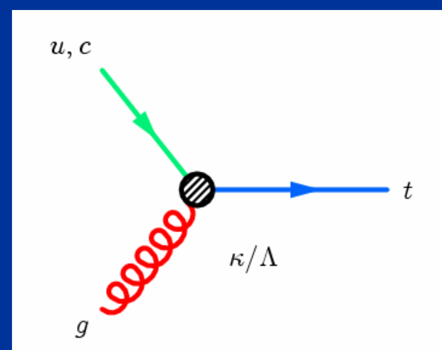
ATLAS's Sensitivity to Anomalous FCNC Single Top Production



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Motivation

- Top quark has great potential for probing new physics due to its unique properties:
  - Huge mass ~ 175 GeV; close to EWSB scale.
  - It does not hadronize; width ~ 1.42 GeV.
- There is only one dominant decay channel: $t \rightarrow bW$.
- In SM, flavour-changing neutral current (FCNC) involving top quarks is extremely suppressed; occurs only at one-loop order due to GIM mechanism, eg Br(t->cg) ~ 10^{-11}.
- So any signal will be evidence of new physics!
- Q: *Are there any models which can give us sizable top FCNC that we can see in experiments?*

- Extensions to SM can enhance top FCNC interactions up to many orders of magnitudes, --> as a result get an increase in the production cross section as well as FCNC decay branching.

Ref [1], q = u,c	SM	2-Higgs doublet model	SUSY
Br($t \to q\ g$)	5 x 10^{-11}	~ 10^{-5}	~ 10^{-3}
Br($t \to q\ \gamma$)	5 x 10^{-13}	~ 10^{-7}	~ 10^{-5}
Br($t \to q\ Z$)	~ 10^{-13}	~ 10^{-6}	~ 10^{-4}

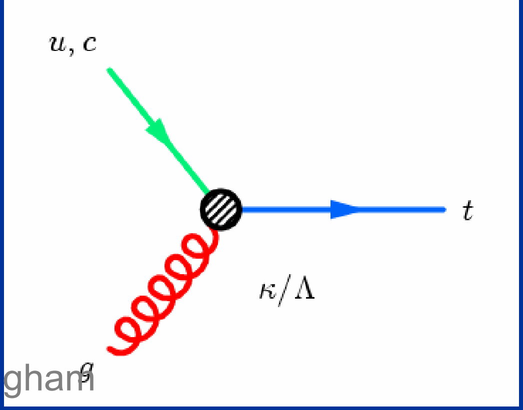
- My study is to estimate sensitivity of ATLAS detector to anomalous FCNC single top production u(c) + g -> t. (TopReX 4.10, Pythia 6.2) (fast detector sim – ATLFAST) (Athena 10.0.1)

Model independent approach

- Since we don't know which model is correct, a useful way is to adopt a model-independent approach using an effective Lagrangian.
- For anomalous top couplings 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_{gq} = anomalous coupling strength
Λ = scale of new physics

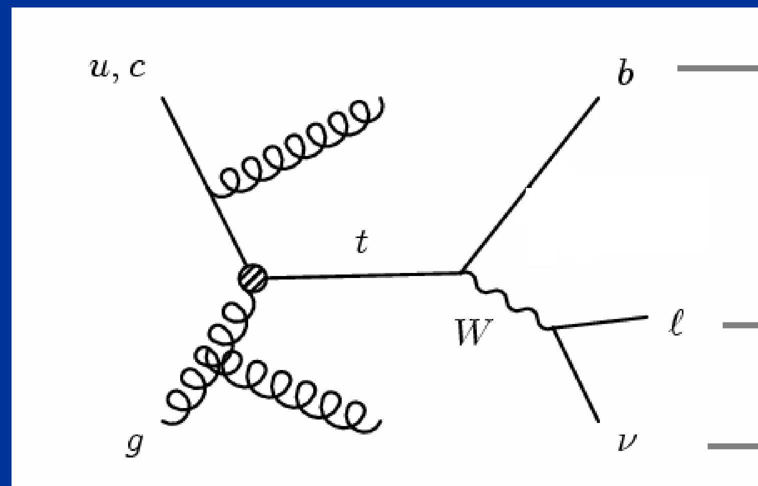


Current constraints

Ref [1,2]	LEP2	Tevatron	HERA
Br($t \rightarrow q\ g$)	< 17 %	< 29%	< 13% [3]
Br($t \rightarrow q\ \gamma$)	< 3.2%	< 3.2% (CDF)	< 0.66%
Br($t \rightarrow q\ Z$)	< 7%	< 32% (CDF)	-

Signal

- Signal at tree level: ug/cg -> t -> bW -> b l v.



B-tagged jet

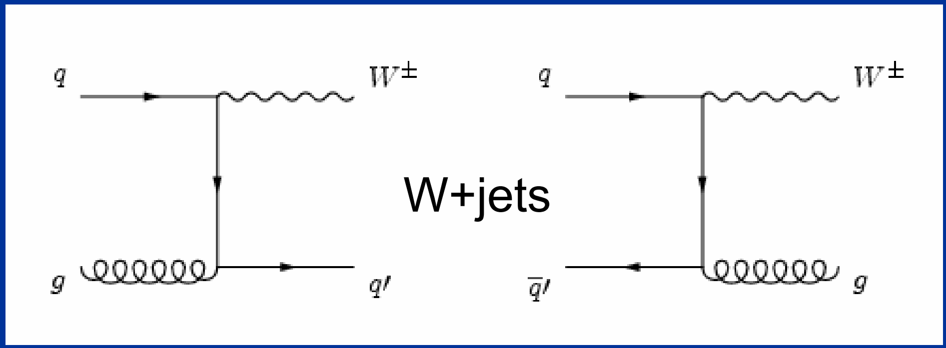
Isolated lepton

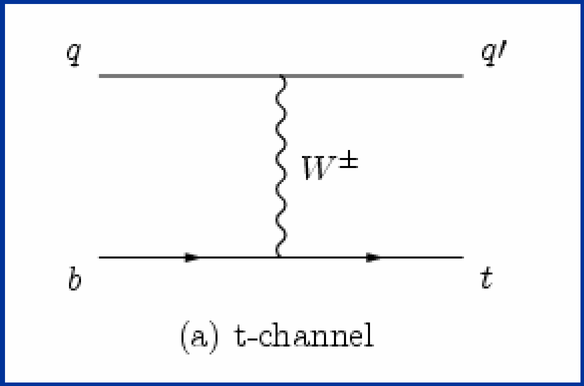
Missing pT

- After reconstructing the top, count top event within a mass window, e.g. 140-190 GeV. Look for excess.
- For κ_{gq}/Λ = 0.1 TeV^{-1} (used in simulation):
  - σ(u + g -> t) = 76 pb (incl. tbar)
  - σ(c + g -> t) = 15.3 pb
- Cross section scales as $(\kappa/\Lambda)^2$ for κ_{gq}/Λ<~0.2 TeV^{-1}

Background

- Background:
  - W + n jets
  - EW t-chan. single top
- Less problematic:
  - Wbb
  - Ttbar
  - Wcc
- Negligible:
  - Wt- and s-channels single top





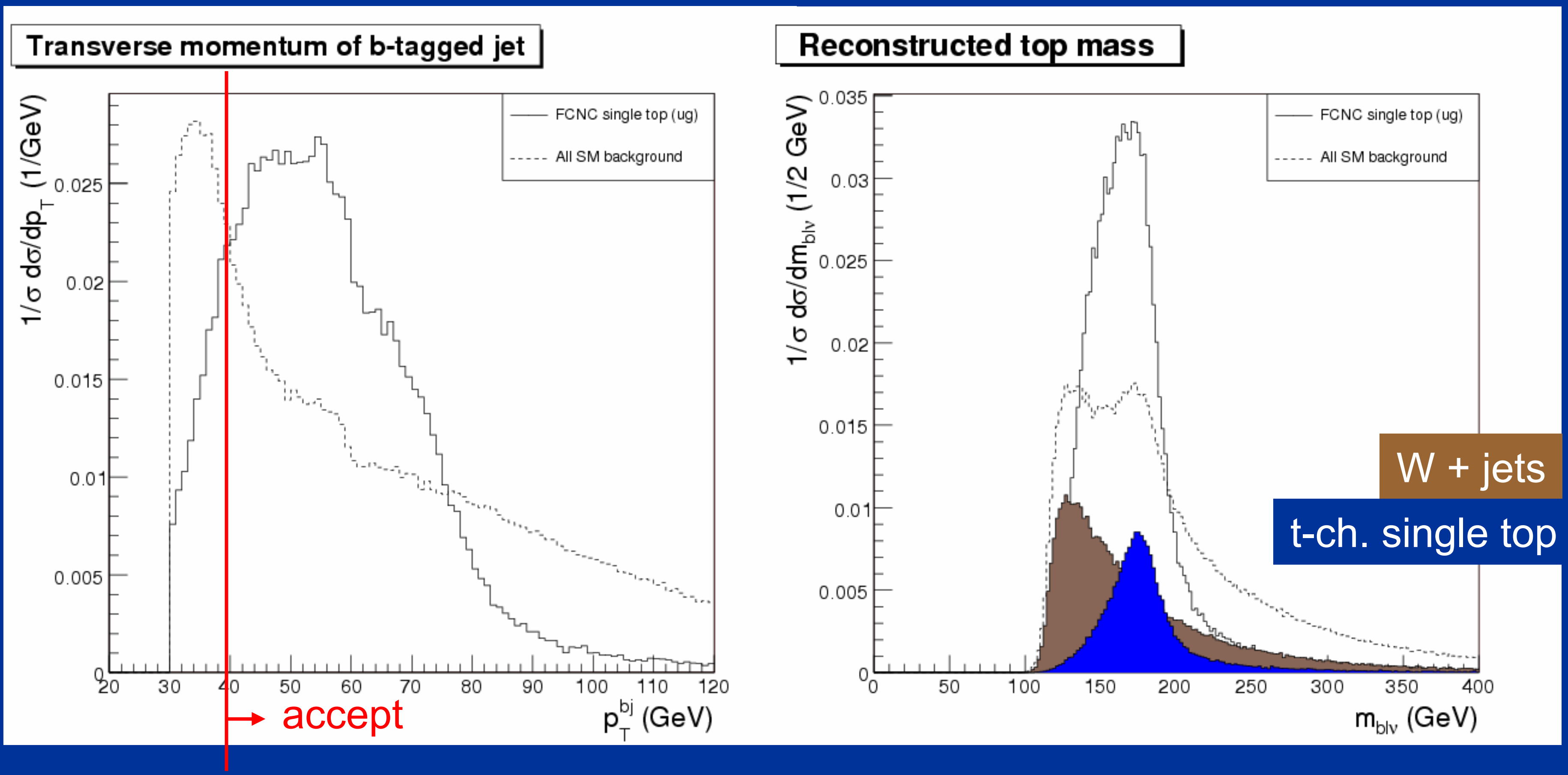
(a) t-channel

Event selection

- Basic cuts:
  - Exactly 1 isolated lepton (e/mu), pT > 20GeV
  - 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) < 280 GeV
  - W pT > 30 GeV
  - $\Delta R(b, W^{rec}) < 4.0$

Kinematics plots

After basic cuts…



mt window 140-190 GeV

After cuts…

Process	Accept. eff.	σ (before) pb	σ (after)	n/10fb^{-1}	
ug	1.04 %	76.10	0.80	8020	S ~10k
cg	1.74 %	15.33	0.27	2701	
W+j	0.09 %	8964.00	7.67	76745	**81 %**
ewt-t	0.38 %	246.60	0.94	9407	**10 %**
Wbb	0.57 %	71.14	0.41	4073	4 %
tt	0.03 %	886.00	0.23	2320	2 %
Wcc	0.07 %	263.20	0.17	1729	2 %
ewt-wt	0.13 %	51.57	0.06	646	0.7 %
ewt-s	0.25 %	10.65	0.03	261	0.3 %

B ~ 100k

Note: Cross section for W+j, Wbb, Wcc include Br(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_{gq}/Λ is as large as 0.038 TeV^{-1}, corresponding to FCNC branching of 2.57×10^{-3}.
- In absence of signal, we can set an upper limit, $\kappa_{gq}/\Lambda < 0.022$ TeV^{-1} at 95% CL, corr. to FCNC branching of 8.45×10^{-4}.

	5σ	95 %CL
$\kappa(gq)/\Lambda$	0.038 TeV^{-1}	< 0.022 TeV^{-1}
Br($t \to gq$)	2.57×10^{-3}	< 8.45×10^{-4}

Current limit: < 13% [3]

1. **Hence ATLAS is ~100 times more sensitive!**
2. **Single top production is the most sensitive channel to anomalous tqg coupling (has been deemed by many as hopeless!)**

Systematic uncertainty

- What is the systematic (and statistical) uncertainty of the sensitivity estimates?
- Sources of systematic unc:
  - Physics (theory/model): $\delta\sigma$, ISR/FSR…
  - Detector: JES, b-tagging eff, luminosity…

Cross section unc $\delta\sigma$

- Affected by:
  - Choice of PDF set
  - Scales, renormalization and factorization
  - δmt
- Results of $\delta\sigma$:

NLO σ

ug	cg	wj	wbb	wcc	wt	t	s	tt
+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 (%)
δσ (signal)	+ 16.6% − 15.6%
δσ (bgnd)	+ 6.2% − 5.8%
δ luminosity (5%)	± 2.5%
ISR	± 12.0%
FSR	± 5.7%
B-tag (±10%)	+ 12.8% − 4.8%
JES (ljet 1%?, bjet 3%?)	?
Total (so far)	**+ 25.7%** **− 22.0%**

Error for κ is half as Br ~ κ^2

BR(t->qg) < 8.45 ± 0.054 (MC stat) +2.2−1.9 (sys) x 10^{-4} @ 95%CL

Current work and prospects

- Now trying to complete study of systematic uncertainty:
  - Jet energy scale
  - B-fragmentation
  - …
- Plan to publish the result in an ATLAS note soon…
- Prospects:
  - Improvement can come from the use of statistical techniques (eg maximum likelihood).
  - Need more realistic study with trigger, full Geant simulation.
  - NLO (ie 2->2) simulation for signal processes.
  - Volunteer?

References

1. ‘1999 CERN Workshop on SM physics (and more) at the LHC’ Yellow report. hep-ph/0003033
2. Talk by Sergey Slabospitsky (CMS) at PRS SM meeting, 17 March 2004
3. Hep-ph/0604119

Others relevant papers:

- M. Hosch, K. Whisnant, B.-L. Young (1997) Phys Rev D 56 (5725)
- O. Cakir and SA Cetin, J. Phys. G: Nucl. Part. Phys., 31, N1-N8 (2005)
- ATLAS studies on FCNC top decay:
  - ATL-PHYS-PUB-2005-02
  - ATL-PHYS-PUB-2005-009
- Hep-ph/0605003 – ‘New physics effects in the flavor-changing neutral couplings of the top quark’