Status of an updated study of predictions for W/Z processes

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Meeting of the WG on EW precision measurements at the LHC

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Motivation

- Electroweak precision physics requires excellent control of predictions for W and Z observables, in some cases at the per mil level.
- Predictions including EW and/or QCD higher-order corrections are provided by a number of publicly available Monte Carlo programs. The usage of these tools and their combination is not trivial and has to be done with care.
- Estimates of theoretical uncertainties often rely on comparisons of tools that differ in the implementation of higher-order corrections.

Before one can interpret differences in predictions of different implementations of higher orders as a measure of the theoretical uncertainty, one has to make sure that two codes that have the same perturbative approximation, the same input parameters (couplings, masses, PDFs), the same setup (choice of scales, acceptance cuts), should yield exactly the same results, within the accuracy of the numerical integration.

Motivation

This study we will provide a collection of benchmark numbers for total cross sections and distributions obtained with the most used publicly available codes for W/Z production at hadron colliders.

These results will serve

1) to verify that a given code works properly according to what its authors have foreseen,
2) to demonstrate explicitly the level of agreement of different codes that include identical subsets of radiative corrections, and
3) to expose the impact of different subsets of higher-order corrections and of differences in their implementations.

See also earlier studies:

Tevatron-for-LHC Report, arXiv:0705.3251 (2007); Les Houches report, hep-ph/0604120 (2006)

Status

Participants:

- NNLO QCD: DYNNLO, FEWZ M.Grazzini, D.de Florian, G.Ferrera; F.Petriello, Y.Li
- NLO QCD⊗Pythia: POWHEG S.Alioli, P.Nason, E.Re
- QED PS/SF: HORACE, PHOTOS, RADY G.Montagna, O.Nicrosini, A.Vicini; Z.Was; S.Dittmaier, M.Krämer, A.Mück
- EW NLO: HORACE, RADY, SANC, WINHAC, WZGRAD G.Montagna, O.Nicrosini, A.Vicini; A.Arbuzov, D.Bardin, S.Bondarenko, L.Kalinowskaya; W.Plazek; S.Dittmaier, M.Krämer, A.Mück; D.Wackeroth
- EW NLO⊗QED PS/YFS/SF: HORACE, RADY, WINHAC G.Montagna, O.Nicrosini, A.Vicini; W.Plazek; S.Dittmaier, M.Krämer, A.Mück
- NLO QCD+NLO EW: RADY, SANC, POWHEG_BMNNP, POWHEG_BW S.Dittmaier, M.Krämer, A.Mück; A.Arbuzov, D.Bardin, S.Bondarenko, L.Kalinowskaya; L.Barze, G.Montagna, P.Nason, O.Nicrosini, F.Piccinini; C.Bernaciak, D.Wackeroth
- NNLO QCD+NLO EW: FEWZ F.Petriello, Y.Li
- (NLO QCD+NLO EW)⊗Pythia: POWHEG_BMNNP, POWHEG_BW L.Barze, G.Montagna, P.Nason, O.Nicrosini, F.Piccinini; C.Bernaciak, D.Wackeroth
- (NLO QCD+NLO EW)⊗Pythia⊗PHOTOS: POWHEG_BMNNP L.Barze, G.Montagna, P.Nason, O.Nicrosini, F.Piccinini

Status

- ✓ We have agreed on a common setup (input parameters, acceptance cuts, choice of scales) that will be used by all groups to compute their numbers.
- ✓ We have chosen a set of observables relevant for the charged (CC) and neutral-current (NC) Drell-Yan process.
- Ongoing: Benchmarks results are being produced for CC and NC processes with acceptance cuts at LO, NLO QCD, NLO EW, NLO QCD+Pythia, NNLO QCD, NLO QCD+EW, NNLO QCD+NLO EW, NLO QCD+NLO EW+PS (QCD and QED), and when only including a QED PS.
- Ongoing: Collecting feedback/input from experimentalists and suggestions for further studies.
- Goal for publication of the report: end of 2012.

Choice of setup, cuts and observables

Input parameters:

$$
\begin{aligned}
\alpha(0) &= 1/137.035999074, & \alpha_s &\equiv \alpha_s^{NLO}(M_Z^2) = 0.12018 \\
M_Z &= 91.1876 \text{ GeV}, & \Gamma_Z &= 2.4952 \text{ GeV} \\
M_W &= 80.385 \text{ GeV}, & \Gamma_W &= 2.085 \text{ GeV} \\
M_H &= 125 \text{ GeV}, & & \\
m_e &= 0.510998928 \text{ MeV}, & m_\mu &= 0.1056583715 \text{ GeV}, \quad m_\tau = 1.77682 \text{ GeV} \\
m_u &= 0.06983 \text{ GeV}, & m_c &= 1.2 \text{ GeV}, \quad m_t = 173.5 \text{ GeV} \\
m_d &= 0.06984 \text{ GeV}, & m_s &= 0.15 \text{ GeV}, \quad m_b = 4.6 \text{ GeV} \\
|V_{ud}| &= 0.975, & |V_{us}| &= 0.222 \\
|V_{cd}| &= 0.222, & |V_{cs}| &= 0.975 \\
|V_{cb}| = |V_{ts}| = |V_{ub}| &= & |V_{td}| &= |V_{tb}| = 0
\end{aligned}
$$

PDF: MSTW2008NLO in LO, NLO and NLO$\otimes$PS and MSTW2008NNLO in NNLO calculations (and α_s accordingly).

Scales and factorization schemes: QCD factorization is performed in the $\overline{\mathrm{MS}}$ scheme and $\mu_r = \mu_f = \mu_{\mathrm{QCD}} = M_{l\nu}$ in the W boson case and $\mu_r = \mu_f = \mu_{\mathrm{QCD}} = M_{l^+l^-}$ in the Z boson case. QED factorization in DIS and $\mu_{QED} = \mu_{QCD}$.

Choice of setup, cuts and observables

- For NLO EW predictions, we work in the on-shell renormalization scheme and use the following Z and W mass renormalization constants:

$$\delta M_Z^2 = \mathcal{R}e\Sigma^Z(M_Z^2), \quad \delta M_W^2 = \mathcal{R}e\Sigma^W(M_W^2).$$

  where Σ^V denotes the transverse part of the unrenormalized vector boson self energy.
- For the sake of simplicity and to avoid additional sources of discrepancies $\alpha(0)$ is used throughout in both the calculation of CC and NC cross sections.
- Constant width scheme.
- Pythia version 6.4.26, Perugia tune (PYTUNE(320)). When producing NLO QCD+EW results with Pythia, the QED showering effects are switched off by setting `MSTJ(41)=MSTP(61)=MSTP(71)=1`.

Choice of setup, cuts and observables

Cuts:

$$\begin{aligned}
\text{Tevatron}: &\quad p_T(\ell) > 25\ \text{GeV}, \quad |\eta(\ell)| < 1, \quad \not{p}_T > 25\ \text{GeV}, \quad \ell = e,\ \mu, \\
\text{LHC}: &\quad p_T(\ell) > 25\ \text{GeV}, \quad |\eta(\ell)| < 2.5, \quad \not{p}_T > 25\ \text{GeV}, \quad \ell = e,\ \mu, \\
\text{LHCb}: &\quad p_T(\ell) > 20\ \text{GeV}, 2 < \eta(\ell) < 4.5, \quad \not{p}_T > 20\ \text{GeV}, \quad \ell = e,\ \mu\ ,
\end{aligned}$$

and $M_{ll} > 50$ GeV in NC cross sections.
in addition in the 'calo' setup we apply:

Tevatron and LHC	
electrons	muons
combine e and γ momentum four vectors, if $\Delta R(e,\gamma) < 0.1$	reject events with $E_\gamma > 2$ GeV for $\Delta R(\mu,\gamma) < 0.1$
reject events with $E_\gamma > 0.1\ E_e$ for $0.1 < \Delta R(e,\gamma) < 0.4$	reject events with $E_\gamma > 0.1\ E_\mu$ for $0.1 < \Delta R(\mu,\gamma) < 0.4$

Choice of setup, cuts and observables

Observables: $l = e^{\pm}, \mu^{\pm}$

- Z: σ_Z, $\frac{d\sigma}{dM_{ll}}$, $\frac{d\sigma}{dp_T^l}$, and $d\sigma/dQ_T(Z)$.
- W: σ_W, $\frac{d\sigma}{dM_T(l\nu)}$, $\frac{d\sigma}{dp_T^{l,\nu}}$, and $d\sigma/dQ_T(W)$.
- W/Z ratios: $\frac{\sigma_W}{\sigma_Z}$, $\frac{d\sigma_W/dX_M(W)}{d\sigma_Z/dX_M(Z)}$ with $X_M(V) = M_T^V/M_V, V = W, Z$, $\frac{d\sigma_W/dX_p(W)}{d\sigma_Z/dX_p(Z)}$ with $X_p(V) = p_T^V(l)/M_V, V = W, Z$, and $\frac{d\sigma/dQ_T(W)}{d\sigma/dQ_T(Z)}$.

We consider the Tevatron (1.96 TeV) and the LHC at both 8 TeV and 14 TeV.

Further studies

We hope to be able to also include a

- definition and estimate of theoretical uncertainties due to missing higher order corrections (EW, QCD, mixed EW-QCD);
- $(*)$ discussion of different EW input schemes and gauge invariant treatments of the finite width;
- $(*)$ discussion of an IBA for W and Z production (mainly for implementation in QCD only codes);
- discussion of A_{FB} at high M_{ll} and of $(*)$ $d\sigma/dM_{ll}$ at small M_{ll}.

$(*)$: Please see Alessandro's talk in this session.

Snowmass 2013 *Energy Frontier* subgroup: Precision Study of Electroweak Interactions

What is the future of EW physics at high-energy colliders ?

First community planning meeting at Fermilab, October 11-13, 2012:

For more information, please visit www.snowmass2013.org, or contact the EW subgroup conveners: Ashutosh Kotwal, Michael Schmitt, D.W.