

Top Quark Properties from top pair events and decays



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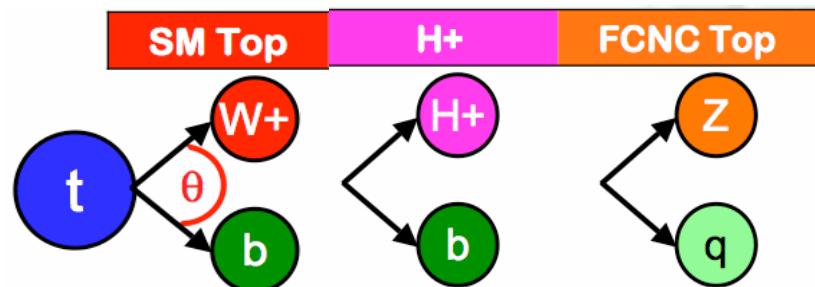
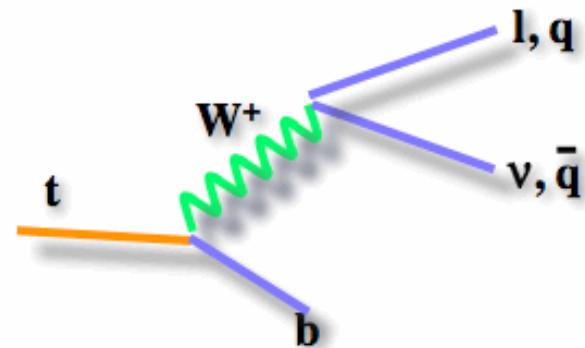


For CDF and D0 Collaborations

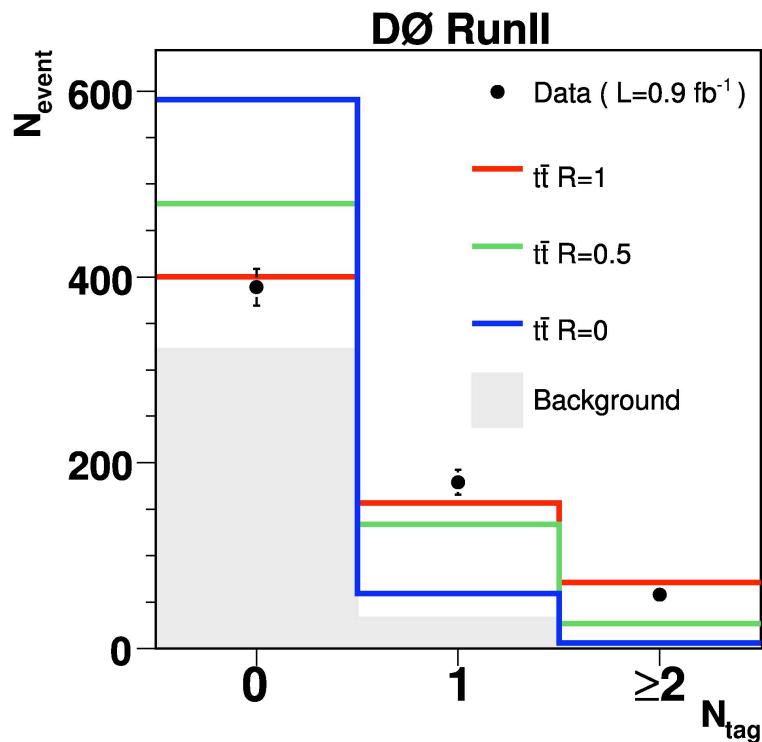
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Top Properties Analyses

- Within the SM the top quarks decays into Wb
- Probing the nature of $t \rightarrow Wb$ vertex:
 - W Helicity Measurement
- Can the top quark decay into other particles?
 - Search for Charged Higgs
 - Search for FCNC top decays
 - Search for Invisible Top Decays

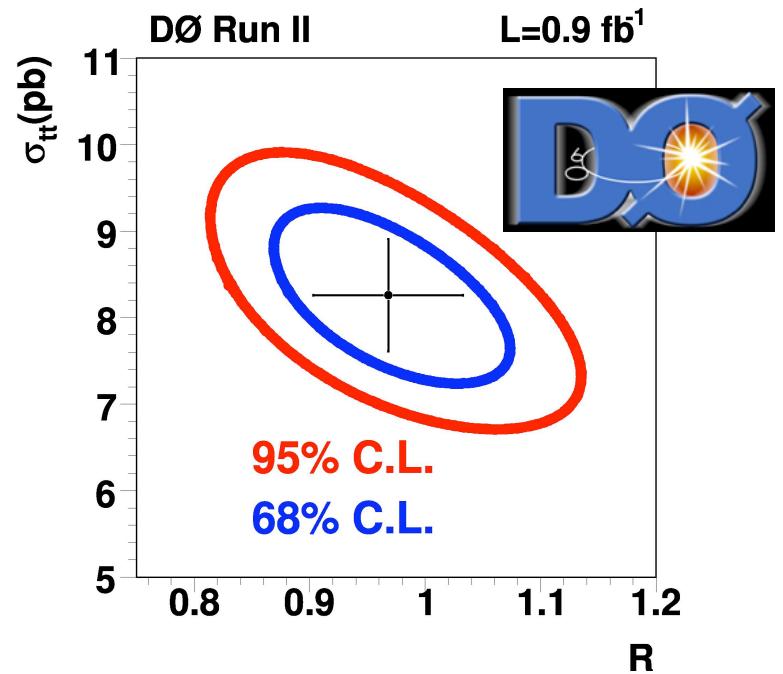


Measurement of $R = \text{BR}(t \rightarrow W b) / \text{BR}(t \rightarrow W q)$



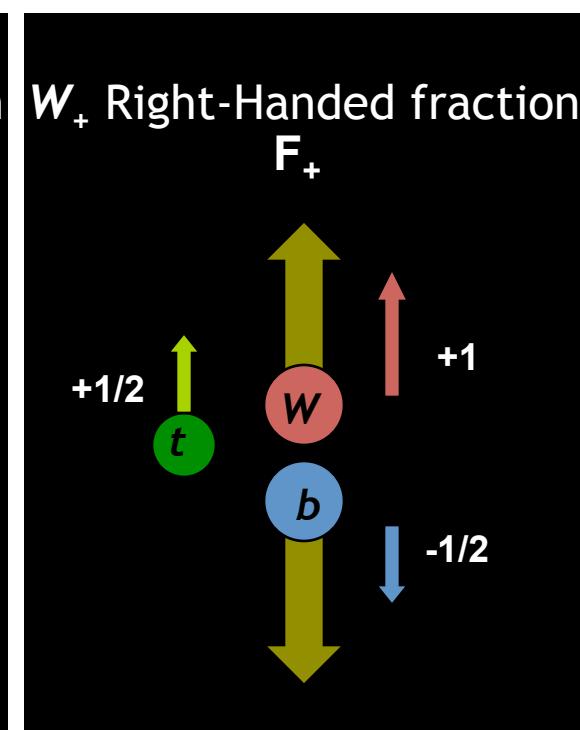
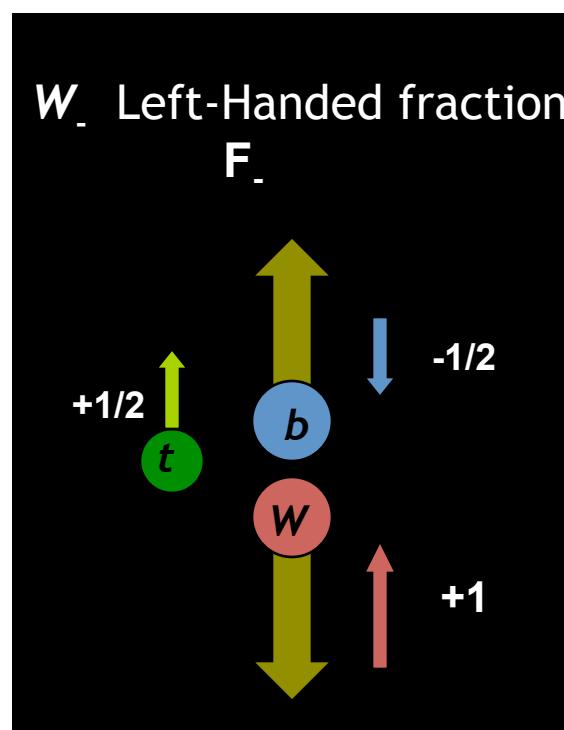
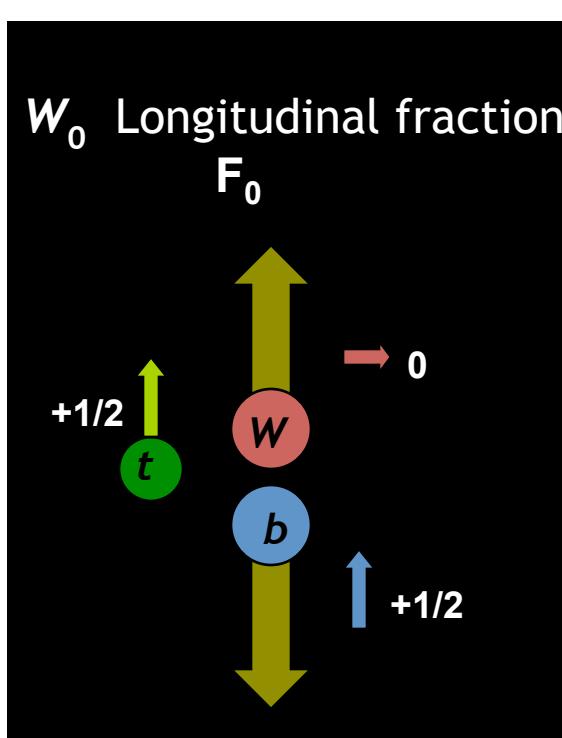
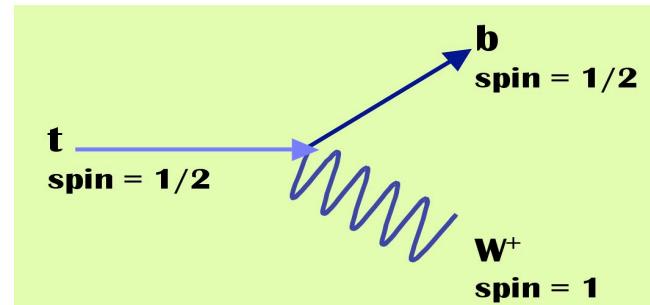
$R = 0.97 \pm 0.09 \text{ (stat+syst)}$
 $\sigma_{tt} = 8.2 \pm 0.9 \text{ (stat+syst)} \pm 0.5 \text{ (lumi)}$

- Using lepton + jets channel with and without b-tagging requirement



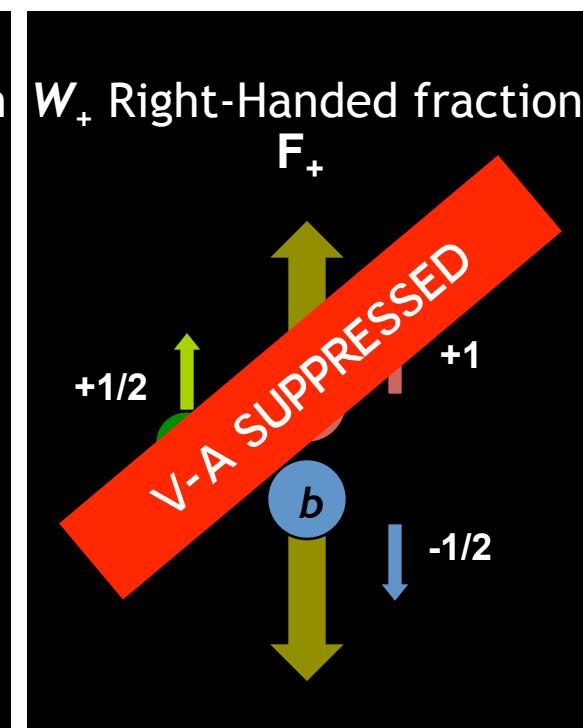
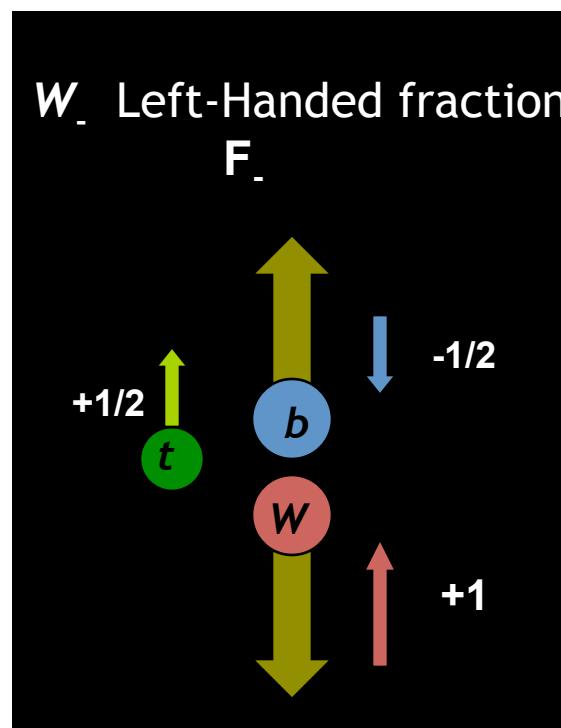
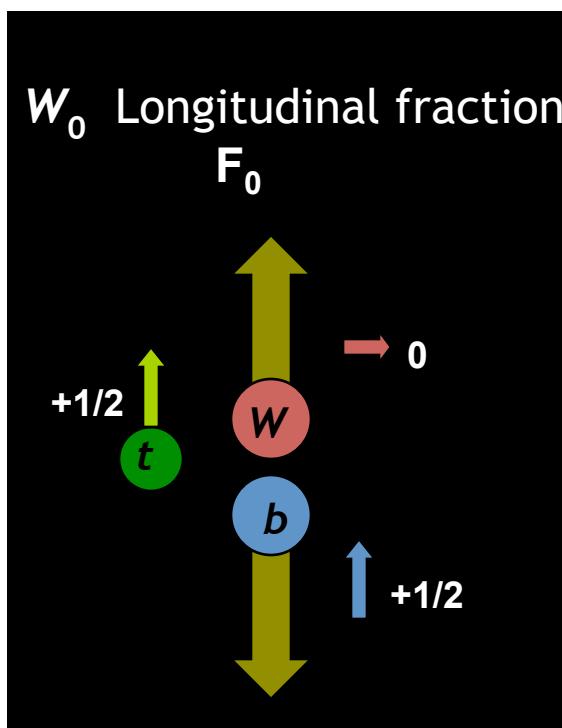
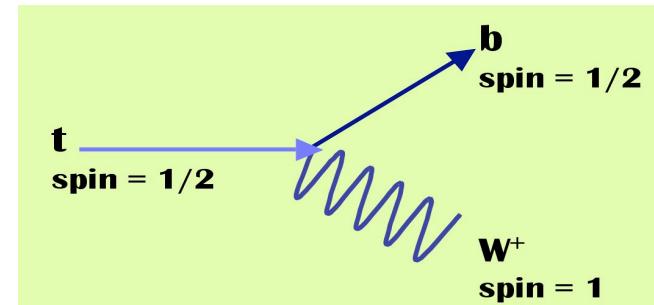
W Helicity

- Spin information of the top quark is preserved in its decay products
- Examining the V-A nature of $t \rightarrow W b$ vertex provides stringent test of the SM



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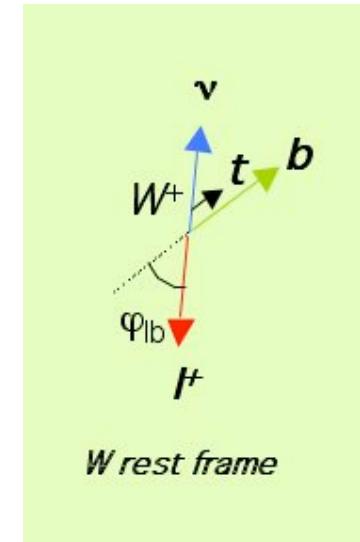
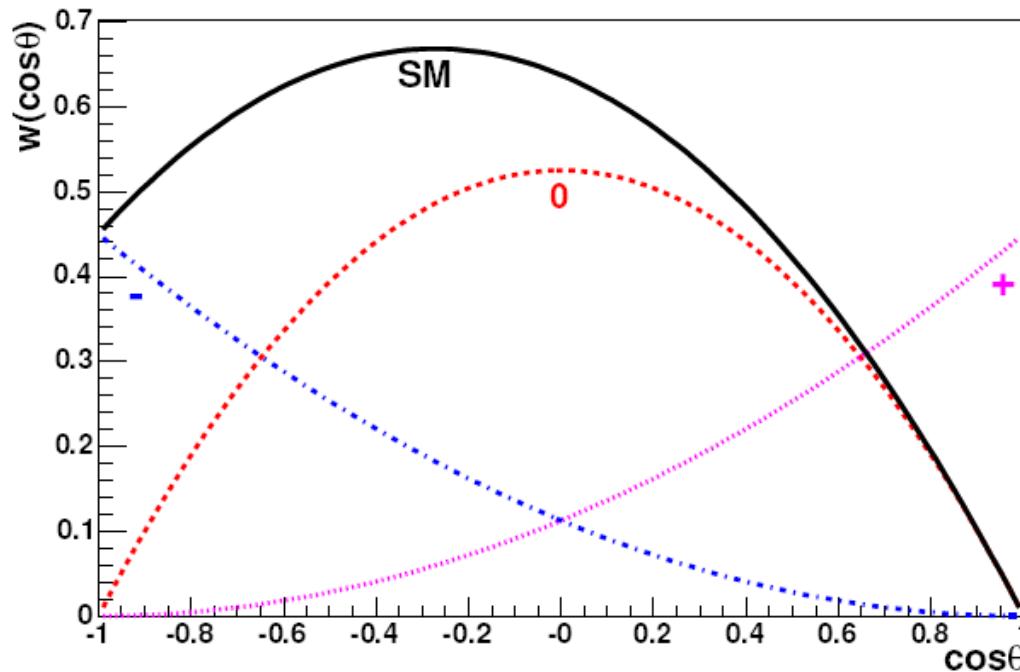


W Helicity

- In the Standard Model ($m_b = 0$):

$$w(\cos\varphi_{l\bar{b}}) = F_- \cdot \frac{3}{8}(1 - \cos\varphi_{l\bar{b}})^2 + F_0 \cdot \frac{3}{8}(1 - \cos^2\varphi_{l\bar{b}}) + F_+ \cdot \frac{3}{8}(1 + \cos\varphi_{l\bar{b}})^2$$

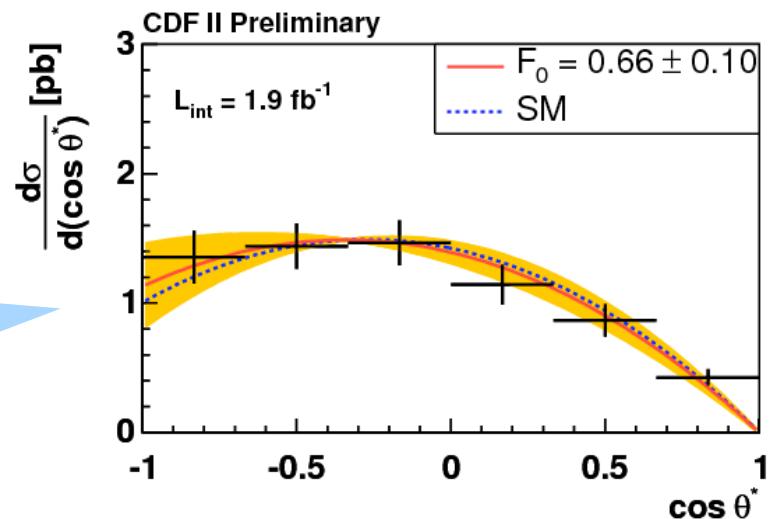
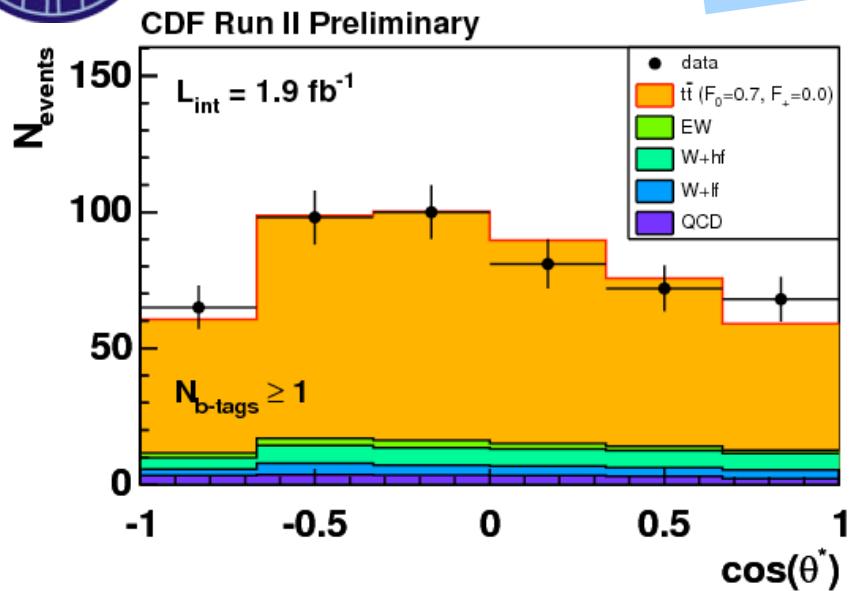
$$F_- = 0.3 \quad F_0 = 0.7 \quad F_+ = 3.6 \times 10^{-4}$$



- Measure angle between the lepton direction in the W rest frame and the W boson direction in the top rest frame

W Helicity Measurement

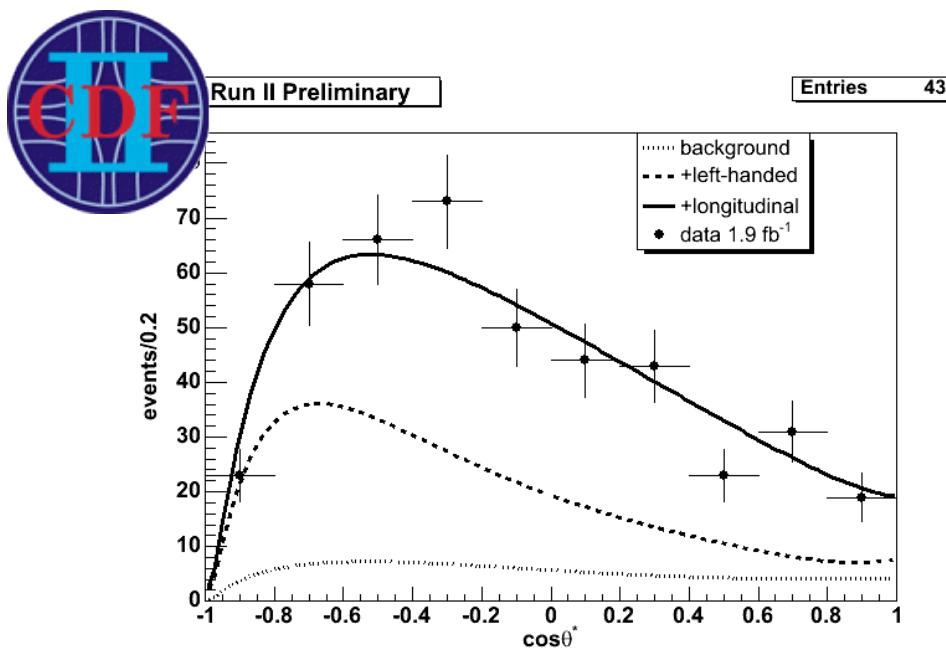
- 1. Full Reconstruction of $\cos \theta^*$
- applying event selection efficiency
- and event reconstruction migration matrix



$F_0 = 0.66 \pm 0.10(\text{stat}) \pm 0.06 (\text{syst})$
 $F_+ < 0.12$ at 95% C.L.

W Helicity Measurement

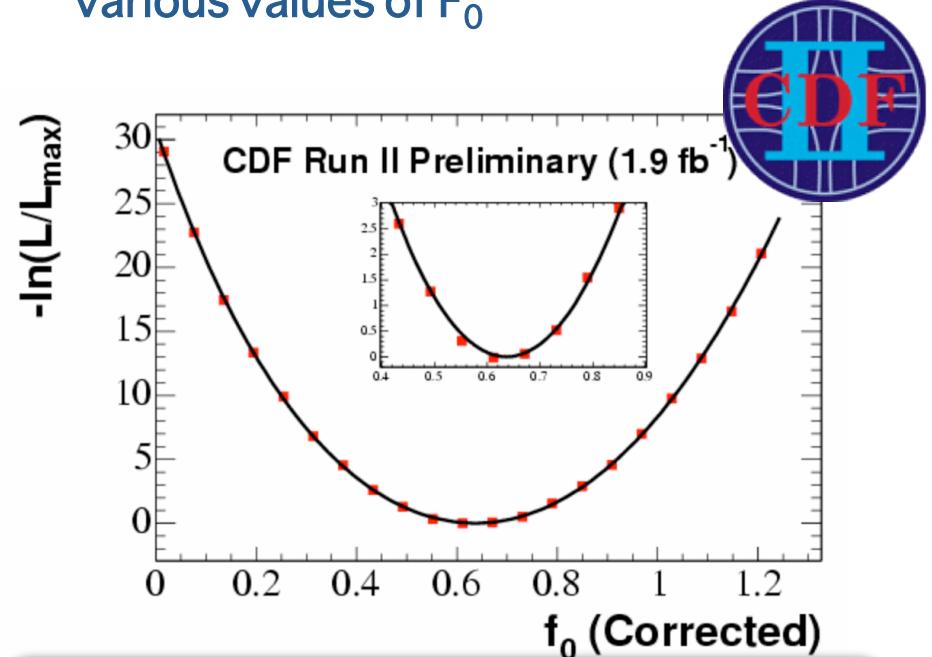
- 2. Template method $\cos \theta^*$
- fit to the combination of templates



$$F_0 = 0.59 \pm 0.11(\text{stat}) \pm 0.04 (\text{syst})$$

$$F_+ < 0.07 \text{ at } 95\% \text{ C.L.}$$

- 3. Matrix Element Method
- utilizing ME probability density for various values of F_0



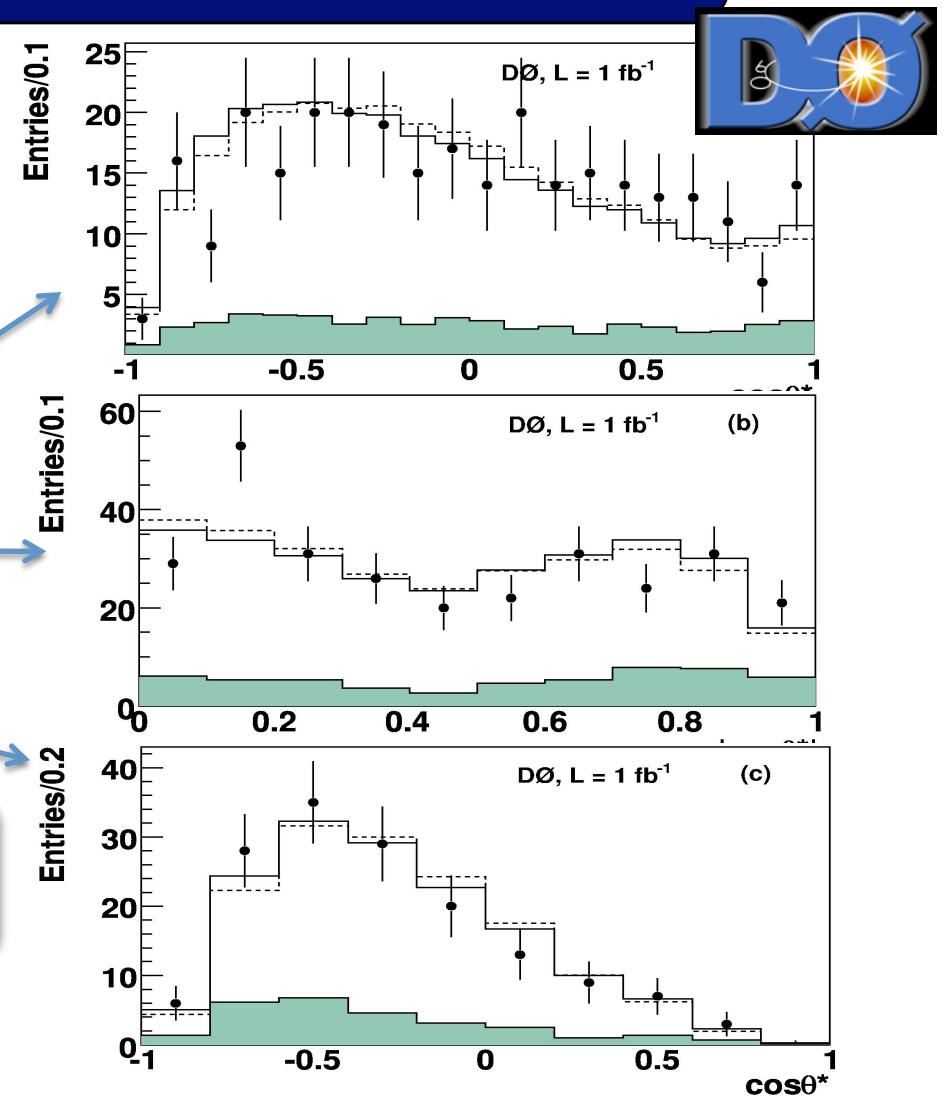
$$F_0 = 0.64 \pm 0.08(\text{stat}) \pm 0.07 (\text{syst})$$

W Helicity Measurement

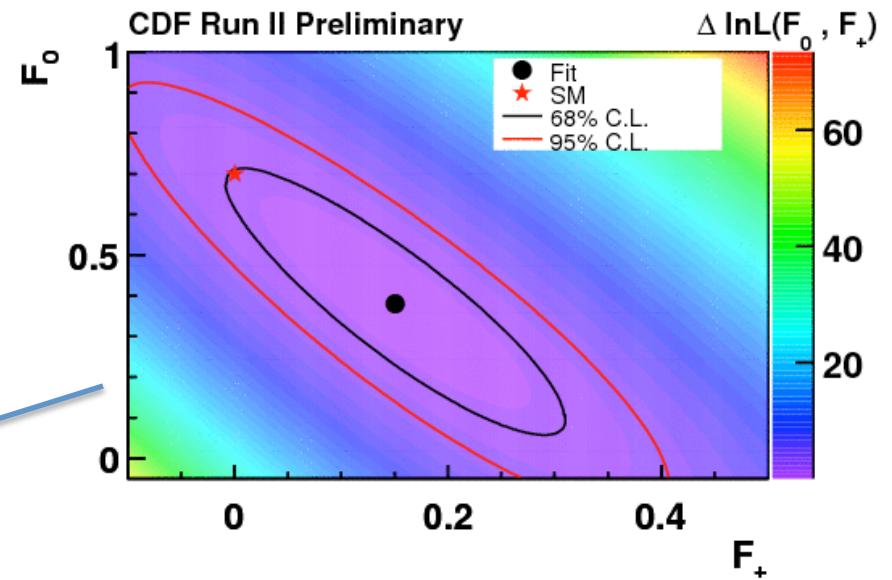
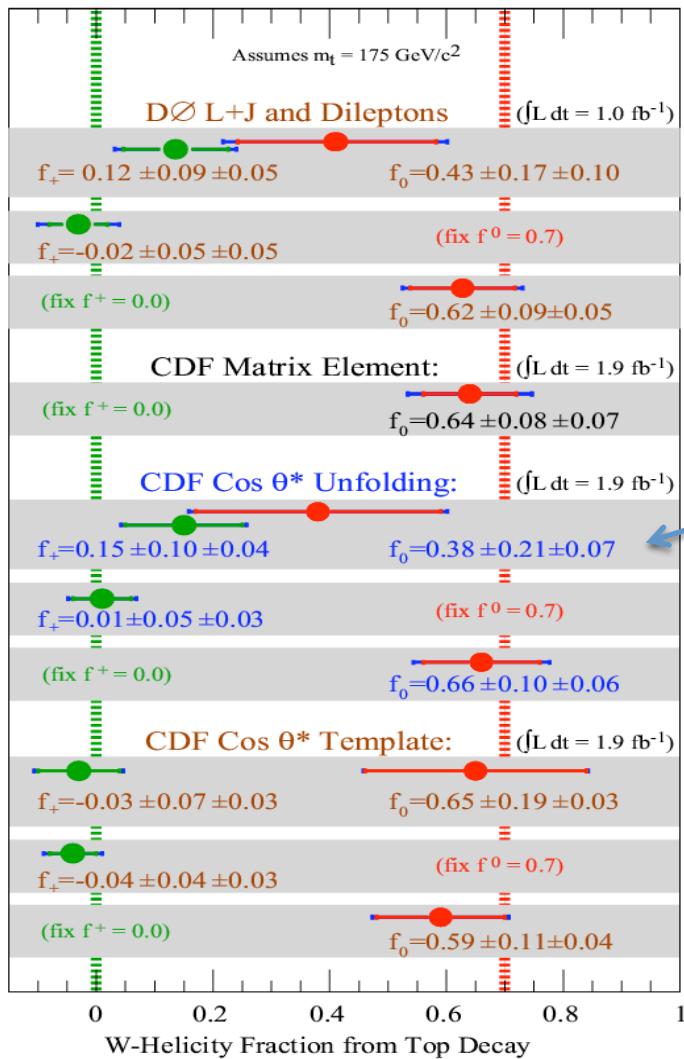
- Utilize several channels
- Use the binned likelihood fit $L(F_0, F_+)$

- Leptonic W decays ($l+jets$)
- Hadronic W decays ($l + jets$)
- Dilepton events

$$F_0 = 0.62 \pm 0.09(\text{stat}) \pm 0.05 (\text{syst})$$
$$F_+ = 0.02 \pm 0.05(\text{stat}) \pm 0.05 (\text{syst})$$

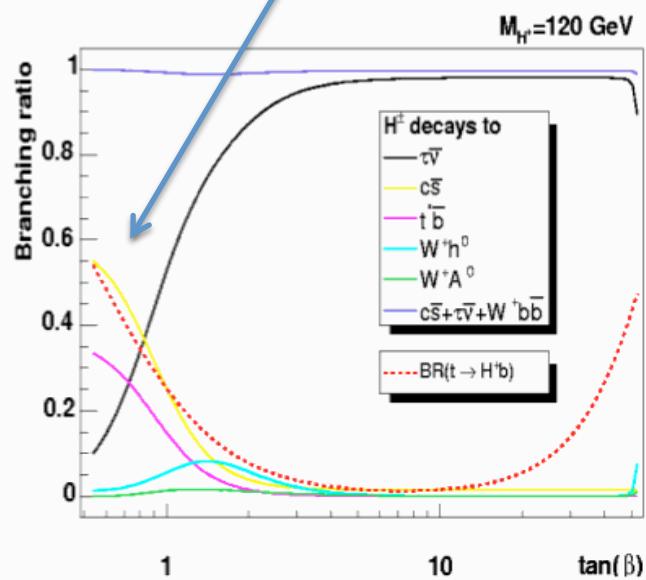
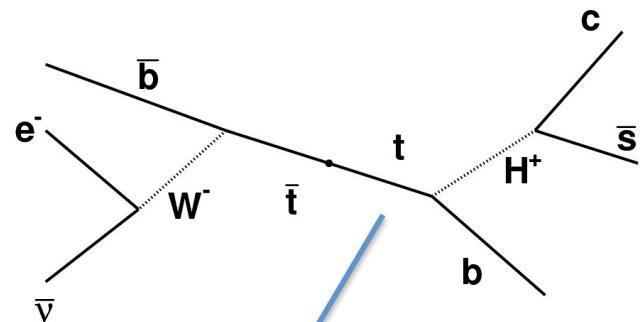


Summary of W Helicity Measurements



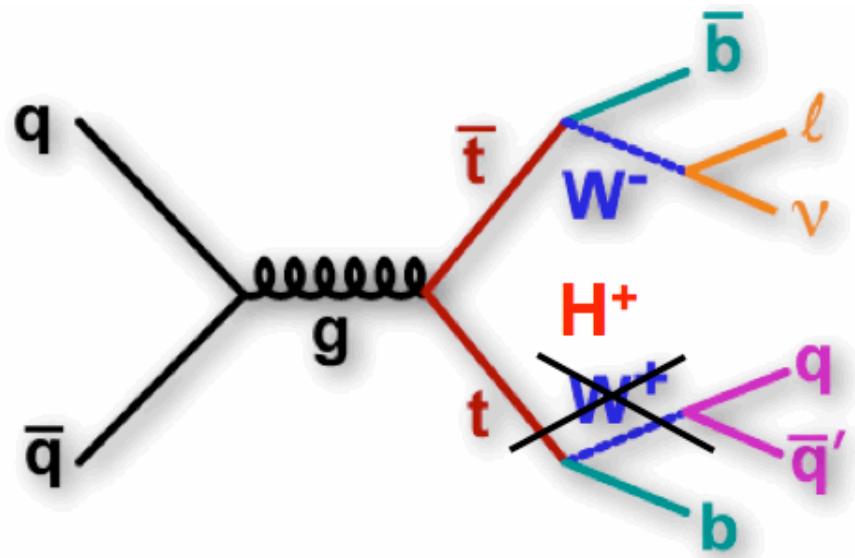
- With more statistics we start doing simultaneous fits for F_0 and F_+
- Results in good agreement with the SM

Search for Charged Higgs

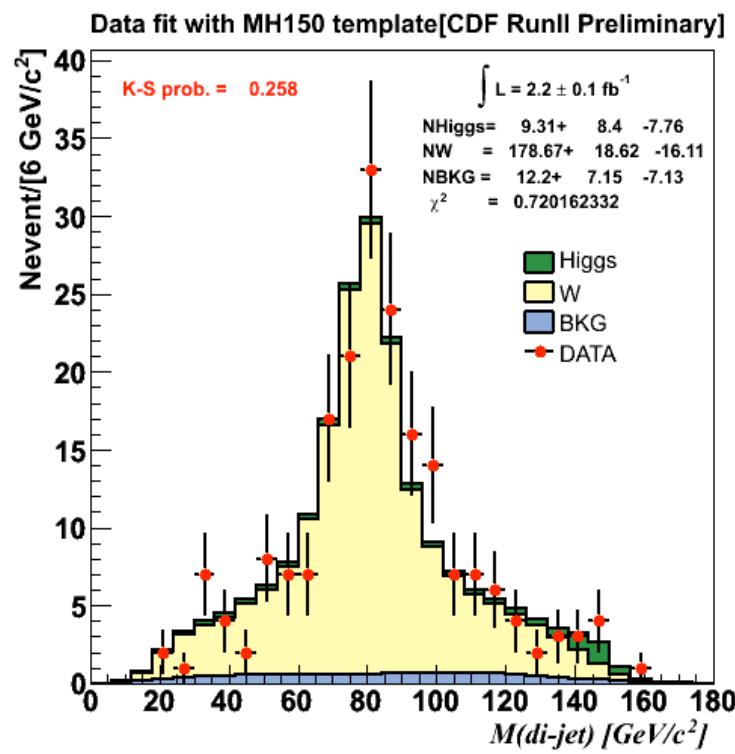


- Explore the possibility that $t \rightarrow H^+ b$ with subsequent $H^+ \rightarrow c \bar{s}$

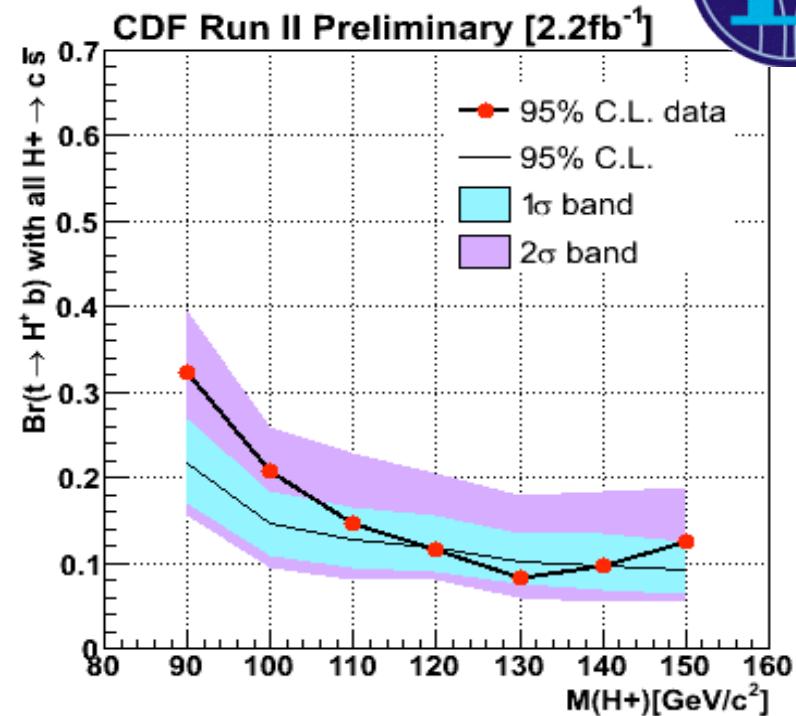
Reconstruct event kinematics:



Charged Higgs Search Results

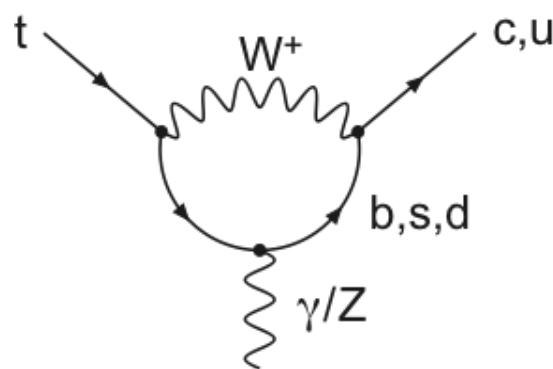


Limit on BR ($t \rightarrow H^+ b$):



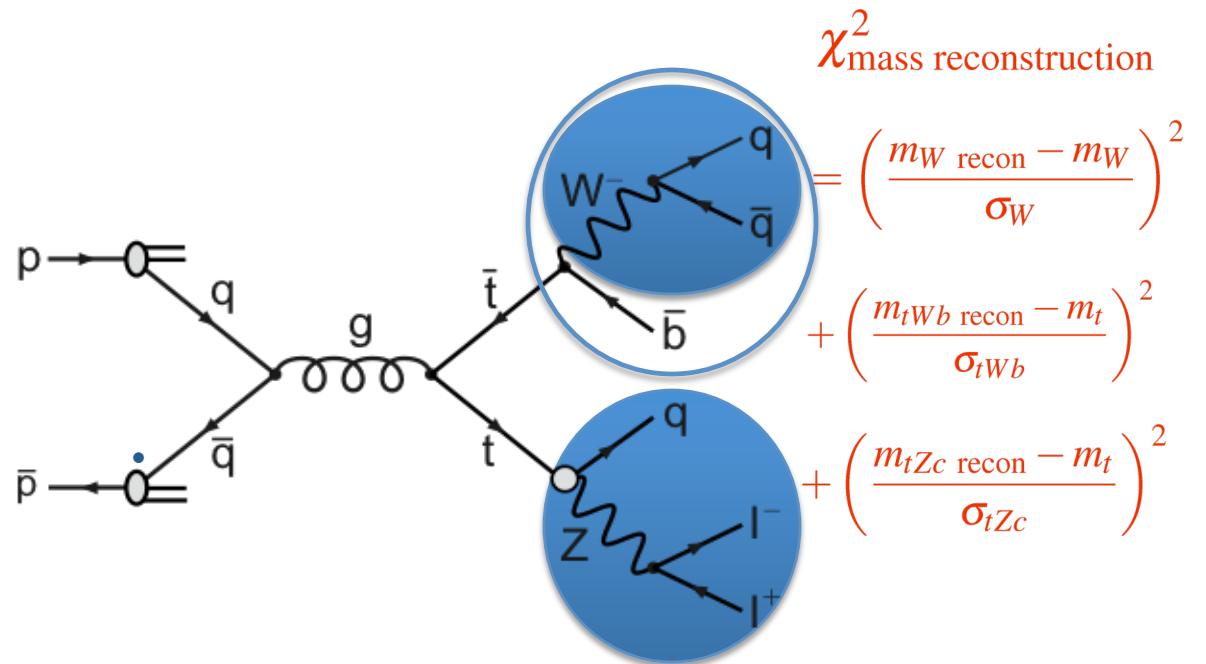
Search for Top Flavor Changing Neutral Currents ($t \rightarrow Zq$)

$\text{BR}(t \rightarrow Zq) \sim \mathcal{O}(10^{-14})$ – extremely rare
Beyond SM can be as high as $\mathcal{O}(10^{-4})$



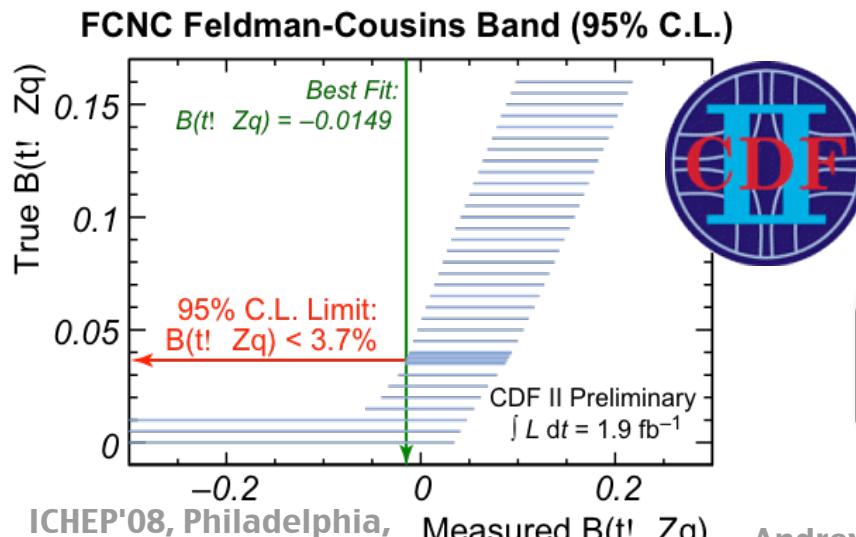
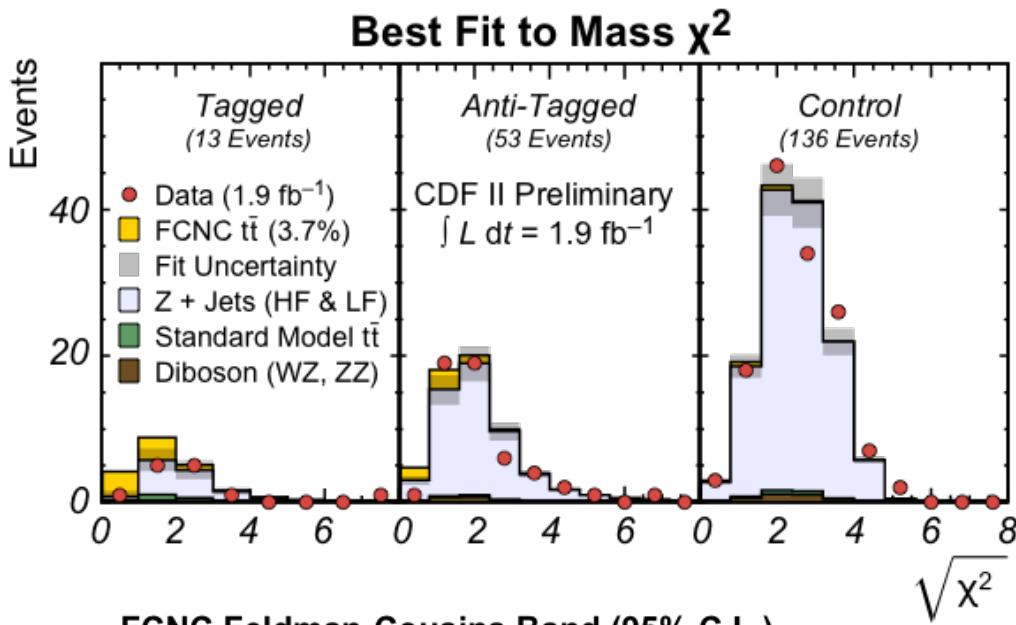
Top FCNC Decay
via Penguin Diagram

- Reconstruct event kinematics:



- Dominant Background: $Z + 4$ jets

Top FCNC Search Results



ICHEP'08, Philadelphia,
30-July-08

Andrew Ivanov

- Exploit full kinematics shape instead of counting experiment
- Control systematic shape uncertainties via morphing templates
- Simultaneous fit to mass χ^2 -distribution in two signal and one control regions
- Employ Feldman-Cousins prescription for setting limit

**$BR(t \rightarrow Zq) < 3.7\%$
(95% C.L.)**

*World's Best
Measurement!*

Search for Invisible Top decays

$$\text{Yield} \propto \mathcal{P}(t\bar{t} \rightarrow Wb Wb) +$$

$$\mathcal{P}(t\bar{t} \rightarrow Wb XY) \cdot \mathcal{R}_{W\text{X}/WW}$$

$$\mathcal{P}(t\bar{t} \rightarrow XY XY) \cdot \mathcal{R}_{XX/WW}$$

- Assume theoretical cross section for ttbar
- Search for deficit in the event yield

Relative Acceptance when one top decays into Wb while the other one to XY

Relative acceptance when both tops decay to XY

Results:

CDF Run II Preliminary 1.9 fb⁻¹

Decay	$\mathcal{R}_{W\text{X}/WW}$ (%)	Upper Limit (%) (175 GeV)	Upper Limit (%) (172.5 GeV)	Upper Limit (%) (170 GeV)
$\mathcal{B}(t \rightarrow Zc)$	32	13	15	18
$\mathcal{B}(t \rightarrow gc)$	27	12	14	17
$\mathcal{B}(t \rightarrow \gamma c)$	18	11	12	15
$\mathcal{B}(t \rightarrow \text{invisible})$	0	9	10	12

Conclusions

- Top Quark Physics becomes a precision field
- Top Properties measurements are still statistically limited
- So far measurements are mostly consistent with the Standard Model
- More Top Physics results are at:
 - http://www-cdf.fnal.gov/physics/new/top/public_tprop.html
 - http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html