Inclusive Drell-Yan Measurements with ATLAS and CMS

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on behalf of the ATLAS and CMS Collaborations

EW precision physics at the LHC, CERN, June 30th, 2014

Selected points for discussion

Consistency of external HO QCD and EW calculations and consistency with the Monte Carlo signal and background simulations:

- EW parameter scheme and SM inputs (e.g. Vcs sensitivity)
- Application of HO EW effects : QED FSR correction usually to the data via Monte Carlo unfolding while 'missing' HO EW (=HO EW except QED FSR) corrections are applied via external calculations to the theory predictions
- Evaluation of systematic uncertainties for HO EW : in particular QED FSR for off-resonant, low and high mass Drell-Yan productions
- Evaluation of HO EW except QED FSR systematic uncertainties for all mass ranges and in particular in presence of kinematic cuts : effect of EW parameter scheme choice (including 'missing' HO EW corrections per EW scheme)

Further HO QCD and EW calculations including issues of QCD scale choices and scale uncertainties

Selected examples

1) EW parameter choices for precision W and Z measurements, c.f. series of discussions in EW LPCC meetings and at Les Houches 2013 : Physics at TeV Colliders
https://phystev.in2p3.fr/wiki/_media/2013:talks:leshouches_uklein_09.06.2013.pdf

2) ATLAS low mass, single differential Drell-Yan measurement,
for ICEHP2014 : JHEP 06 (2014) 112 [arXiv:1404.1212]

3) CMS double differential y_Z-p^T_Z measurement,
for DIS2014 : CMS-PAS-SMP 13-013 (slides prepared by Markus Stoya)
[ATLAS double differential y_Z-p^T_Z measurement : arXiv:1406.3660 submitted to JHEP]

1) SM input parameters and EW scheme

- Nominal EW schema for CC and NC Drell Yan : G_μ scheme

$$\frac{1}{\alpha_G} = \frac{\sqrt{2}G_\mu M_W^2}{\pi}\left(1 - \frac{M_W^2}{M_Z^2}\right); \quad \sin^2\theta_W = 1 - \frac{M_W^2}{M_Z^2}$$

- Use for a cross check for NC DY : $\alpha(M_Z)$ scheme including HO EW corrections
→ see low mass DY

<u>Update of EW parameters:</u>

❖ PDG 2012 change : Mw = 80.385 GeV (80.403 GeV),
W width 2.085 GeV (2.091 GeV) and 'a Higgs' mass of 125 GeV (120 GeV)

→ use SM theory as strict as possible, e.g. using ONLY measured masses and ONE constant as input BUT CALCULATE ALL OTHER values

✓ PDG2012 predictions, but partial widths calculated for α_S=0.120

✓ ZFITTER package update from Sabine and Tord Riemann (private comm.)
ZFITTER v.6_44beta (Jan 2013), D. Bardin et al., CPC 133 (2001) 229,
A. Arbuzov et al., CPC 174 (2006) 728-758

➔ Cross checks showed excellent agreement between PDG2012 predictions and ZFITTER

➔ New : use an EW set in agreement with nominal NNLO α_S=0.118

A consistent SM input parameter set

m_Z = 91.1876(0) GeV

m_W = 80.385(15) GeV

m_H = 125(0) GeV

m_{top} = 173.5(1) GeV

G_F=1.1663787d-5

$\sin^2\theta_w$ = 0.222897222252391828

α_G= 7.562395636697338 48E-003

vec_up= 0.4056074066028 8463

vec_dn= -0.7028037033014 4226

vec_le= -0.1084111099043 2690

} calculated by SANC

Widths : PDG2012 [partial widths by ZFITTER using α_S=0.118]

Γ_Z(ll) = 84.000 MeV Γ_W(lnu) = 227.27 MeV (LO!)

Γ_Z = 2494.9 MeV Γ_W = 2090.6 MeV

PDG2012 uses CKM fitter results, but consistent with UTfitter results [Note: using FEWZ, one has to use Vus=Vcd=0.2252D0,

but for MCFM and DYNNLO this constraint is not needed]

Vud = 0.97427 Vus = 0.22534 Vub = 0.00351

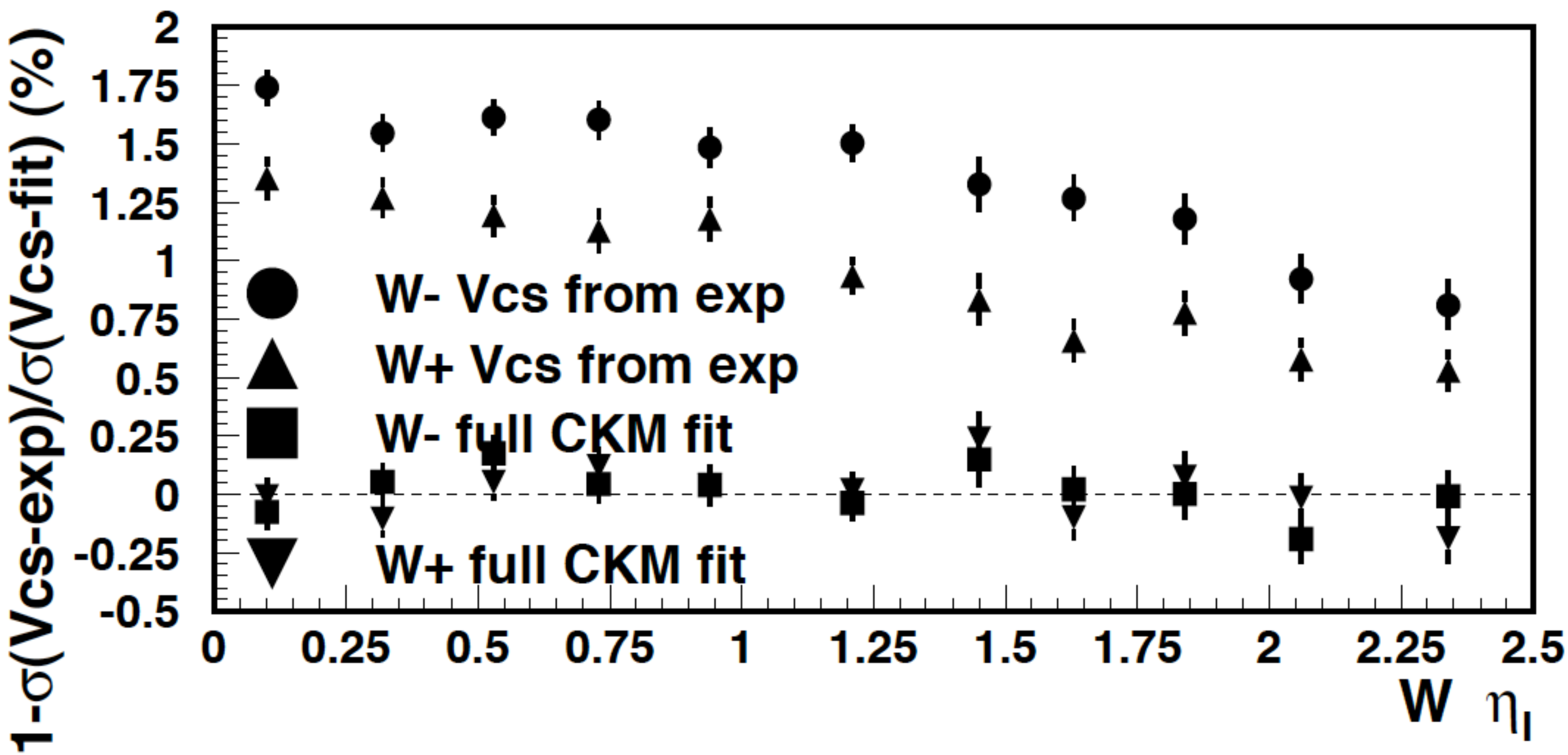
Vcd = 0.22520 Vcs = 0.97344 Vcb = 0.0412

Vtd = 0.00867 Vts = 0.0404 Vtb = 0.999146

U. Klein, Les Houches
arXiv:1405.1067

Effects of CKM V_{cs} value choice

- ➔ Case study : Use of experimental determined CKM values versus fitted values
- ➔ Deviations are largest for use of exp. Vcs value, Vcs=1.006+-0.023, evaluated w.r.t. use of fitted Vcs but experimental CKM values otherwise
- ❖ checked CKM fitter and UT fitter results → consistent values with much smaller errors, but fits assume strict SM and unitarity for all generations
- ❖ effect on W- and W+ predictions are in the 0.8% to 1.7% range and eta-dependent



➔**Issue : Consistency of CKM values in external calculations (e.g. APPLgrid) and PDF fits**

SM inputs, EW scheme and HO EW corrections

SM best partial W width contains full (QED FSR and missing HO EW) HO EW corrections for total inclusive cross sections : $\Gamma_W(lnu)$ = 226.36 MeV.

→ To evaluate 'missing HO' EW corrections for W decay (kinematic dependencies) using external EW programs, and then we have to use the **LO partial width : $\Gamma_W(lnu)$ = 227.27 MeV**

→ thus we can control the HO EW except QED FSR corrections

'missing HO EW ' == all NLO EW corrections except QED FSR

→ QED FSR correction is done usually via MC unfolding , e.g. using PHOTOS and **unfolded ATLAS/CMS DY data are corrected for QED FSR**

→ very good agreement between SANC and PHOTOS for QED FSR for resonant production: "QED Bremsstrahlung in decays of electroweak bosons" A. B. Arbuzov, R. R. Sadykov, Z. Was [arXiv:1212.6783]

→ **Issue : QED FSR systematic uncertainties arising from 2nd order ME contributions, and for off-peak NC and CC DY production**

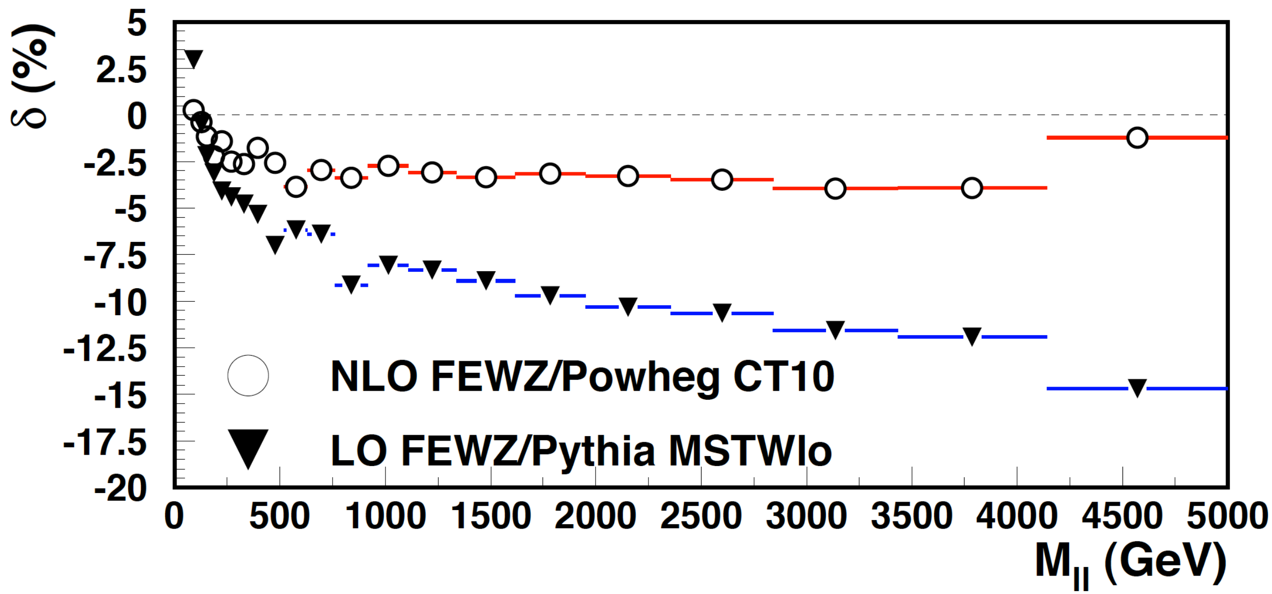
→ **Issue : Matching of the QED FSR corrections to remaining HO EW except QED FSR corrections, and its systematic uncertainty**

Matching of QCD cross sections to MC

U. Klein, Les Houches
arXiv:1405.1067

- To match the different EW parameter schemes in the MC to external programs ➔ form ratio at same QCD order (LO EW) and use same PDF
- FEWZ G_μ EW scheme calculations (LO EW) done at either NLO or LO QCD and using same PDF as used for the MC generation → usually common PDG based input are used for ALL MC generations → different effects on different signal and background channels

Neutral Current
Drell-Yan total
cross section ratios



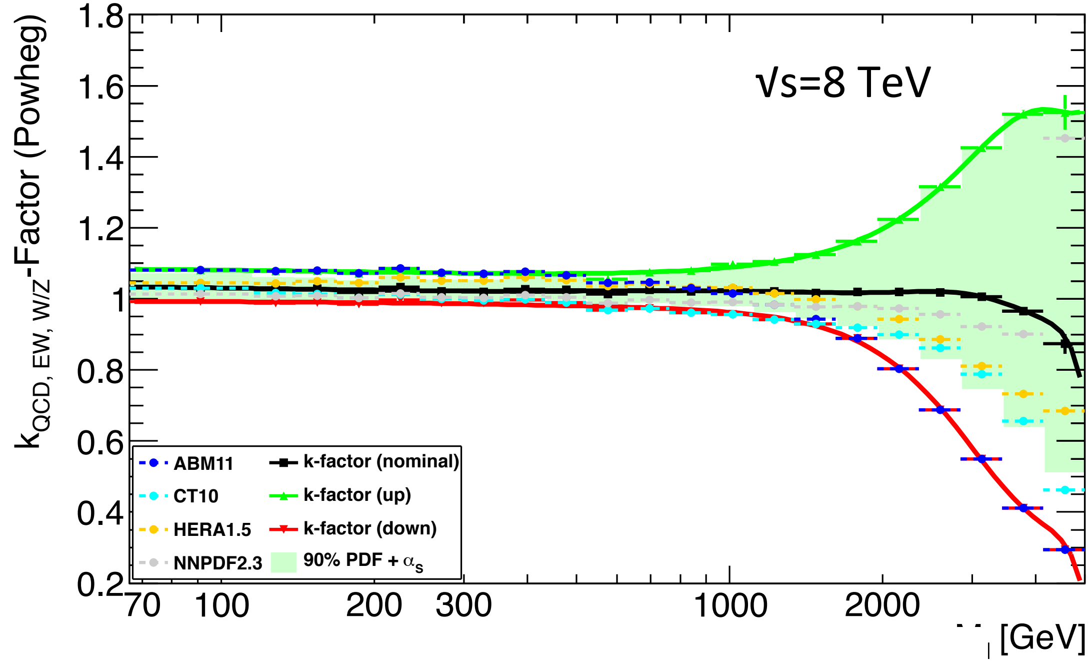
➔ EW parameter settings in Powheg close to FEWZ G_μ scheme; Pythia is off

➔ **<u>Issue :</u> To get a 'best' MC modelling for sub-% measurements (e.g. phi*, Z→μμ) with fine bins and kinematic cuts → 'MC reweigthing' methods using k-factors or other weights**

“k-factors” and photon-induced contributions

ATLAS-CONF-2013-017 related work

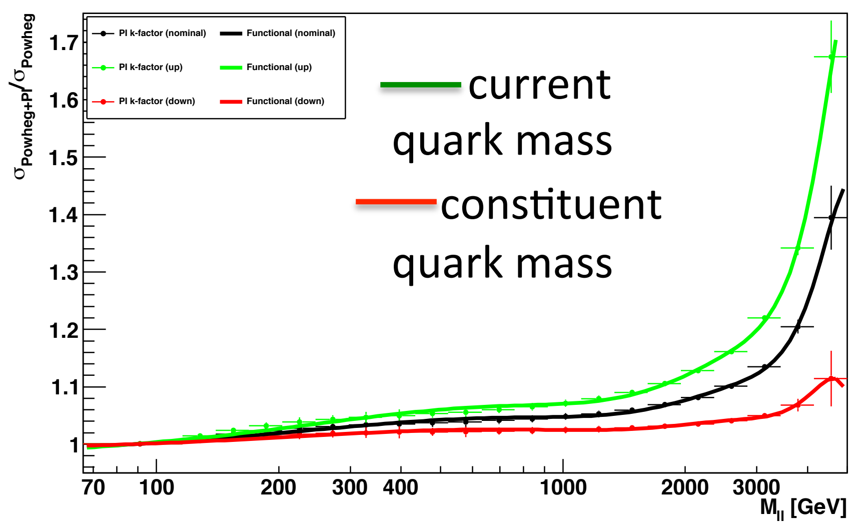
- novel method of “k-factors” : NNLO QCD + NLO EW + real W,Z radiation “k-factor” w.r.t. nominal ATLAS NC DY Powheg MC
- <u>photon-induced contribution</u> w.r.t. nominal “k-factor” reweighted NC DY MC estimated using updated MRST200qed grid (R.Thorne private comm. Dec 2012) <u>with</u> fid. lepton cuts



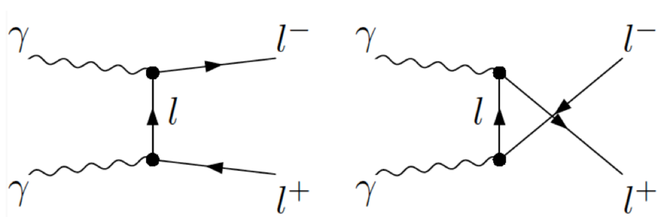
‘uncertainty’ via change in quark mass

→ upper limit : current quark mass

→ alternative : constituent quark mass



→ use the mean of both (black line) in ATLAS searches and SM analyses



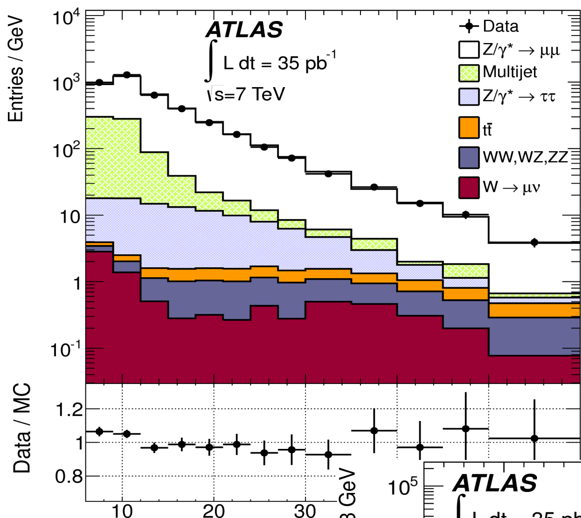
arXiv:1404.1212

2) Low Mass Drell-Yan Cross Sections

NEW

Extended kinematic range 0.035 fb^{-1} (2010)
12 < $m_{\mu\mu}$ < 66 GeV
$p_{T,1}$ > 6 GeV $p_{T,2}$ > 9 GeV $|\eta_\mu|$ < 2.4

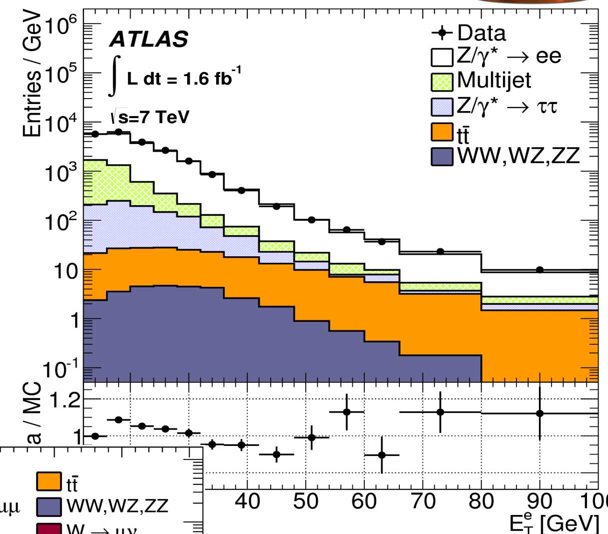
Nominal kinematic range 1.6 fb^{-1} (2011)
For l=e,μ : 26 < m_{ll} < 66 GeV
$p_{T,l,1}$ > 15 GeV $p_{T,l,2}$ > 12 GeV $|\eta_l|$ < 2.4

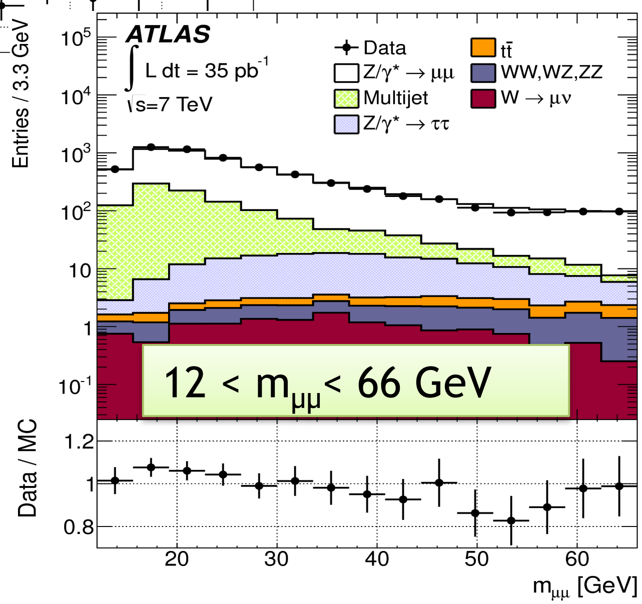


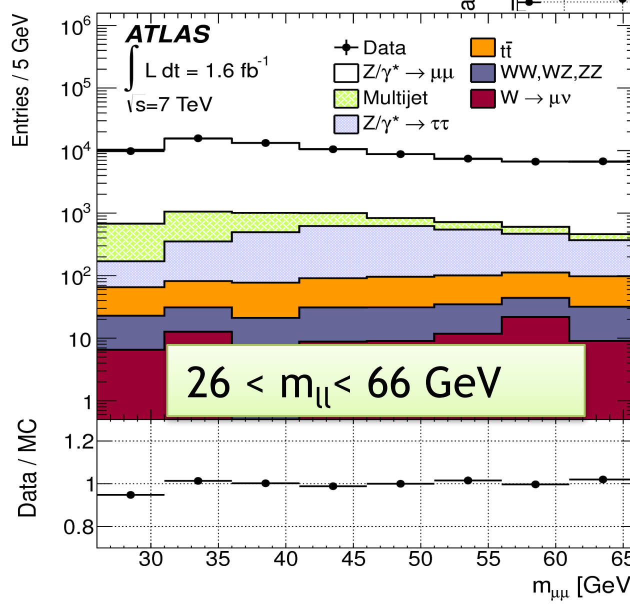
$p_{T,\mu}$

→ data-driven : multi-jet background using template fits and reverse isolation
→ MC-based : all other background

$E_{T,e}$

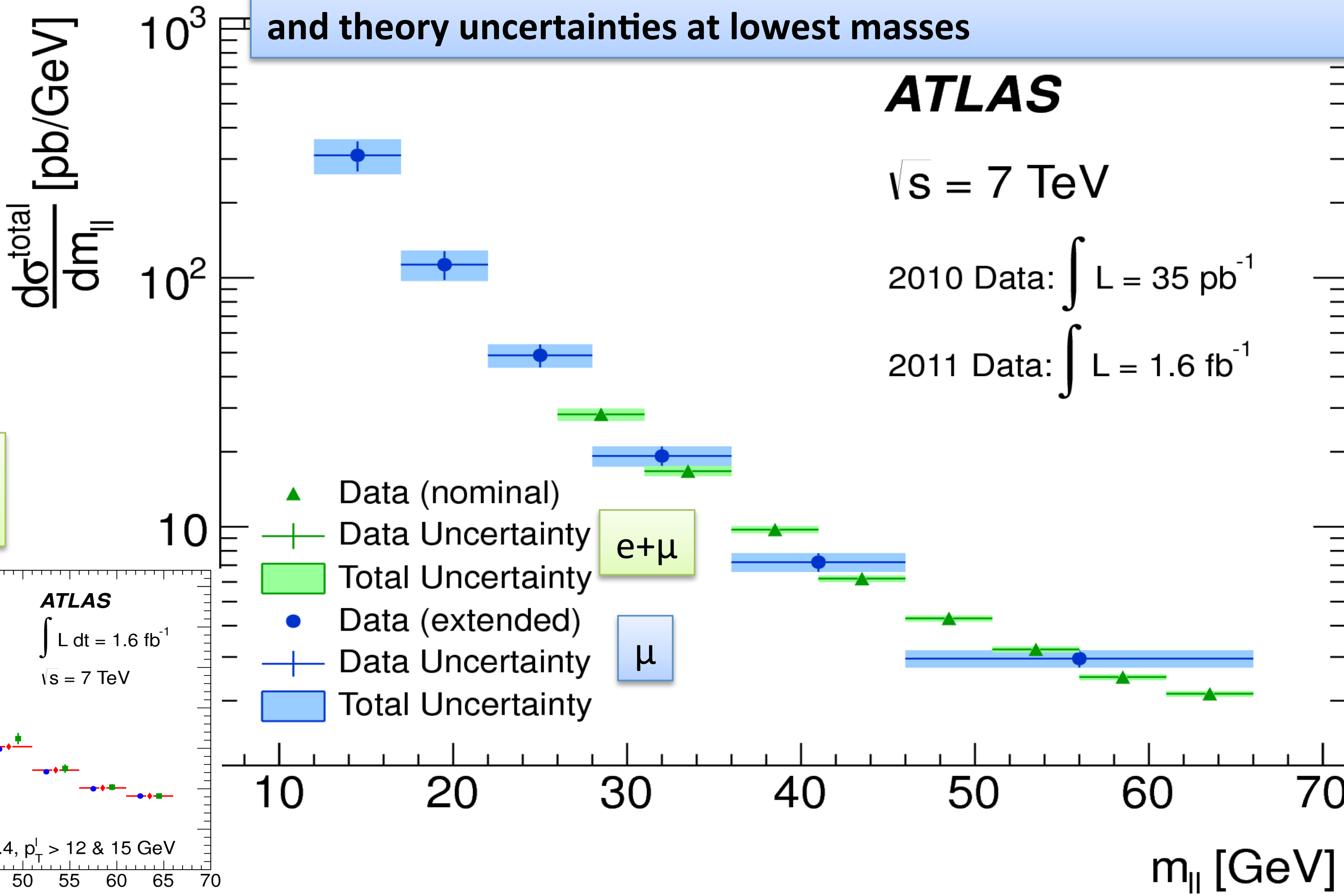




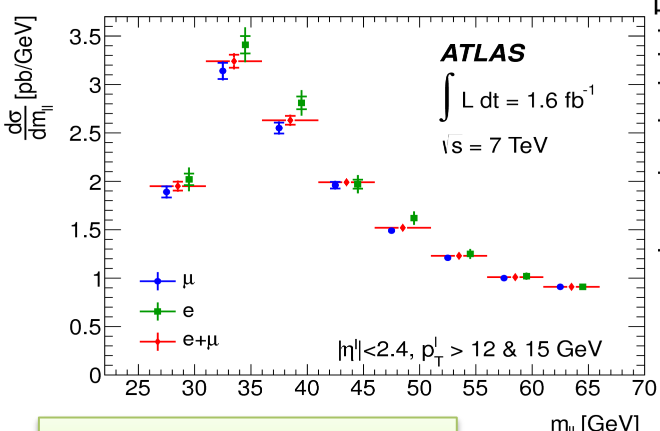


Low Mass Drell-Yan Cross Sections

Extrapolated to full phase space → large acceptance corrections and theory uncertainties at lowest masses



Fiducial e and μ cross sections

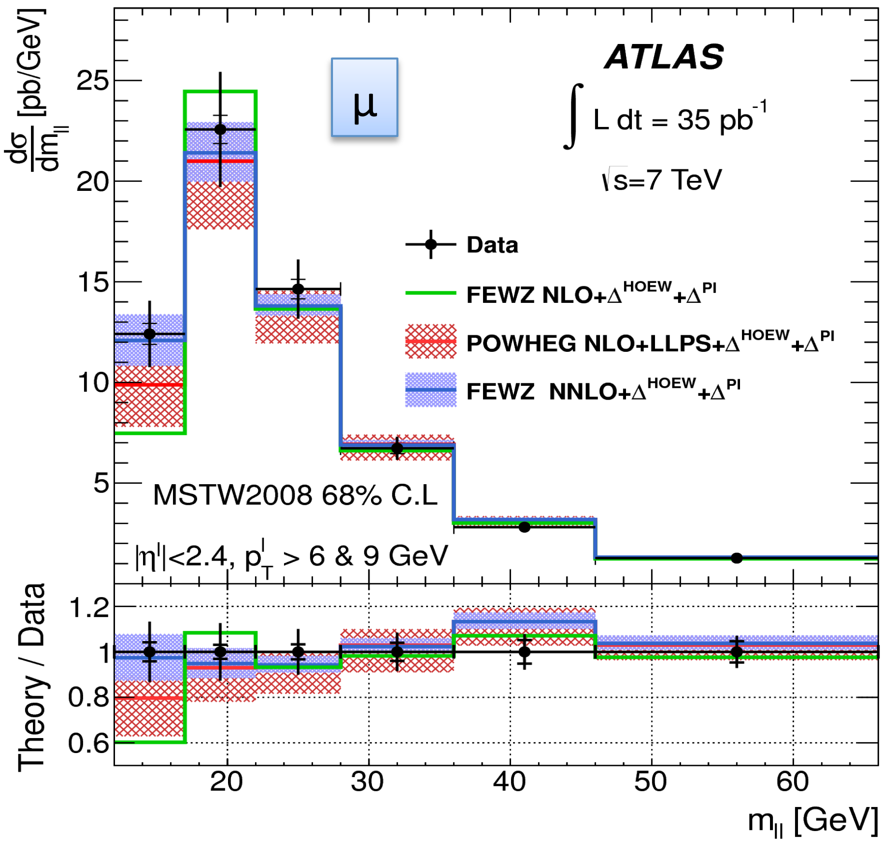


$26 < m_{ll} < 66$ GeV

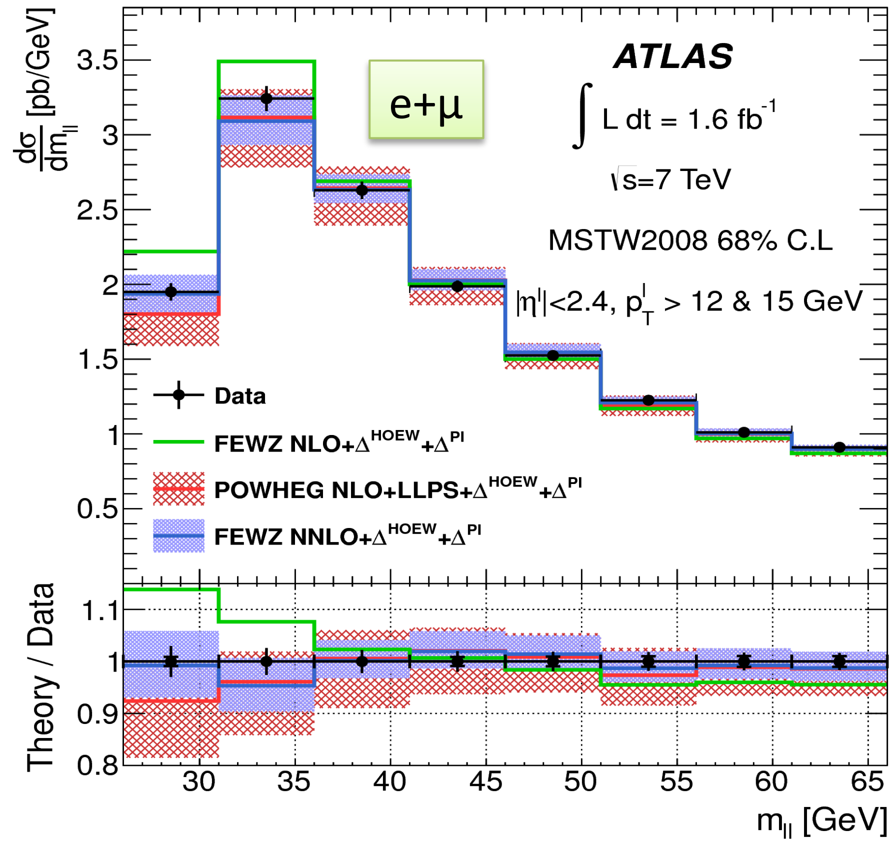
arXiv:1404.1212

Comparisons with Theory

Extended kinematic range 0.035 fb^{-1} (2010)
$12 < m_{\mu\mu} < 66$ GeV
$p_{T,1} > 6$ GeV $p_{T,2} > 9$ GeV $|\eta_\mu| < 2.4$



Nominal kinematic range 1.6 fb^{-1} (2011)
For l=e,μ : $26 < m_{ll} < 66$ GeV
$p_{T,l,1} > 15$ GeV $p_{T,l,2} > 12$ GeV $|\eta_l| < 2.4$



'Born'-level data are well described by NNLO QCD and by NLO QCD matched with parton showers, both calculations include HO EW except QED FSR (1-5%) and photon-induced (MRTS2004qed with two quark mass schemes : 2-3%) contributions **.**

arXiv:1404.1212

Cross Section Results

Nominal kinematic range 1.6 fb^{-1}

For l=e,μ : 26 < m_{ll}< 66 GeV

$p_{T,l,1}$ > 15 GeV $p_{T,l,2}$ > 12 GeV $|\eta_l|$ < 2.4

Unfolded data to 'Born'-level and dressed levels

(D: recombined QED FSR within R(e,γ)<0.1)

→ stat.error of 1% and correlated and uncorrelated systematic uncertainties in the range of 0.6-2.4%

Nominal EW scheme : G_μ

Alternative EW scheme : $\alpha(M_Z)$

HO EW except QED FSR based on NLO QCD, benchmarked FEWZ vs SANC

Theory calculations at 'Born'-level

$m_{\ell\ell}$ [GeV]	Powheg $\frac{d\sigma}{dm_{\ell\ell}}$ [pb/GeV]	Powheg δ^{pdf} [%]	Powheg δ^{scale} [%]	Fewz NLO $\frac{d\sigma}{dm_{\ell\ell}}$ [pb/GeV]	Fewz NLO δ^{pdf} [%]	Fewz NLO δ^{scale} [%]	Fewz NNLO $\frac{d\sigma}{dm_{\ell\ell}}$ [pb/GeV]	Fewz NNLO δ^{pdf} [%]	Fewz NNLO δ^{scale} [%]
26–31	1.80	2.5	$^{+7.3}_{-11.4}$	2.22	2.7	$^{+4.9}_{-7.9}$	1.93	$^{+3.5}_{-2.7}$	5.7
31–36	3.12	2.4	$^{+5.3}_{-10.0}$	3.49	2.7	$^{+4.7}_{-6.3}$	3.04	$^{+3.2}_{-2.5}$	4.5
36–41	2.64	2.3	$^{+4.6}_{-8.8}$	2.69	2.6	$^{+4.1}_{-5.0}$	2.58	$^{+3.1}_{-2.4}$	2.3
41–46	2.03	2.2	$^{+3.5}_{-7.5}$	2.00	2.6	$^{+3.6}_{-4.2}$	1.98	$^{+3.1}_{-2.3}$	2.1
46–51	1.54	1.9	$^{+3.7}_{-6.1}$	1.50	2.5	$^{+3.2}_{-3.5}$	1.51	$^{+3.0}_{-2.2}$	1.7
51–56	1.19	2.4	$^{+4.5}_{-5.1}$	1.17	2.4	$^{+2.8}_{-2.9}$	1.18	$^{+2.9}_{-2.2}$	1.3
56–61	1.00	2.4	$^{+2.3}_{-4.7}$	0.97	2.4	$^{+2.6}_{-2.6}$	0.98	$^{+2.9}_{-2.1}$	1.3
61–66	0.90	2.1	$^{+2.0}_{-4.5}$	0.87	2.3	$^{+2.3}_{-2.3}$	0.88	$^{+2.8}_{-2.1}$	1.2

Table 8. Theory predictions for NLO+LLPS and for fixed-order calculations at NLO and NNLO including higher-order electroweak corrections, for the nominal analysis of the differential cross section $\frac{d\sigma}{dm_{\ell\ell}}$ as a function of the invariant mass $m_{\ell\ell}$. The scale uncertainty is defined as the envelope of variations for $0.5 \leq \mu_R, \mu_F \leq 2$ for Powheg. For Fewz the scale uncertainty is defined by the variation $0.5 \leq \mu_R = \mu_F \leq 2$.

Acceptances calculated with FEWZ NNLO QCD

$m_{\ell\ell}$ [GeV]	$\frac{d\sigma}{dm_{\ell\ell}}$ [pb/GeV]	δ^{stat} [%]	$\mathcal{D}$	$\mathcal{A}$	$\delta^{scale}_{\mathcal{A}}$ [%]	$\delta^{pdf+\alpha_s}_{\mathcal{A}}$ [%]
26–31	1.95	0.9	0.98	0.069	$^{-4.2}_{+4.2}$	$^{-2.0}_{+1.4}$
31–36	3.24	0.7	0.98	0.194	$^{-2.8}_{+3.6}$	$^{-1.6}_{+1.1}$
36–41	2.63	0.8	0.99	0.270	$^{-1.2}_{+1.1}$	$^{-1.4}_{+0.9}$
41–46	1.99	0.9	1.00	0.321	$^{-1.2}_{+1.0}$	$^{-1.2}_{+0.8}$
46–51	1.52	0.9	1.05	0.356	$^{-0.9}_{+0.6}$	$^{-1.0}_{+0.7}$
51–56	1.23	1.0	1.11	0.381	$^{-0.4}_{+0.5}$	$^{-1.0}_{+0.6}$
56–61	1.01	1.0	1.19	0.406	$^{-0.9}_{+0.3}$	$^{-0.9}_{+0.6}$
61–66	0.91	1.0	1.30	0.427	$^{-0.6}_{+0.4}$	$^{-0.8}_{+0.5}$

strong QED FSR effects!

$m_{\ell\ell}$ [GeV]	Δ^{HOEW} [%]	Δ^{PI} [pb/GeV]	δ^{scheme} [%]
26 – 31	1.10	0.005 ± 0.002	+4.6
31 – 36	3.10	0.051 ± 0.018	+1.5
36 – 41	3.92	0.053 ± 0.019	+0.8
41 – 46	4.25	0.045 ± 0.016	+0.5
46 – 51	4.46	0.036 ± 0.013	+0.4
51 – 56	4.43	0.029 ± 0.010	+0.4
56 – 61	4.47	0.023 ± 0.008	+0.3
61 – 66	4.09	0.019 ± 0.007	+0.4

$$\Delta^{HOEW} = \Delta^{HOEW}_{\alpha(M_Z)} - \delta^{scheme}$$

arXiv:1404.1212

Cross Section Results

Extended kinematic range 0.035 fb^{-1}

$12 < m_{\mu\mu} < 66$ GeV

$p_{T,1} > 6$ GeV $p_{T,2} > 9$ GeV $|\eta_\mu| < 2.4$

Unfolded data to 'Born'-level and dressed level:

(D: recombined QED FSR within R(e,γ)<0.1)

→ **stat.error of 3-5% and systematic uncertainties in the range of 5.2-12.6%**

Nominal EW scheme : G_μ

Alternative EW scheme : $\alpha(M_Z)$

HO EW except QED FSR based on NLO QCD

Theory calculations at 'Born'-level

$m_{\ell\ell}$ [GeV]	$\frac{d\sigma}{dm_{\ell\ell}}$ [pb/GeV]	δ^{stat} [%]	δ^{syst} [%]	δ^{tot} [%]	$\mathcal{D}$	$\mathcal{A}$	$\delta^{scale}_{\mathcal{A}}$ [%]	$\delta^{pdf+\alpha_s}_{\mathcal{A}}$ [%]
12–17	12.41	4.2	12.6	13.3	1.00	0.04	$^{-7.1}_{+7.5}$	$^{-4.1}_{+2.7}$
17–22	22.57	3.1	12.3	12.7	0.98	0.20	$^{-3.7}_{+4.2}$	$^{-3.0}_{+2.0}$
22–28	14.64	3.3	9.5	10.0	0.98	0.30	$^{-0.4}_{+0.8}$	$^{-2.3}_{+1.6}$
28–36	6.73	4.0	7.4	8.5	0.99	0.35	$^{-0.3}_{+0.3}$	$^{-1.8}_{+1.2}$
36–46	2.81	5.2	5.7	7.8	1.02	0.39	$^{-0.3}_{+0.4}$	$^{-1.3}_{+0.9}$
46–66	1.27	4.7	5.2	7.1	1.16	0.43	$^{-0.4}_{+0.7}$	$^{-1.0}_{+0.6}$

QED FSR effects!

	POWHEG			FEWZ NLO			FEWZ NNLO		
$m_{\mu\mu}$ [GeV]	$\frac{d\sigma}{dm_{\mu\mu}}$ [pb/GeV]	δ^{pdf} [%]	δ^{scale} [%]	$\frac{d\sigma}{dm_{\mu\mu}}$ [pb/GeV]	δ^{pdf} [%]	δ^{scale} [%]	$\frac{d\sigma}{dm_{\mu\mu}}$ [pb/GeV]	$\delta^{pdf+\alpha_s}$ [%]	δ^{scale} [%]
12–17	9.88	2.3	$^{+12.3}_{-20.9}$	7.47	2.7	$^{+10.7}_{-15.8}$	12.09	$^{+3.7}_{-3.0}$	10.0
17–22	20.99	2.6	$^{+8.4}_{-15.6}$	24.46	3.0	$^{+10.1}_{-13.3}$	21.22	$^{+3.7}_{-2.8}$	6.1
22–28	13.69	2.6	$^{+5.5}_{-12.1}$	13.65	2.9	$^{+6.2}_{-8.6}$	13.56	$^{+3.4}_{-2.6}$	2.3
28–36	6.92	2.3	$^{+6.2}_{-10.8}$	6.61	2.7	$^{+5.0}_{-6.5}$	6.74	$^{+3.3}_{-2.5}$	1.3
36–46	3.18	2.3	$^{+4.4}_{-8.6}$	3.01	2.6	$^{+4.0}_{-4.4}$	3.10	$^{+3.1}_{-2.3}$	1.2
46–66	1.31	2.2	$^{+2.9}_{-5.7}$	1.24	2.4	$^{+2.8}_{-3.0}$	1.28	$^{+2.9}_{-2.1}$	1.3

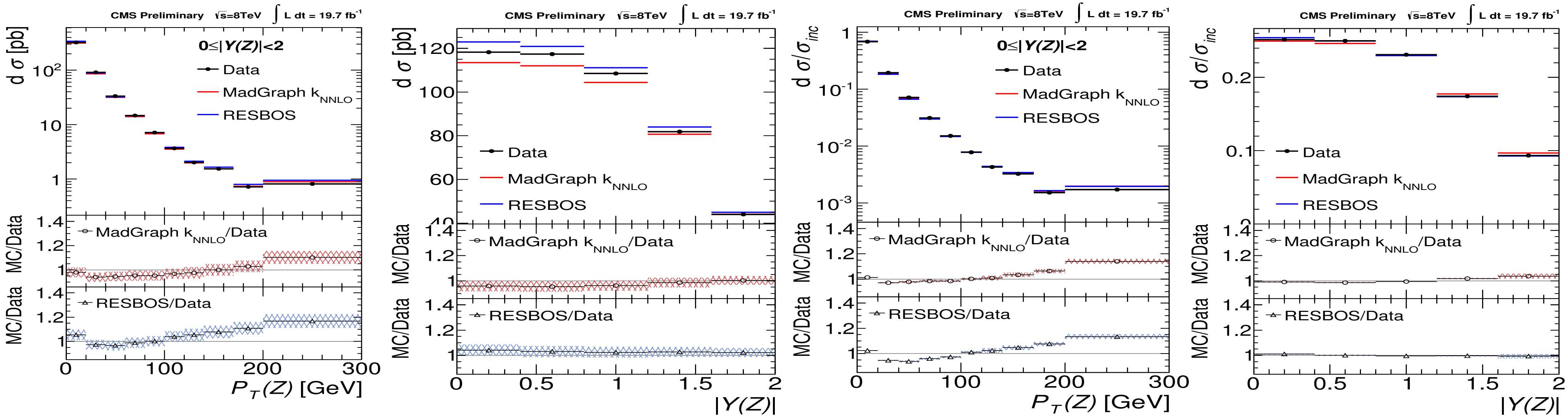
$m_{\ell\ell}$ [GeV]	Δ^{HOEW} [%]	Δ^{PI} [pb/GeV]	δ^{scheme} [%]
12 – 17	0.37	0.000 ± 0.000	+5.4
17 – 22	1.58	0.190 ± 0.070	+3.2
22 – 28	3.04	0.240 ± 0.087	+0.9
28 – 36	3.77	0.150 ± 0.054	+0.5
36 – 46	4.38	0.085 ± 0.030	+0.3
46 – 66	4.64	0.037 ± 0.013	+0.2

- Fixed order based predictions HO QCD and EW predictions show significant uncertainties in the presence of rather harsh kinematic cuts and significant acceptance corrections.
- Large QED FSR effects underneath the Z-peak (as expected) --> QED FSR modelling.

3) 8 TeV differential cross-section $P_T(Z^0)$,$Y(Z^0)$

CMS-PAS-SMP 13-013 : Z→ μμ

absolute cross-section | normalized cross-section



- 5 bins in $Y(Z^0)$, 10 in $P_T(Z^0)$, QED FSR corrected
- Experimental uncertainties of preliminary results on absolute cross sections are ~3% and for normalised cross sections ~1%
- O(%) total experimental uncertainties
- no theoretical uncertainties evaluated yet → theory uncertainty consideration from external papers
- for discussion : optimal scale choice and scale uncertainties

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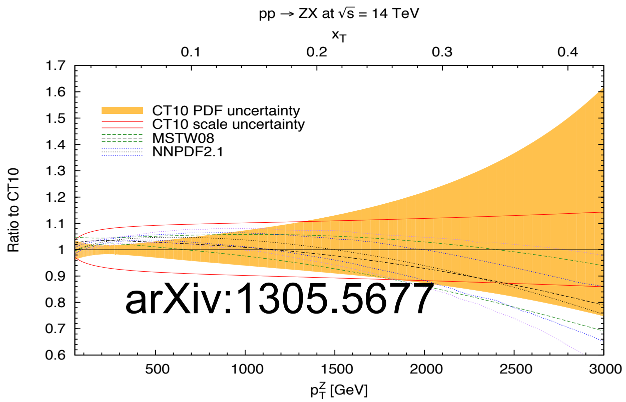
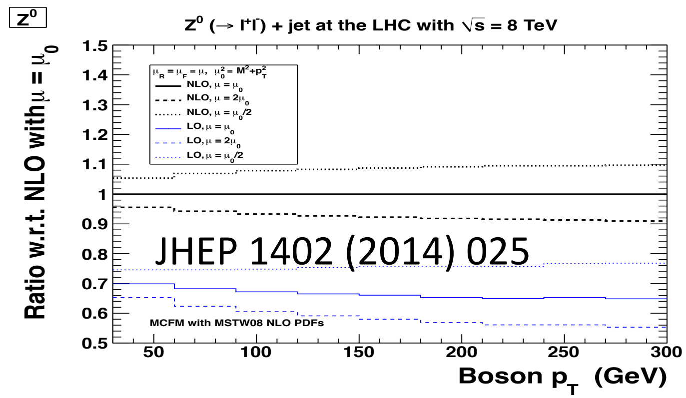
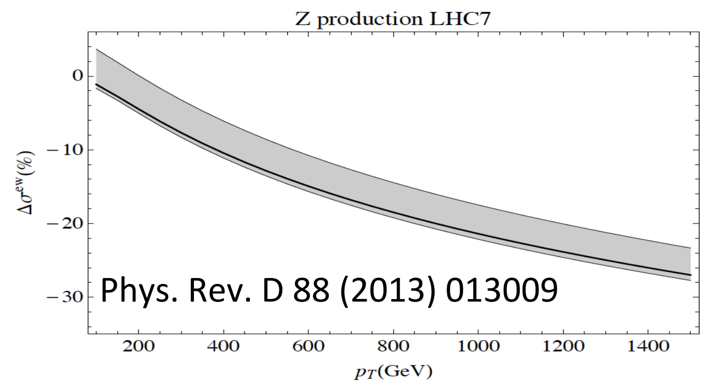
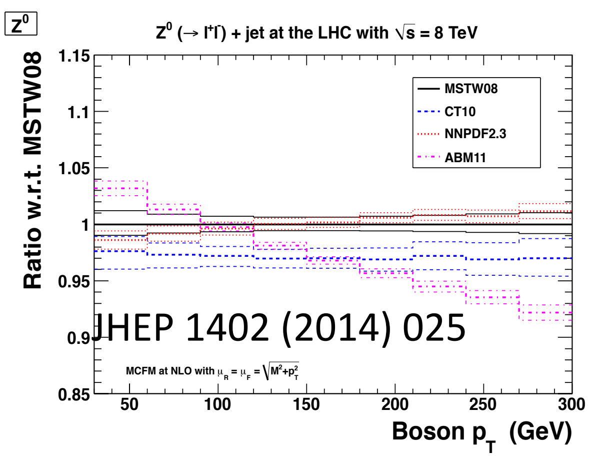
Theory considerations









- Scale uncertainties (Z^0+jet NLO)
- EWK correction
- PDF uncertainty (gluon)

The theory uncertainties are LARGER than the experimental uncertainties following those papers

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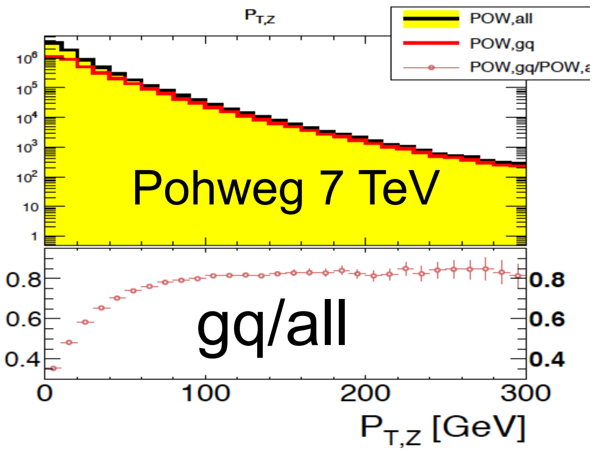
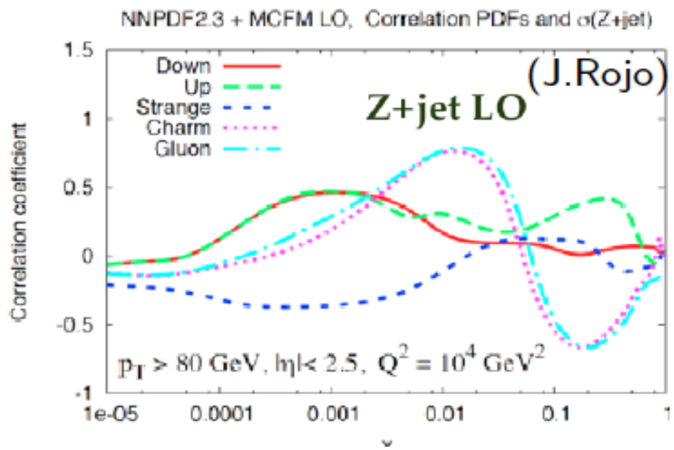
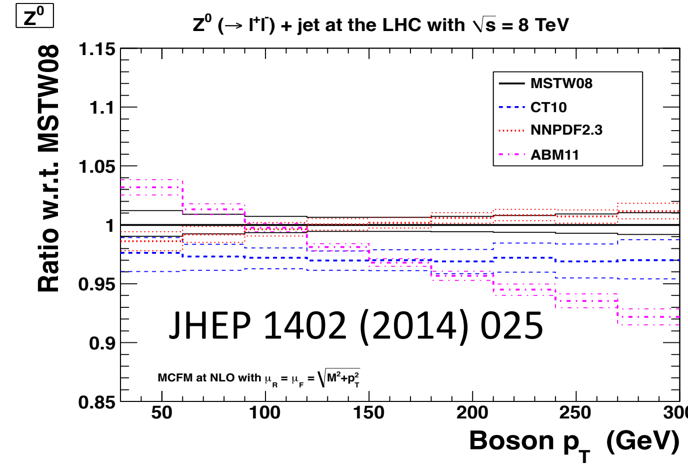
High $P_T(Z^0)$ for gluon PDF constraint?





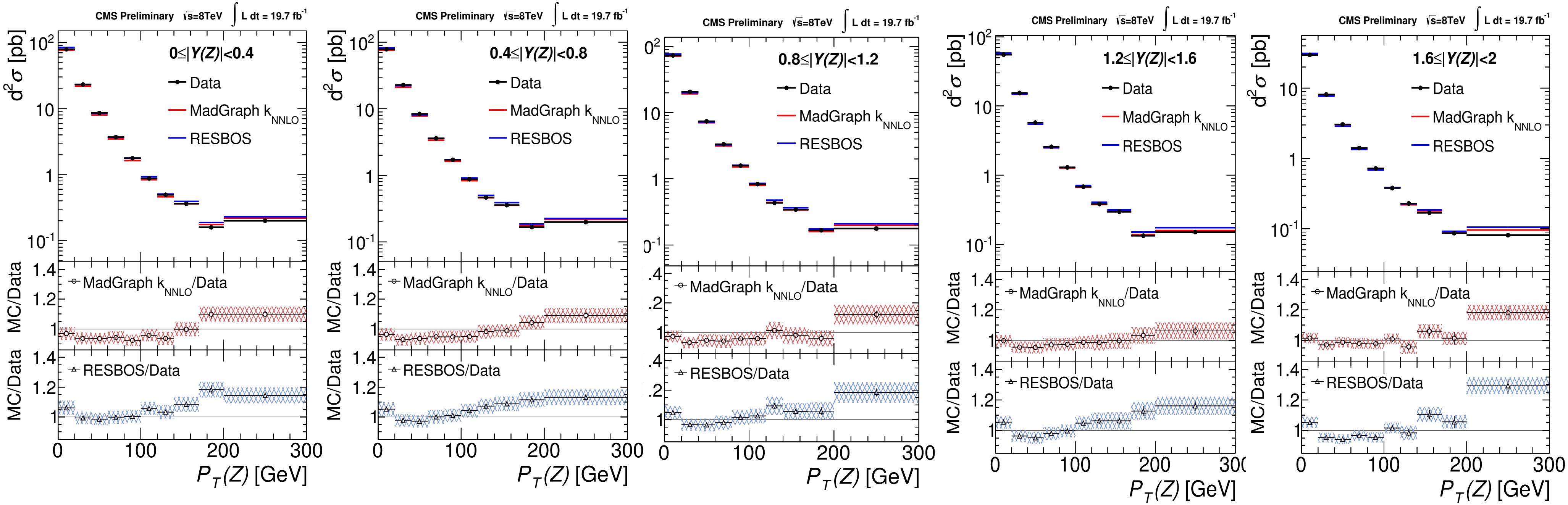


- High $P_T(Z^0)$ dominated by qg
- (gluon) PDF uncertainty is a few % at high $P_T(Z^0)$

Discussion within PDF community of possibility to use $P_T(Z)$ in the future to constrain gluon pdf

Z+jet@(NNLO+NLO EWK) could be useful in PDF fits in future if theory is well under control (and if there are no search surprises …)

Absolute cross-section in |Y|(Z^0) bins



Similar trend ($\mathcal{O}$(10%)) that theory calculations over-predict across Y(Z^0)
Note : Theory is not corrected for 'missing' HO EW effects (HO EW except QED FSR) – preliminary comparisons

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A wish list for discussion & studies

.. some tasks are already under study also in LPCC and EW experimental and theory WG's

- ➔ "optimal" choice (and documentation) of EW parameters and SM inputs for *matched* QCD and EW calculations for consistency of data-theory comparisons and data unfolding → sensible choice of SM inputs

- ➔ optimal choices for QCD scales and scale uncertainty evaluations : should be done by experiments or external theory papers? Scale uncertainties are sensitive to fiducial cuts.

- ❖ Precision evaluation of 'missing' HO EW (ISR, interferences, weak) corrections and QED FSR modelling : application of 'missing' HO EW corrections and remaining systematics, QED FSR systematic uncertainties for off-peak DY production : Is the publication of the 'dressed' corrections useful?

A wish list for discussion & studies

.. some tasks are already under study also in LPCC and EW experimental and theory WG's

- Improved modelling of $p_T(W,Z)$: implementation of resummation into NLO MC models (but e.g also control of resummation scale) → do we need 'resummed PDFs' or 'MC PDFs' ?

- NEW HO QCD (N^3LO for inclusive DY) and 'missing' HO EW for $p^T_{Z,W}$

→ 'missing' HO EW corrections (+systematics) for more complex kinematic variables like phi*(Z), $M_T(W)$, W polarisation, also in the presence of kinematic cuts

- Precision off-peak Drell-Yan : Improved modelling and measurement proposals for non-resonant photon-induced dilepton productions, but also for the <u>NLO</u> gamma-p induced dilepton and W productions (all photon PDFs are currently LO determinations anyway)

Additional Material

Weak Mixing Angle $\sin^2\theta_W^{eff}$

Leptonic effective weak mixing angle measurement:

- based on raw A_{FB} spectra
- MC (PYTHIA) A_{FB} spectra generated with values of $0.218 \leq \sin^2\theta_W^{eff} \leq 0.238$ (default 0.232) to calculate weights in bins of m_{ll} and $\cos\theta^*_{CS}$
- weights used to create templates for various weak mixing angle values and reconstruct raw A_{FB} spectra
- compare predicted and measured raw asymmetries (X^2 test) over A_{FB} mass range $70 < m_{ll} < 250$ GeV.

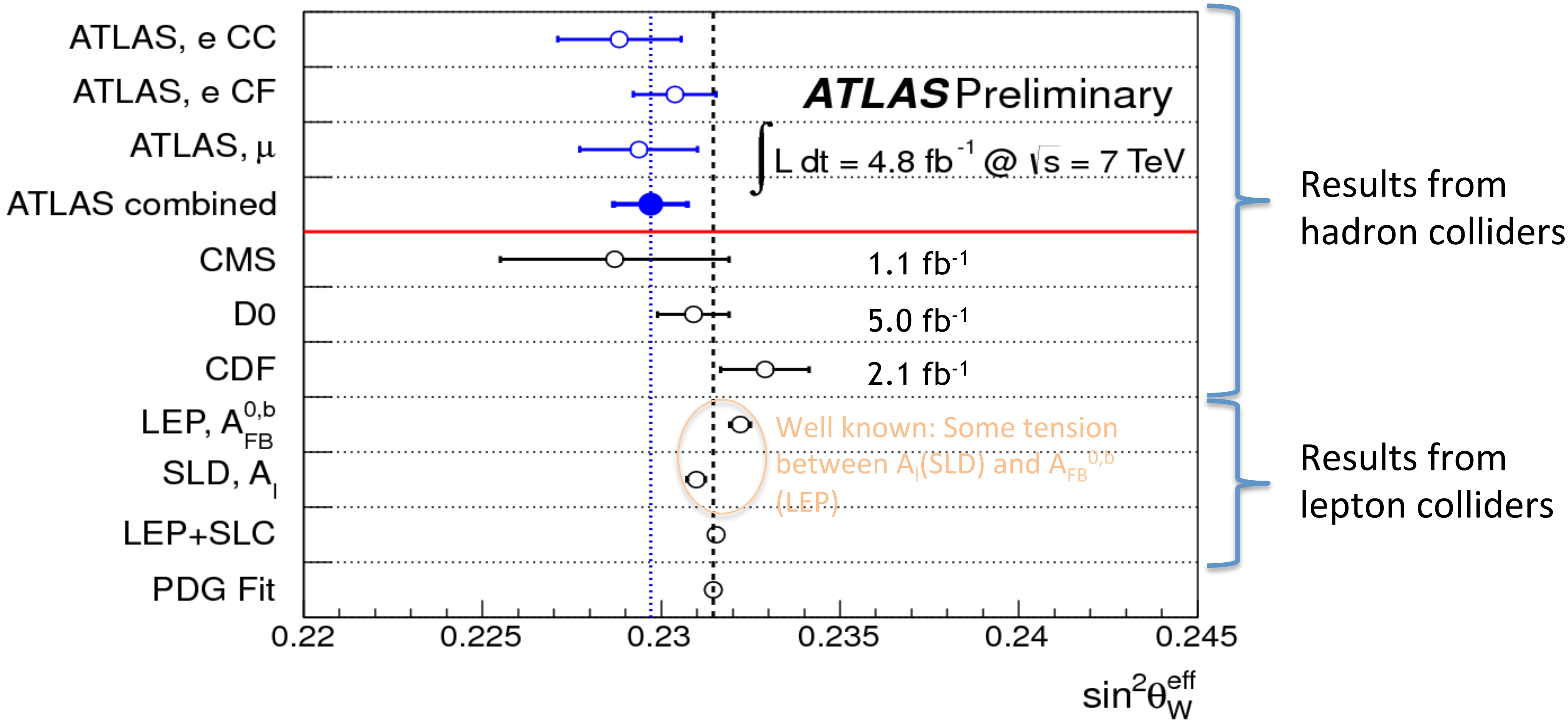
Systematic uncertainties from

- unfolding (checked with a data re-weighting procedure),
- MC dependence and higher order QCD and EW corrections,
- PDFs, MC statistics,
- backgrounds and other experimental effects.

Uncertainty source	CC electrons (10^{-4})	CF electrons (10^{-4})	Muons (10^{-4})	Combined (10^{-4})
PDF	9	5	9	7
MC statistics	9	5	9	4
Electron energy scale	4	6	–	4
Electron energy smearing	4	5	–	3
Muon energy scale	–	–	5	2
Higher-order corrections	3	1	3	2
Other sources	1	1	2	2

→ Dominant uncertainty due to PDFs is correlated between the three measurements.

Weak Mixing Angle $\sin^2\theta_W^{eff}$



ATLAS measurement for A_{FB} mass range 70 < m_{ll} < 250 GeV :

$$\sin^2\theta_W^{eff} = 0.2297 \pm 0.0004(\text{stat.}) \pm 0.0009(\text{syst.}) = 0.2297 \pm 0.0010(\text{tot.})$$

First hadron collider e and μ results combined results !

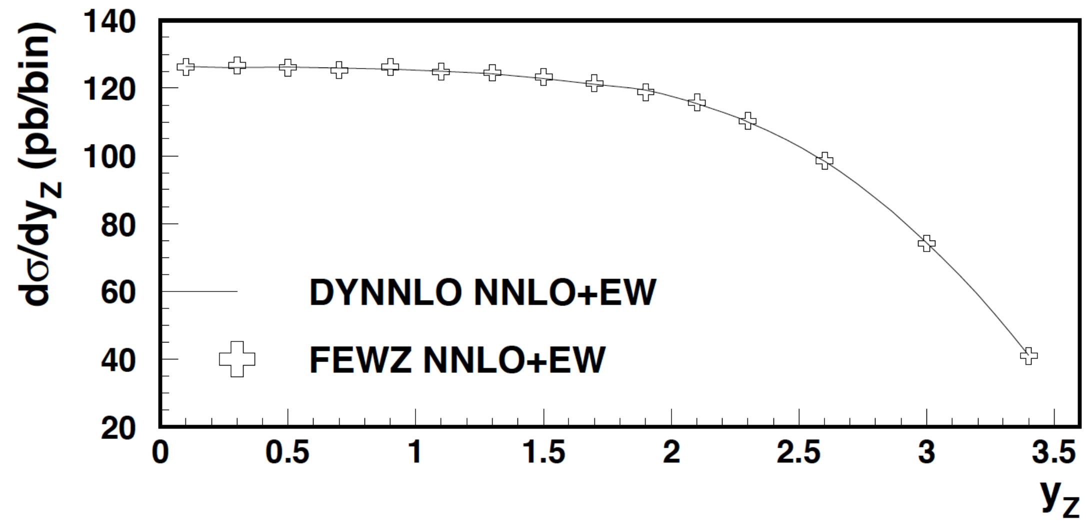
→ in agreement within 1.8σ with PDG global fit value.

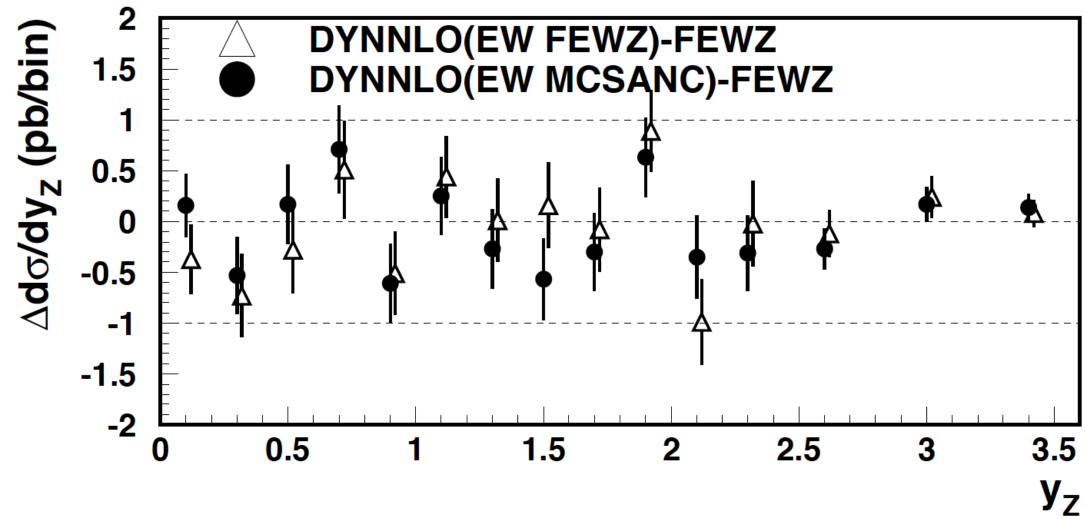
NC DY : 66-116 GeV NNLO QCD+NLO missing EW predictions for yz

U. Klein, Les Houches
arXiv:1405.1067

High precision
NC DY yZ predictions
using
either missing EW
(FEWZ) or missing EW
(MCSANC)
applied in additive
way to the NNLO QCD
DYNNLO y_Z prediction

→ method works and can be used also for CC DY
→ using there also additive vs factored results





Photon induced (PI) updated

U. Klein, Les Houches
arXiv:1405.1067

- Discussion with R Thorne and G Watt at Dec '12 PDF4LHC meeting

➔ new MRST2004qed grid which contains an alternative input model for the photon in the proton obtained by evolution from an effective quark mass, :

➔ model 1 : based on current masses of 6 and 10 MeV

➔ model 2 : based on constituent masses of 300MeV → hence ALWAYS smaller

Max. deviation of model 2 w.r.t. model 1 is 80% at highest masses

➔ New proposal (also supported by R. Thorne):

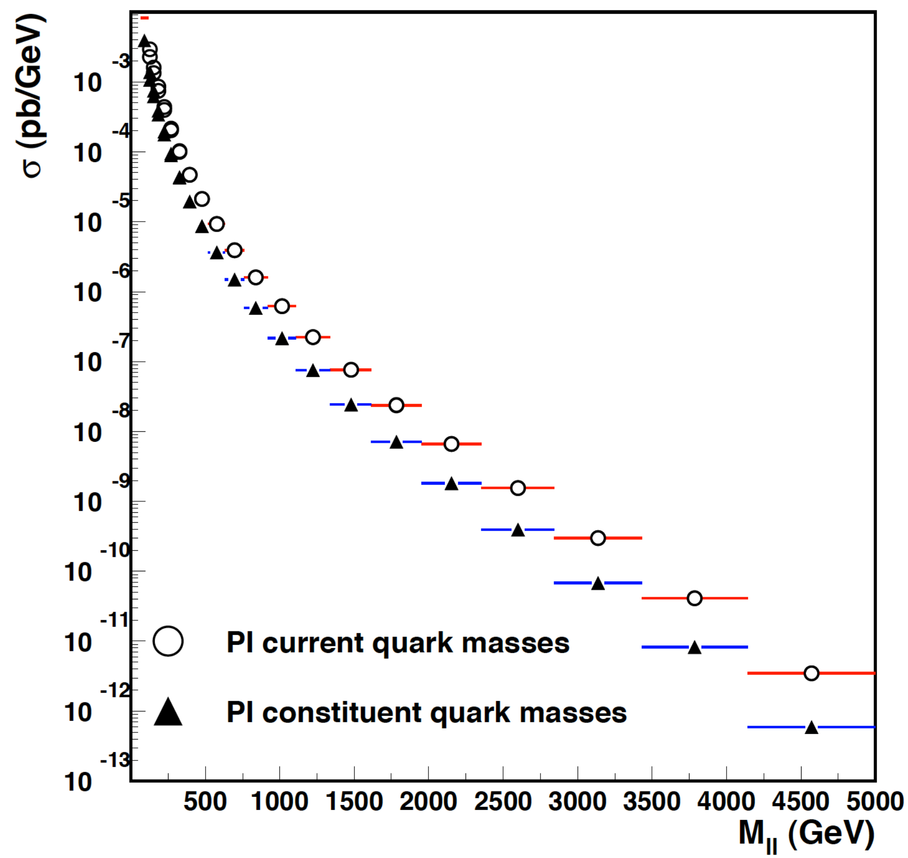
Take the mean of both and use symmetric 'uncertainties'

- Plot : PI with pT>25, |η|<2.5 for both models

➔plot for 8 TeV for illustration

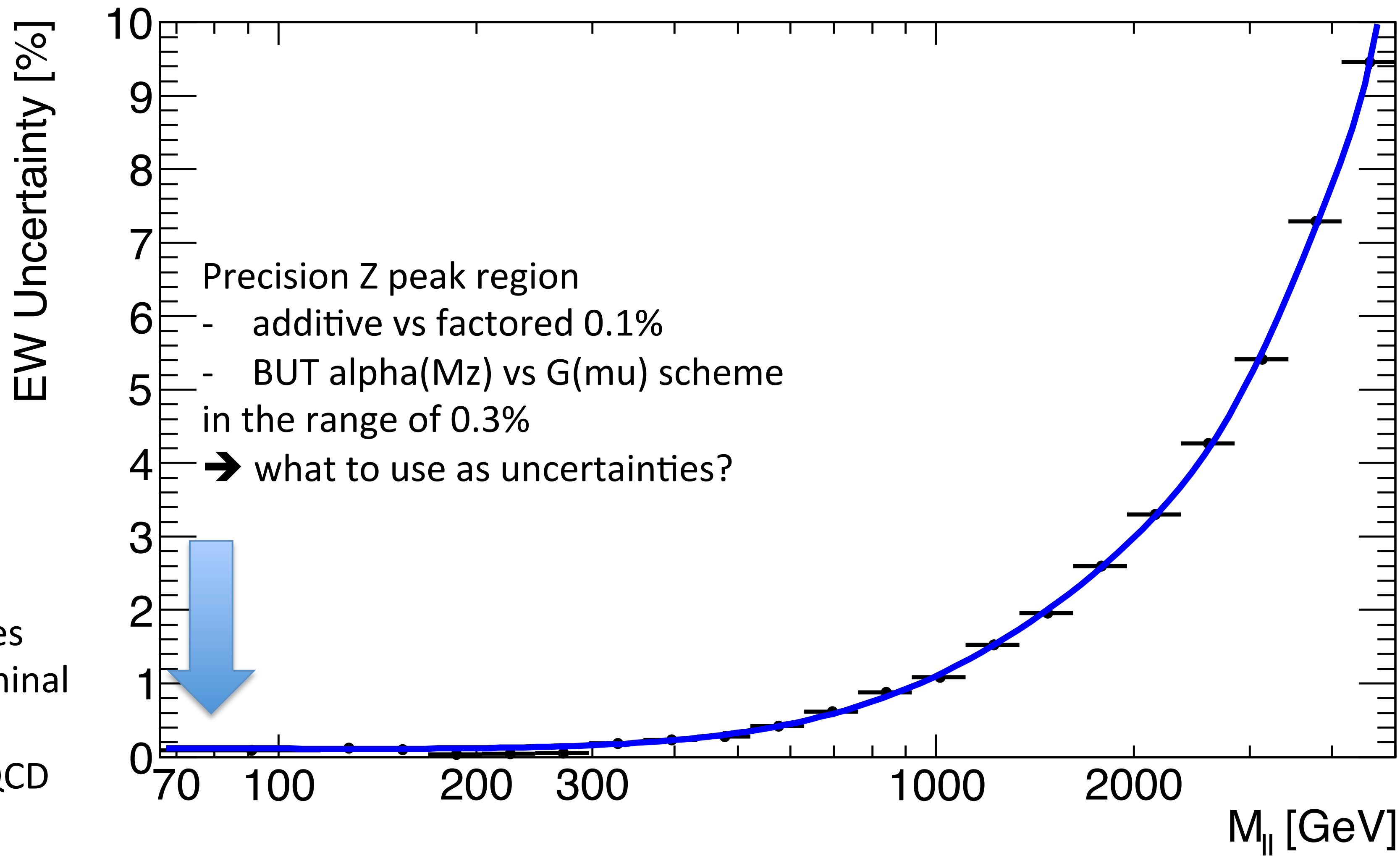
➔SAME procedure for SM (low mass, high mass and Z peak region NC DY) and Z' searches (NC DY is the background)

➔ NLO PI : small w.r.t. present errors (few % and scale dep)



U. Klein, Les Houches
arXiv:1405.1067

NC DY missing EW 'systematics'



→ applied as symmetric uncertainties around nominal missing EW corrected QCD prediction (nominal : additive)

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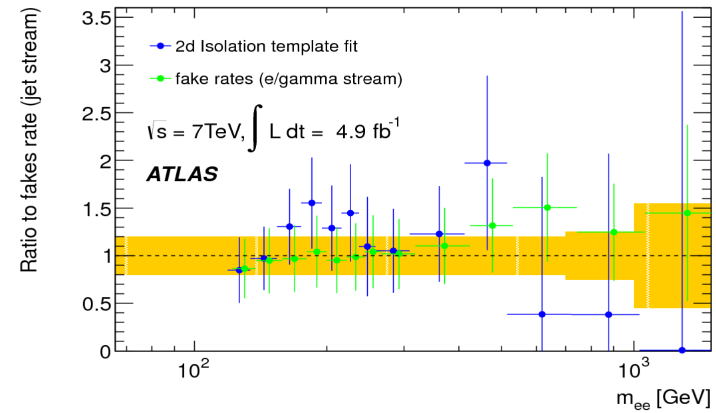
L= 4.9 fb^{-1}

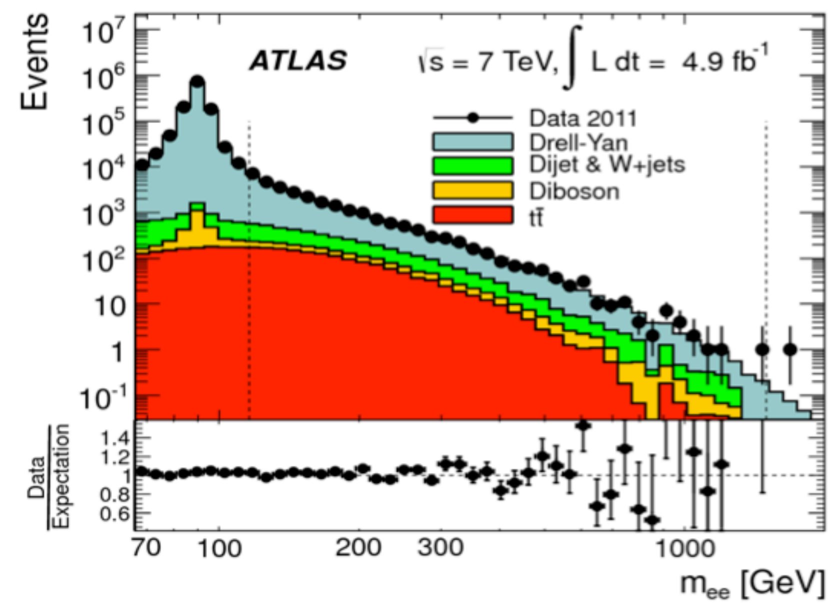
High Mass Drell-Yan

$Z/\gamma^* \rightarrow e^+e^-$

- SM cross-sections measured for $p_{T,e}$ > 25 GeV $|\eta_e|$ < 2.5 and 116 < m_{ee} < 1500 GeV
- Main backgrounds from dijet and W+jets (6-16%), derived from data measuring the jet-to-electron fake rate in jet-enriched control sample



Source of uncertainty	Uncertainty [%] in m_{ee} bin	
	116–130 GeV	1000–1500 GeV
Total background estimate (stat.)	0.1	7.6
Total background estimate (syst.)	1.3	3.1
Electron energy scale & resolution	2.1	3.3
Electron identification	2.3	2.5
Electron reconstruction	1.6	1.7
Bin-by-bin correction	1.5	1.5
Trigger efficiency	0.8	0.8
MC statistics (C_{DY} stat.)	0.7	0.4
MC modelling	0.2	0.3
Theoretical uncertainty	0.3	0.4
Total systematic uncertainty	4.2	9.8
Luminosity uncertainty	1.8	1.8
Data statistical uncertainty	1.1	50



Note that based on the update of the ATLAS Luminosity measurement (EPJ C73 (2013) 2518) the measured cross-sections given here and in the paper need to be scaled up by 1.4%. The luminosity uncertainty stays at the previous value of 1.8%.

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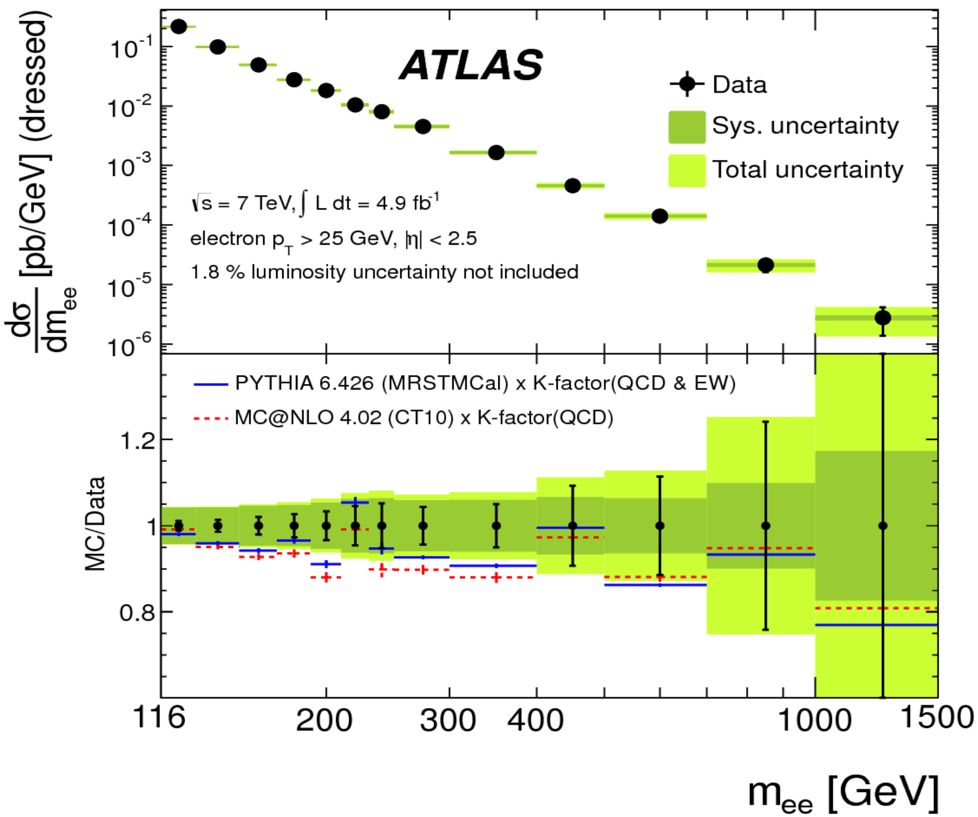
L= 4.9 fb^{-1}

High Mass Drell-Yan Cross Sections

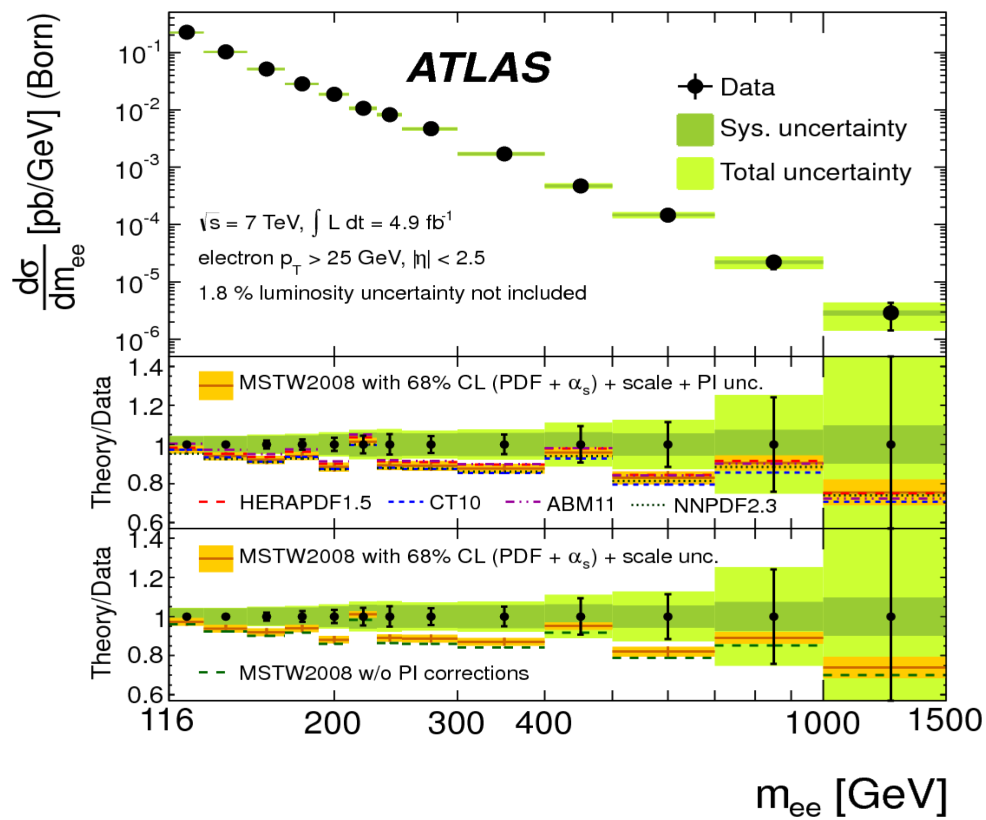
Unfolded to 'dressed-level'

- corrected for detector effects and recombined QED FSR within R(e,γ)<0.1
- comparisons with Monte Carlo simulations normalised to number of data events and k-factors as indicated
- photon-induced processes are not included



Unfolded to 'Born-level'

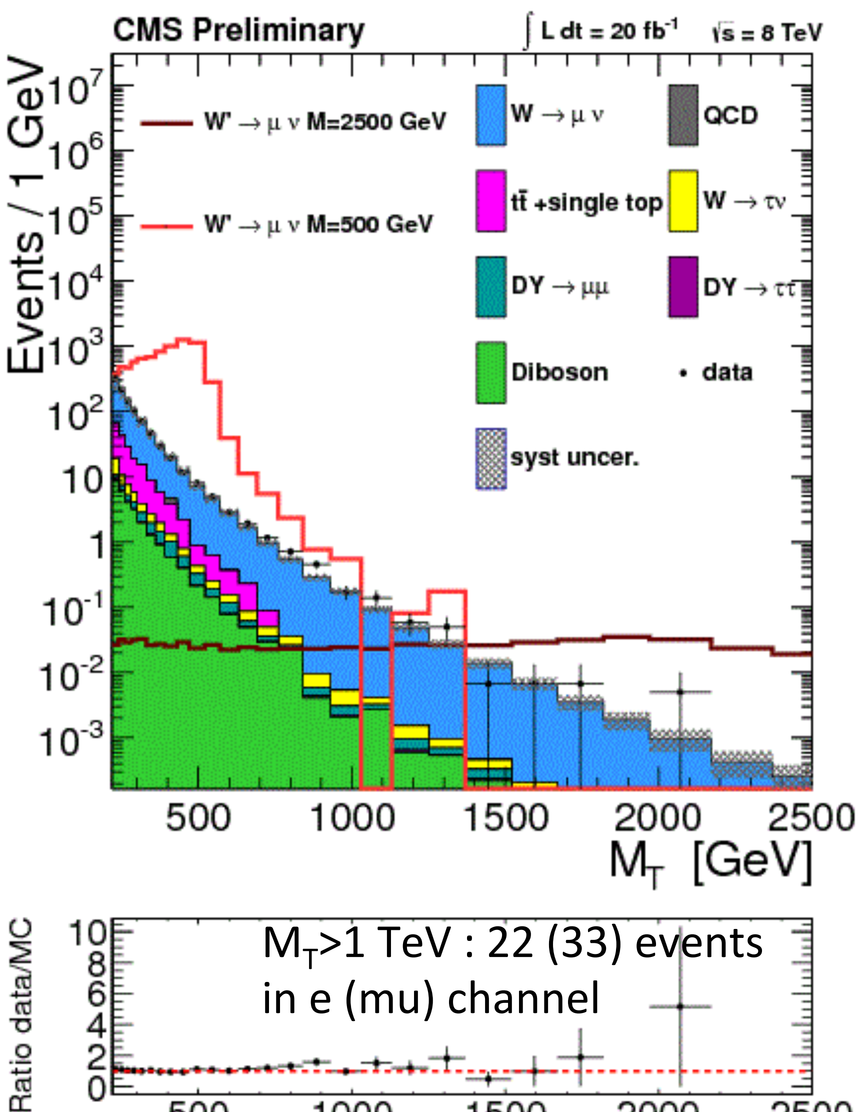
- corrected for detector effects and QED FSR
- comparison to fixed order pQCD NNLO QCD predictions using recent NNLO PDFs, including HO EW except QED FSR corrections, photon-induced contributions (1-8%) and real W and Z radiation (0.1-2%).



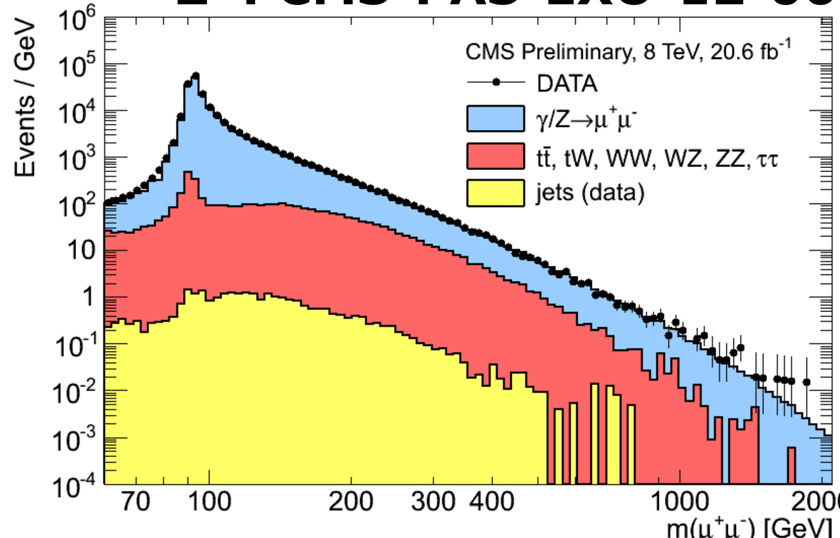
20 fb^{-1}

Searches at 8 TeV

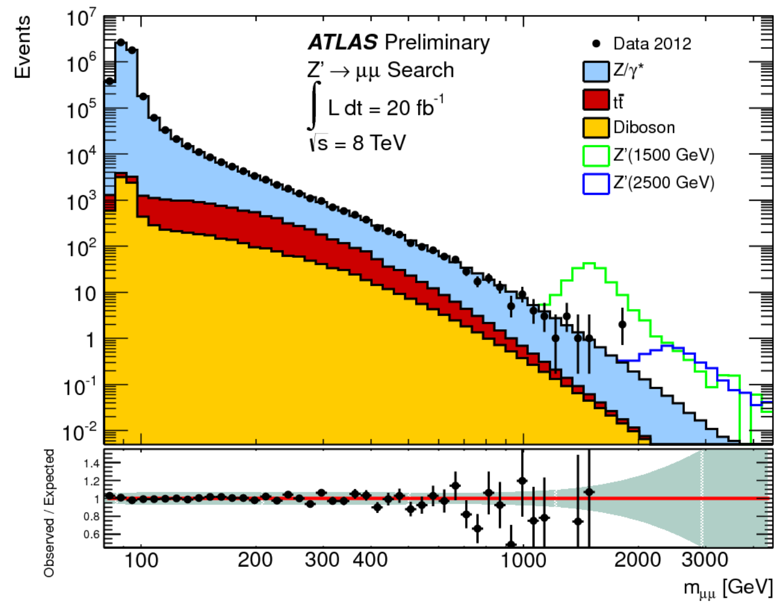
W': CMS-PAS-EXO-12-060



Z' : CMS-PAS-EXO-12-061



Z' : ATLAS-CONF-2013-017



shaded band: mass-dep. bgd. syst.