

# Third MODE Workshop on Differentiable Programming for Experiment Design



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## Optimization of Radio Detectors of Ultra-High Energy Neutrinos 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. Radio detection remains the most promising technique at these energies. 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, we 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, we 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, we will outline preliminary results toward an end-to-end optimization of the detector layout using differential programming and deep learning. In particular, we will present results for a normalizing-flow-based energy and direction reconstruction which, for the first time, enables event-by-event non-Gaussian uncertainty predictions.

We estimate that these improvements can as much as triple the science potential of the IceCube-Gen2 radio detector.

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