FEWZ: A Fully Exclusive Numerical Code for QCD and EW Correction to Drell-Yan Process

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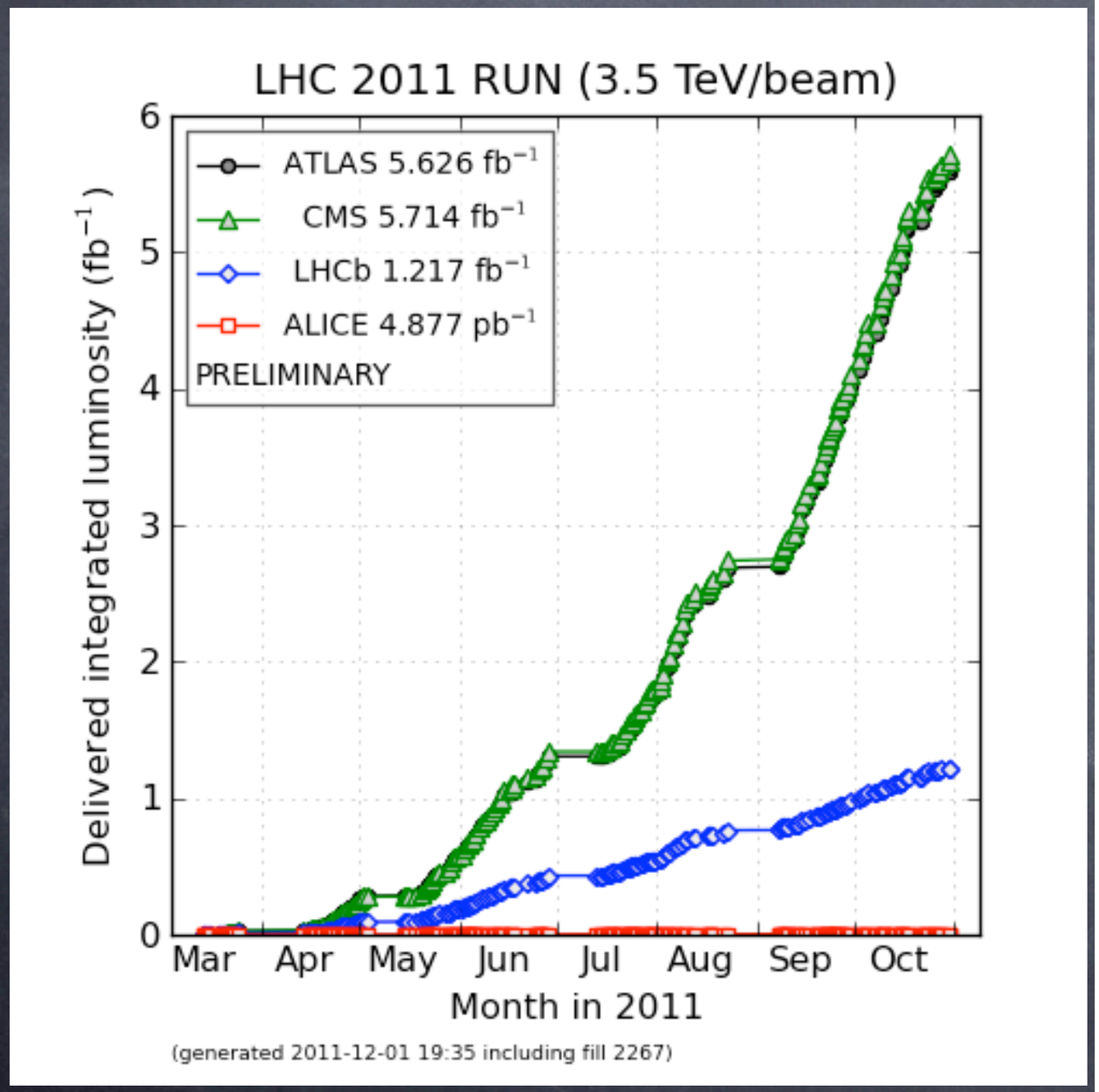
Phenomenology 2012 Symposium
Pittsburgh, PA
Tuesday, May 8, 2012

Outline

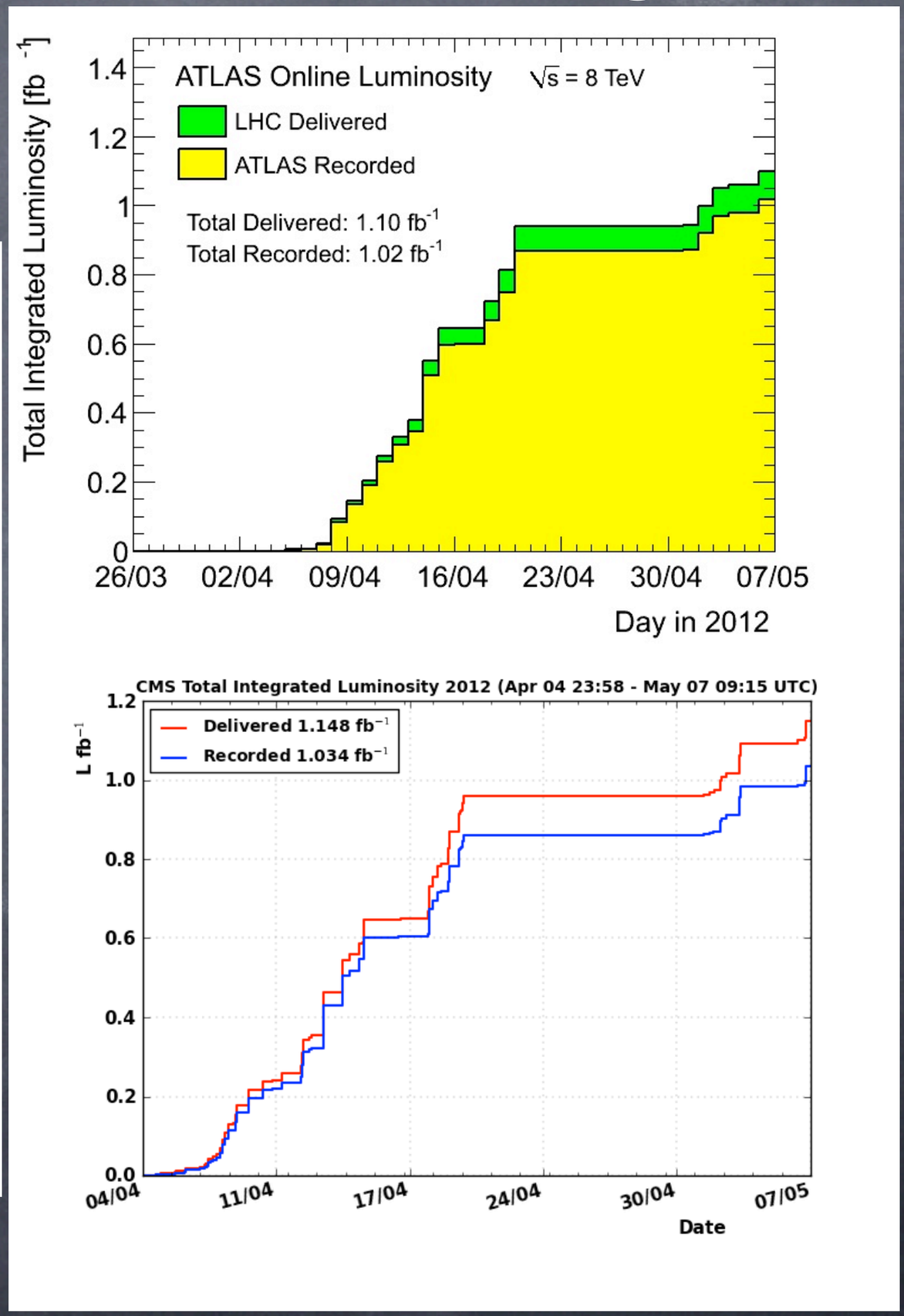
- EW Gauge Boson Production
- FEWZ 2.1 with new improvement
- FEWZ 3.0/3.1 with NLO QED/EW corrections
- Concluding Remarks

LHC: Up and Running

@ 7 TeV 2010～2011
@ 8 TeV 2012



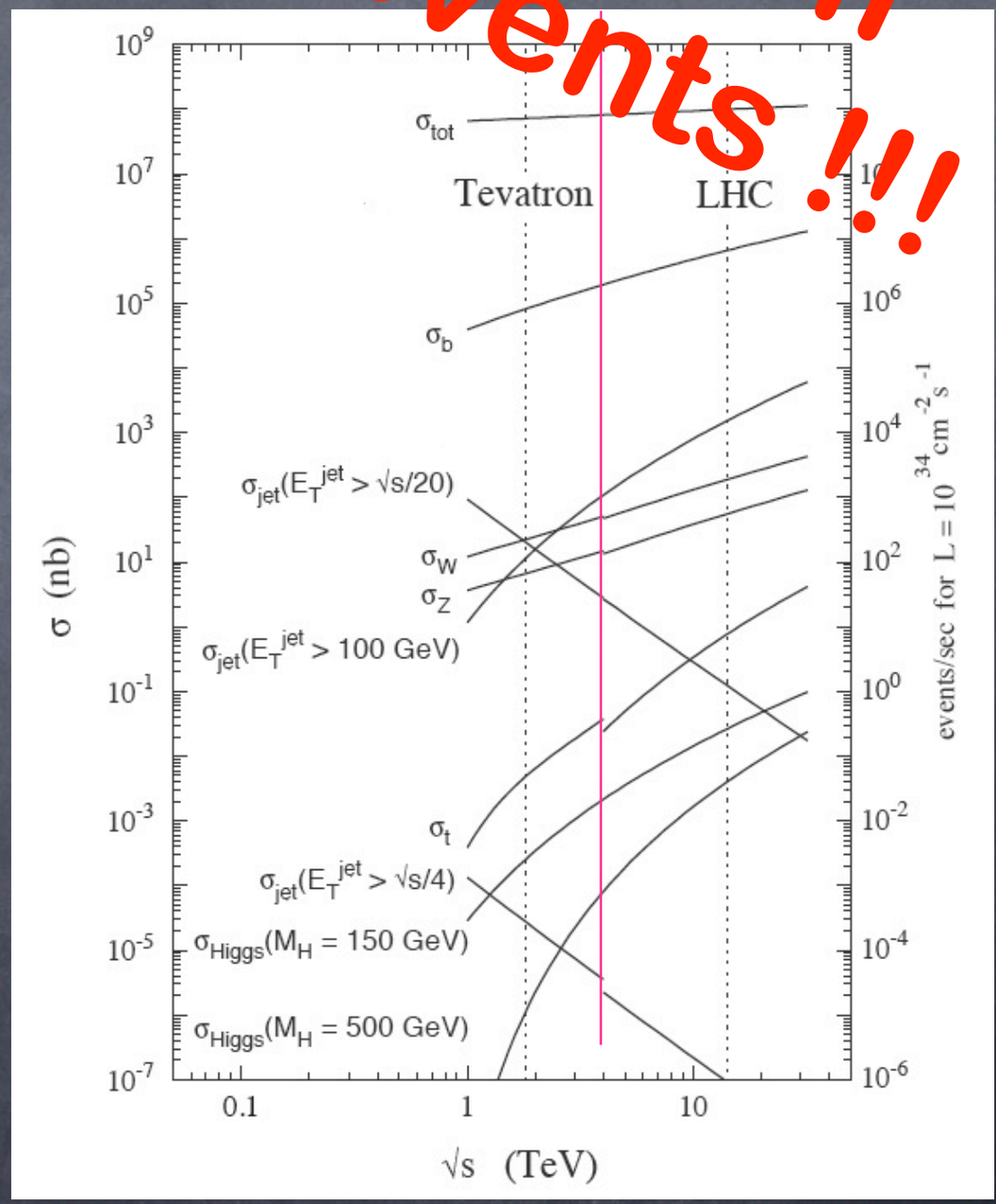
$$\mathcal{L}_{int} \sim 10 fb^{-1}$$



Z & W's at Hadron Colliders

- Z & W production still very interesting
  - playing an important role in LHC physics
- σ_Z, σ_W
  - large production cross sections: 1~10's of nbs

100m events !!!

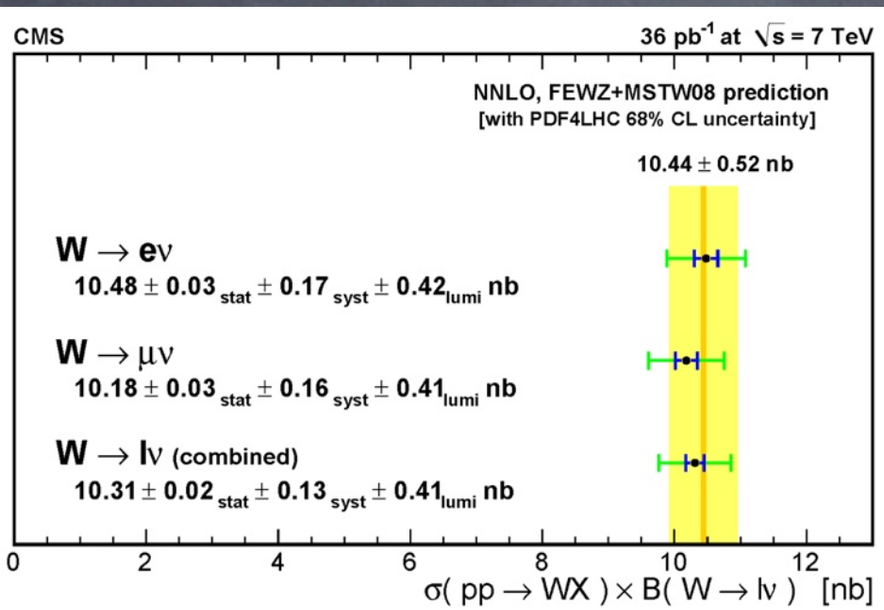


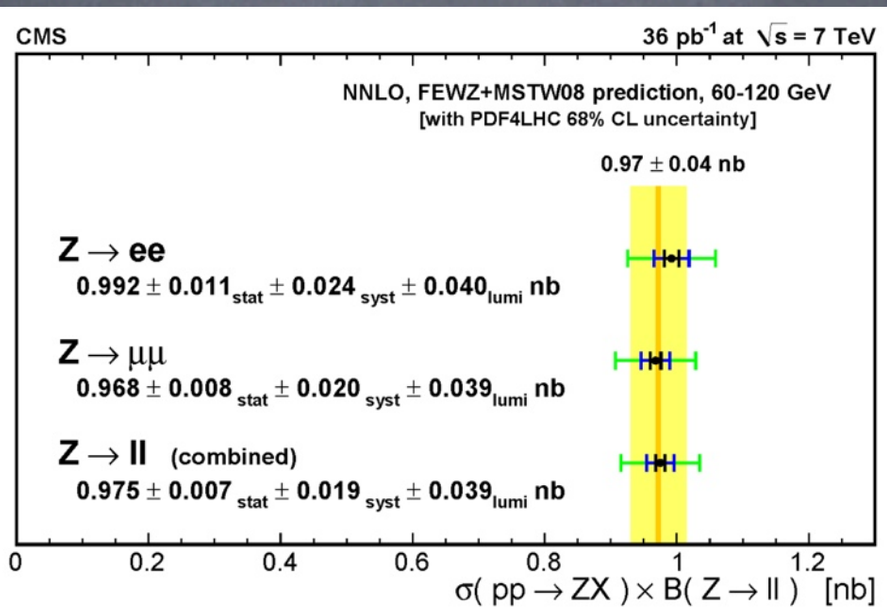
Z & W's at Hadron Colliders

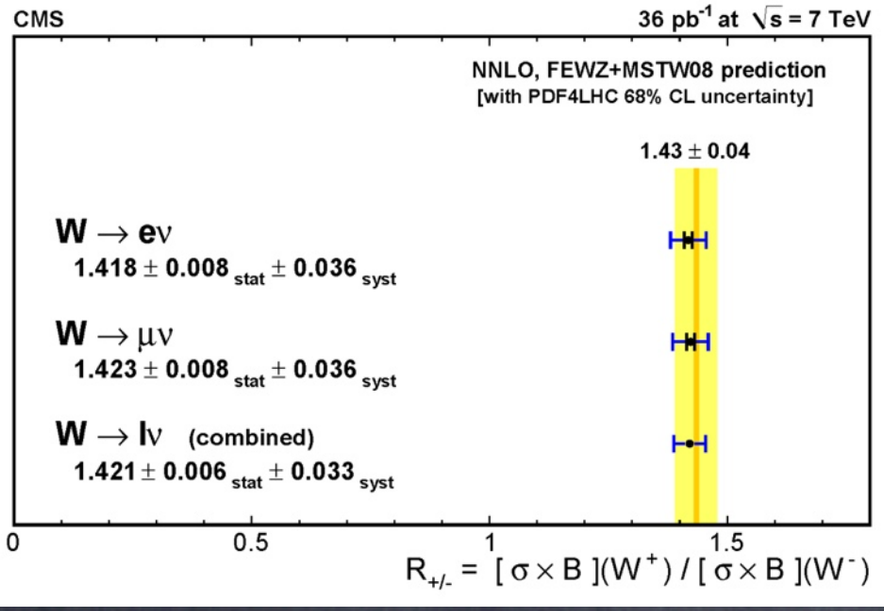
- Clean Signal from their leptonic decay
- Detector calibration and performance
- Luminosity monitoring
- Look at new analysis tools
  - Low Z pT study: aT, etc.
  - Beam thrust: systematic theoretical treatment of jet veto
- Potential discovery of new physics beyond SM:
  - Bump search: new gauge bosons, extra dimensions, composite particles, etc.
  - Deviation in lepton forward-backward asymmetry AFB
- Rich information on precision electroweak physics
  - Forward-backward asymmetry AFB helps determine weak mixing angle
- Study of perturbative QCD
  - pT distribution starts at NLO
  - DY as a theoretical laboratory for QCD techniques
    - pQCD fails at low pT and PS threshold region
    - Resummation technique first worked out for DY
- PDF measurement:
  - Distribution in Z rapidity measures/constraints PDFs
  - Low mass production sensitive to PDFs at small x value

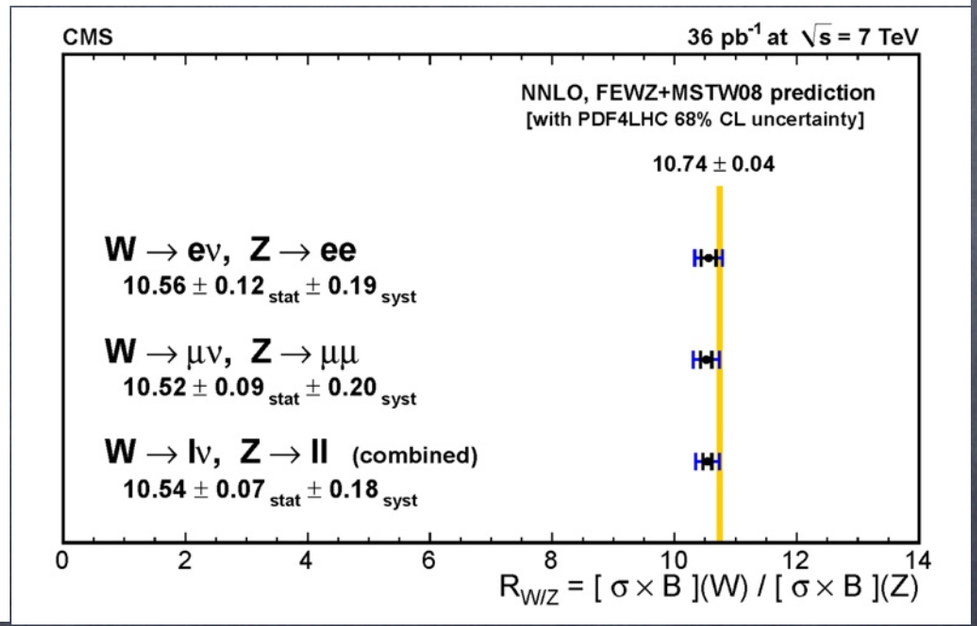
Standard Candle

FEWZ: Precision Drell-Yan









Inclusive Cross Section at CMS

arXiv:hep-ex/1107.4789

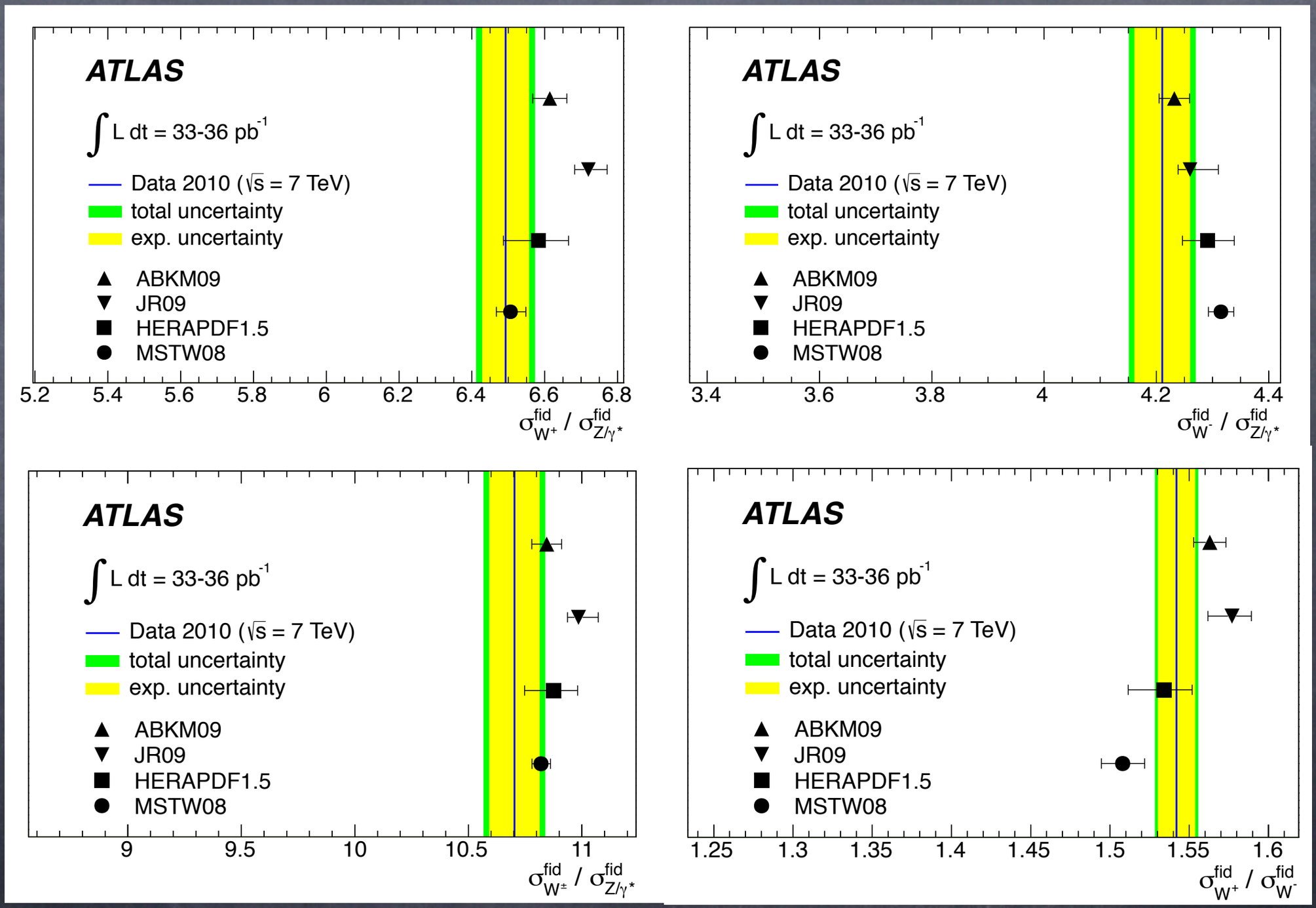
- Large amount of data → small statistical error
- Percent level physics requires NNLO QCD

FEWZ: Precision Drell-Yan

arXiv:hep-ex/1109.5141

Measured in Fiducial Volume of the ATLAS detector

Results of different PDF sets as well as their uncertainties are calculated using FEWZ



FEWZ

- Fortran based numerical code:
  compute W/Z DY cross sections in hadron colliders:
    - two executables: FEWZw & FEWZz, for charged and neutral current DY production respectively
    - perturbative order in QCD, CM energy and collider type (Tevatron or LHC)
    - fully exclusive in final state particles kinematics
    - numerical integration parameters (Vegas)
    - PDF sets (CTEQ, MSTW, HERA, NNPDF etc.)

FEWZ 2.1: New Features

- PDF error propagation & LHAPDF support
- input file for run configuration
- simultaneous generation of predefined histograms
- various bin sizes
- smoothing parameters
- cumulative histograms
- reduced run time for NNLO calculations

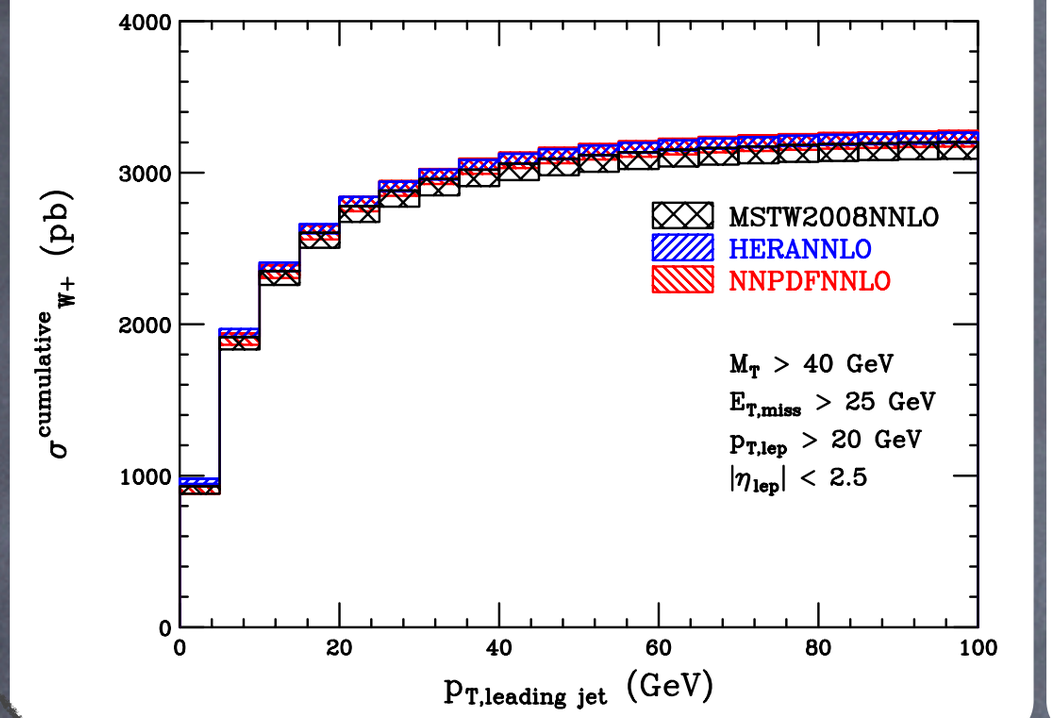
FEWZ at Work

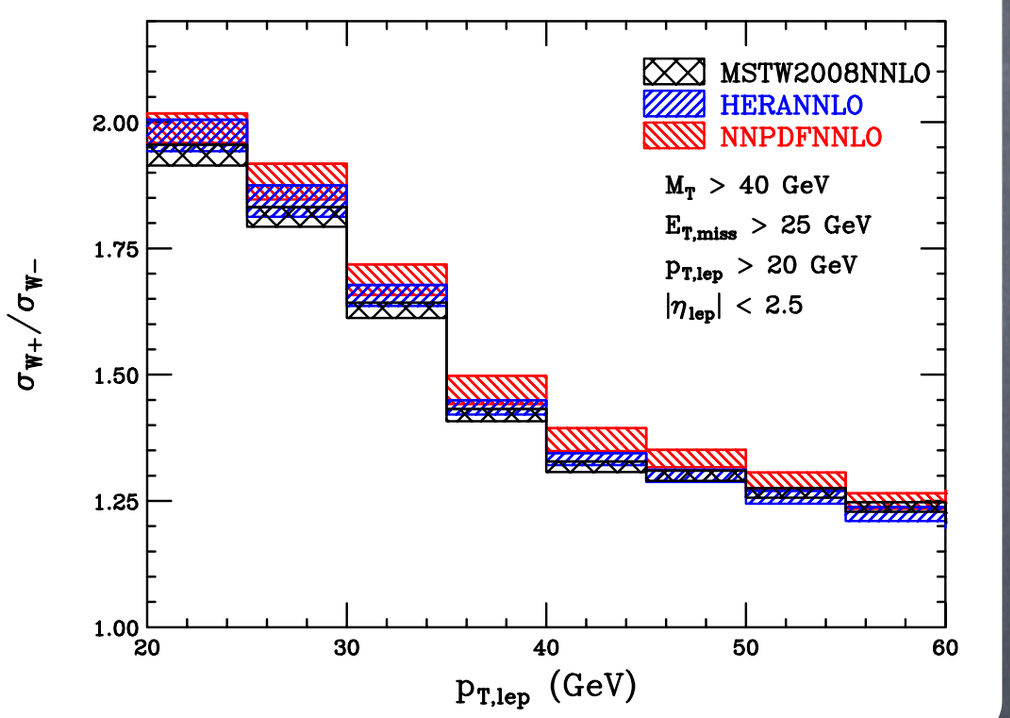
LHC @ 7 TeV
W production

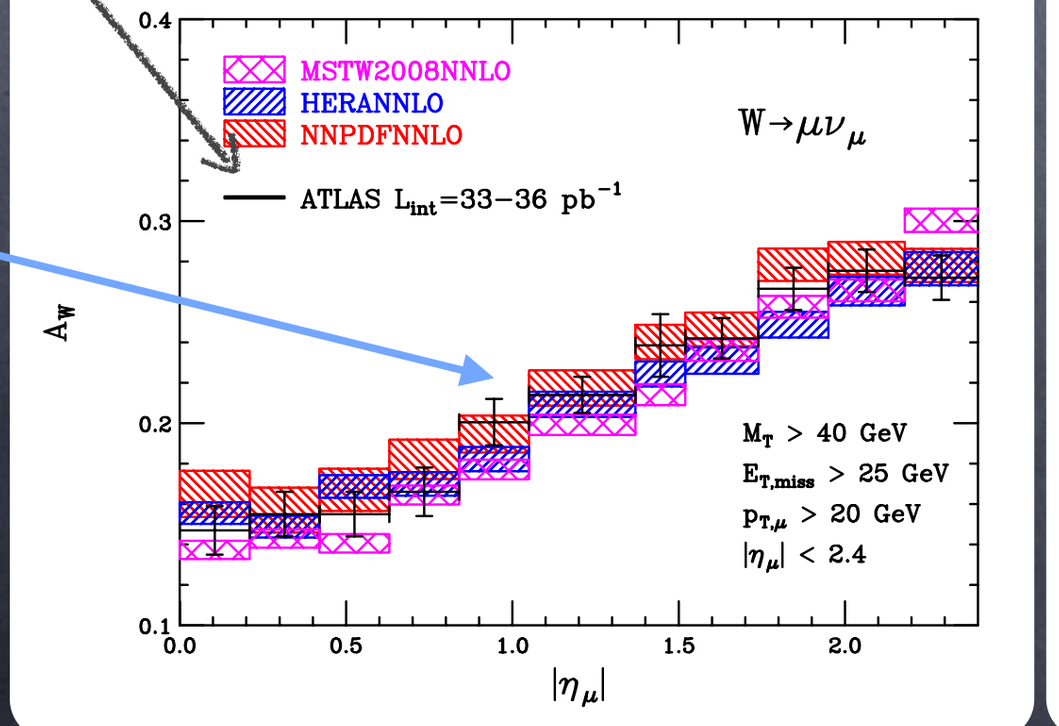
arXiv:hep-ph/1201.5896

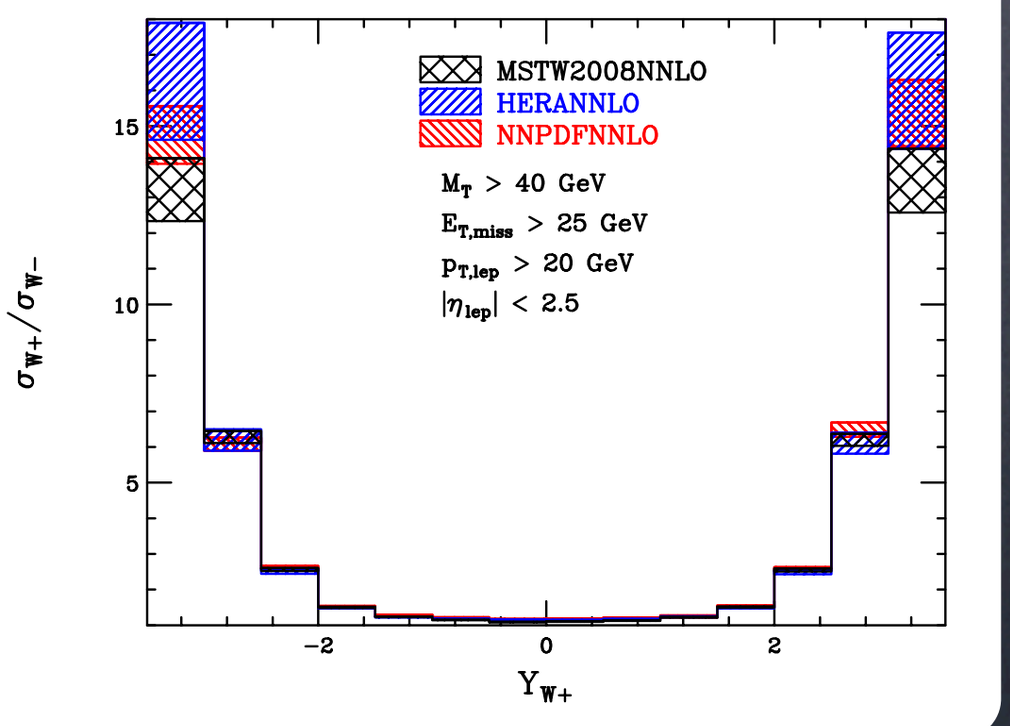
ATLAS data points are shown

Histogram with various bin sizes









QED Corrections

- With percent level physics - EW corrections needed: $\alpha_{EW} \sim \alpha_s^2$
- Full NLO QED to Z implemented as our first step
  - Negative QED corr. tends to cancel positive QCD correction (arXiv:0907.0276, arXiv:hep-ph/0611241)
  - Can shift Z pole in the resonance region
  - QED FSR can cause difference depending on how we reconstruct leptons in the calorimeter

FEWZ 3.0

- QED corrections included for percent level precision and FSR effect: Combined QED and QCD correction in a single run → no more unfolding
- Electroweak input coupling schemes
- Massive and massless lepton final states
- Input parameters and histograms for photon radiation
- For completeness, tree level photon initiated channel is also included for PDF set with photon distribution function

FEWZ at Work

- Comparison with Dittmaier and Huber's results for LHC @ 7 TeV using MRST2004QED

Preliminary

Percentage Corrections

M_{ll}/GeV	> 50	> 100	> 200	> 500	> 1000	> 2000
LO(D.)	738.733(6)	32.7236(3)	1.48479(1)	0.0809420(6)	0.00679953(3)	0.000303744(1)
LO_0	738.789(9)	32.723(4)	1.483(1)	0.0809449(8)	0.0067993(6)	0.0003038(1)
LO_μ	738.769(9)	32.728(4)	1.483(1)	0.0809451(8)	0.0067993(6)	0.0003037(1)
$\delta^{\gamma\gamma,LO}$(D.)	0.17	1.15	4.30	4.92	5.21	6.17
$\delta^{\gamma\gamma,LO}$	0.17	1.15	4.30	4.92	5.21	6.18
$\delta^{QED,rec}$(D.)	-1.81	-4.71	-2.92	-3.36	-4.24	-5.66
$\delta_0^{QED,rec}$	-1.80(1)	-4.83(4)	-2.84(8)	-3.46(1)	-4.33(4)	-5.66(18)
$\delta_\mu^{QED,rec}$	-1.78(1)	-4.74(9)	-2.90(10)	-3.45(1)	-4.44(7)	-5.21(31)
δ_μ^{QED}(D.)	-3.34	-8.85	-5.72	-7.05	-9.02	-12.08
δ_μ^{QED}	-3.39(1)	-9.05(8)	-5.78(7)	-7.28(1)	-9.29(7)	-12.50(31)

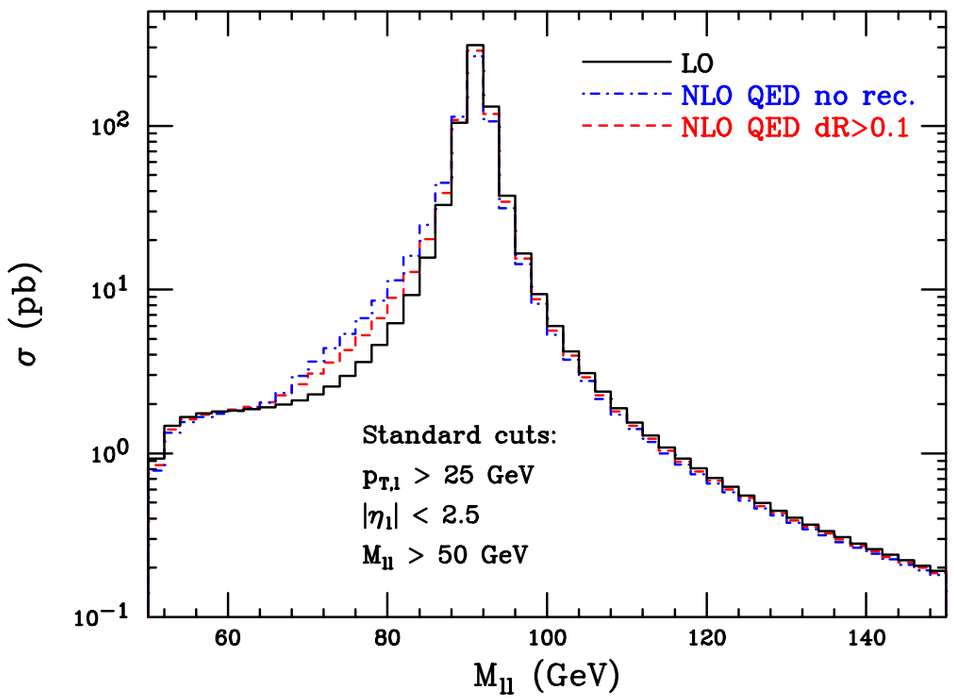
- "D." represents the results of Dittmaier etc.
- "0" means the result with massless lepton
- "μ" denotes the result with muon mass

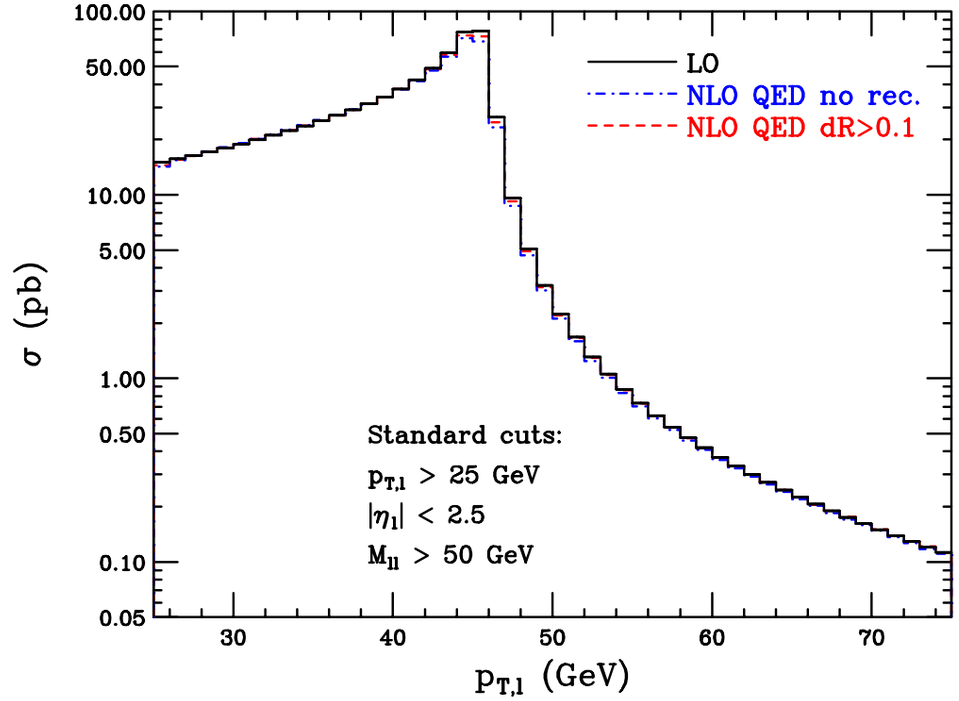
photon-initiated channel

FEWZ at Work

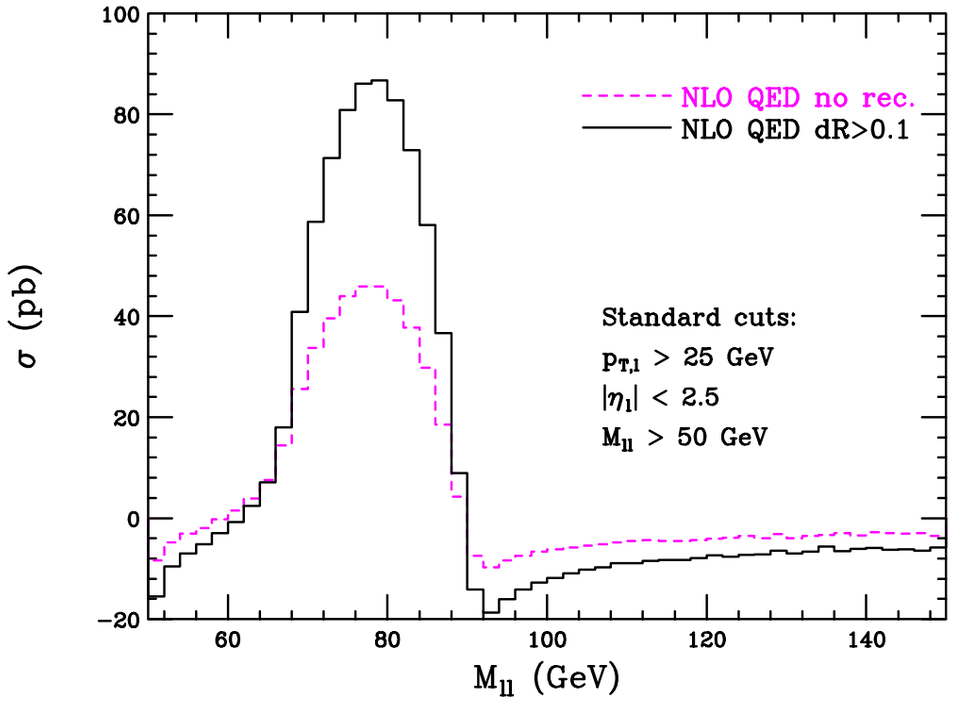
LHC @ 7 TeV
Z production

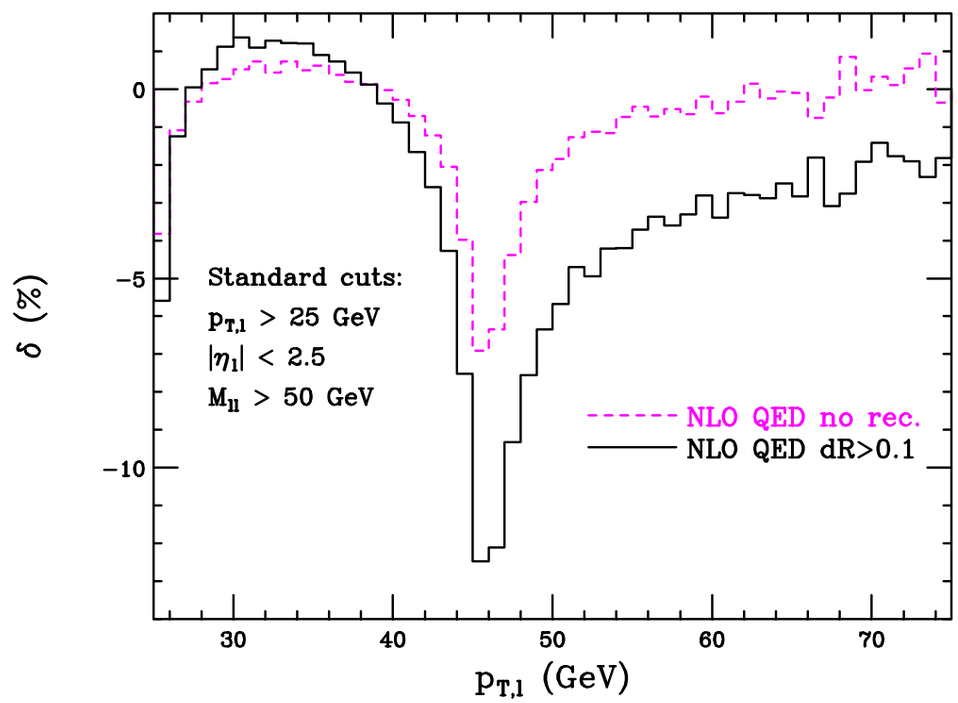
Preliminary





Z pole is shifted to slightly lower value



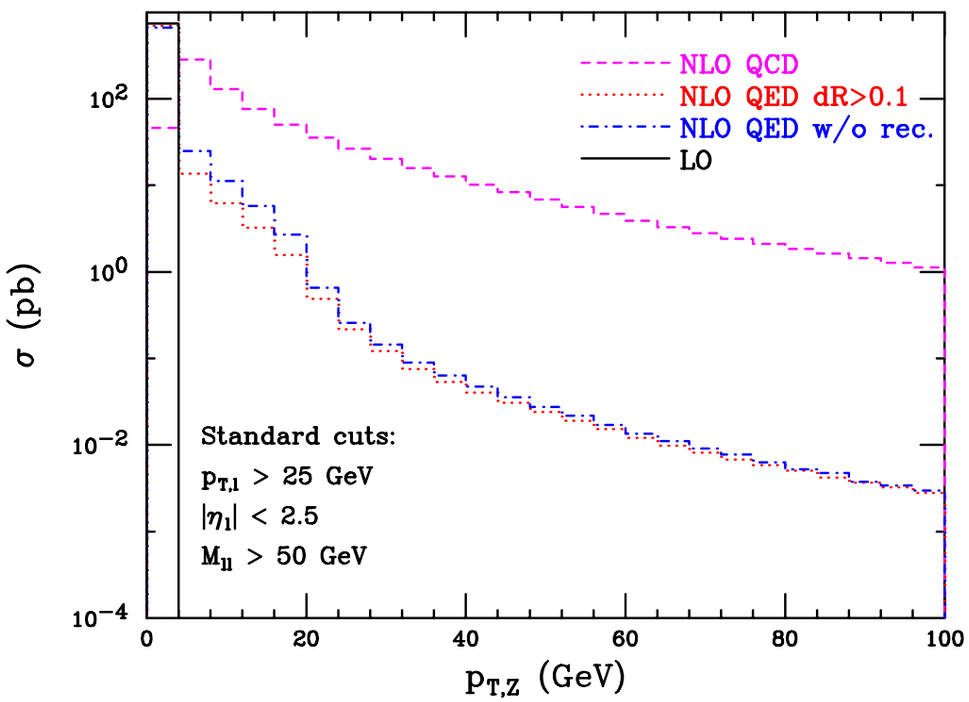


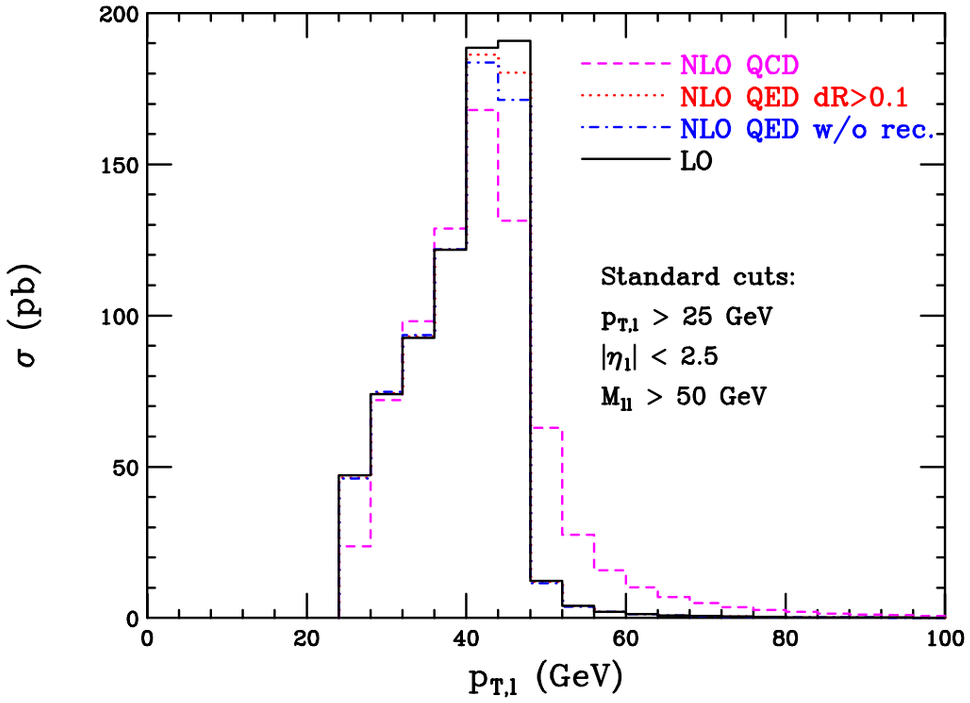
NLO QED correction is enhanced when photon lepton recombination is off due to log(Ml/Mz)

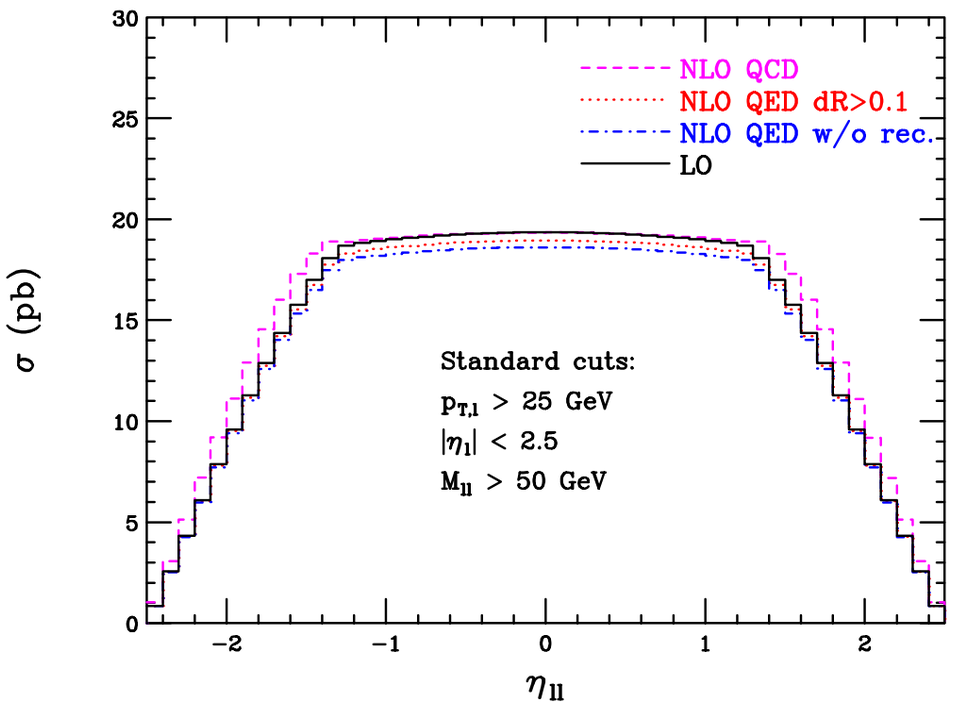
LHC @ 7 TeV
Z production

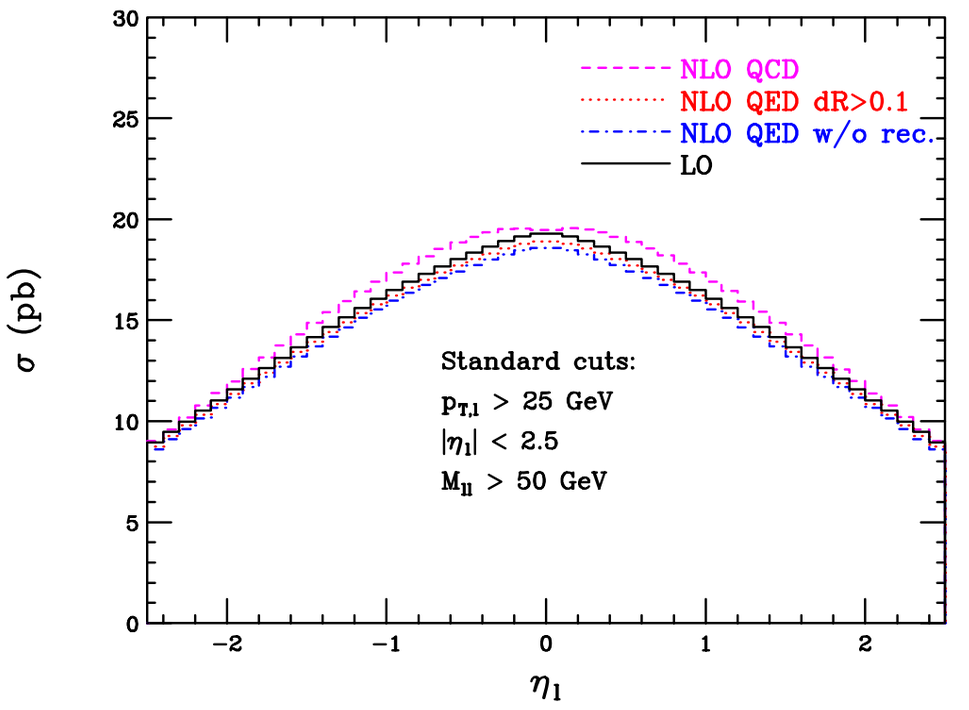
FEWZ at Work

Preliminary



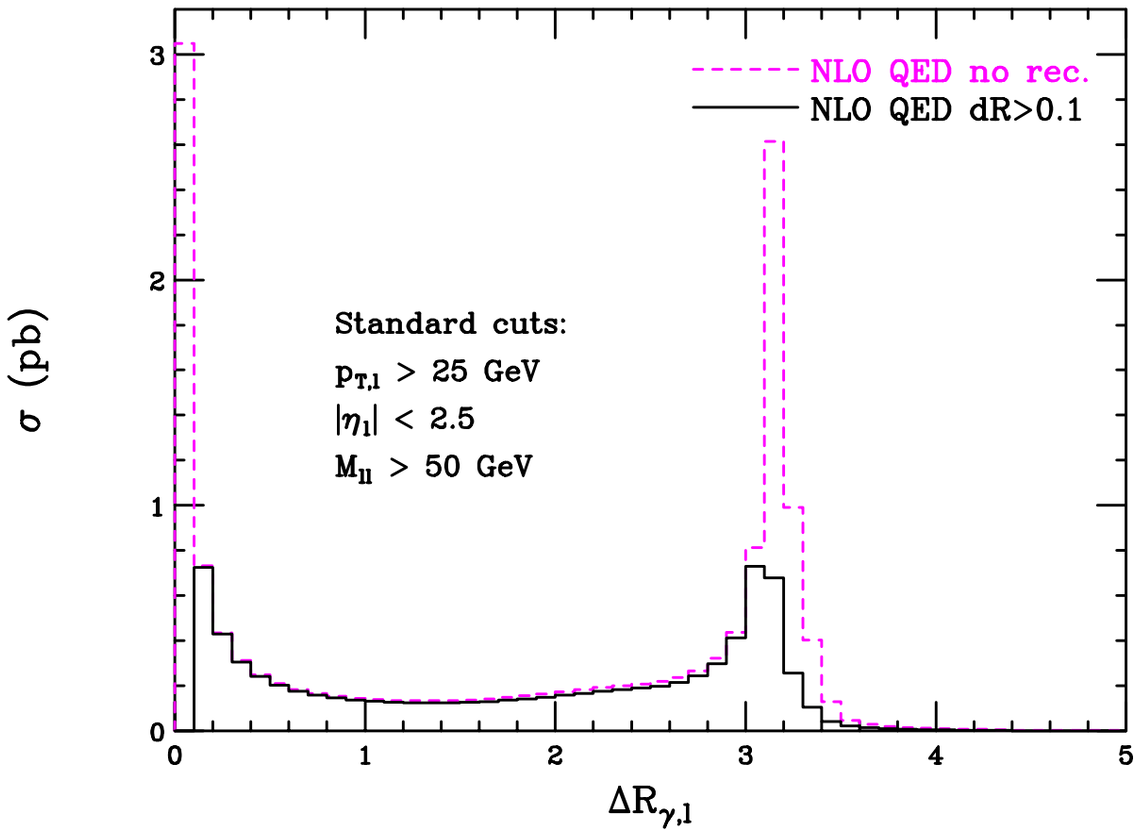




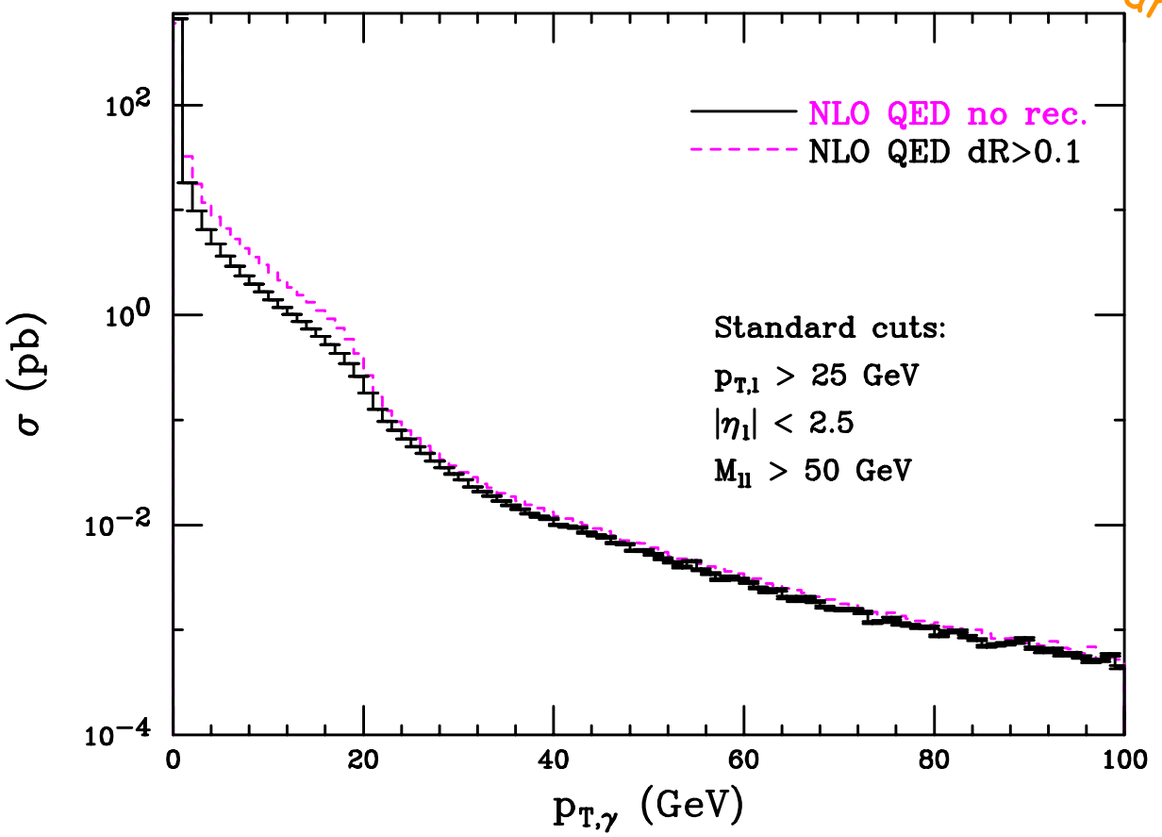


FEWZ at Work

- Can also use FEWZ to study $pp \to Z+\gamma$
- The photon pT distribution has a sudden drop at Mz/2-25GeV due to the Jacobian peak in



Preliminary



EW Corrections

- Implementation of full EW corrections is currently under debugging
- Can Cause more negative shift of Z pole
- Relative large correction in higher mass region due to EW Sudakov logarithms: -10% for LHC @ 14 TeV
- Expect FEWZ 3.1 with EW correction coming up very soon

Further developments

- EW correction for W is also important for better determining W mass, which will be added in the future
- Small pT resummation for W and Z is also considered to be added for more accurate pT distribution
- EW⊗QCD ($\alpha_{EW} \cdot \alpha_s$) corrections level physics
  - effects only estimated (arXiv:0907.0276)
  - true calculation would be helpful

Conclusions

- EW gauge boson production is still a very important process at the LHC
  - standard candles
  - key processes for EW precision physics & PDFs
  - implications for BSM physics
- New version of FEWZ will provide NNLO QCD and NLO EW accuracy
  - true percent level physics
  - accurate differential distributions