# Search for a right-handed W boson decaying to a heavy neutral lepton

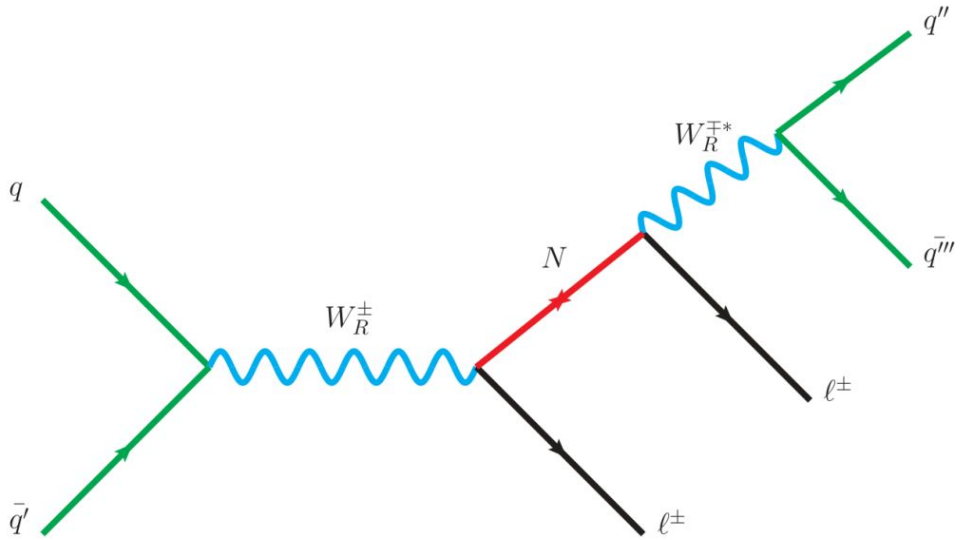
Mentee: Trong Le (Middlebury College)
Mentor: Michael Krohn (Univ of Minnesota)

# Abstract

**Abstract**: The goal of the project is to look for the right-handed W ($W_R$) boson and a heavy neutrino. Even though only left-handed W bosons are predicted by the Standard Model, there is no fundamental reason why right-handed W bosons should not exist, and many extensions to the Standard Model predict the existence of $W_R$. For this project, we will analyze simulated data to improve the event selection from the previous analysis done on Run2 data (collected from 2016-2018) in order to increase the sensitivity of the search for a $W_R$ boson.

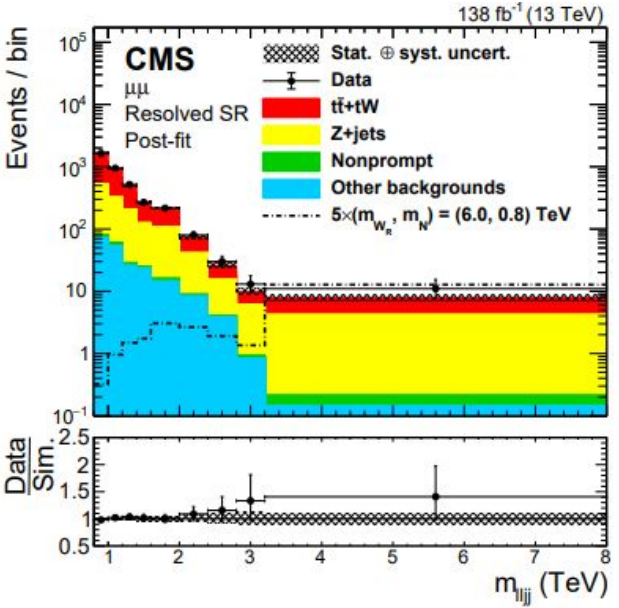
# Theory

- Only left-handed W bosons are predicted by the Standard Model
- **Left-Right Symmetric Models** (LRSM) bring left-right symmetry to the weak force and predict a **right-handed gauge boson** ($W_R$) and **heavy neutrino** (N)

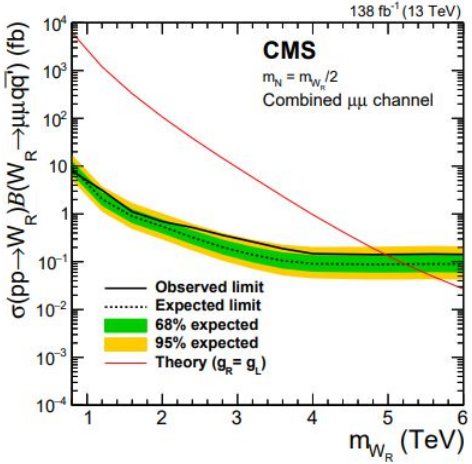


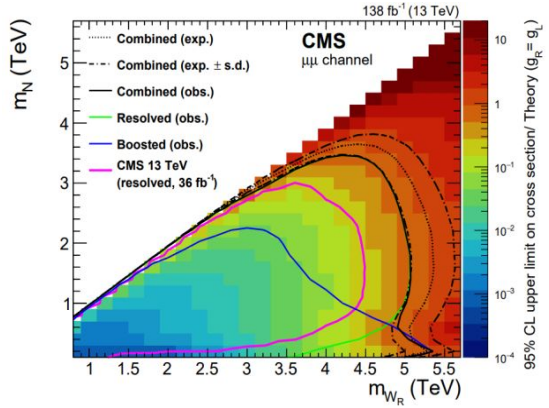
# Previous Findings

- Run2 analysis selected events with 2 jets and 2 well-reconstructed, well-isolated leptons (electrons or muons).
- Run2 analysis searched for signal in the 4 object invariant mass ($m_{lljj}$) distribution
- The primary backgrounds across the entire $m_{lljj}$ spectrum are DY and ttbar
- There was **much more background in lower $m_{lljj}$ regions than higher**



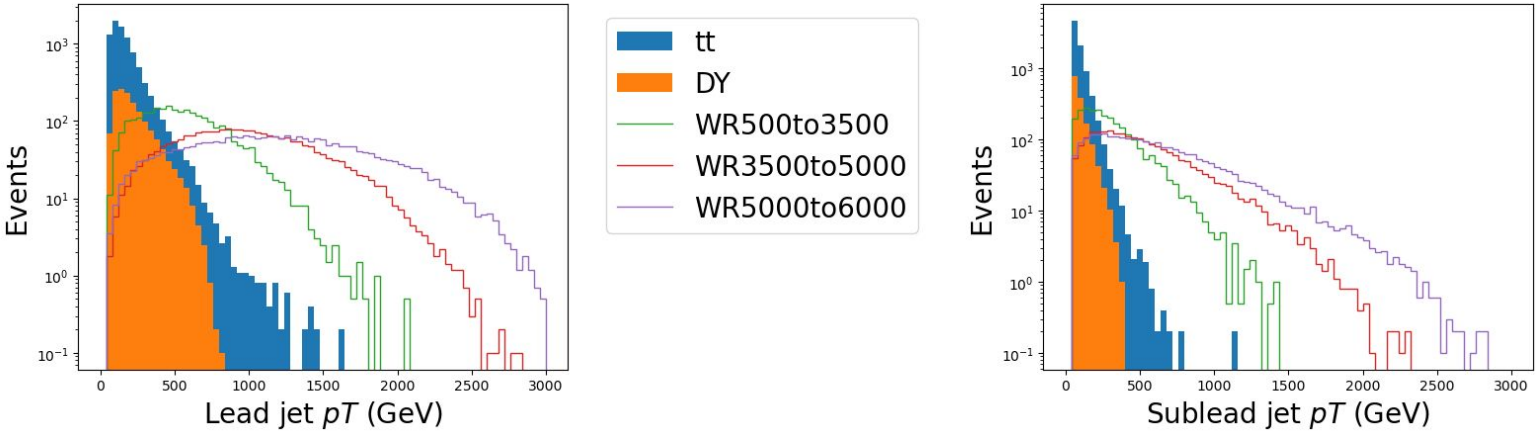
# Previous Findings




- All $m_{Wr}$, $m_N$ mass points within black solid contour in heat map were excluded, for a theory assuming $g_R = g_L$
  - For $m_N = 1/2\ m_{WR}$, $m_{WR} < 5000$ GeV is excluded
- Run3 analysis aims to **reduce the background across the entire $m_{lljj}$ spectrum** with the hope of making the **sensitivity of the low $m_{lljj}$ region more comparable to the high $m_{lljj}$ region**

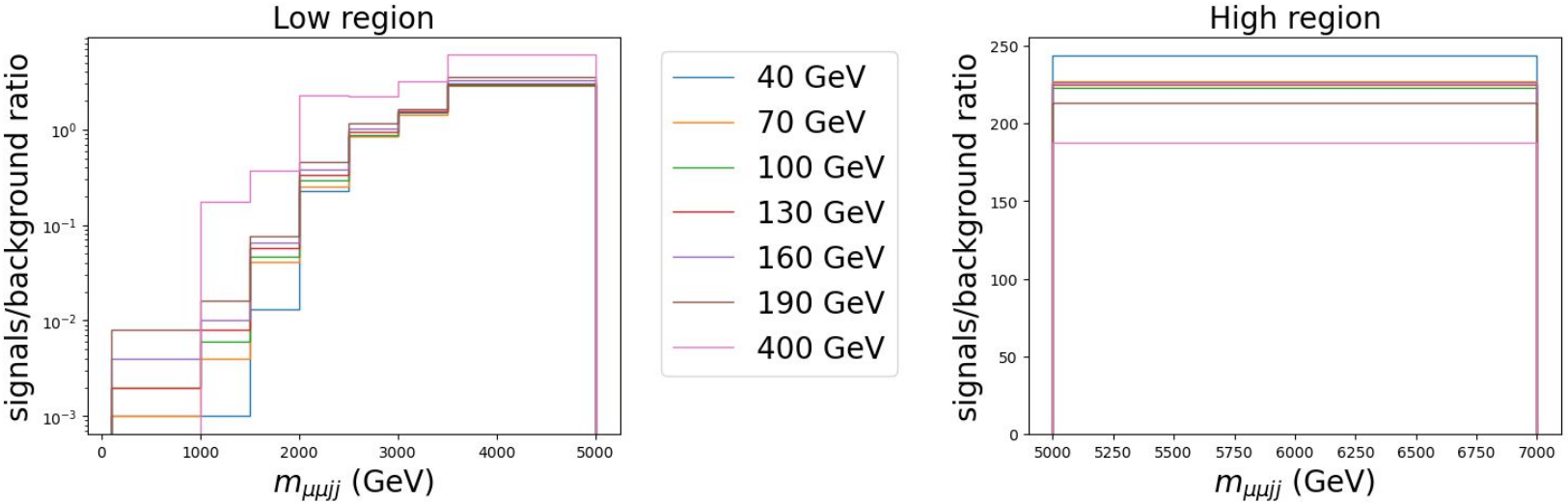
# Methods – jet pT




Goal: maximize the signal/background ratio

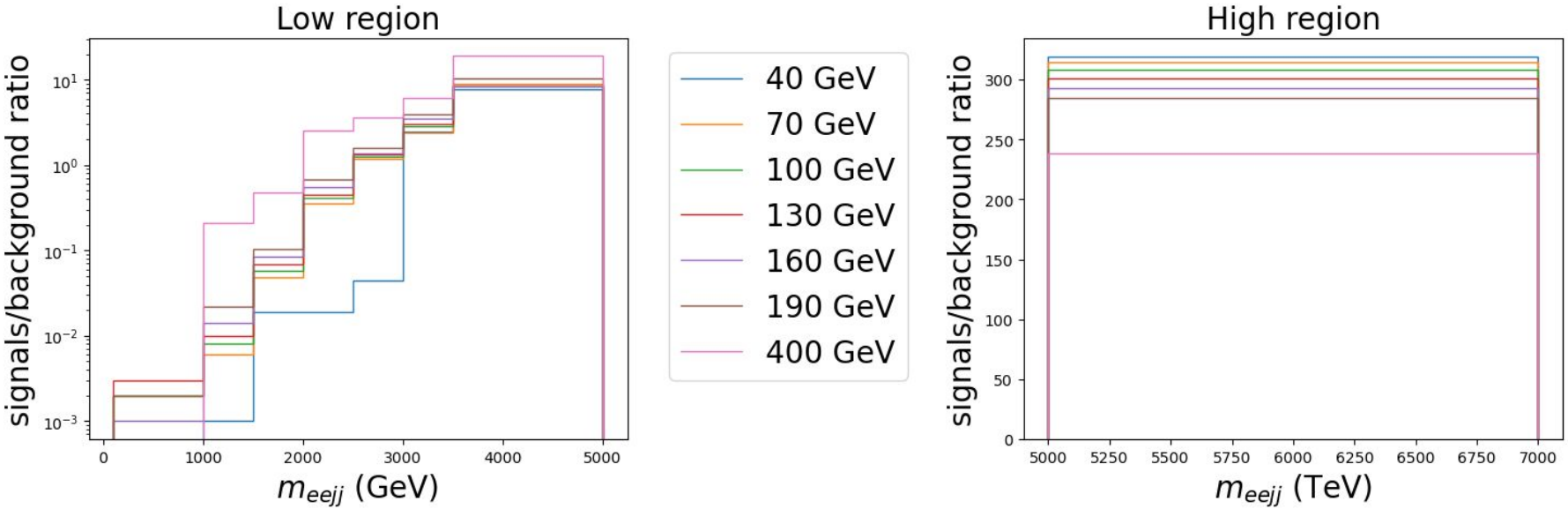
- There is considerably more background than signal at low jet pT values
- **First strategy:** setting a **higher jet pT cutoff** than 40 GeV, which was used by the event selection in Run2

# Results – jet pT, μμ selection




- Raising the jet pT cutoff improves the S/B for all $m_{lljj}$ values below 5000 GeV
- The optimal value for this cutoff will need to be set by other considerations, like the background estimation technique

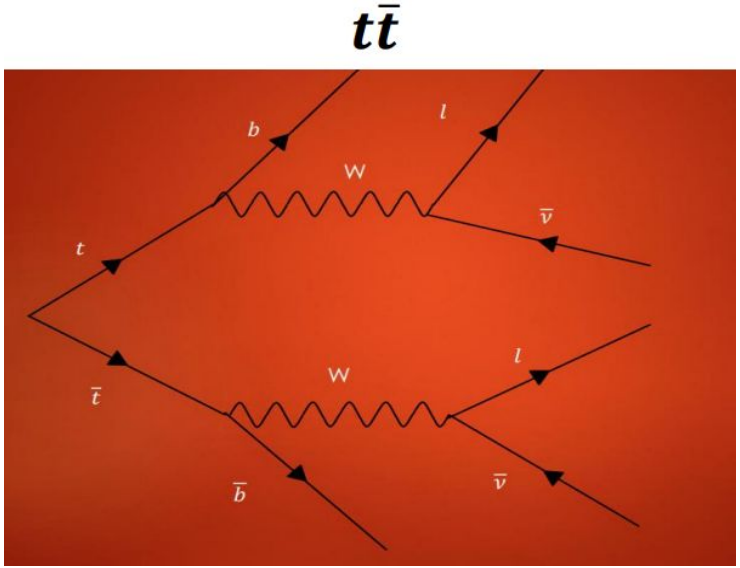
# Results – jet pT, ee selection




Conclusions are the same as the μμ selection

# Methods – b-tagging jets

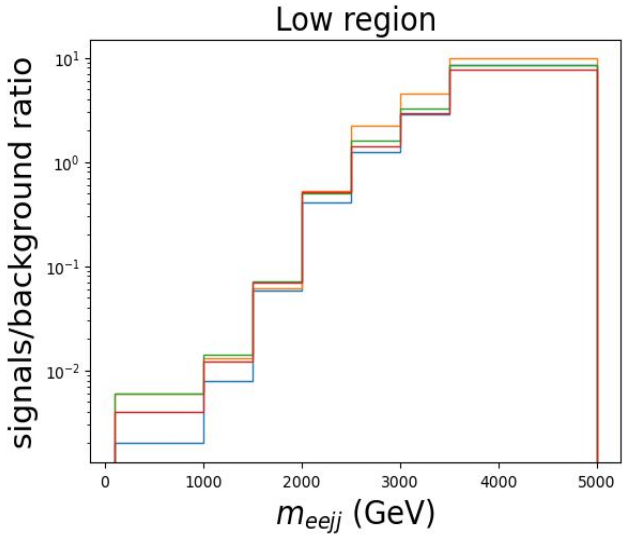
- The ttbar background decays into b-quarks
- b-tag score is the probability that a jet contains a b-quark decay
- **Second strategy:** removing events that contain jets above different b-tag score thresholds to remove ttbar background

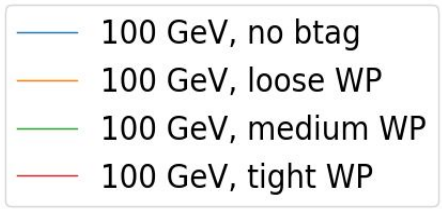


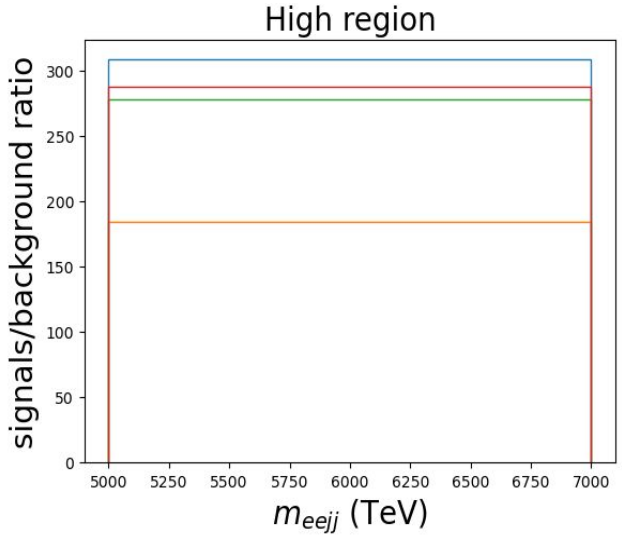
# Results – b-tagging jets, μμ selection


- Medium WP is nearly best across entire $m_{lljj}$ spectrum
- b-tagging doesn't improve S/B above 5000 GeV, but there is very little ttbar events in simulated sample in this region so it's hard to draw conclusions

# Results – b-tagging jets, ee selection

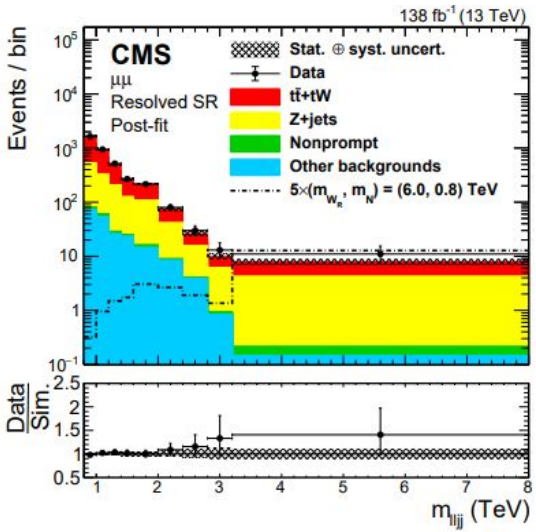


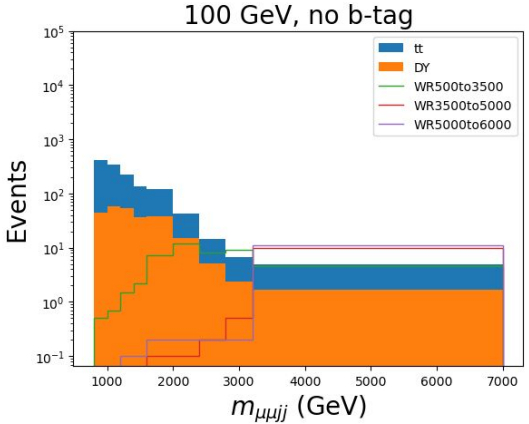



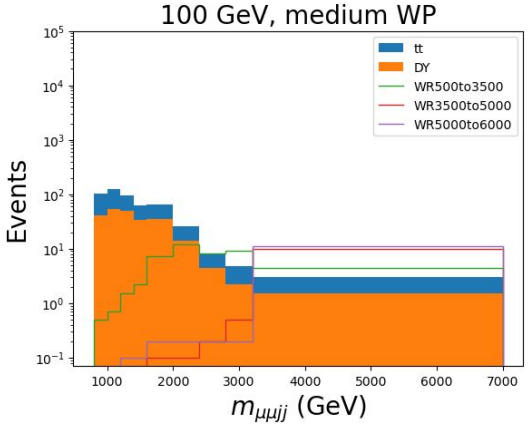




- The medium WP is best at low $m_{lljj}$ and the loose WP is best at high $m_{lljj}$, except for above 5000 GeV

# Results




- Raising the jet pT cutoff reduced the DY and ttbar background, primarily in the low $m_{\mu\mu jj}$ region
- Adding b-tag requirement reduced the ttbar background without reducing signal

# Future Work

- Next steps:
  - The same jet pT threshold is used to select jets in general and to select jets to have their b-tag threshold checked. We would like to separate these thresholds
  - Incorporate the new, optimal jet pT and b-tagging requirements into the Run2 analysis
    - the b-tagging requirement brings additional uncertainties that reduces the sensitivity of the search; need to understand if the sensitivity gained from applying a b-tag cut will outweigh the sensitivity loss from the b-tag uncertainty
  - Perform this analysis on Run3 data