Top quark property measurements with the ATLAS detector and probing for new physics

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on behalf of the ATLAS Collaboration

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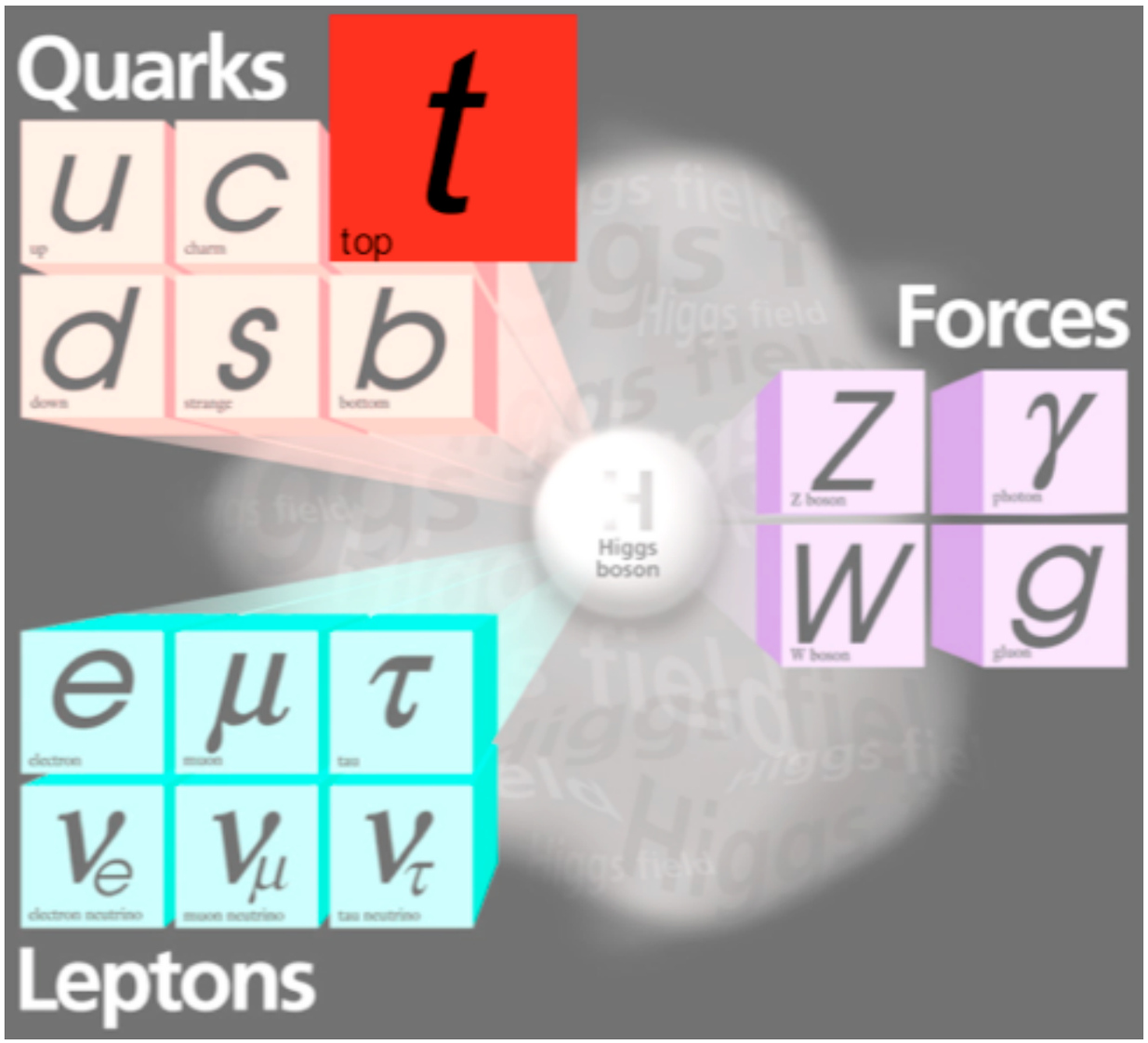
Outline

- Introduction
- Charge asymmetry
- FCNC decay and single top production
- Wtb vertex
- … and many more results
- Conclusions

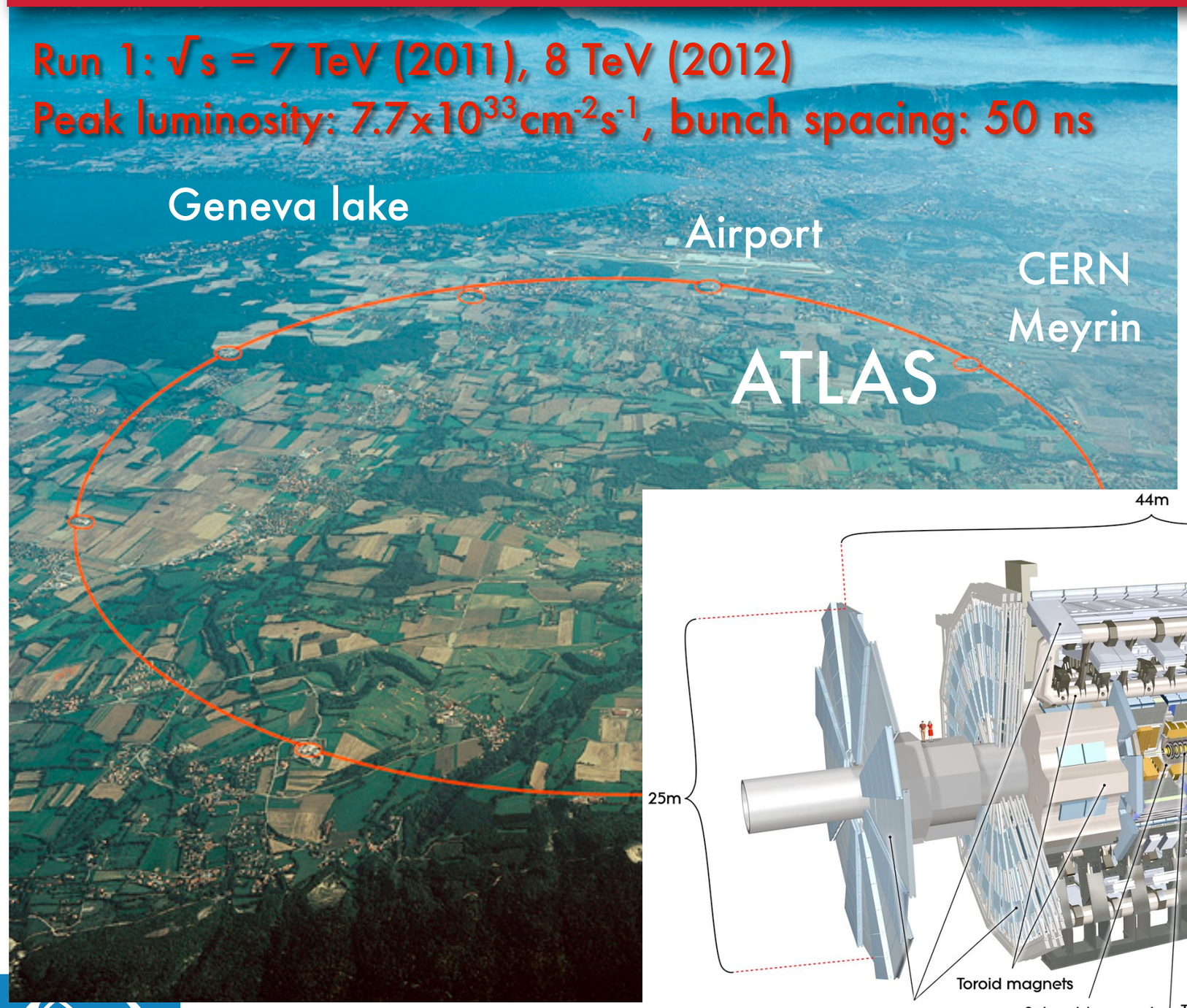
Introduction

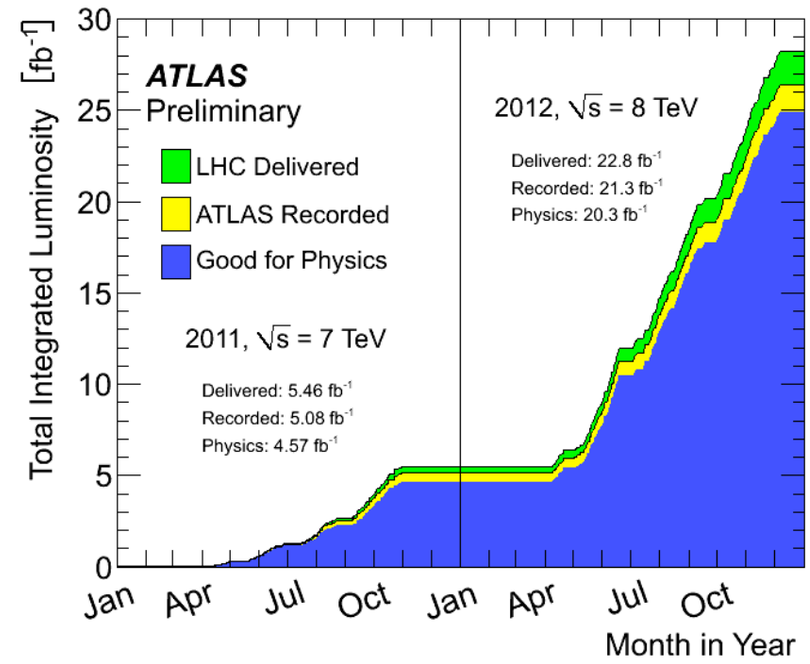
The top quark



- Discovered in 1995 at the Tevatron
- Pointlike particle as massive as a gold atom (the only natural Yukawa coupling!)
- Only quark decaying before hadronising (information on a bare quark!)
- Standard Model predicts all its properties given its mass (any deviation means new physics!)

LHC and ATLAS





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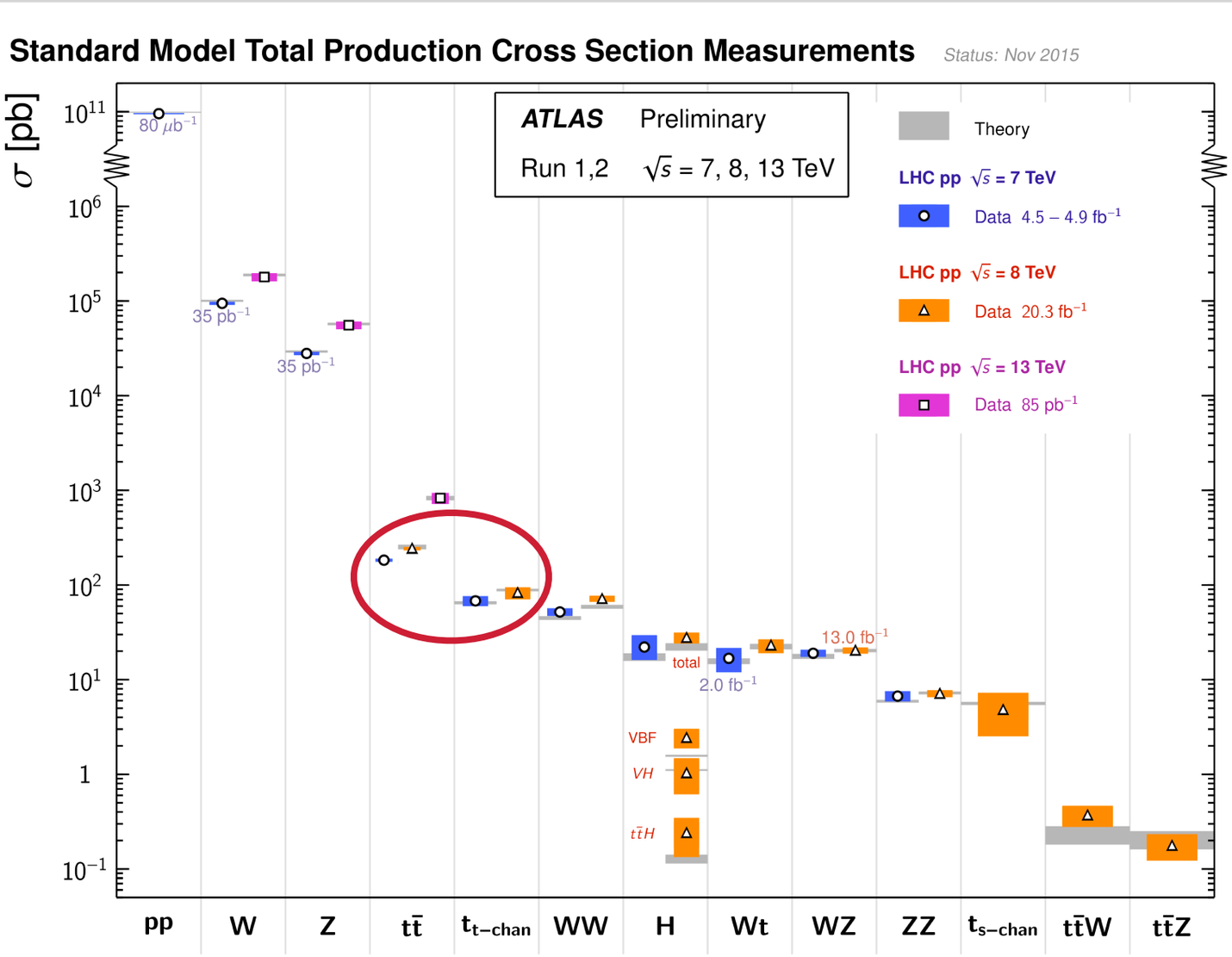
Top quark production

The LHC is a top factory

Tops, tops, tops...



Several million top quarks produced in Run 1

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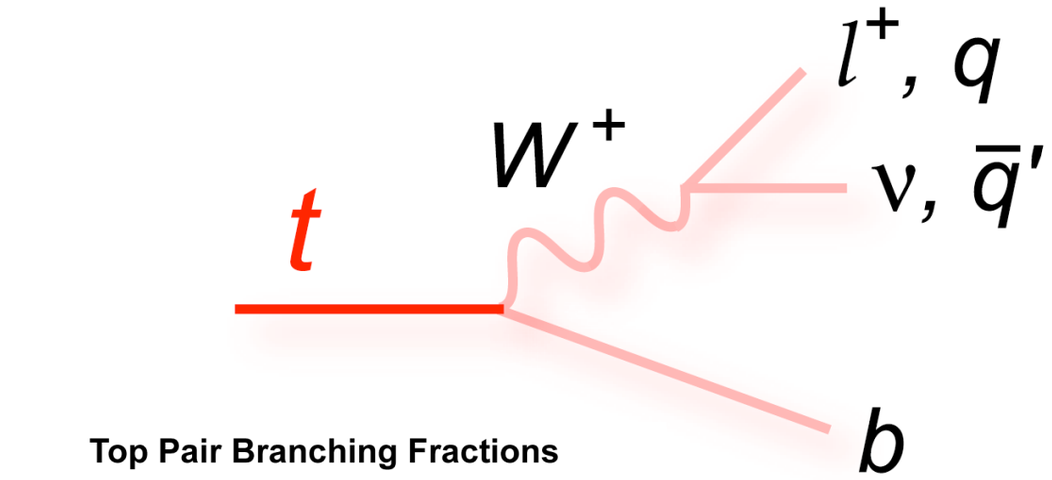
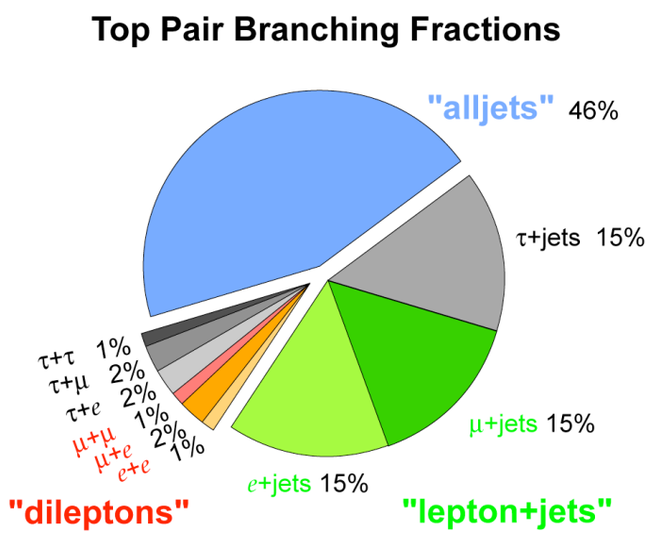
Top quark decay

- Top quarks decay to Wb with about 100% BR
- Experimental signatures based on W decay

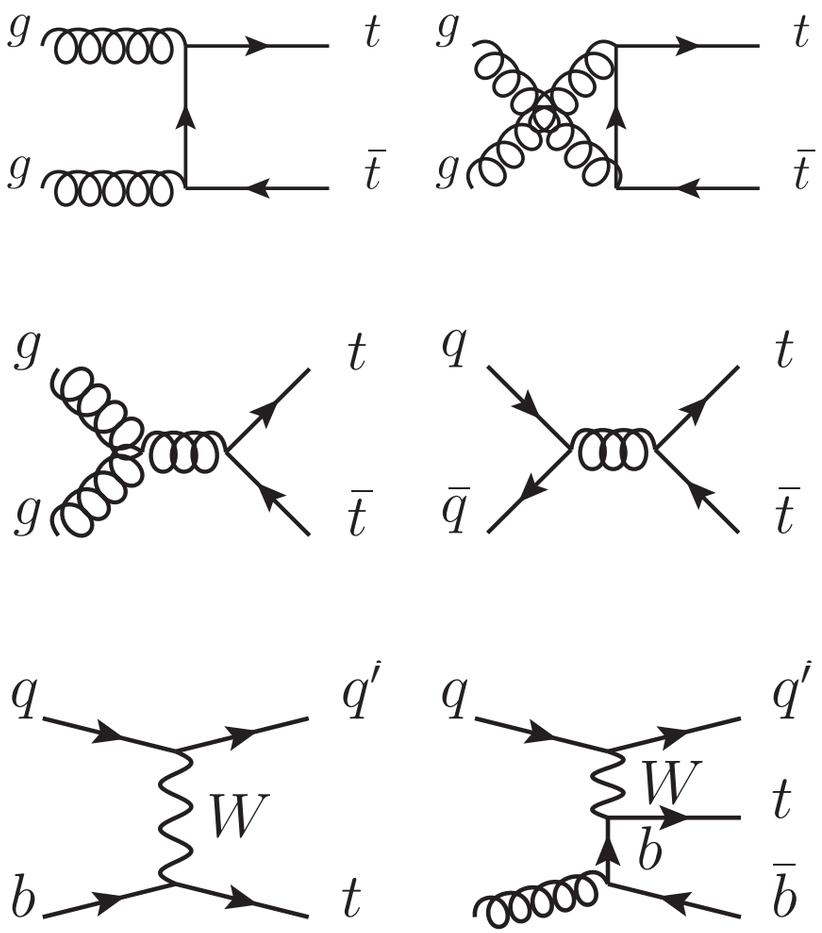




- Three signatures for top pairs
  Jets include hadronic tau decays
  Leptons include leptonic tau decays
- All-jets: high rate, large background (multijet)
- Lepton+jets: medium rate, acceptable background (W+jets)
- Dilepton: low rate, small background (Z+jets, diboson)

Measurements and searches

Standard Model



Cross section

Charge asymmetry

Spin correlations

Top polarisation

Mass

Charge

W helicity

Couplings

New physics

Resonances

Vector Like Quarks

Scalar tops

FCNC

Anomalous Wtb vertex

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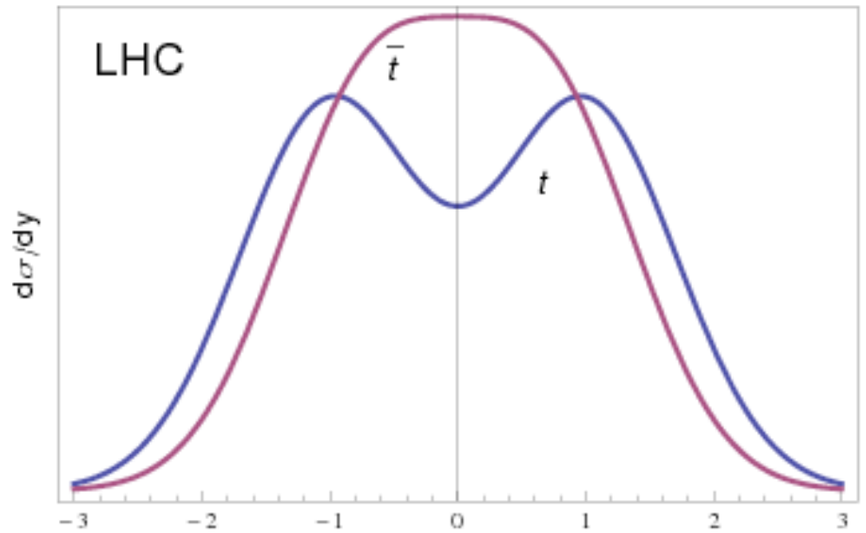
Charge asymmetry

Observables

Central-forward asymmetry due to interference at NLO and PDFs



Rodrigo, arXiv:1207.0331

Top-antitop asymmetry

l+jets and dilepton
requires kinematic reconstruction

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

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

Leptonic asymmetry

dilepton only
no kinematic reconstruction

$$\Delta|\eta| = |\eta_{l^+}| - |\eta_{l^-}|$$

$$A_{\mathrm{C}}^{\ell\ell} = \frac{N(\Delta|\eta| > 0) - N(\Delta|\eta| < 0)}{N(\Delta|\eta| > 0) + N(\Delta|\eta| < 0)}$$

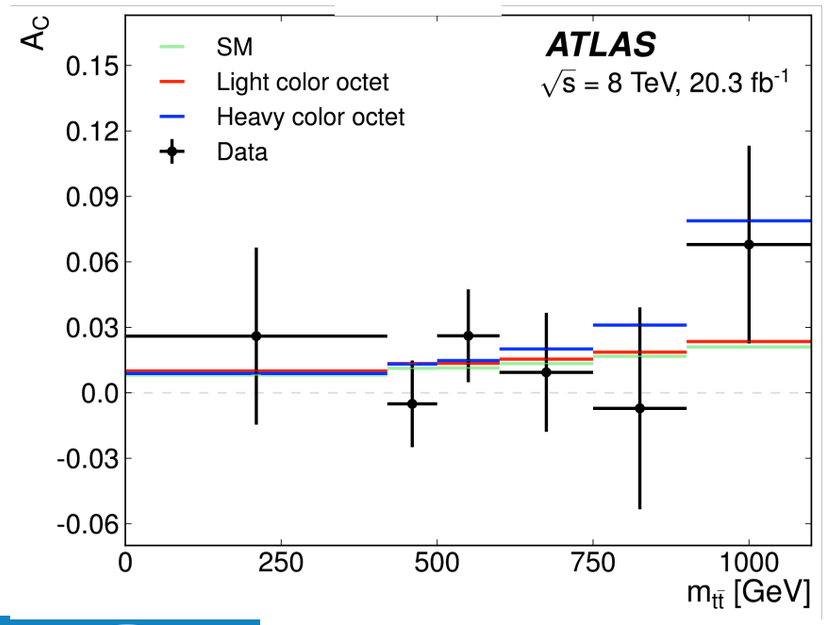
Lepton+jets @ 8 TeV

Inclusive and differential measurements, uncertainty dominated by statistics
Full event reconstruction with kinematic fit, unfolded to parton level
All results compatible with theoretical predictions in SM

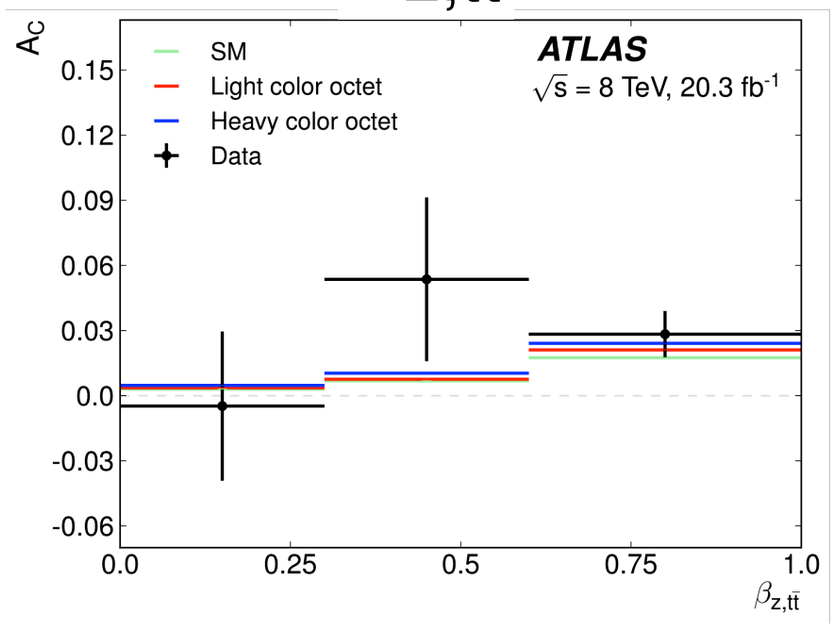
$$A_C = 0.009 \pm 0.005 \text{ (stat. + syst.)}$$

arXiv:1509.02358

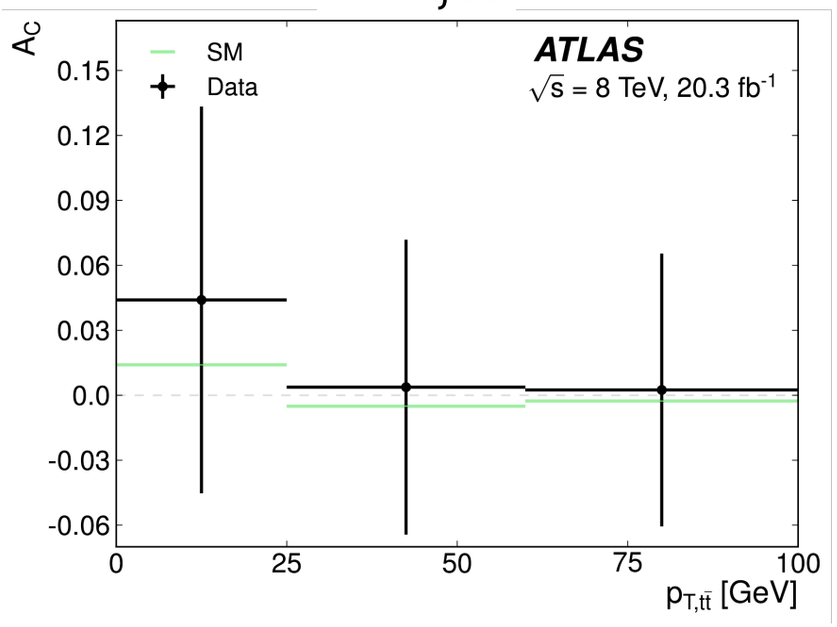
$m_{t\bar{t}}$



$\beta_{z,t\bar{t}}$



$p_{T,t\bar{t}}$



Boosted top @ 8 TeV

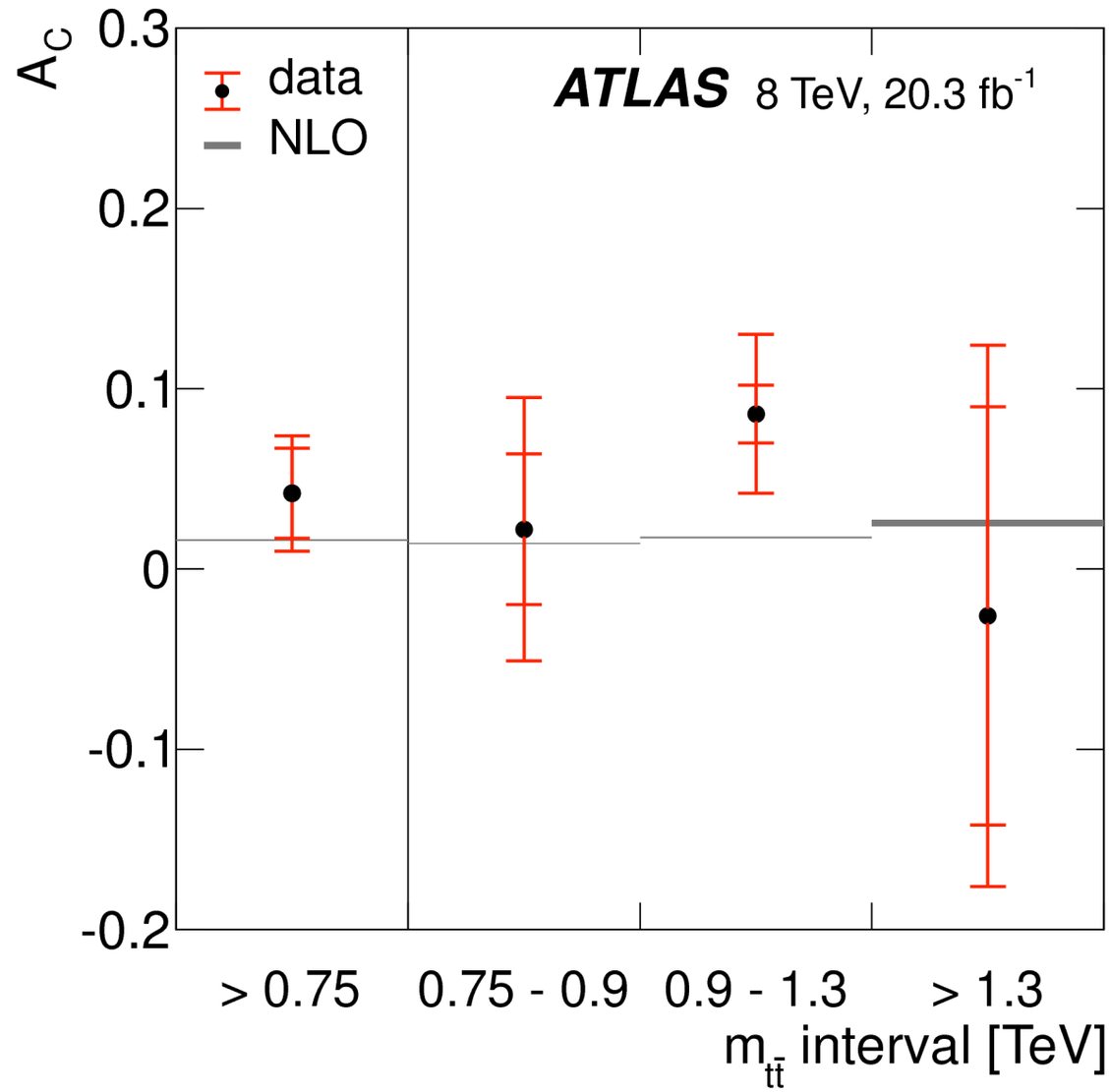
Inclusive and differential measurements in the fiducial phase-space
$m_{tt} > 0.75$ TeV, $-2 < \Delta|y| < 2$

Hadronic top decay reconstructed from substructure of large-R jet (top-tagging)

Unfolded to parton level

All results compatible with theoretical predictions in SM

arXiv:1512.06092



Dilepton @ 7 TeV

Inclusive ttbar and leptonic asymmetry measurements

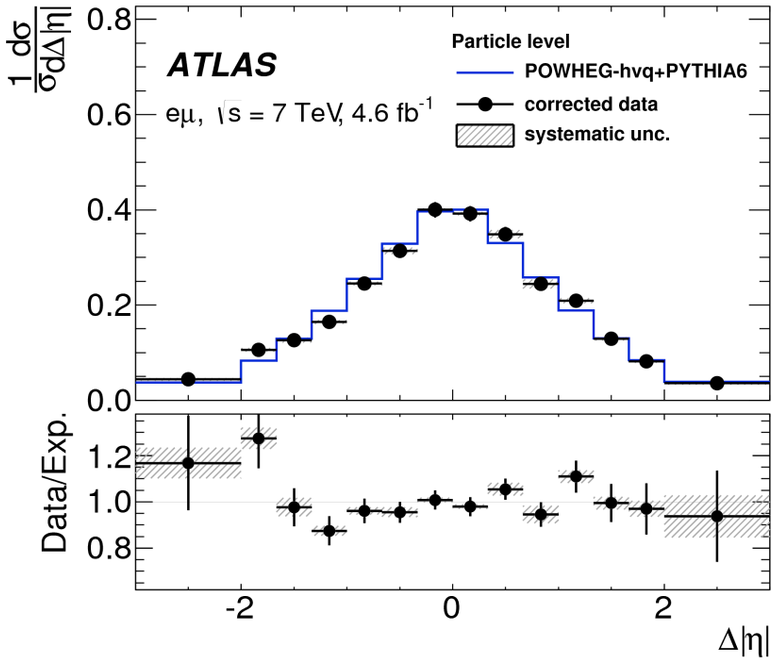
Uncertainty dominated by statistics

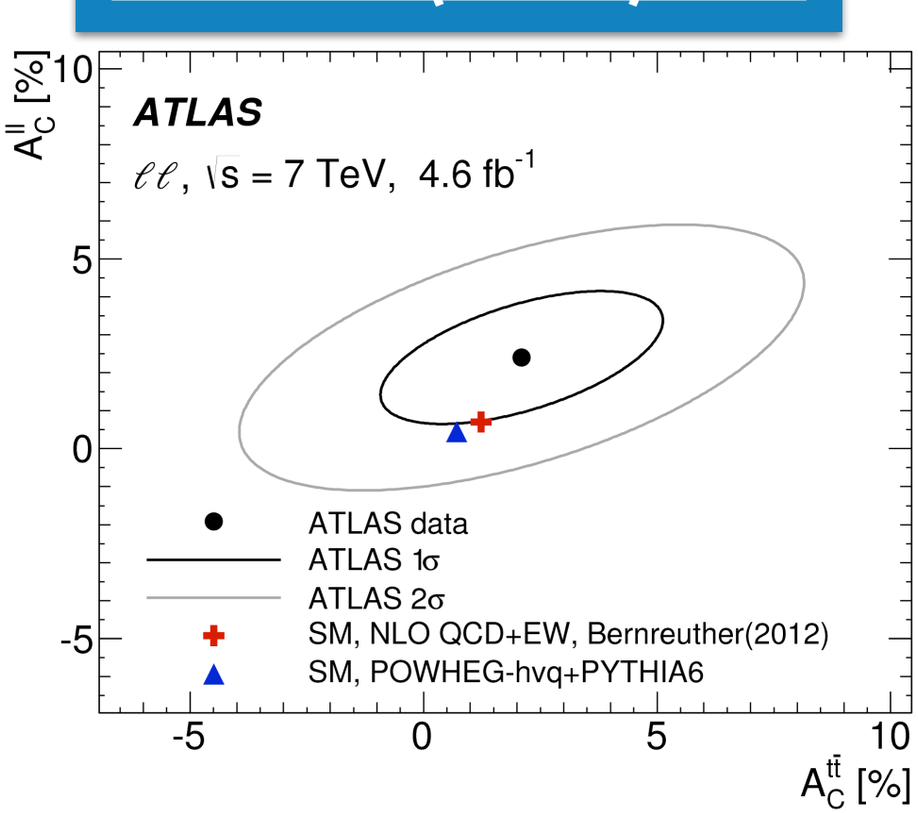
Event reconstruction with neutrino weighting technique

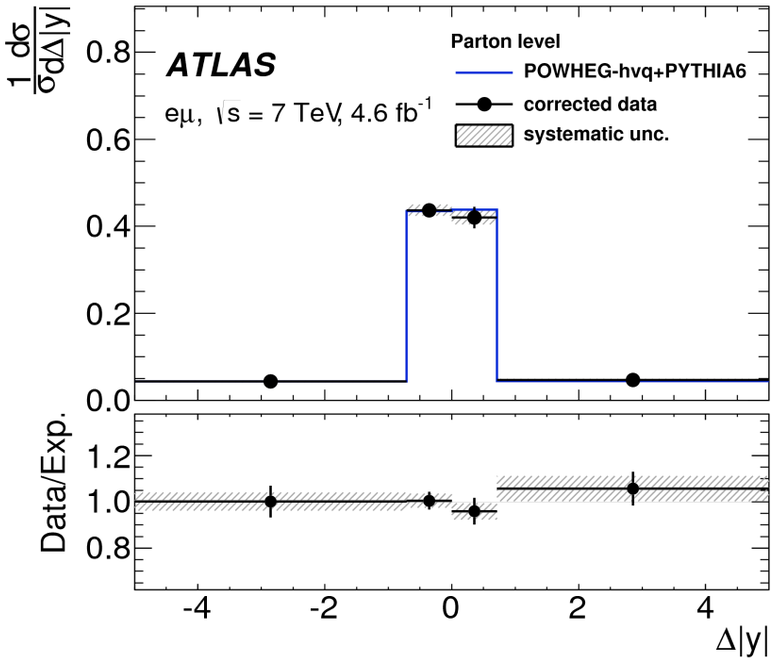
Asymmetry and distributions unfolded to parton level

All results compatible with theoretical predictions in SM

[JHEP 05 (2015) 061]







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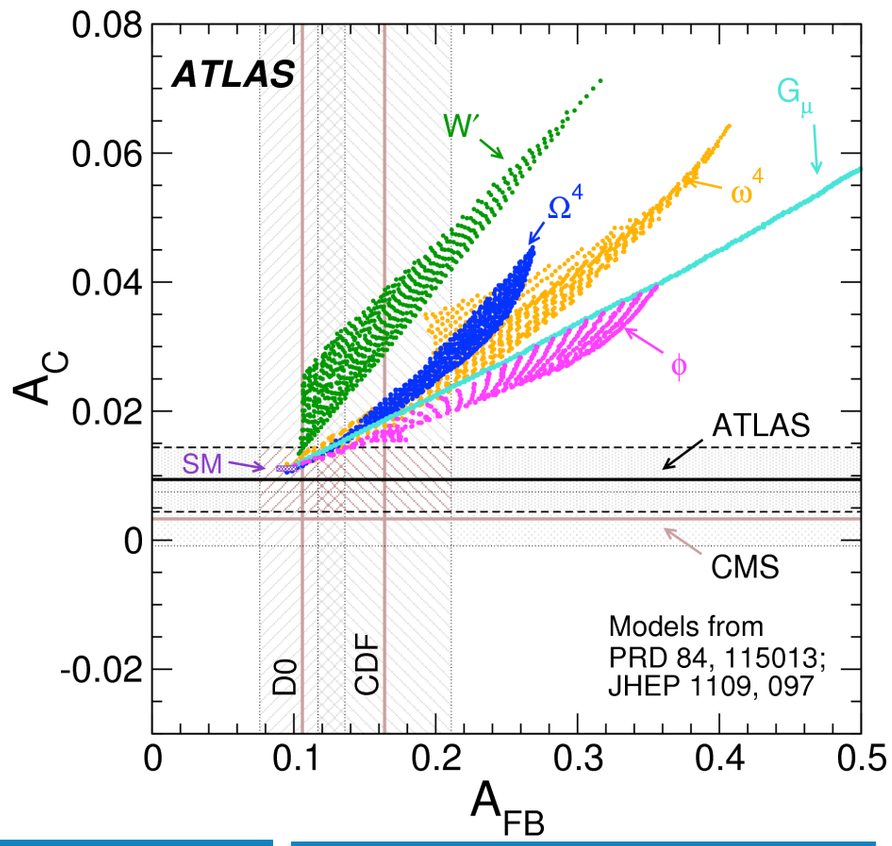
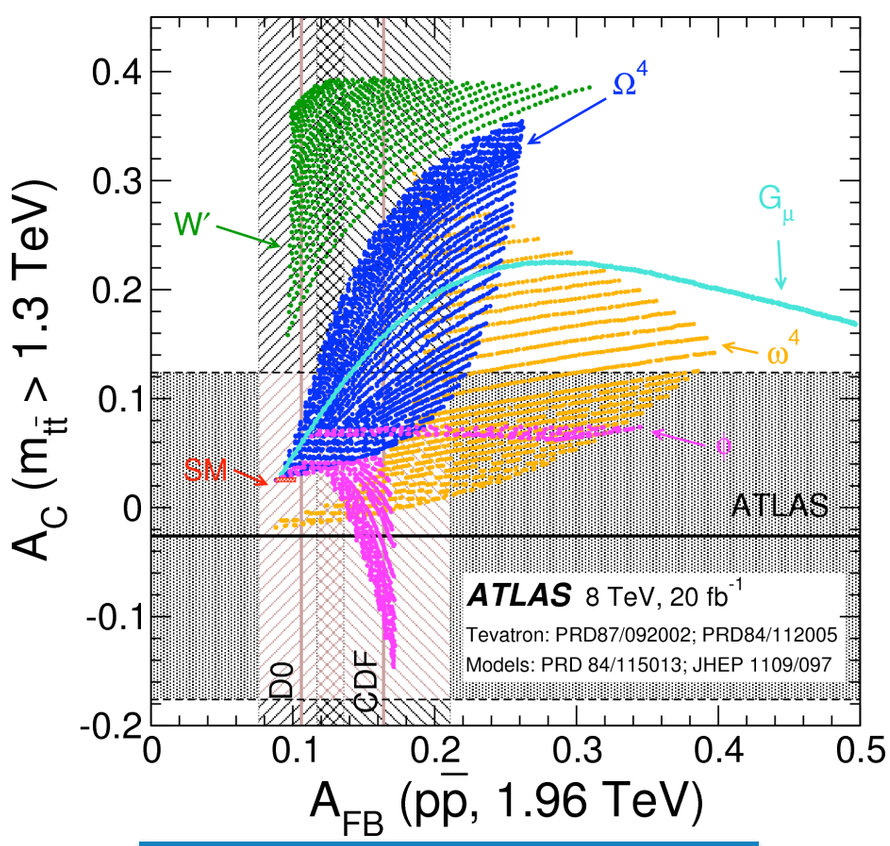
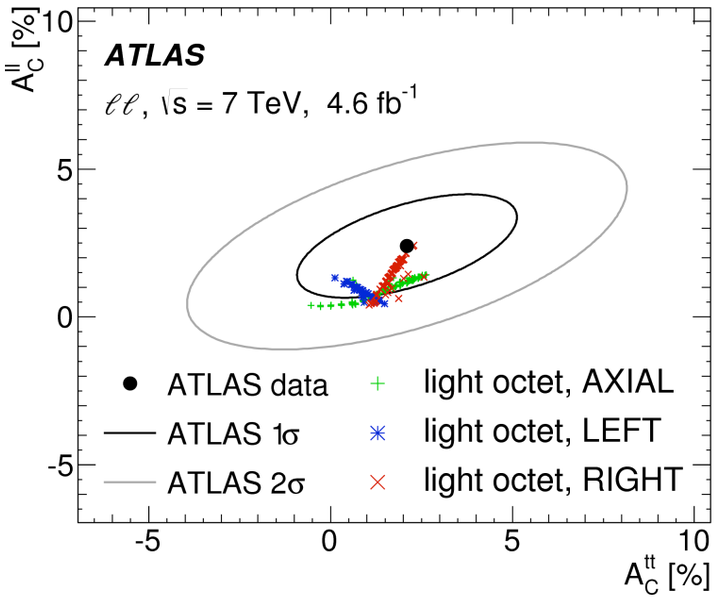
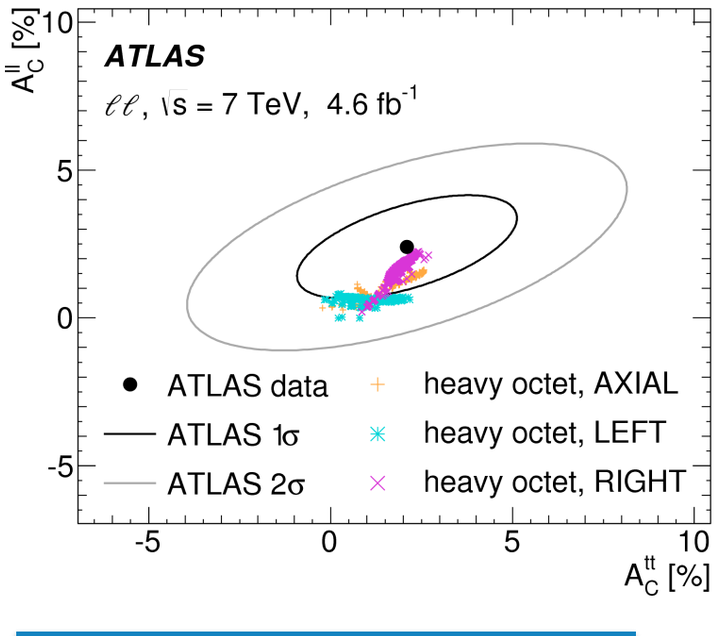
CA Summary

Comparisons with BSM models
compatible with Tevatron results
W′ model strongly disfavoured









arXiv:1509.02358

arXiv:1512.06092

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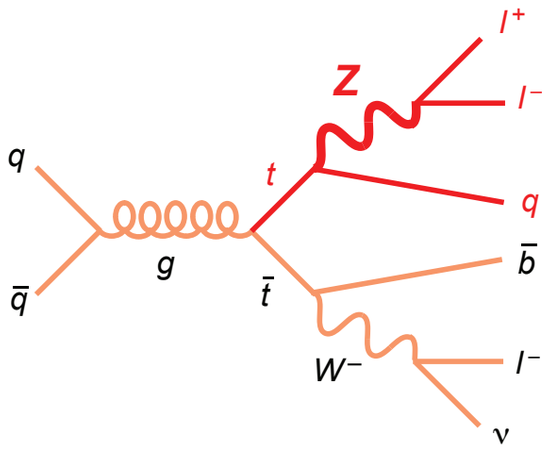
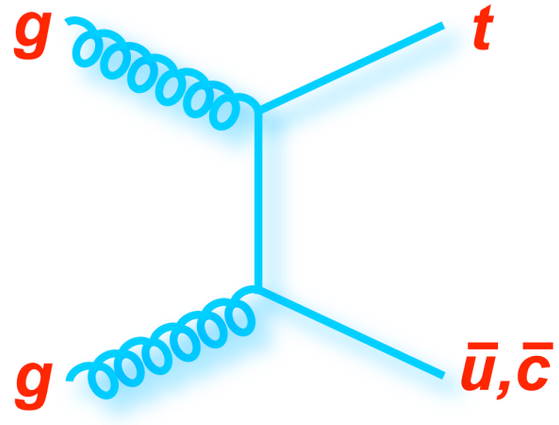
Flavour Changing Neutral Current

FCNC vertices



Highly suppressed in SM
Strong enhancement in BSM possible

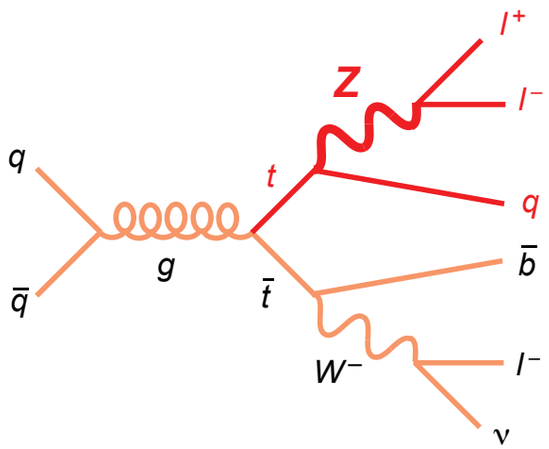


K. Agashe et al., arXiv:1311.2028

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}	$\leq 10^{-5}$	$\leq 10^{-5}$	$\leq 10^{-9}$	$\leq 10^{-4}$

t→Zq @ 8 TeV

Events with 3 leptons, at least 2 jets, at least 1 jet b-tagged, and MET

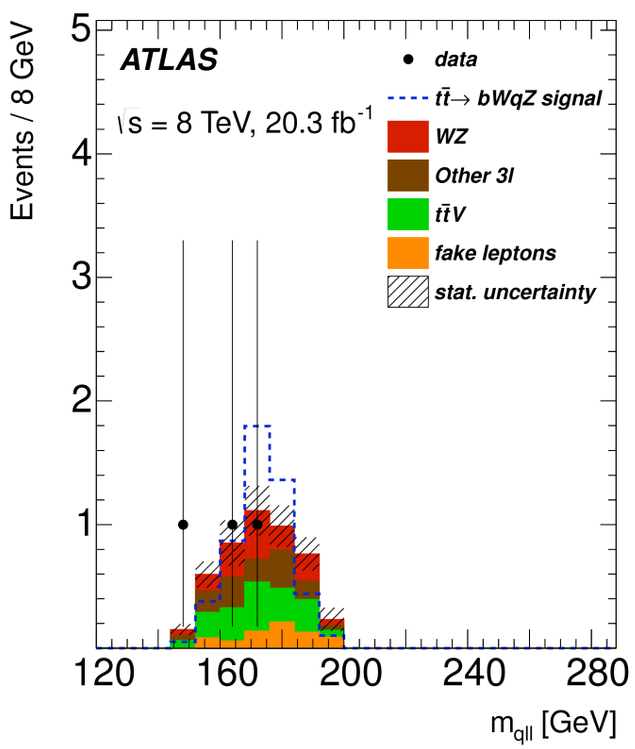


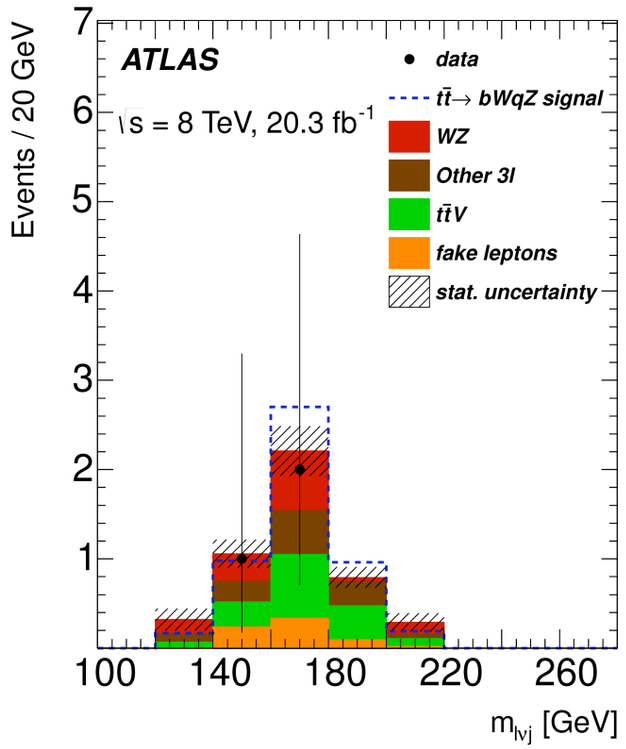
Event reconstruction via χ^2 minimisation

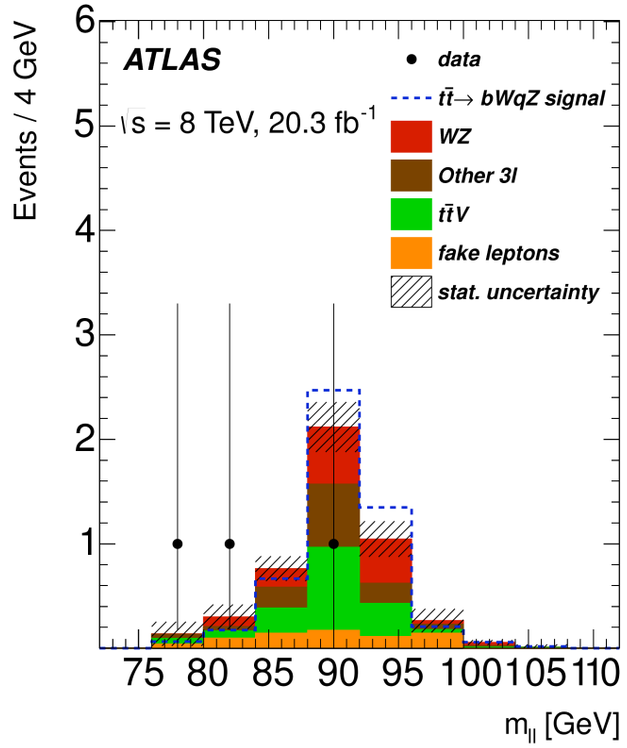
No evidence for signal

BR(t→Zq) < $7 \cdot 10^{-4}$ @ 95% CL

arXiv:1508.05796







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t→Hq @ 7 and 8 TeV

Events with 1 lepton, at least 4 jets (H→bb) and MET

Combination with other Higgs decay modes

No evidence for signal

BR(t→Hu) < 0.46% @ 95% CL

BR(t→Hc) < 0.45% @ 95% CL

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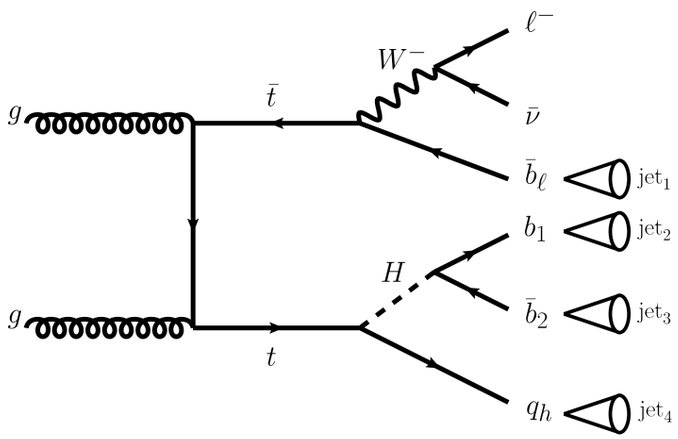
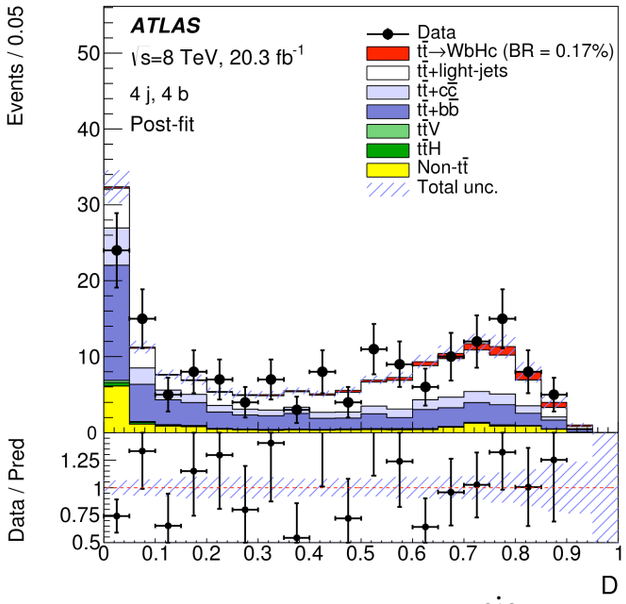
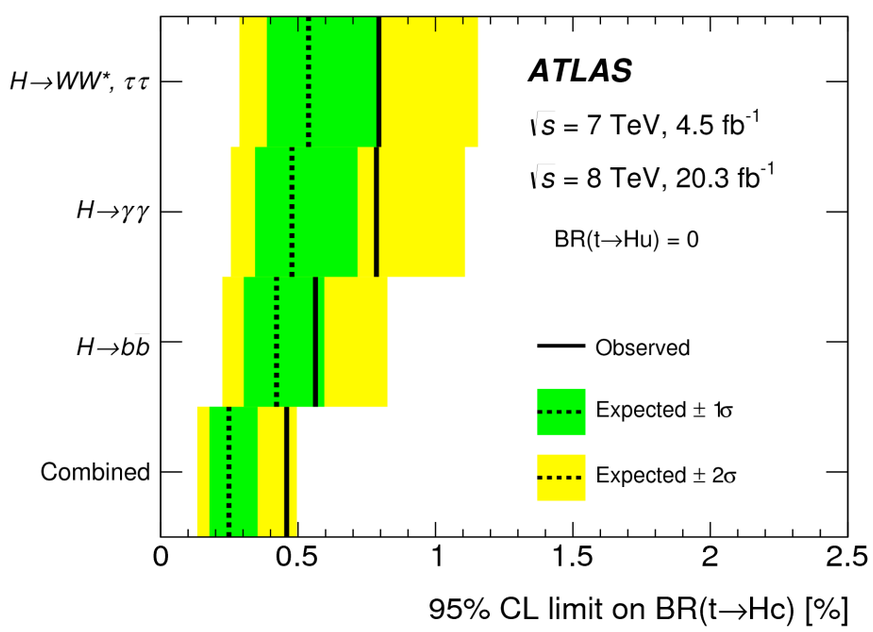
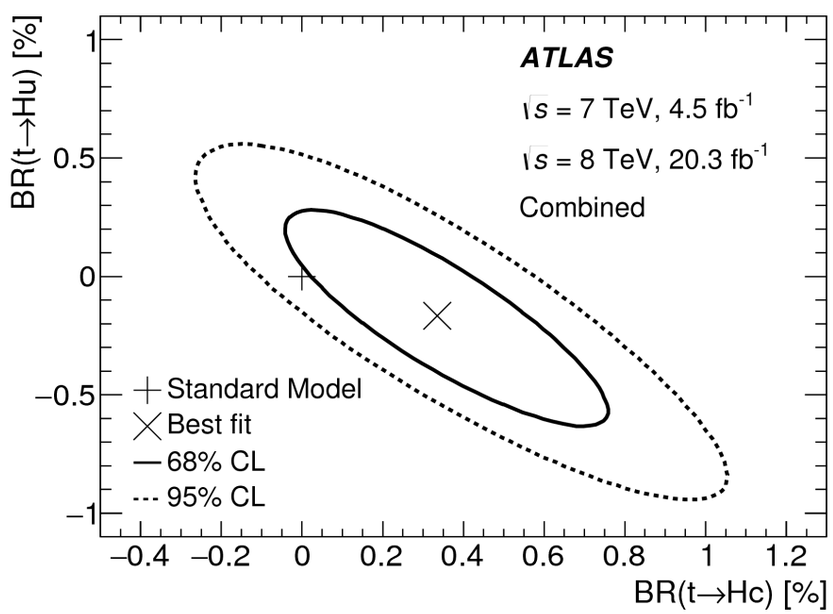


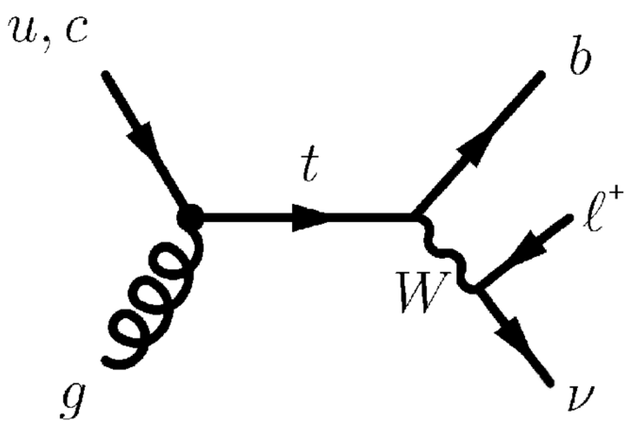


$$D(\mathbf{x}) = \frac{P^{\mathrm{sig}}(\mathbf{x})}{P^{\mathrm{sig}}(\mathbf{x}) + P^{\mathrm{bkg}}(\mathbf{x})}$$





qg→t @ 8 TeV



Events with 1 lepton, 1 jet and MET

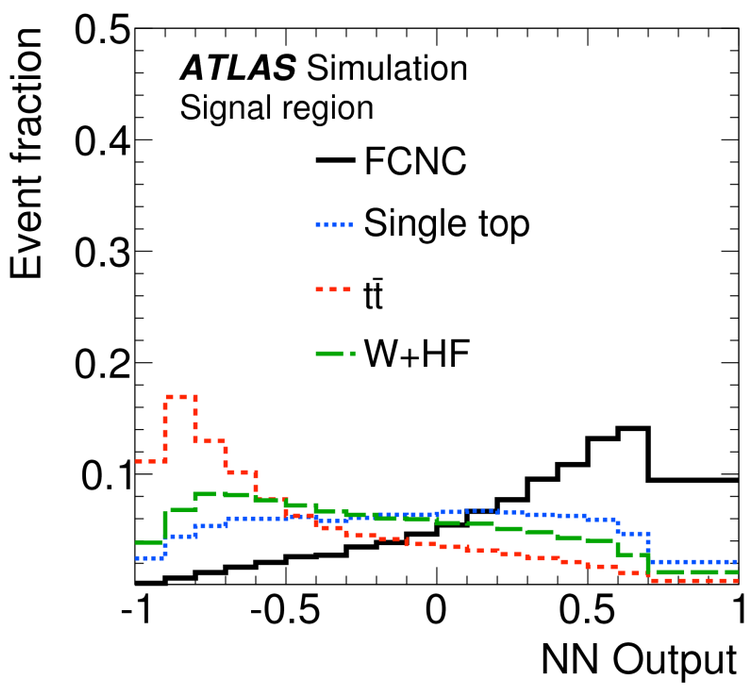
Selection via neural network

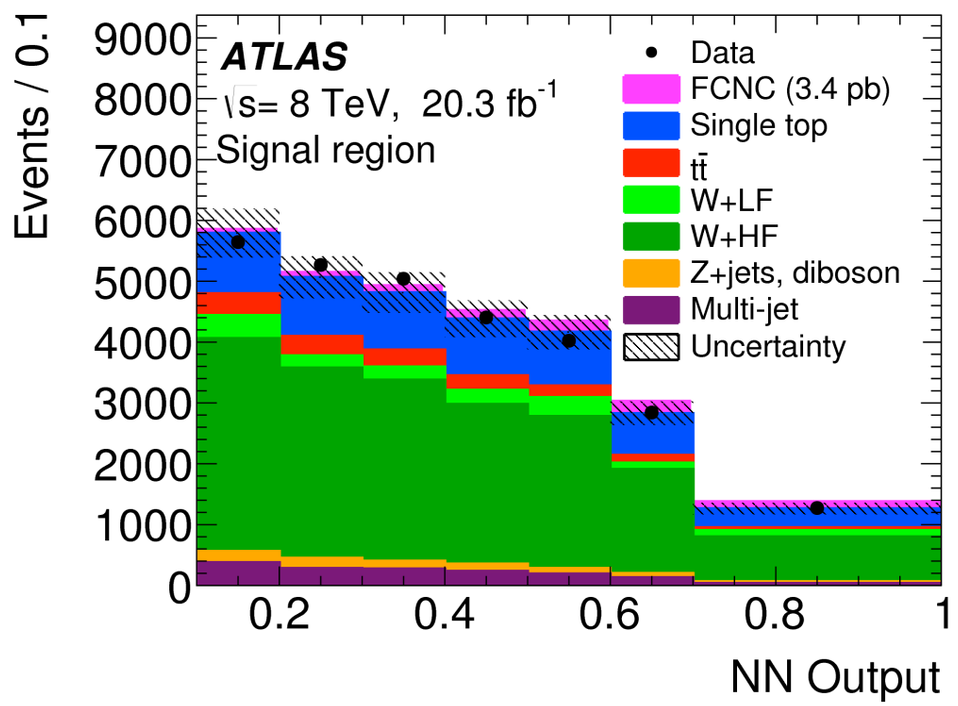
No evidence for signal

BR(t→ug) < 4.0 · 10^{-5} @ 95% CL

BR(t→cg) < 20 · 10^{-5} @ 95% CL

arXiv:1509.00294

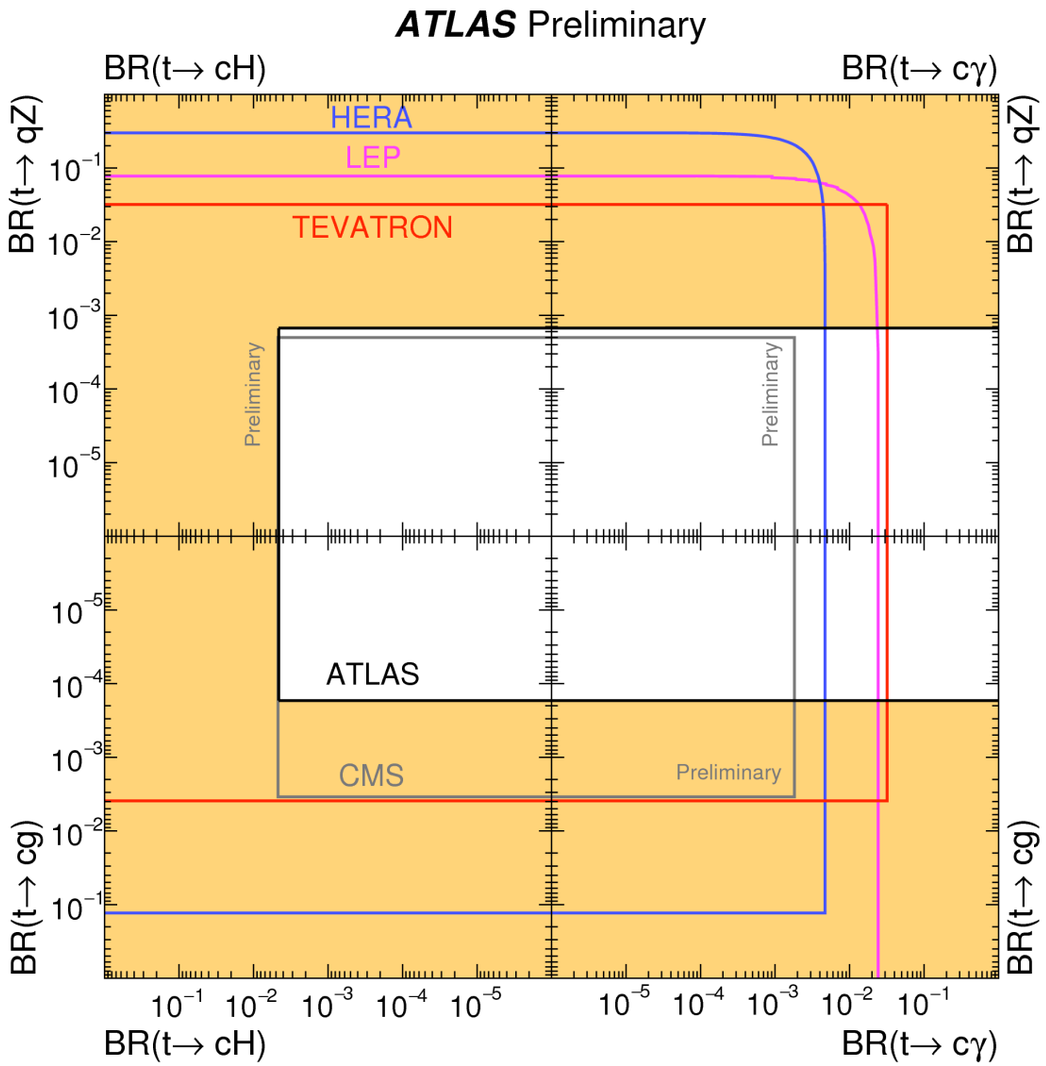




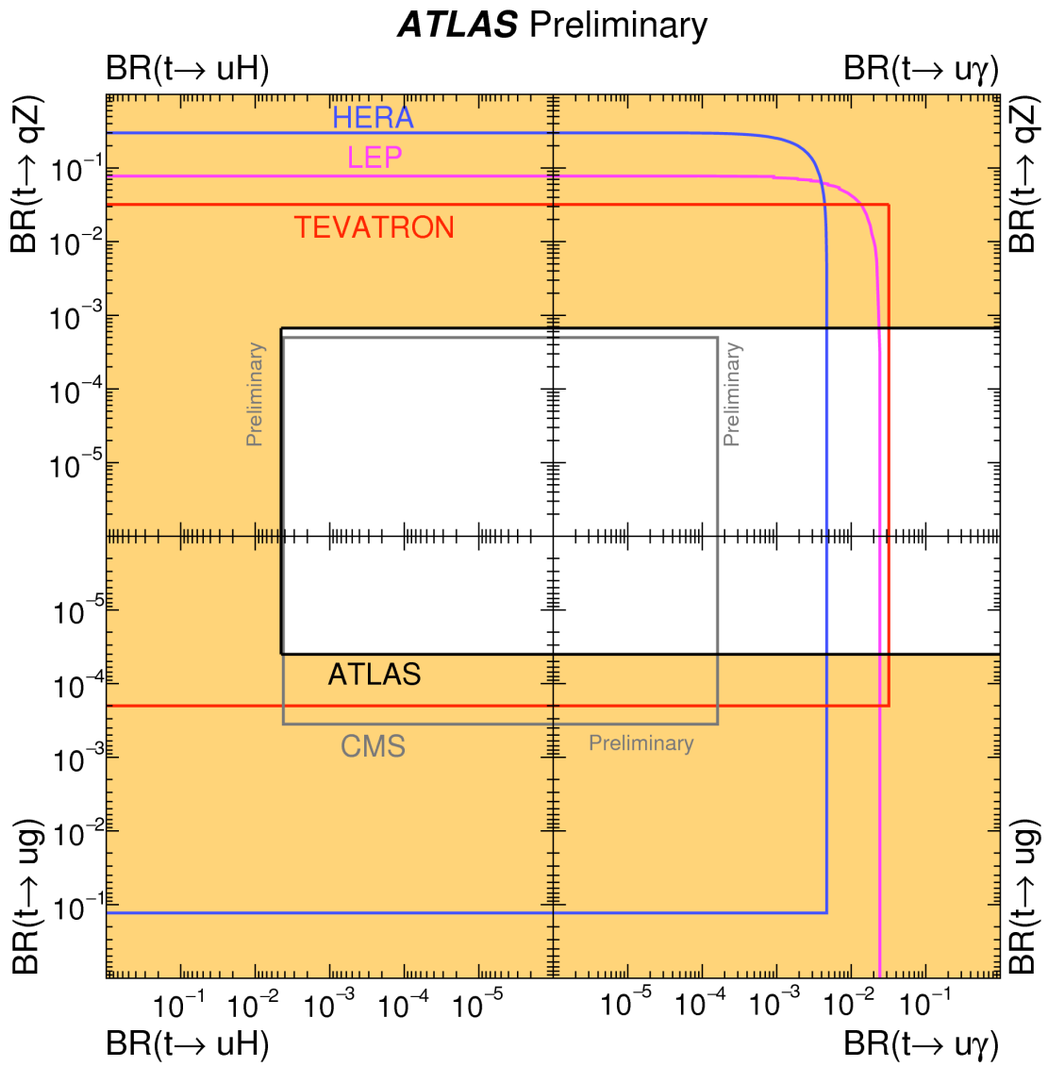
FCNC Summary

Present best FCNC limits

t→cX



t→uX



Anomalous Wtb vertex

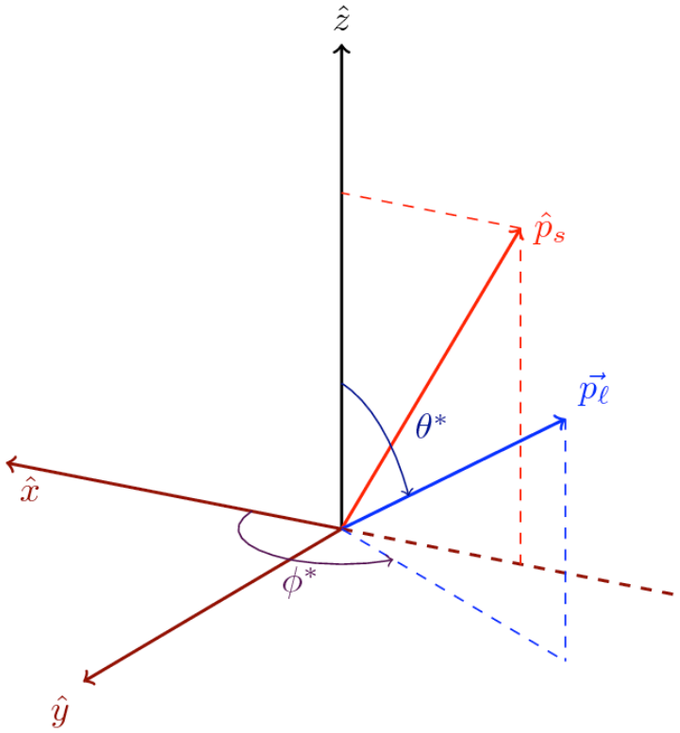
Observables

Effective Lagrangian for the Wtb vertex

$$\mathcal{L}_{Wtb} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}\left(V_{\mathrm{L}}P_{\mathrm{L}} + V_{\mathrm{R}}P_{\mathrm{R}}\right)tW_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{m_{W}}\left(g_{\mathrm{L}}P_{\mathrm{L}} + g_{\mathrm{R}}P_{\mathrm{R}}\right)tW_{\mu}^{-} + \mathrm{h.c.}$$

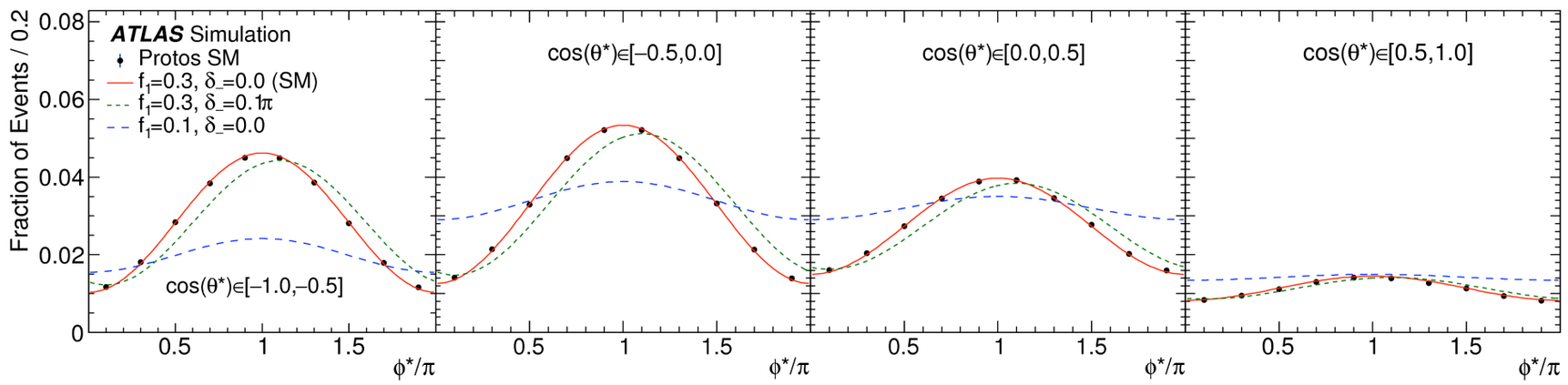
SM: $V_L = V_{tb}$, $V_R = g_{L,R} = 0$

W direction in top rest frame



arXiv:1510.03764

Expectation for different fractions f_1 of transversely polarised W and phases δ_-



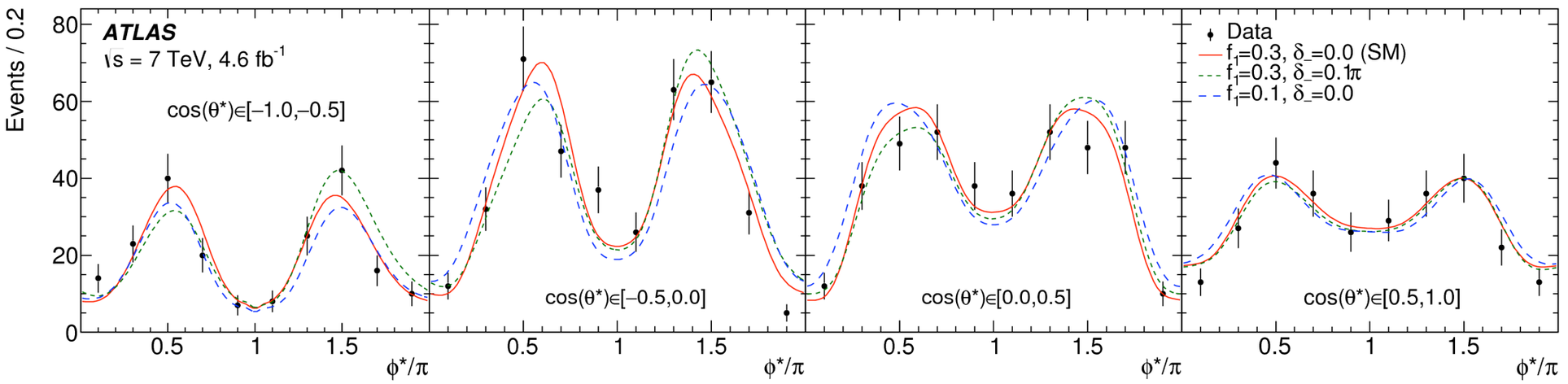
single top @ 7 TeV

Events with 1 lepton, 1 b-jet, 1 forward jet and MET

Cut based background rejection

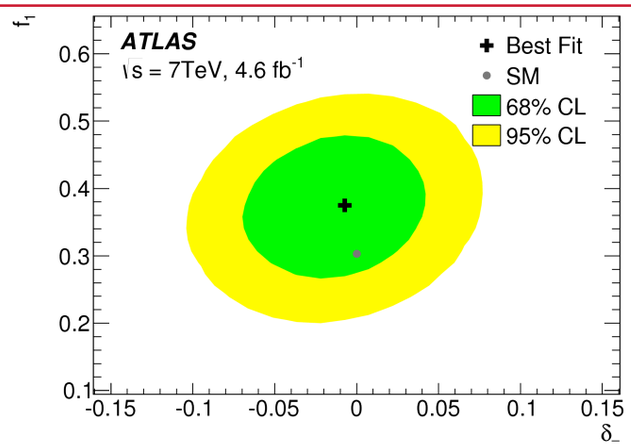
Unbinned likelihood fit

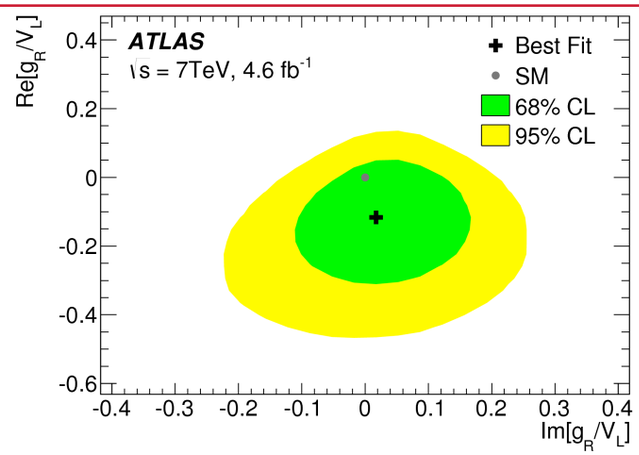
arXiv:1510.03764



$$f_1 = 0.37 \pm 0.05\ (\text{stat.}) \pm 0.05\ (\text{syst.}),$$
$$\delta_- = -0.014\pi \pm 0.023\pi\ (\text{stat.}) \pm 0.028\pi\ (\text{syst.}).$$

$$\text{Re}\left[\frac{g_R}{V_L}\right] \in [-0.36, 0.10] \quad \text{and} \quad \text{Im}\left[\frac{g_R}{V_L}\right] \in [-0.17, 0.23]$$





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… and much more

Further recent results

- For more results see TopPublicResults
- More properties, e.g.:
  - spin correlations: PRL 114 (2015) 142001, arXiv:1510.07478
  - color flow: PLB 750 (2015) 475-493
  - top quark pole mass: JHEP 10 (2015) 121

- More top quark measurements in Giuseppe Salamanna's talk
- More searches for exotic top quark production in Jose Benitez's talk

Conclusions

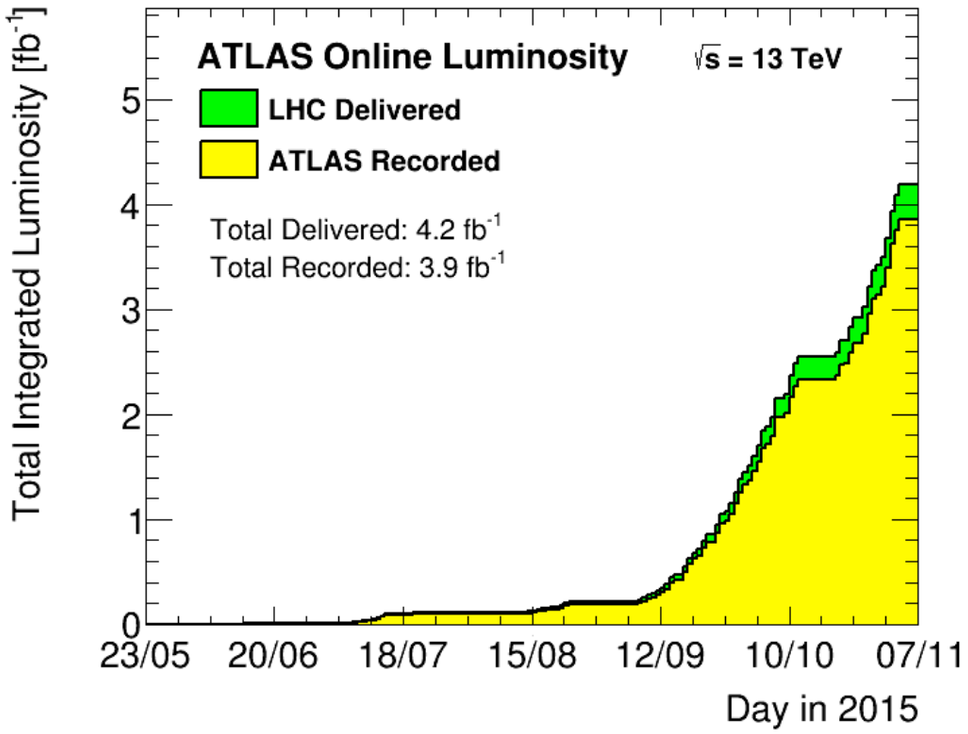
Summary and outlook

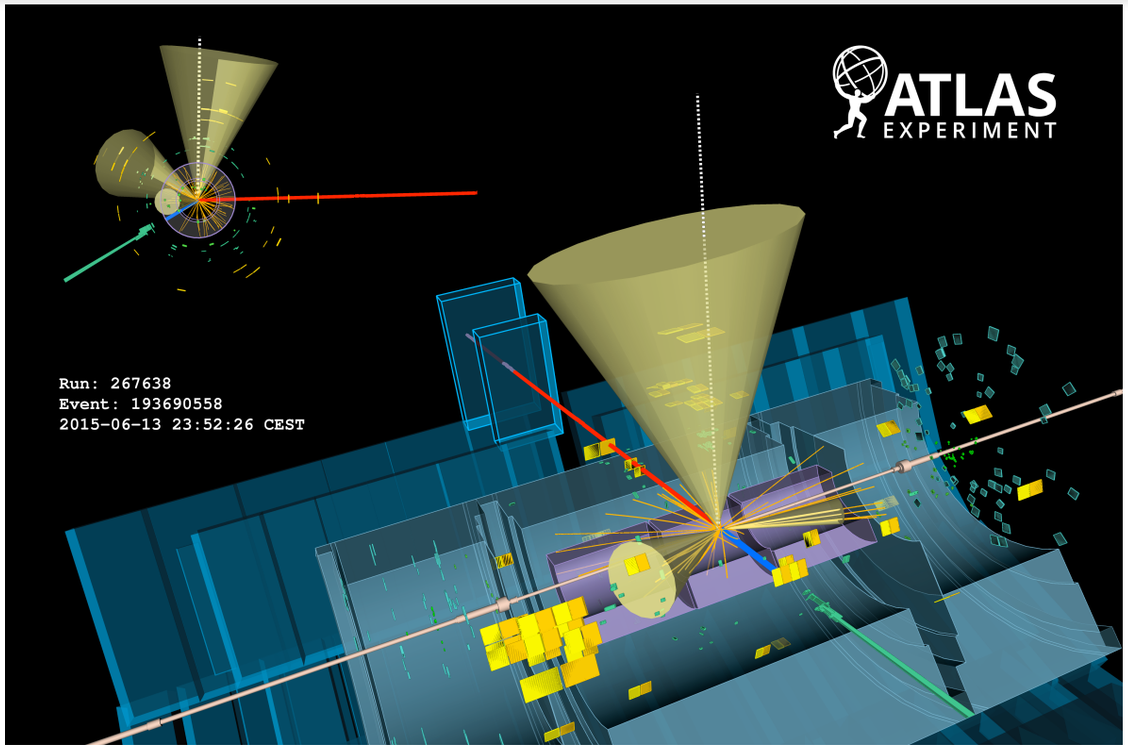
- Millions of top quarks have been produced at the LHC
- Precision measurements of properties and searches for new physics
- In particular: charge asymmetry, FCNC and Wtb vertex structure
- In spite of many direct and indirect searches… no evidence for deviations from SM predictions (yet)

- Boosted topologies to play important role, not only for searches (top tagging techniques already thoroughly exercised)
- Single top t-channel well established in SM, now used for BSM searches and measurements
- More millions of top quarks in Run 2
- Stay tuned for more!

Backup

Run2 performance





ATLAS pp 25ns run: August-November 2015										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
93.5	99.4	98.3	99.4	100	100	100	100	100	100	97.8
All Good for physics: 87.1% (3.2 fb^{-1})										

Luminosity weighted relative detector uptime and good data quality (DQ) efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at √s=13 TeV between August-November 2015, corresponding to an integrated luminosity of 3.7 fb^{-1}. The lower DQ efficiency in the Pixel detector is due to the IBL being turned off for two runs, corresponding to 0.2 fb^{-1}. Analyses that don't rely on the IBL can use those runs and thus use 3.4 fb^{-1} with a corresponding DQ efficiency of 93.1%.