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Investigating the hadron nature of high-energy photons with PeVatrons

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In high energy Gamma-Ray Astronomy with shower arrays the most discriminating signature of the photon-induced showers against hadron-induced cosmic-ray ones is the content of muons in the observed events.
In the electromagnetic γ-showers the muon production is due to the dominant channels: photo-production of pions followed by the decay $\pi \rightarrow \mu\nu$, prompt leptonic decay of charmed particles in the shower, and electromagnetic pair production $\gamma \rightarrow \mu^+\mu^-$.
The number of muons is typically a few percent of that in a hadron showers where muons are abundantly generated by charged pions decay.

In high energy photo-production process the photon exhibits an internal structure which is very similar to that of hadrons, with a small relative probability of order α ($\simeq 1/137$).
Indeed, photon-hadron interactions can be understood if the physical photon is viewed as a superposition of a bare photon and an accompanying small hadronic component which feels conventional hadronic interactions.

Information on photo-production γp and $\gamma\gamma$ cross-sections are limited to $\sqrt{s} \leq 200$ GeV from data collected at HERA. Starting from $E_{lab} \approx 100$ TeV the difference between different extrapolations of the cross sections increases to more than 50\% at $E_{lab} \approx 10^{19}$ eV, with important impact in the observables used to select the photon-initiated air showers.

Recently, the LHAASO experiment opened the PeV-sky to observations detecting a number of PeVatrons in a background-free regime starting from about $E_{lab} \approx 100$ TeV. This result provides a beam of pure high energy primary photons allowing to measure for the first time the photo-production cross section even at energies not explored yet.
The future air shower array SWGO in the Southern Hemisphere, where the existence of Super-Pevatrons emitting photons well above the PeV is expected, could extend the study of the hadron nature of the photons in the PeV region.

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