QUARKNET

Race & Associates, Ltd.

Virgina Tech University

Implementation Plans
2024 and 2025

Implementation plans proposed by participating teachers during workshops held during 2024 and 2025 workshops are presented. Within each workshop year, plans are numbered to protect the identity of the teachers who proposed them.

August 2026

Implementation Plans

Friday 07 June 2024

Several Implementation Plans were proposed by Teacher 1

- Top Quark Mass Activity
- Quarknet PD Momentum Unit Plan
- DZero_events_0.pdf
- Calculating Mass of a Top Quark

Teacher #2

“Noise” in Data

Virginia Physics Standards 2018 PH.1.C

a) interpreting, analyzing, and evaluating data

- ***record and present data in an organized format that communicates relationships and quantities in appropriate mathematical or algebraic forms***
- ***use data in building and revising models, supporting explanation for phenomena, or testing solutions to problems***
- ***analyze data using tools, technologies, and/or models (e.g., computational, mathematical, statistical) in order to make valid and reliable scientific claims or determine an optimal design solution***
- ***analyze data graphically and use graphs to make predictions;***
- ***consider limitations of data analysis when analyzing and interpreting data***
- ***evaluate the impact of new data on a working explanation and/or model of a proposed process or system***
- ***analyze data to optimize a design***

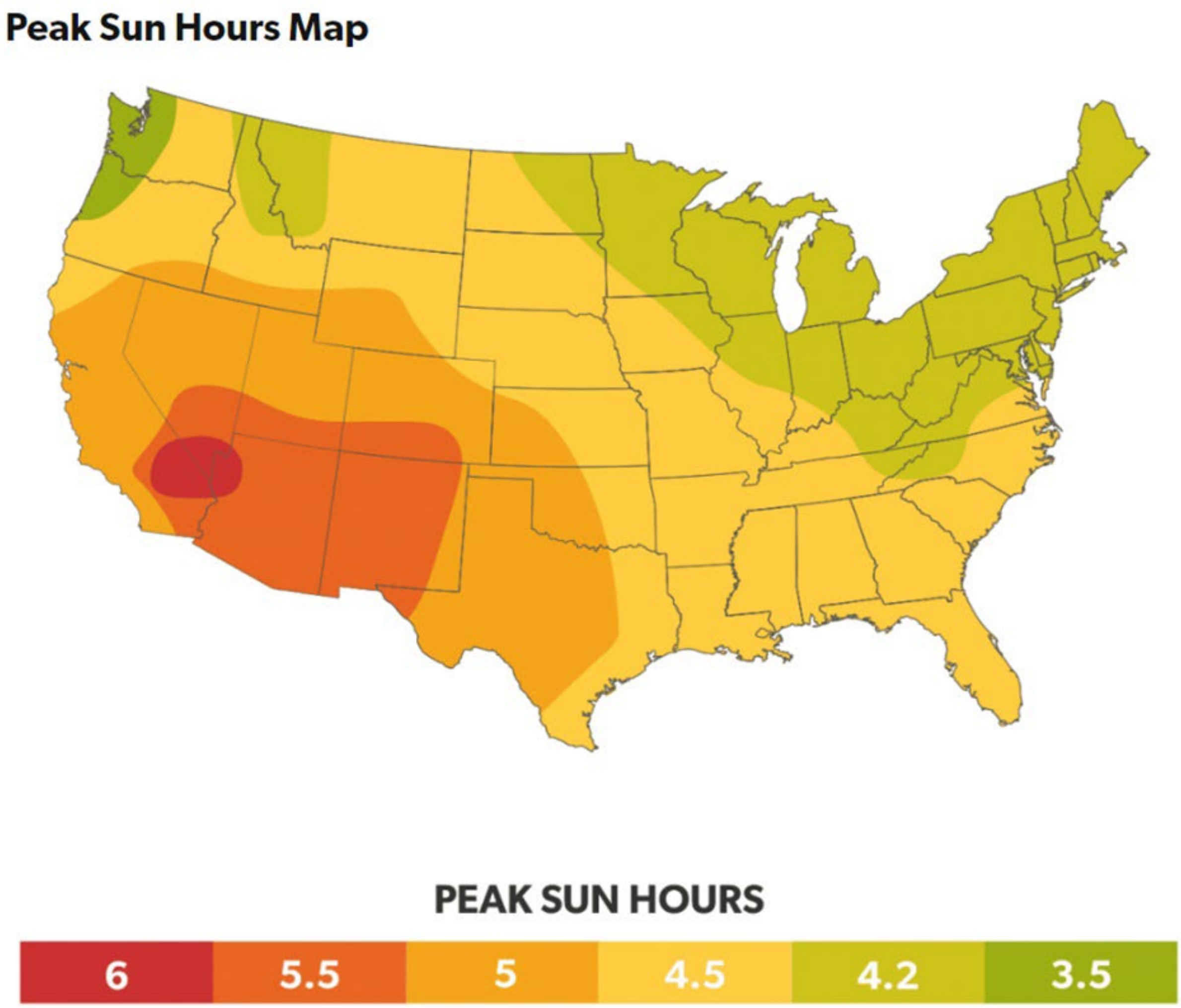
Imagine for a minute that you have been asked to participate in an experiment where you measure both the brightness and amount of direct ultraviolet light exposure on a summer day. Your data will be recorded over each day for several weeks and then published.

There’s just one problem, weather. You have collected data in both perfectly sunny, partly cloudy, and rainy conditions. Do we automatically assume that all of your data is perfectly valid? Do you just go ahead and make a graph of your daily data? Or do you somehow average the data?

If the clouds change every single moment, what should you do?

Teacher #2

What about smoke in the air?



Not every location has sunlight 100 percent of the day.

Let's try this…
Each of you will be given five dice. A six represents a perfectly clear day, a one or two represents a rainy day with no possibility of sun.
For each roll, take out the die that you roll where there is a one or two.

Teacher #2

Repeat until you have no dice left. As a class, we will record the results for each roll. Create a histogram of the data.

Then the students will participate in the half-life/lifetime experiment from QuartNet.

Teacher #3

Can you determine the significant data? Signal and Noise: The Basics

Thomas Physics

Name ______________________________

Date________________________________

Class_______________________________

INTRODUCTION:

1. What Do You Think? When scientists speak of noisy backgrounds, are they necessarily speaking about sound? _______

a. Give an example in an experiment of where background noise is sound. (Hint look at example in part 2)

b. Give an example in an experiment of where background noise is not sound.

ANALYSIS PART 1: NOISE IN OUR DAILY LIVES

Sound Waveforms Listen to two short audio tracks. One track is a drummer and the other is a recording of a tribal bells ceremony. Below is a depiction of the waveform for a regular drum beat (link to drum file) sample:

Figure 1. Typical drum waveform. https://www.soundsnap.com/search/audio/checker+drum/score and the other a tribal bells ceremony (link to tribal bells ceremony):

Figure 2: Tribal bell dance. https://www.soundsnap.com/search/audio/BTF+06+Tribal_30_Bells-+Dance-+People-+Crowd-General-+Ambience_06/score

Signal and Noise: The Basics. (2018, June 30). QuarkNet. https://new.quarknet.org/data-portfolio/activity/signal-and-noise-basics

Teacher #3

2. What Do You Think? Suppose you are on vacation and observe a tribal bells ceremony. You notice it becomes difficult to tell what you are hearing because of the increasing noise from the crowd, so you try to get closer to the ceremony.

a. What do you hear?

b. Does moving closer to the ceremony solve the problem?

c. Compare the wave form for the drum and the wave form of the tribal bells ceremony.

d. Record the similarities and differences.

e. Suppose the drum track had a lot of noise in it; what would the picture of the waveform in Figure 1 look like?

ANALYSIS PART 2: NOISE IN OUR DAILY LIVES

Video Noise Consider the images shown below:

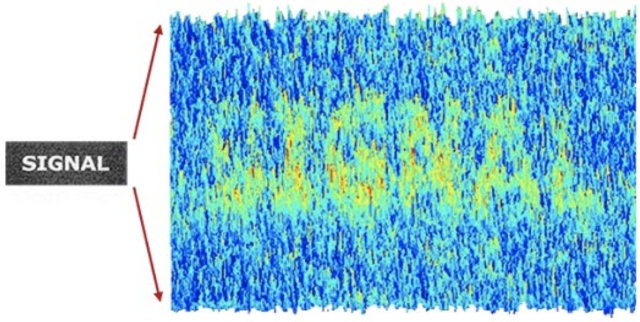


Figure 3.

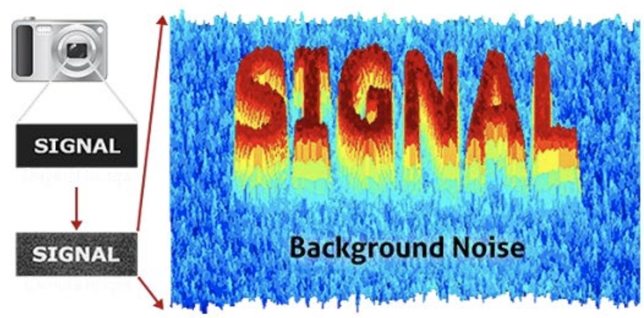


Figure 4.

Figure 3 https://cdn.cambridgeincolour.com/images/tutorials/noise_signal2_new.png
Figure 4 https://cdn.cambridgeincolour.com/images/tutorials/noise_signal1_new.png

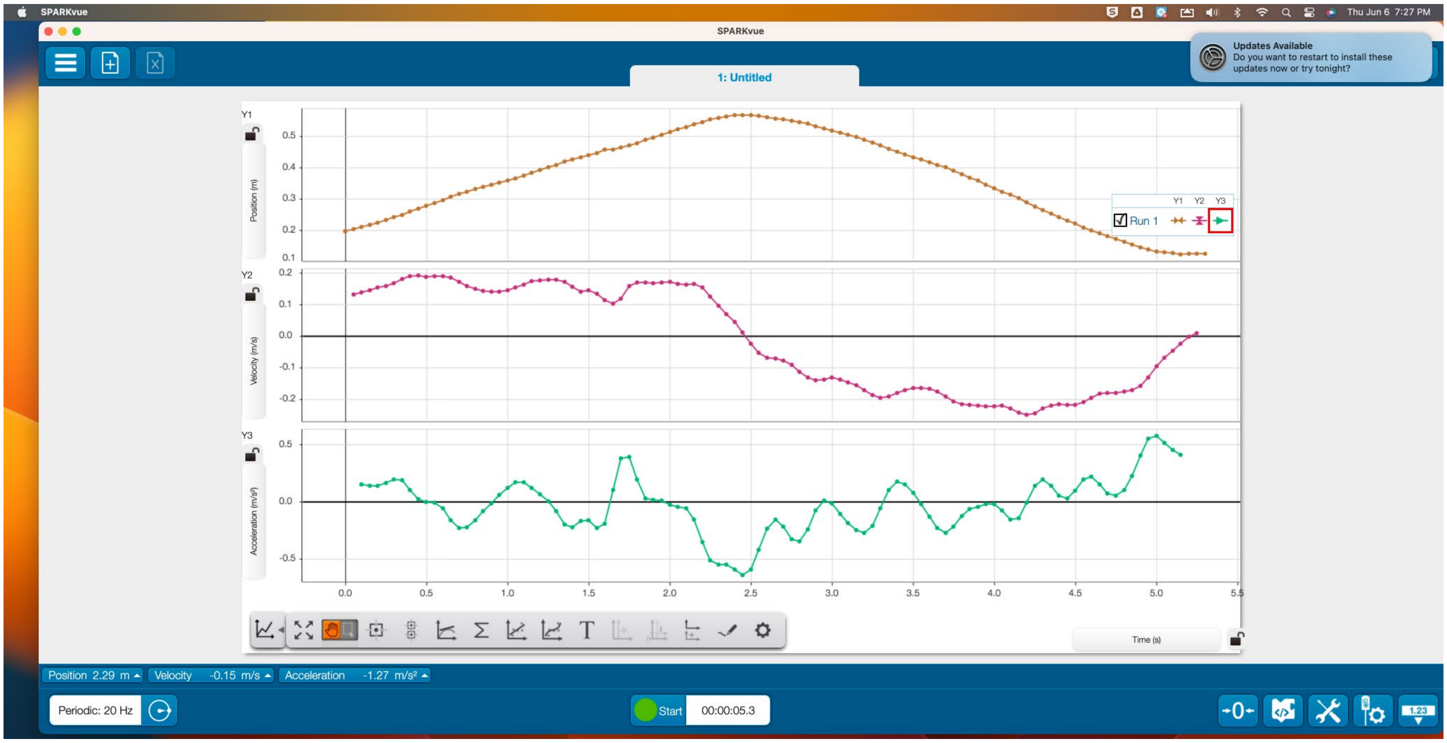
3. What Do You Think? You are working the video board at the local recording studio. You notice that there are controls labeled contrast and gain. Contrast controls the difference between the brightest and the darkest the image can be. Gain controls the amplitude of the signal.

Describe how the contrast and gain knobs were adjusted to create the image in Figure 4 from the image in Figure 3.

Signal and Noise: The Basics. (2018, June 30). QuarkNet. https://new.quarknet.org/data-portfolio/activity/signal-and-noise-basics

Teacher #3

ANALYSIS PART 3: MOTION GRAPHS

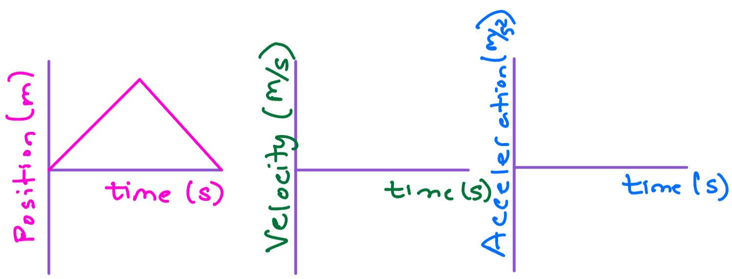


4. Analyze and Comment: Look at graphs created with a motion detector - Position vs Time, Velocity vs. Time, Acceleration vs. Time

a. When you created Position vs. Time graphs using a motion detector, what precautions did you take to get as smooth data as possible?

b. Could you look at the Velocity vs. Time graph and the Acceleration vs. Time graph and sketch the Position vs. Time graph? Why or why not?

c. Sketch an ideal Velocity vs. Time graph and Acceleration vs. time graph from the given Position vs. Time Graph.



Signal and Noise: The Basics. (2018, June 30). QuarkNet. https://new.quarknet.org/data-portfolio/activity/signal-and-noise-basics

Teacher #3

ANALYSIS PART 4: NOISE IN AN INSTRUMENT READOUT

Cosmic Ray Detector Noise

Similar to sound waves created by hitting drums, the cosmic ray detector "hears" signals produced by muons that pass through one of the counters. When the muon passes through the counter, it produces a brief flash of light that is converted into an electronic "signal." The figure below shows what a typical muon signal looks like when plotting PMT voltage vs. time

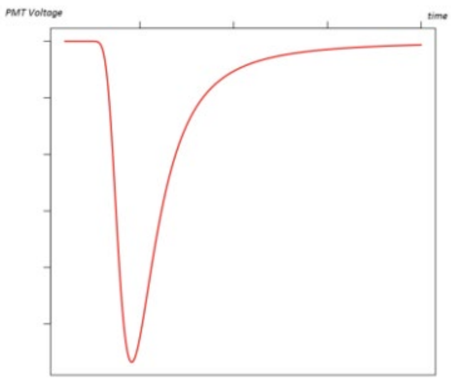


Figure 5. A typical muon signal

https://upload.wikimedia.org/wikipedia/commons/thumb/2/2a/Landau_distribution.svg/1024px-Landau_distribution.svg.png

This plot shows a very smooth curve which is the ideal representation of ideal data. However, there are lots of other things happening in addition to the muon passing through, and all of these things can add noise to the data. This noise could come from a variety of sources and can have a variety of shapes. Below is an example of what a noisy readout looks like, next to a less-noisy readout where the signal is easier to see.

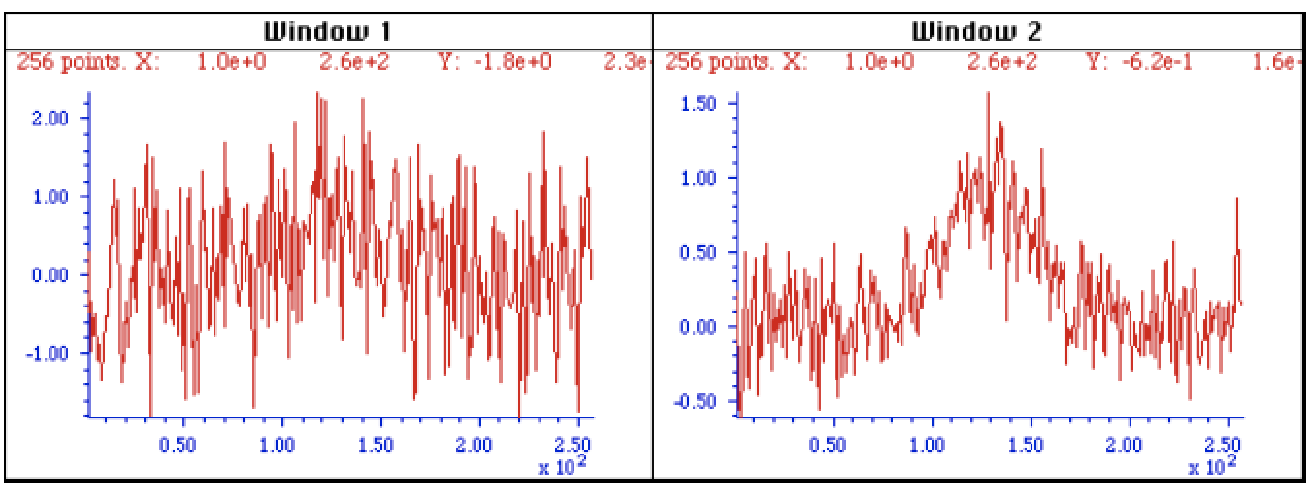


Figure 6: Noisy vs. less-noisy readout.

https://terpconnect.umd.edu/~toh/spectrum/Figure3.GIF

Signal and Noise: The Basics. (2018, June 30). QuarkNet. https://new.quarknet.org/data-portfolio/activity/signal-and-noise-basics

Teacher #3

Physicists need to know how well to trust that a signal is present. One measure of this is the signalto-noise ratio. If the readout is very noisy as in the left readout in Figure 6 above, the signal does not clearly rise out of the noise and the signal-to-noise ratio is small. When the signal clearly rises above the noise as in the right readout in Figure 6 above, the signal-to-noise ratio is larger. The bigger the signal-to noise-ratio, the more we can trust that a signal is present.

5. What Do You Think? When looking at the readouts shown above, Student A said that both of the readouts have so much zigzagging that it is impossible to decide if there is a signal present. Student B said that the zigzags on the right were smaller and the peak was higher than the zigzags on either side, so the readout on the right must have a signal.

a. Who is correct, Student A or Student B? Explain your reasoning.

b. Describe the details that led you to the claim that a signal is present in a noisy readout.

ANALYSIS PART 4: T. O'Donell - CUORE- CRYOGENIC UNDERGROUND OBSERVATORY FOR RARE EVENTS

What does Dr. O'Donell team use to get better resolution in the graphs?

huge detector - 13 floors

Underground clean room

Roman Lead

experiment running for years

ANALYSIS PART 5: CONSEQUENCES OF BETTER RESOLUTION

1. Cost - huge dollar cost to implement these procedures

2. Trade off - Wifi Signals Better resolution not as penetrating (shorter distance)

Signal and Noise: The Basics. (2018, June 30). QuarkNet. https://new.quarknet.org/data-portfolio/activity/signal-and-noise-basics

Teacher #5

QUARKNET Lesson

Data Portfolio Activity: TOTEM1

Vocabulary

i. Event
ii. Momentum
iii. Energy
iv. Interaction
v. Net

Intro

1. Review systems – open vs closed; "universal" vs "local"
   a. ***Open systems*** allow interactions through its borders; therefore, the net momentum of the system before and after an event is not conserved. This is because there will be unbalanced forces acting on the system, which **may** (or **will**?) do work on it.
   b. ***Closed systems*** do not allow interactions through its borders. This means that there are no net external forces acting on it. Under these circumstances, momentum is conserved.
   c. ***Global systems:*** Basically, the whole universe. Conservation of momentum is a universal principle of Physics; it stems from the symmetry of space – the fact that experiments under the exact same conditions will yield the exact same results regardless of how the set ups are (a) located; and/or (b) rotated in relation to each other.
   d. ***Local systems:*** Any system that is not global (i.e., the universe) is a "local" system.
      - Example: Consider a collision between two elastic objects A and B. If we look at A only, we will see it change momentum (the action force of A on B). If we look at both objects, total momentum is conserved.

2. Review (or introduce) conservation of momentum in 2D
   a. Graphically: have them calculate vectors using triangle, protractor, and ruler.
   b. Mathematically: have them add vectors using components. Compare the two methods.

3. Big questions:
   a. Do relativistic particles obey the Conservation of Momentum Principle?
   b. If so, how can we use this information to find out if other particles exist?
   c. If we find out there must be other particles in the collision (that perhaps we cannot detect), then:
      i. How can we use conservation principles to measure at least some of their properties?
      ii. What could prevent us from being able to detect certain particles in the first place?

Teacher #5

ACTIVITIES

- TOTEM1
- Mass of Z Boson
- Mass of Top Quark
- Mass of Muon
- Mass of Higgs boson (Perimeter Institute)
- Energy, Mass and Momentum
- The Case of the Hidden Neutrino

Highlights – what these activities might help with:

A. Dimensional analysis;
B. Vector addition (in particular, velocity vectors)
C. E^2 vs p^2 plot – helps with AP, where they have to analyze different plots and figure out what they mean;
D. E^2 vs p^2 plot – also helps with linearization (in AP); can lead to a project where they linearize graphs using log-log or monolog paper;
E. Conservation of Momentum and Energy principles being universal;
F. Histograms and estimating error in value obtained (FWHM);
G. Using data to "discover" new things – particles, "rules", etc.

Other uses (outside physics)

H. Decay activities can be used in the teaching of Calculus:
   - Mean Lifetime, Part 1: Dice
   - Mean Lifetime, Part 2: Cosmic Muons

Possible Implementation Plans

1. ***Use as an end-of-the-year project***
   Students could work on relativistic vector addition and conservation of energy. If so, I would introduce some of the relativity formulas and ideas we discussed. I would also explore the "natural units system" and talk about the energy-mass-momentum equivalence (I would have to be careful with explanations: "relativisticaly" speaking, length and time are not two but one dimension, etc.

2. ***Use them as examples of concepts we see classically***
   - Addition of vectors (kinematics, for velocity vectors)
   - Conservation of momentum
   - Conservation of energy (I am not sure how that would fit.)

Teacher #6

Activity: Minimizing Noise in a Cosmic Ray Muon Detector

Objective: Students will learn about cosmic ray muons, their detection, and how to minimize noise in a cosmic ray muon detector. They will also gain hands-on experience with basic principles of physics, data acquisition, and analysis.

Materials:

- Cosmic Ray Muon Detector (e.g., QuarkNet Muon Detector)
- Oscilloscope
- Power supply
- Shielding materials (e.g., lead blocks, aluminum foil)
- Cables and connectors
- Data acquisition software
- Computer
- Notebook and pen for recording observations

Duration: 2 class periods (90 minutes each)

Activity Outline

Day 1: Introduction and Initial Setup

1. Introduction to Cosmic Ray Muons (20 minutes)

- **Lecture:** Briefly explain cosmic rays, muons, and their significance in particle physics.
- **Discussion:** Discuss the challenges in detecting muons and the concept of noise in detection systems.

2. Overview of the Detector (20 minutes)

- **Presentation:** Describe the components of the muon detector and how it works.
- **Demonstration:** Show the students how to set up the detector and connect it to the oscilloscope and computer.

3. Initial Detector Setup (30 minutes)

- **Hands-On:** Students will work in groups to set up their detectors.
  - Connect the power supply.
  - Connect the detector to the oscilloscope and computer.
  - Install the data acquisition software on the computer.

4. Data Collection (20 minutes)

- **Activity:** Students will collect initial data from the detector without any noise reduction measures.
- **Observation:** Record the number of muon hits and noise events detected.

Day 2: Minimizing Noise

1. Review and Discuss Initial Findings (15 minutes)

- **Discussion:** Students share their observations and discuss potential sources of noise in their initial data.

2. Implementing Noise Reduction Techniques (45 minutes)

- **Hands-On:** Students will experiment with different noise reduction techniques:
    - **Shielding:** Use lead blocks or aluminum foil to shield the detector from external sources of radiation.
    - **Grounding:** Ensure all components are properly grounded to reduce electrical noise.
    - **Environmental Control:** Minimize vibrations and electromagnetic interference by choosing a quiet location away from other electronic devices.
- **Experiment:** Test each noise reduction technique individually and in combination, recording data for each configuration.

3. Data Analysis (20 minutes)

- **Activity:** Compare the data collected with and without noise reduction measures.
- **Analysis:** Identify which techniques were most effective in reducing noise and improving the signal-to-noise ratio.

4. Conclusion and Discussion (10 minutes)

- **Discussion:** Summarize the findings and discuss the importance of minimizing noise in scientific experiments.
- **Q&A:** Address any remaining questions and encourage students to think about other applications of noise reduction in physics and engineering.

Assessment

1. Lab Report:

- Students will write a lab report summarizing their setup, experiments, observations, and conclusions.
- The report should include graphs or tables comparing the data before and after implementing noise reduction techniques.

2. Presentation:

- Each group will present their findings to the class, explaining the effectiveness of different noise reduction methods and their impact on the detection of cosmic ray muons.

Extension Activity

Build a Shielded Enclosure:

- As an extension, students can design and build a custom shielded enclosure for the detector, testing its effectiveness in further reducing noise and improving muon detection accuracy.

This activity not only teaches students about cosmic ray muons and their detection but also imparts practical skills in experimental setup, data collection, and analysis, which are crucial for any budding physicist.

Implementation Plan – Teacher #7 - 2024-25 - QuarkNet

Links and notes: (NOTE: buy dice)

- Standard model and nature of science
  - Early 'nature of science lab' - mass of penny histograms and how they've changed over time with composition as per how they're made: https://new.quarknet.org/data-portfolio/activity/mass-us-pennies
    - (do class-wide histogram with sticky notes on whiteboard - they put their 'data point' as a sticky note and add it to the graph)
    - Consider adding other types of coins as 'noise' in the data (can then do 'noise in our daily lives activity on quarknet)
  - Particle "card-sort'" activity: https://new.quarknet.org/data-portfolio/activity/shuffling-particle-deck
    - Periodic table "card sort" activity / discussion - finding patterns - how was this organized and how it was an example of many observation experiments leading to hypothesis that could be tested
    - Have them do the card sort activity for particles (Rebecca's edited version with names removed): https://drive.google.com/file/d/1sMZl9JfRLkL5CbsaPedDYD-aLiY8DG1k/view
      - Modify this activity by adding the dates of 'discovery' (physical observation)
      - Have students all do sorting then have them do a gallery walk and come up with one master sorting taking the features they like best from all the groups -> compare this to the standard model
      - Discuss historic experiments - which were observation experiments, which were testing experiments?
      - Discuss the naming of the particles - and how that, in some cases, came from the order of discovery and puzzles they created - such as strangeness
      - Discuss the pairing of particles - such as electron neutrinos with elections in specific experiments
  - 1st dice decay activity? https://docs.google.com/presentation/d/1t_H-MkuYUZCz8GFsqAvRUkJYuoN0Sx2ynL7T_boIvfM/edit
  - What is a muon? What is a lifetime? Dice decay lifetime activity: https://kevinm283.sg-host.com/data-portfolio/activity/cosmic-muon-lifetime
    - Exponential decay video: https://docs.google.com/presentation/d/1t_H-MkuYUZCz8GFsqAvRUkJYuoN0Sx2ynL7T_boIvfM/edit
  - Standard model video: https://www.youtube.com/watch?v=XYcw8nV_GTs
  - Have students explore the particle adventure page: https://particleadventure.org/
    - Possible questions to use when students go through this: https://docs.google.com/document/d/18GgAh2D9g0VJ2DxeCCmdjHgdw48b4eExJx5R_fSelLc/edit#heading=h.gjdgxs

- And/OR have them look at fermilab's nature of matter page: https://www.fnal.gov/pub/inquiring/matter/index.html
- Have students practice particle reaction 'balance' equations such as they would with chemical reactions based on the conserved quantities: https://drive.google.com/file/d/1las8eFkBaRRnnRUhgrew-th0Teiogrms/view
- Hunt for solar neutrinos: https://www.pbs.org/wgbh/nova/neutrino/

- Special relativity:
    - Using real data to estimate the speed of muons: https://kevinm283.sg-host.com/data-portfolio/activity/how-speedy-are-these-muons
    - Muon tomography: https://www.youtube.com/watch?v=rbzt8gDSYIM
    - Relativity and the light clock: https://new.quarknet.org/node/2502
    - Time dilation video: https://www.youtube.com/watch?v=rbzt8gDSYIM
    - Relativity simulation: http://relativityland.org/
- Energy and momentum and mass:
    - Learn more about W and Z creation: https://atlas.physicsmasterclasses.org/en/wpath.htm
    - Relating energy, momentum and mass: https://kevinm283.sg-host.com/data-portfolio/activity/energy-momentum-and-mass
    - Minute physics video: https://www.youtube.com/watch?si=4aeOXN0IpIbuw9Nd&v=NnMIhxWRGNw&feature=youtu.be
    - (note there's also a top quark mass activity in quarknet)
    - Muon mass and arachne: https://arachne.quarknet.org/masterclass.html?filename=/disks/arachne/outreach/muondecayDST/v8r2p2_2063_2085/63/MV_00002063_0005_numip_v05_1004041746_RecoData_DST_v8r2p2.root&entry=476&slice=1&filetype=dst (see bottom of agenda) https://new.quarknet.org/node/2503
    - Ultimate speed old video: https://www.youtube.com/watch?v=B0BOpiMQXQA
    - Momentum and energy conservation:
        - Subatomic bomb squad: https://www.fnal.gov/pub/today/archive/archive_2012/today12-04-20_NutshellReadMore.html
        - Calculating the z-boson mass using E^2 = p^2 + m^2 (with c set to 1) https://new.quarknet.org/data-portfolio/activity/calculate-z-mass (z-boson mass events from proton-proton collisions: https://quarknet.org/page/z-mass-calculation-event-images)
- (OPTIONAL) - E&M portion -> detectors:
    - https://quarknet.org/data-portfolio/activity/mapping-poles
    - https://docs.google.com/document/d/14JAf-Yx79PG_XkJvrasK37n5fQKTgFekQudDGpAGdHs/edit
    - https://docs.google.com/presentation/d/1t_H-MkuYUZCz8GFsqAvRUkJYuoN0Sx2ynL7T_bolvfM/edit

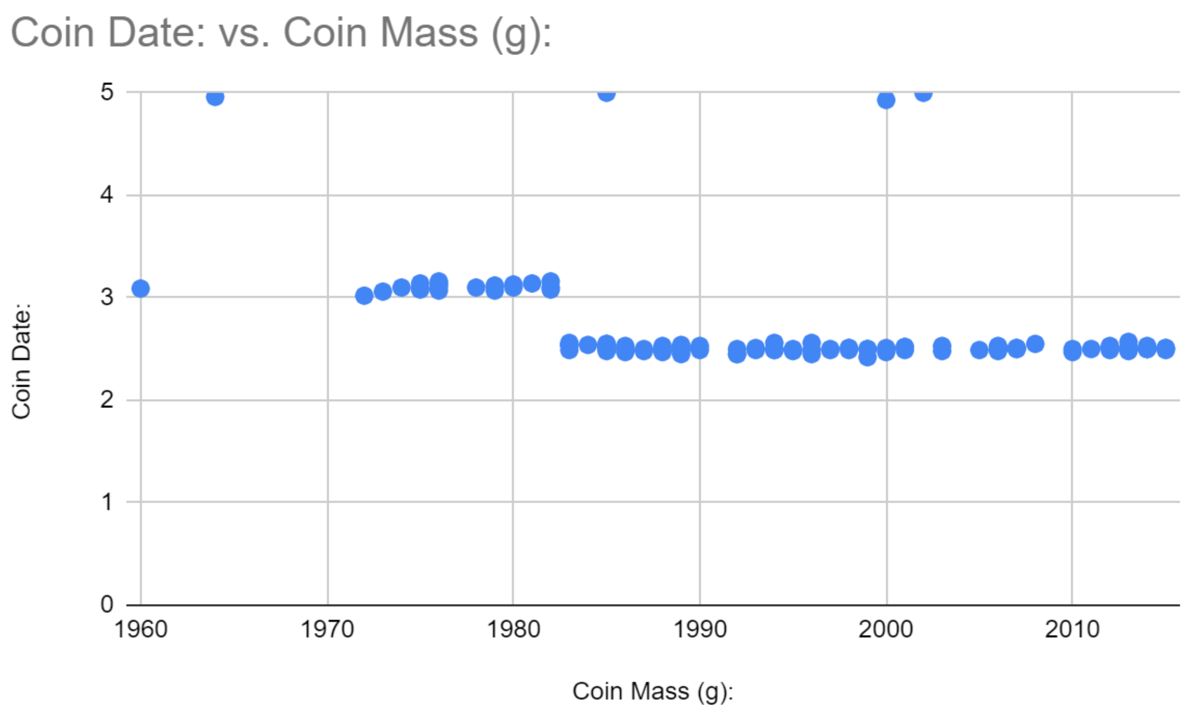
Extraneous ideas:

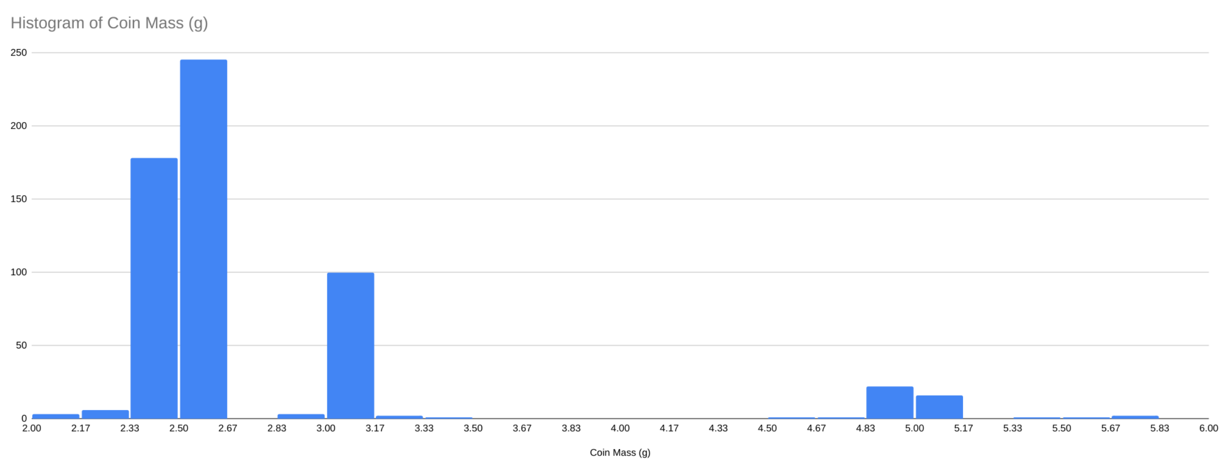
- See if we can watch a live NASA launch online in the fall

Teacher #8

Implementation of activities in my class:

1: Penny Lab:
This is the lab activities I am planning to implement on the first day of the school year teach my students concept about how to use histograms and give them concepts about isotopes which they might have learned a little bit about in their Chemistry class





2: Energy Momentum and Mass:
This is the lab activities I am trying to implement at the end of the first-semester project for DE and the end-of-the-year project for Honors.

Teacher #8

3: Calculation of Mass of a Z- Boson:

This is the project I am going to use at the end of the year project. Students have learned how to use protractors to measure angles and find components of a vector and the resultant of two or more than two vectors while doing the vector chapters. Also, nuclear and particle physics will be introduced during the second semester. So, this will be an end-of-year project that combines the concepts students have learned the entire year.

Mass Energy and Momentum	6/7/2024 1:16 PM	File folder
Mass of Z Boson	6/7/2024 1:14 PM	File folder
Penny Mass	6/7/2024 1:16 PM	File folder
Built a motor	2/8/2019 2:48 PM	Adobe Acrobat Docu..
cosmicmuonplots	6/7/2024 1:20 PM	Adobe Acrobat Docu..
edited_mgb-Dice Lifetime and Halflife dmr ...	6/7/2024 1:18 PM	Adobe Acrobat Docu..
Mean Lifetime Cosmic - Student dmr-mgb p...	6/7/2024 1:19 PM	Adobe Acrobat Docu..
Muon Lifetime Teacher Notes dmr -mgbpost...	6/7/2024 1:19 PM	Adobe Acrobat Docu..

4: Rolling a dice: for conceptual at the end-of-year fun….

Teacher #9

PHYSICS

QUARKNET DATA ACTIVITIES – IMPLEMENTATION PLAN

ACTIVITY	CONCEPT	CLASS AND UNIT
1. Mass of U.S. Pennies	Intro to data collection, histograms	PHY/AP1/AP2 Intro Units
2. Mapping the Poles	Intro to Fields	PHY/AP2 E-M Units
3. Making it 'round the Bend	Effects of electric and magnetic fields	PHY/AP2 E-M Units
4. Signal and Noise	Intro to signals / mapping	PHY/AP2 Waves Units
5. Shuffling Particle Deck	Intro to particles ('Match Game' for PHY and 'Go Fish' for AP2)	PHY/AP2 – Atomic Unit / Modern Physics Unit
6. Quark Workbench + Particle Adventure	Intro to particles – part II	AP2 – Modern Physics Unit
7. The Hidden Neutrino	show conservation laws in special relativity	AP2 – Modern Physics Unit
8. What Heisenberg Knew	Intro to Uncertainty	AP2 – Modern Physics Unit
9. Mean Lifetime Dice Game	Intro to Nuclear Decay	AP2 – Modern Physics Unit
10. Relativity Concepts + RelativityLand.org	Tutorial Intro to Relativity	AP2 – Modern Physics Unit

PLUS:

Incorporate every video and link shared with us to open the corresponding unit, introduce concepts, and elicit questions.

Implementation Plans

Friday 01 August 2025

Teacher #1

Class: Physics 1, AP Physics

When to present: Physics 1: During Particle Physics/NOS unit at beginning, AP Physics: Either during E&M or after AP Exams

Description:

Cosmic Watch Labs: Use detectors in conjunction with large QuarkNet CRMD for lab to help introduce students to the basic ideas behind particle detection (scintillators, photomultipliers, coincidence, etc). Have students hypothesize how coincidence rates will change as detectors are spaced apart, moved (inside vs outside, altitude changes), detector area overlap varies, and more. We can also experiment with radiation sources and shielding

MINERvA Masterclass: I would like to have my students do this masterclass this year.


Total Count: 205
Uptime: 0:01:03
Rate: 4.103+/-0.287


Total Count: 200
Uptime: 0:05:58
Rate: 0.689+/-0.049
WOW!

Teacher #2

Class: Online Physics (10-12th grade)

When to present: This lesson could occur just before a more in-depth lesson on Particle Physics or possibly as a lead-in for best practices for a lab at the beginning of a school year.

Description: I would love to continue the shielding lesson using the Cosmic Watches. In the workshop, we tested the Cosmic Watches in a lead housing and we tested them near a welding rod made of tungsten which was 2% thoriated. I would love to try to determine what other materials could be found that could affect it.

Teacher #3

Class: AP Physics & Physics

When to present: AP Physics: after the AP exam. Physics: as a mini particle physics unit

Description: Students will be provided a mini lesson on particle physics (use particle cards as an introduction) and conduct investigation using the Cosmic Watches.

- Investigations: Distance vs. Count Rate & Altitude Study
- Students can also design their own experiments to test

Teacher #4

Class: AP Physics C Mechanics

When to present: After the AP Exam or a club after School

Description: I will have the students use the cosmic clocks to conduct three experiments, collect data and analyze the data graphically.

Experiment 1. Measure count rate vs solid angle.Graph rate vs separation.

Experiment 2, Measure count rate vs zenith angle.

Experiment 3. Measure count rate vs separation distance from a potassium source.

Experiment 4. Measure count rate vs altitude.

Teacher #5

Class: Chemistry 1

When to present: Introduction of periodic organization -trends

Description: Teams of students will organize cards depicting fundamental characteristics of elements. Start with atomic size. (this is before I teach them atomic number). This activity can be performed prior to atomic structure and in conjunction with the “Alien periodic table”. This will help students see that the periodic table makes sense and that it has a specific meaningful order. It is a foundation for learning about the Standard Model and parallels the methods used by scientists to organize the elements into the periodic table.