

DØ Single Top Matrix Element Analysis

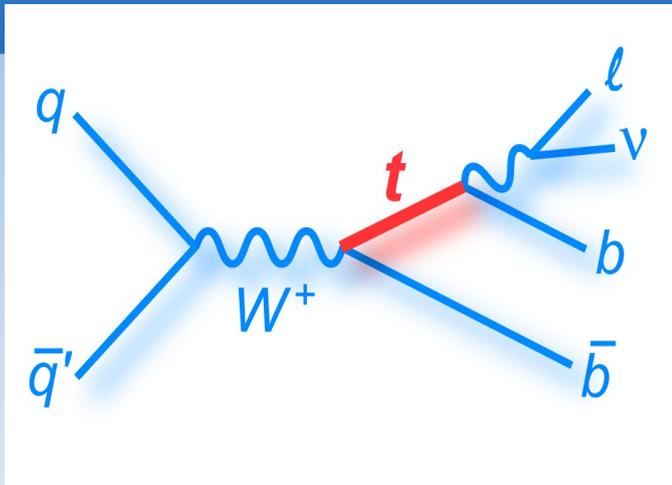
Monica Pangilinan
Brown University
on behalf of



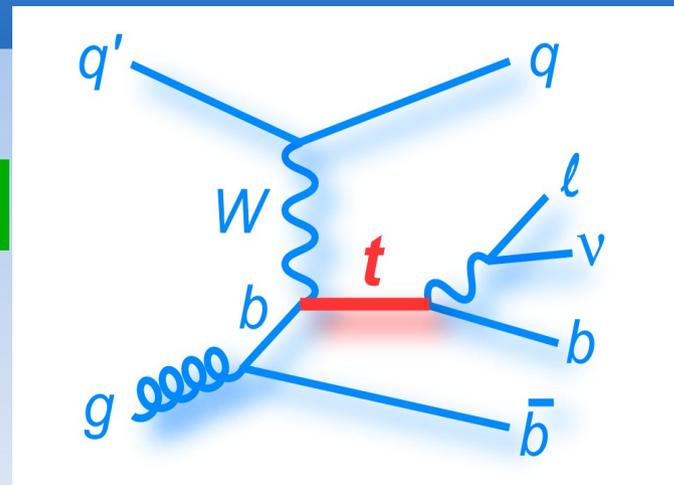
APS April Meeting
May 3, 2009

Motivation

s channel

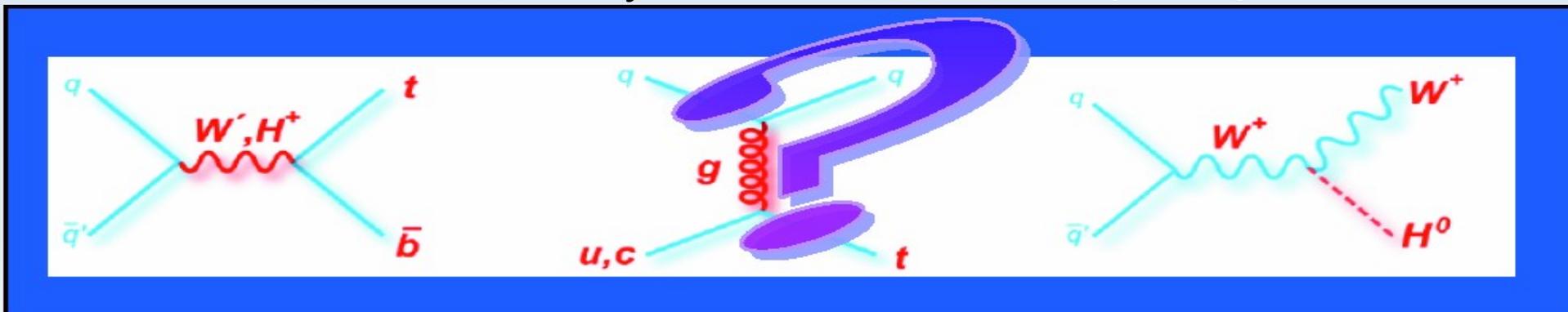


t channel



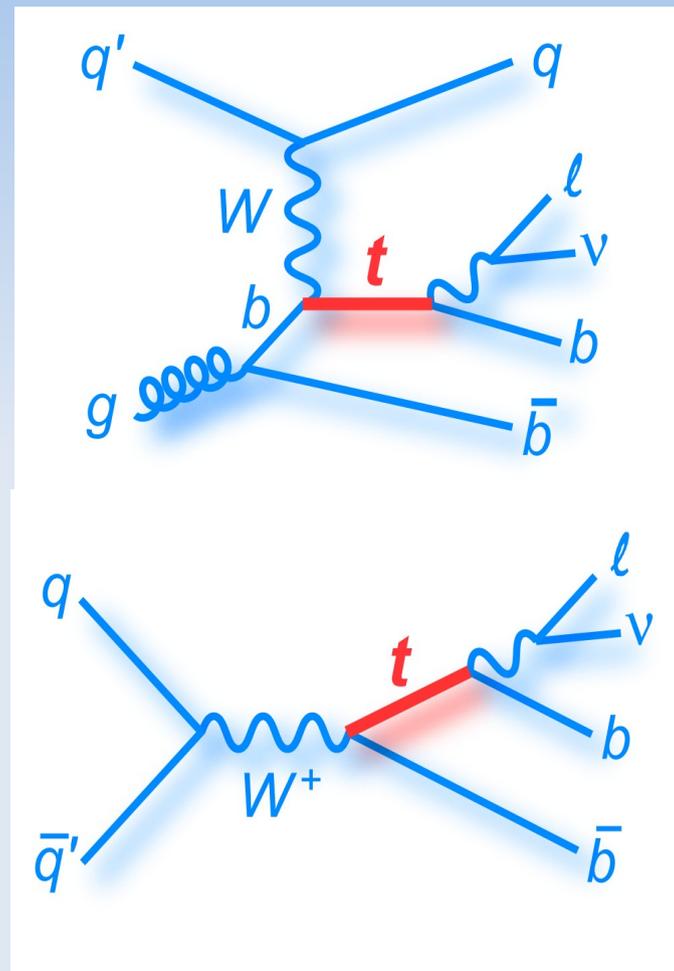
- Investigate Wtb coupling
 - Direct measurement of $|V_{tb}|$
 - Checks unitarity of CKM matrix
 - Anomalous Wtb couplings
- Study top quark properties
 - Polarization, lifetime, decay width

- Window to new physics
 - s channel: charged Higgs, heavy W'
 - s+t channel: flavor changing neutral currents
 - 4th quark generation?



Event Selection

- 1 isolated lepton
- Missing Transverse Energy
- At least one b-tag jet and at least one more jet
- Signal acceptance increased by 18% compared to 2006 evidence analysis (Phys. Rev. Lett. 98, 181802 (2007), Phys. Rev. D 78, 012005 (2008))
 - Logical OR of many trigger conditions
 - Looser jet eta and pt cuts
 - Loosened the b-jet identification criteria for the 2 tag case



Matrix Element

- Multivariate techniques try to approximate discriminant

$$D_S(\vec{x}) = P(S|\vec{x}) = \frac{P_S(\vec{x})}{P_S(\vec{x}) + P_B(\vec{x})}$$

- Matrix Element uses the full event information (4-momenta) to calculate discriminant

$$P(\vec{x}) = \frac{1}{\sigma} \times \frac{\partial \sigma}{\partial \vec{x}}$$

where

$$d\sigma(\vec{x}) = \sum_{i,j} \int d\vec{y} \left[f_i(q_1, Q^2) dq_1 \times f_j(q_2, Q^2) dq_2 \times \frac{\partial \sigma_{hs,ij}(\vec{y})}{\partial \vec{y}} \times W(\vec{x}, \vec{y}) \times \Theta_{\text{Parton}}(\vec{y}) \right]$$

Parton distribution functions for initial parton i,j carrying momentum q

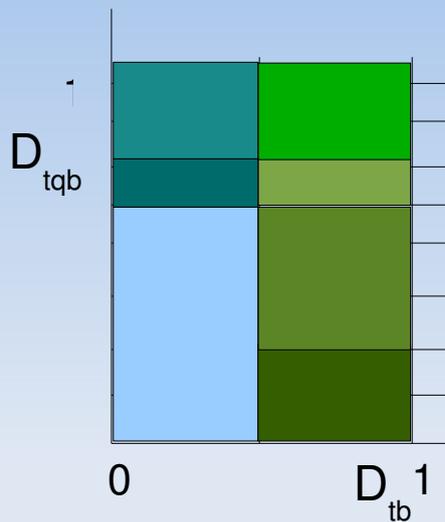
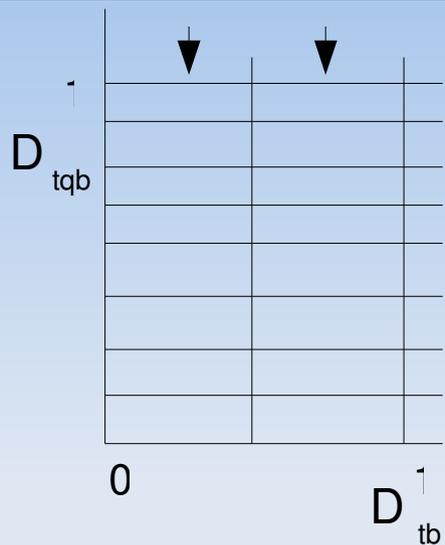
Differential cross section for the hard scatter. Uses leading-order matrix element

Transfer function which relates observed state in the detector (x) to original partons (y)

2006 Evidence Analysis

- Additional Matrix Elements:
 - 2 jets: tb , tq , Wbb , Wcg , Wgg , WW , WZ , ggg , $t\bar{t}$
 - 3 jets: tbg , tqg , tqb , $Wbbg$, $t\bar{t}$, $Wugg$
- 2-D discriminant (tb vs tqb) reordered into 1-D signal/background bins
- $H_T = \sum_{\text{lepton}, E_T, \text{jets}} |E_T|$ divided regions at 175 GeV
 - Separates sample into $t\bar{t}$ enriched and W +jets enriched sets

Presentation of Discriminant

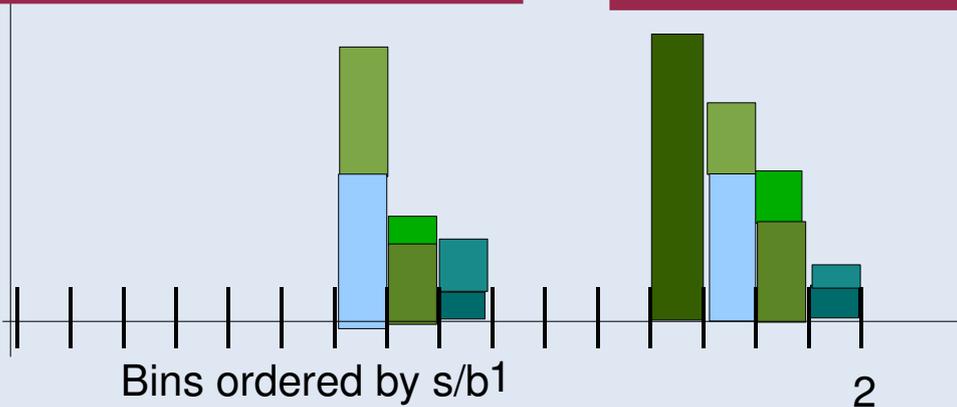
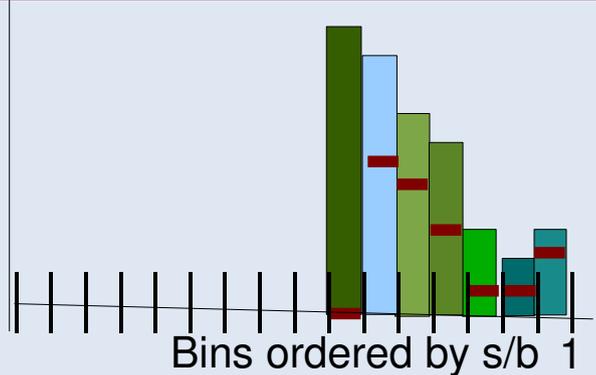


- s/b = 0.90
- s/b = 0.85
- s/b = .80
- s/b = .60
- s/b = .34
- s/b = .16
- s/b = .15

Step 1: tb and tqb 2-D discriminant divided into 16 bins total

Step 2: Merge bins so that have sufficient background -> 7 bins total

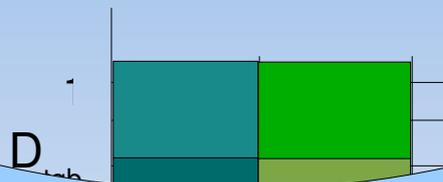
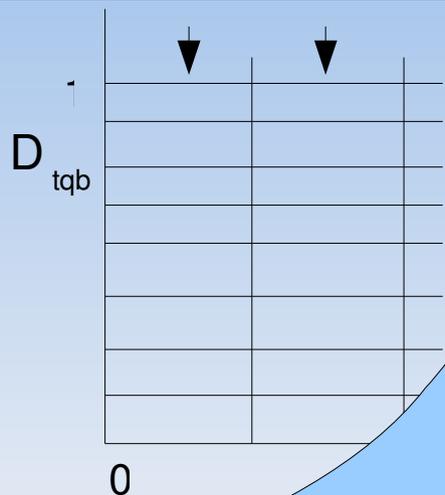
Step 3: Merged bins s/b computed



Step 4: Merged bins ordered by s/b in 16 bins from 0 to 1. Red line signifies H_T cut where below the red line is yield < 175 GeV and above is yield > 175 GeV

Step 5: Histogram divided into low H_T region [0,1] and high H_T region [1,2]. Also these regions are rebinned to 16 bins from [0,2]

Presentation of Discriminant

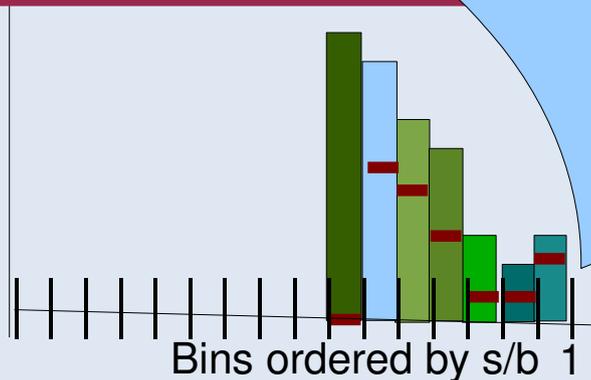


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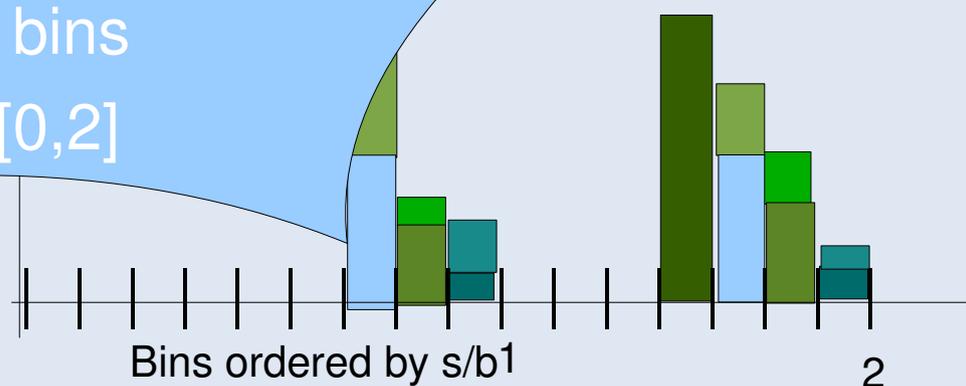
- Analysis uses 40 bins on tqb axis and 20 bins in tb axis = 800 bins total

- Rebin final output from 1600 bins to 100 bins from [0,2]

Step 1: tb and tqb 2-D divided into 16 bins total



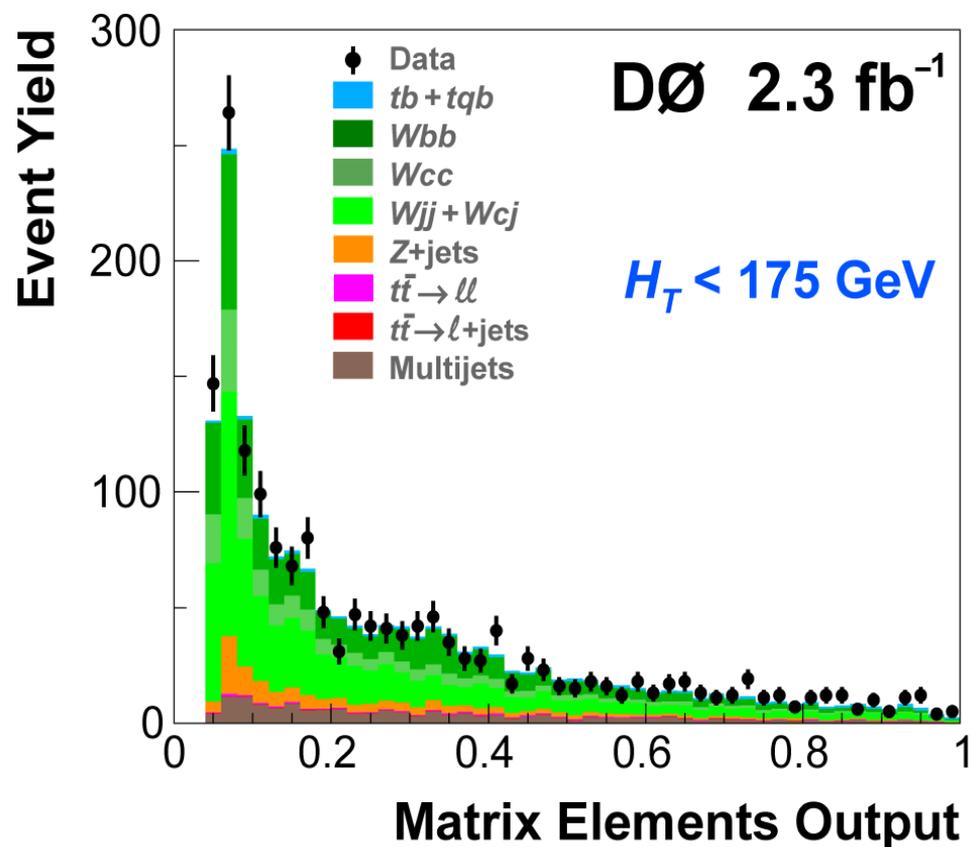
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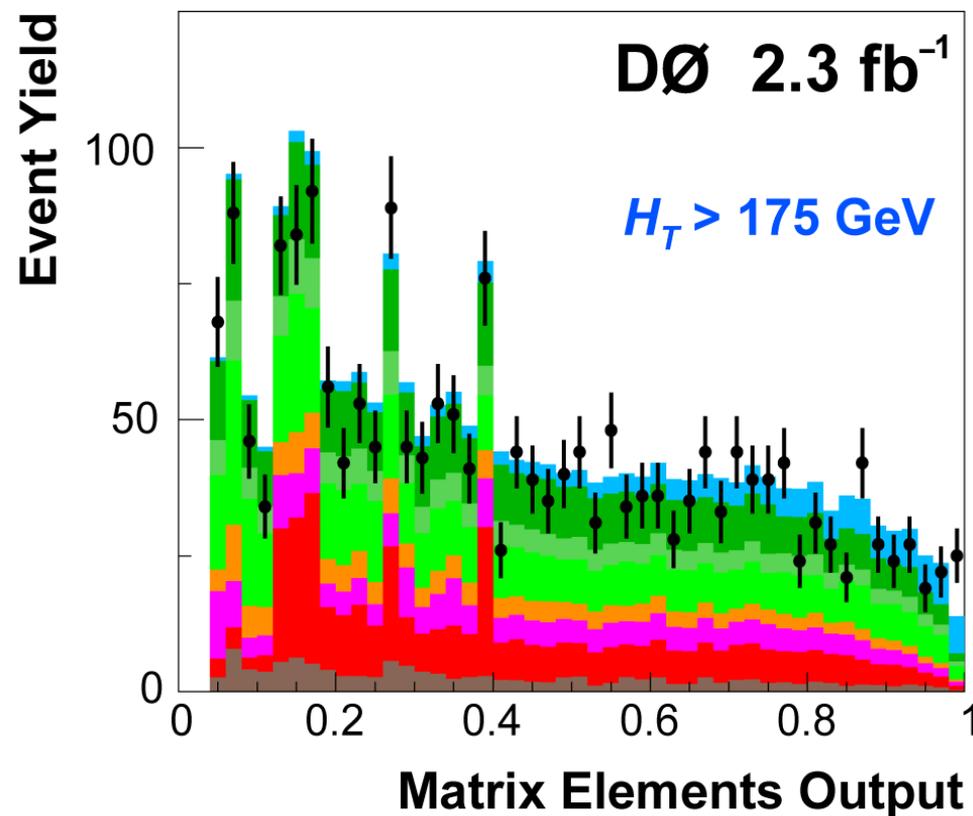
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Discriminant Output



$H_T < 175$ GeV

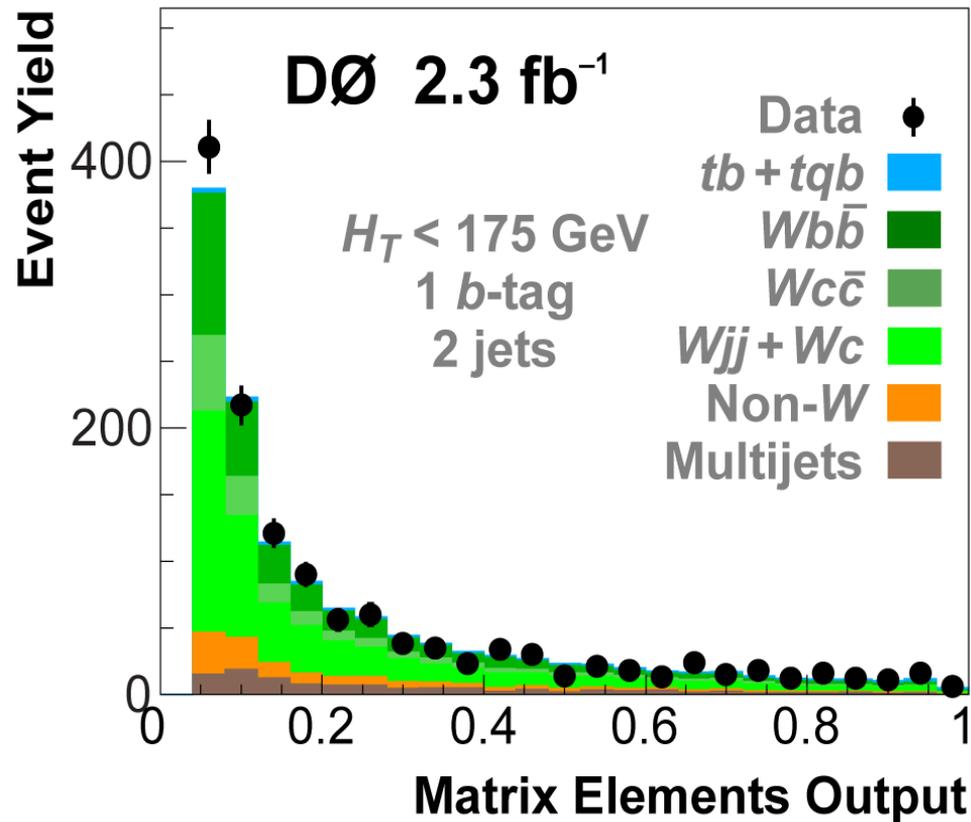


$H_T > 175$ GeV

- Analysis is done on 16 separate channels
- These plots use all 16 channels combined

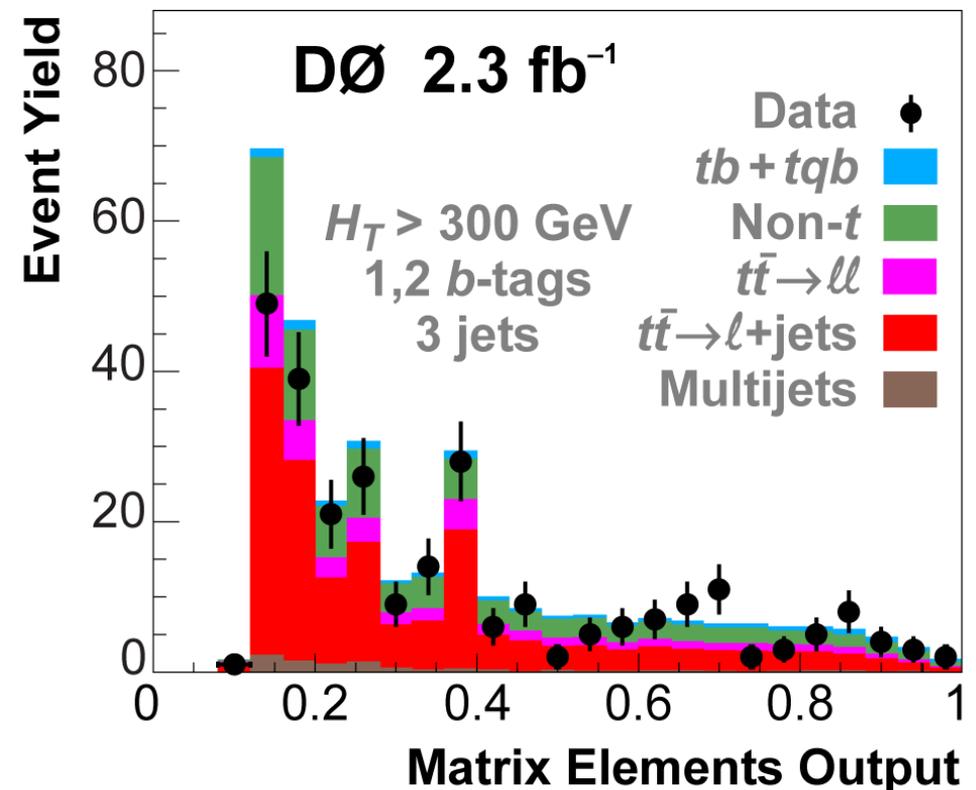
Cross-Check Samples

W+Jets Cross-Check Sample



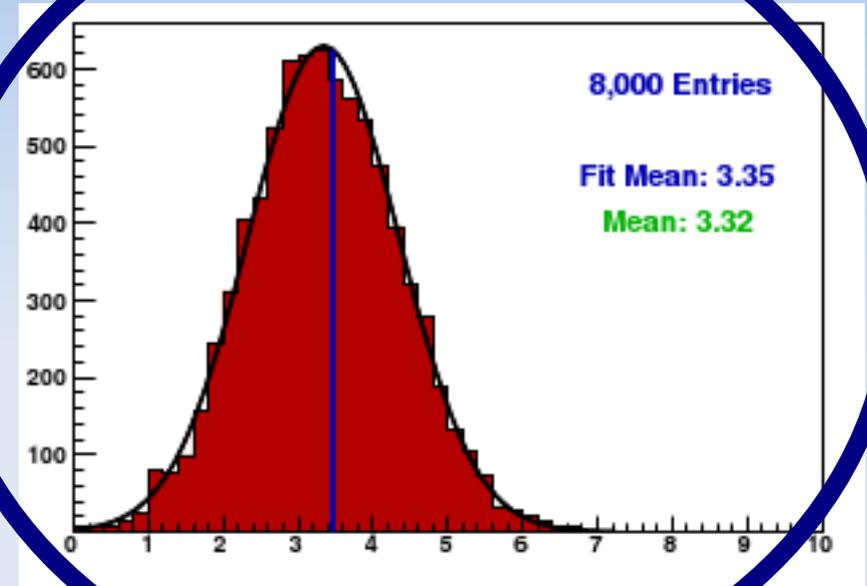
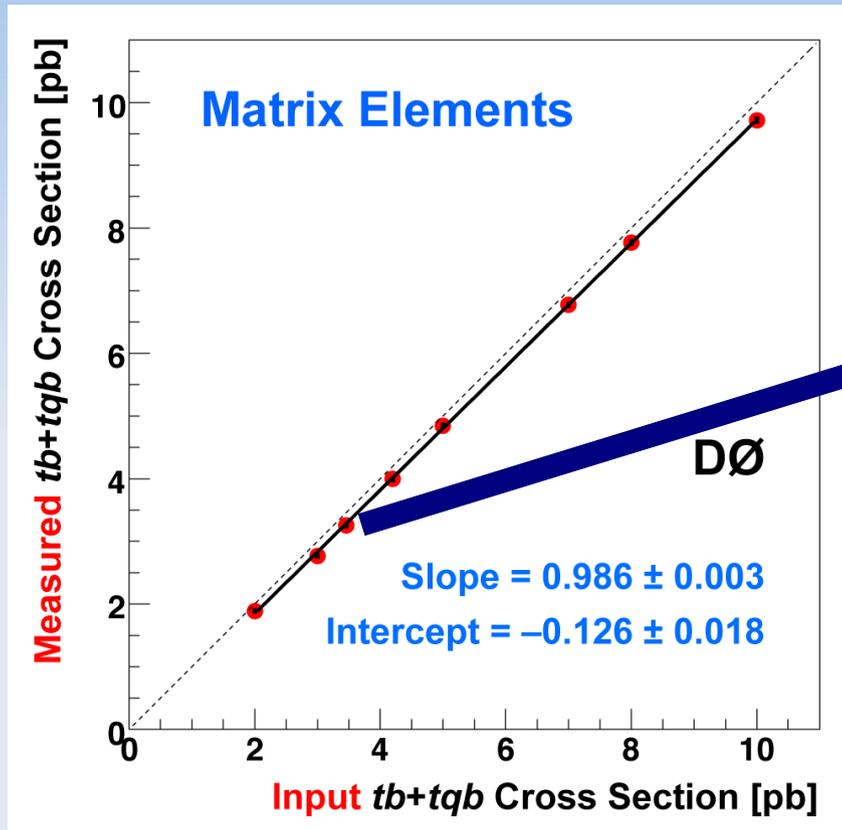
W+jets enriched sample:
 $H_T < 175$ GeV

$t\bar{t}$ -Pairs Cross-Check Sample



$t\bar{t}$ enriched sample:
 $H_T > 300$ GeV

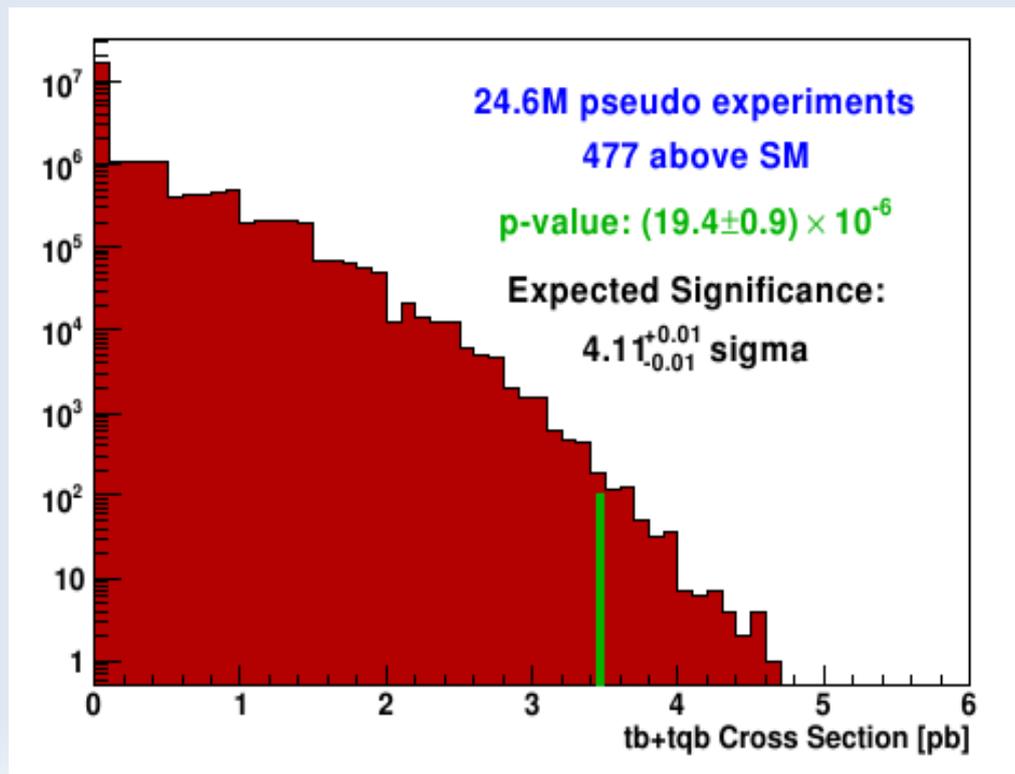
Linearity



- Many DØ experiments generated with different input single top cross section
- Measured the cross section using ME
- Use the fit mean to generate response curve of the method

Expected Cross Section

- Significance:
 - Using a background only cross section, p-value determined by how many cross sections are measured above theoretical cross section of 3.46 pb
 - p-value converted to significance



Theoretical Cross Section:

3.46pb

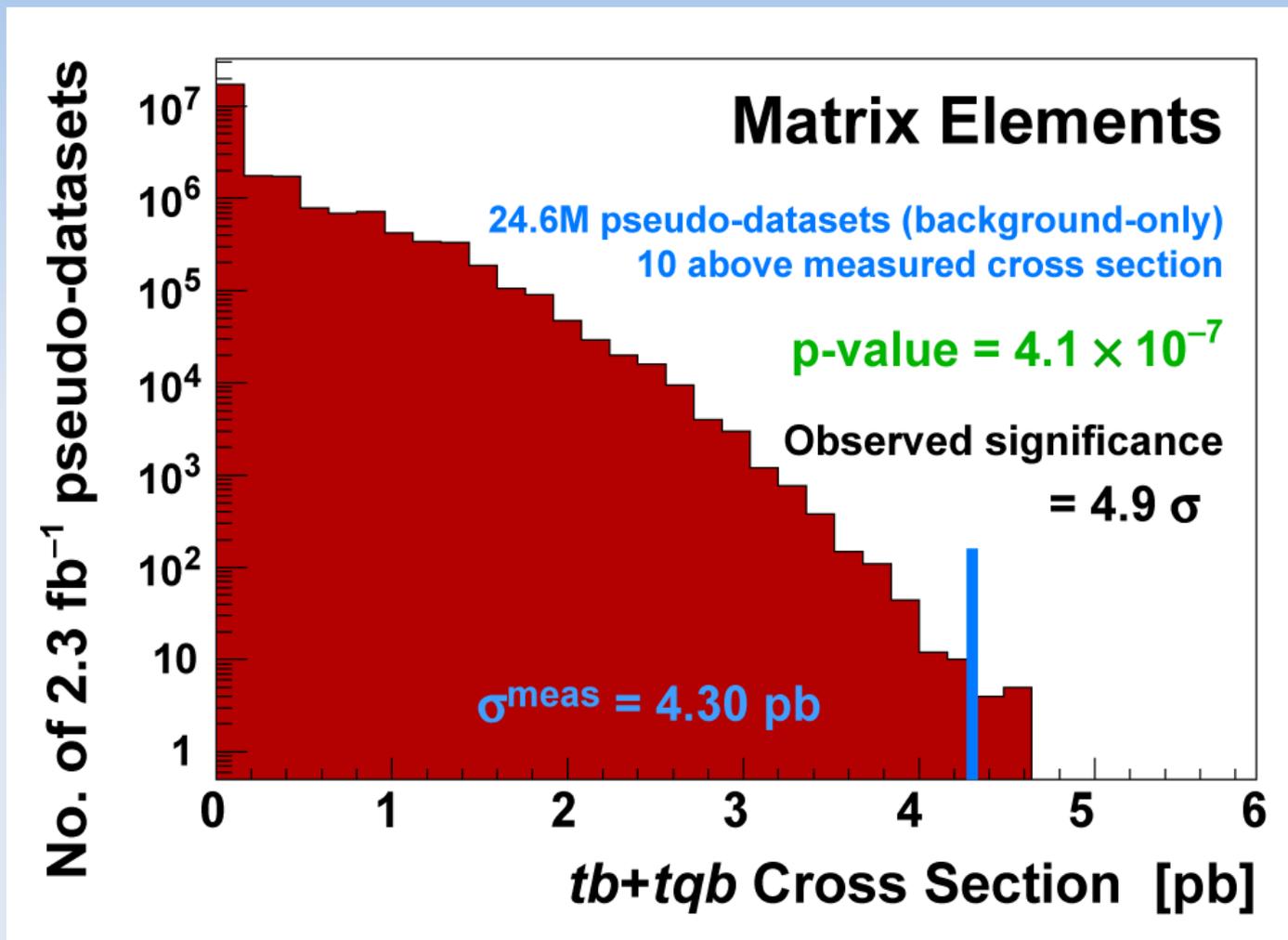
Expected Cross Section:

$3.60 +1.10 - 0.96$ pb

Significance:

4.1σ

Measured Cross Section



Significance:
 4.9σ

Measured Cross Section:
 $4.30 +0.98 - 1.20 \text{ pb}$

Conclusion

- Aside from a larger dataset with a larger signal acceptance, ME analysis improved by adding more matrix elements, s/b ordered bins, and sample split by H_T
- Single top finally discovered using Matrix Element as a combination input with the other multivariate techniques
 - BNN/BDT correlation: 74%
 - ME/BDT correlation: 60%
 - ME/BNN correlation: 57%



Measured Cross Section:
ME: $4.30 + 0.98 - 1.20$ pb
Combination: 3.94 ± 0.88 pb

Significance:
 4.9σ
 5.0σ