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Advancing Ultra-High Energy Neutrino Astronomy through Deep Learning and Differential Programming

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Detection of neutrinos at ultra-high energies (UHE, E >10^{17}eV) would open a new window to the most violent phenomena in our universe. However, owing to the expected small flux of UHE neutrinos, the detection rate will be small, with just a handful of events per year, even for large future facilities like the IceCube-Gen2 neutrino observatory at the South Pole. In this contribution, I will discuss how to substantially enhance the science capabilities of UHE neutrino detectors by increasing the detection rate of neutrinos and improving the quality of each detected event, using recent advances in deep learning and differential programming. First, I will present neural networks replacing the threshold-based trigger foreseen for future detectors that increase the detection rate of UHE neutrinos by up to a factor of two. Second, I will outline and present preliminary results towards an end-to-end optimization of the detector layout using differential programming and deep learning, which will improve the neutrino direction and energy determination. I will present new results of a deep, ResNet-based neural network that, combined with Normalizing Flows, predicts the full Posterior PDF of neutrino direction and energy. The expected improvements are estimated to be equivalent to building an up to three times larger detector, accelerating the research field by a decade.

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