Electroweak Measurements at CMS: W/Z cross-sections (inclusive and differential)

Working Group on Electroweak precision measurements at the LHC
April 4, 2011

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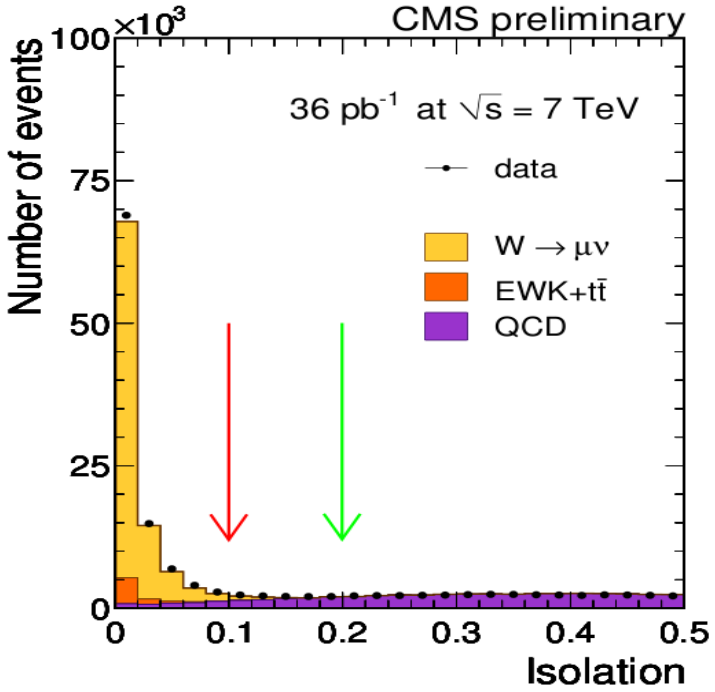
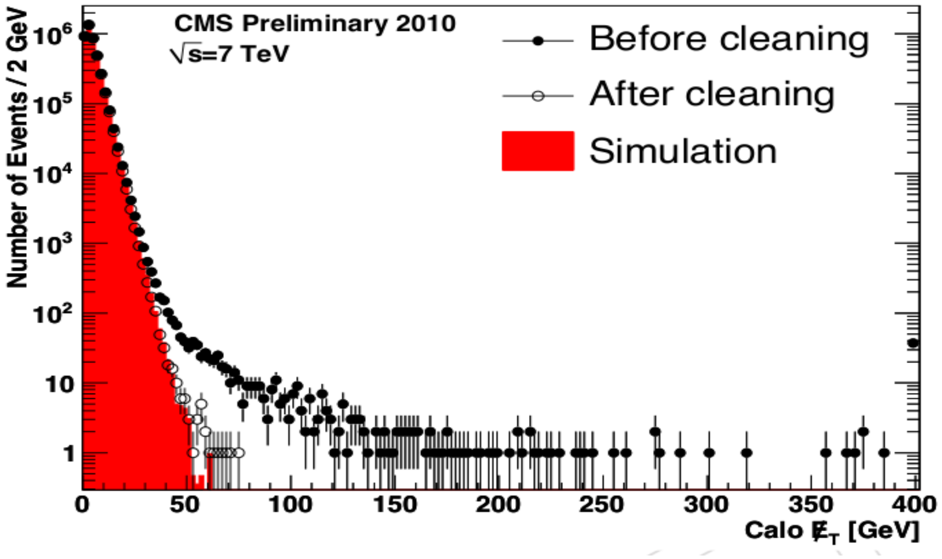
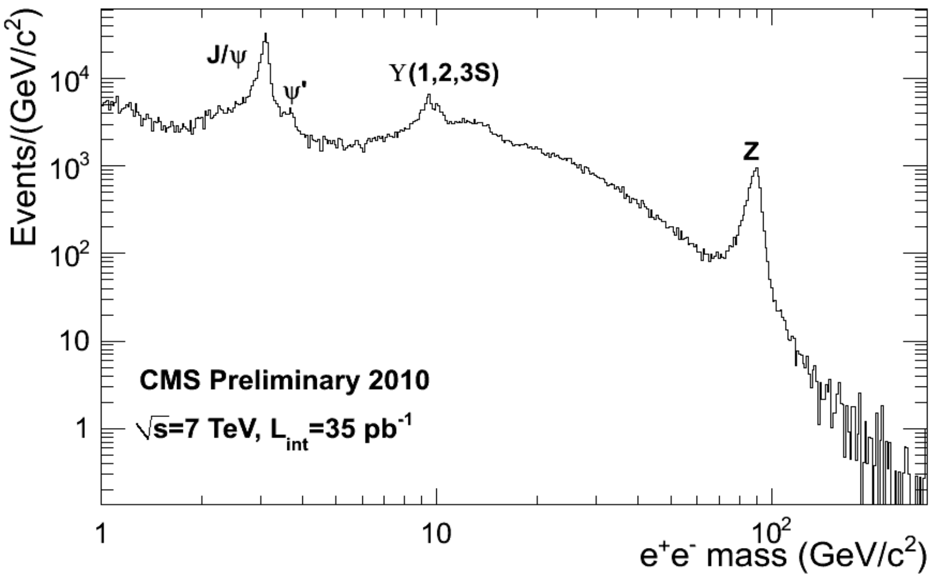
On behalf of the CMS Collaboration

Introduction

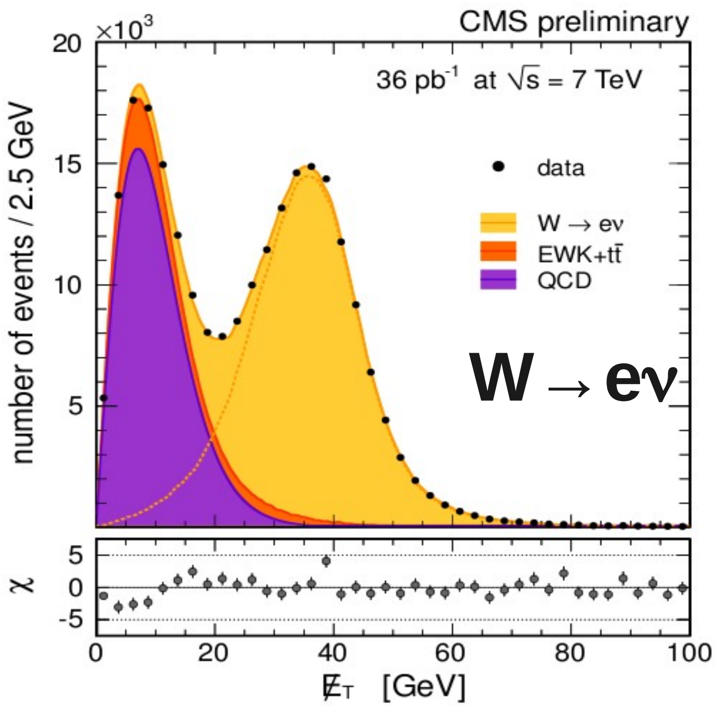
- CMS is now well-calibrated and able to accurately reconstruct the key tools for electroweak physics: muons, electrons, and missing transverse energy
- Electroweak results covered here:
  - Inclusive cross-section
  - Differential cross-sections
  - Multiboson production



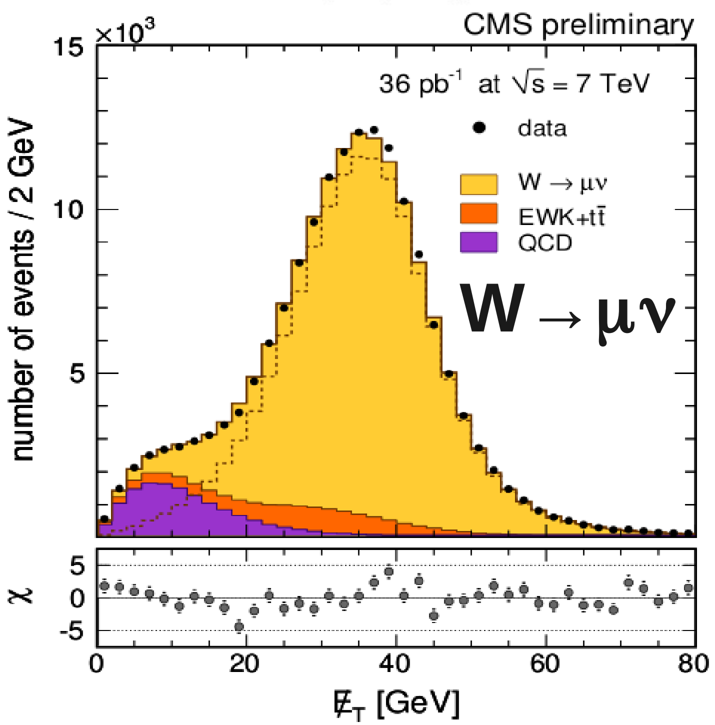


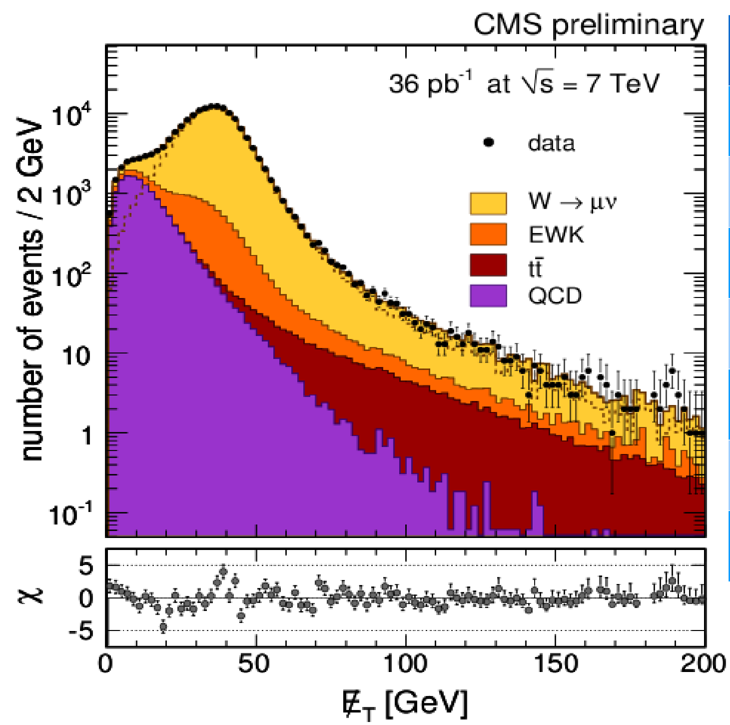


Measurement of W Inclusive Cross-section



- Cross-sections based on fit to missing transverse energy distribution
  - MET corrected in EWK and signal shape on event-by-event basis using study of hadronic recoil in Z→ll events
  - Signal fit parameters, EWK, and top backgrounds determined from MC, QCD from data
- PDF errors from CT10,MSTW08NLO, NNPDF2.0 using PDF4LHC recommendations





Systematic Uncertainties (%)

	eν	μν
Lepton Id/Reco	1.3	0.9
Experimental	1.5	1.1
Acceptance (PDF)	0.6	0.7
Other theory	0.7	0.8
Theoretical	0.9	1.1
Total	1.7	1.6
Lumi	4.0	4.0

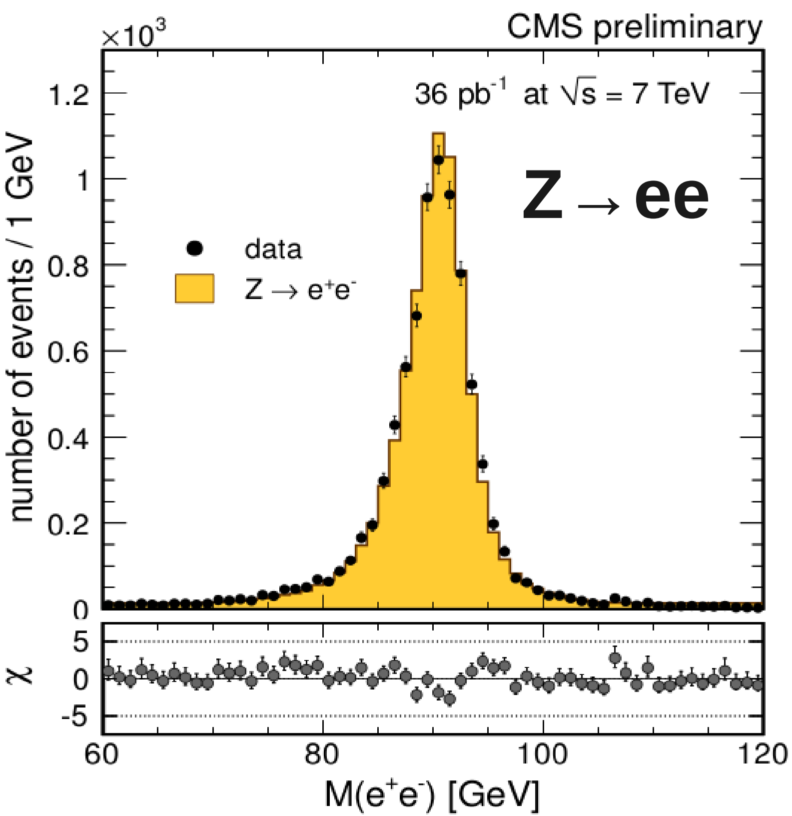
CMS-PAS-EWK-10-005

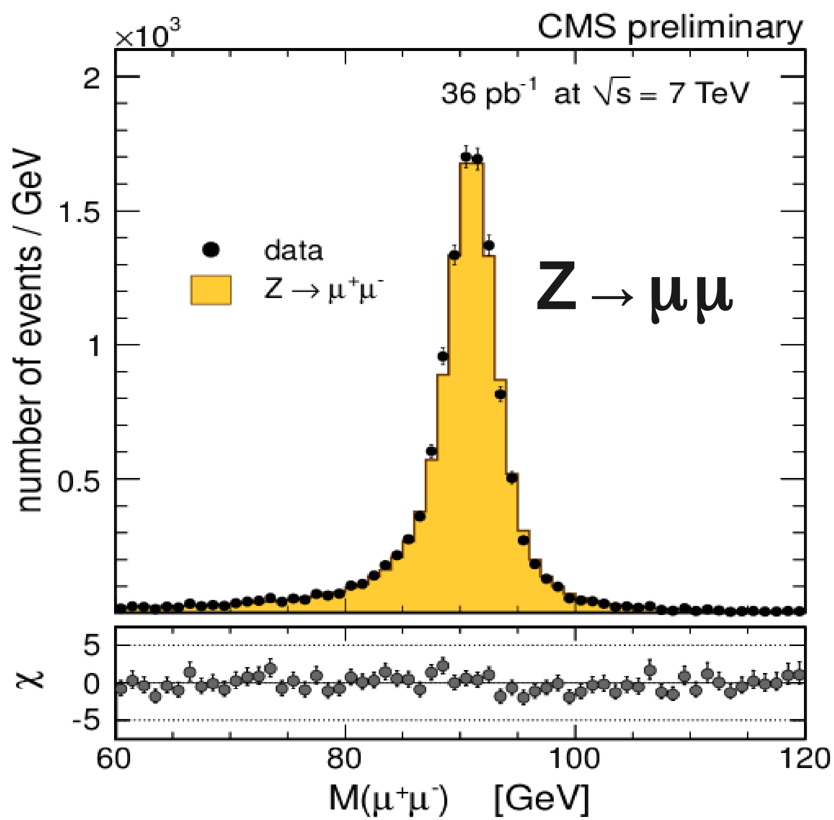
Measurement of Z Inclusive Cross-section

- 60 GeV < m_{ll} < 120 GeV
- Muon measurement performs simultaneous fit to cross-section, trigger and other efficiencies
  - Minimal experimental uncertainty
- Measurement is now limited by theory uncertainties

Systematic Uncertainties (%)

	ee	μμ
Experimental	1.8	0.7
Acceptance (PDF)	0.9	1.2
Other theory	1.4	1.6
Theoretical	1.7	2.0
Total	2.5	2.1
Lumi	4.0	4.0





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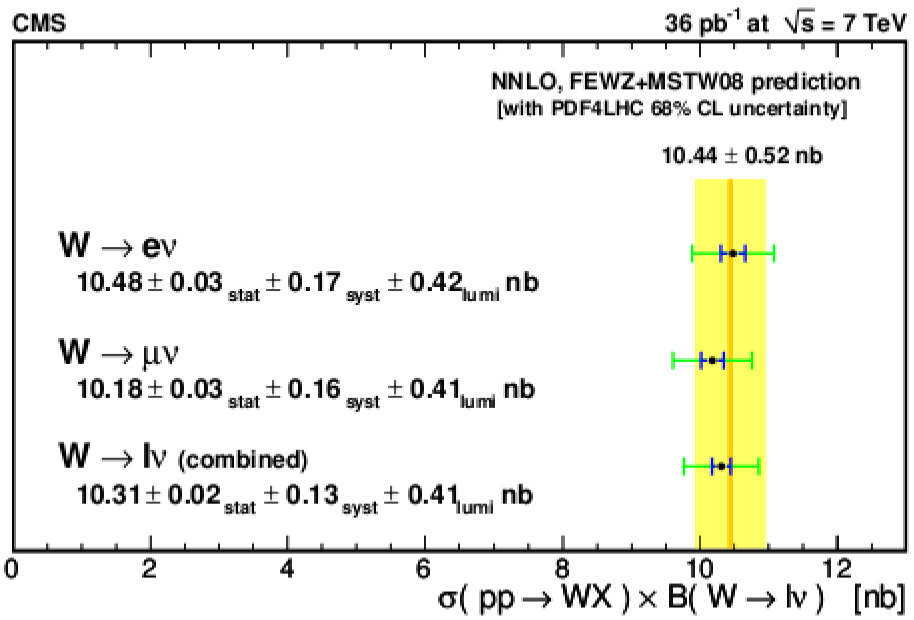
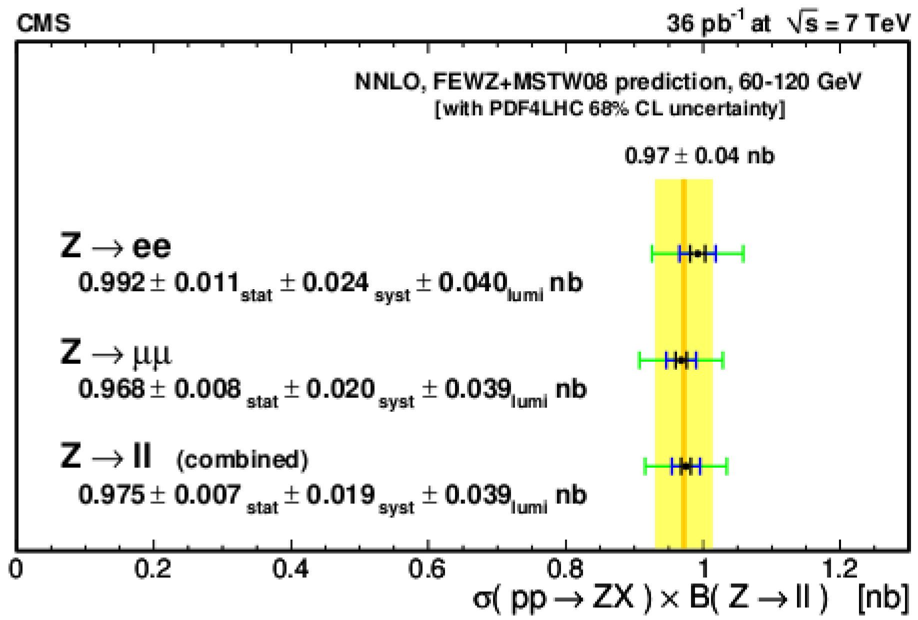
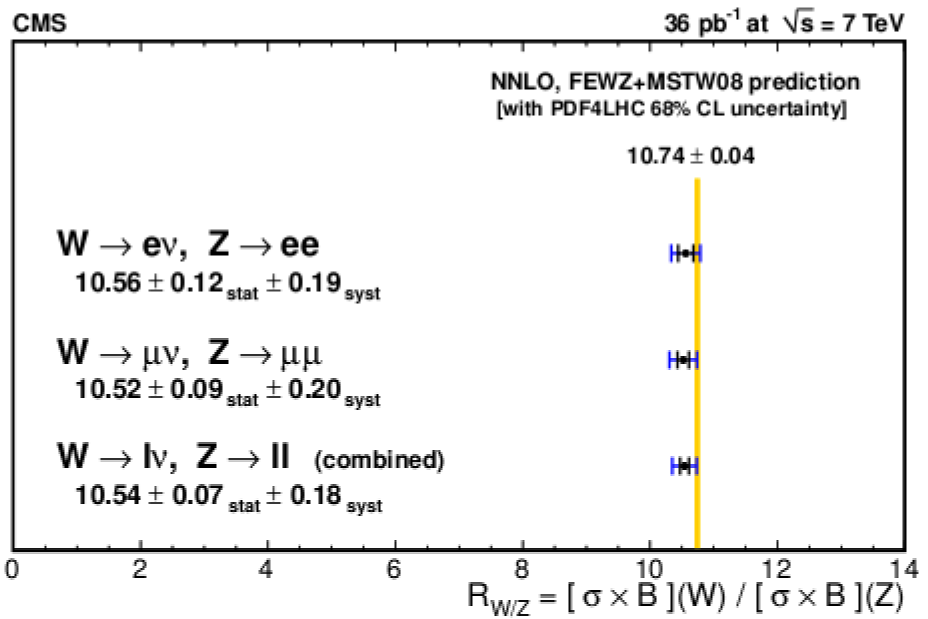
Summary of Inclusive Results







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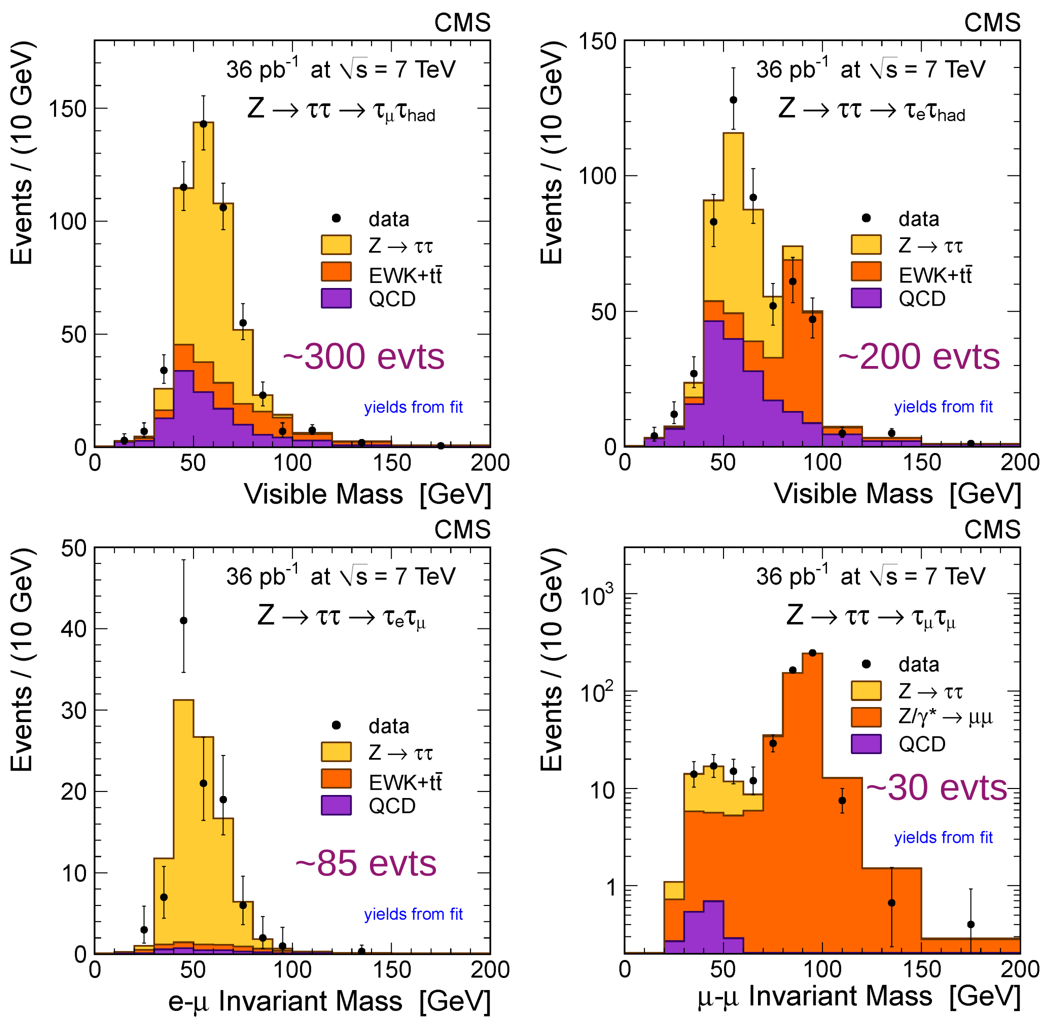
Tau Decays of Electroweak Bosons



- Tau decays are important for many searches, EWK boson decays are an ideal way to calibrate the reconstruction
- Z decay measurement uses four channels
  - electron-hadron
  - muon-hadron
  - muon-muon
  - muon-electron

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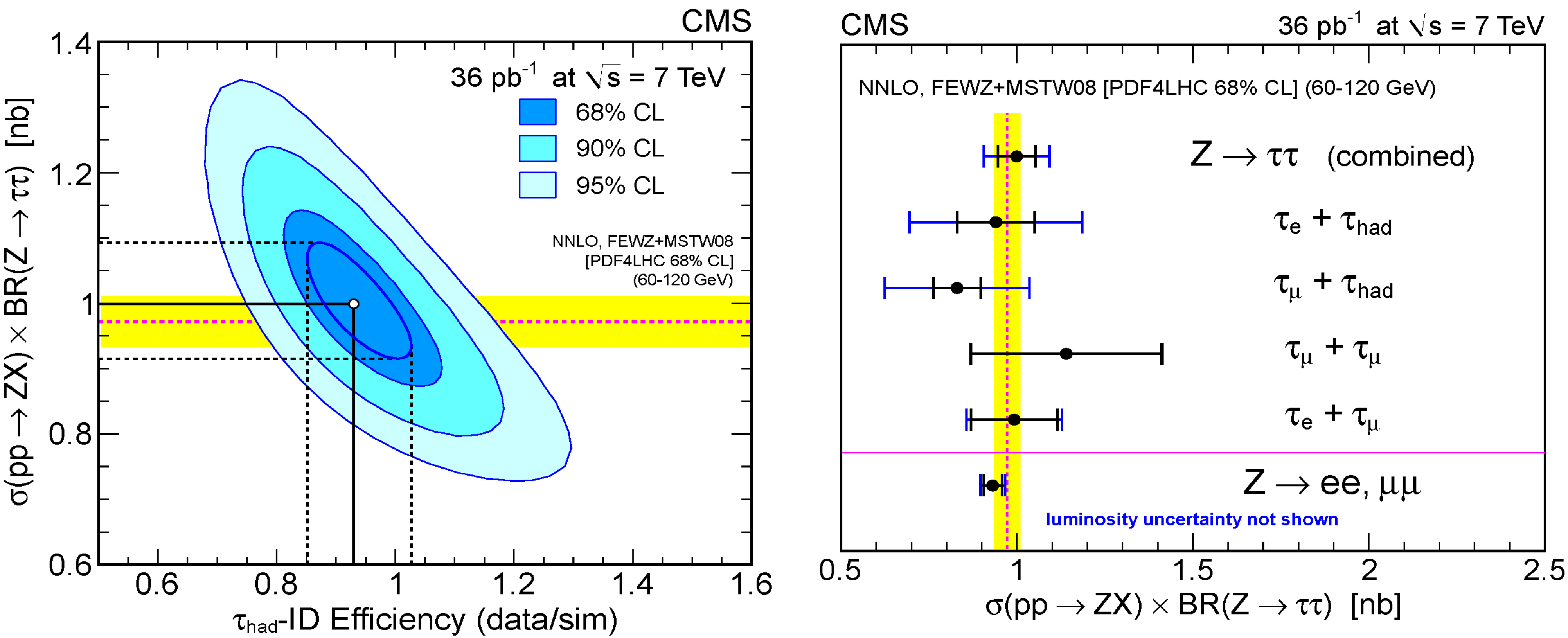
Z Cross-section to Taus



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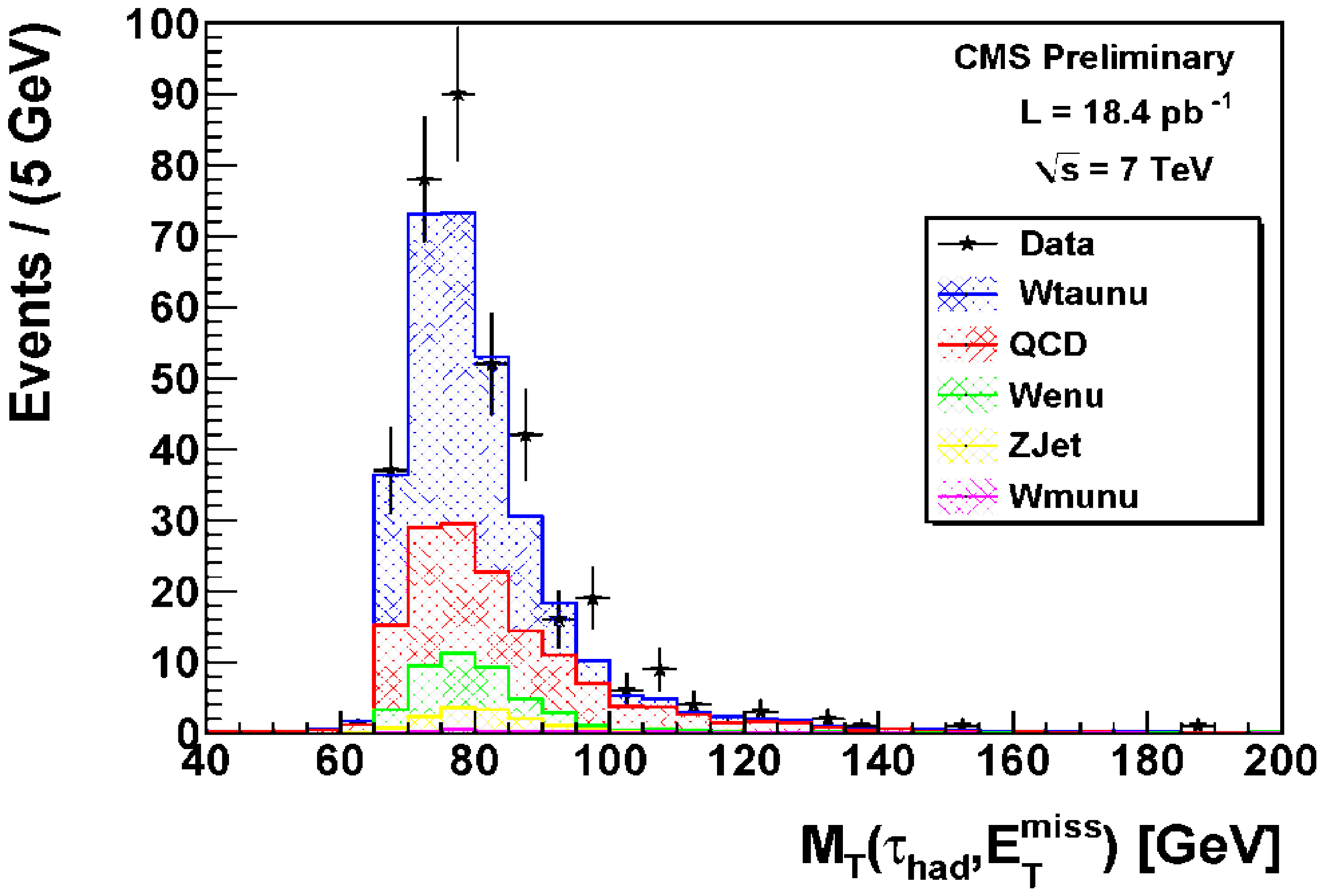
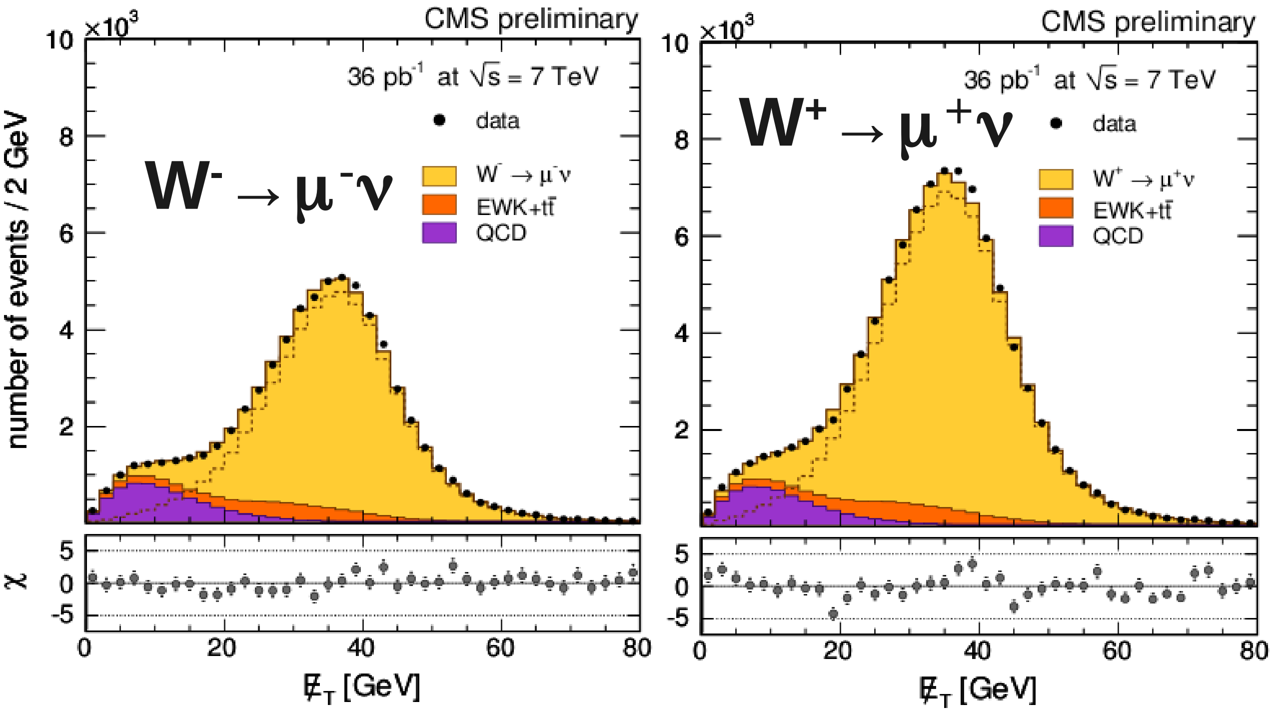
Observation of W $\rightarrow\tau\nu$

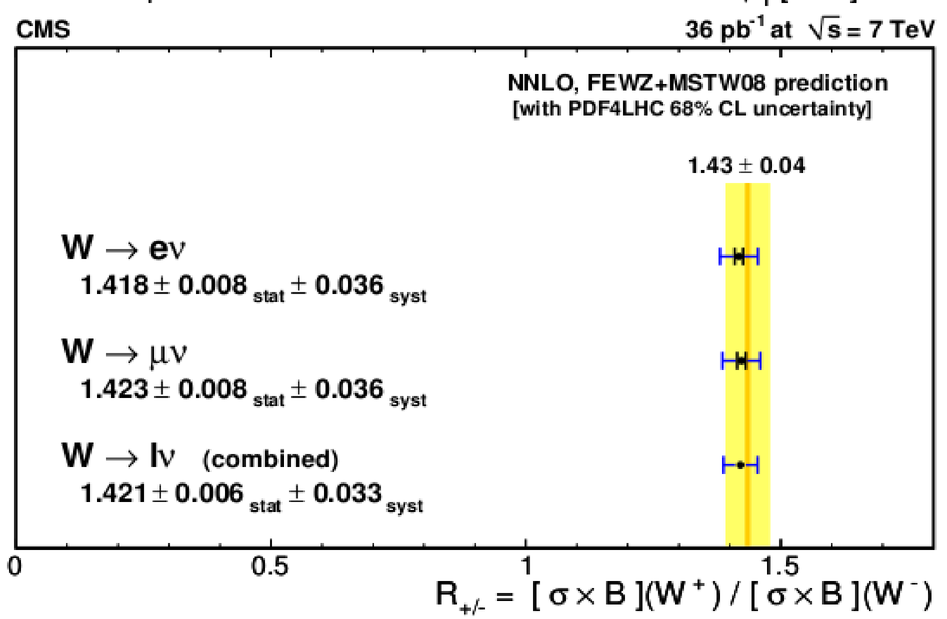


- Data-driven QCD background (ABCD technique)

CMS-PAS-EWK-11-002

- Up/down valence quark distribution in pp collisions results in rate difference between positive and negative W bosons
- Using same technique as the inclusive measurement, fit charge-separated samples independently



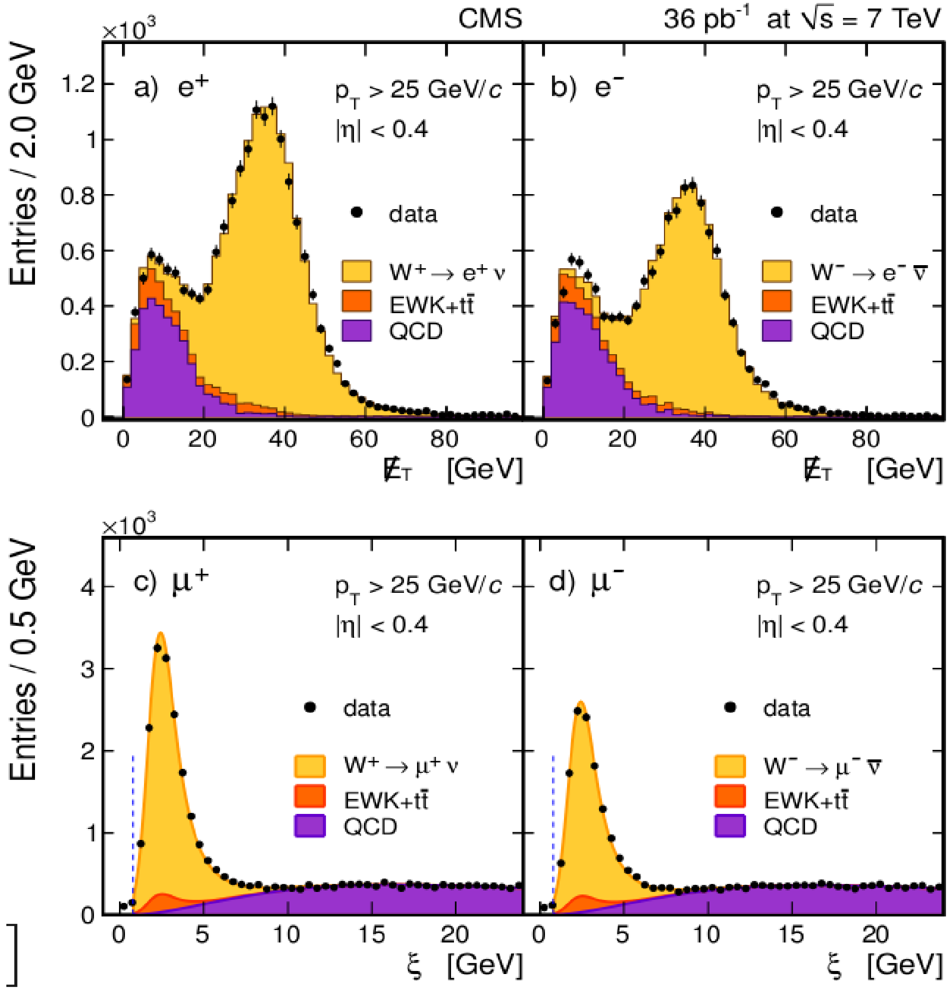


CMS-PAS-EWK-10-005

$$\mathcal{A}(\eta) = \frac{d\sigma/d\eta(W^+ \to \ell^+\nu) - d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}{d\sigma/d\eta(W^+ \to \ell^+\nu) + d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}$$

- Valence and sea distributions change as a function of *x*, leading to a change in the W charge distribution as a function of y_W
  - Measurement with η_l is a good substitute with fewer uncertainties.
- Similar analysis to inclusive charge asymmetry, but a different variable is used for muon fits

$$\xi = \sum_{\Delta R<0.3} \left[p_T(tracks) + E_T(em) + E_T(had) \right]$$



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Systematic Uncertainties

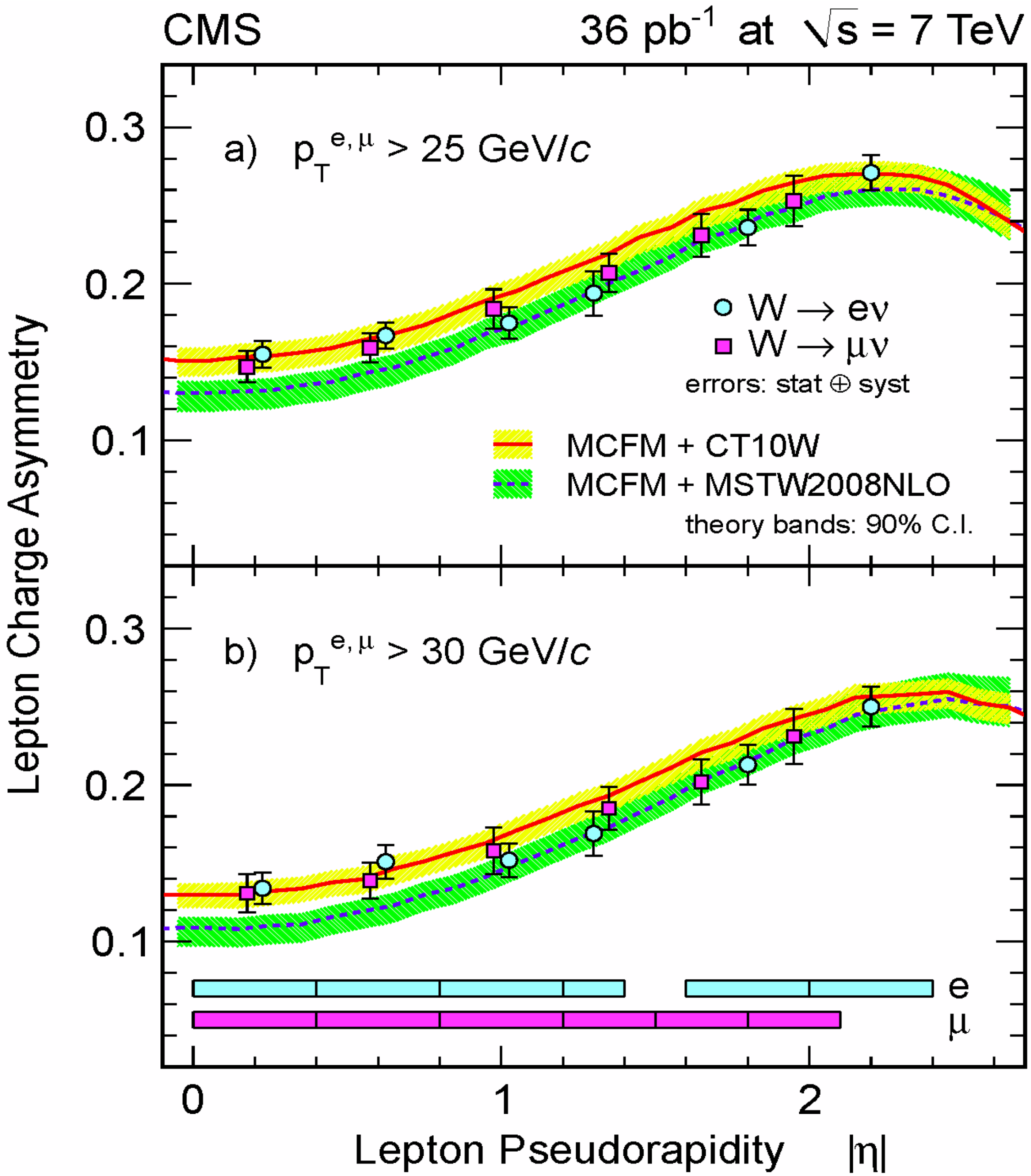
- Charge misidentification small
  - Rate shown to be < 10^{-4} for muons based on cosmic ray data
  - Electron charge misidentification reduced by requiring consensus of three charge extraction techniques
- Leading uncertainties are the efficiency difference between positive and negative leptons and the energy/momentum scale
- Two lepton p_T ranges considered:

  > 20 GeV/c

  > 30 GeV/c

$p_T^\ell > 25$ GeV/c	Electron Channel						Muon Channel					
$\|\eta\|$ bin	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.4]	[1.6, 2.0]	[2.0, 2.4]	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.5]	[1.5, 1.8]	[1.8, 2.1]
Charge Misident.	0.02	0.03	0.03	0.08	0.09	0.10	0	0	0	0	0	0
Eff. Ratio	0.70	0.70	0.70	0.70	0.70	0.70	0.59	0.39	0.92	0.72	0.81	1.17
e/μ Scale	0.11	0.09	0.19	0.47	0.40	0.45	0.50	0.48	0.50	0.48	0.50	0.42
Sig. & Bkg. Estim.	0.16	0.19	0.26	0.33	0.25	0.25	0.23	0.29	0.34	0.40	0.53	0.58
Total	0.73	0.73	0.77	0.90	0.85	0.87	0.80	0.68	1.10	0.95	1.08	1.37

$p_T^\ell > 30$ GeV/c	Electron Channel						Muon Channel					
$\|\eta\|$ bin	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.4]	[1.6, 2.0]	[2.0, 2.4]	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.5]	[1.5, 1.8]	[1.8, 2.1]
Charge Misident.	0.02	0.02	0.03	0.07	0.08	0.10	0	0	0	0	0	0
Eff. Ratio	0.70	0.70	0.70	0.70	0.70	0.70	0.59	0.39	0.93	0.72	0.82	1.18
e/μ Scale	0.07	0.17	0.26	0.46	0.53	0.55	0.80	0.78	0.83	0.81	0.73	0.77
Sig. & Bkg. Estim.	0.16	0.19	0.26	0.33	0.25	0.25	0.20	0.20	0.27	0.35	0.51	0.56
Total	0.72	0.75	0.79	0.91	0.92	0.93	1.01	0.90	1.27	1.14	1.21	1.52



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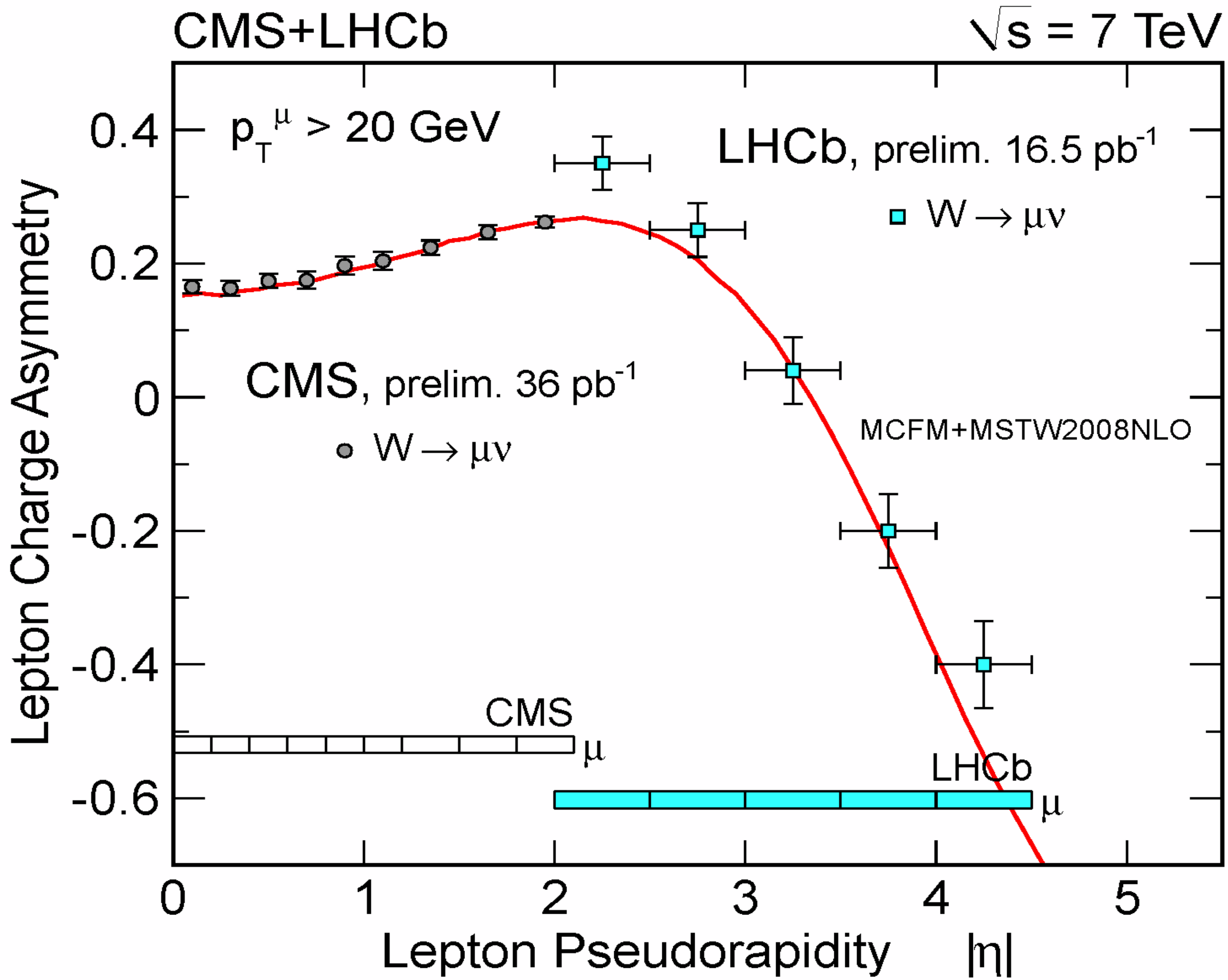
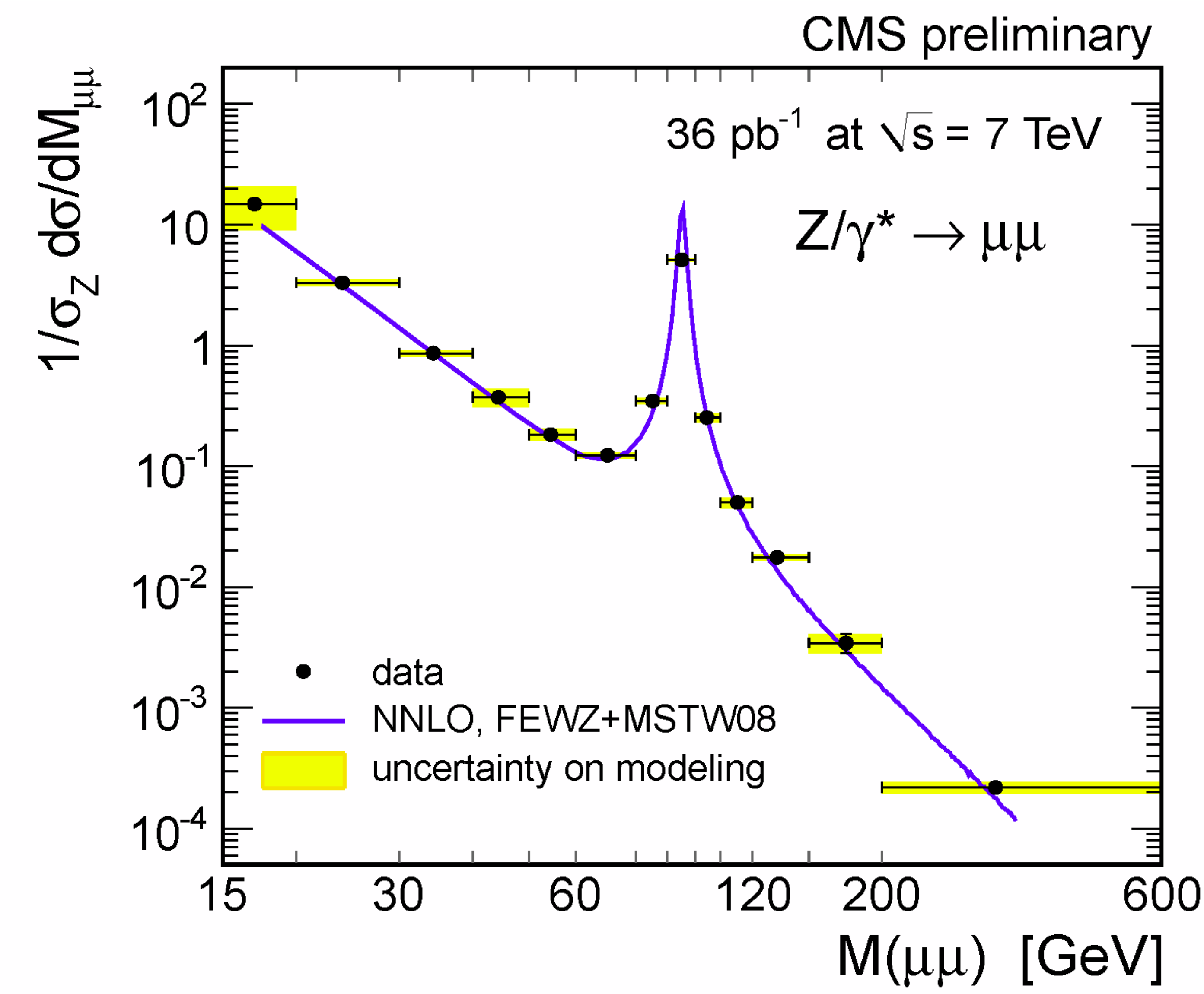


Caveats

- Very preliminary, not part of publication on the topic
- Only muons (no electrons)
- Uncertified systematic errors

Z/Drell-Yan Results

Drell-Yan (μμ)



- Selection (μ_1)
  - $|\eta| < 2.1$
  - $p_T > 16$ GeV
  - Triggered
- Selection (μ_2)
  - $|\eta| < 2.4$
  - $p_T > 7$ GeV
- Backgrounds
  - QCD
  - ττ
  - tt

CMS-EWK-10-007

Questions for the Community

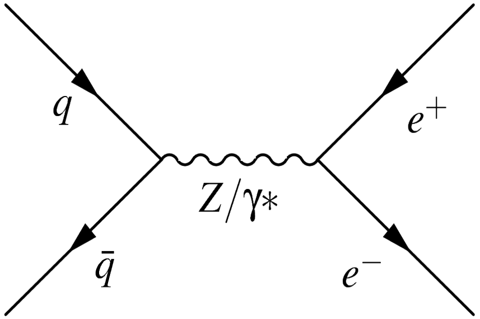
- Significant differences observed between FEWZ (NNLO) and acceptance-corrected data
  - Effect seems to be due to acceptance differences between (POWHEG + Pythia event shower) and FEWZ
  - FEWZ NNLO calculation significantly different from POWHEG at low mass
- Intended strategy is to reweight POWHEG using FEWZ results binned by boson p_T and y
  - Discussion ongoing on POWHEG and FEWZ authors, further input very welcome!

Z Differential Measurements

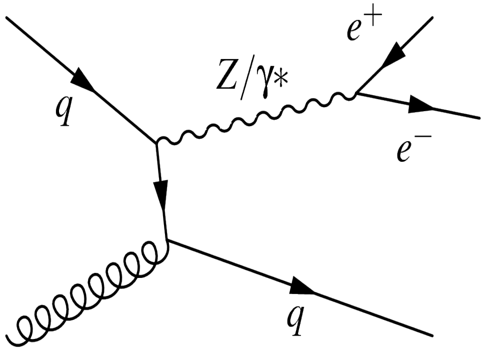
$$\frac{1}{\sigma}\frac{d\sigma(Z\rightarrow l^{+}l^{-})}{dy}$$

- Rapidity measurement probes PDF distributions primarily
  - At tree level, simple correlation:

$$y=\ln\frac{x\sqrt{s}}{m_Z}$$



$$\frac{1}{\sigma}\frac{d\sigma(Z\rightarrow l^{+}l^{-})}{dq_T}$$

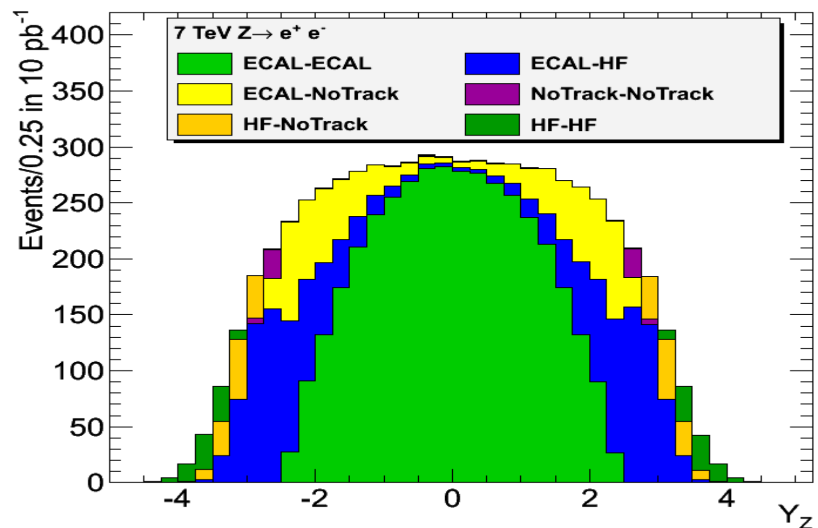


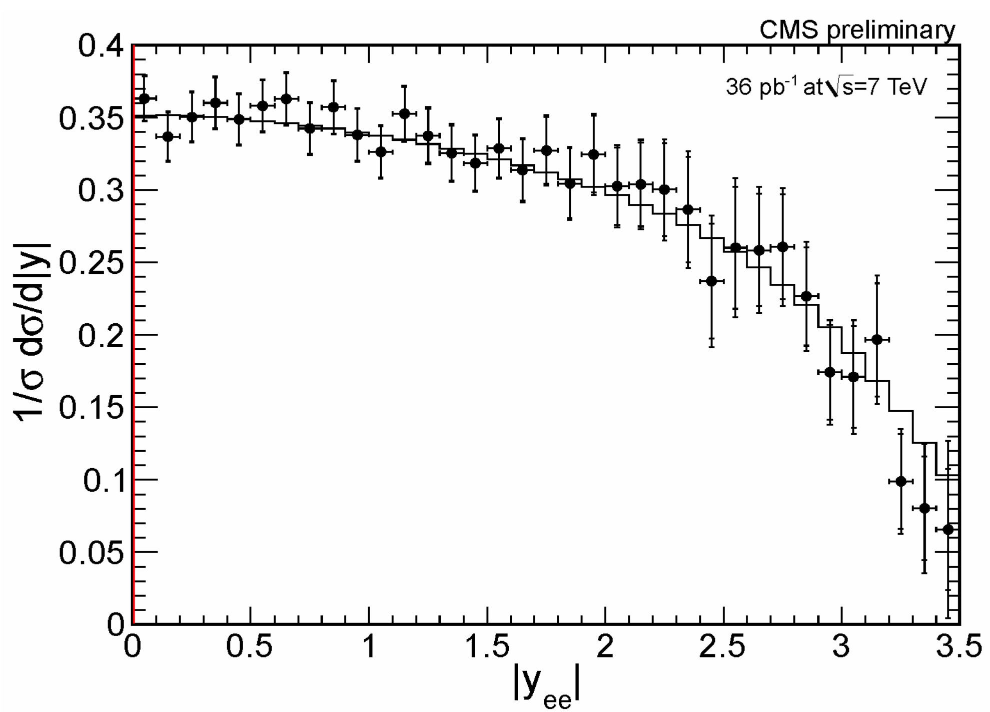
- Transverse momentum measurement probes both perturbative and non-perturbative QCD predictions as well as PDFs

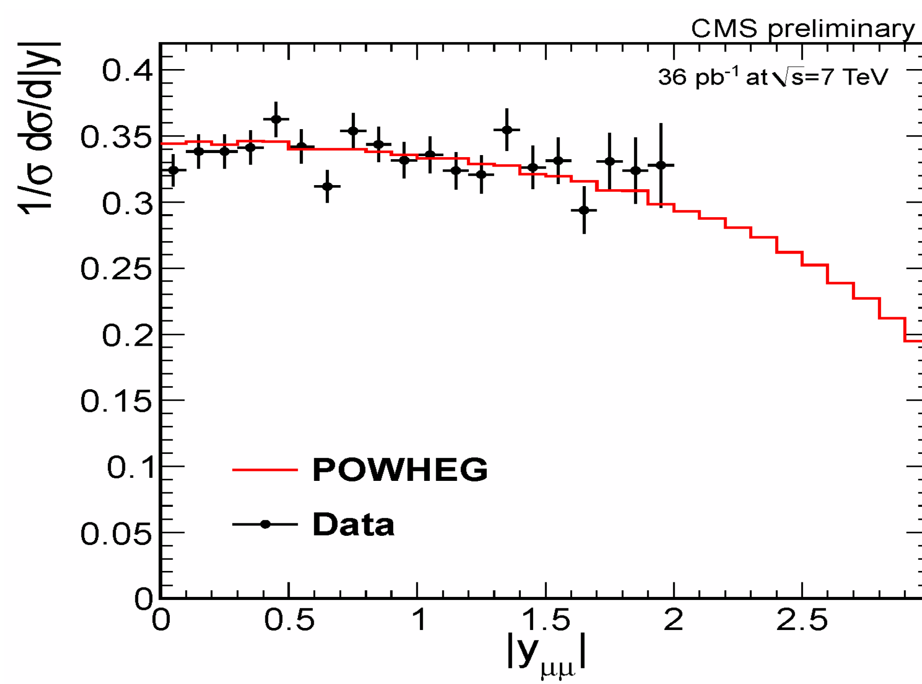
60 GeV < m_{ll} < 120 GeV

Rapidity Measurement

- Electron measurement includes forward electrons (HF)
  - $|\eta| < 2.5$ or $4.6 < |\eta| < 3.1$
- Muon measurement for $|\eta| < 2.1$
- Final measurement made in $|y|$, unfolded for resolution effects







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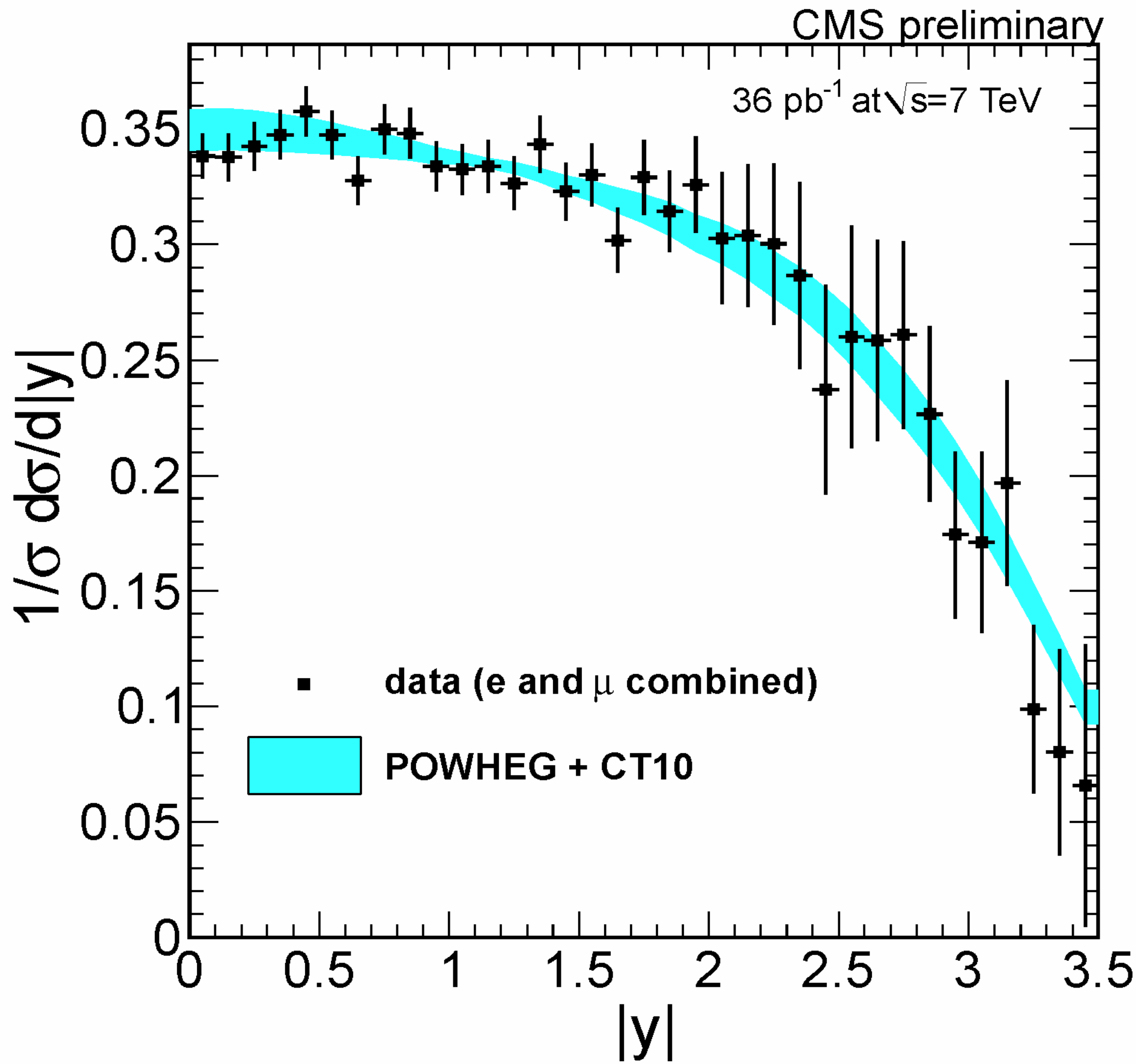
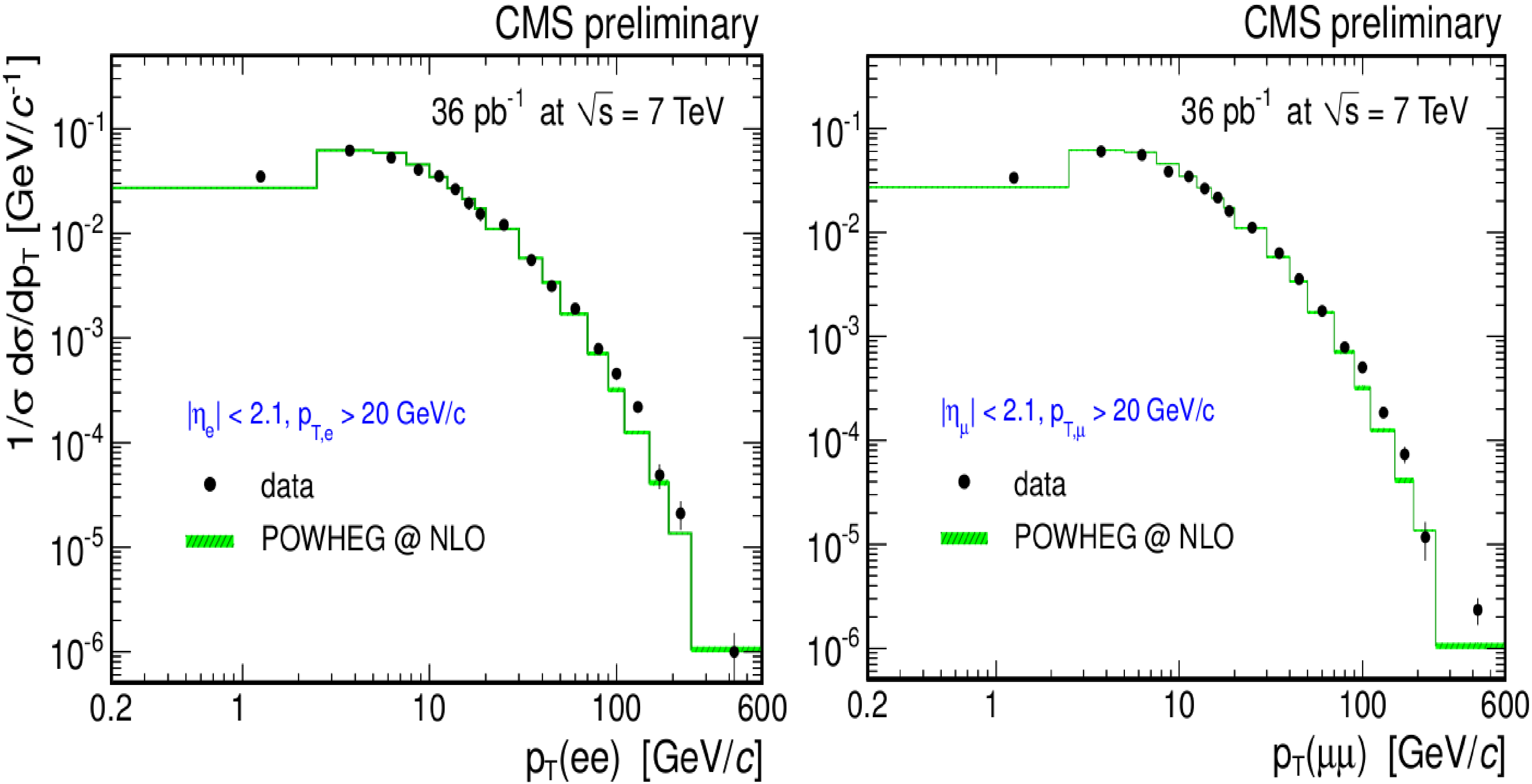


CMS-PAS-EWK-10-010

Transverse Momentum Measurement



Results reported for defined acceptance ($|\eta_l|<2.1$ and $p_{T,l} > 20$ GeV/c) to enable simpler comparison to theory

Differences between POWHEG and observation at both low and high p_T

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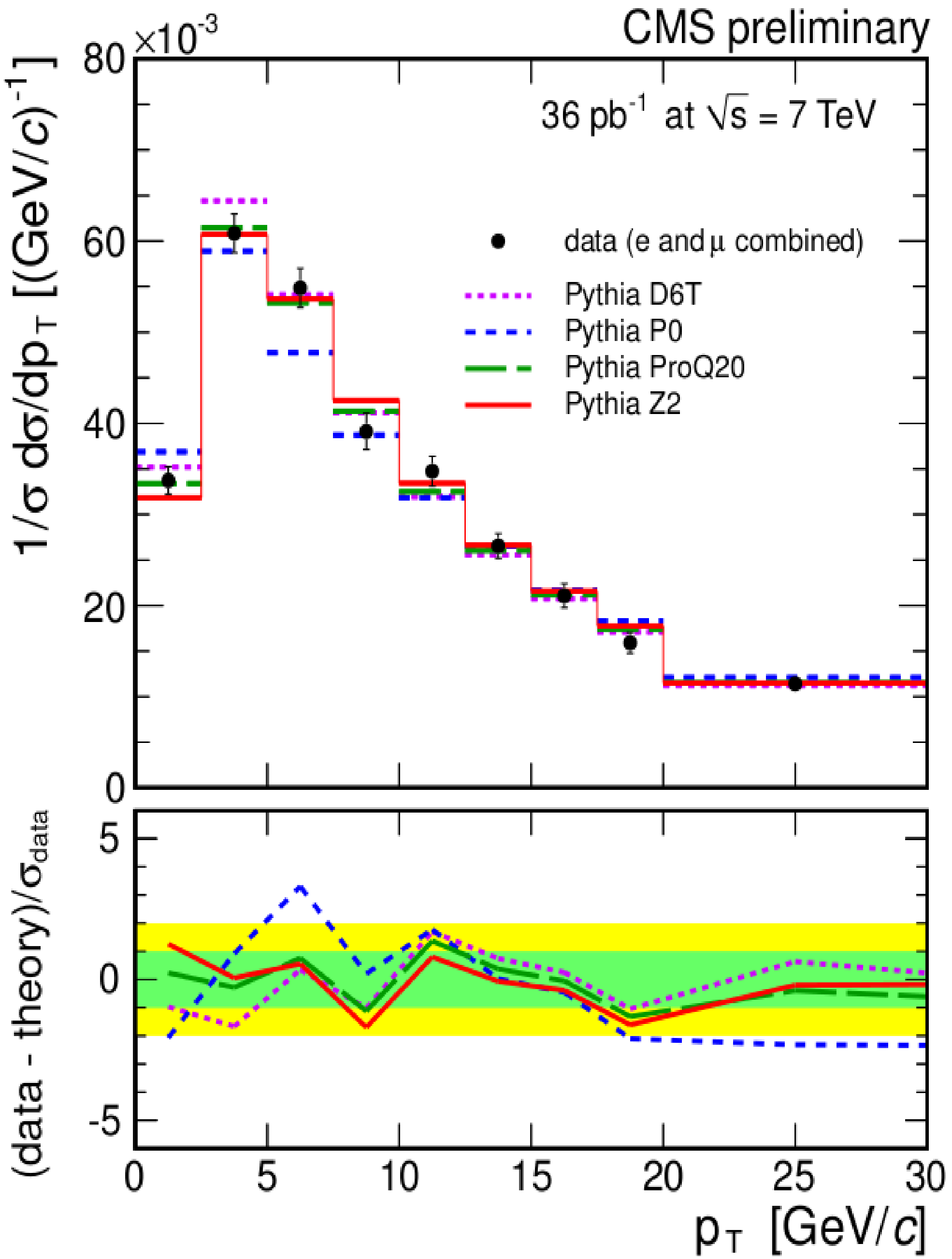
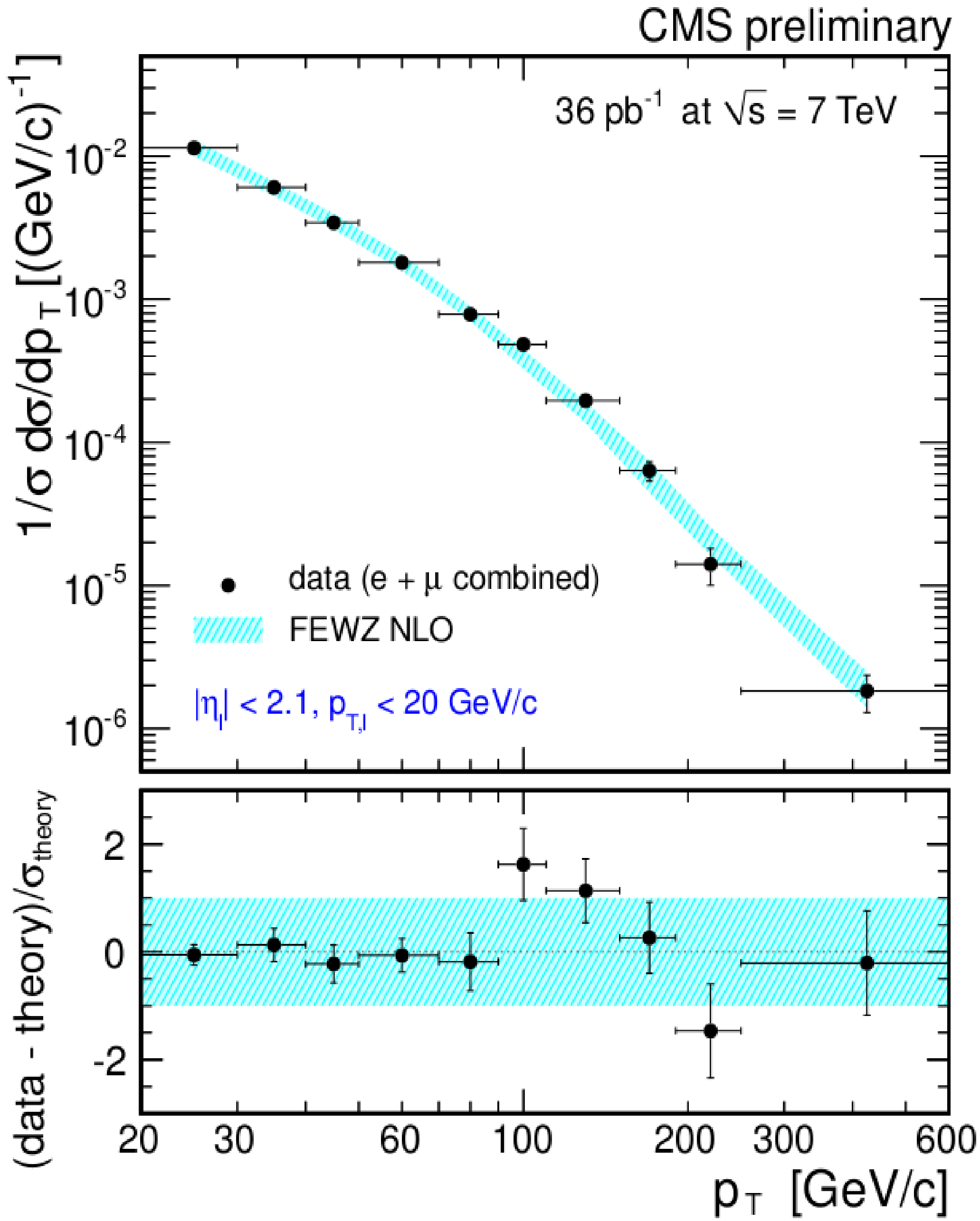
Comparisons to Pythia and FEWZ





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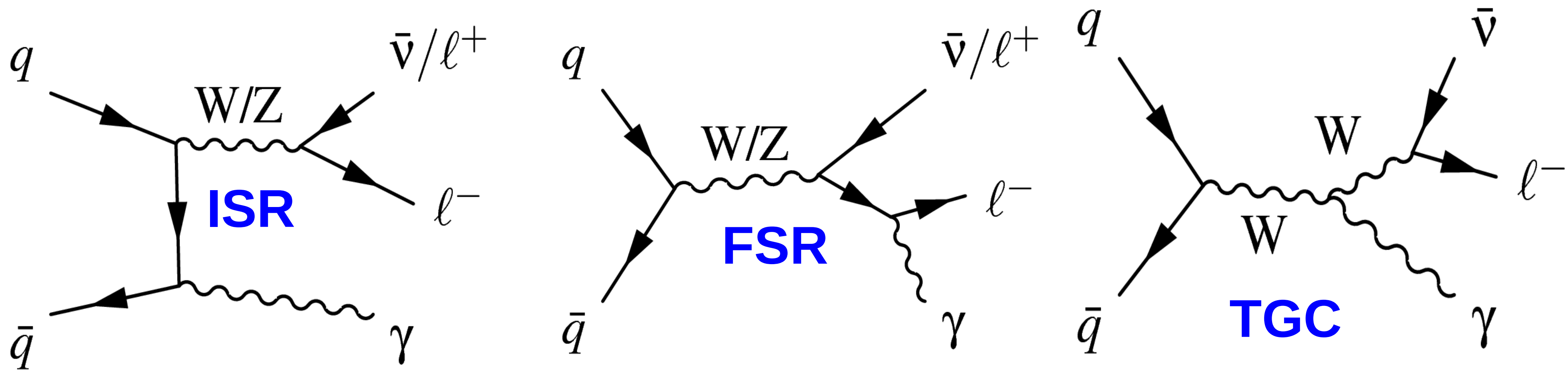
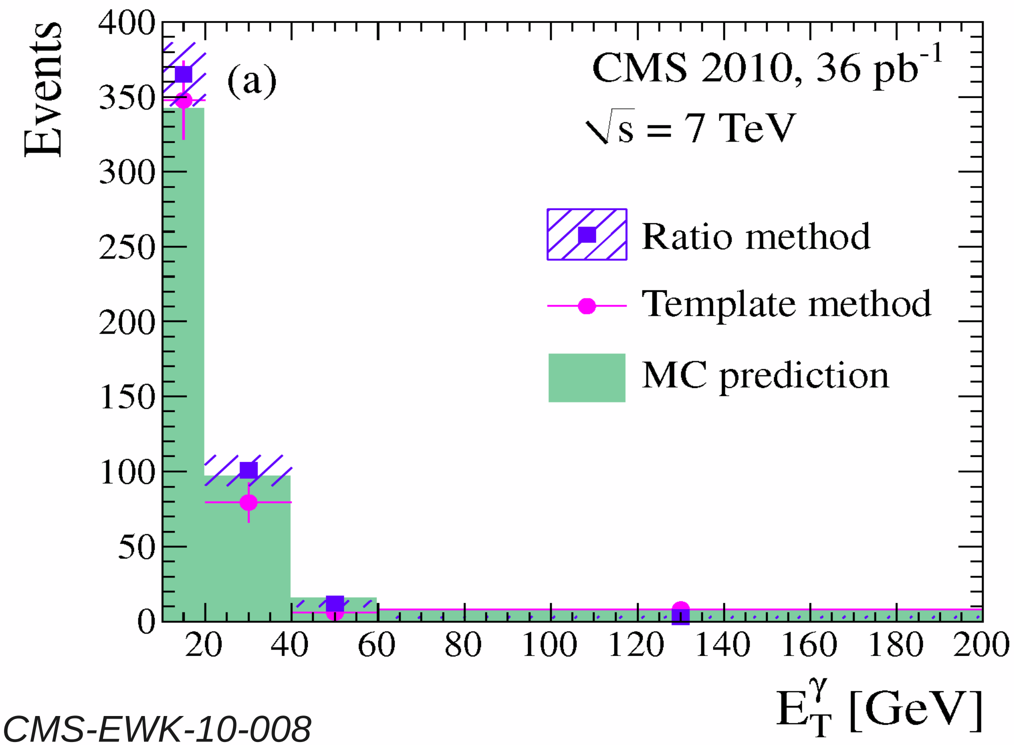
Di-bosons



- Kinematic requirements
  - $E_T(\gamma) > 10$ GeV
  - $p_T(l) > 20$ GeV
  - $\Delta R(\gamma,l) > 0.7$
  - MET > 35 GeV
- Dominant V+jet background estimated from data



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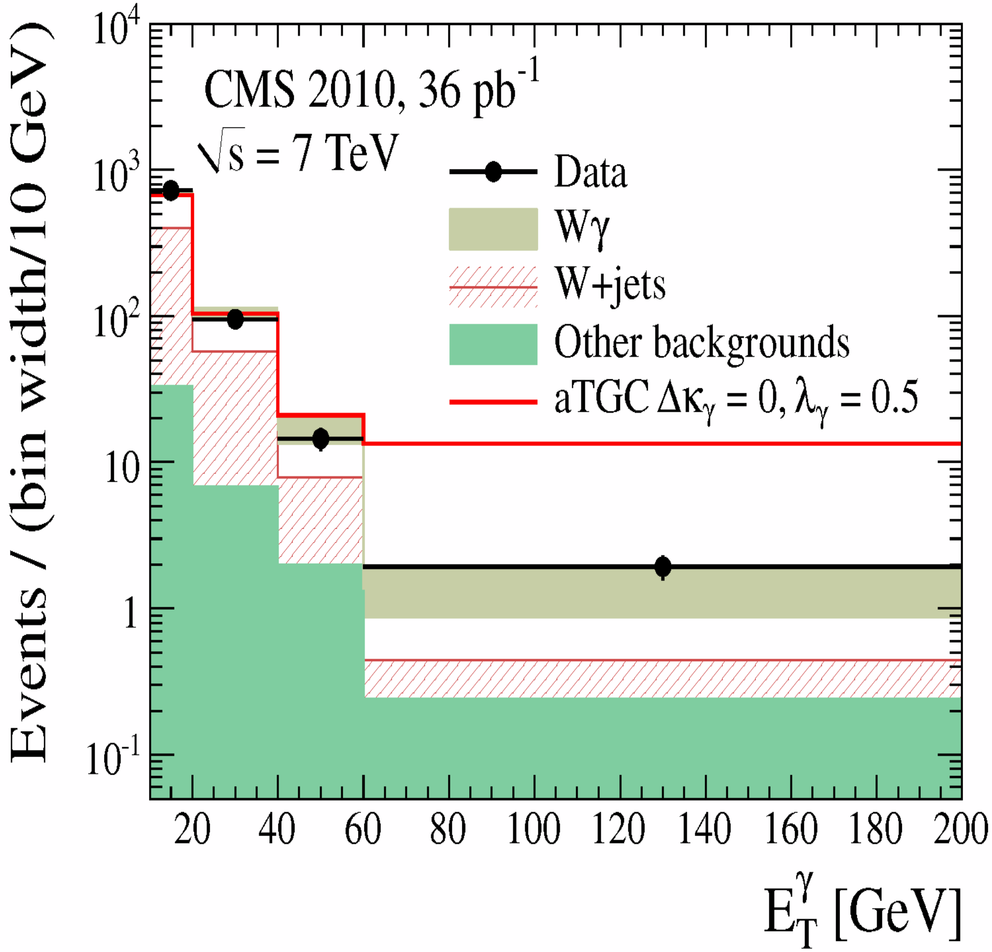
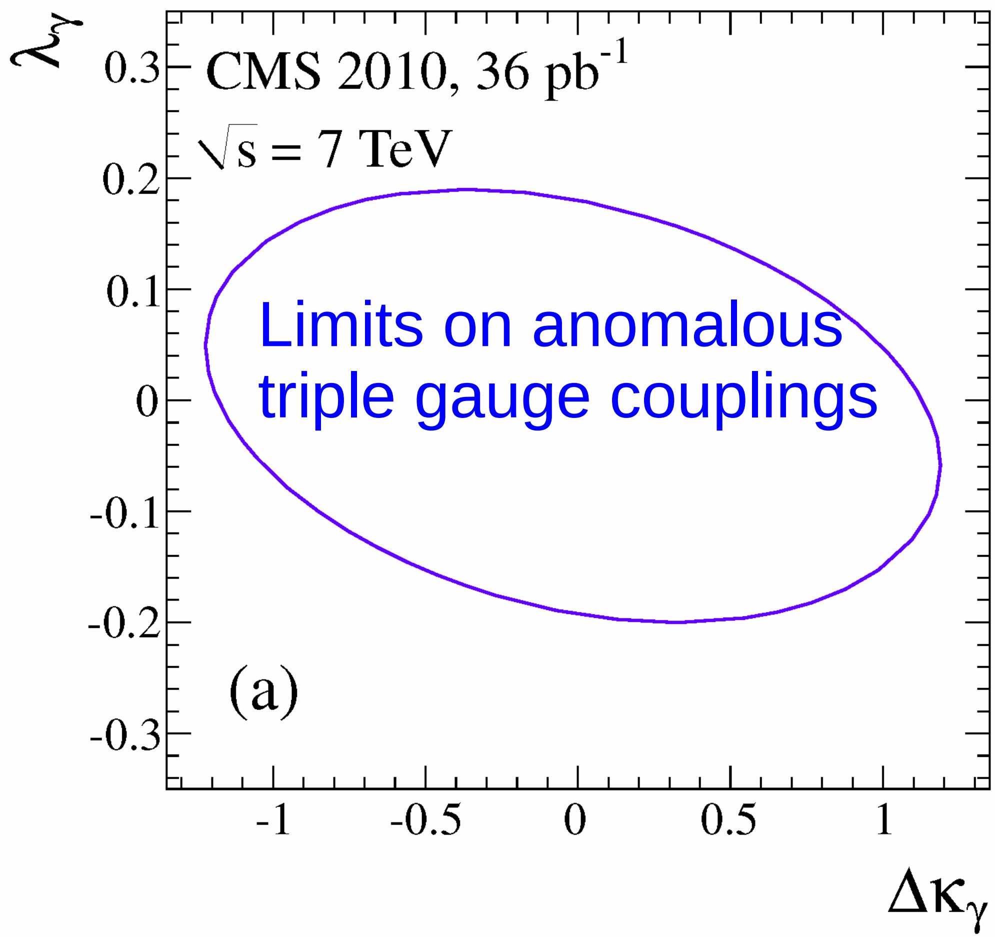




$\sigma(pp \rightarrow W\gamma \rightarrow e\nu\gamma) = 56.7 \pm 6.9$ (stat.) ± 5.1 (syst.) ± 6.2 (lumi.) pb

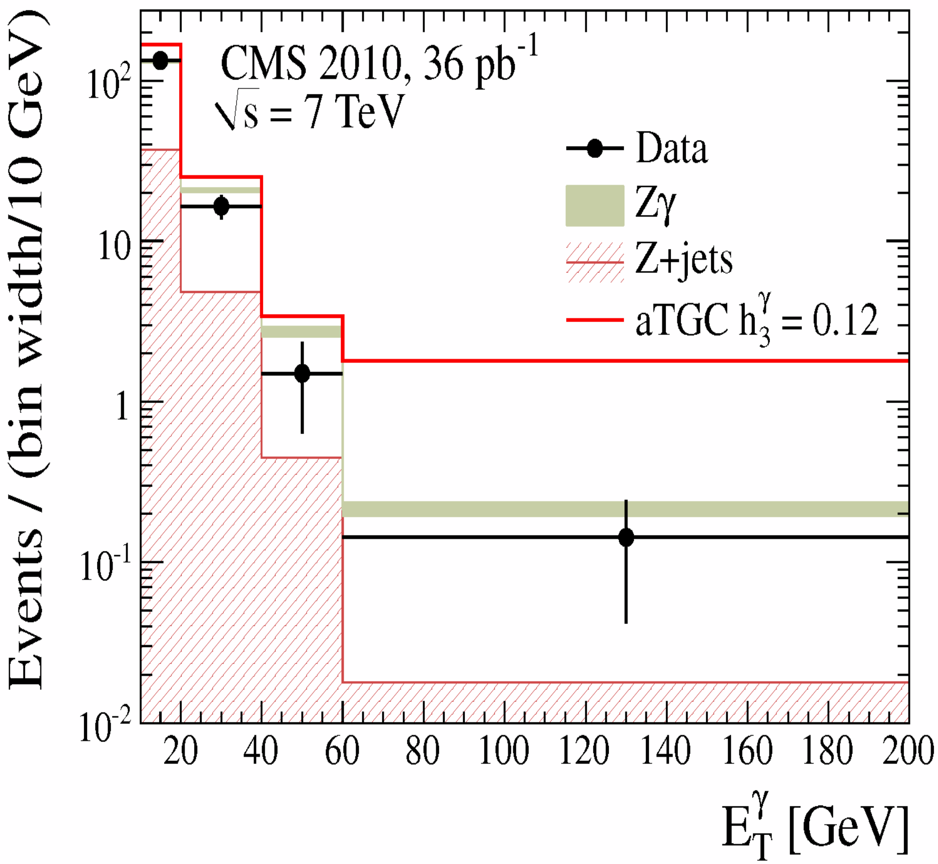
$\sigma(pp \rightarrow W\gamma \rightarrow \mu\nu\gamma) = 55.0 \pm 7.2$ (stat.) ± 5.0 (syst.) ± 6.1 (lumi.) pb

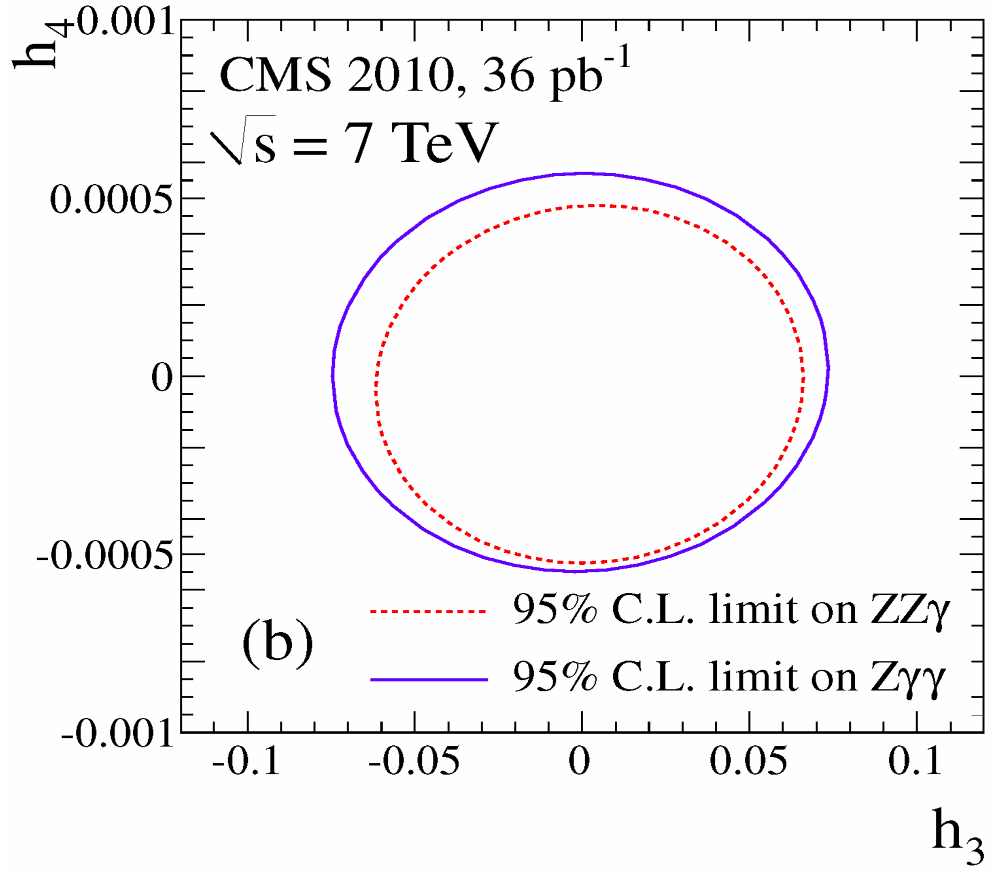
$\sigma(pp \rightarrow W\gamma \rightarrow l\nu\gamma) = 55.9 \pm 5.0$ (stat.) ± 5.0 (syst.) ± 6.1 (lumi.) pb

$\sigma(pp \rightarrow W\gamma \rightarrow l\nu\gamma) = 49.4 \pm 3.0$ pb (NLO)

CMS-EWK-10-008

$m_{ll} > 50$ GeV





$\sigma(pp \rightarrow Z\gamma \rightarrow ee\gamma)$ = 9.4 ± 1.4 (stat.) ± 0.7 (syst.) ± 1.0 (lumi.) pb

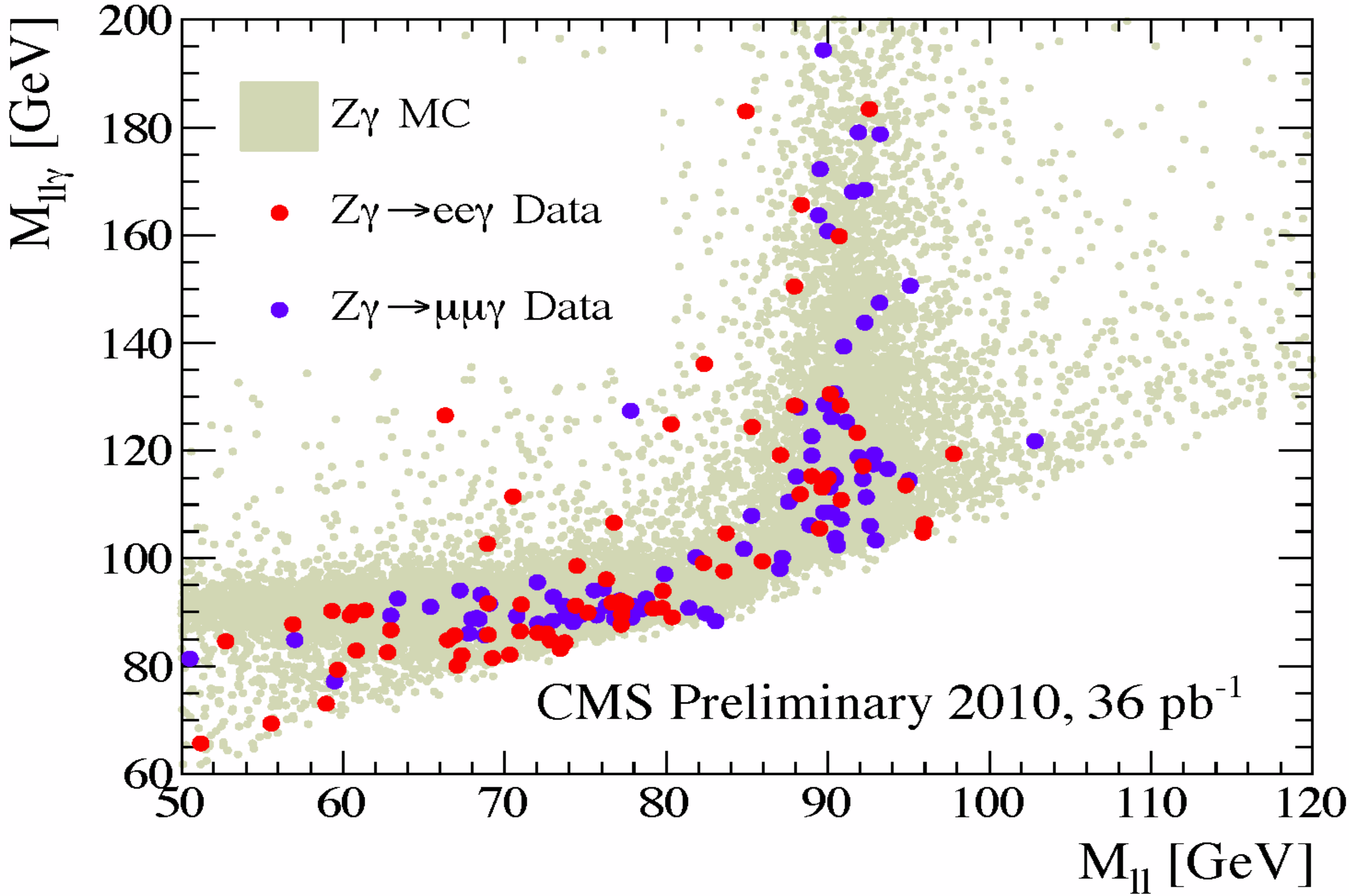
$\sigma(pp \rightarrow Z\gamma \rightarrow \mu\mu\gamma)$ = 9.2 ± 1.4 (stat.) ± 0.6 (syst.) ± 1.0 (lumi.) pb

$\sigma(pp \rightarrow Z\gamma \rightarrow ll\gamma)$ = 9.3 ± 1.0 (stat.) ± 0.6 (syst.) ± 1.0 (lumi.) pb

$\sigma(pp \rightarrow Z\gamma \rightarrow ll\gamma)$ = 9.6 ± 0.4 pb (NLO)

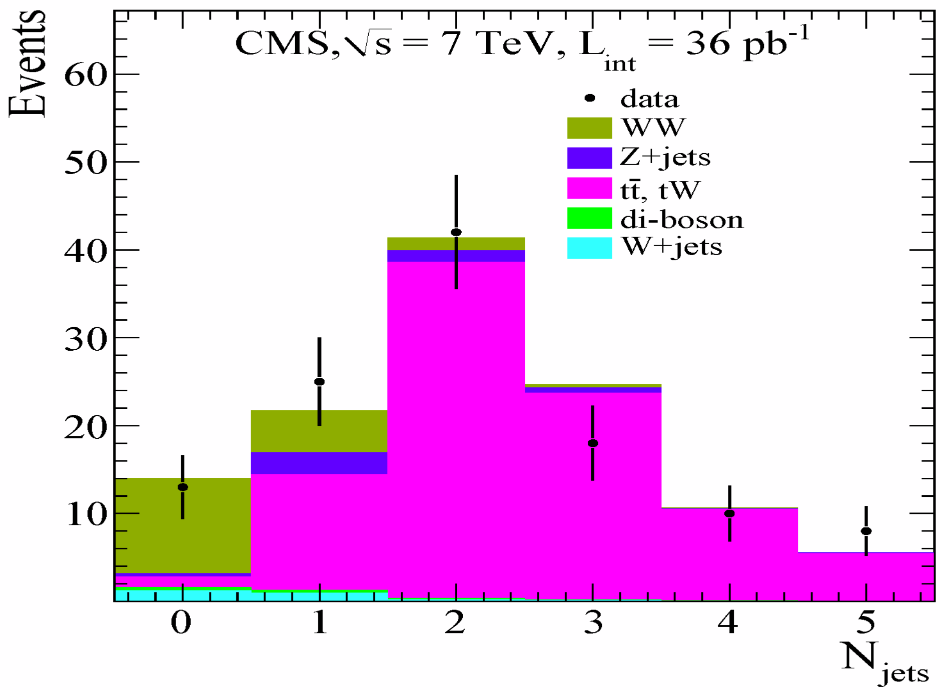
CMS-EWK

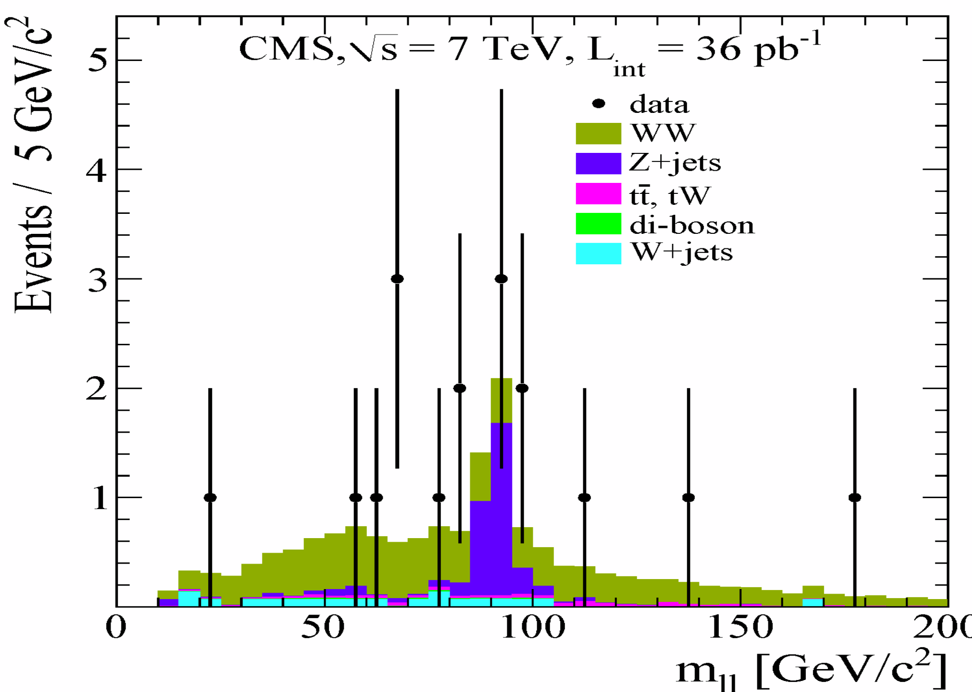
Zγ Mass distributions



CMS-EWK-10-008

WW





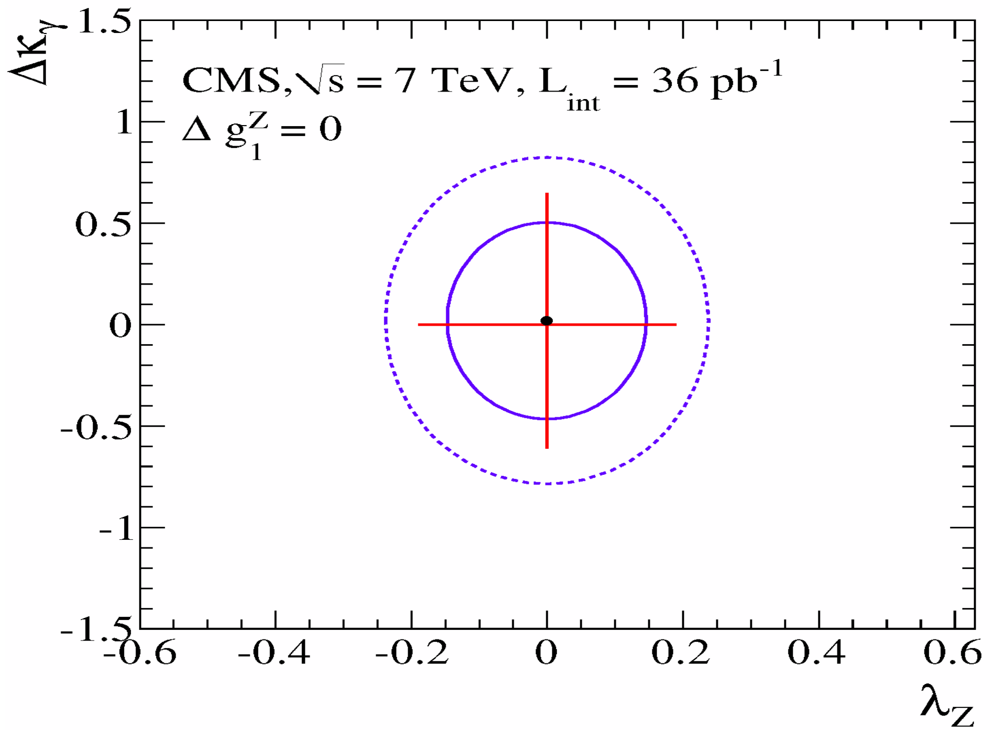
- Measurement sensitive to anomalous TGCs
  - Important background process for Higgs search
- Selection to reject DY, top, W+jets
  - 0 jets with p_T > 25 GeV and no b-tagged jets at all
  - Lepton p_T > 20 GeV
  - MET > 35 GeV
  - Veto m_{ll} < 12 GeV and 76 < m_{ll} < 106 GeV

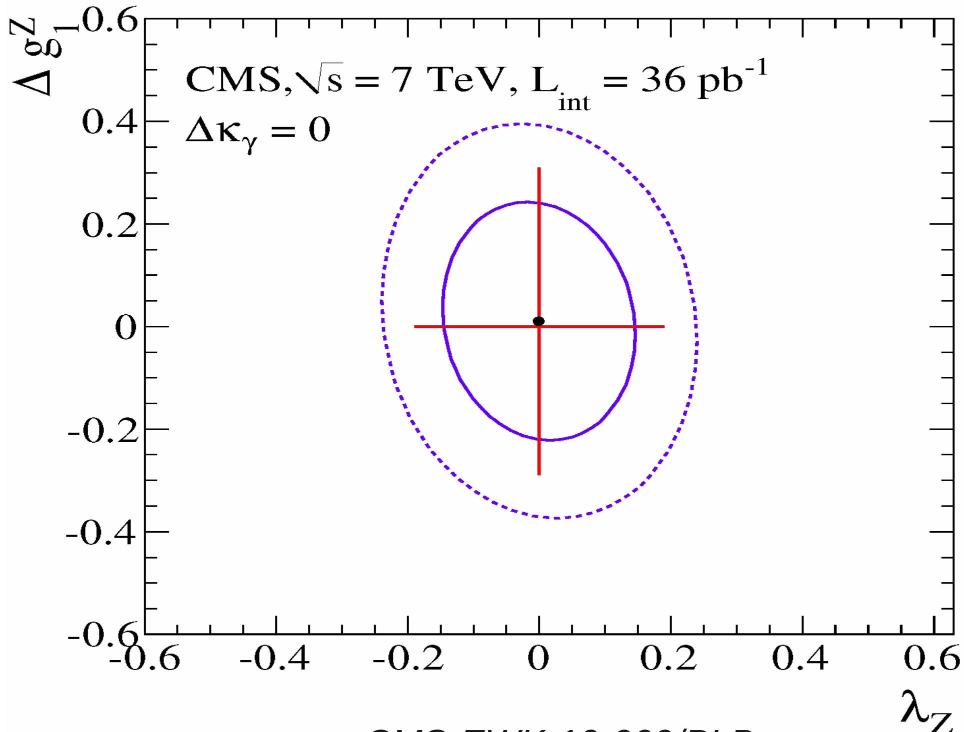
CMS-EWK-10-009/PLB

$\sigma(pp \to WW)$ = 41.1 ± 15.3 (stat.) ± 5.8 (syst.) ± 4.5 (lumi.) pb
$\sigma(pp \to WW)$ = 43.0 ± 2.0 pb (NLO)

$$\frac{\sigma_{WW}}{\sigma_W} = [4.46 \pm 1.66(stat.) \pm 0.64(syst.)] \cdot 10^{-4}$$

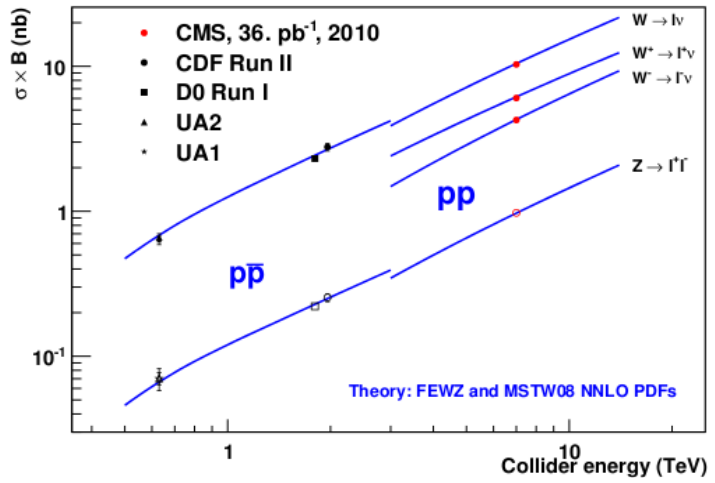
$$\frac{\sigma_{WW}}{\sigma_W} = [4.45 \pm 0.30] \cdot 10^{-4} (NLO)$$

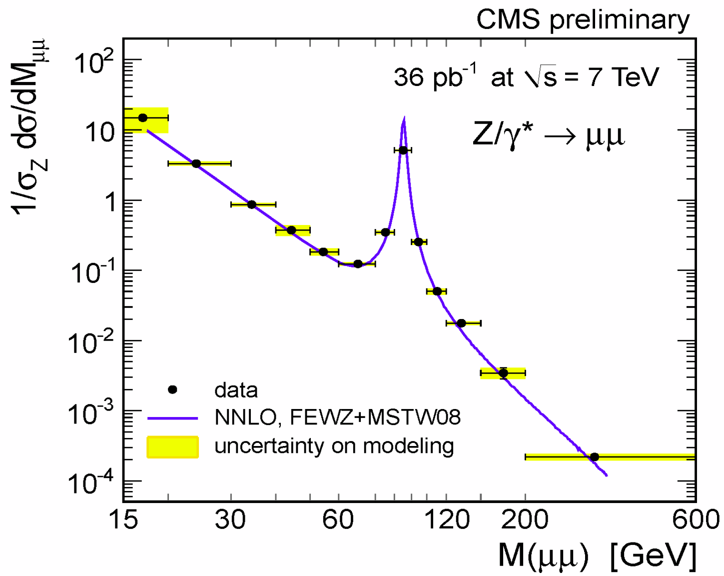


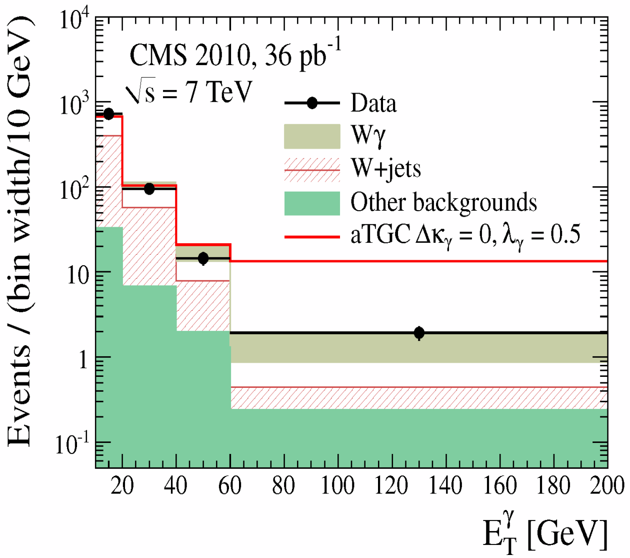


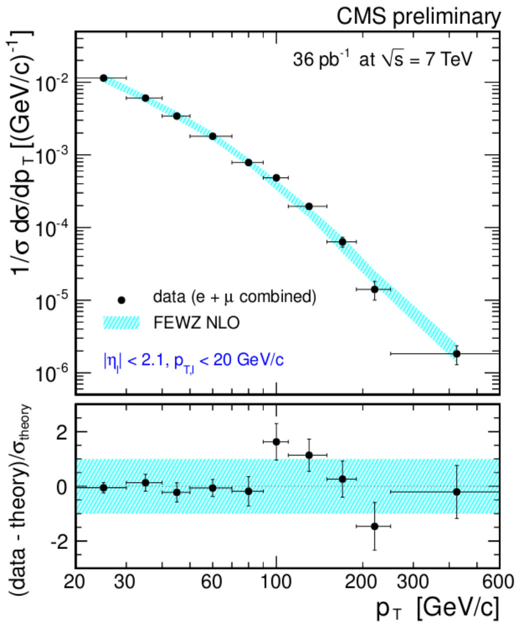
CMS-EWK-10-009/PLB

- CMS has completed precise measurements of the inclusive production of electroweak bosons
- The focus is now shifting to multi-particle and differential measurements
  - More information to compare, combine, and use to understand both electroweak physics and the backgrounds to new physics



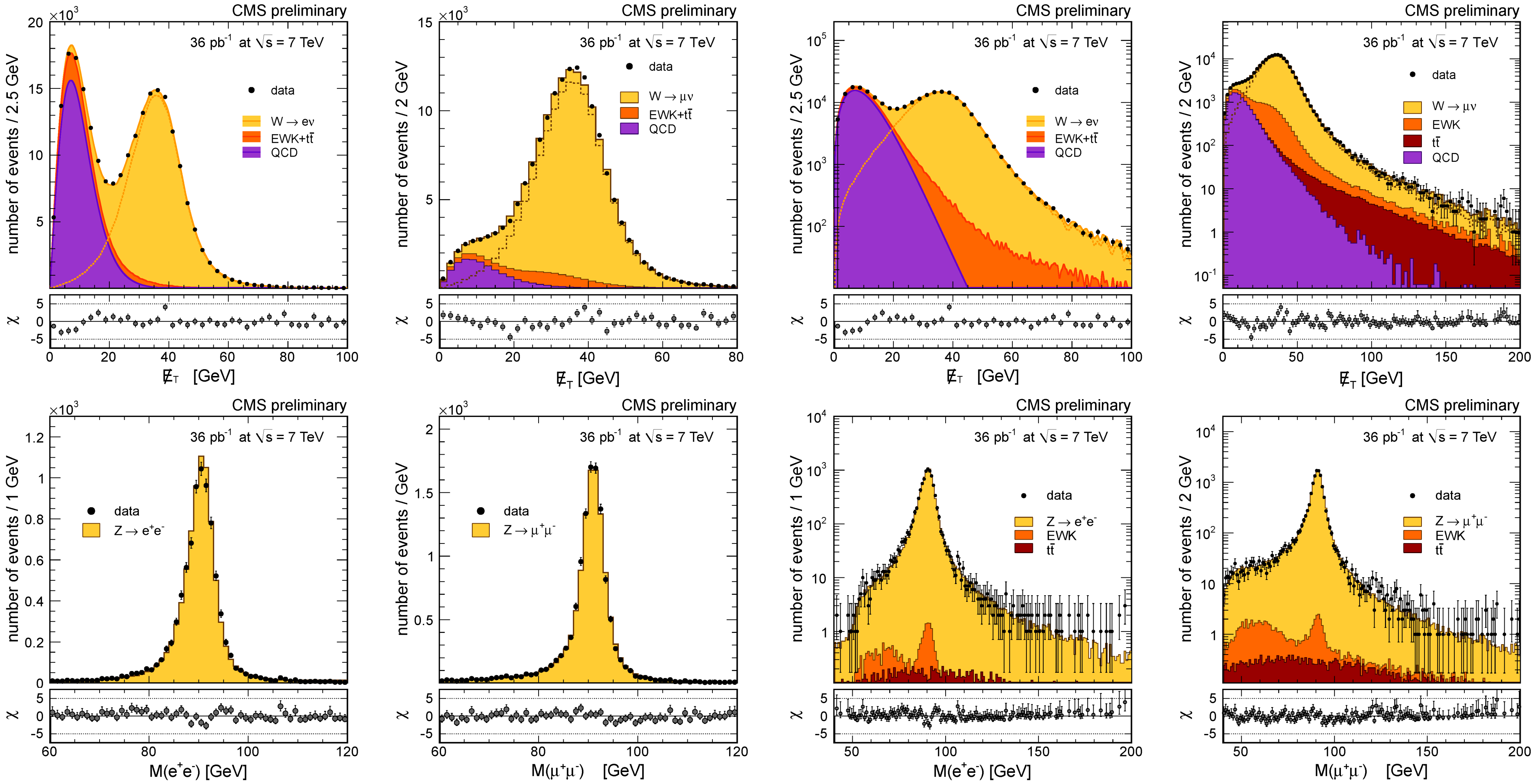






Additional Material

Further plots on Inclusive



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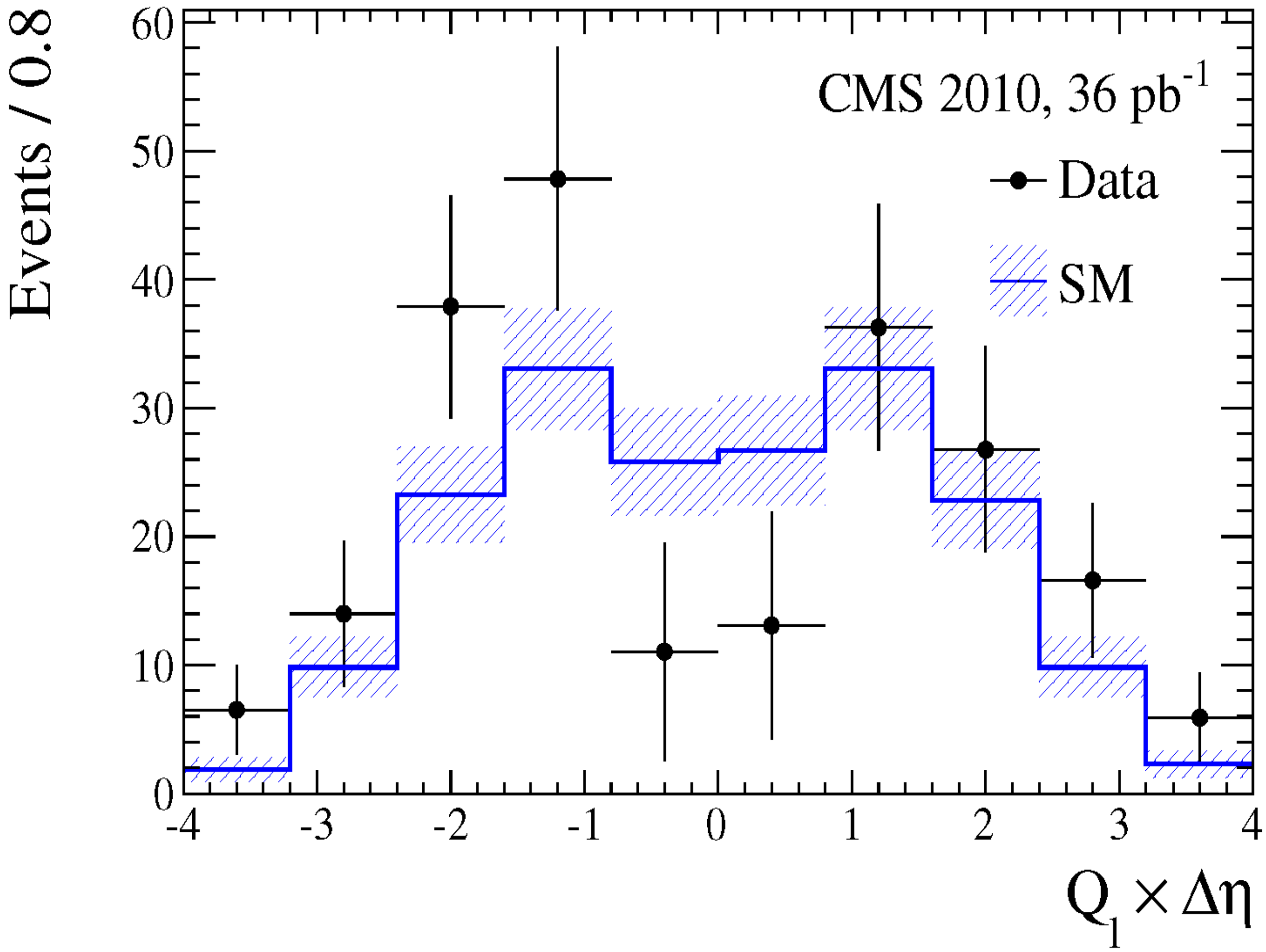
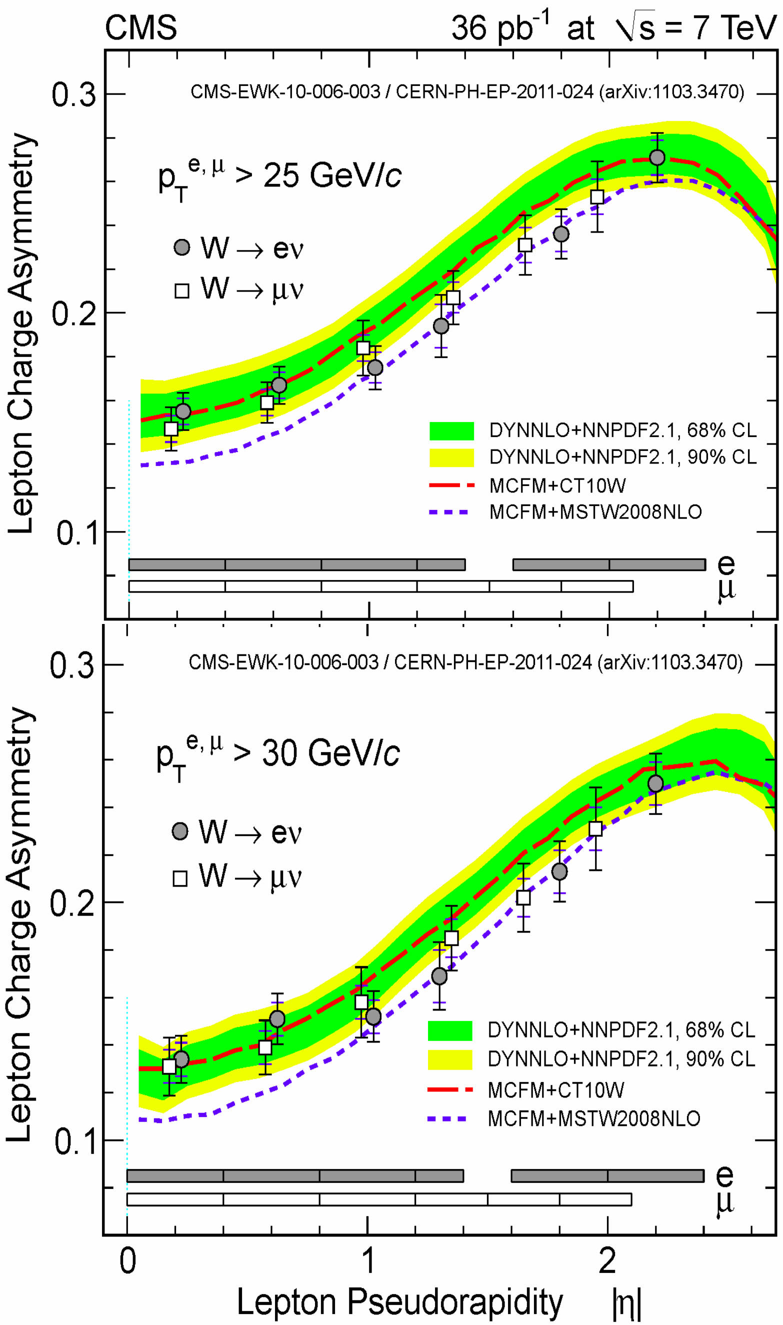
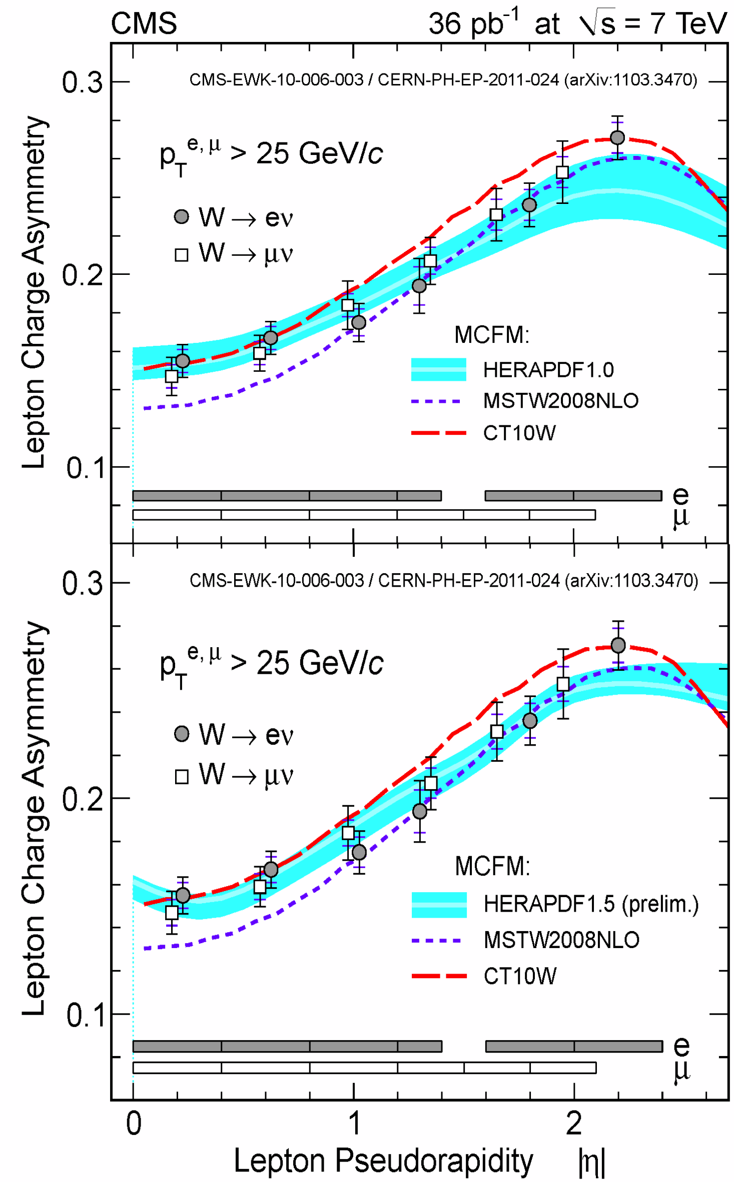

Events / 0.8
CMS 2010, 36 pb-1
Data
SM
0
10
20
30
40
50
60
-4
-3
-2
-1
0
1
2
3
4
Q_l × Δη

Comparison to NNPDF and HERAPDF



NNPDF predictions courtesy of Juan Rojo



CMS-PAS-EWK-10-006

HERAPDF predictions courtesy of Katerina Lipka