Università degli Studi
di Milano

Istituto Nazionale
di Fisica Nucleare

Photon-induced contribution in lepton-pair production

Alessandro Vicini
University of Milano, INFN Milano

CERN PDF4LHC
September 4th 2008

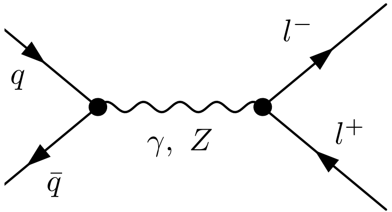
with: C. M. Carloni Calame, G. Montagna, O. Nicrosini, (HORACE)

G. Balossini, F. Piccinini, M. Moretti, M. Treccani

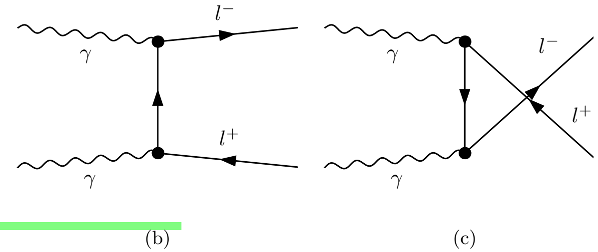
papers: CMCC, GM, ON, AV: JHEP 0612:016 (2006), JHEP 0710:109 (2007)

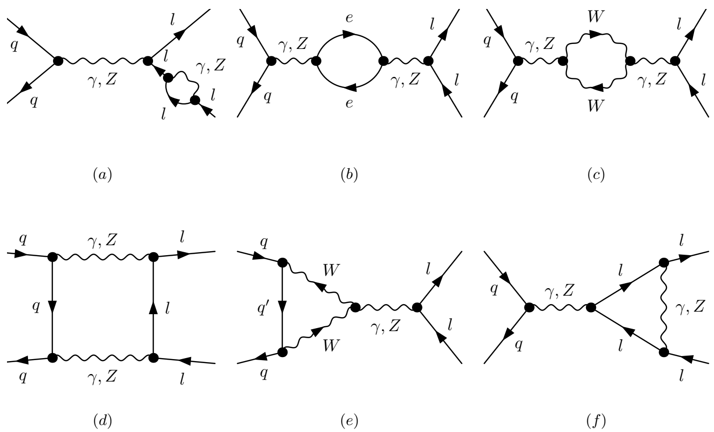
workshop proceedings: hep-ph/0604120 Les Houches, Physics at TeV colliders 2005
arXiv:0705.3251 TeV4LHC: top and EW working group
arXiv:0803.0678 Les Houches, Physics at TeV colliders 2007

The partonic process $p_i p_j \to l^+ l^- (1\gamma)$ at $\mathcal{O}(\alpha)$

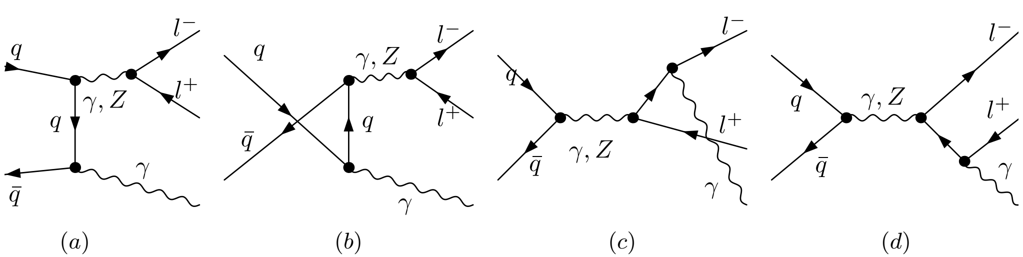


Born

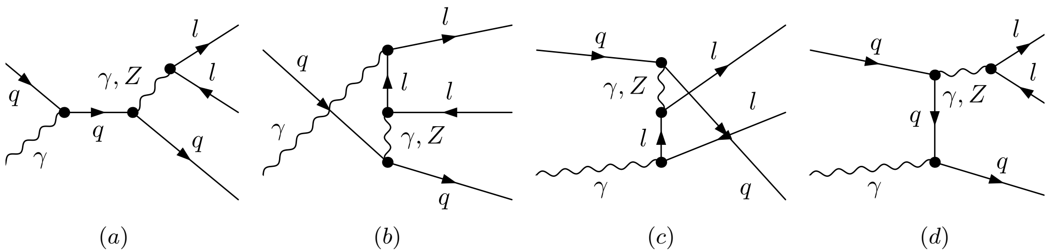




O(α) virtual



O(α) real bremsstrahlung



O(α) photon induced

The hadronic process $pp(p\bar{p}) \to l\bar{l}X$ at $\mathcal{O}(\alpha)$

$$\sigma(pp \to l\bar{l}X) = \sum_{a,b} \int_0^1 dx_1 dx_2 q_a(x_1) q_b(x_2) \hat{\sigma}\left(ab \to l\bar{l}(1\gamma)\right)$$

- Initial state QED radiation → collinear singularities
  that have to be factorized and reabsorbed in the *pdf*s

- QED interaction of the partons in the proton → photon density in the proton

- The consistent calculation of O(α) corrections to partonic subprocesses, with at least one quark/photon in the initial state, requires
  - subtraction of initial state collinear divergences
  - use of *pdf*s whose evolution kernel includes QED effects

- The hadronic cross-section must be independent of the regulator used for the collinear singularities

- Which is the impact of: additional QED evolution of quark densities
  additional partonic subprocesses

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$$q_a(x) \to q_a(x, M^2) - \Delta q_a(x, M^2)$$

$$\Delta q_i(x, M^2) = \int_x^1 dz \; q_i\left(\frac{x}{z}, M^2\right) \frac{\alpha}{2\pi} Q_i^2 \left[P_{q\to q\gamma}(z)\left(\log\left(\frac{M^2}{m_i^2}\right) - 2\log(1-z) - 1\right)\right]_+ + f_q(z)$$
$$+ \; q_\gamma\left(\frac{x}{z}, M^2\right) \frac{\alpha}{2\pi} Q_i^2 \left[P_{\gamma\to q\bar{q}}(z)\left(\log\left(\frac{M^2}{m_q^2}\right)\right)\right] + f_\gamma(z) \qquad (3.3)$$
$$\Delta q_\gamma(x, M^2) = \sum_{i=q,\bar{q}} \int_x^1 dz \; q_i\left(\frac{x}{z}, M^2\right) \frac{\alpha}{2\pi} Q_i^2 \left[P_{q\to\gamma q}(z)\left(\log\left(\frac{M^2}{m_i^2}\right) - 2\log(1-z) - 1\right)\right]_+ + \bar{f}(z)$$

☺ generalization to the multiple emission case: in each emission the leading singularity is removed
the integrated cross-section is independent of the initial state quark masses

Check: Total cross-section for different values of the initial state quark masses (CC channel)

Including exact $\mathcal{O}(\alpha)$ corrections

M_up	2053.07±0.22 (pb)
M_up / 50	2053.09±0.23 (pb)
M_up / 100	2052.98±0.24 (pb)

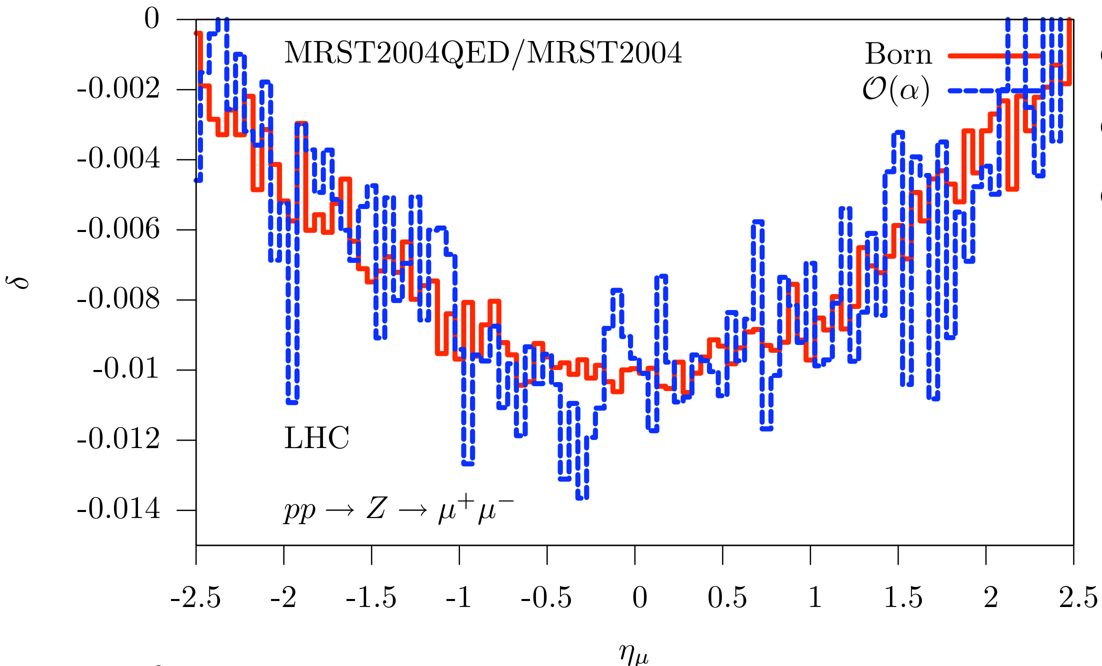
Best we can: $\mathcal{O}(\alpha)$ matched with parton-shower

M_up	2053.48±0.28 (pb)
M_up / 50	2053.73±0.32 (pb)
M_up / 100	2053.38±0.35 (pb)

Z observables: only q-qbar processes MRST2004QED vs MRST2004

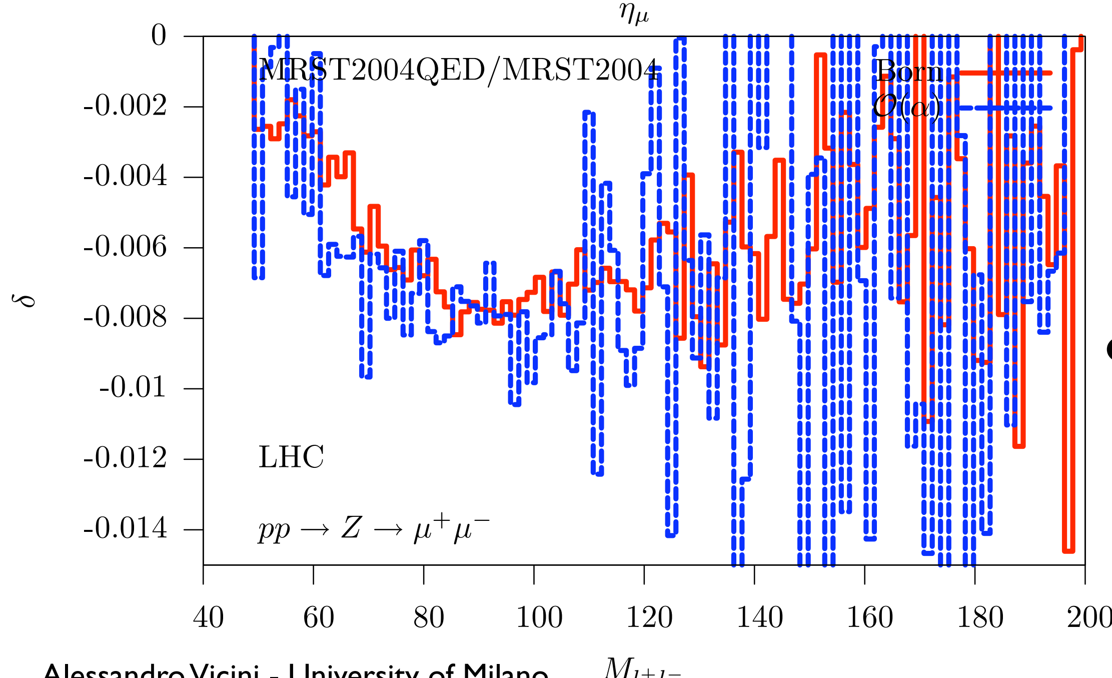
Preliminary

δ = MRST2004QED/MRST2004 -1



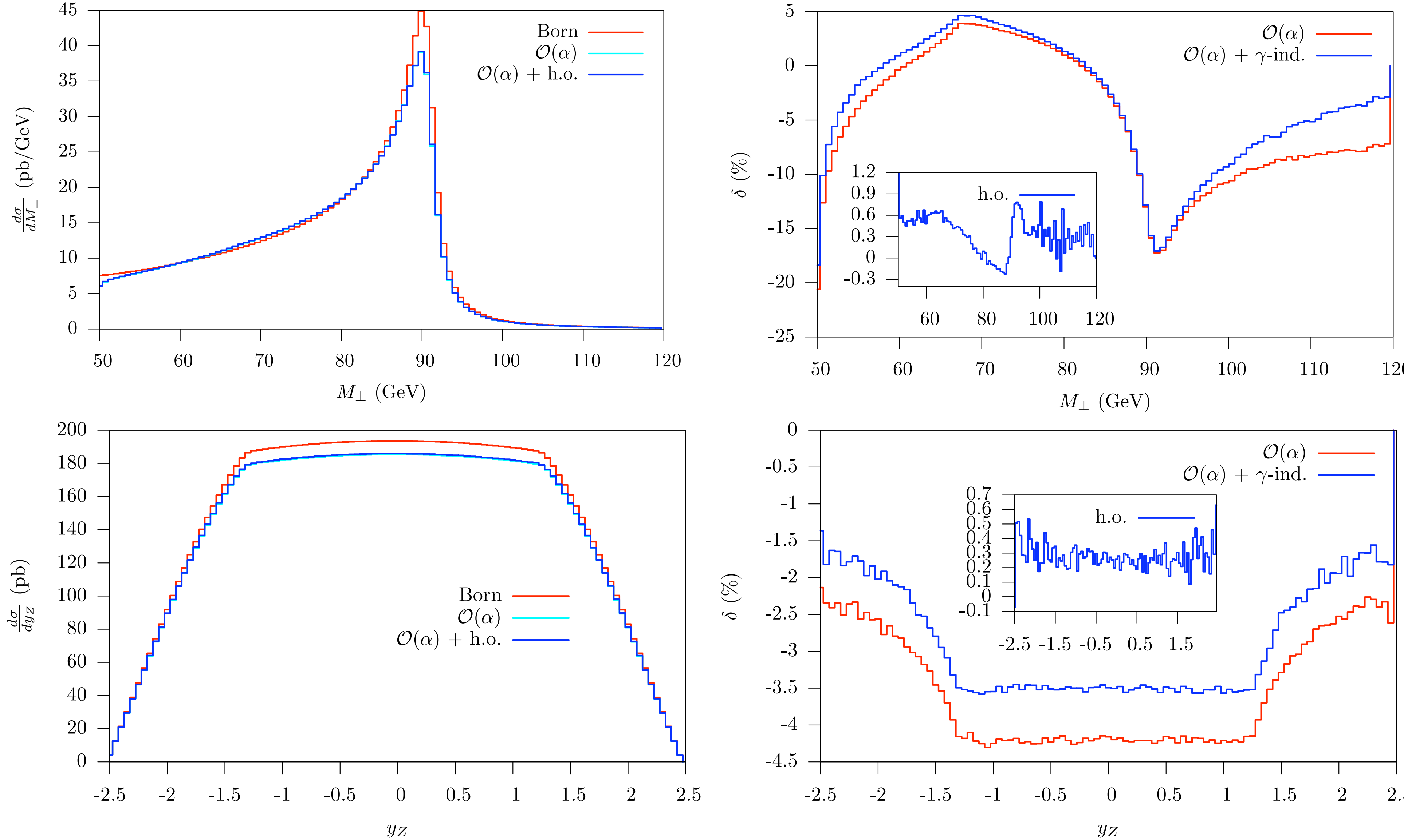
- effects at the several per mille level
- they are not flat
- the total cross-section changes by almost 1 %

	σ_tot (pb)
MRST2004	717(1)
MRST2004QED	712(1)



- at O(α) only the use of MRST2004QED is consistent

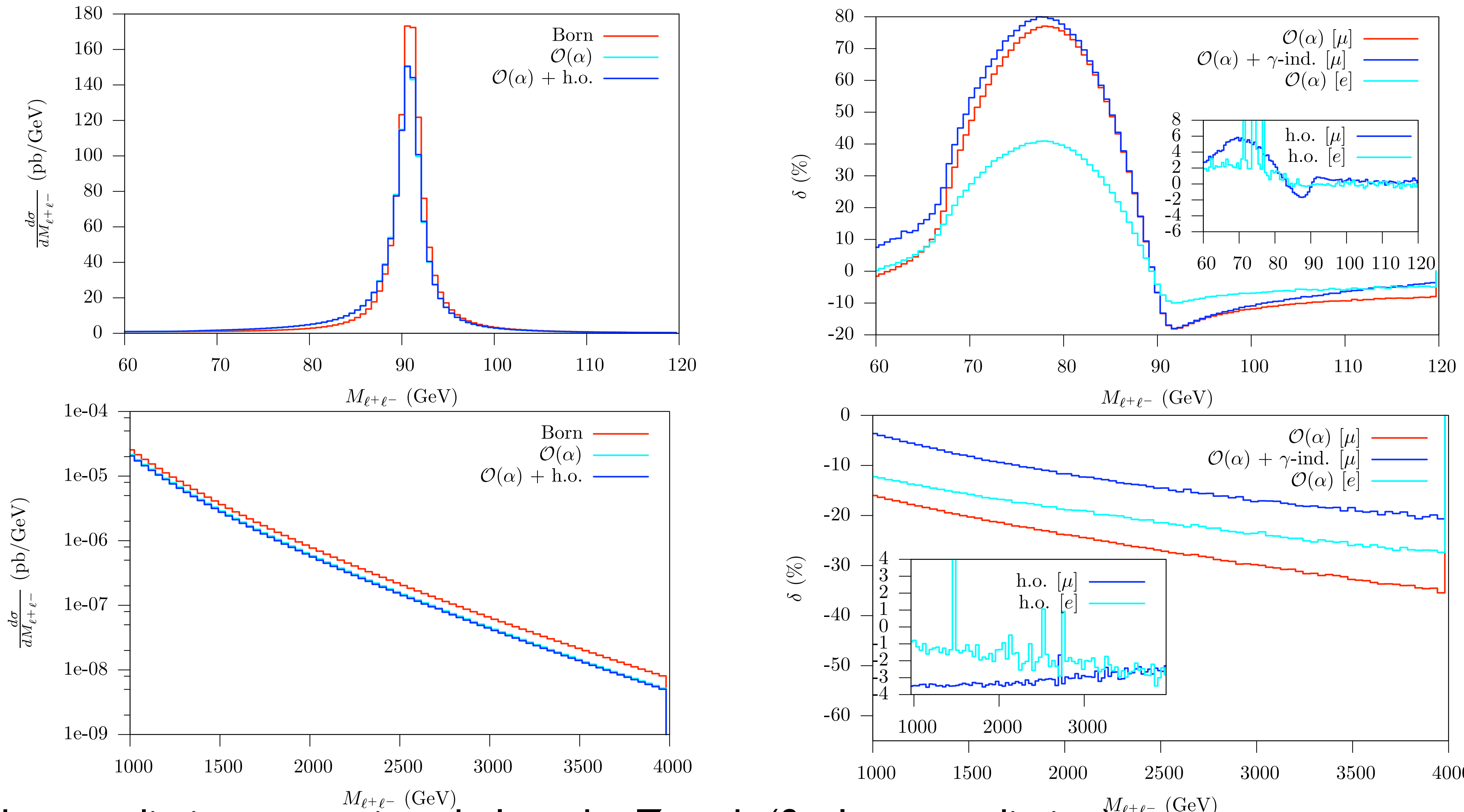
Z observables: transverse mass and Z rapidity distributions



- above the Z peak, not negligible effect of the photon-induced processes

- Z rapidity: QED h.o. and photon-induced contribute at the several per mille level

Z observables: invariant mass distribution (LHC)



- huge radiative corrections below the Z peak (final state radiation)
  low invariant mass lepton pairs important e.g. in SUSY searches
- in the large mass tail, large negative corrections (EW Sudakov logs)
  not negligible effect of (tree-level) photon-induced subprocess

Combining QCD and EW corrections

in collaboration with C. M. Carloni Calame, G. Balossini, G. Montagna, O. Nicrosini, F. Piccinini, M. Moretti, M. Treccani

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- Additive combination of QCD and EW corrections:

$$\left[\frac{d\sigma}{d\mathcal{O}}\right]_{QCD\oplus EW} = \left\{\frac{d\sigma}{d\mathcal{O}}\right\}_{QCD} + \left\{\left[\frac{d\sigma}{d\mathcal{O}}\right]_{EW} - \left[\frac{d\sigma}{d\mathcal{O}}\right]_{Born}\right\}_{HERWIG\ PS}$$

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- QCD = ALPGEN (with CKKM-MLM Parton Shower matching), ResBos-CSS, MC@NLO, FEWZ, MCFM

- EW = HORACE interfaced with HERWIG QCD Parton Shower

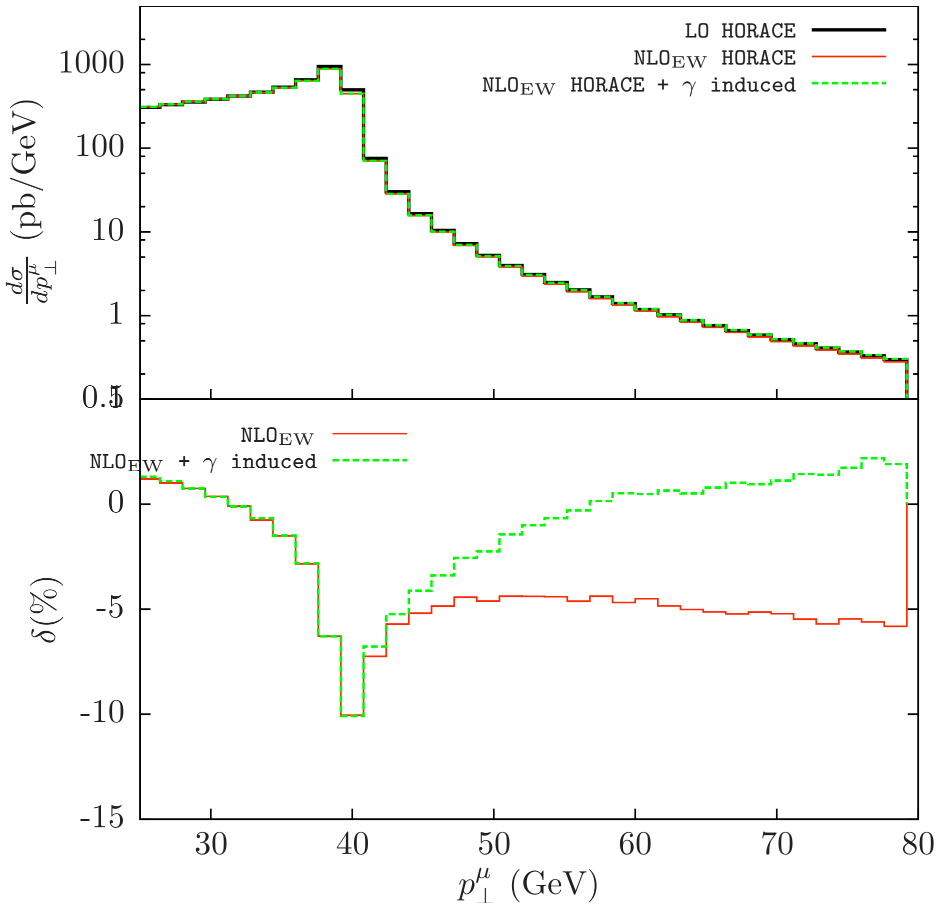
NLO-EW corrections convoluted with QCD PS ⇒ inclusion of $\mathcal{O}(\alpha\alpha_s)$ terms

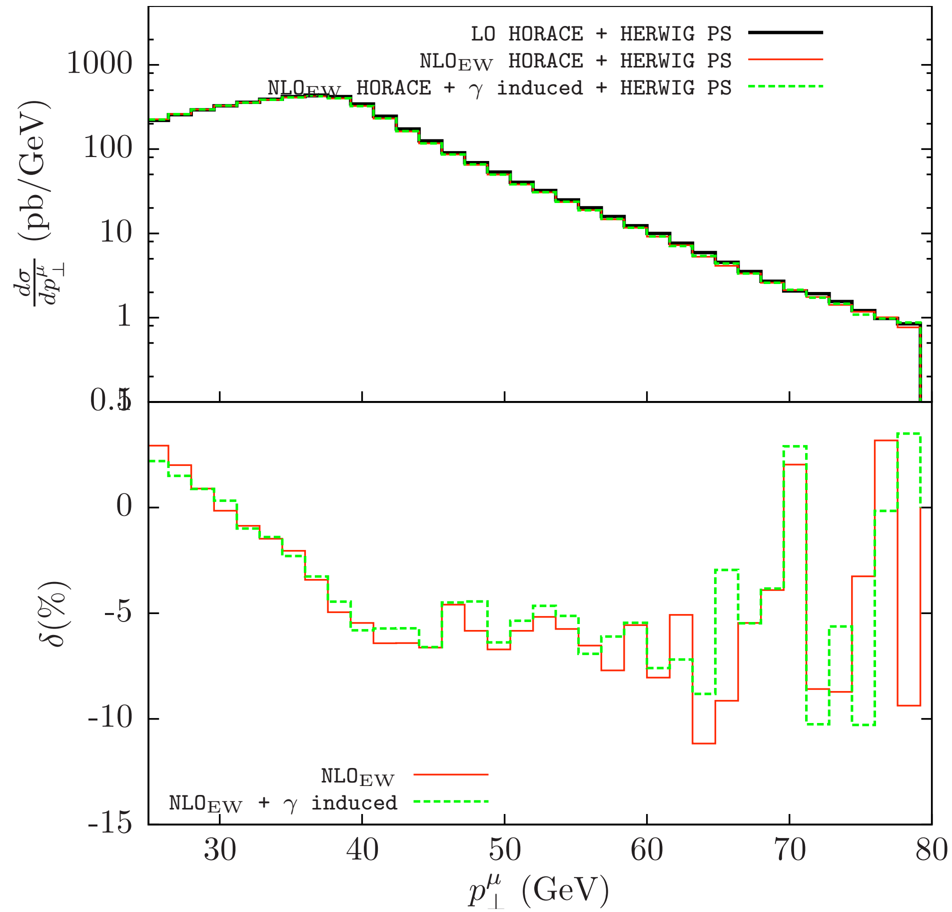
not reliable when hard non collinear radiation is important

➜ a full 2-loop $\mathcal{O}(\alpha\alpha_s)$ calculation is needed

see: J.H. Kühn, A.Kulesza, S.Pozzorini, M.Schulze, hep-ph/0703283
W. Hollik, T.Kasprzik, B.A. Kniehl, arXiv:0707.2553

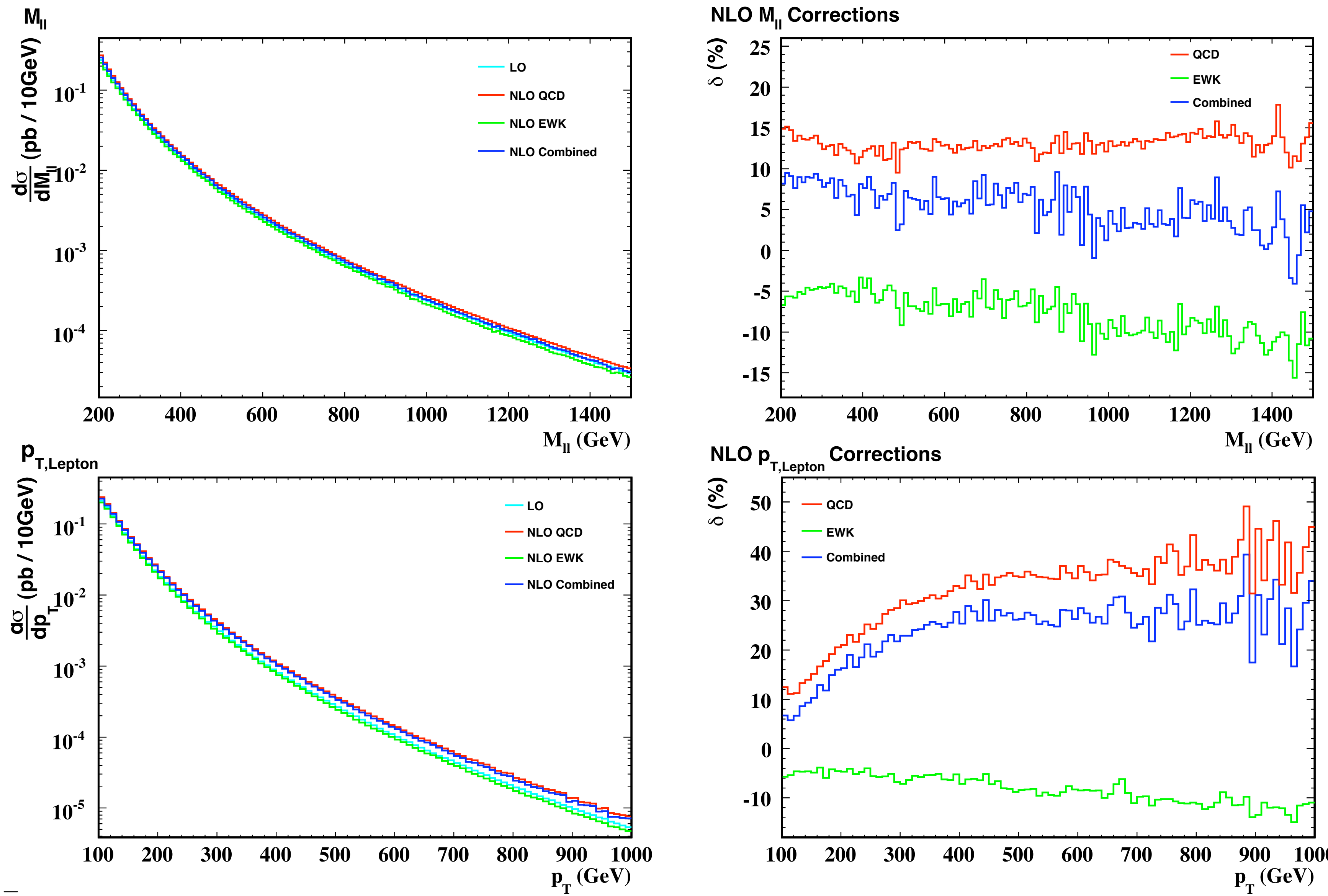
W precision physics: QCD+EW,   parton shower effects, CC-DY





- the EW corrections at the W resonance are responsible for a shift of MW of order 100 MeV
- the convolution with QCD Parton Shower modifies the relative effect and shape of the EW corrections
- the effect of the photon induced process disappear after the convolution with the Parton Shower

QCD+EW @ the LHC: $M_{inv}^{e^+e^-}$ and $p_\perp^e$ distributions   Les Houches 2007



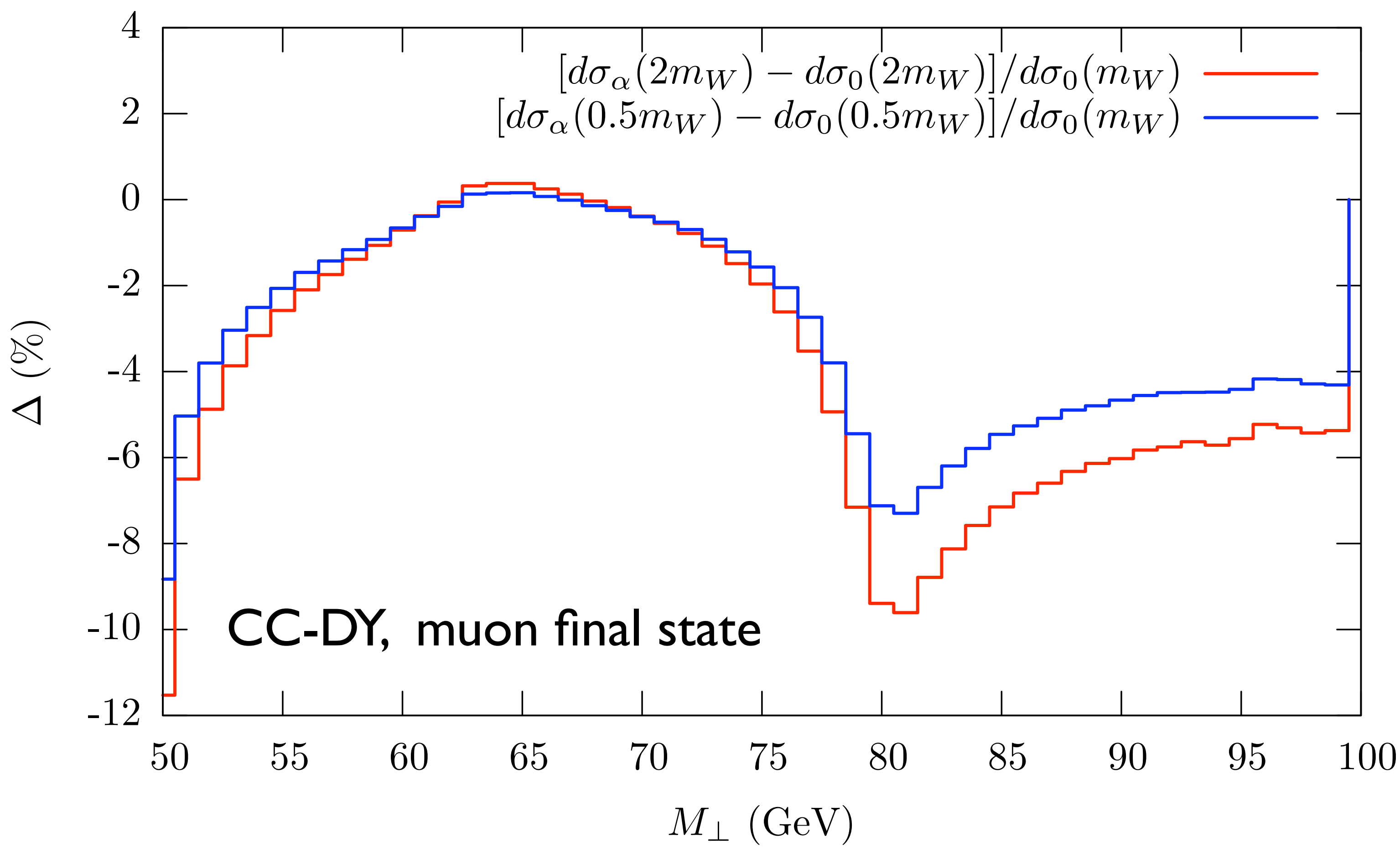
$M_{inv}^{l^+l^-} > 200\text{GeV}$

The negative effect of virtual EW Sudakov logs is partially cancelled by the inclusion of undetected real Z boson emission (U. Baur, Phys.Rev.D75 (2007) 013005)

Relevant to set correct limits on the searches for heavy gauge bosons

NLO-EW corrections and *pdf*'s QCD factorization scale change

- a NLO-EW calculation is LO-QCD →
  the Born is stabilized when including NLO- and NNLO-QCD corrections
  the pure O(α) corrections suffer of "large" QCD factorization scale variation effects



Conclusions

- impact of the QED evolution of the quark *pdf*s at the several per mille level on DY total cross-section and distributions

- photon-induced subprocesses give a positive contribution to cross-sections
  contribute to inclusive signatures (like real Z emission)

- impact of extra photon-induced subprocesses relevant in all the kinematical regions where resonance diagrams are not dominant
  - well below the Z resonance (SUSY searches)
  - large invariant/transverse mass tail (new heavy gauge bosons)

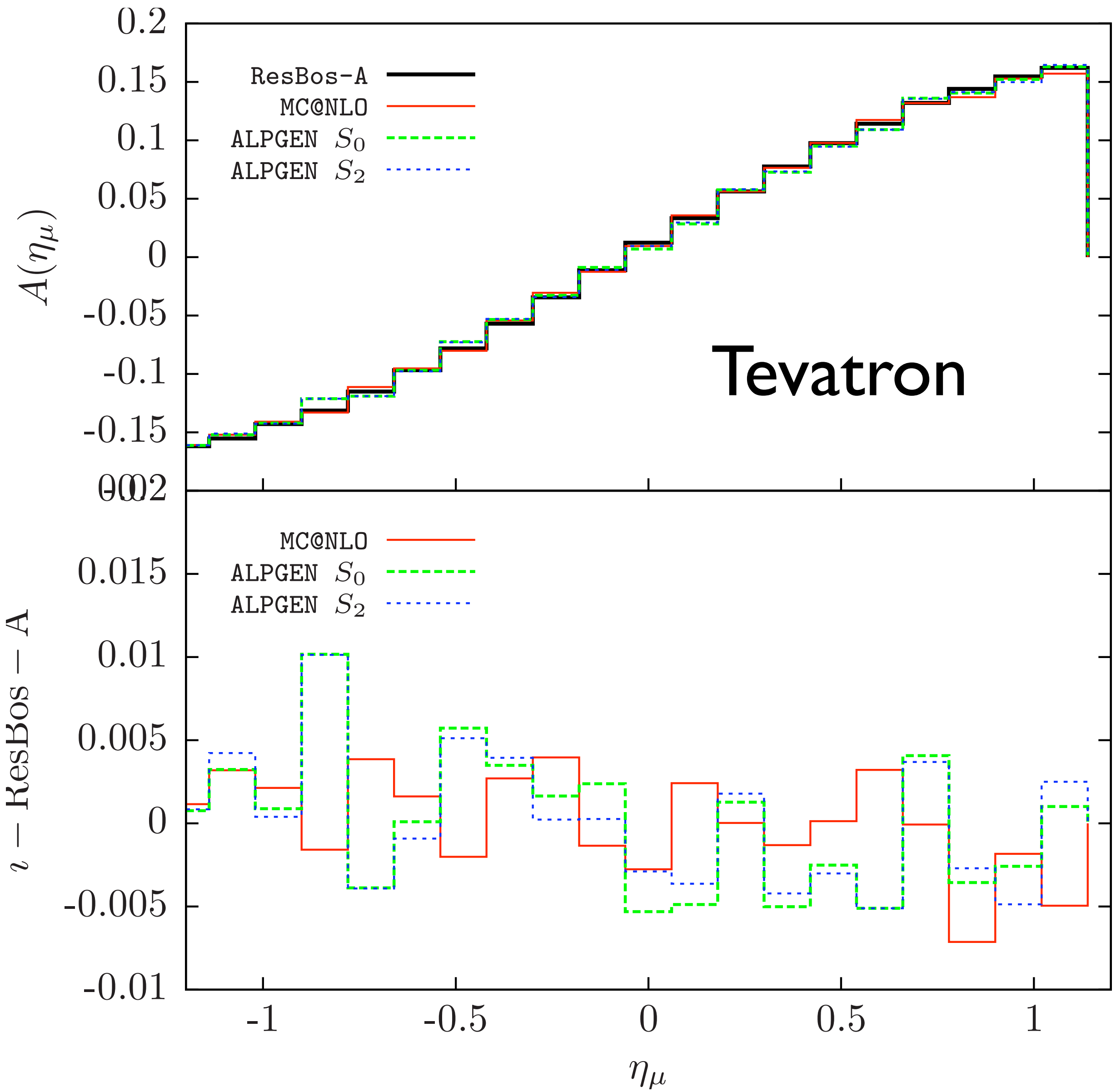
- realistic description of the EW effects on any observable only after convolution with QCD parton shower → many effects are washed away

- Which is the stability of NLO-EW corrections under a change of the *pdf*'s QCD factorization scale?

Extra slides

pdf constraining: Charge asymmetry

$$A(\eta_\mu) = \frac{d\sigma^+/d\eta_\mu - d\sigma^-/d\eta_\mu}{d\sigma^+/d\eta_\mu + d\sigma^-/d\eta_\mu}$$



Stability of the prediction w.r.t. different generators

The asymmetry is large and changes sign

pdf constraining: Charge asymmetry

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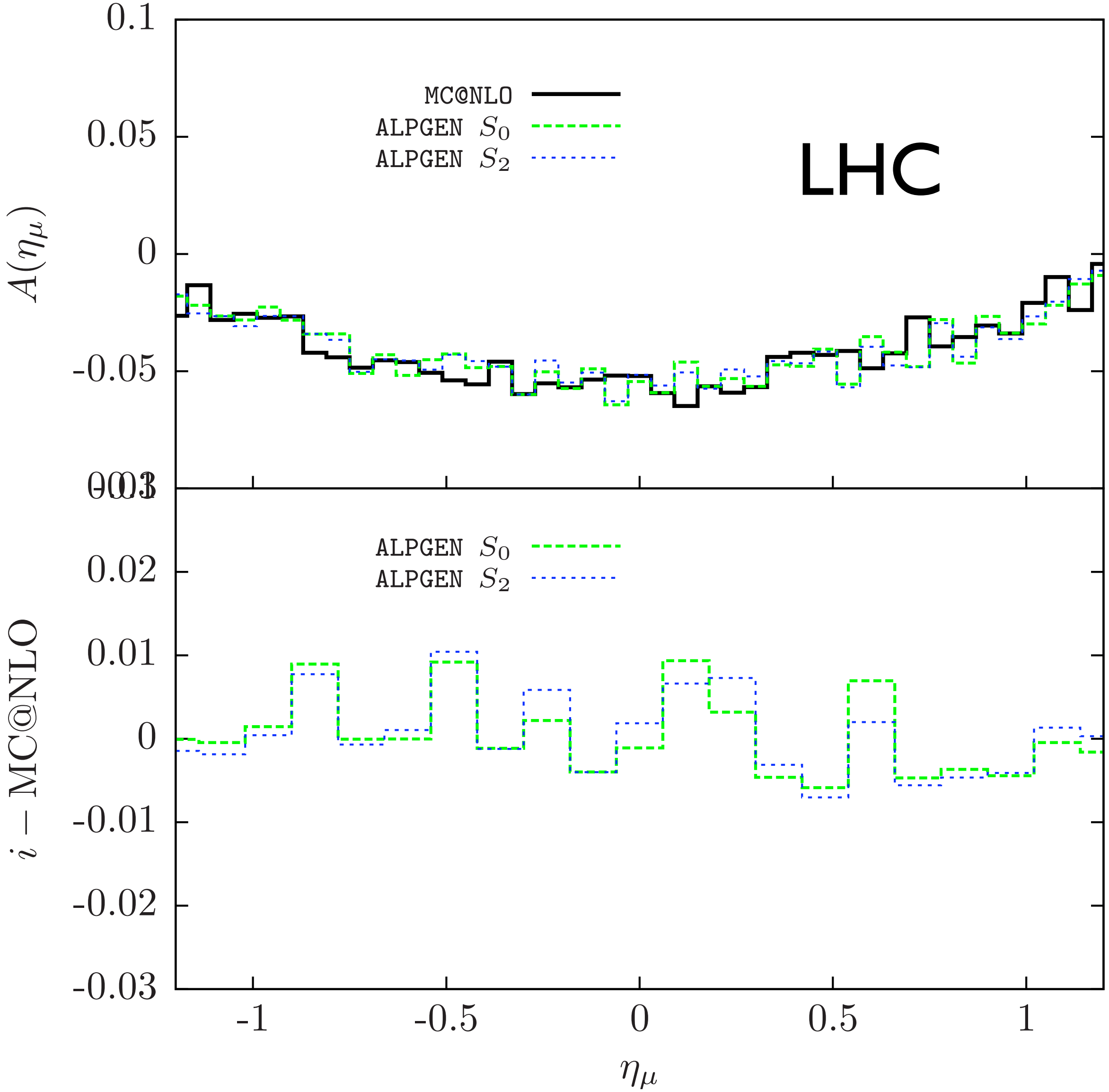
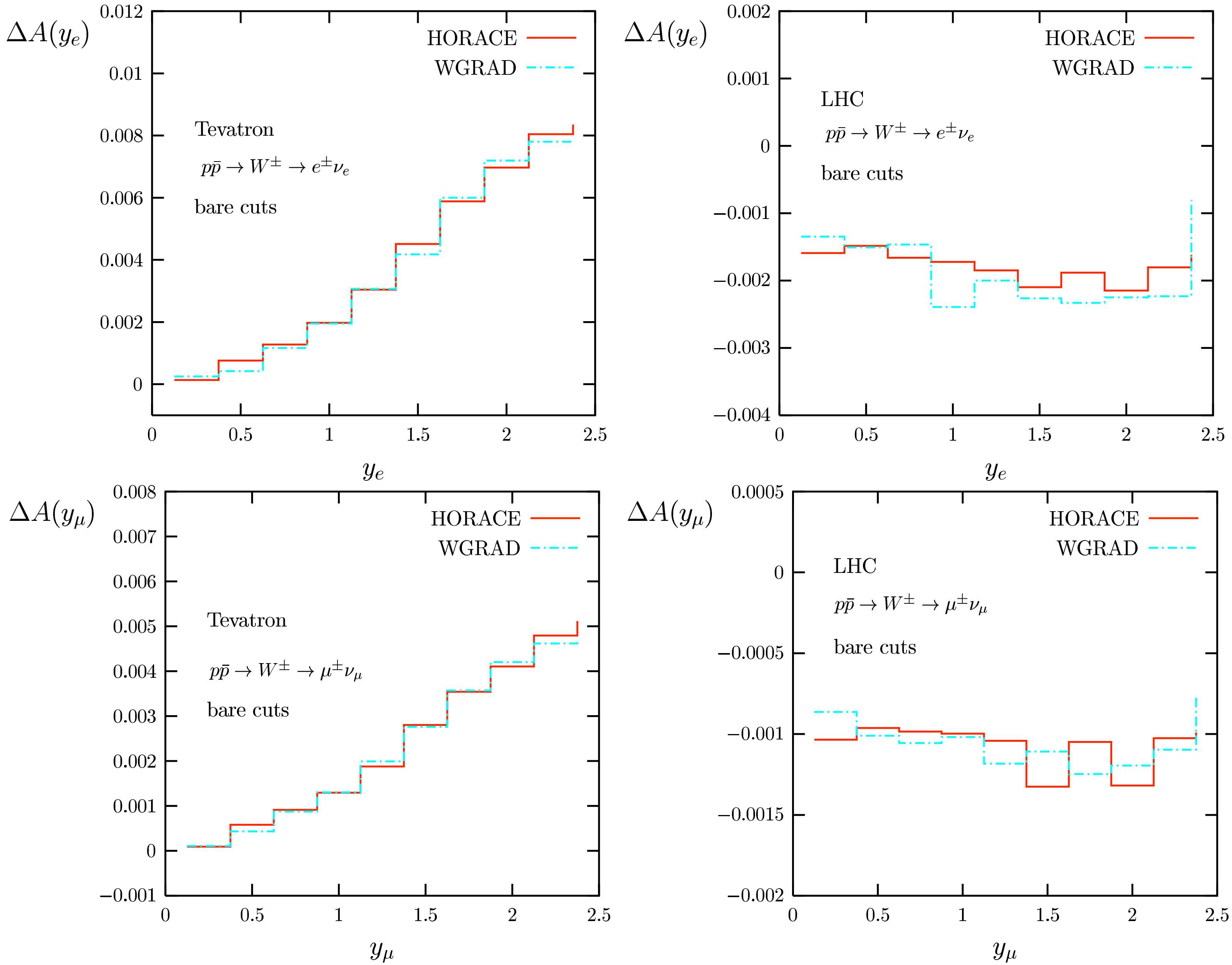


good agreement of MC@NLO and ALPGEN

The asymmetry is smaller than at the Tevatron and always negative

pdf constraining: Charge asymmetry

(TEV4LHC workshop)



O(α) EW effects are moderate in size and well under control.

Multiple photon emission is negligible