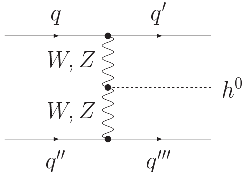
Karlsruhe Institute of Technology

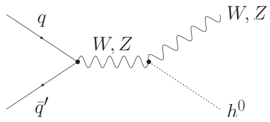
New-physics effects in (VH and) VBF-Higgs production

Michael Rauch | LHC HXSWG 8th meeting, Jan 2015

INSTITUTE FOR THEORETICAL PHYSICS

VH and Vector-boson-fusion Higgs





- mediated by *HWW* and *HZZ* couplings

VBF: [Han, Valencia, Willenbrock; Figy, Oleari, Zeppenfeld; Campbell, Ellis, Berger]

- clear signature due to two tagging jets
- QCD corrections relatively small $\sim$ 5% [Figy, Oleari, Zeppenfeld; Harlander et al.; Bolzoni et al.]
- EW corrections of same size [Ciccolinni, Denner, Dittmaier; Figy, Palmer, Weiglein]

VH:

- similar matrix elements
- boosted *H* in exp. analyses

Two dedicated tools for NLO QCD + anomalous couplings:

- VBFNLO [Zeppenfeld, MR et al.]
  VBF in VBF approx., WH(j)
- HAWK [Denner, Dittmaier, Kallweit, Mück]
  VBF, VH including interferences

NLO EW in both cases treated additively (no EW corrections to anomalous couplings)

Effective Field Theories

General structure of $HV_1^\mu V_2^\nu$ vertex ($V = W, Z, \gamma, g$)

$$T^{\mu\nu} = a_1(p_1, p_2) g^{\mu\nu} + a_2(p_1, p_2)[p_1 \cdot p_2 g^{\mu\nu} - p_2^\mu p_1^\nu] + a_3(p_1, p_2) \varepsilon^{\mu\nu\rho\sigma} p_{1\,\rho} p_{2\,\sigma}$$

SM (LO): HWW, $HZZ \propto a_1$, $a_2 = a_3 = 0$

$H\gamma\gamma$, $Hgg \propto a_2$, $a_1 = a_3 = 0$

Alternative parametrization given by dimension-6 operators of effective Lagrangian

$$\mathcal{L}_{eff} = \frac{f_{WW}}{\Lambda_6^2} \mathcal{O}_{WW} + \frac{f_{BB}}{\Lambda_6^2} \mathcal{O}_{BB} + \frac{f_W}{\Lambda_6^2} \mathcal{O}_W + \frac{f_B}{\Lambda_6^2} \mathcal{O}_B + \text{ CP-odd part}$$

$$= \frac{eM_W}{\Lambda_6^2} \left(\frac{1}{2\cos^2\theta_W} \left(\cos^2\theta_W f_W + \sin^2\theta_W f_B \right) Z_{\mu\nu} Z^\mu \partial^\nu H - \frac{1}{2\cos^2\theta_W} \left(\sin^4\theta_W f_{BB} + \cos^4\theta_W f_{WW} \right) HZ_{\mu\nu} Z^{\mu\nu} + \frac{1}{2} f_W \left(W^+_{\mu\nu} W^\mu_- + W^-_{\mu\nu} W^\mu_+ \right) \partial^\nu H - f_{WW} HW^+_{\mu\nu} W_-^{\mu\nu} \right) + \; H\gamma\gamma,\, HZ\gamma \text{ terms, CP-odd part}$$

Direct correspondence to a_i

$$a_2^{HWW} = \frac{2eM_W}{\sin\theta_W \Lambda_6^2} \left(f_{WW} - \frac{1}{2} f_W \right)$$

$$a_2^{HZZ} = \frac{2eM_W}{\sin\theta_W \Lambda_6^2} \left(\cos^2\theta_W f_{WW} + \left(\frac{\sin^2\theta_W}{\cos^2\theta_W} - \sin^2\theta_W \right) f_{BB} - \frac{1}{2} f_W - \frac{\sin^2\theta_W}{2\cos^2\theta_W} f_B \right)$$

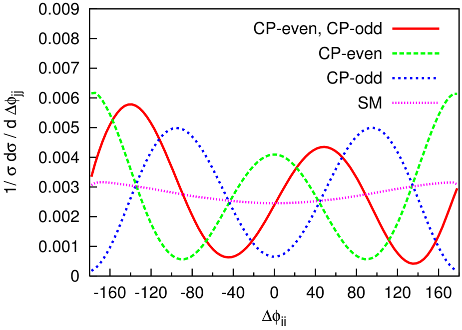
(only subset shown here, see `https://www.itp.kit.edu/~vbfnloweb/wiki/doku.php?id=documentation:details:anomaloushiggs` for all relations)

$\rightarrow$ for these dimension-6 operators no momentum dependence of a_i

Physical Observables – $\Delta\Phi_{jj}$

Particular sensitivity given by azimuthal angle difference of the two tagging jets $\Delta\phi_{jj}$

[Hankele, Klämke, Zeppenfeld, Figy]



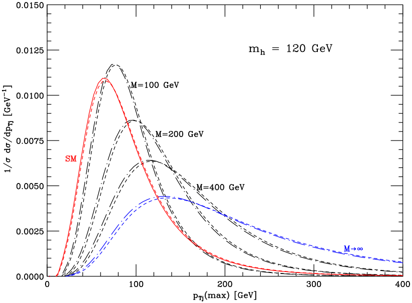
SM: $a_1 \neq 0$
CP-even: $a_2 \neq 0$
CP-odd: $a_3 \neq 0$
CP-even,CP-odd: $a_2 = a_3 \neq 0$

- almost flat distribution for SM $= a_1$-Term
- $\cos(2\Delta\phi_{jj})$-behaviour for a_2 and a_3 terms
- admixture of a_2 and a_3 can be determined via phase shift of distribution

Physical Observables – $p_T(j)$

New-physics effects can also modify transverse-momentum distributions

$a_1 = 0, a_2 = a_3 = \text{const.}$ [Figy, Zeppenfeld]



- Huge c.s. increase for large p_T
- $\rightarrow$ dominated by (D6-op.)^2-term
- $\leftrightarrow$ violates EFT expansion: D8-op. $\times$ SM of same order
- $\rightarrow$ eventually unitarity violation
- $\Rightarrow$ higher-order operators become equally important
- effective parametrization by form factor, e.g.
  $$a_i(q_1, q_2) = a_i(0,0)\left[\left(1-\frac{q_1^2}{M^2}\right)\left(1-\frac{q_2^2}{M^2}\right)\right]^{-1}$$
- $\rightarrow$ p_T distrib. can become SM-like

$\Rightarrow$ New-physics effects can modify p_T distributions

$\Leftrightarrow$ Non-observation of modified p_T distribution not sufficient
$\Rightarrow$ need to check other observables as well

$\rightarrow$ When using $D6$-operators, need to ensure that exclusion is not based purely on large-p_T region