Measurement of the $Z \to \tau\tau$ Cross Section with the ATLAS Detector

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Introduction

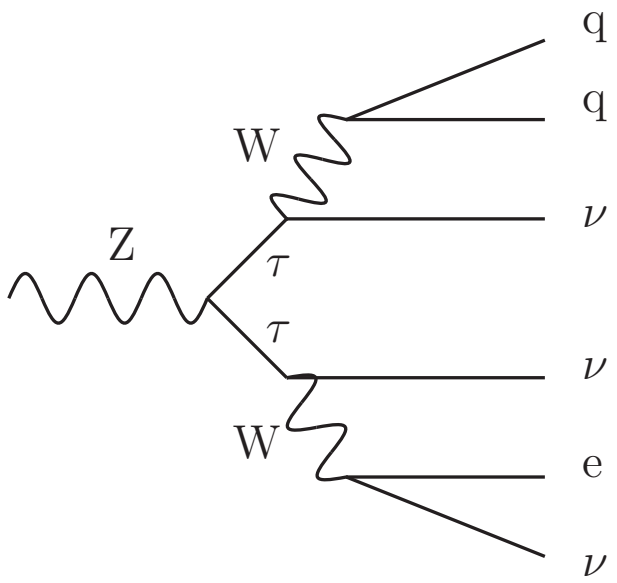
$$\mathrm{Z} \rightarrow \tau\tau$$

- Useful to check Standard Model predictions.
- Possible “Standard Candel” for other processes.
- Background for the Higgs hunt ($\mathrm{H} \rightarrow \tau\tau$).
- Produced with *pp* collisions at $\sqrt{s} = 7$ TeV, with a luminosity of 36 pb^{-1}.

Candidates for $Z \to \tau\tau$

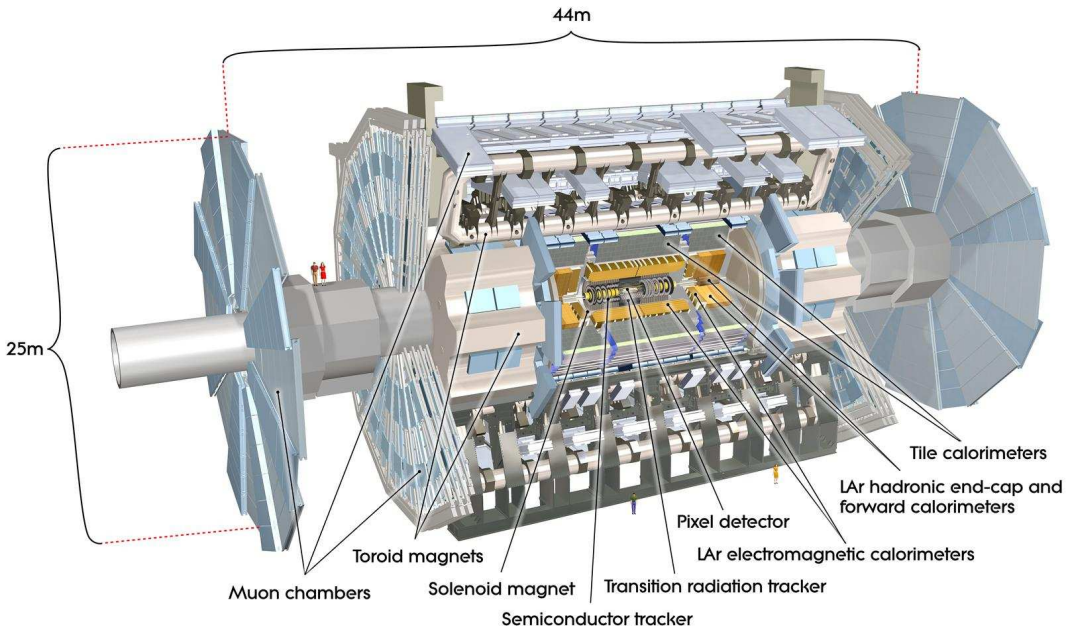
- Leptonic ($\sim$ 12%)
  - $Z \to \tau\tau \to e + \mu$ ($\sim$ 6%)
  - $Z \to \tau\tau \to \mu + \mu$ ($\sim$ 3%)
  - $Z \to \tau\tau \to e + e$ ($\sim$ 3%)
- Semi-leptonic ($\sim$ 46%)
  - $Z \to \tau\tau \to e + \text{jets}$ ($\sim$ 23%)
  - $Z \to \tau\tau \to \mu + \text{jets}$ ($\sim$ 23%)
- Hadronic ($\sim$ 42%)
  - $Z \to \tau\tau \to \text{jets}$

The Hadronic channel and the $\tau_e\tau_e$ channel are not taken into account, because of the huge background contamination.



ATLAS
(A Toroidal Lhc ApparatuS)

- Inner Tracker
- Electromagnetic Calorimeter
- Hadronic Calorimeter
- Muon Spectrometer



Selection of Physical Objects

Electron

- $E_T > 16GeV$
- $|\eta| < 2.47$ ($1.37 < |\eta| < 1.52$ not considered)
- Trigger efficiency 89% (73%) for the medium (tight) trigger.

Muon

- $p_T > 15GeV$ ($10GeV$) semileptonic (leptonic) channel.
- $|\eta| < 2.4$
- Trigger efficiency 92%

Jets

- Anti-k_T algorithm with $R = 0.4$
- $p_T > 20GeV$
- $|\eta| < 4.5$

Missing Transverse Momentum

- $E_T^{miss} = E_T^{miss}(calo.) + E_T^{miss}(muon) - E_T^{miss}(energy\ loss)$

Leptons must be isolated from jets!!

Selection of Physical Objects

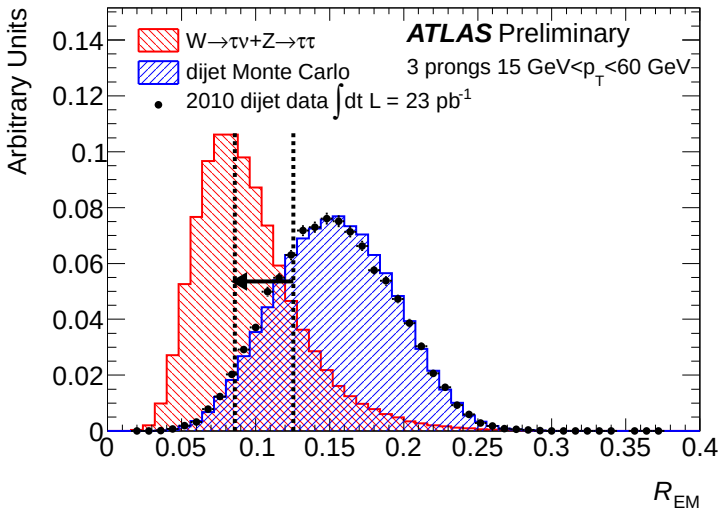
Hadronic τ

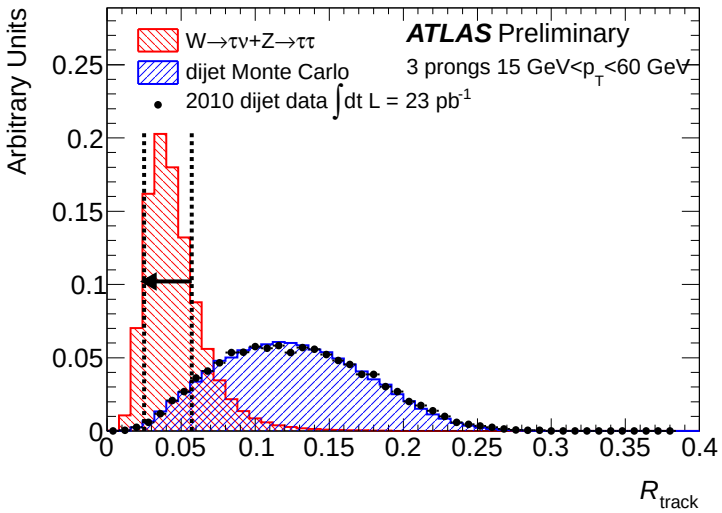
- $p_T > 1GeV$ for every single track
- $p_T > 20GeV$ for every jet
- $|\eta| < 2.47$ ($1.37 < |\eta| < 1.52$ not considered)

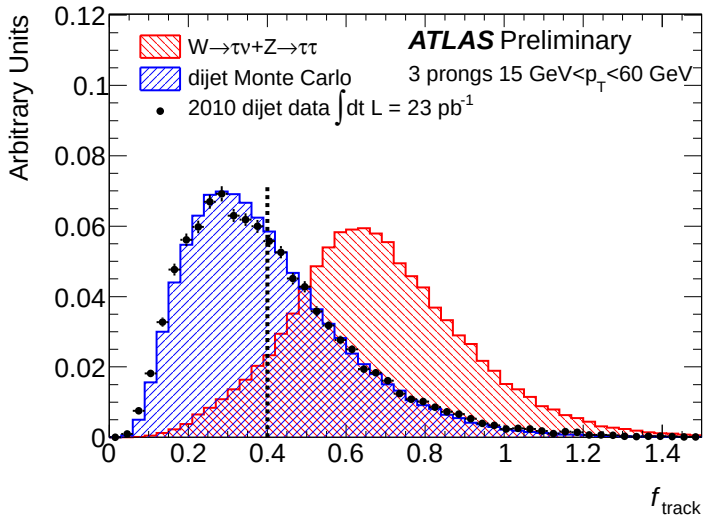
Other criteria must be taken into account:

- Energy weighted transverse width in the EM Calorimeter (R_{em})
- p_T weighted track width (R_{track})
- Fraction of p_T carried by the leading track

Selection of Hadronic τ







Semileptonic Channel

$\tau_e\tau_h$

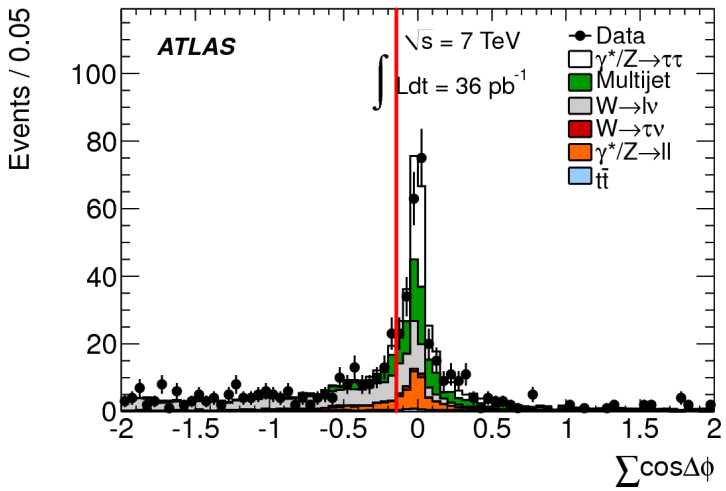
- One isolated tight electron: E_T >16 GeV
- Hadronic τ: p_T >20 GeV

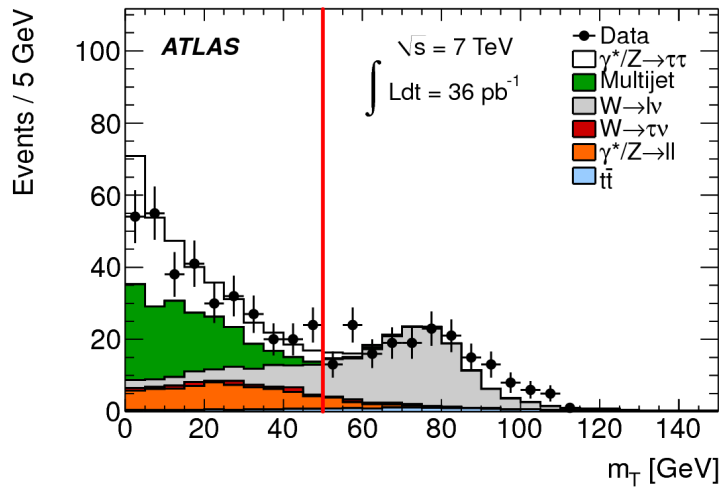
$\tau_\mu\tau_h$

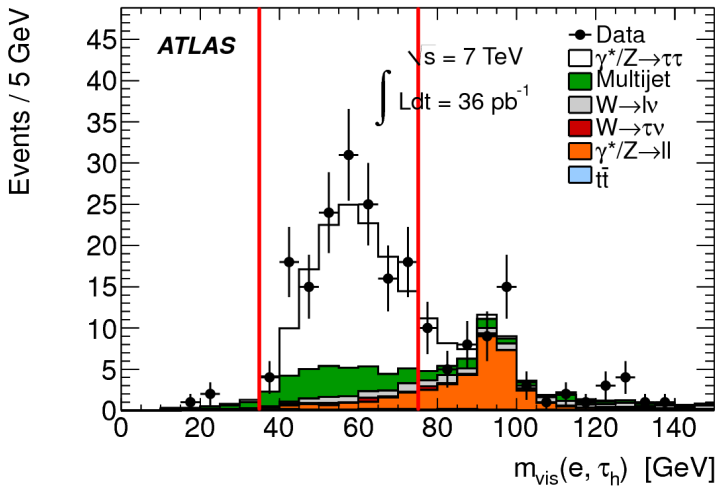
- One isolated muon: p_T >15 GeV
- Hadronic τ: p_T >20 GeV

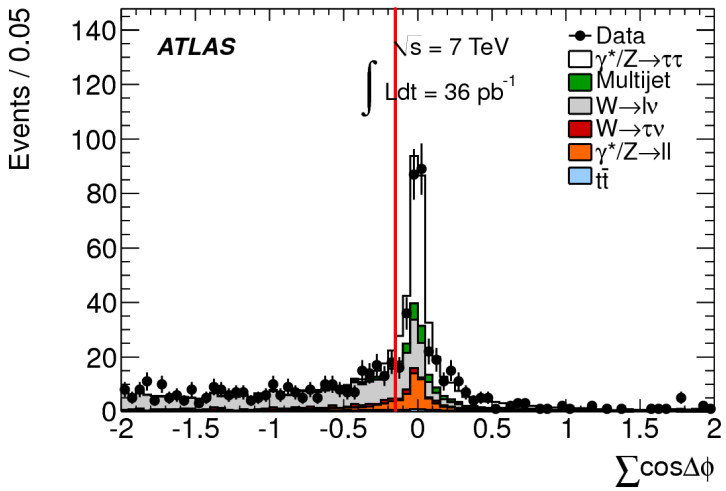
Both Channels

- Only one lepton
- E_T^{miss} azimuthal range ($\sum \cos(\Delta\phi) > -0.15$)
- $m_T < 50$ GeV
- $35 < m_{vis} < 75$ GeV


ATLAS
√s = 7 TeV
∫ Ldt = 36 pb-1
Data
γ*/Z→ττ
Multijet
W→lν
W→τν
γ*/Z→ll
tt̄
Events / 0.05
∑cosΔφ


ATLAS
√s = 7 TeV
∫ Ldt = 36 pb-1
Data
γ*/Z→ττ
Multijet
W→lν
W→τν
γ*/Z→ll
tt̄
Events / 5 GeV
mT [GeV]


ATLAS
√s = 7 TeV
∫ Ldt = 36 pb-1
Data
γ*/Z→ττ
Multijet
W→lν
W→τν
γ*/Z→ll
tt̄
Events / 5 GeV
mvis(e, τh) [GeV]


ATLAS
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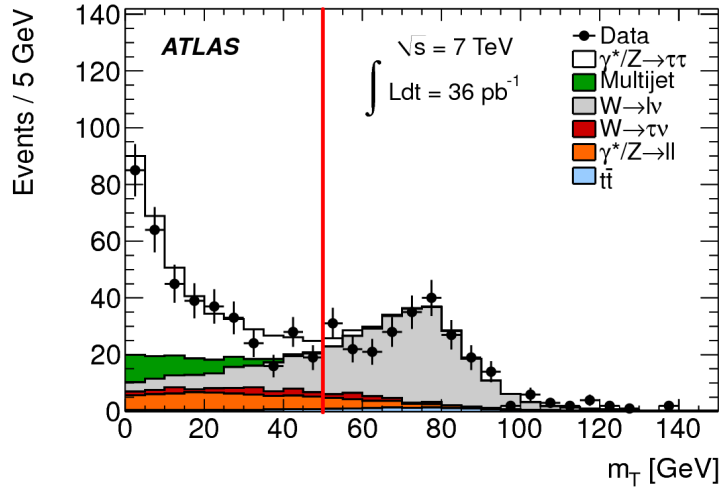
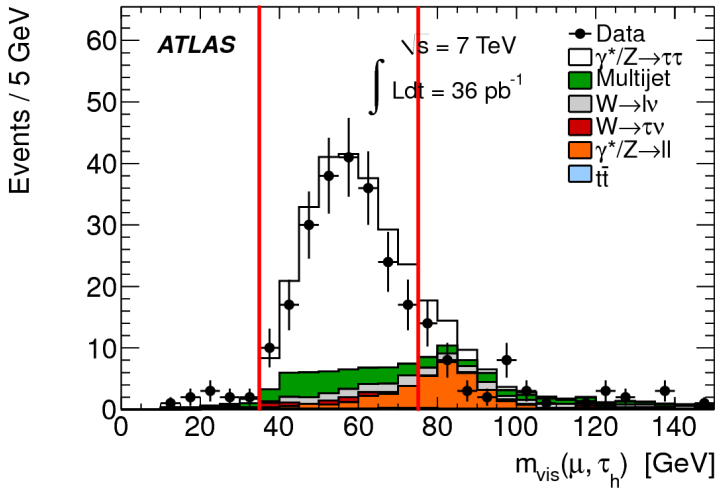
∫ Ldt = 36 pb-1
Data
γ*/Z→ττ
Multijet
W→lν
W→τν
γ*/Z→ll
tt̄
Events / 0.05
∑cosΔφ


ATLAS
√s = 7 TeV
∫ Ldt = 36 pb-1
Data
γ*/Z→ττ
Multijet
W→lν
W→τν
γ*/Z→ll
tt̄
Events / 5 GeV
m_T [GeV]


ATLAS
√s = 7 TeV
∫ Ldt = 36 pb-1
Data
γ*/Z→ττ
Multijet
W→lν
W→τν
γ*/Z→ll
tt̄
Events / 5 GeV
m_vis(μ, τ_h) [GeV]

Leptonic Channel

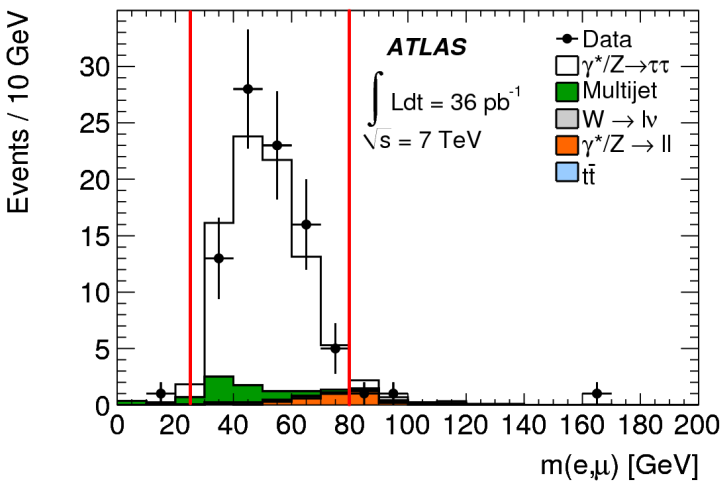
$\tau_e\tau_\mu$

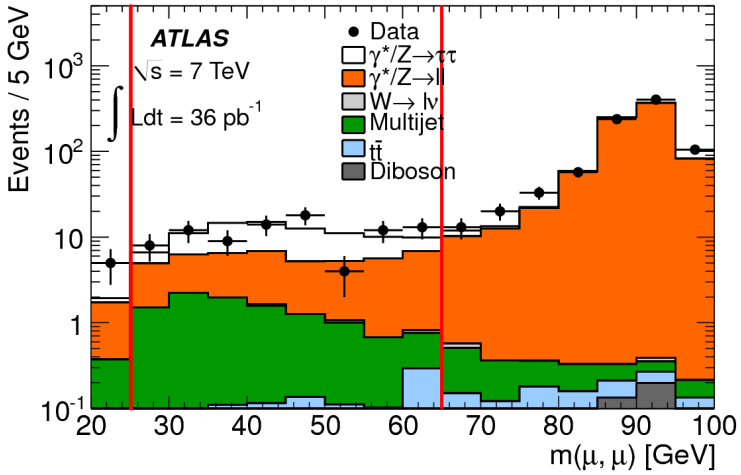
- One medium electron: E_T >16 GeV
- One Muon: p_T >10 GeV
- $25 < m_{e\mu} < 80$ GeV
- $\sum \cos\Delta\phi > -0.15$
- $\sum E_T + E_T^{miss} < 150$ GeV

$\tau_\mu\tau_\mu$

- First muon with p_T >10 GeV
- Second muon with $p_T > 15$ GeV
- $25 < m_{\mu\mu} < 65$ GeV
- Boosted Decision Tree

$\tau e \tau_\mu$ & $\tau_\mu \tau_\mu$





Background

	$\tau_\mu\tau_h$	$\tau_\mu\tau_h$	$\tau_\mu\tau_e$	$\tau_\mu\tau_\mu$
$\gamma^*/Z \to \ell\ell$	11.1 ± 0.5	6.9 ± 0.4	1.9 ± 0.1	36 ± 1
$W \to \ell\nu$	9.3 ± 0.7	4.8 ± 0.4	0.7 ± 0.2	0.2 ± 0.1
$W \to \tau\nu$	3.6 ± 0.8	1.5 ± 0.4	< 0.2	< 0.2
$t\bar{t}$	1.3 ± 0.1	1.02 ± 0.08	0.15 ± 0.03	0.8 ± 0.1
Multijet	24 ± 6	23 ± 6	6 ± 4	10 ± 2
Total background	49 ± 6	39 ± 6	9 ± 4	47.2 ± 2.2
$\gamma^*/Z \to \tau\tau$	186 ± 2	98 ± 1	73 ± 1	44 ± 1
Total expected events	235 ± 6	135 ± 6	82 ± 4	91 ± 3

Several cuts are considered into the analysis in order to avoid this background.

Cross Section Calculation

$$\sigma(Z \to \tau\tau) \times BR = \frac{N_{obs} - N_{bkg}}{A_Z \cdot C_Z \cdot \mathcal{L}}$$

A_Z: Acceptance factor $\sim \mathcal{O}(10^{-1})$

C_Z: Correction factor $\sim \mathcal{O}(10^{-1})$

$\mathcal{L} \sim 36\text{pb}^{-1}$

Systematic Uncertainties

Systematic Uncertainty	$\tau_\mu \tau_h$	$\tau_e \tau_h$	$\tau_e \tau_\mu$	$\tau_\mu \tau_\mu$
Muon efficiency	3.8%	...	2.2%	8.6%
Muon d_0 (shape & scale)	...	...	...	6.2%
Muon resolution & energy scale	0.2%	...	0.1%	1.0%
Electron efficiency, resolution & charge misidentification	...	9.6%	5.9%	...
τ_h identification efficiency	8.6%	8.6%	...	...
τ_h misidentification	1.1%	0.7%	...	...
Energy scale (e/τ/jets/E_T^{miss})	10%	11%	1.7%	0.1%
Multijet estimate method	0.8%	2%	1.0%	1.7%
W normalization factor	0.1%	0.2%	...	...
Object quality selection criteria	1.9%	1.9%	0.4%	0.4%
Pileup description in simulation	0.4%	0.4%	0.5%	0.1%
Theoretical cross section	0.2%	0.1%	0.3%	4.3%
A_Z systematics	3%	3%	3%	4%
Total systematic uncertainty	15%	17%	7.3%	14%
Statistical uncertainty	9.8%	12%	13%	23%
Luminosity	3.4%	3.4%	3.4%	3.4%

Systematic Uncertainties

Systematic Uncertainty	$\tau_\mu \tau_h$	$\tau_e \tau_h$	$\tau_e \tau_\mu$	$\tau_\mu \tau_\mu$
Muon efficiency	3.8%	···	2.2%	8.6%
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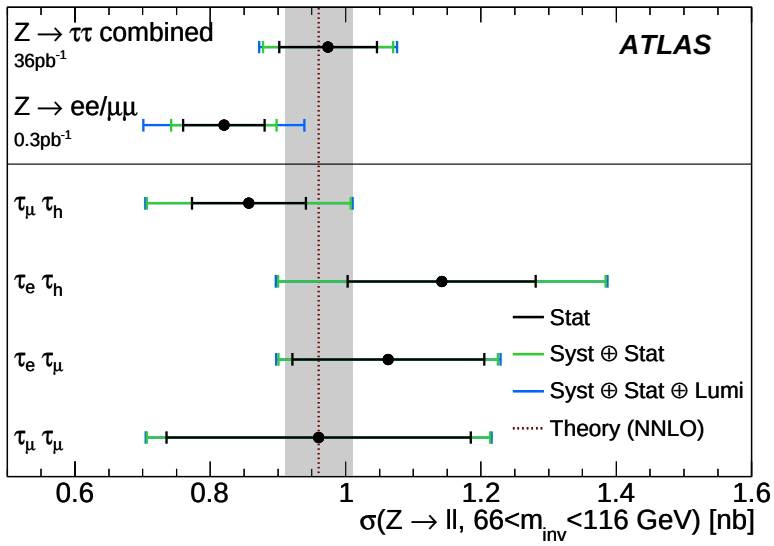
Luminosity	3.4%	3.4%	3.4%	3.4%

Results

$$\sigma(Z \to \tau\tau, 66 < m_{inv} < 116\,GeV)$$

Theoretical	0.96 ± 0.05 nb
CMS	$1.00 \pm 0.05(stat) \pm 0.08(syst) \pm 0.04(lumi)$ nb
ATLAS	$\mathbf{0.97 \pm 0.07(stat) \pm 0.06(syst) \pm 0.03(lumi)}$ **nb**



$$\sigma(Z \to \ell\ell, 66 < m_{inv} < 116\,GeV)$$

CMS	$0.974 \pm 0.007(stat) \pm 0.007(syst) \pm 0.010(theor.) \pm 0.039(lumi)$ nb
ATLAS	$0.937 \pm 0.006(stat) \pm 0.009(syst) \pm 0.016(theor.) \pm 0.032(lumi)$ nb

References

- **Measurement of the $Z \to \tau\tau$ cross section with the ATLAS detector.** ATLAS Collaboration. *Phys. Rev. D* ***84****, 112006 (2011)*
- **Measurement of the Inclusive $W^{\pm}$ and Z/γ^{*} Cross Sections in the e and μ Decay Channels in pp Collisions at $\sqrt{s} = 7$ TeV with the ATLAS Detector** ATLAS Colaboration. *Phys. Rev.* ***D*** *85 (2012) 67004*
- **Measurement of the Inclusive W and Z Production Cross Sections in pp Collisions at $\sqrt{7} = 7$ TeV** CMS Collaboration. *JHEP 10 (2011) 007*