

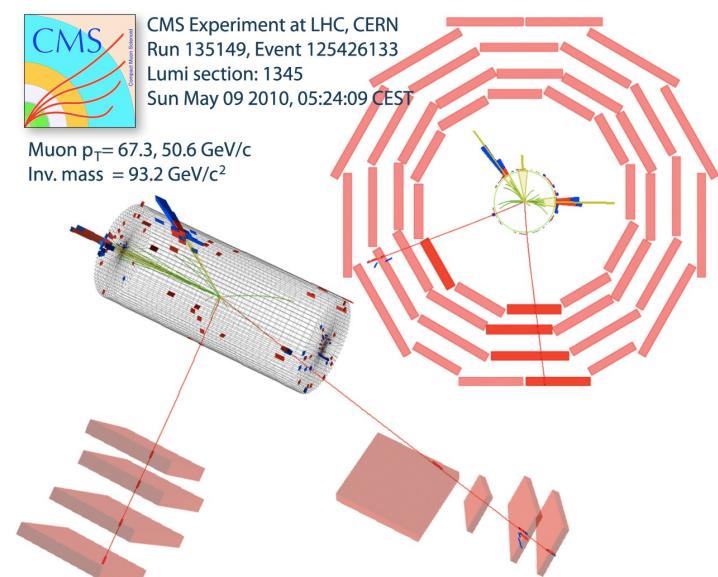
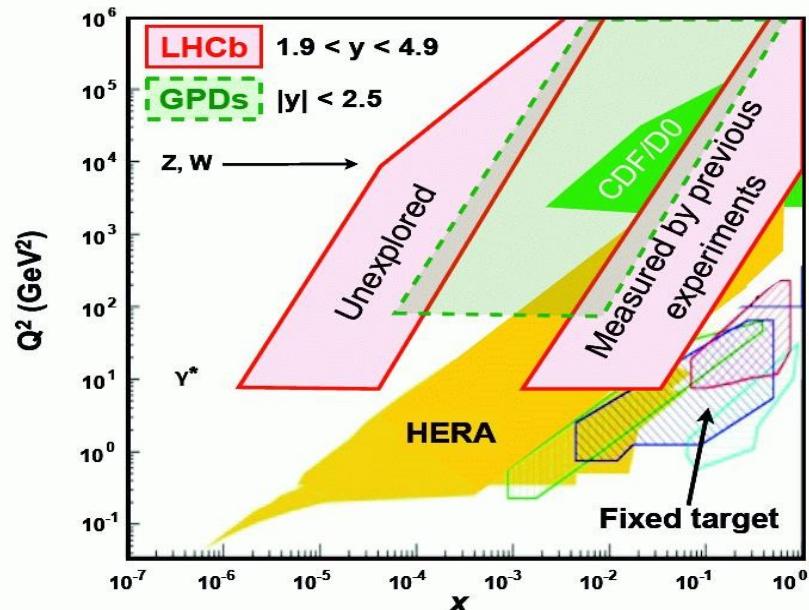
W/Z measurements at CMS

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on behalf of the CMS collaboration

Outline

- ◆ W/Z processes
- ◆ CMS detector reach
- ◆ Recent W results
- ◆ Recent Z (and DY) results
- ◆ 8 vs 7 TeV - challenges with 2012 data
- ◆ LHC EWK physics result combinations

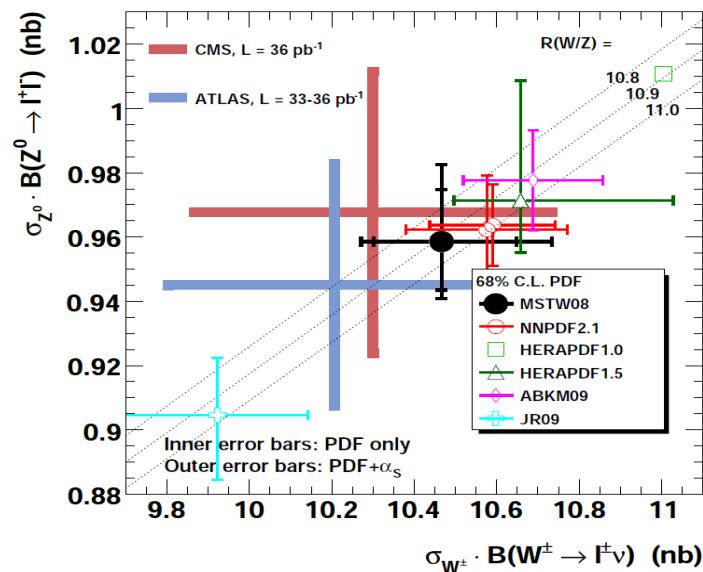


Jonathan Anderson and LHCb

W/Z processes

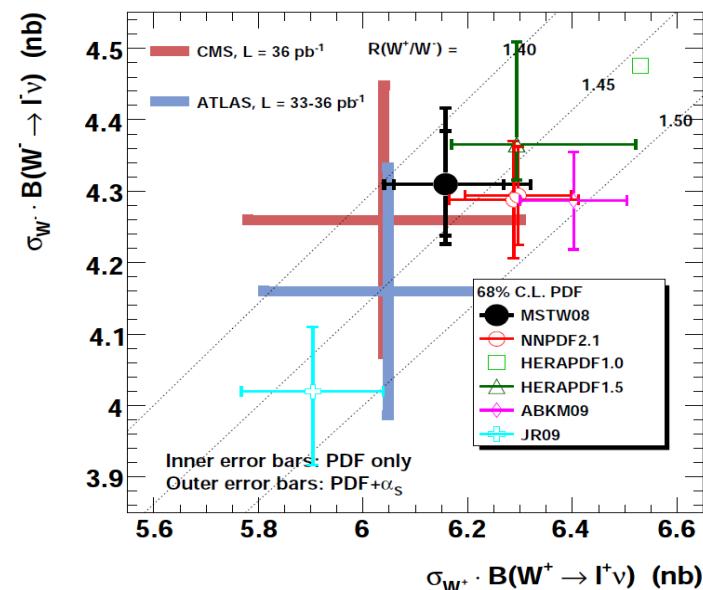
- ◆ Standard candles for detector commissioning, monitoring and performance
 - alignment and calibration (source of “prompt” muons)
 - energy and momentum resolution and scales (Z constraints)
 - lepton efficiency determination (tag-and-probe with Z events)
 - MET studies (W and Z similarities)
 - luminosity monitoring/determination
- ◆ Precise determination/tests of SM parameters/predictions given relatively low theoretical uncertainties
- ◆ Precise determination of the Parton Distribution Functions (PDF) - crucial for understanding physics at hadron colliders
- ◆ Main background for various Higgs and BSM searches

NNLO W and Z cross sections at the LHC ($\sqrt{s} = 7$ TeV)



G. Watt (September 2011)

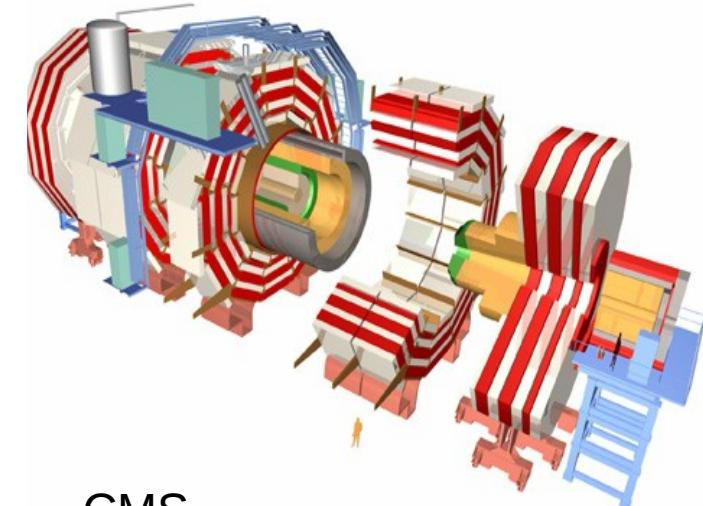
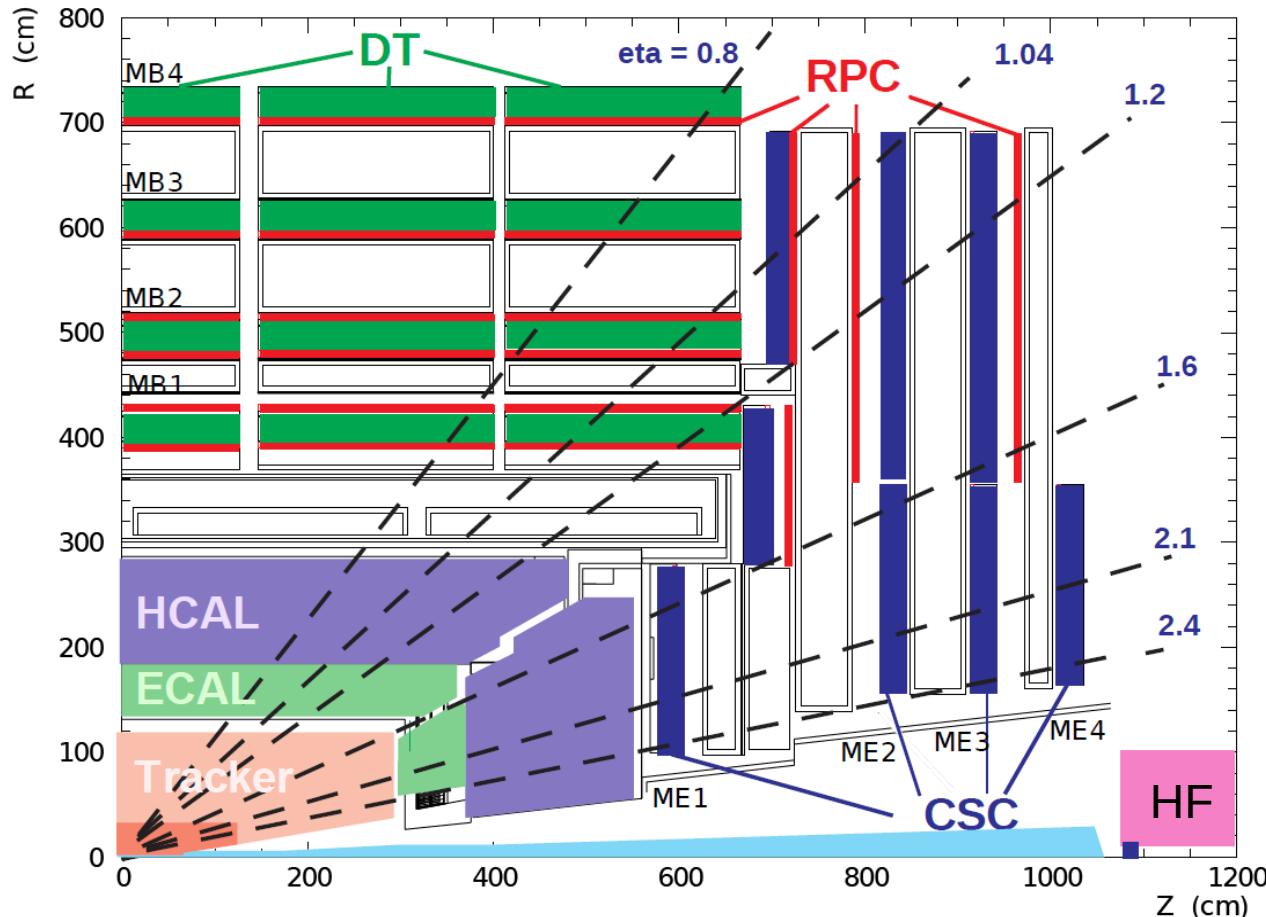
NNLO W^+ and W^- cross sections at the LHC ($\sqrt{s} = 7$ TeV)



G. Watt (September 2011)

FROM : arXiv:1201.1295v1 [hep-ph]

CMS detector reach

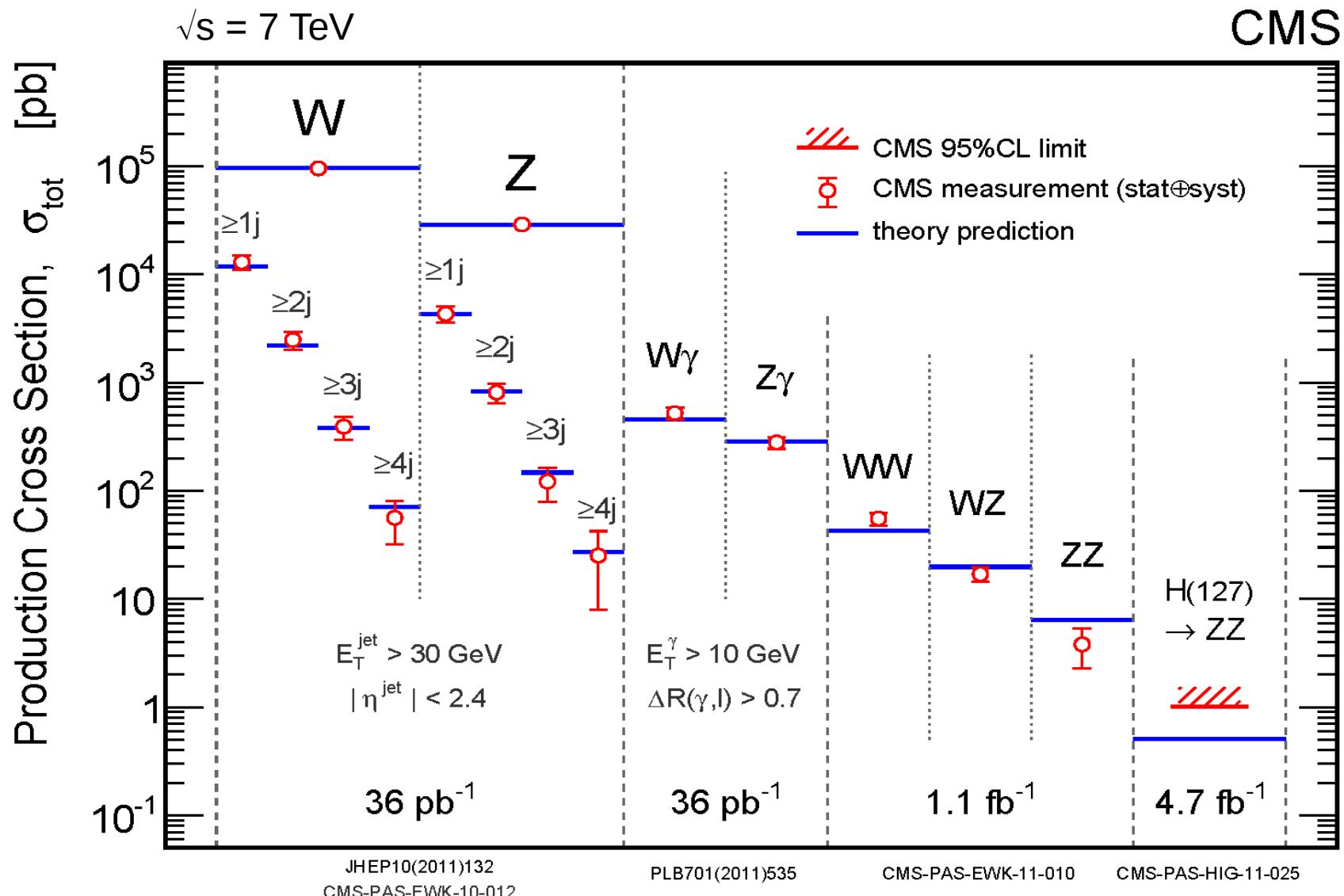


CMS

- ◆ CMS can detect leptons upto 2.4-2.5 in pseudorapidity ($\eta = -\log[\tan(\theta/2)]$) and, effectively, in di-lepton rapidity (Y).
- ◆ CMS has the option to explore the HF calorimeter for electron reconstruction upto 5 in η (lower resolution than ECAL).

EWK cross-section measurements

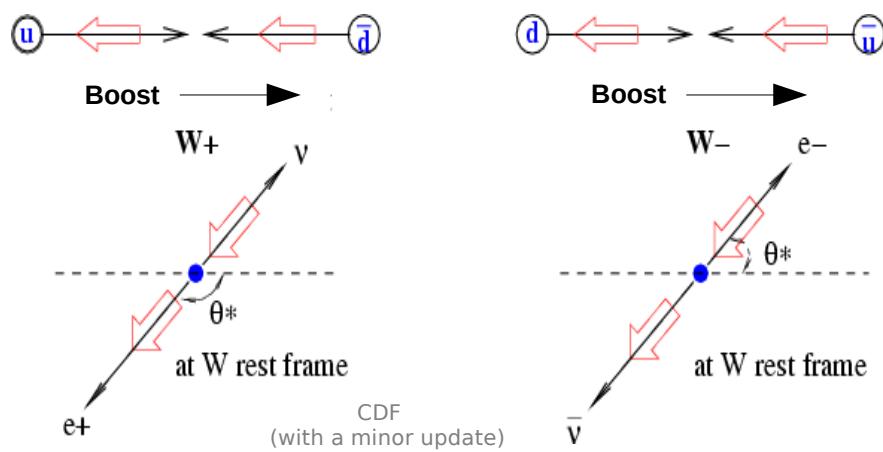
- ◆ CMS follows an extensive program of precision measurements in the EWK sector
- ◆ It is being worked on with the 2012 8 TeV data



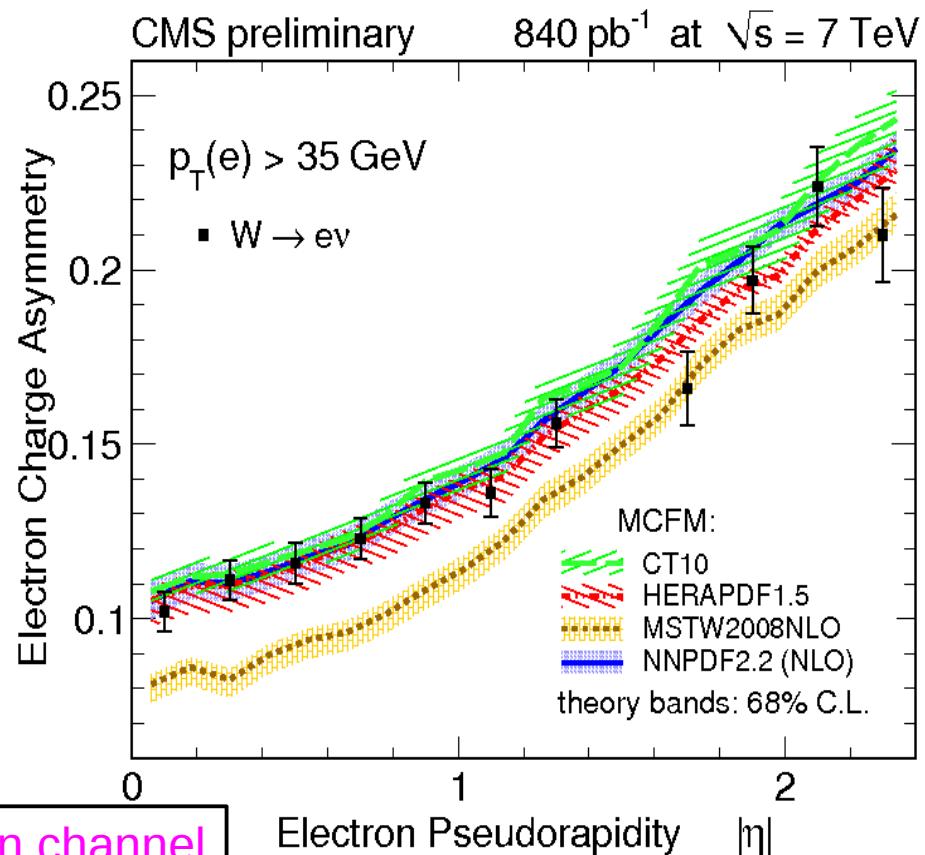
W lepton charge asymmetry

- ◆ An excellent probe on parton distributions in the proton
- ◆ It needs a “single lepton” trigger with relatively low p_T threshold

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



The main uncertainties in the measurement are from signal/background shape variations, energy scale and statistical (including from efficiency sources).

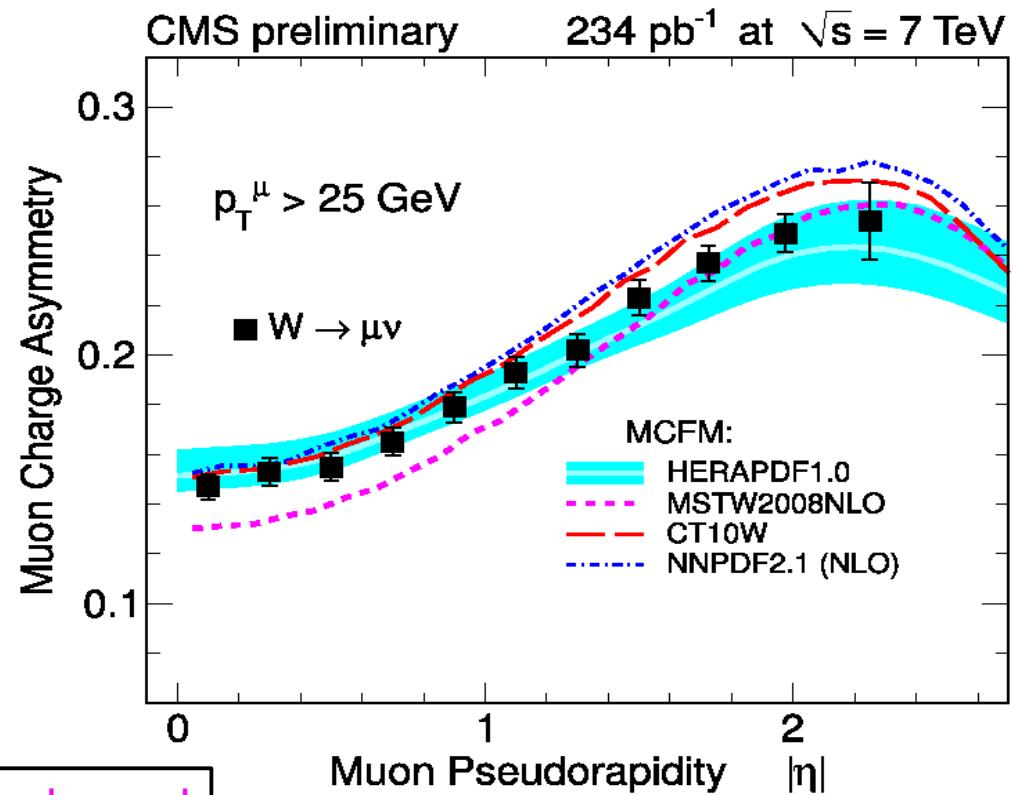
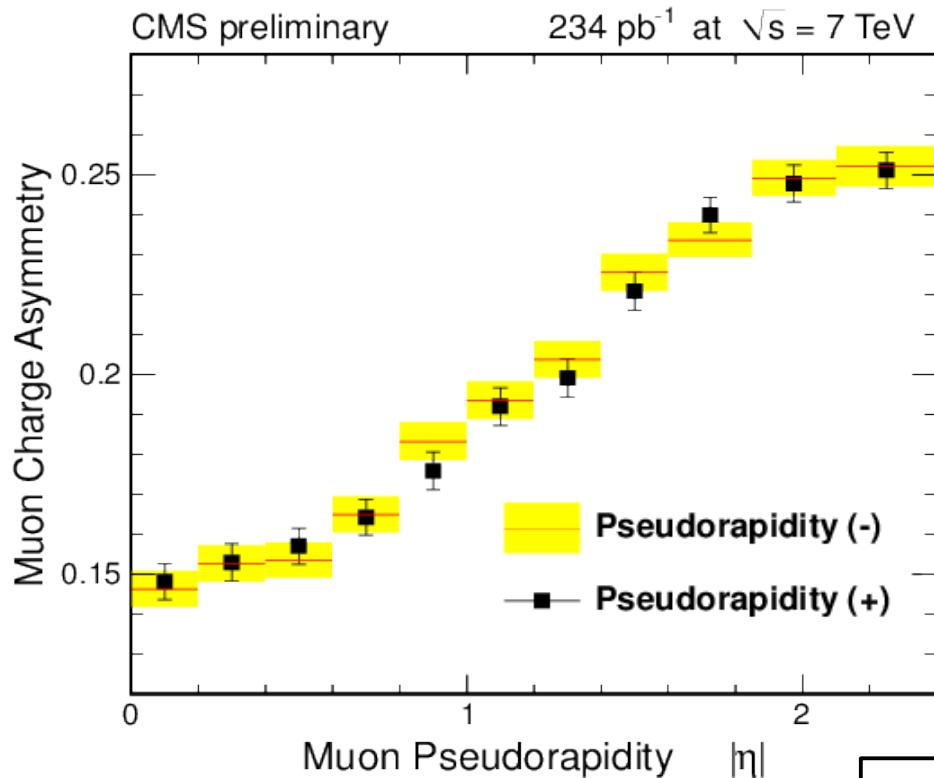


W lepton charge asymmetry (2)

The main uncertainties in the measurement in the muon channel are from signal/background shape variations, momentum scale and statistical (including from efficiency sources).

A paper is in preparation with the full amount of 2011 data in the muon channel.

Studies with 2012 data are conducted in parallel with the paper.



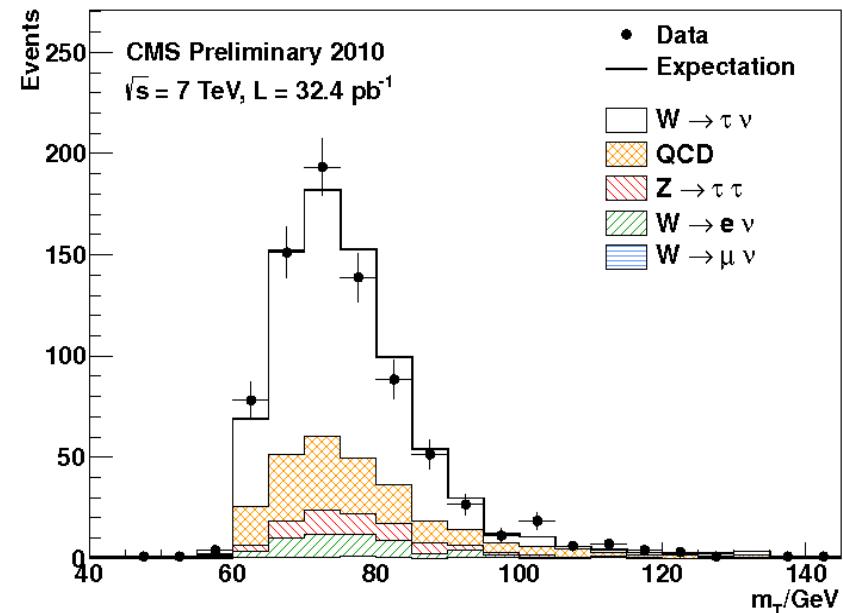
Muon channel

$W \rightarrow \tau \nu$ (inclusive)

- Tau-leptons are important for various searches
- This is a primary reason to investigate W/Z tau decays
- There are significant uncertainties from trigger efficiencies and energy scales (tau ID-ed in its hadronic decay channel)

Channel	$\sigma(pp \rightarrow WX) \times \mathcal{B}$ (nb)	NNLO (nb)
$W \rightarrow \tau \nu$	$8.96 \pm 0.51(\text{stat.})^{+2.32}_{-2.26}(\text{syst.}) \pm 0.36(\text{lumi.})$	10.44 ± 0.52
$W^+ \rightarrow \tau^+ \nu$	$5.26 \pm 0.39(\text{stat.})^{+1.36}_{-1.29}(\text{syst.}) \pm 0.21(\text{lumi.})$	6.15 ± 0.29
$W^- \rightarrow \tau^- \nu$	$3.40 \pm 0.33(\text{stat.})^{+0.92}_{-0.93}(\text{syst.}) \pm 0.14(\text{lumi.})$	4.29 ± 0.23

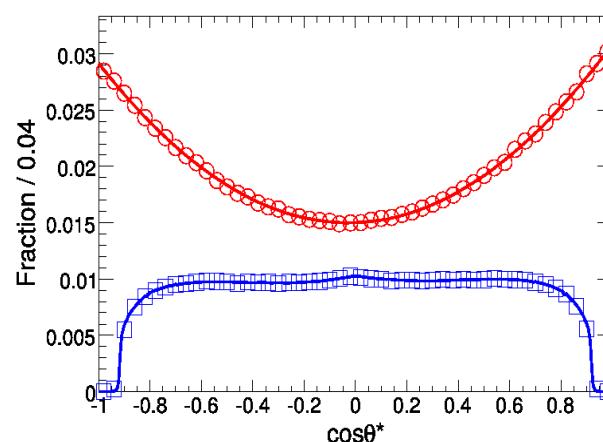
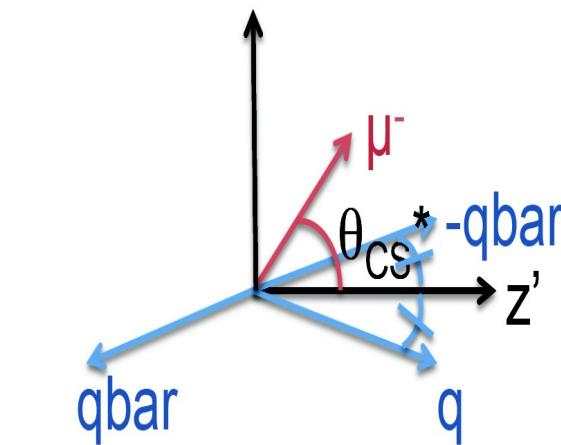
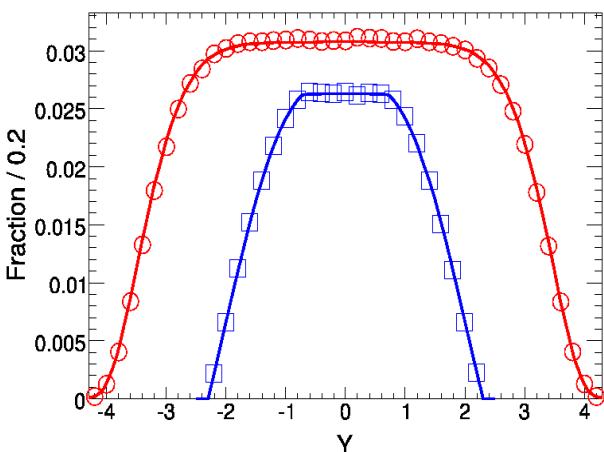
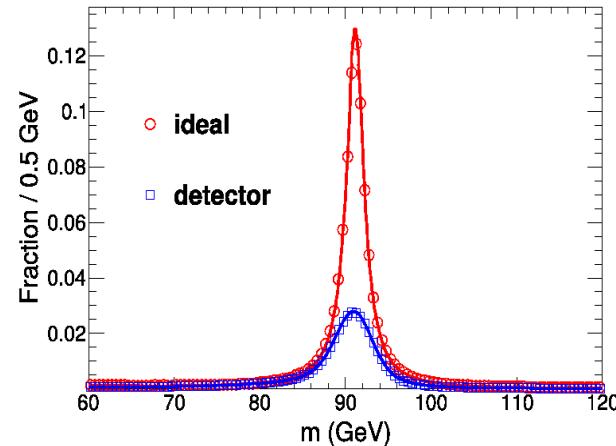
$$R_{+-} = \frac{\sigma(pp \rightarrow WX) \times \mathcal{B}(W^+ \rightarrow \tau^+ \nu)}{\sigma(pp \rightarrow WX) \times \mathcal{B}(W^- \rightarrow \tau^- \nu)} = 1.55 \pm 0.19(\text{stat.})^{+0.11}_{-0.13}(\text{syst.})$$



Measurements are consistent with expectations within the significant experimental errors.

Weak mixing angle $\sin^2\theta_W$

- ◆ The distributions of Z events contain information about the weak mixing angle
- ◆ It is not straightforward to extract it as the detector acceptance changes the observables significantly
- ◆ Still, analyzing the proper data distributions keeps the systematics under control



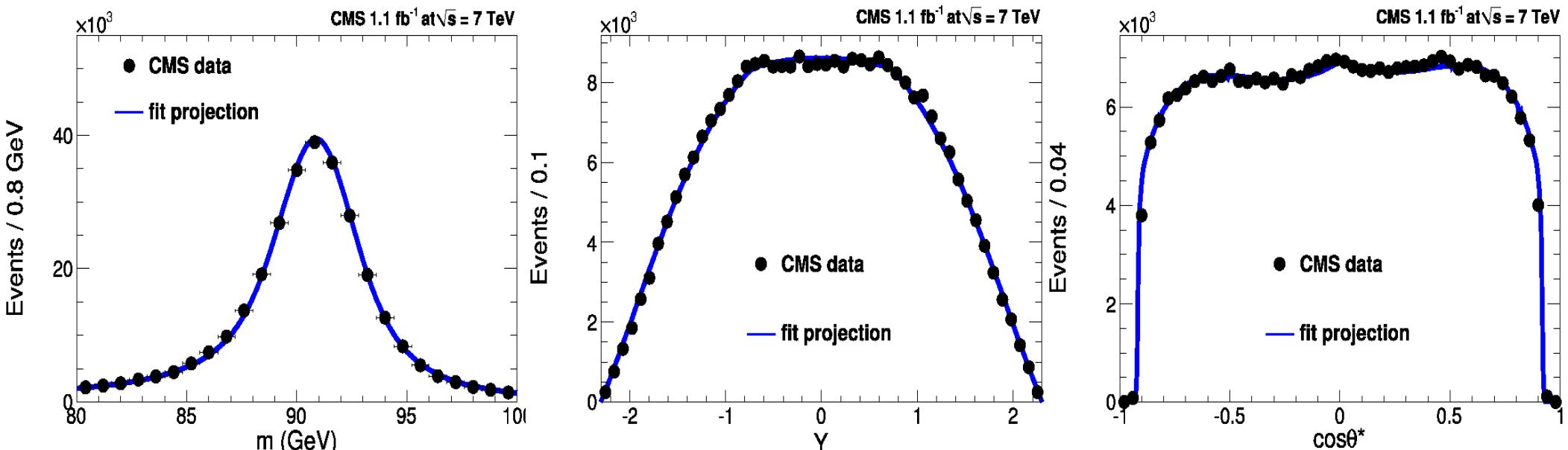
The effects of the detector acceptance are shown on the left vs the analyzed variables.

Weak mixing angle $\sin^2\theta_W$ (2)

- The analysis uses a multivariate technique to extract the weak mixing angle
- It achieves $\sim 1\%$ precision comparable to previous measurements
- Main systematic uncertainties come from PDFs, background (including QED) modeling as well as resolution (alignment) effects

$$\sin^2 \theta_{\text{eff}} = 0.2287 \pm 0.0020 \text{ (stat.)} \pm 0.0025 \text{ (syst.)}$$

Data distributions and projections of the probability density functions from the fit



Drell-Yan (DY) forward backward asymmetry

- The analysis has a common ground with the weak mixing angle analysis
- However it **explores the asymmetry effect cased by the interference** between the amplitudes of the virtual photon and Z
- Depending on the V and V-A couplings the phenomenon is a precision test on SM predictions around the Z peak region
- At higher invariant masses it is potentially sensitive to new physics (mediators)

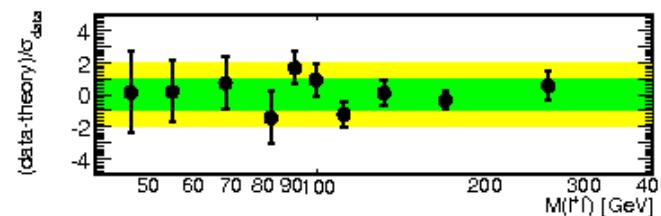
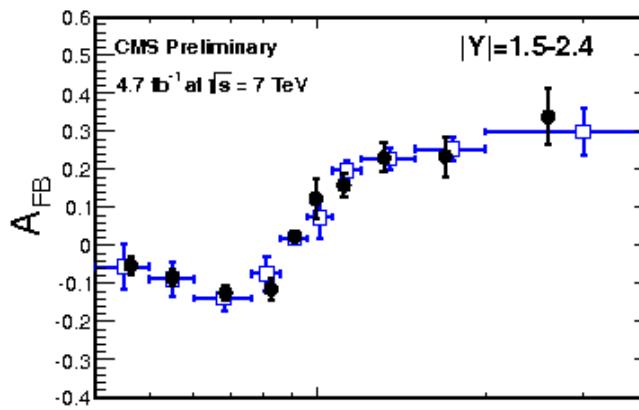
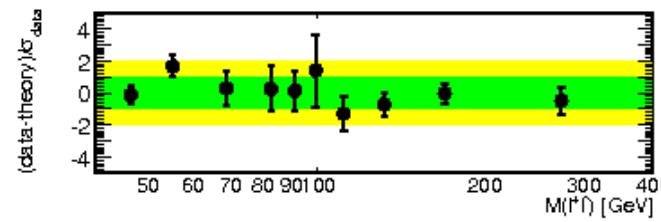
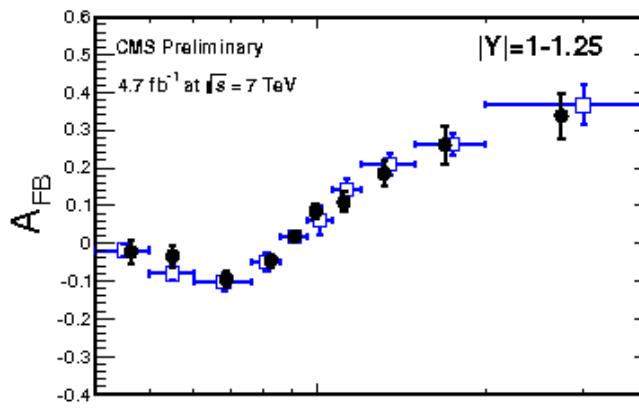
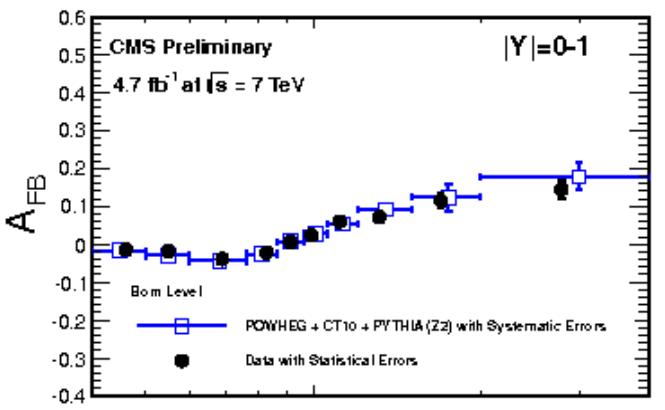
$$\frac{d\sigma}{d(\cos\theta^*)} = A(1 + \cos^2\theta^*) + B\cos\theta^*$$

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \frac{N_F - N_B}{N_F + N_B} = \frac{3B}{8A}$$

$$A_{FB}(M, Y) = \frac{F(M, Y) - B(M, Y)}{F(M, Y) + B(M, Y)} = \frac{N[\cos\theta(M, Y) > 0] - N[\cos\theta(M, Y) < 0]}{N[\cos\theta(M, Y) > 0] + N[\cos\theta(M, Y) < 0]}$$

DY forward-backward asymmetry (2)

Born level



These are the combined results from both lepton channels in the CMS acceptance region.

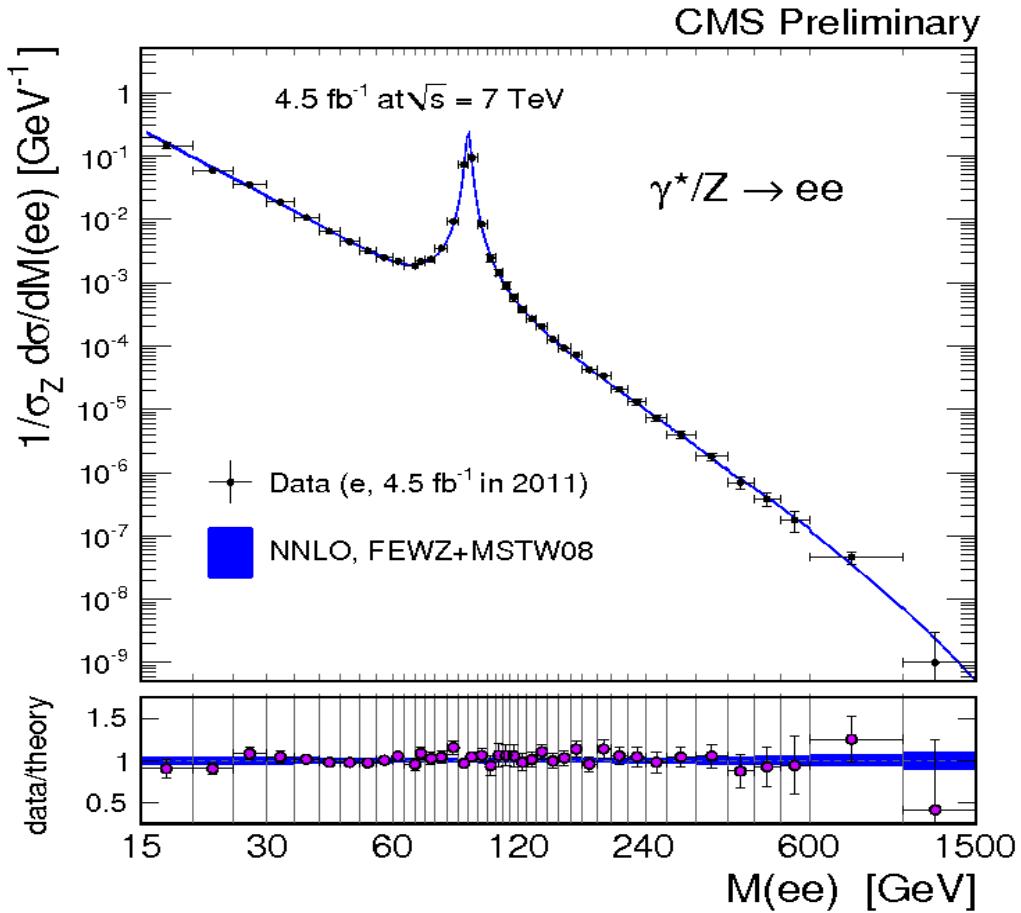
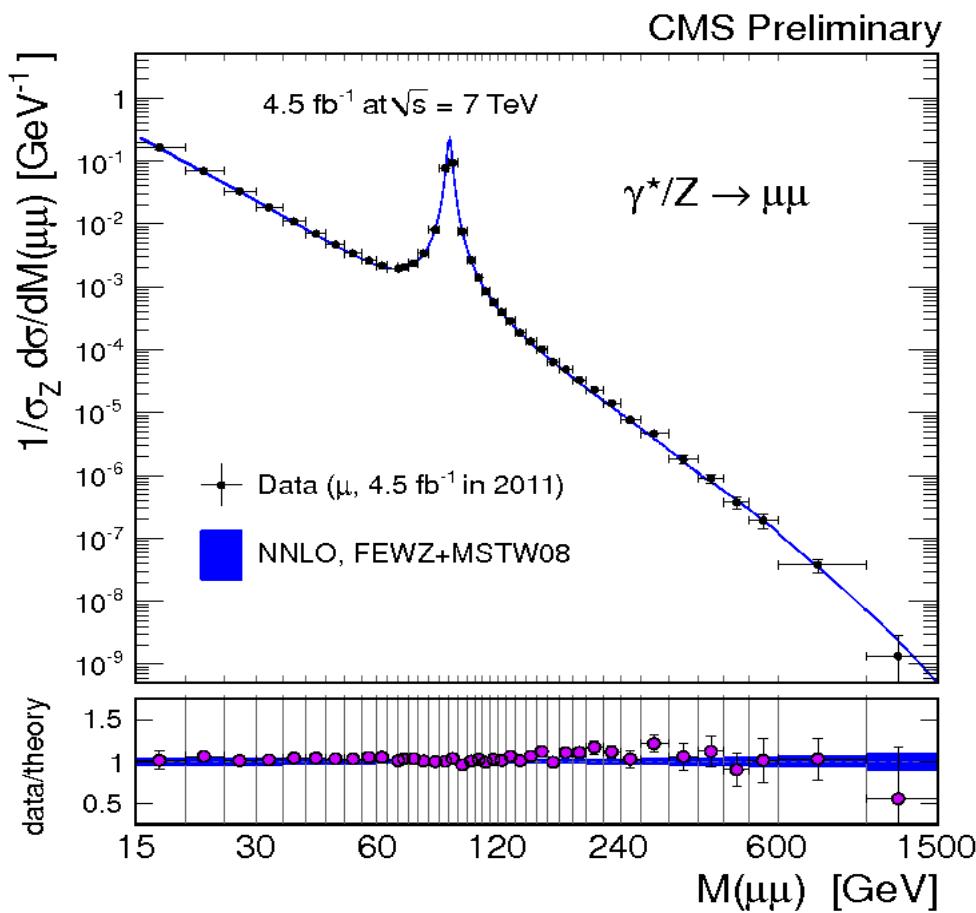
There are experimental reasons the rapidity ranges to be large.

The measurements are in agreement with expectations.

The paper is being finalized.

DY differential cross-section measurement

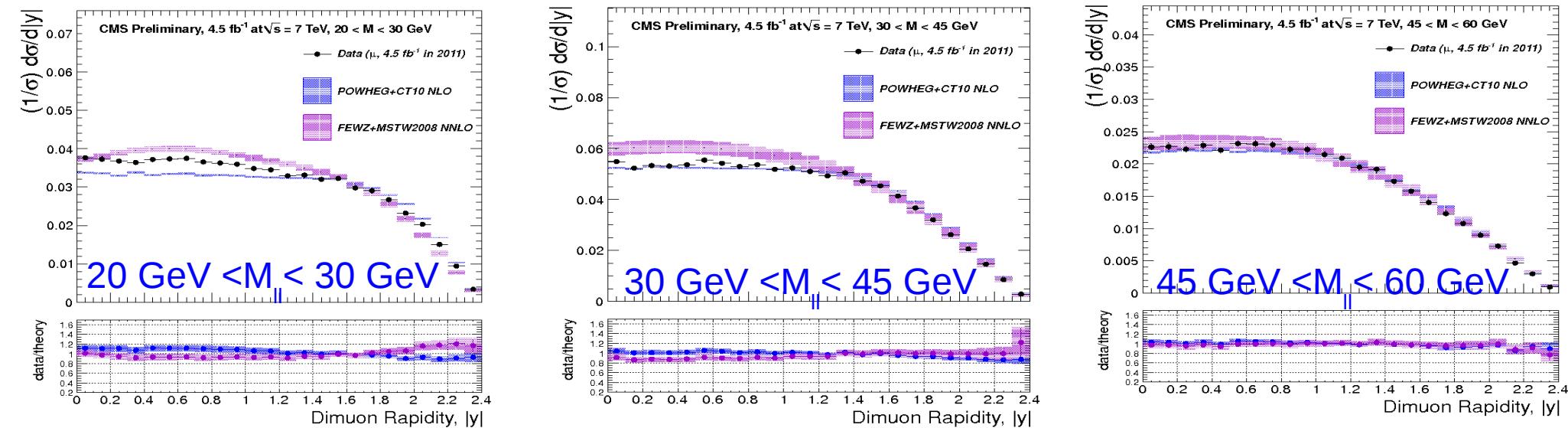
- Performed in **40 invariant mass bins** starting from 15 GeV and **normalized to the Z peak**
- It is given in the full phase space but will be available in the acceptance region as well



The data distribution is well described by NNLO (some fluctuations are under scrutiny). At low invariant masses there is a difficult to control “modeling” uncertainty, at high invariant masses - the statistics plays a major role.

DY double differential cross-section measurement

- Performed in **24 rapidity bins between 0 and 2.4** (12 Y-bins for the highest mass bin) and **6 mass ranges: (20-30), (30,45), (45,60), (60,120), (120, 200), (200,1500) GeV**
- It is in the CMS acceptance region and for muons only yet, **normalized to the Z peak**



There is expected sensitivity to the order of calculations and modeling at lowest masses but we also see it upto 40 GeV.

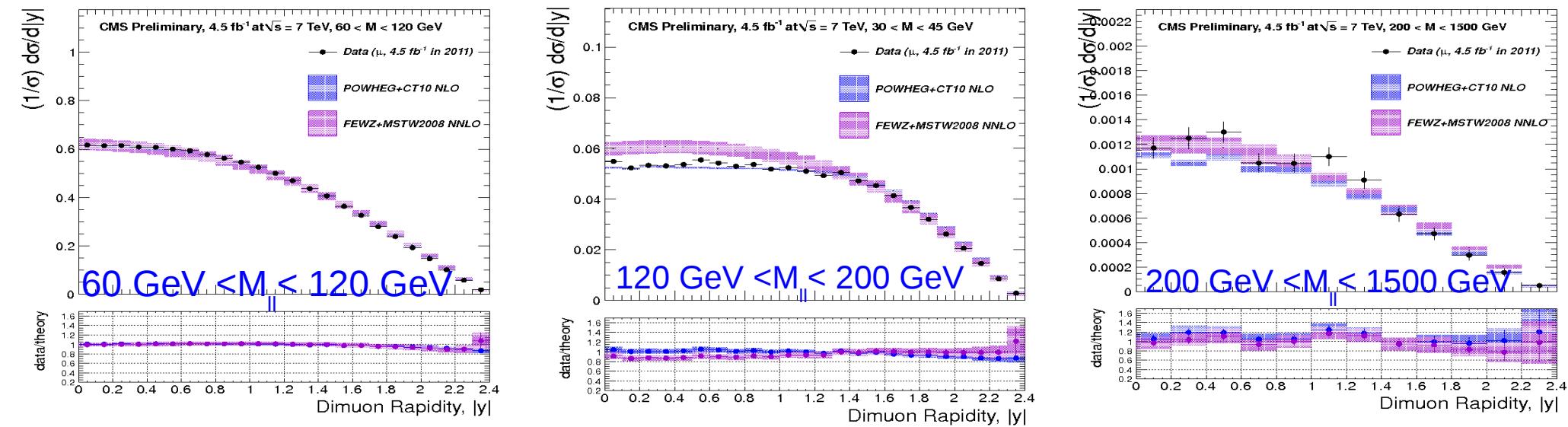
When the analysis is finalized, data is clearly to disfavor models**.

* CMS-PAS-EWK-11-007;

** Assuming no New Physics, this is a separate important topic.

DY double differential cross-section measurement

- Currently we only compare to MSTW2008NNLO and POWHEG(CT10)+Pythia MC.
- No extensive theoretical uncertainties are yet available
(we expect them to be smaller than the PDF uncertainties though).



Moving away from the Z peak we gain discrimination power again.

The full covariance matrix is to be included in the paper being finalized. Studies in the electron channel are also being finalized and are part of the paper in preparation. At this point we can test the influence of different parts of the data on global PDF fits – for now no correlations are discussed.

Planned analyses in 2012

- ◆ W/Z inclusive cross-section
- ◆ W charge asymmetry
- ◆ W transverse momentum cross-sections
- ◆ Z transverse momentum cross-sections
- ◆ Weak mixing angle
- ◆ Forward-backward asymmetry
- ◆ Drell-Yan differential cross-sections
- ◆ Angular coefficients of the Drell-Yan process

8 vs 7 TeV (2012 vs 2011)

- ◆ One of the first EWK analysis with 8 TeV is to be the W/Z cross-section measurement
 - **special low luminosity runs** with special triggers (close to 2010 data) $\sim 20 \text{ pb}^{-1}$
 - expected precision of the order of the one achieved in the previous CMS measurement
 - target: ICHEP
- ◆ Some of the analyses will explicitly aim at 8 vs 7 TeV comparisons
- ◆ Data analyses of 2012 data are expected to deal with some complications:

(unprescaled triggers in “regular” data)					
<----- Trigger thresholds ----->					
<u>Energy</u>	<u>Interactions pbc*</u>	<u>Single mu</u>	<u>Single e</u>	<u>Double mu</u>	<u>Double e</u>
8 TeV	15-30	ISO:24 GeV 40 GeV (eta <2.1, 2.4)	27/32 GeV (lower efficiency)	17, 8 GeV 22, 8 GeV 22, 22 GeV	27, 15 GeV
7 TeV	5-10	ISO: 17/24 GeV 30/40 GeV	27/32 GeV (early data)	6, 6 GeV 13, 8 GeV 17, 8 GeV	17, 8 GeV

*pbc- per beam (bunch) crossing

... or prescaled triggers with lower thresholds

LHC EWK physics result combinations

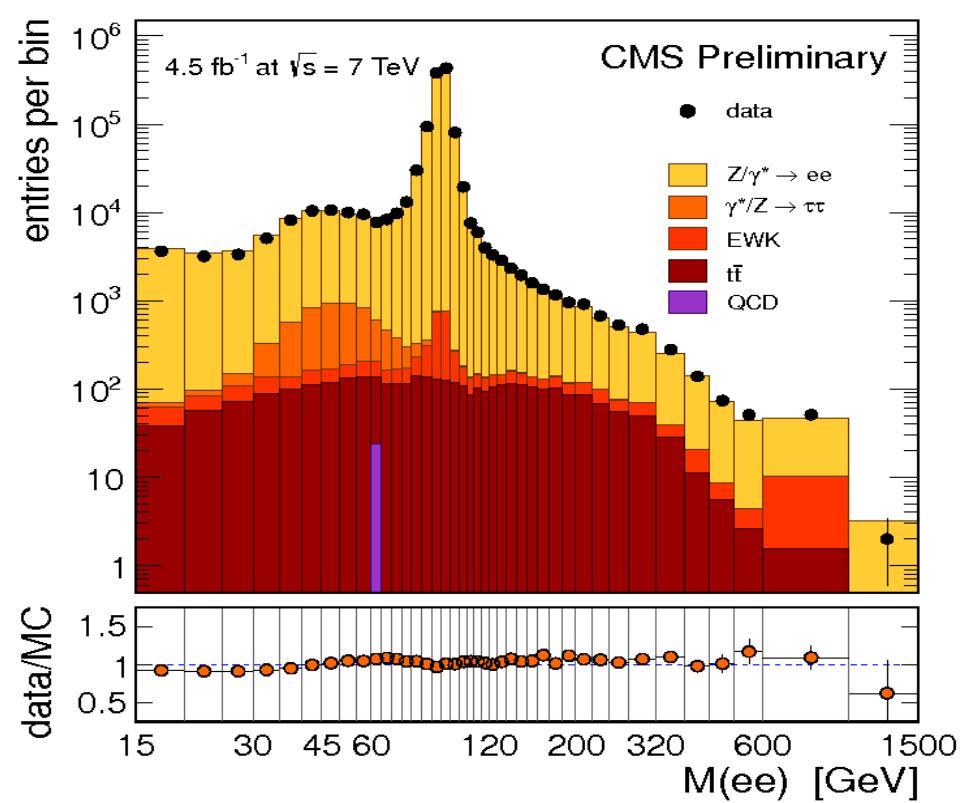
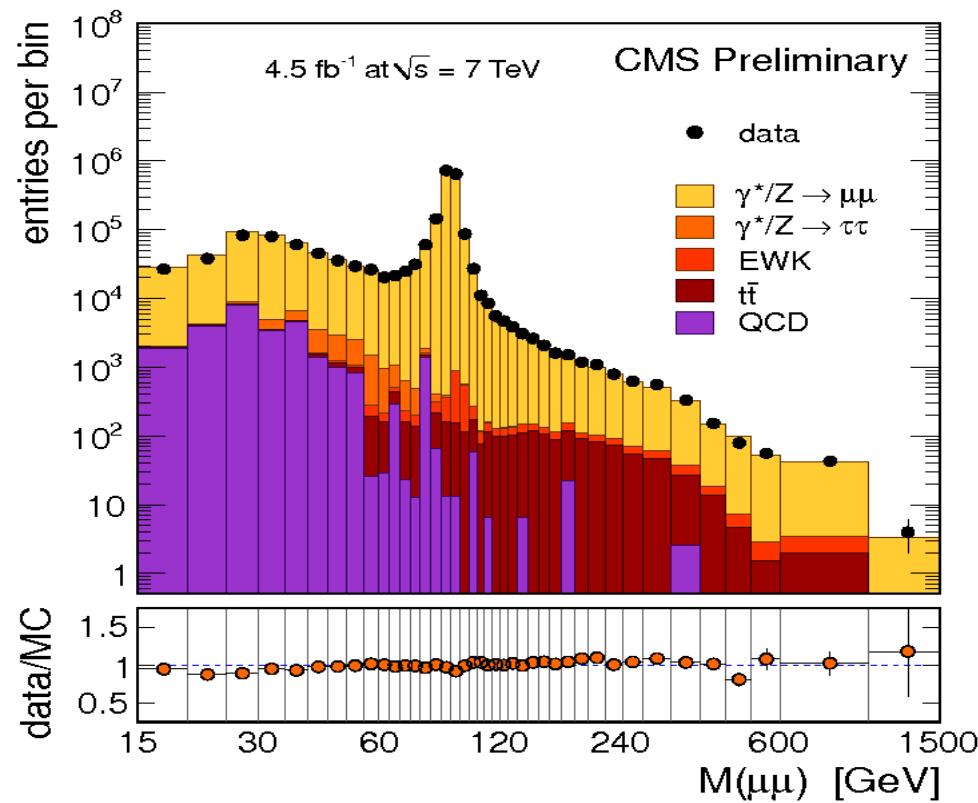
- ◆ Not all results obtained by the different collaborations are suitable for a combination
 - when different kinematic cuts or fiducial volumes
 - different normalizations
 - multi-dimensional distributions
- ◆ “Single number” precision results are **good candidates for combinations**
 - **weak mixing angle**
 - **W and Z cross-sections and ratios** (including 8 vs 7 TeV)
- ◆ Special results giving new insights at high energies are also good candidates
 - **associated production**, especially ratios ($V+q$)
 - **1D dependencies with significant constraining power** (lepton charge asymmetry)
 - proton parton composition dedicated analyses (**special PDF studies**)
- ◆ More “elaborate” results will be anyway used in global fits
 - DY multi-dimensional analyses/fits
 - **HOWEVER**, it is good to consider in advance **what additional information may be needed for combining results from different experiments**
 - this information is anyway needed in the global fits (PDG, PDF, etc.)

Summary

- ◆ SM analyses being currently performed on lepton and di-lepton spectra yield precision of the order of one per cent and are mostly limited by systematics
- ◆ PDFs are either a main limitation or measurements are directly probing the PDFs
- ◆ Some analyses are performed in the detector acceptance alone
- ◆ When applicable complimentary “lepton definitions” are used
- ◆ Most of the analyses are being repeated with 8 TeV data (part of them with special runs)
- ◆ It is proper time to negotiate common criteria between LHC experiments though we should also maintain consistence with the already public analyses (papers)
- ◆ We should probably avoid trying to produce common LHC results in every single analysis case but there are very obvious cases where such results are extremely helpful

Spare

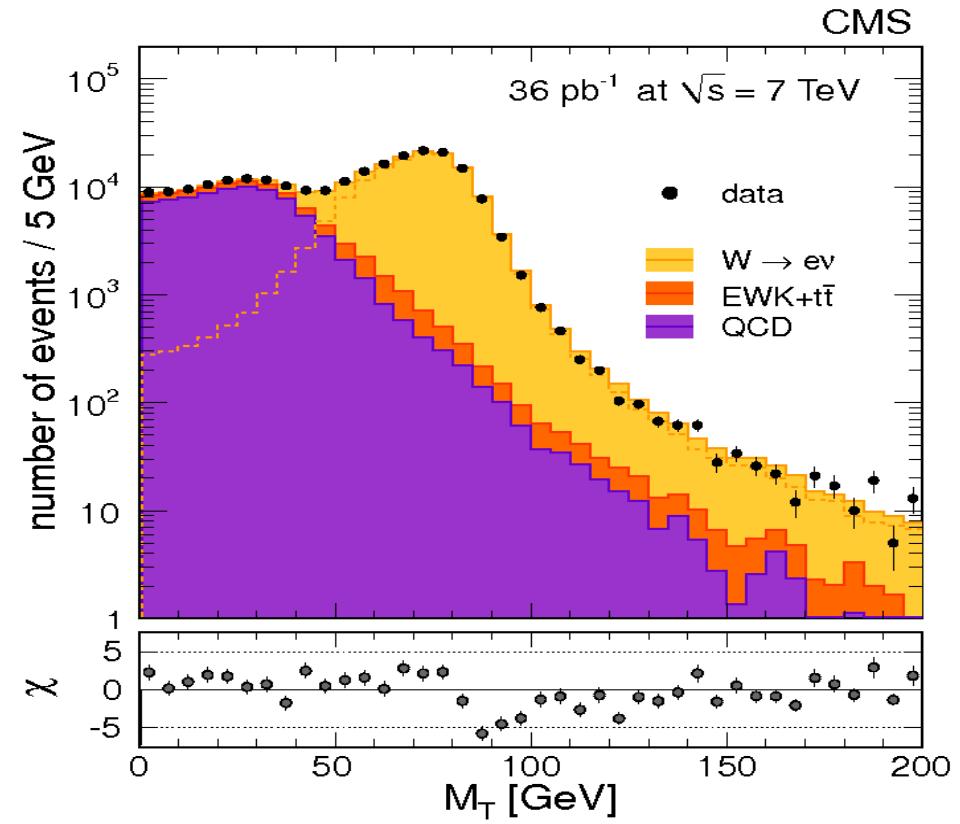
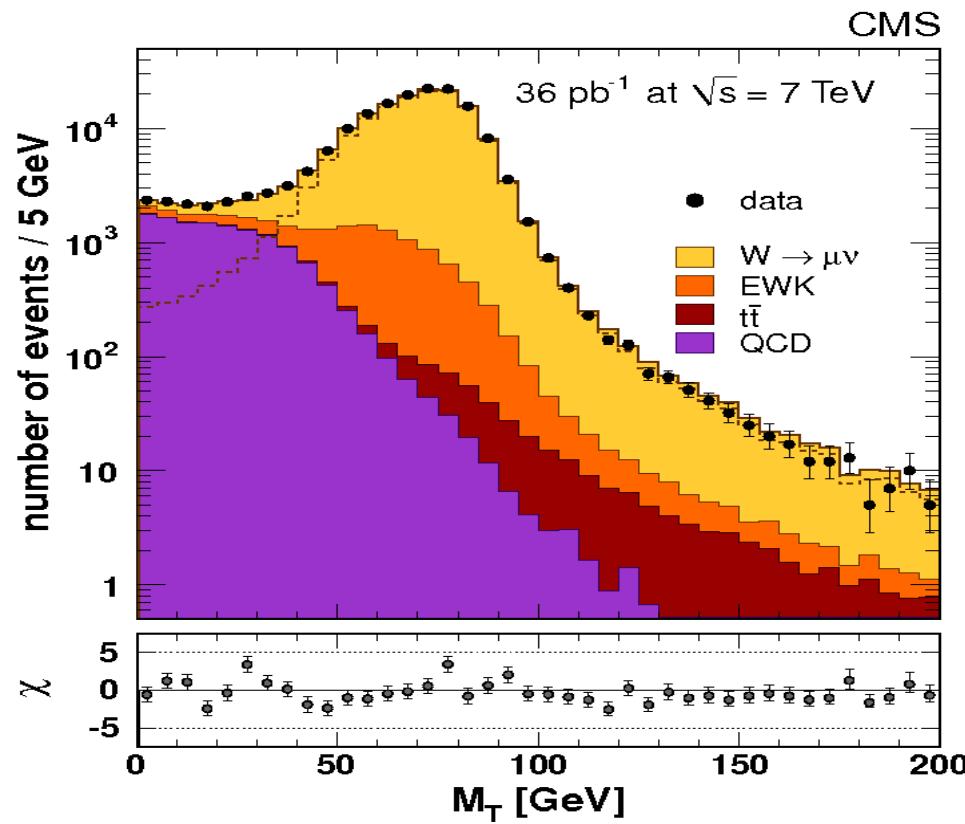
DY analysis



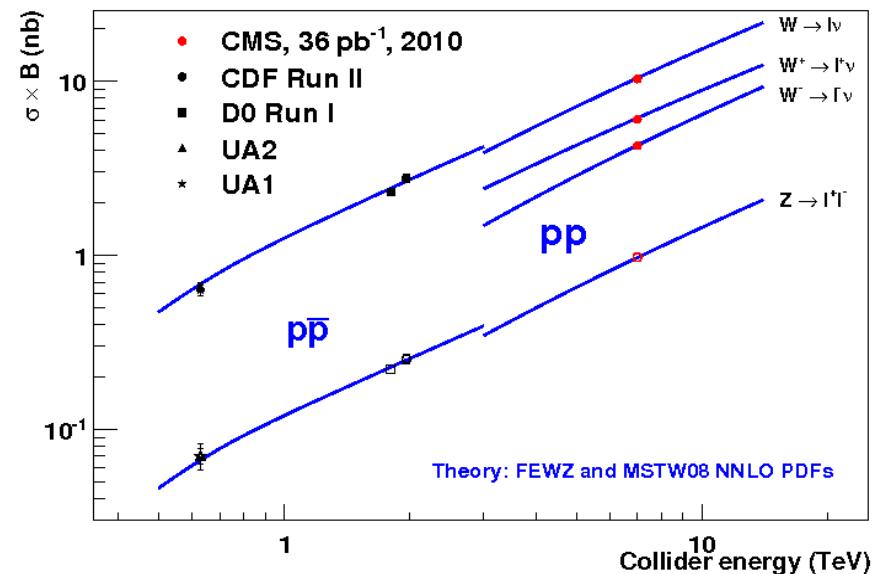
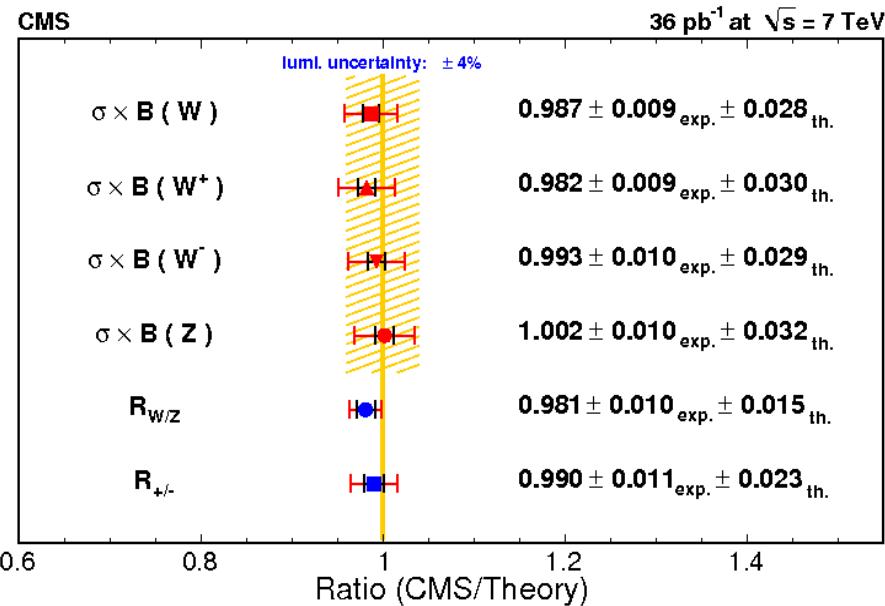
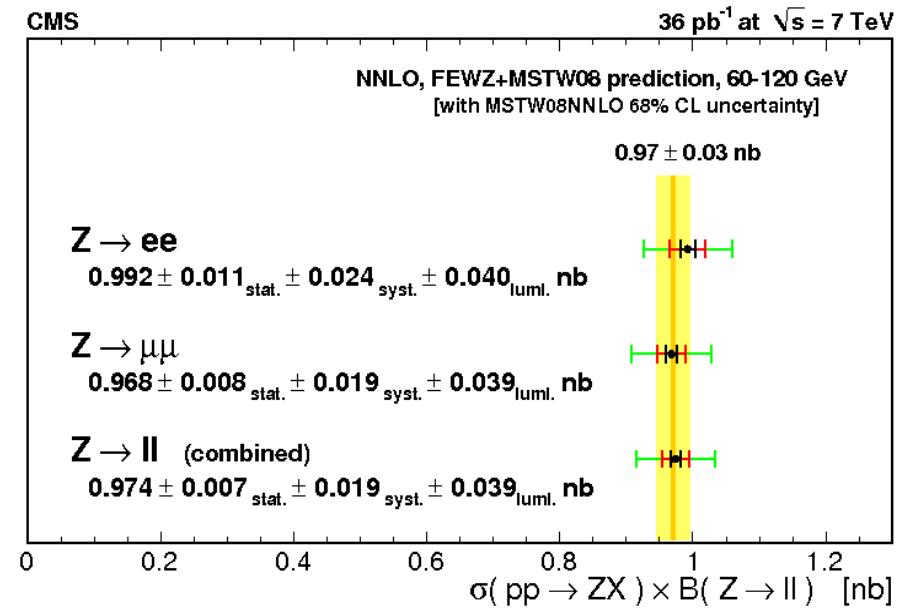
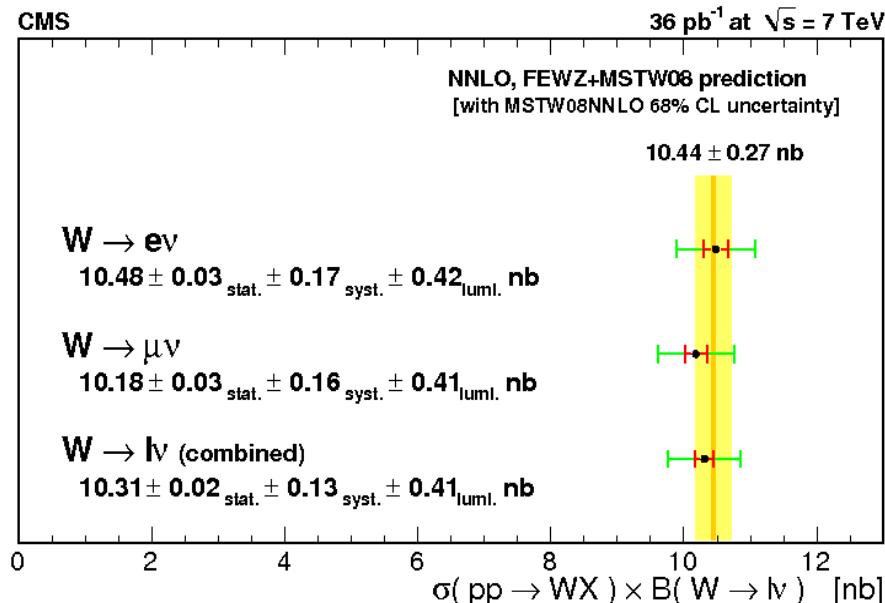
The electron yields are “cleaner” for the price of lower efficiency.

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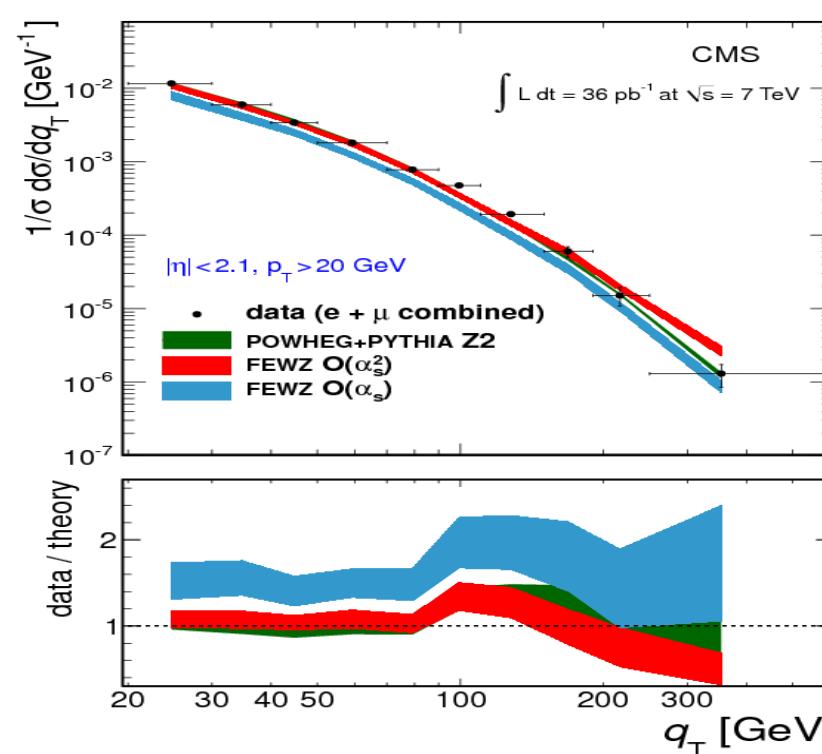
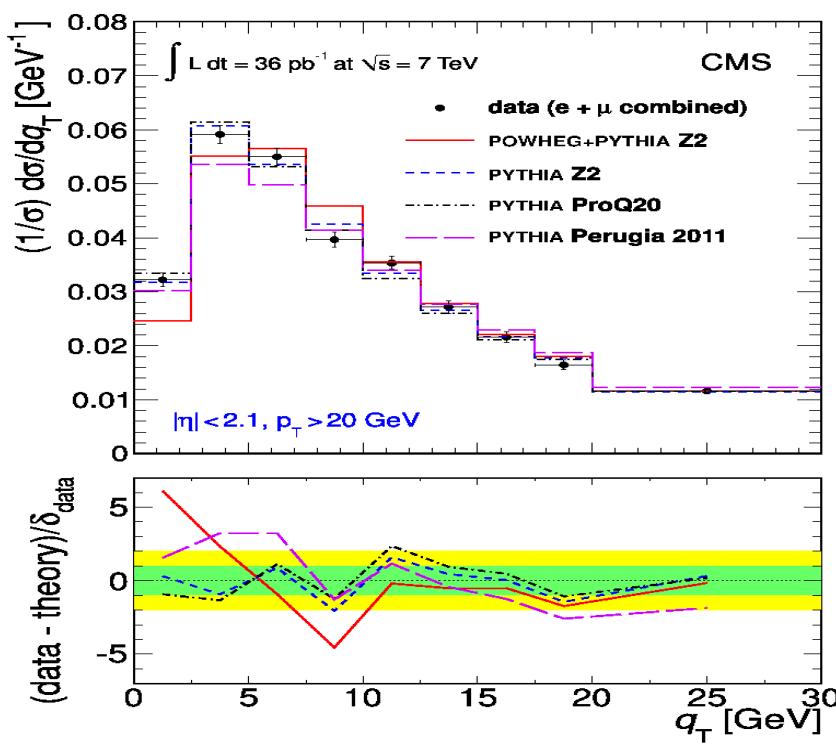
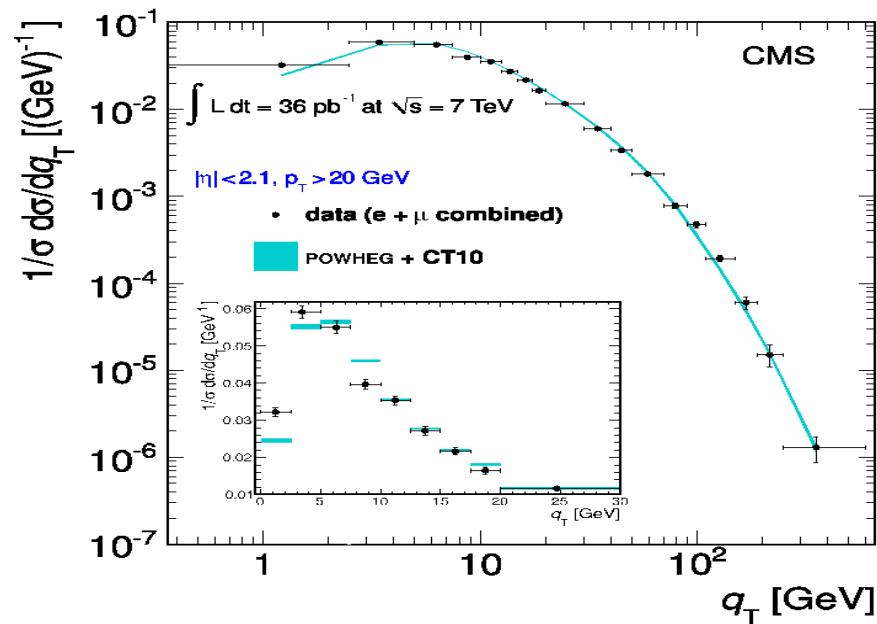
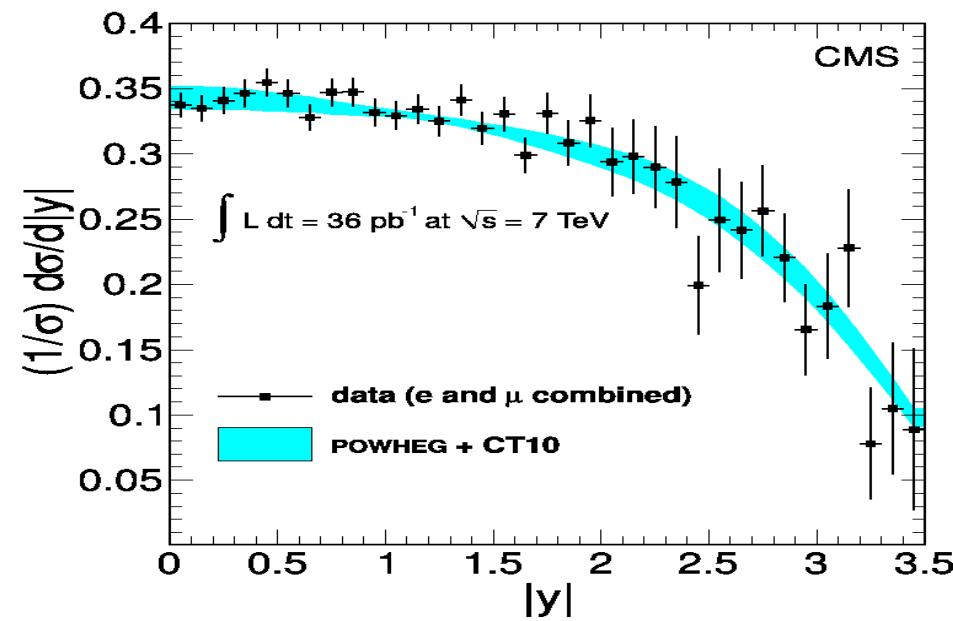
W analysis



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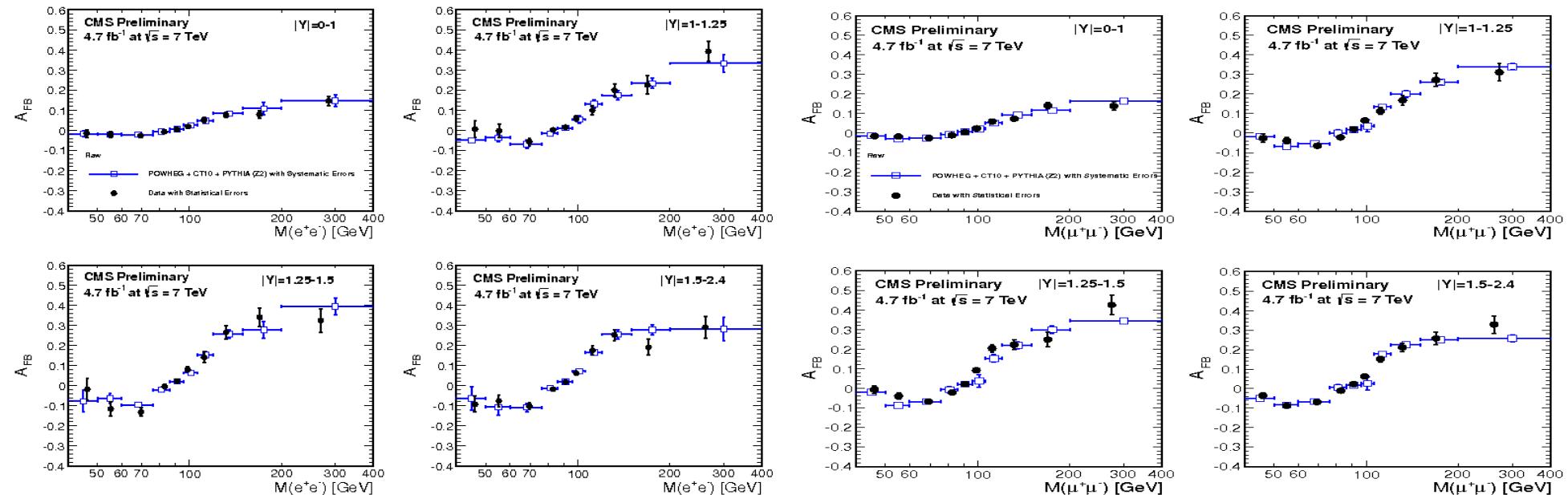


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"Raw" AFB measurement



For complete W/Z results see:

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP#Vector_Boson_Production