Contribution ID: **259** Type: **Poster**

Searching for the sources of the most energetic cosmic rays

Although more than 60 years have passed since the discovery of ultra-high-energy cosmic rays ($E > 10^{18}\,\mathrm{eV}$) (Linsley 1963), the origin of these particles remains one of the most compelling open questions in Astroparticle Physics. The recent detection of the "Amaterasu particle" by the Telescope Array Collaboration, the second most energetic cosmic ray ever detected (2.44×10^{20} eV), has motivated investigations not only into its possible candidate sources (Abbasi et al. 2023, Unger & Farrar 2024) but also into other highly energetic events. These particles are less deflected by cosmic magnetic fields due to their extremely high energy, which aids in backtracking them to their sources. However, uncertainties in the magnetic fields and in energy measurements, along with limited information about the mass composition of these particles, make these studies quite challenging. Therefore, the aim of this work is to analyze the most energetic events detected by the Pierre Auger Observatory to search for their origin. One of the goals is to calculate the localization volumes from which these particles originate using the most up-to-date Galactic magnetic field models and to statistically correlate these volumes with known astrophysical objects from catalogs. Central to our approach is the development of a new release of the Monte Carlo propagation code SimProp (Aloisio et al. 2017), which is well suited (and widely used) for phenomenological studies of ultra-high-energy cosmic ray propagation in intergalactic environments. We are currently developing updated models of photodisintegration losses of ultra-high-energy nuclei, vital for understanding the maximum production distances of these high-energy events.

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