Validation of Powheg EW: current status and future steps

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LHC EW Precision
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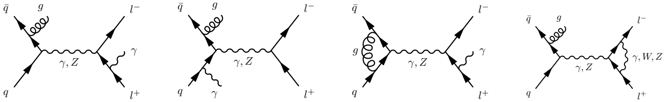
perturbative accuracy

- The POWHEG-BOX V2 W_ew/Z_EW packages
  1. `POWHEG_W_ew_BMNNP`, CC DY, latest version: **svn v. 3546**
     Barzè et al, JHEP 1204 (2012) 037
  2. `POWHEG_Z_ew_BMNNPV`, NC DY, latest version: **svn v. 3547**
     Barzè et al, EPJC 73 (2013) 6, 2474

  additional authors for recent developments: M. Chiesa, H. Martinez, J. Zhou

  - NLO QCD $\oplus$ NLO EW fixed order $(\mathcal{O}(\alpha_s) \oplus \mathcal{O}(\alpha))$ matrix elements
  - NLOPS QCD$\otimes$EW accuracy through matching with QCD/QED shower

- (part of) factorized terms of $\mathcal{O}(\alpha_s\alpha)$ included, i.e. correctly taken into account the NLO contribution with one additional radiation in the soft/collinear limit



  - tested with
    1. fixed order calculation of $\mathcal{O}(\alpha_s\alpha)$ terms in pole approximation
       Dittmaier, Huss, Schwinn, NPB 885 (2014) 318, NPB 904 (2016) 216
    2. independent code
       Mück, Oymanns, arXiv:1612.04292

NLO validation

- detailed comparison with independent codes

S. Alioli et al., arXiv:1606.02330

- CC DY (W^+)

code	LO	NLO QCD	NLO EW μ	NLO EW e
HORACE	2897.38(8)	$\times$	2988.2(1)	2915.3(1)
WZGRAD	2897.33(2)	$\times$	2987.94(5)	2915.39(6)
RADY	2897.35(2)	2899.2(4)	2988.01(4)	2915.38(3)
SANC	2897.30(2)	2899.9(3)	2987.77(3)	2915.00(3)
DYNNLO	2897.32(5)	2899(1)	$\times$	$\times$
FEWZ	2897.2(1)	2899.4(3)	$\times$	$\times$
POWHEG-w	2897.34(4)	2899.41(9)	$\times$	$\times$
POWHEG_BMNNP	2897.36(5)	2899.0(1)	2988.4(2)	2915.7(1)
POWHEG_BW	2897.4(1)	2899.2(3)	2987.7(4)	$(\times)$

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- very good agreement also for differential distributions

Input parameter schemes

- W_ew
  1. **scheme 0**: $\alpha(0)$, M_W, M_Z as input
  2. **scheme 1**: G_μ, M_W, M_Z as input (default)
- Z_ew
  1. **scheme 0**: $\alpha(0)$, M_W, M_Z as input (default)
  2. **scheme 1**: $\alpha(M_Z^2)$, M_W, M_Z as input
  3. **scheme 2**: G_μ, M_W, M_Z as input
  4. **scheme 3**: $\alpha(Q^2)$, M_W, M_Z as input
     with $\alpha(Q^2) = \alpha(0)/(1 - \Delta\alpha(Q^2))$

- the input $M_{W/Z}$ and $\Gamma_{W/Z}$ are the "on-shell" W and Z parameters (running width scheme, as in PDG), while POWHEG, as many others EW codes, uses the position of the complex pole (fixed width) for the matrix element calculations (automatic internal conversion)

$$M_V = \frac{M_V^{OS}}{\sqrt{1 + \left(\frac{\Gamma_V^{OS}}{M_W^{OS}}\right)^2}} \qquad \Gamma_V = \frac{\Gamma^{OS}}{\sqrt{1 + \left(\frac{\Gamma_V^{OS}}{M_W^{OS}}\right)^2}}$$

to allow a **SM** $\sin^2\vartheta^l_{eff}$ template fit (closure test)

- precise fitting formulae have been derived both for M_W and $\sin^2\vartheta^l_{eff}$ as functions of the input parameters:
  - G_μ, $\alpha(0)$, M_Z
  - M_H, m_t, $\Delta\alpha(M_Z)$, $\alpha_s(M_Z)$

G. Degrassi, P. Gambino, M. Passera, A. Sirlin, hep-ph/9708311
A. Ferroglia, G. Ossola, M. Passera, A. Sirlin, PRD65 (2002) 113002
M. Awramik, M. Czakon, A. Freitas, JHEP 0611 (2006) 048; M. Awramik et al., PRD69 (2004) 053006
A. Freitas, W. Hollik, W. Walter, G. Weiglein, PLB495 (2000) 338; NPB632 (2002) 189
G. Degrassi, P. Gambino, P.P. Giardino, JHEP05 (2015) 154

- the coefficients have been tuned on available two-loops complete calculations for M_W and $\sin^2\vartheta^l_{eff}$ $\Longrightarrow$

$$M_W = f(\sin^2\vartheta^l_{eff})$$

- given an input value for $\sin^2\vartheta^l_{eff}$, we can convert it to a M_W value and use as input for the POWHEG_ew matrix element calculations in the G_μ scheme (or any other code working with M_W as input parameter) where everywhere $M_W = M_W(\sin^2\vartheta^l_{eff})$

h.o. contributions (for Z_ew): running couplings

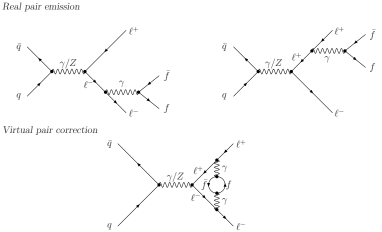
- **ew_ho 1**:
  - running of e^2 $(\Delta\alpha)$
  - $m_t - m_b$ splitting $(\Delta\rho)$
- $\Delta\alpha$ resummed to all orders $\alpha(0) \to \alpha(Q^2) = \frac{\alpha(0)}{1-\Delta\alpha(Q^2)}$
- $\Delta\rho$ up to two-loop accuracy
- terms of $\mathcal{O}(\Delta\alpha\Delta\rho)$ correct up to two loops

Dittmaier and Huber, JHEP 01 (2010) 060

- numerical results validated against D-H

higher order contributions (for W_ew and Z_ew)

- leptonic pair corrections: virtual and real photon converting to a lepton pair
  $\sim \mathcal{O}(\alpha^2 L^2) \sim$ two-photon contribution



S. Antropov, A. Arbuzov, R. Sadykov, Z. Was, arXiv:1706.0557

- Sudakov form factor modified to consider the running of α_{QED} (e^+e^- and $\mu^+\mu^-$ contribution)
- **emalpharunning 1**
- checked vs. Horace predictions, without considering kinematic effects on the real emissions (to be added with PHOTOS/PYTHIA)

multiphoton effects beyond $\mathcal{O}(\alpha)$

- introduced through QED shower with PHOTOS or PYTHIA
- several internal consistency checks
- comparisons between PHOTOS and PYTHIA, which point out the differences in the generation of radiation between the two codes
- not available yet systematic comparison with all existing independent approaches
  - $\Longrightarrow$ this brings to the discussion on further steps:
  - required comparison between different codes after QCD$\otimes$QED showering