Measurement of Electroweak Vector Boson Pair Productions in pp Collision with the CMS Detector at LHC

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Introduction

Aim:

Measurement of electroweak vector boson pair production, decaying to semileptonic and fully leptonic final states.

Motivation:

- **Test of the Standard Model at $\sqrt{s}$ = 7 and 8 TeV**
- **Sensitive self-interaction between gauge bosons via TGC- possible candle for new physics**
- **Background for high mass Higgs searches**
- **Understanding necessary for exploring WW Scattering**

8 TeV

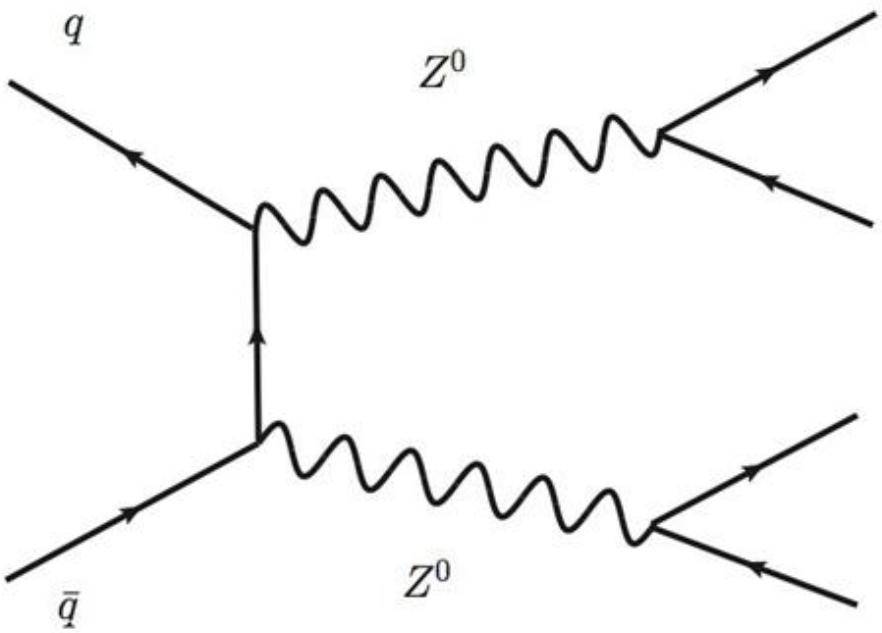
$ZZ \rightarrow l^- l^+ l^{-\prime} l^{+\prime}$

SMP-13-005

Signature:

Four leptons $l^- l^+ l^{-\prime} l^{+\prime}$, $l=e,\mu$, $l' = e,\mu,\tau$

Include $Z \rightarrow \tau\tau$ for the second candidate



Event selection:

$P_T^{\,l}$ >20(10) GeV leading (other) lepton(s)

$|\eta^{\,l}| < 2.5\ (2.4)$, $l=e(\mu)$

$60 < m_{ll} < 120$ GeV (each pair)

$20/30 < m_{\tau\tau} < 90$ GeV ($e\mu$/other)

Background:

Jet is misidentified as lepton in WZ/Z+Jets

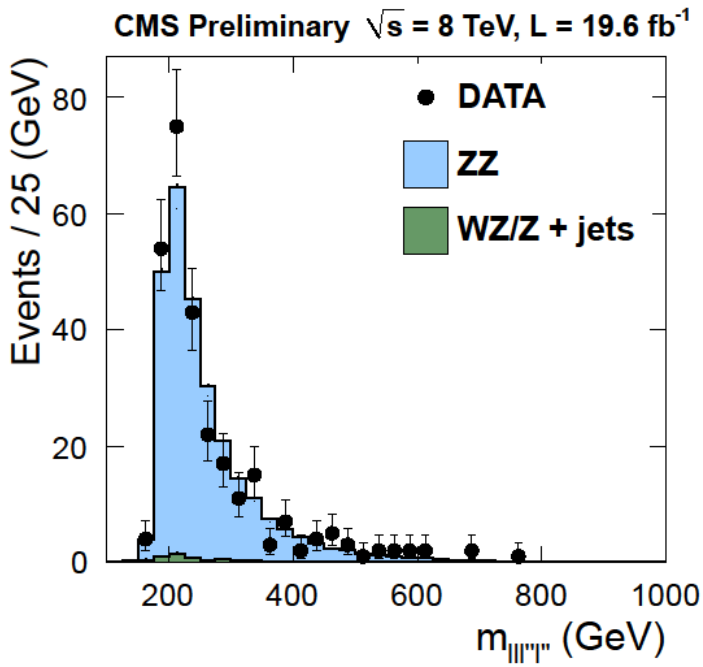
And tt. Data driven estimate – control region with relaxed isolation.

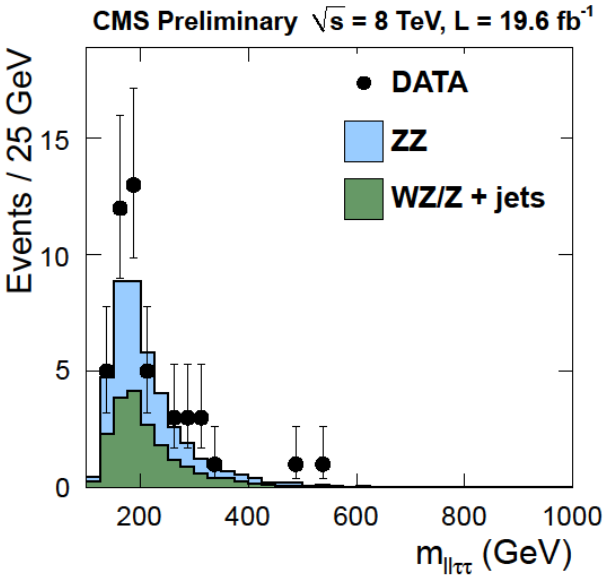
8 TeV

ZZ → $l^-l^+ l^{-\prime}l^{+\prime}$

SMP-13-005

m $_{l^-l^+ l^{-\prime}l^{+\prime}}$





Decay	Cross-Section
μμμμ	σ(pp→ZZ)=7.3+0.8/-0.8(stat.)+0.6/-0.5(syst.)±0.4(theo.)±0.3(lum.)pb
eeee	σ(pp→ZZ)=7.2+1.0/-0.9(stat.)+0.6/-0.5(syst.)±0.4(theo.)±0.3(lum.)pb
μμee	σ(pp→ZZ)=8.1+0.7/-0.6(stat.)+0.6/-0.5(syst.)±0.4(theo.)±0.3(lum.)pb
llττ	σ(pp→ZZ)=7.7+2.1/-1.9(stat.)+2.0/-1.8(syst.)±0.4(theo.)±0.3(lum.)pb
Total	σ(pp→ZZ)=7.7+0.5/-0.5(stat.)+0.5/-0.4(syst.)±0.4(theo.)±0.3(lum.)pb
Theoretical	σ = 7.7±0.6 pb (MCFM, qq(NLO), gg(LO)

8 TeV

ZZ→ℓνℓν

SMP-12-016

Signature:

Two opposite charge leptons $+E_t^{miss}$

Event selection:

P_T^l > 20 GeV, l=e,μ

$(m_{ll}$ -91) <7.5 GeV

di-lepton P_T >45 GeV

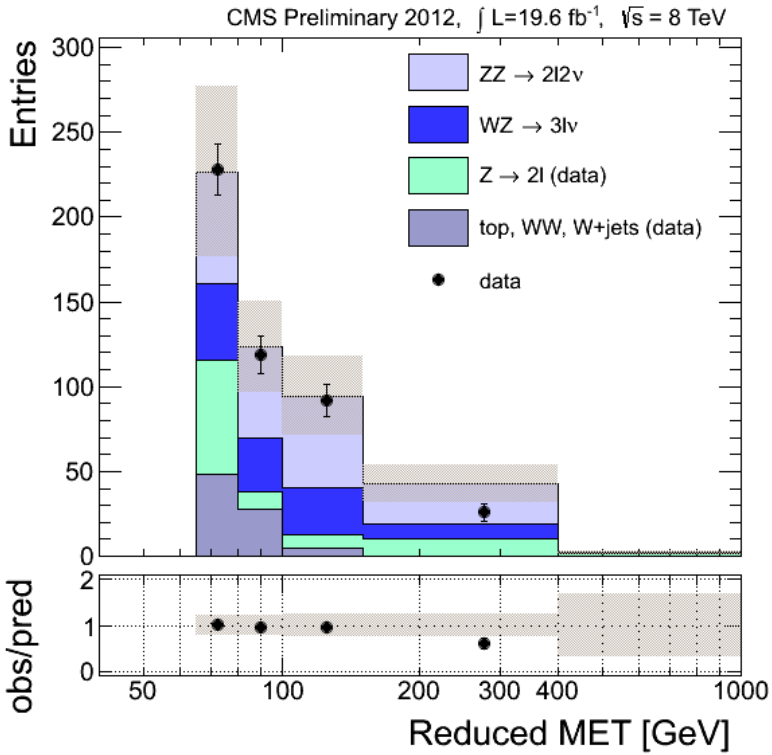
b-tag veto for jet with P_T > 20GeV

No jets with P_T >30GeV,

No additional lepton with P_T > 10GeV

Reduced $-E_t^{miss}$ >65GeV

$\Delta\Phi$ (E_T^{miss}, l) >0.2, $\Delta\Phi$ (E_T^{miss}, jet) >0.5



Background:

WZ, Z+Jets, WW, top

Measured σ (pp → ZZ) = 6.8 ± 0.8 (stat.) +1.8/-1.4(syst.) ± 0.3 (lum.) pb

Theoretical σ (pp → ZZ) = 7.7± 0.6 pb (MCFM, qq (NLO), gg(LO)

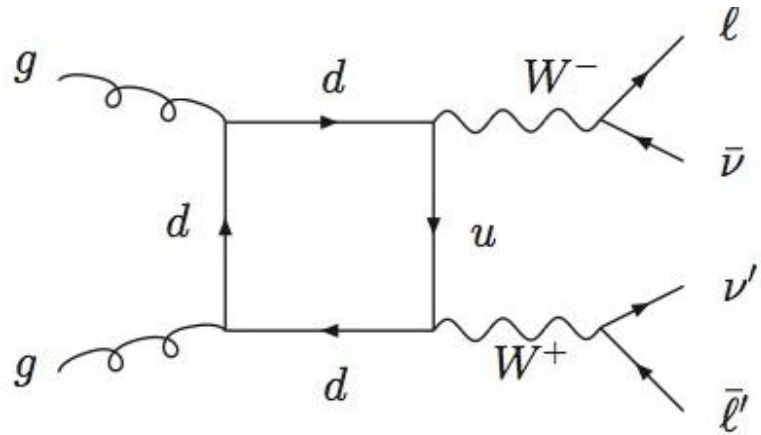
8 TeV

WW→ℓνℓν

SMP-12-013

Signature:

Two opposite charge leptons $+E_t^{miss}$



Event selection:

P_T^l > 20 GeV, 3rd l veto >10 GeV

No jet with P_T >30GeV

E_T^{miss} >45/40/20 GeV (ee,μμ,eμ)

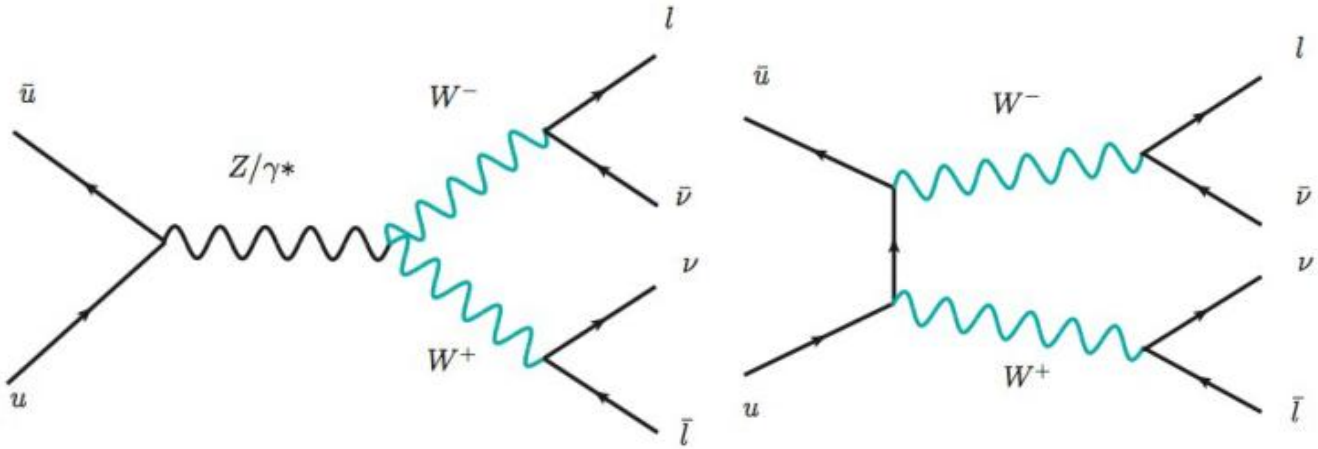
$M_{ll} - m_z$ >15 GeV (ee, μμ)

M_{ll} > 12 GeV (ee, μμ)

di-lepton P_T > 45 GeV

Background:

V+Jets, Top, VV

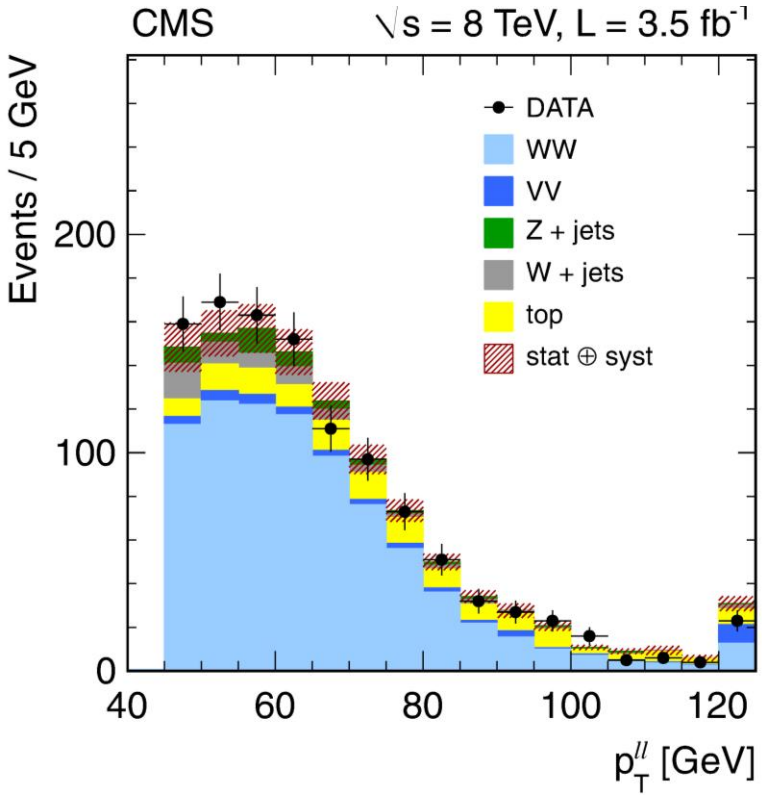


8 TeV

WW→lνlν

SMP-12-013

P_T^{ll}



event yields

Channel	lνlν
$W^+ W^-$	684±50
Tt and tW	132±23
W+Jets	60±22
WZ and ZZ	27±3
Z/γ ∗+jets	43±12
Wγ (∗)	14±5
Total background	275±35
Signal + background	959±60
Data	1111

Measured σ (pp → $W^+ W^-$) = 69.9 ± 2.8 (stat.) ± 5.6 (syst.) ± 3.1 (lum.) pb

Theoretical σ = $57.3^{+2.3}_{-1.6}$ pb, Higgs contribution at mh125GeV +4%

8 TeV

WZ→lllν

SMP-12-006

Signature:

Two opposite charge leptons + 3rd l + E_T^{miss}

Event selection:

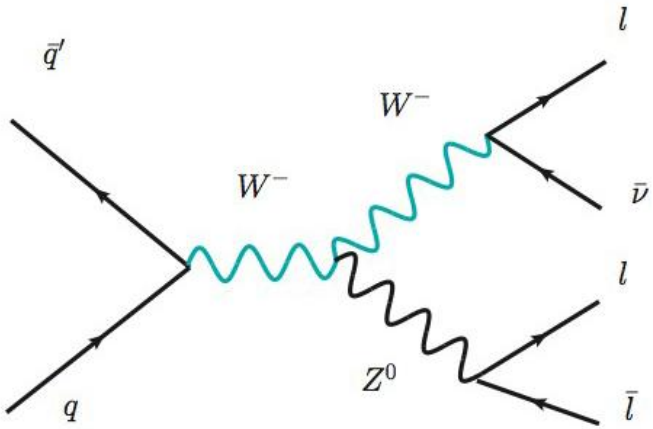
Z reconstruction:

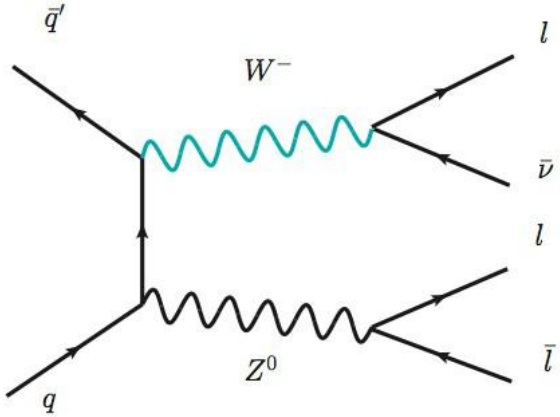
P_T^l >20 (10) GeV

71 < m_{ll} < 111 GeV (and closest to m_z)

W reconstruction:

P_T^l >20 GeV, E_T^{miss} >30GeV





Background:

- Fake lepton – real Z plus a jet faking a lepton – the dominant background
- Non peaking – no Z boson (e.g. ttbar)
- Prompt lepton- real Z and a isolated lepton(-like) object (e.g. ZZ,Z)

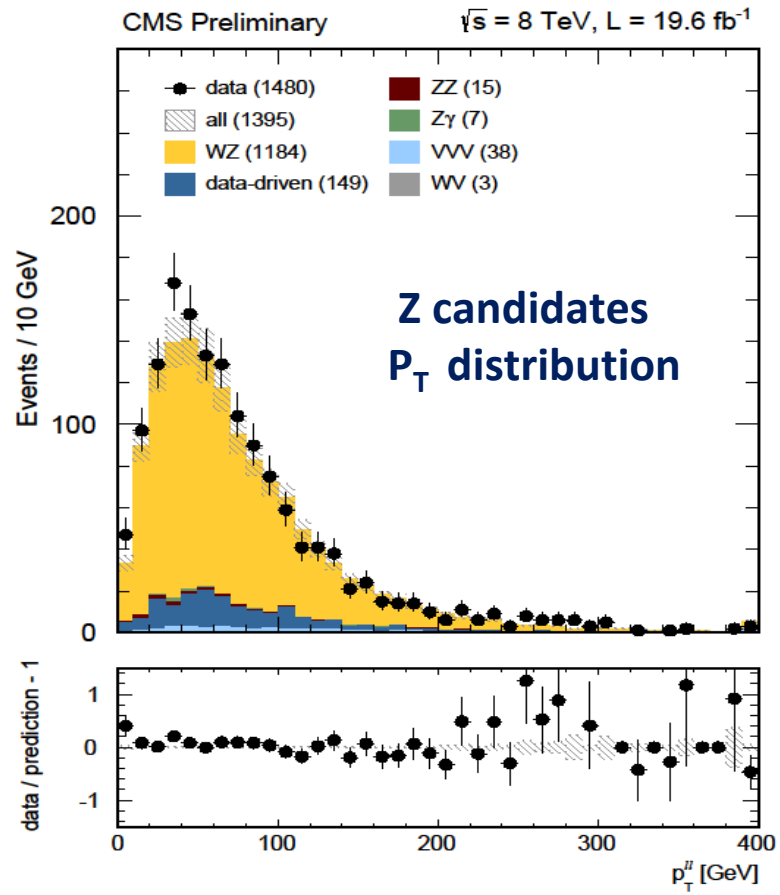
8 TeV

WZ→lllν

SMP-12-006

Event yields

sample	eee	eeμ	μμe	μμμ
Z+Jets	9.8±4.4	16.9±6.0	14.5±5.4	13.8±4.5
top	1.4±0.4	2.7±0.3	6.2±0.7	9.1±1.0
ZZ	2.4±0.1	3.1±0.1	3.9±0.1	5.8±0.1
Zγ	2.4±0.9	0.4±0.4	3.8±1.2	0
WV	0.1+0.1	0.1±0.1	0.2±0.1	2.2±0.7
VVV	6.1±0.3	7.9±0.3	10.4±0.4	13.4±0.4
WZ	193.9±1.4	245.8±1.6	315.9±1.9	428.0±2.2
Total MC	216.0±4.7	277.0±6.3	354.9±6.0	472.3±5.2
Data-driven	14.8±1.4	27.1±2.9	47.9±3.4	59.0±4.6
Data	235	288	400	557



Measured σ = 24.61 ± 0.76 (stat.) ± 1.13(syst.) ± 1.08 (lum.) pb

σTheoretical σ = 21.9 $^{+1.2}_{-0.88}$ pb (NLO)

7 TeV

WW + WZ → ℓν jj

SMP-12-015

Signature:

lepton + E_T^{miss} +Jets

One W boson decays leptonically (l=e,μ)

the other boson (W/Z) decays hadronically (jj)

Event selection:

P_T^{l} > 35(25) GeV, l=e(μ)

$|\eta^{l}|$ <2.5(2.1), l=e(μ)

M_T^{W} >50(30) GeV, l=e(μ)

E_T^{miss} > 30(25) GeV, l=e(μ)

P_T^{jet} > 35GeV, $|\eta^{jet}|$ <2.5

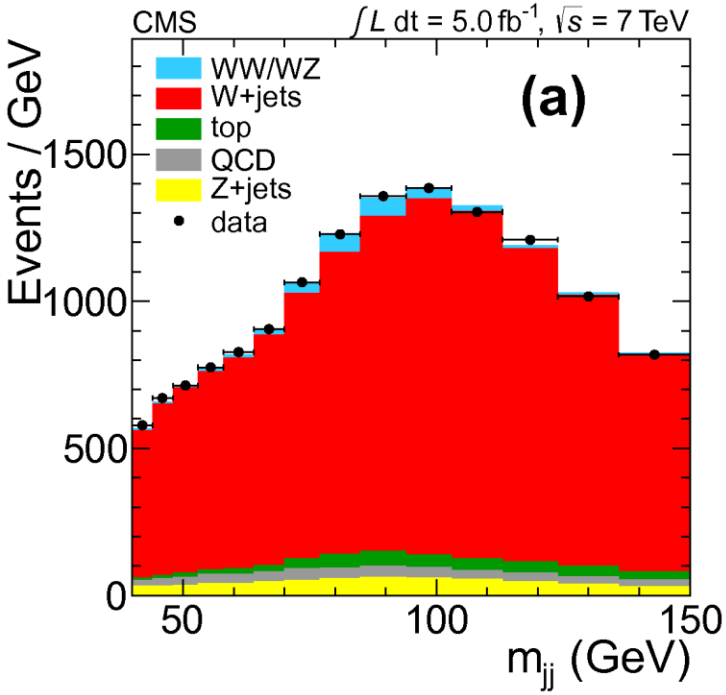
Jet b-tag veto

Background:

Wjets (dominant), top, Z+Jets,

Jet→ l misidentification

the dijet invariant mass before background subtraction



7 TeV

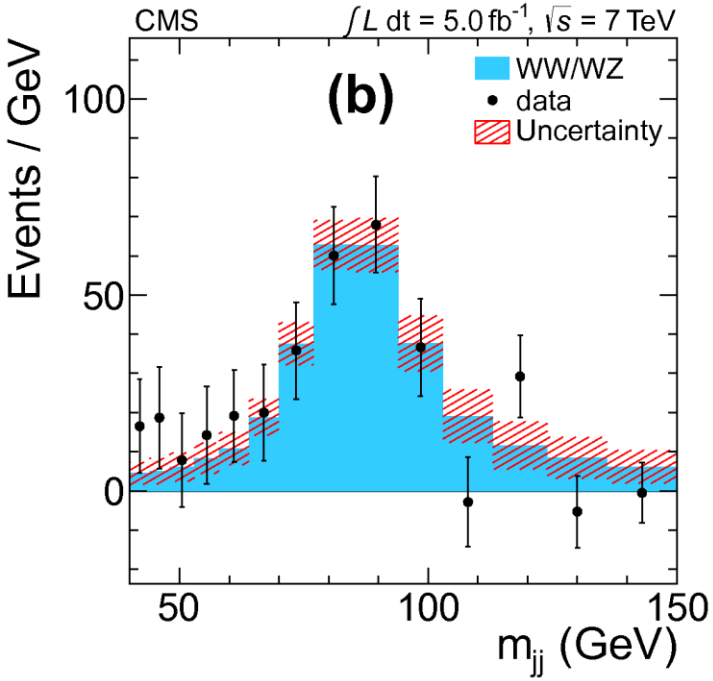
WW + WZ → ℓν jj

SMP-12-015

Event yields

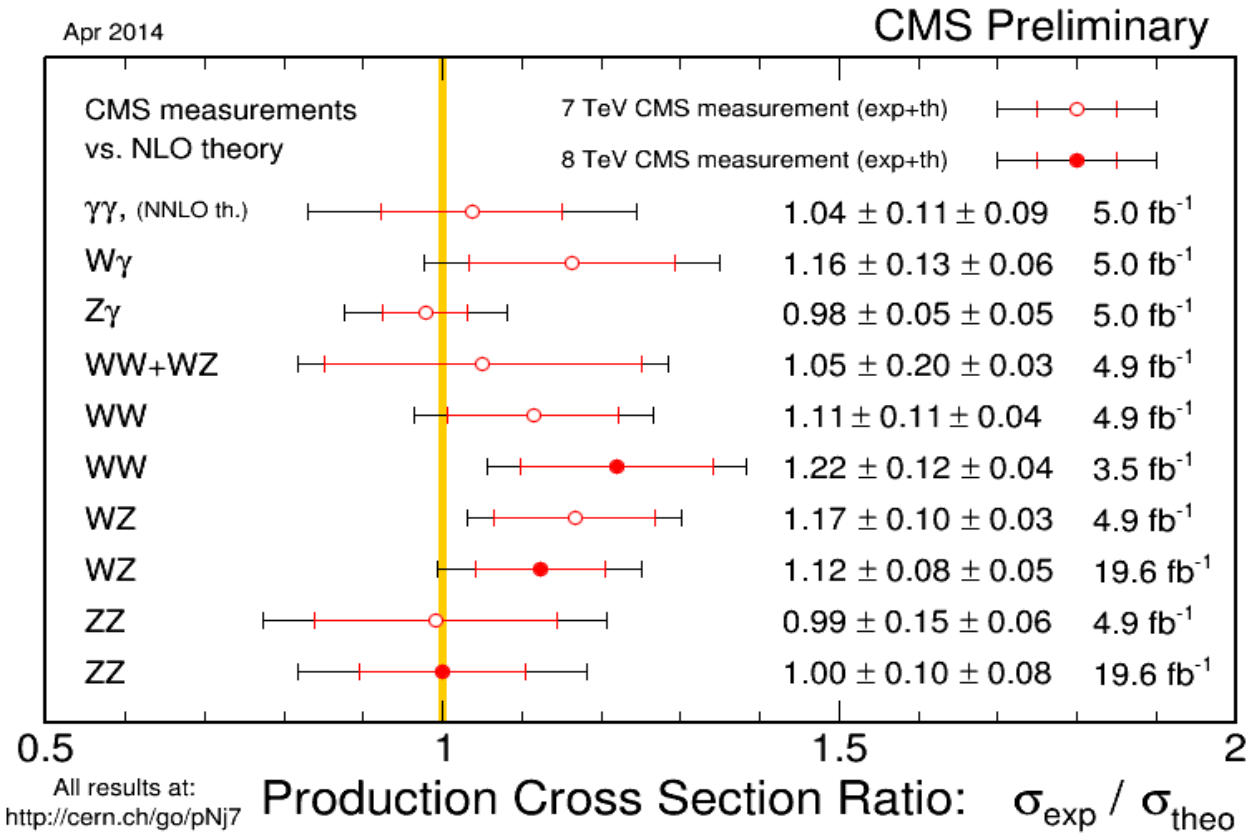
Process	Muon channel	Electron channel
Diboson (WW+WZ)	1899±373	783±306
W+Jets	67384±586	31644±850
ttbar	1662±117	946±67
Single top	650±33	308±17
Drell-Yan+Jets	3609±155	1408±64
Multi-jet (QCD)	296±317	4195±867
Fit χ^2/dof (probability)	9.73/12 (0.64)	5.30/12 (0.95)
Total from fit	75420	39371
Data	75419	39365
Acceptance X efficiency	5.153×10^{-3}	2.633×10^{-3}
Expected WW+WZ yield from simulation	1697±57	867±29

The dijet invariant mass after subtraction of all components except the electroweak WW+WZ processes



Measured σ (pp → WW+WZ) = 68.9 ± 8.7 (stat.) ± 9.7(syst.) ± 1.5 (lum.) pb
Theoretical σ = 65.6 ± 2.2 pb

Combined results



Conclusion:

Production cross-section has been measured and is found compatible with the Standard Model predictions.