Update on Powheg ew

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with M. Chiesa and the Powheg_ew team

- A proposal for the (SM) direct determination of $\sin^2 \vartheta_{eff}^{\ell}$

- Fixed vs running width

- **independent quantities in the SM:**
    - ▸ 3 in the electroweak gauge sector (to be specified)
    - ▸ $\alpha_s(Q^2)$, for a given Q^2, e.g. $Q^2 = M_Z^2$
    - ▸ lepton masses, m_t, m_H
    - ▸ light quark masses (including c and b) crucial for the running of $\alpha \implies$ circumvented by using low-energy data and dispersion relations
- possible triplets of input (Lagrangian) parameters
    - ▸ (e, M_W, M_Z), (g, M_W, M_Z), $(g, \sin\vartheta, M_Z)$, …
- **renormalization scheme**: input parameters need to be defined with reference to three data points
- $\implies$ everything else is calculated in terms of input parameters
- conceptually, independently of any simplified assumption (e.g. factorization properties at the Z peak), every parameter can be directly determined through a template fit procedure to any observable, provided our theoretical prediction of the observable allows us to freely move the measured parameter without spoiling the accuracy of the calculation
- **the above can be achieved in a formally clear way if we provide a renormalization scheme which adopts the measured parameter as an independent parameter**

# requirement for an input/renormal. scheme

- **minimize the parametric uncertainty of the reference observables** defining the scheme
  - e.g. the LEP (G_μ, α, M_Z) scheme
- **minimize the effects of higher order corrections**, in order to have stable predictions in perturb. theory
  - e.g. the (G_μ, M_W, M_Z) scheme used for DY at Tevatron/LHC
- **minimize the parametric uncertainty** due to imperfect knowledge of other Lagrangian parameters (e.g. m_t, $\Delta\alpha_h$)

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which scheme for direct determination of $\sin^2\vartheta_{eff}^\ell$ at the LHC?

in the spirit of the horizontal dashed line
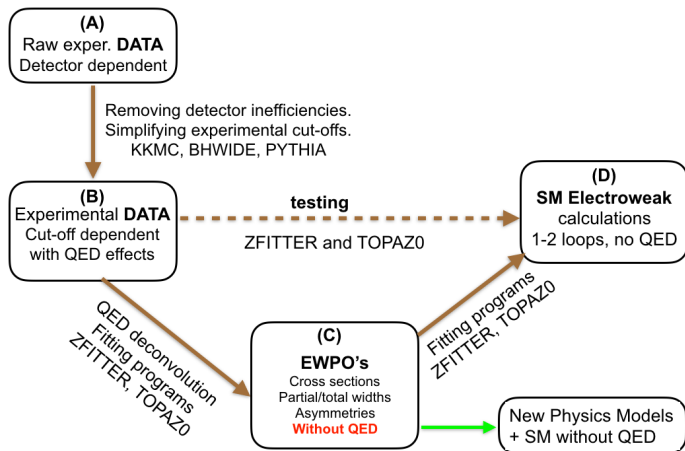
A. Freitas, J. Gluza, , S. Jadach, in arXiv:1809.01830

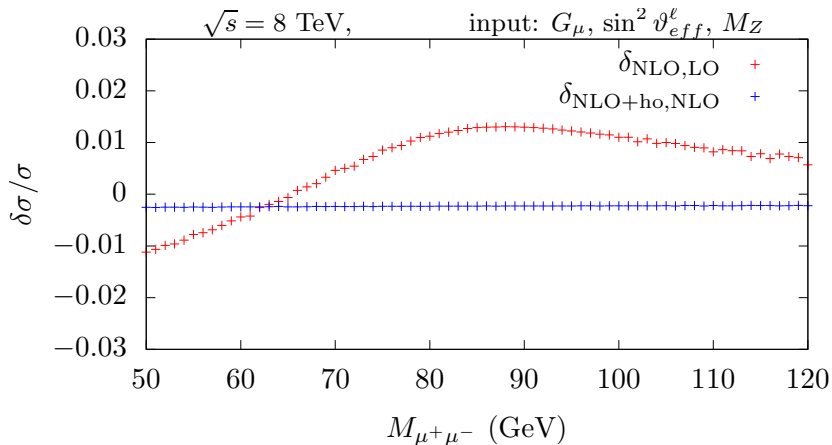# α/G_μ, M_Z, $\sin^2\vartheta_{eff}^\ell$ as reference data

- our Lagrangian parameters: e, $\sin^2\vartheta$, M_Z
- e and M_Z renormalized parameters fixed as usual through α/G_μ and M_Z value measured at LEP
- $\sin^2\vartheta$ renormalized parameter fixed at $\sin^2\vartheta_{eff}^\ell$
  - this can be achieved by requiring that the ratio $\frac{g_V^\ell}{g_A^\ell}$ does not get radiative corrections
  - procedure independent of QED corrections because g_L and g_R receive the same corrections
- the scheme can be used for making predictions
  - "drawback": parametric uncertainty inherited by the LEP measurement of $\sin^2\vartheta_{eff}^\ell$

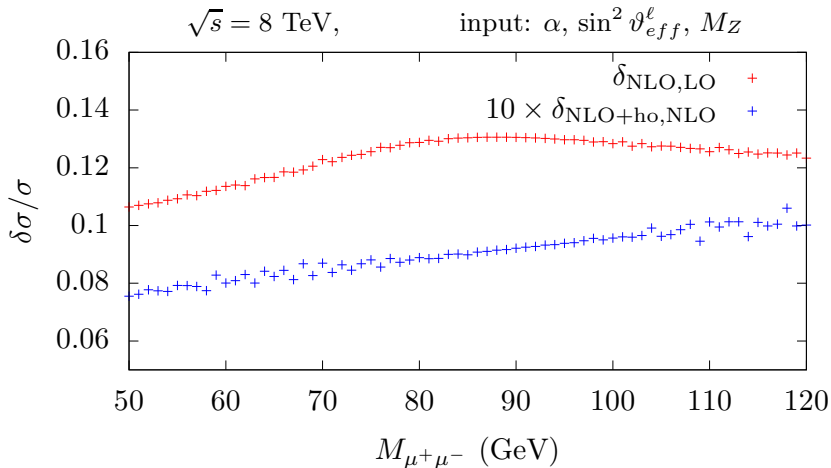# α/G_μ, M_Z, $\sin^2\vartheta^\ell_{eff}$ as reference data

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- most important: the scheme can be used in a fitting procedure to measure $\sin^2\vartheta^\ell_{eff}$ with a template fit

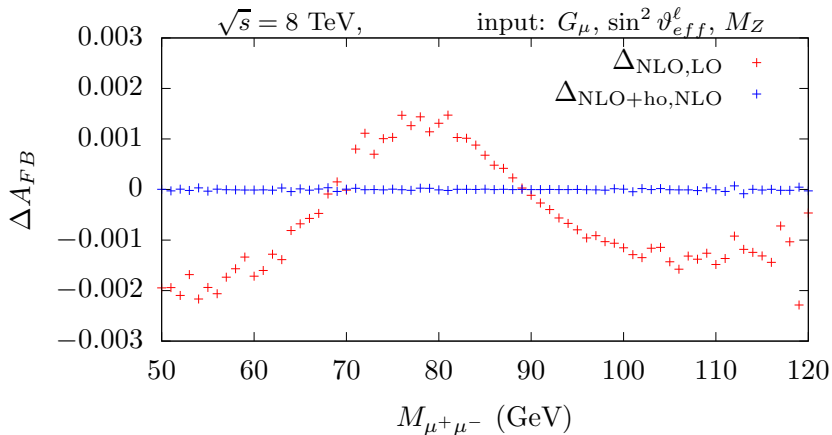# convergence of pert. th. on $d\sigma/dM_{\ell\ell}$
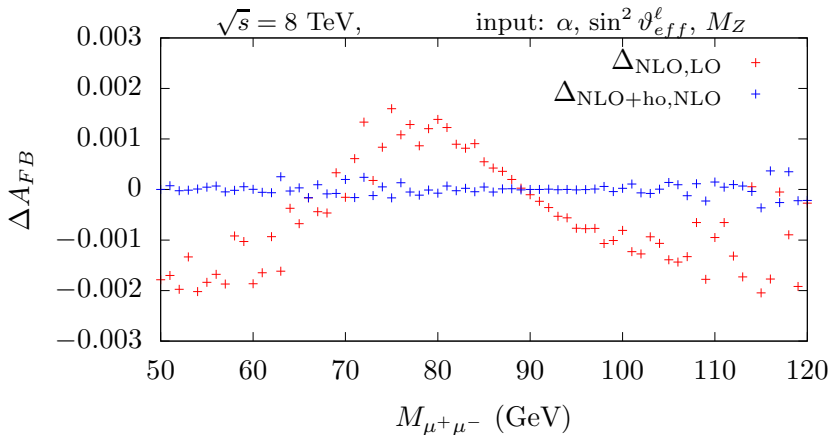
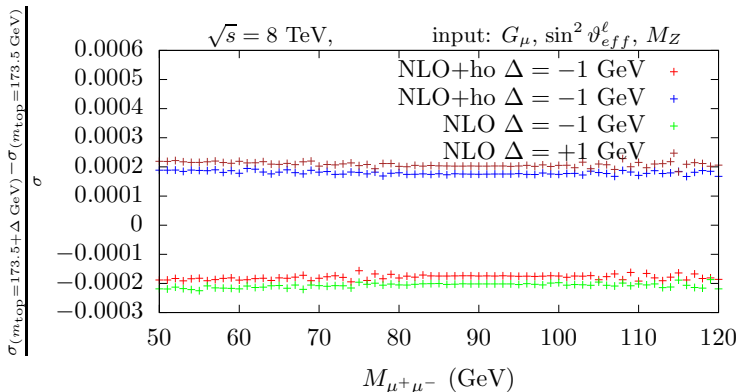**PRELIMINARY**

PRELIMINARY

$\sqrt{s} = 8$ TeV, input: α, $\sin^2 \vartheta_{eff}^{\ell}$, M_Z

$\delta_{\mathrm{NLO,LO}}$ +

$10 \times \delta_{\mathrm{NLO+ho,NLO}}$ +

$\delta\sigma/\sigma$ vs $M_{\mu^+\mu^-}$ (GeV)

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$\Delta_{\mathrm{NLO,LO}}$

$\Delta_{\mathrm{NLO+ho,NLO}}$

ΔA_{FB}

$M_{\mu^+\mu^-}$ (GeV)
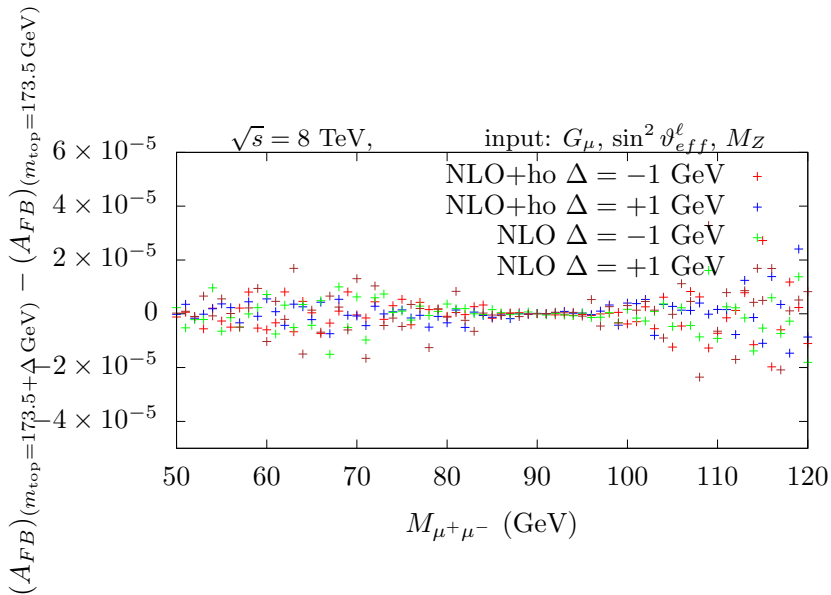
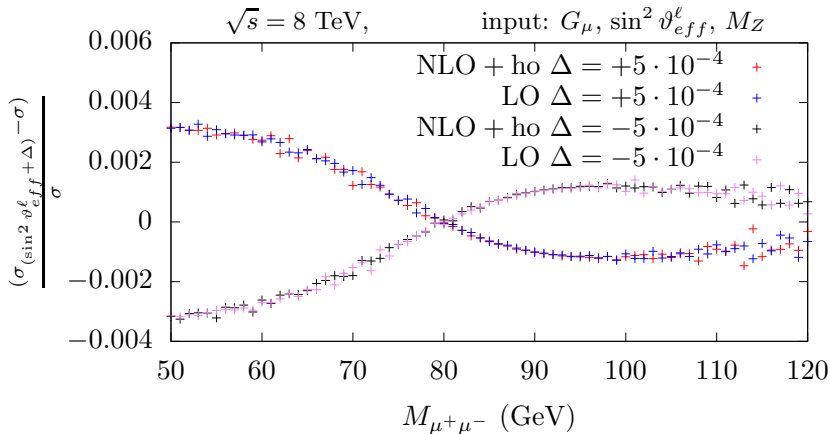# parametric dependence on m_{top}

PRELIMINARY

- parametric dependence on $\Delta\alpha_h$ available, when using α as input (according to most recent parameterizations), numerics to be done
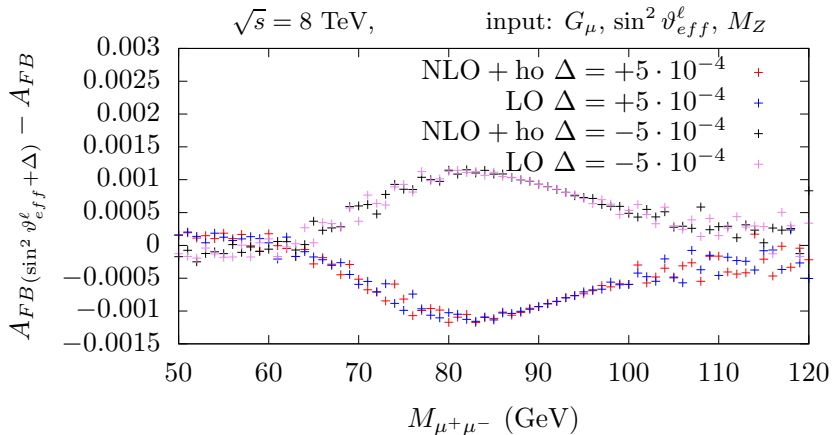- parametric dependece on α_s available, numerics to be done

sensitivity to $\sin^2 \vartheta_{eff}^{\ell}$: $d\sigma/dM_{\ell\ell}$

PRELIMINARY

sensitivity to $\sin^2 \vartheta_{eff}^{\ell}$: A_{FB}

PRELIMINARY

Running vs fixed Z width: first considerations

- The definition of Z mass as the zero of the real part of the inverse propagator (the one implied by LEP running width parameterization) is gauge dependent starting from $\mathcal{O}(\alpha^2)$
  - the complex pole position gives a gauge independent mass definition

    e.g. A. Sirlin, Phys.Rev.Lett. 67 (1991); R.G. Stuart, Phys.Lett. B262 (1991), S. Willenbrock and G. Valencia,

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- neglecting terms of $\mathcal{O}(\alpha^2)$, a gauge invariant definition (closely related to the LEP measured values), is

$$M_{OS}^2 = M_{\text{pole}}^2 \left(1 + \frac{\Gamma_{\text{pole}}^2}{M_{\text{pole}}^2} \right)$$

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- in general it has been shown that a calculation (for a generic process) which uses running widths in the boson propagators meets gauge violations, which can become severe (extensive numerical studies during the nineties in view of LEP2)

  <div align="right">e.g. Argyres et al., Phys.Lett. B358 (1995)</div>

  - e.g.: $f\bar{f} \to 4$ fermions @LEP2 and @LHC
  - it involves the self-gauge coupling at tree level
  - $\implies$ the width is related to the imaginary parts of the fermionic corrections; to restore gauge invariance (at least) the imaginary part of the fermionic correction to the self-gauge coupling has to be included (idea of the fermion loop scheme)

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- for DY, at one loop, as long as no bosonic corrections are put in the denominator, no problems of gauge invariance arise around the Z pole
- for one loop calculations, the two parameterizations of the Z lineshape can be adopted
  - they can give different predictions of the lineshape
    - which can be expected to decrease when comparing the two scheme at LO level or at NLO level (to be numerically investigated)