Standard Model measurements by ATLAS and CMS in the top quark and electroweak sector

Freya Blekman

on behalf of the ATLAS and CMS collaborations

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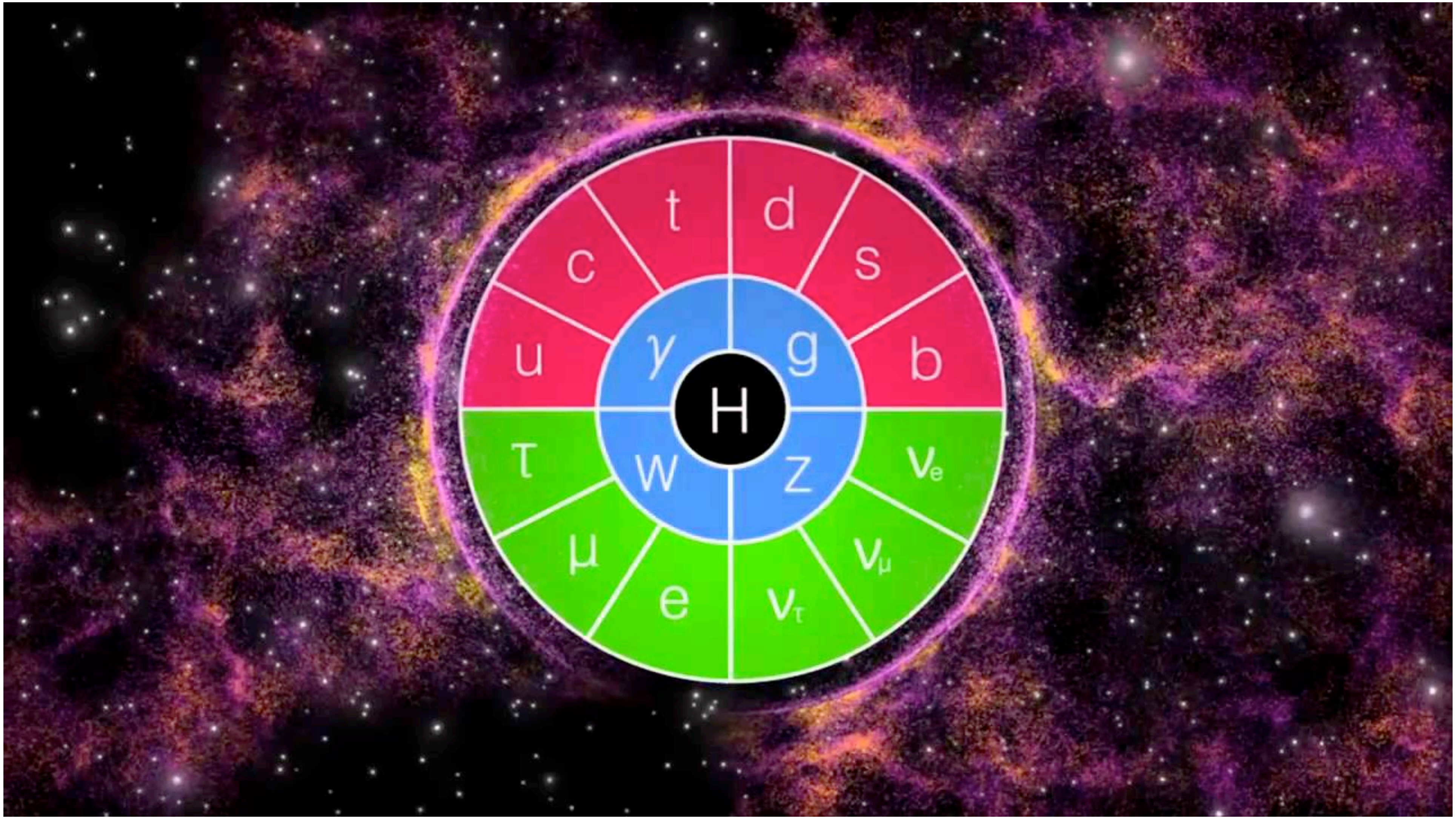
The Standard Model!

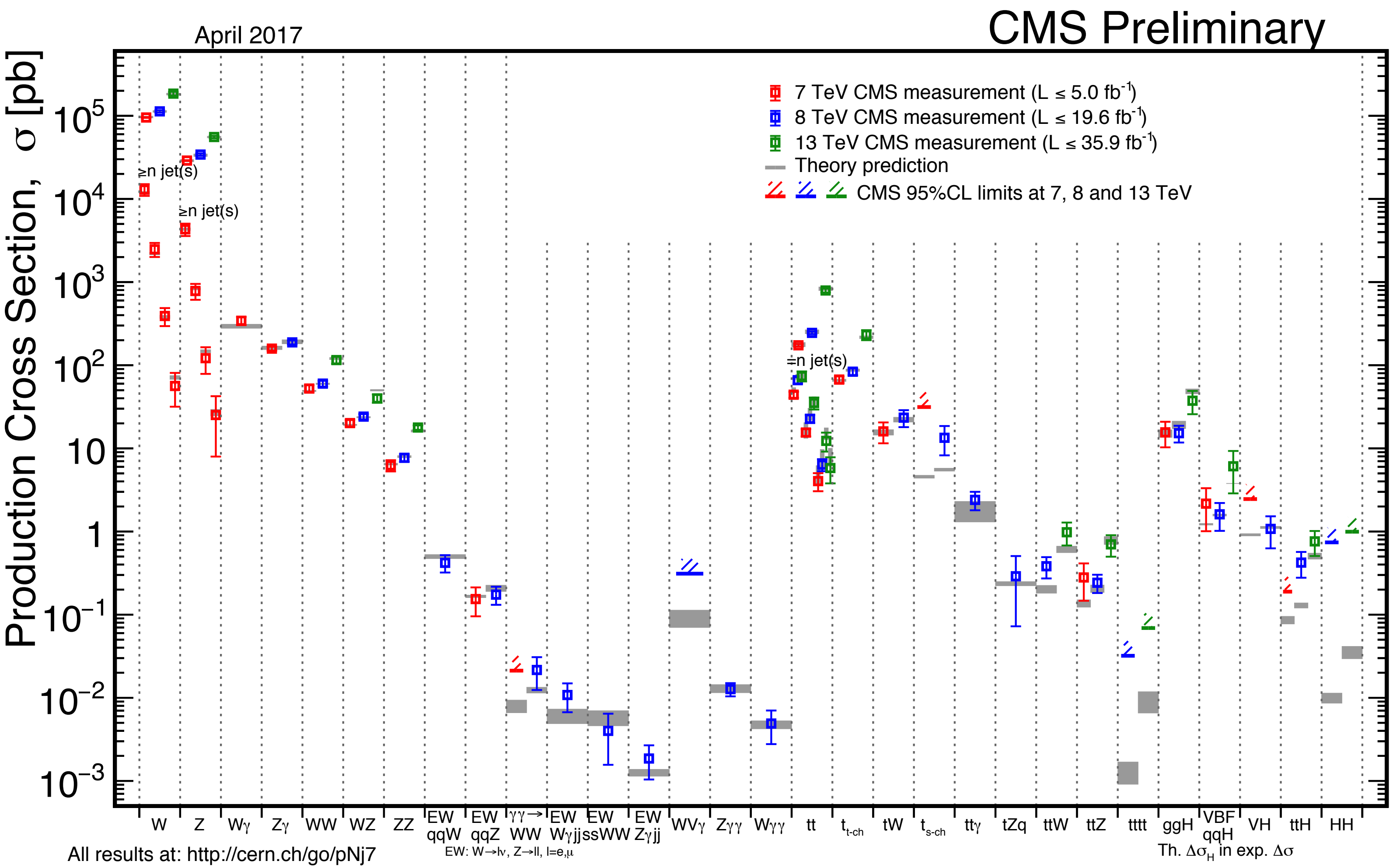


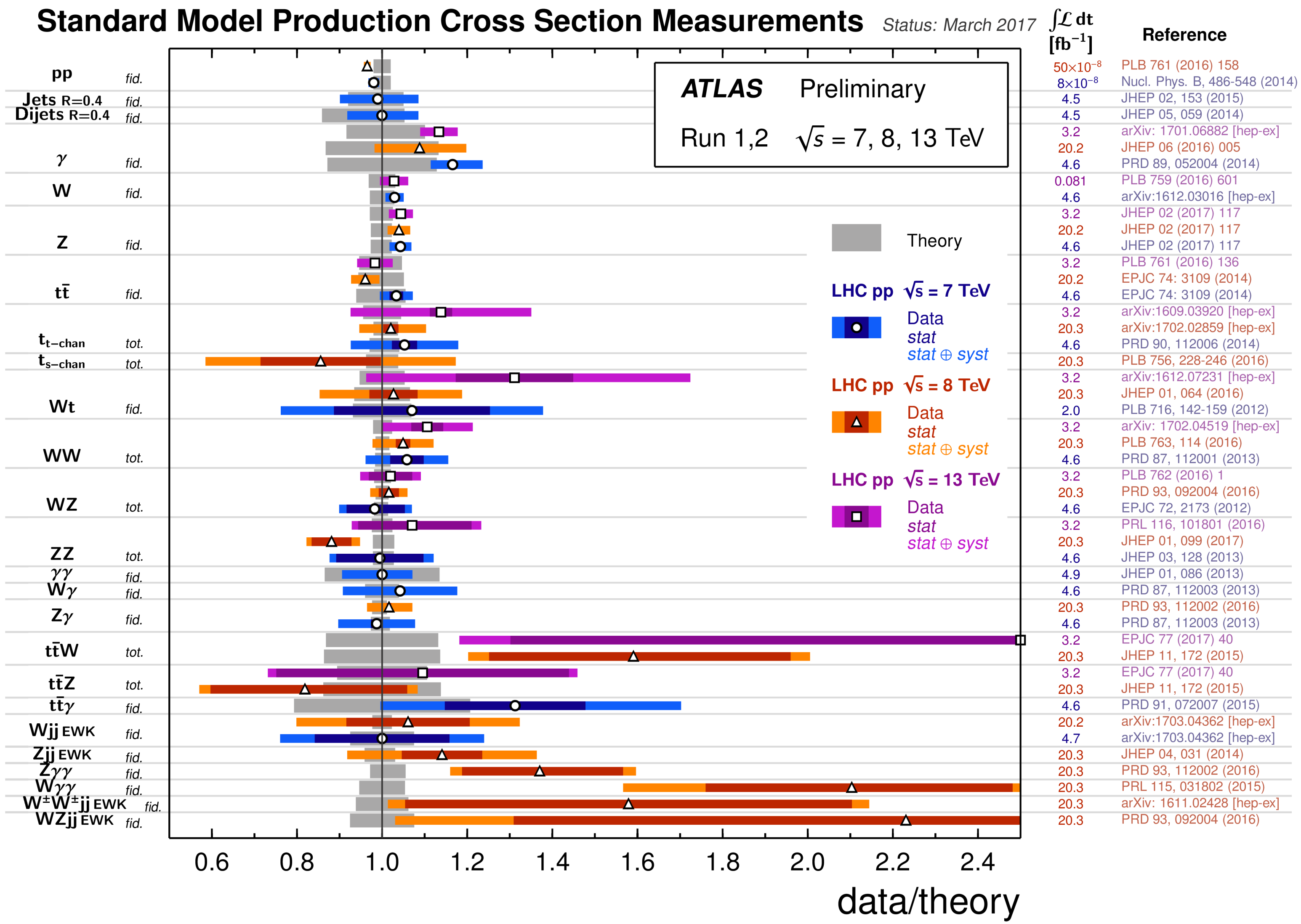
Why?

- **Direct test of anomalies / indirect presence of high scale physics as access via loops**
- **Looking for generic BSM physics not just one (fashionable) model**
- No model dependence assumed, SM measurements do not assume Standard Model is correct
- Direct searches tend to focus on low hanging fruits (bumps, excesses in tails or regions where SM predicts very low background), the bulk of the distribution where kinematic behaviour is similar to SM is much more challenging

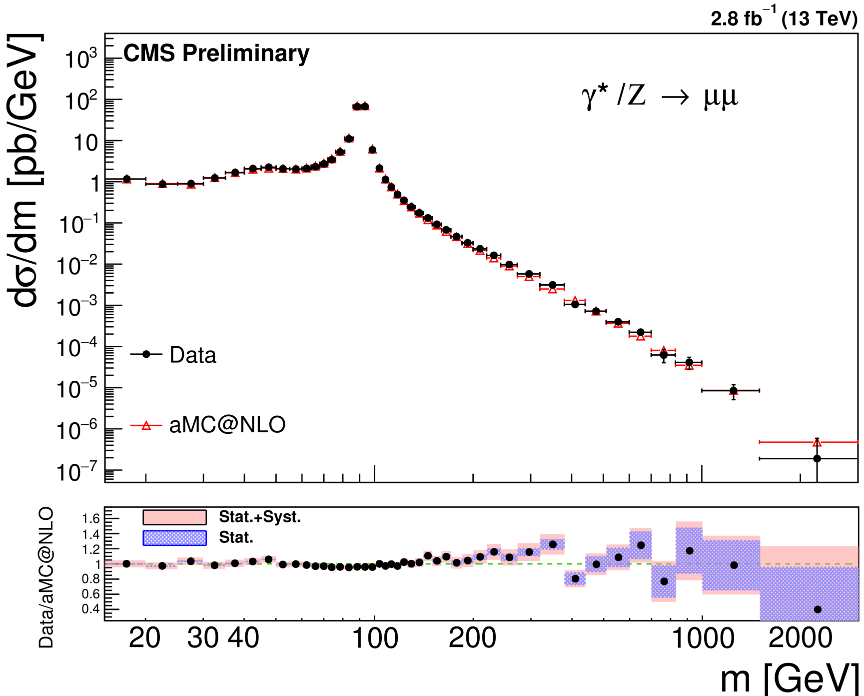
- **Traditionally available in hepData/Rivet already**
  - **Including correlations etc, this has been done in SM phyiscs for several years**
    - **Recaster-friendly!!!**

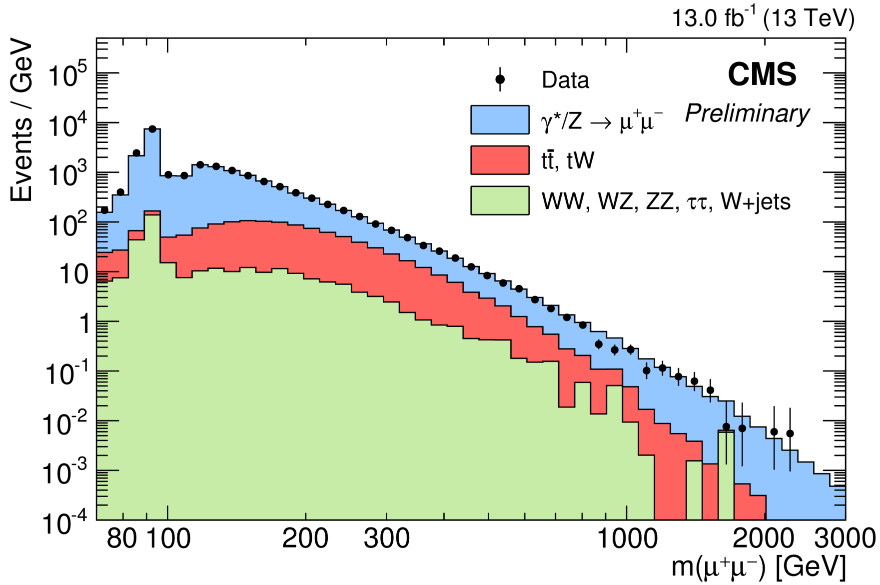
  - Guideline for new purpose-built search analysis, if necessary :)


April 2017
CMS Preliminary
Production Cross Section, σ [pb]
7 TeV CMS measurement (L ≤ 5.0 fb⁻¹)
8 TeV CMS measurement (L ≤ 19.6 fb⁻¹)
13 TeV CMS measurement (L ≤ 35.9 fb⁻¹)
Theory prediction
CMS 95%CL limits at 7, 8 and 13 TeV
≥n jet(s)
W Z Wγ Zγ WW WZ ZZ EW qqW EW qqZ γγ→WW EW Wγjj EW ssWW EW Zγjj WVγ Zγγ Wγγ tt t-ch tW ts-ch ttγ tZq ttW ttZ tttt ggH VBF qqH VH ttH HH
EW: W→lν, Z→ll, l=e,μ
Th. ΔσH in exp. Δσ
All results at: http://cern.ch/go/pNj7


Standard Model Production Cross Section Measurements
Status: March 2017
∫ℒ dt [fb⁻¹]
Reference
ATLAS Preliminary
Run 1,2 √s = 7, 8, 13 TeV
Theory
LHC pp √s = 7 TeV
Data
stat
stat ⊕ syst
LHC pp √s = 8 TeV
Data
stat
stat ⊕ syst
LHC pp √s = 13 TeV
Data
stat
stat ⊕ syst
pp fid.
Jets R=0.4 fid.
Dijets R=0.4 fid.
γ fid.
W fid.
Z fid.
tt̄ fid.
tt−chan tot.
ts−chan tot.
Wt fid.
WW tot.
WZ tot.
ZZ tot.
γγ fid.
Wγ fid.
Zγ fid.
tt̄W tot.
tt̄Z tot.
tt̄γ fid.
Wjj EWK fid.
Zjj EWK fid.
Zγγ fid.
Wγγ fid.
W±W±jj EWK fid.
WZjj EWK fid.
0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4
data/theory
50×10⁻⁸ PLB 761 (2016) 158
8×10⁻⁸ Nucl. Phys. B, 486-548 (2014)
4.5 JHEP 02, 153 (2015)
4.5 JHEP 05, 059 (2014)
3.2 arXiv: 1701.06882 [hep-ex]
20.2 JHEP 06 (2016) 005
4.6 PRD 89, 052004 (2014)
0.081 PLB 759 (2016) 601
4.6 arXiv:1612.03016 [hep-ex]
3.2 JHEP 02 (2017) 117
20.2 JHEP 02 (2017) 117
4.6 JHEP 02 (2017) 117
3.2 PLB 761 (2016) 136
20.2 EPJC 74: 3109 (2014)
4.6 EPJC 74: 3109 (2014)
3.2 arXiv:1609.03920 [hep-ex]
20.3 arXiv:1702.02859 [hep-ex]
4.6 PRD 90, 112006 (2014)
20.3 PLB 756, 228-246 (2016)
3.2 arXiv:1612.07231 [hep-ex]
20.3 JHEP 01, 064 (2016)
2.0 PLB 716, 142-159 (2012)
3.2 arXiv: 1702.04519 [hep-ex]
20.3 PLB 763, 114 (2016)
4.6 PRD 87, 112001 (2013)
3.2 PLB 762 (2016) 1
20.3 PRD 93, 092004 (2016)
4.6 EPJC 72, 2173 (2012)
3.2 PRL 116, 101801 (2016)
20.3 JHEP 01, 099 (2017)
4.6 JHEP 03, 128 (2013)
4.9 JHEP 01, 086 (2013)
4.6 PRD 87, 112003 (2013)
20.3 PRD 93, 112002 (2016)
4.6 PRD 87, 112003 (2013)
3.2 EPJC 77 (2017) 40
20.3 JHEP 11, 172 (2015)
3.2 EPJC 77 (2017) 40
20.3 JHEP 11, 172 (2015)
4.6 PRD 91, 072007 (2015)
20.2 arXiv:1703.04362 [hep-ex]
4.7 arXiv:1703.04362 [hep-ex]
20.3 JHEP 04, 031 (2014)
20.3 PRD 93, 112002 (2016)
20.3 PRL 115, 031802 (2015)
20.3 arXiv: 1611.02428 [hep-ex]
20.3 PRD 93, 092004 (2016)

Intro: SM precision vs direct search





- Very often, searches and SM measurements examine same data
  - Usually searches have more data, and are released earlier, but also larger uncertainties
  - SM measurements give very good feedback about more subtle effects, typically take longer but provide useful output like unfolded distributions and standard tools regarding data availability for pheno such as hepdata and rivet
- Example: Differential cross sections
  - useful input to theory and generator community
  - Serve different goal but very similar distributions
    - In case of dileptons: range is also very similar!
    - Often measurements come much later due to detailed systematic studies

CMS-PAS-SMP-16-009
CMS-PAS-EXO-16-031

Detailed model comparison

- Another way to compare SM measurements is because they tend to set limits on (generic) BSM-sensitive couplings
- Example: constraints on flavour-changing neutral currents, anomalous couplings, lepton universality
- Typically these measurements compare the standard model behaviour to predictions obtained from various modified effective lagrangians
- These model-independent limits are usually not as sensitive as dedicated searches and only valid in same fiducial space as the measurement

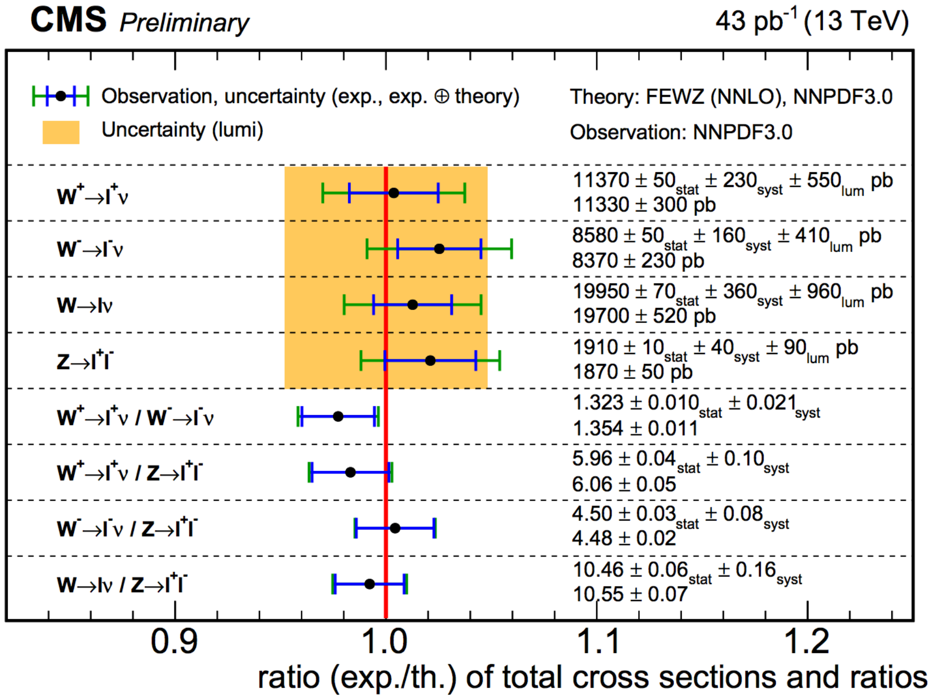
the Electroweak sector

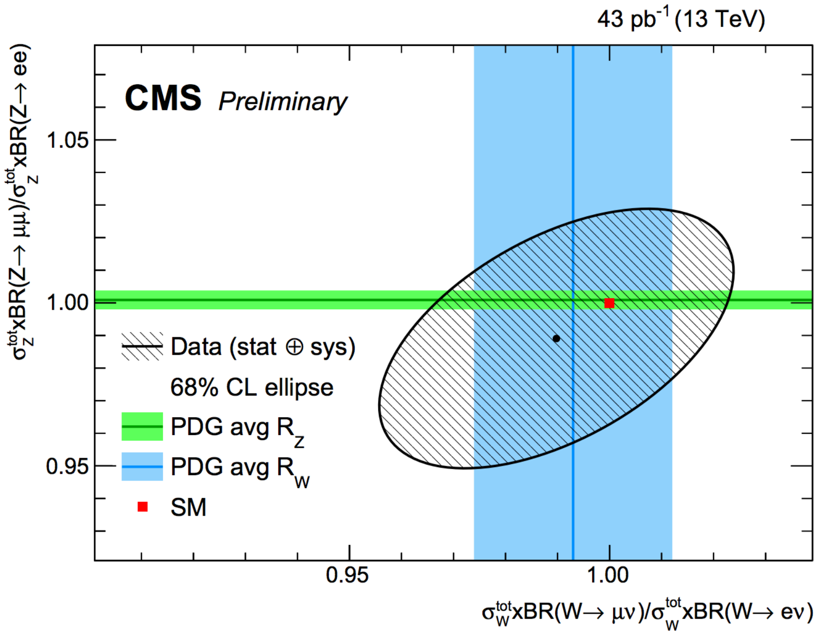
Sensitivity to electroweak symmetry breaking mechanism,direct and via loops

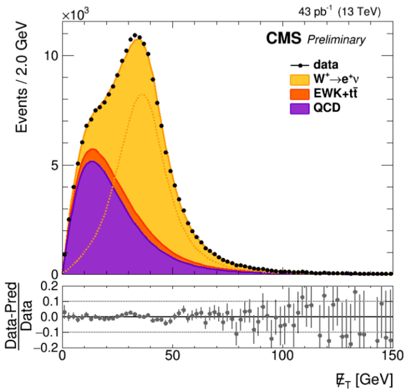
Differential cross sections sensitive to changes in shape (resonances, modified couplings etc)

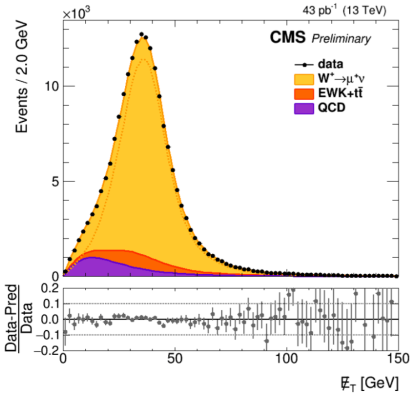
Pair and triple-production of γ,Z,W used to constrain triple/quartic gauge couplings

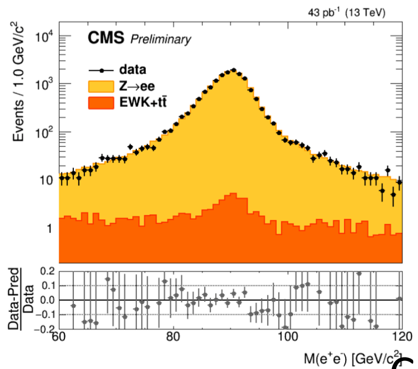
CMS:Lepton universality in W, Z production

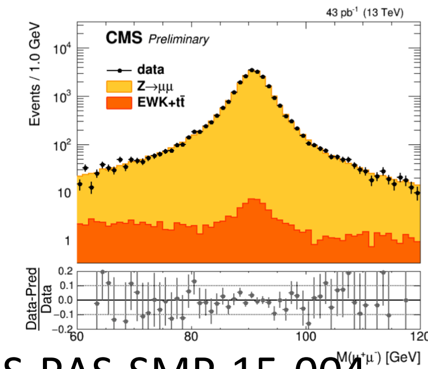






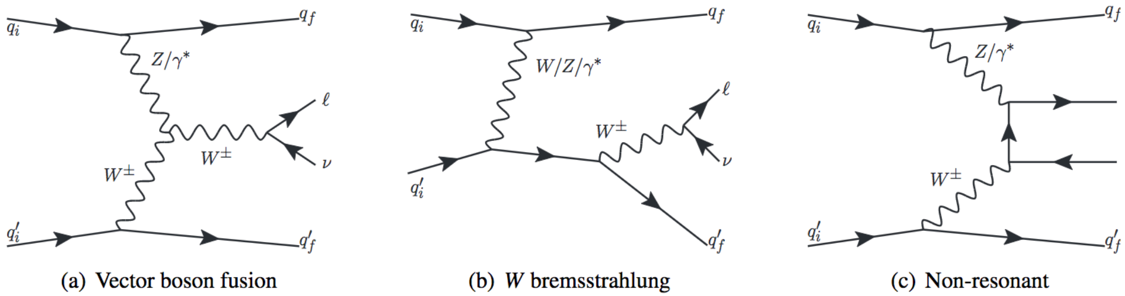


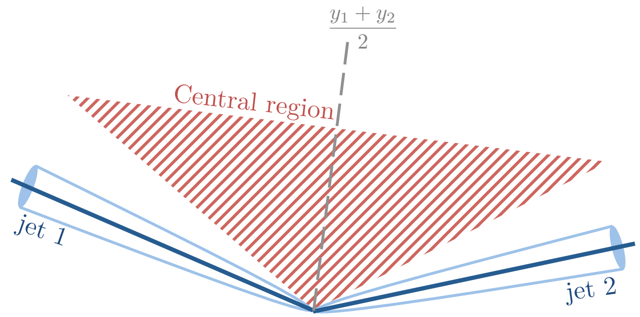




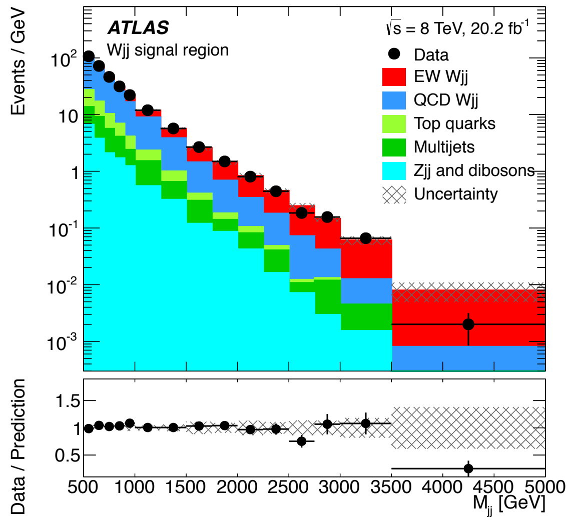
CMS-PAS-SMP-15-004

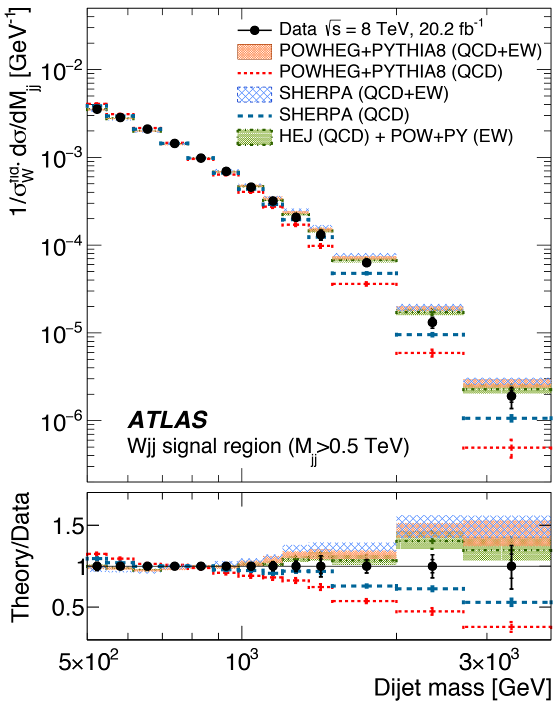
ATLAS electroweak Wjj production and constraints anomalous gauge couplings





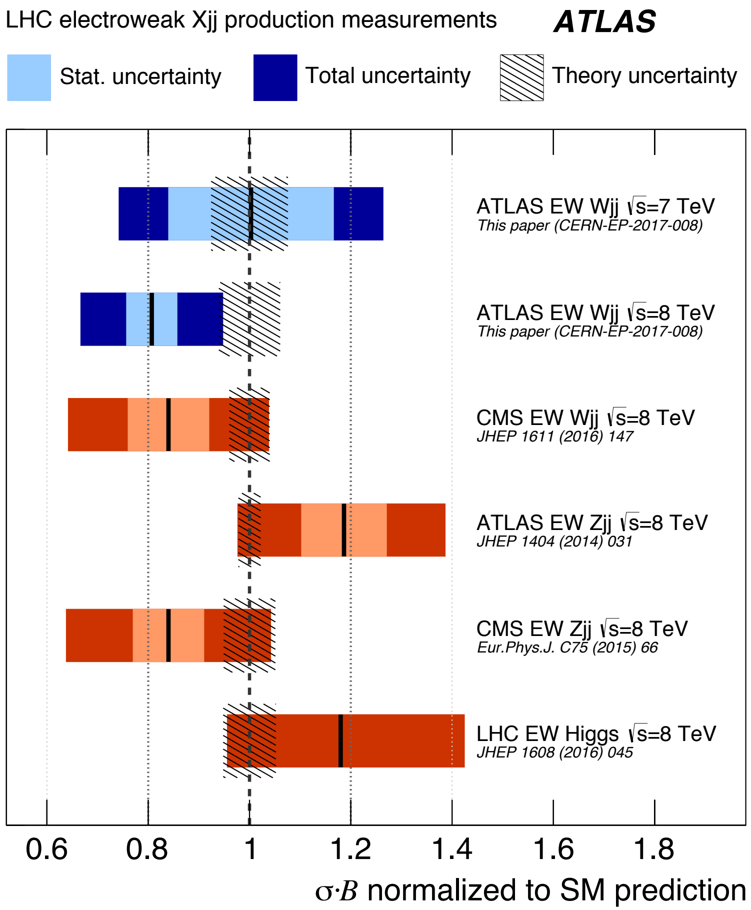
- Select electroweak production W boson with two forward jets
  - Using 'rapidity gap' selection
- Sensitive variable: invariant mass jets
  - both observed and unfolded distributions available

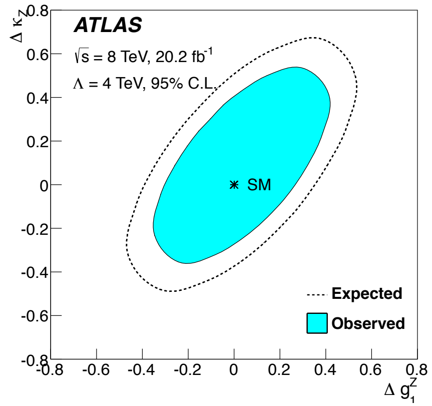


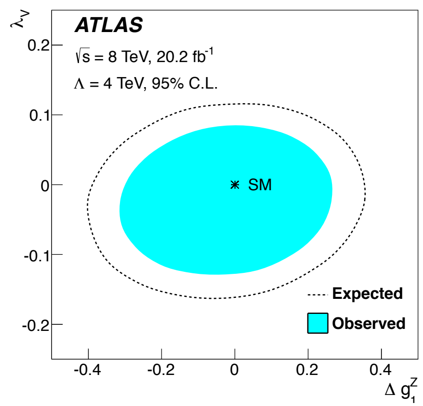


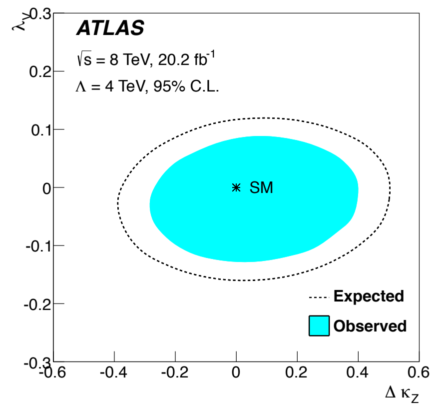
Source:ATLAS: arxiv 1703.04362

ATLAS electroweak Wjj production and constraints anomalous gauge couplings









$$i\mathcal{L}_{\rm eff}^{WWV} = g_{WWV}\Big\{\Big[g_1^V V^\mu (W^-_{\mu\nu}W^{+\nu} - W^+_{\mu\nu}W^{-\nu}) + \kappa_V W^+_\mu W^-_\nu V^{\mu\nu} + \frac{\lambda_V}{m_W^2} V^{\mu\nu} W^{+\rho}_\nu W^-_{\rho\mu}\Big] - \Big[\frac{\tilde\kappa_V}{2} W^-_\mu W^+_\nu \epsilon^{\mu\nu\rho\sigma} V_{\rho\sigma} + \frac{\tilde\lambda_V}{2m_W^2} W^-_{\rho\mu} W^{+\mu}_\nu \epsilon^{\nu\rho\alpha\beta} V_{\alpha\beta}\Big]\Big\},$$

Source:ATLAS: arxiv 1703.04362

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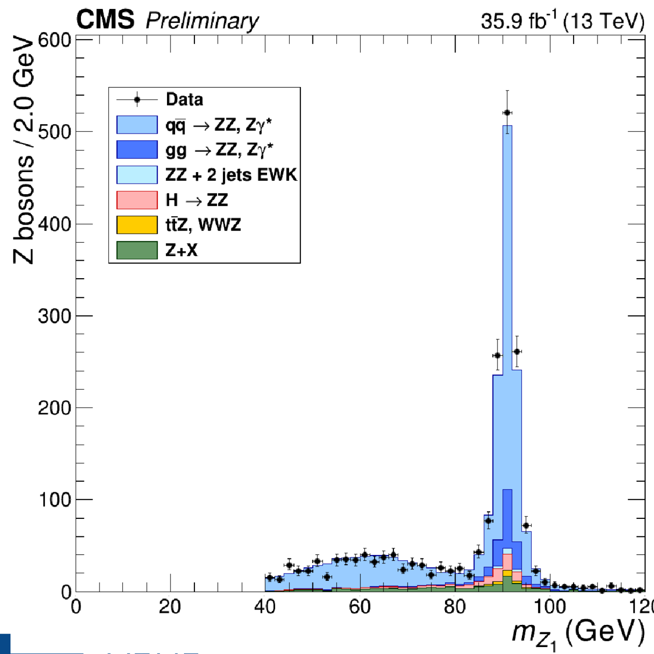
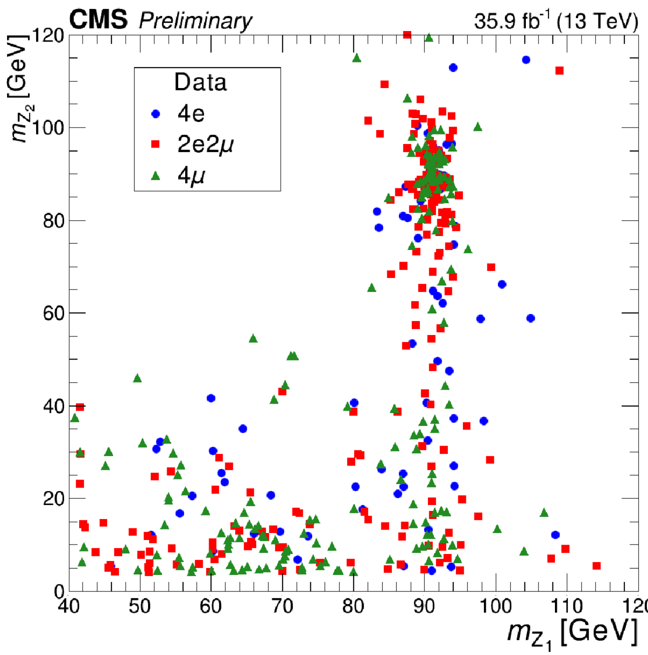
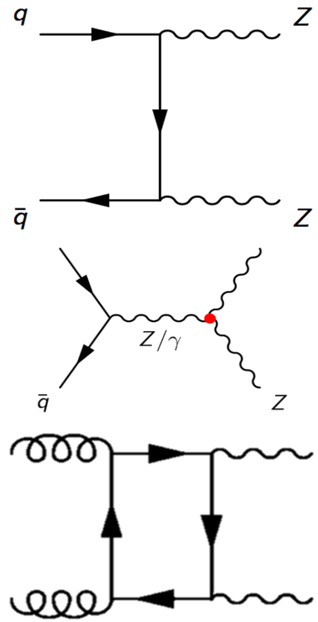
CMS: aTGC from ZZ production

- Using large (36 fb^{-1}) 2016 dataset at 13 TeV to measure ZZ production, and anomalous couplings
- Also measures Z->4 leptons branching ratio
- Includes fiducial & differential cross sections that can be used as input for theory and BSM searches
- Also sets limits on BSM at ZZγ and ZZZ vertex







CMS-PAS-SMP-16-017

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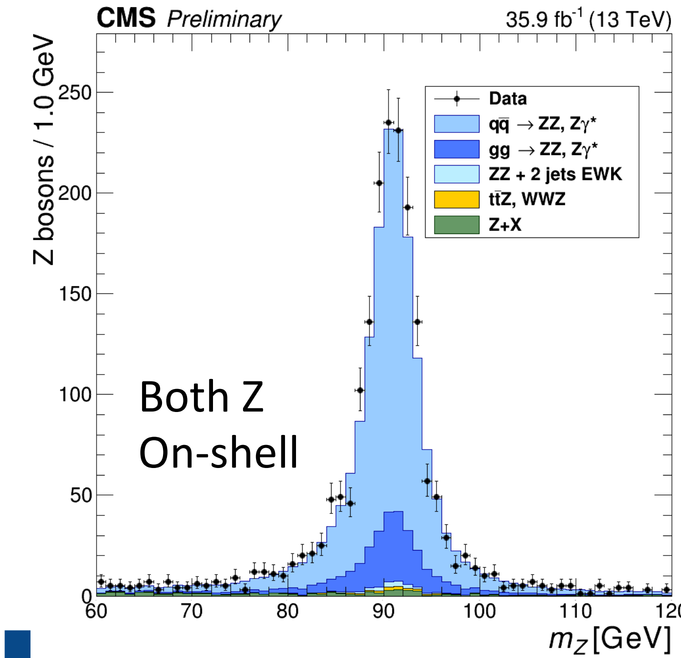

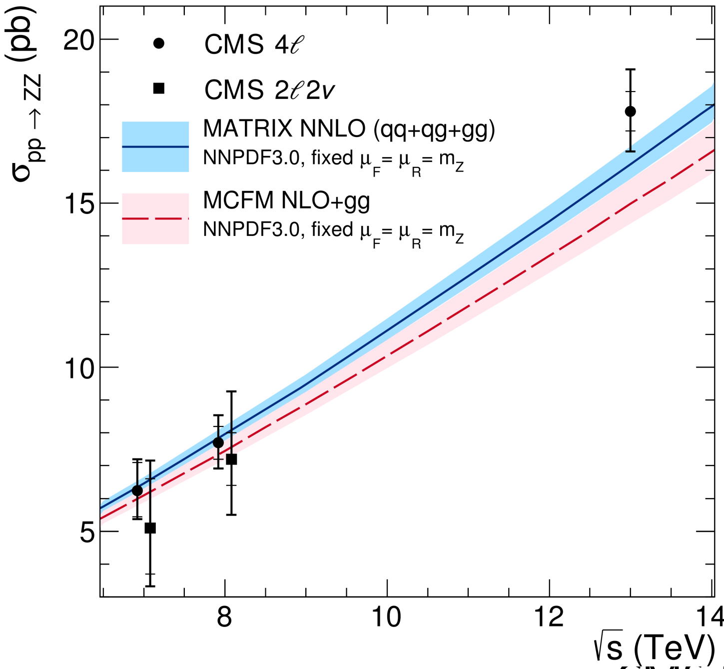

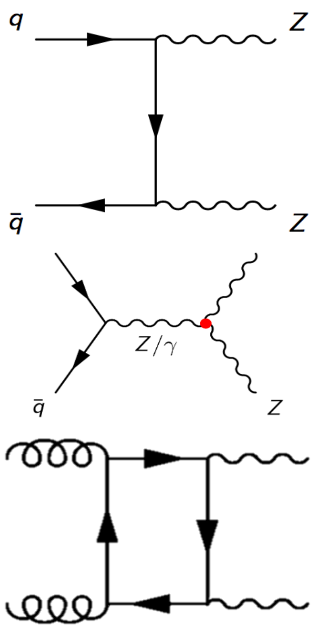

CMS-PAS-SMP-16-017

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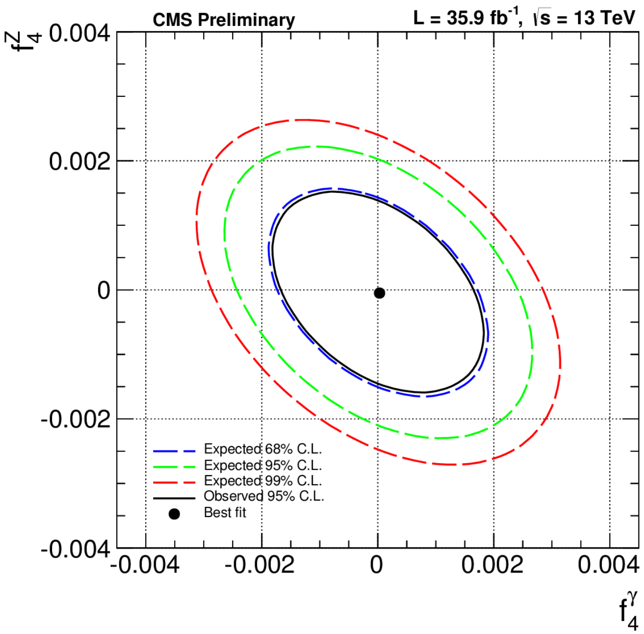
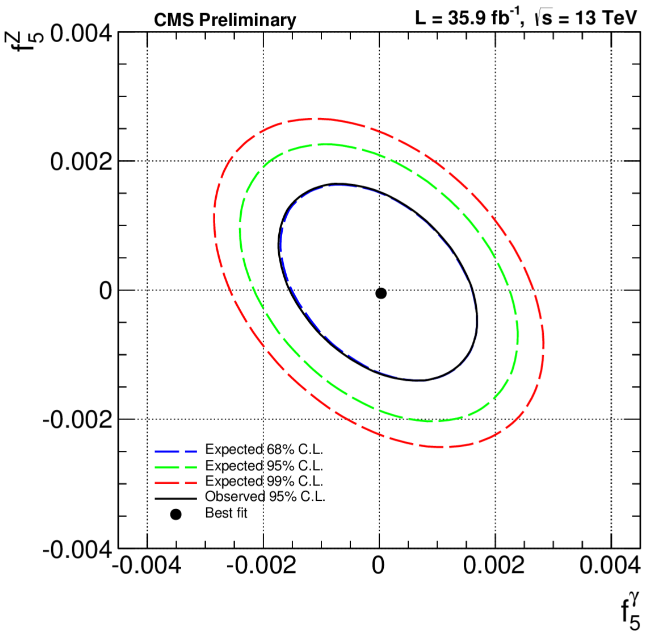
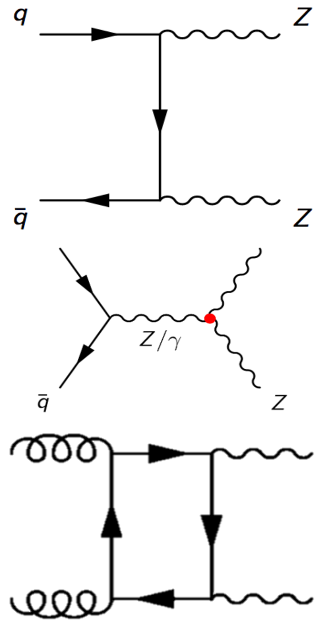


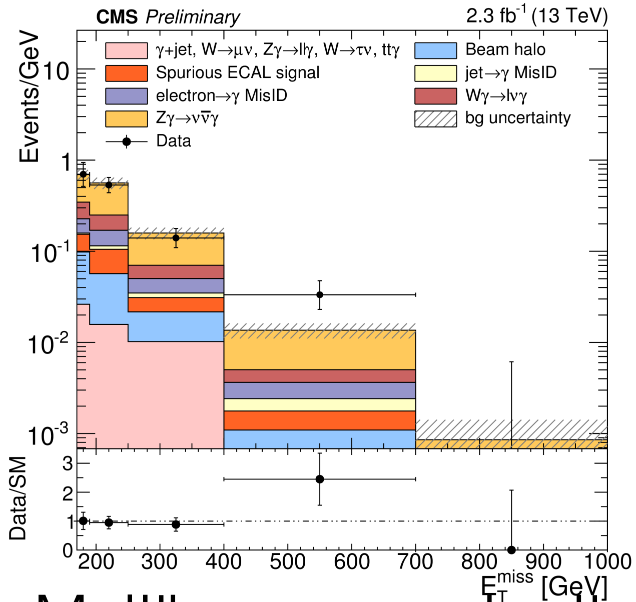




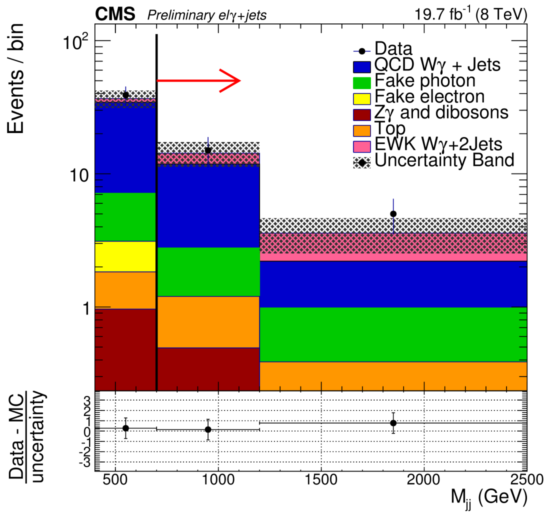
CMS-PAS-SMP-16-017

Triple gauge boson constraints

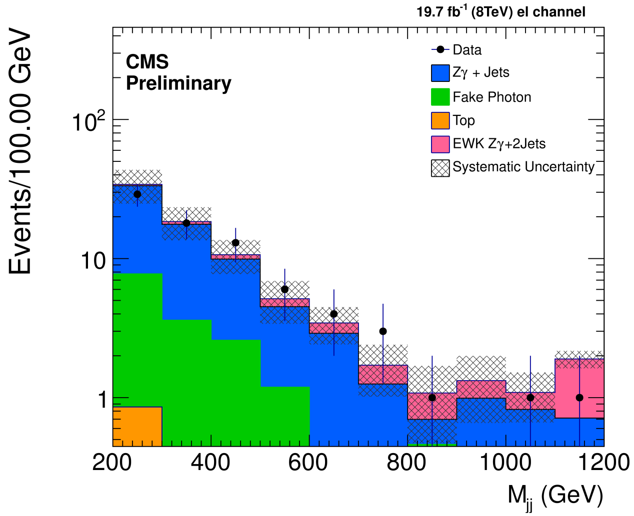
CMS-PAS-SMP-16-004



CMS-PAS-SMP-14-011



CMS-PAS-SMP-14-018



Multiboson production with photons

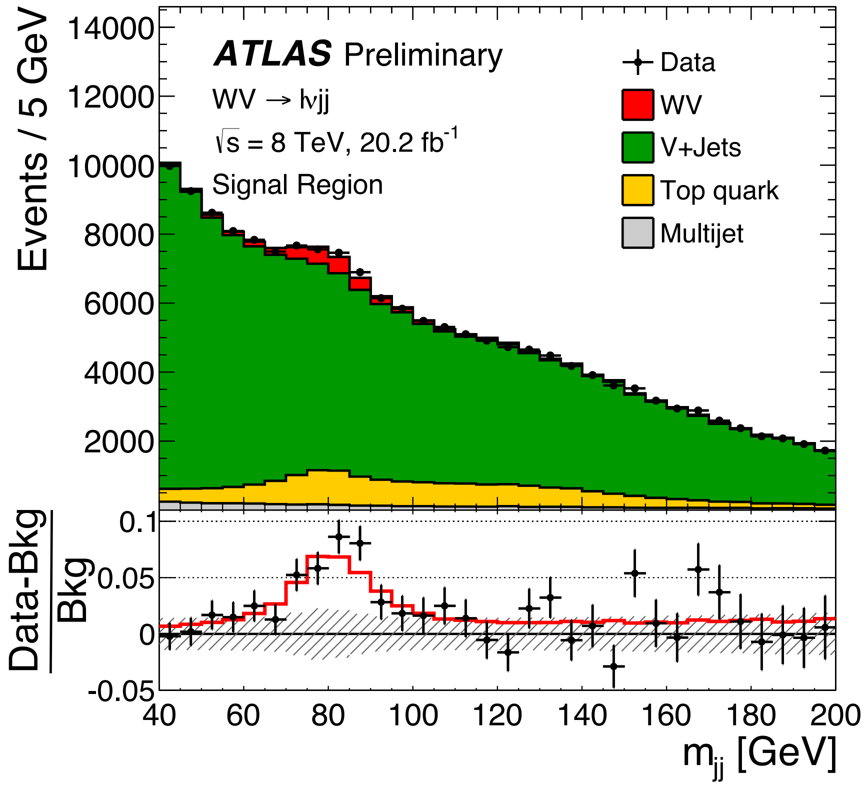
- Provides sensitivity to EWK sector
- Highest rate triboson production
- Access to BSM though Triple/Quartic-Gauge-Couplings
  - Using effective SM Lagrangean with Dim-6 and Dim-8 operators

aTGC: ATLAS WW/WV semileptonic

NEW

- YSF talk by Margherita Spalla tonight!

- Select one isolated lepton, E_T^{miss} and look at mass of jets
- Allows selection of W+Z/W(hadronic) sample, again can be used to constraints WVV couplings



Coming soon!

aTGC: ATLAS WW/WV semileptonic

- YSF talk by Margherita Spalla tonight!

Measurement of WW/WZ production in semileptonic decay channels and search for anomalous gauge couplings with the ATLAS detector

18 Apr 2017, 19:05
8m
UZ Obergurgl

Young Scientist Forum | Higgs and the Standar... | YSF

Speaker

Margherita Spalla (Universita di Pisa & I...)

Description

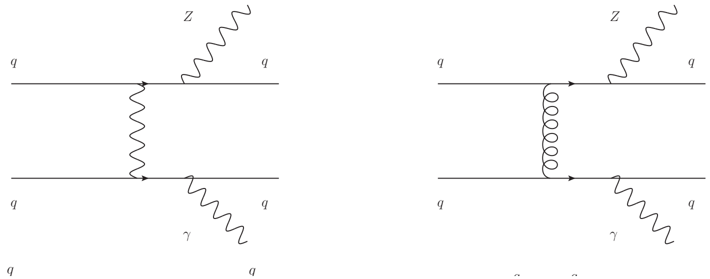
The measurements of the production of two massive vector gauge bosons represent an important test of the Standard Model of particle physics since they probe the structure of the triple gauge boson couplings as well as test of higher-order calculations in quantum chromodynamics. In this talk, a new measurement of the production of WW or WZ boson pairs with one W decaying leptonically and one W or Z decaying hadronically is presented. The cross-section is measured in proton-proton collision data taken with the ATLAS detector at a center-of-mass energy of 8 TeV. The hadronic boson decay is reconstructed in two ways: as two resolved small-radius jets, and as a single large-radius jet. The transverse-momentum distribution of the hadronically-decaying boson is used to search for new physics, proving limits on anomalous triple gauge couplings.

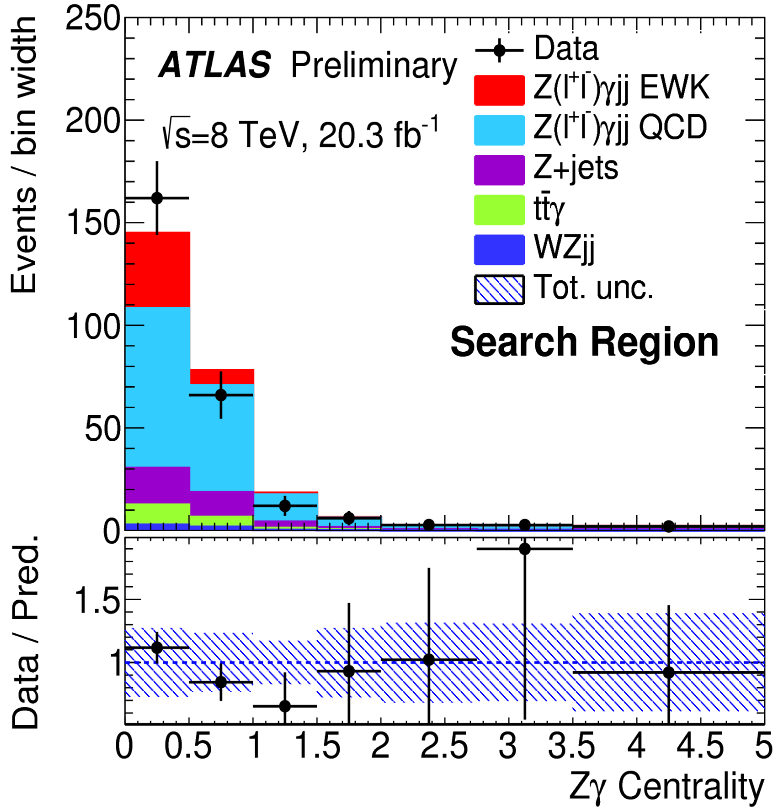
NEW ATLAS: Zγjj incl Vector boson scattering

- Zγjj contains fourth-order electroweak coupling processes, incl. vector boson scattering (VBS)
  - Sensitive to BSM in quartic gauge couplings
- Large interference between VBS and rest of SM: challenge to disentangle
- Sensitive to rapidity gaps, two central bosons, and dijet mass > 500 GeV
- Data-MC agreement verified in control regions at lower jj mass
- Using centrality of leading 2 jets

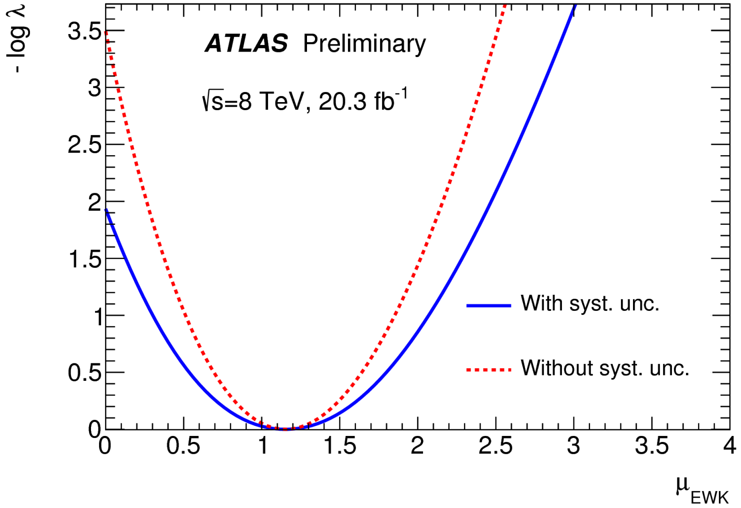
$$\zeta \equiv \left|\frac{\eta - \bar{\eta}_{jj}}{\Delta\eta_{jj}}\right| \quad \text{with} \quad \bar{\eta}_{jj} = \frac{\eta_{j_1} + \eta_{j_2}}{2}, \quad \Delta\eta_{jj} = \eta_{j_1} -$$

to discriminate between QCD and EWK Zγjj process





ATLAS: Zγjj incl Vector boson scattering



- Measures fiducial cross sections for VBS production
- In signal region and control regions at with inverted ξ and mjj selection
- Purity of ~18% & consistent with VBFNLO prediction
- VBS Zγjj corresponds to 2σ significance
- Observed VBS Zγjj cross section of 1.1 ± 0.5 (stat) ± 0.4 (syst) fb

  SM prediction: 0.95 ± 0.09 fb
- VBS Zγjj still limited by statistical uncertainties
- Main systematic uncertainty: jet energy scale
  - Larger datasets (and smaller systematic uncertainties) needed for 3/5σ observation

ATLAS: Zγjj incl Vector boson scattering

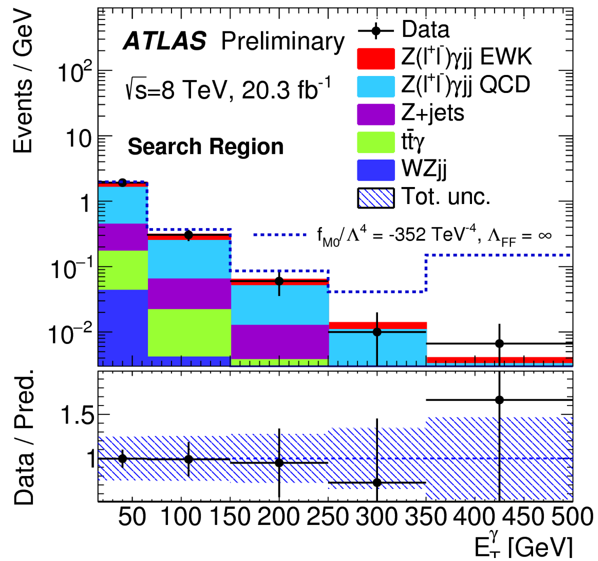
NEW

- Also examines high E_T^{miss} ($Z \to \nu\nu$) and high E_T^{γ} regions for BSM contributions
  - Constrain aQGC by dim-8 operators

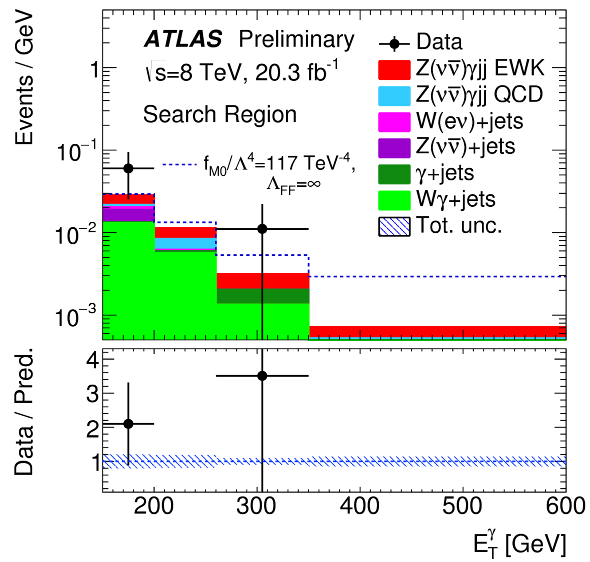
$$\mathcal{L} = \mathcal{L}^{SM} + \sum_i \frac{c_i}{\Lambda^2}\mathcal{O}_i + \sum_j \frac{f_j}{\Lambda^4}\mathcal{O}_j$$

  - Setting limits for
    - f_{T9}/Λ^4, f_{T8}/Λ^4, f_{T0}/Λ^4 : $\pm 5.2 \times 10^3$, $\pm 2.4 \times 10^3$, $\pm 2.4 \times 10^1$ TeV^{-4}
    - f_{M0}/Λ^4, f_{M1}/Λ^4, f_{M2}/Λ^4, f_{M3}/Λ^4 : $\pm 2.3 \times 10^2$, $\pm 5 \times 10^2$, $\pm 1.3 \times 10^3$, $\pm 2.5 \times 10^3$
    - Including limits on Λ of order ~1 TeV depending on Wilson coefficient

not allowed to show actual numbers yet but keep an eye on ATLAS public pages!



Zγjj with Z->ll



Zγjj with Z->νν

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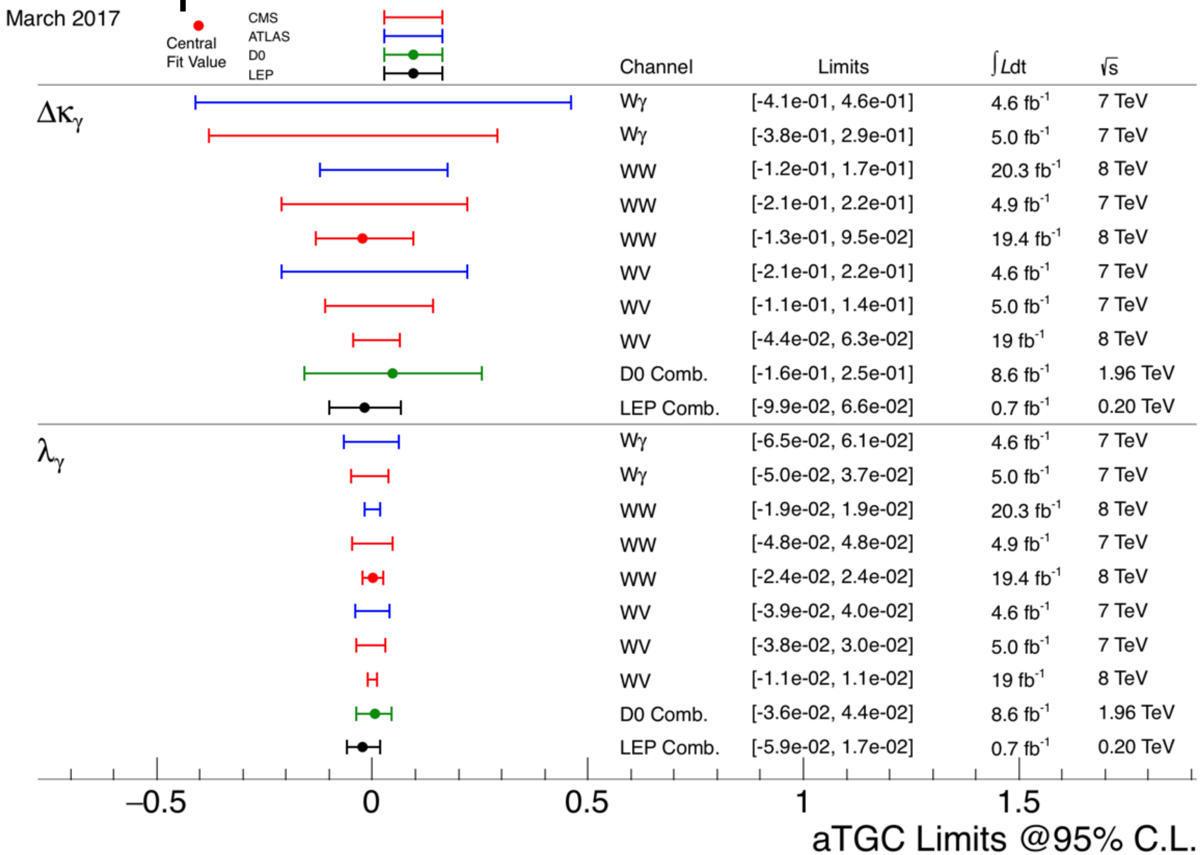
All coupling limits – all in one place!

- **All** aTGC/aQGC results from **ATLAS**, **CMS** and earlier experiments:



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

the Top quark sector

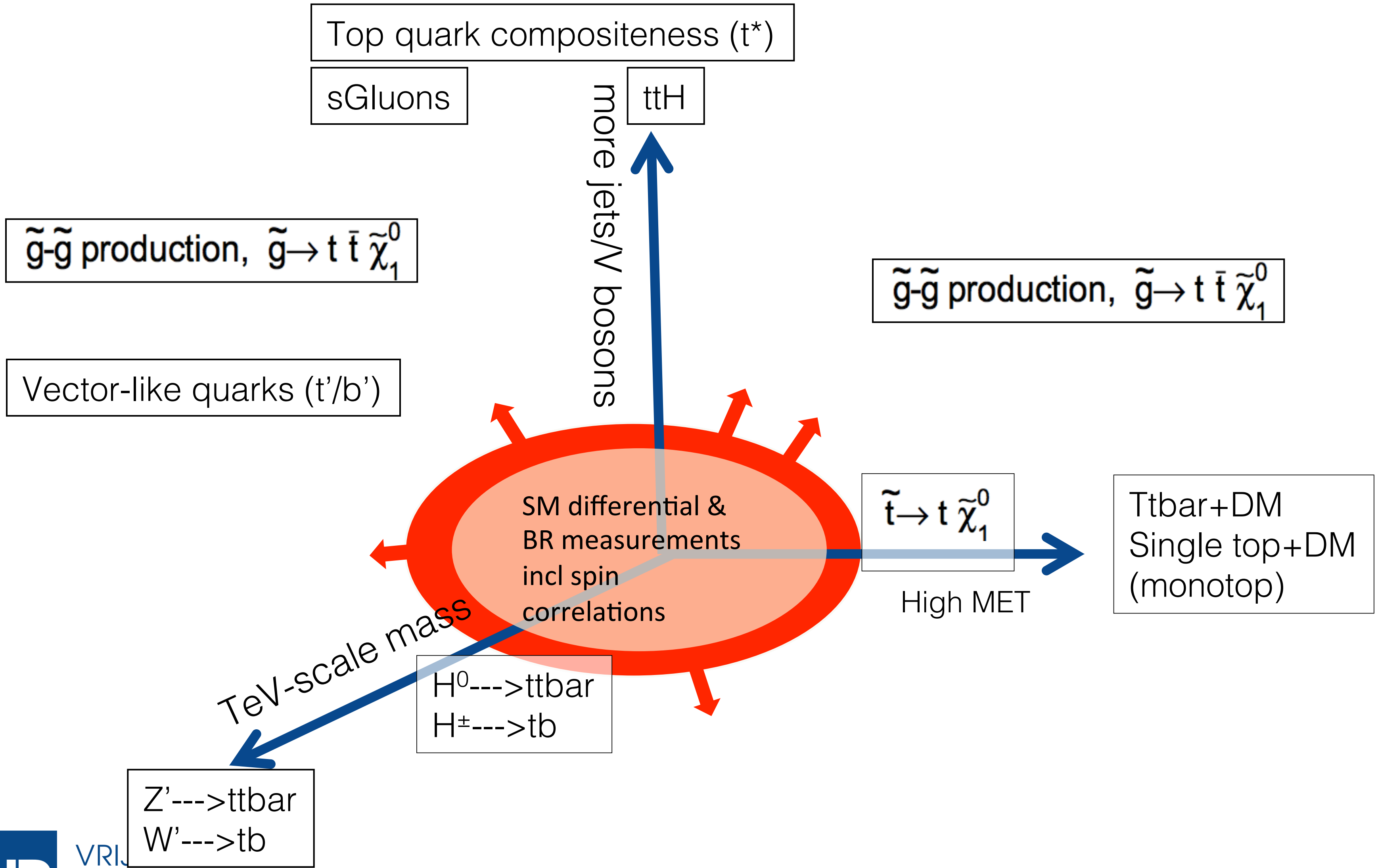
Same considerations as W/Z sector, and in addition:

Enhanced sensitivity in loops due to special role of (heavy) top quark?

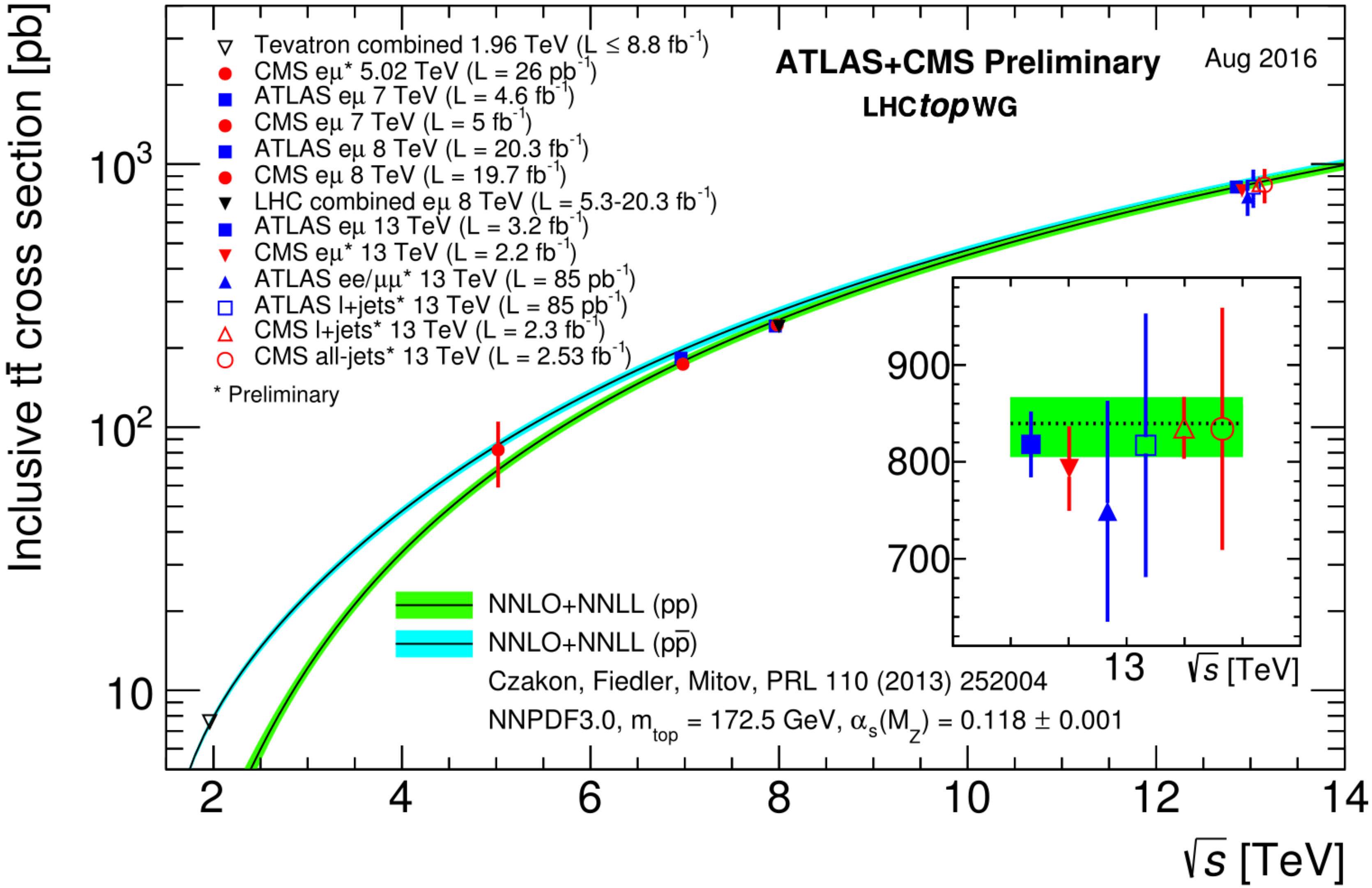
Kinematic distributions probe new physics at the W-t-b vertex

Rare decays provide sensitivity to anomalous couplings, flavour changing neutral currents.

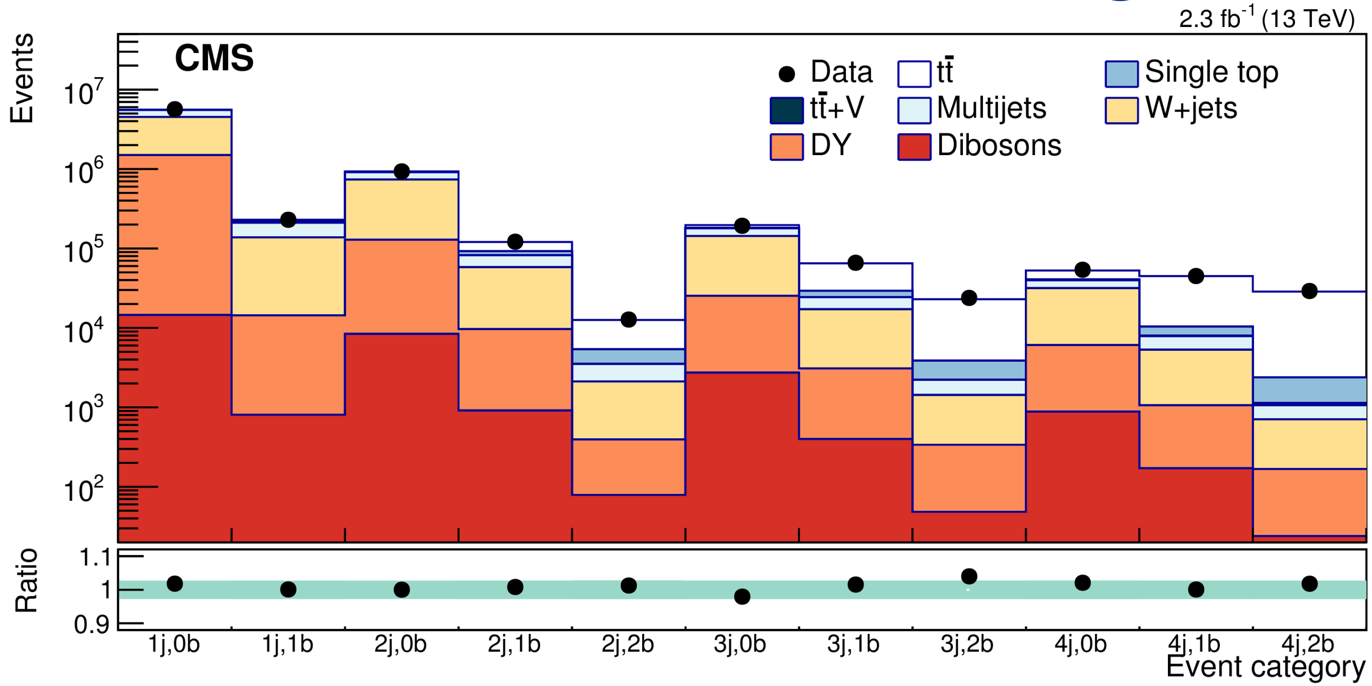
Extreme phase space ttbar: background for searches



Top cross section



Top cross section: high precision

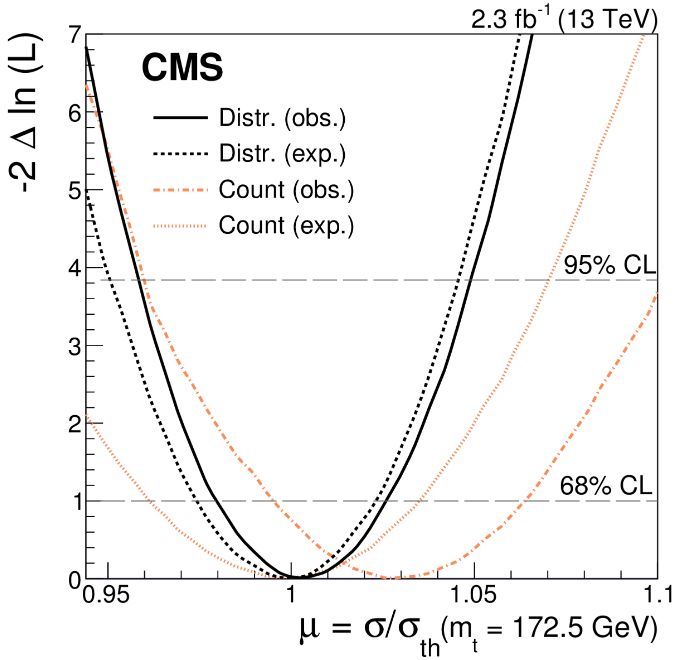


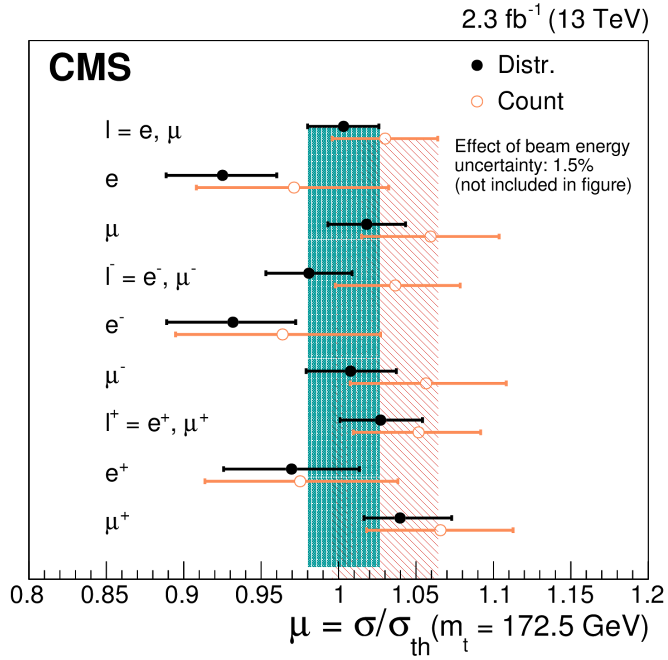
TOP-16-006:
Fit to all jet and tag multiplicities in e/μ+jets channel
Shape fit to mass(l,b)$_{min}$ in each bin

- 834.6 ± 0.003% (stat) ± 0.027% (syst) ± 0.027% (lumi)
- Statistical uncertainty on permille scale
- Essentially a global fit analysis in l+jets with b tags in the N_{jet} =1-4 bins
- How to improve further?
  - Significant improvement luminosity measurement not expected
  - Understanding modelling W+jets production largest uncertainty
  - Accuracy can be used to constrain top pole mass

CMS TOP-16-006 arXiv:1701.06228

Top cross section: high precision





TOP-16-006:
Fit to all jet and tag multiplicities in e/μ+jets channel
Shape fit to mass(l,b)$_{min}$ in each bin

- 834.6 ± 0.003% (stat) ± 0.027% (syst) ± 0.027% (lumi)
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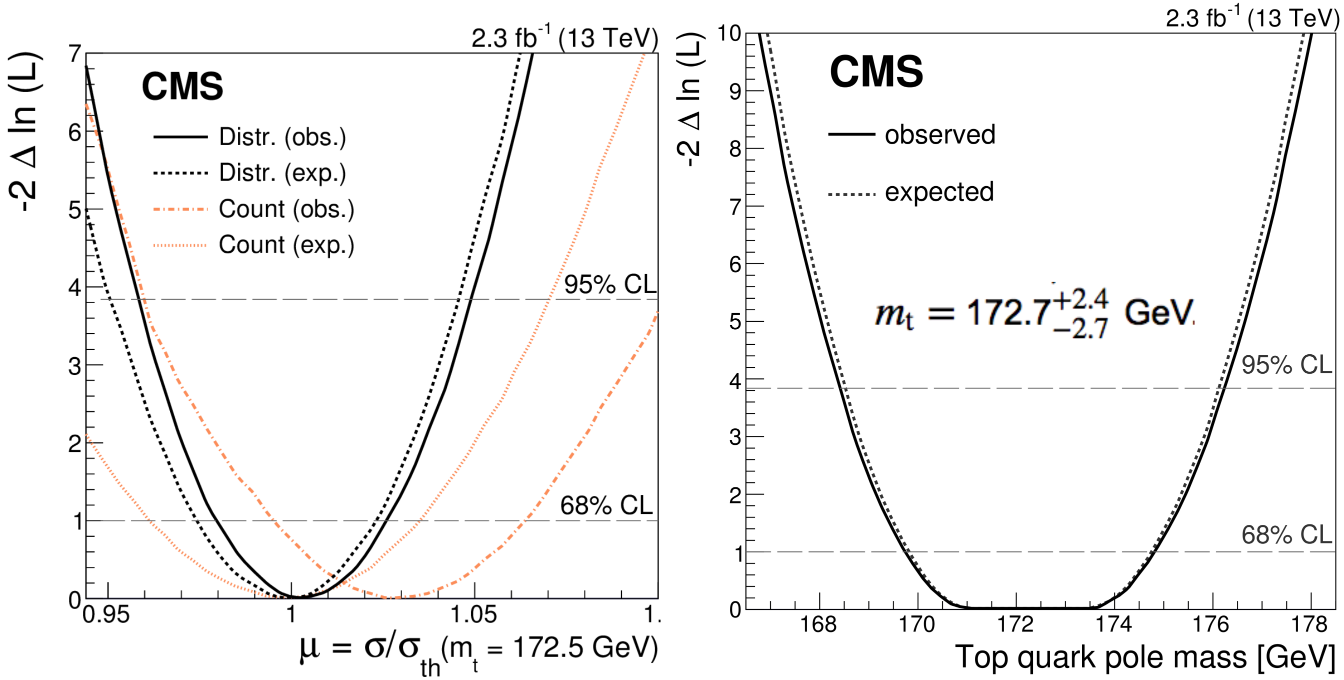

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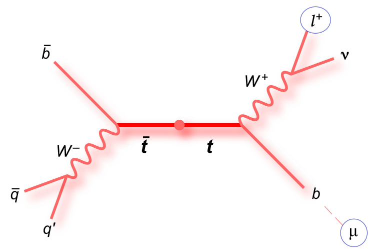
CMS TOP-16-006 arXiv:1701.06228

ATLAS Top charge and CP asymmetry

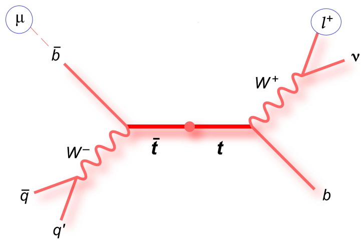
- identification of top charge via b (soft lepton) charge and lepton charge
- Lepton from B mesons can be different charge depending on presence b to c cascade decays

- Uses top likelihood fitter (similar to in top mass measurement) to associate top quark to b jet

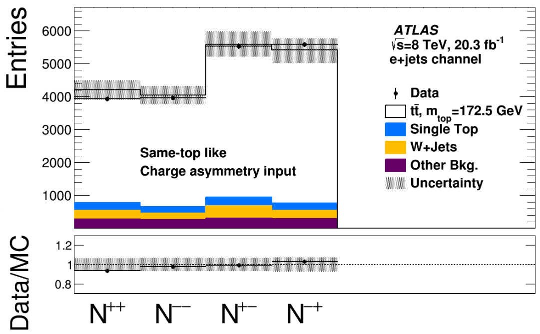
- Counts number of right/ wrong combinations (N^{++} etc) and uses this as input to asymmetry
- First ever direct limits on A^{bl} and A^{cl} and substantial improvements on other CP asymmetries



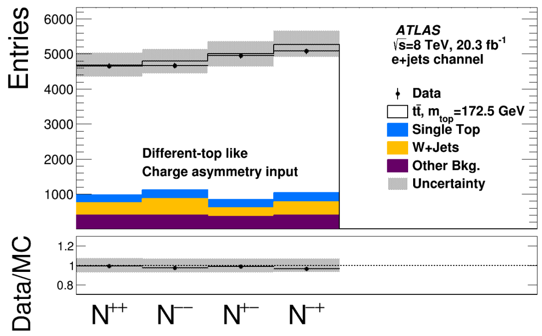
(a) Same-top SMT muon



(b) Different-top SMT muon



(a) e+jets channel.

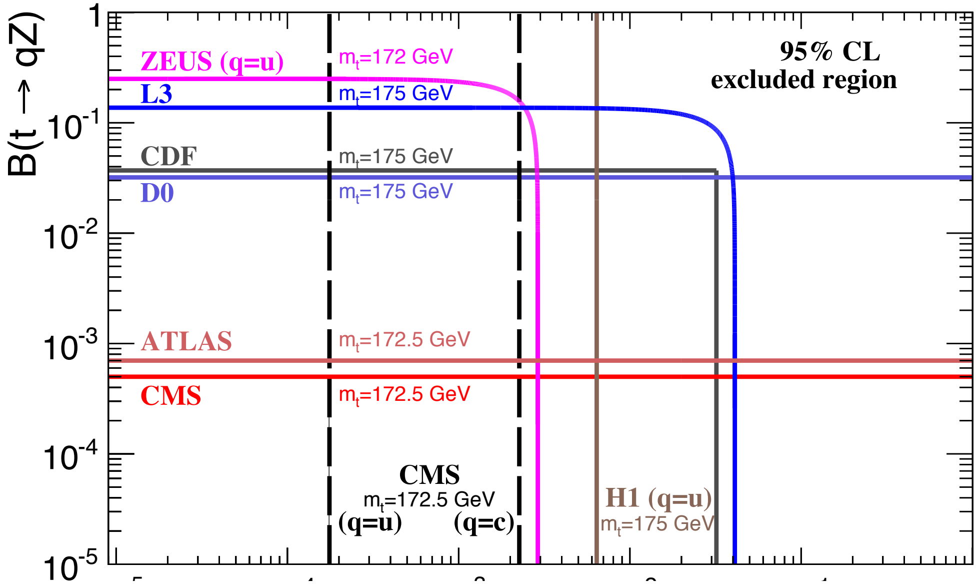


(a) e+jets channel.

	Data (10^{-2})	MC (10^{-2})	Existing limits (2σ) (10^{-2})		SM prediction (10^{-2})	
A^{ss}	-0.7 ± 0.8	0.05 ± 0.23	-		$< 10^{-2}$	[19]
A^{os}	0.4 ± 0.5	-0.03 ± 0.13	-		$< 10^{-2}$	[19]
A^{b}_{mix}	-2.5 ± 2.8	0.2 ± 0.7	< 0.1	[95]	$< 10^{-3}$	[96] [95]
$A^{b\ell}_{dir}$	0.5 ± 0.5	-0.03 ± 0.14	< 1.2	[94]	$< 10^{-5}$	[19] [94]
$A^{c\ell}_{dir}$	1.0 ± 1.0	-0.06 ± 0.25	< 6.0	[94]	$< 10^{-9}$	[19] [94]
A^{bc}_{dir}	-1.0 ± 1.1	0.07 ± 0.29	-		$< 10^{-7}$	[97]

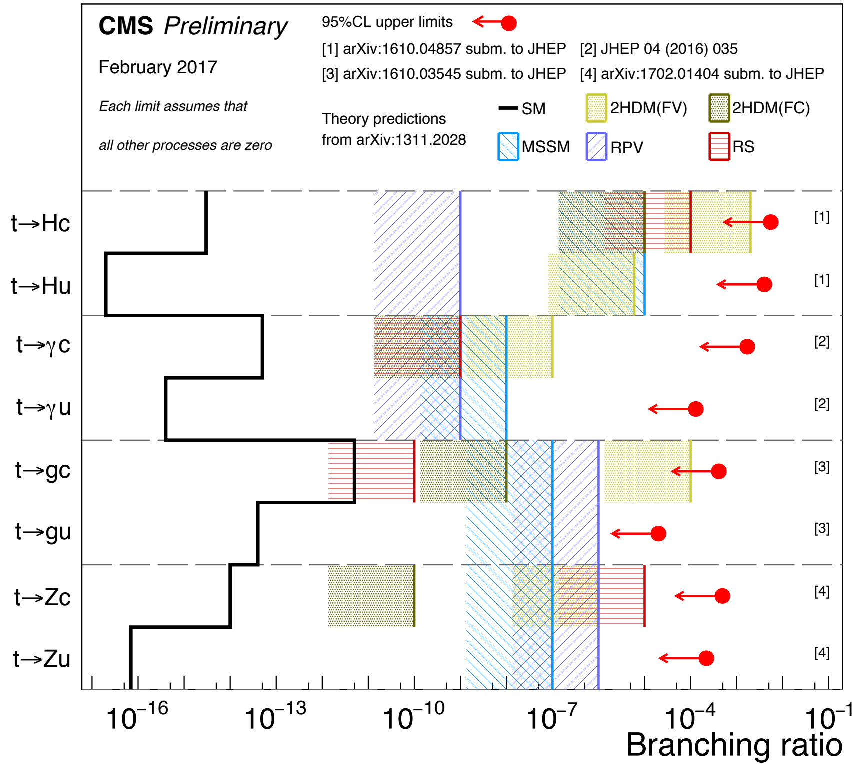
ATLAS:arXiv 1610.07869

FCNC in the top quark sector



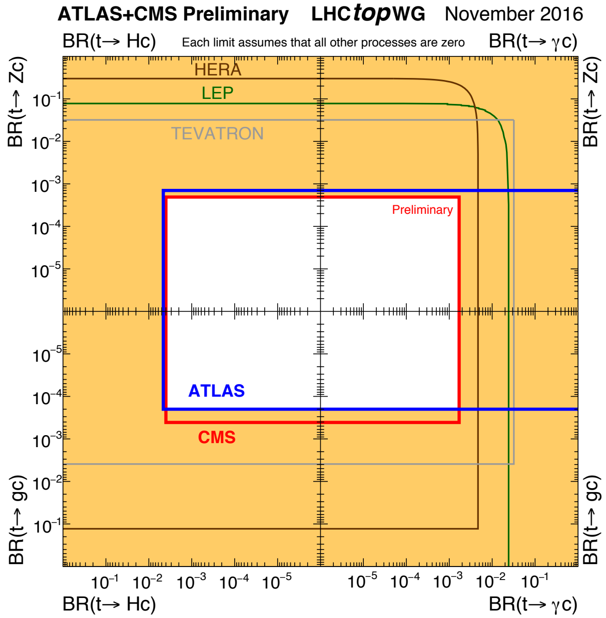
	SM	QS	2HDM	FC 2HDM	MSSM	$\not R$ SUSY
$t \to uZ$	8×10^{-17}	1.1×10^{-4}	—	—	2×10^{-6}	3×10^{-5}
$t \to u\gamma$	3.7×10^{-16}	7.5×10^{-9}	—	—	2×10^{-6}	1×10^{-6}
$t \to ug$	3.7×10^{-14}	1.5×10^{-7}	—	—	8×10^{-5}	2×10^{-4}
$t \to uH$	2×10^{-17}	4.1×10^{-5}	5.5×10^{-6}	—	10^{-5}	$\sim 10^{-6}$
$t \to cZ$	1×10^{-14}	1.1×10^{-4}	$\sim 10^{-7}$	$\sim 10^{-10}$	2×10^{-6}	3×10^{-5}
$t \to c\gamma$	4.6×10^{-14}	7.5×10^{-9}	$\sim 10^{-6}$	$\sim 10^{-9}$	2×10^{-6}	1×10^{-6}
$t \to cg$	4.6×10^{-12}	1.5×10^{-7}	$\sim 10^{-4}$	$\sim 10^{-8}$	8×10^{-5}	2×10^{-4}
$t \to cH$	3×10^{-15}	4.1×10^{-5}	1.5×10^{-3}	$\sim 10^{-5}$	10^{-5}	$\sim 10^{-6}$

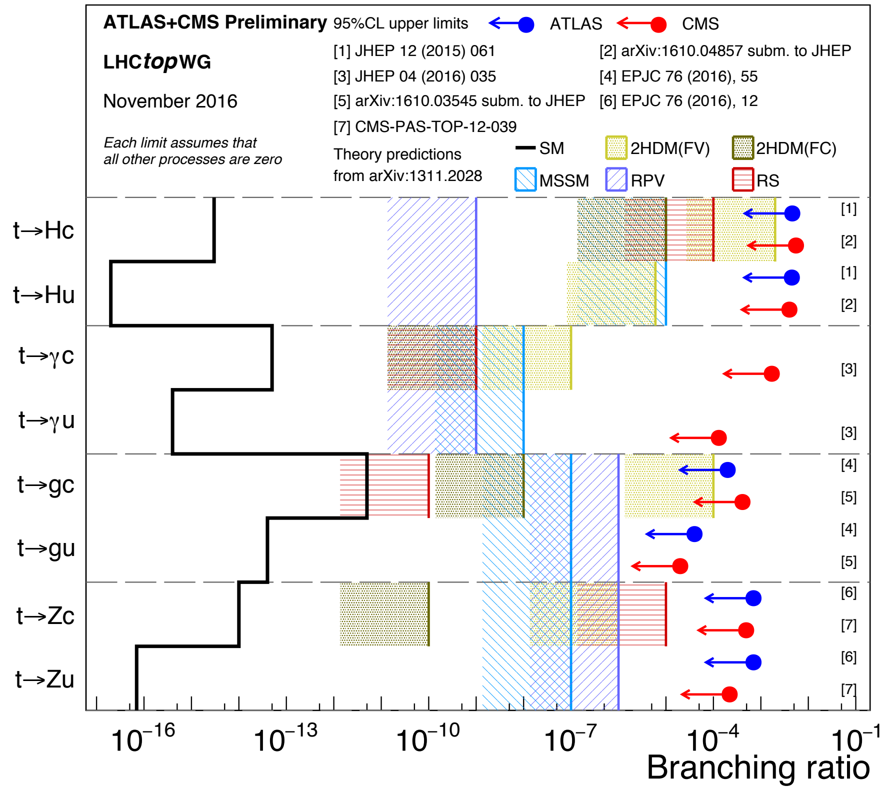
arXiv:hep-ph/0409342



- Heavily suppressed in SM and enhanced in many BSM
  - excellent tool for model-independent ‘measurement-search’
  - Topic for a whole other talk! Many analyses available sensitive to most couplings

FCNC in the top quark sector





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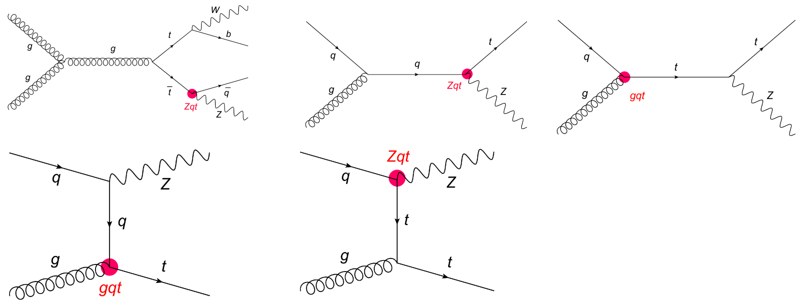
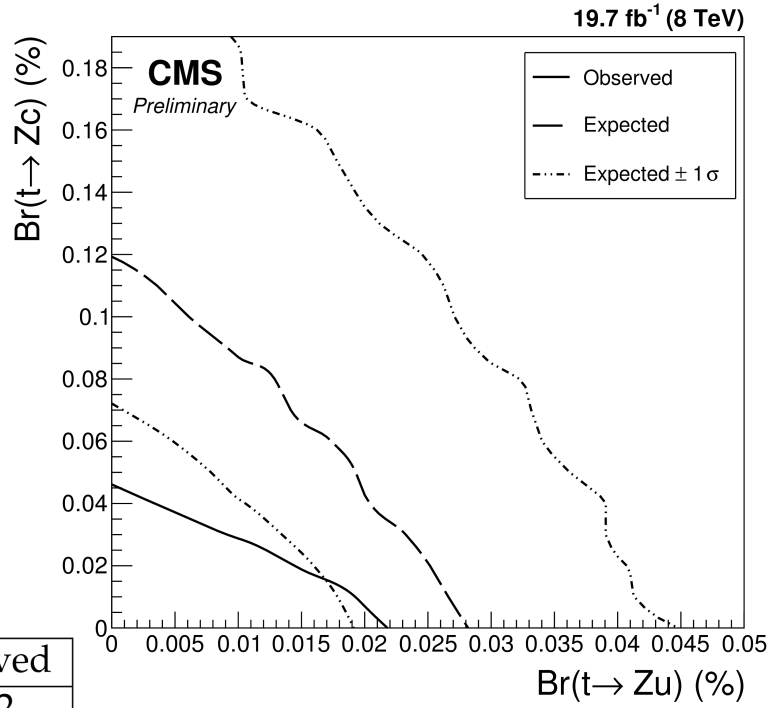
CMS: tZq production + FCNC @8TeV



$$\mathcal{L} = \sum_{q=u,c} \Big[\sqrt{2} g_s \frac{\kappa_{tgq}}{\Lambda} \bar{t} \sigma^{\mu\nu} T_a (f_q^L P_L + f_q^R P_R) q G^a_{\mu\nu} + \frac{g}{\sqrt{2} c_W} \frac{\kappa_{tZq}}{\Lambda} \bar{t} \sigma^{\mu\nu} (\hat{f}_q^L P_L + \hat{f}_q^R P_R) q Z_{\mu\nu} + \frac{g}{4 c_W} \zeta_{tZq} \bar{t} \gamma^\mu (\bar{f}_q^L P_L + \bar{f}_q^R P_R) q Z_\mu \Big] + \text{h.c.}$$

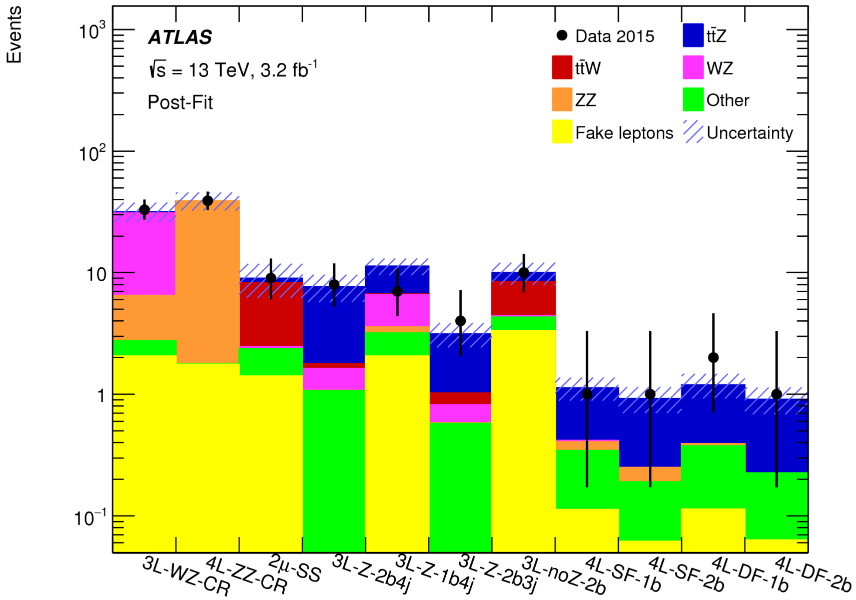
Branching ratio	Expected	1σ range	2 σ range	Observed
$\mathcal{BR}$(t→ Zu) (%)	0.027	0.018-0.042	0.014-0.065	0.022
$\mathcal{BR}$(t→ Zc) (%)	0.118	0.071-0.222	0.049-0.484	0.049

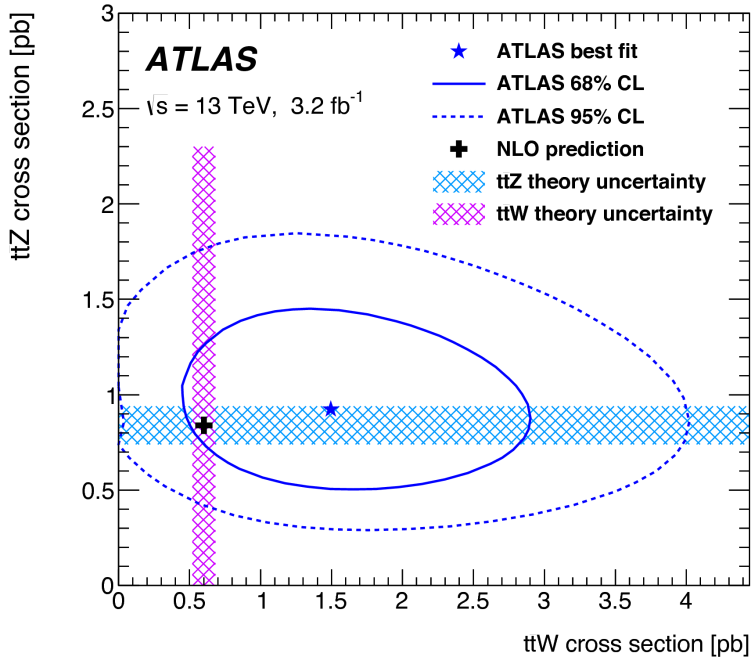


- Small but not yet significant excess of tZq production
  - but cross section measured 10+8-7 fb (MC@NLO 8.2 +0.59-0.03 (scale))
- BDT shape fit analysis using effective SM lagrangean (O(4)) including both strong and electroweak production tZq
  - Very competive limits, factor 2 improvement w.r.t previous CMS tZq FCNC analysis

CMS: TOP-12-039 arXiv: 1702.01404

ATLAS: ttbar+Z/W





- ttbar+W and Z boson at 13 TeV
  - Sensitivity:
    - SS-dilepton channel for ttW
    - 3/4-lepton channel for ttZ
  - Observed cross sections consistent with Standard Model – but ttW NLO maybe not high enough order?

ATLAS: arXiv:1609.01599

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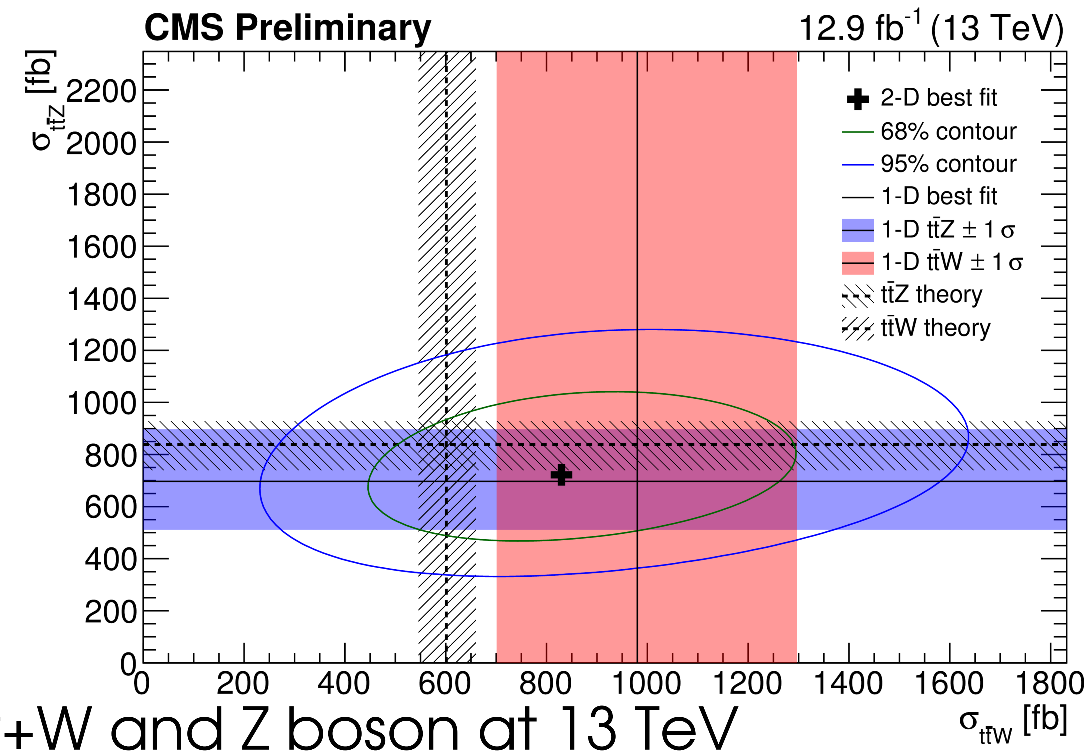
CMS: ttbar+Z/W



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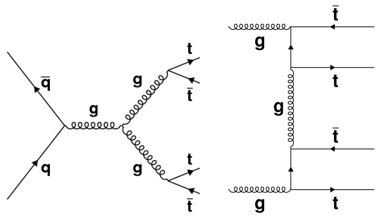
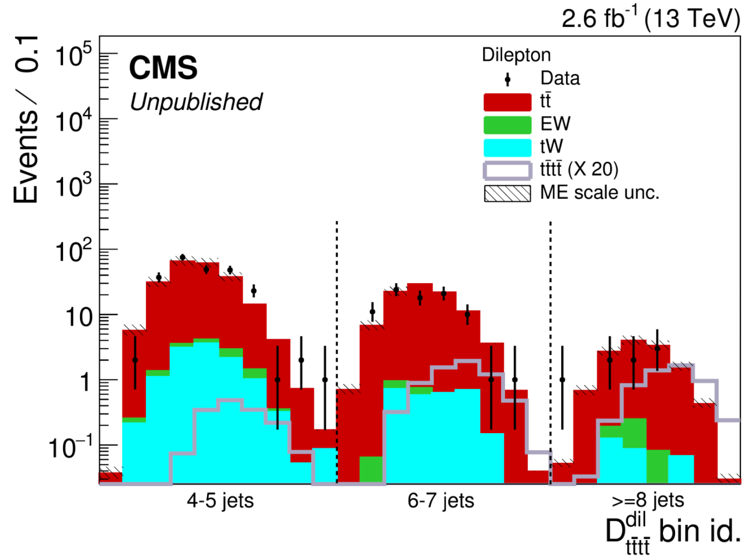
CMS-PAS-TOP-16-017

Rare decays: Four tops



- Rare SM process enhanced by many BSM models such as MSSM,2HDM, ADD and some DM models
- NLO cross section 9.2 fb in SM
  - observation should be feasible in LHC Run 3
    - Or earlier if enhanced by BSM…

- Analysis combines OS dilepton and single-lepton final state
  - With template fit in jet and tag multipllcity bins to BDT including information extra hadronic top quarks
  - 2015 results are combined with SS dilepton search in recent CMS paper
- Preliminary results from 2016 dataset using BSM search strategy
  - No identification of hadronic tops
  - Same-sign dileptons + b-tagged jets
  - CMS SS dlieptons: 42 fb (PAS SUS-16-035)
  - ATLAS SS dileptons: 60 fb (CONF-2017-013)



Channel	Expected limit ($\times\sigma^{SM}_{t\bar{t}t\bar{t}}$)	Observed limit ($\times\sigma^{SM}_{t\bar{t}t\bar{t}}$)	Expected limit (fb)	Observed limit (fb)
Single lepton	$16.4^{+9.8}_{-5.7}$	17.2	151^{+90}_{-52}	158
Dilepton (opposite sign)	$24.7^{+16.7}_{-9.2}$	14.5	227^{+154}_{-84}	134
Combined (this analysis)	$12.8^{+8.3}_{-4.5}$	10.2	118^{+76}_{-41}	94
Dilepton (same sign [12])	$11.0^{+6.2}_{-3.8}$	12.9	101^{+57}_{-35}	119
Combined	$7.7^{+4.1}_{-2.6}$	7.4	71^{+38}_{-24}	69

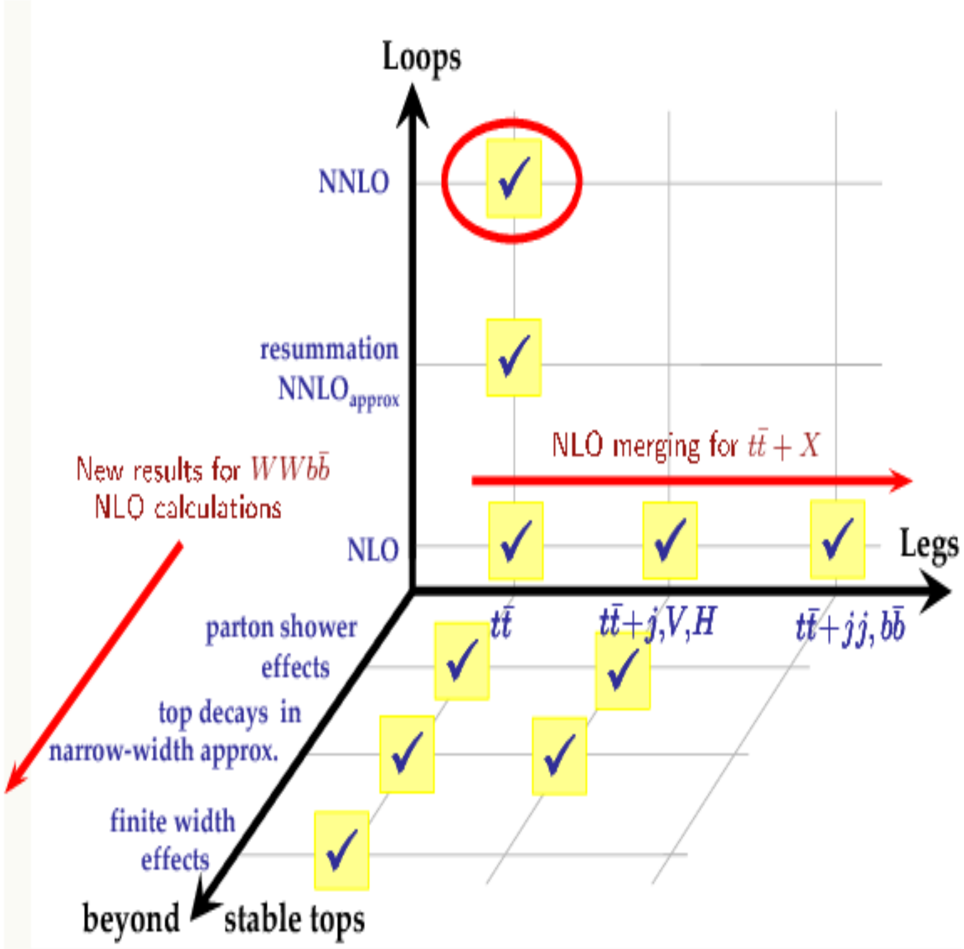
CMS TOP-16-016 arxiv 1702.06164

Conclusion/Outlook

- SM measurements provide precision SM information and model independent BSM constraints
  - In general the **agreement with the SM is good** …when appropriate order SM calculations are available
- Majority results are unfolded or at least provided in theorist-friendly format
- **No deviations yet**
  - **But we'll keep looking!**
- Many of the more sensitive analyses such as anomalous couplings, FCNC and double-differential cross sections are still statistics limited
  - so will gain from the final LHC Run2 datasets
  - **Expect many new carefully measured results in the future!**

Backup

Top quarks as a background



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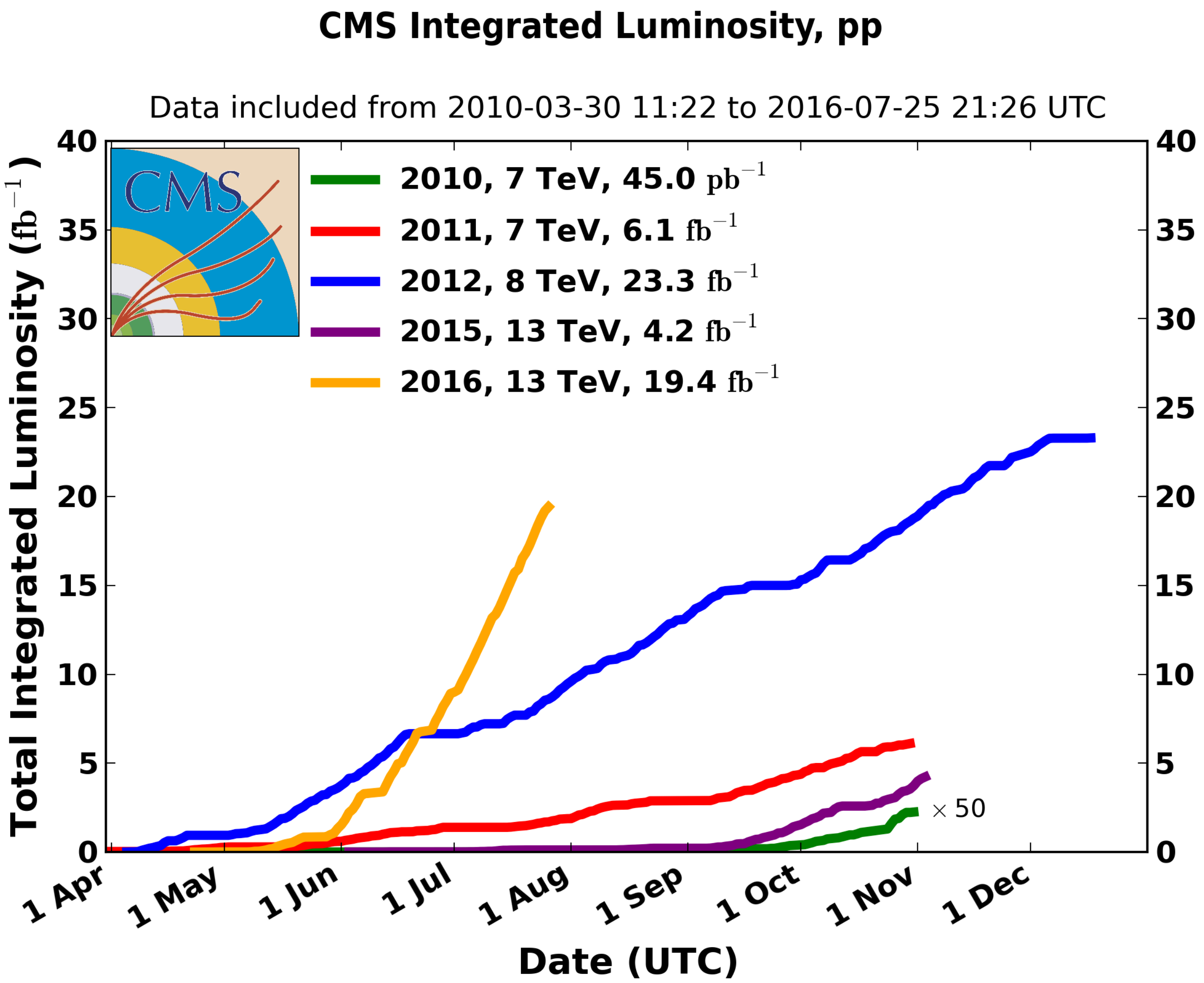
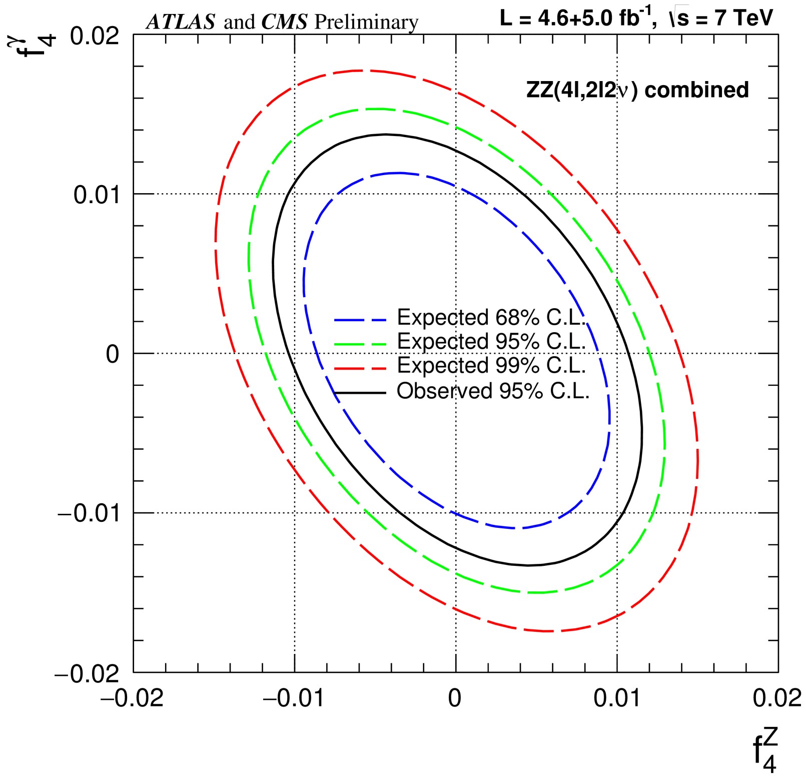
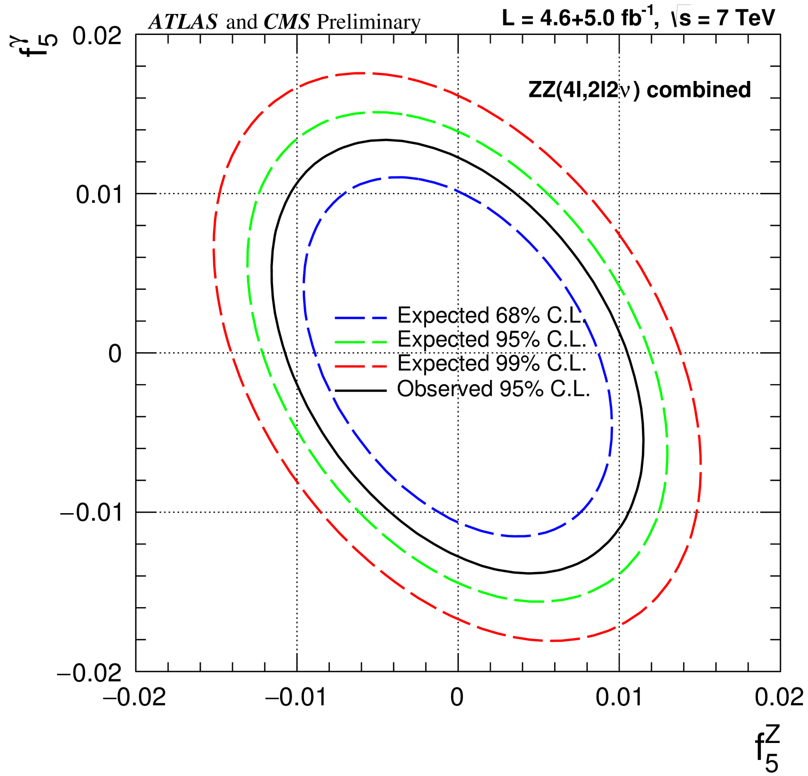

CMS Integrated Luminosity, pp
Data included from 2010-03-30 11:22 to 2016-07-25 21:26 UTC
CMS
2010, 7 TeV, 45.0 pb^{-1}
2011, 7 TeV, 6.1 fb^{-1}
2012, 8 TeV, 23.3 fb^{-1}
2015, 13 TeV, 4.2 fb^{-1}
2016, 13 TeV, 19.4 fb^{-1}
× 50
Total Integrated Luminosity (fb^{-1})
0
5
10
15
20
25
30
35
40
1 Apr
1 May
1 Jun
1 Jul
1 Aug
1 Sep
1 Oct
1 Nov
1 Dec
Date (UTC)

aTGC two-parameter deltaNLL





- Combined ATLAS+CMS limits on aTGCs for $\Lambda=\infty$
  - All other coupling parameters are set to SM values

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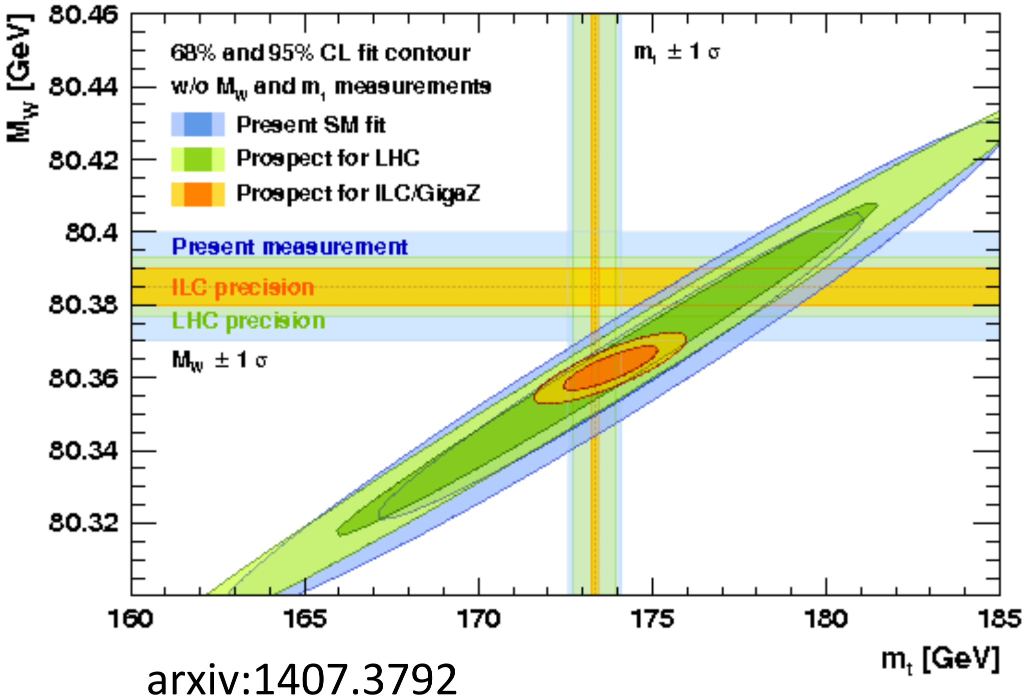
CMS-PAS-SMP-15-001

Top mass vs BSM



arxiv:1407.3792

Top quark and new physics

- Standard model predicts top kinematics
- Top physics = SM cross check
- Deviations are signs of new physics
- This new physics is at large mass scales, making it a good candidate to fix the holes in the SM

$$\left(\begin{array}{l}\text{Top pair production rate}\\ \text{Top mass}\\ \text{Single top production rate}\\ B(t\longrightarrow Wb)\\ |V_{tb}|\\ \text{W helicity}\\ \text{Top polarization}\\ \text{Anomalous couplings}\\ \text{Spin correlations}\\ \text{Rare decays}\\ \text{Top width}\\ \quad\ldots\end{array}\right)$$

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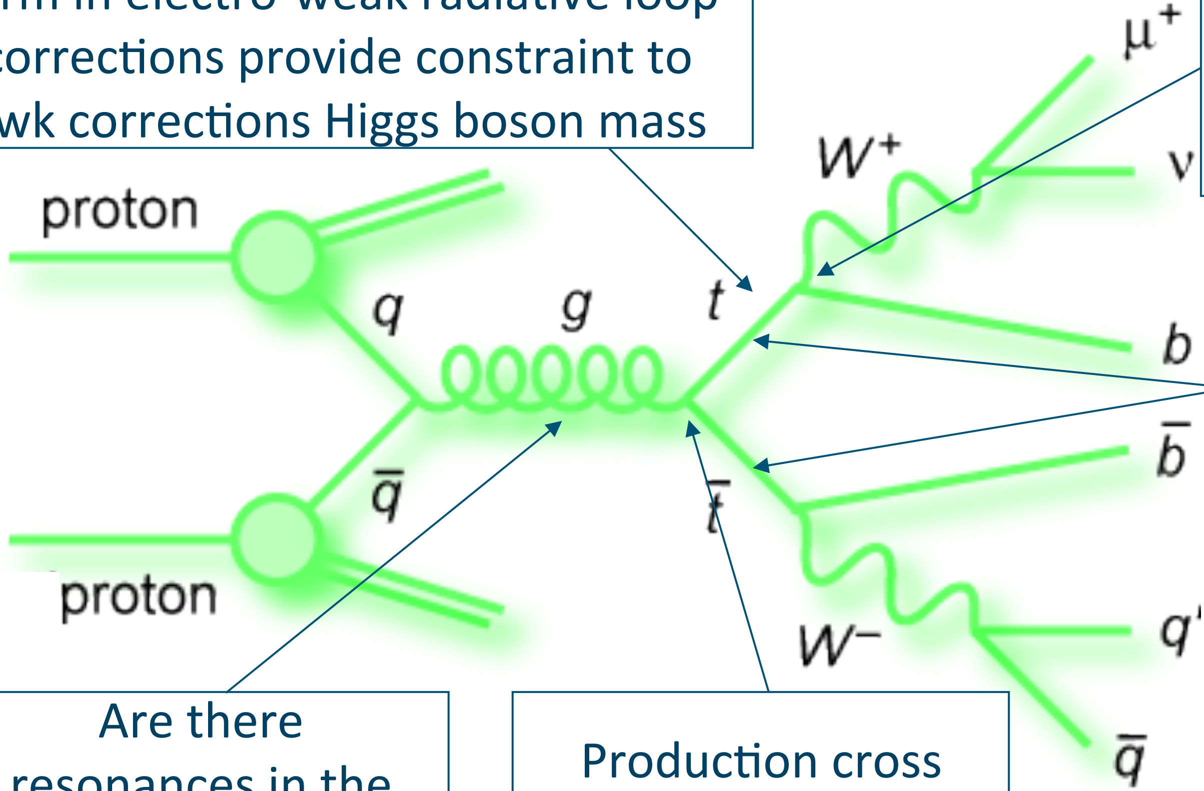
Why top physics is interesting?

Measure top quark mass - dominant term in electro-weak radiative loop corrections provide constraint to ewk corrections Higgs boson mass

BR($t \rightarrow Wb$)≈1 in SM. Measurement of V_{tb} is test standard model



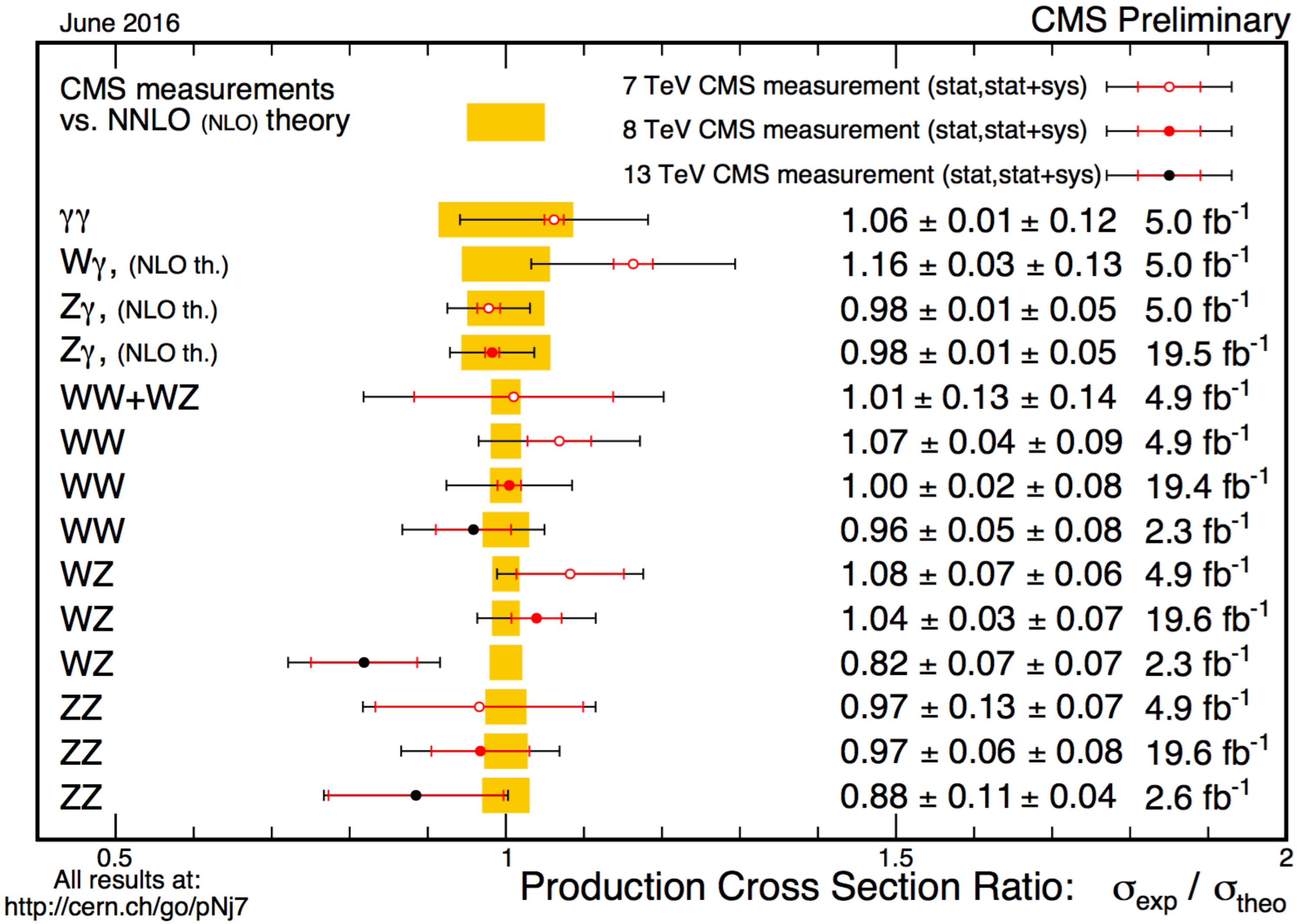
Spin of W boson is direct probe of top spin and the only way to measure spin correlations in unbound quarks

Are there resonances in the top quark pair spectrum?

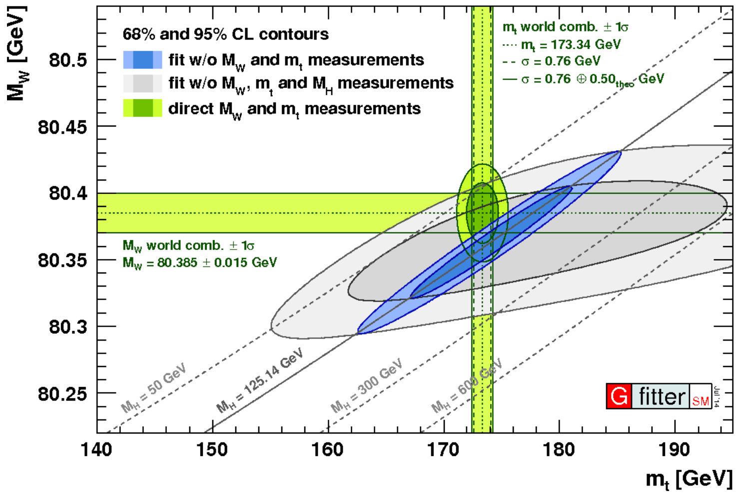
Production cross section can be accurately predicted by QCD calculations

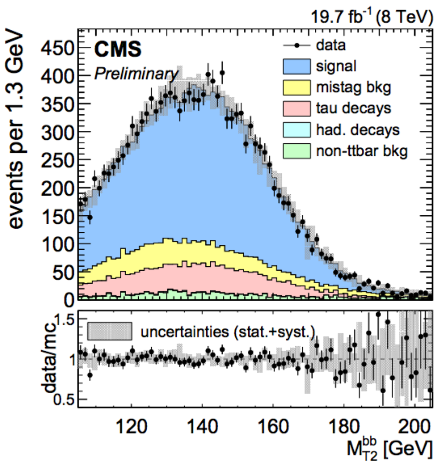
Are there other objects that decay to b quarks and W bosons?

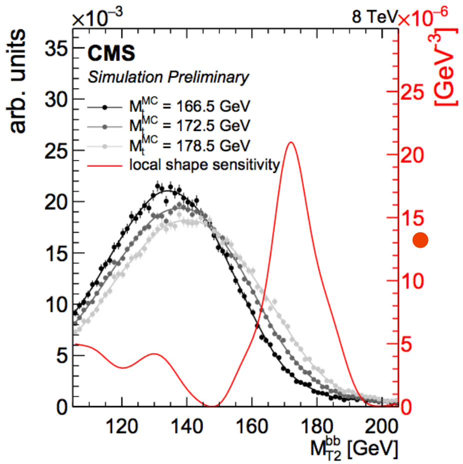
Diboson production



Top mass vs BSM







- In SM fits: dependence top mass w.r.t. Higgs and W boson important
- CMS: latest mass measurement in dileptons using MT2/MAOS (search-like variables)
- Single measurement with a <1 GeV uncertainty:
  - m_t=172.22 ± 0.18 (stat) +0.89 -0.93 (syst) GeV
  - Fractional:± 0.001% ±0.005%
- Top quark mass measurements are getting more and more accurate
  - Theory: NLO MSbar vs pole mass uncertainty is of order 1/2 GeV

CMS-PAS-TOP-15-008