Model-Independent measurement of the t-channel single top quark production cross-section at D0

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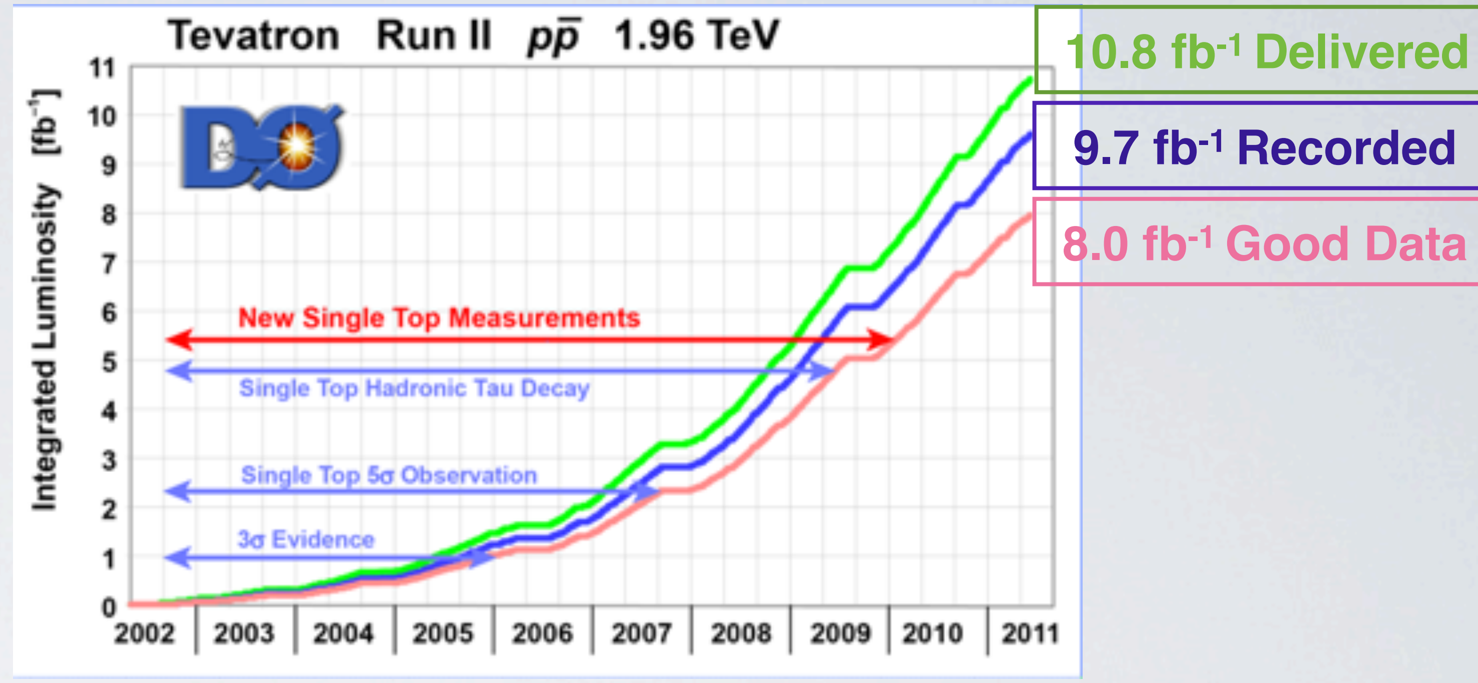
Outlines :

* Tevatron and D0 Detector
* Single Top Production
* Event Selection
* Challenge involved and Motivation
* Signal and background Modeling
* MVA Techniques
* Cross-section Measurement
* Systematic Uncertainties
* Combined Result

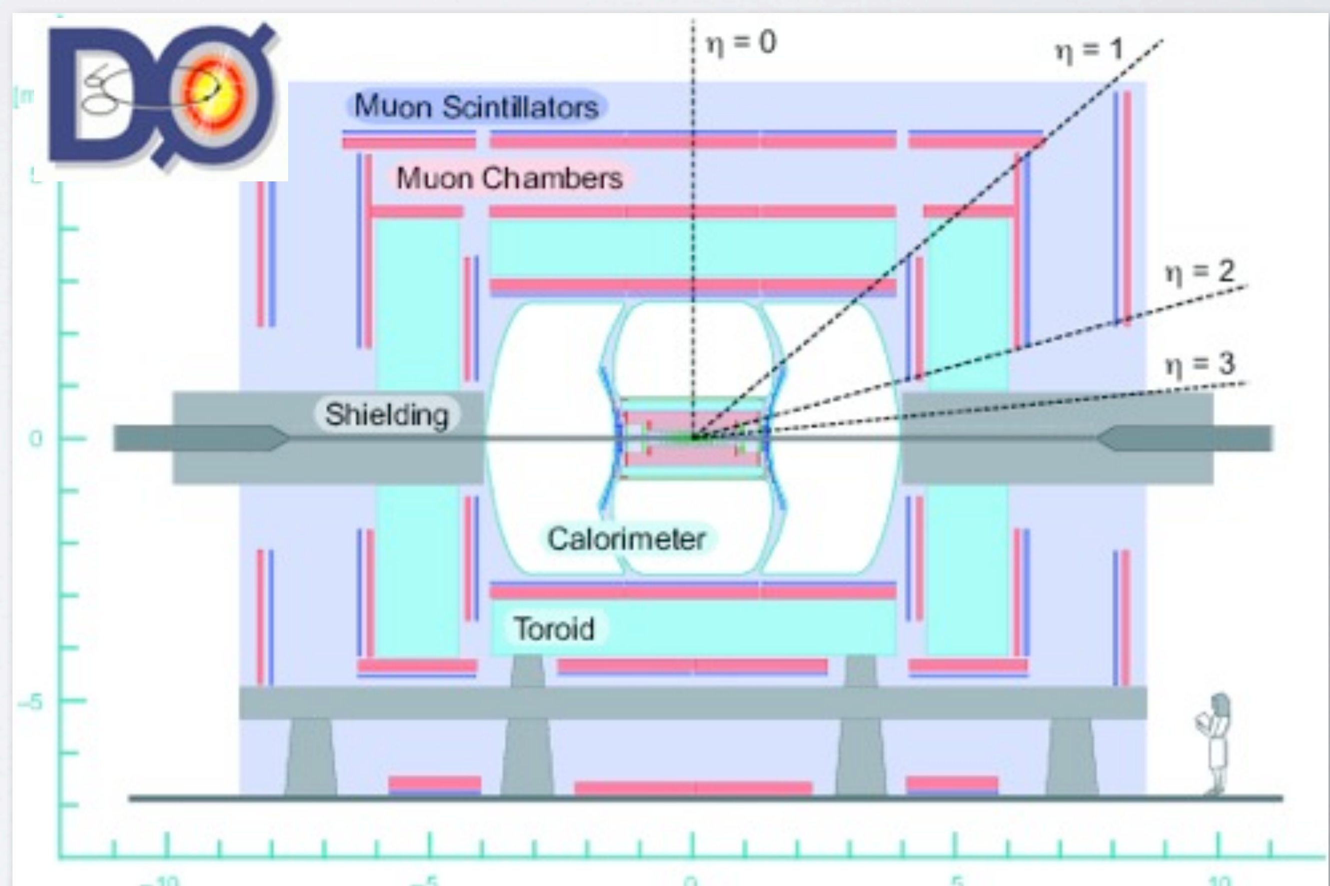
Tevatron Collider and DZero Detector



The Tevatron Collider

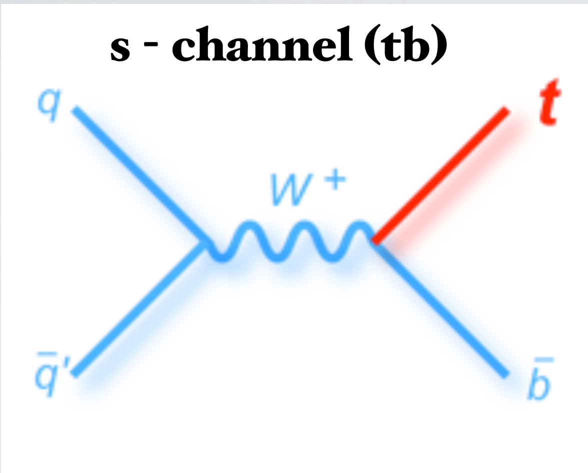
- Proton-antiproton collider with center of mass energy, $\sqrt{s}$= 1.96 TeV.
- 36x36 bunches with 396 ns between crossing.
- Inst. luminosity ~$3x10^{32}cm^{-2}s^{-1}$.
- Target of recording 10 fb^{-1} till the end of this fiscal year.

The DØ detector is a multi-purpose particle detector to study interactions originating from proton-antiproton collisions at the Tevatron Collider at Fermilab.

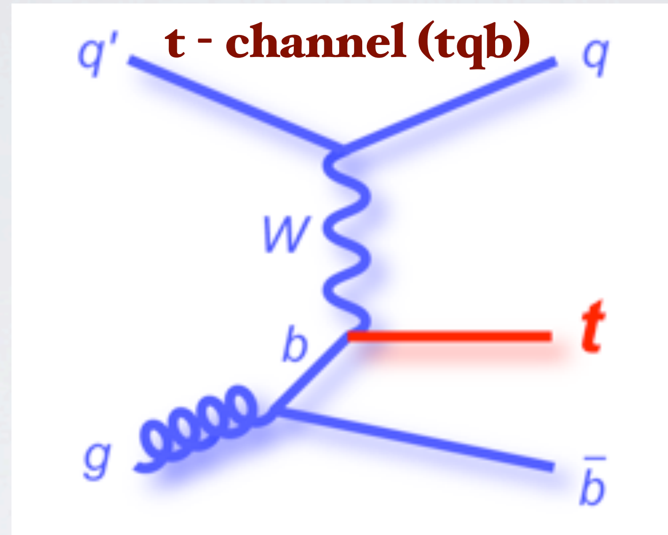


Single Top Quark Production

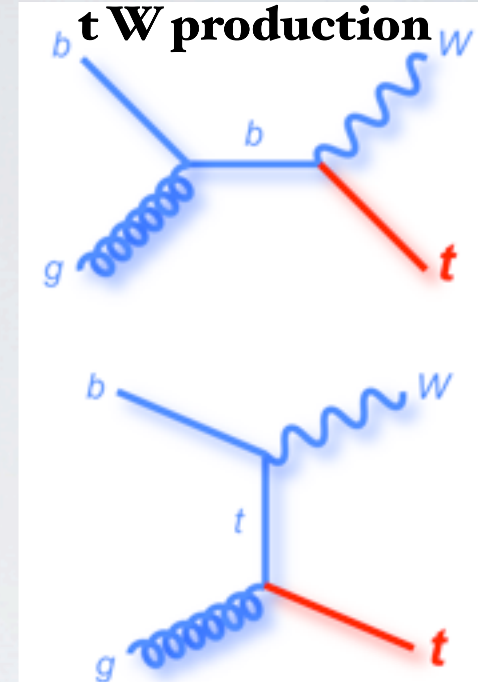
Three modes via which Single Top can be produced in Hadron Colliders.



σ_{SM} = 1.04 ± 0.04 pb



σ_{SM} = 2.26 ± 0.12 pb

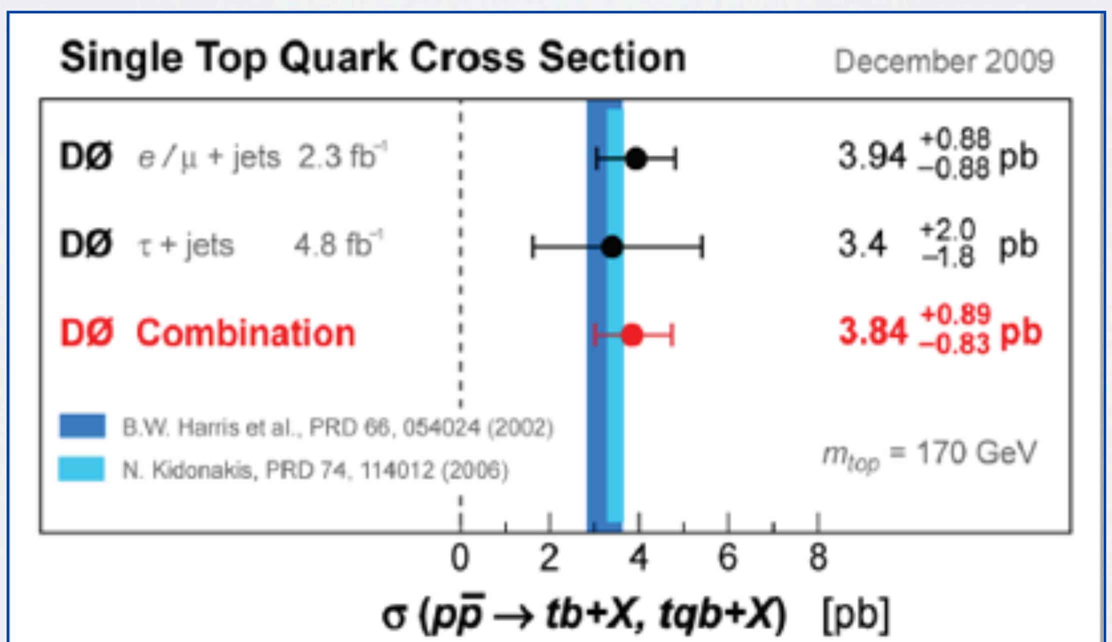


σ_{SM} = 0.29 ± 0.06 pb

To small to see at the Tevatron

Top Mass = 172.5 Gev; σ = (N)NLO pb
N. Kidonakis, PRD 74, 114012 (2006)

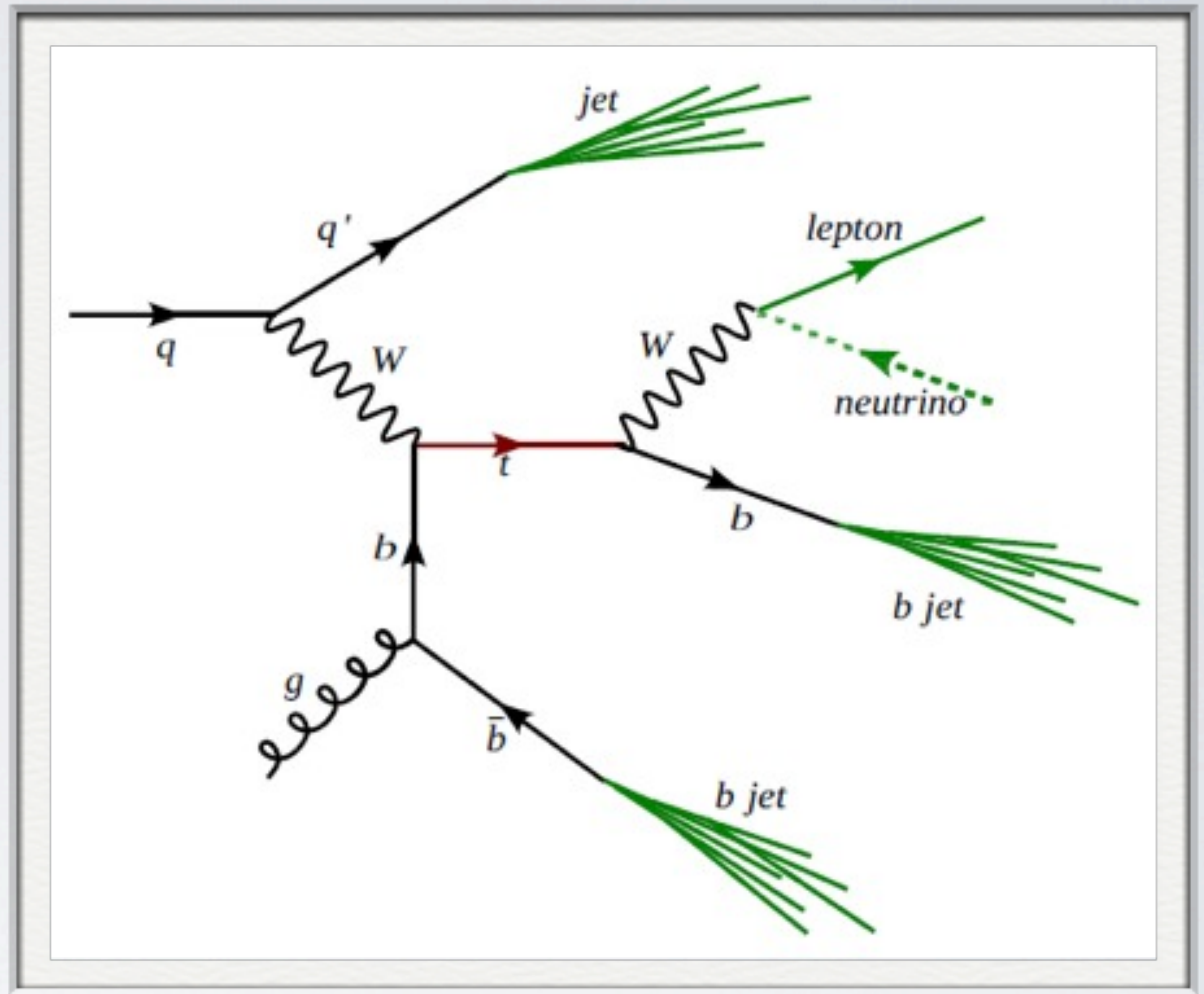
Result till 2009



5σ Observation with uncertainty of 22% (with 18% statistical and 13% systematics)

Event Signatures and Selection

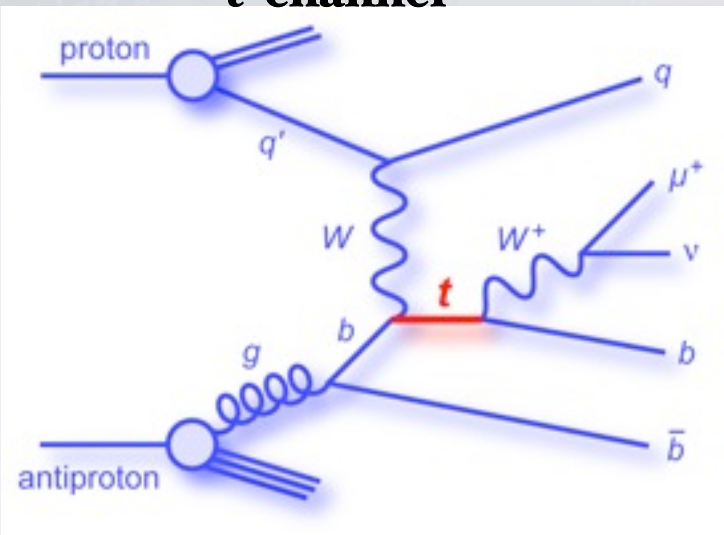
- **One High p_T isolated Lepton**
  - **Electron Selection** - $p_T > 15$ GeV, $|\eta| < 1.1$
  - **Muon Selection** - $p_T > 15$ GeV, $|\eta| < 2.0$
- **Large Missing transverse energy**
  - 15 GeV < MET < 200 GeV
- **Two, three and four jets**
  - $p_T > 25$ GeV (jet1), $p_T > 15$ GeV (other jets)
  - $|\eta| < 3.4$
- **Total Transverse Energy**
  - H_T > 120 - 160 GeV
- **B-Tagging Selection**
  - One ''tight'' jets or Two ''loose'' jets originating from fragmentation of b quarks.



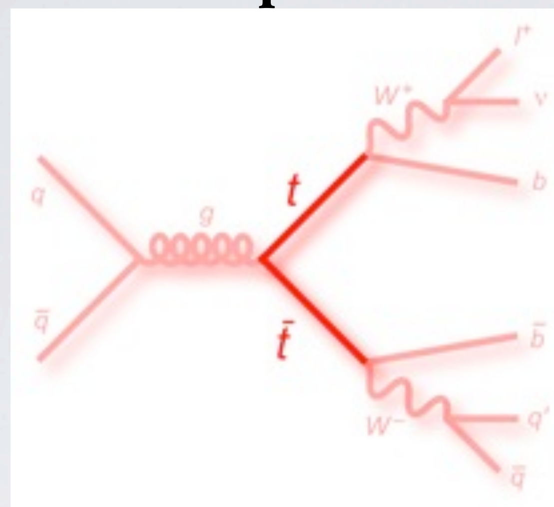
$\sigma_{SM} = 2.26 \pm 0.12$ pb

Challenge and Motivation of the analysis

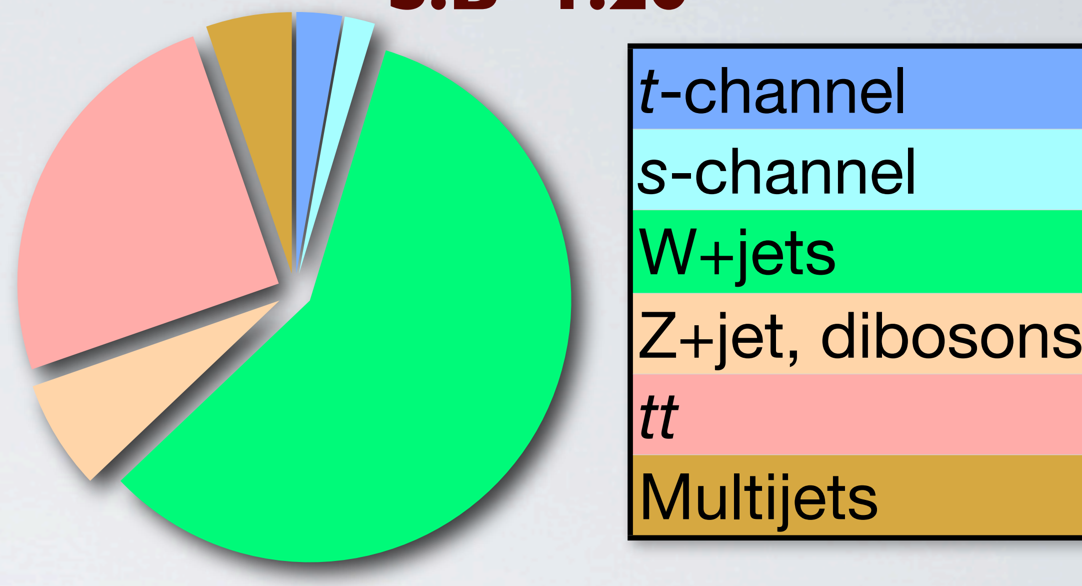
t-channel



Top Pairs

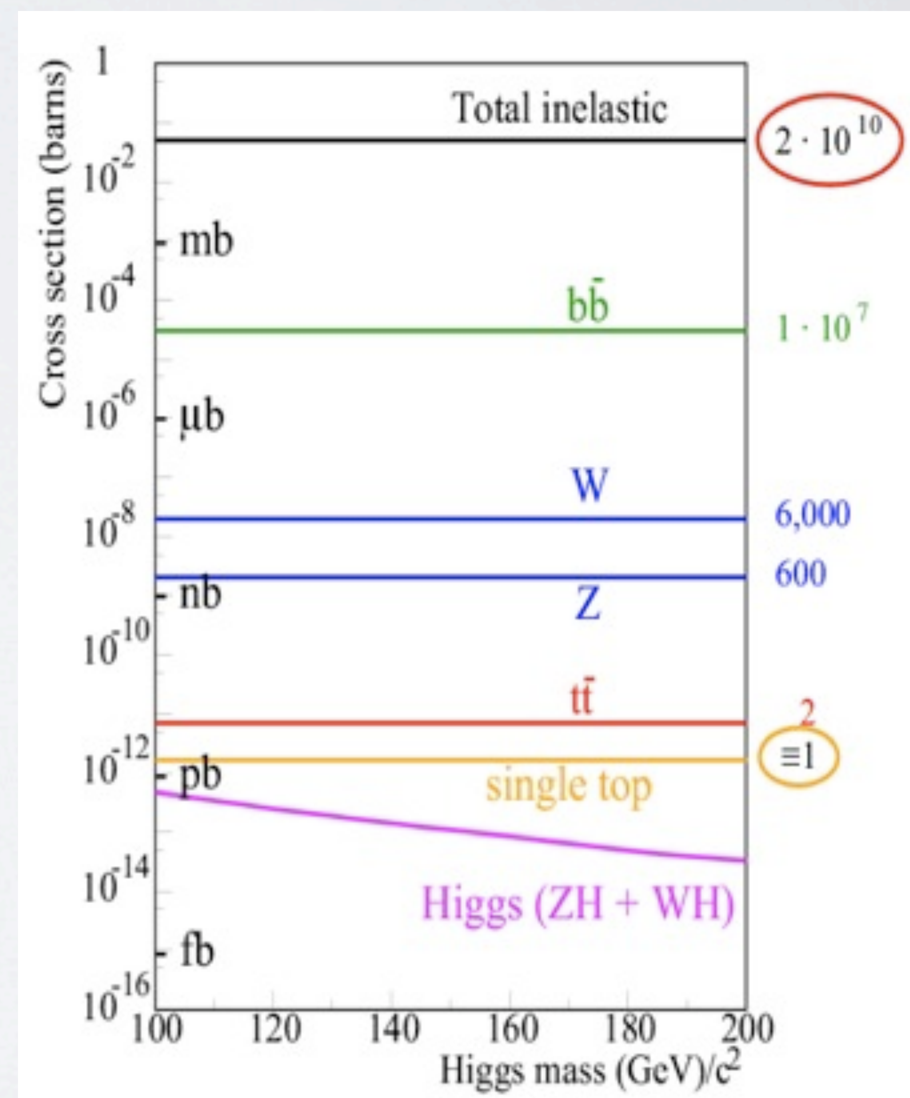


S:B~1:20



Experimentally Very Challenging :

- Smaller cross section as compared to top pair production
- Mostly found in events with two and three jets.
- Background dominated after b-jet identification S:B ~ 1:20
- ttbar, multijets, W+jets backgrounds mimics signal signature

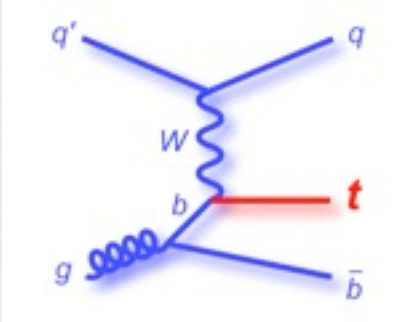


Motivation of studying single top:

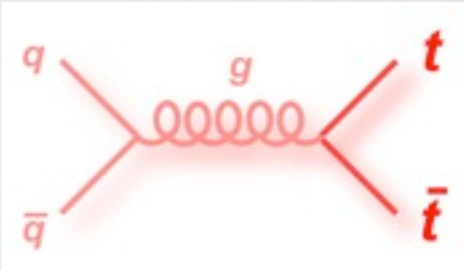
- ☆ Sensitive to many beyond SM processes. t-channel process is sensitive to flavor-changing neutral currents (FCNC) and fourth generation quark.
- ☆ Direct Probe of the Wtb interaction with no assumption on the number of quark families or unitarity of the CKM matrix.

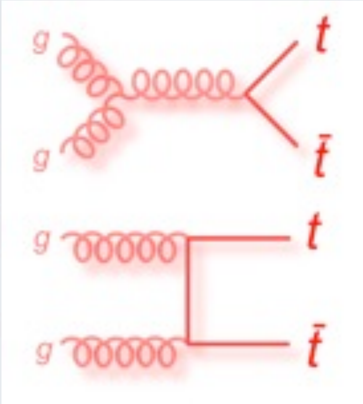
Signal and Background Modeling

- Single Top Signal events are modeled using SINGLETOP
  - Based on COMPHEP
  - PYTHIA for parton hadronization

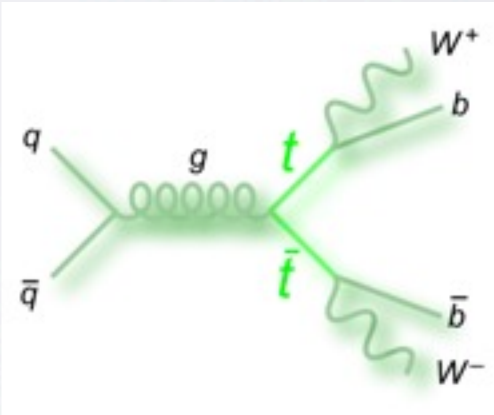


- Top pair background is modeled using APLGEN event generator and PYTHIA for parton hadrinization.

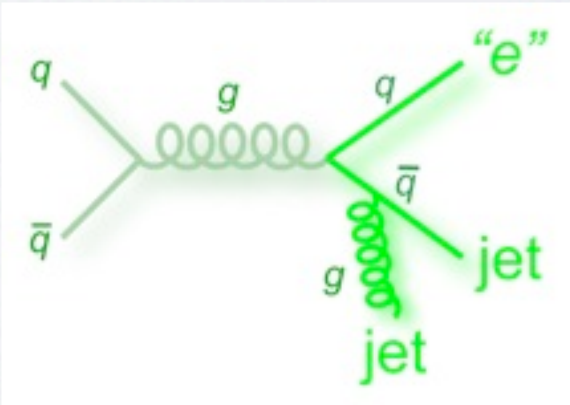




- W+jets modeled using ALPGEN+PYTHIA. Dominant background for single top.



- Multijet background is modeled directly from data.
- Z+jets is modeled using ALPGEN+PYTHIA.
- Dibosons are modeled with PYTHIA.



Event Yields after b-tagging

Background dominated after b-jet identification

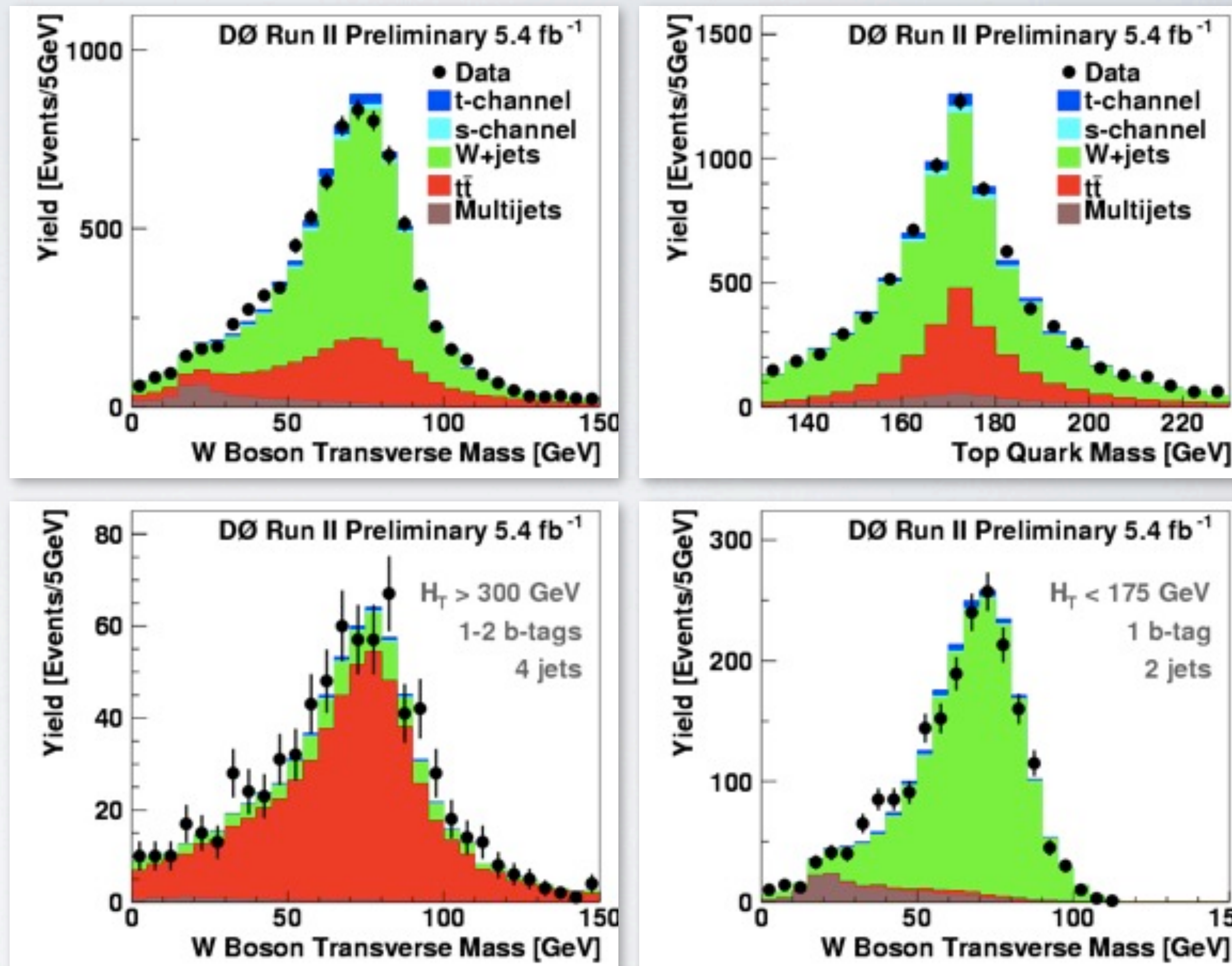
S:B~1:35 (t-channel)

preliminary

Event Yields in 5.4 fb^{-1} of DØ Data

e,μ, 2,3,4-jets, 1,2-tags combined

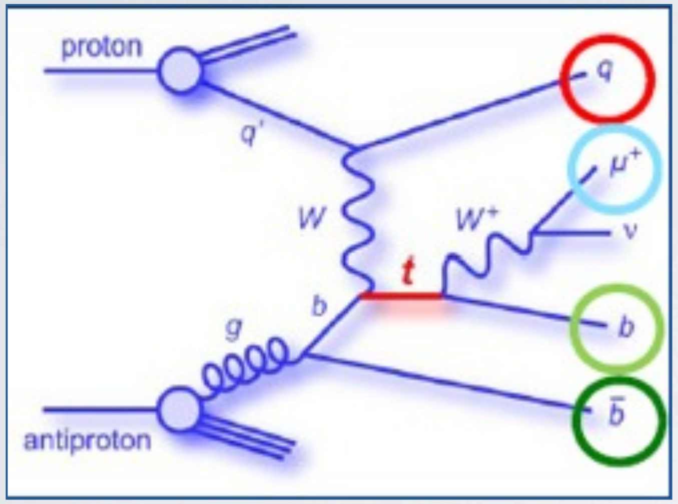
tqb	239 ± 28
tb	160 ± 27
W+jets	4,943 ± 598
Z+jets, dibosons	576 ± x113
$t\bar{t}$ pairs	2,124 ± 383
Multijets	451 ± 56
Total prediction	**8,492 ± 987**
Data	**8,471**

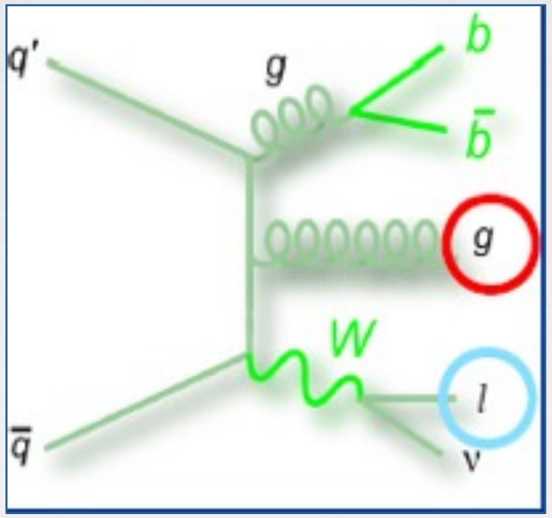


Tuesday, May 10, 2011

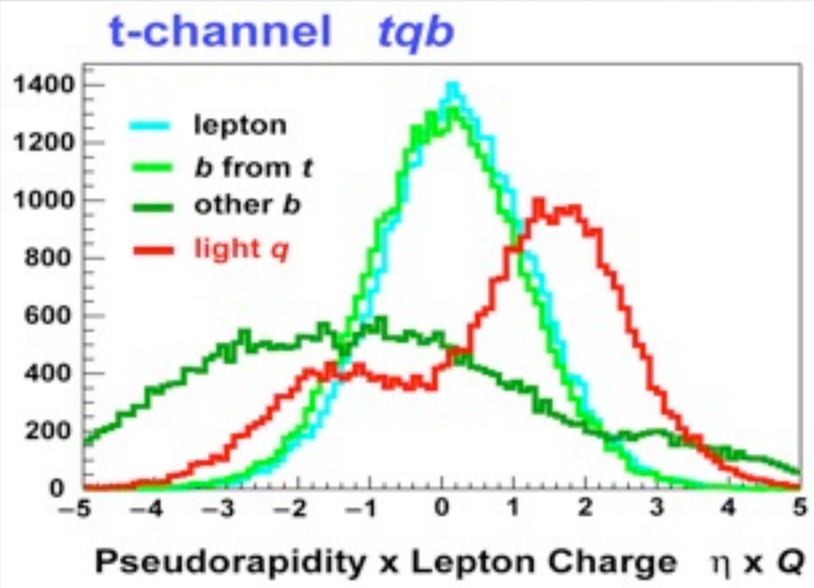
Multivariate Analysis

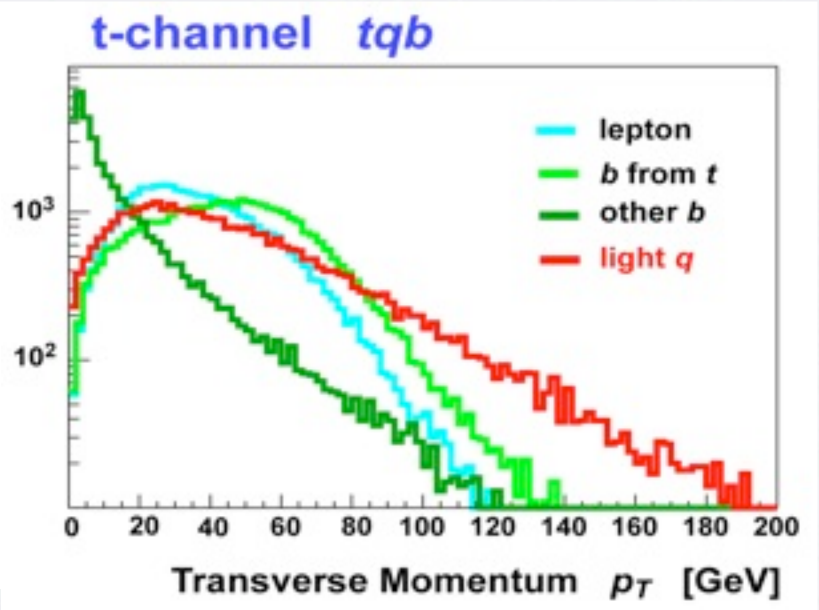
➢ **Exploit kinematic differences between signal and background. Three Multivariate Analysis Techniques are used to separate signal from background. Combined different distribution with some discrimination power in one variable with larger discrimination.**

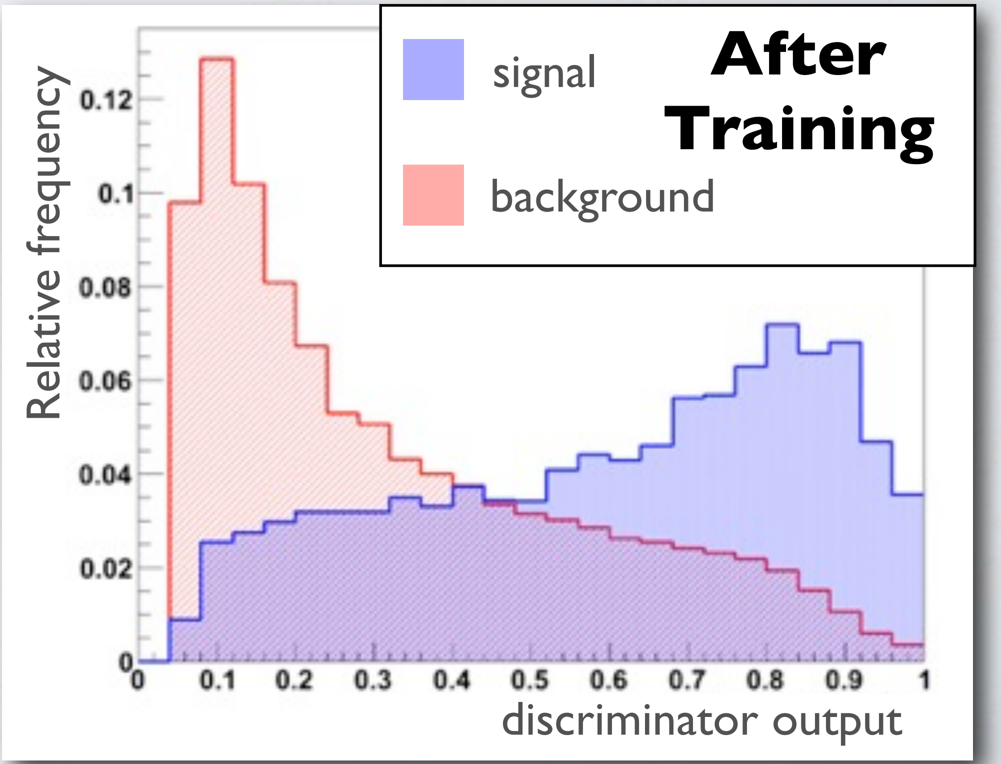




Even though final states of signal and background are consistent of the same particle types, MVA can extract the signal due to characteristics shape of variables with high discriminating power.



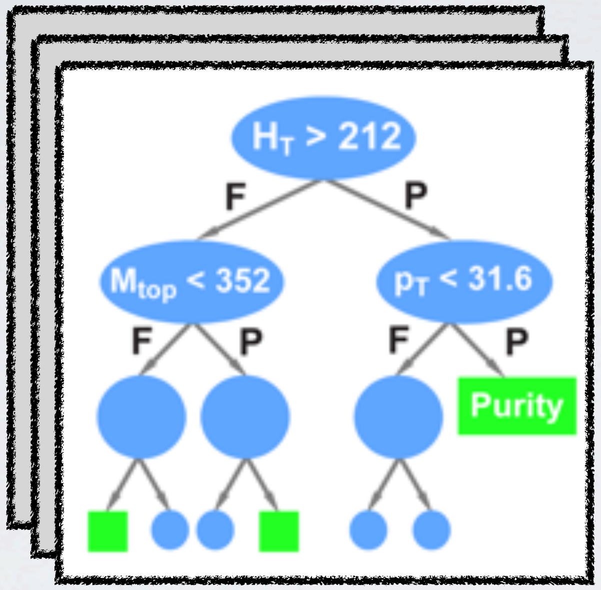




Multivariate Techniques Used

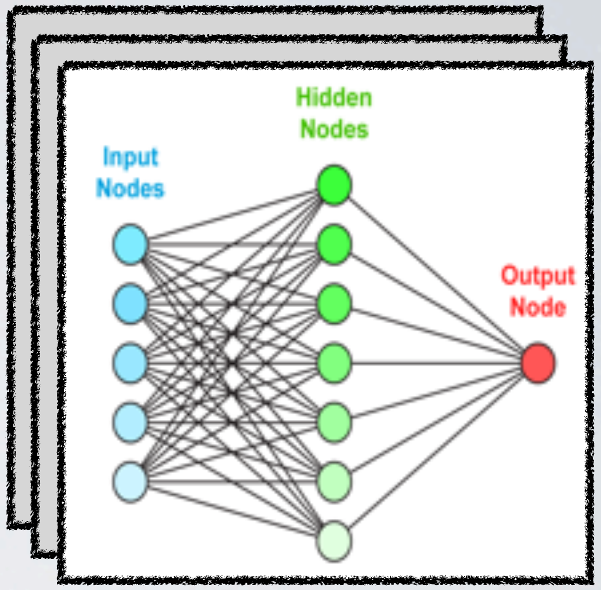
Boosted Decision Tree (BDT)

- Apply sequential cuts keeping failing events.
- Performance is boosted by averaging multiple tree produced by enhancing misclassified events.



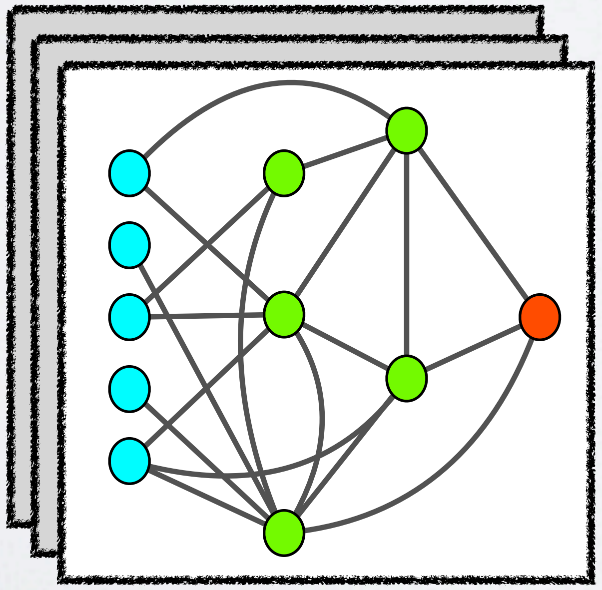
Neural Networks (NN)

- NN train on signal and background, producing one output discriminant.
- Bayesian NN (BNN) average over many networks, improving the performance.



Neuroevolution of Augmenting Topologies (NEAT)

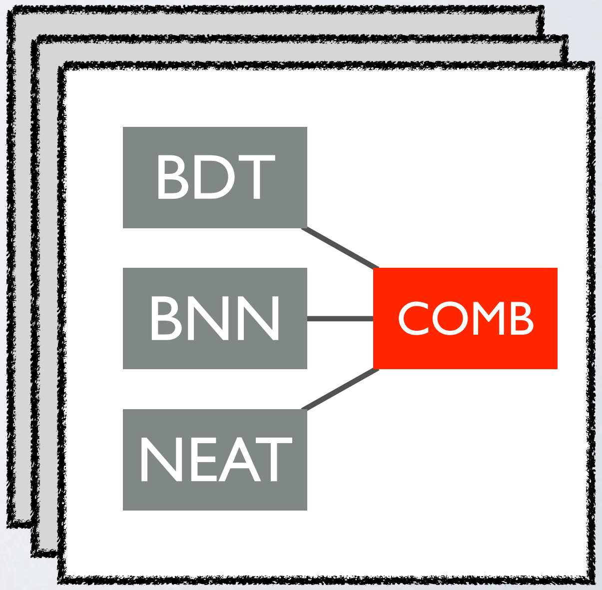
- Genetic algorithms evolve a population of NN.
- Topology of the NN is also part of the training.



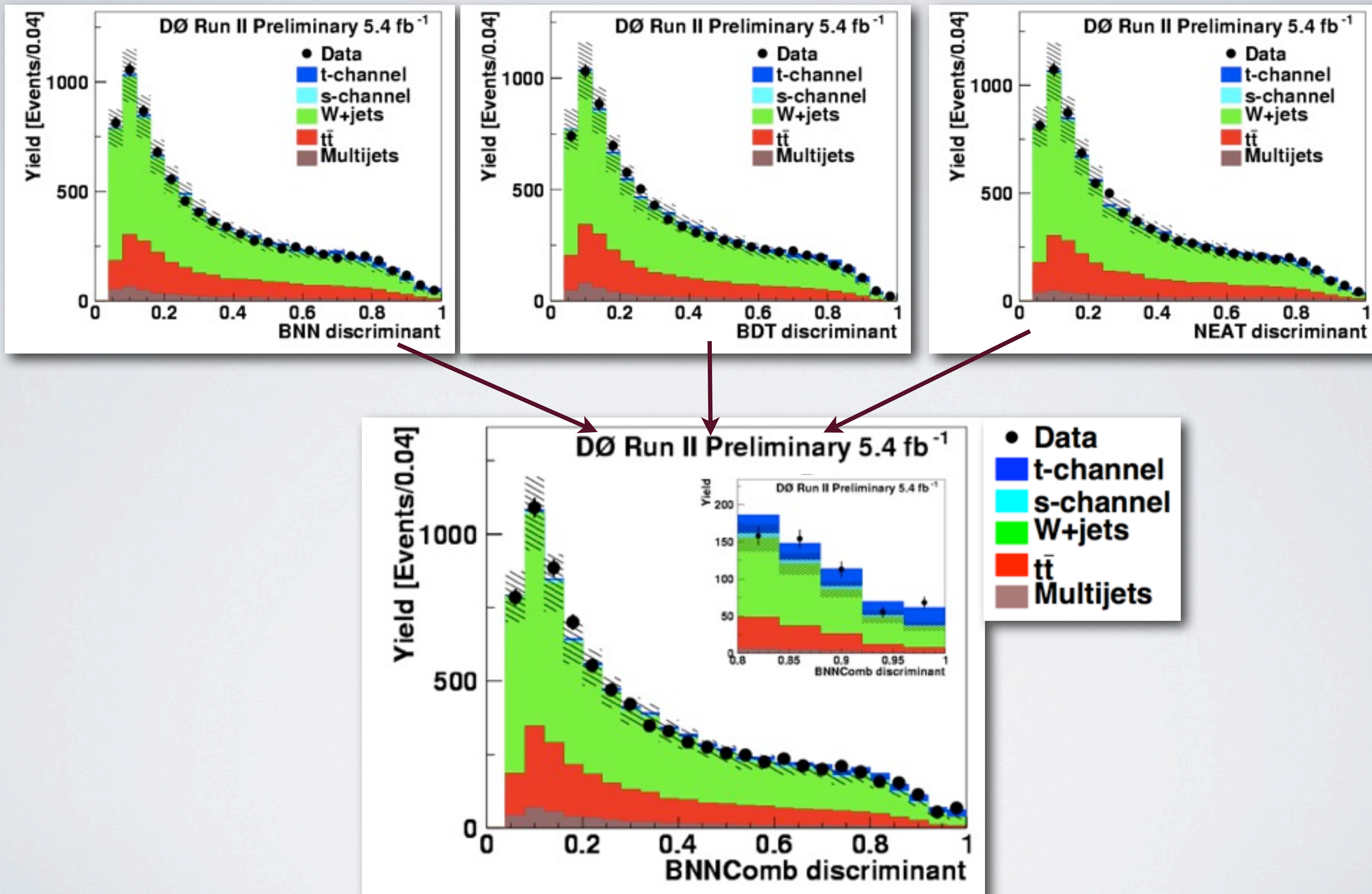
BNN Combination

Correlation between methods ~58-85%

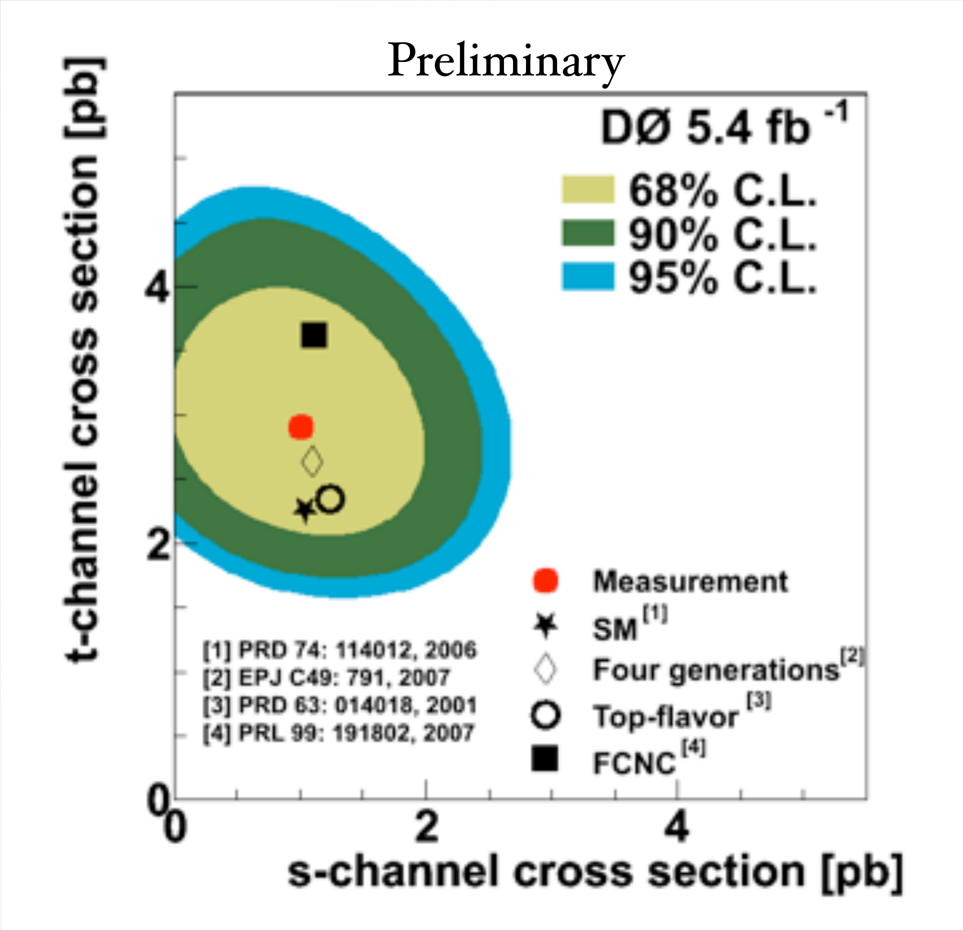
- Different discriminant are combined in one.

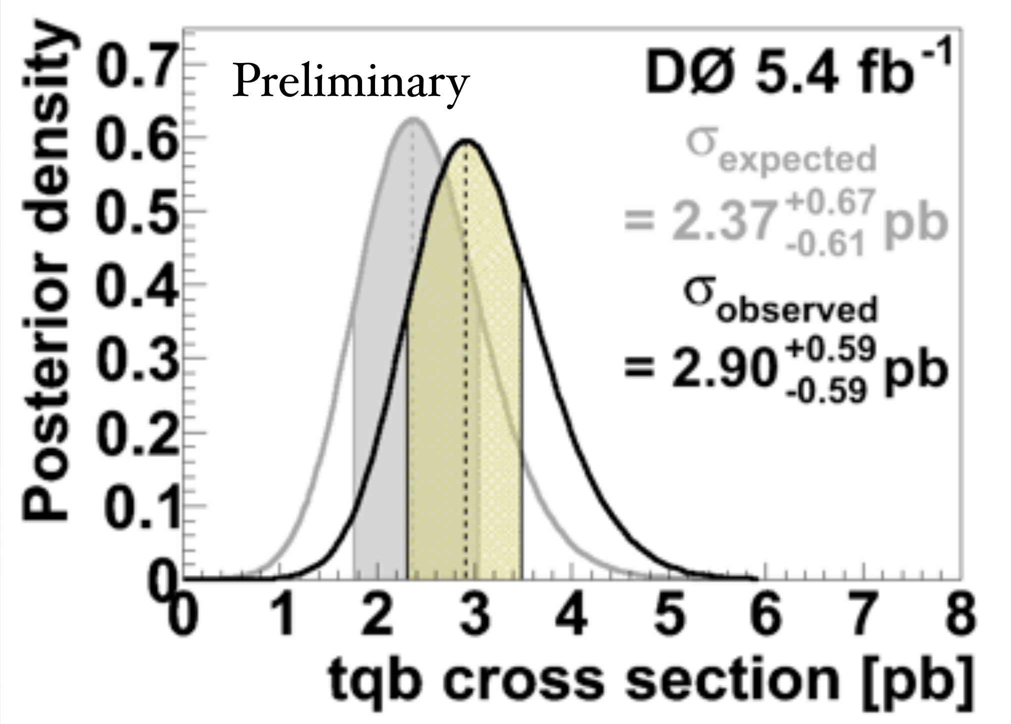


Discriminant Outputs for t-channel



Cross-Section Measurement





Measured Value = Peak of the curve
Uncertainty = width of the curve

- **Cross-section measurement is done without assuming SM s-channel. A single discriminant is used to measure the s and t - channels simultaneously.**
- **A 2D Bayesian posterior probability density is computed.**
- **A 1D Bayesian posterior probability density is obtained by integrating s-channel signal assuming a flat prior.**
- **The estimated significance for this result is larger than five standard deviations (5σ).**
- **The total error of 20% with a systematic uncertainty of 11%.**
- **The largest uncertainties come from the jet energy scale and resolution, corrections to the b tagging efficiency, and the corrections for the jet flavor composition in W+jets events.**

Systematic Uncertainties

Main Sources of systematic uncertainties :

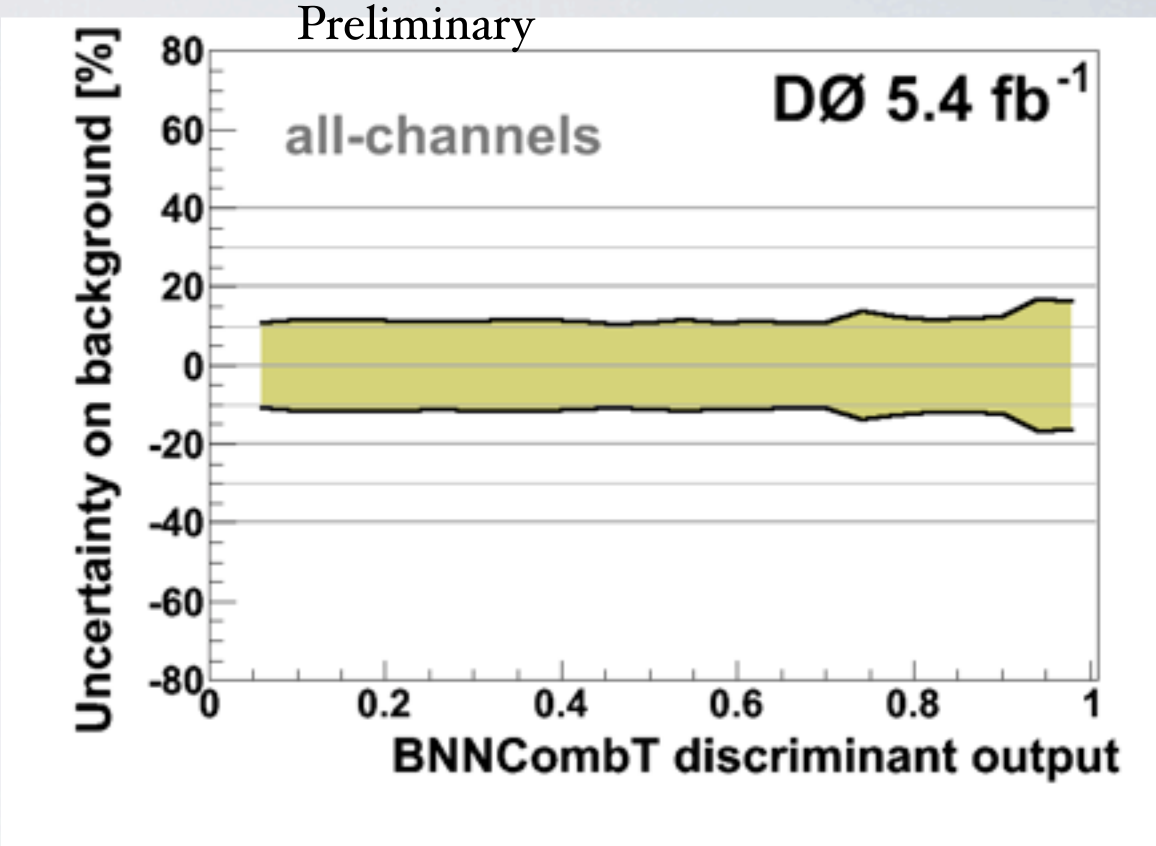
* Jet Energy Scale (< 15%)

* Jet Energy Resolution (<12%)

* W+jets heavy flavor scale factor (12%)

* Taggability and B-tagging

* Integrated Luminosity (6%)



Other Source of uncertainties :

* Color reconnection (1%)

* Relative b/light-jet calorimeter response (<1%)

* Higher order jet fragmentation effects (few % for ttbar)

Conclusions

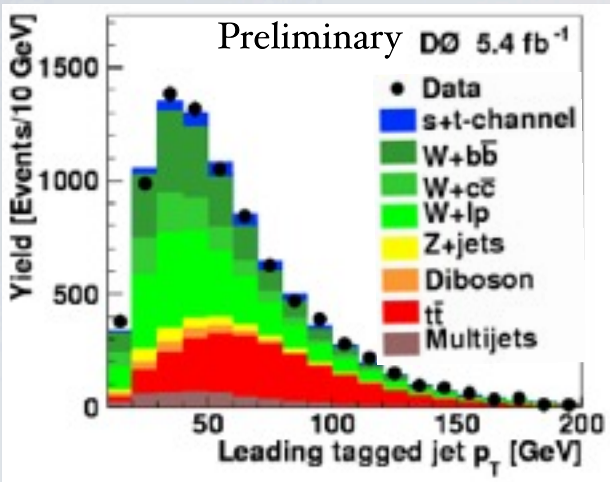
Preliminary

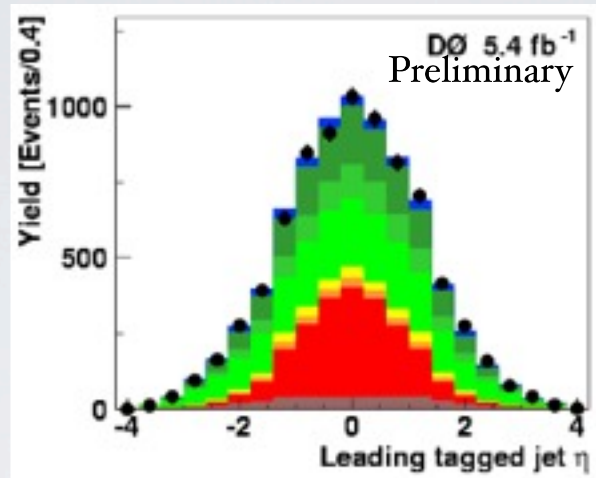
Top mass [GeV]	cross sections [pb]			
	t-channel		s-channel	
170	2.80	+0.57 -0.61	1.31	+0.77 -0.74
172.5	**2.90**	**+0.59 -0.59**	**0.98**	**+0.62 -0.63**
175	2.53	+0.58 -0.57	0.65	+0.51 -0.50

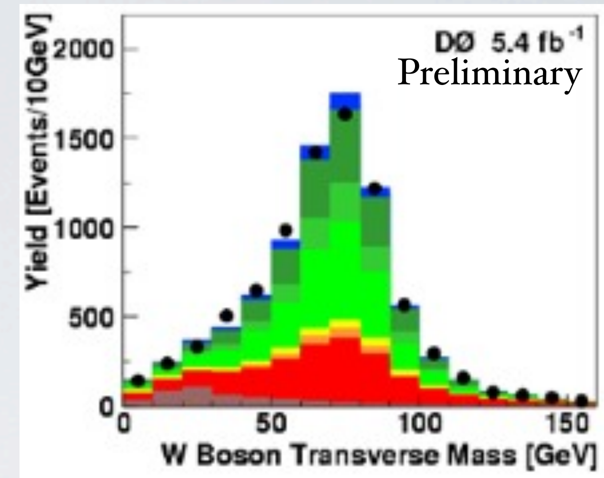
- An ambitious single top program is being pursued at D0.
- New model-independent measurement of t-channel cross section was presented by DØ using twice as much data as the observation result.
- Significance of the results is estimated to be larger than five standard deviations (5σ) and also the measurement has a relative low uncertainty.
- More cross sections measurements and search for new physics are expected to be ready soon based on this new dataset.
- The next big challenge is to measure s-channel cross section. This is one of the Tevatron legacy measurements because s-channel cross section is expected to be very low at LHC.

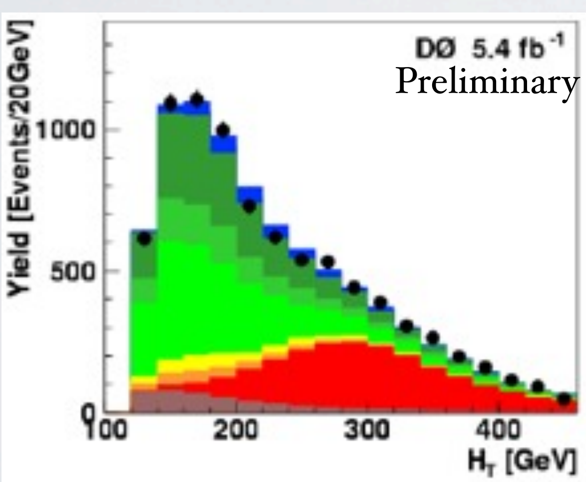
BACKUP

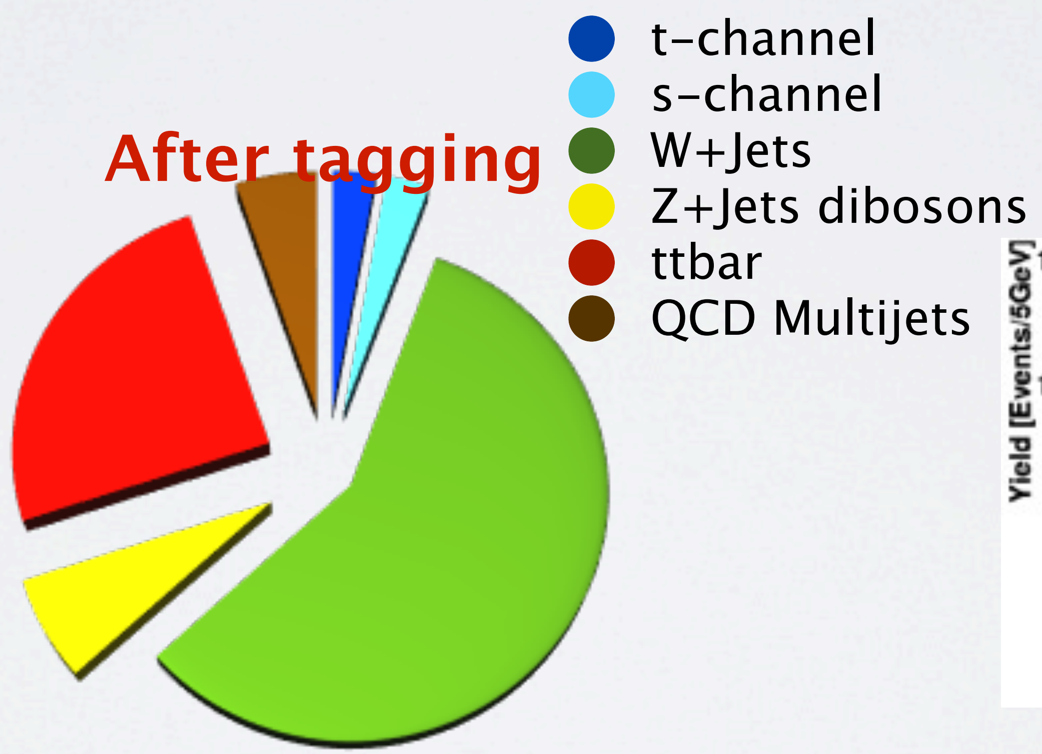
Background Modeling after tagging

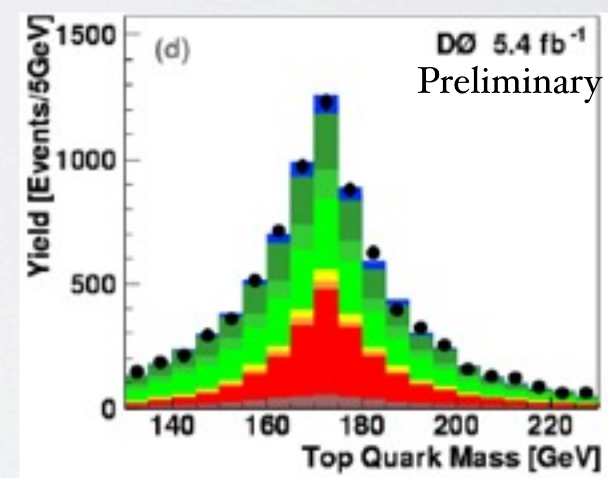












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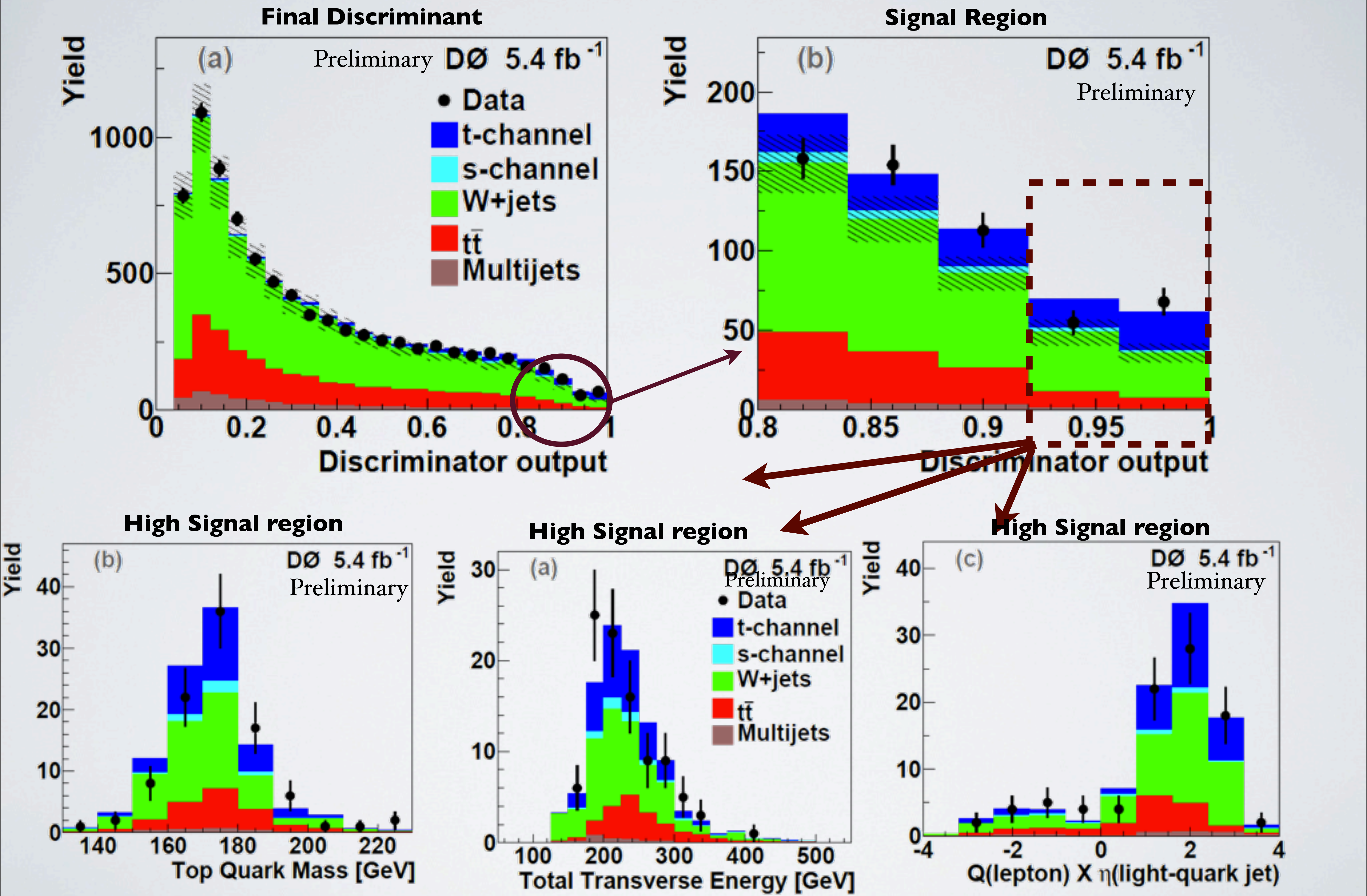
More Results

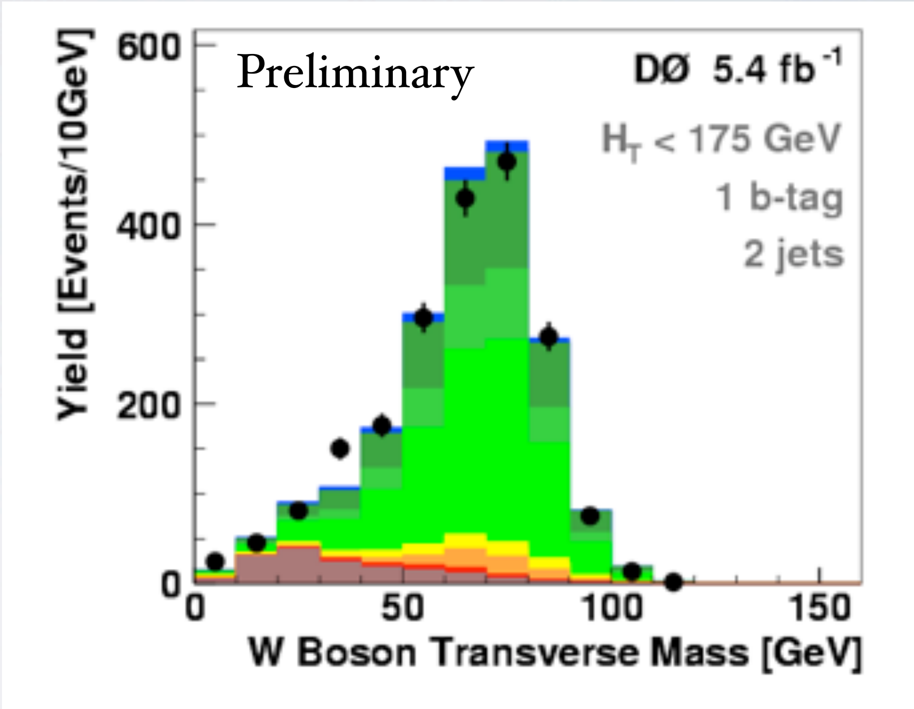


Cross-Checks

Crosscheck to see if background model reproduces the data in regions dominated by one type of background for both electron and muon channels.

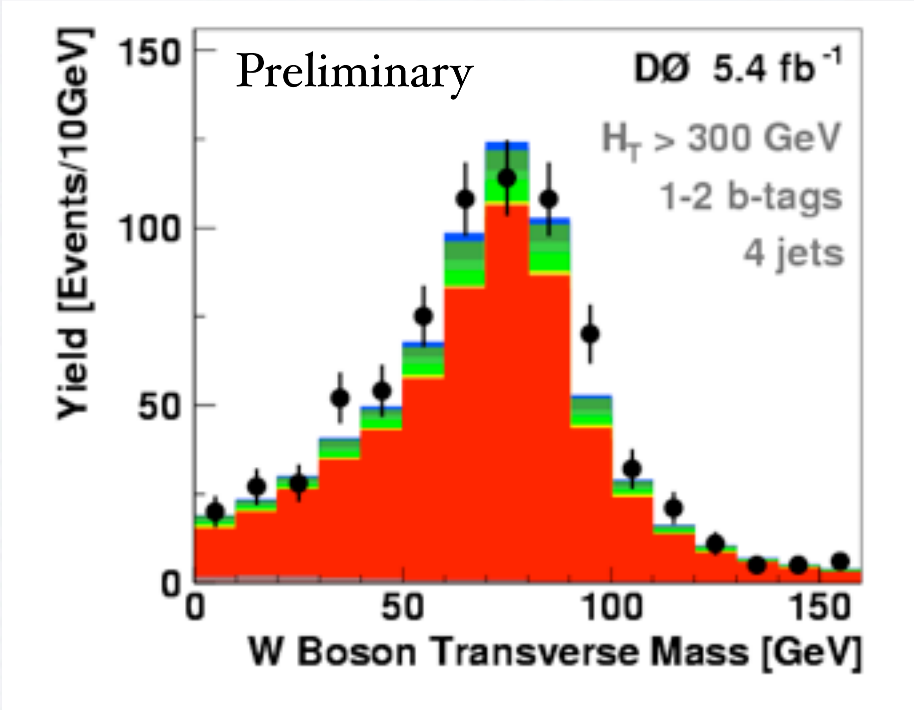
* "W+jets" sample
  - Exactly 2 jets
  - $H_T < 175$ GeV
  - 1 b-tagged jet

For w+jets sample, w+jets events form **82%** of the sample and ttbar events form less than 2%.



* "TTbar" sample
  - Exactly 4 jets
  - $H_T > 300$ GeV
  - 1 or 2 b-tagged jets

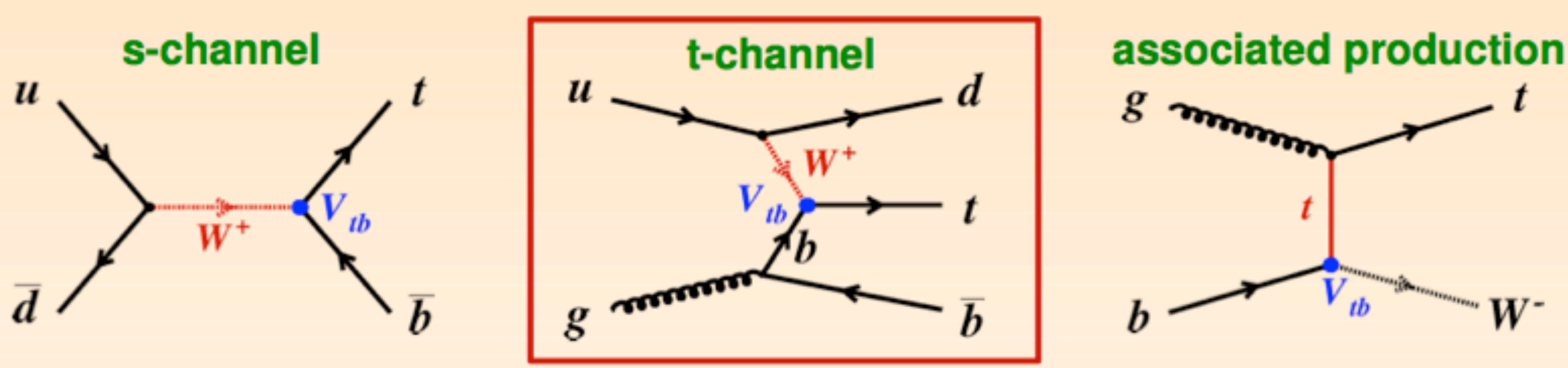
For ttbar sample, ttbar events form **84%** of the sample and w+jets events form only 12%.



Single top s-channel as legacy measurement

- Evidence and observation of s-channel.
- It will be difficult for the LHC to improve any measurement from Tevatron.

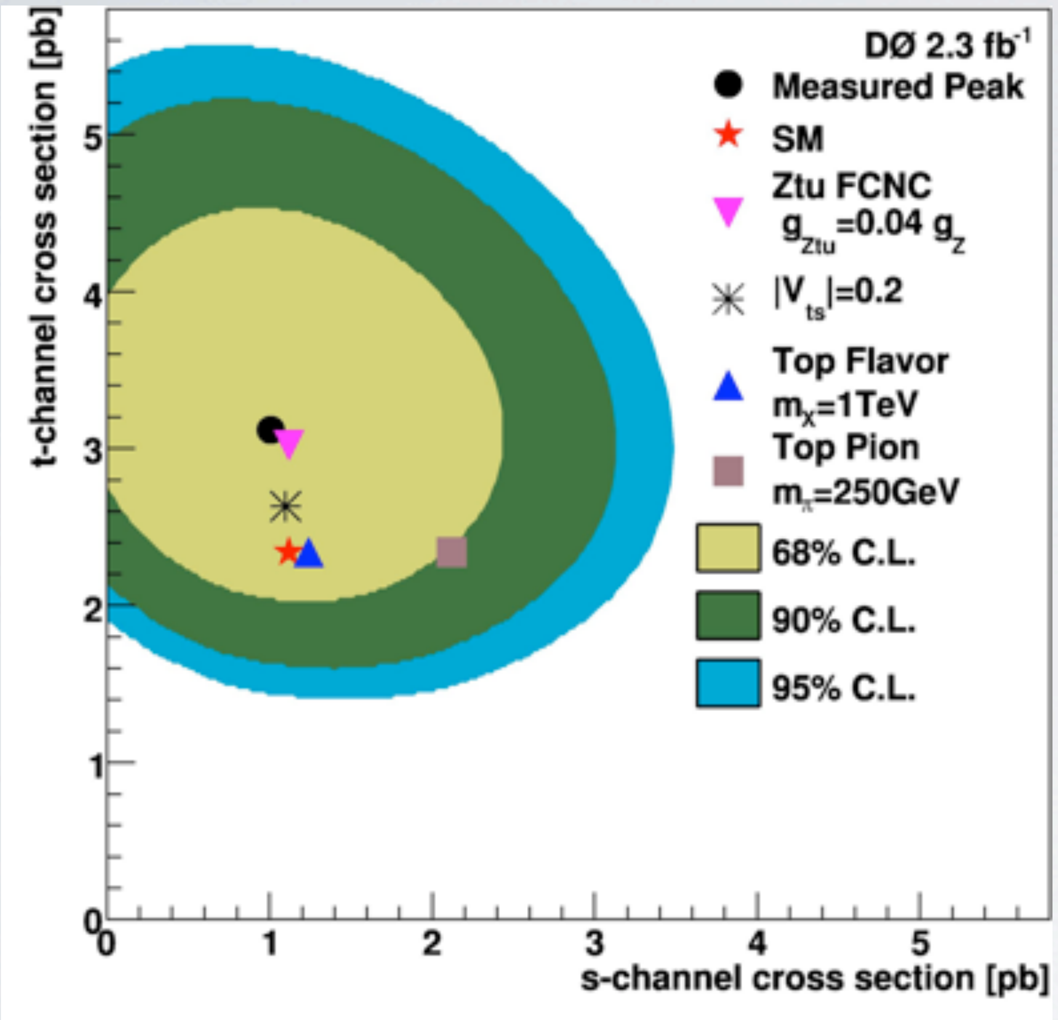
Jeannine Wagner-Kuhr, Physics at the Terascale Workshop DESY,12.11.2009



1) PRD 74, 114012 (2006) 2) values scaled to 10TeV based on PRD 70, 114012 (2004); Nucl. Phys. B726, 109 (2005) 3) JHEP 0910, 042 (2009)	Tevatron [pb] √s=1.96 TeV	LHC [pb] √s=7 TeV	LHC [pb] √s=10 TeV
s-channel	1.0 [1)]	3	**5** [2)]
t-channel	2.2 [1)]	65	**124** [3)]
associated production	0.26 [1)]	11	**29** [2)]

Evidence of t-channel - 2.3 fb^{-1} Analysis

arXiv:0907.4259v2 [hep-ex]



Observed Cross-section = $3.14^{+0.94}_{-0.81}$ pb