Pseudo Observables in EW Higgs production

Universität Zürich[UZH]

Jonas M. Lindert

work in collaboration with:
A. Greljo, G. Isidori, D. Marzocca

Future of VBF measurements
Durham, 22th September 2016

Run-II Higgs Precision Era

- Run-I Higgs legacy:
  - ✓ discovery of the Higgs!
  - ✓ all measured rates and BRs are in very good agreement with SM

- Run-II Higgs prospects:
  - ➡ precision probe of the Higgs sector
  - ➡ as long as direct BSM searches indicate no clear signal: $\Lambda_{NP} \gg m_h$
  - ➡ search and parametrize smooth deviations from the SM
  - ➡ has to be done in the **most general** and **theoretically unbiased** way

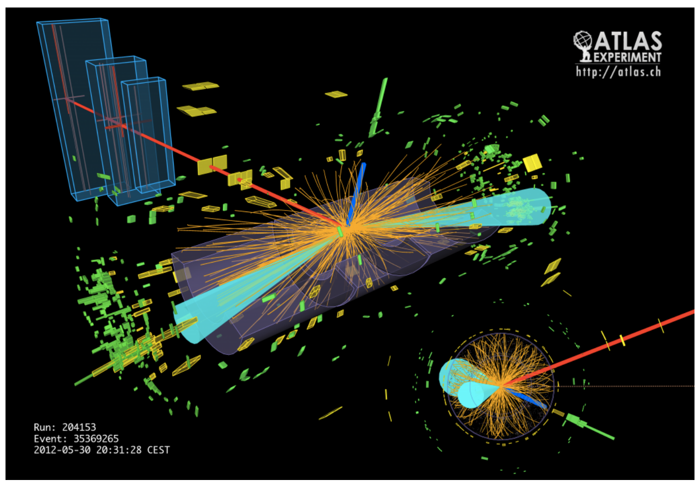
(SM)EFT?

- dynamical assumptions (H ∈ doublet?)
- basis choice
- fix order in perturbation theory
- flavour assumptions
- ….

…still: EFT approach is of course very powerful!

Pseudo Observables

How to parametrize smooth deviations from the SM
in the **most general** and **theoretically unbiased** way?



$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\Psi} \not{D} \psi + h.c. + \bar{\Psi}_i y_{ij} \psi_j \phi + h.c. + |D_\mu \phi|^2 - V(\phi)$$

Experimental Observables

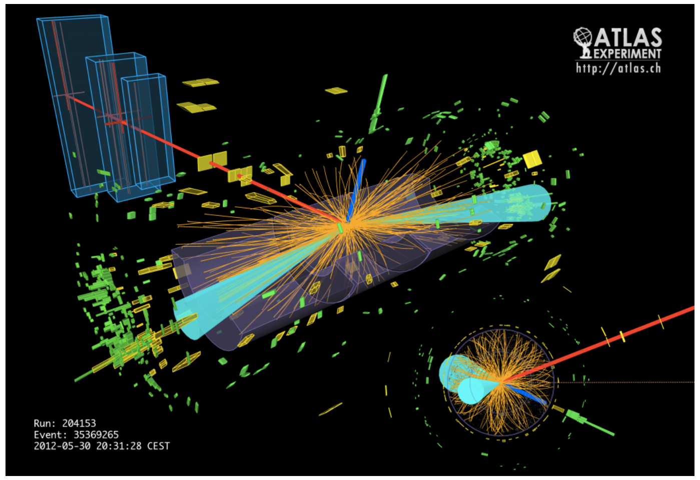
Raw data on tape,
reconstructed events
fiducial cross sections, …

Lagrangian parameters

Gauge structure, couplings,
running masses,
Wilson coefficients, …

Pseudo Observables

How to parametrize smooth deviations from the SM
in the **most general** and **theoretically unbiased** way?



$$\begin{aligned}\mathcal{L} = &-\tfrac{1}{4} F_{\mu\nu} F^{\mu\nu} \\ &+ i\bar{\psi} \not{D} \psi + h.c. \\ &+ \bar{\psi}_i y_{ij} \psi_j \phi + h.c. \\ &+ |D_\mu \phi|^2 - V(\phi)\end{aligned}$$

Experimental Observables

Raw data on tape,
reconstructed events
fiducial cross sections, …

Pseudo Observables

Pole masses, decay width,
kappas, form factors, …

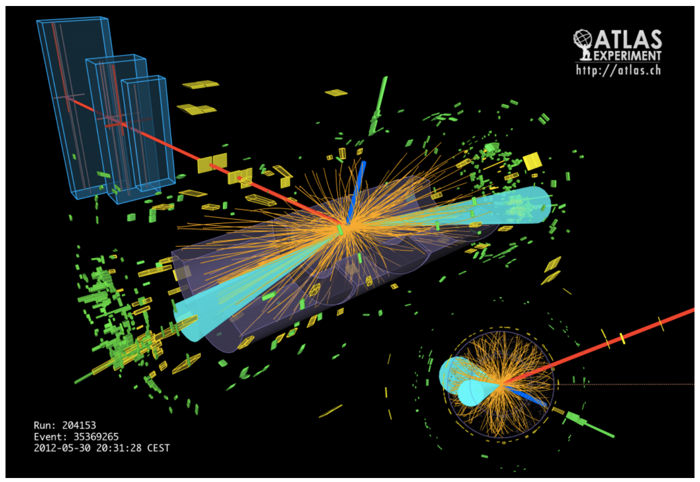
Lagrangian parameters

Gauge structure, couplings,
running masses,
Wilson coefficients, …

pioneered in the context of Z-pole PO
[Bardin, Grunewald, Passarino, '99]

Pseudo Observables

How to parametrize smooth deviations from the SM
in the **most general** and **theoretically unbiased** way?



$$
\begin{aligned}
\mathcal{L} = & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \\
& + i \bar{\Psi} \not{D} \psi + h.c. \\
& + \bar{\Psi}_i y_{ij} \Psi_j \phi + h.c. \\
& + |D_\mu \phi|^2 - V(\phi)
\end{aligned}
$$

Experimental Observables	Pseudo Observables	Lagrangian parameters
Raw data on tape, reconstructed events fiducial cross sections, …	*Pole masses, decay width, kappas, form factors, …*	*Gauge structure, couplings, running masses, Wilson coefficients, …*

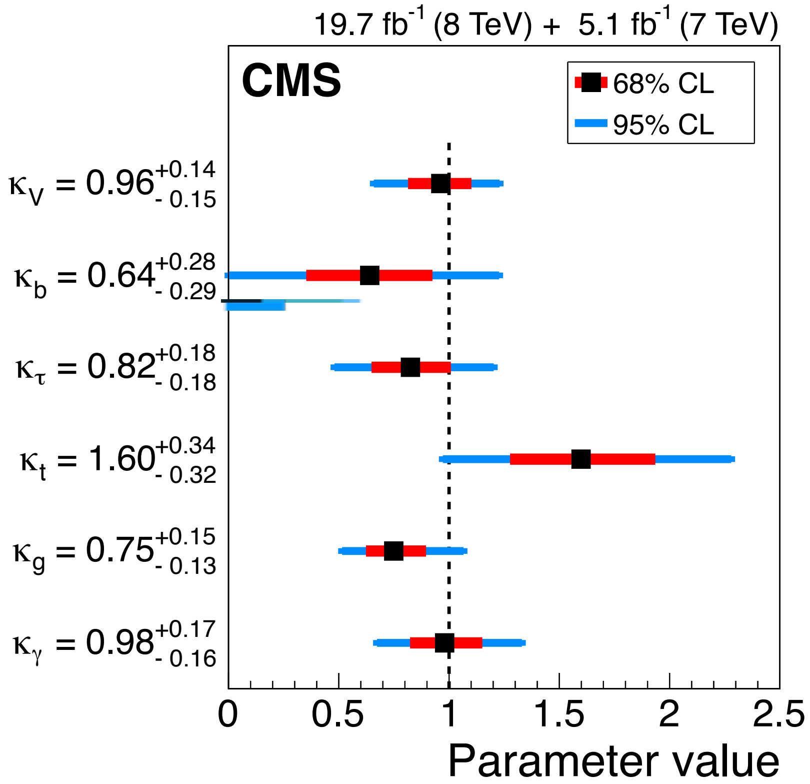
encode experimental information as *idealised Observables*

can be *matched* to an explicit model (at the desired perturbative order)

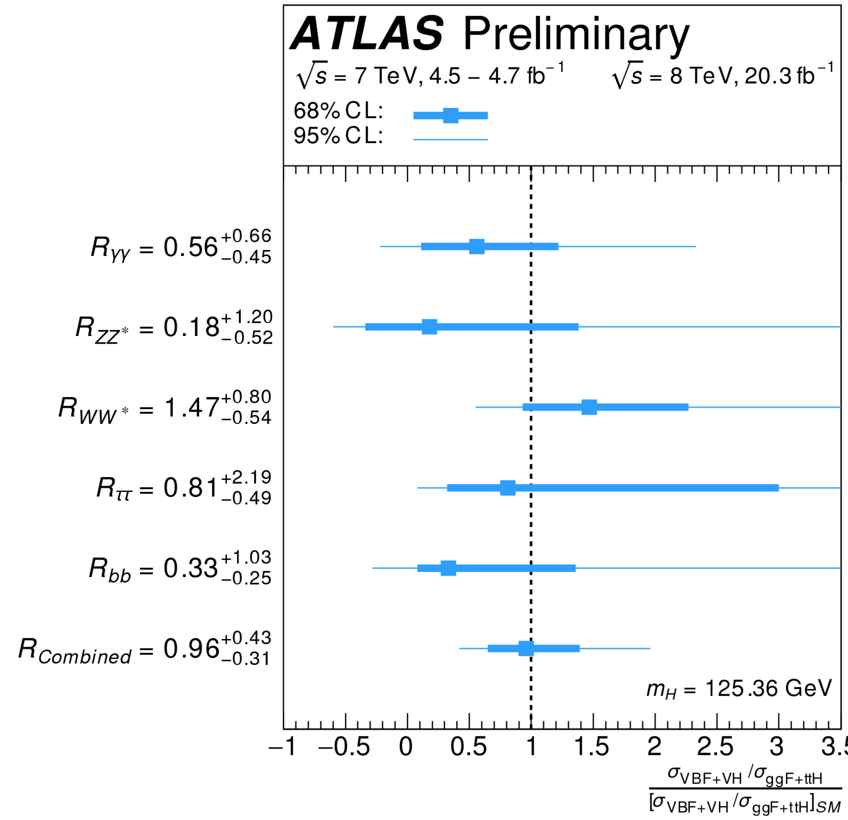
Kappas

Coupling strength scaling factors

$$\sigma(ii \to h+X) \times \mathrm{BR}(h \to ff) = \sigma_{ii} \frac{\Gamma_{ff}}{\Gamma_h} = \frac{\kappa_{ii}^2 \, \kappa_{ff}^2}{\kappa_h^2} \sigma_{SM} \times \mathrm{BR}_{SM}$$



CMS-HIG-14-009



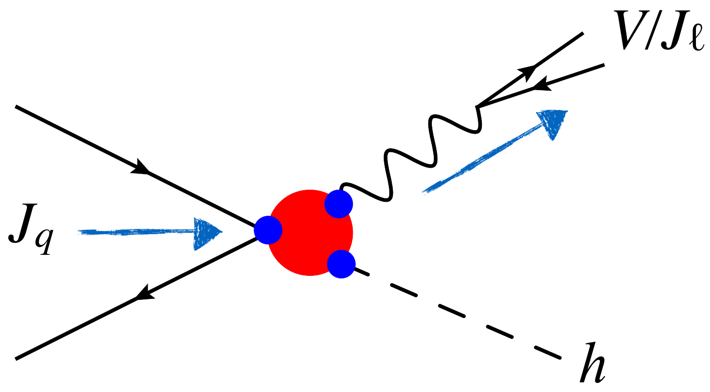
Main problem: loss of information for NP effects modifying kinematical distributions!

Pseudo Observables

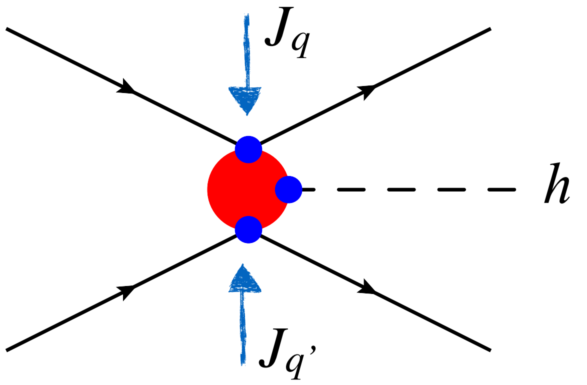
goal:
encode **all experimental information**
on a **certain physical process**
in a **few parameters**
with a **well-defined theoretical interpretation**

EW Higgs production

VH



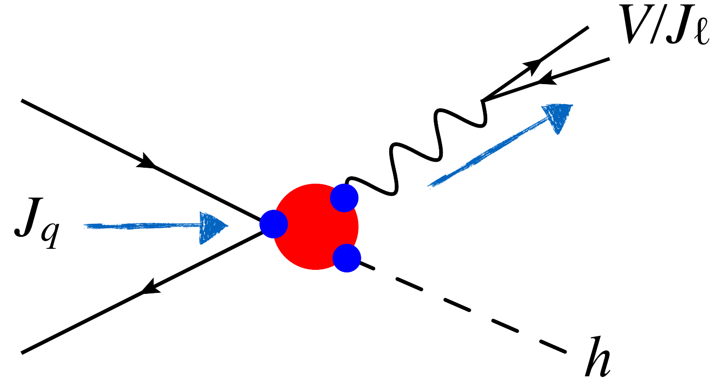
VBF



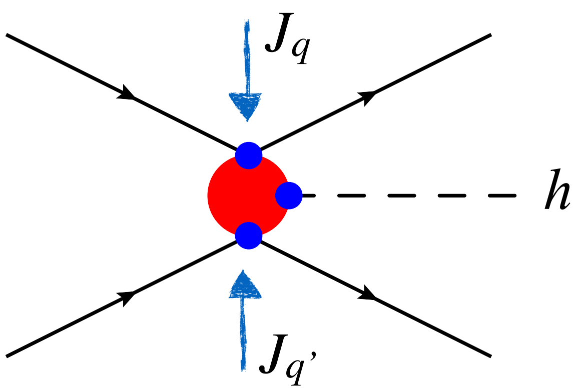
Physical process: 2 on-shell EW currents + on-shell H

EW Higgs production

VH

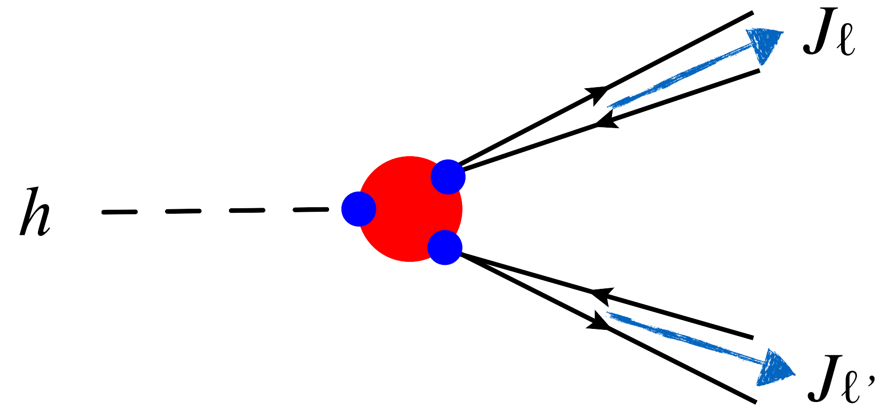


VBF



Physical process: 2 on-shell EW currents + on-shell H

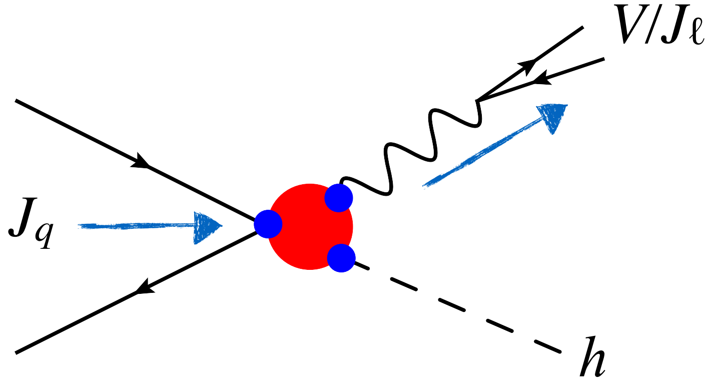
same as:



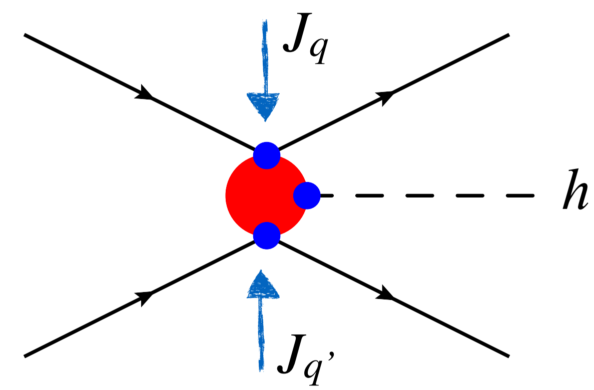
[Gonzalez-Alonso, Greljo, Isidori, Marzocca, '14,'15]

EW Higgs production

VH

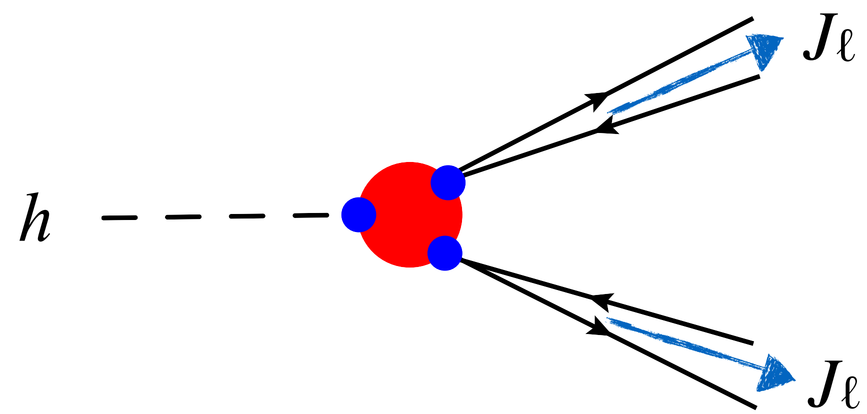


VBF



Physical process: 2 on-shell EW currents + on-shell H

same as:



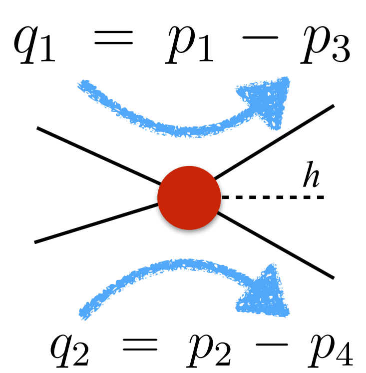
[Gonzalez-Alonso, Greljo, Isidori, Marzocca, '14,'15]

all three processes are described by the same correlation function:

$$\langle 0|\mathcal{T}\left\{J_f^\mu(x), J_{f'}^\nu(y), h(0)\right\}|0\rangle$$

(in different kinematic regimes and with different fermionic currents)

PO for VBF Higgs production



1) Decompose amplitude into flavour structures allowed by Lorentz symmetry

neutral currents:

$$\mathcal{A}_{n.c}(q_i(p_1)q_j(p_2) \to q_i(p_3)q_j(p_4)h(k)) = i\frac{2m_Z^2}{v}\bar{q}_i(p_3)\gamma_\mu q_i(p_1)\bar{q}_j(p_4)\gamma_\nu q_j(p_2)\mathcal{T}^{\mu\nu}_{n.c.}(q_1,q_2),$$

$$\mathcal{T}^{\mu\nu}_{n.c.}(q_1,q_2) = \left[F_L^{q_iq_j}(q_1^2,q_2^2)g^{\mu\nu} + F_T^{q_iq_j}(q_1^2,q_2^2)\frac{q_1\cdot q_2\ g^{\mu\nu} - {q_2}^\mu {q_1}^\nu}{m_Z^2} + F_{CP}^{q_iq_j}(q_1^2,q_2^2)\frac{\varepsilon^{\mu\nu\rho\sigma}q_{2\rho}q_{1\sigma}}{m_Z^2}\right]$$

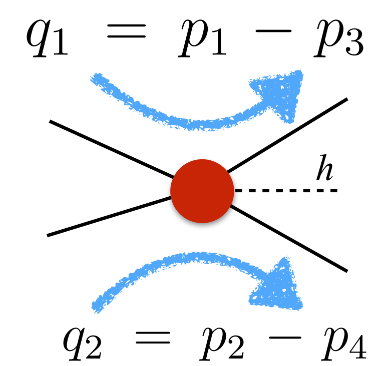
charged currents:

$$\mathcal{A}_{c.c}(u_i(p_1)d_j(p_2) \to d_k(p_3)u_l(p_4)h(k)) = i\frac{2m_W^2}{v}\bar{d}_k(p_3)\gamma_\mu u_i(p_1)\bar{u}_l(p_4)\gamma_\nu d_j(p_2)\mathcal{T}^{\mu\nu}_{c.c.}(q_1,q_2),$$

$$\mathcal{T}^{\mu\nu}_{c.c.}(q_1,q_2) = \left[G_L^{ijkl}(q_1^2,q_2^2)g^{\mu\nu} + G_T^{ijkl}(q_1^2,q_2^2)\frac{q_1\cdot q_2\ g^{\mu\nu} - {q_2}^\mu {q_1}^\nu}{m_W^2} + G_{CP}^{ijkl}(q_1^2,q_2^2)\frac{\varepsilon^{\mu\nu\rho\sigma}q_{2\rho}q_{1\sigma}}{m_W^2}\right]$$

→try measure these form-factors as accurate as possible!

PO for VBF Higgs production



2) Perform an momentum expansion around the physical poles (of the SM states)

$$F_X(q_1^2, q_2^2) = \sum_V \frac{(\text{const})_{2V}}{(q_1^2 - m_V^2)(q_2^2 - m_V^2)} + \frac{(\text{const})_{1V}}{(q_{1,2}^2 - m_V^2)} + (\text{const}) + f_{\text{reg}}(q_1^2, q_2^2)$$

2 poles | 1 pole | no poles

for example for the longitudinal form-factors:

$$F_L^{q_i q_j}(q_1^2, q_2^2) = \kappa_{ZZ} \frac{g_Z^{q_i} g_Z^{q_j}}{P_Z(q_1^2) P_Z(q_2^2)} + \frac{\epsilon_{Zq_i}}{m_Z^2} \frac{g_Z^{q_j}}{P_Z(q_2^2)} + \frac{\epsilon_{Zq_j}}{m_Z^2} \frac{g_Z^{q_i}}{P_Z(q_1^2)} + \Delta_{L,n.c.}^{\text{SM}}(q_1^2, q_2^2) \ ,$$

$$G_L^{ijkl}(q_1^2, q_2^2) = \kappa_{WW} \frac{g_W^{ik} g_W^{jl}}{P_W(q_1^2) P_W(q_2^2)} + \frac{\epsilon_{Wik}}{m_W^2} \frac{g_W^{jl}}{P_W(q_2^2)} + \frac{\epsilon_{Wjl}}{m_W^2} \frac{g_W^{ik}}{P_W(q_1^2)} + \Delta_{L,c.c}^{\text{SM}}(q_1^2, q_2^2)$$

$$P_V(q^2) = q^2 - m_V^2 + i m_V \Gamma_V$$

3) Define PO from the residues on the poles such that SM corresponds to $k_i \to 1, \quad \epsilon_j \to 0$

PO counting

Higgs (EW) decay amplitudes

<table>
<tr><th>Amplitudes</th><th>Flavor + CP</th><th>Flavor Non Univ.</th><th>CPV</th></tr>
<tr><td>$h \to \gamma\gamma, 2e\gamma, 2\mu\gamma$
$4e, 4\mu, 2e2\mu$</td><td>$\kappa_{ZZ}, \kappa_{Z\gamma}, \kappa_{\gamma\gamma}, \varepsilon_{ZZ}$
$\varepsilon_{Ze_L}, \varepsilon_{Ze_R}$</td><td>$\varepsilon_{Z\mu_L}, \varepsilon_{Z\mu_R}$</td><td>$\varepsilon^{CP}_{ZZ}, \delta^{CP}_{Z\gamma}, \delta^{CP}_{\gamma\gamma}$</td></tr>
<tr><td rowspan="2">$h \to 2e2\nu, 2\mu 2\nu, e\nu\mu\nu$</td><td rowspan="2">$\kappa_{WW}, \varepsilon_{WW}$
$\varepsilon_{Z\nu_e}$, $\mathrm{Re}(\varepsilon_{We_L})$</td><td>$\varepsilon_{Z\nu_\mu}$, $\mathrm{Re}(\varepsilon_{W\mu_L})$</td><td>$\varepsilon^{CP}_{WW}$, $\mathrm{Im}(\varepsilon_{We_L})$</td></tr>
<tr><td colspan="2">$\mathrm{Im}(\varepsilon_{W\mu_L})$</td></tr>
</table>

Higgs (EW) production amplitudes

<table>
<tr><th>Amplitudes</th><th>Flavor + CP</th><th>Flavor Non Univ.</th><th>CPV</th></tr>
<tr><td>VBF neutral curr.
and Zh</td><td>$[\ \kappa_{ZZ}, \kappa_{Z\gamma}, \kappa_{\gamma\gamma}, \varepsilon_{ZZ}\ ]$
$\varepsilon_{Zu_L}, \varepsilon_{Zu_R}, \varepsilon_{Zd_L}, \varepsilon_{Zd_R}$</td><td>$\varepsilon_{Zc_L}, \varepsilon_{Zc_R}$
$\varepsilon_{Zs_L}, \varepsilon_{Zs_R}$</td><td>$\left[\ \varepsilon^{CP}_{ZZ}, \delta^{CP}_{Z\gamma}, \delta^{CP}_{\gamma\gamma}\ \right]$</td></tr>
<tr><td rowspan="2">VBF charged curr.
and Wh</td><td rowspan="2">$[\ \kappa_{WW}, \varepsilon_{WW}\ ]$
$\mathrm{Re}(\varepsilon_{Wu_L})$</td><td>$\mathrm{Re}(\varepsilon_{Wc_L})$</td><td>$[\varepsilon^{CP}_{WW}]$, $\mathrm{Im}(\varepsilon_{Wu_L})$</td></tr>
<tr><td colspan="2">$\mathrm{Im}(\varepsilon_{Wc_L})$</td></tr>
</table>

[…] : present both in production and decays.

- ➡ Flavor-independent PO probed in h→4f
- ➡ in EW production focus on quark contact terms

Matching PO to effective couplings

- at LO there is a direct correspondence between PO and these effective couplings

$$
\begin{aligned}
\mathcal{L}^{eff} &= \kappa_{ZZ}\frac{m_Z^2}{v}Z_\mu Z^\mu h + \kappa_{WW}\frac{2m_W^2}{v}W_\mu^+ W^{-\,\mu} h + \\
&- \frac{\epsilon_{\gamma\gamma}}{2}\frac{h}{v}A_{\mu\nu}A^{\mu\nu} - \epsilon_{Z\gamma}\frac{h}{v}Z_{\mu\nu}A^{\mu\nu} - \frac{\epsilon_{ZZ}}{2}\frac{h}{v}Z_{\mu\nu}Z^{\mu\nu} - \epsilon_{WW}\frac{h}{v}W_{\mu\nu}^+ W^{-\,\mu\nu} + \\
&- \frac{\tilde{\epsilon}_{\gamma\gamma}}{2}\frac{h}{v}A_{\mu\nu}\tilde{A}^{\mu\nu} - \tilde{\epsilon}_{Z\gamma}\frac{h}{v}Z_{\mu\nu}\tilde{A}^{\mu\nu} - \frac{\tilde{\epsilon}_{ZZ}}{2}\frac{h}{v}Z_{\mu\nu}\tilde{Z}^{\mu\nu} - \tilde{\epsilon}_{WW}\frac{h}{v}W_{\mu\nu}^+ \tilde{W}^{-\,\mu\nu} + \\
&+ \sum_f \epsilon_{Zf^{ij}}\ \frac{2h}{v}Z_\mu \bar{f}^i\gamma^\mu f^j + \\
&+ \epsilon_{We^{ij}}\ \frac{2h}{v}W_\mu^+ \bar{\nu}_{e^i L}\gamma^\mu e_L^j + \epsilon_{Wu_L^i d_L^j}\ \frac{2h}{v}W_\mu^+ \bar{u}_L^i\gamma^\mu d_L^j + \epsilon_{Wu_R^i d_R^j}\ \frac{2h}{v}W_\mu^+ \bar{u}_R^i\gamma^\mu d_R^j + h.c.
\end{aligned}
$$

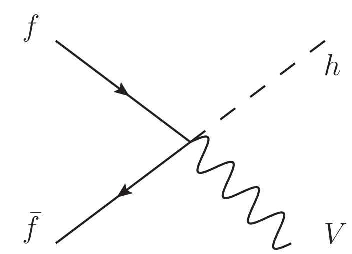
- can easily be implemented in any Monte Carlo (via publicly available UFO model)

  …tested within Sherpa & MadGraph_aMC@NLO

Matching PO to effective couplings

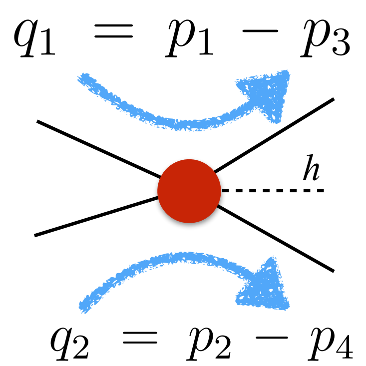
- at LO there is a direct correspondence between PO and these effective couplings

$$
\begin{aligned}
\mathcal{L}^{eff} &= \kappa_{ZZ}\frac{m_Z^2}{v}Z_\mu Z^\mu h + \kappa_{WW}\frac{2m_W^2}{v}W_\mu^+ W^{-\,\mu}h + \\
&- \frac{\epsilon_{\gamma\gamma}}{2}\frac{h}{v}A_{\mu\nu}A^{\mu\nu} - \epsilon_{Z\gamma}\frac{h}{v}Z_{\mu\nu}A^{\mu\nu} - \frac{\epsilon_{ZZ}}{2}\frac{h}{v}Z_{\mu\nu}Z^{\mu\nu} - \epsilon_{WW}\frac{h}{v}W_{\mu\nu}^+ W^{-\,\mu\nu} + \\
&- \frac{\tilde{\epsilon}_{\gamma\gamma}}{2}\frac{h}{v}A_{\mu\nu}\tilde{A}^{\mu\nu} - \tilde{\epsilon}_{Z\gamma}\frac{h}{v}Z_{\mu\nu}\tilde{A}^{\mu\nu} - \frac{\tilde{\epsilon}_{ZZ}}{2}\frac{h}{v}Z_{\mu\nu}\tilde{Z}^{\mu\nu} - \tilde{\epsilon}_{WW}\frac{h}{v}W_{\mu\nu}^+ \tilde{W}^{-\,\mu\nu} + \\
&+ \sum_f \epsilon_{Zf^{ij}}\ \frac{2h}{v}Z_\mu \bar{f}^i\gamma^\mu f^j + \\
&+ \epsilon_{We^{ij}}\ \frac{2h}{v}W_\mu^+\bar{\nu}_{e^i L}\gamma^\mu e_L^j + \epsilon_{Wu_L^i d_L^j}\ \frac{2h}{v}W_\mu^+\bar{u}_L^i\gamma^\mu d_L^j + \epsilon_{Wu_R^i d_R^j}\ \frac{2h}{v}W_\mu^+\bar{u}_R^i\gamma^\mu d_R^j + h.c.
\end{aligned}
$$



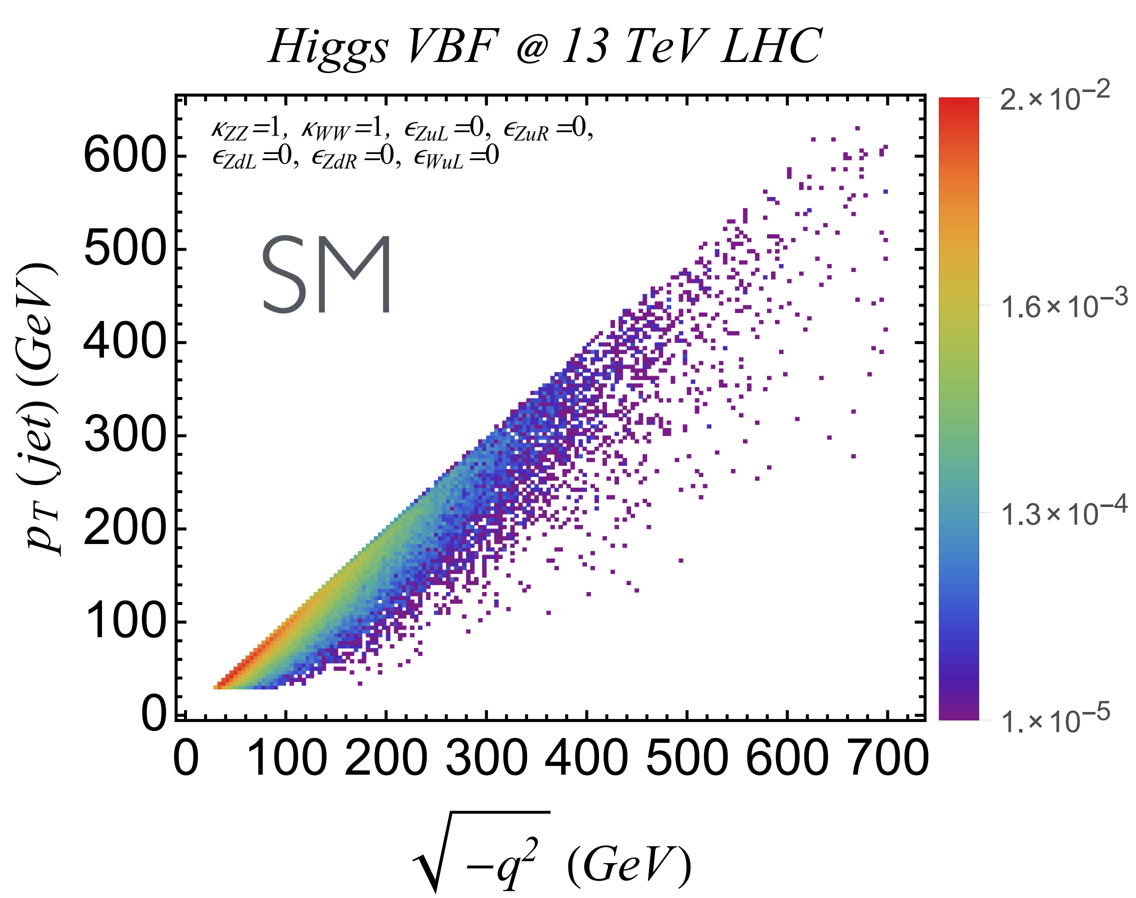
- can easily be implemented in any Monte Carlo (via publicly available UFO model)
  …tested within Sherpa & MadGraph_aMC@NLO

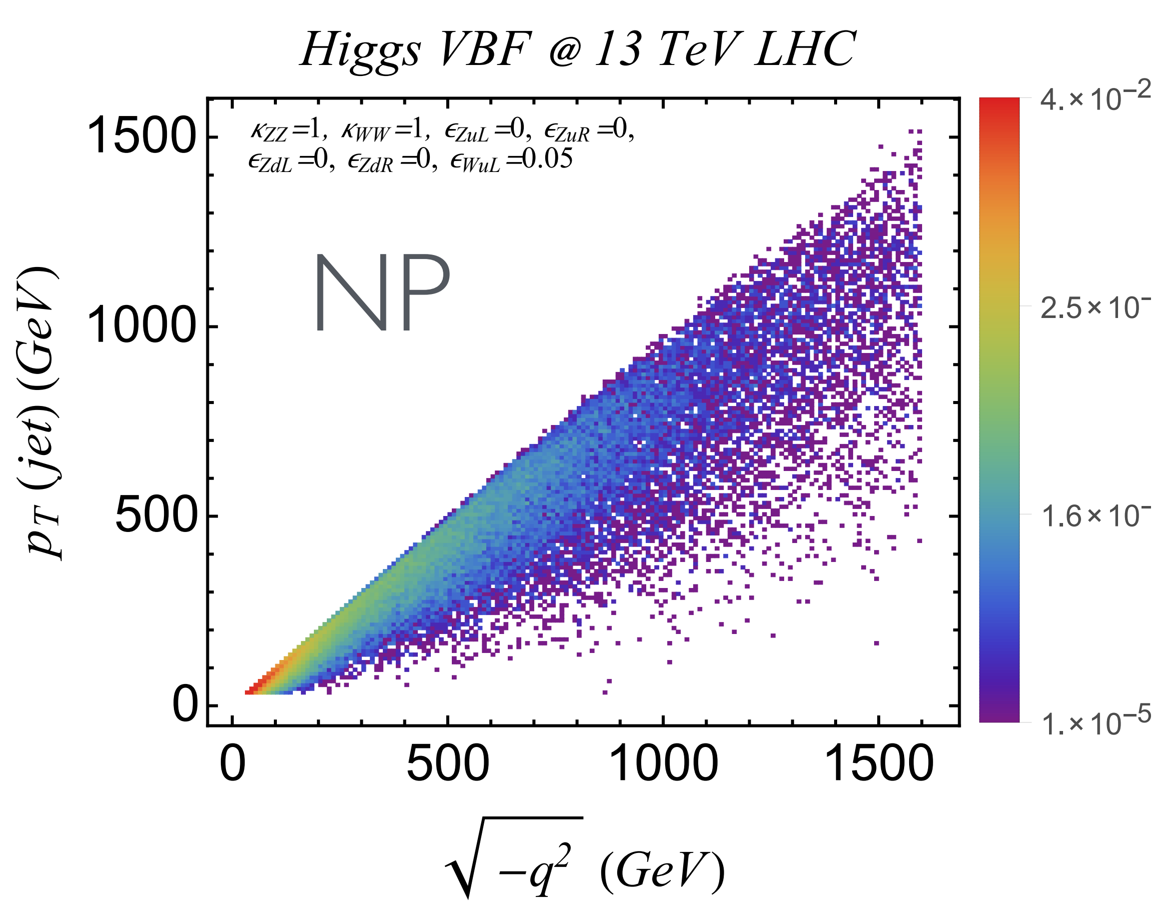
Measurement of PO in VBF



Practical problem:

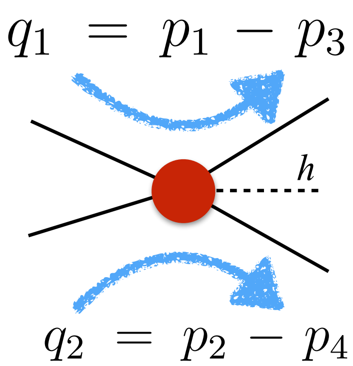
- $F_X(q_1^2, q_2^2)$, $G_X(q_1^2, q_2^2)$ not directly measurable
- not even q_1^2, q_2^2 measurable (in particular not in H→WW)
- construct proxy:





$$\Rightarrow \quad q_i^2 \approx -p_{\mathrm{T,i}}^2$$ (for Higgs produced near threshold)

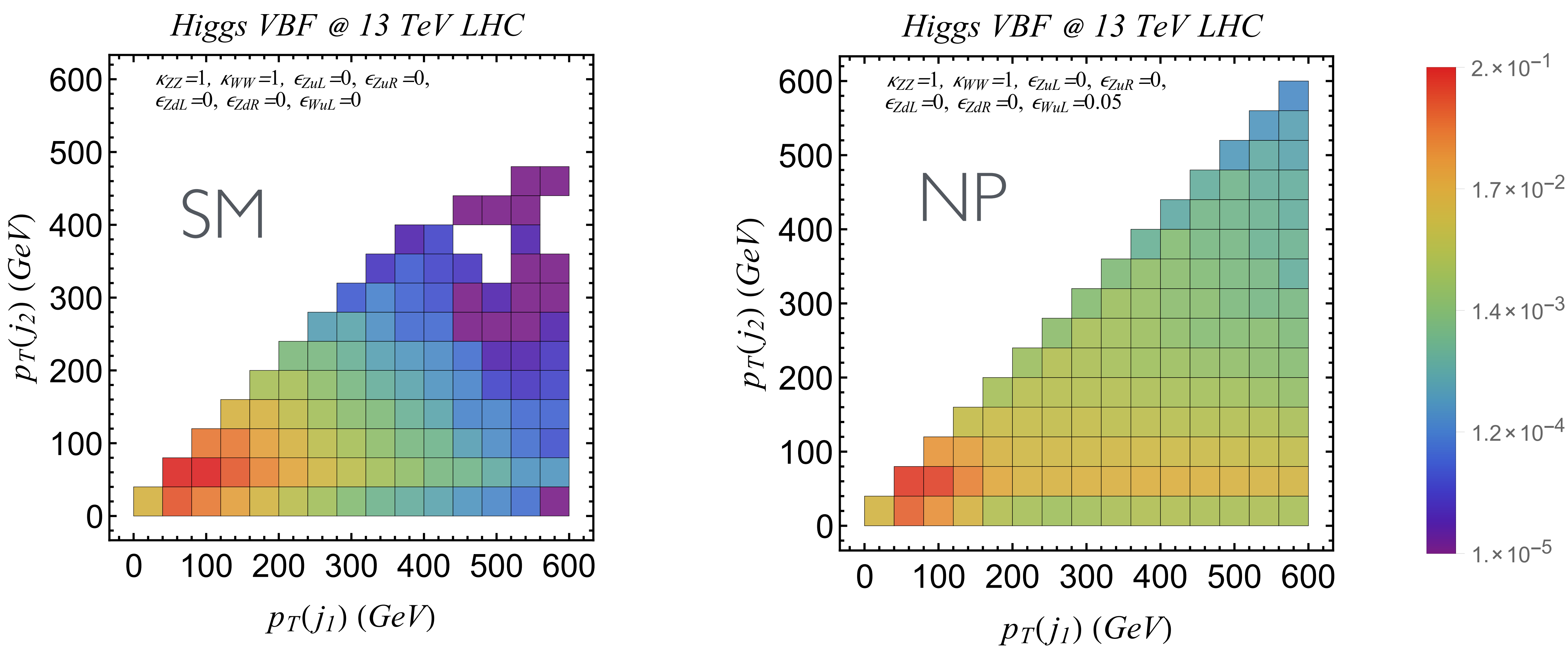
Measurement of PO in VBF



- Crucial measurement:
  double differential cross section in jet pT's
  (order by pT and/or $\Delta\eta_{ij}$)

$$\boxed{\frac{\mathrm{d}^2\sigma}{\mathrm{d}p_{\mathrm{T,j_1}}\mathrm{d}p_{\mathrm{T,j_2}}}}$$

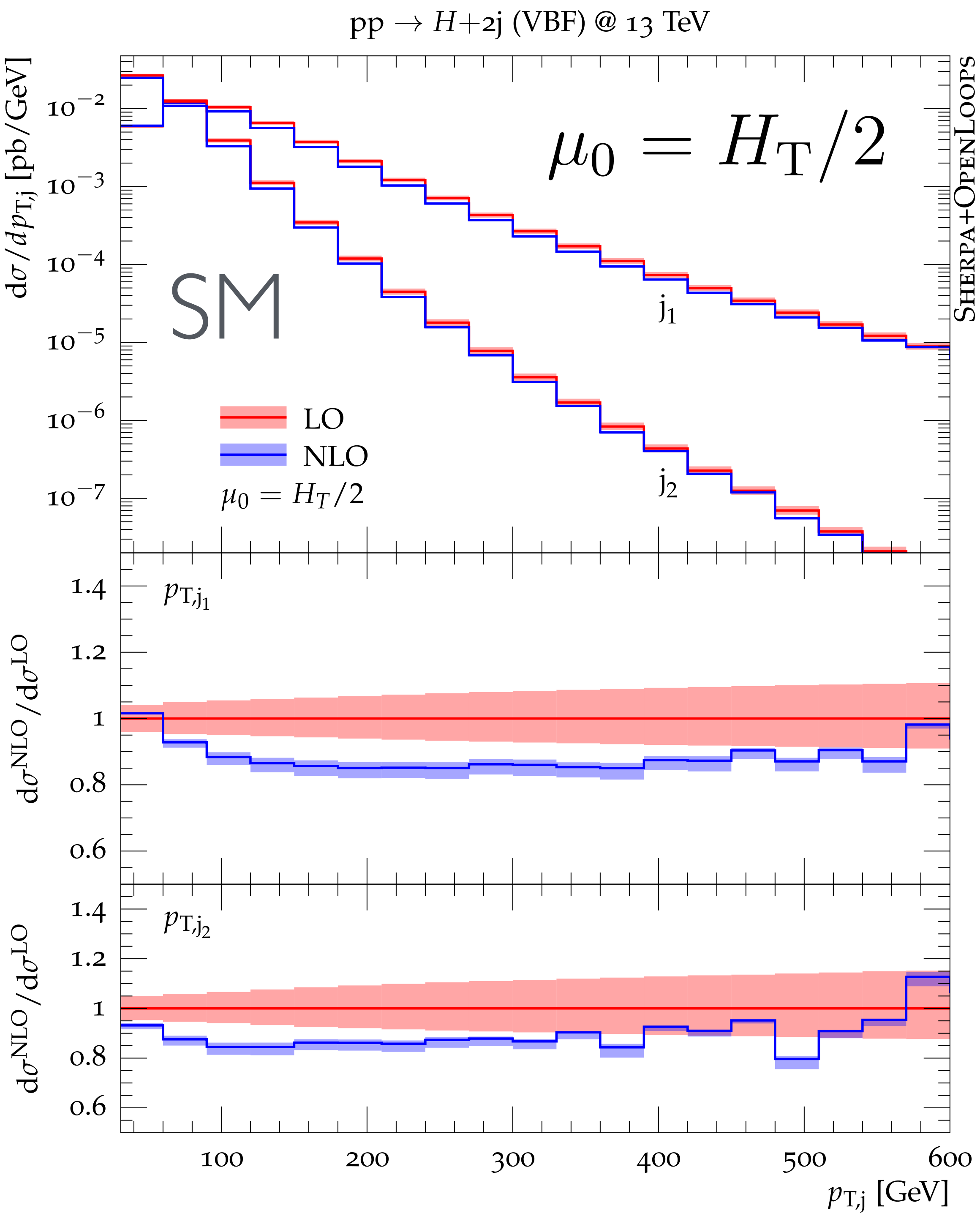
- allows for extraction/fit of PO! $F(q_1^2, q_2^2) \to \tilde{F}(p_{T1}^2, p_{T2}^2)$

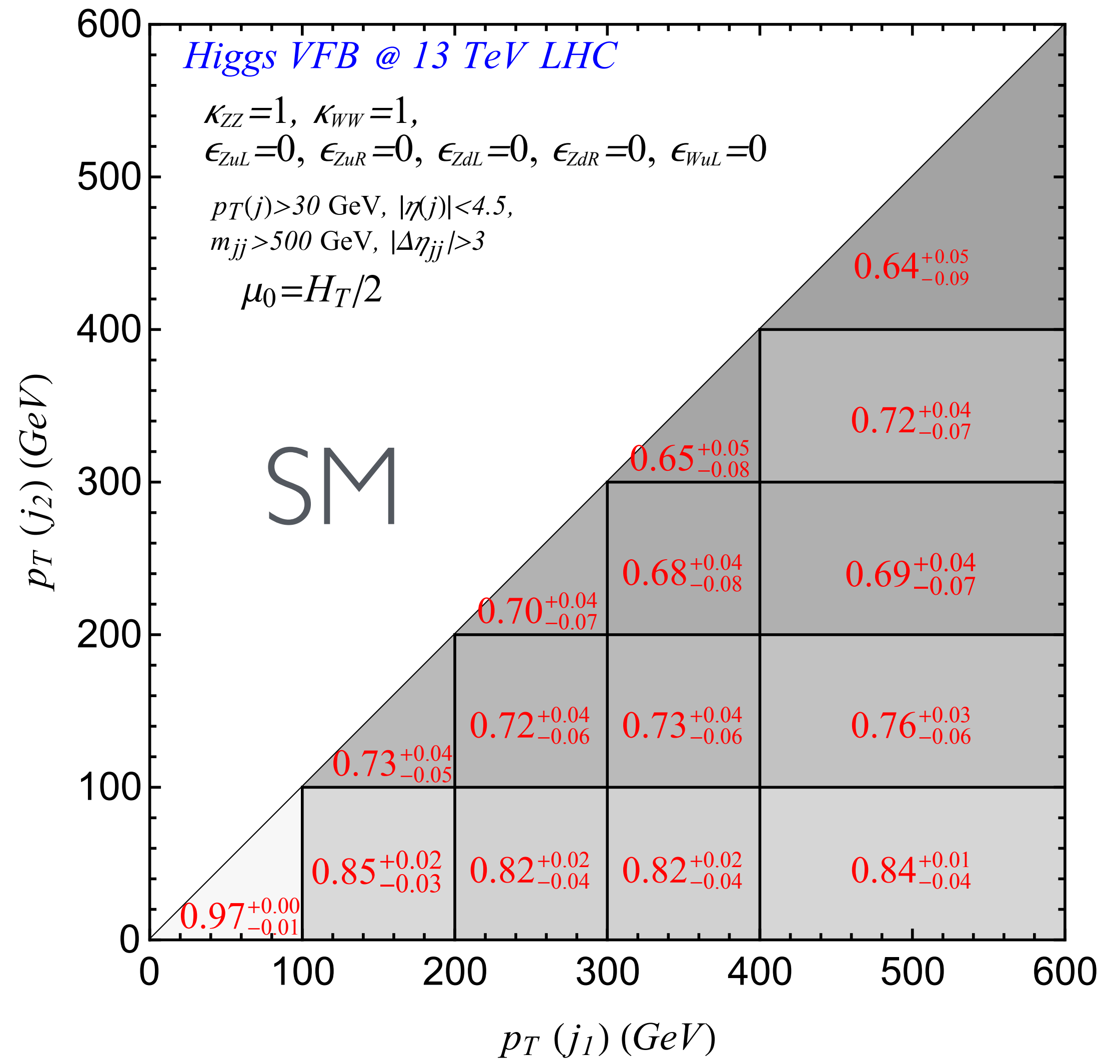


NLO QCD corrections

$$p_{\mathrm{T,j_{1,2}}} > 30~\mathrm{GeV}, \quad |\eta_{\mathrm{j_{1,2}}}| < 4.5, \quad \text{and} \quad m_{\mathrm{j_1 j_2}} > 500~\mathrm{GeV}$$

$$\Delta\eta_{j_1 j_2} > 3$$



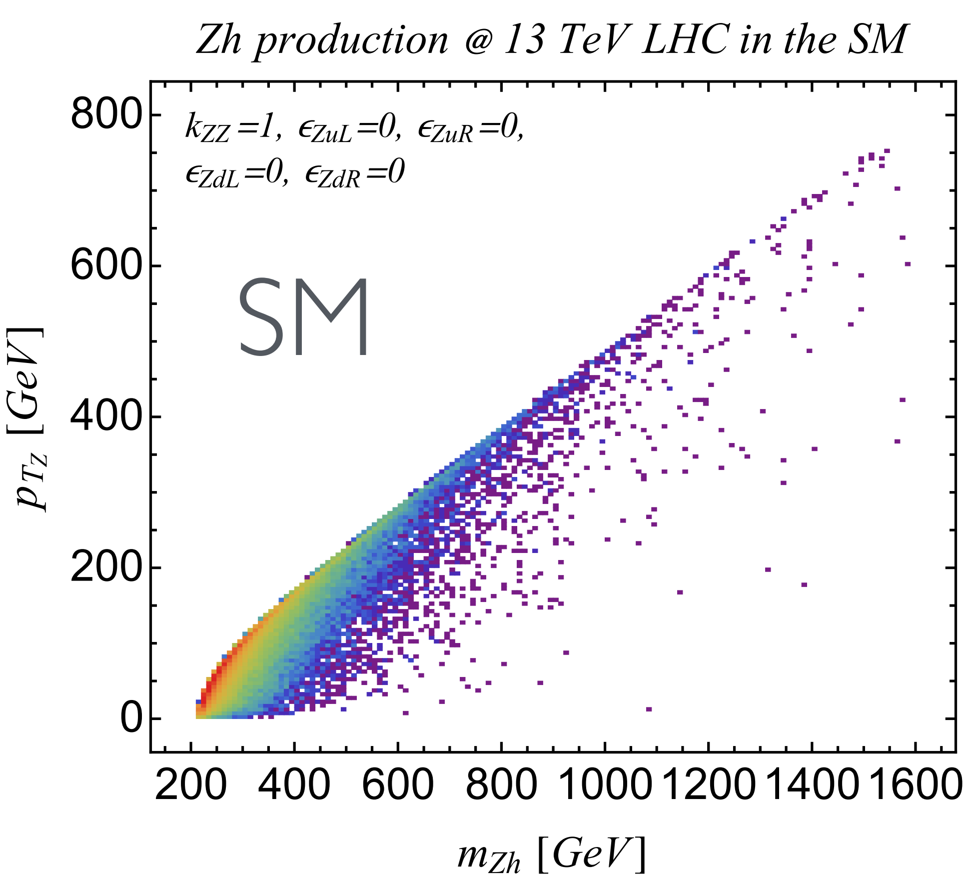


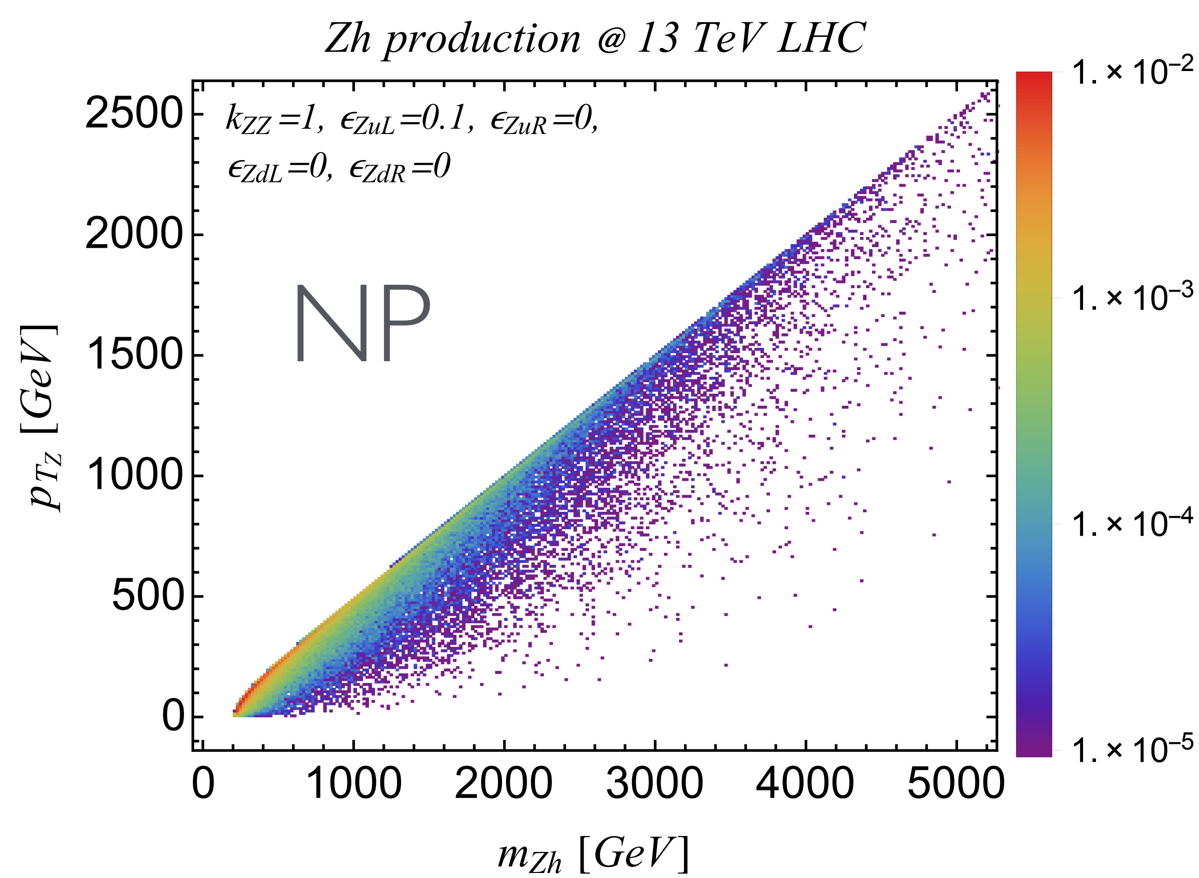
- mild NLO QCD corrections: max ~15-35%
- NNLO ~10% shape effects
- NLO EW ~10-15% shape effects

Measurement of PO in VH

Practical problem:

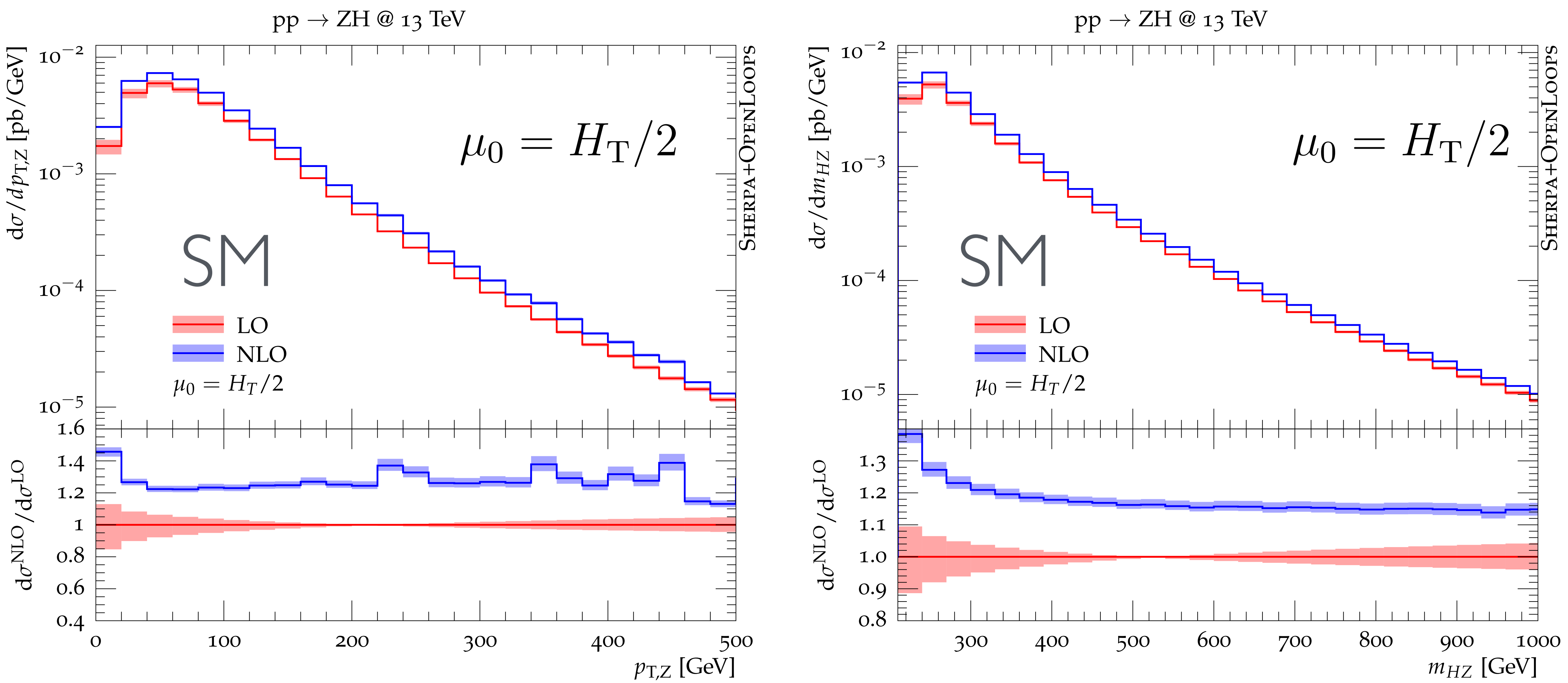
- process governed by $q^2 = m_{Vh}^2$
- not measurable in all decay modes (V=W or H→WW)





$m_{Vh}^2 \to 4p_{\mathrm{T}}^2$ for $|p_{\mathrm{T}}| \to \infty$

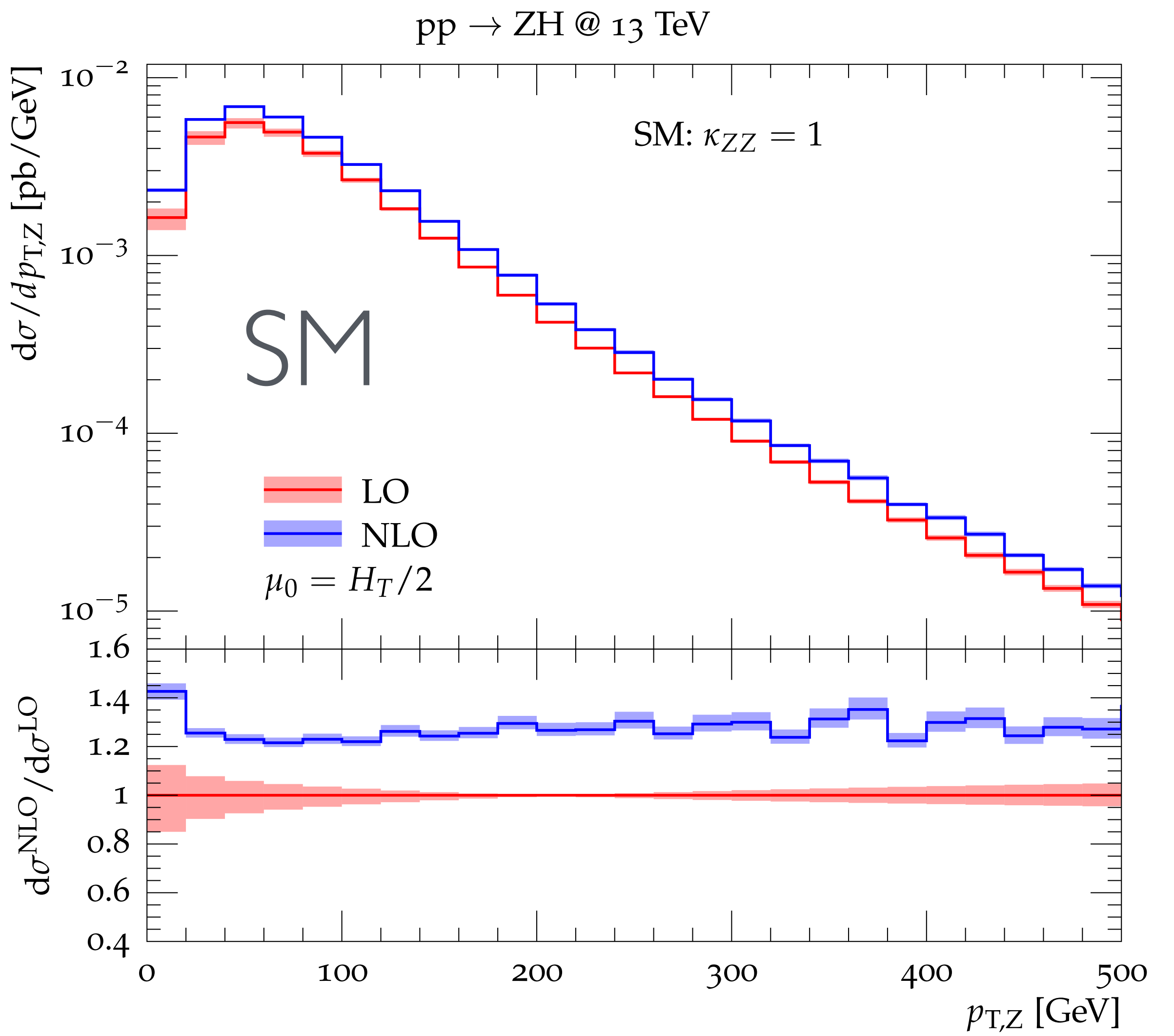
NLO QCD corrections

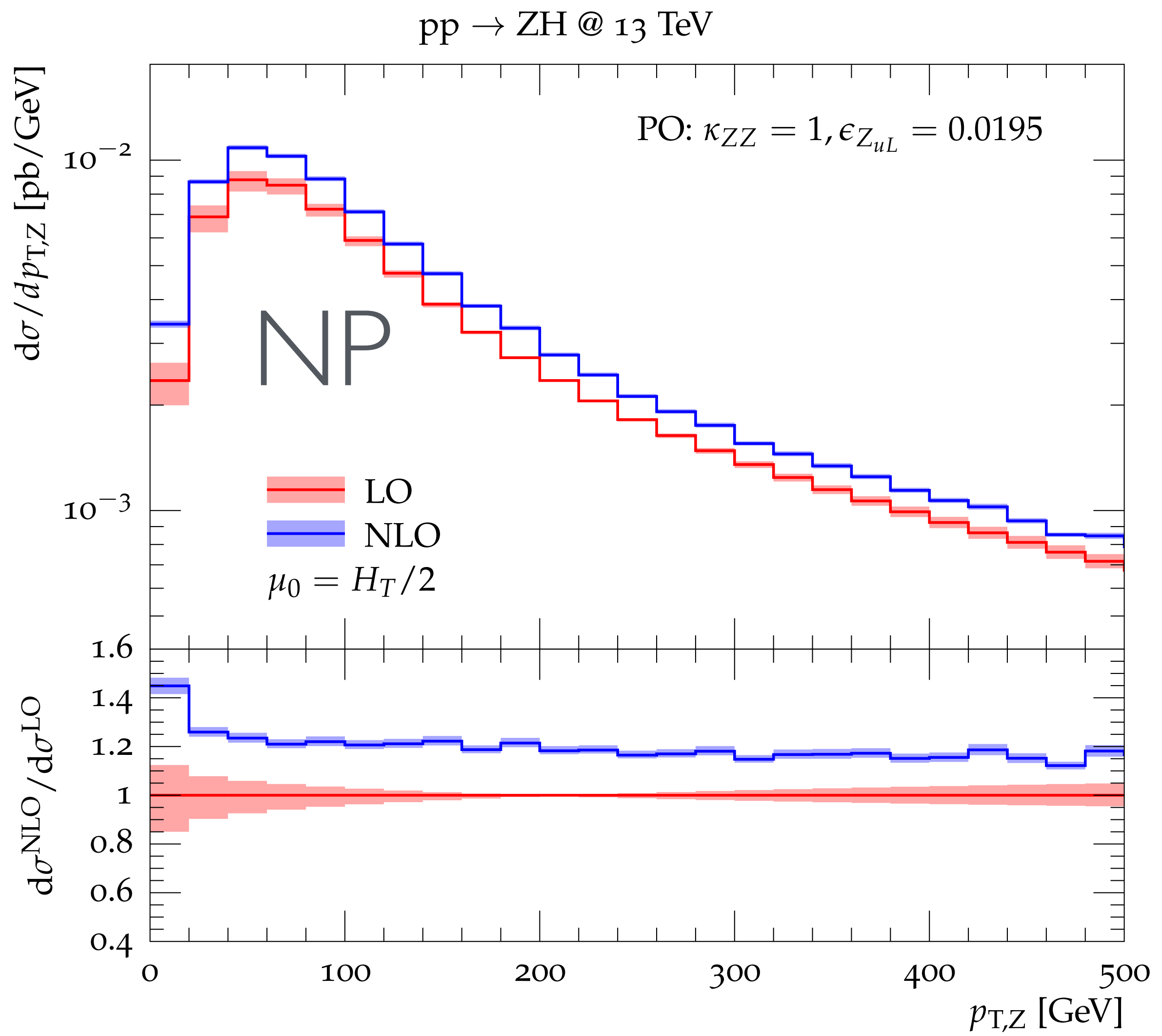


- canonical scale in VH is $\mu_0 = Q = \sqrt{(p_h + p_Z)^2}$
- but stabilisation of shapes with $\mu_0 = H_T/2$
- QCD corrections mostly affect overall normalisation

NLO QCD corrections in PO

- process independent implementation of Higgs PO @ NLO QCD in Sherpa+OpenLoops



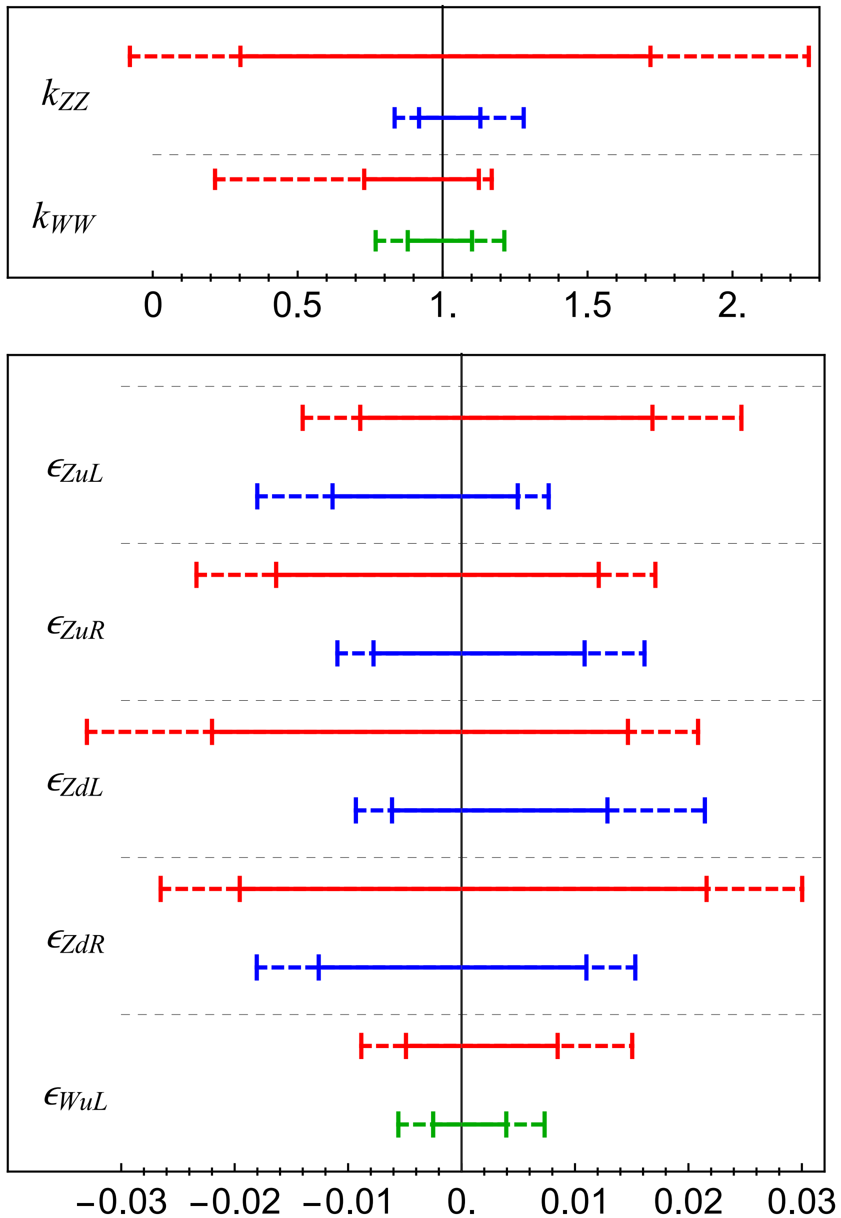


- NP shapes largely unaffected by QCD corrections
- detailed study in preparation

Prospects for HL-LHC

$\kappa_{ZZ}\ ,\quad \kappa_{WW}\ ,\quad \epsilon_{Zu_L}\ ,\quad \epsilon_{Zu_R}\ ,\quad \epsilon_{Zd_L}\ ,\quad \epsilon_{Zd_R}\ ,\quad \epsilon_{Wu_L}$

Assume: flavour universality & CP



HL-LHC with 3 ab^{-1}

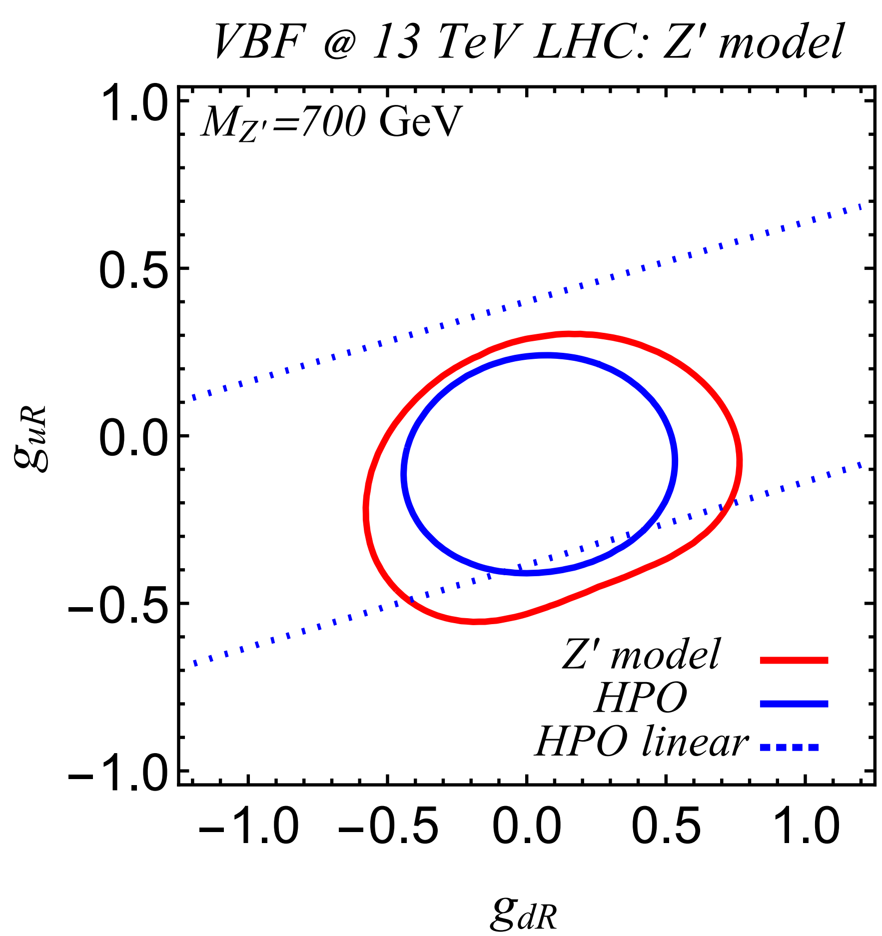
Very simplified study:

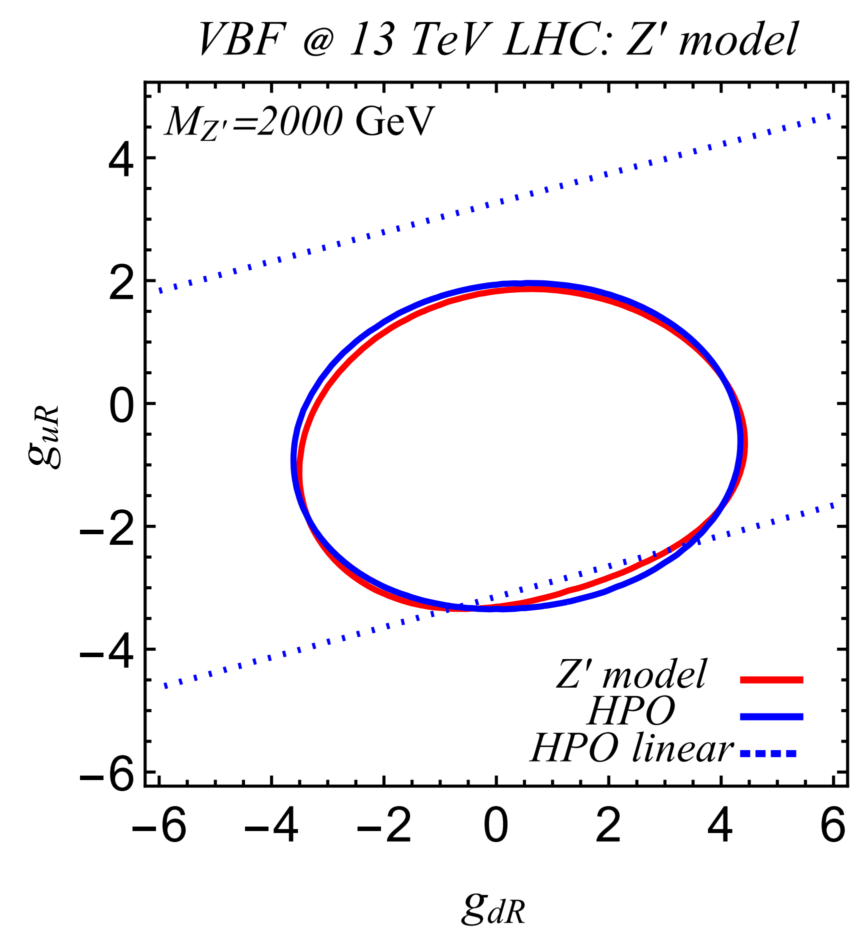
- ignore backgrounds
- assumed systematic uncertainty due to missing higher orders: 10% (However, still statistics limited!)
- assume SM rates @ HL-LHC
  - for VBF: h→2l2v ~2000 signal events (SM)
  - for ZH: h→2l2v ~130 signal events (SM)
  - for WH: h→4l ~ 67 signal events (SM)
- percent level constraints on PO feasible!

Match PO to toy model: Z'

$$\mathcal{L} \supset -2g_H m_Z Z^\mu Z'_\mu h + \sum_{f=f_L,f_R} g^f_{Z'} \bar{f}\gamma^\mu f Z'_\mu \quad \xleftrightarrow{\text{matching}} \quad \epsilon_{Zf} = g_H g^f_{Z'} \frac{v m_Z}{M^2_{Z'}} = g_f \frac{v m_Z}{M^2_{Z'}}$$

consider parameter space: $\{g_{d_R}, g_{u_R}\}$





- for $\Lambda_{NP} \gg m_h$ PO nicely reproduce limits obtained in explicit model
- if possible always perform quadratic fit of PO

HPO vs. SMEFT

- HPO and SMEFT interpretation go hand in hand
- add a given perturbative order HPO can be matched to coefficients of dim-6 of SMEFT

HPO

LO matching

dim-6 EFT (Higgs Basis)

$$
\begin{aligned}
\kappa_{ZZ} &= 1 + \delta c_z + g^2 c_{z\Box}\,, \\
\kappa_{WW} &= 1 + \delta c_w + g^2 c_{w\Box}\,, \\
\varepsilon_{Zf} &= \frac{2m_Z}{v}\left(\delta g^{Zf} + \frac{g^2}{2}(T_3^f - Q_f s_\theta^2)c_{z\Box} + \frac{e^2 Q_f}{2} c_{\gamma\Box}\right), \\
\varepsilon_{Wf} &= \frac{\sqrt{2}m_W}{v}\left(\delta g^{Wf} + \frac{g^2}{2} c_{w\Box}\right)\,, \\
\varepsilon_{ZZ} &= \varepsilon_{ZZ}^{\mathrm{SM-1L}} - \frac{g^2 + g'^2}{2} c_{zz}\,, \\
\varepsilon_{Z\gamma} &= \varepsilon_{Z\gamma}^{\mathrm{SM-1L}} - \frac{gg'}{2} c_{z\gamma}\,, \\
\varepsilon_{\gamma\gamma} &= \varepsilon_{\gamma\gamma}^{\mathrm{SM-1L}} - \frac{e^2}{2} c_{\gamma\gamma}\,, \\
\varepsilon_{WW} &= \varepsilon_{WW}^{\mathrm{SM-1L}} - \frac{g^2}{2} c_{ww}\,,
\end{aligned}
$$

$$
\begin{aligned}
\Delta\mathcal{L}_{\mathrm{hvv}}^{D=6} \;=\; \frac{h}{v}\Big[& 2\delta c_w m_W^2 W_\mu^+ W_\mu^- + \delta c_z m_Z^2 Z_\mu Z_\mu \\
& + c_{ww}\frac{g_L^2}{2} W_{\mu\nu}^+ W_{\mu\nu}^- + \tilde{c}_{ww}\frac{g_L^2}{2} W_{\mu\nu}^+ \tilde{W}_{\mu\nu}^- + c_{w\Box} g_L^2 \left(W_\mu^- \partial_\nu W_{\mu\nu}^+ + \mathrm{h.c.}\right) \\
& + c_{gg}\frac{g_s^2}{4} G_{\mu\nu}^a G_{\mu\nu}^a + c_{\gamma\gamma}\frac{e^2}{4} A_{\mu\nu} A_{\mu\nu} + c_{z\gamma}\frac{e g_L}{2c_\theta} Z_{\mu\nu} A_{\mu\nu} + c_{zz}\frac{g_L^2}{4c_\theta^2} Z_{\mu\nu} Z_{\mu\nu} \\
& + c_{z\Box} g_L^2 Z_\mu \partial_\nu Z_{\mu\nu} + c_{\gamma\Box} g_L g_Y Z_\mu \partial_\nu A_{\mu\nu} \\
& + \tilde{c}_{gg}\frac{g_s^2}{4} G_{\mu\nu}^a \tilde{G}_{\mu\nu}^a + \tilde{c}_{\gamma\gamma}\frac{e^2}{4} A_{\mu\nu} \tilde{A}_{\mu\nu} + \tilde{c}_{z\gamma}\frac{e g_L}{2c_\theta} Z_{\mu\nu} \tilde{A}_{\mu\nu} + \tilde{c}_{zz}\frac{g_L^2}{4c_\theta^2} Z_{\mu\nu} \tilde{Z}_{\mu\nu}\Big]
\end{aligned}
$$

HPO vs. SMEFT

- HPO and SMEFT interpretation go hand in hand
- add a given perturbative order HPO can be matched to coefficients of dim-6 of SMEFT

HPO ⟷ **EFT**

HPO:

- Basis and EFT independent
- directly related to physical properties of process at hand
- allows to classify *ALL* information that can be experimentally obtained from a given process
- defined at all-orders in perturbation theory

EFT:

- allows to relate *different process classes* with same operators (e.g. ttbar and VBF)
- combined predictions/limits across different classes of processes
- allows for studies of UV completion

Conclusions

- Higgs Pseudo Observables (HPO) offer a framework for model independent parametrisation of NP effects in Higgs decays and Higgs EW production
- based on physical properties of the Green functions
- can easily be matched to specific models
- trivial factorization of soft QCD and QED radiation
- LL+NLL EW effects via redefinition of PO
- can be extended to VBF-V

- FeynRules model for Higgs PO @ LO+PS is publicly available at:
  http://www.physik.uzh.ch/data/HiggsPO/
  …can easily be used within Sherpa or MadGraph_aMC@NLO
  …NLO QCD+PS will follow soon!

Backup slides