The Search for Single Top Quark Production in the μ + Jets Channel at DØ

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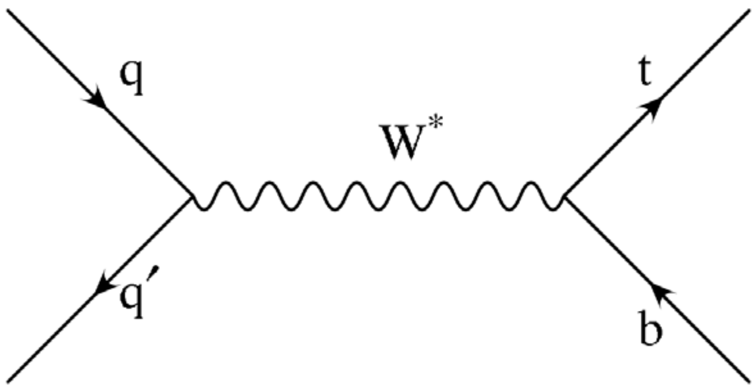
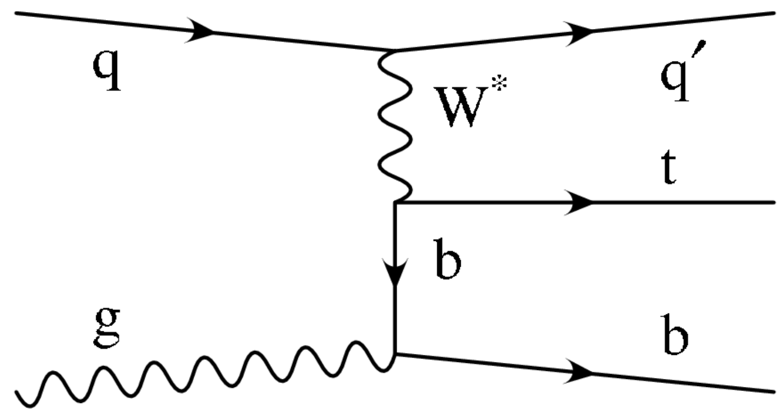
On behalf of the DØ Collaboration

Single Top Production





s-channel

$\sigma_{\mathrm{NLO}} = 0.88 \pm 0.07$ pb

t-channel

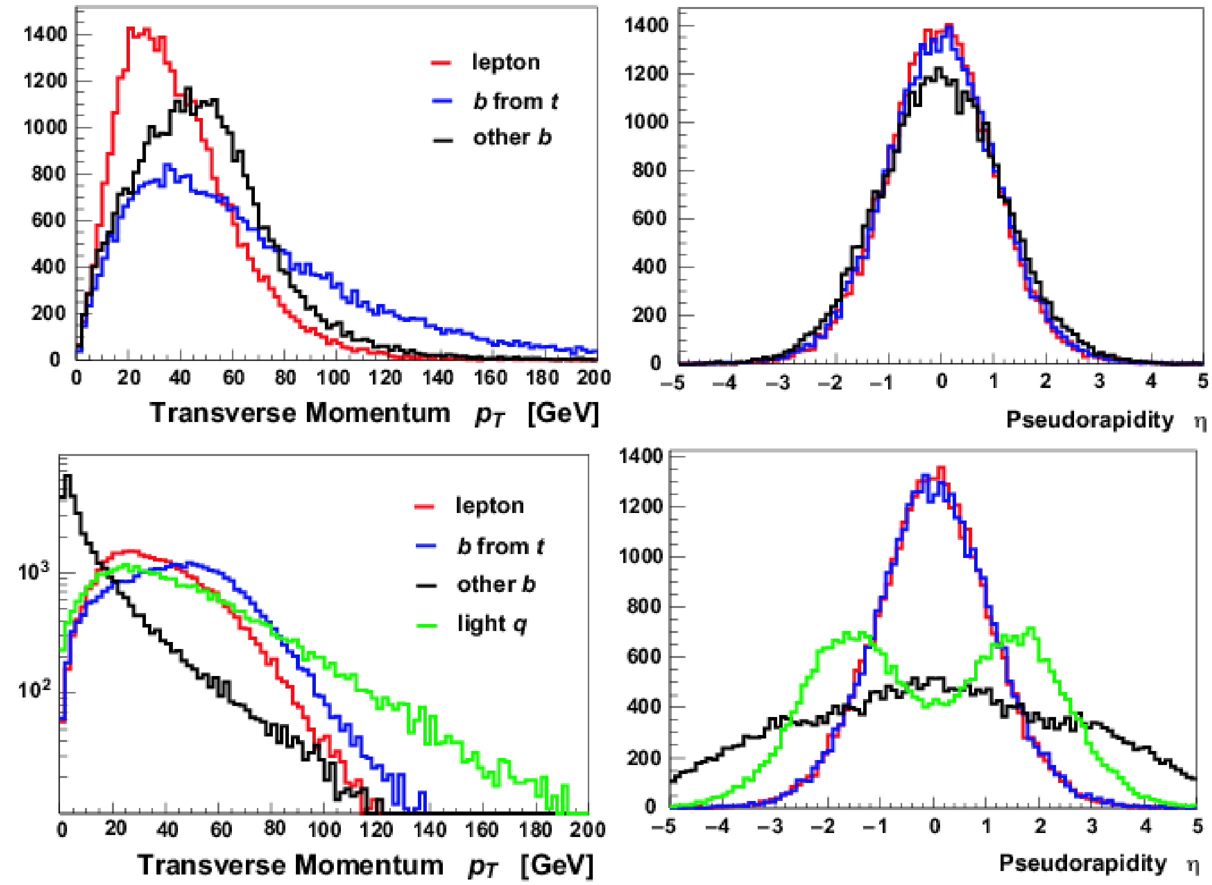
$\sigma_{\mathrm{NLO}} = 1.98 \pm 0.23$ pb

- Tevatron is proton-antiproton collider at center of mass energy of 1.96 TeV
- Top quarks are produced and decay through the electroweak interaction
  - Measure CKM matrix element V_{tb}, observe top quark polarization
  - Possible process to observe new physics
- Event signature: high P_T muon, missing transverse energy (MET), $\geq$ 2 jets

MC Distributions

s-channel

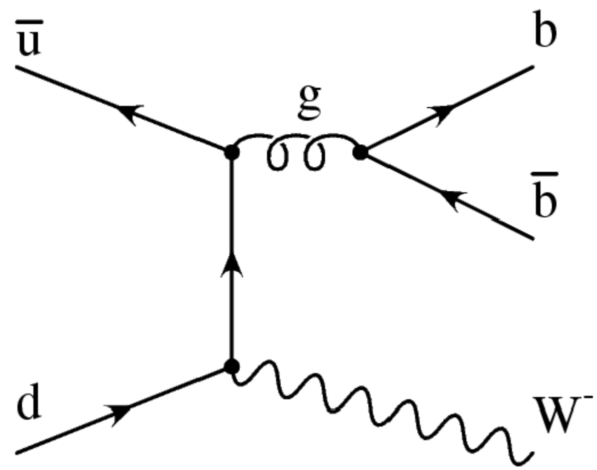
t-channel



(t and $\bar{t}$ combined)

Backgrounds

- **W/Z + jets production**
  - e.g. Wjj, $Wc\bar{c}$, $Wb\bar{b}$, Zjj, $Zc\bar{c}$, many others…
  - Estimated from data.
- **Multijet production (heavy flavor production)**
  - Jet fluctuates to mimic an isolated μ.
  - $Z \rightarrow b\,\bar{b}$ for muon channel ($\approx$ 10-16%) .
  - Estimated from data.
- **Top pair production**
  - $t\,\bar{t} \rightarrow$ dileptons, $t\,\bar{t} \rightarrow \mu$ + jets.
  - Estimated from MC.
- **Other ($Z \rightarrow \mu\,\bar{\mu}$)**
  - Estimated from MC ($\approx$ 11% in soft lepton tagging analysis).

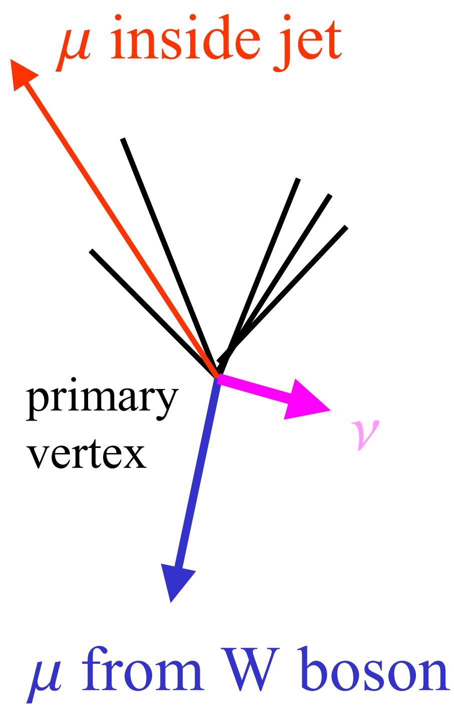


W+2 jet production

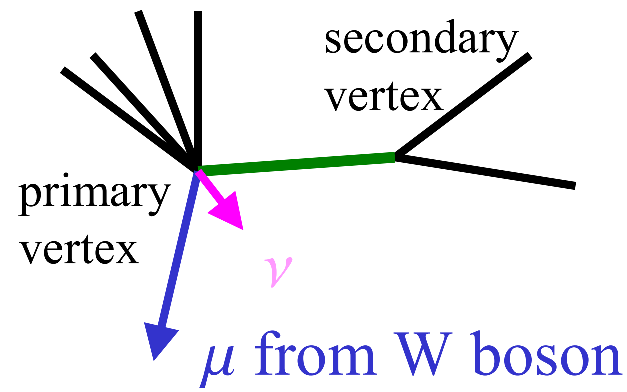
Event Selection

- Run II data set: 158 pb^{-1}
- One high momentum muon:
  - $P_T > 15$ GeV ($|\eta^{\text{detector}}| < 2.0$)
- Missing transverse energy:
  - MET > 15 GeV
- At least two jets ($2 \leq N_{jet} \leq 4$):
  - Jet $E_T > 15$ GeV ($|\eta^{\text{detector}}| < 3.4$)
  - Leading jet $E_T > 25$ GeV ($|\eta^{\text{detector}}| < 2.5$)
- "Triangle Cuts":
  - Removes poorly reconstructed events (discussed in *e*+jets single top talk).
- At least one b-tagged jet:
  - Soft lepton tag (SLT)
  - Secondary vertex tag (SVX)
  - Jet Lifetime Impact Probability tag (JLIP)

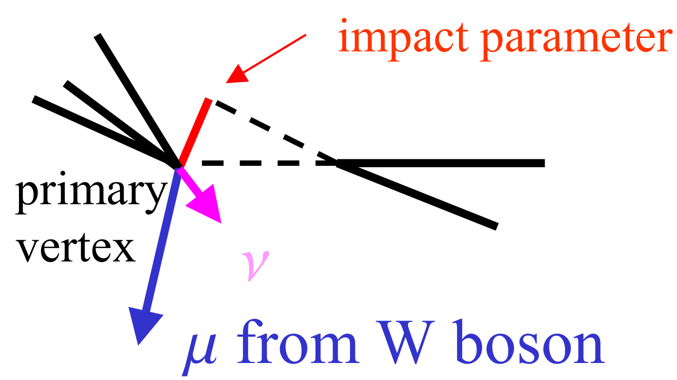
b-tagging Methods



Soft Lepton Tag



Secondary Vertex Tag



Jet Lifetime Impact Probability Tag

Orthogonal Analyses

Full Data Set

Electrons | Muons

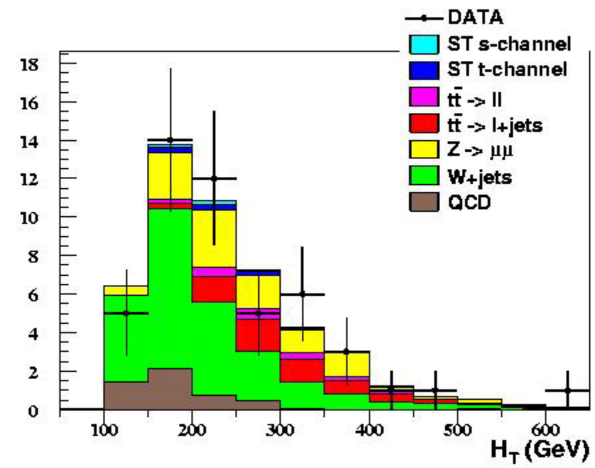
Electrons → SLT, SVT/JLIP

Muons → SLT, SVT/JLIP

- The analyses are split into orthogonal channels:
  - studied independently,
  - combined later.
- Events are first scanned for a SLT, if a SLT is found then the event is not used in the SVT/JLIP analysis.

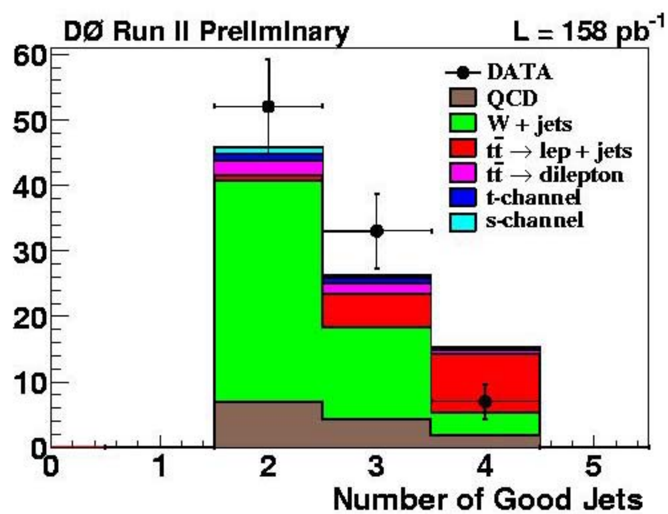
Data/MC Comparisons

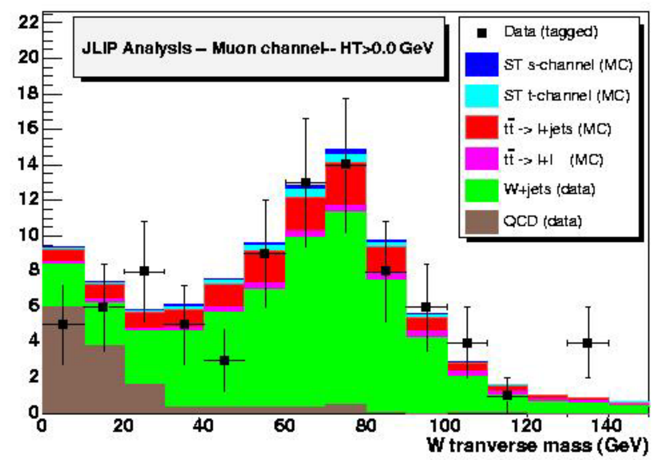
Event yields after preselection.



SLT

SVT



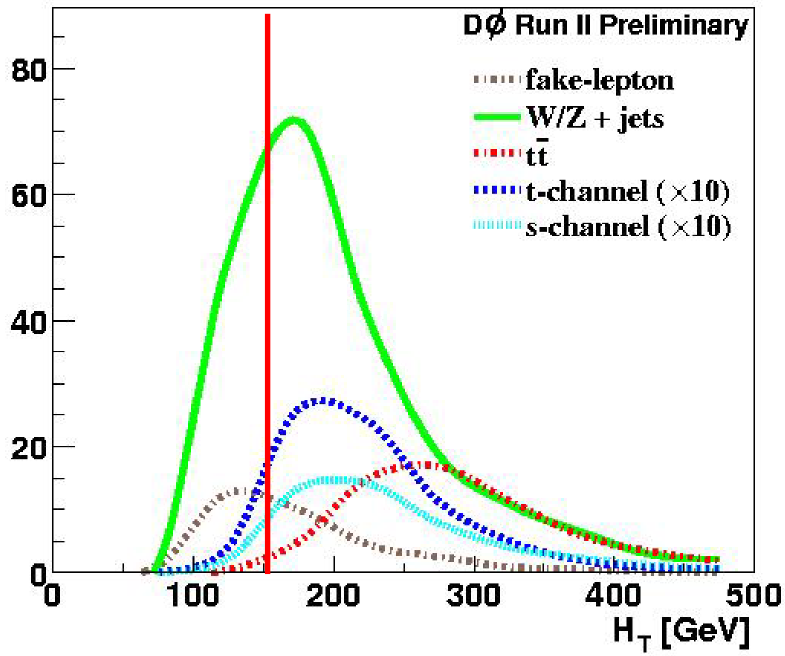


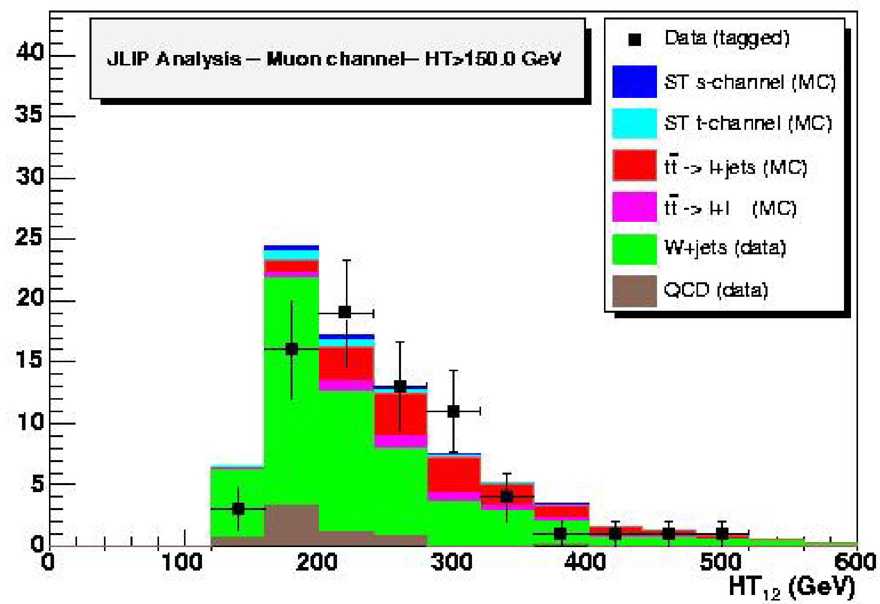
JLIP

Final Event Selection

$H_T = P_T^{\,\mu} + \text{MET} + \Sigma\, E_T(\text{jet}) > 150$ GeV

(Only use two highest E_T jets in $\Sigma\, E_T$(jet) .)

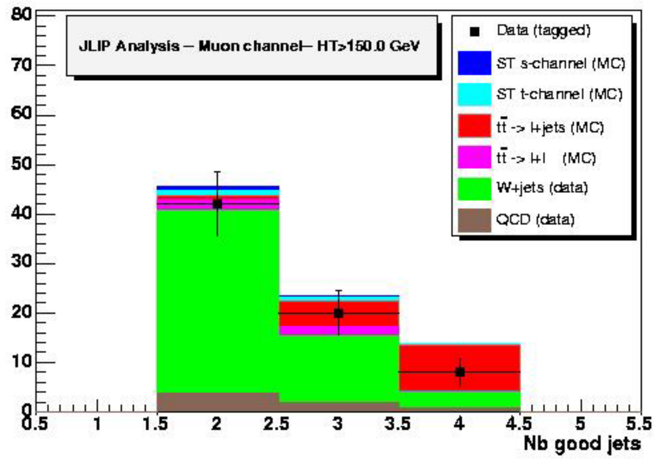




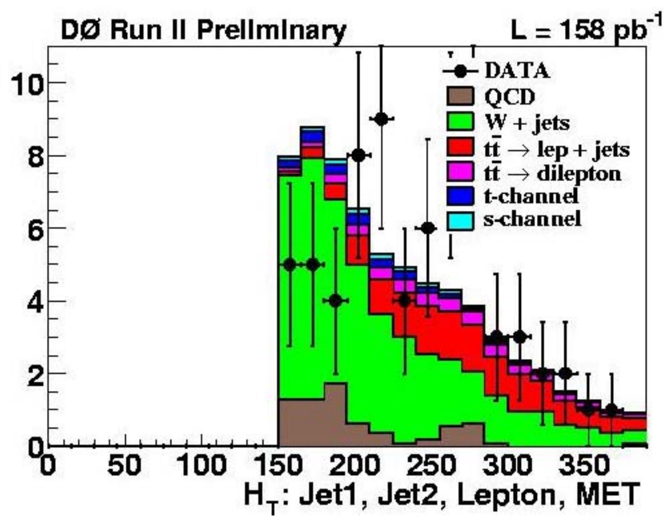
H_T distributions for the e+μ (JLIP + SLT) channel combination.

Event Yields

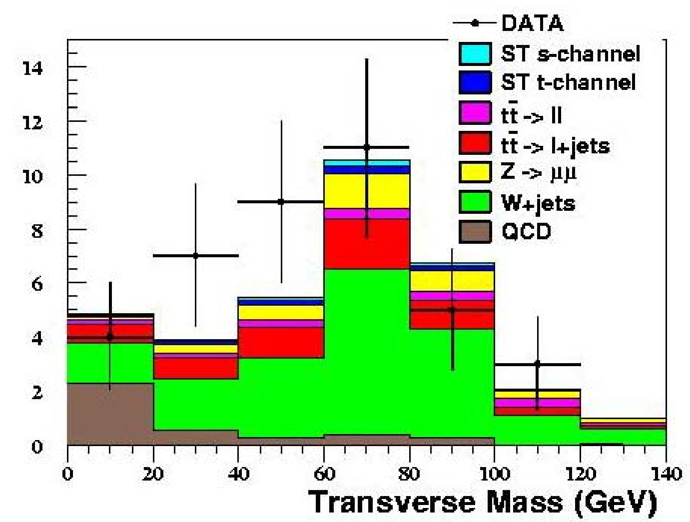
JLIP



SVT



SLT



Acceptances

Muon Channel	SLT	SVT	JLIP
s+t combined	$0.32 \pm 0.01 \pm 0.03$	$0.76 \pm 0.01 \pm 0.14$	$0.79 \pm 0.01 \pm 0.13$

Where do we lose events?

1. Lepton identification efficiency $\approx$ 38%
2. b-tagging efficiency $\approx$ 50%
3. Remaining event selection efficiency $\approx$ 90%

Summary of Yields

Muon Channel	SLT	SVT	JLIP
Signal			
s+t combined	1.4 ± 0.3	3.5 ± 0.9	3.6 ± 0.8
Backgrounds			
$t\bar{t} \to l$+jets	6.1 ± 1.5	14.7 ± 3.6	14.8 ± 3.8
$t\bar{t} \to ll$	2.0 ± 0.4	4.3 ± 1.1	4.4 ± 1.1
$Z \to \mu\mu$+jets	10.3 ± 3.5	—	—
W+jets + fake-l sum	22.4 ± 3.9	48.41 ± 8.8	60.0 ± 11.4
Sum of bkgds for s+t combined	40.8 ± 6.1	67.5 ± 10.0	79.2 ± 12.4
Observed events	43	75	70

Systematic Uncertainties

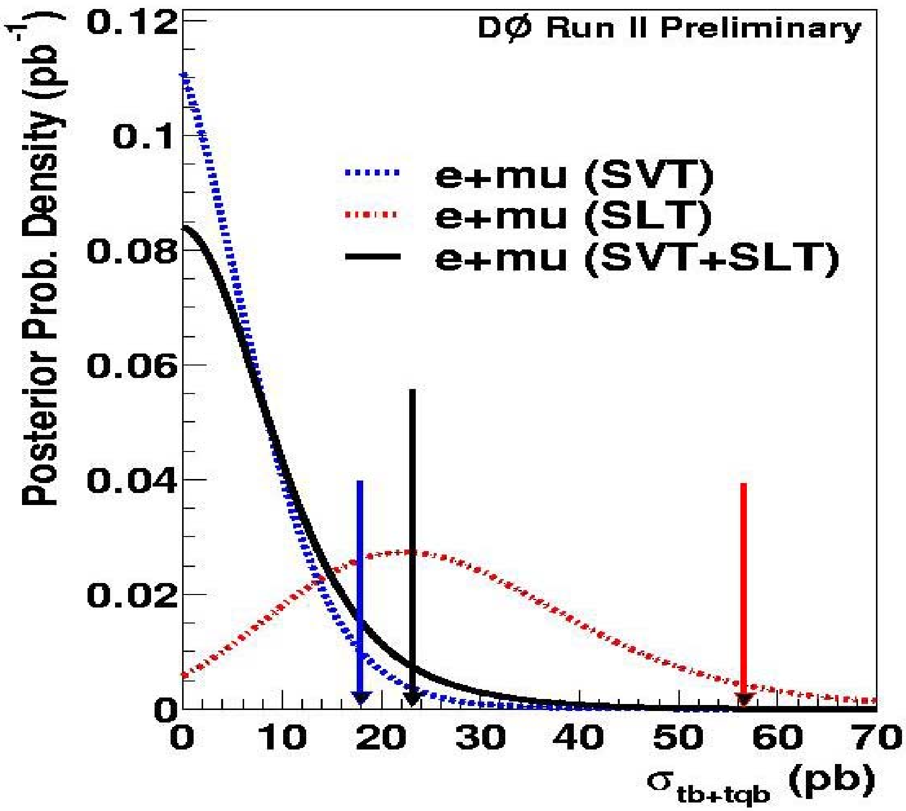
- Largest systematics on the MC signal: jet energy scale, trigger, tagger modeling ≈ 20%
- MC background: normalization ≈ 25%
- Data backgrounds (W/Z + jet): tagging probability estimate ≈ 20%

Cross Section Limits

Tagger	Expected	Observed
SLT	45 pb	49 pb
SVT	29 pb	36 pb
JLIP	32 pb	26 pb

- Cross section limits for s+t channel combined.
- Most sensitive tagger is the SVT.
- We use the Bayesian method to extract limits.

Posterior Distribution



SVT dominates limit calculation due to its larger acceptance.
(tb = s-channel and tqb = t-channel)

Conclusions

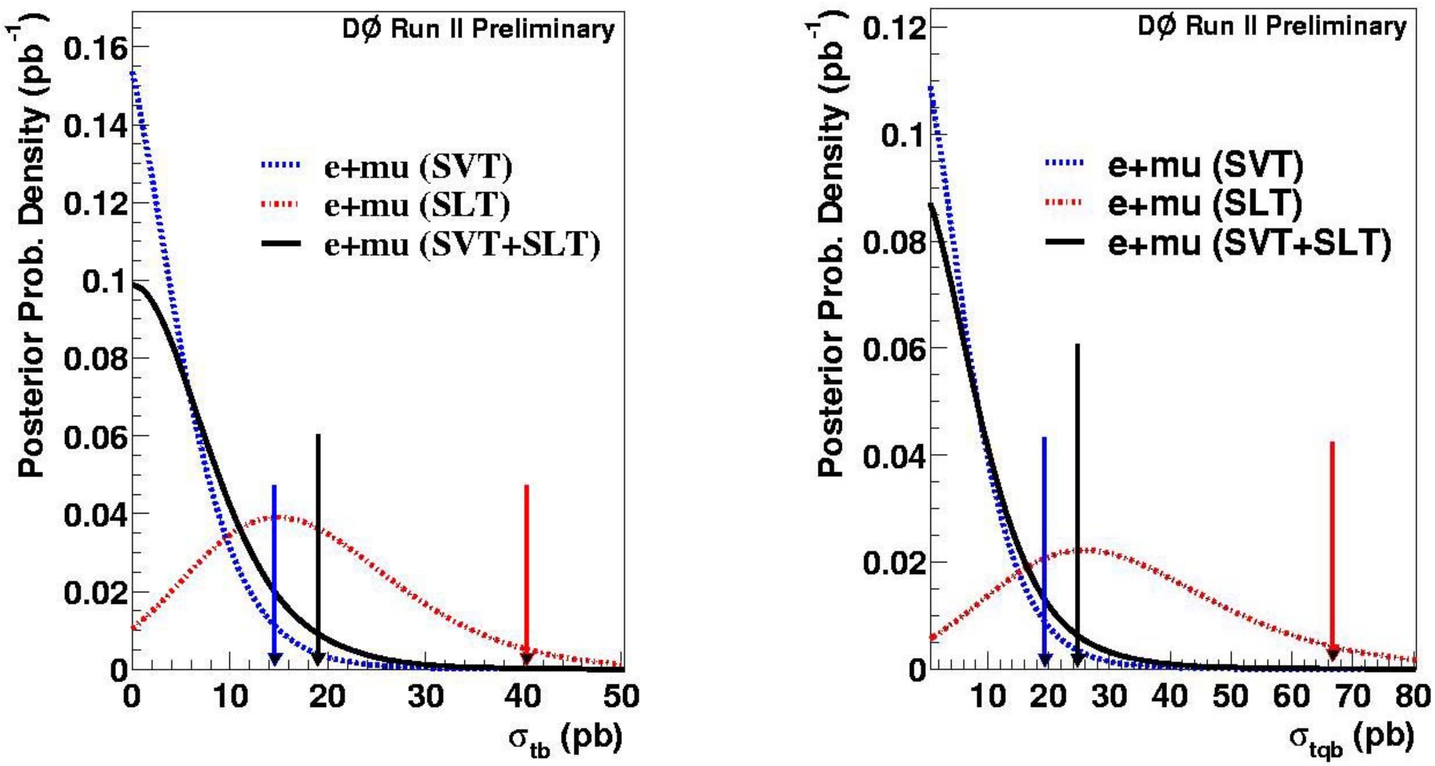
- Using between 156 pb^{-1} and 169 pb^{-1} of Run II data taken at DØ, we get the following observed upper limits on single top quark production at a 95% CL (e+μ, SVT+SLT):
  - 19 pb s-channel, 25 pb t-channel
  - 23 pb s+t combined
- Run I results (95% CL limits, ≈ 110 pb^{-1}, $\sqrt{s} = 1.8$ TeV):
  - DØ: < 17 pb s-channel, < 22 pb t-channel
  - CDF: < 18 pb s-channel, < 13 pb t-channel, < 14 pb t+s combined
- Future plans
  - Short term (improve b-tagging efficiency, W+jets background estimate and acceptance, use likelihood fitting).
  - Long term (use Neural Networks to improve signal and background separation).

Backup Slides

Bayesian Method

- We use Bayes theorem to calculate the cross section with a flat prior ("maximum entropy").
- Systematic uncertainties and error correlations are included using a multivariate Gaussian.
- We extract an upper limit on the cross section by integrating the posterior probability up to 0.95:
  - $\int_0^{\sigma(UL)} \text{Posterior}(\sigma \mid N_{\text{observed}}) = 0.95$
- Computation of the upper limit on the cross section is also done with a Modified Frequentist Method and produces similar results.

Posterior Distributions



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