



Race & Associates, Ltd.

**QuarkNet Teachers Workshop  
CMS e-lab  
July 29 -31, 2025**

**Implementation Plans Proposed by  
Participating Teachers**

The following pages provide examples of proposed implementation plans created by participating teachers during the workshop. Each plan is numbered to preserve the identity of the individual teacher.

August 2026

## **QuarkNet Implementation Plan #1**

Focus: Science Practice Data Analysis

As a science department at my school, we are all increasing instruction on data analysis as New York State is assessing students in clusters that include data/graphical analysis. Every Friday, we plan to practice these cluster type questions.

My first unit in physics class is about math and science skills, so I would use the histogram activity during this unit. "Energy momentum and mass" to linearize data.

### **Histogram uncertainty.**

Part 1: Keep the same. analyze different sample sizes and determine uncertainty.

Part 2: Change topic depending on the course. Keep the same for Physics.

Part 3: Create a histogram with labeled sticky notes

Collect data: topic specific

Intro physics- students still struggle with metric estimations, so I would just have them measure height. Determine the mean height of a physics student with uncertainty.

Fermi Friday- metric estimations order of magnitude. (Jellybeans in an Olympic size pool, etc.)  
Analyze class data?

(Number of molecules in the classroom - chemistry)

### **Calculating g - revisit the histogram.**

Analyze class data.

Talk about significant figures, why do we estimate g at 10?

### **Mass calculation of Z.**

Content: Conservation of mass and energy.

Skill: vector trig

Keeping the physics simple, but still including a mini lecture on particle physics, practice calculations and graphing results as a class

## **Implementation Plan #2**

### **Physical Science**

#### Unit 1: Graphing & Data Analysis

- [Histograms: The Basics](#) ([Student Guide](#)) ([Teacher Guide](#)) - After Fish Graphing activity, having students create another type of graph and practice with analysis (ACT Prep)
- ([SEP- 1, 2, 3, 4, 6, 7, 8](#)) Objective: Students will create and interpret graphs (line, histogram, etc.) based on data collected in laboratory investigations or simulations and support a claim about the relationship between independent variables.
- [Data Analysis & Graphing Guided Notes](#) ([Data Analysis & Graphing Slides](#))
  - Students review and go into more detail on types of graphs, how to read them, and how to create graphs
  - We currently do a [Fish Graph Activity](#) where students create a line graph with 3 lines and analyze the graphs

### **Implementation Plan #3**

Activity title or description of what will be implemented:

The Histogram activity in the data activities portfolio will be used. Our students complete a free fall lab in order to find and verify the acceleration due to gravity. The physical science histogram activity written by Colin Hobart will be used to introduce/remind the students of what a histogram is. We will then use this to gather data to look at as a class between lab groups then as collective sections. With the whole group data, we can apply the standard deviation and mean in order to verify the acceleration due to gravity. We will also add the histogram analysis from the e-labs to our penny lab we use in the beginning of the school year.

Class(es) in which used:

Honors Physics  
Physics

Grade Level(s):

11-12

Connected curriculum topic(s) or practice(s):

Free Fall  
Data analysis  
Using mathematical routines to interpret data  
Communicating results with groups  
Modern Physics

Reason(s) for choosing:

The histogram works great in an extension to what we already do in this lab. The lab has students analyze the data from free falls in order to find and verify the acceleration due to gravity. Adding the e-labs to the later labs fits perfectly with the standard model we teach already.

Expected challenges or pitfalls:

Differing levels of math skill, correct data interpretation, lab groups delivering data on time

Other comments:

# Implementation Plan #4

## Lesson Plan: You Are Smarter Than ChatGPT!

**Grade:** 3rd-4th

**Time Frame:** 40–45 minutes

**Tools:** A printed or projected version of the bar graph, ChatGPT, Markers or highlighters, Whiteboard or chart paper, error data

**Worksheets:** [“Smarter Than ChatGPT”](#) Worksheet

**Big Idea:** AI can be helpful, but it’s important to think for yourself and double-check information—because even smart tools like ChatGPT can make mistakes.

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### Objectives:

- Accurately read and interpret a bar graph.
  - Identify and correct AI-generated errors.
  - Understand that AI (like ChatGPT) can make mistakes.
  - Practice critical thinking and data verification skills.
- 



ChatGPT gave me:

Type of Activity	Number of Children
Reading	10
Playing	20
Baking	13
Washing hands	17

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## Lesson Procedure:

### 1. Hook (5 min)

Ask students:

“Have you ever asked a computer or Alexa or Siri for help with something?”

Let a few students share.

Say:

“Today we’re going to find out if a computer is always right... or if YOU might be smarter!”

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### 2. Show the Graph (5 min)

Display the bar graph “*Activities at Home.*”

Ask:

- What do you notice?
- What does this graph show us?
- Which activity had the most kids? Least?

Encourage students to use correct terms like **title**, **x-axis**, **y-axis**, and **bars**.

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### 3. The Challenge (10 min)

Say:

“I asked ChatGPT, a super smart AI, to read this graph for me. Here's what it told me...”

Pass out or project ChatGPT’s version of the data. Display ChatGPT page showing what ChatGPT gave me as an answer.

Ask:

- Does it look right to you?
- Let’s check!

Work together as a class to compare the AI’s answers to the actual graph and identify the errors.

Additional: Can have ChatGPT pull data from graphs in front of students. Occasionally it gets things correct.

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#### 4. Independent Activity (15 min)

Distribute the **Student Worksheet**. Students will:

- Record the correct numbers from the graph.
  - Compare them to ChatGPT's answers.
  - Write about **why it's important to check AI answers.**
- 

#### 5. Discussion and Wrap-Up (5–10 min)

Lead a brief discussion:

- Can ChatGPT (or other AI) be helpful?
- Why is it still important to use our own brains?
- What should we do when AI gives us information?

Write this class rule on the board:

**“ChatGPT can help—but always double-check important info!”**

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#### Assessment:

- Completion and accuracy of the student worksheet
- Participation in discussion
- Ability to explain why checking AI is important

## Implementation Plan #5

### Application 1

First day of APP2 do histogram activities as precursor to Maxwell-Boltzmann distribution for thermo - no time to develop here due to laptop issues - goal is to show how wider (larger range) means less tall

### Application 2

#### Making it 'Round the Bend - Qualitative and/or Quantitative

##### Standards: AP Physics 2 Standards

EK 1.E.6.a: Magnetic dipole moment is a fundamental source . . .

EK 3.A.2: Forces are described by vectors.

EK 3.C.3: A magnetic force results from the interaction of a moving . . .

##### ENDURING UNDERSTANDINGS

Scientists can use data to develop models based on patterns in the data.

##### LEARNING OBJECTIVES Qualitative Treatment:

##### As a result of this investigation, students will know and be able to:

- Describe the direction of motion of an electrically charged particle when interacting with an electric field.
- Describe the direction of motion of an electrically charged particle when interacting with a magnetic field.
- Describe the conditions needed for an electrically charged particle to travel through a region of crossed electric and magnetic fields with velocity unchanged.
- Describe the path traveled by an electrically charged particle entering a region of magnetic field.
- Describe how the right-hand rule can predict the curvature of an electrically charged particle in a magnetic field.

##### Equations/principles to remember:

$$F_e = qE \quad F_m = qv \times B \quad \text{Right hand rule}$$

I would use this plan as an application to reinforce E&M concepts. Students especially struggle with electrostatics, so this puts everything together nicely.

Simulation:

<https://quarknet.org/data-portfolio/activity/making-it-%E2%80%98round-bend>

Student:

## **Implementation Plan #5**

[https://quarknet.org/sites/default/files/content/portfolio/file/2024-01/round\\_the\\_bend\\_qual\\_student\\_05jun2018.pdf](https://quarknet.org/sites/default/files/content/portfolio/file/2024-01/round_the_bend_qual_student_05jun2018.pdf)

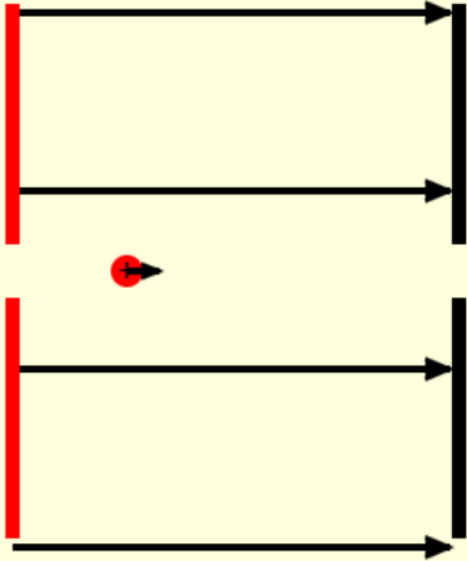
[https://quarknet.org/sites/default/files/content/portfolio/file/2024-01/round\\_the\\_bend\\_quant\\_student\\_15aug2019%20%281%29.pdf](https://quarknet.org/sites/default/files/content/portfolio/file/2024-01/round_the_bend_quant_student_15aug2019%20%281%29.pdf)

Teacher notes: [https://quarknet.org/sites/default/files/content/portfolio/file/2024-01/edited\\_Makin%27%20It%20Round%20the%20Bend%20%20Qual%20Teacher%20Notes\\_dmr\\_1%20posted%200622.pdf](https://quarknet.org/sites/default/files/content/portfolio/file/2024-01/edited_Makin%27%20It%20Round%20the%20Bend%20%20Qual%20Teacher%20Notes_dmr_1%20posted%200622.pdf)  
[https://quarknet.org/sites/default/files/content/portfolio/file/2024-01/Makin%27%20It%20Round%20the%20Bend%20Quan%20Teacher%20Notes\\_dmr\\_13Aug10%20posted%200622.pdf](https://quarknet.org/sites/default/files/content/portfolio/file/2024-01/Makin%27%20It%20Round%20the%20Bend%20Quan%20Teacher%20Notes_dmr_13Aug10%20posted%200622.pdf)

## **Part 1 - Accelerator**

## Implementation Plan #5

### Ion Accelerator



Electric field = 1000 N/C

Charge Attributes  
mass/charge = 20 E-9 kg/C

t = 1.47 E-6 s

x = 54.0 mm    vx = 73.5 km/s

## Part 2 - Velocity Selector

Implementation Plan #5

### Velocity Selector

$x = 208 \text{ mm}$        $y = 93 \text{ mm}$        $v_x = 100 \text{ km/s}$        $v_y = 89 \text{ km/s}$

Electric field = 1000 N/C

Magnetic field = 19 mT

$t = 2.08\text{E-}6\text{s}$

Charge Attributes  
mass/charge = 20 E-9 kg/C

Initial  $v_x = 100 \text{ km/s}$

Play   Pause   Step <<   Step >>   Reset

1 - Accelerator   2 - Velocity Selector   3 - Mass Spectrometer

### Part 3 Mass Spectrometer

# Implementation Plan #5

**Mass Spectrometer**  
 $t = 2.98E-6s$   
 $x = 298 \text{ mm}$      $v_x = 100 \text{ km/s}$   
 $y = 25 \text{ mm}$      $v_y = 46 \text{ km/s}$

**Velocity Selector Controls**  
Electric field 1 = 1000 N/C  
Magnetic field = 19 mT

**Mass Deflector Controls**  
Magnetic field 2 = 50.00 mT  
Charge Attributes  
mass/charge = 20 E-9 kg/C  
Initial  $v_x = 100 \text{ km/s}$

- 
-

## Implementation Plan #6

### Materials:

- Small Objects to drop
- Measuring tape
- Ladder
- Phone

### Procedure

- Students may work in pairs.
- Students will take turns dropping different objects from the same height (ceiling). Their partner will record the drop on their phone. They will then record the free fall time from their video. Repeat each trial 3 times. The data will be shared in a Google Sheet with the entire class. Each group of students will construct a histogram per object using the collective data with time bin widths on the horizontal and frequency on the vertical axis.
- Calculate the average time and standard deviation.
- Use  $d = v_i t + \frac{1}{2} a t^2$  to calculate  $g$ .
- Compare this value of  $g$  to the known value of  $9.81 \text{ m/s}^2$ .
- Discuss sources of error.

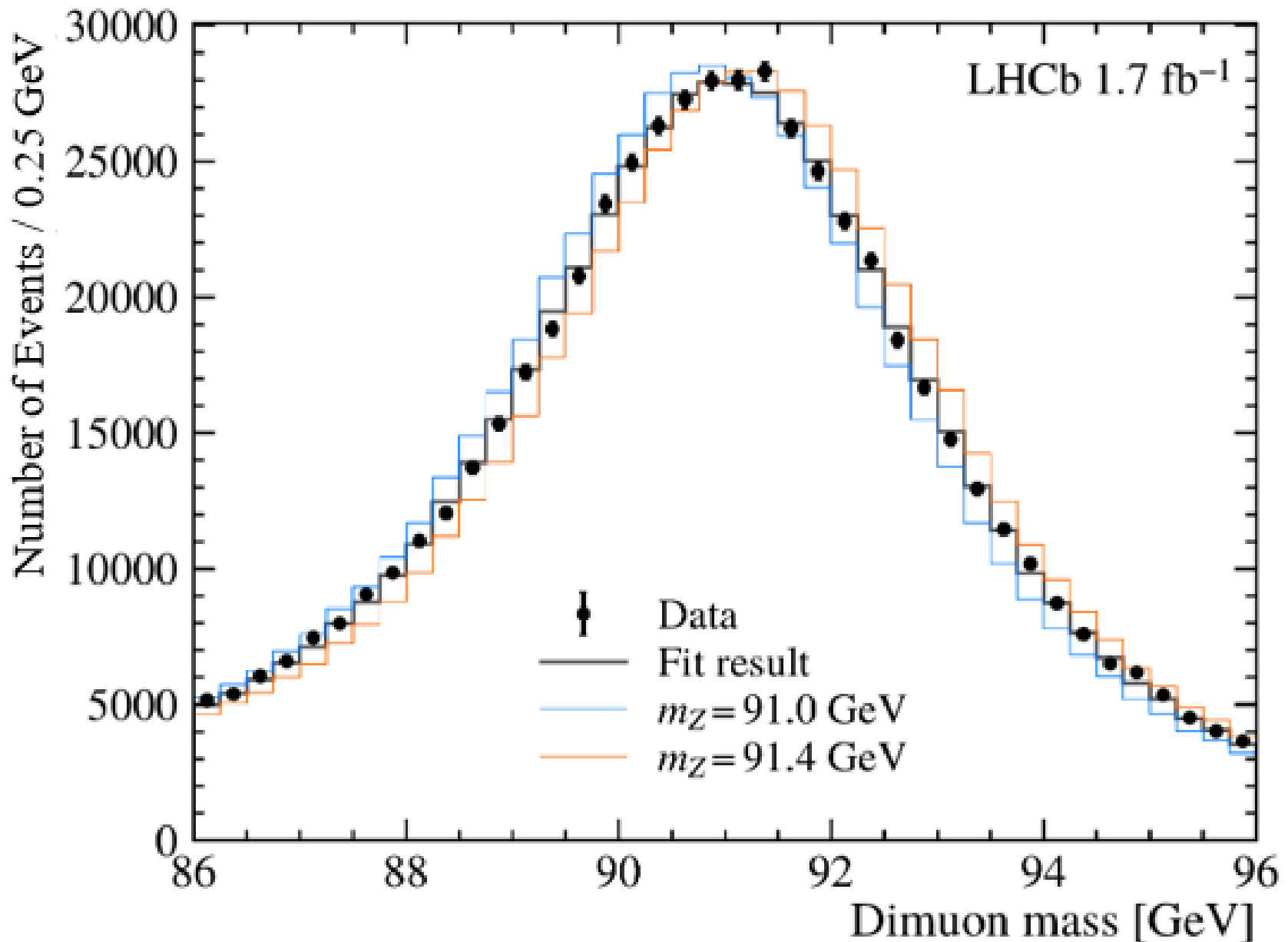
## Implementation Plan 7a

### Z Mass Data Analysis

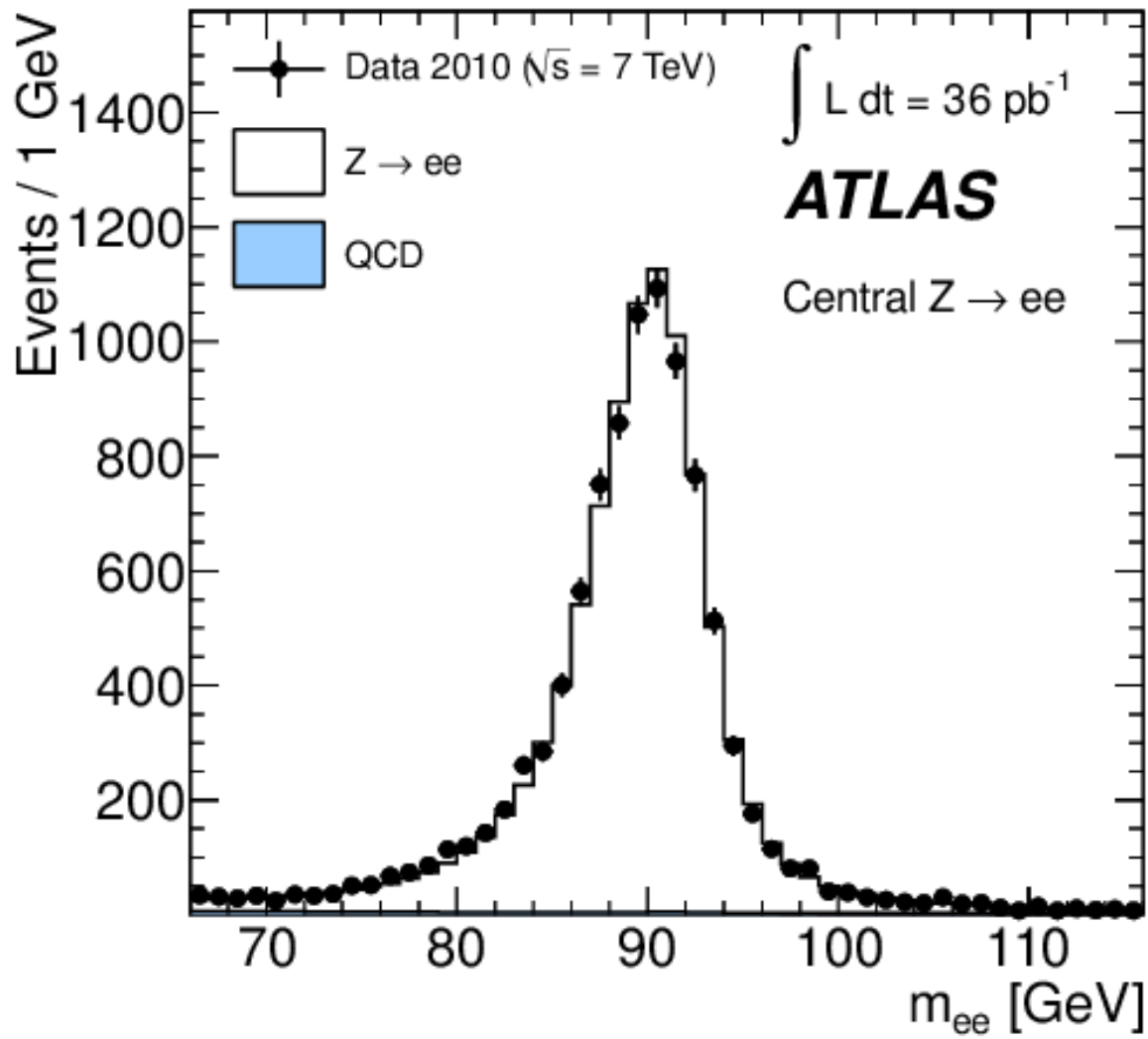
<b>Grade/ Grade Band:</b> 6-12, depending on student graphing skills	<b>Topic:</b> Z Mass Data Analysis	<b>Lesson # _____ in a series of _____ lessons</b>
<b>Brief Lesson Description:</b> Simple lesson to introduce students to identifying the components of a graph, analyzing the data in the graph through answering ACT-style questions, writing a claim to answer a question and providing evidence to support the claim.		
<b>Performance Expectation(s):</b> <b>IOD 201.</b> Select one piece of data from a simple data presentation <b>IOD 202.</b> Identify basic features of a table, graph, or diagram (e.g., units of measurement) <b>IOD 302.</b> Understand basic scientific terminology <b>EMI 401.</b> Determine which simple hypothesis, prediction, or conclusion is, or is not, consistent with a data presentation		
<b>Specific Learning Outcomes:</b> <i>I can describe</i> the labels in the graph <b>in order to identify</b> the components of a graph <b>by reading</b> the information in various graphs. <i>I can analyze</i> the data in several graphs <b>in order to estimate</b> the most probable mass of the Z boson <b>by comparing</b> the information in several graphs.		
<b>Narrative / Background Information</b>		
<b>Prior Student Knowledge: B</b> This lesson assumes students have little to no knowledge of graphs. Students should understand that matter is made up of particles too small to be seen. This should include particles in a general sense, atoms more specifically and could include particles smaller than the atom.		
<b>Science &amp; Engineering Practices:</b> Analyze and interpret data to determine similarities and differences in findings. Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. Construct and/or support an argument with evidence, data, and/or a model.	<b>Disciplinary Core Ideas:</b> N/A	<b>Crosscutting Concepts:</b> N/A
<b>Possible Preconceptions/Misconceptions:</b> Students may assume that they need to understand exactly what every quantity/unit is on the graphs. Reassure them that to analyze data on a graph you don't necessarily need to know exactly what a Z boson is. Z could stand for zebra. It doesn't matter what GeV is. It could be pounds (lb). Relate this to the ACT test where the content on the test will probably be something they have never seen but they can still wade through the text/data representations and pull out the necessary information.		
<b>LESSON PLAN – 5-E Model</b>		
<b>ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:</b> Instruct students to read the first Learning Objective: <i>I can describe</i> the labels in the graph <b>in order to identify</b> the components of a graph <b>by reading</b> the information in various graphs. Tell students that this is what they will do in the <b>ENGAGE</b> section. Relate this lesson to the importance of data analysis skills for evaluating situations in everyday life and the ACT science test. Give students copies of the first 2 QuarkNet Z-boson mass graphs. Instruct students to 1) look at the graphs and make notes/highlight/underline areas of the graphs that they understand and areas that they don't understand; 2) find 2 similarities and differences between the graphs; 3) identify the information contained in the graph.		
<b>EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:</b> As a class, discuss the words written on the graphs. Differentiate between the title of the graph (a description of the information contained in the graph) and the labels of the axes (the names of the variables in the graph). Define the vocabulary words. Call on students to describe similarities and differences in the graphs.		
<b>EXPLAIN: Concepts Explained and Vocabulary Defined:</b> Fill in the context of the data for the students. Explain the data was collected at various labs, which are labeled on the graphs. Explain that the Z boson is a type of particle that is smaller than an atom. Scientists have designed and run experiments to figure out the properties of the Z boson. One of those properties is its mass (weight). Explain to students that they will use the graphs to determine the mass, or weight, of the Z-boson. Remind students of the second Learning Objective: <i>I can analyze</i> the data in several graphs <b>in order to estimate</b> the mass of the Z boson <b>by comparing</b> the information in several graphs.		

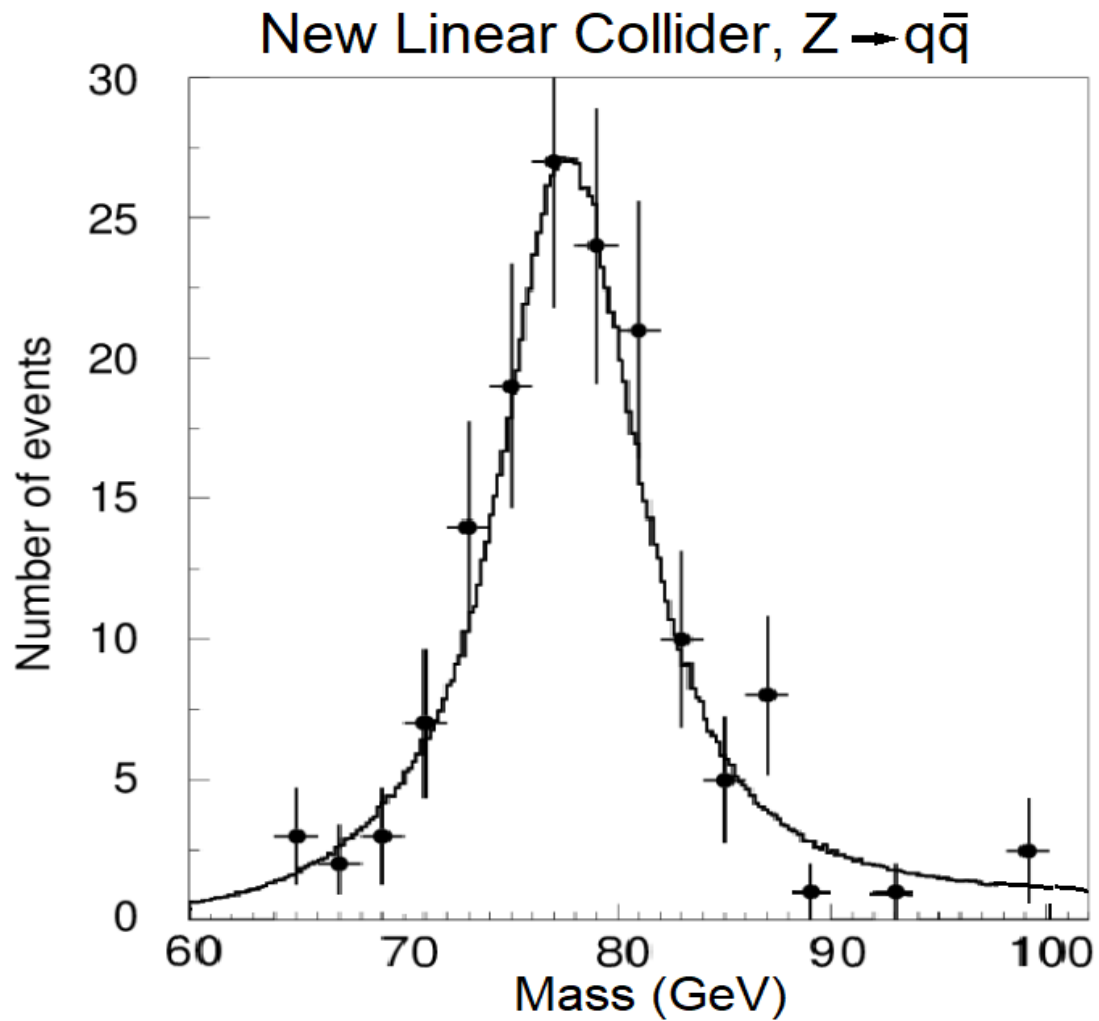


# Measure the Z-boson mass and uncertainty



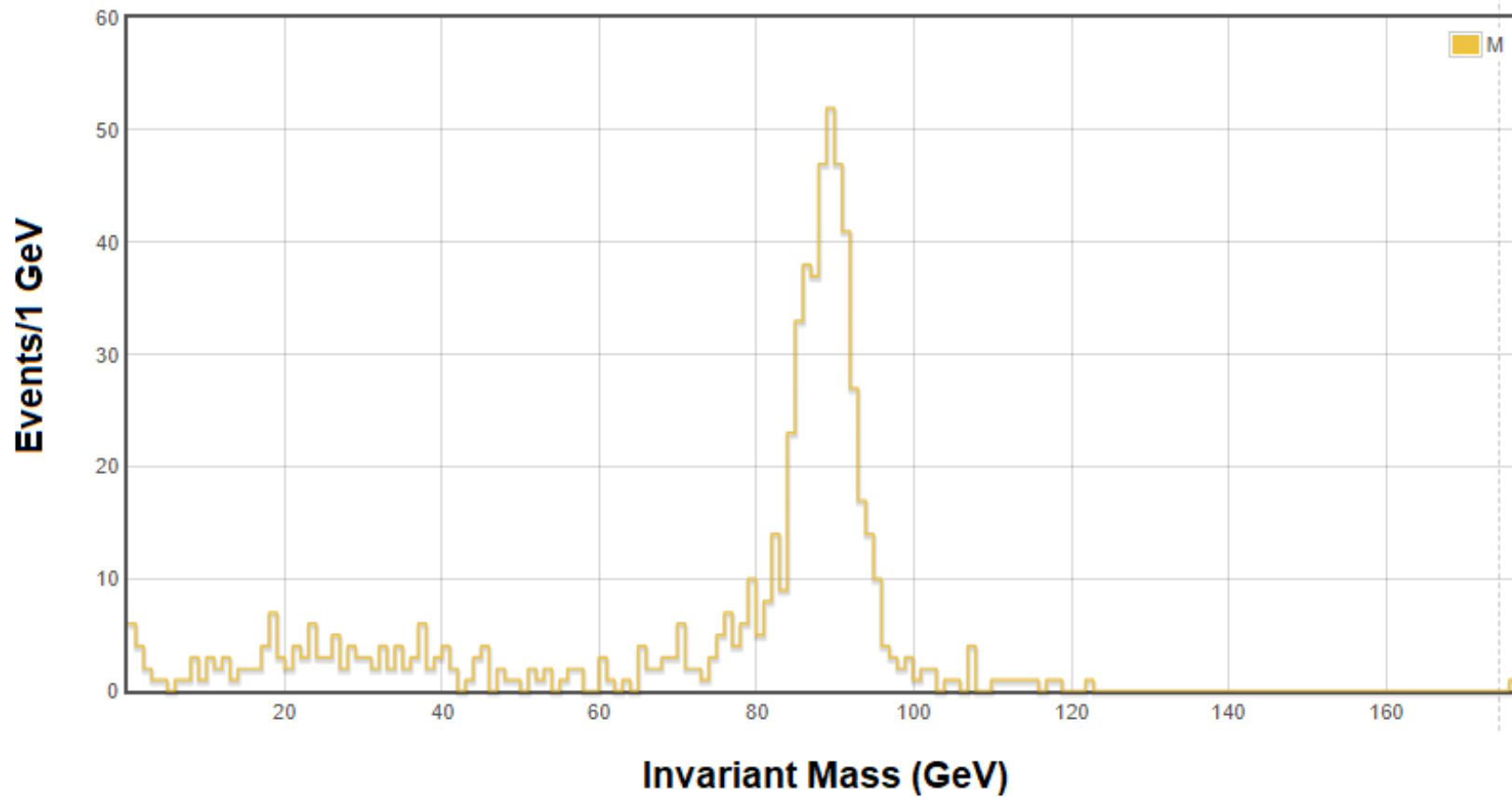
# Measure the Z-boson mass and uncertainty



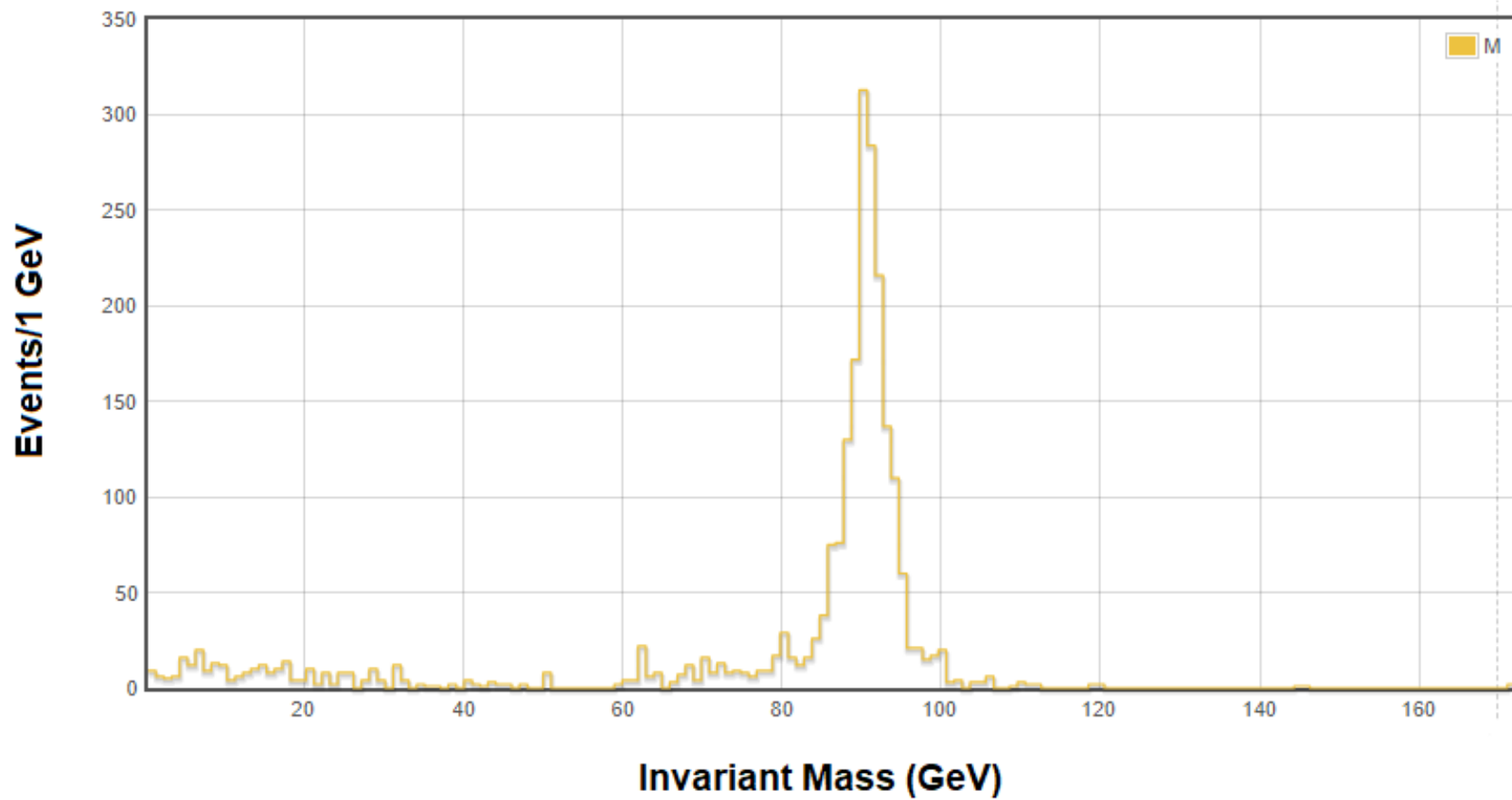


# Measure the Z-boson mass and uncertainty

## QuarkNet CMS e-Lab, $Z \rightarrow ee$



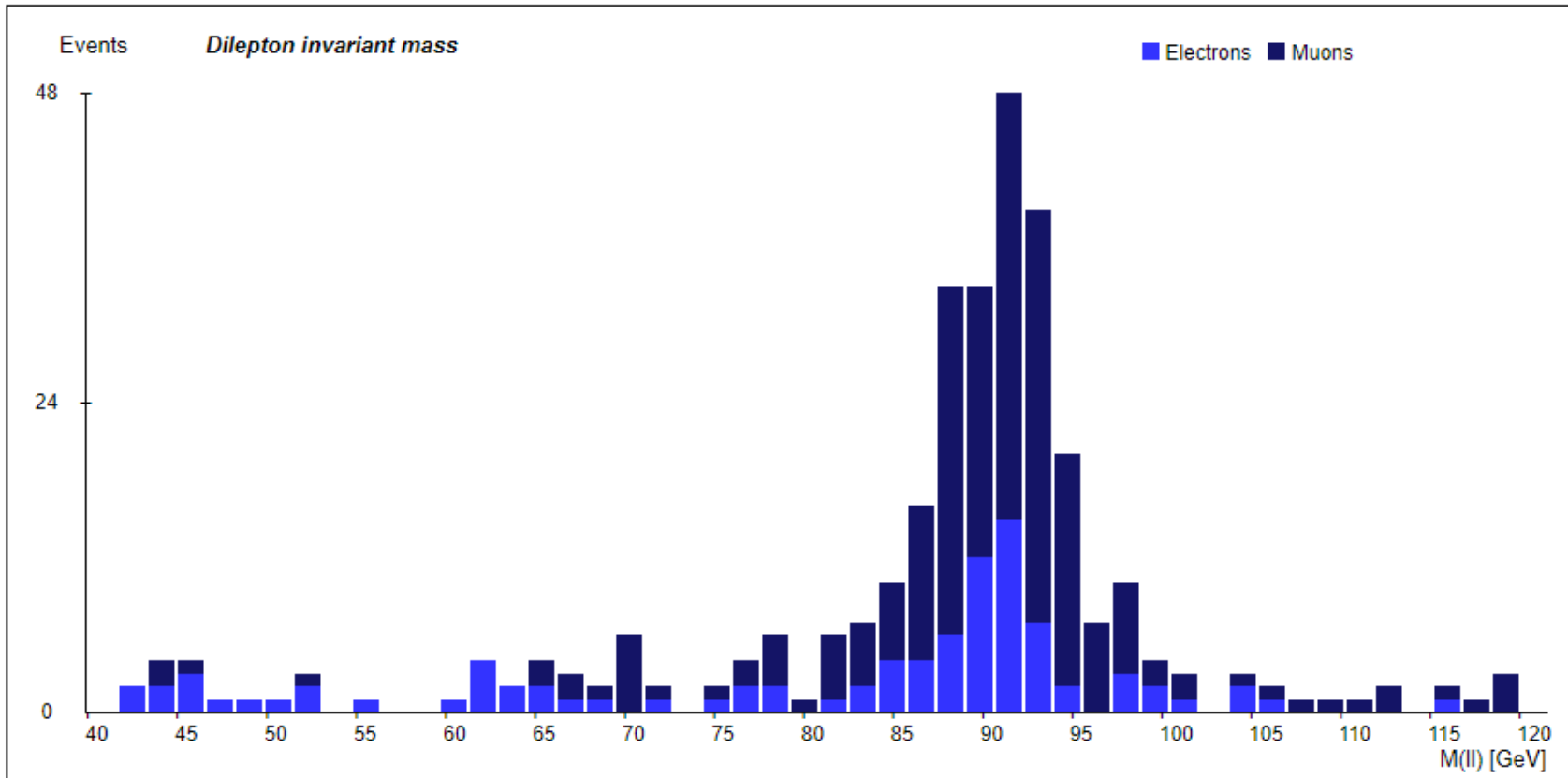
### QuarkNet CMS e-Lab, $Z \rightarrow \mu\mu$



# Measure the Z-boson mass and uncertainty

## OPlOT – MasterClass – Combination for all institutes on 2023-05-26

Start Student Moderator Tutor Administrator



## Implementation Plan #8

Using histograms to determine the acceleration due to gravity

- Students will time how long it takes for a ball to fall to the ground
- Use the  $X = 1/2at^2 + V_0t + X_0$  to find the acceleration
- Create a sticky note histogram
- Use that value of g in future calculations

Momentum-Energy bridge

- Calculate z-boson mass by hand (<https://quarknet.org/data-portfolio/activity/z-mass-spreadsheet-extension>)
- Use excel to calculate z-boson mass
  - [https://docs.google.com/spreadsheets/d/1ZJSZb-cpp\\_yKfA39EEjpTkrPMvibhDVLk3Up\\_HW2LWw/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1ZJSZb-cpp_yKfA39EEjpTkrPMvibhDVLk3Up_HW2LWw/edit?usp=sharing)
- Use ChatGPT to get more sample data
  - create 100 entries on a data table for P1, P2, theta1, and theta2 that fit this model: 
$$\left( (P1 + P2)^2 - (P1 \cdot \sin(\theta1) + P2 \cdot \sin(\theta2))^2 + (P1 \cdot \cos(\theta1) + P2 \cdot \cos(\theta2))^2 \right)^{1/2} = (\# \text{ between } 89 \text{ and } 93)$$

## Implementation Plan #9

### Science and/or Engineering Practices I Want to Try with My Students:

I want to focus on two key practices from the *Next Generation Science Standards (NGSS)*:

1. **Analyzing and Interpreting Data**
  2. **Using Mathematics and Computational Thinking**
- 

### Planned Activities:

#### Activity 1: Investigating Graph Quality and Data Representation

Students will explore how graph quality—such as axis labels, bin size, and resolution—affects data interpretation. They will analyze a series of histograms with varying bin sizes and visual quality to determine how misleading or helpful each is in communicating information.

#### Activity 2: AI Limitations in Graph Extraction

Students will attempt to use AI tools (like ChatGPT or online graph extractors) to pull numerical data from images of histograms. They will compare the extracted data to the original dataset and critique the limitations of current AI in reading graphical data.

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### Implementation Plan:

These activities will be implemented during our **data analysis unit**, particularly when we begin interpreting real-world data and graphs in science. Students will first engage in a mini-lesson on histogram construction and how bin size affects interpretation. Next, we will run an inquiry-based activity where students compare AI-generated extractions with actual data to assess accuracy and limitations.

#### Structure:

- **Day 1:** Introduction to histograms and bin sizes (mini-lesson + practice)
  - **Day 2:** AI Extraction Challenge – students use tools to extract and analyze data
  - **Day 3:** Group discussion and written reflection on findings and implications
-

## Cross-Curricular Applications:

- **Math:** Reinforces concepts of data grouping, mean, mode, and standard deviation.
  - **Computer Science:** Introduces students to AI tools, data scraping, and algorithmic limitations.
  - **English/ELA:** Students write a short argument piece explaining whether or not AI can be trusted for data extraction and analysis, citing evidence from their activity.
- 

## Extensions and Additional Uses:

- Students could apply these skills to **evaluate graphs used in media**, identifying when a graph may mislead due to poor design choices.
- In engineering design tasks, students might **use histogram analysis** to interpret test results (e.g., material strength or thermal properties).
- Students could simulate their own "AI tool" by writing rules or using spreadsheets to analyze image data and compare their process to that of actual AI tools.

Fermilab Quark Net  
**Implementation Plan #10**

[Theparticleadventure.org](http://Theparticleadventure.org)

Quark net particle cards

<https://quarknet.org/data-portfolio/activity/shuffling-particle-deck>

Tabetha's resources will help

[Implemintation Plan for 2023 and 2025](#)

WOW!!!

Fermilab is amazing!! Cern is Amazing!!!

I wish everyone could see it!

My original thoughts for this implementation go like this:

A virtual field trip for students that shows what is really happening in Science Today.

Justification: High school students (and teachers) are often stuck in a curriculum that NEEDS to teach a lot of base knowledge. Classical science! Very rarely do students get to explore what is currently going on in Science. I see this week as a way to introduce students to current science. Answering questions like:

- What is happening?
- Where is it happening?
- Why are we accelerating Particles?
- What are we getting out of it?
- What and how are the observations measured?
- Why? Why? Why?

We cannot take a field trip to Fermi lab and Cern.....but we can bring Fermilab and Cern to the students!!

**STEP 1: Create a sheet of Virtual Fieldtrips.** This is my goal.

Create Videos and experiences that are short but build discussion and knowledge.

Show students the real life happenings that are going on in science.

**With that being said, here is more to my Implementation plan:**

9th Grade. Two distinct lessons:

**While teaching measurement and scientific method:**

Introduce Histograms  
Do two or three Histograms based on measurements  
Discussion of

**While teaching the periodic table, I am going to add elementary particles.**

Since this is 9th grade: A quick version of this is

Introduction to Fermilab/Cern. With Pictures and videos  
Introduction to Particle accelerators. With pictures and Videos  
A look at the dispersion pictures with discussion  
A quick discussion of smaller particles.

**11/12 Grade:**

**This would be a “Throw it in” kind of thing. In other words I want to implement it but not sure what time.**

Introduction to Fermilab/Cern. With Pictures and videos  
Introduction to Particle accelerators. With pictures and Videos  
A look at the dispersion pictures with discussion  
A quick discussion of smaller particles.

For the Seniors, I would like to have them dive deeper into parts of this. This would be a research project. This would be very specific topics. For example:

Hadron Collider  
Tevatron  
Higgs Boson  
Neutrinos  
Quarks  
Strong Nuclear Force  
Neutrino Experiment at Fermi  
History of Fermilab  
History of Cern  
Other Particles  
Linear Accelerators  
Other world Accelerators  
Weak Nuclear Force.

**This project would be looking for scratching the surface of these topics.  
Pictures, ideas, definitions,**

**Then we put these all together for complete “Booklet”**

# Implementation Template Plan #11

## Class(es) in which used:

PHY211 - Introductory course for 9th and 10th - Algebra Only

PHY421 - Introductory for 9-12th - Trigonometry based

PHY511 - Similar to AP Physics 1

PHY521 - Similar to AP Physics C

## 2023 Activities: Neutrino Focus

Shuffling the Particle Deck - to get familiar with the standard model

Particle Reactions - Feynman Diagrams

Conservation Laws and how they relate to particle physics

Coding for all classes - need to work on this

Quantum Mechanics

Mysteries of the Unknown - Neutrino Mass?, Dark Matter and Energy?

## 2025 Activities: Histogram Focus

Dice, Histograms and Probability

Signal and Noise: The Basics

- Level 1: Signal and Noise: Cosmic Muons

Histograms: The Basics

- Level 1: Histograms: Uncertainty

CMS Data - Finding the Bump

Pennies in a film canister activity

## 2023 Resources:

[How to make a neutrino beam](#) - Cartoon

[How to make a neutrino beam](#) - Fermilab

[How do you detect neutrinos?](#) - Fermilab

[Energy, Momentum and Mass](#) - Lab

[All about Neutrinos](#) - Fermilab

[Particle Adventure](#) - Interactive

[What particle fits your personality?](#) - Survey

[Educational Resources](#) - CERN

[PHeT Simulations](#) - General Physics

[Even Bananas](#) - Fermilab

## 2025 Resources:

[Claude](#) - AI Science Resource

[Physics Topic Cheat Sheets](#) - Atlas Resource

[Atlas Fact Sheets](#) - Atlas Resource

[Don Lincoln Particle Physics Videos](#) - Fermilab

[Particle Physics Course for High School](#) - CERN

[NSF Videos](#)

[The Physics Classroom](#) - General Physics

# Implementation Template Plan #11

Pedagogy:

2023

- Introduction into the structure of an atom
  - Protons, Neutrons, and Electrons
  - Strong Force, Electromagnetic Force
  - Move into the Standard Model
    - Quarks
    - Higgs Boson
    - 4 Fundamental Forces and the Force Bosons
- Introduction into Nuclear Decay
  - Alpha, Beta, and Gamma
  - Talk about Beta Decay and Weak Force
  - History of how beta decay led to the hypothesis of a neutrino
  - Move into the Standard Model
- Introduction of Light's Wave Particle Duality
  - History
  - Photoelectric Effect
  - How this led to Quantum Physics
- Introduction to Quantum Physics
- Introduction of Relativity
  - Relative Motion - Newtonian
  - How light doesn't behave this way
  - Time Dilation
- Physics Big Questions

2025

- Introduction to Histograms
  - Gather Data from a lab determining a constant and creating a histogram
    - Discussion of Standard Deviation, Mean
- Energy and Momentum
  - Use CMS Data to determine Z Mass
  - Need homework questions that involve particle physics language

[Implementation Plans from 2025](#)

## Implementation Plan #12 (2025):

### Activity 1: [Calculate the Z-Mass](#)

Target students: 9th grade AP Physics 1

Description: My 9th graders need more practice with vector addition and trigonometry, so this is an opportunity to continue practicing these skills at the beginning of the momentum unit. Analyzing this data, which is visually unfamiliar to students, is a way to apply their knowledge of conservation of momentum in a new situation. I would have students work in pairs, using different data sets, and use the class data to build upon the concept of histograms. Analyzing the class data, and then comparing it to the “real” data, allows students to not only get a glimpse of particle physics experiments, but increase their proficiency with data analysis.

Relevant content: Using histograms to analyze class data during the “calculate g” lab earlier in the year.

### Activity 2: [Heisenberg's Laser](#)

Target students: 11th/12th AP Physics C

Description: This is an excellent lesson to do post-AP exam in May. Often, students are eager to learn about physics concepts that are not taught in the AP curriculum. I intend to do a mini-unit on modern physics to close out the year. This is a great way to get hands-on learning in the classroom with quantum concepts, phenomena that are often studied in world-class facilities. With these students, a more teacher hands-off approach will give them the freedom to set up the experiment, gather data, and analyze the data on their own. I think this is an effective way to kick off the unit with a fun concept of uncertainty, and then dive deeper into other quantum concepts.

## Implementation Plan #13

### QuarkNet Data Activities

#### **Energy, Momentum, and Mass**

<https://quarknet.org/data-portfolio/activity/energy-momentum-and-mass>

This particular data activity involves graphing and linearization. Both are very important skills for all levels of high school science.

**Background:** In physics (grade 11-12), students cover topics of mass, momentum, energy, electricity and magnetism. Students can utilize their background knowledge to help them understand and interact with introductory particle physics.

One of the handouts includes rules for linearizing graphs. This is covered in AP Physics I, but (my school's) regular physics does not get much exposure to it. Having the students explore this data activity will allow for low stakes practice with linearization and interpretation of complex data.

**Activity:** I would have them copy the data table from the student sheet into either Desmos or Google Sheets. We would explore the relationship between the two variables by looking at the shape of the graph. It would be a mix of partner/group work and class discussion. After establishing the graphical relationship, students would try/suggest different ways to linearize the data (either offer suggestions if they have limited background knowledge or try different things together as a class on the projector). After linearizing the data we would write out the slope-intercept equation for the line and talk about what each of the values mean and how this shows the relationship between the variables. We would also discuss what the value of the slope means in the context of our data.

**Extension/Alternative:** Students could hand graph if they need practice with fixed scaling on the x and y axis, drawing a line of best fit, or just hand graphing in general.

#### **Calculate Z Mass**

<https://quarknet.org/data-portfolio/activity/calculate-z-mass>

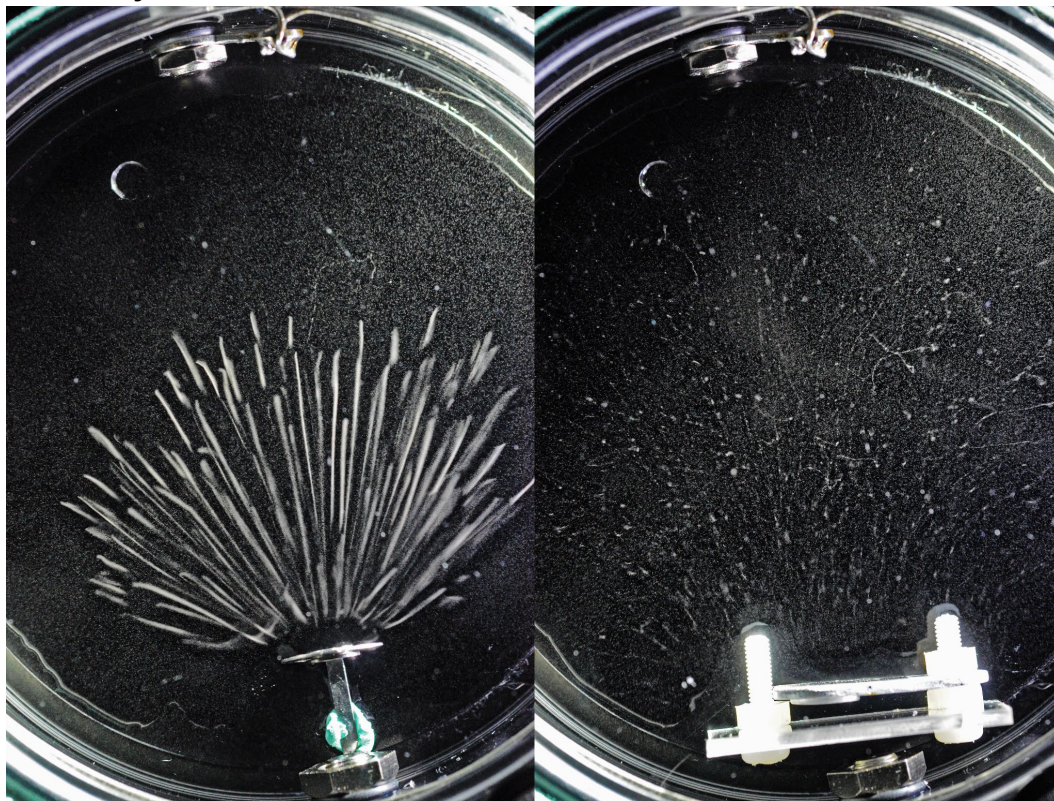
This activity could work well in AP Physics after we explore and practice vector addition and components. While they may not have been introduced to conservation of energy/momentum concepts yet, physically measuring the angles and using trigonometry is a good refresh of SohCahToa for students.

**Background:** Any physics class that explores vector addition/subtraction at angles. AP Physics I could easily explore this during many different units, though the activity itself looks at momentum.

**Activity:** After introduction/practice with vectors I would give them the student sheet, protractors, and printouts of collision events to complete measurements and calculate the net momentum. After getting those calculations, we would go over background information on the z boson (including the relevant equation to calculate the mass) and talk about what that value means and how scientists use that information.

## Implementation Plan #14

### Chemistry



- 1) Show the phenomenon of the cloud chamber
- 2) Ask students their observations
- 3) Ask them to try to explain their observations
- 4) Ask students to explain any differences in the paths
- 5) Ask students to explain why would the objects perhaps have these different paths, are there any assumptions we can make about the properties of the objects causing it
- 6) Students do an information hunt to learn more about the matter around them. They learn about atoms, protons, electrons.