Search for Flavor Changing Neutral Currents in Single Top Quark Production using $2.3\,\mathrm{fb}^{-1}$ at DØ

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on behalf of the D0 Collaboration

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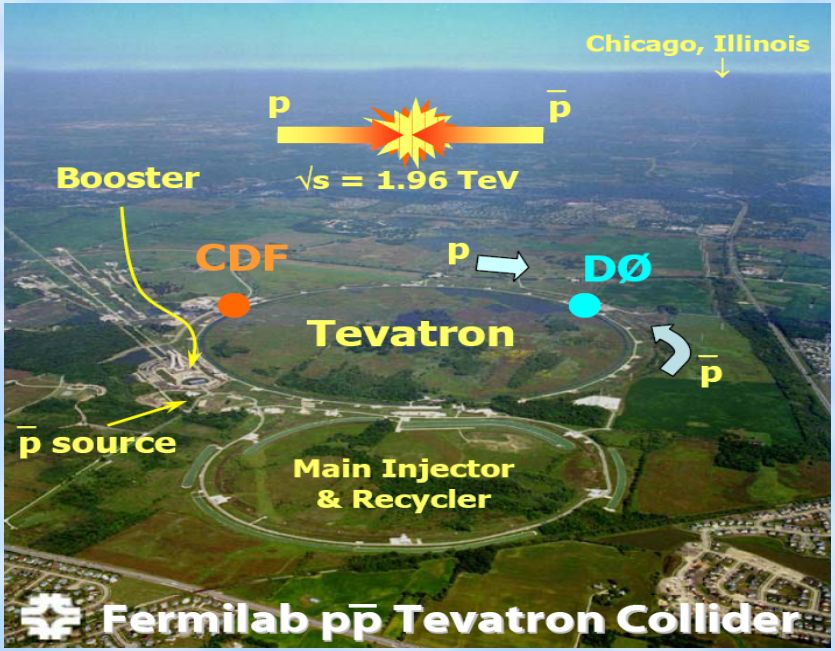
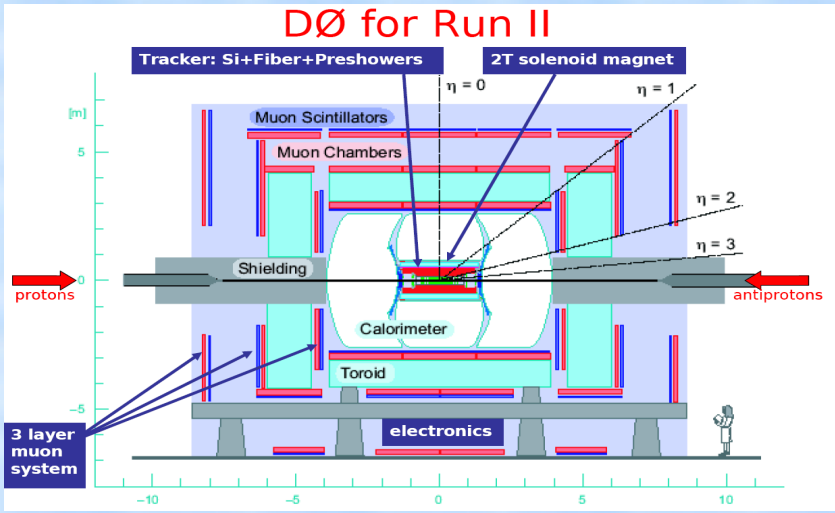
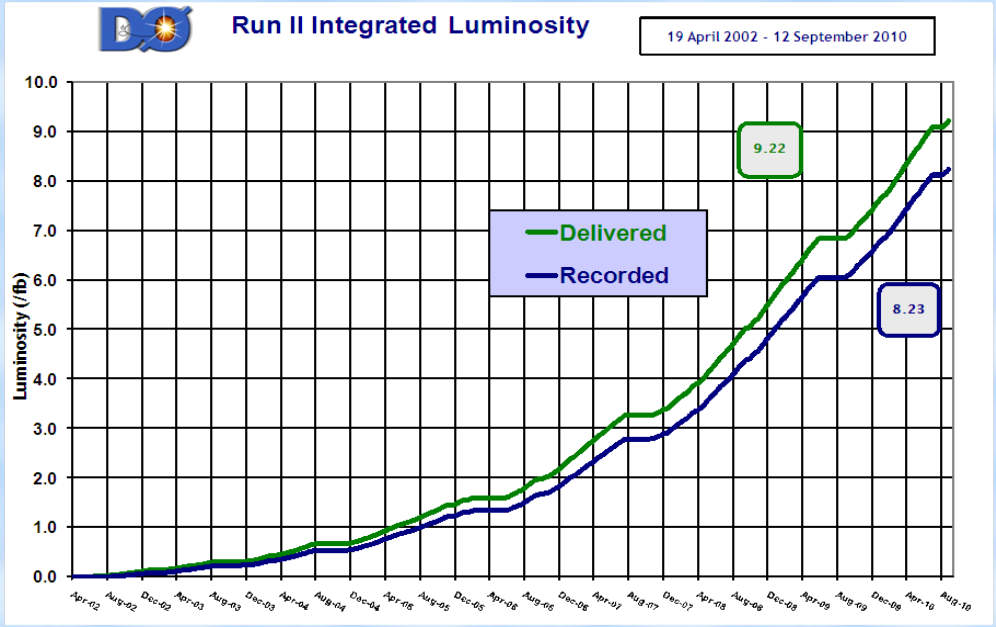
Tevatron



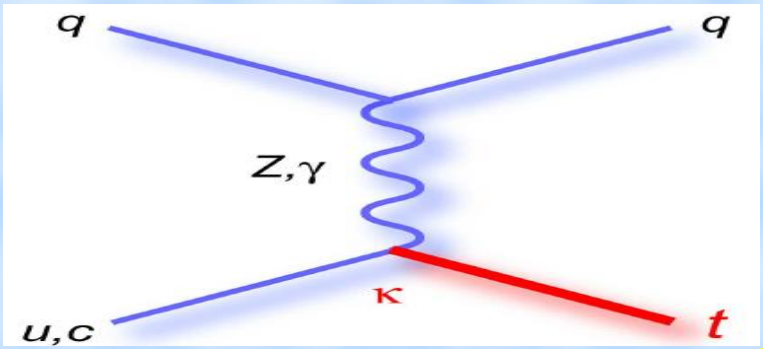


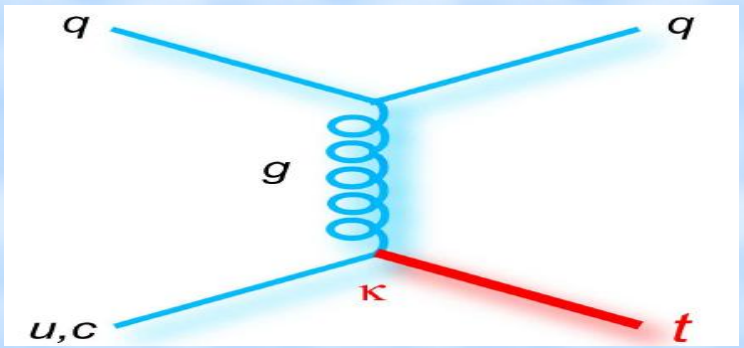
– 396 ns between bunches

– has delivered about 9.2 fb^{-1} since 2002



FCNC





models with soliton structure of the top quark

Flavor Changing Neutral Currents

change flavor of quarks without changing the charge

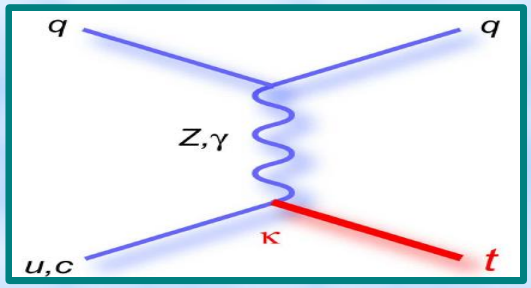
models with top quark as a composite object

models with new dynamical interactions of the top quark

models with multiple Higgs doublets, such as SUSY

FCNC: exchange photons and Z-bosons

- FCNC through photons and Z-bosons:



- CDF constraints (95% CL):

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

*(Phys. Rev. Lett. **80**, 2525 (1998))*

- L3 (LEP) direct constraints on FCNC parameters: $k_{\gamma,Z} < 0.4$

(Phys. Lett. B459, 290 (2002))

- ZEUS (HERA) constraints (95% CL): $k_{\gamma} < 0.174$

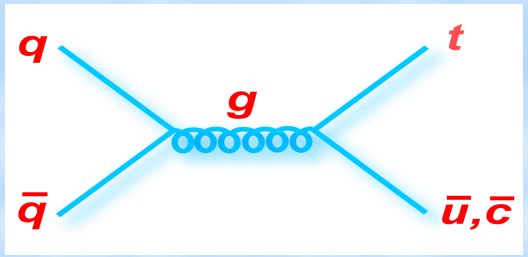
(Phys. Lett. B559, 153 (2004))

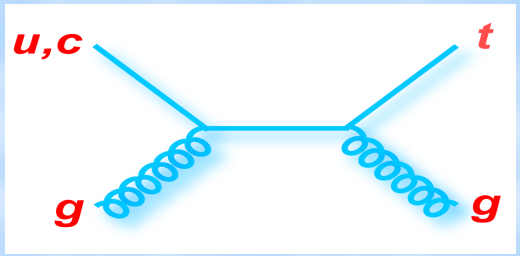
- CDF recent constraints (95% CL): $\mathcal{B}(t \to Zq) < 3.7\%$

(Phys. Rev. Lett. 101, 192002 (2008))

FCNC: exchange of gluons

- Vertex *tgc (tgu)*





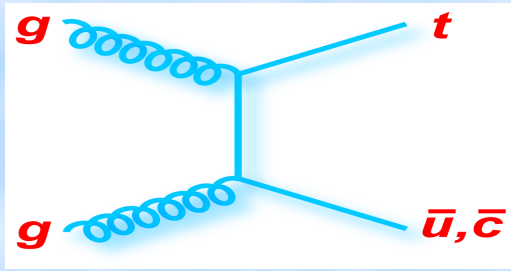
$$\frac{\kappa_f}{\Lambda} g_s \bar{f} \sigma^{\mu\nu} \frac{\lambda^a}{2} t G^a_{\mu\nu}$$

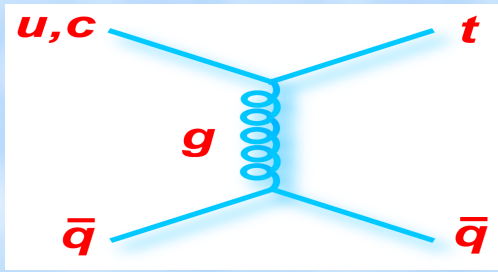
where, *f*: *u*-quark, or *c*-quark

G: gauge field tensor of gluon

κ_f: strength of *tug* or *tcg* couplings

Λ: scale of new physics





- TEVATRON searches for FCNC through gluons:

- previous D0 results ($\mathbf{230\,pb^{-1}}$; 2006)

$k_g^c/\Lambda < 0.15\ TeV^{-1}$ $k_g^u/\Lambda < 0.037\ TeV^{-1}$

(Phys. Rev. Lett. ***99****, 191802 (2007))*

- CDF results ($\mathbf{2.2\,fb^{-1}}$; 2008)

$(k_g^c/\Lambda) < 0.105\ TeV^{-1}, (k_g^u/\Lambda) < 0.025\ TeV^{-1}$

(Phys. Rev. Lett. ***102****, 151801 (2009))*

FCNC search: CompHEP samples

- For this search we used our experience of D0 FCNC search analysis, 2006
- We generated CompHEP MC signal FCNC samples

  for $p, \bar{p} \to \bar{t}\,q + t\,\bar{q}$ with subsequent top decays

- We consider the following four processes:

  $q\bar{q} \to t\bar{c}$, $gg \to t\bar{c}$, $cq(\bar{q}) \to tq(\bar{q})$, $cg \to tg$,

  and, also t replaced with $\bar{t}$

  coupling → κ_c / Λ

  and, also c replaced by u.

  coupling → κ_u / Λ

- Samples: *tgc* K_c=0.03, K_u=0.0 → $(K_c/\Lambda)^2$=0.0009 TeV^{-2}

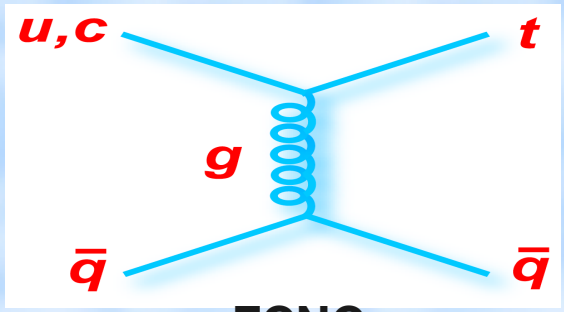
  tgu K_u=0.03, K_c=0.0 → $(K_u/\Lambda)^2$=0.0009 TeV^{-2}

FCNC search: selection and S/B

- Event selection

Phys. Rev. Lett. ***103****, 092001 (2009)*

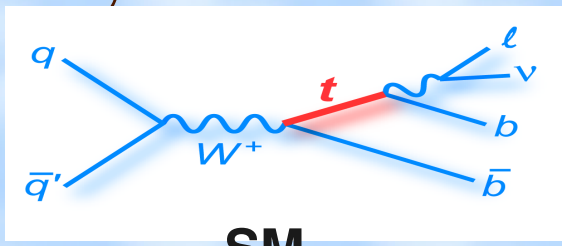
- is identical to the D0 Observation Single Top Analysis



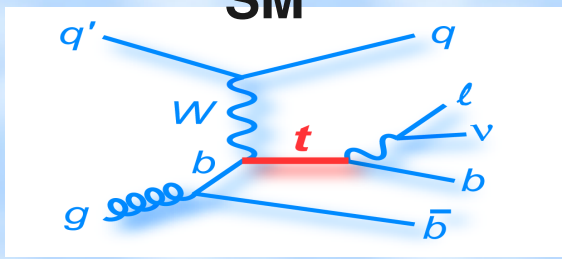
FCNC

- W from top decays leptonically
- exactly one of the jet is required

  to be b-tagged (in contrast with SM)



SM



- Signal modeling

  - we model the signal kinematics and obtain the acceptance for the signal sample at only one value of the FCNC coupling (0.03); then we scale the CS correspondingly

- Background modeling

  - SM single top processes considered as background

  - double top production, W+jets...

FCNC search: multivariate analysis

- Bayesian Neural Networks
- Discriminating variables

Variables considered for the observation analysis	+	Variables used in the previous FCNC analysis in each analysis channel
18 - 28 per channel		10 variables

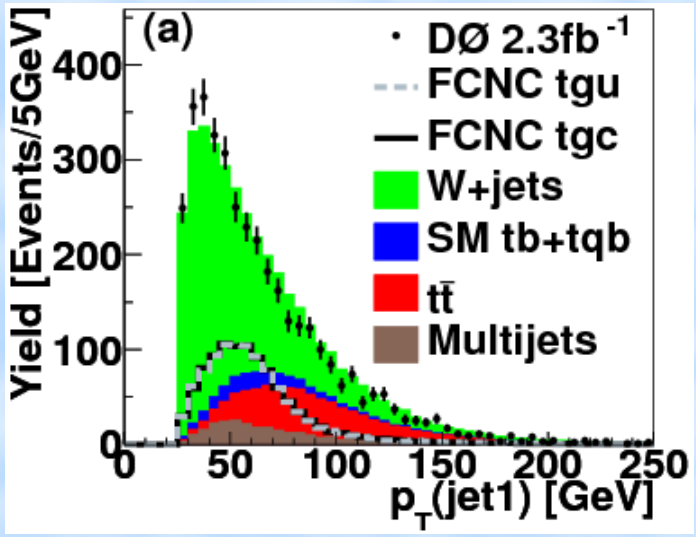
- Stable list of final variables: ~24 per channel

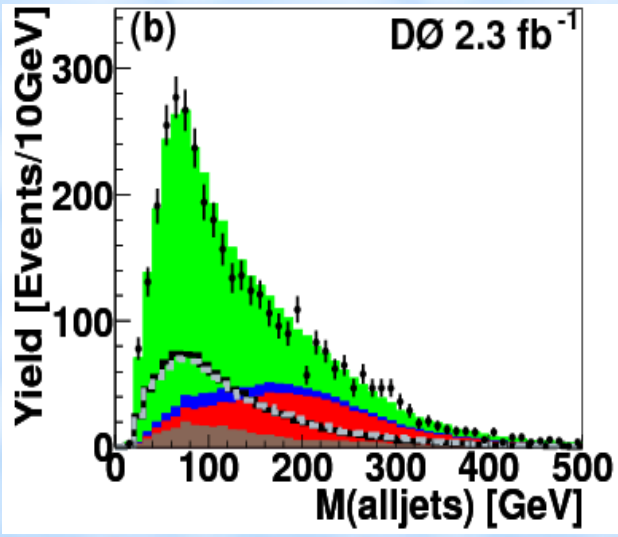
  - *«Object Kinematics», «Jet Widths», «Angular correlations»,*

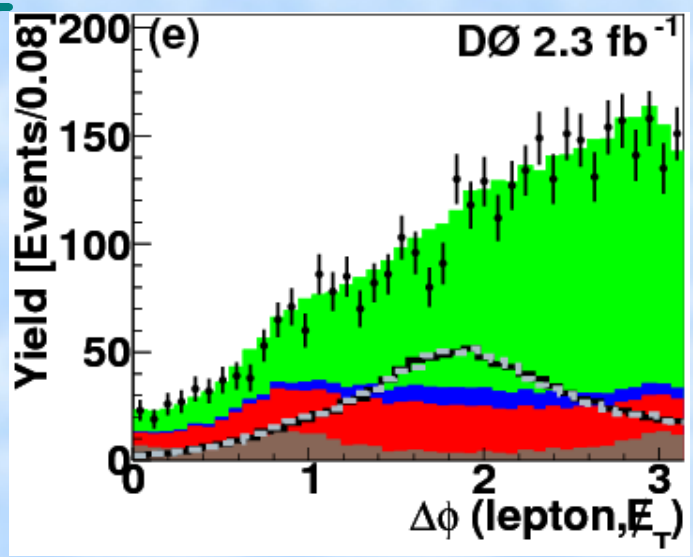
    «Event Kinematics», «Top Quark Reconstruction»

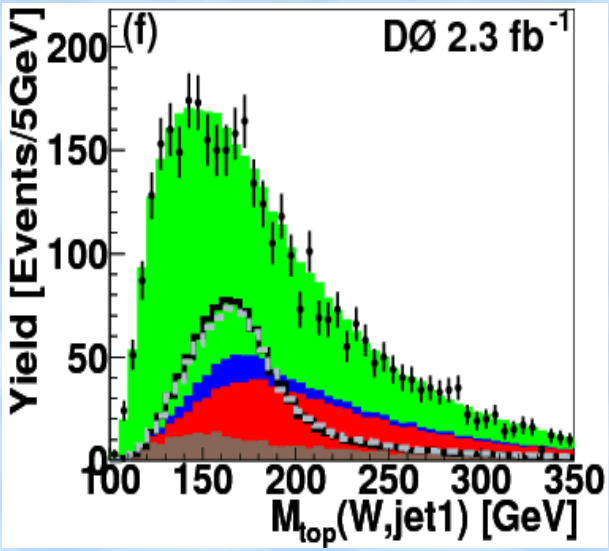
FCNC analysis: discriminating variables

Plots compare the observed data to the background for some discriminating variables





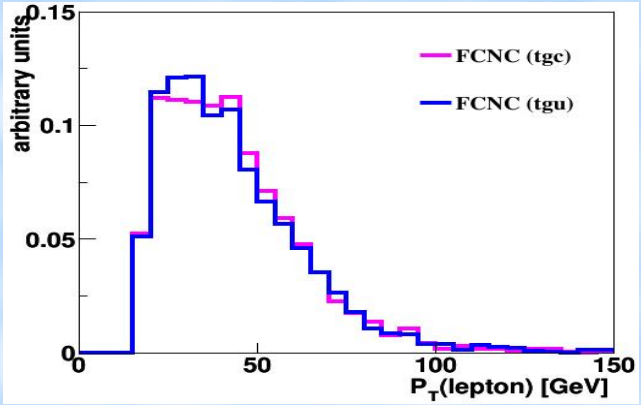


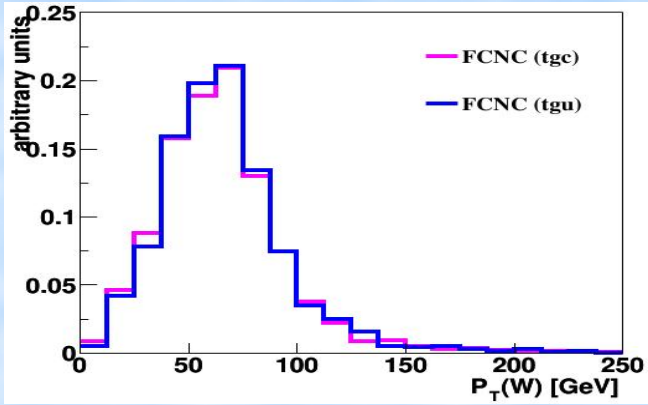


FCNC search: BNN training

- Kinematics of the FCNC processes

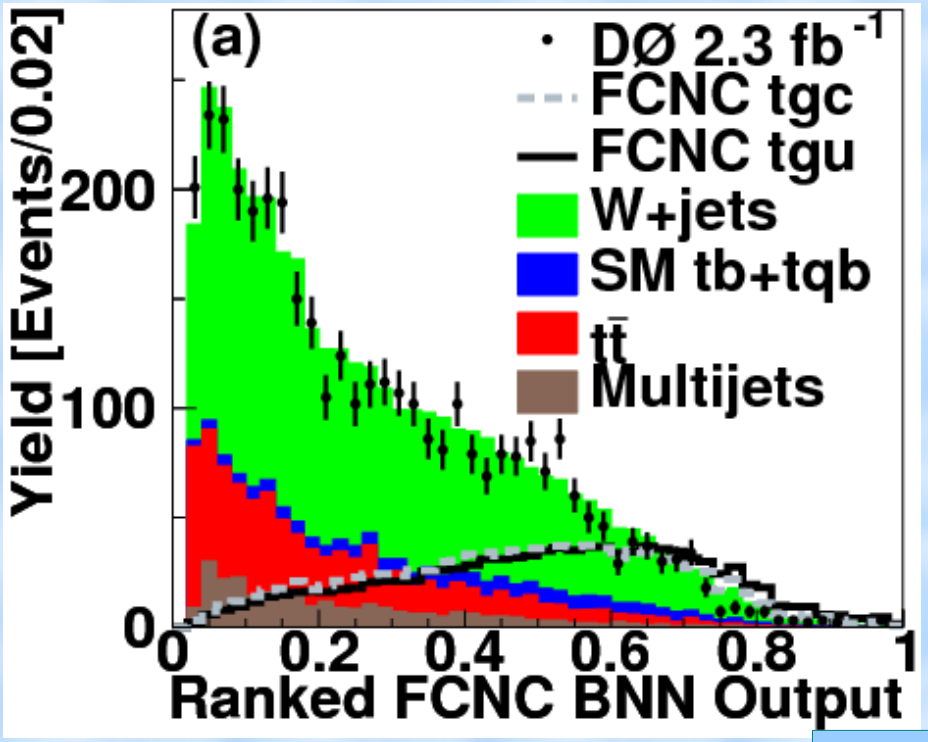
  are similar

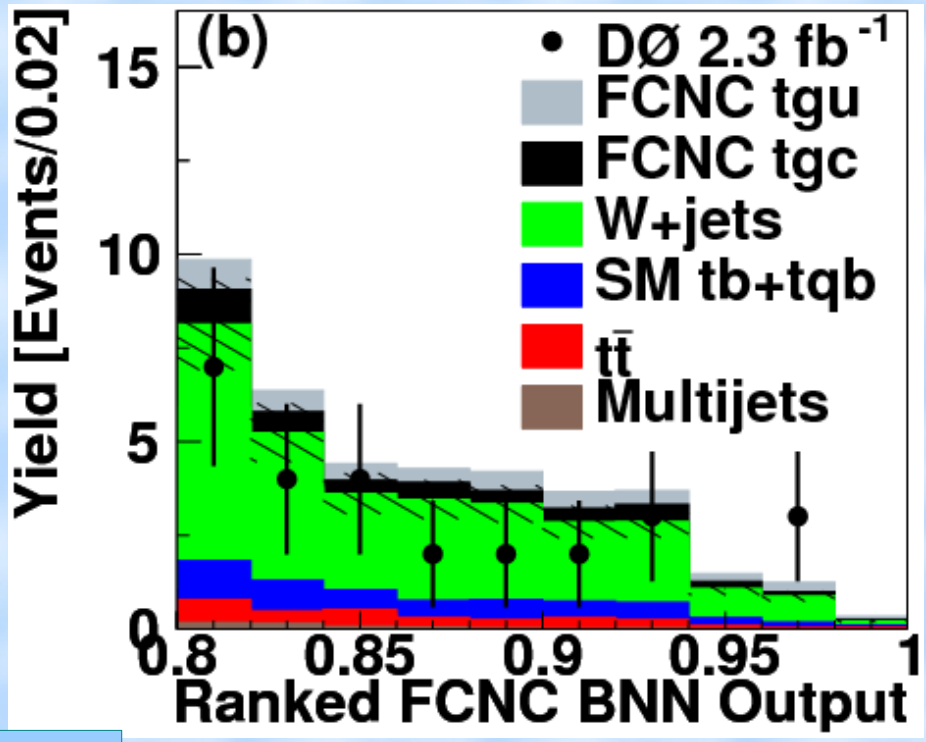




- two FCNC signal processes (tgc, tgu) combined into a single signal for training the BNN
- Separate BNNs are trained for each choice of lepton flavor (e or mu), jet multiplicity (2,3 or 4) and data-taking period (*RunIIa* and *RunIIb*) — 12 in total

FCNC search: BNN discriminant plots





Comparison between background and data for all twelve BNN discriminant combined for

(left) whole discriminant range *(right) high discriminant region*

FCNC search: systematics and setting limits

- Systematic uncertainties
  - mainly from JES, b-tagging, normalization
  - when setting limits on FCNC coupling additional signal CS uncertainty is included

Relative Systematic Uncertainties	
Components for Normalization	
Integrated luminosity	6.1%
cross section top pair	12.7%
single top cross section	8.4%
Z+jets cross section	5.8%
Diboson cross sections	5.8%
Branching fractions	1.5%
Parton distribution functions (signal acceptances only)	3.0%
Triggers	5.0%
. . .	

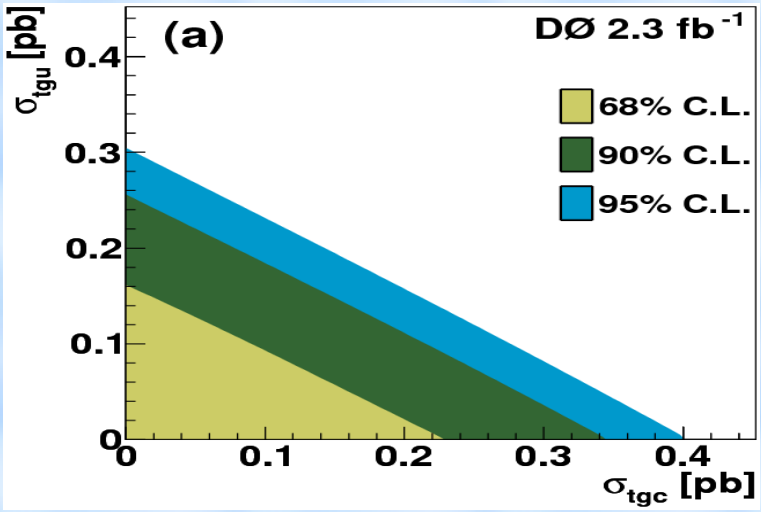
*(D0 Collaboration, Phys. Rev. D **78**, 012005 (2008))*

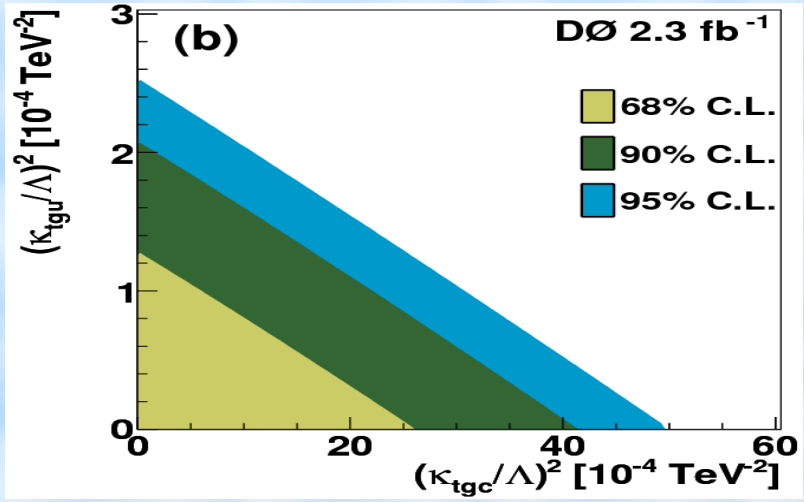
- The observed data are consistent with the background expectation
  - we proceed to set limits on the FCNC couplings

FCNC search: statistical analysis

- We determine the FCNC limits for up and charm quark couplings using a Bayesian approach

  - first we obtain a 2D posterior as a function of both cross sections and as a function of both couplings, using the BNN distribution for data, background and signals



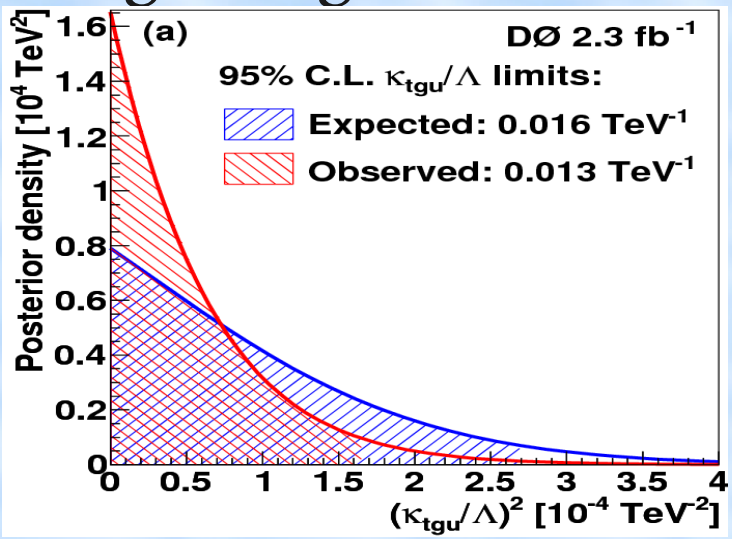


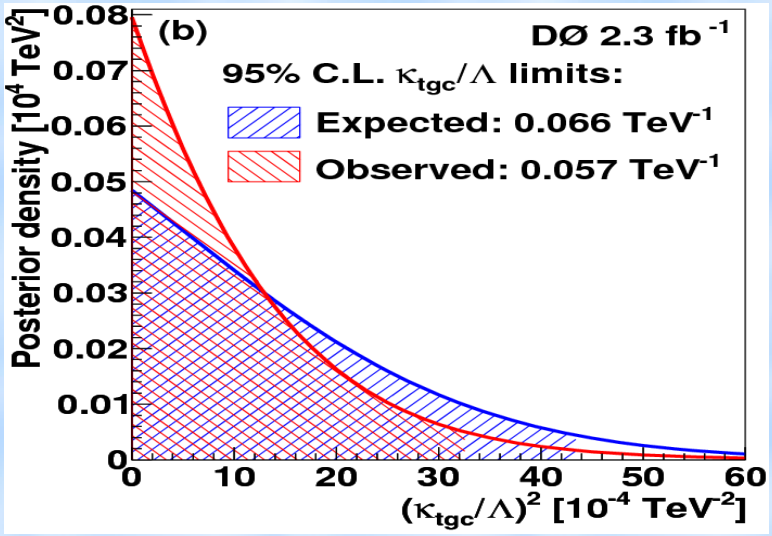
The 2-dimensional posterior probability density as a function of

(left) FCNC cross sections *(right) the squared FCNC couplings*

FCNC search: limits

- One-dimensional posterior densities as a function of CS are derived from the general 2-dimensional posterior by integrating over the axes





The 1-dimensional posterior probability as a function of

(left) squared tgu coupling *(right) squared tgc coupling*

- Limits on the couplings can be translated into decay branching fraction limits

FCNC search: results

- Observed 95% C.L. limits on cross sections, couplings and branching fractions:

	tgu	tgc
Cross section	0.20 pb	0.27 pb
κ_{tgq}/Λ	0.013 TeV^{-1}	0.057 TeV^{-1}
$\mathcal{B}(t \to qg)$	2.0×10^{-4}	3.9×10^{-3}

- for comparison
  - previous D0 results (2006): $k_g^u/\Lambda < 0.037\ TeV^{-1}$ $k_g^c/\Lambda < 0.15\ TeV^{-1}$
  - CDF results (2008): $\mathcal{B}(t \to u+g) < 3.9 \times 10^{-4}$ $\mathcal{B}(t \to c+g) < 5.7 \times 10^{-3}$
    $\kappa_{tug}/\Lambda < 0.018\ \text{TeV}^{-1}$ $\kappa_{tcg}/\Lambda < 0.069\ \text{TeV}^{-1}$

FCNC search: conclusion

- We presented a search for FCNC interactions through gluons
- Using $\mathbf{2.3\,fb^{-1}}$ of integrated luminosity recorded by the D0 detector at Fermilab we set limits on the couplings, branching fractions and cross sections

	tgu	tgc
Cross section	0.20 pb	0.27 pb
κ_{tgq}/Λ	0.013 TeV^{-1}	0.057 TeV^{-1}
$\mathcal{B}(t \to qg)$	2.0×10^{-4}	3.9×10^{-3}

- This branching fraction and FCNC couplings limits are the most stringent at the moment
- The paper: arXiv:1006.3575
- We could set stronger limits with new D0 data