# Underlying Event Study PHYS 594

**Adam Vendrasco** 



#### Outline

- Background and Physics Introduction
- Data Collection and Processing
- Overall Results
- Analysis of Results



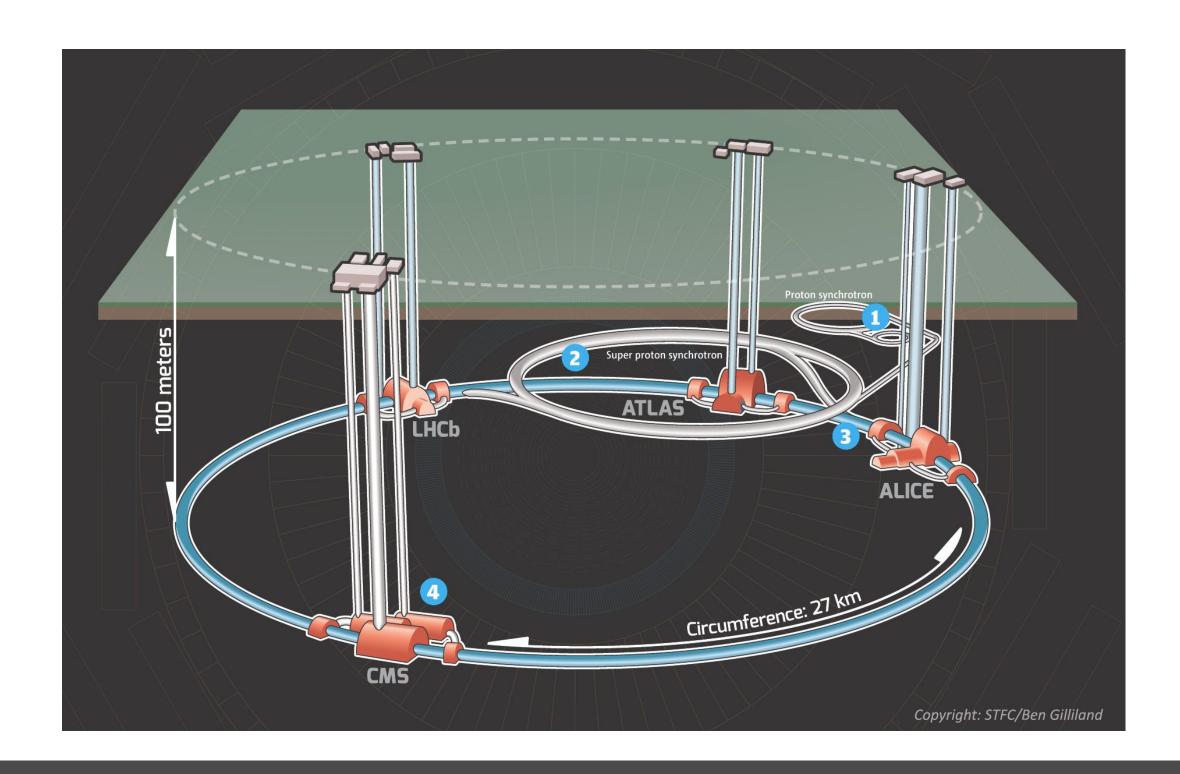
# Background Information



At the Large Hadron Collider (LHC) proton-proton beams are collided at center-of-mass energy  $\sqrt{s}=13$  TeV.

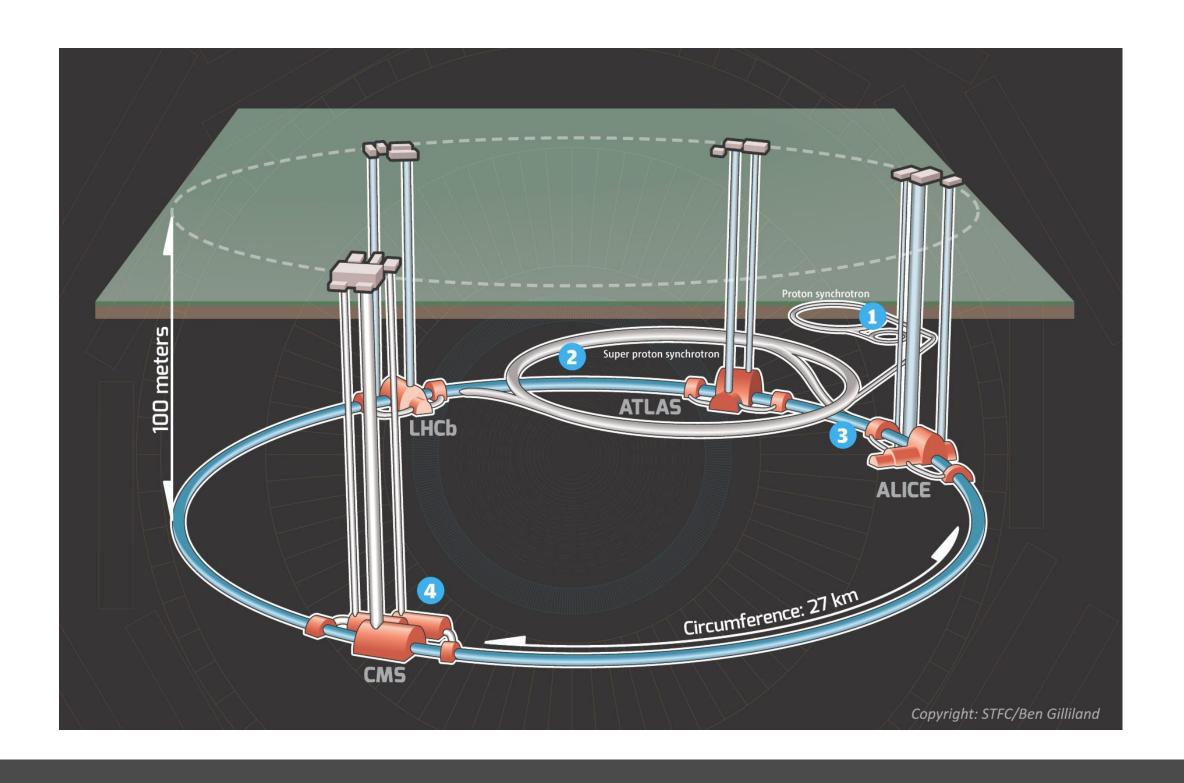


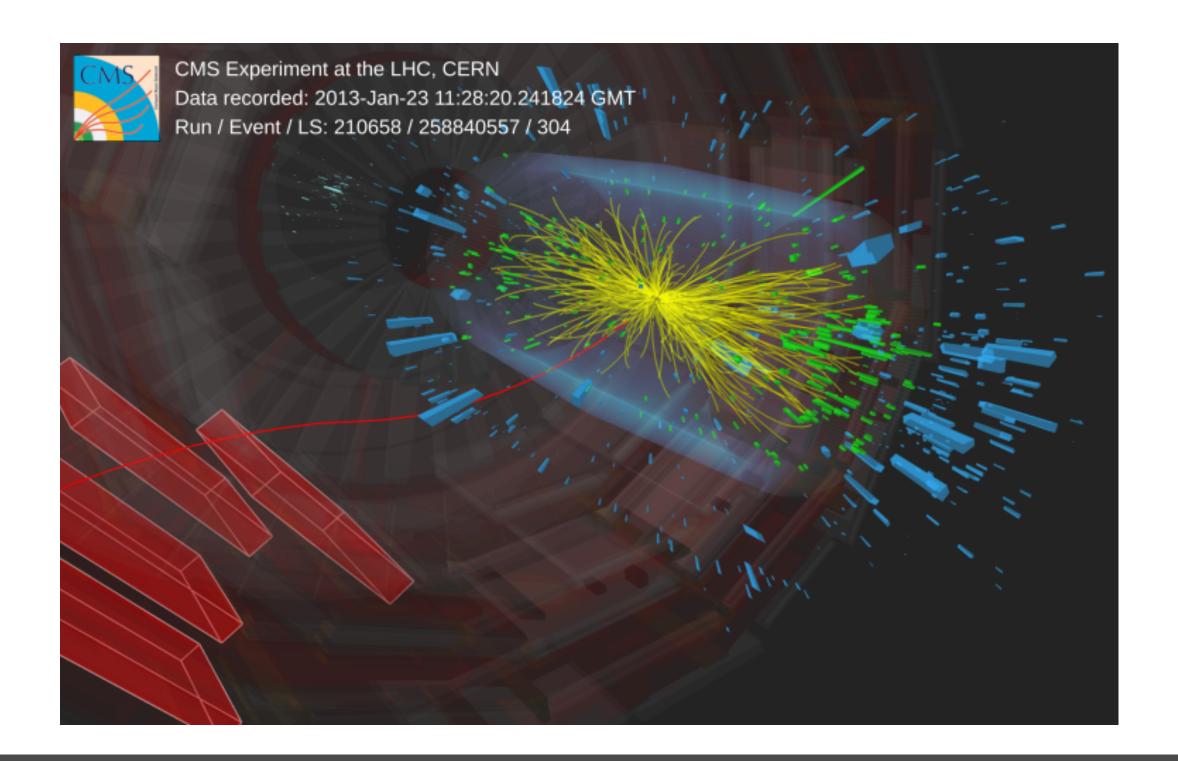
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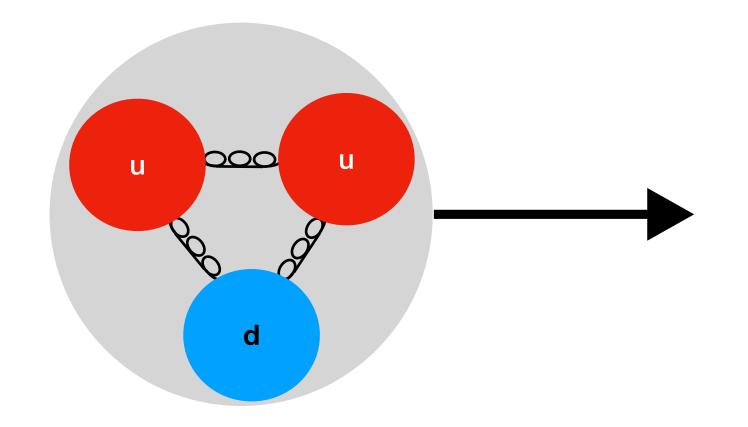


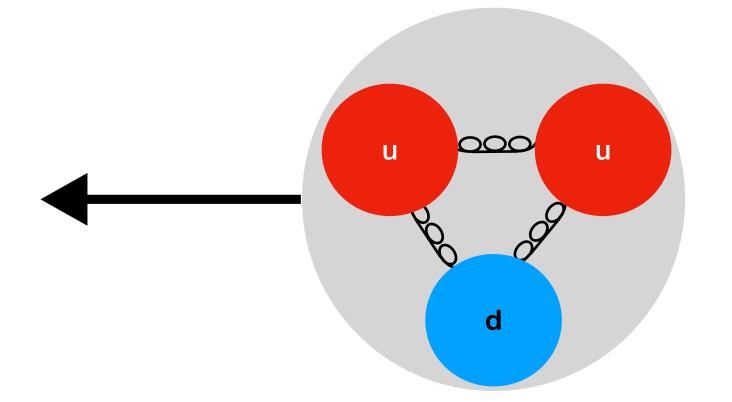
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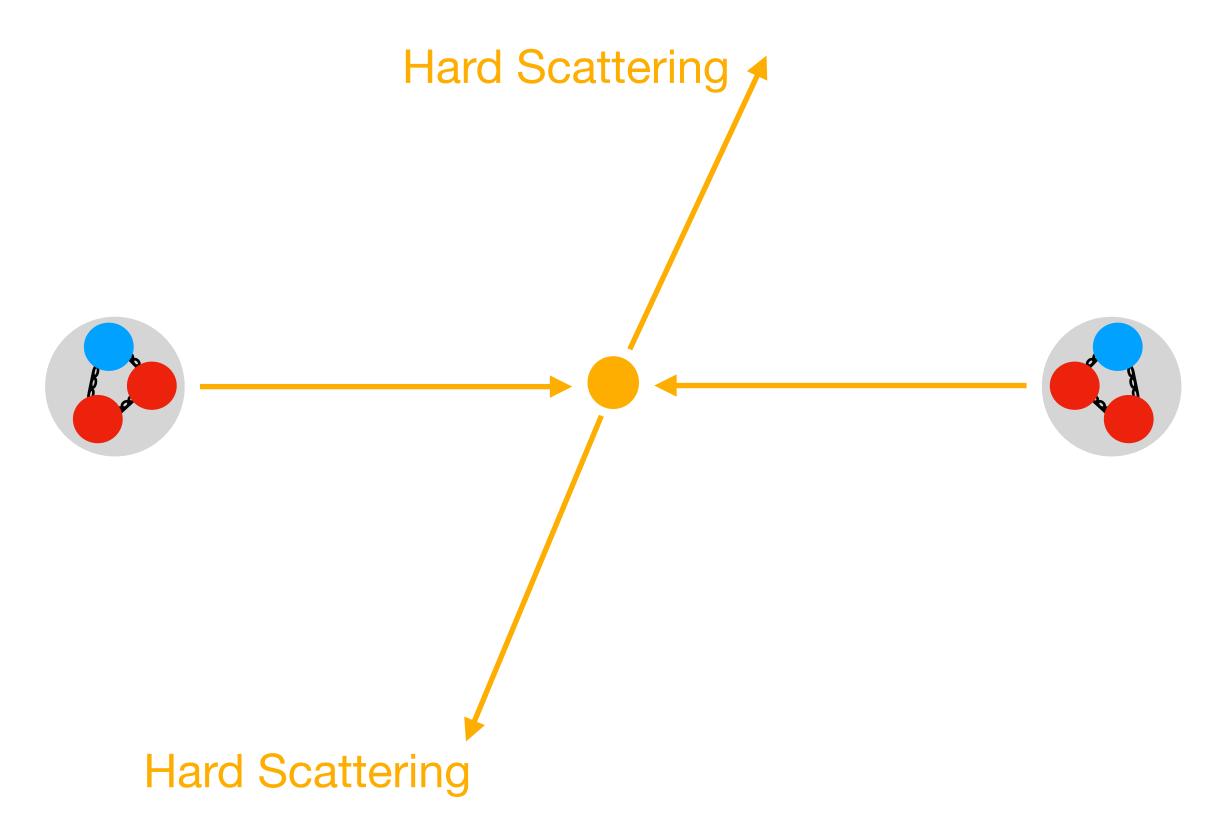






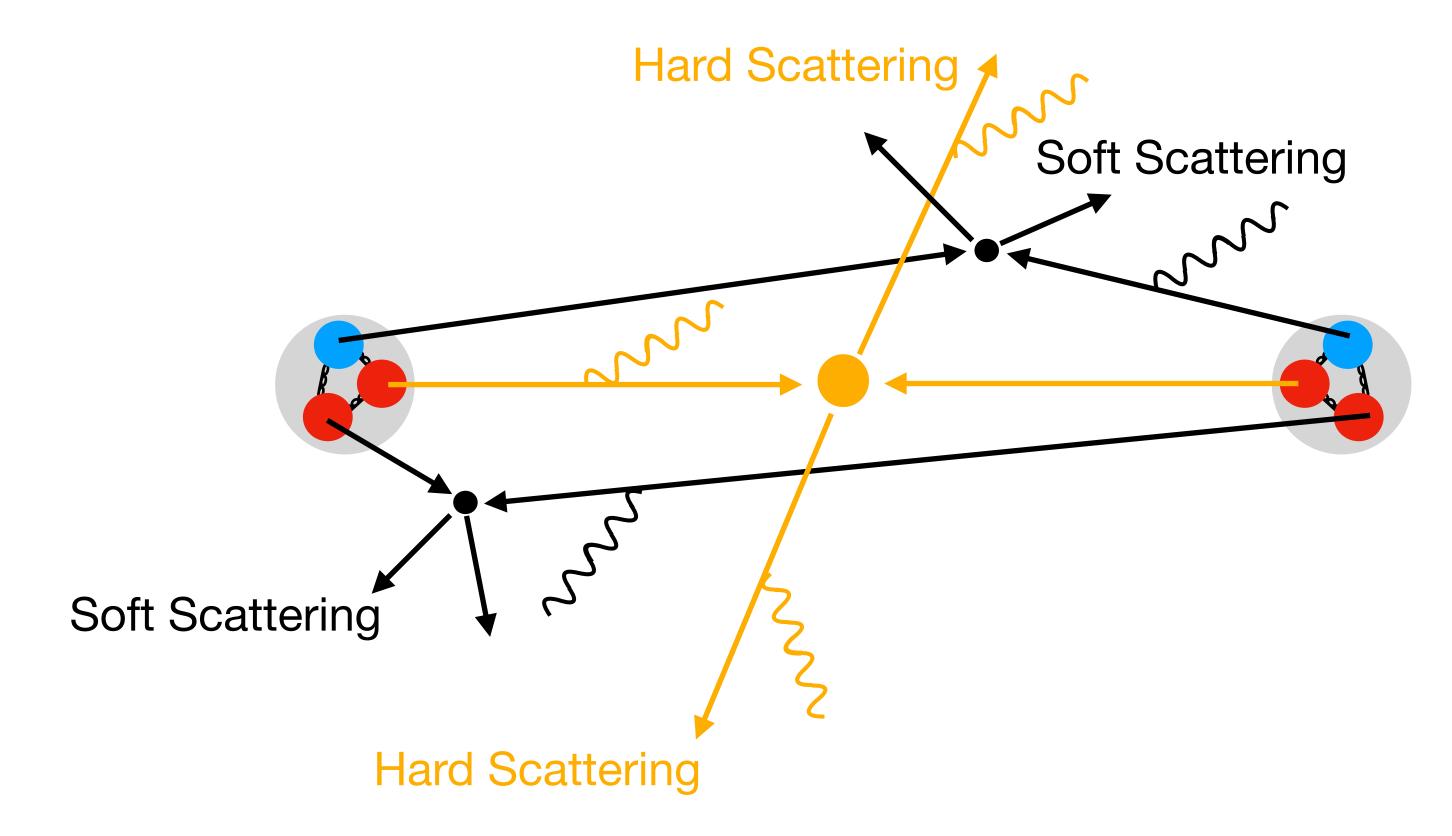
Idealized collision



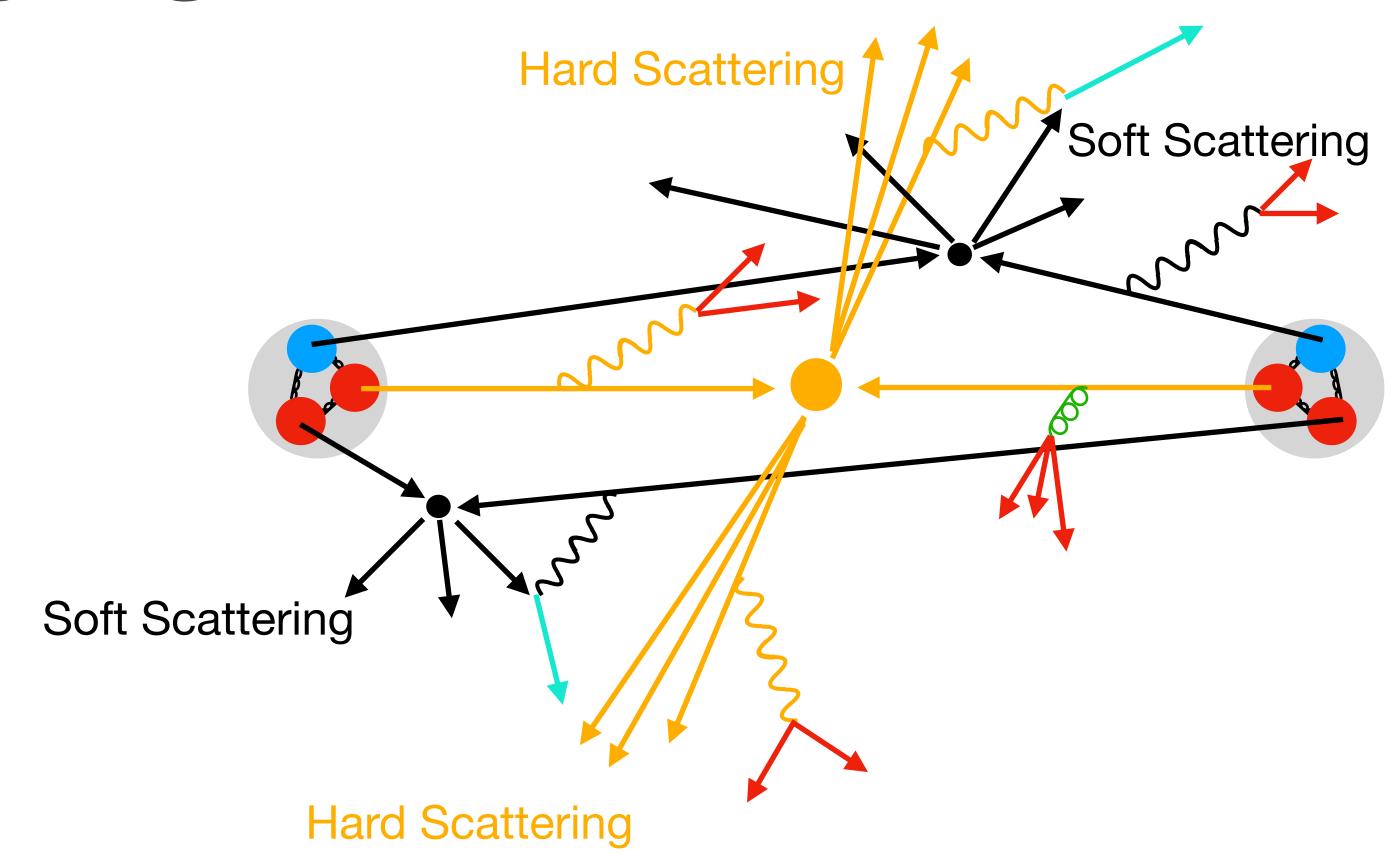


Idealized collision





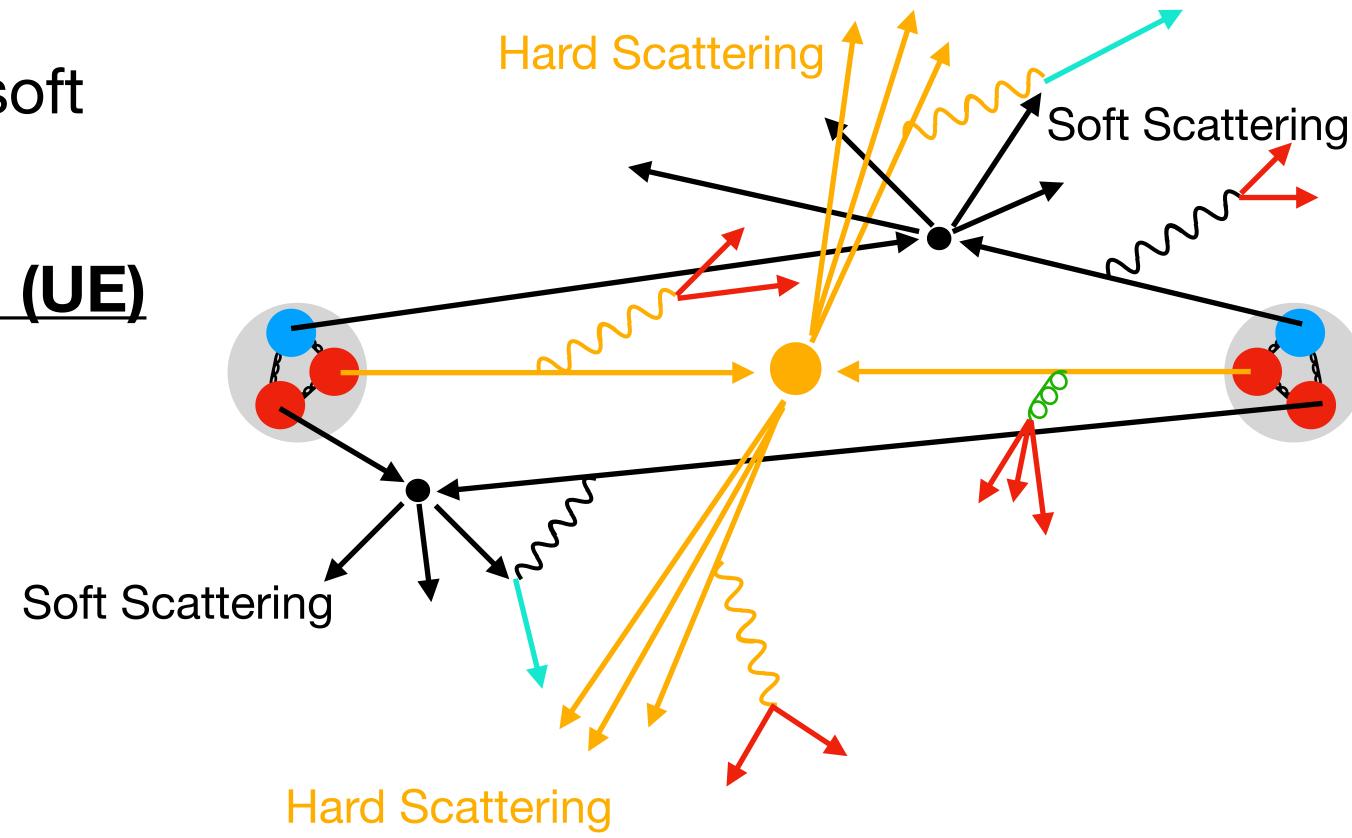






Overall we want to characterize these soft scattering events

Also known as <u>Underlying Events (UE)</u>



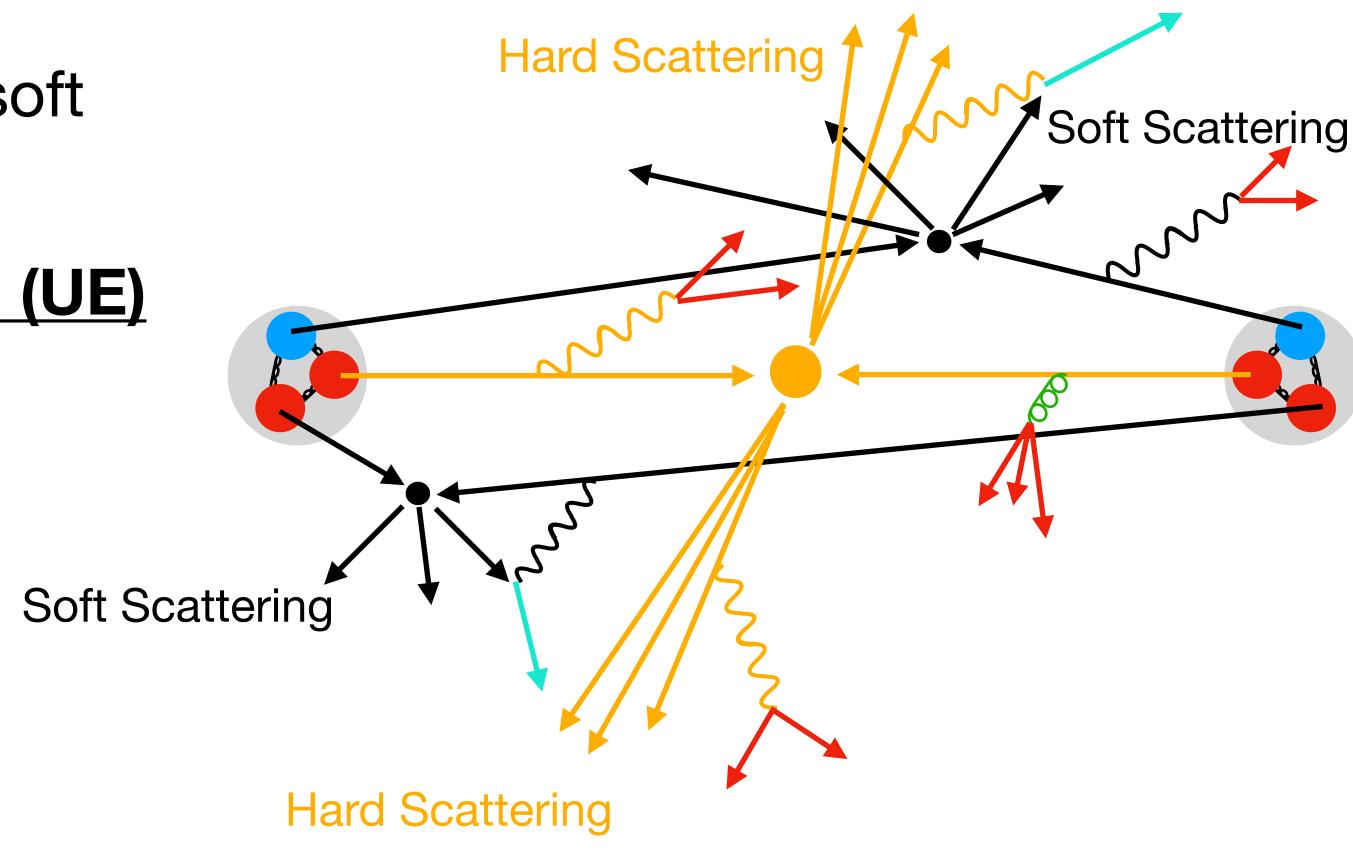


Overall we want to characterize these soft scattering events

Also known as <u>Underlying Events (UE)</u>

Often times these events are heavy suppressed

- Particle multiplicity
- Low momentum





In this study,

- We want to constrain properties of the z-boson using UE.
  - Is it possible to use ML techniques to help us?
  - Can we use the obvious hard scatter events to tell us information about the UE?



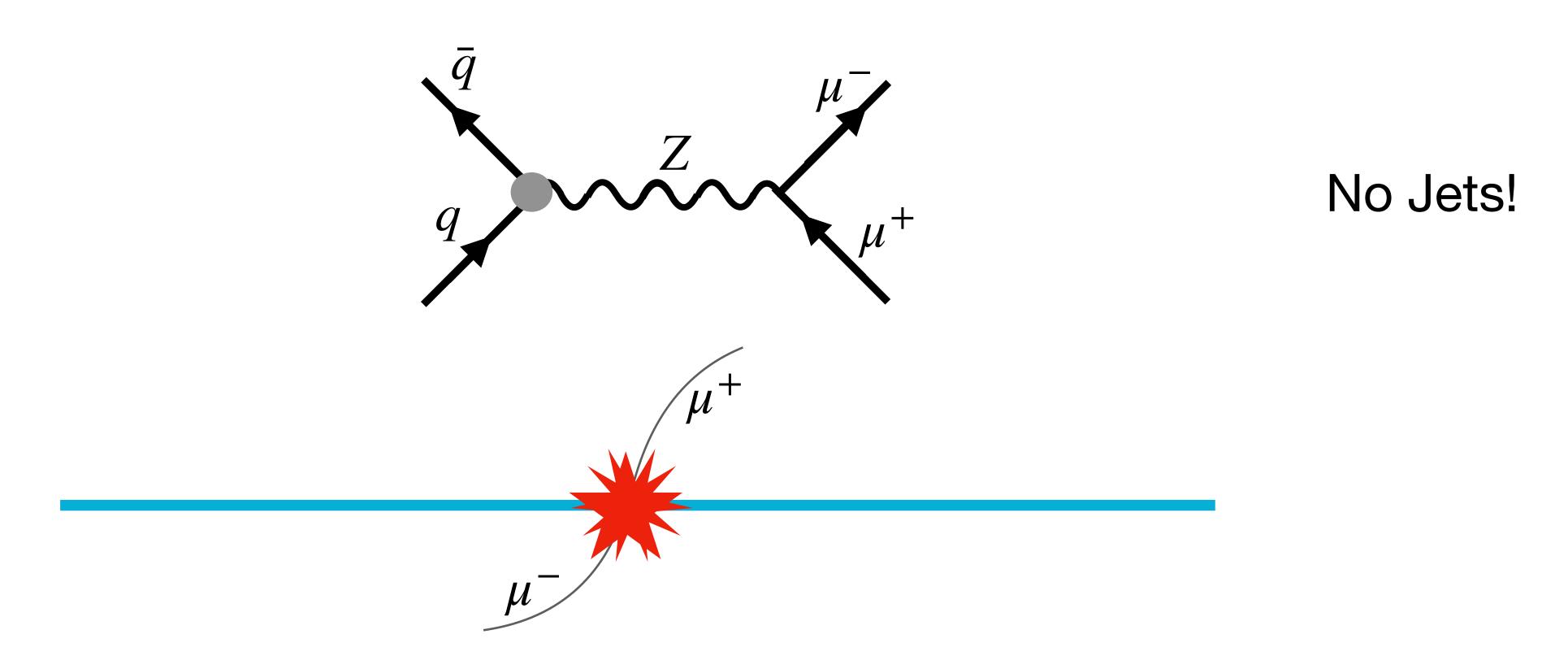
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  - Is it possible to use ML techniques to help us?
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Can we use ML to predict properties of the hard scatter using the UE?

If yes then we can use this to constrain various aspects of interesting physics. (Z-mass, W-mass...etc)





 $Z \rightarrow \mu^{+}\mu^{-}$  Feynman Diagram





Periodically, CERN will release data open to the public on data collected during beam collisions.

- As of April 4th, 2024 (with the help of Dr. Lee), I was able to get data from 2016 via the CERN Open Data Portal.
- NanoAOD ROOT file



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----> PFCands_phi
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PFCands_trkChi2
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We only care about the Particle Flow Candidates (PFCands).



Using Uproot, a data reader and writer we can,

- Read in all relevant data about the PFCands
- Filter that data on some cuts (pT, pseudorapidity)
- Select events that have exactly 2 Muons
- Store relevant properties of both the Muons and the Non Muon particles
- Do some data manipulation with TLorentz Vectors output 4-vectors.
- These 4-vectors will be the input into our Neural Network.

Uproot and Neural Network



# Overall Results and Analysis



#### Final Model and Results

The model that performed best at predicting the dimuon Pz was a Sequential, 4-layer DNN with Linear Regression and RELU activation.

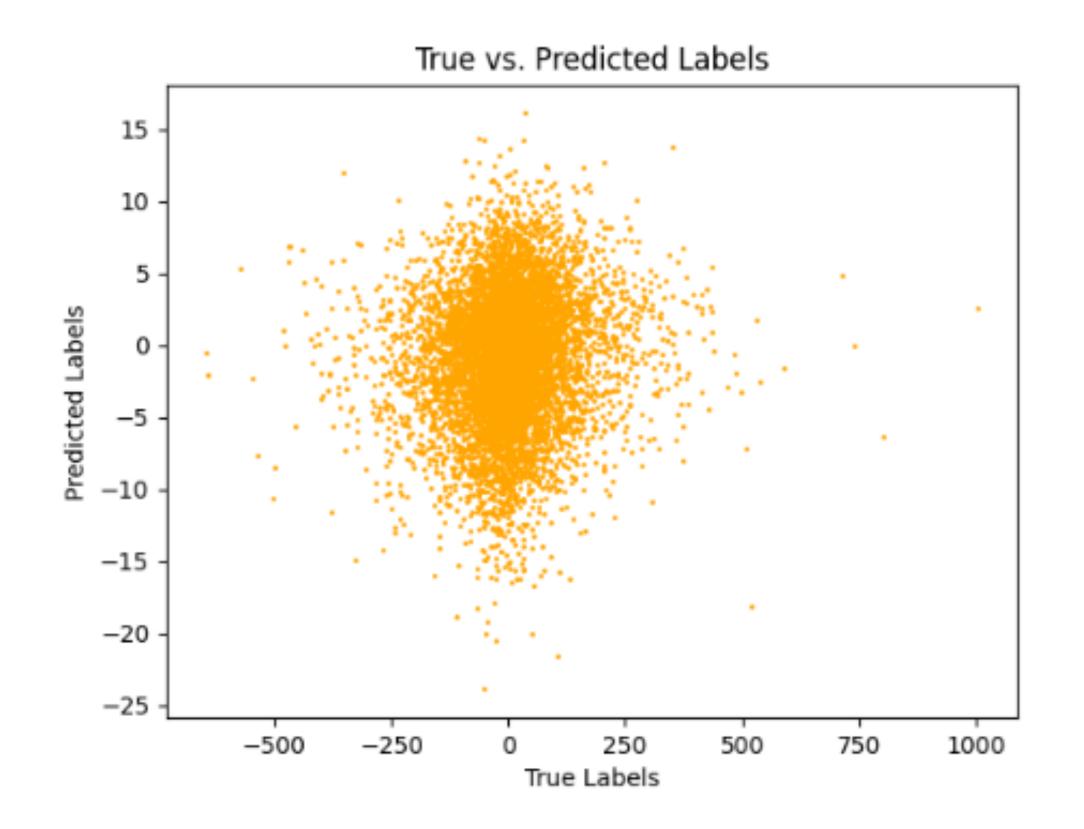
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    tf.keras.layers.Dense(100, activation='relu'),
    tf.keras.layers.Dense(10, activation='relu'),
    tf.keras.layers.Dense(1)
])
```

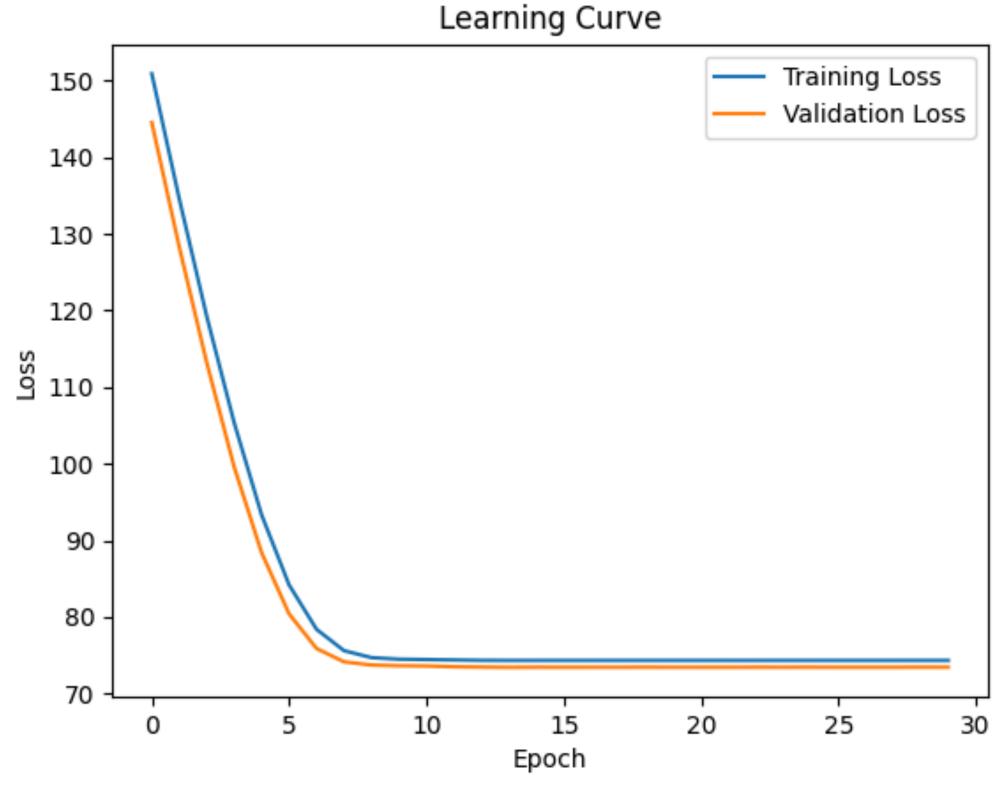
<u>Labels</u>: Muon Pz calculated with TLorentz Vectors

Features: Non Muon Pz calculated using TLorentz Vectors

Final Model

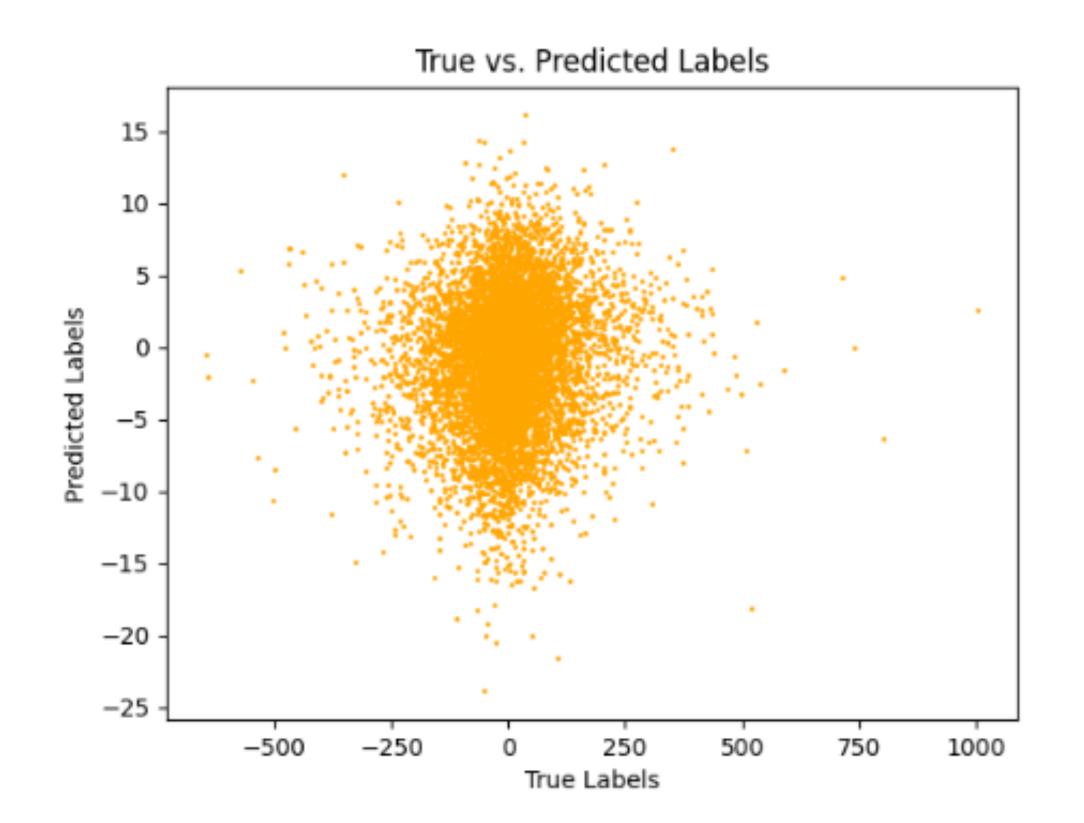


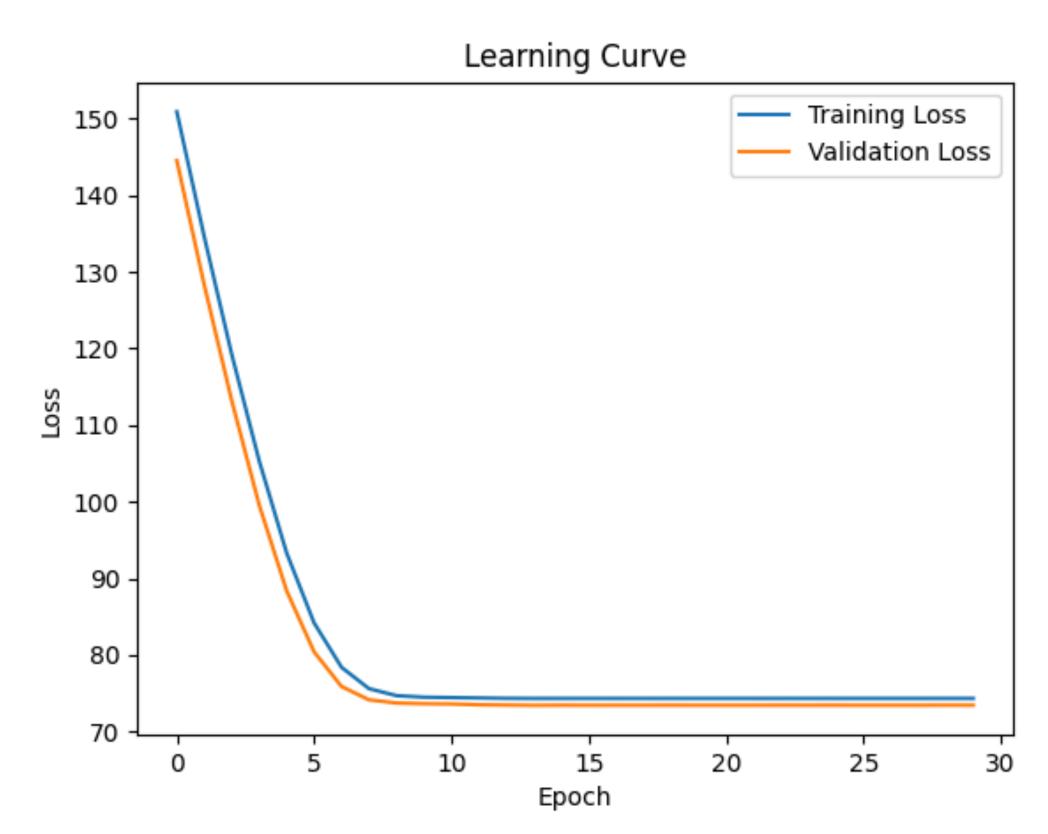








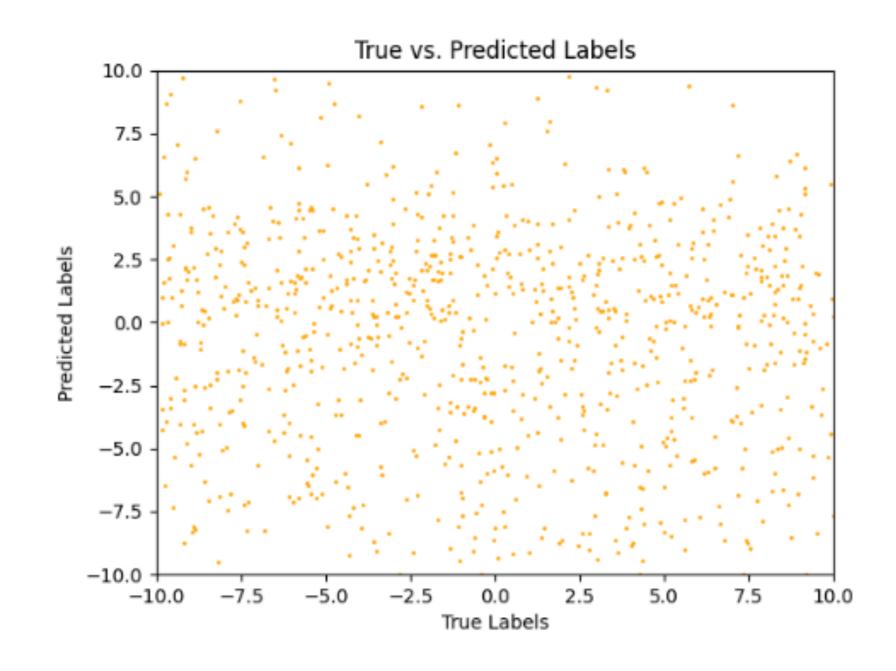


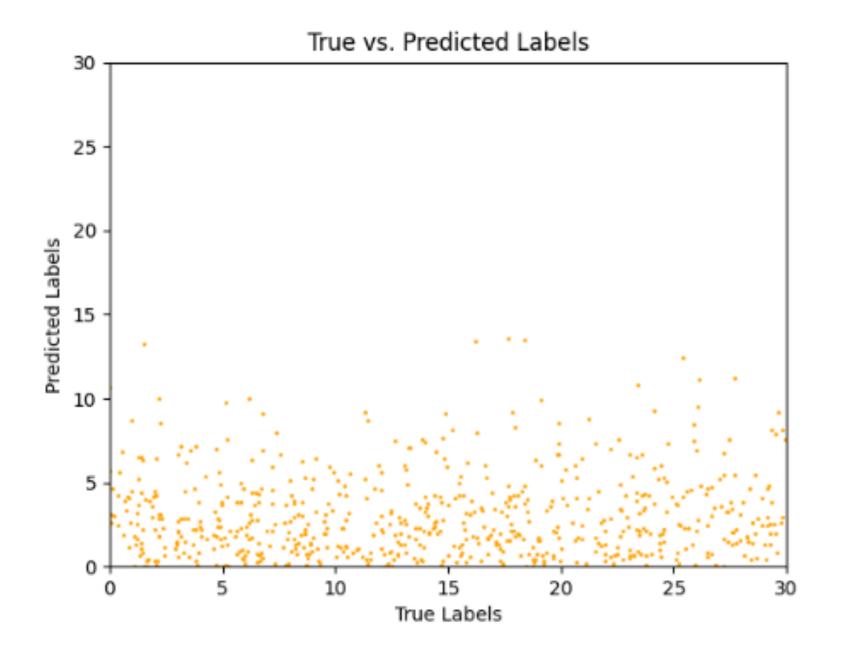


Perhaps there is a underlying linear relationship?



Unfortunately no, or at least not seen initially



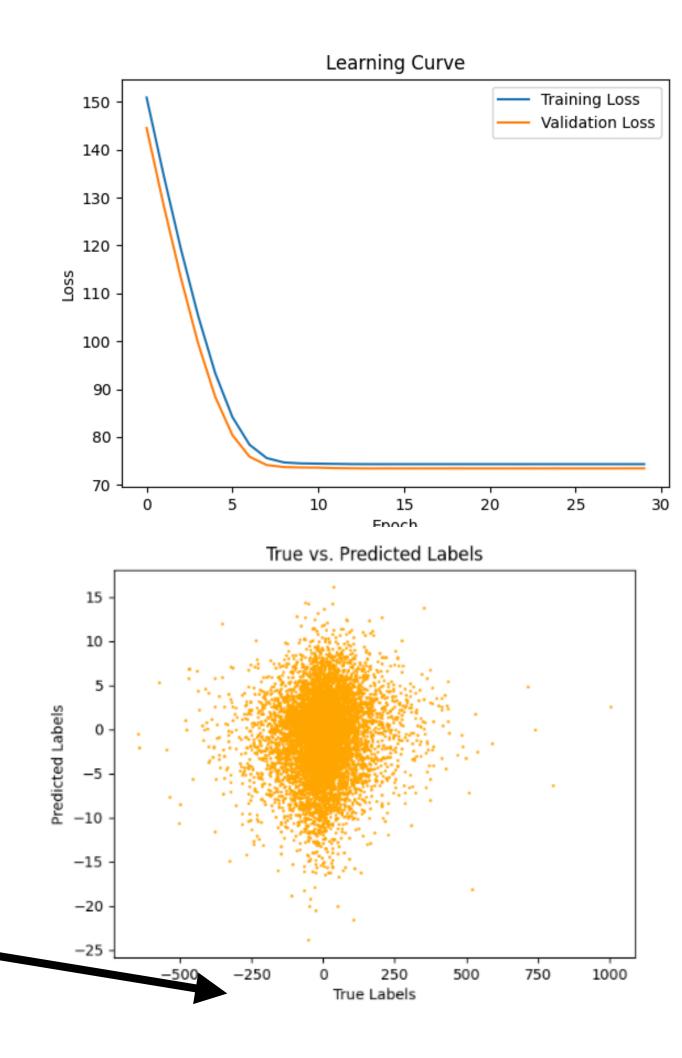




Based on these losses it seems the model is learning to some extent

 Can not seem to extrapolate past the given data and predict the dimuon Pz

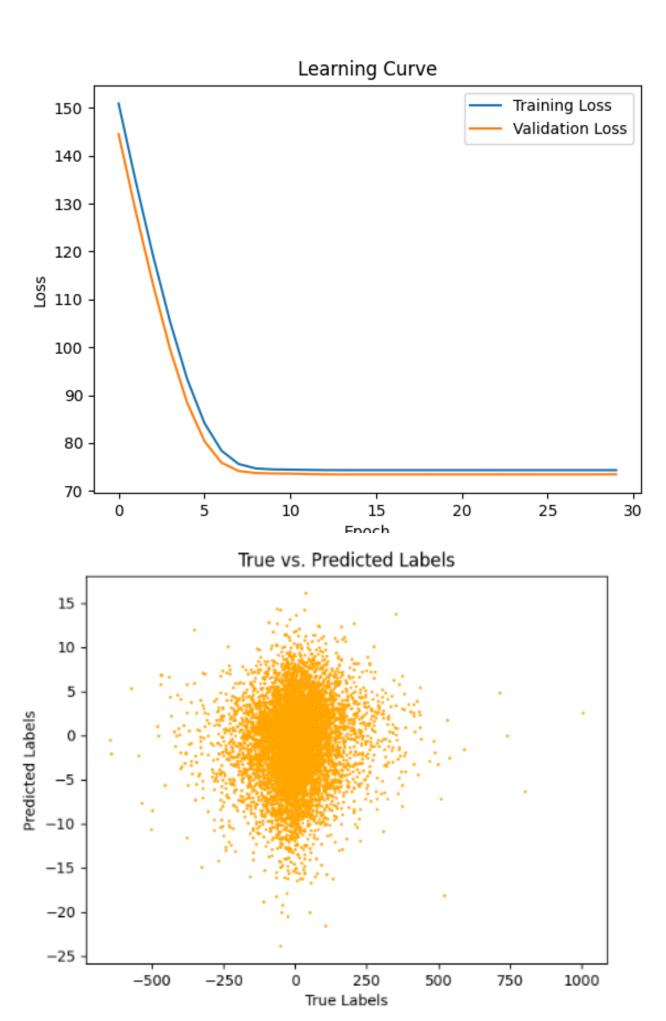
Could be the True Labels (Muon Pz).





I hope to continue this project more in the future with Dr. Lee if he is interested in continuing.

If so I plan to add vertex information on the dimuons to help limit the variability





Thanks again for the semester!

Fantastic class and I will see everyone around the Department!

