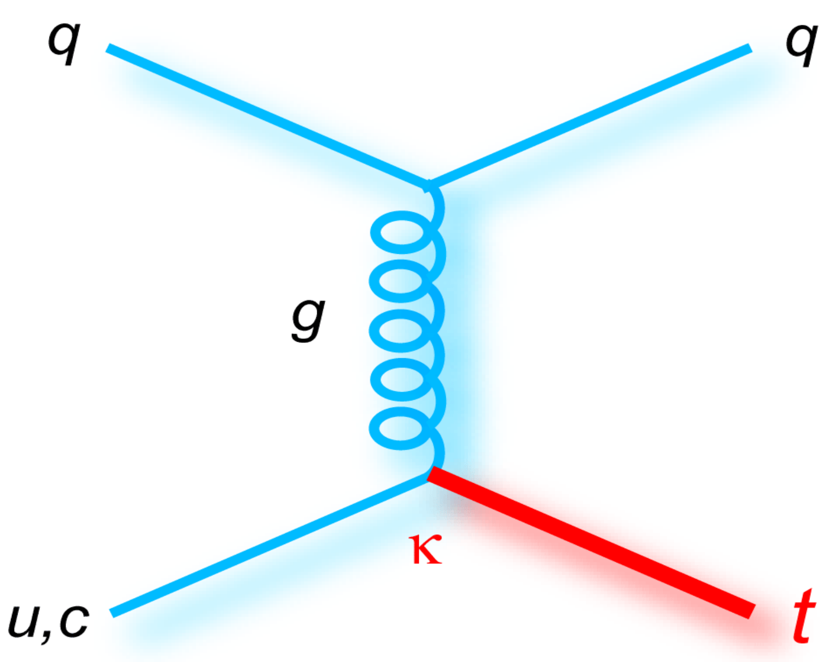
Search for single top quarks via flavor-changing neutral currents (FCNC)



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DPF, Hawaii

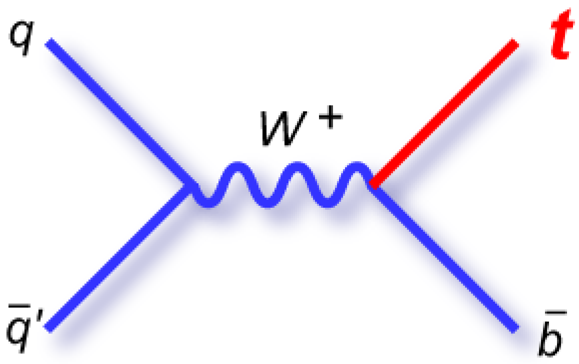
1 November 2006

Outline

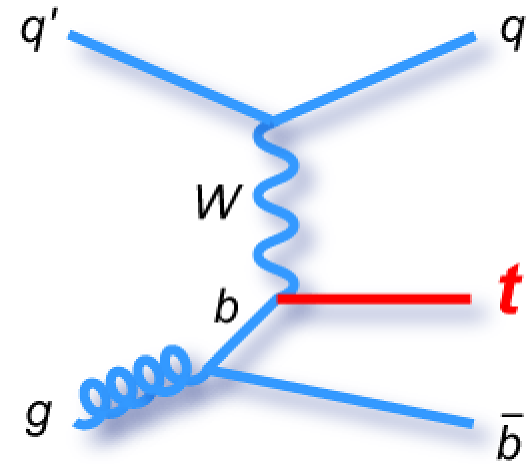
- Introduction
  - Single top quarks at the Tevatron
- Status of FCNC searches (top quark sector)
- Details of the analysis
  - Signal modeling
- Event yields and kinematic distributions
- Neural network analysis
- Results: limits on FCNC couplings
- Conclusions

Single top quarks at the Tevatron

- In the Standard Model, production of single top quarks can occur through a W boson exchange

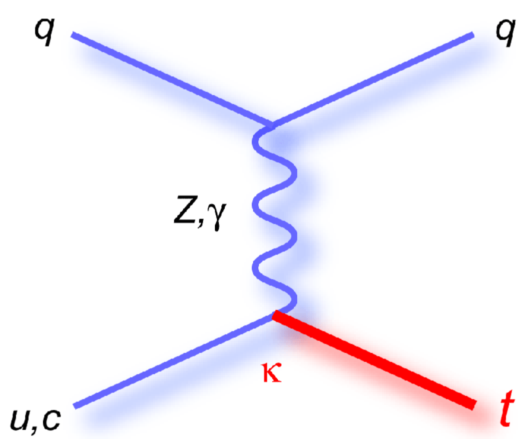


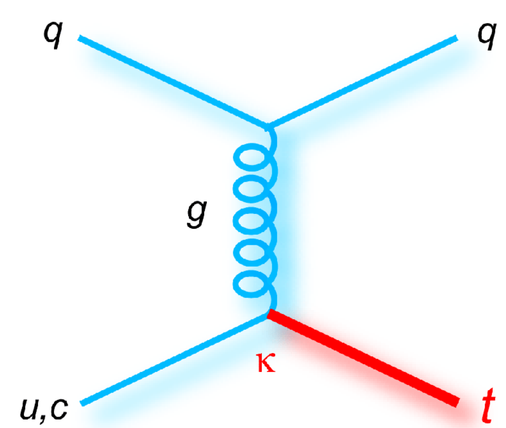
$\sigma_{NLO} = 0.88 \pm 0.07$ pb



$\sigma_{NLO} = 1.98 \pm 0.22$ pb

- Additional single top events are also possible from non-SM interactions, for example, from ***flavor-changing neutral-currents* (FCNC)**

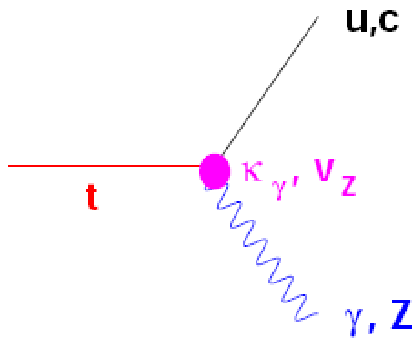




Status of FCNC searches (top quark sector)

- Exchange of a Z/γ:

  - Limits from studies of the FCNC decays of the top quark



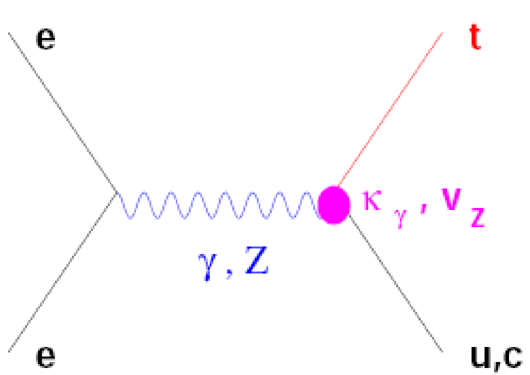
$B(t \to q\gamma) < 0.032$, and $B(t \to qZ) < 0.33$

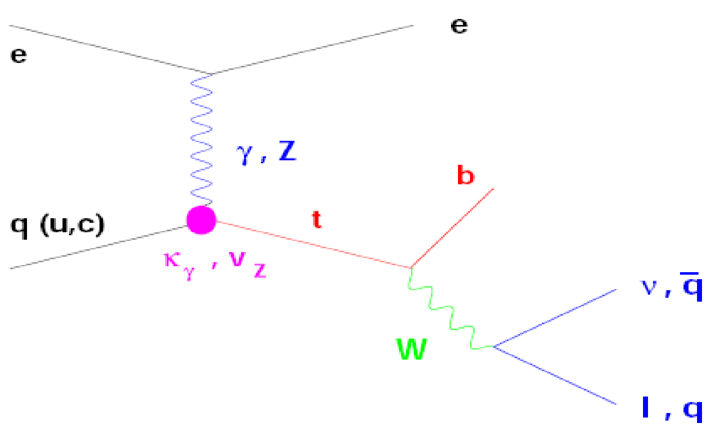
$(\kappa_\gamma < 0.4)$ $(\kappa_Z < 0.7)$

(CDF at Tevatron)

Phys. Rev. Lett. 80, 2525 (1998), Phys. Lett. B426, 393 (1998)

  - Limits from studies of single top-quark production and decay





$\kappa_{\gamma,Z} < 0.4$ (L3 at LEP)

Phys. Lett. B549, 290 (2002)

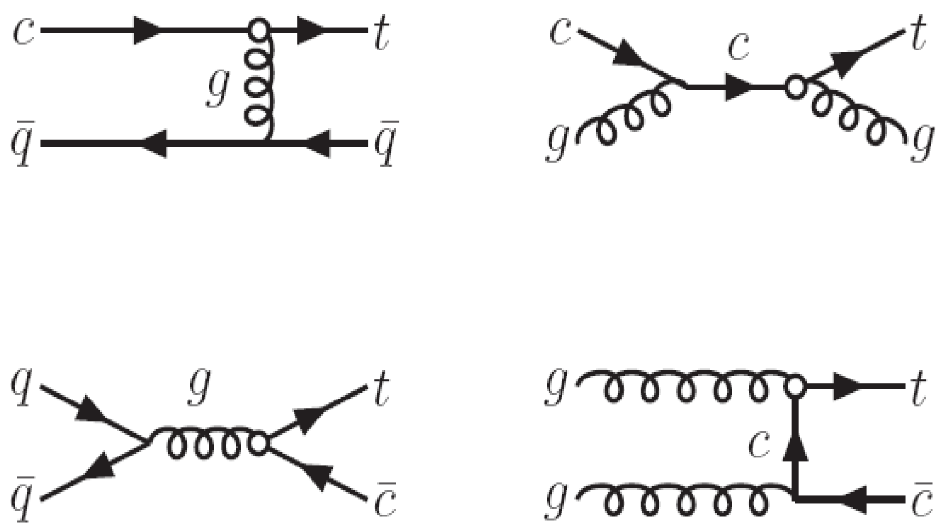
$\kappa_\gamma < 0.18$ (ZEUS at HERA)

Phys. Lett. B559, 153 (2004)

Status of FCNC searches (top quark sector)

- <u>Exchange of a gluon:</u> ← *focus of present search!*

Representative 2->2 Feynman diagrams



- Phenomenological results using data from HERA

  $- \kappa_{u,c} / \Lambda < 0.4\ \text{TeV}^{-1}$ (hep-ph/0604119)

Details of the analysis

- Data sample: **230 pb^{-1}** of lepton+jets data
  (lepton: electron or muon)

[Phys. Lett. B **622**, (2005)]

- Backgrounds:
  - W/Z+jets and diboson production ("W+jets")
  - Top-pair production ("ttbar")
  - Multi-jet events

- Selections:
  - Leptons: $p_T > 15$ GeV
    $|\eta_{det}| < 1.1$ (electron)
    $|\eta_{det}| < 2.0$ (muon)
  - MET: 15 GeV<MET<200 GeV
  - Njets: $2 \leq$ Njets ≤ 4
  - Jets: $E_T > 15$ GeV, $|\eta_{det}| < 3.4$
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Include SM single top production ("tb" and "tqb")

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(≥ one b-tagged jets)

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Require only one b-tagged jet ("SVT")

Signal modeling

- Use LO CompHEP event generator

Effective Lagrangian:

$$\frac{\kappa_f}{\Lambda} g_s \bar{f} \sigma^{\mu\nu} \frac{\lambda^a}{2} t G^a_{\mu\nu}$$

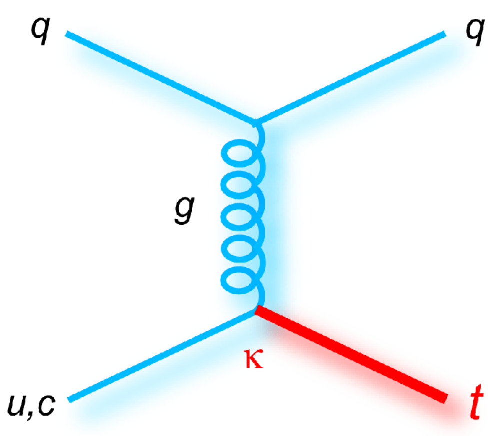
where,

f: *u*-quark, or *c*-quark

G: gauge field tensor of gluon

κ_f: strength of *tgu* or *tgc* couplings

Λ: scale of new physics



- We correct the LO cross section to NLO by a K-factor of 1.6 [Phys. Rev. D 72, 074018 (2005)]

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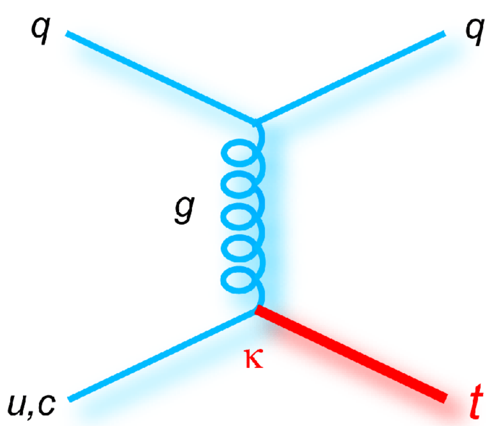


- We correct the LO cross section to NLO by a K-factor of 1.6 [Phys. Rev. D 72, 074018 (2005)]

- The production cross sections scale up quadratically with κ_f / Λ

  (effect of FCNC couplings on top quark decay is negligible for $\kappa_f / \Lambda < 0.2$ TeV^{-1})

- Therefore, signal samples for any value of κ_f / Λ can be scaled quadratically to obtain the kinematic distributions at any other value of κ_f / Λ

- We choose that value to be $\kappa_f / \Lambda = 0.03$ TeV^{-1}

Event yields

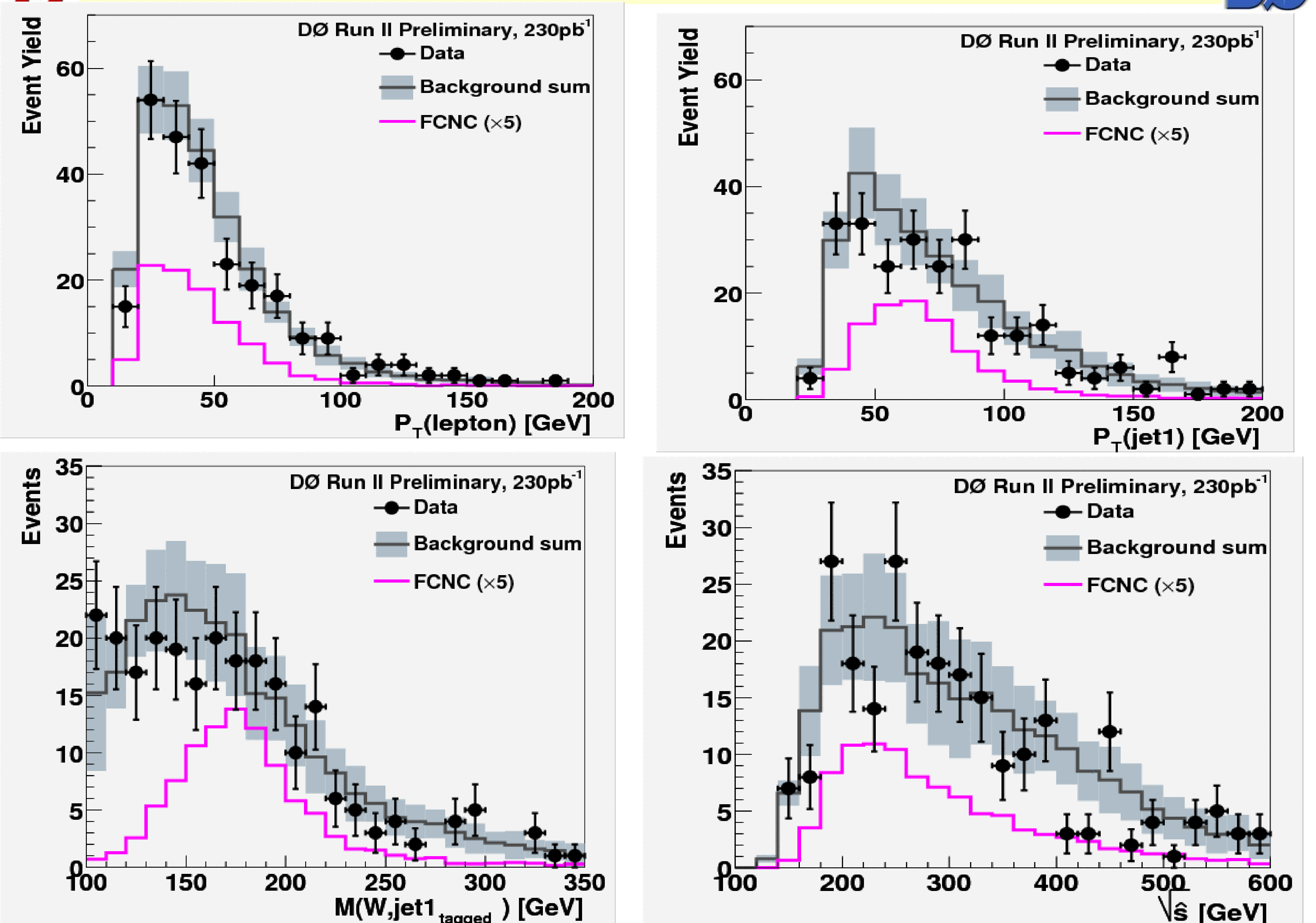
- Event yields after full detector simulation, and same selections as in the SM single top search

	Electron channel	Muon channel
Signals: "*tug*"	8.4 ± 2.1	9.8 ± 2.7
"*tcg*"	0.6 ± 0.2	0.6 ± 0.2
Backgrounds		
SM single top	6.4 ± 1.4	6.1 ± 1.4
ttbar	31.8 ± 6.9	31.4 ± 7.0
W+jets	84.6 ± 10.2	76.8 ± 8.5
multi-jets	13.7 ± 4.3	17.2 ± 1.5
Sum of Backgrounds	**136.5 ± 13.4**	**131.5 ± 12.7**
Observed	**134**	**118**

Dominant systematic uncertainties

Systematic Uncertainties	
Integrated luminosity	6.5 %
Lepton ID	4 %
Theory cross sections	9 – 18 %
Jet Fragmentation	5 %
Jet ID	1 – 9 %
Jet Energy Scale	1 – 16 %
b-tag modeling	5 – 13 %
Trigger Modeling	2 – 8 %

Kinematic distributions



- We use neural networks to separate the FCNC signals from the backgrounds
- When training, we consider
  - Signal: sum of *tgc* and *tgu* processes
  - Background: sum of all SM processes

- We consider the following 10 input variables representing

Individual object kinematics

p_T(jet1), p_T(tagged jet),

η(lepton), Missing E_T

Global event kinematics

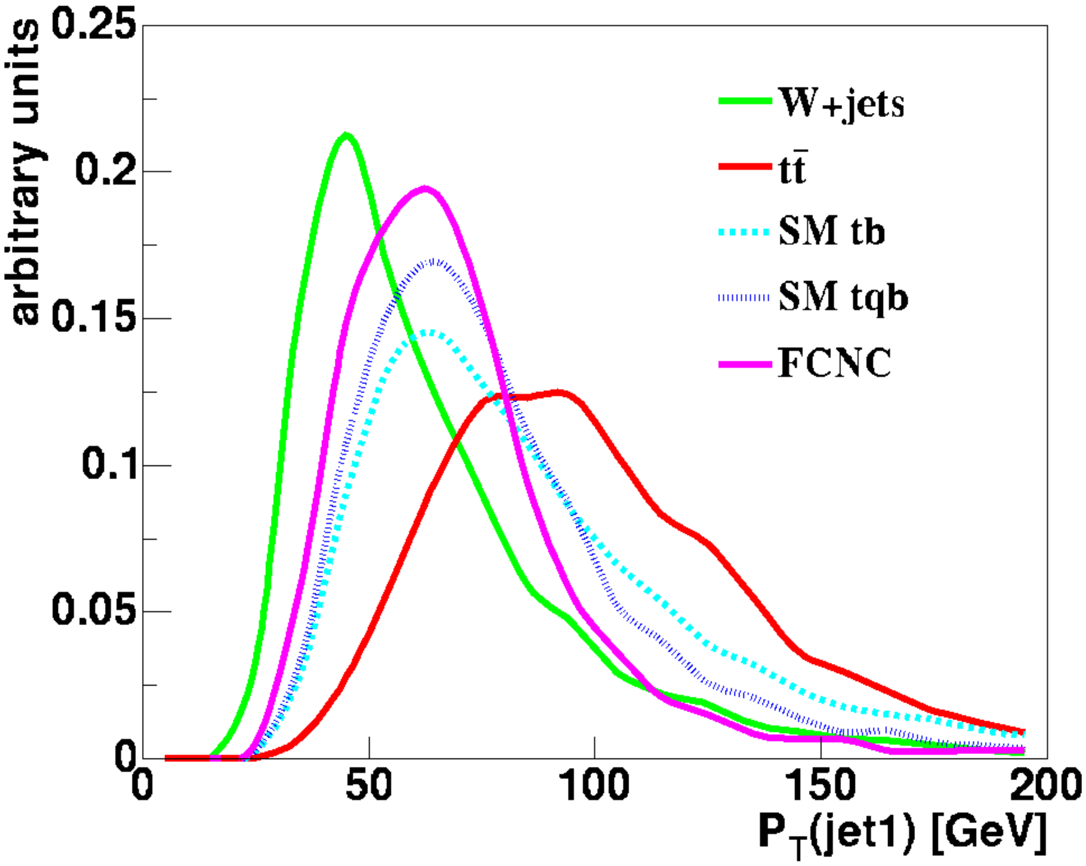
H_T(jet1, jet2), p_T(W),

p_T(jet1, jet2), M(all jets),

Top Mass (using tagged jet)

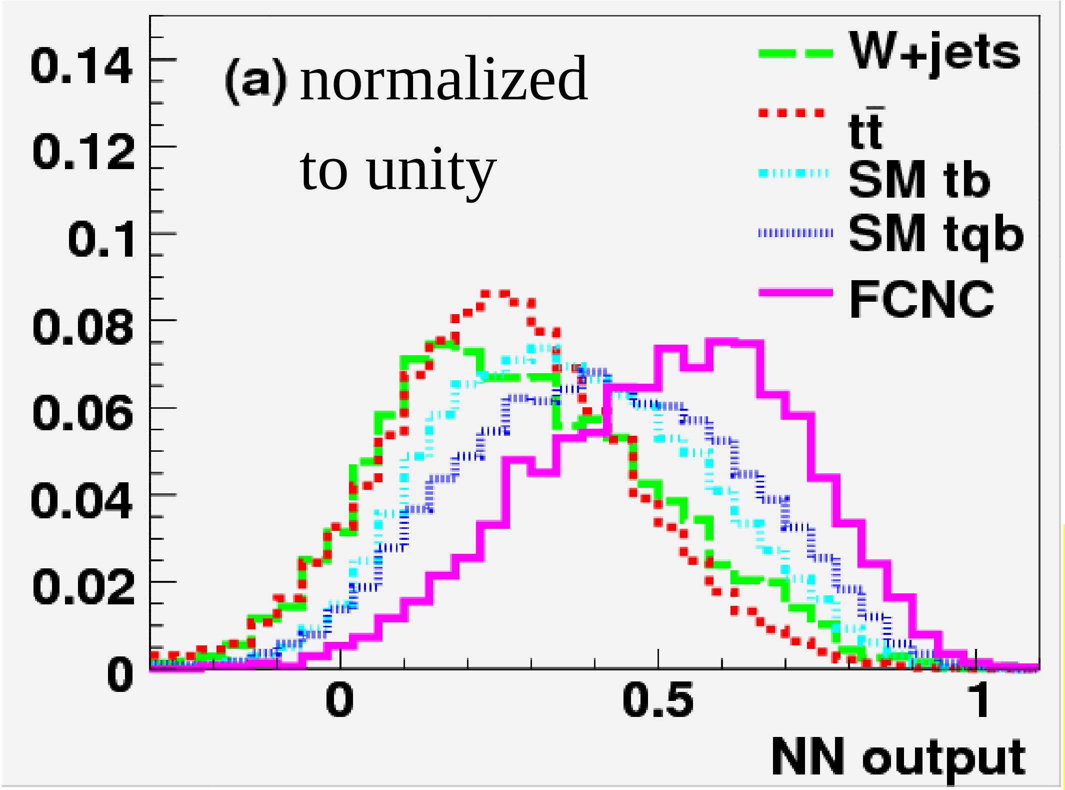
Angular correlations

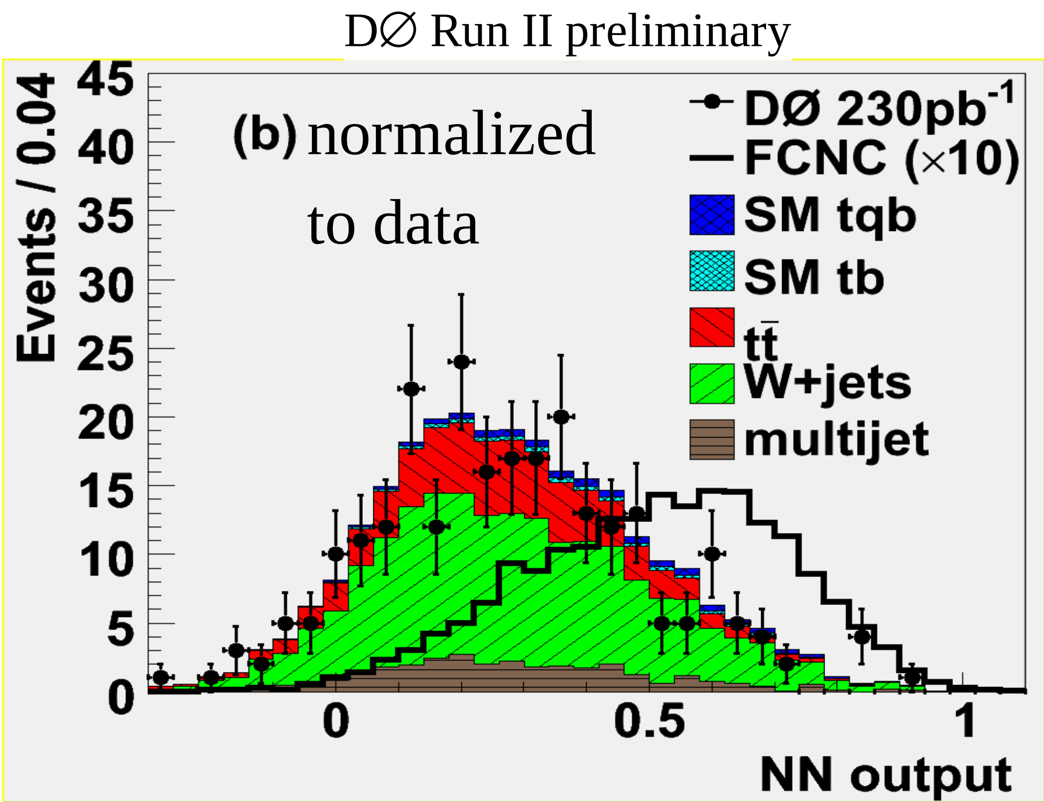
Cos(lepton, jet1) in the lab frame



Neural network output

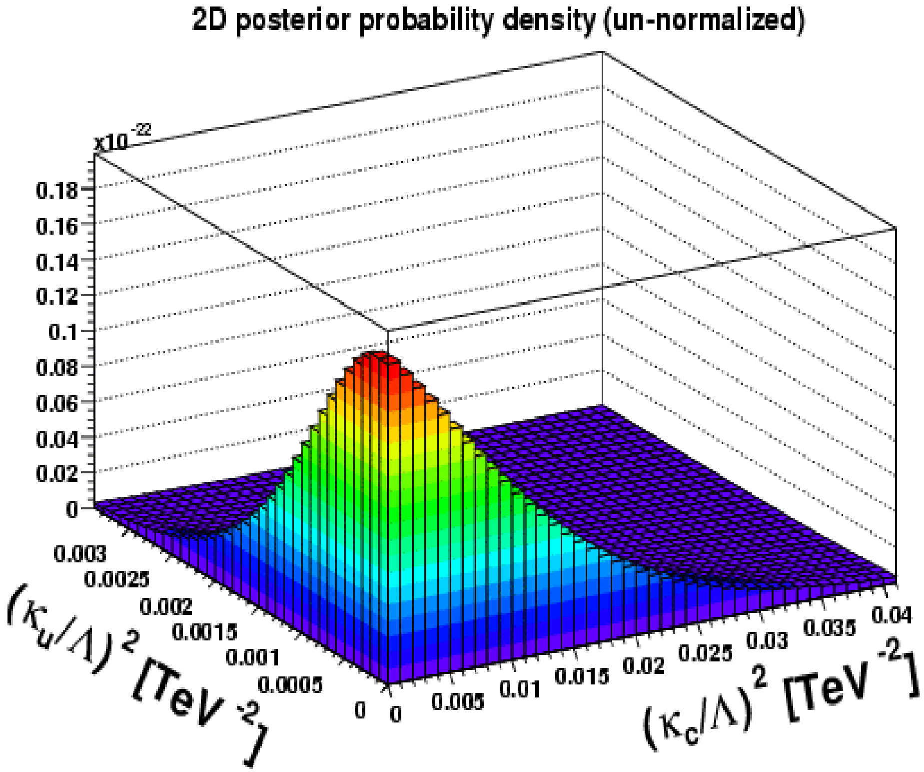
- For combined electron and muon channels



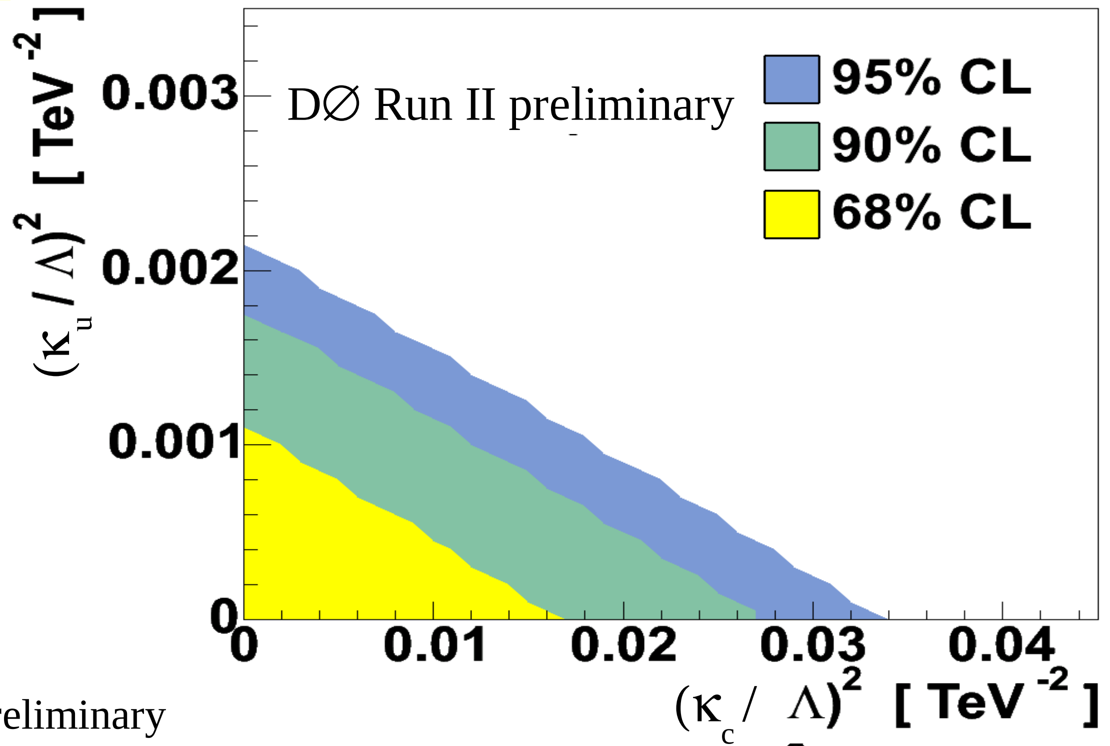


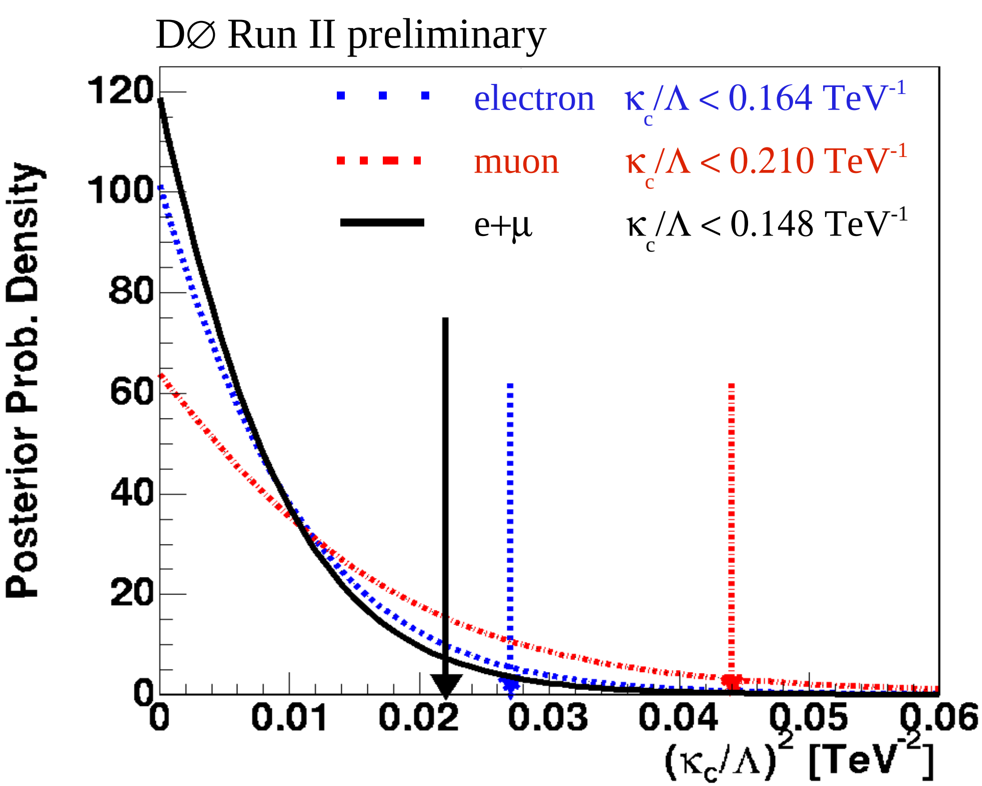
- We use Bayesian statistics to extract limits on κ_u / Λ and κ_c / Λ
  - we assume priors flat in $(\kappa_u / \Lambda)^2$ and $(\kappa_c / \Lambda)^2$
- We compute the posterior probability density in the 2-D plane of $(\kappa_u / \Lambda)^2$ versus $(\kappa_c / \Lambda)^2$, from which we extract

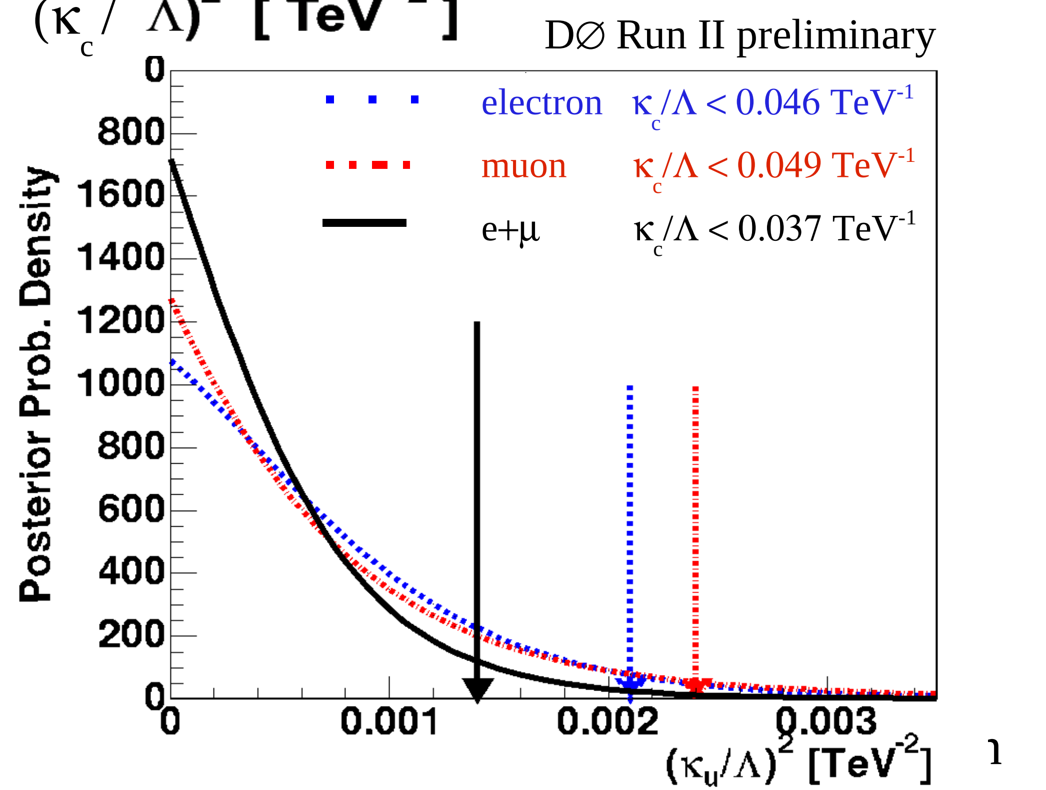
  (a) 2-D limit contours, and (b)1-D limits



Observed Limits (electron and muons combined)





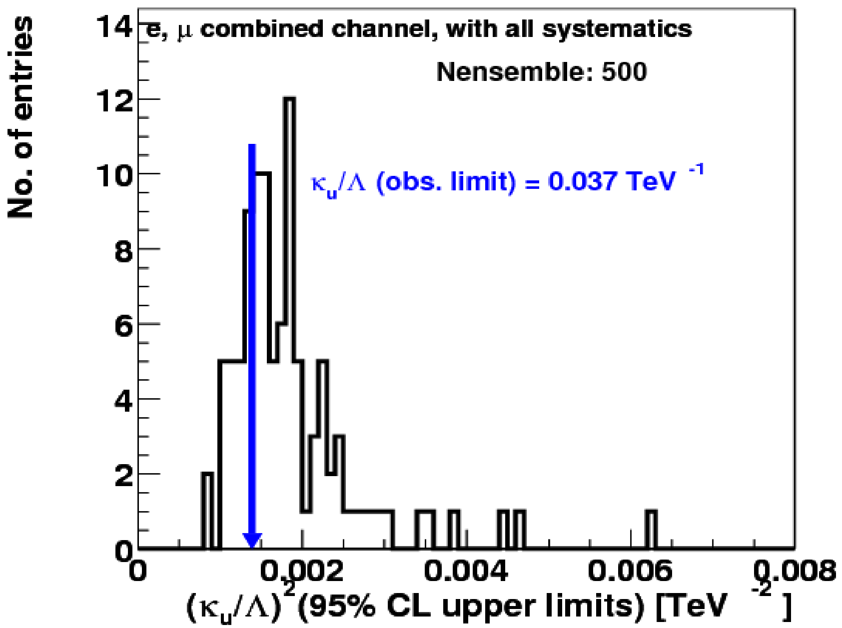


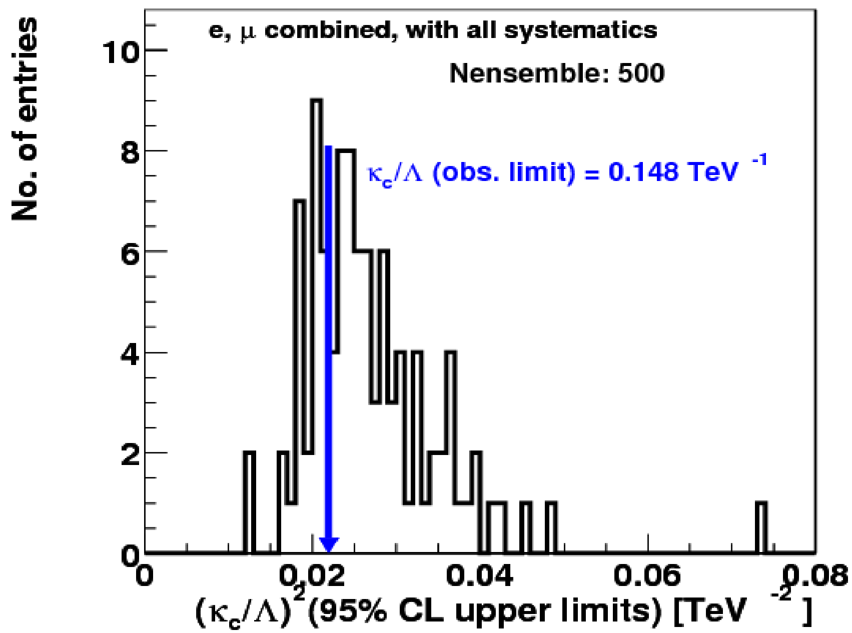
Summary of limits

95% CL upper limits in TeV^{-1}		
	Observed (Expected)	
	κ_u/Λ	κ_c/Λ
Electron channel	0.046 (0.052)	0.164 (0.190)
Muon channel	0.049 (0.050)	0.210 (0.205)
e+μ combined	0.037 (0.041)	0.148 (0.161)

(For expected limits, the data is set to the estimated background yield)

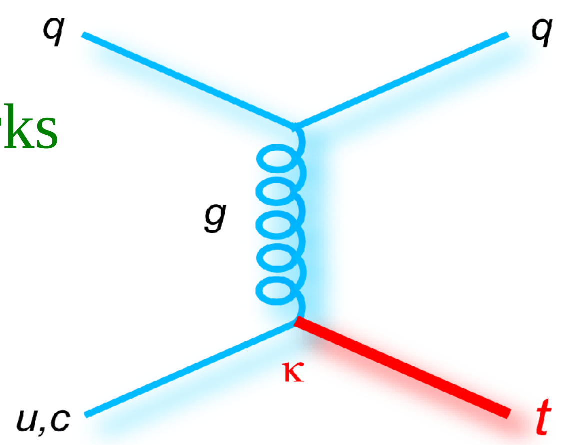
Ensemble tests





Conclusions

- We performed a first search at the Tevatron for FCNC interactions involving the top quark and a gluon
  - we looked for the production of single top quarks



- We found no evidence of an FCNC signal
  - limits, at 95% CL, on the FCNC couplings are

  $\kappa_u / \Lambda < 0.037\ \mathrm{TeV}^{-1}$, $\kappa_c / \Lambda < 0.148\ \mathrm{TeV}^{-1}$

  - these are much better than previous limits (0.4 TeV^{-1}, hep-ph/0604119)
    – by a factor 11 for κ_u / Λ
    – by a factor 3 for κ_c / Λ

- Draft for publication is in preparation

Back-up slides

Single top production cross sections via FCNC

- The cross sections can be significantly enhanced depending on the value of the coupling κ

NLO cross sections of single top production through FCNC interactions involving gluons

κ/Λ [TeV^{-1}]	$\sigma(t)$ [pb]
0.01	0.9
0.03	8.0
0.07	45.0
0.11	110.0
0.19	323.0