Search for Anomalous Wtb Couplings with 0.9 fb^{-1} of D0 Data

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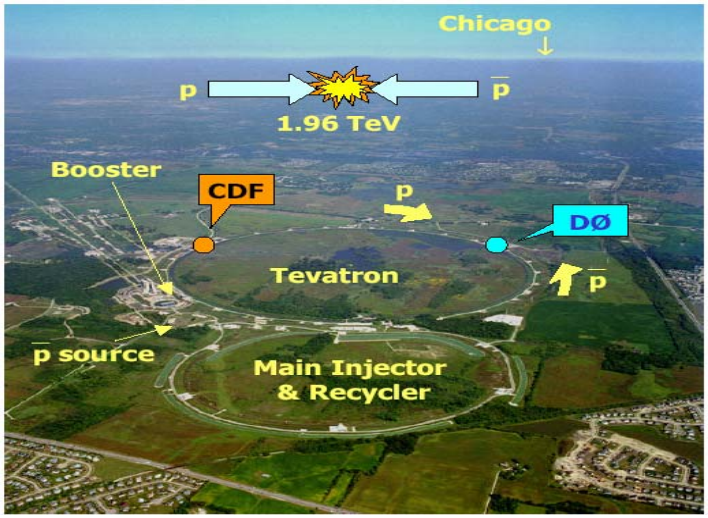
For the D0 Collaboration

PHENO 2008

Tevatron and the D0 Experiment

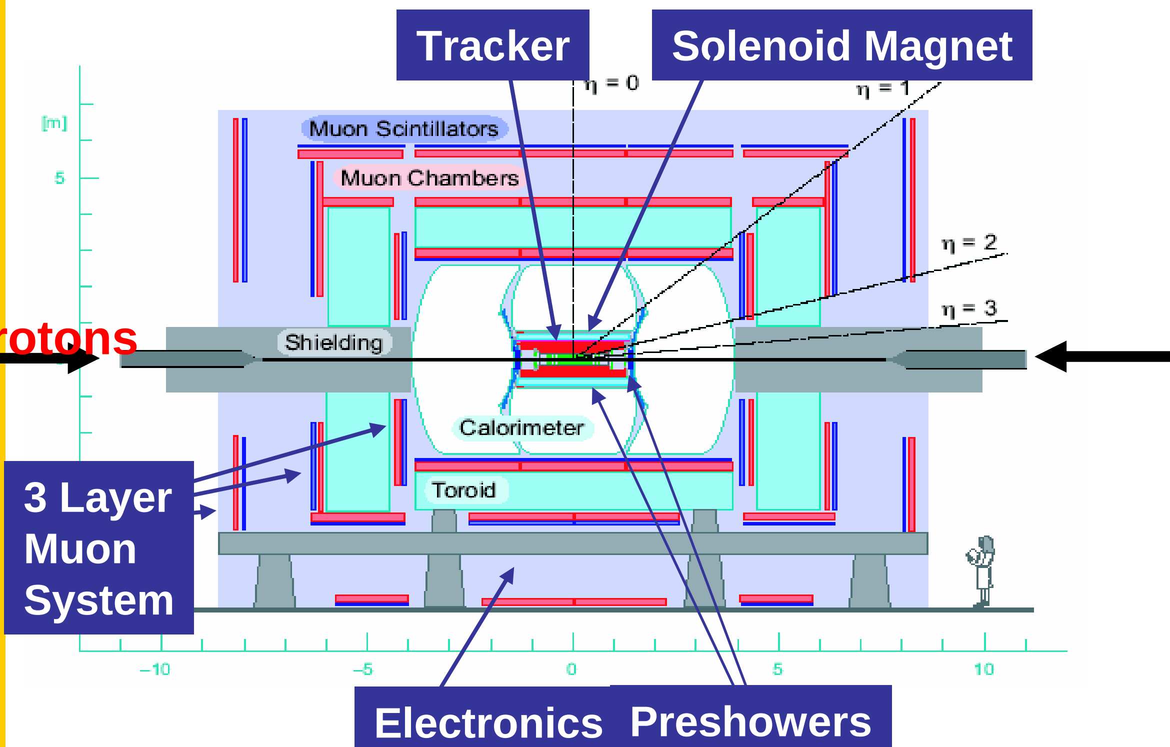


Highest-energy accelerator currently in operation

- Only place where Top quarks can be produced

D0 – Multipurpose detector

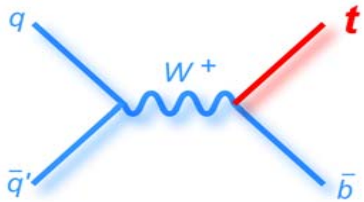
- Silicon and fiber detectors for charged particles tracking, immersed in 2Tsolenoid
- Liquid argon Calorimeter
- Muon system—Wire chambers 1.8 T iron toroid



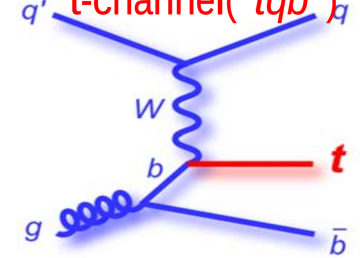
Introduction

- New physics can manifest itself either in terms of
  - new particles or
  - Modified couplings changing the cross-sections of existing processes and angular distributions of SM processes

s-channel(“*tb*”)



t-channel(“*tqb*”)



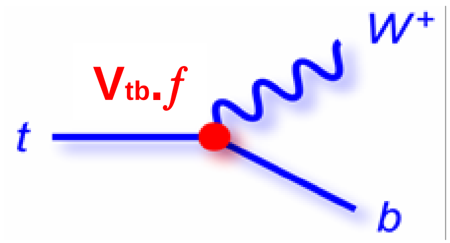
	s-channel	t-channel
Tev:	**σ ~1 pb**	**σ ~ 2pb**
LHC:	**σ ~11 pb**	**σ ~ 235pb**

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 Wtb coupling
- D0 and CDF have recently shown evidence for single top production
- We use same 0.9 fb^{-1} data set and selection cuts to look for anomalous Wtb couplings as was used in D0 single top evidence analysis (Phys. Rev. Lett. 98,181802(2007))

Anomalous Wtb Couplings

- The most general (up to dimension 5) CP-conserving Wtb vertex can be parameterized with the effective Lagrangian given by



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

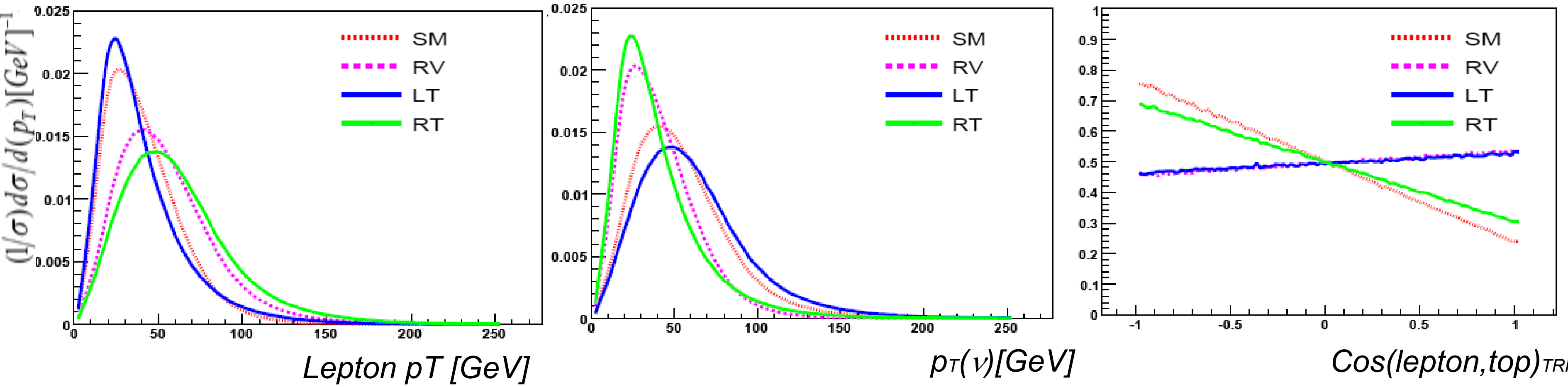
where, $L_{T,V} \simeq V_{tb}.f^{L}_{T,V}$ and $R_{T,V} \simeq V_{tb}.f^{R}_{T,V}$

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

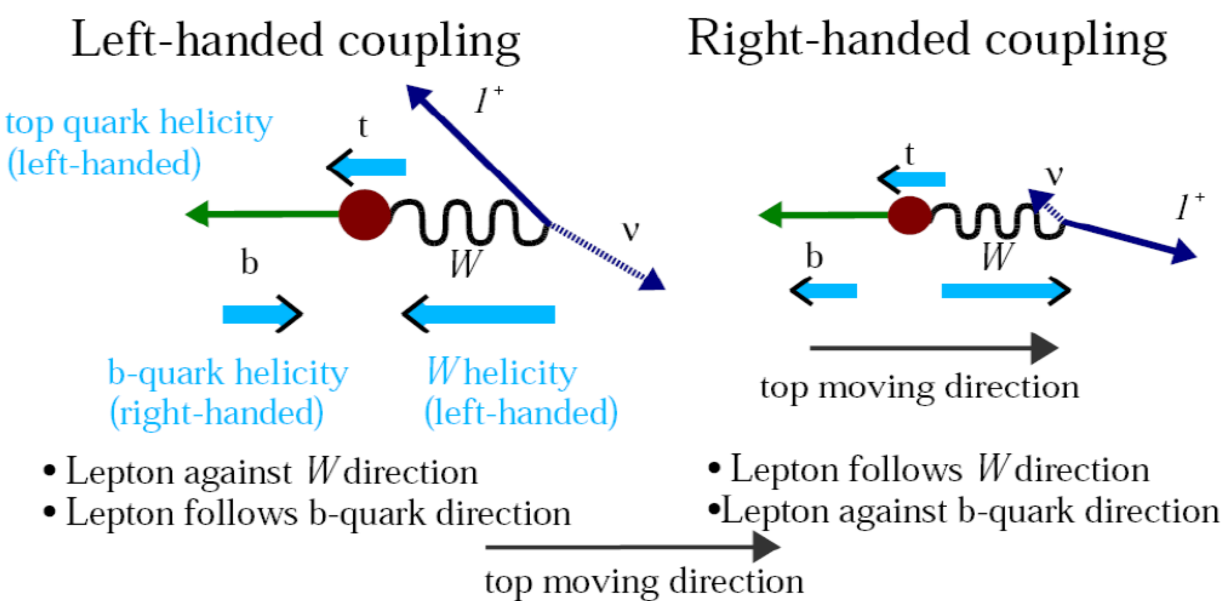
- The size of right handed vector coupling, R_V, is indirectly constrained by the measured rate of $b \to s\gamma$, and has an upper bound of $R_V \leq 0.04$. First direct constraints come from W helicity measurement in top decays in ttbar events.

- There are no experimental constraints on left- and right-handed tensor couplings

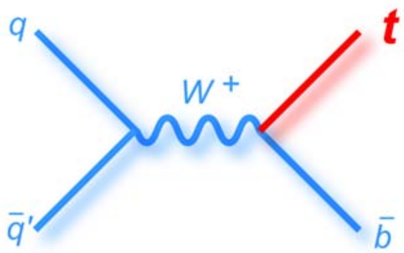
SM vs Anomalous Couplings



Presence of anomalous couplings changes the production cross section, kinematics, and angular distributions



Search Strategy



- Starting from a general Lagrangian with anomalous Couplings, the square of matrix element for leading order *ud−>tb* process, in the limit of $m_b \rightarrow 0$, can be written as:

$$M \cdot M^{\dagger} = a \cdot L_V^2 + b \cdot R_V^2 + c \cdot L_T^2 + d \cdot R_T^2 + e \cdot L_V \cdot L_T + g \cdot R_V \cdot R_T$$

Consider single top production with the
Standard Model (LV) coupling with added contribution from either
- the right-handed vector (RV) coupling, or
- the left-handed tensor (LT) coupling, or
- the right-handed tensor (RT) coupling

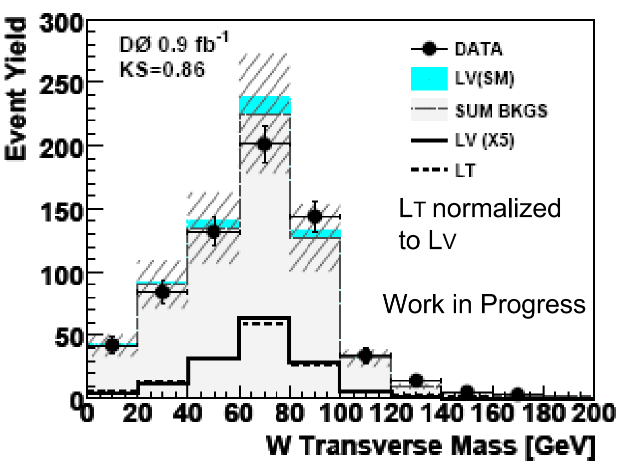
- For each scenario calculate discriminants that separate signal from background
- Calculate 2D posterior probability densities for each scenario

MC Samples & Event Selection

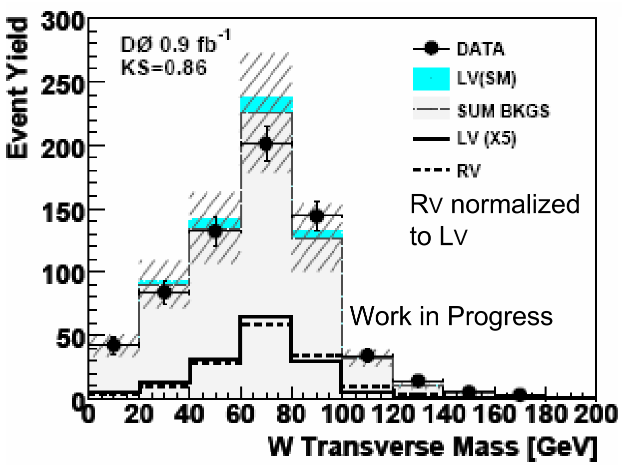
- Single top signal events with anomalous couplings are generated with the CompHEP-SingleTop Monte Carlo event generator
- The background samples W+jets and ttbar events, are generated using ALPGEN with a jet matching algorithm. The multijet background is modeled using a data sample designed to contain mis-identified leptons.

- Select one isolated electron or muon with p_T>15 GeV, Missing E_T >15 GeV, 2-4 jets with at least one b-tagged jet

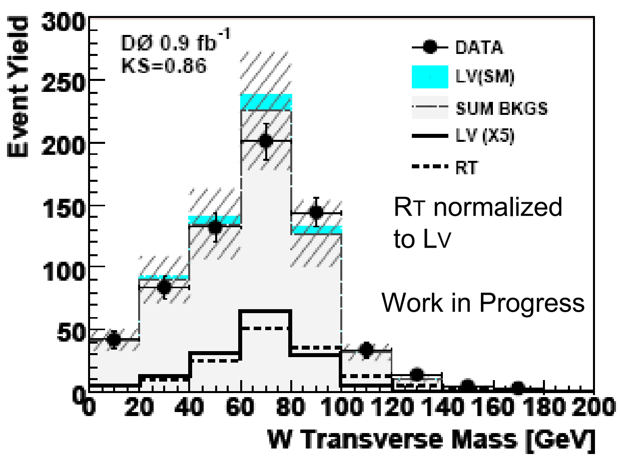
L_V-L_T SCENARIO



L_V-R_V SCENARIO

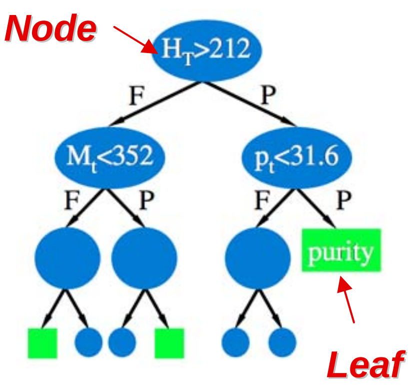


L_V-R_T SCENARIO



Multivariate Analysis

- Use Boosted Decision Trees (DT) multivariate technique to discriminate signal from background
- For every analysis train 2 signals against sum of backgrounds, 2,3,4 jets combined, with same input variables as for single top analysis

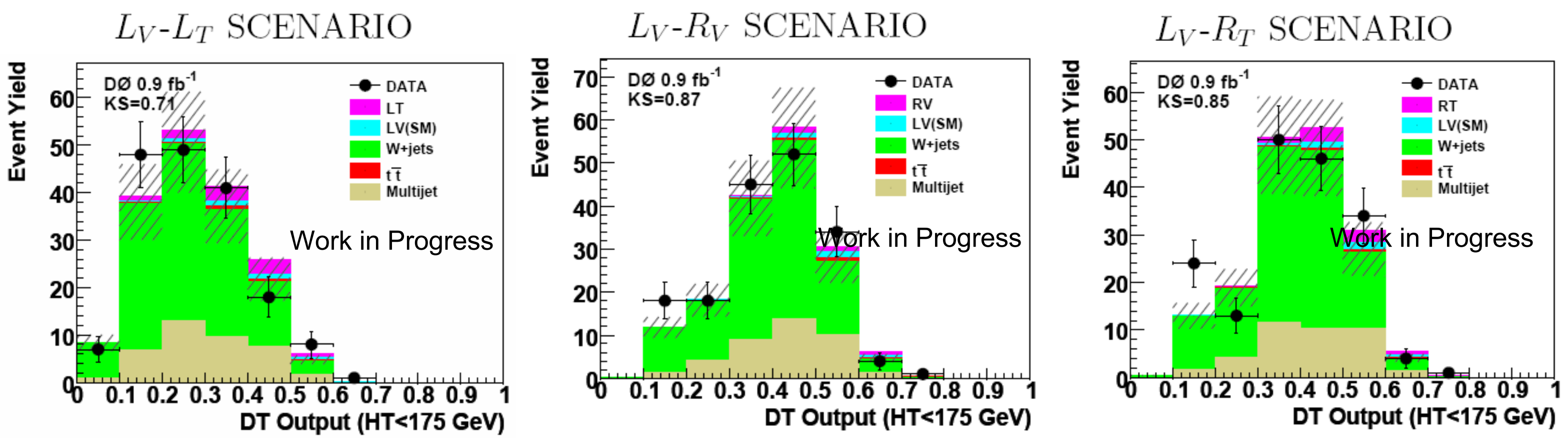


- *L_V-R_V* Scenario.
  - -SM single top with left handed vector coupling only:*(tb + tqb)L_V*
  - -Anomalous single top with right handed vector coupling only:*(tb + tqb)R_V*
- *L_V-R_T* Scenario.
  - -SM single top with left handed vector coupling only:*(tb + tqb)L_V*
  - -Anomalous single top with right handed tensor coupling only:*(tb + tqb)R_T*
- *L_V-L_T* Scenario.
  - -SM single top with left handed vector coupling only:*(tb + tqb)L_V*
  - -Anomalous single top with left handed tensor coupling only:*(tb + tqb)L_T*
  - -Anomalous single top with left handed tensor coupling only:*(tb + tqb)L_V+L_T*

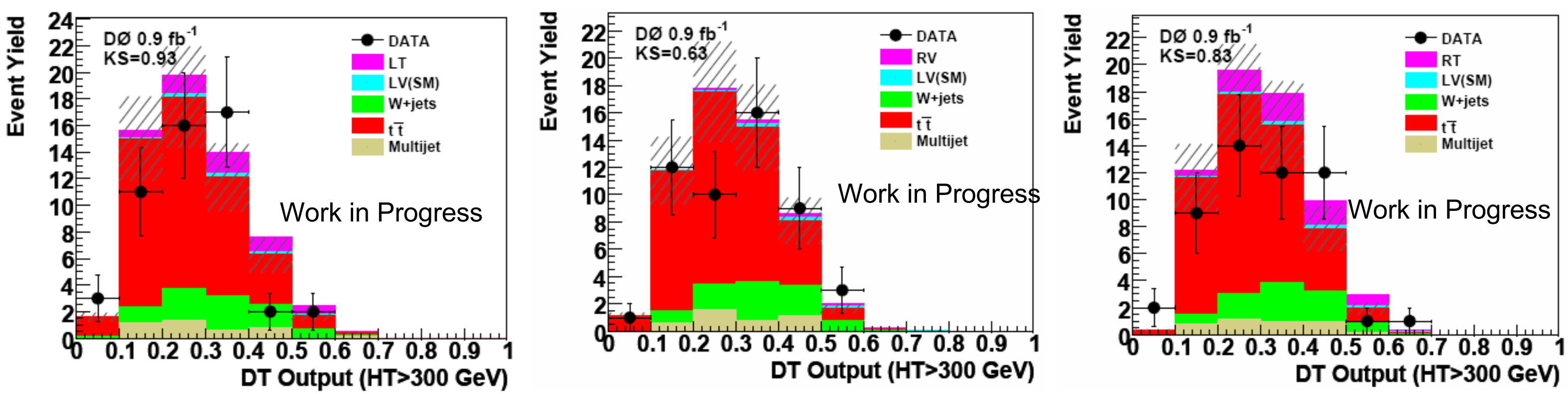
4 different trees for each scenario (2 lepton × 2 *b*-tag choices)

DT Output for Bkgnd Like Samples

W+jets like sample: 2 jets, 1 tag, HT(lepton,MET,all jets)<175GeV

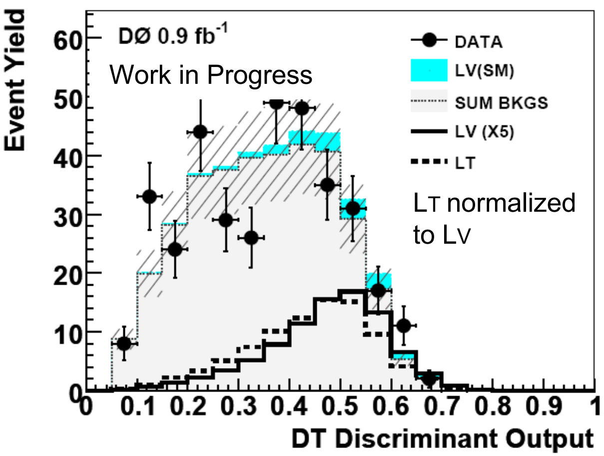


ttbar like sample = 4 jets, =1 tag HT(lepton,MET,all jets)>300GeV

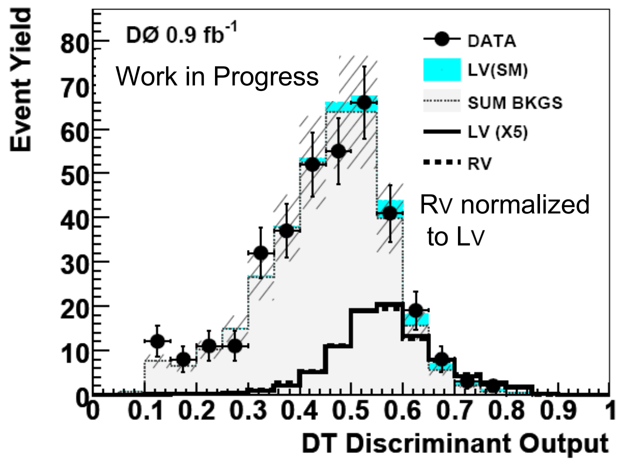


Within uncertainties, data is consistent with background model in background dominated regions

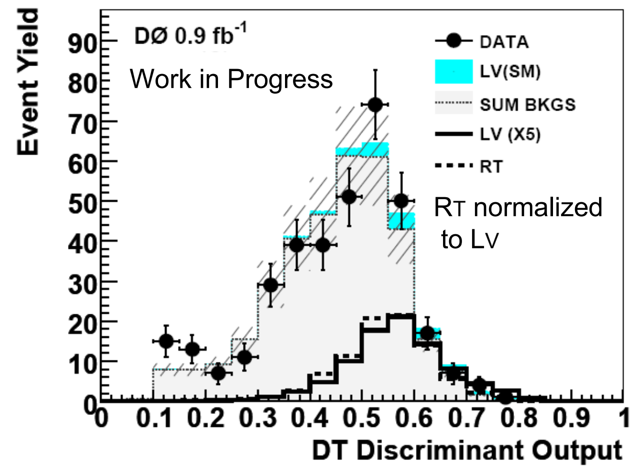
Boosted Decision Trees Output



L_V-L_T SCENARIO



L_V-R_V SCENARIO



L_V-R_T SCENARIO

Cross Section Measurement

Binned likelihood from discriminant distribution

- Compute posterior probability density of two single top signals using Bayes' theorem:
  - Flat positive-defined prior for the cross section
  - Systematic uncertainties are treated as Gaussian nuisance parameters

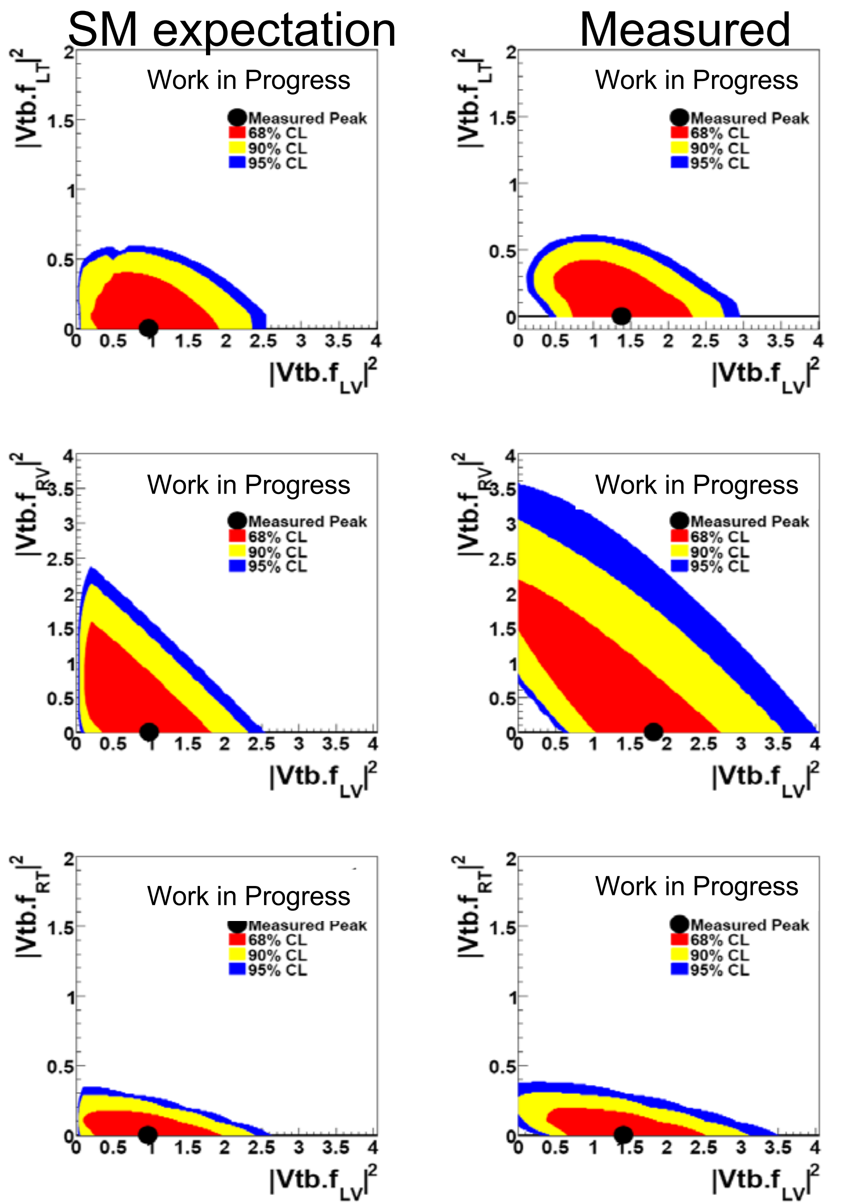
12 distributions with 100 bins each that go into this calculation for each scenario

Summary of Results

- Simultaneous limit setting for two signals by calculating 2D posterior probability density

- Cross-sections are calculated in e,mu,2,3,4 jets,1,2 tag channels and then combined. Same for limits on $|V_{tb}.f|^2$

- Peak of the 2D distribution corresponds to measured cross-section and 1D projection of posterior densities is used to set limit on individual couplings and cross sections



Conclusion

- We looked for any deviations from standard model by looking at the Wtb vertex in single top production, where anomalous couplings can change angular distributions, as well as production cross section

- From two dimensional posterior density distributions we measure cross sections and set limits on each coupling

- Data seem to prefer standard model left coupling over right vector, or right or left tensor coupling

- Work in progress – results will be finalized soon

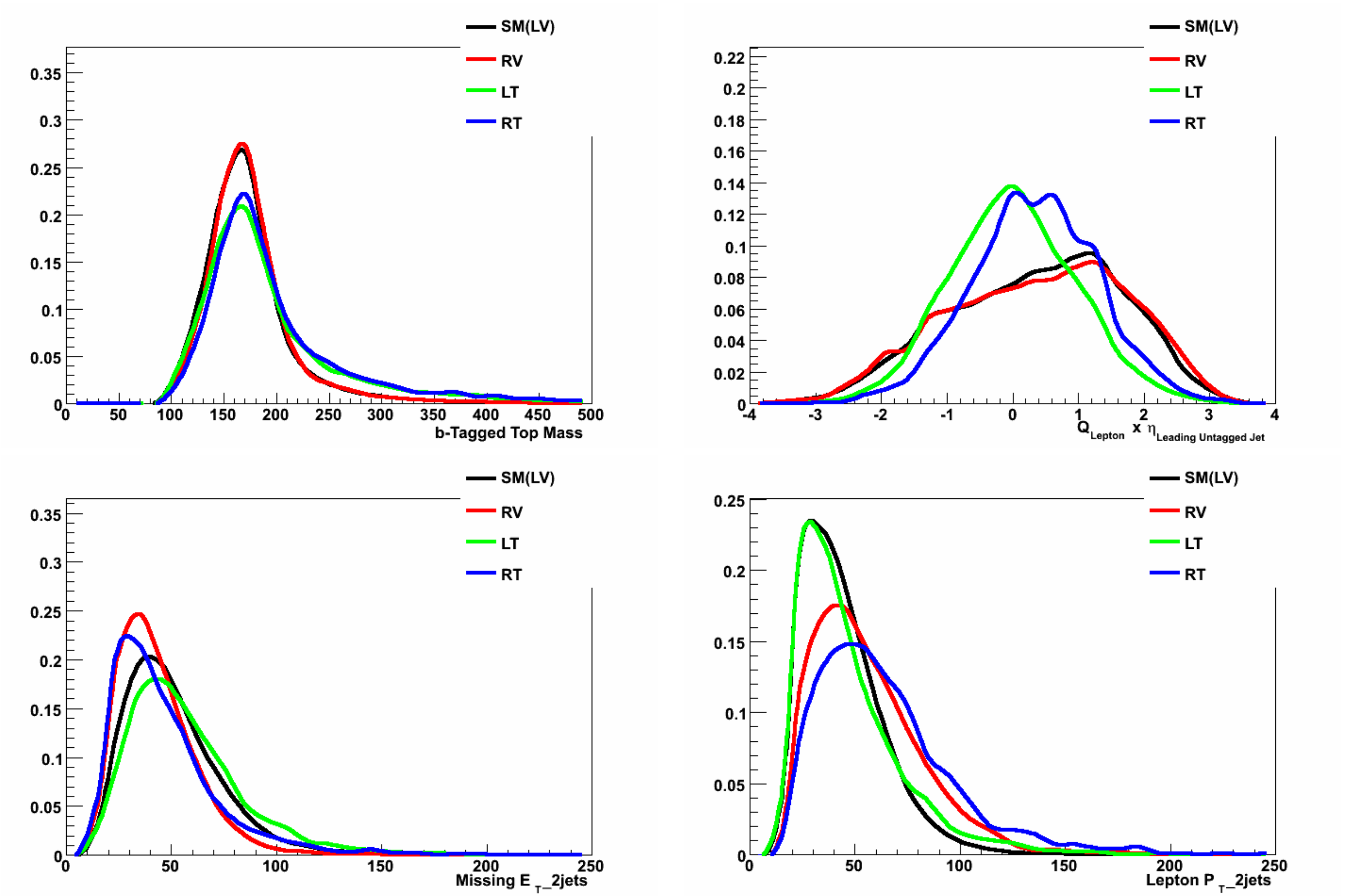
Signal Acceptance

Signal Acceptances

Signals	Electron Channel Single tag	Electron Channel Double tag	Muon Channel Single tag	Muon Channel Double tag
LH Vector (LV)				
tb_{LV}	1.3 ± 0.1 %	0.47 ± 0.08 %	1.0 ± 0.2 %	0.40 ± 0.08 %
tqb_{LV}	1.1 ± 0.1 %	0.09 ± 0.02 %	0.9 ± 0.1 %	0.07 ± 0.01 %
LH Tensor(LT)				
tb_{LT}	1.2 ± 0.1 %	0.48 ± 0.08 %	1.1 ± 0.2 %	0.45 ± 0.09 %
tqb_{LT}	1.1 ± 0.1 %	0.10 ± 0.02 %	0.9 ± 0.2 %	0.09 ± 0.02 %
$LV + LT$				
tb_{LV+LT}	1.2 ± 0.1 %	0.48 ± 0.08 %	1.1 ± 0.2 %	0.47 ± 0.09 %
tqb_{LV+LT}	1.0 ± 0.1 %	0.09 ± 0.02 %	0.9 ± 0.1 %	0.08 ± 0.02 %
RH Vector(RV)				
tb_{RV}	1.3 ± 0.2 %	0.45 ± 0.08 %	1.1 ± 0.2 %	0.42 ± 0.08 %
tqb_{RV}	1.1 ± 0.1 %	0.09 ± 0.02 %	0.9 ± 0.2 %	0.08 ± 0.02 %
RH Tensor(RT)				
tb_{RT}	1.5 ± 0.2 %	0.60 ± 0.01 %	1.3 ± 0.2 %	0.53 ± 0.11 %
tqb_{RT}	1.1 ± 0.1 %	0.10 ± 0.02 %	0.9 ± 0.2 %	0.09 ± 0.02 %

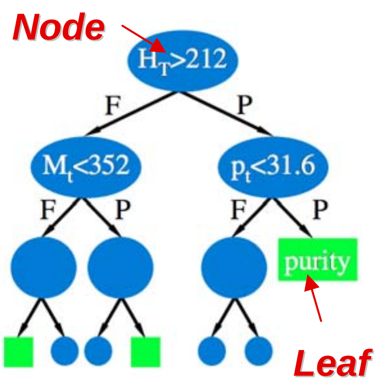
Acceptances for anomalous production are very similar to standard model single top

Some Input Variables



Boosted Decision Trees

- Machine-learning technique, widely used in social sciences, some use in HEP
  - Start at first "node " : For each variable, find splitting value with best separation between two children (mostly signal in one, mostly background in the other)
  - Select variable and splitting value with best separation to produce two "branches". Repeat recursively on each node
  - Stop when improvement stops or when too few events are left Decision tree output for each event = leaf purity closer to 1(0) for signal (background)



$$Purity = \frac{N_{Signal}}{N_{Signal} + N_{Background}}$$

- Improve performance of DT by using adaptive boosting , which averages over many trees, diluting the piecewise nature of the DT output