Latest electroweak and Higgs physics results from LHC

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on behalf of the ATLAS and CMS collaborations

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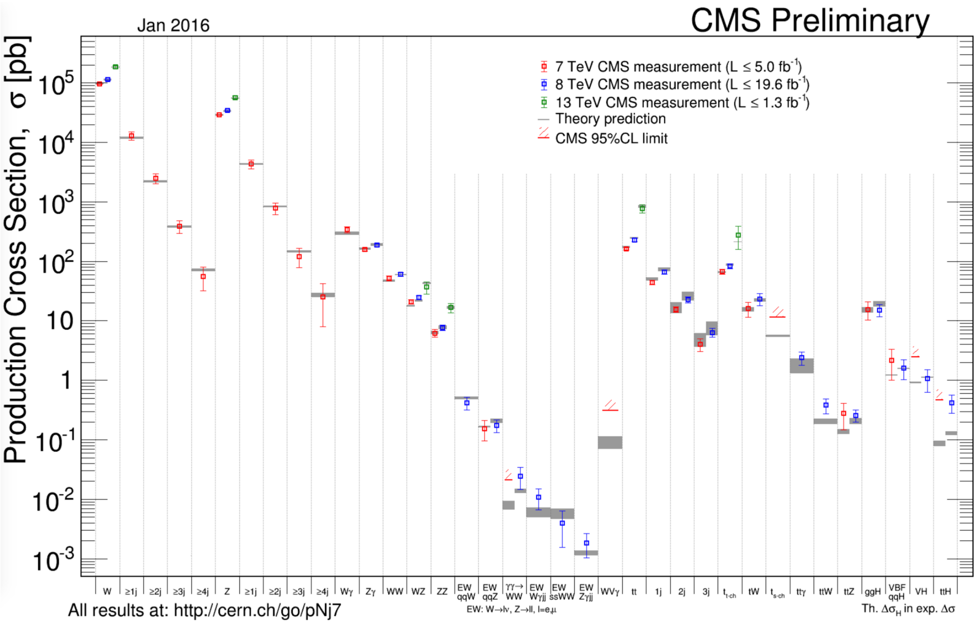
Max-Planck-Institut für Physik (Werner-Heisenberg-Institut)

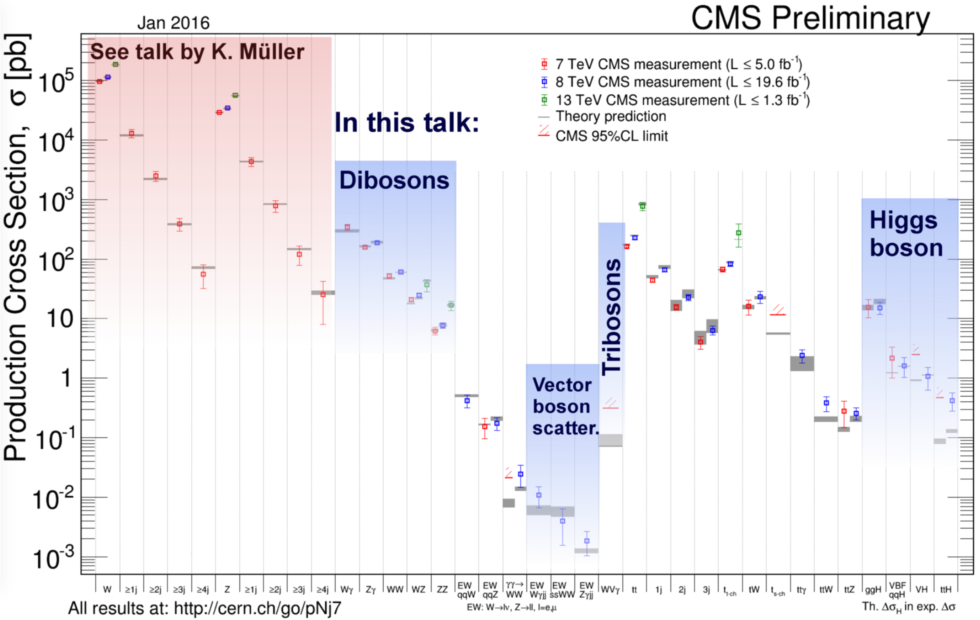
ATLAS EXPERIMENT

CMS

Standard Model in its full glory



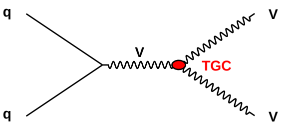
Standard Model in its full glory



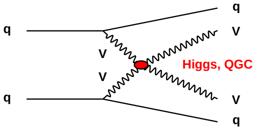
Electroweak physics

- Test of the theoretical Standard Model predictions with higher order corrections.
- Indirect search for new physics manifested through anomalous gauge couplings.

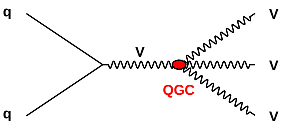
Diboson production



Vector Boson Scattering



Triboson production



DIBOSONS

		7 TeV	8 TeV	13 TeV
Wγ	ATLAS	PRD 87, 11203 (2013)	-	-
	CMS	PRD 89, 092005 (2014)	-	-
Zγ	ATLAS	PRD 87, 11203 (2013)	STDM-2014-01	-
	CMS	PRD 89, 092005 (2014)	STDM-2014-01	-
WW	ATLAS	PRD 87, 112001 (2013)	ArXiv:1603.01702	-
	CMS	PLB 699 (2011) 25	ArXiv:1507.03268	-
	CMS	JHEP 07 (2013) 116	PAS FSQ-13-008	
WZ	ATLAS	EPJC 72, 2173 (2012)	ArXiv:1603.02151	-
	CMS	PAS SMP-12-006	PAS SMP-12-006	PAS SMP-16-002
ZZ	ATLAS	JHEP 03, 128 (2013)	ATLAS-CONF-2012-020	PRL 116, 101801 (2016)
	CMS	JHEP 01, 063 (2013)	PLB 740 (2015) 250	PAS SMP-15-005
	CMS	EPJC 75 (2015) 511	EPJC 75 (2015) 511	

VBS

		8 TeV
Wγjj	ATLAS	-
	CMS	PAS SMP-14-011
Zγjj	ATLAS	-
	CMS	PAS SMP-14-018
WWjj	ATLAS	PRL 113, 141803 (2014)
	CMS	PRL 114, 051801 (2014)
WZjj	ATLAS	ArXiv:1603.02151
	CMS	PRL 114, 051801 (2014)

TRIBOSONS

		8 TeV
Wγγ	ATLAS	PRL 115, 031802 (2015)
	CMS	PAS SMP-15-008
Zγγ	ATLAS	STDM-2014-01
	CMS	PAS SMP-15-008
WWγ	ATLAS	-
WZγ	CMS	PRD 90 (2014) 032008

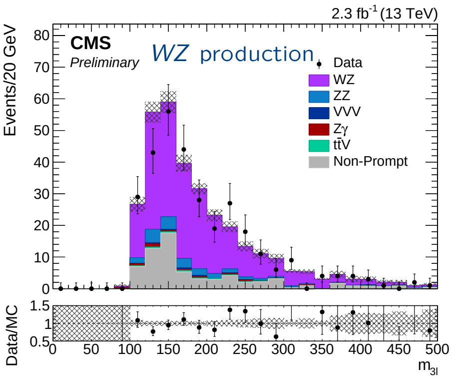
Older results, all in good agreement with Standard Model predictions.
New results, shown today.

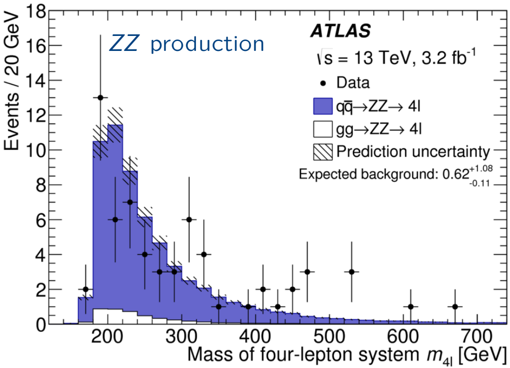
Diboson production at 13 TeV

CMS PAS-SMP-16-002; CMS PAS-SMP-15-005, ATLAS PRL 116, 101801 (2016)

Sensitivity to new physics increases with increasing collision energy.

First measurements of the total diboson cross sections at 13 TeV:





CMS *WZ*	$40.9 \pm 3.4(stat)^{+3.1}_{-3.3}(syst) \pm 0.4(th) \pm 1.3(lum)$ pb.	$\sigma^{tot}_{NLO} = 42.6^{+1.6}_{-0.8}$ pb.
ATLAS *ZZ*	$16.7^{+2.2}_{-2.60}(stat)^{+0.9}_{-0.7}(syst)^{+1.0}_{-0.7}(lum)$ pb.	$\sigma^{tot}_{NNLO} = 15.6 \pm 0.4$ pb.
CMS *ZZ*	$16.7^{+2.9}_{-2.6}(stat)^{+0.7}_{-0.5}(syst) \pm 0.3(th) \pm 0.8(lum)$ pb.	$\sigma^{tot}_{NNLO} = 16.5^{+0.7}_{-0.5}$ pb.

- All measurements in good agreement with (N)NLO theory.
- Accuracy still smaller than at 8 TeV due to larger statistical uncertainty.

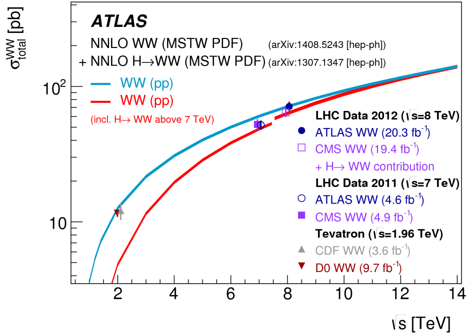
Dibosons at 8 TeV: *WW*, *WZ*

ATLAS arXiv:1603.01702, CMS arXiv:1507.03268; ATLAS arXiv:1603.02151

ATLAS *WW*	$71.1^{+1.1}_{-1.1}(stat)^{+5.7}_{-5.0}(syst) \pm 1.4(lum)$ pb.	$\sigma^{tot}_{NNLO} = 63.2^{+2.0}_{-1.8}$ pb.
CMS *WW*	$60.1 \pm 0.9(stat) \pm 3.2(exp) \pm 3.1(th) \pm 1.6(lum)$ pb.	$\sigma^{tot}_{NNLO} = 59.8^{+1.3}_{-1.1}$ pb.
ATLAS *WZ* fiducial	$35.1 \pm 0.9(stat) \pm 0.8(syst) 0.8(lum)$ fb.	$\sigma^{fid}_{NLO} = 30.0 \pm 2.1$ pb.

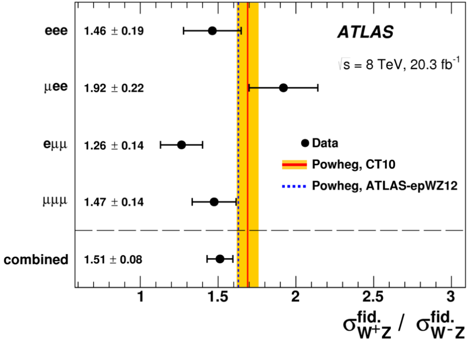
WW production

- Recent theoretical improvements: NNLO qq (+8%); NNLL (up to 7%);
- Measurement agrees well with NNLO.



WZ production

- Unprecedented precision: ~4% on σ^{fid}.
- Measured rate higher than MC NLO.
- Ratio $\sigma^{fid}_{W^+Z}/\sigma^{fid}_{W^-Z}$ consistent with NLO, theory systematics cancels out.



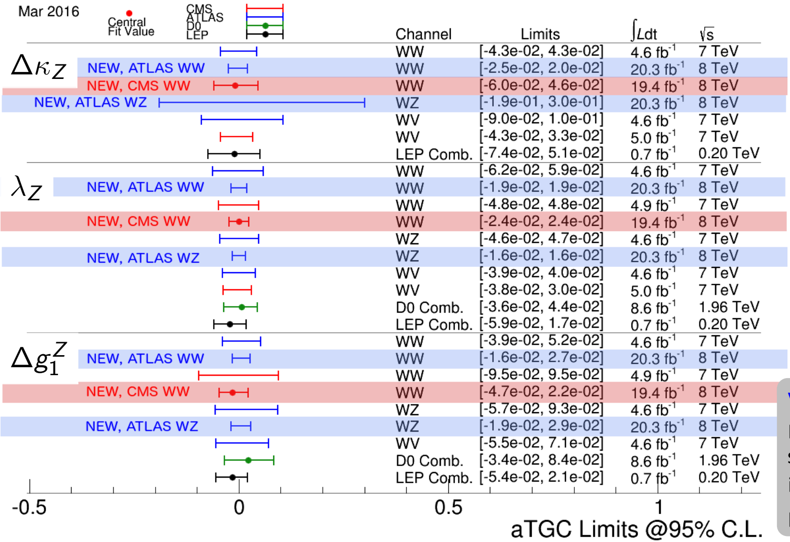
Limits on charged aTGC (WWZ)

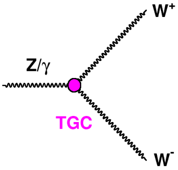
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC

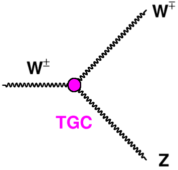
Extended Lagrangian for triple gauge couplings with anomalous contributions ($V \equiv Z, \gamma$):

$$\mathcal{L} \propto (1 - \Delta g_1^V)(W^+_{\mu\nu} W^{-\mu} - W^{+\mu} W^-_{\mu\nu}) V^\nu + (1 - \Delta k^V) W^+_\mu W^-_\nu V^{\mu\nu} + \frac{\lambda^V}{m_W^2} W^{+\nu}_\mu W^{-\rho}_\nu V^\mu_\rho$$

Limits extracted from variables correlated with $\hat{s}$: $p_T^{lead.\ lepton}$ or $m_{\ell\ell}$ in WW; m_T^{WZ} in WZ.







WZ measurement provides the most stringent model-independent limits.

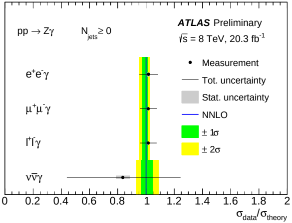
Dibosons at 8 TeV: Neutral aTGC from $Z\gamma$

ATLAS STDM-2014-01, CMS arXiv:1602.07152, CMS JHEP 04 (2015) 164,
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC

Most precise $Z\gamma$ cross-section measurement in the $Z\gamma \to \ell^+\ell^-\gamma$ channel.

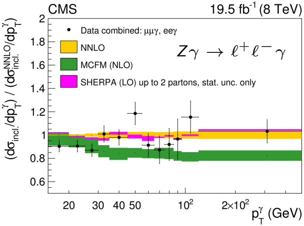
- Good agreement with NNLO predictions.

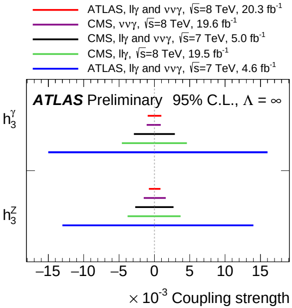
CMS $Z\gamma \to \ell\ell\gamma$	$2063 \pm 19(stat) \pm 98(syst) \pm 54(lum)$ fb.
σ_{NNLO}	2241 ± 22 fb.
CMS $Z\gamma \to \nu\nu\gamma$	$52.7 \pm 2.1(stat) \pm 6.6(syst) \pm 1.4(lum)$ fb.
σ_{NNLO}	$50.0\pm^{+2.4}_{-2.2}$ fb.

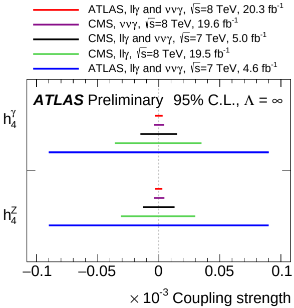


$Z\gamma \to \nu\bar{\nu}\gamma$ most sensitive channel to neutral aTGC, due to large BR($Z \to \nu\bar{\nu}$).

- Discriminant: E_T^γ. NNLO corrections of E_T^γ distribution to be taken into account.



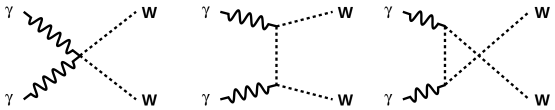




Exclusive $\gamma\gamma \to W^+W^-$ production

CMS PAS-FSQ-13-008

- Allows for the test of anomalous quartic gauge couplings:



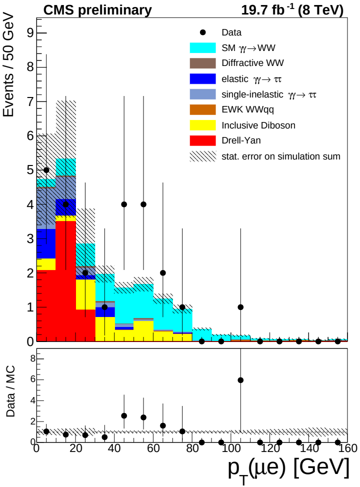
Requiring $\mu^{\pm}e^{\mp}$ pairs with no additional charged particles from the same vertex.

- Signal significance: 3.6σ.
- $\sigma(pp \to p'W^+W^-p' \to p'\mu^{\pm}e^{\mp}p') = 12.3^{+5.5}_{-4.4}$ fb.

$\sigma_{NLO} = 6.9 \pm 0.6$ fb.

Limits on anomalous quartic gauge couplings obtained from the $p_T(\mu e)$ spectrum.

(Deviations from SM expected at high values of p_T).

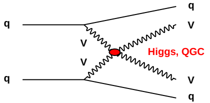


Diboson production via Vector Boson Scattering

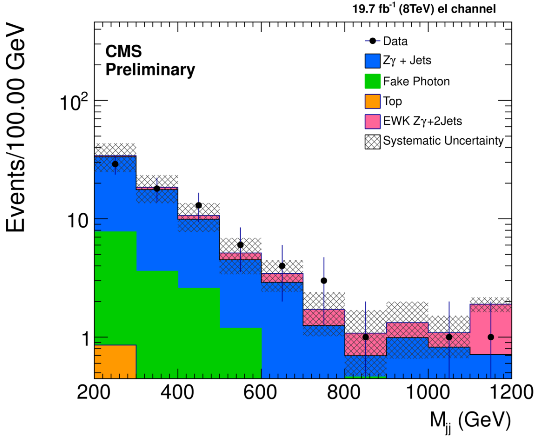
CMS PAS-SMP-14-011, CMS PAS-SMP-018, ATLAS arXiv:1603.02151

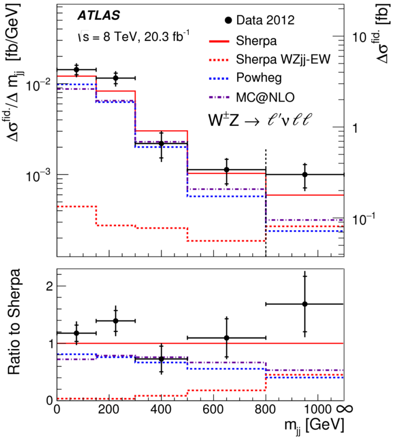
Test of Higgs mechanism and sensitivity to quartic gauge couplings.

- First evidence of VBS in $pp \to WWjj$ production.
  ATLAS: PRL 113, 141803; CMS(WWjj, WZjj): PRL 114 (2015) 051801
- Recent measurements:



CMS $Z\gamma jj$ fid.	First evidence, 3σ!	$1.86^{+0.89}_{-0.75}(stat)^{+0.42}_{-0.27}(syst) \pm 0.05(lum)$ fb.	$\sigma_{LO} = 1.26 \pm 0.12$ fb.
CMS $W\gamma jj$ fid.	2.7σ	$10.8 \pm 4.1(stat) \pm 3.4(syst) \pm 0.6(lum)$ fb.	$\sigma_{LO} = 6.1 \pm 1.2$ fb.
ATLAS $WZjj$ fid.	-	upper limit: 0.63 fb at 95% CL.	$\sigma_{NLO} = 0.13 \pm 0.01$ fb.



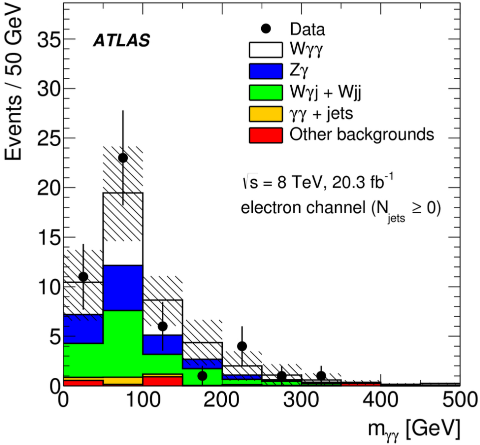


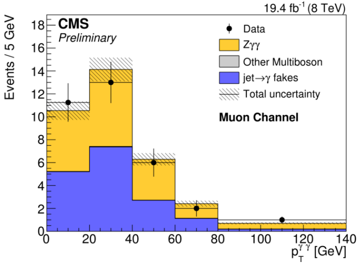
Triboson production

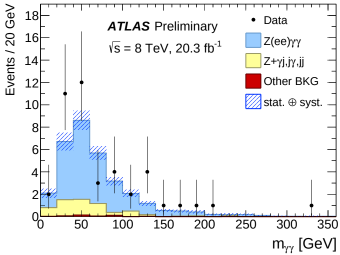
CMS PAS-SMP-15-008, ATLAS PRL 115 (2015) 031802, ATLAS STDM-2014-01

First observation of tribosons and test of the anomalous quartic gauge couplings.

ATLAS $W\gamma\gamma$ fid.	First evidence, 3σ	$6.1^{+1.1}_{-1.0}(stat) \pm 1.2(syst) \pm 0.2(lum)$ fb.	$\sigma_{NLO} = 2.90 \pm 0.16$ fb.
CMS $W\gamma\gamma$ fid.	2.4σ	$6.0 \pm 1.8(stat) \pm 2.3(syst) \pm 0.2(lum)$ fb.	$\sigma_{NLO} = 4.76 \pm 0.53$ fb.
CMS $Z\gamma\gamma$ fid.	Observation, 5.9σ	$12.7 \pm 1.4(stat) \pm 1.8(syst) \pm 0.2(lum)$ fb.	$\sigma_{NLO} = 12.95 \pm 1.47$ fb.





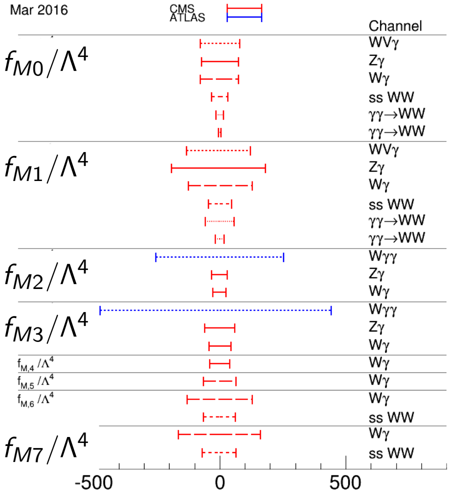


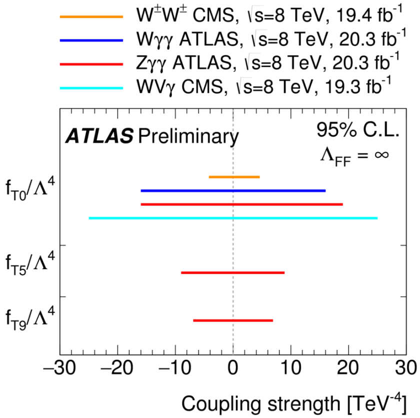
Limits on anomalous quartic gauge couplings (aQGC)

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC, ATLAS STDM-2014-01

Derived from the measurements of the $\gamma\gamma \to WW$, VBS and triboson production.

Discriminants: $p_T(e\mu)$ in $\gamma\gamma \to WW$; p_T^W & $m_{Z\gamma}$ in VBS; $m_{\gamma\gamma}$ & $p_T^{lead.\ photon}$ in tribosons.

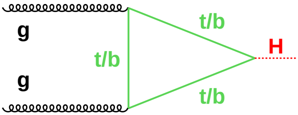




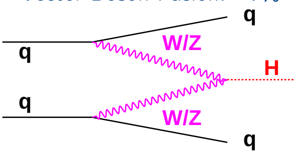
- No deviation from Standard Model; probing new regions unexplored up to now.

Production at 7, 8 or 13 TeV

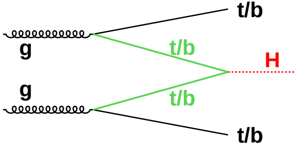
Gluon fusion: ~87%



Vector Boson Fusion: ~7%

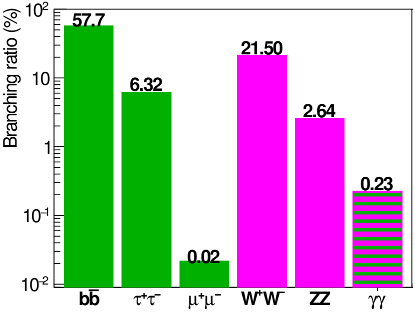


Associated with $t\bar{t}$, $b\bar{b}$: ≤1%



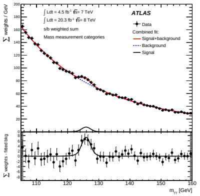
Associated with W,Z: ~5%

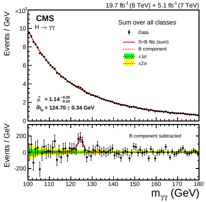
Decays

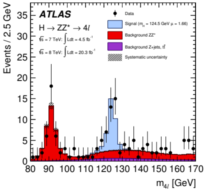


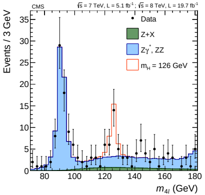
Higgs boson mass

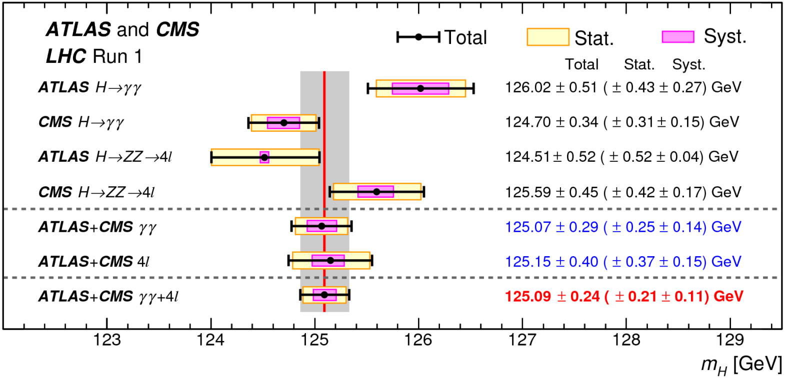
The Higs boson mass is measured in $\gamma\gamma$ and 4ℓ final states: Phys.Rev.Lett. 114, 191803











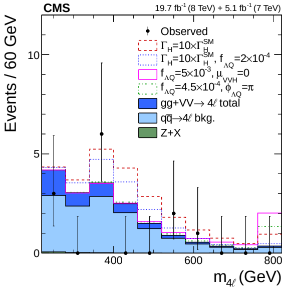
- Measurement precision of 0.2%, predominantly limited by a statistical uncertainty.

Higgs boson decay width and lifetime

Decay width (Γ_H):

Eur.Phys.J. C75 (2015) 335; PRD 92 (2015) 072010; PLB 736 (2014) 64

- Direct measurement from observed $\gamma\gamma$ and 4ℓ peaks (on-shell Higgs production).
- Indirect measurement via comparison of signal event yields from on-shell and off-shell Higgs production.
  Higgs couplings assumed to be the same for on- and off-shell Higgs production.

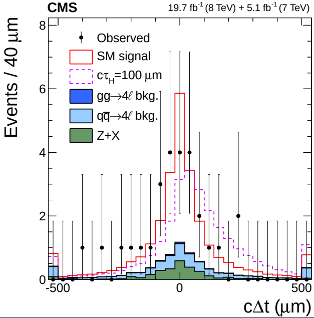


Limits at 95%CL	Direct	Indirect
ATLAS Run 1	<2.6 GeV	<22.7 MeV
CMS Run 1	<1.7 GeV	<22 MeV <26 MeV$^{(*)}$
SM prediction	4.1 MeV	

$^{(*)}$ <46 MeV if anomalous couplings allowed

Higgs boson lifetime (τ_H):

- Measured with $H \to 4\ell$ events, based on the Higgs boson flight distance in the detector. (Distance between the 4ℓ decay vertex and the beam-spot production vertex.)
- CMS Run 1: $\tau_H(s) < 1.9{\cdot}10^{-13}$ at 95% CL.
  SM: $\tau_H(s) = 1.6{\cdot}10^{-22}$.

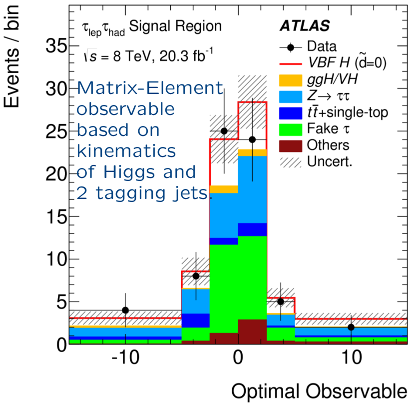


arXiv:1602.04516; arXiv:1602.04305;

Based on previous tests of fixed spin-parity hypotheses: assuming a spin-0 Higgs boson.
Probing HVV interactions for admixtures of anomalous couplings to SM tensor structure.

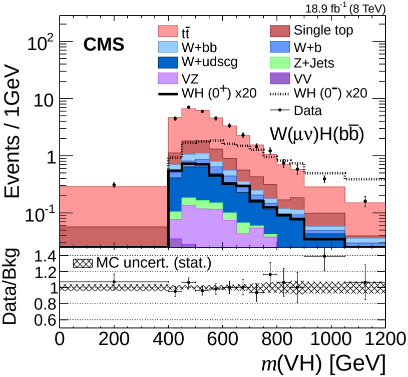
- Studies of $H \to WW$ and $H \to ZZ$ decay kinematics and differential $H \to \gamma\gamma$ cross sections show no sign of anomalous CP-even or CP-odd couplings.

New: Direct probe of pseudoscalar terms (CP-violation) via VBF ($H \to \tau\tau$).



- Limits improved by a factor of 10.

New: Probing pseudoscalar terms via VH ($H \to bb$).



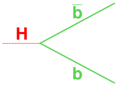
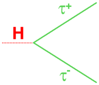
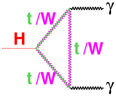
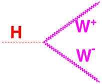
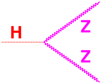
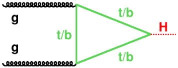
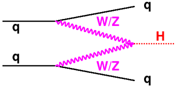
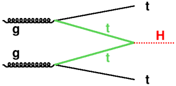
- VH alone cannot set competitive limits.
- VH + $H \to VV$ with SM ratio for Htt/Hbb: ~70 times better exclusion limit.

ATLAS-CONF-2015-044, CMS-PAS-HIG-2015-002

Based on event rates from all accessible combinations of Higgs productions and decays.

Assuming a single Higgs state with the SM tensor structure, $m_H = 125.09 \pm 0.21(stat) \pm 0.11(syst)$.

Narrow-width approximation.

		 bb, 2.6σ	 ττ, 5.5σ	 γγ, >> 5σ	 WW, >> 5σ	 ZZ, >> 5σ
	ggF >> 5σ	no measurement	✓	✓	✓	✓
	VBF 5.4σ (4.7σ exp)	no measurement	✓	✓	✓	✓
	VH 3.5σ (4.2σ exp)	✓	✓	✓	✓	no measurement
	ttH 4.4σ (2.0σ exp)	✓	✓	✓	✓	no measurement

ATLAS+CMS combination: observation of the VBF production and $H \to \tau\tau$ decays.

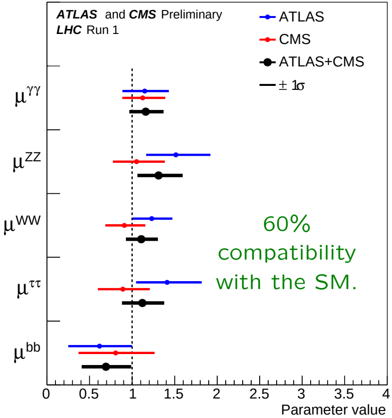
Signal strengths

ATLAS-CONF-2015-044, CMS-PAS-HIG-2015-002

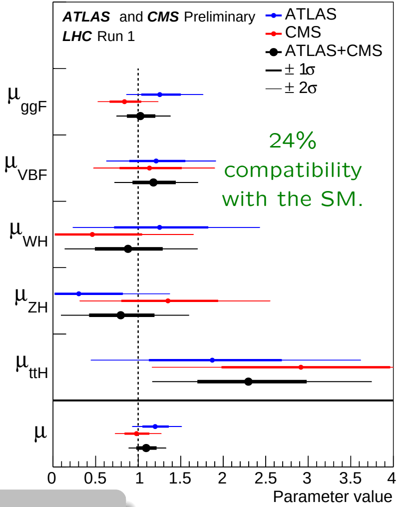
$$\mu_{prod}^{decay} = \frac{\sigma_{prod} \cdot BR_{decay}}{\sigma_{prod}^{SM} \cdot BR_{decay}^{SM}} = \mu_{prod} \cdot \mu^{decay}$$

Decay modes, $\mu_{prod} = 1$

Production modes, $\mu_{decay} = 1$



60% compatibility with the SM.



24% compatibility with the SM.

Global: $\mu = 1.09^{+0.07}_{-0.07}(stat)^{+0.04}_{-0.04}(exp)^{+0.03}_{-0.03}(thbg)^{+0.07}_{-0.06}(thsig)$

ATLAS-CONF-2015-044, CMS-PAS-HIG-2015-002

Using $gg \to H \to ZZ$ as a reference:

$$\sigma_{prod} \cdot BR_{decay} = \sigma(gg \to H \to ZZ) \cdot \frac{\sigma_{prod}}{\sigma_{ggF}} \cdot \frac{BR_{decay}}{BR_{ZZ}}.$$

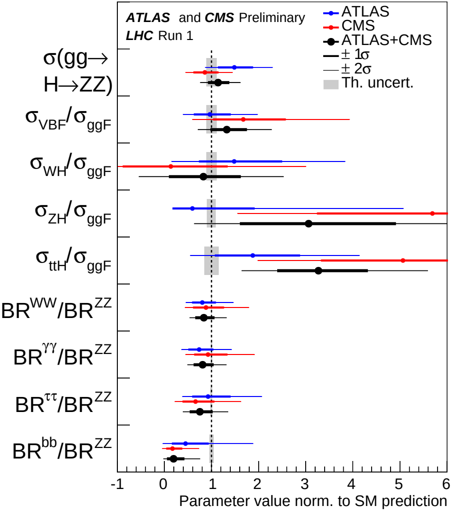
The most model-independent results.

- Insensitive to theory uncertainty on inclusive σ_{prod}.
- Independent of the total Higgs width.

16% compatibility with the SM.

$\sigma_{ttH}/\sigma_{ggF}$: 2.4$\sigma$ excess over SM prediction, mainly due to $ttH, H \to multilepton$ events.

BR^{bb}/BR^{ZZ}: 2.5σ deficit w.r.t. SM. Pulled down by excesses in $\sigma_{ttH}/\sigma_{ggF}$ and σ_{ZH}/σ_{ggF}.

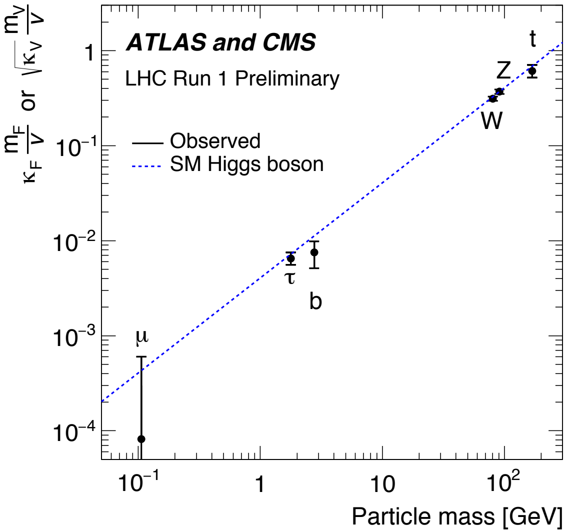


ATLAS-CONF-2015-044, CMS-PAS-HIG-2015-002

$$\sigma_{prod} \cdot BR_{decay} = \frac{\sigma_{prod}(\vec{\kappa}) \cdot \Gamma_{decay}(\vec{\kappa})}{\Gamma_H} \text{ where } \kappa^2_{prod} = \frac{\sigma_{prod}}{\sigma^{SM}_{prod}},\ \kappa^2_{decay} = \frac{\Gamma_{decay}}{\Gamma^{SM}_{decay}},\ \Gamma_H = \frac{\kappa^2_H \Gamma^{SM}_H}{1 - BR_{BSM}}.$$

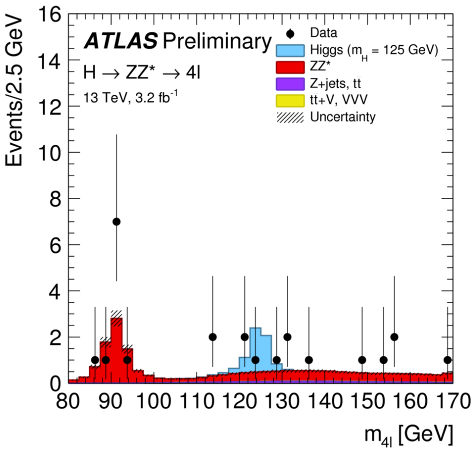
κ denotes the modification of the SM coupling related to the physics beyond the SM.

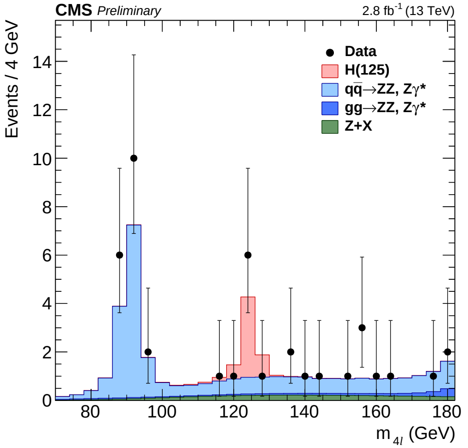
Assuming $BR_{BSM} = 0$,
no new particles in the loops
and $\kappa_i \geq 0$:



$H \rightarrow ZZ^* \rightarrow 4\ell$ at 13 TeV

ATLAS-CONF-2015-059, CMS-PAS-HIG-15-004





- Expected signal significance: 2.8σ.
- Slight deficit of observed events:

$m_{4\ell} \in [118 - 129 GeV]$		
N^{obs}	N^{exp}_{S+B}	N^{exp}_{S}
4	6.65±0.58	4.57±0.54

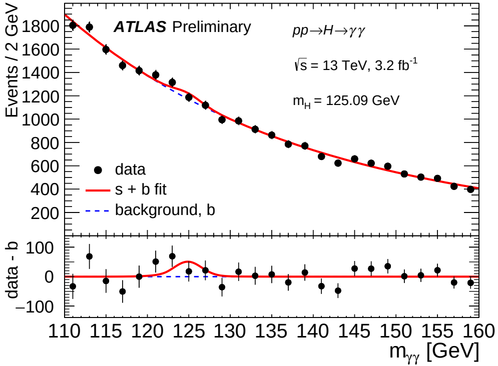
- Compatibility with SM signal: 1.4σ.

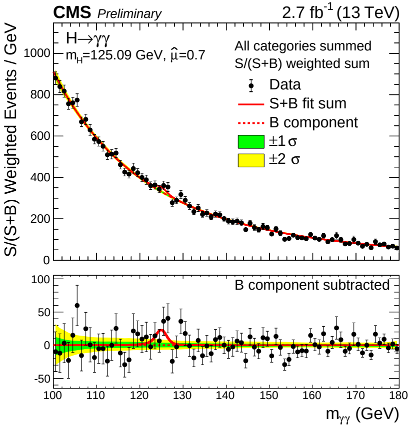
- Expected signal significance: 3.4σ. (based on a 2D-fit to $(m_{4\ell}, D_{kin})$)
- Observed signal significance: 2.5σ.
- Signal strength: $\mu = 0.82^{+0.57}_{-0.43}$

$H \to \gamma\gamma$ at 13 TeV

ATLAS-CONF-2015-060, CMS-PAS-HIG-15-005

Mass fixed to 125.09 GeV in the fit to data.



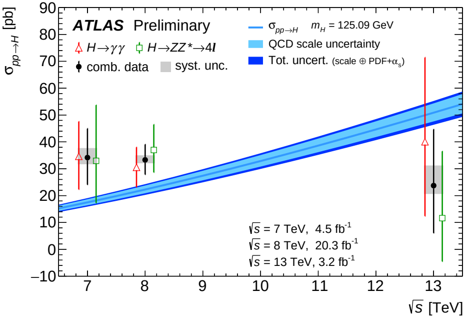


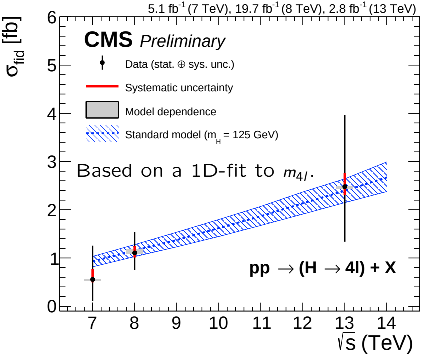
- Expected signal significance: 1.9σ. (Inclusive analysis.)
- Observed signal significance: 1.5σ.
- $N_S = 113 \pm 74(stat)^{+43}_{-25}(syst)$, $N_S^{exp} = 143 \pm 71(stat)^{+39}_{-6}(syst)$.

- Expected signal significance: 2.7σ. (8 different diphoton categories.)
- Observed signal significance: 1.7σ.
- Signal strength: $\mu = 0.69^{+0.47}_{-0.42}$

$H \to ZZ$ and $H \to \gamma\gamma$ cross sections

ATLAS-CONF-2015-069, CMS-PAS-HIG-15-004





ATLAS $H \to ZZ$ and $H \to \gamma\gamma$ combination at 13 TeV:

- Expected signal significance: 3.4σ.
- Observed signal significance: 1.4σ.
- Compatibility of the combined measurement at 13 TeV with the SM signal: 1.3σ.

Total (ATLAS) and fiducial (ATLAS, CMS) cross sections fully consistent with the Standard Model.

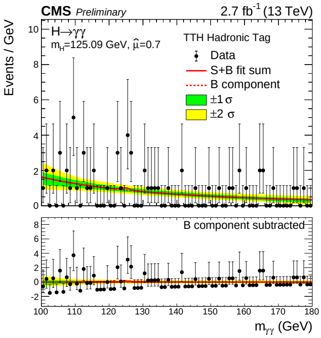
ttH production at 13 TeV

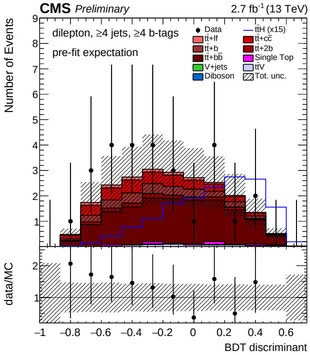
CMS-PAS-HIG-15-005, CMS-PAS-HIG-16-004, CMS-PAS-HIG-15-008

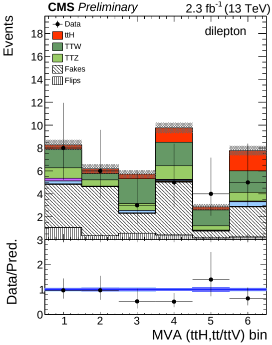
Excess of events observed in Run 1 with both ATLAS and CMS (multilepton events).

	ATLAS	CMS	Combined
$\mu(ttH)$	$1.9^{+0.8}_{-0.7}$	$2.9^{+1.0}_{-0.9}$	$2.3^{+0.7}_{-0.6}$

First look at 13 TeV:







Diphoton: $\mu = 3.8^{+4.5}_{-3.6}$.

$b\bar{b}$ lepton+jets: $\mu = -0.4^{+2.1}_{-2.1}$.

$b\bar{b}$ dilepton: $\mu = -4.7^{+3.7}_{-3.8}$.

$b\bar{b}$ combined: $\mu = -2.0^{+1.8}_{-1.8}$.

multilepton dilepton: $\mu = -0.5^{+1.0}_{-0.7}$.

multilepton trilepton: $\mu = 5.8^{+3.3}_{-2.7}$.

multilepton combined: $\mu = 0.6^{+1.4}_{-1.1}$.

Similar sensitivity as in Run-1. Overall agreement with the SM.

Many searches performed recently.

Diboson resonances (Run 2)

Diphoton	ATLAS-CONF-2016-018
Diphoton	CMS-PAS-EXO-16-018
$ZZ \to \ell\ell qq$	ATLAS-CONF-2016-016
$ZZ \to \ell\ell\nu\nu$	ATLAS-CONF-2016-012
$ZZ \to \ell\ell\nu\nu$	CMS-PAS-HIG-16-001
$ZZ \to 4\ell$	CMS-PAS-HIG-15-004
$ZZ \to 4\ell$	ATLAS-CONF-2015-059
$Z\gamma$	ATLAS-CONF-2016-010
$Z\gamma$	CMS-PAS-HIG-16-014
$VV \to \nu\nu qq$	ATLAS-CONF-2015-068
$VV \to \ell\ell qq$	ATLAS-CONF-2015-071
$VV \to \ell\nu qq$	ATLAS-CONF-2015-075
$VV \to qqqq$	ATLAS-CONF-2015-073

Diboson resonances (Run 2 cont'd and Run 1)

$A \to Zh$	ATLAS-CONF-2016-015
$A \to Zh$	CMS-PAS-HIG-16-010
Wh	ATLAS-CONF-2015-074
$hh \to 4b$	CMS-PAS-HIG-16-002
$hh \to bb\tau\tau$	CMS-PAS-HIG-16-013
$hh \to 4b$	ATLAS-CONF-2016-017
$hh \to bb\gamma\gamma$	ATLAS-CONF-2016-004
WW	JHEP01 (2016) 172
ZZ	Eur.Phys.J C76 (2016) 45
$A \to Zh$	arXiv:1603.02991
$hh \to 4\gamma$	arXiv:1603.06896
hh	arXiv:1510.01181
hh	Phys.Rev.D92 (2015) 092004

Dark Matter with SM Higgs boson

$\gamma\gamma + MET$	ATLAS-CONF-2016-011
$H \to \gamma\gamma + MET$	Phys.Rev.Lett.115,131801(2015)
$H \to bb + MET$	arXiv:1510.06218
$ZH, H \to inv$	CMS-PAS-HIG-16-008
$H \to inv$	CMS-PAS-HIG-15-012
VBF $H \to inv$	JHEP01 (2016) 172

Light pseudoscalars

$H \to aa \to \mu\mu bb$	CMS-PAS-HIG-14-041
$H \to aa \to \mu\mu\tau\tau$	CMS-PAS-HIG-15-011
$H \to aa \to \mu\mu\tau\tau$	Phys.Rev.D92 (2015) 052002
$H \to aa \to 4\tau$	arXiv:1511.03610
$H \to aa \to$ boosted τ	CMS-PAS-HIG-14-022
$H \to aa \to 4\gamma$	arXiv:1509.05051
$H \to aa \to 4\ell$	Phys.Rev.D92 (2015) 092001
$H \to aa \to 4\mu$	PLB 752 (2016) 146

Exotic and rare decays

FCNC $t \to Hq$	JHEP12 (2015) 061
LFV $H \to \mu\tau$	JHEP11 (2015) 211
LFV $H \to e\tau, \mu\tau$	CMS-PAS-14-040

Charged Higgs

H^{++}	CMS-PAS-HIG-14-039
$H^{+} \to tb$	JHEP03 (2016) 127
$H^{+} \to c\bar{s}$	JHEP12 (2015) 1
$H^{+} \to \tau\nu, tb$	JHEP11 (2015) 018

Neutral Higgs to fermions

$A \to \tau\tau$	ATLAS-CONF-2015-068
$A \to \tau\tau$	CMS-PAS-HIG-14-029
$a \to bb$	arXiv:1511.03610
$A \to \mu\mu$	PLB 752 (2016) 221
$A \to bb$	JHEP11 (2015) 071

Higgs boson(s) beyond the Standard Model

Many searches performed recently.

No sign of new physics, except perhaps in...

Diboson resonances (Run 2)

Diphoton	ATLAS-CONF-2016-018
Diphoton	CMS-PAS-EXO-16-018
$ZZ \to \ell\ell qq$	ATLAS-CONF-2016-016
$ZZ \to \ell\ell\nu\nu$	ATLAS-CONF-2016-012
$ZZ \to \ell\ell\nu\nu$	CMS-PAS-HIG-16-001
$ZZ \to 4\ell$	CMS-PAS-HIG-15-004
$ZZ \to 4\ell$	ATLAS-CONF-2015-059
$Z\gamma$	ATLAS-CONF-2016-010
$Z\gamma$	CMS-PAS-HIG-16-014
$VV \to \nu\nu qq$	ATLAS-CONF-2015-068
$VV \to \ell\ell qq$	ATLAS-CONF-2015-071
$VV \to \ell\nu qq$	ATLAS-CONF-2015-075
$VV \to qqqq$	ATLAS-CONF-2015-073

Diboson resonances (Run 2 cont'd and Run 1)

$A \to Zh$	ATLAS-CONF-2016-015
$A \to Zh$	CMS-PAS-HIG-16-010
Wh	ATLAS-CONF-2015-074
$hh \to 4b$	CMS-PAS-HIG-16-002
$hh \to bb\tau\tau$	CMS-PAS-HIG-16-013
$hh \to 4b$	ATLAS-CONF-2016-017
$hh \to bb\gamma\gamma$	ATLAS-CONF-2016-004
WW	JHEP01 (2016) 172
ZZ	Eur.Phys.J C76 (2016) 45
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$hh \to 4\gamma$	arXiv:1603.06896
hh	arXiv:1510.01181
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Dark Matter with SM Higgs boson

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$H \to \gamma\gamma + MET$	Phys.Rev.Lett.115,131801(2015)
$H \to bb + MET$	arXiv:1510.06218
$ZH, H \to inv$	CMS-PAS-HIG-16-008
$H \to inv$	CMS-PAS-HIG-15-012
$VBF\ \ H \to inv$	JHEP01 (2016) 172

Light pseudoscalars

$H \to aa \to \mu\mu bb$	CMS-PAS-HIG-14-041
$H \to aa \to \mu\mu\tau\tau$	CMS-PAS-HIG-15-011
$H \to aa \to \mu\mu\tau\tau$	Phys.Rev.D92 (2015) 052002
$H \to aa \to 4\tau$	arXiv:1511.03610
$H \to aa \to boosted\ \tau$	CMS-PAS-HIG-14-022
$H \to aa \to 4\gamma$	arXiv:1509.05051
$H \to aa \to 4\ell$	Phys.Rev.D92 (2015) 092001
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Charged Higgs

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$H^{+} \to c\bar{s}$	JHEP12 (2015) 1
$H^{+} \to \tau\nu, tb$	JHEP11 (2015) 018

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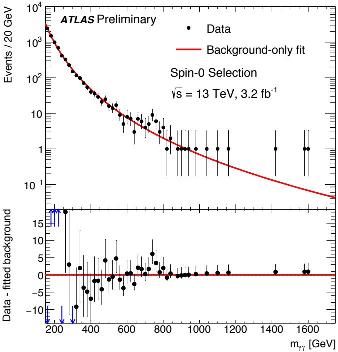
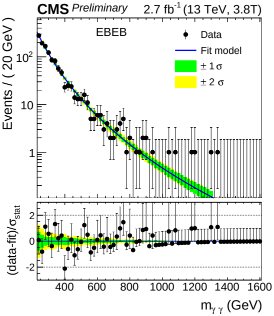
$a \to bb$	arXiv:1511.03610
$A \to \mu\mu$	PLB 752 (2016) 221
$A \to bb$	JHEP11 (2015) 071

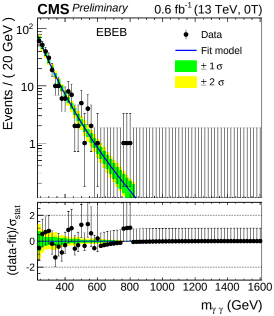
Excess of diphoton events at 750 GeV

CMS-PAS-EXO-16-018, ATLAS-CONF-2016-018

observed in searches for spin-0 (extended Higgs sector) and spin-2 (graviton) resonances.







ATLAS spin-0 (spin-2) analysis:

- Largest excess at 750 GeV; $\Gamma_X/m_X = 6\%(7\%)$.
- Local significance: 3.9σ (3.6σ).
- Global: 2.0σ (1.8σ).
- Run-1 compatibility (gg): 1.2σ (2.7σ).
  Run-1 compatibility (qq): 2.1σ (3.3σ).

CMS spin-0 (spin-2) analysis:

- Largest excess at 760 GeV; $\Gamma_X/m_X = 1.4\%$.
- Local significance: 2.8σ (2.9σ).
- Global: $<1.0\sigma$.
- Combined with Run-1: 3.4σ local.
  1.6σ global.
- Run 1 and Run 2 fully compatible.

Summary

Studies of electroweak and Higgs boson production with Run 1 data almost completed.

- Electroweak data consistent with the SM, sensitive to NNLO QCD corrections.
- Evidence for vector boson scattering and triboson production in several channels.
- Competitive limits set on anomalous tripple and quartic gauge couplings.

- Properties of the discovered Higgs boson consistent with Standard Model predictions. (Still no direct evidence of $H \to bb$ or even rarer processes like $H \to \mu\mu$.)
- More data needed to explore couplings to fermions, anomalous trilinear couplings etc.
- Wide range of direct searches for Higgs bosons beyond the Standard Model: no(?) sign of new physics yet.

First results with 13 TeV data available.

- Consistent with the Standard Model, still limited by statistical uncertainty.

Eagerly avaiting new data...