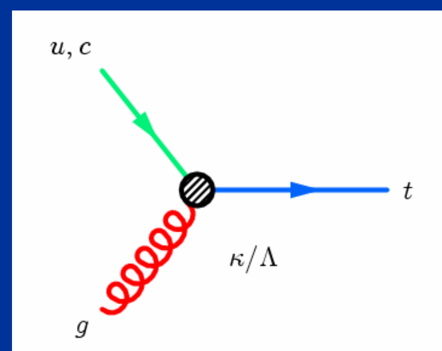
Search for anomalous FCNC single top quark production with ATLAS



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Motivation

- At the LHC, top physics is important:
  - Check SM prediction (e.g. single top, quantum no.)
  - Good understanding essential (top as background)
  - Probing new physics
- In SM, flavour-changing neutral current (FCNC) involving top quarks is extremely suppressed; occurs only at one-loop order due to GIM mechanism, e.g. $B(t \to cg) \sim 10^{-12}$.
- Many new physics model predicts much larger FCNC interaction rate – a few orders of magnitude.
- Hence there's an increase in the top production cross section as well as FCNC decay branching.

Ref [1], q = u,c	SM	2-Higgs doublet model	MSSM	R̸-MSSM
B($t \to q\, g$)	5 x 10^{-12}	~ 10^{-4}	~ 10^{-4}	~ 10^{-3}
B($t \to q\, \gamma$)	5 x 10^{-14}	~ 10^{-7}	~ 10^{-6}	~ 10^{-5}
B($t \to q\, Z$)	~ 10^{-14}	~ 10^{-6}	~ 10^{-6}	~ 10^{-4}

[1] hep-ph/0605003

- My study: to estimate sensitivity of ATLAS detector to anomalous FCNC single top production $u(c) + g \to t$.
- Tools:
  - TopReX 4.10, Pythia 6.2
  - ATLFAST

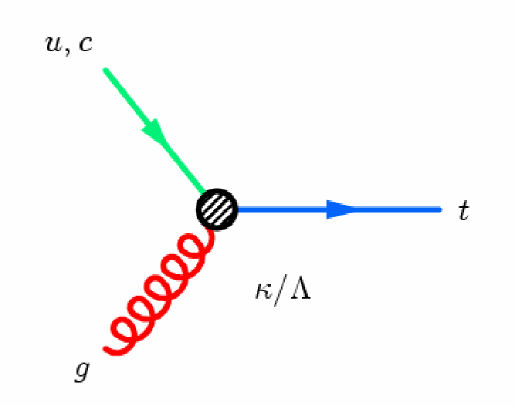
  (Athena 10.0.1)

Model independent approach

- Since we don't know which model is correct, a useful way is to adopt a model-independent approach using effective Lagrangians.
- For anomalous couplings of top to gluon and up/charm quarks, the strength is given by κ/Λ as in

$$\mathcal{L}_{tq}^{g} = -g_s \frac{\kappa_{tq}^{g}}{\Lambda} \bar{t}\, \sigma^{\mu\nu} T^a (f_{tq}^{g} + i h_{tq}^{g} \gamma_5)\, q\, G_{\mu\nu}^{a} + \text{H.c.}$$

κ_{qg} = anomalous coupling strength
Λ = scale of new physics



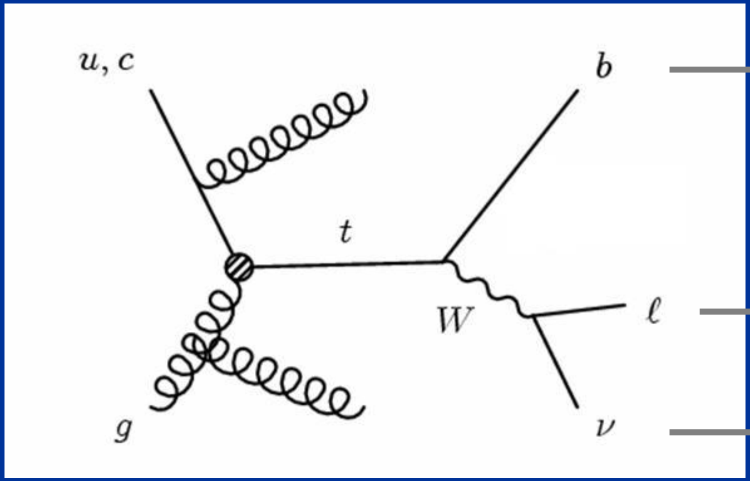
Current constraints

	LEP2	Tevatron	HERA
B($t \to q\, g$)	< 17 %	< 29%	< 13% [2]
B($t \to q\, \gamma$)	< 3.2%	< 3.2% (CDF)	< 0.66%
B($t \to q\, Z$)	< 7%	< 32% (CDF)	-

[2] hep-ph/0604119

Signal

- Signal at tree level: ug/cg $\rightarrow$ t -> bW $\rightarrow$ b ℓ ν.



B-tagged jet

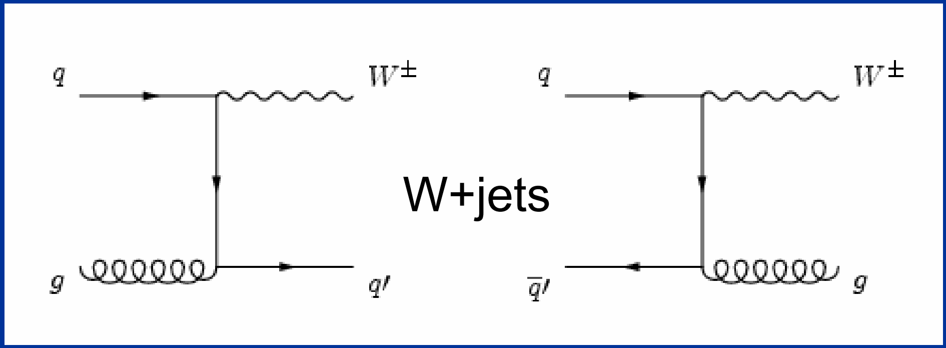
Isolated lepton

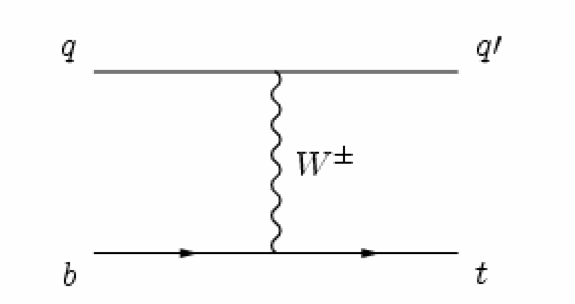
Missing pT

- After reconstructing the top, count top event within a mass window, e.g. 140−190 GeV (adopted here). Look for excess.
- For $\kappa_{gq}/\Lambda = 0.1\ \text{TeV}^{-1}$ (used in simulation):
  - $\sigma(u + g \rightarrow t) \approx 76$ pb (incl. $\bar{t}$)
  - $\sigma(c + g \rightarrow t) \approx 15$ pb
- Cross section scales as $(\kappa/\Lambda)^2$ for $\kappa_{gq}/\Lambda <$ ~0.2 TeV^{-1}

Background

- Background:
  - W + n jets (n=1,2,3,…)
  - EW t-chan. single top
- Less problematic:
  - $Wb\bar{b}$
  - $t\bar{t}$
  - $Wc\bar{c}$
- Negligible:
  - Wt- and s-channels single top





(a) t-channel

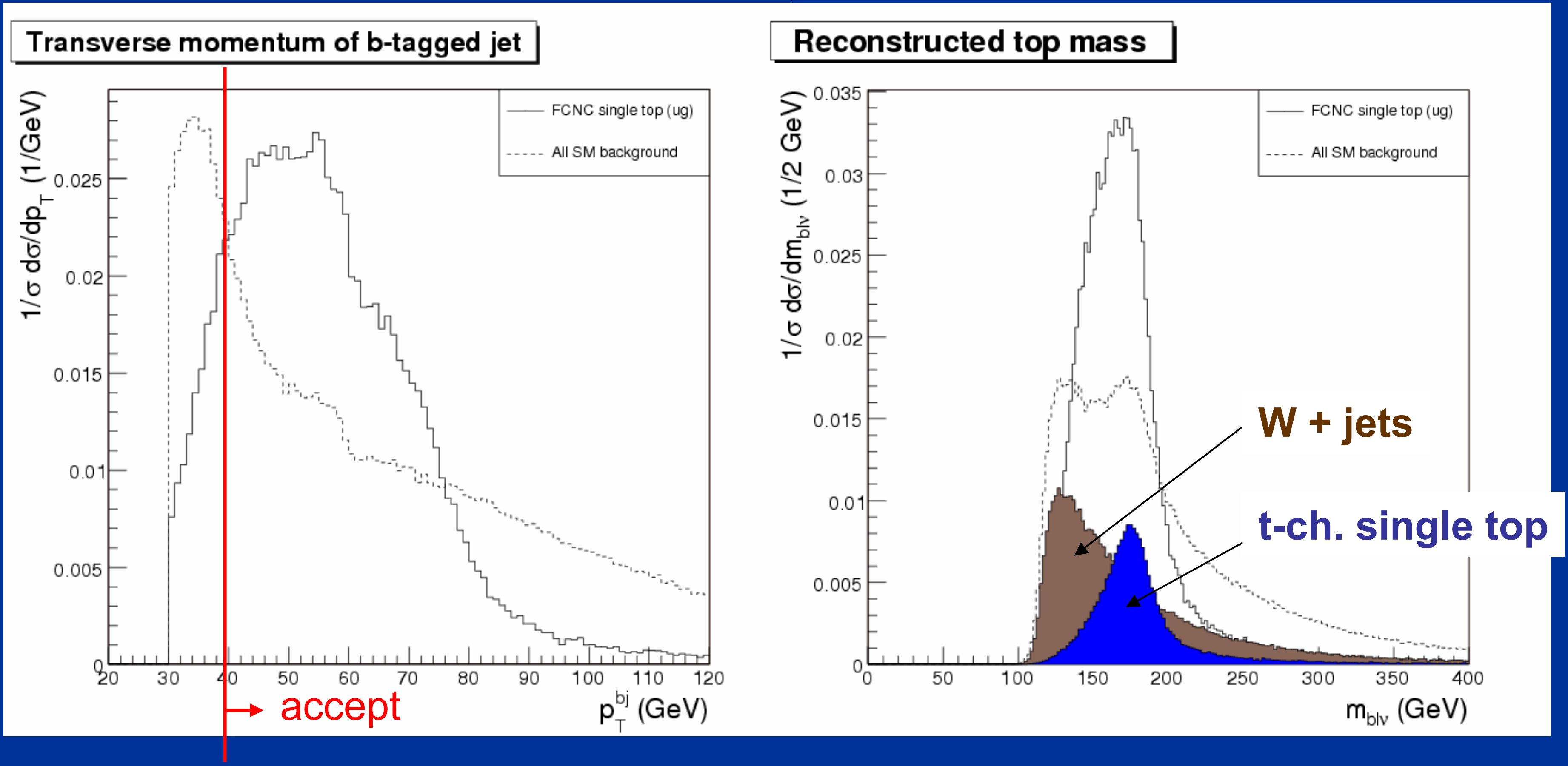
Event selection

- Basic cuts
  - Exactly 1 isolated lepton (e/mu), pT > 20 GeV
  - Exactly 1 b-tagged jet, pT > 30 GeV (and leading)
  - Missing pT > 20 GeV

- Further, optimized cuts
  - B-jet pT > 40 GeV
  - Reconstructed top, pT < 20 GeV
  - Inv. mass (bjet,lep) > 55 GeV
  - HT (Scalar sum of pT of lepton, all jets, ptmiss) < 270 GeV
  - W pT > 30 GeV
  - $\Delta R\ (b, W^{rec}) < 4.0$

Kinematics plots

After basic cuts…



mtop window 140−190 GeV

After cuts…

Process	Accept. eff.	σ (before) pb	σ (after)	$n/10fb^{-1}$	
ug	1.04 %	76.12	0.80	8022	S ~10k
cg	1.74 %	15.33	0.27	2701	B ~100k
W+j	0.09 %	8971.00	7.68	76805	**81 %**
ewt-t	0.38 %	246.60	0.94	9407	**10 %**
$Wb\bar{b}$	0.57 %	71.14	0.41	4073	4 %
$t\bar{t}$	0.03 %	886.00	0.23	2320	2 %
$Wc\bar{c}$	0.07 %	263.20	0.17	1729	2 %
ewt-tW	0.13 %	51.57	0.06	646	0.7 %
ewt-s	0.25 %	10.65	0.03	261	0.3 %

Note: Cross section for W+j, Wbb, Wcc include B(W->e/mu)

Sensitivity

- Sensitivity of ATLAS is estimated for 10 fb^{-1} (1 yr LHC, 10^{33} cm^2s^{-1}) assuming equal anomalous coupling for top-gluon to u and c quarks.
- Estimator for signal significance = $S/\sqrt{B}$.
- 5σ discovery is possible if κ_{qg}/Λ is as large as 0.038 TeV^{-1}, corresponding to FCNC branching of 2.60 x 10^{-3}.
- In absence of signal, we can set an upper limit, $\kappa_{qg}/\Lambda < 0.022$ TeV^{-1} at 95% CL, corr. to FCNC branching of 8.56 x 10^{-4}.

	5σ	95 %CL
$\kappa(gq)/\Lambda$	> 0.038 TeV^{-1}	< 0.022 TeV^{-1}
$B(t \rightarrow qg)$	> 2.60 x 10^{-3}	< 8.56 x 10^{-4}

Current limit: < 13%

Systematic uncertainties

- Physics + modelling
  - Q-scales dependence
  - Choice of PDF
  - Input top mass
  - ISR/FSR
  - B-quark fragmentation

  (Q-scales dependence, Choice of PDF, Input top mass: $\Delta\sigma$, rate only)
- Detector performance
  - B-tagging
  - Jet energy scales (JES)
- Other systematic effects
  - Pile up
  - Luminosity measurement ΔL

Cross section uncertainty, $\Delta\sigma$

PS MC with LO ME **NLO σ**

ug	cg	Wj	$Wb\bar{b}$	$Wc\bar{c}$	tW	t	s	$t\bar{t}$
+16.4 −15.4 %	+16.9 −16.3 %	+15.4 −14.3 %	+28.4 −22.4 %	+28.8 −22.8 %	+29.2 −29.2 %	+3.76 −4.12 %	+6.08 −6.03 %	+12.3 −12.3 %

Result on ΔBR

	Systematics	ΔBR
rate only	$\Delta\sigma$ (signal)	+ 16.6% − 15.6%
	$\Delta\sigma$ (bgnd)	+ 6.6% − 6.2%
	Δ lumi. (±5%)	± 2.5%
rate + shape	ISR (20% on/off)	± 3.6%
	FSR (20% on/off)	± 6.0%
	B-fragmentation (ε_b= − 0.0035)	± 1.0%
	B-tag (±10%)	+ 12.8% − 4.8%
	JES (b-jet, ±3%)	+ 1.6% − 0.8%
	JES (light-jet, ±1%)	± 0.0%
	Pile up (low lumi.)	+ 8.0%
	Total sys. unc.	**+ 24.6%** **− 19.0%**

$B(t \to qg) < 8.56 \times 10^{-4}$ (95%CL)

$\Delta B(sys) = (+2.1 - 1.6) \times 10^{-4}$

ΔB(MC stat) = 0.64%

$= \pm 0.055 \times 10^{-4}$

(smaller for real data)

Note: $\Delta\kappa$ is half as B ~ κ^2

Conclusion

- This fast simulation study suggests that, given 10 fb^{-1}, ATLAS can set limit on FCNC top decay:

  $B(t \rightarrow qg) < 8.56 \pm 0.055$ (MC stat) $+2.1-1.6$ (sys) x 10^{-4} @ 95%CL

  i.e. 2 orders of magnitude better than current limit (< 0.13).
- Results reported in comm. ATL-COM-PHYS-2006-056; waiting for approval, comments welcomed!
- Cf. result from top FCNC decay in $t\bar{t}$:

  $B(t \rightarrow qg) < 1.4$ x 10^{-3} @ 95%CL [ATL-PHYS-PUB-2005-009]
- Follow-up work needed (any interest?):
  - Full detector simulation
  - More sophisticated analysis technique beyond simple-cuts: statistical techniques (e.g. maximum likelihood), sideband.
  - NLO (i.e. 2→ 2) simulation for signal processes.