# Status of POWHEG_EW V2 (for NC DY)

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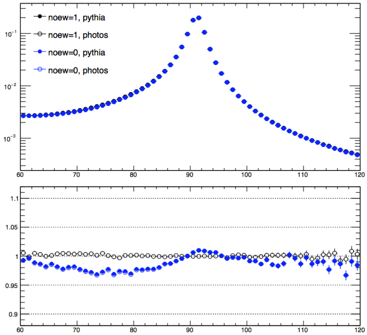
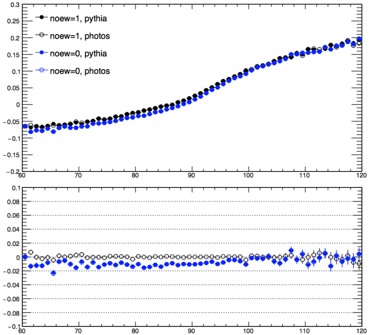
LHC EW subgroup meeting
25-26 April 2018, CERN

# from exercises of Aleko presented at a previous meeting




- difference sensitive to the input parameter scheme: $\sim 3\%$ with $G_\mu$, $\sim 1\%$ 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

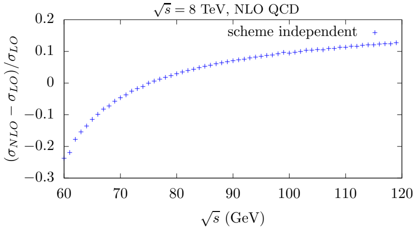
- splitting of EW NLO corrections into separate (gauge invariant) contributions with proper flags (QCD and full EW separation already available)
  - pure QED $\surd$
    - (ISR+FSR) from IFS interference
  - pure weak $\surd$
- addition of pheno subleading contributions
  - photon induced contributions $\surd$ (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 $\surd$

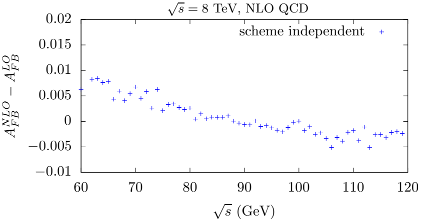
    S. Dittmaier, M. Huber, JHEP01(2010)060
- analysis of separate NLO classes for $d\sigma/dM_{\mu^+\mu^-}$ and $dA_{FB}/dM_{\mu^+\mu^-}$

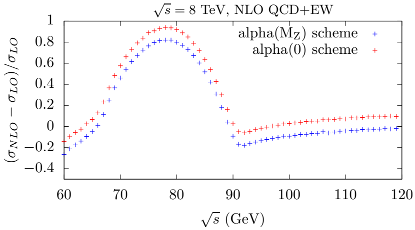
  available for $d\sigma/dM_{\mu^+\mu^-}$ in S. Dittmaier, M. Huber, JHEP01(2010)060
  - their uncertainties estimated by varying the input parameter scheme
    - $\alpha(M_Z)$, $\alpha(0)$, $G_\mu$

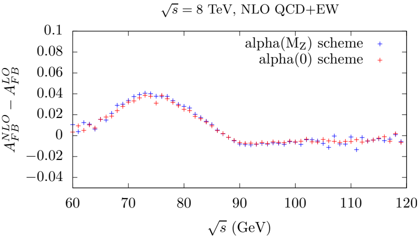
# some PRELIMINARY results

- NLO QCD + EW

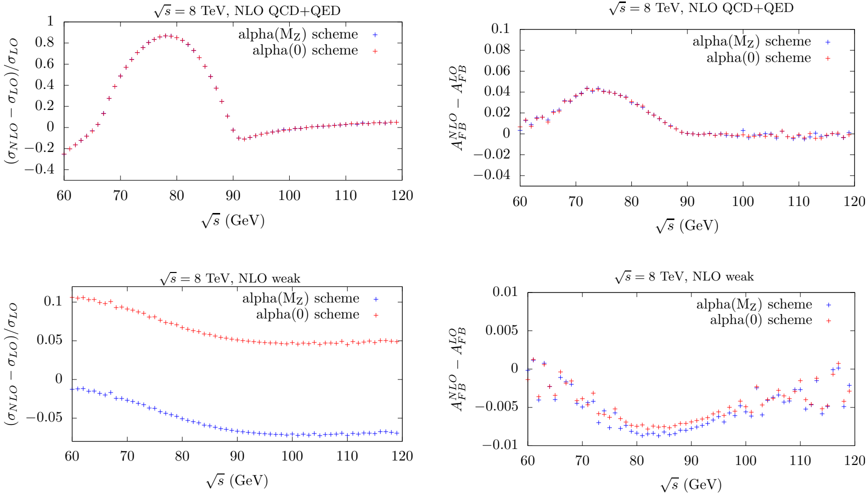


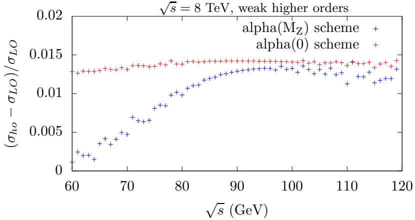



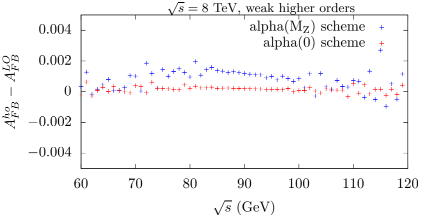



# NLO QED vs. pure weak

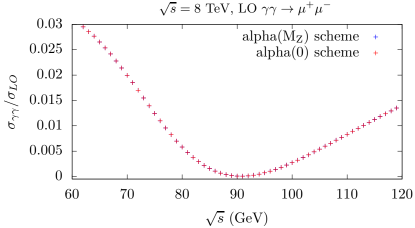


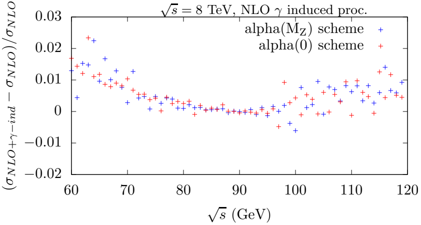
- weak higher orders




- $\gamma$ 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:
  - $G_\mu$, $\alpha(0)$, $M_Z$
  - $M_H$, $m_t$, $\Delta\alpha(M_Z)$, $\alpha_s(M_Z)$

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

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

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

- 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 $2\sigma$ errors: $\Delta_{1\sigma} m_t = 5.1$ GeV; $\Delta_{1\sigma}\alpha = 36 \cdot 10^{-5}$

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

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

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 $2\sigma$ 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 $G_\mu$ 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 |