Search for Single Top

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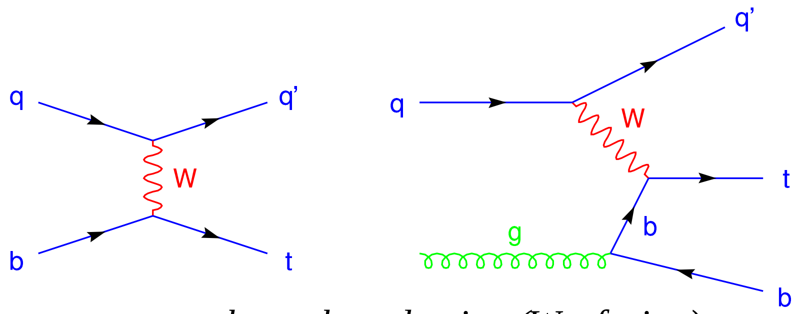
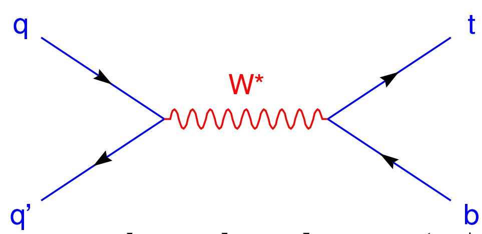
Outline of Presentation:

1. Motivation
2. Signal Event Selection
3. Background Composition and Modeling
4. Signal and Background Yield
5. A Priori Upper Limit on the Cross-Section
6. Outlook

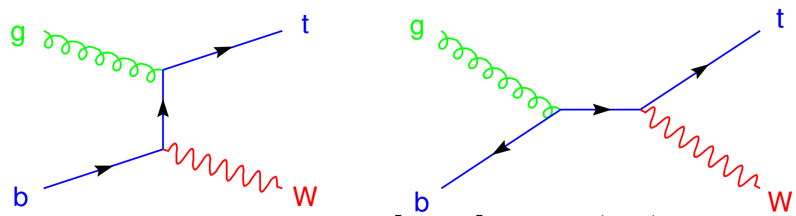
- Electroweak top production at the Tevatron in Run II:



t-channel production (Wg fusion)



s-channel production (W^*)



associated production (tW)

- Predicted cross sections at $\sqrt{s} = 1.96$ TeV:

Process	Name	σ_{theory}	Reference
$qg \to tbq'$	t-channel	1.98 ± 0.13 pb	Stelzer et al.
$qq' \to tb$	s-channel	0.88 ± 0.05 pb	Smith et al.
$gb \to tW$	tW-production	0.09 ± 0.02 pb	Tait et al.

- Cross section is proportional to V_{tb}^2
- Sensitive to non-Standard Model top quark interactions
- Allows top polerization studies (Run IIb)
- Related to light SM Higgs searches (same final state)
- In Run IIa we are sensitive to discover Single Top! How much Single Top will be detected by this summer?
  $\rightarrow$ Reminder of the talk will cover this

Event Topology:

- ◇ Lepton, $\not{E}_T$, 2 Jets, b-tag

Event Veto:

- ◇ Veto Zs, dileptons, conversions

Kinematic Cut:

- ◇ Reconstructed top mass 140 GeV $< M_{l\nu b} <$ 210 GeV

Tight electron:
- Fiducial and CEM
- $E_T \geq$ 20 GeV
- $P_T \geq$ 10 GeV/c
- $E/p(P_T \leq$ 50 GeV/c
- $E_{HAD}/E_{EM} \leq$ 0.055+0.00045*E
- $L_s hr$ <0.2
- $|\Delta z|$ <3 cm
- $Q \times \Delta x$ >-1.5 and 3.0 cm
- $\chi^2_{Strip} < 10$
- $|\Delta z_0| <$ 60 cm
- # axial, stereo segments $\geq$3
- Isolation $<$ 0.1

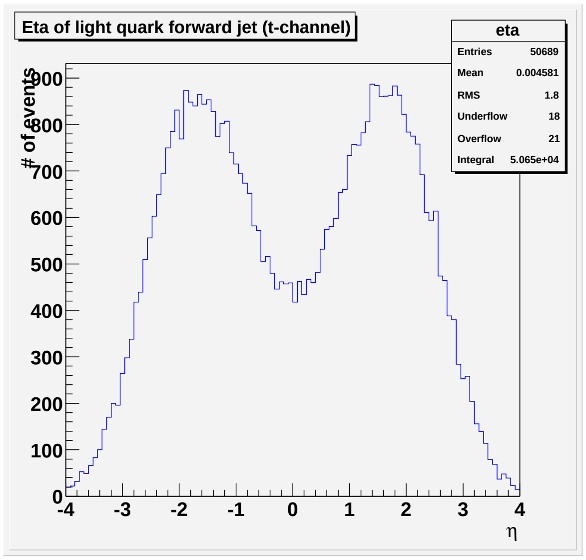
Missing E_T:
- Muon corrected $\not{E}_T >$ 20 GeV

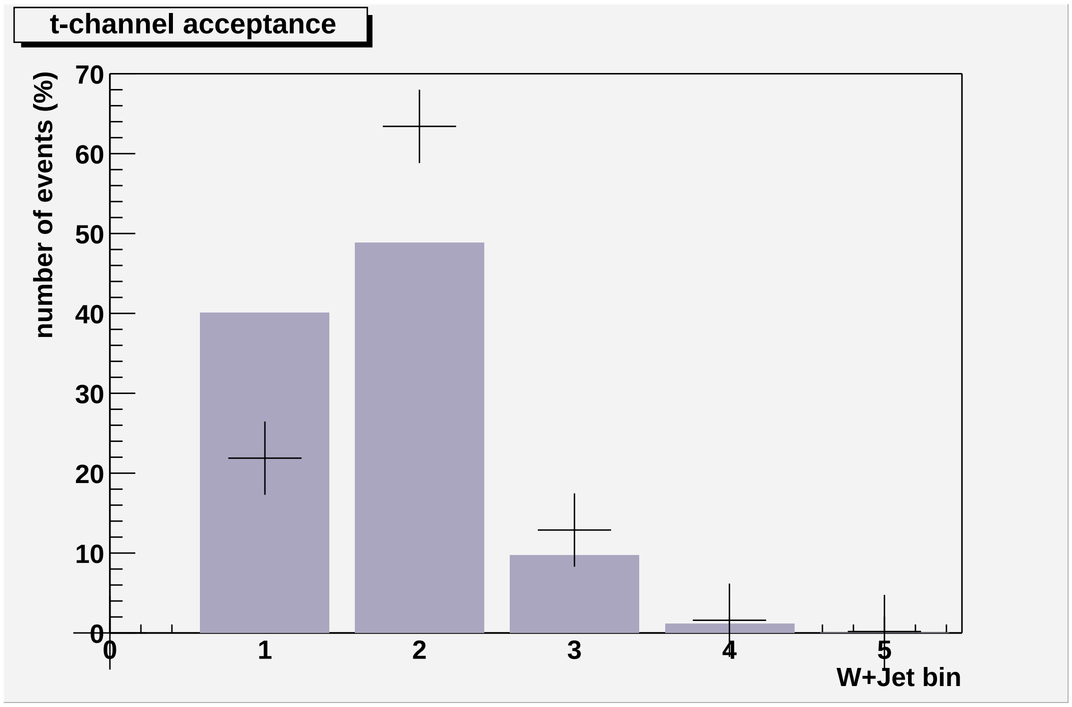
Tight muon:
- Fiducial CMUP or CMX
- $P_T \geq$ 20 GeV/c
- E_{EM} <max(2.2+0.0115*(p-100))
- E_{HAD} <max(6.6+0.0280*(p-100))
- $|\Delta x|_{CMU}$ <3.0 cm
- $|\Delta x|_{CMP}$ <5.0 cm
- $|\Delta x|_{CMX}$ <6.0 cm
- $|\Delta z_0|$ $\geq$60 cm
- # axial, stereo segments $\geq$3
- Isolation $<$ 0.1

Tight Jets:
- E_T $\geq$15 GeV
- $|\eta|$ <2.8 GeV

t-channel light quark jet is quite forward

→ Extending jet-eta (from 2.0) to $|\eta| < 2.8$ will increase acceptance in W+2jet bin





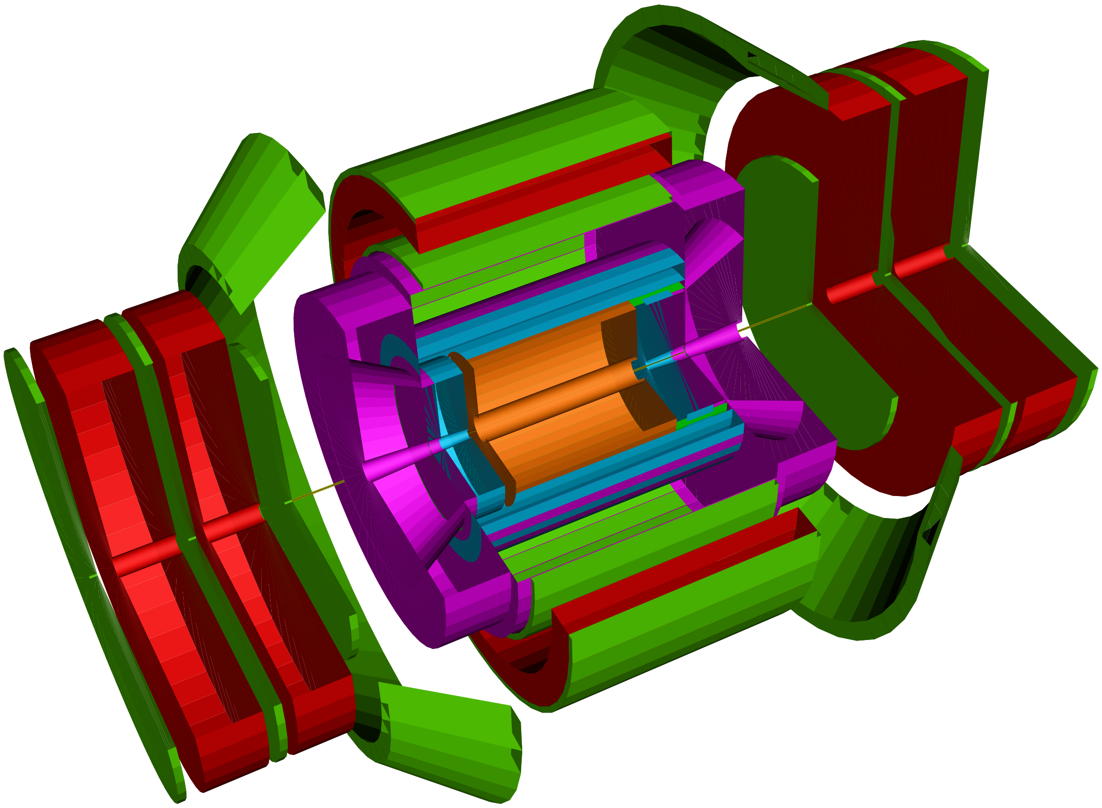
- Increased t-channel acceptance in W+2jet bin (∼ 29.6%)

- Q: How do single top backgrounds behave?

Measure acceptance change in W+2jet bin:

	$\eta < 2.4$	$\eta < 2.8$	$\eta < 3.2$
t-channel	+15.6%	+29.7%	+29.7%
s-channel	+1.6%	+1.9%	+1.9%
$Wb\bar{b}$	+2.2%	+3.2%	+3.2%
Wc	+13.5%	+25.7%	+25.7%
$t\bar{t}$	-9.1%	-12.9%	-12.9%

- t-channel increase dominates
- Wc increases but $t\bar{t}$ decreases
- Numbers saturate at $\eta < 2.8$
- Always gain in terms of $S/\sqrt{B}$



- ◇ Serious data taking since March 2002
- ◇ Instantaneous Luminosity $\mathcal{L} = 2...4 \cdot 10^{31}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- ◇ Data collected up to January shutdown 2003:
  - $\int \mathcal{L}dt^{CEM} = \int \mathcal{L}dt^{CMUP} =\ 57.5\ \mathrm{pb}^{-1}$
  - $\int \mathcal{L}dt^{CMX} =\ 47.3\ \mathrm{pb}^{-1}$
- ◇ Hope to add + $100\ \mathrm{pb}^{-1}$ until summer 2003

Calculating the expected Single Top Yield:

$$\boxed{\mathcal{N}_{W^*} = \varepsilon_{W^*}^{CEM} \int \mathcal{L}dt^{CEM} + \varepsilon_{W^*}^{CMUP} \int \mathcal{L}dt^{CMUP} + \varepsilon_{W^*}^{CMX} \int \mathcal{L}dt^{CMX}}$$

with: $\varepsilon_{W^*} = \mathcal{A}_{W^*}^{MC} \cdot \varepsilon_{z0}^{data} \cdot \varepsilon_{trig}^{data} \cdot \frac{\varepsilon_{leptonID}^{data}}{\varepsilon_{leptonID}^{MC}} \cdot \frac{\varepsilon_{tag}^{data}}{\varepsilon_{tag}^{MC}}$

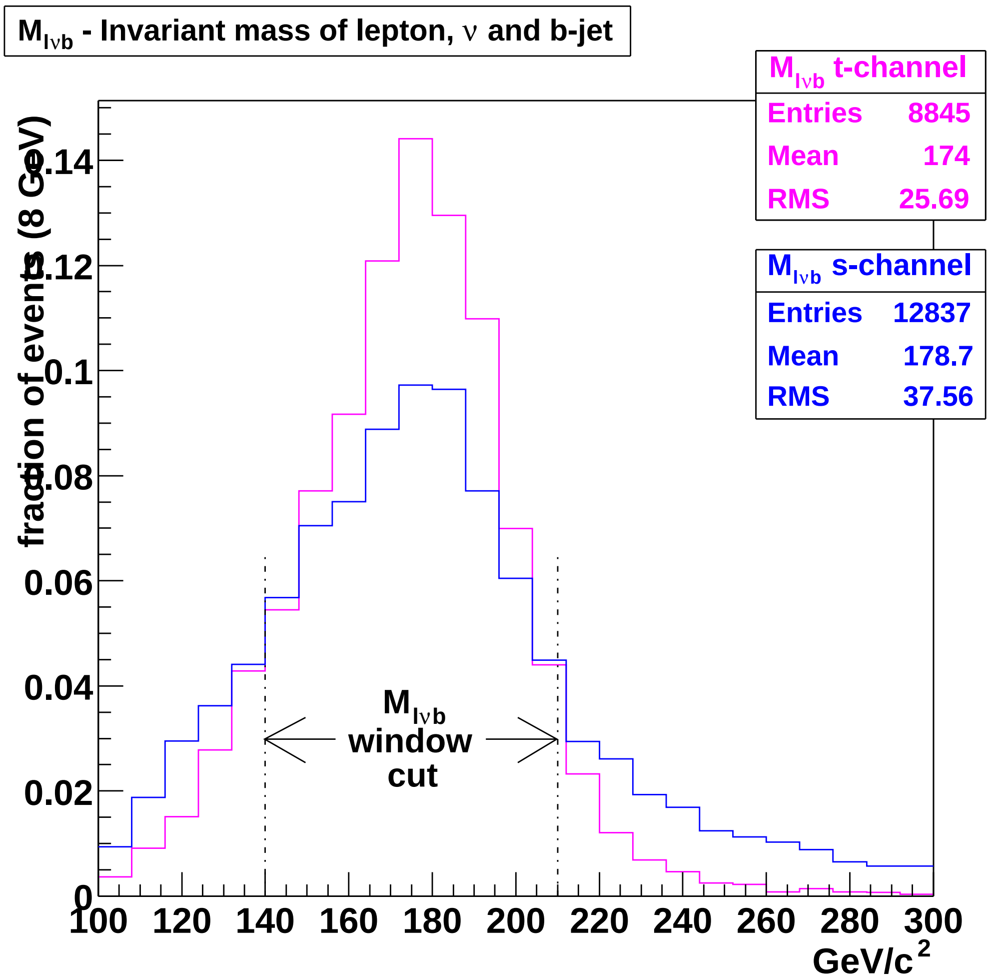
- Z Vertex Efficiency:
  - $\varepsilon_{z0}^{data} = 0.951$
- Trigger Efficiency:
  - $\varepsilon_{trig}^{CEM\ data} = 0.968$
  - $\varepsilon_{trig}^{CMUP\ data} = 0.904$
  - $\varepsilon_{trig}^{CEM\ data} = 0.901$
- Lepton ID and Muon Reconstruction Efficiency:
  - $\varepsilon_{leptonID}^{CEM\ data} / \varepsilon_{leptonID}^{CEM\ MC} = 0.989$
  - $\varepsilon_{leptonID}^{CMUP\ data} / \varepsilon_{leptonID}^{CMUP\ MC} = 0.937 \times 0.962$
  - $\varepsilon_{leptonID}^{CMX\ data} / \varepsilon_{leptonID}^{CMX\ MC} = 1.015 \times 0.978$
- B-tagging Efficiency:
  - $\varepsilon_{tag}^{data} / \varepsilon_{tag}^{MC} = 0.890$

s-channel yield for 157.5 (147.3) pb^{-1}

Bin	1 jet	2 jet	3 jet	4 jet	total
Isolated Lepton					
CEM	1.087	2.748	0.810	0.165	4.914
CMUP	0.546	1.371	0.393	0.087	2.446
CMX	0.291	0.679	0.200	0.038	1.234
$\sum$	1.925	4.797	1.403	0.290	8.595
Isolated Lepton + Met					
CEM	0.976	2.448	0.717	0.144	4.383
CMUP	0.481	1.213	0.343	0.076	2.157
CMX	0.252	0.596	0.172	0.031	1.073
$\sum$	1.710	4.257	1.232	0.251	7.613
Isolated Lepton + Met + b-tag					
CEM	0.250	1.006	0.312	0.061	1.640
CMUP	0.127	0.502	0.141	0.032	0.808
CMX	0.062	0.253	0.074	0.013	0.403
$\sum$	0.438	1.760	0.527	0.106	2.851
... + Vetos (Z, dilepton, conversions)					
CEM	0.248	0.995	0.306	0.059	1.621
CMUP	0.127	0.500	0.141	0.032	0.805
CMX	0.062	0.251	0.073	0.013	0.401
$\sum$	0.436	1.746	0.521	0.104	2.826
...+ mass window cut					
CEM	0.164	0.658	0.186	0.037	1.052
CMUP	0.084	0.321	0.087	0.020	0.516
CMX	0.040	0.171	0.049	0.008	0.270
$\sum$	0.288	1.151	0.322	0.066	1.838

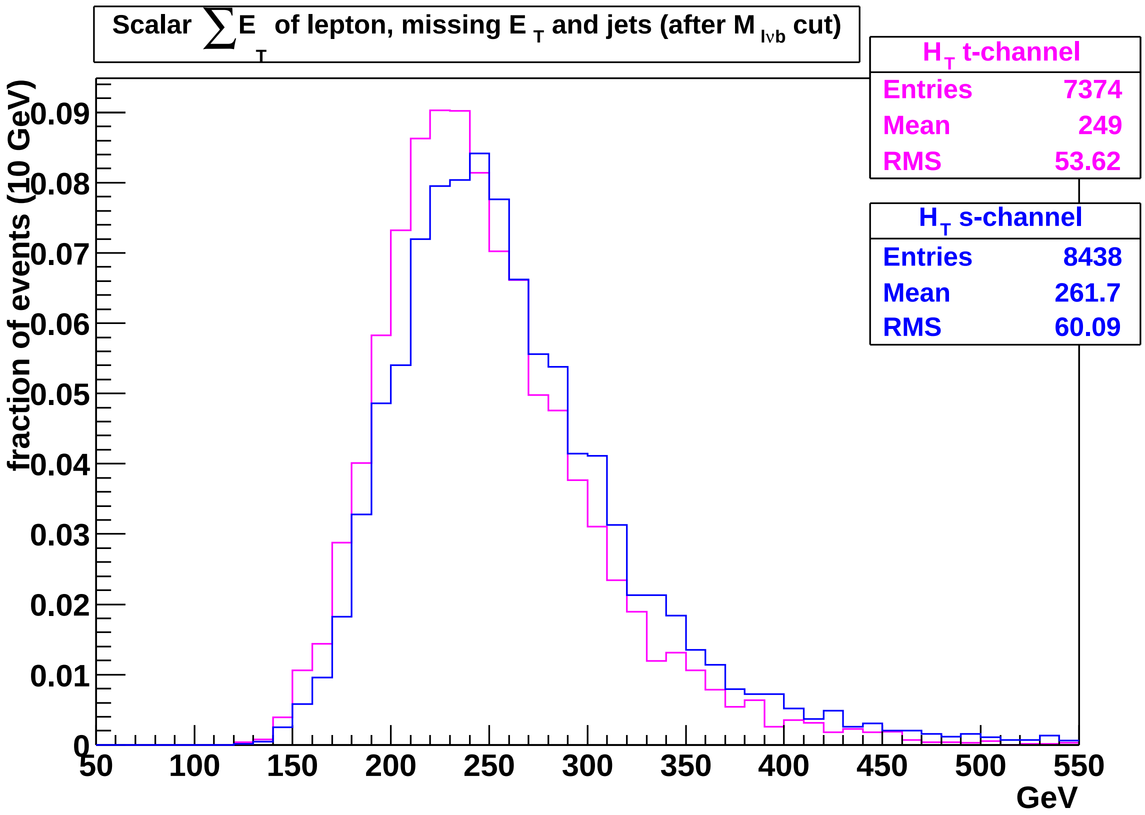
t-channel yield for 157.5 (147.3) pb^{-1}

Bin	1 jet	2 jet	3 jet	4 jet	total
Isolated Lepton					
CEM	3.229	6.893	1.290	0.162	11.849
CMUP	1.614	3.628	0.629	0.092	6.094
CMX	0.789	1.664	0.297	0.032	2.855
$\sum$	5.632	12.185	2.216	0.287	20.797
Isolated Lepton + Met					
CEM	2.871	6.130	1.129	0.145	10.526
CMUP	1.443	3.181	0.558	0.080	5.379
CMX	0.690	1.451	0.265	0.025	2.496
$\sum$	5.003	10.762	1.952	0.250	18.401
Isolated Lepton + Met + b-tag					
CEM	0.563	1.603	0.345	0.045	2.561
CMUP	0.274	0.859	0.161	0.022	1.318
CMX	0.138	0.369	0.074	0.010	0.592
$\sum$	0.975	2.831	0.581	0.076	4.471
... + Vetos (Z, dilepton, conversions)					
CEM	0.558	1.580	0.339	0.044	2.525
CMUP	0.274	0.854	0.159	0.021	1.311
CMX	0.137	0.367	0.074	0.010	0.589
$\sum$	0.969	2.801	0.573	0.075	4.424
...+ mass window cut					
CEM	0.453	1.329	0.247	0.037	2.068
CMUP	0.226	0.702	0.117	0.015	1.061
CMX	0.111	0.313	0.054	0.008	0.488
$\sum$	0.790	2.344	0.418	0.060	3.617



- Constrain $M_{l\nu}$ to $m_W = 80.22$ GeV to get $p_{\nu z}$
- In double tagged sample, we take b-jet with highest $+\eta$ $(-\eta)$ for t $(\bar{t})$-decay
- All generic jet corrections are applied

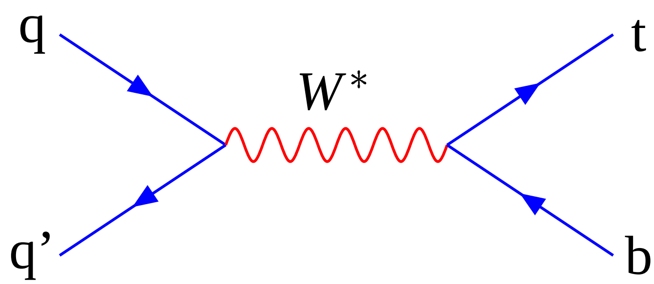
- H_T after all analysis cuts:



- H_T includes all jets with $E_T \geq 8$ GeV and $|\eta| < 2.8$
- Shapes of both signal channels are almost identical
  $\rightarrow$ Motivation for combined search for s and t-channel

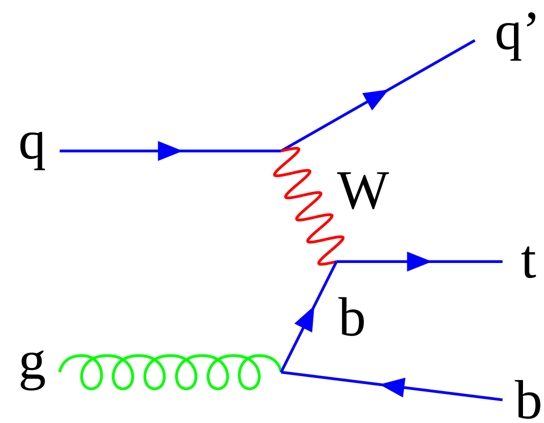
s-channel:

- 512K Pythia MC events
- All W decay channels
- Realistic silicon and beam-offset



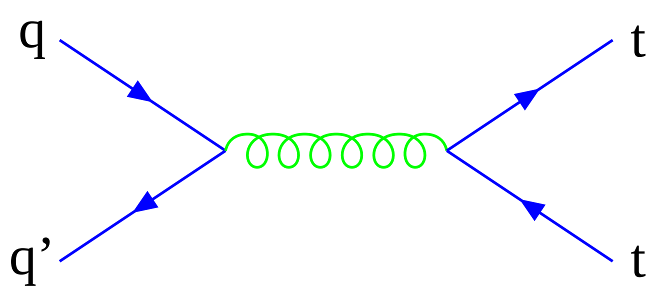
t-channel:

- 512K Pythia MC events
- All W decay channels
- Realistic silicon and beam-offset



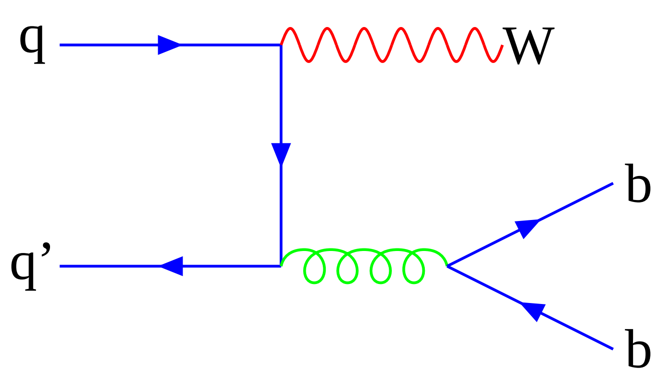
$t\bar{t}$ (top background):

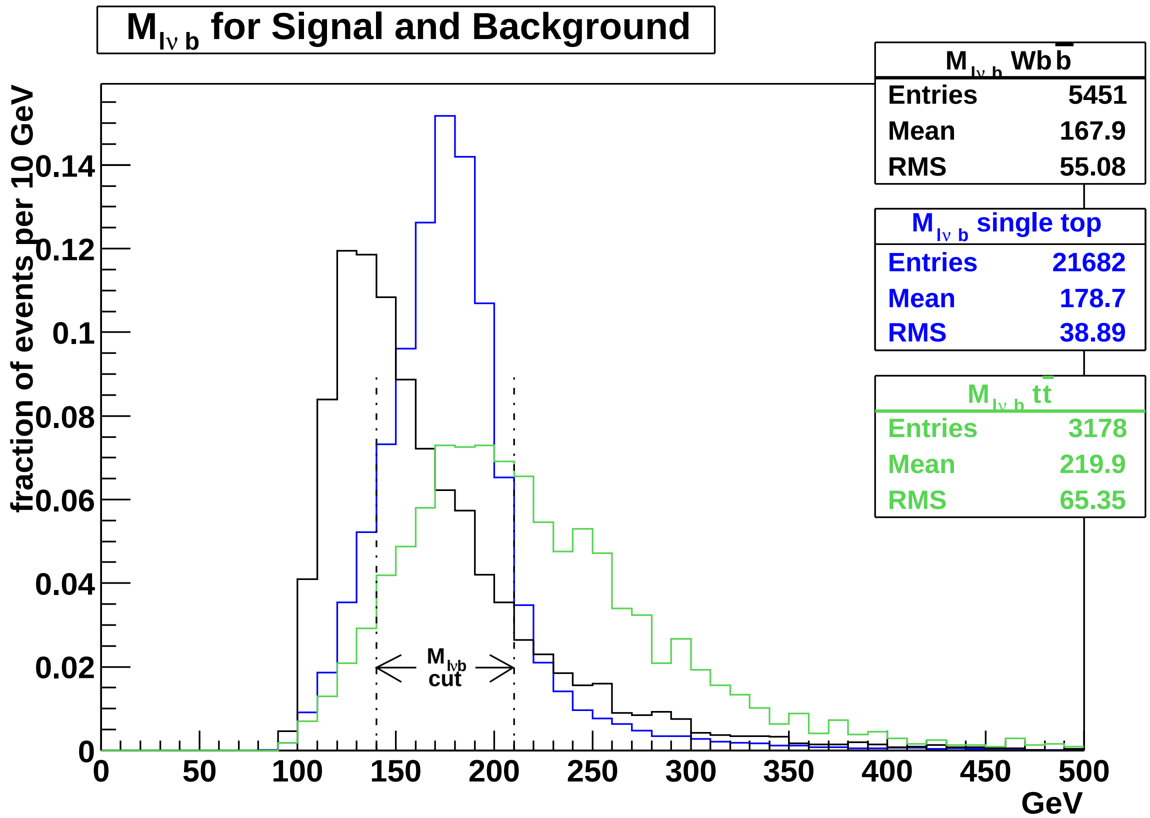
- 240K Herwig MC events
- All W decay channels
- Realistic silicon and beam-offset



$Wb\bar{b}$ (non top background):

- 230K Alpgen/Herwig MC events
- $W \rightarrow e\nu$ decay only
- Realistic silicon and beam-offset

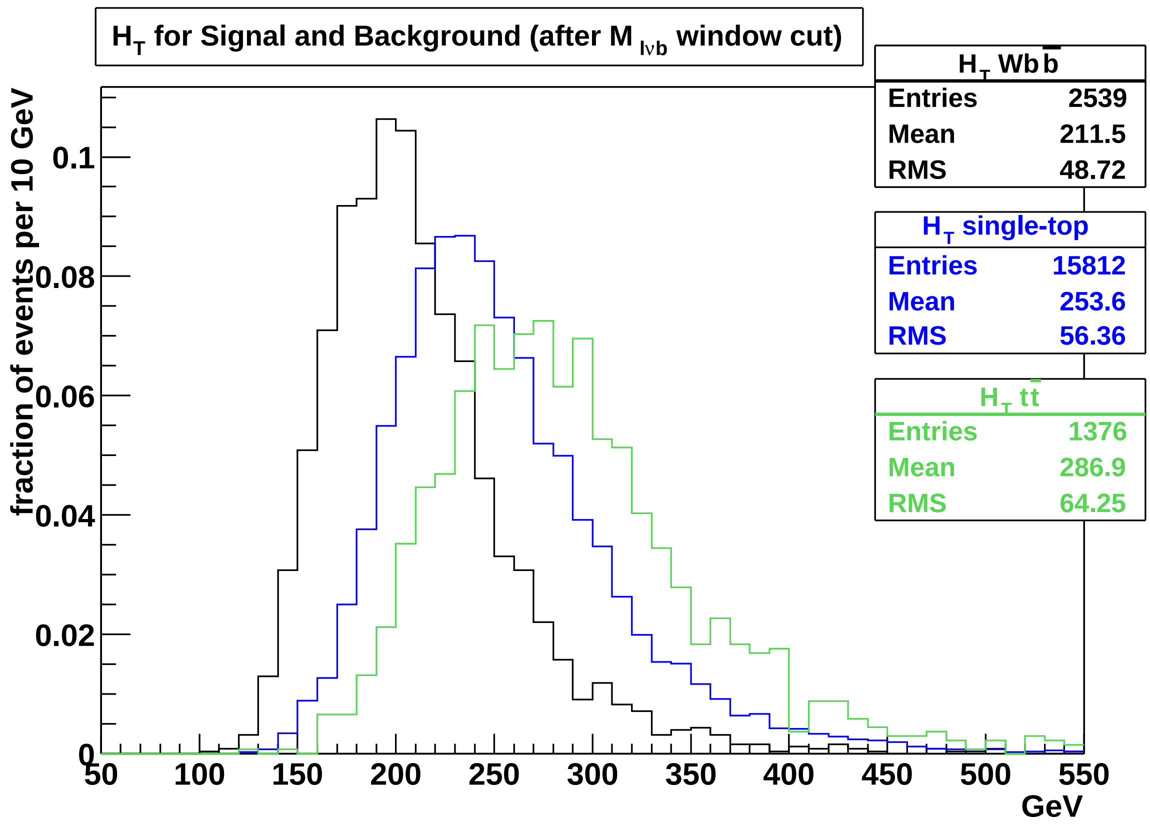




- $M_{l\nu b}$ window cut improves signal strength

Process:	s-channel	t-channel	$t\bar{t}$	$Wb\bar{b}$
Cut efficiency: $\varepsilon_{M_{l\nu b}}$	65.7%	83.6%	44.2%	45.3%

- H_T after all analysis cuts:



- H_T for signal and background is well separated
  $\rightarrow$ Fit for signal and background content to include shape information
- Need to estimate relative contributions to set an a priori limit on cross-section

Single Top Yield in W+2jet bin:

s-channel (σ_s=0.884 pb^{-1})	$\mathcal{A}$	$\mathcal{N}$
Produced	-	138
Lepton	4.05%	4.80
Lepton+$\not{E}_T$	3.59%	4.26
Lepton+$\not{E}_T$+b-tag	1.67%	1.76
...+Vetos (Z, dilepton)	1.66%	1.75
...+ mass window cut	1.09%	**1.15**

t-channel (σ_t=1.980 pb^{-1})	$\mathcal{A}$	$\mathcal{N}$
Produced	-	311
Lepton	4.60%	12.19
Lepton+$\not{E}_T$	4.06%	10.76
Lepton+$\not{E}_T$+b-tag	1.20%	2.83
...+Vetos (Z, dilepton)	1.19%	2.80
...+ mass window cut	0.99%	**2.34**

Top Background Yield in W+2jet bin:

$t\bar{t}$ ($\sigma_{t\bar{t}}$=6.7 pb^{-1})	$\mathcal{A}$	$\mathcal{N}$
Produced	-	1055
Lepton	3.46%	31.03
Lepton+$\not{E}_T$	3.16%	28.30
Lepton+$\not{E}_T$+b-tag	1.43%	11.42
...+Vetos (Z, dilepton)	0.85%	6.75
...+ mass window cut	0.37%	**2.98**

Non-Top Background Yield in W+2jet bin:

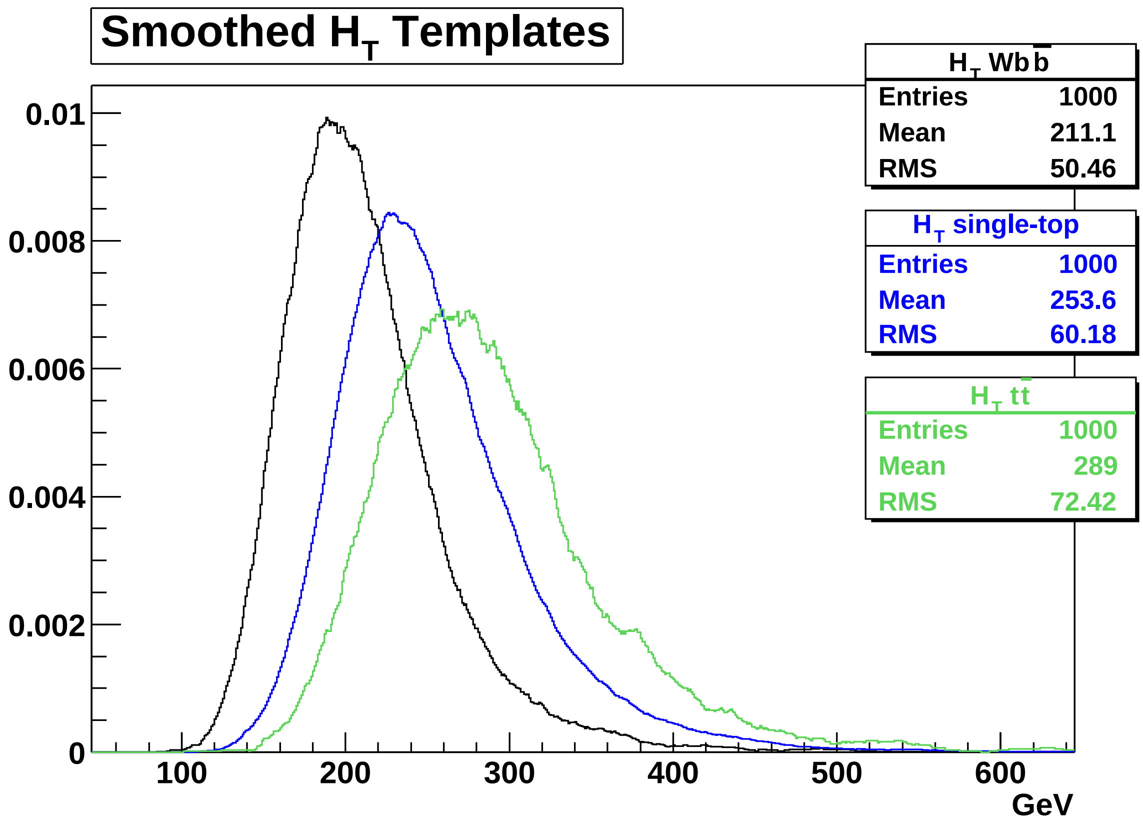
Source	$\mathcal{N}$
Mistags	7.94
$Wb\bar{b}$	11.02
$Wc\bar{c}$	4.24
Wc	11.71
$WW/WZ, Z \to \tau\tau$	2.19
non-W	6.57
extra Z+$b\bar{b}$	0.22
Total tagged events	43.89
After mass window cut ($\epsilon^{Wb\bar{b}}_{M_{l\nu b}}$)	**19.90**

Summary of S/B in W+2jet bin:

s-channel	1.15
t-channel	2.34
$t\bar{t}$	2.98
non-top	19.90
Total	26.37
$S/\sqrt{B}$	0.73

◇ Perform pseudo CDF experiments

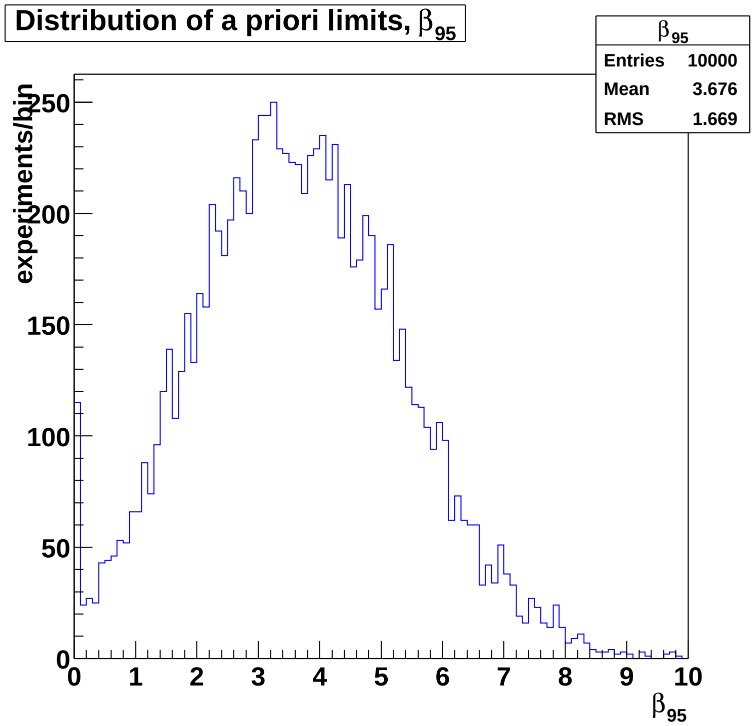
→ Pick random H_T values from smoothed templates



◇ Use Pierre's fitter to fit for relative signal, top and non-top background content

→ Allows to set upper limit on cross-section

- Frequentist upper limit at 95% C.L.
  $\rightarrow$ Need to find a value N_{95} such that repeated pseudo-experiments result in a fitted signal content $N_s' > N_{expected}$ 95% of the time



- Plot shows 10 000 performed pseud-experiments where this condition is met
- Scale is in terms of relative signal content β
- $\beta_{95} \times \sigma_{st} = 3.67 \times \sigma_{st} \approx 10.5$ pb a priori limit at 95% C.L

OUTLOOK:

- Extending jet-eta definition to $|\eta| < 2.8$ looks promising
- Need to perform a Method II background calculation for new selection criteria
- Still room for optimization
- Big improvements also possible in lepton acceptance (CMU muons, Plug electrons)
- Higher b-tagging efficiencies will boost analysis
- An improved cross-section limit compared to Run-I seems feasible by this summer