Università degli Studi
di Milano

INFN
Istituto Nazionale
di Fisica Nucleare

Drell-Yan processes at hadron colliders

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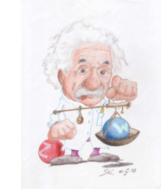
meeting of the American Physical Society
division of Particles and FIelds

Detroit, July 28th 2009

Drell-Yan processes and precision physics



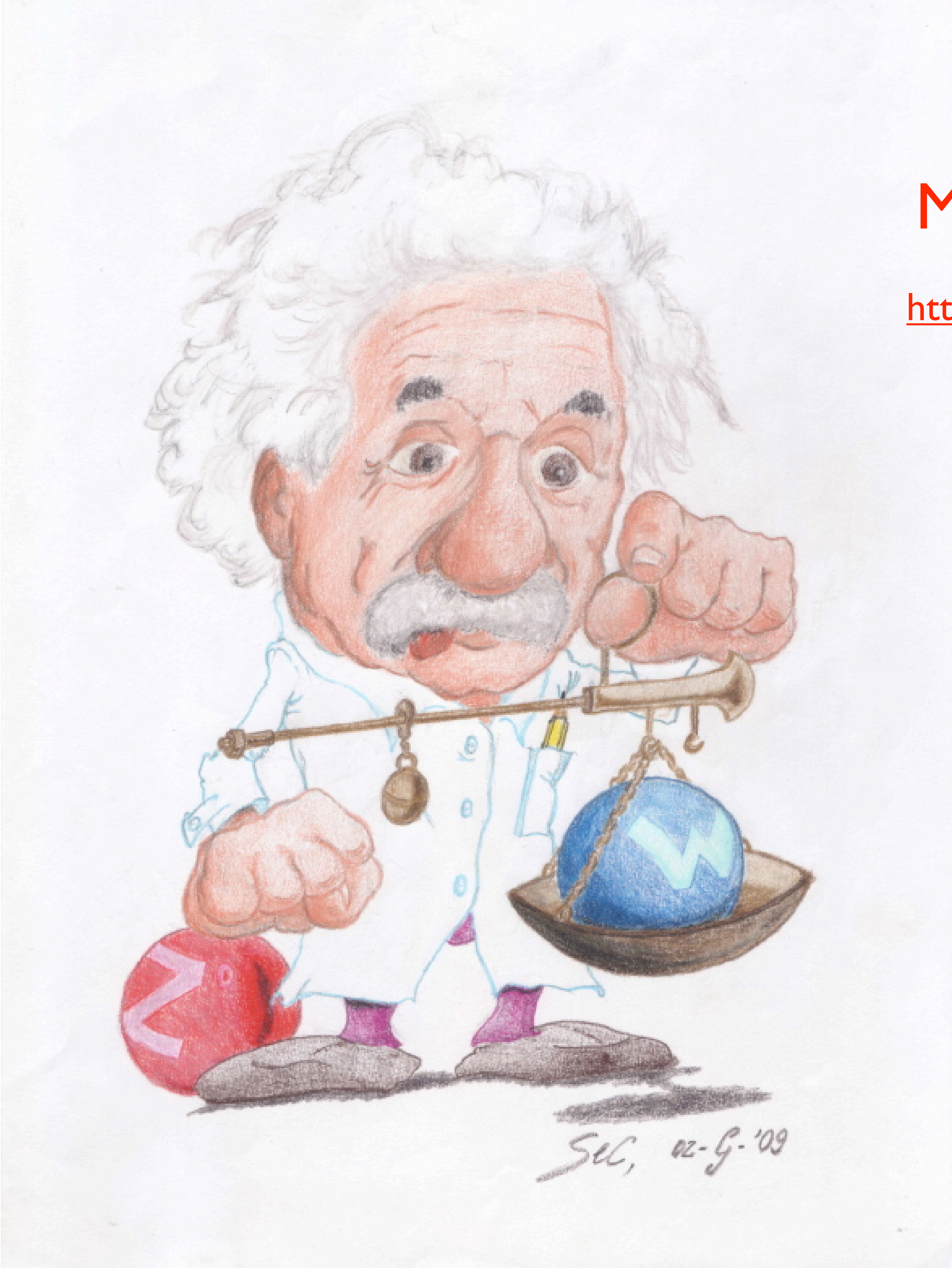
- High precision measurement of EW parameters
- Important constraint of the proton PDF parametrization
- Promising tool to monitor the collider lumonisity
- Relevant background to searches of New Physics signals

Outline

- introduction

- fixed order results (QCD and EW)
- multiple gluon/photon emission
- matched results at NLO (QCD and EW)
- interplay of QCD and EW corrections

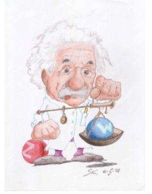
- uncertainties on W mass

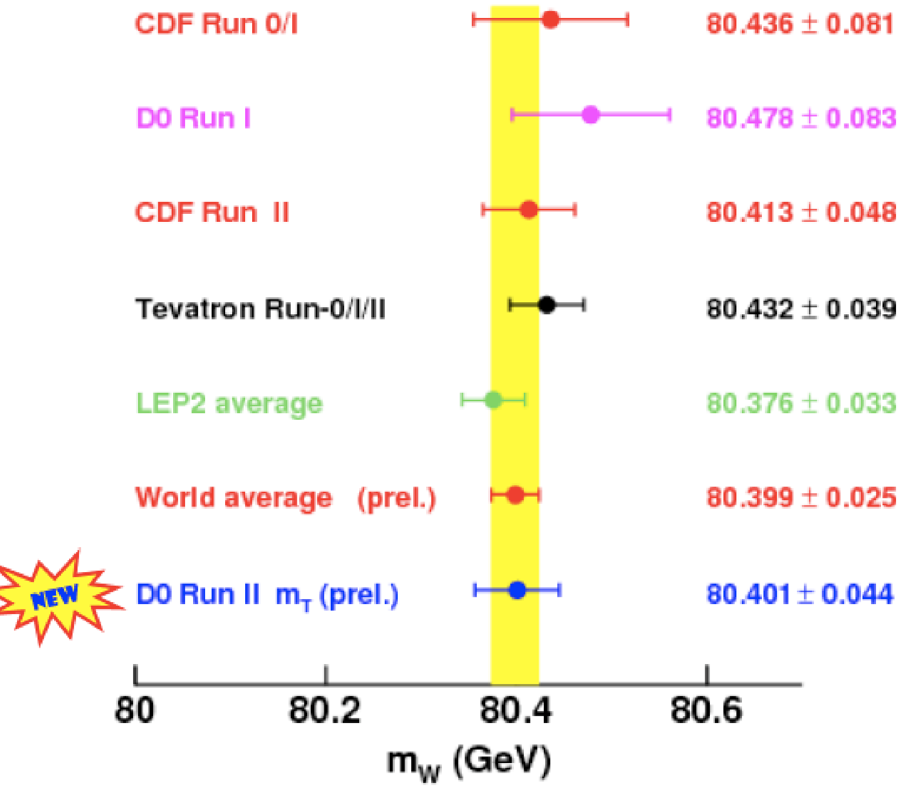


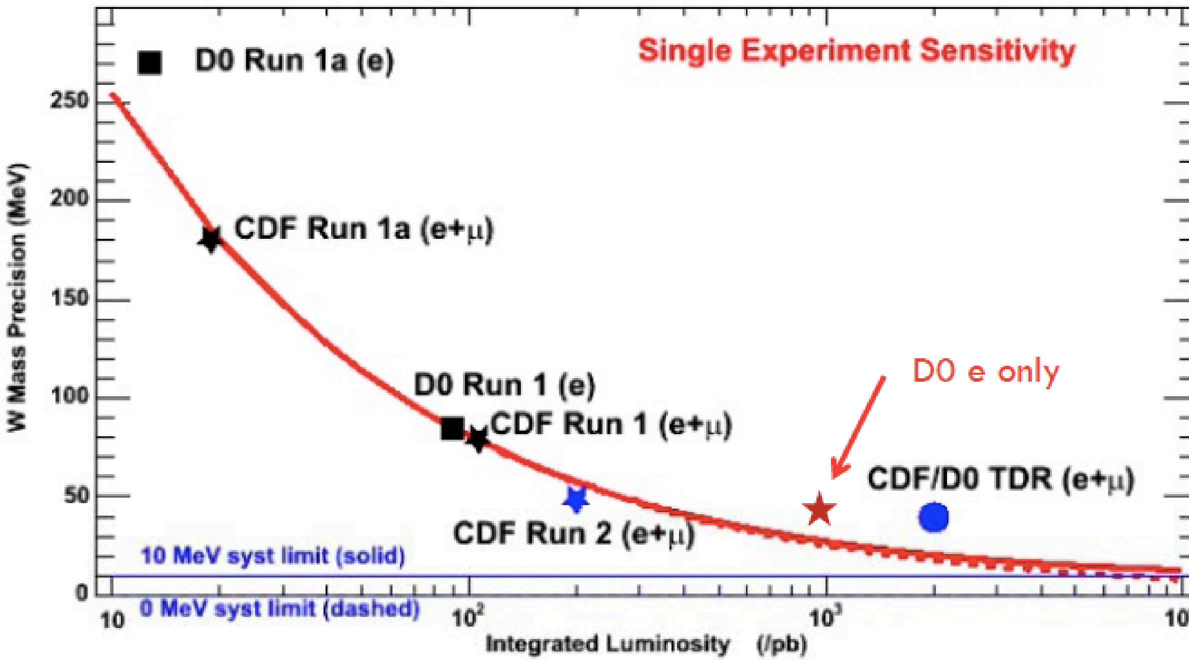
W mass workshop
Milano, March 17-18 2009

http://wwwteor.mi.infn.it/~vicini/wmass.html

A real challenge



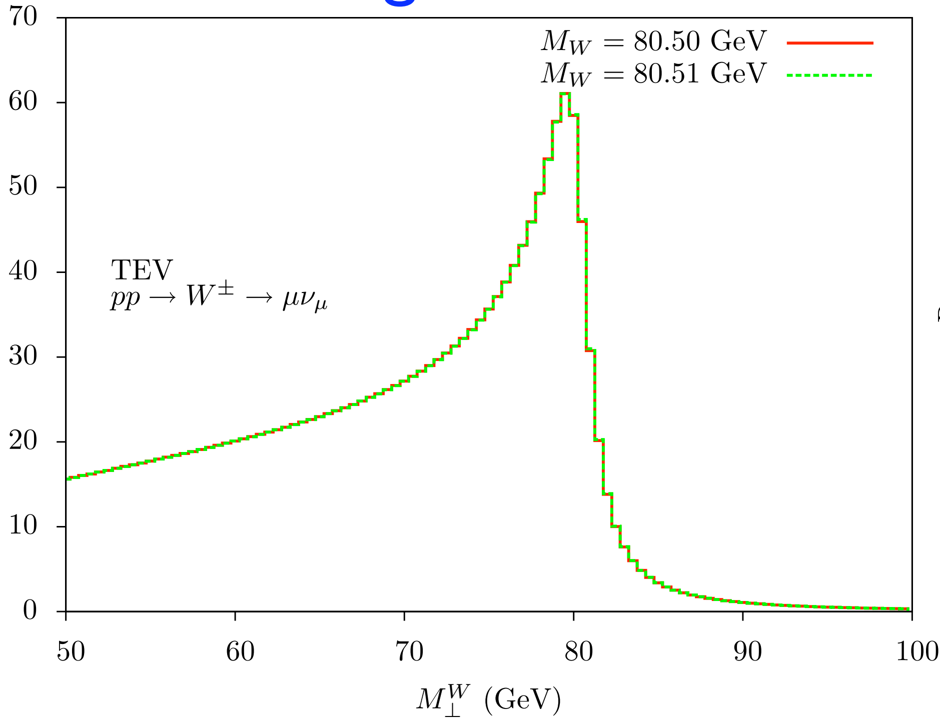


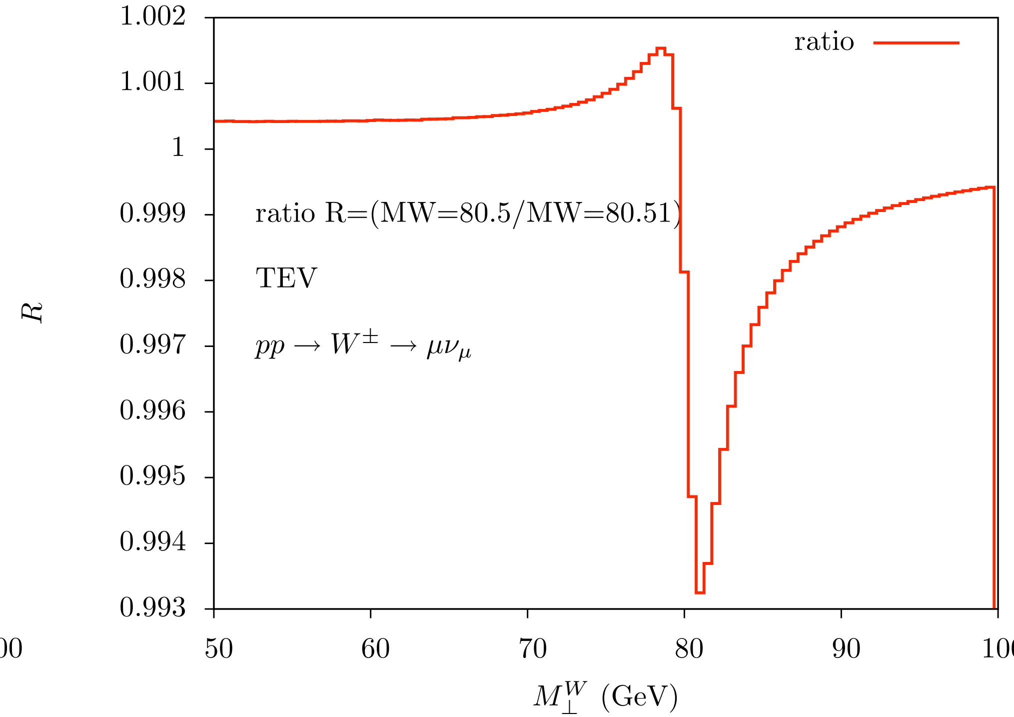


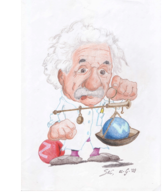
Final Tevatron error on MW:~15 MeV ?

J.Zhu, arXiv:0907.3239

A real challenge II







The ratio of two distributions generated with nominal MW which differ by 10 MeV shows a deviation from unity at the level of few per mille, with non trivial shape

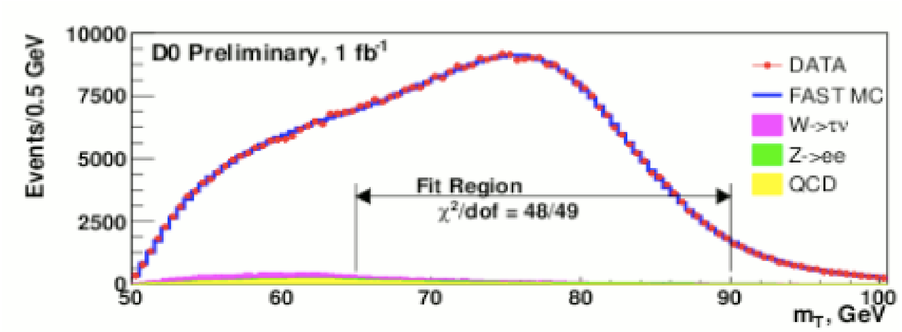
in turn

If we aim at measuring MW with 10-15 MeV of error, are we able to control the shape of the distributions and the theoretical uncertainties at the few per mille level?

Not all the radiative corrections have the same impact on the MW measurement
not all the uncertainties are equally bad on the final error

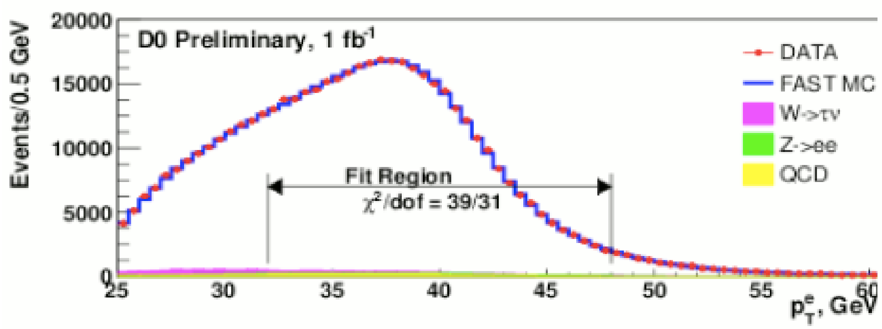
Relevant distribution for the W mass measurement

jacobian peak at the value of the physical W mass

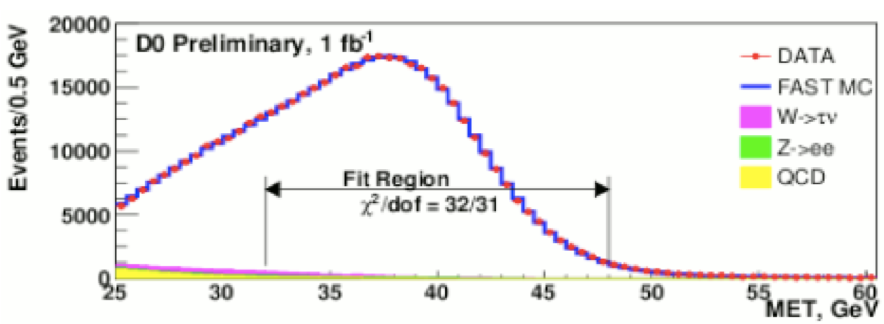


W transverse mass

$$M_\perp^W = \sqrt{2 p_\perp^l p_\perp^\nu \, (1 - \cos \phi_{l\nu})}$$



lepton transverse momentum



missing transverse momentum

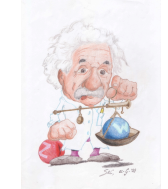
The simulation of the missing transverse momentum requires
a detailed knowledge of the QCD radiation to all orders

Open questions

cfr M.Lancaster talk in Milano workshop

- general estimate of QCD uncertainties (e.g. missing NNLO)
- uncertainties in the PT(W) description
- validation of different algorithms to combine QCD and QED effects
- impact of (ISR-) QED radiation on the PT(W,Z) determination
- *pdfs* uncertainties
- validation of the description of higher order EW (mostly QED) effects

Radiative corrections and simulation tools: fixed order QCD



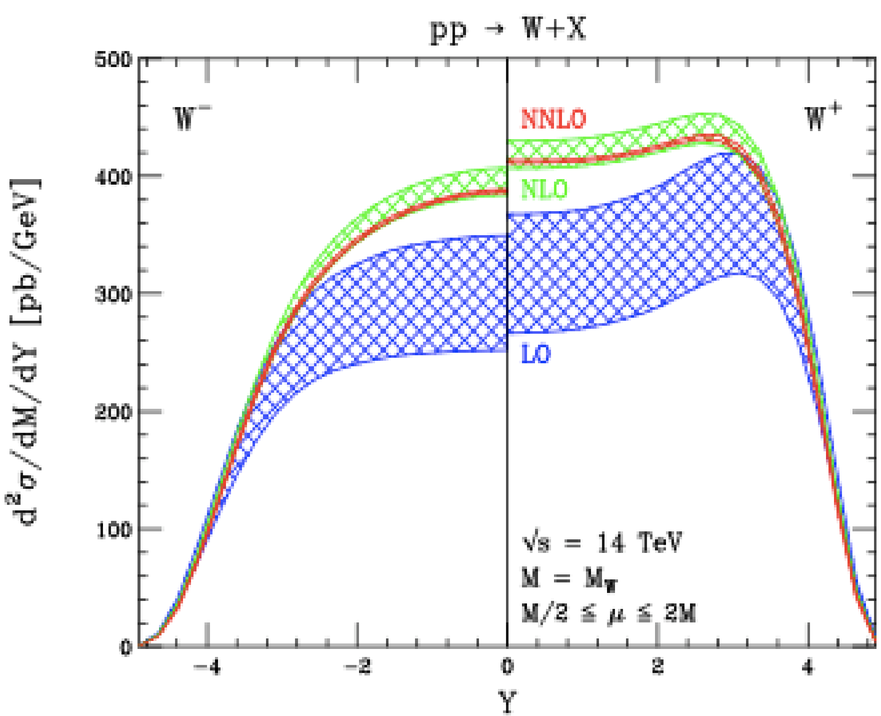
G. Altarelli, R.K.Ellis, G. Martinelli, Nucl.Phys.. **B157** (1979) 461
G. Altarelli, R.K.Ellis, M. Greco, G. Martinelli, Nucl.Phys.. **B246** (1984) 12 — NLO total

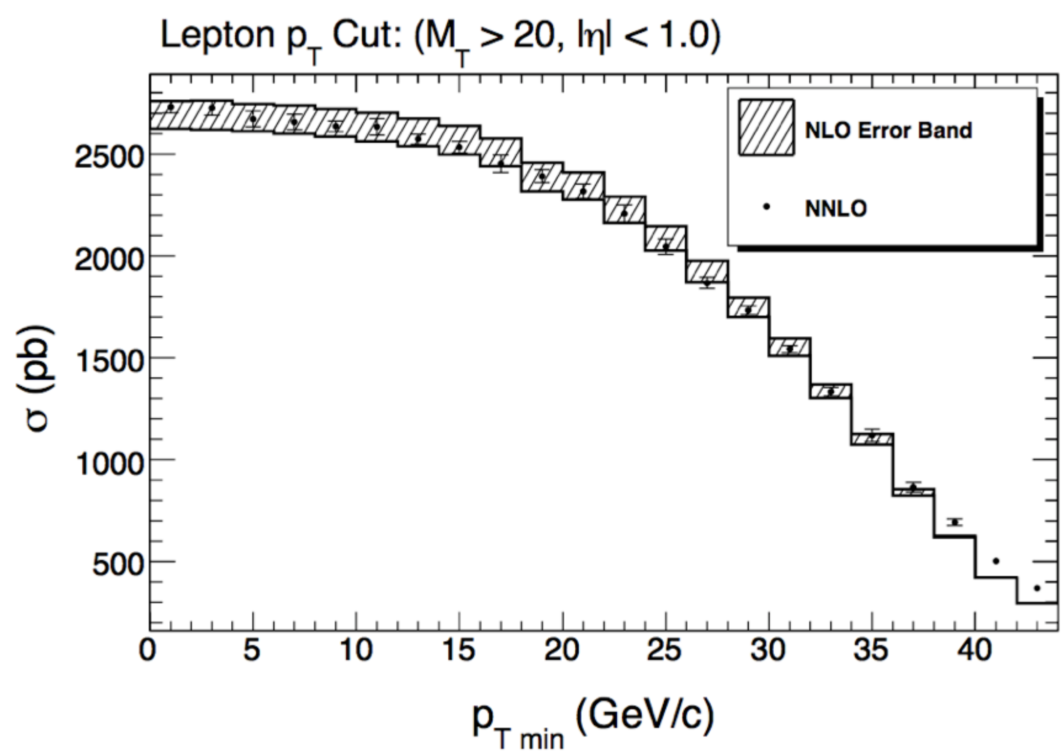
R. Hamberg, W. L. van Neerven, T. Matsuura, Nucl.Phys. **B359** (1991) 343
W. L. van Neerven and E.B. Zijstra, Nucl.Phys. **B382** (1992) 11 — NNLO total

J. M. Campbell and R.K. Ellis, Phys.Rev.**D65** (2002) 113007 — MCFM — NLO differential

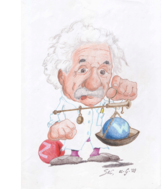
C. Anastasiou, L.J. Dixon, K. Melnikov, F. Petriello., Phys.Rev. **D69** (2004) 094008
K. Melnikov and F. Petriello, Phys.Rev. **D74** (2006) 114017 — NNLO differential

FEWZ





Radiative corrections and simulation tools: fixed order EW



W production

Pole approximation — D.Wackeroth and W. Hollik, PRD 55 (1997) 6788
U.Baur et al., PRD 59 (1999) 013002

Exact O(α) — V.A. Zykunov et al., EPJC 3 (2001) 9
S. Dittmaier and M. Krämer, PRD 65 (2002) 073007 — DK
U. Baur and D. Wackeroth, PRD 70 (2004) 073015 — WGRAD2
A. Arbuzov et al., EPJC 46 (2006) 407 — SANC
C.M.Carloni Calame et al., JHEP 0612:016 (2006) — HORACE

Photon-induced processes — S. Dittmaier and M. Krämer, Physics at TeV colliders 2005
C.M.Carloni Calame et al., JHEP 0612:016 (2006) — HORACE
A. B.Arbuzov and R.R.Sadykov, arXiv:0707.0423 — SANC

Z production

only QED — U.Baur et al., PRD 57 (1998) 199

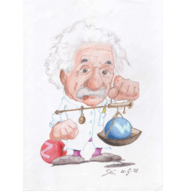
Exact O(α) — U.Baur et al., PRD 65 (2002) 033007 — ZGRAD2
V.A. Zykunov et al., PRD75 (2007) 073019
C.M.Carloni Calame et al., JHEP 0710:109 (2007) — HORACE

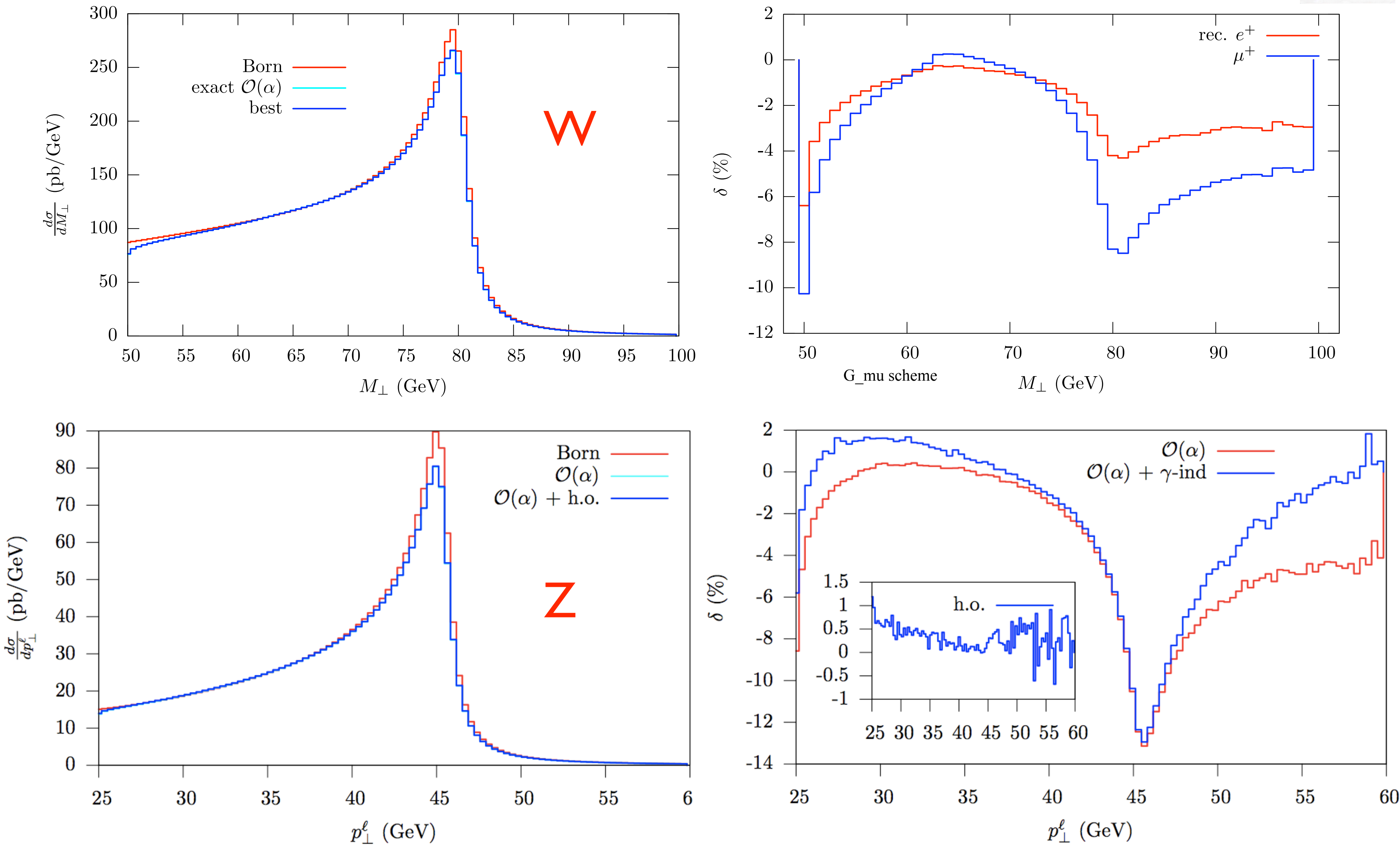
Photon-induced processes — C.M.Carloni Calame et al., JHEP 0710:109 (2007) — HORACE

Tuned comparisons

Les Houches 2005 — hep-ph/0604120
TeV4LHC workshop — arXiv:0705.3251
Les Houches 2007 — arXiv: 0803.0678

Radiative corrections and simulation tools: fixed order EW





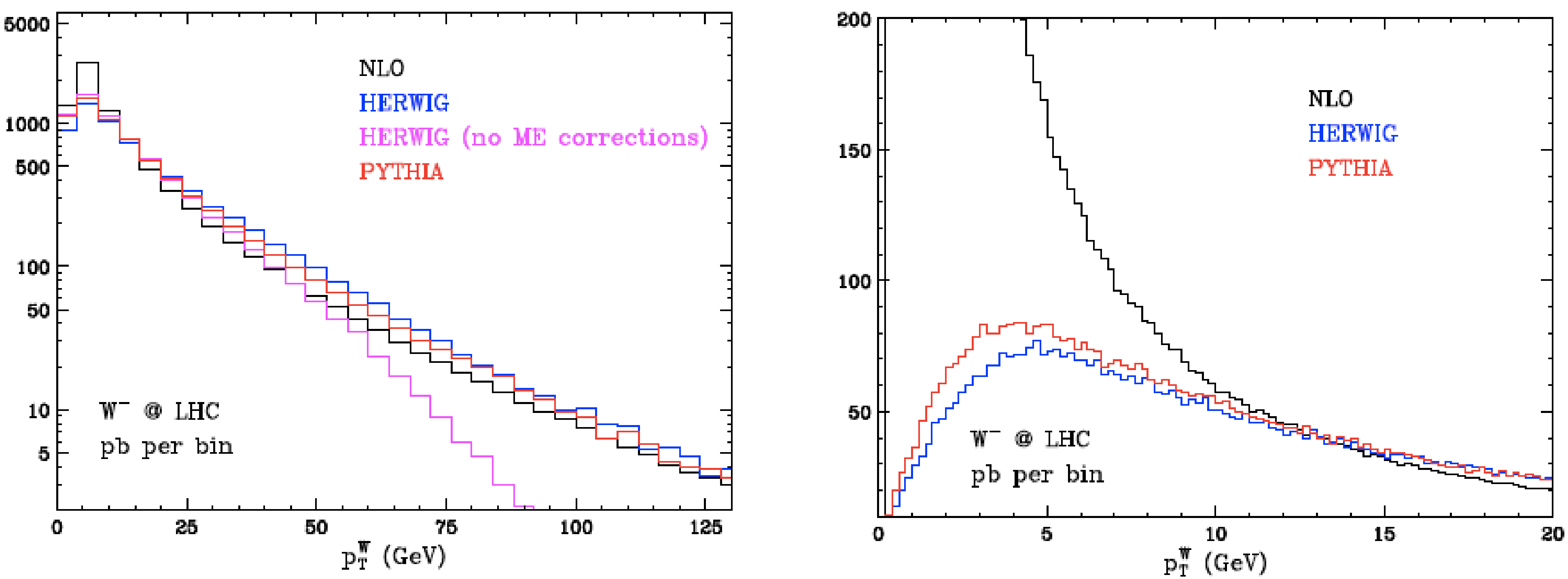
Simulation tools: QCD multiple emissions

HERWIG G. Marchesini, B.R.Webber, G.Abbiendi, I.G.Knowles, M.Seymour, L.Stanco, Comp.Phys.Commun.67 (1992) 465
G.Corcella, I.G.Knowles, G.Marchesini, S.Moretti, K.Odagiri, P.Richardson, M.H.Seymour, B.R.Webber, JHEP 0101:010,2001

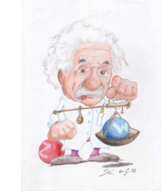
PYTHIA T.Sjostrand, S.Mrenna, P.Skands, JHEP 0605:026,2006

Resbos no Y-term
G.A. Ladinsky, C.-P. Yuan, Phys.Rev.D50:4239,1994.
C. Balazs, C.-P. Yuan, Phys.Rev.D56:5558-5583,1997.
F. Landry, R. Brock, P.M. Nadolsky, C.-P. Yuan, Phys.Rev.D67:073016,2003

W^- @ LHC, no K-factors



Simulation tools: QED multiple emissions



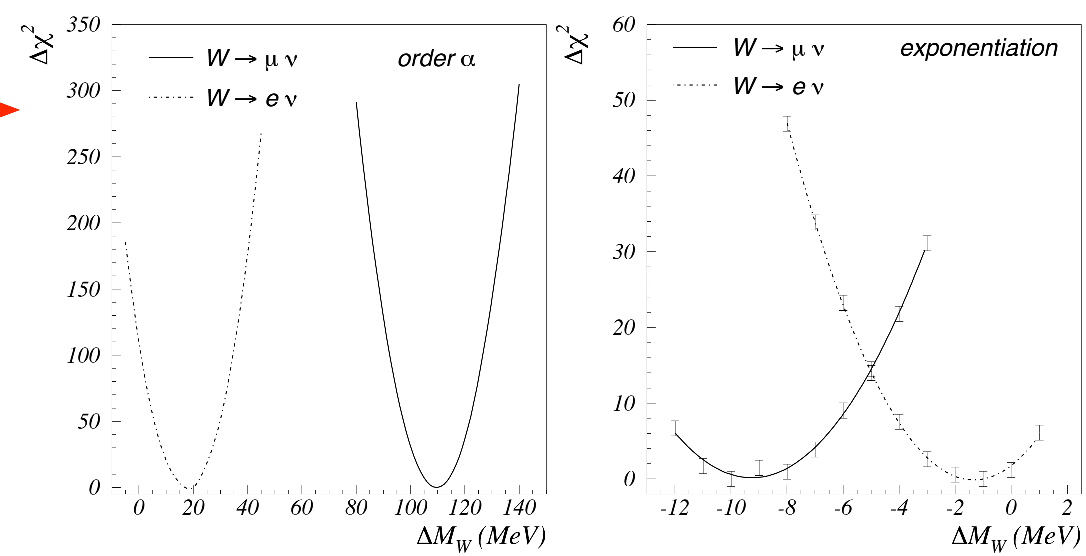
W	S.Jadach and W.Placzek, EPJC 29 (2003) 325	WINHAC	YFS
	C.M.Carloni Calame et al.,PRD 69 (2004) 037301,	HORACE 1.0	PS
	S.Brensing, S.Dittmaier, M. Krämer and M.M.Weber, arXiv:0708.4123	DK	structure function
	P.Golonka, Z.Was, Eur.Phys.J.C45 (2006) 97	PHOTOS	PS
Z	C.M.Carloni Calame et al., JHEP 0505:019 (2005)	HORACE 1.0	

Tuned comparisons demonstrate agreement between the different codes at the per mille level

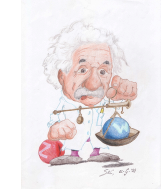
Shift induced in the extraction of MW from higher order QED effects (very simplified detector for muons and electrons)

$$\Delta M_W^{\alpha} = 110 \text{ MeV}$$

$$\Delta M_W^{exp} = -10 \text{ MeV}$$



Radiative corrections and simulation tools: QCD matching



ALPGEN
M.L.Mangano et al., JHEP **0307**, 001 (2003)

LO-QCD matched with HERWIG QCD Parton Shower   MLM prescription

SHERPA
F. Krauss et al., JHEP **0507**, 018 (2005)

LO-QCD matched with QCD Parton Shower   CCKW algorithm

MADGRAPH/MADEVENT
T.Stelzer, W.F.Long, Comp.Phys.Commun.81 (1994) 357, F.Maltoni, T.Stelzer, JHEP 02 (2003) 027

LO-QCD matched with QCD Parton Shower   MLM prescription

Resbos
C.Balazs and C.P. Yuan, Phys.Rev. **D56** (1997) 5558

NLO-QCD matched with resummation of NLL and NNLL of log(p_T^W/m_W)

MC@NLO
S. Frixione and B.R.Webber., JHEP **0206**, 029 (2002)

NLO-QCD matched with the HERWIG QCD Parton Shower

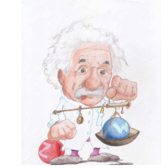
POWHEG
P.Nason, JHEP **0411** 040 (2004)   S.Frixione, P.Nason, C.Oleari, JHEP **0711** 070 (2007)

NLO-QCD matched with any vetoed QCD Parton Shower

BCDFG
G.Bozzi, S.Catani, D.De Florian, G.Ferrera, M.Grazzini, Nucl.Phys.**B815** (2009) 174

NLO-QCD matched with resummation of NLL of log(p_T^W/m_W)
(factorized prescription, explicit dependence on the resummation scale)

Radiative corrections and simulation tools: QCD matching



BCDFG Bozzi, Catani, De Florian, Ferrera, Grazzini

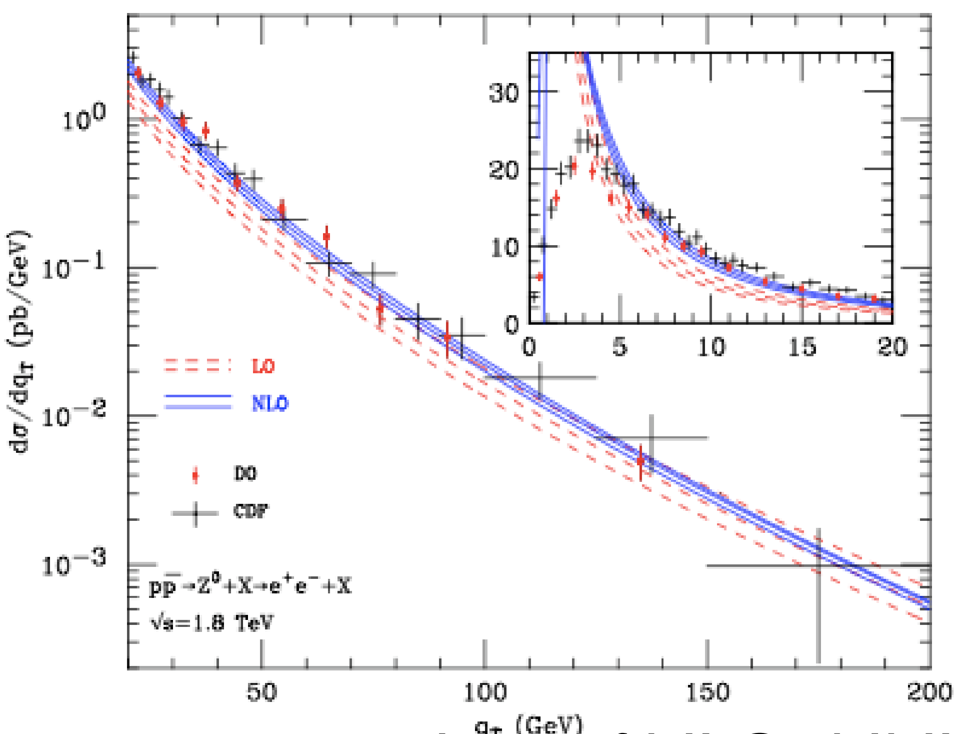
$$\frac{d\hat{\sigma}^{(\mathrm{res.})}_{V\,ab}}{dq_T^2}(q_T, M, \hat{s}; \alpha_S(\mu_R^2), \mu_R^2, \mu_F^2) = \frac{M^2}{\hat{s}} \int_0^\infty db\, \frac{b}{2}\, J_0(bq_T)\, \mathcal{W}^V_{ab}(b, M, \hat{s}; \alpha_S(\mu_R^2), \mu_R^2, \mu_F^2)$$

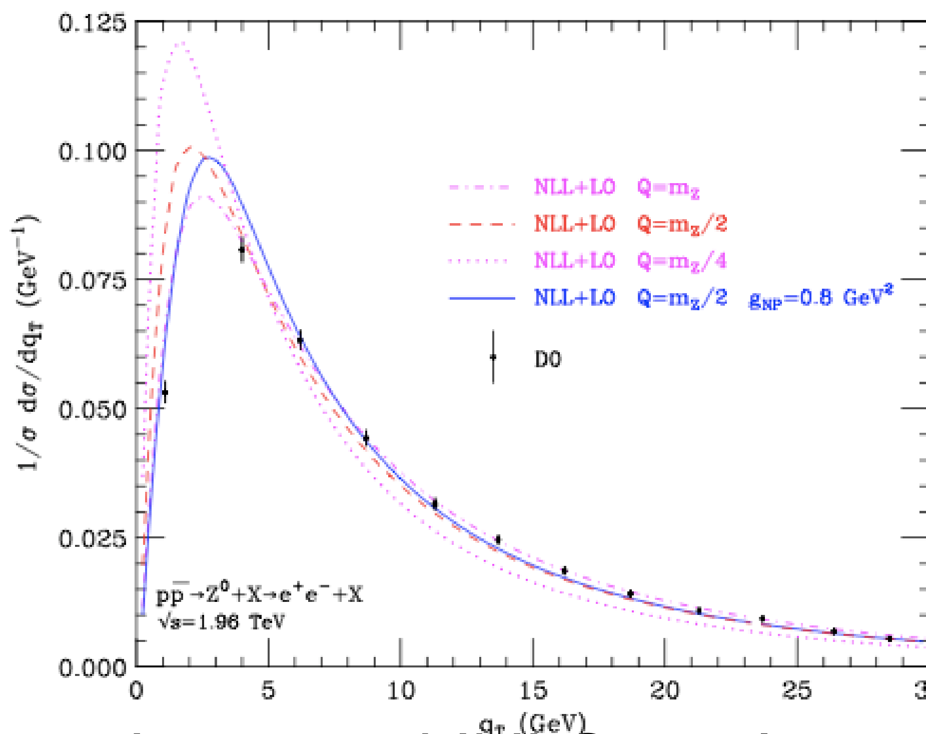
process dependent

$$\mathcal{W}^V_N(b, M; \alpha_S(\mu_R^2), \mu_R^2, \mu_F^2) = \mathcal{H}^V_N\left(M, \alpha_S(\mu_R^2); M^2/\mu_R^2, M^2/\mu_F^2, M^2/Q^2\right) \times \exp\{\mathcal{G}_N(\alpha_S(\mu_R^2), L; M^2/\mu_R^2, M^2/Q^2)\} \;,$$

universal

Q is the resummation scale

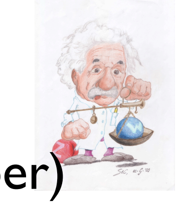




in progress: matching of NLO+NNLL using the recent NNLO results in

Catani, Cieri, Ferrera, de Florian, Grazzini, arXiv:0903.2120

Radiative corrections and simulation tools: QCD matching

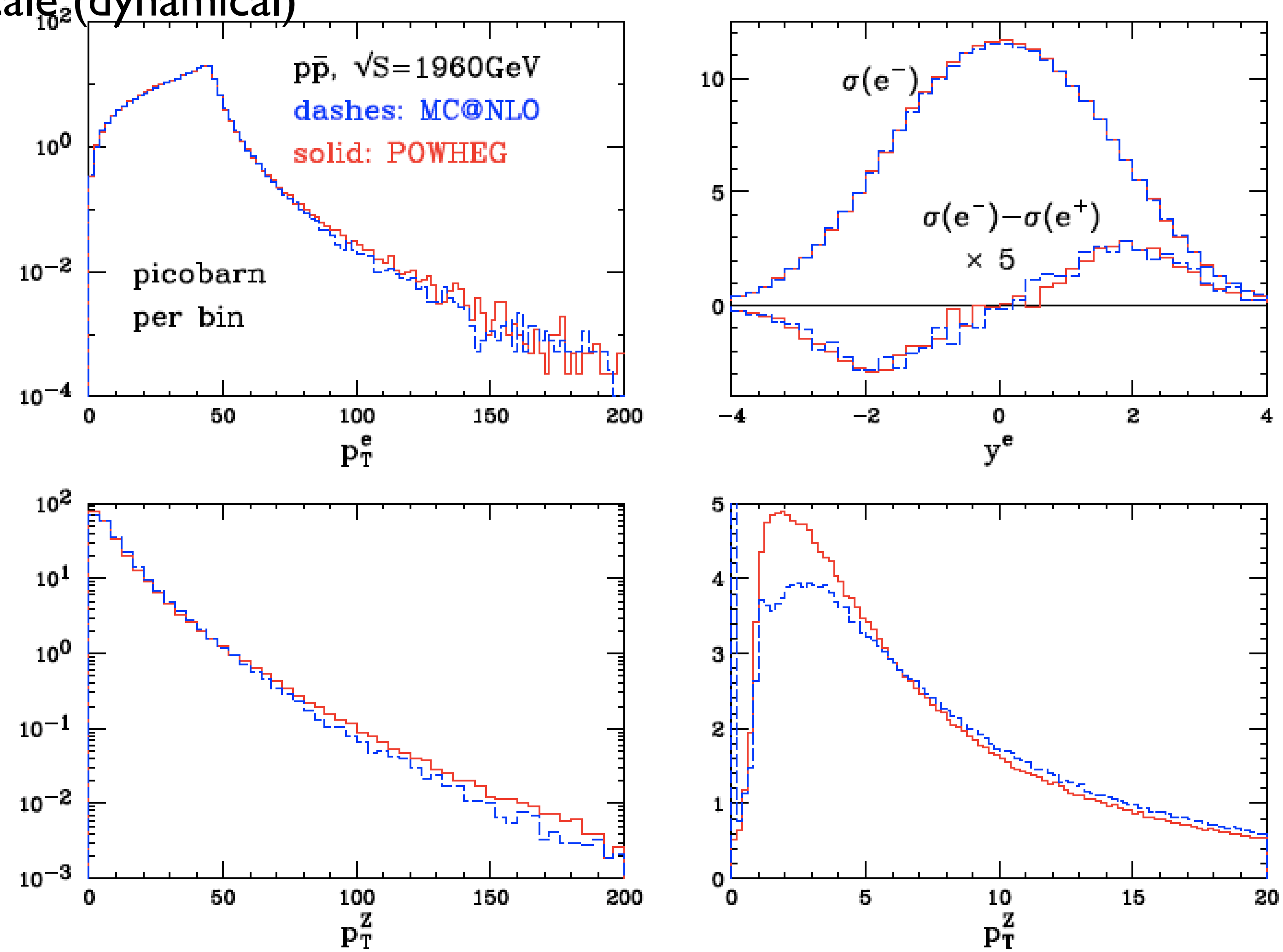


POWHEG (Alioli, Nason, Oleari, Re)

- normalization & hardest emission with NLO accuracy
- rest of the radiation by any vetoed shower, allowed to radiate below the virtuality of the hardest emission
- no matching scale (dynamical)

MC@NLO (Frixione, Webber)

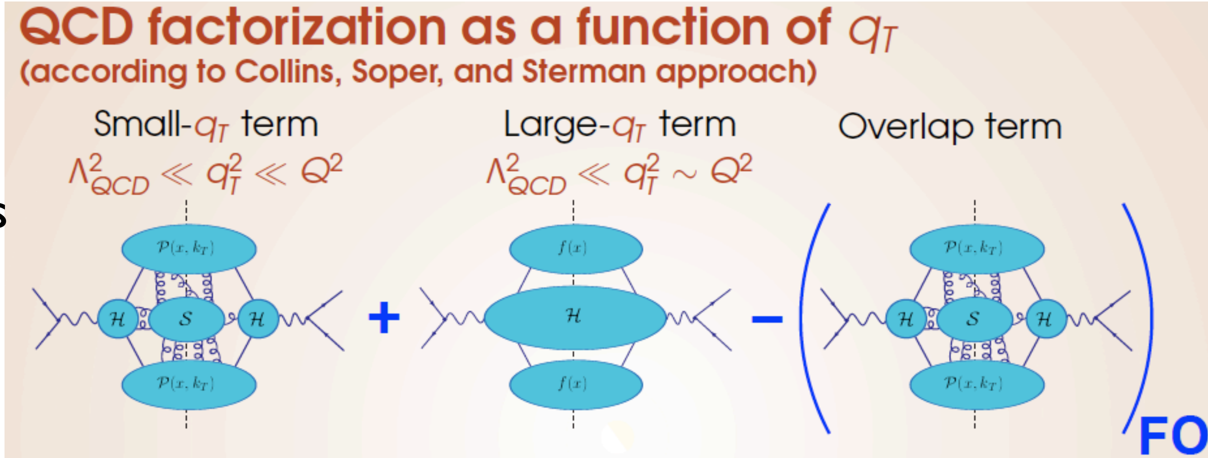
- event generation at NLO
- merging with HERWIG Parton Shower using PS-dependent counterterms
- fixed matching scale



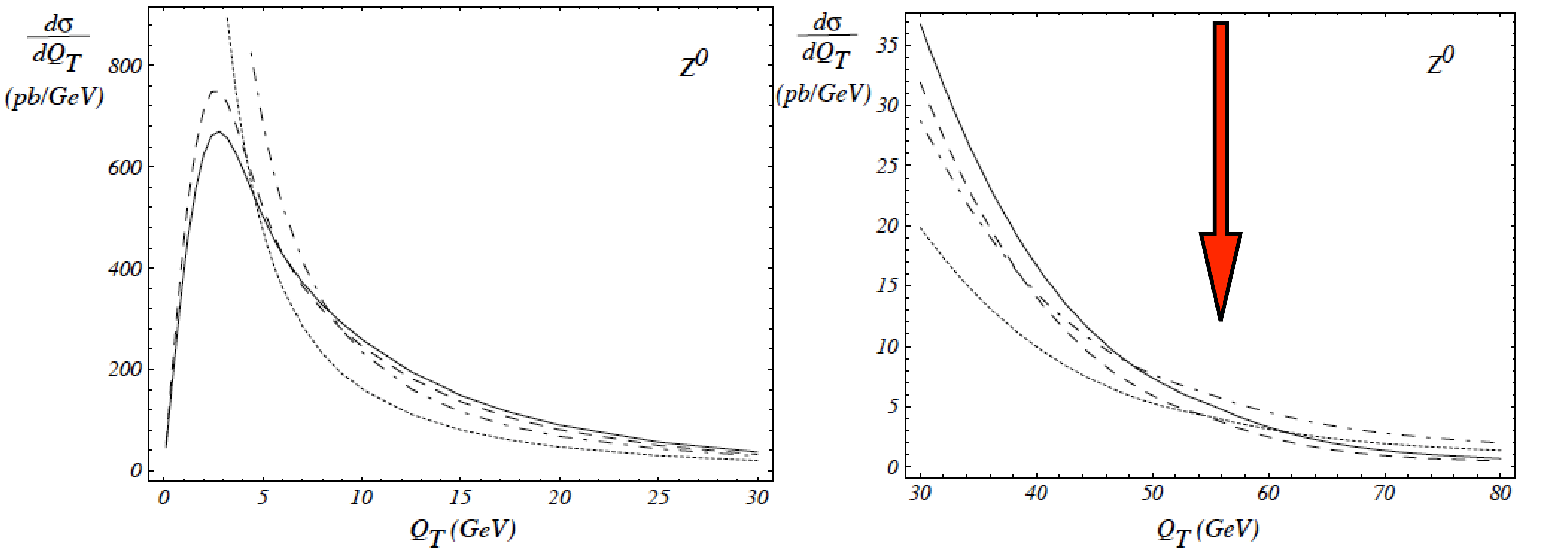
Radiative corrections and simulation tools: QCD matching

RESBOS

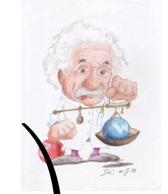
- Finite order: part of the NNLO results lepton spin correlation at NLO
- Resummed term *W* at NNLL for Sudakov factor and non-collinear *pdfs*
- Two representations of the hard-vertex function *H*



matching at the crossing point between resummed and fixed order results



Radiative corrections and simulation tools: QCD matching



RESBOS, POWHEG, MC@NLO and BCDFG

share NLO-QCD accuracy and the resummation of LL of $\log\left(\frac{p_\perp^W}{m_W}\right)$

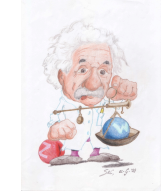
differ by the inclusion of subleading/higher order terms

because of
- different inclusion of NNLO terms (partial vs absent)
- resummation of different subleading logs
  HERWIG vs PYTHIA showers in POWHEG
  vs logs in RESBOS/BCDFG
- different matching prescriptions
  between fixed order and resummed results

the impact depends on the observable under study
(W transverse mass vs lepton transverse momentum)

W mass workshop: tuned comparison of QCD codes as necessary condition
to isolate the effect of the various prescriptions
- how to transfer PT(Z) information in the PT(W) distributions ?
- which is the impact on MW ?

Radiative corrections and simulation tools: EW matching



HORACE 3.2

C.M.Carloni Calame, G.Montagna, O.Nicrosini, A.Vicini,
JHEP 0612:016 (2006) JHEP 0710:109 (2007)

- exact $\mathcal{O}(\alpha)$ partonic cross-section

$$d\sigma^{\alpha,ex} \equiv d\sigma^{\alpha,ex}_{SV} + d\sigma^{\alpha,ex}_{H}$$

- parton-shower (PS) $\mathcal{O}(\alpha)$

$$d\sigma^{\alpha,PS} = \left[\Pi_S(Q^2)\right]_{\mathcal{O}(\alpha)} d\sigma_0 + \frac{\alpha}{2\pi} P(x) I(x) dx\; dc\; d\sigma_0 \equiv d\sigma^{\alpha,PS}_{SV} + d\sigma^{\alpha,PS}_{H}$$

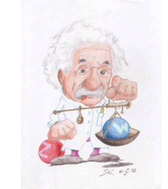
- resummed PS + exact $\mathcal{O}(\alpha)$

$$d\sigma^{\infty}_{matched} =$$
$$\Pi_S(Q^2) F_{SV} \sum_{n=0}^{\infty} d\hat{\sigma}_0 \frac{1}{n!} \prod_{i=0}^{n} \left(\frac{\alpha}{2\pi} P(x_i)\; I(k_i)\; dx_i\; d\cos\theta_i\; F_{H,i} \right)$$

$$F_{SV} = 1 + \frac{d\sigma^{\alpha,ex}_{SV} - d\sigma^{\alpha,PS}_{SV}}{d\sigma_0} \qquad F_{H,i} = 1 + \frac{d\sigma^{\alpha,ex}_{H,i} - d\sigma^{\alpha,PS}_{H,i}}{d\sigma^{\alpha,PS}_{H,i}}$$

- at $\mathcal{O}(\alpha)$ it coincides with the exact calculation
- QED higher orders coincide with pure PS

Radiative corrections and simulation tools: EW matching



HORACE 3.2

C.M.Carloni Calame, G.Montagna, O.Nicrosini, A.Vicini,
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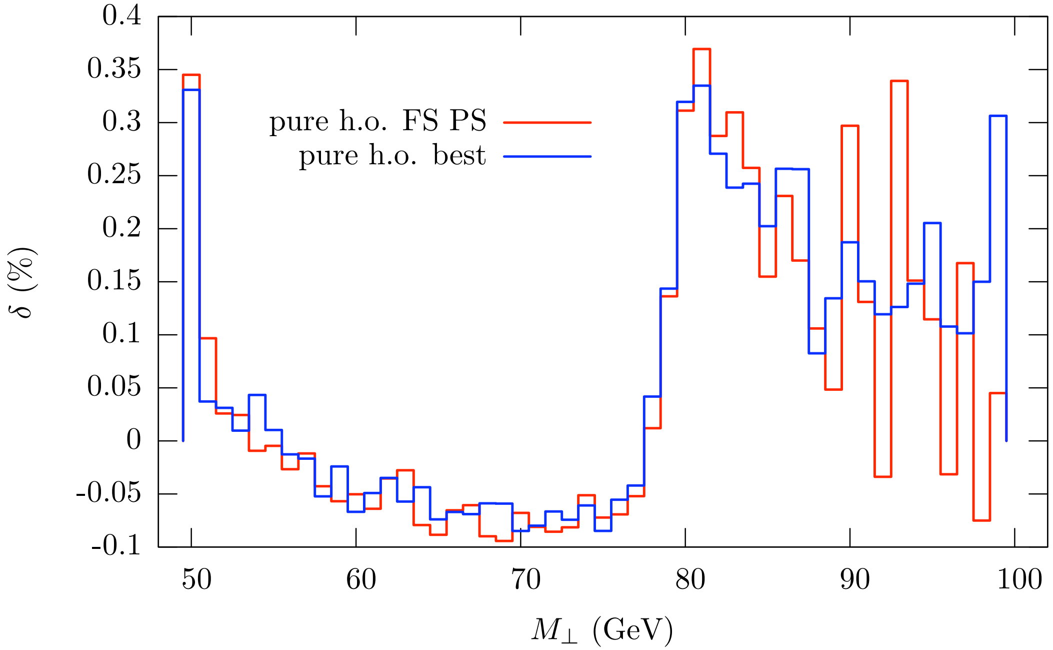
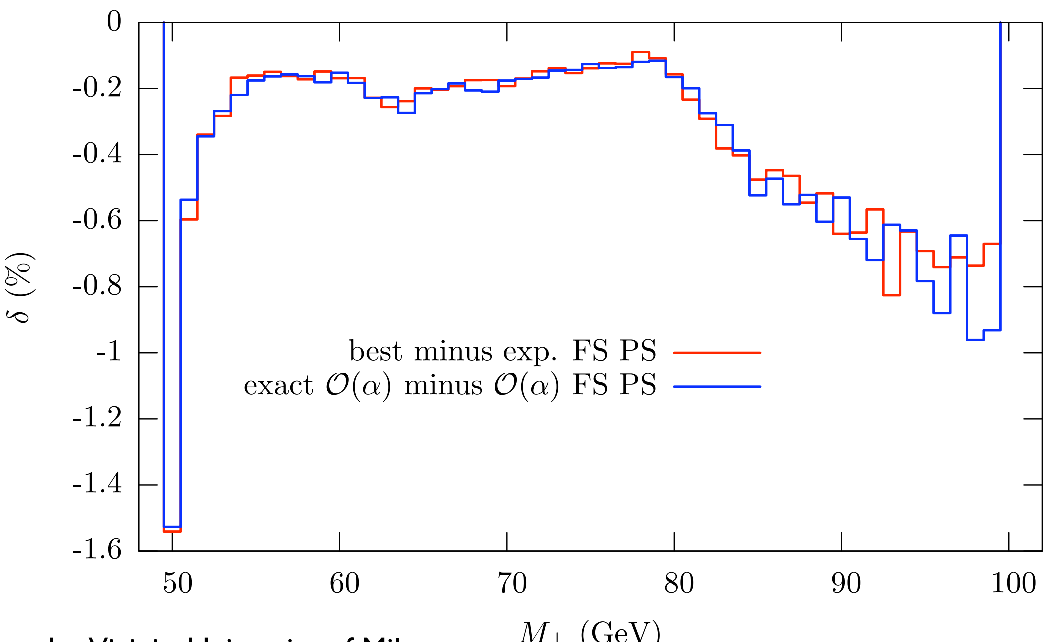
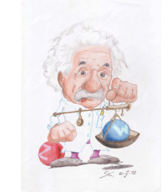


effect of multiple photon radiation



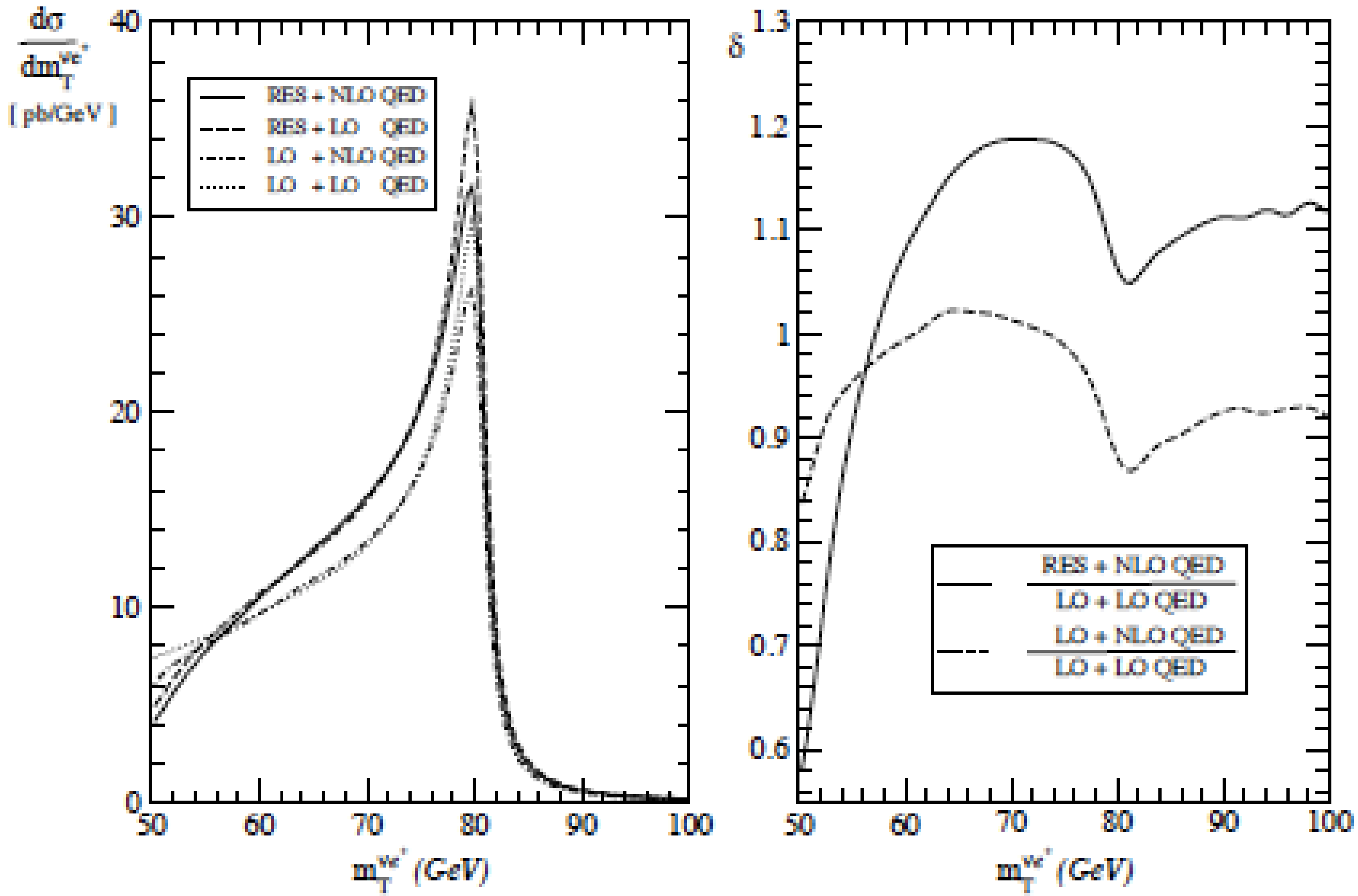
pure Parton Shower compared with the full calculation

Radiative corrections and simulation tools: QCD + FS-QED



RESBOS-A

Q.-H. Cao and C.-P. Yuan, Phys. Rev. Lett. **93** (2004) 042001



soft gluon resummation + NLO final state QED radiation

cfr: the combination of MC@NLO+PHOTOS in N.Adam, V.Halyo, S.Yost, W.Zhu, JHEP 0809:133,2008

the (QCD+EW) combination in S.Jadach, M.Skrzypek, P.Stephens, Z.Was, W.Placzek, Acta.Phys.Polon.B38:2305 (2007)

Radiative corrections and simulation tools: QCD+EW combination

HORACE⊗HERWIG + MC@NLO

G. Balossini, C.M.Carloni Calame, G.Montagna, M.Moretti, O.Nicrosini, F.Piccinini, M.Treccani, A.Vicini, arXiv:0907.0276

- Additive combination of QCD and EW corrections:

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

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

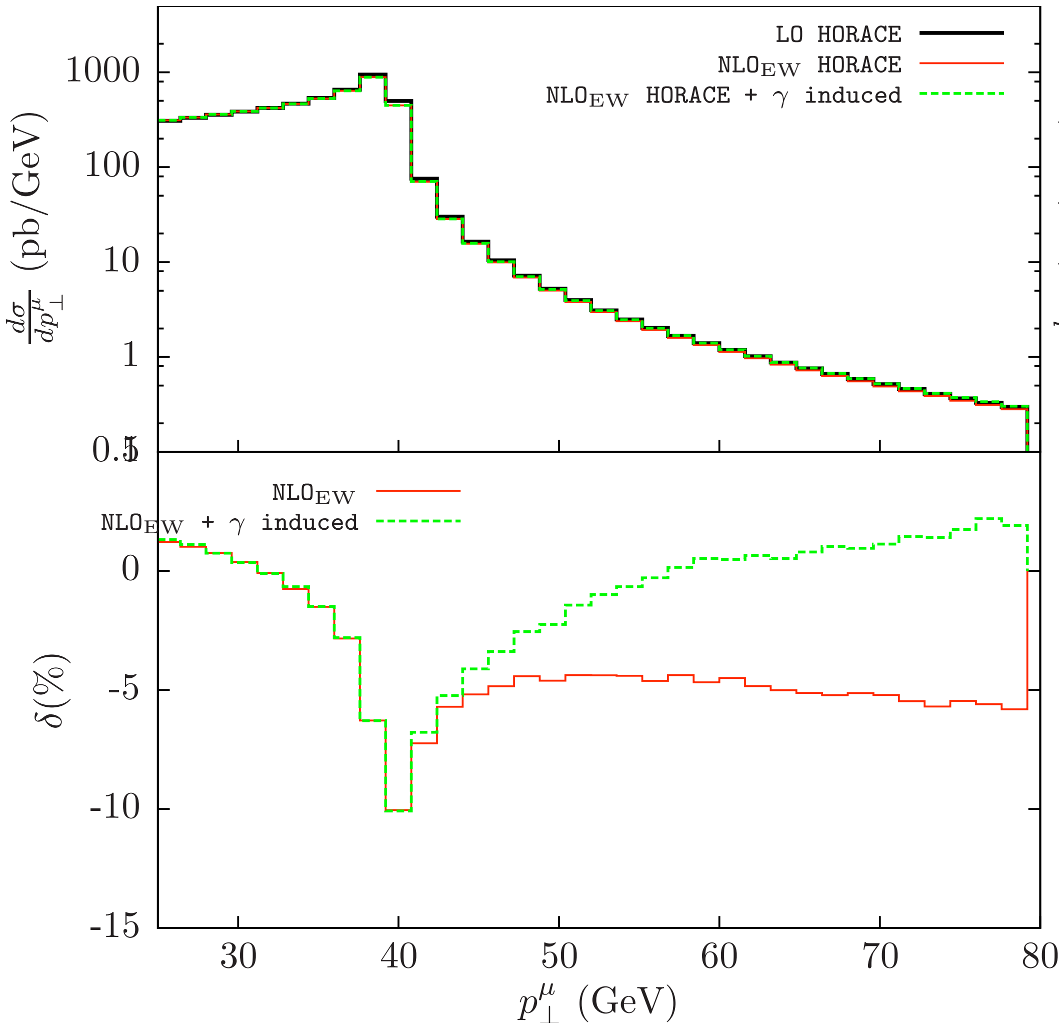
NLO-EW corrections convoluted with QCD PS ⇒ inclusion of $\mathcal{O}(\alpha\alpha_s)$ terms

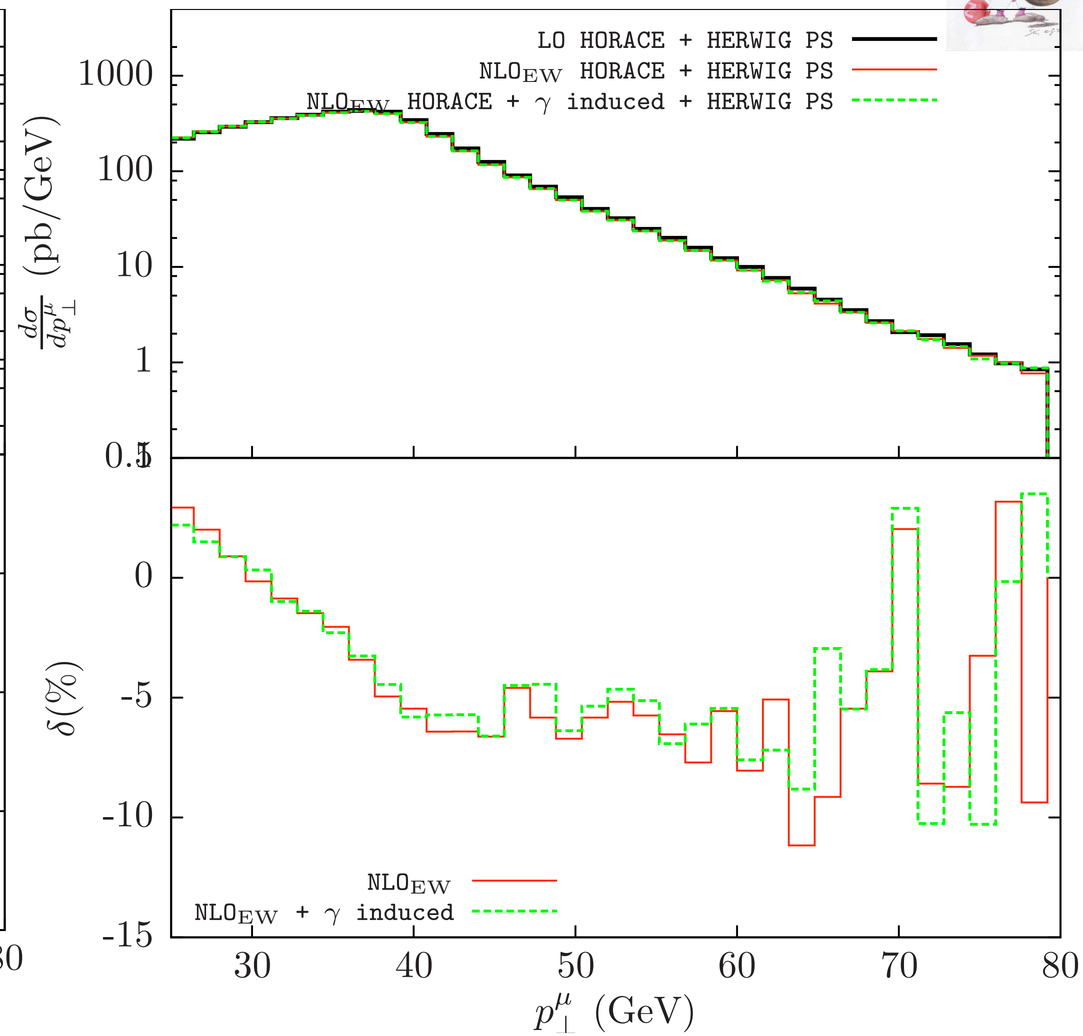
not reliable when hard non collinear radiation is important

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

- SANC group is including in their package QCD corrections to DY and interfaces to HERWIG/PYTHIA

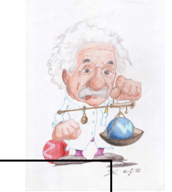
convolution of EW corrections with QCD Parton Shower

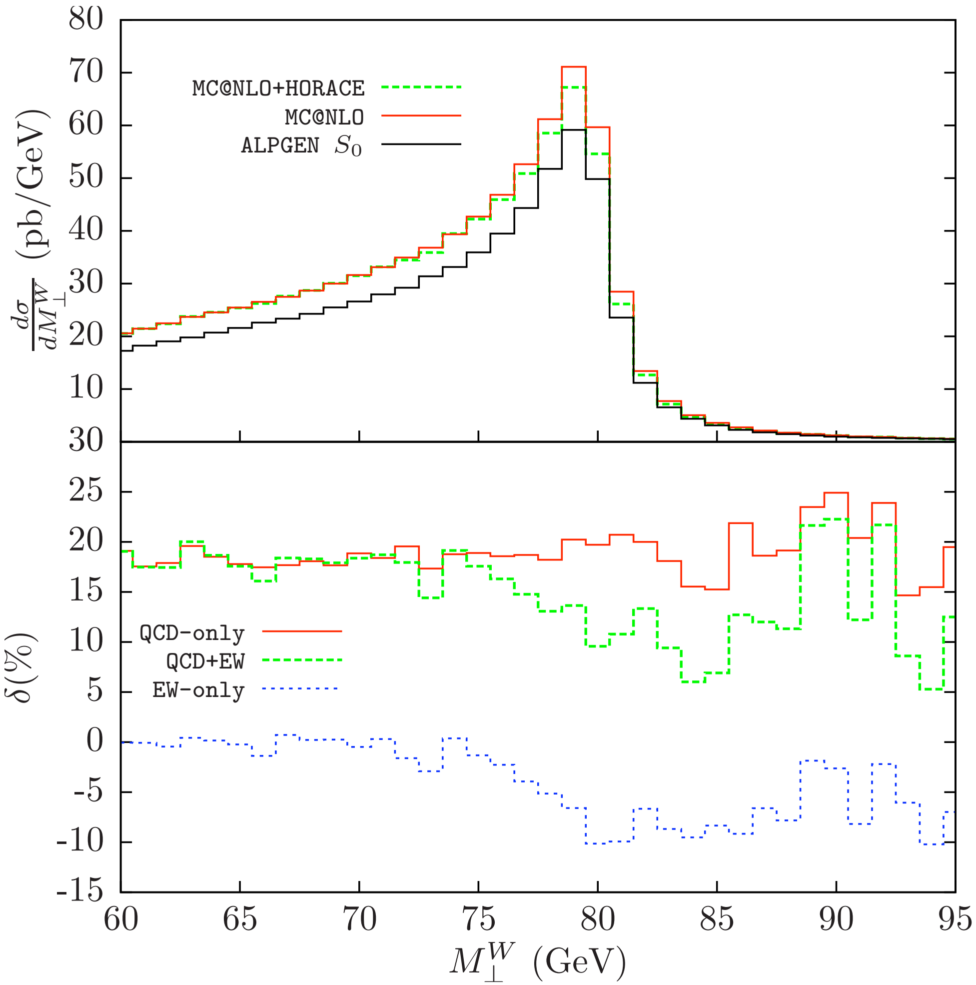


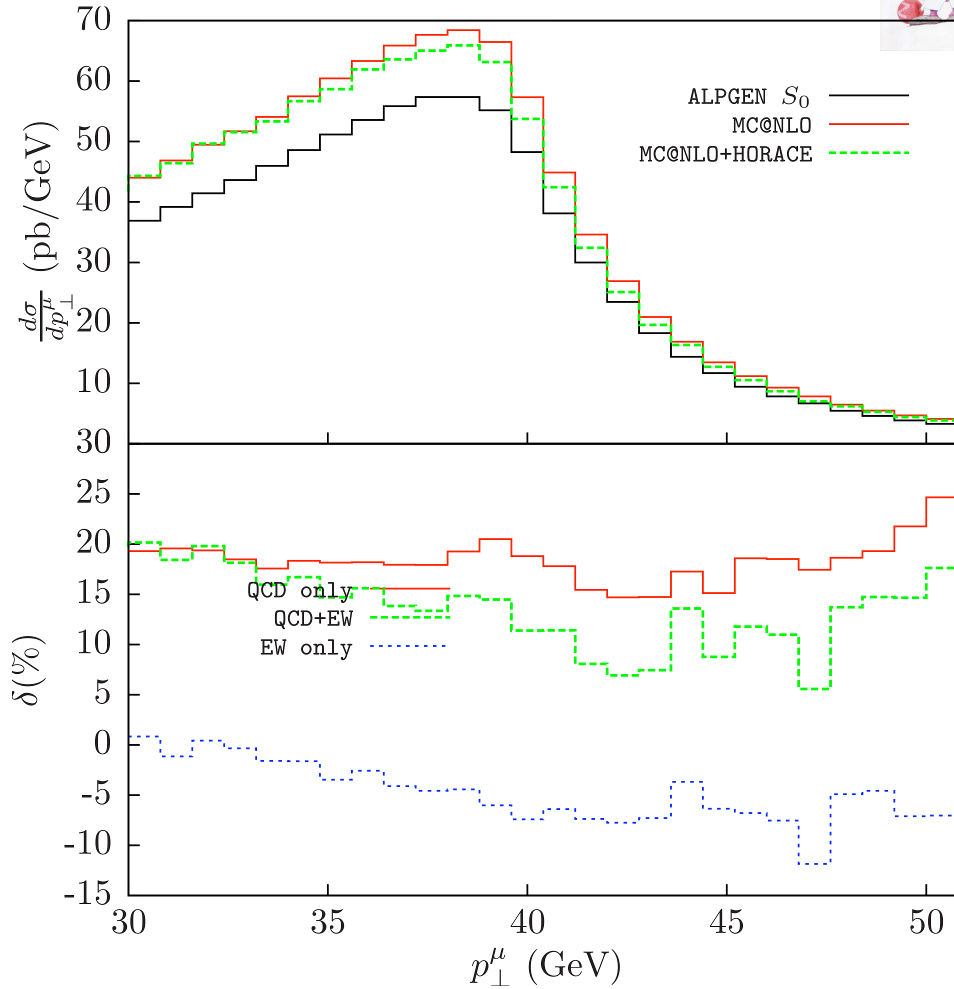


- the convolution with QCD Parton Shower modifies the relative effect and shape of the EW corrections

Tevatron: QCD+EW combination

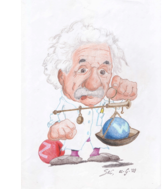


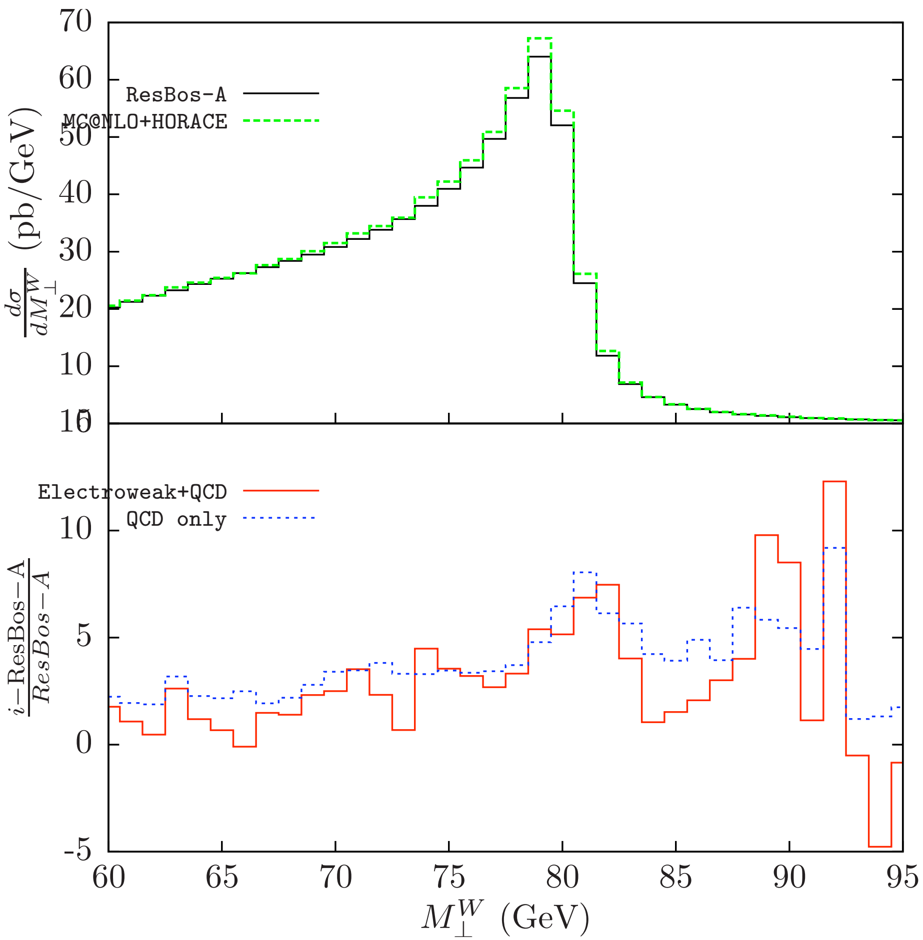


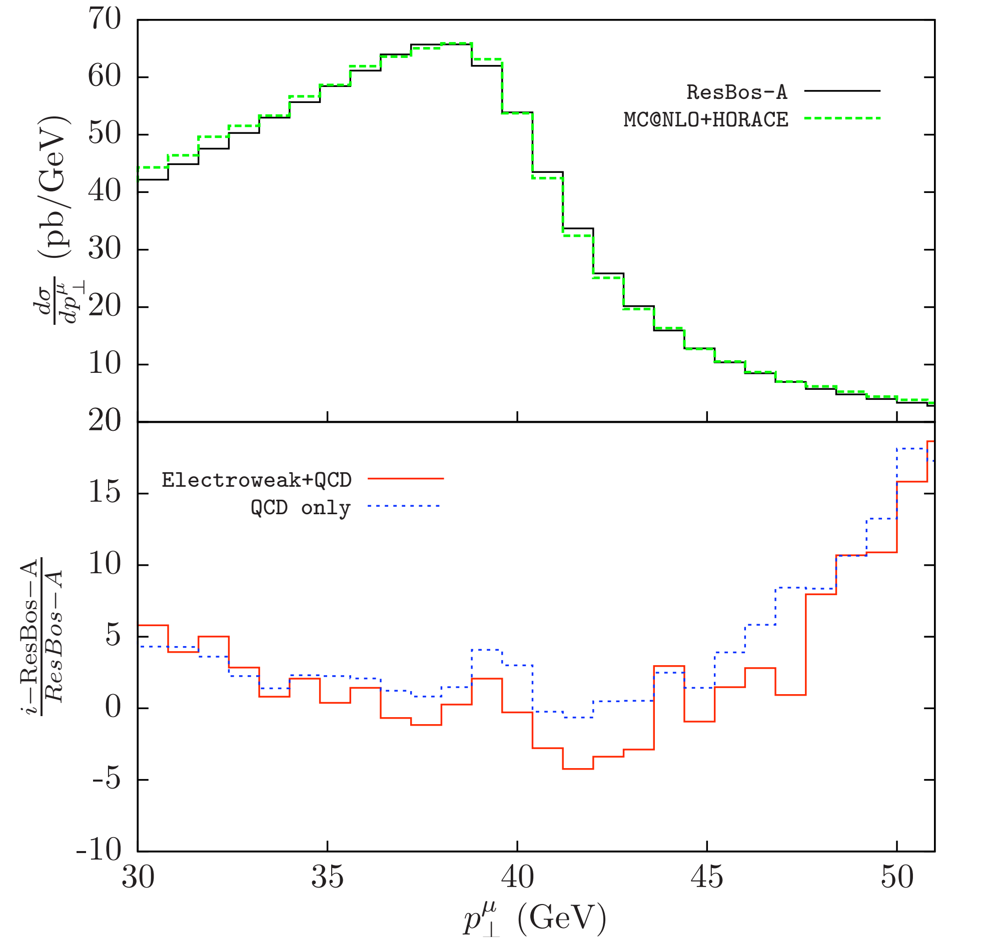


- the relative effect expressed in units Born+PS
- positive QCD corrections compensate negative EW corrections
- the convolution with QCD Parton Shower modifies the relative effect and shape of the EW corrections

Absolute comparison: ResBos(CSS)-A vs MC@NLO + HORACE

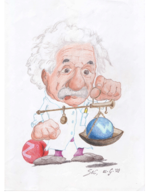




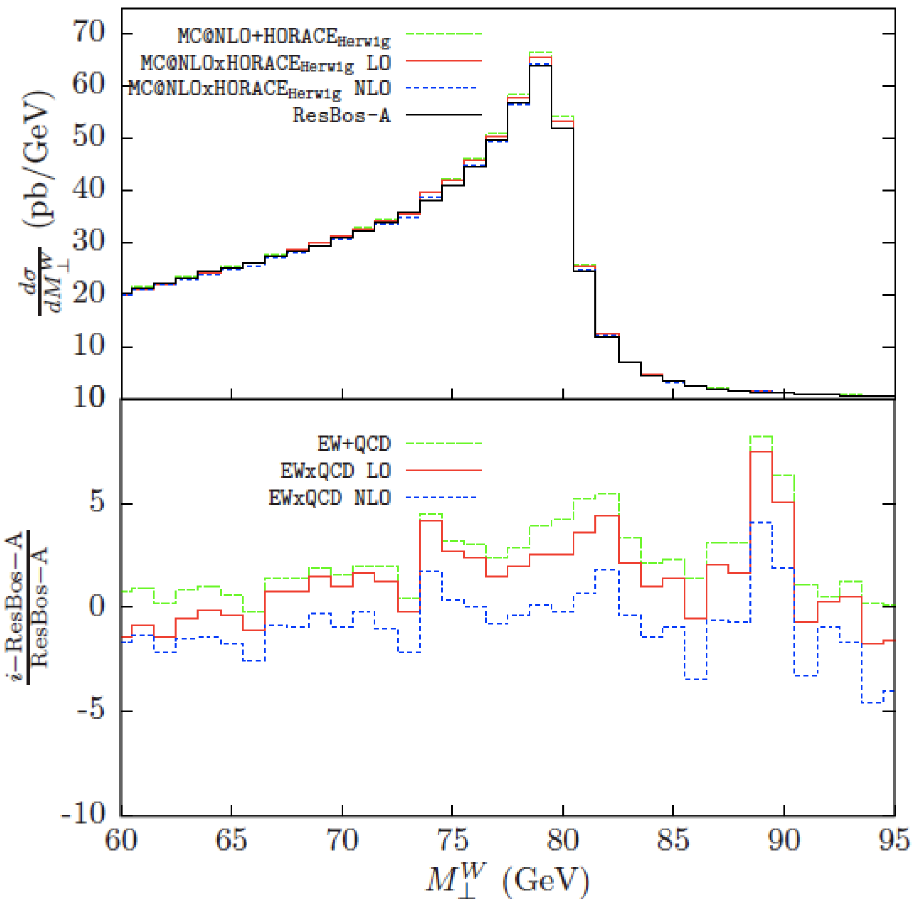


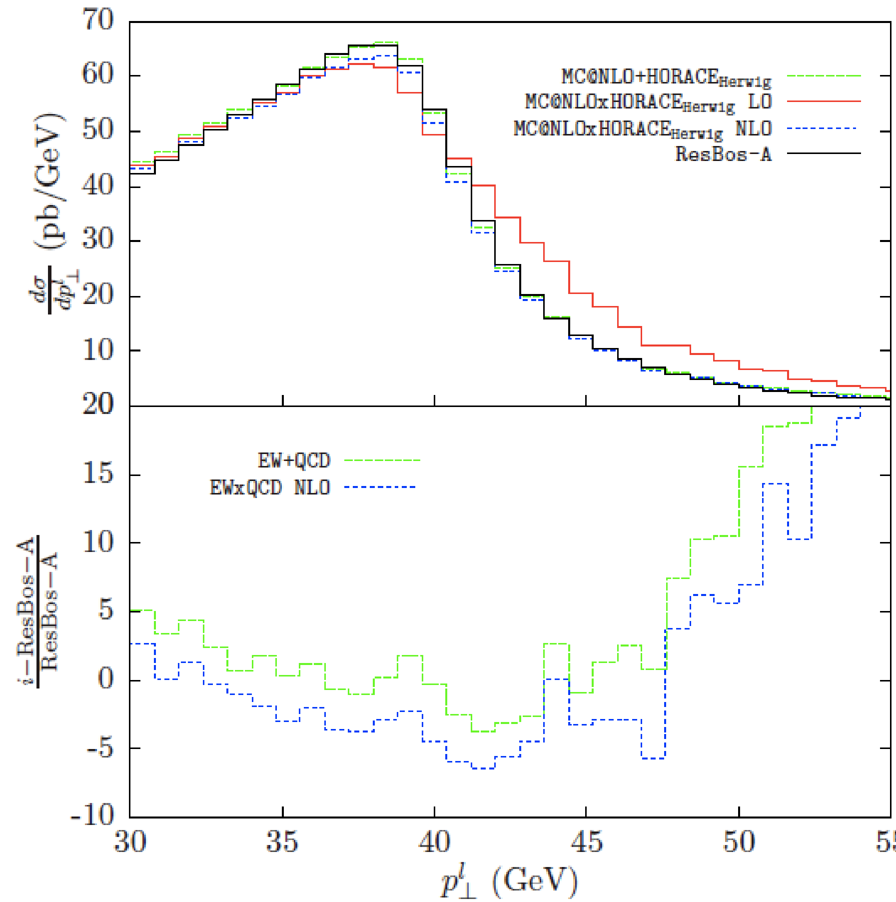
- Different normalization of the distributions
- Around the jacobian peak, agreement at a few % level
- in the soft $M_\perp^W$ tail and in the hard $p_\perp^\mu$ tail, differences can reach the 15 % level
- Around the jacobian peak, bulk of the EW effects by QED final state radiation

QCD+EW combination: factorized prescription



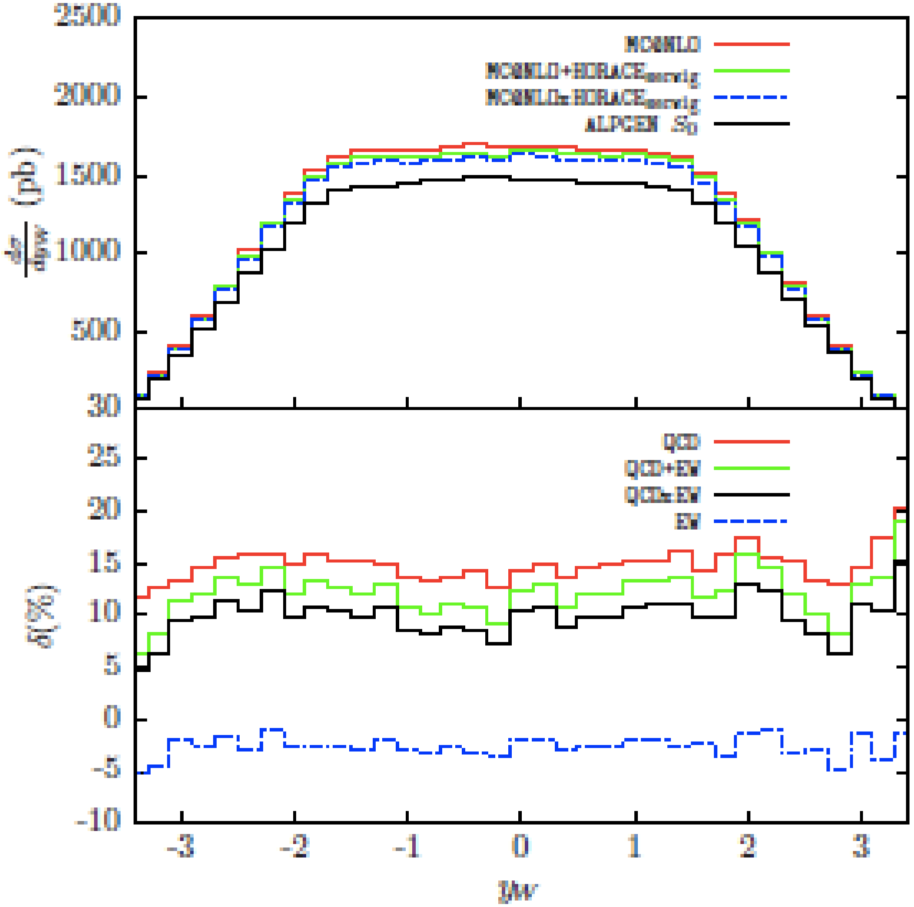
$$\left[\frac{d\sigma}{d\mathcal{O}}\right]_{\rm QCD\otimes EW} = \left(1 + \frac{[d\sigma/d\mathcal{O}]_{\rm MC@NLO} - [d\sigma/d\mathcal{O}]_{\rm HERWIG\ PS}}{[d\sigma/d\mathcal{O}]_{\rm LO/NLO}}\right) \times$$
$$\times \left\{\frac{d\sigma}{d\mathcal{O}_{\rm EW}}\right\}_{\rm HERWIG\ PS},$$

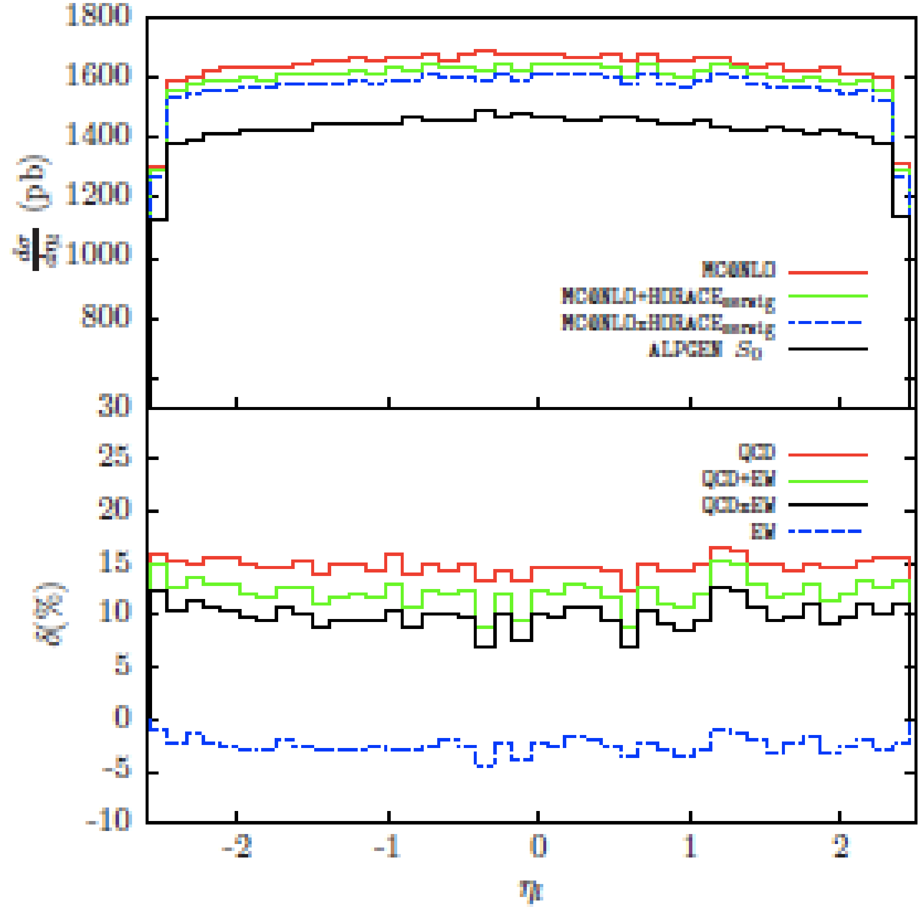


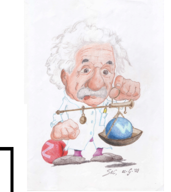


- When expanded it coincides with the additive prescription
- It includes subleading terms of O(α_s^2) absent in the additive prescription
- Differences are at the few per cent level

pdf constraining: W rapidity and lepton pseudo-rapidity



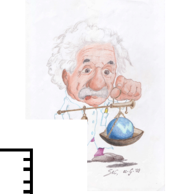


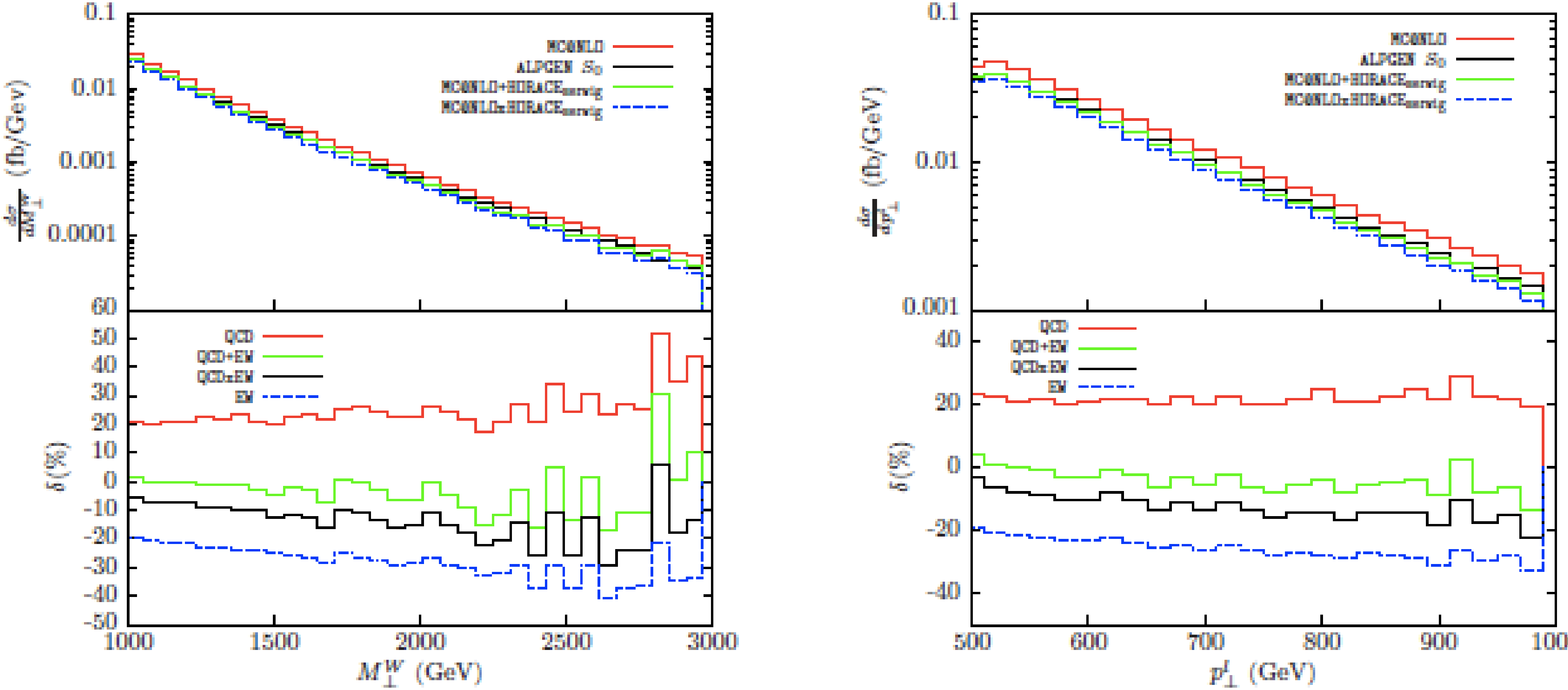


Both QCD and EW corrections are quite flat
partial cancellation +15 -3 %

The deltas are defined in unit (Born+PS)

New physics searches: QCD and EW





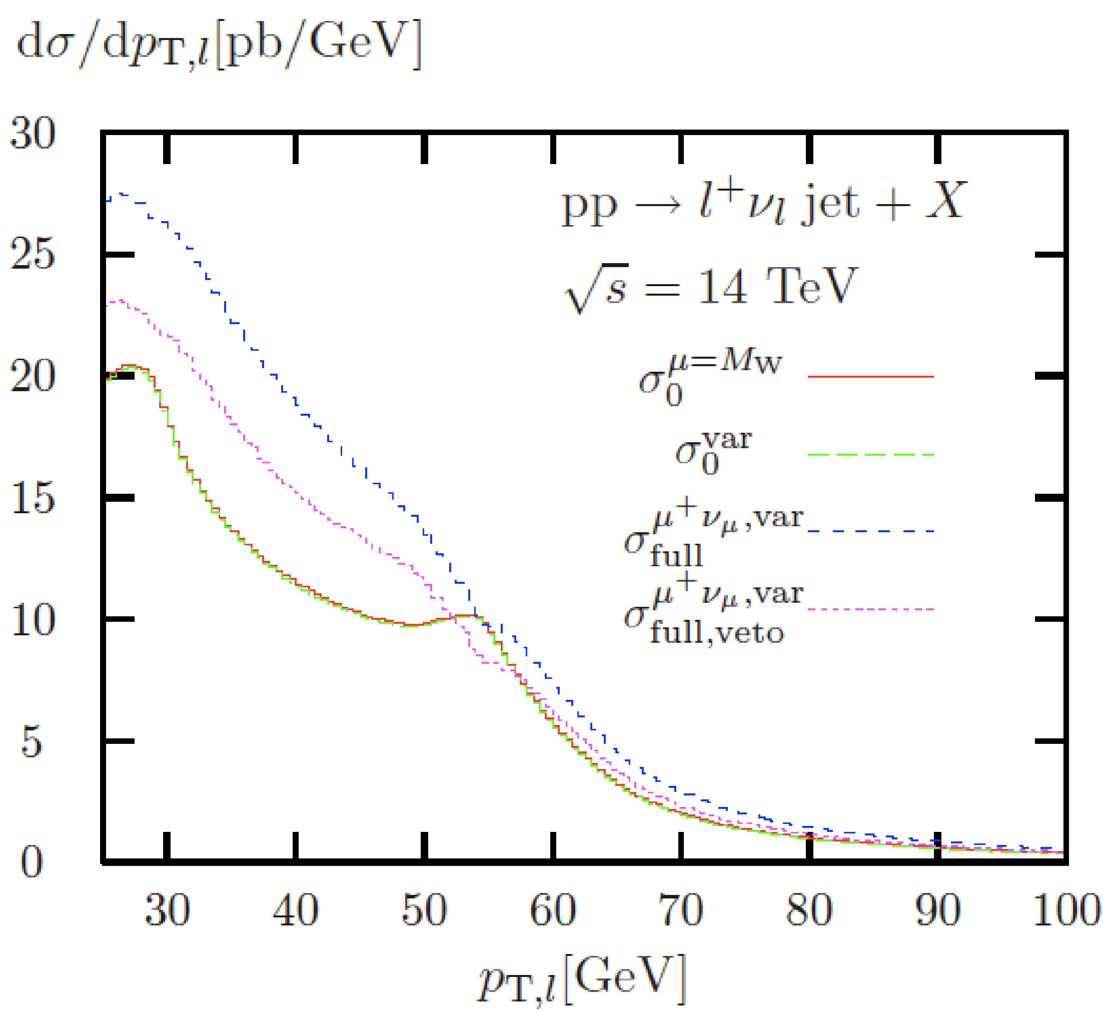
Large cancellation of positive QCD and negative EW corrections

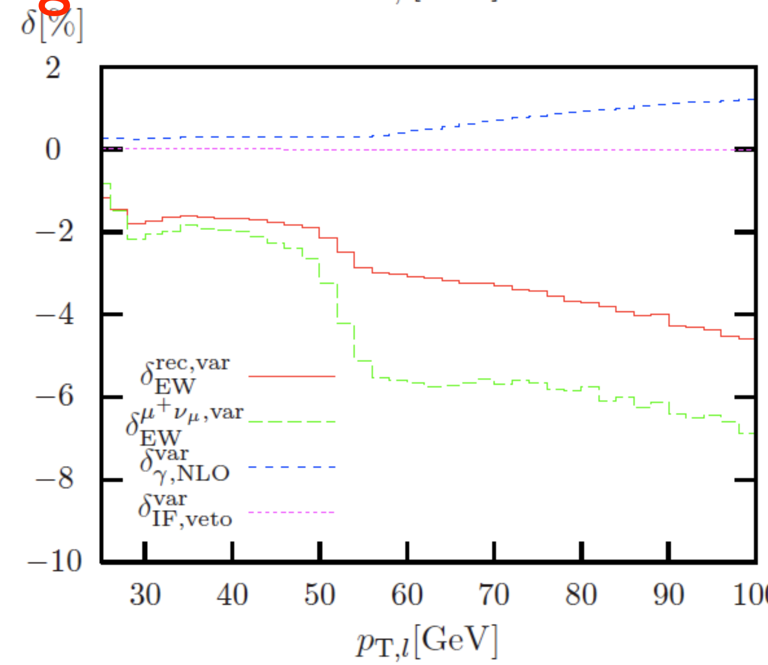
Important dependence on the choice of the *pdf* scale $\mu_F = \sqrt{M_{l\nu}^2 + (p_\perp^W)^2}$

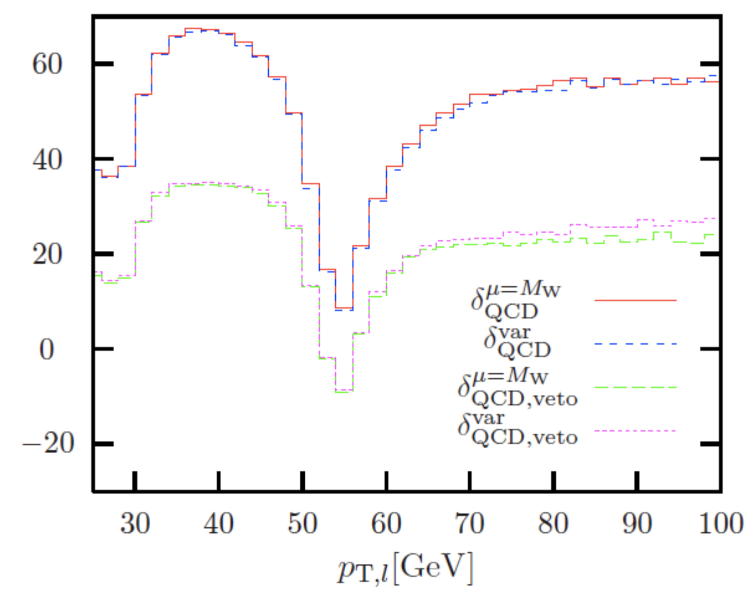
Relevant to set correct limits on the searches for heavy gauge bosons

More effects contribute at the per cent level
(real gauge boson radiation, NNLO-QCD, 2-loop EW Sudakov)

Towards $\mathcal{O}(\alpha\alpha_s)$: W production at large transverse momentum







see: J.H. Kühn, A.Kulesza, S.Pozzorini, M.Schulze, hep-ph/0703283
arXiv:0708.0476
W. Hollik, T.Kasprzik, B.A. Kniehl, arXiv:0707.2553
A.Denner, S.Dittmaier, T.Kasprzik, A.Mueck, arXiv:0906.1656

EW corrections to Z+jet production
EW corrections to W+jet production
QCD corrections to W+photon production

Uncertainties on the MW measurement (I)

Summary of uncertainties

systematic uncertainties

Source	$\sigma(m_W)$ MeV m_T	$\sigma(m_W)$ MeV p_T^e	$\sigma(m_W)$ MeV $\not{E}_T$
Experimental			
Electron Energy Scale	34	34	34
Electron Energy Resolution Model	2	2	3
Electron Energy Nonlinearity	4	6	7
W and Z Electron energy loss differences (material)	4	4	4
Recoil Model	6	12	20
Electron Efficiencies	5	6	5
Backgrounds	2	5	4
Experimental Total	35	37	41
W production and decay model			
PDF	9	11	14
QED	7	7	9
Boson p_T	2	5	2
W model Total	12	14	17
Total	37	40	44
statistical	23	27	23
total	44	48	50

Jan Stark Milano, March 17-18, 2009

m_T Fit Uncertainties

Source	$W \to \mu\nu$	$W \to e\nu$	Correlation
Tracker Momentum Scale	17	17	100%
Calorimeter Energy Scale	0	25	0%
Lepton Resolution	3	9	0%
Lepton Efficiency	1	3	0%
Lepton Tower Removal	5	8	100%
Recoil Scale	9	9	100%
Recoil Resolution	7	7	100%
Backgrounds	9	8	0%
PDFs	11	11	100%
W Boson p_T	3	3	100%
Photon Radiation	12	11	100%
Statistical	54	48	0%
Total	60	62	-

EW uncertainties on the MW measurement (II)

- The description of the second radiated photon should be validated
  how large are the terms neglected in the Parton Shower approach?
  missing are
  subleading terms of O(α^2)
  moderate optimism based on

$$d\sigma^{\infty}_{matched} = F_{SV}\, \Pi(Q^2,\varepsilon)\, \sum_{n=0}^{\infty} \frac{1}{n!}\, \left(\prod_{i=0}^{n} F_{H,i}\right) |\mathcal{M}_{n,LL}|^2\, d\Phi_n$$

correction to all orders

n-photon correction a product of 1-photon corrections

fully differential calculation

$(1 + \delta_1)\,(1 + \delta_2)\,(1 + \delta_3)\ \ldots.$

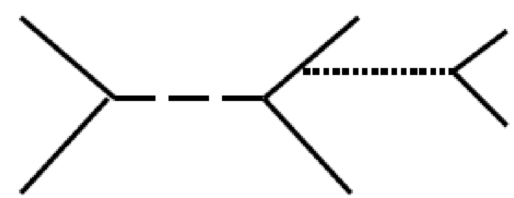
1-photon corrections exact, n-photon corrections approximated as δ^n

As $\delta \approx 3/140 \approx$ 2%, the uncertainty of the procedure of the order of

140 MeV x δ^2 = 0.1 MeV ?

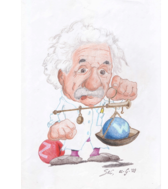
- The production of a lepton pair which escapes detection is of O(α^2) and is logarithmically enhanced; can not exclude an effect comparable to the second photon (10 MeV)

Pair creation is not included in the current version of Horace



- The input scheme choice (α(0) vs G_μ, use of $\alpha_\mu^{tree}\ vs\ \alpha_\mu^{1-loop}$) has a non-trivial impact depending on the code (O(α) vs matched)

EW uncertainties on the MW measurement (III)



Observed shifts on W mass

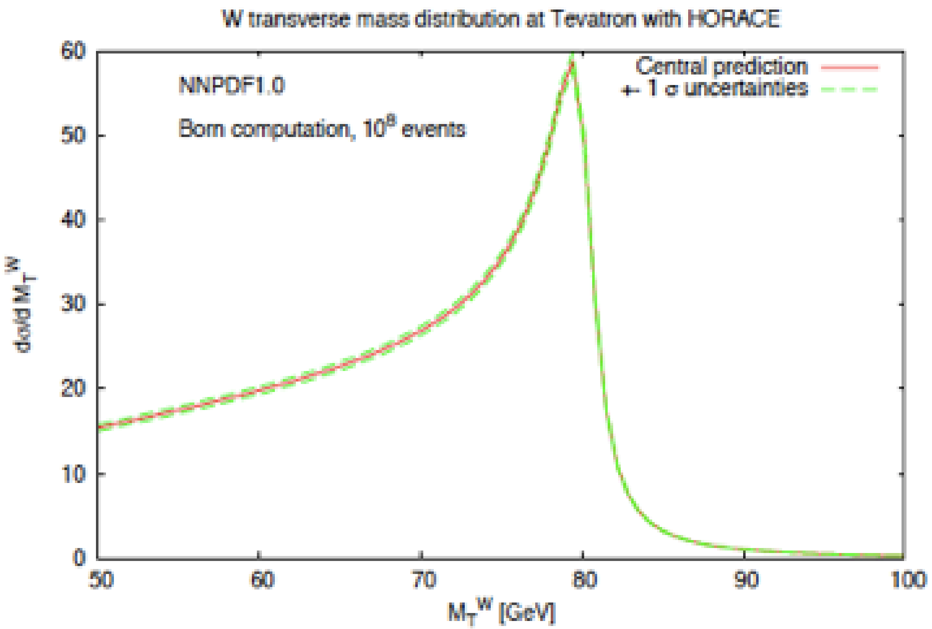
	m_T		p_T		$\not{E}_T$	
	e	μ	e	μ	e	μ
born - O(α)	147 ± 2.0	154 ± 1.8	174 ± 2.5	208 ± 2.5	105 ± 2.6	93 ± 2.0
born - match	137 ± 2.1	136 ± 2.4	163 ± 2.6	187 ± 2.4	96 ± 2.8	76 ± 1.9
O(α) - match	11 ± 2.4	19 ± 2.0	12 ± 2.9	22 ± 2.8	9 ± 3.1	18 ± 2.2
born - LL 1g	143 ± 2.2	148 ± 1.5	167 ± 2.6	198 ± 2.2	104 ± 2.8	89 ± 1.8
born - LL ng	138 ± 2.2	138 ± 1.5	162 ± 2.6	184 ± 2.2	104 ± 2.8	85 ± 1.8
LL1g - LL ng	5 ± 2.5	10 ± 1.6	5 ± 3.1	15 ± 2.3	1 ± 3.2	5 ± 1.8
LL1g - O(α)	1 ± 2.4	3 ± 1.8	3 ± 2.9	5 ± 2.6	1 ± 3.1	1 ± 2.1
LLng - match	4 ± 2.5	5 ± 1.7	4 ± 3.0	2 ± 2.5	10 ± 3.2	10 ± 2.0

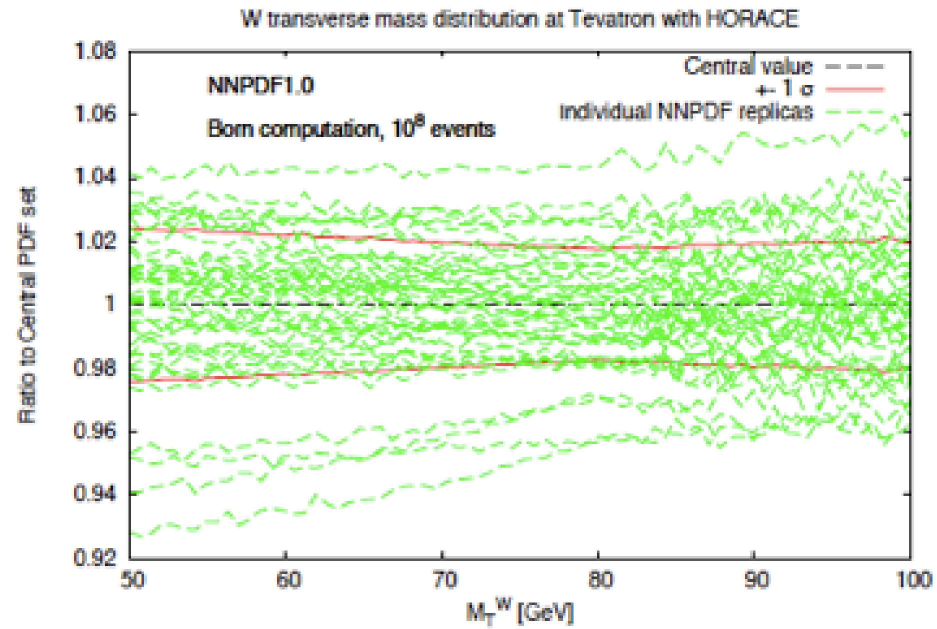
Going to more photons reduces the EWK effect on the W mass
The shift is −11 MeV and −19 MeV

The difference between O(a) and LL1g is small (a few MeV)

I. Bizjak : W mass Mar 2009 7/12

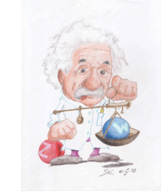
PDF dependence of M_T^W distribution - An update





- Differences in shape and normalization in individual NNPDF replicas
- Determine M_W independently for each error PDF $M_W^{(k)}$ and compute uncertainties

$$\delta_{M_W}^{\mathrm{PDFs}}\Big|_{\mathrm{NNPDF}} = \left(\frac{1}{N_{\mathrm{rep}}-1} \sum_{k=1}^{N_{\mathrm{rep}}} \left(M_W^{(k)} - \langle M_W \rangle \right)^2 \right)^{1/2}$$



PDF uncertainties on the MW measurement

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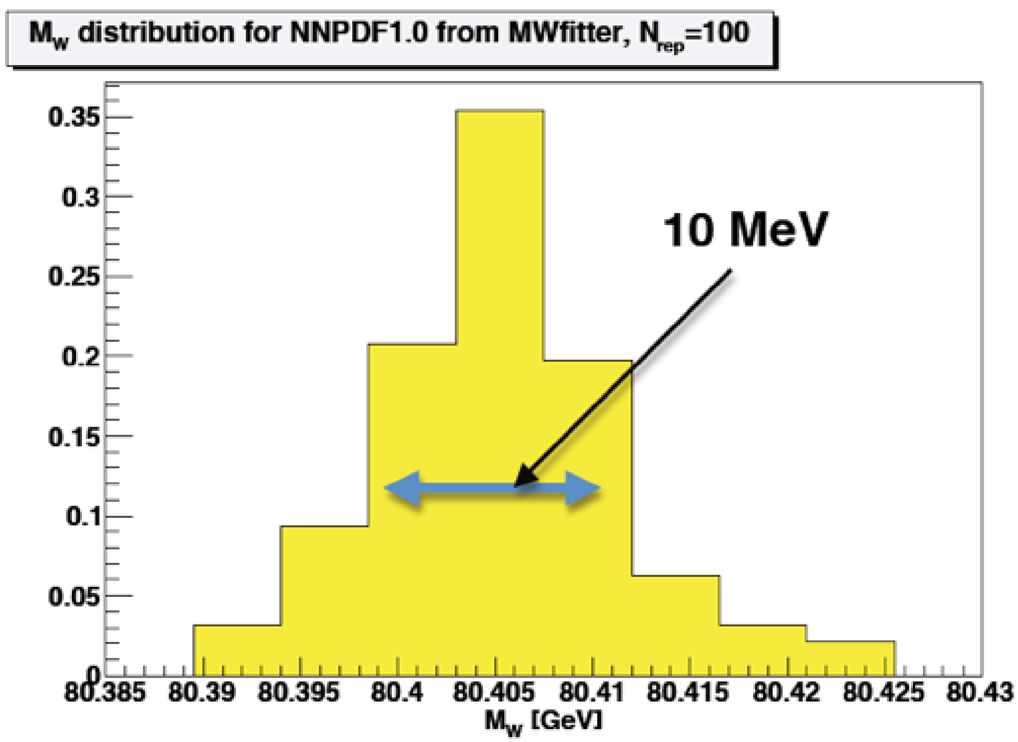
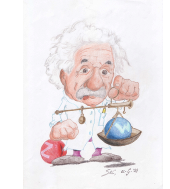
Effects in M_W determination - Preliminary

PDF uncertainty in m_T^W channel close to CDF estimate: $\delta_{M_W}^{\mathrm{PDFs}}\left(m_T^W\right) \sim 11$ MeV



Conclusions



- Intense theoretical activities to match the very high experimental accuracy of the observables relevant for the W mass measurement

- At this level of accuracy, the differences between the various recipes (RESBOS, POWHEG, MC@NLO, BCDFG) which allow to match fixed order and resummed QCD results should be scrutinized in detail.
  Inclusion of NNLO results?

- EW corrections are under control at $O(\alpha)$ + QED multiple photon emission LL;
  the remaining ambiguities are at $O(\alpha^2)$ single-log

- A missing contribution potentially important is given at $O(\alpha^2)$ by all the extra lepton pairs lost in the detector

- The QCD-EW interplay has non negligible effects.
  Different recipes show a spread of the results at the per cent level.
  The full calculation of $O(\alpha\alpha_s)$ corrections will definitely solve these ambiguities

- The role of the *pdf*s in the prediction may be less trivial than expected but is strictly connected to the non-perturbative QCD contribution to the lepton pt spectrum