LaThuile 2013

XVII Rencontres de Physique de La Vallée d'Aoste

Diboson studies at CMS

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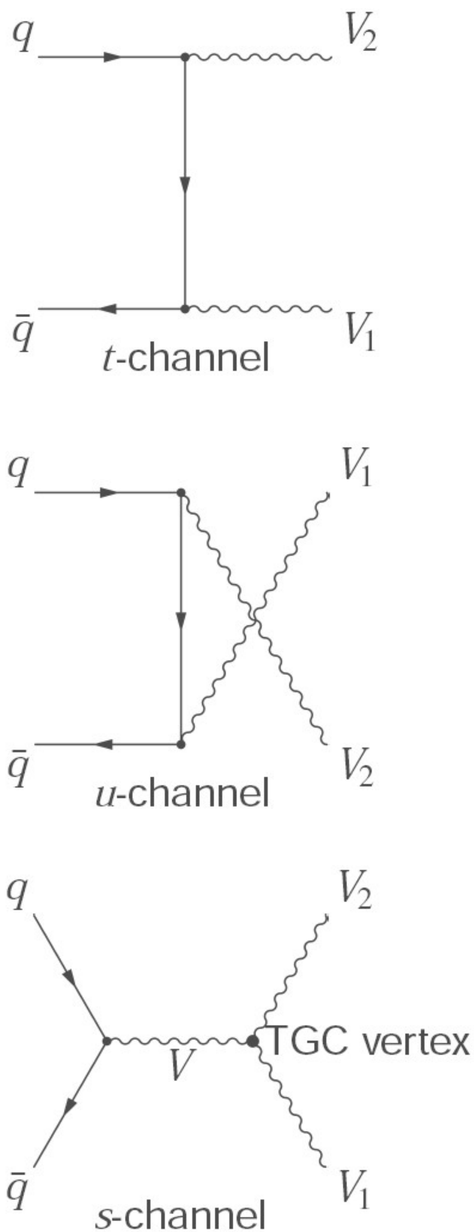
On behalf of CMS collaboration

Importance of diboson studies



- Diboson measurements are an important **test of the Standard Model (SM)**
- Diboson processes are the backgrounds for New Physics and Higgs search measurements
- Vector boson self-interactions are fundamental prediction of SM resulting from non-Abelian nature of the SU(2)xU(1) gauge theory
- Measurement of anomalous triple and quartic gauge boson couplings (aTGC and aQGC) is an **indirect search for New Physics**

CMS diboson cross section measurements overview

	Int. luminosity		*Cross section measurement phase space*	
	@ 7TeV	*@ 8TeV*		
ZZ→2l2l' **(l = e/μ;l' = e/μ/τ)**	**5.0 fb^{-1}**	**5.3 fb^{-1}**	$60<M(Z_{1,2})<120$ GeV	pp→ZZ+X
Wγ→lνγ	**5.0 fb^{-1}**	-	$E_T^{\gamma}>15/60/90$ GeV & $\Delta R(l,\gamma)>0.7$	pp→Wγ→lνγ+X
Zγ→llγ	**5.0 fb^{-1}**	-	$E_T^{\gamma}>15/60/90$GeV & $\Delta R(l,\gamma)>0.7$ & $M^{ll}>50$GeV	pp→Zγ→llγ+X
Zγ→ννγ	**5.0 fb^{-1}**	-	$E_T^{\gamma}>145$ GeV & $\lvert\eta^{\gamma}\rvert<1.4$	pp→Zγ→ννγ+X
W^+W^-→lνlν	**4.9 fb^{-1}**	**3.5 fb^{-1}**	full	pp→W^+W^-+X
W^+W^-+WZ→lνjj	**5.0 fb^{-1}**	-	full	pp→WW+WZ+X
WZ→lνll	**1.0 fb^{-1}**	-	full	pp→WZ+X
Exclusive **γγ→W^+W^-**	**5.0 fb^{-1}**	-	full $P_T(\mu,e)>20$GeV & $\lvert\eta(\mu,e)\rvert<2.4$ & $P_T(\mu e)>100$GeV	pp→$p^{(*)}W^+W^-p^{(*)}$ →$p^{(*)}e\mu p^{(*)}$

New!

Dominant backgrounds

	Main background
$ZZ\to 2l2l'$ ($l = e/\mu; l' = e/\mu/\tau$)	WZ/Z+jets [jet is misidentified as a lepton $\to$ fake lepton]
$Z\gamma\to\nu\nu\gamma$	jets events [one jet is misidentified as a photon + MET due to misidentified of jet energy] non-collision events containing [fake photons]
$Z\gamma\to ll\gamma$	Z+jets events [jet is misidentified as a photon $\to$ fake photon]
$W\gamma\to l\nu\gamma$	W+jets events [jet is misidentified as a photon $\to$ fake photon]
$W^+W^-\to l\nu l\nu$	W+jets [jet is misidentified as a lepton $\to$ fake lepton] top-quark events
$W^+W^-+WZ\to l\nu jj$	W+jets

Dominant backgrounds always derived from data, others with small contribution from the simulation.

CMS bkg from data determination methods

Used for:

Fake rate method (often used for fake leptons, jets misidentified as leptons)

- Select data control sample dominated with background to measure the probability (“fake rate”=FR) for a loose lepton object (fake lepton) to pass the tight requirements used in the selection
- Use the FR to extrapolate the yield from a loose lepton sample (background enriched) to the fully selected leptons

WW (W+jet bkg)
ZZ (Z+jet, WZ+jet, tt bkg)

Template fit method (often used for fake photons, jets misidentified as photons)

- Perform a two component fit using the signal and background templates in discriminating observable

Vgamma (V+jet bkg)
WW+WZ->2l2j (W+jets bkg)

Data/MC scale factor

- Using the data control sample dominated with background to rescale the simulation

WW ($W\gamma$ bkg)*

Measurement of efficiency

- Measurement of the selection efficiency and applying it to background dominated data control sample

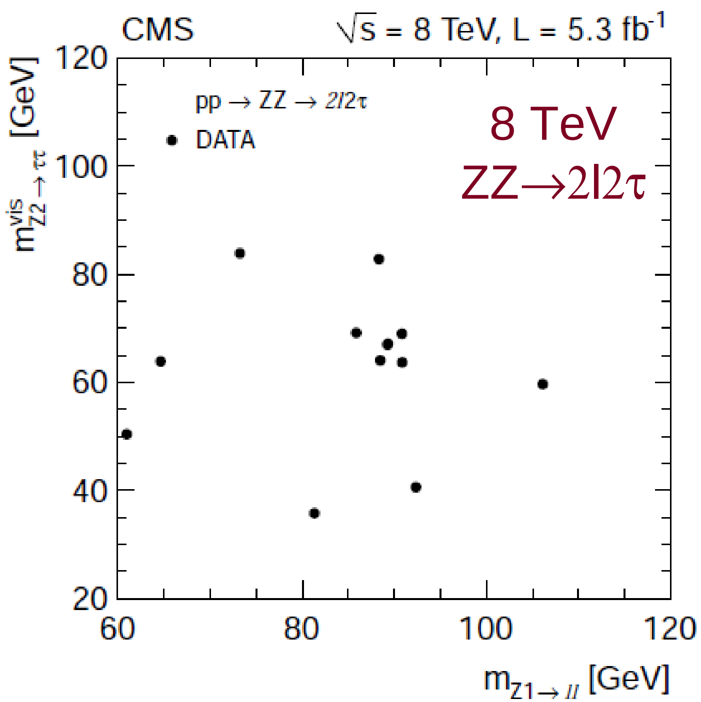
WW (tt bkg)

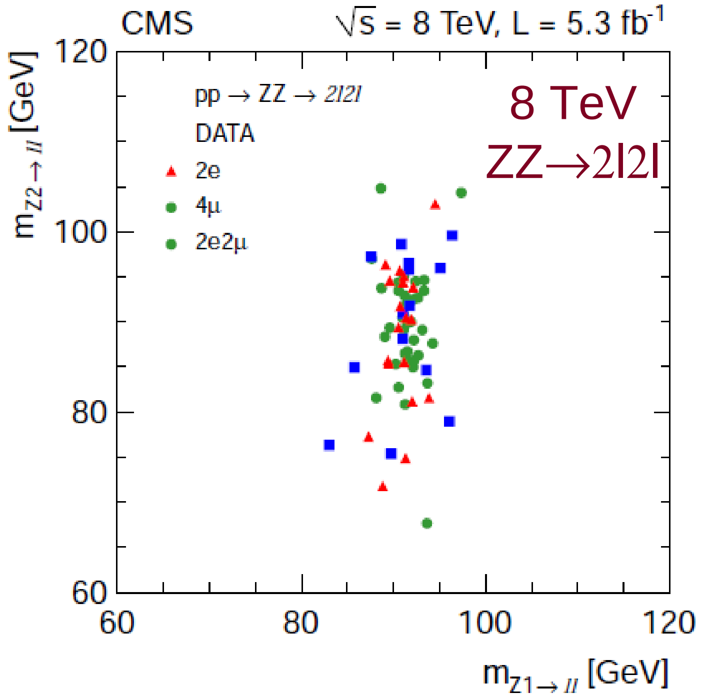
ZZ→2l2l' (l = e/μ; l' = e/μ/τ) signature and selection

ZZ final state expected to have only small contribution from background processes
• algorithms tuned to maximize the lepton-reconstruction efficiency

Signature
4 isolated leptons

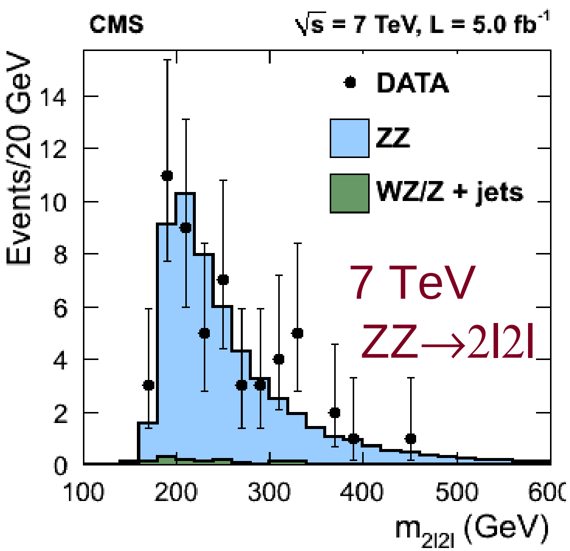
Backgrounds
Zbb, tt, Z+jets, ZW+jets
(estimated from data: fake rate method)

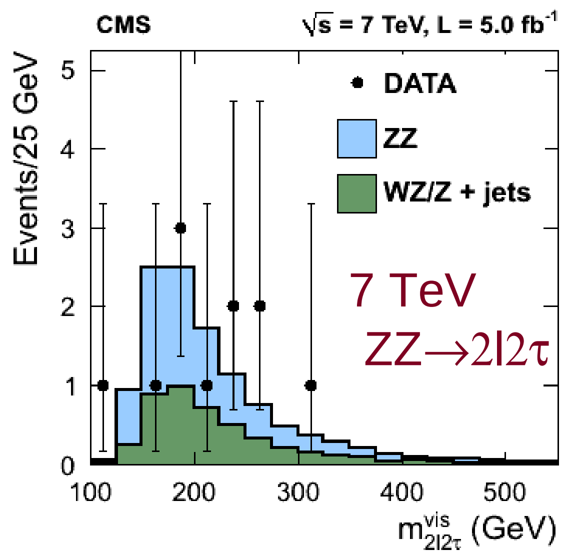




Selection
- 4 isolated leptons (P_T^l>20/10/7/5 GeV; different selection for different final state)
- 2 same flavour opposite charge lepton pairs
- Both Z candidate masses in Z mass window (60 < M_Z < 120 GeV)

ZZ→2l2l' (l = e/μ; l' = e/μ/τ) results (7 and 8 TeV)





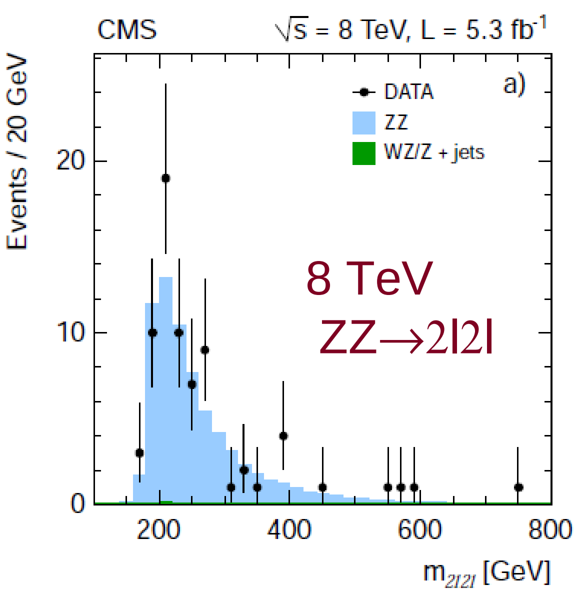
J. High Energy Phys. 1301 (2013) 063, [arXiv:1211.4890] [CERN-PH-EP-2012-336]

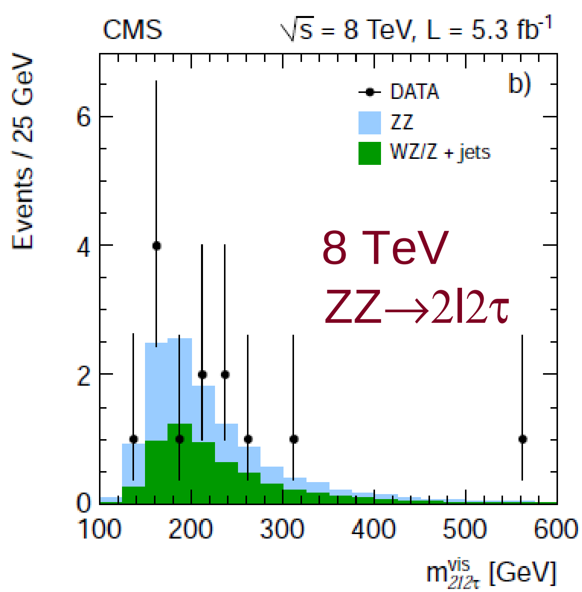
σ(pp→ZZ; 60 < $M_{Z1,2}$< 120 GeV) @ 7 TeV:
6.24 $^{+0.86}_{-0.8}$ (stat.) $^{+0.41}_{-0.32}$ (syst.) ± 0.14 (lumi.) pb
Theory (MCFM): 6.3 ± 0.4 pb

Data in agreement with the SM expectations in all channels.

Results dominated by statistic uncertainty.

To include all the final states in the calculation of the cross section, a simultaneous fit to the numbers of observed events in all the decay channels is performed.





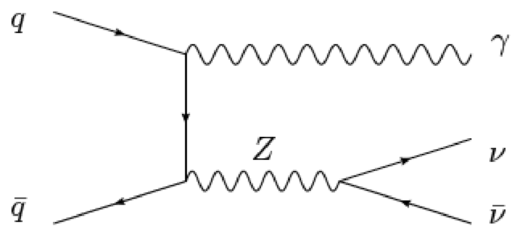
@ 8 TeV:

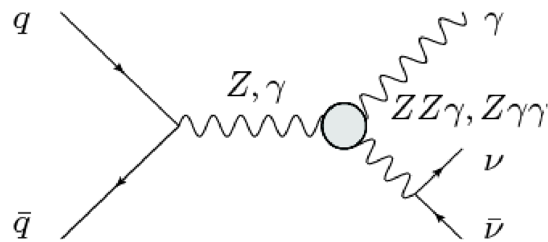
Channel	4e	4μ	2e2μ	2ℓ2τ
ZZ	11.6 ± 1.4	20.3 ± 2.2	32.4 ± 3.5	6.5 ± 0.8
Background	0.4 ± 0.2	0.4 ± 0.3	0.5 ± 0.4	5.6 ± 1.4
Signal+background	12.0 ± 1.4	20.7 ± 2.2	32.9 ± 3.5	12.1 ± 1.6
Data	14	19	38	13

σ(pp→ZZ; 60 < $M_{Z1,2}$< 120 GeV) @ 8 TeV:
8.4 ± 1.0 (stat.) ± 0.7 (syst.) ± 0.4 (lumi.) pb
Theory (MCFM): 7.7 ± 0.4 pb

submitted to Phys. Lett. B [arXiv:1301.4698] [CERN-PH-EP-2012-376]

$Z\gamma \to \nu\nu\gamma$ production and signature





SM forbidden vertex!

Visible signal is from ECAL only
⇒ non-collision background (beam halo, cosmic muons) is significant

Backgrounds

jets→"γ"+MET (estimated from data: fake rate method)

W→eν (estimated from data: measurement of efficiency)

γ+jet, γγ, Wγ (estimated from MC)

non-collision
(estimated from data: template method fit on photon timing)

Signature
1 isolated photon + large MET

Selection

$Z\gamma \to \nu\nu\gamma$ signature

- Isolated high P_T photon (E_T^{γ}>145 GeV due to on-line selection) in ECAL barrel
- Large missing transverse energy (MET>130 GeV)

Reduction of collision backgrounds (γ+jet, jets, Wγ)

- Veto events containing significant charged track or hadronic activity (jet veto)

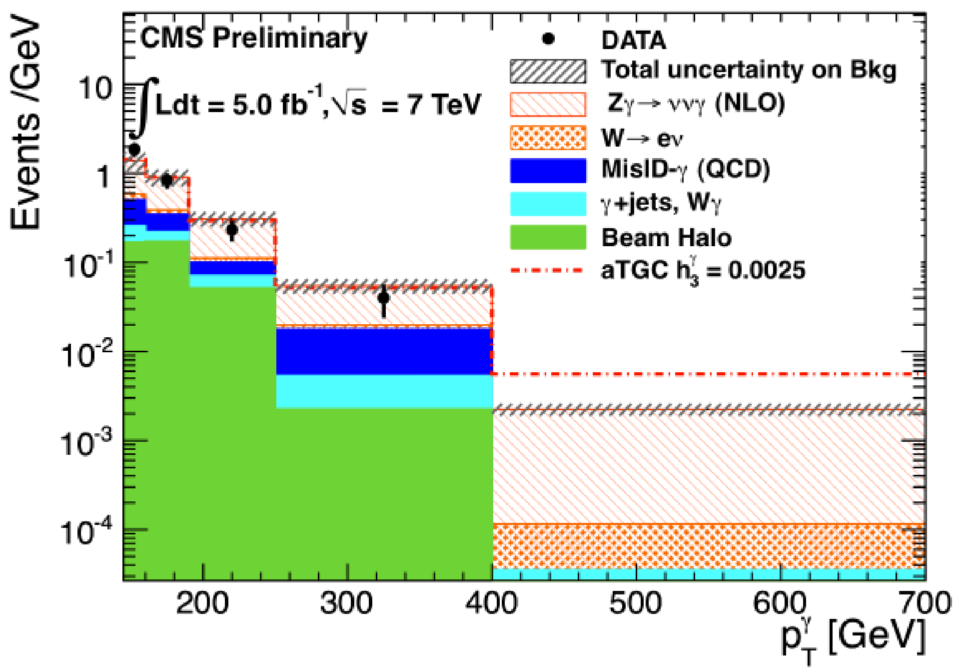
Reduction of non-collision background (photon produced from cosmic muon or beam-halo)

- Photon timing required to be consistent with beam crossing
- Veto events with cosmic muon tracks

$Z\gamma \rightarrow \nu\nu\gamma$ results

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP12020

Source	Estimate
Misidentified jets	11.2 ± 2.8
Beam-gas processes	11.1 ± 5.6
Misidentified electrons	3.5 ± 1.5
$W\gamma$	3.3 ± 1.0
$\gamma\gamma$	0.6 ± 0.3
γ+jet	0.5 ± 0.2
Total	30.2 ± 6.5
$Z\gamma \rightarrow \nu\nu\gamma$ (NLO)	45.3 ± 6.9
data	73



- Beam halo one of the main backgrounds
- Still large statistical uncertainty
- Main systematic from beam halo background estimation and jet and track veto efficiency
- Measured cross section in agreement with SM NLO calculations

$\sigma(pp \rightarrow Z\gamma \rightarrow \nu\nu\gamma;\ E_T^{\gamma} > 145\text{GeV}\ |\eta^{\gamma}| < 1.4)$ @ 7 TeV:

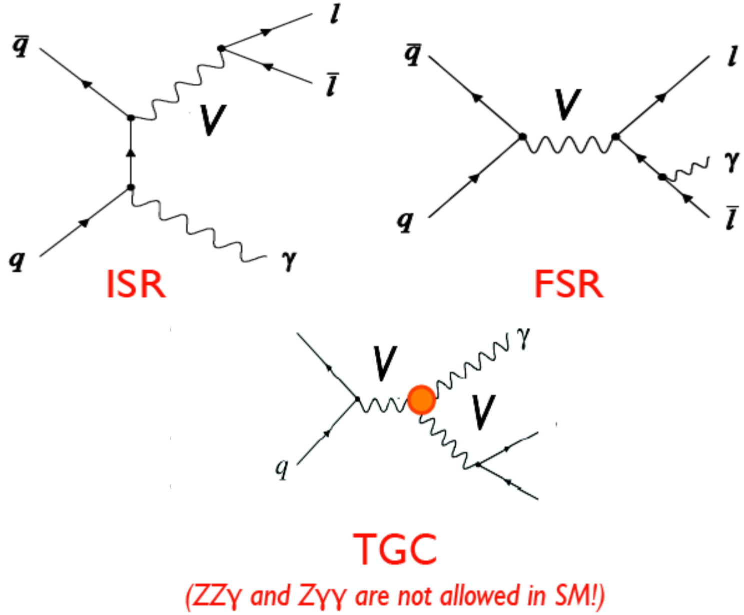
21.3 ± 4.2 (stat.) ± 4.3 (syst.) ± 0.5 (lumi.) fb

Theory (BAUR): 21.9 ± 1.1 fb

Wγ→lνγ and Zγ→llγ production and selection

Backgrounds (Wγ / Zγ)

V+jets, tt+jets / Z/γ*+jets
(estimated from data: template method fit)
DY, multiboson
(estimated from data: measurement of electron pixel seed track efficiency)
Zγ, γ+jets, ttγ, multijet / multijet, $t\bar{t}$, photon+jet, other diboson proceses
(estimated from MC)



Selection

Wγ→lνγ (l=e/μ) signature

- 1 isolated lepton (P_T^l>35 GeV due to on-line selection)
- Isolated photon (E_T^γ>15 GeV)
- Large transverse mass of W (MTW>70 GeV due to on-line selection)

Reduce jet/electron misidentified as photon background

- Require tight selection for photon

Reduce other diboson/DY backgrounds

- Veto events with second lepton

Zγ→llγ (l=e/μ) signature

- 2 isolated leptons (P_T^l>20 GeV due to on-line selection)
- Isolated photon (E_T^γ>15 GeV)
- M^{ll} > 50 GeV

Reduce jet misidentified as photon background

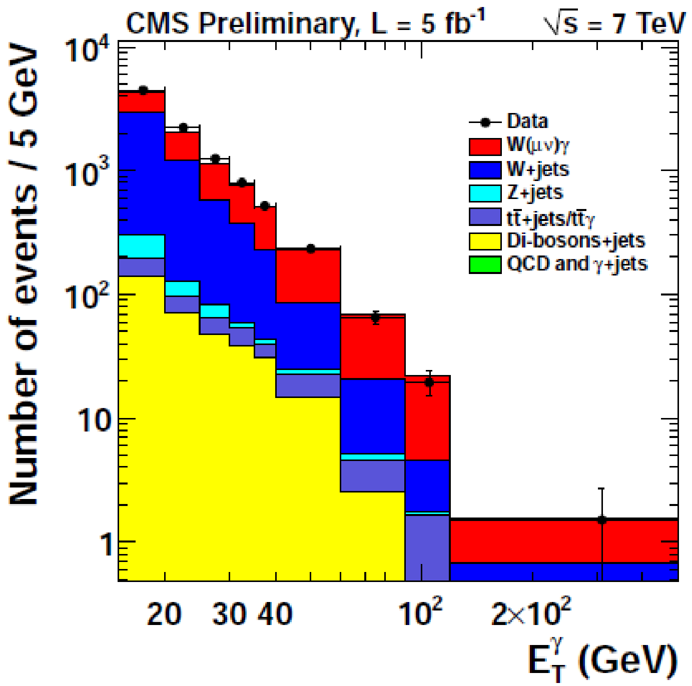
- Require tight selection for photon

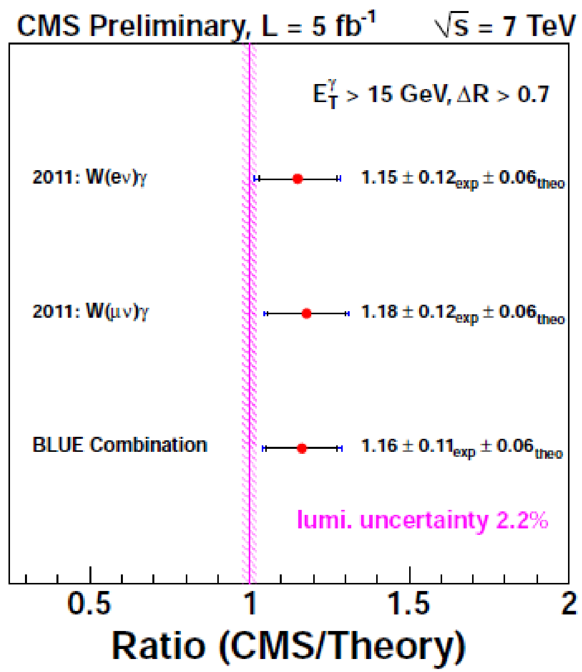
Wγ→lνγ results

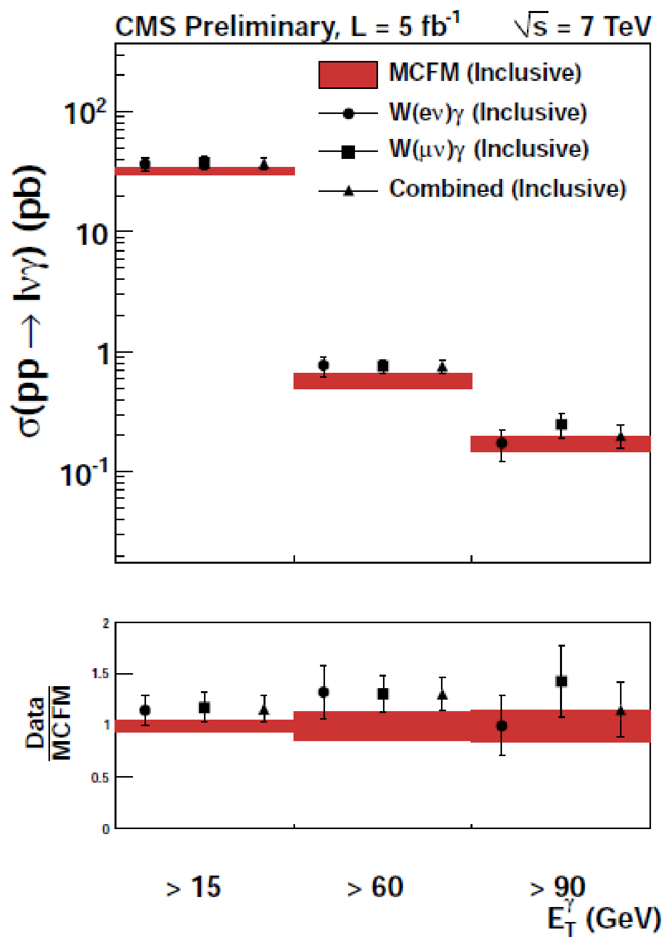
(pb)	$E_T(\gamma)$>15GeV	$E_T(\gamma)$>60GeV	$E_T(\gamma)$>90GeV
W(lν)γ	37.0±0.8(stat)±4.0(syst)±0.8(lumi)	0.76±0.05(stat)±0.08(syst)±0.02(lumi)	0.200±0.025(stat)±0.038(syst)±0.004(lumi)
NLO(MCFM)	31.81±1.80(syst)	0.58±0.08(syst)	0.173±0.026(syst)

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEWK11009

- Measurement dominated by systematic uncertainty
- Dominant systematic uncertainty from W+jet background estimation (correlation of MET and fake photon cluster shape)
- Measured cross section for lower $E_T(\gamma)$ values 1 σ higher then expected from NLO calculation (MCFM) consistent between e/mu channels





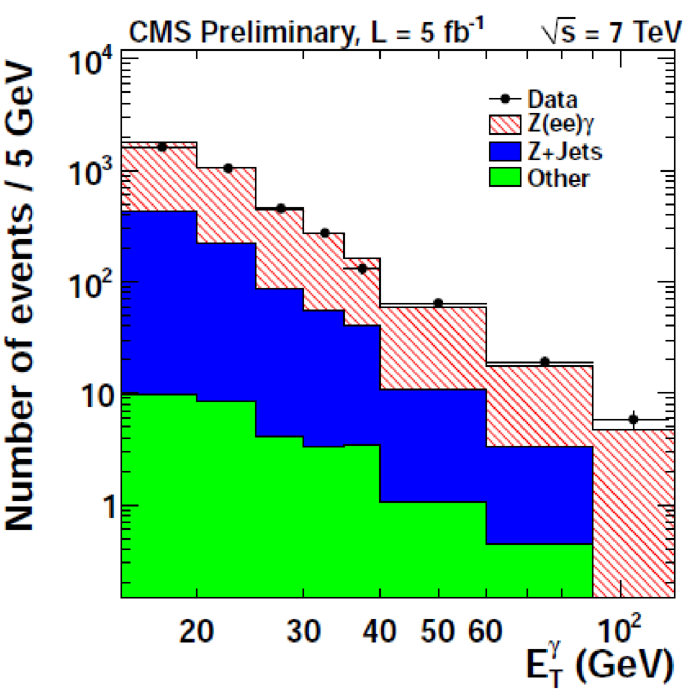


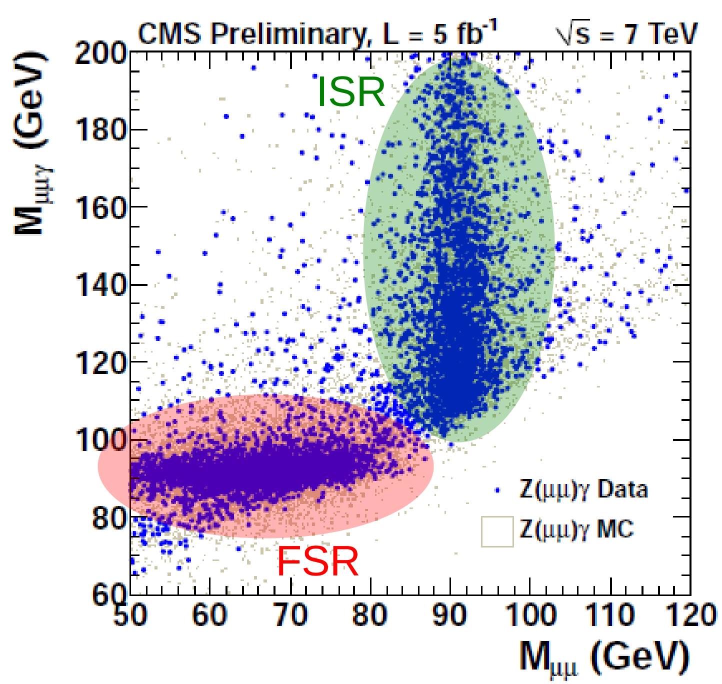
Zγ→llγ results

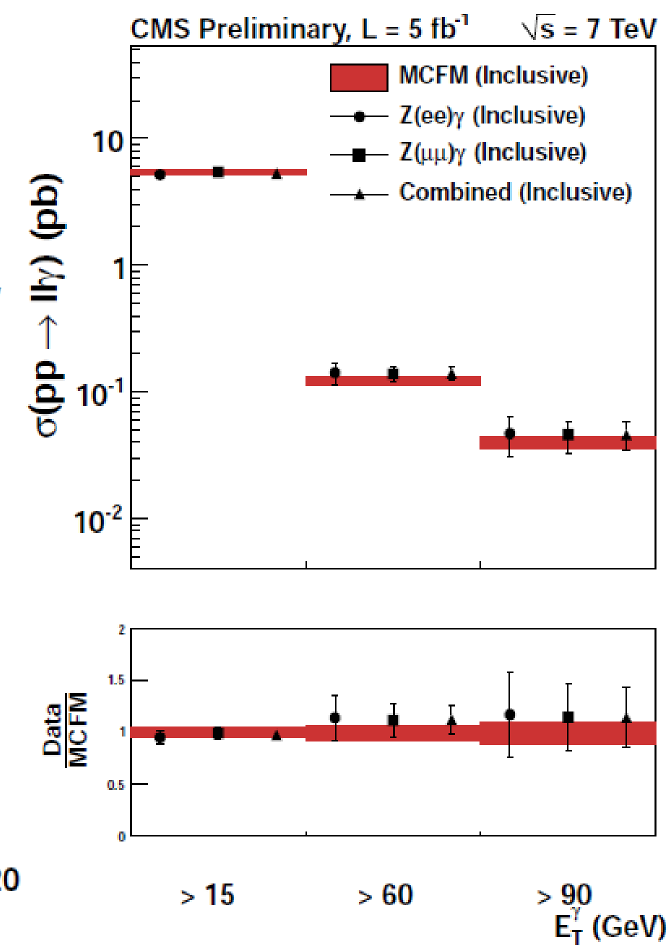
		σ(pp→Zγ→llγ) @ 7 TeV	Theory (MCFM)
ΔR(l,γ)>0.7 & M^{ll}>50 GeV	$E_T(\gamma)$>15GeV	5.33 ± 0.08(stat) ± 0.25(syst) ± 0.12(lumi) pb	5.4 ± 0.2(syst) pb
	$E_T(\gamma)$>60GeV	0.140 ± 0.011(stat) ± 0.013(syst) ± 0.003(lumi) pb	0.124 ± 0.009(syst) pb
	$E_T(\gamma)$>90GeV	0.046 ± 0.007(stat) ± 0.009(syst) ± 0.001(lumi) pb	0.040 ± 0.004(syst) pb

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEWK11009

- Measured cross section in agreement with NLO calculation (MCFM)

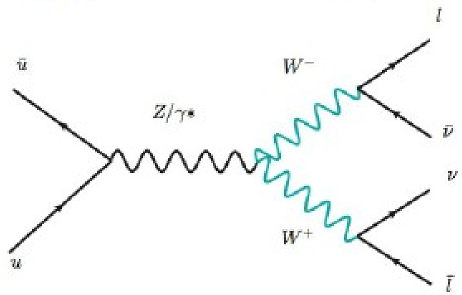


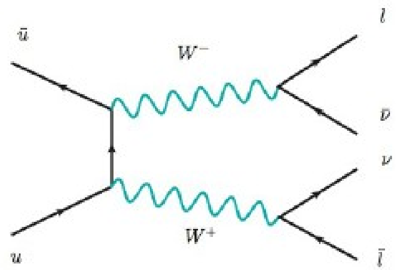




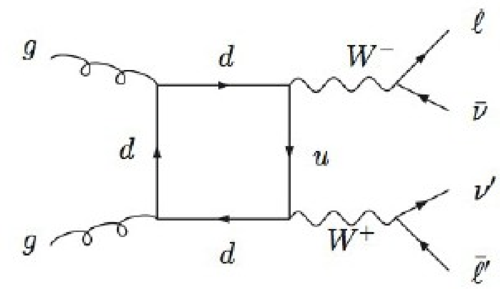
$W^+W^- \to l\nu l\nu$ production and signature

- $q\bar{q} \to WW$ (97 %)





- $gg \to WW$ (3 %)



Signature
2 isolated oppositely charged leptons
+ large MET

Backgrounds
$t\bar{t}$, tW (estimated from data: efficiency measurement)
W+jets (estimated from data: fake rate method)
multijet (estimated from data: fake rate method)
$W\gamma^*$ (estimated from data: Data/MC scale factor)
DY (estimated from data: Data/MC scale factor)
dibosons ($W\gamma$, WZ, ZZ) (estimated from MC)

$W^+W^- \rightarrow l\nu l\nu$ selection and systematic uncertainty

Cross section measured at 7TeV and 8TeV using the same strategy.

Selection

$W^+W^- \rightarrow l\nu l\nu$ ($l=e/\mu$) signature

- Two isolated high P_T leptons with opposite charge ($P_T^l > 20$ GeV)
- Large missing transverse energy (MET tighter selection in same flavour final state)

Reduce Z background

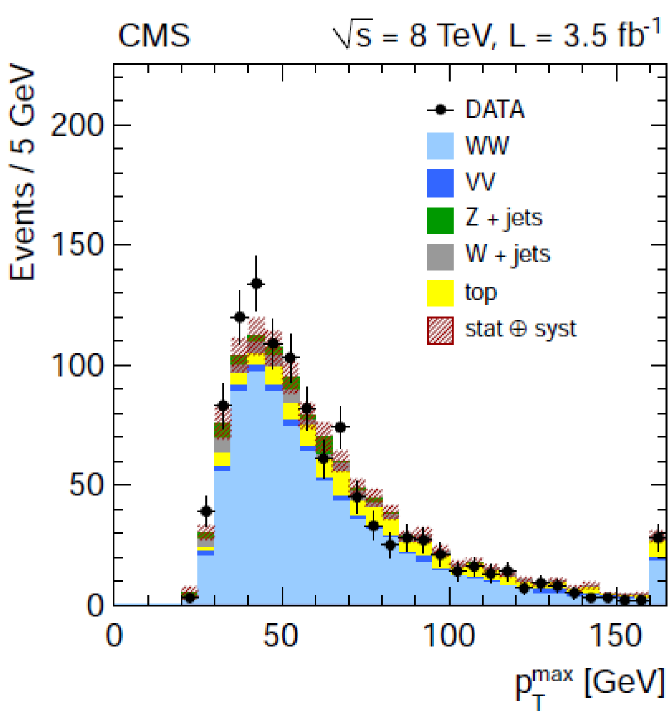
- Veto events in Z mass window for same flavour final state

Reduce top-quark decay background

- Veto events with high P_T jets ($P_T^{jet} > 30$ GeV)
- Veto events with top-tagged jets

Reduce other diboson backgrounds (WZ/ZZ)

- Veto events with third lepton

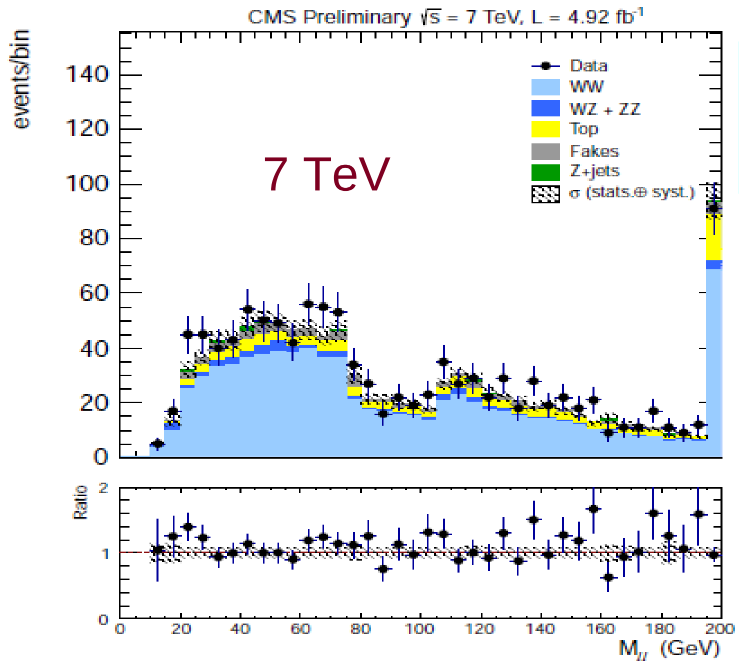


Main systematic uncertainty

- Jet veto efficiency unc. 4.7% (higher order corrections contributions to the WW/Z efficiency ratio unc.)
- Uncertainty on the background estimations ~ 15% dominated by the top quark bkg (statistical uncertainty in the control sample, systematic uncertainties on top-tagging efficiency measurement) and W+jets backgrounds (FR efficiency unc.)

$W^+W^- \to l\nu l\nu$ results (7 and 8 TeV)

Sample	Yield ± stat. ± syst.
$gg \to W^+W^-$	$46.0 \pm 0.6 \pm 14.2$
$q\bar{q} \to W^+W^-$	$750.9 \pm 4.1 \pm 53.1$
$t\bar{t}$ +tW	$128.5 \pm 12.8 \pm 19.6$
W+jets	$59.5 \pm 3.9 \pm 21.4$
WZ+ZZ	$29.4 \pm 0.4 \pm 2.0$
Z/γ^*	$11.0 \pm 5.1 \pm 2.6$
$W+\gamma$	$18.8 \pm 2.8 \pm 4.7$
$Z/\gamma^* \to \tau\tau$	$0.0 \pm 1.0 \pm 0.1$
Total Background	$247.1 \pm 14.6 \pm 29.5$
Signal + Background	$1044.0 \pm 15.2 \pm 62.4$
Data	1134

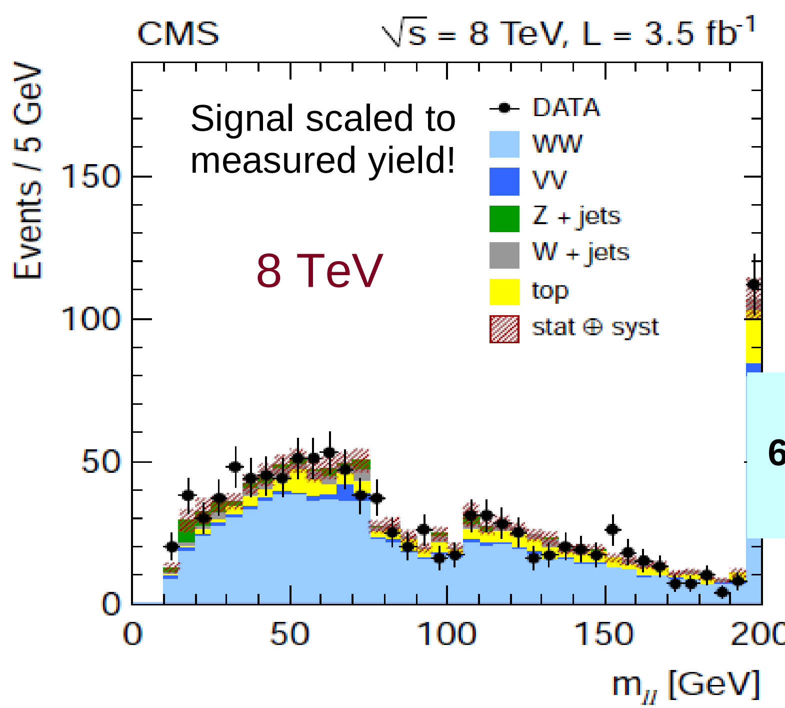


σ(pp→W^+W^-) @ 7 TeV:
52.4 ± 2.0 (stat.) ± 4.5 (syst.) ± 1.2 (lumi.) pb
Theory (MCFM): 47.0 ± 2.0 pb

CMS-PAS-SMP-12-005

Measured cross section is higher then NLO expectation.

Channel	$2\ell'2\nu$
W^+W^-	684 ± 50
$t\bar{t}$ and tW	132 ± 23
W+ jets	60 ± 22
WZ and ZZ	27 ± 3
Z/γ^*+jets	43 ± 12
$W\gamma^{(*)}$	14 ± 5
Total background	275 ± 35
Signal + background	959 ± 60
Data	1111



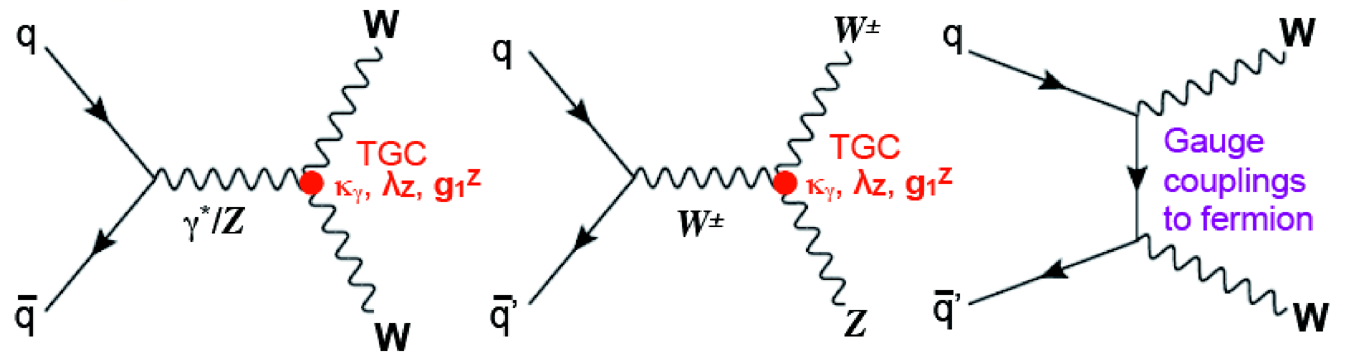
Not accounted for in theory calculation:	
Contributions from new boson (Higgs)	4%
Diffractive production	1%
Double parton scattering	
QED exclusive production	

σ(pp→W^+W^-) @ 8 TeV:
69.9 ± 2.8 (stat.) ± 5.6 (syst.) ± 3.1 (lumi.) pb
Theory (MCFM): $57.3^{+2.4}_{-1.6}$ pb

submitted to Phys. Lett. B [arXiv:1301.4698]
[CERN-PH-EP-2012-376]

WW+WZ→lνjj production and signature

WRT leptonic decay mode:
- S/B is worse → stronger cuts are applied
+ 6x larger BR → access to higher boson P_T and diboson mass



s-channel WW — s-channel WZ — t-channel WW (similar diagrams for WZ, ZZ)

Signature
1 isolated lepton + MET + 2 jets

Backgrounds
W+jets, dibosons, tt, t, DY+jets, multijet (template fit from data)

➔ Jet resolution doesn't allow to cleanly separate WW from WZ, so get admixture of the two.
➔ Large background. The main thrust of the analysis is to model this well & control systematics.

Selection

WW+WZ→lνjj signature
- 1 and only 1 isolated high P_T lepton ($P_T^{\mu(e)}$>25(30) GeV)
- Exactly 2 high P_T jets (P_T^{jet}>35 GeV)
- MET>25(30) GeV for μ(e)
- MTW>30(50) GeV for μ(e)

Reduce top backgrounds
- Veto events containing b-tagged jet
- Additional jet selection to improve S/B ($\Delta\eta_{jj}$,P_T(jj),..)

WW+WZ→lνjj results

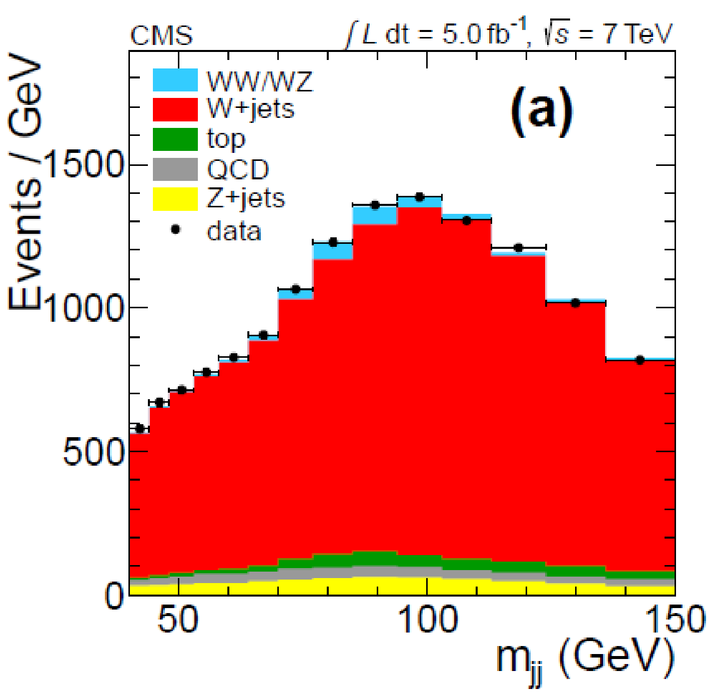
- Signal and background yields determined by the unbinned maximum likelihood fit on M(jj) distribution

Process	Shape	Constraint on normalization
Diboson (WW+WZ)	sim.	Unconstrained
W+jets	sim.	31314 pb ± 5% (NLO) [24]
$t\bar{t}$	sim.	163 pb ±7% (NLO) [25]
Single top	sim.	85 pb ±5% (NNLO) [26–28]
Drell-Yan+jets	sim.	3.05 nb ±4.3% (NNLO) [29]
Multijet	data	E_T^{miss} fit in data (see text)

W+jets: float factorization/renorm & ME-PS matching scales to get good modeling of data

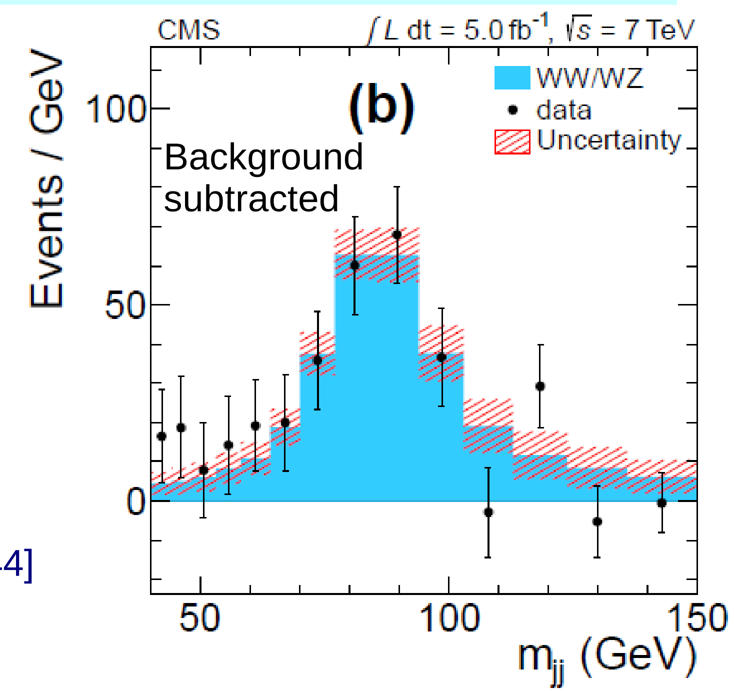
Process	Muon channel	Electron channel
Diboson (WW+WZ)	1899 ± 373	783 ± 306
W+jets	67384 ± 586	31644 ± 850
$t\bar{t}$	1662 ± 117	946 ± 67
Single top	650 ± 33	308 ± 17
Drell–Yan+jets	3609 ± 155	1408 ± 64
Multijet (QCD)	296 ± 317	4195 ± 867
Fit χ^2/dof (probability)	9.73/12 (0.64)	5.30/12 (0.95)
Total from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

σ(pp→WW+WZ) @ 7 TeV:
68.9 ± 8.7 (stat.) ± 9.7 (syst.) ± 1.5 (lumi.) pb
Theory (MCFM): 65.6 ± 2.2 pb



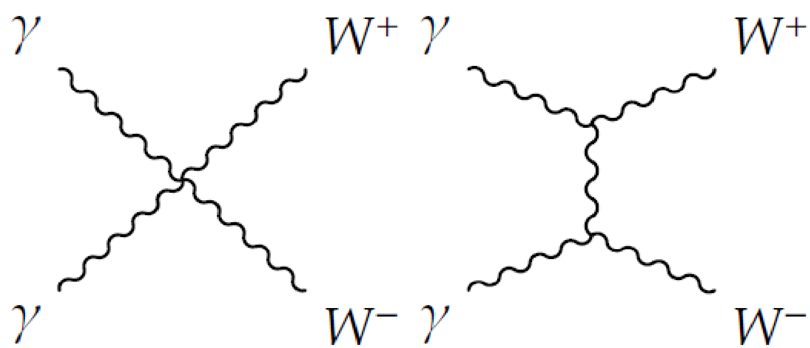
Significance of observation is 4.3 σ (using the profile likelihood ratio)

accepted by EPJC [arXiv:1210.7544] [CERN-PH-EP-2012-311]



$pp \to p^{(*)}\gamma\gamma p^{(*)} \to p^{(*)}W^+W^-p^{(*)}$ cross section measurement

A search for exclusive or quasi-exclusive W^+W^- production by two-photon exchange.



Signature
2 isolated leptons

Backgrounds
inclusive/hard-scatter W^+W^-
W+jet (from data, fake rate)
$\gamma\gamma \to \tau^+\tau^-$ (from data, MC/data norm)
DY $\to \tau^+\tau^-$

Selection
$\gamma\gamma \to W^+W^-$ signature
- eμ vertex with no associated charged tracks
- $P_T(e\mu) > 30$ GeV
- $M(e\mu) > 20$ GeV

signal exp.	*background exp.*	*data*
2.2 ± 0.5	0.84 ± 0.13(stat.)	2

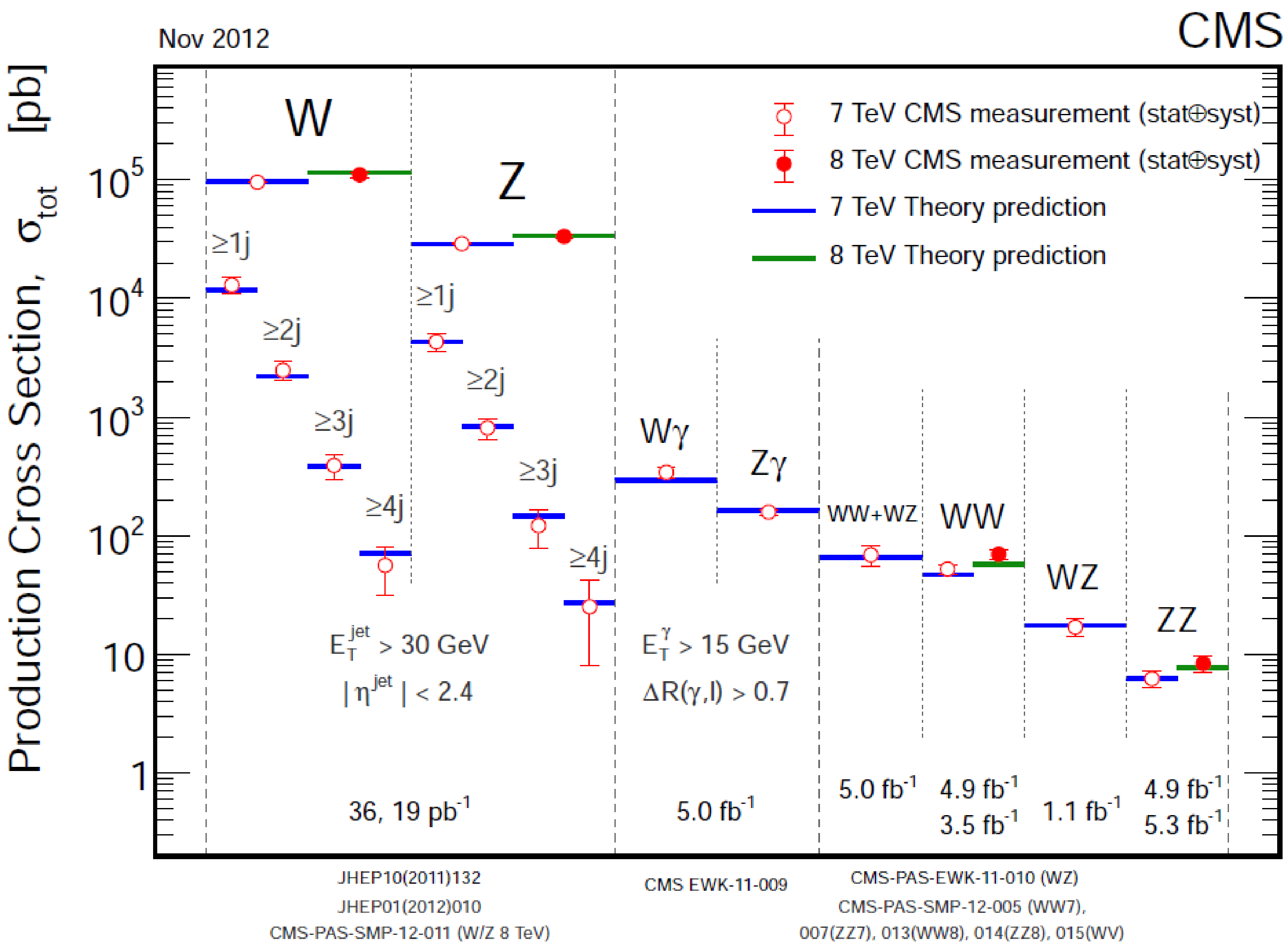
- Efficiencies and theoretical predictions for the signal are checked using $\gamma\gamma \to \mu^+\mu^-$ events
- Backgrounds are constrained from data using control samples in the N(tracks) and $P_T(e\mu)$ distributions.

The significance of the signal is 1.1 σ, with upper limit on the cross section of 8.4 fb at 95% CL (Theory: 3.8 ± 0.9 fb).

Exclusive $\sigma(pp \to p^{(*)}W^+W^-p^{(*)} \to p^{(*)}e\mu p^{(*)}$; $P_t^{e,\mu} > 20$GeV & $|\eta^{e,\mu}| < 2.4$ & $P_T(e\mu) > 100$GeV)
@ 7 TeV:
< 1.9 fb (95% CL)

http://cms-physics.web.cern.ch/cms-physics/public/FSQ-12-010-pas.pdf

CMS diboson xsection summary



Vector boson couplings: triple and quartic couplings

- SM gives exact values for vector boson couplings, but they are the least well measured quantities in EWK physics
- Anomalous TGC (aTGC) and QGC are the signature of New physics
- Anomalous couplings result in an increase of cross section at high boson P_T

We parametrize anomalous contributions to TGC and QGC

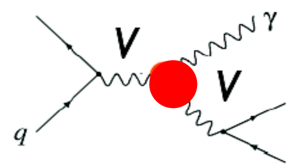
WWV vertex

Assumptions: electromagnetic gauge invariance, C and P symmetry conservation, Lagrangian $SU(2)_L xU(1)_Y$ invariant

$$\Delta\kappa_Z = \Delta g_1^Z - \Delta\kappa_\gamma \cdot \tan^2\theta_W, \quad \lambda = \lambda_\gamma = \lambda_Z$$

"LEP parametrization"

Nucl. Phys. B282 (1987) 253.
Phys. Rev. D41 (1990) 2113



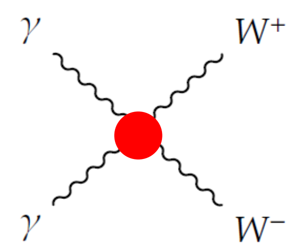
Zgamma channel

Assumptions: CP-conservation

ZZ channel

Assumptions: electromagnetic gauge invariance

Nucl.Phys. B282 (1987) 253



WWγγ vertex

Assumptions: electromagnetic gauge invariance, C, P, and $SU(2)_C$ symmetry

Phys.Lett. B288 (1992) 210-220

- Using the approach **without form factor for aTGC** and both **with and without form factor for aQGC**
- **CLs and profile likelihood criteria** were used to set the upper limit

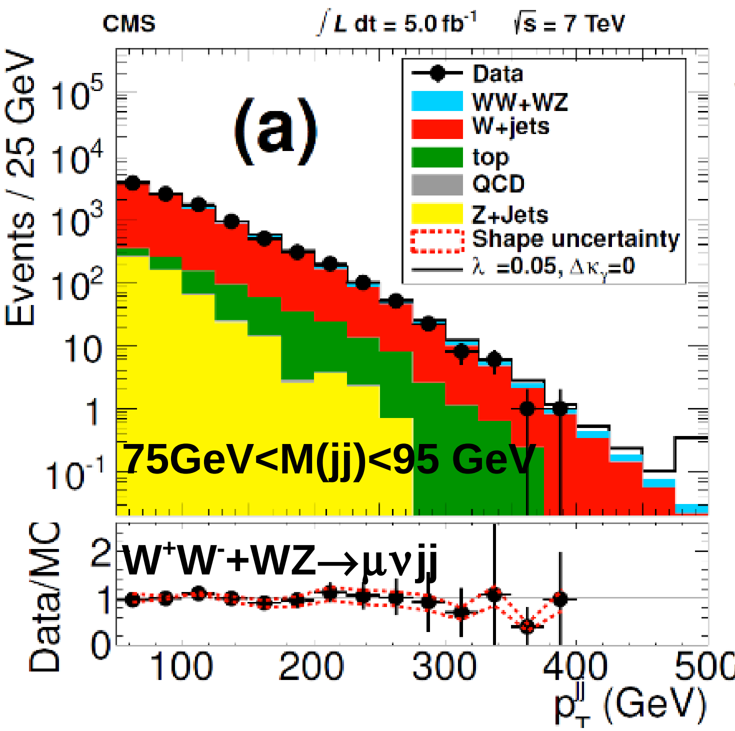
CMS vector boson coupling measurements

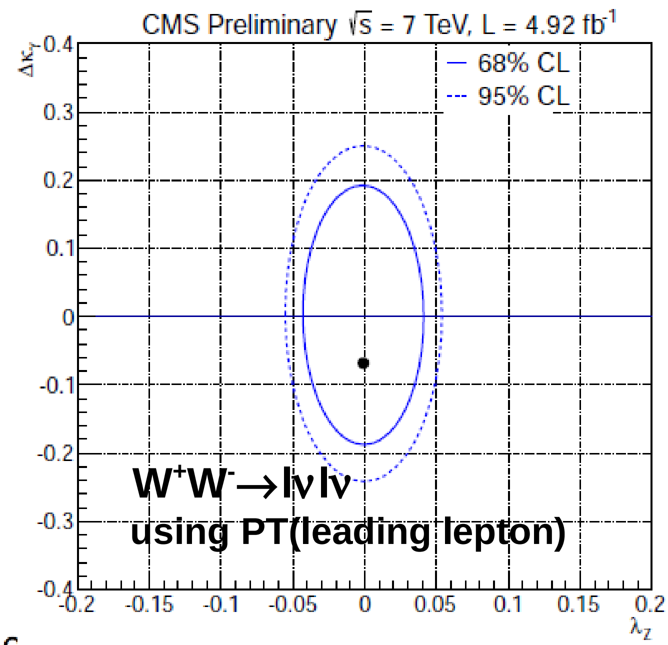
	Int. luminosity @ 7 TeV	*Vertex*	*Measured parameters*	*Variable for limit setting*
$ZZ \rightarrow 2l2l'$ ($l = e/\mu; l' = e/\mu/\tau$)	**$5.0\ fb^{-1}$**	ZZZ, $ZZ\gamma$	$f^Z_4, f^Z_5, f^\gamma_4, f^\gamma_5$	$M(2l2l)$
$W\gamma \rightarrow l\nu\gamma$	**$5.0\ fb^{-1}$**	$WW\gamma$	$\lambda^\gamma, \Delta\kappa^\gamma$	E_T^γ
$Z\gamma \rightarrow ll\gamma$	**$5.0\ fb^{-1}$**	$ZZ\gamma$, $Z\gamma\gamma$	$h^Z_3, h^Z_4, h^\gamma_3, h^\gamma_4$	E_T^γ
$Z\gamma \rightarrow \nu\nu\gamma$	**$5.0\ fb^{-1}$**	$ZZ\gamma$, $Z\gamma\gamma$	$h^Z_3, h^Z_4, h^\gamma_3, h^\gamma_4$	E_T^γ
$W^+W^- \rightarrow l\nu l\nu$	**$4.9\ fb^{-1}$**	$WW\gamma$, WWZ	$\lambda^Z, \Delta\kappa^\gamma, \Delta g_1^Z$	$P_T(l)$
$W^+W^- + WZ \rightarrow l\nu jj$	**$5.0\ fb^{-1}$**	$WW\gamma$, WWZ	$\lambda^Z, \Delta\kappa^\gamma$	$P_T(jj)$
Exclusive $\gamma\gamma \rightarrow W^+W^-$	**$5.0\ fb^{-1}$**	$WW\gamma\gamma$	$a^W_0/\Lambda^2, a^W_C/\Lambda^2$	$P_T(e\mu)$

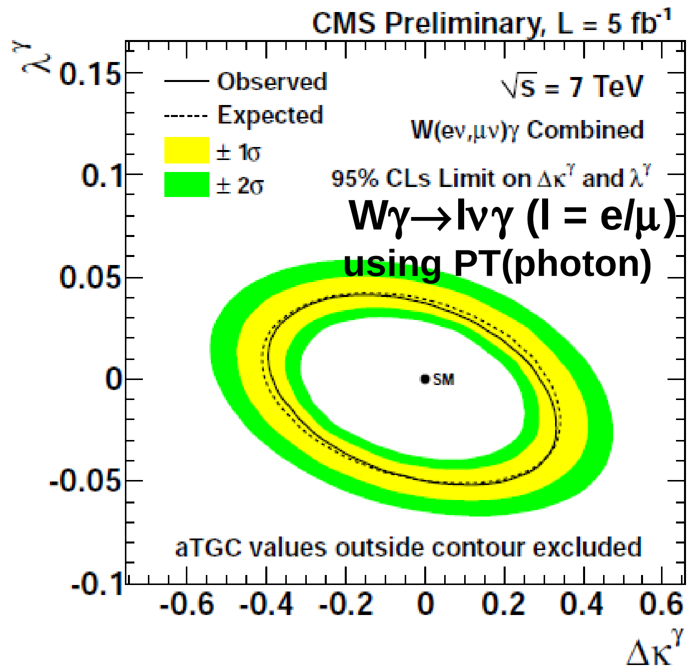
New!

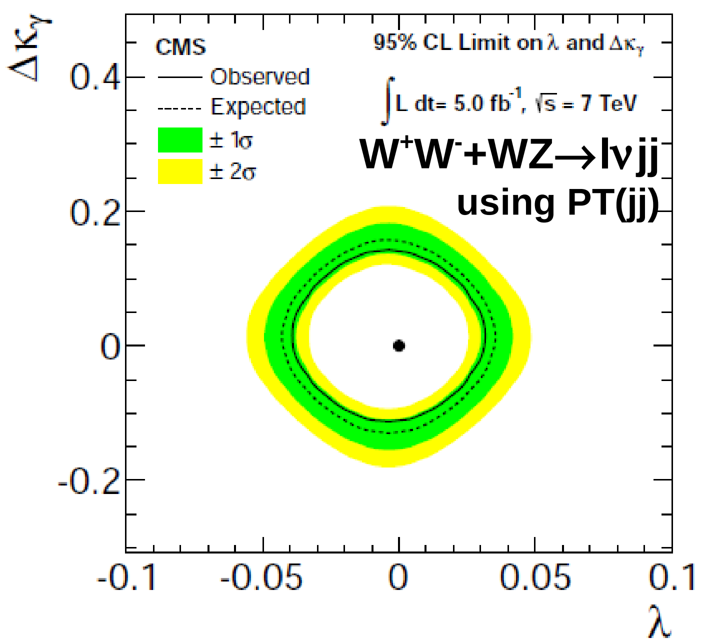
ZZ: J. High Energy Phys. 1301 (2013) 063, [arXiv:1211.4890] [CERN-PH-EP-2012-336]
$W\gamma$ & $Z\gamma$: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEWK11009
$Z\gamma \rightarrow \nu\nu\gamma$: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP12020
W^+W^-: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP12005
$W^+W^- + WZ \rightarrow l\nu jj$: accepted by EPJC [arXiv:1210.7544] [CERN-PH-EP-2012-311]
$\gamma\gamma \rightarrow W^+W^-$: http://cms-physics.web.cern.ch/cms-physics/public/FSQ-12-010-pas.pdf

Charged TGC results





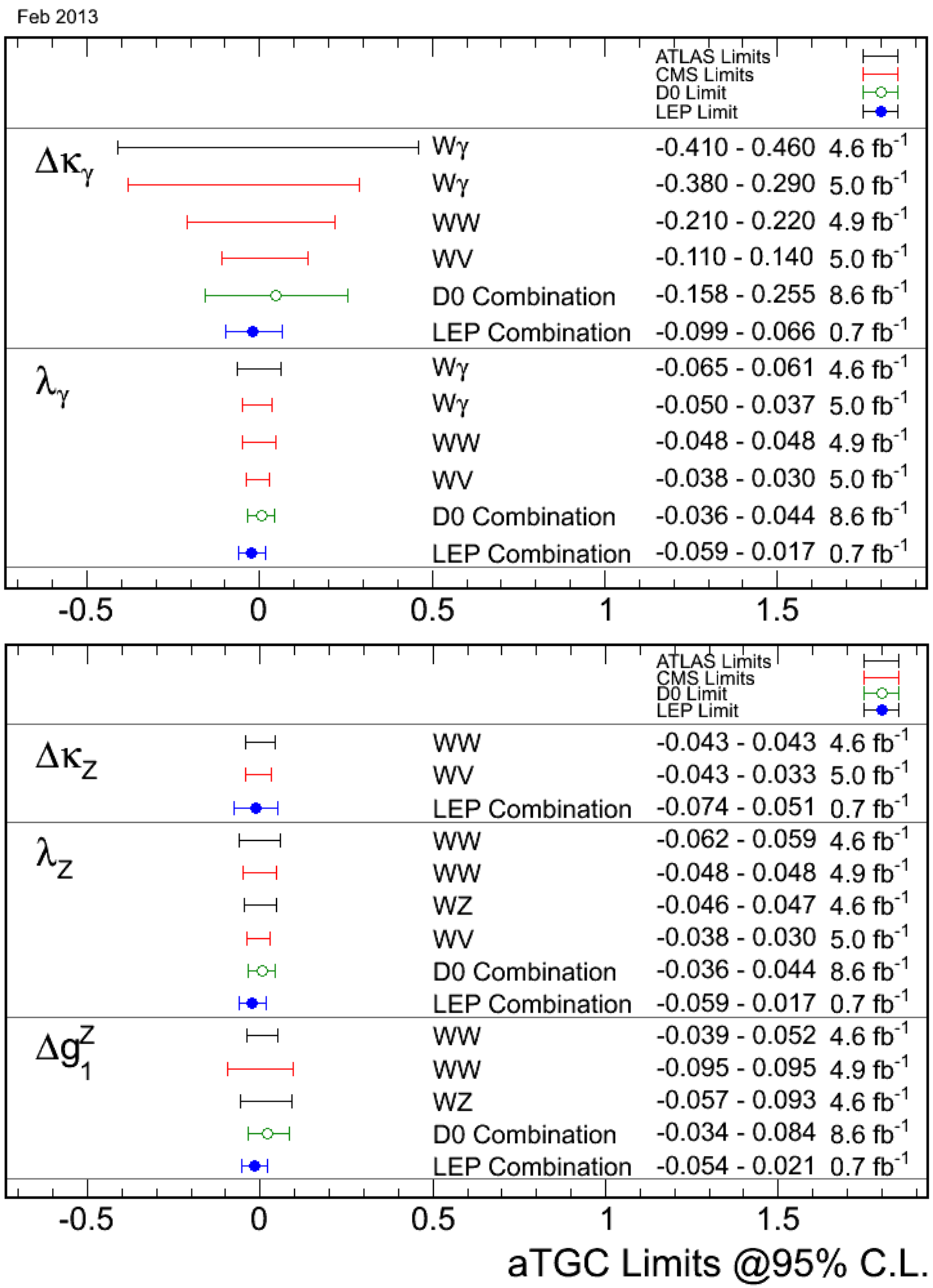




95% C.L.	$\Delta\kappa^\gamma$	λ	Δg_1^Z
$W\gamma \to l\nu\gamma$	[-0.38, 0.29]	[-0.05, 0.037]	-
$W^+W^- \to l\nu l\nu$	[-0.21, 0.22]	[-0.048, 0.048]	[-0.095, 0.095]
$W^+W^- + WZ \to l\nu jj$	[-0.111, 0.142]	[-0.038, 0.030]	-

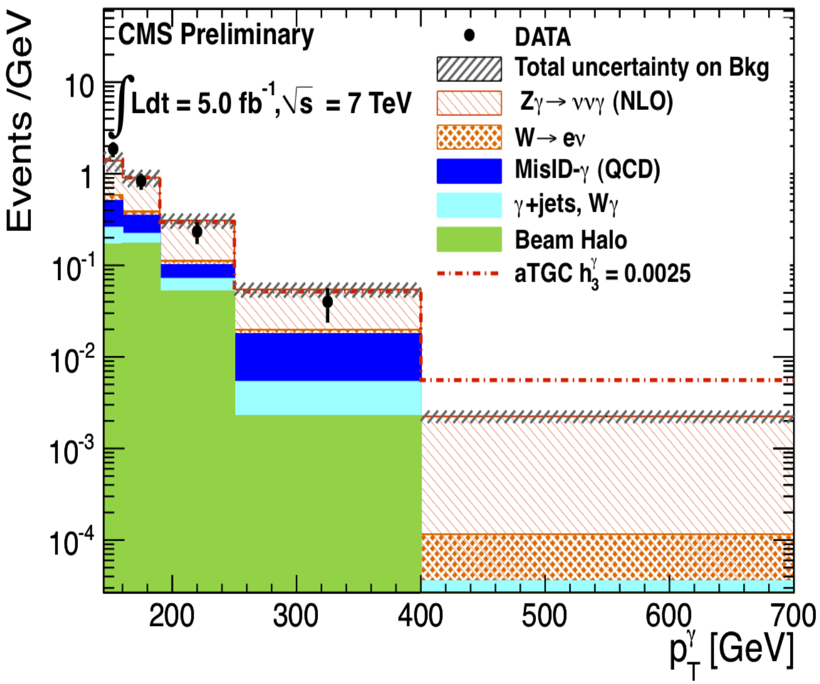
- Results are in the agreement with SM (no aTGC signal)
- Setting upper limits on aTGC parameters

Charged TGC at LHC, LEP, Tevatron

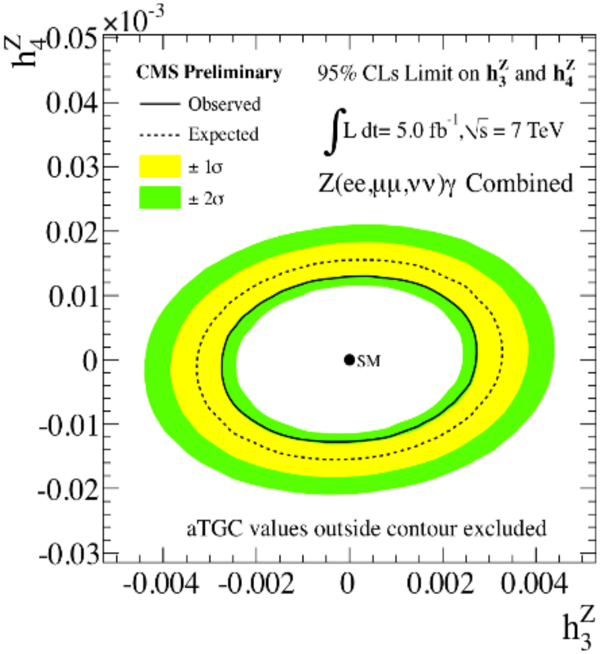


https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC

Zγ TGC results



Z→νν has 6x higher BR then Z→ll and no FSR production contribution.
⇒ more sensitive to aTGC.

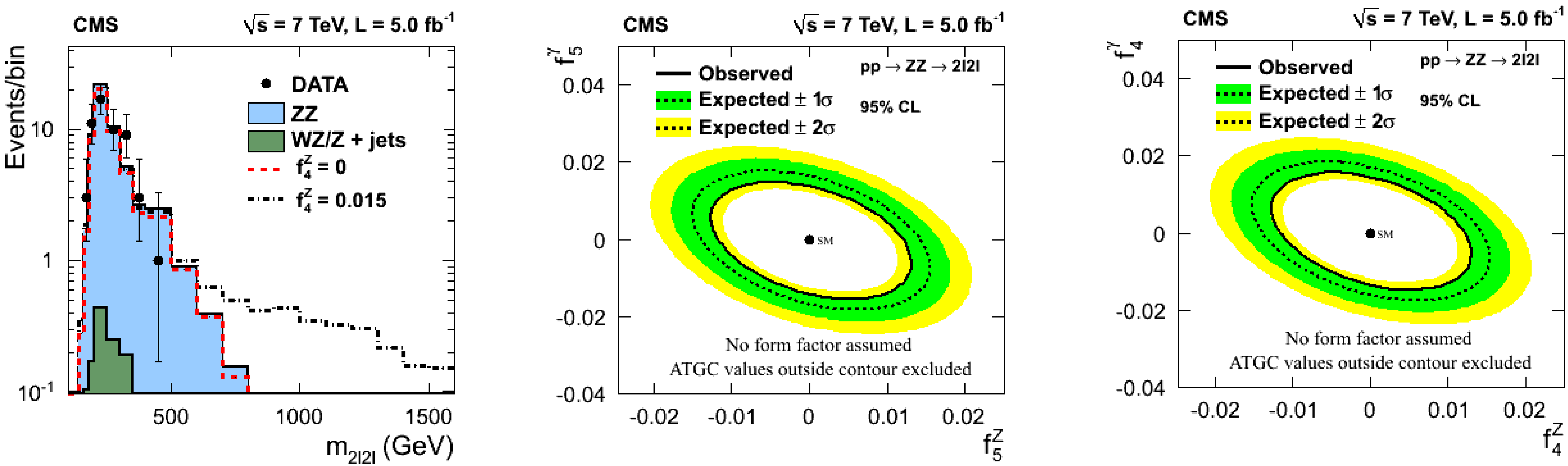


- Results are in the agreement with SM (no aTGC signal)
- Setting upper limits on aTGC parameters

LHC sensitivity exceeds LEP experiments.

x10^-3	h^Z_3	h^Z_4	h^γ_3	h^γ_4
Zγ→llγ	[-8.6, 8.4]	[-0.080, 0.079]	[-10, 10]	[-0.088, 0.088]
Zγ→ννγ	[-3.1, 3.1]	[-0.014, 0.014]	[-3.2, 3.2]	[-0.016, 0.016]
Zγ→ννγ,llγ	[-2.7, 2.7]	[-0.013, 0.013]	[-2.9, 2.9]	[-0.014, 0.015]

ZZ TGC results



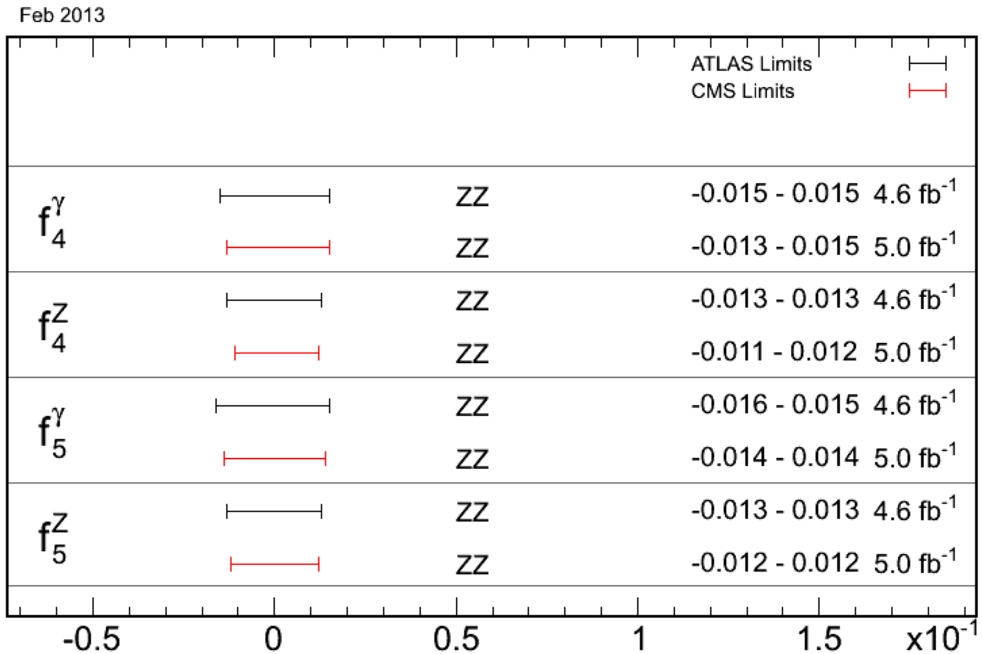
- Results are in the agreement with SM (no aTGC signal)
- Setting upper limits on aTGC parameters

LHC sensitivity exceeds LEP experiments.

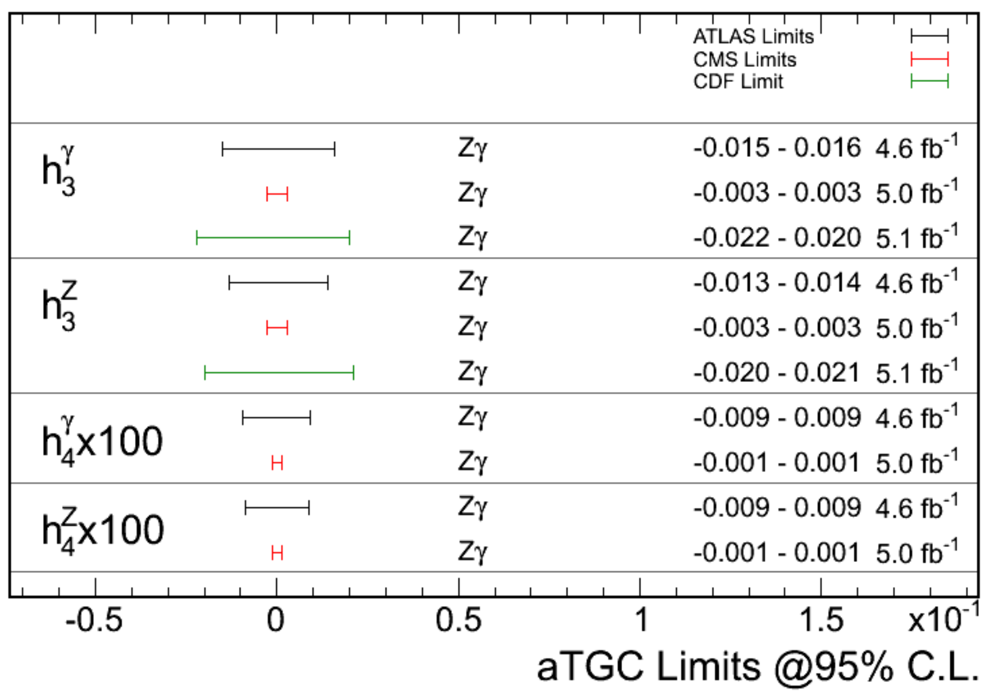
	f^{Z}_{4}	f^{Z}_{5}	f^{γ}_{4}	f^{γ}_{5}
ZZ→2l2l'	[-0.011, 0.012]	[-0.012, 0.012]	[-0.013, 0.015]	[-0.014, 0.014]

Neutral TGC at LHC, Tevatron

Parameter	LEP
f_4^γ	$[-0.17,\ 0.19]$
f_4^Z	$[-0.28,\ 0.32]$
f_5^γ	$[-0.35,\ 0.32]$
f_5^Z	$[-0.34,\ 0.35]$

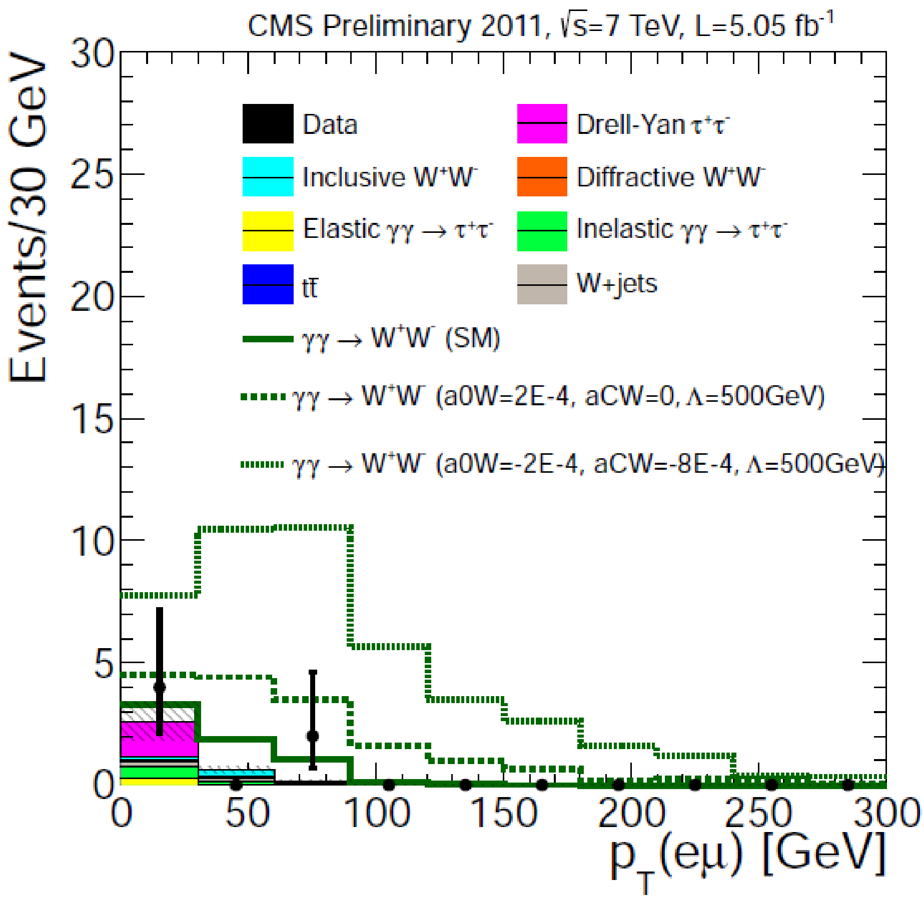


Parameter	LEP
h_1^γ	$[-0.05,\ 0.05]$
h_2^γ	$[-0.04,\ 0.02]$
h_3^γ	$[-0.05,\ -0.00]$
h_4^γ	$[0.01,\ 0.05]$
h_1^Z	$[-0.12,\ 0.11]$
h_2^Z	$[-0.07,\ 0.07]$
h_3^Z	$[-0.19,\ 0.06]$
h_4^Z	$[-0.04,\ 0.13]$



https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC

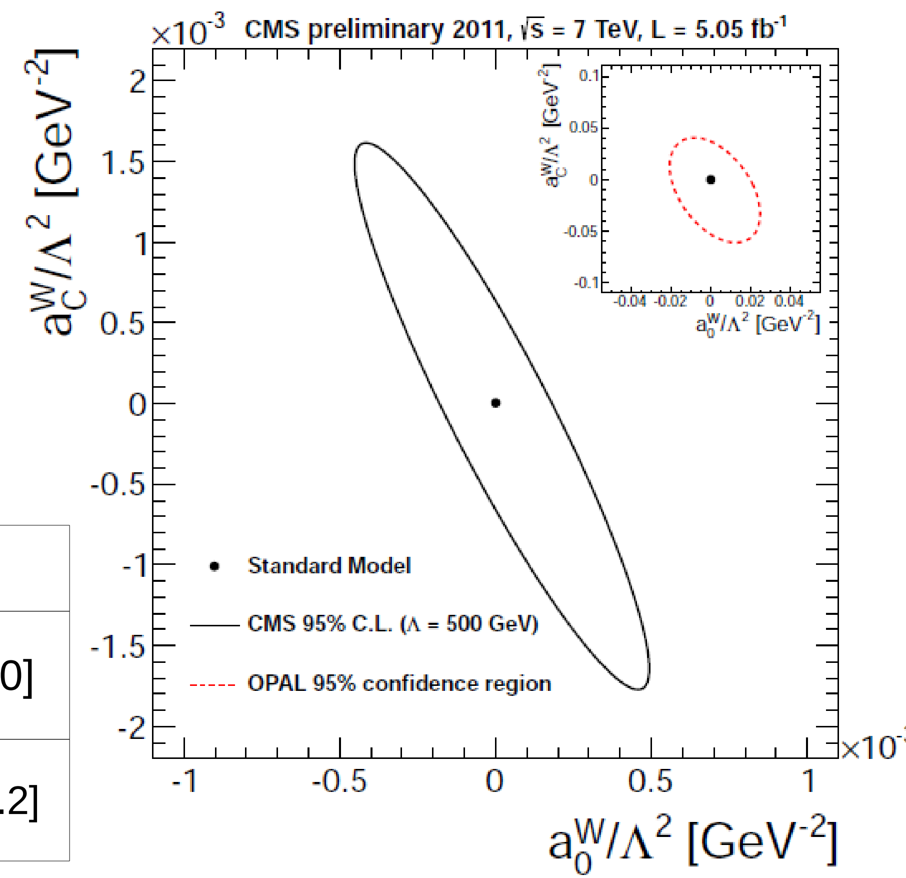
$pp\to p^{(*)}\gamma\gamma p^{(*)}\to p^{(*)}W^+W^-p^{(*)}$ QGC results



The tail of the dilepton transverse momentum distribution (P_T> 100 GeV) studied for deviations from the Standard Model.

- No events observed → setting upper limits on aQGC

Sensitivity exceeds LEP experiments !



$x10^{-6}$	a^W_0/Λ^2	a^W_C/Λ^2
$pp\to p^{(*)}\gamma\gamma p^{(*)}\to p^{(*)}W^+W^-p^{(*)}$ (form factor Λ=500GeV)	[-170, 170]	[-600, 600]
$pp\to p^{(*)}\gamma\gamma p^{(*)}\to p^{(*)}W^+W^-p^{(*)}$ (no form factor)	[-2.8, 2.8]	[-10.2, 10.2]

http://cms-physics.web.cern.ch/cms-physics/public/FSQ-12-010-pas.pdf

Summary

CMS performed measurements of many diboson production processes with full 2011 dataset (7 TeV) and several measurements with $5 fb^{-1}$ of 2012 dataset (8 TeV)

- All measurements are in agreement with NLO expectations

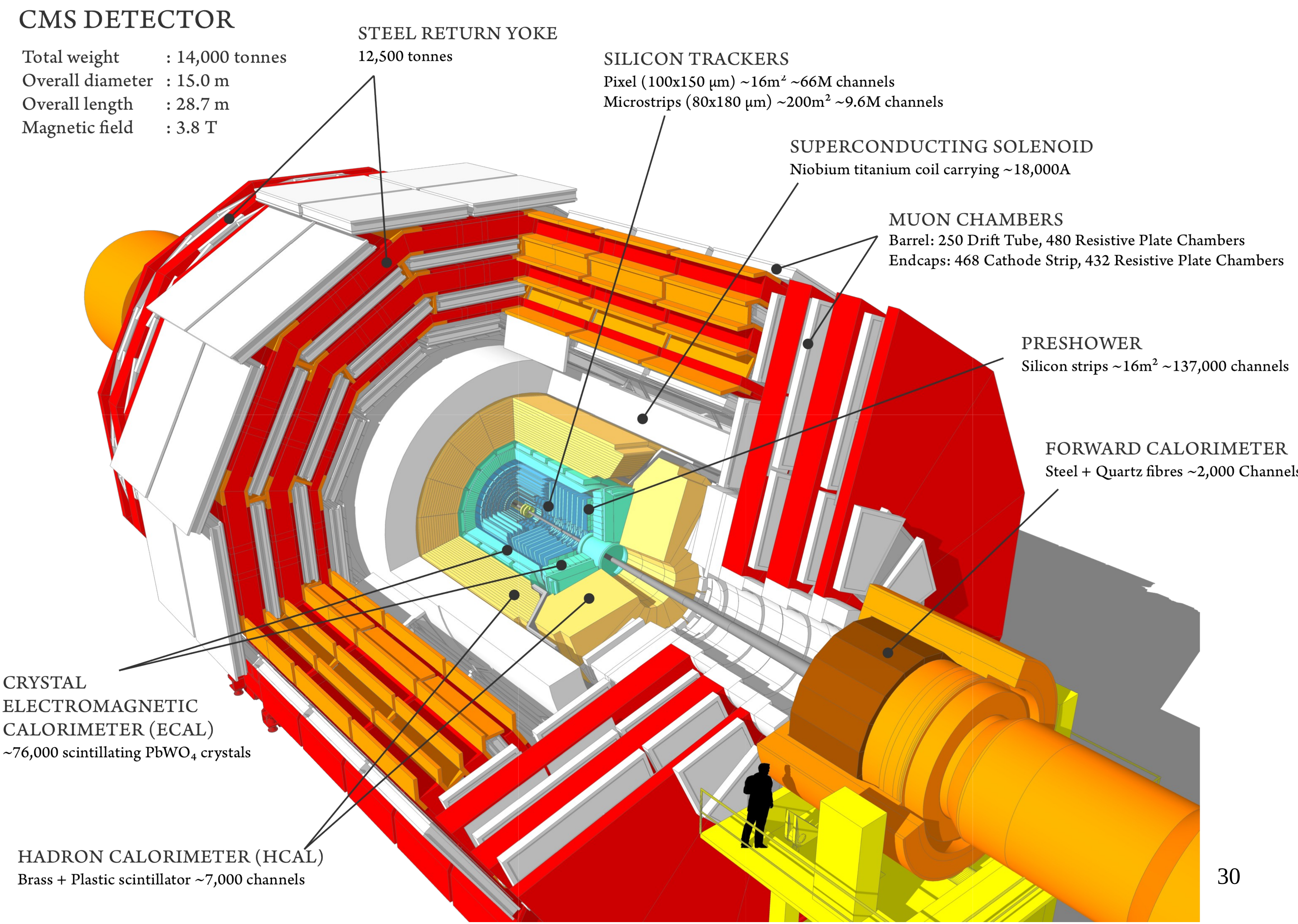
aTGC search measurements performed in most channels

- No aTGC signal is observed
- Upper limits on aTGC parameters are set

Performed first hadron collider measurement of QGC with WW exclusive production

- Upper limits on aQGC parameters are set

Backup


CMS DETECTOR
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T
STEEL RETURN YOKE
12,500 tonnes
SILICON TRACKERS
Pixel (100x150 μm) ~16m^2 ~66M channels
Microstrips (80x180 μm) ~200m^2 ~9.6M channels
SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers
PRESHOWER
Silicon strips ~16m^2 ~137,000 channels
FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels