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

on behalf of the CDF and DØ Collaborations

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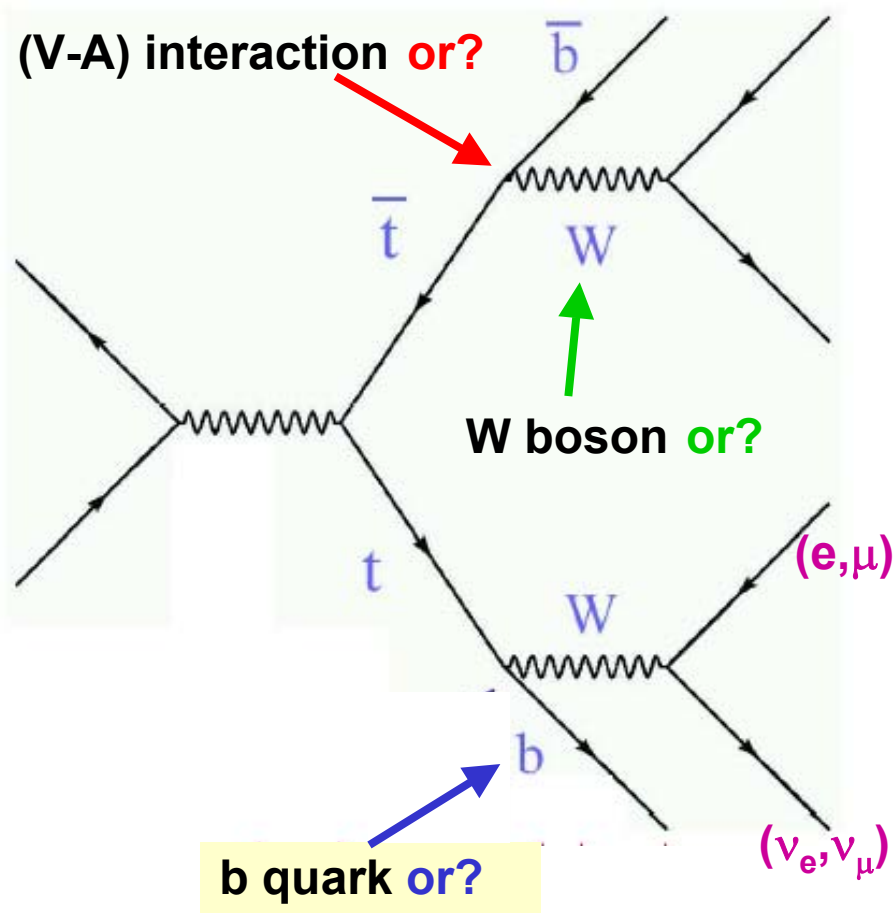
Top Quark Properties



top decay properties:

- W helicity measurements:

➔SM excludes right handed W polarization

- search for t→H^+b

➔prediction of light, charged Higgs in SSM

- BR(t→Wb)/BR(t→Wq)

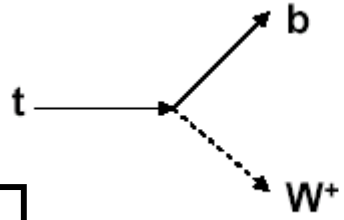
➔contribution from FCNC or 4^{th} generation quark

single top production:

➔measurement of $|V_{tb}|$

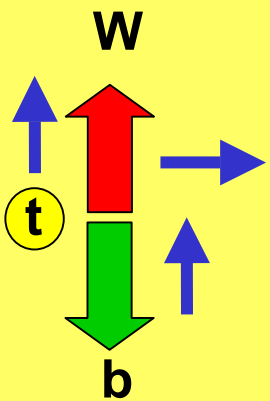
W Helicity in Top Decays

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



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

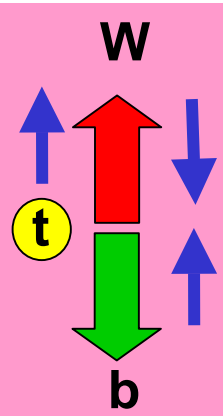
helicity states of the W:



fraction of longitudinally polarized W

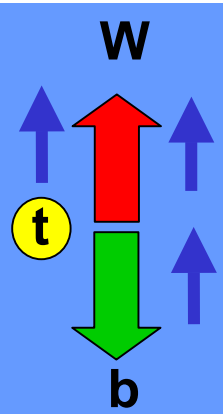
$$f_0 = \frac{m_t^2}{2M_W^2 + m_t^2 + m_b^2}$$

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



left handed fraction

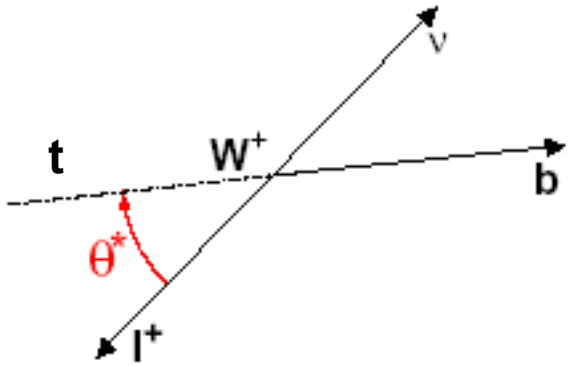
$$f_- \approx 30\%$$



right handed fraction

$$f_+ \approx 0\%$$

W Helicity Measurement



W polarizations can be disentangled:

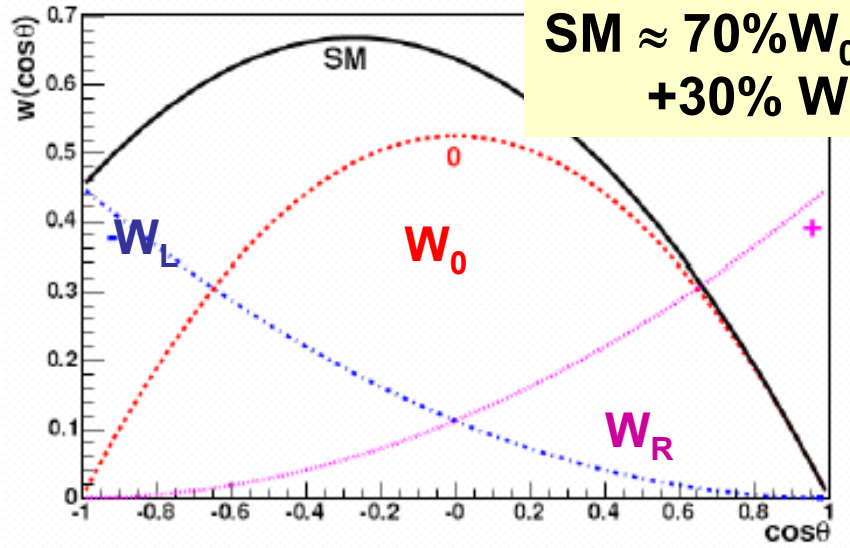
- cos θ^* distribution (in W rest frame)
- lepton p_T distribution

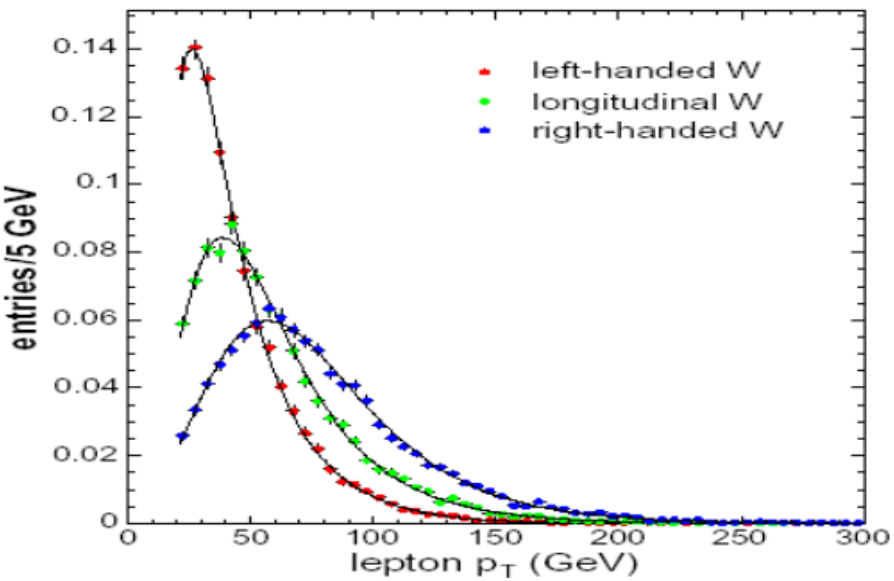
➔longitudinal W-polarization:

- leptons are emitted perpendicular to W boson direction
- harder p_T distribution

➔left-handed W:

- leptons are emitted opposite to W boson direction
- softer p_T distribution

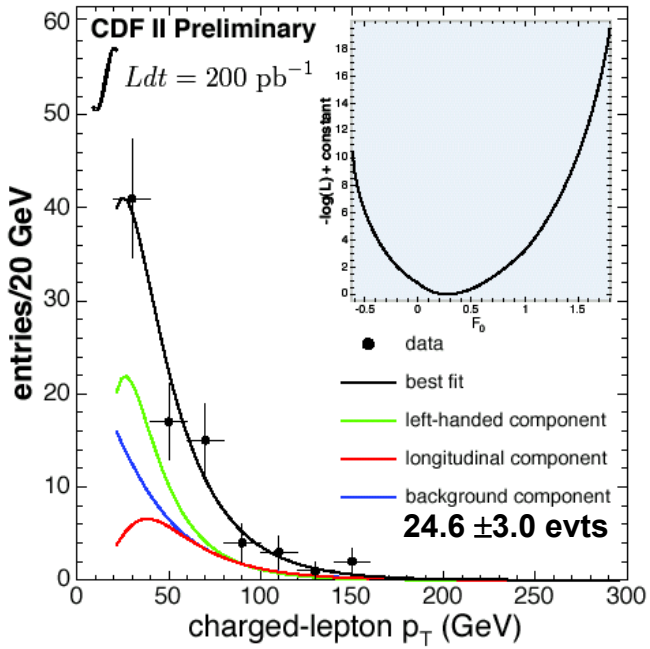




Limits on f_0

likelihood analysis of p_T spectrum

combined lepton+jet and di-leptons samples: 70 events

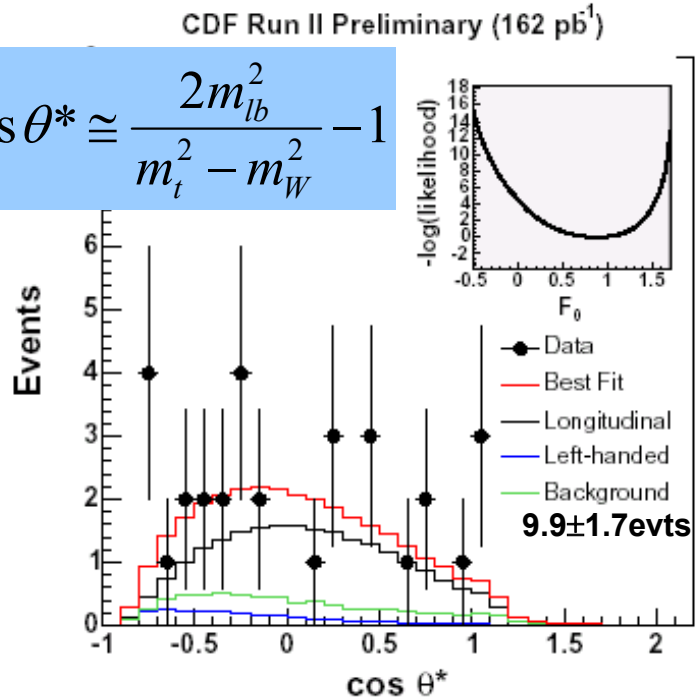


$$f_0 = 0.27^{+0.35}_{-0.21}(stat+syst)$$

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

likelihood analysis of cosθ*

combined lepton+jet sample: 31 events



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

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

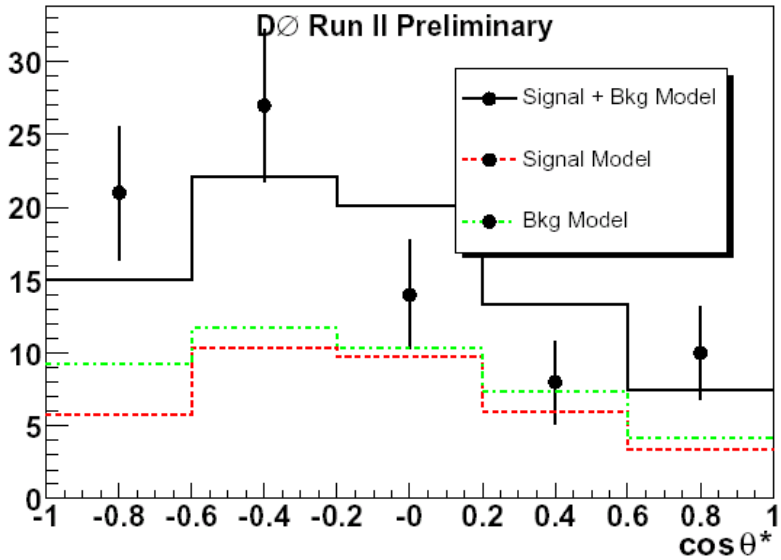
SM-assumption: f_+=0 – no right handed W

main systematic uncertainties: background normalization, m_t

Limits on f_+

- lepton+jets sample (169 pb^{-1})
- simulate templates of cos θ^* for $0 \leq f_+ \leq 0.3$
- likelihood analysis with f_0=70%

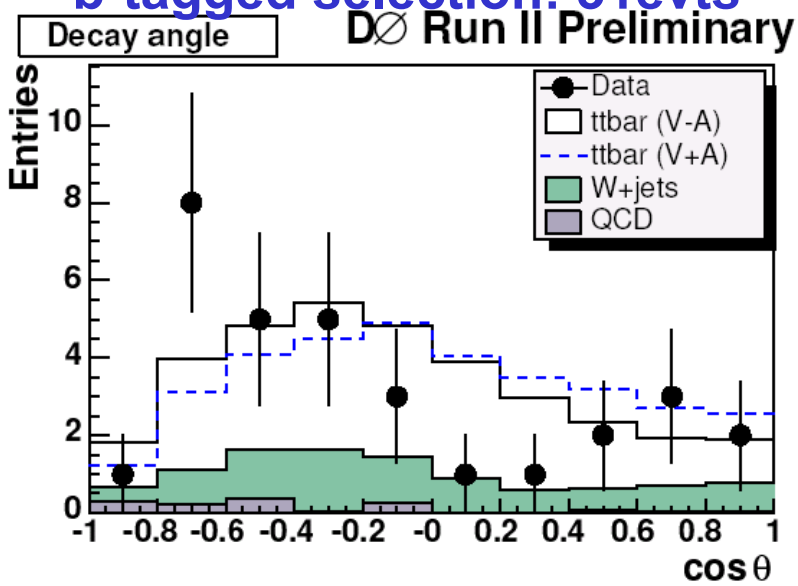
topological selection: 80 evts



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

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

b-tagged selection: 31evts



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

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

➔W helicity determinations are compatible with Standard Model expectations

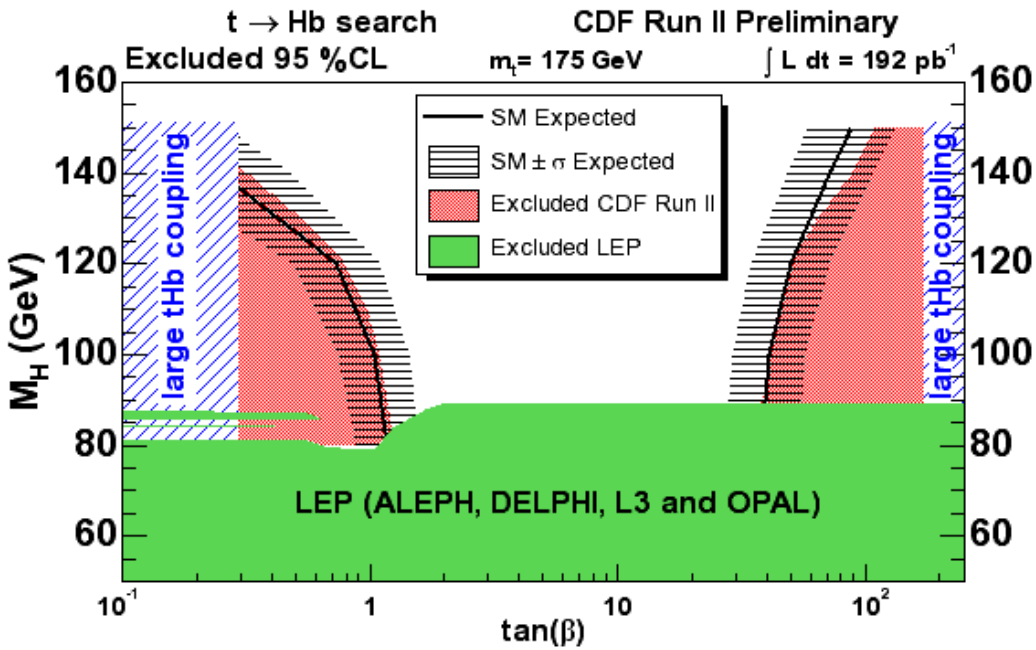
MSSM Search for t→H⁺b

- for charged Higgs-bosons with $m_H < m_t$, the decay t→H⁺b modifies tt signatures 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:

- **σ(tt→dilepton)**
- **σ(tt→lepton+jets)**
- **limit on σ(tt→lepton+τ)**



model independent analysis: BR(t→Hb) < 0.70 @95%CL

Limit on $|V_{tb}|$

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

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

- limit on R from BR(t➔Wb)/B(t➔Wq) using tag-rate $R\varepsilon_b$:
  the probabilities for 0-,1- and 2- tagged top events are
  $\varepsilon_0=(1-R\varepsilon_b)^2$ $\varepsilon_1=2R\varepsilon_b(1-R\varepsilon_b)$ $\varepsilon_2=(R\varepsilon_b)^2$
  - ➔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

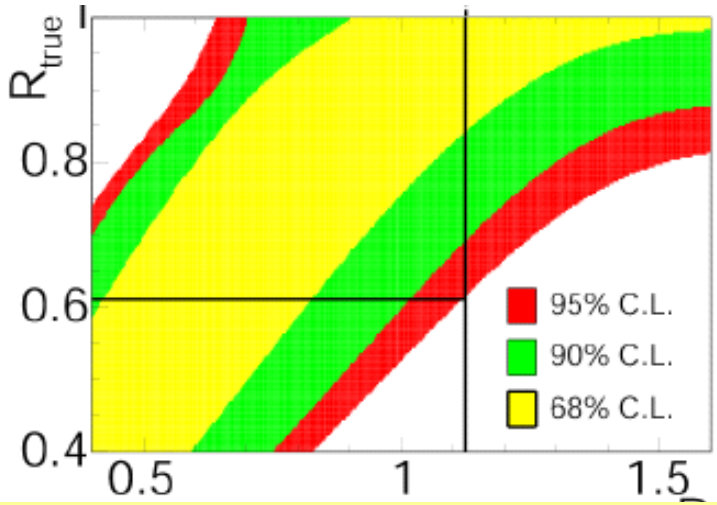
Determination of R

CDF: tagging probability calibrated on data $\Delta\varepsilon_b = 0.436 \pm 0.032$

$$R = 1.12^{+0.27}_{-0.23}(stat + syst)$$

$$R > 0.61 @ 95\% CL$$

$$|V_{tb}| > 0.79 @ 95\% CL$$

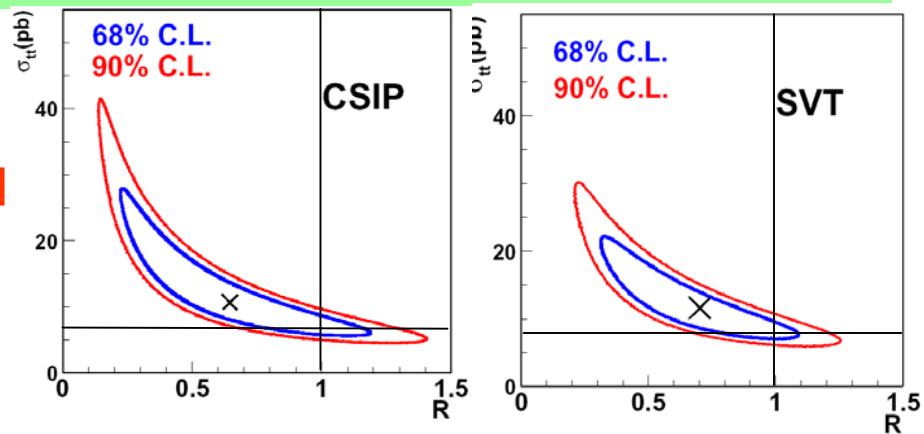


DØ: impact parameter algorithm for b-tagging:

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

secondary vertex algorithm for b-tagging:

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

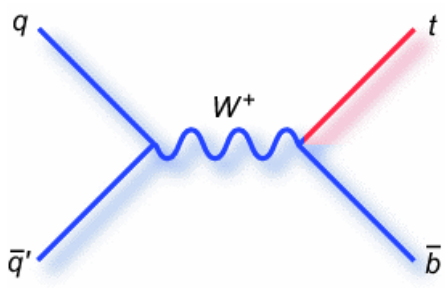


➔independent cross-section determination

➔measurements compatible with SM

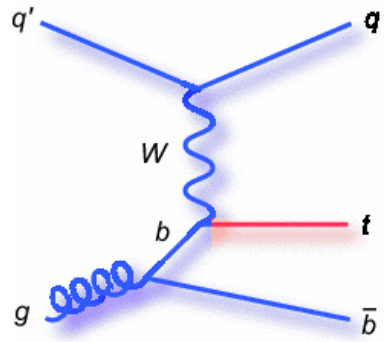
➔main systematic uncertainties: difference of b-tagging probability between the data and the simulation

Single Top Production



s-channel

$\sigma_s \sim 0.9$ pb



t-channel

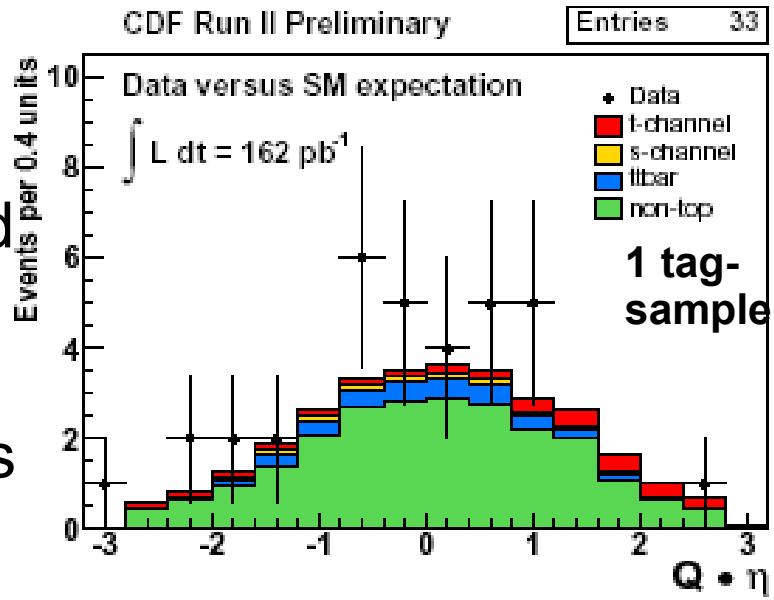
$\sigma_t \sim 2.0$ pb

- **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 about half of the top quark pair production cross section (2.9 pb vs. 6.7 pb) but: signal/background is much worse**
  - **fewer jets, softer kinematics, lower acceptance**
  - **signature: isolated lepton, missing E_T, ≥2 jets**
  - **s-channel: 1 or 2 b-tags t-channel: 1 b-tag + 1 jet**
  - **major backgrounds: W+jets, top-pairs, fake leptons**

➔**Single top production has not been observed yet!**

Single Top Search

CDF:
- W + 2 jets events
- combined channel: 42 evts observed - 38.1 ± 5.9 expected
- $\varepsilon \approx 1\%$ for $S/B \approx 1/10$
- 1 tag evts: $Q_L \cdot \eta_{jet}$ distribution to disentangle s and t channels



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

expected limit: $\sigma_s < 12.1$ pb

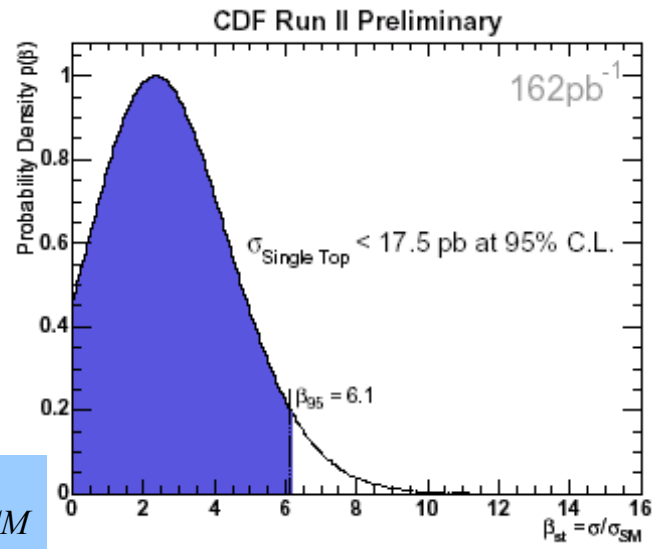
***t*-channel:** $\sigma_t < 10.1$ pb (95% CL)

expected limit: $\sigma_s < 11.2$ pb

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

expected limit: $\sigma_s < 13.6$ pb

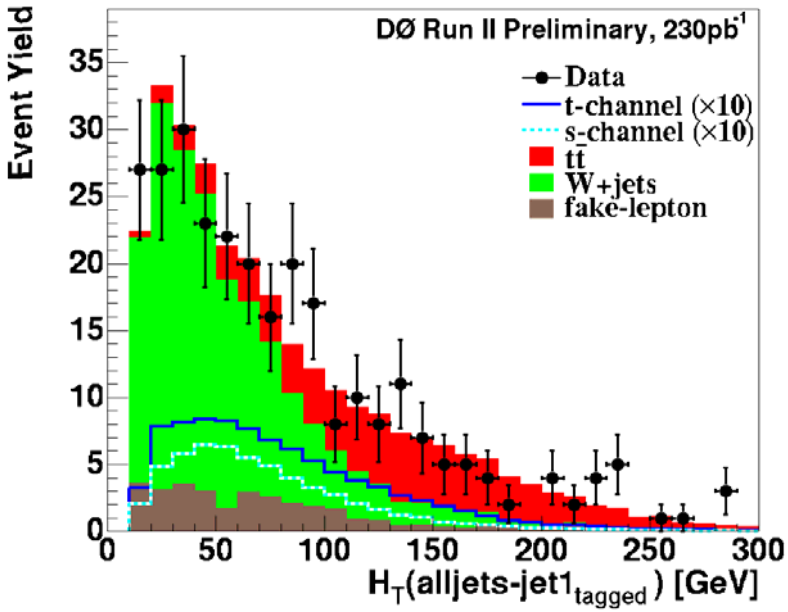
most likely cross-section: $2.7^{+1.8}_{-1.7} \cdot \sigma_{SM}$

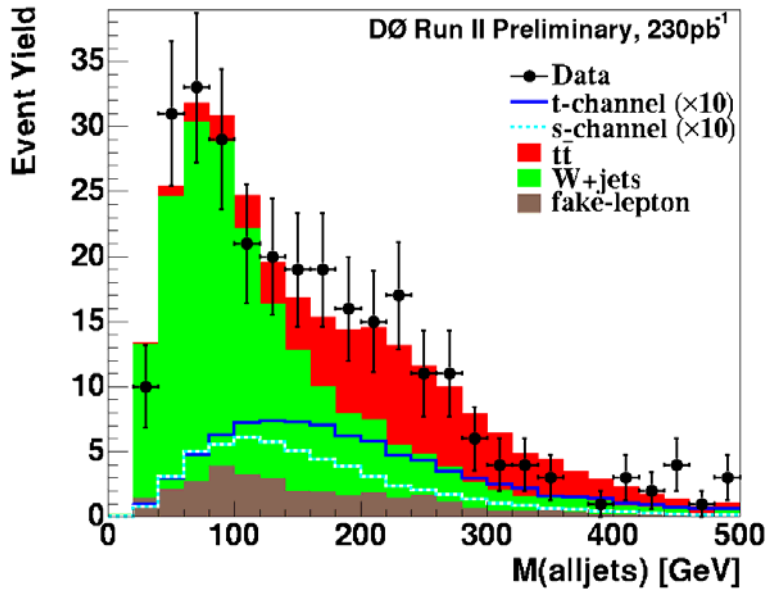


Single Top Search

DØ: 230 pb^{-1}

- 2 analysis strategies after pre-selection: cut-based analysis and Neural Network analysis in lepton+jets samples for W+≥2jets: $\varepsilon \approx 1.9 - 2.7\%$ for S/B≈1/15
- 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

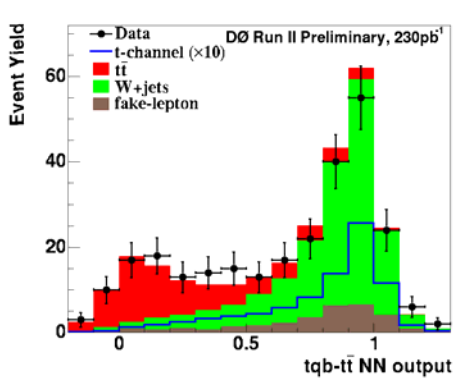
DØ: 230 pb^{-1}

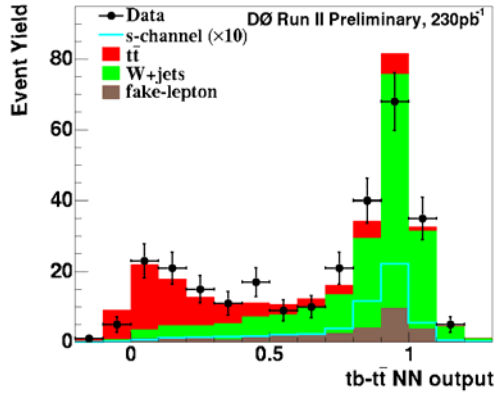
- **training of 8 different Neural Networks in order to separate the Wbb and the tt-background for s- and t-channels separately for the electron and muon sample**

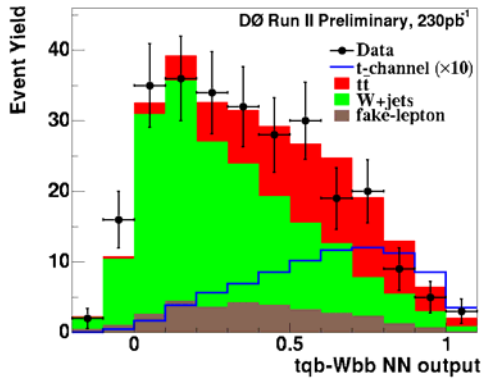
➔11 variables used per NN-analysis

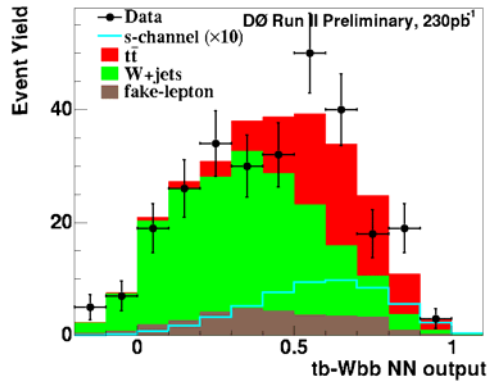
➔good separation for tt-background, less for Wbb

➔ limits extracted from 2D binned 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:

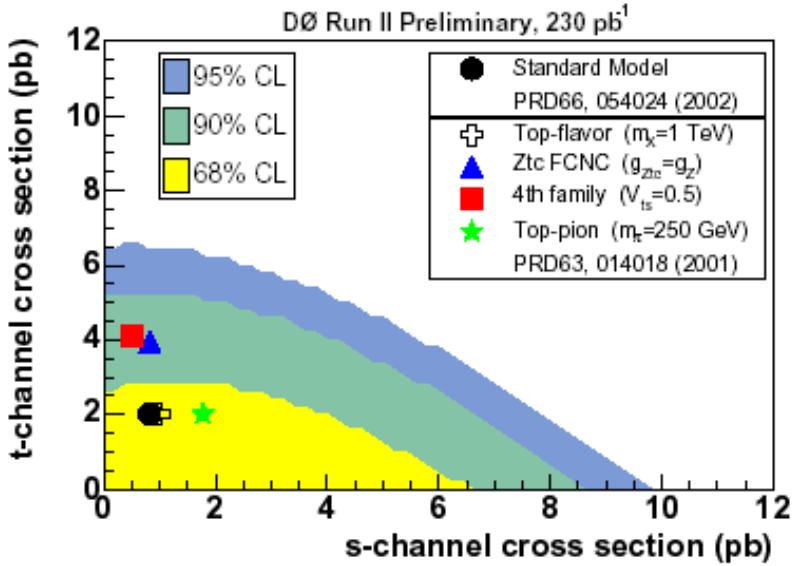
s-channel: $\sigma_s < 6.4$ pb (95% CL)

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**

➔ **with current precision still 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**