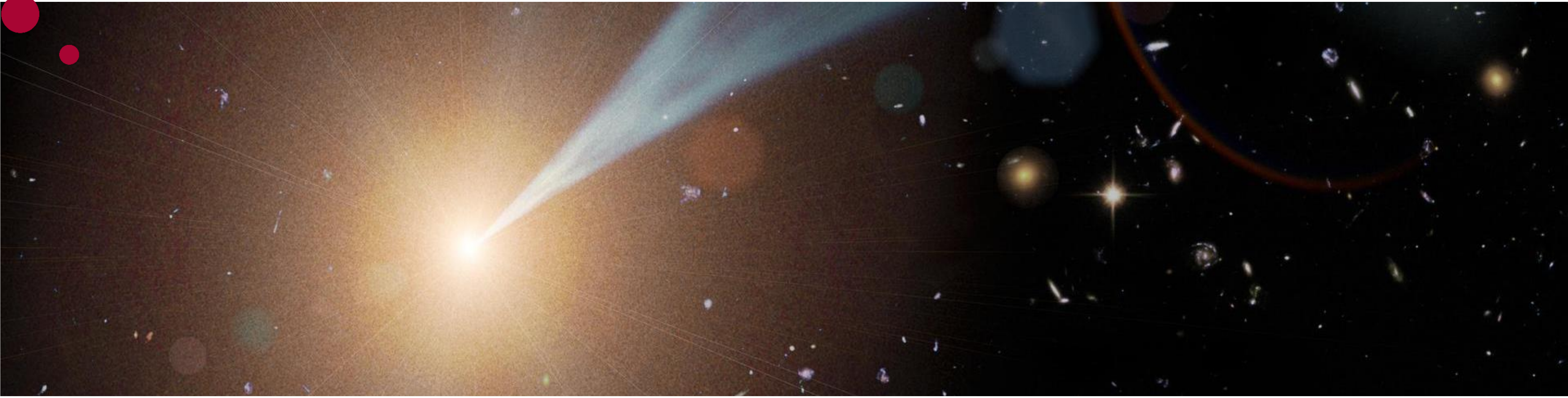

Improved limits on cosmogenic fluxes from Ultra-High Energy Cosmic Rays

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Ultra-High Energy Cosmic Rays

- Cosmogenic ν and γ-rays to probe UHE CR models
- Observations with next-generation neutrino/CR detectors → want lower limits in fluxes
- $E_{\text{CR}} > 50$ EeV ⇒ Nucleon spectrum

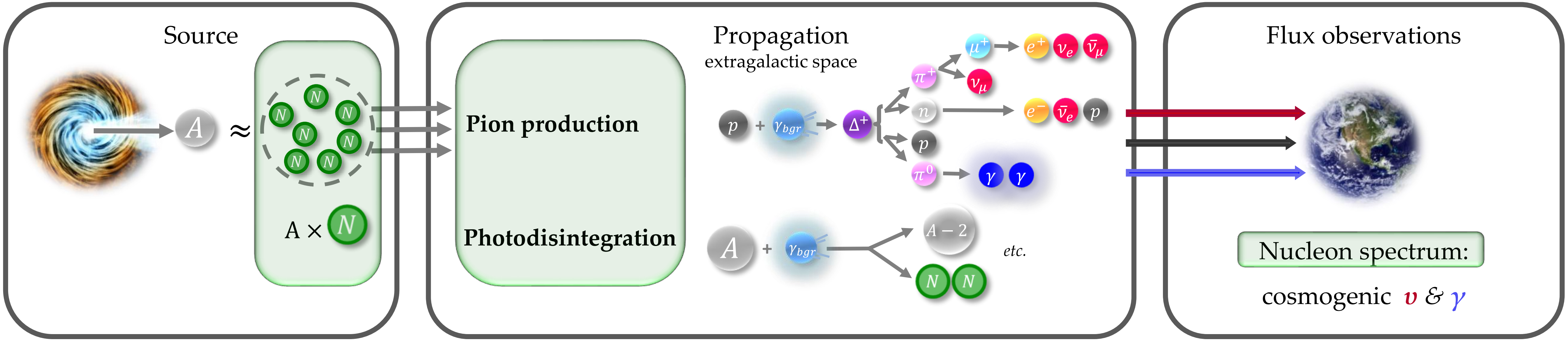

Photo image credits:
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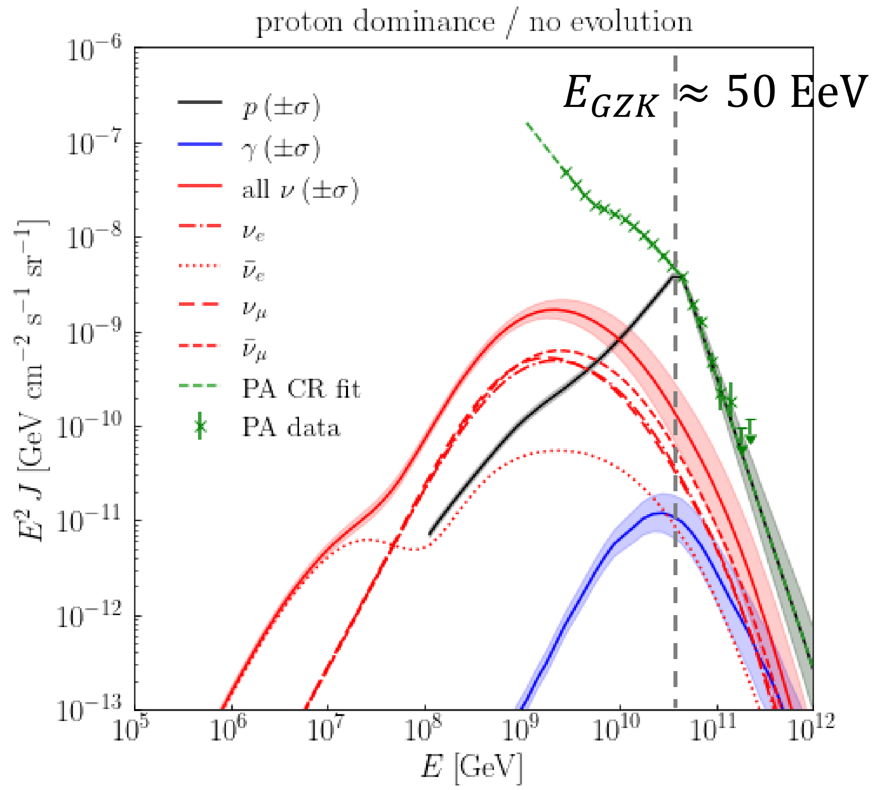
Cosmogenic fluxes

- *Deriving lower limits*
  - CRPropa3 Monte Carlo code [1]
  - **Proton dominated** emission with $E > E_{GZK} \approx 50$ EeV
  - **Fit** to Pierre Auger CR data [2]: $J_{\text{CR}}(E_{\text{CR}}) \propto E_{\text{CR}}^{-\gamma}, \gamma = 5.2 \pm 0.4$
  - Above 50 EeV ⇒ **can be treated as nucleon spectrum:**
    - $J_{\text{N}}(E_{\text{N}}) \simeq A_{\text{o}}^{2-\gamma} J_{\text{CR}}(50\text{ EeV}) \left(\frac{E_{\text{N}}}{50\text{ EeV}}\right)^{-\gamma}$
    - A_{o} is **observed** mass group
  - using 2 types of **source evolution** with redshift:
    1) no evolution/constant comoving source density
    2) Star Formation Rate [3]



⇒ We get the resulting **cosmogenic fluxes**

[1] R. Alves Batista et al. JCAP 05 (2016) 038, arXiv:1603.07142
[2] A. Aab et al., (Pierre Auger Collab.), Phys. Rev. Lett. 125 no. 12, (2020) 121106, arXiv:2008.06488
[3] H. Yuksel et al, Astrophys. J. Lett. 683 (2008) L5–L8, arXiv:0804.4008

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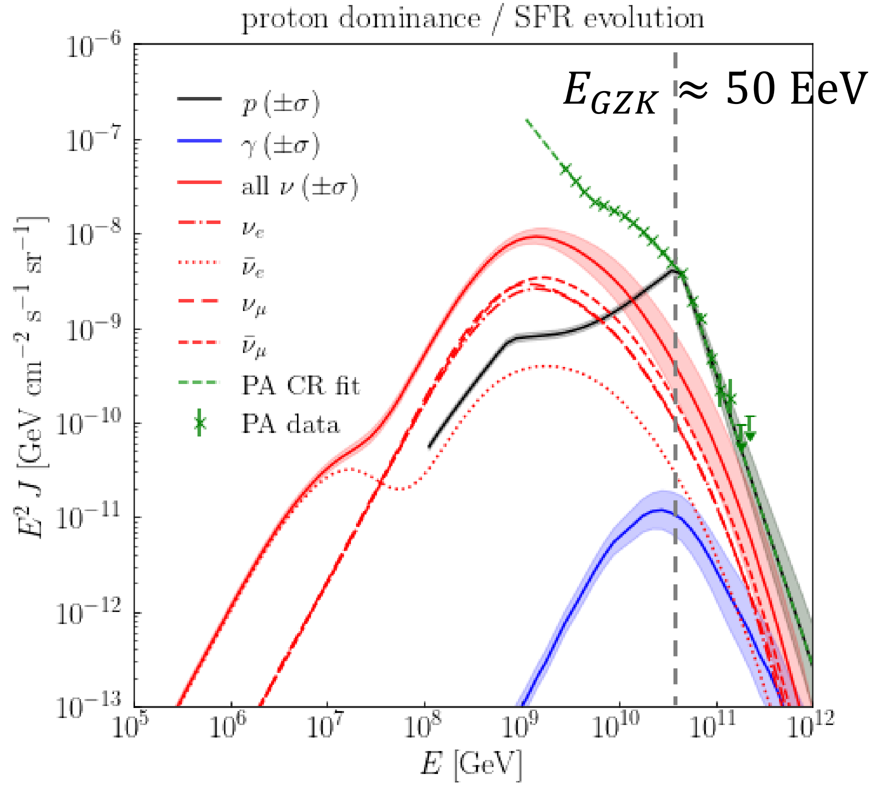

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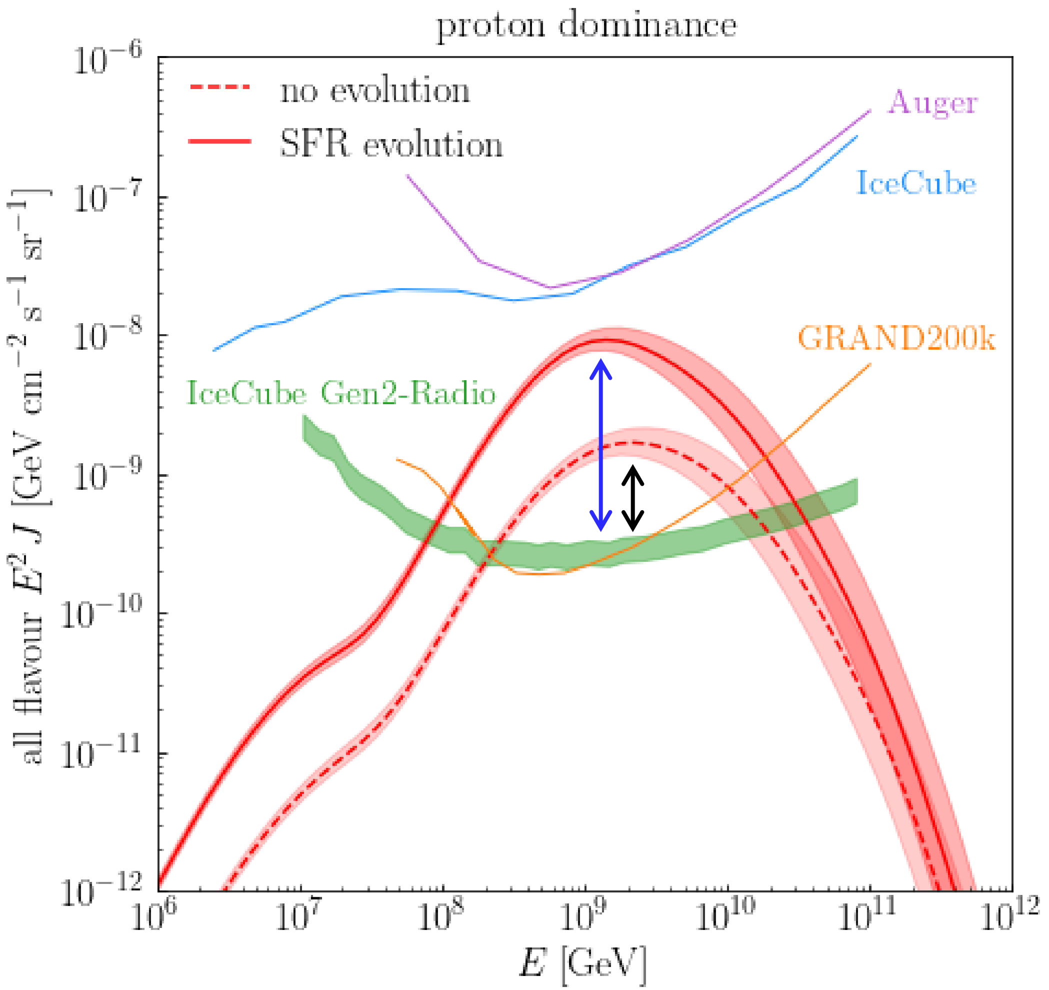
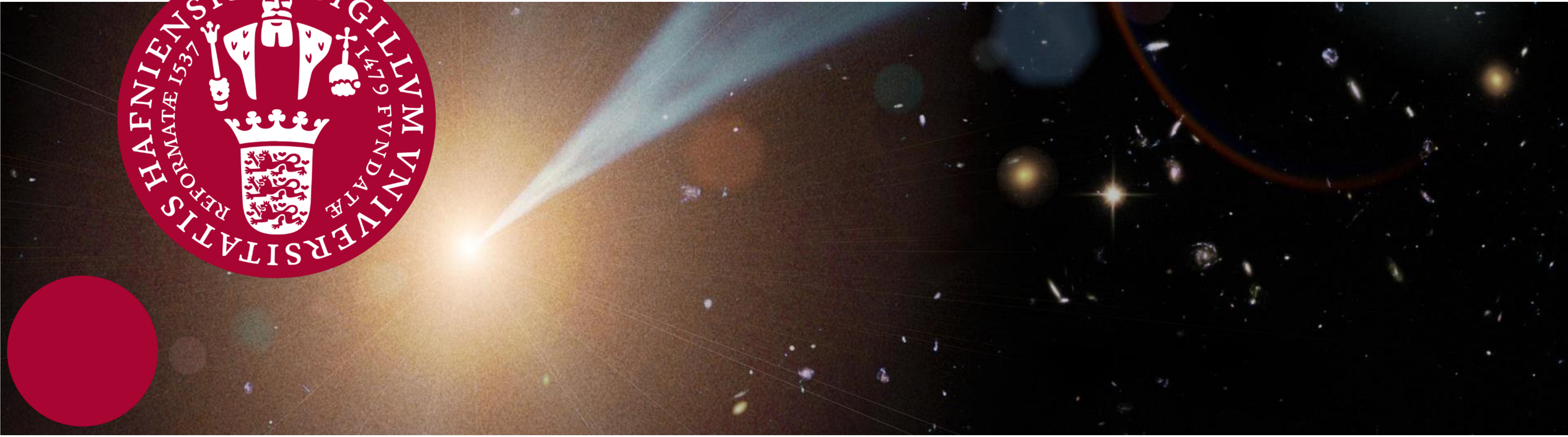
Minimal ν flux prediction

- *Observing cosmogenic neutrino fluxes*
  - Next-generation neutrino/CR experiments capable of **observing cosmogenic neutrinos** if observed proton contribution is:
    - 2% (“SFR evolution”)
    - 10% (“no evolution”)
- *Minimal fluxes*
  - Our flux predictions can be considered **lower limits** of the cosmogenic emission due to bound $E_{\mathrm{CR}} \geq 50$ EeV
  - Only **depend on the observed** average mass composition A_o:
    - Scales as $J \propto A_o^{-3.2}$ compared to proton case



[4] M. G. Aartsen et al., (IceCube-Gen2 Collab.) arXiv:2008.04323
[5] J. Álvarez-Muñiz et al., (GRAND Collab.) 219501, arXiv:1810.09994.
[6] M. G. Aartsen et al., (IceCube Collab.) arXiv:1807.01820
[7] A. Aab et al., (Pierre Auger Collab.) arXiv:2008.06486.

VILLUM FONDEN



[Link to proceedings]

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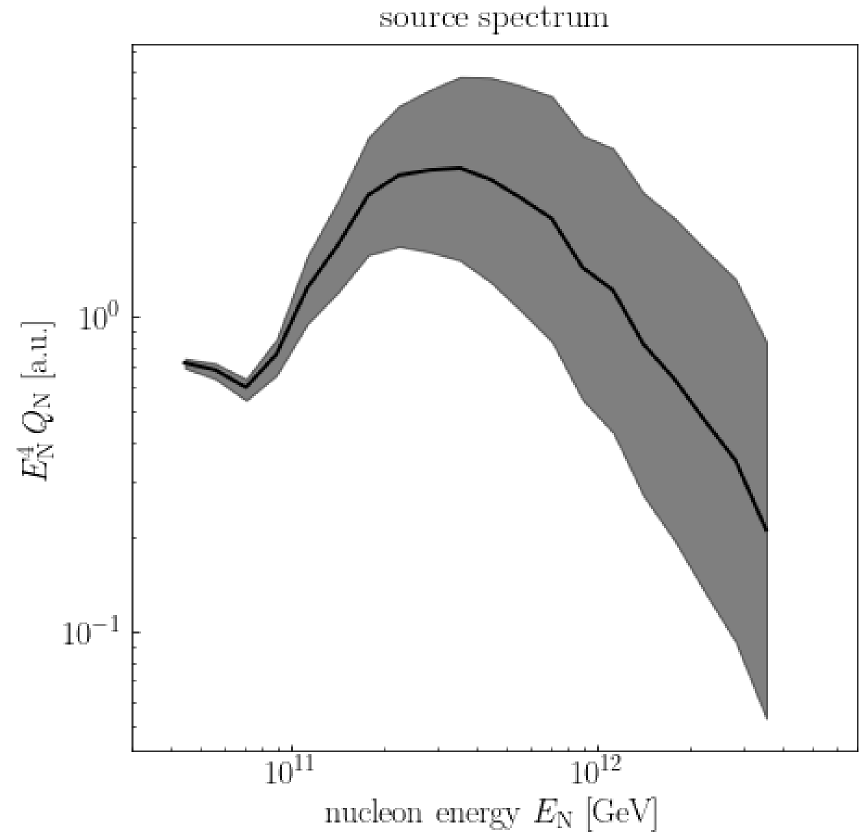
Back-up slides

Backup: Source spectrum

- *Source spectrum*
  - Emission spectrum at source, proton dominated
  - Spectral index around $\gamma \approx 4$ (y-axis $E_N^4\, Q_N$)
  - SFR case ≈ no evolution case



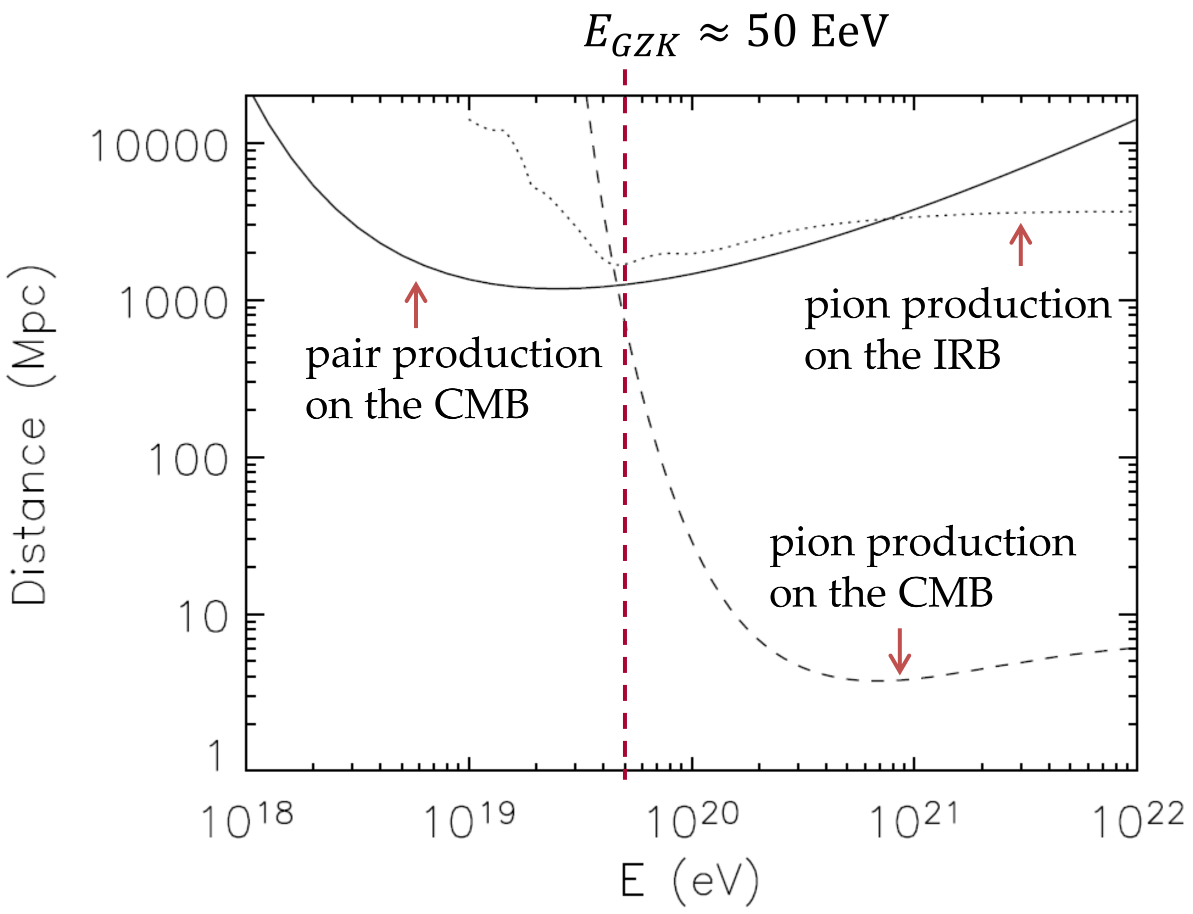
Backup: Energy loss lengths

- ***Energy loss lengths for protons (z = 0)***

From E. Armengaud et al. (2006)

CRPropa: A Numerical Tool for the Propagation of UHE Cosmic Rays, γ−rays and Neutrinos arXiv:astro-ph/0603675

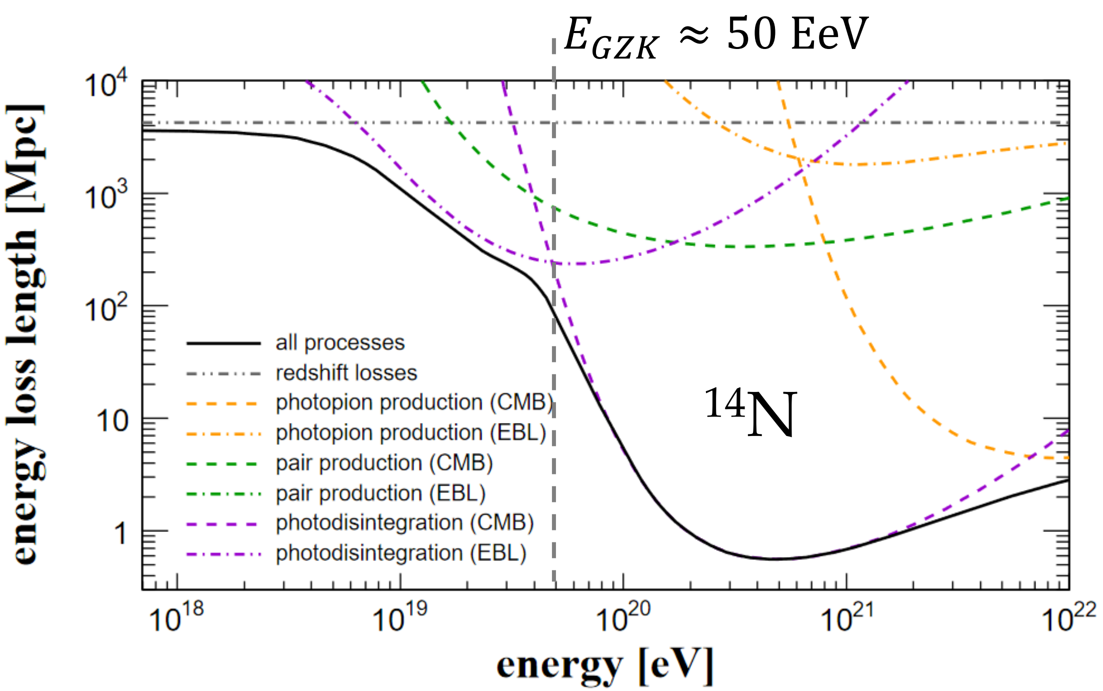
- Must stay above 50 EeV to treat UHE CR spectrum as **nucleon spectrum**

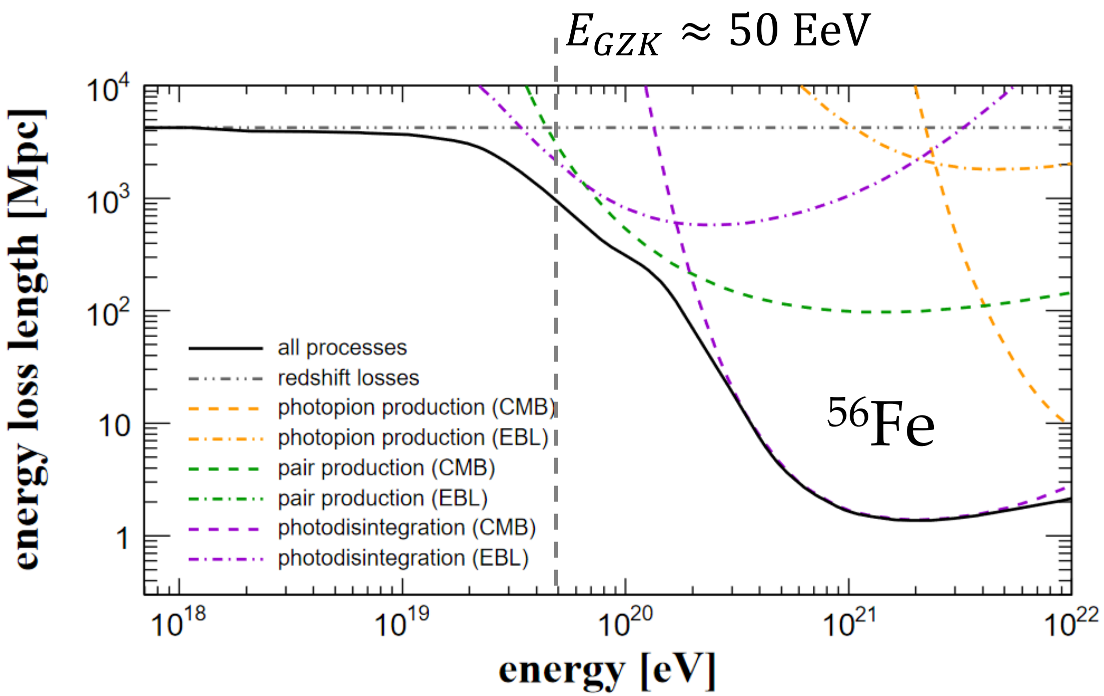


Backup: Energy loss lengths

- *Energy loss lengths for* ^{14}N *and* ^{56}Fe $(z = 0)$

  From R. A. Batista et al., JCAP10 (2015) 063, [arXiv:1508.01824]





$J \propto A_o^{2-5.2\pm0.4} \Rightarrow$ 0.02 % 0.0003 %