COMETA workshop on EFT in HH and VBS

Monday 17 March 2025 - Wednesday 19 March 2025

Paris

Book of Abstracts

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VBS measurement in semileptonic final states with ATLAS Run-2 data

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Vector boson scattering (VBS) processes probe the fundamental structure of electroweak (EW) interactions and provide a high sensitivity to new physics phenomena affecting gauge and Higgs couplings. The semileptonic final states, where one of the scattered electroweak boson decays hadronically into a quark/antiquark pair and the other boson decays leptonically into electrons, muons or neutrinos, has high statistics in the WW, WZ and ZZ processes. The hadronically decaying gauge boson can be reconstructed as two small-radius jets or one large-radius jet in case of high boost. Semileptonic final states VBS was studied in an ATLAS Run-2 analysis using 139/fb of proton collisions at a center-of-mass energy of 13 TeV, allowing to measure the fiducial cross section for EW diboson production accompanied with jets in semileptonic final states. The results are also interpreted in an Effective Fields Theories (EFT) framework to set constraints on anomalous Quartic Gauge Couplings (aQGC) through dimension-8 operators.

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HEFT Multi-Higgs Production in VBF

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We have studied the production of 2, 3 and 4 Higgs bosons from the collision of Goldstone bosons using the equivalence theorem in HEFT. This work has been compared with results from both ATLAS and CMS. The measurements are being updated by the collaborations with the latest results.

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Double Higgs Production in Vector Boson Fusion at NLO QCD in HEFT

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We present a calculation of the NLO QCD corrections to Higgs boson pair production in vector boson fusion, combined with the leading operators parametrising anomalous interactions in non-linear Effective Field Theory (HEFT). Based on our Monte Carlo implementation using GoSam+Whizard, we investigate the effects of anomalous Higgs couplings on various observables.

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The effect of single Higgs backgrounds and Higgs branching fractions in the SMEFT interpretation

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Some SMEFT parameters contribute to both di-Higgs and single-Higgs productions. Taking the HH->bbyy channel (JHEP 01(2024) 066) as example, we present the results on the effects of single Higgs backgrounds and Higgs branching fractions and discuss about the evaluation of systematical uncertainties.

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Double Higgs production via VBF NLO in SMEFT

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The process of double Higgs boson production via vector boson fusion (VBF), although strongly suppressed compared to the gluon fusion channel, remains an important area of study. Not only can it provide valuable insights into the EW sector and the mechanism of EWSB, but it is also highly sensitive to BSM physics. In this talk, we explore the impact of dimension-6 and dimension-8 SMEFT operators on VBF double Higgs production. We estimate and present the maximal effects, taking into account available constraints on SMEFT Wilson coefficients from fits to experimental data, perturbative unitarity constraints and the validity of the EFT expansion.

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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

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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 at particle accelerators like the LHC.
The MEM avoids the application of strict selection requirements to the data. It accounts for the entire dataset (with minimal preselection), which is very important when dealing with such rare processes.
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. Building a MEM at LO is already a highly challenging task, and incorporating NLO formalism substantially amplifies this difficulty due to the increased computational demands and complex theoretical requirements.
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 in many more analyses).
This MEM framework utilizes state-of-the-art Matrix Elements at NLO from the POWHEG-BOX-V2 [1] and MG5_@NLO software packages, and can be extended to include Higgs boson pair production at full NLO QCD in SMEFT [2].
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 have demonstrated that this NLO framework is functional and effective.
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}.

References:
[1] G. Heinrich, S.P. Jones , M. Kerner, G. Luisoni , L. Scyboz
Probing the trilinear Higgs boson coupling in di-Higgs production at NLO QCD including parton shower effects , JHEP 06 (2019) 066 [https://inspirehep.net/literature/1725744]
[2] G. Heinrich, J, Lang
Renormalisation group effects in SMEFT for di-Higgs production ,[https://arxiv.org/pdf/2409.19578]

Track/session:

Plenary track

ATLAS internal discussion / 19

VBS aQGC Reweighting study

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This talk will present an investigation into generating EFT aQGC samples using the internal Madgraph LO matrix element reweighting method. The study focuses on the semi-leptonic VBS process applied to the new aQGC recommendation superset of the Eboli model. The aim is to assess the accuracy and reliability of the approach and, if possible, validate it as an alternative to the EFT decomposition method commonly used in ATLAS. If successful, this method could significantly reduce the number of EFT samples required.

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The Art of Counting: where to cut-off SMEFT and HEFT in Higgs Pair Production

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RGE effects in SMEFT predictions for HH production

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HHH and HH production as probes of the Higgs self-couplings

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Triple and double VBF-Higgs production as probes of SMEFT/HEFT interactions

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SMEFT effects and CP violation in diboson production via gluon-fusion

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VBS constraints on Higgs interactions in HEFT [TBC]

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TBC