Status of POWHEG_EW V2 (for NC DY)

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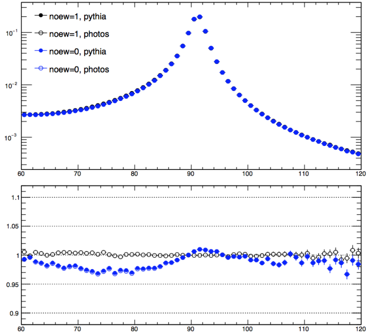
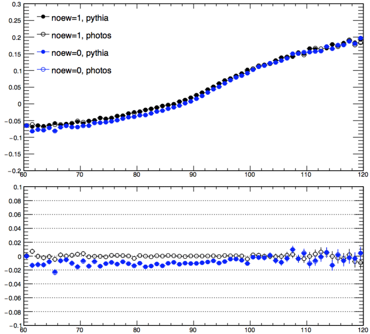
LHC EW subgroup meeting
25-26 April 2018, CERN

from exercises of Aleko presented at a previous meeting





- difference sensitive to the input parameter scheme: $\sim 3\%$ with G_μ, $\sim 1\%$ with $\alpha(0)$
- accuracy: NLO (QCD+EW)$\otimes$PS(QCD$\otimes$QED)

work in progress in two directions

M. Chiesa, C.M. Carloni Calame, G. Montagna, O. Nicrosini, F.P., A. Vicini, J. Zhou

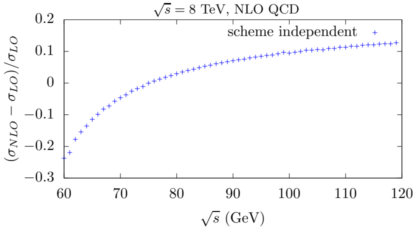
- splitting of EW NLO corrections into separate (gauge invariant) contributions with proper flags (QCD and full EW separation already available)
  - pure QED $\surd$
    - ⋆ (ISR+FSR) from IFS interference
  - pure weak $\surd$
- addition of pheno subleading contributions
  - photon induced contributions $\surd$ (for NLO)
    - ⋆ LO $\gamma\gamma \to \mu^+\mu^-$
    - ⋆ NLO $\gamma q \to \mu^+\mu^- q$
  - higher-order weak effects (dominated by $\Delta\alpha$ and $\Delta\rho$) with NNLO accuracy $\surd$

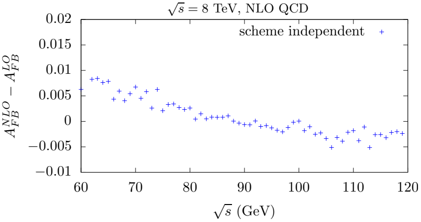
    S. Dittmaier, M. Huber, JHEP01(2010)060
- analysis of separate NLO classes for $d\sigma/dM_{\mu^+\mu^-}$ and $dA_{FB}/dM_{\mu^+\mu^-}$

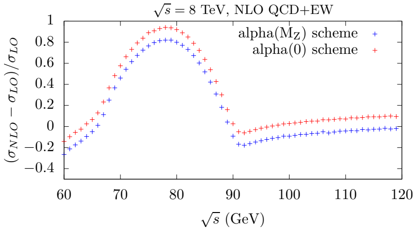
  available for $d\sigma/dM_{\mu^+\mu^-}$ in S. Dittmaier, M. Huber, JHEP01(2010)060
  - their uncertainties estimated by varying the input parameter scheme
    - ⋆ $\alpha(M_Z)$, $\alpha(0)$, G_μ

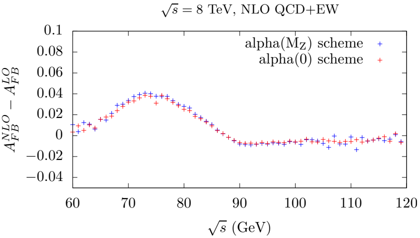
some PRELIMINARY results

- NLO QCD + EW

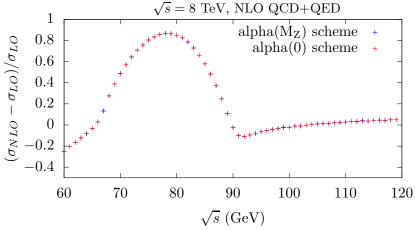


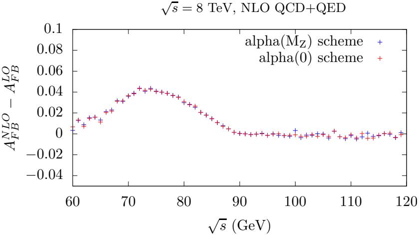


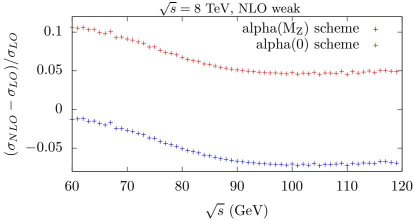


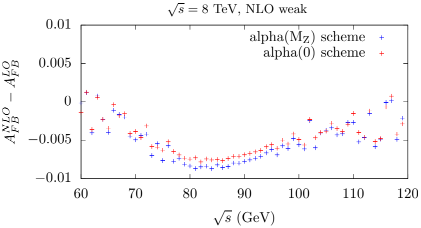


NLO QED vs. pure weak

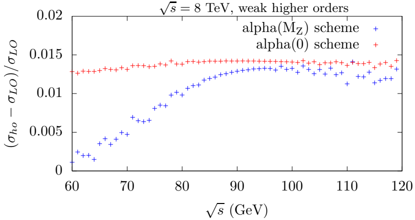


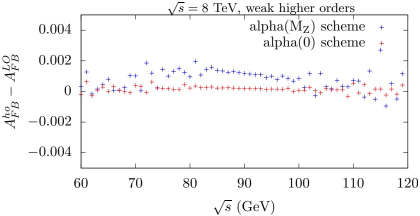




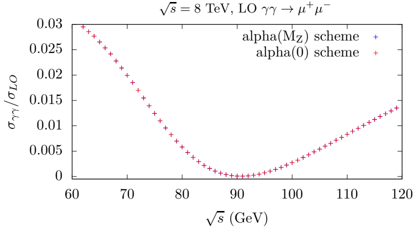


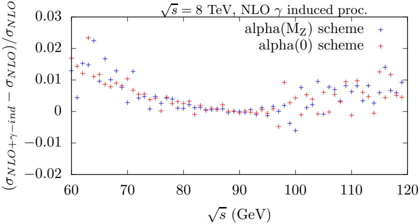
- weak higher orders





- γ induced contributions





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

- 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 $\sin^2\vartheta^l_{eff}$

$$
\begin{aligned}
M_W \;=\;& M_W^0 - c_1\left(\log\frac{M_H}{100\,\mathrm{GeV}}\right) - c_2\left(\log\frac{M_H}{100\,\mathrm{GeV}}\right)^2 \\
+\;& c_3\left(\log\frac{M_H}{100\,\mathrm{GeV}}\right)^4 - c_4\left(\frac{\Delta\alpha}{0.05924}-1\right) \\
+\;& c_5\left[\left(\frac{m_t}{174.3\,\mathrm{GeV}}\right)^2-1\right] - c_6\left[\left(\frac{m_t}{174.3\,\mathrm{GeV}}\right)^2-1\right]^2 \\
-\;& c_7\left(\log\frac{M_H}{100\,\mathrm{GeV}}\right)\left[\left(\frac{m_t}{174.3\,\mathrm{GeV}}\right)^2-1\right] \\
-\;& c_8\left(\frac{\alpha_s(M_Z)}{0.119}-1\right) + c_9\left(\frac{M_Z}{91.1875\,\mathrm{GeV}}-1\right)
\end{aligned}
$$

$$
\begin{aligned}
M_W^0 &= 80.3768\ \mathrm{GeV} & c_1 &= 0.05619\ \mathrm{GeV} & c_2 &= 0.009305\ \mathrm{GeV} & & \\
c_3 &= 0.0005365\ \mathrm{GeV} & c_4 &= 1.078\ \mathrm{GeV} & c_5 &= 0.5236\ \mathrm{GeV} & & \\
c_6 &= 0.0727\ \mathrm{GeV} & c_7 &= 0.00544\ \mathrm{GeV} & c_8 &= 0.0765\ \mathrm{GeV} & c_9 &= 115.0\ \mathrm{GeV}
\end{aligned}
$$

- the above eq. reproduces (the calculated) M_W within 0.3 MeV when 65 GeV $\leq M_H \leq 1$ TeV and the other parameters move within their 2σ errors: $\Delta_{1\sigma} m_t = 5.1$ GeV; $\Delta_{1\sigma}\alpha = 36 \cdot 10^{-5}$

$$
\begin{aligned}
\sin^2\vartheta^l_{eff} &= \sin^2\vartheta^l_0 + d_1\left(\log\frac{M_H}{100\,\mathrm{GeV}}\right) + d_2\left(\log\frac{M_H}{100\,\mathrm{GeV}}\right)^2 \\
&+ d_3\left(\log\frac{M_H}{100\,\mathrm{GeV}}\right)^4 + d_4\left[\left(\frac{M_H}{100\,\mathrm{GeV}}\right)^2 - 1\right] + d_5\left(\frac{\Delta\alpha}{0.05907} - 1\right) \\
&+ d_6\left[\left(\frac{m_t}{178.0\,\mathrm{GeV}}\right)^2 - 1\right] + d_7\left[\left(\frac{m_t}{178.0\,\mathrm{GeV}}\right)^2 - 1\right]^2 \\
&+ d_8\left[\left(\frac{m_t}{178.0\,\mathrm{GeV}}\right)^2 - 1\right]\left[\left(\frac{M_H}{100\,\mathrm{GeV}}\right)^2 - 1\right] \\
&+ d_9\left(\frac{\alpha_s(M_Z)}{0.117} - 1\right) + d_{10}\left(\frac{M_Z}{91.1876\,\mathrm{GeV}} - 1\right)
\end{aligned}
$$

$$
\begin{aligned}
\sin^2\vartheta^l_0 &= 0.2312527, \qquad d_1 = 4.729\cdot 10^{-4}, \qquad d_2 = 2.07\cdot 10^{-5} \\
d_3 &= 3.85\cdot 10^{-6}, \qquad d_4 = -1.85\cdot 10^{-6}, \qquad d_5 = 2.07\cdot 10^{-2} \\
d_6 &= -2.851\cdot 10^{-3}, \qquad d_7 = 1.82\cdot 10^{-4}, \qquad d_8 = -9.74\cdot 10^{-6} \\
d_9 &= 3.98\cdot 10^{-4}, \qquad d_{10} = -6.55\cdot 10^{-1}
\end{aligned}
$$

the above eq. reproduces (the calculated) $\sin^2\vartheta^l_{eff}$ within $4.5\cdot 10^{-6}$ when 10 GeV $\leq M_H \leq 1$ TeV and the other parameters move within their 2σ errors: $\Delta_{1\sigma}m_t = 5.1$ GeV; $\Delta_{1\sigma}\alpha = 36\cdot 10^{-5}$

- we can solve the second equation for one parameter, e.g. $\Delta\alpha$, and introduce its expression in the first giving

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

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

$\sin^2\theta^l_{eff}$	M_W (GeV)
0.2305	80.415
0.2310	80.389
0.2315	80.363
0.2320	80.337