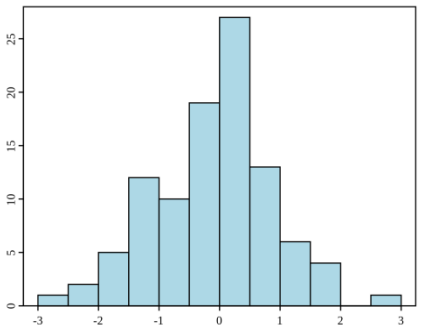
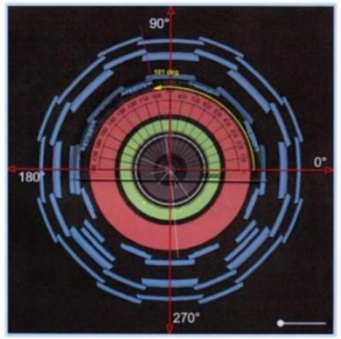
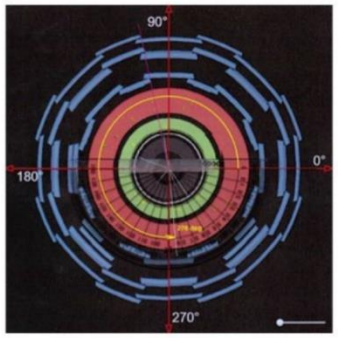
HISTOGRAMS: UNCERTAINTY



Measure angles in ATLAS





INTRODUCTION

- **Particle physicists rely on histograms** to find new particles and to measure the characteristics of particles.
- Sometimes the **probability** of a particular interaction occurring is **small**.
- In such cases, particle physicists collect **huge amounts of data** in the hope of finding this interaction as a small bump in the histogram.
- This activity builds histogram skills required in many of the other activities in the **Data Activities Portfolio**.
- In this activity, students will **construct histograms, identify the best value to represent the data, and report the uncertainty in their answers.**

LEARNING OBJECTIVES

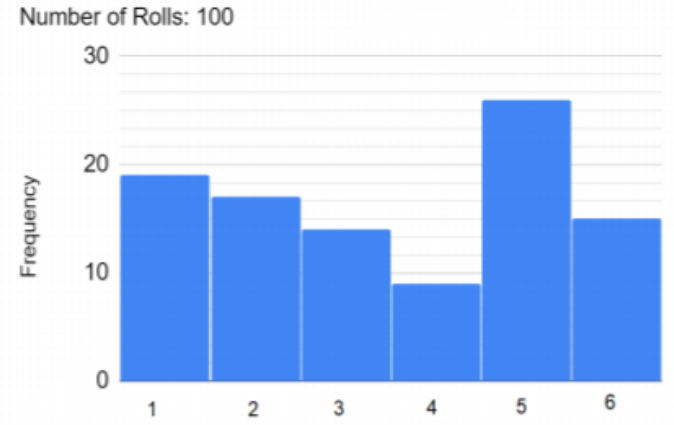
Students will know and be able to:

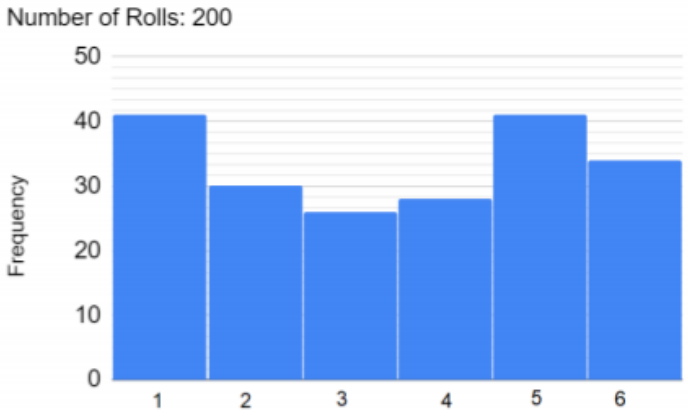
- Determine the uncertainty for a particular bin.
- Determine the best value to represent the data.
- Determine the uncertainty in the best value to represent the data.

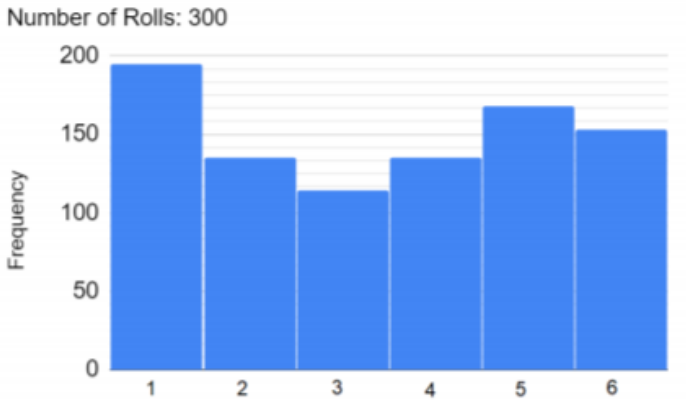
- Part 1- Rolling of dice
- Part 2- Measuring the angle **phi (φ)** at which muons emerge after collisions **in ATLAS.**
- Part 3- Defining uncertainty for a Gaussian distribution.

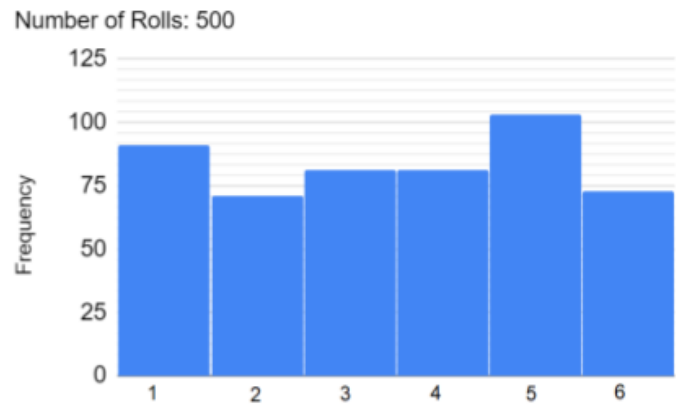
Part 1-Rolling of Dice

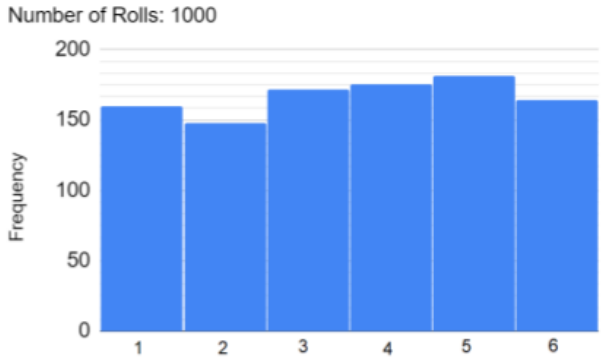
- The student pages present the following histograms and ask questions to lead them to see that there is no preferred number when rolling a six-sided die.
- Also, they should notice that each set of 100 rolls yields a different result, but if the number of rolls is large, then there seems to be no preferred number.
- When all of the sides have equal probability of being rolled, then the die is said to be a fair die.











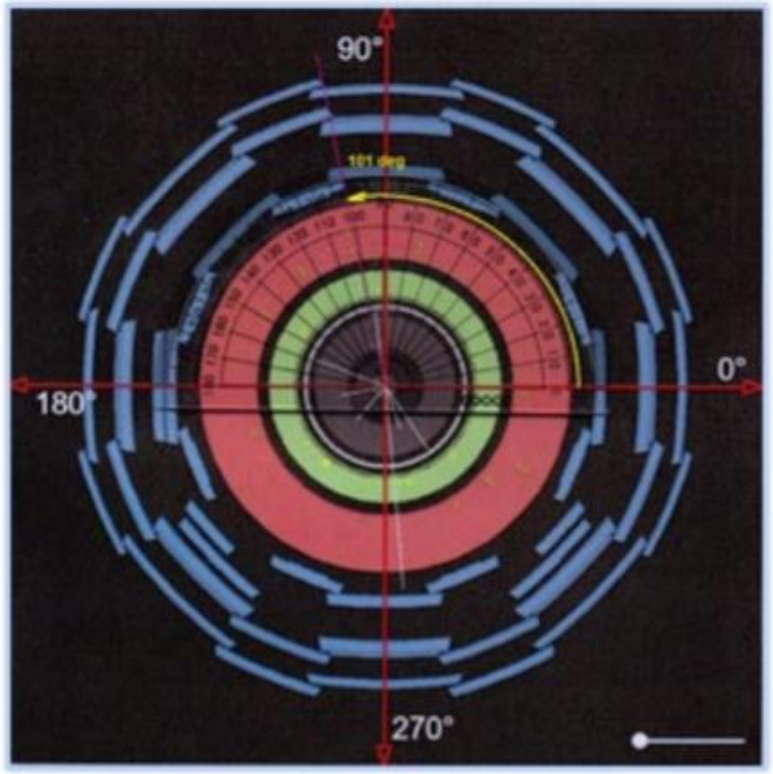
Histograms generated using https://academo.org/demos/dice-roll-statistics/

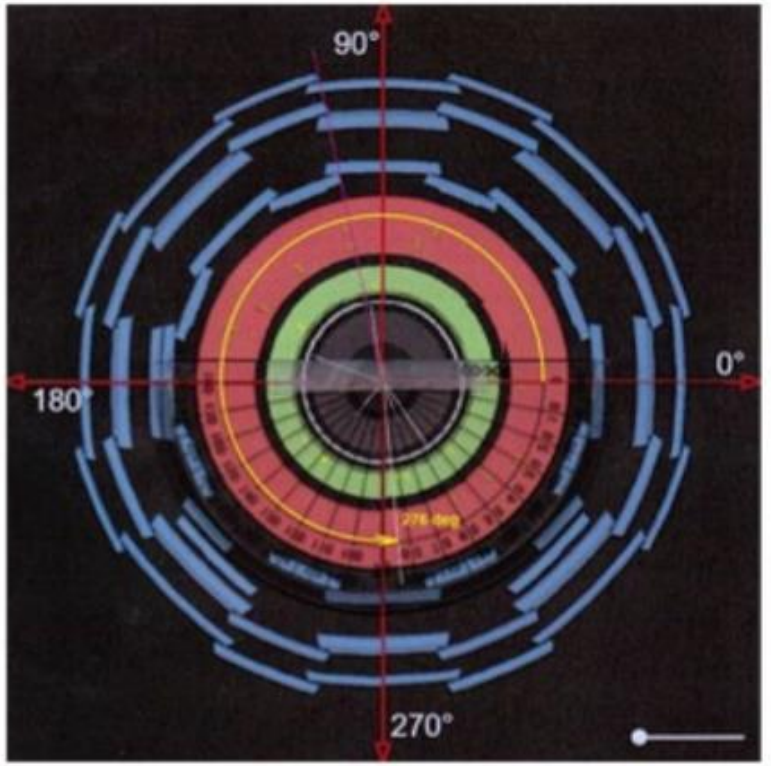
Part 2
ATLAS Measuring the ANGLE **phi (φ)**

- Muons emerge at a particle angle **phi (φ)** after collision events inside the ATLAS detector.
- The physicists wanted to see if there was a preferred angle for the muons to emerge from a collision. The angle phi (φ) is measured around the LHC beam pipe which is the direction of motion for the incoming particles. Figure 1 shows how to measure the angle.

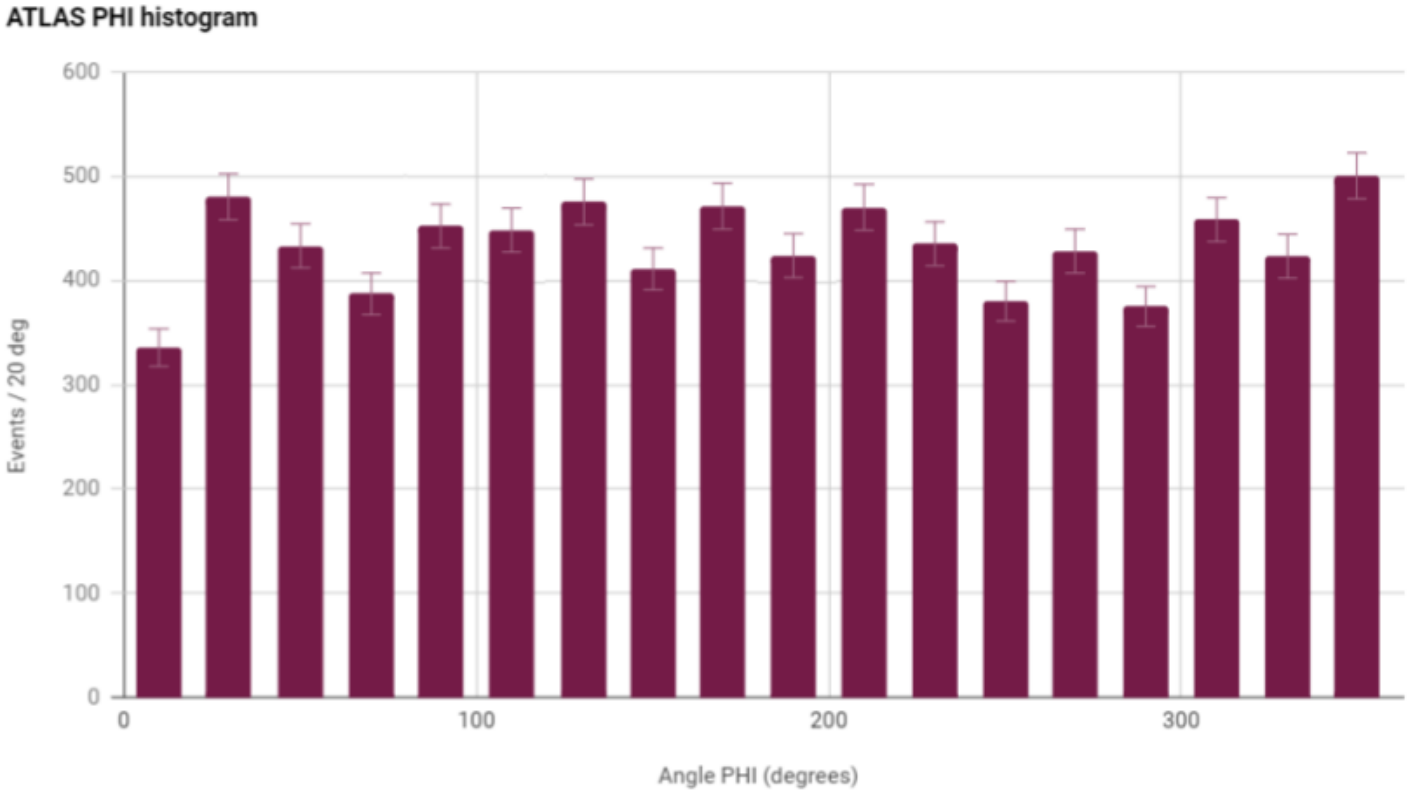
Part 2
ATLAS Measuring the Angle **phi (φ)**

Measure angles in ATLAS





Part 2
ATLAS Measuring the ANGLE **phi (φ)**



Part 3: Defining uncertainty for a Gaussian distribution.

- In a Gaussian (or normal) distribution, the data values can be less than or greater than the mean.
- Figure 3 below shows the shape of a typical Gaussian distribution.
- The standard deviation in the **Gaussian distribution** is approximated by finding the width of the Gaussian when the frequency is half of the maximum value and dividing by 2
- **(Full-Width Half-Maximum over 2, or FWHM/2).**

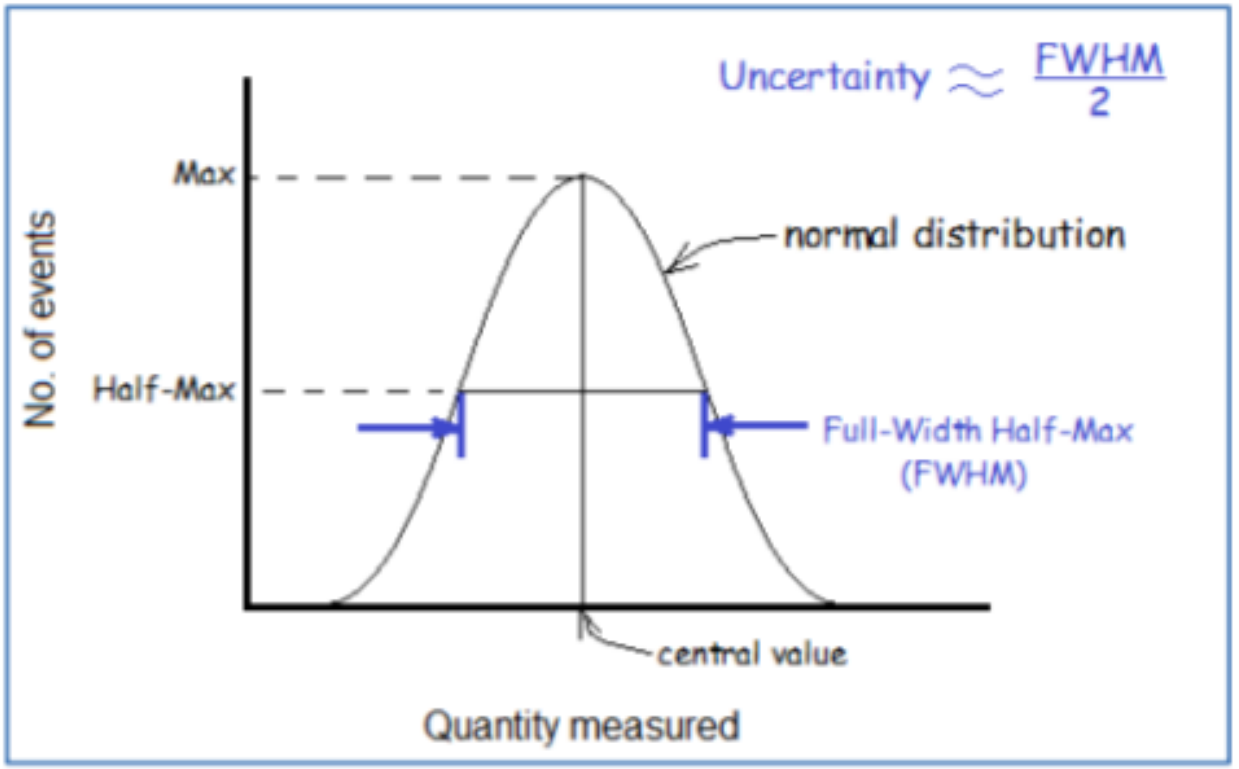


Figure 3: Defining uncertainty for a Gaussian distribution.

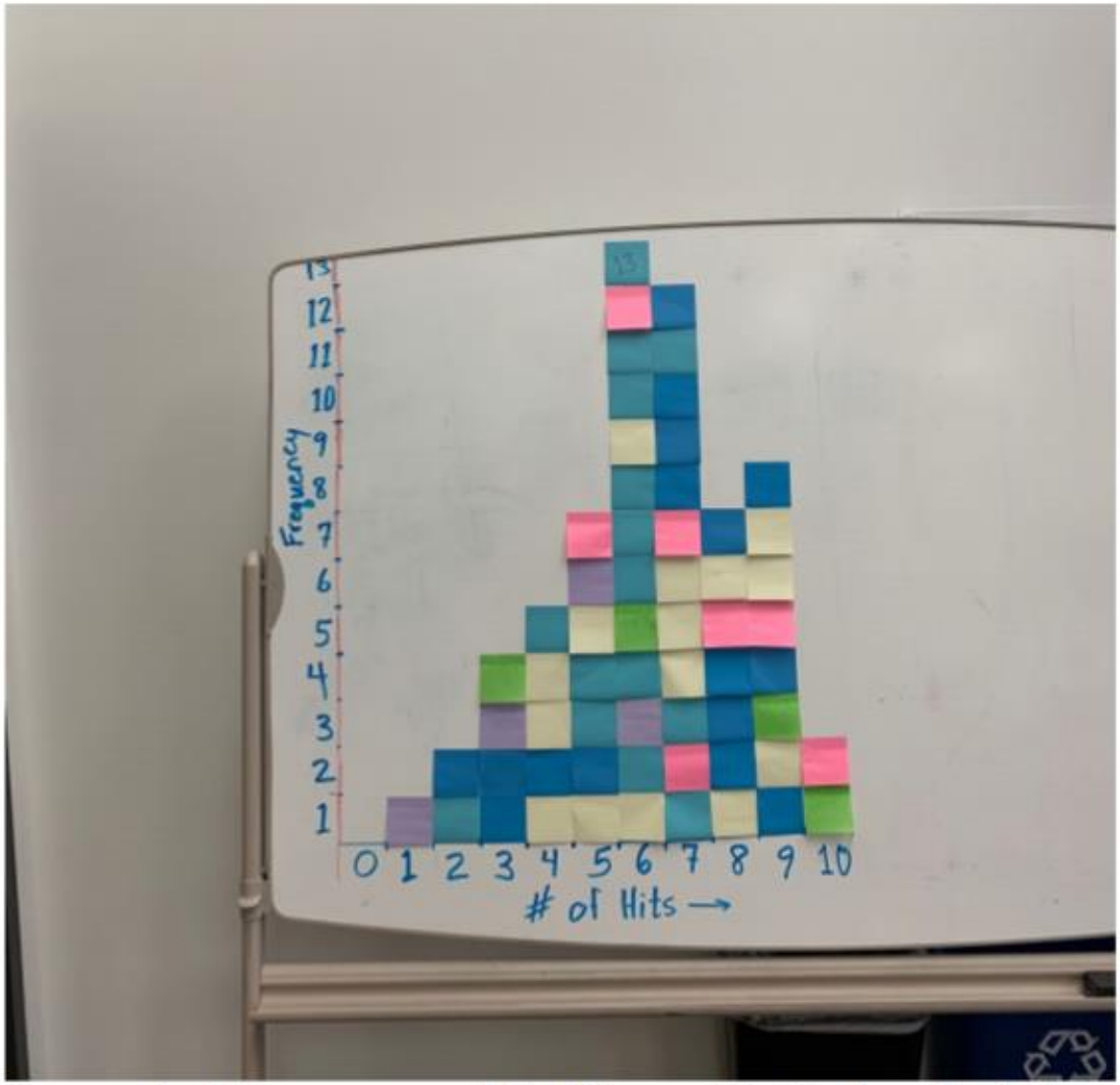


Figure 4: Histogram of Rolling with Rutherford data.

- The uncertainty for each bin is found by using the standard deviation Poisson distribution √N.
- The uncertainty of the histogram is found using the approximation of the standard deviation of the Gaussian distribution FWHM/2.

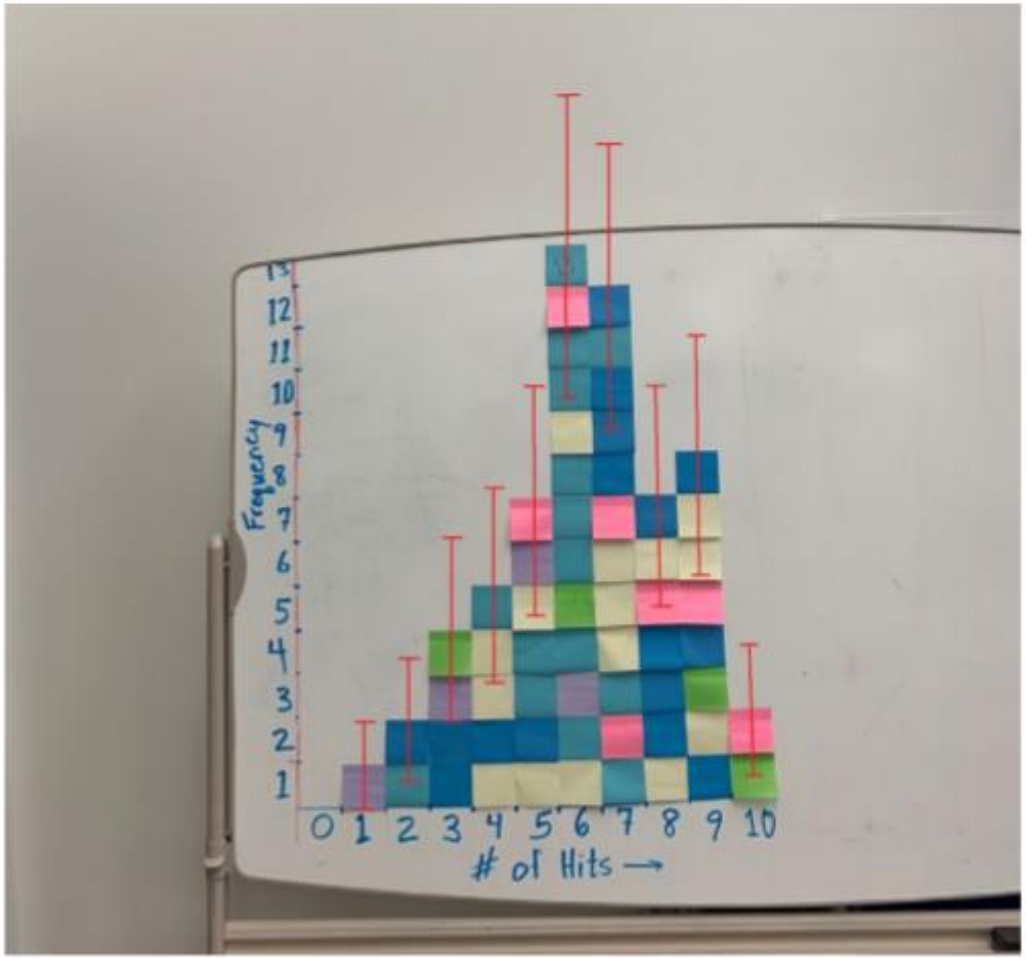


Figure 5: Histogram of Rolling with Rutherford data with bin error bars.

Figure 6 shows the histogram with FWHM identified.

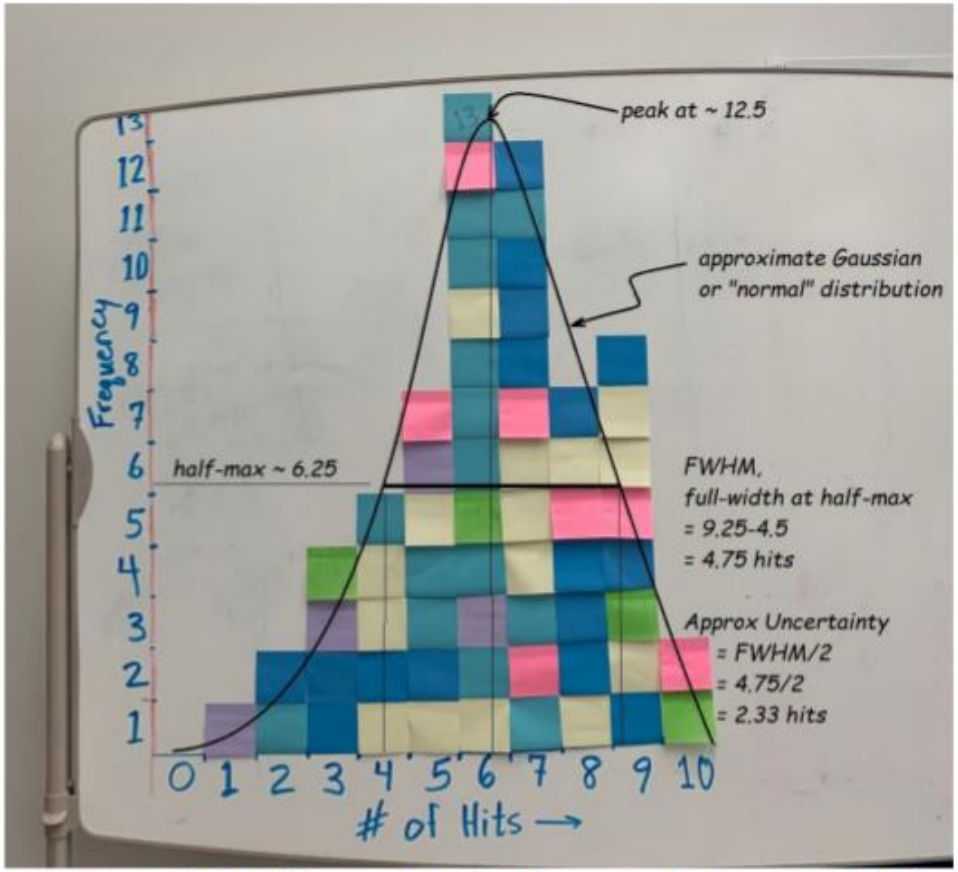


Figure 6: Histogram of Rolling with Rutherford data with bin error bars.

Three Histograms for Assessment

Student Instructions:

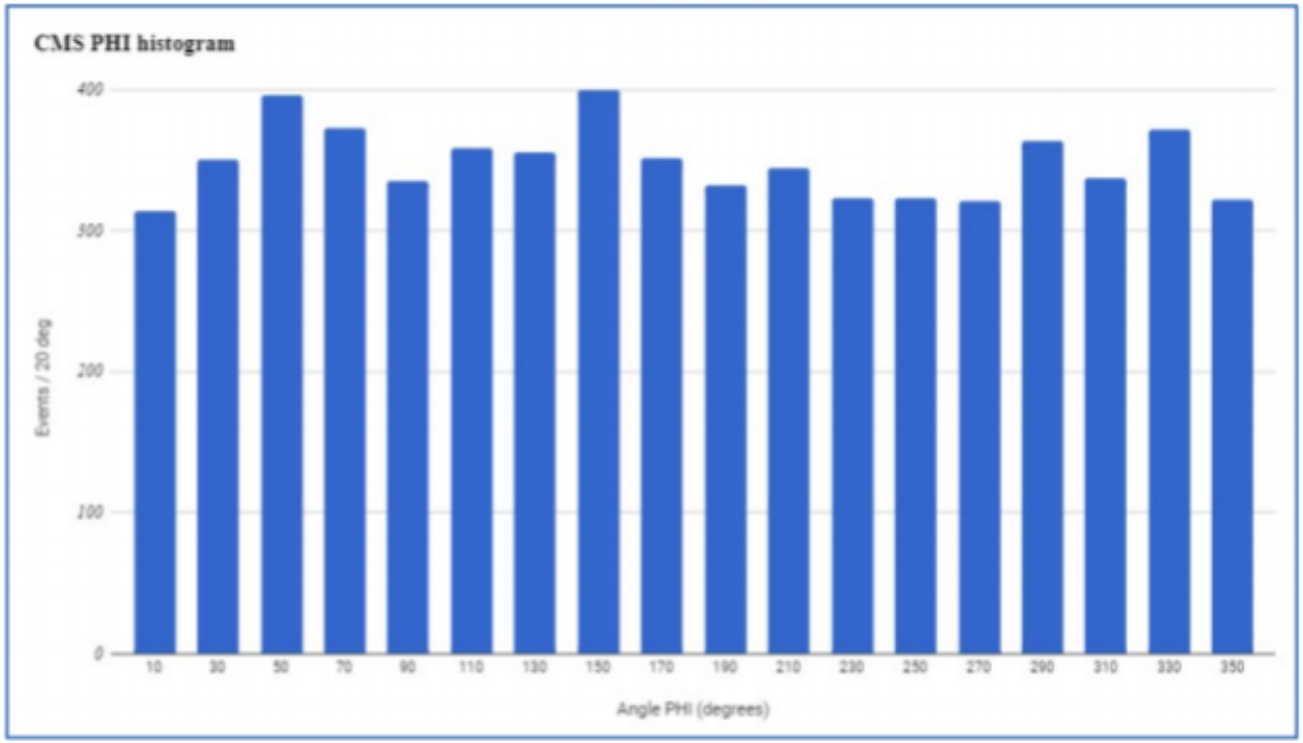
For Histogram 1:

- Calculate the uncertainty of each bin.
- Draw the error bars on each bin.

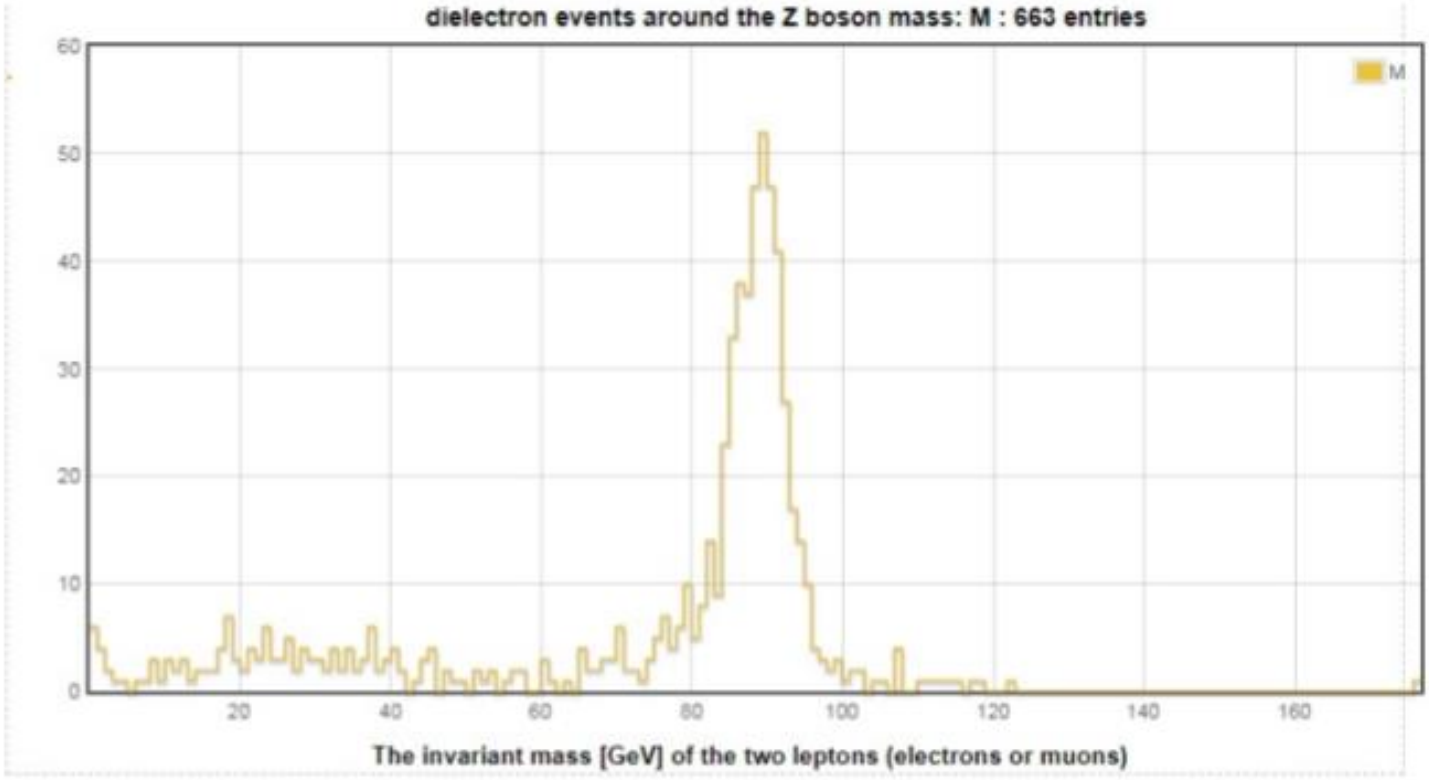
For Histograms 2 and 3:

- Calculate the uncertainty of each bin.
- Draw the error bars on each bin.
- Determine the uncertainty of the peak using FWHM.
- Make a claim about the most likely particle mass in GeV including uncertainty. Support your claim with evidence and reasoning.

Histogram 1: Angle measurements from the CMS detector



Histogram 2: Mass plot from CMS



Histogram 3: Mass plot from CMS