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Parameter Estimation with Neural Simulation-Based Inference in ATLAS

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Neural Simulation-Based Inference (NSBI) is a powerful class of machine learning (ML)-based methods for statistical inference that naturally handle high dimensional parameter estimation without the need to bin data into low-dimensional summary histograms. Such methods are promising for a range of measurements at the Large Hadron Collider, where no single observable may be optimal to scan over the entire theoretical phase space under consideration, or where binning data into histograms could result in a loss of sensitivity. This work develops an NSBI framework that, for the first time, allows NSBI to be applied to a full-scale LHC analysis, by successfully incorporating a large number of systematic uncertainties, quantifying the uncertainty coming from finite training statistics, developing a method to construct confidence intervals, and demonstrating a series of intermediate diagnostic checks that can be performed to validate the robustness of the method. As an example, the power and feasibility of the method are demonstrated for an off-shell Higgs boson couplings measurement in the four lepton decay channel, using ATLAS experiment simulated samples. The proposed method is a generalisation of the standard statistical framework at the LHC, and can benefit a large number of physics analyses. This work serves as a blueprint for measurements at the LHC using NSBI.

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