Contribution ID: **23** Type: **Regular talk**

Likelihood-Free Frequentist Inference for Calorimetric Muon Energy Measurement

Friday 13 May 2022 14:00 (25 minutes)

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 interactions at different configurations of the 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 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 intervals within an LFI setting. Waldo reframes the well-known Wald test to convert parameter point estimates from any prediction algorithm to confidence sets that are guaranteed to have the nominal coverage even in finite samples. We exploit an existing LFI framework, which 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) that has proposed this new avenue as an alternative to curvature-based measurements in a magnetic field.

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Session Classification: Workshop