

Search for Anomalous Wtb Couplings in Single Top Quark Production at DØ

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for the DØ collaboration

New Perspectives 2012
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Fermilab

travel funds available for students and postdocs



New Perspectives 2012



June 14th
Wilson Hall
Ramsey Auditorium



registration for poster session, student talks and travel funds at:
http://www.fnal.gov/orgs/gsa/pages/events/new_perspectives

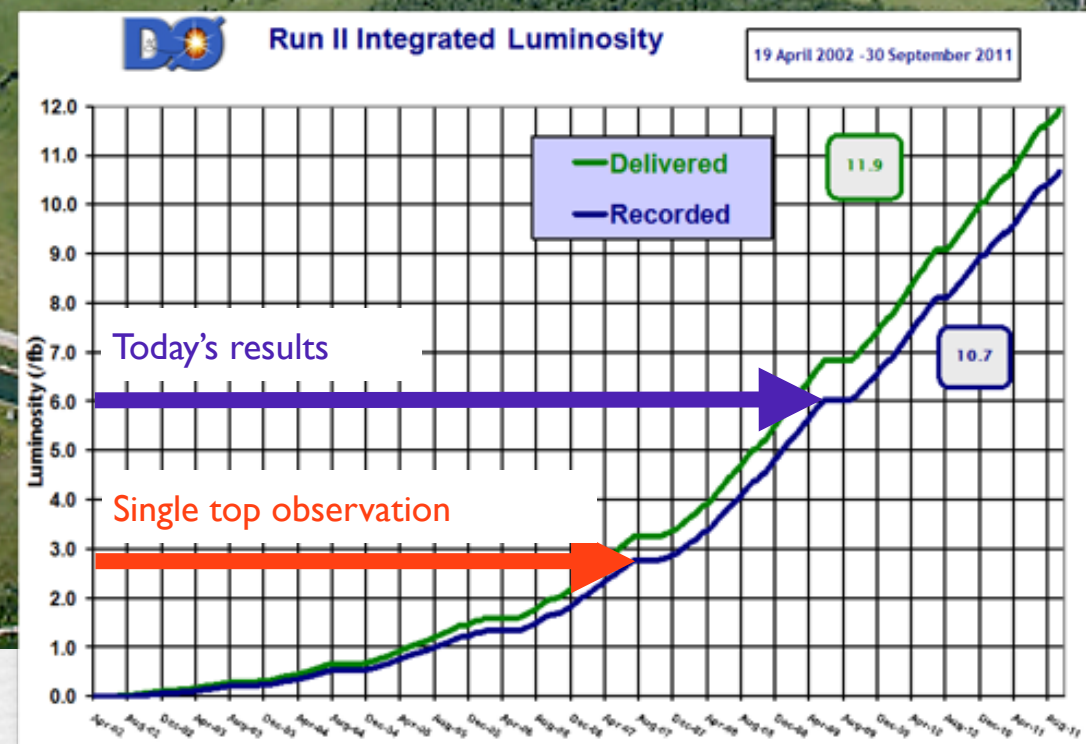
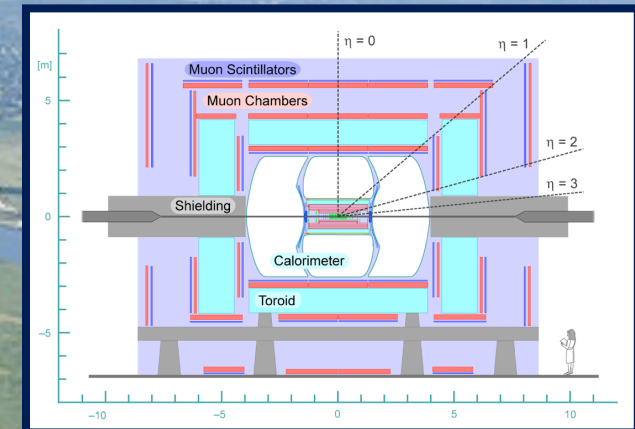
date	6/14/12	location	Wilson Hall Ramsey Auditorium	time	8:30 AM	event	GSA event in conjunction with the Fermilab Users' Meeting
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Outlines

- ❧ Tevatron and DØ detector
- ❧ Introduction to Anomalous Wtb Couplings
- ❧ Analysis Strategy
- ❧ Multivariate Analysis Technique
- ❧ Discriminant Outputs and Limit Calculation
- ❧ Conclusions

Tevatron and DØ detector

Tevatron



Introduction

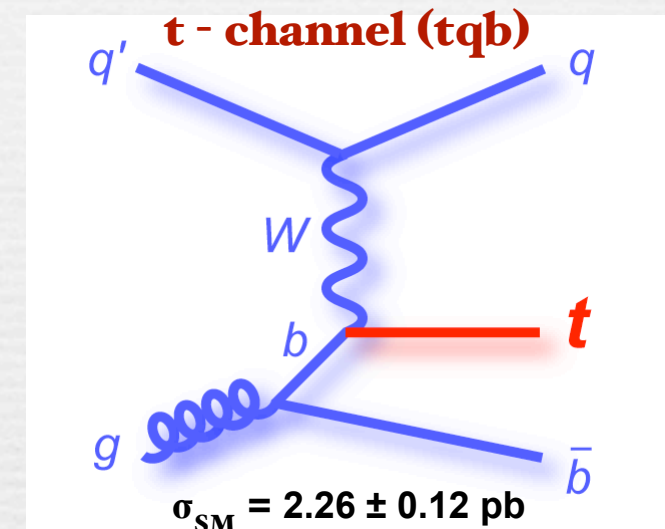
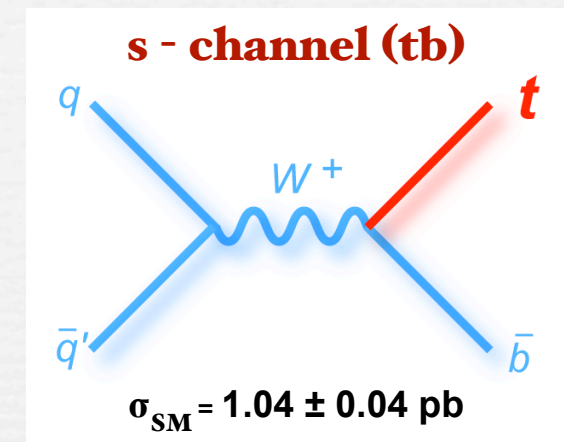
- New Physics can manifest itself either in terms of
 - new particles or
 - modified couplings that change the cross sections of existing processes and angular distributions of SM processes

Modifications to top quark interactions, in particular with weak gauge bosons, could yield the first signs of new physics.

- Single top production cross section is directly proportional to the square of CKM matrix element V_{tb} times the Wtb coupling

- DØ has recently shown an improved measurement of single top quark production cross section: **PRD 84, 112001 (2011)**

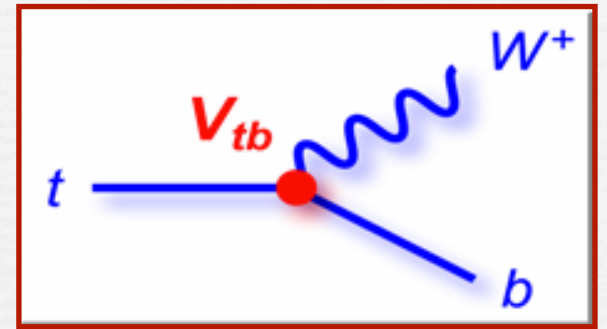
We use the same 5.4 fb^{-1} dataset and event selection to look for anomalous Wtb couplings



*Top Mass = 172.5 GeV; $\sigma = (N) \text{ NLO pb}$
N. Kidonakis, PRD 74, 114012 (2006)*

Anomalous Wtb Couplings in Single Top

The large mass of the top quark implies large couplings to the EWSB sector of the SM and may have non-SM interactions with the weak gauge bosons.



Single top quark production provides a unique probe to study top quark interactions with W boson.

The most general, CP -conserving Wtb vertex can be parameterized with an effective Lagrangian by :

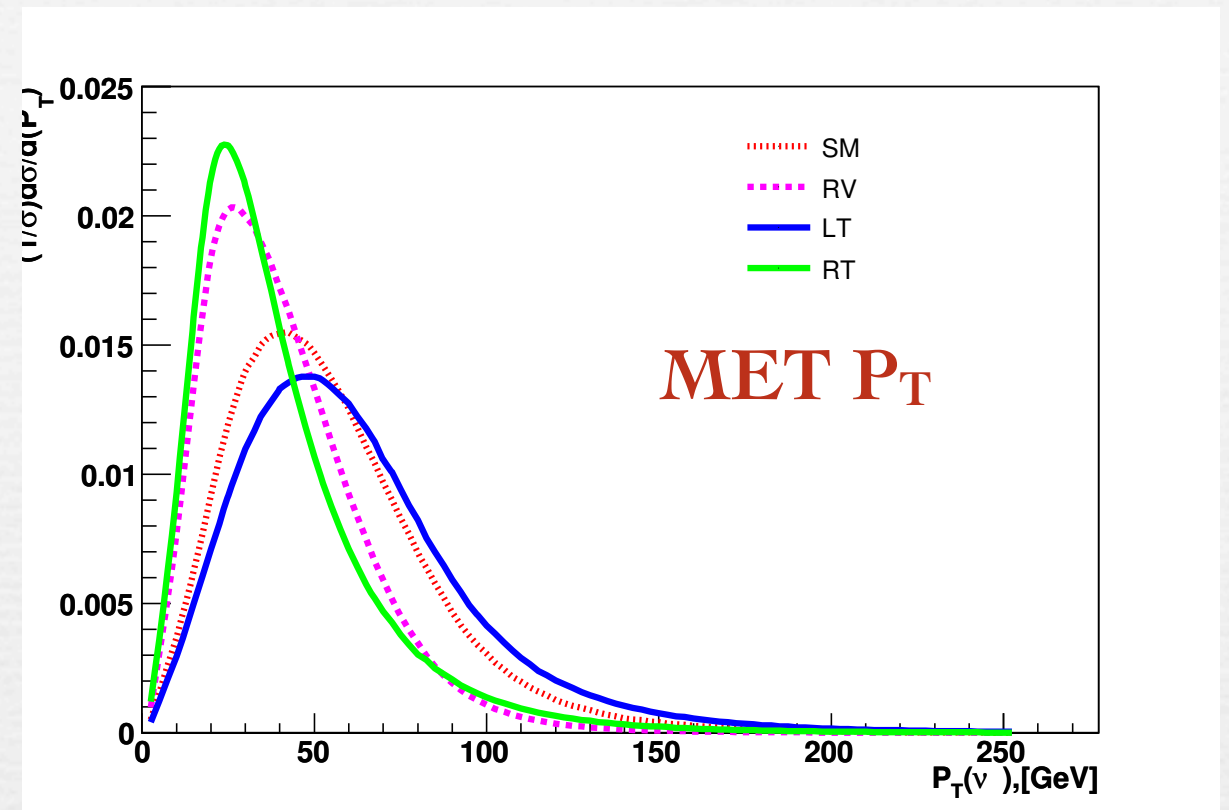
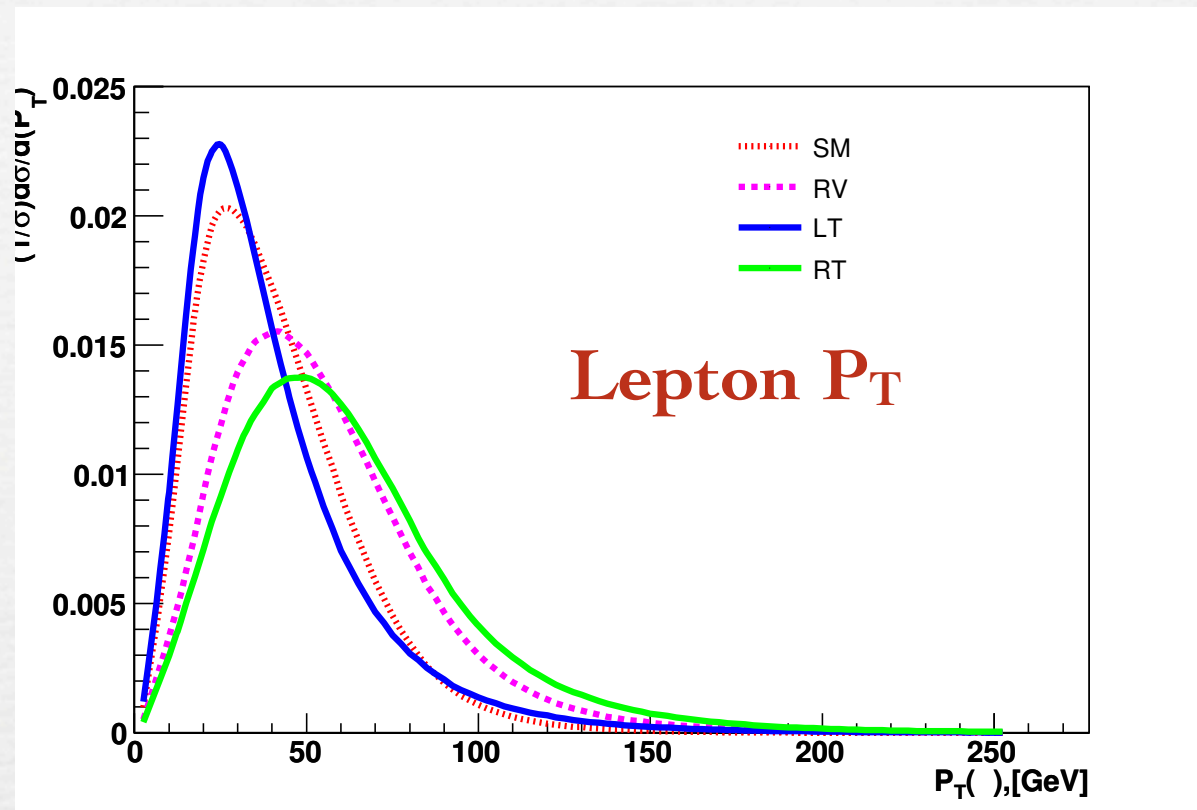
$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^\mu(L_V P_L + R_V P_R)tW_\mu^- - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_\nu}{M_W}(L_T P_L + R_T P_R)tW_\mu^- + h.c.$$

Vector Left and Right Couplings
Tensor Left and Right Couplings

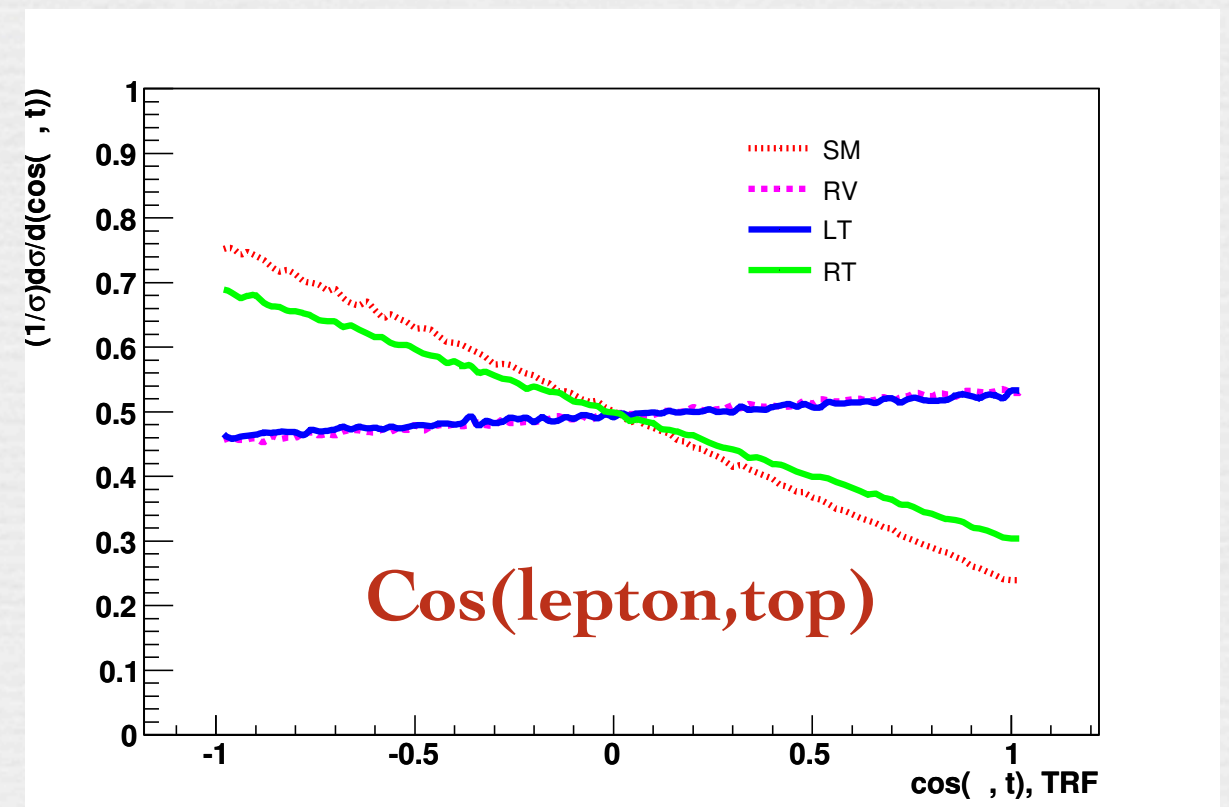
Where, $\mathbf{L}_{V,T} = \mathbf{V}_{tb} \cdot \mathbf{f}^{\mathbf{L}_{V,T}}$ and $\mathbf{R}_{V,T} = \mathbf{V}_{tb} \cdot \mathbf{f}^{\mathbf{R}_{V,T}}$

Within Standard Model, $L_V \equiv V_{tb} \approx 1$ and $R_V = L_T = R_T = 0$.

SM vs. Anomalous Couplings



Event kinematics and angular distributions are sensitive to the presence of anomalous couplings



Search Strategy

We have studied the Wtb couplings and set new limits on anomalous contributions to them.

Out of 4 couplings ($\mathbf{L}_V, \mathbf{R}_V, \mathbf{L}_T, \mathbf{R}_T$), we consider three pairing scenarios with left-handed vector coupling (SM) :

$(\mathbf{L}_V, \mathbf{R}_V) ; (\mathbf{L}_V, \mathbf{L}_T) ; (\mathbf{L}_V, \mathbf{R}_T)$

(assuming that for each case, other two non-SM couplings are negligible)

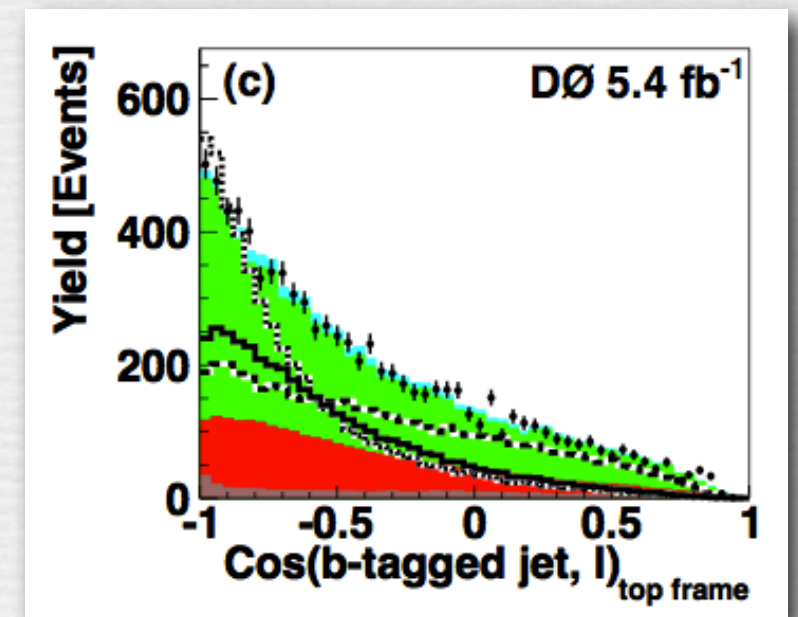
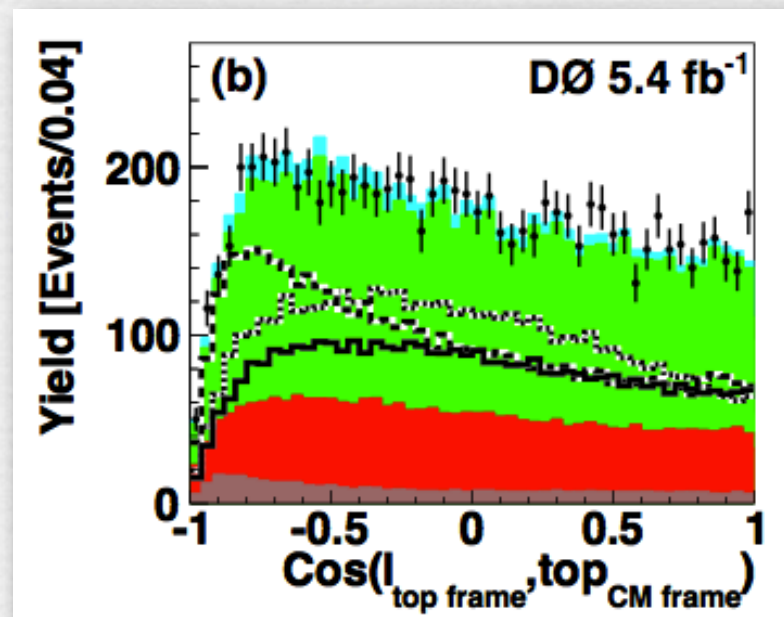
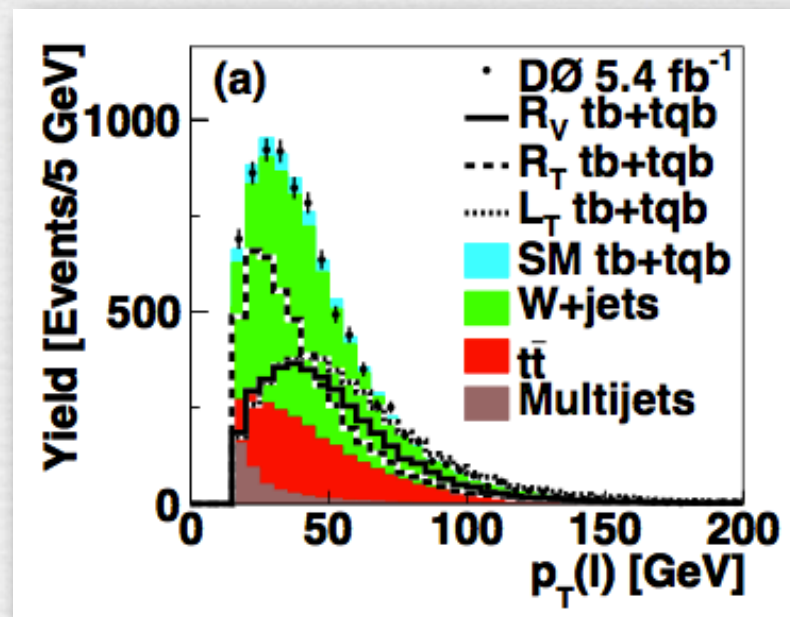
Some assumptions ::

- Single top quarks are produced exclusively through W boson exchange.
- Other single top quark production mechanisms such as FCNC, decay of new scalar boson or exchange of new vector boson are not considered.
- $|V_{td}|^2 + |V_{ts}|^2 \ll |V_{tb}|^2$; Wtb vertex dominates top quark production and decay.

Samples and Event Selection

- Single top quark signal events with the SM and anomalous Wtb couplings are modeled using the **COMPHEP-SINGLETOP** event generator.
- Main background contributions **W +jets**, **$t\bar{t}$** and **Z +jets** are modeled with **ALPGEN+PYTHIA**; **multijets** background is modeled directly with an independent data sample and **dibosons** are modeled using **PYTHIA**.

★ **Select One high- p_T isolated electron or muon with $p_T > 15$ GeV; Missing $E_T > 15$ GeV; 2-4 jets with at least one jet originating from a b quark.**



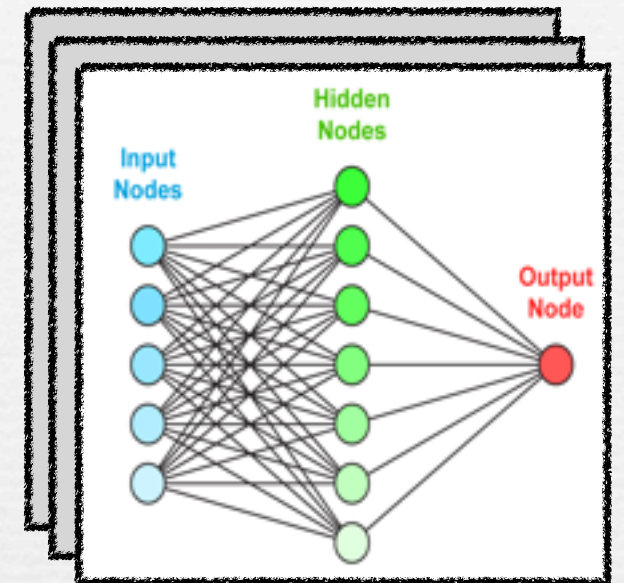
Multivariate Analysis

Bayesian Neural Networks (BNN) multivariate technique is used to discriminate between signal and background.

Three separate BNN training scenarios are studied :

1. **L_V vs. R_V : Signal** - single top sample with right-handed vector coupling i.e, $f_{R_V}^T = 1$
Backgrounds - L_V , W +jets, $t\bar{t}$, Z +jets, diboson, multijets
2. **L_V vs. L_T : Signal** - single top sample with left-handed tensor coupling i.e, $f_{L_T}^T = 1$
Backgrounds - L_V , W +jets, $t\bar{t}$, Z +jets, diboson, multijets
3. **L_V vs. R_T : Signal** - single top sample with right-handed tensor coupling i.e, $f_{R_T}^T = 1$
Backgrounds - L_V , W +jets, $t\bar{t}$, Z +jets, diboson, multijets

*** Analysis is carried out in 6 independent channels based on the number of identified b jets (1 and 2) and jet multiplicity (2, 3 and 4), because the backgrounds are different in each channel.**

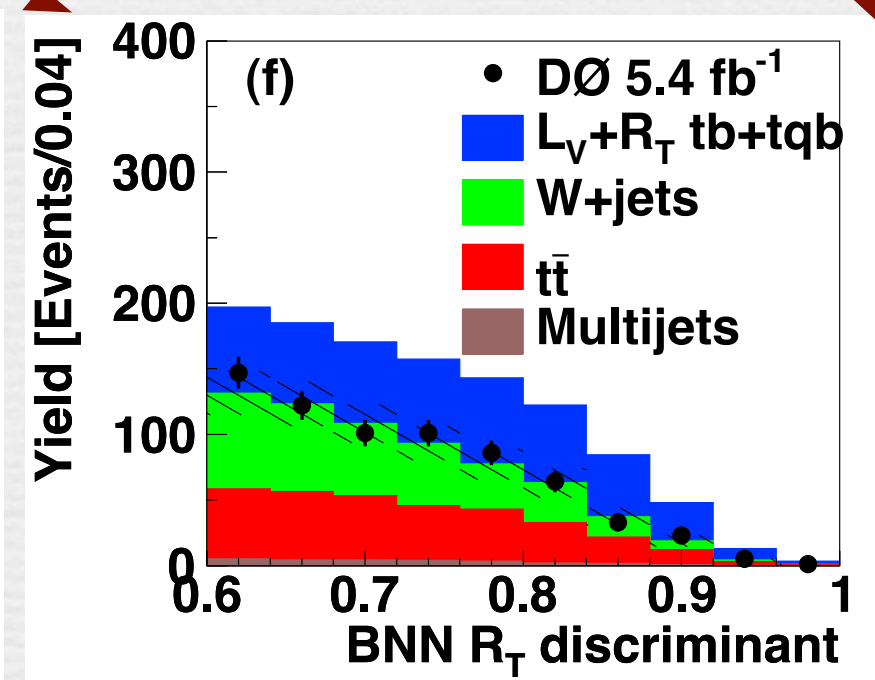
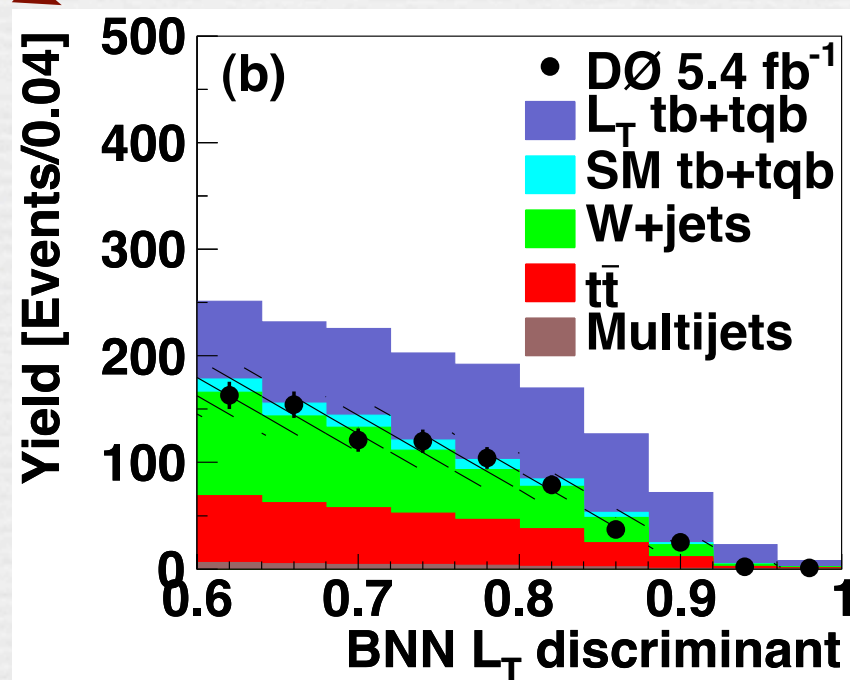
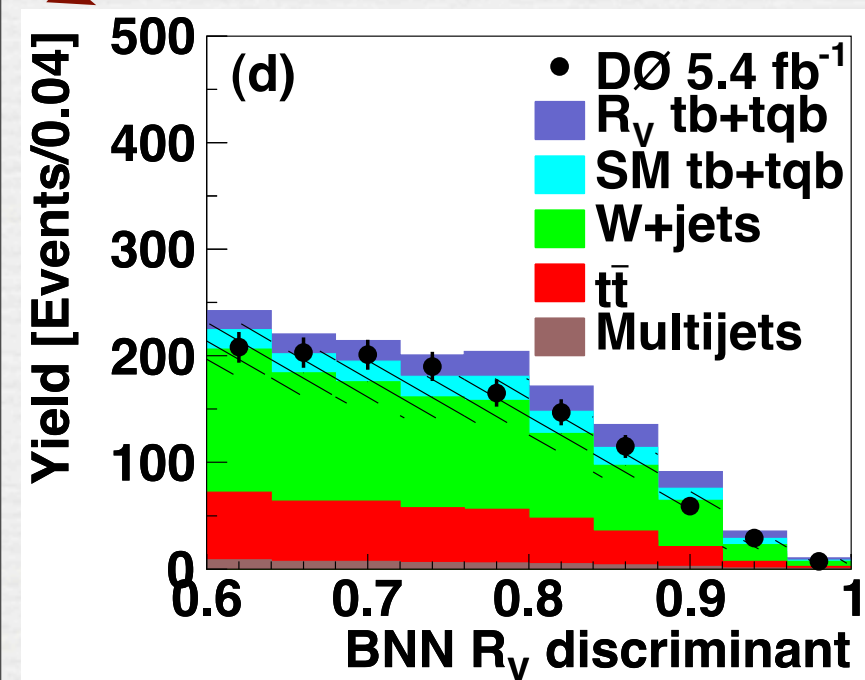
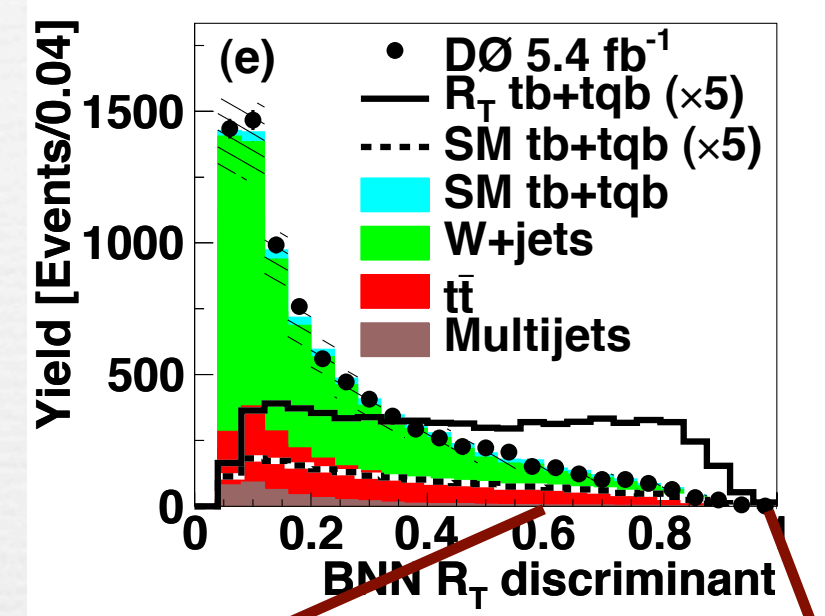
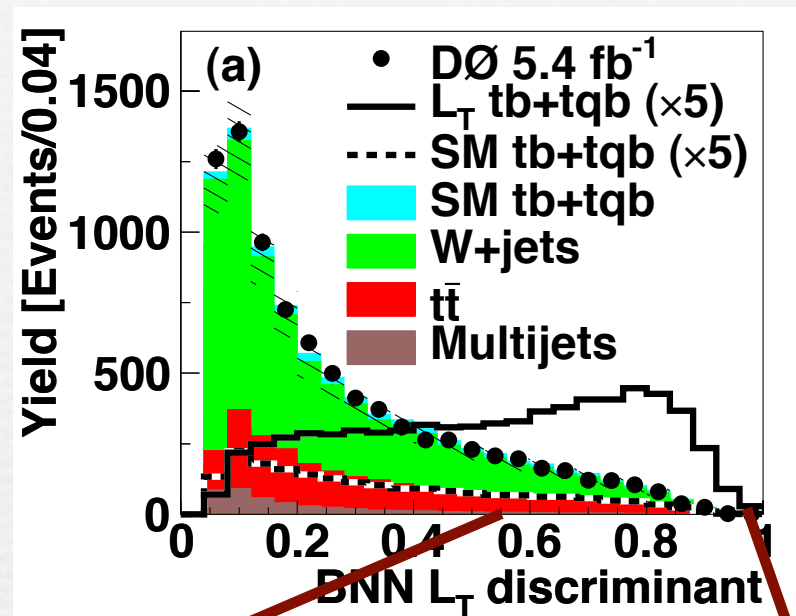
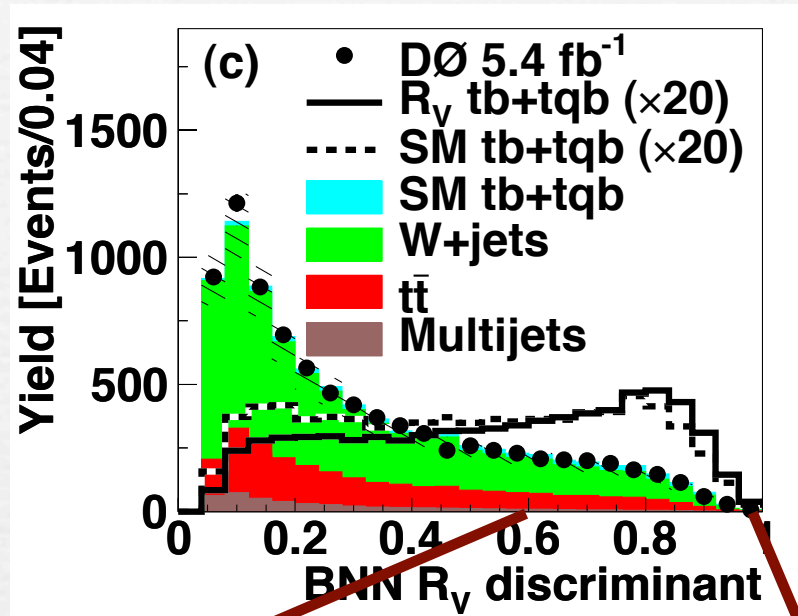


Discriminant Outputs

L_V vs. R_V

L_V vs. L_T

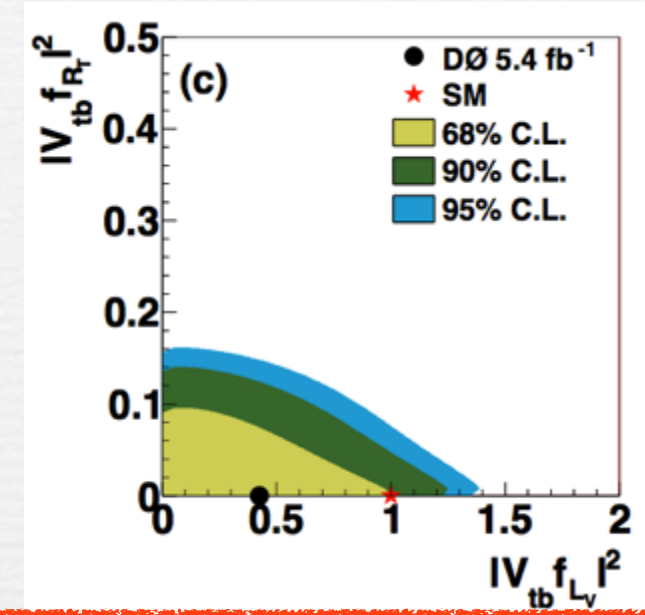
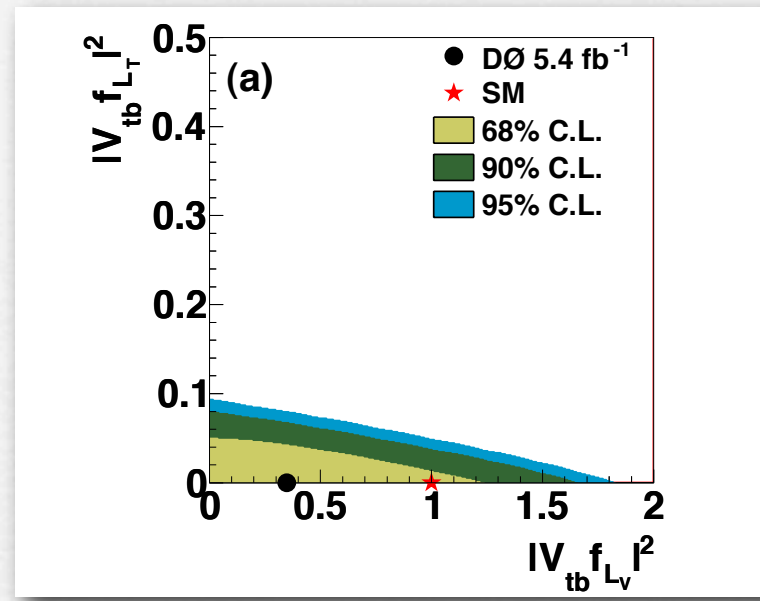
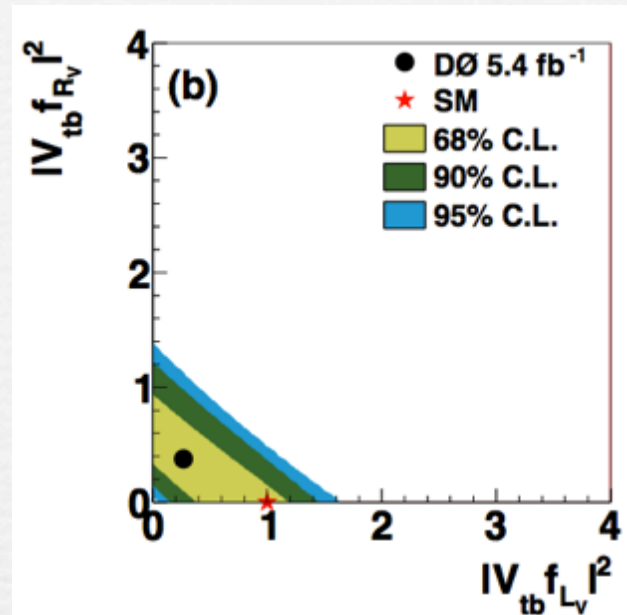
L_V vs. R_T



Limit Calculation

- A Bayesian statistical approach is followed to compare data to the signal predictions given by different anomalous couplings using BNN discriminant output distributions.
- We compute a 2D posterior probability as a function of $|V_{tb} \cdot f_V^L|^2$ and $|V_{tb} \cdot f_X|^2$, where $V_{tb} \cdot f_X$ is one of the two non-SM couplings $X = \{R_V, L_T\}$.
- For the (L_V vs. R_T) scenario, the two couplings interfere and hence to account for the effect of interference a third sample is used for which both couplings $f_V^L = 1$ and $f_T^R = 1$.
- A uniform prior probability of non-negative values of SM and non-SM couplings is used.
- Systematic uncertainties are treated as Gaussian nuisance parameters.
- We do not observe any significant deviations from the SM expectations.
- We compute 95% C.L. upper limits on the anomalous couplings by integrating out the left-handed vector coupling to get a 1-D posterior probability density.

Conclusions



$$|R_V|^2 < 0.93 @ 95\% \text{ C.L.} \quad |L_T|^2 < 0.06 @ 95\% \text{ C.L.} \quad |R_T|^2 < 0.13 @ 95\% \text{ C.L.}$$

PLB 708, 21 (2012)

- Single top quark production provides us with a window onto the top quark electroweak interaction.
- We can also probe for extensions of the electroweak interaction by searching for anomalous single top quark production.
- We find no evidence for anomalous couplings and set 95% C.L. limits on these couplings.
- These limits represents improvements by a factor of approx. 2.5 to 5.0 as compared to the previous limits.