

# Cosmic Ray Spectrum and Composition Analysis at IceCube, using Graph Neural Networks

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IceCube Neutrino Observatory is a multi-component detector embedded deep within the South-Pole Antarctic ice. The integrated operation of IceCube with its surface array, IceTop, makes it a unique three-dimensional detector. This facilitates detailed cosmic-ray analysis in the transition region from Galactic to extragalactic sources. This work will present the recent results from improvements made to estimate energy spectrum and composition with cosmic-ray measurements from IceCube and IceTop. For the energy and mass estimation, the work will detail a unique Graph Neural Networks-based approach that benefits from using signal-footprint information and reconstructed cosmic-ray air shower parameters. The implementation improves upon the standard likelihood-based analysis and reduces the computing time and cost for performing such analysis. In addition to this, the work will also introduce new composition-sensitive parameters for improving cosmic-ray composition estimation, potentially improving our understanding of high-energy muon deposits in cosmic-ray air-showers.

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