Top Decay Properties and Search for Single Top Production at the Tevatron

in behalf of the CDF and DØ Collaborations

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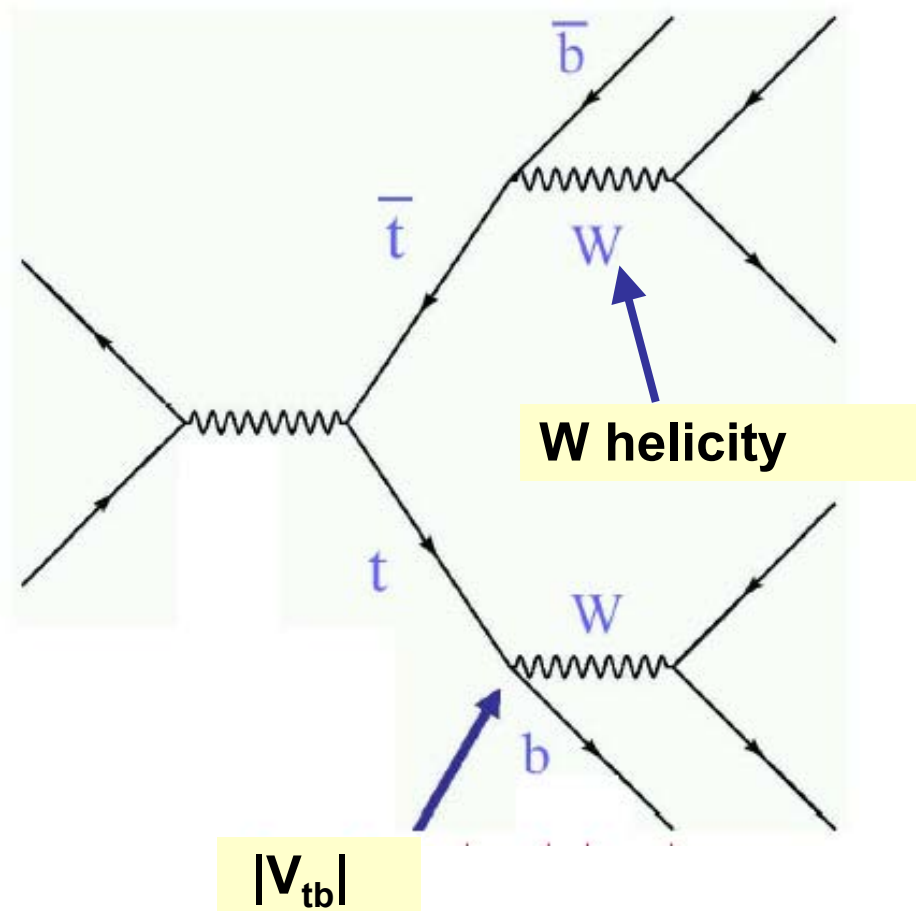
Top Quark Properties



top decay properties:

- W helicity measurements:

➔SM excluded right handed W polarization

- search for $t \rightarrow H^+b$

➔prediction of light, charged Higgs in SSM

- $BR(t \rightarrow Wb)/BR(t \rightarrow Wq)$

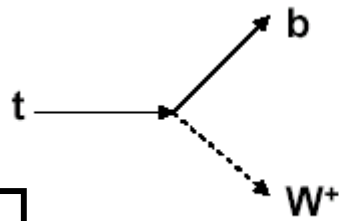
➔contribution from FCNC or 4th generation quark

single top search:

- ultimate measurement of $|V_{tb}|$

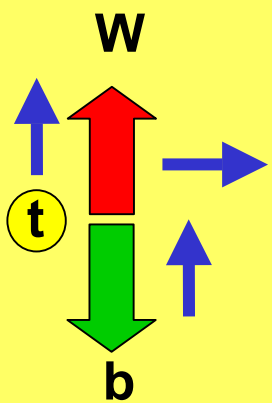
W Helicity in Top Decays

top decay in the SM: (V-A) charged current interaction



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

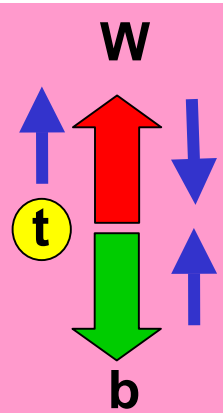
helicity states of the W:



f_0 fraction of longitudinally polarized W

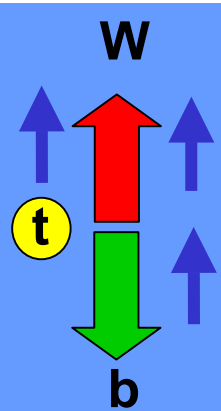
$$f_0 = \frac{m_t^2}{2M_W^2 + m_t^2 + m_b^2}$$

$$= (70.1 \pm 1.6)\%$$



left handed fraction f_-

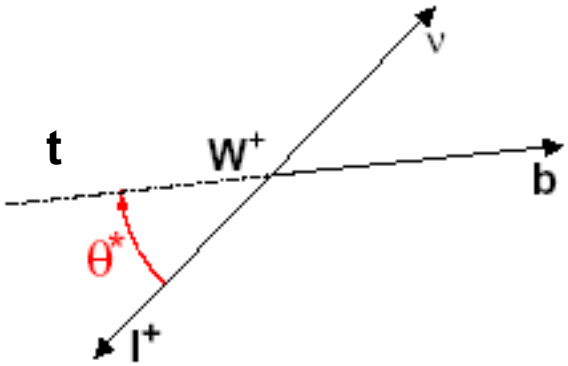
$$f_- \approx 30\%$$

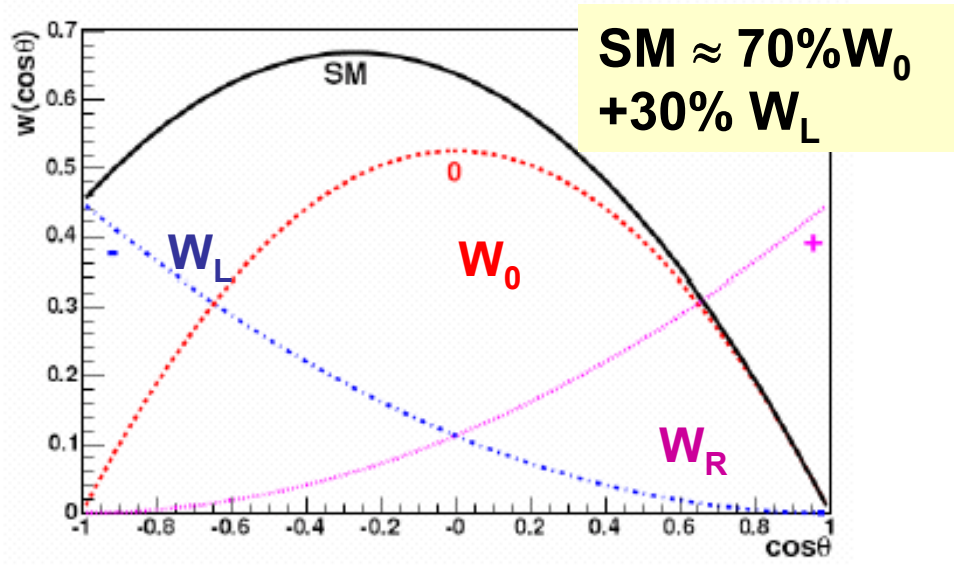


right handed fraction f_+

$$f_+ \approx 0\%$$

W Helicity Measurement





W polarizations can be disentangled:

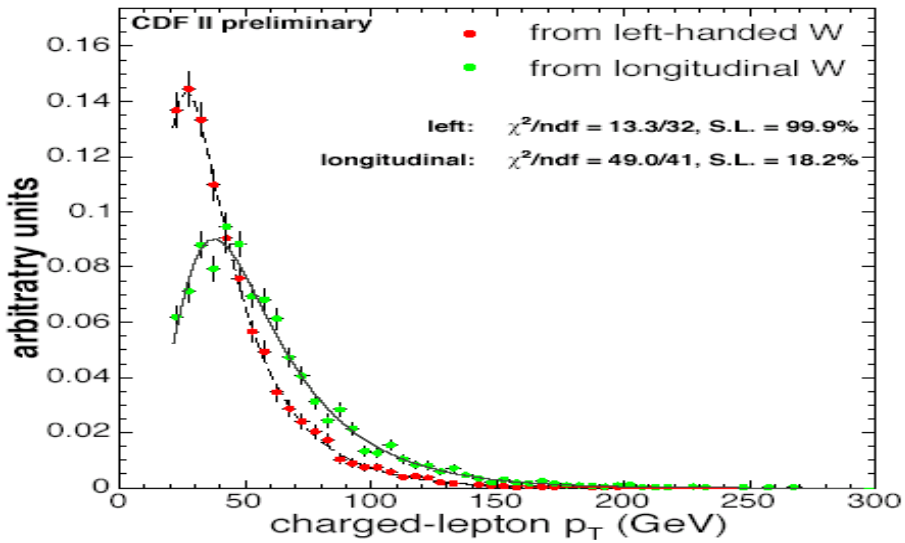
- cos θ^* distribution
- lepton p_T distribution

➔longitudinal W-polarization:

- leptons are emitted perpendicular
- harder p_T distribution

➔left-handed W:

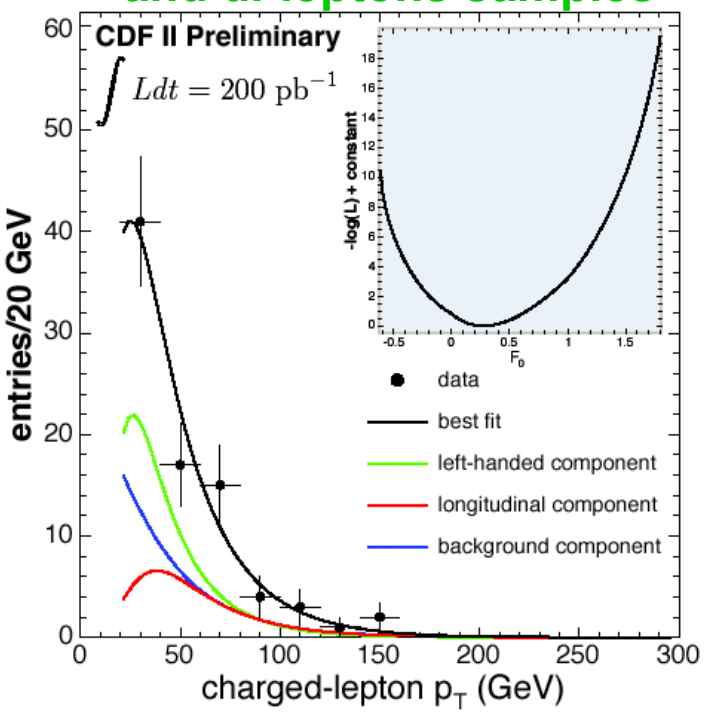
- leptons are emitted opposite
- soft p_T distribution



Longitudinal W Polarization

likelihood analysis of p_T spectrum

combined lepton+jet and di-leptons samples

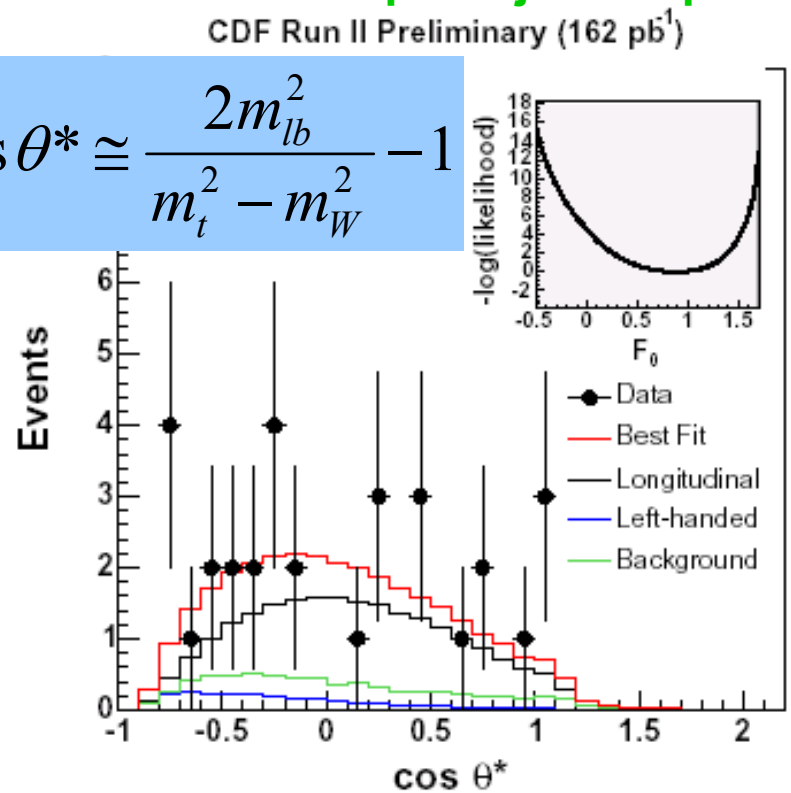


$$f_0 = 0.27^{+0.35}_{-0.21}(stat + syst)$$

$$f_0 < 0.88 @ 95\%CL$$

likelihood analysis of $\cos\theta^*$

combined lepton+jet sample



$$\cos\theta^* \cong \frac{2m_{lb}^2}{m_t^2 - m_W^2} - 1$$

$$f_0 = 0.89^{+0.30}_{-0.34}(stat) \pm 0.17(syst)$$

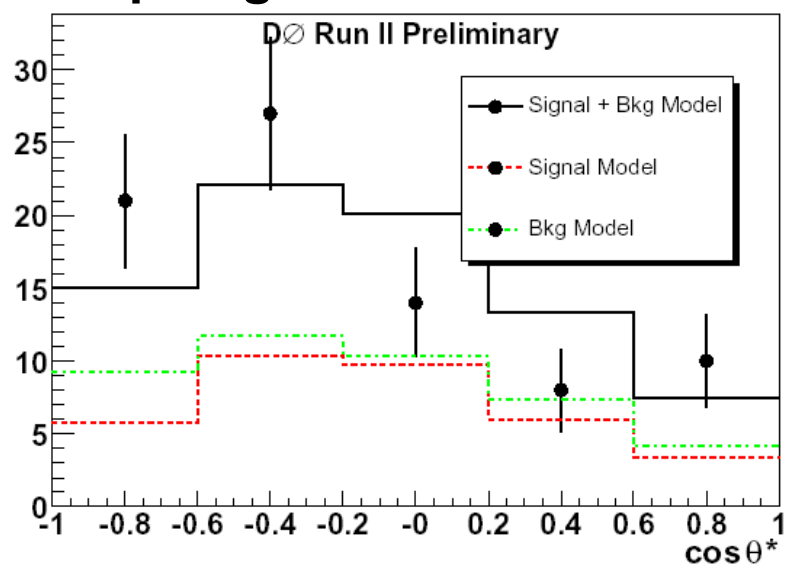
$$f_0 > 0.25 @ 95\%CL$$

main systematic uncertainties: background normalization, m_t

Limit on Right-Handed W

- analysis of lepton+jets sample (169 pb^{-1})
- simulate templates for various f_+ contributions, f_0 fixed at 70%
- likelihood analysis

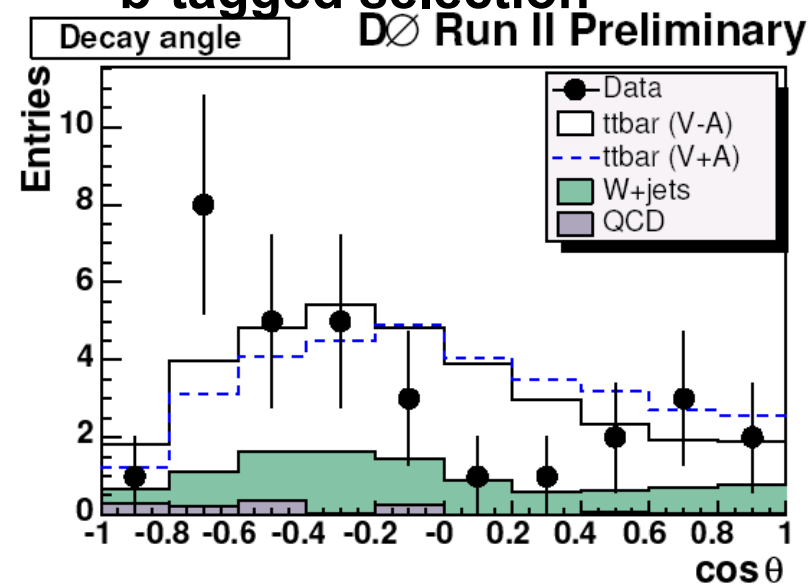
topological selection



$$f_+ = -0.11 \pm 0.19(stat)$$

$$f_+ < 0.24@90\%CL(stat+syst)$$

b-tagged selection



$$f_+ = -0.13 \pm 0.23(stat)$$

$$f_+ < 0.24@90\%CL(stat+syst)$$

systematic uncertainties: background normalization, m_t, jet energy scale

MSSM Search for $t \rightarrow H^+b$

- for charged Higgs-bosons with $m_H < m_t$, thedecay $t \rightarrow H^+b$ modifies tt event topologies according to $H^\pm$ decay modes

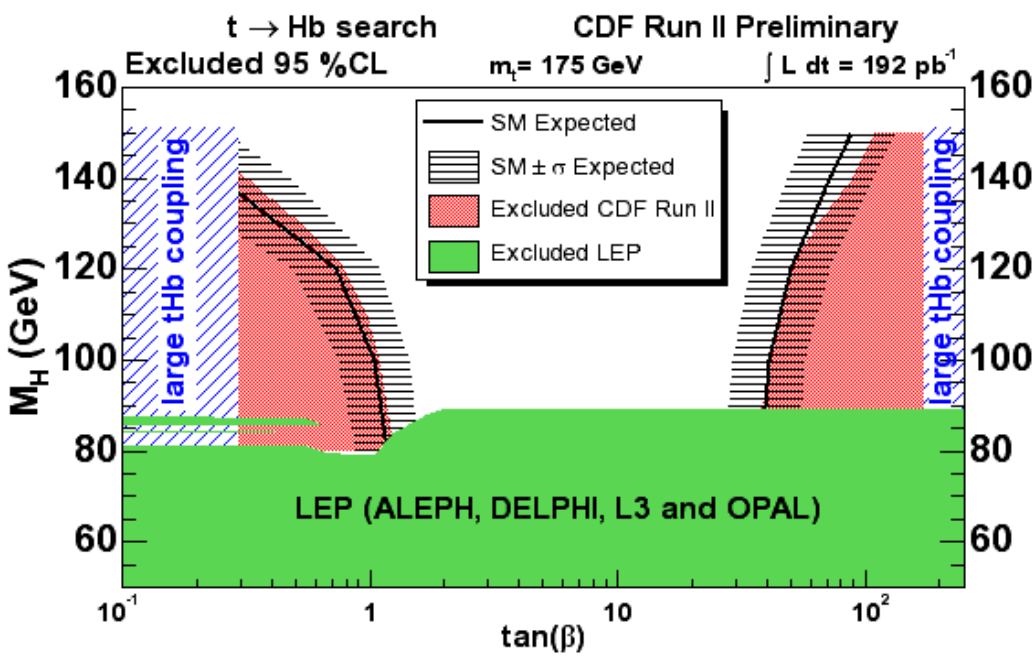
large tanβ: $H^\pm \rightarrow \tau\nu$ excess of τ decays

small tanβ: $H^\pm \rightarrow cs$ excess in all-hadronic decays

$H^\pm \rightarrow Wbb$ 2 extra b jets

inputs for $H^\pm$ limits:

- **$\sigma(tt \rightarrow dilepton)$**
- **$\sigma(tt \rightarrow lepton+jets)$**
- **limit on $\sigma(tt \rightarrow lepton+\tau)$**



BR t→Wb/t→Wq

Unitarity constraint on the CKM-matrix with 3 families
➔Br(t→Wb) at nearly 100% in the SM

$$R = \frac{|V_{tb}|^2}{|V_{td}|^2 + |V_{ts}|^2 + |V_{tb}|^2} > 0.998 @ 90\% CL(PDG)$$

- model independent limit on R using tag-rate $R\varepsilon_b$
  for 0-,1- and 2- tagged events:
  $\varepsilon_0=(1-R\varepsilon_b)^2$ $\varepsilon_1=2R\varepsilon_b(1-R\varepsilon_b)$ $\varepsilon_2=(R\varepsilon_b)^2$
  ➔estimate background level in tt-sample
  ➔compare tag rates with expectation
  ➔compute most likely value of $R\varepsilon_b$ and set lower limit on R

CDF: 0-, 1- and 2-tagged lepton+jets and di-lepton samples

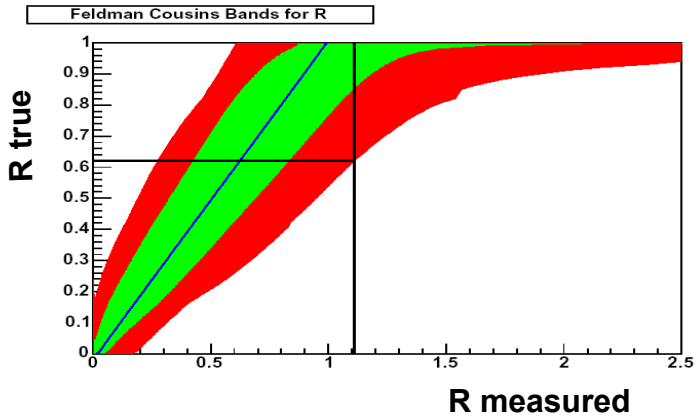
DØ: 1- and 2-tagged lepton+jets samples with two different b-tagging algorithms

Determination of R

CDF: tagging probability from simulation $\Delta\varepsilon_b$=0.436±0.032

$$R = 1.11^{+0.21}_{-0.19}(stat + syst)$$

$$R > 0.62 @ 95\% CL$$



DØ: impact parameter algorithm for b-tagging:

$$R = 0.65^{+0.34}_{-0.30}(stat)^{+0.17}_{-0.12}(syst)$$

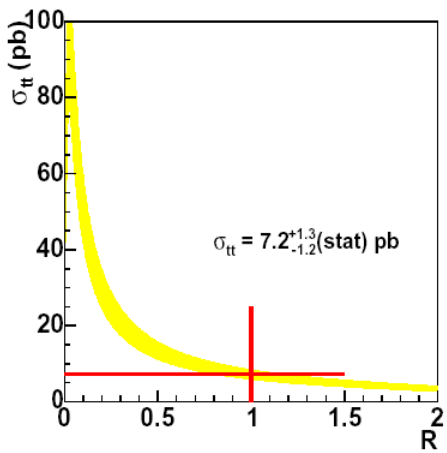
secondary vertex algorithm for b-tagging:

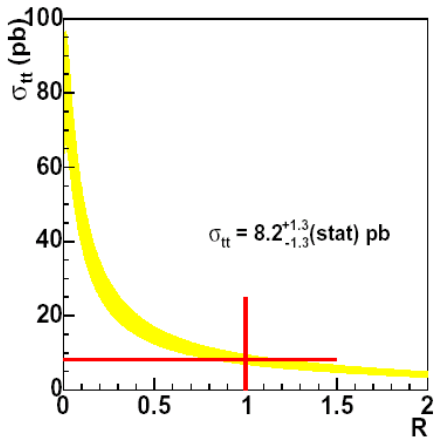
$$R = 0.70^{+0.27}_{-0.24}(stat)^{+0.11}_{-0.10}(syst)$$

➔measurements compatible with SM

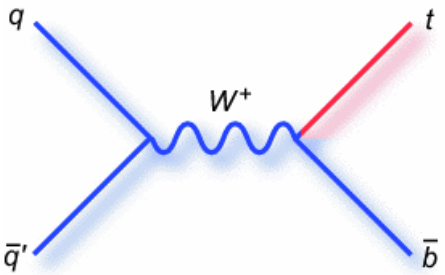
➔independent cross-section determination

➔main systematic uncertainties: difference of b-tagging probability between the data and the simulation





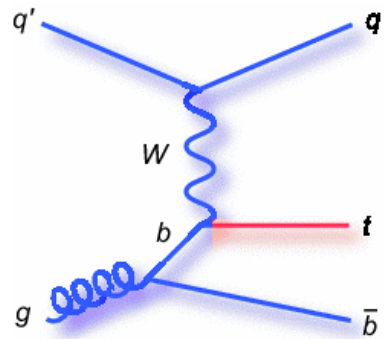
Single Top Production



s-channel

$\sigma_s \sim 0.9$ pb

⇒ new charged particles



t-channel

$\sigma_t \sim 2.0$ pb

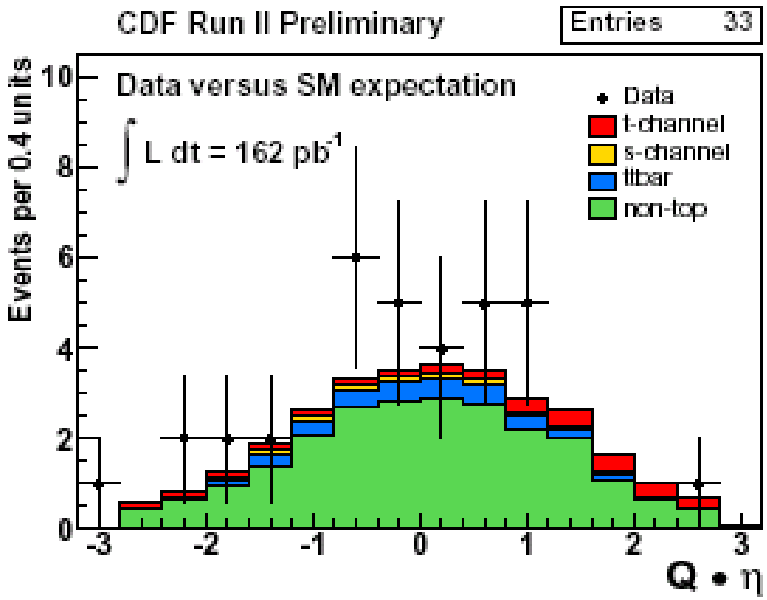
⇒ anomalous couplings, FCNC

- **Single top quarks produced by weak interaction are a direct probe of top quark's weak couplings.**
  - **Measure V_{tb} without assuming three-generation unitarity.**
- **Cross section is close to top quark pair production cross section (2.9 pb vs. 7.5 pb), but: signal/background is much worse**
  - **fewer jets, softer kinematics, lower acceptance**
  - **signature: isolated lepton, missing E_T, jets≥2**
  - **s-channel: 1 b-tag t-channel: 2 b-tags**
  - **major backgrounds: W+jets, top-pairs, fake leptons**

➔Single top production has not been observed yet!

Single Top Search

CDF:
- event shape analysis
- after selection 42 events observed 38.1 ± 5.9 expected in combined channel
- $Q_L \bullet \eta_b$ distribution to disentangle s and t channels



s-channel: $\sigma_s < 13.6$ pb (95% CL)

expected limit: $\sigma_s < 12.1$ pb

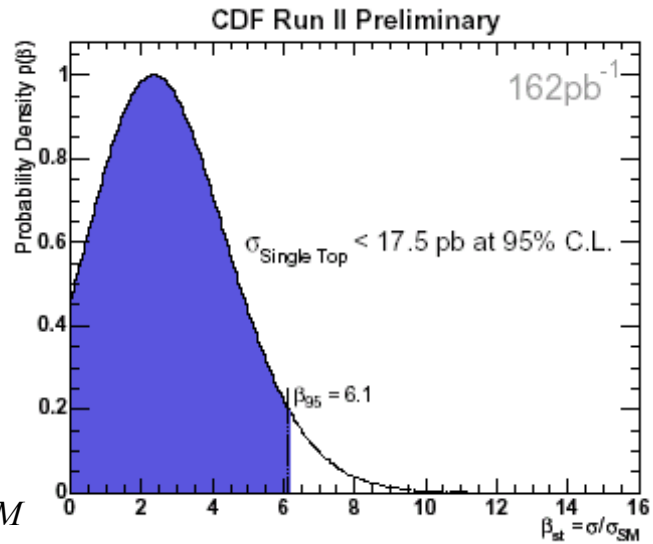
t-channel: $\sigma_t < 10.1$ pb (95% CL)

expected limit: $\sigma_s < 11.2$ pb

combined analysis: $\sigma_{s+t} < 17.5$ pb (95% CL)

expected limit: $\sigma_s < 13.6$ pb

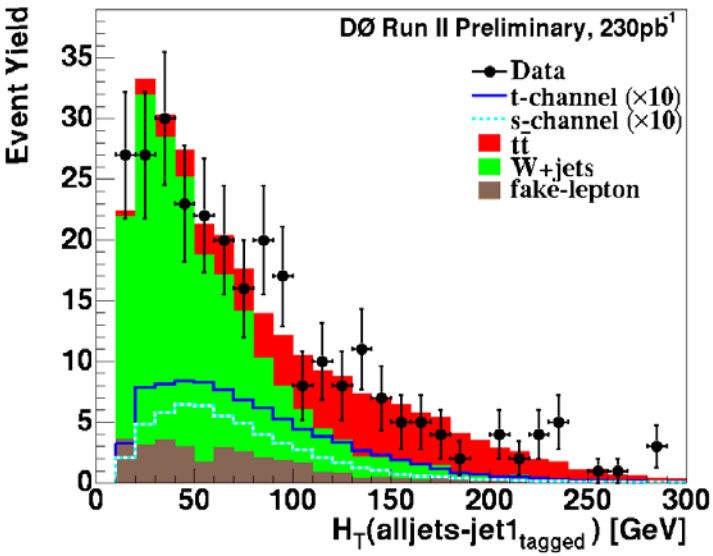
most likely cross-section: $2.7^{+1.8}_{-1.7} \bullet \sigma_{SM}$

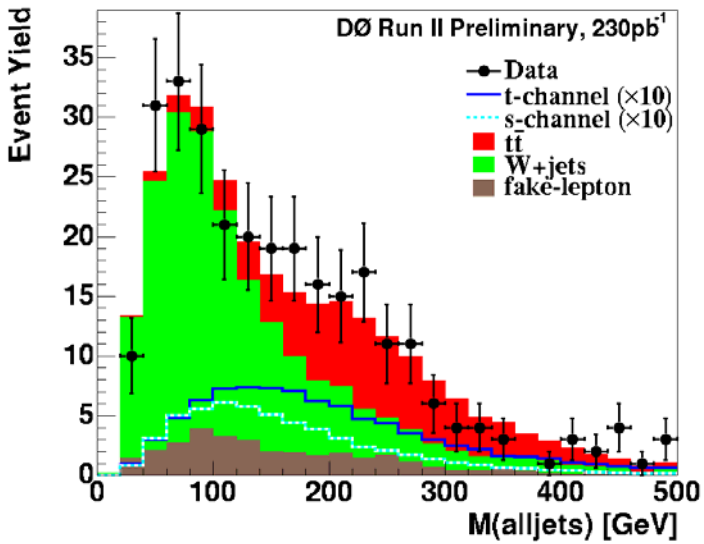


Single Top Search

DØ: 230 pb^{-1}

- 2 analysis strategies after pre-selection: cut-based analysis and Neural Network analysis in lepton+jets samples
- detailed study discriminative power of 25 kinematic variables: object kinematics, global event kinematics and angular variables
- cut-based analysis using the 6-7 most efficient cuts
- major systematic uncertainties:b-tagging simulation, JES





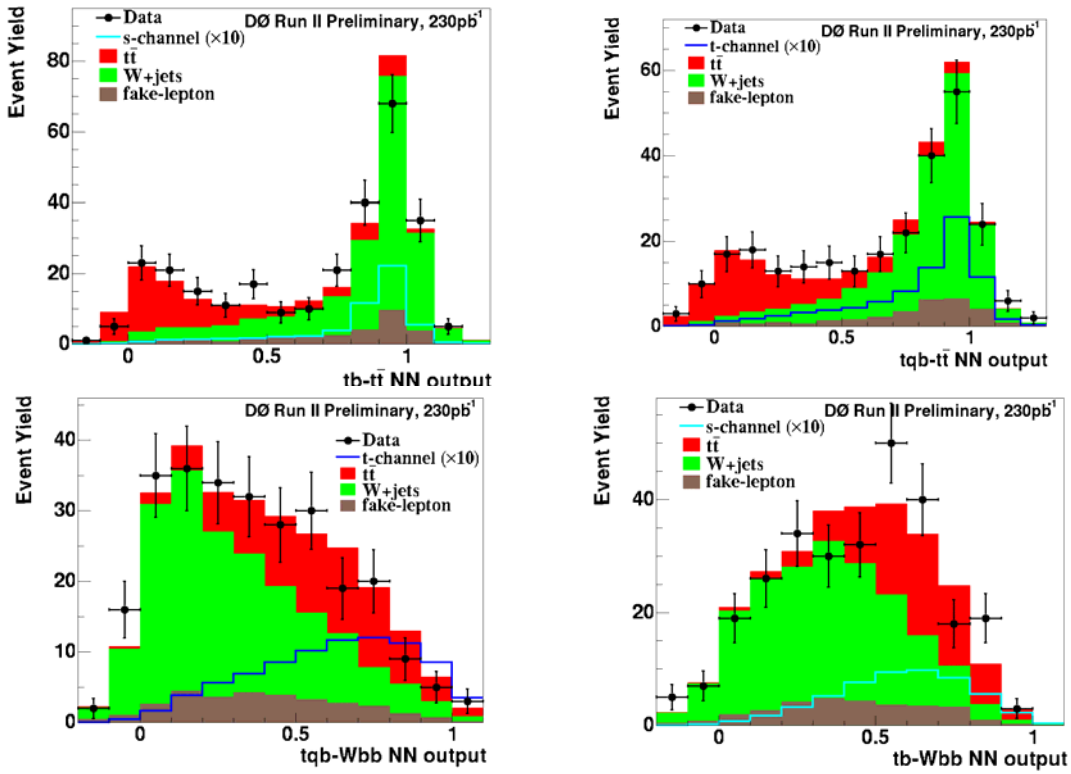
Neural Network Analysis

DØ: 230 pb^{-1}

- training of 4 different Neural Networks in order to separate the Wbb and the tt-background in the single and the double tagged channels separately

➔ good separation for tt-background, less for Wbb

➔ 2 dimensional kinematic likelihood on tt and Wbb NN-output



Single Top Results

cut based analysis:

s-channel: $\sigma_s < 10.6$ pb (95% CL)

expected limits: $\sigma_s < 9.8$ **pb**

t-channel: $\sigma_t < 11.3$ pb (95% CL)

expected limits: $\sigma_t < 12.4$ **pb**

NN-based analysis:

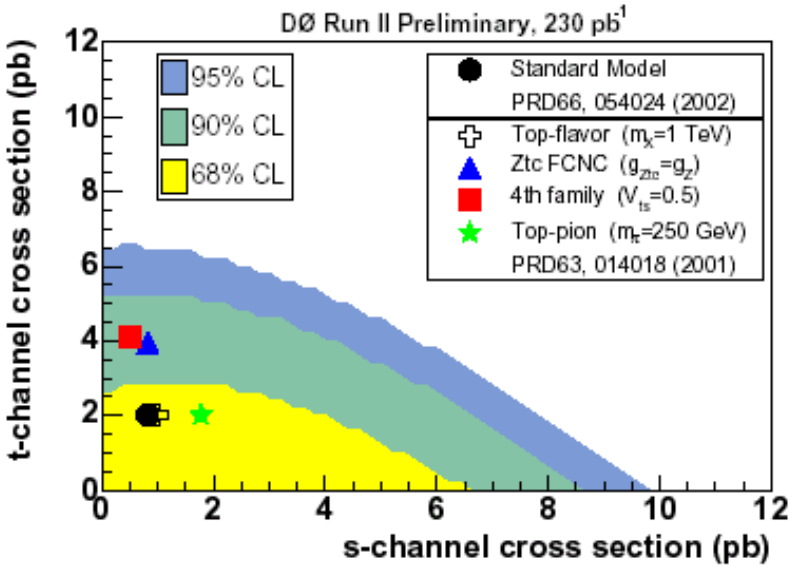
s-channel: $\sigma_s < 6.4$ pb (95% CL)

expected limits: $\sigma_s < 4.5$ **pb**

t-channel: $\sigma_t < 5.0$ pb (95% CL)

expected limits: $\sigma_t < 5.8$ **pb**

- single top production expected with the Tevatron Run II data
- improvements on acceptance and systematics ongoing in CDF and DØ



- comparison of exclusion limits in the s (tb-muon) and t (tqb-electron) channels
- close in sensitivity to non SM contributions such as FCNC or 4th quark family

Summary

- **Study of top-properties allows to investigate in detail Standard Model prediction**

➔ increased statistics will allow for precision studies

- **No deviations from Standard Model expectations have been observed so far**

➔ room for new physics

- **Substantially improved limits for single top search with respect to Run I results**

➔further improvements in analysis will allow to reduce the integrated luminosity necessary for single top observation