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Reach for W' Production through Single Top Decay at LHC

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What is a W'?

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- A W' results from many theories attempting to tie in $SU(2)_L$
- If a theory uses $SU(2)_L$ X $SU(2)_R$, a W' will be the $SU(2)_R$ analog to the W in the $SU(2)_L$ space. This would have the same general properties as a W boson (charged axial-vector boson with charge coupling up-type quarks to down-type)
- Many higher dimensional theories will cause a higher mass resonance of the W boson, which would have the same properties in all ways save the mass.

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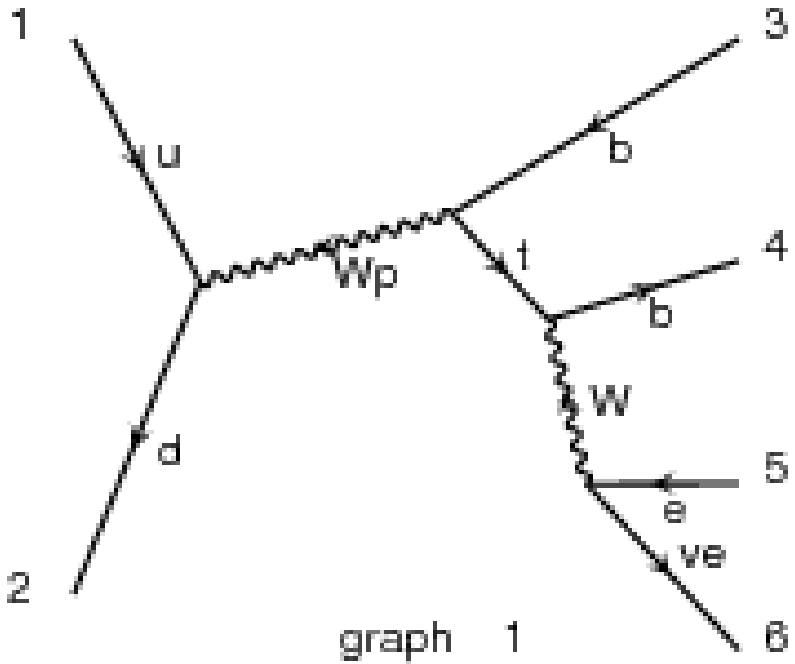
Differences to W Boson

Key Differences to look for...

- A W' could potential couple with both a left and right handed component, or strictly to one or the other, depending on one theory or another.
- A W' is not restricted to having any of the W boson's parameters, and could have a different mass or coupling.
- There are some theories that restrict W' coupling to only top-down, in order to attempt to explain T-$\overline{T}$ asymmetry. Such W's could be detected by this method, but the evaluation of the coupling would be wrong.

Detection Signal

Due to its high mass and the general rarity of top events, one of the cleanest detection signals of a W' boson would be S-channel Single Top production.



The events would be detected as

- A high energy jet, unlikely to be b-tagged

  and a top quark which decays into...

- A b-tagged jet

  And a W boson, which will decay into...

- A charged lepton
- missing energy (this is used to reconstruct the neutrino by fitting this and the lepton to the W mass)

Detection Simulation

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(1) Generate signal in MadEvent

(2) Pass output to Pythia to simulate hadronization

(3) Run PGS to simulate detector inefficiency, b-tagging

(a) Adjust PGS to use an Anti-kt jet clustering algorithm

(b) Modify Jet Energy to compensate for limited scope of cone size.

Differences Between Right and Left

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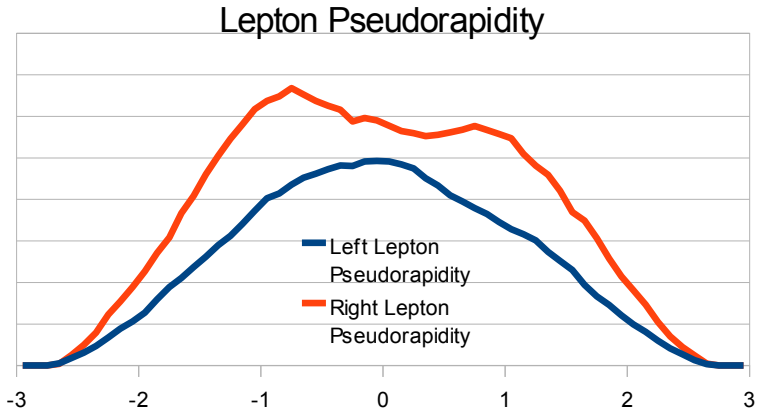
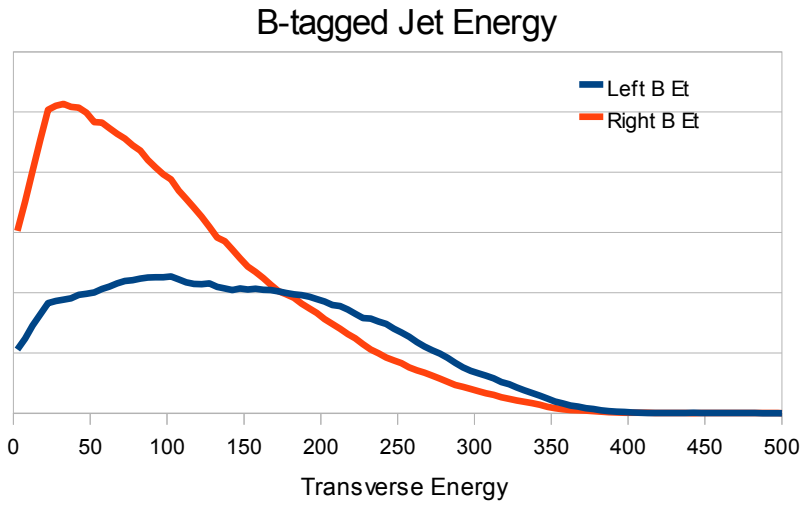
- For a pure-Right Handed W', there is no interaction with SM W, whereas a Left-handed W' will have interference effects.
- These effects will be positive or negative according to the sign of V_{tb} (a positive term will denote a destructive intereference).



- The shape of the lepton-energy spectrum is different due to loss angular correlation in the right-handed W' that is conserved with the left-handed.
- A right-handed W' also has a branching fraction W' → tb since there is no right-handed neutrino to couple to for a neutrino-lepton pair.



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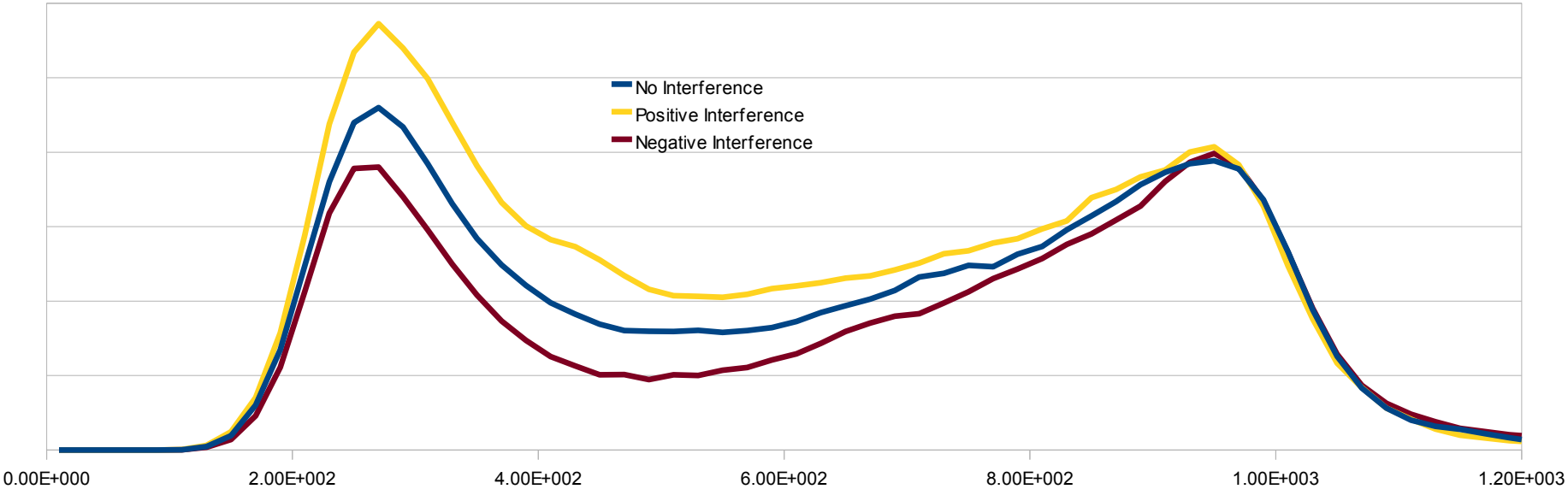
Interference Effects

Due to interference between the W and W' for left handed W's:

- The cross-section changes slightly in magnitude, but not in shape
- The magnitude of the interference can by described by a multiplicative factor based on the W' mass.

Below is the reconstructed mass peak for a 1000 GeV W' for a general S channel single-top generation process after cuts.



Differences Between + and –

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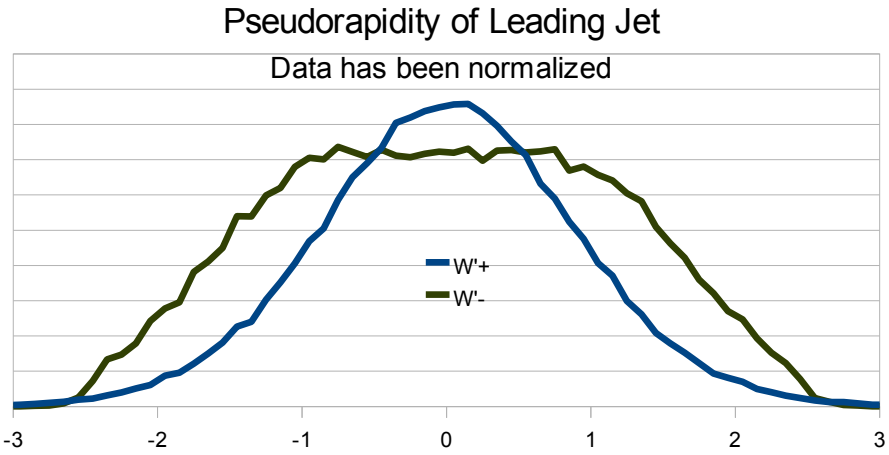
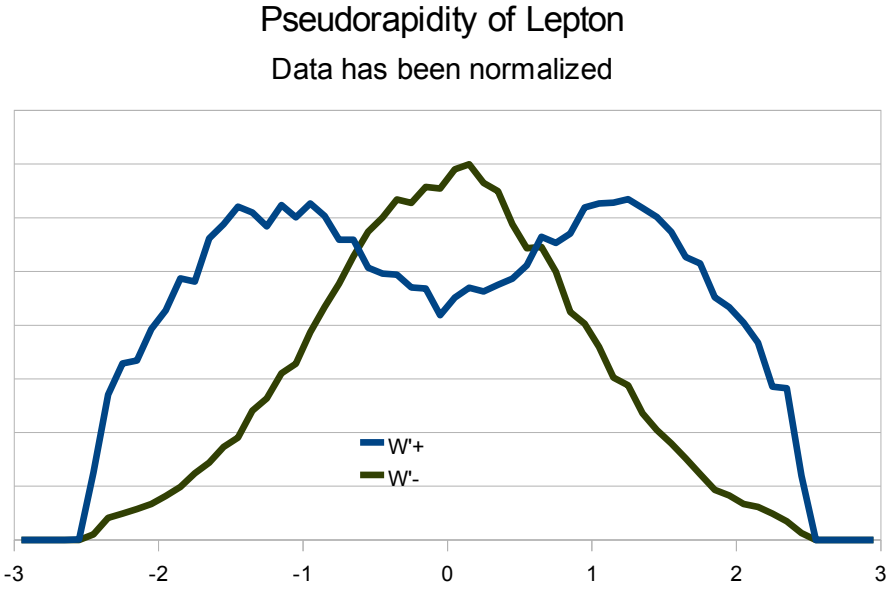
- A W'+ tends to have a wider peak for leading jet then for a W'-
- This will cause a larger proportion of + to – events to be missed due to jet cuts.



- On the other hand, a W'+ has its lepton peak at a non-zero pseudorapidity
- This will cause a relatively high number of events to be cut due to lepton cuts.



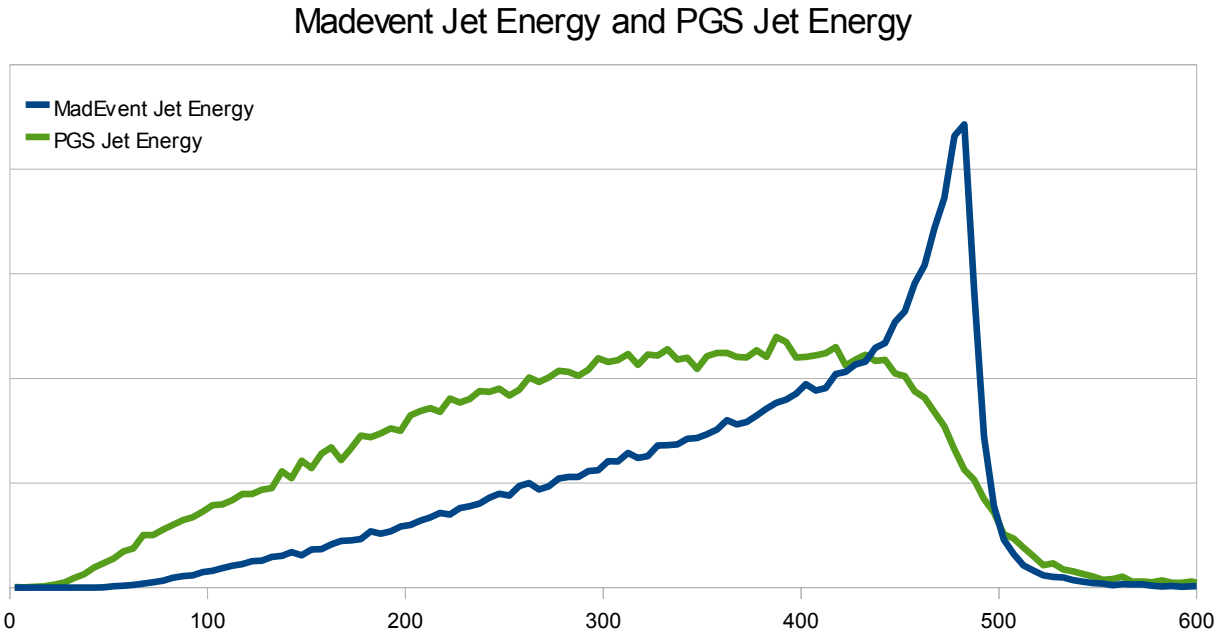
- After all cuts, the W'+ cross-section is about 3 times as large as the W'-.

Jet Energy Correction

Due to the jets hadronization, some of the jet's energy is missed due to limited cone size, some of energy of the initial quark is lost outside the grouping of the jet, typically at low energies

To correct for this, a program was written to go through event by event through MadEvent and PGS, and compare the transverse energy of the leading jet in each situation.

A more significant effect, especially at higher energies, is the energy smearing. This has the effect of broadening out the energy peak from the jet recoiling against the top to lower energies.



The approximate correction was given by

$\%\ \text{Correction} = A/E + B/E^2$

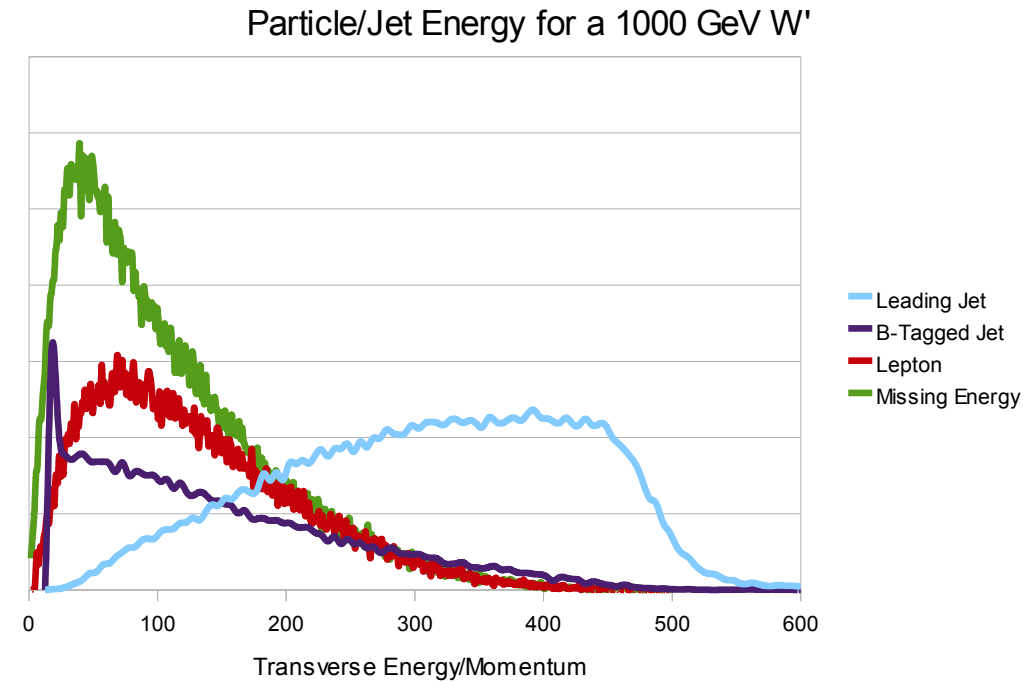
$A = 2.214$

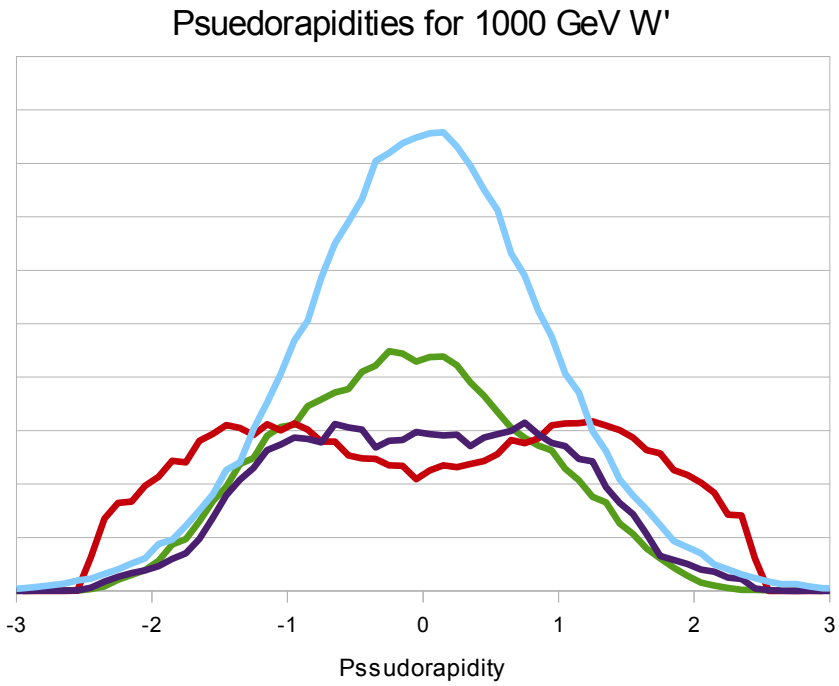
$B = 61.96$

Signal Characteristics

For given W' Mass:

- Leading jet has energy approaching half the W' mass, at least equal to .2*$M_{W'}$.
- Second jet should approach half M_{top} in the top rest frame
- A single, boosted Lepton and missing energy generally at least 20 GeV
- All particles should be approximately central, so restrict $|\eta|<2.5$





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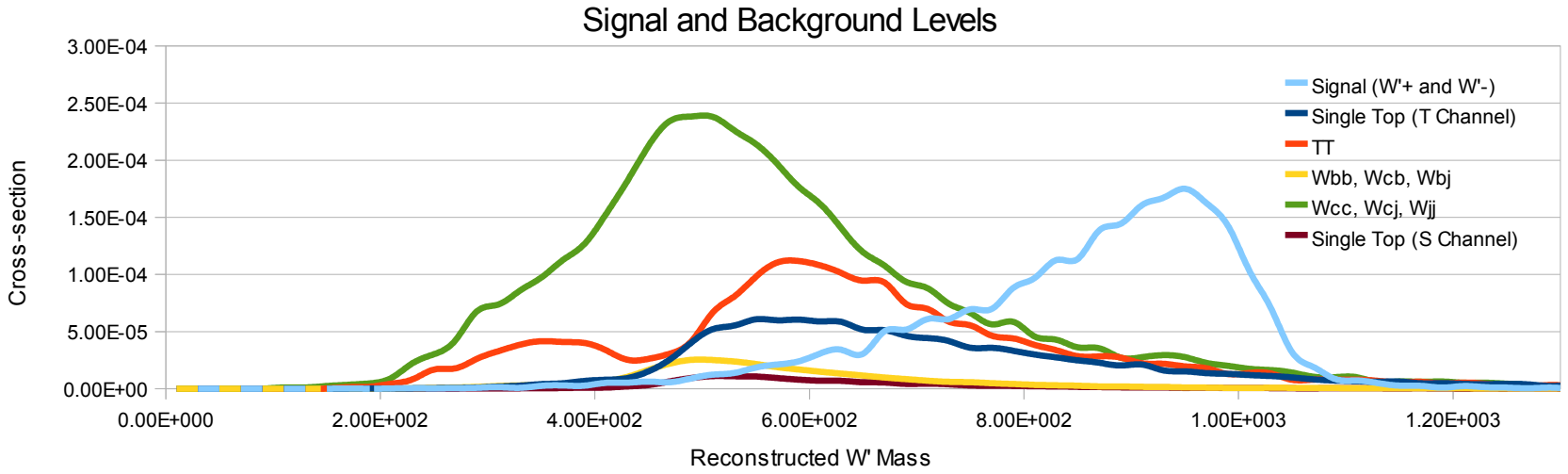
Backgrounds

Backgrounds will be events which produce a high energy jet, a b jet, and a W boson to produce leptons. Background Channels Include:

T-Channel Single Top, S-Channel Single Top, $T\overline{T}$ production (not full hadronic), W+jets production channels (Wjj, Wcj, Wcc), Wb+jet channels (without top quarks)

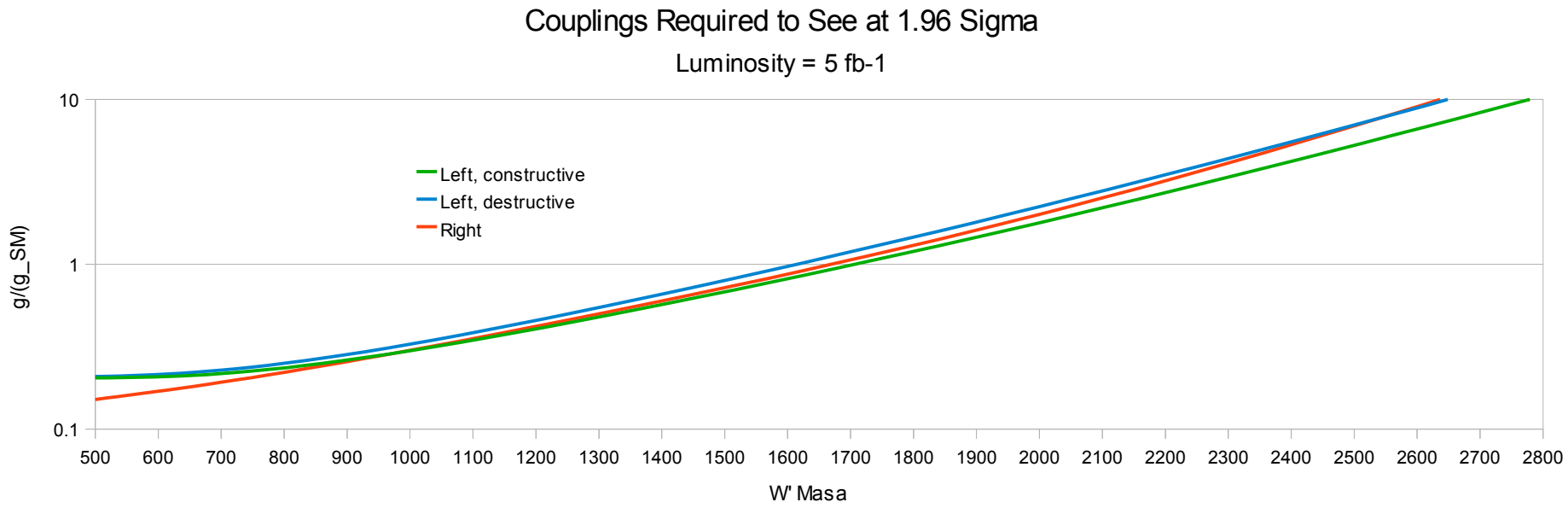
•Background Events tend to peak significantly lower then the signal for a given set of cuts, thus allowing for a large cut to be made by analyzing the W' mass peak



Results

Assuming a 95% Confidence Level Exclusion of the signal would be visible at a given luminosity, it is possible to compute an approximate minimum excluded coupling. This can be done simply by manipulating the number of signal events by multiplying by g/g_{SM}.

The required coupling for a massive W' goes up approximately exponentially with the W' mass for left-handed (both interferences) as well as for the right handed, and can be used to set limits on the coupling in each situation. Any W', regardless of model, which falls above this line can effectively be ruled out at 5 fb^{-1} by this channel alone.



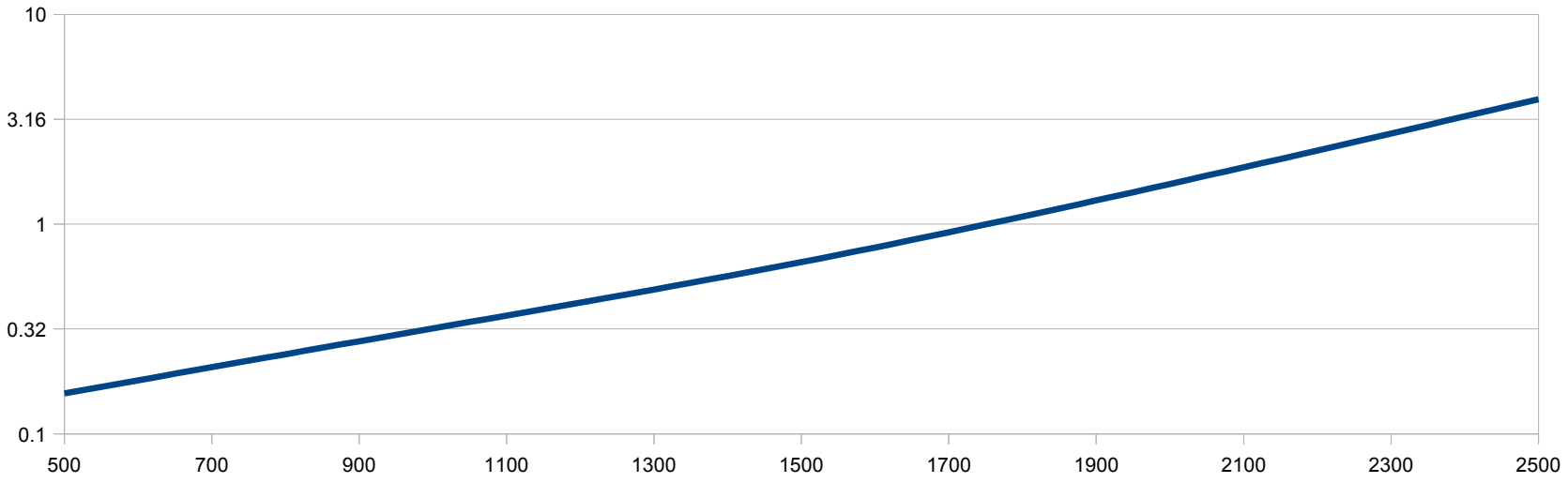
Results

Analyzing the previous graph, we see that at 5 fb-1, a W' of up to 1650 GeV should be excludable at the LHC assuming $g=g_{SM}$ and a pure right-handed W'. If the W' is left handed, depending on the effects of interference a W' would be excluded below between 1700 GeV (for constructive interference) and 1800 GeV (for destructive interference)

A coupling of approximately $5g_{SM}$ would be viable to around 2400 GeV.

8000 GeV Run Extension

Results follow a similar pattern to at 7000 GeV, but goes out of detection range at a slightly higher mass, since the production of a W' is increased at higher energies. Exclusion at $g=g_{SM}$ should now be viable up to approximately 1800.



Conclusion

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- S-Channel Single Top able to exclude a large range of potential W' values at 95% C.L.
- Additional channels open if one ignored the top mass cut, allowing W' → ZW channels, but that is not covered in this analysis.