Recent results on W/Z measurements from CMS

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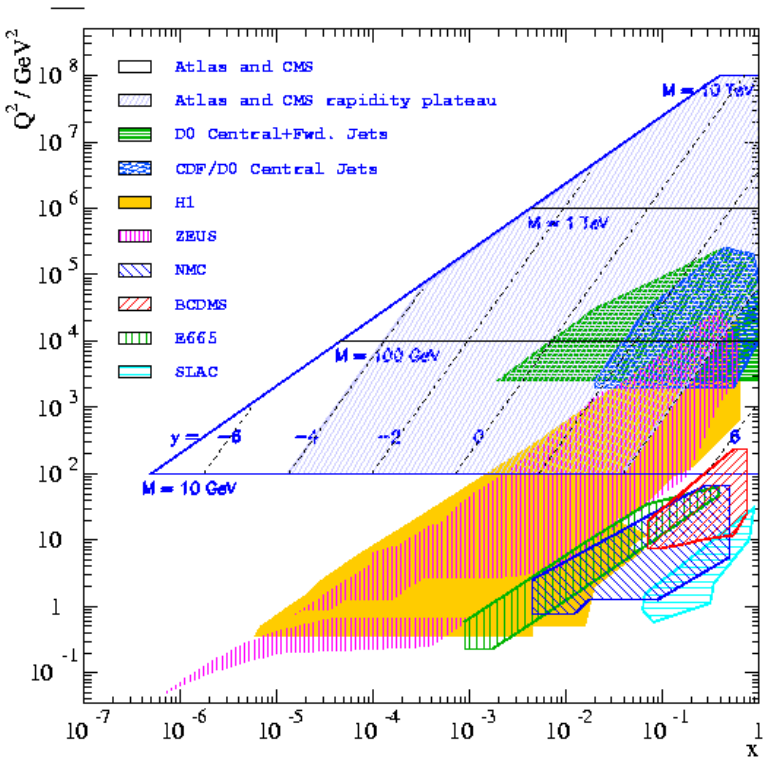
On behalf of the CMS Collaboration

- Muon charge asymmetry in inclusive W events (7 TeV)
- Drell-Yan double differential cross sections (7 TeV)
- Inclusive W/Z production cross sections (8 TeV)
- Measurement of the Z transverse momentum (8 TeV)

Why still W/Z physics at the LHC ?

- Useful experimental candle
- Used to calibrate the detector, check luminosity measurements, calculate efficiencies with tag-and-probe methods etc.
- A check of MC models for the description of SM backgrounds to searches

- Total and differential cross sections are calculated at NNLO
- Powerful distributions to constrain the proton PDFs. A particle of mass M~100 GeV in central rapidities probe x~0.001-0.1 at higher Q^2 than HERA.



As this is a QCD conference I will emphasize the comparison to QCD models and theory and the extraction of PDFs

Muon charge asymmetry in W events

CMS PAS SMP-12-021

u dbar->W^+, d ubar->W^-, expect more W^+ than W^-, dependence on η gives information on

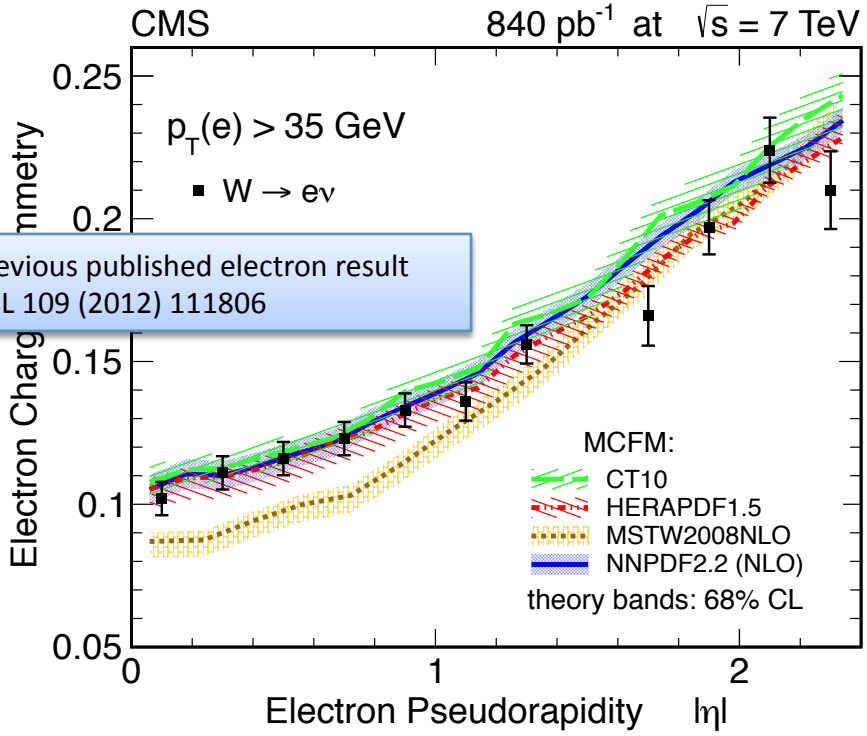
$$A_W \approx \frac{u_v - d_v}{u_v + d_v + 2u_{sea}}$$

in x Bjorken 0.001-0.1

Experimentally the lepton asymmetry is measured:

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

Events extracted from a fit to the missing E_T, after corrections



New results based on the full 7 TeV dataset, based on 20 M W->μυ events, superseding the previous one in muons, in two bins of p_T, >25 and >35 GeV and 11 bins in |η|

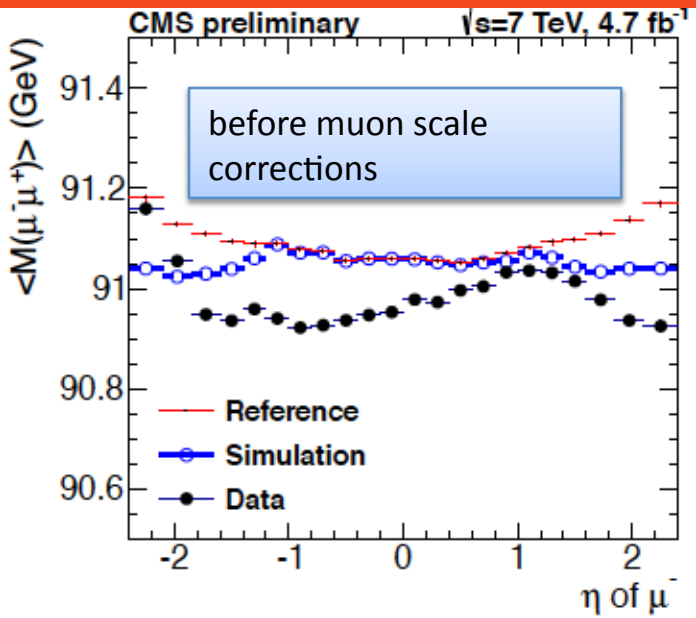
Muon corrections

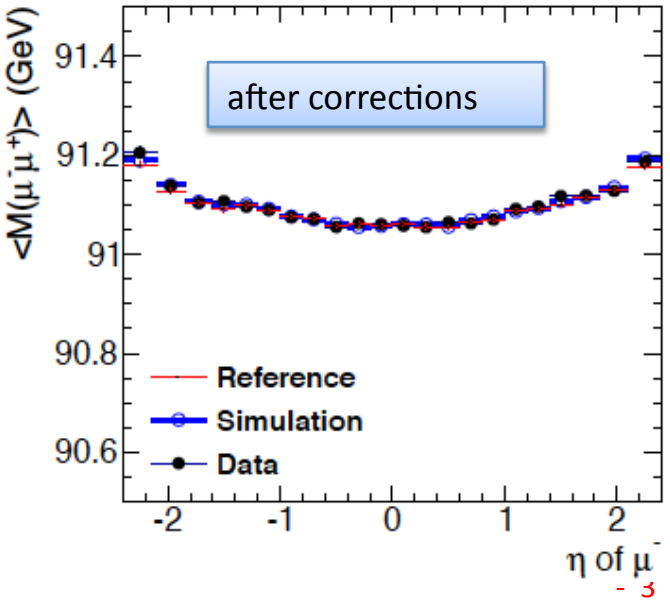
Muon corrections:

• residual misalignment (charge dependent) and mis-modeling of magnetic field, correcting the $<1/p_T>$ in bins of η and ϕ, using Z->μμ events

• correct M(μμ) in bins of muon Q, η and ϕ

• muon efficiency evaluated with tag-and-probe separately for positive and negative muon in bins of η and p_T and ratio used to correct raw charge asymmetries.

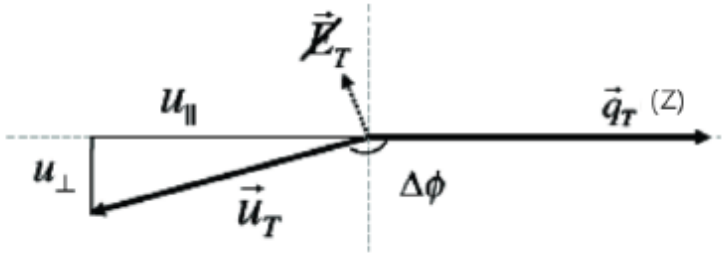


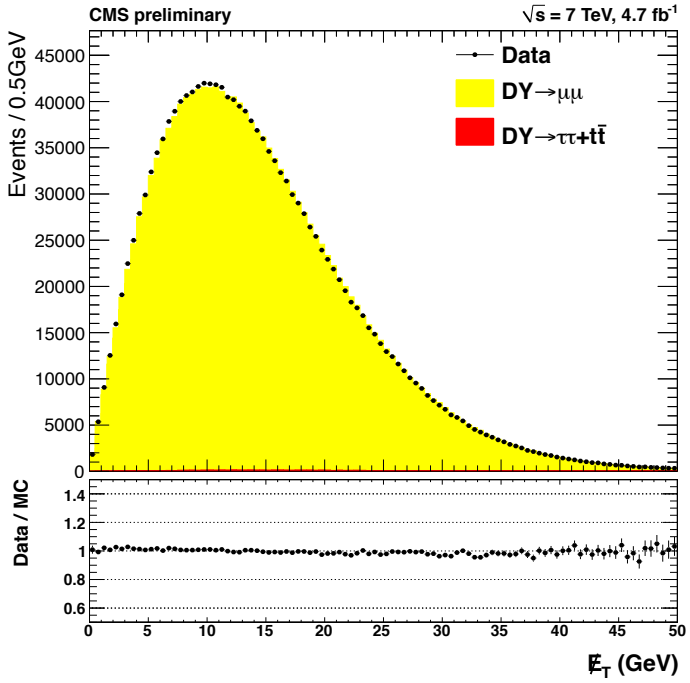


MET corrections

Missing E_T resolution and scale affected by pileup, correction applied in the MC to reproduce the data. Use the hadronic-recoil in Z->μμ events where there is no missing E_T:

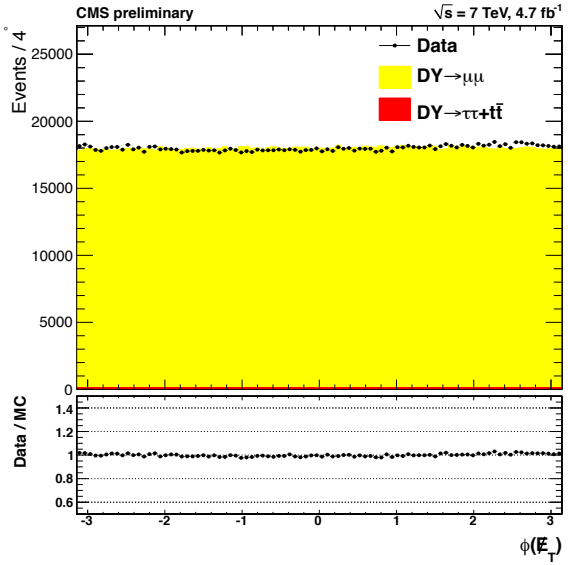
$$\vec{u} = -\vec{\not{E}}_T - \vec{q}_T$$





The two components $u_{||}$ and u_{perp} are studied vs the number of vertices and q_T, their resolution and the scale of $u_{||}$ in MC are tuned to what found in data. Additional correction needed for ϕ modulation of missing E_T.

Excellent agreement data-MC after these corrections are applied to MC W events.

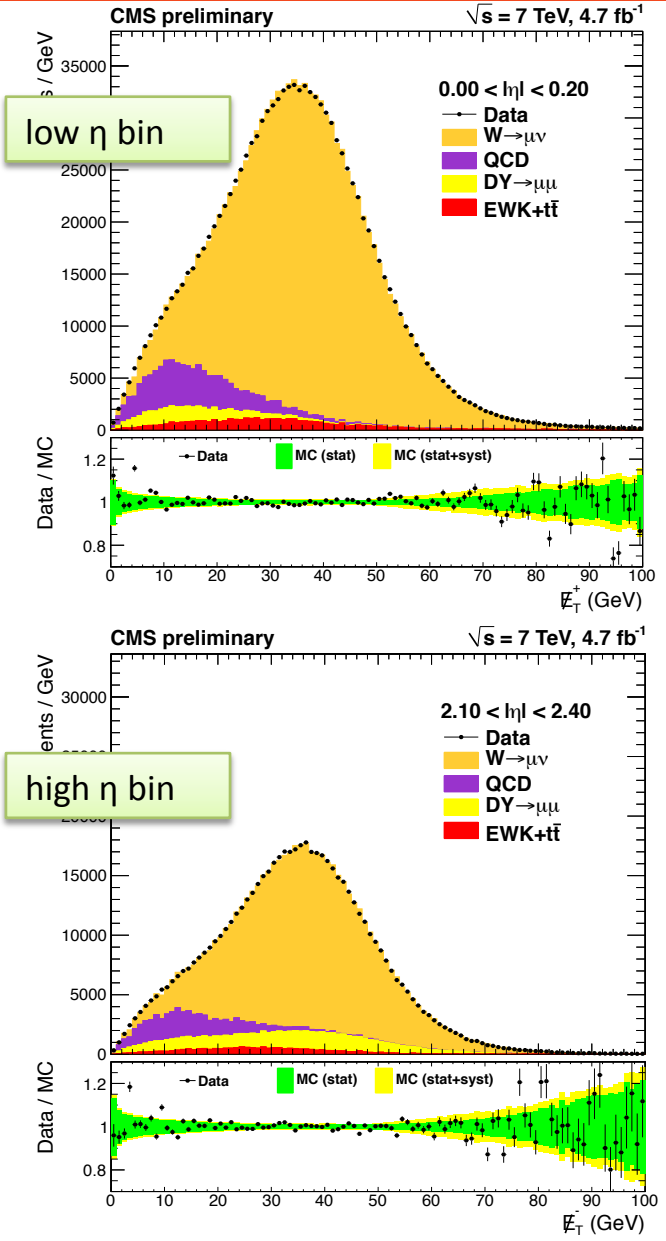


Signal extraction

Signal is extracted from a binned maximum-likelihood fit to the missing E_T in each η bin with templates from simulation and:

- W^+ and W^- yields as free parameters

- QCD allowed to float, with ratio +/- determined from a QCD enriched sample
- Drell Yan rescaled using yields in a control sample
- top background is normalized to the theoretical cross section.
- W ->τν normalized to W->μυ



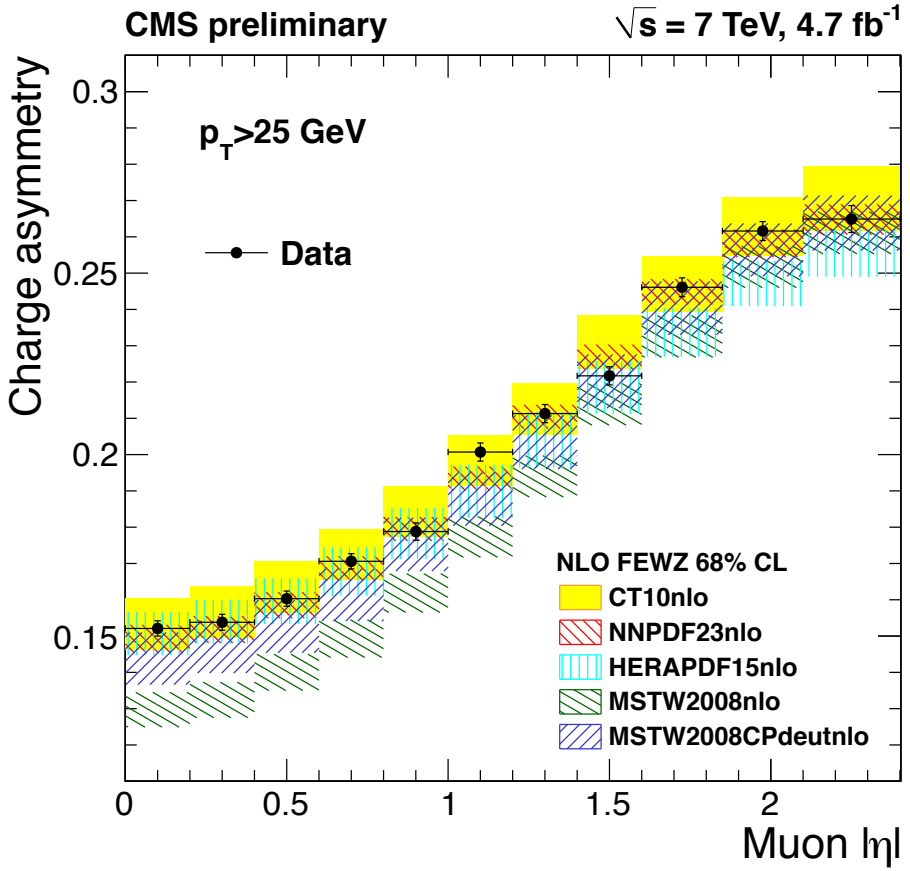
Muon charge asymmetry in W events

$$\mathcal{A}^{true} = \mathcal{A}^{raw} - \frac{1-(\mathcal{A}^{raw})^2}{2}\left(r^{W^+/W^-} - 1\right)$$

Corrected for the ratio r of efficiencies

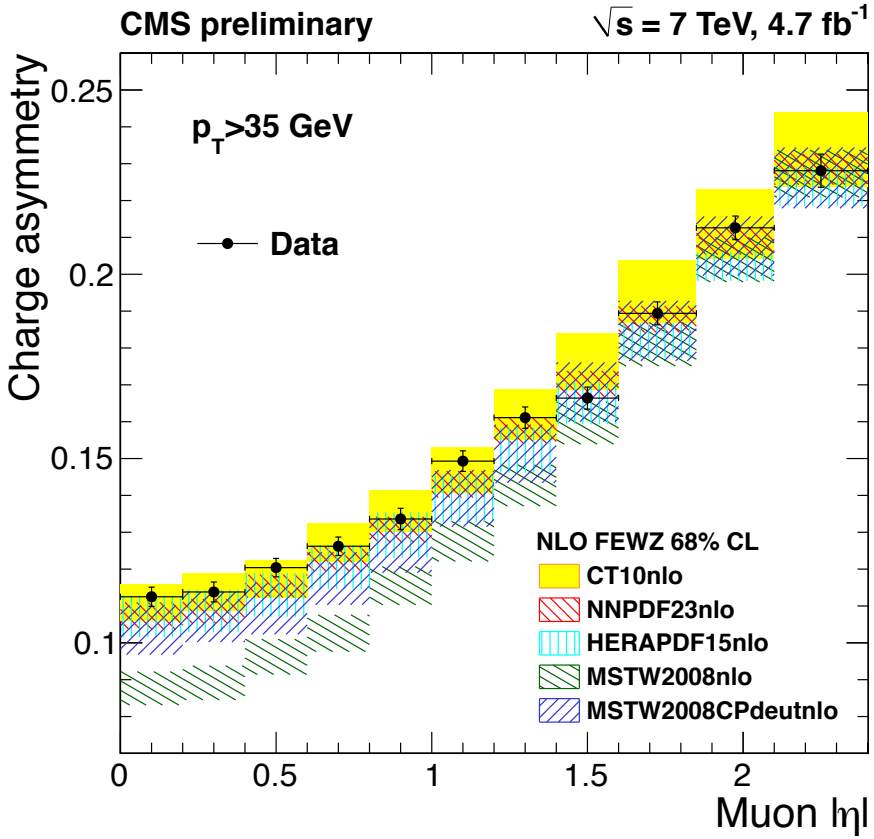
Main systematics: muon efficiency , muon scale (for p_T>35 GeV), QCD background. Table of correlations of systematics between bins provided

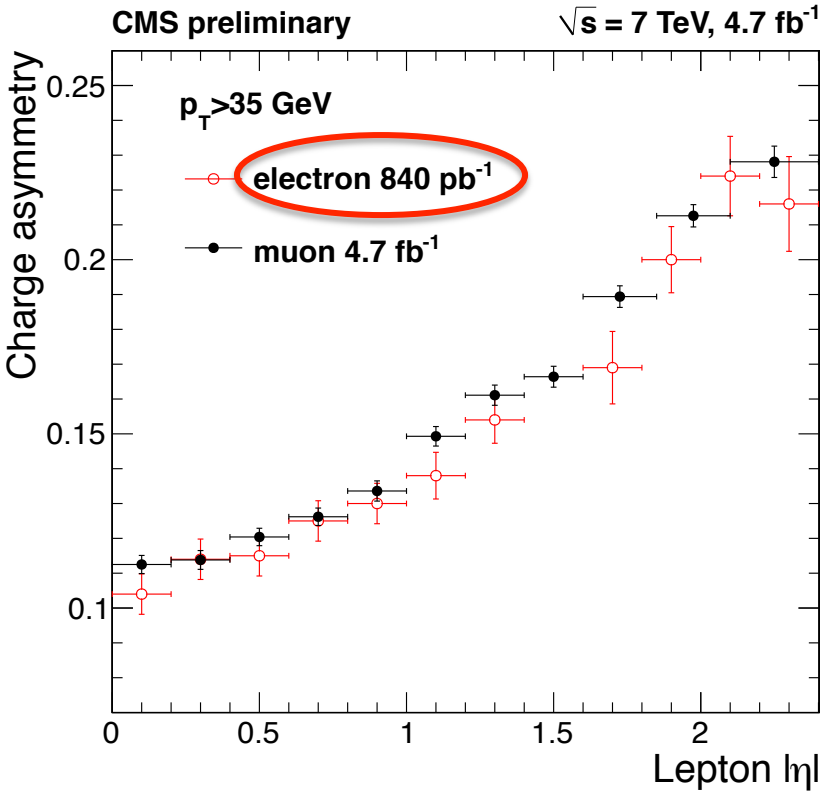
- CT10 and HERA 1.5 in good agreement
- NNPDF2.3 including previous CMS electron results + others LHC also agrees
- MSTW08 poor agreement, MSTW2008CPdeut agrees better



Uncertainty per bin 0.2-0.4%

Muon charge asymmetry in W events

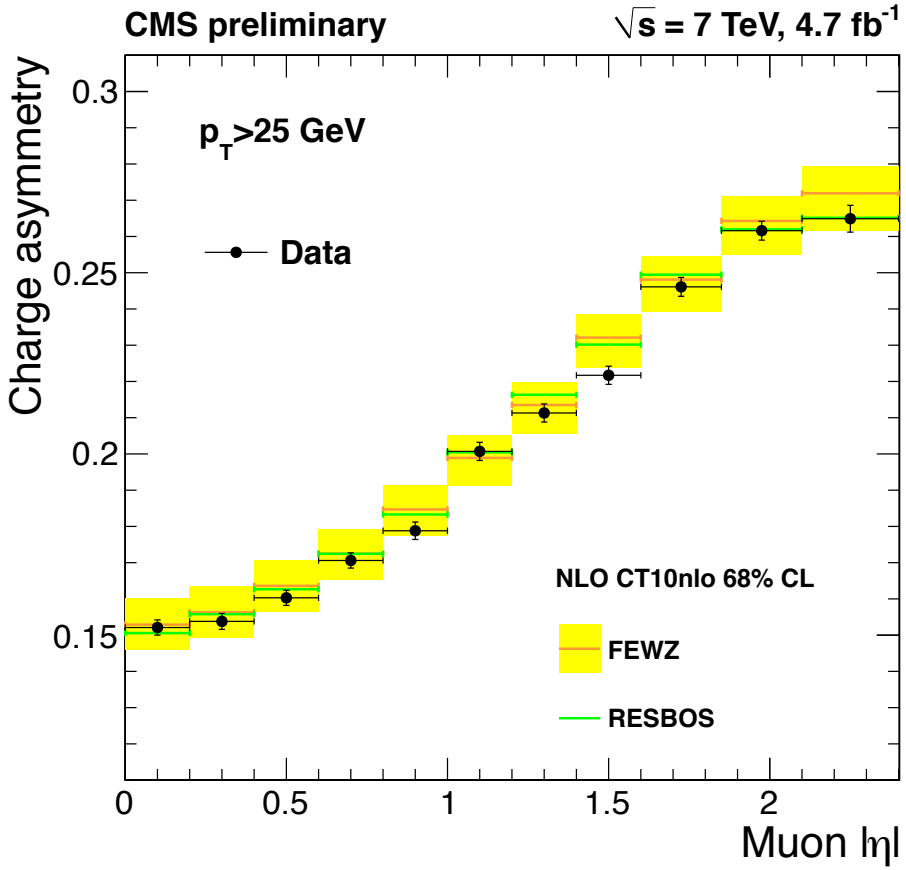


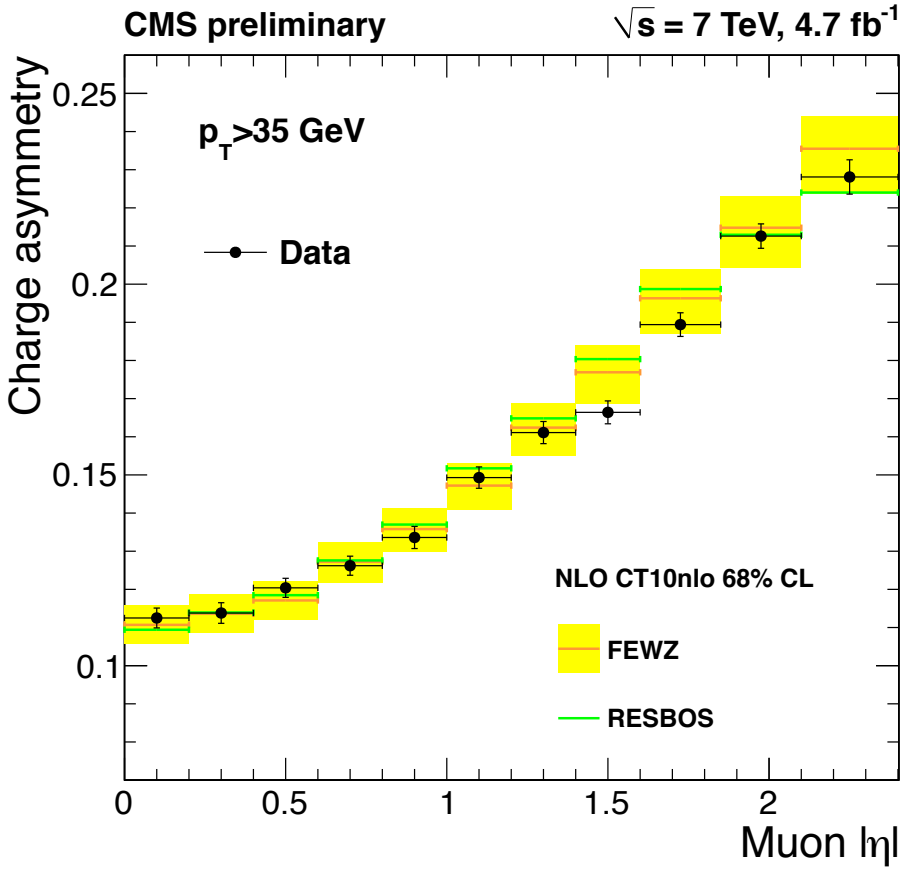


Same for bin also at higher p_T threshold, where there is less background and lepton charge asymmetry closer to W charge asymmetry

Good agreement with CMS previous results on muon and electron asymmetries, but much improved precision

Muon charge asymmetry in W events





RESBOS: resummation in boson q_T, but very close to FEWZ which is fixed order

Conclusion on the W charge asymmetry: significantly smaller experimental errors, can distinguish between different PDFs

Drell-Yan differential cross sections

CMS PAS SMP-13-003

- Drell-Yan cross sections measured in the range in mass 20-1500 GeV, for electron and muons separately and combined

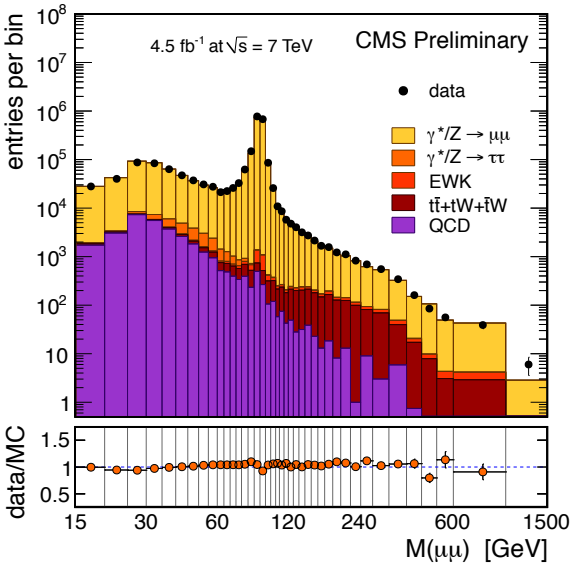
- 2011 data at √s=7 TeV used

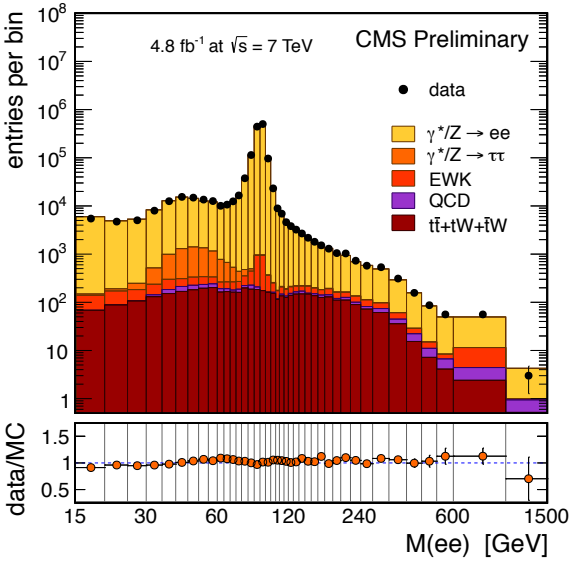
- Data-driven background estimations for QCD (mainly at low mass) and top (high mass)

- NNLO/NLO corrections on an event-by-event basis in Y and p_T based on ratio FEWZ/POWHEG.

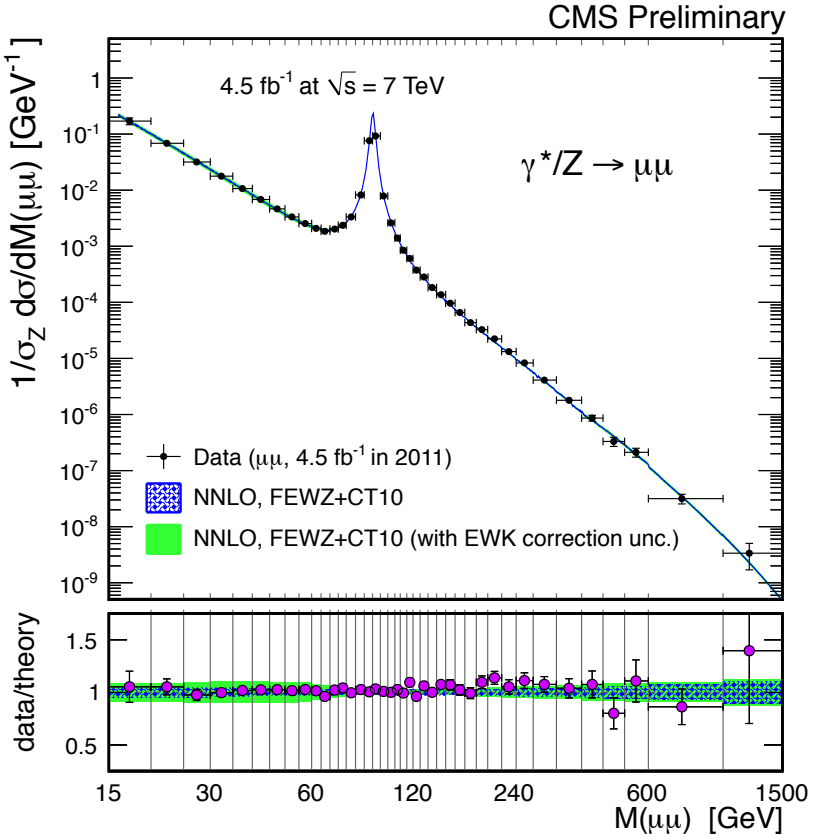
- Cross section are unfolded to the true level and corrected for FSR effects.

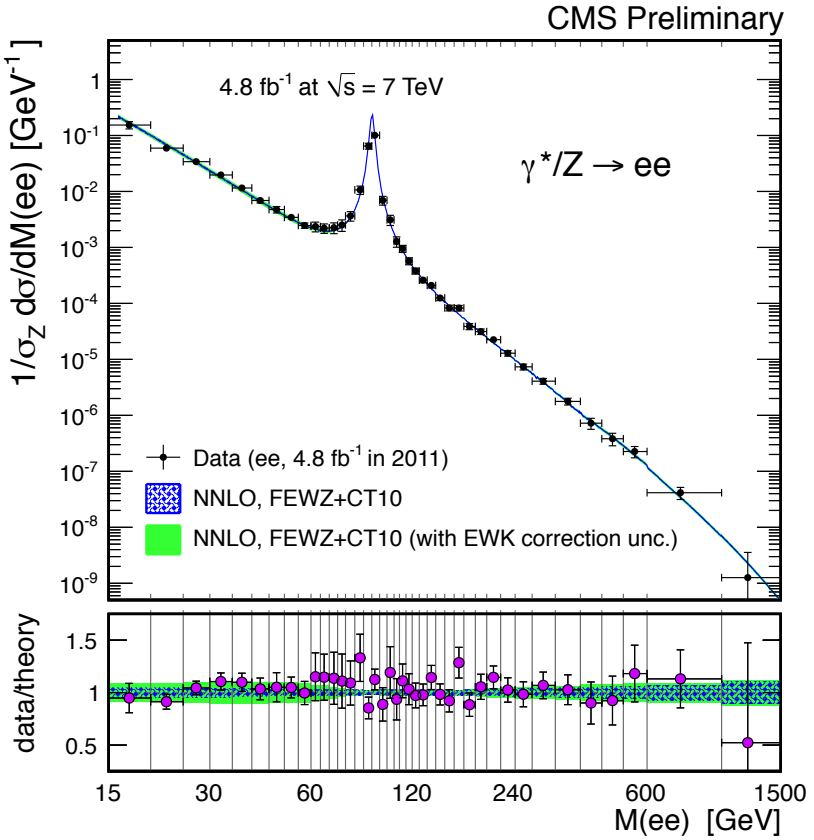
- Main systematics due to muon efficiency and electron energy scale - total of <12% up to 200 GeV





DY dσ/dM cross sections





Cross section dσ/dM in 40 bins extrapolated to the full acceptance and normalized to the Z-peak region, so that many systematics (luminosity, pileup, efficiency, PDFs in acceptance) cancel out.

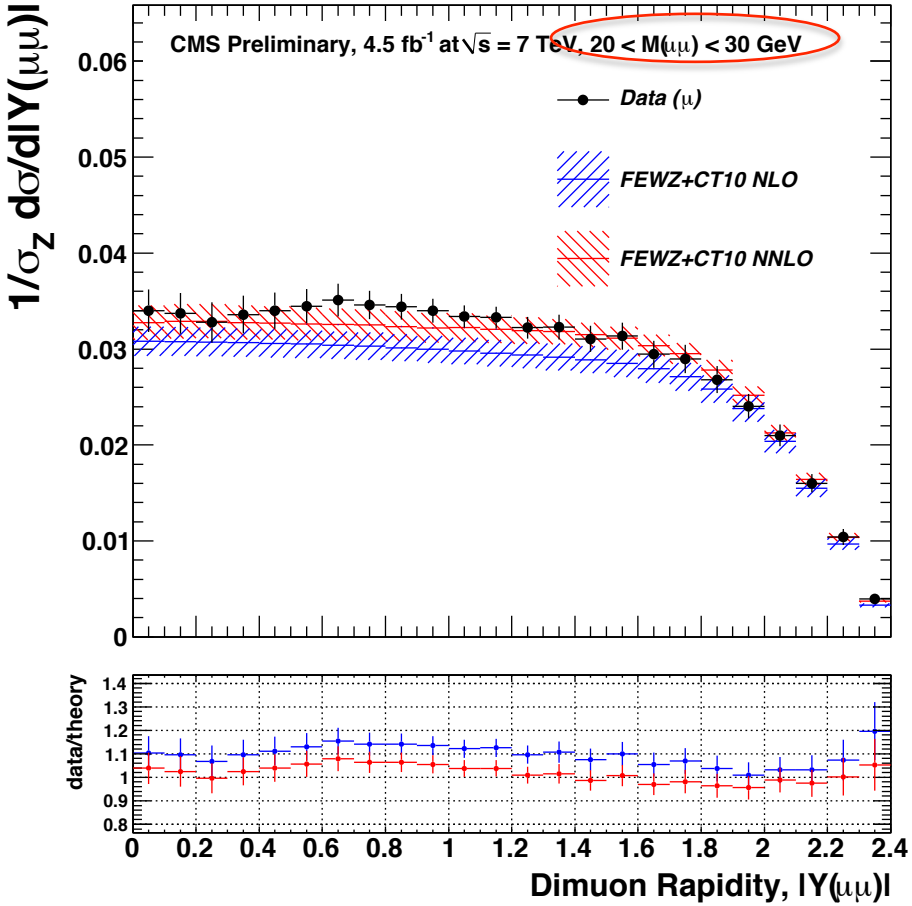
Cross sections are in excellent agreement with NNLO calculation FEWZ. EWK corrections include γγ process.

DY dσ/dMdY cross sections

Integrated dσ/dM cannot discriminate between PDFs, need double differential cross section in M and Y.

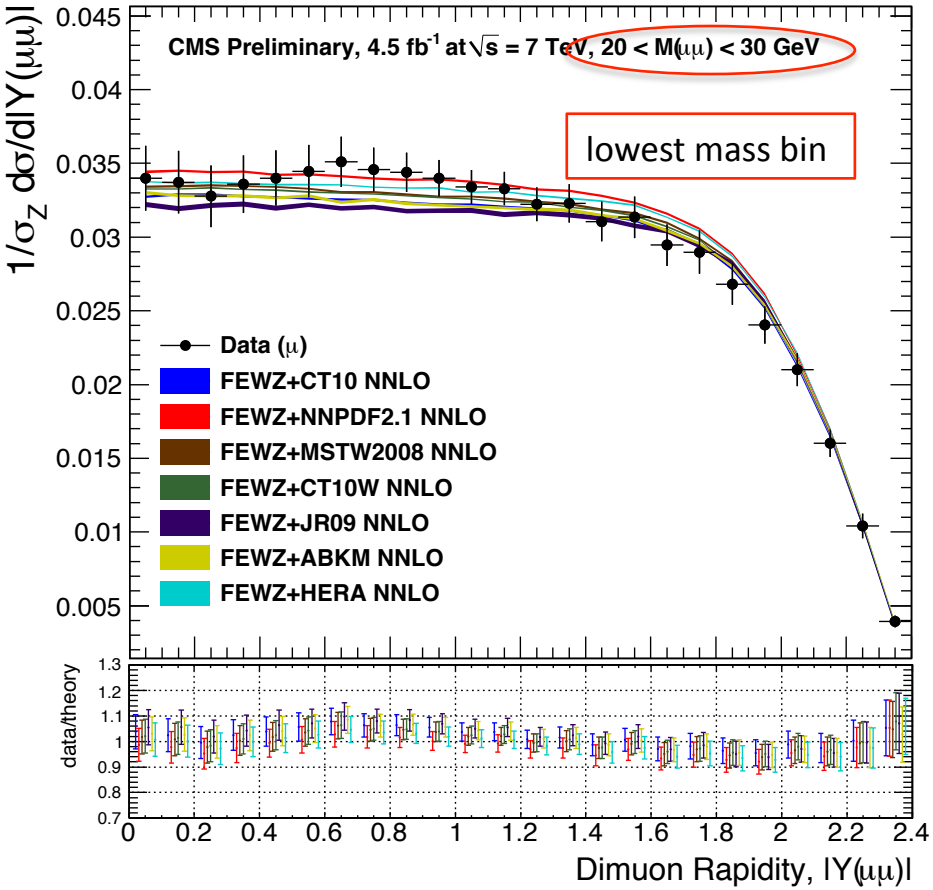
Measured for the dimuon, 6 bins in mass M and as a function of the dimuon rapidity Y in the range 0-2.4.

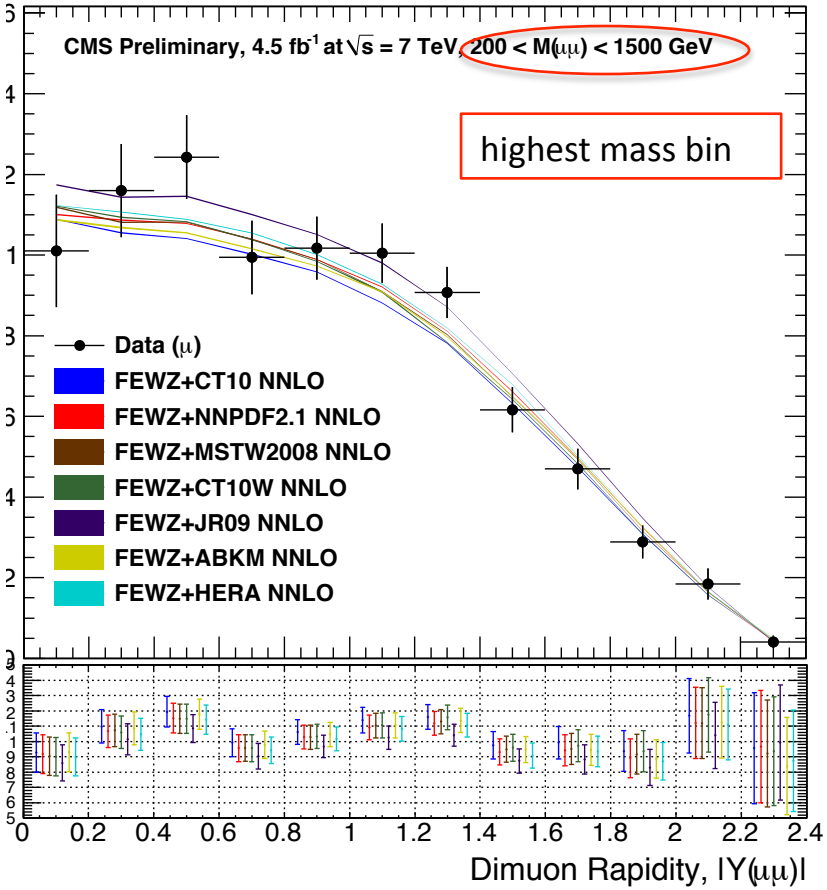
Measurement done in acceptance region.



Comparison to FEWZ NLO and FEWZ NNLO shows that NNLO is relevant, especially at low mass.

DY dσ/dMdY cross sections





Uncertainties in ratios are experimental +statistical of theoretical calculation

Sensitivity to parton densities at Bjorken x~ (M/√s) $e^{-|Y|}$

These data can provide valuable inputs to constrain the PDFs

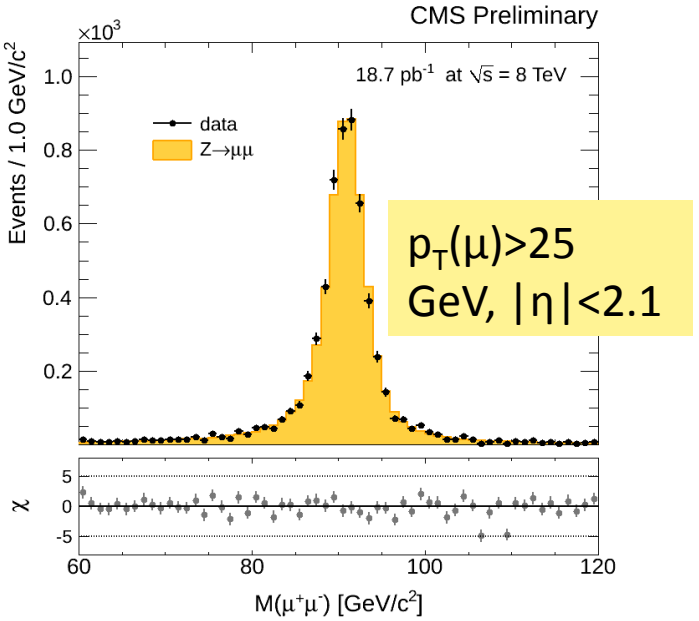
Inclusive W/Z production at 8 TeV

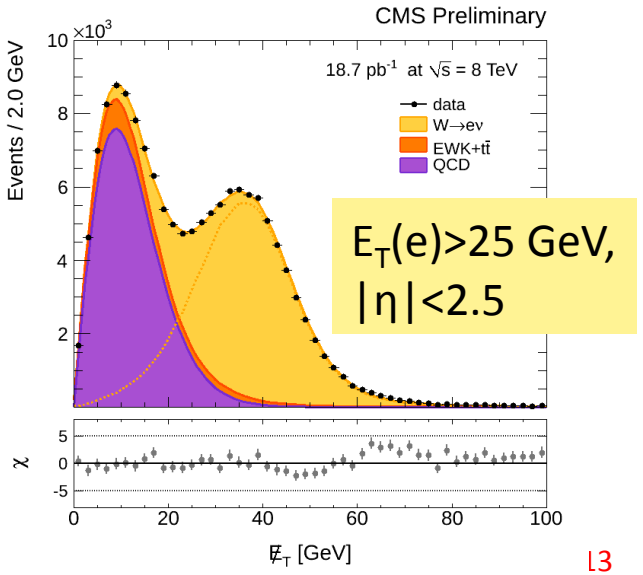
CMS PAS SMP-12-011

- Special run in 2012, with low pileup and low trigger thresholds for e and μ, 18.7 pb^{-1} of data collected. LHC beams separated in transverse plane, luminosity levelling like for LHCb.
- Low trigger thresholds: single leptons, at L1, p_T>12 GeV (electrons), >7 (muons); at HLT p_T>22 GeV (electrons), >15 (muons).

- Z events identified from the from the dilepton invariant mass, cross section is calculated in the region $60 < m_{ll} < 120$ GeV.

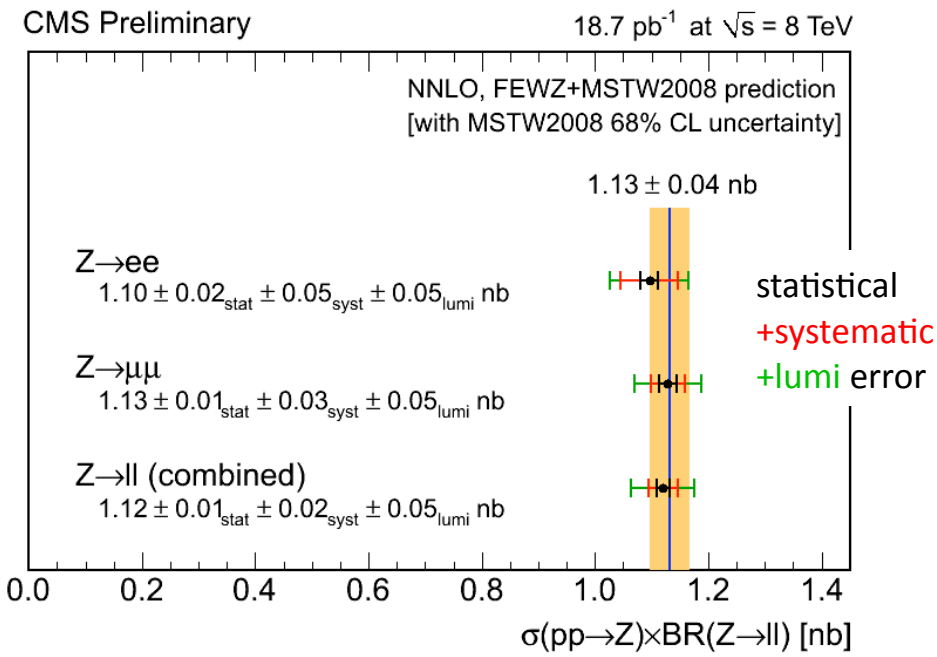
- W events extracted from a binned ML fit to the missing E_T distribution

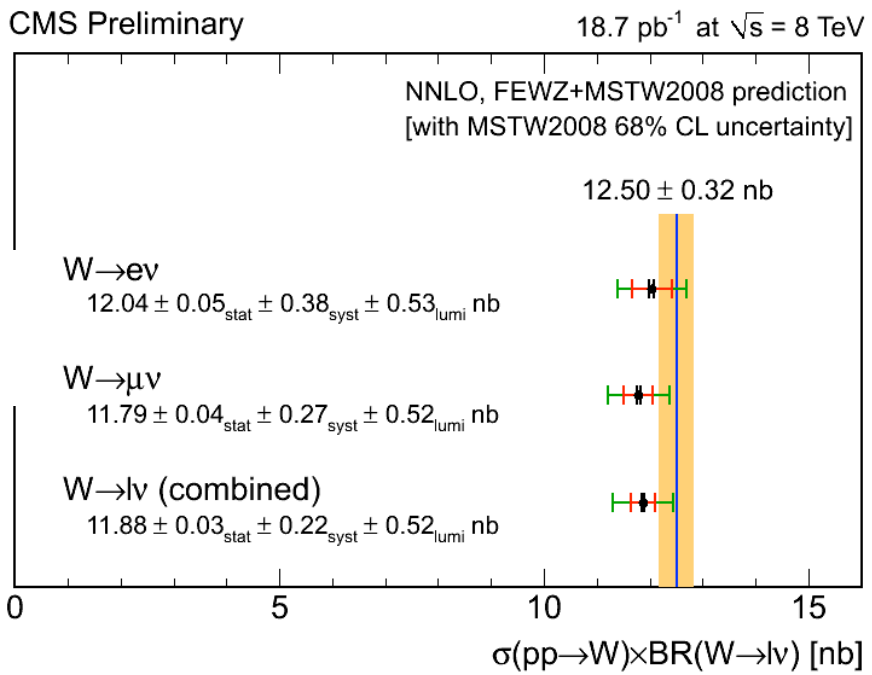




Cross sections

Cross sections are extrapolated to the full phase-space, ~2% experimental errors, 4.4% luminosity:



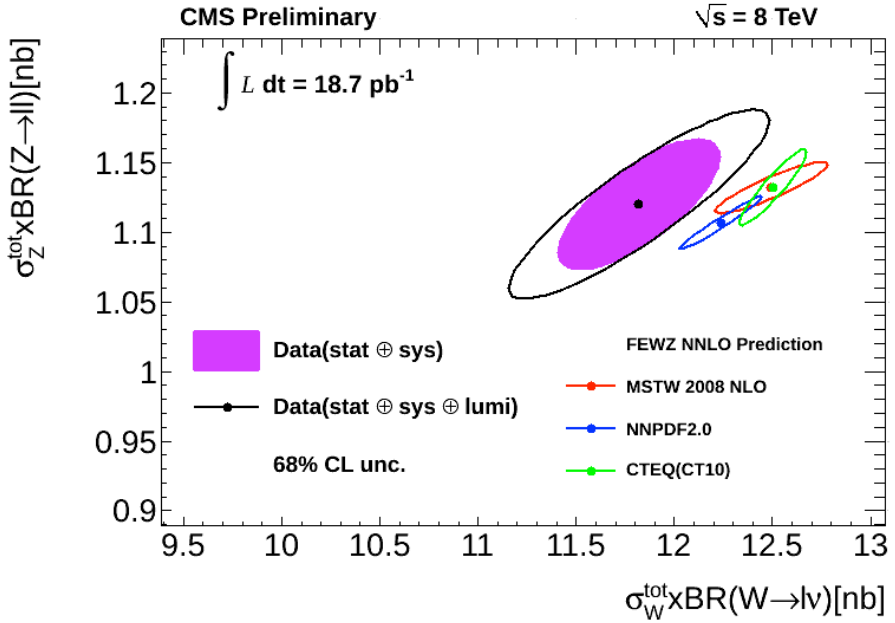


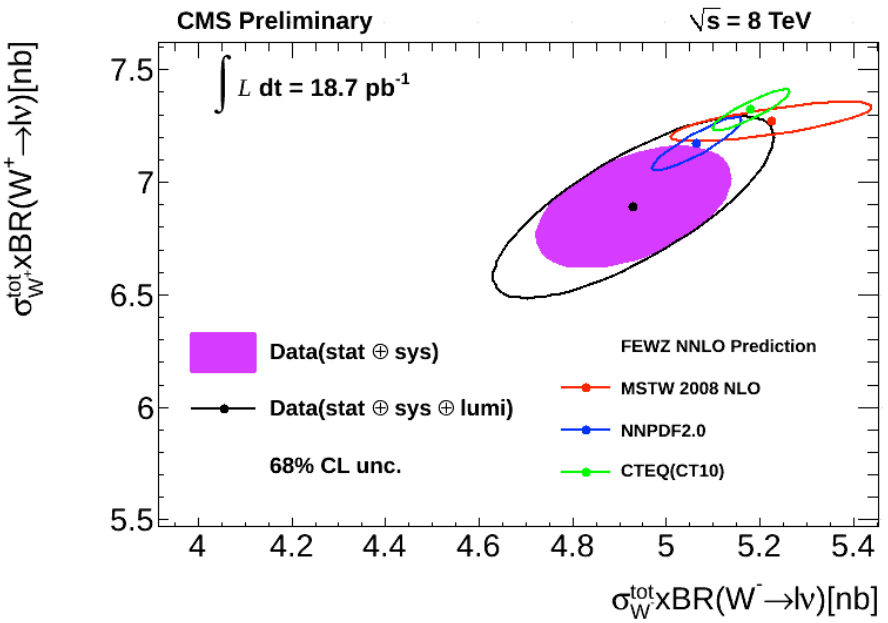
Measurements well in agreement with theory cross sections, calculated at NNLO with FEWZ and the MSTW2008 PDF. Main theory uncertainties (total 2-3%): PDFs, higher-order QCD, EWK radiative corrections (NLO).

Cross sections correlations

$$\frac{\sigma_{W^+} + \sigma_{W^-}}{\sigma_{Z^0}} \sim \frac{u(x_1) + d(x_1)}{0.29\,u(x_1) + 0.37\,d(x_1)}$$

$$\frac{\sigma_{W^+}}{\sigma_{W^-}} \sim \frac{u(x_1)\,\bar{d}(x_2)}{d(x_1)\,\bar{u}(x_2)} \sim \frac{u(x_1)}{d(x_1)}$$





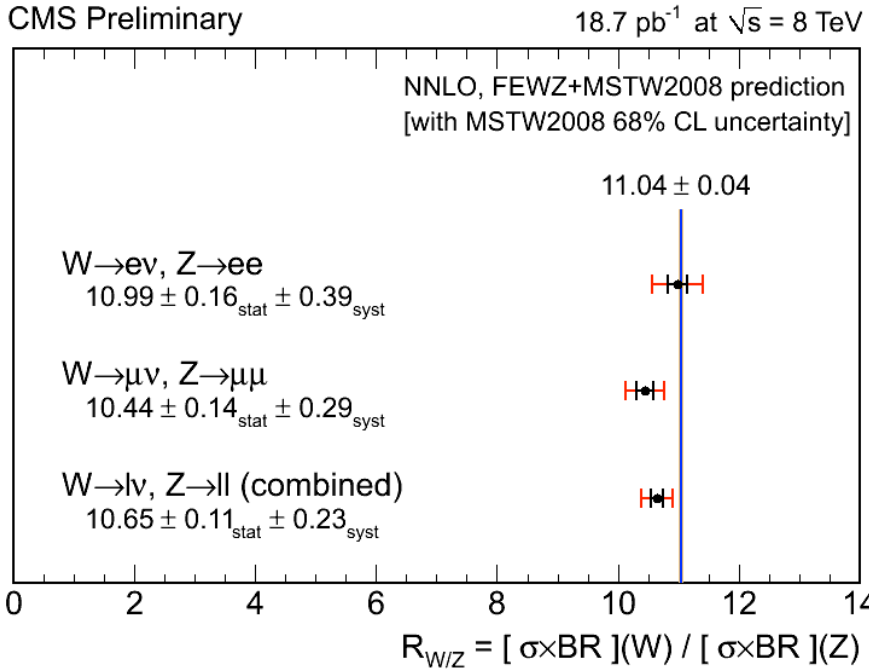
Z and W cross sections are highly correlated, sensitivity to proton PDFs in these correlations, the ratio W/Z depends little on PDFs

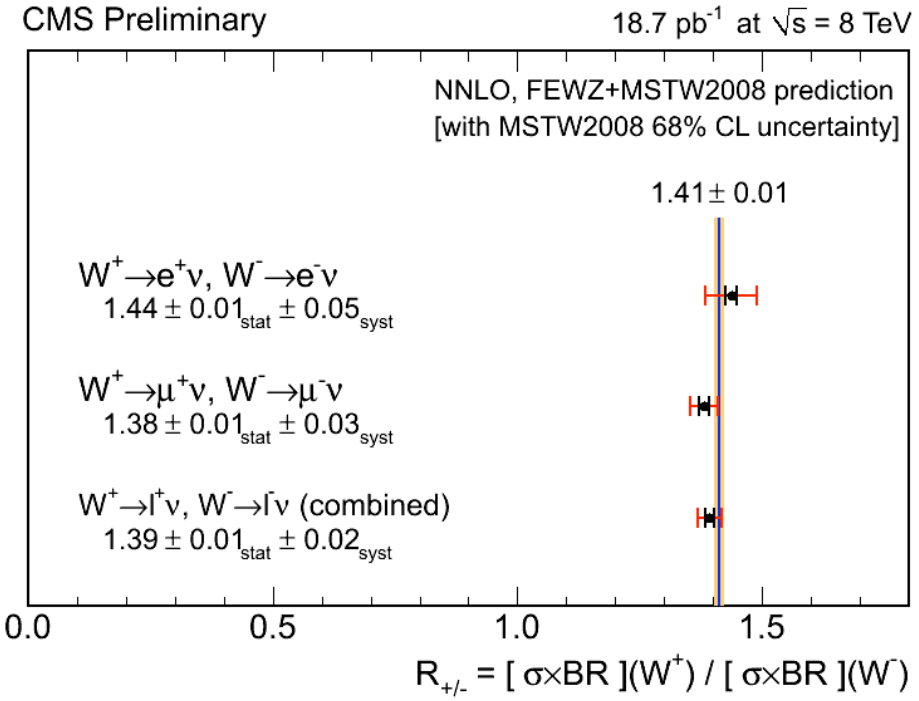
W^+ vs W^-, sensitive probe of u/d ratio

(S. Forte, G. Watt)

Cross sections ratios

W/Z and W^+/W^- ratios measured, many systematics cancel, total systematics reduced to ~2%

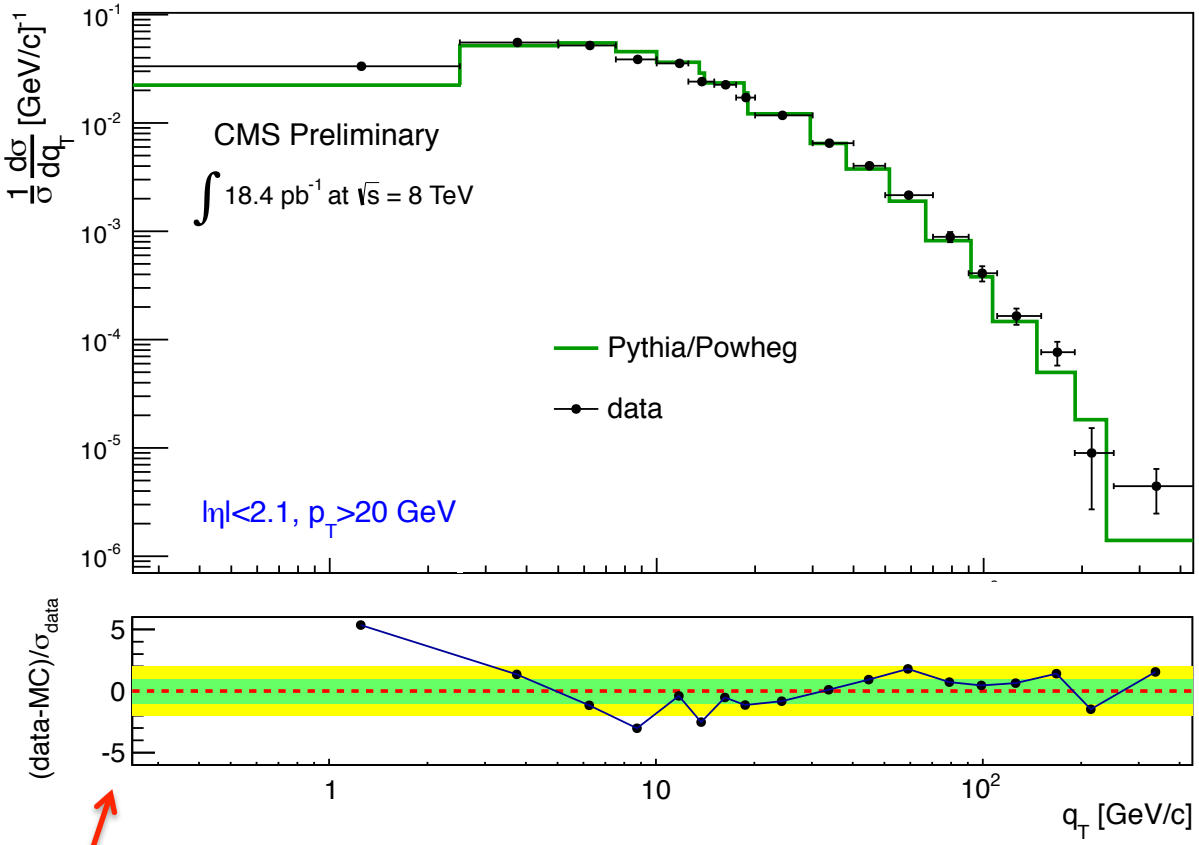




Good agreement with the theory, which also has a much reduced uncertainty

Z q_T distribution at √s=8 TeV

CMS PAS SMP-12-025

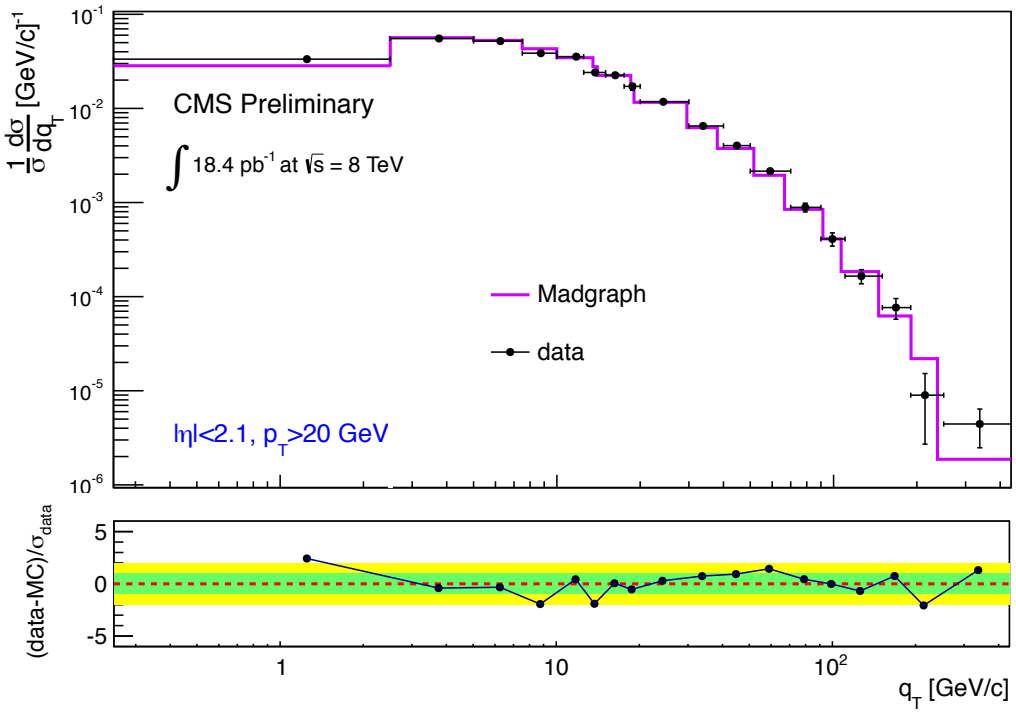


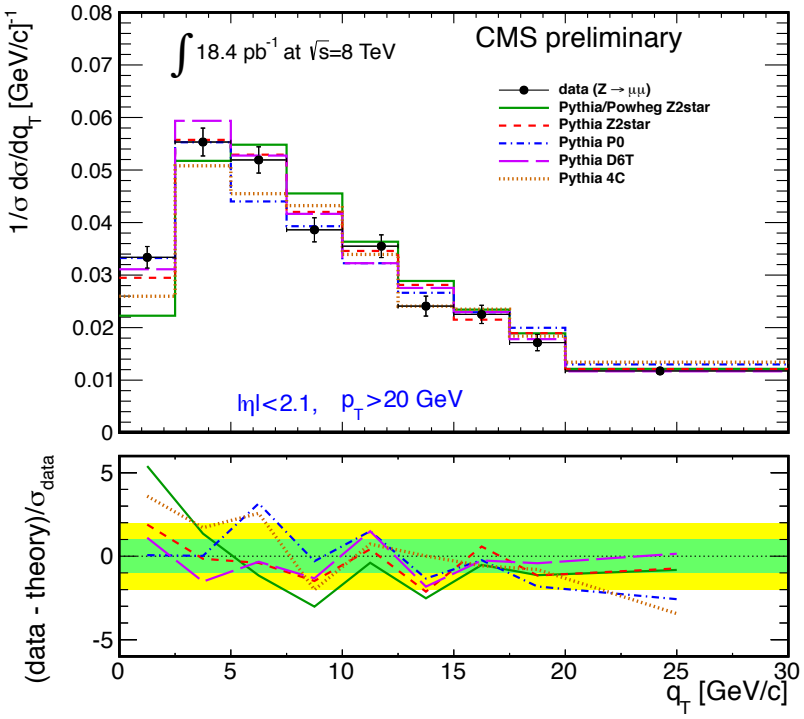
Measured in the dimuon channel, ~ 7000 events in the low pile-up run. Normalized cross section at before FSR level.

Low q_T region region: sensitive to the underlying events

High q_T region region: sensitive to higher order QCD corrections

Z q_T distribution





MADGRAPH performs better compared to PYTHIA+POWHEG over the whole range of q_T

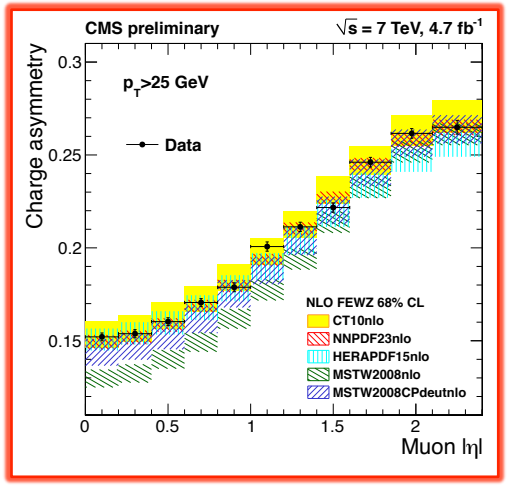
Comparison with different tunes at low q_T: confirmation that the Z2star tune, determined in low-momentum-scale processes, is the best also in this high-momentum-scale process

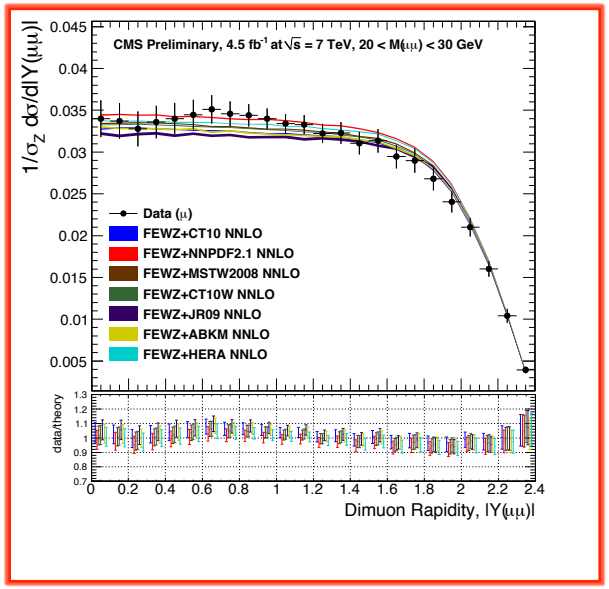
Summary

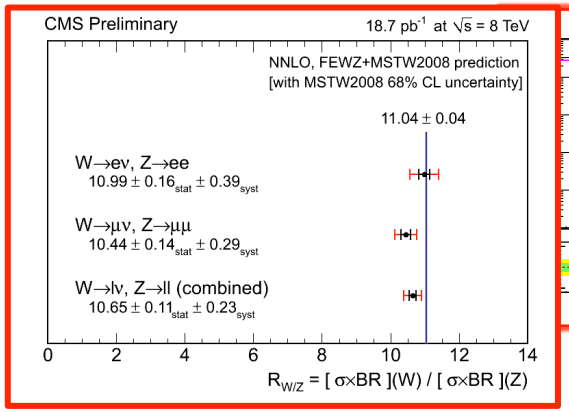
Recent important W and Z physics providing input to EWK and QCD:

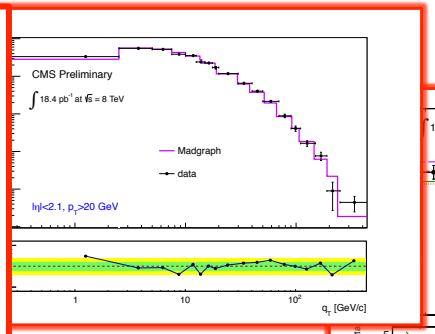
- High precision data at 7 TeV constrain PDFs further

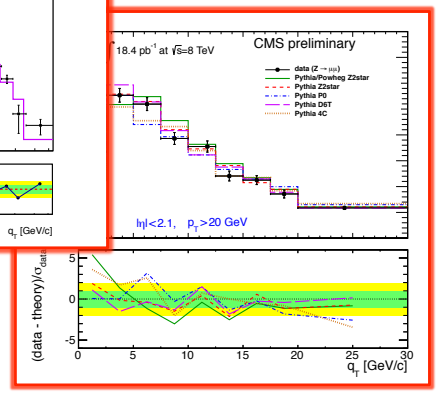
- Cross sections measured at 8 TeV with low pileup run, analysis of 20 fb^{-1} in progress







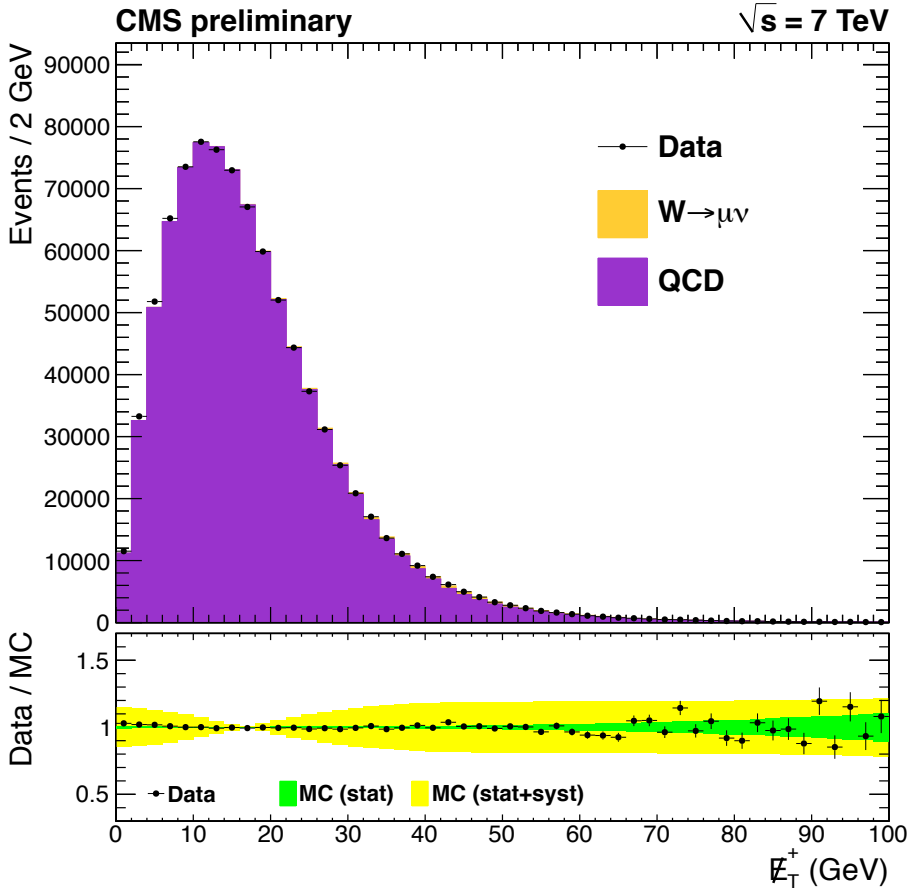


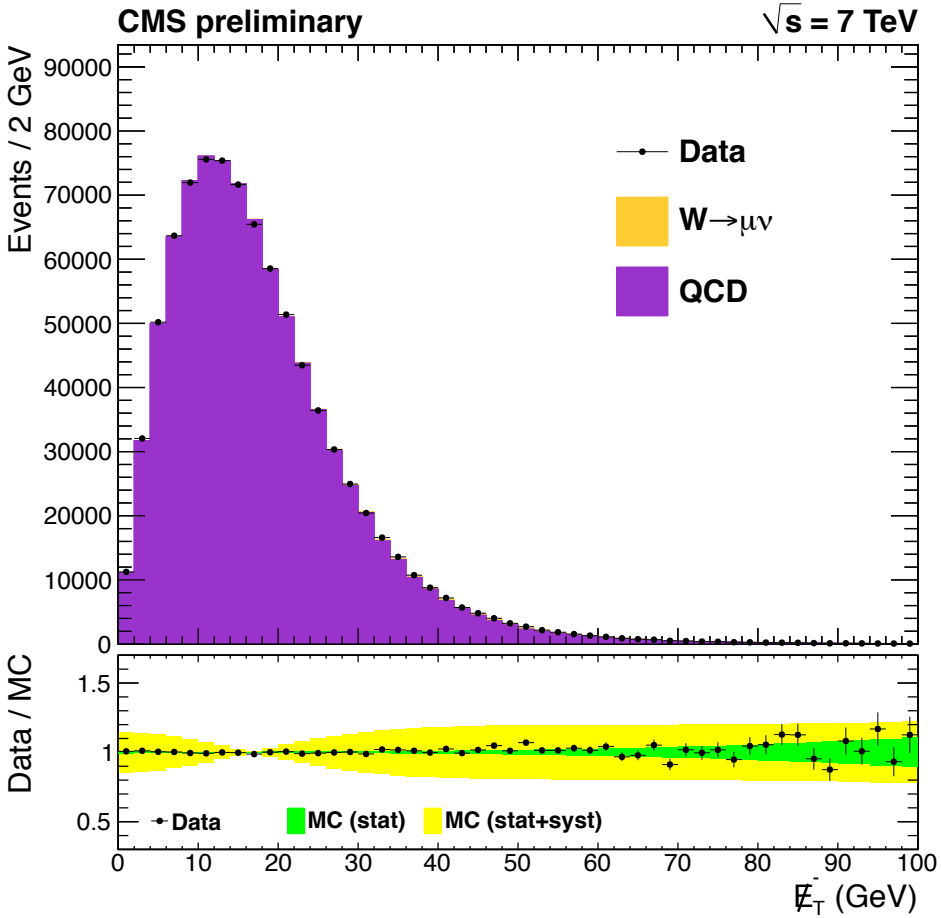


Backup

$\lvert\eta\rvert$ bin	0.0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2	1.2-1.4	1.4-1.6	1.6-1.85	1.85-2.1	2.1-2.4
$p_T > 25$ GeV											
Stat. unc.	0.096	0.098	0.094	0.093	0.098	0.099	0.099	0.099	0.093	0.094	0.106
Efficiency	0.111	0.133	0.121	0.122	0.170	0.175	0.170	0.168	0.165	0.175	0.268
QCD +/-	0.120	0.113	0.110	0.105	0.102	0.103	0.097	0.104	0.108	0.094	0.183
QCD shape	0.070	0.065	0.065	0.067	0.068	0.069	0.078	0.082	0.092	0.083	0.087
Muon scale	0.045	0.050	0.050	0.049	0.051	0.054	0.054	0.058	0.054	0.054	0.055
PDF	0.028	0.026	0.023	0.025	0.018	0.020	0.027	0.031	0.042	0.050	0.069
Drell-Yan bkg.	0.002	0.001	0.002	0.003	0.000	0.007	0.001	0.013	0.019	0.038	0.046
$\not{E}_T$ Φ modul.	0.011	0.009	0.033	0.012	0.029	0.034	0.044	0.045	0.055	0.049	0.038
Recoil	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.003
PU	0.017	0.013	0.011	0.005	0.014	0.025	0.022	0.031	0.019	0.028	0.000
Luminosity	0.002	0.003	0.004	0.004	0.006	0.009	0.012	0.017	0.024	0.033	0.040
$t\bar{t}$ bkg.	0.012	0.013	0.012	0.012	0.011	0.011	0.010	0.009	0.008	0.007	0.005
$W \to \tau\nu$ bkg.	0.026	0.026	0.026	0.026	0.026	0.025	0.025	0.025	0.025	0.025	0.024
W q_T	0.003	0.004	0.004	0.005	0.008	0.011	0.008	0.009	0.006	0.003	0.000
Total syst. unc.	0.189	0.197	0.190	0.186	0.221	0.229	0.227	0.233	0.239	0.241	0.355
Total unc.	0.212	0.220	0.212	0.208	0.242	0.249	0.248	0.253	0.256	0.259	0.371
$p_T > 35$ GeV											
Stat. unc.	0.116	0.119	0.114	0.114	0.124	0.121	0.123	0.123	0.118	0.123	0.141
Efficiency	0.120	0.138	0.116	0.107	0.159	0.164	0.171	0.176	0.186	0.194	0.325
QCD +/-	0.151	0.138	0.135	0.128	0.133	0.118	0.116	0.122	0.137	0.120	0.168
QCD shape	0.030	0.025	0.017	0.023	0.024	0.022	0.018	0.017	0.031	0.031	0.037
Muon scale	0.122	0.135	0.134	0.141	0.146	0.154	0.162	0.170	0.161	0.172	0.189
PDF	0.008	0.008	0.007	0.011	0.012	0.010	0.017	0.022	0.031	0.040	0.058
Drell-Yan bkg.	0.010	0.009	0.009	0.003	0.006	0.010	0.008	0.009	0.009	0.020	0.040
$\not{E}_T$ Φ modul.	0.002	0.009	0.010	0.003	0.008	0.028	0.037	0.035	0.022	0.022	0.001
Recoil	0.005	0.006	0.005	0.004	0.005	0.004	0.005	0.004	0.004	0.006	0.008
PU	0.015	0.003	0.005	0.018	0.019	0.002	0.007	0.003	0.013	0.014	0.032
Luminosity	0.001	0.002	0.000	0.000	0.000	0.001	0.004	0.010	0.016	0.025	0.039
$t\bar{t}$ bkg.	0.011	0.013	0.012	0.011	0.011	0.010	0.010	0.009	0.007	0.006	0.005
$W \to \tau\nu$ bkg.	0.013	0.012	0.013	0.012	0.012	0.012	0.011	0.012	0.011	0.011	0.011
W q_T	0.004	0.002	0.004	0.004	0.007	0.005	0.006	0.009	0.009	0.001	0.014
Total syst. unc.	0.232	0.240	0.225	0.221	0.257	0.258	0.267	0.277	0.287	0.294	0.423
Total unc.	0.260	0.268	0.252	0.248	0.285	0.285	0.294	0.303	0.311	0.318	0.446

Backup


CMS preliminary
√s = 7 TeV
Events / 2 GeV
Data
W→μν
QCD
Data / MC
Data
MC (stat)
MC (stat+syst)
$\not\!\!E_T^+$ (GeV)


CMS preliminary
√s = 7 TeV
Events / 2 GeV
Data
W→μν
QCD
Data / MC
Data
MC (stat)
MC (stat+syst)
$\not\!\!E_T^-$ (GeV)