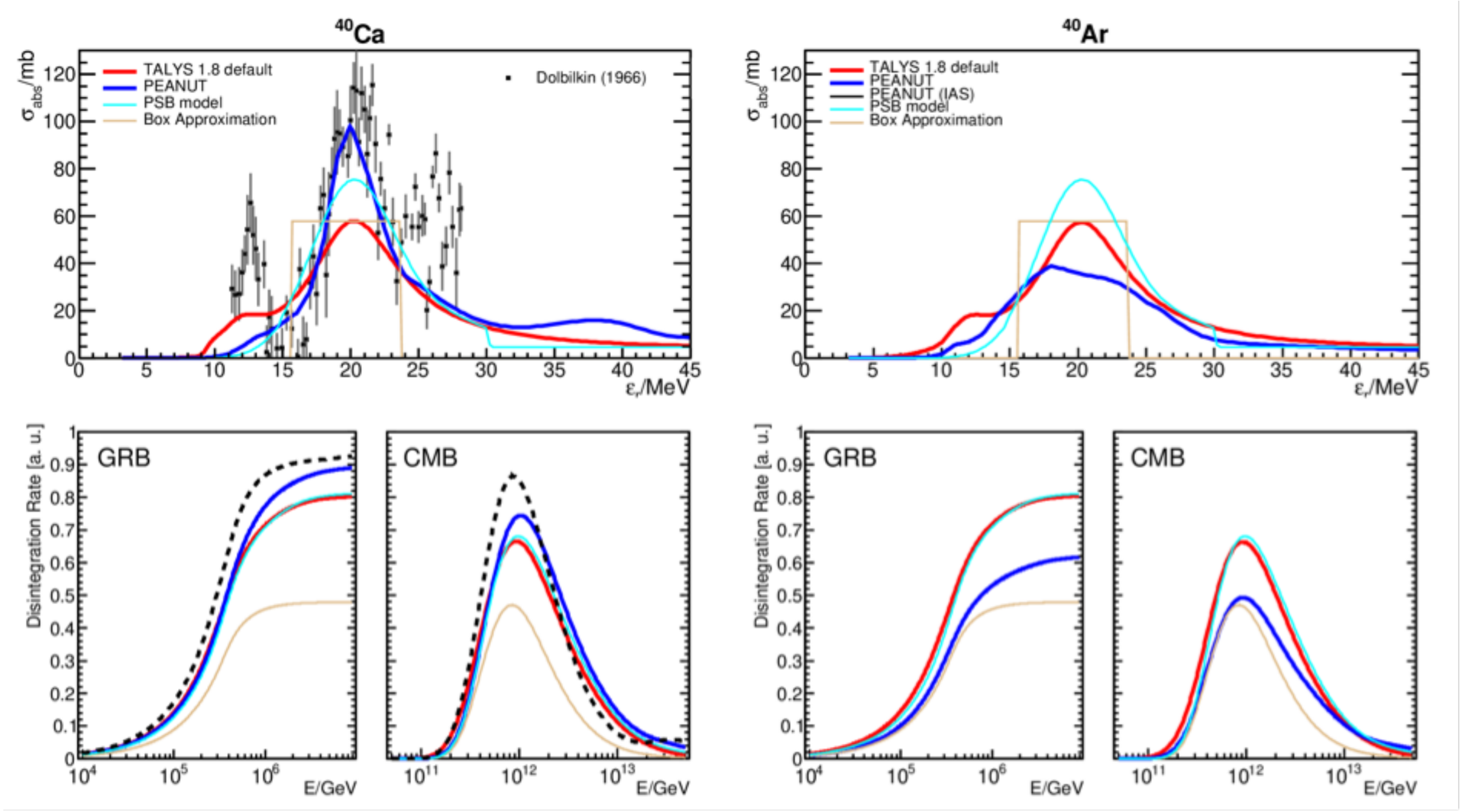
ASTROPHYSICAL SCENARIOS EXPLAINING UHECR DATA





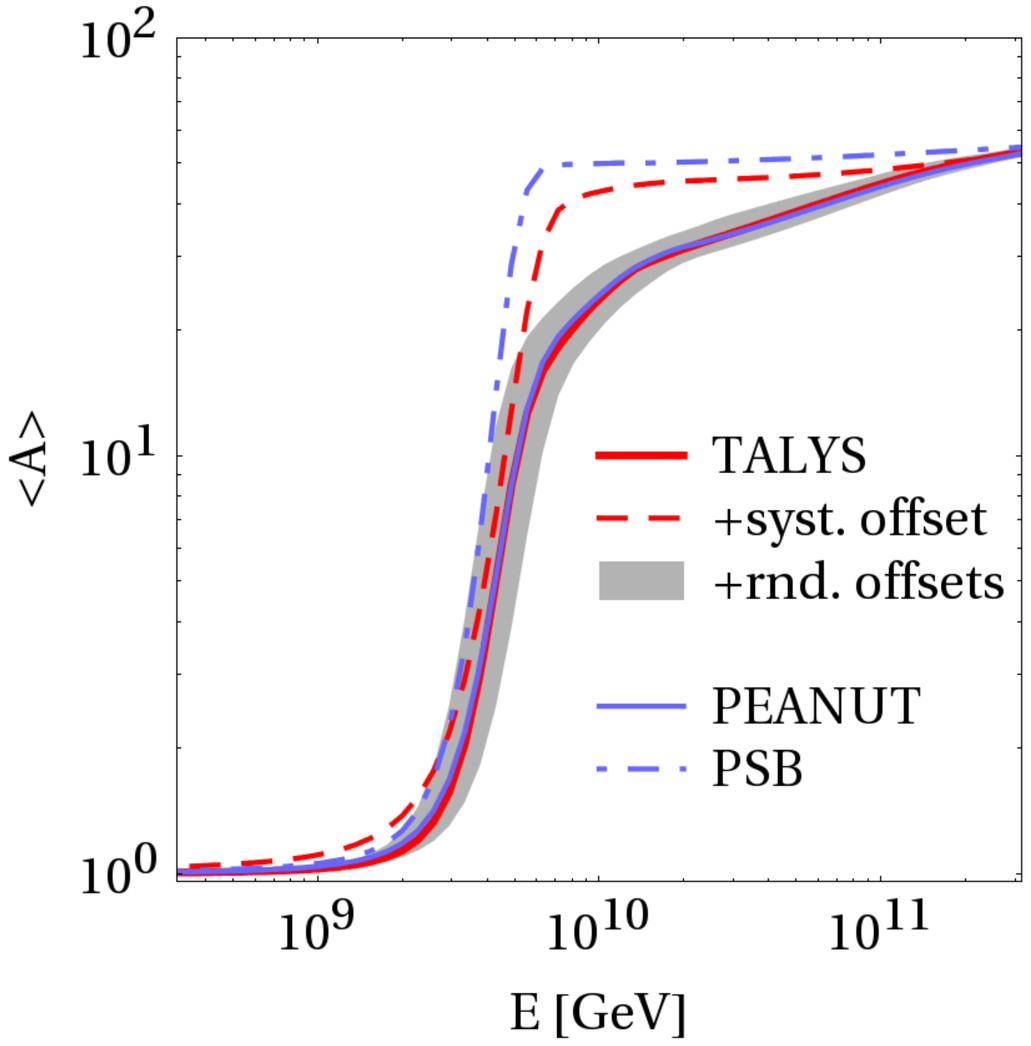
The Pierre Auger Collab. JCAP 2017

CROSS SECTION UNCERTAINTIES AND DISINTEGRATION RATES



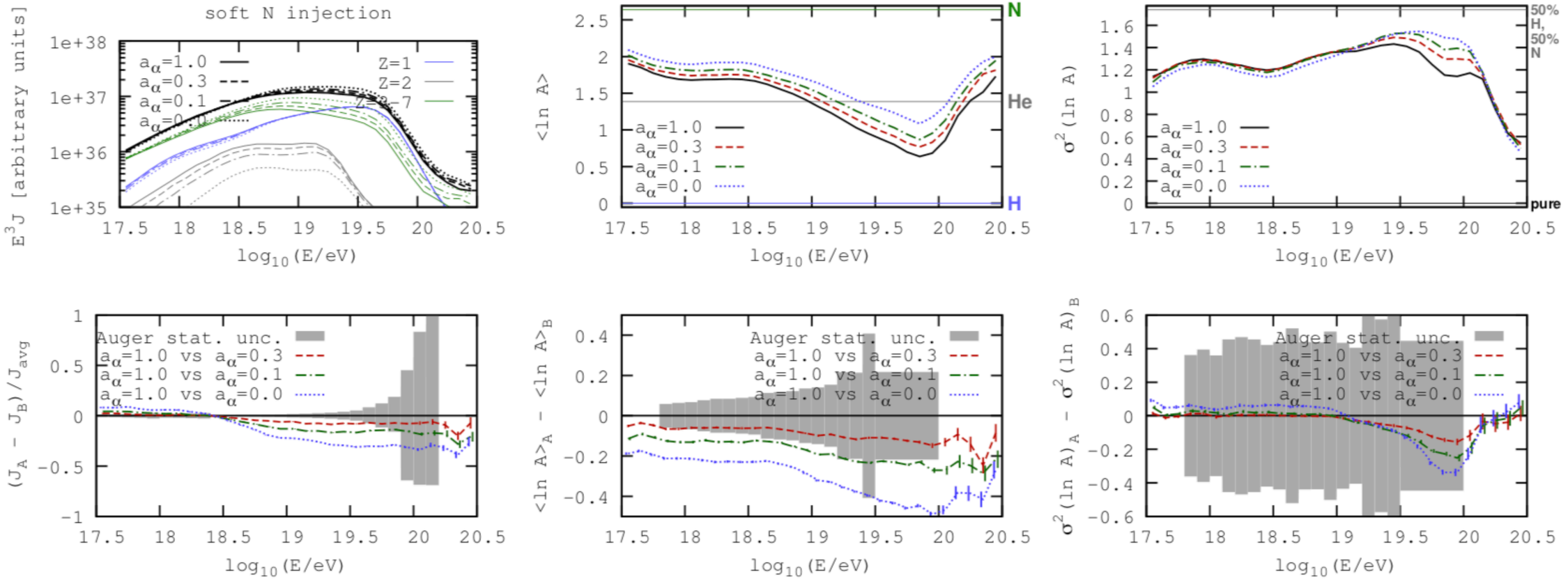
DB, Fedynitch & Winter, Sci. Reports 2017

CROSS SECTION UNCERTAINTIES AND AVERAGE MASS



DB, Fedynitch & Winter, Sci. Reports 2017

CROSS SECTION UNCERTAINTIES AND EXPECTED SPECTRA



Alves Batista, **DB**, di Matteo, van Viet & Walz JCAP2015

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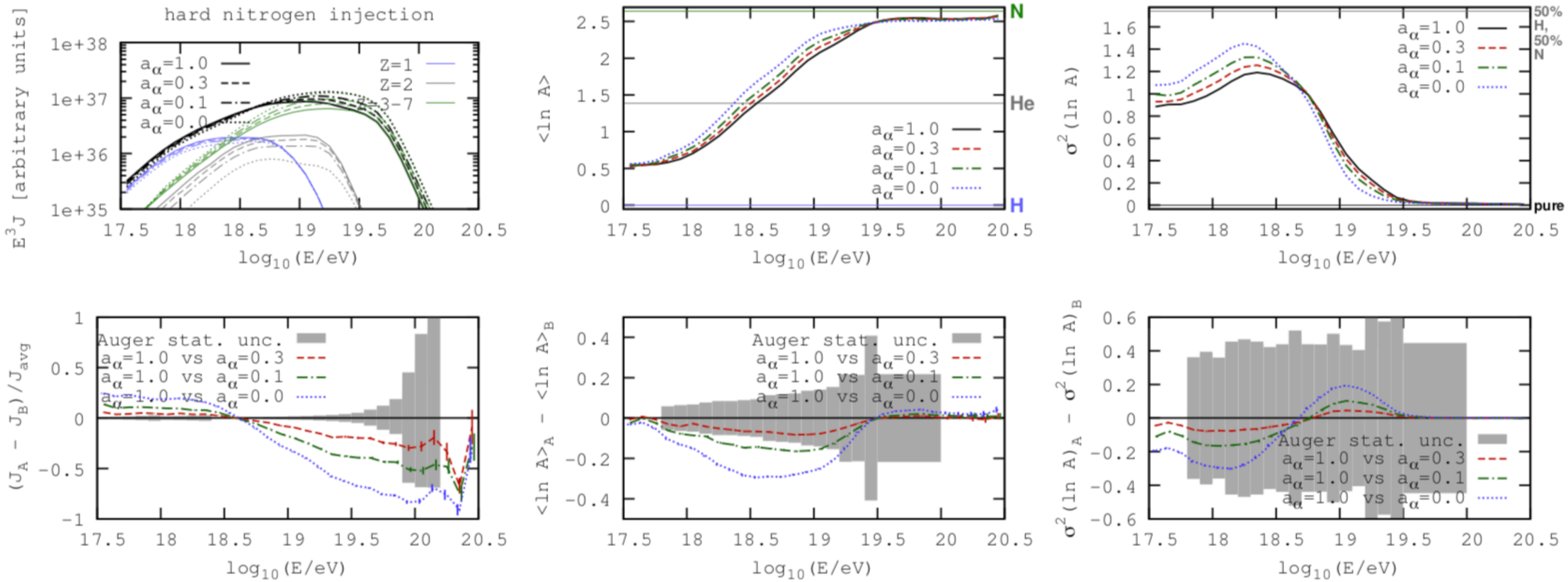

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