Same-sign dilepton analysis with $14.3\,\mathrm{fb}^{-1}$ @ $8\,\mathrm{TeV}$

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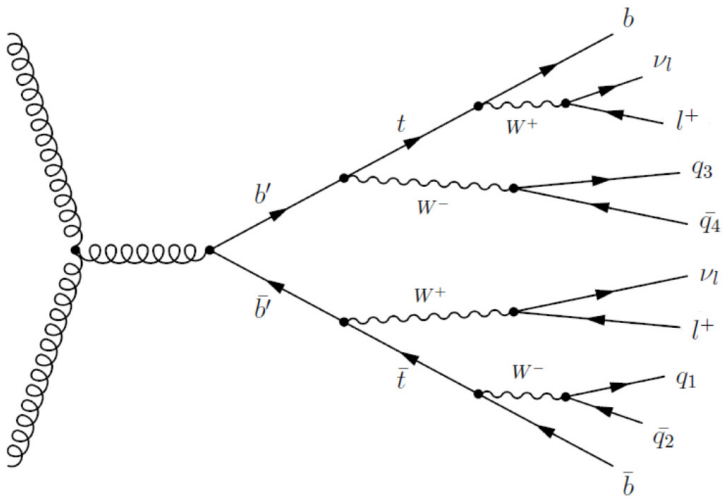
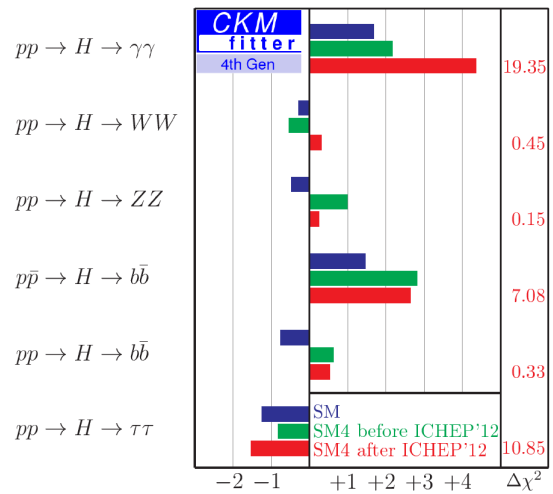
3.12.2013

Fourth generation down-type quark (b')

- Looking for pair production of chiral 4th generation quarks as simple SM extension
- Consider decay: $b' \to tW^- \to bW^+W^-$ (100% BR)
  or $b' \to qW^-$ $(q = u, c, t)$
- Could play interesting role in EW symmetry breaking
- Not excluded in extended Higgs sector (Two-Higgs-doublet models)



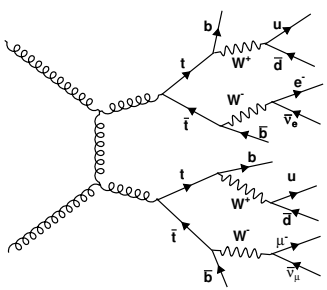
(a) b' pair production and decay



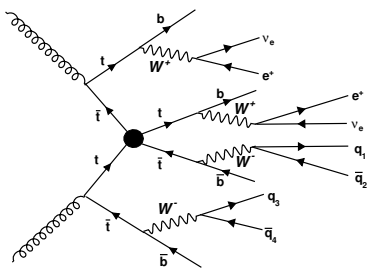
(b) Exclusion of SM4 in presence of Higgs (5.3σ) arXiv:1209.1101

Enhanced four top quark production

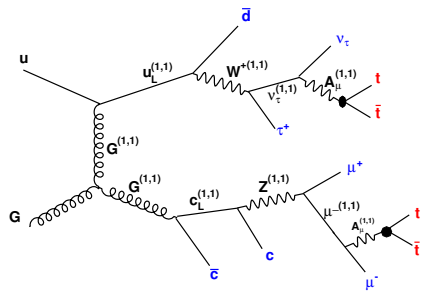
- Looking for enhanced production cross section of four top quarks
- SM prediction is small $(\sim 1\,\mathrm{fb})$
- Several new physics models can increase this cross section
  - Contact interaction
  - Two universal extra dimensions under real projective plane geometry (2UED/RPP) $\rightarrow$ constrain KK mass.
  - Sgluon pair production



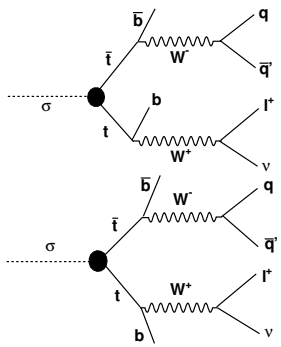
(c) SM



(d) Contact Interaction



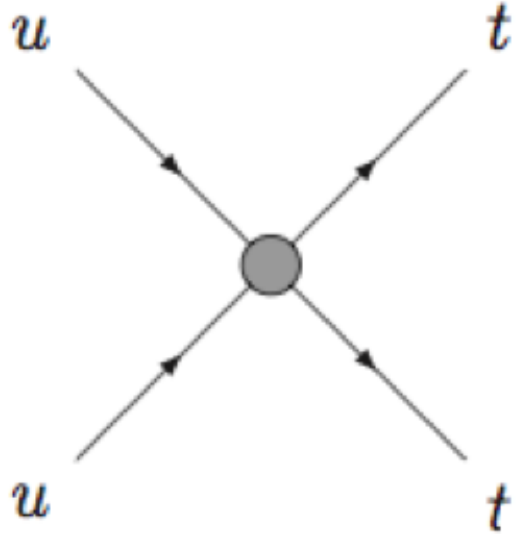
(e) 2UED/RPP



(f) Sgluon pair production

Same-sign top production tt

- Production of same-sign top pairs : only in $uu \to tt$ mediated by a heavy particle exchange (s-/t-channel) `arXiv:1104.1385 [hep-ex]`.



- If new particle mass much larger than electroweak symmetry breaking (EWSB) $\Rightarrow$ effective four-fermion contact interaction:

$$\mathcal{L}_{4F} = \frac{1}{2}\frac{C_{LL}}{\Lambda^2}(\bar{u}_L\gamma^\mu t_L)(\bar{u}_L\gamma_\mu t_L) + \frac{1}{2}\frac{C_{RR}}{\Lambda^2}(\bar{u}_R\gamma^\mu t_R)(\bar{u}_R\gamma_\mu t_R) - \frac{1}{2}\frac{C_{LR}}{\Lambda^2}(\bar{u}_L\gamma^\mu t_L)(\bar{u}_R\gamma_\mu t_R) - \frac{1}{2}\frac{C'_{LR}}{\Lambda^2}(\bar{u}_{La}\gamma^\mu t_{Lb})(\bar{u}_{Rb}\gamma_\mu t_{Ra}) + \text{h.c.}$$

- Proton-proton collider: $\sigma(\bar{u}\bar{u} \to \overline{tt}) \ll \sigma(uu \to tt)$

Vector Like Quarks

- Several extensions to the SM that address the hierarchy problem without SUSY postulate the existence of additional vector-like quarks (VLQ)
- Left and right components transform the same way under weak isospin group
- Allow for a gauge invariant mass term, independent of the Higgs
- Higgs production/decay rates are not effected
- Assumed mixing with quarks of 3^{rd} generation only
- Tree level flavor changing neutral currents arise

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1. Considering pair production of partners of bottom (B) and top (T) quarks.
2. Decay modes:
   - $B \to Wt/Zb/Hb$
   - $T \to Wb/Zt/Ht$
3. For B quark, the signal is indistinguishable from b' if $B \to tW$ is 100%.

Strategy

- We study events with two same-sign charged leptons in the final state
  - $\rightarrow$ rare SM signature
  - $\rightarrow$ possible contributions from BSM physics

Final states

- two same-sign charged leptons
- 2 or more jets (and b-jets)
- high $\not{E}_T$ and $H_T \left(= \sum \left(p_T^{\text{Leptons}} + p_T^{\text{jets}} \right) \right)$

Irreducible backgrounds (MC)

- Diboson WZ/ZZ+jets (Alpgen)
- Diboson $W^{\pm}W^{\pm} + jj$ (MadGraph)
- $t\bar{t} + W(+j)$, $t\bar{t} + Z(+j)$, $t\bar{t} + WW$ (MadGraph)

Lepton fakes and Charge MisId (data-driven)

- Lepton mis-reconstruction (Fakes)
  - using "matrix method"
- Electron charge mis-identification (Charge MisId)
  - measuring Charge MisId rate in same-sign events within Z-peak
  - reweighting OS events and treat as SS
  - correcting for overlap with fakes

- Top Common Object selection

Electrons

- $E_T > 25\,\mathrm{GeV}$
- $|\eta| < 2.47$, excluding $1.37 < |\eta| < 1.52$
- Isolated

Jets

- $p_T > 25\,\mathrm{GeV}$ and $|\eta| < 2.5$

Muons

- $p_T > 25\,\mathrm{GeV}$
- $|\eta| < 2.5$
- Combined muon (ID + MS)
- Mini-isolated

b -Jets

- Using a neuronal network (MV1)
- Working point 70%

Event preselection

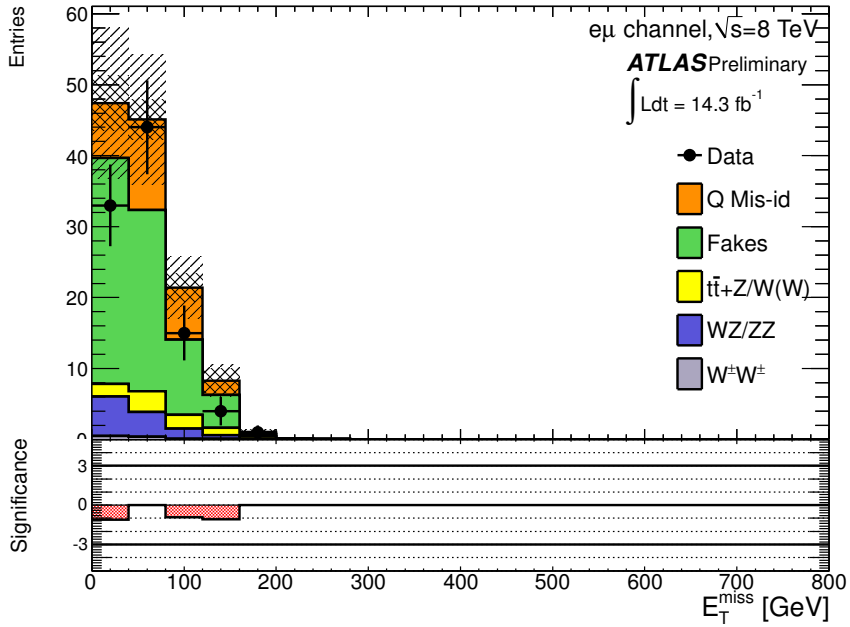
- Single lepton trigger & Good Run List (data)
- Cosmic rejection and e/μ overlap rejection
- Invariant mass ($ee/\mu\mu$ events)
  - Z-veto: $|m_{inv} - m_Z| > 10\,\mathrm{GeV}$
  - $m_{inv} \geq 15\,\mathrm{GeV}$

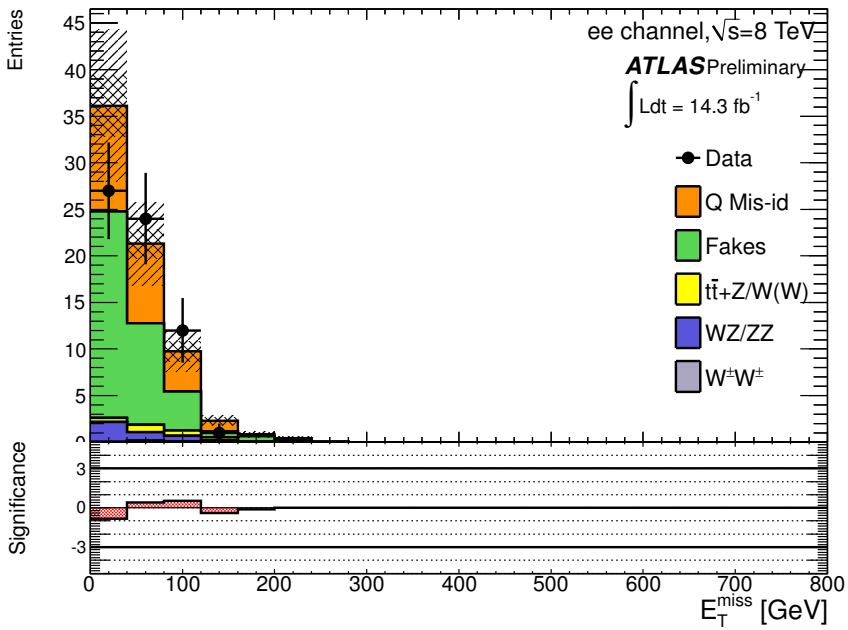
Additinal selection (optimized, based on expected limit)

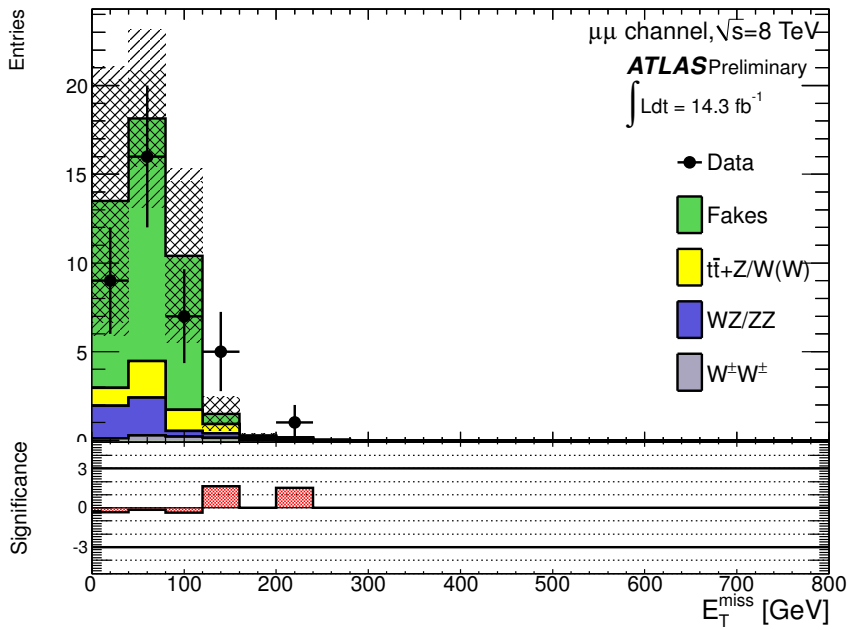
- Exactly two same-sign leptons
  - Classification into $ee/e\mu/\mu\mu$
- $\not{E}_T \geq 40\,\mathrm{GeV}$, $H_T \geq 650\,\mathrm{GeV}$
- $N_{\text{jets}} \geq 2$, $N_{b\text{Jets}} \geq 1$ (b-tagging)

Control Region

- Same-sign dileptons
- Event preselection
- $100\,\mathrm{GeV} < H_T < 400\,\mathrm{GeV}$
- No $\not{E}_T$ cut
- $N_{\mathrm{Jets}} \geq 2$, $N_{b\mathrm{Jets}} \geq 1$







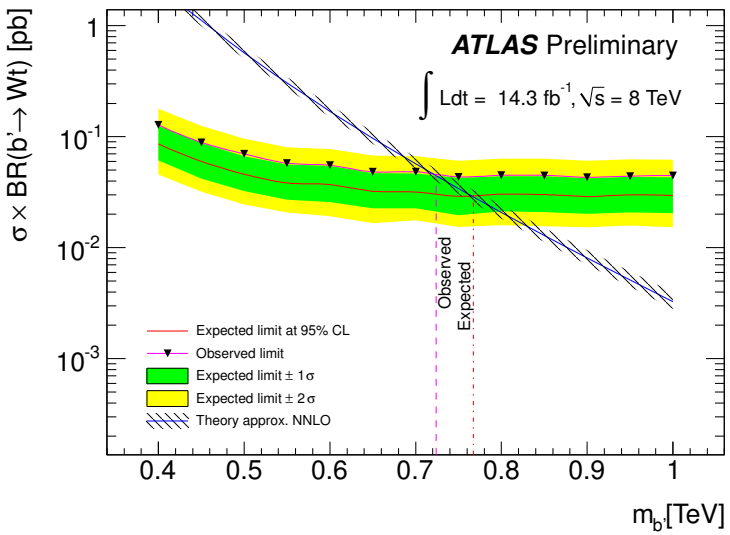
Expected yields and observed data in signal region

Backgrounds	Channel		
Samples	ee	$e\mu$	$\mu\mu$
Q MisId	$0.6 \pm 0.1 \pm 0.2$	$0.9 \pm 0.1 \pm 0.3$	—
Fakes	$0.8 \pm 0.4 \pm 0.3$	$0.2 \pm 0.4 \pm 0.1$	< 1.1
Diboson			
• WZ/ZZ+jets	$0.3 \pm 0.2 \pm 0.1$	$0.3 \pm 0.1^{+0.4}_{-0.2}$	$0.4 \pm 0.2 \pm 0.1$
• $W^{\pm}W^{\pm}$+2 jets	$0.17 \pm 0.09 \pm 0.05$	$0.3 \pm 0.2 \pm 0.1$	$0.2 \pm 0.1 \pm 0.1$
$t\bar{t} + W/Z$			
• $t\bar{t}W$(+jet(s))	$0.6 \pm 0.2 \pm 0.3$	$1.9 \pm 0.2 \pm 0.6$	$1.3 \pm 0.2 \pm 0.4$
• $t\bar{t}Z$(+jet(s))	$0.18 \pm 0.03 \pm 0.06$	$0.66 \pm 0.05 \pm 0.22$	$0.31 \pm 0.04 \pm 0.10$
• $t\bar{t}W^+W^-$	$0.024 \pm 0.003^{+0.010}_{-0.007}$	$0.072 \pm 0.005^{+0.028}_{-0.020}$	$0.055 \pm 0.004^{+0.022}_{-0.016}$
Total	$2.7 \pm 0.5 \pm 0.4$	$4.4 \pm 0.5^{+0.9}_{-0.7}$	$2.3 \pm 1.2 \pm 0.5$
$b' \to tW(800\,\mathrm{GeV})$	1.1 ± 0.069	3.1 ± 0.12	1.9 ± 0.095
Observed	3	10	2

- Uncertainties shown (BG): yield $\pm$ stat. $\pm$ syst.
- Uncertatnties shown (Signal): yield $\pm$ stat.

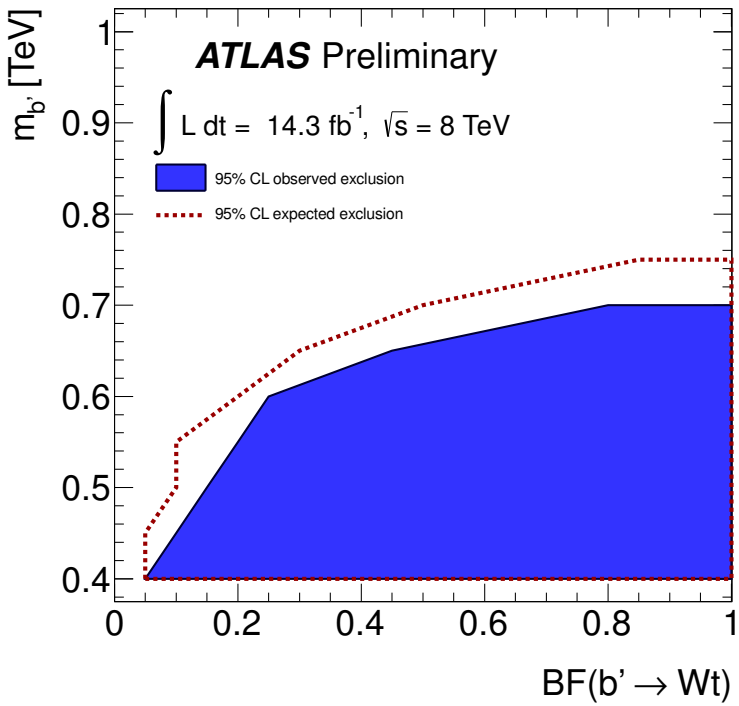
Limit on b'

Left: Limits assuming 100% branching fraction of $b' \to Wt$
Right: Limits set as a function of $b' \to Wt$ branching fraction



Observed limit: $m_{b'} \geq 0.72$ TeV

Expected limit: $m_{b'} \geq 0.77$ TeV

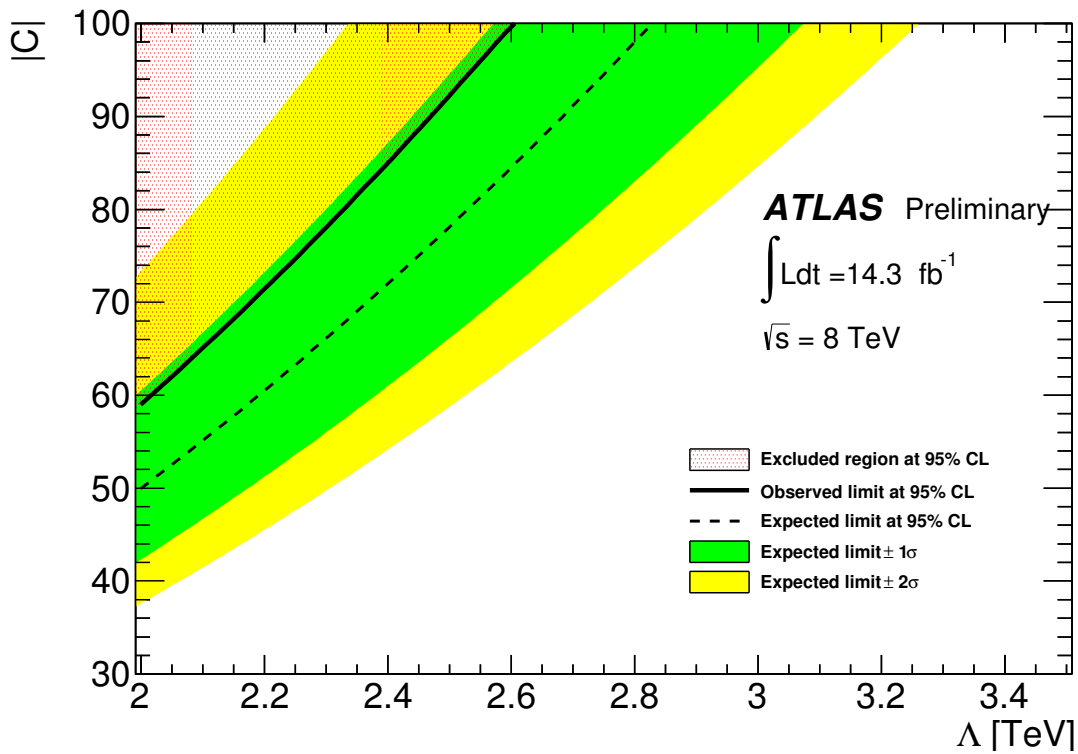


Limit on $t\bar{t}t\bar{t}$

Limits for SM and a general four-fermion contact interaction with coupling strength C/Λ^2

	95% C.L. upper limit [fb]	
Process	Expected 1σ range	Observed
Standard Model	43-89	85
Contact interaction	29-61	59

Expected and observed limits on $m_B\sigma(pp \to t\bar{t}t\bar{t})$

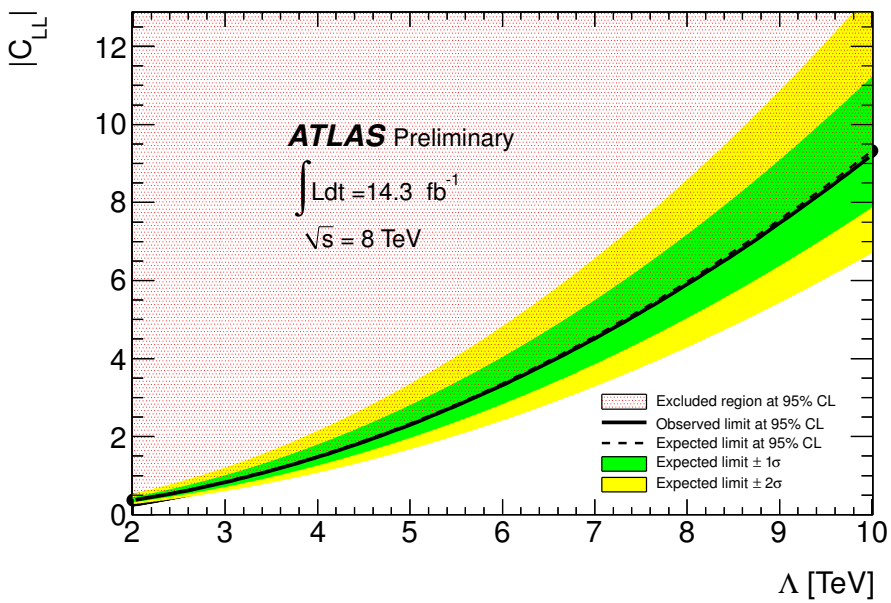


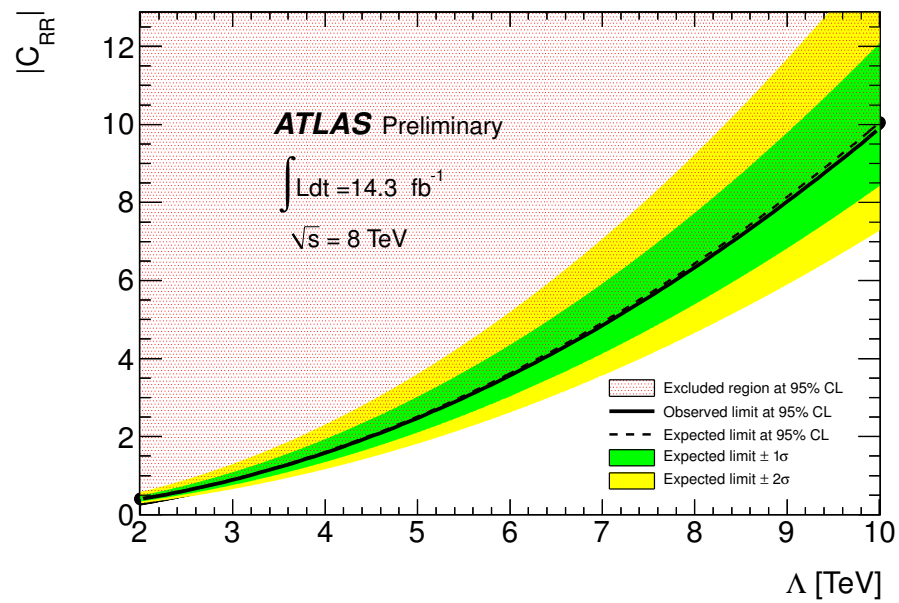
Limit on tt

Limits for an effective four-fermion contact interaction, for three different chirality configurations. The coupling strength is respectively C_{LL}/Λ^2, C_{LR}/Λ^2, and C_{RR}/Λ^2

	95% C.L. upper limit [pb]	
Chirality configuration	Expected 1σ range	Observed
Left-left	0.14-0.28	0.19
Left-right	0.15-0.30	0.20
Right-right	0.15-0.32	0.21

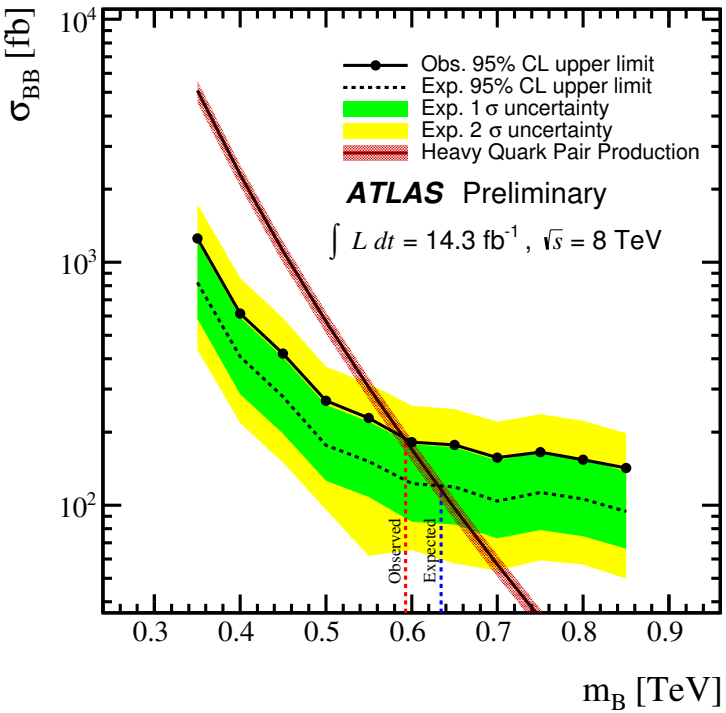
Expected and observed limits on the same-sign top quark signal production cross-section $m_B\sigma(pp \to tt)$.

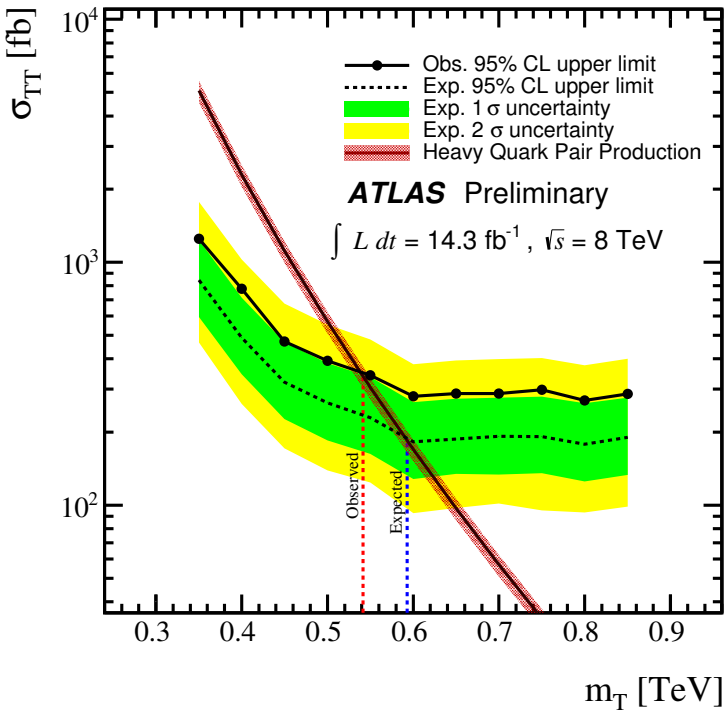




Limit on VLQ

Limits for B/T singlets in the most natural scenario (arXiv:0907.3155)





Observed limit: $m_B \geq 0.59$ TeV

Expected limit: $m_B \geq 0.63$ TeV

Observed limit: $m_T \geq 0.54$ TeV

Expected limit: $m_T \geq 0.59$ TeV

Summary

- Using partial 2012 data set ($\mathcal{L} = 14.3\,\mathrm{fb}^{-1}$) at $8\,\mathrm{TeV}$
- Observed no significant excess $\rightarrow$ setting limits
  1. $b' \rightarrow Wt$
     - $m_{b'} \geq 0.72$ TeV

     Also produced limits as a function of the $b' \rightarrow Wt$ branching fraction
  2. VLQ (for B/T singlets in the most natural scenario)
     - $m_B \geq 0.59$ TeV
     - $m_T \geq 0.54$ TeV

     Also produced limits for different branching ratios in a 2D plane
  3. Same-sign top pair
     - Left-left chirality: $\sigma(uu \rightarrow tt) < 0.19$ pb
     - Left-right chirality: $\sigma(uu \rightarrow tt) < 0.20$ pb
     - Right-right chirality: $\sigma(uu \rightarrow tt) < 0.21$ pb
  4. Four tops:
     - SM: $\sigma(pp \rightarrow t\bar{t}t\bar{t}) < 85$ fb
     - Contact interaction: $\sigma(pp \rightarrow t\bar{t}t\bar{t}) < 59$ fb
     - Sgluon: $m_\sigma \geq 0.80$ TeV
     - 2UED/RPP: $m_{KK} \geq 0.90$ TeV

CONF note: ATLAS-CONF-2013-051

Considered systematics

- Lepton energy scale, SF ($< 2\%$)
- Jets: JES ($< 11\%$), JER, reco eff. ($< 3\%$), JVF SF ($< 3\%$), b-tag SF ($< 5\%$)
- $\not{E}_T$: Cell, PileUp ($< 1\%$)

- Luminosity: 3.6%
- Diboson (WZ/ZZ +jets) cross-section: 34%
- $W^{\pm}W^{\pm} + jj$ cross-section: 25%
- $t\bar{t} + W + j$ cross-section: 30%
- $t\bar{t} + Z + j$ cross-section: 50%
- $t\bar{t} + WW$ cross-section: +38%/ - 26%

- b cross-section: HATHOR ($< 20\%$)
- PDF: +1%/ - 0.9% estimated from reweighting method
- Parton shower: 6% estimated from More/Less PS samples

- Lepton fakes: 10%/2%/10% ($ee/e\mu/\mu\mu$)
- QMisId: 7% estimated from difference between QMisId methods yields