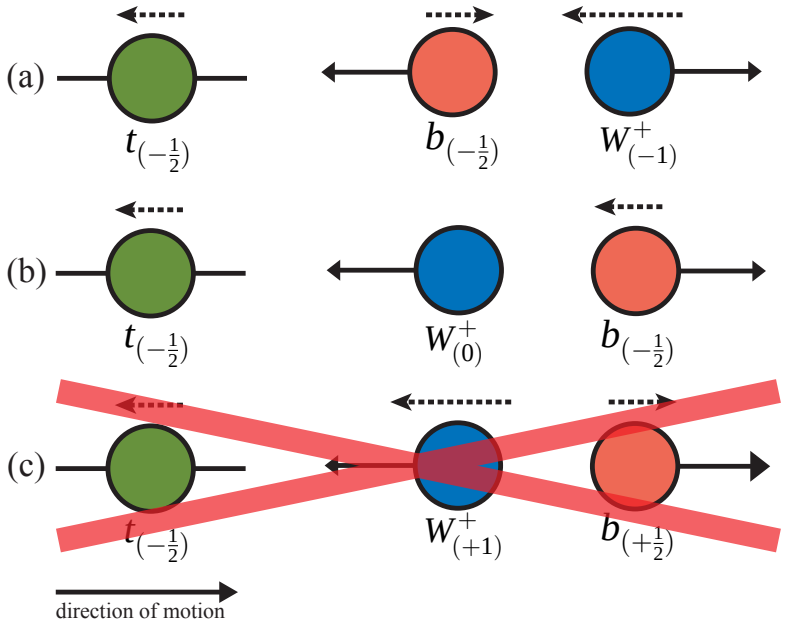
A Measurement of the Fraction of Longitudinally-Polarized W Bosons Produced in Top-Quark Decays Using Charged-Lepton p_T

Nathan Goldschmidt Kenneth Bloom Stephen Miller
David Gerdes Dante Amidei

New Perspectives June 4, 2004

Introduction/Physics Motivation



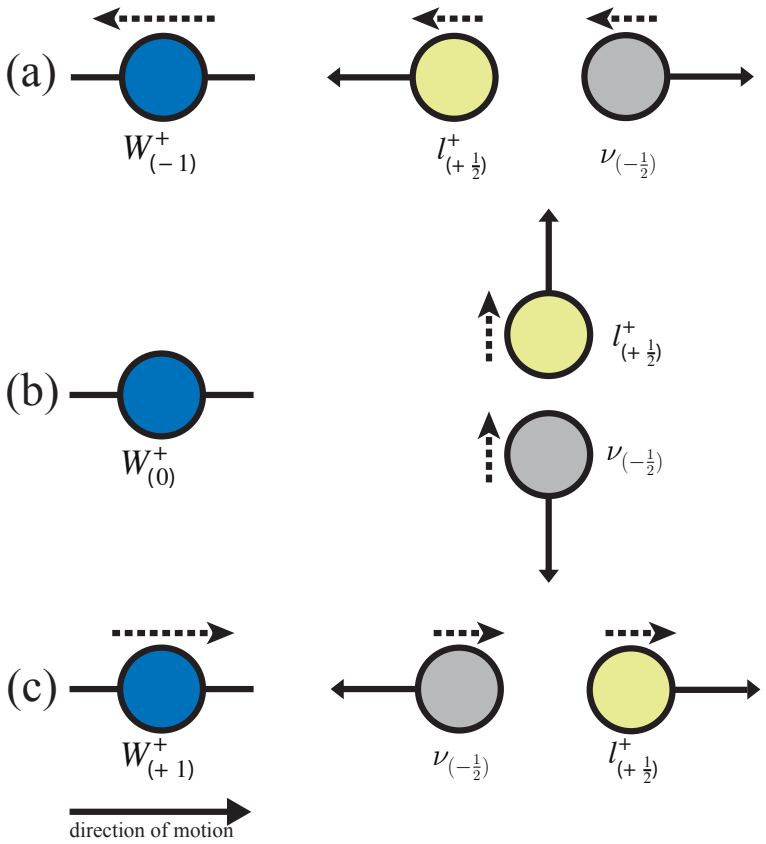
- SM: Only left-handed and longitudinal Ws may be produced in the top-quark rest frame.
- SM: $t \to W_0 b$ is enhanced

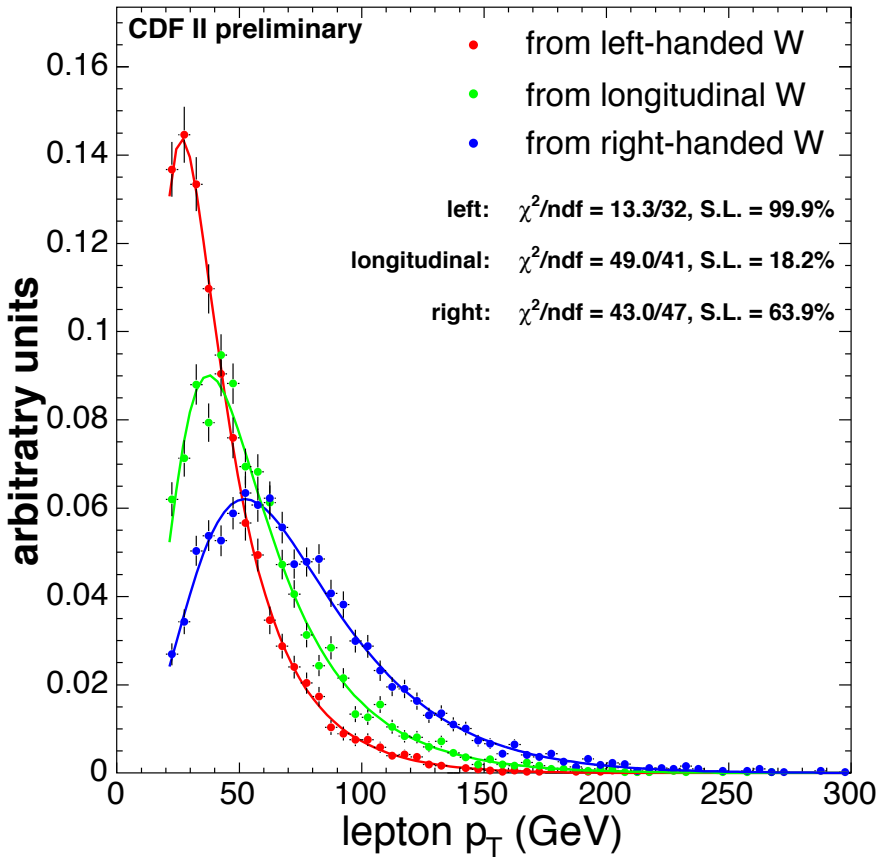
$$F_0 = \frac{\Gamma(W_0)}{\Gamma(W_0) + \Gamma(W_T)}$$

$$= (1 + 2(m_W/m_t)^2)^{-1} \simeq 0.7$$

- Exploring the the tWb coupling should lend insight to the nature of EWSB.
- It's a reasonable place to look for new physics.
- Here is an opportunity to test a prediction of the SM.

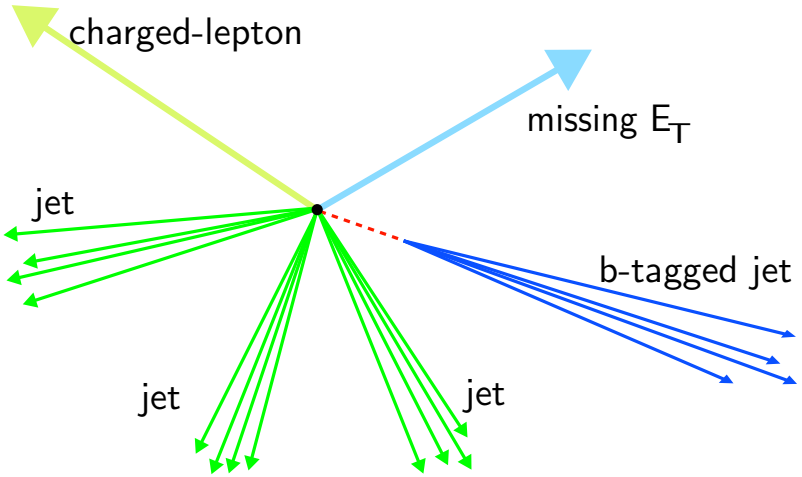
Measurement Strategy



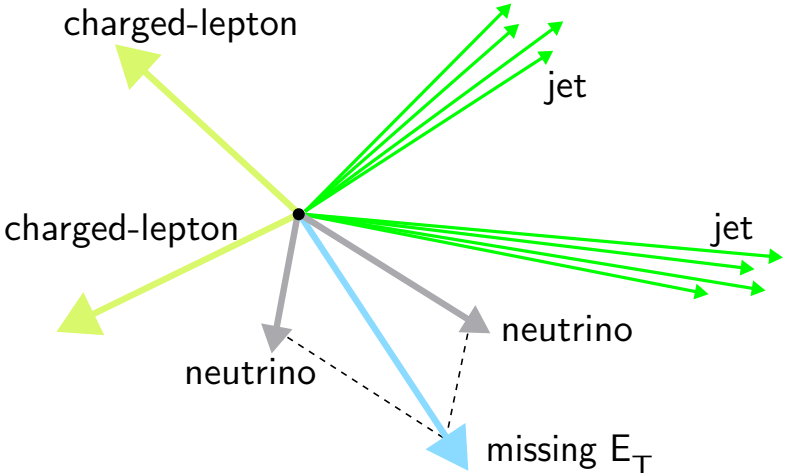


- Charged-lepton p_T is affected by the W helicity.
- We can estimate the helicity content of $t\bar{t}$ samples by analyzing their charged-lepton p_T spectra.

Lepton+Jet and Dilepton $t\bar{t}$ Samples



lepton+jets signature



dilepton signature

- Drawn from data recorded at CDF II through September 2003
- $\int Ldt = 162 - 192$ pb^{-1}

sample	charged leptons
lepton+jets	57
dilepton	26
total	83

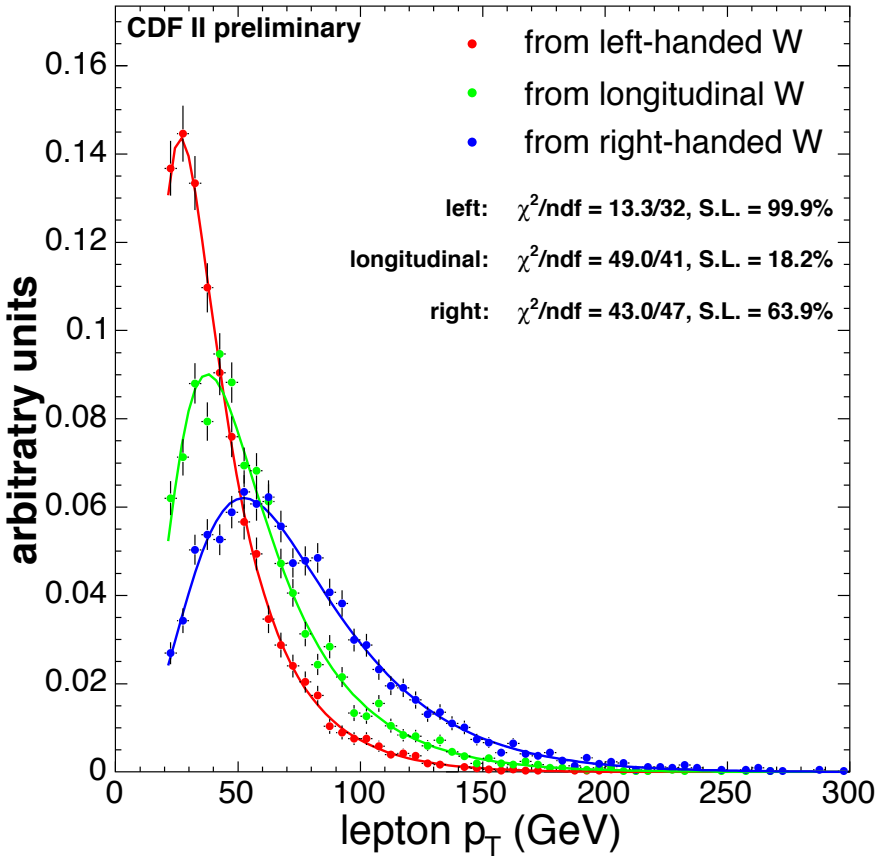
The Likelihood Function (simplified)

$$\mathscr{L}(F_0, \beta) = G(\beta; \mu, \sigma) \prod_{i=1}^{N} P(x_i; F_0, \beta)$$

$$P(x_i; F_0, \beta) = \beta P(x_i; \text{b.g.}) + (1-\beta)\{F_0 P(x_i; 0) + (1-F_0) P(x_i; -1)\}$$

- F_0: the fraction of longitudinally-polarized Ws
- β: the background fraction
- $\mu \pm \sigma$: prior estimate of the background fraction
- $G(\beta; \mu, \sigma)$: Gaussian constraint on the background fraction
- $P_s(x_i; \text{b.g.})$: PDF of charged-leptons with $p_T = x_i$, given they are due to a background process
- $P_s(x_i; h)$: PDF of charged-leptons with $p_T = x_i$, given they are due to a W (from top decay) with helicity h

The Signal Model



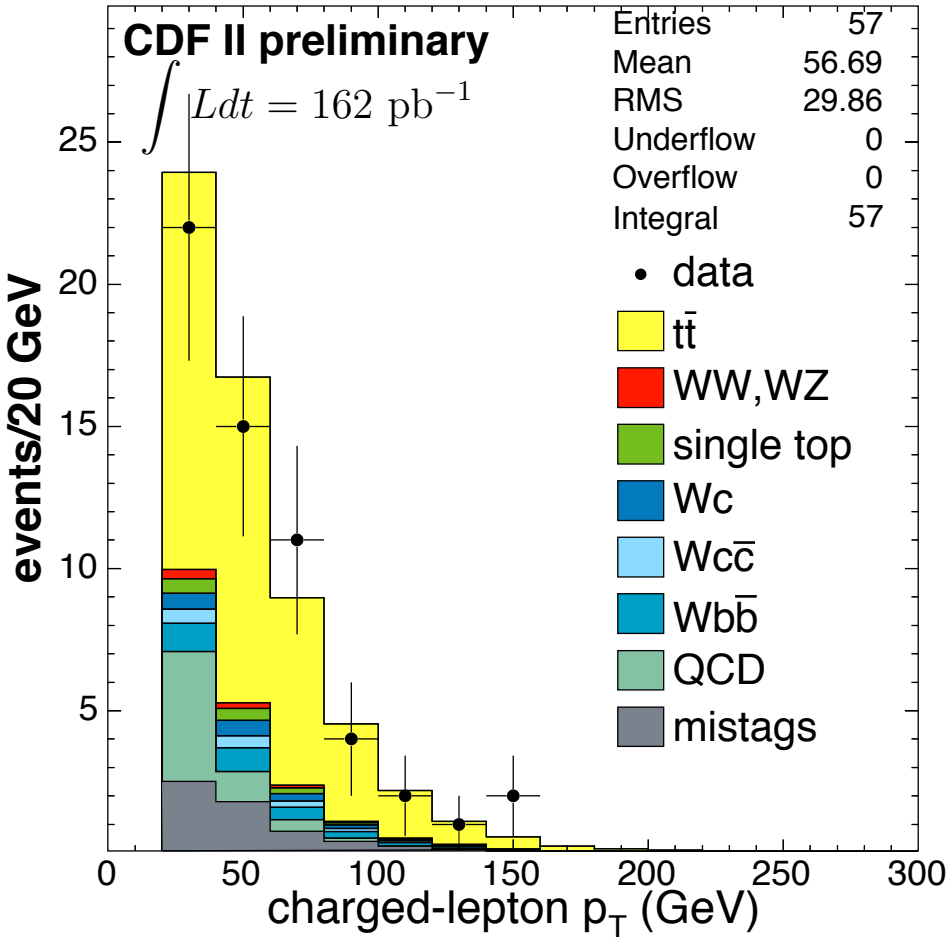
- Derived from `HERWIG v6.5x` inclusive $t\bar{t}$ Monte Carlo
- These samples have W-helicity fixed, $h = -1, 0$ or 1
- After detector simulation, reconstruction and selection we fit to an analytic form
- We also use these samples to estimate the acceptance bias correction

Systematic Uncertainties

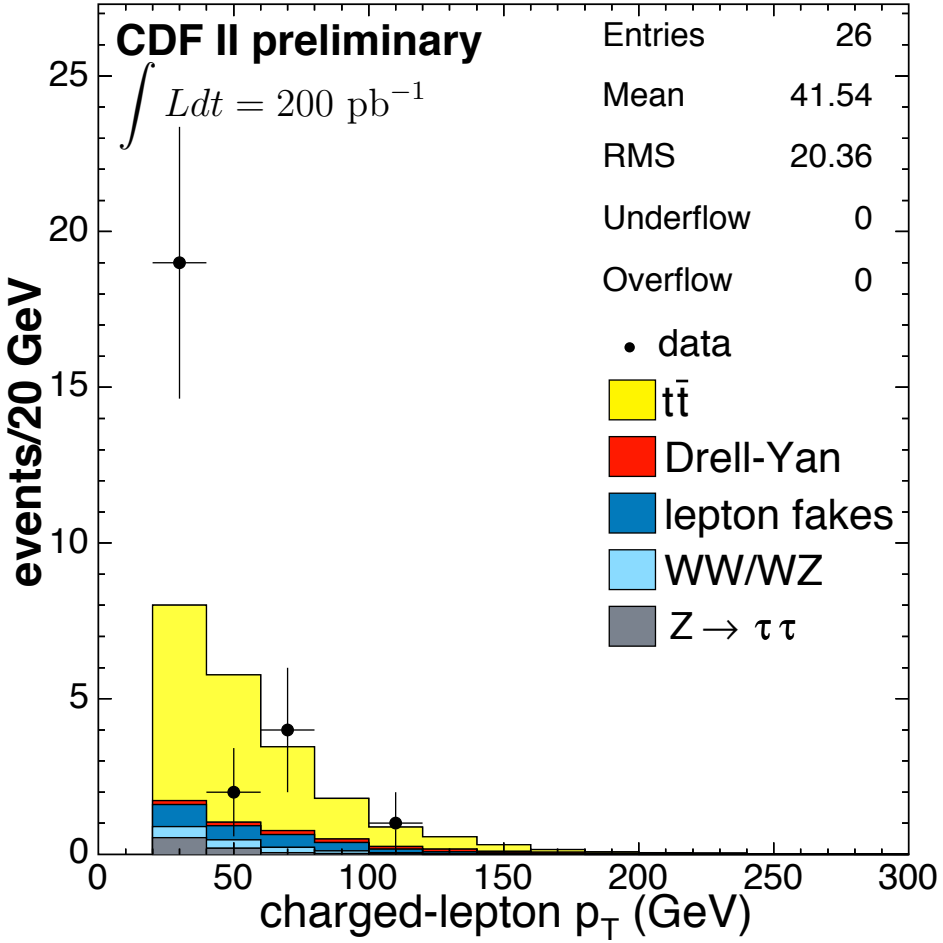
Source	$\Delta\hat{F}_0$ (l+jets)	$\Delta\hat{F}_0$ (dileptons)	$\Delta\hat{F}_0$ (combined)
bg normalization	0.11	0.04	0.10
top mass uncertainty	0.09	0.12	0.11
ISR/FSR	0.04	0.06	0.05
PDF uncertainty	0.03	0.04	0.03
shape uncertainty	0.03	0.02	0.02
MC statistics	0.01	0.01	0.01
acceptance correction	0.01	0.03	0.02
trigger correction	0.01	0.02	0.02
total	0.17	0.16	0.17

Signal, Background Models with Data

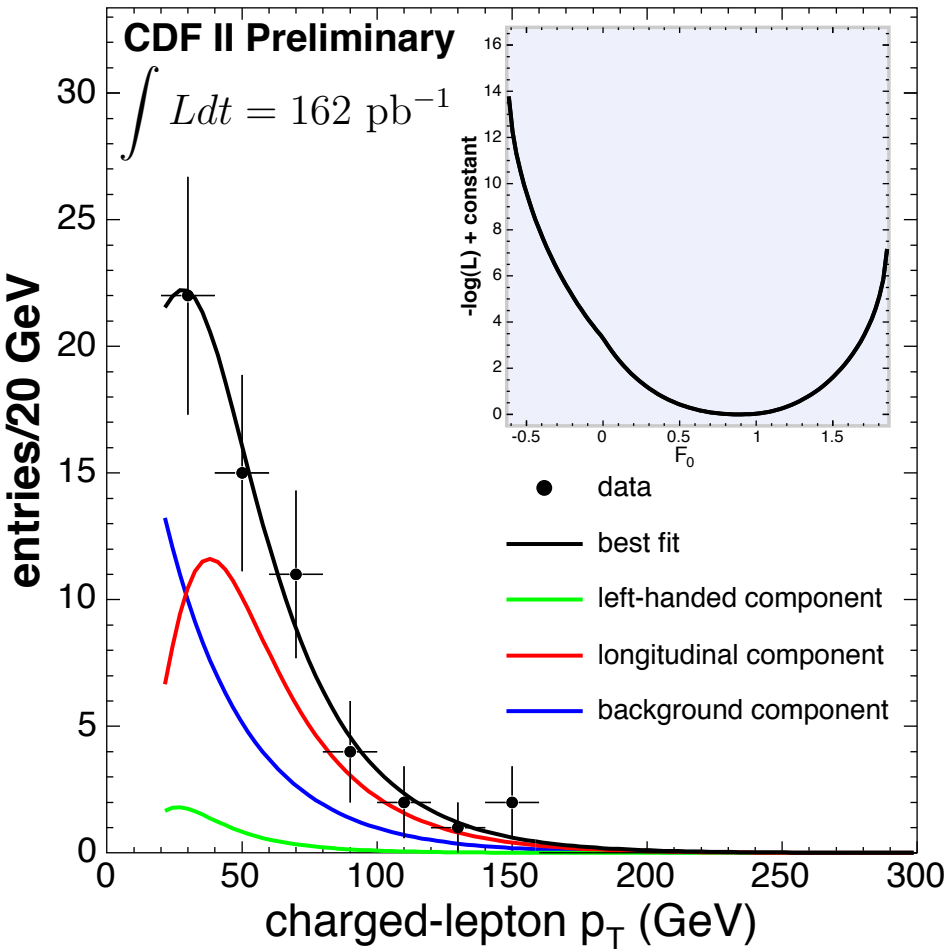
lepton+jets data

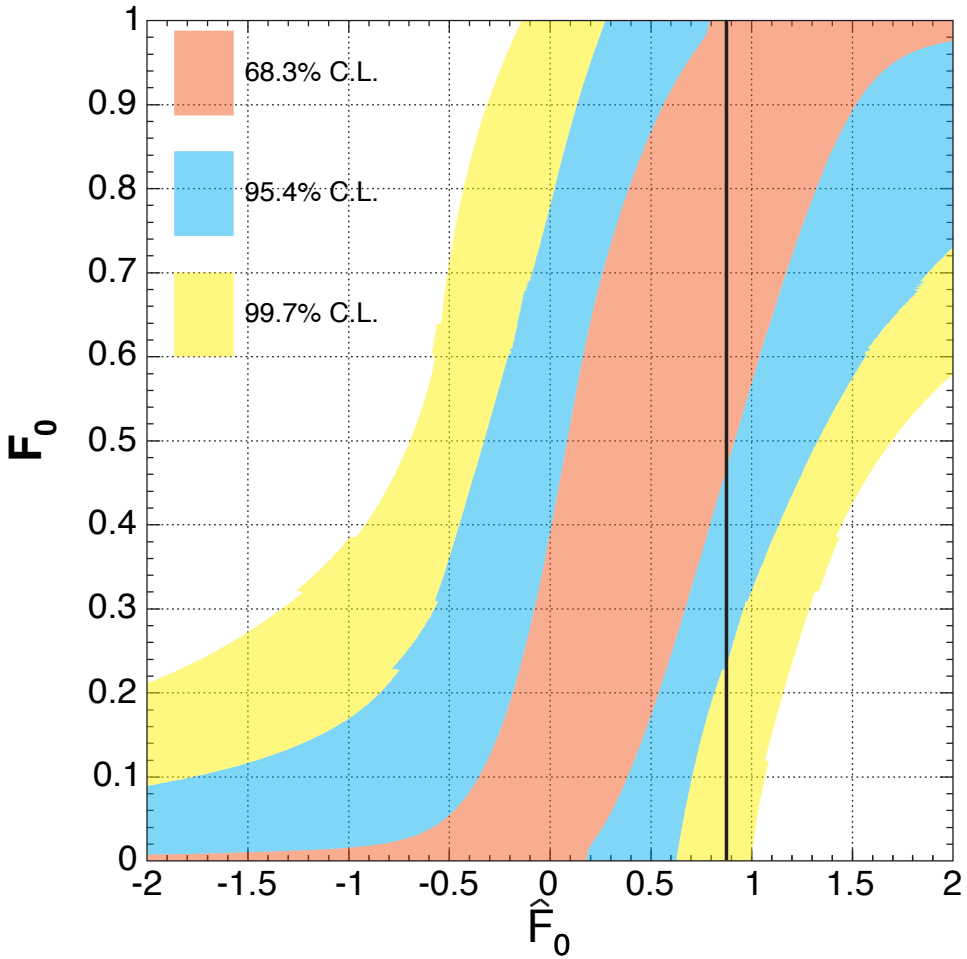


dilepton data



Lepton+Jets Only Result



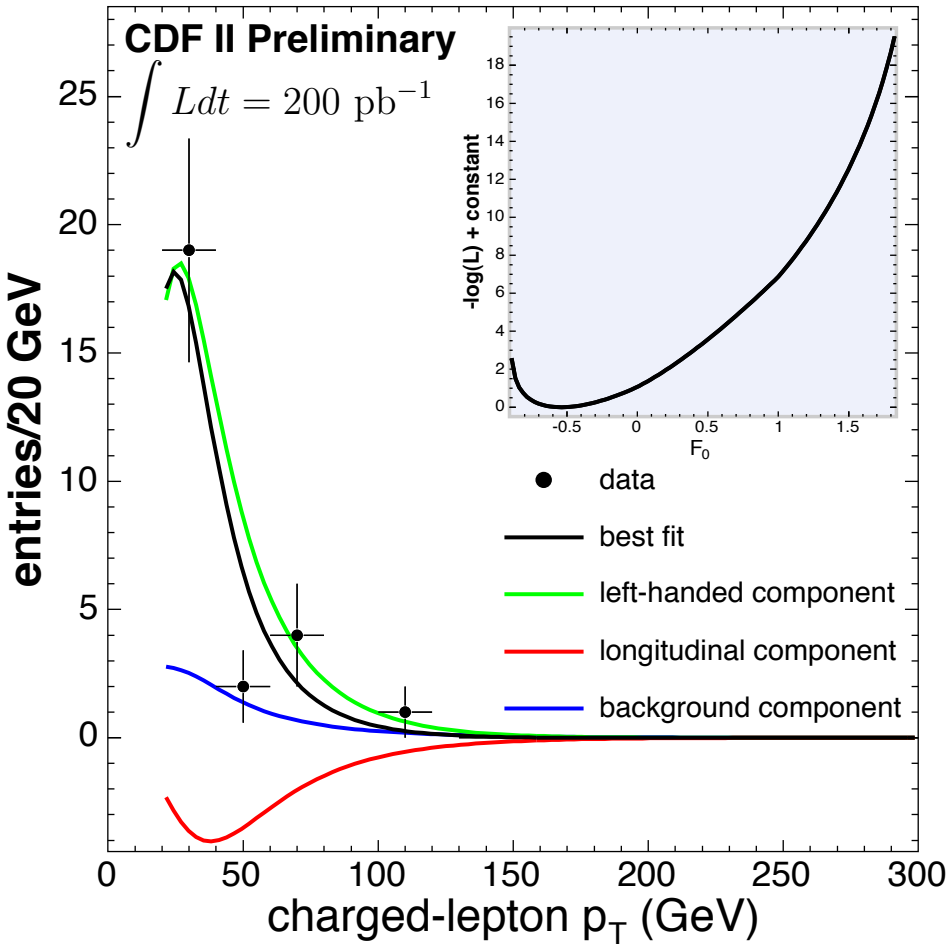


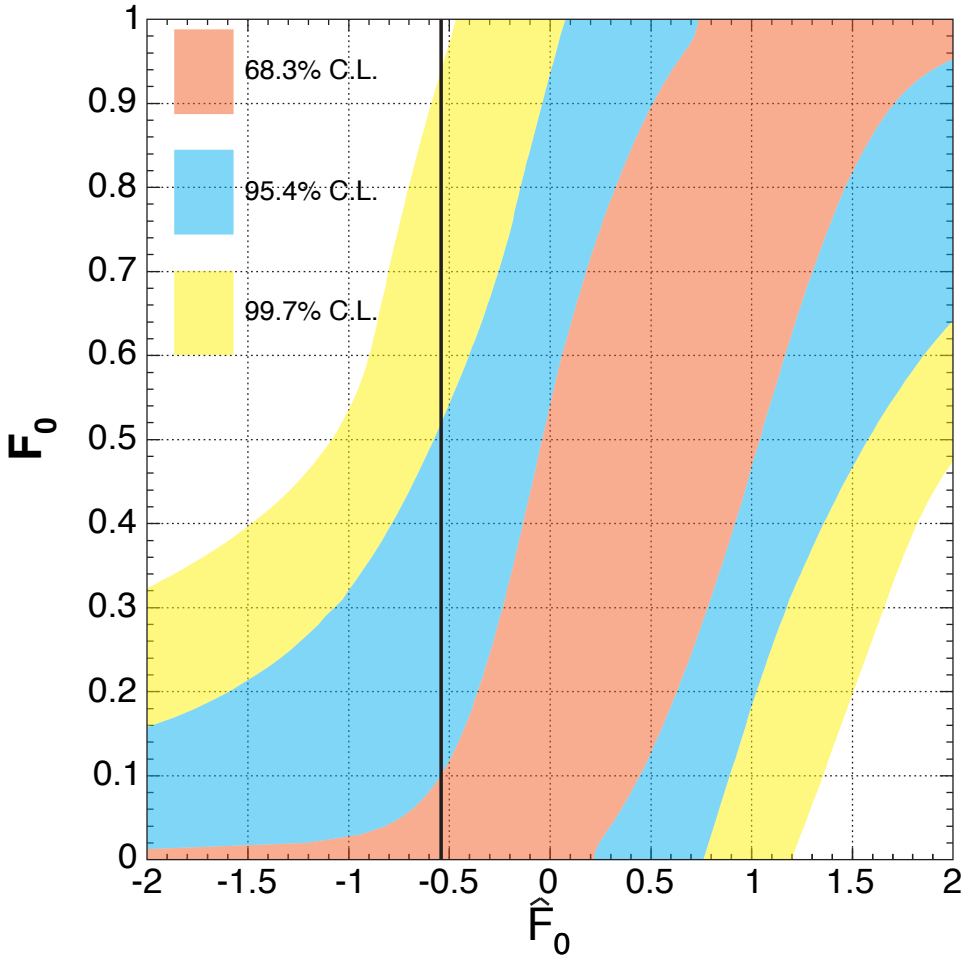
$\hat{F}_0 = 0.88$

$F_0 = 0.88^{+0.12}_{-0.47}$ (stat. + syst.)

$F_0 > 0.24$ @ 95% CL

Dilepton Only Result

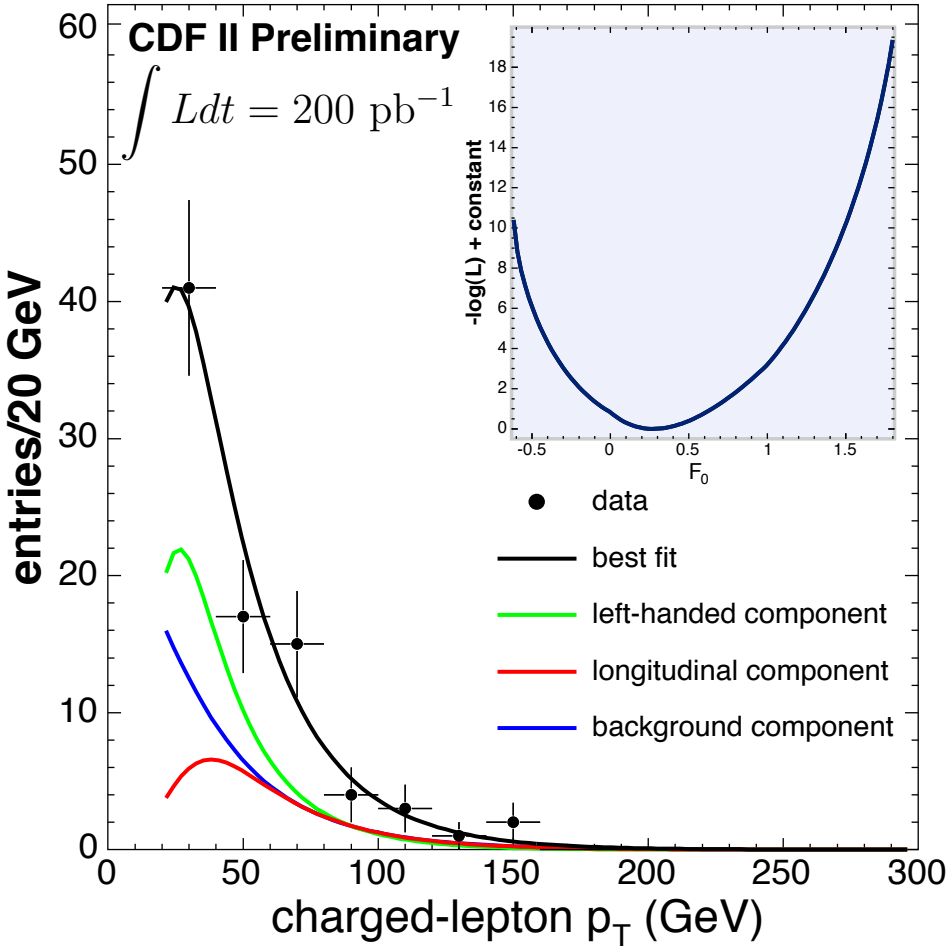


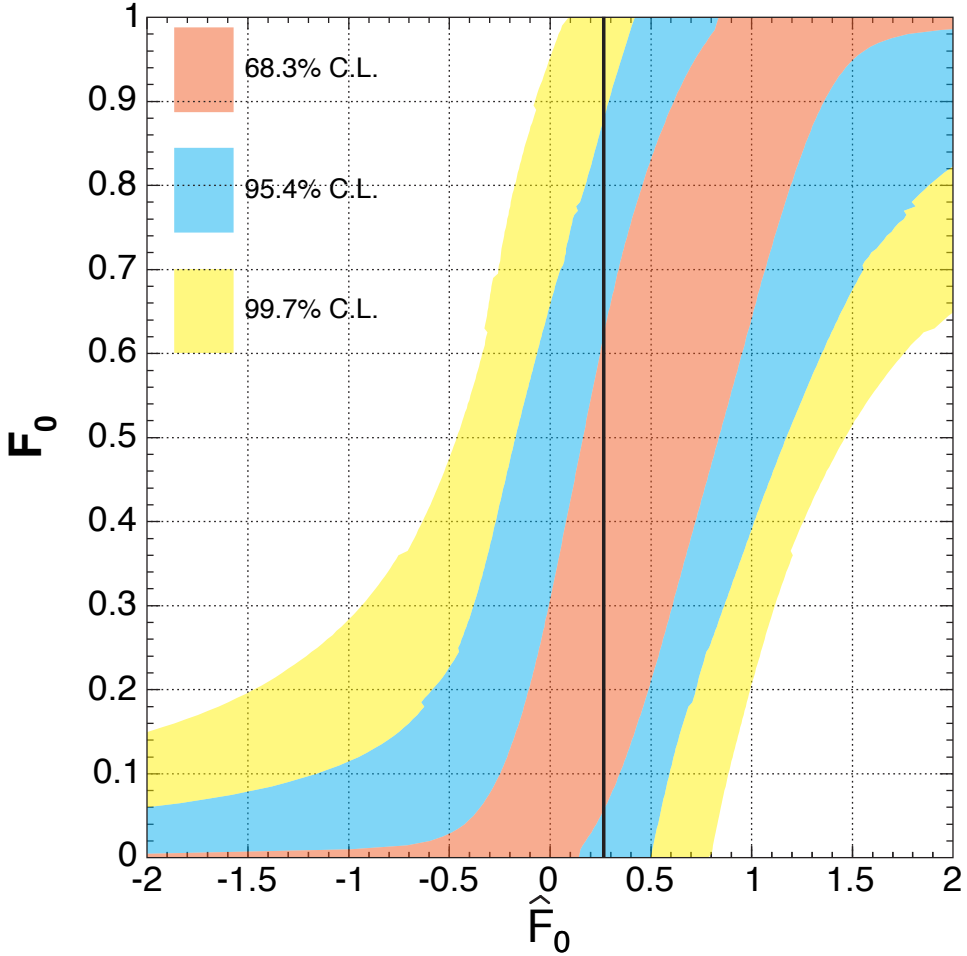


$\hat{F}_0 = -0.54$

$F_0 < 0.52$ @ 95% CL

Combined Result





$\hat{F}_0 = 0.27$

$F_0 = 0.27^{+0.35}_{-0.21}$ (stat. + syst.)

$F_0 < 0.88$ @ 95% CL

Conclusions

- We measured F_0 in the $t\bar{t}$ lepton+jets and dilepton channels
- The combined result, $F_0 = 0.27^{+0.35}_{-0.21}$ (stat. + syst) is consistent with the SM prediction $F_0 = 0.7$
- The lepton+jets result, $F_0 = 0.88^{+0.12}_{-0.47}$ (stat. + syst.) is consistent with the SM
- The discrepancy in the dilepton sample, $F_0 < 0.59$ @ 95% CL is tantalizing, but it's just at the 2 σ level.
- Stay tuned: CDF will continue to study the tWb coupling. Will the discrepancy in the dileptons persist?
- Please visit the public page for this analysis:

http://www-cdf.fnal.gov/physics/top/RunIIWjets/webpages/whelicity_pt/public/