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

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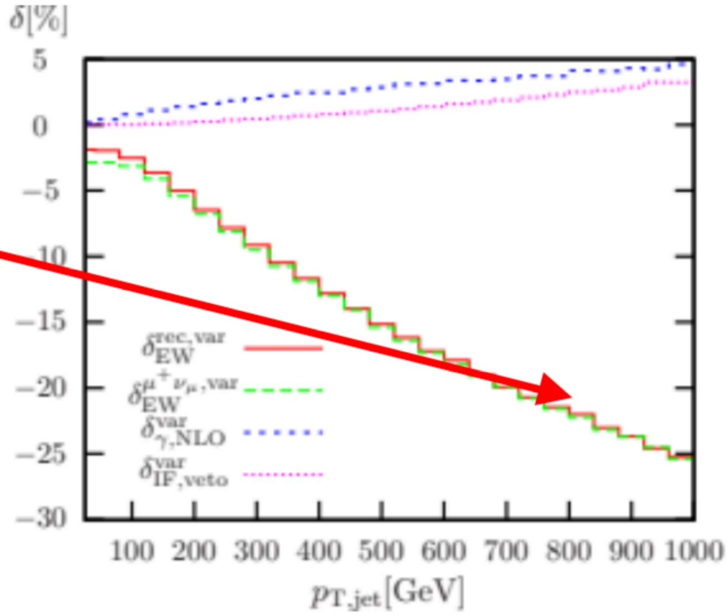
Based on M. C.,C.L. Del Pio, F. Piccinini, Eur.Phys.J.C 84 (2024) 5, 539

NLO EW corrections

- Common wisdom: δ_{EW}^{NLO} ~ some%
- But…

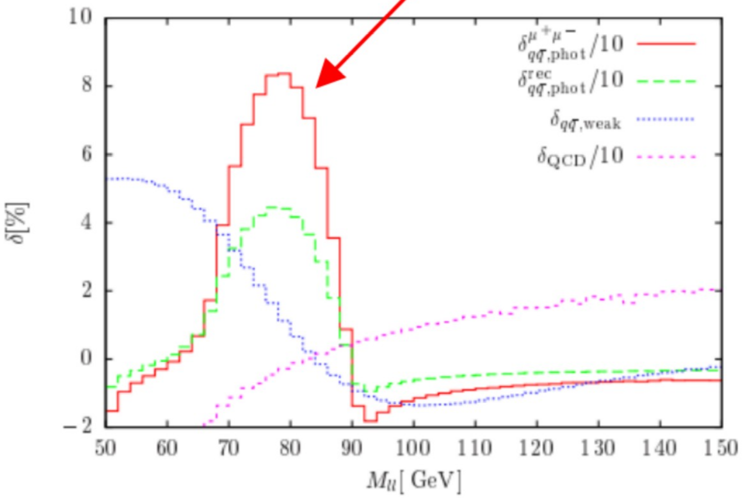
Weak Sudakov corrs.

(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 (Δα,Δρ) up to α^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) (α, 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) (α_0, G_μ, M_Z) : LEP1 scheme, all parameters measured at high accuracy
4) $(\alpha_{\overline{MS}}, s^2_{W,\ \overline{MS}}, M_Z)$: useful for sw2 measurement at high-energy arxiv:2402.14659, 2302.10782

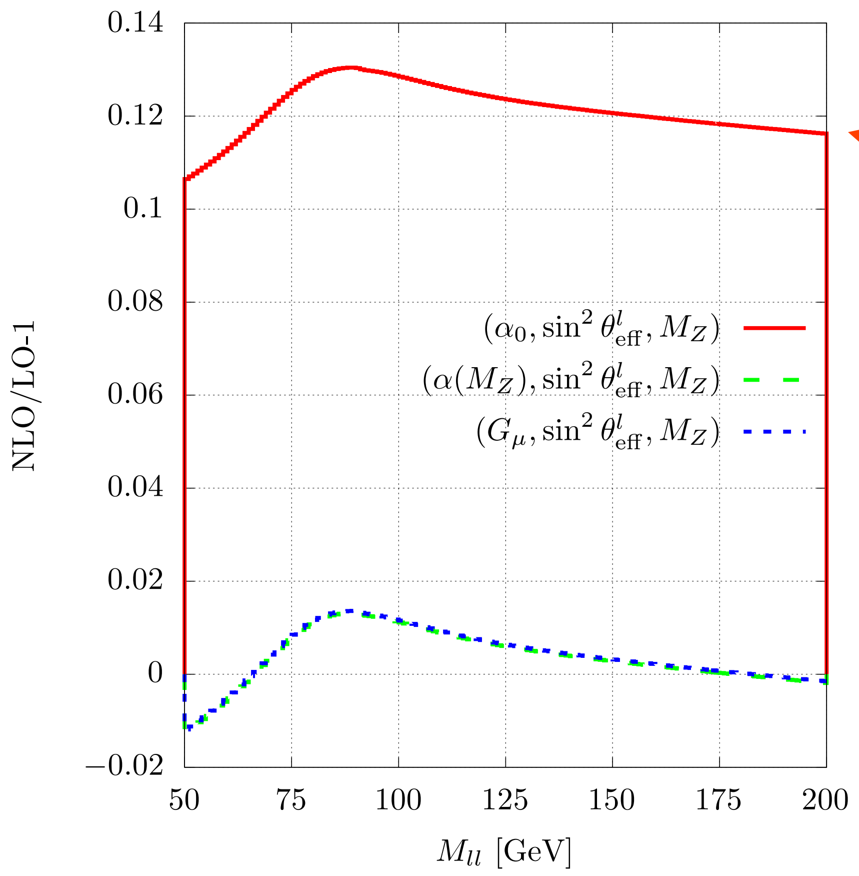
α stands for either $\alpha_0,\ \alpha(M_Z),\ \alpha(G_\mu)$

EW input parameters choice

Possible criteria

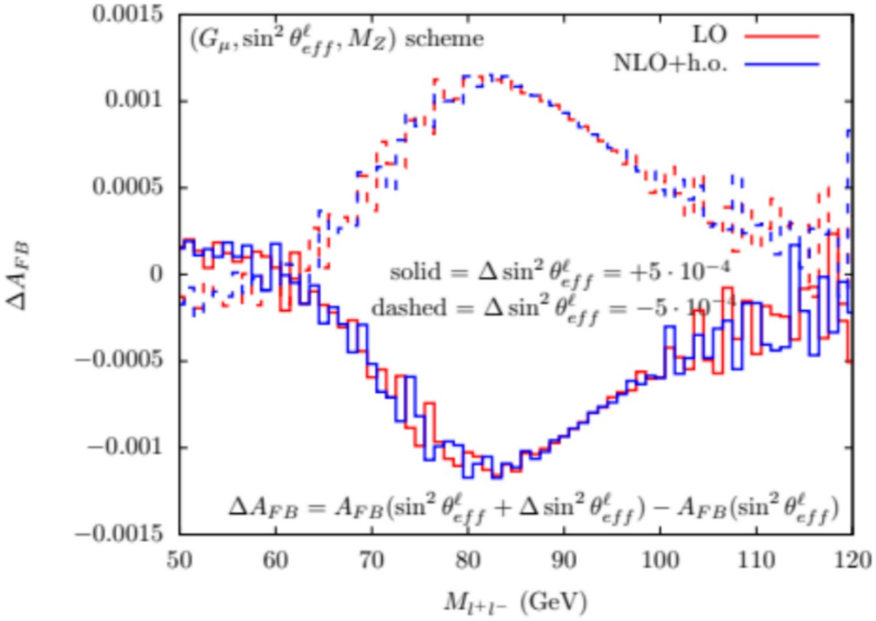
- Size of radiative corrections/convergence of perturbative expansion/missing higher-order effects
- Experimental precision on inputs/parametric uncertainties on predictions
- Need of having a specific free parameter to perform fits (see MW and sw measurements)

Size of radiative corrections: example



α(0) scheme:
large corrections ~ 2 Δα

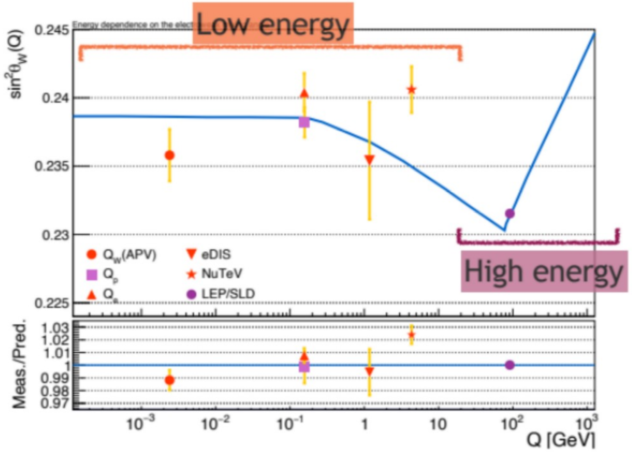
Free parameters and template fit measurements



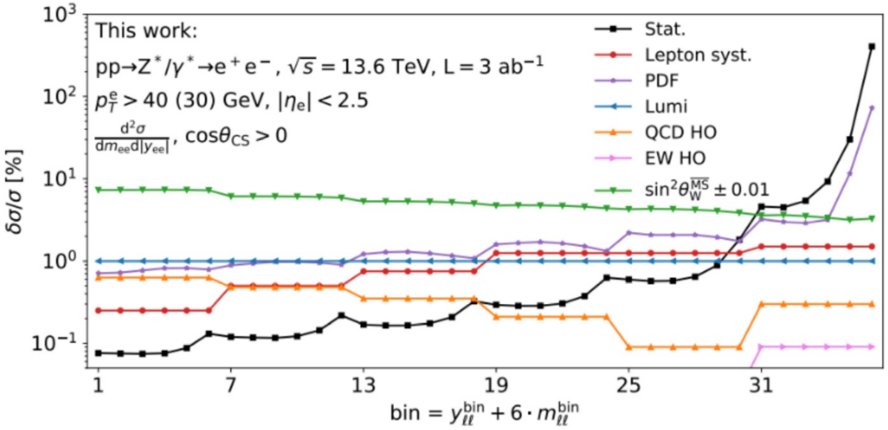
Stability of sensitivity to $s^2_{W,eff}$ against radiative corrections

MS-bar running

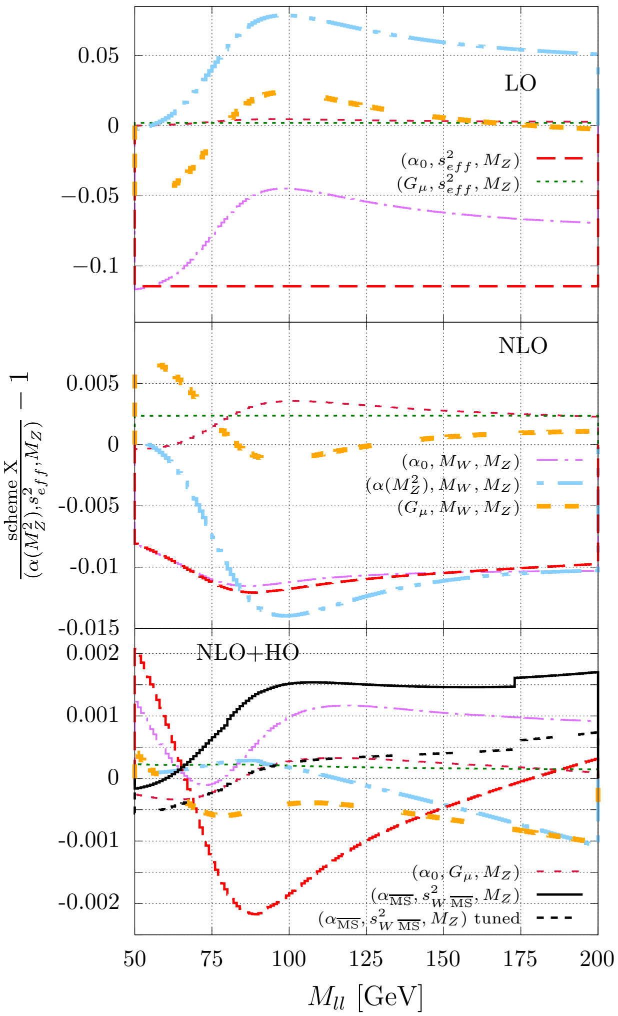
$s^2_{W,\overline{MS}}(\mu^2_R)$



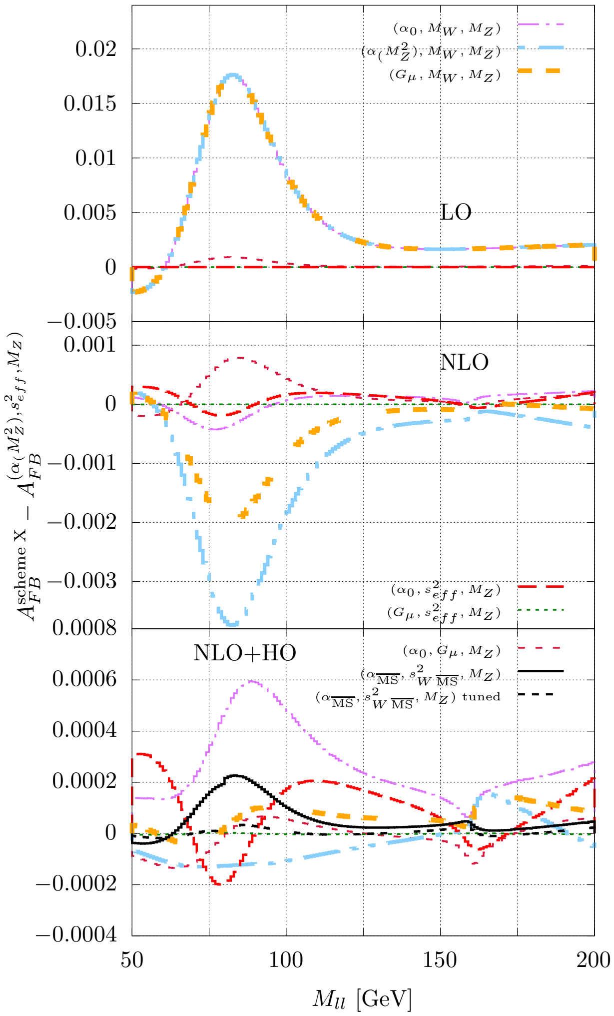
J. Erler and M. Schott, Progr. Part. Nucl. Phys. 106, 68-119, 2019



Predictions from different EW input schemes

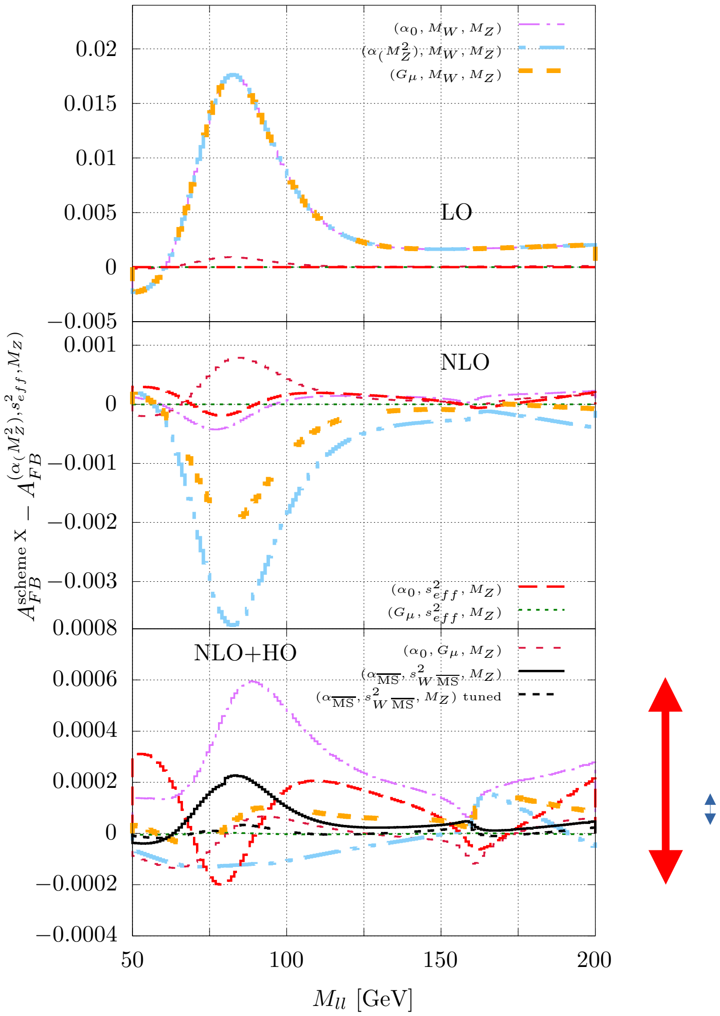


Spread reduced when including NLO and NLO+universal fermionic corrs.



Smaller effects: overall Δα, Δρ 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 ~some 10^-4 (relevant for sw2 measurement)

But…

1) might be an overestimate: schemes with coupling effectively defined at MZ have smaller corrections and thus smaller missing h.o. effects (compared to the schemes using α(0), that give the larger spread). Resulting spread ~10^-5

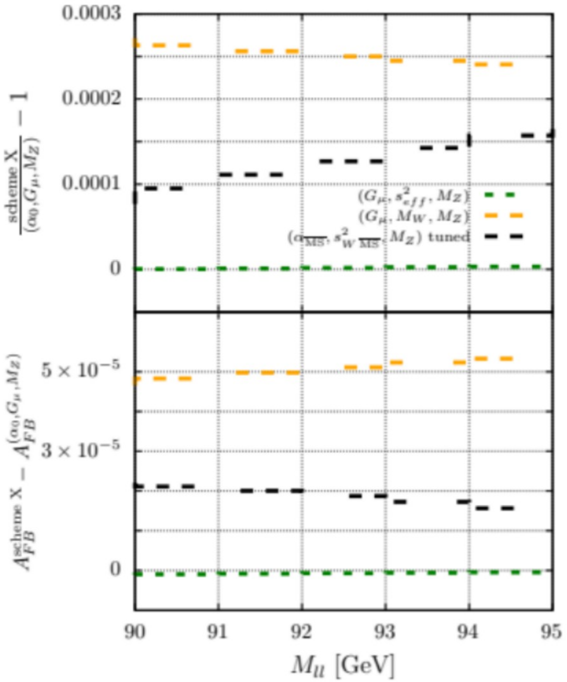
2) different approach at LEP1: comparison of schemes with TUNED input parameters as a function of (α, G_μ, M_Z)

Predictions for LEP1-like tuning to (α, G_μ, M_Z)

Start from (α, G_μ, M_Z)

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

Derive X from the relation between $\Delta r_X(X)$ and the parameters (α, G_μ, M_Z)



$\Gamma_{Z\ell\bar{\ell}}$

Bardin et al., CERN 95-03, 1995

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

Agreement within 10^{-4}

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

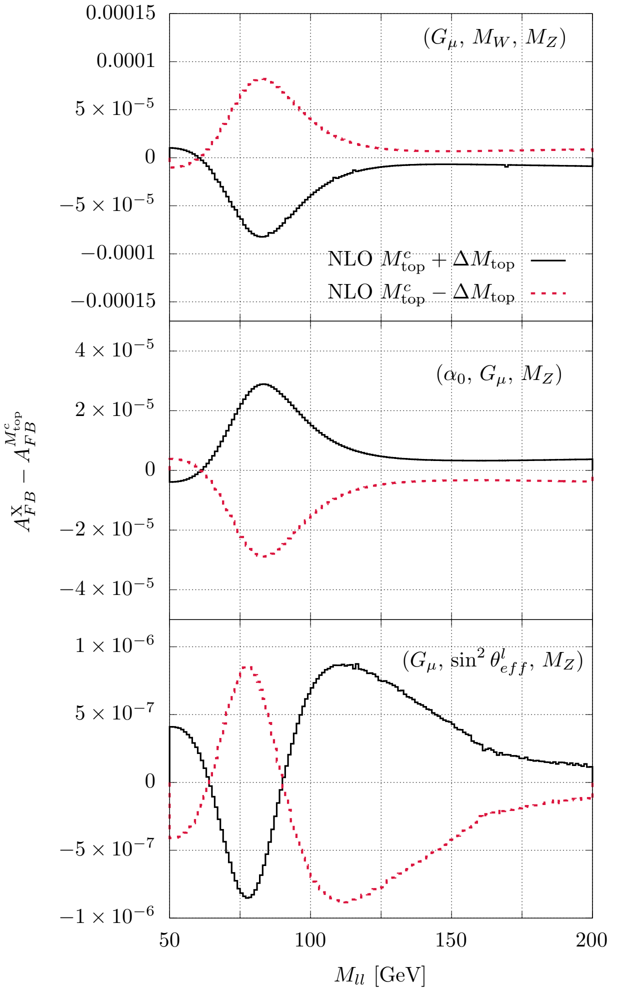
Conclusions

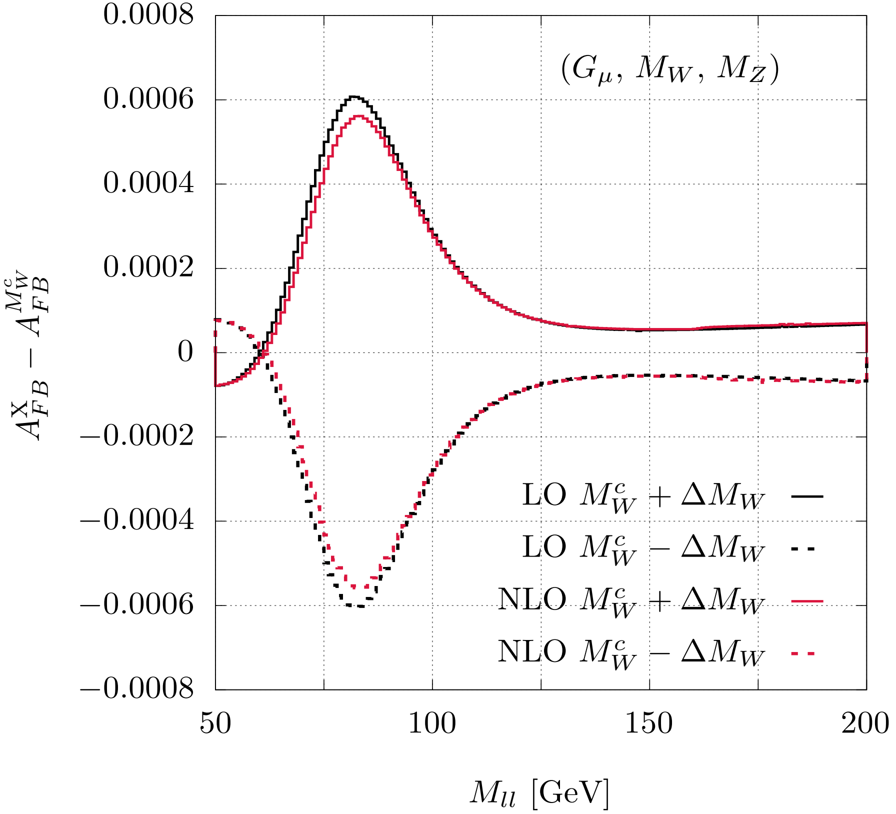
- Electroweak input parameter choice connected to accuracy of theory predictions/theory uncertainties

- 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





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

$M_W = 80.385 \pm 0.015\, GeV$

Th. uncertainties from other details of the calculation