Search for Electroweak Top Quark Production at DØ

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The Top Quark

- Discovered in 1995 at the Tevatron
- Heaviest particle to date:

  $m_t = 171.4 \pm 2.1$ GeV / c^2

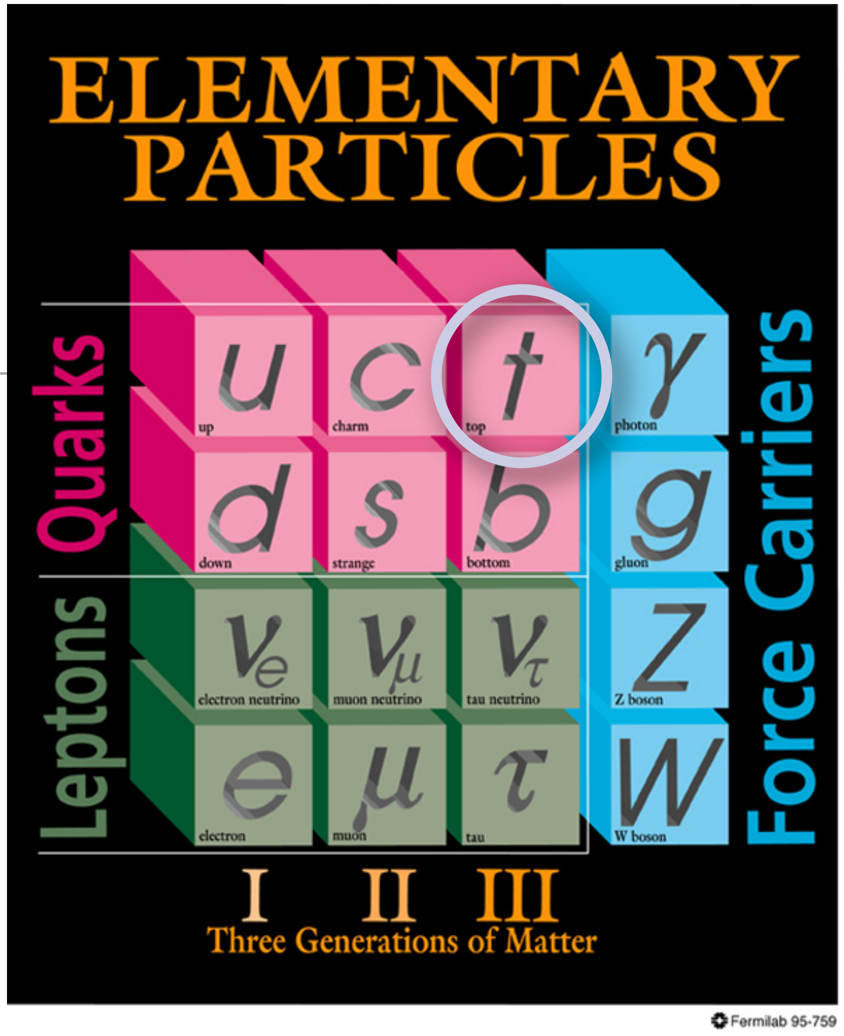
  close to the scale of electroweak symmetry breaking.

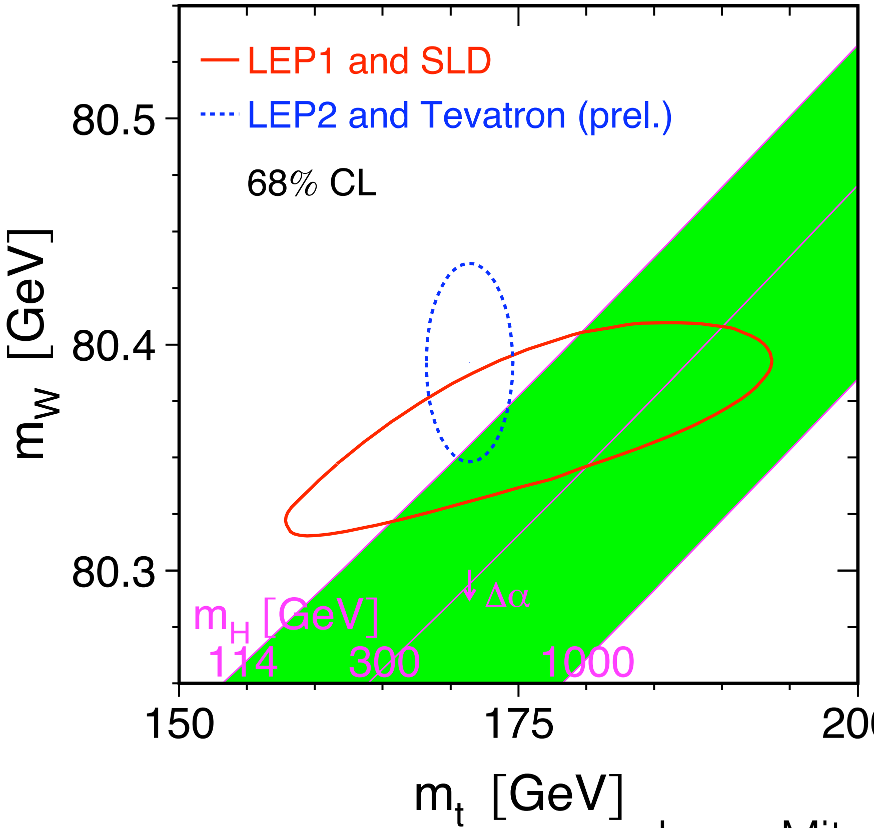
  ➡ Beyond the Standard Model effects?

  ➡ Has a large effect in loop corrections that are in powers of m_t

- Predicted lifetime of $\approx 0.5 \times 10^{-24}$ s, too short to form bound states

  ➡ Retains more information from the fundamental collision

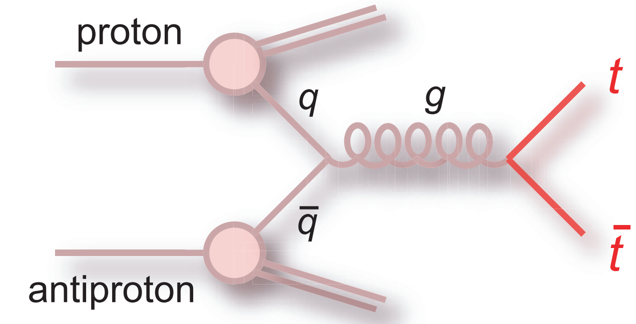


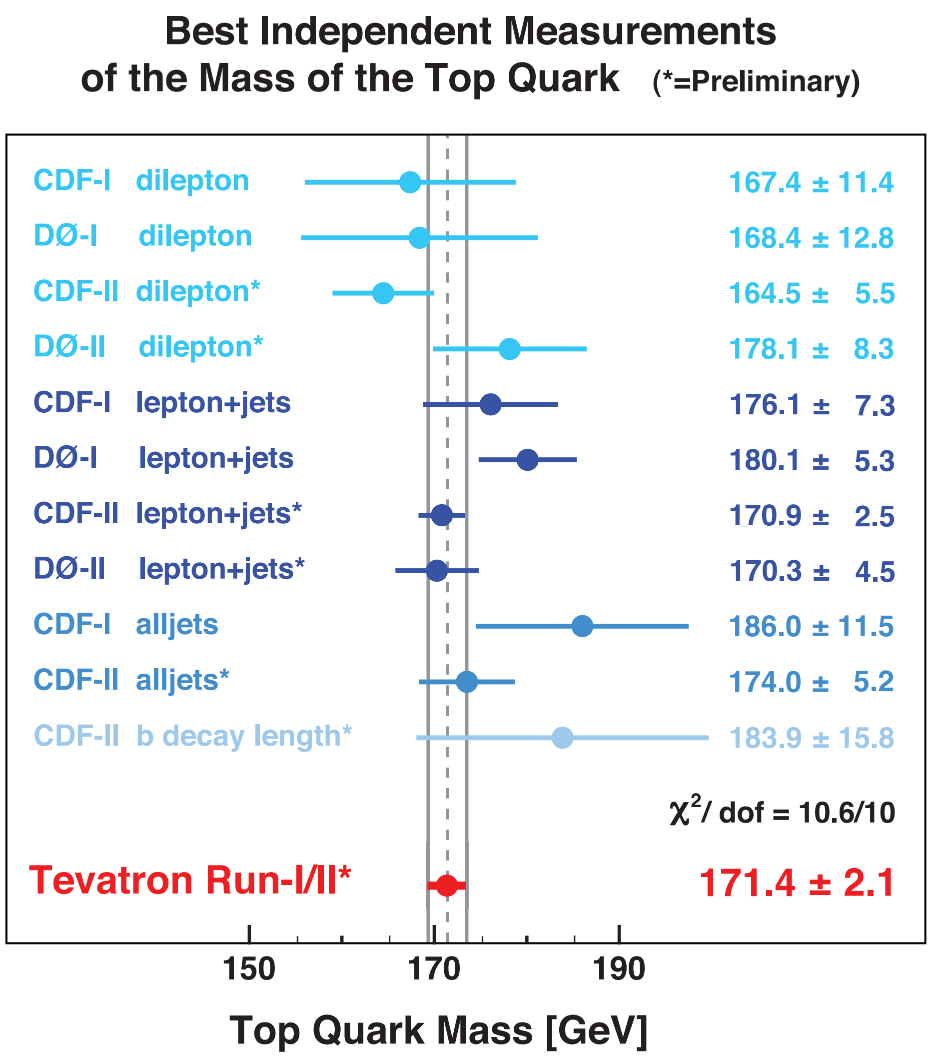


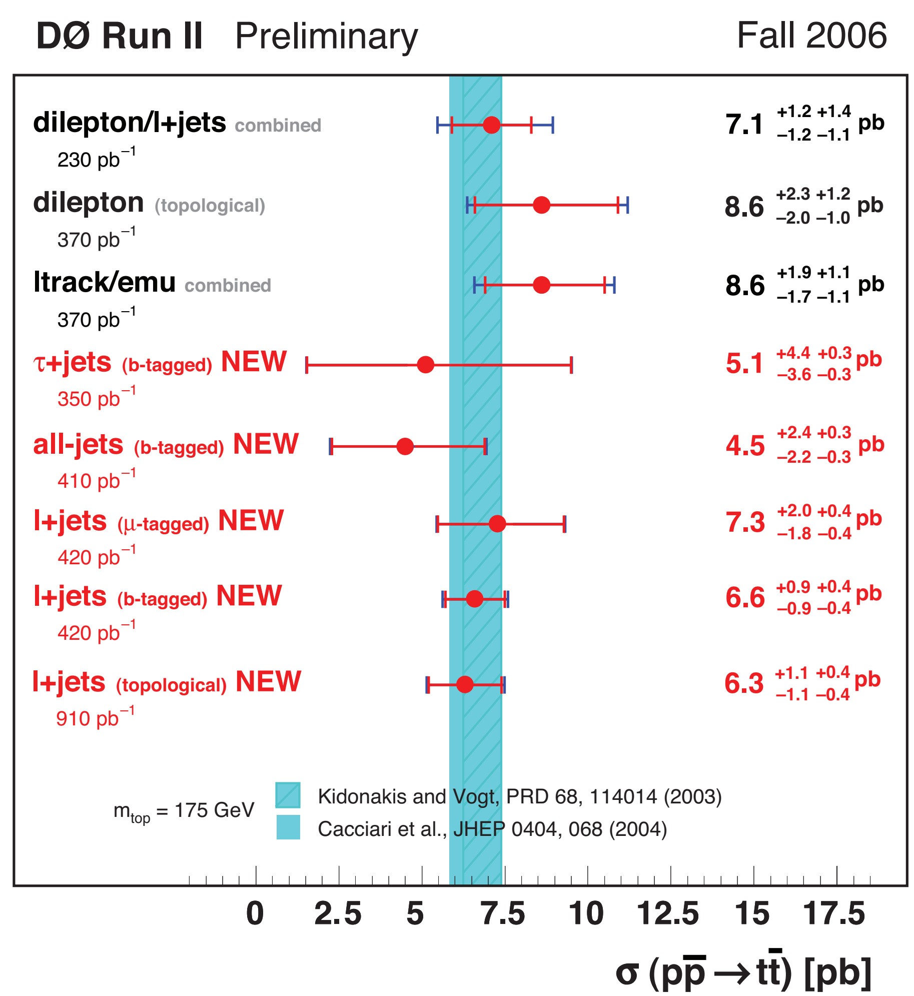
Top Pair Production

- So far, the top quark has only been observed in pairs, produced by the strong force.

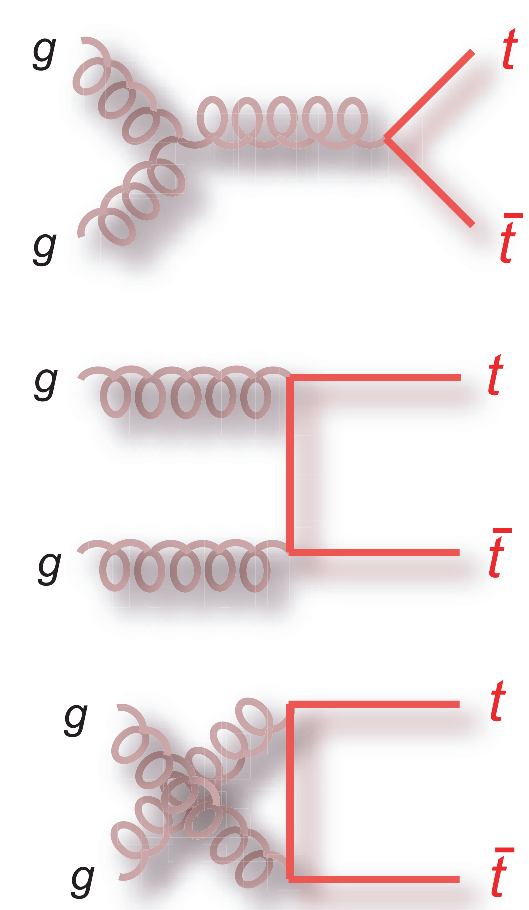
85% $q\bar{q}$ annihilation at the Tevatron







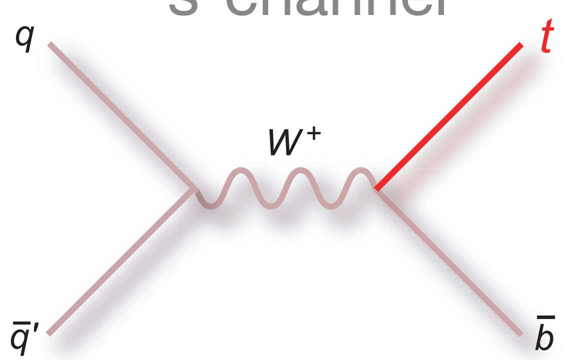
15% gluon fusion



NLO cross sections at m_t = 175 GeV, Phys.Rev. D70 (2004) 114012

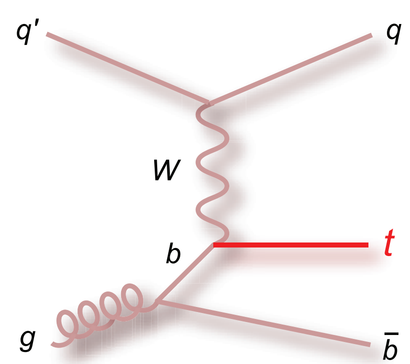
Electroweak Top Quark Production

s-channel



$$\sigma_{tb} = 0.88 \pm 0.07\,\mathrm{pb}$$

t-channel



$$\sigma_{tqb} = 1.98 \pm 0.23\,\mathrm{pb}$$

tW production is negligible at the Tevatron

DØ Limits (95% confidence level)

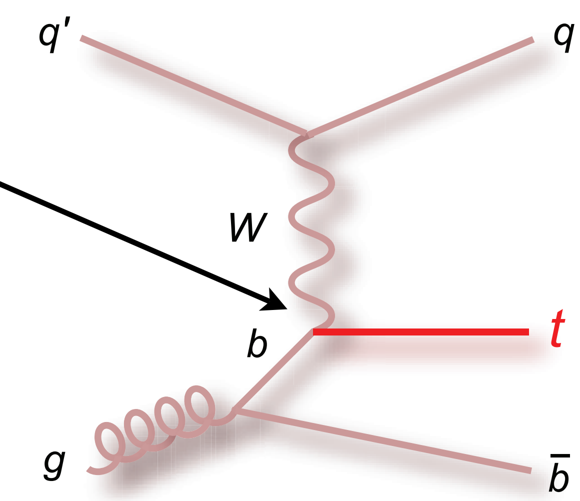
Methodology	Integrated Luminosity	s-channel	t-channel
Cut-based	230 pb^{-1}	10.6 pb	11.3 pb
Neural Network	230 pb^{-1}	6.4 pb	5.0 pb
Likelihood	370 pb^{-1}	5.0 pb	4.4 pb

CDF Limits

Methodology	Integrated Luminosity	s+t-channel
Neural Network	695 pb^{-1}	$\sigma < 3.4$ pb @ 95% CL
Likelihood	955 pb^{-1}	$\sigma < 2.7$ pb @ 95% CL
Matrix Element	955 pb^{-1}	$\sigma = 2.7^{+1.5}_{-1.3}$ pb

Why is Electroweak Production Interesting?

- Electroweak production is directly proportional to $|V_{tb}|^2$



$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

  ➡ Current limits to $|V_{tb}|^2$ assume the CKM matrix is unitary. Without that assumption, it is virtually unconstrained:

  $0.07 \leq |V_{tb}| \leq 0.9993$ (90% CL)

  S. Eidelman *et al*, Phys. Lett. B **592**, 1 (2004)

  ➡ Single top production tests that assumption

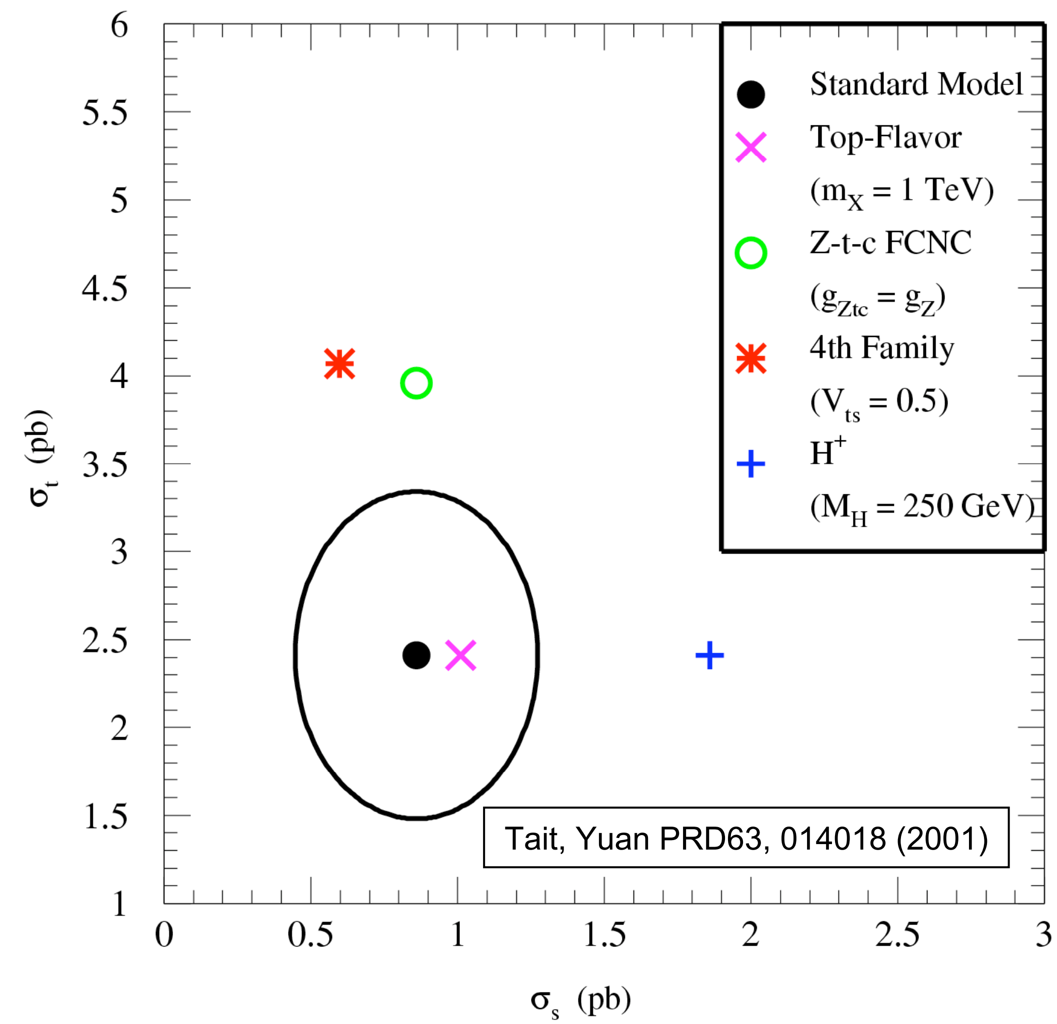
- Good place to study the V−A charged current interaction

  ➡ The Standard Model predicts the top quark to be produced highly polarized

  ➡ Because the top quark decays before it has time to hadronize, it preserves its polarization

Why is Electroweak Production Interesting?

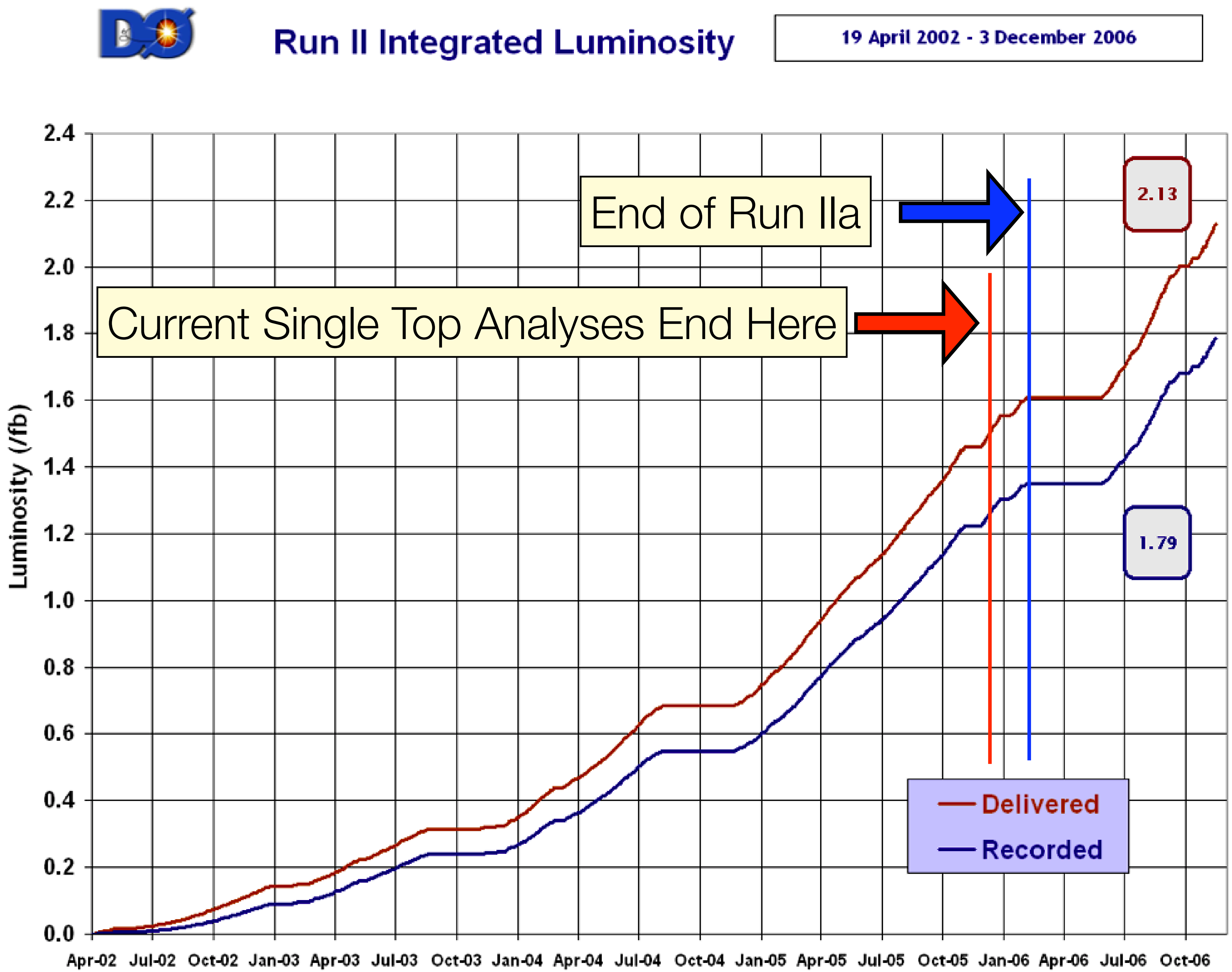
- Sensitive to new physics.
- s-channel and t-channel have different sensitivities.
    - The s-channel is more sensitive to charged resonances, like top pions or charged Higgs particles.
    - The t-channel is more sensitive to FCNC and other new interactions.



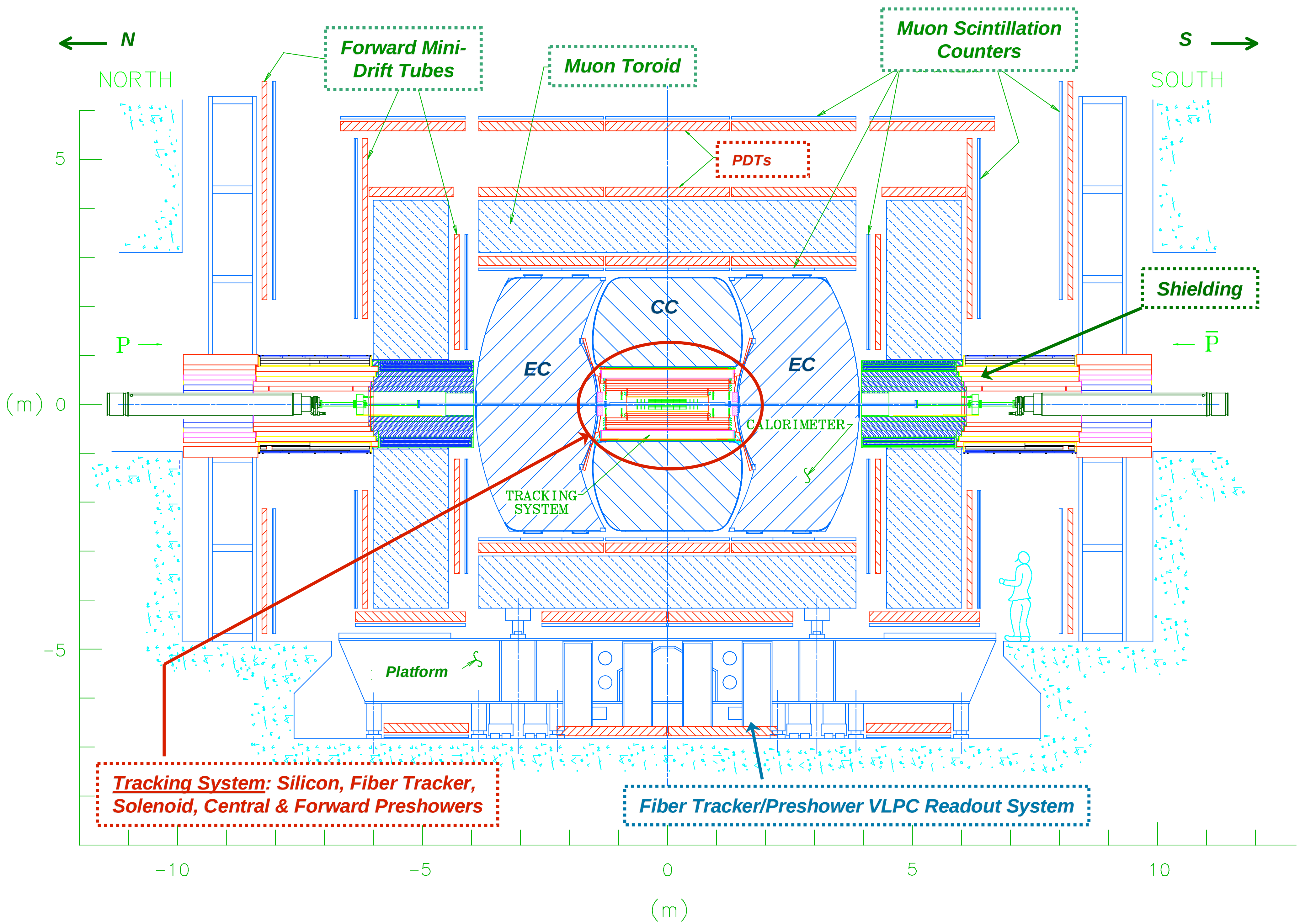
Fermilab and the Tevatron

- The Tevatron is a $p\bar{p}$ collider with $\sqrt{s}$ = 1.96 TeV
- Just a few weeks ago reached the milestone: 2 fb^{-1} have been delivered in Run II.
- Where the top quark was discovered 10 years ago using less than 100 pb^{-1}
- It is currently the only place to study the top quark.

The Tevatron Performance: over 2 fb^{-1} Delivered



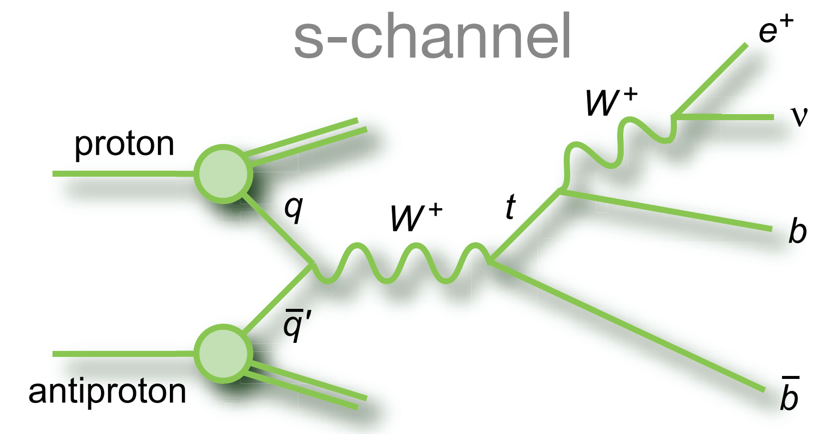
The DØ Detector



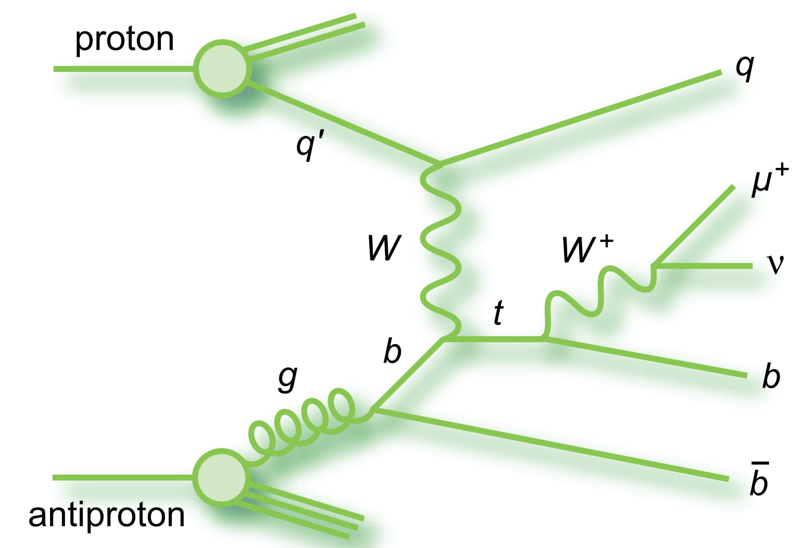
How does Single Top Look?

- The event signature for single top is:
  - a charged lepton and a neutrino (missing E_T) coming from the *W* decay
  - a bottom quark coming from the top quark decay
  - in s-channel, the other bottom quark ($\bar{b}$ on the diagram)
  - in t-channel, the light quark (q in the diagram). This one is often quite forward.
  - in t-channel, the second bottom quark from gluon splitting ($\bar{b}$ on the diagram) is usually not observed.

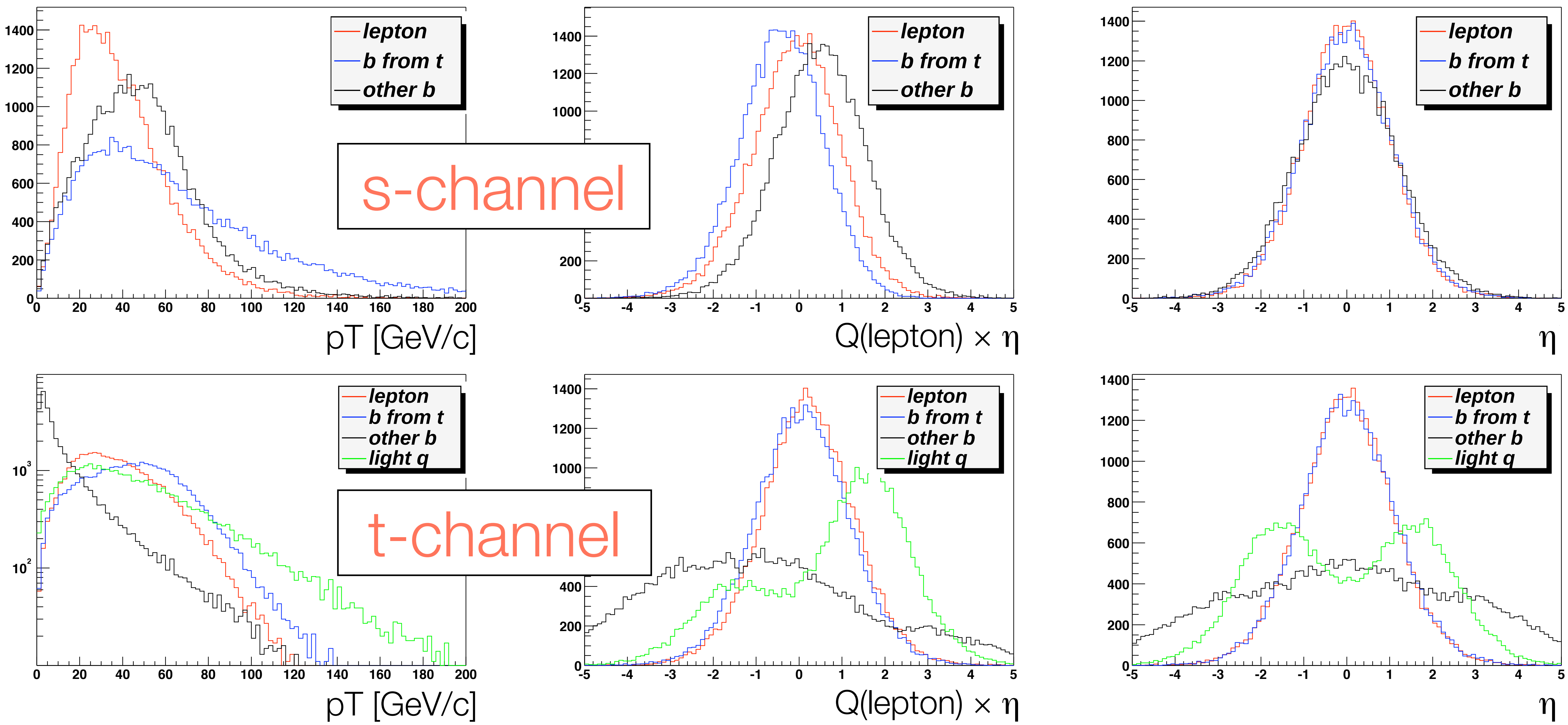
s-channel



t-channel

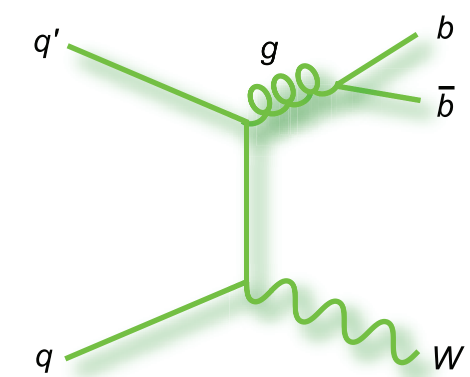


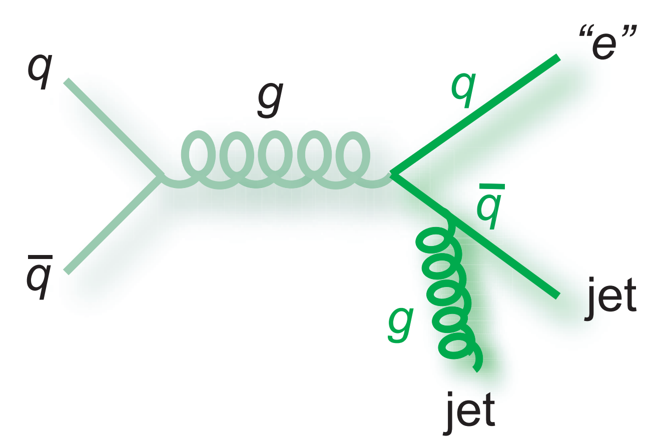
Single Top Parton Distributions



Why hasn't Single Top been observed yet?

- The single top cross section is not that much smaller than that of $t\bar{t}$, which was first observed over 10 years ago
  - ➡ Top pair production has a much more unique event signature.
  - ➡ Single-top is kinematically between top pair and *W*+jets.
- The main background is *W*+jets.
  - *W*+$b\bar{b}$
  - *W*+charm and *W*+light jets that get tagged
- B-tagging is key to reducing the large background
- Other Backgrounds
  - Multijet (i.e. fake lepton)
  - $t\bar{t}$ (more so in higher jet multiplicity bins)





Analysis Overview

- Loose event selection (leave more to the NN, DT, ME).
- Work in separate lepton, jet, and tag bins.
- Background Modeling
  - *W*+jets and $t\bar{t}$: Alpgen/Pythia with MLM matching
    - The heavy flavor content for the *W*+jets sample is measured in data and a k-factor of 1.5 is applied to the *W*+$c\bar{c}$ and *W*+$b\bar{b}$ MC samples.
  - multijet (fake lepton) background: orthogonal data sample.
- Before *b*-tagging (where single-top is negligible), the multijet sample is scaled to the fake lepton yield, and the *W*+jets sample is scaled to the real lepton yield minus the $t\bar{t}$ yield.
- We model the single-top signal with the Monte Carlo generator SingleTop, a version of CompHEP modified to reproduce NLO distributions.

Event Selection

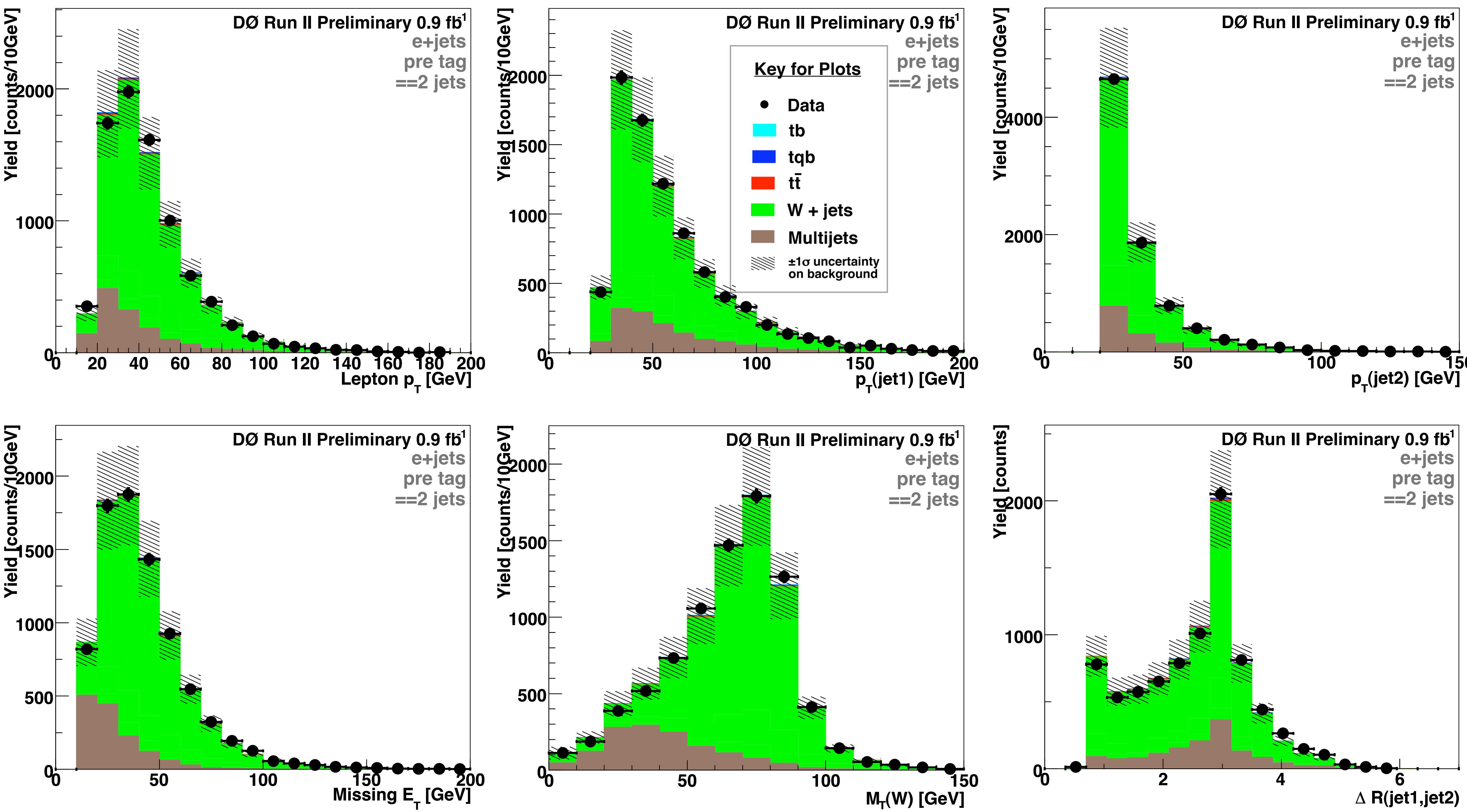
- Good data quality
- Good primary vertex
- lepton+jets triggered data
- Leptons: “tight” electron with $p_T > 15$ GeV, $|\eta| < 1.1$,
  or “tight” muon with $p_T > 18$ GeV, $|\eta| < 2.0$.
- Veto on second charged lepton
- Jets: leading $p_T > 25$ GeV, second jet $p_T > 20$ GeV, others $p_T > 15$ GeV.
  leading $|\eta| < 2.5$, $|\eta| < 3.4$ for subsequent jets.
- 15 GeV $< \not{E}_T <$ 200 GeV
- “Triangle” cuts: don’t take events that have the missing E_T aligned or anti-aligned with the lepton or the leading jet, since that’s probably due to mismeasurement.

Yields Before *b*-Tagging

Yields Before b-Tagging

	Electron Channel					Muon Channel				
	1 jet	2 jets	3 jets	4 jets	5+ jets	1 jet	2 jets	3 jets	4 jets	5 jets
Signals										
tb	4	14	7	2	0	3	10	5	1	0
tqb	9	27	14	5	1	6	20	11	3	1
tb+tqb	14	41	21	6	2	9	31	16	5	1
Backgrounds										
$t\bar{t}\rightarrow ll$	9	35	28	10	4	5	27	22	8	3
$t\bar{t}\rightarrow l$+jets	2	26	103	128	67	1	14	71	99	43
$Wb\bar{b}$	659	358	149	42	5	431	312	161	47	10
$Wc\bar{c}$	1,592	931	389	93	10	1,405	1,028	523	131	21
Wjj	23,417	5,437	1,546	343	51	15,476	4,723	1,591	385	85
Multijets	1,691	1,433	860	256	86	498	329	223	58	10
Background Sum	27,370	8,220	3,075	874	223	17,816	6,434	2,592	727	172
Data	27,370	8,220	3,075	874	223	17,816	6,432	2,590	727	173

Data/MC Comparisons Before *b*-Tagging (2 jet bin, electron channel)

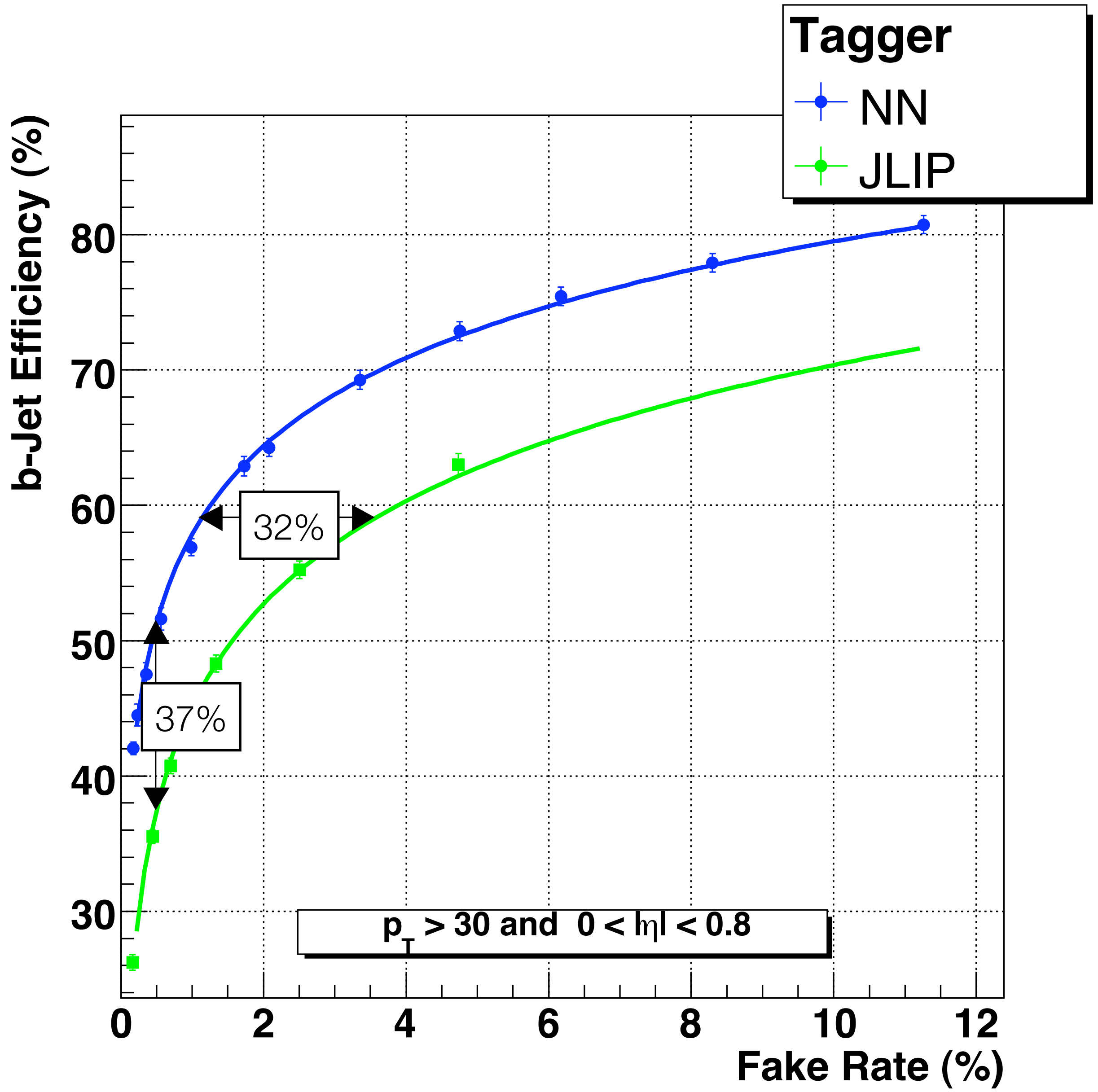


B-Tagging

- As mentioned in the introduction, *b*-tagging is one of the key ways we decrease the large background
- One of the recent improvements at DØ is the new Neural Network Tagger.
- The plots on the right show its performance on data in comparison to JLIP, an older tagger.

Rank	Variable	Description
1	SVT_{SL} DLS	Decay Length Significance of the Secondary Vertex (SV)
2	CSIP Comb	Weighted combination of the tracks' IP Significances
3	JLIP Prob	Probability that the jet originates from the PV
4	SVT_{SL} χ^2_{dof}	Chi Square per degree of freedom of the SV
5	SVT_L N_{Tracks}	Number of tracks used to reconstruct the SV
6	SVT_{SL} Mass	Mass of the SV
7	SVT_{SL} Num	Number of SV found in the jet

Table 1: NN input variables ranked in order of power.



"TIGHT" operating point
Efficiency: 50%, Fake Rate: 0.5%

Signal : Background

Percentage of s-channel *tb* selected events and S:B ratio (white squares = no plans to analyze)

Electron + Muon	1 jet	2 jets	3 jets	4 jets	≥ 5 jets
0 tags	8% 1 : 11,000	19% 1 : 1,600	9% 1 : 1,200	3% 1 : 1,100	1% 1 :1,000
1 tag	6% 1 : 270	24% 1 : 55	12% 1 : 73	3% 1 : 130	1% 1 : 200
2 tags		9% 1 : 12	4% 1 : 27	1% 1 : 92	0% 1 :110

Percentage of t-channel *tqb* selected events and S:B ratio (white squares = no plans to analyze)

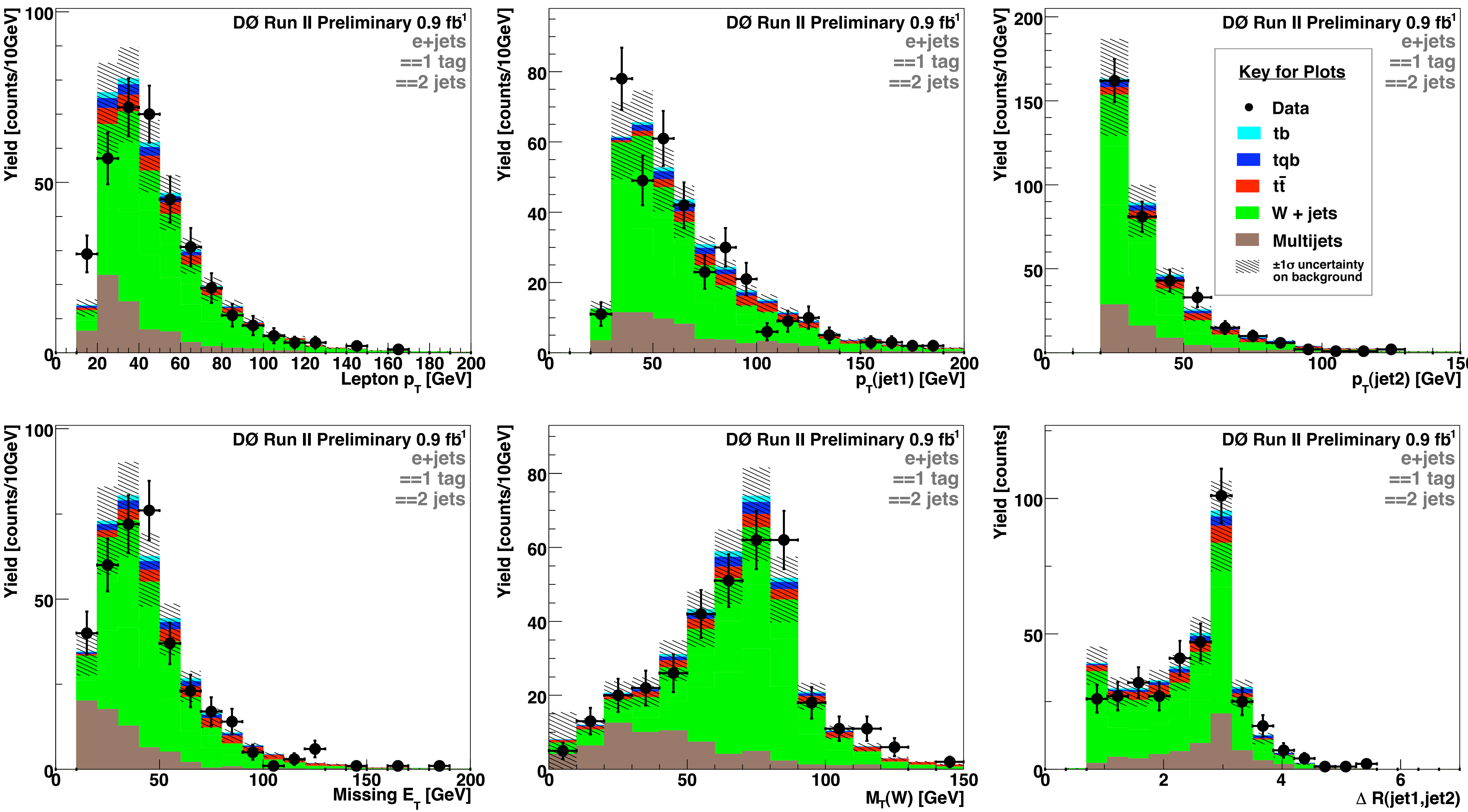
Electron + Muon	1 jet	2 jets	3 jets	4 jets	≥ 5 jets
0 tags	10% 1 : 4,400	27% 1 : 520	13% 1 : 400	4% 1 : 360	1% 1 : 300
1 tag	6% 1 : 150	20% 1 : 32	11% 1 : 37	4% 1 : 58	1% 1 : 72
2 tags		1% 1 : 100	2% 1 : 36	1% 1 : 65	0% 1 : 70

Yields with One *b*-Tagged Jet

Yields with One b-Tagged Jet

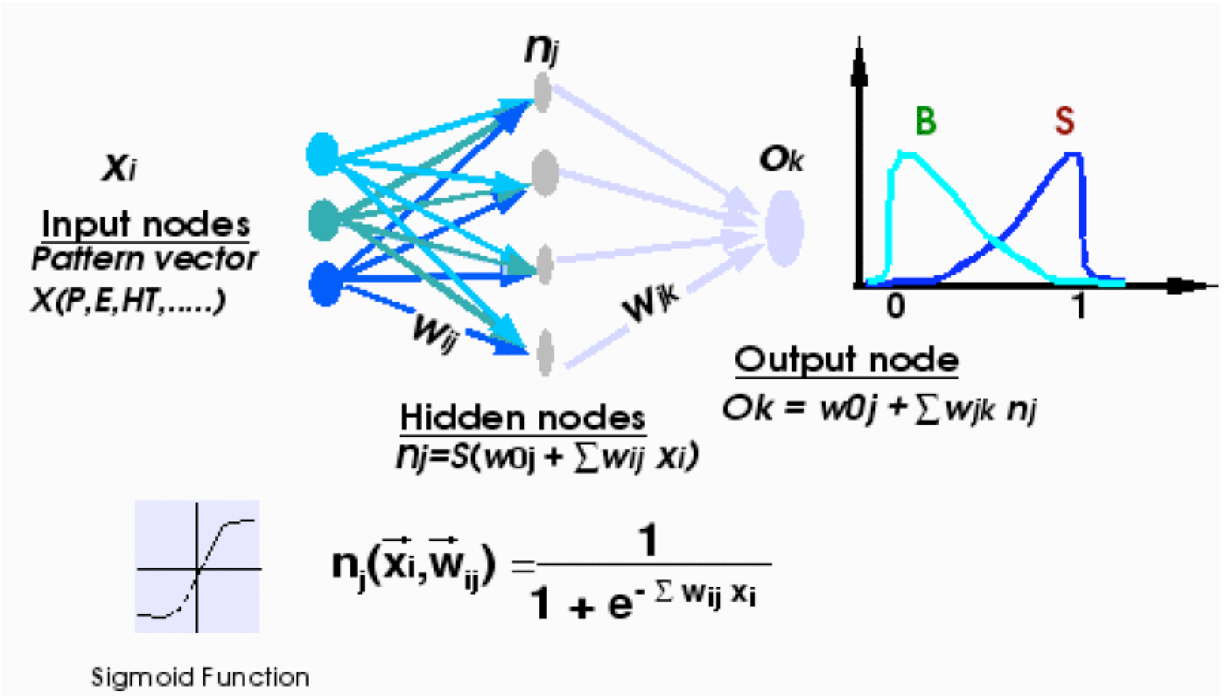
	Electron Channel					Muon Channel				
	1 jet	2 jets	3 jets	4 jets	5+ jets	1 jet	2 jets	3 jets	4 jets	5 jets
Signals										
tb	2	7	3	1	0	1	5	2	1	0
tqb	3	11	6	2	1	2	9	5	2	0
tb+tqb	5	18	9	3	1	3	14	7	2	1
Backgrounds										
$t\bar{t}\to ll$	4	16	13	5	2	2	13	10	4	1
$t\bar{t}\to l$+jets	1	11	47	58	30	0	6	32	45	20
$Wb\bar{b}$	188	120	50	14	2	131	110	56	16	4
$Wc\bar{c}$	81	74	36	9	1	64	74	46	13	2
Wjj	175	61	20	5	1	125	58	23	6	2
Multijets	36	66	48	18	7	17	26	24	8	2
Background Sum	484	348	213	110	43	340	286	191	93	30
Data	445	357	207	97	35	289	287	179	100	38

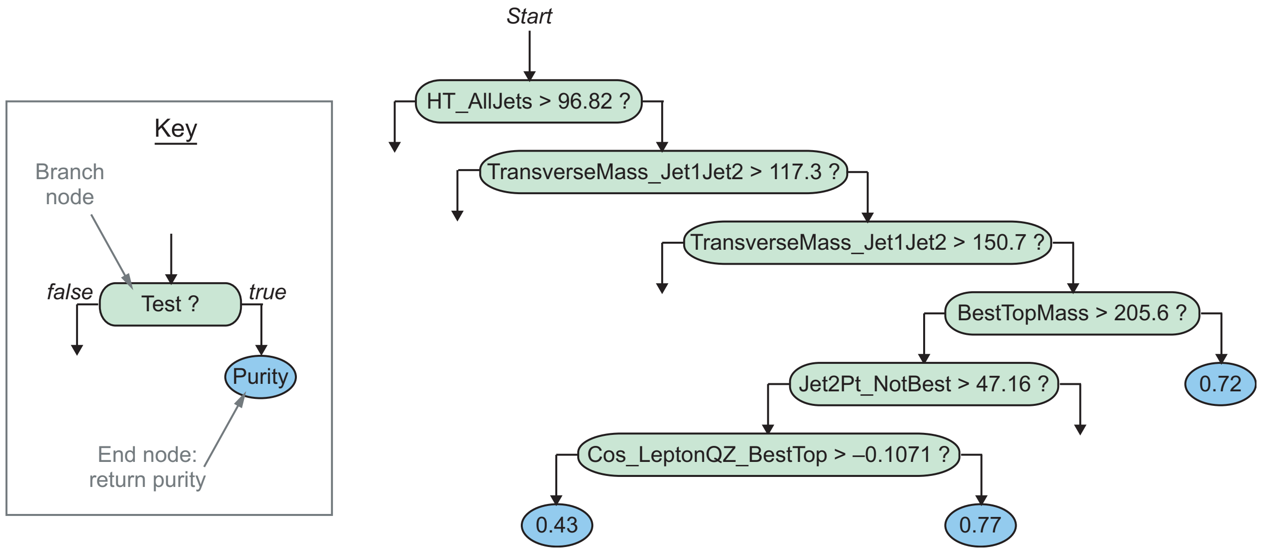
Data/MC Comparisons After *b*-Tagging (2 jet bin, electron channel, one tag)



How to proceed

- Method 1: Optimized cuts-based, but shown not to be competitive
- Method 2: Neural Networks. Bayesian Neural Networks show lots of promise
- Method 3: Boosted Decision Trees





- Method 4: Matrix Element. This is the focus of this presentation

Matrix Element Method

- The matrix element encodes all the kinematic information.

$$\mathrm{d}\sigma = \frac{|\mathcal{M}|^2}{F}\mathrm{d}Q$$

Where *F* is the flux factor and d*Q* is the Lorentz invariant phase space factor.

- The method makes maximal use of the information. The matrix element contains all the properties of the interaction. (practical limitation: LO matrix element.)

- The method requires no training. It is firmly grounded in the physics.

The Main Idea of the Matrix Element Method

- Assume a particular process (e.g. t-channel single top). The probability to observe a particular configuration of jets and leptons given that process is proportional to the differential cross section of that process for such an configuration.

$$P(\mathrm{config}\,|\,\mathrm{process}) \sim \frac{\mathrm{d}\sigma_{\mathrm{process}}}{\mathrm{d}(\mathrm{config})}$$

- Can determine the probability of an observed configuration assuming (given) signal and its probability assuming (given) background.

- Bayes' rule:

$$P(\mathrm{signal}\,|\,\mathrm{config}) = \frac{P(\mathrm{config}\,|\,\mathrm{signal})\,P(\mathrm{signal})}{P(\mathrm{config}\,|\,\mathrm{signal})P(\mathrm{signal}) + P(\mathrm{config}\,|\,\mathrm{back})P(\mathrm{back})}$$

The Matrix Element Analysis

- Being more explicit:

$$D(x) = \frac{P(x|S)}{P(x|S) + P(x|B)}$$

where

$$P(x|S) = \frac{1}{\sigma_s}\left(\frac{d\sigma_s}{dx}\right) \qquad P(x|B) = \sum_i w_i P(x|B_i) \qquad P(x|B_i) = \frac{1}{\sigma_{b_i}}\left(\frac{d\sigma_{b_i}}{dx}\right)$$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}x} \sim \sum_{i_{\mathrm{perm}}} \int \mathrm{d}^n y \frac{|M(y,i)|^2}{F(y)} f_1(y) f_2(y) \mathrm{TF}(y,x,i) \qquad \sigma = \int \mathrm{d}x \frac{\mathrm{d}\sigma}{\mathrm{d}x}$$

- *y*: the parton-level information
- *x*: the reconstructed information
- *F*: the flux factor
- f_1 and f_2: the two PDFs
- TF: the transfer function, relating parton and reconstructed information.

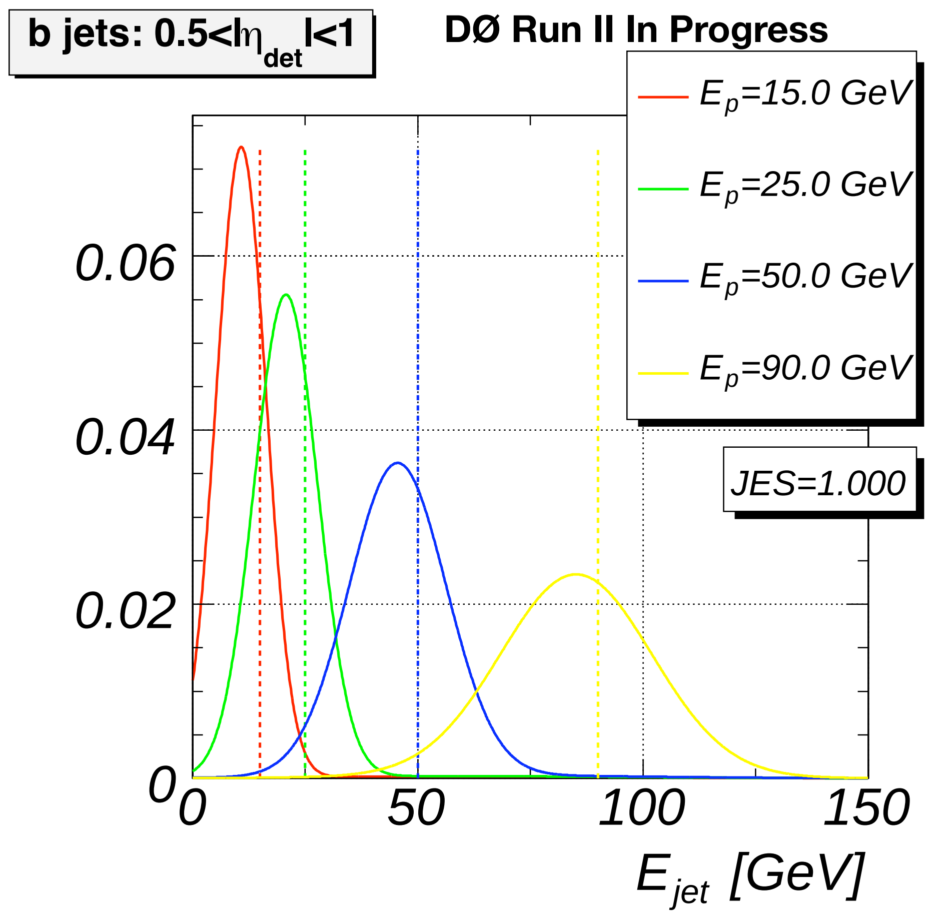
The Transfer Functions

- We measure reconstructed values, but the Matrix Element uses parton values.
    ➡ Transfer Functions
- We assume:
    - can use per-object transfer functions
    - the angles are perfectly measured
- For jets, we use a double Gaussian form parameterized in energy in η bins. There are separate parameterizations for light, b, and b(→μ) jets jets.

$$W_{object}(E_{parton}, E_{object}) = \frac{1}{\sqrt{2\pi}(p_2 + p_3 p_5)} \times \left(e^{\frac{-(E_{object} - E_{parton} - p_1)^2}{2p_2^2}} + p_3 e^{\frac{-(E_{object} - E_{parton} - p_4)^2}{2p_5^2}}\right)$$

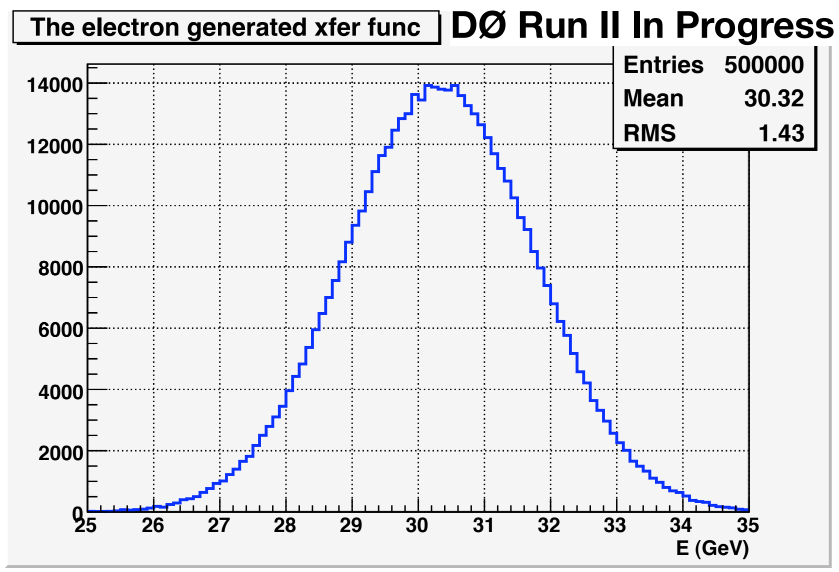
- For electrons, we use a single Gaussian parameterized in energy and η.
- For muons we use a single Gaussian parameterized in (q/p_T), η, and if there are silicon tracker hits.

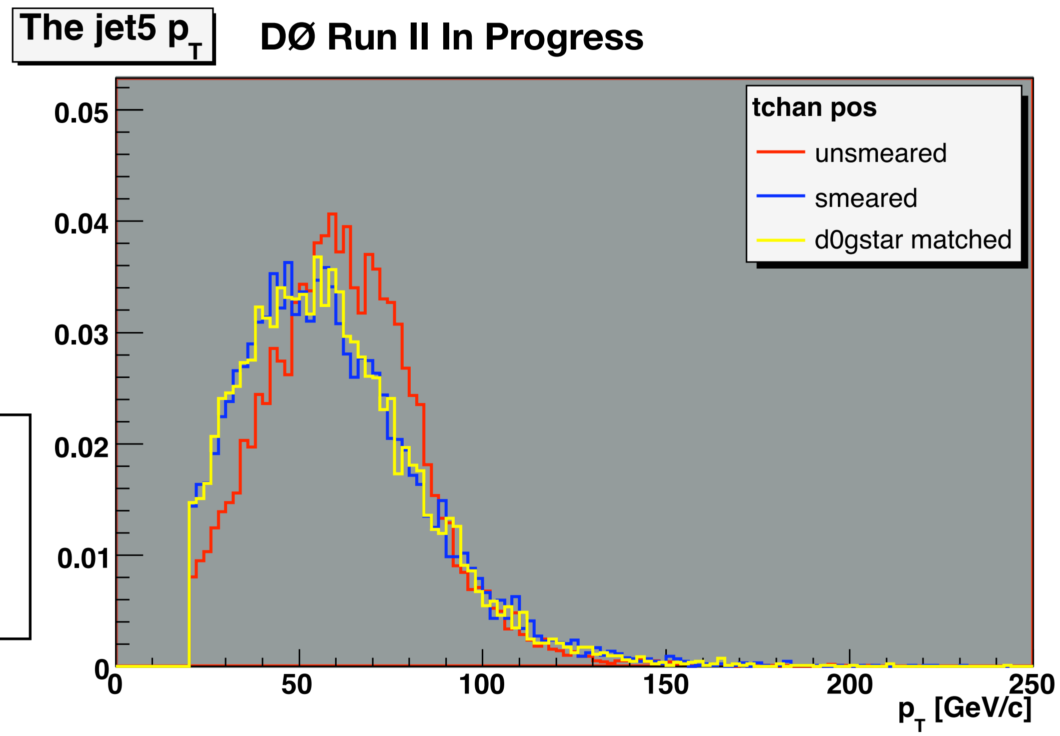
Transfer Functions (cont.)



The jet transfer function for b-jets

The electron transfer function, Ep = 30 GeV, η = 0.3





Applying the jet transfer function on the bottom quark from the top decay (blue) vs. full GEANT simulation (yellow)

B-Tagging

- Another feature that I view as part of the transfer function is the assignment of jets to partons. We sum all possible assignments.
- If we do not have extra information, we weigh each permutation equally:

$$d\sigma = 0.5 d\sigma(j_1 \to q_1, j_2 \to q_2) + 0.5 d\sigma(j_2 \to q_1, j_1 \to q_2)$$

- However, if we do have one *b*-tagged jet, and we are calculating the t-channel cross-section, where we are using diagrams of the type b u → e^+ ν_e b d, we can do better:

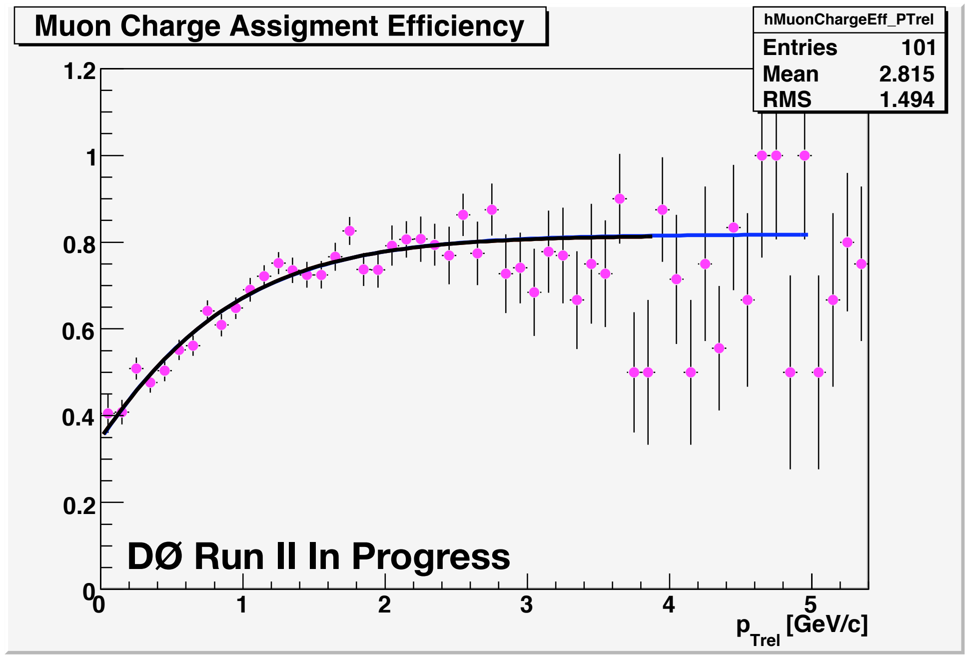
$$d\sigma = \epsilon_b(j_{\text{tag}})[1 - \epsilon_l(j_{\text{untag}})] d\sigma(j_{\text{tag}} \to b, j_{\text{untag}} \to d)$$

$$+[1 - \epsilon_b(j_{\text{untag}})]\epsilon_l(j_{\text{tag}}) d\sigma(j_{\text{untag}} \to b, j_{\text{tag}} \to d)$$

- The extension to 3 jets is straightforward.

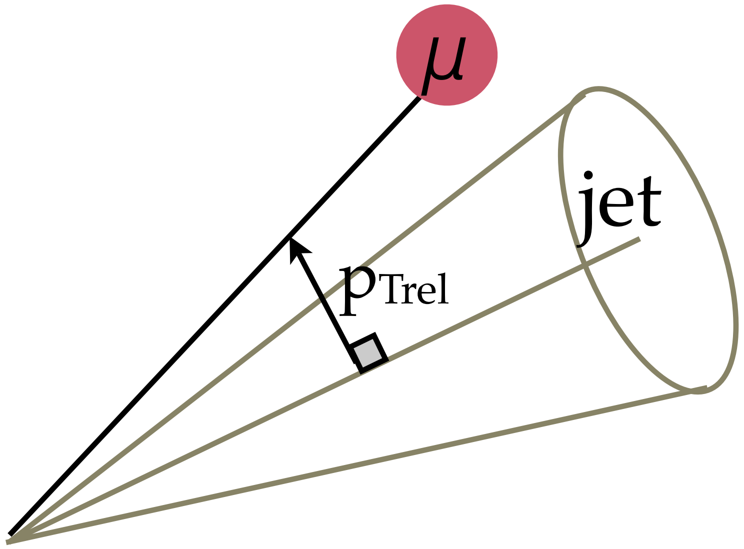
Muon Charge

- The s-channel, which has a *b*-jet and a *b̄*-jet as the two jets, can benefit from *b*-tagging since the tagging efficiency depends on η and p_T.



- But maybe if a *b*-quark decays leptonically we can use the muon charge:
  - all good: $b \to \mu^- \bar{\nu} c$ $\quad \bar{b} \to \mu^+ \nu \bar{c}$
  - but also: $b \to x\bar{x}c \to \mu^+ \bar{\nu} s$ $\quad \bar{b} \to x\bar{x}\bar{c} \to \mu^- \nu \bar{s}$

- Use p_{Trel}, or the p_T of the muon relative to the jet. Muons from charm quarks are expected to have a lower p_{Trel}. Do the same as for *b*-tagging.



- It will be used in the next round.

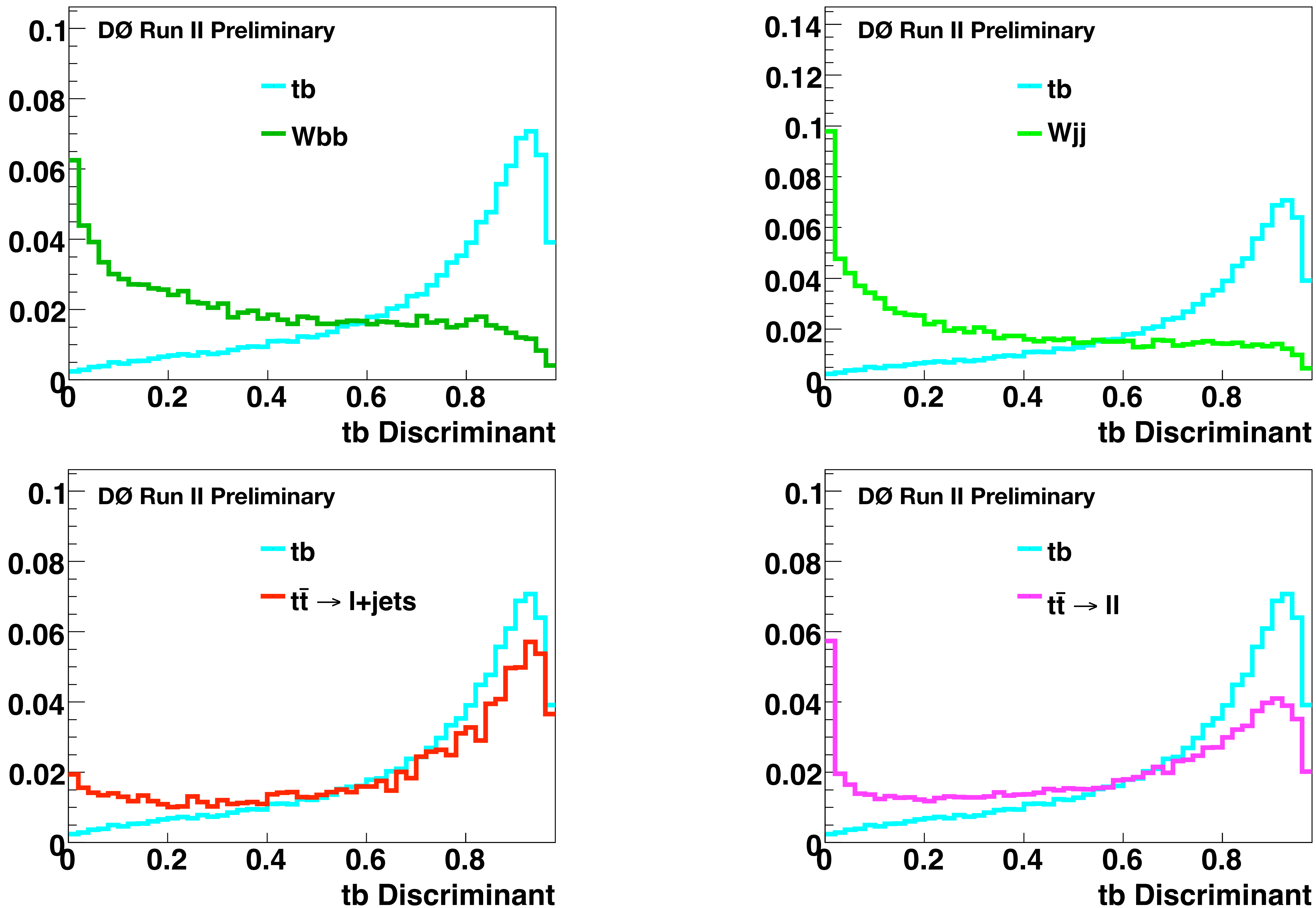
The Details

- We are using MadEvent LO matrix elements, and CTEQ6L1 pdfs.
- We look at events with 2 and 3 jets.
- The Matrix Elements we now use are:
  - Signal: s-channel or t-channel single-top
  - Background: *Wbb*, *Wcg*, and *Wgg* (2 jets); *Wbbg* (3 jets)

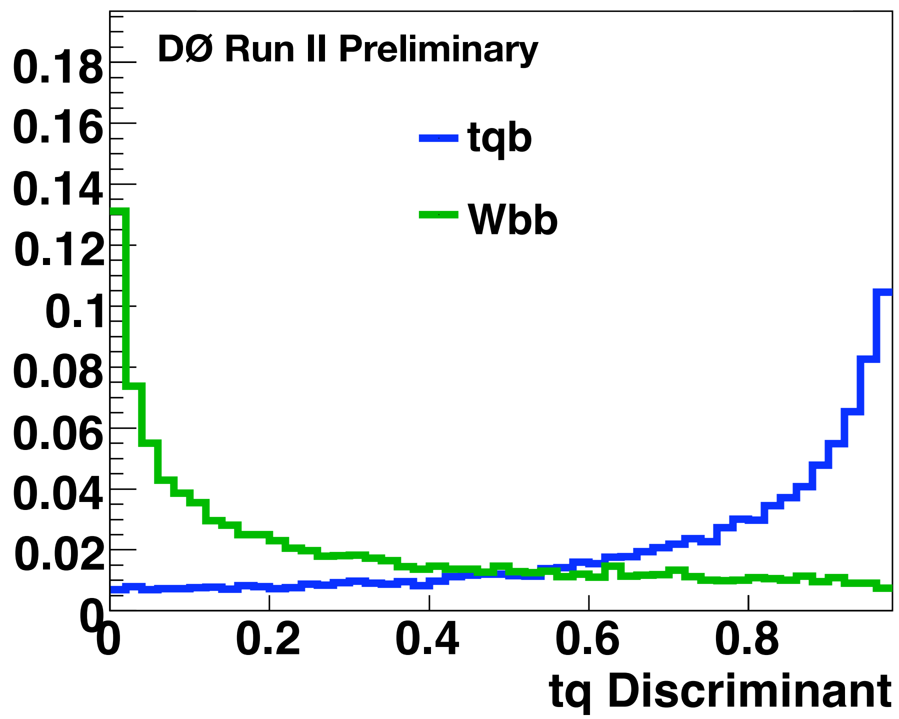
$$P(x|B) = w_{Wbb}P(x|Wbb) + w_{Wcg}P(x|Wcg) + w_{Wgg}P(x|Wgg)$$

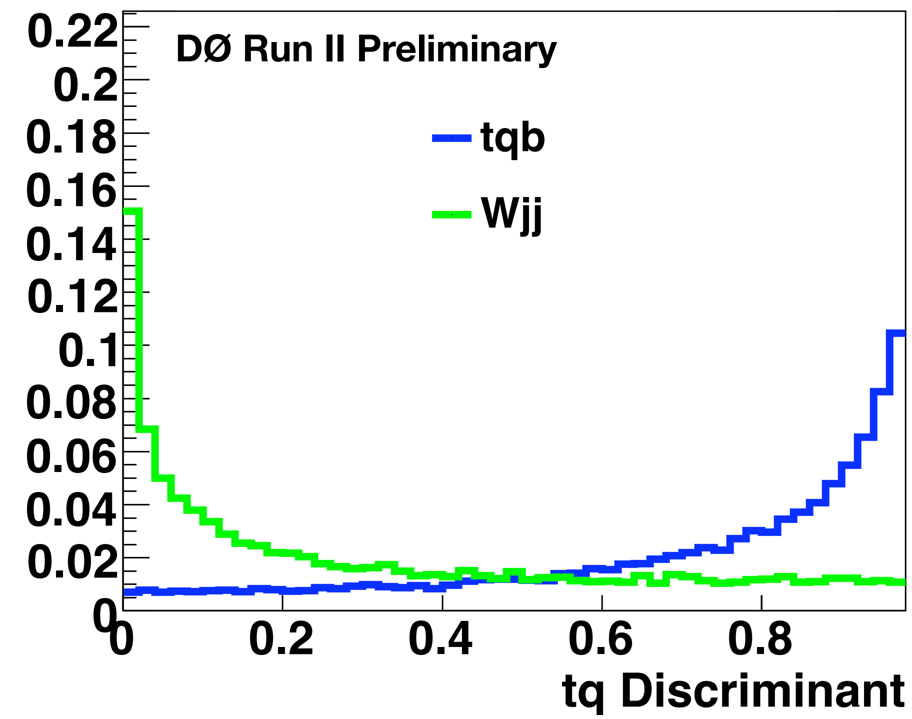
- Major upgrade under way: $t\bar{t}$ matrix elements.
- Also adding extra 3 jet *W*+jets and signal matrix elements.

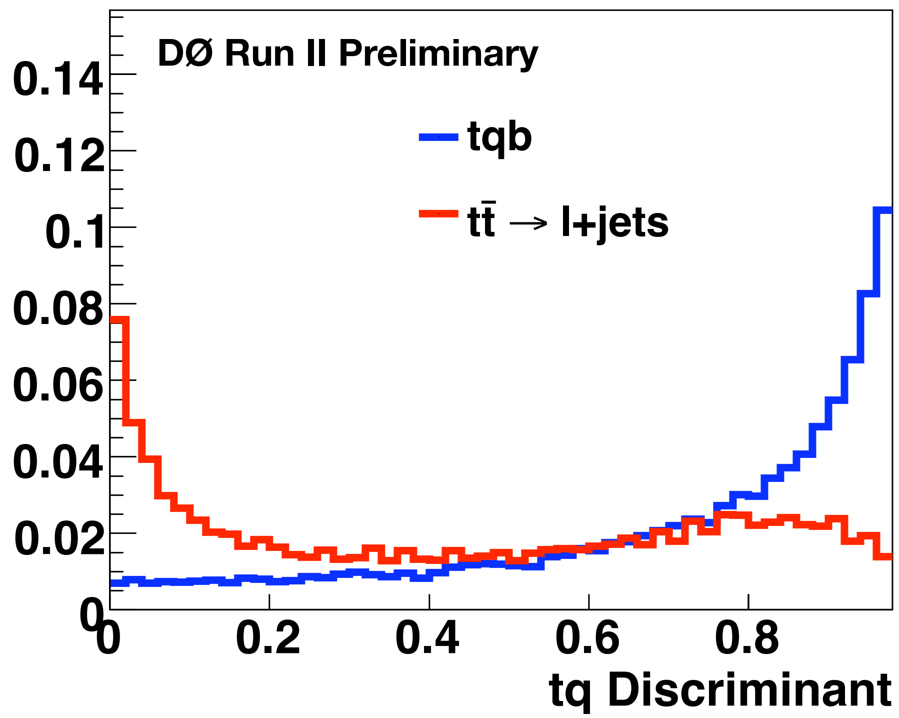
s-Channel Discriminant Plots, 2 Jets

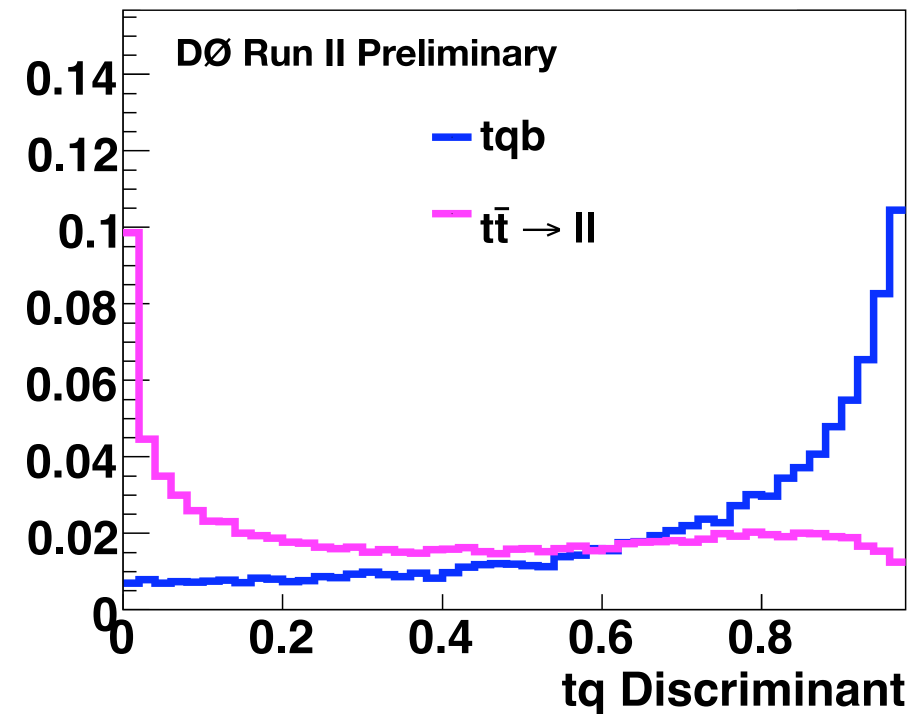


t-Channel Discriminant Plots, 2 Jets

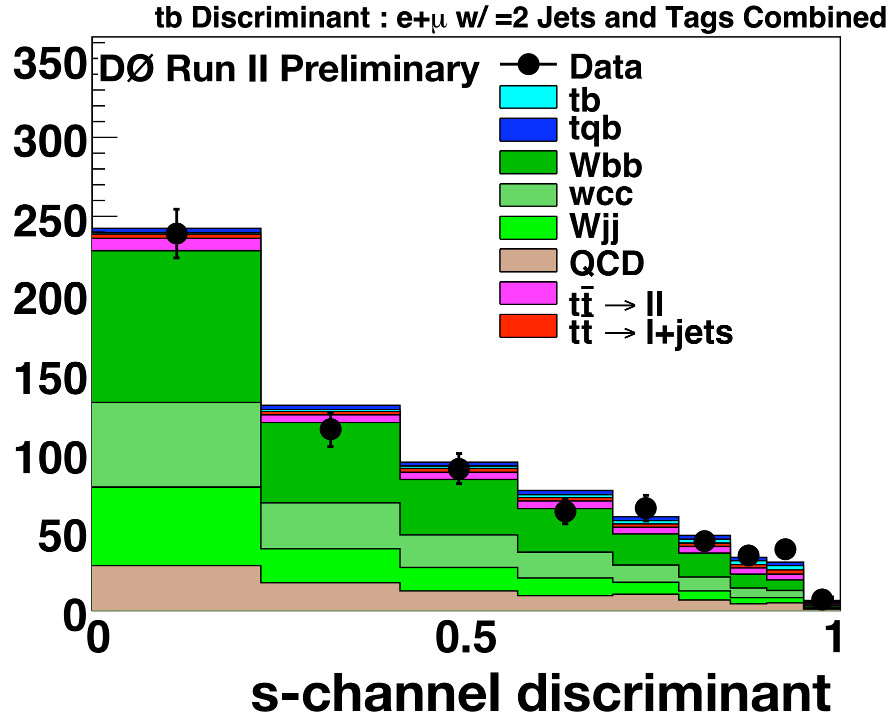


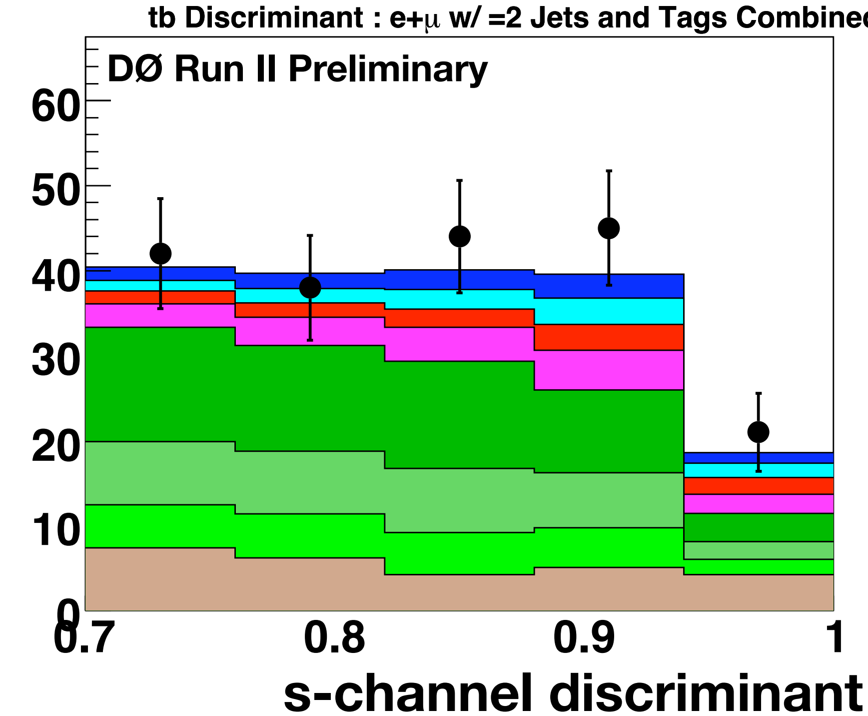


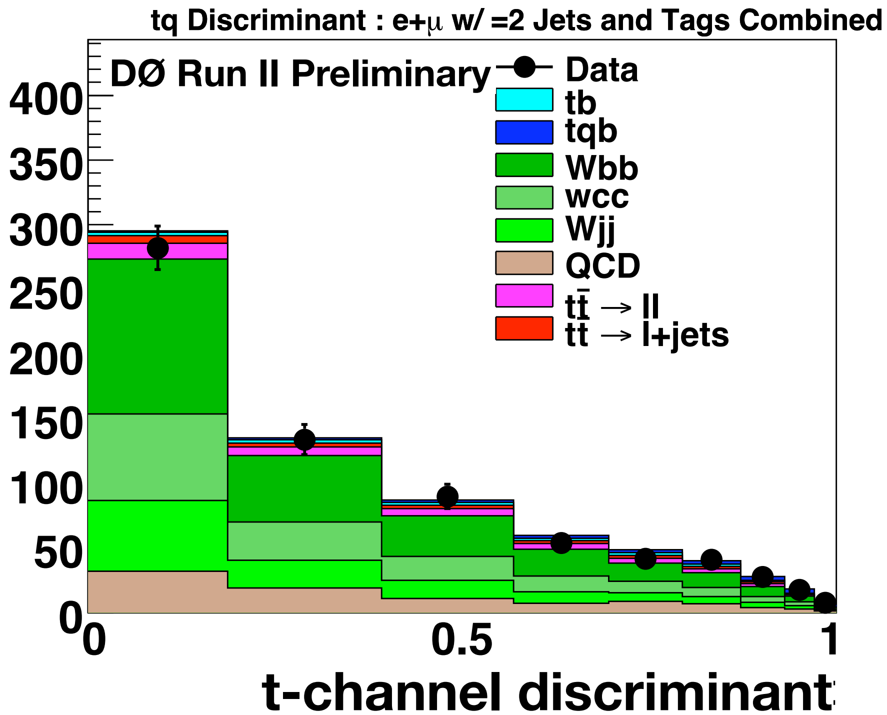


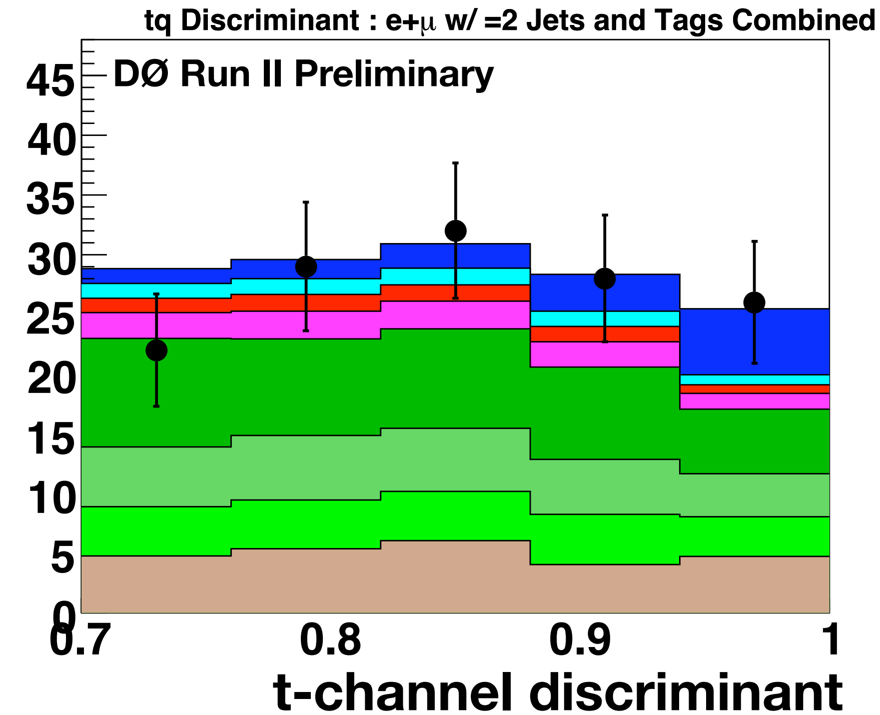


Discriminant Results, 2 Jets

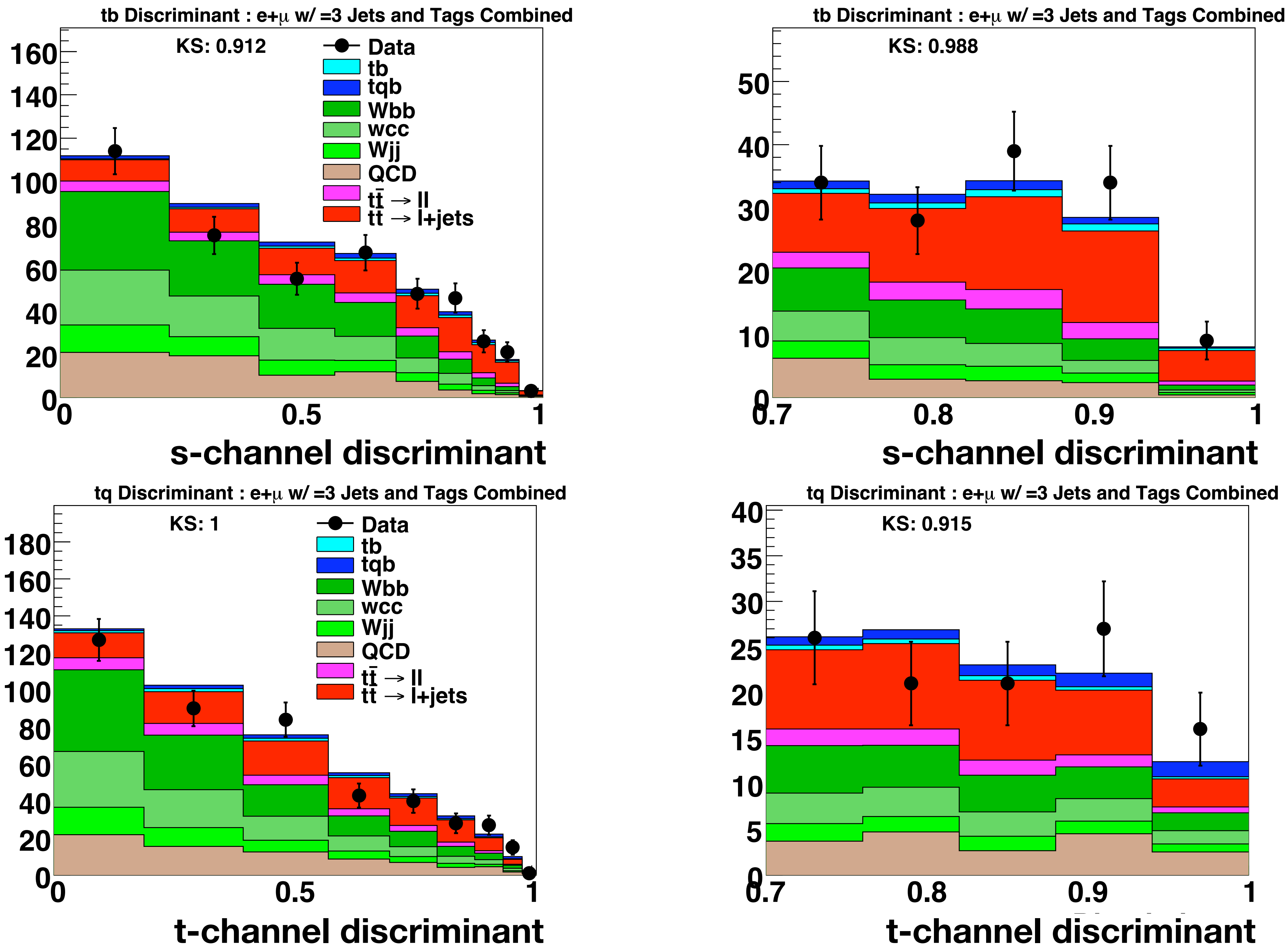








Discriminant Results, 3 Jets



Systematics

- We have two types of systematics: overall normalization and shape-changing.
- Currently, we treat the jet energy scale and the tag rate function systematics as shape-changing systematics, everything else is flat.

	Single-Tagged Two-Jets Electron Channel Percentage Errors							
	tb	tqb	$t\bar{t}lj$	$t\bar{t}ll$	Wbb	Wcc	Wjj	Mis-ID e
Components for Normalization								
Luminosity	(6.1)	(6.1)	6.1	6.1	—	—	—	—
Cross section	(16.0)	(15.0)	18.0	18.0	—	—	—	—
Branching fraction	(1.0)	(1.0)	1.0	1.0	—	—	—	—
Matrix method	—	—	—	—	18.2	18.2	18.2	18.2
Primary vertex	2.4	2.4	2.4	2.4	—	—	—	—
Electron ID	5.5	5.5	5.5	5.5	—	—	—	—
Jet ID	1.5	1.5	1.5	1.5	—	—	—	—
Jet fragmentation	5.0	5.0	7.0	5.0	—	—	—	—
Trigger	3.0	3.0	3.0	3.0	—	—	—	—
Components for Normalization and Shape								
Jet energy scale	1.4	0.3	9.9	1.7	—	—	—	—
Flavor-dependent TRFs	2.1	5.9	4.6	2.4	4.4	6.3	7.4	—
Statistics	0.7	0.7	1.3	0.8	0.9	0.9	0.4	5.6
Combined								
Acceptance uncertainty	10.8	12.1	—	—	—	—	—	—
Yield uncertainty	19.3	19.3	24.1	21.1	18.8	19.3	19.7	19.1

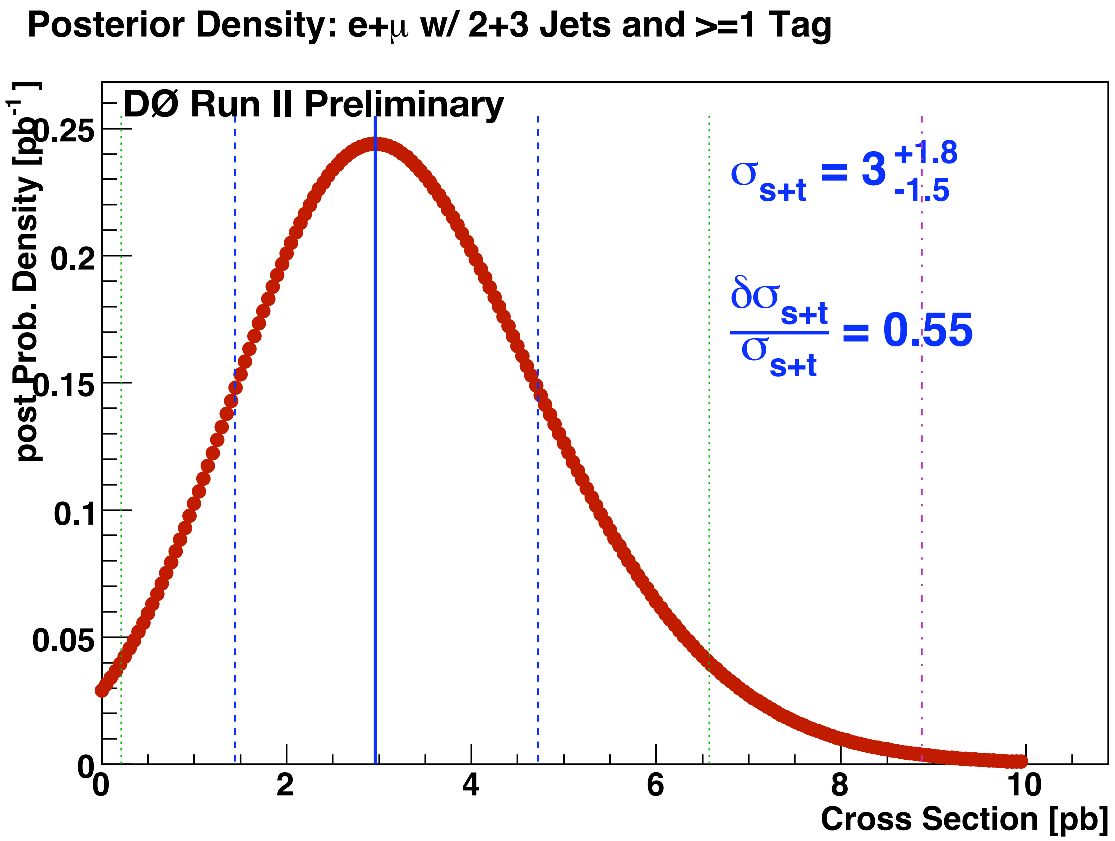
TABLE 29: Electron channel uncertainties, requiring exactly one tag and two jets.

Expected Sensitivity

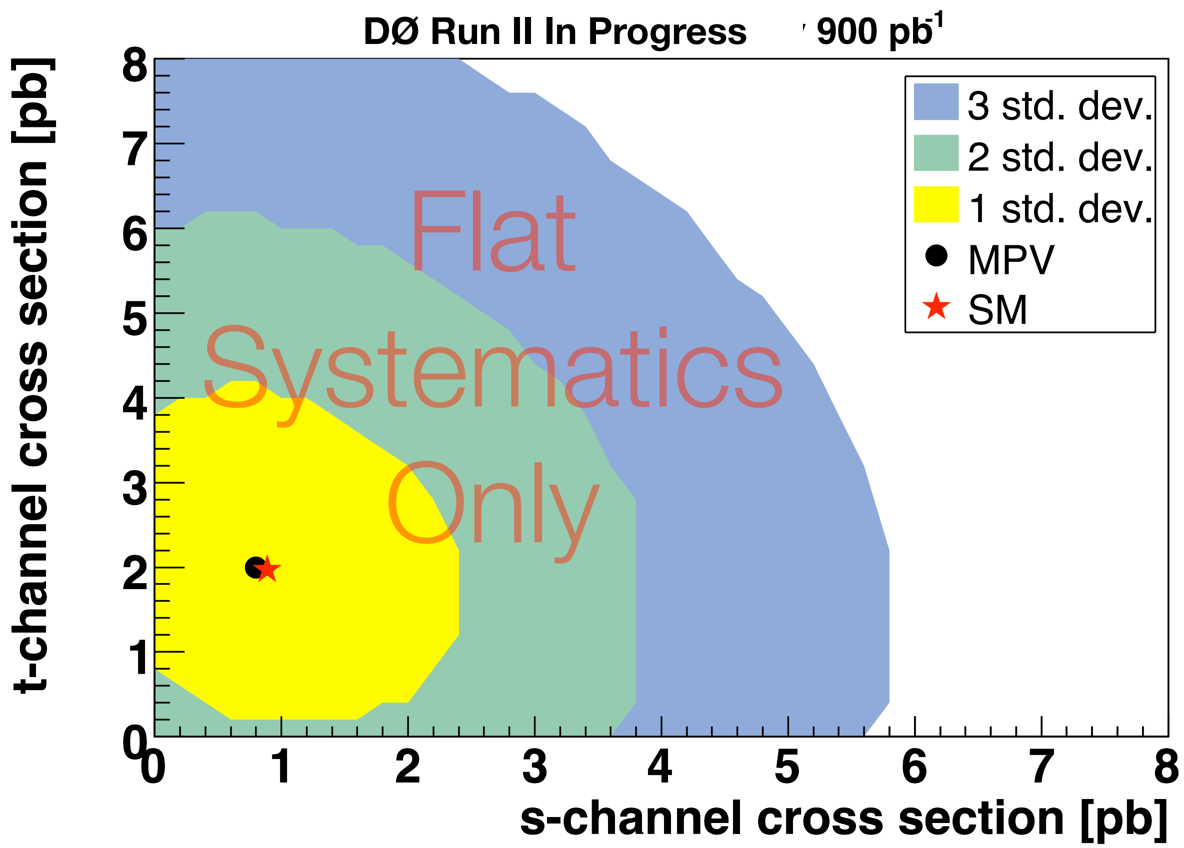
no Data, just MC

- We build a 2-D histogram of s-channel vs t-channel discriminant and run our Bayesian limit setting framework to determine the posterior. We can require the SM ratio, $\sigma_t/\sigma_s = 2.25$, or in future updates, not.

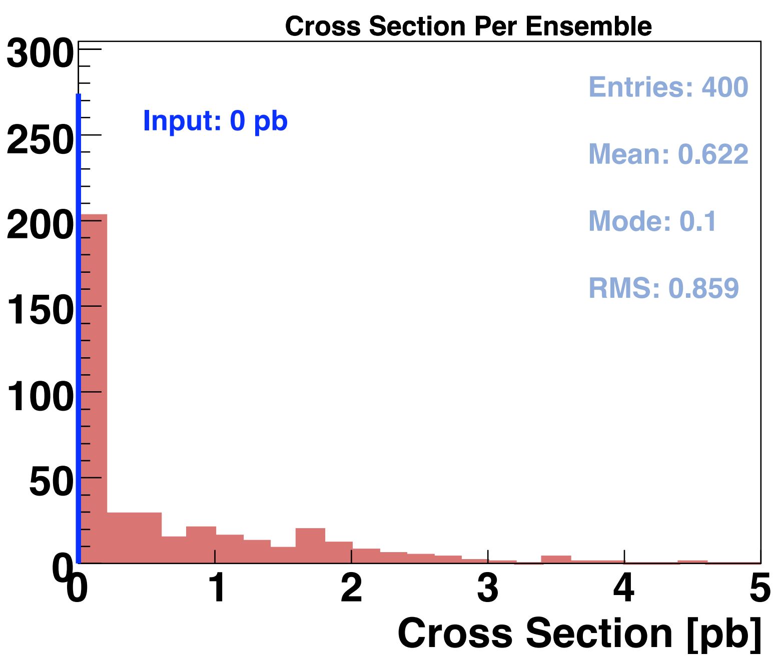
Assuming SM ratio

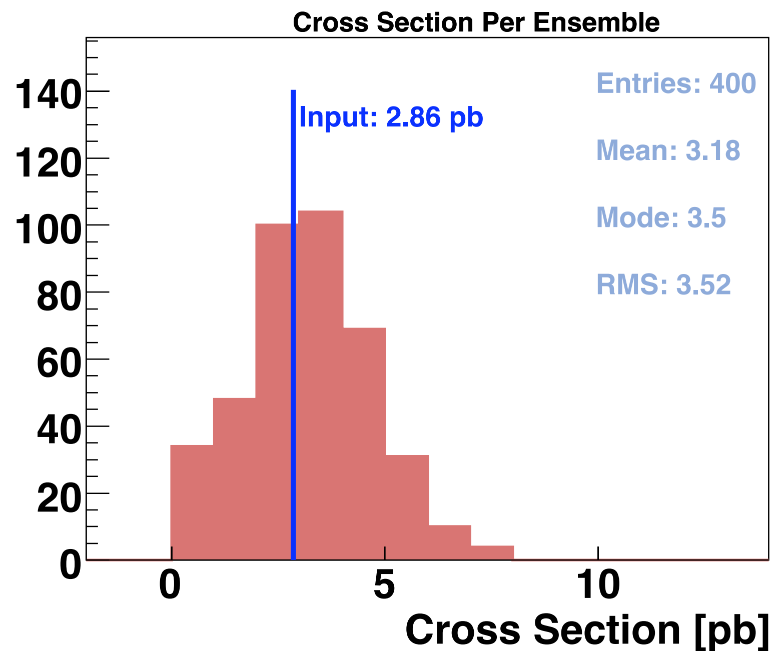


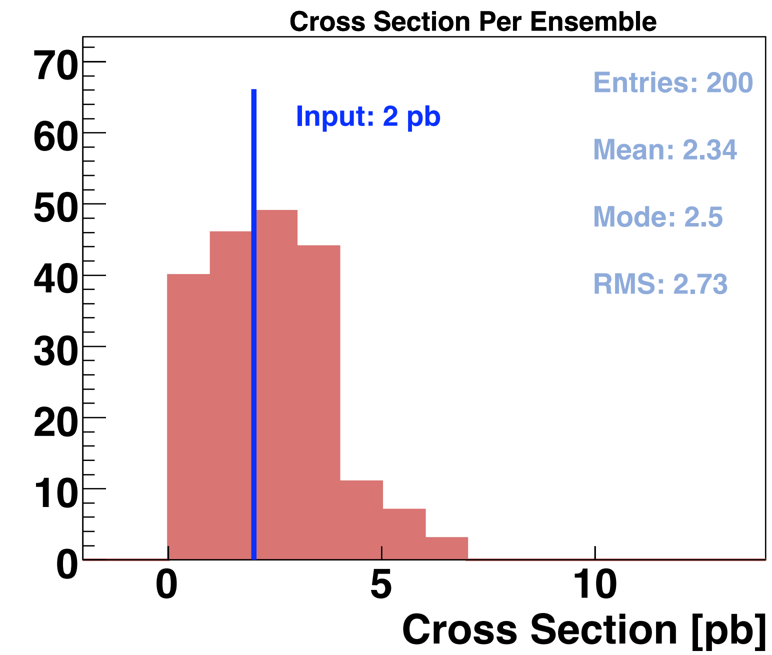
Not assuming SM ratio

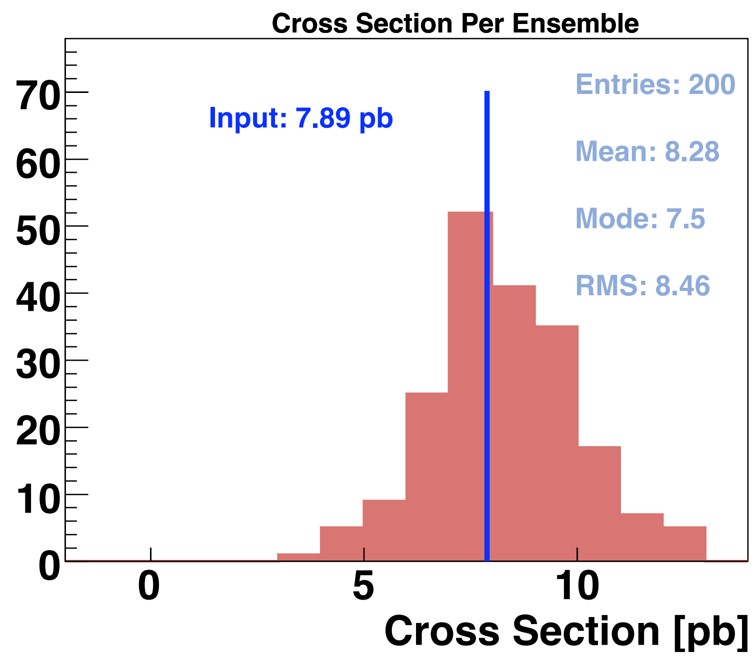


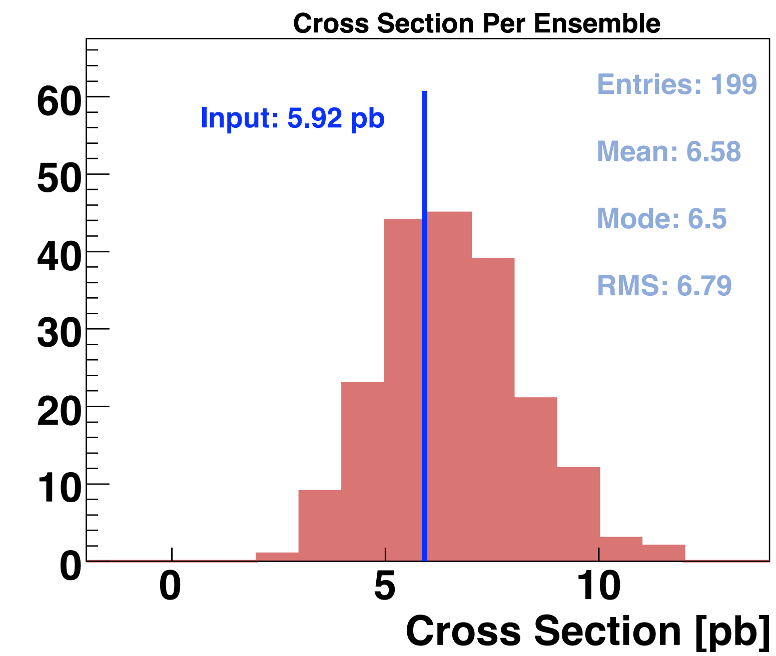
MC Ensemble Test Results

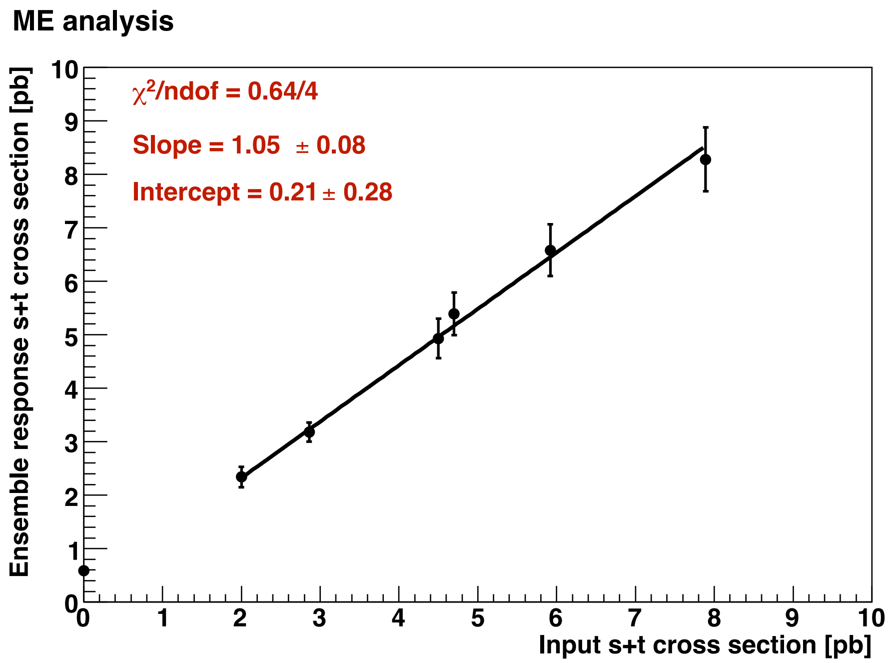




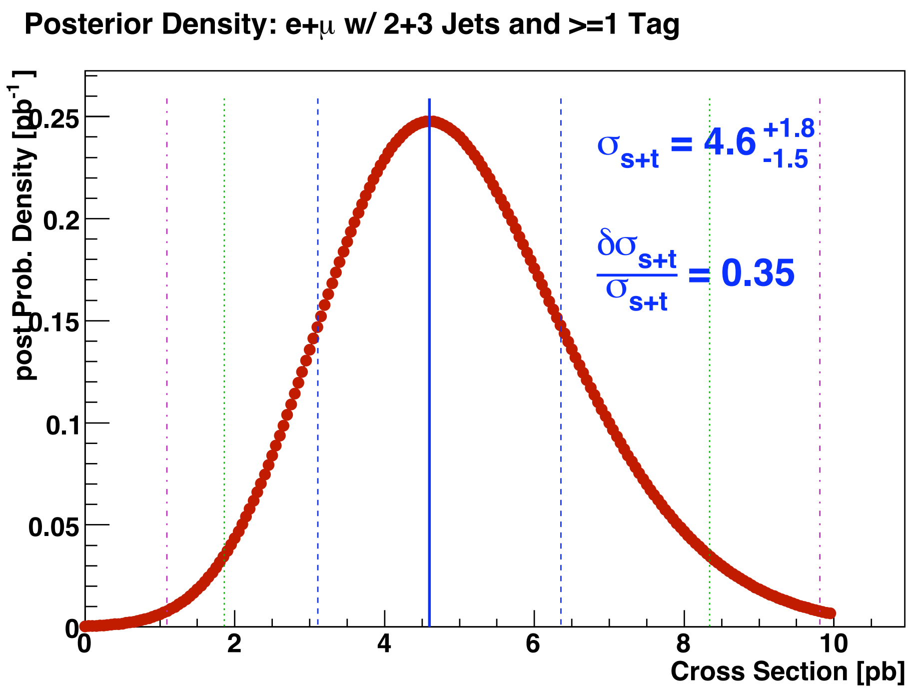


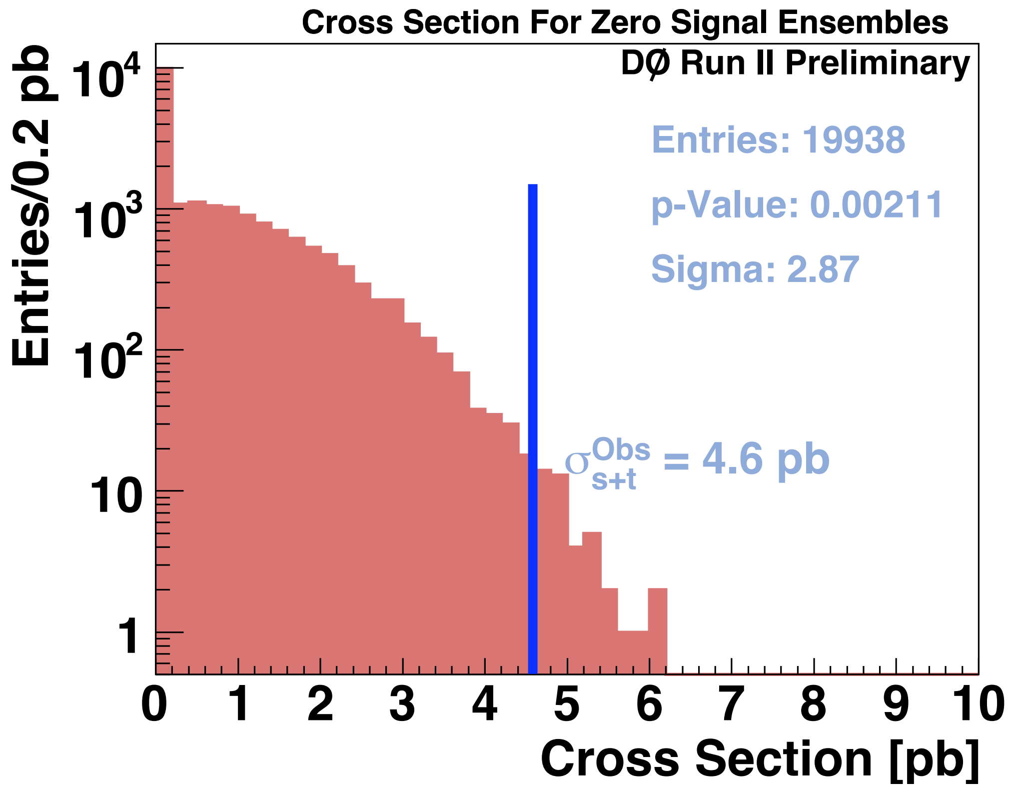


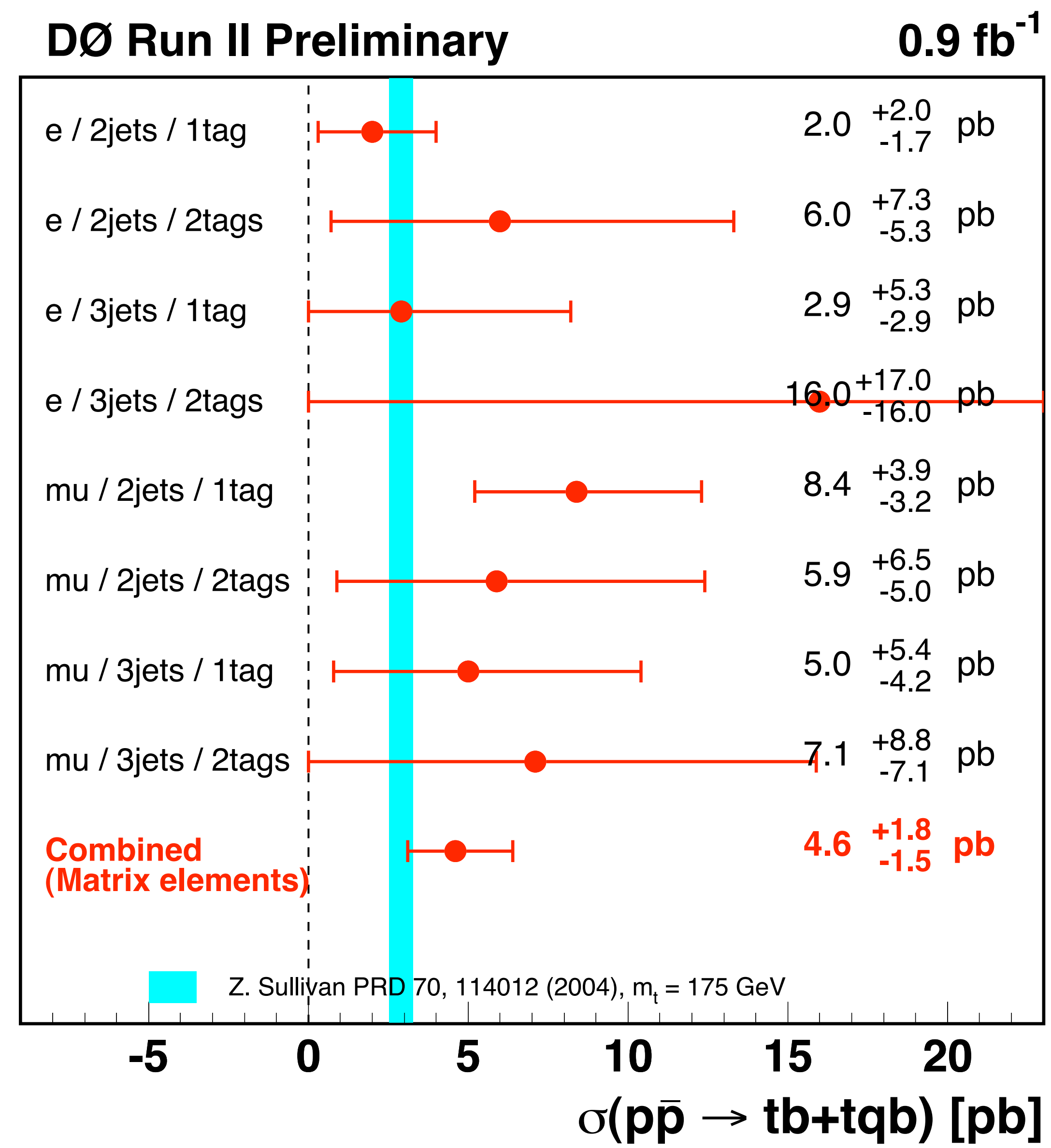




Observed Results (Matrix Element)



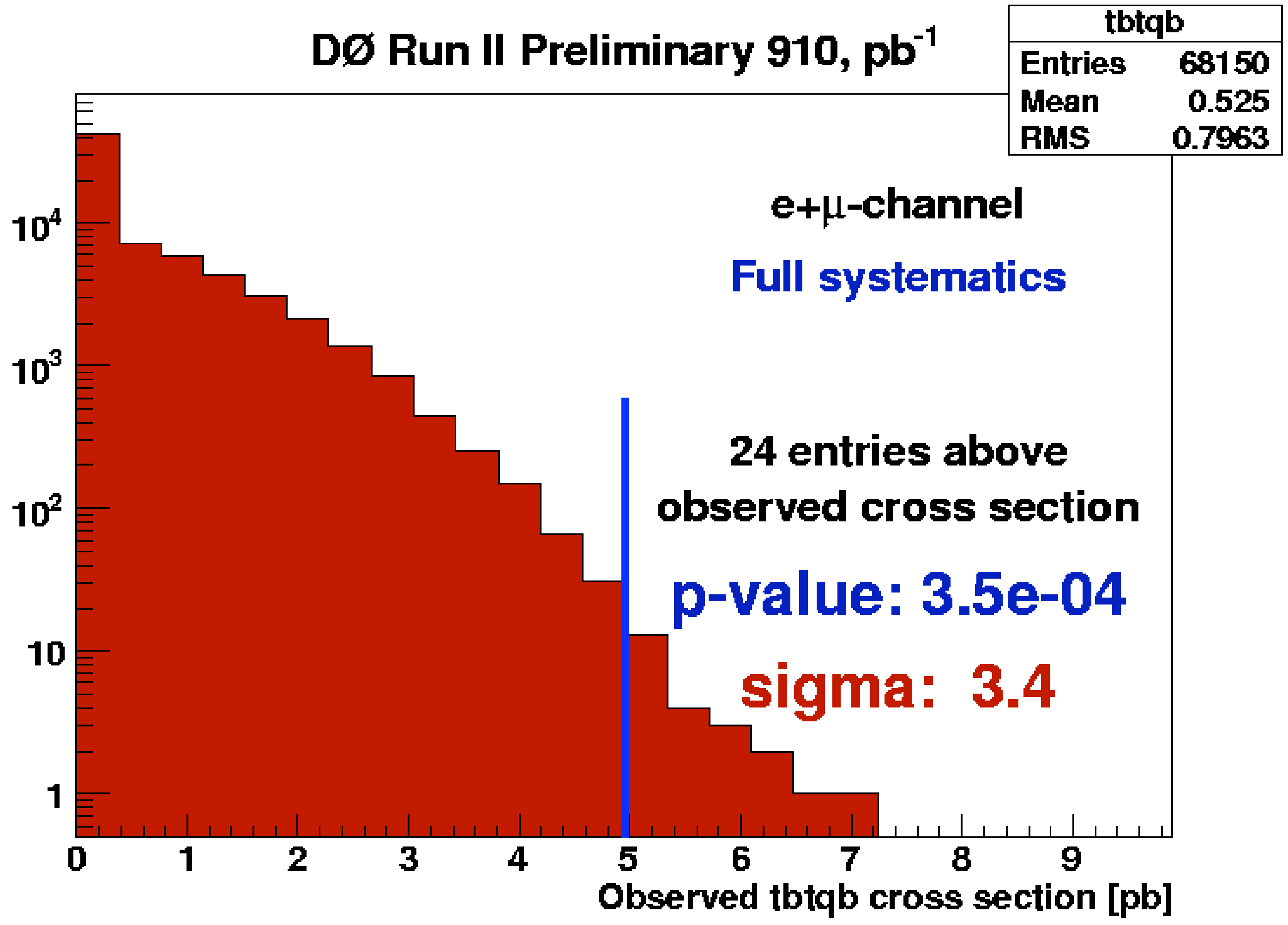




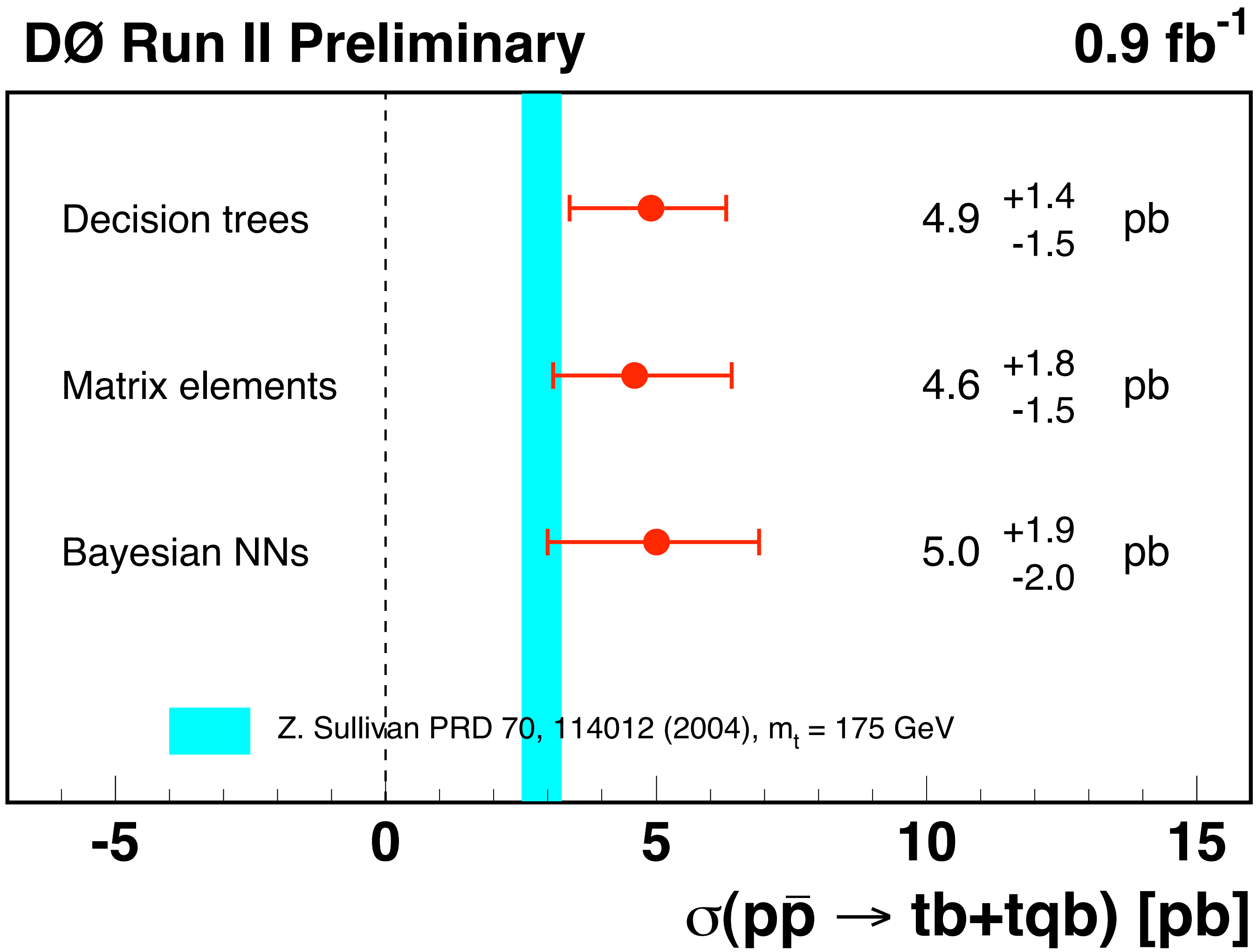
Observed Results (Preliminary Evidence!)

Decision Trees - p-value

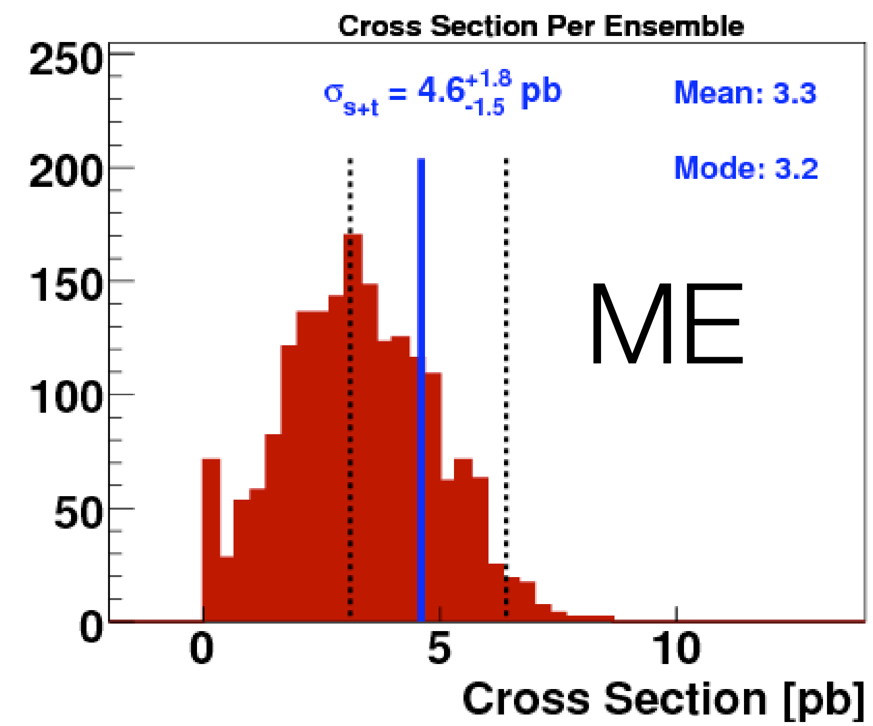
A 3.4σ excess!!

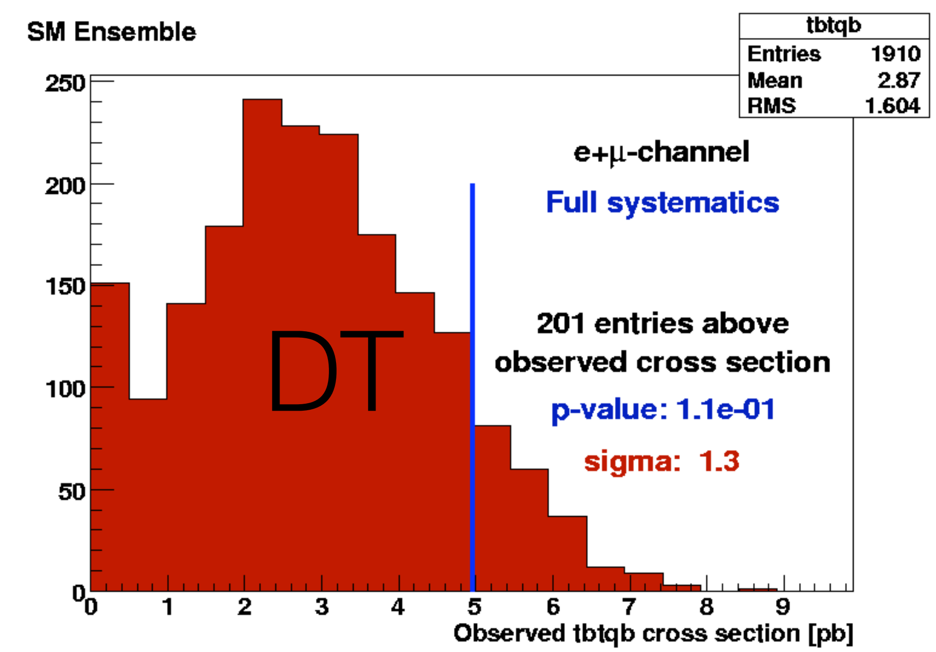


Observed Results



SM compatibility = 21%





Summary / Outlook

- Preliminary first evidence for single-top production!
- The matrix element method is being updated with the addition of $t\bar{t}$ matrix elements and other improvements.
- An extra ~100 pb^{-1} of data will probably be added soon.
- In the longer term, the Tevatron is gathering new data as we speak. By the end or Run IIb, it is on track to have delivered 7-8 fb^{-1}.
- Run IIb has improvements that will help the physics.
    - The new Silicon Tracker Layer 0 will improve b-tagging.
    - Upgraded trigger will ensure we can keep triggering on the data we need.
- At the LHC the cross section is two orders of magnitude greater.
- The excitement is just beginning!

Backup Slides

Estimating the Multijet Background Yield

- The multijet background yield is estimated by solving the following system equations for the real and fake lepton yields:

$$
\begin{aligned}
N_{\mathrm{loose}} &= N^{\mathrm{fake}-\ell}_{\mathrm{loose}} + N^{\mathrm{real}-\ell}_{\mathrm{loose}} \\
N_{\mathrm{tight}} &= N^{\mathrm{fake}-\ell}_{\mathrm{tight}} + N^{\mathrm{real}-\ell}_{\mathrm{tight}} = \varepsilon_{\mathrm{fake}-\ell}\, N^{\mathrm{fake}-\ell}_{\mathrm{loose}} + \varepsilon_{\mathrm{real}-\ell}\, N^{\mathrm{real}-\ell}_{\mathrm{loose}}
\end{aligned}
$$

- N_{loose} is the data yield with a "loose" lepton ID.
- N_{tight} is the data yield with a "tight" lepton ID.
- ϵ_{real-l} is the probability of a real lepton to pass the tight requirements given it has passed the loose. It is measured in MC, with a data/MC scale factor measured in $Z \rightarrow l^+l^-$ events.

Loose vs. Tight

loose electron: isolation EM fraction, shower shape, track match.
tight electron: loose + likelihood
loose muon: "medium" muon with cosmic veto, Δr(jet, muon) > 0.5
tight muon: loose + track isolation

- ϵ_{fake-l} is the probability of a "fake" lepton to pass the tight requirements given it has passed the loose. It is measured in data with the standard selections but missing E_T < 10 GeV.

Yields Before b-Tagging

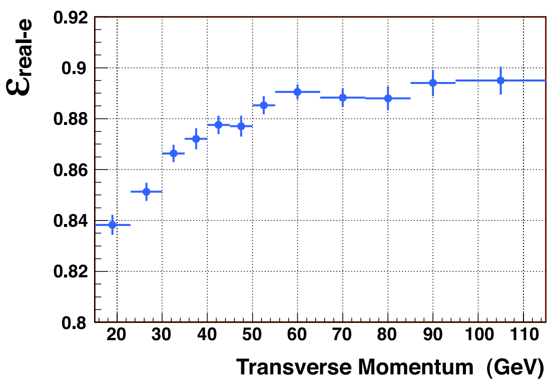
- For all MC, apply:
    - Cross section weights (including heavy flavor corrections)
    - Trigger weights: the trigger efficiency for such an event measured in data.
    - object ID weights: correction factors to take into account differences in data and MC object reconstruction efficiency.
- Create an orthogonal sample by reversing the tight lepton criteria, and normalize it to $N^{tight}_{fake\text{-}l}$. This is the multijet sample.
- From $N^{tight}_{real\text{-}l}$, subtract the $t\bar{t}$ yield. Scale the *W*+jets MC sample to this amount. This is the *W* sample.

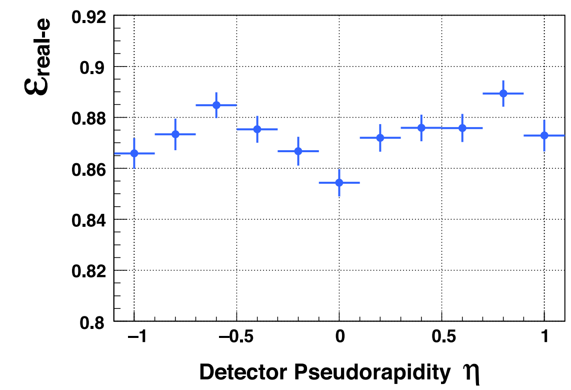
The Matrix Method

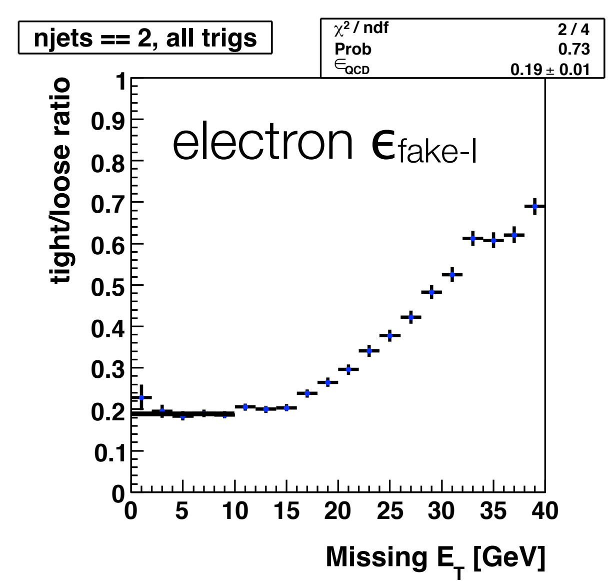
- The multijet background yield is estimated by solving the following equations:

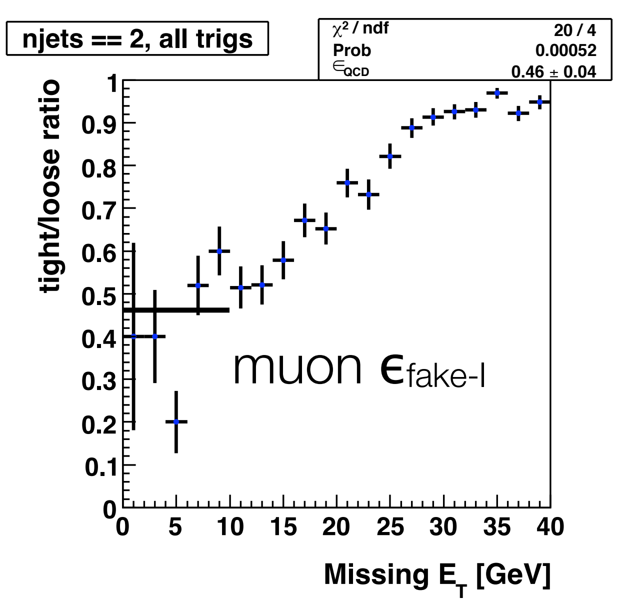
$$
\begin{aligned}
N_{\text{loose}} &= N^{\text{fake}-\ell}_{\text{loose}} + N^{\text{real}-\ell}_{\text{loose}} \\
N_{\text{tight}} &= N^{\text{fake}-\ell}_{\text{tight}} + N^{\text{real}-\ell}_{\text{tight}} = \varepsilon_{\text{fake}-\ell}\, N^{\text{fake}-\ell}_{\text{loose}} + \varepsilon_{\text{real}-\ell}\, N^{\text{real}-\ell}_{\text{loose}}
\end{aligned}
$$

- Measure $\epsilon_{\text{fake-l}}$ on data using the same selection except missing E_T < 10 GeV
- Measure $\epsilon_{\text{real-l}}$ in three steps:
  - Measure $\epsilon^{\text{MC}}_{\text{real-l}}$ using MC truth and the analysis selection criteria
  - Measure $\epsilon^{\text{Z-data}}_{\text{real-l}}$ / $\epsilon^{\text{Z-MC}}_{\text{real-l}}$ using the EM-ID or Muon ID tools
  - $\epsilon_{\text{real}-l} = \dfrac{\epsilon^{Z-\text{data}}_{\text{real}-l}}{\epsilon^{Z-\text{MC}}_{\text{real}-l}}\, \epsilon^{\text{MC}}_{\text{real}-l}$









Yields

Yields Before b-Tagging

	Electron Channel					Muon Channel				
	1 jet	2 jets	3 jets	4 jets	5+ jets	1 jet	2 jets	3 jets	4 jets	5 jets
Signals										
tb	4	14	7	2	0	3	10	5	1	0
tqb	9	27	14	5	1	6	20	11	3	1
$tb+tqb$	14	41	21	6	2	9	31	16	5	1
Backgrounds										
$t\bar{t}\to ll$	9	35	28	10	4	5	27	22	8	3
$t\bar{t}\to l$+jets	2	26	103	128	67	1	14	71	99	43
$Wb\bar{b}$	659	358	149	42	5	431	312	161	47	10
$Wc\bar{c}$	1,592	931	389	93	10	1,405	1,028	523	131	21
Wjj	23,417	5,437	1,546	343	51	15,476	4,723	1,591	385	85
Multijets	1,691	1,433	860	256	86	498	329	223	58	10
Background Sum	27,370	8,220	3,075	874	223	17,816	6,434	2,592	727	172
Data	27,370	8,220	3,075	874	223	17,816	6,432	2,590	727	173

Yields with One b-Tagged Jet

	Electron Channel					Muon Channel				
	1 jet	2 jets	3 jets	4 jets	5+ jets	1 jet	2 jets	3 jets	4 jets	5 jets
Signals										
tb	2	7	3	1	0	1	5	2	1	0
tqb	3	11	6	2	1	2	9	5	2	0
$tb+tqb$	5	18	9	3	1	3	14	7	2	1
Backgrounds										
$t\bar{t}\to ll$	4	16	13	5	2	2	13	10	4	1
$t\bar{t}\to l$+jets	1	11	47	58	30	0	6	32	45	20
$Wb\bar{b}$	188	120	50	14	2	131	110	56	16	4
$Wc\bar{c}$	81	74	36	9	1	64	74	46	13	2
Wjj	175	61	20	5	1	125	58	23	6	2
Multijets	36	66	48	18	7	17	26	24	8	2
Background Sum	484	348	213	110	43	340	286	191	93	30
Data	445	357	207	97	35	289	287	179	100	38

Yields with Zero b-Tagged Jets

	Electron Channel					Muon Channel				
	1 jet	2 jets	3 jets	4 jets	5+ jets	1 jet	2 jets	3 jets	4 jets	5 jets
Signals										
tb	3	5	2	1	0	1	4	2	1	0
tqb	6	16	7	2	1	4	11	6	2	0
$tb+tqb$	9	21	10	3	1	5	15	7	2	1
Backgrounds										
$t\bar{t}\to ll$	5	14	11	4	1	3	10	8	3	1
$t\bar{t}\to l$+jets	2	13	43	47	24	1	7	28	35	15
$Wb\bar{b}$	471	222	92	27	3	300	187	97	28	6
$Wc\bar{c}$	1,511	856	352	84	9	1,341	953	475	117	19
Wjj	23,242	5,376	1,526	338	50	15,351	4,665	1,569	379	84
Multijets	1,655	1,365	808	236	78	481	302	198	49	7
Background Sum	26,886	7,845	2,832	735	165	17,476	6,124	2,375	610	131
Data	26,925	7,833	2,831	752	178	17,527	6,122	2,378	599	125

Yields with Two b-Tagged Jets

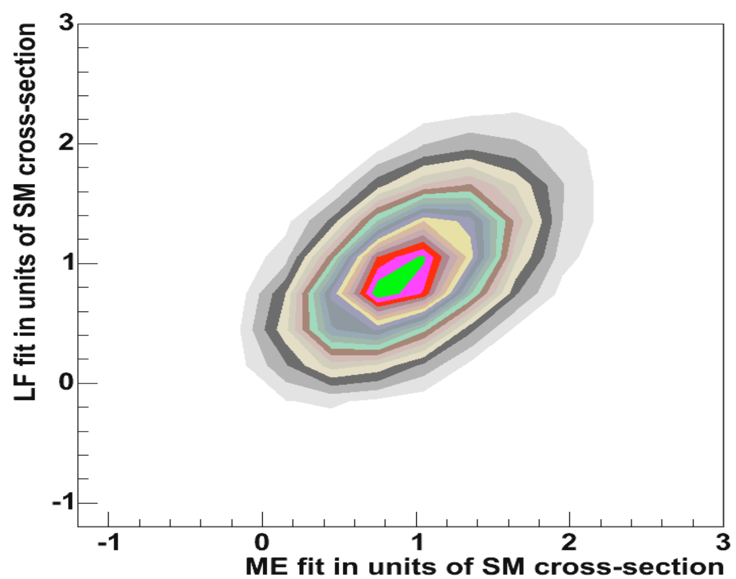
	Electron Channel					Muon Channel				
	1 jet	2 jets	3 jets	4 jets	5+ jets	1 jet	2 jets	3 jets	4 jets	5 jets
Signals										
tb	—	2.3	1.1	0.3	0.1	—	1.9	0.9	0.3	0.1
tqb	—	0.3	0.8	0.4	0.2	—	0.2	0.7	0.4	0.1
$tb+tqb$	—	2.6	1.9	0.7	0.2	—	2.1	1.6	0.6	0.2
Backgrounds										
$t\bar{t}\to ll$	—	5.5	4.6	1.7	0.7	—	4.6	3.8	1.4	0.5
$t\bar{t}\to l$+jets	—	1.7	13.6	21.8	11.7	—	1.0	10.2	18.0	8.1
$Wb\bar{b}$	—	16.2	6.8	1.8	0.3	—	15.3	8.2	2.3	0.6
$Wc\bar{c}$	—	1.6	1.1	0.4	0.1	—	1.6	1.5	0.5	0.1
Wjj	—	0.1	0.1	0.0	0.0	—	0.1	0.1	0.0	0.0
Multijets	—	2.5	3.2	2.7	1.4	—	1.5	1.9	0.4	0.8
Background Sum	—	27.5	29.4	28.4	14.2	—	24.1	25.7	22.7	10.1
Data	—	30	37	22	10	—	23	32	27	10

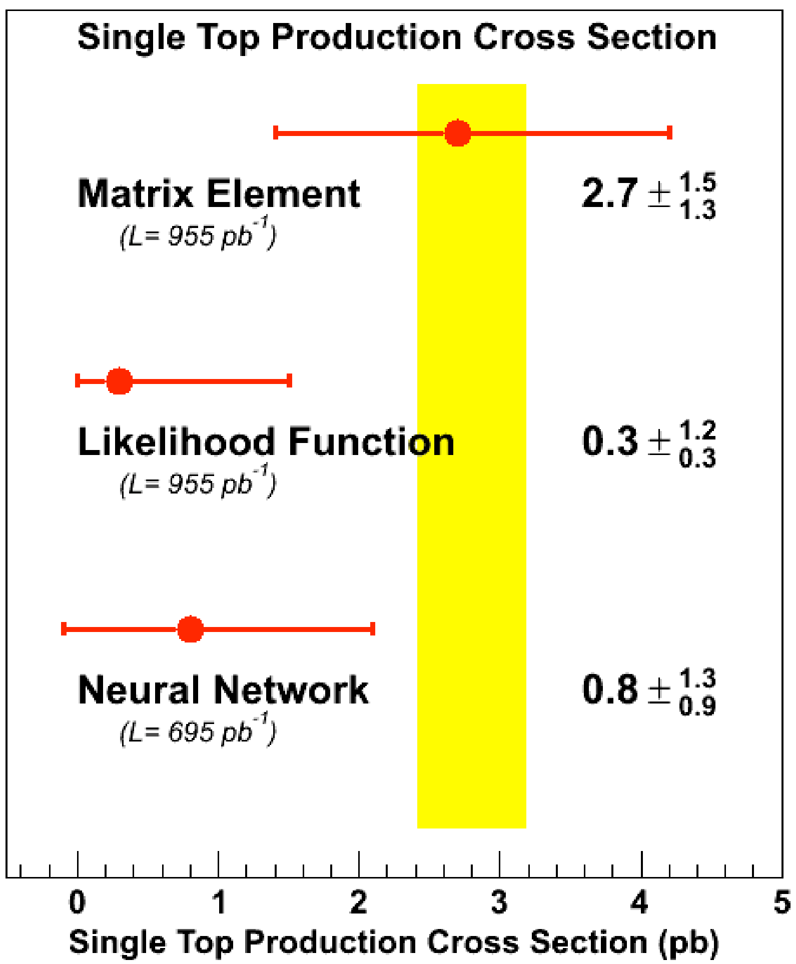
CDF’s DPF Results, shown by Bernd Stelzer

Compatibility of the New Results

Compatibility of the two new results?

- Performed common pseudo-experiments
  - Fitting EPD and LF discriminants
  - Correlation among fit results: ~53%
  - 6% of the pseudo-experiments had a difference in fit results at least as bad as the difference observed in data
- *The results we observe in the data are compatible at the ~6% level*





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Measuring Heavy Flavor Fraction in Data

	Scale Factor α to Match Heavy Flavor Fraction to Data			
	1 jet	2 jets	3 jets	4 jets
Electron Channel				
0 tags	1.53 ± 0.10	1.48 ± 0.10	1.50 ± 0.20	1.72 ± 0.40
1 tag	1.29 ± 0.10	1.58 ± 0.10	1.40 ± 0.20	0.69 ± 0.60
2 tags	—	1.71 ± 0.40	2.92 ± 1.20	-2.91 ± 3.50
Muon Channel				
0 tags	1.54 ± 0.10	1.50 ± 0.10	1.52 ± 0.10	1.38 ± 0.20
1 tag	1.11 ± 0.10	1.52 ± 0.10	1.32 ± 0.20	1.86 ± 0.50
2 tags	—	1.40 ± 0.40	2.46 ± 0.90	3.78 ± 2.80

TABLE 21: Scale factor α for the $Wb\bar{b}$ and $Wc\bar{c}$ yields to match the data in each jet bin, for 0 tag, 1 tag, and 2 tag samples. The uncertainties are statistical only.

Background Sample Optimization

- Different W+jets backgrounds have different processes, so ideally, for P(x|B) we would use a background model that well describes the data. Alternately, we can treat it as optimization:

$$P(x|B) = w_{Wbb}P(x|Wbb) + w_{Wcg}P(x|Wcg) + w_{Wgg}P(x|Wgg)$$

We optimized the discriminator by assigning different weights:

weight per background	wbb	wcb	wgg
Electron 1tag	0.2	0.4	0.4
Electron 2tag	0.67	0	0.33
Muon 1tag	0.4	0.4	0.2
Muon 2tag	1	0	0

Cross Checks