Learning Particle Physics: From Simulation to Inference with Neural Networks

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Neural networks are transforming the way we simulate and analyze data in particle physics. Modern experiments produce enormous amounts of data, and understanding them requires complex and computationally expensive simulations. Machine learning offers new ways to make these steps faster, more efficient, and even invertible.

Neural networks can be used throughout the full simulation chain: from the interpolation of interaction cross sections, via the generation of artificial particle events, to modeling the detector response, machine learning enables high-precision predictions. In the inverse direction, neural networks can reconstruct the underlying physical processes from the measured high-dimensional data. Along the way, we focus on incorporating physics knowledge—such as exact and approximate symmetries—into network architectures and training objectives, alongside the precise quantification of uncertainties to ensure physically meaningful predictions.