Top Quark Physics at the Tevatron

QFTHEP 2010

L. Dudko

SINP MSU, Moscow

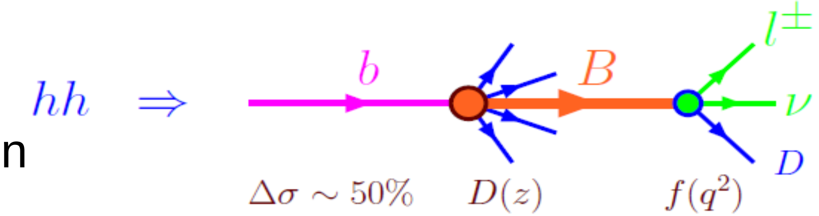
For the D0 and CDF collaborations

Why We Like Top Quark

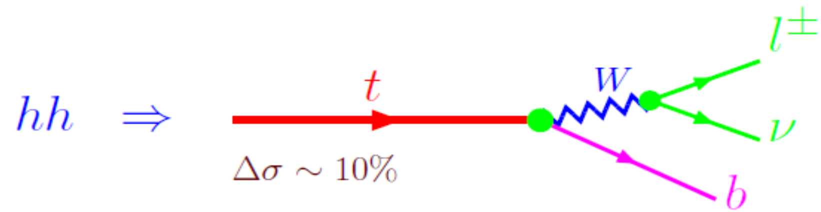
- We do not expect the formation of top hadrons therefore, top quark decays before hadronization

$$\tau_t = \frac{1}{\Gamma_{\rm tot}} \simeq \frac{1}{1.60\ \text{ГэВ}} = 4\times 10^{-25}\quad \text{сек}$$

$$\tau_{\text{адр}} \sim \frac{1}{\Lambda_{\text{КХД}}} \simeq 5\ \ \text{ГэВ}^{-1} = 3.3\times 10^{-24}\quad \text{сек}$$



$$\text{Uncertainty} \sim \Delta\sigma \otimes D(z) \otimes f(q^2)$$



$$\text{Uncertainty} \sim \Delta\sigma$$

- Top quark decays through ONE decay channel

$$t \to bW^+,\ \text{BR}(t\to \text{other}) \le \mathcal{O}(10^{-3})$$

- The total and differential rates are calculated with $\mathbb{O}$(10%) accuracy

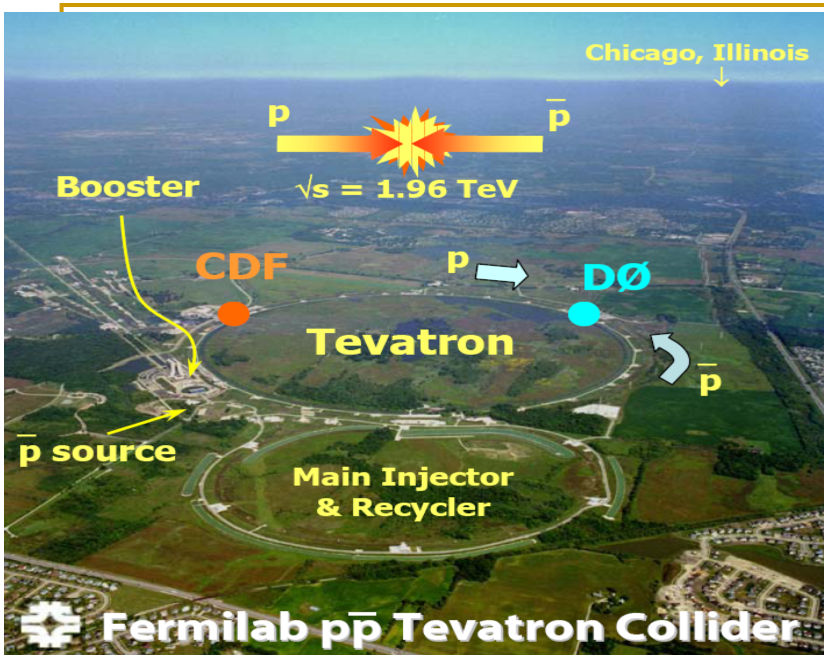
- Top quark is unique and powerful instrument to study SM physics and search for manifestation of New Physics beyond SM

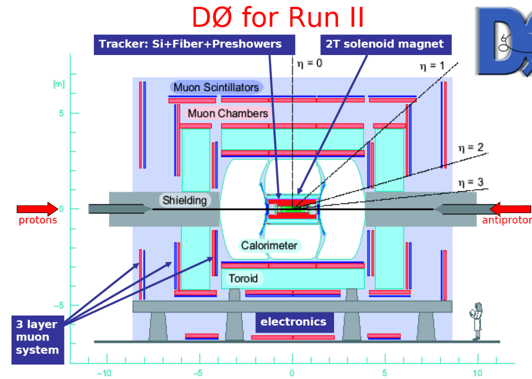
Study of Top Quark

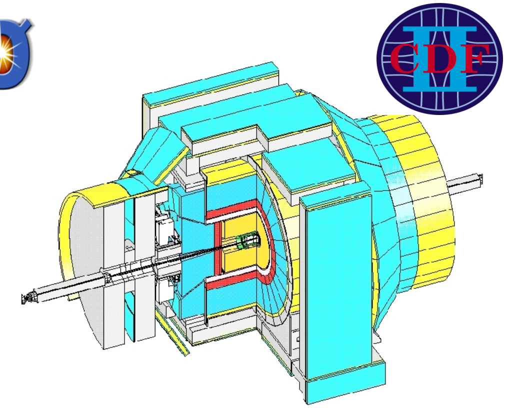
- total production cross section ($t\bar{t}$ pair and single top)
- differential distributions, like $M(t\bar{t})$, $p_{\top}$, ..., spin correlations
- m_t, $\Gamma_{tot}(t \to X)$, V_{tb}
- the top production and decays due to new physics
- $gt\bar{t}$, $Wt\bar{b}$ vertexes, rare top decays

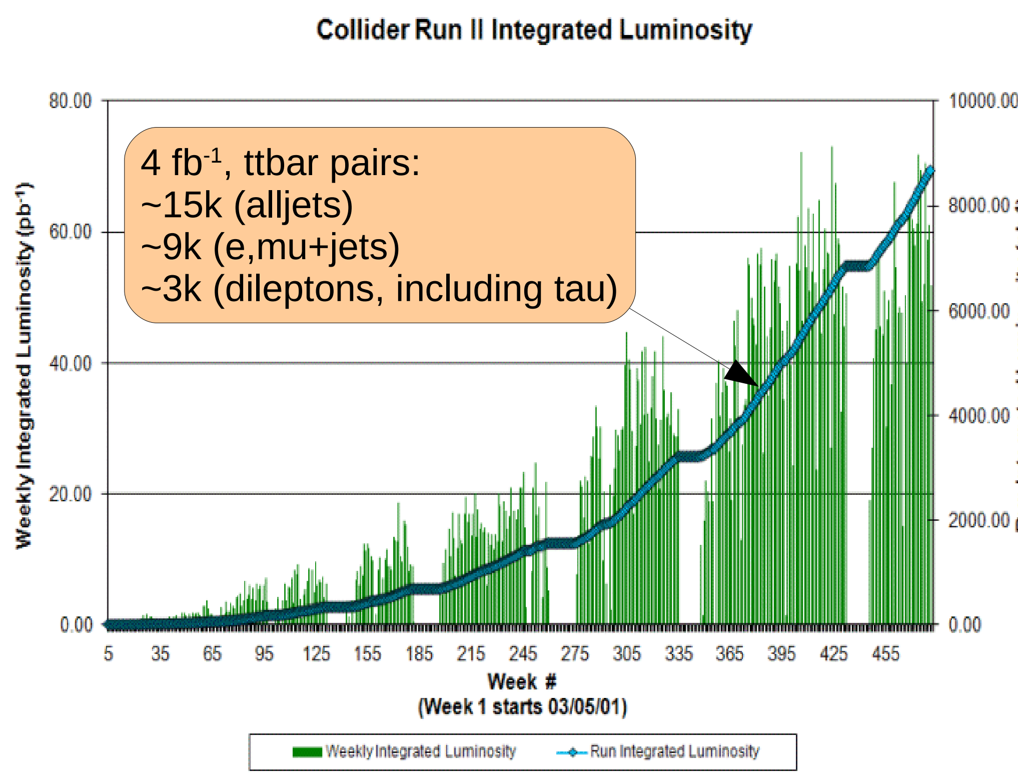
◇ New Physics (beyond SM) can manifest itself by different ways

- anomalous $gt\bar{t}$ couplings
- anomalous $Wt\bar{b}$ couplings
- Flavor Changing Neutral Current (FCNC)
- new bosons ($H^{\pm}$, W', W_R, Z', η_T, ρ_T, ...)
- extra dimensions, ...







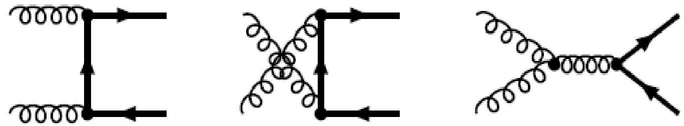


- 1.96 TeV p-anti p collider
- 396 ns between bunches
- Has delivered 8.7 fb^{-1} of data since 2001
- running smoothly, expect 10 fb^{-1} at the end of 2010

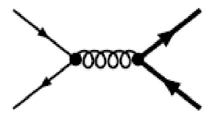
Production Processes

- $t\bar{t}$ production (QCD)

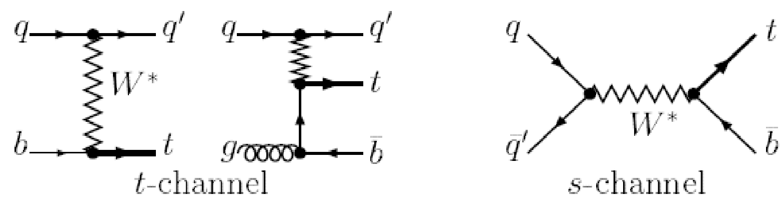
$gg \to t\bar{t}$



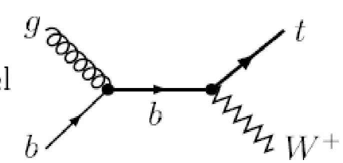
$q\bar{q} \to t\bar{t}$



- single top production (electro-weak)

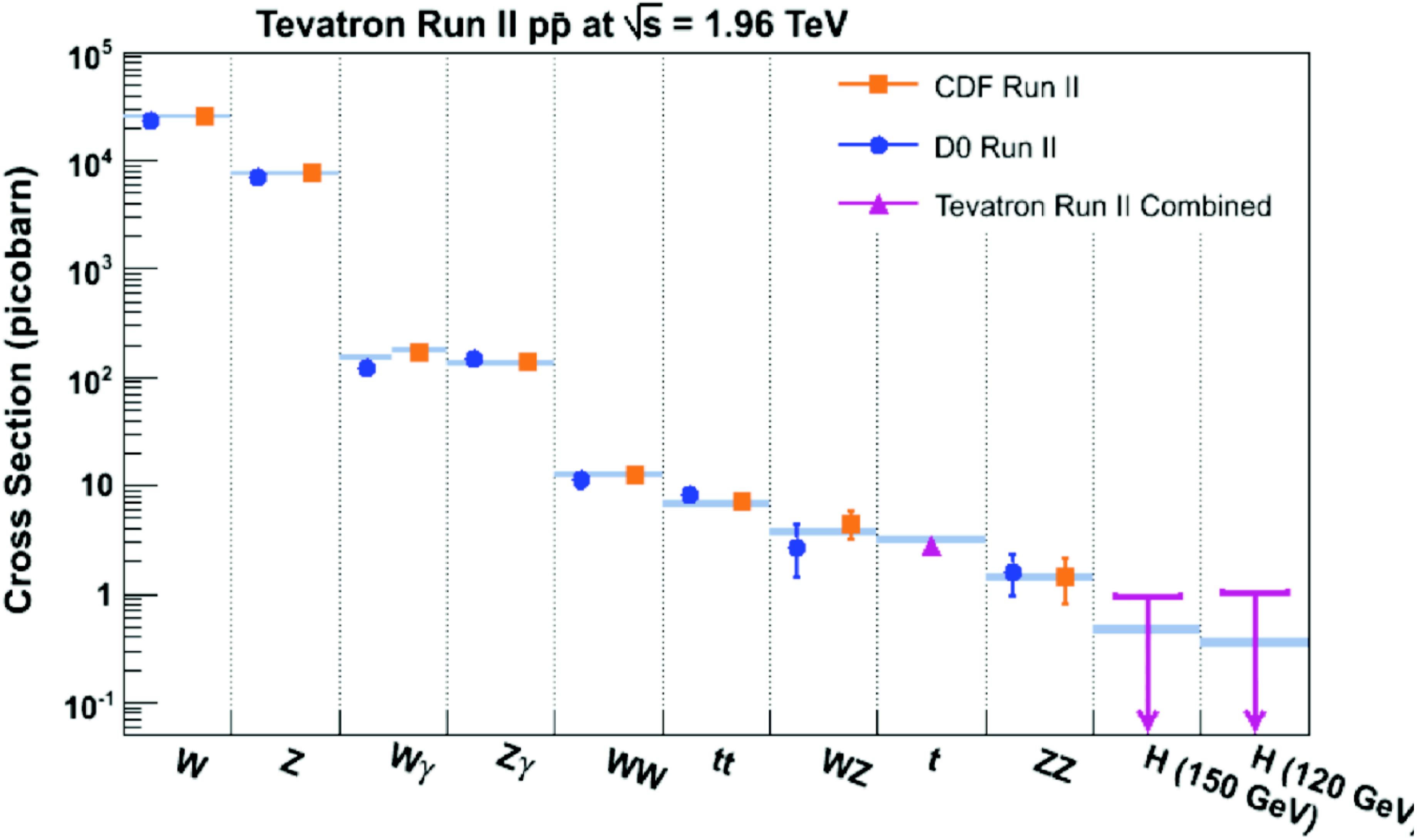


tW-channel



- $t\,\bar{t}\,b\,\bar{b}$
- $t\,\bar{t}\,H$, $t\,\bar{t}\,W^{\pm}$, $t\,\bar{t}\,Z$
- t-quark production due to new interactions

Tevatron Cross Sections



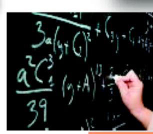
Analysis Methods

Counting events

Establish selection, estimate expected background → **Find number of data events** → **Subtract expected background data from data events**

Templates/Likelihood

Reconstruct the best discriminating variable X (ex. an invariant mass) → **Form signal and background templates of X** → **Perform a maximum likelihood fit between data and templates**



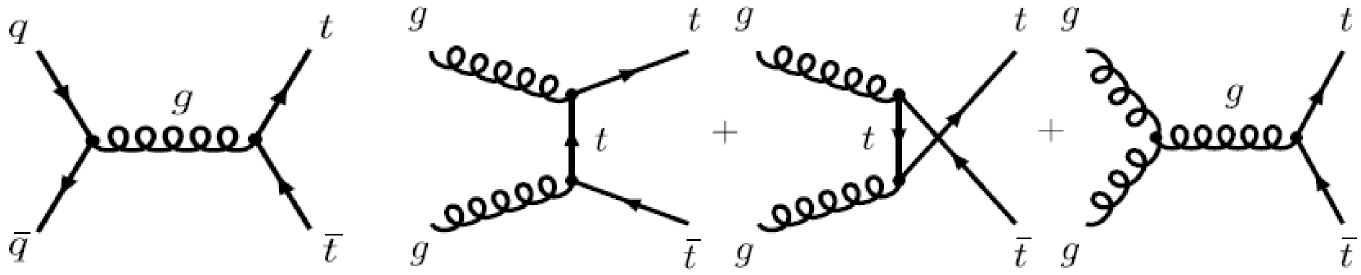
Matrix Element

Form per-event probability using matrix elements → **Evaluate the probability of each event for signal and background hypotheses** → **Use probability into one likelihood (discriminant type or as a function of a parameter)**

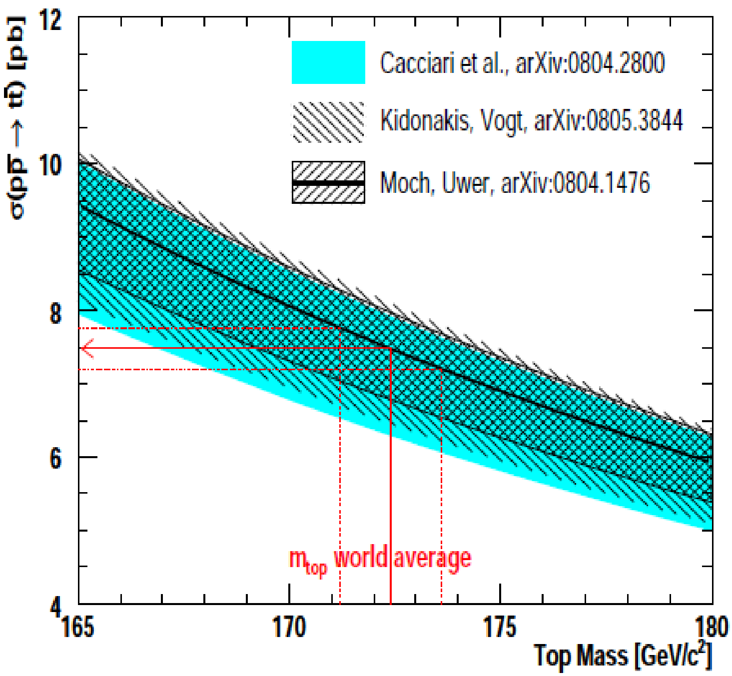
Neural Networks, Boosted Decision Trees

Find good discriminating variables (well modeled in MC) → **Input variables from MC to train a multivariate package** → **Use output as a discriminant, likelihood fit between data and MC**

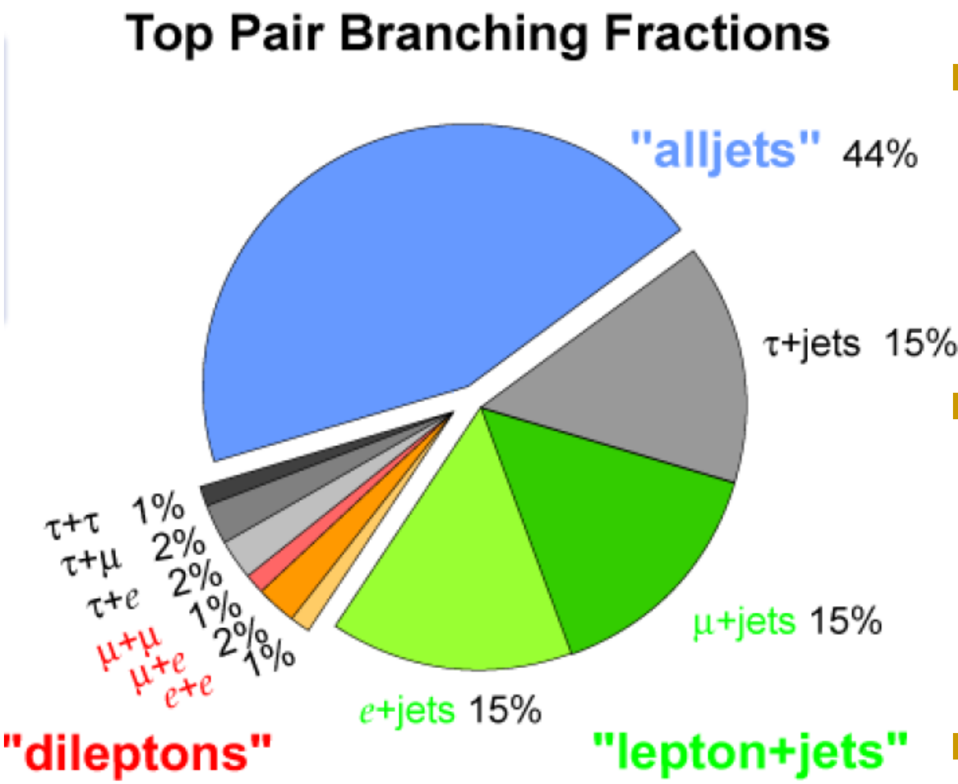
Top Pair Production (QCD)



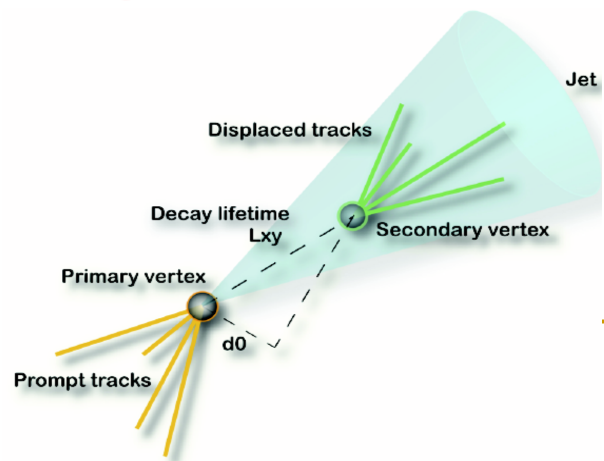
	process	$\sigma_{t\bar{t}}$ [pb]	
Run I	90% $q\bar{q} \to t\bar{t}$	$5.19^{+0.52}_{-0.68}$	Cacciari
$p\bar{p}$, 1.8	10% $gg \to t\bar{t}$	5.24 ± 0.31	Kidonakis
Run II	85% $q\bar{q} \to t\bar{t}$	$6.70^{+0.71}_{-0.88}$	Cacciari
$p\bar{p}$, 1.96	15% $gg \to t\bar{t}$	6.77 ± 0.42	Kidonakis
LHC	10% $q\bar{q} \to t\bar{t}$	833^{+52}_{-39}	Bonciani
pp, 14	90% $gg \to t\bar{t}$	873^{+2}_{-28}	Kidonakis



Top Pair Analysis Channels



- Dileptons
  - Small rate, small backgrounds
  - Main background: Drell-Yan
- Lepton + Jets
  - Good rate and manageable backgrounds
  - Main background: W+jets
- All-hadronic (alljets)
  - Large rate, large background
  - Main background: multijets

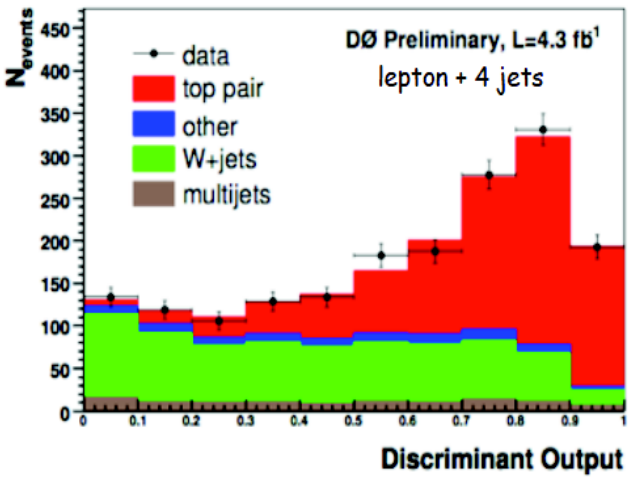


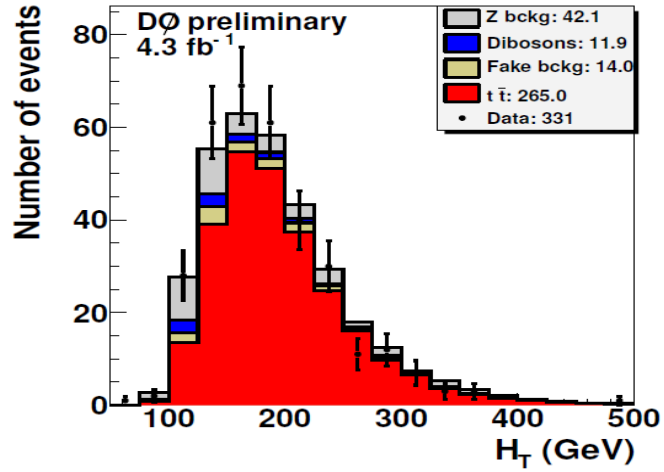
Identification of b-quarks through secondary vertex is a critical point to reduce backgrounds

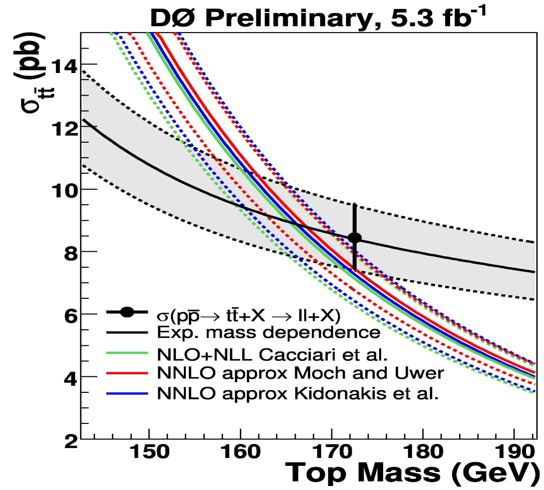
$t\bar{t}$: Cross section measurements

Recent D0 and CDF analysis in different channels

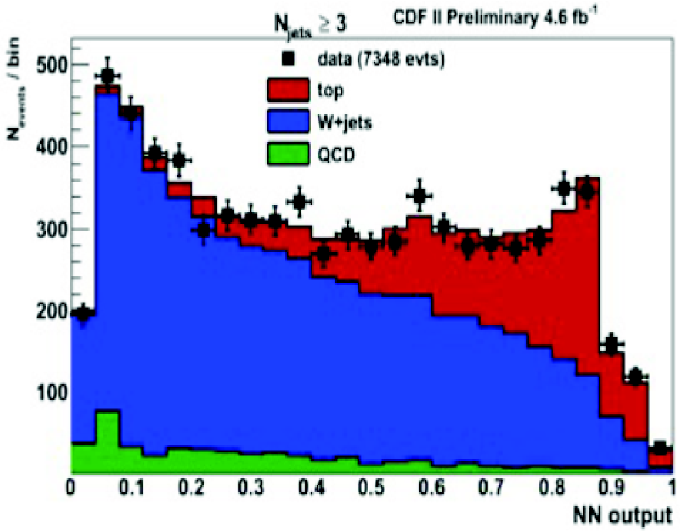
$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{\sum_i \mathcal{A}_i x \mathcal{L}_i}$$

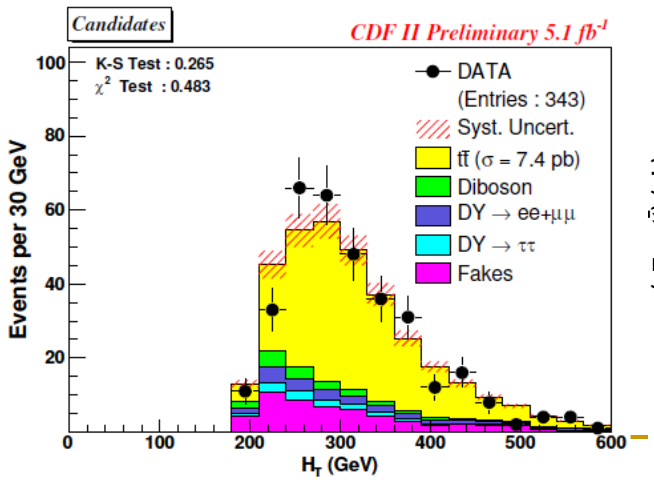


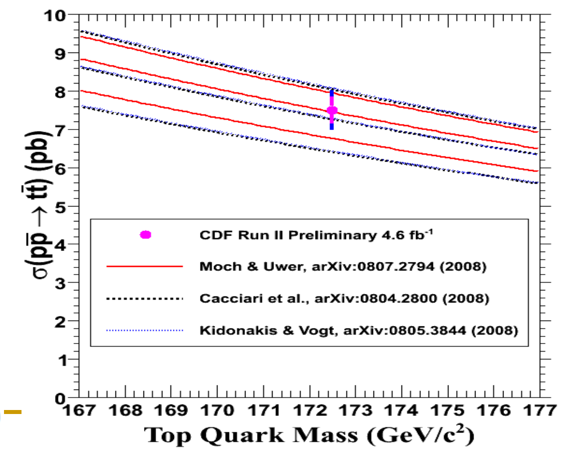




$$\ell\ell: \quad \sigma_{t\bar{t}} = 8.4 \pm 0.5\,(\mathrm{stat})\;^{+0.9}_{-0.8}\,(\mathrm{syst})\;^{+0.7}_{-0.6}\,(\mathrm{lumi})\;\mathrm{pb}.$$

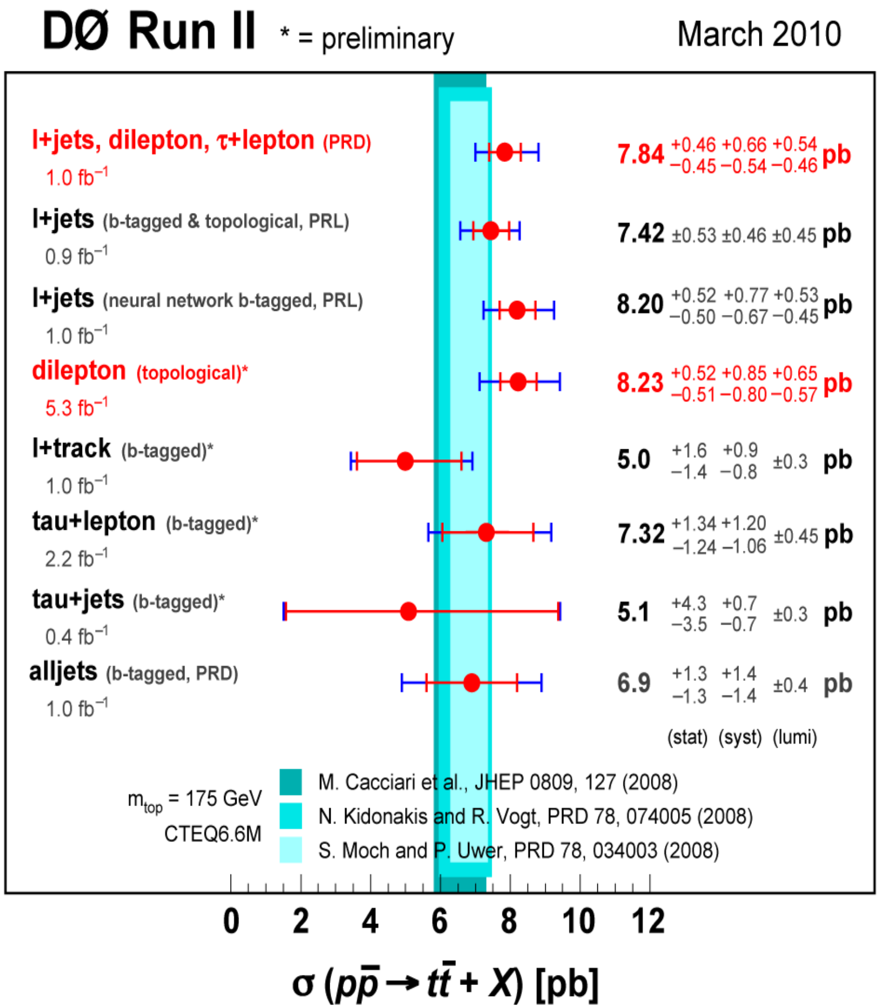


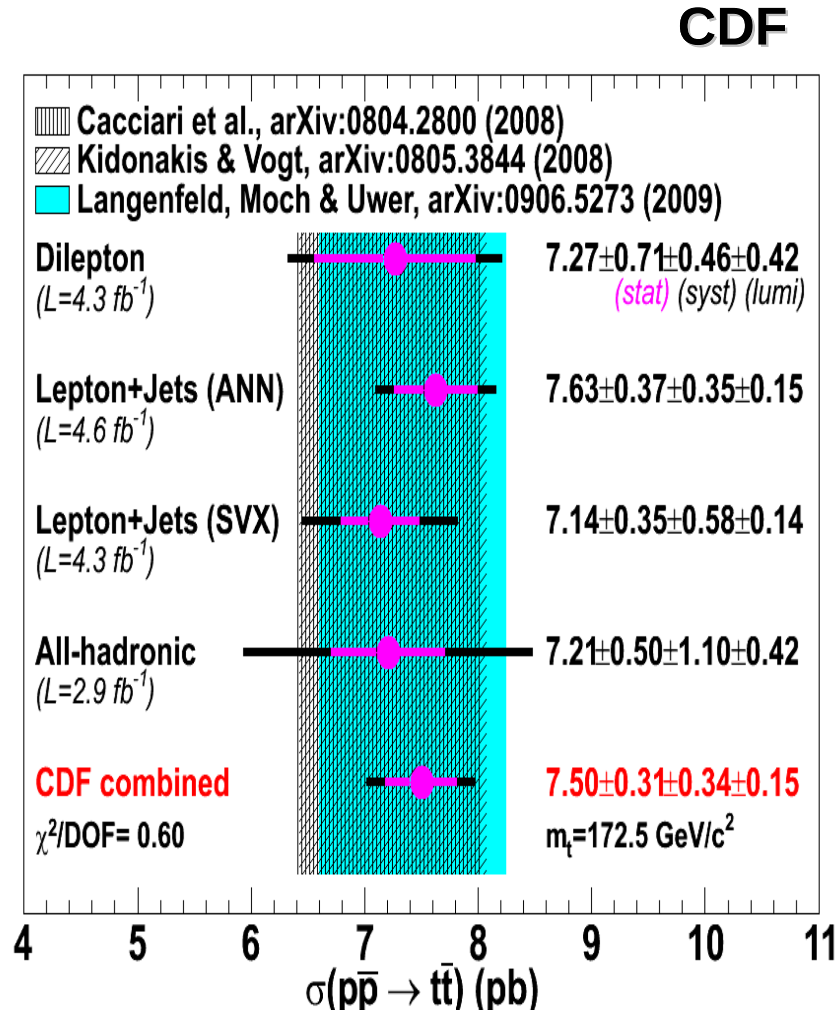




$$\sigma_{t\bar{t}} = 7.40 \pm 0.58_{stat} \pm 0.63_{syst} \pm 0.45_{lumi}\;\mathrm{pb}$$

$t\bar{t}$: Cross section measurements

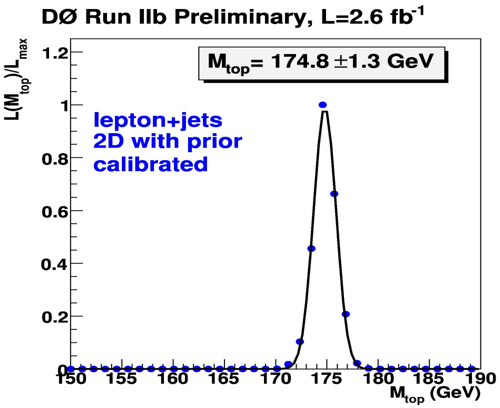


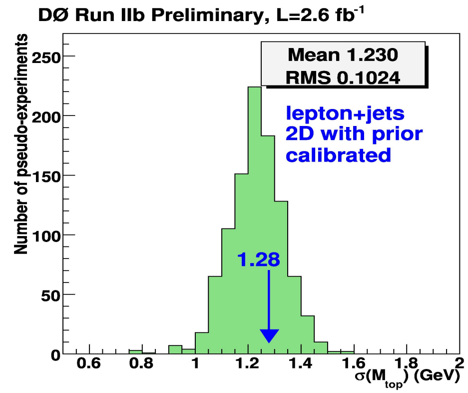


Tevatron combination is in progress

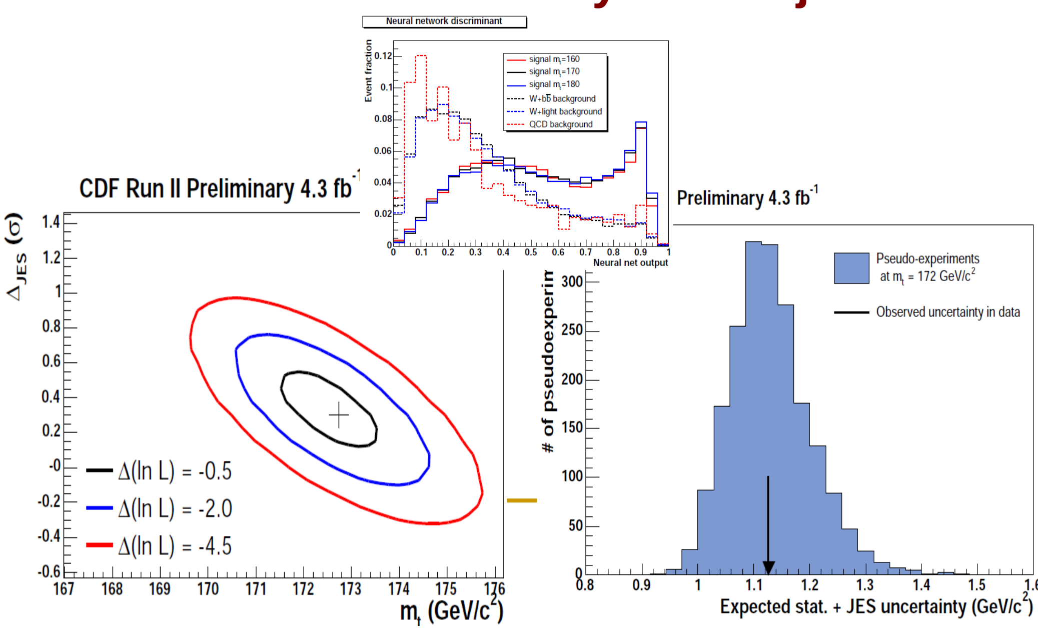
$t\bar{t}$: Top Mass Measurement

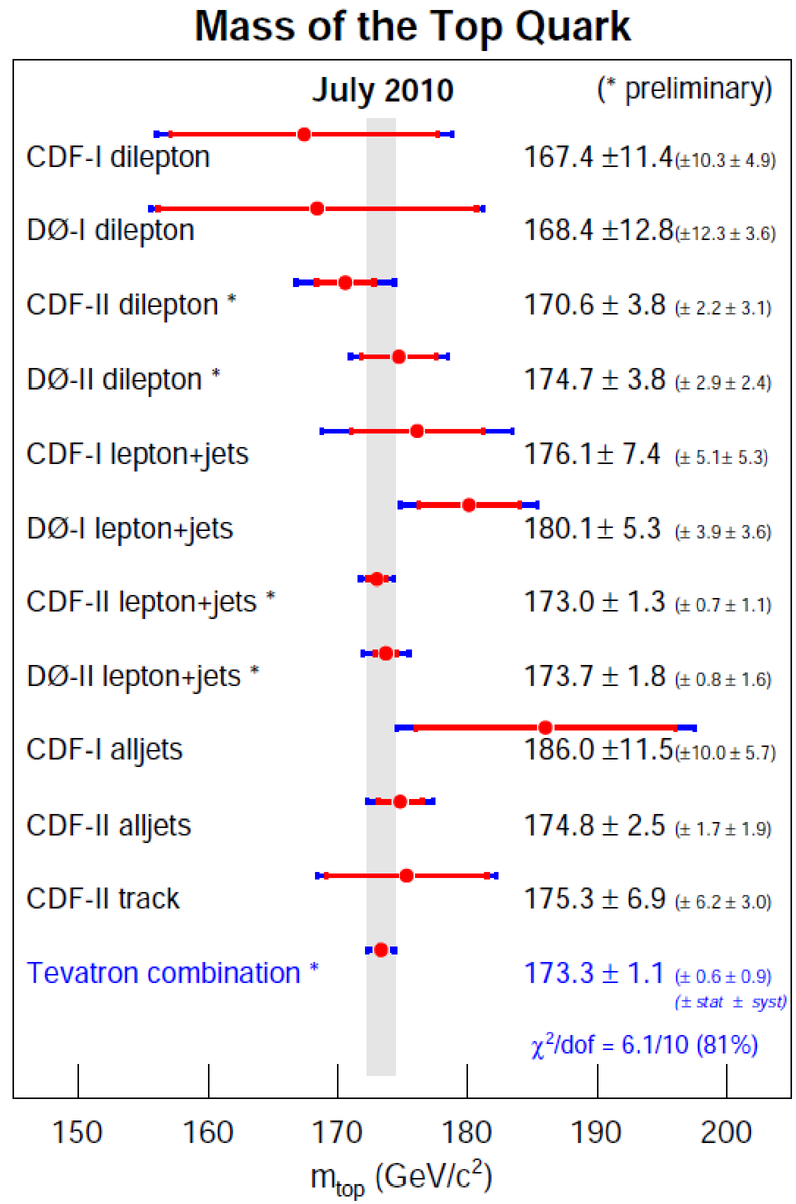
D0 matrix element analysis in l+jets channel





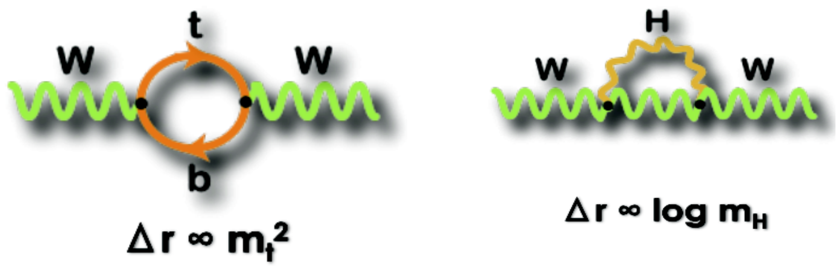
CDF Neural Network analysis in l+jets chann.

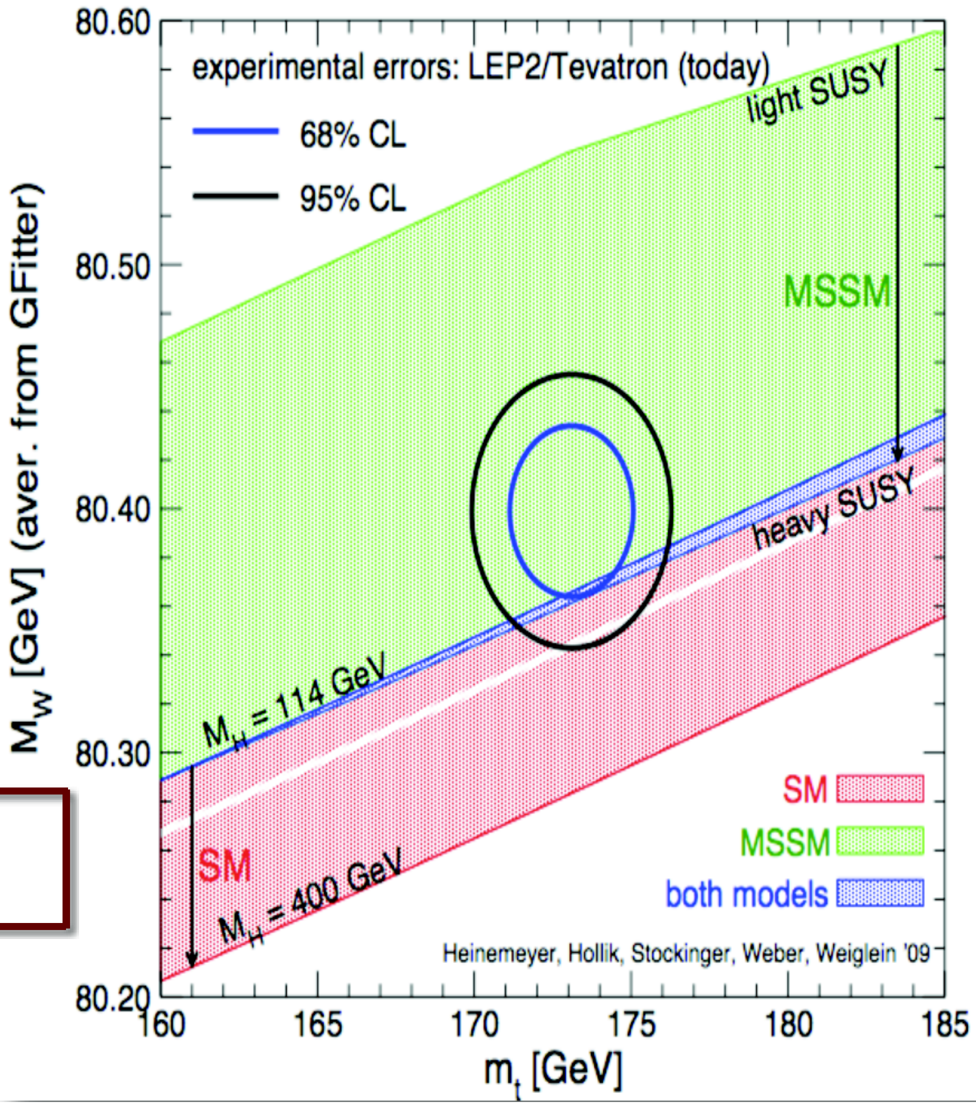




Top Mass → Indirect Constraints

- Measuring the W boson mass and top quark mass precisely allows for prediction of the mass of the Higgs boson





Tevatron (Winter 09):
m_t=173.1 ± 0.6 (stat) ± 1.1 (syst) GeV

World Average:
m_W=80399±23MeV

$t\bar{t}$: Direct measurements

$$R = \frac{\mathcal{B}(t\to Wb)}{\mathcal{B}(t\to Wq)} = \frac{|V_{tb}|^2}{|V_{tb}|^2 + |V_{ts}|^2 + |V_{td}|^2}$$

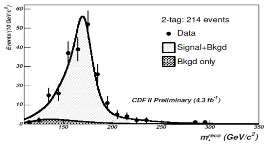
D0 900 pb^{-1} $R = 0.97^{+0.09}_{-0.08}$; **R > 0.79 @95%CL**

CDF 162 pb^{-1} $R = 1.12^{+0.21}_{-0.19}(\text{stat})^{+0.17}_{-0.13}(\text{syst})$

R > 0.61 @95%CL

$$\Gamma_t = \Gamma_t^0 \left(1 - \frac{M_W^2}{m_t^2}\right)^2 \left(1 + 2\frac{M_W^2}{m_t^2}\right)\left[1 - \frac{2\alpha_s}{3\pi}\left(\frac{2\pi^2}{3} - \frac{5}{2}\right)\right]$$

$\Gamma_t^{SM} \approx 1.5$ GeV



CDF 4.3 fb^{-1} Direct Fit Γ_t < 7.5 GeV; τ_t > 8.7x10^{-26} s @ 95% CL; $\Gamma_t = 1.9^{+1.9}_{-1.5}$ GeV

D0 2.3 fb^{-1} Indirect Fit Γ_t = 2.1 ±0.6 GeV; τ_t < 5x10^{-25} s @ 95% CL

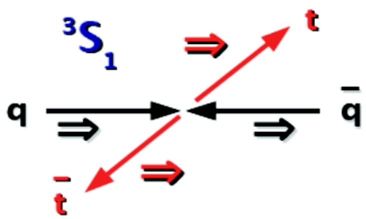
$$\Gamma_t = \frac{\sigma(t\text{–channel})\,\frac{\Gamma(t\to Wb)_{SM}}{\sigma(t\text{–channel})_{SM}}}{\mathcal{B}(t\to Wb)}$$

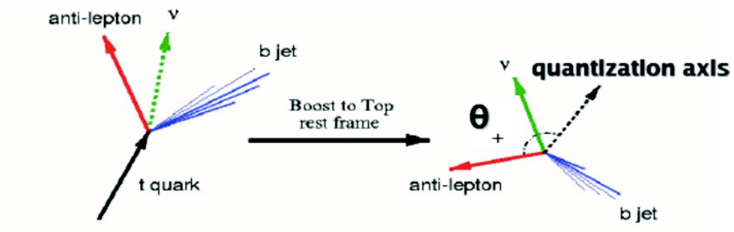
D0 1 fb^{-1} direct top antitop mass difference: $m_{top} - m_{antitop} = 3.8 \pm 3.7$ GeV

Top charge:

CDF 2.7 fb^{-1} measurement excludes top charge -4/3 with 95% CL
D0 370 pb^{-1} measurement excludes top charge -4/3 with 92% CL

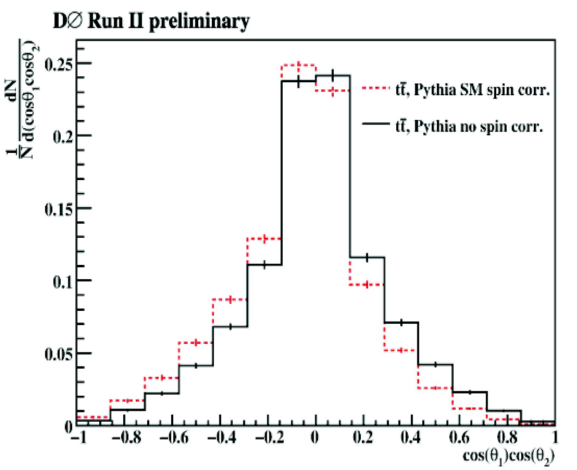
$t\bar{t}$: Spin Correlations (dilepton channel)

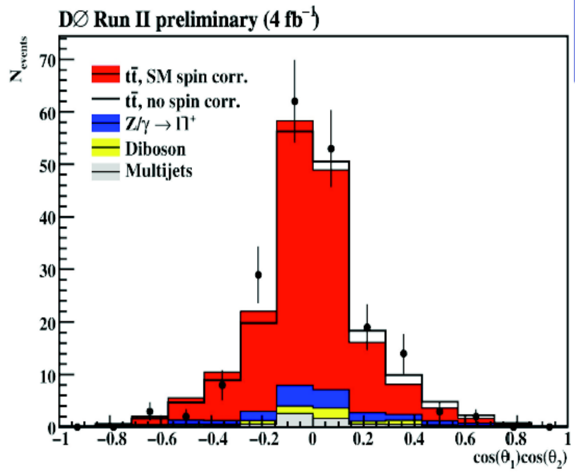




$$\frac{1}{\sigma}\frac{d^2\sigma}{d\cos\theta_+ d\cos\theta_-} = \frac{1+\kappa\cos\theta_+\cos\theta_-}{4}$$

$$\mathbf{K} = \frac{N(\uparrow\uparrow)+N(\downarrow\downarrow)-N(\uparrow\downarrow)-N(\downarrow\uparrow)}{N(\uparrow\uparrow)+N(\downarrow\downarrow)+N(\uparrow\downarrow)+N(\downarrow\uparrow)}$$





SM predicts κ =0.78

D0 4 fb^{-1}

K = $-0.17^{+0.64}_{-0.53}$ Beam axis

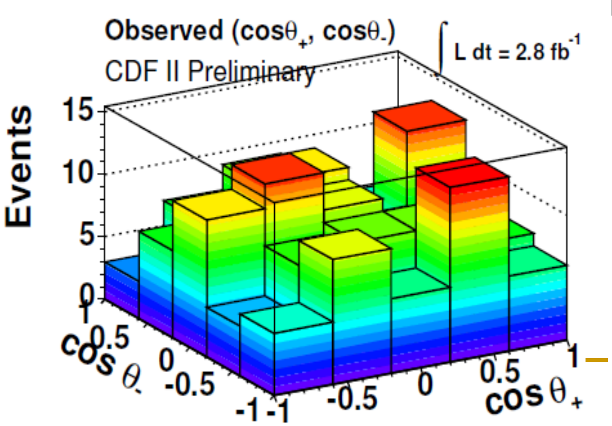
CDF 2.8 fb^{-1}

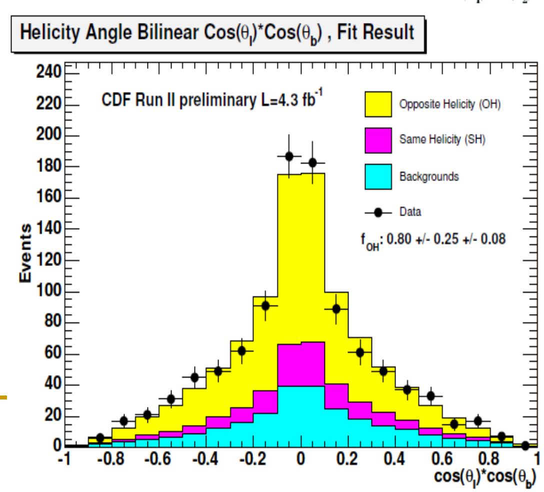
K = $0.32^{+0.55}_{-0.78}$ 2.8 fb^{-1}

Off-diagonal axis

CDF 4.3 fb^{-1}

K = 0.60 ±0.5(stat)±0.16



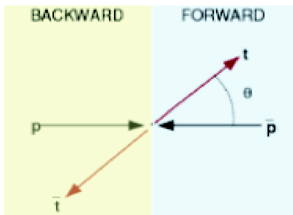


In agreement with SM within 1σ (CDF) and 2σ (D0)

Forward-Backward Asymmetry

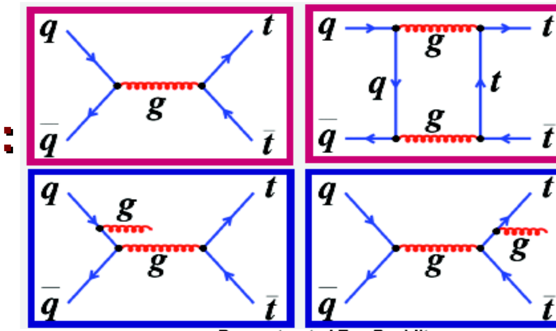
$$\left(N_{\bar{t}}(y) = N_t(-y) \right)$$

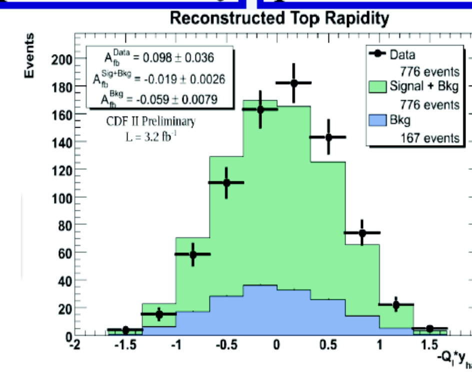
$$A_{fb} = \frac{F - B}{F + B}$$



Due to interference terms SM predicts at NLO (may be less at NLO+NLL):

$A_{fb}^{ppbar} = 0.05 \pm 0.015$





D0 results

$A_{FB}^{ppbar} = 0.12 \pm 0.08$ (stat) ± 0.01 (syst) 0.9 fb^{-1}

$A_{FB}^{ppbar} = 0.08 \pm 0.04$ (stat) ± 0.01 (syst) 4.3 fb^{-1}

CDF results:

$A_{FB}^{ppbar} = 0.193 \pm 0.065$ (stat) ± 0.024 (syst) 3.2 fb^{-1}

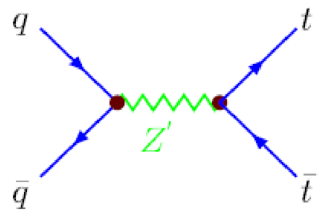
$A_{FB}^{ppbar} = 0.17 \pm 0.07$ (stat) ± 0.04 (syst) 1.9 fb^{-1}

$A_{FB}^{ttbar} = 0.24 \pm 0.13$ (stat) ± 0.04 (syst) 1.9 fb^{-1}

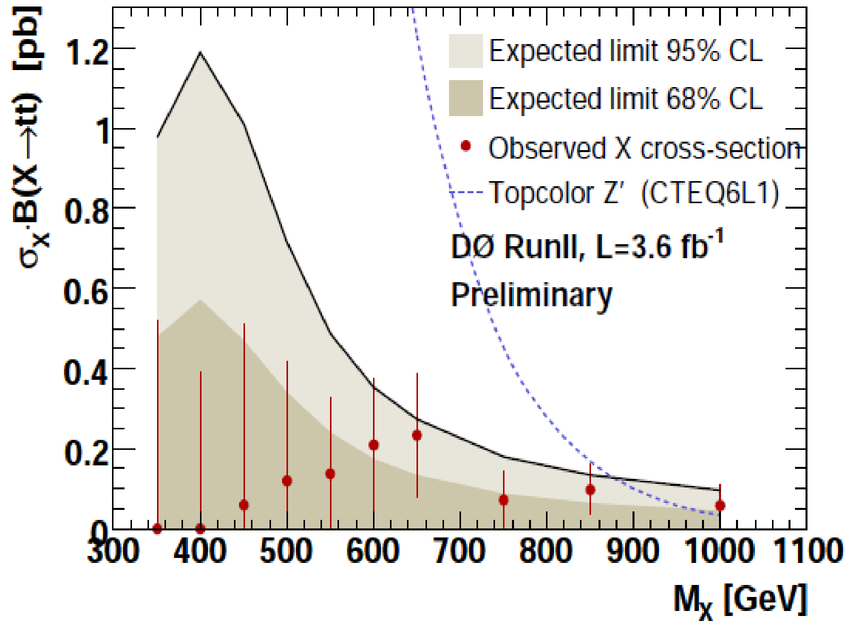
$A_{FB}^{ppbar} = 0.15 \pm 0.05$ (stat) ± 0.024 (syst) 5.3 fb^{-1}

$A_{FB}^{ttbar} = 0.158 \pm 0.072$ (stat) ± 0.017 (syst) 5.3 fb^{-1}

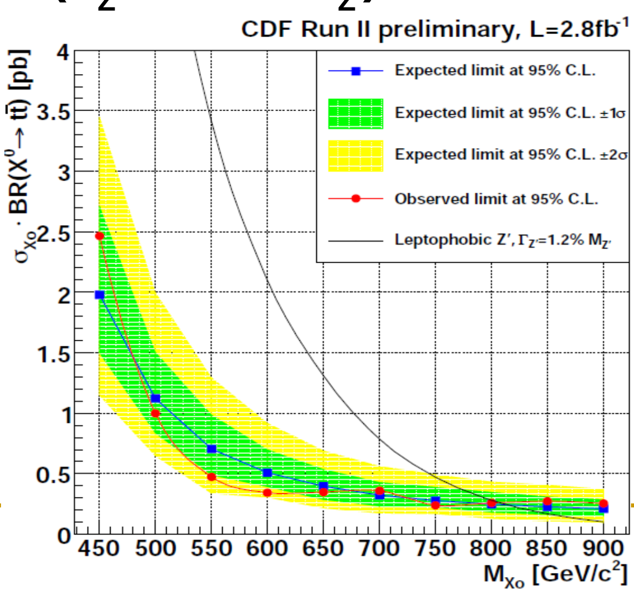
$t\bar{t}$: Resonant Top Pair production



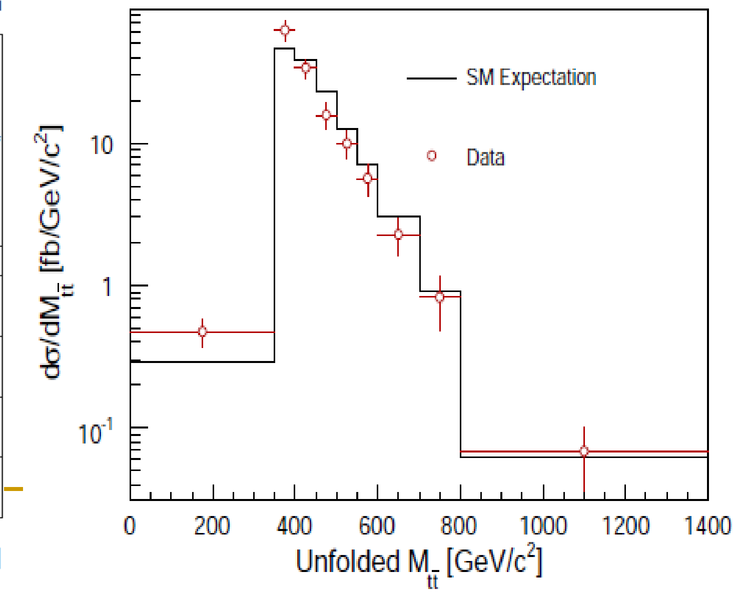
No evidence for a narrow Resonance decaying to $t\bar{t}$ At D0 3.6 fb^{-1} measurement In l+jets channel.
Leptophobic Z' bozon with $M_{Z'}$ < 820 GeV and $\Gamma_{Z'} = 0.012 M_{Z'}$ is excluded @95% CL



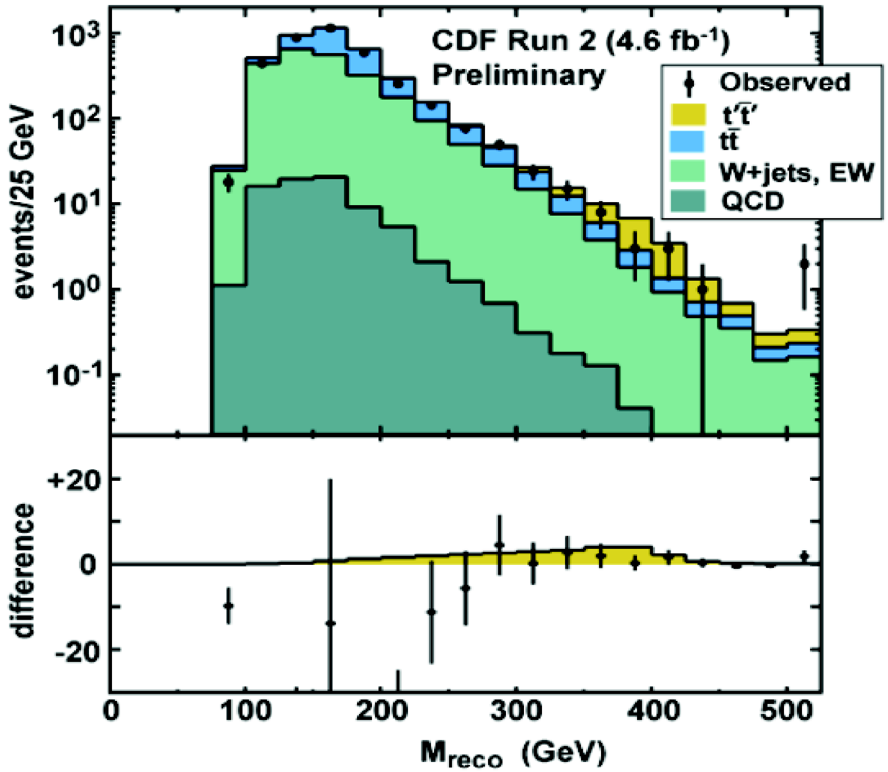
CDF 2.8 fb^{-1} search in all jets channel
Excluded $M_{Z'}$ < 820 GeV ($\Gamma_{Z'} = 0.012 M_{Z'}$)
is excluded @95% CL

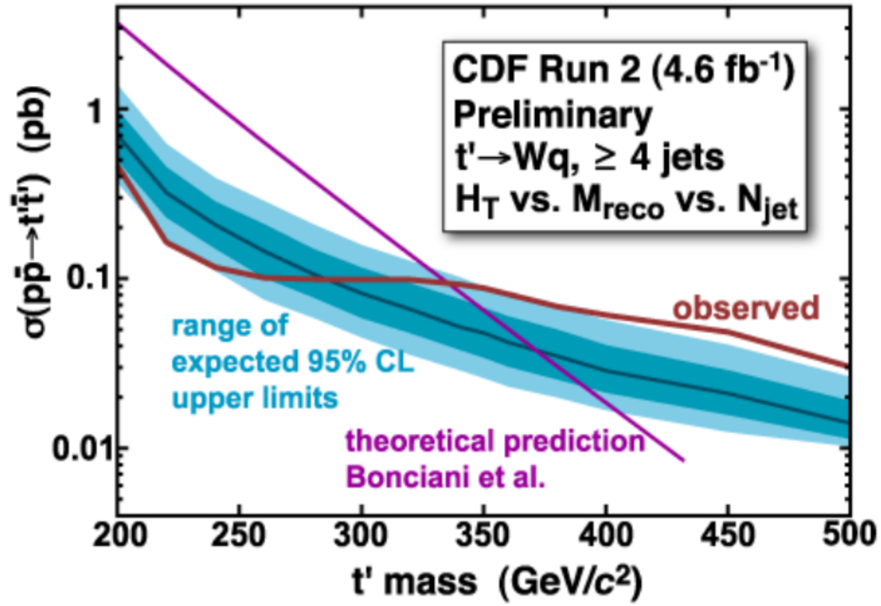


No evidence of Resonance in CDF 2.7 fb^{-1} l+jets Measurements Of $d\sigma/dM_{t\bar{t}}$



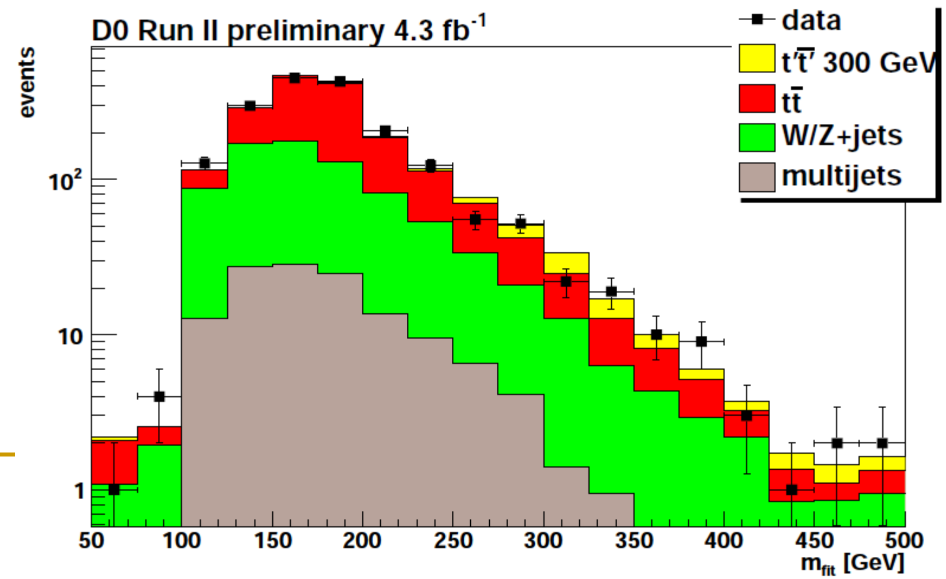
$t\bar{t}$: 4th generation t' search



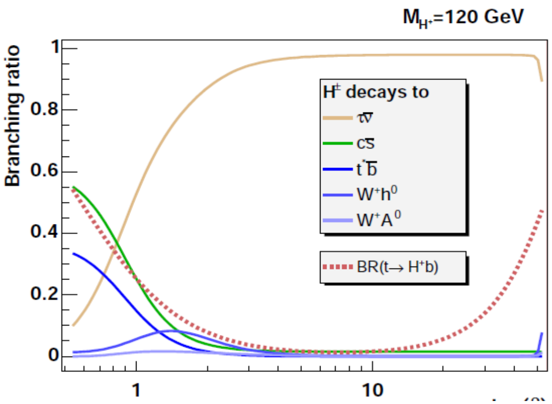


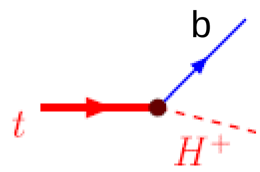
CDF 4.6 fb^{-1}
Exclude $M_{t'}$ < 335 GeV @95% CL

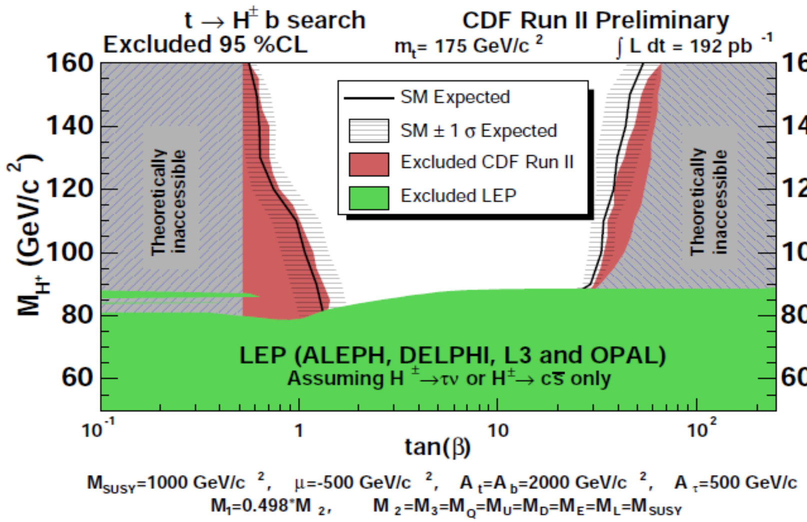
D0 4.3 fb^{-1}
Exclude $M_{t'}$ < 296 GeV @95% CL

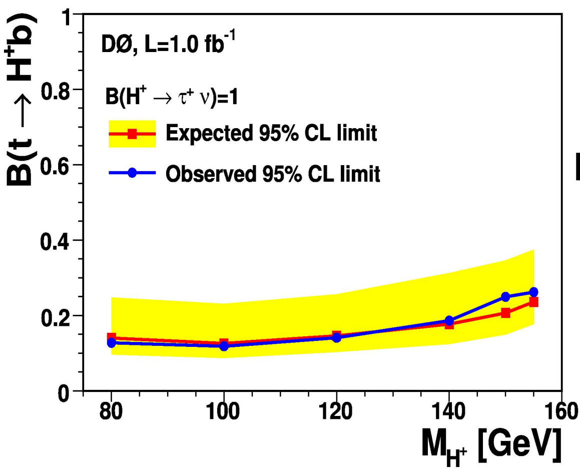


$t\bar{t}$: MSSM Charge $H^{\pm}$ in decays of t





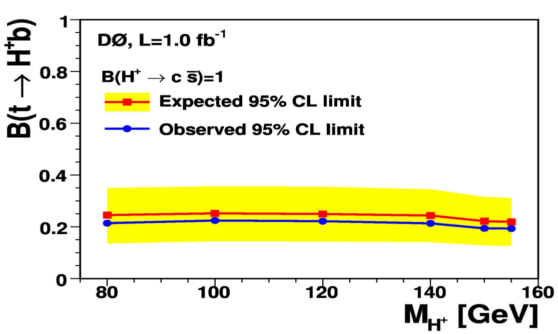


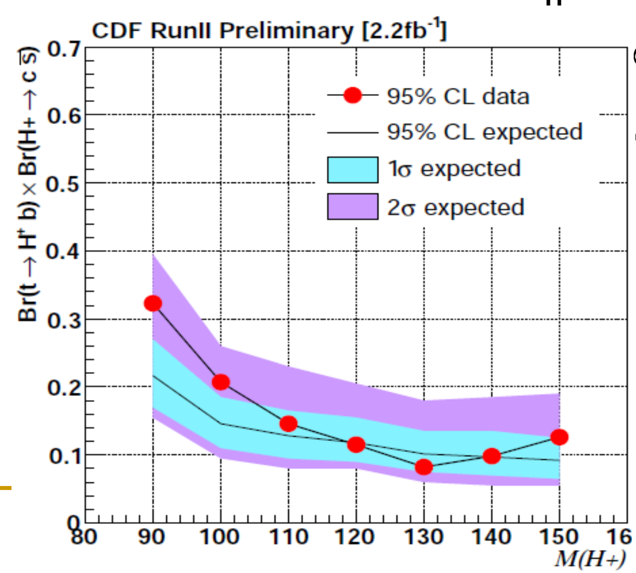


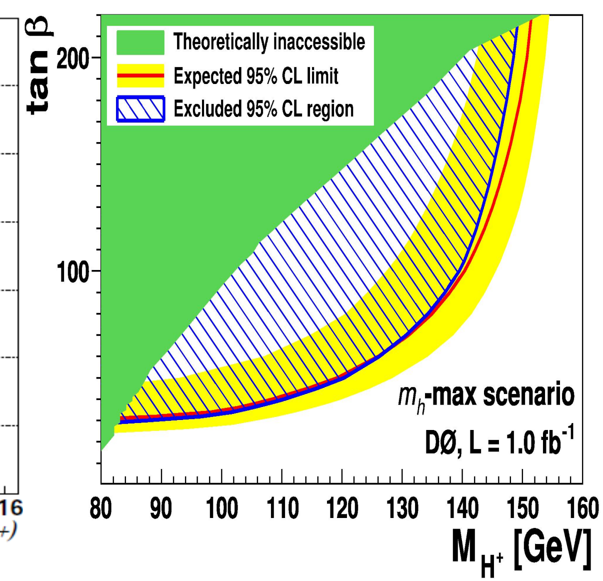
$M_H < M_t$

D0 and CDF

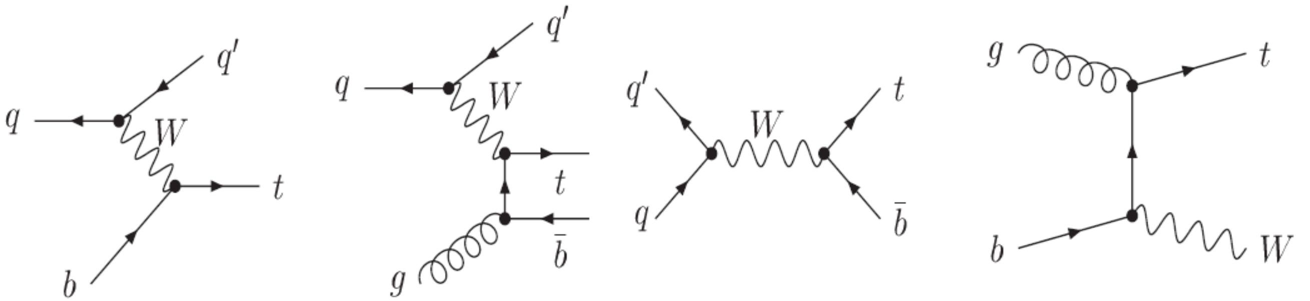
Have excluded Br($t \rightarrow H^+b$) and M_H in different decay channels of H^+







Top Single Production (EWK)



t-channel *s*-channel *Wt* associated production

t-channel $(Q_W^2 < 0)$
s-channel $(Q_W^2 > 0)$
associated tW $(Q_W^2 = M_W^2)$

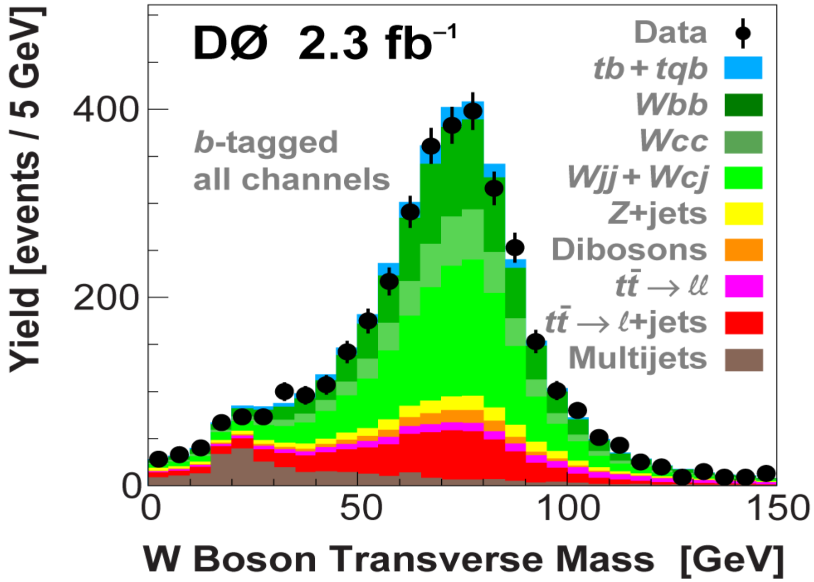
	$t/\bar{t}$	σ_S [pb]	σ_T [pb]	σ_{tW} [pb]	
Run I	$t, \bar{t}$	$0.75^{+0.10}_{-0.09}$	$1.46^{+0.20}_{-0.16}$	—	Sullivan
Run II	$t, \bar{t}$	$0.88^{+0.12}_{-0.11}$	$1.98^{+0.28}_{-0.22}$	—	Sullivan
1.96 TэB		0.98 ± 0.04	2.16 ± 0.12	0.26 ± 0.06	Kidonakis
	t	$6.56^{+0.69}_{-0.63}$	$155.9^{+7.5}_{-7.7}$	—	Sullivan
LHC	$\bar{t}$	$4.09^{+0.43}_{-0.39}$	$90.7^{+4.3}_{-4.5}$	—	
14 TэB	t	$7.2^{+0.6}_{-0.5}$	146 ± 5	41 ± 4	Kidonakis
	$\bar{t}$	4.0 ± 0.2	89 ± 4	41 ± 4	

Single Top $t(\bar{t})$ issues

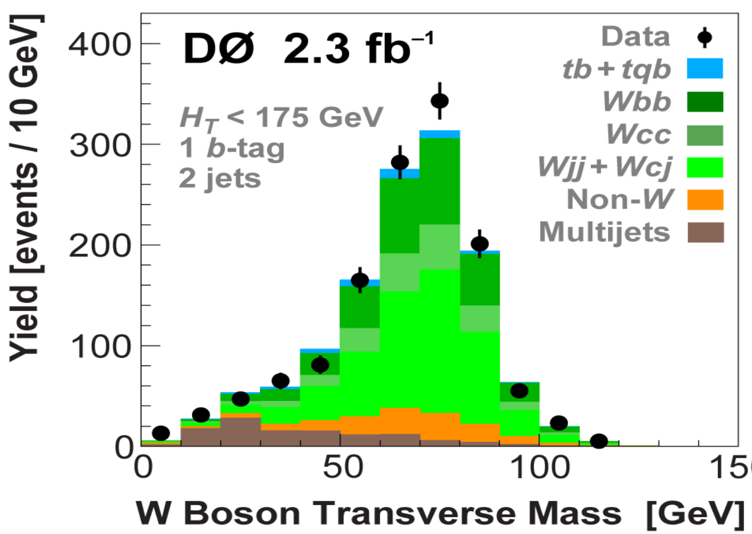
- Independent electroweak channel of top quarks with Wtb vertex in production, not only in the decay of top
- Direct measurement of V_{tb} CKM element
- Unique spin correlations
- Significant background for the Higgs search
- Wide spectrum of «New Physics» to test
- XS is about 40% of $t\bar{t}$ rate but the background is significantly larger, therefore sophisticated analysis techniques have been developed
- Observed in 2009, 14 years after top quark discovery

$t(\bar{t})$: D0 Analysis, Selection

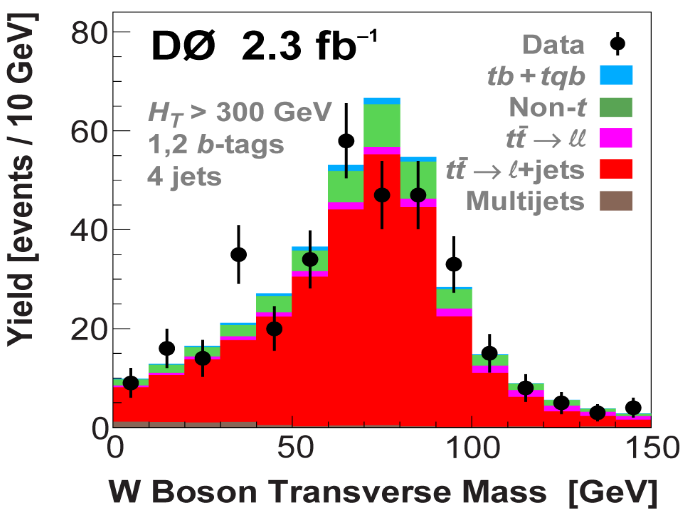
Event Yields in 2.3 fb^{-1} of DØ Data	
e,μ, 2,3,4-jets, 1,2-tags combined	
tb + tqb	223 ± 30
W+jets	2,647 ± 241
Z+jets, dibosons	340 ± 61
tt̄ pairs	1,142 ± 168
Multijets	300 ± 52
Total prediction	4,652 ± 352
Data	4,519



W+Jets Cross-Check Sample

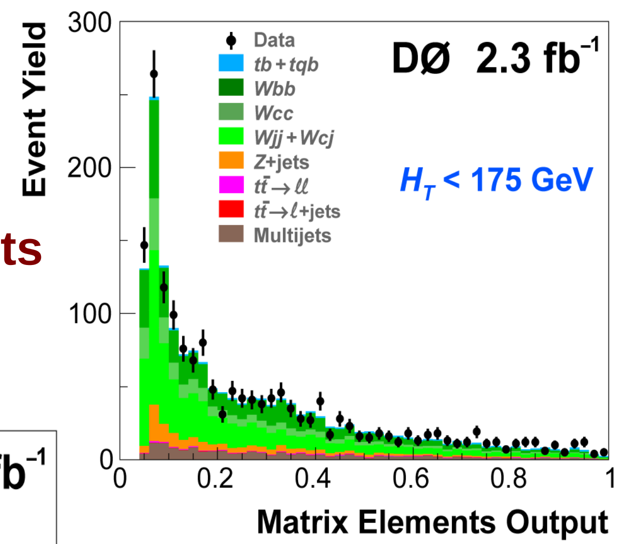


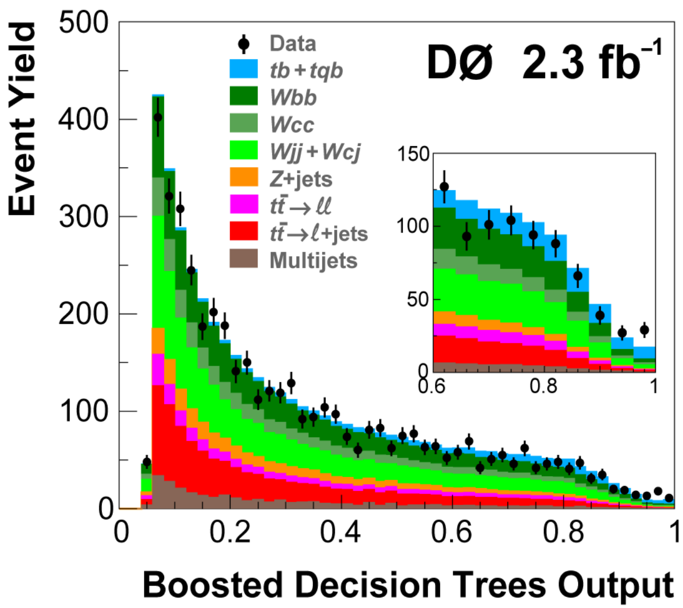
tt̄-Pairs Cross-Check Sample

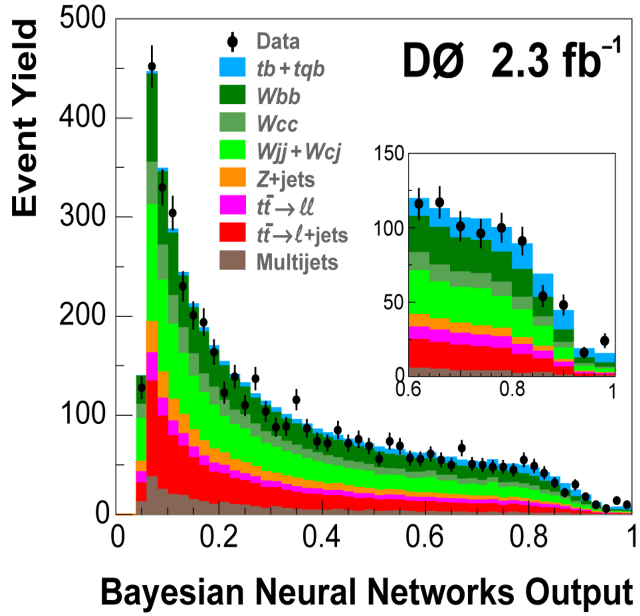


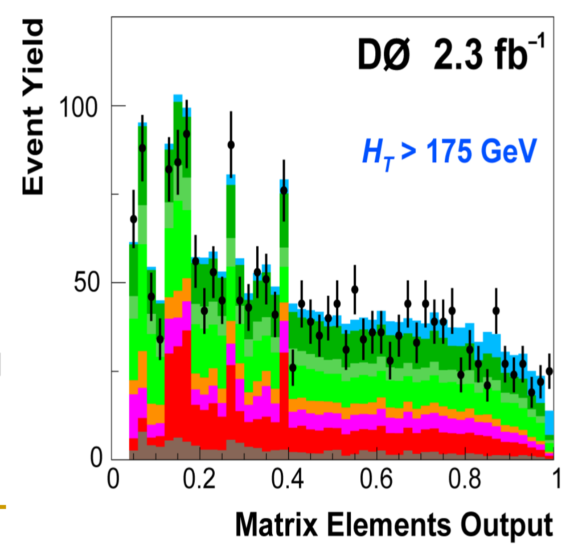
$t(\bar{t})$: D0 High Level Analysis

Three parallel analysis methods: BNN, BDT, ME
Analyse the shapes of discriminants to get final results



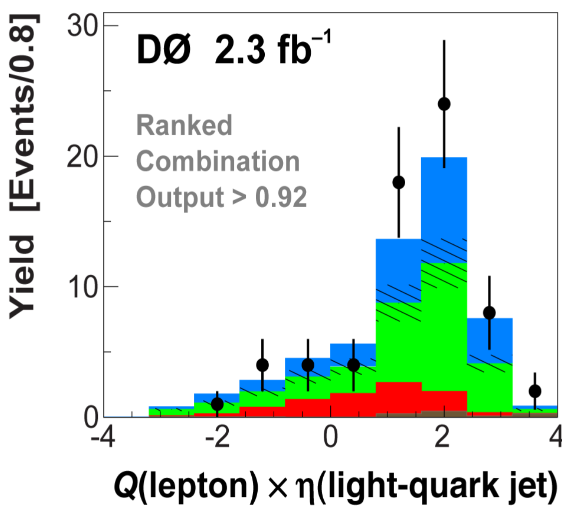




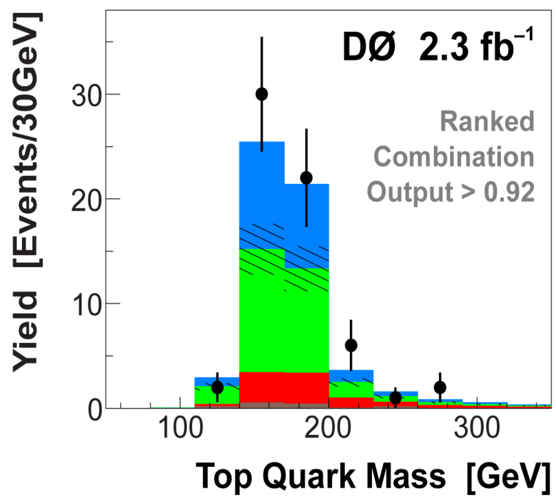


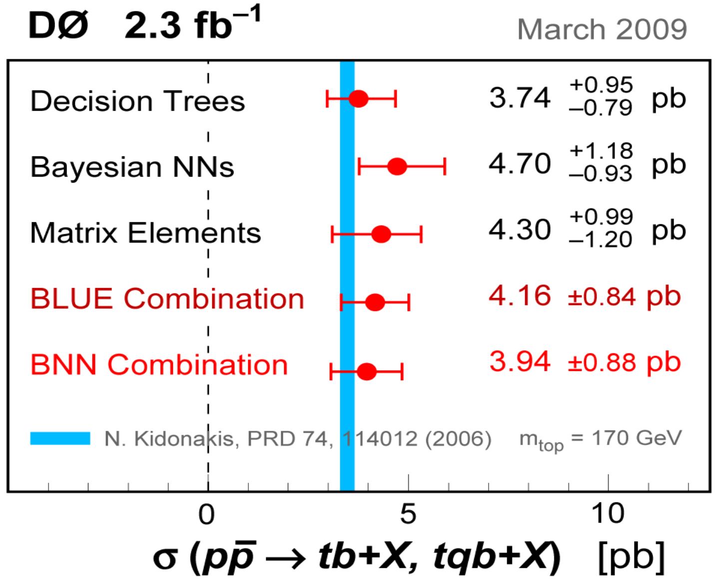
$t(\bar{t})$: D0 Combination of BNN,BDT,ME

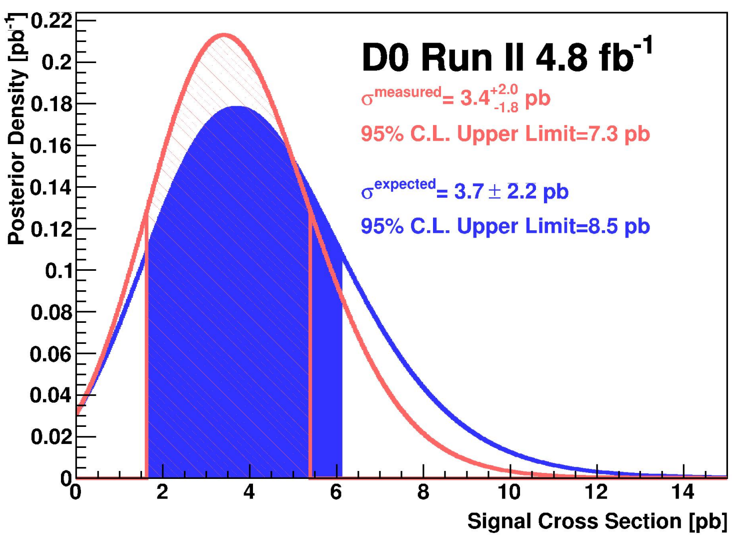
High Signal Region – $Q \times \eta$

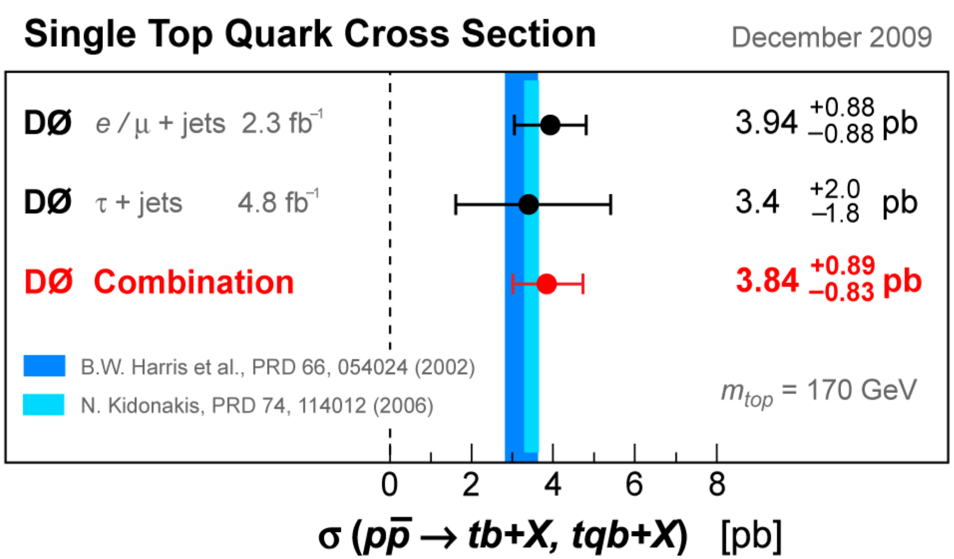


High Signal Region – m_{top}



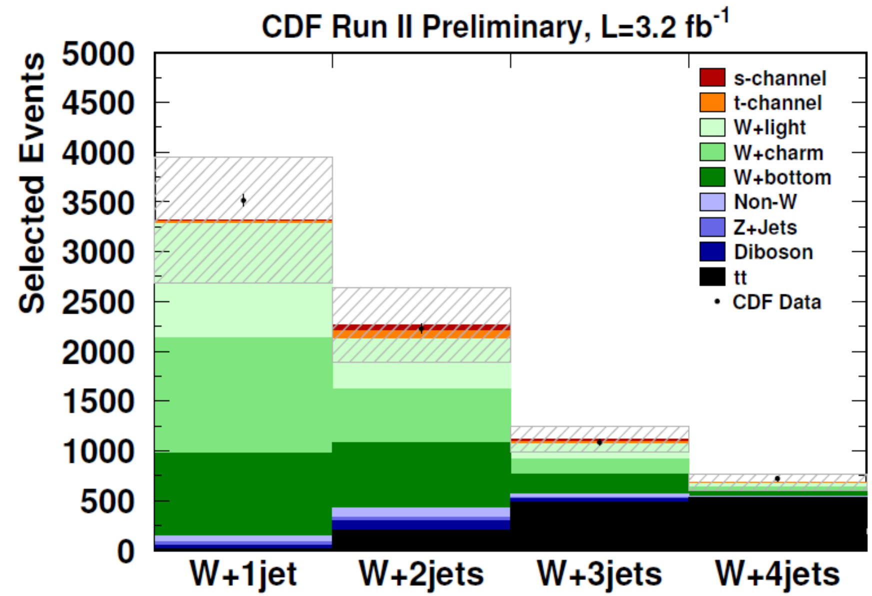


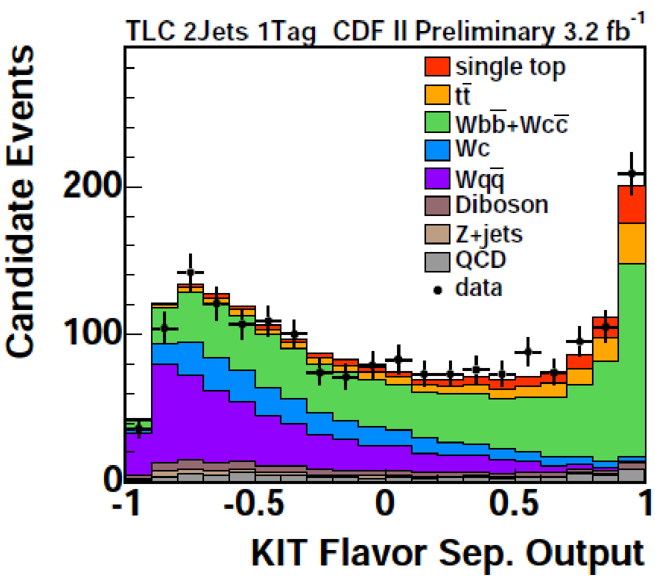


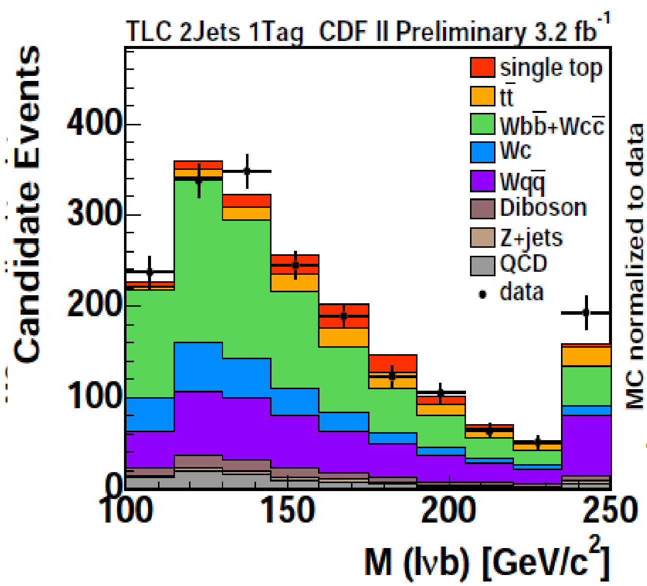


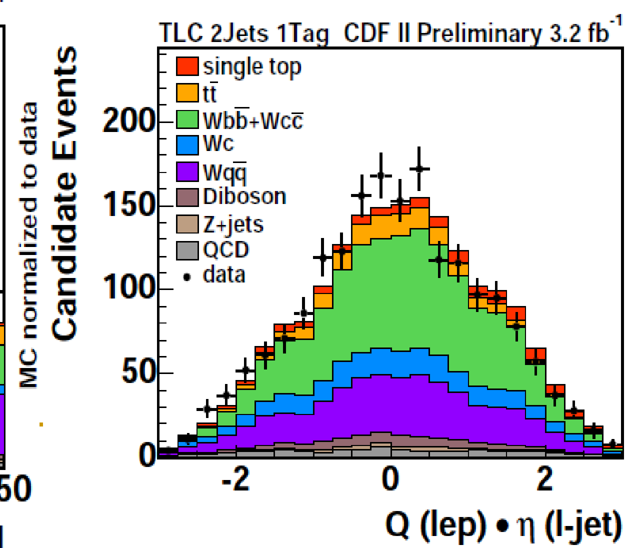
$t(\bar{t})$: CDF Analysis, Selection

Process	3.2 fb^{-1} $\ell + \not\!\!E_T$ + jets	2.1 fb^{-1} $\not\!\!E_T$ + jets
s-channel signal	77.3 ± 11.2	29.6 ± 3.7
t-channel signal	113.8 ± 16.9	34.5 ± 6.1
$W + HF$	1551.0 ± 472.3	304.4 ± 115.5
$t\bar{t}$	686.1 ± 99.4	184.5 ± 30.2
Z+jets	52.1 ± 8.0	128.6 ± 53.7
Diboson	118.4 ± 12.2	42.1 ± 6.7
QCD+mistags	777.9 ± 103.7	679.4 ± 27.9
Total prediction	3376.5 ± 504.9	1404 ± 172
Observed	3315	1411



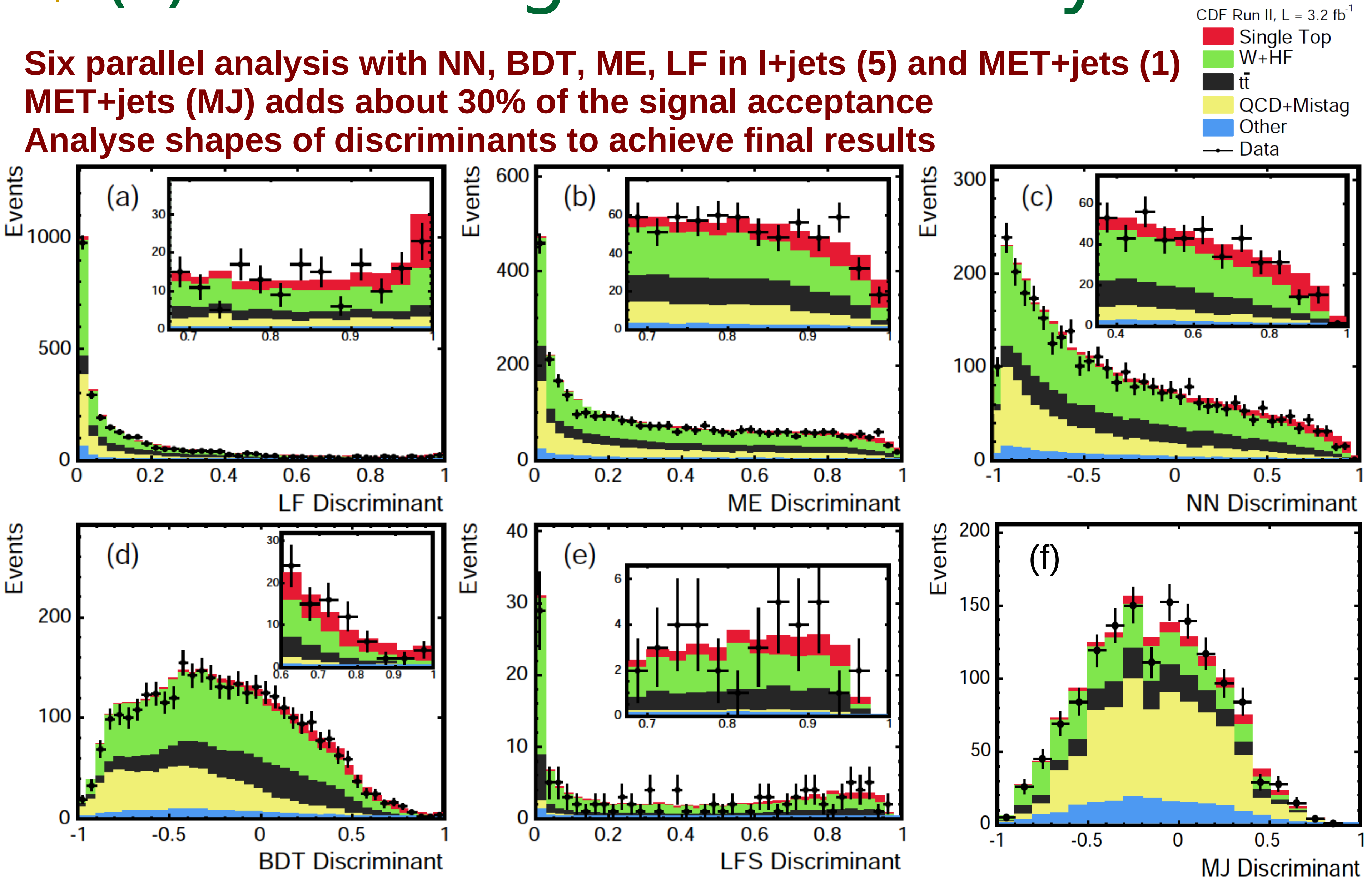






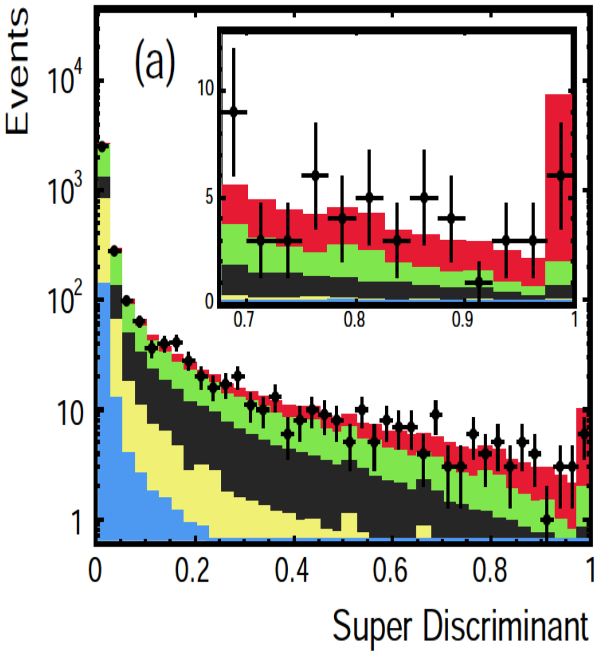
$t(\bar{t})$: CDF High Level Analysis

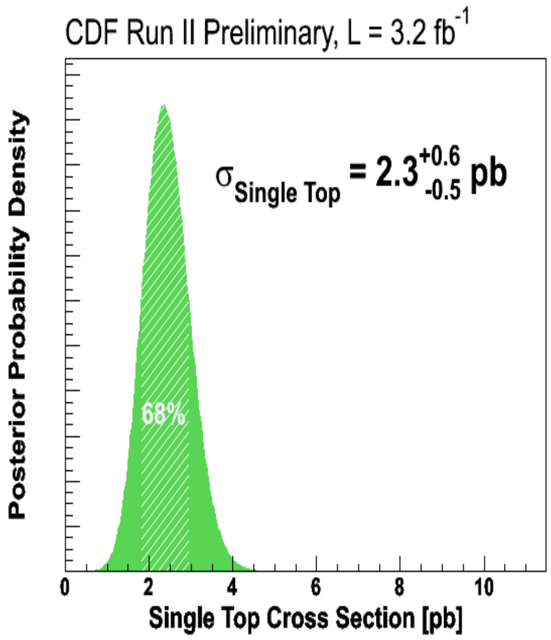
Six parallel analysis with NN, BDT, ME, LF in l+jets (5) and MET+jets (1)
MET+jets (MJ) adds about 30% of the signal acceptance
Analyse shapes of discriminants to achieve final results

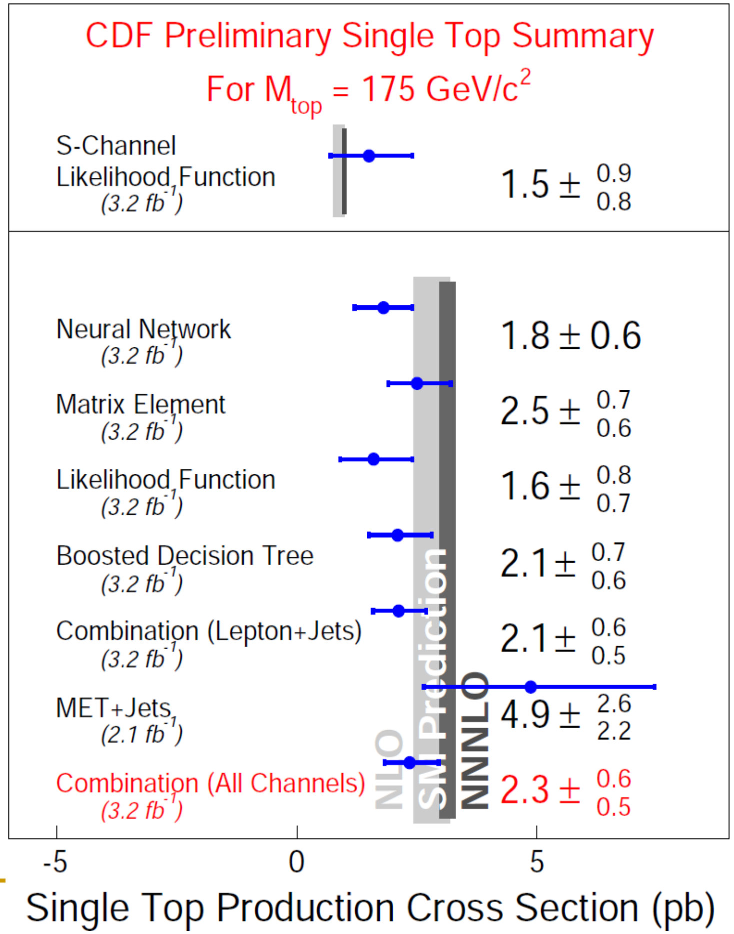


$t(\bar{t})$: CDF Combination of Six Analysis

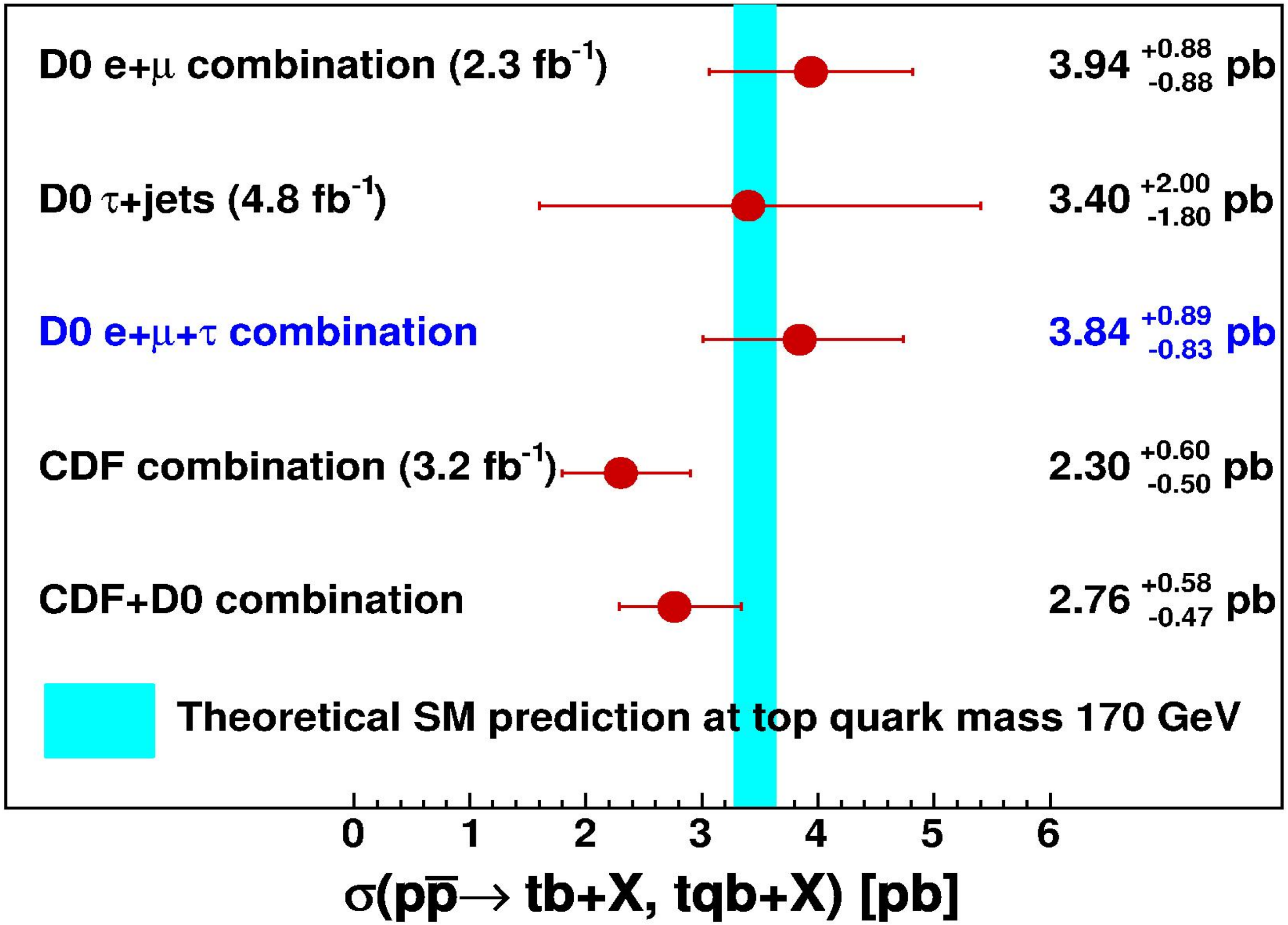
LF, ME, NN, BDT, LFS discriminants are combined with Super Discriminant (SD)
SD is neural network trained with neuro-evolution (about 13% improvement)
Final results achieved by fit over two orthogonal discriminants SD and MJ



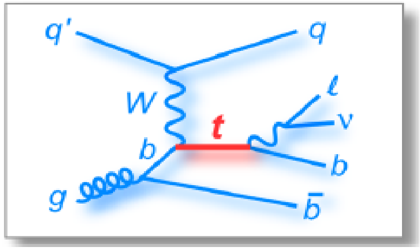


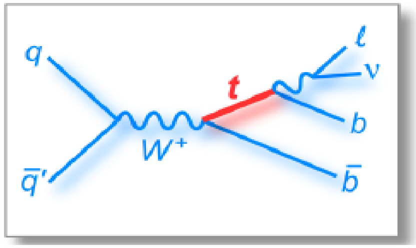


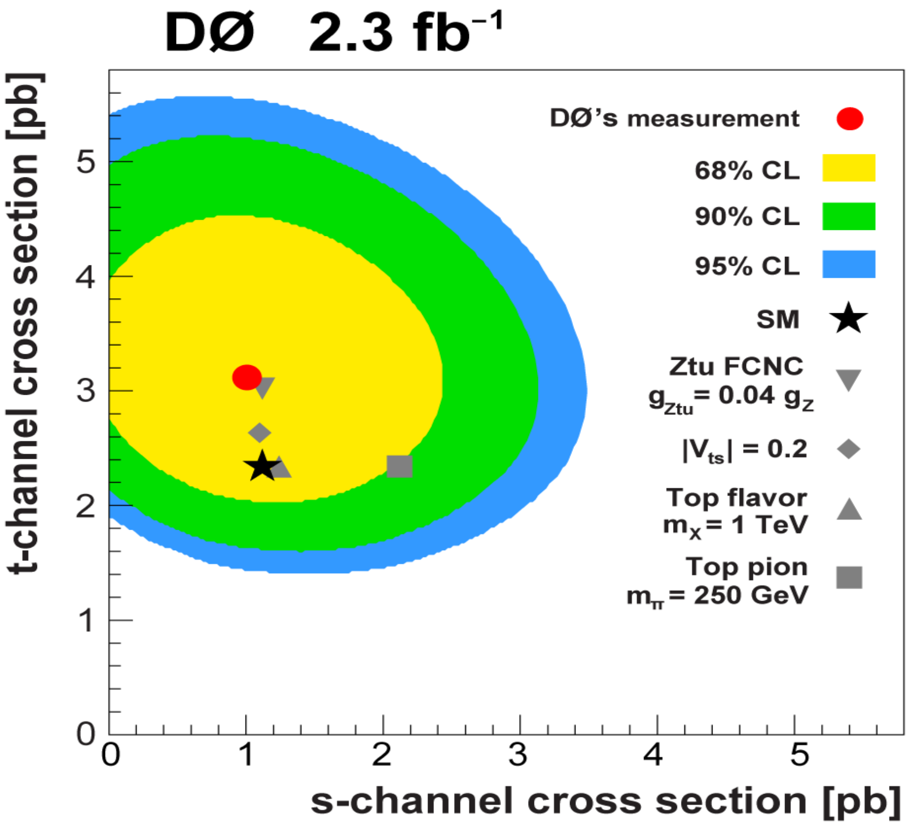
$t(\bar{t})$: Tevatron Combination (D0⊕CDF)

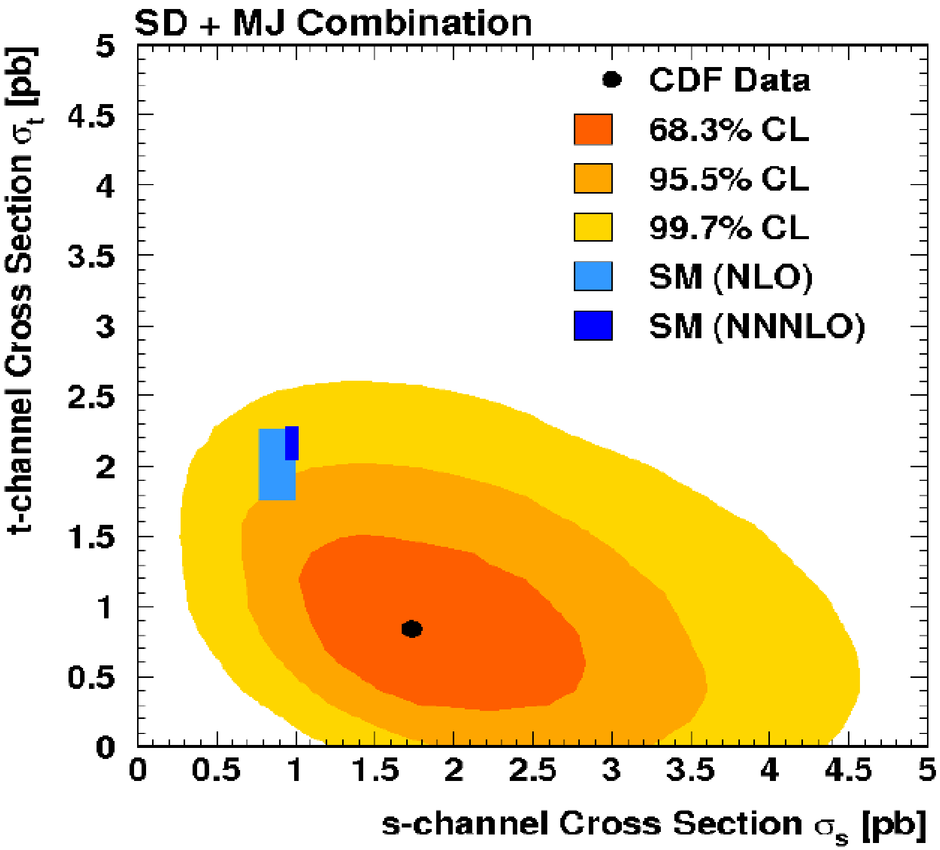


$t(\bar{t})$: t- and s-channels of single top production



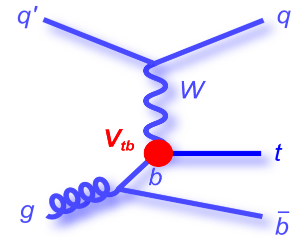


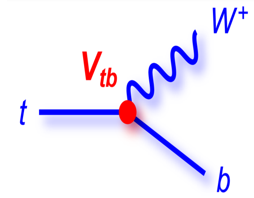




$t(\bar{t})$: Direct measurement of V_{tb}

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = V_{CKM} \begin{pmatrix} d \\ s \\ b \end{pmatrix} \qquad V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



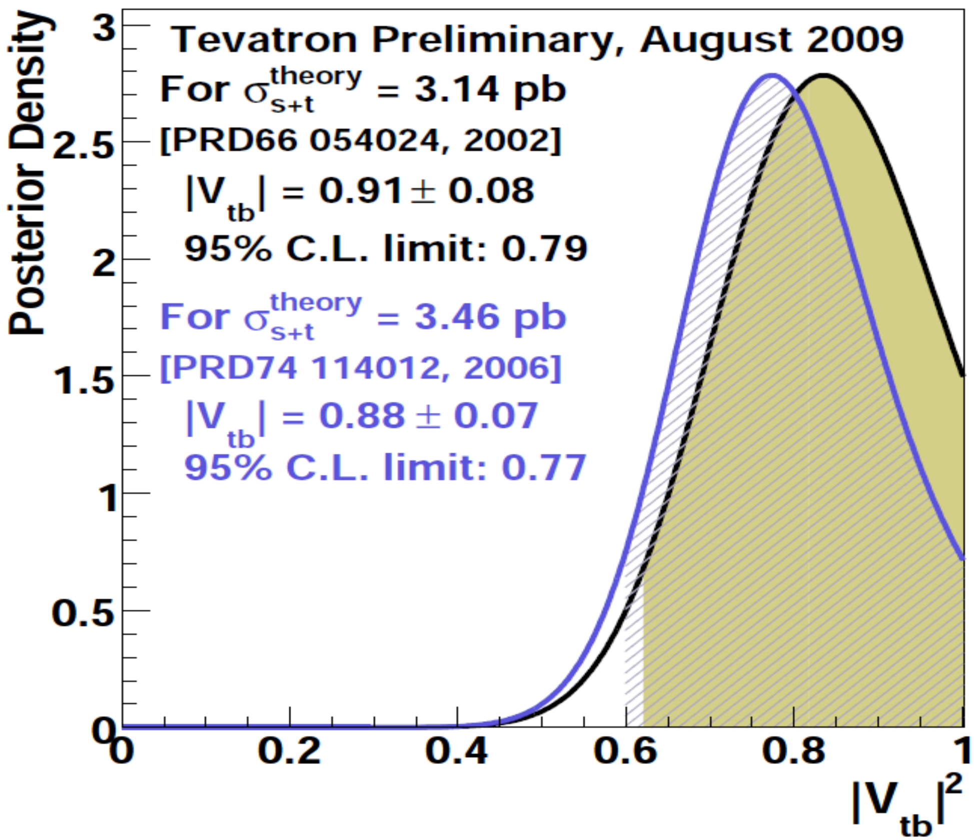


$$\Gamma^{\mu}_{Wtb} = -\frac{g}{\sqrt{2}} V_{tb} \left\{ \gamma^{\mu} \left[f_1^L P_L + f_1^R P_R \right] - \frac{i\sigma^{\mu\nu}}{M_W} (p_t - p_b)_{\nu} \left[f_2^L P_L + f_2^R P_R \right] \right\}$$

$$f_1^L = 1,\; f_2^L = f_1^R = f_2^R = 0$$

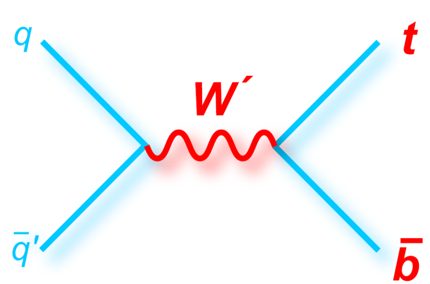
$$|V_{tb}|^2 \gg |V_{td}|^2 + |V_{ts}|^2$$

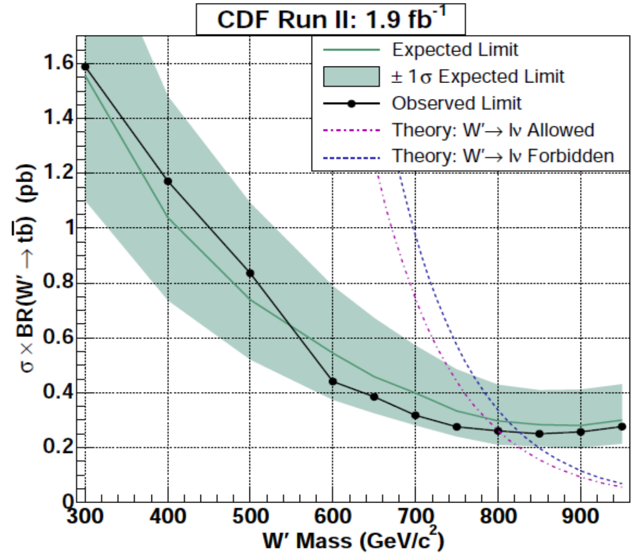
Measurement does not assume 3 generations or unitarity

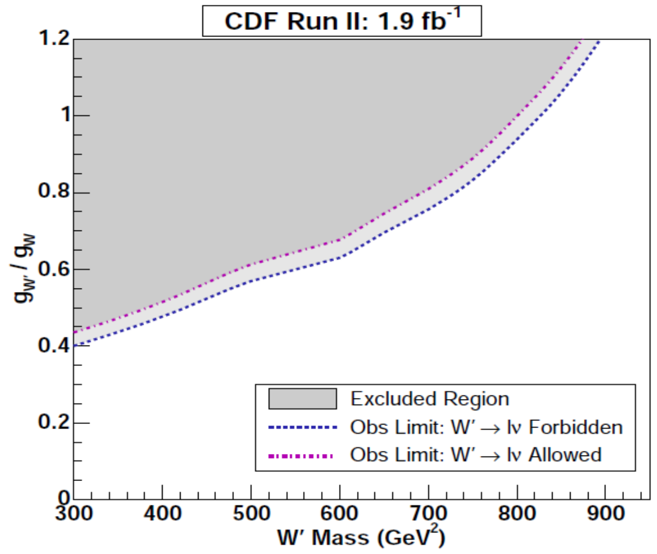


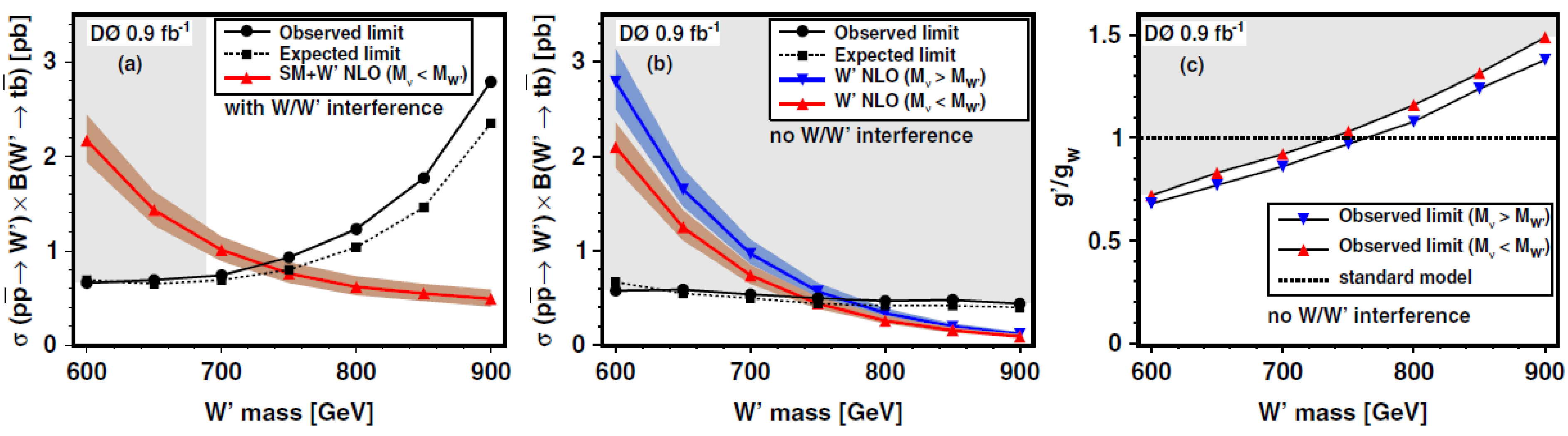
$t(\bar{t})$: W' search

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



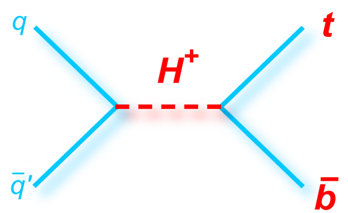




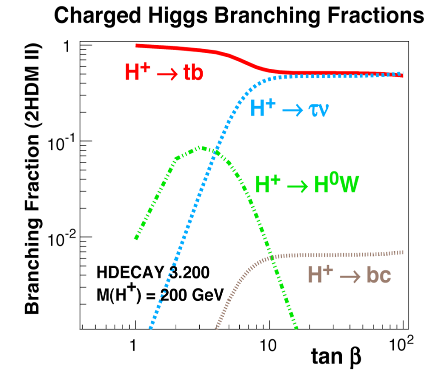


$t(\bar{t})$: Charged Higgs Search

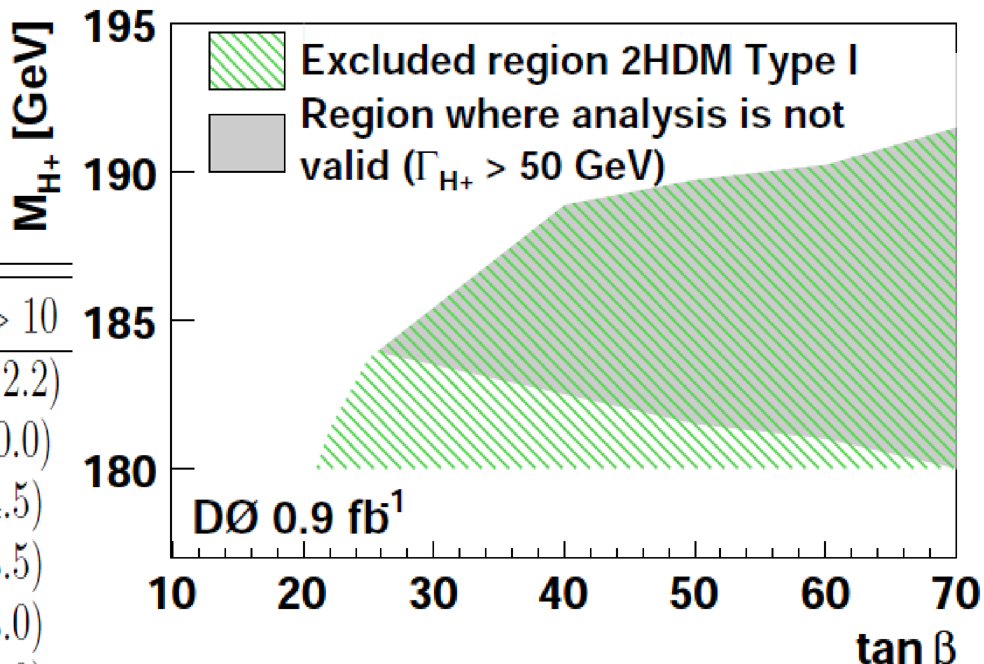
$M_H > M_{top}$



$$\mathcal{L} = H^+ \bar{q}_i \left[g_L^{ij} \left(\frac{1-\gamma^5}{2} \right) + g_R^{ij} \left(\frac{1+\gamma^5}{2} \right) \right] q_j$$



D0 limits @900 pb^{-1}
For Type I, II, III 2HDM



M_{H+} (GeV)	$\tan\beta < 0.1$	$\tan\beta = 1$	$\tan\beta = 5$	$\tan\beta > 10$
180	12.9 (11.4)	14.3 (12.2)	13.7 (11.7)	13.7 (12.2)
200	[5.9 (9.6)]	6.3 (9.9)	6.5 (10.0)	6.5 (10.0)
220	[2.9 (4.2)]	3.0 (4.4)	3.0 (4.5)	3.0 (4.5)
240	[2.3 (3.1)]	2.4 (3.3)	2.6 (3.5)	2.6 (3.5)
260	[3.0 (2.8)]	3.0 (2.9)	3.0 (3.0)	3.0 (3.0)
280	[4.0 (2.6)]	4.2 (2.7)	4.5 (2.9)	4.5 (2.9)
300	[4.5 (2.4)]	4.7 (2.4)	4.9 (2.5)	4.9 (2.5)

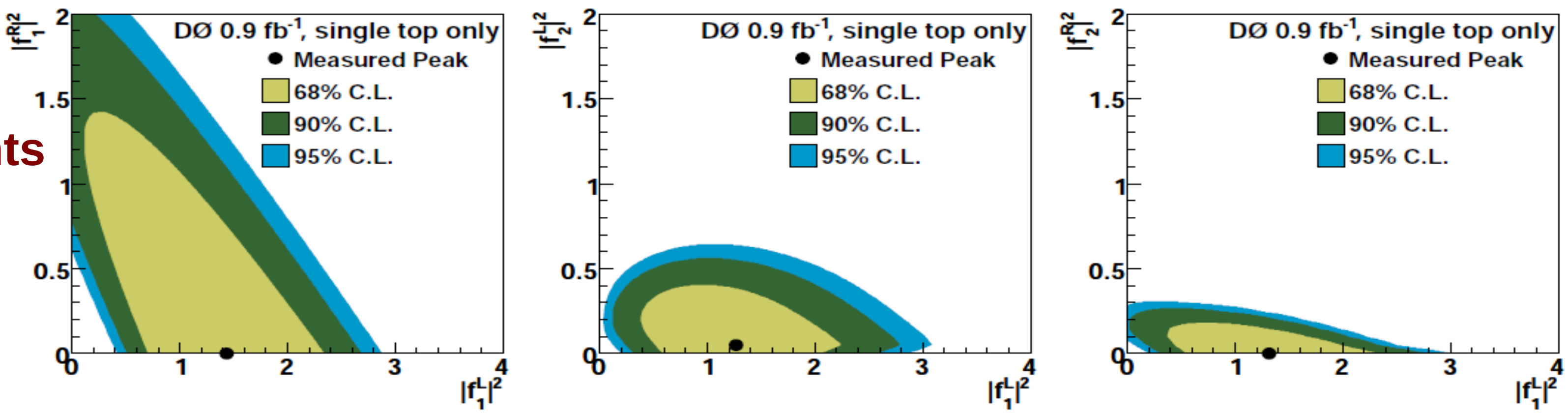
$t(\bar{t})$: Anomalous Wtb couplings

$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}V_{tb}(f_1^L P_L + f_1^R P_R)tW_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}V_{tb}}{M_W}(f_2^L P_L + f_2^R P_R)tW_{\mu}^{-} + h.c.$$

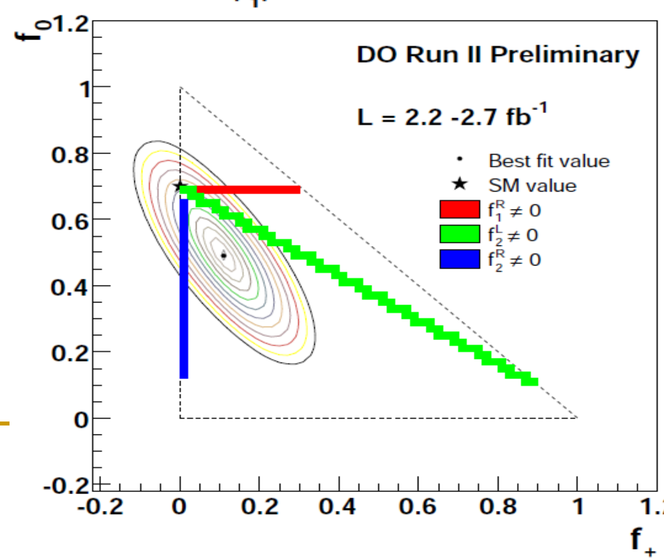
SM: $f_1^L = 1,\ f_2^L = f_1^R = f_2^R = 0$

$$P_L = (1-\gamma_5)/2$$
$$P_R = (1+\gamma_5)/2$$

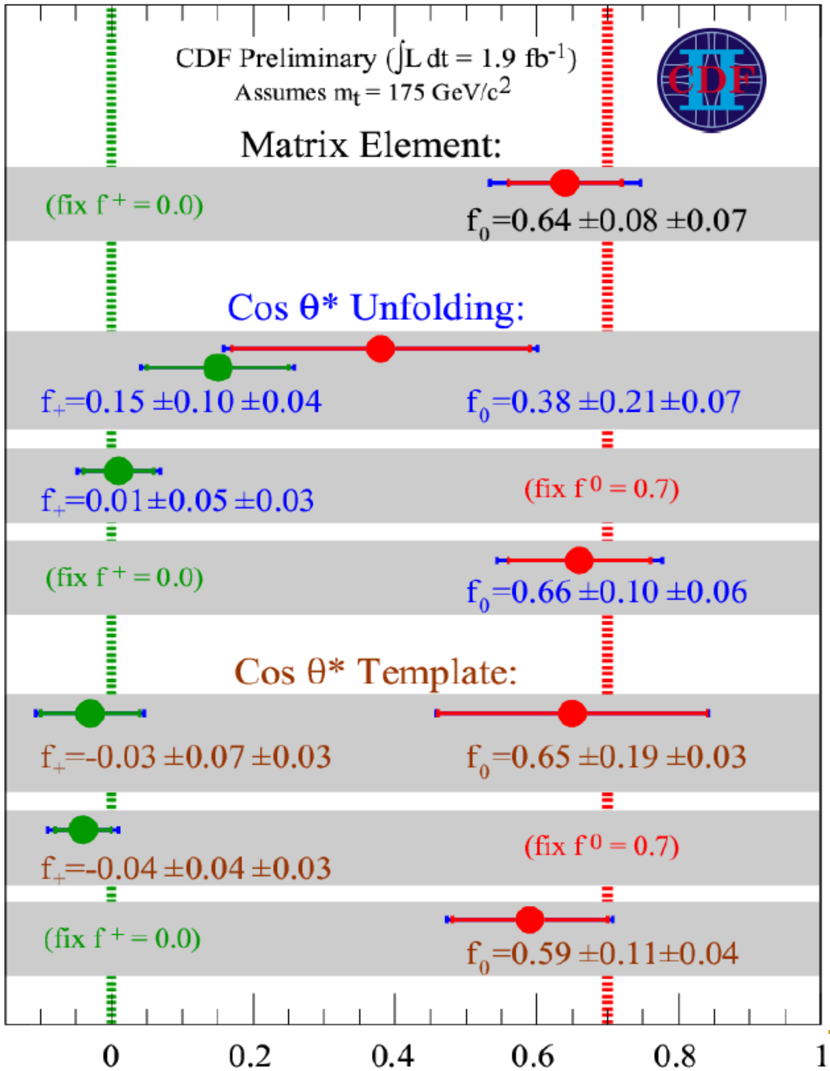
First direct Measurements In D0

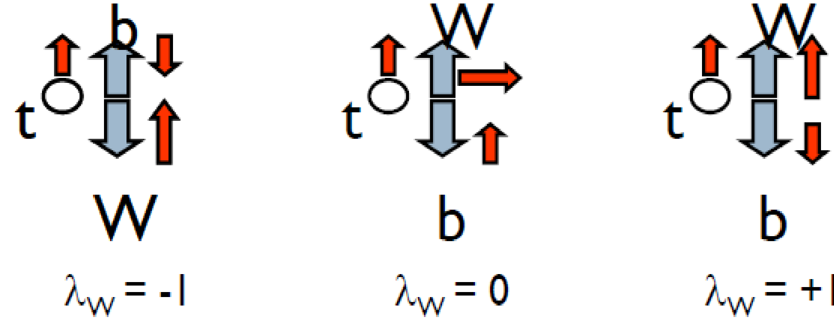


Scenario	Coupling	Coupling limit if $f_1^L = 1$
(f_1^L, f_1^R)	$\lvert f_1^L\rvert^2 = 1.36^{+0.56}_{-0.46}$	
	$\lvert f_1^R\rvert^2 < 0.72$	$\lvert f_1^R\rvert^2 < 0.72$
(f_1^L, f_2^L)	$\lvert f_1^L\rvert^2 = 1.44^{+0.65}_{-0.51}$	
	$\lvert f_2^L\rvert^2 < 0.30$	$\lvert f_2^L\rvert^2 < 0.19$
(f_1^L, f_2^R)	$\lvert f_1^L\rvert^2 = 1.16^{+0.51}_{-0.44}$	
	$\lvert f_2^R\rvert^2 < 0.19$	$\lvert f_2^R\rvert^2 < 0.20$



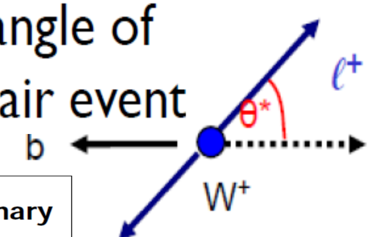
$t\bar{t}$: W helicity in top decays

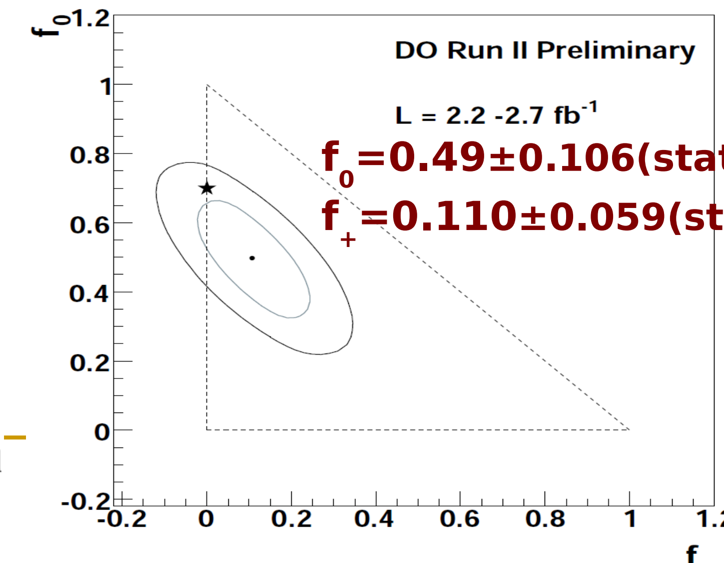




$$F_- \approx \frac{2M_W^2}{m_t^2 + 2M_W^2} = 0.30 \qquad F_0 \approx \frac{m_t^2}{m_t^2 + 2M_W^2} = 0.70 \qquad F_+ = 0$$

Reconstruct helicity angle of lepton in top quark pair event



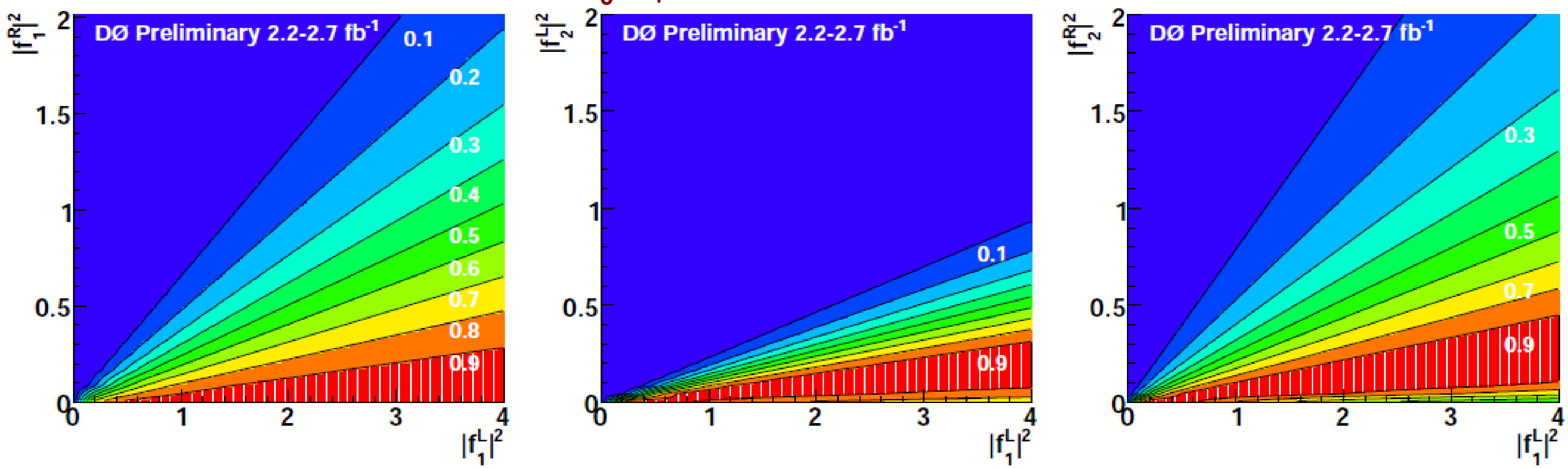


f_0=0.49±0.106(stat)±0.085(sys)

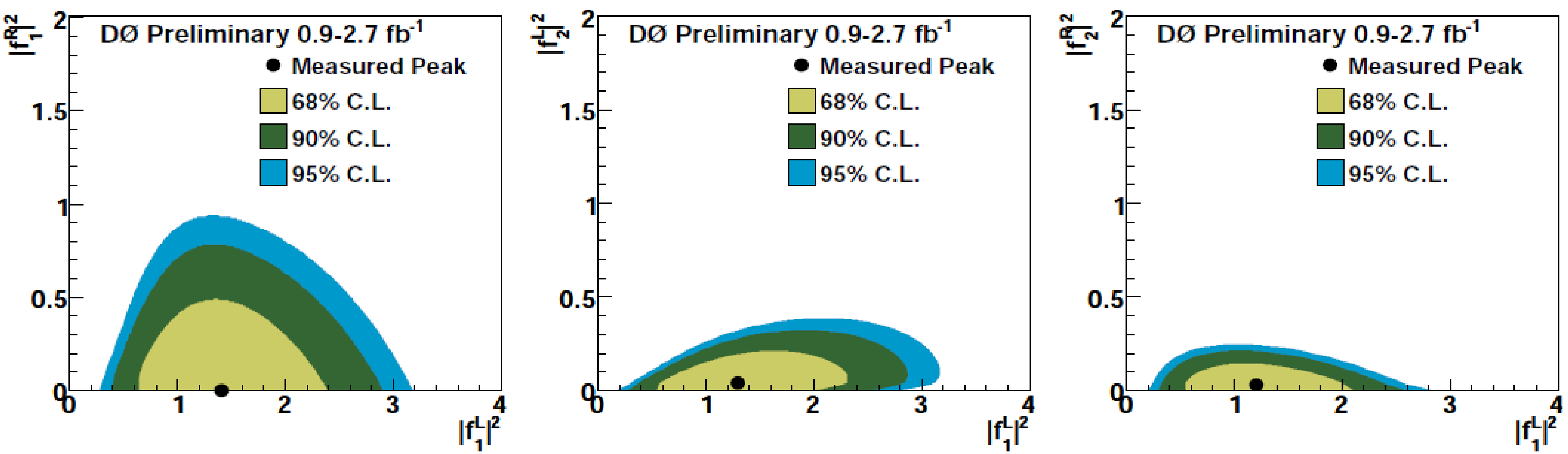
f_+=0.110±0.059(stat)±0.052(sys)

$t\bar{t}$ and $t(\bar{t})$: Anomalous Wtb

Constraint from W-helicity f_0, f_+ ($t\bar{t}$)

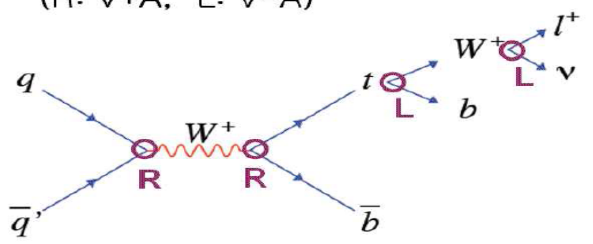


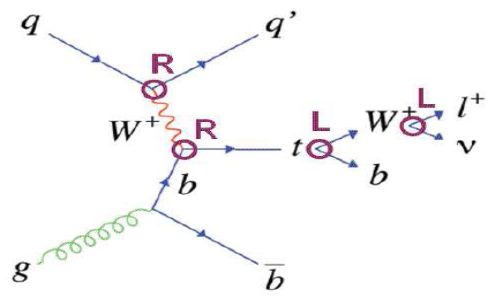
Combined constraints from W-helicity and single top measurements

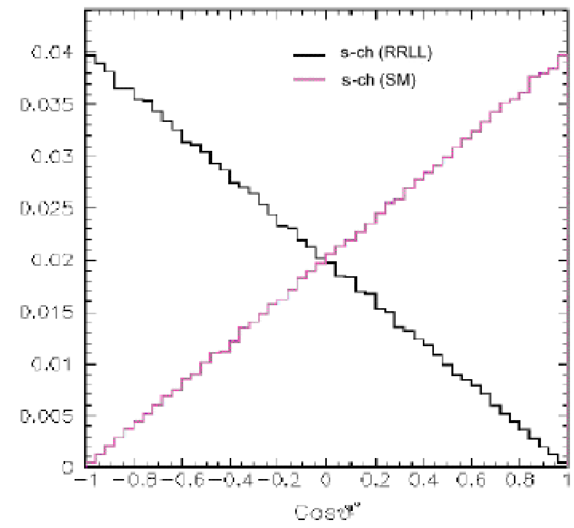


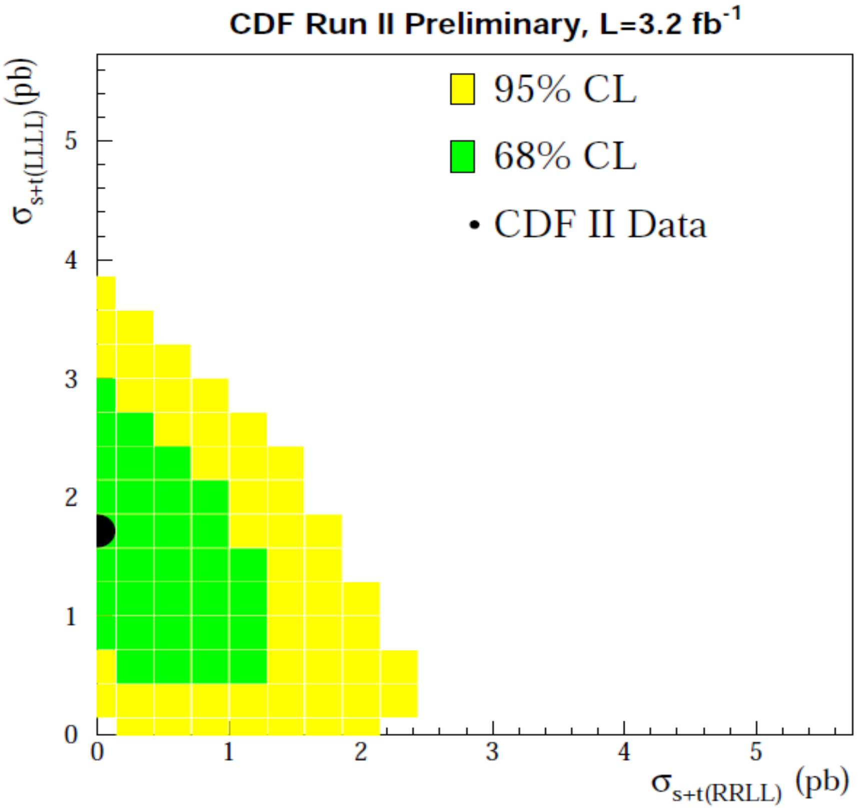
CDF single top polarization search

(R: V+A, L: V−A)



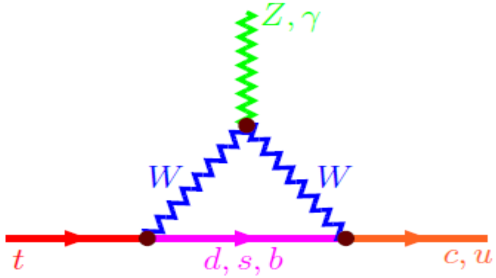






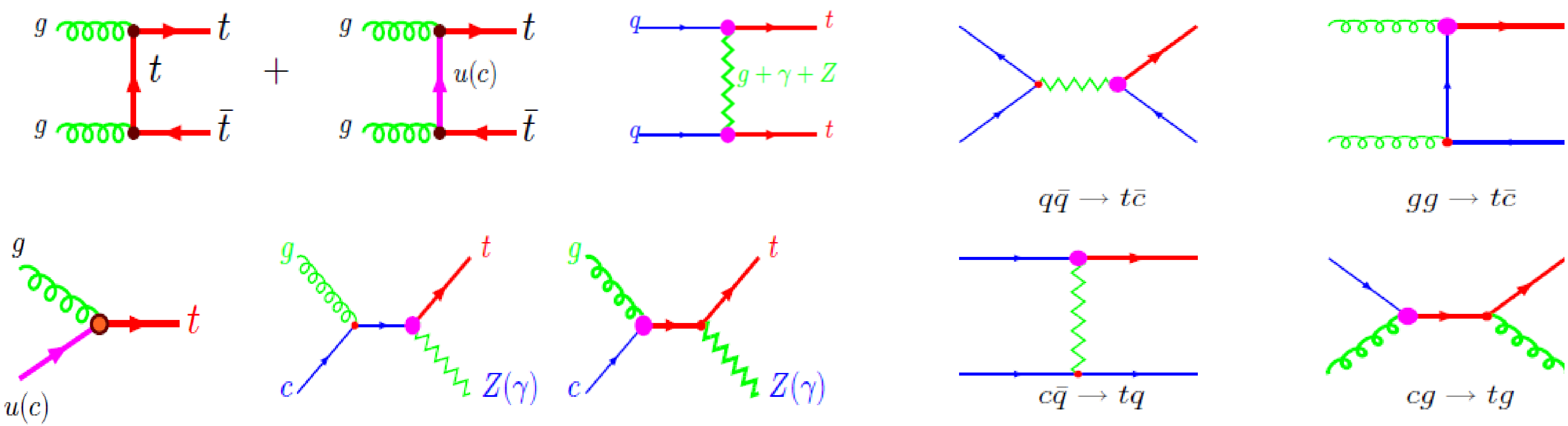
FCNC Search

Flavor Changing Neutral Currents (FCNC) $t \to qg$, $t \to q\gamma$, $t \to qZ$



	SM	two-Higgs	SUSY
$B(t \to cg)$	$5 \cdot 10^{-11}$	10^{-6}	10^{-3}
$B(t \to c\gamma)$	$5 \cdot 10^{-13}$	10^{-6}	10^{-5}
$B(t \to cZ)$	$\sim 10^{-13}$	10^{-9}	10^{-4}

FCNC processes lead to additional contribution to $t\bar{t}$ and $t(\bar{t})$ or exotic final states



$t(\bar{t})$: FCNC Search in Single Top

$$g_s \frac{\kappa_{tug}}{\Lambda} \bar{u}\, \sigma^{\mu\nu} \frac{\lambda^a}{2} t\, G^a_{\mu\nu} + g_s \frac{\kappa_{tcg}}{\Lambda} \bar{c}\, \sigma^{\mu\nu} \frac{\lambda^a}{2} t\, G^a_{\mu\nu} + h.c.$$

CDF NN search @2.2 fb^{-1}

$\sigma(u(c) + g \to t) < 1.8$ @95% CL

Converted to coupling limits:

$$\kappa_{tug}/\Lambda < 0.018 \ \text{TeV}^{-1} \ \text{assuming} \ \kappa_{tcg} = 0$$
$$\kappa_{tcg}/\Lambda < 0.069 \ \text{TeV}^{-1} \ \text{assuming} \ \kappa_{tug} = 0$$

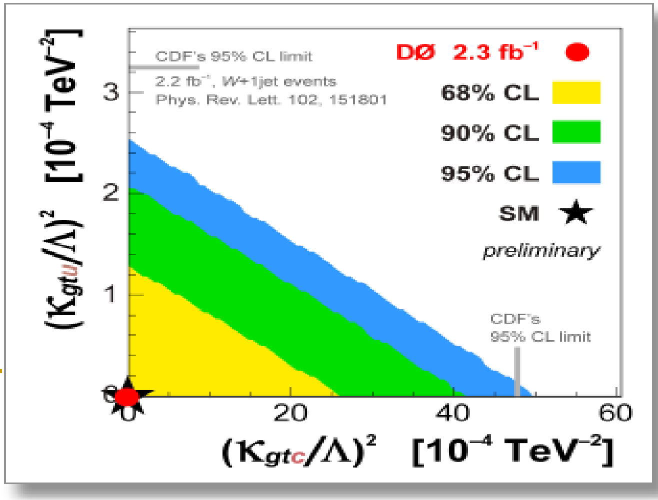
Or Branching limits:

$$\mathcal{B}(t \to u + g) < 3.9 \times 10^{-4}$$
$$\mathcal{B}(t \to c + g) < 5.7 \times 10^{-3}$$

D0 NN analysis @2.3 fb^{-1}

$$q\bar{q} \to t\bar{u},\ ug \to tg,\ gg \to t\bar{u}$$

κ_{gtu}/Λ	$<$	0.013 TeV^{-1}
κ_{gtc}/Λ	$<$	0.057 TeV^{-1}
$B(t \to gu)$	$<$	2.0×10^{-4}
$B(t \to gc)$	$<$	3.9×10^{-3}
$\sigma(gtu)$	$<$	0.20 pb
$\sigma(gtc)$	$<$	0.27 pb
at 95% CL		

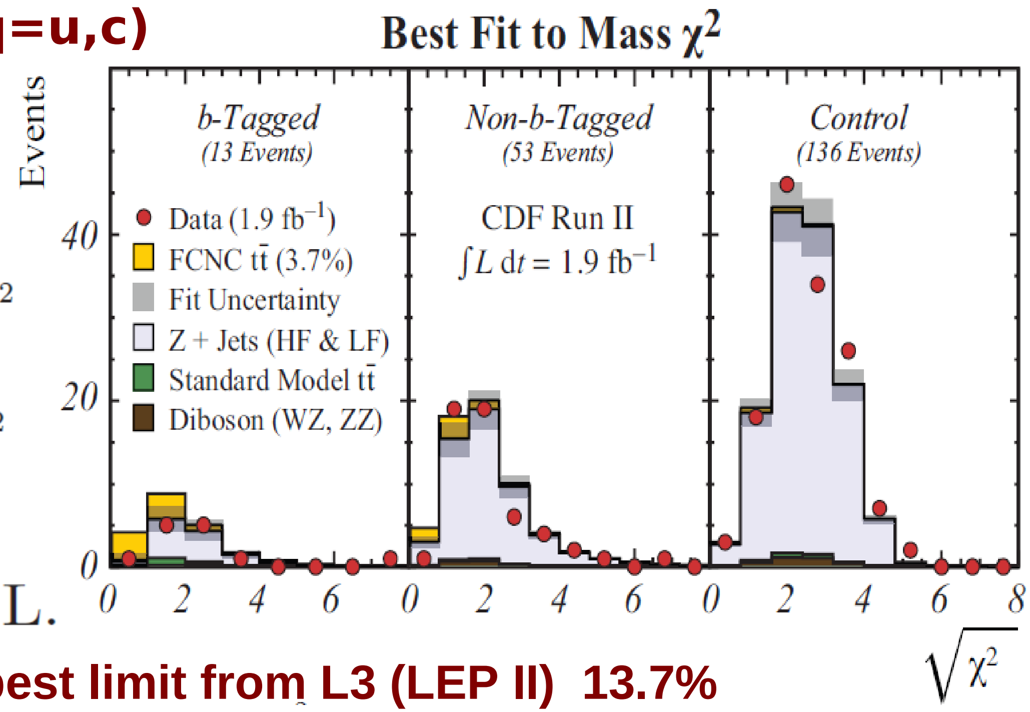


$t\bar{t}$: FCNC in the decay of top

1.9 fb^{-1} CDF Search for $t \to Zq$ (q=u,c)
In top pair production:
$t\bar{t} \to WbZq$ and $t\bar{t} \to ZqZq$

Construct permutation mass:

$$\chi^2 = \left(\frac{m_{W,\mathrm{rec}} - m_W}{\sigma_W}\right)^2 + \left(\frac{m_{t\to Wb,\mathrm{rec}} - m_t}{\sigma_{t\to Wb}}\right)^2 + \left(\frac{m_{t\to Zq,\mathrm{rec}} - m_t}{\sigma_{t\to Zq}}\right)^2$$



The result of the fit:

$$\mathcal{B}(t \to Zq) < 3.7\% \text{ at } 95\% \text{ C.L.}$$

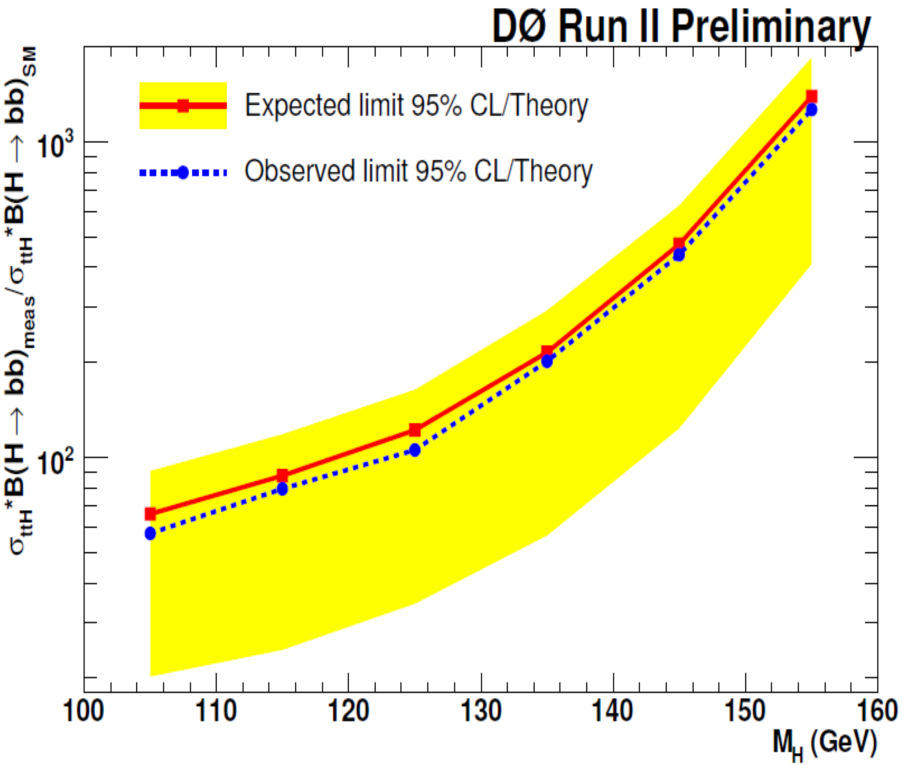
Significantly improves the previous best limit from L3 (LEP II) 13.7%

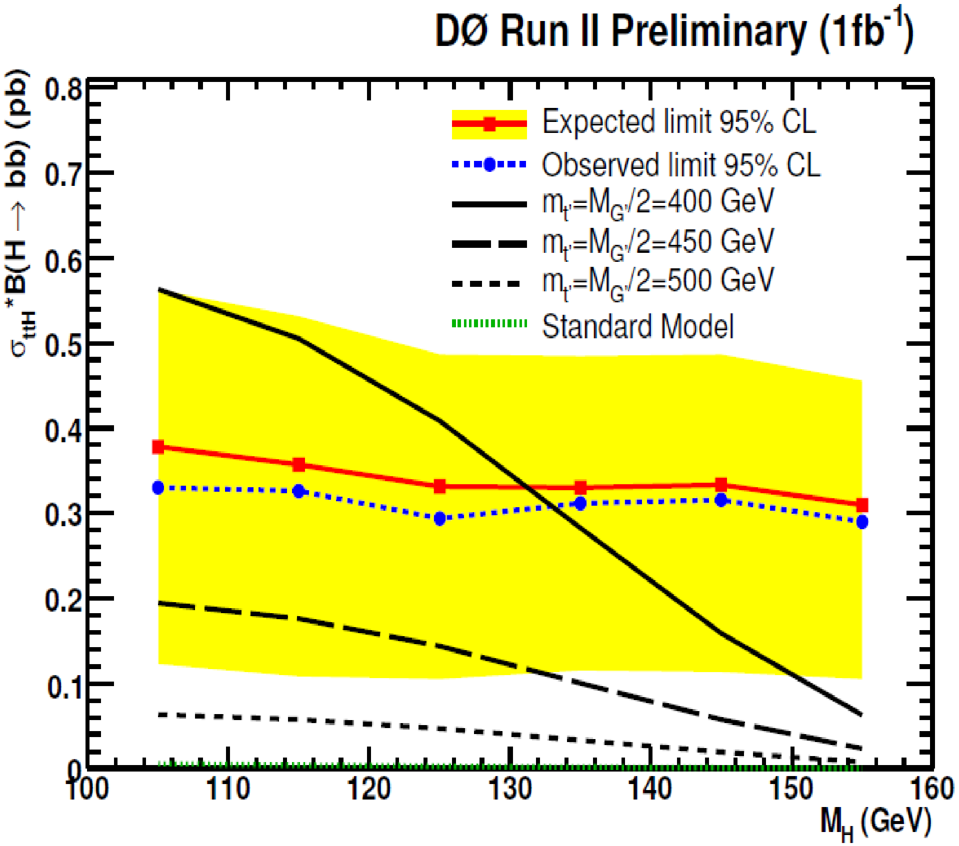
1.9 fb^{-1} CDF Indirect Search for invisible top decays

Decay	$\mathcal{R}_{wx/ww}$ (%)	Upper Limit (%) (175 GeV)	Upper Limit (%) (172.5 GeV)	Upper Limit (%) (170 GeV)
$\mathcal{B}(t \to Zc)$	32	13	15	18
$\mathcal{B}(t \to gc)$	27	12	14	17
$\mathcal{B}(t \to \gamma c)$	18	11	12	15
$\mathcal{B}(t \to \text{invisible})$	0	9	10	12

Search for ttH channel in D0 $1fb^{-1}$

$$t\bar{t}H \rightarrow t\bar{t}b\bar{b}$$





Conclusion

- Tevatron demonstrates a good agreement with SM in top sector. There are no any evidence of deviation from SM in top physics.
- Tevatron is still the main place for top physics, many analysis are published and we expect more with the nearest future expected statistic of 10 fb^{-1}
- Details are available in the dedicated D0 and CDF publications (>150) and in the following links:

http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html
http://www-cdf.fnal.gov/physics/new/top/public_mass.html