# Lab 5
# PHYS434 A

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## 1 Overview of the ATLAS Experiment at LHC

The ATLAS detector, one of the two general purpose detectors at the LHC, is used as the example to demonstrate the general concept of collider detectors. The Higgs bosons can be detected by the ATLAS detector from proton-proton scattering at the Large Hadron Collider (LHC). The Higgs itself does not have that long life period in order for it to hit the ATLAS detector, but its child particles can. ATLAS detector has spatial resolving capabilities, which basically means that it can trace the jets back to their original starting place. Jets are referring the collimated stream of particles created from the decay of a certain particle. The jets, which ATLAS detector is interesting to measure, are called "Higgs-jets", which occur after Higgs Boson decays into a bottom-anti-bottom pair.
The detector is made by superconducting solenoid magnets, several kinds of calorimeters, and a semiconductor tracker. Outside of that is a muon chamber, which includes three toroids. The calorimeters are spread out over different range of angles around the center axis of the trajectory. All of the calorimeters cover a pseudo-rapidity of $|\eta| < 4.9$, which is defined by

$$\eta = -ln[tan(\frac{\theta}{2})]$$

where $\theta$ is the angle above the x-axis, which points towards the center of LHC ring. Moreover, the muon spectrometer measures the deflected muons over $\eta < 2.7$.

## 2 Simulated Data

Simulations that simulate real data are made of both the signal and the background, in order to optimize discrimination. The signal here is the Higgs Boson decaying into a bottom quark and an anti-bottom quark. Both the Higgs data and the background, QCD data are simulated with 14 parameters, the main two that discussed in the ATLAS article, are $Pt$ and $\eta$.

## 3 Reconstruction

There are several ways that ATLAS reconstructs the produced data. The first is jet labeling. Below are two examples of jets:

**Truth Jets** Truth Jets carry the true information about the jets in simulations. Since they rarely leave energy deposit in the calotimeters, they do not include low-interacting particles like muons.

**Calorimeter Jets** Calorimeter Jets are made by re-clustering parts of the original jets and removing everything with a transverse momentum, Pt, that is less than 5% of their parent's jet Pt.

In simulations, the truth jets are reconstructed by using the same method as real data. All other types are made from the simulations and then analyzed.
What's more, muons and photons are reconstructed differently. Muons are reconstructed from measurements of the spectrometer, and having $Pt > 5GeV$ and $|\eta|$ ¡ 2.5 in order to be triggered. Photons are measured from energy deposit clusters in the electromagnetic calorimeters, and are labeled differently depending on whether

or not they can be traced back. The phrotons must have $E_T > 175GeV$ and $|\eta| < 1.37or1.52 < |\eta| < 2.37$ to be sent to analysis.

# 4 Trigger

Triggering a Higgs jet candidate relies largely on Pt. There is an angular separation between a Higgs decay that depends on the transverse momentum:

$$\triangle R \approx \frac{2m_H}{Pt}$$

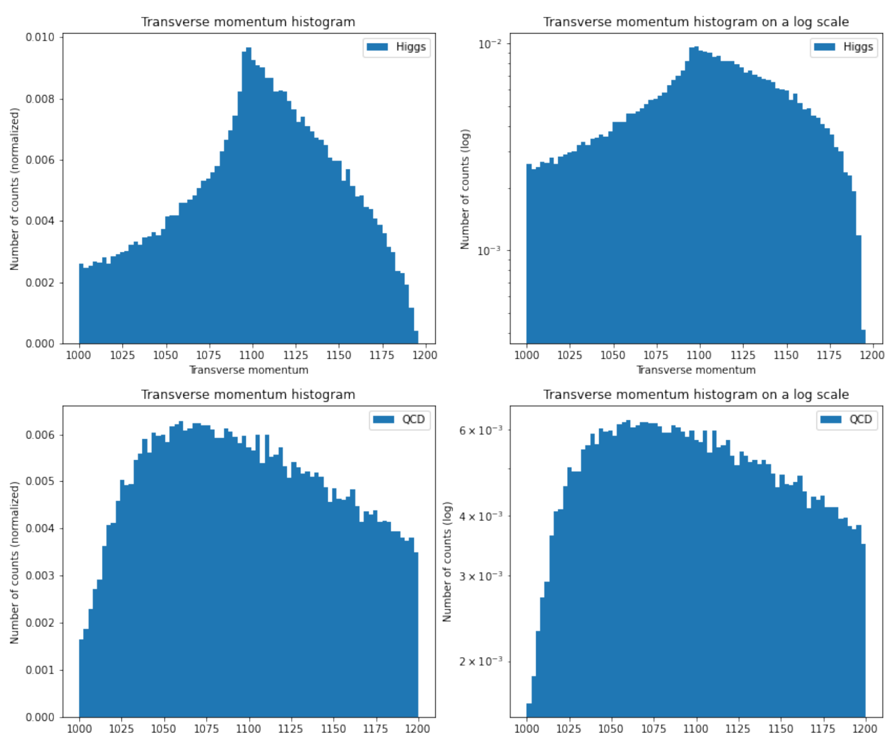
$m_H$ here is the mass of the Higgs boson. Higgs with Pt ¿ 250 GeV and $|\eta| < 2.0$ are considered for analysis, and bottom quarks from the Higgs decay with Pt ¿ 5 GeV and $|\eta| < 2.5$ are triggered. In order to obtain a signal set, only the Higgs with the hightest Pt are used in order to reduce the systematic effects from initial state radiation.

# 5 Rough Data Analysis

The transverse momentum is the main way of tagging jets, hence, we want to plot histograms for both Higgs and background, QCD data. Next, we can compare Higgs with background to see what the major differences between them and similar places between them

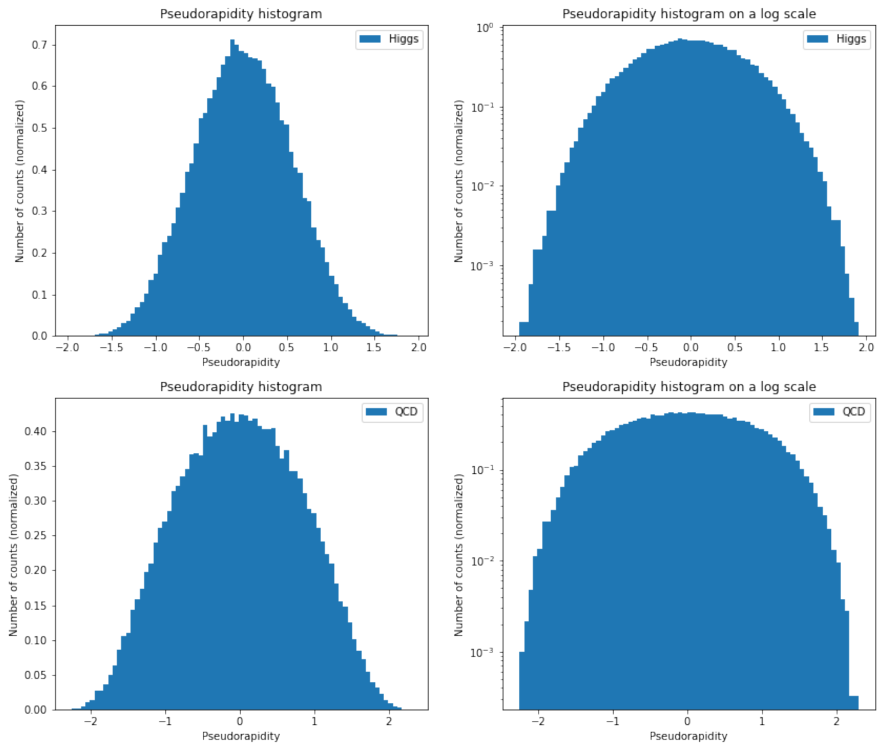
## 5.1 Transverse Momentum

The Higgs data has a very sharp distribution at the center position. On the other hand, QCD data does not have that. However, the probability of finding signals for both of them has only 0.004 differences. Therefore, it is hard to figure out a signal, in our case, Higgs boson.



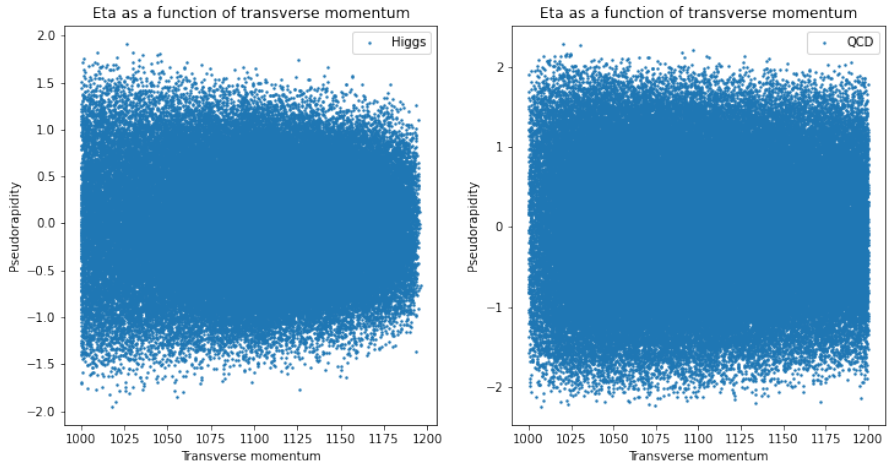
## 5.2 Pseudo rapidity

For pseudo-rapidity, the distributions for both datasets are very similar to each other. In fact, the Higgs data is more likely to be a Guassian distribution. However, since they are very similar, it is hard looking for a signal. Thererfore, we need to look at other attributes.




## 5.3 transverse momentum VS Pseudo rapidity

Before directly plotting the rest of the dataset, the relationship between $\eta$ and $P_t$ is the first thing I want to see, since it can help us to distinguish signals.




As we can see from the graph above, the distribution for QCD is uniformly across the whole region of the dataset. On the other hand, the distribution for Higgs is narrowing down toward positive x-axis. In other word, the range of pseudorapidity decreases as the transverse momentum increases for Higgs dataset.

## 5.4 Rest of the Dataset

For this part, I am going to plot the rest of the data attributes as histograms to compare the background distribution. Before, plotting the data, there are some useful equations:

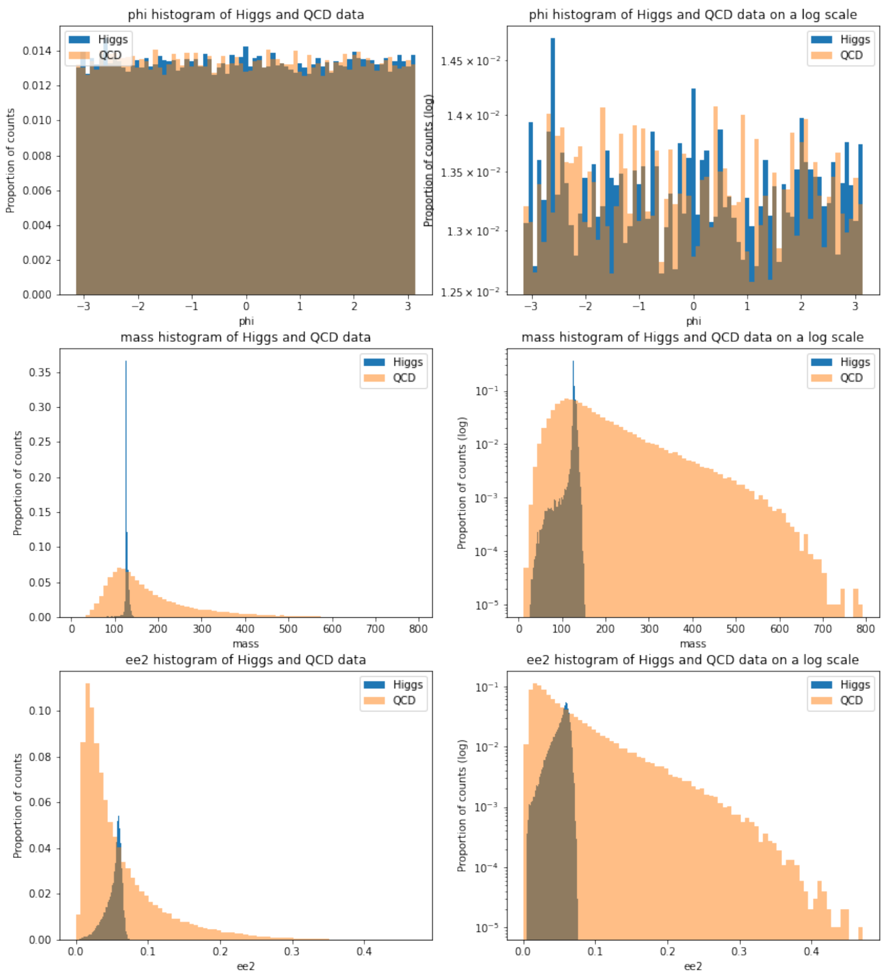
$$\triangle R = \sqrt{\triangle\eta^2 + \triangle\phi^2}$$

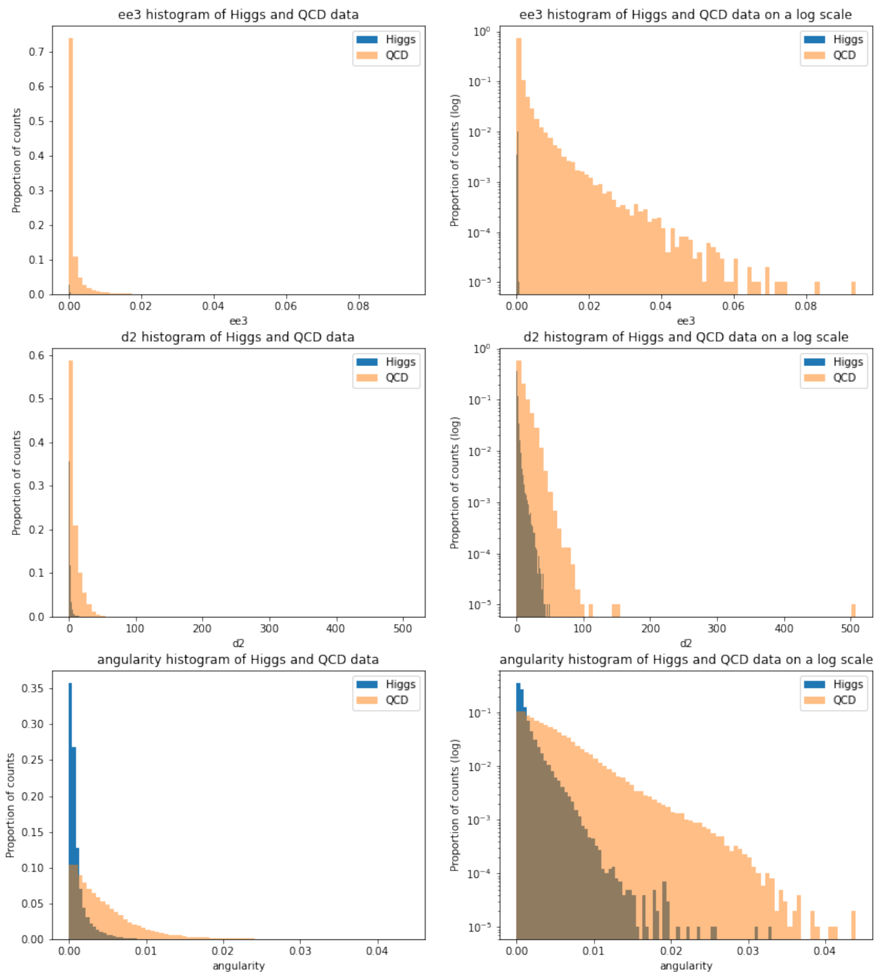
$$e_2 = \Sigma_{i<j\in J} P_T, iP_T, j\triangle R_{ij}\frac{1}{P_{T,J}^2}$$

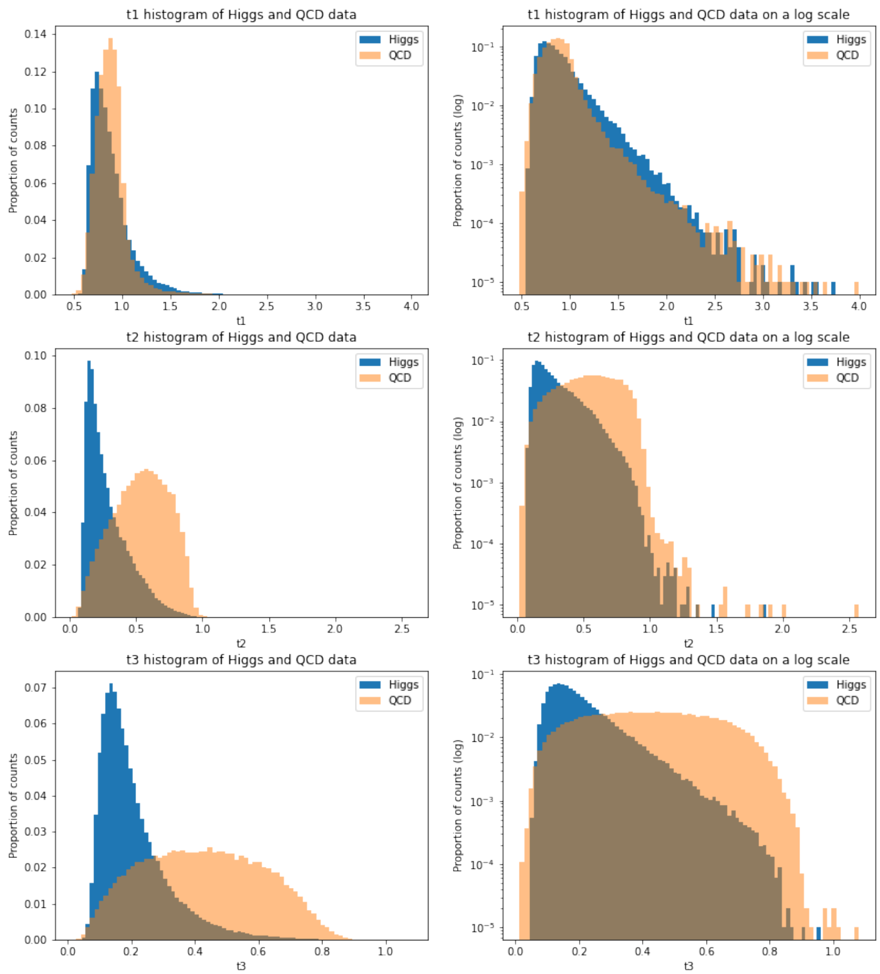
$$e_3 = \Sigma_{i<j<k\in J} P_T, iP_T, jP_T, k\triangle R_{ij}\triangle R_{ik}\triangle R_{jk}\frac{1}{P_{T,J}^3}$$

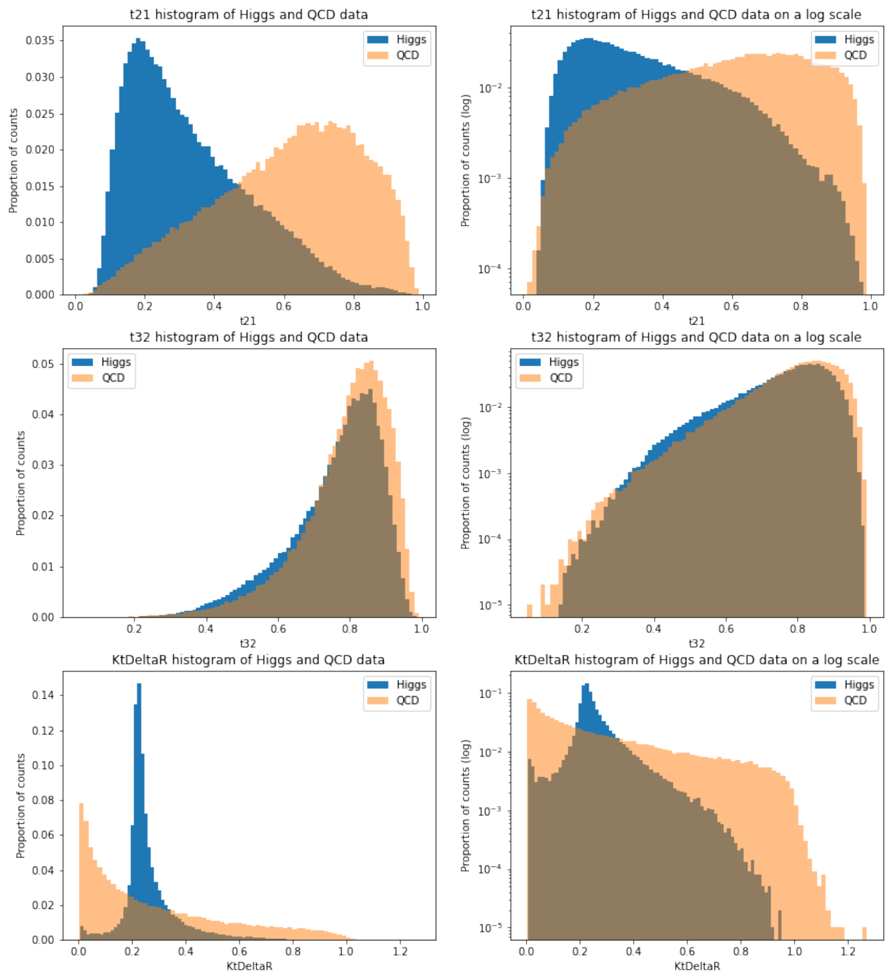
$$D_2 = \frac{e_2}{e_3}$$

Below are the plots.


phi histogram of Higgs and QCD data
phi histogram of Higgs and QCD data on a log scale
mass histogram of Higgs and QCD data
mass histogram of Higgs and QCD data on a log scale
ee2 histogram of Higgs and QCD data
ee2 histogram of Higgs and QCD data on a log scale
Higgs
QCD
Proportion of counts
Proportion of counts (log)
phi
mass
ee2


ee3 histogram of Higgs and QCD data
ee3 histogram of Higgs and QCD data on a log scale
d2 histogram of Higgs and QCD data
d2 histogram of Higgs and QCD data on a log scale
angularity histogram of Higgs and QCD data
angularity histogram of Higgs and QCD data on a log scale
Higgs
QCD
Proportion of counts
Proportion of counts (log)
ee3
d2
angularity


t1 histogram of Higgs and QCD data
t1 histogram of Higgs and QCD data on a log scale
t2 histogram of Higgs and QCD data
t2 histogram of Higgs and QCD data on a log scale
t3 histogram of Higgs and QCD data
t3 histogram of Higgs and QCD data on a log scale
Higgs
QCD
Proportion of counts
Proportion of counts (log)
t1
t2
t3




Only $\phi$ distribution seems to be uniform ans same for both Higgs and QCD, which makes sense since the jets would be independent with $\phi$ direction. The mass, $e_2, e_3, and D_2$ distributions all have a greater spread in the QCD data, which covers most of the part for Higgs data. This makes sense because QCD data has multiple particles, thus, it has a greater variety of measured masses and a wider array of energy. Moreover, the shapes of each parameters for QCD and Higgs are sometimes same ans sometimes different. It indicates that the mean value of the Higgs and QCD data may differ.