QCD+EW corrections in FEWZ

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Working group on EW precision measurements at the LHC
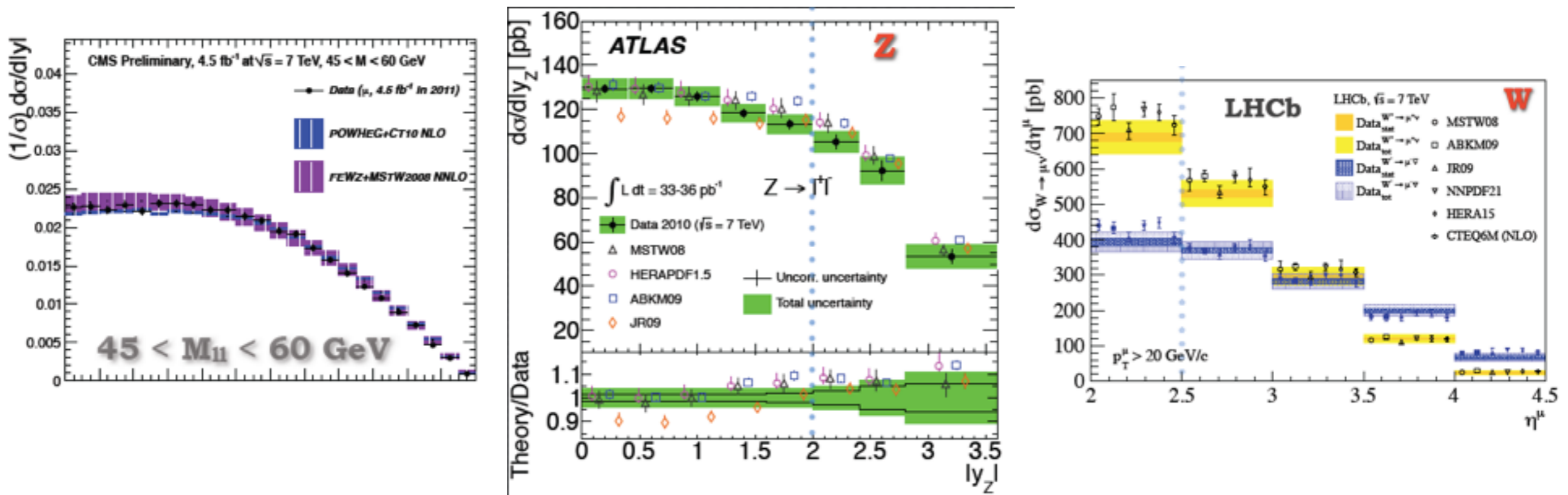October 9, 2012

Outline

- Brief motivation

- What is in the new FEWZ 3

- Details of input choices

- Results

- Conclusions and postscript

Motivation

- Motivation for this work is the impressive experimental results shown below

- Approaching (or at) percent-level errors in numerous measurements, with impact on precision determination of PDFs, electroweak parameters, and deviations from the SM
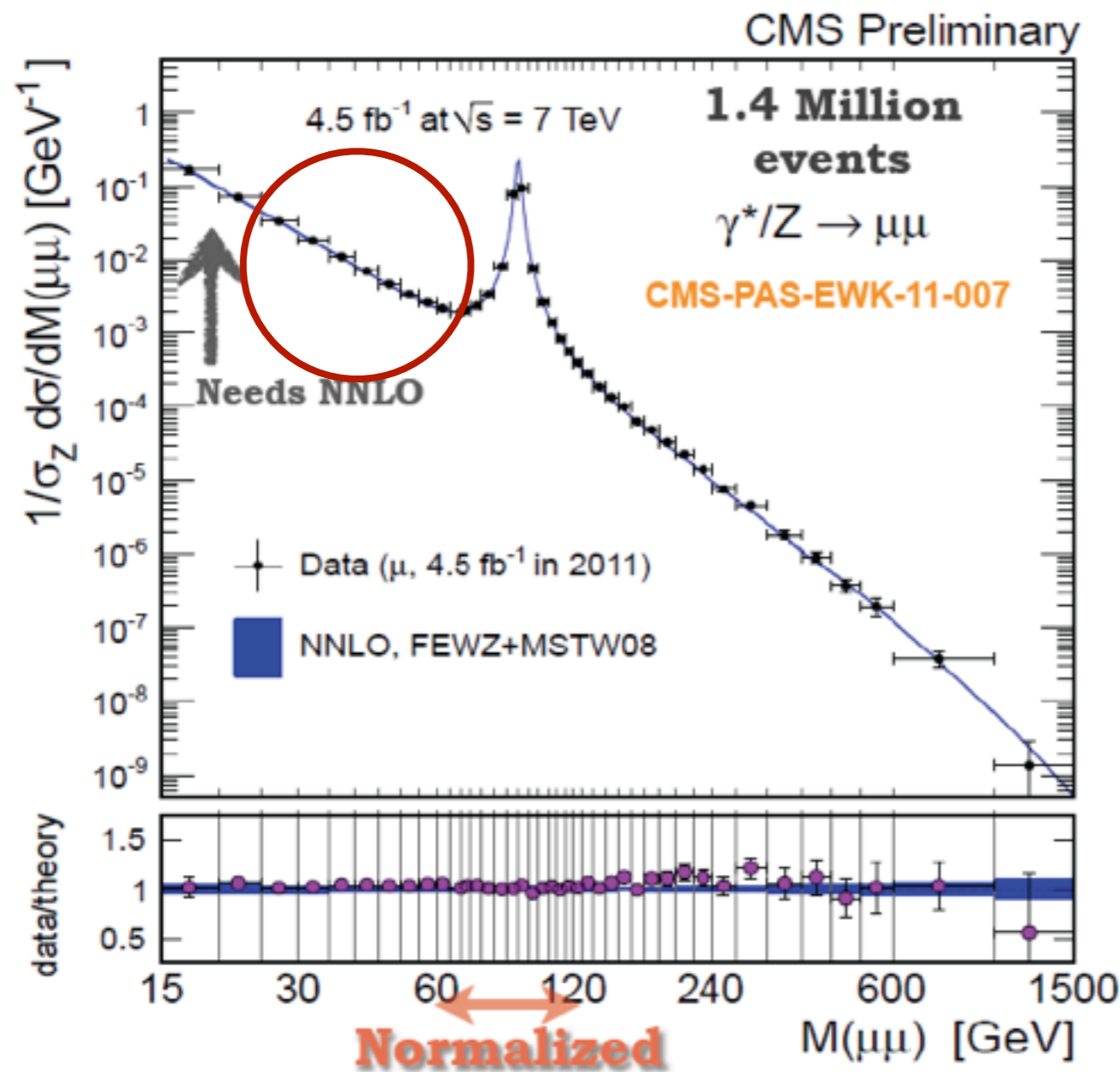
EW corrections

- Starting also to probe kinematic regions off the Z-peak, where electroweak corrections must be included
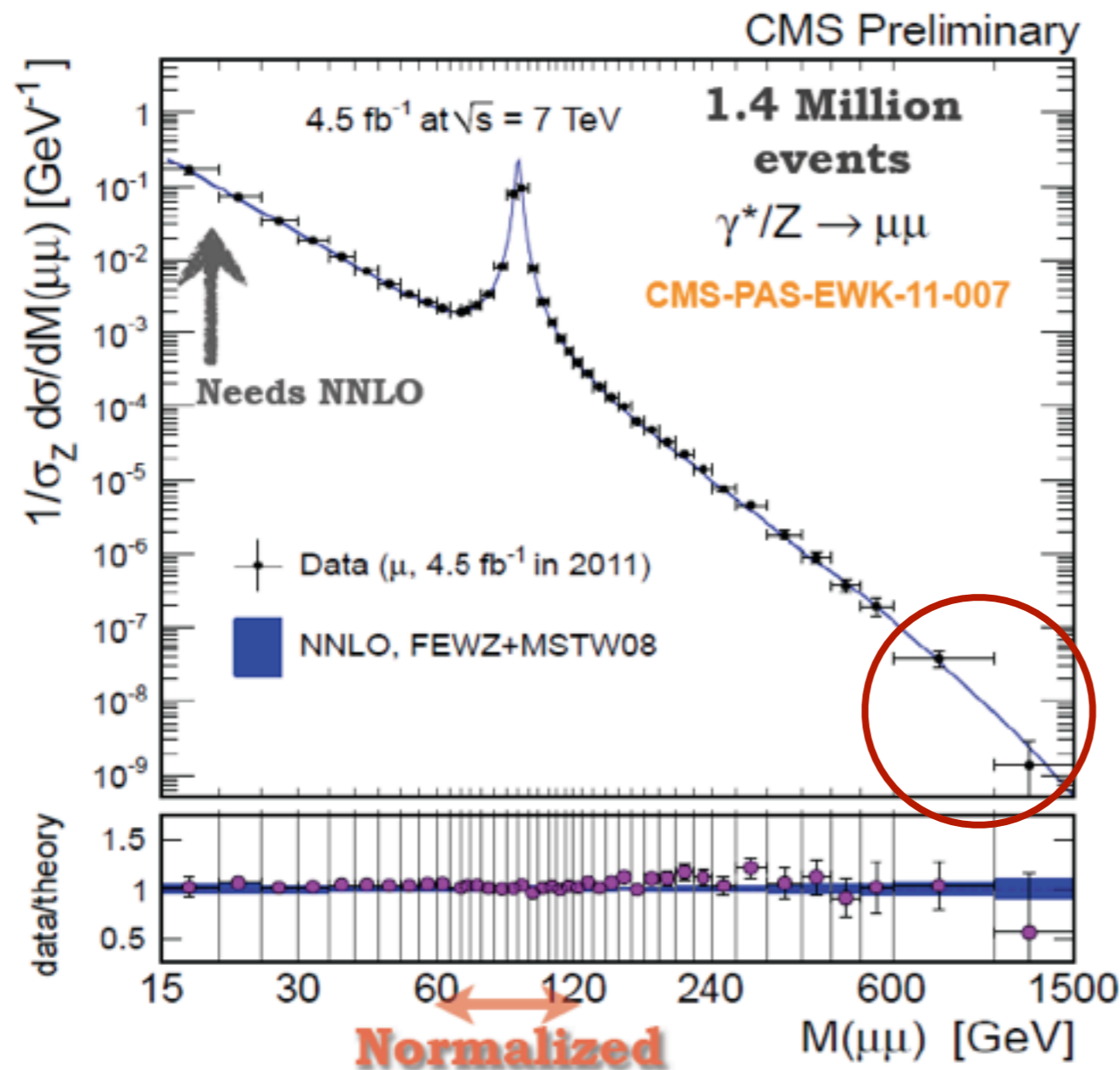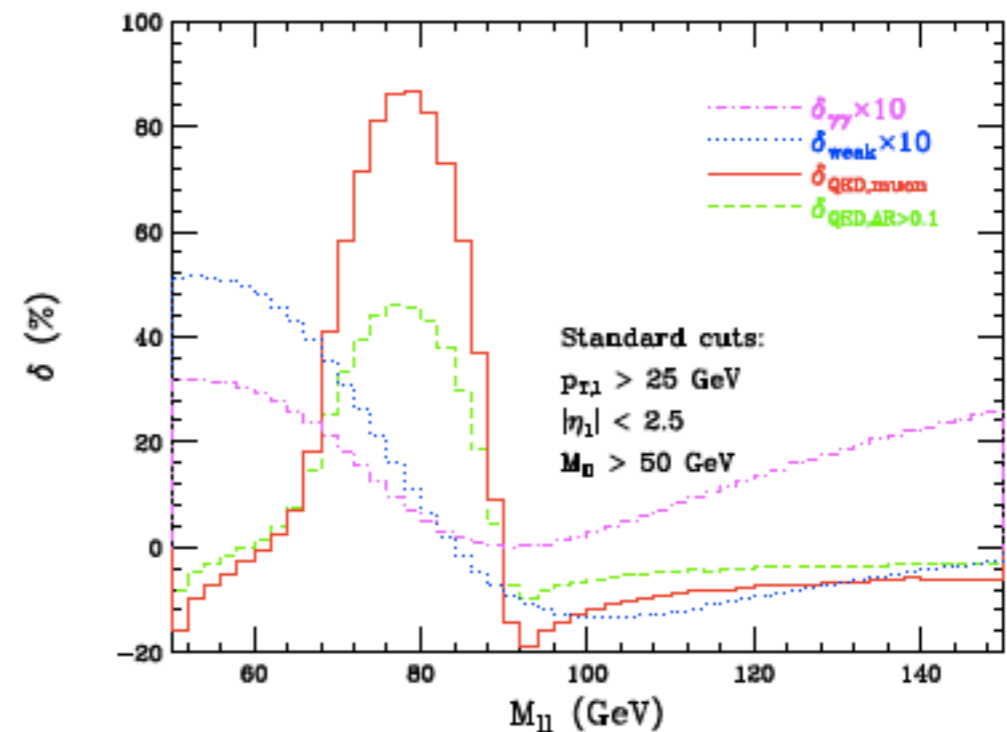

- Numbers for 14 TeV LHC:

    Sudakov corrections: $\delta_{Sud} \approx -(3\text{-}6)\%$
    $\gamma\gamma \to ll$: $\delta_{\gamma\gamma} \approx +5\%$
    QED: $\delta_{QED} \approx -(3\text{-}4)\%$

EW corrections

- Starting also to probe kinematic regions off the Z-peak, where electroweak corrections must be included

- High M_{ll}, numbers for 14 TeV LHC:

  Sudakov corrections: $\delta_{Sud} \approx -(3-6)\%$
  $\gamma\gamma \rightarrow ll$: $\delta_{\gamma\gamma} \approx +5\%$
  QED: $\delta_{QED} \approx -(3-4)\%$

- $M_{ll} < M_Z$, for 14 TeV LHC:

Goals

- Very modest goal, motivated by experimental request: include the higher-order QCD and EW corrections in a single code

- FEWZ 3: NNLO QCD+NLO EW in the additive approximation; no control over mixed $O(\alpha \alpha_S)$

- NLO EW using complex-mass scheme

- Intended usage is for reasonably-inclusive distributions; don't look at bins very near Jacobian peaks, $p_{T,Z}=0$

New features in FEWZ 3

- NNLO QCD+NLO EW with additive combination

- Photon-induced contributions at LO

- Support for G_μ and $\alpha(M_Z)$ schemes (also manual input, but then only QED corrections used)

- Logarithmically-enhanced fermion-mass terms included

- Ability to turn on/off QED FSR/ISR, weak contributions

- Supports dynamical scale choice

Input file

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Alpha QED (0) is for photon-induced channels (which use photon PDFs); set to zero to turn off these channels

'Alpha QED (0)   = ' 0.007297352568d0   *used for $\gamma\gamma \to ll$, only if the PDF set has this option*

'Alpha QED (Mz)   = ' 0.007756146746d0

'Fermi constant (1/Gev^2)   = ' 1.16637d-5

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Only QED corrections is on if the input scheme is manual

Input scheme: 0. Manual input; 1. Gmu scheme; 2. AlphaMz scheme

'Which input scheme: = ' 1   *Our default choice*

Input file

PHOTON RECOMBINATION-------------------------------
'DeltaR sep. for photon recomb.   = ' 0.1d0
'Minimum pT for observable photon   = ' 10d0
'Maximum eta for observable photon = ' 2.5d0
PHOTON CUTS--------------------------------------
'Minimum Number of Photon   = ' 0
'Maximum Number of Photon   = ' 1

'Lep-Photon deltaR minimum   = ' 0.0d0

Combine photon four-momentum with lepton i within this radius in η-Φ plane

Can study either inclusive or exclusive photon multiplicities

Benchmarking

- Detailed study of NLO EW corrections by Dittmaier, Huber 0911.2329

$$p_{T,l^\pm} > 25 \text{ GeV}, \ |\eta_{l^\pm}| < 2.5.$$

M_{ll}/GeV	> 50	> 100	> 200	> 500	> 1000	> 2000
LO(DH)/pb	738.733(6)	32.7236(3)	1.48479(1)	0.0809420(6)	0.00679953(3)	0.000303744(1)
LO_0/pb	738.789(9)	32.723(4)	1.483(1)	0.0809449(8)	0.0067993(6)	0.0003038(1)
LO_μ/pb	738.769(9)	32.728(4)	1.483(1)	0.0809451(8)	0.0067993(6)	0.0003037(1)
$\delta^{\gamma\gamma,LO}(\text{DH})/\%$	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
$\delta^{QED,rec}(\text{DH})/\%$	-1.81	-4.71	-2.92	-3.36	-4.24	-5.66
$\delta_0^{QED,rec}/\%$	-1.79	-4.80	-2.94	-3.41	-4.33	-5.81
$\delta_\mu^{QED,rec}/\%$	-1.77	-4.78	-2.93	-3.41	-4.33	-5.83
$\delta_\mu^{QED}(\text{DH})/\%$	-3.34	-8.85	-5.72	-7.05	-9.02	-12.08
$\delta_\mu^{QED}/\%$	-3.38	-9.09	-5.85	-7.22	-9.28	-12.47
$\delta^{weak}(\text{DH})/\%$	-0.71	-1.02	-0.14	-2.38	-5.87	-11.12
$\delta^{weak}/\%$	-0.70	-1.02	-0.14	-2.38	-5.87	-11.11

DH account for the mixing of quark and photon PDFs from collinear singularities; we have not (yet) included this
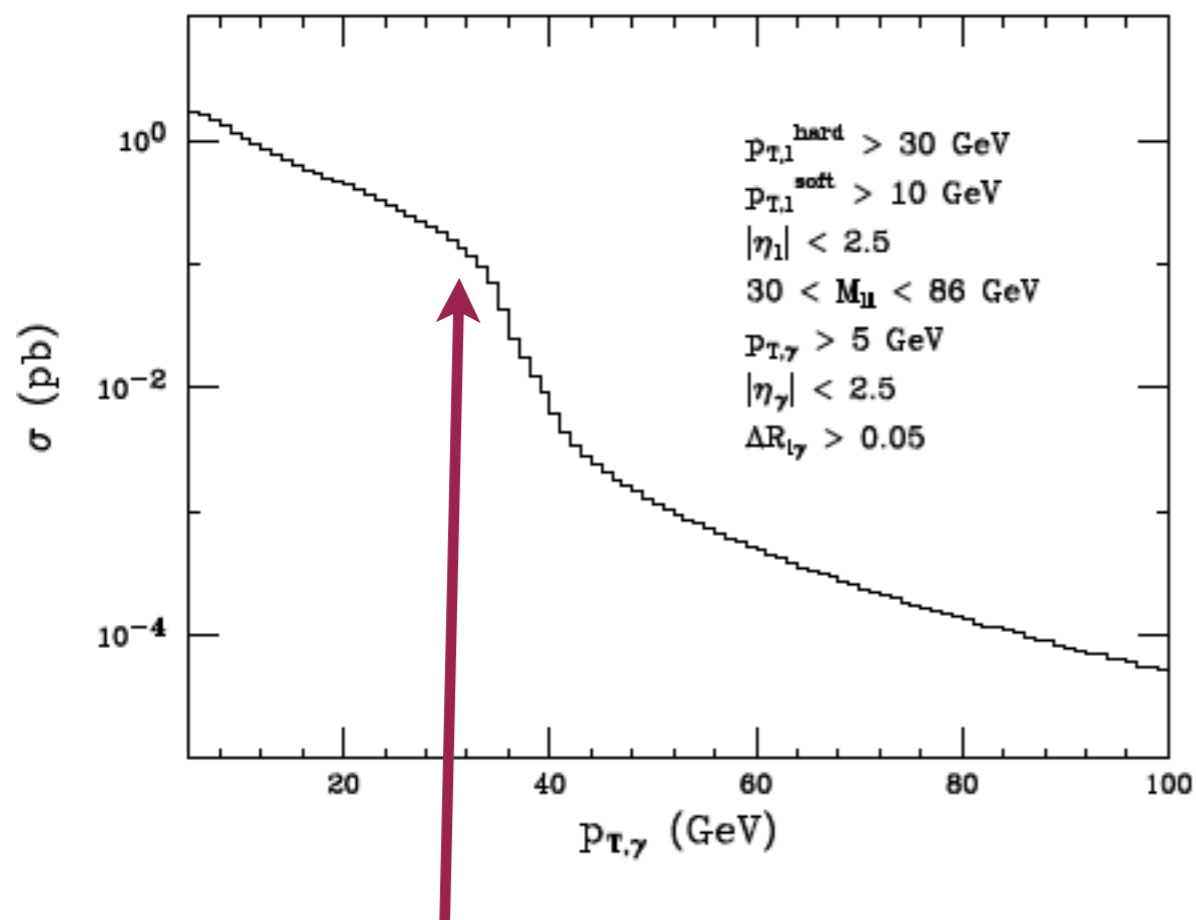
Distributions

- Some results from NNLO QCD+NLO EW combination:
obtained with MSTW2008 NNLO PDFs; hatched regions show 68%CL PDF-only error
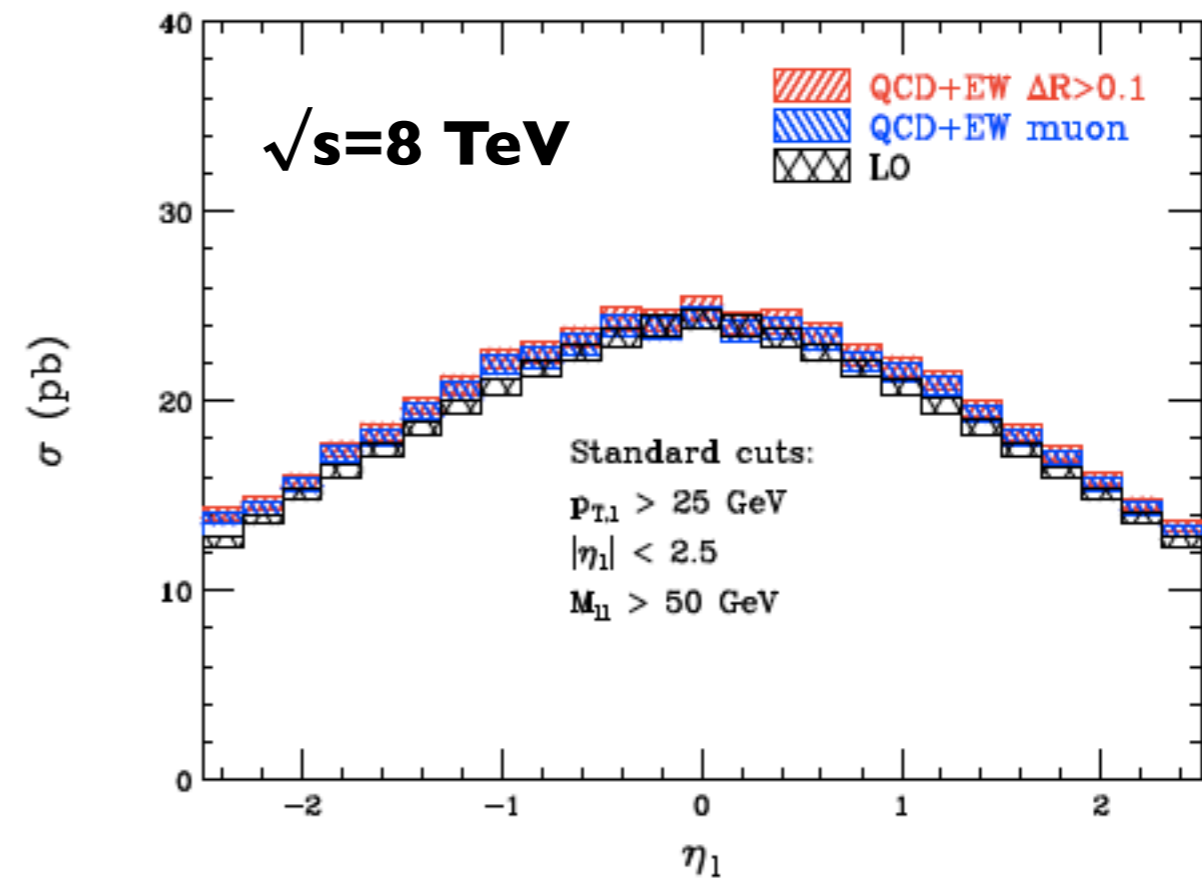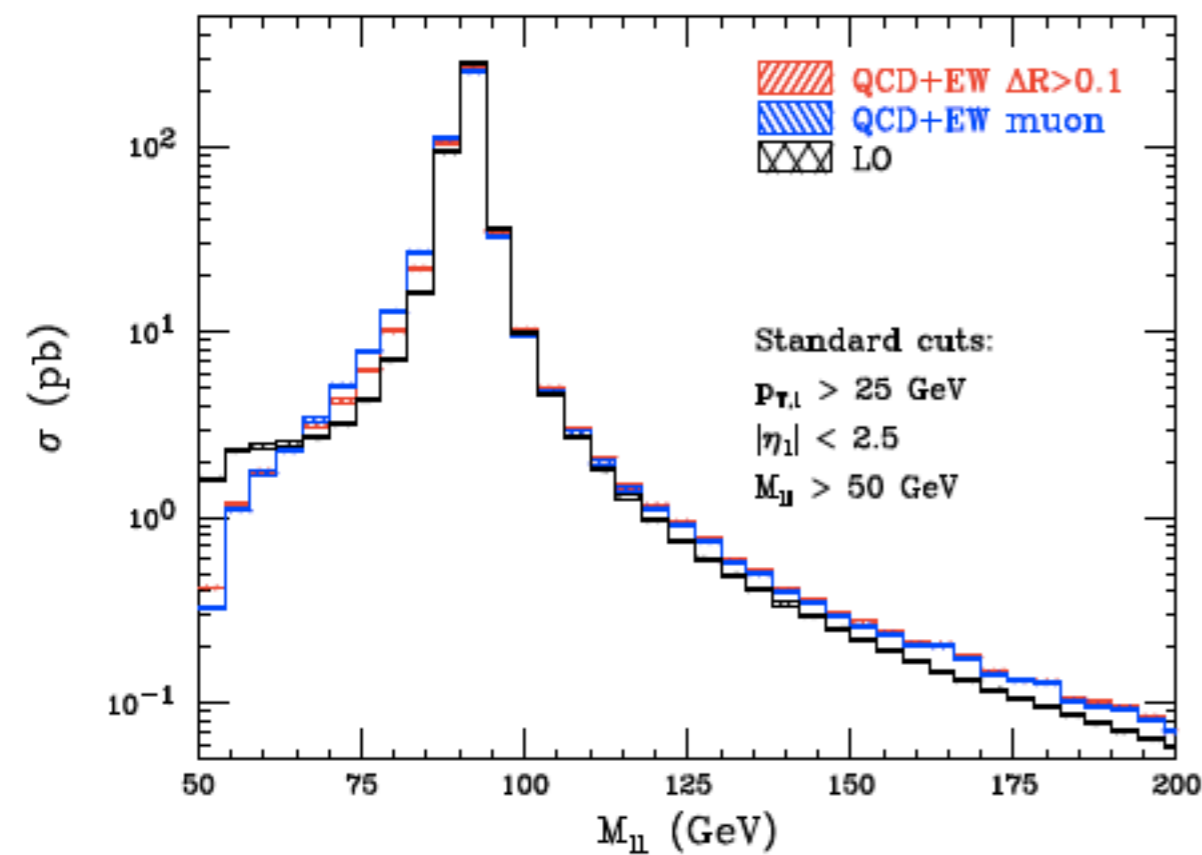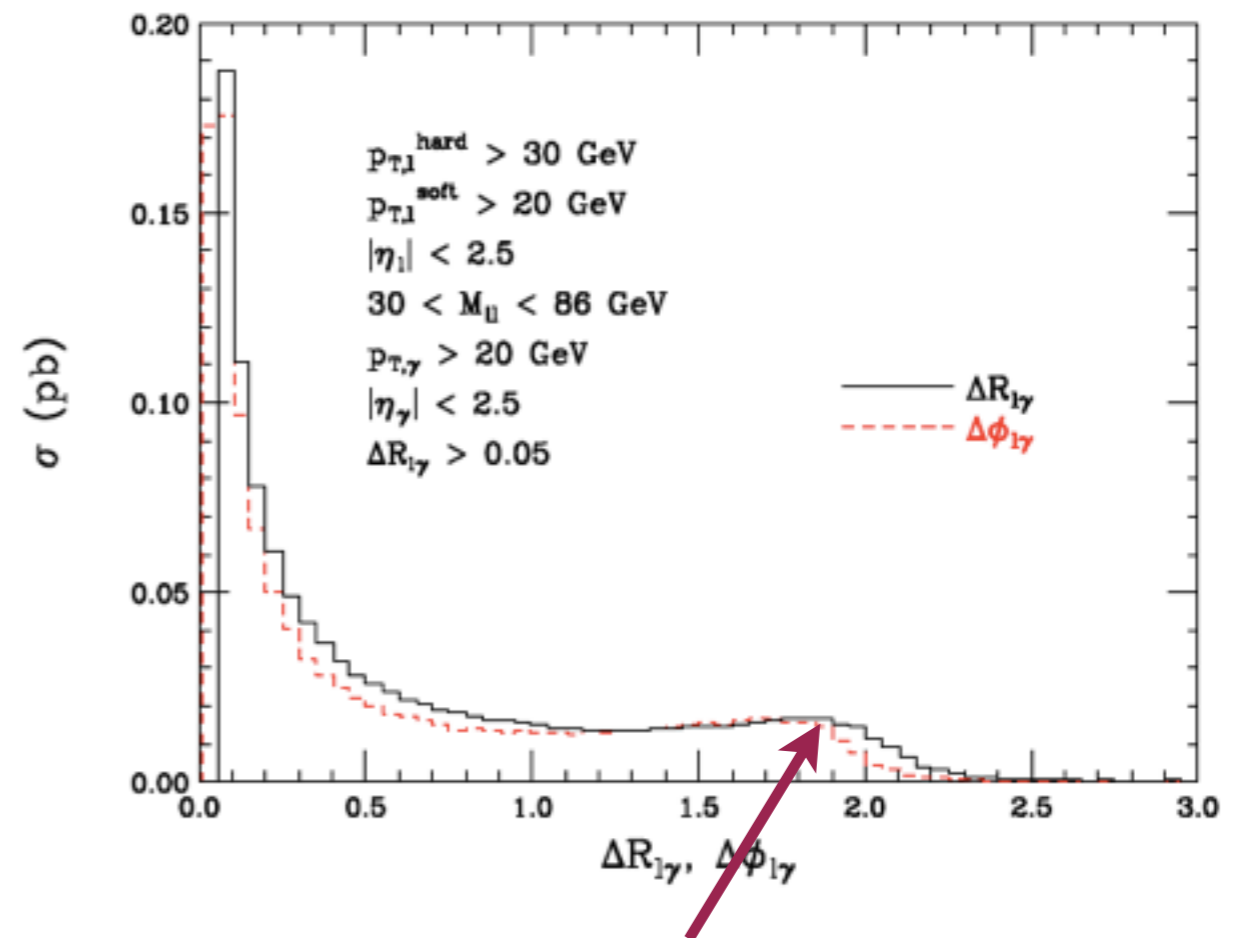
Distributions

- Some results for photon kinematics below the Z-peak (please note, LO only in such observables)
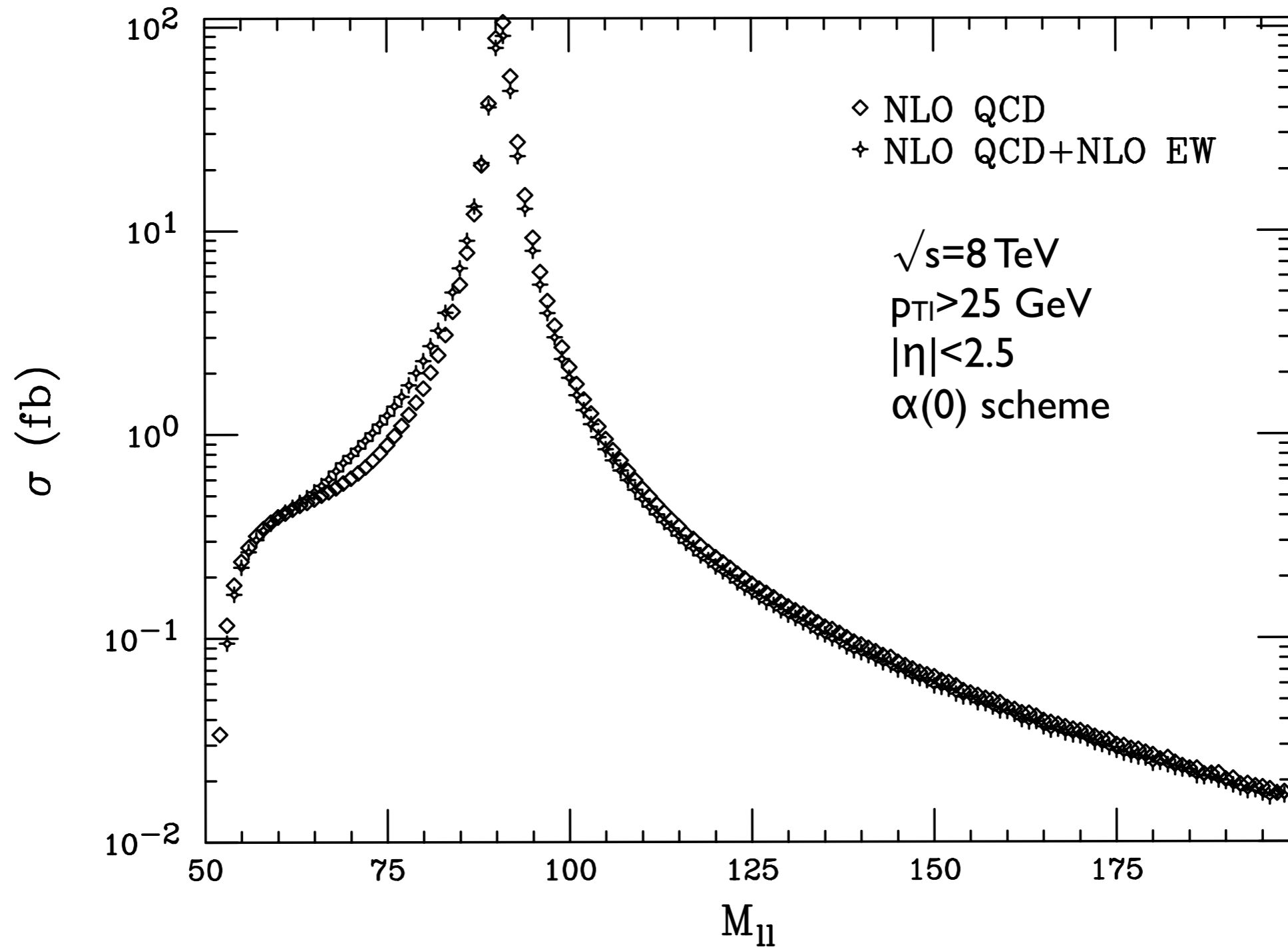

$p_{T,l}^{hard} > 30$ GeV
$p_{T,l}^{soft} > 10$ GeV
$|\eta_l| < 2.5$
$30 < M_{ll} < 86$ GeV
$p_{T,\gamma} > 5$ GeV
$|\eta_\gamma| < 2.5$
$\Delta R_{l\gamma} > 0.05$

Shoulder corresponds to maximum p_T for FSR photons from on-shell Z production recoiling against hard lepton

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$\Delta R_{l\gamma}$
$\Delta\phi_{l\gamma}$

$$\pi - \arccos(p_{T,\gamma,min}/M_Z)$$

Corresponds to maximal $\Delta\Phi_{l\gamma}$ for on-shell Z production

Benchmark study numbers

Conclusions

- Have presented a new version of FEWZ that has NLO EW corrections combined with NNLO QCD in the additive approximation

- EW corrections in the complex-mass-scheme; good agreement with previous literature

- Have shown representative results, including some numbers for the benchmark study

- As always, look forward to feedback from experimental colleagues

PS:

- The following plots were shown at ICHEP:
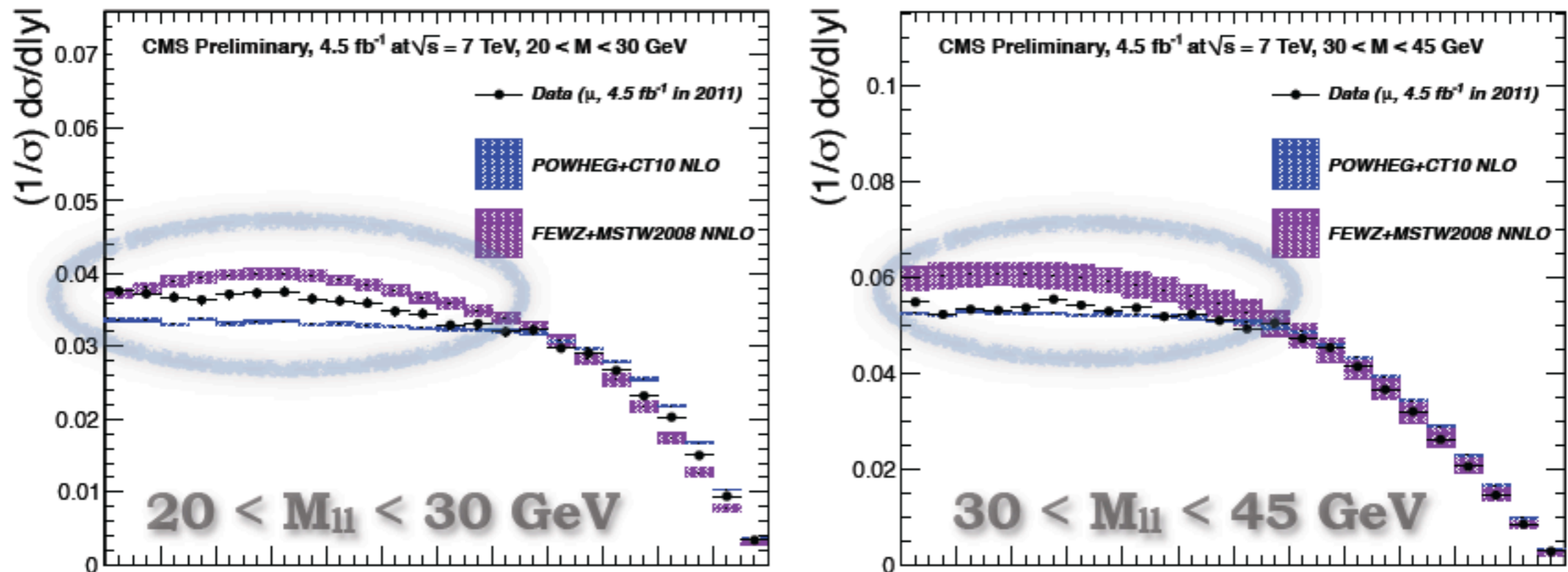
- We contacted CMS to find out details about this study and was told that updated calculations would appear (our initial testing in the 30-45 GeV bin revealed no sign of a NLO/NNLO discrepancy, or need for resummation). Nothing yet... is there an update?