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A novel implementation of the Matrix Element Method at next-to-leading-order (NLO) for the measurement of the Higgs tri-linear coupling in di-Higgs production at the LHC

One of the LHC's priorities, following the discovery of the Higgs boson, is to observe the production of Higgs pairs and to measure the Higgs tri-linear coupling λ_{3H}.

Due to the rarity of di-Higgs production, measuring λ_{3H} has proven to be highly challenging. Exclusion limits have been observed using a variety of approaches, including cut-based methods and boosted decision trees (BDTs).
To address this difficulty from a new perspective, our work explores the application of the Matrix Element Method (MEM), a technique that has demonstrated its effectiveness in multiple analyses in which measurements were performed in processes that were rare (at the time).One can mention the primordial role of the MEM in measuring the top-quark mass at Tevatron, or its role in the first evidence for single top production in the s-channel at the LHC for example.

The MEM is a statistically optimal multivariate method that maximizes the utilization of both the experimental and theoretical information available to an analysis, making it inherently well-suited to rare process searches and Standard Model measurements.
Most MEM studies have been limited to leading-order (LO) accuracy, with extensions to next-to-leading-order (NLO) explored only in specific cases due to the additional complexities introduced by virtual and real contributions.
To contribute to the measurement of λ_{3H} from LHC data in the $gg \to HH \to b\bar{b}\gamma\gamma$ channel, we developed a MEM framework by working on a new NLO implementation (which can be applied to many more analyses). This MEM framework utilizes state-of-the-art Matrix Elements at NLO from the POWHEG-BOX-V2 and MG5_@NLO software packages. The framework is implemented within a modified version of MoMEMta, a software designed for managing multi-variable phase-space integration, which has been extended to incorporate this new NLO implementation.

To our knowledge, this work marks the first application of the MEM at NLO accuracy to the search for HH and the measurement of λ_{3H}. This also represents the first application of the MEM using this new NLO formalism.
We also applied this framework to Monte Carlo (MC) simulated samples in a search for λ_{3H}, achieving promising results.

This study aims to introduce this new approach to the community and position the MEM (at NLO) as a competitive alternative to other established methods to determine the Higgs self-coupling λ_{3H}.

Secondary track

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