

PDF-sensitive measurements

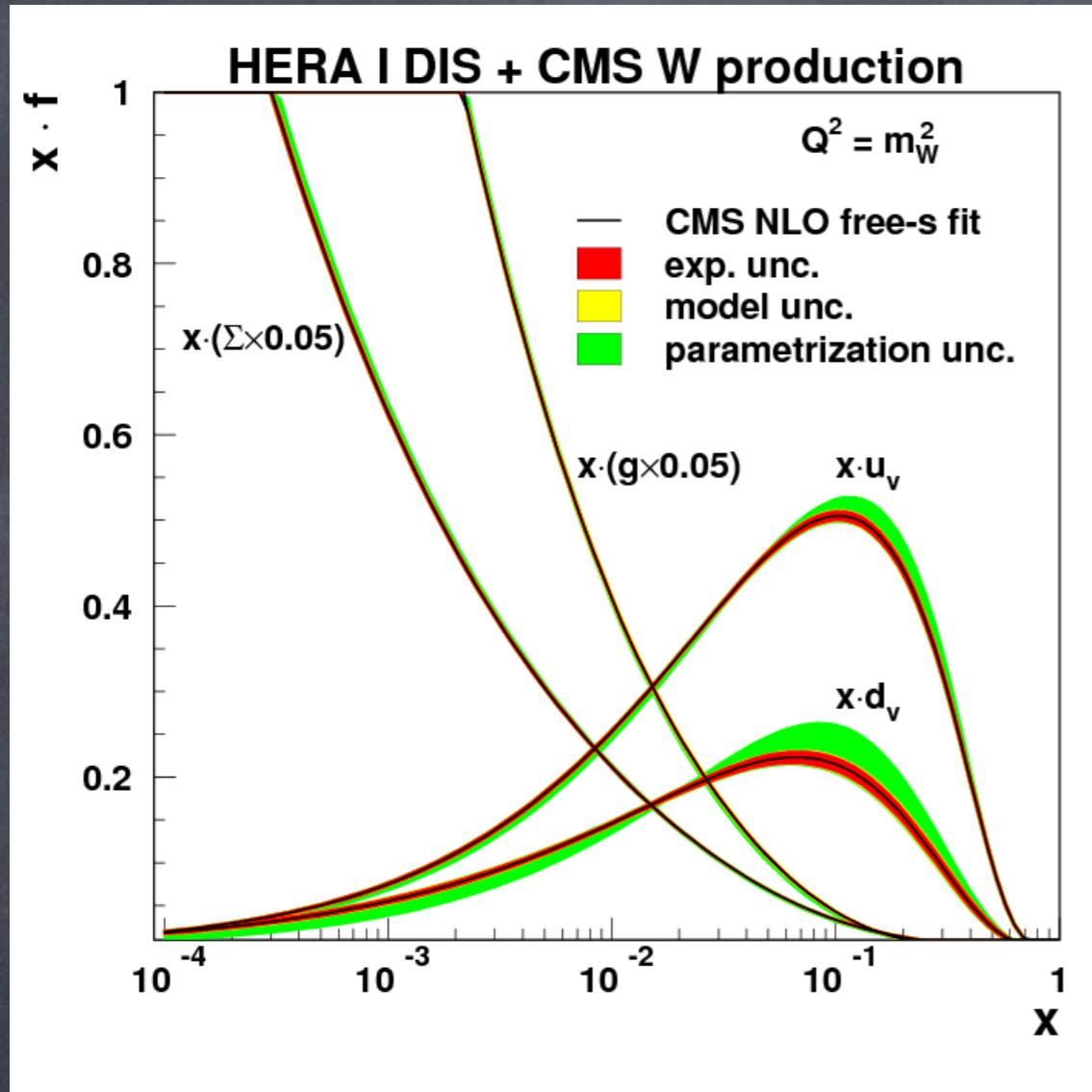
in Run I at CMS

...and some future plans

Benasque PDF workshop 15-21/02/2014

M. Gouzevitch, K. Lipka on behalf of CMS

General overview of the Run I results



The classification is approximative : only dominant sensitivity is indicated

Links to analyses and HEPDATA
 availables at

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP>
<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP>

1) Valence quarks + light sea :

- V measurements : $x < 0.1$
 - W asymmetry = $f(p_{T,W}, y_W)$
 - DY = $f(y_{V^*/Z}, p_{T,V^*/Z})$
- Jet measurements at high p_T : $x > 0.1$

W/Z + jets ?

2) Sea quarks :

- c/b and heavy quark schemes:
 - W + c = $f(y_c)$
 - Z + b = $f(y_b), f(p_{T,b}), f(p_{T,Z})$

3) Gluon :

- Inclusive jets = $f(p_T, y)$
- V = $f(p_{T,V}, y_V)$
- Ttbar production
- γ + jets

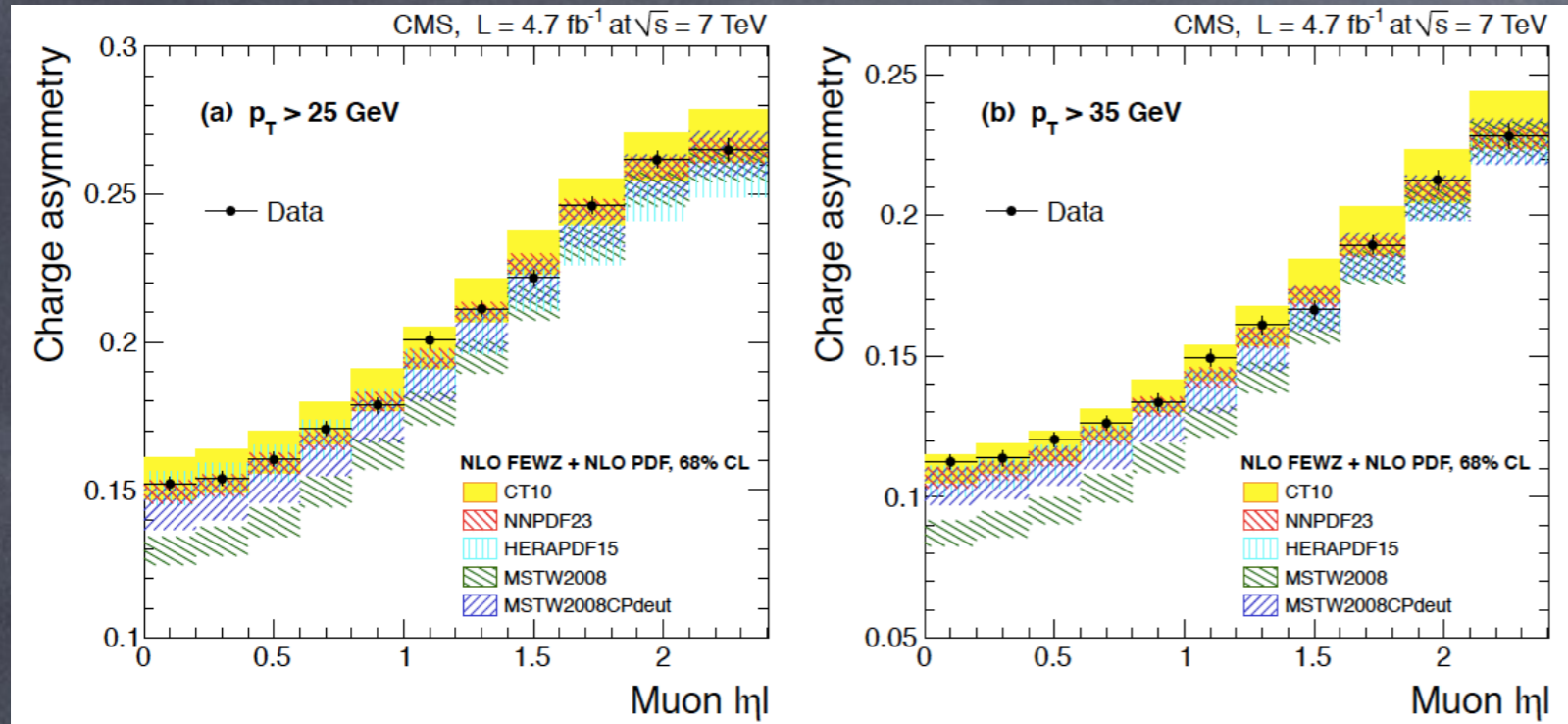
4) α_s :

- Jets
- Ttbar

5) Where CMS data are already used

1.1) Valence and light sea : W asymmetry

Phys. Rev. Lett. 109 (2012) 111806



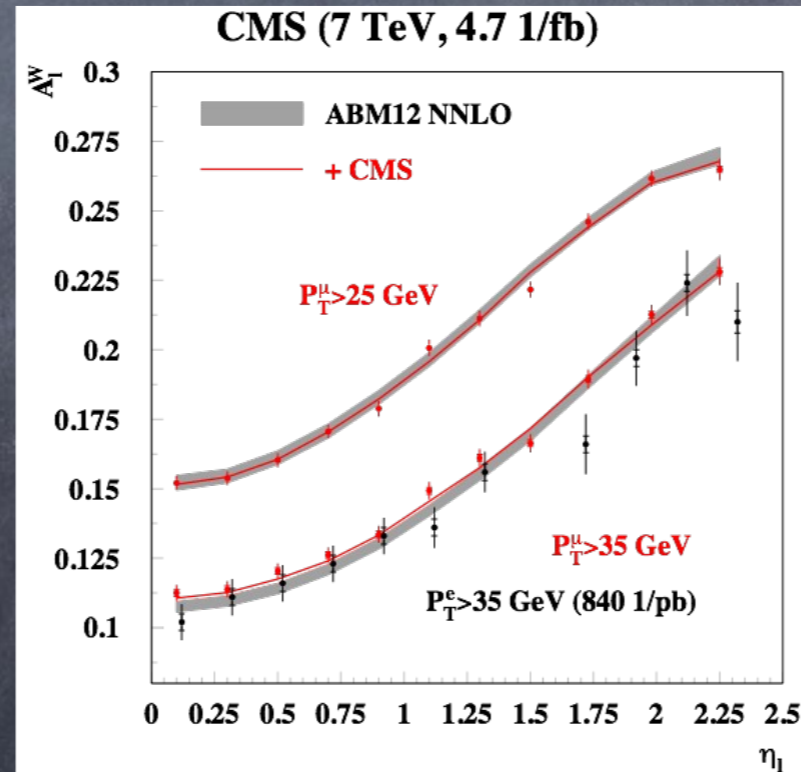
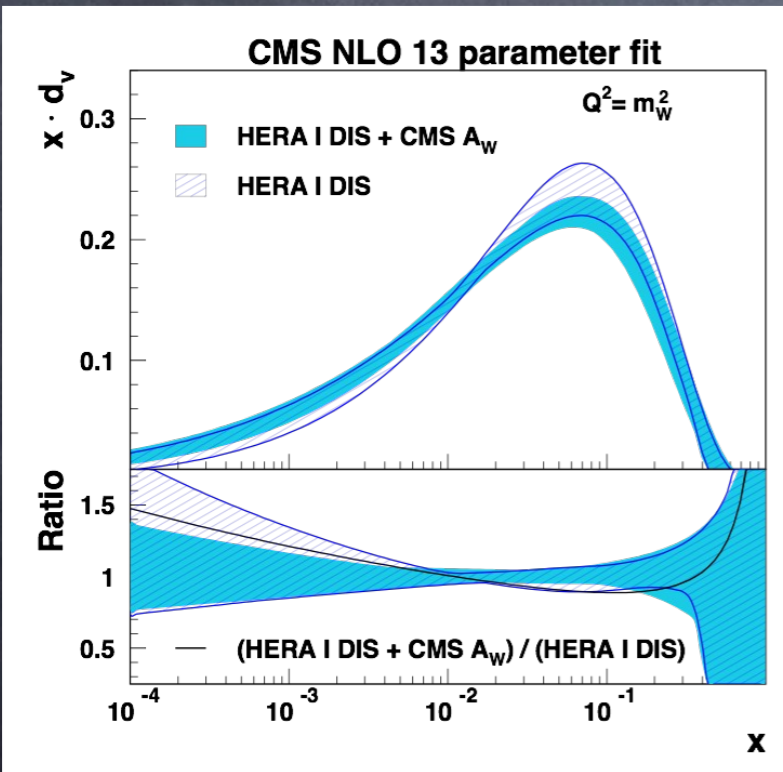
1) Electron **7 TeV, 1 fb⁻¹**

SMP-12-001 – HEPDATA

2) Muon **7 TeV, 5 fb⁻¹**

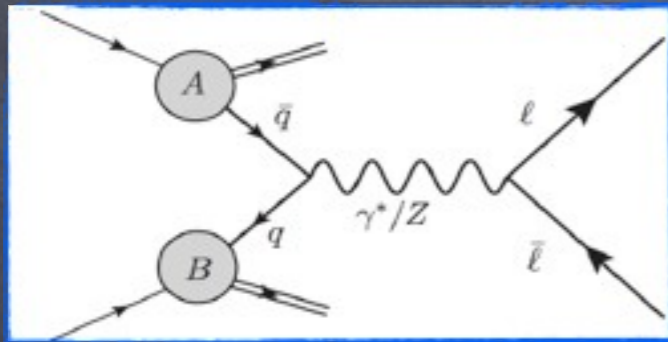
SMP-12-021 – HEPDATA

Included in PDF fits by CMS, ABM, NNPDF at NLO and NNLO



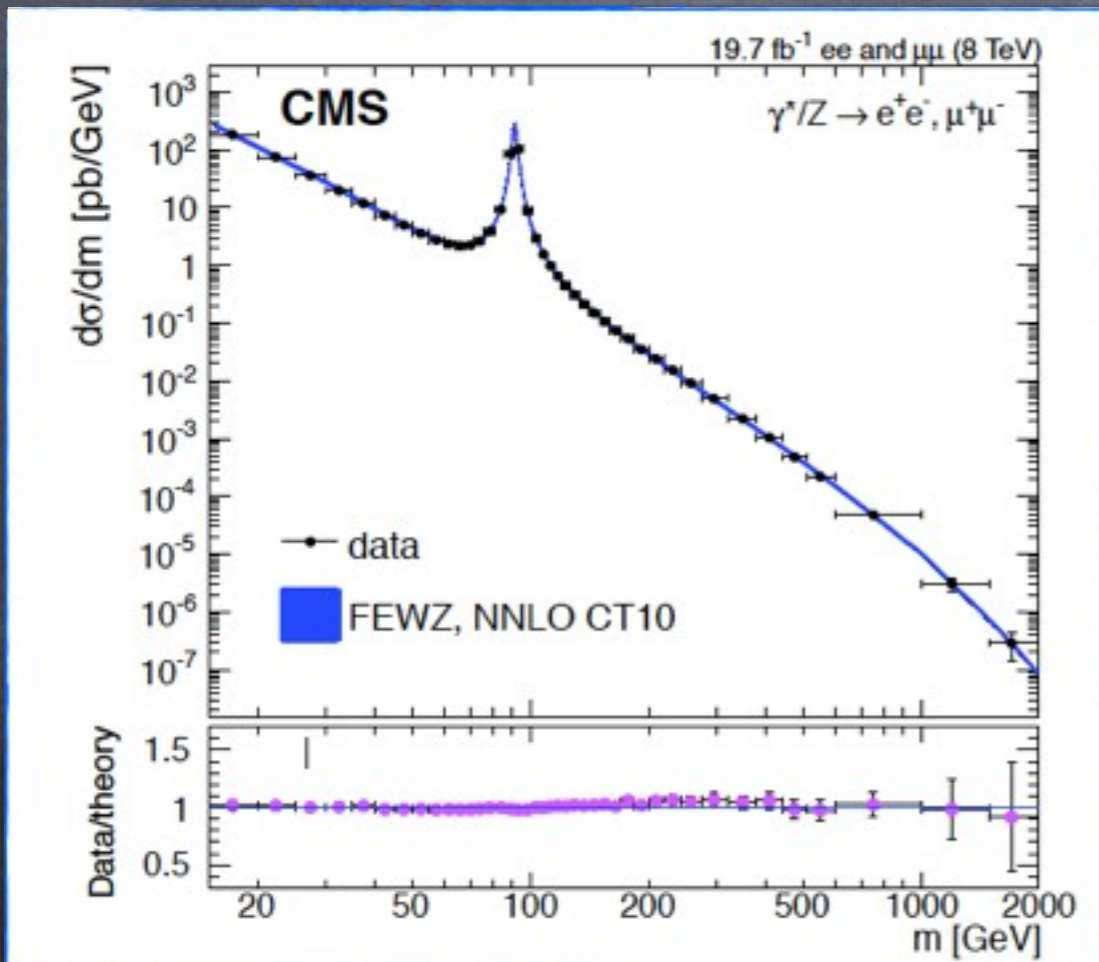
8 TeV measurement ongoing covariance matrix will be published in a similar form

1.2) Valence and light sea : neutral Drell-Yan



probe light quark distributions: u, d, s
 expect constraints at $0.001 < x < 0.3$

SMP-14-003, arXiv:1412.1115



1)

7 TeV, 5 fb⁻¹

SMP-13-003 – HEPDATA

2)

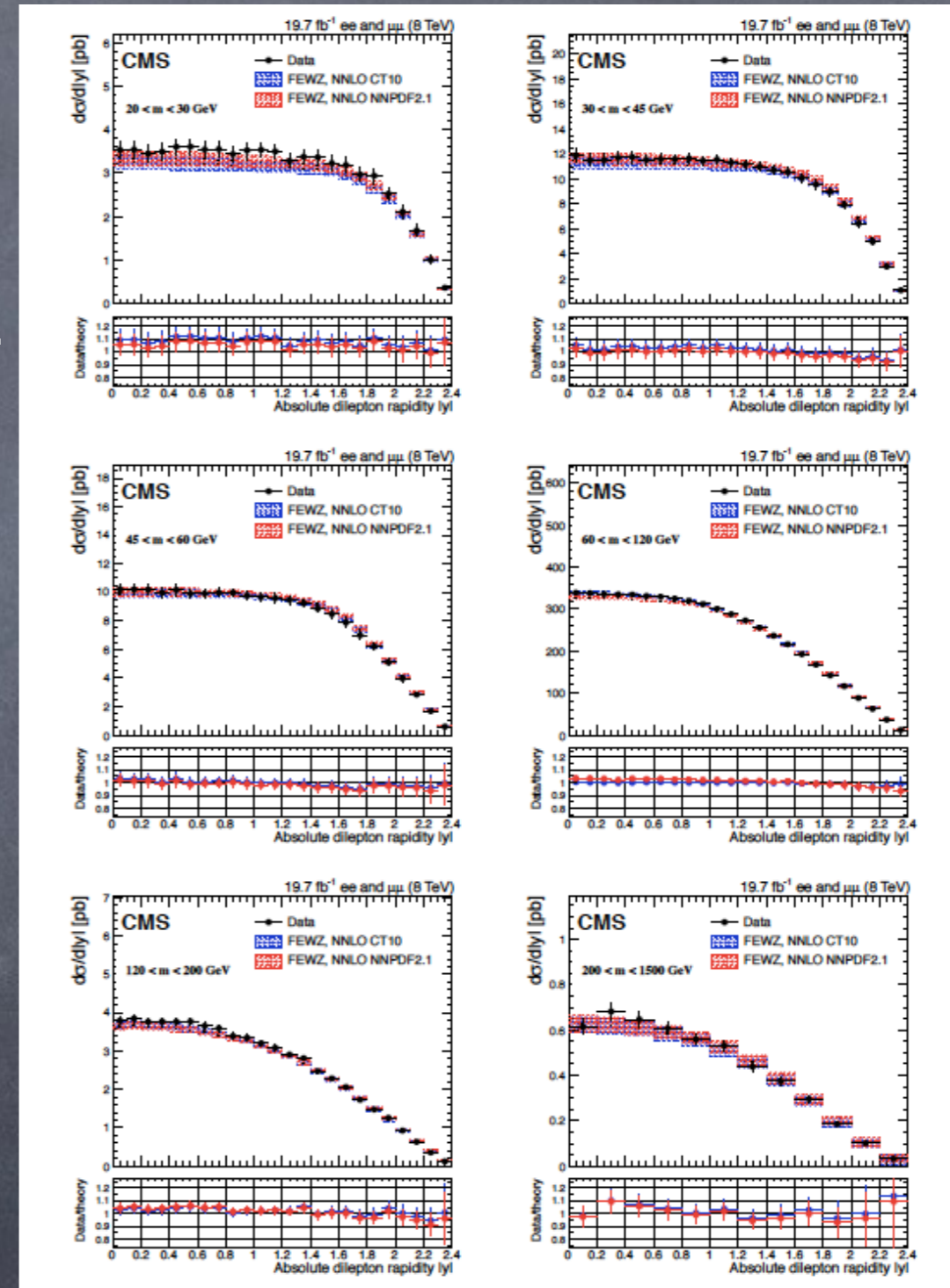
8 TeV, 20 fb⁻¹

SMP-14-003

- Measurement done normalised to Z peak cross section.
- Correlation provided with Z cross section.
- Differential cross section for $15 < m < 2000$ GeV
- Double-differential cross section for $20 < m < 1500$ GeV
- $0 < |y| < 2.4$.
- Analysis in referee review. HEPDATA would come as soon as it ends.
- For fun : second most accessed CMS measurement at HEPDATA (1034 times – nov. 2014)

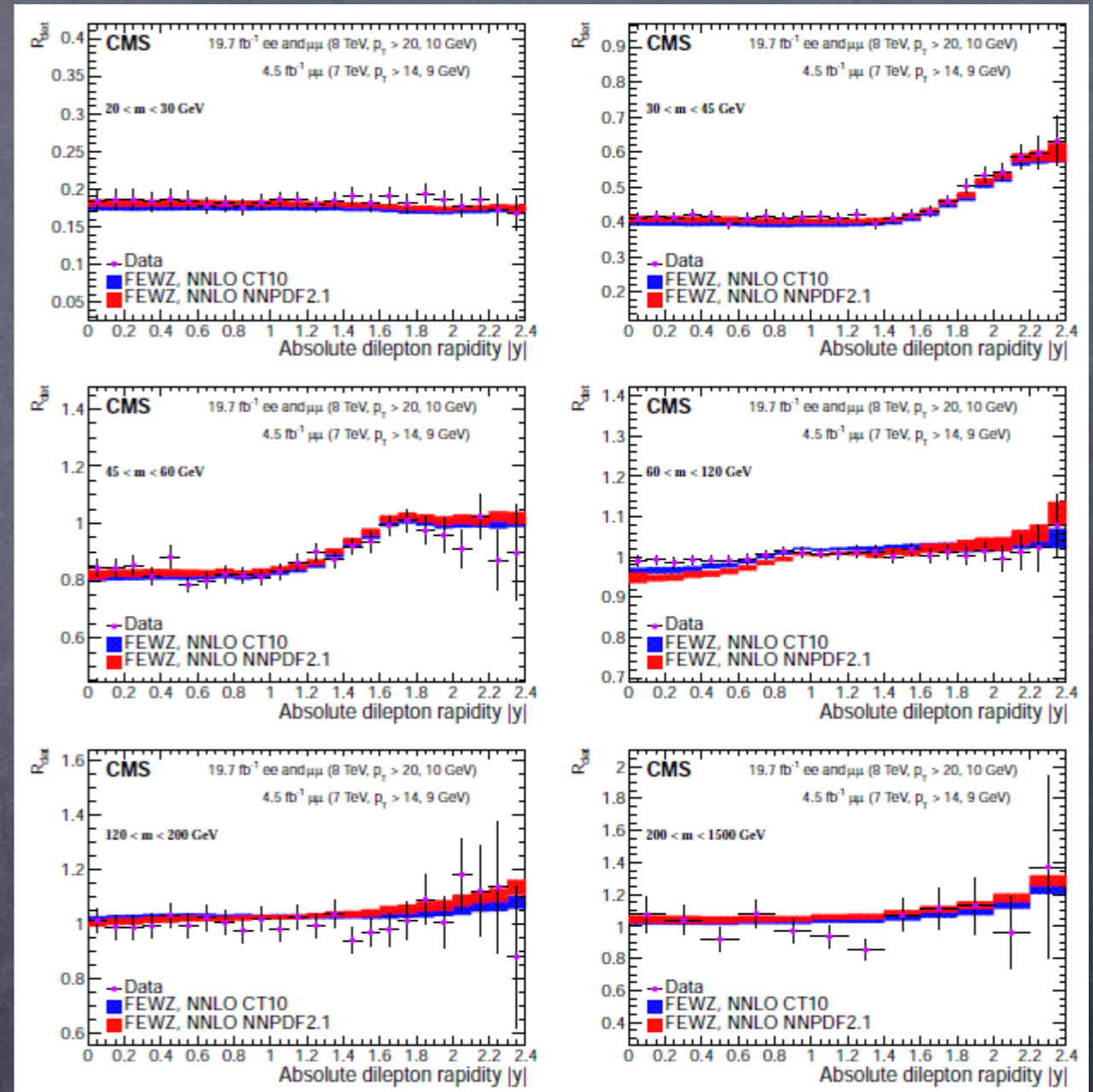
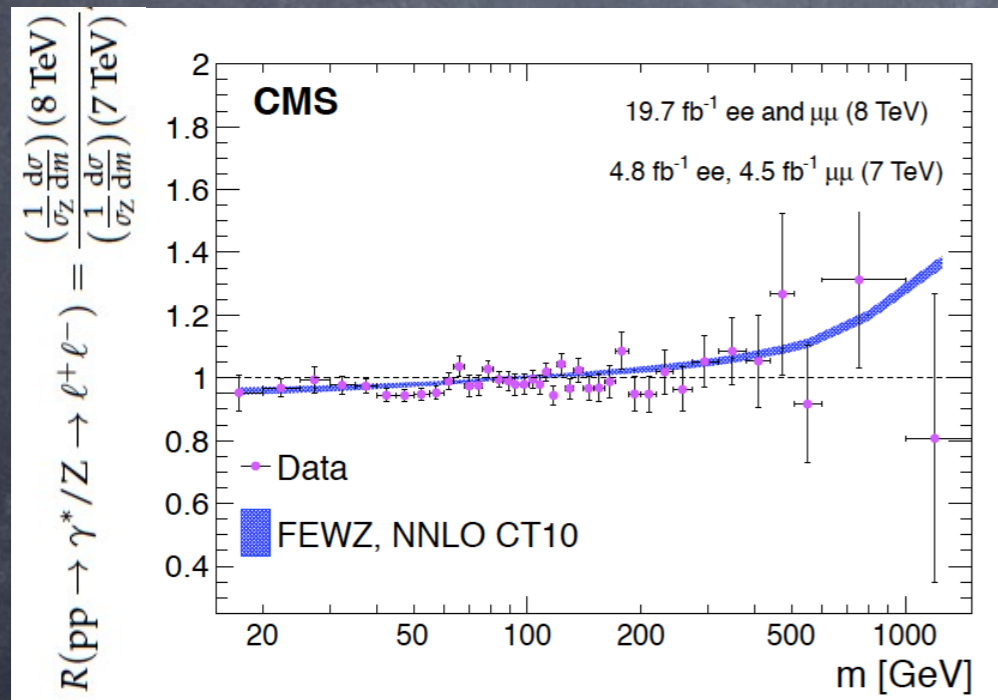
1.2) Valence and light sea : neutral Drell-Yan

- Double-differential cross sections done with high precision.
- NNLO calc. required for low mass region otherwise PDF fits do not converge well.
- For acceptance corrections NLO+PS MC is used reweighted for NNLO as function of m .
- At peak region and above NLO cross sections are enough.
- EWK corrections included



1.2) Valence and light sea : neutral Drell-Yan

- First published by CMS 8 TeV / 7 TeV ratio. We are excited to see impact on PDFs.
- By construction ratio normalised to nearly 1 around Z mass.
- Globally well described by NNLO PDFs
- Low dependance on η at low mass.



1.3) W,Z inclusive cross section

7 TeV, 36 pb⁻¹

-EWK-10-005 – HEPD.

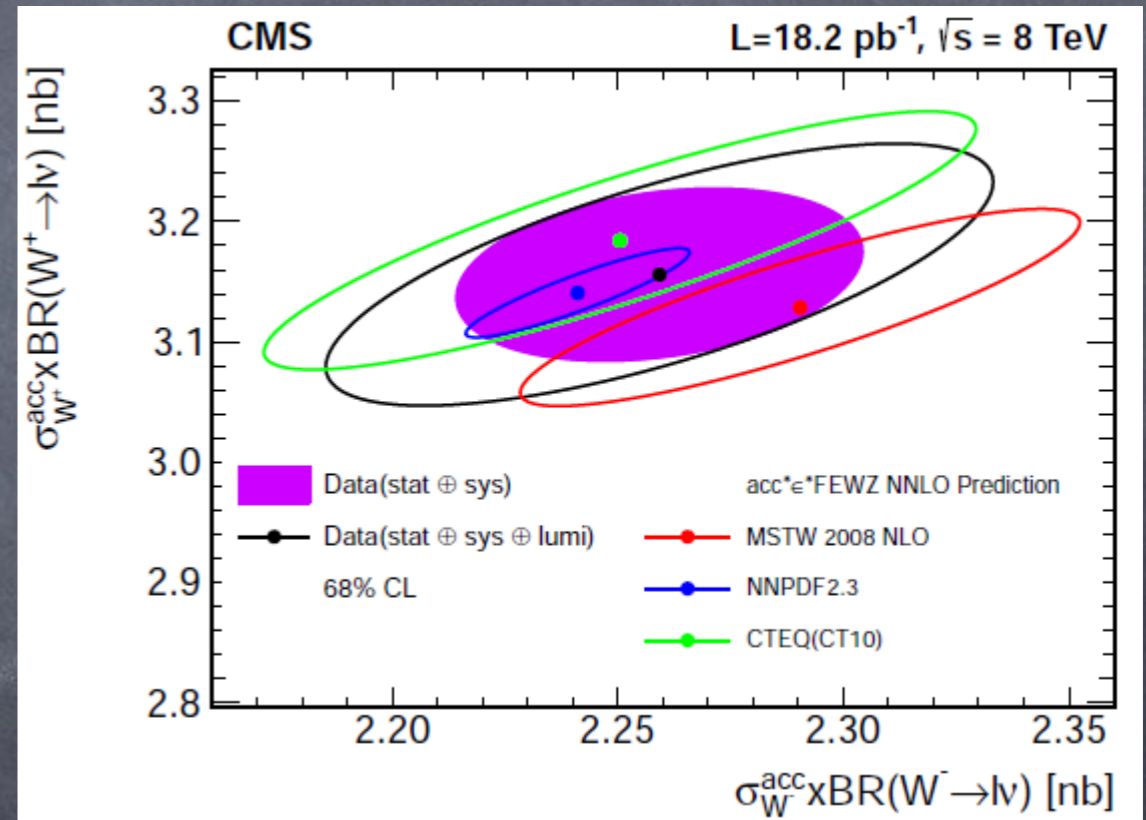
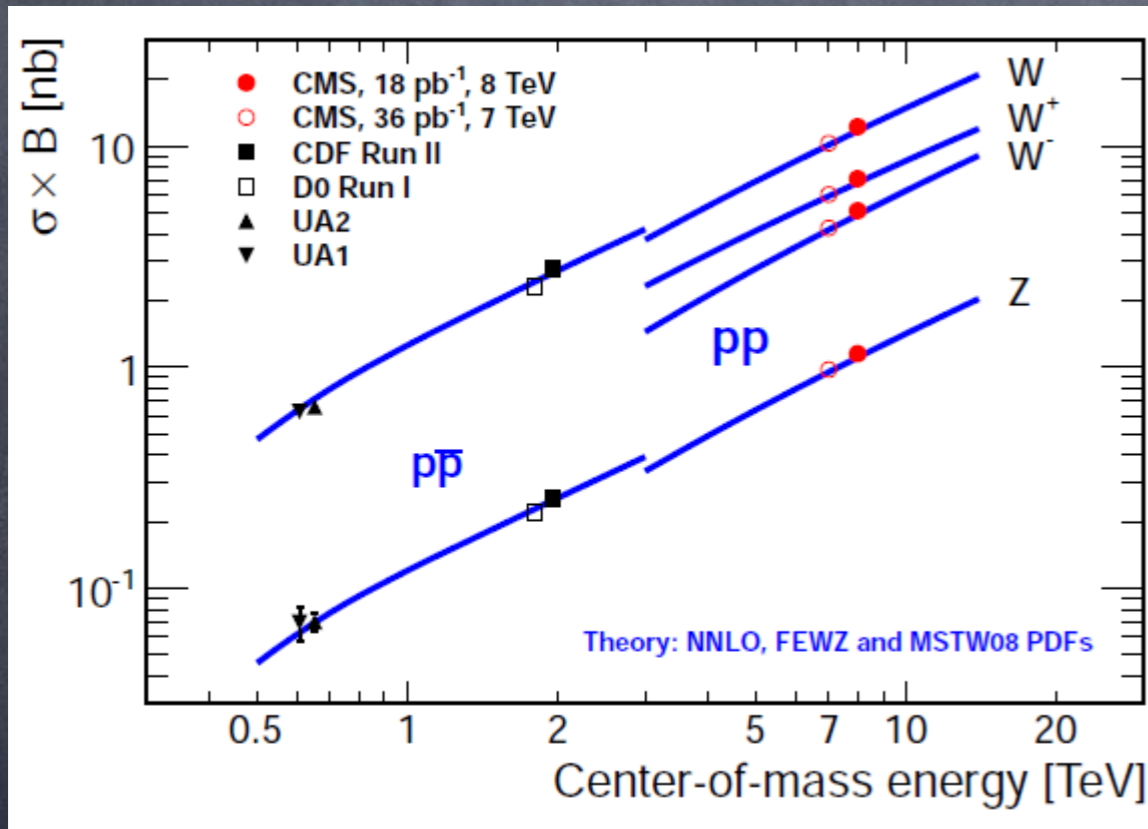
8 TeV, 18 pb⁻¹

SMP-12-011 – HEPD.

1) Precise results are public based on low PU data.

2) Clearly sensitive to the previous generation of PDFs from « PDF4LHC »-recommendation era.

3) In contrary to Atlas data not used in PDF fits. Why ?



2.1) Sea-quarks - Z+b jets

1) 7 TeV, 5 fb⁻¹

Sensitive to the flavour scheme

JHEP 1406 (2014) 120, [arXiv:1402.1521](#)

SMP-13-004 – HEPD.

Cross section	Measured	MADGRAPH (5F)	aMC@NLO (5F)	MCFM (parton level)	MADGRAPH (4F)	aMC@NLO (4F)
σ_{Z+1b} (pb)	$3.52 \pm 0.02 \pm 0.20$	3.66 ± 0.22	$3.70^{+0.23}_{-0.26}$	$3.03^{+0.30}_{-0.36}$	$3.11^{+0.47}_{-0.81}$	$2.36^{+0.47}_{-0.37}$
σ_{Z+2b} (pb)	$0.36 \pm 0.01 \pm 0.07$	0.37 ± 0.07	$0.29^{+0.04}_{-0.04}$	$0.29^{+0.04}_{-0.04}$	$0.38^{+0.06}_{-0.10}$	$0.35^{+0.08}_{-0.06}$
σ_{Z+b} (pb)	$3.88 \pm 0.02 \pm 0.22$	4.03 ± 0.24	$3.99^{+0.25}_{-0.29}$	$3.23^{+0.34}_{-0.40}$	$3.49^{+0.52}_{-0.91}$	$2.71^{+0.52}_{-0.41}$
$\sigma_{Z+b/Z+j}$ (%)	$5.15 \pm 0.03 \pm 0.25$	5.35 ± 0.11	$5.38^{+0.34}_{-0.39}$	$4.75^{+0.24}_{-0.27}$	$4.63^{+0.69}_{-1.21}$	$3.65^{+0.70}_{-0.55}$

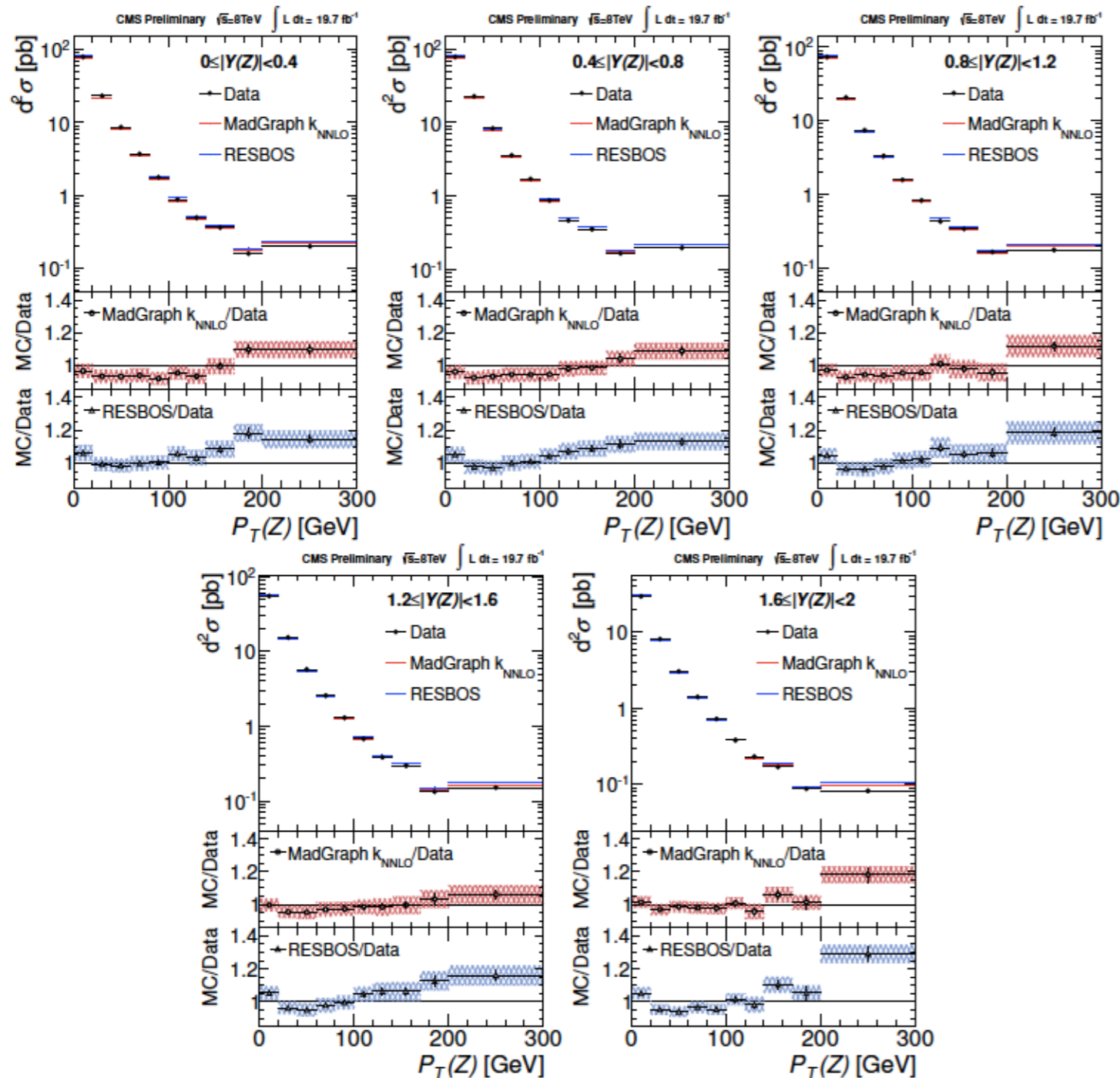
2) 8 TeV, 20 fb⁻¹

SMP-14-010 – close to preliminary

Similar to 7 TeV but with a differential measurement

3.1) Gluons : Z-boson transverse momentum

Drell-Yan@Z peak ($81 < m_{ll} < 101$ GeV): probe u, d, g PDF



8 TeV, 20 fb⁻¹

Few % uncertainties for $p_{T,Z} \sim 100$ GeV
double-differential cross sections
in $p_{T,Z}$ and y_Z

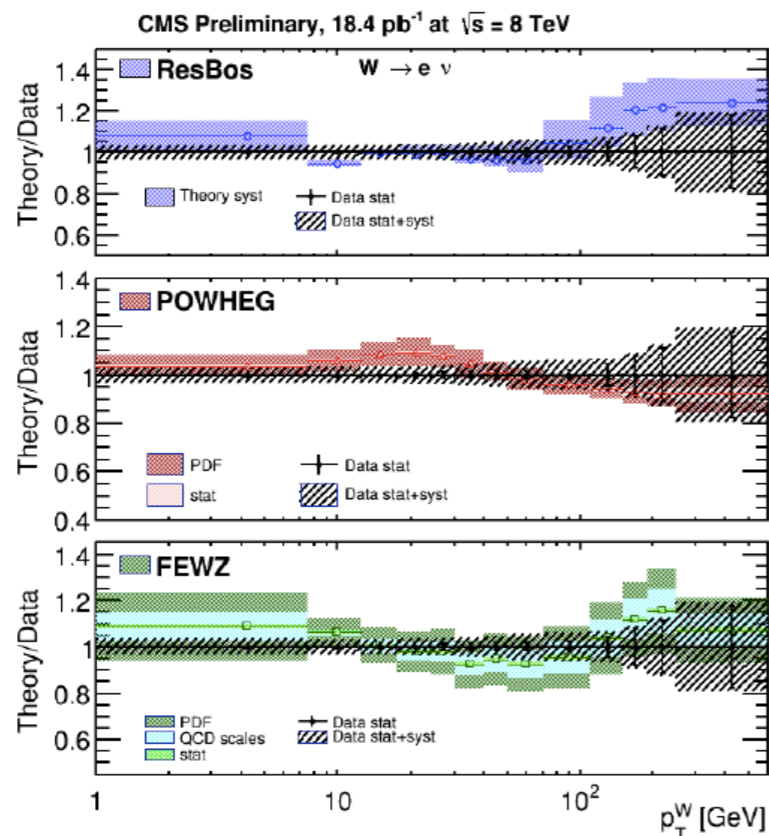
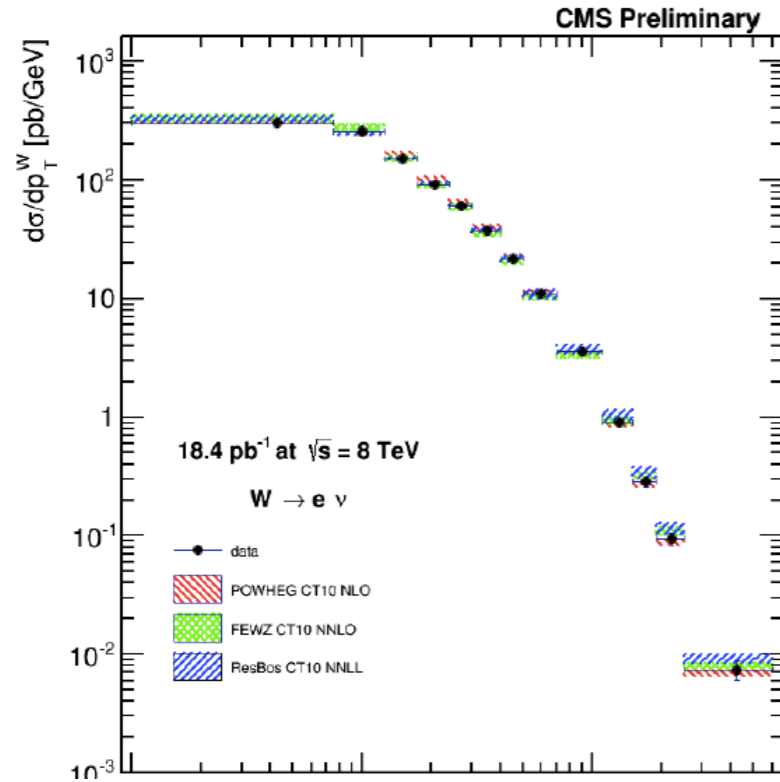
Preliminary SMP-14-004

Analysis is final review stage soon
public,
full covariance matrix
will be provided in Spring 2015

3.2) W-boson transverse momentum

Preliminary SMP-13-006

8 TeV, 20 pb⁻¹ (low PU run)



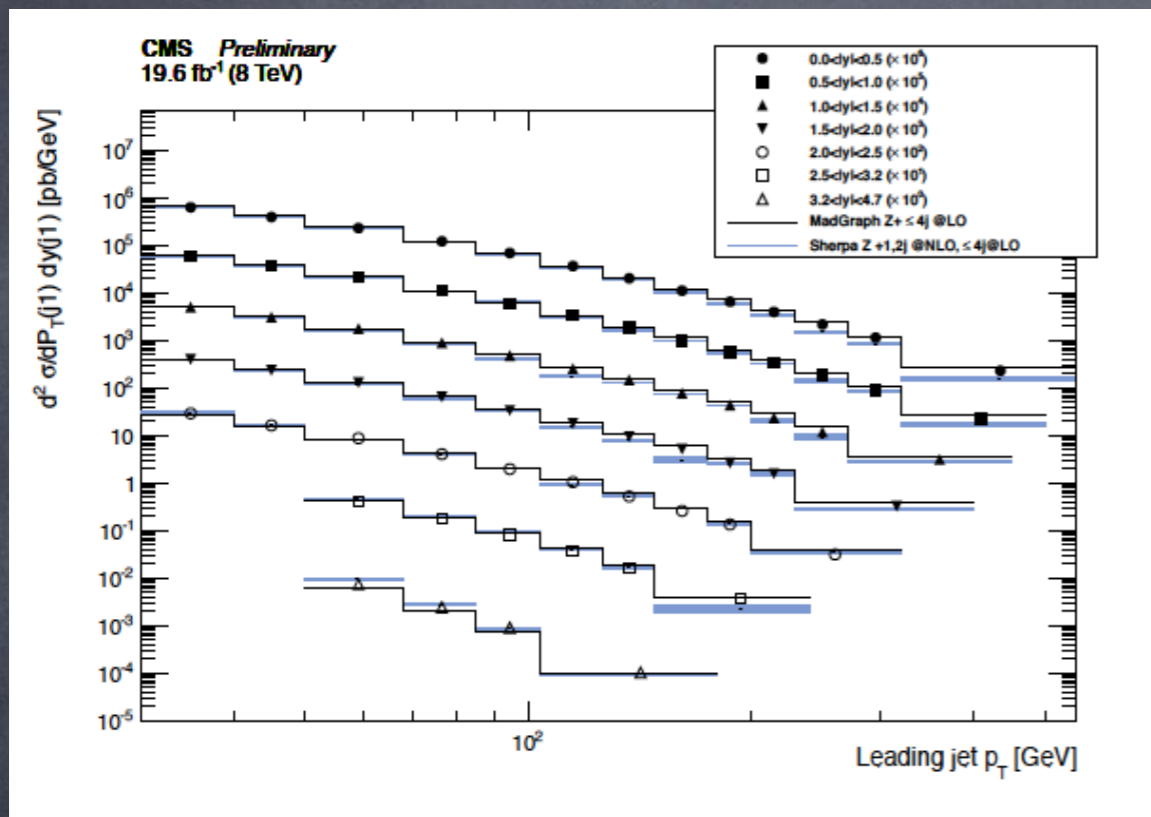
- muon and electron channels,
- measurements performed for W^+ and W^- .
- ratio to $p_{T,Z}$ and high precision normalised shepes under production.

- Interesting to try since it is not very precise above $p_{T,W} = 100$ GeV due to lack of stats

3.3) Gluons : what about Z, W + jets ?

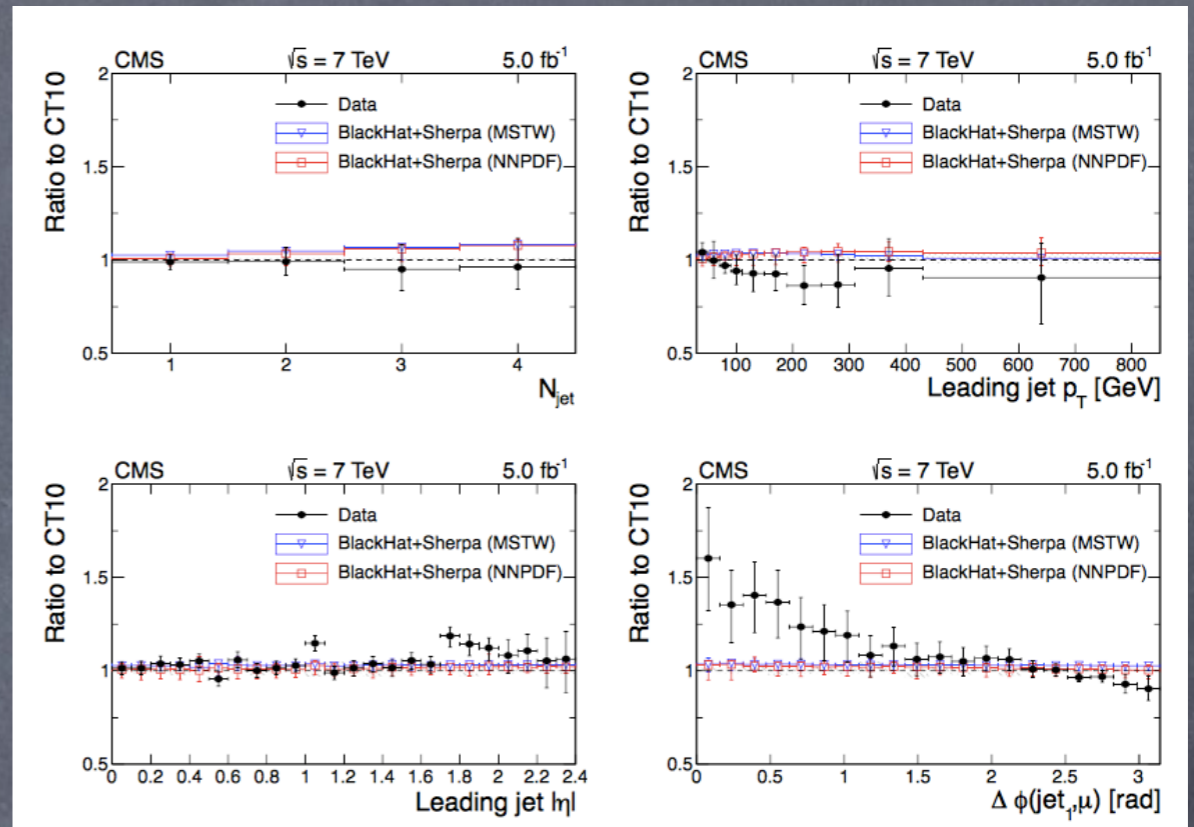
Z+jets, 8 TeV Full Luminosity

CMS-PAS-SMP-14-009



W+jets, 7 TeV (Ongoing 8 TeV)

SMP-12-023, arXiv:1406.7533

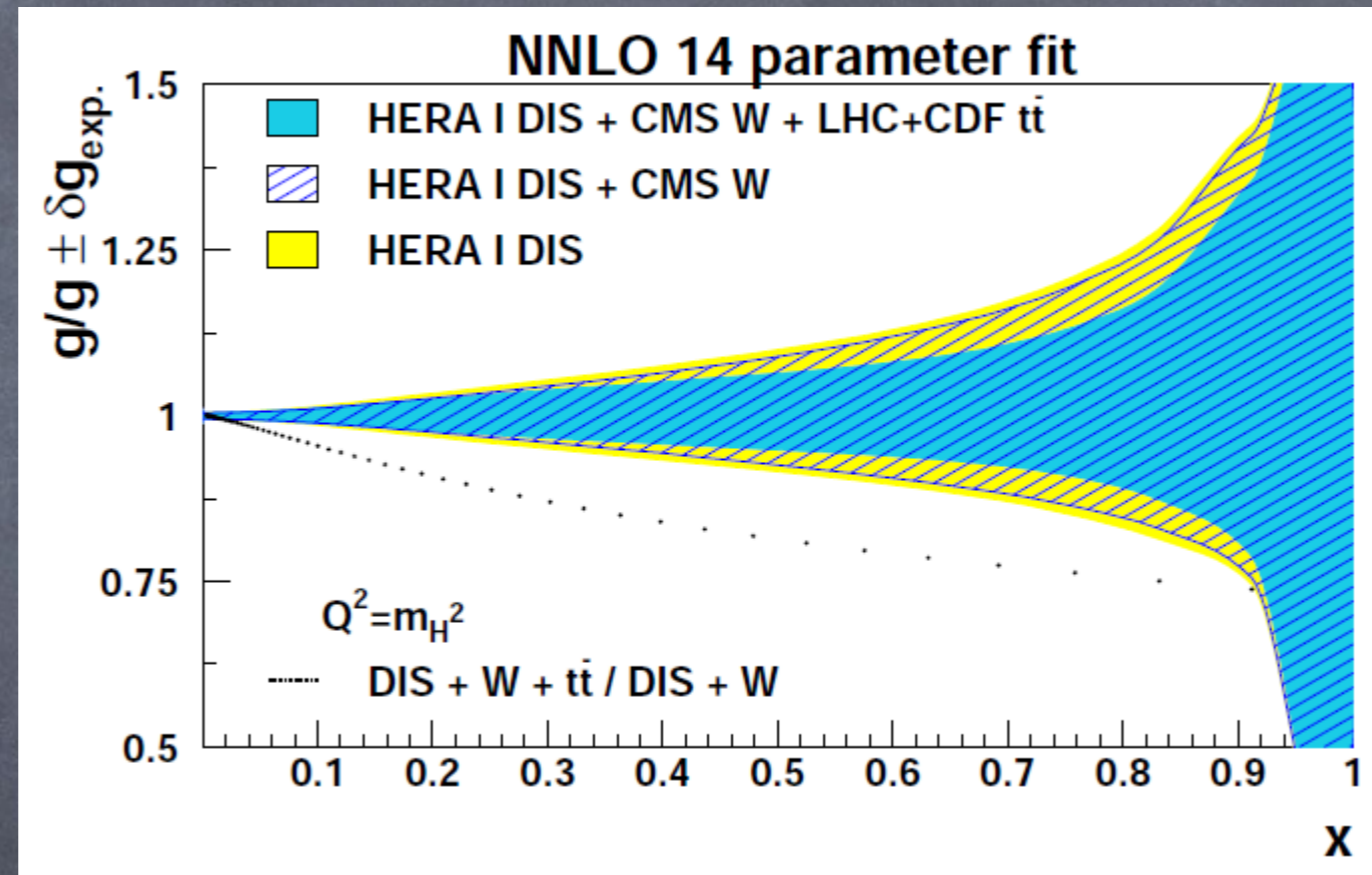


- Differences in Sherpa/Madgraph larger than PDF error
- Data could be used in the PDF fit, but not clear the advantage wrt to the inclusive $p_{T,V}$.

3.4) Gluons : ttbar production

- Inclusive top cross section at 7 TeV a usual suspect for PDF fits at NNLO. At NLO it cannot be used due to large k-factors.

JHEP 1501 (2015) 082



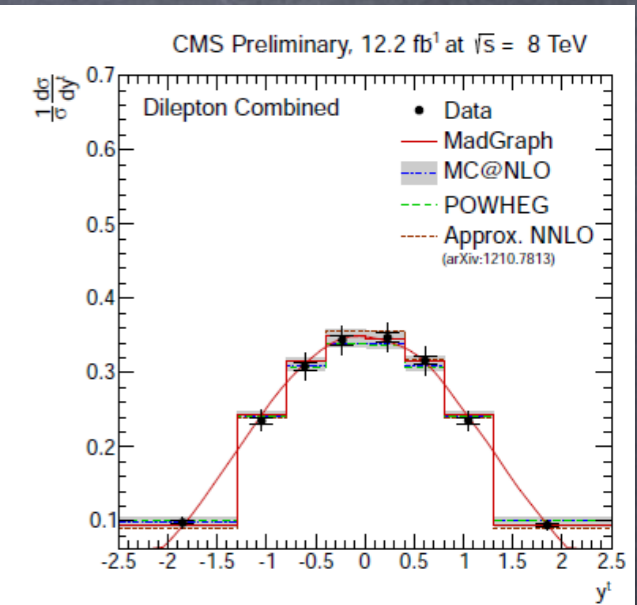
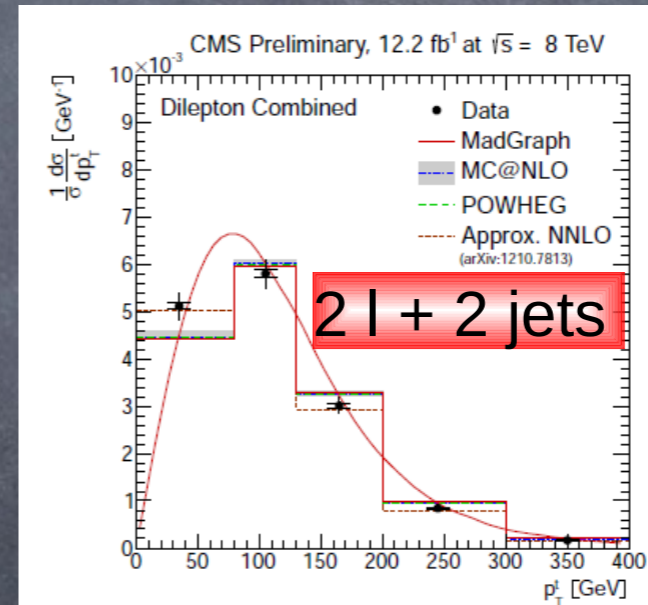
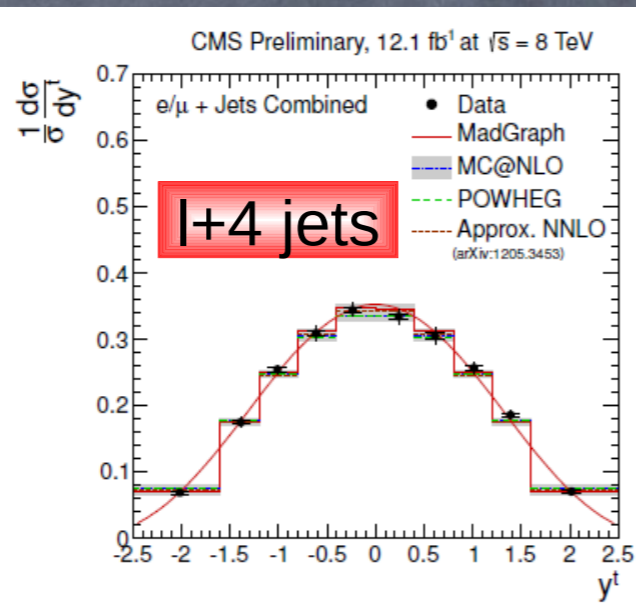
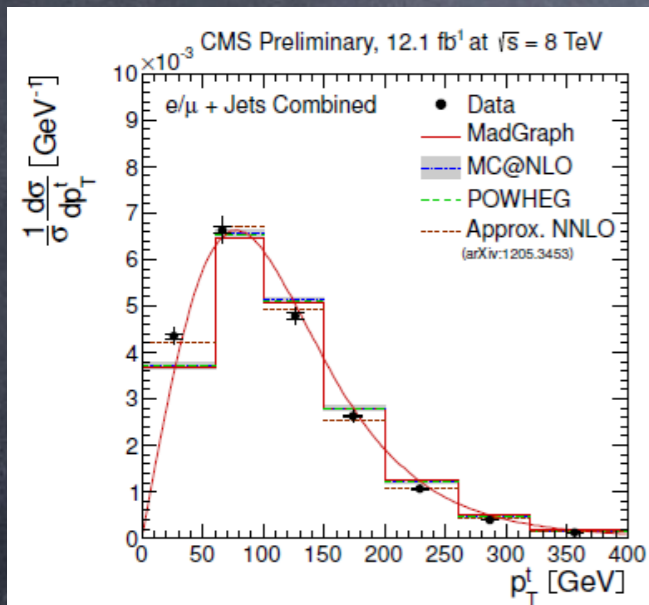
A study of PDF impact from ATLAS+CMS
Xsections - inclusive at 7-8 + normalised differential at 7 TeV :

- Moderate improvement for large-x gluon.
- Need to be careful on correlations between differential cross section and total cross section.

3.4) Gluons : ttbar production

8 TeV, 12 fb⁻¹

- At 8 TeV enough statistics for a precise differential measurement naturally increases (O(100k) events).
- Approximative NNLO predictions available for single-top observables (DiffTop).
- In 2015 publication expected soon.

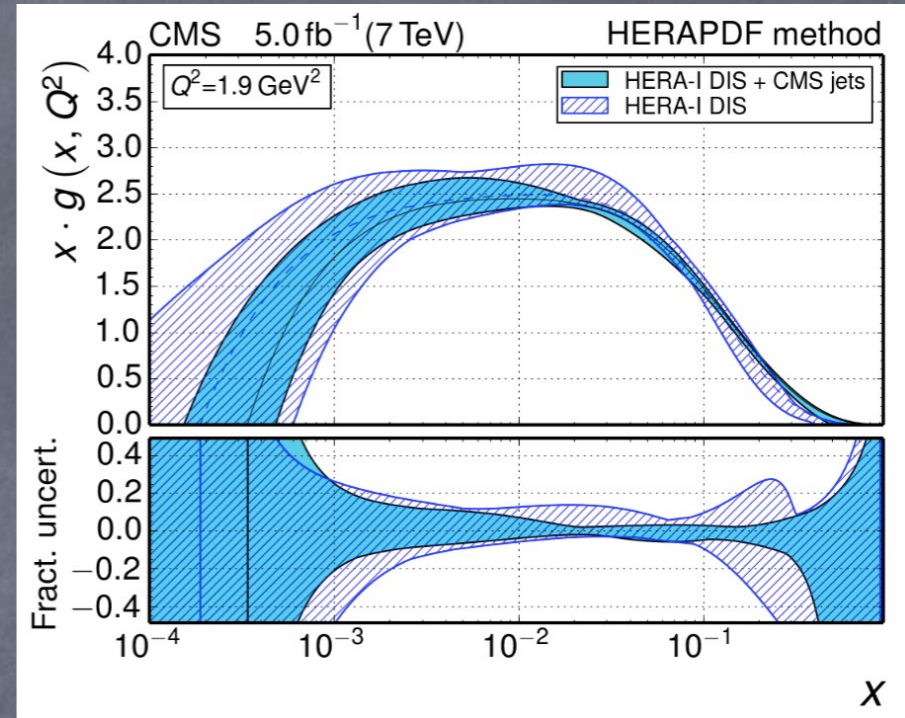
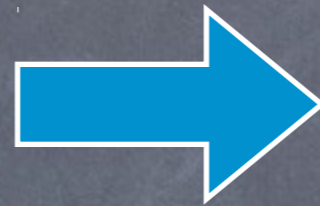
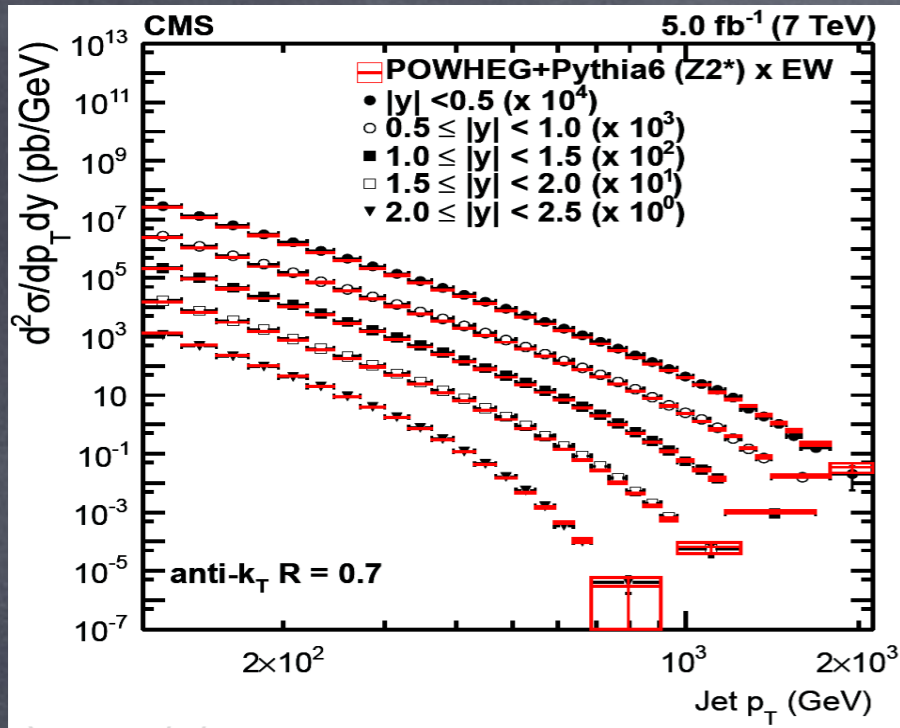


Preliminary TOP-12-027
Preliminary TOP-12-028

3.5) Gluons / High-x quarks : inclusive jets

Inclusive jets at 7 TeV included in PDF fits

SMP-12-28, arXiv: 1410.6765



7 TeV, 5 fb⁻¹

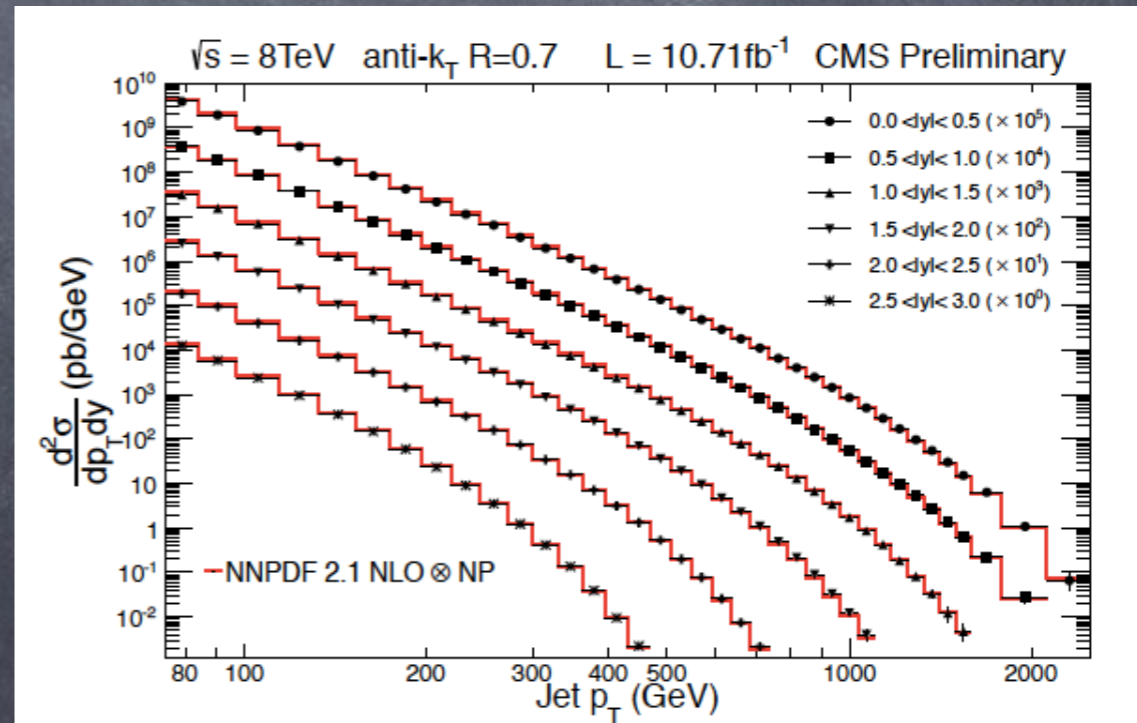
QCD-11-004 - HEPDATA

8 TeV, 10 fb⁻¹

Preliminary SMP-12-012

- Full data set and ratio to 7 TeV ongoing.
- Analysis of jets at $\sqrt{s}=2.76$ GeV ongoing

Preliminary result CMS PAS SMP-12-012

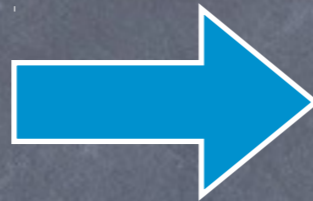


3.5) Gluons / High-x quarks : inclusive jets

Few ingredients important to remind :

- SMP-12-028 change JES prescription for QCD-11-004 data. Stability of α_s fits have shown that the assumptions that single pion response uncertainty (3 %) was correlated over the detector was too strong.

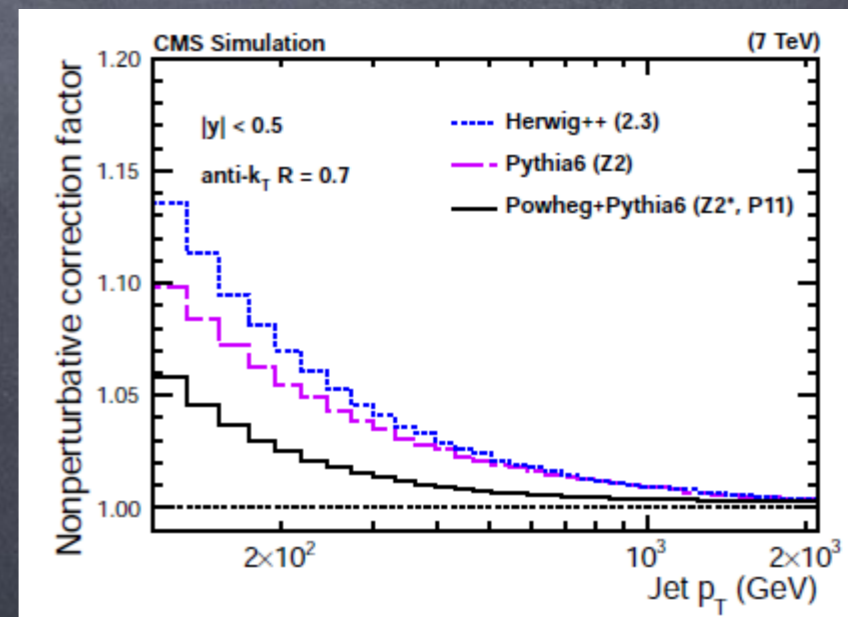
JEC2 single-particle response



JEC2a	single-particle response barrel
JEC2b	single-particle response endcap
JEC2c	single-particle decorrelation $ y < 0.5$
JEC2d	single-particle decorrelation $0.5 \leq y < 1.0$
JEC2e	single-particle decorrelation $1.0 \leq y < 1.5$

- The NLO+PS POWHEG+PYTHIA (average of Z2* and P11) is included into the NP corrections estimate with PYTHIA (Z2)/HERWIG(2.3). Enveloppe is used.

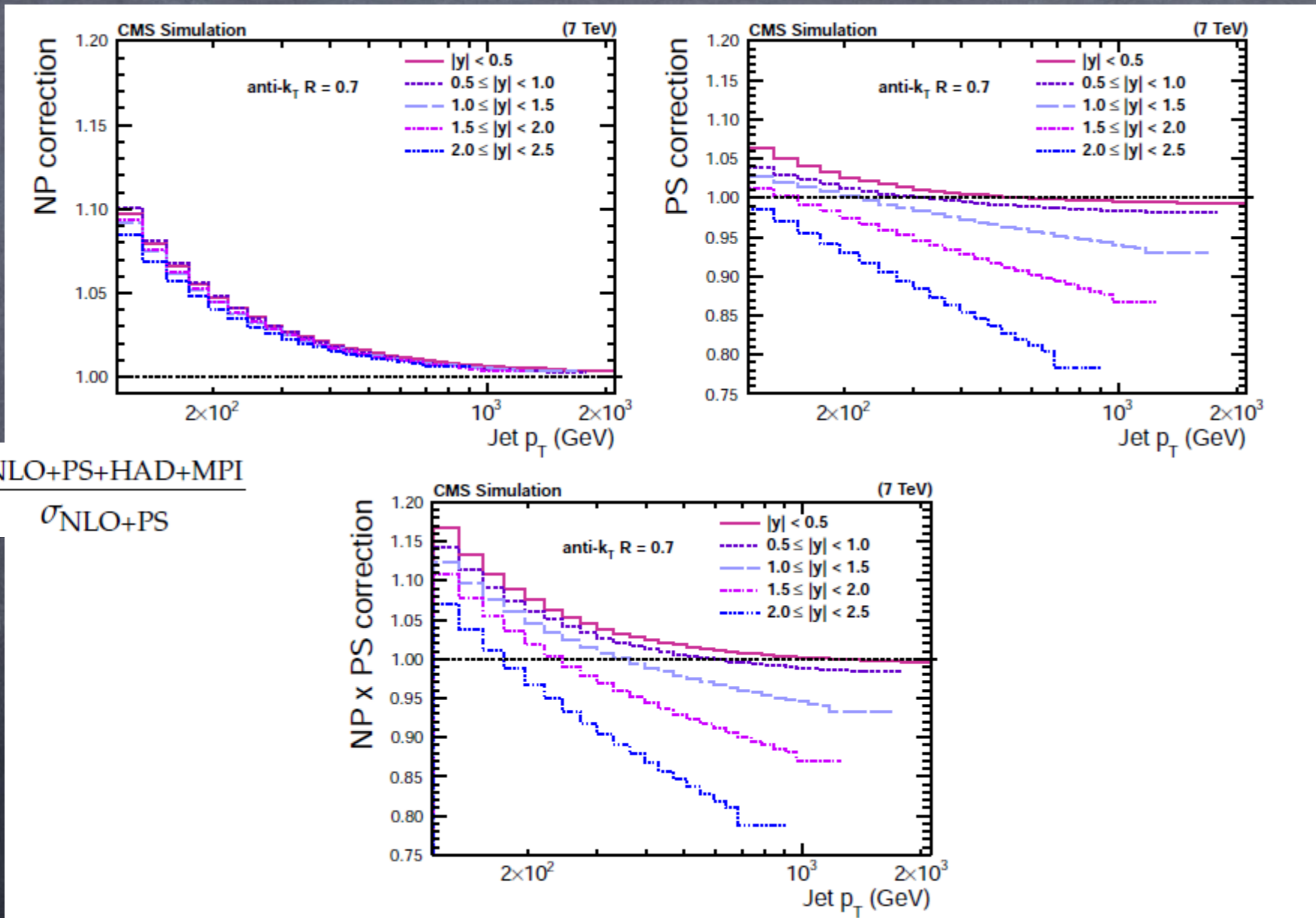
$$C_{\text{NLO}}^{\text{NP}} = \frac{\sigma_{\text{NLO+PS+HAD+MPI}}}{\sigma_{\text{NLO+PS}}}$$



3.5) Gluons / High-x quarks : inclusive jets

Interesting discussion on PS corrections.

- May be a sizable effect. But require a dedicated POWHEG tuning.
- Need to find a way to estimate the associated uncertainties.

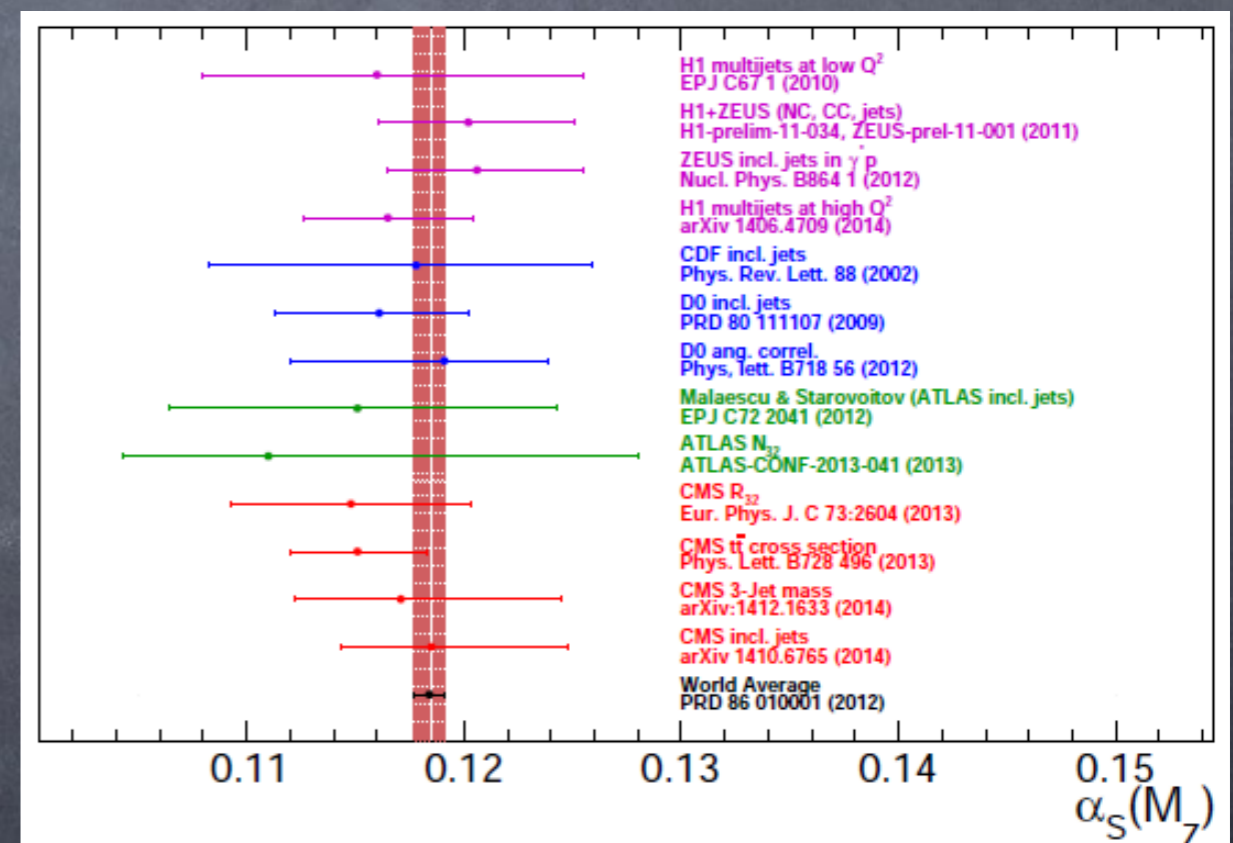
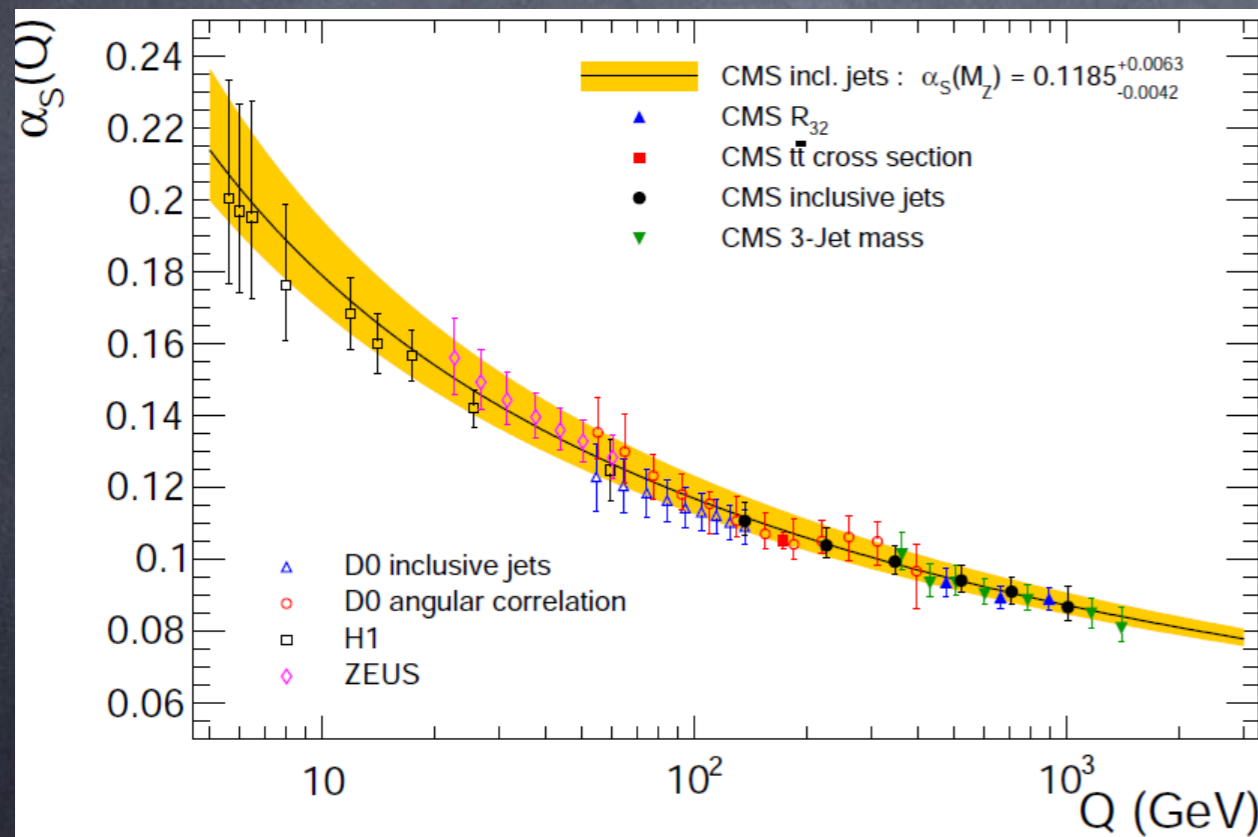


$$C_{\text{NLO}}^{\text{NP}} = \frac{\sigma_{\text{NLO+PS+HAD+MPI}}}{\sigma_{\text{NLO+PS}}}$$

$$C_{\text{NLO}}^{\text{PS}} = \frac{\sigma_{\text{NLO+PS}}}{\sigma_{\text{NLO}}}$$

4.1) Strong coupling : jets counting

- Nearly all Run I α_s results are published or under journal review. All 7 TeV based. Only 8 TeV inclusive jets is left to come.
- CMS is covering the high mass tail above 500 GeV of the α_s running. 8 TeV results shall extend up to $\mu = 2$ TeV.
- Top production provide the most precise hadrons colliders extraction at a scale close to M_Z because it is NNLO.
- Usual mantra : for jets need NNLO to take full advantage of data precision...



5.1) Where CMS data are used ?

- Some PDF sets may have been forgotten. Don't hesitate to remind me if you spot it.
- Surprisingly Inclusive W/Z cross sections from CMS seems not have been used...

	NNPDF	MSTW	CTEQ	ABM	CMS internal
W charge asymmetry (e, μ) EWK-10-006 (35 pb ⁻¹)		MSTWCPdeut MMHT2014			
W charge asymmetry (e) SMP-12-001 (840 pb ⁻¹)	NNPDF2.3 NNPDF3.0	MSTWCPdeut MMHT2014		ABM12	
W charge asymmetry (μ) SMP-12-021 (5 fb ⁻¹)	NNPDF3.0		CT14		SMP-12-021
DY SMP-13-003 W/Z inclusive EWK-10-005 SMP-12-011	NNPDF3.0	MMHT2014			Internally
Z p _T and y EWK-10-010		MSTWCPdeut MMHT2014			
Inclusive jets QCD-11-004	NNPDF3.0	MSTWCPdeut MMHT2014	CT14		SMP-12-028
W+c SMP-12-002	NNPDF3.0				SMP-12-021
Ttbar cross sections	NNPDF3.0	MSTWCPdeut MMHT2014		ABM12	

Future plans

The measurement that may still be done with 8 TeV data:

- Associated Zc production - probing intrinsic charm. May be not enough statistics. Would need Run II.
- Measurements of ratios Z/W, W+/W-, Z+jet/W+jets
- DY very low m_{ll} , low p_T : possible access to photon PDF

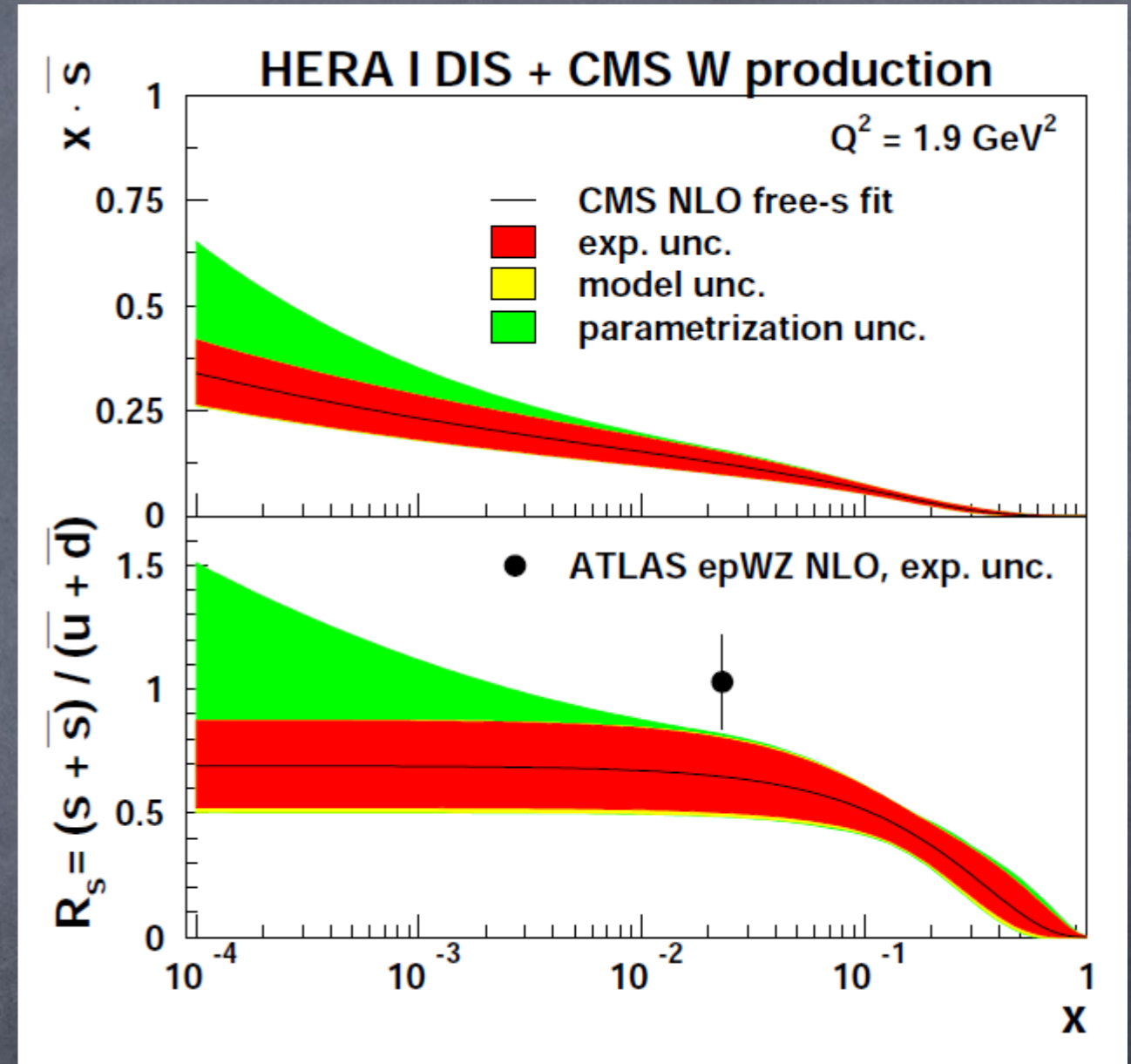
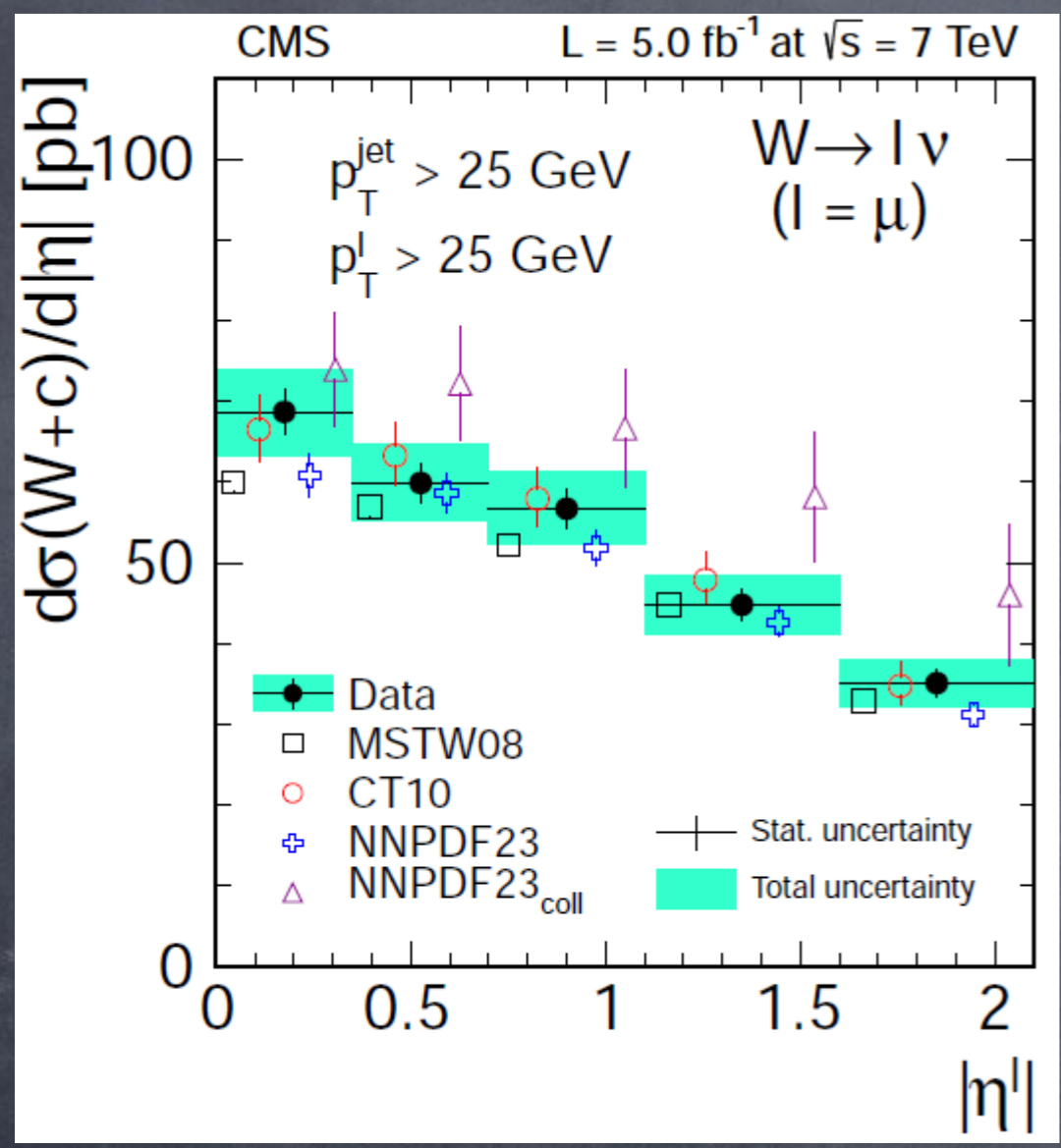
Conclusions

- All the 7 TeV data are public and submitted to HEPDATA
- At 8 TeV only Z/W inclusive is public. DY is in journal review and $p_{T,Z}$ close to become public. Can probably go to the summer generation of PDFs.
- For other results one would need to wait at least 6 months.

2.1) Sea quarks - W+c jets: s PDF

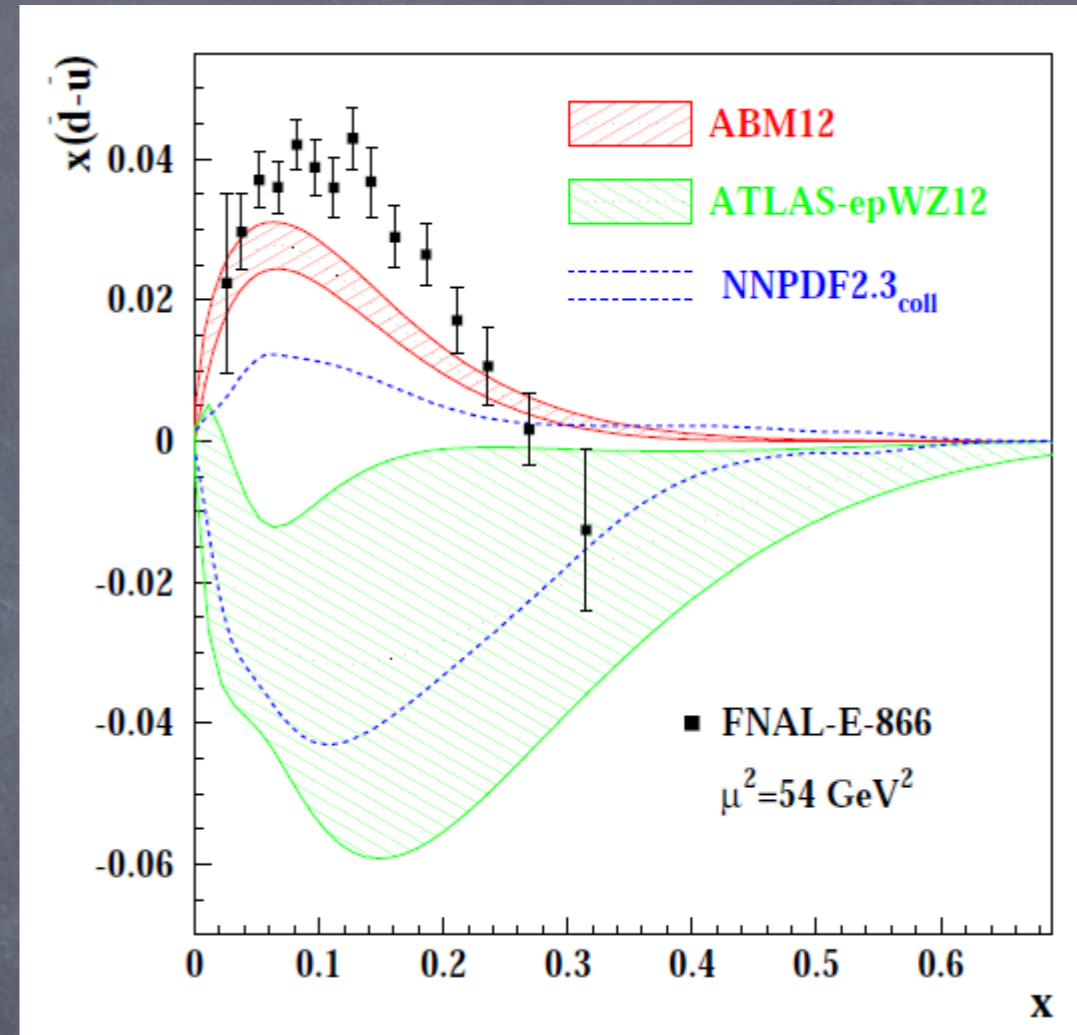
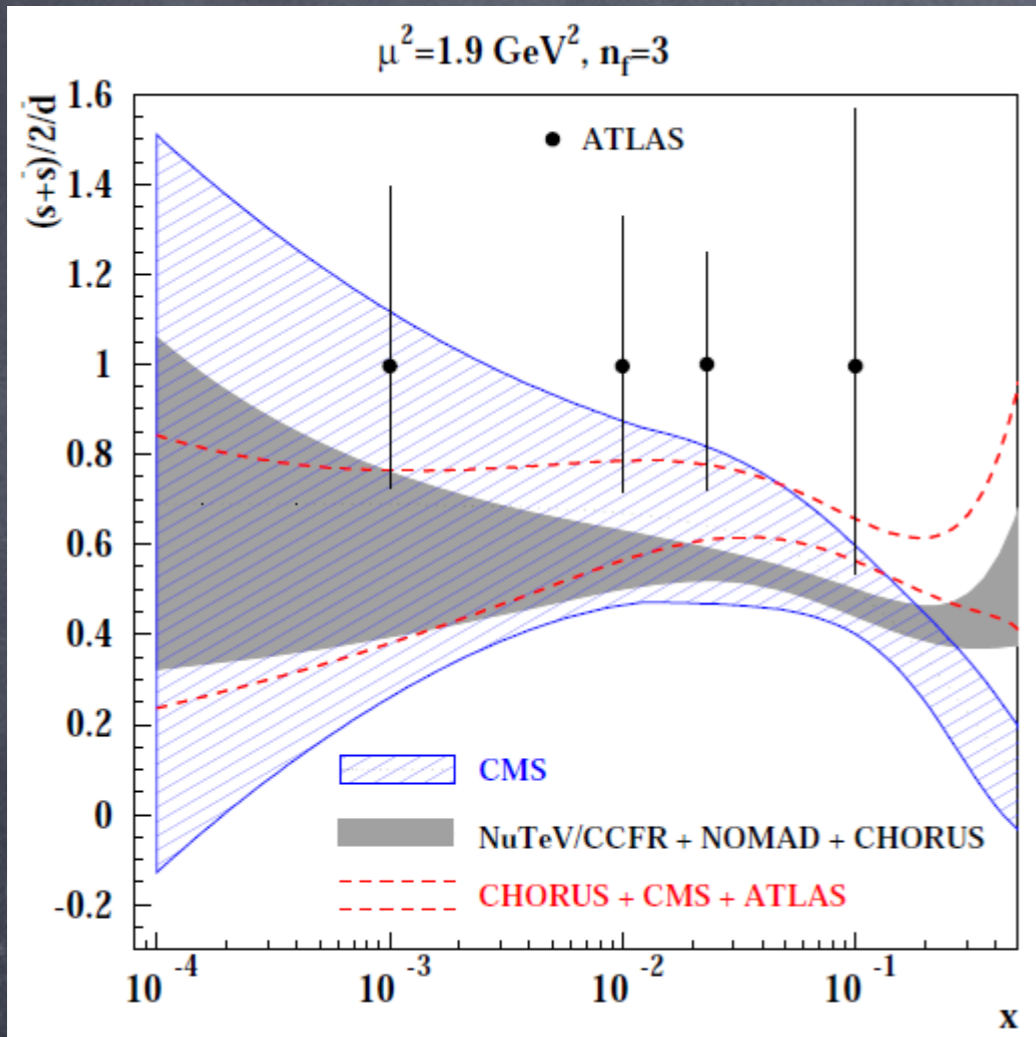
7 TeV, 5 fb⁻¹

SMP-12-002 – HEPD.



SMP-12-021 – HEPD.

2.1) Sea quarks - W+c jets: s PDF



arXiv:1404.6469v1 [hep-ph] 25 Apr 2014

3.4) Gluons : ttbar production

