

OU REU: Higgs Phenomenology

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Necessary Tools

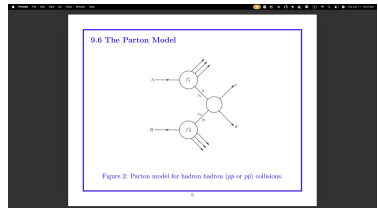
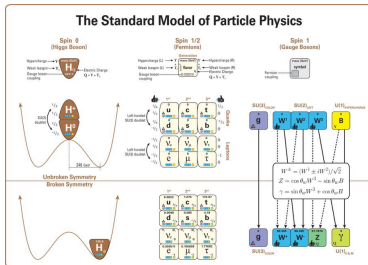
- ▶ Quantum Mechanics (Shankar)
- ▶ Special Relativity (Landau and Lifshitz)
- ▶ Elementary particle physics (Griffiths)
- ▶ Quantum Field Theory (Peskin and Schroeder)
- ▶ MadGraph5
- ▶ Pythia8
- ▶ Delphes
- ▶ Root Analysis

Brief description

- ▶ Phenomenology studies particle decays, cross sections, branching ratios, predictions for experiments, and searches for better channels for particle production
- ▶ Marks the bridge between SM theory and experimental data
- ▶ Provides ideas for future experiments and puts constraints on theories
- ▶ Focuses on the interactions of Higgs bosons and the Brout-Englert-Higgs mechanism
- ▶ Uses the Higgs boson to search for new BSM physics

Brief description of Higgs

- Produced via proton-proton collisions which allows for partons (quark or gluon pairs inside of the proton) to interact



Brief description of Higgs cont.

- ▶ Main production modes: gluon fusion, vector boson fusion, and associative production
- ▶ Detection of the Higgs uses the invariant mass distribution to infer a Higgs was produced

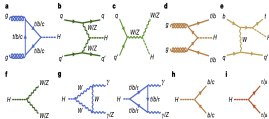


Fig. 1: Examples of Feynman diagrams for Higgs boson production and decay. a-e, The Higgs boson is produced via gluon-gluon fusion (a), vector boson fusion (b, c) and associated production with vector bosons (d), top or bottom quark pairs (e), or singly top quark (f). F, The Higgs boson decays into a pair of vector bosons (g), a pair of photons or a Z boson and a photon (g), a pair

of quarks (h), and a pair of charged leptons (i). Loop induced Higgs boson interactions with gluons or photons are shown in blue, and processes involving couplings to W or Z bosons in green, to quarks in orange, and to leptons in red. Two different shades of green (orange) are used to separate the WW and ZZ (bb and tt) production processes.

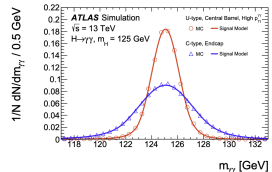


Figure 1: Invariant mass distributions of simulated $H \rightarrow \gamma\gamma$ events reconstructed in the categories with the best (U-type, central-barrel, high- $p_T^{\gamma\gamma}$; open circles) and the worst (C-type, endcap; open squares) experimental resolutions. The signal model derived from a fit to the simulated events is superimposed (solid lines).

Summer Project

- ▶ Project: Proton-Proton collisions generating charged vector boson and higgs boson
- ▶ $PP \rightarrow W^\pm H$ with $W^\pm \rightarrow \ell\nu$ and $H \rightarrow b\bar{b}$
- ▶ Confirm ATLAS and CMS results ¹
- ▶ Future project: research $H \rightarrow c\bar{c}$

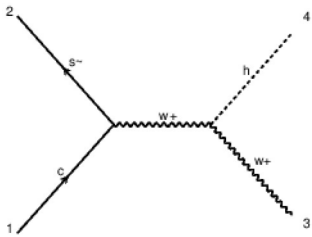


diagram 1

QCD=0, QED=2

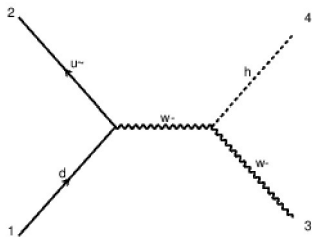


diagram 1

QCD=0, QED=2

¹arXiv:2410.19611v2 [hep-ex] <https://doi.org/10.48550/arXiv.2410.19611>

Brief Summary of Paper

- ▶ 1. The paper goes over Higgs decays into $b\bar{b}$ and $c\bar{c}$ by the VH production mode as it provides a clean way to produce Higgs
- ▶ 2. The higgs boson is reconstructed either by two small-R or one large-R jet(s)
- ▶ 3. Measurements are supported by the diboson process, used to get the $VZ, Z \rightarrow b\bar{b} Z \rightarrow c\bar{c}$
- ▶ 4. This study improves previous estimates on the uncertainties in the signal of the decay by approximately 15 percent ²

²page 1-3 and 39-40 arXiv:2410.19611v2 [hep-ex]
<https://doi.org/10.48550/arXiv.2410.19611>

Method

- ▶ 1. Generate events with MadGraph5
- ▶ 2. Use PYTHIA for hadronization
- ▶ 3. Use Delphs for a virtual detector simulator
- ▶ 4. Compare results to experimental data
- ▶ 5. Should end up with $PP \rightarrow \ell\nu b\bar{b}$ with $\ell\nu b\bar{b}/H$ as the background

Questions?