Race & Associates, Ltd.

University of New Mexico
2023-2025

Examples of Student Work
Implementation Plan and Posters Created by QN Teachers

The following pages present an example of student work from a classroom visit by a QuarkNet staff teacher who engaged students in two QuarkNet DAP activities, *Shuffling the Particle Dec*k, and *Rolling with Rutherford*. This visit was at a public high school where the teacher is a participant in QuarkNet at the University of New Mexico Center. Each group example represents the work by a group of students. After the group completed their work, the whole class engaged in a "field trip" around the classroom to learn the justification for each group's work. (As per email from S. Wood December 15, 2023.)

After this, an implementation plan proposed for a participating teacher (2024). Finally, three posters created by teacher groups during a workshop (2025) are presented (individual teachers are identified when this information was included in the poster that was posted by them on the website).

August 2026

Particle Cards

Organize the cards on the next slide based on the properties printed on the front of each one. Resize the cards as necessary to see the information, and then arrange them in groups based on what makes sense to you.

Group 1: Quarks

TOP QUARK
DISCOVERED: 1995

MATTER PARTICLE

Mass:	$173 \cdot 10^3$ MeV/c^2
Electric Charge:	$+2/3$
Strong Charges:	blue, red, green
Weak Charge:	$+1/2$
Lifetime:	$6 \cdot 10^{-25}$ s

CHARM QUARK
DISCOVERED: 1974

MATTER PARTICLE

Mass:	1300 MeV/c^2
Electric Charge:	$+2/3$
Strong Charges:	blue, red, green
Weak Charge:	$+1/2$
Lifetime:	10^{-12} s

UP QUARK
DISCOVERED: 1969

MATTER PARTICLE

Mass:	2 MeV/c^2
Electric Charge:	$+2/3$
Strong Charges:	blue, red, green
Weak Charge:	$+1/2$
Lifetime:	unlimited

BOTTOM QUARK
DISCOVERED: 1977

MATTER PARTICLE

Mass:	4200 MeV/c^2
Electric Charge:	$-1/3$
Strong Charges:	blue, red, green
Weak Charge:	$-1/2$
Lifetime:	$2 \cdot 10^{-12}$ s

STRANGE QUARK
DISCOVERED: 1969

MATTER PARTICLE

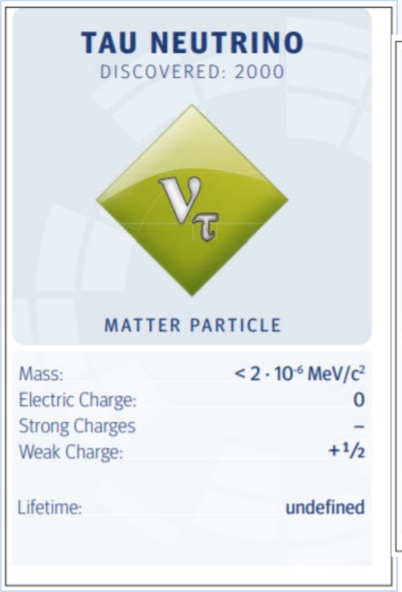
Mass:	100 MeV/c^2
Electric Charge:	$-1/3$
Strong Charges:	blue, red, green
Weak Charge:	$-1/2$
Lifetime:	$5 \cdot 10^{-8}$ s

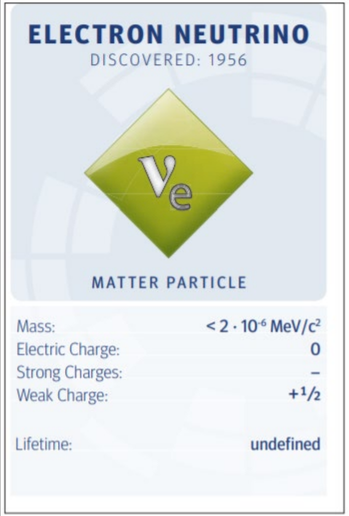
DOWN QUARK
DISCOVERED: 1969

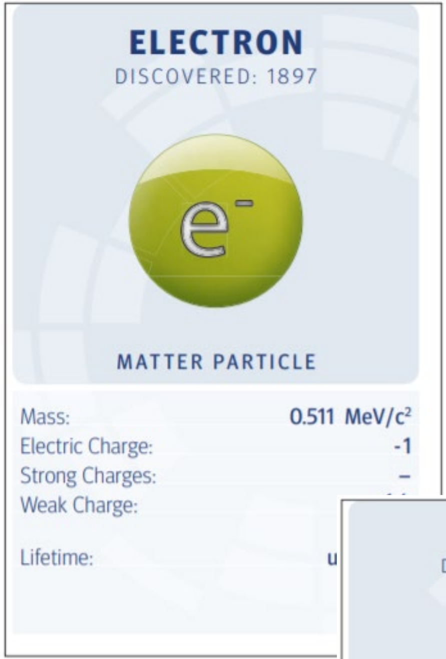
MATTER PARTICLE

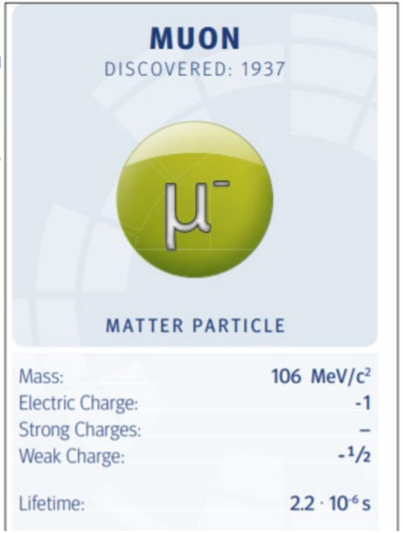
Mass:	5 MeV/c^2
Electric Charge:	$-1/3$
Strong Charges:	blue, red, green
Weak Charge:	$-1/2$
Lifetime:	900 s

Group 2: Leptons

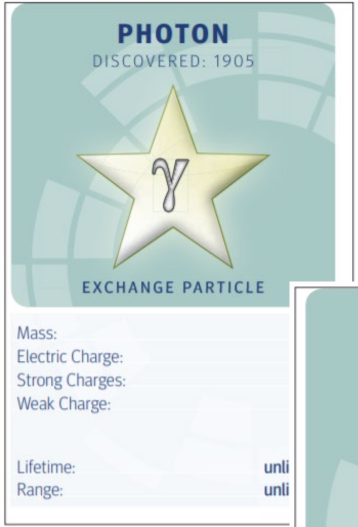


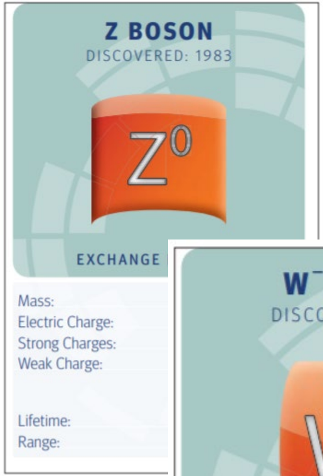


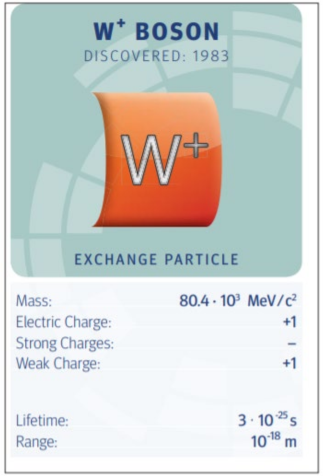


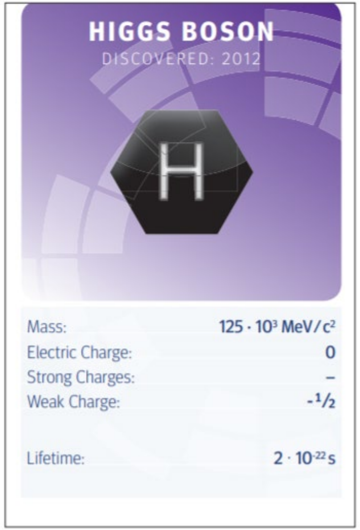


Group 3: Bosons

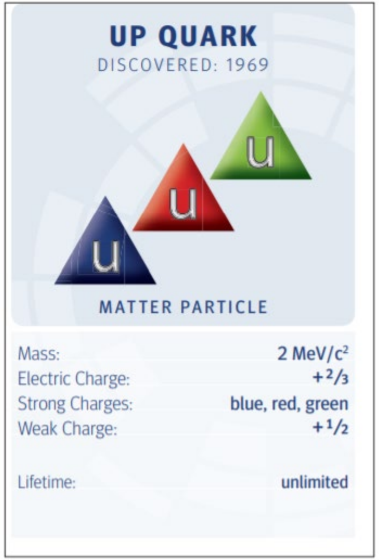


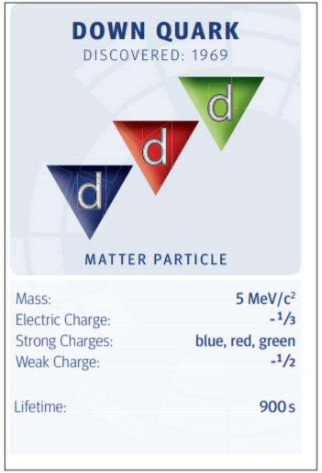


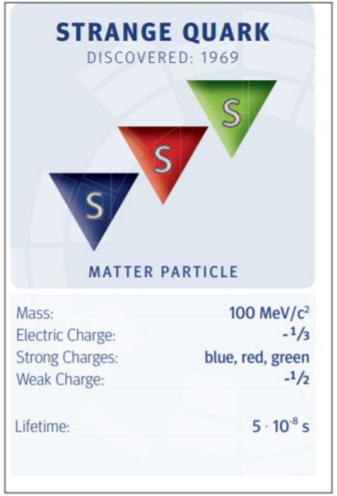


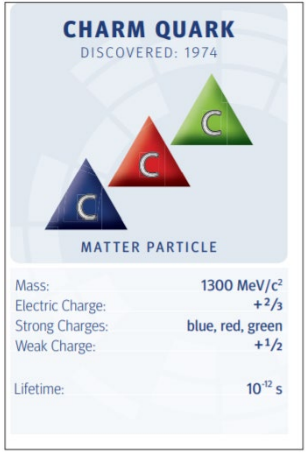


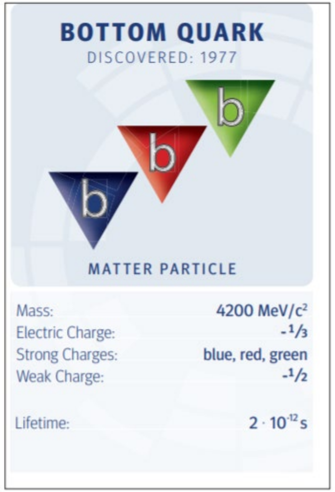
Group 4: Quarks

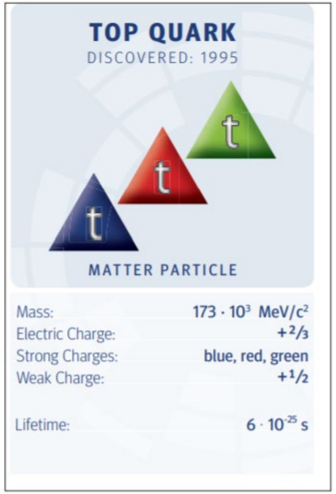




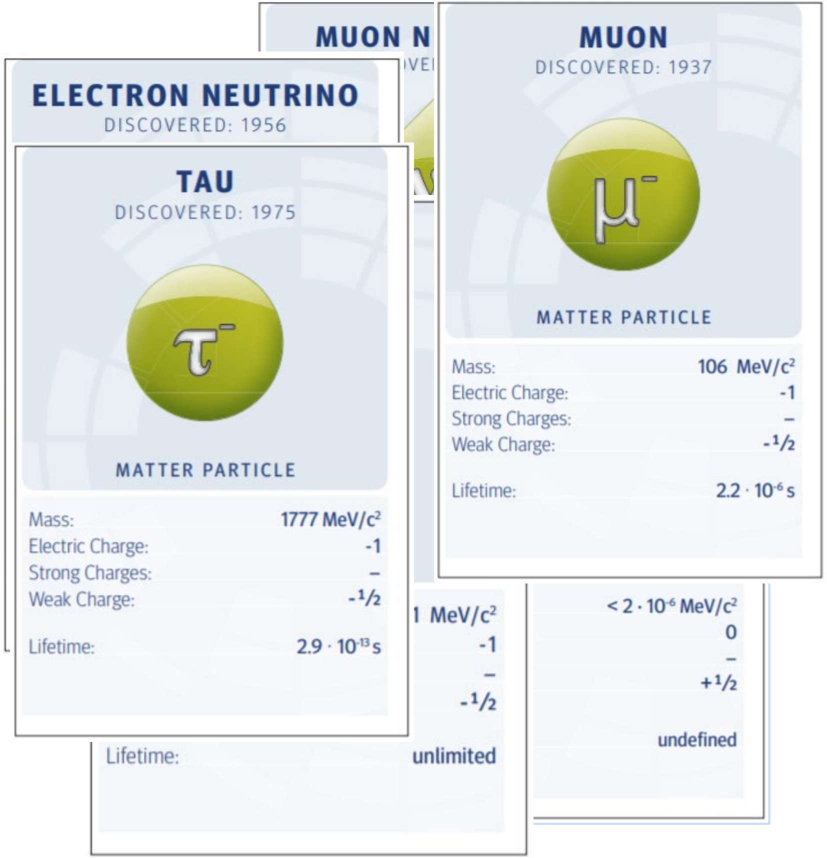




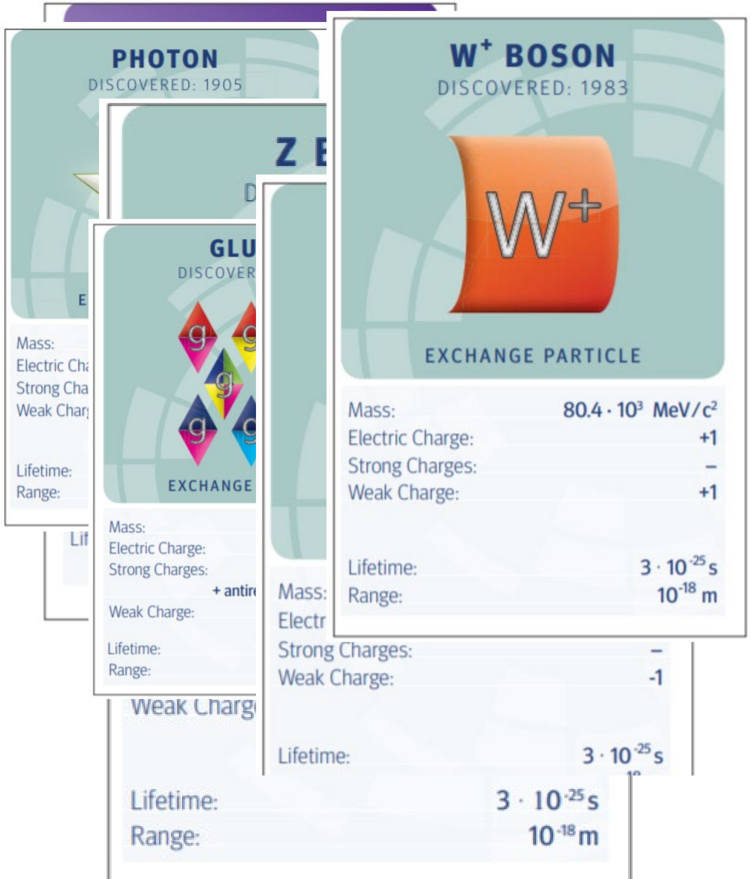




Group 5: Leptons



Group 6: Bosons



Implementation Ideas: 2024-2025 School Year

1. Chemistry -
   a. 3D printed quarks - Why are protons positive? How are protons and neutrons the same/different? (part of atomic structure topic)
      i. Quark Workbench 2D/3D | QuarkNet
   b. Elements Colab notebook/assignment
      i. Increasing familiarity with periodic table/periodic trends

2. Physics
   a. What happens when protons collide activity
      i. Energy - what is it? $E=mc^2$
      ii. Nicole's slide with fruit
   b. Motion graphing (position v time graphs)
   c. Velocity graphing
   d. Introductory graphing template notebook (Just an idea right now)

3. StepUP
   a. Careers with physics degrees

Cosmic Watches Stairwell Anomaly
QuarkNet 2025

Abstract:

We measured the event rate of atmospheric muons using a portable muon detector (Cosmic Clock). The muon detector was used to map the muon event rate as a function altitude in an enclosed 4-story building.

Introduction

Cosmic Rays are a common source of daily background radiation. Ground based radiation is typically composed of muons. Due to the relativistic speed of the muons, these fundamental leptons can survive to and below the Earth's surface. The number of muon events are expected to decrease from their atmosphere source due to the short 2.2x10-6 secs muon lifetime.

Materials

- Cosmic Watch/ muon detector
- Portable Power Source
- Stairwell with 4 levels

Method

Cosmic ray events were detected using a "Cosmic Watch". This is a detector that is composed of a 4cm x 4cm scintillator, a silicon photomultiplier, a data acquisition device, and a power supply. (Seen below.) Data was collected after running the cosmic watch for three minutes in each level of the stairwell. The cosmic watch was placed in the southeast corner of the stairwell on the railing. (Level 1 did not have a railing, so the detector was placed on the door push bar at the same level as the raining.) We compared the muon flux at each level.

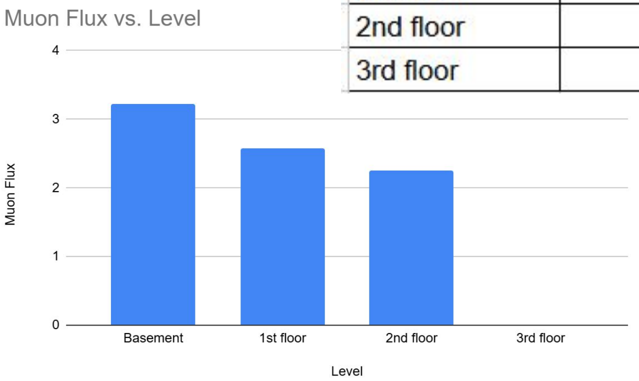
Results

As we descended the stairwell, the muon flux increased.

Discussion

Our expected results were that the muon flux to decrease as the floor level decreased. We were surprised by the results of the muon flux increasing as the floor level decreased. Due to these results, we ran the tests with a different cosmic watch, and found similar results. We wonder if this is because of the stairwell or if we would see these results in other areas.

Level	Muon Flux
Basement	3.217
1st floor	2.581
2nd floor	2.253
3rd floor	0.007



Brie Logan and Gordon Zwartz

Effect of Distance on Radiation Intensity from Fiestaware

Bill Siefert, Tim Lam, and Kelly Lasater

Procedure:

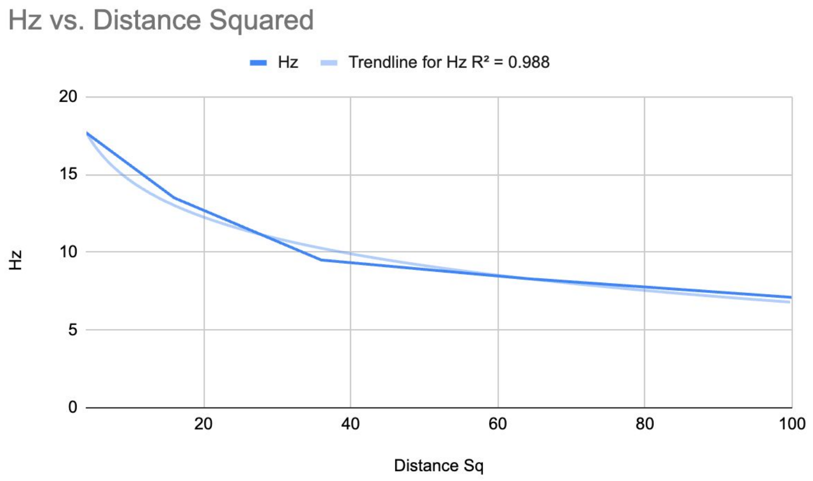
1. Place the Cosmic Watch on a table, turn sensor side to face sample.
2. Place sample 2 cm from the sensor, record counts per second (Hz) from the detector averaged for one minute.
3. Repeat data collection every 2 cm up to 10cm.
4. Data was recorded in a spreadsheet and graphed as Hz by distance^2.

Materials:

Cosmic Watch, Fiestaware plate, ruler, stopwatch

Results:

Counts per second decreased as distance between source and detector increased.



Cosmic Watch Experiment: Measuring Radiation vs. Distance

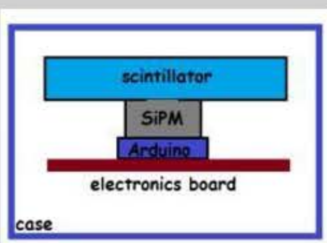
Mitchell, K.[1], Pickel, A.[2], Reynolds, S.[1], Wood, S.[3]
[1]Atrisco Heritage Academy HS, Albuquerque, NM; [2]21st Century Public Academy, Albuquerque, NM; [3]Quarknet Staff
k North High School Emeritus and Quarknet Fellow

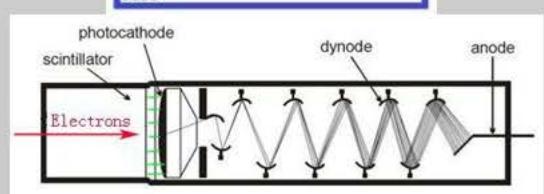
Motivation

his experiment allows students to visualize how adiation rate changes as distance from a source increased. Students also develop roblem-solving and experimental design skills hrough performing an authentic scientific xperiment.

Background

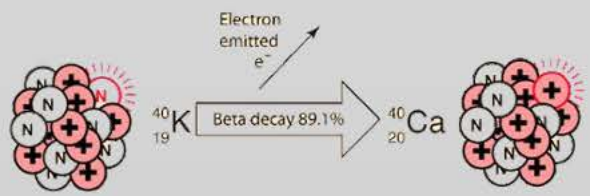
This experiment was conducted with a Cosmic Watch, a small cosmic ray detector that consists f a 4cm x 4xm scintillator, a silicon hotomultiplier, a programmable Arduino taking lata, a small screen to read data, and supporting lectronics. It was designed at the Massachusetts nstitute of Technology by Spencer Axani. This letector was designed to be used by teachers, tudents, and experiments to build on their own nd make meaningful measurements of cosmic ays.





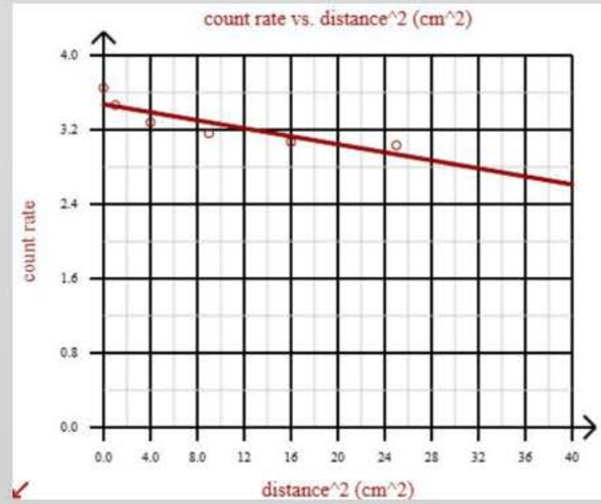
Experimental Procedure

The radiation source for our experiment was a salt substitute with KCl which contains small amounts of the radioactive isotope potassium-40, which undergoes beta decay, emitting electrons and neutrinos. The cosmic watch detects the electrons.



We turned the cosmic watch on its side to point at the salt substitute for our measurements. We began with establishing a baseline count rate without the salt substitute, then began taking measurements with the salt substitute at increasing distances from the cosmic watch at 1 cm intervals. For each distance, we allowed the watch to take data for 5 minutes.

Data and Results



Data Set 1

$$y = (-0.02155) * x + (3.474)$$

Correlation: 0.87075

As the radiation source was moved further from the cosmic watch, the detected count rate decreased as expected, but not as linearly as expected. This could be due to additional environmental radiation sources interfering with the data.

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