Top Properties at CDF

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for the CDF collaboration

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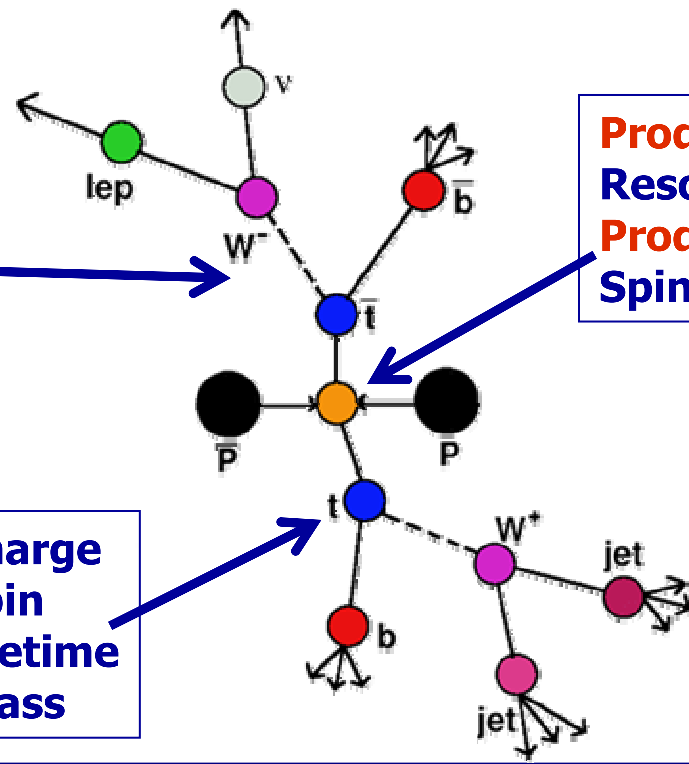
Outline:

- Introduction
- Top cross section
- Top production mechanism
- W helicity
- Summary

Why Is the Top Quark Interesting?

- **Only fermion with mass at EW scale (world combination summer '06: 171.4±1.2±1.8 GeV), ~40 times heavier than the bottom quark.**
- **Very wide (1.5 GeV/c^2)→ opportunity to probe bare quark properties .**
- **Top special relation to the Higgs boson.**
- **Is it the SM top? Is it only the SM top? Is the top gateway to new physics?**

Branching ratios
Rare decays
Non-SM decays
Decay kinematics
W helicity
Anomalous coupling
$|V_{tb}|$

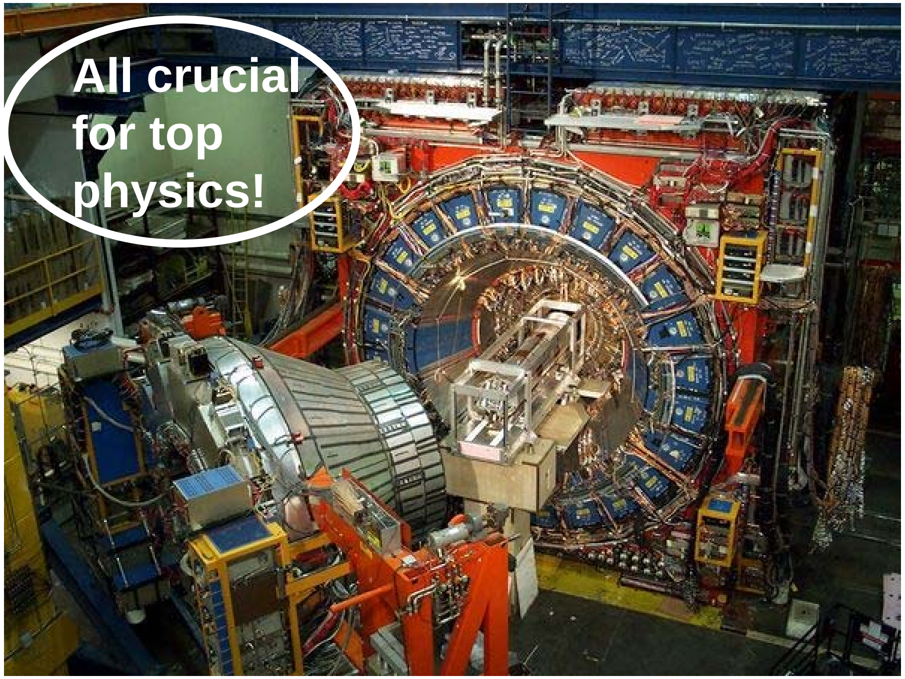


Production cross section
Resonance production
Production mechanisms
Spin polarization

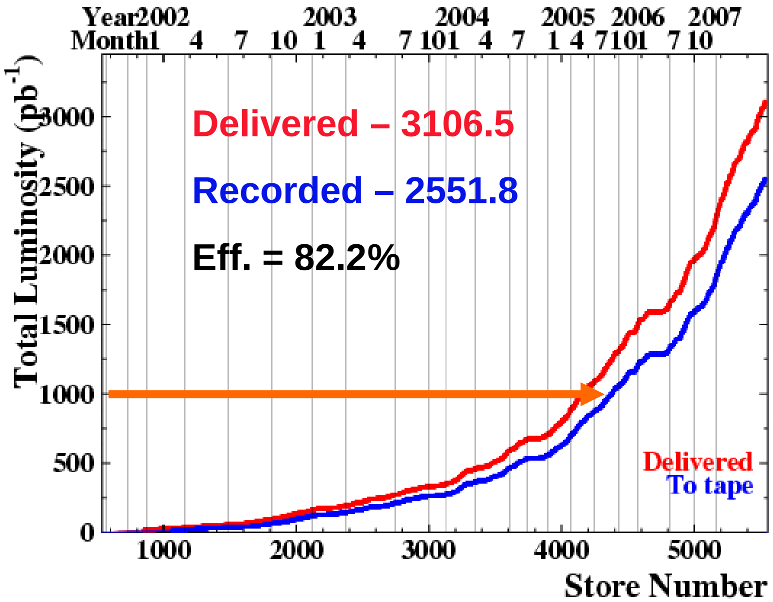
Top charge
Top spin
Top lifetime
Top mass

CDF

- Inner silicon tracker – essential for vertexing and b-tagging
- Central outer tracker
- Solenoid
- EM and HAD calorimeters
- Muon system



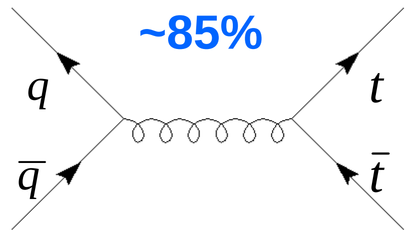
- All current top quark property measurements use ttbar sample.
- Results shown in this talk use ~1fb^{-1} of data

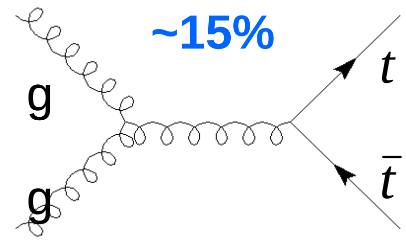


Top Pair Production and Cross Section

Top pair production

Main mechanism for top physics at Tevatron





For top mass = 175 GeV (strong dependency on the top mass)

@ √s= 1.96 TeV (theoretical):

$$\sigma_{t\bar{t}} = 6.7 \pm 0.8\, pb$$

(JHEP 0404:068(2004),

PRD 68, 114014 (2003))

Why do we measure the cross section?

- **Can we confirm the SM top pair cross-section?**
- **Cross section requires understanding of all background processes in sample.**
- **These samples and their composition are the basis for every top property measurement.**

How do we measure it?

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{A \cdot \varepsilon \cdot \int L}$$

selected events

estimated bkg

geometric and kinematic acceptance

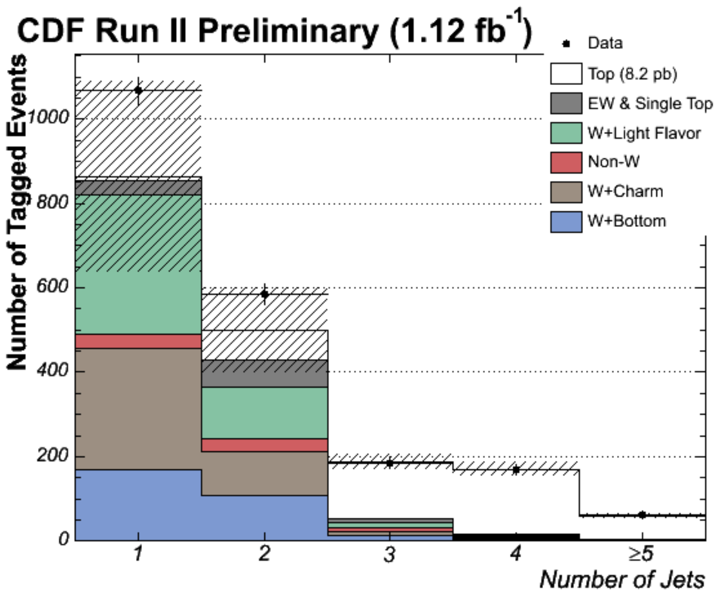
integrated luminosity

Several measurements in CDF – new physics might affect different channels differently.

Cross Section Results in the Lepton+Jets Channel

- **Signal Region:**
  - Isolated lepton (e or μ).
  - Missing transverse energy (neutrino)
  - 3 or more jets:
    - At least one b tagged

- **Good compromise between backgrounds and acceptance.**



- **Backgrounds:**
  - W + light flavor (~40% of total bkg)
  - W+ heavy flavor (~35% of total bkg)
  - non-W (~15% of total bkg)
  - EW (diboson, single top, Z→tau tau, ~10% of total bkg)

- Assume tt production cross section, σ_{tt} .
- Estimate backgrounds using σ_{tt} .
- Measure a new σ_{tt}, iterate between pretagged and tagged samples until convergence.

- **World's best measurement:** $8.2 \pm 0.5\ (stat) \pm 0.9\ (syst)\ pb$

- **Double-tag result:** $8.8 \pm 0.8\ (stat) \pm 1.3\ (syst)\ pb$

Top Pair Production Mechanism: $\sigma(gg \to t\bar{t})/\sigma(p\bar{p} \to t\bar{t})$

Large theoretical uncertainties,

up to a factor of 2

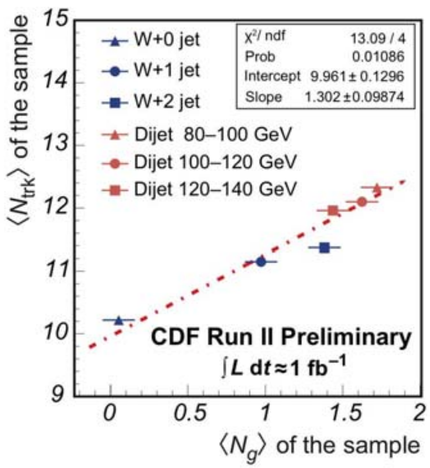
- **Tests pQCD**
- **At 1.96 TeV:** **~85% top pairs from qq**
  ~15% top pairs from gg

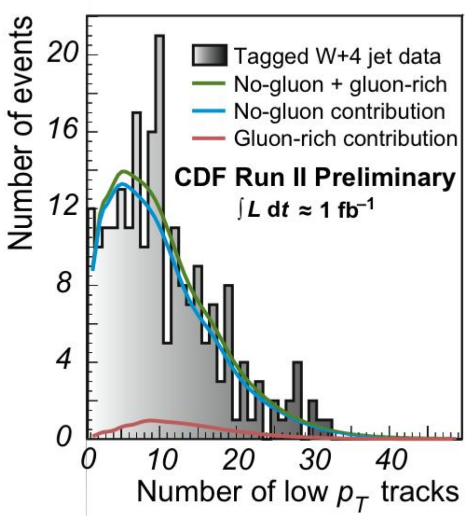
Method I :

Look at correlations between the gluon content in the event and the number of low P_T tracks.

- gg initial state tends to have greater underlying event activity.

$$\frac{\sigma(gg \to t\bar{t})}{\sigma(p\bar{p} \to t\bar{t})} = 0.01 \pm 0.16(stat) \pm 0.07(syst)$$



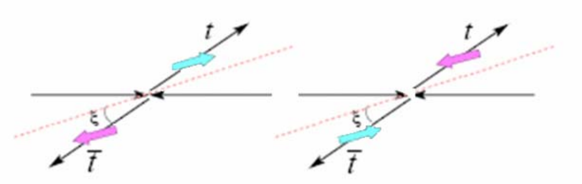


- **Calibrate <N_{trk}> vs. <N_g> correlation using W+jets and dijet data.**
- **Fit lepton+jets data to gluon-rich and no-gluon <N_{trk}> templates.**

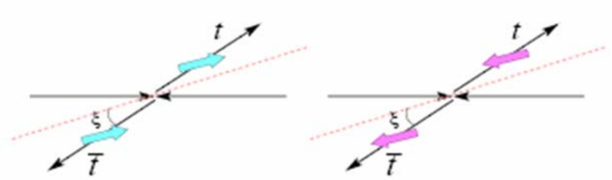
Production Mechanism – Method II

Use ttbar production and decay kinematics:

- pairs originate from gg tend to be produced in the forward region with unlike spin.



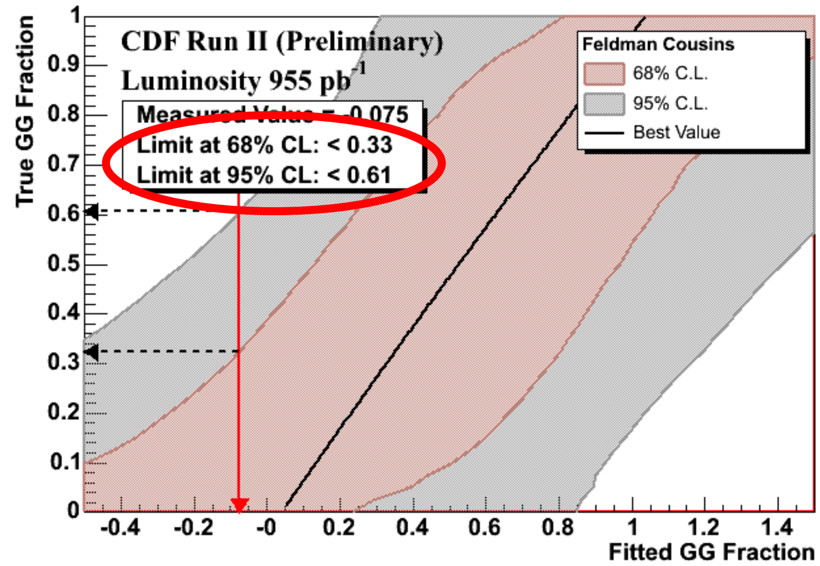
- pairs originate from qq tend to be produced centrally with like spin.



- Fully reconstruct the event, using lepton+jets channel.
- Use NN with 8 inputs containing production and spin correlation information.
- Fit the data to templates constructed from NN output.

Decay includes spin correlations

- Define the off-diagonal basis. (hep-ph/960419)
- Many discriminators: e.g.: angle between lepton and off-diagonal axis in top rest frame.



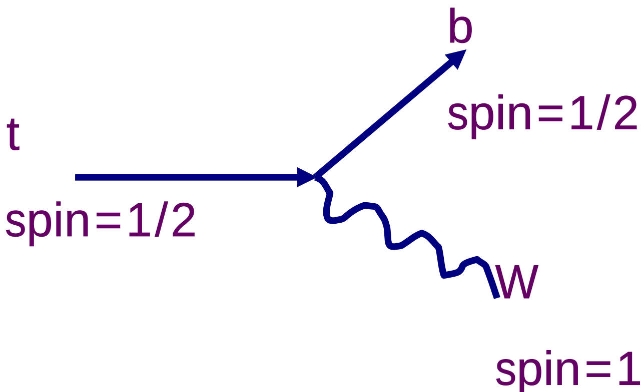
W helicity in top quark decays

SM top decays via the weak interaction

→ V-A coupling like all other fermions:

$$\frac{ig}{2\sqrt{2}}\bar{t}\gamma^{\mu}\left(1-\gamma^{5}\right)V_{tb}bW_{\mu}$$

Helicity: $H=\vec{J}\cdot\vec{P}$

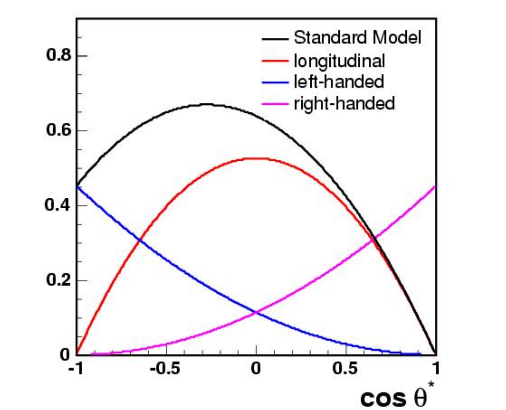


The longitudinal fraction:

$$f_0=\frac{\Gamma(W_0)}{\Gamma(W_0)+\Gamma(W_L)+\Gamma(W_R)}\approx\frac{m_t^2}{2m_w^2+m_t^2}$$

SM prediction of helicity fractions (M_t=175GeV):

- **longitudinal f_0 = 0.7**
- **left-handed f_- = 0.3**
- **right-handed f_+ = 0**

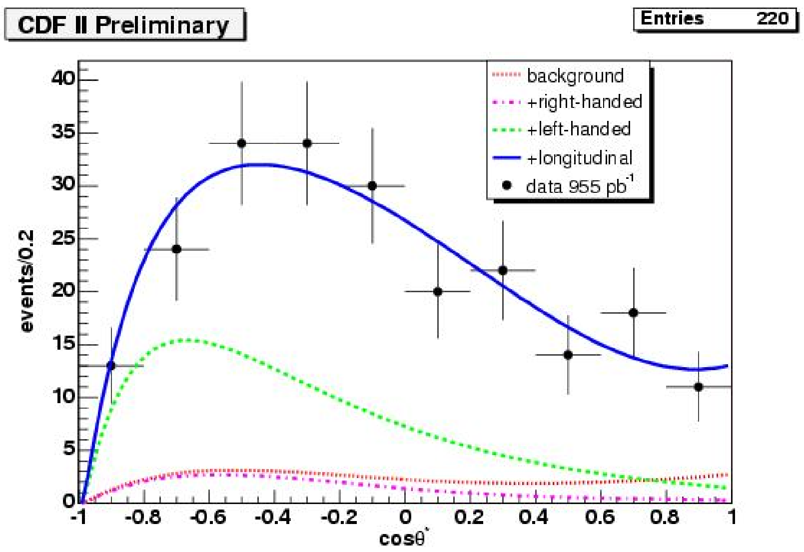


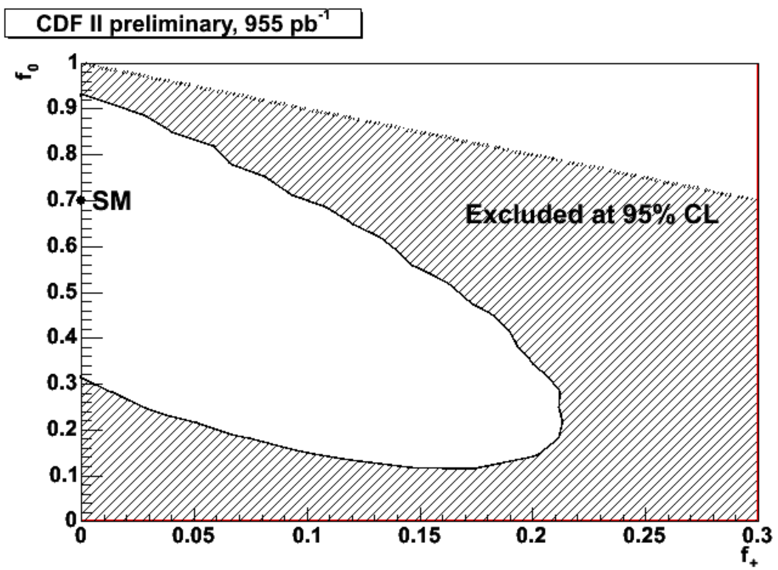
This measurement:

- **Test of the SM, non-zero V+A?**
- **EWSB – prediction of high longitudinal W fraction**

W Boson Helicity

- Use lepton+jets, fully reconstruct the event.
- Calculate cos(θ*) for signal and background and construct templates.
- Use templates in likelihood fitter to fit data and extract helicity fractions:
  - fix right-handed fraction to 0, fit for longitudinal fraction.
  - fix longitudinal fraction to SM expectation, fit for right-handed fraction.
  - fit simultaneously longitudinal and right-handed fraction.





W Boson Helicity - Results

$f_0 =$ 0.60 ± 0.12 ± 0.06, f_+ = 0 fixed

f_+ = -0.06 ± 0.06 ± 0.03, f_0 fixed to SM value @M_t =175 GeV

Measurement limited by statistics, consistent with SM expectation

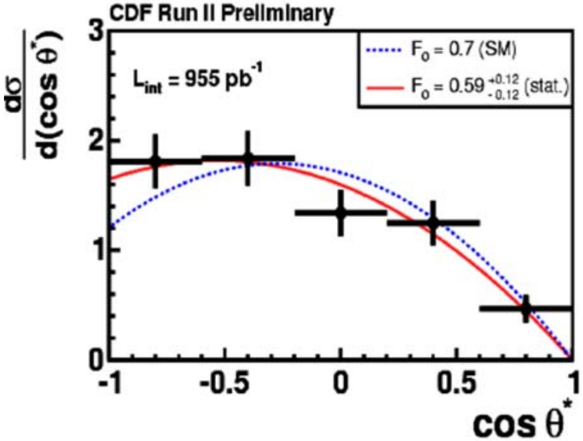
→ Set an upper limit on f_+ : $f_+ < 0.11$@95% C.L

Simultaneous fit:

$$f_0 = 0.74 \pm 0.25(stat) \pm 0.06(syst)$$
$$f_+ = -0.06 \pm 0.10(stat) \pm 0.03(syst)$$

Similar analysis constructs templates taking efficiencies and reconstruction effects into account:

$$f_0 = 0.59 \pm 0.12(stat) \pm 0.06(syst)$$
$$f_+ < 0.10 \quad @95\% \ C.L$$

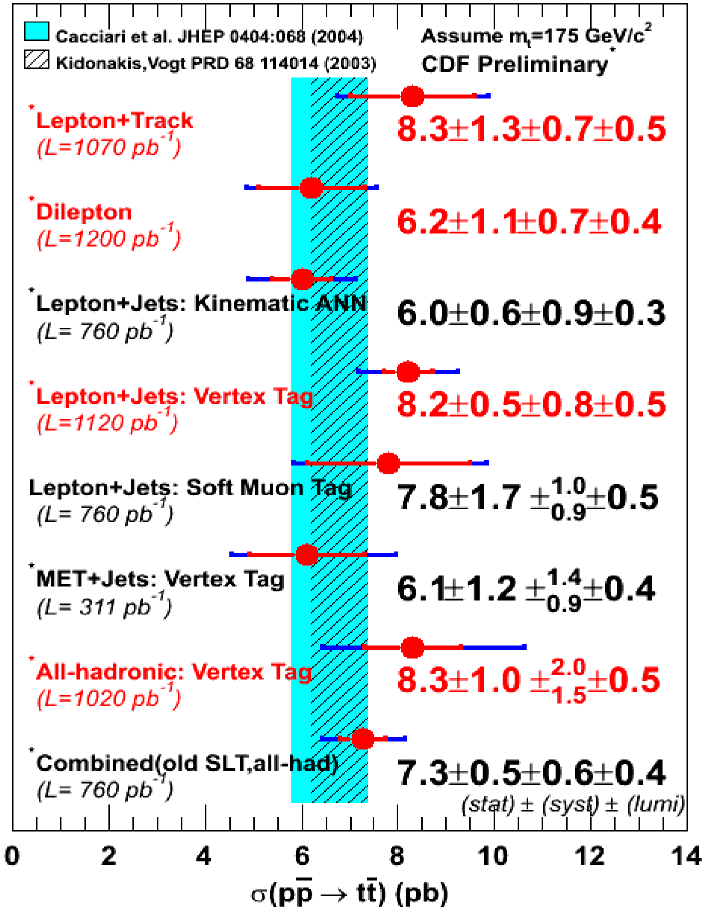


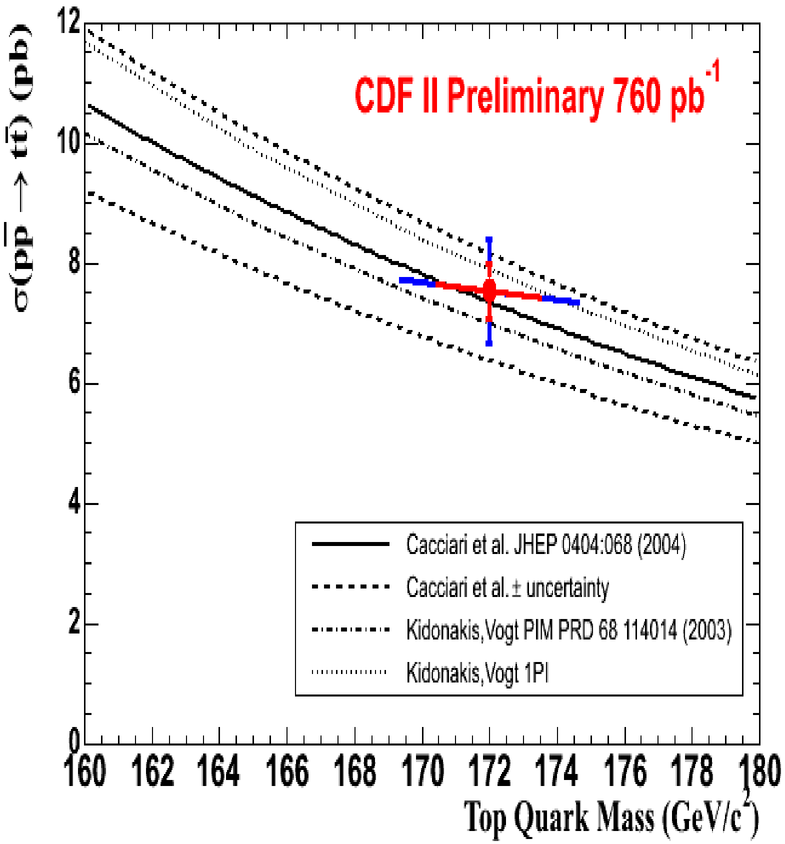
Summary

- In $1fb^{-1}$ of data - few hundreds reconstructed ttbar events in the current datasets.
- Lots of exciting top physics at CDF: spin correlation, anomalous coupling, production asymmetry, top charge, resonant production searches, FCNC searches…
- Besides cross sections, all top property measurements are still statistically limited.
- However, top properties becoming precision measurements.
- Results with $2fb^{-1}$ coming soon.
- All measurements so far consistent with SM predictions.

Backup Slides

Cross Section Summary





Helicity of W Bosons and the tWb Vertex