



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

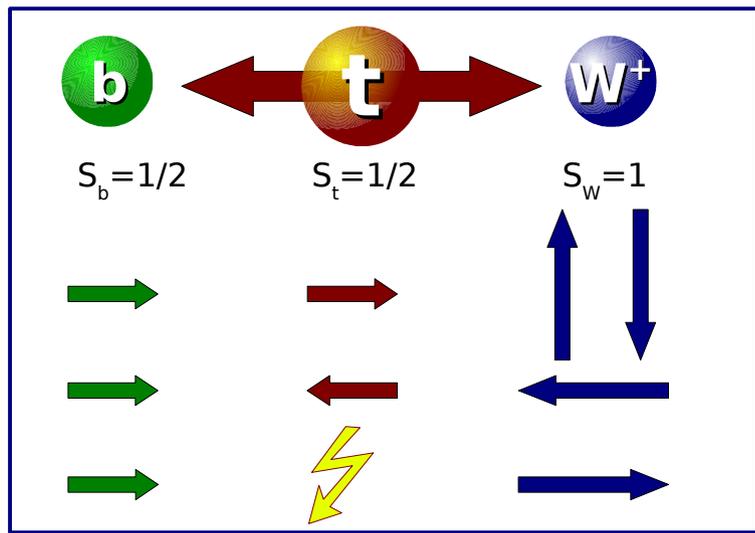


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W-Boson Helicity in Top-Quark Decays

- 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 $m_t = 175 \text{ GeV}/c^2$, $m_b = 0$

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

$$F_- = 0.3$$

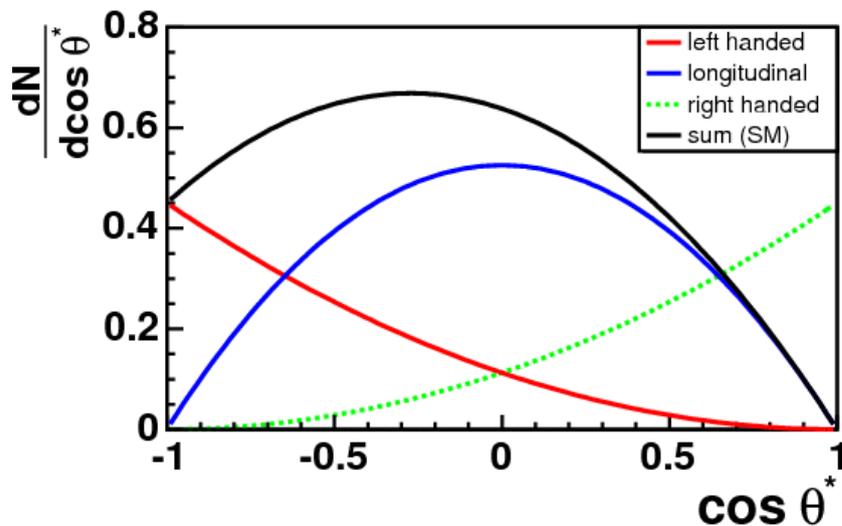
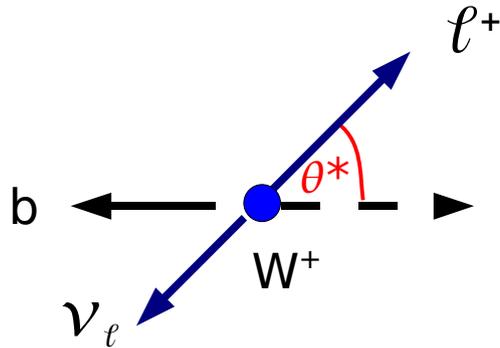
$$F_+ = 0.0$$

longitudinal

left-handed

right-handed

Sensitive Observable: $\cos\theta^*$



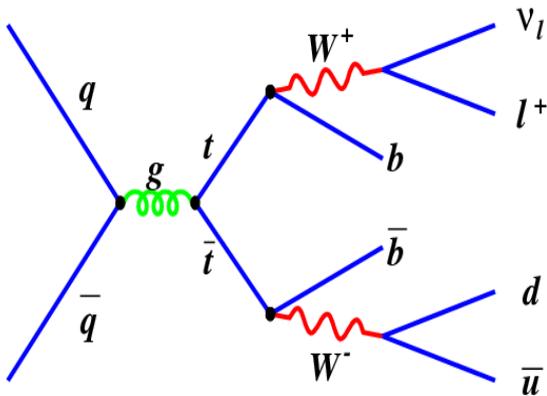
- Angle between the direction of the charged lepton in the W-boson rest frame and the direction of the W-boson in the top-quark rest frame
- Characteristic angular distribution depending on the polarization of the W-boson
- To calculate θ^* we have to reconstruct the four-vectors of top-quark, W-boson, 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:

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

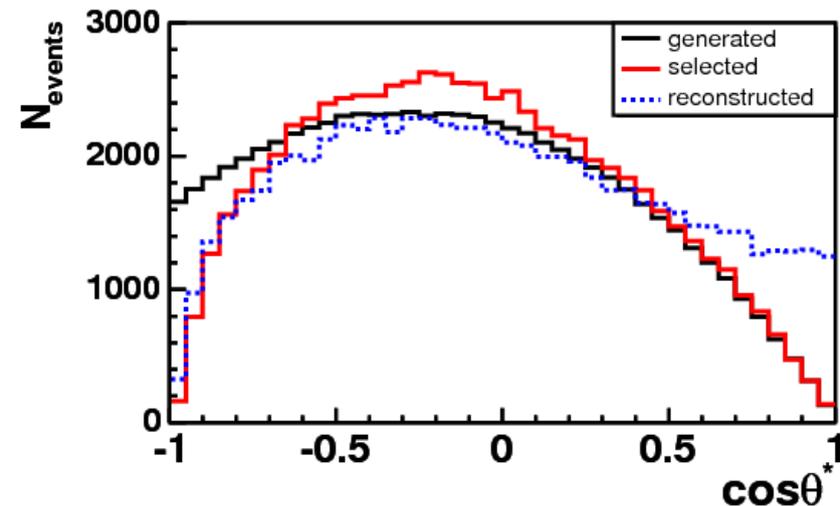
- Neutrino four-vector is obtained from MET and W -boson mass-constraint
 - All possibilities to assign the jets to the 2 b -quarks and 2 light quarks are considered
- Leads to a multiplicity of possibilities to reconstruct the event
- The challenge is to find the right hypothesis for each event using 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**
 - by applying **efficiency** and **migration matrix**
- Two separate measurements:
 - measure F_0 , fix $F_+ = 0.0$ (SM)
 - measure F_+ , fix $F_0 = 0.7$ (SM)
 - One free parameter
- Combined measurement:
 - F_0 and F_+ are both free parameters
- Perform binned likelihood fit

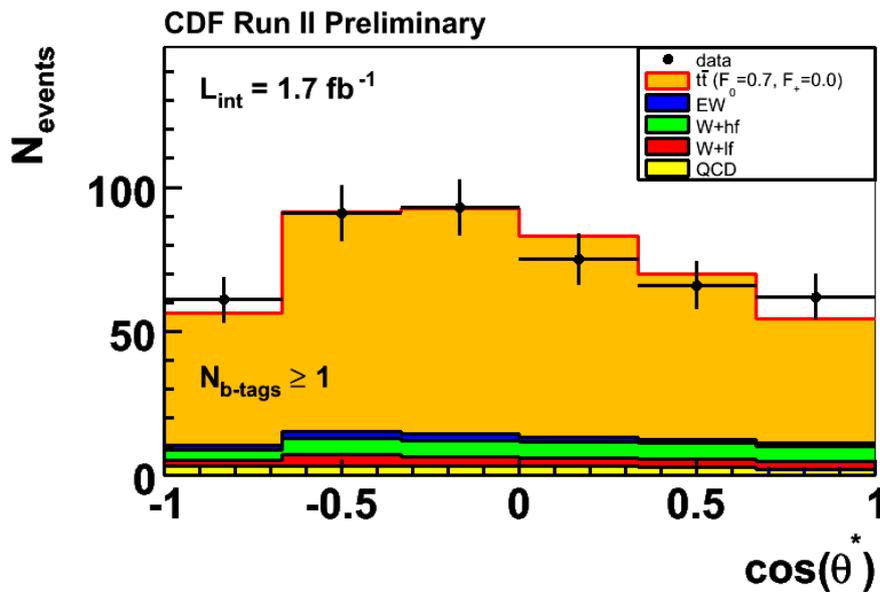


Results (1 parameter fit)

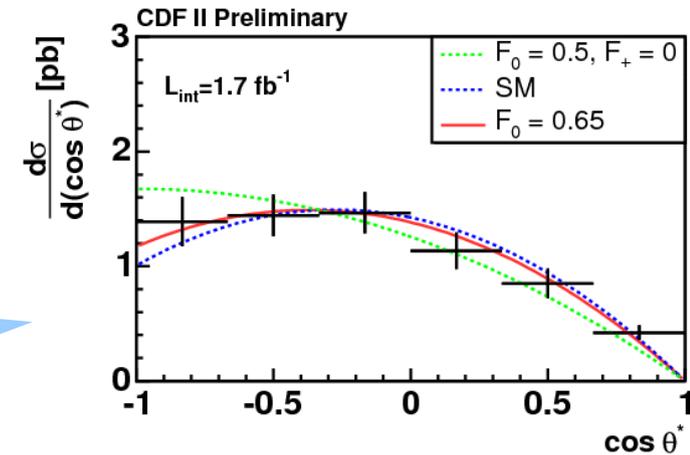
448 candidates in $L_{\text{int}}=1.7\text{fb}^{-1}$

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

$$F_0 = 0.65 \pm 0.10 (\text{stat}) \pm 0.06 (\text{syst})$$



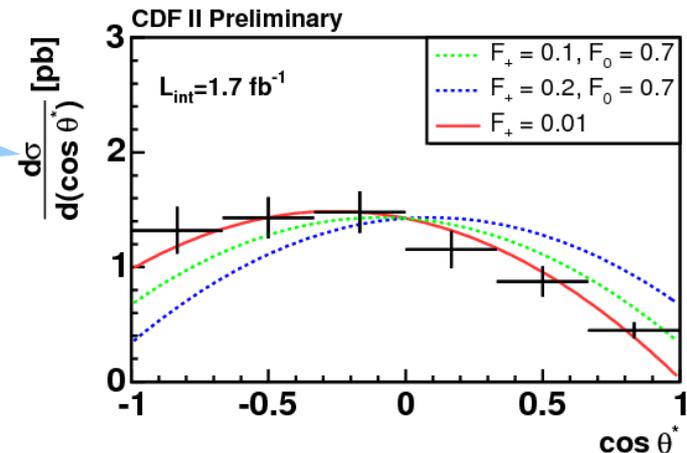
Correct distribution for event-selection and reconstruction effects



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

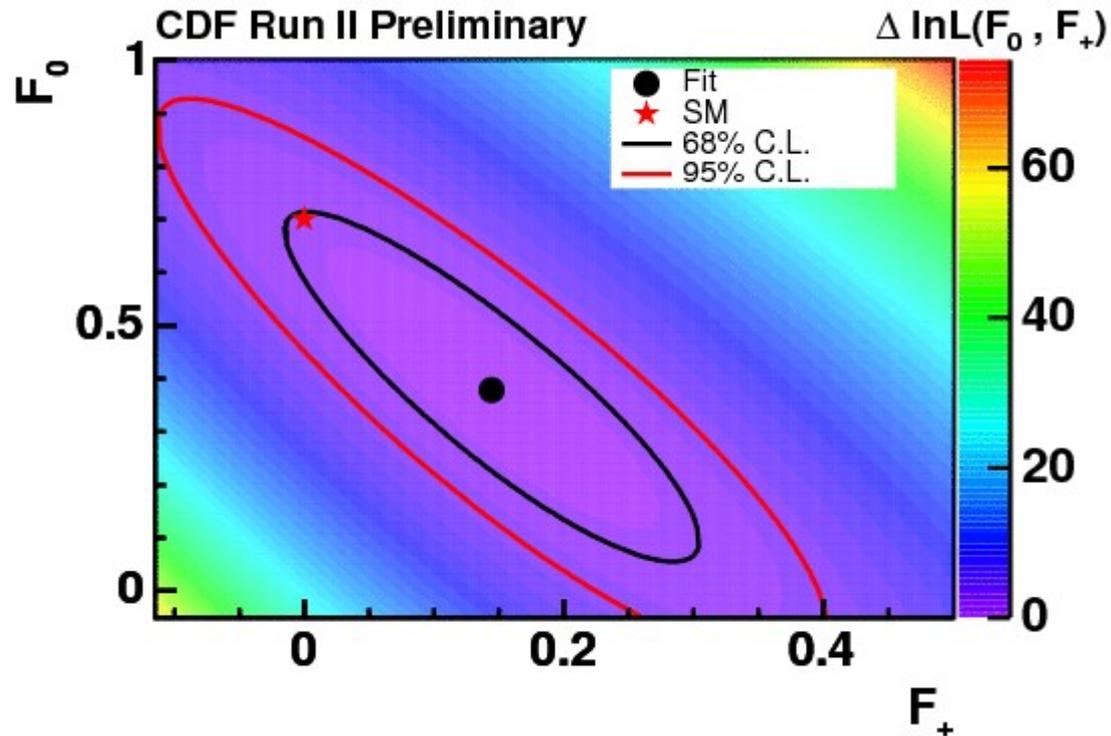
$$F_+ = 0.01 \pm 0.05 (\text{stat}) \pm 0.03 (\text{syst})$$

$$F_+ < 0.12 \text{ @ } 95\% \text{ C.L.}$$



Results (2 parameter fit)

448 candidates in $L_{\text{int}}=1.7\text{fb}^{-1}$



$$F_0 = 0.38 \pm 0.22 (\text{stat}) \pm 0.07 (\text{syst})$$

$$F_+ = 0.15 \pm 0.10 (\text{stat}) \pm 0.04 (\text{syst})$$

Conclusion

- Results are within the uncertainties in agreement with the standard model prediction.
- Analysis is still statistically limited.