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

Ajay Kumar, Delhi University

On behalf of the CMS Collaboration

Abstract

We present an overview of measurement of electroweak vector boson pair production, decaying to semileptonic and fully leptonic final states. The data analyzed were taken at √S = 7 & 8 TeV by the CMS detector at the Large Hadron Collider.

Motivation

➢Test of the Standard Model at √s = 7 and 8 TeV

➢ Sensitive to the self-interaction between gauge bosons via trilinear gauge couplings (TGC)- possible candle for new physics

➢ Background for high mass Higgs searches

➢ Help to validate the reliability of the techniques used in the Higgs searches

➢Understanding necessary for exploring WW Scattering

1 ZZ→ llll

Selection

➢llll:

➢Well identified and isolated leptons.

➢Significance of impact parameter (SIP_{3D}) < 4

➢ Z leptons pair with , $60 < m_{Z1} < 120$ GeV

➢Another pair of lepton (l^+l^-) with , $60 < m_{Z2} < 120$ GeV, if more than one Z2 pair, choose one with highest scalar sum P_T

➢Among four selected leptons, at least one have P_T 20GeV & another P_T > 10GeV

➢Any opposite charge pair of leptons satisfy $m_{ll'}$ > 4GeV

llττ:

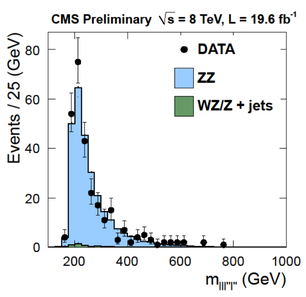
➢Z_1 →$l^+ l^-$ with one lepton P_T > 20GeV and other P_T >10GeV

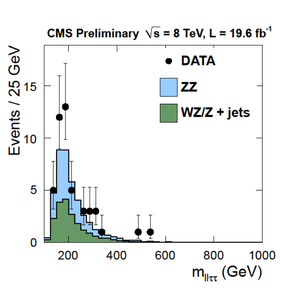
➢Z_2 → $\tau^+\tau^-$, with τ decays to e, μ,τ_h , $P_T{}^l$ >10Gev & $P_T{}^{\tau h}$ > 20GeV

➢m_{z1} as above

➢m_{z2} m_{min} < visible mass ($m_{\tau\tau}$) < 90 GeV, where m_{min} is 20GeV for Z_2→ ττ →eμ and 30GeV for all others.

Distribution of four-lepton reconstructed mass. The background shape are taken from data.





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

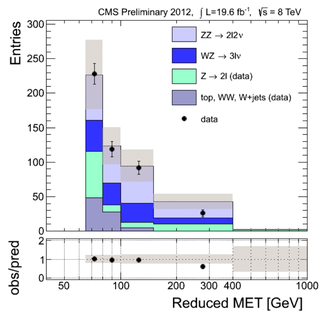
2 ZZ→ℓνℓν

Selection

variable	Value
Dilepton Invariant mass	$\lvert m_{ll} - 91\rvert < 7.5$GeV
Dilepton P_T	>45GeV
Jet veto	No jet with P_T >30GeV
Reduced E_T^{miss}	>65GeV
E_T^{miss} balance	0.4 <B <1.8
ΔΦ (E_T^{miss}, jet)	>0.5 rad
ΔΦ (E_T^{miss}, lep.)	>0.2 rad
Lepton veto	No additional leptons (e/μ) with P_T >10GeV

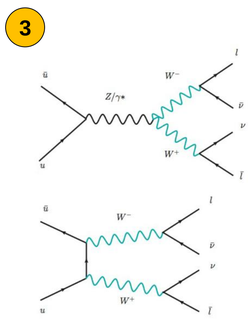
Reduced E_T^{miss} distribution .

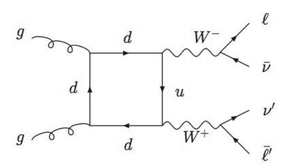
DY and non-resonant backgrounds are estimated with data-driven methods.



σ (pp → ZZ) = 6.8 ± 0.8 (stat.) +1.8/-1.4(syst.) ± 0.3 (lum.) pb at 8TeV

3 WW→lνℓν





Selection

➢Only 2 high P_T (>20 GeV) isolated leptons (e or μ) with opposite charge

➢Require high missing transverse energy

➢Events with one or more jets surviving jet selection and with corrected E_T >30 GeV & |η| <4.7 rejected

➢Soft muon veto, b-jet veto on jets with $15 < E_T < 30$ GeV

➢Projected $E_T{}^{miss}$, this is the component of E_T^{miss} transverse to the closest lepton if it is closer than π/2 in azimuthal angle, and full $E_T{}^{miss}$ otherwise. It is required to be >45 GeV for $e(\mu)^+e(\mu)^-$ & >20GeV for $e(\mu)^{+}e(\mu)^{-}$

➢ $\Delta\Phi_{(ll,jet)}$ < 165 degrees only in e^+e^- & $\mu^+\mu^-$ when E_T >15 GeV

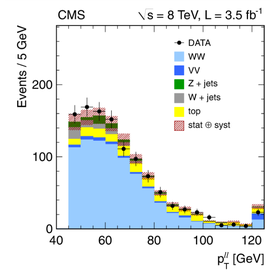
➢Reject events with m_{ll} within ±15 GeV of Z mass in e^+e^- & $\mu^+\mu^-$ final state

➢Also rejetcs m_{ll} < 12 GeV

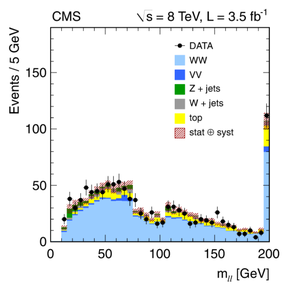
➢$P_T{}^{ll}$ > 45 GeV

➢Third lepton veto

$P_T{}^{ll}$ distribution. The last bin includes the overflow.



Dilepton invariant mass distribution. The last bin includes the overflow.

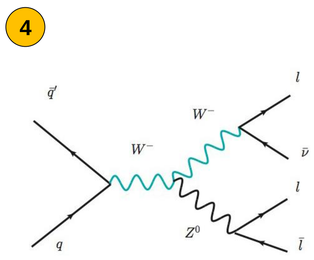


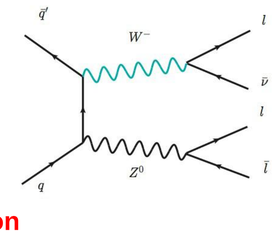
Expected and observed event yields for the W^+W^- selection. The uncertainties correspond to the statistical and systematic uncertainties added in quadrature:

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

σ (pp → W^+W^-) = 69.9 ± 2.8 (stat.) ± 5.6 (syst.) ± 3.1 (lum.) pb at 8 TeV.

4 WZ→lllν





Selection

➢A pair of SF, opposite charge , isolated, leading lepton P_T> 20 GeV & second leading lepton P_T >10 GeV used to choose Z candidate

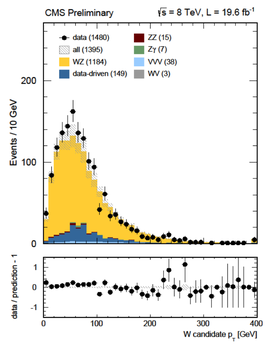
➢ require $|m_{ll} - m_z| < 20$ GeV

➢In case several matching pair found, select the one closest to nominal Z mass

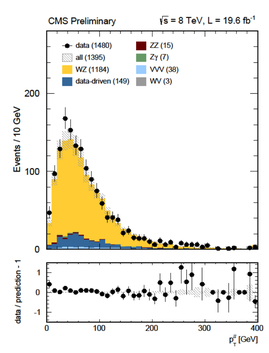
➢Require third high P_T (>20 GeV) isolated lepton associated W boson

➢Require high missing transverse energy > 30 GeV

W candidates P_T distribution



Z candidates P_T distribution



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

σ (pp → WZ+X) = 24.61 ± 0.76 (stat.) ± 1.13(syst.) ± 1.08 (lum.) pb at 8TeV

5 WW + WZ → ℓν jj

Selection

➢one well isolated & identified lepton,p_T 25(35) GeV μ(e).

➢Large missing transverse energy >25(30) GeV μ(e).

➢Exactly two jets, P_T >35GeV.

➢Lepton is required to be consistent with primary vertex (PV) of event.

➢PV is chosen as one with highest Σ P_T^2 of its associated tracks.

➢W transverse mass > 30(50) GeV μ(e).

➢combined isolation $\Sigma_{\Delta R<0.3}$ ECAL+HCAL+tracker <10% (5%) μ(e) p_T.

➢Jet b-tag veto, loose CSV.

➢Secondary lepton veto.

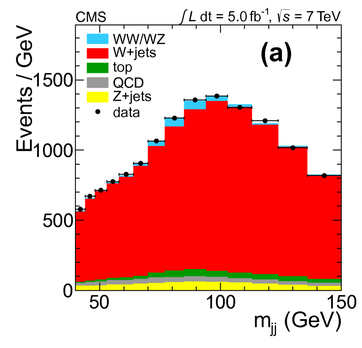
Event yields

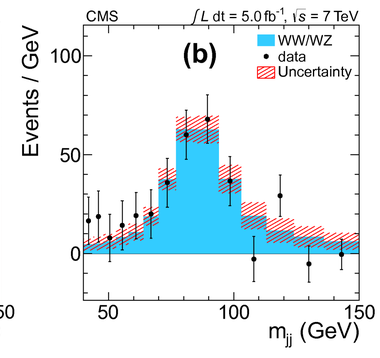
Process	Muon channel	Electron channel
Diboson (WW+WZ)	1899±373	783±306
W+Jets	67384±586	31644±850
ttbar	1662±117	946±67
Single top	650±33	308±17
Drell-Yan+Jets	3609±155	1408±64
Multi-jet (QCD)	296±317	4195±867
Fit χ^2 /dof (probability)	9.73/12 (0.64)	5.30/12 (0.95)
Total from fit	75420	39371
Data	75419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

Distribution of :

a.)the dijet invariant mass before background subtraction.

b.) the dijet invariant mass after subtraction of all components except the electroweak WW+WZ processes.





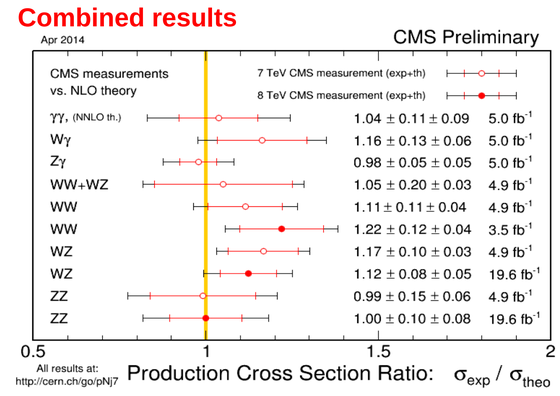
σ (pp → WW+WZ) = 68.9 ± 8.7 (stat.) ± 9.7(syst.) ± 1.5 (lum.) pb at 7TeV

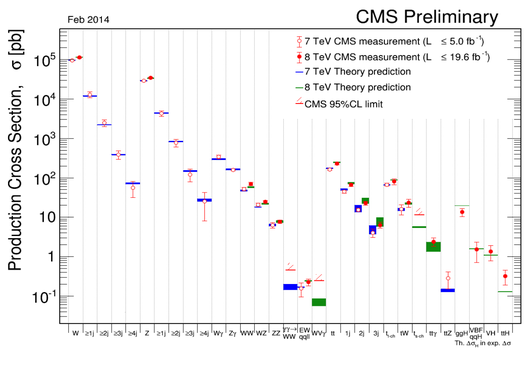
References

1. The CMS Collaboration , "Measurement of ZZ production cross section and anomalous trilinear gauge couplings in llll' decay at sqrt(s)= 8 TeV at the LHC", Technical Report CMS-PAS-SMP-13-005, CERN, Geneva, 2013.
2. The CMS Collaboration , "Measurement of ZZ production cross section at 7 and 8 TeV and anomalous gauge couplings limits in 2l2nu decay channel", Technical Report CMS-PAS-SMP-12-016, CERN, Geneva, 2013.
3. The CMS Collaboration , "Measurement of WW production rate", Technical Report CMS-PAS-SMP-12-013, CERN, Geneva, 2012.
4. The CMS Collaboration , "Measurement of WZ production rate", Technical Report CMS-PAS-SMP-12-006, CERN, Geneva, 2013.
5. The CMS Collaboration, "Measurement of the sum of WW and WZ production with W+dijet events in pp collisions at sqrt(5) = 7TeV, The European Physical Journal C73(2013),n0.2,doi:10.1140/epjc/sl0052-013-2283-3.

Email: a.kumar@cern.ch

Combined results





Conclusion

Experimental results are compatible with the Standard Model predictions.