Measurements of differential Drell-Yan cross sections with the ATLAS detector

Elena Yatsenko (LAPP/CNRS)
on behalf of the ATLAS collaboration

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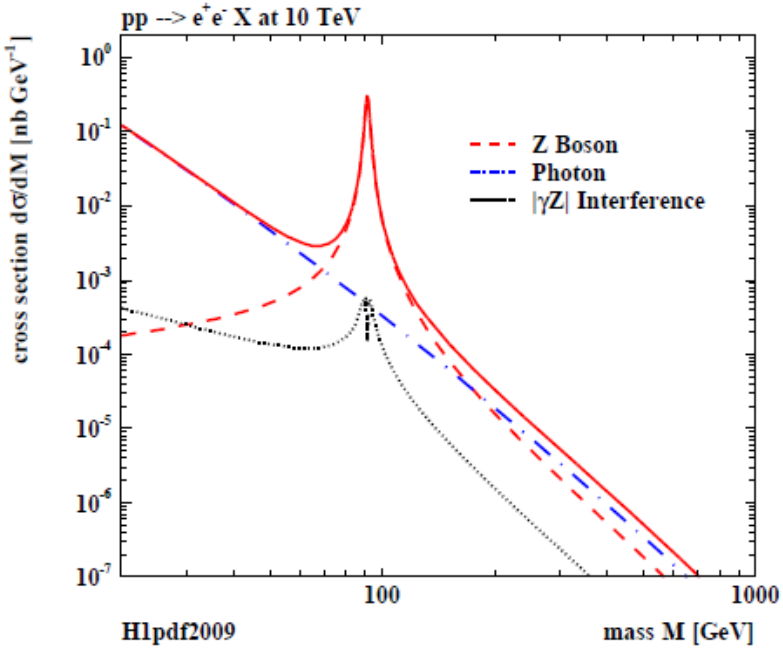
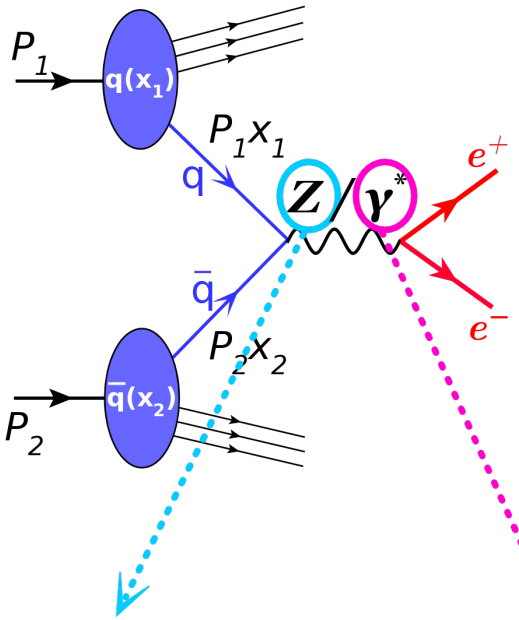
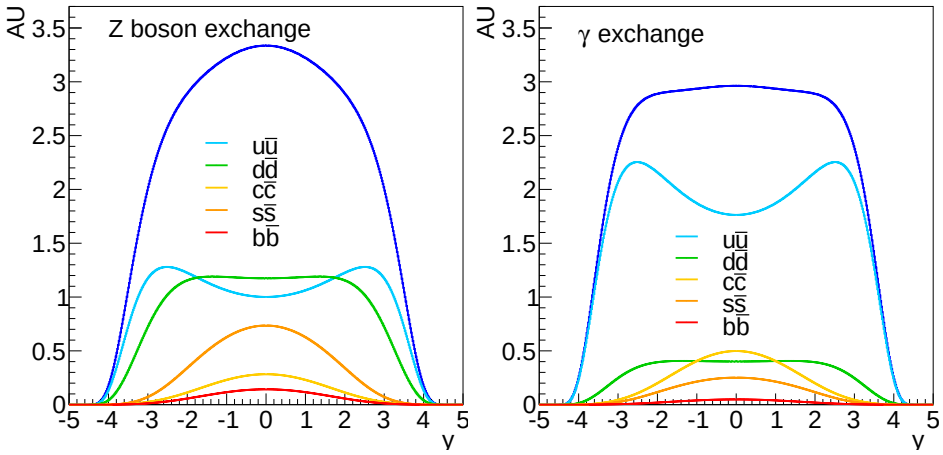
Introduction

- Below and above the Z mass peak the Drell-Yan cross-section is dominated by a virtual photon exchange.



- Measurements in **low and high mass** regions are complementary to the Z peak cross-section.
- These regions have different sensitivity to the up-type, down-type and anti-quark densities.





$$\sigma_{\gamma^*} \sim 0.44(u\bar{u} + c\bar{c}) + 0.11(d\bar{d} + s\bar{s} + b\bar{b})$$
$$\sigma_Z \sim 0.29(u\bar{u} + c\bar{c}) + 0.37(d\bar{d} + s\bar{s} + b\bar{b})$$

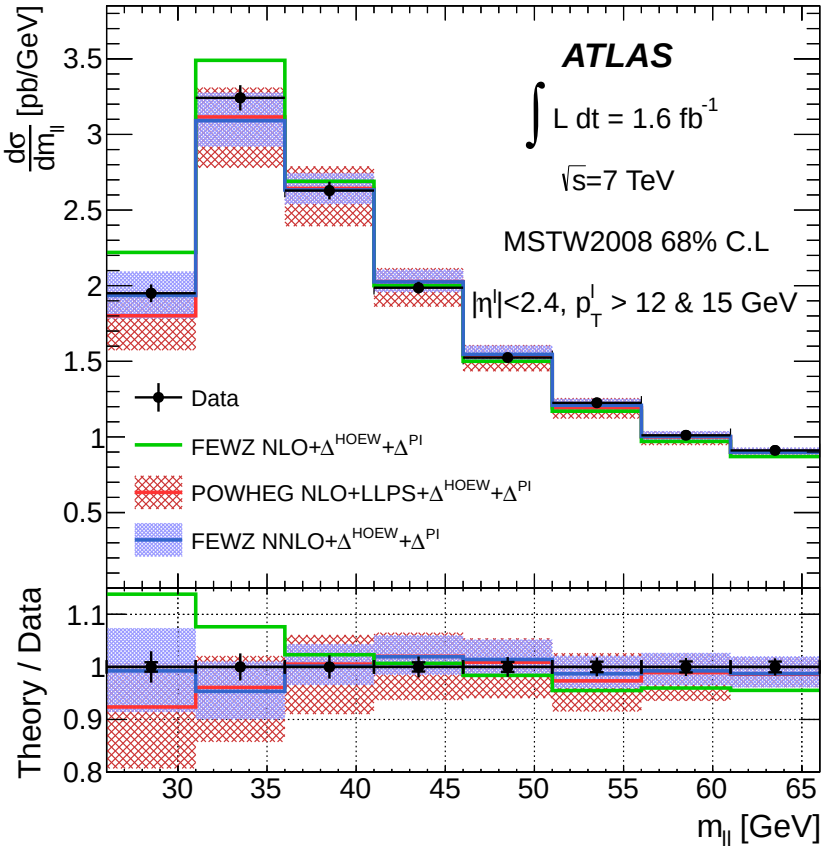
Low mass Drell-Yan measurement at 7 TeV JHEP 06 (2014) 112

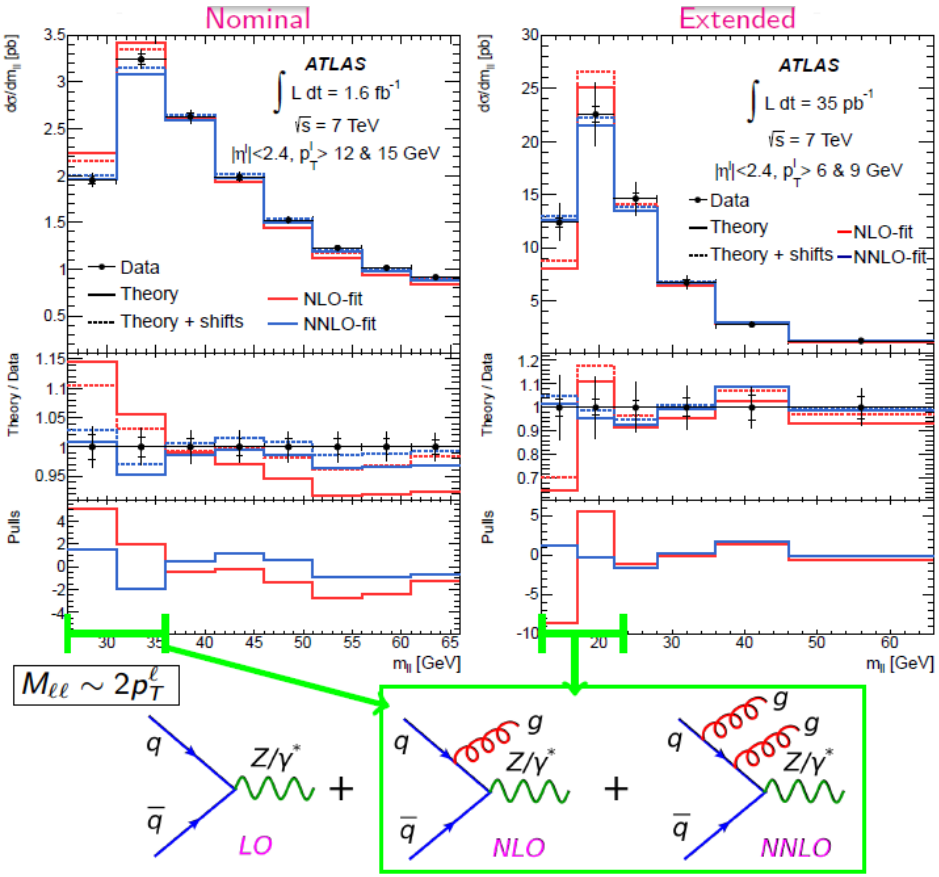
The measurement is made with two setups:

1. *Nominal*: $26 < M_{\ell\ell} < 66$ GeV ($\ell = \mu, e$) with 1.6 fb^{-1} 2011 data
2. *Extended*: $12 < M_{\mu\mu} < 66$ GeV with 35 pb^{-1} of 2010 data.

Precision: **1.6 - 3.0%** (nominal), **7 - 13%** (extended)

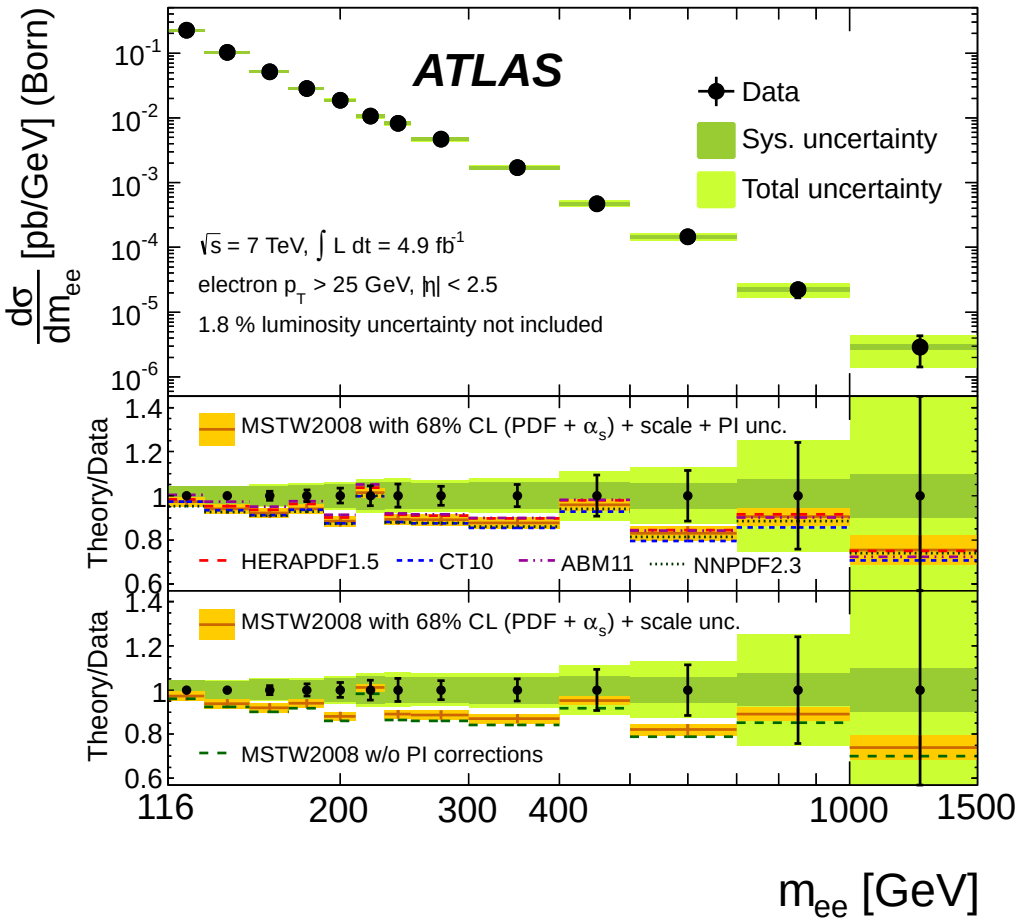
QCD analysis of the data is performed by including the data in the NLO and NNLO fits of HERA DIS data.





High mass Drell-Yan measurement at 7 TeV Phys.Lett.B 725(2013)

- The high mass Drell-Yan region was first measured by ATLAS at $\sqrt{s} = 7$ TeV using 4.9 fb^{-1} of 2011 data.
- Single differential measurement in mass range $116 - 1500$ GeV in electron channel.
- Precision: Systematic unc. **4.2% - 9.8%**
  Statistical unc. **1.1% - 50%**.



High mass Drell-Yan measurement at 8 TeV

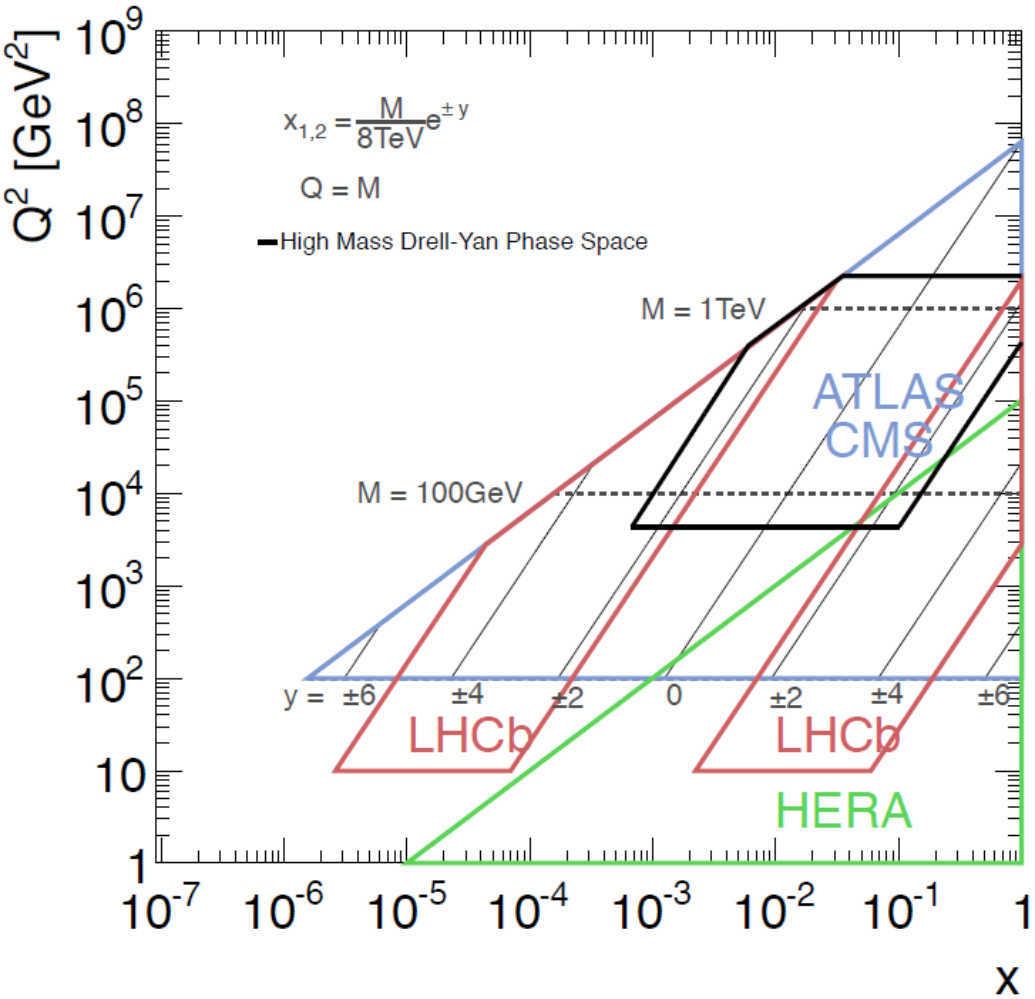
"Measurement of the double-differential high-mass Drell-Yan cross section in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector" *new

$116 < M_{\ell\ell} < 1500$ GeV ($\ell = \mu, e$)

Goals of the measurement:

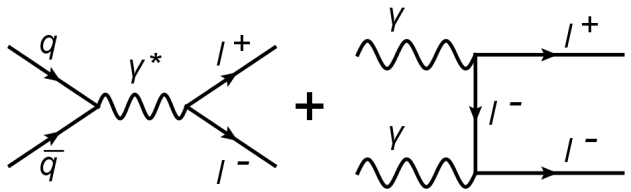
1. **Double differential** cross-section $\frac{d^2\sigma}{dM_{\ell\ell}d|y_{\ell\ell}|}$ and $\frac{d^2\sigma}{dM_{\ell\ell}d|\Delta\eta_{\ell\ell}|}$
2. $M_{\ell\ell}$ differential cross-section

- Extension of (x, Q^2) kinematic plane towards higher x
  => Possibility to constrain poorly known **large x** anti-quark PDFs.
- Sensitivity to photon induced process $\gamma\gamma \to \ell\ell$
  => Sensitivity to the largely unconstrained photon PDFs.



High mass Drell-Yan: selection

The cross-section for the Drell-Yan and photon induced processes is measured in the electron and muon channels.



- 20.3 fb^{-1} of $\sqrt{s} = 8$ TeV data

Fiducial region:

- $116 < M_{\ell\ell} < 1500$ GeV ($\ell = \mu, e$)
- $p_T^{\ell,\text{lead.}} > 40$ GeV, $p_T^{\ell,\text{sub-lead.}} > 30$ GeV
- $|\eta^\ell| < 2.5$

The measured dimensions:

$\frac{d^2\sigma}{dM_{\ell\ell}d|y_{\ell\ell}|}$:

- sensitivity for PDF constrains in a new kinematic region (x from 10^{-3} to ~ 1).
- Increase of photon induced process contribution at small $|y_{\ell\ell}|$ and large $M_{\ell\ell}$.

$\frac{d^2\sigma}{dM_{\ell\ell}d|\Delta\eta_{\ell\ell}|}$:

- is measured for the first time!
- Increase of photon induced process contribution at large $|\Delta\eta_{\ell\ell}|$ and large $M_{\ell\ell}$.

High mass Drell-Yan: uncertainties of the measurement

The dominant sources of uncertainties:

Electron channel

- Determination of the multijet and $W + jets$ background (**1% - 5%**).
- Energy scale: $<$ **0.5%** - **4%**
- Top background estimate (up to **4%**).

Muon channel

- Top background estimate (up to **3.5%**)
- Reconstruction efficiency correction: **0.5%** - **1%**.
- Muon momentum scale calibration **0.4%**.

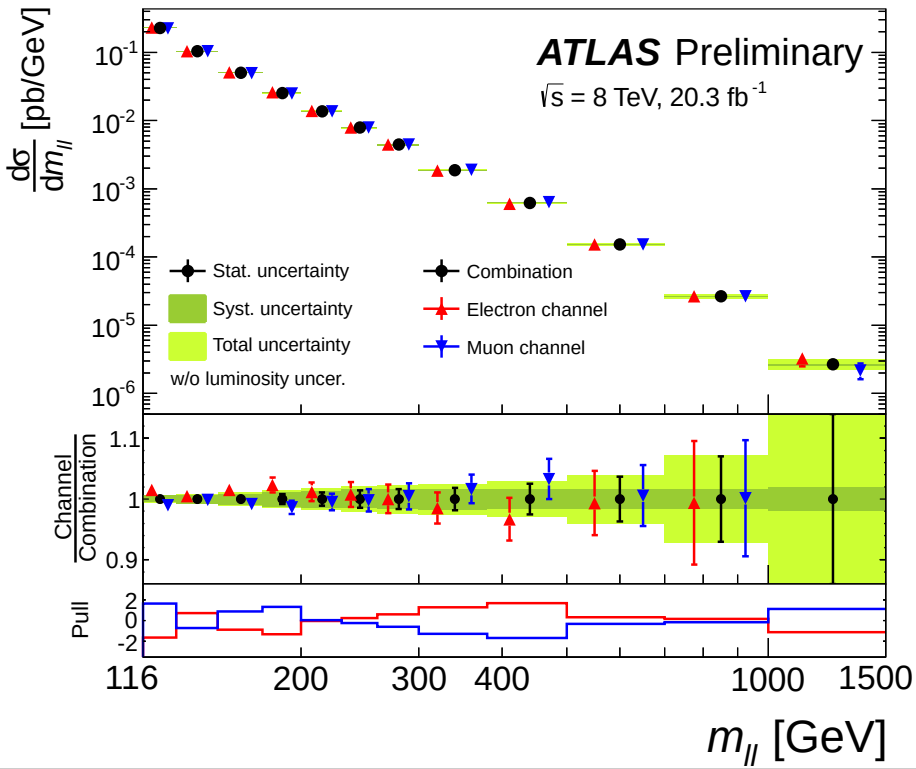
Two channels are combined using χ^2 minimization technique

Statistical uncertainty is *significantly reduced* **1.1%** - **50%** at 7 TeV $\rightarrow$ **0.3%** - **17%** at 8 TeV

Systematic uncertainty 0.5% - 3%.

Experimental precision of the combined cross-section is better than **1%** at low $M_{\ell\ell}$ (excl. luminosity uncertainty of 1.9%).

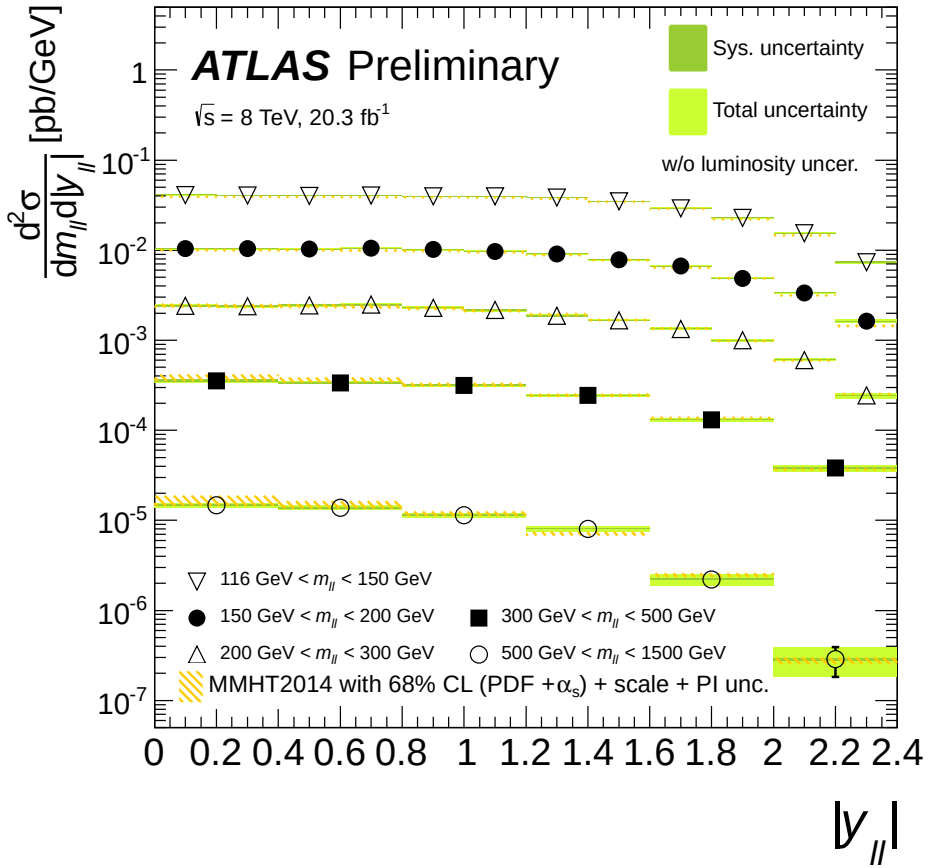
Precision of double-differential measurements: **1%** - **7%** (syst.), 1% - 36% (stat.).

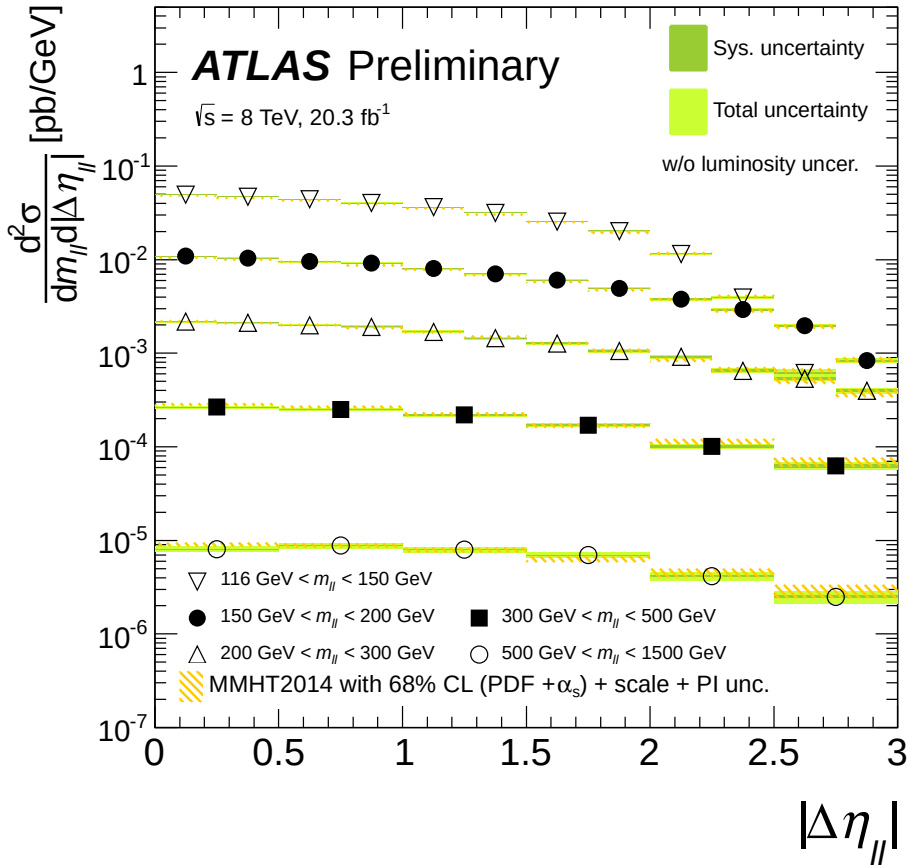


High mass Drell-Yan: results and comparison to theory I/II

The measured cross-sections are compared to NNLO QCD predictions using FEWZ 3.1:

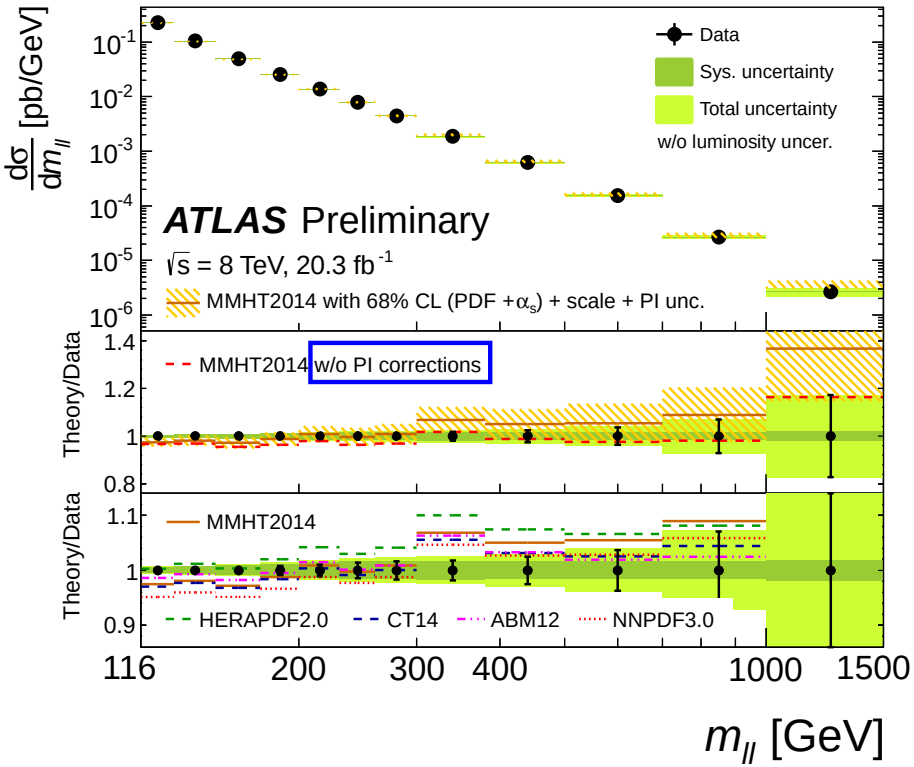
- MMHT14NNLO PDF
- NLO EW corrections are included
- Photon induced contribution is included (at LO), using NNPDF2.3QED photon PDF
- G_μ electroweak scheme
- $\mu_R = \mu_F = M_{\ell\ell}$

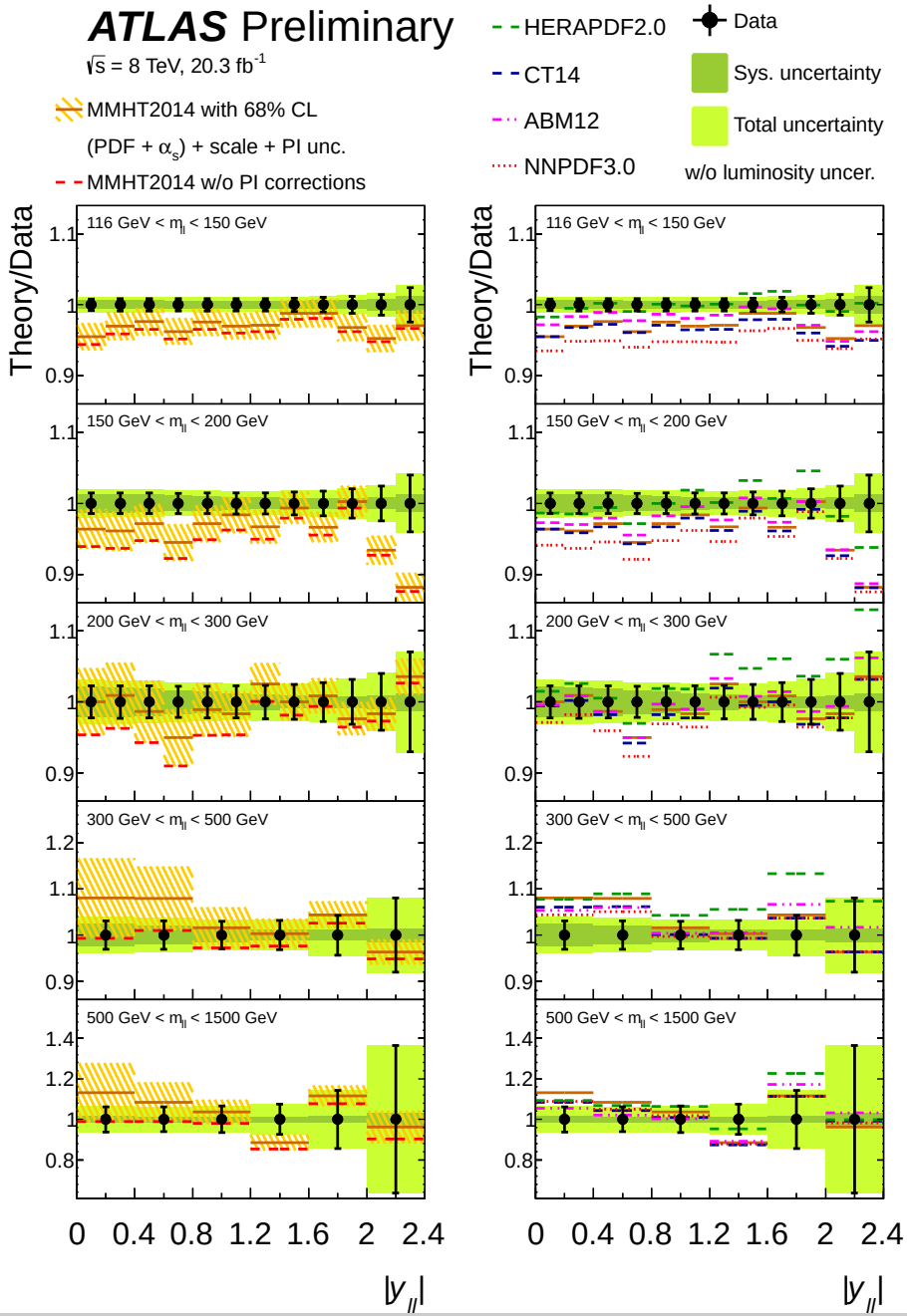




High mass Drell-Yan: results and comparison to theory II/II

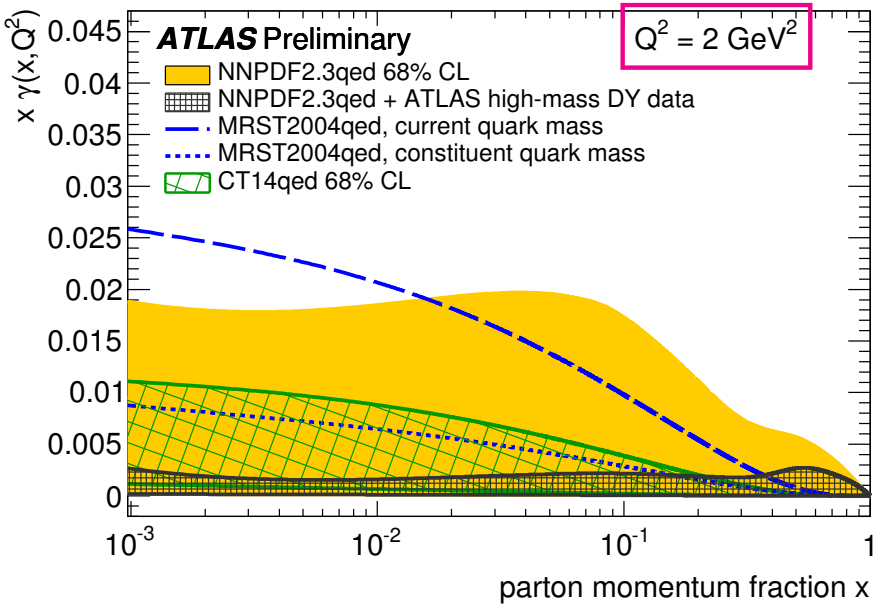
- The measured cross-sections are compared to theoretical predictions using a selection of recent PDFs.
- Theory uncertainties are larger than measurement uncertainties
  => potential for PDF constraints.
- Photon induced contribution reaches 15%.

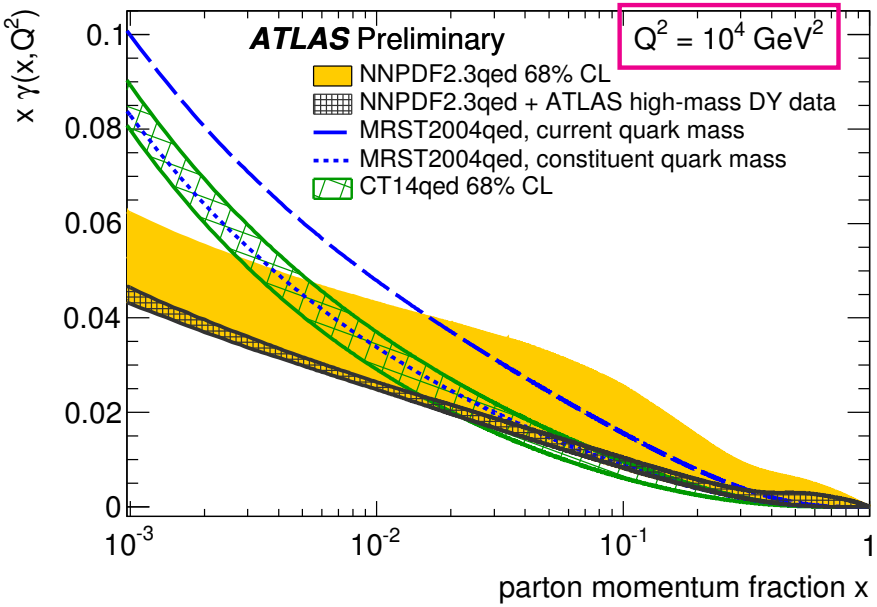




High mass Drell-Yan: photon PDFs

- The measured data are compatible with all modern proton PDFs, when photon PDF is fixed to NNPDF2.3QED.
- However, the data can yield more information on the photon PDF.
- An impact of the data on photon PDF is studied using Bayesian reweighting on MC replicas of NNPDF2.3QED with fixed MMHT14NNLO PDF.
- Each replica is weighted using χ^2 value, which indicates it's compatibility with the data.





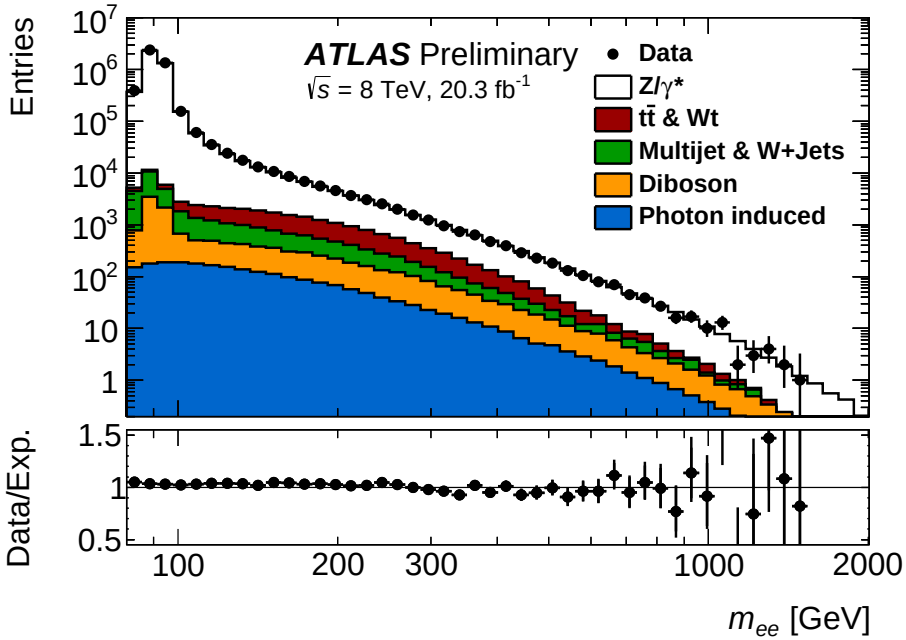
- The observed significant reduction of uncertainties confirms the **strong sensitivity of the data to the photon PDF**.

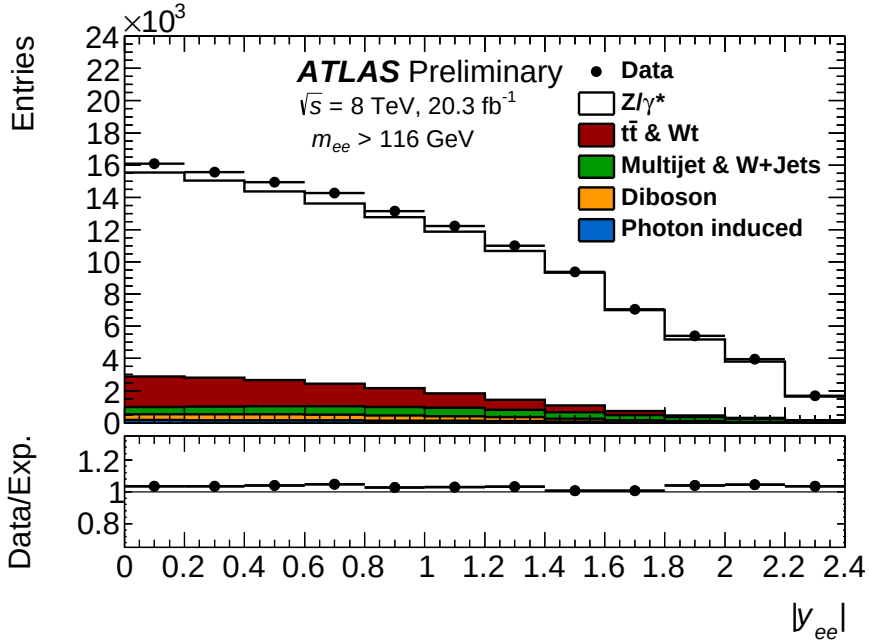
Conclusions

- The ATLAS neutral current Drell-Yan measurements cover the invariant dilepton mass range between 12 and 1500 GeV.
- The measurements agree well with the NNLO QCD calculations corrected for higher-order electroweak effects.
- High mass DY measurement at 8 TeV: the theoretical uncertainties arising from PDFs, the choice of scales and a variation of α_S are found to be larger than the measurement uncertainties, indicating potential for **proton PDF** constrains.
- The potential of the High mass Drell-Yan data for dramatic reduction of **photon PDF** uncertainties is demonstrated.

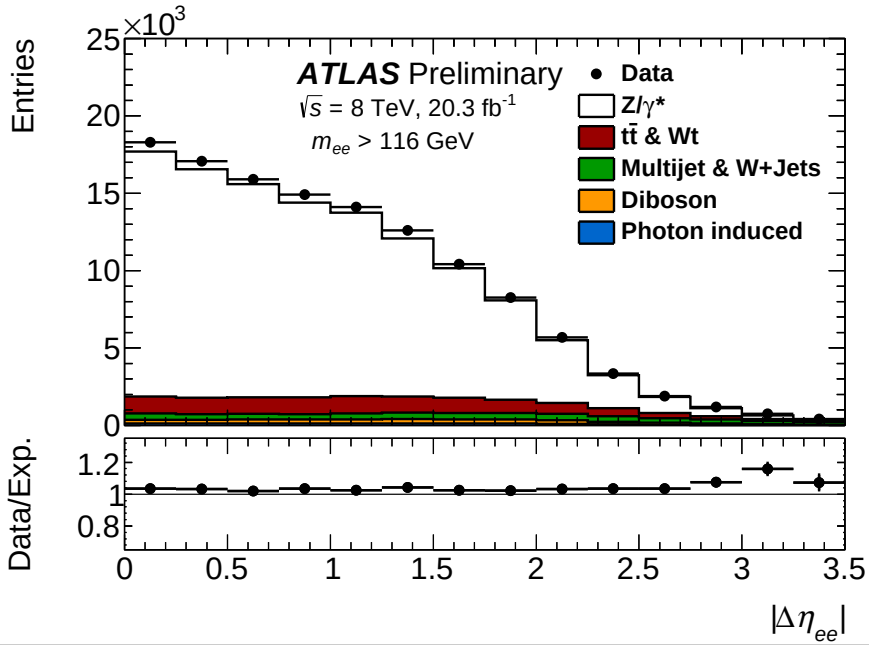
Backup slides

High mass Drell-Yan: background estimate

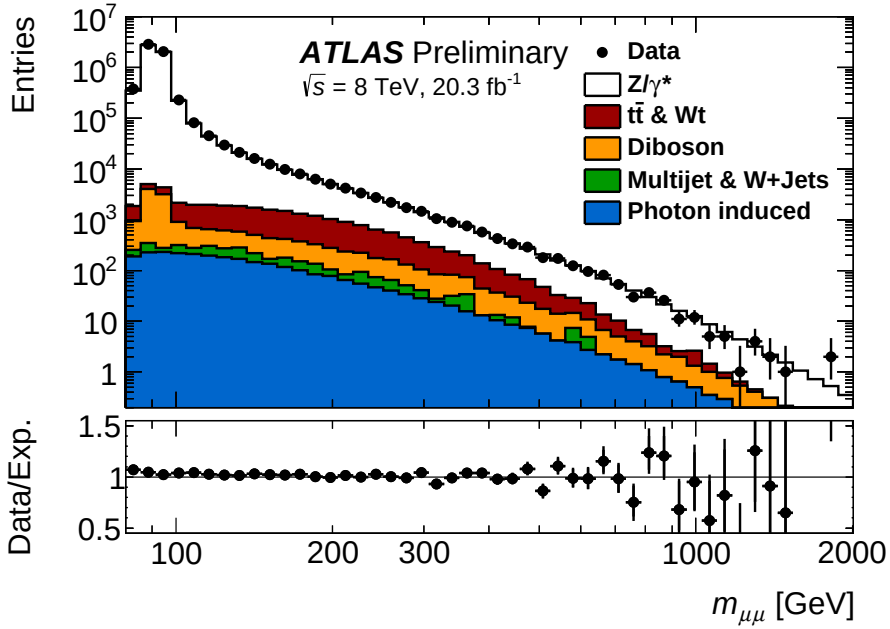


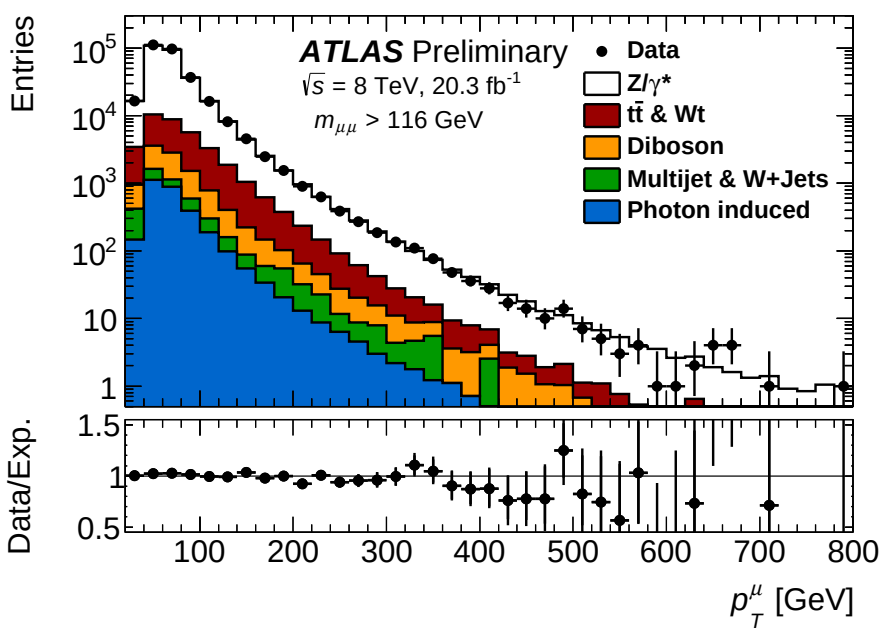


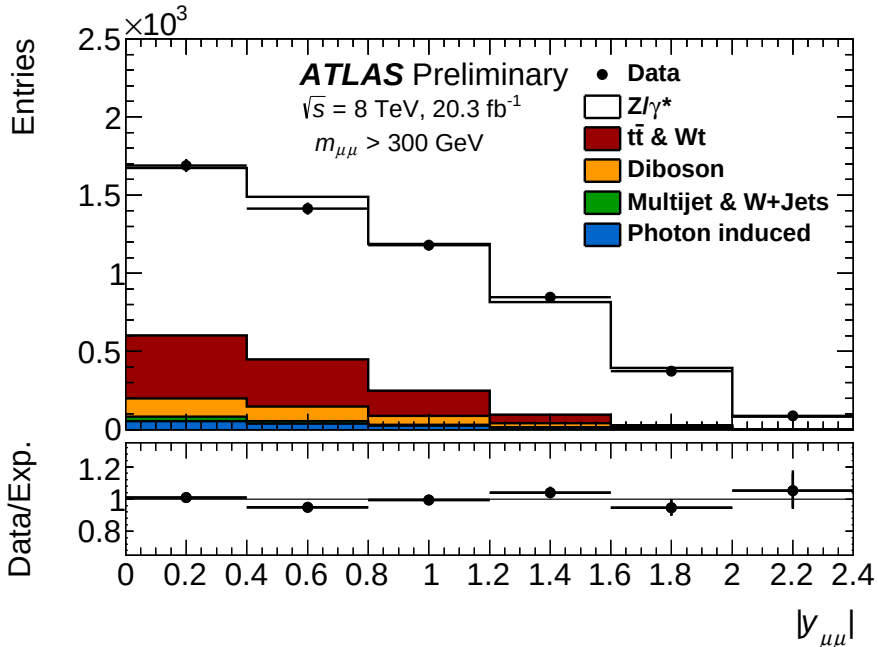
- The **dominant** source of background is $t\bar{t}$ and Wt production: **9%** in electron channel, **9%** in muon channel. MC estimate is cross-checked with electron-muon pairs in data.
- Multijets with $W + jets$ are *sub-dominant* contributions: **4%** in electron channel, $< \mathbf{1\%}$ in muon channel. Data-driven technique is used for the estimate of this background.

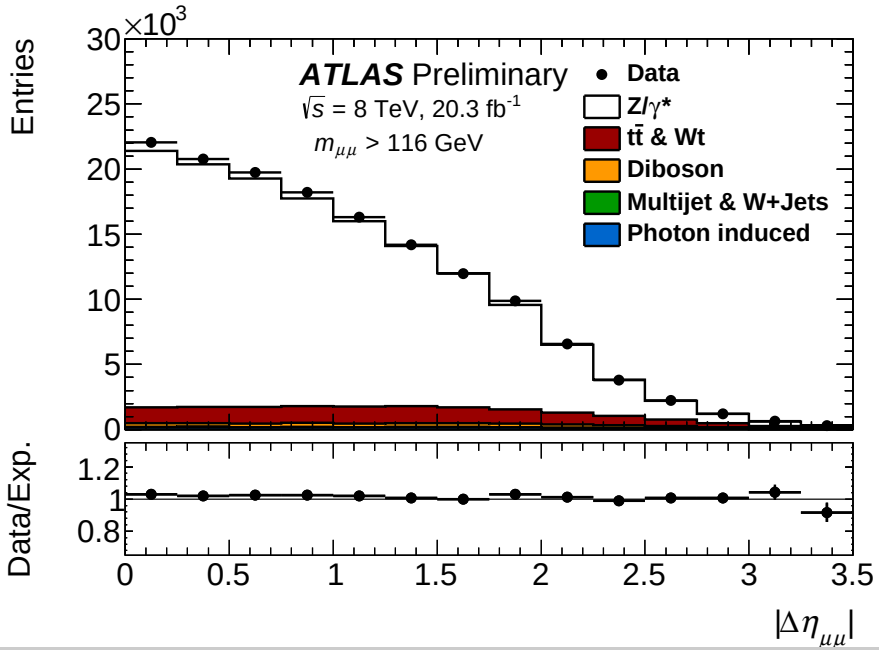


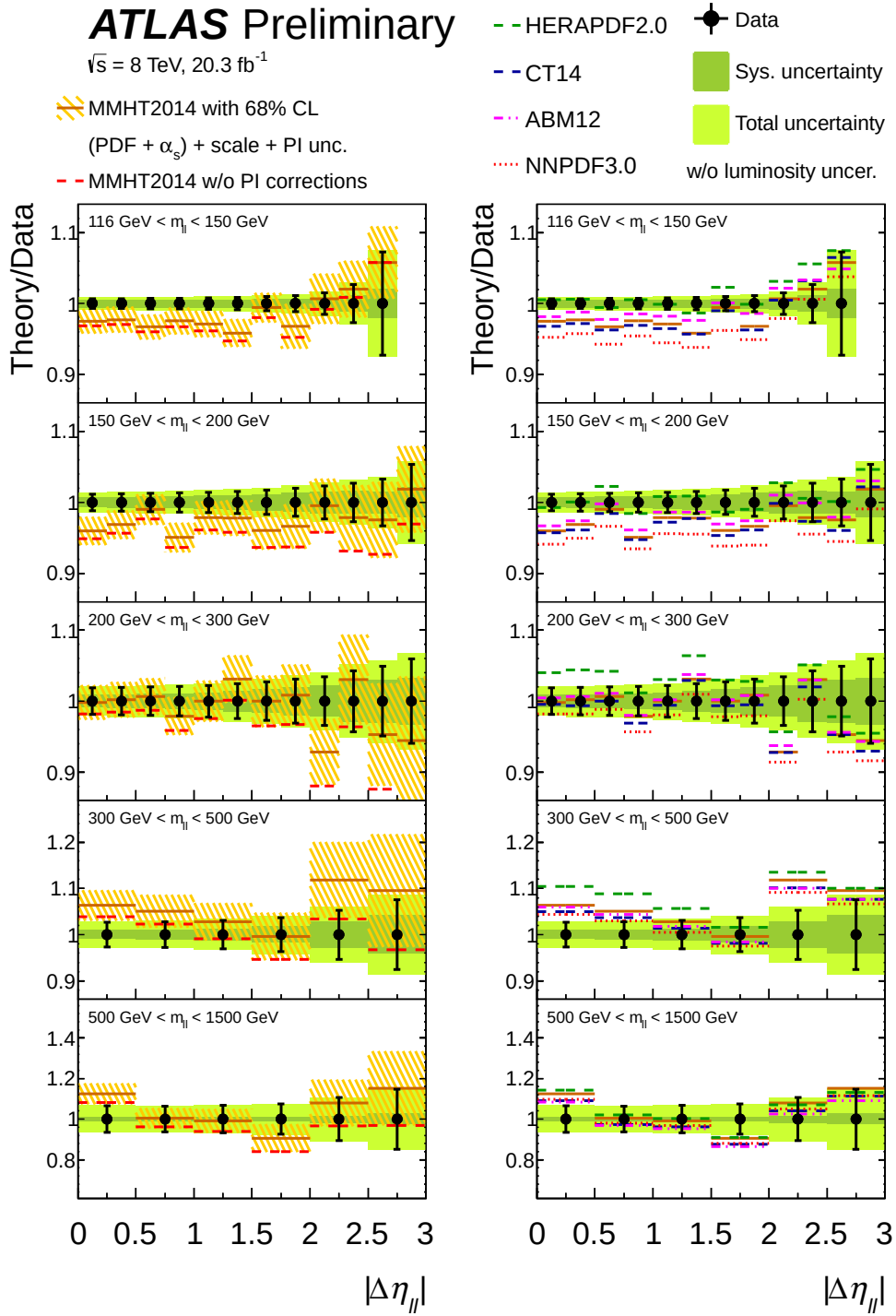
HMDY at 8 TeV: kinemtaic distributions in μ channel










ATLAS Preliminary
√s = 8 TeV, 20.3 fb-1
MMHT2014 with 68% CL
(PDF + αs) + scale + PI unc.
MMHT2014 w/o PI corrections
HERAPDF2.0
CT14
ABM12
NNPDF3.0
Data
Sys. uncertainty
Total uncertainty
w/o luminosity uncer.
Theory/Data
116 GeV < mll < 150 GeV
150 GeV < mll < 200 GeV
200 GeV < mll < 300 GeV
300 GeV < mll < 500 GeV
500 GeV < mll < 1500 GeV
|Δηll|