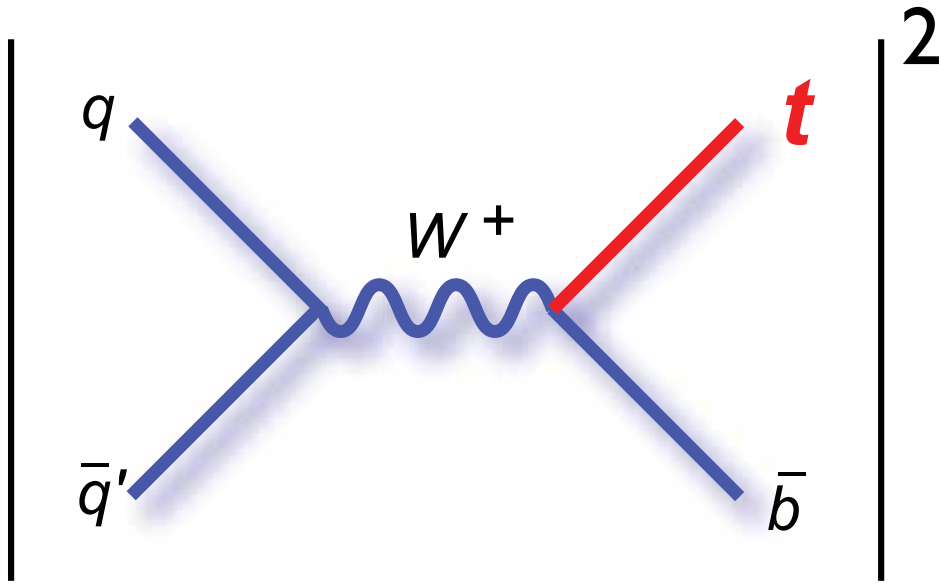
Measuring Single Top Quark Production at DØ With The Matrix Element Method

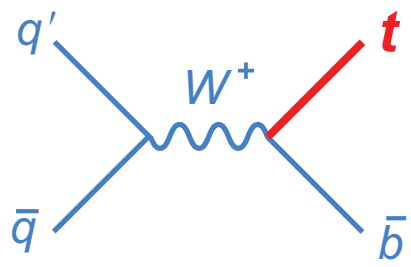


Thomas Gadfort
University of Washington
Rencontres de Moriond EW 2007

"Single Top" Production

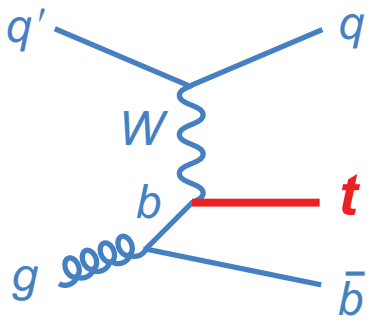
- Single top is electroweak top quark production. Two modes at Tevatron:

(a)



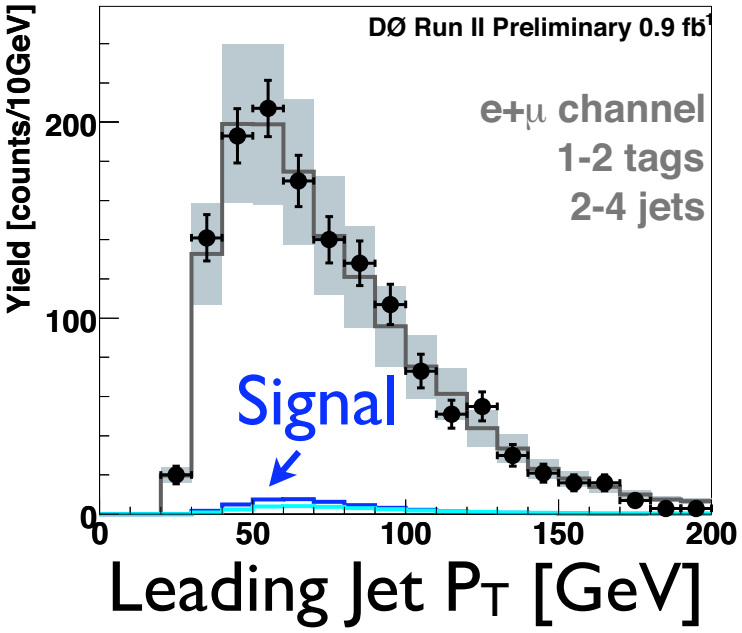
$$\sigma_s^{\mathrm{NLO}} = 0.88 \pm 0.11\mathrm{pb}$$

(b)



$$\sigma_t^{\mathrm{NLO}} = 1.98 \pm 0.25\mathrm{pb}$$

- Search in lepton+jets decay channel → lots of W+jets background



- Signal to Background ~ 1:20 (after tagging!)
- Need multivariate technique to improve S:B
  - Ex: Neural networks, Decision Trees, etc...
- Idea: Use single top differential cross section as discriminating variable
- How can we do that?

Matrix Element Method

- The differential cross section, at the detector level, is the integral of the parton differential cross section convoluted with a detector resolution function.

$$\underbrace{\frac{d\sigma}{d\vec{x}}}_{\text{Detector level differential cross section}} \propto \int \underbrace{\frac{f(q_1)}{q_1}\frac{f(q_2)}{q_2}dq_1 dq_2}_{\text{CTEQ6 LO Parton distribution functions}} \times \underbrace{|\mathcal{M}(\vec{y})|^2 d\Phi(\vec{y})}_{\text{Leading order matrix elements from Madgraph times phase space factor}} \times \underbrace{W(\vec{y}|\vec{x})}_{\text{Probability density for parton event } \mathbf{y} \text{ given measured event } \mathbf{x}}$$

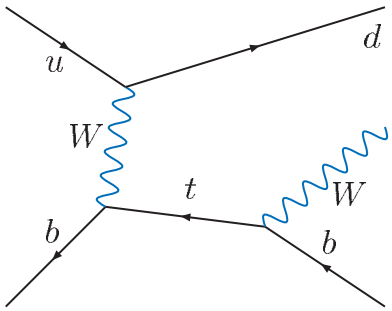
- Create probability density P(x) by normalizing the differential cross section

$$P(\vec{x}) = \frac{1}{\sigma}\frac{d\sigma}{d\vec{x}} \qquad \sigma = \int \frac{d\sigma}{d\vec{x}}\, d\vec{x}$$

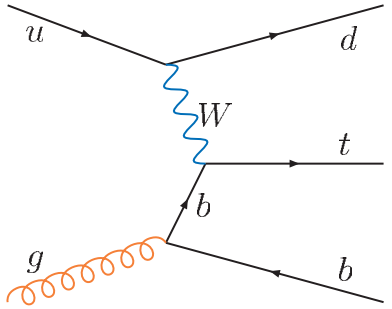
- Requires integrating over parton phase space to evaluate $|\mathcal{M}|^2$
- We can improve description by including more matrix elements

Signal and Background Matrix Elements

- Signal: Use s-channel and t-channel
  - 2 jet s/t-channel use 2→2 diagrams
  - 3 jet s-channel uses 2→2 with ISR
  - 3 jet t-channel uses 2→3 w/ g→bb



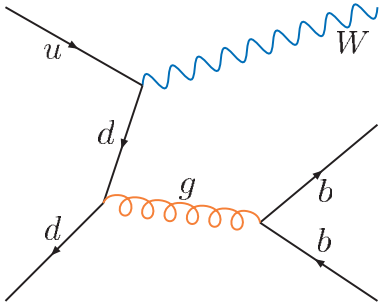
t-channel w/ 2 jets

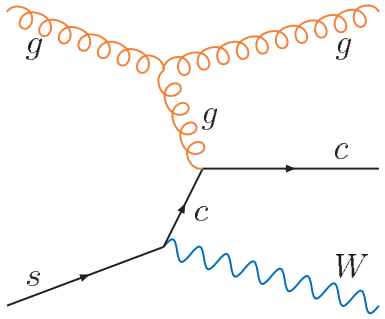


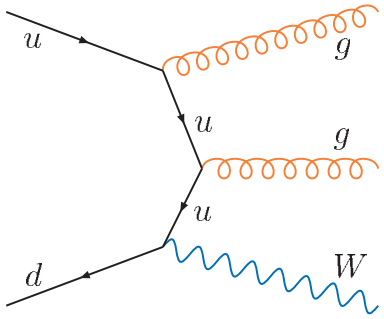
t-channel w/ 3 jets

- Background: W+jets is largest background
  - W+jets matrix elements selected based on yield after b-tagging

$$= 1 \text{ Tag}: \quad \sim 33\% \text{ Wb} + \text{X}, \quad \sim 33\% \text{ Wc} + \text{X}, \quad \sim 33\% \text{ Wl} + \text{X}$$







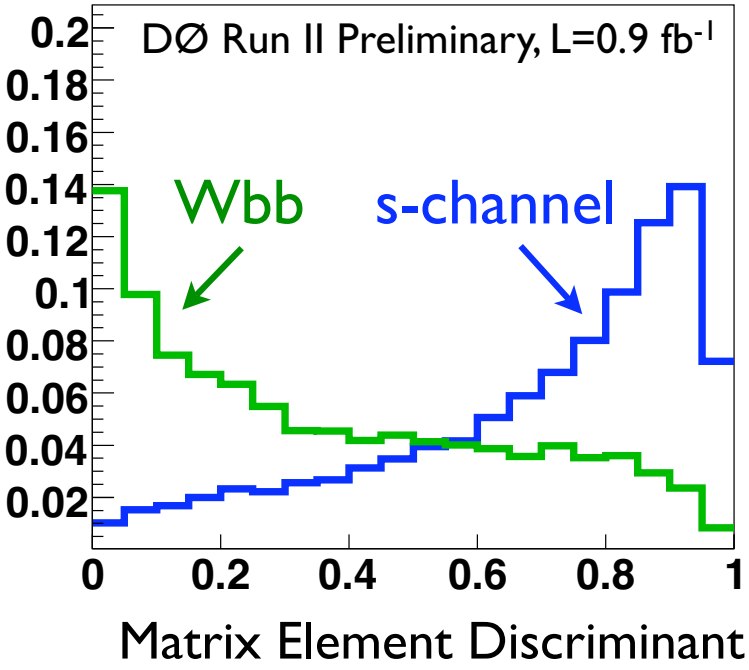
$$= 2 \text{ Tags}: \quad \sim 100\% \text{ Wbb} + \text{X}$$

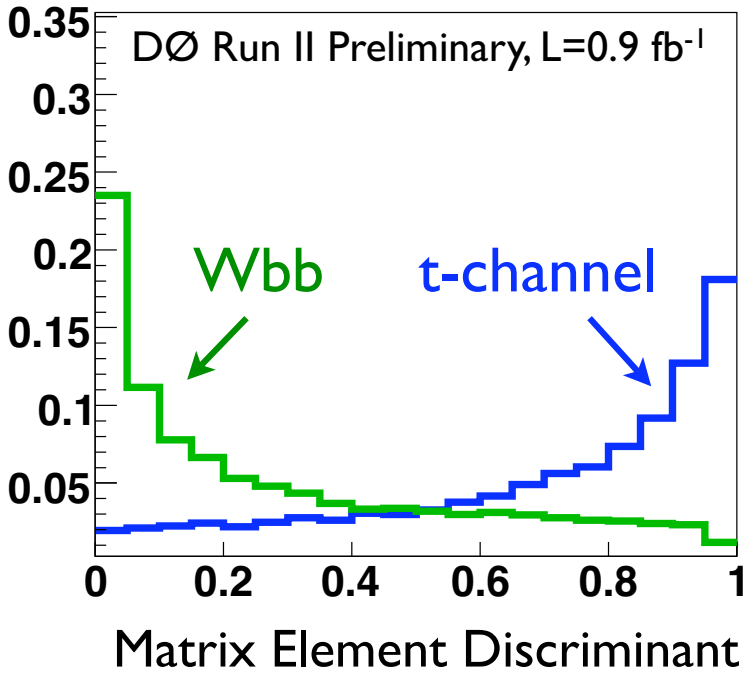
  - Events with three jets use two jet diagrams with ISR gluon radiation.

Signal-Background Separation Power

- Combine signal and background probabilities using the a-posteriori Bayesian probability for the signal hypothesis given the event $\vec{x}$.

$$P(tb+tqb|x) \equiv D(\vec{x}) = \frac{P_{\mathrm{tb+tqb}}(\vec{x})}{P_{\mathrm{tb+tqb}}(\vec{x}) + P_{\mathrm{Background}}(\vec{x})}$$



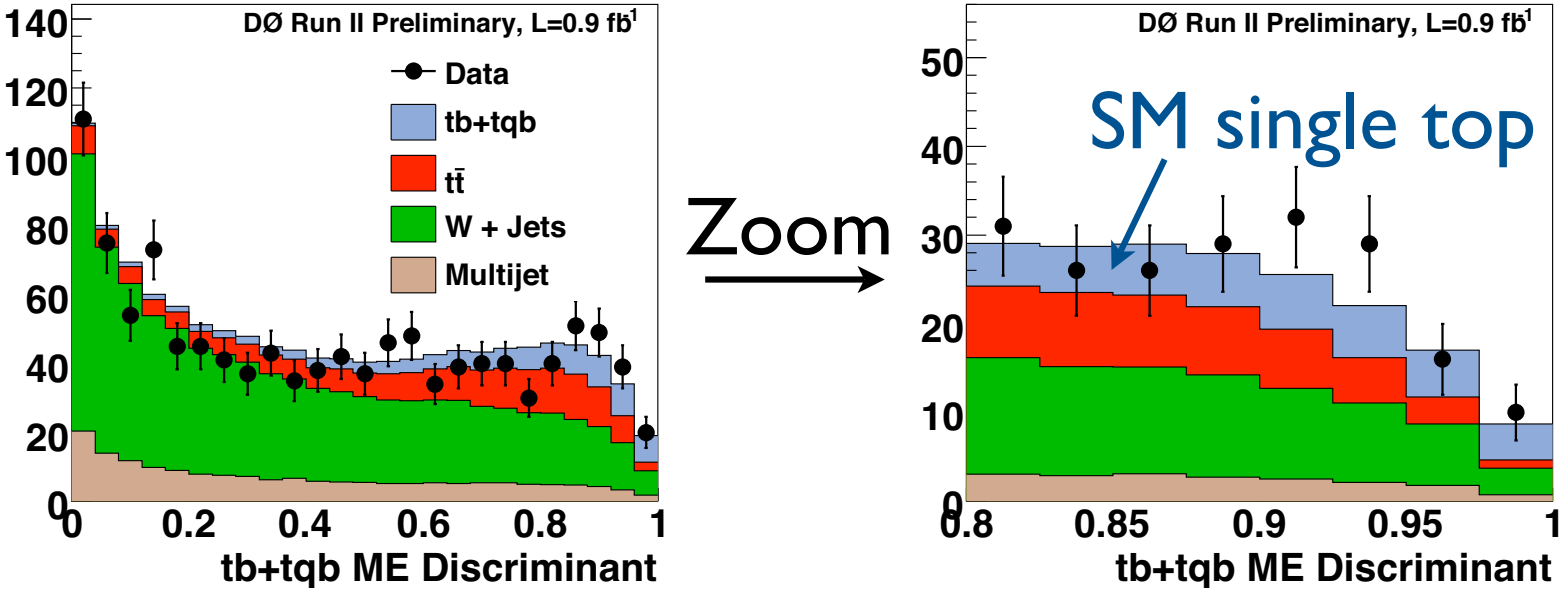


Result: Great separation power!

Results And Conclusion

- Evaluating discriminant for signal, background, and data events yields a 2.9σ excess of data over background → measure single top cross section.

$$\sigma_{tb+tqb} = 4.6^{+1.8}_{-1.5}\text{pb}$$



- Result has been submitted to PRL (hep-ex/0612052) with a PRD to come
- What's next: Add the >1 fb^{-1} on tape, 5σ observation, precise $|V_{tb}|$, and of course, keep an eye out for new physics...