EW precision measurements at the LHC: theory review

Luca Barzè
- CERN -

DIS 2013

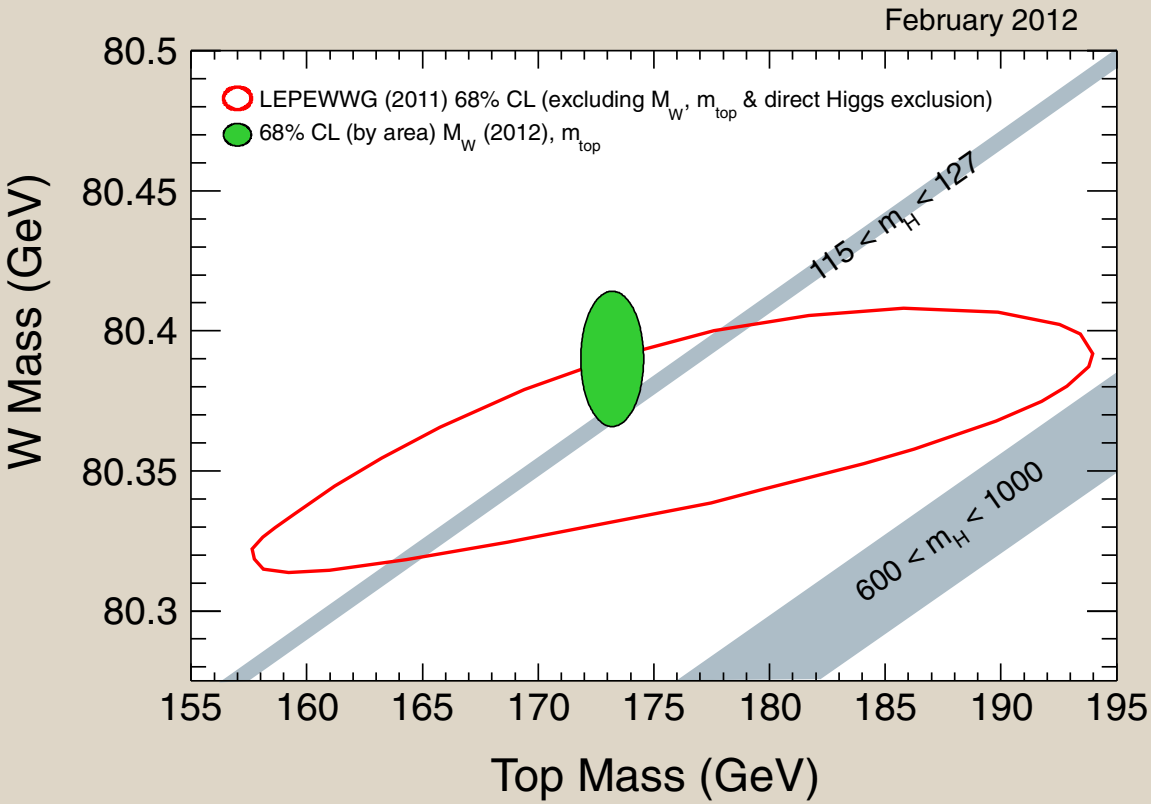
Marseille - April, 25 2013

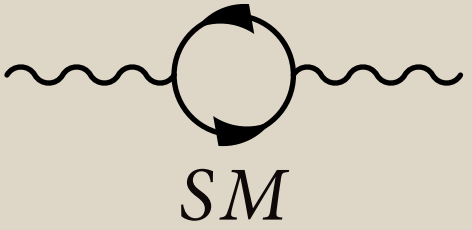
Outline

- Precision physics at LHC
- Drell-Yan processes
- effects of mixed QED⊗QCD radiative corrections
  - on W mass
  - on $\sin^2 \vartheta_W$
- conclusions.

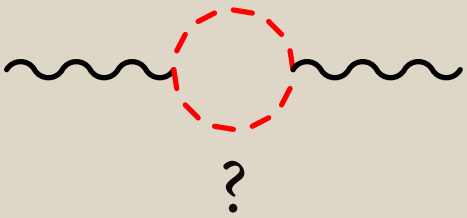
Precision tests of the Standard Model

$$M_W = \sqrt{\frac{\pi\alpha}{\sqrt{2}G_\mu}} \frac{1}{\sin\vartheta_W \sqrt{1-\Delta r(m_{\text{top}}, m_{\text{H}}, \ldots)}}$$





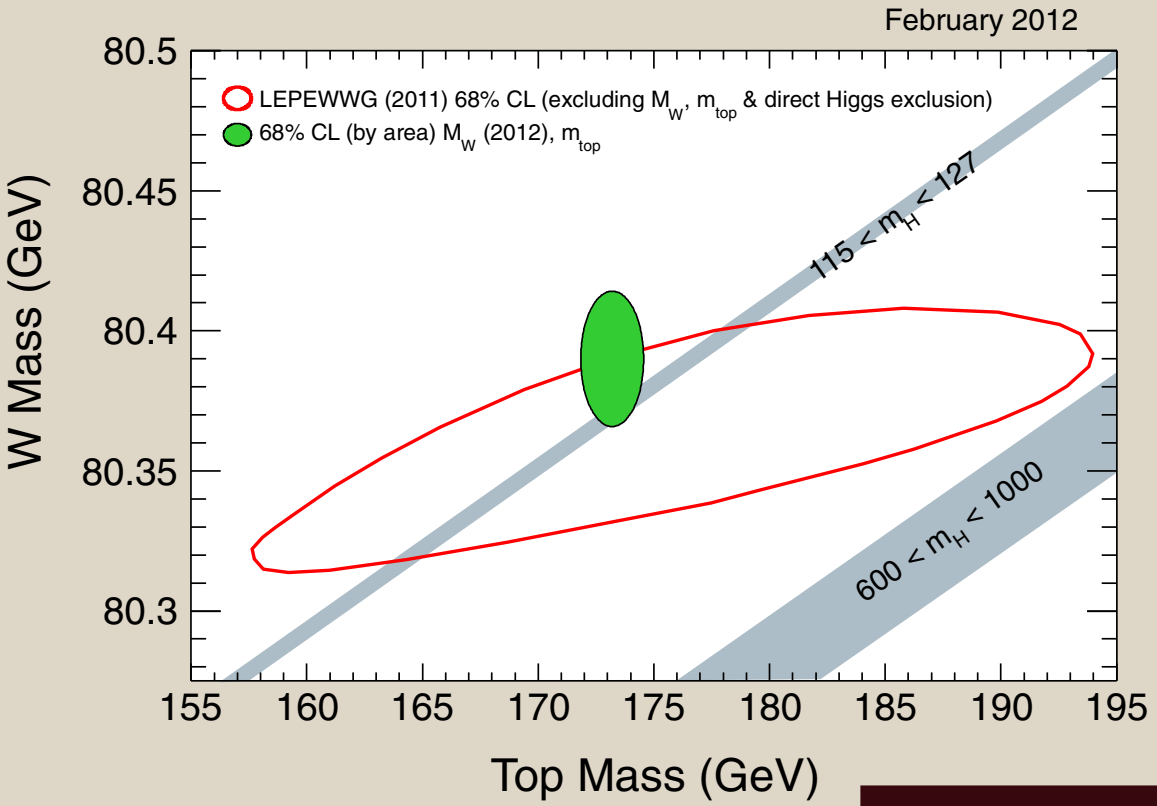
SM

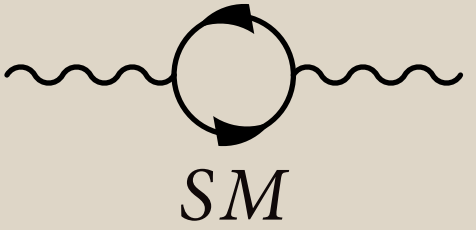


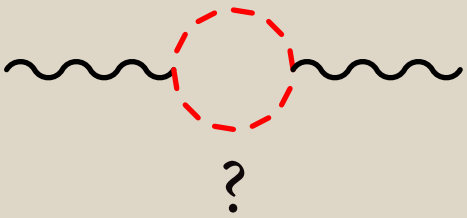
?

Precision tests of the Standard Model

$$M_W = \sqrt{\frac{\pi\alpha}{\sqrt{2}G_\mu}} \frac{1}{\sin\vartheta_W \sqrt{1-\Delta r(m_{\text{top}}, m_{\text{H}}, \ldots)}}$$







LHC?

Drell-Yan for precision physics at LHC

NC/CC Drell - Yan processes at LHC:

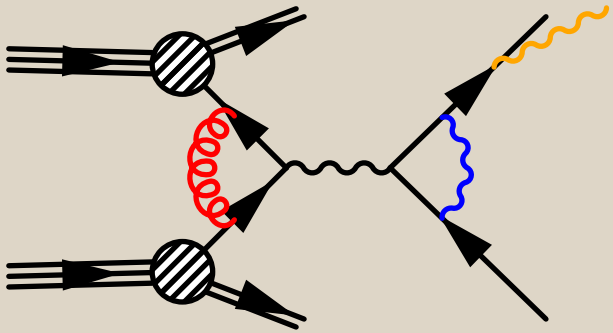
extraction of PDFs / luminosity monitoring / calibration of detectors / M_W ($\Delta M_W^{LHC} \lesssim 15$ MeV or better), Γ_W, $\sin^2\vartheta_W$ / background for BSM / ...

- clear experimental signature;
- integrated luminosity at the end of 2012 → $\mathcal{L} \sim 20\ \text{fb}^{-1}$

  - $\sigma^{tot}_{W\to l\nu} \sim 10$ nb

    $\Rightarrow$ $\sim 2 \cdot 10^8$ W in the data
  - $\sigma^{tot}_{Z\to l\bar{l}} \sim 1$ nb

    $\Rightarrow$ $\sim 2 \cdot 10^7$ Z in the data

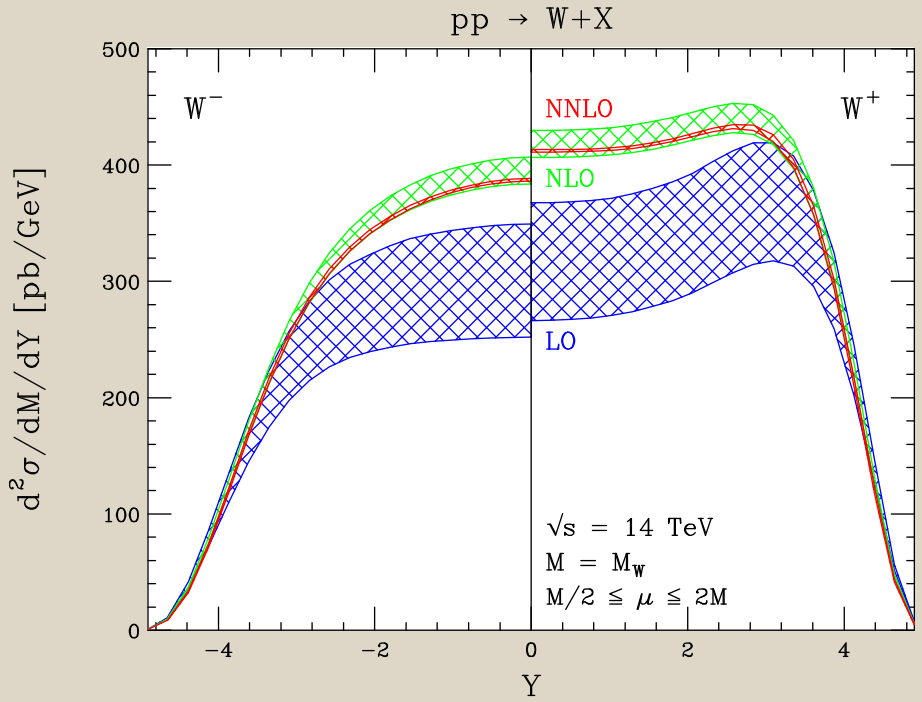


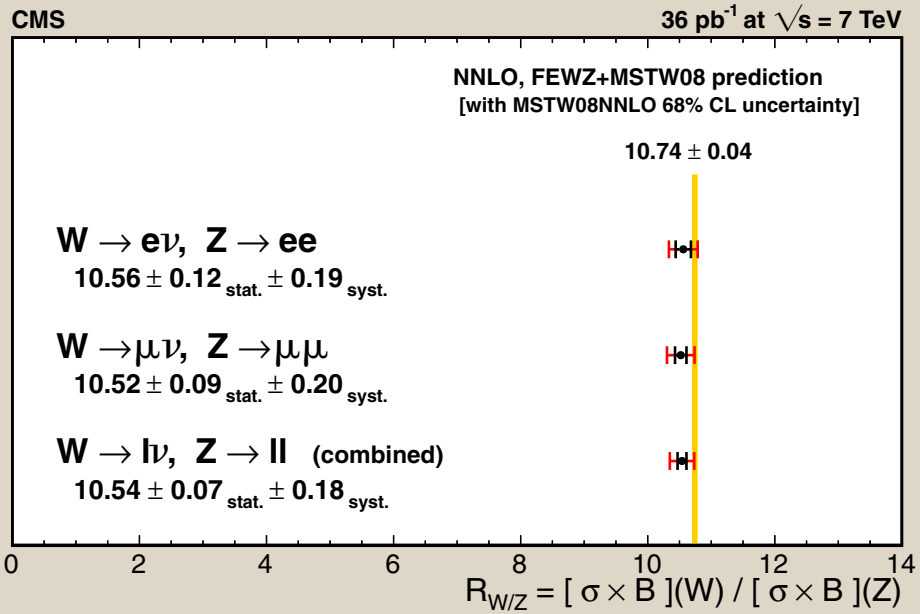
Experimental accuracy at LHC for DY total cross section ~ 1 %

Exact QCD NNLO

$$\sigma = \sigma_0 + \sigma_{\alpha_s} + \sigma_{\alpha} + \sigma_{\alpha_s^2} + \ldots$$

- $O(\alpha_s)^2 \longrightarrow$ DYNNLO Catani & al., PRL 103 (2009) 082001
- $O(\alpha_s)^2 \oplus O(\alpha_{EW}) \longrightarrow$ FEWZ Petriello & al., PRD86 (2012) 094034
  PRD74 (2006) 114017

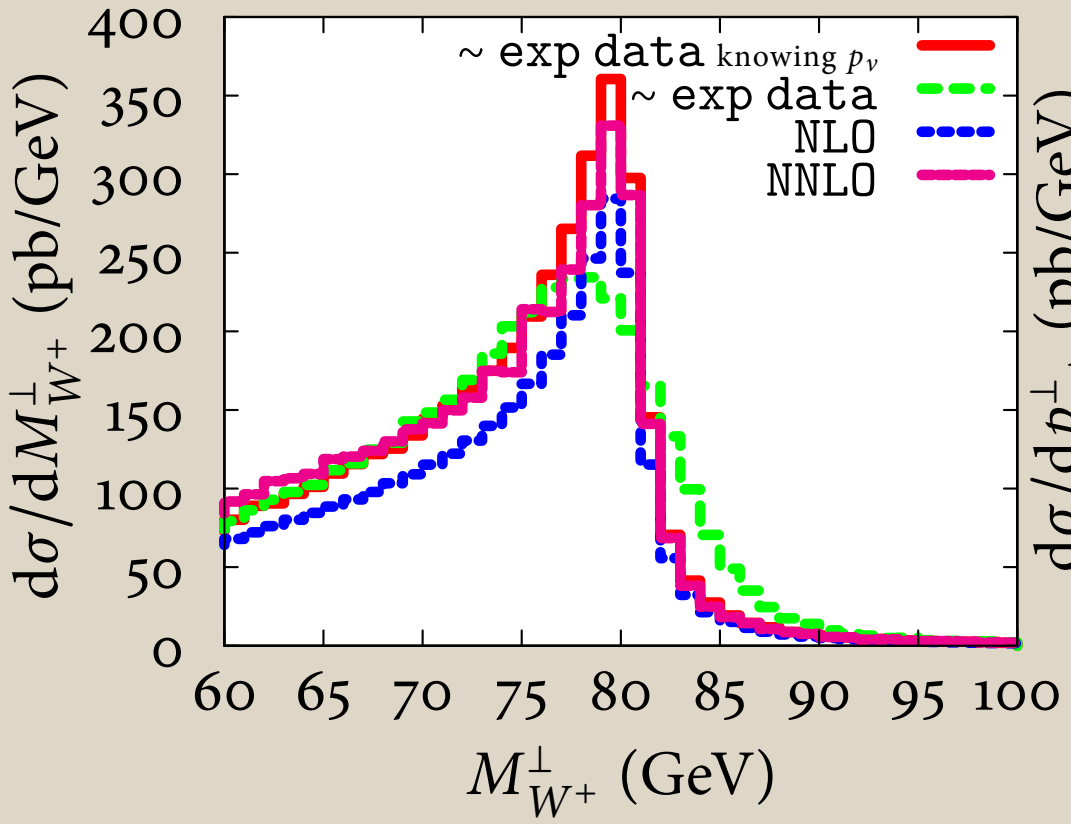




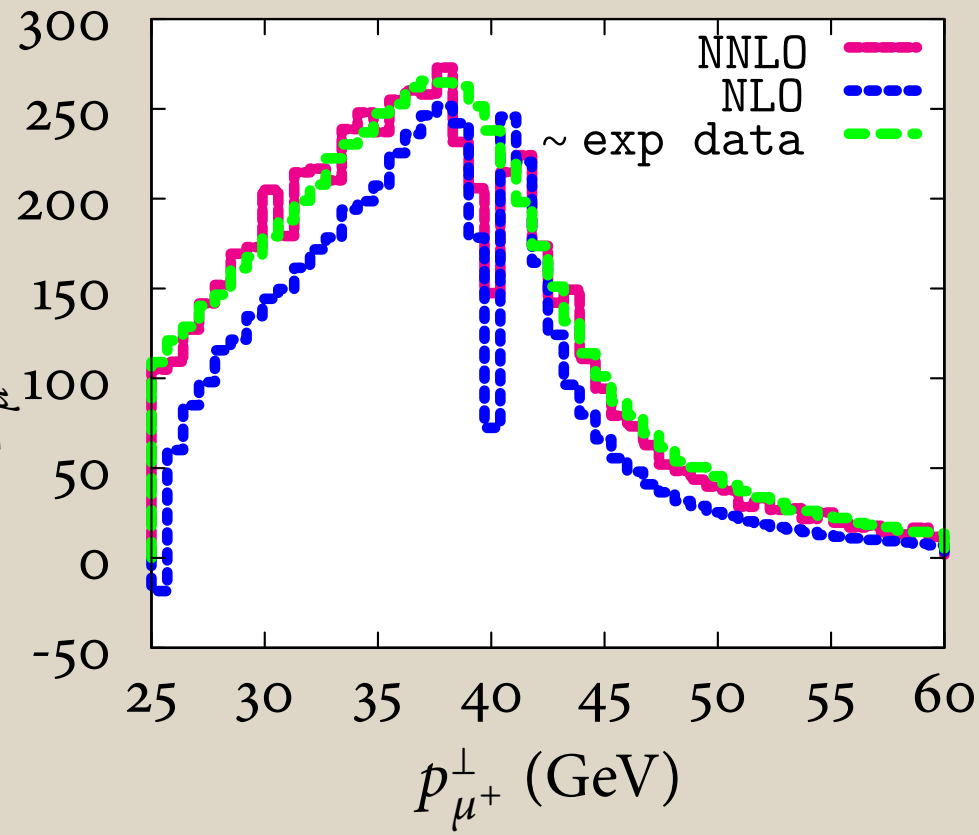
W Mass measurement

$$\sigma_{NNLO}^{\text{exp cut}} = \begin{cases} 3270 \pm 50 \text{ pb (if } M_W = 80.5 \text{ GeV)} \\ 3258 \pm 50 \text{ pb (if } M_W = 80.4 \text{ GeV)} \end{cases}$$

can't use inclusive quantities!



will depend on p_ν

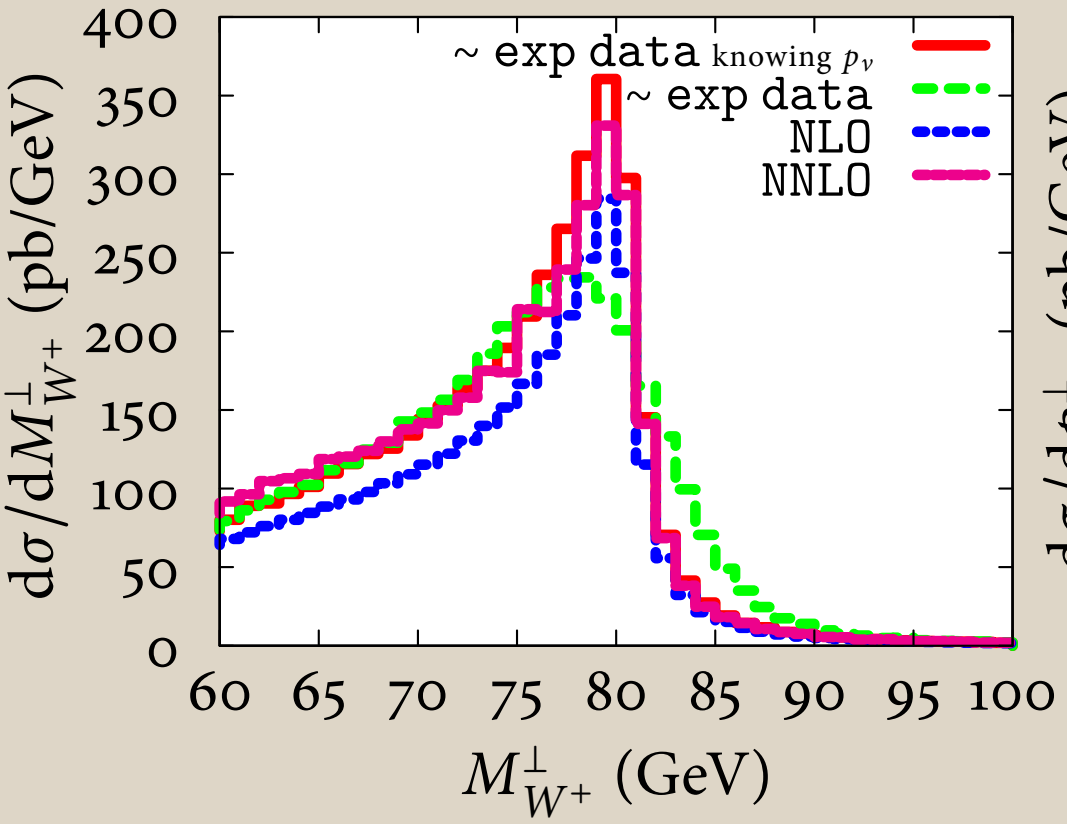


not IR safe

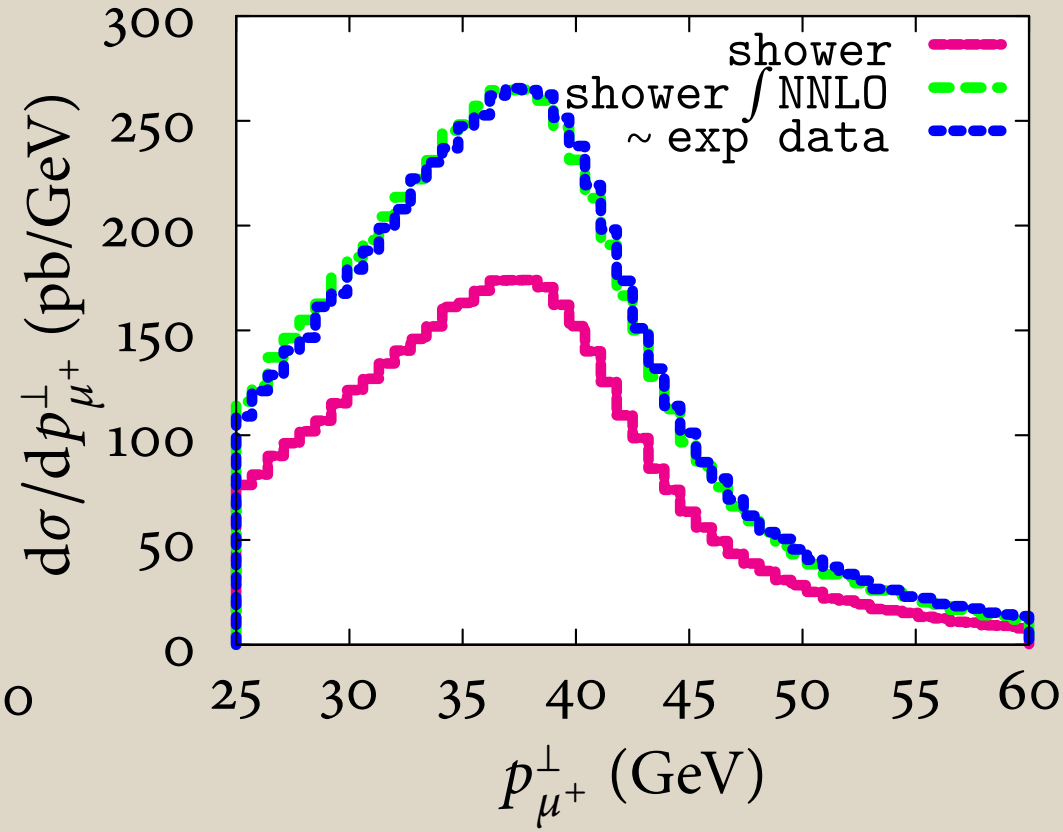
W Mass measurement

$$\sigma_{NNLO}^{\text{exp cut}} = \begin{cases} 3270 \pm 50 \text{ pb (if } M_W = 80.5 \text{ GeV)} \\ 3258 \pm 50 \text{ pb (if } M_W = 80.4 \text{ GeV)} \end{cases}$$

can't use inclusive quantities!



will depend on p_ν



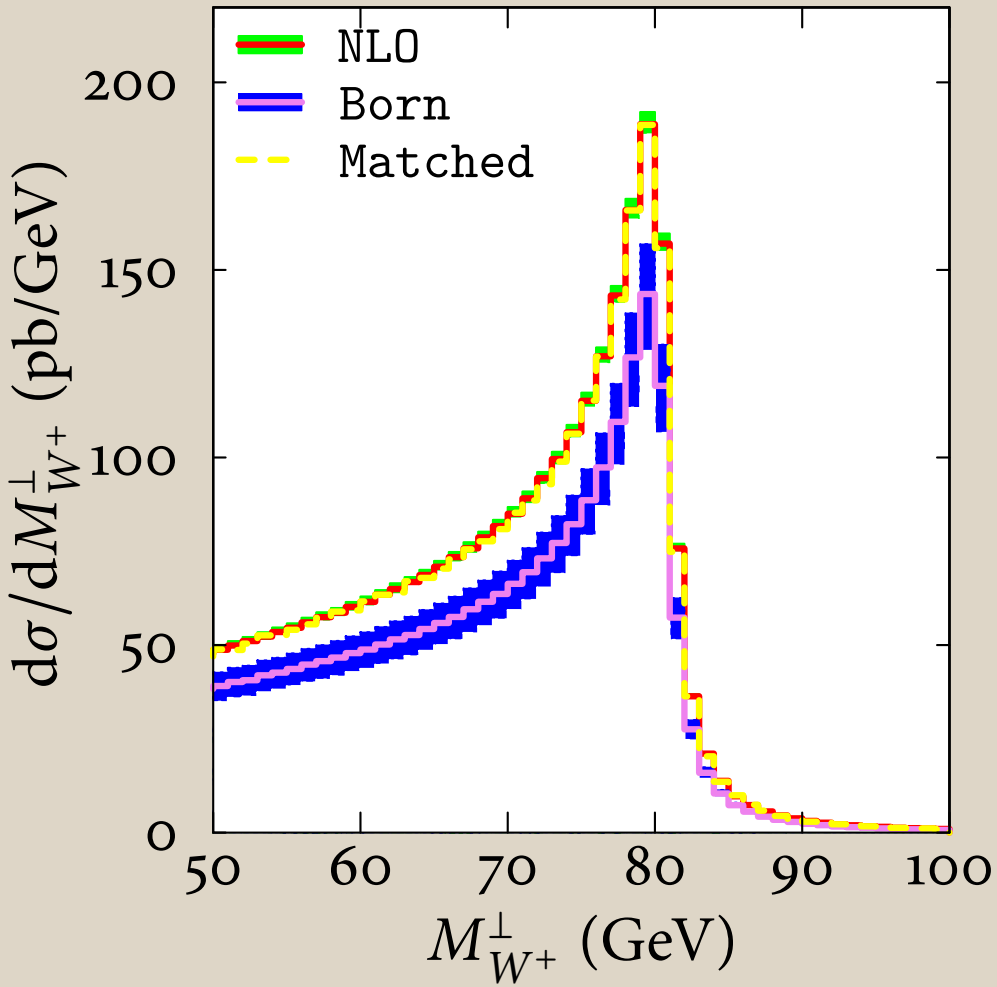
(at least) NLO on total σ.

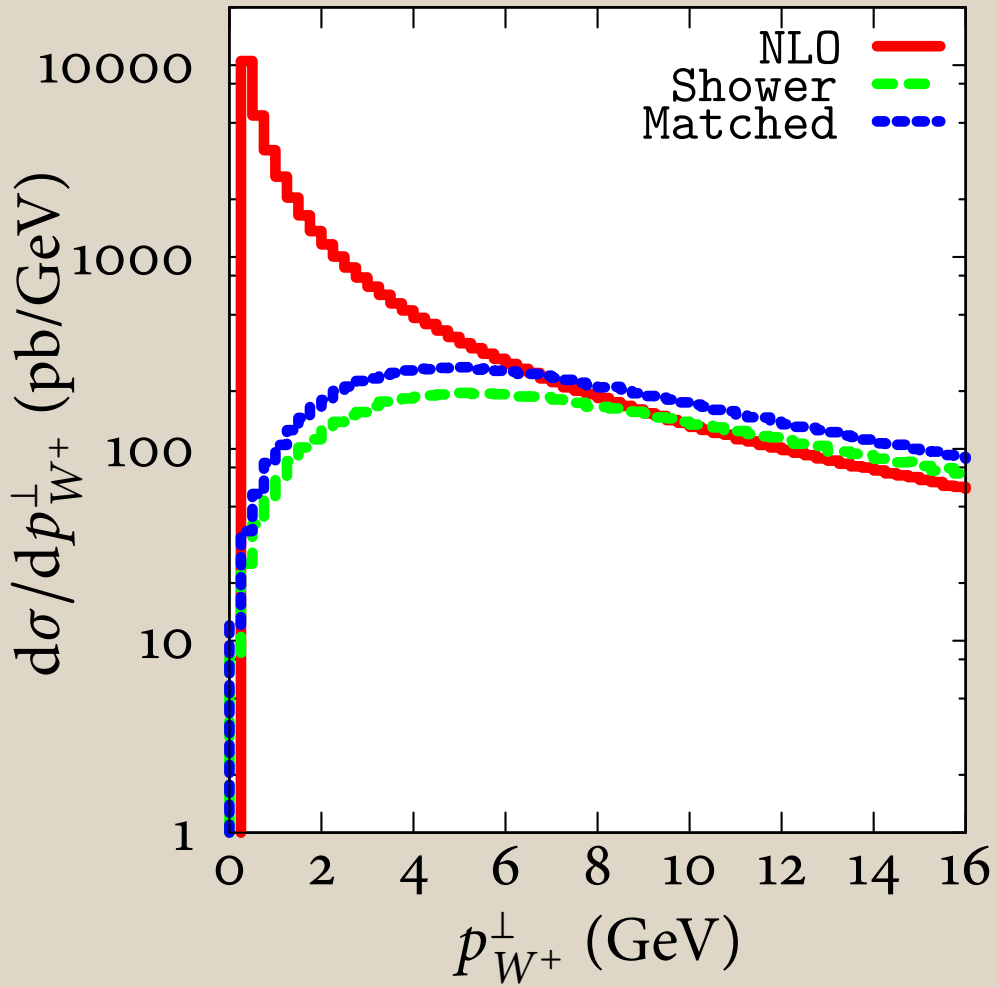
Matching QCD NLO w shower

Normalization at α_s Shapes of low $p_\perp$
Shapes of high $p_\perp$ Realistic events
Reduced dependence on $\mu_{R/F}$ ...

EW NLO w $n\gamma$

Normalization at α_{EW}
$\Delta M_W^{NLO} \sim 100$ MeV
$\Delta M_W^{n\gamma} \sim 10$ MeV





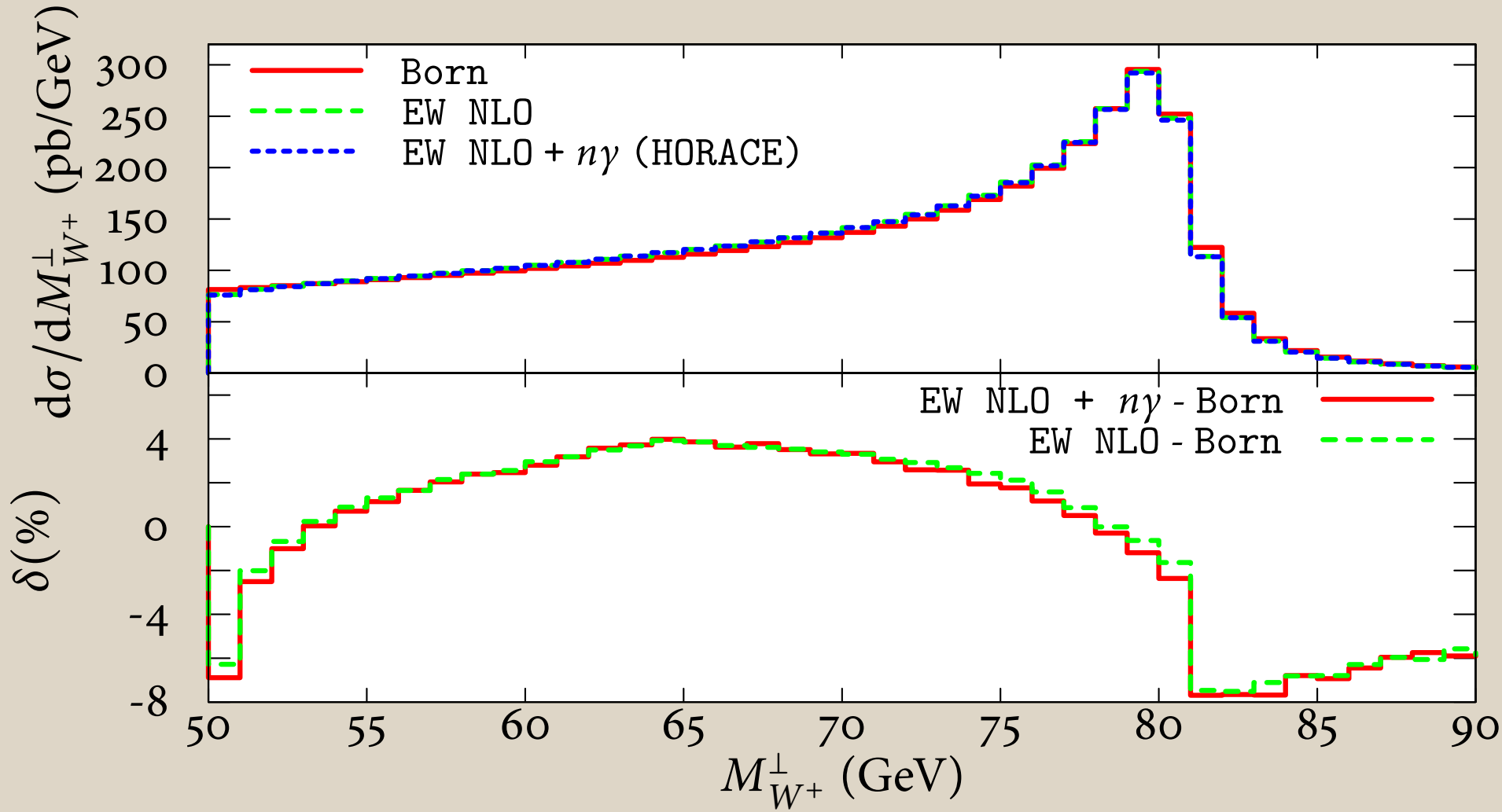
Matching QCD NLO w shower

Normalization at α_s — Shapes of low $p_\perp$
Shapes of high $p_\perp$ — Realistic events
Reduced dependence on $\mu_{R/F}$ — ...

EW NLO w $n\gamma$

Normalization at α_{EW}
$\Delta M_W^{NLO} \sim 100$ MeV
$\Delta M_W^{n\gamma} \sim 10$ MeV

Carloni & al. PRD69 (2004) 037301



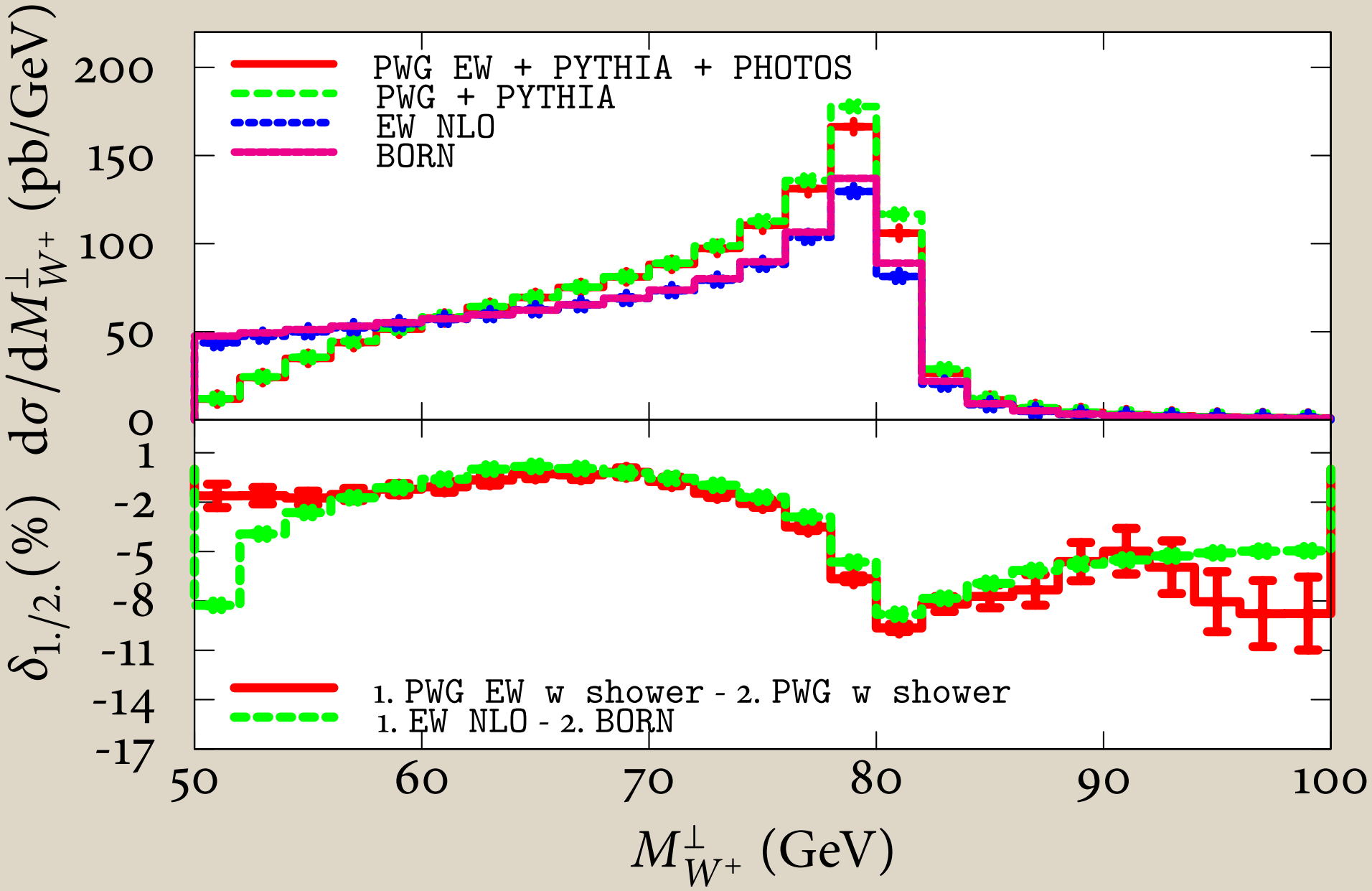
Exact NLO⊗shower corrections

$$\sigma = \sigma_0 + \sigma_{\alpha_s} + \sigma_{\alpha}$$
$$+ \sum_{n\geq 2} a_s^n \alpha_s^n L^{2n} + \ldots + \sum_{n\geq 2} a^n \alpha^n L^{2n} + \ldots$$
$$+ \sum_{n\geq 1, m\geq 1} a_s^n \alpha_s^n L^{2n} a^m \alpha^m L^{2m} + \ldots$$

- $O(\alpha_s)\otimes$QCD shower
  - POWHEG-BOX JHEP 1006 (2010) 043
  - (a)MC@NLO JHEP 0206 (2002) 029
  - SHERPA JHEP 04 (2011) 24
- $O(\alpha_{EW})\otimes$QED shower
  - HORACE JHEP 0612 (2006) 016
  - Z/WINHAC⊗SANC Acta Phys.Polon B40 (2009)
  - PHOTOS EPJC45:97-107,2006
- $O(\alpha_s)\otimes$QCD resummation$\oplus\gamma$FSR → RESBOSa PRL 93:042001(2004)
- $(O(\alpha_s) \oplus O(\alpha_{EW})) \otimes$ QE/CD shower → POWHEG-BOX
  W_ew-BMNNP JHEP 1204 (2012) 037 / arXiv:1302.4606
  W_ew-BW PRD85 (2012) 093003

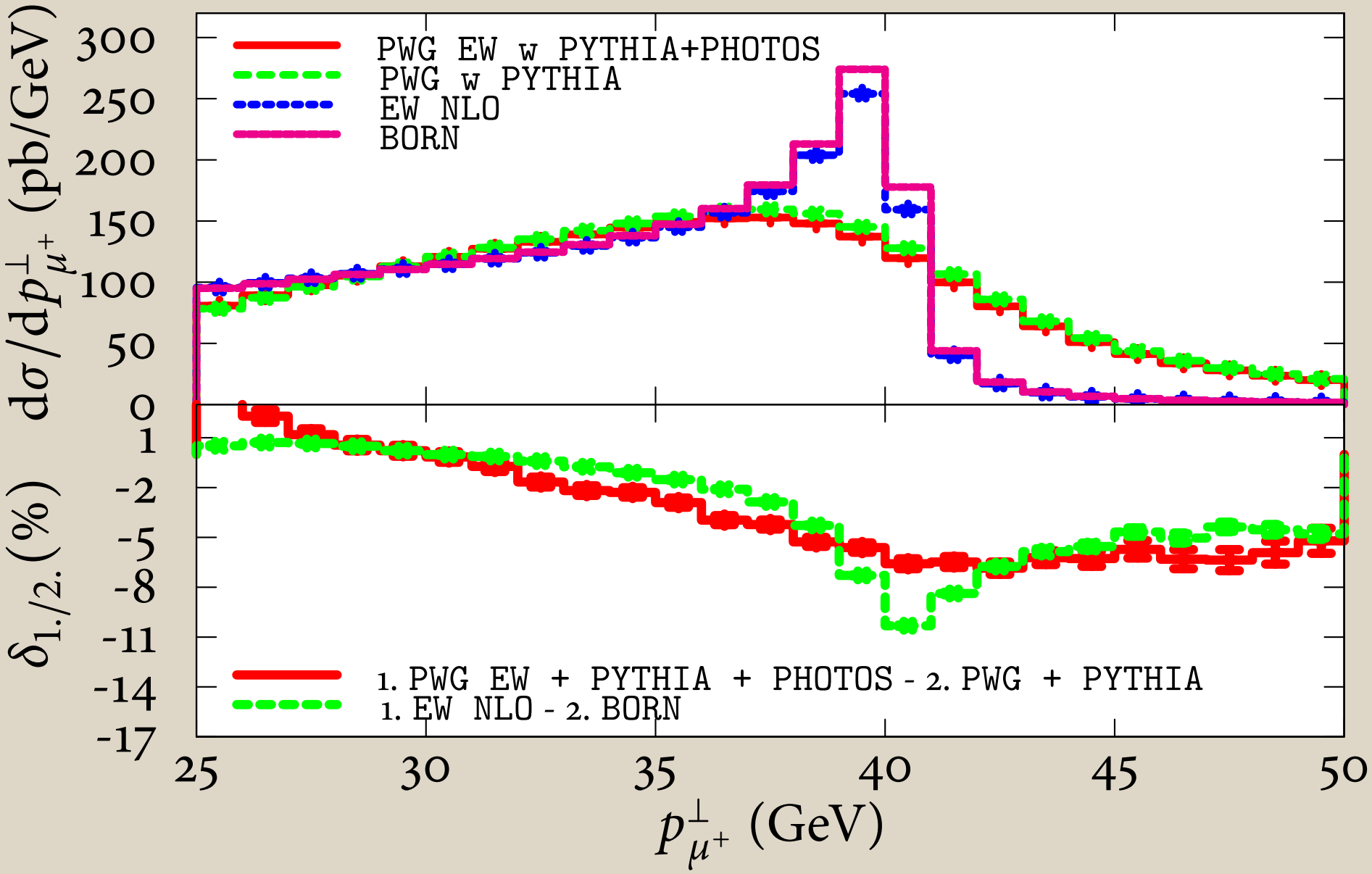
QCD⊗QED on inclusive observables

- Barzè & al. JHEP 1204 (2012) 037

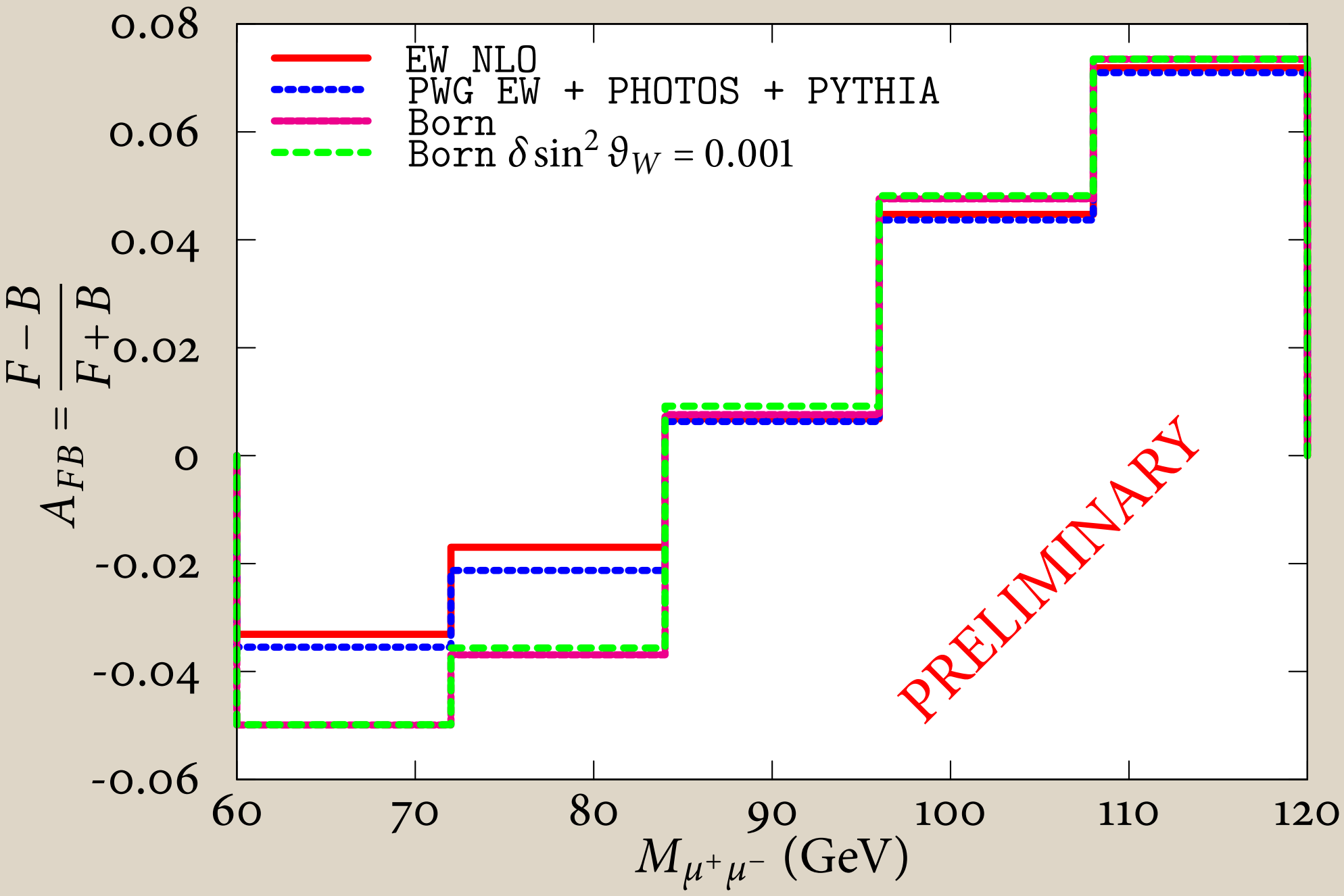


QCD⊗QED on exclusive observables

- Barzè & al. JHEP 1204 (2012) 037



Z Forward/Backward asymmetry $\Rightarrow \sin^2\vartheta_W$



Conclusions

- LHC will integrate a huge statistics
  $\rightarrow$ high precision EW measurements will be possible;
- QCD NLO and QCD Parton shower are fundamental to describe data;
- QCD NNLO is important on inclusive quantities (and in high $p_\perp$ tails);
- EW NLO and QED shower needed for precision physics
- for really precise measurements QCD$\otimes$QED not negligible;
  $\rightarrow$ estimate of effects on M_W and $\sin^2\vartheta_W$.

Conclusions

- LHC will integrate a huge statistics
  $\rightarrow$ high precision EW measurements will be possible;
- QCD NLO and QCD Parton shower are fundamental to describe data;
- QCD NNLO is important on inclusive quantities (and in high $p_\perp$ tails);
- EW NLO and QED shower needed for precision physics
- for really precise measurements QCD$\otimes$QED not negligible;
  $\rightarrow$ estimate of effects on M_W and $\sin^2\vartheta_W$.

THANK YOU!