PHENO 2004

Madison Wisconsin, April 26, 2004

DØ single top searches in the μ+jets channel

Summary

- Single top production at the Tevatron and properties
- Search strategy
- B-tagging:
  - Soft Muon Tagger and Secondary Vertex Tagger
  - Background estimation from MC and from data
- Systematic errors, events yields and plots of distributions
- Expected limits for 158 pb^{-1} of collected data

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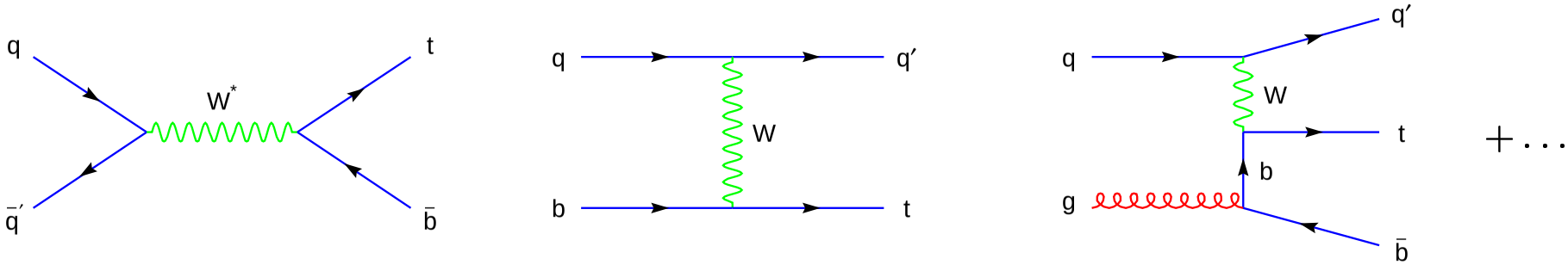
on behalf of the DØ collaboration

Electroweak production of the top quark

Two completely independent processes through W-exchange:
<u>s-channel:</u> $p\bar{p}\to t\bar{b}+X$ ($t\bar{b}$, $\bar{t}b$); and <u>t-channel:</u> $p\bar{p}\to tq\bar{b}+X$ ($tq\bar{b}$, $\bar{t}\bar{q}b$, tq, $\bar{t}\bar{q}$)

NLO σ for $\sqrt{s} = 1.96\,\mathrm{TeV}$ and $M_t = 175\,\mathrm{GeV}/c^2$ (hep-ph/9604223, hep-ph/0207055)

$$\boxed{\sigma_s = 0.88 \pm 0.07\,pb} \qquad \boxed{\sigma_t = 1.98 \pm 0.21\,pb}$$



Total production cross section $\sim 40\%$ of $t\bar{t}$, but...

- Access to Wtb vertex $\longrightarrow$ Measure V_{tb} directly, test unitarity of CKM
- Test V$-$A structure $\longrightarrow$ New physics: W$'$, top pions $\pi^{\pm}$, $\tilde{t}$, anomalous couplings?
- Study top polarization, mass

Run I 95% CL limits:

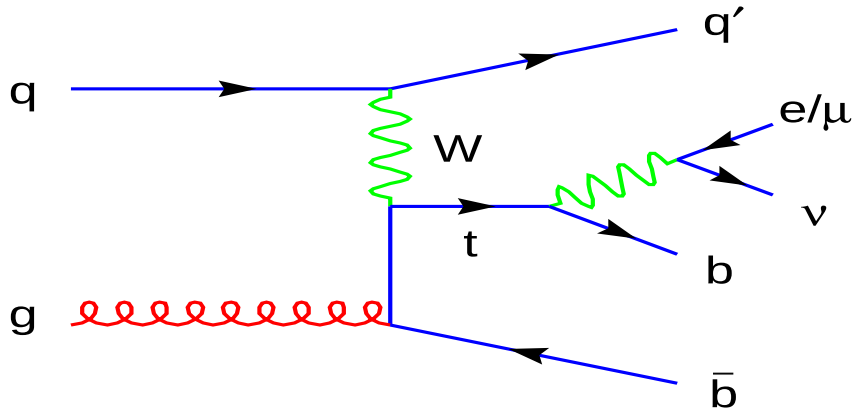
$\sigma_s < 17\,pb$ (DØ) ; 18 pb (CDF) $\qquad$ $\sigma_t < 22\,pb$ (DØ) ; 13 pb (CDF)

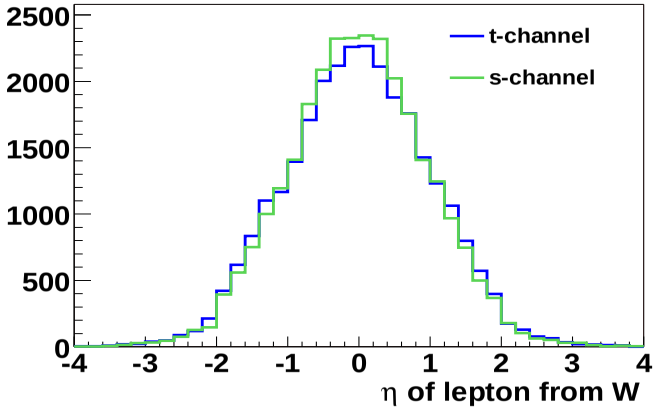
With increased $\mathcal{L}$, increased production cross section (+30%), and b-tagging

$\downarrow$

Flagship discovery in Run II

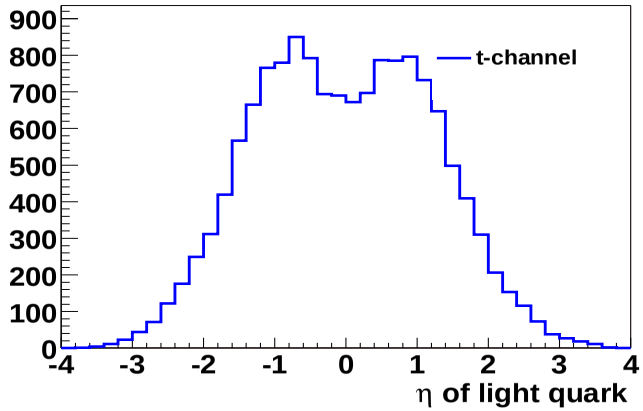
Signal topology



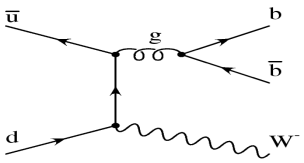


The signature we are looking for:

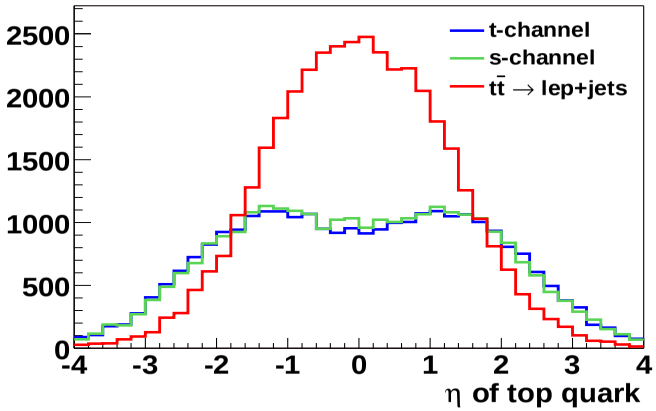
- One high-p_T isolated lepton (from W)
- $\not{E}_T$ (ν from W)
- One b-quark jet (from top)
- A light flavor jet and/or another b-jet



Main backgrounds:

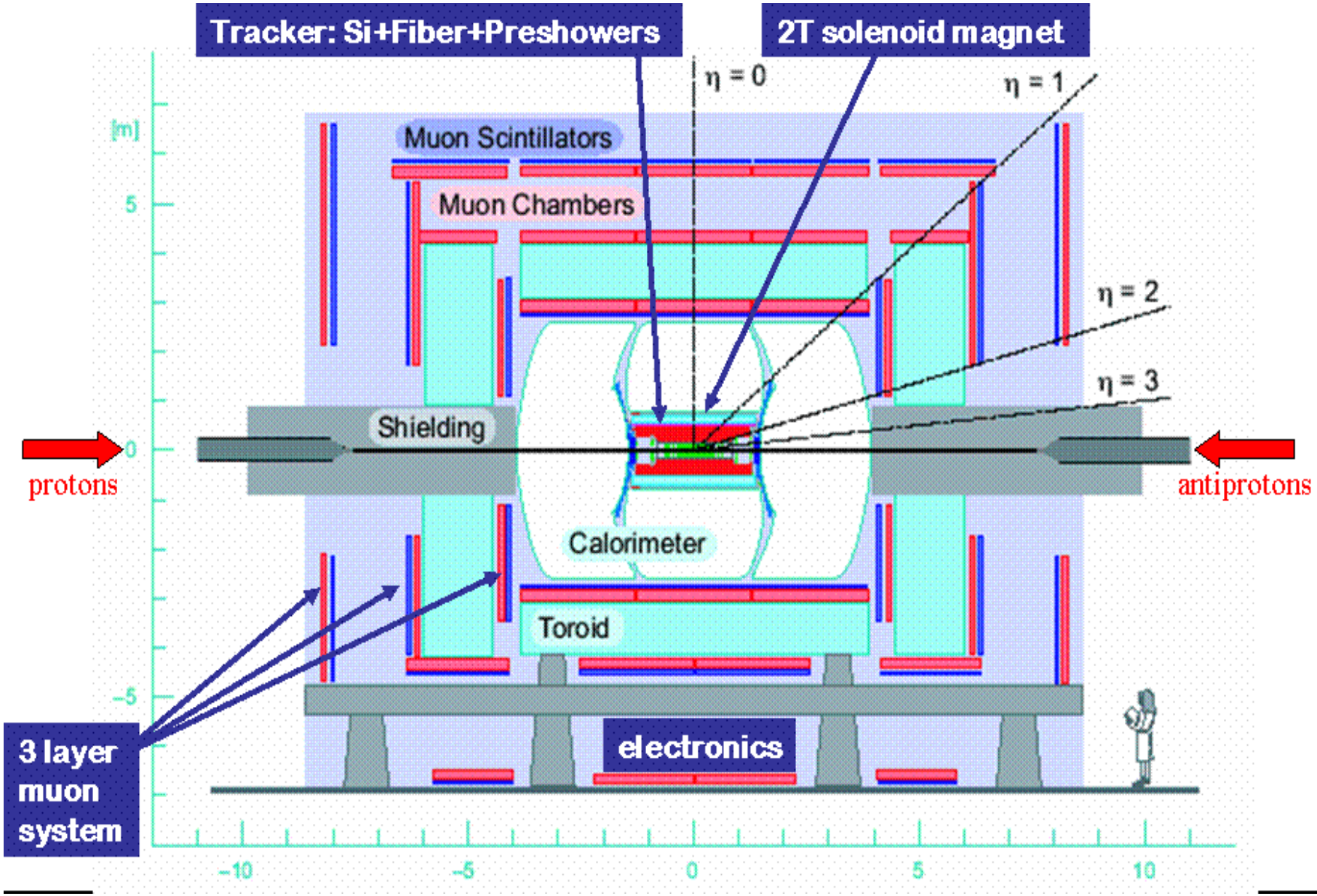


- W+jets (from data)
- $t\bar{t} \to \ell$+jets and $t\bar{t} \to \ell\ell$
- misreconstructed multi-jets events
- Z$\to\mu\mu$ only for soft-muon tag analysis



The Run II DØ detector

So far 320 pb^{-1} of data recorded in Run II @ $\sqrt{s} = 1.96\,\text{TeV}$



Search cuts and MC samples

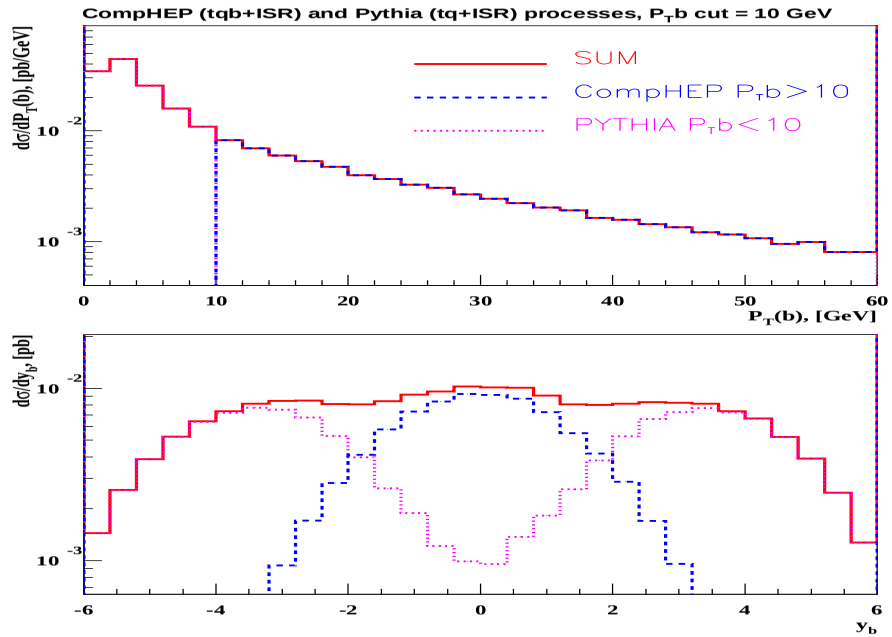
Loose preselection to keep data with similar final state objects to signals

Reject mismeasured events and regions not well described by bkgd. models

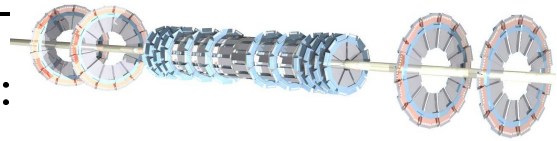
- 1 good quality isolated muon: $E_{\mathrm{T}} > 15\,\mathrm{GeV}$, $|\eta| < 2$
- $2 \leq N_{\text{good jets}} \leq 4$
- Leading jet: $E_{\mathrm{T}} > 25\,\mathrm{GeV}$, $|\eta| < 2.5$; Other jets: $E_{\mathrm{T}} > 15\,\mathrm{GeV}$, $|\eta| < 3.4$
- $\not{E}_{\mathrm{T}}^{JES} > 15\,\mathrm{GeV}$, $\not{E}_{\mathrm{T}} > 15\,\mathrm{GeV}$
- $N_{\text{noise jets}} \leq 2$, $\not{E}_{\mathrm{T}} < 200\,\mathrm{GeV}$
- Require at least one b-tag by soft-μ tagger / secondary vertex tagger
- Final cut: $H_{\mathrm{T}} = E_{\mathrm{T}}^{\mathrm{jet1}} + E_{\mathrm{T}}^{\mathrm{jet2}} + E_{\mathrm{T}}^{\mu} + \not{E}_{\mathrm{T}} > 150\,\mathrm{GeV}$

MC samples (all interfaced to Pythia):

- SingleTop for signal:
  based on CompHEP, no parton cuts
  NLO with full spin correlations
- Alpgen for $t\bar{t}$
  full spin correlations, no parton cuts
- Pythia for Z$\rightarrow\mu\mu$
  only for soft-muon tag analysis



b-tagging methods



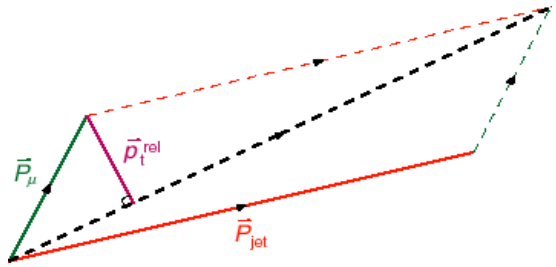
Two different b-tagging algorithms used independently:

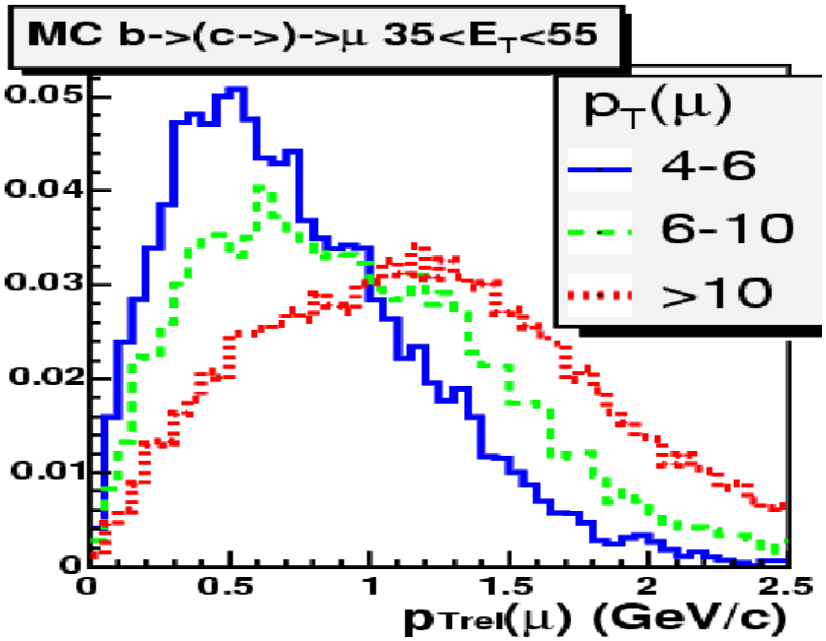
Soft Muon Tagger

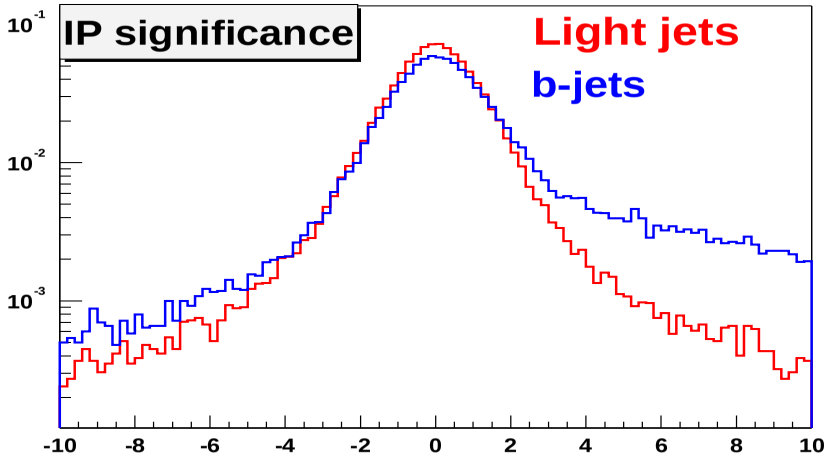
- 11% of b-jets contain a soft muon
- Look for a muon close to a jet:
  $\Delta R(\mu,\text{jet}) \leq 0.5$ and $p_T(\mu) > 4\,\text{GeV}/c$

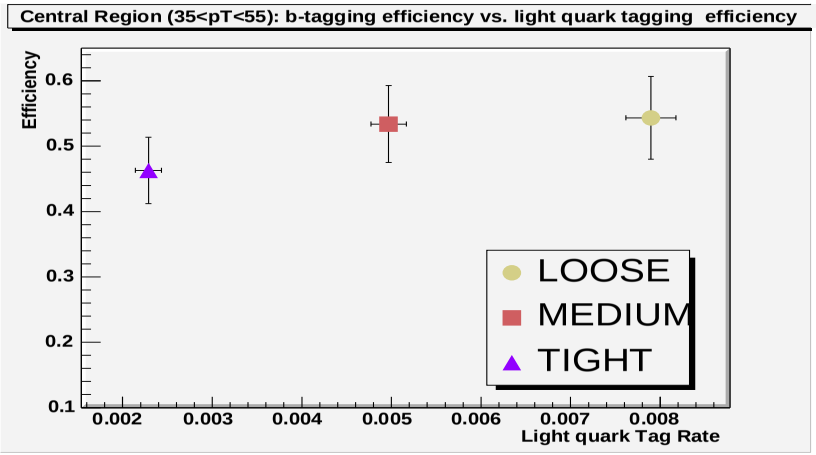
Secondary Vertex Tagger

- Reconstruct a displaced vertex
- Fit tracks with $\text{IP}_{\text{trk}}/\sigma_{\text{trk}} > 3.5$
- Secondary vertex if $\text{IP}_{\text{vtx}}/\sigma_{\text{vtx}} \geq 7$

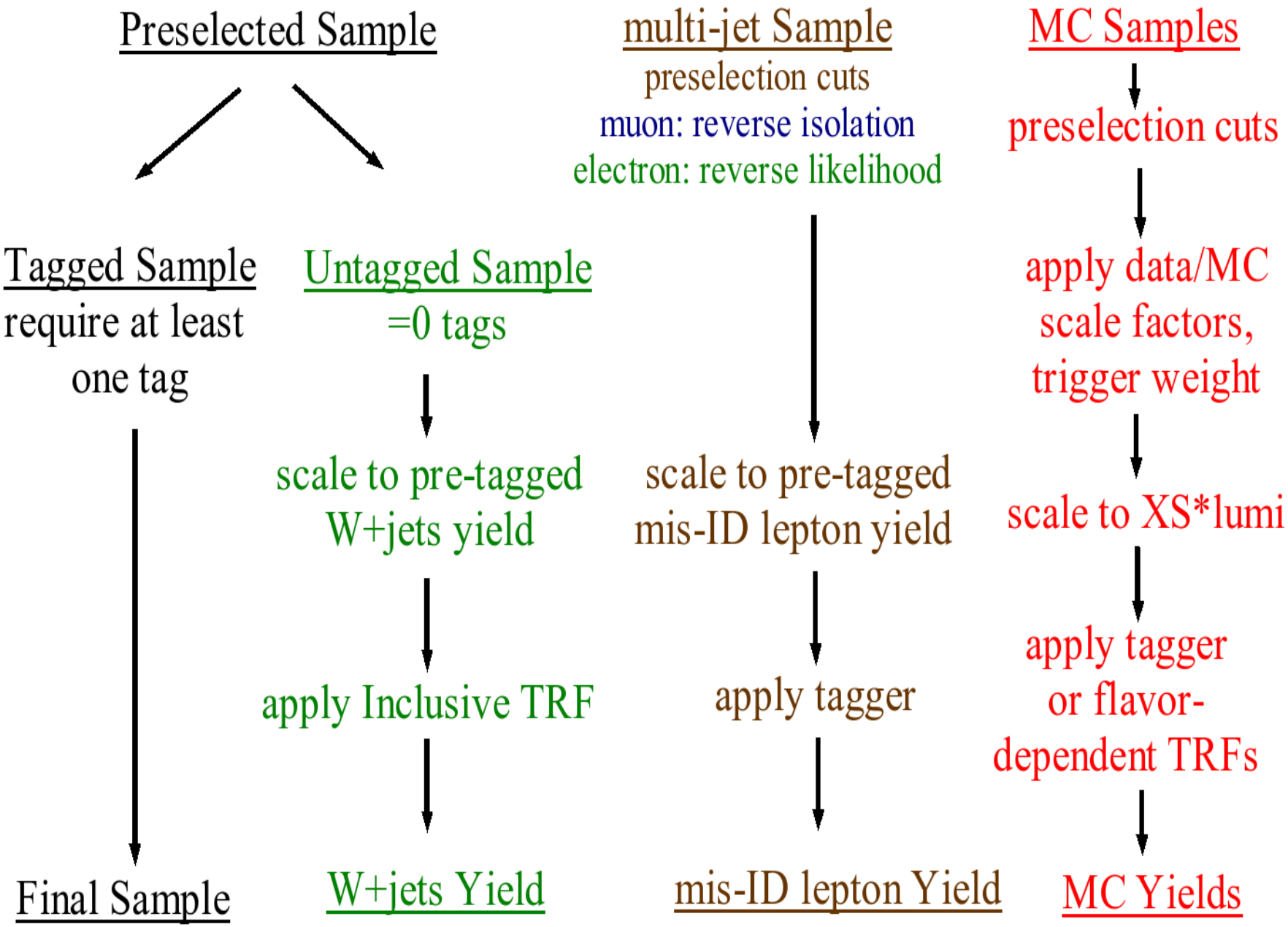








Tagged background estimation methods



Tagged MC estimation methods

For signal, $t\bar{t}$ and Z$\rightarrow\mu\mu$ MC samples:

- ★ Correct from ID efficiencies (measured in Z$\rightarrow$ $\mu^+\mu^-$ data and MC):
  ID, tracking, matching, isolation scale factor $= \varepsilon(data)/\varepsilon(MC) = 0.86 \pm 0.05$
- ★ Apply trigger response and scale to $\sigma\mathcal{L}$
- ★ SVT applies a flavor dependent tag-rate functions after parton matching
  - *b*-flavor TRF: $f(E_{\mathrm{T}}, \eta)$ from μ+jets sample with $p_{\mathrm{T}}(\mu) > 8\,\mathrm{GeV}/c$
    Count number of muon-jets with vertex, correct with $p_{\mathrm{T}}^{\mathrm{rel}}$ templates
  - *c*-flavor TRF: scale *b*-TRF by *c*/*b*-tagging ratio from MC
  - light-quark TRF: Use negative side of IP significance

↓

Probability(tag event) = 1 − Probability(no jet tag)

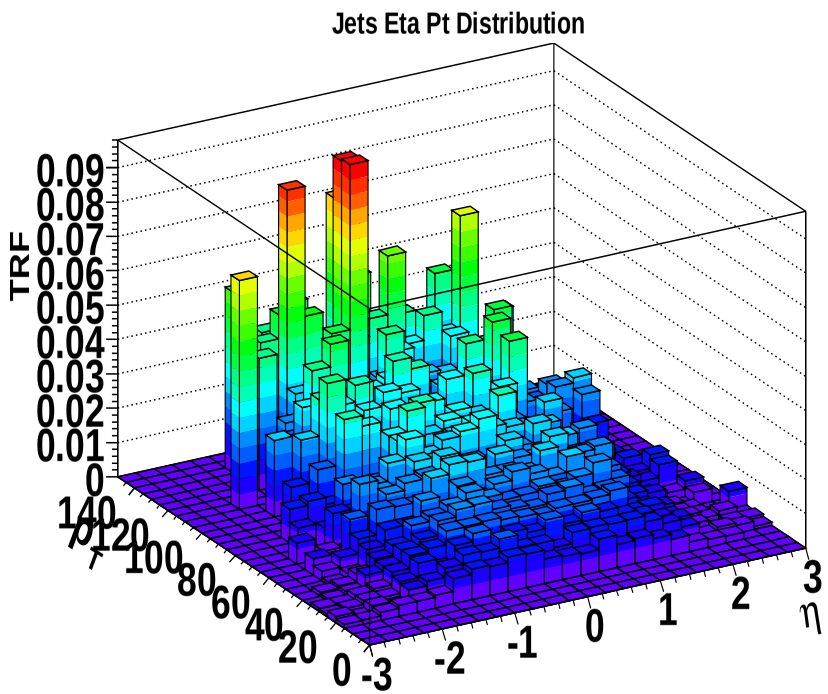
- ★ SLT applies directly the tagger (find soft muon close to jet) on the MC

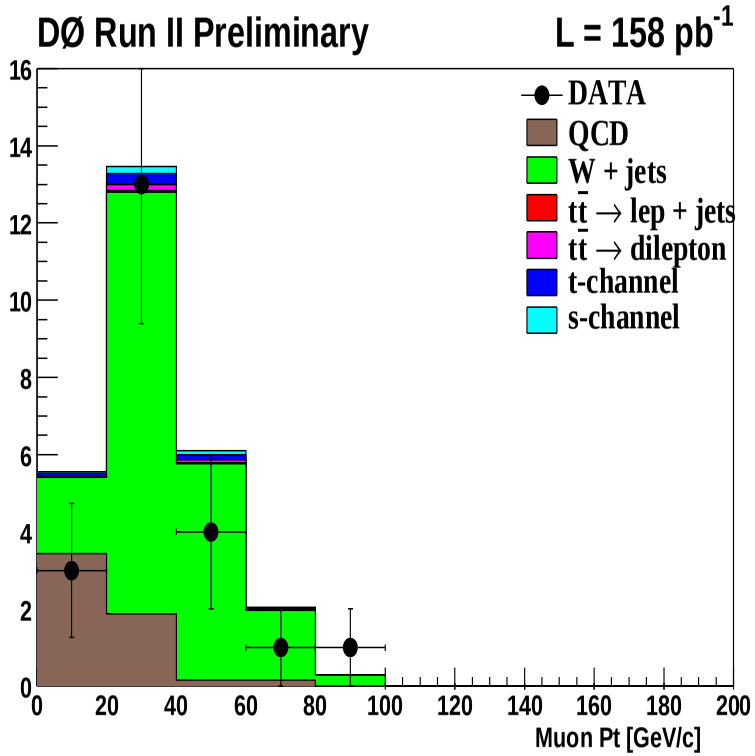
QCD and W+jets estimation from data

QCD: Generate fake-ℓ sample with reverse isolation cut, scale it to size of pretagged sample and apply the tagger

W+jets: Apply inclusive tag-rate function over the preselected sample with 0 tags

- Derive inclusive TRF from multijet sample ➔ Assume that heavy flavor content is the same in W+jets and the multijet sample for events with same jet multiplicity
- Test assumption with a clean W+jets sample: presel + N_{jets}=2 + H_{T}<200 GeV
- The tagger applied directly and the TRF agree within errors





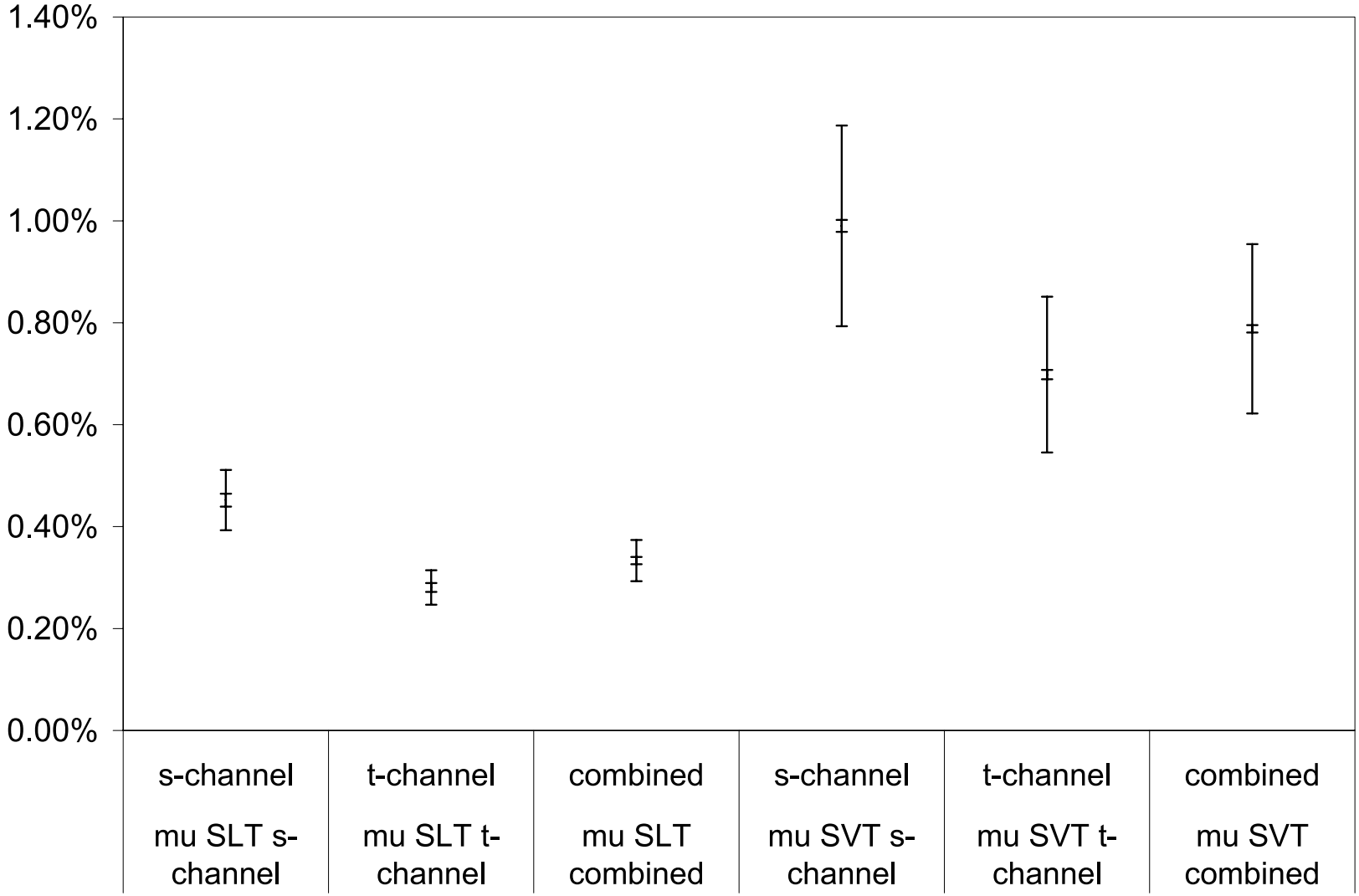
Systematic Uncertainties

MC acceptance uncertainties (%)	
jet energy scale	∼10
trigger	∼10
flavor dep. TRF	∼8
μ ID	6
jet fragmentation	5
tagging μ model (SLT)	3
tagging μ veto (SVT)	3

Data uncertainties (%)	
inclusive TRF	20
Z→ $\mu\mu$ scale factor	16
QCD scale factor	13
W+jets scale factor	3

- ★ Largest uncertainty comes from the heavy flavor composition of the multijet data used to determine the W+jets yield: inclusive TRF
- ★ $t\bar{t}$ and single top production cross sections are ∼15-18%
- ★ Luminosity uncertainty is 6.5%
- ★ W+jets and fake-ℓ from QCD uncertainties are fully anti-correlated
- ★ Total yield uncertainty for W+jets and fake-ℓ is 18%
- ★ Total yield uncertainty for MC backgrounds is ∼25%

MonteCarlo signal acceptance

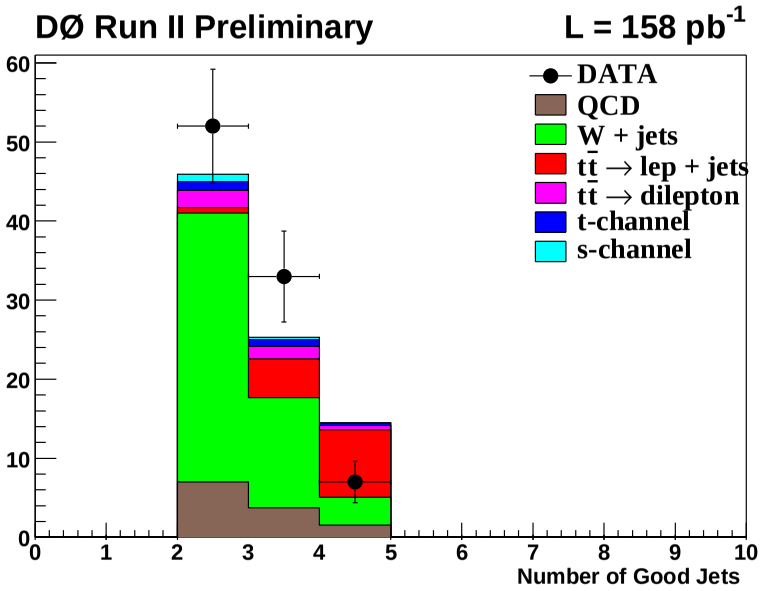


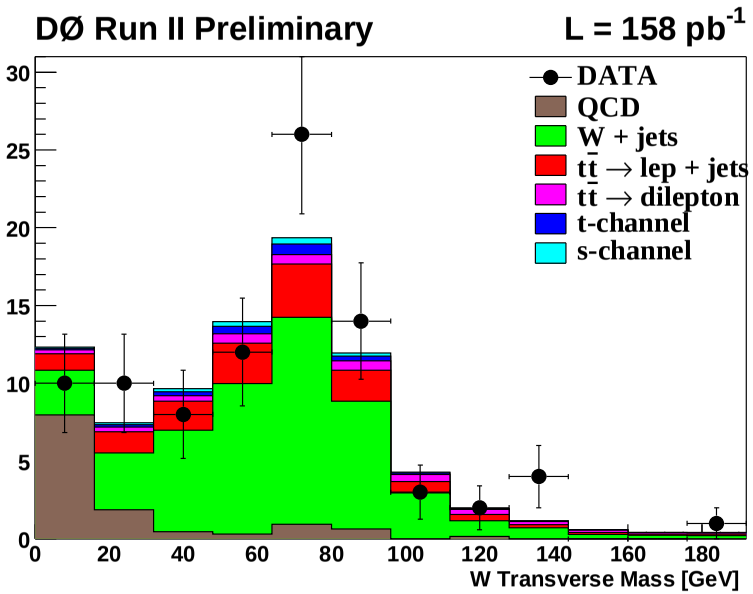
Event yields

	SLT	SVT
Signals		
MC s-channel	0.6 ± 0.1	1.3 ± 0.3
MC t-channel	0.9 ± 0.3	2.1 ± 0.7
MC s+t combined	1.5 ± 0.4	3.4 ± 1.1
Backgrounds		
MC $t\bar{t} \to \ell$+jets	6.2 ± 1.4	14.1 ± 3.4
MC $t\bar{t} \to \ell\ell$	2.2 ± 0.3	4.2 ± 0.7
MC $Z \to \mu\mu$+jets	3.7 ± 0.7	—
W+jets + fake-ℓ data	23.2 ± 4.0	48.9 ± 8.9
Sum of backgrounds	35 ± 4	67 ± 10
Observed data	43 ± 7	76 ± 9
Acceptance	0.3%	0.7%

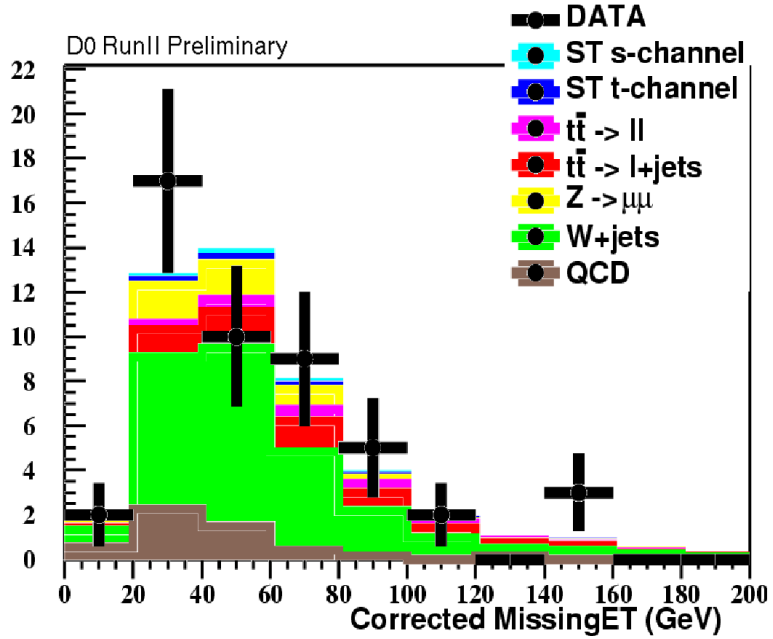
Distributions before final cut on $H_T > 150$ GeV

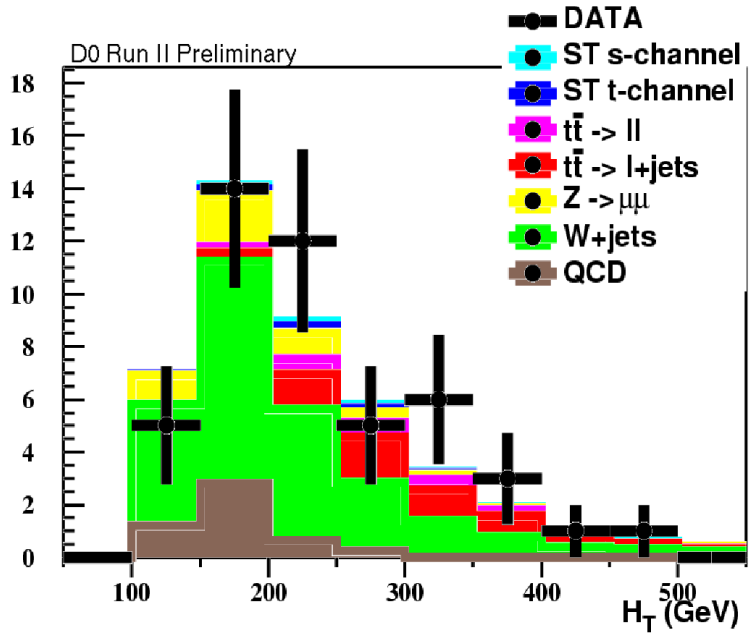
Secondary Vertex Tagger





Soft Muon Tagger





Limit setting: Expected limits

Used Modified Frequentist approach (CL_s method) from LEP

- ★ Derive s- and t-channel limits by taking the other's contribution as background
- ★ Systematic uncertainties are included as fully correlated or fully uncorrelated
- ★ Correlations between channels and background sources are treated properly

  e.g. the $\mathcal{L}$ uncertainty is fully correlated between samples (signal, $t\bar{t}$,...) and analyses (SLT, SVT)
- ★ SVT and SLT analysis are orthogonal: SVT requires a veto on a soft-tagging μ
- ★ Easy combination of taggers and addition of channels

σ 95% CL Expected Upper Limits With Systematics

	SLT	SVT	Combined
s-channel	26	20	17
t-channel	40	34	25
$s+t$ combined	32	27	22

Conclusions

With $158\,pb^{-1}$ of data, we see:

Observed Data	Bkg. expected	$s+t$
119 ± 11	102 ± 10	5 ± 1

Muon channel **expected** limits with systematics taken into account:

$\sigma_s < 17\,pb$ $\sigma_t < 25\,pb$ $\sigma_{s+t} < 22\,pb$ @ 95% CL

- Combine limits with the e-channel: see talk by R. Schwienhorst
- Already better results than in Run I ...
- ...and we haven't applied neural networks yet
- ...nor shape fitting to extract better limits
- The Tevatron and DØ are performing very well
- Many exciting new results to come from this analysis!