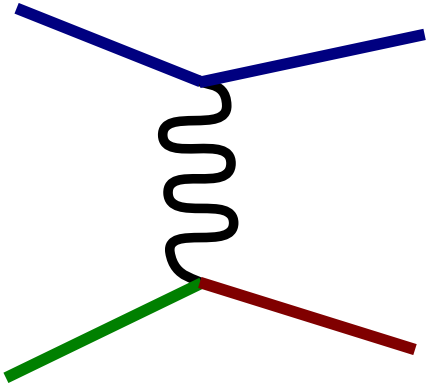
Evidence for t-channel single top production



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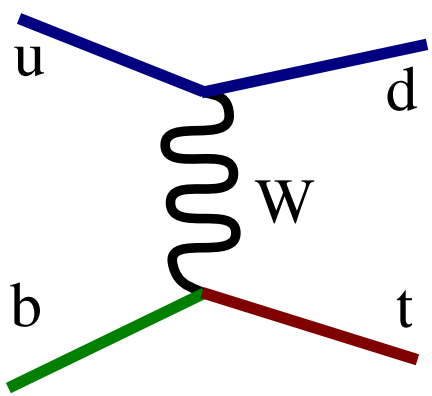
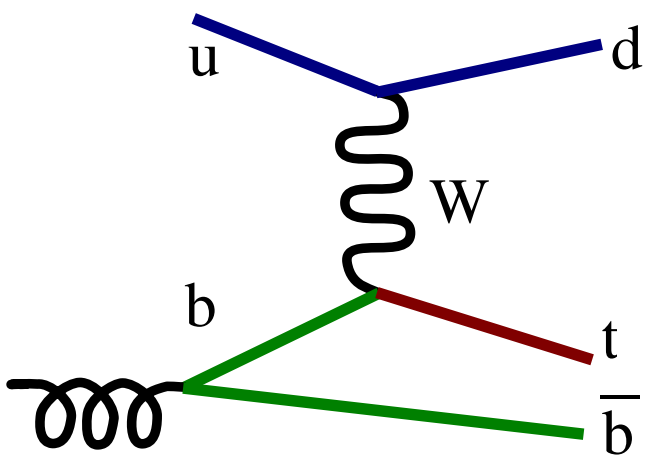
All D0 Meeting, 7/9/2009

Introduction

- Single top observation analysis focused on s+t combined cross section
  - Assume SM s/t ratio
- We can measure s-channel and t-channel individually
  - Different final state objects, kinematics
- t-channel has larger cross section, better sensitivity
  - Use observation dataset to measure t-channel cross section





t-channel signal

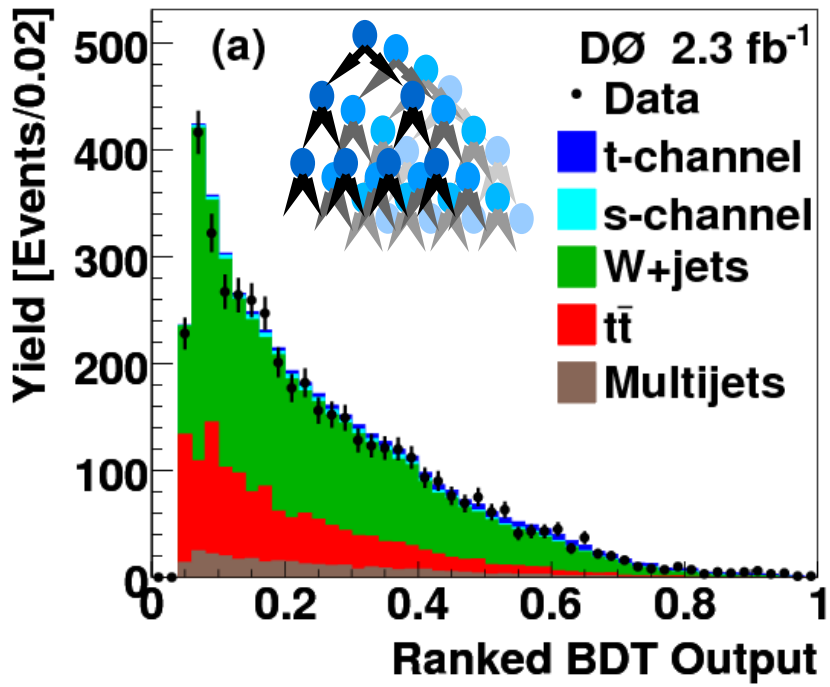
Source	2 jets	3 jets	4 jets
t-channel	77 ± 10	39 ± 6	14 ± 3
s-channel	62 ± 9	24 ± 4	7 ± 2
W+jets	1829 ± 161	637 ± 61	180 ± 18
Z+jets and dibosons	229 ± 38	85 ± 17	26 ± 7
$t\bar{t} \to \ell\ell$, ℓ+jets	222 ± 35	436 ± 66	484 ± 71
Multijets	196 ± 50	73 ± 17	30 ± 6
Total prediction	2615 ± 192	1294 ± 107	742 ± 80
Data	2579	1216	724

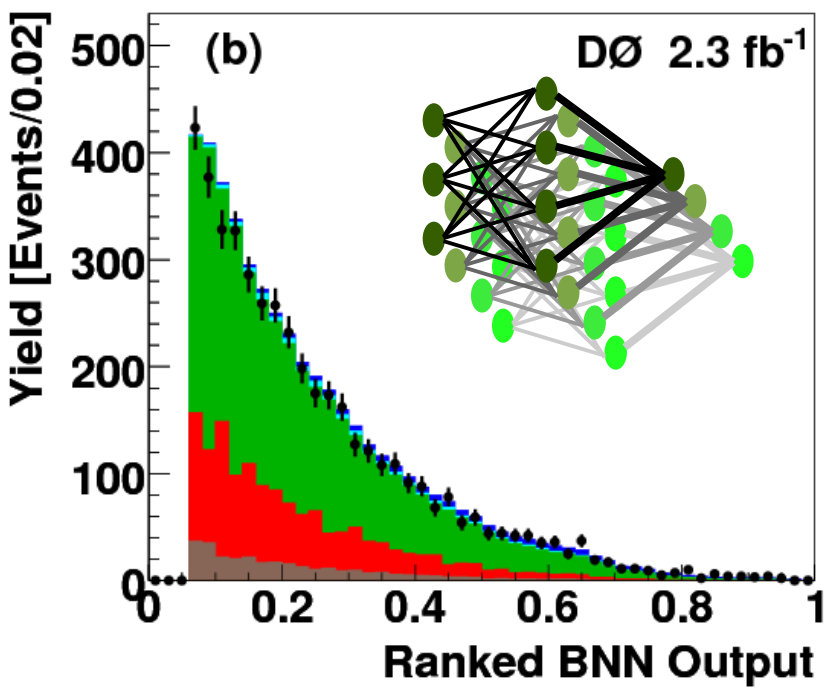
t-channel single top

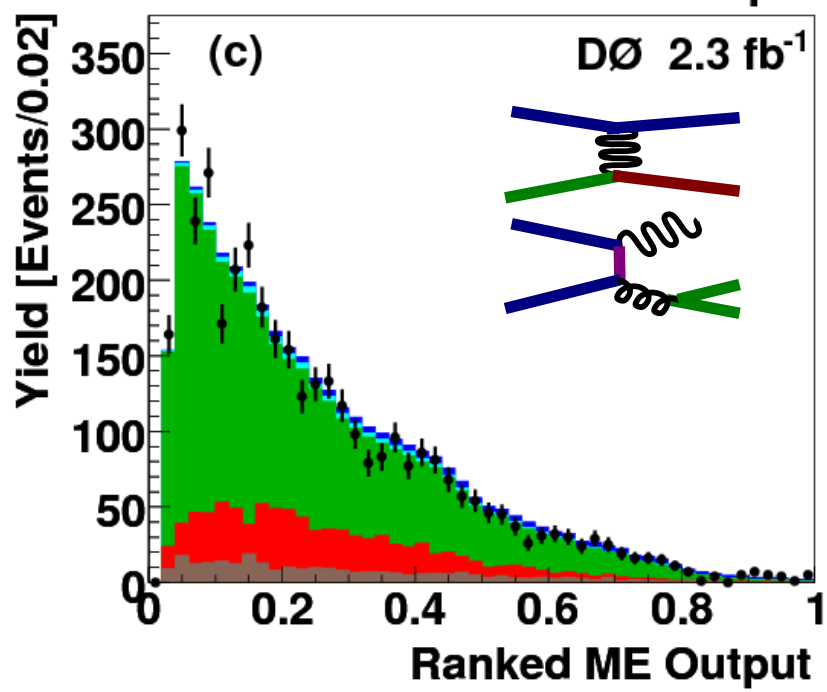
- Train multivariate filters for t-channel single top
  - Same multivariate filters as in observation analysis
    - Boosted Decision Trees
    - Bayesian Neural Network
    - Matrix Element
  - Same variables, settings as in observation analysis
- Train with only t-channel as signal
  - Consider s-channel as background during training
- Then combine using another Bayesian Neural Network
  - just like observation analysis
- Statistical analysis in 2d
  - Bayesian posterior as a function of both s-channel and t-channel
  - Extract t-channel cross section by integrating over s-channel

Individual t-channel discriminants

- Bins ranked by s/b

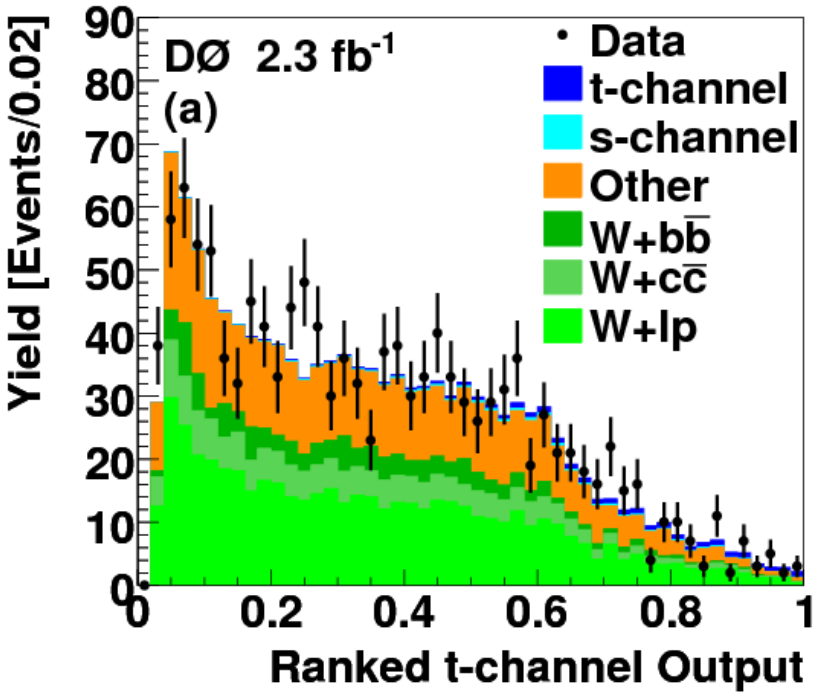




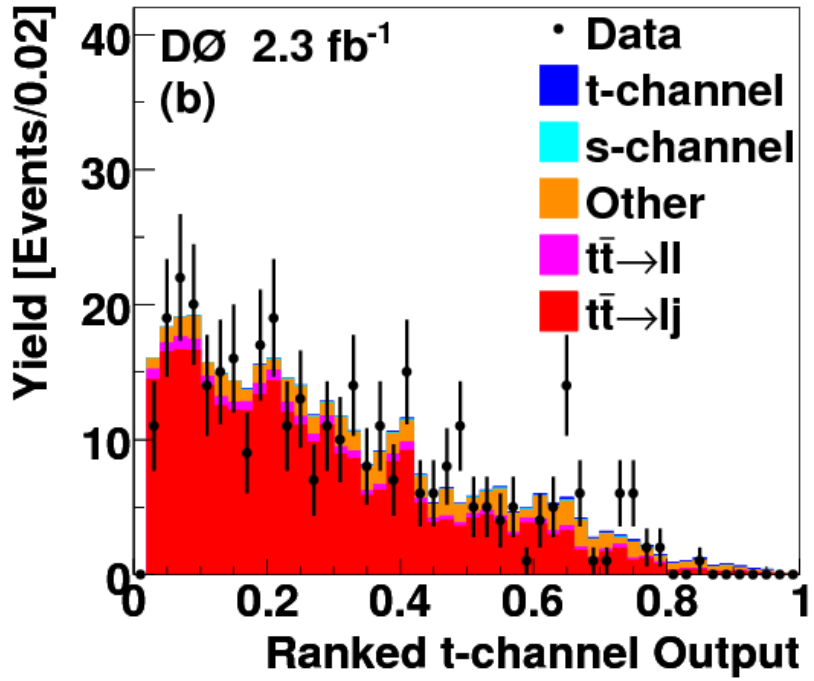


Cross-check samples

W+jets dominated

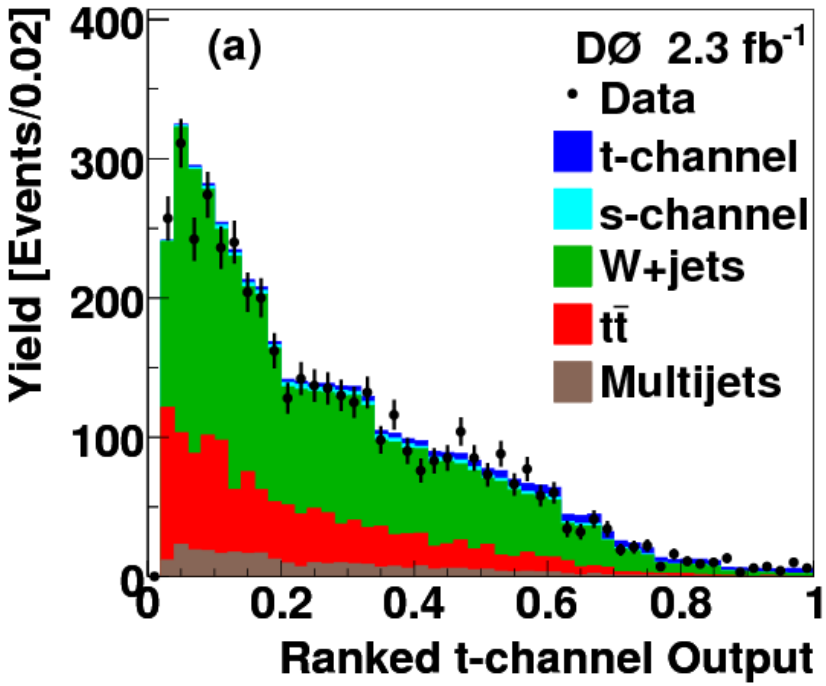


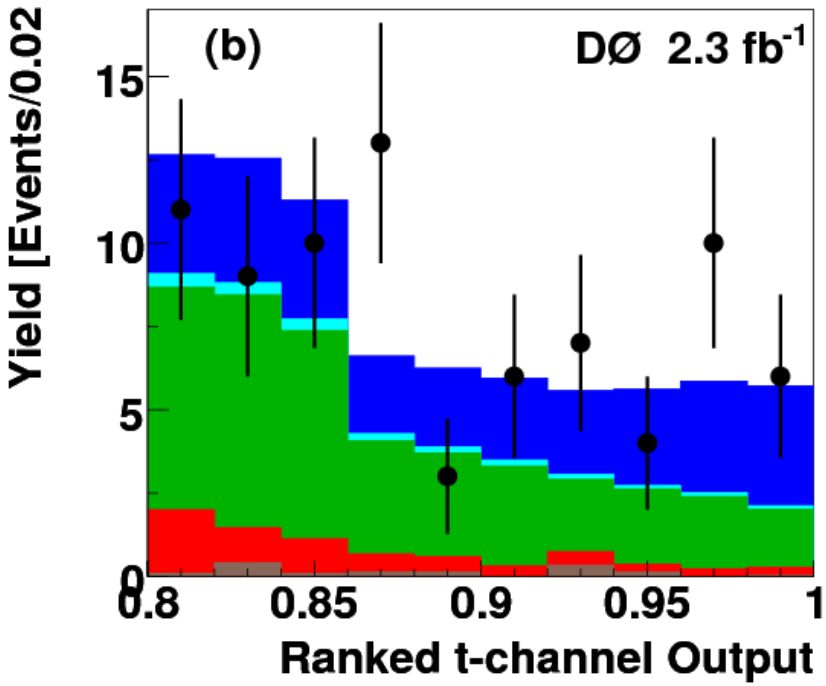
ttbar dominated



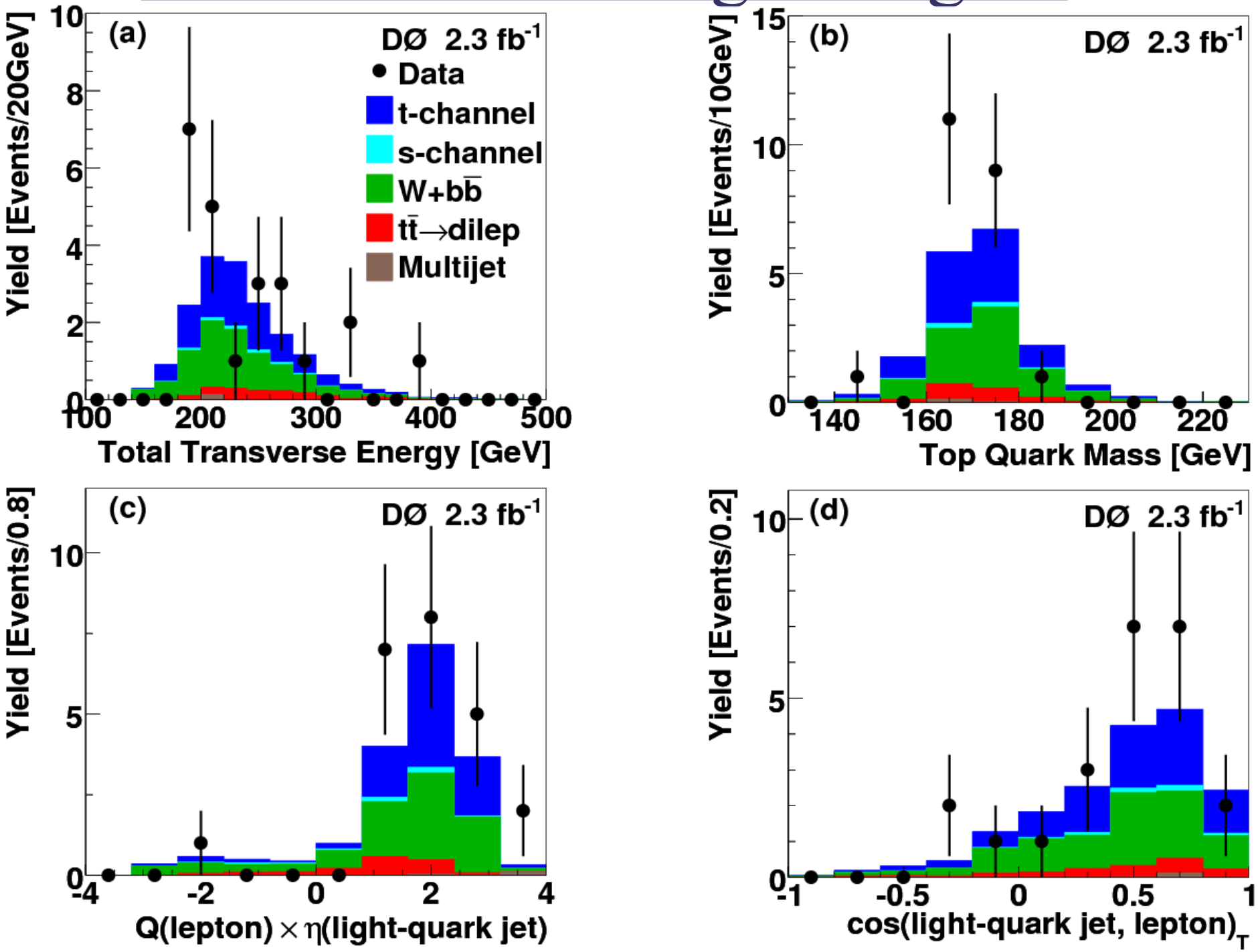
t-channel combination discriminant

- Combine three individual filters using one more BNN
  - Same procedure as in observation analysis
- Bins ranked by s/b



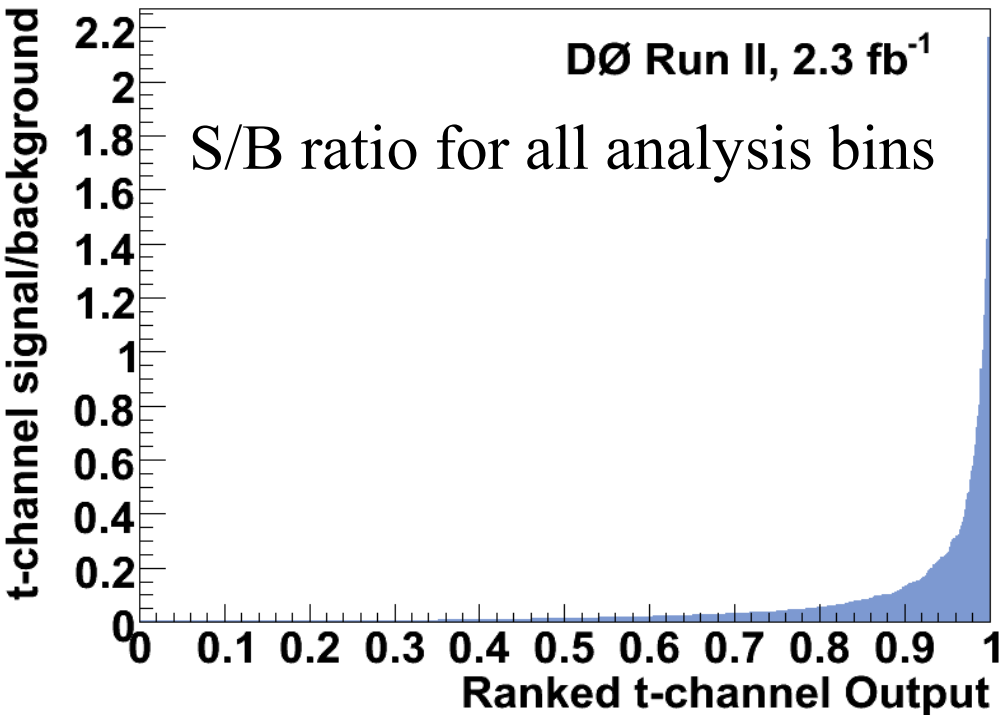


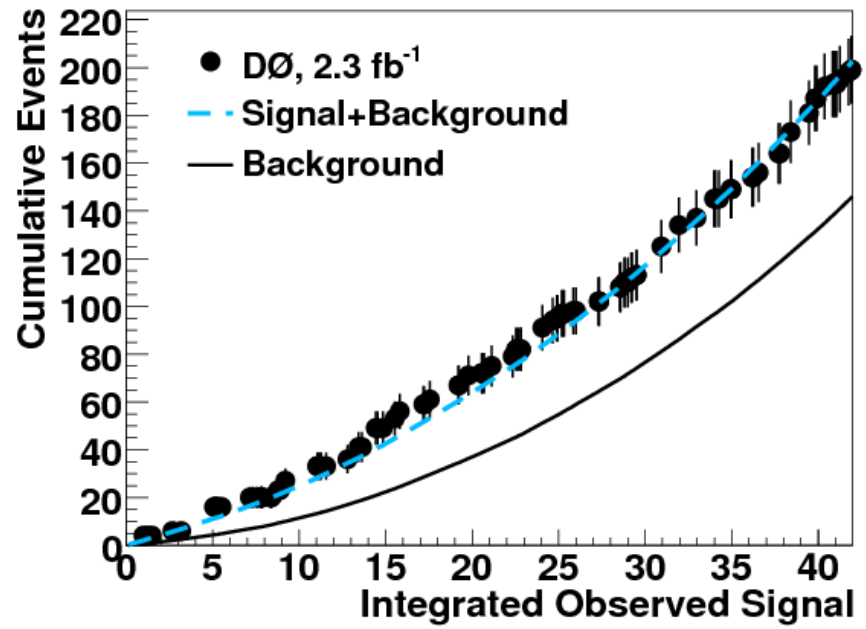
Variables in the signal region

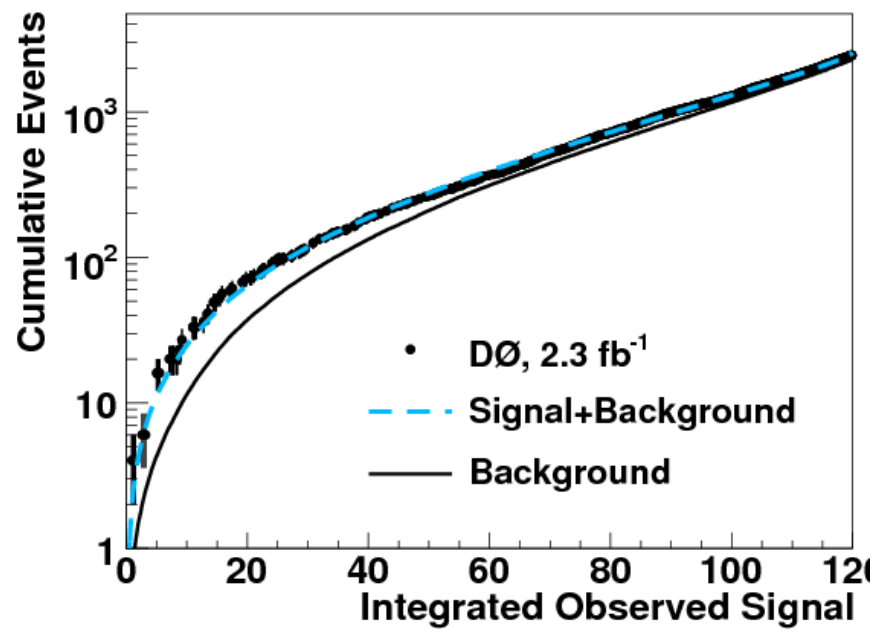


S/B and Cumulative distribution

- Only t-channel as signal

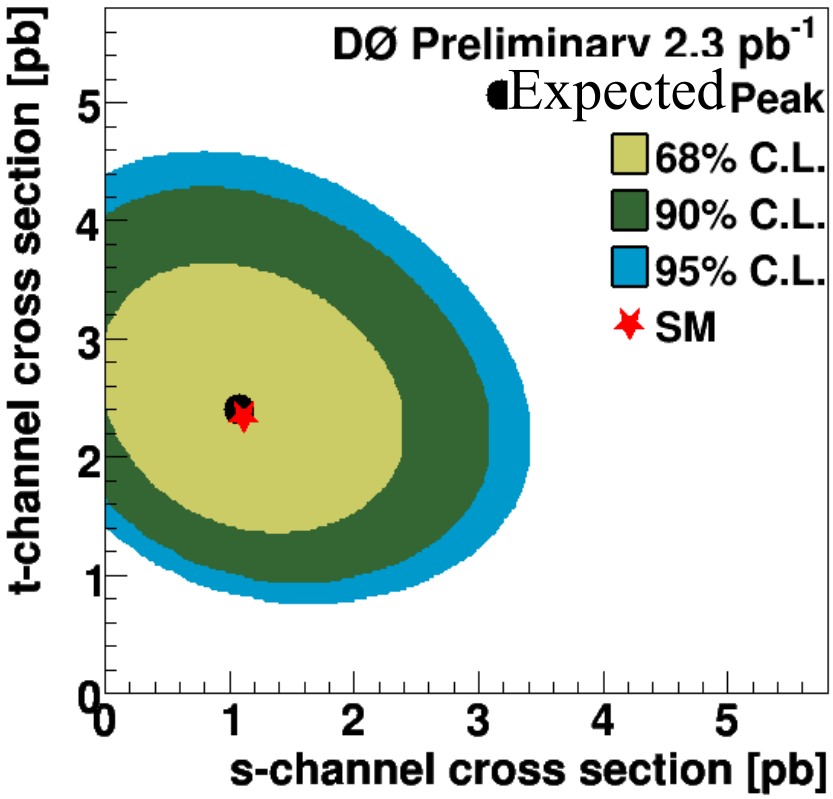


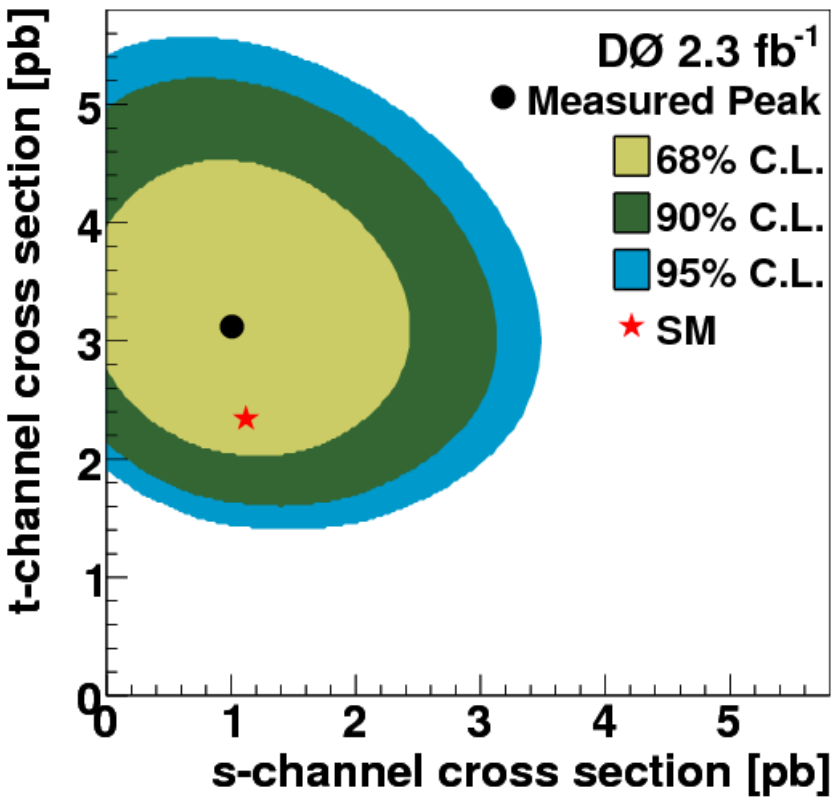




Statistical analysis

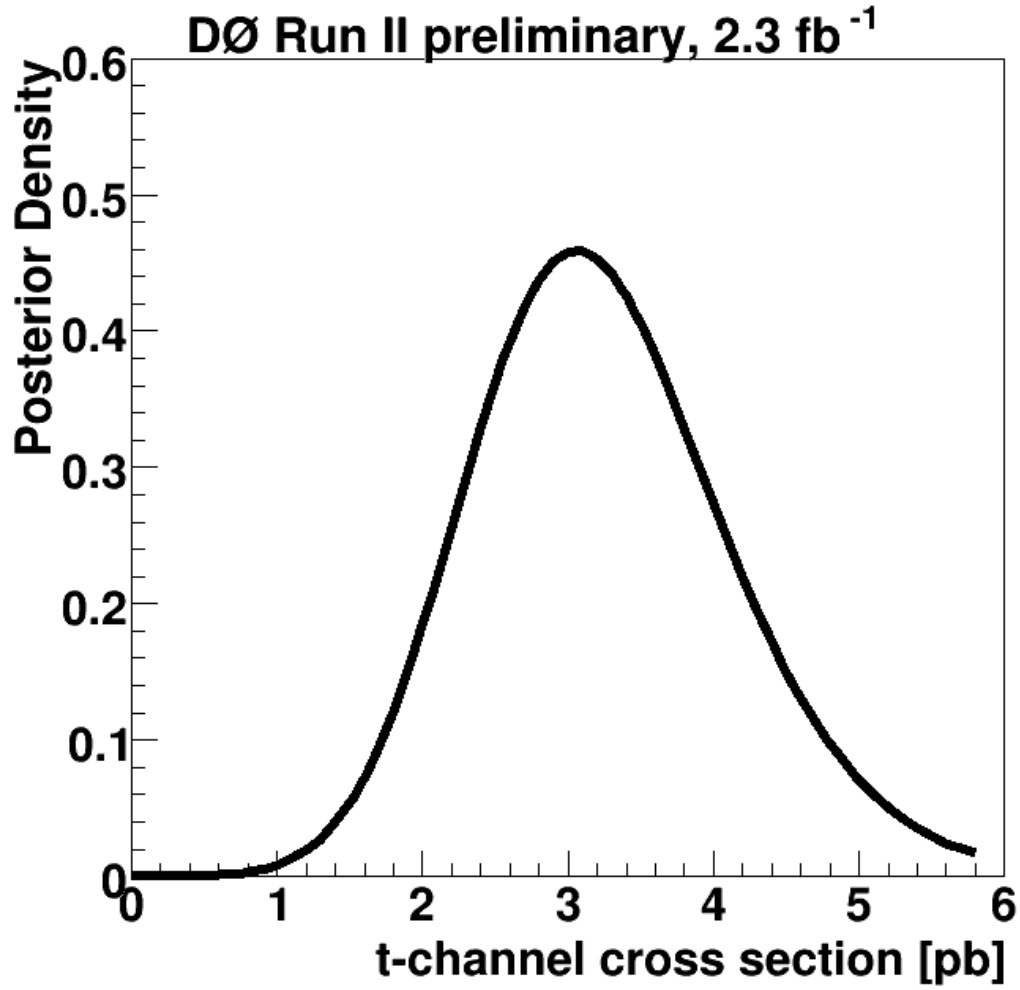
- Evaluate t-channel and s-channel simultaneously
  - No assumptions about cross section ratio or s-channel cross section
  - 2d posterior of s-channel vs t-channel
    - Posterior peak s-channel cross section: 1.05 pb
    - Posterior peak t-channel cross section: 3.14 pb





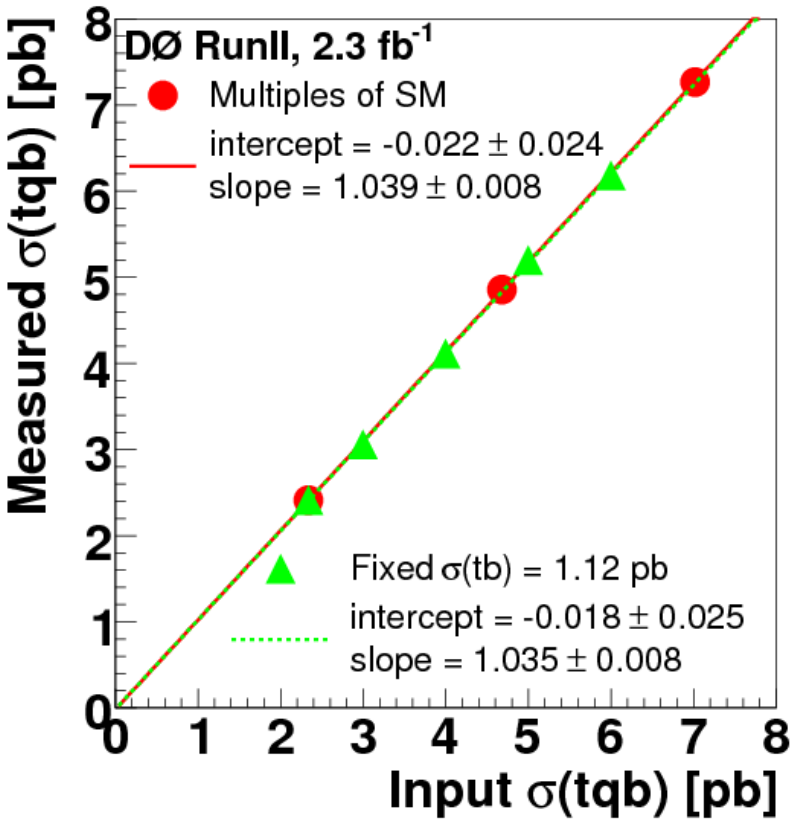
t-channel cross section

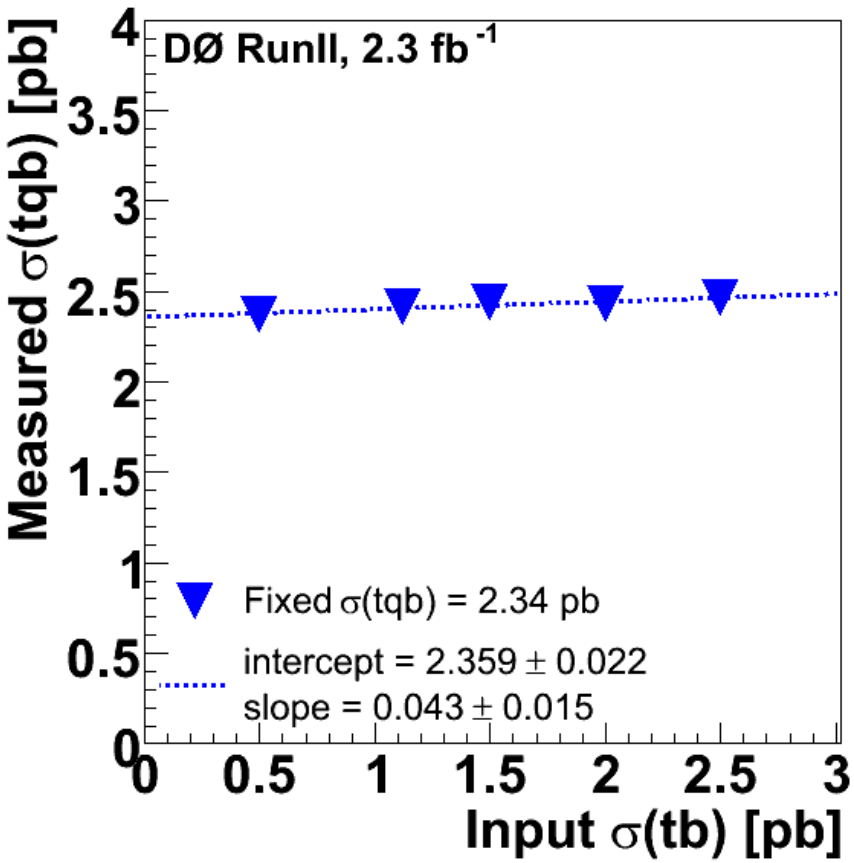
- Integrate 2d posterior over s-channel axis to extract t-channel cross section and uncertainty
  - Observed t-channel XS: $3.14\ ^{+0.94}_{-0.81}$ pb
  - Observed s-channel XS: 1.05 ± 0.81 pb



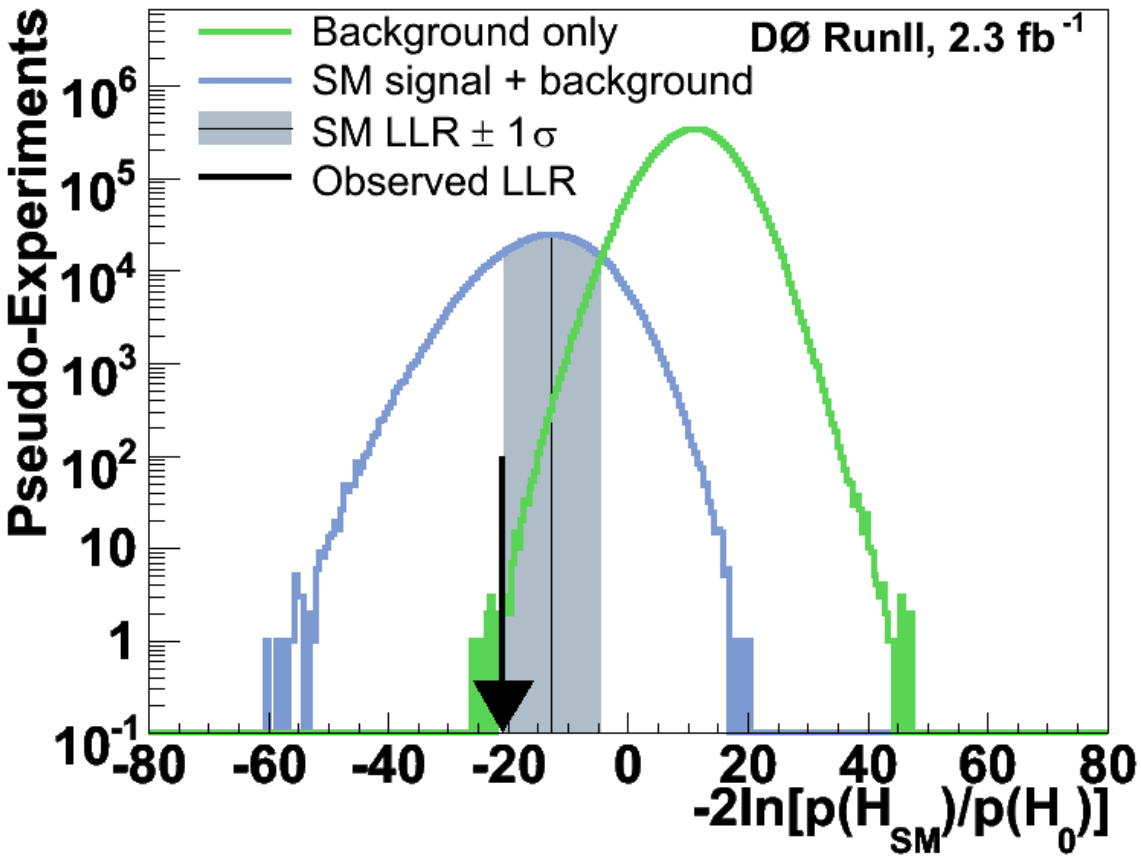
Ensemble testing

- Test linearity with ensembles generated at different t-channel and s-channel cross sections
  - Vary only t-channel or only s-channel or both
- Negligible bias





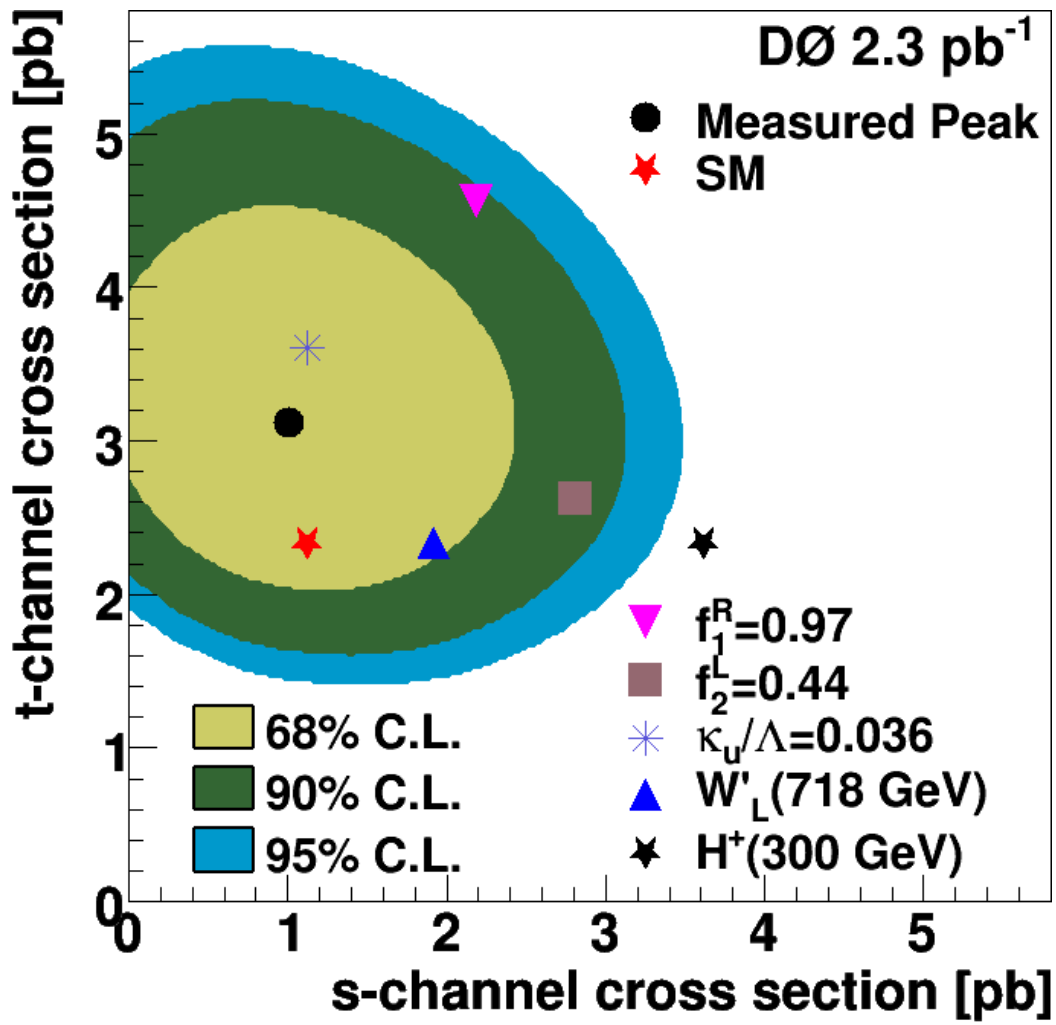
t-channel significance



- Log-likelihood ratio estimate of significance
- Generate 10M background-only pseudo-datasets
- Expected p-value: 9.7E-5, corresponding to 3.7 sigma
- Observed p-value: 8.0E-7, corresponding to 4.8 sigma

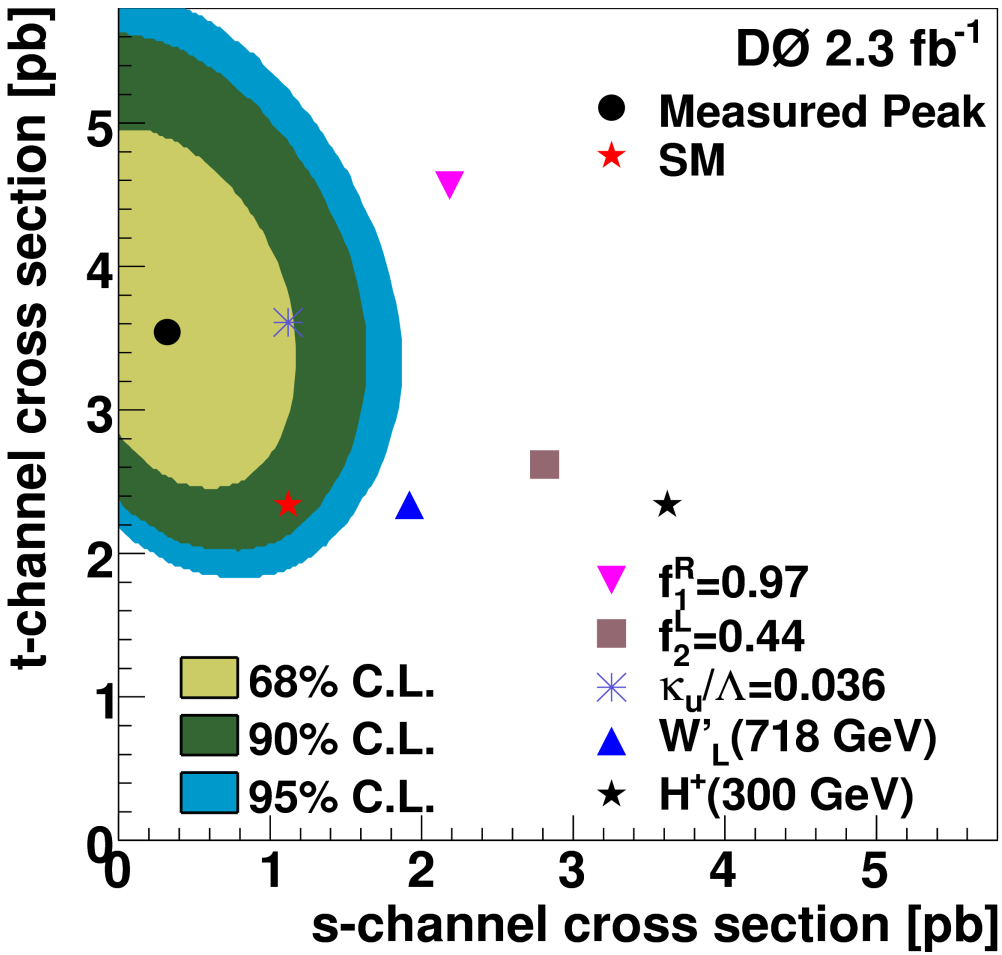
New Physics

- Add points from recent D0 single top new physics searches to 2d posterior plot
  - Anomalous couplings PRL 102, 092002 (2009)
  - FCNC PRL 99, 191802 (2007)
  - New heavy boson W' PRL 101, 211803 (2008)
  - Charged Higgs (tan β>1) PRL 102, 191802 (2009)
  - Points correspond to what is excluded at 95% CL in each dedicated analysis
  - Disclaimers: different kinematics, different top mass



New physics in 2d from observation analysis

- Less sensitivity to t-channel single top
- More sensitivity to s-channel single top
- Would like to show this publicly in observation talks

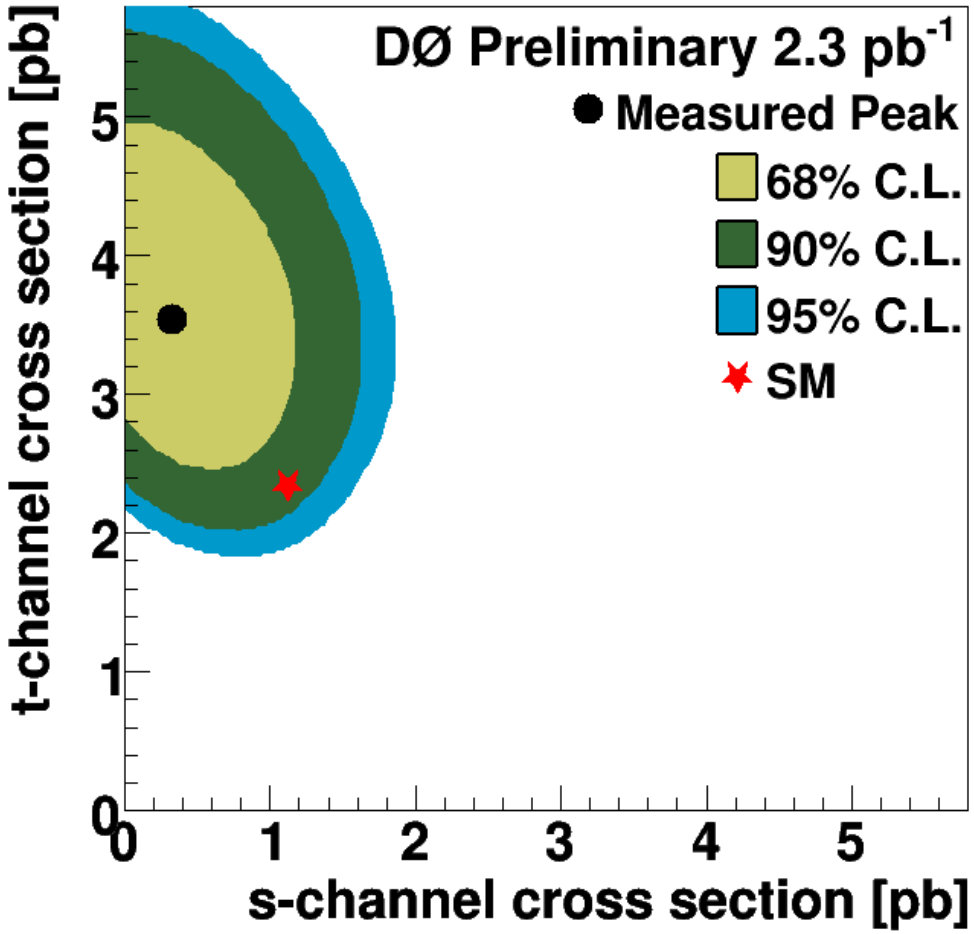


Conclusions

- Evidence for single top quark production in the t-channel
  - 3.6 stdev expected, 4.8 stdev observed
  - Isolate t-channel from s-channel production
  - Model-independent measurement (independent of s-channel XS)
- t-channel analysis builds on observation analysis result
  - Same samples, same uncertainties, same top mass, etc
- PLB draft in collaboration review
- Intend presentation at EPS

Backup material

2d plot from observation analysis



Significance: Log-Likelihood Ratio

- For their evidence and observation analyses, CDF used a log-likelihood ratio approach to measure significance
  - Cross section and uncertainty and |Vtb| all calculated with a Bayesian approach
  - Significance calculated with LLR approach
    - But using the same underlying framework as above
- Log-Likelihood Ratio
  - Frequentist idea: Compare null hypothesis (H_0, background only) and alternative hypothesis (H_1 or H_{SM}, signal+background)
  - Compute likelihood of observing background-only $p(H_0)$ and of observing SM signal + background $p(H_{SM})$
  - Form test statistic $Q = -2 \ln[\, p(H_{SM}) / p(H_0) \,]$
  - Tested on observation analysis, consistent result with PRL

Comparison of filters for t-channel

- Sensitivity for t-channel analysis (and s-channel analysis) when using either observation s+t combination filter or newly trained t-channel filter:
- t-channel filter:
  - t-channel expected BFS: 3.18 Peak/Sigma: 3.23
  - s-channel expected BFS: 1.43
- s+t combination filter:
  - t-channel expected BFS: 3.07 Peak/Sigma: 3.16
  - s-channel expected BFS: 2.0

Training without s-channel

- T-channel combination BNN was trained without s-channel to investigate possible bias
  - Measure observed cross section
  - without systematic uncertainties
- Result:

	t-channel XS	s-channel XS
no-s-channel	2.78 ± 0.63 pb	0.31 ± 0.46 pb
nominal	2.78 ± 0.63 pb	0.28 ± 0.47 pb