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.
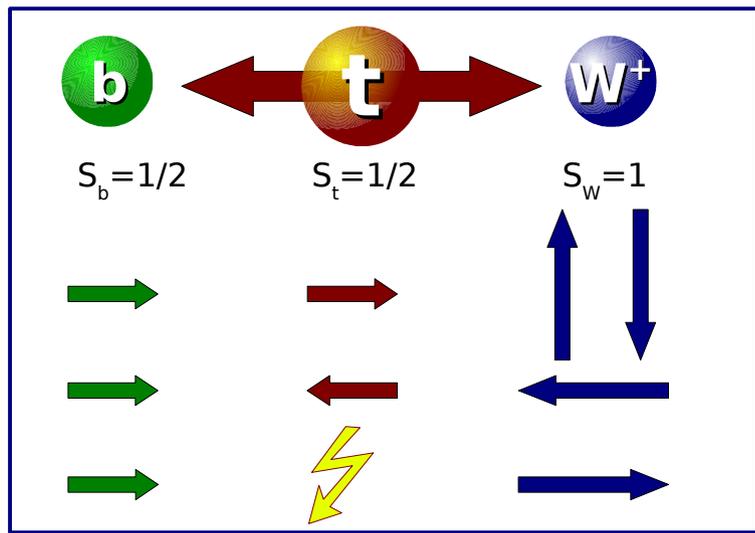
SM prediction for m_t=175 GeV/c², m_b=0

$$F_0 = \frac{m_t^2}{2\,m_W^2 + m_t^2} = 0.7 \quad \text{longitudinal}$$

$$F_- = 0.3 \quad \text{left-handed}$$
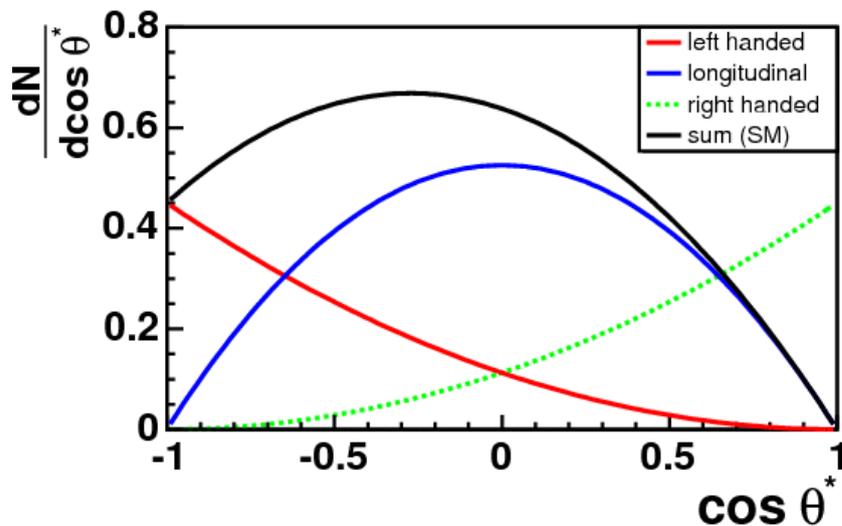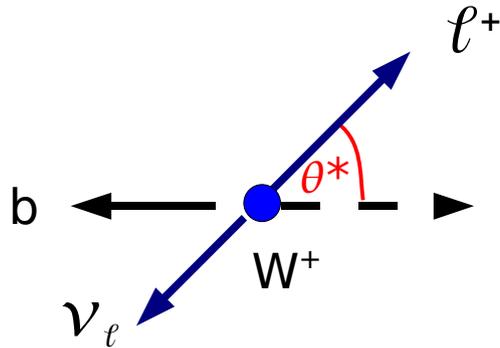
$$F_+ = 0.0 \quad \text{right-handed}$$
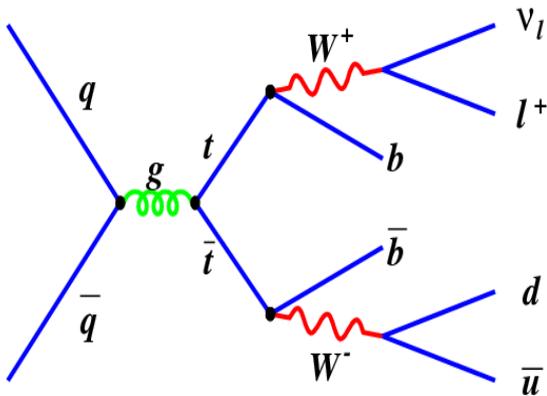
Sensitive Observable: cosθ*

- 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

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

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Full Reconstruction

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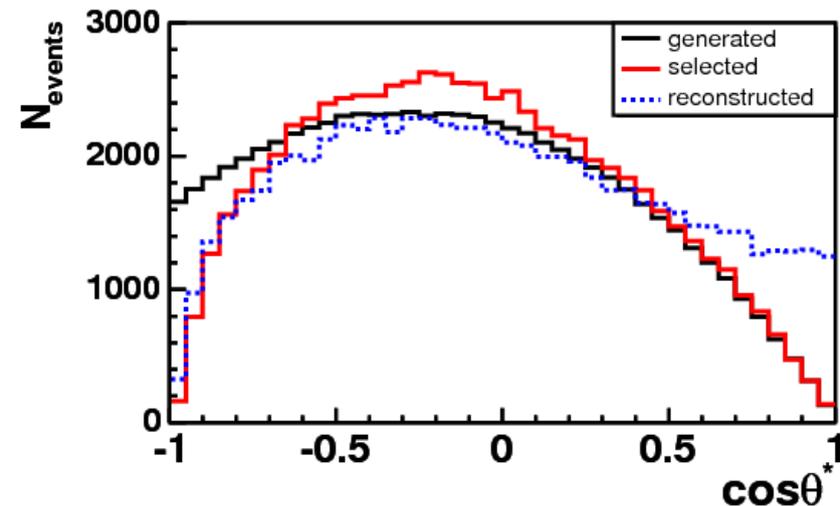

- Neutrino four-vector is obtained from MET and W-boson mass-constraint

- 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)

Number of possibilities to reconstruct one event:

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

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:
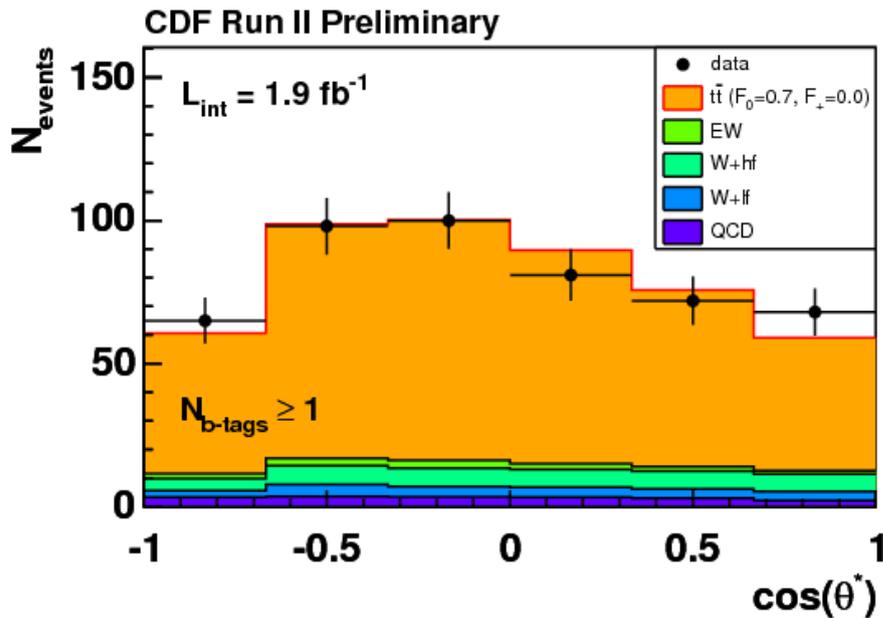 - F_0 and F_+ are both free parameters
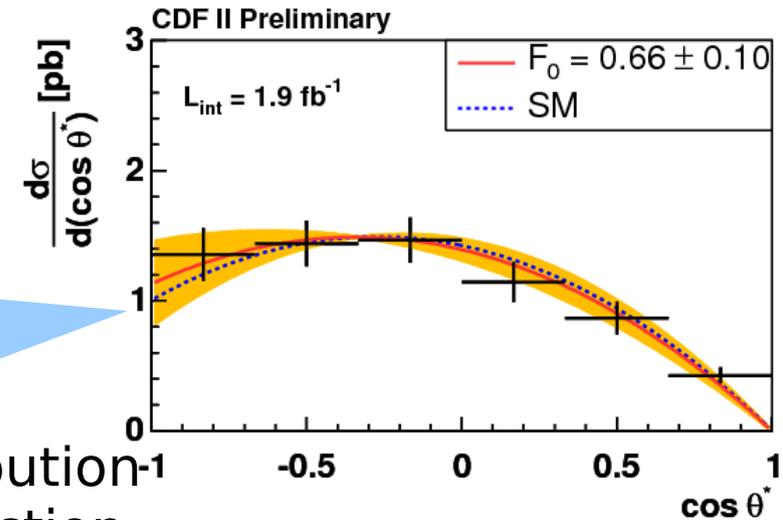- Perform binned likelihood fit

Results (1 parameter fit)

Measurement of F_0 ($F_+=0$):
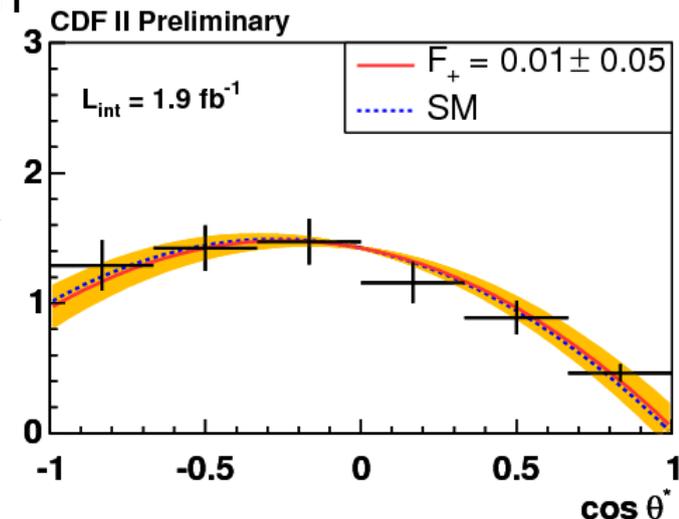
$$F_0 = 0.66 \pm 0.10(stat) \pm 0.06(syst)$$

Correct distribution for event-selection and reconstruction effects

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

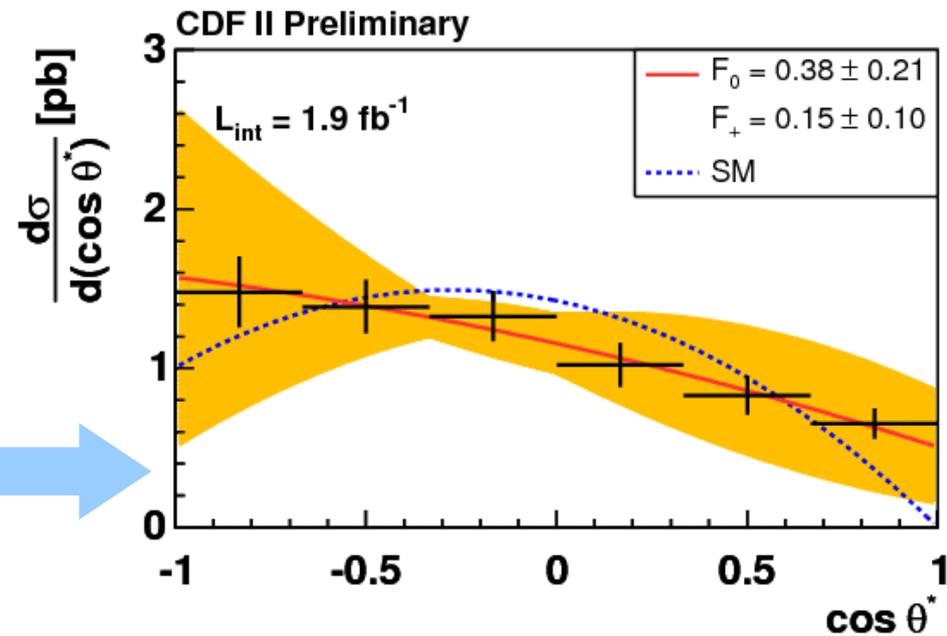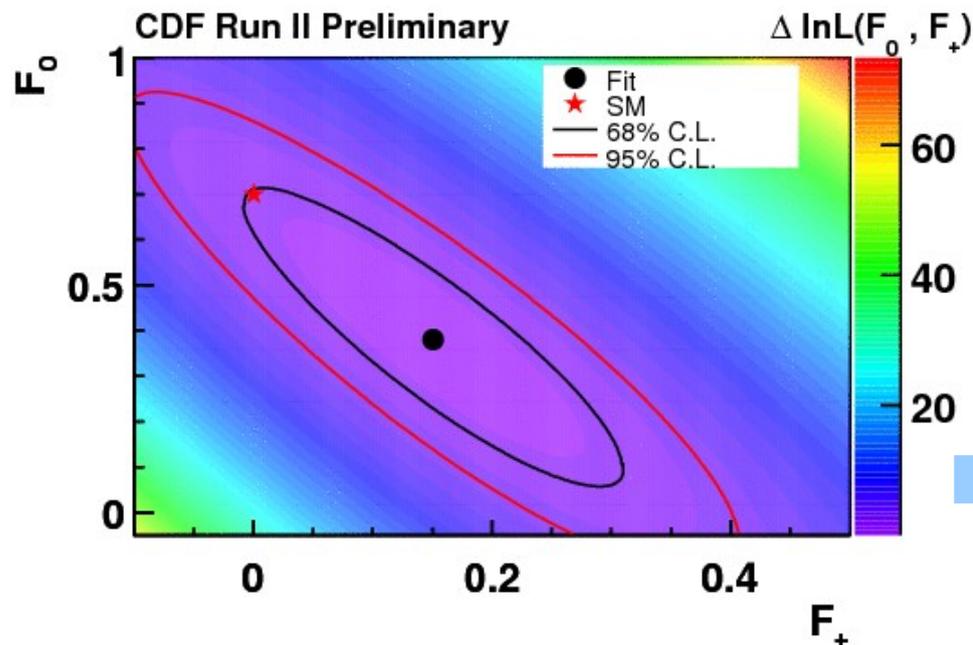$$F_+ = 0.01 \pm 0.05(stat) \pm 0.03(syst)$$

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

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Results (2 parameter fit)

484 candidates in $L_{int}=1.9fb^{-1}$

$$F_0 = 0.38 \pm 0.21 (stat) \pm 0.07 (syst)$$
$$F_+ = 0.15 \pm 0.10 (stat) \pm 0.05 (syst)$$

Conclusion

- Results are within the uncertainties in agreement with the standard model prediction.

- Analysis is still statistically limited.