Karlsruhe Institute of Technology

REPOLO

Michael Rauch | Mini-Workshop on Monte-Carlo Event Reweighting, May 2015

INSTITUTE FOR THEORETICAL PHYSICS

Introduction

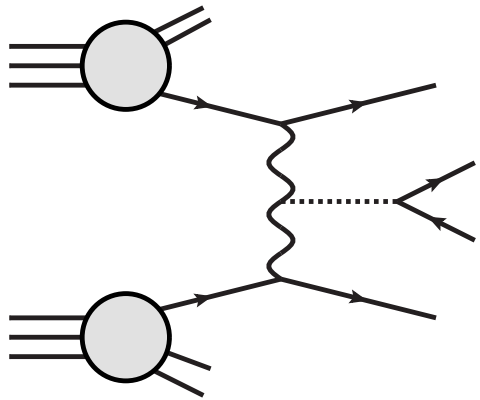
REPOLO:

[Schissler]

(based on VBFNLO framework) [Zeppenfeld, MR, et al.]

RE-weighting **PO**WHEG events at **L**eading **O**rder

- accurate simulation of events necessary
  (NLO, parton shower, detector simulation, . . .)
  → time-consuming
- → Reuse SM events and reweight for different BSM scenarios
  (kinematics of event stays unchanged)
- Input: Les Houches event file (of hard process, both LO and LO+j events)
- Output: Les Houches event file with new weights
- Scope: VBF production of “Higgs-like” boson
  - BSM scenarios
    → anomalous HVV couplings
    → MSSM (real or complex parameters)
    → spin-2 particle
  - Heavy Higgs Boson



BSM scenario

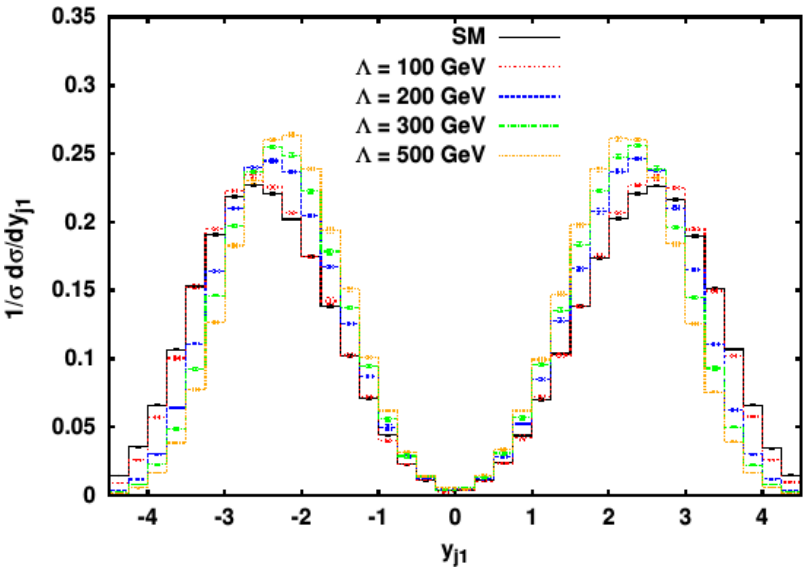
Example 1: anomalous Higgs couplings

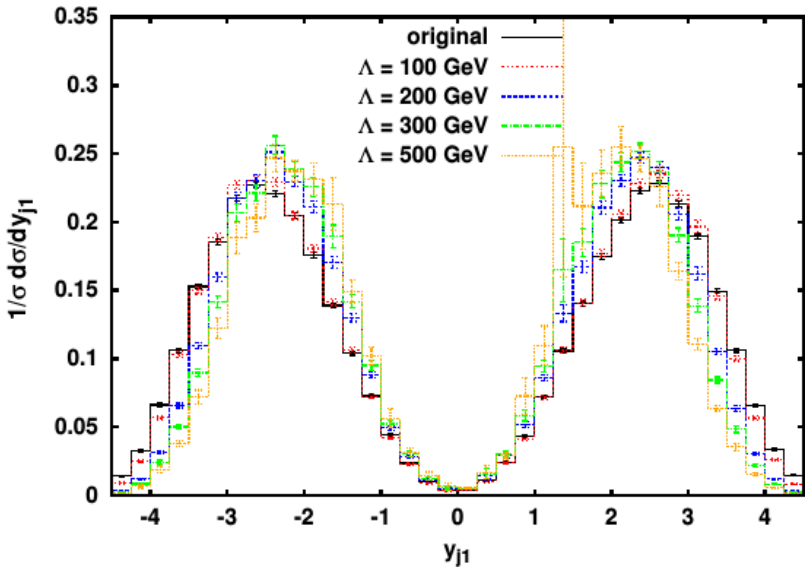
Reweighting with factor $\frac{|\mathcal{M}_{\text{BSM}}|^2}{|\mathcal{M}_{\text{SM}}|^2}$

$$\mathcal{L} = \frac{g_{5e}^{HZZ}}{2\Lambda_5} HZ_{\mu\nu}Z^{\mu\nu} + \frac{g_{5e}^{HWW}}{\Lambda_5} HW^+_{\mu\nu}W^{\mu\nu}_- + \frac{g_{5e}^{HZ\gamma}}{\Lambda_5} HZ_{\mu\nu}A^{\mu\nu} + \frac{g_{5e}^{H\gamma\gamma}}{2\Lambda_5} HA_{\mu\nu}A^{\mu\nu}$$

form factor $F = \frac{\Lambda^2}{q_1^2-\Lambda^2}\frac{\Lambda^2}{q_2^2-\Lambda^2}$ ($q^2_{1,2}$: momentum transfer of t-channel vector bosons)

rapidity of leading jet: VBFNLO REPOLO



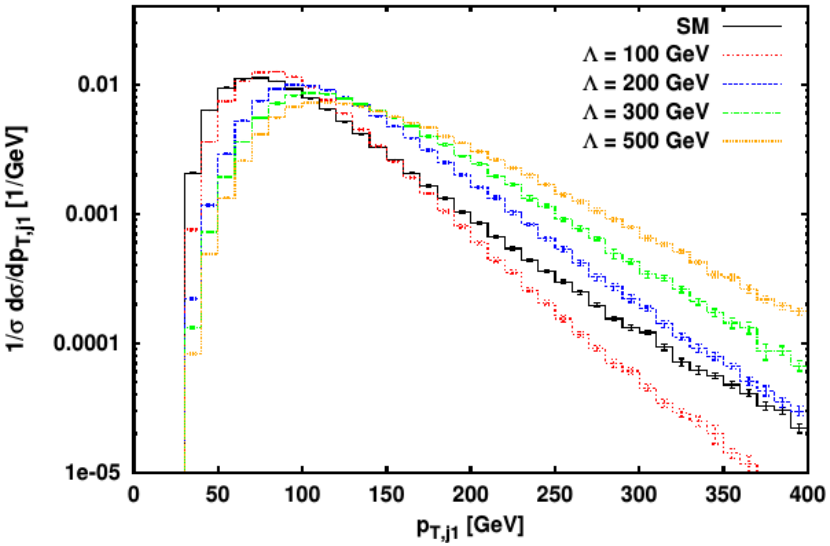


Input set: SM curve → good agreement

BSM scenario (2)

transverse momentum of leading jet:

VBFNLO:



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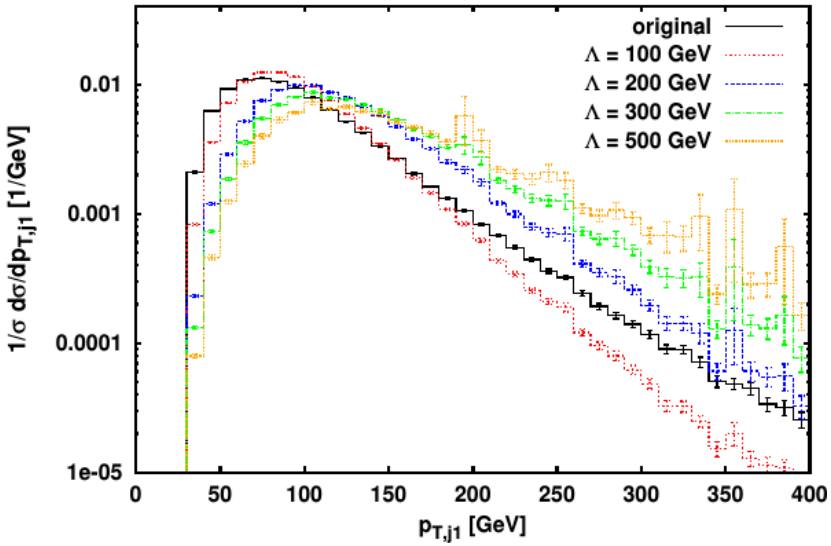


problem of reweighting (intrinsic to method):

significant fluctuations when reweighting factor large

$\rightarrow$ can effectively destroy distributions

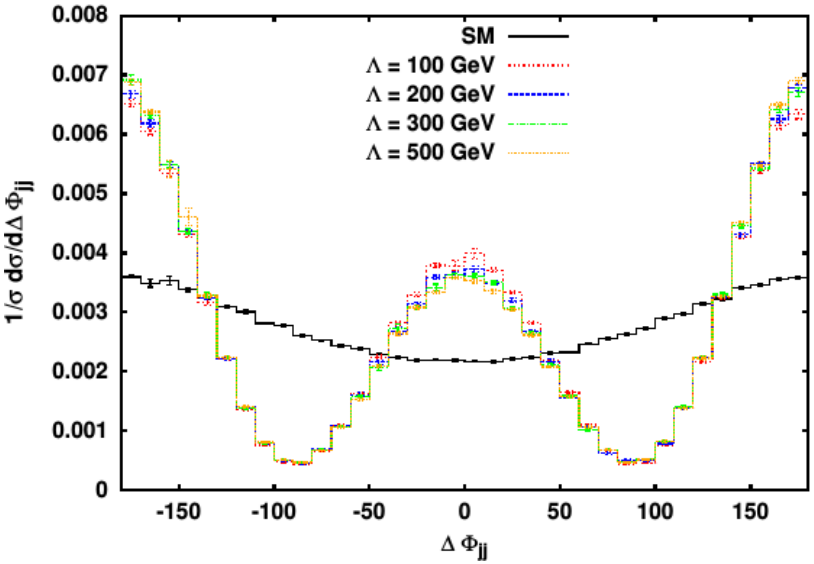
$\leftrightarrow$ possible solution:

- remove regions by cuts (if not relevant)
- generate more SM events in these regions

BSM scenario (3)

Azimuthal angle difference of tagging jets:

VBFNLO:



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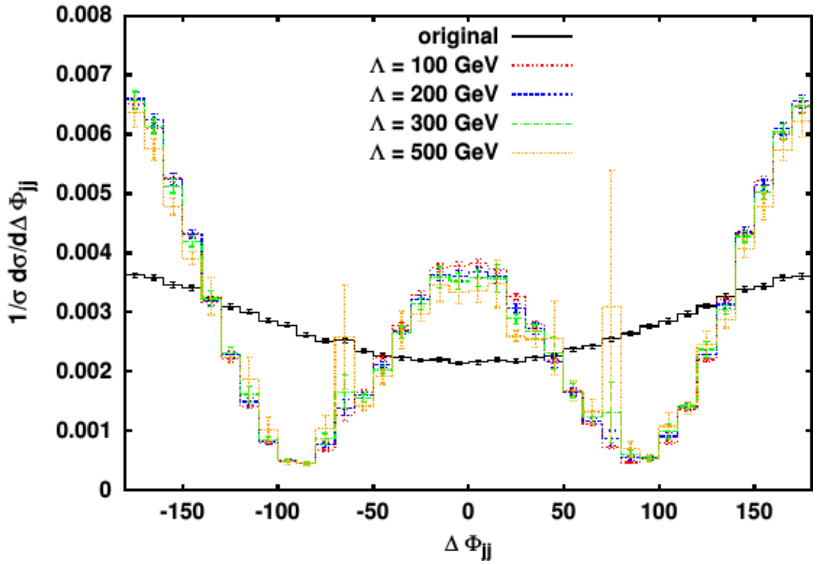


Distribution to test for BSM effects

very good agreement between reweighted and full result

Heavy Higgs scenario

Example 2: Heavy Higgs scenario

Additional heavy Higgs boson, with significant BR to WW, ZZ

- typically large width
  $\rightarrow$ interference with continuum background
  $\rightarrow$ need to consider full process $pp \rightarrow \ell_1\bar{\ell}_1\ell_2\bar{\ell}_2jj$
- $\rightarrow$ How to define signal?
- $\sigma_{S,\text{naive}} = \int \mathrm{d}\Phi \left(|\mathcal{M}_H + \mathcal{M}_B|^2 - |\mathcal{M}_B|^2\right)$
  violates unitarity at large diboson invariant masses
- $\rightarrow$ Define background as $\sigma_B = \int \mathrm{d}\Phi \left(|\mathcal{M}_B + \mathcal{M}_H(m_h)|^2\right)$
  with $m_h \sim 125$ GeV
- $\rightarrow \sigma_{S+I} = \int \mathrm{d}\Phi \left(|\mathcal{M}_B + \mathcal{M}_H(M_H)|^2\right) - \sigma_B$

Input: POWHEG NLO events with pure signal contribution
(Breit-Wigner/CPS-peak at M_H, no interference)

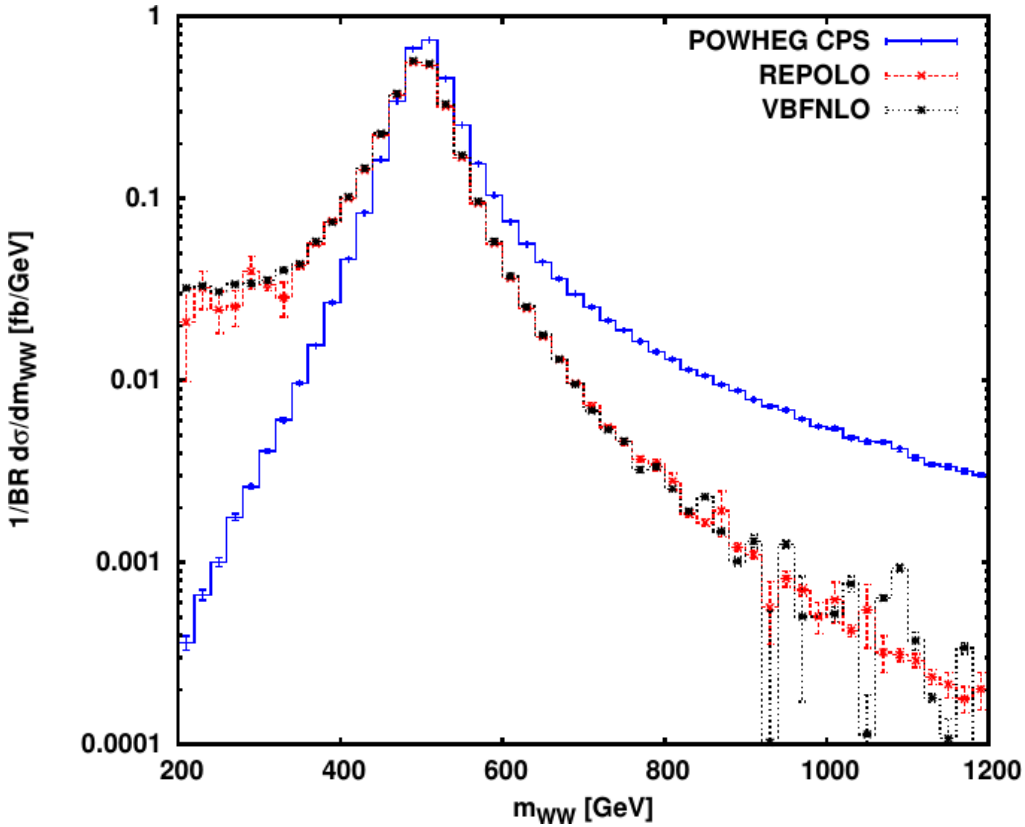
Reweighting with factor

$$\frac{|\mathcal{M}_B + \mathcal{M}_H(M_H)|^2 - |\mathcal{M}_B + \mathcal{M}_H(m_h)|^2}{|\mathcal{M}_H(M_H)|^2}$$

Heavy Higgs scenario(2)

Reweighting with factor

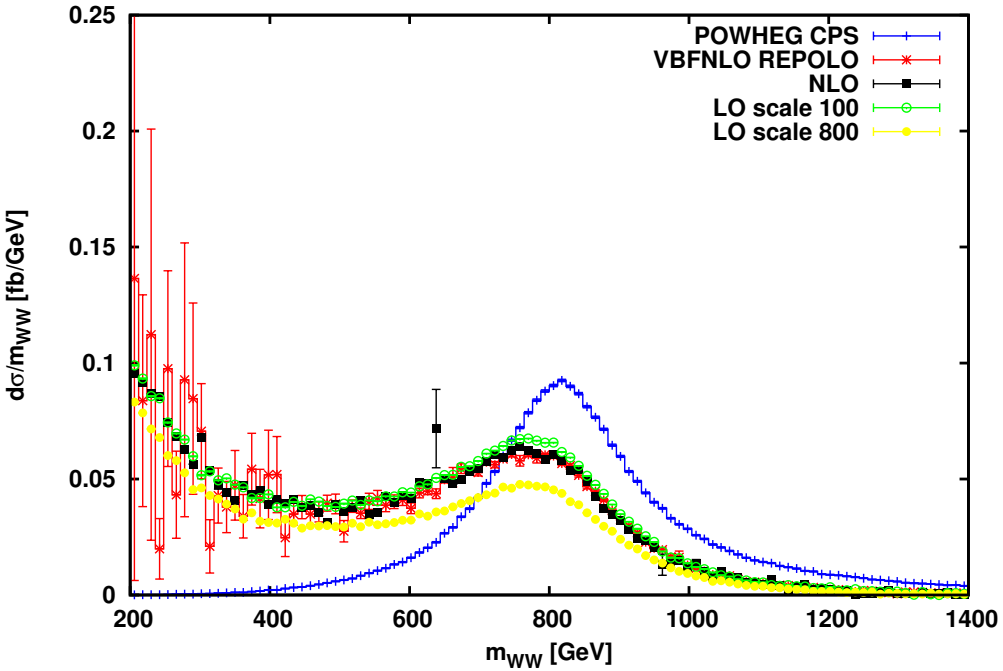
$$\frac{|\mathcal{M}_B + \mathcal{M}_H(M_H)|^2 - |\mathcal{M}_B + \mathcal{M}_H(m_h)|^2}{|\mathcal{M}_H(M_H)|^2}$$



- good agreement between reweighted result and full calculation
- larger errors where reweighting significantly enhances cross section

NLO Accuracy

Input events at NLO QCD
Reweighting performed with LO matrix elements
$\leftrightarrow$ Accuracy of reweighted result?



- Best agreement between reweighted result and NLO curve of full calculation
- $\leftrightarrow$ interference effects do not factorize at individual phase-space points
- also true for BSM Higgs scenarios
  (α_s effects factorize)

$\rightarrow$ Reweighting (approximately) preserves NLO accuracy of input events

Conclusions

REPOLO

Tool for reweighting VBF-Higgs events

- Scenarios considered:
  - BSM: anomalous Higgs couplings, MSSM, Spin-2
  - Heavy Higgs Boson
- Input: LHE event file, Output: LHE file with new weights
- typically very good agreement between reweighted and full result
  problematic phase-space regions: large weights
- preserves (approximately) NLO accuracy of input events

Available on request:

Contact: vbfnlo@itp.kit.edu

BSM scenario

Parameters:

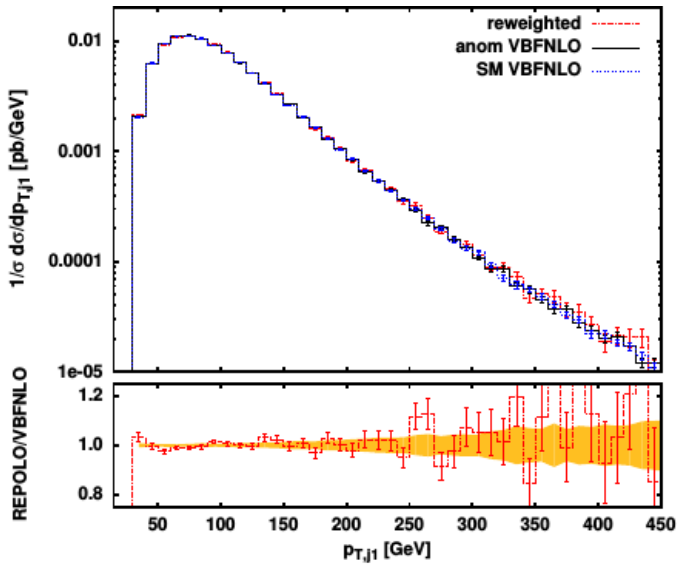
$$\sqrt{S} = 8 \text{ TeV} \qquad \Lambda = 200 \text{ GeV}$$
$$g_{5e}^{HZZ} = 5.058 \qquad g_{5e}^{HWW} = -3.282$$
$$g_{5e}^{HZ\gamma} = -4.108 \cdot 10^{-3} \qquad g_{5e}^{H\gamma\gamma} = 3.264 \cdot 10^{-3}$$

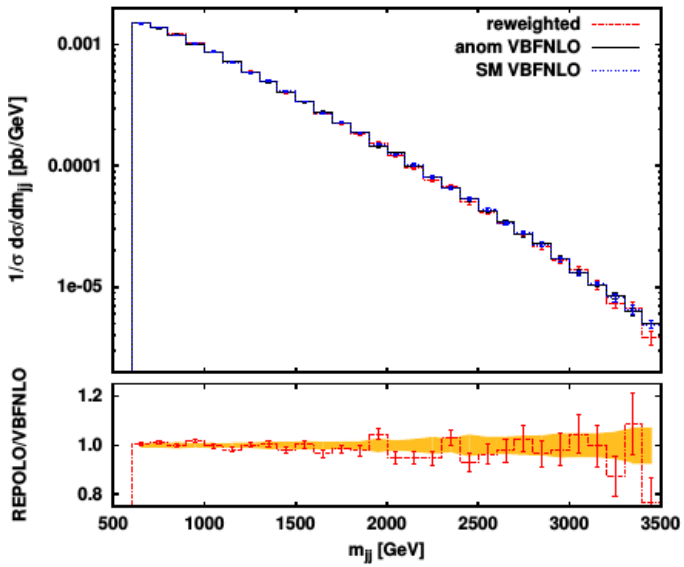
Cuts:

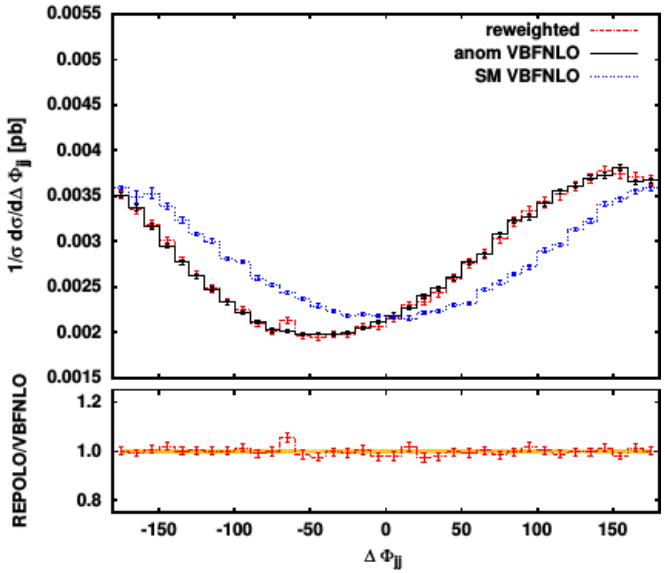
$$p_{T,j,\text{tag}} > 30 \text{ GeV} \qquad p_{T,j} > 20 \text{ GeV} \qquad |y_j| < 4.5$$
$$m_{jj} > 600 \text{ GeV} \qquad \Delta y_{jj}^{\text{tag}} = |y_{j_1} - y_{j_2}| > 4 \qquad y_{j_1} \cdot y_{j_2} < 0$$

BSM scenario 2

SM-Higgs with small CP-odd admixture ($\tilde{d}_B = 0.15$)







Heavy Higgs reweighting

Heavy-Higgs reweighting ($M_H = 800$GeV), various decay modes