Higgs Offshell and Interference

Subgroup Meeting

10 March 2020

Introduction

- Format for this meeting and task force:
  - We will outline status of offshell $H \rightarrow VV$ analyses and points for discussion/open questions.
  - Hope this stimulates some discussion here, connects people with similar interests – form subgroups.
  - Discussions/studies in subgroups continue offline.
  - Joint meetings every 4-5 weeks.
  - Wrap-up meeting to finalize documentation in July.

Brief (historical) review

- First observation that ~10% of $H \to VV$ events in high-mass tail.
  [Kauer, Passarino '12]
- Proposal to use this to constrain Higgs width to O(10 MeV).
  [Caola, Melnikov '13] [Campbell, Ellis, Williams '13]
- Picked up by CMS & ATLAS (2014-2015)
- Realization that this was not model-independent – depends on offshell behavior of Higgs couplings.
  [Englert, Spannowsky+Soreq, '14; Azatov, Grojean, Paul, Salvioni '14, '16]

  → Can use offshell Higgs events to constrain Higgs couplings (at high energies).

Whither Offshell?

- How to best use offshell $H \rightarrow VV$ data to investigate the properties of the Higgs:
  - *Consistent* between theory and experiment;
  - *Practical* for experiments

    (bearing in mind both limited data and limited human resources);
  - *Consistent/translatable* between ATLAS and CMS.
- A simple presentation of data as cross sections, distributions, etc: use only SM as input...
- … but want interpretation of data – relies on theory input.

Questions: framework

- Is anomalous couplings/kappa framework sufficient, or do we need EFT?
  - Higher order corrections limited even for pure SM.
- Are a_i coefficients used by CMS really equivalent to (LO) EFT?
- If EFT, do we need to decide on a basis (Higgs, Warsaw,…)? Are there tools to convert results?
- Should we study specific BSM model(s) which are particularly sensitive to offshell $H \rightarrow VV$?

Questions: EFT

- Constraining coefficients of EFT operators:
  - Many such operators but limited data.
  - **Can we identify operators that are particularly sensitive to offshell H→ VV?**
    - E.g. c_y, c_g of [Azatov, Grojean, Paul, Salvioni] – used by ATLAS
  - Can we identify *flat directions* where operators **not particularly sensitive to offshell Higgs data** (or better probed in other processes)?
  - What theoretical assumptions go into this?
    - EFT might be particularly useful in this regard.
  - Treat width as independent parameter and fit that too? Or determined by model?
- Good tools for SM & EFT simulations?
  - Including with jet bins?

Different production processes

- Not limited to gluon fusion production
- VBF, VH:
  - EFT enhancement for $H \to VV$ are larger than in GF.
  - Fewer events in SM, but might be enhanced by EFT effects.
  - QCD corrections smaller, and easier to determine in these channels (tree-level vs loop-induced)
  - Good tools to simulate with SM & EFT? (including with jet binning)

Goals and timelines

- **Purpose**: allow experts from ATLAS, CMS, & theory to confront these issues and propose feasible guidelines/recommendations as input for experimental analyses.
- Documentation progression:

  twiki → informal note → (citable) arxiv submission
- Timeline: few months, finalize documentation by July.

Discussion points

Kick-off meeting:

- Which models/EFT operators should be investigated, and with what priority?
- How can they be implemented in the experimental tool chains?
- Recommended event generators/prescriptions?
- Global EFT fits compatibility: tools to convert results and for validation?
- Jet-binning and associated uncertainties (theory, others)?
- Theory uncertainty treatment for interfering contributions/channels?
- Theory uncertainty treatment for non-interfering background channels ?
- https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HiggsOffshellTaskForce

Discussion points

Separate discussion:

- Higher order QCD K factors for gg->VV (S, B, I)
- Higher order QCD K factors for VBF/VH->VV (S, B, I)
- Theory uncertainty treatment for non-interfering background channels
- (full NLO QCD+EW corrections to the non-interfering VV background: how to take into account/tools/uncertainty; methods to reduce uncertainty due to EW corrections)
- Theory uncertainty treatment for interfering contributions/channels
- Top quark mass effects on the signal and continuum
- BSM higher order effects in EFT