Measurement of the high-mass Drell-Yan differential cross-section at ATLAS

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- Talk is about analysis published as ATLAS conference note
  - **https://cdsweb.cern.ch/record/1493623**

Measurement of the high-mass Drell-Yan differential cross-section in *pp* collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

The ATLAS Collaboration

Abstract

This note reports a measurement of the high-mass Drell-Yan differential cross-section in proton-proton collisions at a centre-of-mass energy of 7 TeV at the LHC. Based on an integrated luminosity of 4.9 fb^{-1}, the differential cross-section in the $Z/\gamma^* \rightarrow e^+e^-$ channel as a function of the di-electron invariant mass, m_{ee}, is measured in the range $116 < m_{ee} < 1500$ GeV, for a fiducial region in which both electrons have $p_T > 25$ GeV and $|\eta| < 2.5$. A comparison is made to various event generators and to the predictions of perturbative QCD calculations at next-to-next-to-leading order.

Motivation

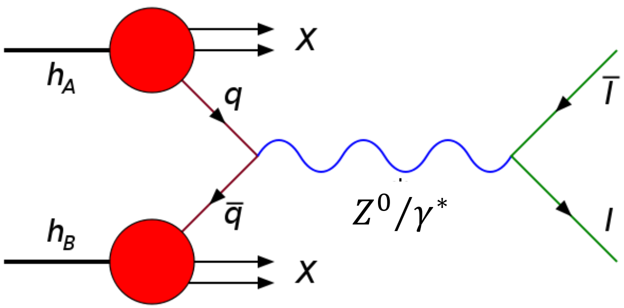
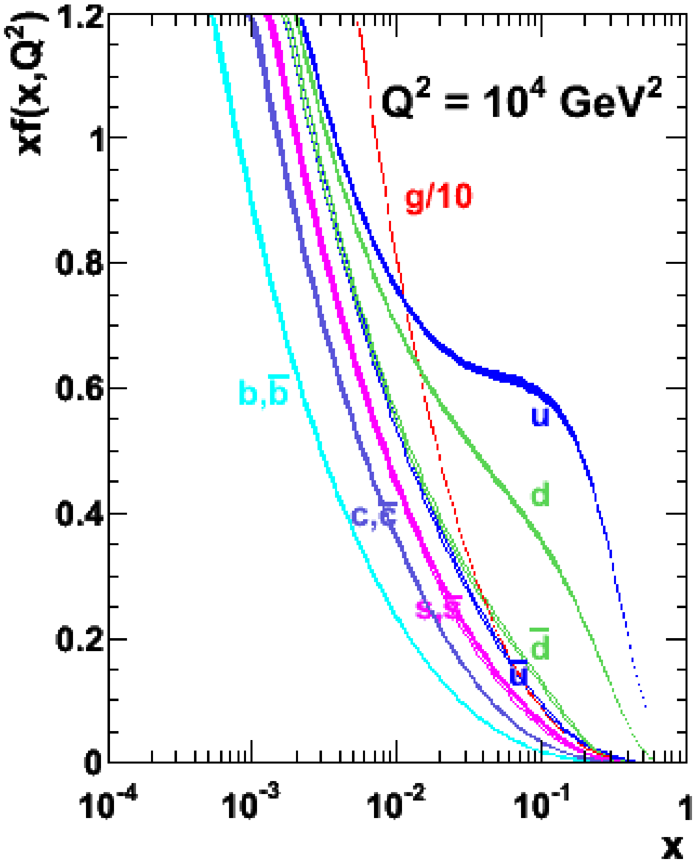


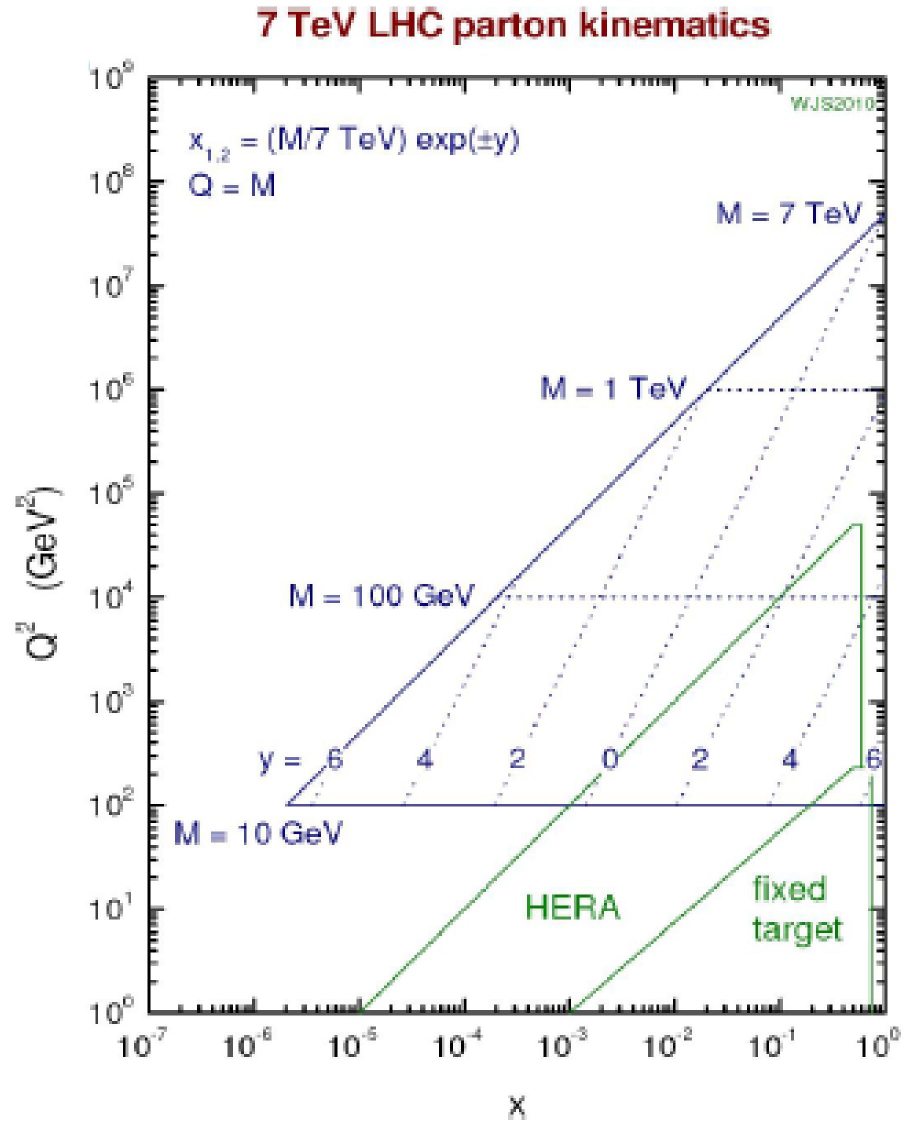
diagramm is LO, process
theoretical predictions at NNLO

- With LHC @ 7 TeV first time possible to measure Drell-Yan process at high invariant masses
- Important background for searches of new resonance decaying to l^+l^- (Zprime)
- Possibility to discover new non-resonance phenomena
- Input for PDF fits

Sensitivity on PDFs

- PDFs we use for LHC extracted from data at much lower $\sqrt{s}$





Measurement sensitive to high x Björken

How to calculate the cross section

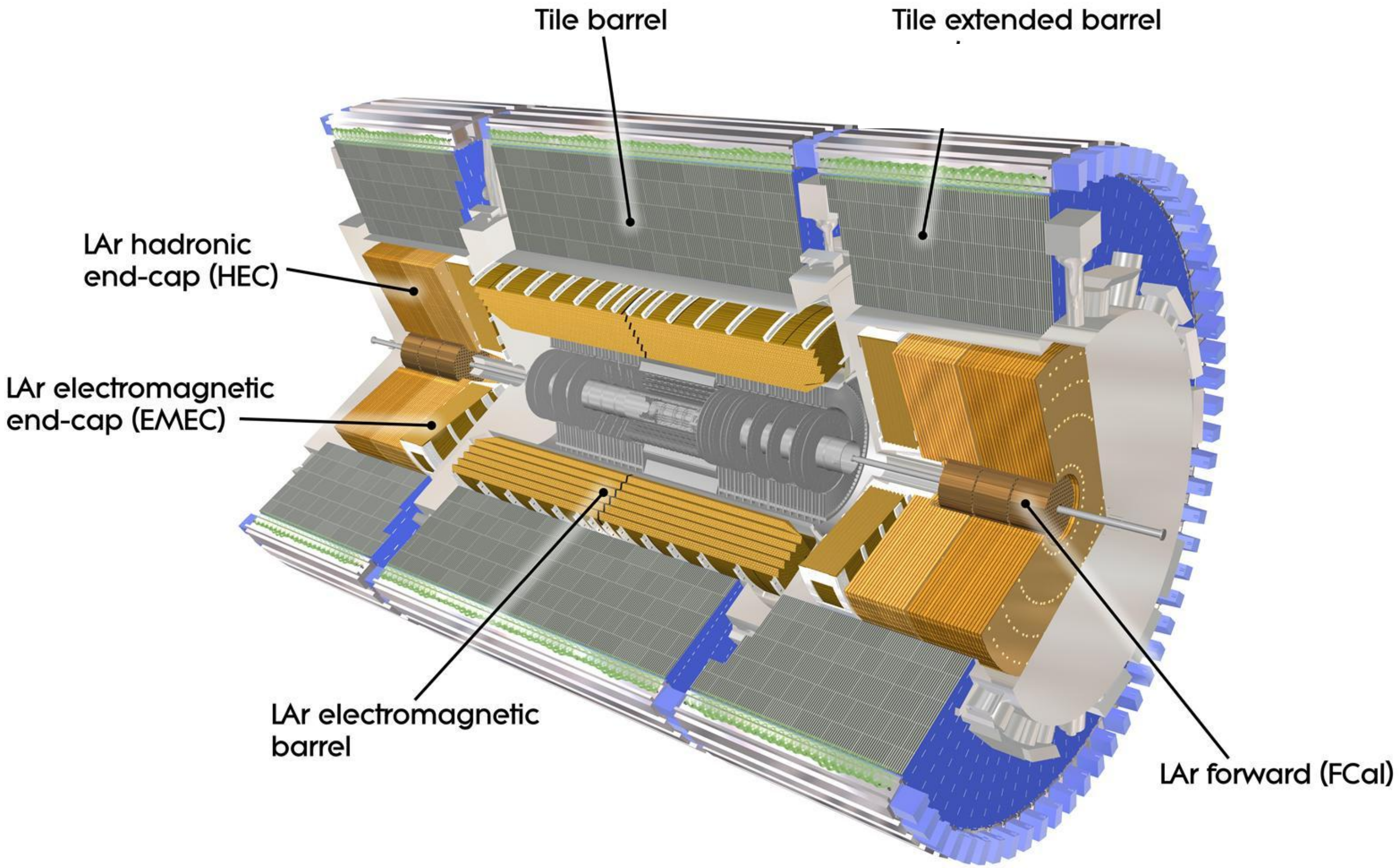
- Cross section of $pp \rightarrow e^{+}e^{-} + X$ is calculated differential in bins of invariant mass (M_{ee})
- „master formular“:

$$\frac{d\sigma}{dM_{ee}}(fid) = \frac{N_{Sel}(M_{ee}) - N_{Bkg}(M_{ee})}{C_{DY}(M_{ee}) * L_{int}} \qquad (p_T(el) > 25\ GeV, |\eta|(el) < 2.5)$$

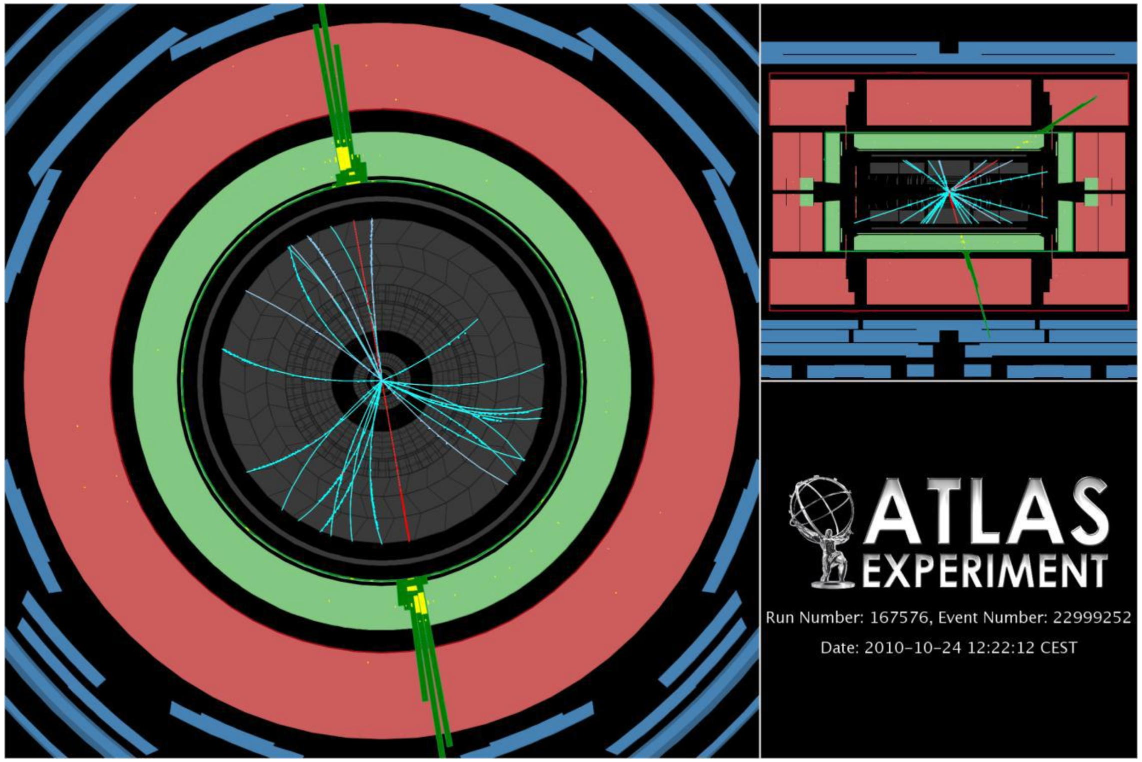
  - N_{Sel} : number of events after selection
  - N_{Bkg} : number of background events
  - C_{DY} : detector efficiency (reconstruction and identification of electrons, trigger efficiency …)
  - L_{int} : integrated luminosity

Data from ATLAS detector

- ATLAS is a multi-purpose detector at the Large Hadron Collider (LHC)



Event selection



- electron (or positron): localized energy deposition in em. calorimeter matching with a well reconstructed track from the inner detector.
- Require two electrons with $p_T > 25$ GeV and $|\eta| < 2.5$

Background

$$\frac{d\sigma}{dM_{ee}}(fid) = \frac{N_{Sel}(M_{ee}) - \boxed{N_{Bkg}(M_{ee})}}{C_{DY}(M_{ee}) * L_{int}}$$

- Dominant background (6-16% depending on m_{ee}) by particles misidentified as electrons
- DiJet (QCD) and jet+real electron (e.g. pp→W(eν)+jets) background estimated with a data driven method
  - Used dataset from 9 different jet-triggers (E_T thresholds from 20 to 240 GeV)
  - Events containing W or Z candidates are removed
  - Calculate the fraction of electron candidates that pass the identification requirement
  - Obtaine a weighted avarage „fake factor“ from the nine samples
  - Apply factor to samples of events that pass the signal selection, but with one or both electron candidates only loosely identified

Background

$$\frac{d\sigma}{dM_{ee}}(fid) = \frac{N_{Sel}(M_{ee}) - \boxed{N_{Bkg}(M_{ee})}}{C_{DY}(M_{ee}) * L_{int}}$$

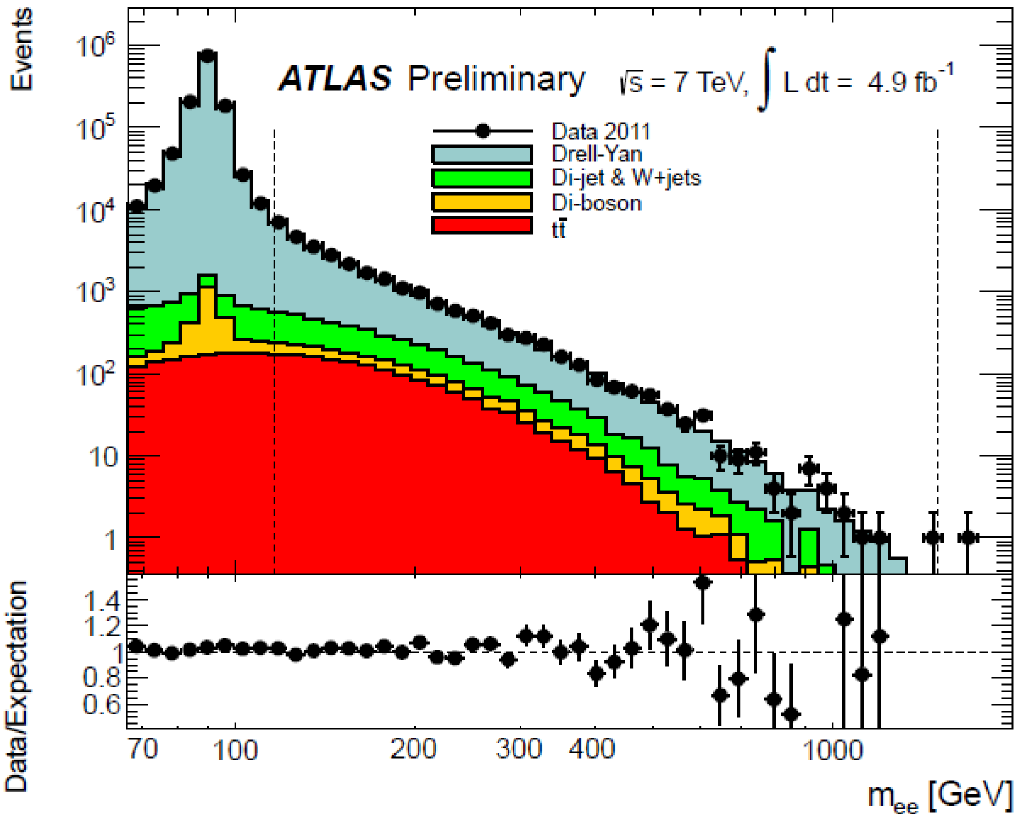
- Smaller irreversible background (up to 5% and 9%) from other processes with two real electrons in the final state
- Di-leptonic decay of $t\bar{t}$ pairs and from diboson (WW, WZ, ZZ) processes
  - Estimate with help of MC simulated samples

Mass distribution

$$\frac{d\sigma}{dM_{ee}}(fid) = \frac{\boxed{N_{Sel}(M_{ee}) - N_{Bkg}(M_{ee})}}{C_{DY}(M_{ee}) * L_{int}}$$

- Used the whole dataset from 2011 @ $\sqrt{s} = 7\,\text{TeV}$

  → integrated luminosity = 4.9 fb^{-1}



Vertical lines indicate the range of the measurement $116 < M_{ee} < 1500$

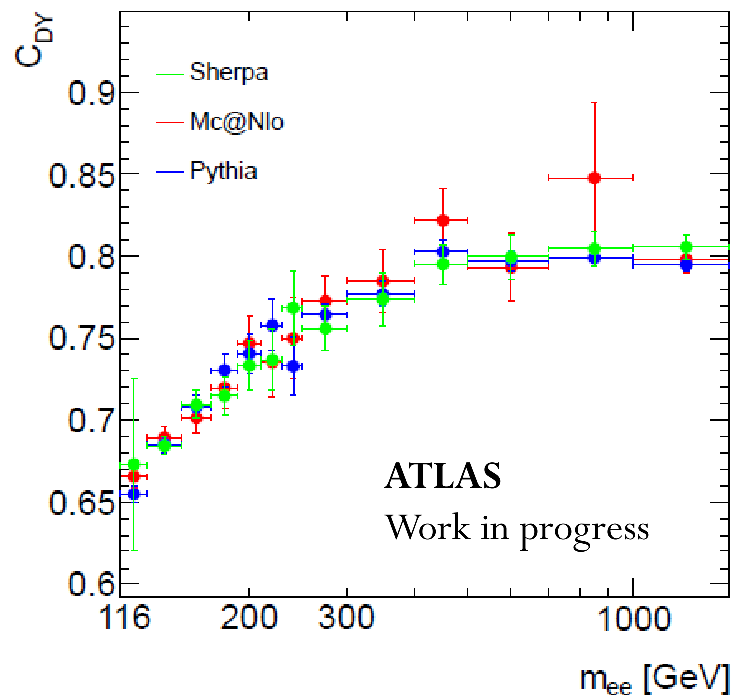
Efficiency

$$\frac{d\sigma}{dM_{ee}}(fid) = \frac{N_{Sel}(M_{ee}) - N_{Bkg}(M_{ee})}{\boxed{C_{DY}(M_{ee})} * L_{int}}$$

- Use complete MC simulation of the signal process to calculate the correction:
  - Inefficiency of the trigger
  - Inefficiency of reconstruction and identification of the electrons

$$C_{DY}(M_{ee}) = \frac{N_{SEL}(M_{ee})}{N_{FID}(M_{ee})}$$

- $N_{FID}(M_{ee})$: events with $P_T > 25$ GeV, $|\eta| < 2.5$ before detector simulation
- $N_{SEL}(M_{ee})$: events after final selection after the detector simulation



Uncertainties (only the dominant ones)

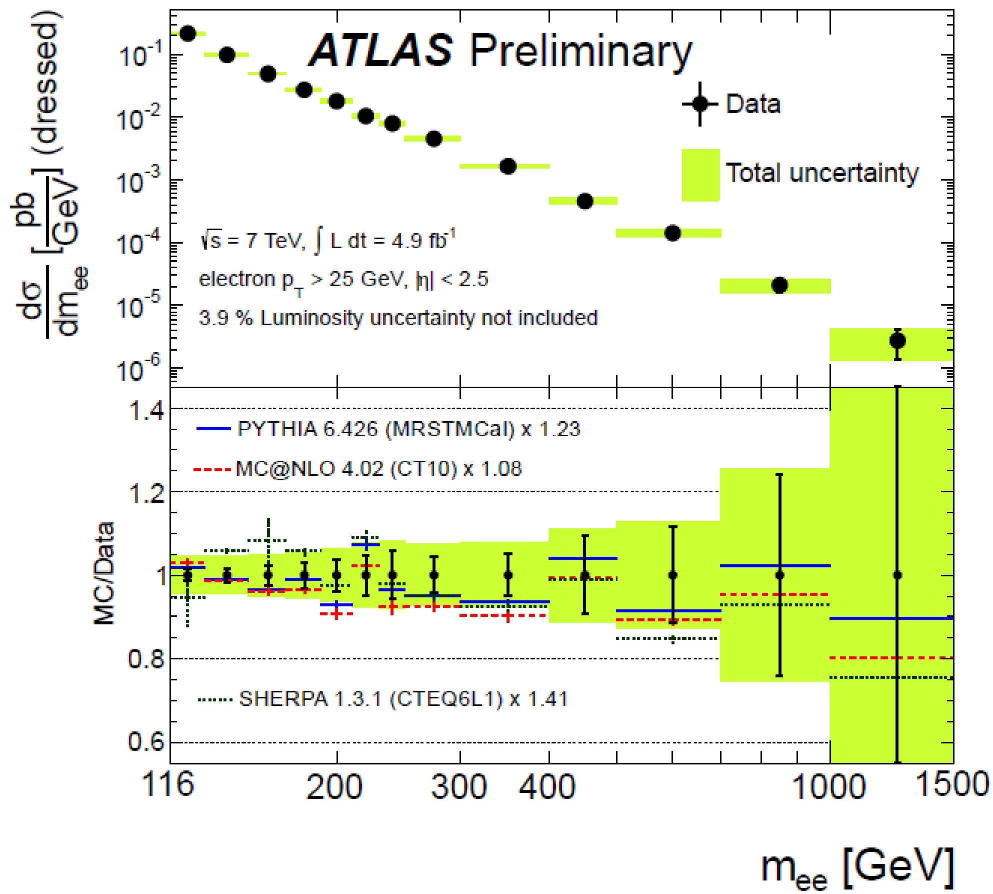
Source of systematic uncertainty	Bin: 116-130 GeV [%]	Bin: 1000-1500 GeV [%]
Total background estimate	1.3	8.2
Electron reconstruction and identification	2.8	3.0
Electron energy scale and resolution	2.1	3.3
Unfolding method	1.5	1.5
Trigger efficiency	0.8	0.8
MC modelling	0.2	0.3
MC statistics	0.7	0.4
Total experimental uncertainty	4.2	9.8
Luminosity uncertainty	3.9	3.9
Theoretical C_{DY}	0.1	0.3
Theoretical $C_{\mathrm{DY}}/E_{\mathrm{DY}}$	0.3	0.4

ATLAS preliminary

Results

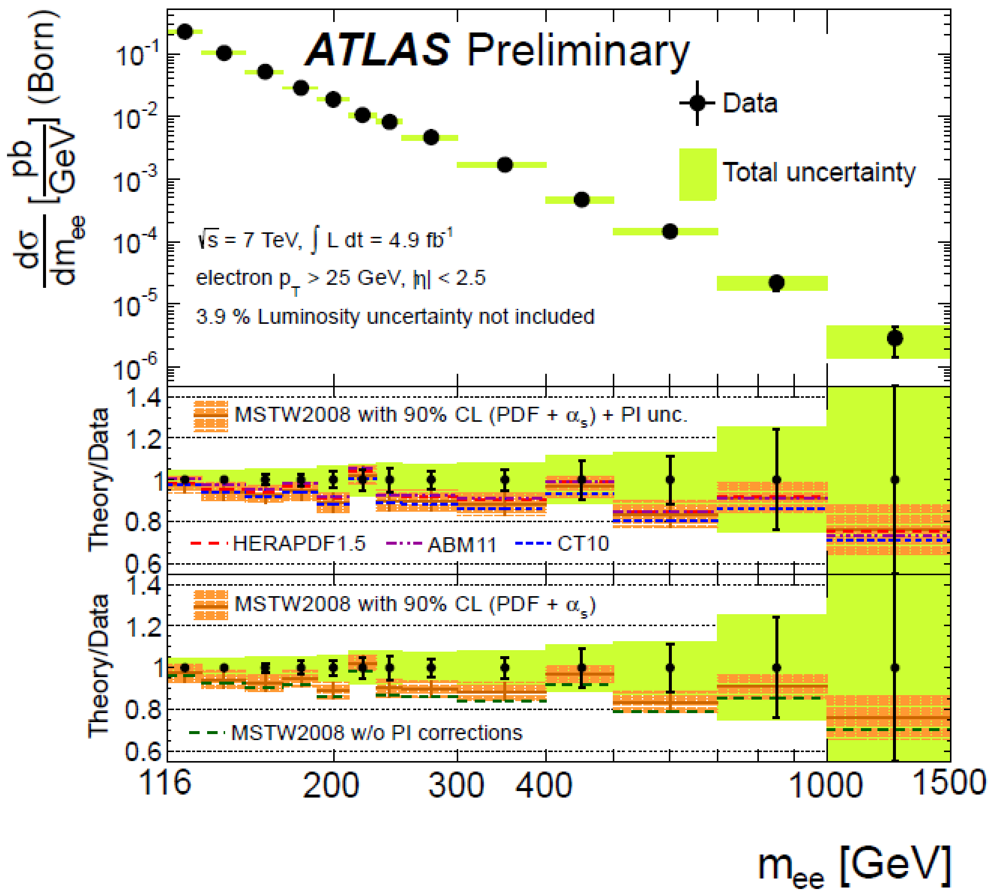
$$\boxed{\frac{d\sigma}{dM_{ee}}(fid)} = \frac{N_{Sel}(M_{ee}) - N_{Bkg}(M_{ee})}{C_{DY}(M_{ee}) * L_{int}}$$

- Compared to different MC generators, scaled to the integrated cross section in the measured region
- MC without any corrections
- Scale factor is given in plot
- Within of the uncertainties good agreement to all generators



Results

$$\boxed{\frac{d\sigma}{dM_{ee}}(fid)} = \frac{N_{Sel}(M_{ee}) - N_{Bkg}(M_{ee})}{C_{DY}(M_{ee}) * L_{int}}$$



- Compared to theoretical prediction calculated with FEWZ (NNLO)
- Comparision of different PDFs
- Influence of photon induced process shown at lower ratio panel

Summary / Outlook

- The differential cross section of the Drell-Yan process $(pp \rightarrow \mathrm{Z}^0/\gamma^* + \mathrm{X} \rightarrow \mathrm{e}^+\mathrm{e}^- + \mathrm{X})$ was measured in bins of invariant mass up to 1.5 TeV in proton-proton collisions at $\sqrt{s} = 7\ TeV$
- The result was compared to different MC predictions and to theoretical predictions calculated with FEWZ
- Conference note is published, paper will follow soon.

https://cdsweb.cern.ch/record/1493623

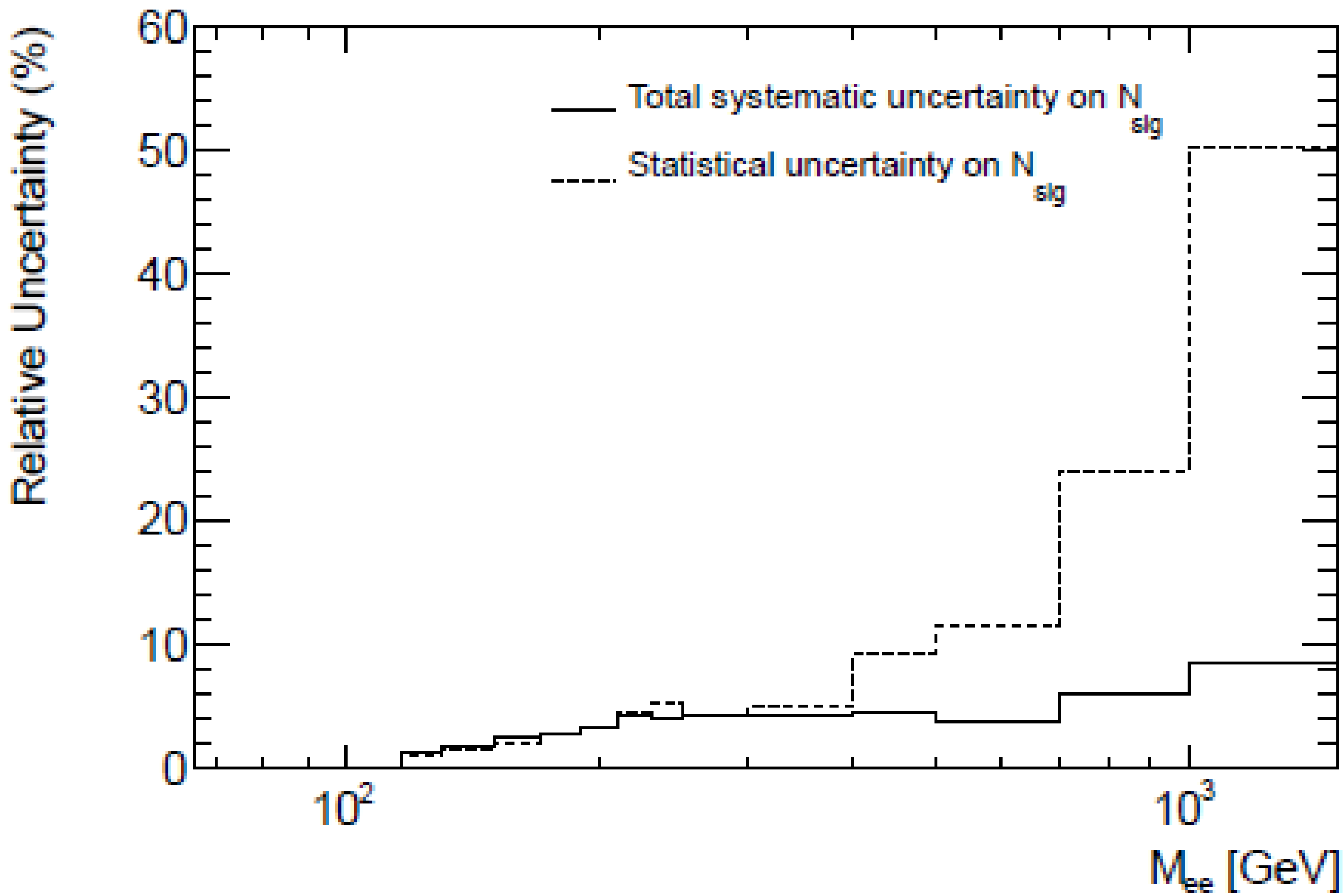
- Work ongoing on influence of the measurement to PDF predictions
- With data from 2012 at $\sqrt{s} = 8\ TeV$ double differential measurement are possible

Backup

Selection

- Good quality of relevant detector components required (tracking system, em. Calorimeter)
- At least one primary vertex with more then 2 tracks
- Trigger requirement (two electron trigger with $P_T > 20$ GeV)
- Two electrons from central region (excluding transition region)
- $P_T > 25$ GeV for both electrons
- Both electrons are at least with medium (good track) quality
- Both electrons have a hit in the first layer of the pixel detector (b-layer)

Uncertainties (signal)



Uncertainties (efficiency)

M_{ee}^{min}	M_{ee}^{max}	C_{DY}	stat.	Trig. Eff.	Rec. Eff	ID Eff	E-scale	E-res	pileup	Z_{pt}	Z_{Vertex}	k-factor	total sys
116	130	0.627	0.7	0.8	1.6	2.3	2.1	0.3	0.1	0.0	0.1	0.1	3.6
130	150	0.661	0.7	0.8	1.6	2.3	1.7	0.2	0.1	0.0	0.5	0.1	3.5
150	170	0.682	1.0	0.8	1.6	2.3	1.6	0.4	0.1	0.1	0.0	0.0	3.4
170	190	0.709	1.3	0.8	1.6	2.3	1.0	0.0	0.1	0.1	0.2	0.0	3.1
190	210	0.720	1.7	0.9	1.6	2.4	1.5	0.1	0.1	0.2	0.2	0.0	3.4
210	230	0.739	2.0	0.8	1.6	2.4	2.0	0.2	0.2	0.1	0.8	0.0	3.7
230	250	0.711	2.4	0.9	1.6	2.4	1.1	0.5	0.2	0.1	0.0	0.0	3.2
250	300	0.741	0.9	0.8	1.6	2.4	1.7	0.2	0.1	0.1	0.0	0.1	3.5
300	400	0.754	1.0	0.8	1.6	2.5	1.7	0.1	0.1	0.1	0.3	0.1	3.6
400	500	0.776	0.9	0.8	1.6	2.6	2.3	0.1	0.0	0.2	0.5	0.1	4.0
500	700	0.771	0.8	0.8	1.7	2.6	2.4	0.0	0.1	0.1	0.2	0.1	4.0
700	1000	0.769	0.6	0.8	1.7	2.6	2.8	0.2	0.1	0.0	0.2	0.1	4.2
1000	1500	0.762	0.4	0.8	1.7	2.5	3.3	0.1	0.1	0.1	0.3	0.1	4.6

Used simulations (MC)

- For signal ($pp \to Z^0/\gamma^* \to e^+e^- + X$): (Pythia, MC@NLO)
- For electroweak background:
  - Diboson [WW,WZ,ZZ] (Herwig)
  - W→eν (Alpgen Jimmy)
  - DY→ee (Pythia LO*)
  - $t\bar{t}$ (MC@NLO)
- QCD background:
  - data driven