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Probing High-Energy Photonuclear Interactions with Muons in Gamma-Ray Air Showers

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Photonuclear interactions are the main source of high-energy muons in gamma-ray-induced extensive air showers (EASs), while the corresponding cross section remains poorly constrained at energies relevant for astrophysical gamma rays. We develop an efficient framework for propagating uncertainties in the photonuclear cross section to the muon content and photon-selection efficiency of EAS experiments. We apply it to the Carpet-2 excess of events from the Cygnus region above 300 TeV. Accounting for the source spectrum substantially changes the expected photon detection efficiency, while the remaining uncertainty of the high-energy photonuclear cross section produces an additional sizeable systematic effect. Their combination removes the apparent tension between the observed excess and the number of muon-poor photon candidates. We also show that observations of gamma-ray sources with Carpet-2-like arrays are sensitive to photonuclear interactions in an energy range that is only weakly constrained by laboratory measurements.

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