Top properties and ttV results @ LHC

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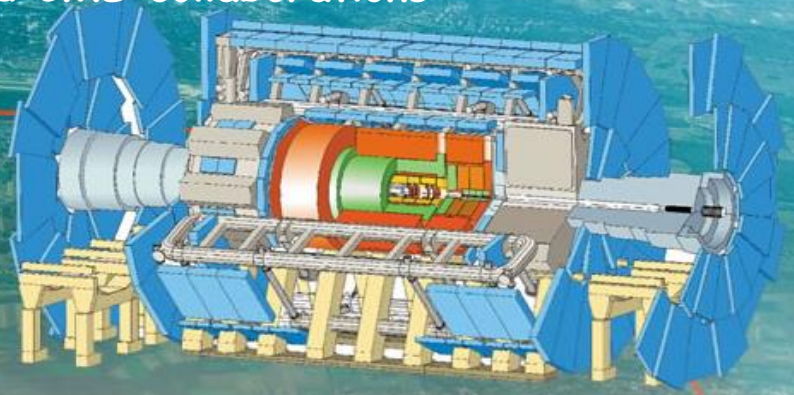
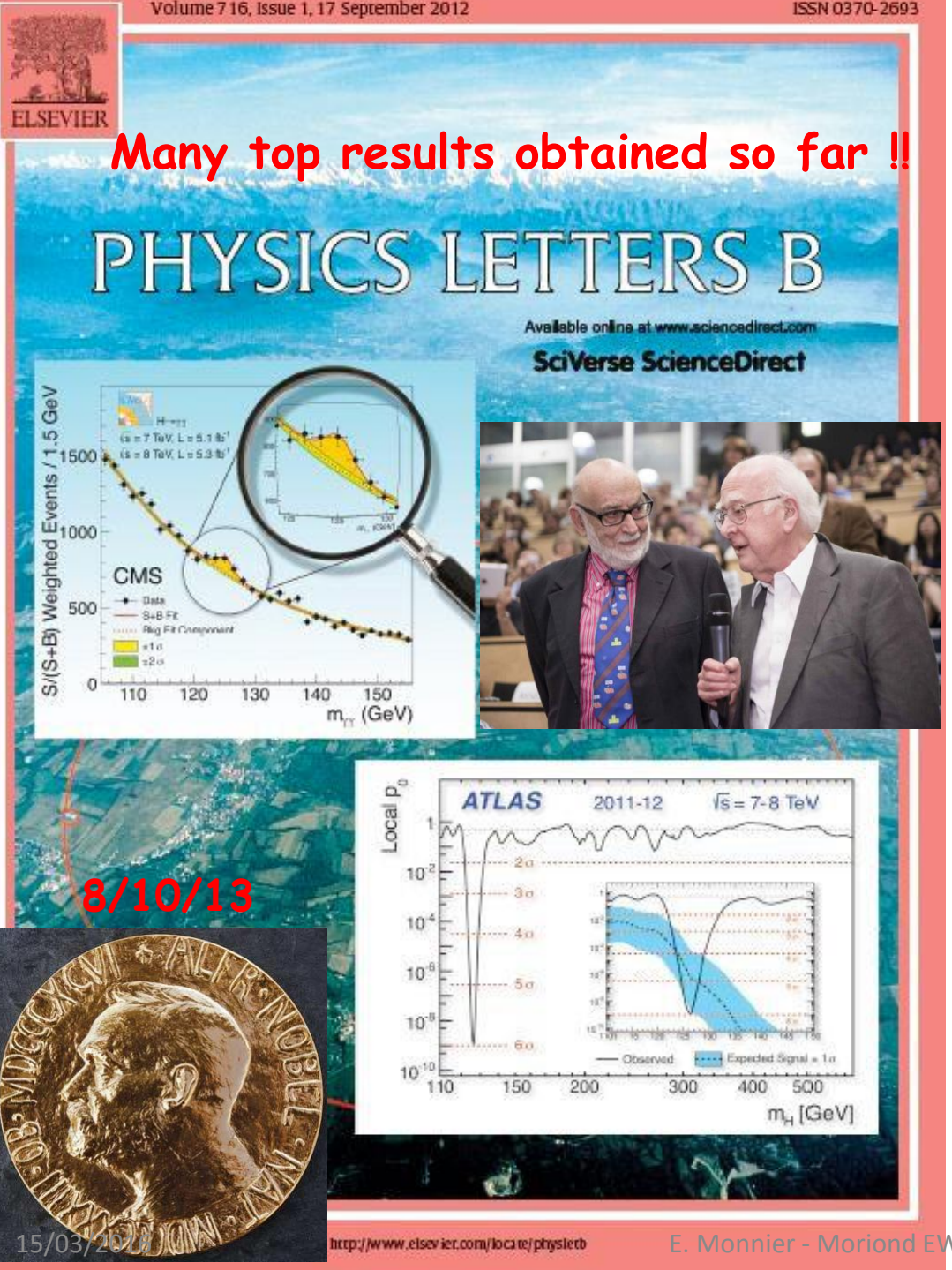
On behalf of the ATLAS and CMS collaborations



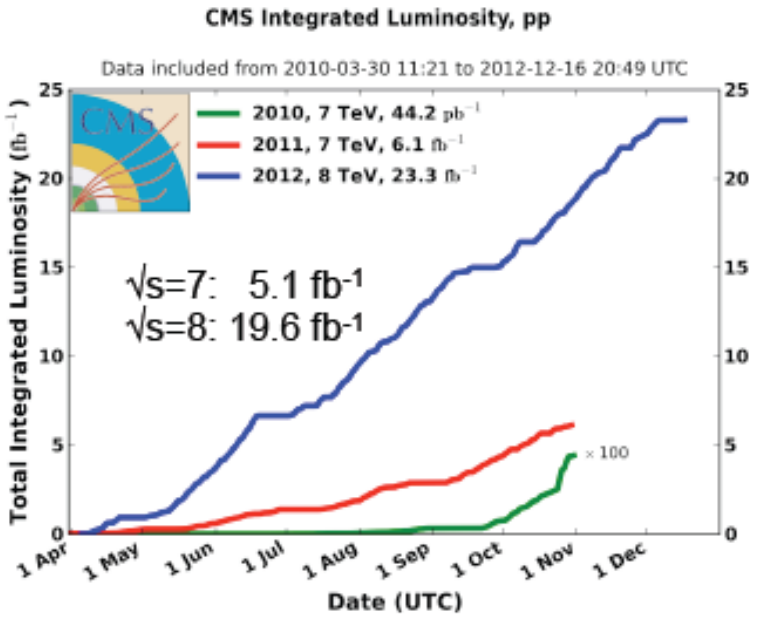
15 March 2016 – Moriond EW@La Thuile

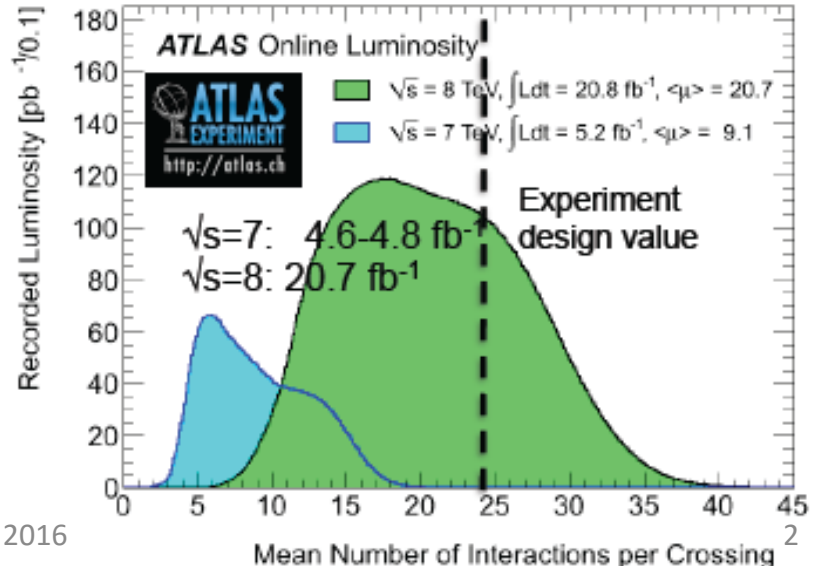


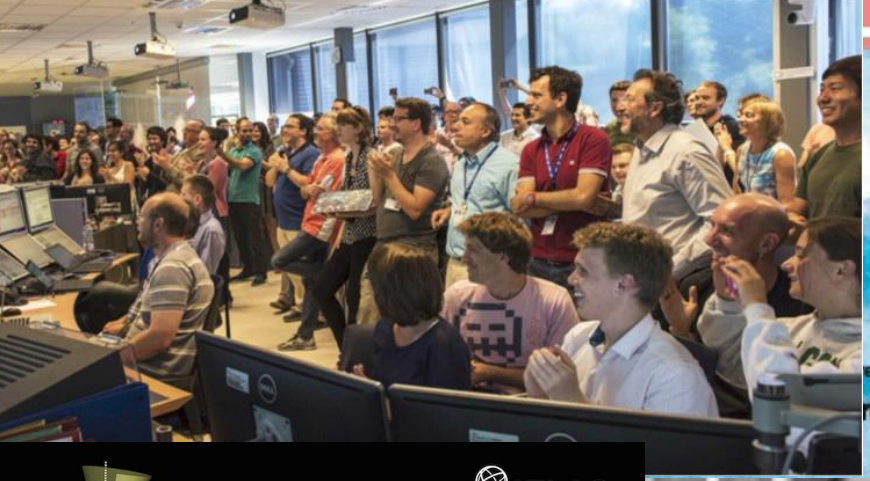
Now "LHC-Run1" data analyzed:

2011~5fb^{-1}@7Tev Outstanding

2012~20fb^{-1}@8Tev LHC !

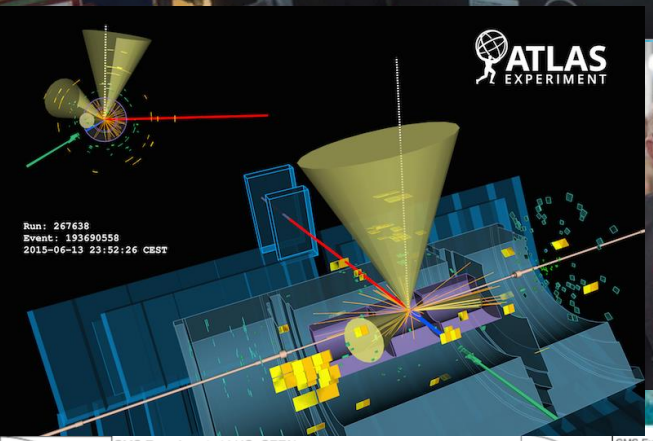


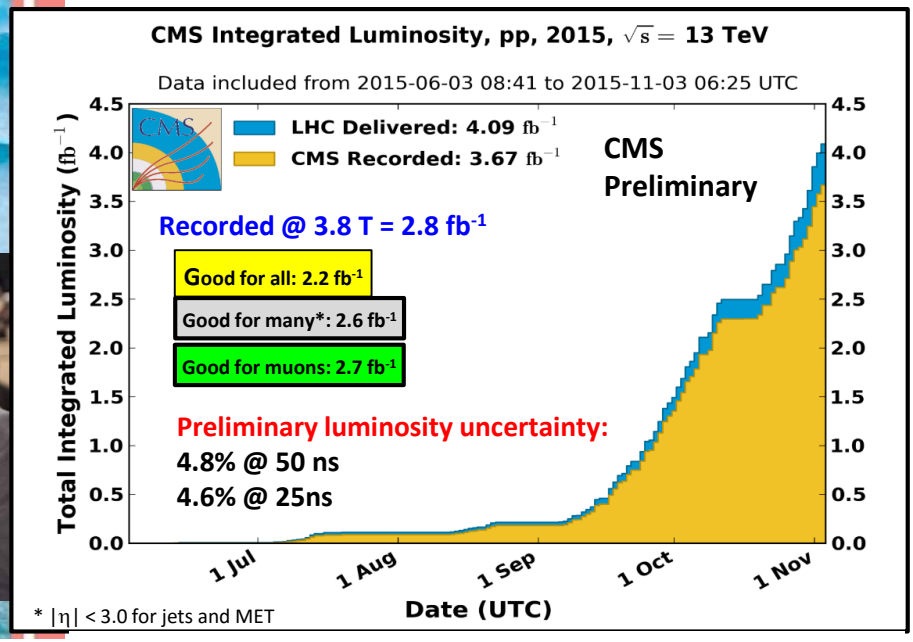


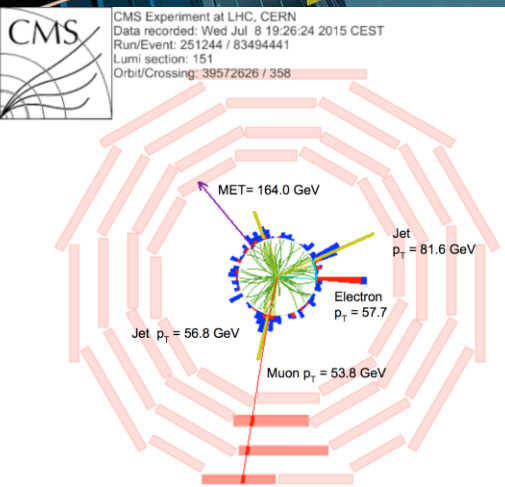


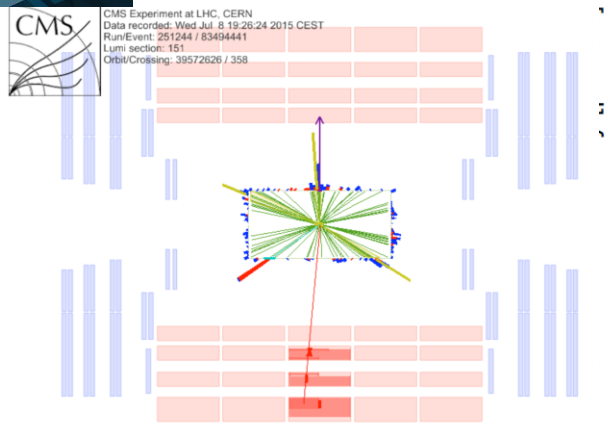
Now "LHC-Run2" data analyzed:
2015~4fb^{-1}@13Tev

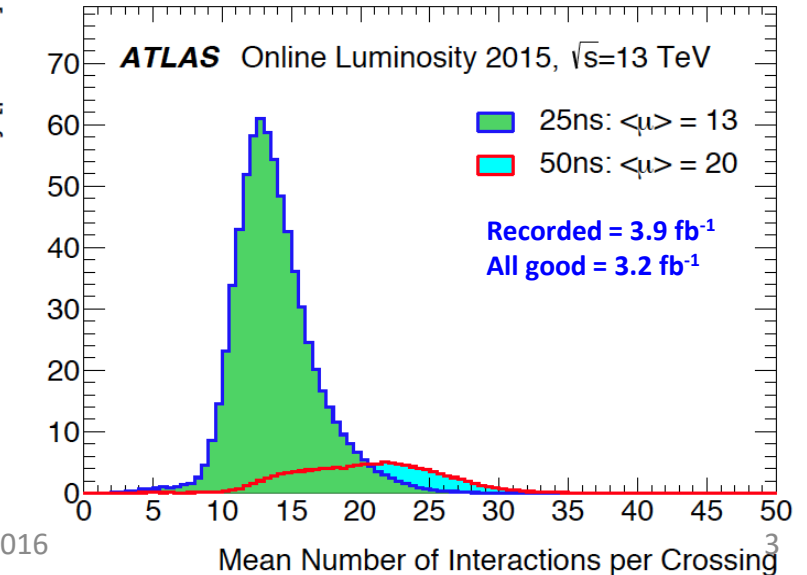
Outstanding LHC !

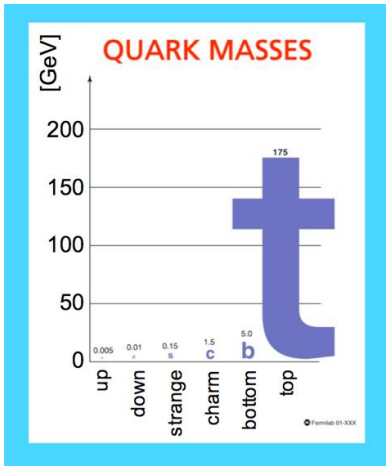




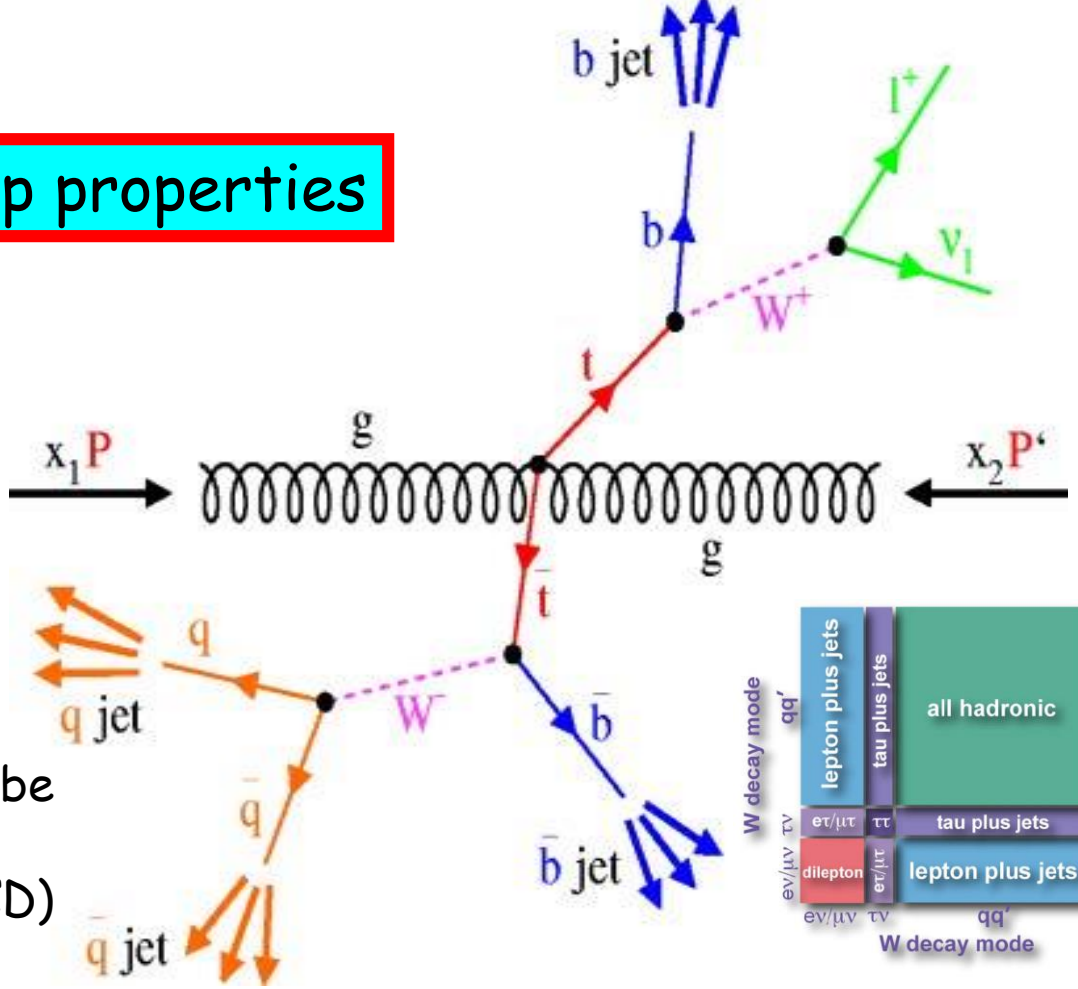






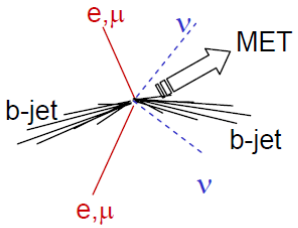


Top properties

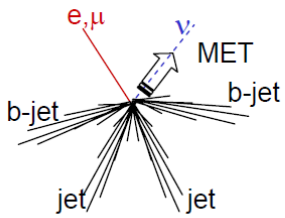


- 6M tt evt @ 8TeV & 25 fb^{-1}
- Heaviest elementary particle
- Coupling to Higgs ~1
- Decay before hadronization (probe bare quark) and before spin decorrelation (predicted by pQCD)
- $\tau_t(10^{-25}) < \tau_{QCD}(10^{-24}) < \tau_{Spin}(10^{-21})$
- Access to true properties through decay products
- Properties sensitive to new physics.
- Look at Spin, Charge, FCNC…

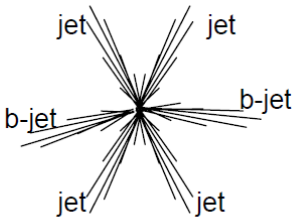
(not inc. τ)	BR	background
dilepton	~5%	low
lepton + jets	~30%	moderate
all hadronic	~44%	high



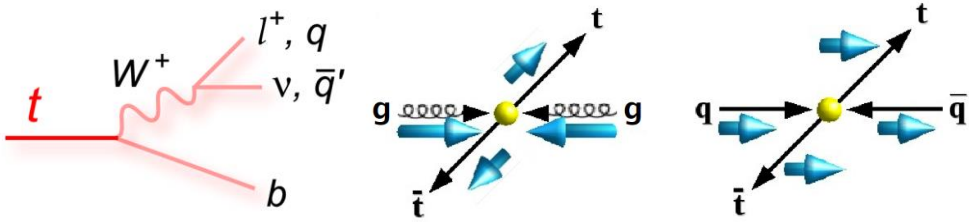
dileptons



lepton + jets



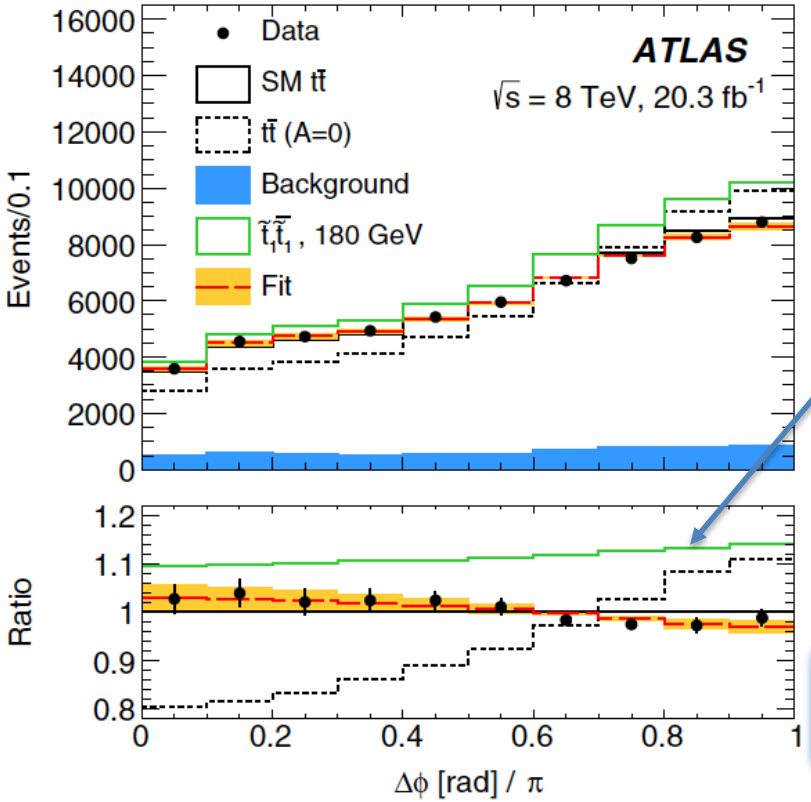
all hadronic

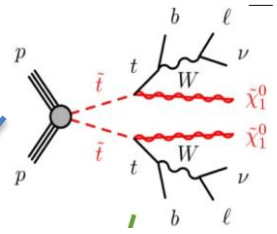


ATLAS, arXiv:1402.03803
CMS, arXiv:1601.01107v1

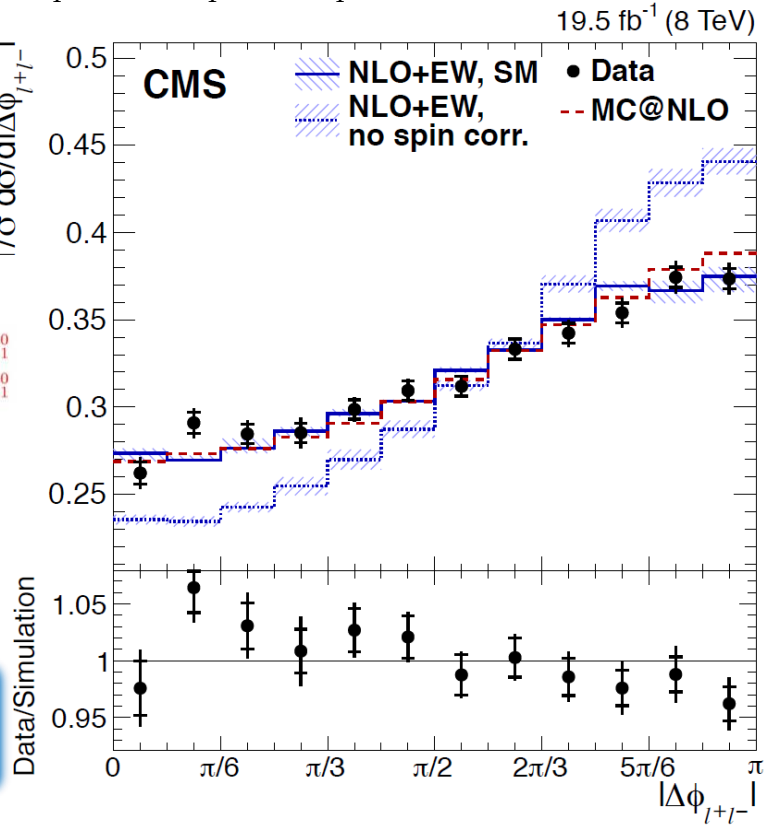
Spin Correlation @ 8TeV

- Gluon helicities → top spin correlation → decay product. Max in low M_{tt} regime
- Lepton final state → ~100% transmission (for quark, depends on flavor)
- Di-lepton angular distribution: best probe in lab frame $\Delta\phi$ (indirect) or in top rest frame vs a direction basis (helicity,…), $\cos\theta_1$, $\cos\theta_1 \cos\theta_1$ …(direct).



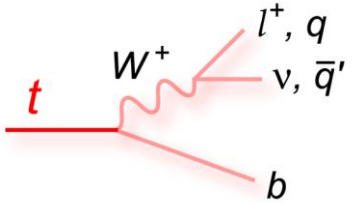


$$f_{SM} = \frac{N_{SM}^{t\bar{t}}}{N_{SM}^{t\bar{t}} + N_{Uncor}^{t\bar{t}}}$$



$f_{SM} = 1.20 \pm 0.05_{(Stat)} \pm 0.13_{(Syst)}$

$f_{SM} = 1.14 \pm 0.06_{(Stat)} \pm 0.13_{(Syst)} {}^{+0.08}_{-0.11}(theo)$

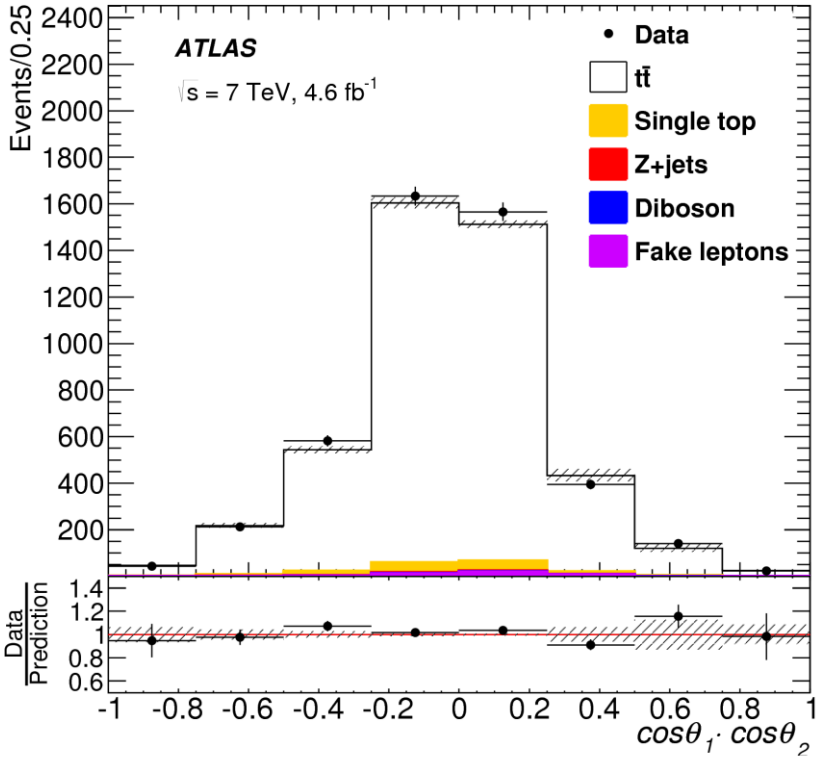


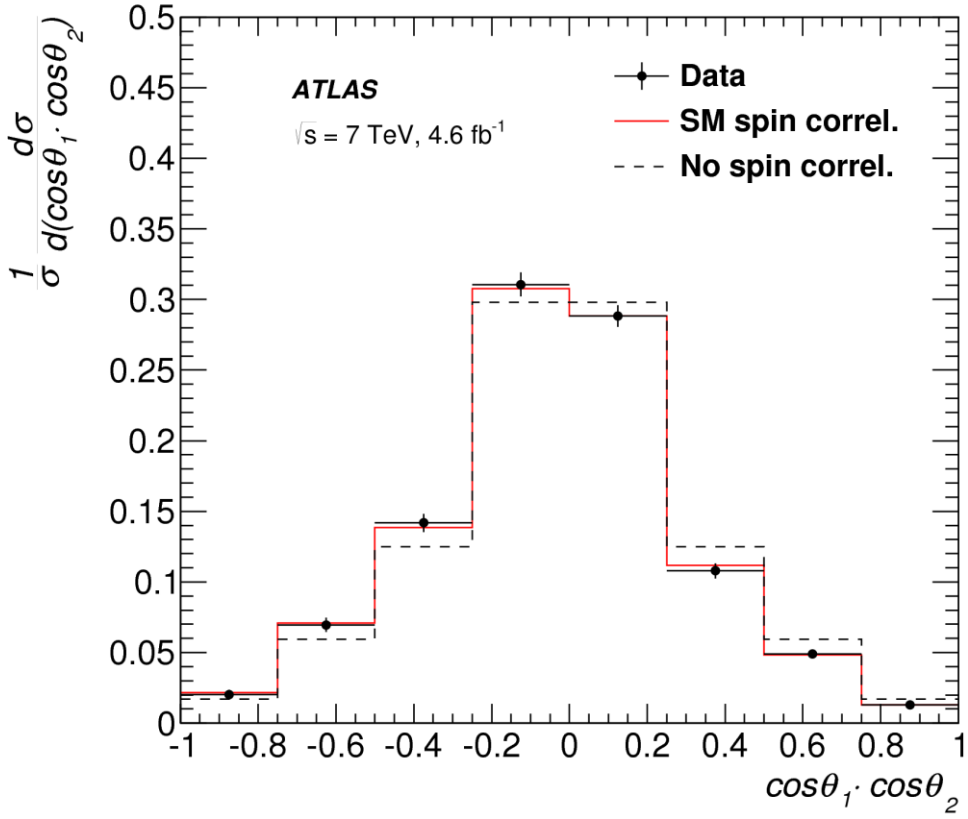
Spin Correlation: direct measurement

ATLAS, arXiv:1402.03803

Theory: Bernreuther et al.
arXiv:1508.05271
arXiv:1305.2066v2
arXiv:1003.3926v1

- Inclusive distrib. unfolded @ parton level
- **2OS ℓ, $\geq$ 2high $p_T$jet, $\geq 1b$, large E_T^{miss}**

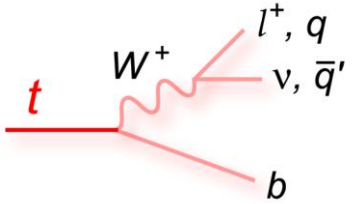




Depend on production & Basis

$C_{helicity} = 0.315 \pm 0.061_{(Stat)} \pm 0.049_{(Syst)} = -9\langle c_1 c_2 \rangle = -4A_h$; $C_{SM\ NLOW} = 0.310 \pm 0.006$

→ converted to $f_{SM} = 1.02 \pm 0.20_{(Stat)} \pm 0.16_{(Syst)}$

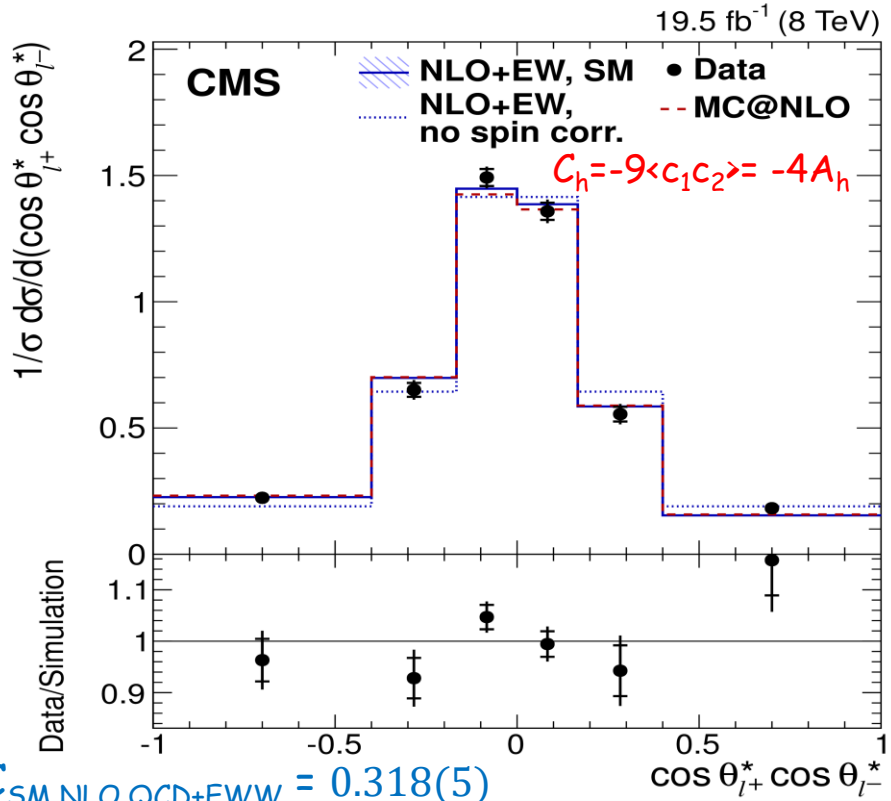


Spin Correlation: direct measurement

CMS, arXiv:1601.01107

Theory: Bernreuther et al.
arXiv:1508.05271
arXiv:1305.2066v2
arXiv:1003.3926v1

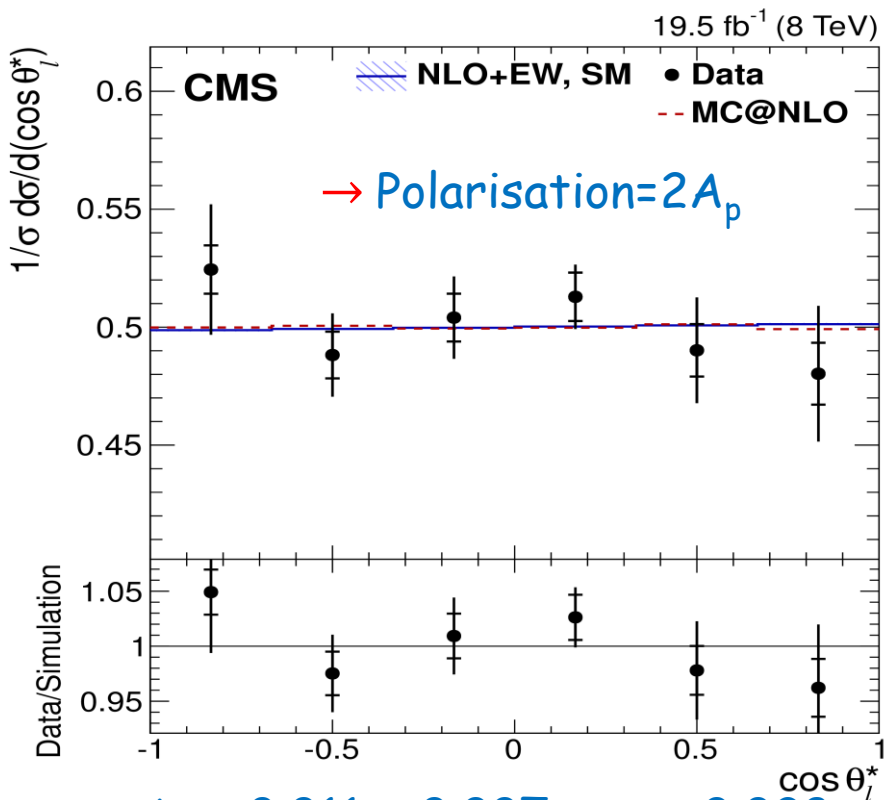
- Inclusive distrib. unfolded @ parton level
- **2OS ℓ, $\geq$ 2high $p_T$jet, $\geq 1b$, large E_T^{miss}**
- Unfolding all angular distributions and get asymmetries: $A_{\Delta\phi}$, A_h , $A_{\cos\varphi}$, A_P ...



$C_{SM\ NLO\ QCD+EWW}$ = 0.318(5)

A_h= -0.069 $\pm$ 0.013$_{(Stat)}$ $\pm$ 0.016$_{(Syst)}$

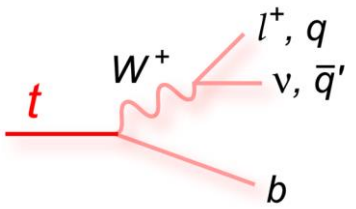
$\rightarrow f_{SM}$= 0.87 $\pm$ 0.17$_{(Stat)}$ $\pm$ 0.21$_{(Syst)}$ $\pm$0.04$_{(theo)}$



A_P= -0.011 $\pm$ 0.007$_{(Stat)}$ $\pm$ 0.028$_{(Syst)}$

P^{CPC} = (-2.2 $\pm$ 5.8)%

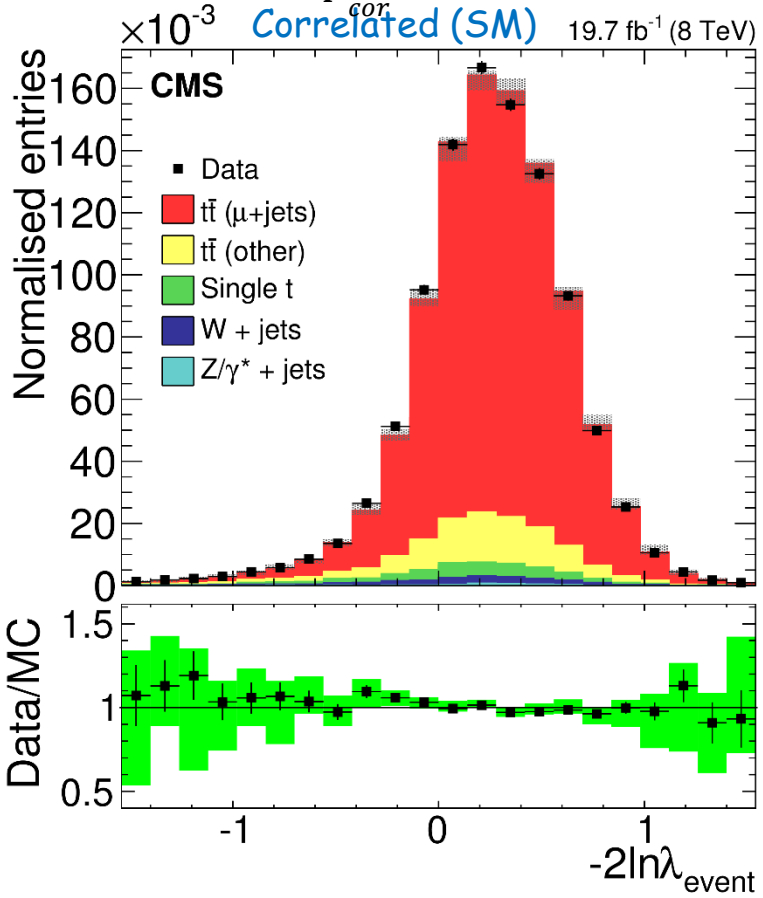
P^{CPV} = (-0.0 $\pm$ 1.6)%

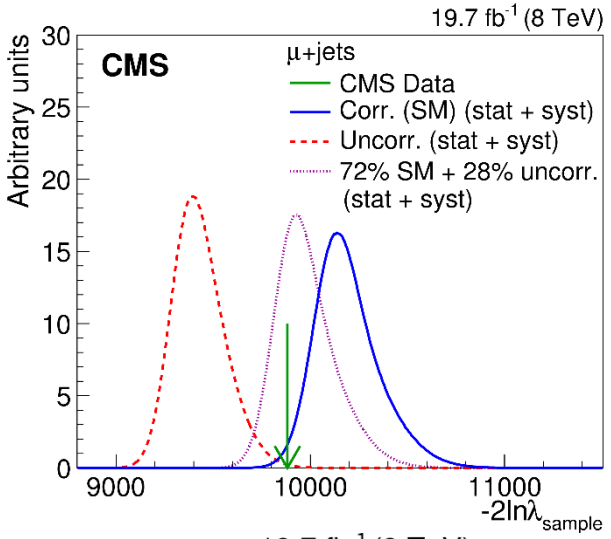


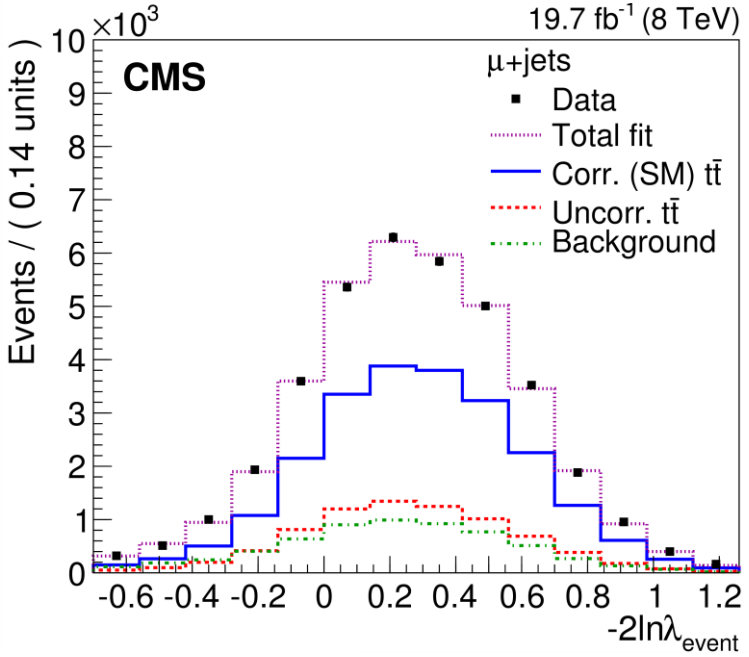
Spin correlation 1l+j 8TeV : ME method

CMS, arXiv:1511.06170

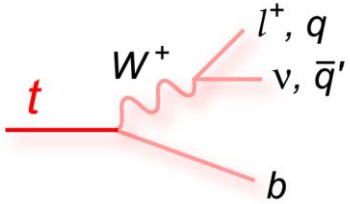
- μ +jets, use matrix element method to get more from distribution, full reco.
- $\lambda_{\text{event}} = \frac{P_{uncor}}{P_{cor}}$, fit -2ln λ_{event} distribution







$f_{SM} = 0.72 \pm 0.08(\text{Stat.}) \,^{+0.15}_{-0.13}(\text{Syst.})$



Spin correlation: Summary most precise f_{SM}

- $\Delta\phi$ 2ℓ : 1.20 ± 0.14 (8TeV) ; 1.19 ± 0.20 (7TeV)
- ME 2ℓ : 0.87 ± 0.18 (7TeV)
- $\Delta\phi$ ℓ+j: 1.12 ± 0.25 (7TeV)

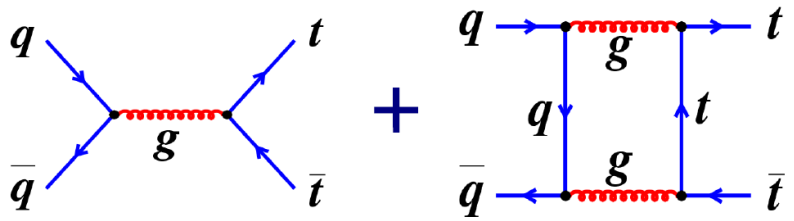
- $\Delta\phi$ 2ℓ : 1.16 ± 0.15 (8TeV)
- D 2ℓ : 0.90 ± 0.16 (8TeV)
- ME ℓ+j: $0.72\ ^{+0.15}_{-0.13}$ (8TeV)

- Consistent with SM, systematic limited already for some of the measurement.

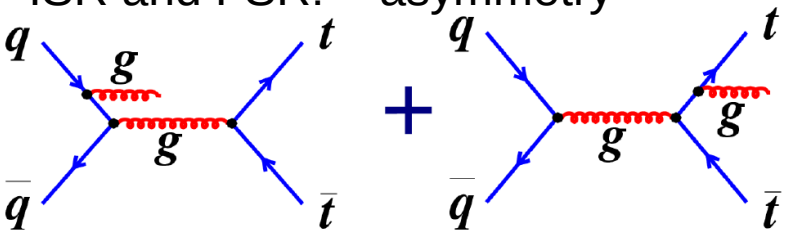
Charge Asymmetry

- top quarks pair production at NLO give non zero charge asymmetry from interferences between diagrams, gg interaction symmetric
- Valence quarks interact with sea anti-quarks & Top quark connected to the incoming parton
- t quark more forward than anti t

tree-level and box diagram: + asymmetry

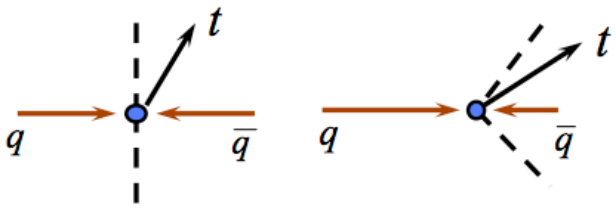


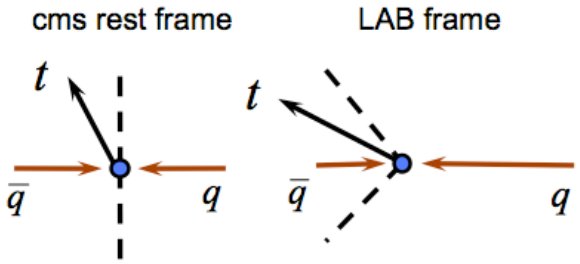
ISR and FSR: − asymmetry

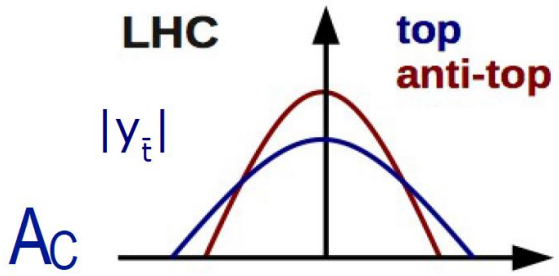


$$A_C = \frac{N(\Delta|y|>0) - N(\Delta|y|<0)}{N(\Delta|y|>0) + N(\Delta|y|<0)}$$

$$\Delta|y| = |y_t| - |y_{\bar{t}}|$$



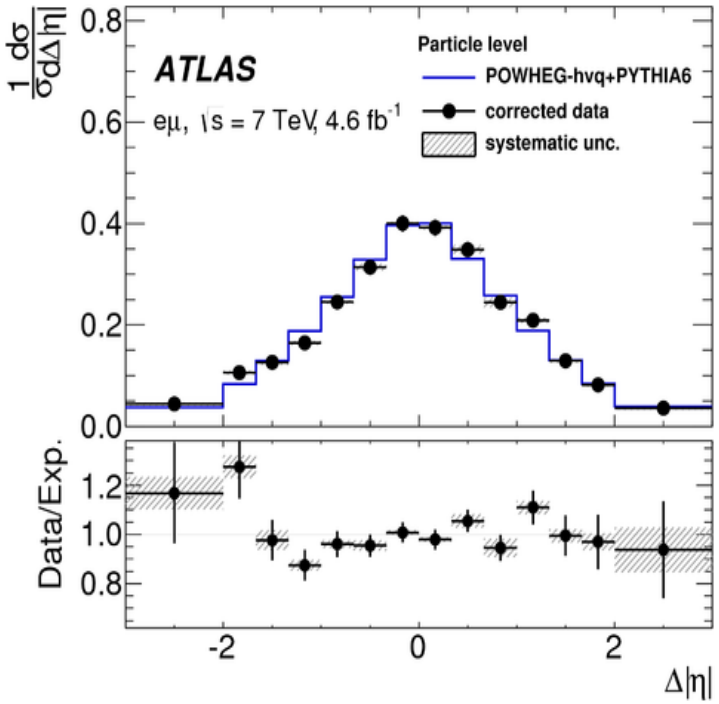


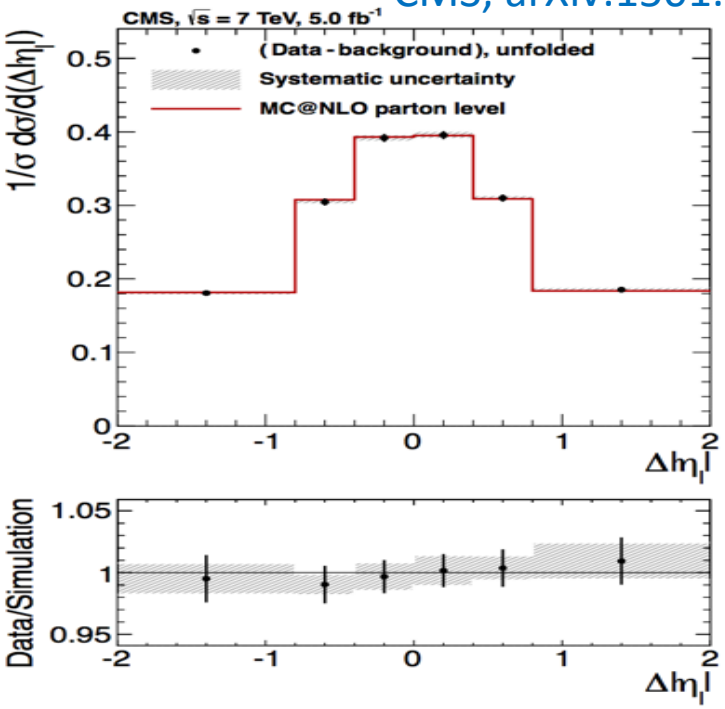


Charge Asymmetry: di-lepton

ATLAS, arXiv:1402.03803
CMS, arXiv:1501.07383

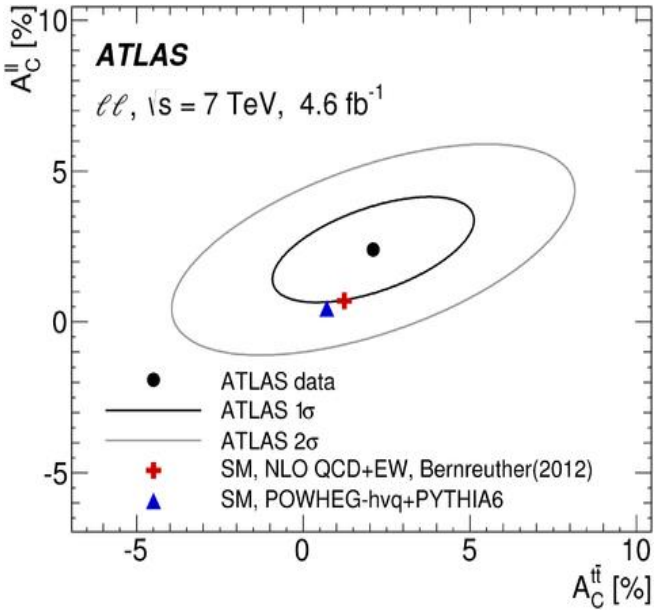
- Inclusive distrib. unfolded @ parton level
- **2OS ℓ, $\geq$ 2high $p_T$jets $+\geq b$ /large E_T^{miss}**





$A_c^{ll} = 0.024 \pm 0.015\ (stat.) \pm 0.009\ (syst.)$
$A_c^{ll} = 0.009 \pm 0.010\ (stat.) \pm 0.006\ (syst.)$
$A_{\mathrm{SM\ NLO\ QCD+EW}}^{\mathrm{ll}} = 0.0070 \pm 0.0005\ (scale)$

$A_c^{tt} = 0.021 \pm 0.025\ (stat.) \pm 0.017\ (syst.)$
$A_c^{tt} = -0.010 \pm 0.017\ (stat.) \pm 0.008\ (syst.)$
$A_{\mathrm{SM\ NLO\ QCD+EW}}^{\mathrm{tt}} = 0.0123 \pm 0.0003\ (scale)$



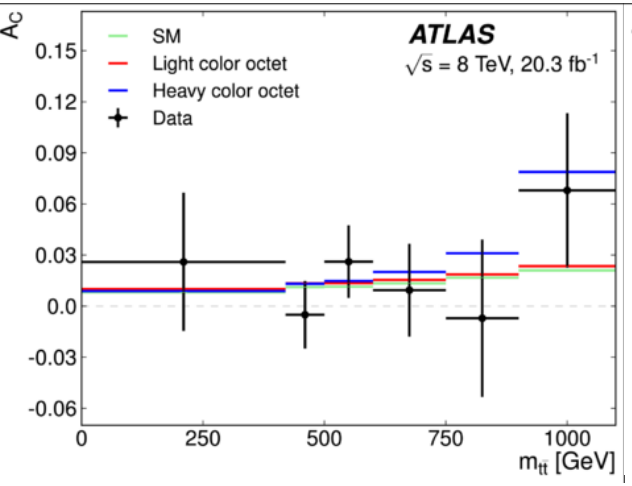
ATLAS, arXiv:1509.02358

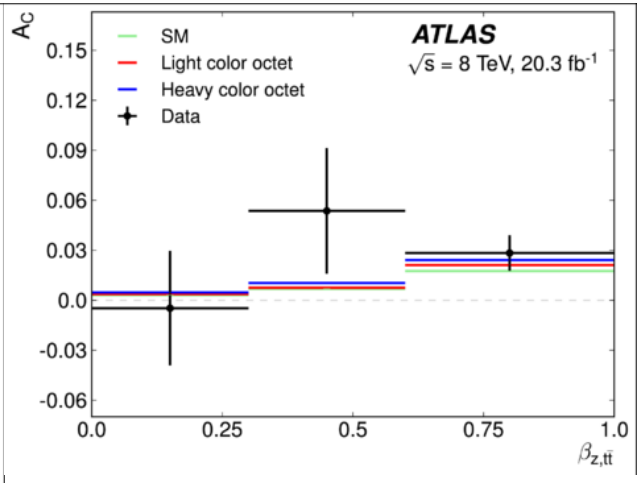
Charge Asymmetry: ℓ+jets @ 8TeV

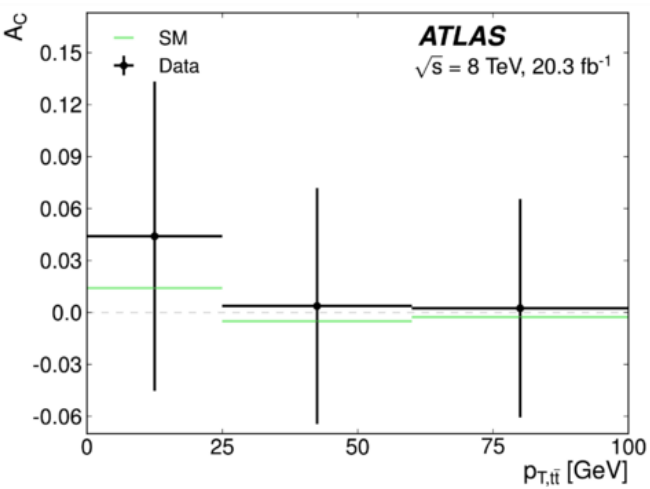
- Inclusive and differential measurements unfolded @ parton level
- **1high p_T tight ℓ, $\geq$ 4high p_T jets, $\geq 0b$ + large E_T^{miss} + m_T^W**
- Full event reco with kinematic fit

$A_c = 0.009 \pm 0.005\ (stat. + syst.)$

	Source of systematic uncertainty	δA_C
(a)	Jet energy scale and resolution	0.0016
	Multijet background normalisation	0.0005
(b)	Initial-/final-state radiation	0.0009
	Monte Carlo sample size	0.0010
	PDF	0.0007
	Statistical uncertainty	0.0044
	Total uncertainty	0.0049



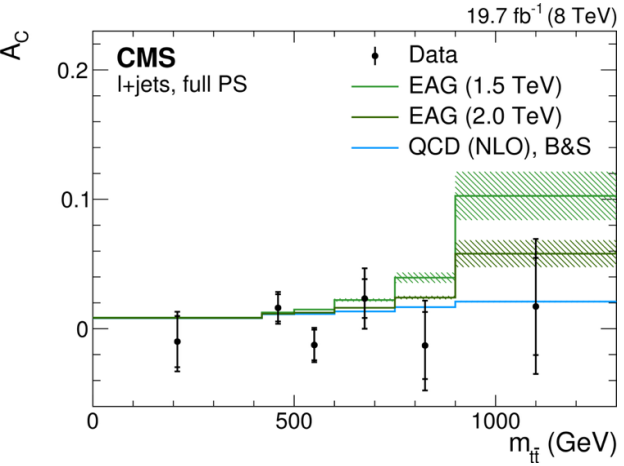


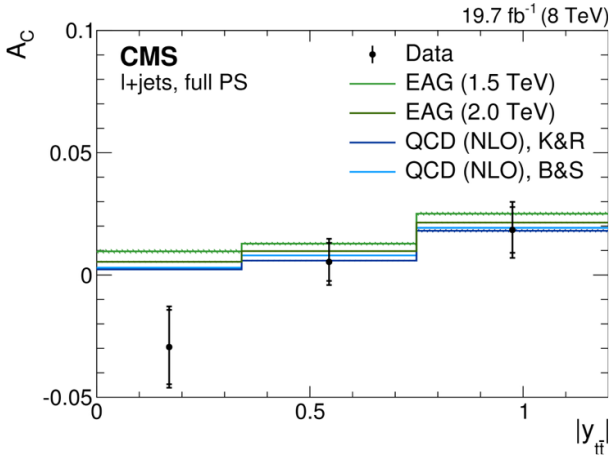


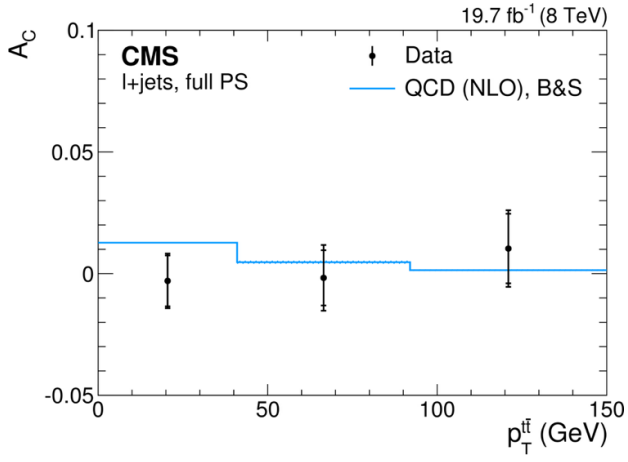
Charge Asymmetry: ℓ+jets @ 8TeV

CMS, arXiv:1507.03119
CMS, arXiv:1508.03862

- Inclusive and differential measurements unfolded @ parton level

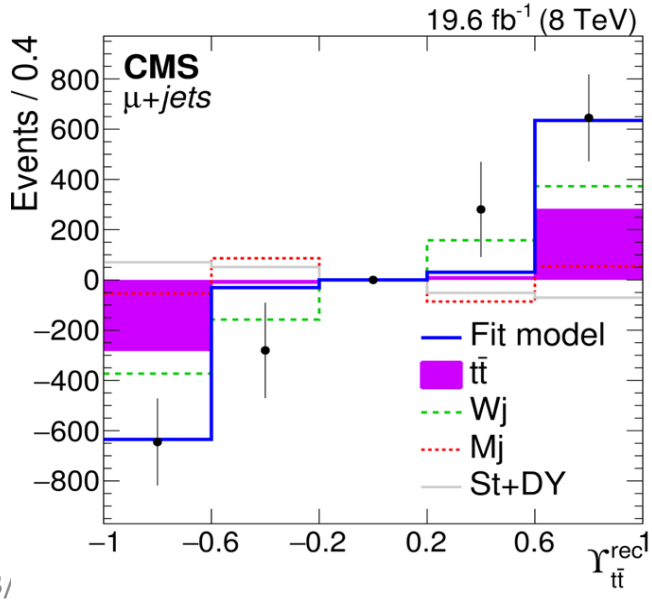




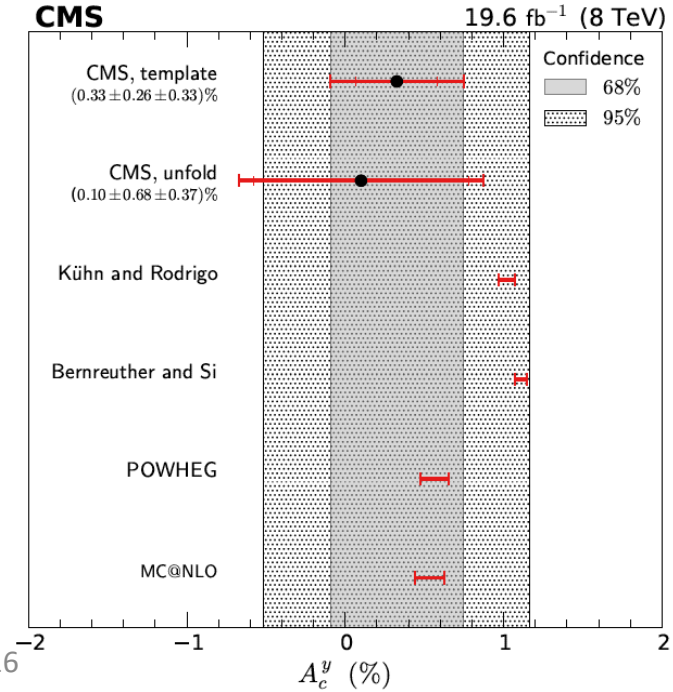


- Alternative template method using shape of $\Delta|\eta|$ distribution

$$A_c = 0.33 \pm 0.26\,(stat.) \pm 0.33\,(syst.)$$



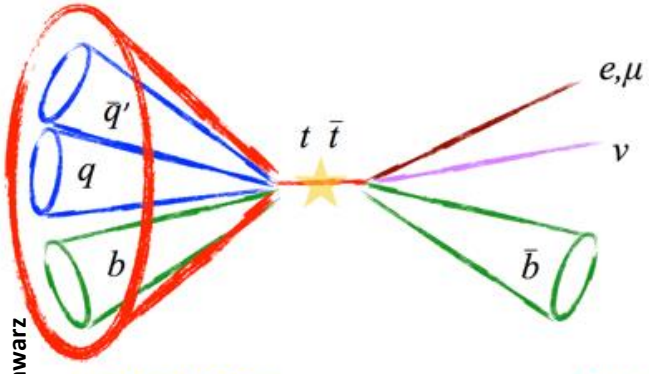
$$\Upsilon_{t\bar{t}} = \tanh \Delta|y|_{t\bar{t}}$$



ATLAS, arXiv:1509.06092

Charge Asymmetry: Boosted top @ 8TeV

- Inclusive and differential measurements @ parton level
- 1high p_T tight ℓ, m_{tt} > 0.75 TeV, -2 < $\Delta|y|$ < 2, Large-R jet R=1.0
- Hadronic top reconstructed with large R jet

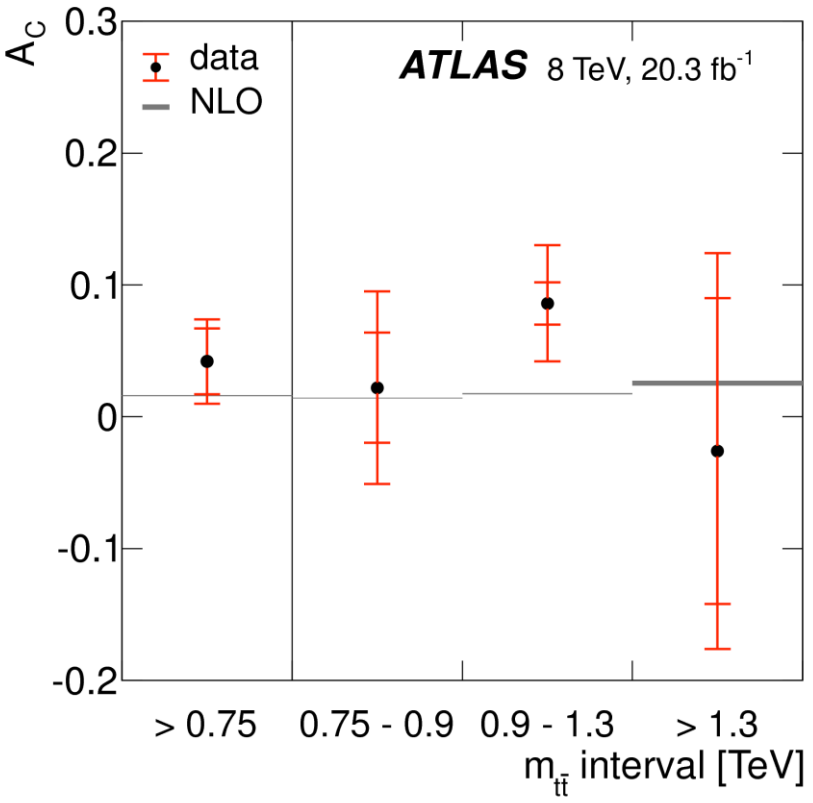


©T. Schwarz

Leptonic Top
Lepton, Small-R Jet
p_T > 25 GeV
*mini-isolation
MET > 20 GeV
MET+MTW > 60 Ge

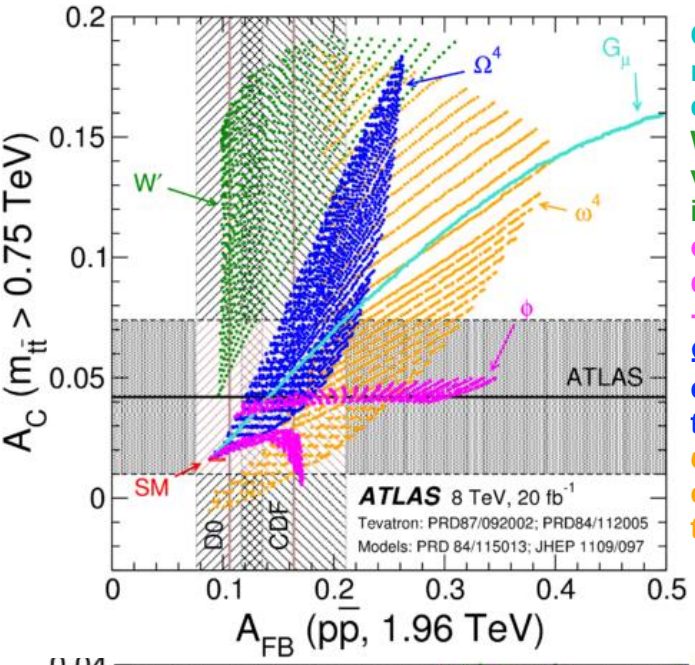
Hadronic Top
- 1 Anti-k_T R=1.0 Large-R Jet
  Trimmed: r_{sub}=0.3, f_{cut}=5%
- p_T > 300 GeV
- m > 100 GeV
- $\sqrt{d_{12}}$ > 40 GeV

Other Criteria
$\Delta\phi(\ell$,Large-R Jet) > 2.3
$\Delta R(\ell$,Small-R Jet) < 1.5
ΔR(Small-R,Large-R) > 1.5
≥ 1 b-tagged Jet
m_{tt} > 750 GeV**



$$A_c = 0.042 \pm 0.032\ (stat. + syst.)$$
$$A_c^{SM} = 0.0160 \pm 0.0004$$

Charge Asymmetry: Summary



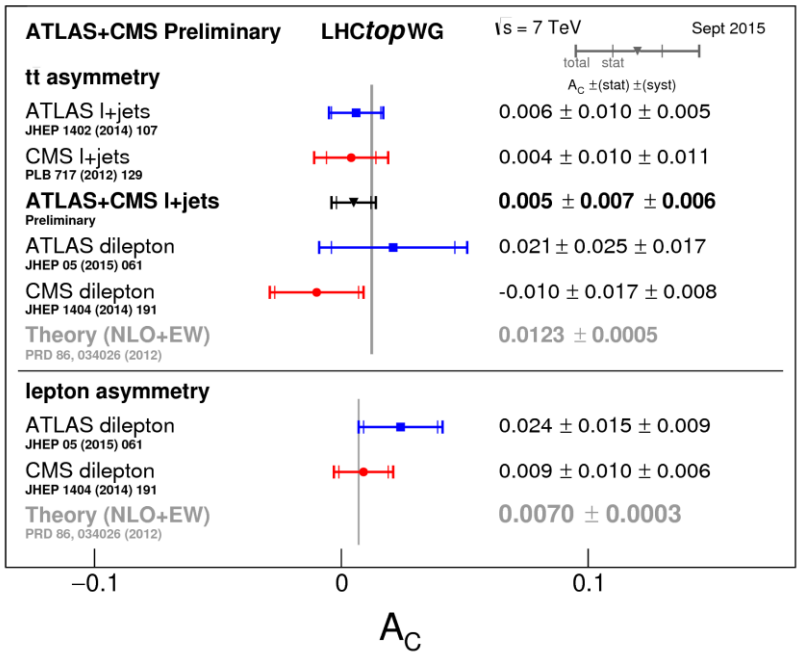
G_μ : A new color-octet neutral vector boson exchanged in the s channel

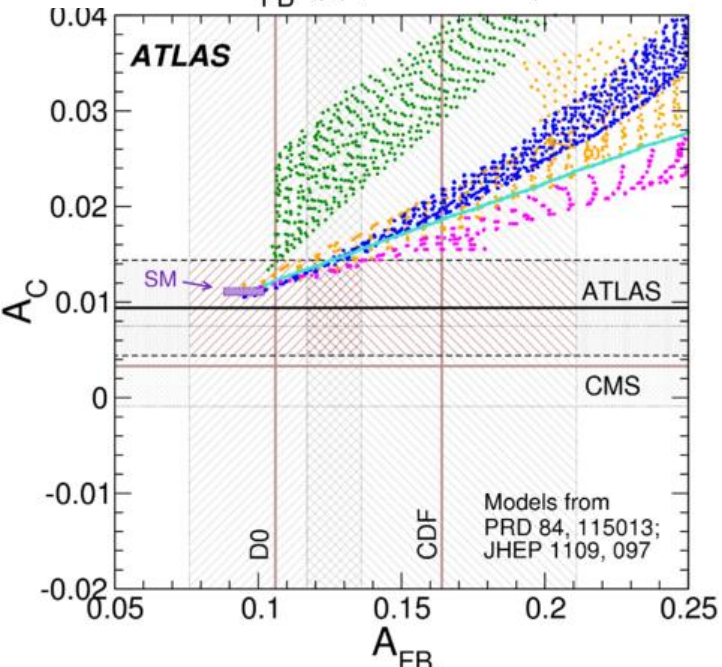
W': A charged color-singlet vector boson Z exchanged in the t channel in dd→ tt

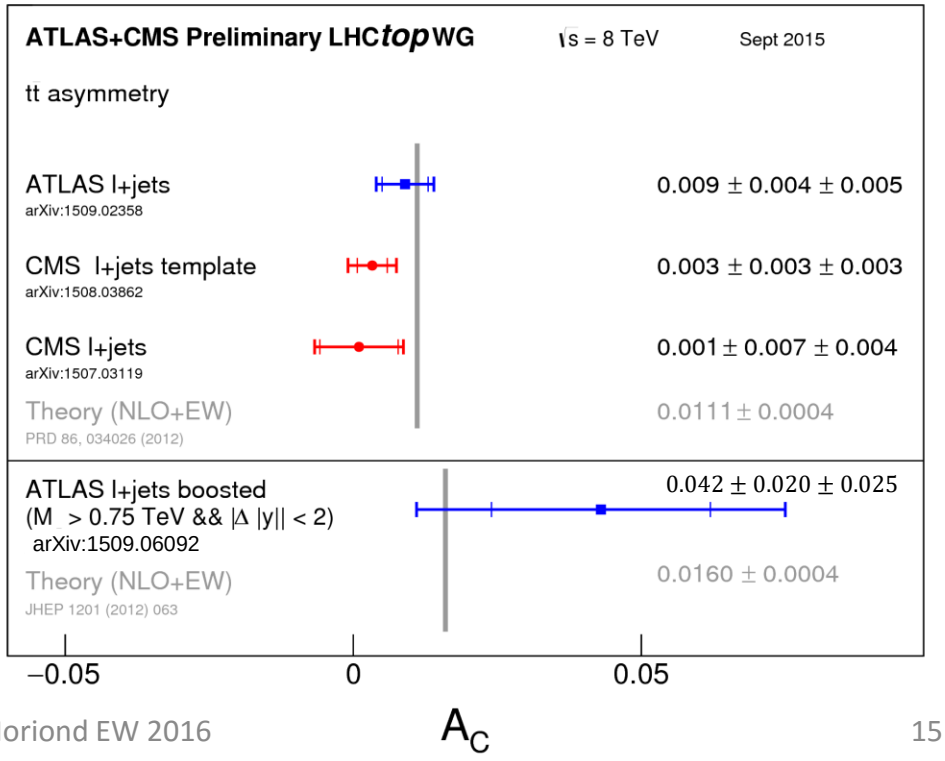
φ : A color-singlet scalar doublet with hypercharge −1/2 exchanged in t channel

Ω^4 : A charge 4/3 scalar color sextet exchanged in the u channel

ω^4 : A charge 4/3 scalar color triplet exchanged in the u channel





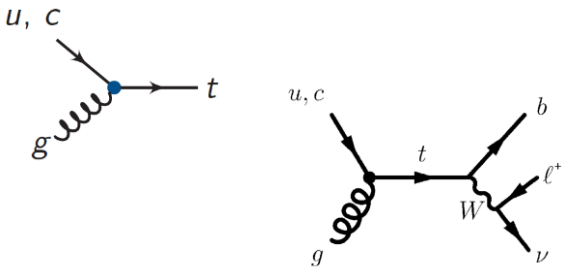


FCNC

- Highly suppressed in SM but not in BSM

K. Agashe et al., arXiv:1311.2028

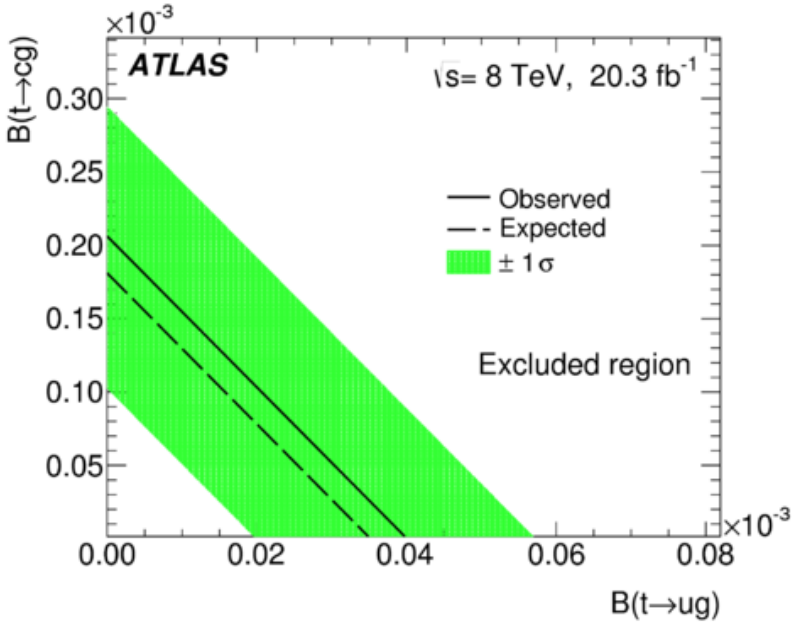
Process	SM	2HDM(FV)	2HDM(FC)	MSSM	RPV	RS
$t \to Zu$	7×10^{-17}	–	–	$\leq 10^{-7}$	$\leq 10^{-6}$	–
$t \to Zc$	1×10^{-14}	$\leq 10^{-6}$	$\leq 10^{-10}$	$\leq 10^{-7}$	$\leq 10^{-6}$	$\leq 10^{-5}$
$t \to gu$	4×10^{-14}	–	–	$\leq 10^{-7}$	$\leq 10^{-6}$	–
$t \to gc$	5×10^{-12}	$\leq 10^{-4}$	$\leq 10^{-8}$	$\leq 10^{-7}$	$\leq 10^{-6}$	$\leq 10^{-10}$
$t \to \gamma u$	4×10^{-16}	–	–	$\leq 10^{-8}$	$\leq 10^{-9}$	–
$t \to \gamma c$	5×10^{-14}	$\leq 10^{-7}$	$\leq 10^{-9}$	$\leq 10^{-8}$	$\leq 10^{-9}$	$\leq 10^{-9}$
$t \to hu$	2×10^{-17}	6×10^{-6}	–	$\leq 10^{-5}$	$\leq 10^{-9}$	–
$t \to hc$	3×10^{-15}	2×10^{-3}	$\leq 10^{-5}$	$\leq 10^{-5}$	$\leq 10^{-9}$	$\leq 10^{-4}$



FCNC: t→qg @ 8TeV

ATLAS, arXiv:1509.00294

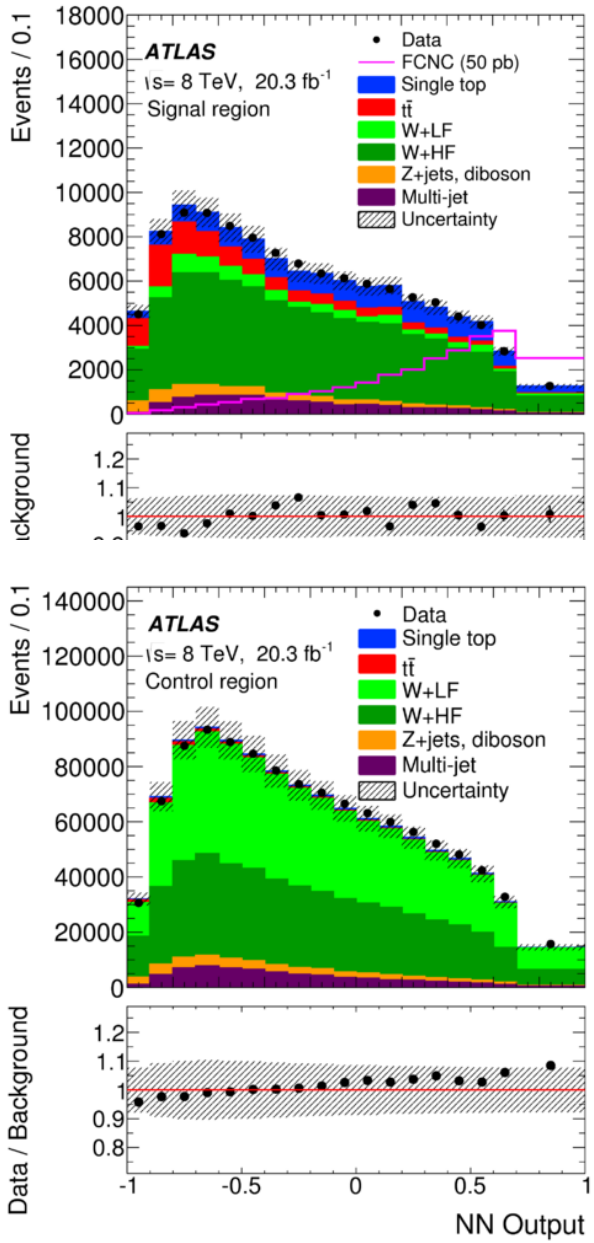
- Not possible in tt because of multijet bckgnd
- t-channel single top selection:
  - 1 lepton,1 b-tagged jet and missing E_T
  - Neural network to separate signal from SM bkgnd.

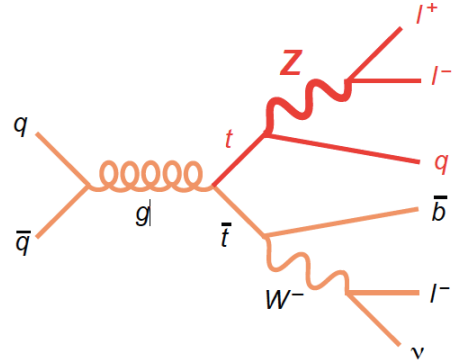


$\sigma_{qg\to t} \times \mathcal{B}(t\to Wb) < 3.4\ (2.9\ exp)$

$\mathcal{B}(t\to ug) < 4 \times 10^{-5}$

$\mathcal{B}(t\to cg) < 20 \times 10^{-5}$





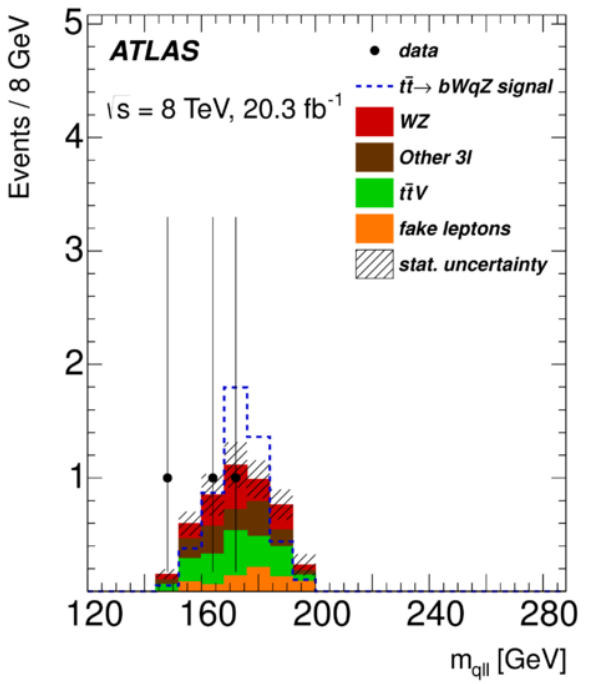
FCNC: t→Zq @ 8TeV

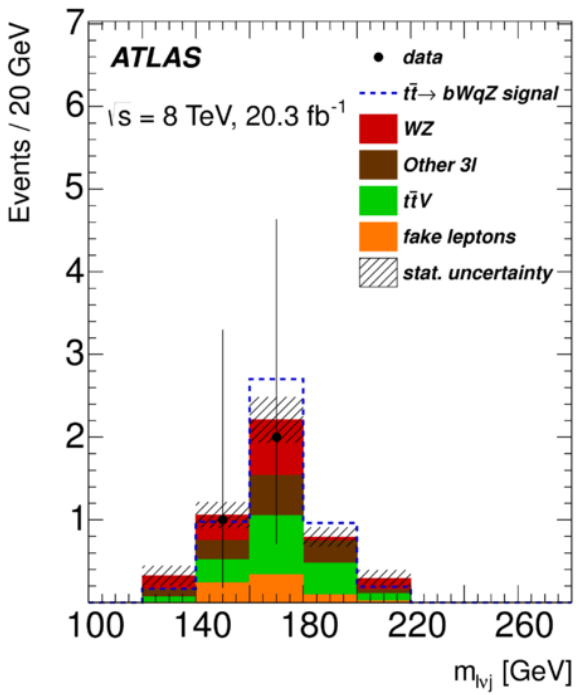
ATLAS, arXiv:1508.05796

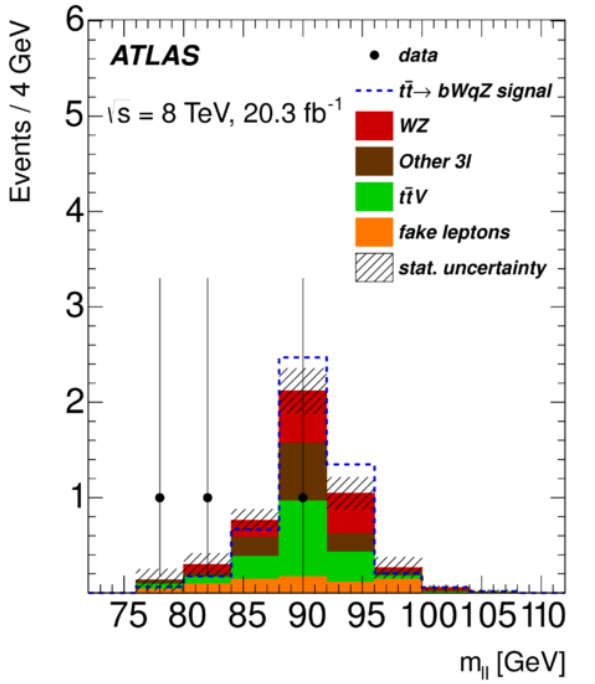
- $3\ell, \geq 2jets, \geq 1b + ETmiss$

$\mathcal{B}(\mathrm{t}\to\mathrm{Zq}) < 7 \times 10^{-4}$ @ 95%CL

Source	Background [%]	Signal [%]
Background modelling	17	—
Signal modelling	—	5.5
Leptons	4.7	2.9
Jets	7.7	4.9
b-tagging	3.9	7.2
$E_{\mathrm{T}}^{\mathrm{miss}}$	3.2	1.5
Luminosity	2.4	2.8
Statistical	8.1	1.5

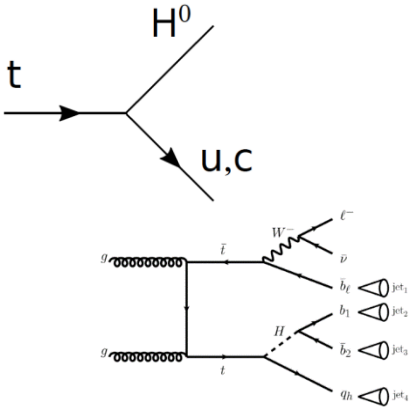






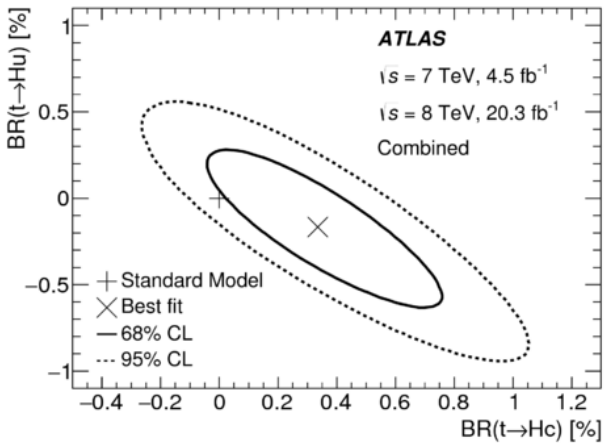
FCNC: t→Hq @ 8TeV

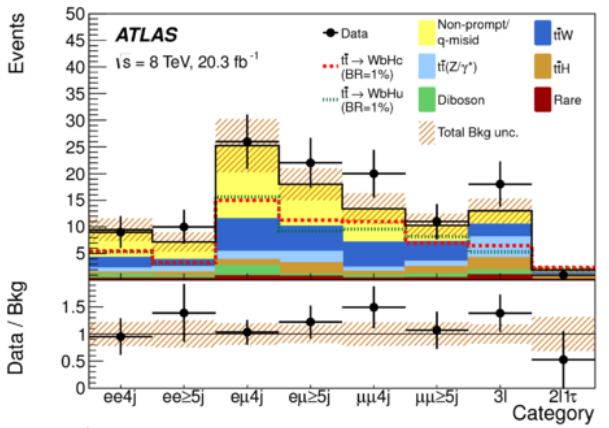
ATLAS, arXiv:1509.06047 (bb)
ATLAS, arXiv:1403.6293 (γγ)
CMS, PAS-TOP-14-019,020 (γγ)
CMS, PAS-TOP-13-007 (ml)

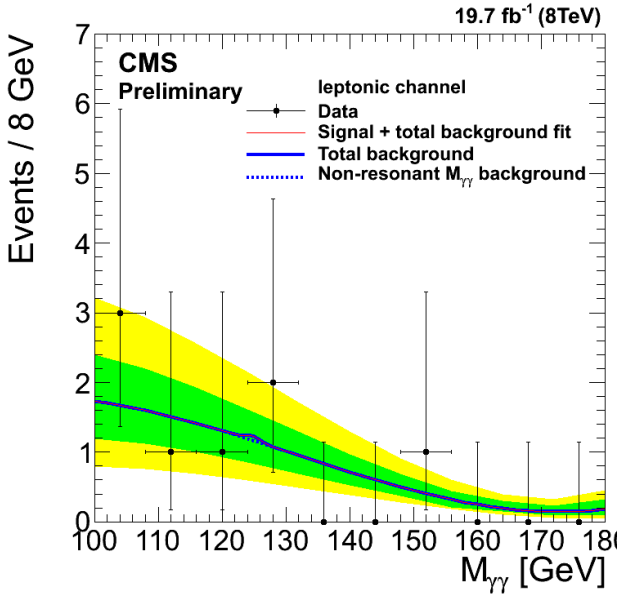


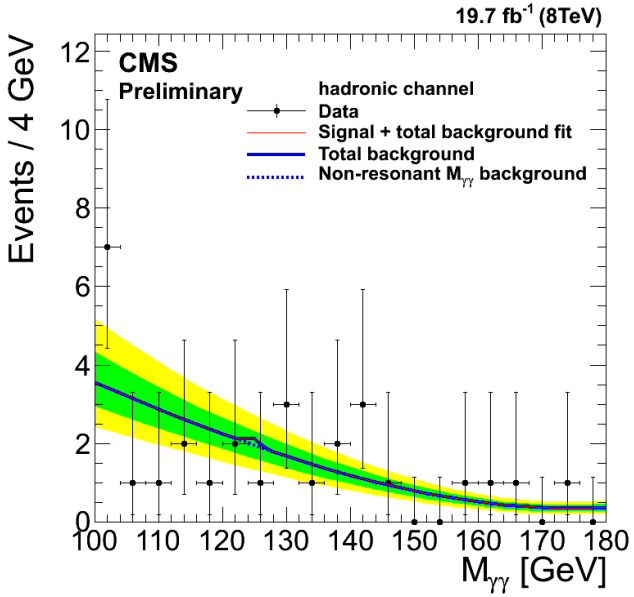
- t → bW (W → l/hν)
- t → Hq, H → bb/γγ

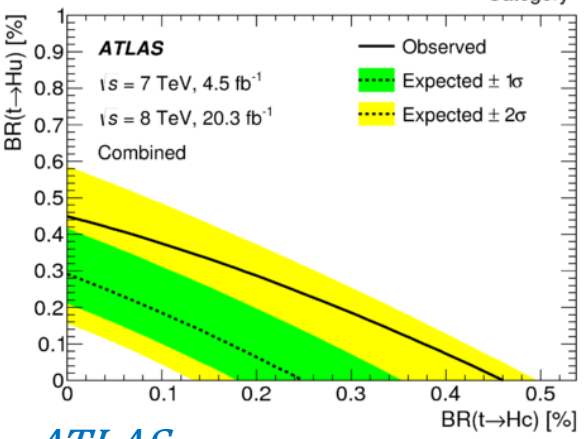
(depending analysis)











ATLAS

$\mathcal{B}(t \to uH) < 0.61\%$

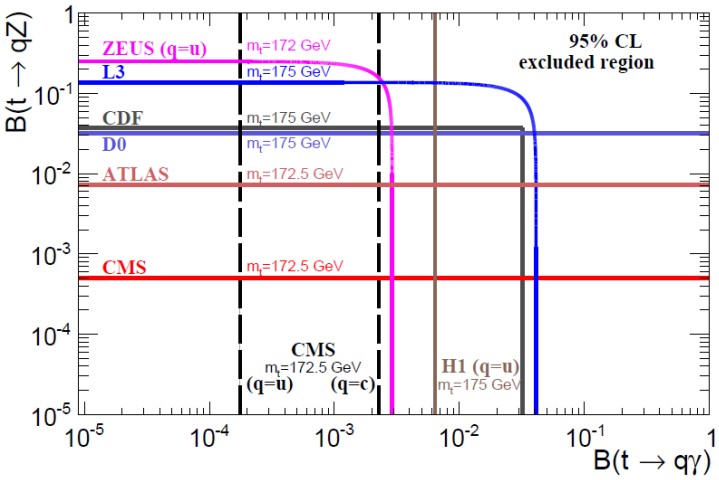
$\mathcal{B}(t \to cH) < 0.56\%$

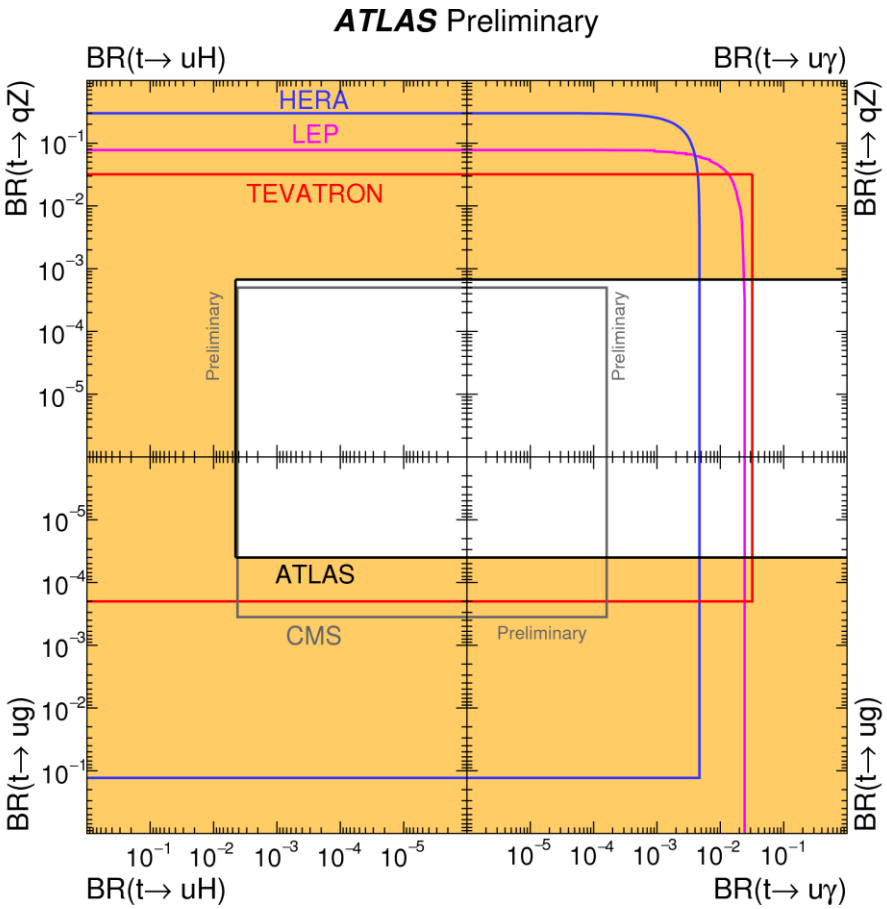
CMS

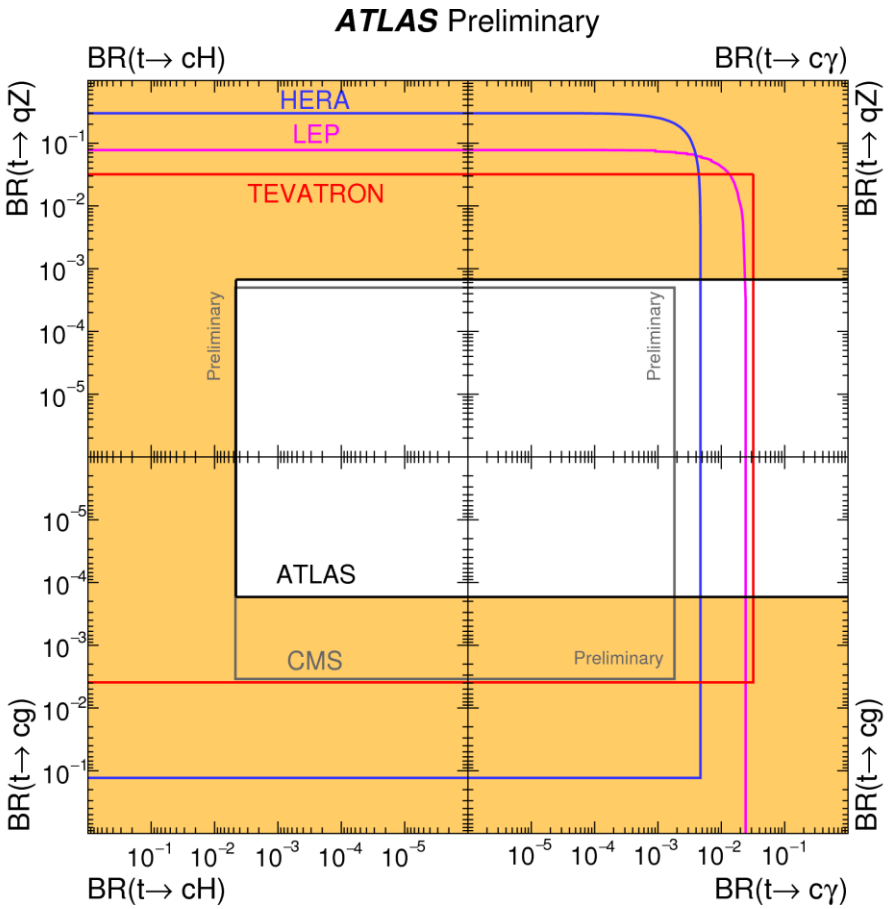
$\mathcal{B}(t \to uH) < 0.42\%$

$\mathcal{B}(t \to cH) < 0.47\%$

FCNC: Summary

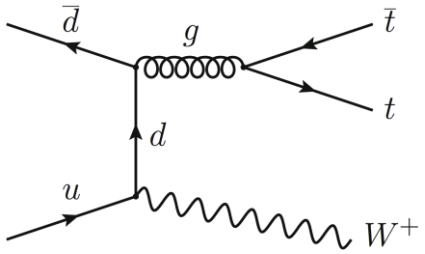


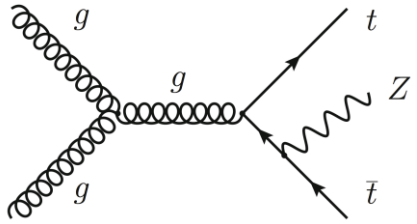


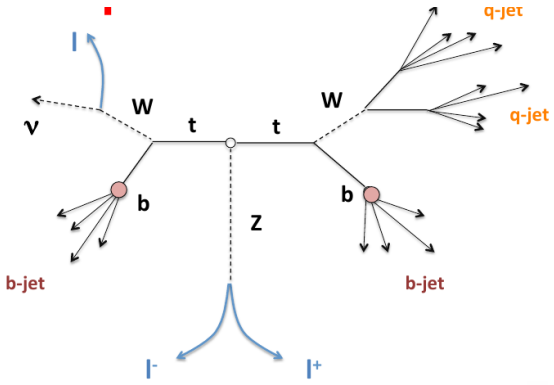


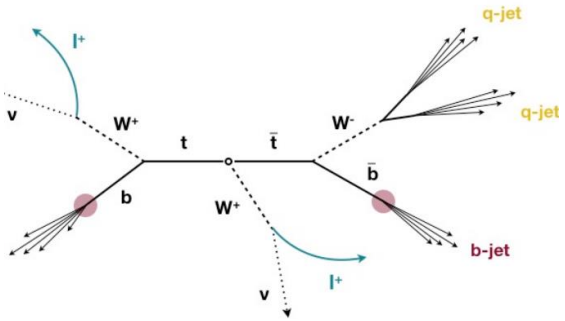
$t\bar{t}W, t\bar{t}Z$@8TeV

- Expected small SM cross sections (~200 fb @ 8TeV) but probe for BSM
- Direct coupling infos to bosons
- Background for ttH and BSM searches
- Dominant production modes:

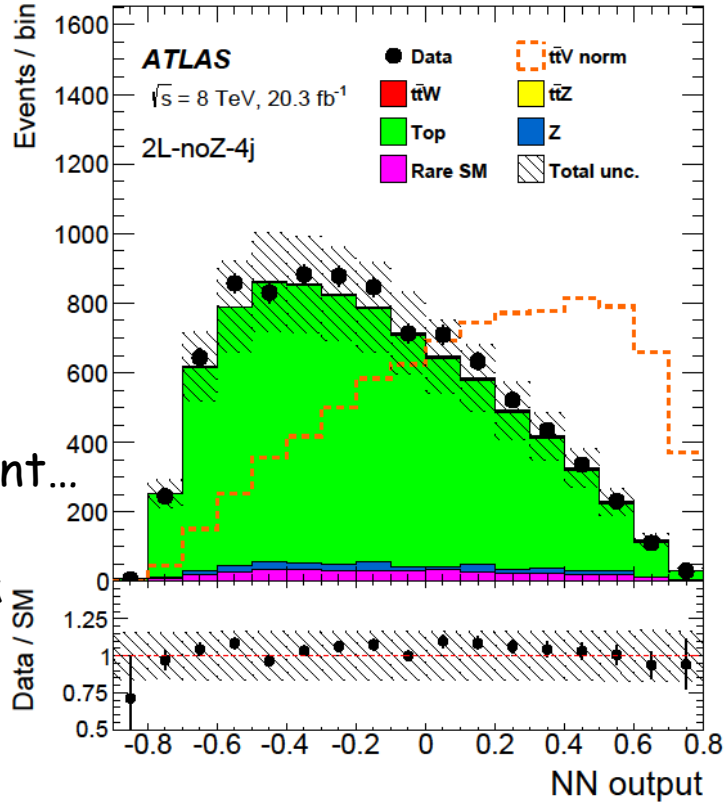








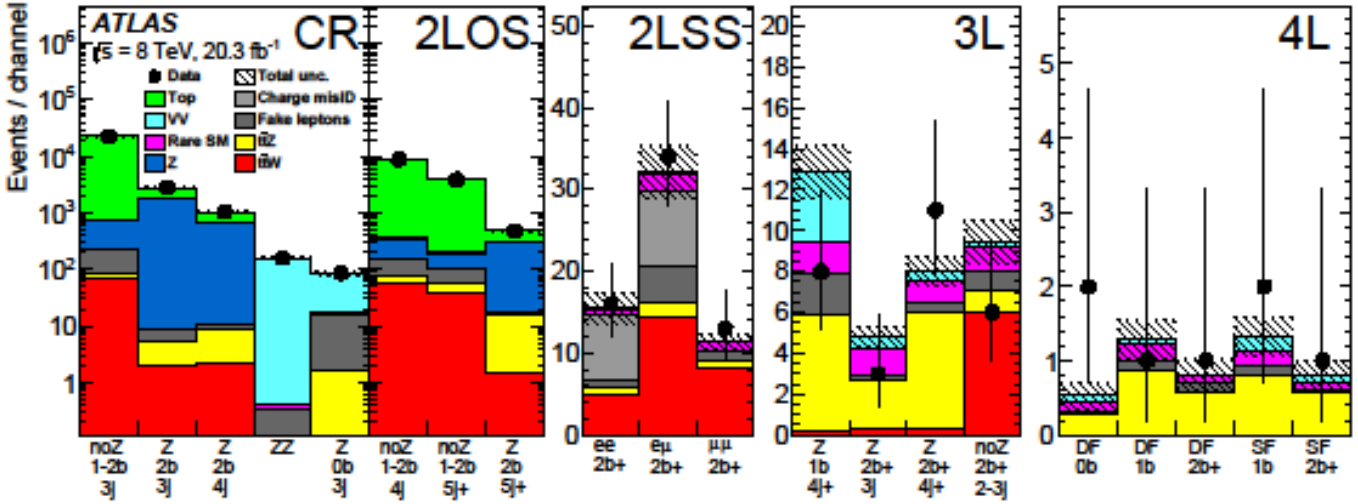
ATLAS, arXiv:1509.05276



- At least 1l p_T > 20 GeV
- p_T > 15 or 7GeV for additional leptons
- Bin of leptons: 2ℓ OS, 2ℓ SS, 3ℓ, 4ℓ
- Jet multiplicity, b jets, $E_T$miss, Z mass constraint…
- 15 SR + 5 CR, NN for 2ℓ OS
- Fake leptons and Charge Misid Bkgnd from data
- CR+SR combined in profile LH
- σ(ttZ) and σ(ttW) as free parameters

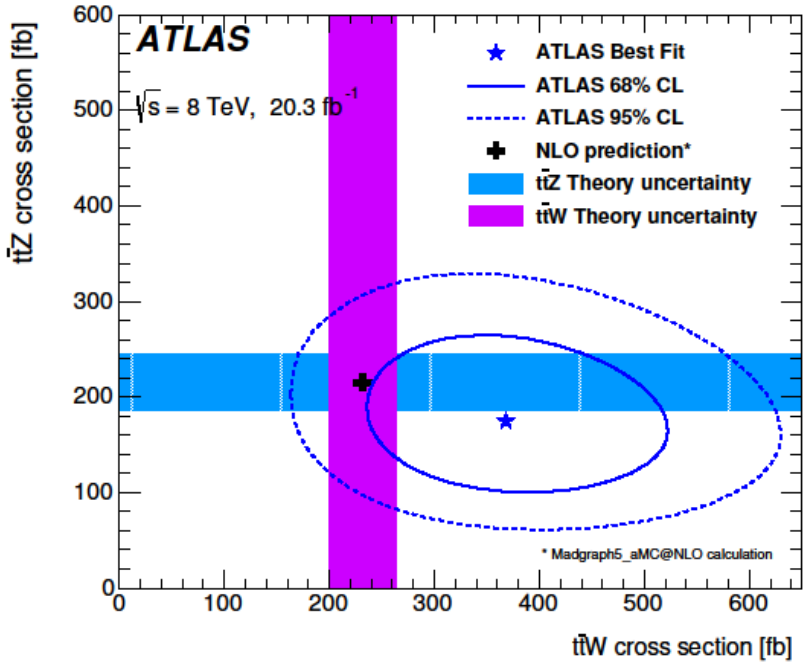
$t\bar{t}W, t\bar{t}Z$@8TeV

ATLAS, arXiv:1509.05276

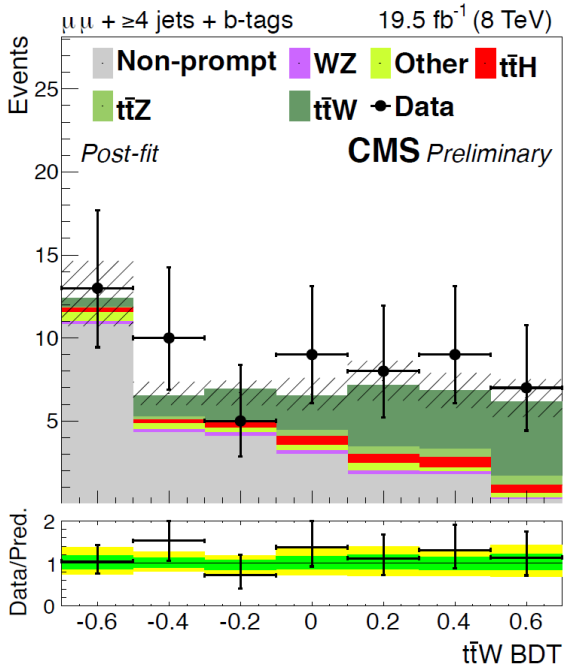


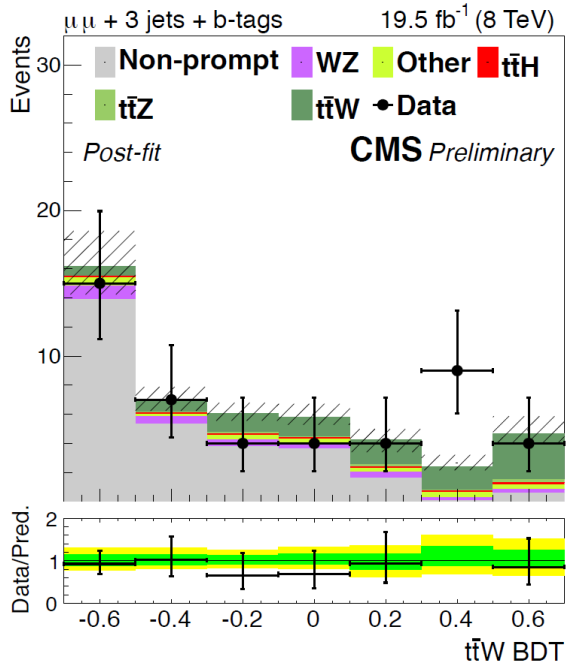
- Cross Sections:
  - $\sigma_{t\bar{t}W} = 369^{+86}_{-79}(\text{stat.}) \pm 44(\text{syst.})$ fb
  - $\sigma_{t\bar{t}Z} = 176^{+52}_{-48}(\text{stat.}) \pm 24(\text{syst.})$ fb

	$t\bar{t}W$ significance		$t\bar{t}Z$ significance	
Channel	Expected	Observed	Expected	Observed
2ℓOS	0.4	0.1	1.4	1.1
2ℓSS	2.8	5.0	-	-
3ℓ	1.4	1.0	3.7	3.3
4ℓ	-	-	2.0	2.4
Combined	3.2	5.0	4.5	4.2



- 5.0σ (3.2σ) for $t\bar{t}W$ (1st obs)
- 4.2σ (4.5σ) for $t\bar{t}Z$



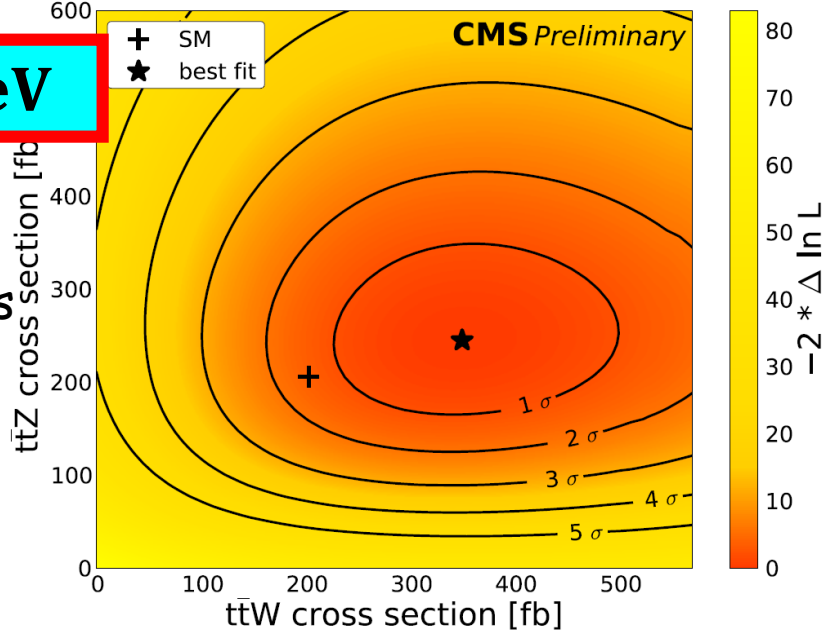


$t\bar{t}W, t\bar{t}Z$@8TeV

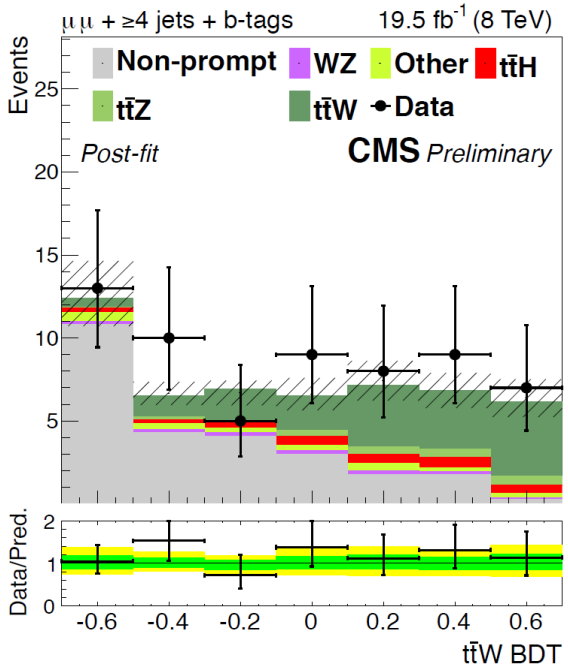
CMS PAS-TOP-14-021

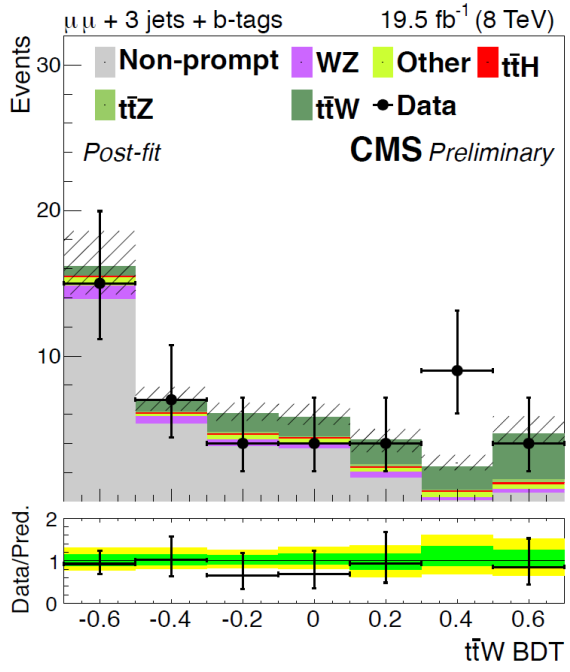
- 1l p_T > 20 GeV
- p_T > 10 for others
- 5SR
- Full reco,
- Matching + Kyne.

→ BDT fit



Reduction in signal strength uncertainty		
Systematic uncertainties removed	$t\bar{t}W$	$t\bar{t}Z$
Signal modeling	5.2%	7.1%
Nonprompt backgrounds	12.5%	0.5%
Inclusive prompt backgrounds	0.7%	2.6%
Prompt backgrounds with extra jets	0.2%	3.4%
Prompt backgrounds with extra heavy flavor jets	0.0%	1.1%
b tagging efficiency	6.1%	7.3%
Jet energy scale	1.4%	< 0.1%
Lepton ID and trigger efficiency	0.3%	0.5%
Luminosity and pileup	0.7%	0.5%
Bin-by-bin statistical uncertainty	4.4%	1.2%
All systematic uncertainties	31%	29%





$t\bar{t}W, t\bar{t}Z$@8TeV

CMS PAS-TOP-14-021

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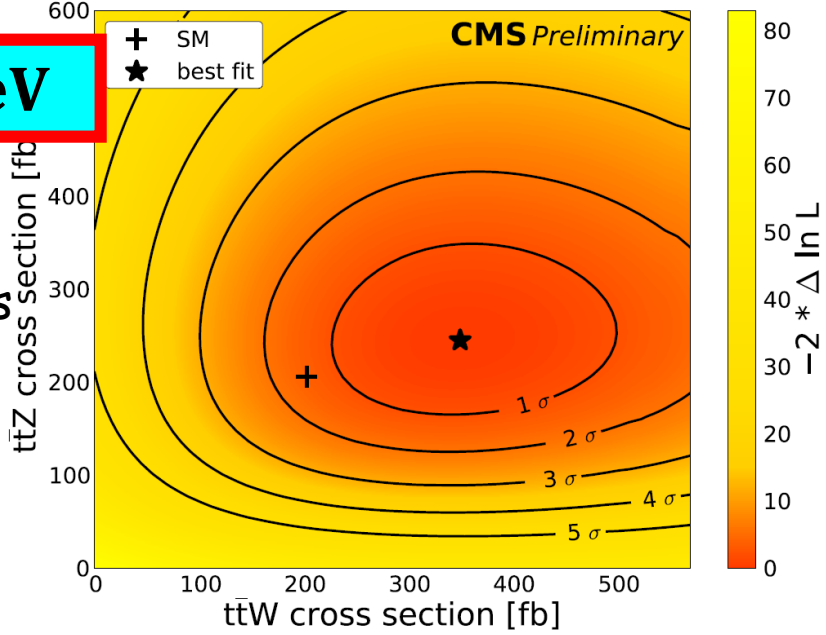


tt̄Z	Cross section (fb)		Signal strength (μ)		Significance	
Channels	Expected	Observed	Expected	Observed	Expected	Observed
OS	206^{+142}_{-118}	257^{+158}_{-129}	$1.0^{+0.72}_{-0.57}$	$1.25^{+0.76}_{-0.62}$	1.8	2.1
3ℓ	206^{+79}_{-63}	257^{+85}_{-67}	$1.0^{+0.42}_{-0.32}$	$1.25^{+0.45}_{-0.36}$	4.6	5.1
4ℓ	206^{+153}_{-109}	228^{+150}_{-107}	$1.0^{+0.77}_{-0.53}$	$1.11^{+0.76}_{-0.52}$	2.7	3.4
OS + 3ℓ + 4ℓ	206^{+62}_{-52}	242^{+65}_{-55}	$1.0^{+0.34}_{-0.27}$	$1.18^{+0.35}_{-0.29}$	5.7	6.4

tt̄W	Cross section (fb)		Signal strength (μ)		Significance	
Channels	Expected	Observed	Expected	Observed	Expected	Observed
SS	203^{+88}_{-73}	414^{+135}_{-112}	$1.0^{+0.45}_{-0.36}$	$2.04^{+0.74}_{-0.61}$	3.4	4.9
3ℓ	203^{+215}_{-194}	210^{+225}_{-203}	$1.0^{+1.09}_{-0.96}$	$1.03^{+1.07}_{-0.99}$	1.0	1.0
SS + 3ℓ	203^{+84}_{-71}	382^{+117}_{-102}	$1.0^{+0.43}_{-0.35}$	$1.88^{+0.66}_{-0.56}$	3.5	4.8

- $\sigma_{t\bar{t}W} = 382^{+117}_{-102}(\text{stat} + \text{syst.})$ fb
- $\sigma_{t\bar{t}Z} = 242^{+65}_{-55}(\text{stat} + \text{syst.})$ fb
- 4.8σ (3.5σ) for tt̄W
- 6.4σ (5.7σ) for tt̄Z (1st obs)

$t\bar{t}W, t\bar{t}Z$@13TeV

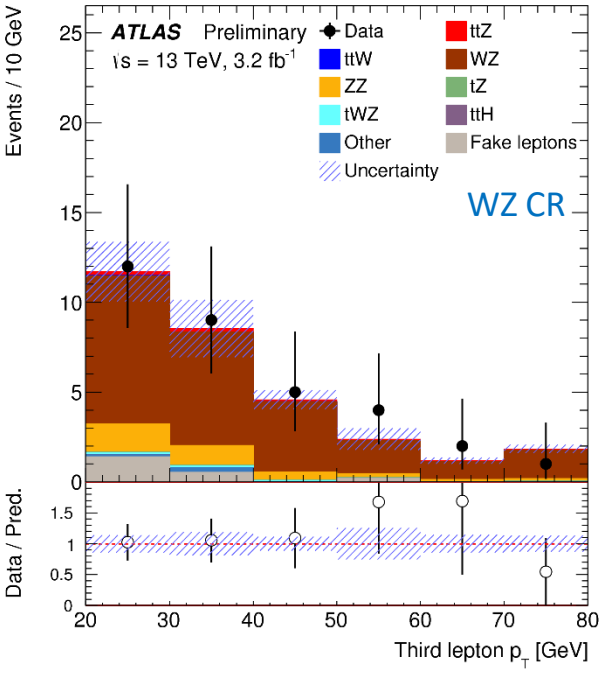
ATLAS-CONF-2016-003

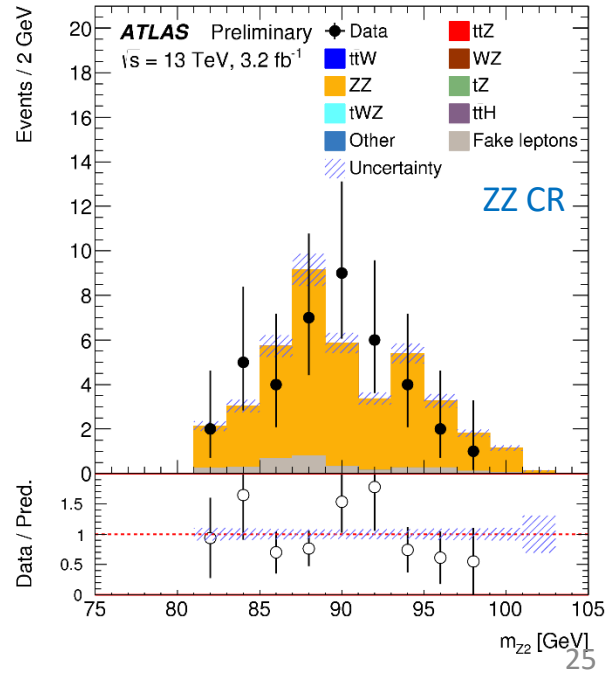
Process	$t\bar{t}$ decay	Boson decay	Channel
$t\bar{t}W^{\pm}$	$(\mu^{\pm}\nu b)(q\bar{q}b)$	$\mu^{\pm}\nu$	SS dimuon
	$(\ell^{\pm}\nu b)(\ell^{\mp}\nu b)$	$\ell^{\pm}\nu$	Trilepton
$t\bar{t}Z$	$(\ell^{\pm}\nu b)(q\bar{q}b)$	$\ell^{+}\ell^{-}$	Trilepton
	$(\ell^{\pm}\nu b)(\ell^{\mp}\nu b)$	$\ell^{+}\ell^{-}$	Tetralepton

Variable	3ℓ-Z-1b4j	3ℓ-Z-2b3j	3ℓ-Z-2b4j	3ℓ-noZ-2b
Leading lepton p_{T}	> 25 GeV			
Other leptons' p_{T}	> 20 GeV			
Sum of lepton charges	± 1			
Z-like OSSF pair	$\lvert m_{\ell\ell} - m_Z \rvert < 10$ GeV			$\lvert m_{\ell\ell} - m_Z \rvert > 10$ GeV
n_{jets}	≥ 4	3	≥ 4	≥ 2 and ≤ 4
$n_{b-\mathrm{jets}}$	1	≥ 2	≥ 2	≥ 2

Region	Z_2 leptons	p_{T34}	$\lvert m_{Z_2} - m_Z \rvert$	$E_{\mathrm{T}}^{\mathrm{miss}}$	$N_{b\text{-jets}}$
4ℓ-DF-1b	$e^{\pm}\mu^{\mp}$	> 35 GeV	-	-	1
4ℓ-DF-2b	$e^{\pm}\mu^{\mp}$	-	-	-	≥ 2
4ℓ-SF-1b	$e^{\pm}e^{\mp}, \mu^{\pm}\mu^{\mp}$	> 25 GeV	> 10 GeV	> 40 GeV	1
			< 10 GeV	> 80 GeV	
4ℓ-SF-2b	$e^{\pm}e^{\mp}, \mu^{\pm}\mu^{\mp}$	-	> 10 GeV	-	≥ 2
			< 10 GeV	> 40 GeV	

Region	$t + X$	Bosons	Fake leptons	Total bkg.	$t\bar{t}W$	$t\bar{t}Z$	Data
3ℓ-WZ-CR	0.51 ± 0.13	26.9 ± 2.5	1.6 ± 1.7	29.0 ± 3.0	0.017 ± 0.005	0.71 ± 0.08	33
4ℓ-ZZ-CR	0.007 ± 0.006	37.9 ± 2.5	3.1 ± 0.9	41.0 ± 2.7	< 0.001	0.031 ± 0.006	40
2μ-SS	1.00 ± 0.19	0.14 ± 0.06	1.7 ± 1.5	2.9 ± 1.5	2.28 ± 0.34	0.65 ± 0.07	9
3ℓ-Z-2b4j	1.06 ± 0.25	0.5 ± 0.4	0.1 ± 0.6	1.7 ± 0.8	0.061 ± 0.013	5.1 ± 0.5	8
3ℓ-Z-1b4j	1.23 ± 0.26	3.4 ± 2.2	2.0 ± 1.7	6.6 ± 2.8	0.037 ± 0.010	4.0 ± 0.4	7
3ℓ-Z-2b3j	0.64 ± 0.23	0.25 ± 0.18	0.1 ± 0.4	1.0 ± 0.5	0.082 ± 0.015	1.75 ± 0.20	4
3ℓ-noZ-2b	0.95 ± 0.15	0.18 ± 0.09	3.6 ± 2.2	4.7 ± 2.2	1.55 ± 0.24	1.35 ± 0.16	10
4ℓ-SF-1b	0.198 ± 0.035	0.22 ± 0.08	0.112 ± 0.032	0.53 ± 0.09	< 0.001	0.59 ± 0.05	1
4ℓ-SF-2b	0.130 ± 0.035	0.11 ± 0.05	0.053 ± 0.016	0.29 ± 0.07	< 0.001	0.57 ± 0.05	1
4ℓ-DF-1b	0.21 ± 0.04	0.022 ± 0.011	0.105 ± 0.027	0.34 ± 0.05	< 0.001	0.67 ± 0.05	2
4ℓ-DF-2b	0.15 ± 0.05	< 0.001	0.055 ± 0.017	0.20 ± 0.05	< 0.001	0.58 ± 0.05	1





$t\bar{t}W, t\bar{t}Z$@13TeV

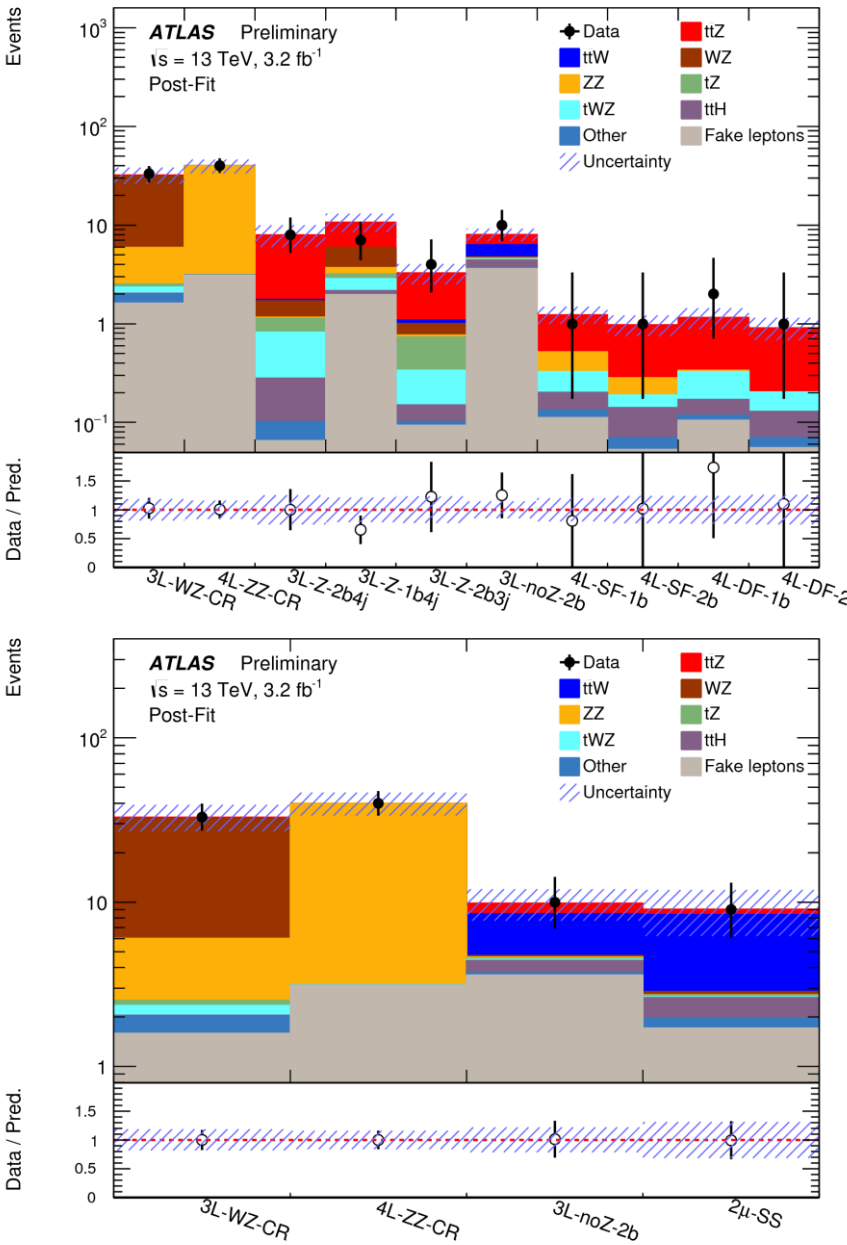
ATLAS-CONF-2016-003

- 8 SR & 2CR fitted together for $t\bar{t}Z$
- 2 SR & 2CR fitted together for $t\bar{t}W$
- Profile LH fit

Uncertainty	$\sigma_{t\bar{t}Z}$	$\sigma_{t\bar{t}W}$
Luminosity	6.4%	7.0%
Reconstructed objects	7.0%	7.3%
Backgrounds from simulation	5.5%	3.7%
Fake leptons and charge misID	3.9%	21%
Total systematic	12%	24%
Statistical	32%	51%
Total	34%	56%

- $\sigma_{t\bar{t}W} = 1.38 \pm 0.70(\text{stat.}) \pm 0.33(\text{syst.})$ pb
- $\sigma_{t\bar{t}W\,(SM)} = 0.57 \pm 0.06$ pb (NLO)

- $\sigma_{t\bar{t}Z} = 0.92 \pm 0.30(\text{stat.}) \pm 0.11(\text{syst.})$ pb
- $\sigma_{t\bar{t}Z\,(SM)} = 0.76 \pm 0.08$ pb



$t\bar{t}W, t\bar{t}Z$@13TeV

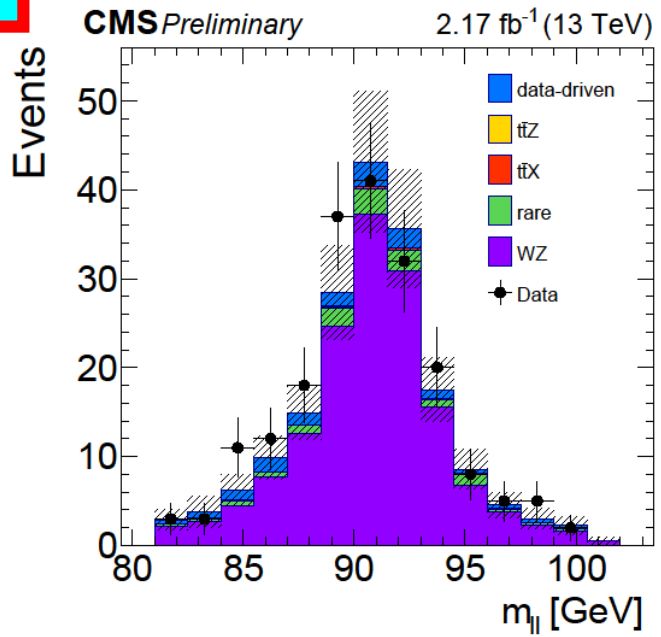
CMS PAS-TOP-16-009

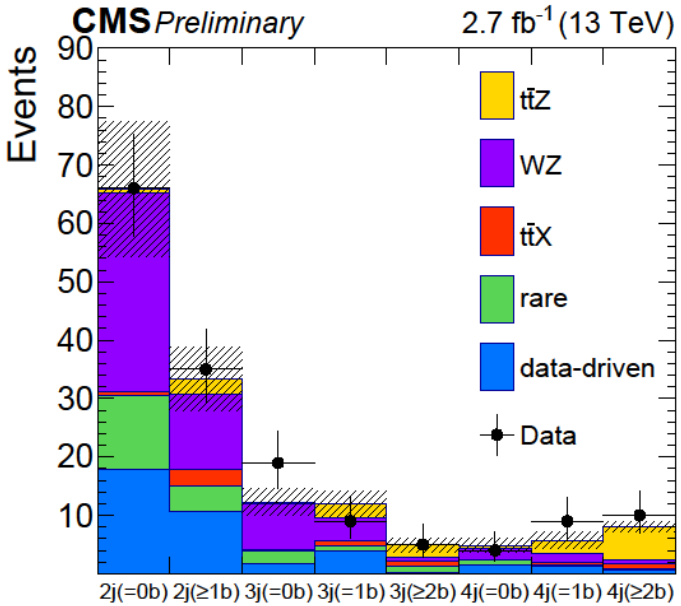
- 8+2 SR & 2CR fitted together for $t\bar{t}Z$
- Profile LH fit

Source	Syst. uncertainties ttZ in 3L	Syst. uncertainties ttZ in 4L
Luminosity	2.7%	2.7%
Jet Energy Scale	2-8%	1-7%
Jet Energy Resolution	1-6%	1%
Trigger	3%	1%
BTagging	1-8%	1-5%
PU modeling	3%	1%
Lepton Id., Eff.	4.5%	5-7%
μ_R/μ_F scale choice	3-4%	4%
PDF choice	3%	3%
Non-prompt background	30%	-
WZ background cross section	20%	-
ZZ background cross section	20%	20%
Rare SM bkg	50%	50%
ttW/ttH/tZq bkg	25%	25%
ttZ MC stat. uncertainty	5-17%	13-20%

Channel	Expected significance	Observed significance
3ℓ analysis	2.9	3.5
4ℓ analysis	1.2	0.9
3ℓ and 4ℓ combined	3.1	3.6

- $\sigma_{t\bar{t}Z} = 1.065^{+0.352}_{-0.313}(\text{stat.})^{+0.168}_{-0.142}(\text{syst.})$ pb

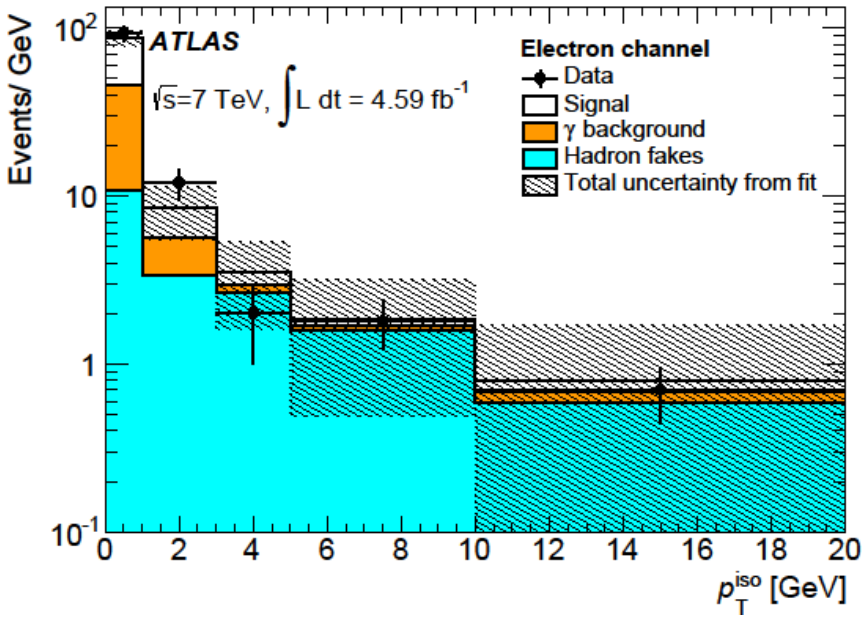




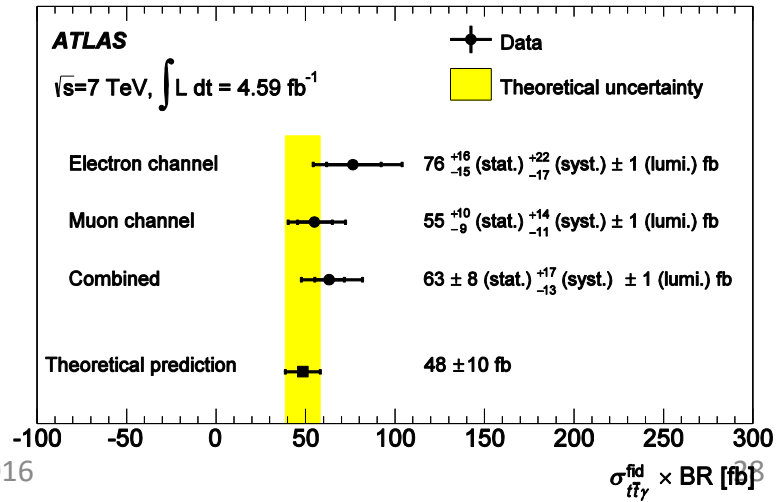
$t\bar{t}\gamma$@8TeV

ATLAS, arXiv:1502.00586

- ℓ+jets channel with at least 1 b-tagged jet, $E_T(\gamma) > 20$ GeV
- profile LH fit to the photon track-isolation distribution
- background template from multijet events with inverted photon shower shape
- measurement within the fiducial phase space



Uncertainty source	Uncertainty [%]
Background template shapes	3.7
Signal template shapes	6.6
Signal modeling	8.4
Photon modeling	8.8
Lepton modeling	2.5
Jet modeling	16.6
b-tagging	8.2
E_T^{miss} modeling	0.9
Luminosity	1.8
Background contributions	7.7



$\sigma^{fid}_{t\bar{t}\gamma} \times \mathrm{BR} = 63 \pm 8(stat.)^{+17}_{-13}(\mathrm{syst.}) \pm 1(lumi.)$ fb

SM: 48 ± 10 fb

first observation of $t\bar{t}\gamma$ @ 5.3σ

Conclusion

- Top studies at full swing with Run1 and now Run2 data
- Lots of property measurements performed and about to be systematics limited.
- Need for improvement to reduce instrumental systematics as wells as theoretical ones.
- Will allow to be more sensitive to new physics through direct and indirect searches
- In 2016 we will have a full run2 year @ 13 TeV and higher luminosity, so higher Tops statistics, 20M tt and 5M t, 20k ttZ to study and search for new phenomena.
- 13 TeV top analysis are just starting to arrive.

A bright future is ahead of us !!

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP