HHH Benchmarks and implementations

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HHH follow-up meeting, CERN/ hybrid
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Discussion in Dubrovnik 15.7.23

Parametrization for resonance enhanced hhh production

Target: pp -> h3 -> h2 h1 -> h1 h1 h1

A priori free parameters: mh1, mh2, mh3, Γ_1, Γ_2, Γ_3, g_h3toptop, g_h3h1h2, g_h2h1h1, g_h1bb [or other final state]Ha

Is it enough ? for sure always offshell contribution from pp > h1* > … > h1 h1 h1

-> introduces additional parameters, there is a minimal set if the above chain exists including other triple scalar and hitoptop couplings…

-> suggestions ??

Make the analysis recastable. Make sure detailed cutflows are on hepdata for given benchmarks, with efficiencies (object reconstruction, etc.) so that the analyses could be included in tools like MadAnalysis, Rivet or CheckMate

Contributing: Roman, Bill, Benjamin, Gilberto, Andreas, Panos, Kazuki, Tania, Hannah

Idea: summarize discussion results in wp

In the meantime... (I)

- some smaller discussions in a meeting with Bill, Holly, and Andreas end of July
- Bill: **BP3 for TRSM not viable for points with masses larger than 600 GeV**

  $\Rightarrow$ **simulation is no longer dominated by resonances** $\Leftarrow$
- **can we choose a subset of (dominant) channels ?**
- **can we get something which is more generic than TRSM ?**
- what about **other parameter points** $\Rightarrow$ **of course possible**

In the meantime...(II)

- some smaller discussions in a meeting with Bill, Holly, and Andreas end of July
- **TR:** at least **we know there is a 125 GeV particle $\Rightarrow$ contributions will be there !!**
  and $t\bar{t}\,h_{125}$ coupling also largish depending on the model
- **if only bump is taken into account no BSM model exists that is described by modelling**
  [nota bene: similar discussion regarding HH searches last week at HiggsDays...]

In the meantime...(III)

- **AP: made model available with general scalar couplings** λ_{ijk}, λ_{ijkl}; κ_i [⇒ next talk]

  [link: https://gitlab.com/apapaefs/twoscalar_generic/]

  ⇒ allows to set couplings by hand ⇐

- !! careful: **you do not guarantee that any theory/ experimental bound is fulfilled any more**

  can e.g. violate unitarity if $h_i\, V\, V$ is modified at will → cross sections can become infinite

- **at least: need to always use autowidth, and respect sum rule for couplings to vector bosons**

Some more thoughts on width and interference

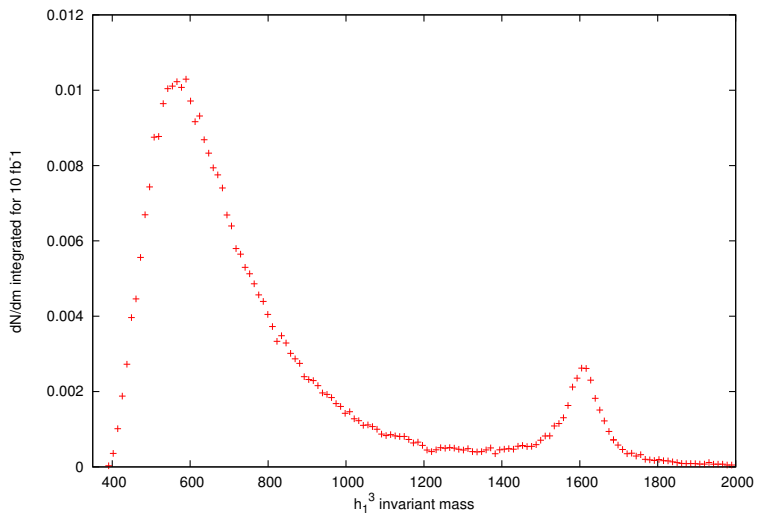
- sample process

$$p\,p \;\to\; h_3 \to\; h_1\,h_2 \;\to\; h_1\,h_1\,h_1$$

  simulating full final state: $p\,p \;\to\; h_1\,h_1\,h_1$

- masses: $125\,\mathrm{GeV},\ 500\,\mathrm{GeV},\ 1600\,\mathrm{GeV}$
- other pars:

  $\kappa_1 = 0.98,\ \kappa_3 = -0.19,\ \mathrm{BR}_{3\to 1\,2} = 4\,\%,\ \mathrm{BR}_{2\to 1\,1} = 90\,\%$



large contribution from offshell h_1

Open discussion points

Road to simplification (?)

1. iff only resonance is produced: **how wrong are we ?**
   what would be the **effort to do a real recast** (in particular with BDTs taking over) ?
2. **are cluster benchmarks feasible ?** in how many dimensions/ variables ?
3. **as 1), but for inclusion of at least h_{125} resonance in s-channel**
   nota bene: **if you want $h_3 \to h_1\, h_2$, h_2 also exists !** and $h_1\, t\, \bar{t}$ **typically sizeable** (otherwise we would not see the 125 GeV)
4. what are **viable regions in parameter spaces** [any models]

Plan for writeup

Suggestion...

1. describe **model already available** (AP/ TR/ ...)
2. describe **possible enhancement of free parameters**, including widths etc: **3 masses, 3 widths, modifications of all triple couplings, modifications of all couplings to $t\bar{t}$** (TR)
3. maybe: **showcase points where the simplified approach is (not) valid** (anyone)

?? Any comments ??

Save the date !! 29.-31.7.24

had a very nice *HHH* workshop in Dubrovnik this year

[https://indico.cern.ch/event/1232581/]

⇒ da capo next year (by popular demand): ⇐
IUC, Dubrovnik, 29.-31.7.2024

! Save the date !

[Pics by IUC Dubrovnik/ V. Brigljevic]