Search for W' boson resonances decaying to a top and a bottom quark and Probing anomalous Wtb Couplings

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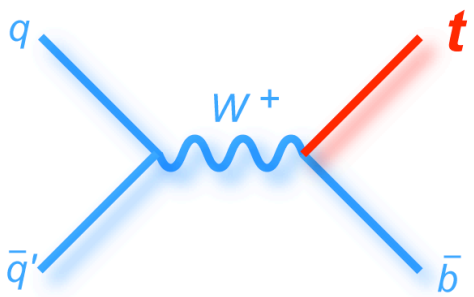
for the D0 collaboration

- Search for Single top
- W' boson resonances
- Anomalous Wtb couplings

Single Top quark production

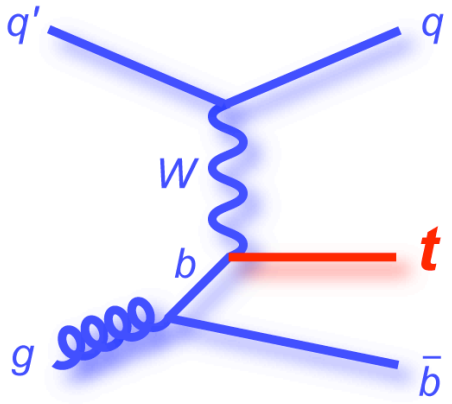
- First evidence presented in 2006
- Main production mechanism for (SM-like) top production:

s-channel "tb"



$\sigma_{NLO} = 0.9 \pm 0.1$ pb

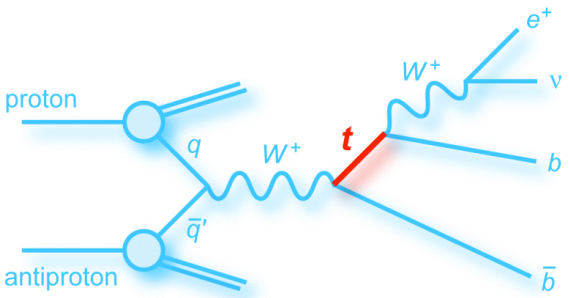
t-channel "tqb"

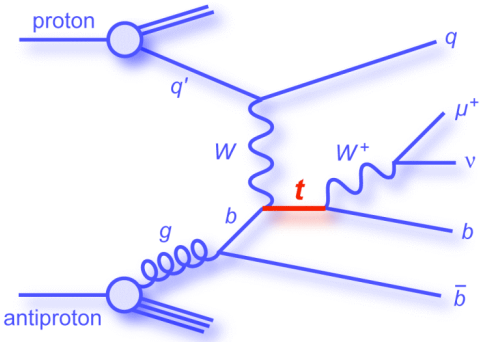


$\sigma_{NLO} = 2.0 \pm 0.3$ pb

m(top)=175 GeV

Single Top quark : event selection





- 1 isolated electron or muon
  - electron $p_T > 15$ GeV and $|\eta_{det}| < 1.1$
  - muon $p_T > 18$ GeV and $|\eta_{det}| < 2.0$
- missing transverse energy
  - MET > 25GeV
- 2, 3 or 4 jets $p_T > 15$ GeV and $|\eta_{det}| < 3.4$
  - leading jet $p_T > 25$ GeV and $|\eta_{det}| < 2.5$
  - second leading jet $p_T > 20$ GeV
- at least 1 b-tagged jet
- backgrounds : W+jets, $t\bar{t}$, dibosons (from MonteCarlo)
  - multijets (from data)
- multivariable analyses : multivariable techniques to discriminate signal from background. the variables describe individual object kinematics, global event kinematics and angular correlations.

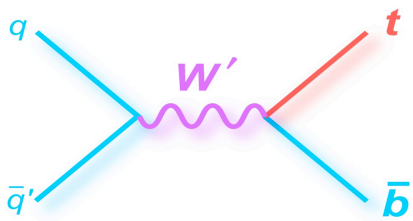
⟹ Cross section measured from 0.9 fb^{-1} dataset

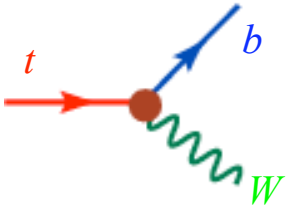
$$\sigma(\bar{p}\,p \rightarrow tb + X, tbq + X) = 4.7 \pm 1.3\,pb$$

Search for New Physics

- New massive particles : charged gauge bosons are predicted in many extensions to the SM.

- Anomalous couplings : changes to the cross-sections changes to the angular distributions of existing SM processes.



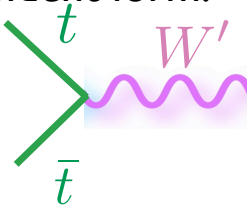


Heavy W' resonances

Heavy W' resonances

- effective $\mathcal{L}$ for W' interactions w/ SM fermions f_{ij} written in a model independent form:

$$\mathcal{L} = \frac{V_{f_i f_j}}{2\sqrt{2}} g_w \bar{f}_i \gamma^\mu (a^R_{f_i f_j}(1+\gamma^5) + a^L_{f_i f_j}(1-\gamma^5)) W'_\mu f_j + h.c.$$

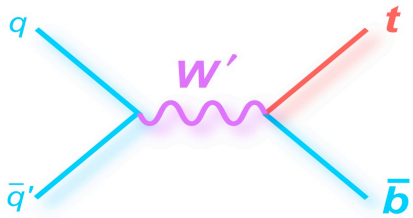


Right and left couplings of W' to quarks

	a^L_{ud}	a^L_{tb}	a^R_{ud}	a^R_{tb}
purely left handed W'_L	1	1	0	0
purely right handed W'_R	0	0	1	1

600 < mass W' < 900 GeV

- Production



- Decay

search for $W' \rightarrow$ 3rd quark generation

- left-handed W'_L with SM couplings, interference with SM taken into account
- right-handed W'_R

  - if $m(W'_R) > m(\nu_R)$ decays to $\ell\nu$ and $\bar{q}q$
  - if $m(W'_R) < m(\nu_R)$ only decays to $\bar{q}q$

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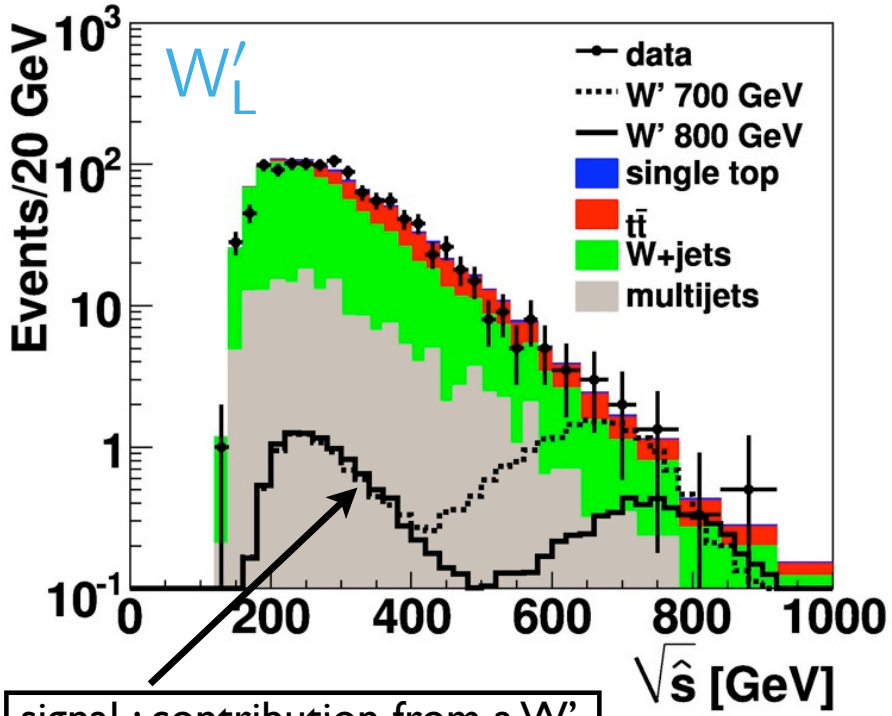
Left-handed W' : selection and event

- single top selection restricted to 2 or 3 jets, same dataset
- tb invariant mass : $\sqrt{\hat{s}}$ reconstructed with the invariant mass of the leading two jets, the charged lepton and the neutrino by adding their measured momentum 4-vector.



signal : contribution from a W'

and a SM W and interference

Left-handed W' : selection and event

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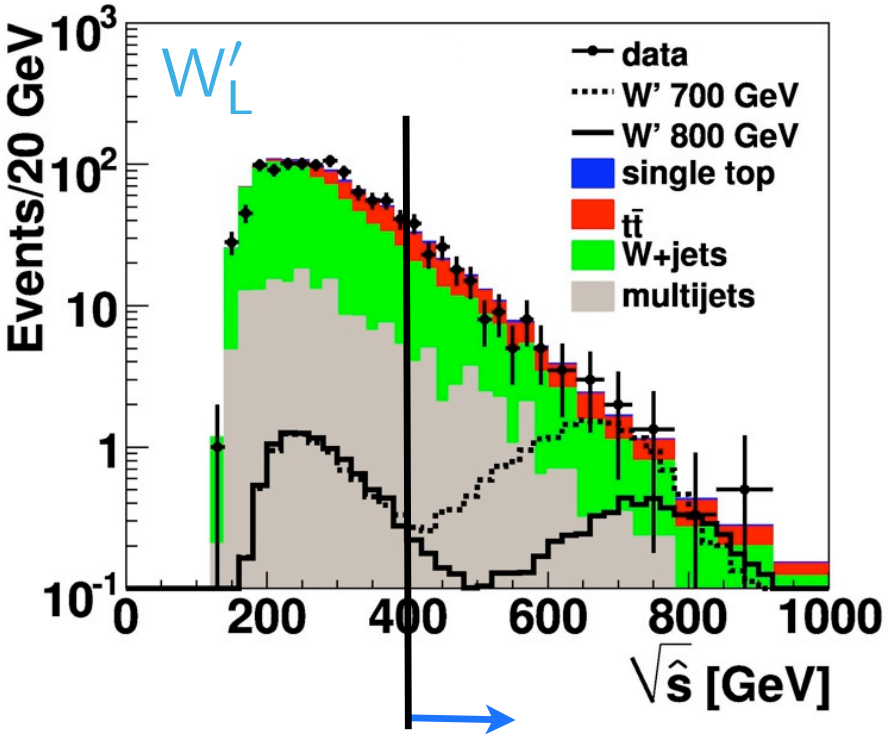

$\sqrt{\hat{s}} > 400$GeV

process	SM + W'_L
single top	6.4 ± 1.4
$t\bar{t}$	59.1 ± 14.4
W + jets	91.0 ± 18.8
multijets	29.7 ± 5.9
Total Bkg	186.1 ± 40.4
Data	182

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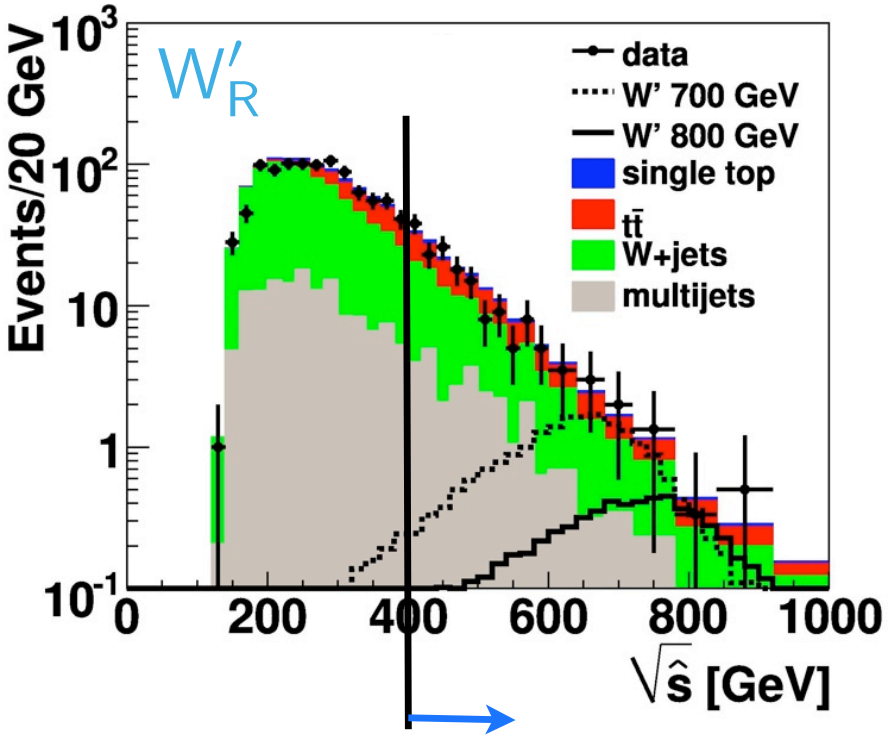
Right-handed W' : selection and event

- single top selection restricted to 2 or 3 jets, same dataset
- tb invariant mass : $\sqrt{\hat{s}}$ reconstructed with the invariant mass of the leading two jets, the charged lepton and the neutrino by adding their measured momentum 4-vector.

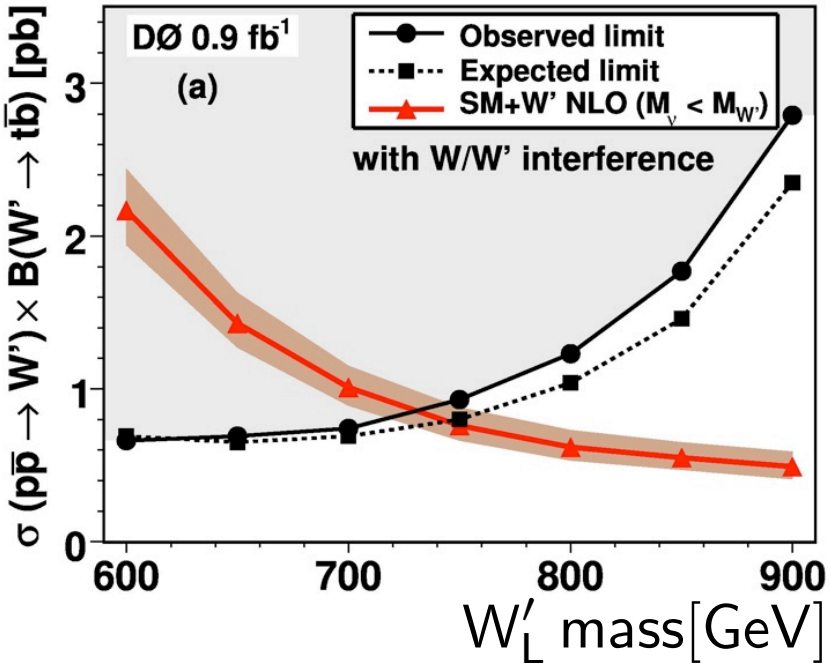


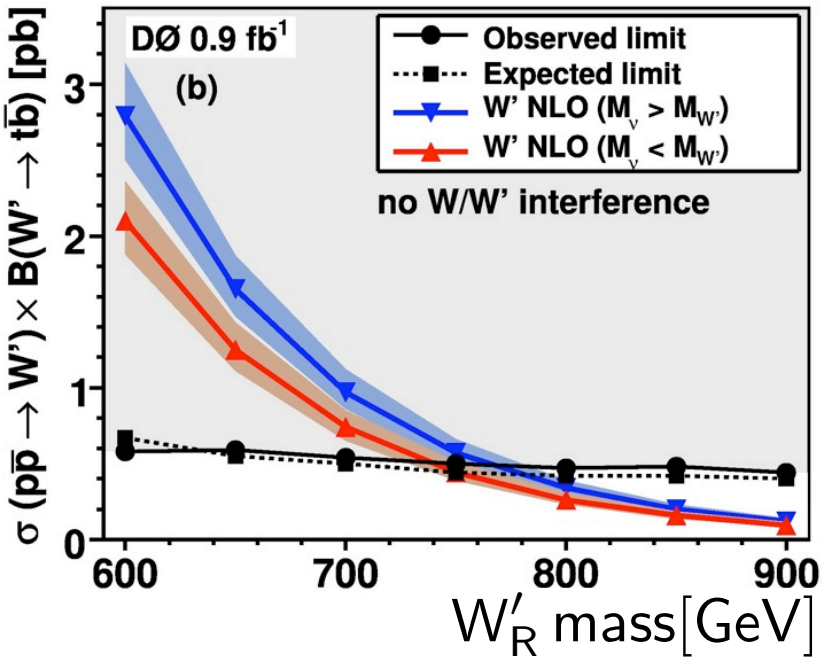
$\sqrt{\hat{s}} > 400$GeV

process	W'_R
single top	10.2 ± 2.2
$t\bar{t}$	59.1 ± 14.4
W + jets	91.0 ± 18.8
multijets	29.7 ± 5.9
Total Bkg	190.0 ± 41.2
Data	182

W' : results

- Limits are derived using a binned likelihood constructed from the $\sqrt{\hat{s}}$ spectrum > 400 GeV





$m(W'_L) >$	731 GeV
$m(W'_R) >$	739 GeV if $m(W'_R) > m(\nu_R)$
$m(W'_R) >$	768 GeV if $m(W'_R) < m(\nu_R)$

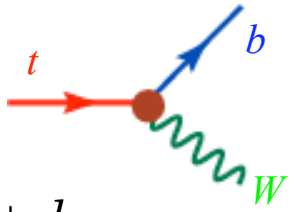
at 95 % C.L.

Anomalous Wtb couplings

Anomalous Wtb couplings

• general CP-conserving Wtb vertex can be parametrized with the effective lagrangian :

$$\mathcal{L} = -\frac{g}{2\sqrt{2}} V_{tb}\bar{b}\{\gamma^{\mu}(f_{L_V}(1-\gamma^5) + f_{R_V}(1+\gamma^5)) + \frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}(f_{L_T}(1-\gamma^5) + f_{R_T}(1+\gamma^5))\}tW_{\mu} + h.c.$$



within SM $f_{L_V} = 1$ $V_{tb} \approx 1$ $f_{R_V} = 0$ $f_{L_T} = 0$ $f_{R_T} = 0$

•Assumption : Wtb vertex dominates top quark production and decay :

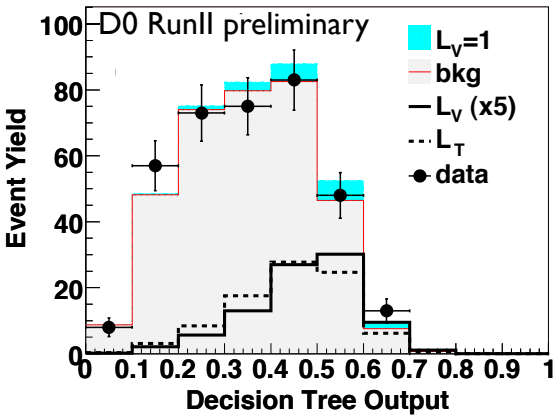
$$|V_{td}|^2 + |V_{ts}|^2 << |V_{tb}|^2$$

•Look at 2 couplings at the same time, assuming the other 2 are negligible.
Consider single top production with the SM Left-handed Vector f_{L_V} coupling with added contribution from

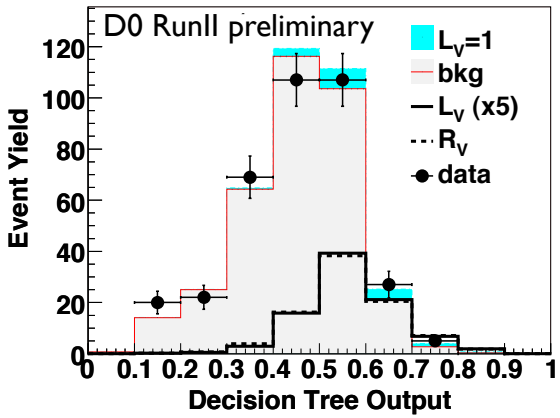
- ✦ the Right-handed Vector f_{R_V} coupling, or
- ✦ the Left-handed Tensor f_{L_T} coupling, or
- ✦ the Right-handed Tensor f_{R_T} coupling

Wtb : multivariable analysis

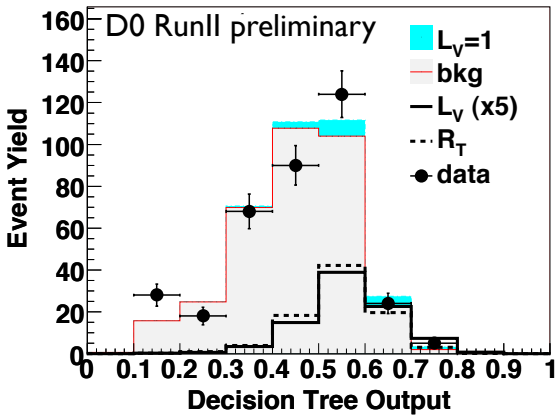
- Same selection as single top search, same dataset.
- For each coupling scenario (2 signal), train trees in 4 analysis channel defined by lepton flavor and b-tag multiplicity.



(f_{L_V}, f_{L_T})



(f_{L_V}, f_{R_V})



(f_{L_V}, f_{R_T})

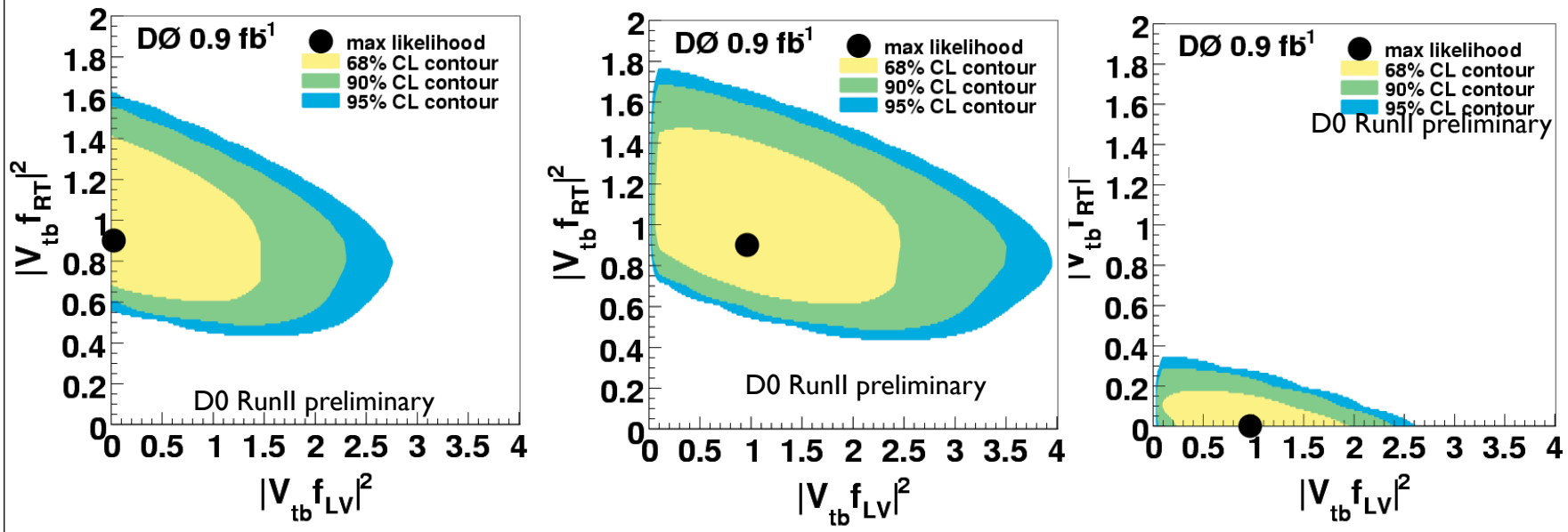
- The cross-section and $|V_{tb} f_X|^2$ are extracted from the discriminant distributions

Wtb : results for (f_{L_V}, f_{R_T})

- A binned likelihood is computed.
- A two-dimensional posterior probability density is computed as a function of $|V_{tb} f_{L_V}|^2$ and $|V_{tb} f_{R_T}|^2$

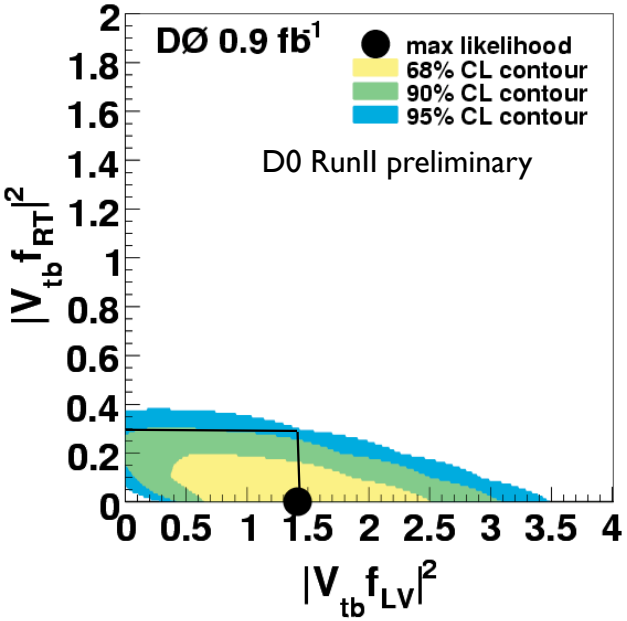
expectation

LV=0, RT=1 | LV=1, RT=1 | LV=1, RT=0



Wtb : results for (f_{L_V}, f_{R_T})

measured from data



- The two-dimensional probability density is projected onto the axis
  - ✦ if the projection has a local maximum, the value is quoted as the coupling

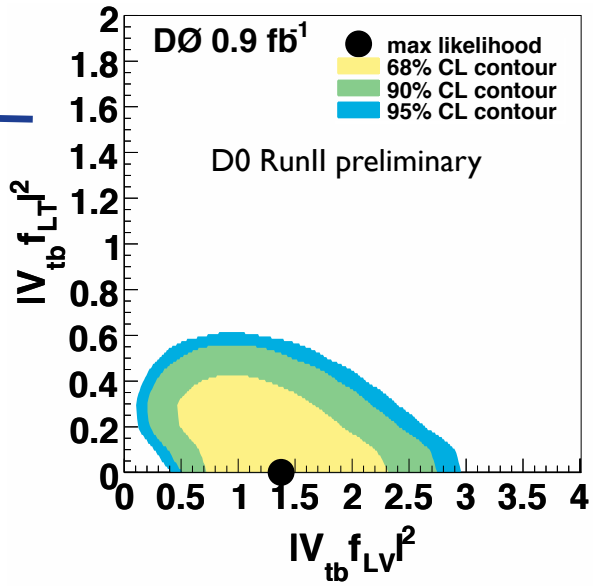
$$|V_{tb} f_{L_V}|^2 = 1.4^{+0.9}_{-0.8}$$

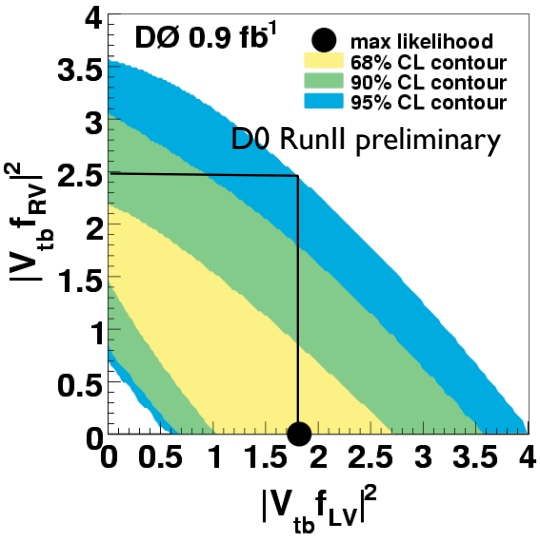
  - ✦ if it doesn't have a local maximum, a 95% C.L. limit is set

$$|V_{tb} f_{R_T}|^2 < 0.3 \text{ at } 95\% \text{ C.L.}$$

Wtb : results

scenario	coupling
(f_{LV}, f_{LT})	$\|V_{tb} f_{LV}\|^2 = 1.4^{+0.6}_{-0.5}$ $\|V_{tb} f_{LT}\|^2 < 0.5$ at 95% C.L.
(f_{LV}, f_{RV})	$\|V_{tb} f_{LV}\|^2 = 1.8^{+1.0}_{-1.3}$ $\|V_{tb} f_{RV}\|^2 < 2.5$ at 95% C.L.
(f_{LV}, f_{RT})	$\|V_{tb} f_{LV}\|^2 = 1.4^{+0.9}_{-0.8}$ $\|V_{tb} f_{RT}\|^2 < 0.3$ at 95% C.L.





Summary

- 0.9 fb^{-1} dataset, evidence of single top electroweak production

$$\sigma(\bar{p}\,p \to tb + X, tbq + X) = 4.7 \pm 1.3\,pb$$

- large potential for searches BSM
  - limits on W' mass

$m(W'_L) >$	731 GeV
$m(W'_R) >$	739 GeV if $m(W'_R) > m(\nu_R)$
$m(W'_R) >$	768 GeV if $m(W'_R) < m(\nu_R)$

at 95 % C.L.

  - limits on anomalous Wtb couplings

scenario	coupling at 95% C.L.
(f_{L_V}, f_{L_T})	$\lvert V_{tb} f_{L_T}\rvert^2 < 0.5$
(f_{L_V}, f_{L_T})	$\lvert V_{tb} f_{R_V}\rvert^2 < 2.5$
(f_{L_V}, f_{L_T})	$\lvert V_{tb} f_{R_T}\rvert^2 < 0.3$

  - search for charged Higgs see Y.Peters [P1][143]
- the Tevatron is performing well : more than 3.5 fb^{-1} recorded by experiment

The search for New Physics is not over