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# Measurement of the W-Boson Helicity Fractions in Top-Quark Decays at CDF

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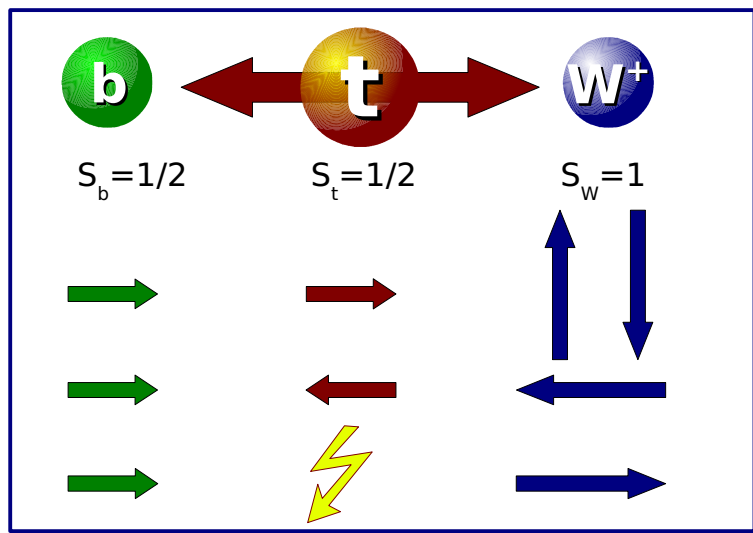
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# W-Boson Helicity in Top-Quark Decays

- Top-quark lifetime is shorter than hadronization time
- Decay products preserve the helicity content of the underlying weak interaction
- Chance to probe the V-A structure of the weak interaction in the top-quark decay
- Helicity fractions that differ from the SM predictions indicate new physics
- For example: V+A component in weak interaction, anomalous couplings in top-decay.



**SM prediction for  $m_t = 175 \text{ GeV}/c^2$ ,  $m_b = 0$**

$$F_0 = \frac{m_t^2}{2m_W^2 + m_t^2} = 0.7$$

$$F_- = 0.3$$

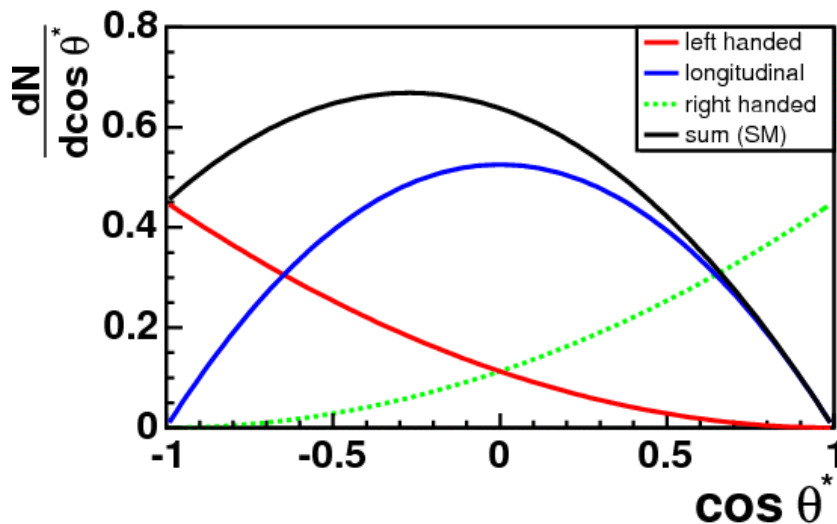
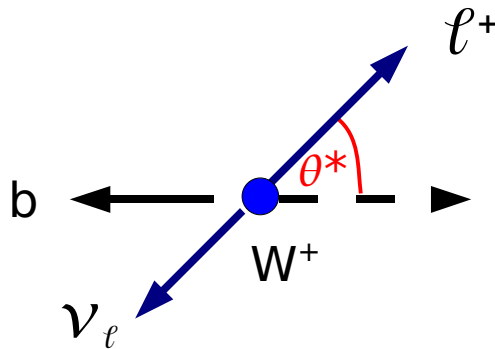
$$F_+ = 0.0$$

longitudinal

left-handed

right-handed

# Sensitive Observable: $\cos\theta^*$



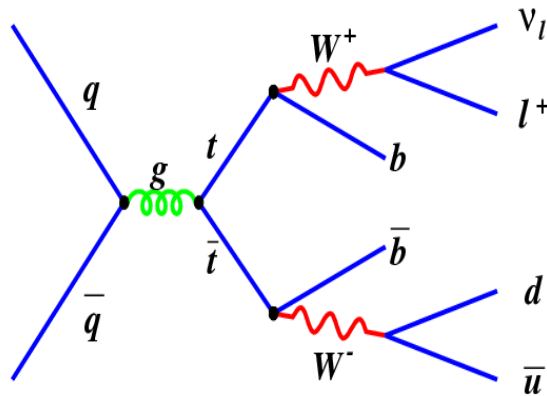
- Angle between the direction of the charged lepton in the W-boson rest frame and the direction of the W-boson in the top-quark rest frame
- Characteristic angular distribution depending on the polarization of the W-boson
- Have to reconstruct four-vectors of top-quark, W-boson, and charged lepton

$$\frac{dN}{d\cos\theta^*} = F_- \cdot \frac{3}{8} (1 - \cos\theta^*)^2 + F_0 \cdot \frac{3}{4} (1 - \cos^2\theta^*) + F_+ \cdot \frac{3}{8} (1 + \cos\theta^*)^2$$

# Full Reconstruction

## Lepton+Jets:

one charged lepton, missing transverse energy, four or more jets (one with a secondary vertex tag)



Number of possibilities to reconstruct one event:

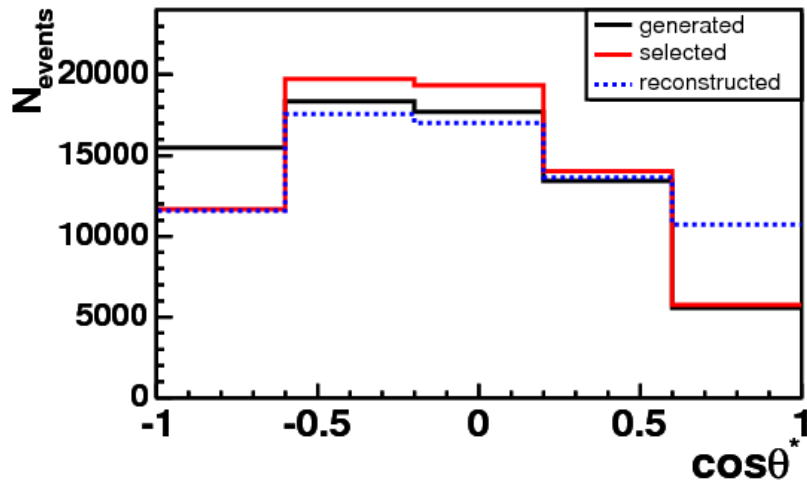
$$N_{hyp} = N_{jets} \cdot (N_{jets} - 1) \cdot (N_{jets} - 2) \cdot (N_{jets} - 3)$$

- Neutrino four-vector is obtained from MET and W-boson mass-constraint
  - All possibilities to assign the jets to the 2 b-quarks and 2 light quarks are considered
- Leads to a multiplicity of possibilities to reconstruct the event
- The challenge is to find the right hypothesis for each event using constraints on:
    - mass of reconstructed W-boson
    - mass difference of the two top-quarks
    - transverse energy of the two top-quarks
    - b-likeness of the jets assigned to the b-quarks (NN b-tagger)

# Measurement

$$\mu_k^{sig,exp} \propto \sum_i \mu_i^{sig,theo} \cdot \epsilon_i \cdot S(i,k)$$

$$\mu_k^{exp} = \mu_k^{sig,exp} + \mu_k^{BG,exp}$$



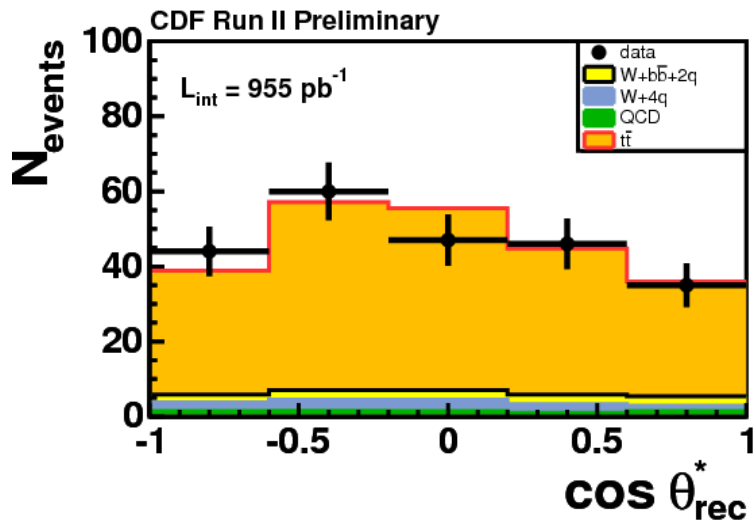
- Calculate expected number of events in each bin of the  $\cos\theta^*$  distribution
- Consider effects due to **event-selection** and **event-reconstruction**
- Two separate measurements:
  - measure  $F_0$ , fix  $F_+ = 0.0$  (SM)
  - measure  $F_+$ , fix  $F_0 = 0.7$  (SM) $\rightarrow$  One free parameter
- Perform binned likelihood-fit

# Results

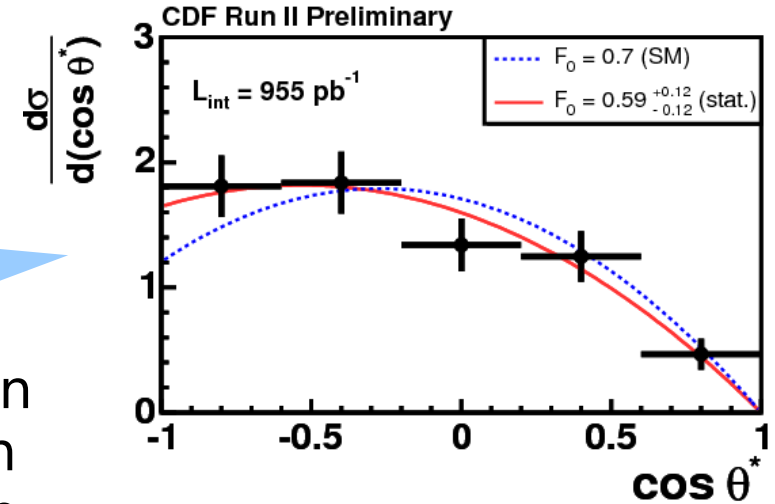
232 candidates in  $L_{\text{int}}=955\text{pb}^{-1}$

## Measurement of $F_0$ ( $F_+=0$ ):

$$F_0 = 0.59 \pm 0.12 (\text{stat})_{-0.06}^{+0.07} (\text{syst})$$



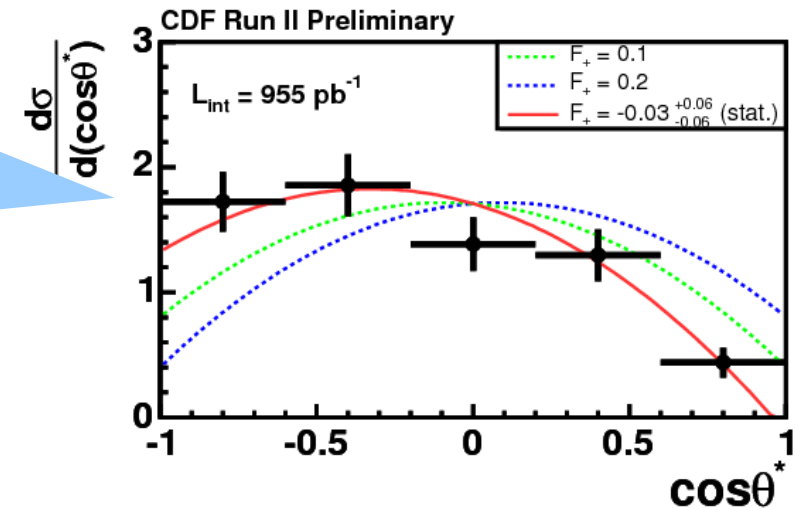
Correct distribution for event-selection and reconstruction effects



## Measurement of $F_+$ ( $F_0=0.7$ ):

$$F_+ = -0.03 \pm 0.06 (\text{stat})_{-0.03}^{+0.04} (\text{syst})$$

$$F_+ < 0.10 \text{ @ } 95\% \text{ C.L.}$$



# Summary

$$F_0 = 0.59 \pm 0.12 (stat)_{-0.06}^{+0.07} (syst)$$

$$F_+ = -0.03 \pm 0.06 (stat)_{-0.03}^{+0.04} (syst)$$

$$F_+ < 0.10 @ 95\% \text{ C.L.}$$

- Results in agreement with standard model prediction
- Analysis is still statistically limited
- Plan to update analysis with more data