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Likelihood-Free Frequentist Inference for Calorimetric Muon Energy Measurement

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Calorimetric muon energy estimation in high-energy physics is an example of a likelihood-free inference (LFI) problem, where simulators that implicitly encode the likelihood function are used to mimic complex particle interactions at different values of the physical parameters. Recently, Kieseler et al. (2022) exploited simulated measurements from a dense, finely segmented calorimeter to infer the true energy of incoming muons and improve the resolution at high energies using a prediction approach based on a custom neural network architecture. Nonetheless, it remains an open question whether these tools produce reliable measures of uncertainty. In this work we present Waldo, a novel method to construct frequentist confidence sets within an LFI setting. WALDO reframes the well-known Wald test and uses Neyman inversion to convert point predictions or posterior distributions from any prediction algorithm or posterior estimator to confidence sets with correct conditional coverage, even for finite observed sample sizes. The LFI framework we exploit also allows to check empirical coverage across the entire parameter space. Finally, we demonstrate the effectiveness of Waldo by applying it to the muon energy estimation problem. Our results further support the work of Kieseler et al. (2022) who proposed this new avenue as an alternative to curvature-based measurements in a magnetic field.

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