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Differentiable Simulation of a Liquid Argon TPC for High-Dimensional Calibration

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Liquid argon time projection chambers (LArTPCs) play a crucial role in the current and coming particle detection experiments, offering exceptional tracking and calorimetric capabilities.
To enhance the accuracy of detector simulations and enable realistic physics analyses, the particle physics community has focused on refining simulators through dedicated calibration measurements. However, the entanglement of various detector modelings poses a challenge to achieving optimal accuracy. In this presentation, a novel approach will be introduced —a LArTPC differentiable simulator focusing—that allows for gradient-based calibration of multiple detector parameters simultaneously. Using this method, the direct extraction of physics information from calibration fits can be achieved, along with a comprehensive consideration of all correlations between parameters that were previously hard to access. While the code is configurable to adapt to multiple geometries, the studies presented here are done using the DUNE ND as a first case study. The process of developing a differentiable simulator through the transformation of a standard simulation tool into a differentiable framework will be presented, discussing its advantages and limitations, and addressing the obstacles encountered when ensuring the preservation of physics quality while extracting meaningful gradient information.

Author: GRANGER, Pierre (Centre National de la Recherche Scientifique (FR))

Presenter: GRANGER, Pierre (Centre National de la Recherche Scientifique (FR))

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