Predicting the UHE photon flux from GZK-interactions of hadronic cosmic rays using CRPropa 3

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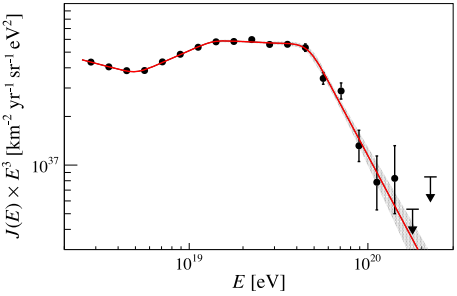
- Pierre Auger Observatory: suppression of cosmic ray spectrum around 50 EeV.

  $\rightarrow$ maximum source energy?

  $\rightarrow$ propagation effect?
- Origin of the suppression can be probed by searching for ultra-high-energy (UHE) photons from GZK interactions:

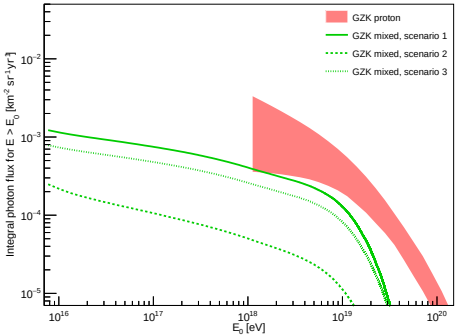
$$p + \gamma_{\mathrm{CMB}} \rightarrow \Delta^{+}(1232) \rightarrow \begin{cases} p + \pi^{0} \\ n + \pi^{+}. \end{cases}$$

- Upper limits on UHE photons from various experiments.
- Simulations of GZK photons help to interprete these limits.



[Pierre Auger Coll. 2020]

- Data of the Pierre Auger Observatory suggest three possible scenarios for cosmic rays at the sources. [Pierre Auger Coll. 2017]
- Simulation of cosmic ray propagation towards earth (CRPropa 3) results in GZK photon predictions at earth.



Resulting photon flux is

- mainly determined by spectral index.
- driven by nitrogen-like elements.
- lower than in previous studies of pure proton propagation.