物理学系 王淦昌楼

JHU generator framework new features for Higgs boson studies

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arXiv:2002.09888
arXiv:1606.03107

JHUGen & MELA package

- JHUGen: event generator, focus on anomalous couplings of the Higgs boson, EFT
- JHUGenMELA & AnalyticalMELA: Matrix Element Likelihood Approach
  - building discriminants: optimize analysis and suppress background
  - re-weighting: per-event ME based probability
- JHUGenLexicon: conversion between different EFT basis and anomalous couplings
- Webpage: http://spin.pha.jhu.edu

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*                              JHU Generator v7.4.0                           *
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*                                                                             *
*   Spin and parity determination of single-produced resonances at hadron colliders   *
*                                                                             *
*         I. Anderson, S. Bolognesi, F. Caola, J. Davis, Y. Gao, A. Gritsan,          *
*          Z. Guo, C. Martin, K. Melnikov, R. Rontsch, H. Roskes, U. Sarica,          *
*                 M. Schulze, N. Tran, A. Whitbeck, M. Xiao, Y. Zhou                  *
*              Phys.Rev. D81 (2010) 075022;  arXiv:1001.3396  [hep-ph],               *
*              Phys.Rev. D86 (2012) 095031;  arXiv:1208.4018  [hep-ph],               *
*              Phys.Rev. D89 (2014) 035007;  arXiv:1309.4819  [hep-ph],               *
*              Phys.Rev. D94 (2016) 055023;  arXiv:1606.03107 [hep-ph].               *
*                                            arXiv:2002.09888 [hep-ph].               *
*                                                                             *
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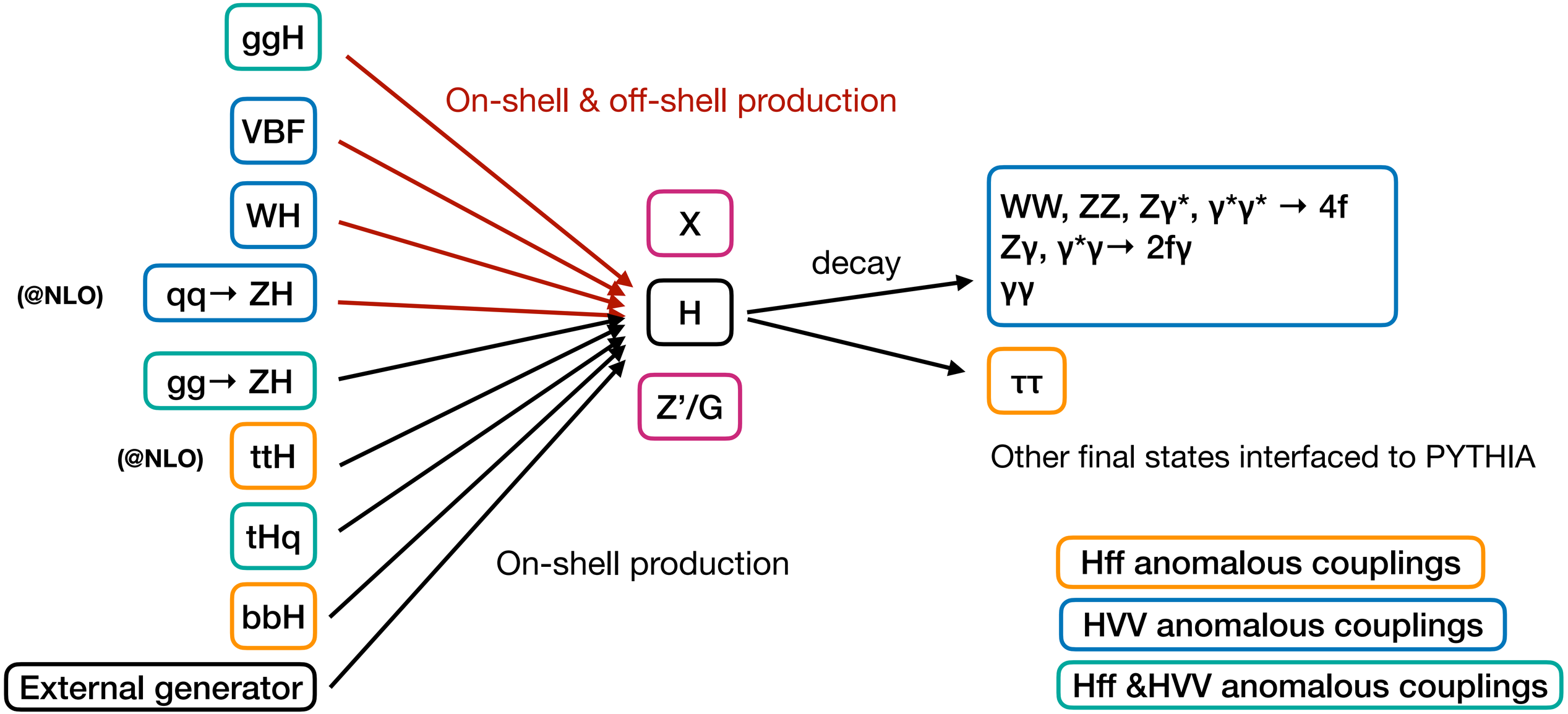
Available processes



Anomalous couplings & EFT

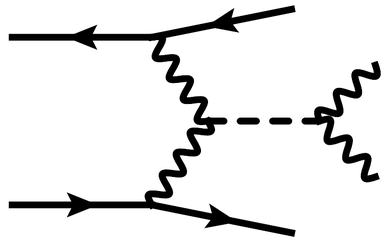
$$A(HV_1V_2) = \frac{1}{v}\left\{ M_{V_1}^2 \left(g_1^{VV} + \frac{\kappa_1^{VV} q_1^2 + \kappa_2^{VV} q_2^2}{\left(\Lambda_1^{VV}\right)^2} + \frac{\kappa_3^{VV}(q_1+q_2)^2}{\left(\Lambda_Q^{VV}\right)^2} + \frac{2q_1\cdot q_2}{M_{V_1}^2} g_2^{VV} \right)(\varepsilon_1\cdot\varepsilon_2) \right.$$
$$\left. -2g_2^{VV}(\varepsilon_1\cdot q_2)(\varepsilon_2\cdot q_1) - 2g_4^{VV}\,\varepsilon^{\varepsilon_1\,\varepsilon_2\,q_1\,q_2} \right\},$$

$$A(Hf\bar{f}) = -\frac{m_f}{v}\bar{\psi}_f\left(\kappa_f + \mathrm{i}\tilde{\kappa}_f\gamma_5\right)\psi_f\,,$$

SM: g_1 ; BSM: $g_{2,4}$, $\kappa_{1,2,3}$
SM: κ_f ; BSM: $\kappa_{f\sim}$

General parameterization, 1 to 1 translation to Effective Lagaragian
$c_{zz} \sim g_2$, $c_{z\Box} \sim \kappa_1$, $c_{ZZ\sim} \sim g_4$
Conversion between different EFT bases through JHUGenLexicon

MELA based discriminants

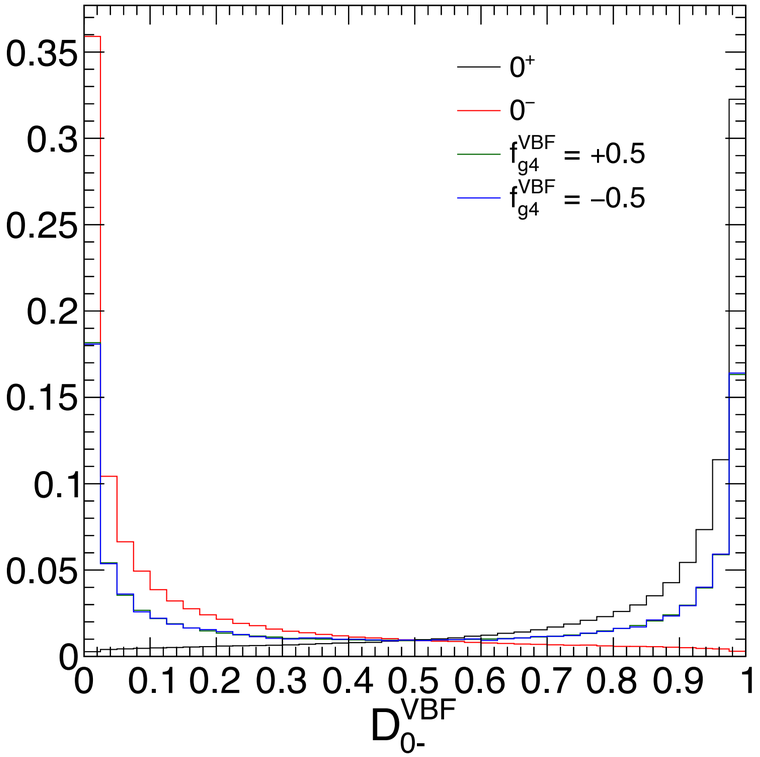


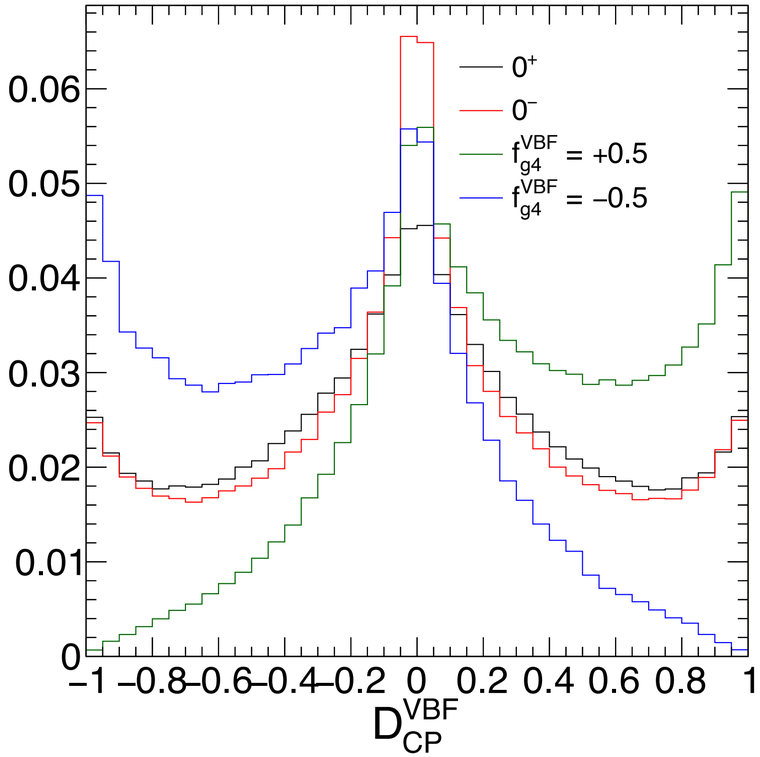
To separate BSM couplings

$$D_{alt} = \frac{P_{sig}}{P_{sig} + P_{alt}}$$

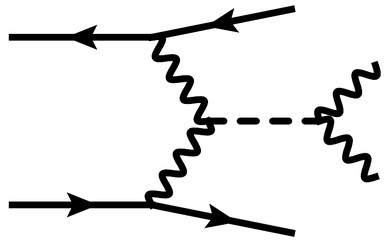
To get interference

$$D_{int} = \frac{P_{int}}{2\sqrt{P_{sig}P_{alt}}}$$

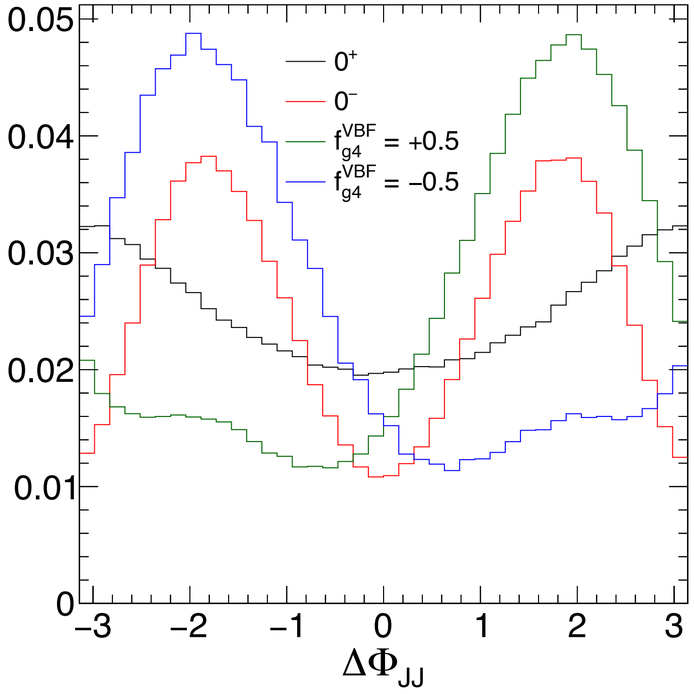


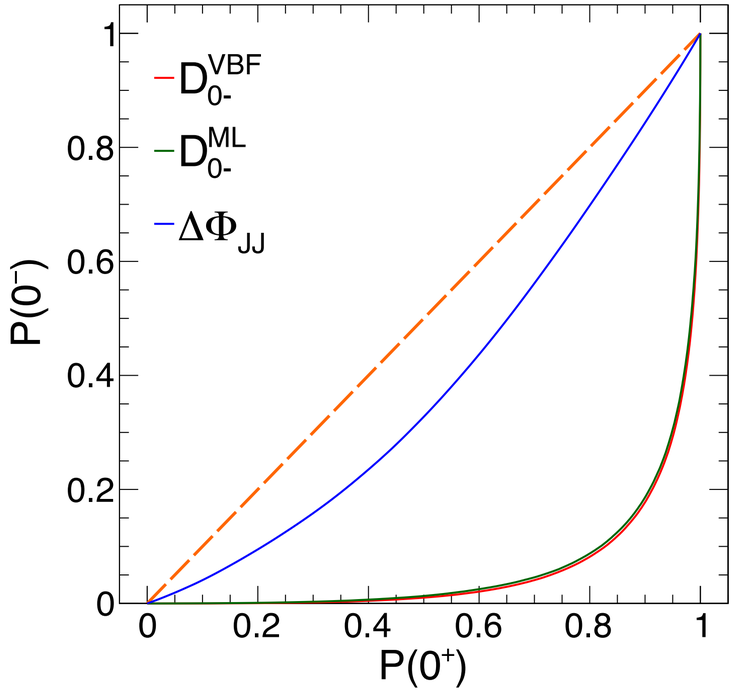


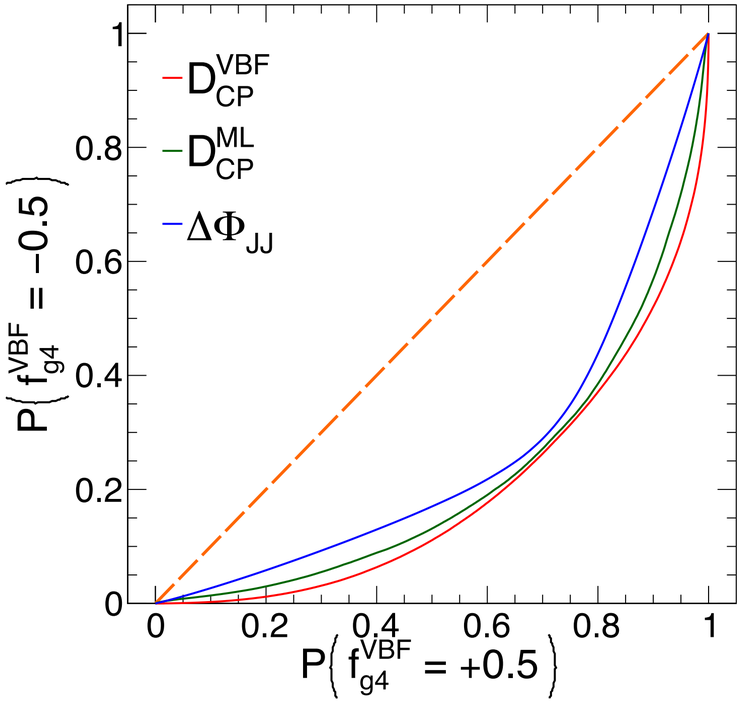
Discriminants



- Partial kinematics carry useful info as well: associated jets
- With the same kinematic inputs, machine learning performs as good as ME
  - Interference more difficult

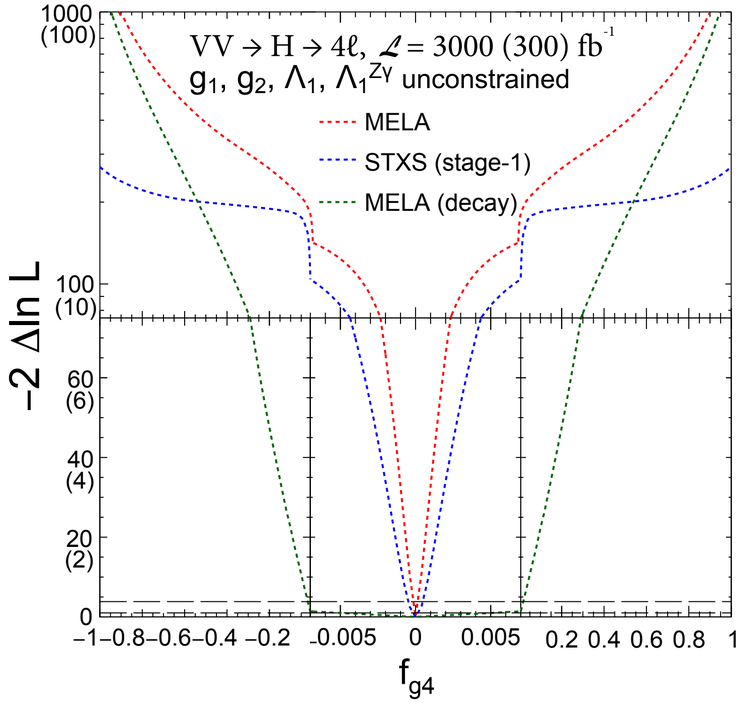


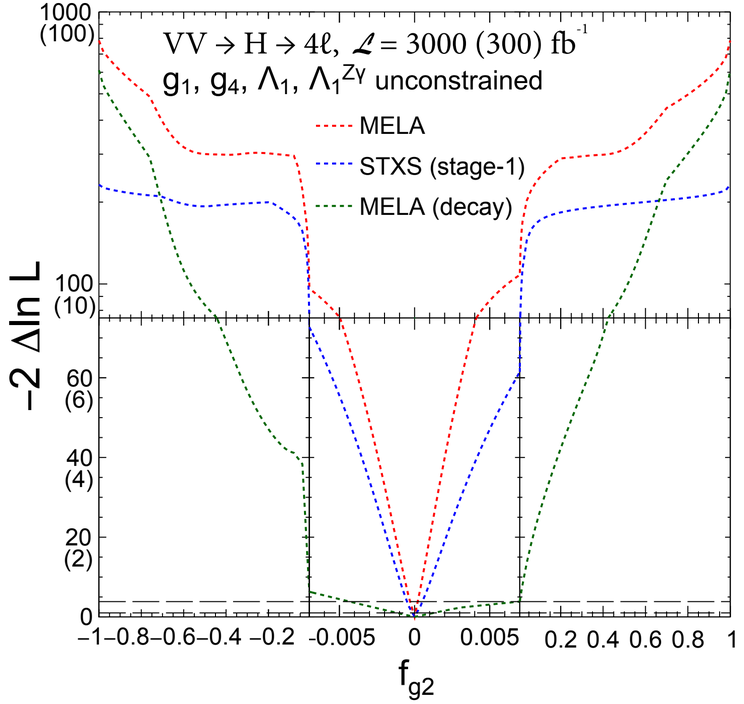




HVV analysis example

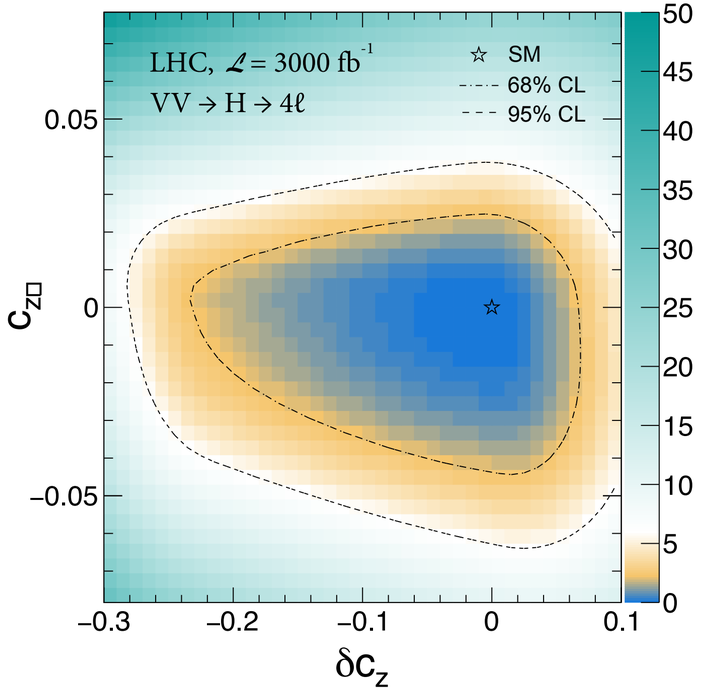
- Using MELA discriminants, the HVV anomalous couplings could be measured simultaneously, example in H→ 4l
- Using STXS bins as discriminants, equivalent to using pT(H), m_{jj}, decay kinematics not exploit
- Using only H → 4l decay, to avoid high q^2 region, more model independent

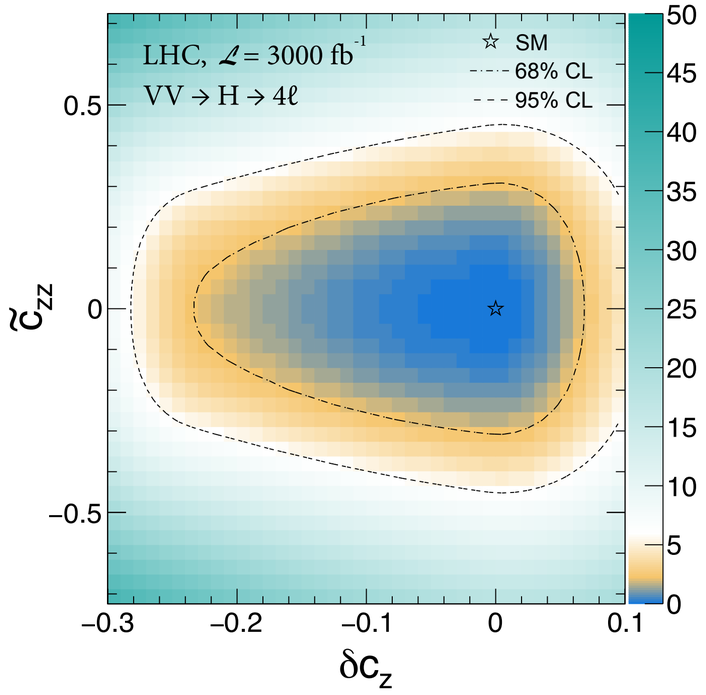


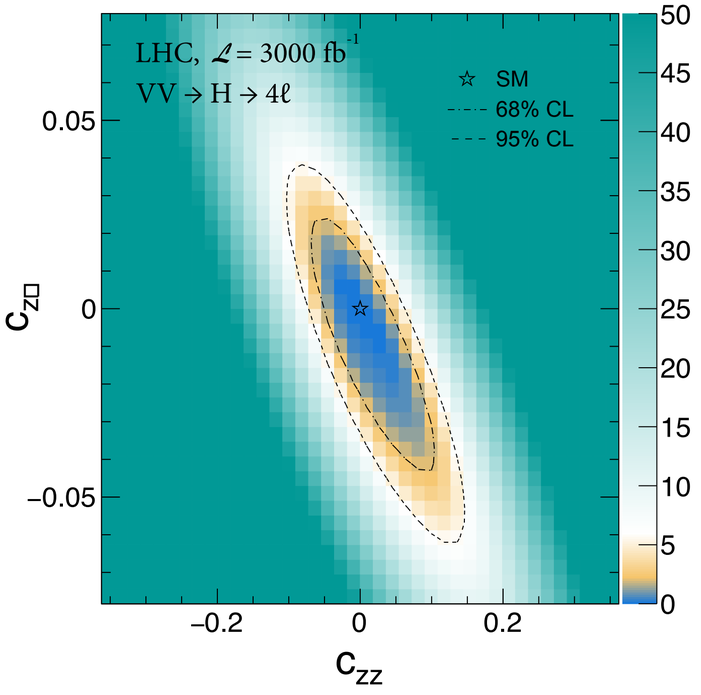


HVV analysis example

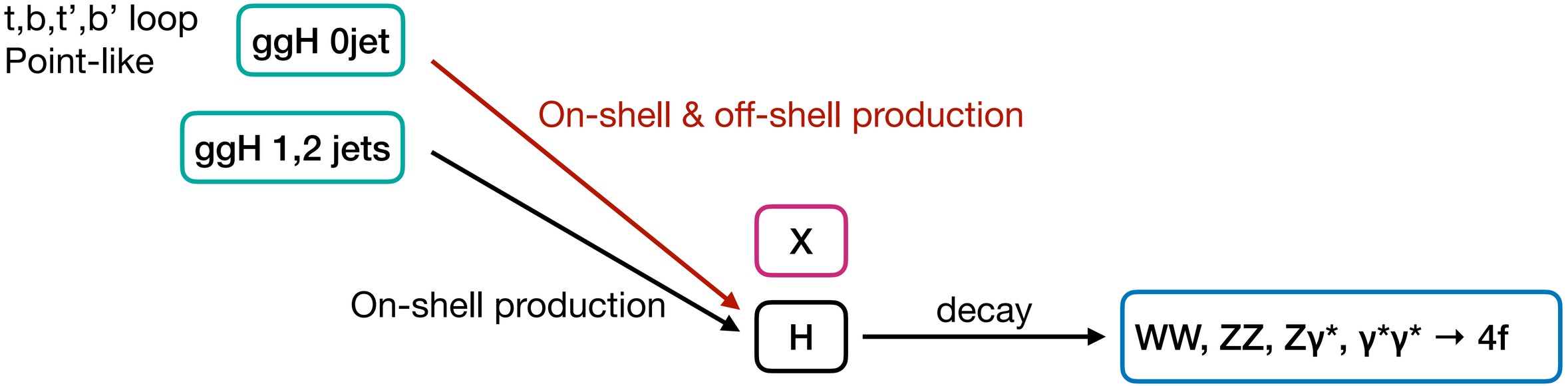
- Using H→ 4l as an example
- The anomalous couplings (g1, g2, g4, κ1) translated to EFT coefficients (δC_z, C_{zz}, $C_{z\Box}$, C_{zz}~)
- Hgg coupling floated, other couplings fixed to SM







Available processes

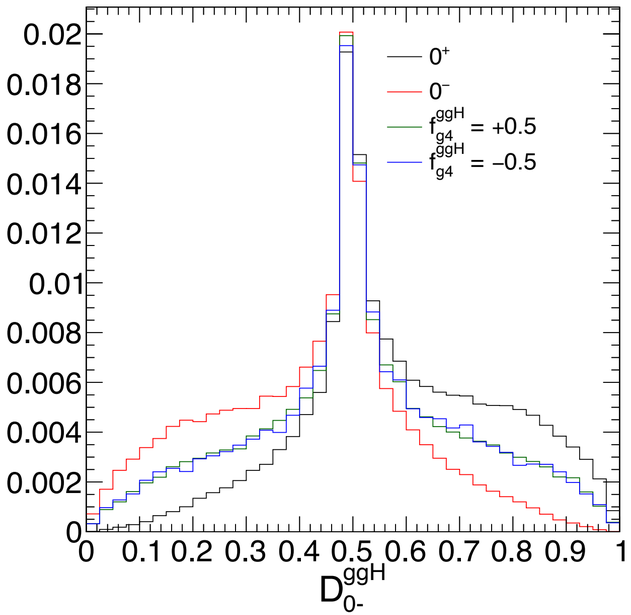


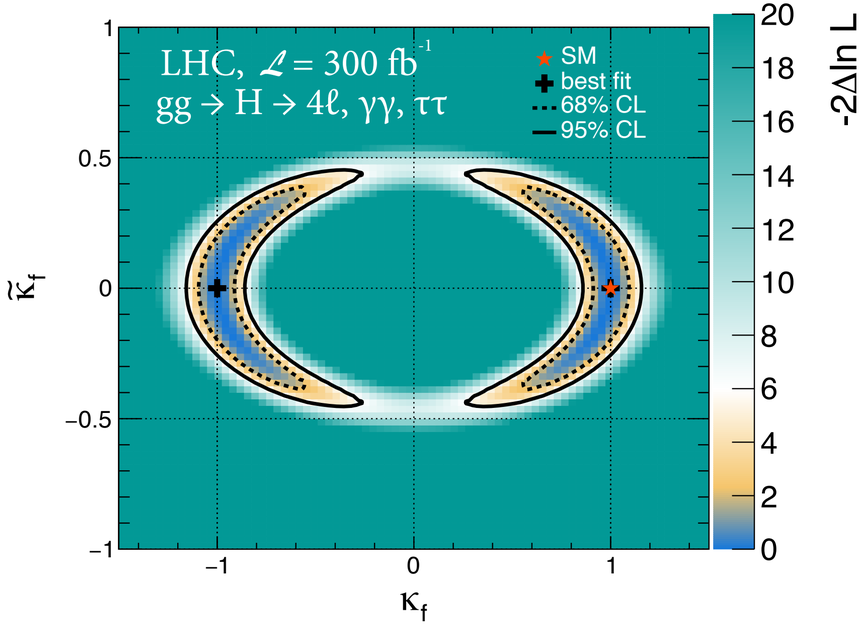
HVV anomalous couplings

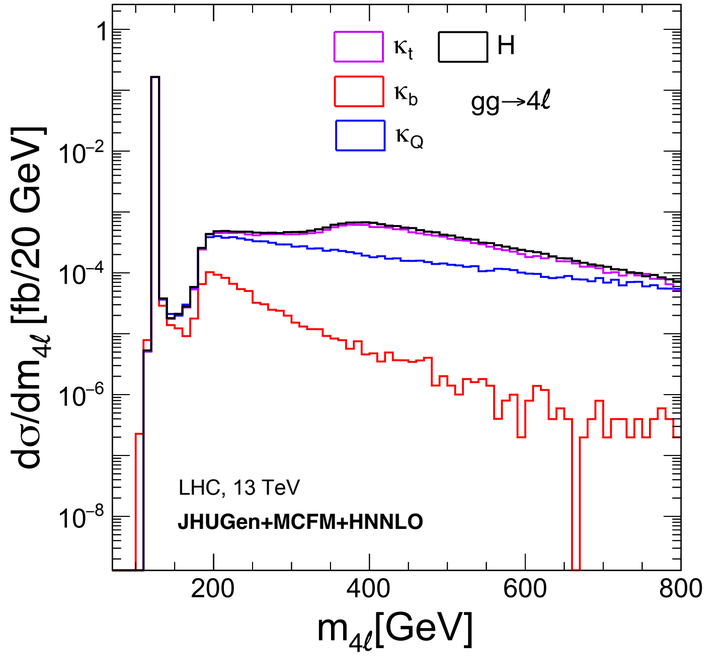
Hff &HVV anomalous couplings

Hgg anomalous couplings

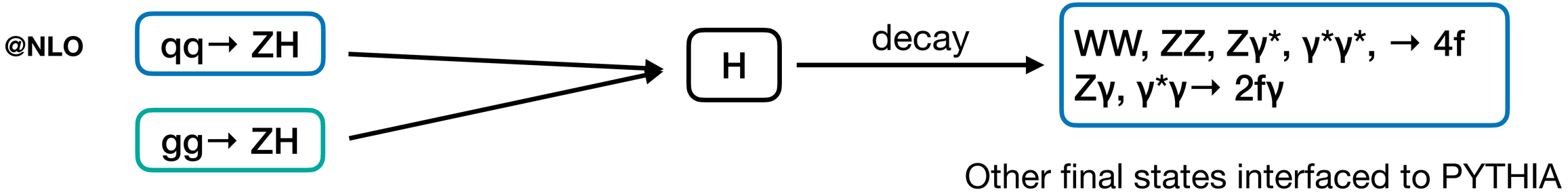
- ggH + 2jet, on-shell H
  - effective Hgg coupling, g_2^{gg} & g_4^{gg}
  - t+b loop: assuming $\kappa_b = \kappa_t$, $\kappa_{b\sim} = \kappa_{t\sim}$
- ggH+0jet, off-shell H
  - Resolve the t and b loop







Available processes

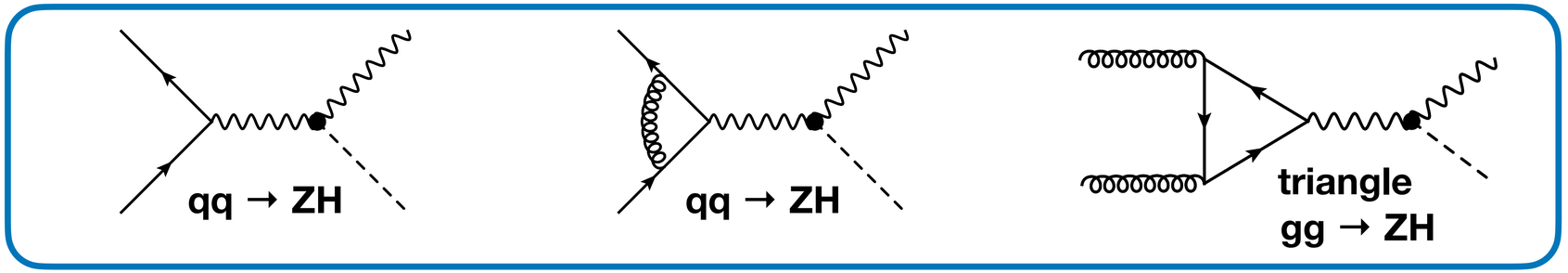


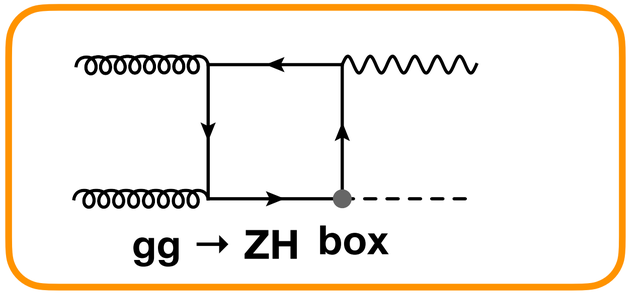
Other final states interfaced to PYTHIA

HVV anomalous coupling

Hff &HVV anomalous couplings

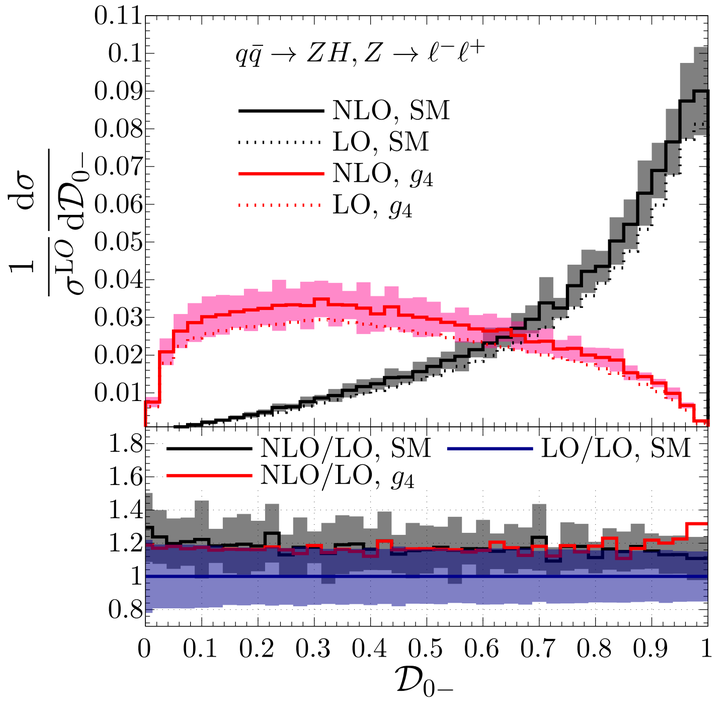
ZH anomalous couplings

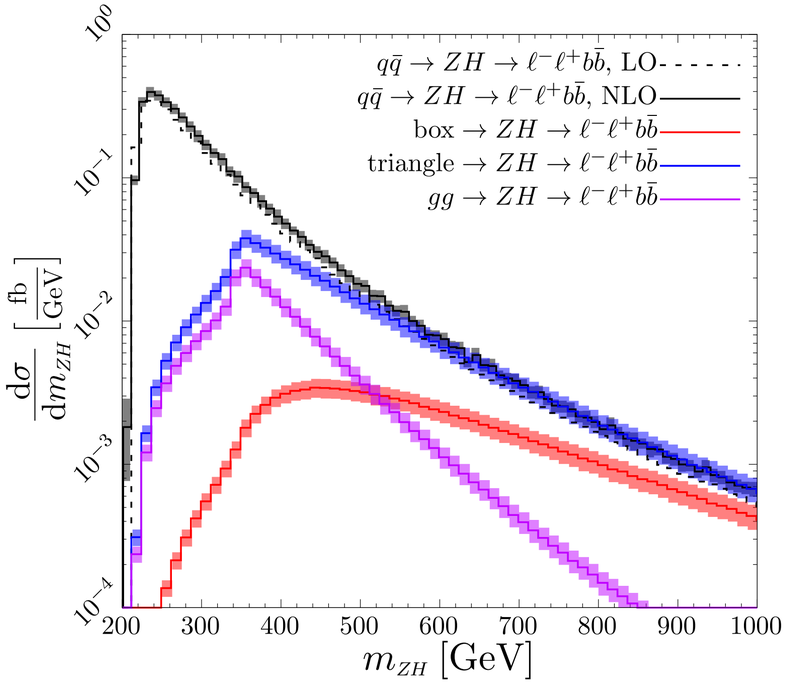


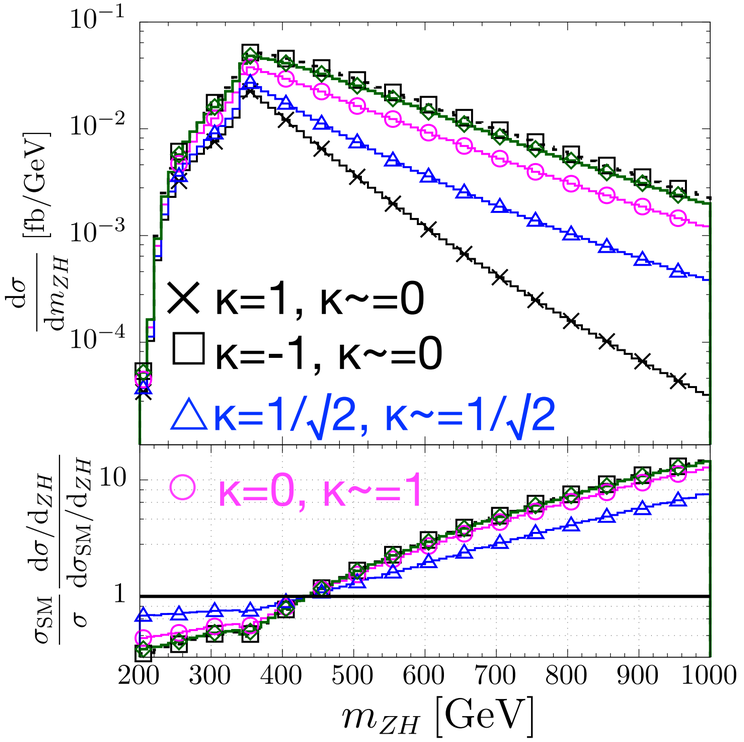


HZZ coupling

Htt coupling



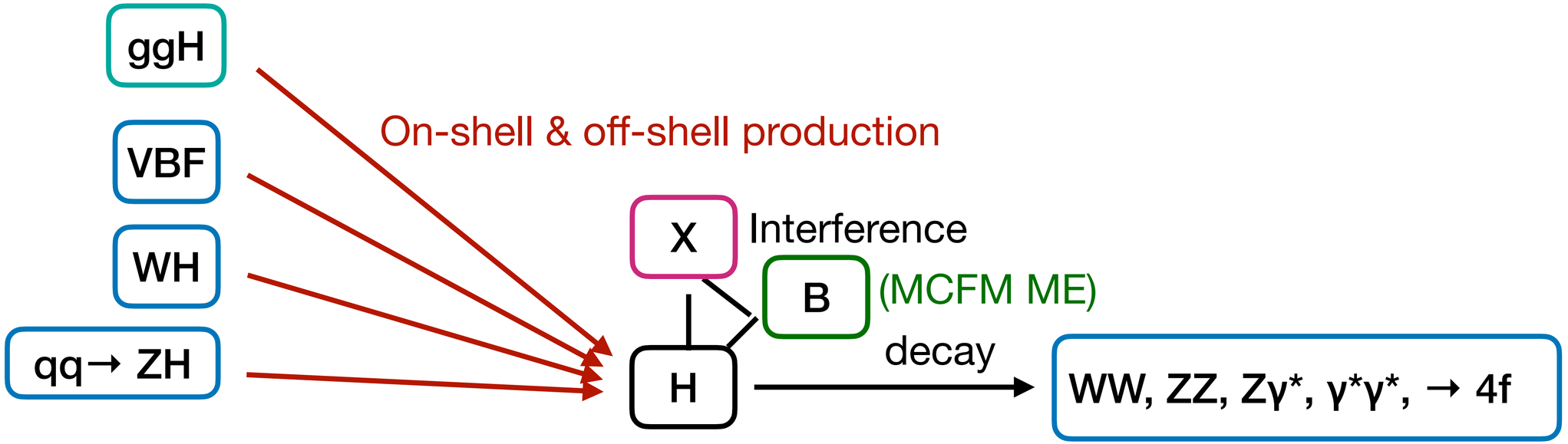




qq→ ZH NLO/LO flat over anomalous HVV coupling

gg→ZH xsec=0 in anomalous HVV coupling
Sensitive to anomalous Hff coupling

Available processes

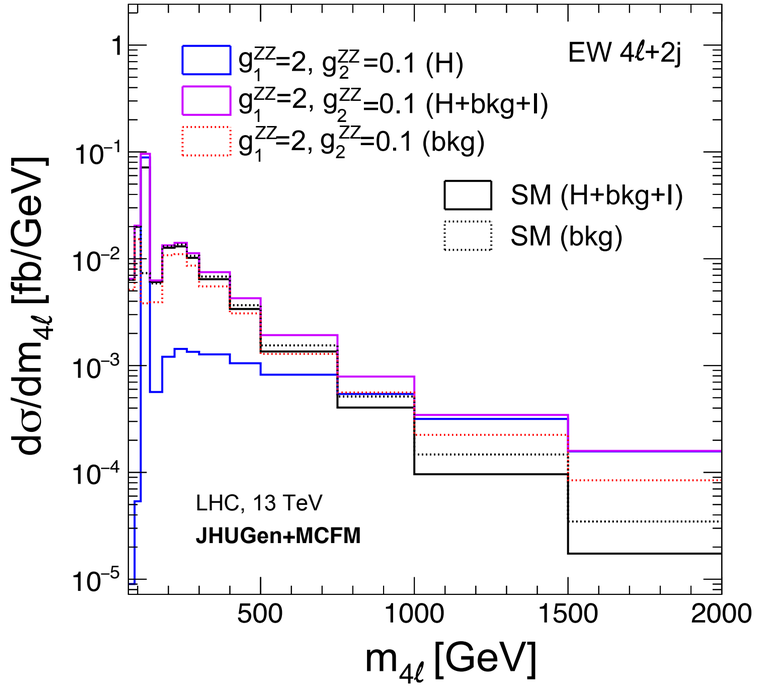


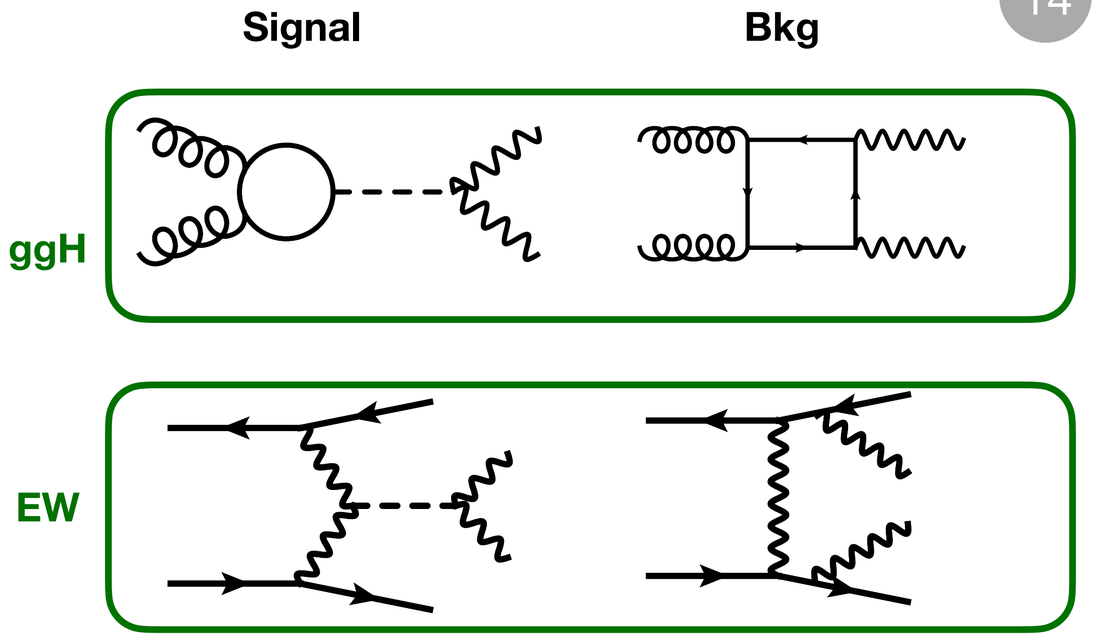
HVV anomalous couplings

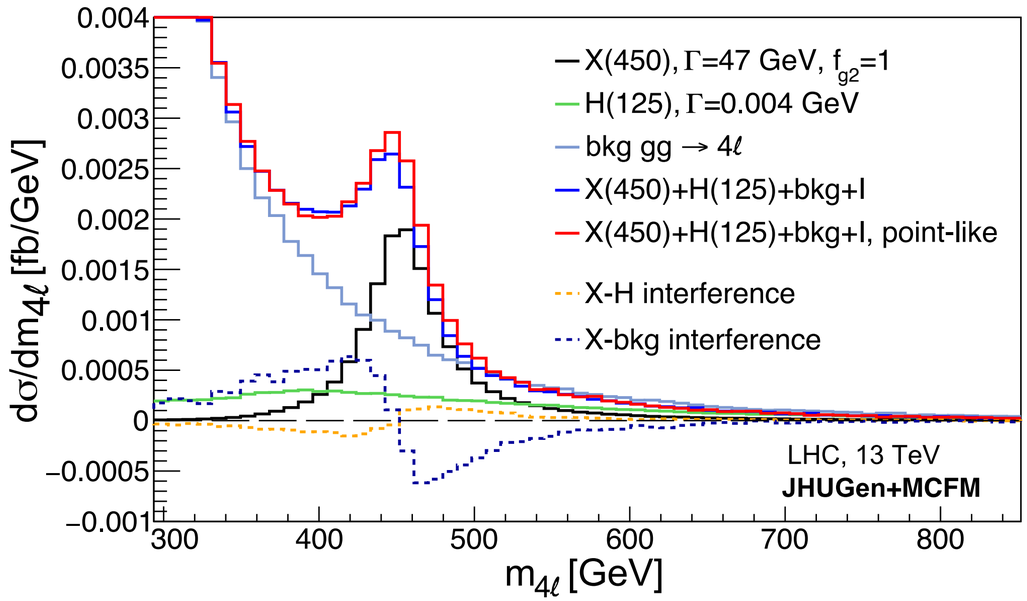
Hff &HVV anomalous couplings

Off-shell effects

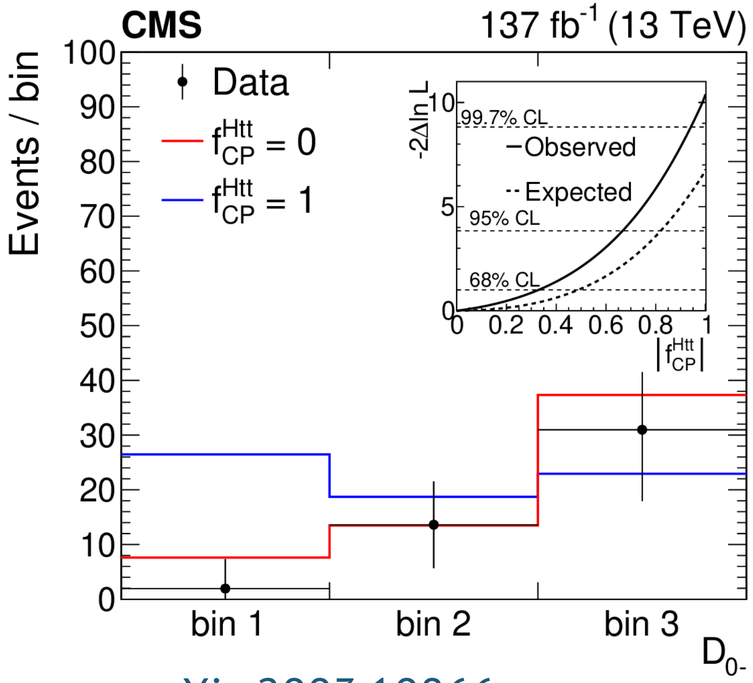
- Under EFT relations, anomalous HVV => anomalous gauge self coupling
  - H→ 4f and EW bkg → 4f shapes affected
- Additional resonance X with any (m_X, Γ_X)
  - Anomalous couplings in XVV
  - Interference with H and bkg





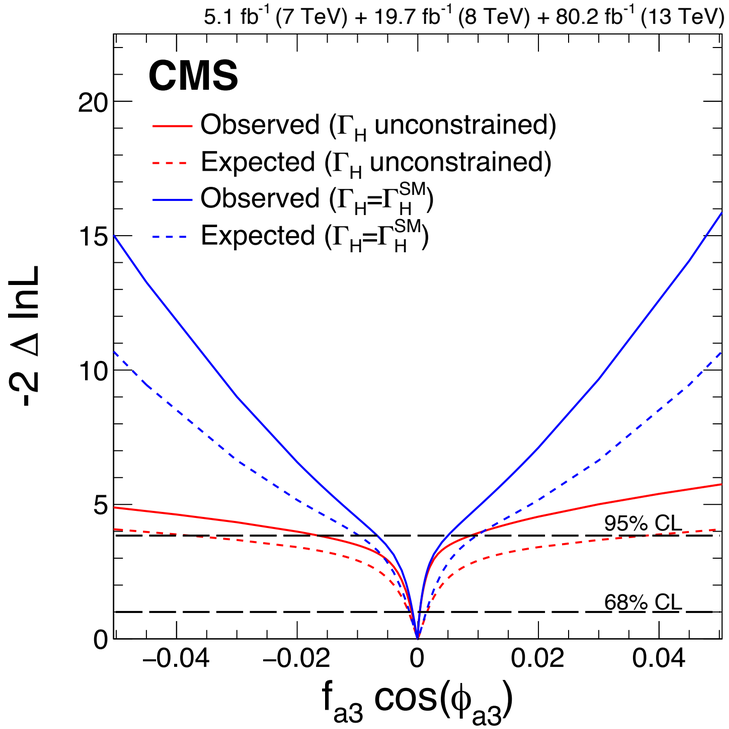


Experimental results using JHUGen

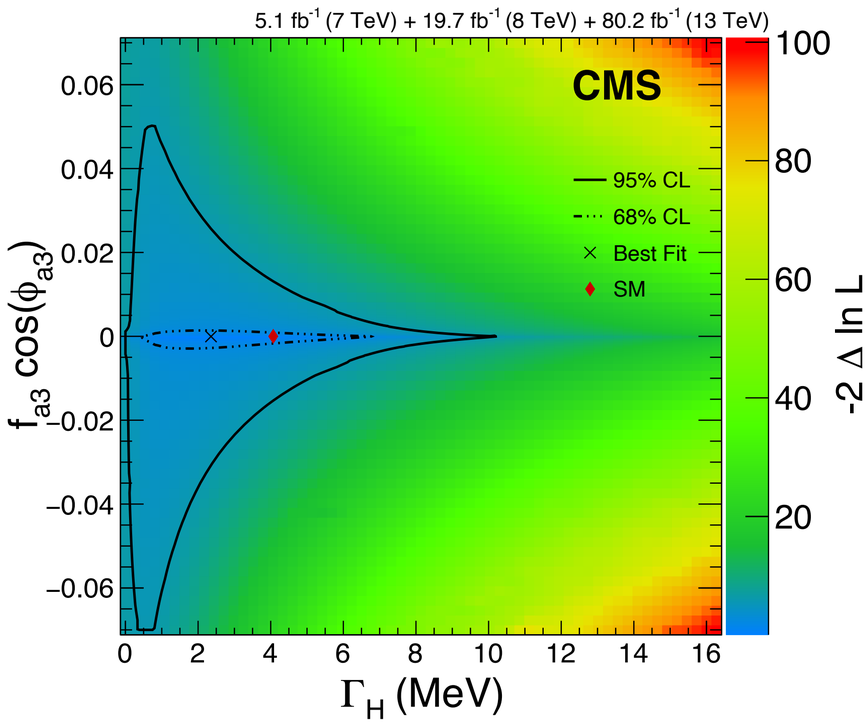


arXiv:2003.10866

PRD 99 (2019) 112003



PRD 99 (2019) 112003



See more results in the talk of Savvas Kyriacou

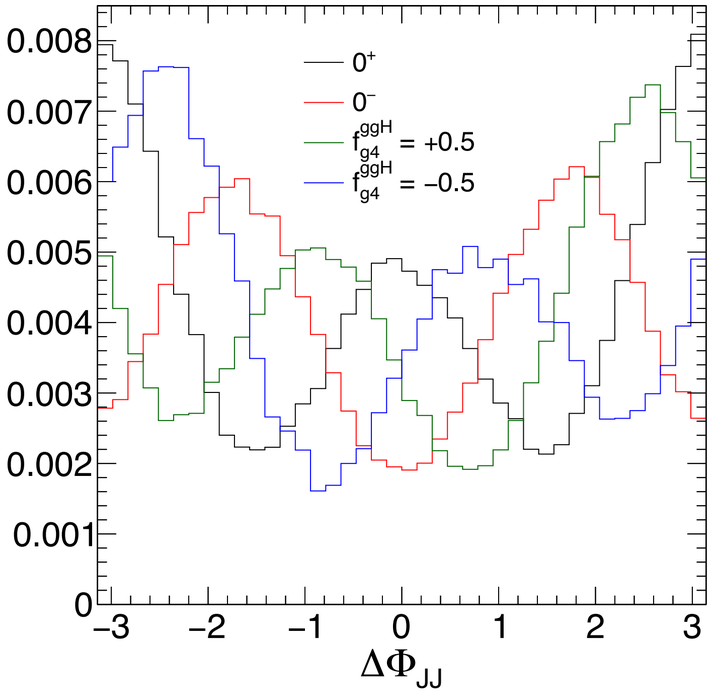
Summary

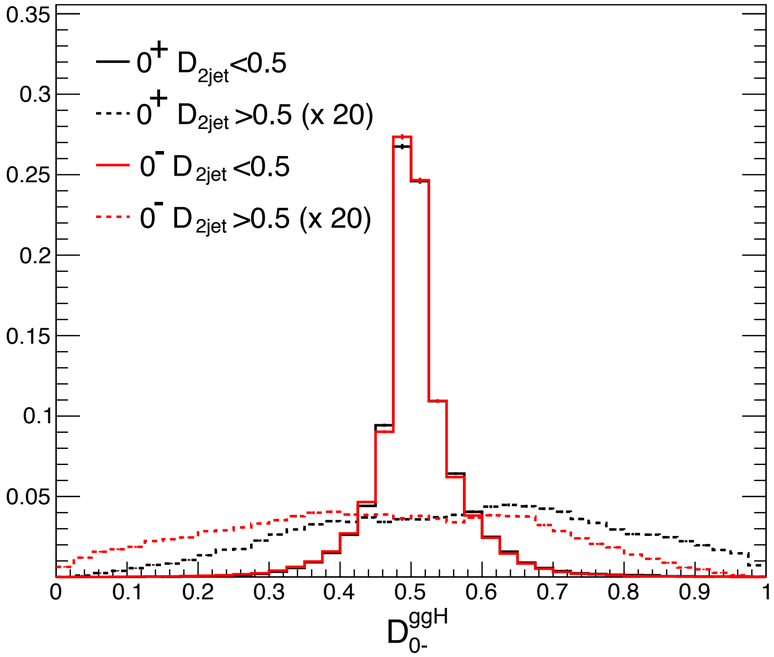
- General framework to study the anomalous couplings of the Higgs boson
- Provide tools for measurements of the anomalous couplings and corresponding EFT coefficients
- New features in recent developments
  - Examples of simultaneous measurements of multiple HVV EFT coefficients
  - ggH and EW on-shell and off-shell anomalous couplings
  - NLO ZH description
  - Additional resonances with anomalous couplings

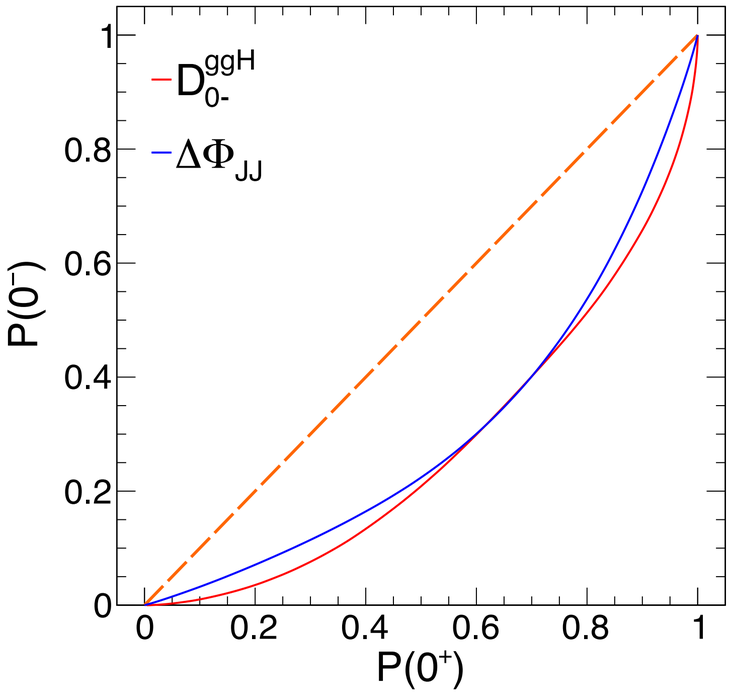
Welcome to join the zoom room here (Meeting ID 936 5606 3779) to discuss more after the session at 13h

More materials

ggH+2jets


0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0⁺
0⁻
f_g4^ggH = +0.5
f_g4^ggH = −0.5
−3
−2
−1
0
1
2
3
ΔΦ_JJ


0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0⁺ D_2jet<0.5
0⁺ D_2jet >0.5 (x 20)
0⁻ D_2jet <0.5
0⁻ D_2jet >0.5 (x 20)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
D_0-^ggH

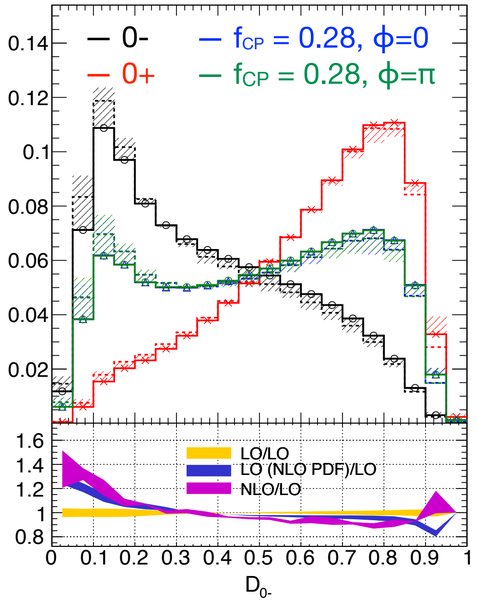

1
0.8
0.6
0.4
0.2
0
D_0-^ggH
ΔΦ_JJ
P(0⁻)
0
0.2
0.4
0.6
0.8
1
P(0⁺)

ttH: ME based discriminants from MELA

- JHUGen generated LO and NLO events
- The MEs use the 4-momentum of tt->(ff'b,ff'b) and H
- small impact from LO/NLO and PDF scale variation

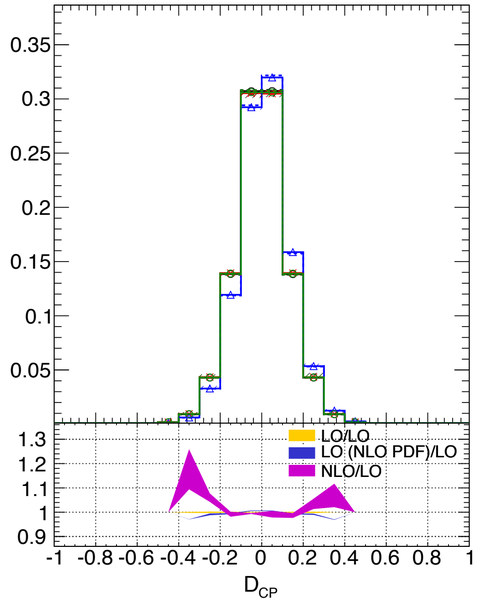
$$\mathcal{D}_{0-} = \frac{\mathcal{P}_{0+}(\vec{\Omega})}{\mathcal{P}_{0+}(\vec{\Omega}) + \mathcal{P}_{0-}(\vec{\Omega})},$$

for 0+ vs 0-



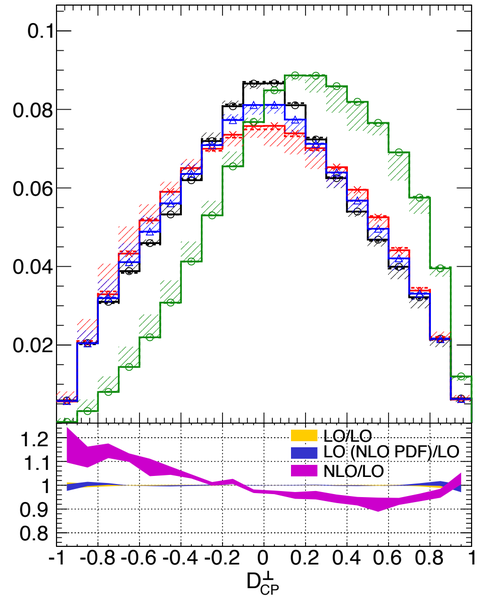
$$\mathcal{D}_{CP} = \frac{\mathcal{P}_{\rm int}(\vec{\Omega})}{\mathcal{P}_{0+}(\vec{\Omega}) + \mathcal{P}_{0-}(\vec{\Omega})},$$

for CP mixture, ϕ=0



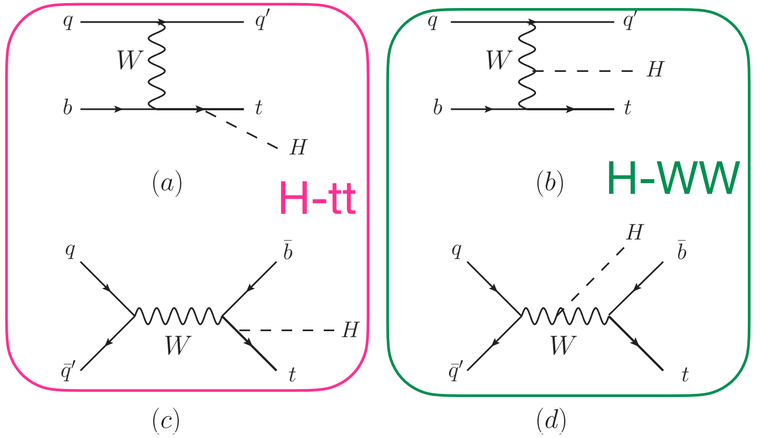
$$\mathcal{D}_{CP}^{\perp} = \frac{\mathcal{P}_{\rm int}^{\perp}(\vec{\Omega})}{\mathcal{P}_{0+}(\vec{\Omega}) + \mathcal{P}_{0-}(\vec{\Omega})},$$

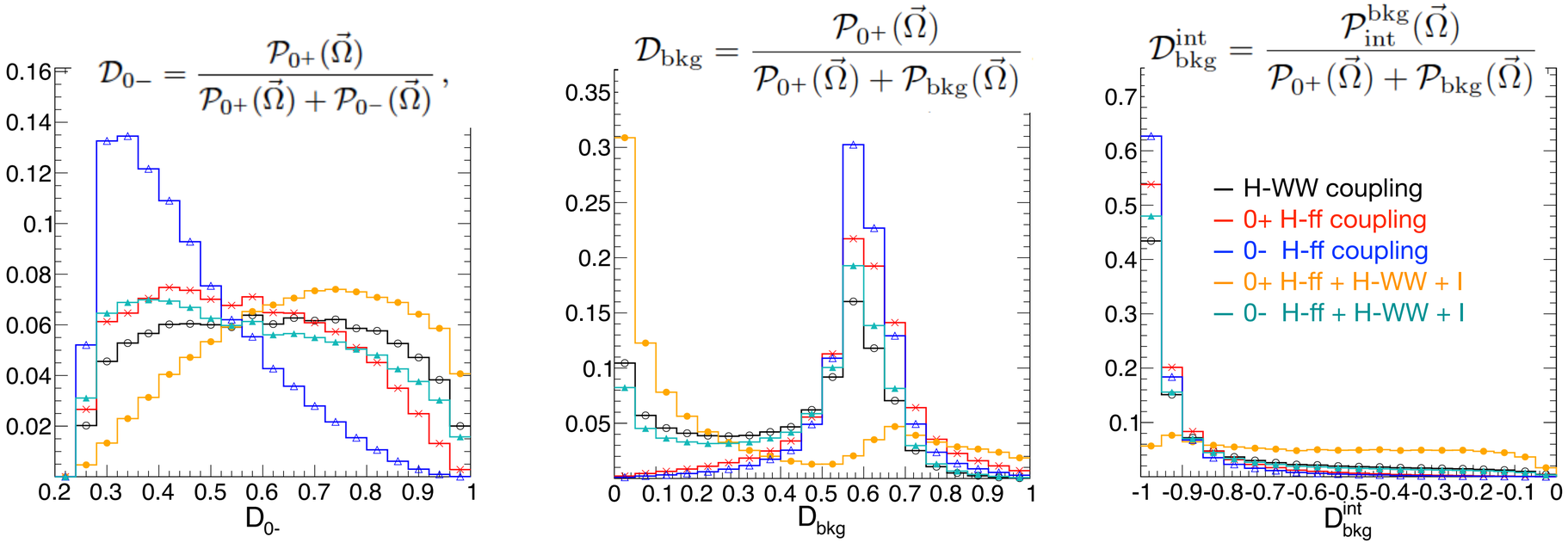
for CP mixture, ϕ=90



tqH process

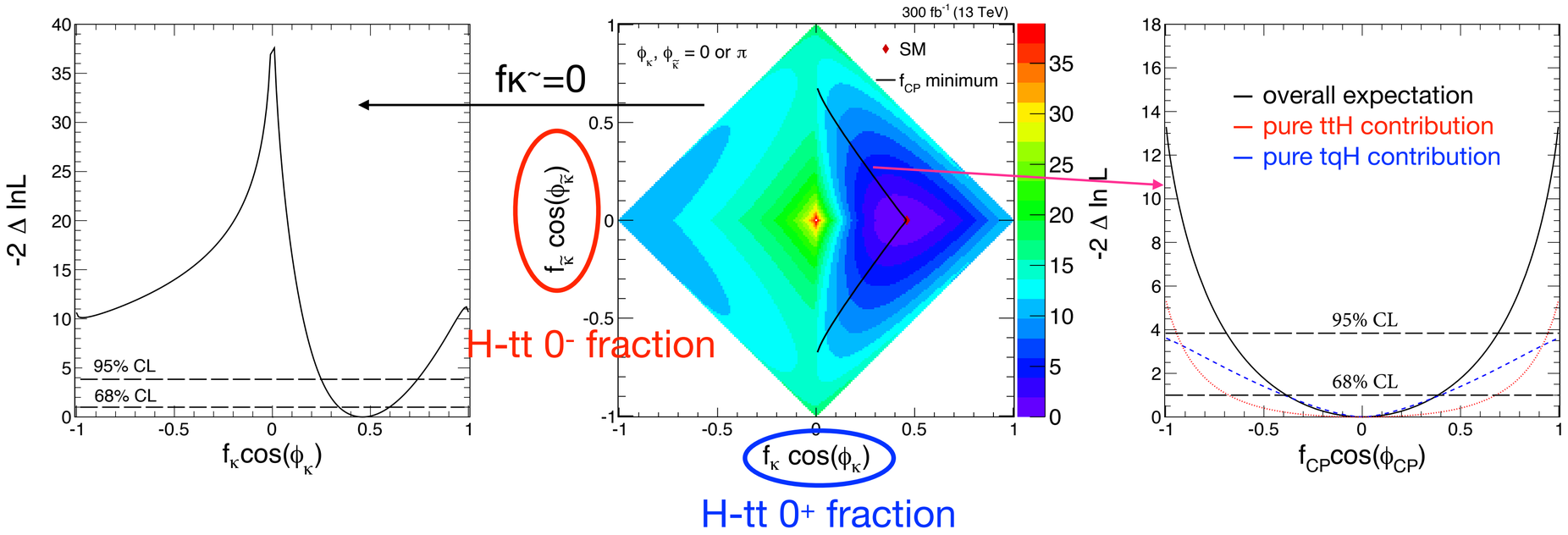
- t-channel + s-channel
- Strong Hff and HVV interference
- Sensitive to the size, sign and CP of the Hff coupling





tqH projection

- Projection on 300 fb^{-1}, 3D analysis
- tqH= H-tt 0^{+}+ H-tt 0^{-} + H-WW; measure x-sec fraction of H-tt 0^{+} and H-tt 0^{-}



- More than 3σ exclusion on 0- and on κ<0
- Note: exclusion will be weaker if WW-H coupling is 0-, could enable it in JHUGen