

# Electroweak input parameter schemes and precise theoretical predictions for Drell-Yan

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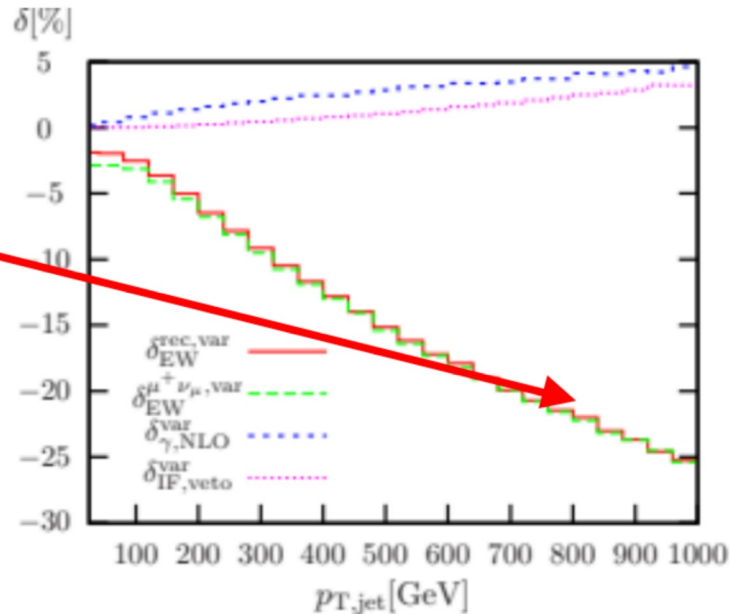
Based on M. C., C.L. Del Pio, F. Piccinini, Eur.Phys.J.C 84 (2024) 5, 539

# NLO EW corrections

- Common wisdom:  $\delta_{EW}^{NLO} \sim \text{some}\%$
- But...

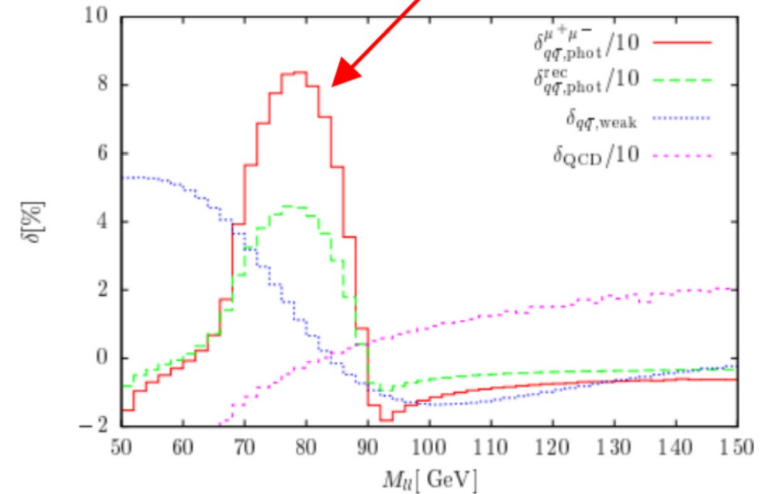
Weak Sudakov  
corrs.

(V+j, from 0906.1656)



QED radiative return

(NC DY from 0911.2329)



In one way or another NLO EW effects included or accounted for in many LHC measurements

# Weak corrections and EW input parameters

Interplay between EW input parameter choices and theory uncertainties/theory accuracy\*

Very important for high-precision measurements, like the weak mixing angle at the LHC

# Setup

- Focus on weak corrections to NCDY (weak mixing angle measurement)
- Accuracy NLO weak w/w-o leading fermionic corrections ( $\Delta\alpha, \Delta\rho$ ) up to  $\alpha^2$
- Calculation implemented/results obtained with `POWHEG-BOX-V2/Z_ew-BMNNPV` \*

`svn co --username anonymous --password anonymous svn://powhegbox.mib.infn.it/trunk/User-Processes-V2/Z_ew-BMNNPV` **revision 4067**,

[arXiv:2402.14659](#), [2302.10782](#), [1906.11569](#), [1612.02841](#), [1302.4606](#)

\*Monte Carlo event generator for NCDY at **NLO QCD +NLO EW matched to QCD and QED parton shower**. Accuracy available few other generators:

`POWHEG-BOX-V2/W_ew-BMNNP` [arXiv:1202.0465](#), [1612.02841](#)

`POWHEG-BOX-RES/HW_ew`, `POWHEG-BOX-RES/HZ_ew`, `POWHEG-BOX-RES/HWj_ew`, `POWHEG-BOX-RES/HZj_ew` [arXiv:1706.03522](#)

`POWHEG-BOX-RES/VV_dec_ew` [arXiv:2005.12146](#)

`POWHEG-BOX-RES/vbs-ssww-nloew` (\*) [arXiv:1906.01863](#)

`POWHEG-BOX-RES/Hjj_ew` (\*) [arXiv:2208.00013](#)

# EW input parameters choice

- There are 3 independent parameters (beside fermion and Higgs masses)
- Some possible choices:
  - 1)  $(\alpha, M_W, M_Z)$  : largely used at the LHC
  - 2)  $(\alpha, \sin^2 \theta_{eff}^l, M_Z)$  : useful for sw2 extraction via template fits beyond LO [arxiv:1906.11569](#)
  - 3)  $(\alpha_0, G_\mu, M_Z)$  : LEP1 scheme, all parameters measured at high accuracy
  - 4)  $(\alpha_{\overline{MS}}, s_W^2, \overline{MS}, M_Z)$  : useful for sw2 measurement at high-energy [arxiv:2402.14659](#), [2302.10782](#)

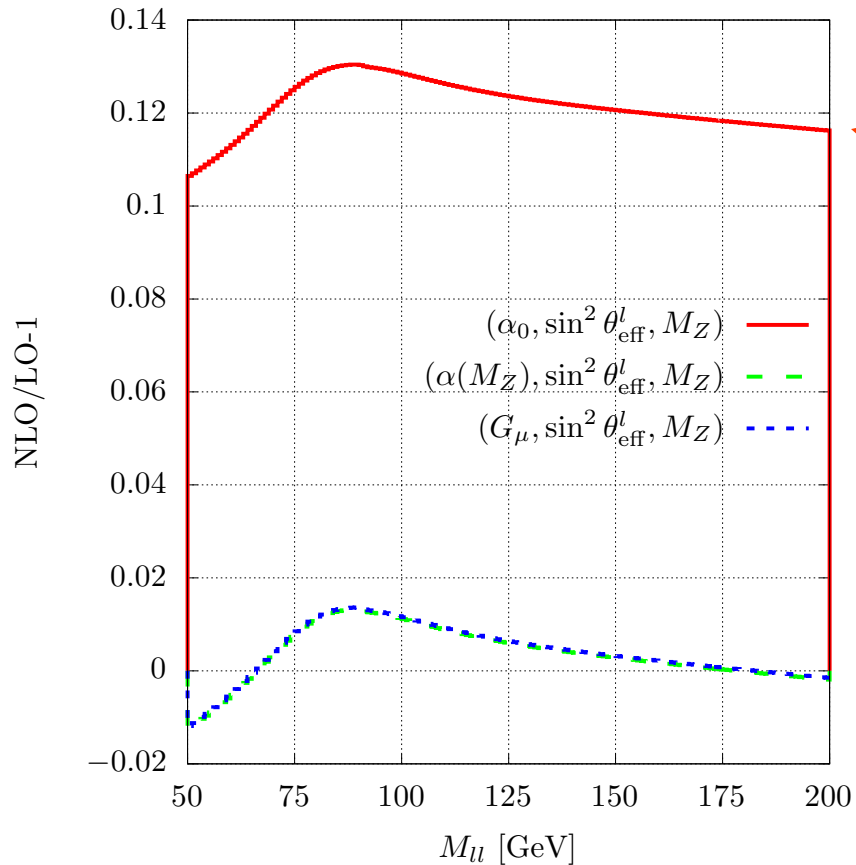
$\alpha$  stands for either  $\alpha_0$ ,  $\alpha(M_Z)$ ,  $\alpha(G_\mu)$

# EW input parameters choice

## Possible criteria

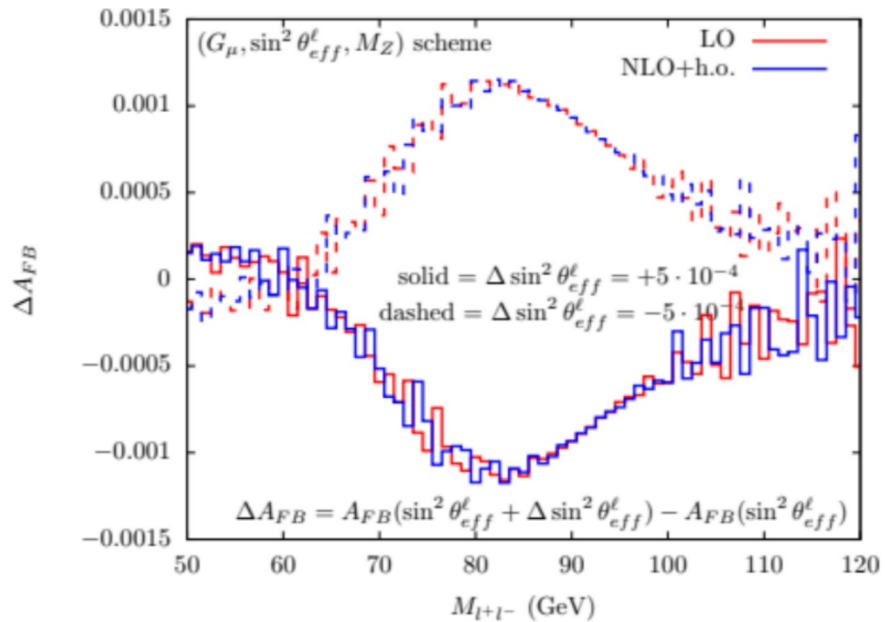
- Size of radiative corrections/convergence of perturbative expansion/missing higher-order effects
- Experimental precision on inputs/parametric uncertainties on predictions
- Need of having a specific free parameter to perform fits (see MW and sw measurements)

# Size of radiative corrections: example



$\alpha(0)$  scheme:  
large corrections  $\sim 2 \Delta\alpha$

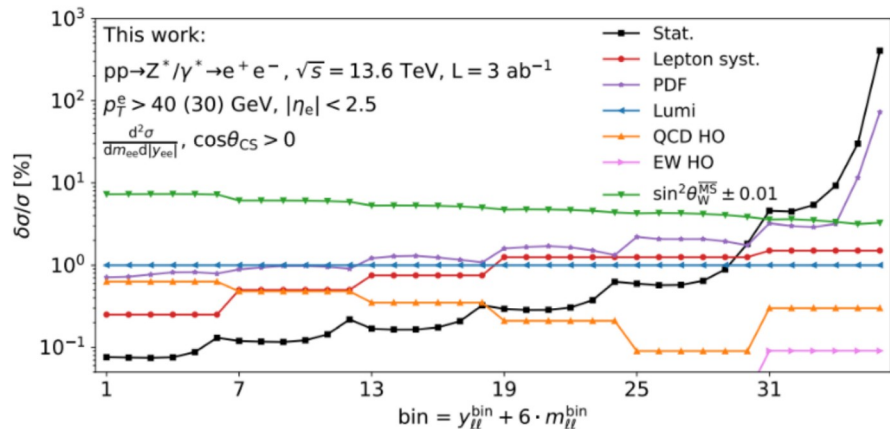
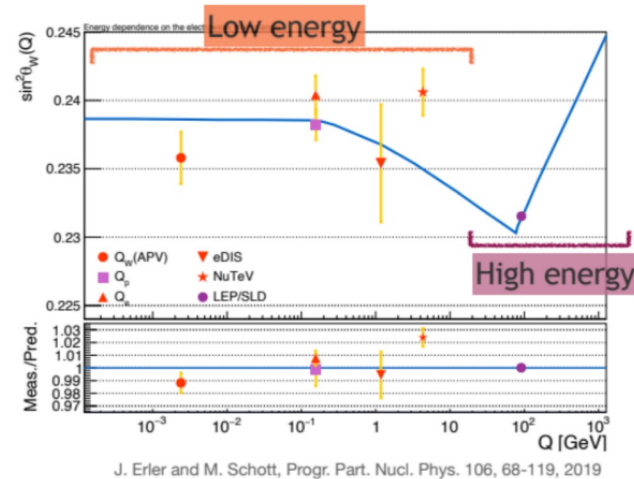
# Free parameters and template fit measurements



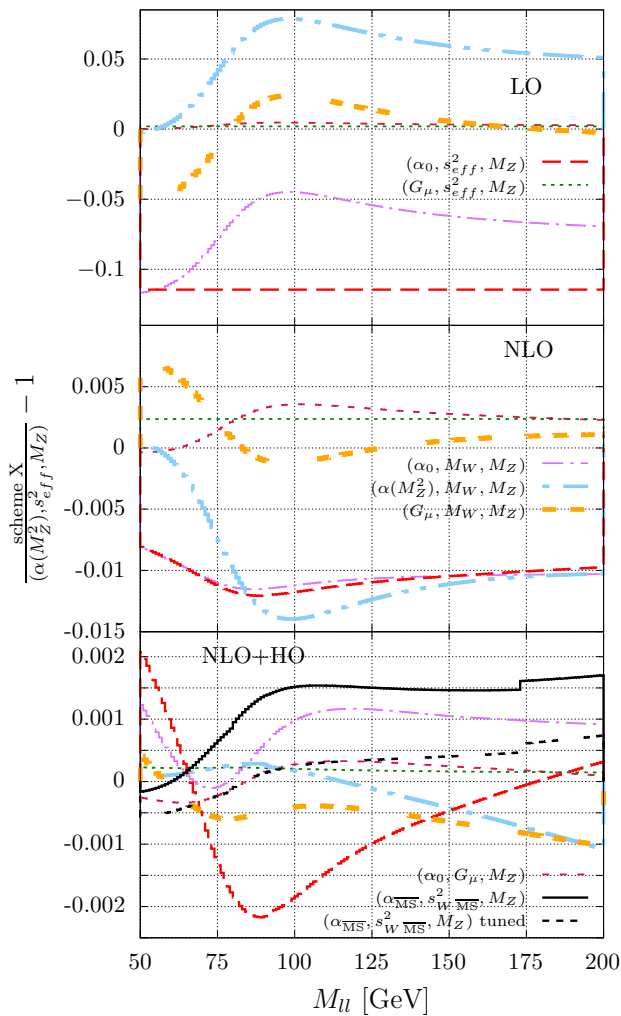
Stability of sensitivity to  $s_{W,eff}^2$  against radiative corrections

MS-bar running

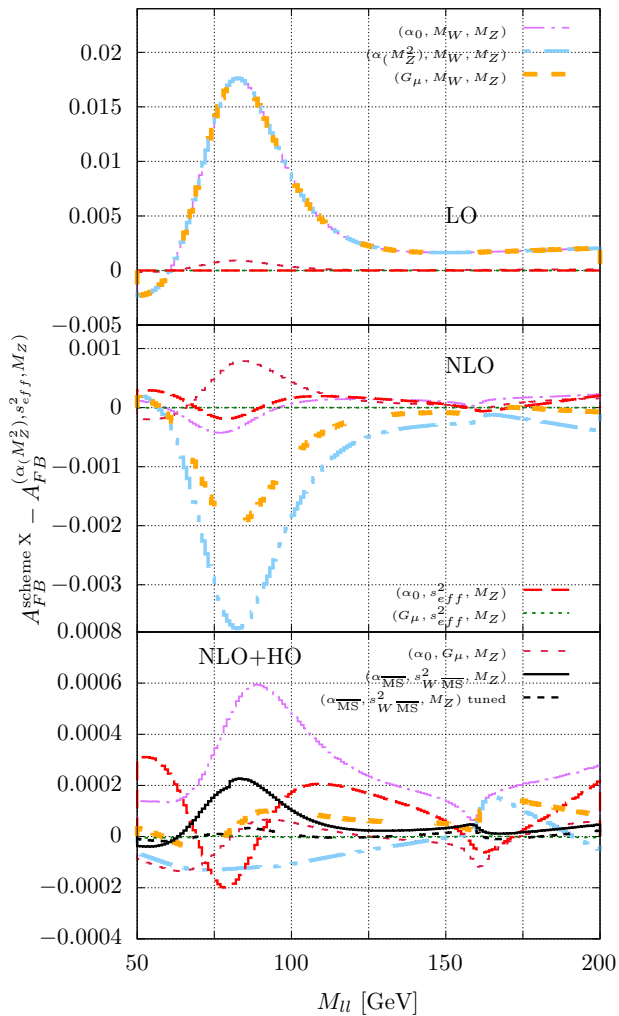
$$s_{W, \overline{MS}}^2(\mu_R^2)$$



# Predictions from different EW input schemes

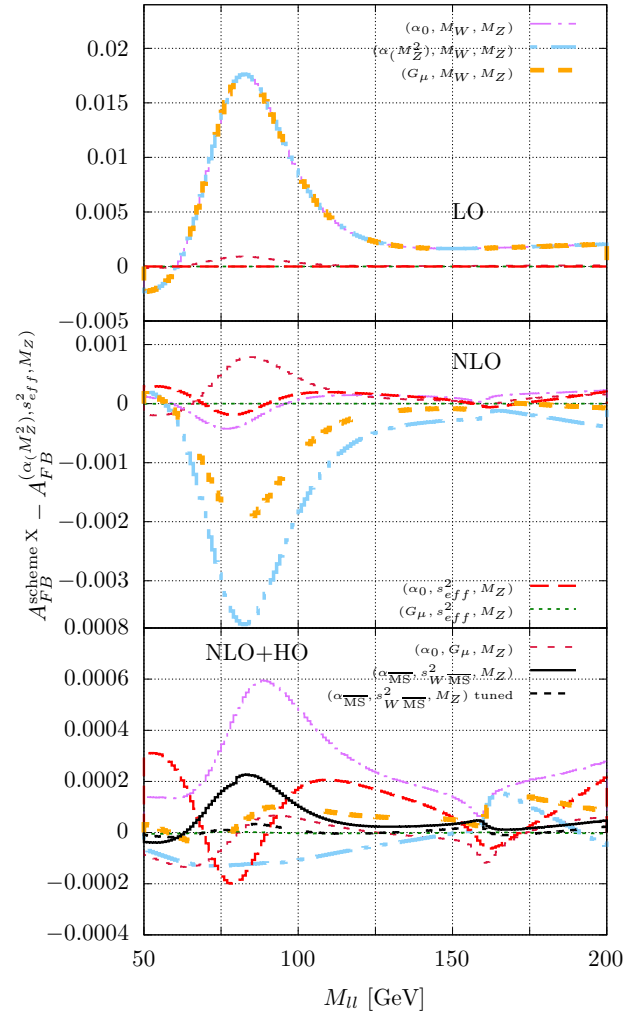


Spread reduced when including NLO and NLO+universal fermionic corr.



Smaller effects: overall  $\Delta\alpha$ ,  $\Delta\rho$  largely cancel in Asymmetry

# Predictions from different EW input schemes



All schemes actually independent: input pars taken from data, no tuning attempt whatsoever

Spread of the predictions measurement of theory uncertainties  $\sim$ some  $10^{-4}$  (relevant for sw2 measurement)

But...

1) might be an overestimate: schemes with coupling effectively defined at  $M_Z$  have smaller corrections and thus smaller missing h.o. effects (compared to the schemes using  $\alpha(0)$ , that give the larger spread). Resulting spread  $\sim 10^{-5}$

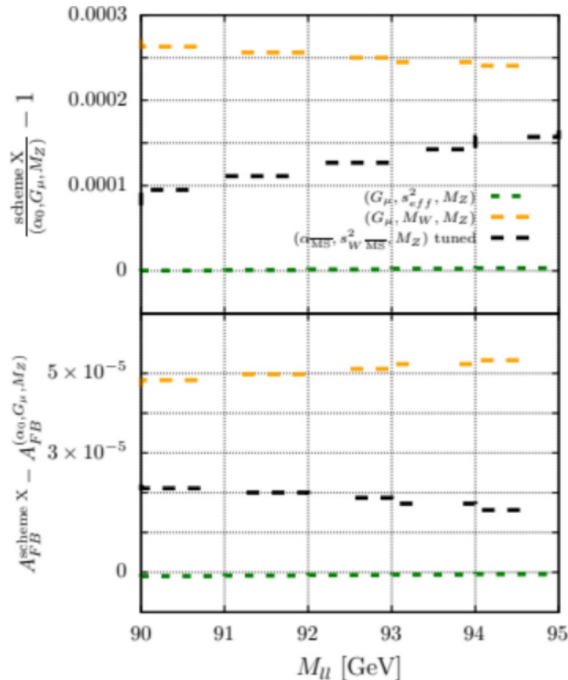
2) different approach at LEP1: comparison of schemes with TUNED input parameters as a function of  $(\alpha, G_\mu, M_Z)$

# Predictions for LEP1-like tuning to $(\alpha, G_\mu, M_Z)$

Start from  $(\alpha, G_\mu, M_Z)$

Compute  $\Delta r_X(X)$ ,  $X$  being  $M_W, s_{W,eff}^2, s_{W,\overline{MS}}^2(M_Z)$

Derive  $X$  from the relation between  $\Delta r_X(X)$  and the parameters  $(\alpha, G_\mu, M_Z)$



$\Gamma_{Zl\bar{l}}$

Bardin et al., CERN 95-03, 1995

Observable	Exp.	Theor. Predictions	Average
$\Gamma_l$ (MeV)	$83.96 \pm 0.18$	BHM $83.919^{+0.020}_{-0.013}$	83.933
		$83.930^{+0.023}_{-0.023}$ LEPTOP	
		TOPAZO $83.931^{+0.015}_{-0.012}$	
		WOB $83.943^{+0.022}_{-0.022}$	
		ZFITTER $83.941^{+0.013}_{-0.021}$	

Agreement within  $10^{-4}$

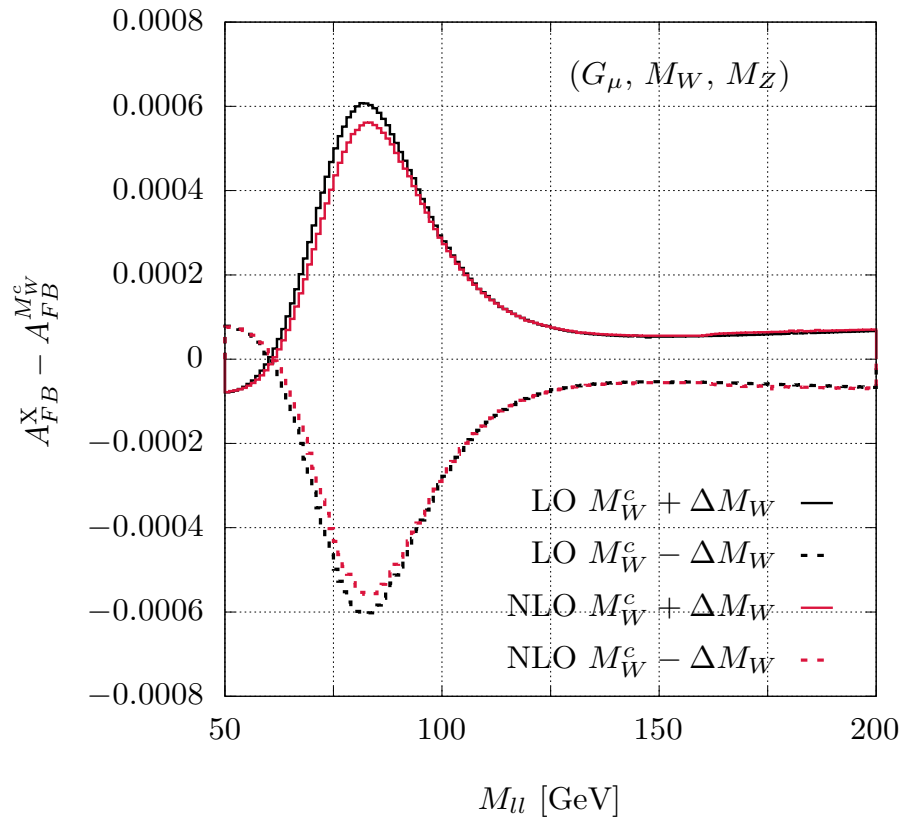
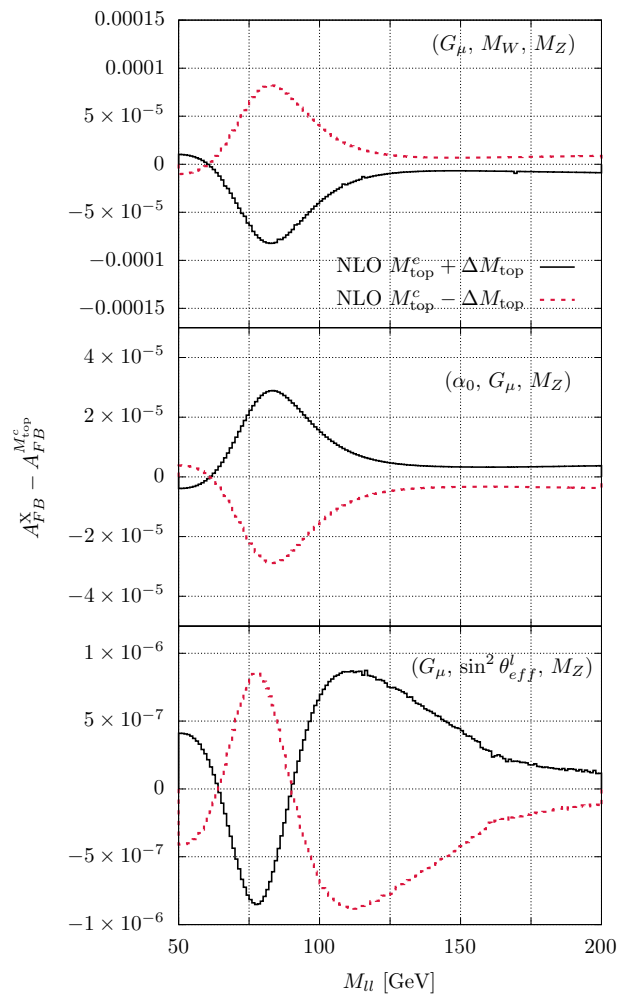
	$(\alpha(M_Z^2), M_W   G_\mu, M_Z)$	$(\alpha(M_Z^2), s_{eff}^2   G_\mu, M_Z)$	$(\alpha(M_Z^2), G_\mu, M_Z)$
$\tilde{s}_{w,NLO+HO}^2$	0.2316749	0.2315919	0.2315965
$\Gamma_e$ LO	$8.58920545 \cdot 10^{-2}$	$8.3203418 \cdot 10^{-2}$	$8.3315838 \cdot 10^{-2}$
$\Gamma_e$ NLO+HO	$8.3697741 \cdot 10^{-2}$	$8.3717562 \cdot 10^{-2}$	$8.3717744 \cdot 10^{-2}$

# Conclusions

- Electroweak input parameter choice connected to accuracy of theory predictions/theory uncertainties
- Update on new  $Z_{ew}$ -BMNNPV: new calculation scheme implemented, in particular the ones designed for the weak mixing angle measurement

Spares

# Parametric uncertainties: examples



$$M_{top} = 173.0 \pm 0.4 \text{ GeV}$$

$$M_W = 80.385 \pm 0.015 \text{ GeV}$$

# Th. uncertainties from other details of the calculation

