Search for W′ boson resonances decaying to a top quark and a bottom quark

Tulika Bose
Brown University
(for the DØ Collaboration)

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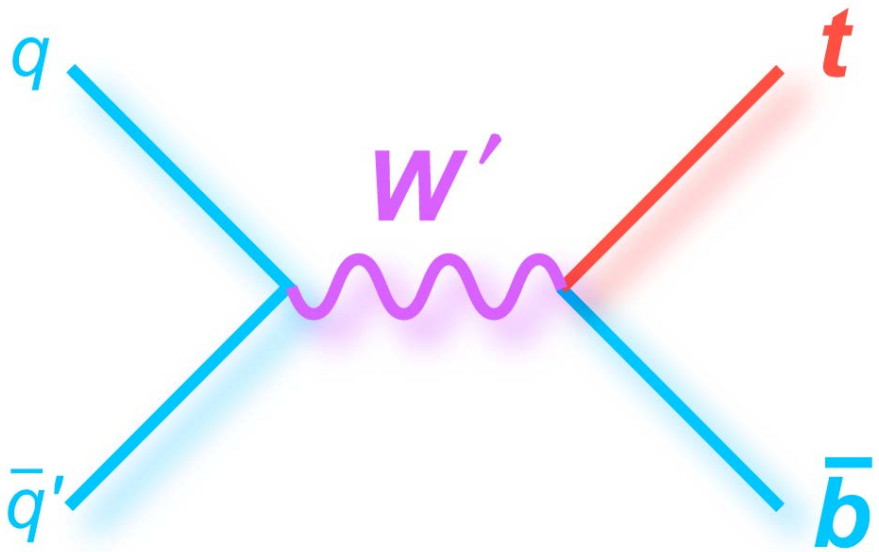
Motivation

- Heavy gauge bosons (W', Z') are predicted by many extensions to the SM
  - Composite and Little Higgs models, Left-right symmetric models, GUTs, UED, Technicolor…
- The single top quark decay channel is a promising searching ground for a W' that interacts hadronically
  - Relatively small multijet background in comparison to light jet channels



Looking for

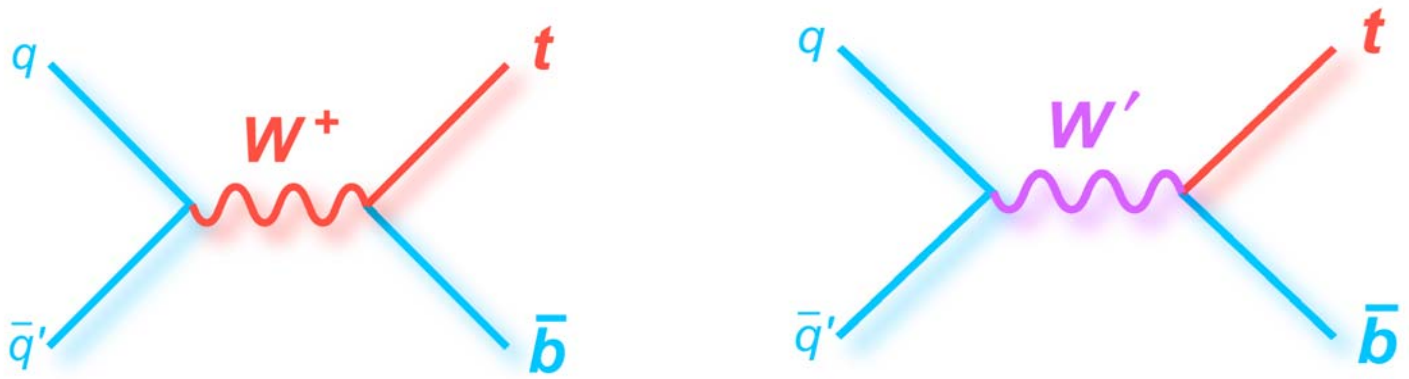
$$W' \rightarrow t\bar{b}$$

or

$$W' \rightarrow \bar{t}b$$

Production Mechanism

- Three different channels possible:
  - s-channel, t-channel, associated tW channel
  - Only s-channel is interesting (resonance)



- The effective Lagrangian for W′ interactions with SM fermions f (generation indices i,j) can be written in a model independent form:

$$L = \frac{V_{ij}}{2\sqrt{2}} g_W \overline{f}_i \gamma^\mu \left[a_{ij}^R (1+\gamma^5) + a_{ij}^L (1-\gamma^5) \right] W' f_j + h.c.$$

Right and left couplings of W′ to quarks

Three of a kind

$$|M|^2 = SM + 2 \cdot a_{ud}^L \cdot a_{tb}^L \cdot (W - W' \ Interference) +$$
$$\left[(a_{ud}^L)^2 (a_{tb}^L)^2 + (a_{ud}^R)^2 (a_{td}^R)^2\right](W') + \left[(a_{ud}^L)^2 (a_{tb}^R)^2 + (a_{ud}^R)^2 (a_{td}^L)^2\right](W')$$

- Three different cases arise:
  - Purely left handed W' $\quad a_{ud}^L = a_{tb}^L = 1,\ a_{ud}^R = a_{tb}^R = 0$
  - Purely right handed W' $\quad a_{ud}^R = a_{tb}^R = 1,\ a_{ud}^L = a_{tb}^L = 0$
  - Left-Right mixed $\quad a_{ud}^L = a_{tb}^R = a_{tb}^L = a_{ud}^R = 1$

- W-W' interference term is proportional to the left couplings only

Analysis Strategy

Look at purely left-handed and right-handed W'

- L-handed W' bosons that interfere with the SM W->tb process
- R-handed W' bosons that do not have the SM interference

  Case a) $M_{\nu R} < M\_W'$

  - Leptonic decay channels are open (l,q)
  - Same cross-section as W'_L with no interference

  Case b) $M_{\nu R} > M\_W'$

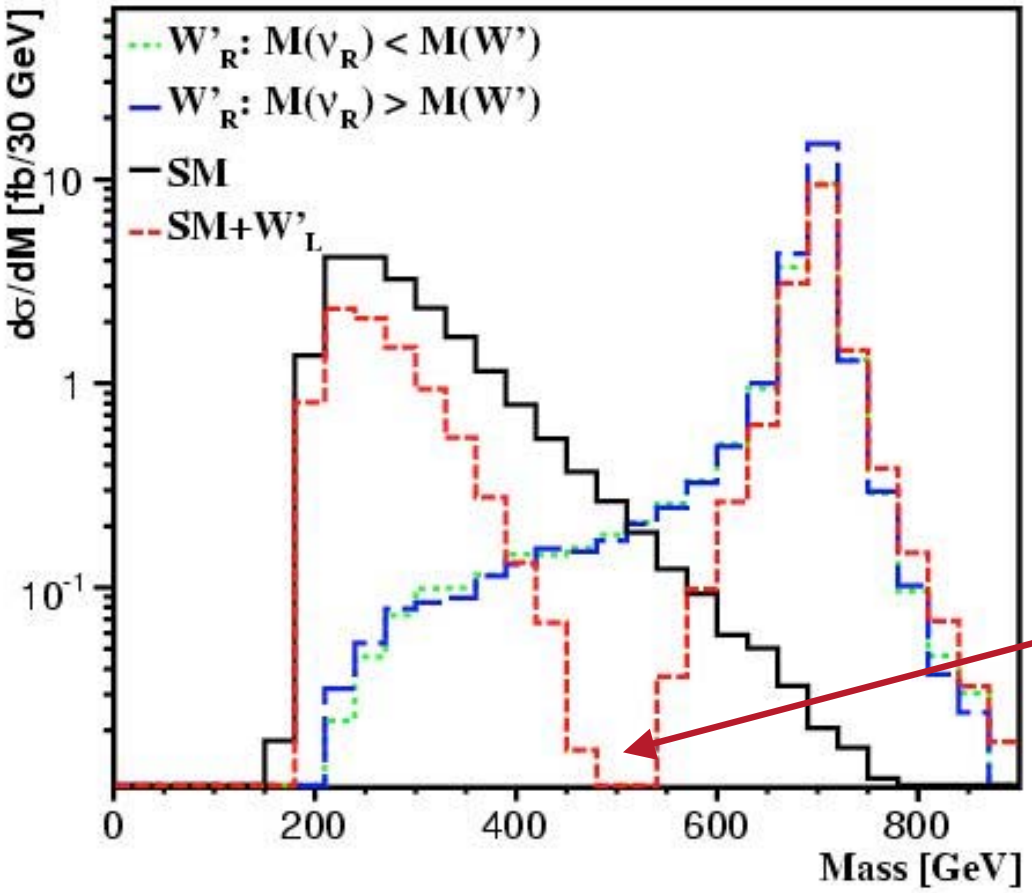
  - Only decays to quarks are allowed (qq)
  - W'_R cross section x B(W'->tb) larger than that of Case (a)

Interference contribution is important and should be taken into account in simulation (Phys. Lett. B 655, 245, 2007)

May reduce the total rate by as much as (16-33)%
(depends on W' mass and its couplings)

W'

Parton level plots

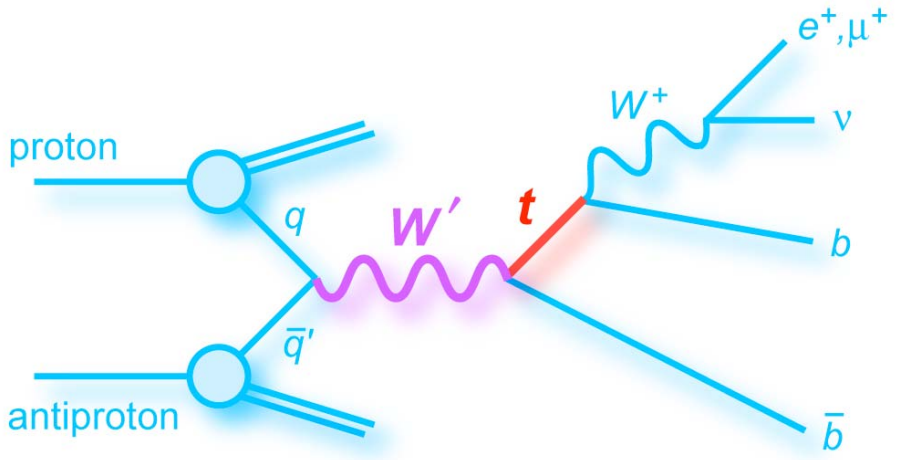


The right-handed l,q and qq sampes have similar shape

Destructive interference

Event Selection

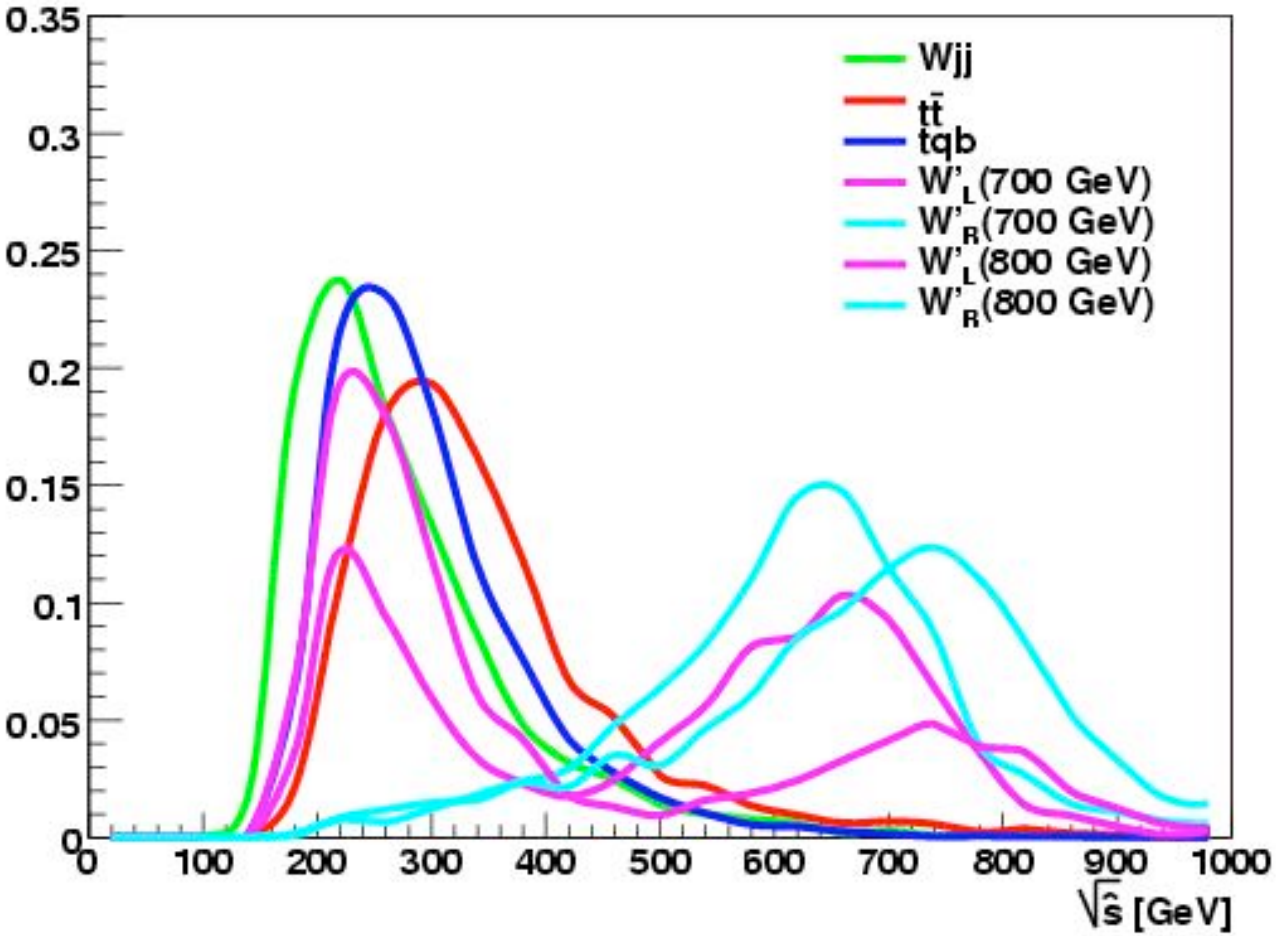
- 1 isolated lepton
  - Electron: $p_T > 15$ GeV, $|\eta| < 1.1$
  - Muon: $p_T > 18$ GeV, $|\eta| < 2.0$
- Missing transverse energy > 15 GeV
- At least one b-tagged jet and at least one more jet
  - 2-3 jets with $p_T > 15$ GeV, $|\eta| < 3.4$
  - Leading jet $p_T > 25$ GeV, $|\eta| < 2.5$
  - Second leading jet $p_T > 20$ GeV
- High efficiency of b-tagging using a neural net tagger



Analysis Method

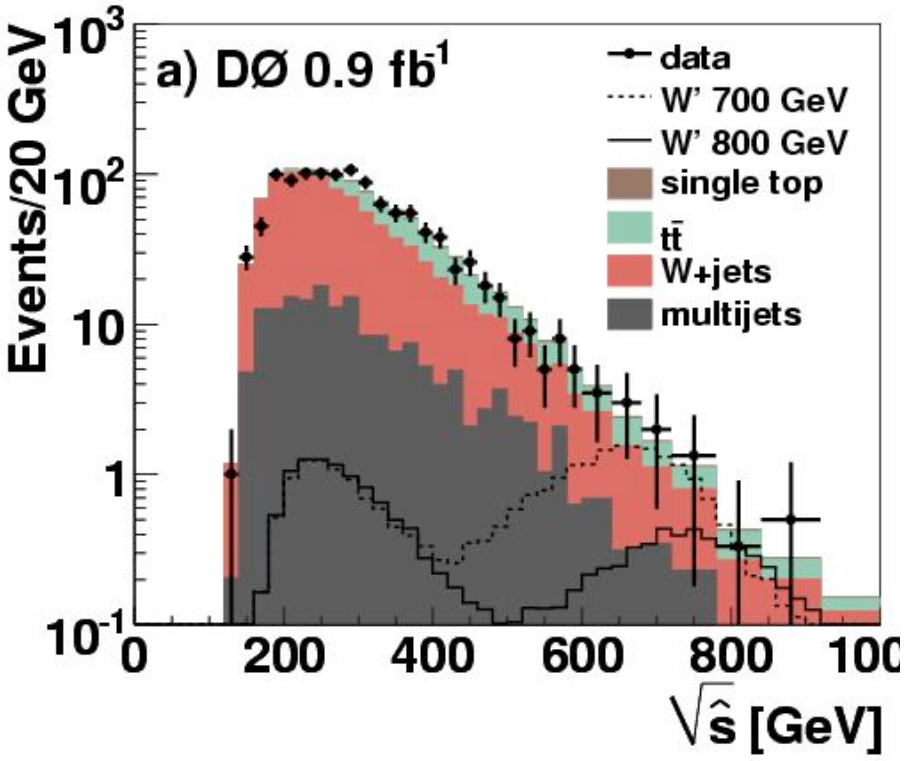
Four-vectors of all final state objects are added to obtain the invariant mass of the W′ boson ("s-hat" or $\sqrt{s}$) :

"s-hat" is used to separate W′ from background

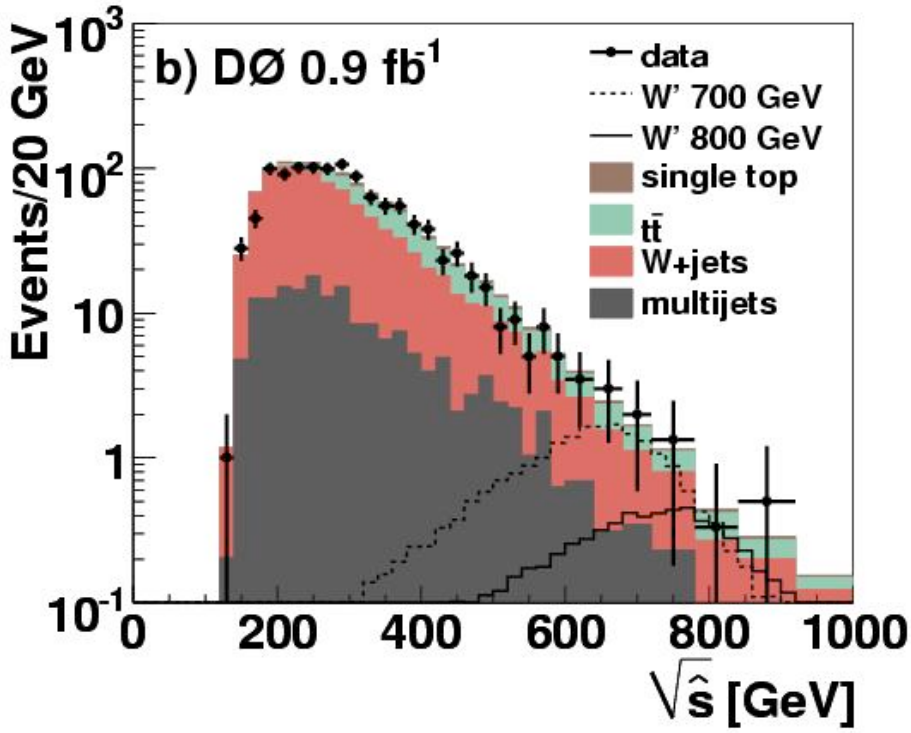


Background Modeling

W'_L



W'_R



Event Yields

Observe no significant excess of events in the final-state invariant mass distribution

TABLE I: Data and SM background event yields.

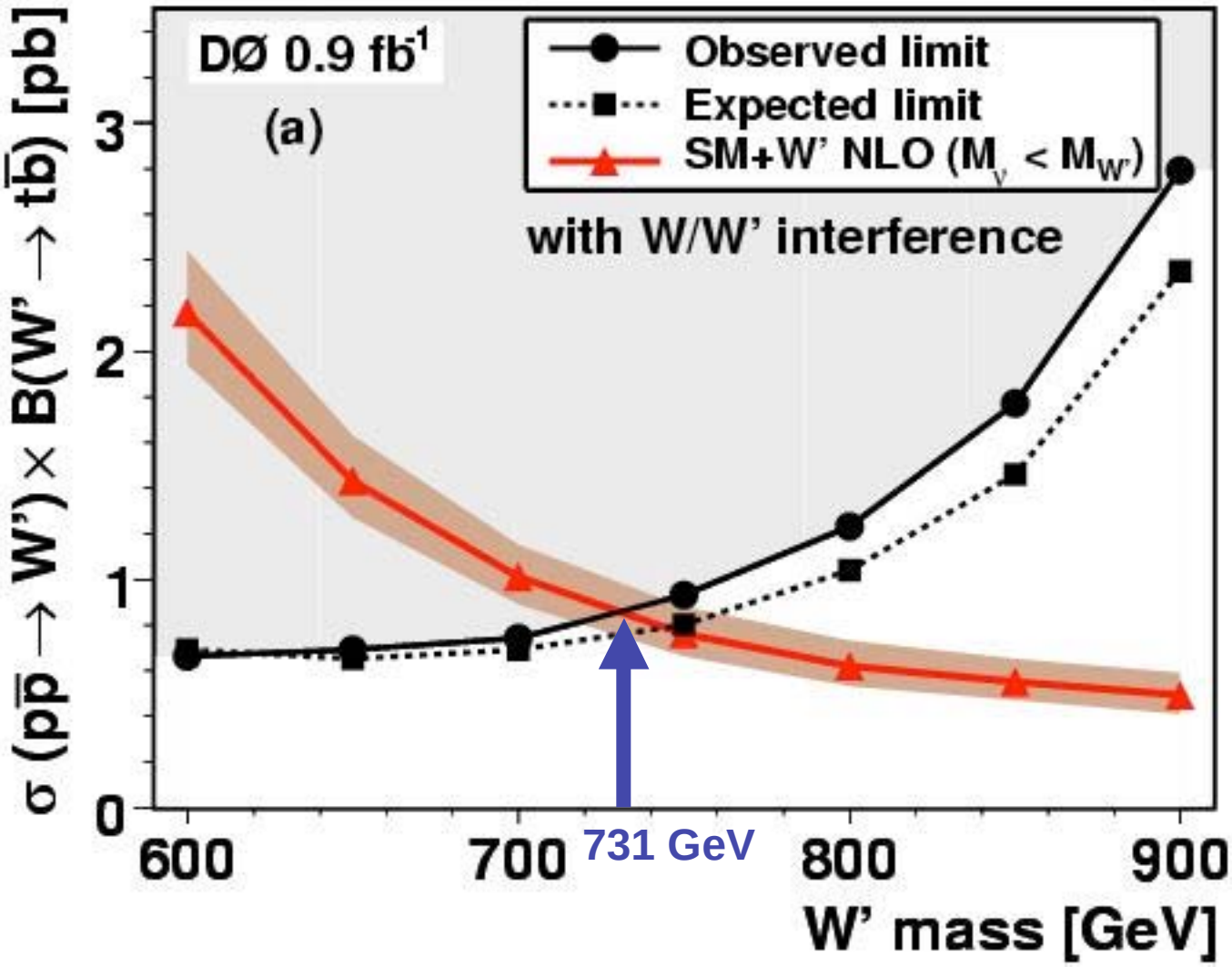
Process	Events	
	SM+W'_L search	W'_R search
Single top	6.4 ± 1.4	10.2 ± 2.2
$t\bar{t}$ production	59.1 ± 14.4	
W+jets	91.0 ± 18.8	
Multijets	29.7 ± 5.9	
Total background	186.1 ± 40.4	190.0 ± 41.2
Data	182	

Use the $\sqrt{\hat{s}}$ distribution to set limits…

Results: W'_L

Using the nominal (nominal - 1σ) NLO x-section

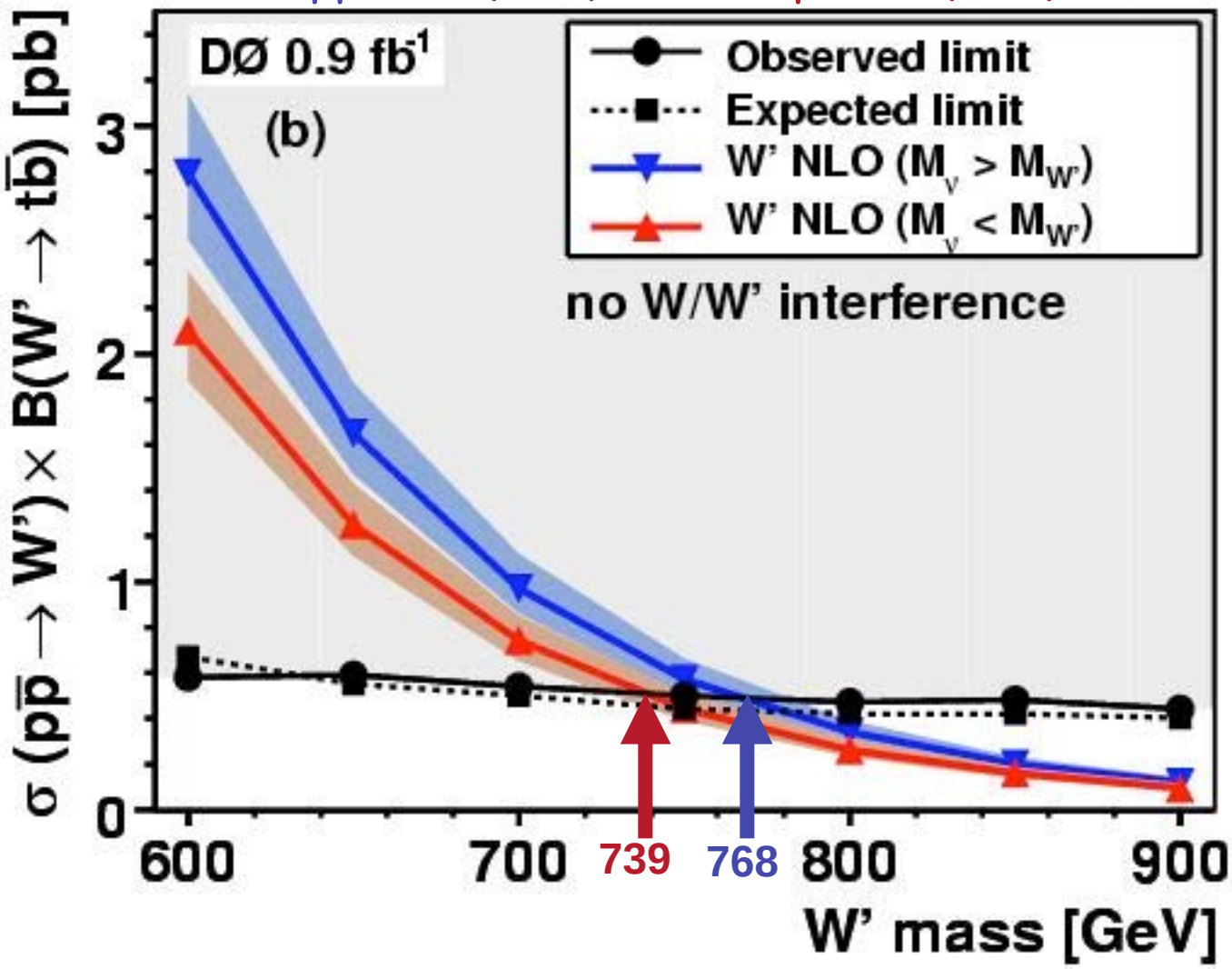
Limit: 731 (718) GeV



Results: W'_R

Using the nominal (nominal - 1σ) NLO x-section

Limit: qq: 768 (750) GeV ; l,q: 739 (725) GeV

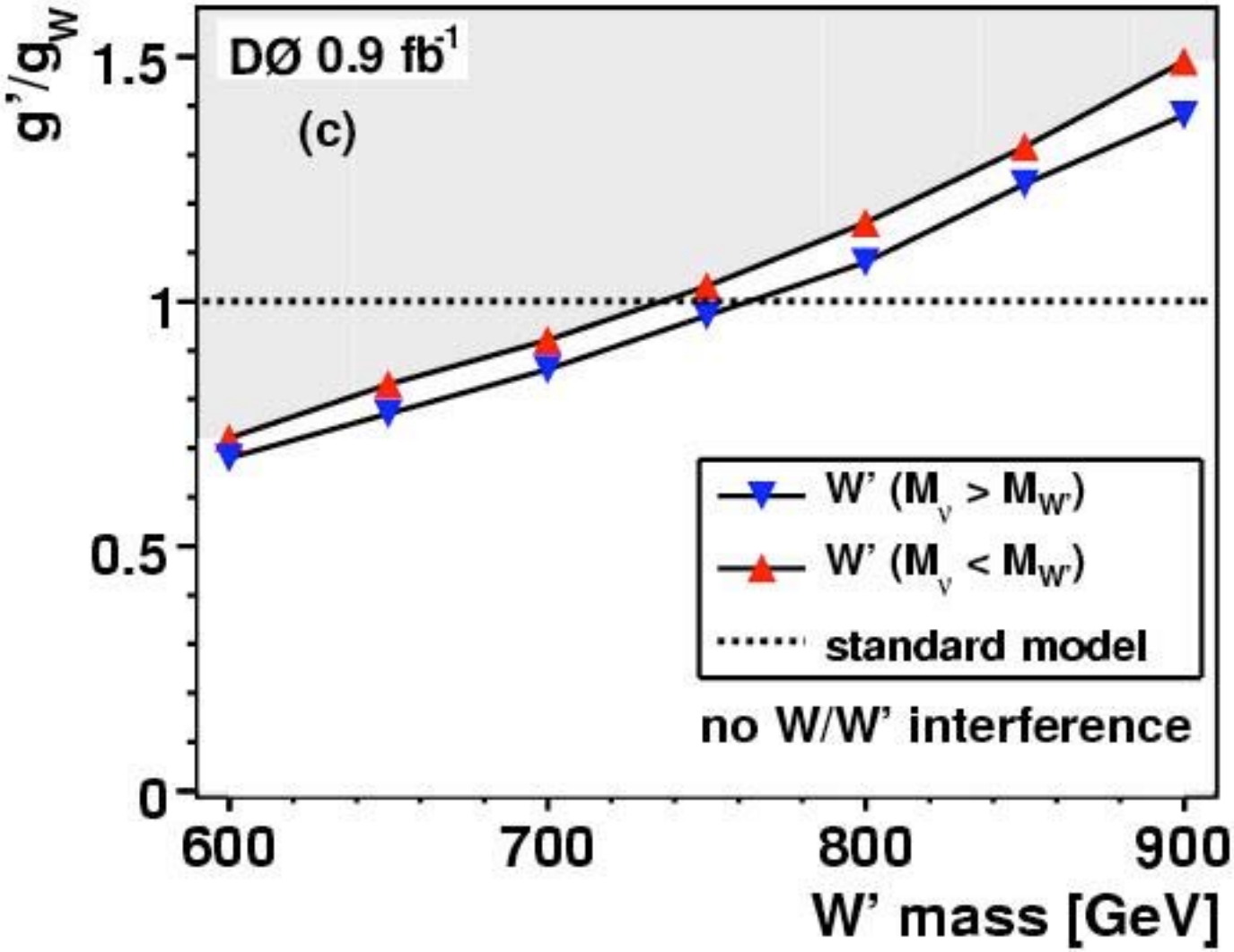


Coupling Strength

- Can convert the measured limits to limits on the coupling strength:
- The leading order s-channel production process has two W′qq′ vertices
  - Thus $\sigma(p\bar{p} \rightarrow W') \times B(W' \rightarrow t\bar{b})$ is proportional to g'^4
    - g' depends on the model being used and is either g_R or g_L.
  - In models with non-SM couplings ($g' \neq g_W$) the reconstructed W invariant mass distribution could be identical to the $g' = g_W$ case but with a normalization that would differ by a factor of g'^4/g^4_W.
- W′ coupling strength limit is calculated from the fourth root of the ratio of the experimentally excluded W′ cross-section and the cross-section with SM couplings.

Coupling Strength

Exclude gauge couplings above 0.68 (0.72) g_W @ $M_{W'}$ = 600 GeV



Conclusions & Outlook

- We have performed a search for W′ bosons in the single top decay channel
- We have no evidence for a W′ boson
- 95% C.L. confidence limits have been set
  - Both masses and couplings
- DØ (0.9 fb^{-1}):
  - W′ mass > 731 GeV [Left-handed; with interference]
  - W′ mass > 739 GeV [Right handed; $W' \rightarrow l\nu$ and $W' \rightarrow qq'$]
  - W′ mass > 768 GeV [Right handed; $W' \rightarrow qq'$ only]
  - Also set limits on the coupling of W′ to fermions as a function of W′ mass
- For more information: arXiv.org:0803.3256, submitted to PRL
- Looking forward to adding more data…