Underlying Event Study
PHYS 594

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THE UNIVERSITY OF TENNESSEE SYSTEM

Outline

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

Background Information

Underlying Events in Particle Physics

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

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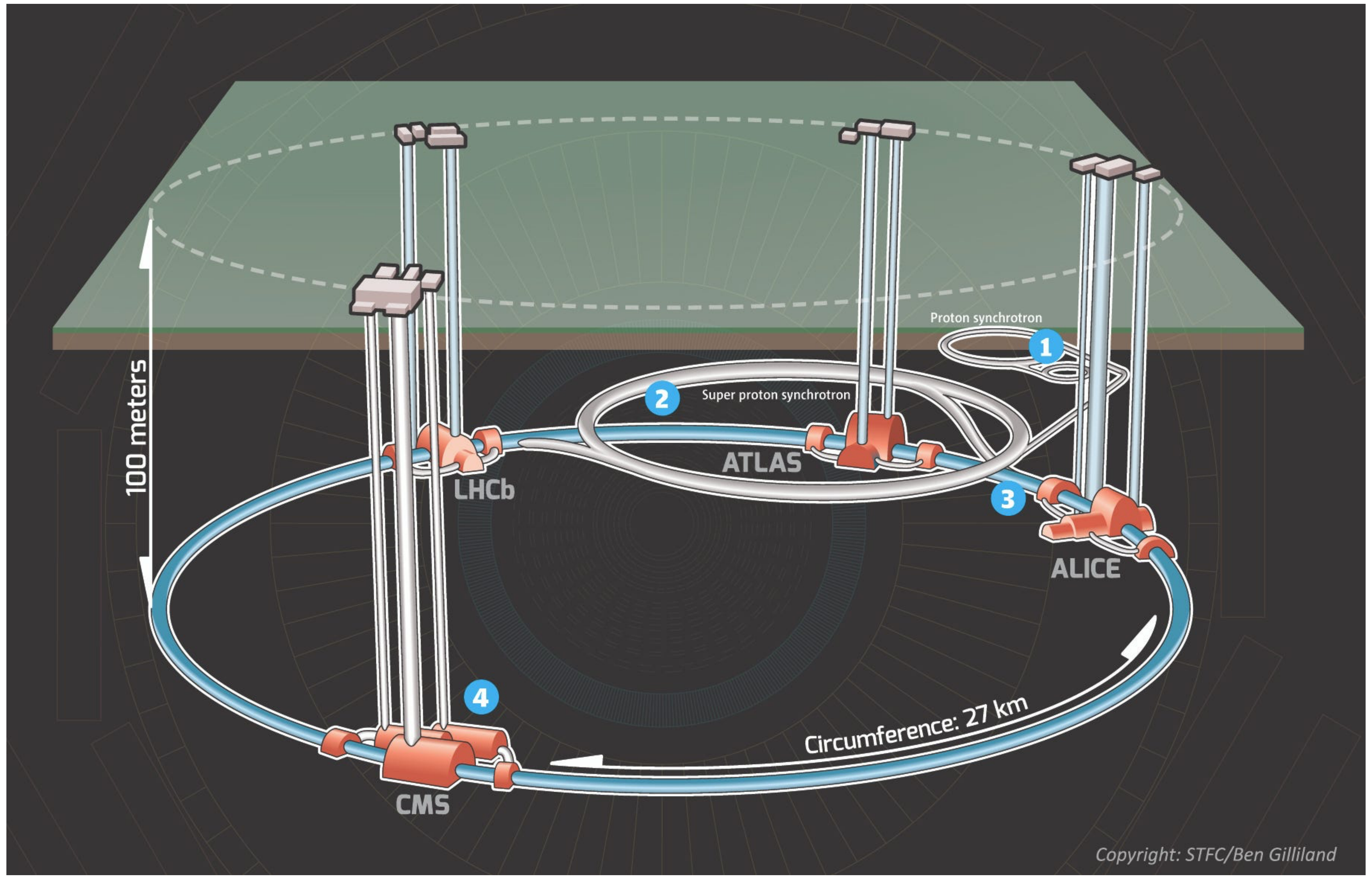

Underlying Events in Particle Physics

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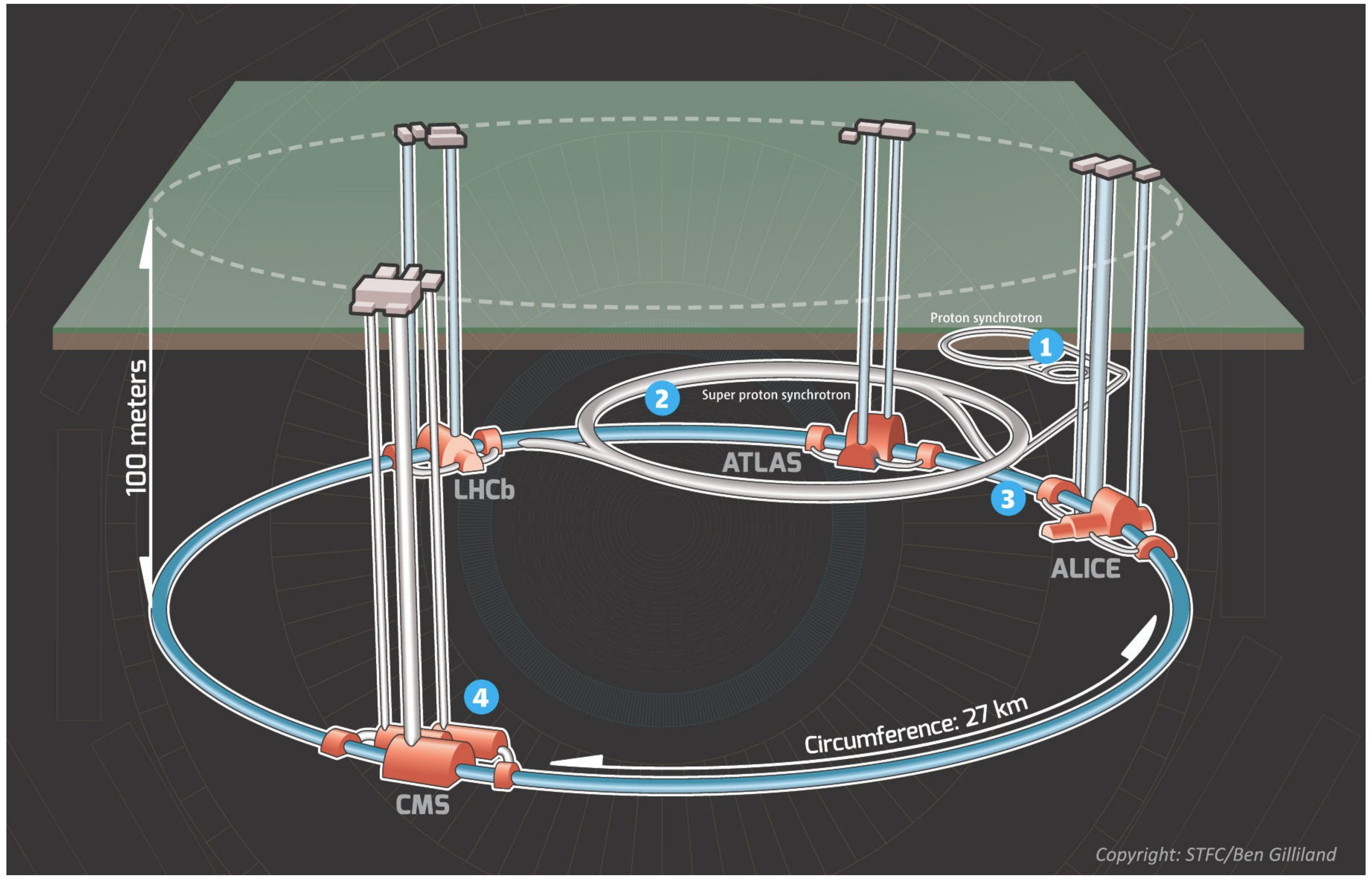
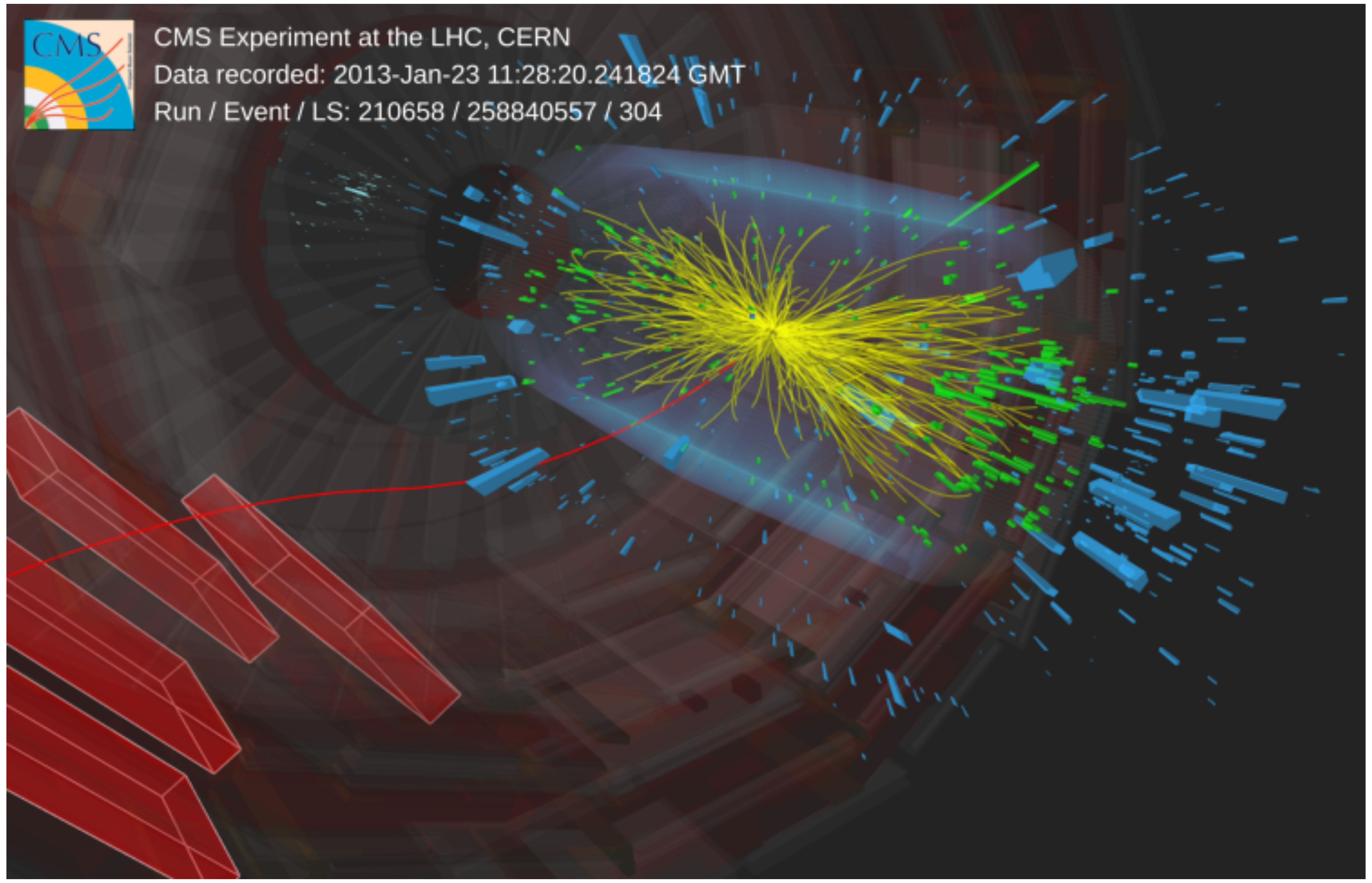
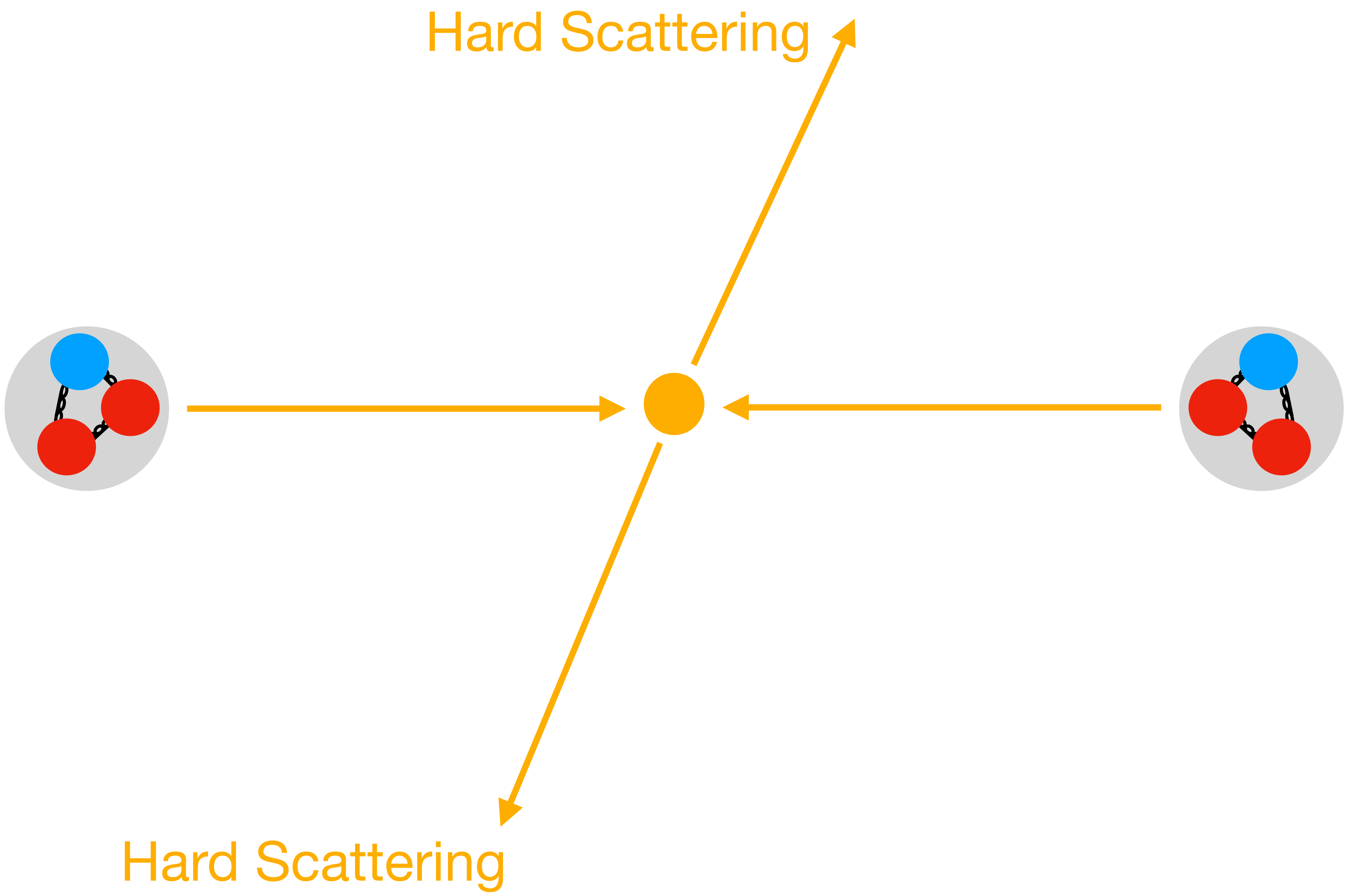




Underlying Events in Particle Physics

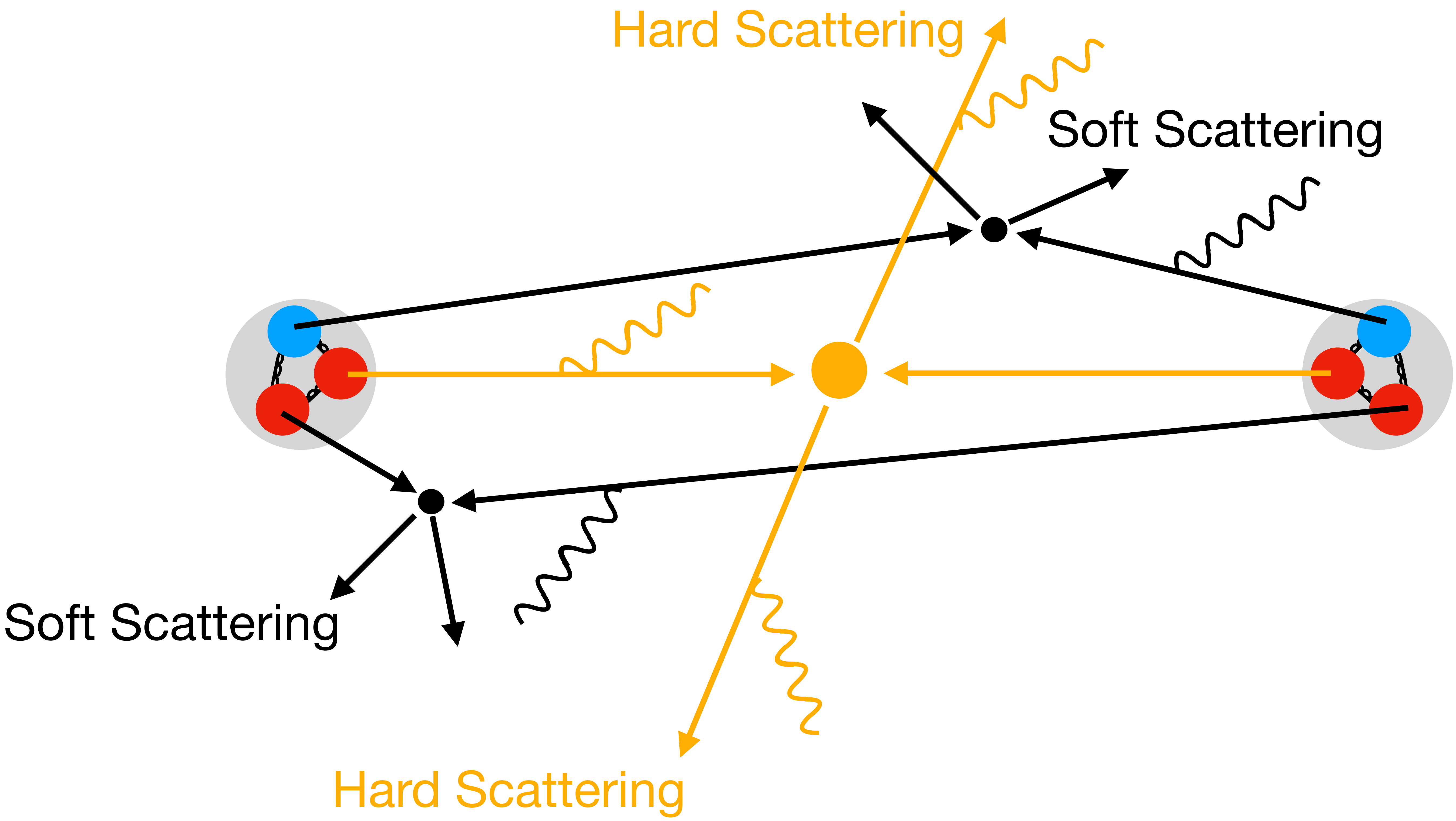
Idealized collision

Underlying Events in Particle Physics



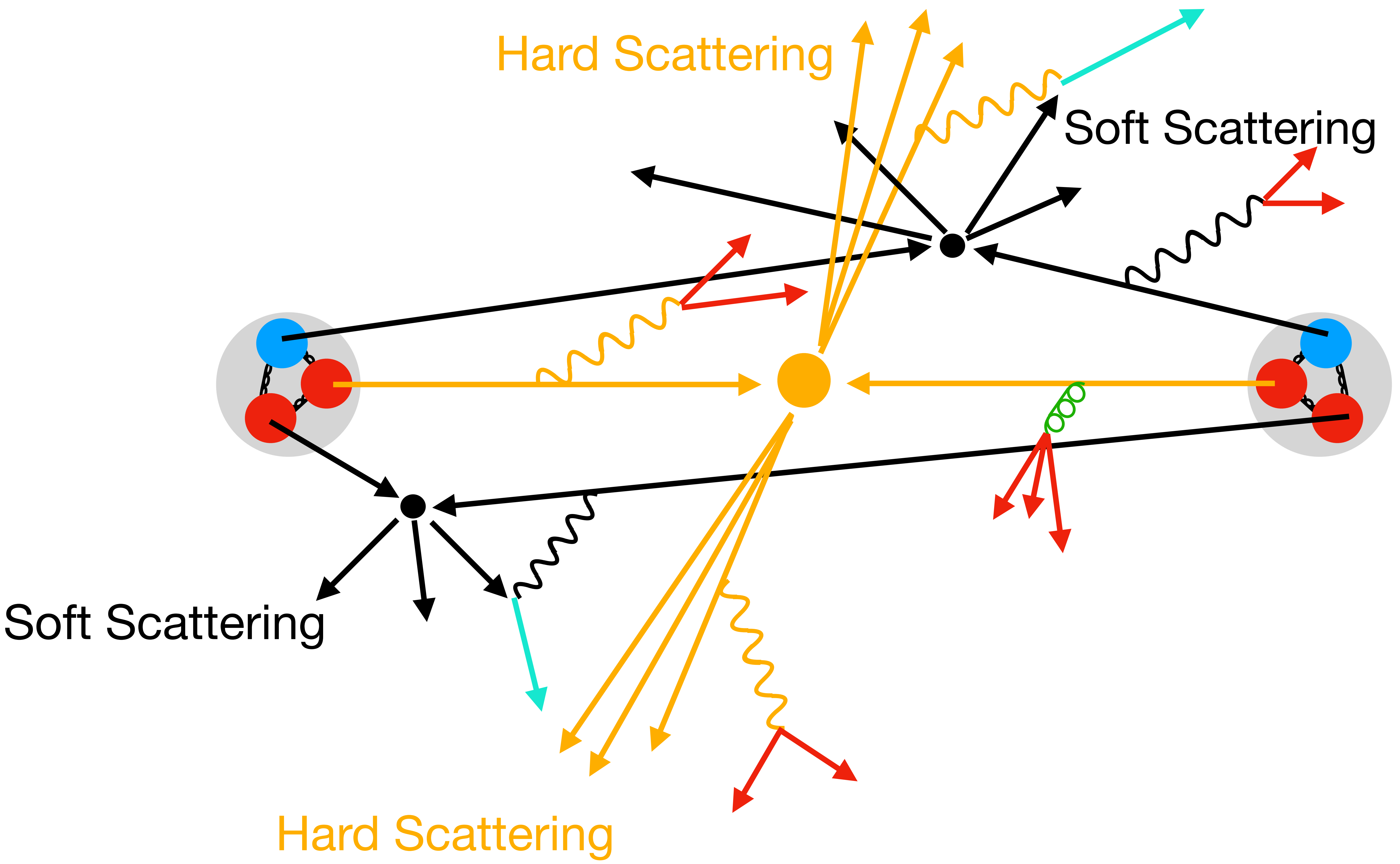
Idealized collision

Underlying Events in Particle Physics



More Realistic collision

Underlying Events in Particle Physics

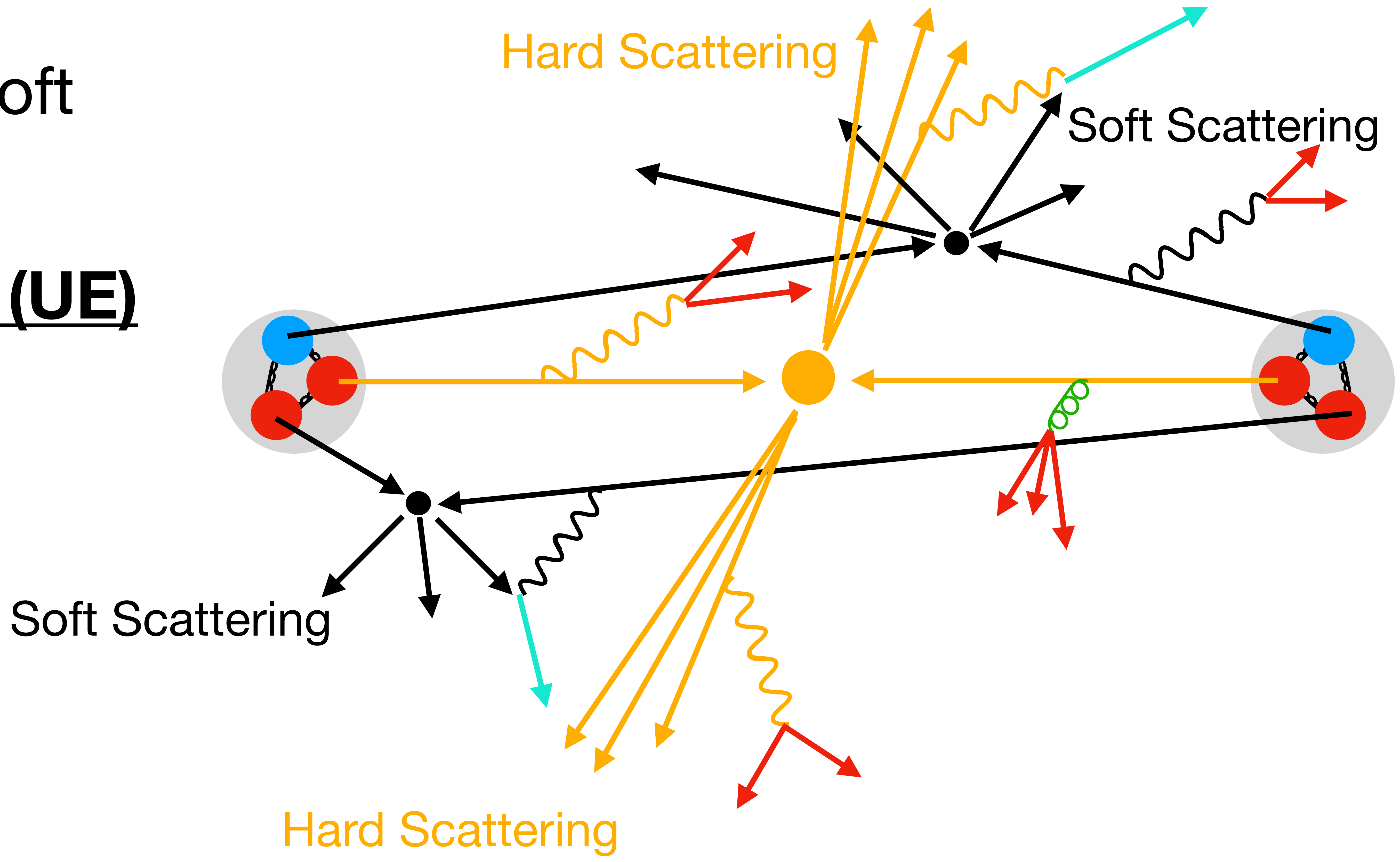


Even More Realistic collision

Underlying Events in Particle Physics

Overall we want to characterize these soft scattering events

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



Even More Realistic collision

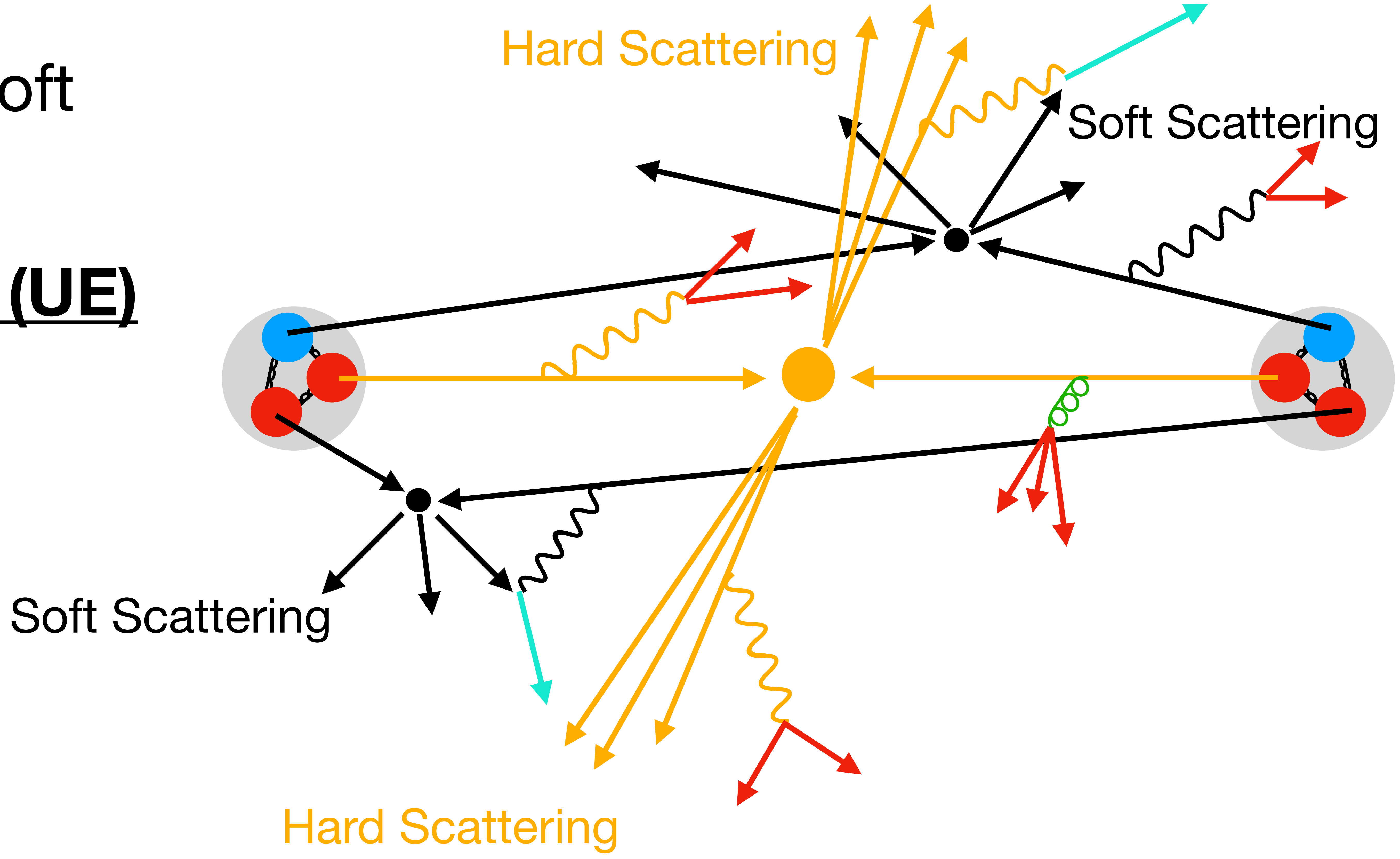
Underlying Events in Particle Physics

Overall we want to characterize these soft scattering events

- Also known as **Underlying Events (UE)**

Often times these events are heavy suppressed

- Particle multiplicity
- Low momentum



Even More Realistic collision

Underlying Events in Particle Physics

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?

Even More Realistic collision

Underlying Events in Particle Physics

In this study,

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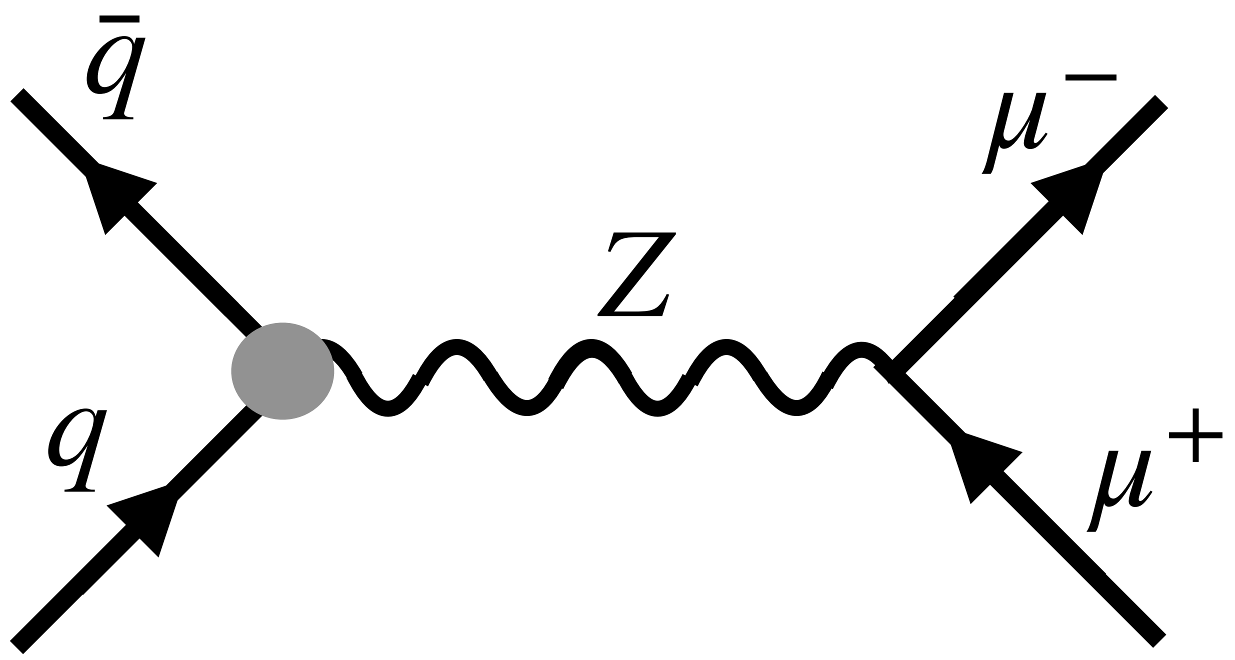
Can we use ML to predict properties of the hard scatter using the UE?

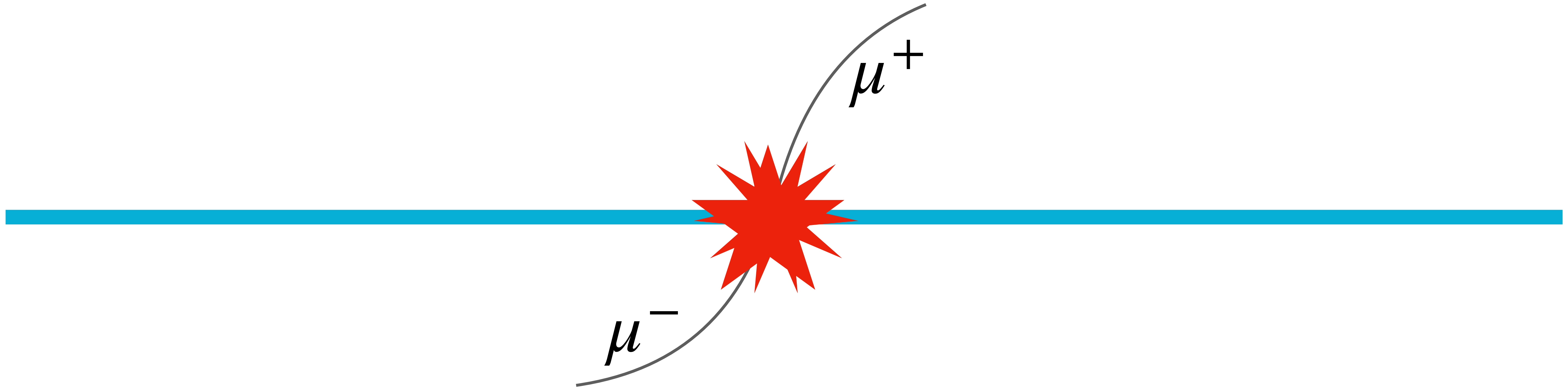
If yes then we can use this to constrain various aspects of interesting physics. (Z-mass, W-mass…etc)

Even More Realistic collision

Underlying Events in Particle Physics



No Jets!



$Z \rightarrow \mu^+\mu^-$ ***Feynman Diagram***

Data Collection and Processing

Data Collection and Processing

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

Raw CMS Detector Hits → Reconstruction → Analysis Object Data (AOD) → MiniAOD → NanoAOD

Data Collection and Processing

```
root://eospublic.cern.ch//eos/opendata/cms/derived-data/PFNano/29-Feb-24/SingleMuon/Run2016G-UL2016_MiniAODv2_PFNanoAODv1/240207_205649/0000/nano_data2016_1.root
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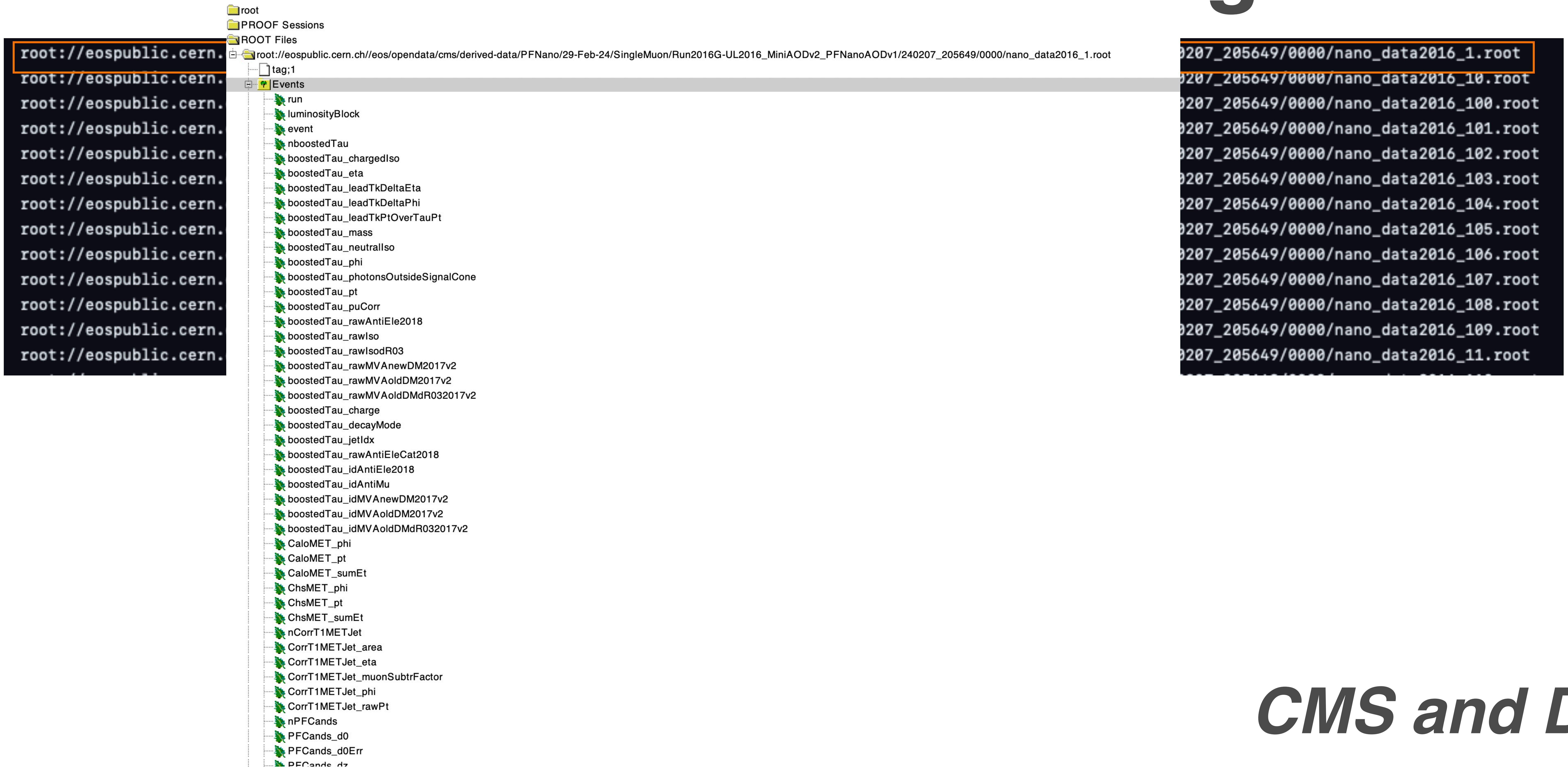
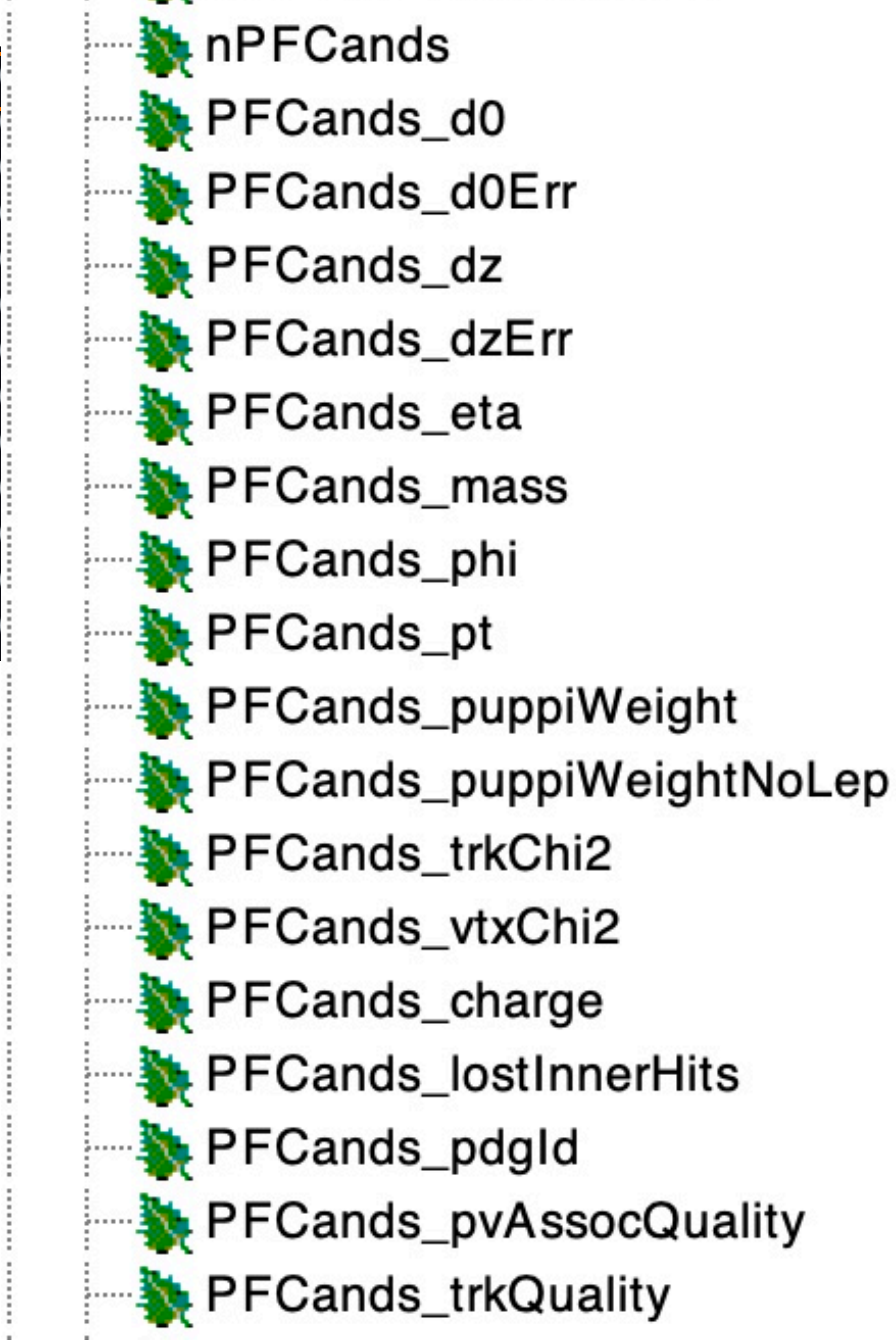
CMS and Data

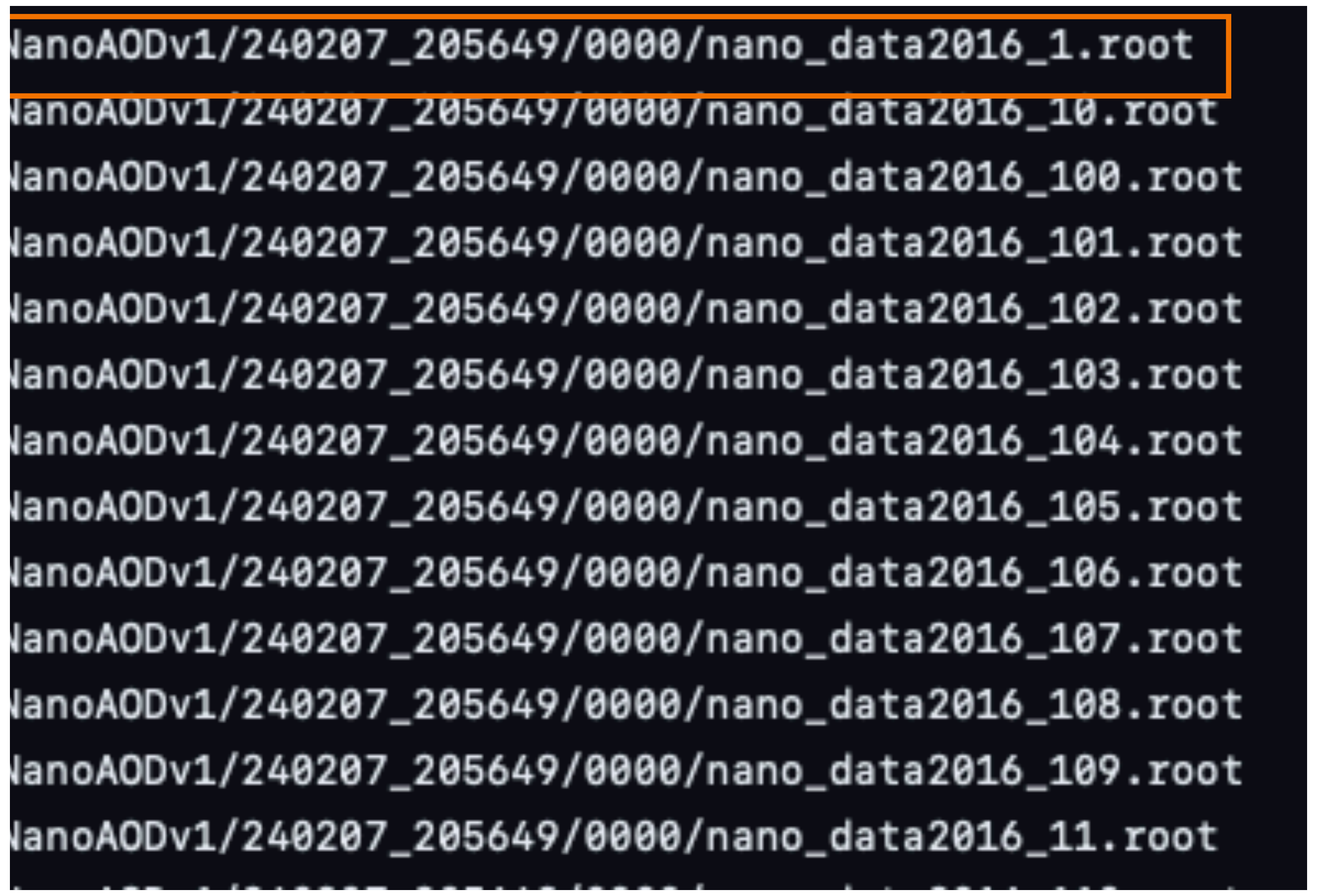
Data Collection and Processing



CMS and Data

Data Collection and Processing





We only care about the Particle Flow Candidates (PFCands).

CMS and Data

Data Collection and Processing

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.

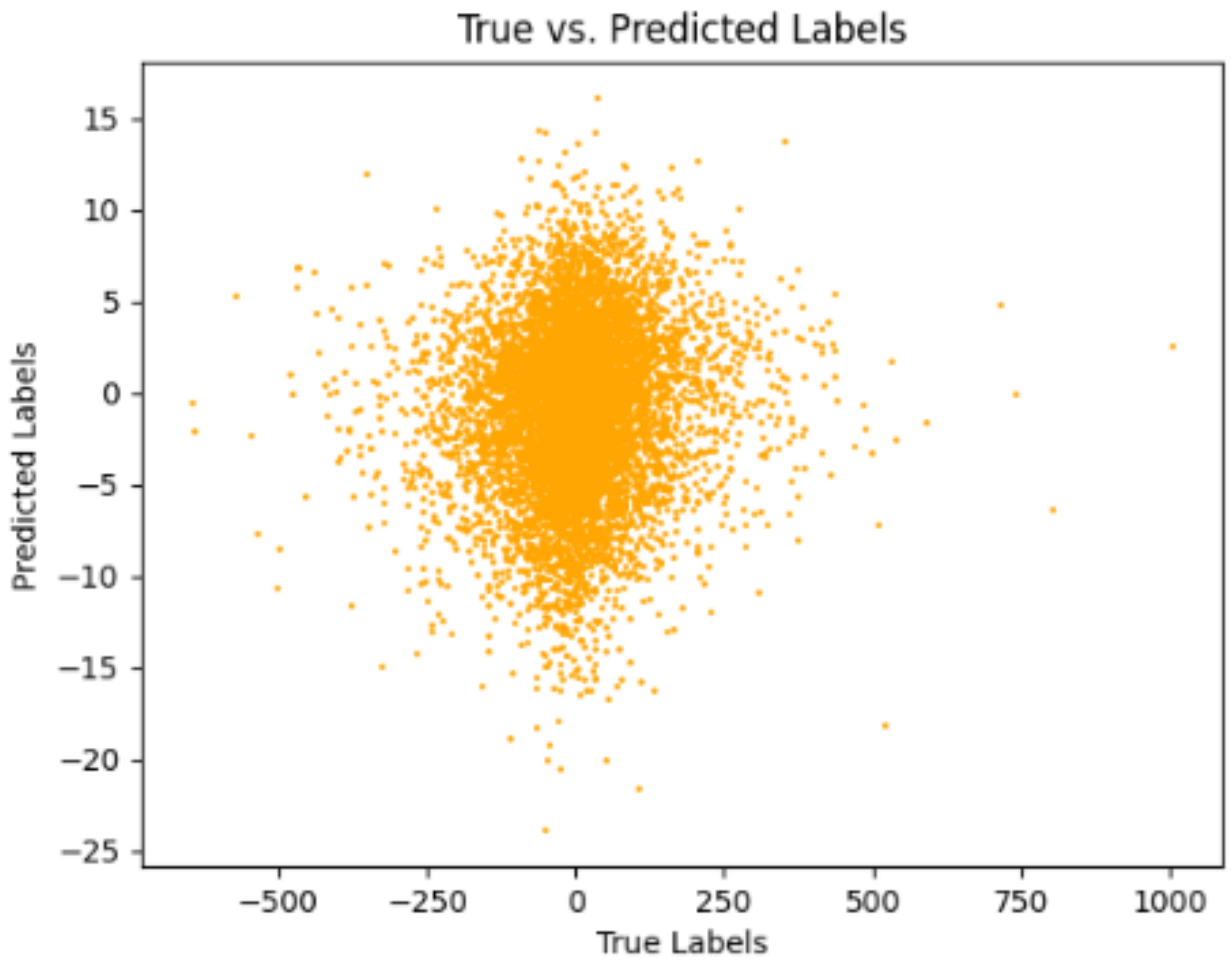
```
model = tf.keras.Sequential([
    tf.keras.layers.Dense(10, activation='relu'),
    tf.keras.layers.Dense(100, activation='relu'),
    tf.keras.layers.Dense(10, activation='relu'),
    tf.keras.layers.Dense(1)
])
```

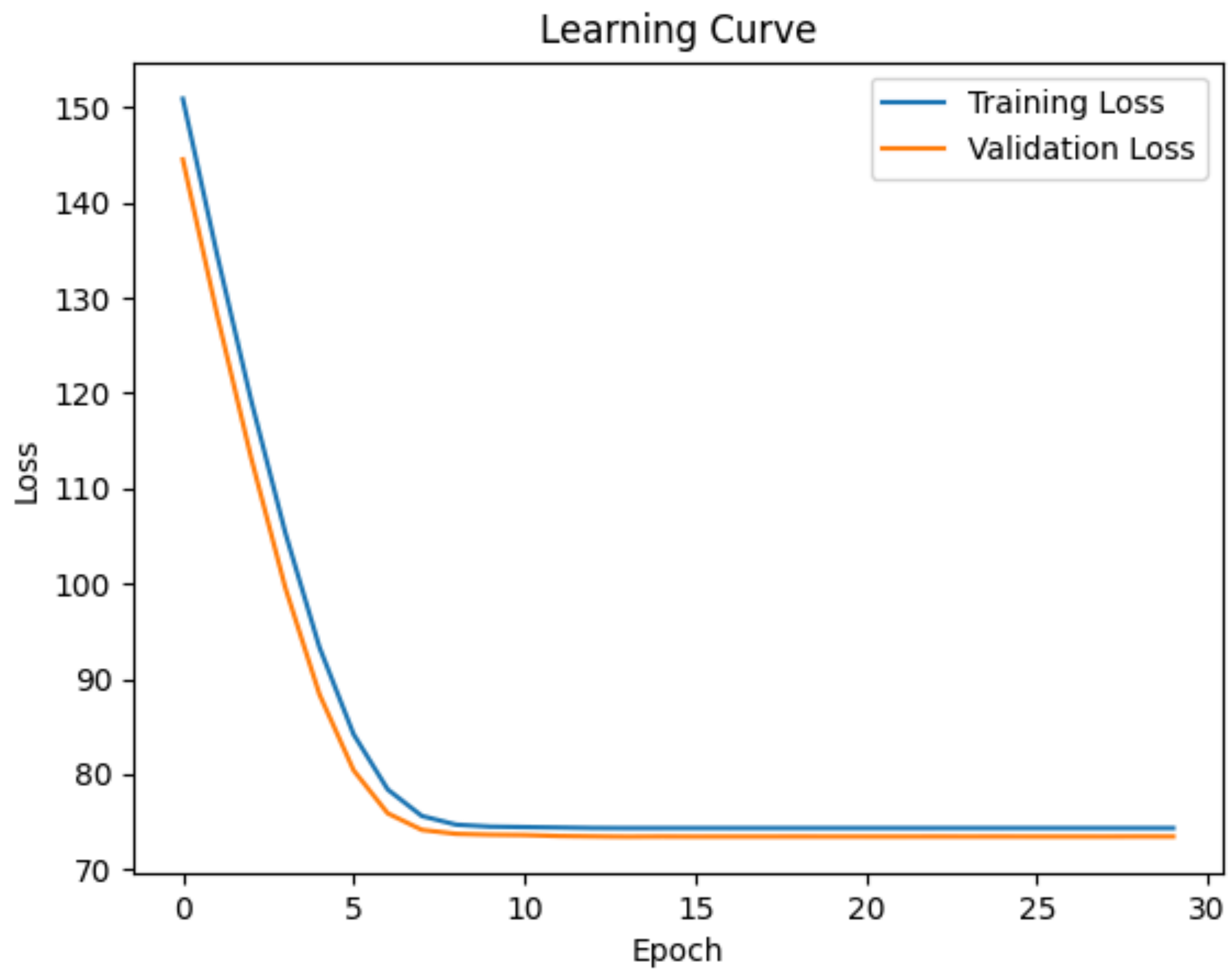
Labels: Muon Pz calculated with TLorentz Vectors

Features: Non Muon Pz calculated using TLorentz Vectors

Final Model

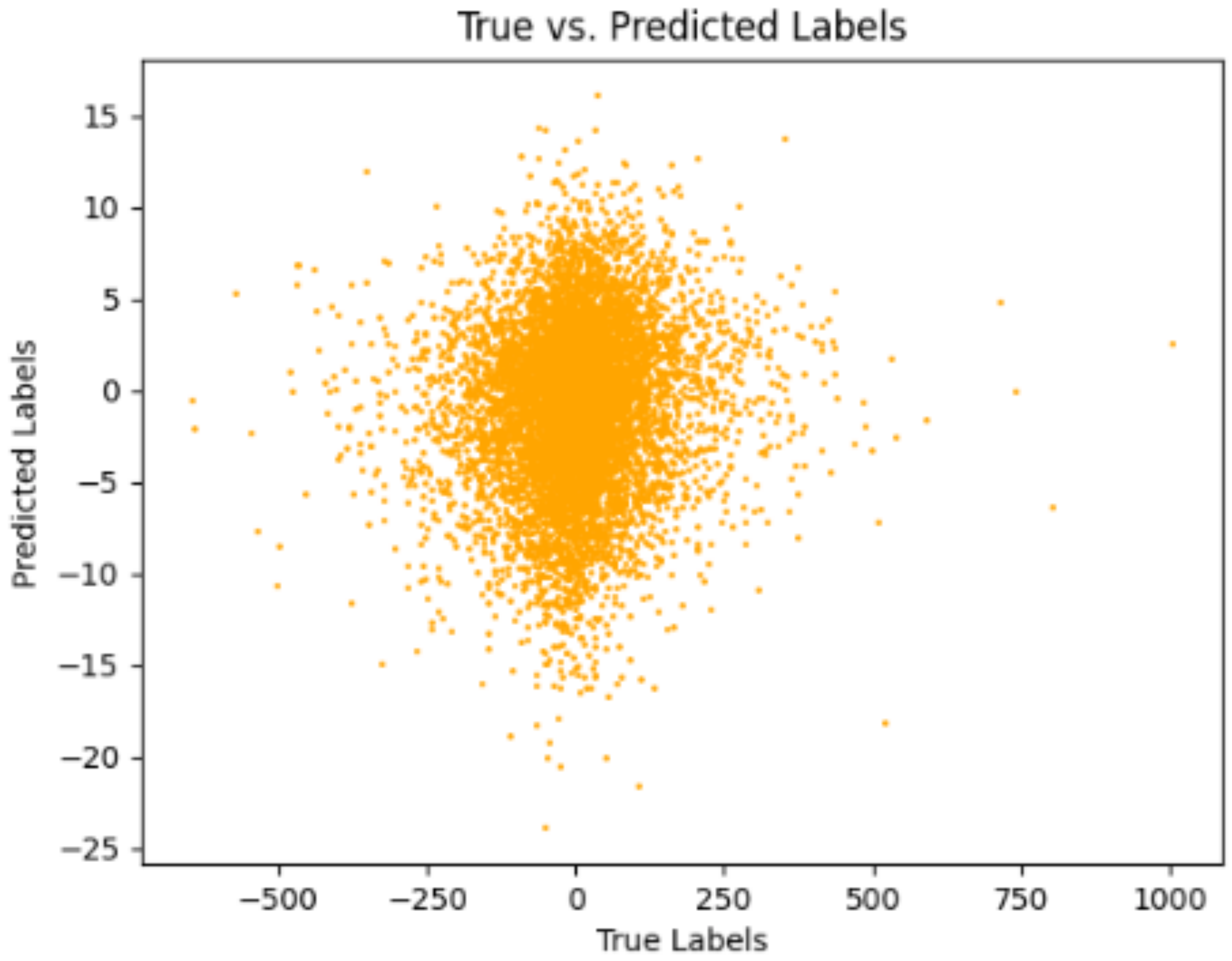
Final Results and Discussion

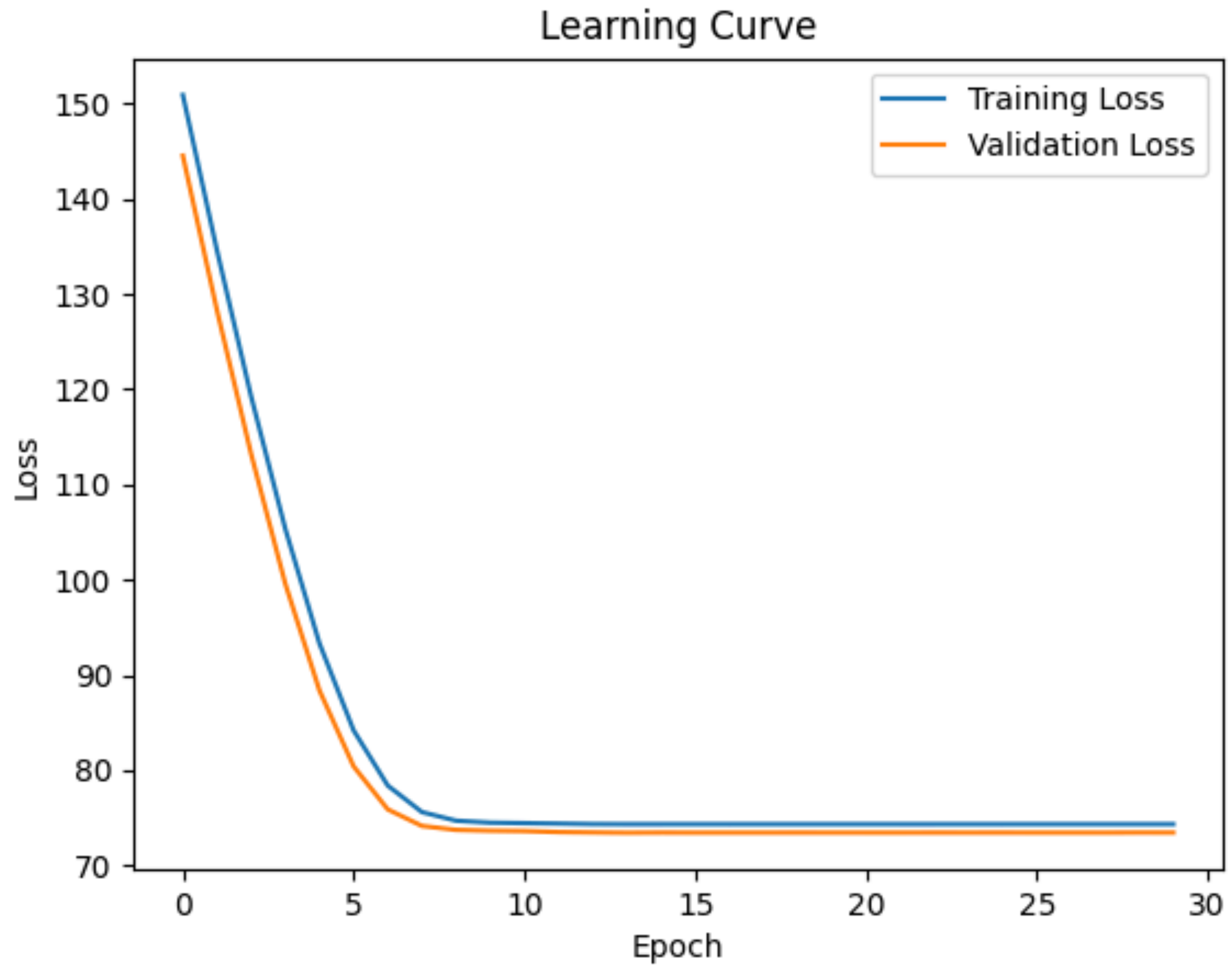




Final Results

Final Results and Discussion



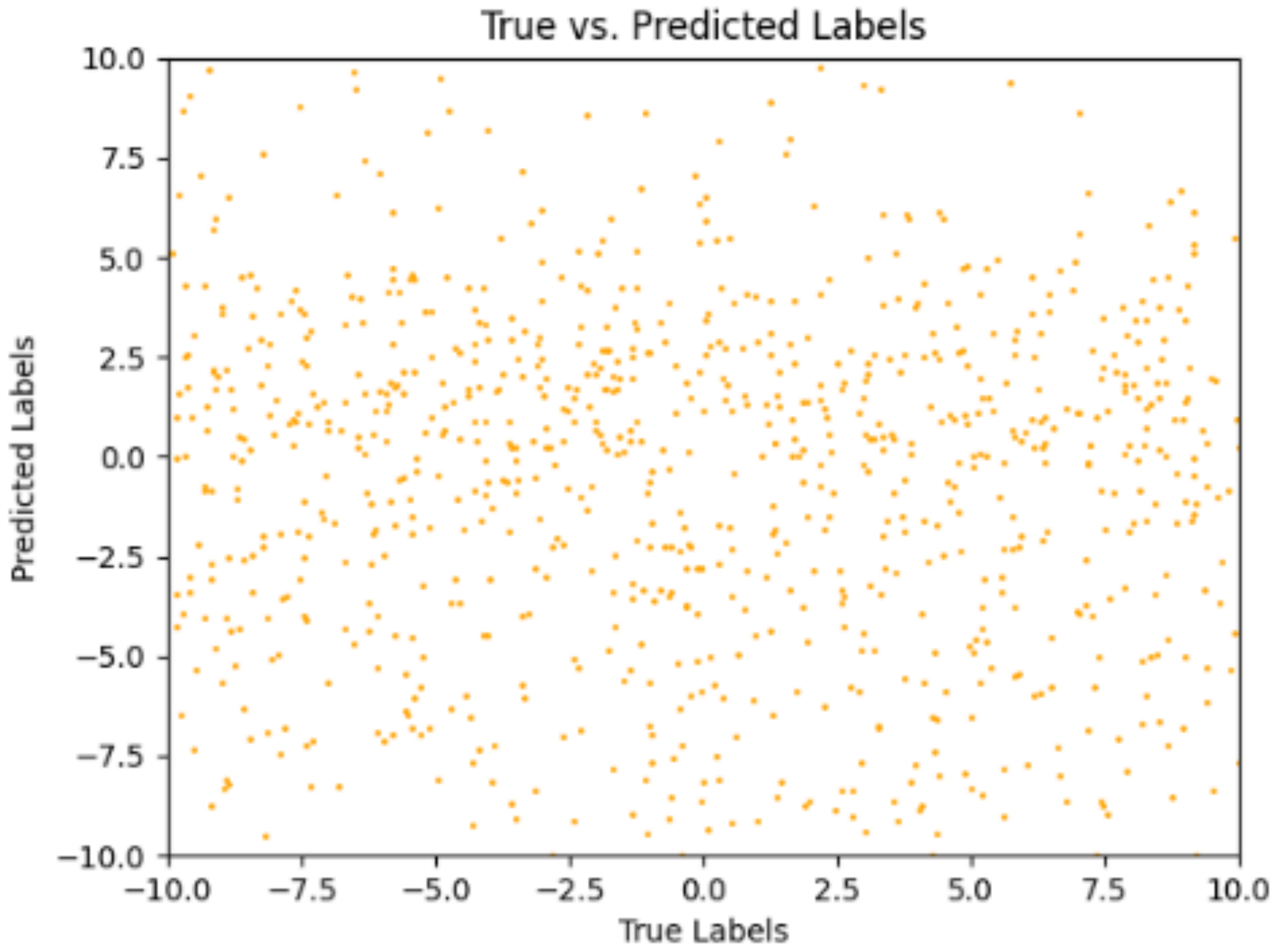


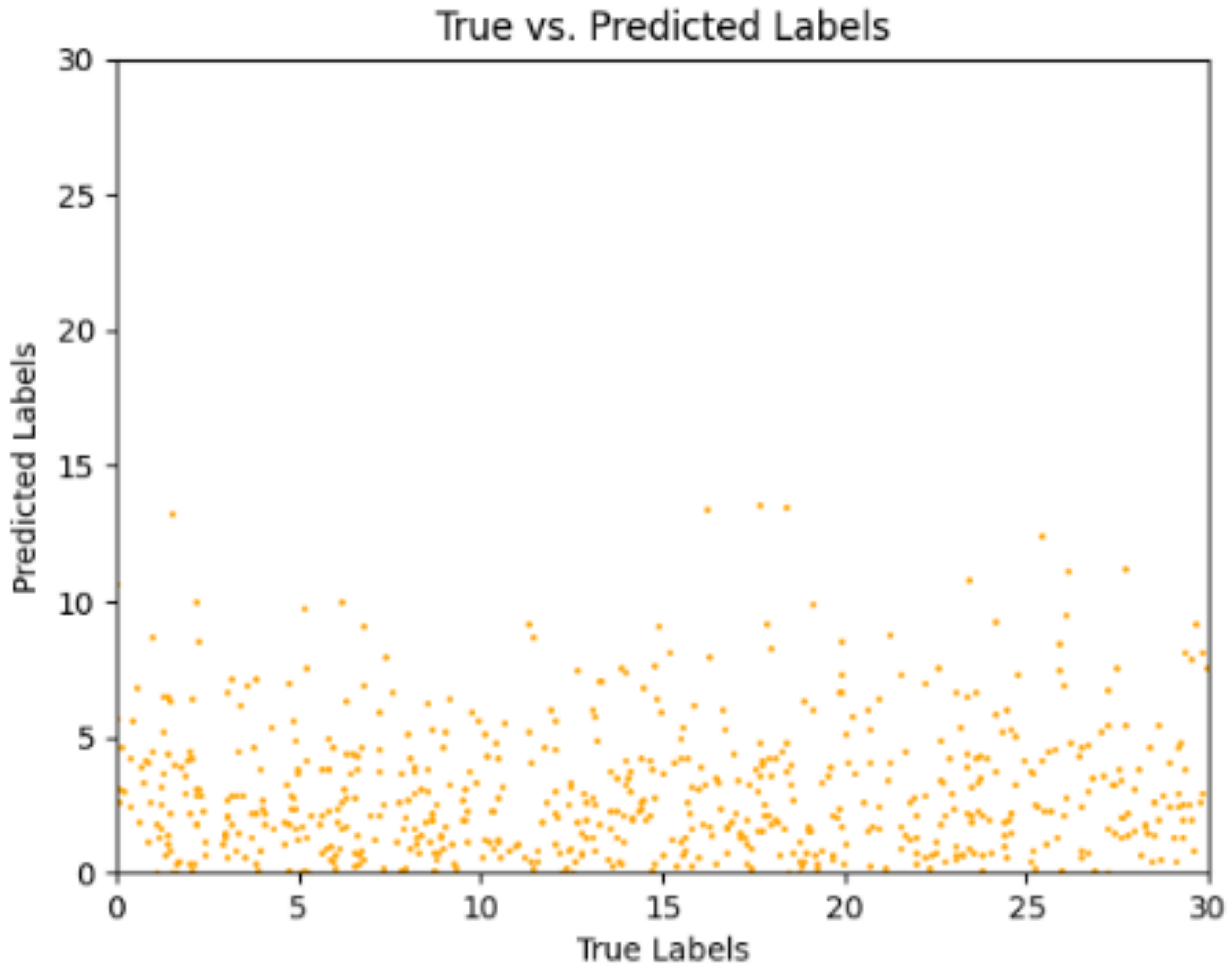
Perhaps there is a underlying linear relationship?

Final Results

Final Results and Discussion

Unfortunately no, or at least not seen initially





Final Results

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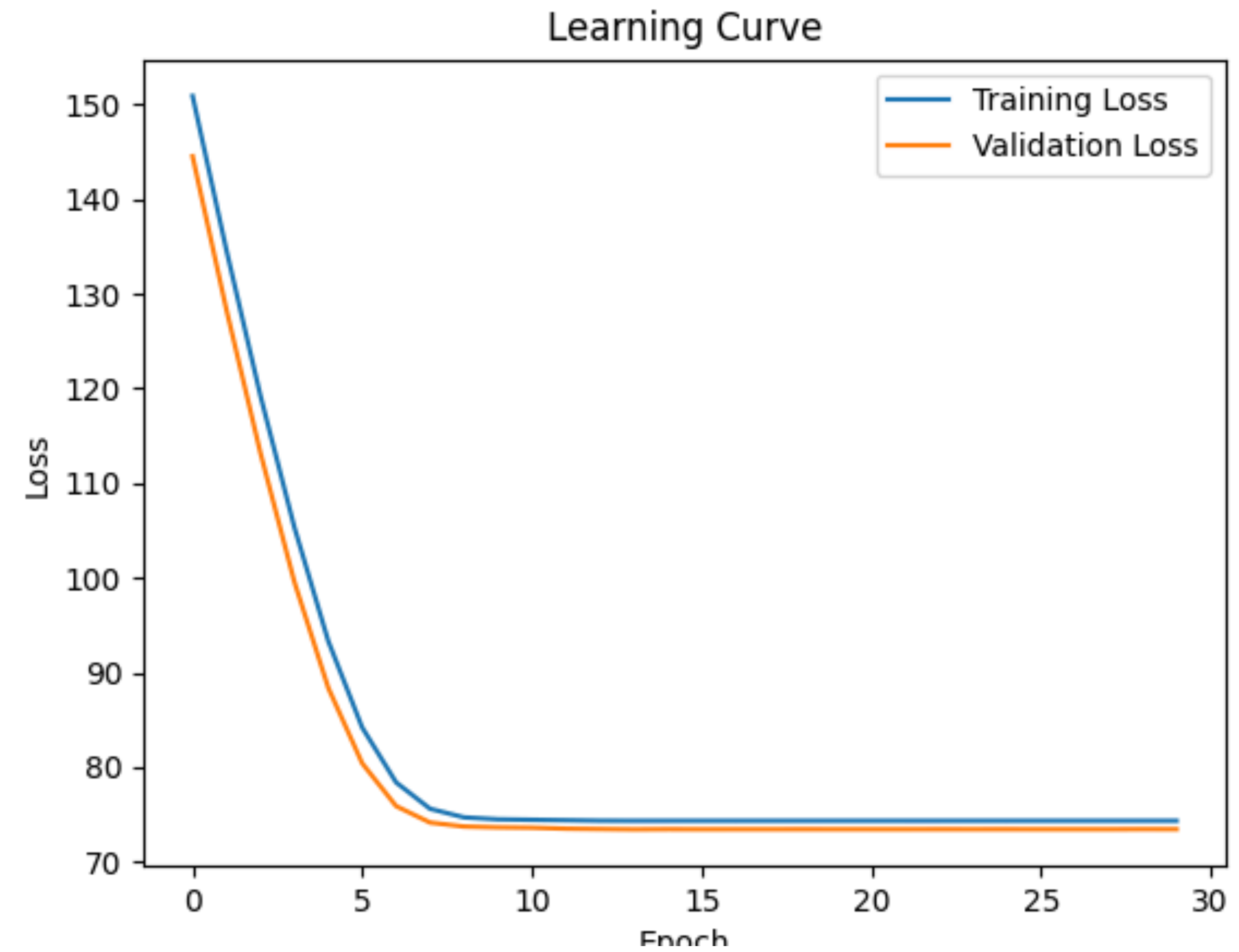
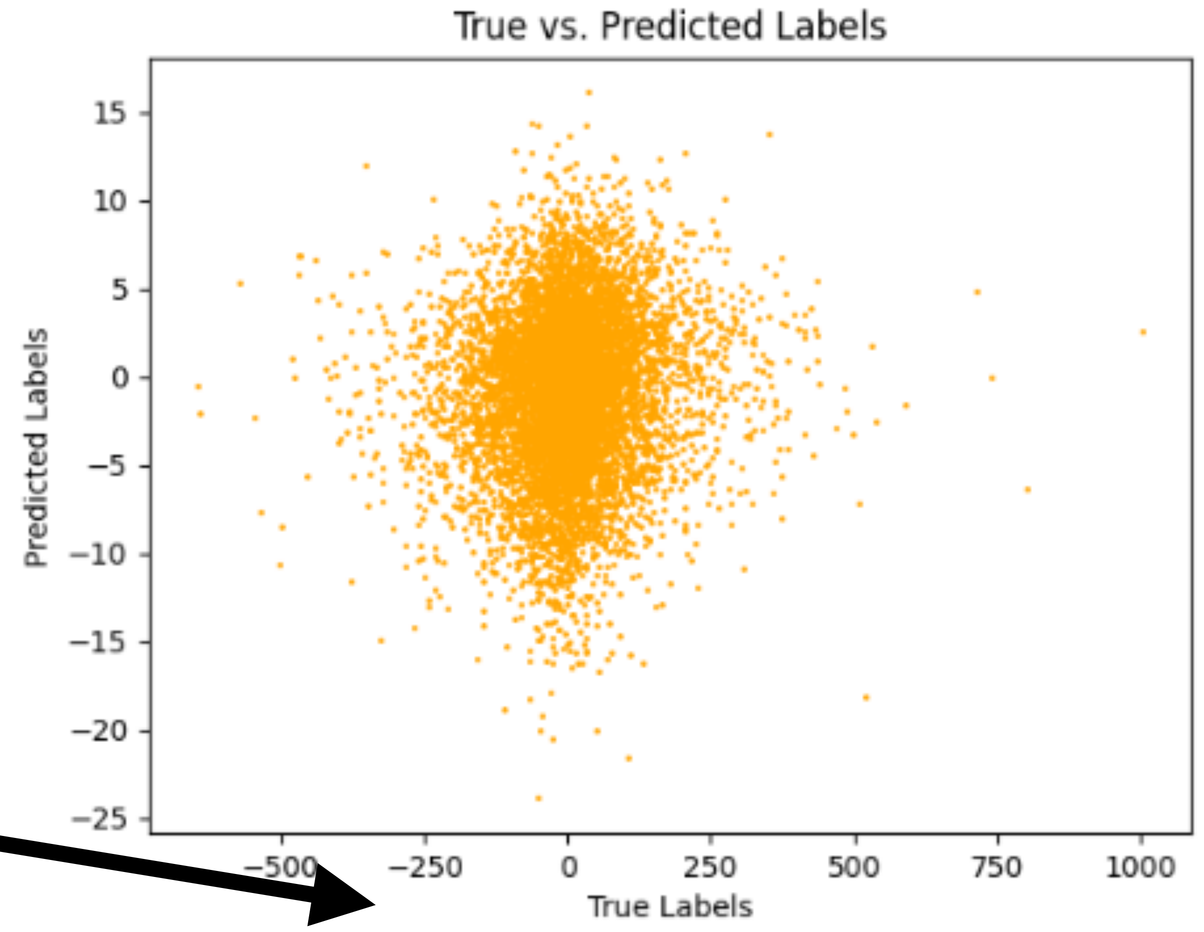


Based on these losses it seems the model is learning to some extent

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

Could be the True Labels (Muon Pz).

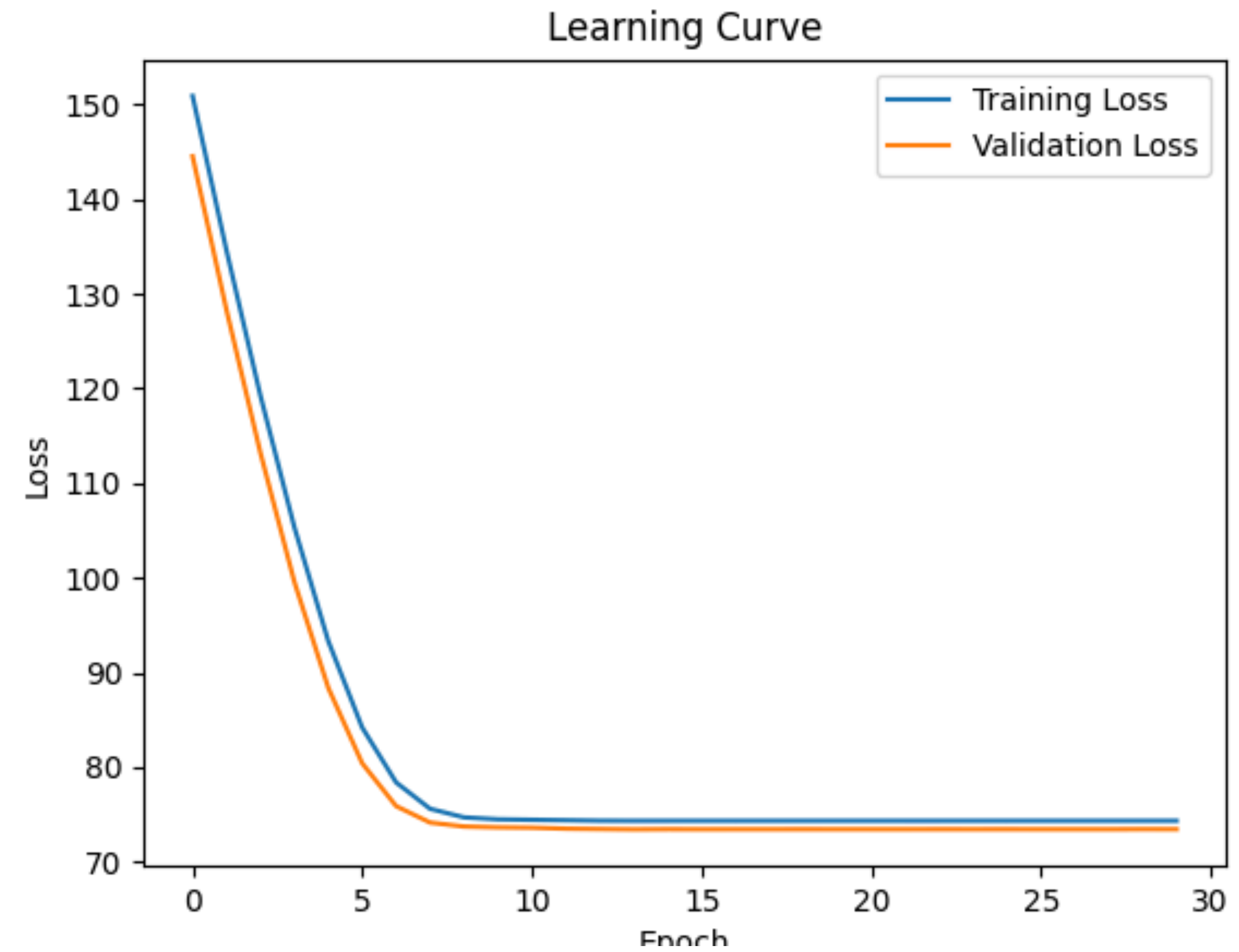


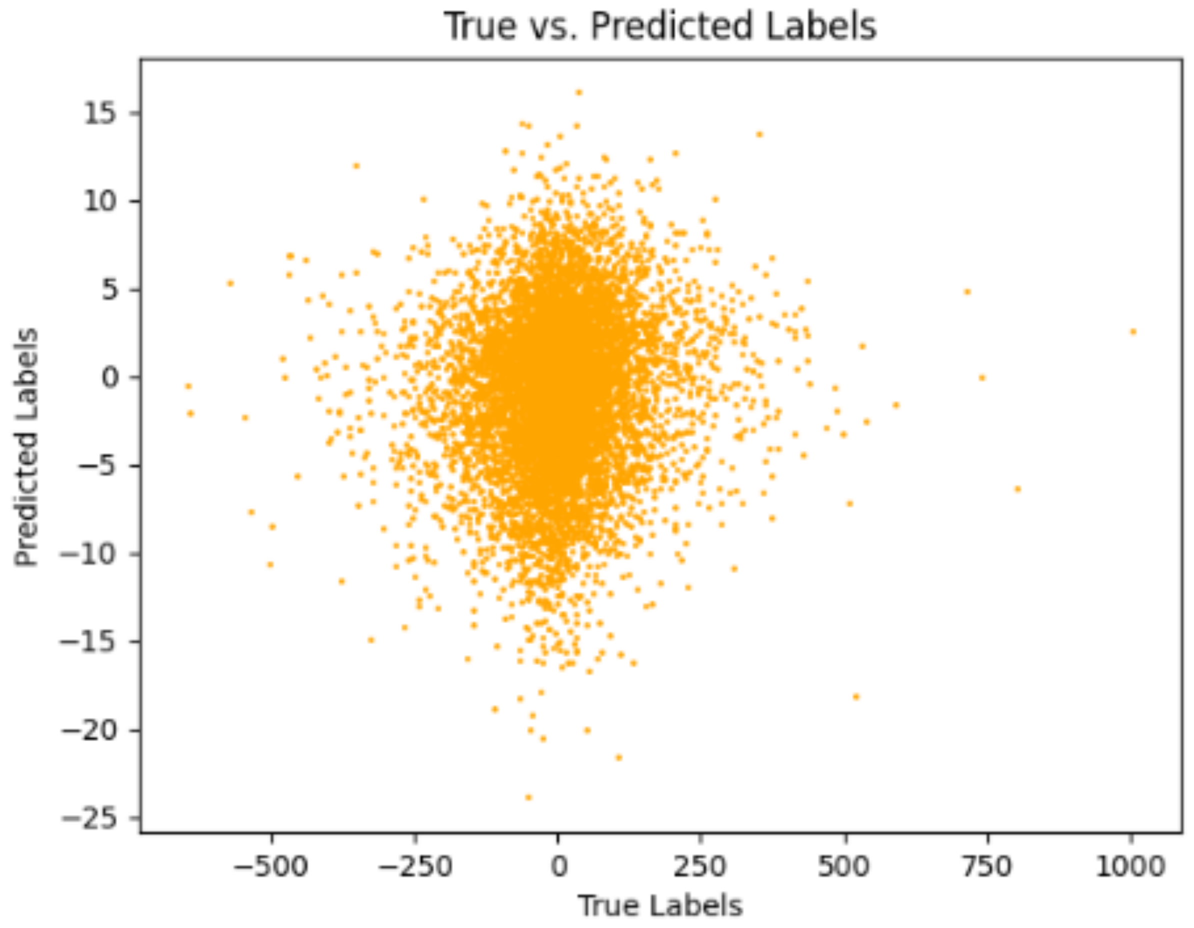
Final Results

Final Results and Discussion

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



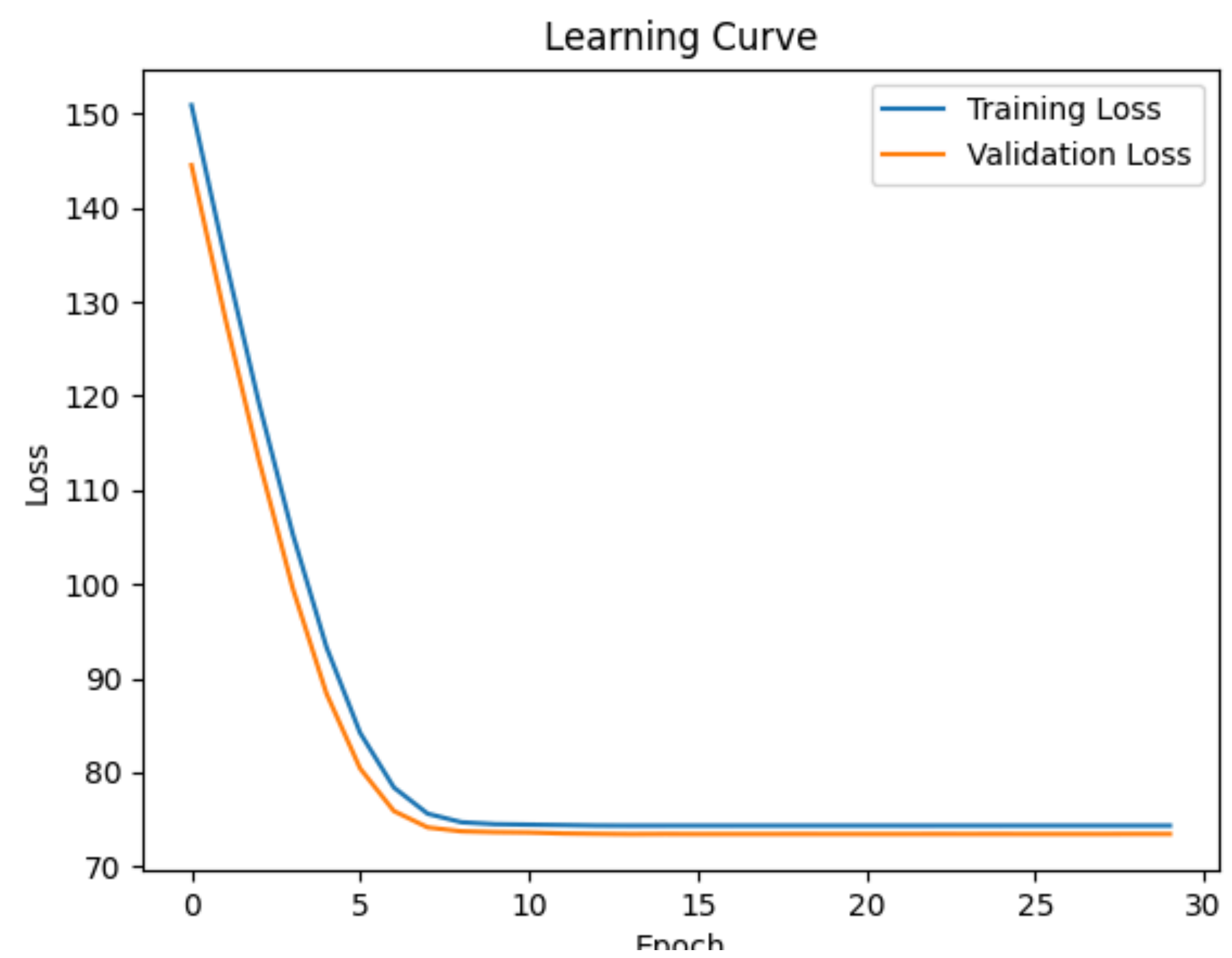


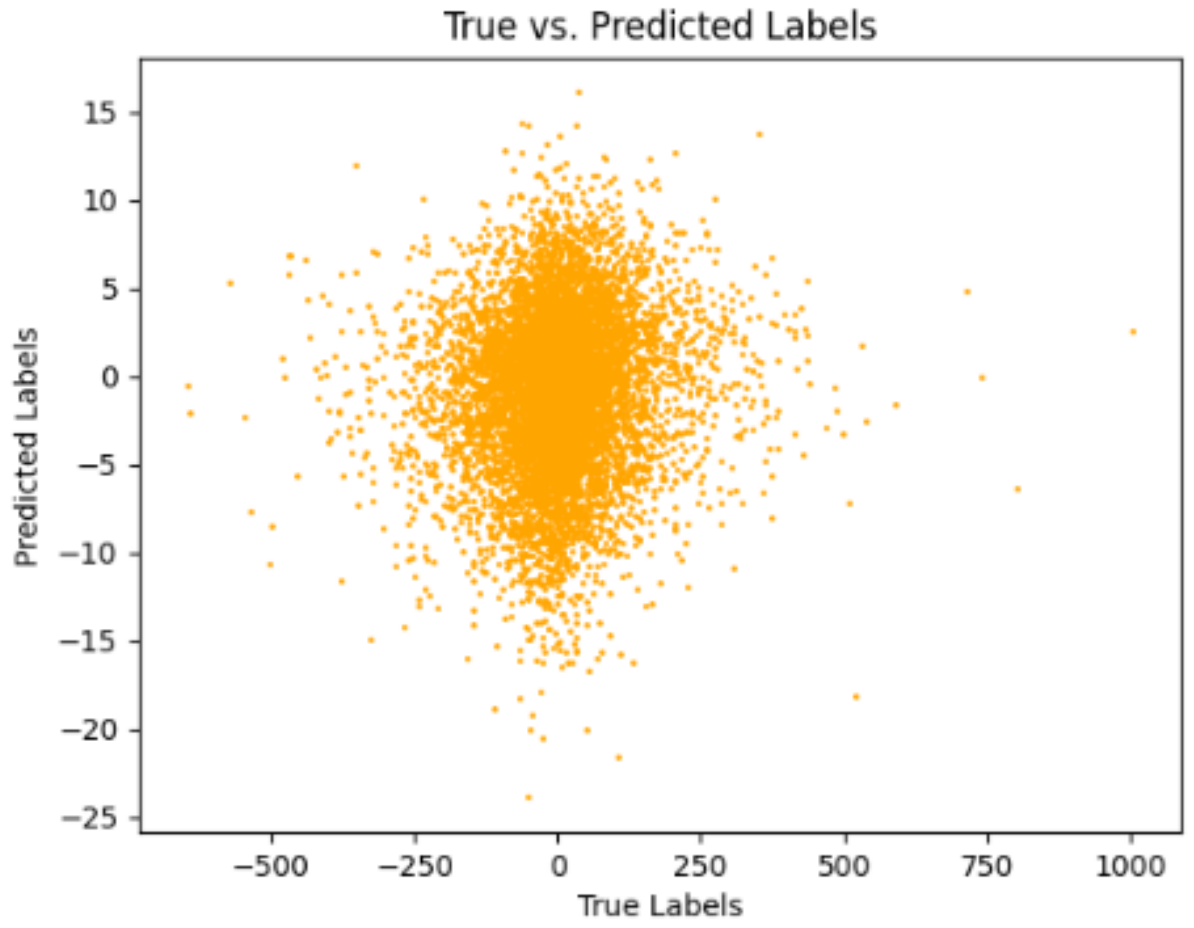
Final Results

Final Results and Discussion

Thanks again for the semester!

Fantastic class and I will see everyone around the Department!





Final Results