Search for W' boson in Top quark decay using the DØ experiment

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Outline

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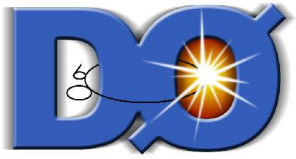
- Results
- Summary



Introduction

W' and Z' bosons typically arise in SM extensions with additional gauge symmetry groups.

Direct search: (typically assume SM strength coupling; suppressed $W' \to WZ$ decays, valid for left and right-handed interactions; assume light/stable right-handed neutrino)

Leptonic decay: $p\bar{p} \to W' \to \ell\nu$ $M_{W'} > 786\,\mathrm{GeV}$ (CDF Run1)

Quark decay: $p\bar{p} \to W' \to qq'$ $M_{W'} < 300\,\mathrm{GeV}$ (CDF Run1)

$M_{W'} > 420\,\mathrm{GeV}$

Quark decay, leptonic decay not allowed:

$p\bar{p} \to W' \to qq'$ $M_{W'} > 800\,\mathrm{GeV}$ (D0 Run1)

$p\bar{p} \to W' \to tq$ $M_{W'} > 566\,\mathrm{GeV}$ (CDF Run1)

(Right-handed interactions only)

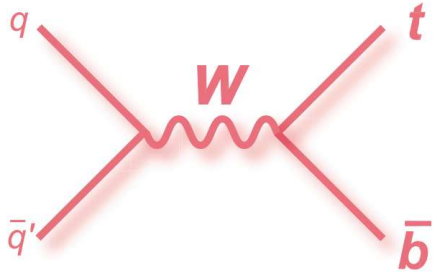
Indirect search: Model dependent limits, depend on interference with SM W boson

W' production and decay

We investigate the following models:

Model 1 (W'_L): SM-like left-handed coupling

Interference with SM process:



$$\sigma_{SM} = 0.88\,\text{pb}$$

$$\sigma_{t\bar{b}} < 6.4\,\text{pb} \quad \text{(DØ)}$$

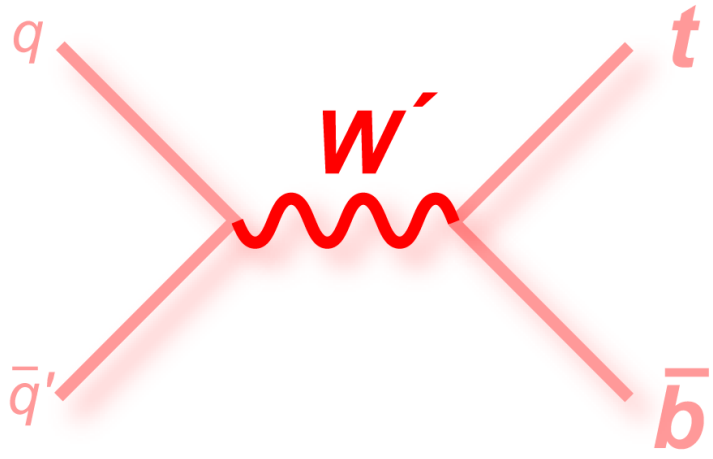
$$\sigma_{t\bar{b}} < 13.6\,\text{pb} \quad \text{(CDF)}$$

Model 2 (W'_R): Right-handed coupling

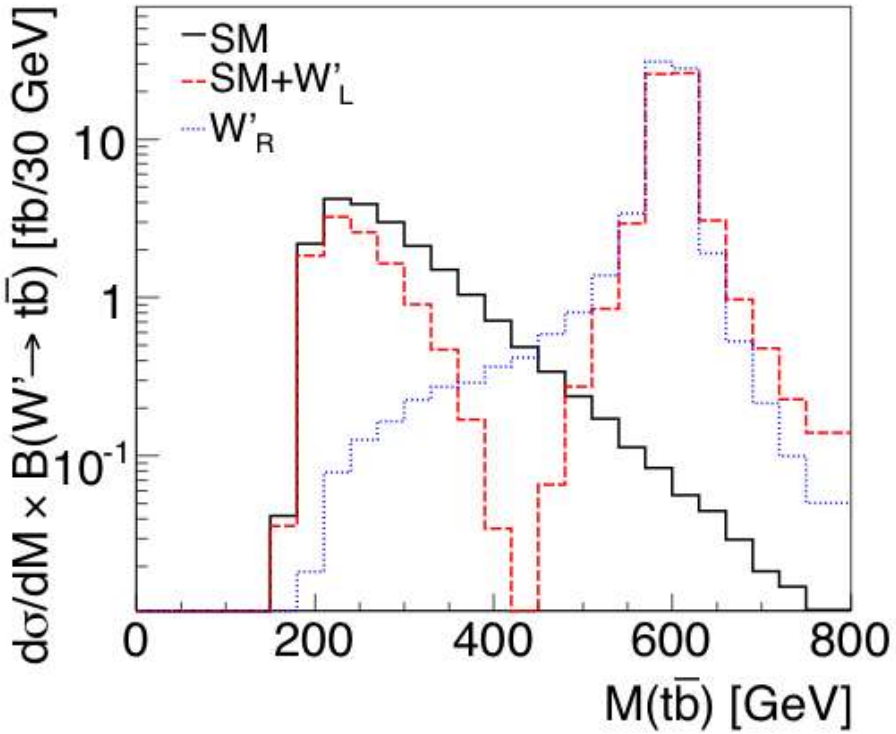
Lepton and quark decays allowed

Model 3 (W'_R): Right-handed coupling

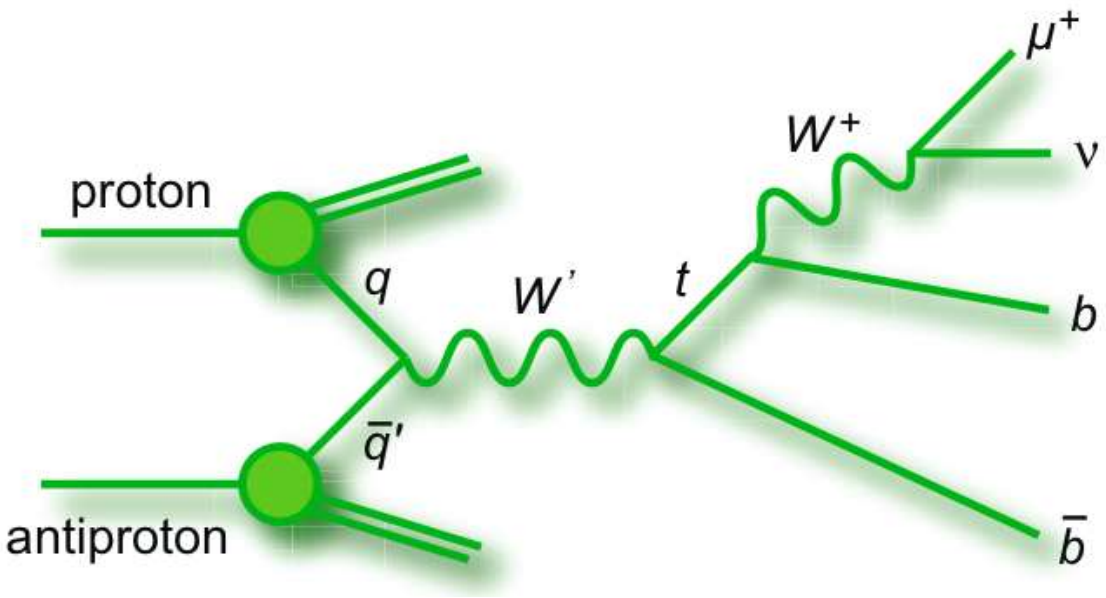
Only quark decays allowed



(E. Boos *et al.*, hep-ph/0610080)



Event signatures



High p_t lepton	$p_T > 15$ GeV
Missing E_t	$E_T > 15$ GeV
High p_t b-jet	$p_T > 15$ GeV
b-jet	$p_T > 15$ GeV

$2 \leq N_{jets} \leq 3$

Backgrounds:

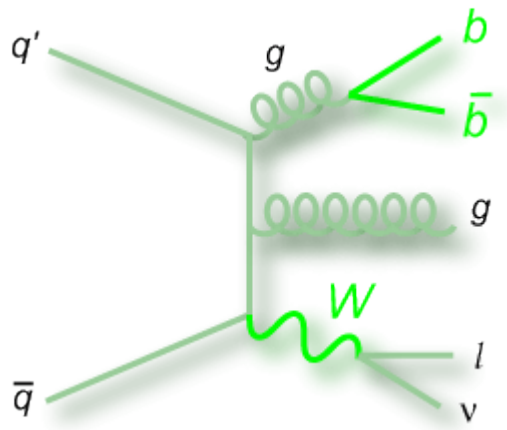
- W/Z + jets production
- multi-jet events (mis-reconstructed lepton)
- top pair production
- WW, WZ
- SM t-channel single top production

Data Analysis Strategy

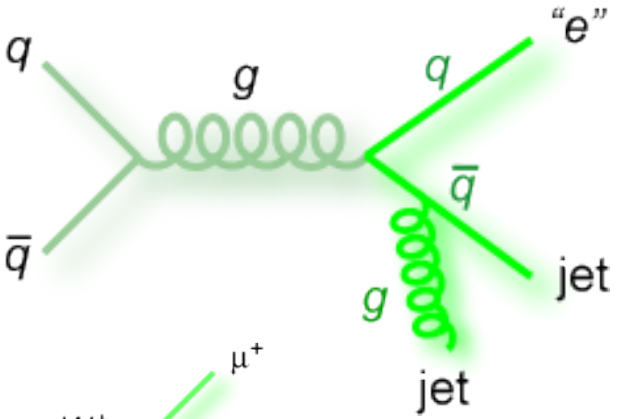
- Use 230 pb^{-1} of DØ Run II data (August 2002-March 2004)
- Use same selection as DØ search for single top quark
  (Phys. Lett. B {622}, 265, 2005)
  - Separate data into independent sets based on
    - lepton flavour (electron,muon)
    - b-tag multiplicity (single tagged, double tagged)
      - look for displaced vertex to identify b-jets (SVT)
- Study invariant mass of all reconstructed final state objects
- Perform binned likelihood analysis of the invariant mass distribution
- Derive W' boson mass constraints for different models

Background estimate

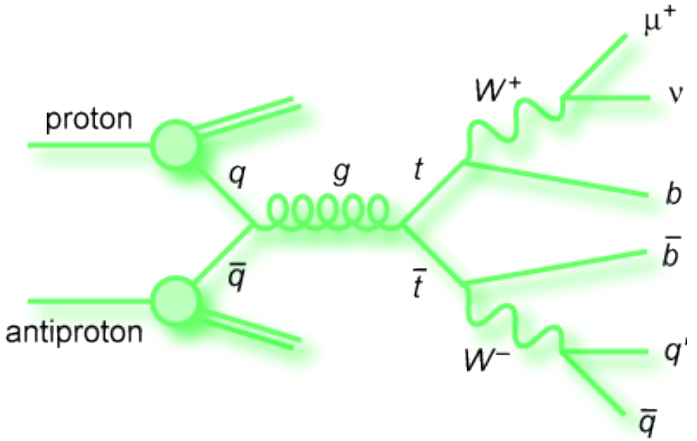
- W/Z+jets production (real-lepton)
  - Wjj, Wbb, Zjj, Zbb
  - Estimated from data and MC
    - Shape and Heavy Flavor fraction from MC
    - Normalization: pre-tagged sample
  - ~ 45-70%



- Mis-reconstructed multi-jet events (fake-lepton)
  - Jet mis-identified as lepton
  - Semi-leptonic decay of HF jets (bb)
  - Estimated from data
  - ~ 2-15%



- Top pair production
  - Contributions from the l+jets channel
  - Estimated from MC (ALPGEN)
  - ~ 15-50%



W' boson simulation

- CompHEP 4.4.3 matrix element generator
- Interference between SM single top and W'_L boson is taken into account in CompHEP
- W' boson signal normalized to the NLO cross-section
  (Z. Sullivan, Phys. Rev. D66 (2002) 075011)

W' mass	Cross section $\times B(W' \to t\bar{b})$ [pb]		
[GeV]	SM+W'_L	W'_R ($\to l$ or q)	W'_R ($\to q$ only)
600	2.17	2.10	2.79
650	1.43	1.25	1.65
700	1.03	0.74	0.97
750	0.76	0.44	0.57
800	0.65	0.26	0.34

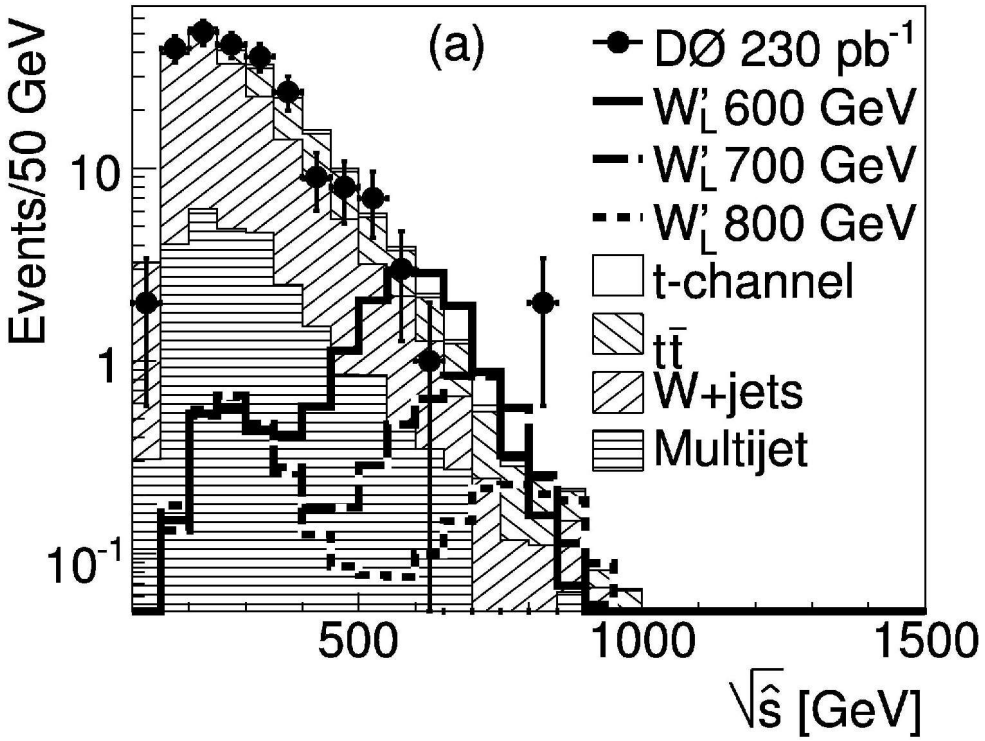
$$B(W' \to t\bar{b}) \sim 3/12 \quad \text{(lepton+quark decays allowed)}$$
$$\sim 3/9 \quad \text{(quark decays allowed)}$$

Event Yields

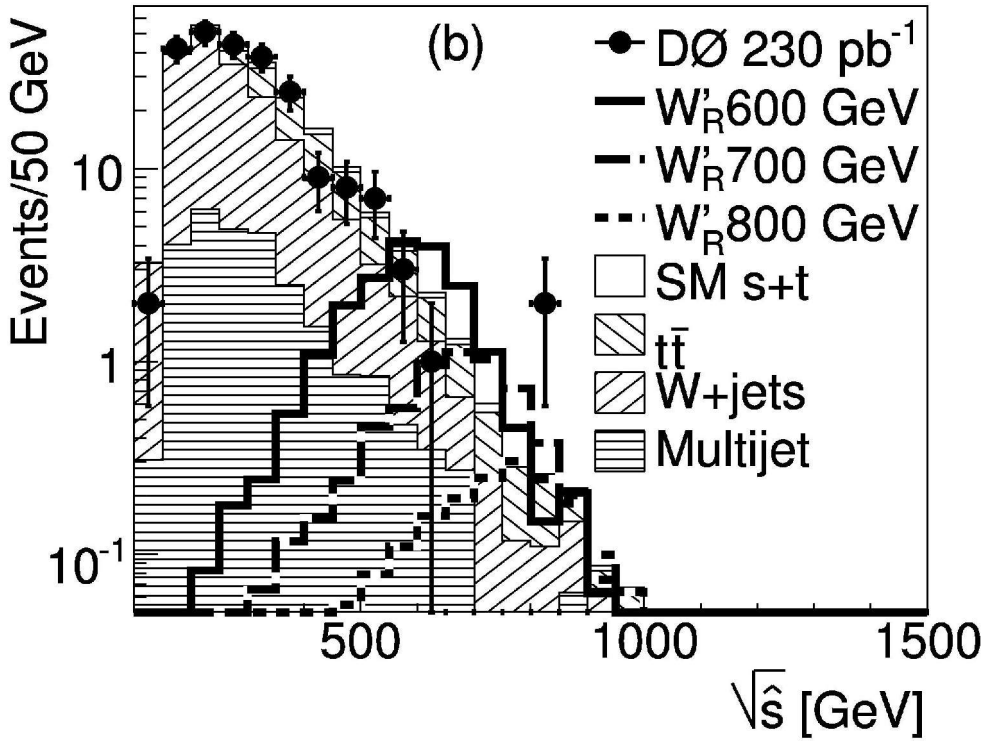
	Event Yields for $\sqrt{\hat{s}} > 400$ GeV		
	SM+W'_L	W'_R ($\rightarrow l$ or q)	W'_R ($\rightarrow q$ only)
Signals			
W' (600 GeV)	13.0 $\pm$2.3	13.8 $\pm$2.4	18.4 $\pm$3.2
W' (650 GeV)	7.1 $\pm$1.3	7.9 $\pm$1.1	10.4 $\pm$1.5
W' (700 GeV)	4.4 $\pm$0.8	4.6 $\pm$0.8	6.0 $\pm$1.1
W' (750 GeV)	2.4 $\pm$0.4	2.6 $\pm$0.5	3.4 $\pm$0.6
W' (800 GeV)	1.6 $\pm$0.3	1.5 $\pm$0.3	1.9 $\pm$0.4
Backgrounds			
SM t-channel		1.9 $\pm$0.8	
$t\bar{t}$		16.9 $\pm$5.6	
W+jets		17.8 $\pm$4.5	
Multijet		4.4 $\pm$1.5	
Background sum		41.0 $\pm$10.2	(stat+syst)
Data		30	

Reconstructed invariant mass

Model 1: W'_L



Model 2 and 3: W'_R



Data consistent with background estimate within uncertainties.

Limit setting procedure

- Use reconstructed invariant mass in region
  400 GeV ≤ $\sqrt{\hat{s}}$ ≤ 1000 GeV
- Use Bayesian approach with flat prior for signal cross-section.
- Derive limits from likelihood function.
- Combined electron, muon and single-tagged, double-tagged analysis channels
- Include all systematic uncertainties taking into account correlations between different sources and histogram bins.

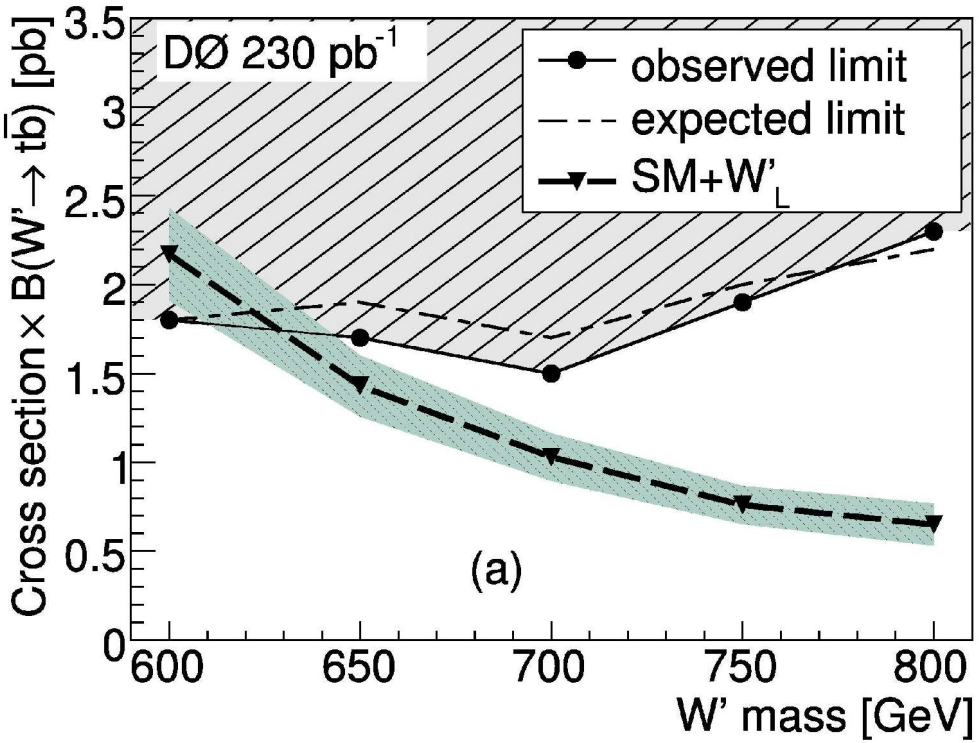
	Signal	Backgrounds
b-tag modeling in MC	4-16%	10-30%
Jet energy calibration	1-2 %	15-30%
Others (trigger, ID,..)	1-5 %	1-5%

- Set upper limits on cross-section x BR as function of W' mass

W' boson mass constraints

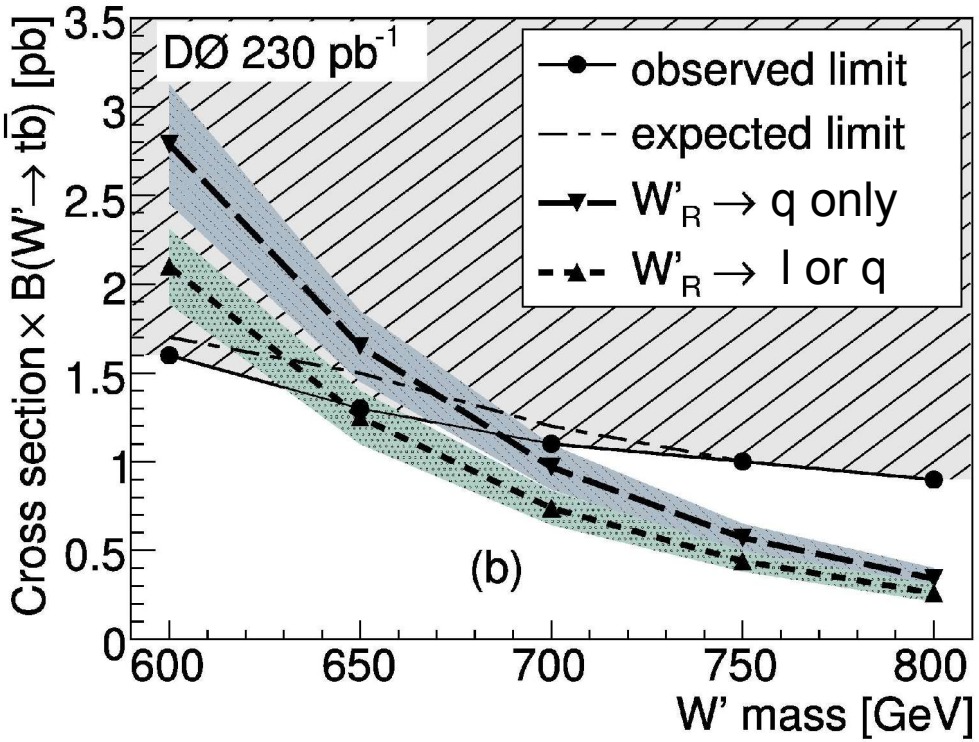
95% CL constraints

Model 1: W'$_L$



$M_{W'} > 610\,\mathrm{GeV}$

Model 2 and 3: W'$_R$



$M_{W'} > 630\,\mathrm{GeV}$ (quark or lepton)

$M_{W'} > 670\,\mathrm{GeV}$ (quark only decay)

Summary

- Search for the production of W' boson in top quark decay channel
- No evidence for W' is found, data is compatible with background estimate
- Calculate constraints on W' boson mass for three different models
  - W'_L: SM-like left-handed coupling
  - W'_R: Right-handed coupling (lepton and quark decay)
  - W'_R: Right-handed coupling (quark decay only)
- First direct search to take into account interference between W' and SM production
- Results published: *Phys. Lett. B 641 (2006) 423*

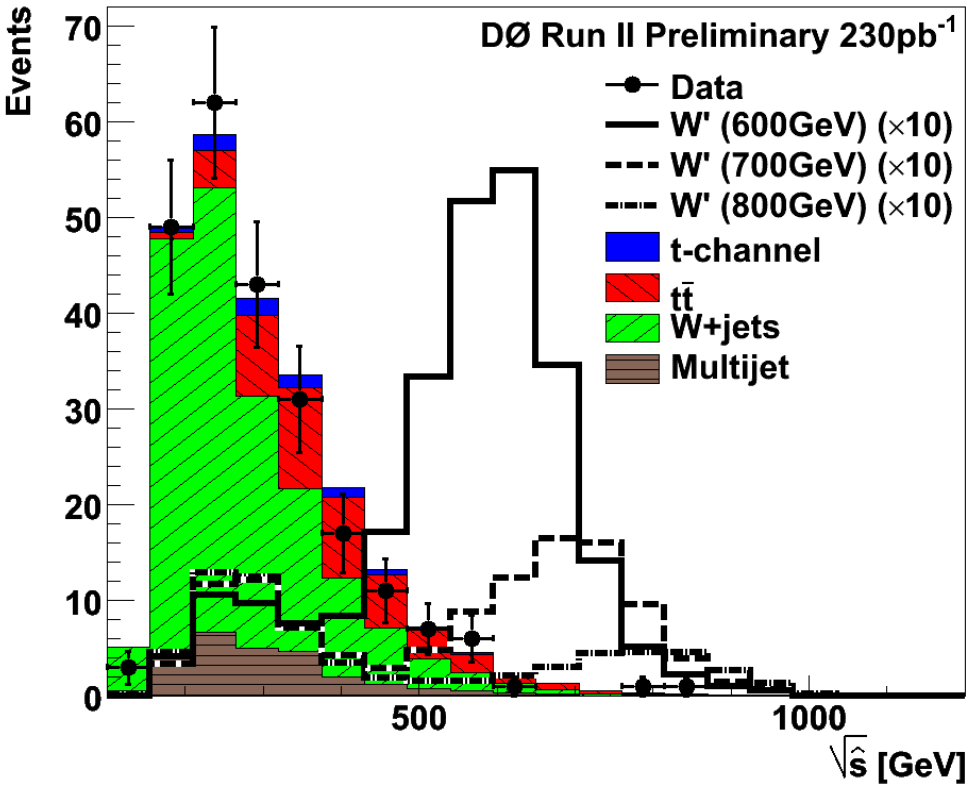
95% CL lower mass limits

W'_L:	$M_{W'} > 610\,\mathrm{GeV}$
W'_R (lepton and quark decay):	$M_{W'} > 630\,\mathrm{GeV}$
W'_R (quark only decay):	$M_{W'} > 670\,\mathrm{GeV}$

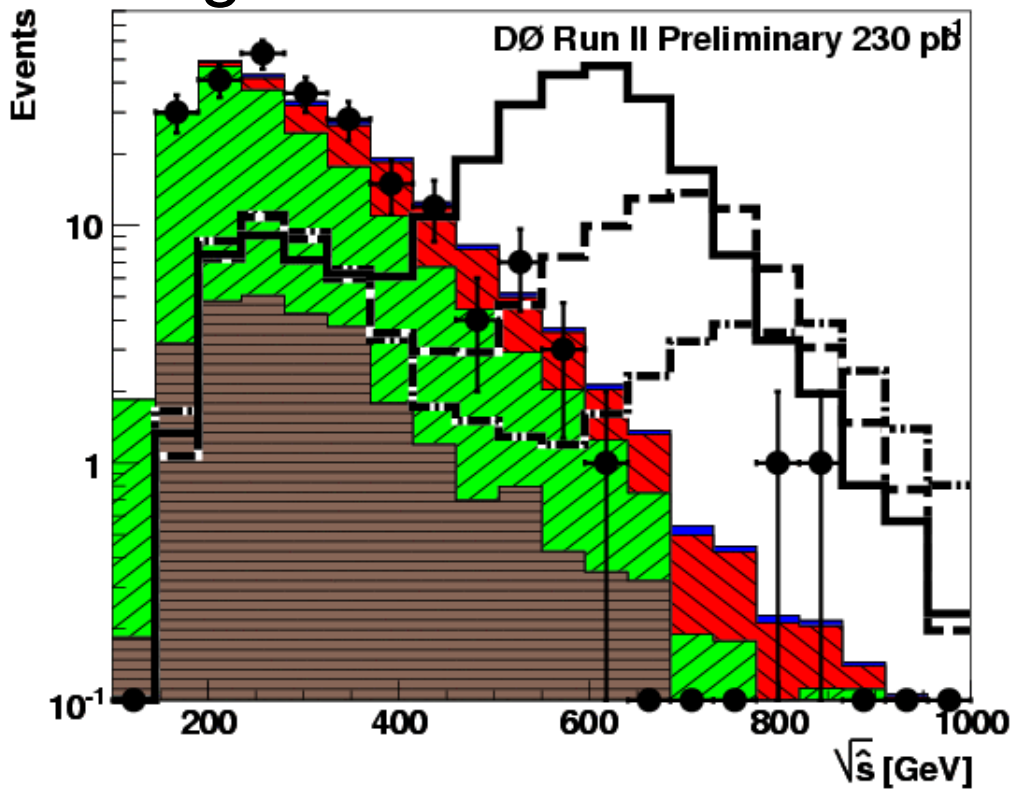
Data/Background comparison

Model 1: W'_L

Linear scale



Log scale



Data consistent with background estimation within uncertainties.