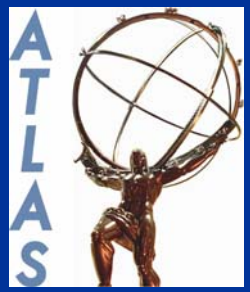
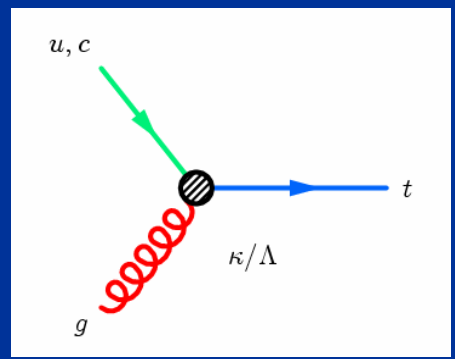
ATLAS's Sentivitity to Anomalous FCNC Single Top Production





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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($t \to q\, g$)	5×10^{-11}	$\sim 10^{-5}$	$\sim 10^{-3}$
Br($t \to q\, \gamma$)	5×10^{-13}	$\sim 10^{-7}$	$\sim 10^{-5}$
Br($t \to q\, Z$)	$\sim 10^{-13}$	$\sim 10^{-6}$	$\sim 10^{-4}$

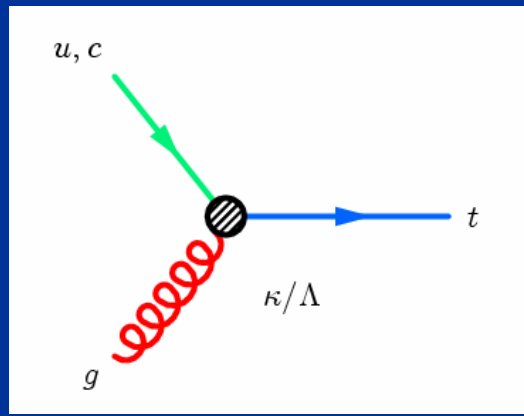
- My study is to estimate sensitivity of ATLAS detector to anomalous FCNC single top production u(c) + g -> t. (TopReX 4.10, Pythia 6.2) (fast detector sim – ATLFAST)

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

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

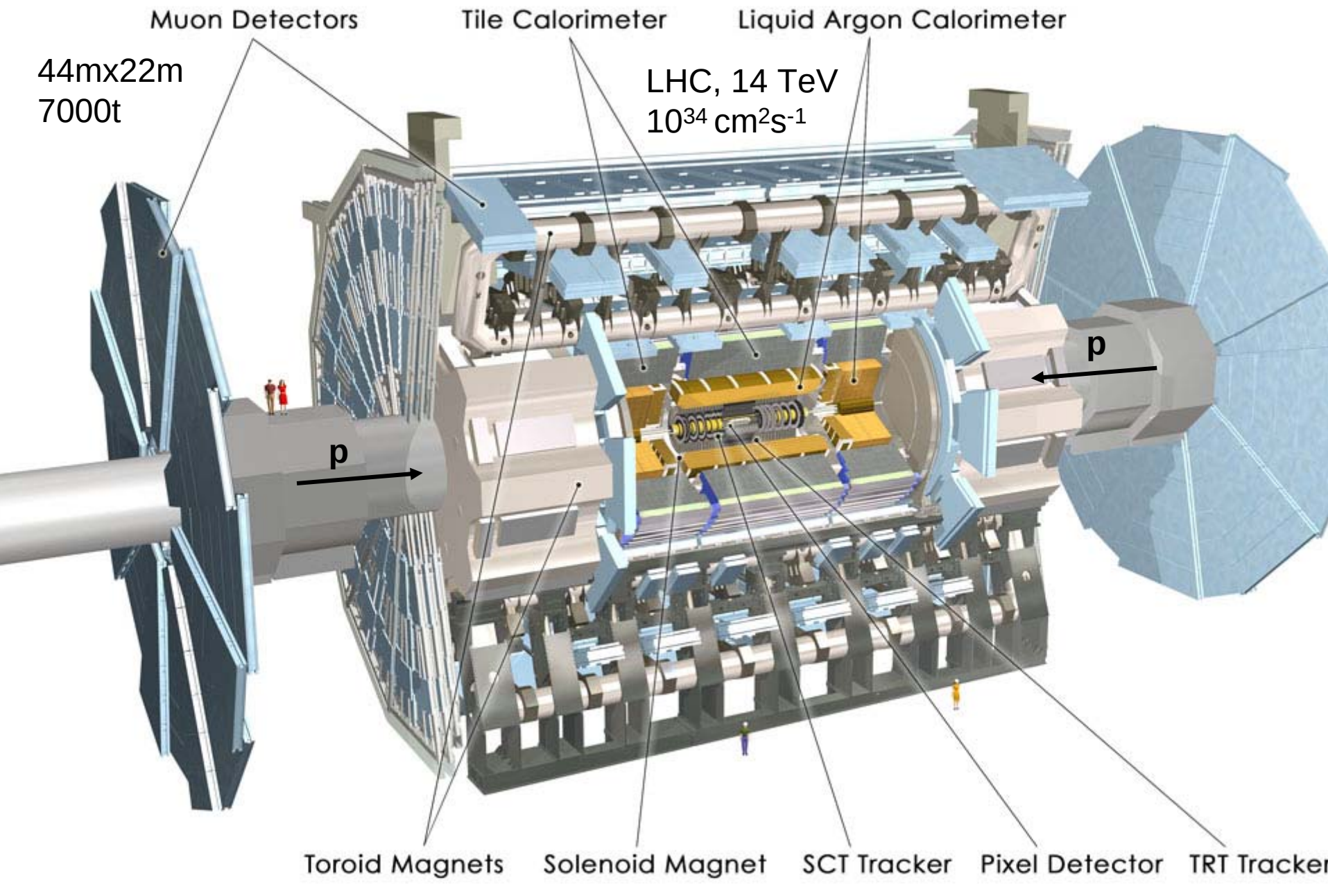
κ_{gq} = anomalous coupling strength
Λ = scale of new physics



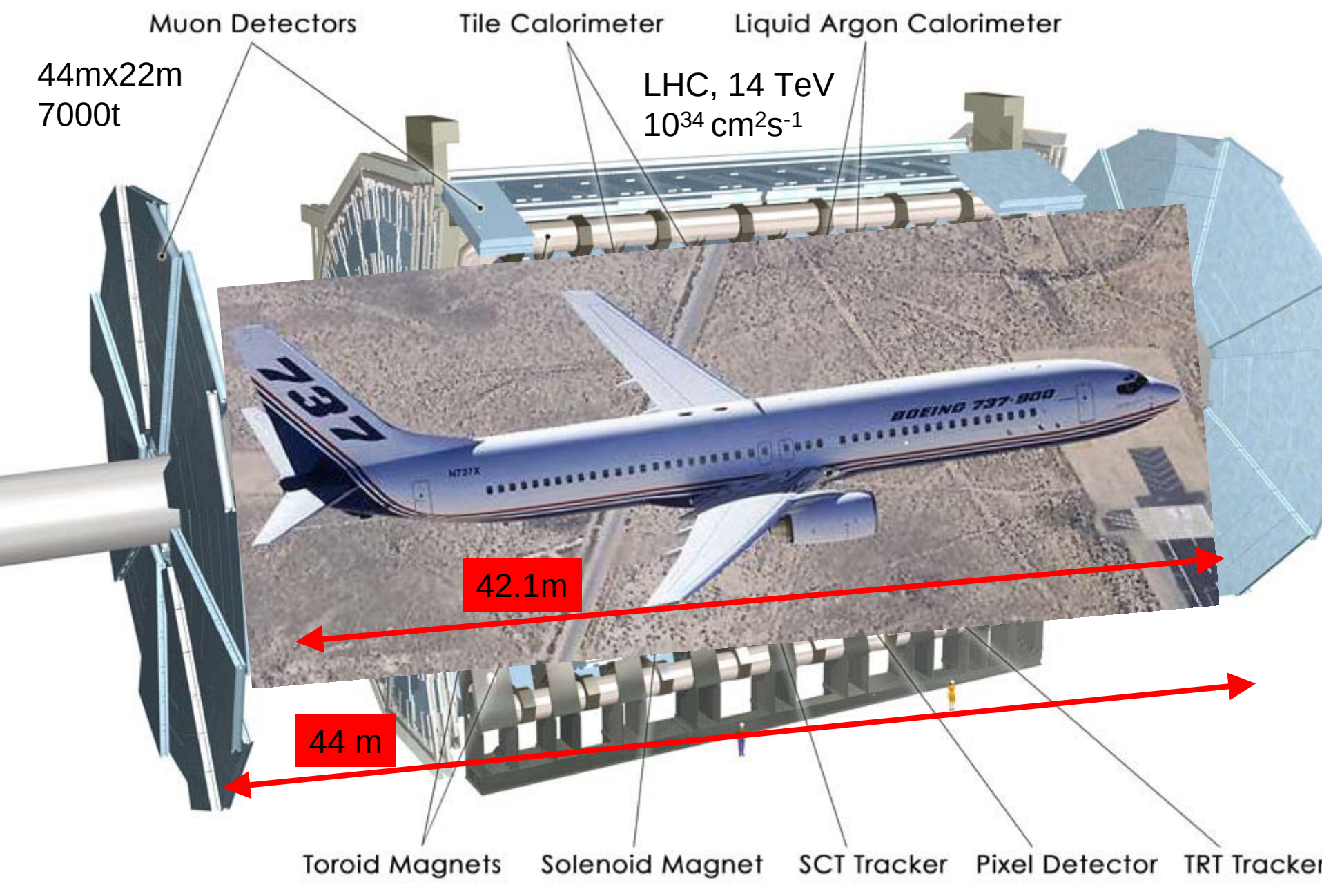
Current constraints

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

ATLAS detector

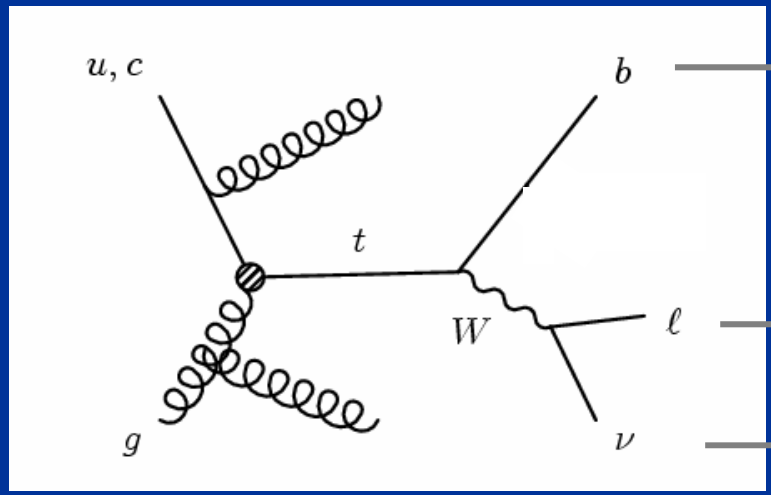


ATLAS detector



Signal

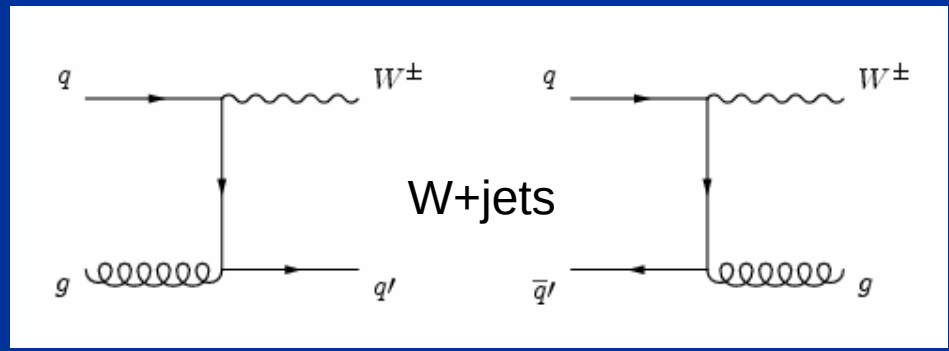
- Signal at tree level: ug/cg -> t -> bW -> b l ν.

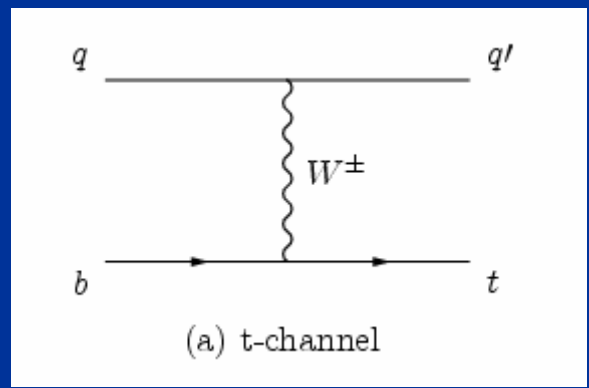


- After reconstructing the top, count top event within a mass window, e.g. 140-190 GeV. Look for excess.
- For $\kappa_{gq}/\Lambda = 0.1$ TeV^{-1} (used in simulation):
  - $\sigma(u + g \rightarrow t) = 76$ pb (incl. tbar)
  - $\sigma(c + g \rightarrow t) = 15.3$ pb
- Cross section scales as $(\kappa/\Lambda)^2$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



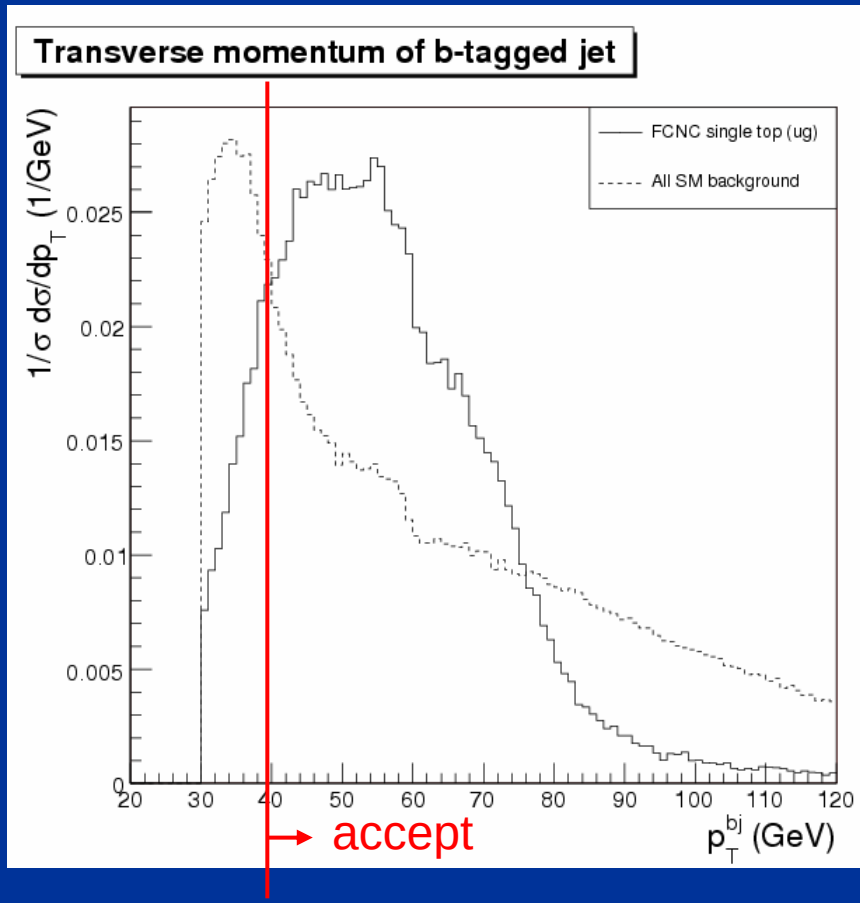


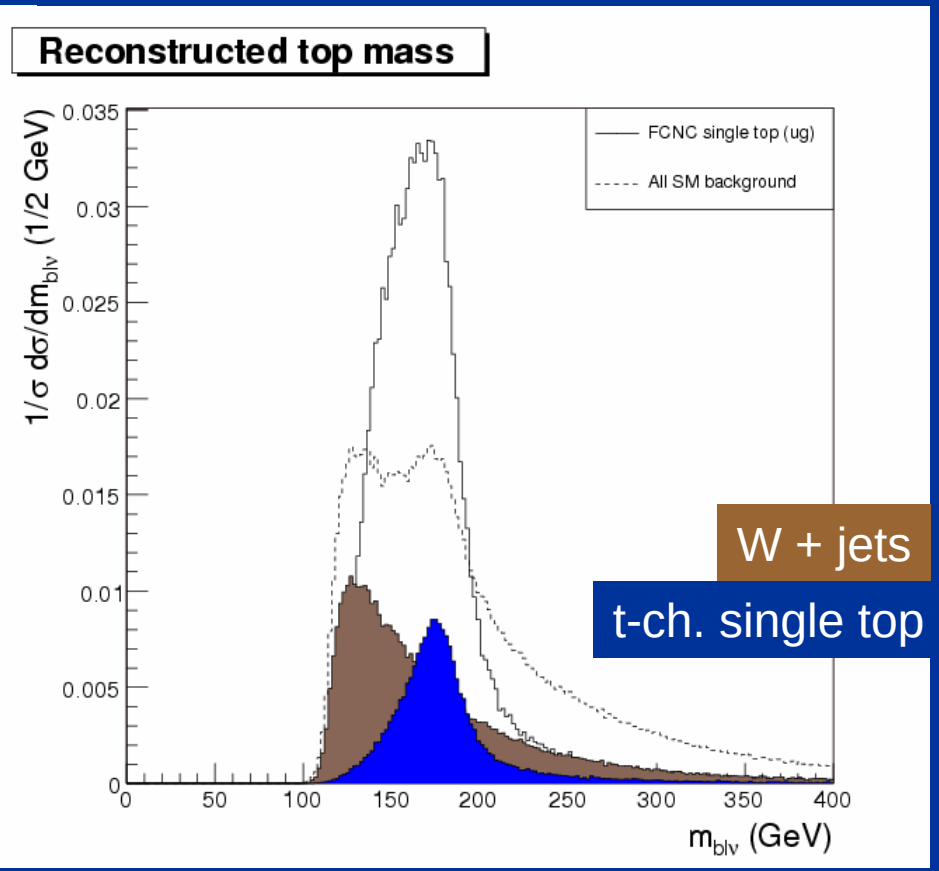
Event selection

- 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 cuts:
  - B-jet pT > 40 GeV
  - Reconstructed top, pT < 20 GeV
  - Inv. mass (bjet,lep) > 55 GeV
  - (Scalar sum of pT of lepton, all jets, ptmiss) < 280 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	1.07 %	91.32	0.977	9766	S ~10k
cg	1.80 %	18.40	0.330	3304	
W+j	0.09 %	8964.00	7.904	79040	**80 %**
ewt-t	0.39 %	246.60	0.955	9546	**10 %**
Wbb	0.59 %	71.14	0.417	4170	4 %
tt	0.03 %	886.00	0.268	2683	3 %
Wcc	0.07 %	263.20	0.180	1804	2 %
ewt-wt	0.13 %	51.57	0.069	693	0.7 %
ewt-s	0.25 %	10.65	0.026	264	0.3 %

B ~ 100k

Note: K-factor of 1.2 used for signal cross sections;
Cross section for W+j, Wbb, Wcc include Br(W->e/mu)

Results

- 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 2.6×10^{-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 8.6×10^{-4}.

	5σ	**95 %CL**	
$\kappa(gq)/\Lambda$	**0.038 TeV^{-1}**	**< 0.022 TeV^{-1}**	
Br($t \rightarrow gq$)	**2.6×10^{-3}**	**< 8.6×10^{-4}**	**< 17% (LEP2)**

Current work and prospects

- Now focusing on systematic uncertainty:
  - Variation of renormalization, factorization scale
  - Parton distribution function (D=CTEQ5L)
  - Top mass uncertainty
  - Parton shower modelling (ISR, FSR)
  - B-tagging efficiency
  - Jet energy scale …
- Improvement can come from the use of statistical techniques (eg maximum likelihood).
- More detailed, realistic study is desired…
  - Full simulation

Conclusion

- Top quark FCNC interactions may be enhanced by non-SM couplings. The rate of single top production may go up – the excess may be detected.
- This study suggests ATLAS detector has ~10 times better sensitivity than current experiments on the anomalous FCNC coupling κ_{gq} with top quarks, given 10 fb^{-1} of LHC data.
- Eagerly waiting for the real data next year!

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Thanks for your attention!

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

Others relevant papers:

1. M. Hosch, K. Whisnant, B.-L. Young (1997) Phys Rev D 56 (5725)
2. O. Cakir and SA Cetin, J. Phys. G: Nucl. Part. Phys., 31, N1-N8 (2005)
3. ATLAS studies on FCNC top decay:
   - ATL-PHYS-PUB-2005-02
   - ATL-PHYS-PUB-2005-009