VH & VBF in the EFT at NLO in QCD

Fabio Maltoni,
Centre for Cosmology, Particle Physics and Phenomenology
Louvain, Belgium

work done in collaboration with
Demartin, Hespel, Mawatari, Vryonidou, Zaro & et al.
1306.6464, 1311.12829, 1407.5089, 1503.XXXXX's,

HIGGS CHARACTERISATION

- Either BSM or Effective field theories:
  - Fully fledged theoretical framework (LAGRANGIAN), i.e. process/observable independent
  - Model dependent (BSM) or model independent frameworks (EFT), the latter valid up to some NP scale Λ.
  - Global approach: Same couplings enter different observables/processes/colliders $\Rightarrow$ fit possible
- MonteCarlo framework(s) available:
  - any production, any decay, any observable
  - Inclusion of higher order effects in QCD and merging/matching to parton showers.

OUR TOOLS

- Full Lagrangians implemented in FeynRules (and UFO)
  - public (and versioned) models : HC [Artoisenet et al. 1306.6464], HEL [Alloul, Fuks, Sanz, 1310.5150], ...
  - Extension available to be used for NLO computations in QCD
- Process simulation with Madgraph5_aMC@NLO
  - Fully automatic LO and NLO (in QCD) computations
  - LO+PS and NLO+PS with PS=HW++, Pythia8, via the MC@NLO method
  - MLM-KT and NLO (FxFx) multi-jet merging
  - Automatic, zero-cost, and event-by-event scale and pdf uncertainties

HC PARAMETRISATION

WRITTEN DIRECTLY IN THE MASS BASIS WITH A SPECIAL EYE ON CP-VIOLATION. NUMBER OF PARAMETERS A BIT REDUNDANT TO EASE EXPERIMENTAL USAGE. FOR THREE-POINT INTERACTIONS ONE-TO-ONE RELATIONS WITH THE HEL BASIS. ALL COUPLINGS ARE REAL EXCEPT KHDW.

$$
\begin{aligned}
\mathcal{L}_0^V = \Big[& c_\alpha \kappa_{\rm SM} \big[\tfrac{1}{2} g_{HZZ}\, Z_\mu Z^\mu + g_{HWW}\, W_\mu^+ W^{-\mu}\big] \\
& - \frac{1}{4}\big[c_\alpha \kappa_{H\gamma\gamma} g_{H\gamma\gamma}\, A_{\mu\nu} A^{\mu\nu} + s_\alpha \kappa_{A\gamma\gamma} g_{A\gamma\gamma}\, A_{\mu\nu} \widetilde{A}^{\mu\nu}\big] \\
& - \frac{1}{2}\big[c_\alpha \kappa_{HZ\gamma} g_{HZ\gamma}\, Z_{\mu\nu} A^{\mu\nu} + s_\alpha \kappa_{AZ\gamma} g_{AZ\gamma}\, Z_{\mu\nu} \widetilde{A}^{\mu\nu}\big] \\
& - \frac{1}{4}\big[c_\alpha \kappa_{Hgg} g_{Hgg}\, G_{\mu\nu}^a G^{a,\mu\nu} + s_\alpha \kappa_{Agg} g_{Agg}\, G_{\mu\nu}^a \widetilde{G}^{a,\mu\nu}\big] \\
& - \frac{1}{4}\frac{1}{\Lambda}\big[c_\alpha \kappa_{HZZ}\, Z_{\mu\nu} Z^{\mu\nu} + s_\alpha \kappa_{AZZ}\, Z_{\mu\nu} \widetilde{Z}^{\mu\nu}\big] \\
& - \frac{1}{2}\frac{1}{\Lambda}\big[c_\alpha \kappa_{HWW}\, W_{\mu\nu}^+ W^{-\mu\nu} + s_\alpha \kappa_{AWW}\, W_{\mu\nu}^+ \widetilde{W}^{-\mu\nu}\big] \\
& - \frac{1}{\Lambda} c_\alpha \big[\kappa_{H\partial\gamma}\, Z_\nu \partial_\mu A^{\mu\nu} + \kappa_{H\partial Z}\, Z_\nu \partial_\mu Z^{\mu\nu} + \big(\kappa_{H\partial W}\, W_\nu^+ \partial_\mu W^{-\mu\nu} + h.c.\big)\big] \Big] X_0
\end{aligned}
$$

HVV INTERACTIONS

$$
\mathcal{L}_0^f = -\sum_{f=t,b,\tau} \bar\psi_f \big(c_\alpha \kappa_{Hff} g_{Hff} + i s_\alpha \kappa_{Aff} g_{Aff}\, \gamma_5\big) \psi_f X_0
$$

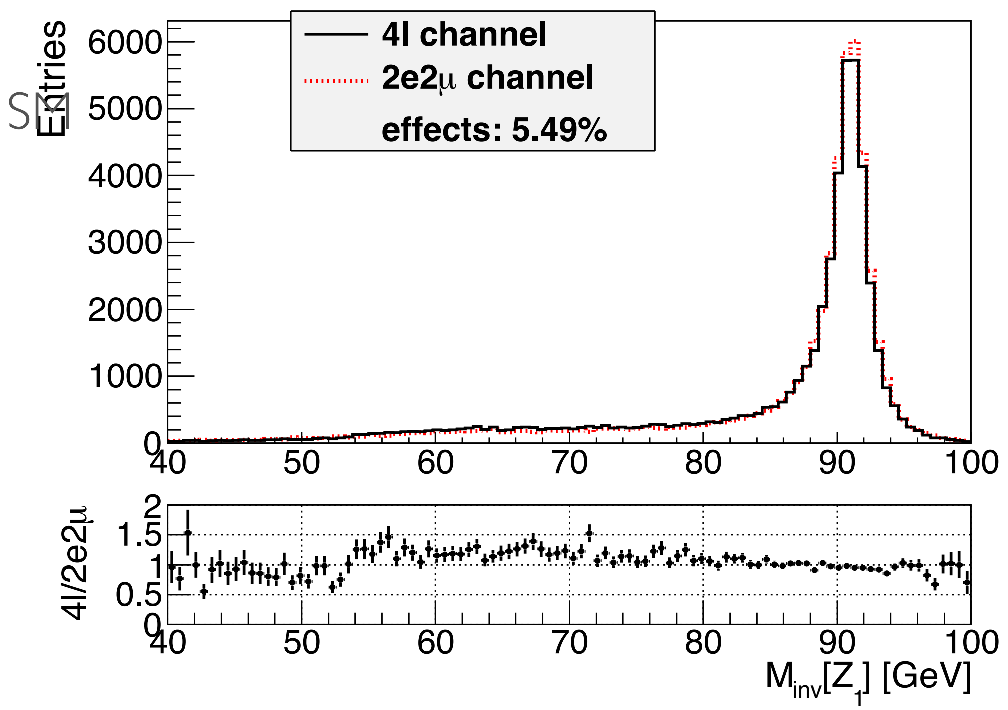
HFF INTERACTIONS

ALL NEEDED COUNTER TERMS TO PERFORM LOOP QCD COMPUTATIONS ARE ALSO INCLUDED IN THE MODEL ⇒ VERY WIDE RANGE OF PROCESSES, INCLUDING DECAY AND PRODUCTION ⇒ SUITABLE FOR A GLOBAL APPROACH.

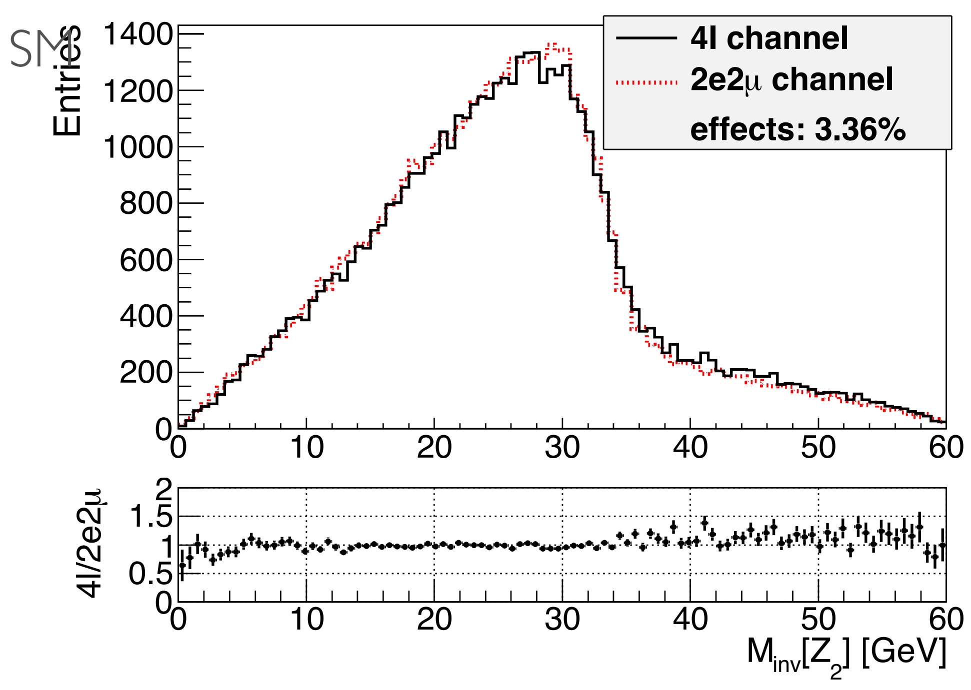
EXAMPLE: H→ZZ→4 LEPTONS

Study of the interference in H decays:

```
./bin/mg5_aMC
> import model HC_X0_NLO
> generate p p > X0 > e+ e- mu+ mu- [QCD]
> output GGH2mu2e
> launch
```




```
./bin/mg5_aMC
> import model HC_X0_NLO
> generate p p > X0 > e+ e- e+ e- [QCD]
> output GGH24l
> launch
```



Very small effects for the Standard Model. Interference with H→gamma* Z, H→gamma* gamma* decay also possible (see Chen et al. 1405.6723, G. Passarino's "Dalitz approach" 1308.0422, ...).

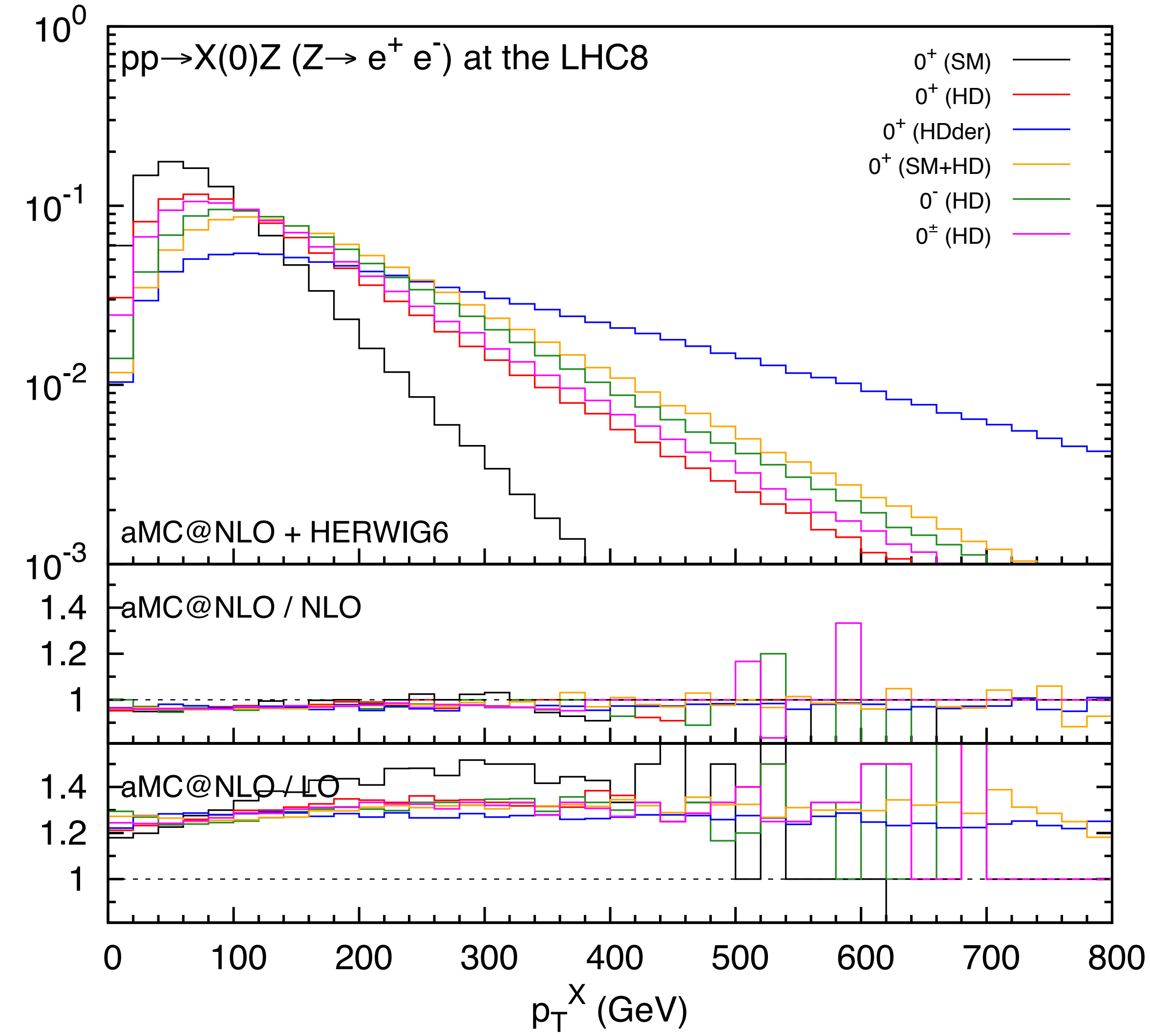
HV

pp→HV at NLO+PS

```
./bin/mg5
> import model HC_X0_NLO
> generate p p > X0 e+ e- [QCD]
> output ZH
> launch
```

scenario	HC parameter choice
0^+(SM)	$\kappa_{\rm SM} = 1 \ (c_\alpha = 1)$
0^+(HD)	$\kappa_{HZZ,HWW} = 1 \ (c_\alpha = 1)$
0^+(HDder)	$\kappa_{H\partial Z,H\partial W} = 1 \ (c_\alpha = 1)$
0^+(SM+HD)	$\kappa_{SM,HZZ,HWW} = 1 \ (c_\alpha = 1, \ \Lambda = v)$
0^-(HD)	$\kappa_{AZZ,AWW} = 1 \ (c_\alpha = 0)$
$0^\pm$(HD)	$\kappa_{HZZ,AZZ,HWW,AWW} = 1 \ (c_\alpha = 1/\sqrt{2})$

[FM, Mawatari, Zaro ,1311.1829]



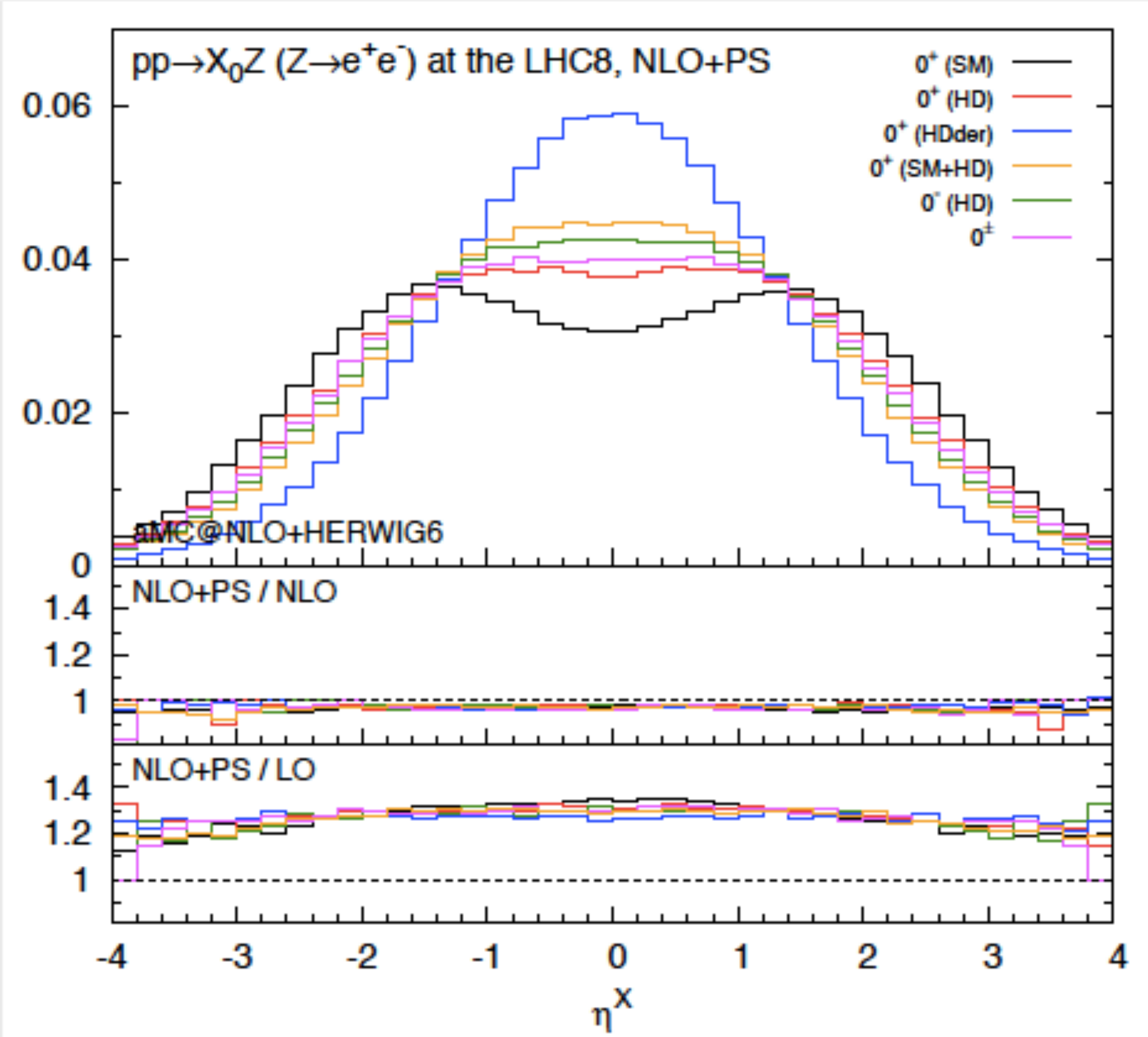
6 HC scenarios considered:
NLO QCD corrections are important in all of them!

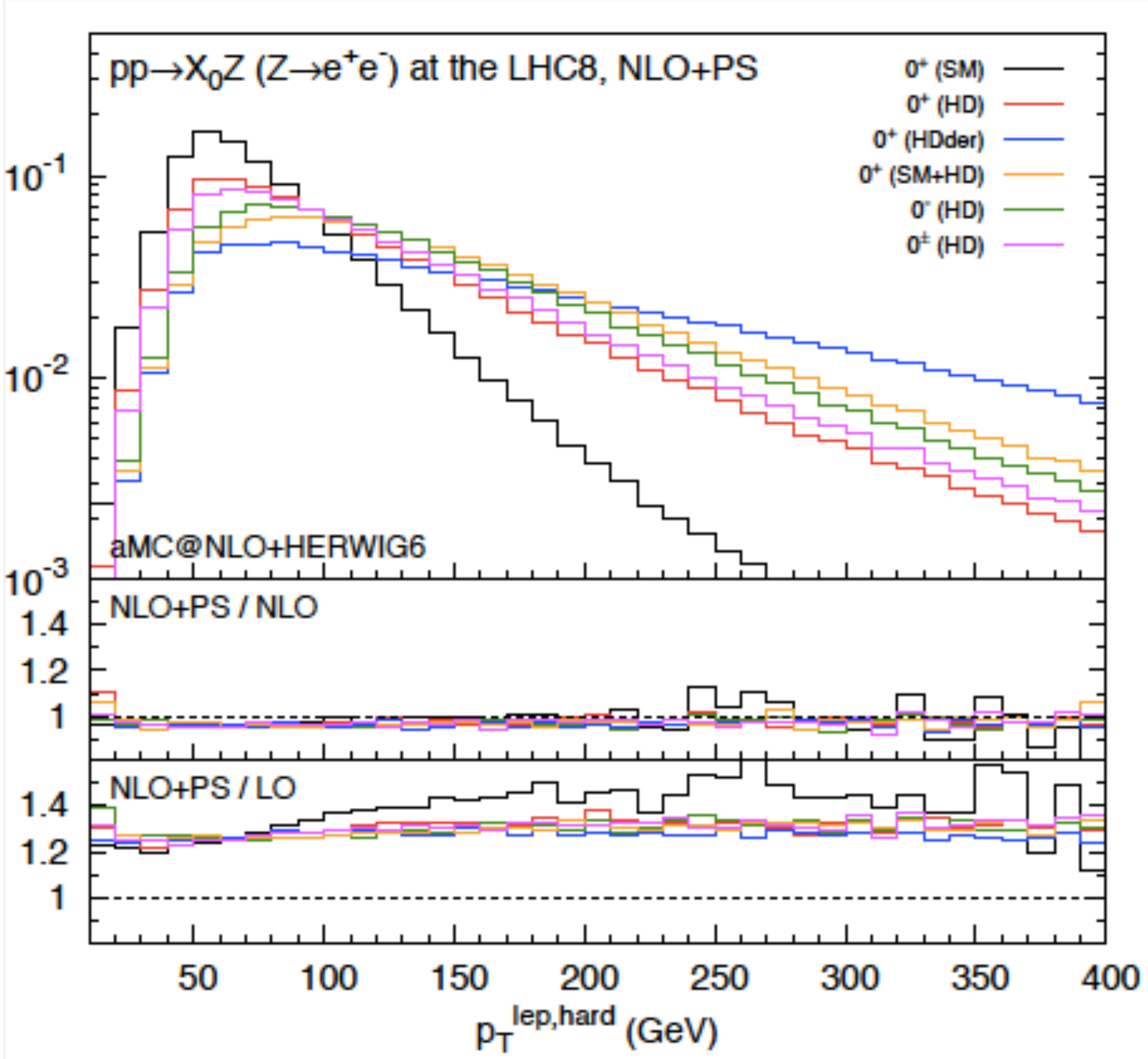
Many studies on HV in "EFT" have appeared, for example [Isidori & Trott 1307.4051, Ellis et al. 1208.6002, 1303.0208,1404.3667, Biekotter et al. 1406.7320, ...]

HV

pp→HV at NLO+PS

[FM, Mawatari, Zaro ,1311.1829]

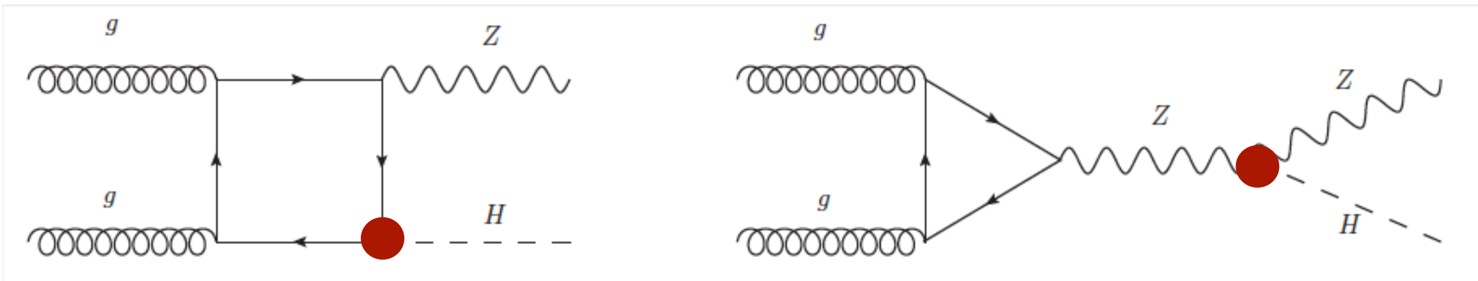


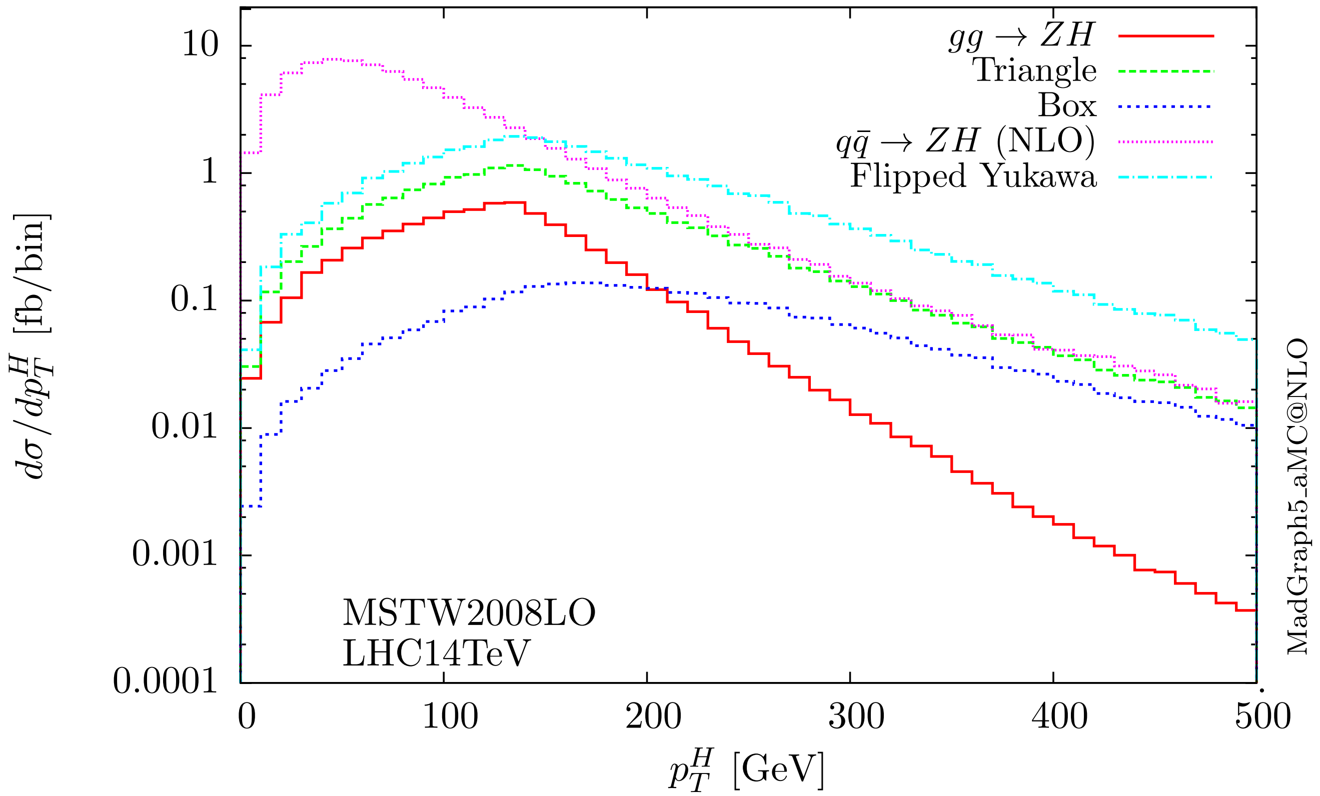


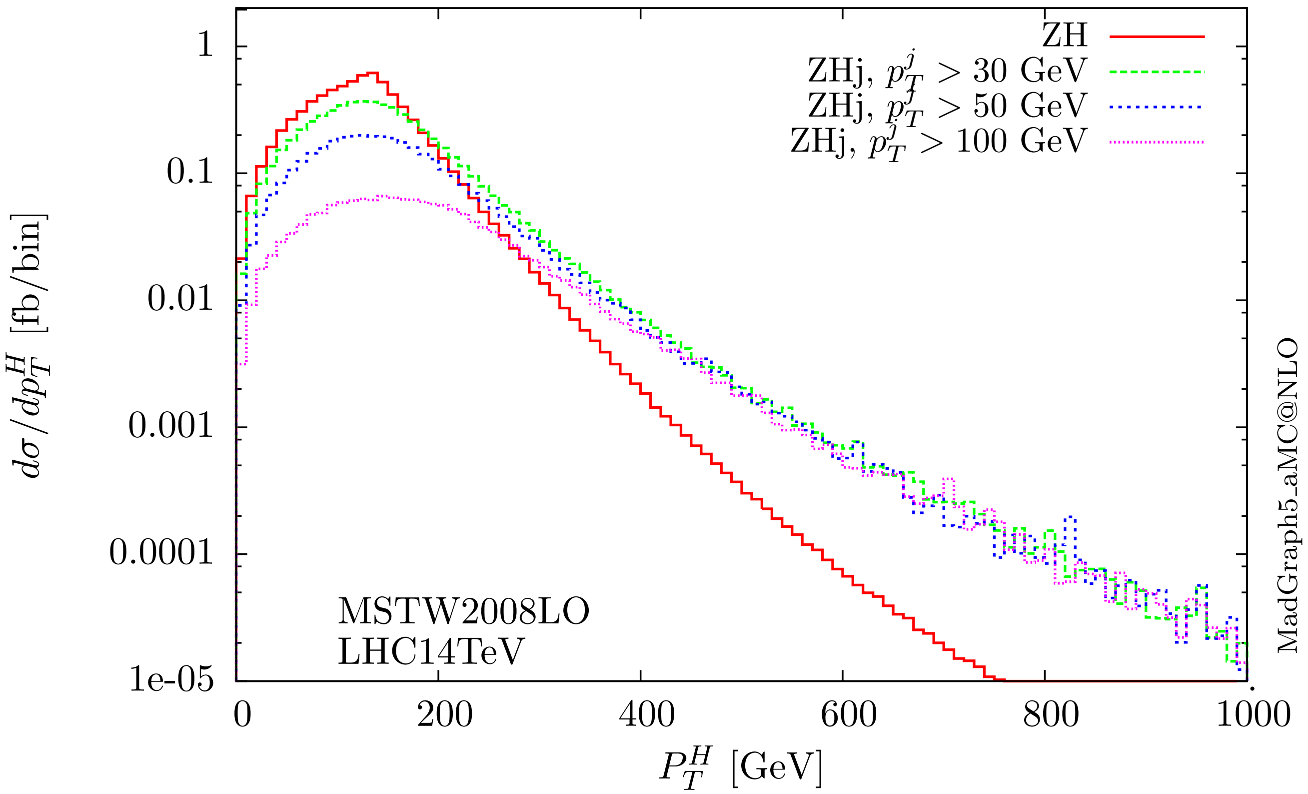
HV

pp→HZ: gg contribution

[Hespel, FM, Vryonidou ,1503.xxxxx]







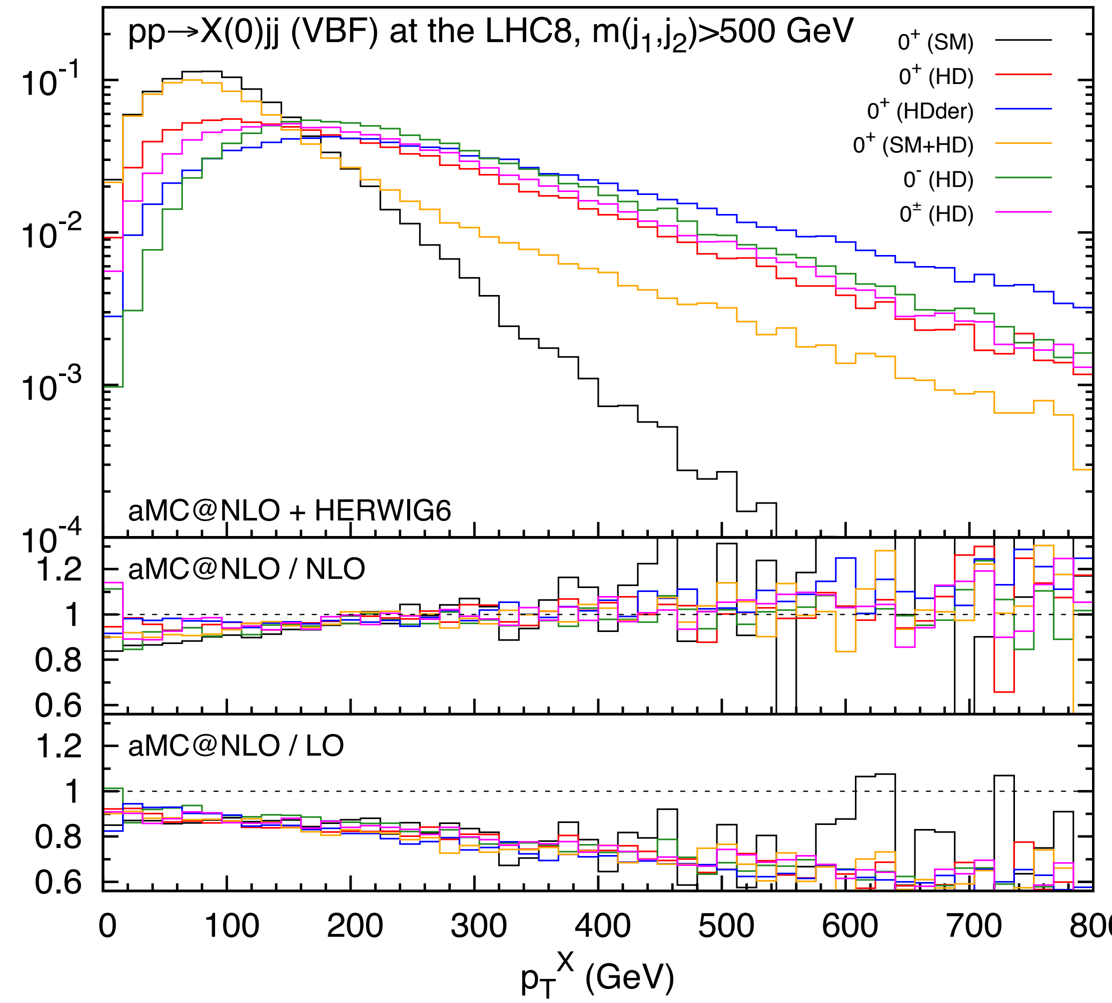
gg→ZH is sensitive to relative phase (and SIGN!) between HVV and ttH coupling (like H→gamma gamma and pp→tHj)! At high pt dominated by 2→3 contributions. Merged samples now available.

PP→HJJ

pp→Hjj (VBF) at NLO+PS

[FM, Mawatari, Zaro ,1311.1829]

```
./bin/mg5
> import model HC_X0_NLO
> generate p p > X0 j j QCD=0[QCD]
> output VBF
> launch
```



6 HC scenarios considered and two cases (w/ and w/o VBF cuts):

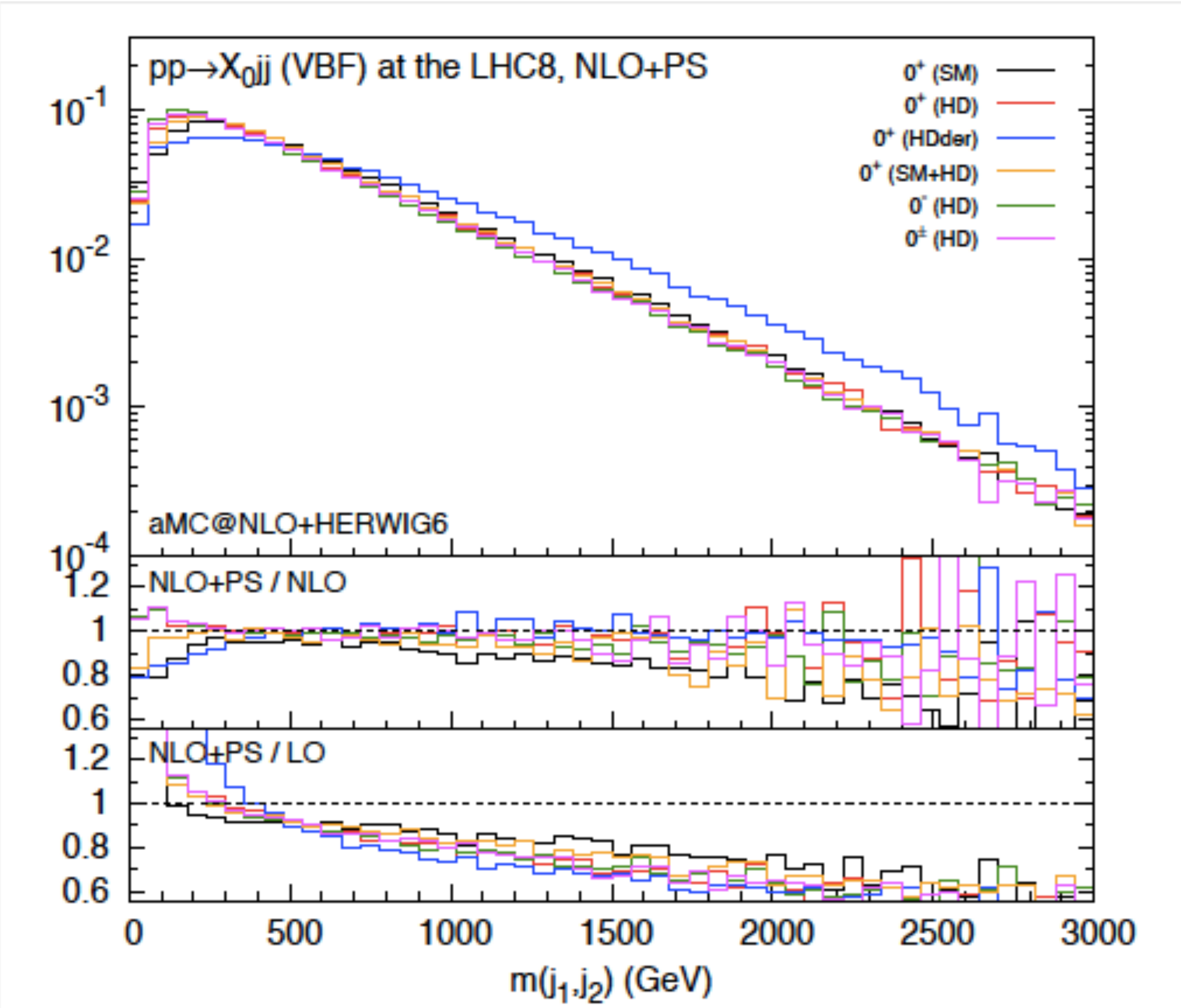
NLO QCD corrections are important for many key observables.

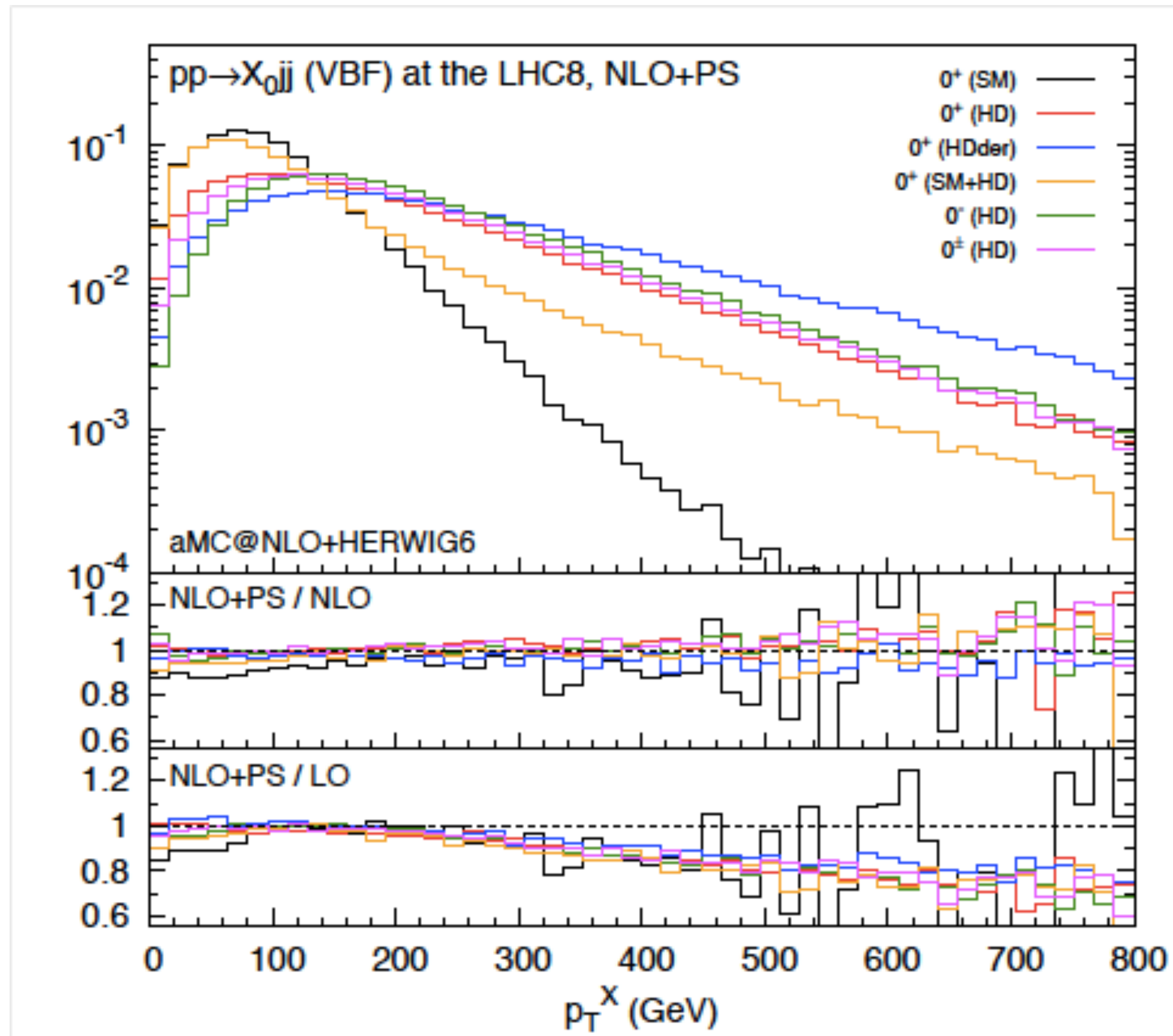
Many studies on VBF in "EFT" have appeared, even very recently [Edezhath 1501.00992, Ellis&Campbell, 1502.02990]

PP→HJJ

pp→Hjj (VBF) at NLO+PS

[FM, Mawatari, Zaro ,1311.1829]



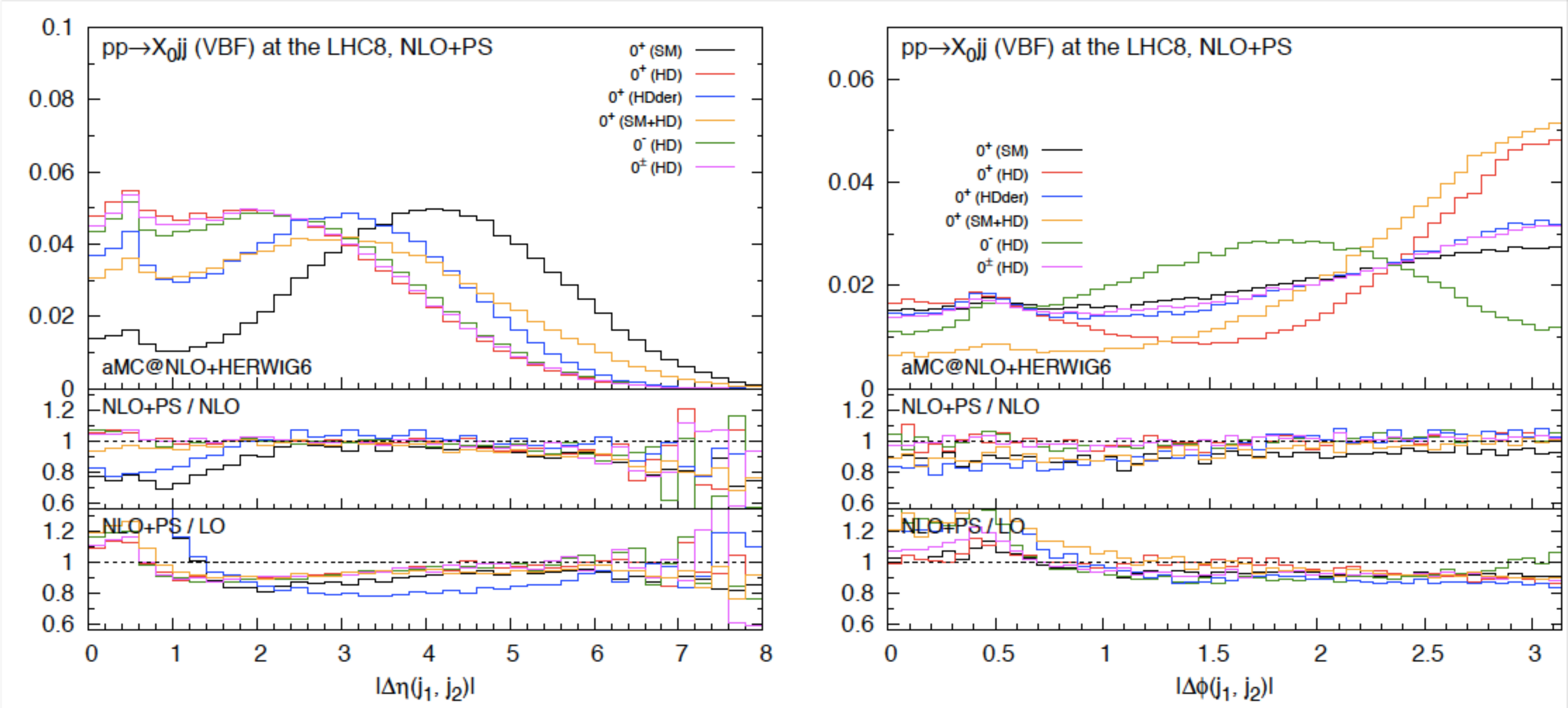


shapes of distributions are greatly affected both NLO and NLO+PS.
Substantial degeneracy between several CP-violating scenarios.

PP→HJJ

pp→Hjj (VBF) at NLO+PS

[FM, Mawatari, Zaro ,1311.1829]



Substantial degeneracy between several CP-violating scenarios is lifted if dedicated observables are built, such as deltaphi(j1,j2).

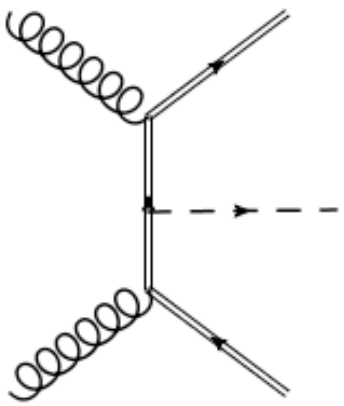
PP→HJJ

pp→Hjj (QCD) at NLO+PS

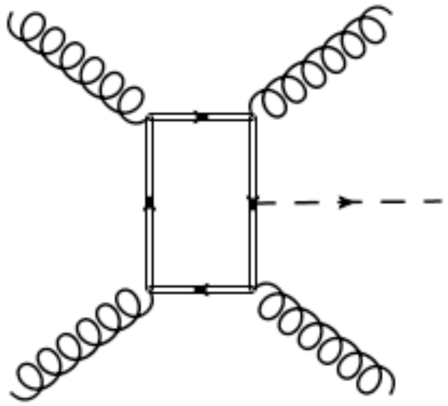
$$\mathcal{L}_0^t = -\bar{\psi}_t \big(c_\alpha \kappa_{Htt} g_{Htt} + i s_\alpha \kappa_{Att} g_{Att} \, \gamma_5 \big) \psi_t \, X_0$$

$$\mathcal{L}_0^{\text{loop}} = -\frac{1}{4} \big[c_\alpha \kappa_{Hgg} g_{Hgg} \, G_{\mu\nu}^a G^{a,\mu\nu} + s_\alpha \kappa_{Agg} g_{Agg} \, G_{\mu\nu}^a \widetilde{G}^{a,\mu\nu} \big]$$

The k's are real! Two ways of directly accessing presence of CP-mixing in top-Higgs interactions at the LHC:



pp→ttH



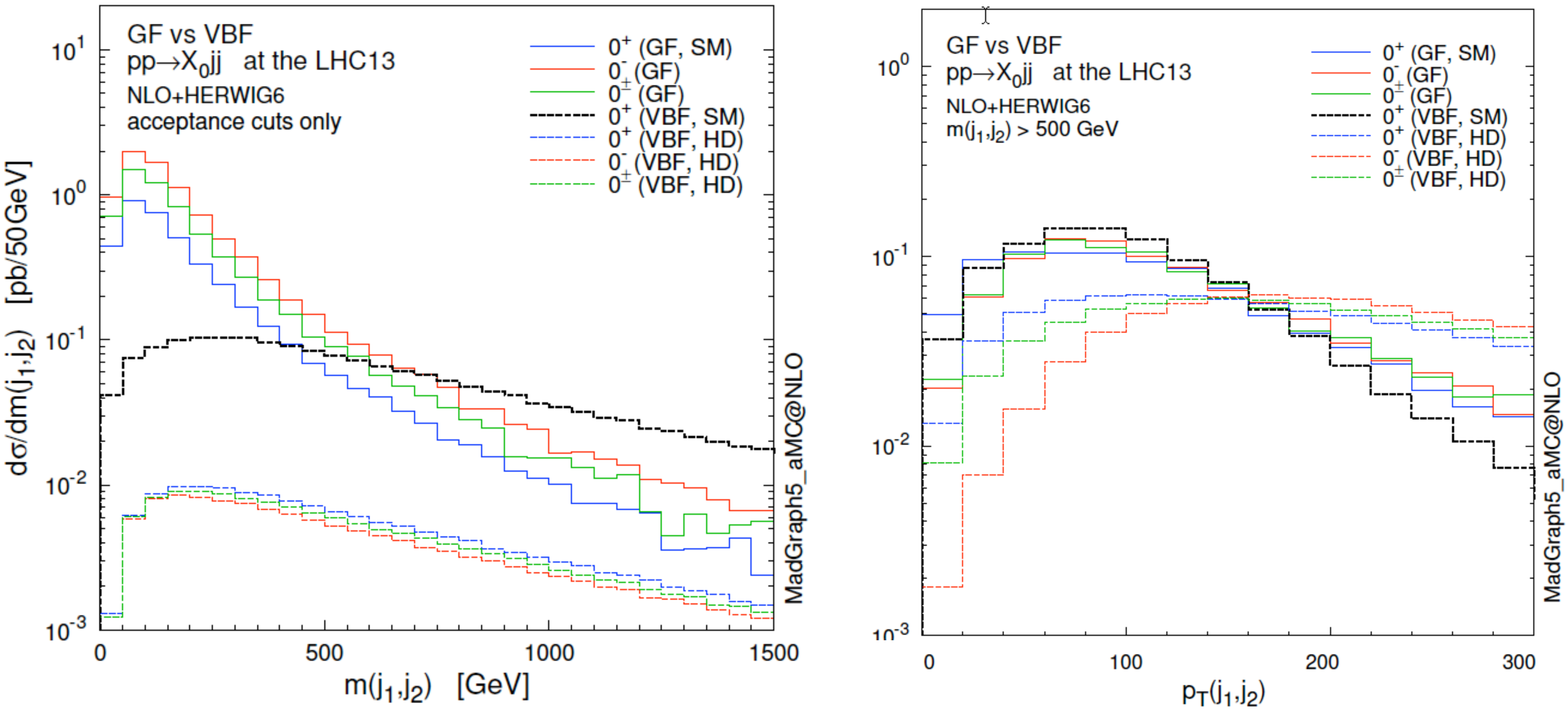
pp→Hjj

Both possible at NLO+PS, (Hjj in the HEFT)

PP→HJJ

pp→Hjj (QCD) at NLO+PS

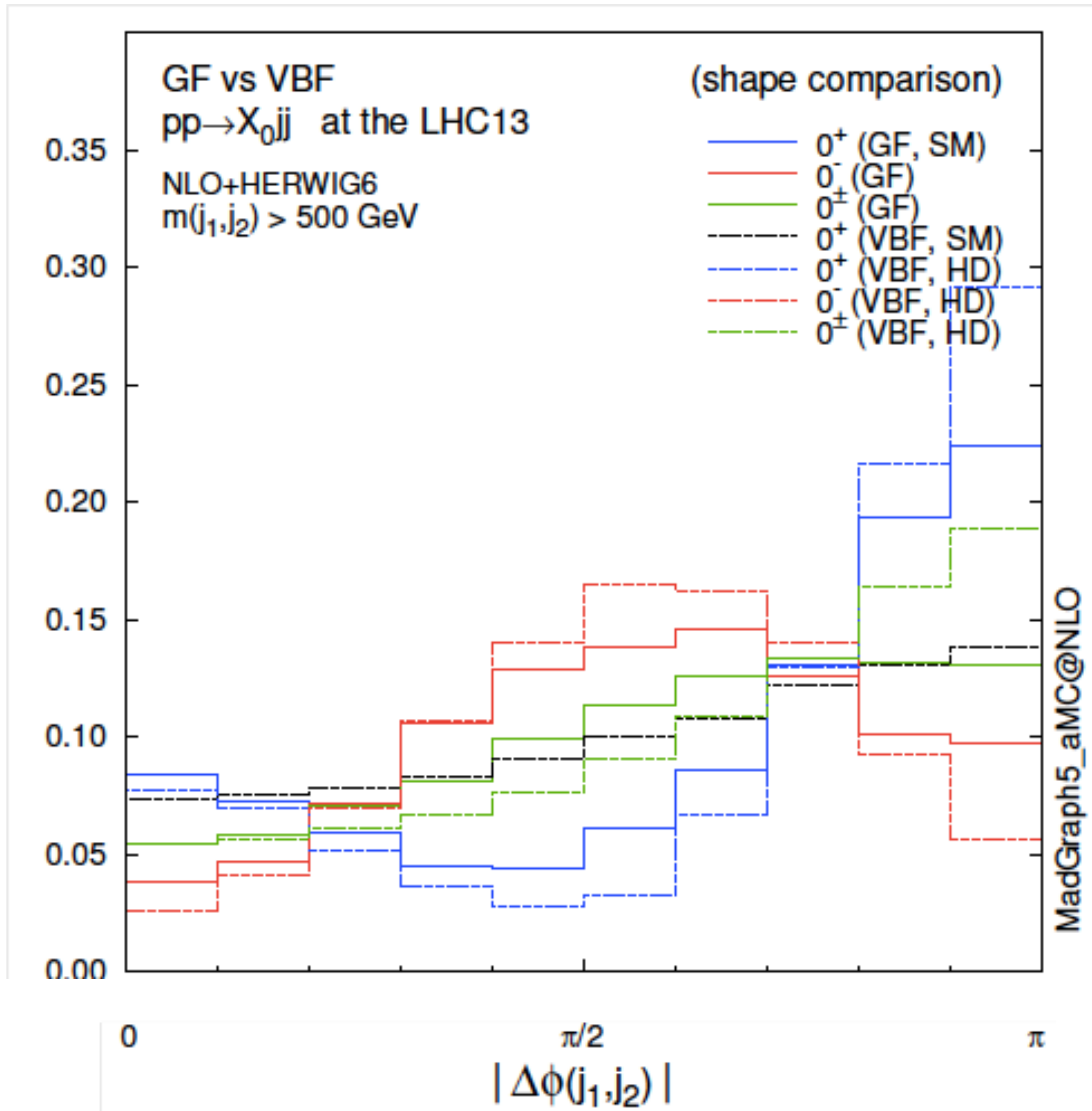
[Demartin et al. ,1407.5089]

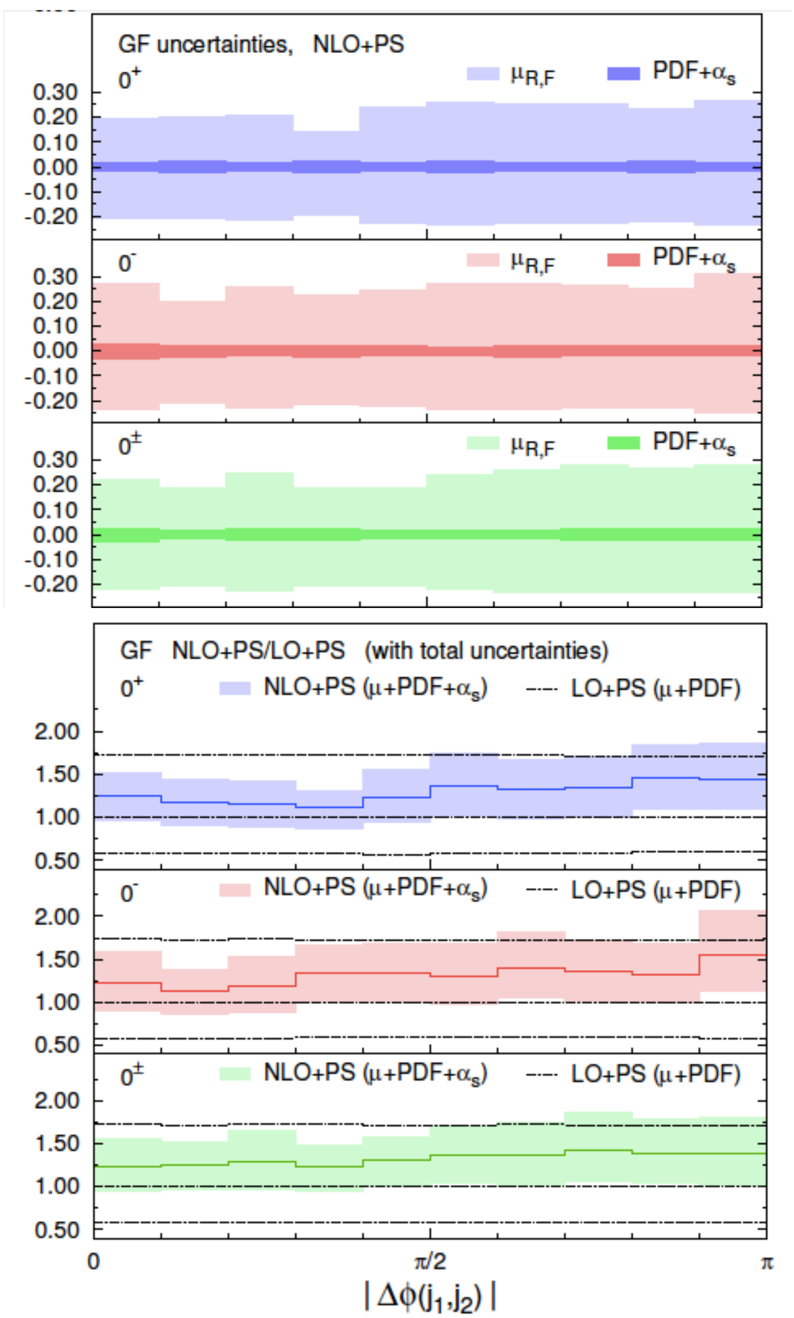


PP→HJJ

pp→Hjj (QCD) at NLO+PS

[Demartin et al. ,1311.1829]



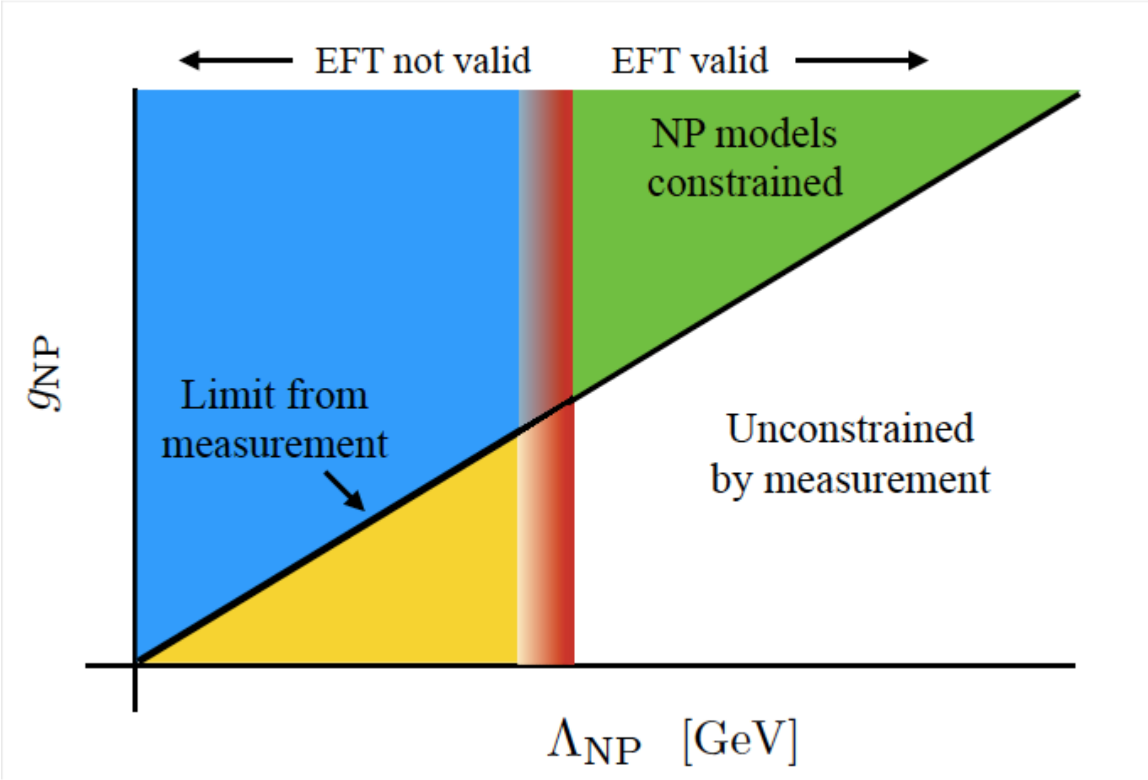


A few comments

- The issue of the validity of EFT's is being discussed extensively in the literature both in the case of Higgs and also for DM.

For Higgs:
[Biekoetter et al. 1406.7320, see Riva's talk]
[Englert and Spannowsky, 1408.5147], ...

For DM:
[Busoni et al, 1307.2253,1402.1275, 1405.3102]
and 1005.3797, 1103.0240, 1109.4398, 1203.1662, ...



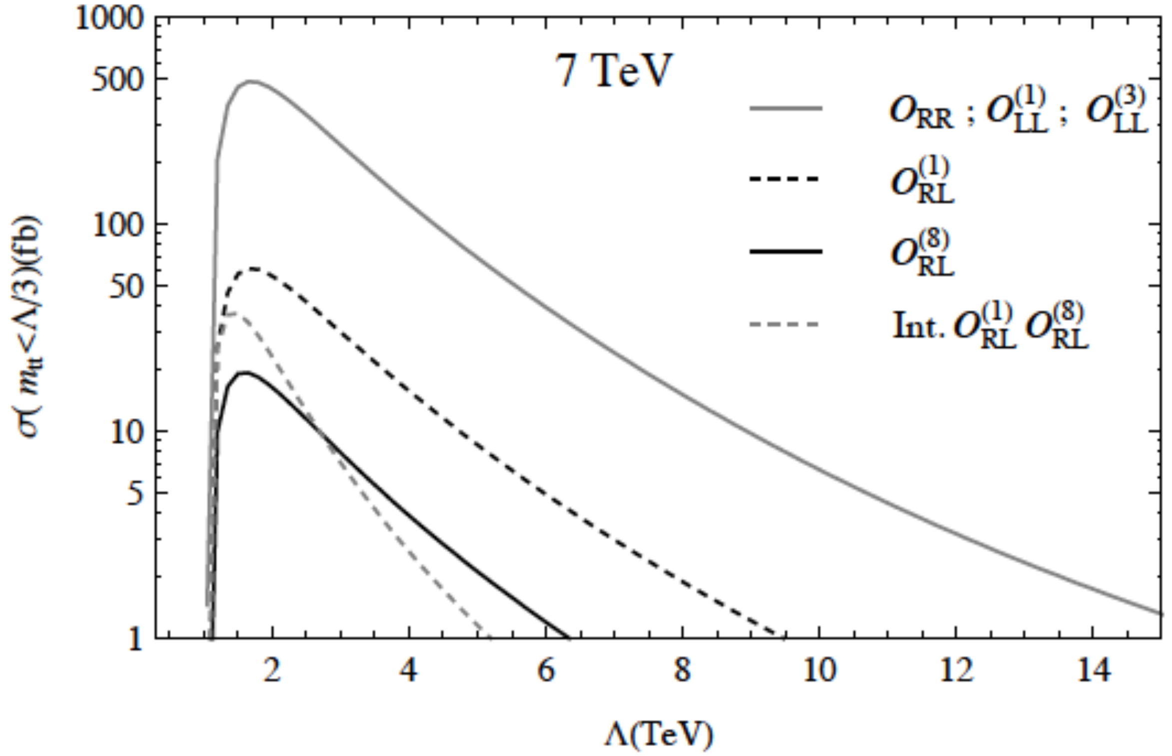
[Englert and Spannowsky, 1408.5147]

- Simple, practical, improvable, legacy friendly solutions do exist!

A few comments

- Criteria to study the behaviour at HE include:
  - Series behaviour: $1/\Lambda^2$ vs $1/\Lambda^4$ (interference vs amplitude squared)
  - Unitarity
  - size of cross sections VS SM
  - validation/comparison with explicit UV completions
- Simple solutions (practical and legacy-friendly) are available:
  - simulations available for different values of $\Lambda>\sqrt{\hat{s}}$

PP→TOP TOP



[Degrande et al. arXiv:1104.1798]

- Possible improvements:
  - Event-by-event determination of the scale including running of the operators, i.e. QCD (and maybe EW) RGE effects [Englert Spannowsky] arXiv:1104.1798

Conclusions

- The EFT gives (the only) solid, systematically improvable, intrinsically **global approach** to test the interactions of the SM particles if NP resides at higher scales.

- MC simulation chain in place to deal with any EFT basis (above or below the ESWB). The possibility of having NLO QCD + PS included automatically. **MC simulations are always done in the mass basis.** Technical possibility of relating couplings to pseudo observables or even including form factors is there.

- Consistency of higher order calculations in QCD and EW is natural in the EFT formulation above the ESWB. QCD (+PS) corrections for the EFT can be important AND results cannot be described by global K-factors.

- Technical (such as HE behaviour) and social/physical (basis choices) can be worked out. For example, MC implementation and translator for different bases that serves all in progress $\Rightarrow$ Do not miss Ken's talk!

THE LAGRANGIAN ABOVE EWSB SCALE

$$\begin{aligned}\mathcal{L}_{\rm SILH} = {} & \frac{\bar{c}_H}{2v^2}\partial^\mu\big[\Phi^\dagger\Phi\big]\partial_\mu\big[\Phi^\dagger\Phi\big] + \frac{\bar{c}_T}{2v^2}\big[\Phi^\dagger\overleftrightarrow{D}^\mu\Phi\big]\big[\Phi^\dagger\overleftrightarrow{D}_\mu\Phi\big] - \frac{\bar{c}_6\lambda}{v^2}\big[H^\dagger H\big]^3 \\ & - \Big[\frac{\bar{c}_u}{v^2}y_u\Phi^\dagger\Phi\ \Phi^\dagger\cdot\bar{Q}_L u_R + \frac{\bar{c}_d}{v^2}y_d\Phi^\dagger\Phi\ \Phi\bar{Q}_L d_R + \frac{\bar{c}_l}{v^2}y_\ell\ \Phi^\dagger\Phi\ \Phi\bar{L}_L e_R + {\rm h.c.}\Big] \\ & + \frac{ig\ \bar{c}_W}{m_W^2}\big[\Phi^\dagger T_{2k}\overleftrightarrow{D}^\mu\Phi\big]D^\nu W_{\mu\nu}^k + \frac{ig'\ \bar{c}_B}{2m_W^2}\big[\Phi^\dagger\overleftrightarrow{D}^\mu\Phi\big]\partial^\nu B_{\mu\nu} \\ & + \frac{2ig\ \bar{c}_{HW}}{m_W^2}\big[D^\mu\Phi^\dagger T_{2k}D^\nu\Phi\big]W_{\mu\nu}^k + \frac{ig'\ \bar{c}_{HB}}{m_W^2}\big[D^\mu\Phi^\dagger D^\nu\Phi\big]B_{\mu\nu} \\ & + \frac{\bar{g}'^2\ c_\gamma}{m_W^2}\Phi^\dagger\Phi B_{\mu\nu}B^{\mu\nu} + \frac{\bar{g}_s^2\ c_g}{m_W^2}\Phi^\dagger\Phi G_{\mu\nu}^a G_a^{\mu\nu}\ ,\end{aligned}$$

$$\begin{aligned}\mathcal{L}_{CP} = {} & \frac{ig\ \tilde{c}_{HW}}{m_W^2}D^\mu\Phi^\dagger T_{2k}D^\nu\Phi\widetilde{W}_{\mu\nu}^k + \frac{ig'\ \tilde{c}_{HB}}{m_W^2}D^\mu\Phi^\dagger D^\nu\Phi\widetilde{B}_{\mu\nu} + \frac{g'^2\ \tilde{c}_\gamma}{m_W^2}\Phi^\dagger\Phi B_{\mu\nu}\widetilde{B}^{\mu\nu} \\ & + \frac{g_s^2\ \tilde{c}_g}{m_W^2}\Phi^\dagger\Phi G_{\mu\nu}^a\widetilde{G}_a^{\mu\nu} + \frac{g^3\ \tilde{c}_{3W}}{m_W^2}\epsilon_{ijk}W_{\mu\nu}^i W^{\nu j}{}_\rho\widetilde{W}^{\rho\mu k} + \frac{g_s^3\ \tilde{c}_{3G}}{m_W^2}f_{abc}G_{\mu\nu}^a G^{\nu b}{}_\rho\widetilde{G}^{\rho\mu c}\end{aligned}$$

$$\begin{aligned}\mathcal{L}_G = {} & \frac{g^3\ \bar{c}_{3W}}{m_W^2}\epsilon_{ijk}W_{\mu\nu}^i W^{\nu j}{}_\rho W^{\rho\mu k} + \frac{g_s^3\ \bar{c}_{3G}}{m_W^2}f_{abc}G_{\mu\nu}^a G^{\nu b}{}_\rho G^{\rho\mu c} + \frac{\bar{c}_{2W}}{m_W^2}D^\mu W_{\mu\nu}^k D_\rho W_k^{\rho\nu} \\ & + \frac{\bar{c}_{2B}}{m_W^2}\partial^\mu B_{\mu\nu}\partial_\rho B^{\rho\nu} + \frac{\bar{c}_{2G}}{m_W^2}D^\mu G_{\mu\nu}^a D_\rho G_a^{\rho\nu}\ ,\end{aligned}$$

$$\begin{aligned}\mathcal{L}_{F_1} = {} & \frac{i\bar{c}_{HQ}}{v^2}\big[\bar{Q}_L\gamma^\mu Q_L\big]\big[\Phi^\dagger\overleftrightarrow{D}_\mu\Phi\big] + \frac{4i\bar{c}'_{HQ}}{v^2}\big[\bar{Q}_L\gamma^\mu T_{2k}Q_L\big]\big[\Phi^\dagger T_2^k\overleftrightarrow{D}_\mu\Phi\big] \\ & + \frac{i\bar{c}_{Hu}}{v^2}\big[\bar{u}_R\gamma^\mu u_R\big]\big[\Phi^\dagger\overleftrightarrow{D}_\mu\Phi\big] + \frac{i\bar{c}_{Hd}}{v^2}\big[\bar{d}_R\gamma^\mu d_R\big]\big[\Phi^\dagger\overleftrightarrow{D}_\mu\Phi\big] \\ & - \Big[\frac{i\bar{c}_{Hud}}{v^2}\big[\bar{u}_R\gamma^\mu d_R\big]\big[\Phi\cdot\overleftrightarrow{D}_\mu\Phi\big] + {\rm h.c.}\Big] \\ & + \frac{i\bar{c}_{HL}}{v^2}\big[\bar{L}_L\gamma^\mu L_L\big]\big[\Phi^\dagger\overleftrightarrow{D}_\mu\Phi\big] + \frac{4i\bar{c}'_{HL}}{v^2}\big[\bar{L}_L\gamma^\mu T_{2k}L_L\big]\big[\Phi^\dagger T_2^k\overleftrightarrow{D}_\mu\Phi\big] \\ & + \frac{i\bar{c}_{He}}{v^2}\big[\bar{e}_R\gamma^\mu e_R\big]\big[\Phi^\dagger\overleftrightarrow{D}_\mu\Phi\big]\ ,\end{aligned}$$

$$\begin{aligned}\mathcal{L}_{F_2} = \Big[& -\frac{2g'\ \bar{c}_{uB}}{m_W^2}y_u\ \Phi^\dagger\cdot\bar{Q}_L\gamma^{\mu\nu}u_R\ B_{\mu\nu} - \frac{4g\ \bar{c}_{uW}}{m_W^2}y_u\ \Phi^\dagger\cdot(\bar{Q}_L T_{2k})\gamma^{\mu\nu}u_R\ W_{\mu\nu}^k \\ & - \frac{4g_s\ \bar{c}_{uG}}{m_W^2}y_u\ \Phi^\dagger\cdot\bar{Q}_L\gamma^{\mu\nu}T_a u_R G_{\mu\nu}^a + \frac{2g'\ \bar{c}_{dB}}{m_W^2}y_d\ \Phi\bar{Q}_L\gamma^{\mu\nu}d_R\ B_{\mu\nu} \\ & + \frac{4g\ \bar{c}_{dW}}{m_W^2}y_d\ \Phi(\bar{Q}_L T_{2k})\gamma^{\mu\nu}d_R\ W_{\mu\nu}^k + \frac{4g_s\ \bar{c}_{dG}}{m_W^2}y_d\ \Phi\bar{Q}_L\gamma^{\mu\nu}T_a d_R G_{\mu\nu}^a \\ & + \frac{2g'\ \bar{c}_{eB}}{m_W^2}y_\ell\ \Phi\bar{L}_L\gamma^{\mu\nu}e_R\ B_{\mu\nu} + \frac{4g\ \bar{c}_{eW}}{m_W^2}y_\ell\ \Phi(\bar{L}_L T_{2k})\gamma^{\mu\nu}e_R\ W_{\mu\nu}^k + {\rm h.c.}\Big]\end{aligned}$$

Relevant Basis of operators at dim 6. Implemented in FeynRules by Alloul, Fuks, Sanz, arXiv:1310.5150. Work to promote it to NLO in QCD in progress. This lagrangian is expressed in terms of mass eigenstates before being passed to the MC.

AC VS HEFT : H→ZZ→4 LEPTONS

$$\mathcal{L} = \frac{1}{2} c_\alpha \kappa_{\rm SM} g_{HZZ}\, Z_\mu Z^\mu X_0 \longrightarrow i c_\alpha \kappa_{\rm SM} g_{HZZ}\, g_{\mu\nu} \qquad ①$$

$$-\frac{1}{4}\frac{1}{\Lambda} c_\alpha \kappa_{HZZ}\, Z_{\mu\nu} Z^{\mu\nu} \longrightarrow i c_\alpha \frac{\kappa_{HZZ}}{\Lambda}\,(g_{\mu\nu} q_1.q_2 - q_{2\mu} q_{1\nu}) \qquad ②$$

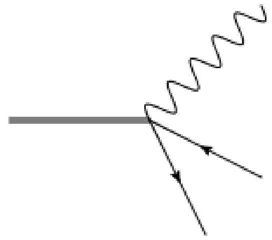
$$-\frac{1}{4}\frac{1}{\Lambda} s_\alpha \kappa_{AZZ}\, Z_{\mu\nu} \widetilde{Z}^{\mu\nu} \longrightarrow i s_\alpha \frac{\kappa_{AZZ}}{\Lambda}\,\epsilon_{\mu\nu\rho\sigma} q_2^\rho q_1^\sigma \qquad ③$$

$$-\frac{1}{\Lambda} c_\alpha \kappa_{H\partial Z}\, Z_\nu \partial_\mu Z^{\mu\nu} \longrightarrow i c_\alpha \frac{\kappa_{H\partial Z}}{\Lambda}\,[g_{\mu\nu}(q_1.q_1 + q_2.q_2) - q_{1\mu} q_{1\nu} - q_{2\mu} q_{2\nu}] \qquad ④$$

Note that for HZZ vertex all parameters are REAL. (The Z is an eigenstate of CP, CP |Z> = + |Z>)

The term ④ gives rise [Contino et al.] to a contact interaction which is independent from the other three only when one of the Z's is off shell:

$$i D^\mu W^i_{\mu\nu} = g\, H^\dagger \frac{\sigma^i}{2} \overleftrightarrow{D}_\nu H - i g\, \bar{\psi} \frac{\sigma^i}{2} \gamma_\nu \psi\,, \qquad i\partial^\mu B_{\mu\nu} = \frac{g'}{2} H^\dagger \overleftrightarrow{D}_\nu H - i g'\, \bar{\psi} Y \gamma_\nu \psi\,,$$



AC VS HEFT : H→ZZ→4 LEPTONS

$$\mathcal{L} = \frac{1}{2} c_\alpha \kappa_{\rm SM} g_{HZZ}\, Z_\mu Z^\mu X_0 \longrightarrow i c_\alpha \kappa_{\rm SM} g_{HZZ}\, g_{\mu\nu} \qquad ①$$

$$-\frac{1}{4}\frac{1}{\Lambda} c_\alpha \kappa_{HZZ}\, Z_{\mu\nu} Z^{\mu\nu} \longrightarrow i c_\alpha \frac{\kappa_{HZZ}}{\Lambda} \left(g_{\mu\nu} q_1.q_2 - q_{2\mu} q_{1\nu}\right) \qquad ②$$

$$-\frac{1}{4}\frac{1}{\Lambda} s_\alpha \kappa_{AZZ}\, Z_{\mu\nu} \widetilde{Z}^{\mu\nu} \longrightarrow i s_\alpha \frac{\kappa_{AZZ}}{\Lambda} \epsilon_{\mu\nu\rho\sigma} q_2^\rho q_1^\sigma \qquad ③$$

$$-\frac{1}{\Lambda} c_\alpha \kappa_{H\partial Z}\, Z_\nu \partial_\mu Z^{\mu\nu} \longrightarrow i c_\alpha \frac{\kappa_{H\partial Z}}{\Lambda} \left[g_{\mu\nu}(q_1.q_1 + q_2.q_2) - q_{1\mu} q_{1\nu} - q_{2\mu} q_{2\nu}\right] \qquad ④$$

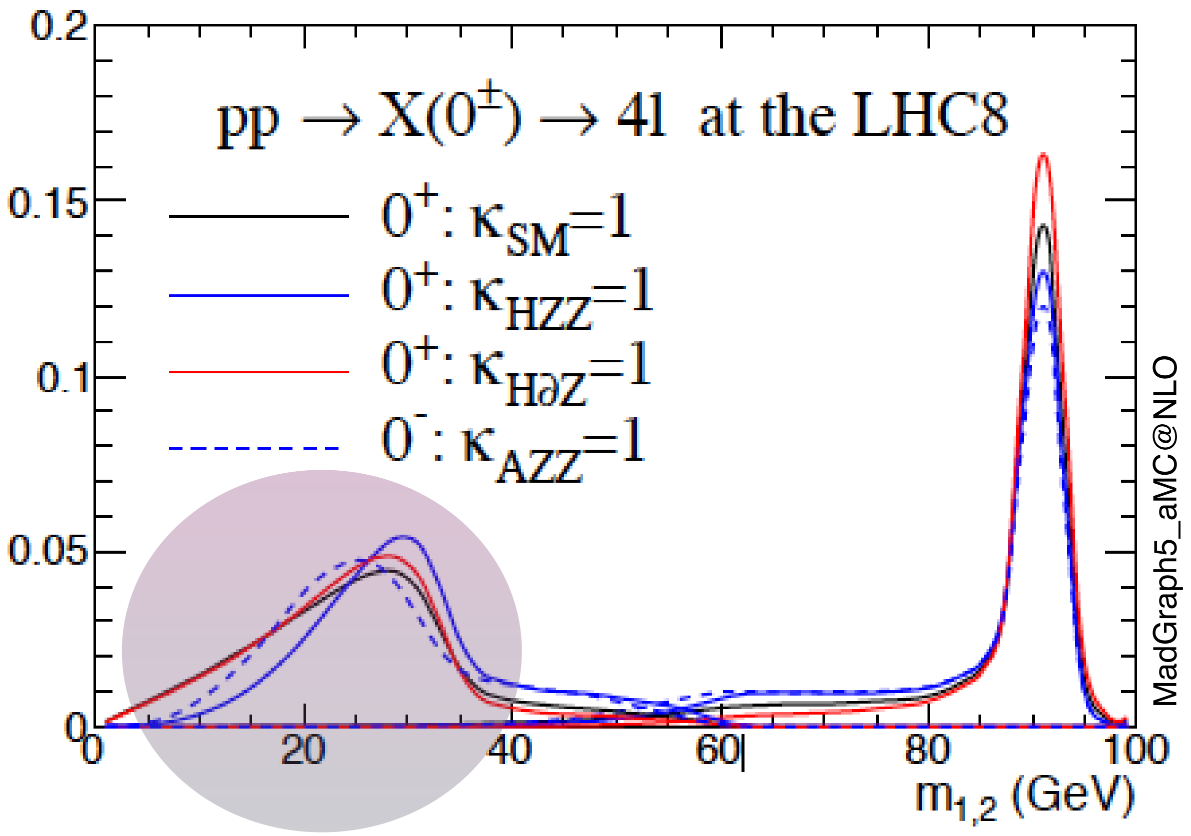
Exact one-to-one correspondence can be found with the [Isidori, Manohar, Trott 1305.06632] at the lowest order in q2 (with f1 = c1 mZ2 + c2 q2 and f2=0).

$$\mathcal{A}_V^{\mathcal{F}} = C_V g_V^2 m_V \frac{\varepsilon_\mu J_\nu^{\mathcal{F}}}{(q^2 - m_V^2)} \left[f_1^V(q^2) g^{\mu\nu} + f_2^V(q^2) q^\mu q^\nu \right. \tag{2}$$

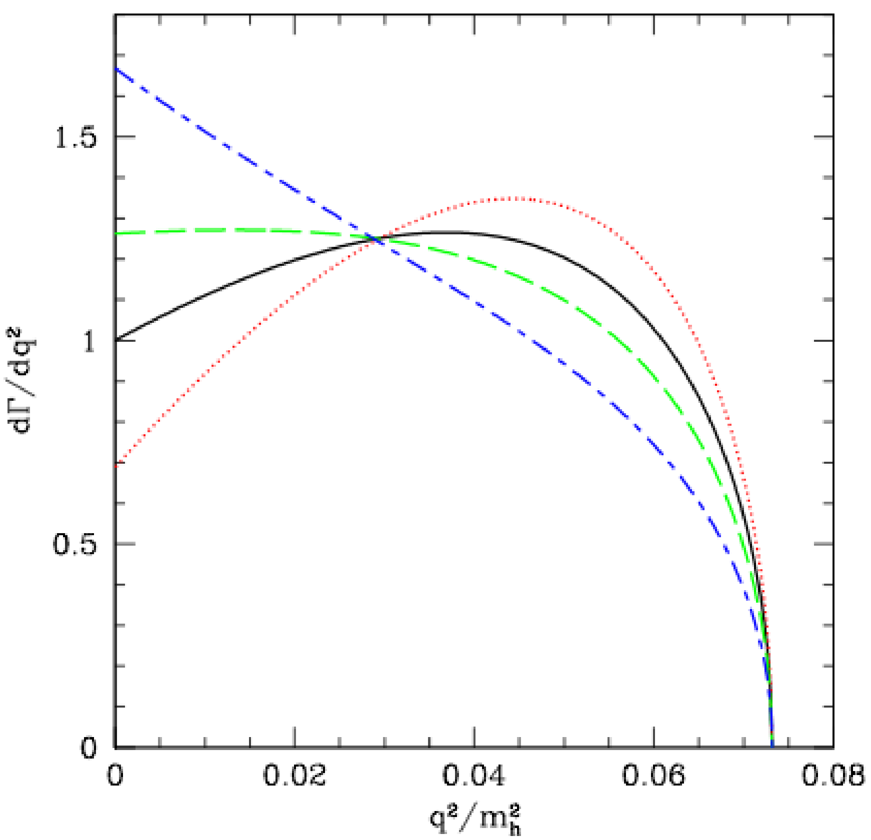
$$\left. + f_3^V(q^2)(p\cdot q\, g^{\mu\nu} - q^\mu p^\nu) + i f_4^V(q^2) \epsilon^{\mu\nu\rho\sigma} p_\rho q_\sigma \right].$$

EXAMPLE: H→ZZ→4 LEPTONS

HC MODEL 1306.6464



ISIDORI ET AL. 1305.0663



...HOWEVER, EFFECTS OF THE CONTACT INTERACTIONS COULD BE ACCESSED IN THE LOW INVARIANT MASS PAIR AND SHOULD BE PART OF ANY PARAMETRISATION OF BSM PHYSICS.