MASS OF U.S. PENNIES
TEACHER NOTES

DESCRIPTION
Students will use an electronic balance to determine the mass of many, many U.S. pennies (a one-cent coin) of varying ages. The composition of the penny has changed over the years. Different compositions can have significantly different masses. A sufficiently random selection of hundreds of pennies should allow the students to discover the years in which the composition changed. (One critical change occurred in 1982 when the composition changed from 95% copper to 97.5% zinc.)

STANDARDS
National Science Education Standards (U.S. National Research Council)

- Unifying Concepts and Processes:
  As a result of this activity . . . students should develop understanding and abilities aligned with the following concepts and process:
  - Evidence, models and explanation
  - Constancy, change, measurement

- Physical Science Content Standard G:
  As a result of this activity . . . students should develop an understanding of:
  - Nature of scientific knowledge.

LEARNING OBJECTIVES
Students will know and be able to:

- Use an electronic scale (or mechanical balance) to accurately determine mass.
- Create and interpret a histogram.

PRIOR KNOWLEDGE
Students must be able to keep careful records of observations.

BACKGROUND MATERIAL
A histogram is a common data representation in particle physics. Histograms are a visual representation of a frequency table. You can find more information on histograms at http://quarknet.fnal.gov/toolkits/new/histograms.html.

Students can explore histograms by collecting and plotting their data from this activity. They will need to construct a frequency table of their observed masses and then create the plot.

IMPLEMENTATION
The mass histogram will very likely reveal the change in penny composition, but there is nothing on that plot to suggest *why* the masses change. The answer to that question requires more investigation.

You should instruct the students to write down as many things about each penny as they can. They can construct their own data tables. If they record the mass *and* mint year of each sample, they'll have enough information to answer the why question posed in the previous paragraph. You might lead a class discussion about what observables they might record before they get started.

Having students mass hundreds of pennies may take a long time. You might consider dividing up the job amongst several groups. Students can histogram their own sample of the entire batch and compare it to a histogram created with the entire, shared data set.

Your scale should have a minimum reading of 0.01g. A less precise scale will not show the small mass differences from pennies of different ages.

You might ask the students to write the procedure that they hope to use to answer question #4 and check it before proceeding.

Finally, question #6 in the student activity is much richer if your penny collection sample was sufficiently random to expose two different masses. You can ensure this by inspecting your penny collection to see if there are enough pre-1982 pennies. You could also *not* inspect your penny collection and see what comes out of the student observations.

ASSESSMENT

You could have the students submit a formal lab report that conforms to your regular practices and requirements. You might also consider having the students present their results in a short presentation.

ADDITIONAL INFORMATION

We based this activity on a similar online activity. You can find it at:
http://ed.fnal.gov/students/hwtools/histogram/basic1.html

The online activity provides several more complicated options than we present in this hands-on activity. You might allow students to explore the activity independently after they have some experience with histograms.

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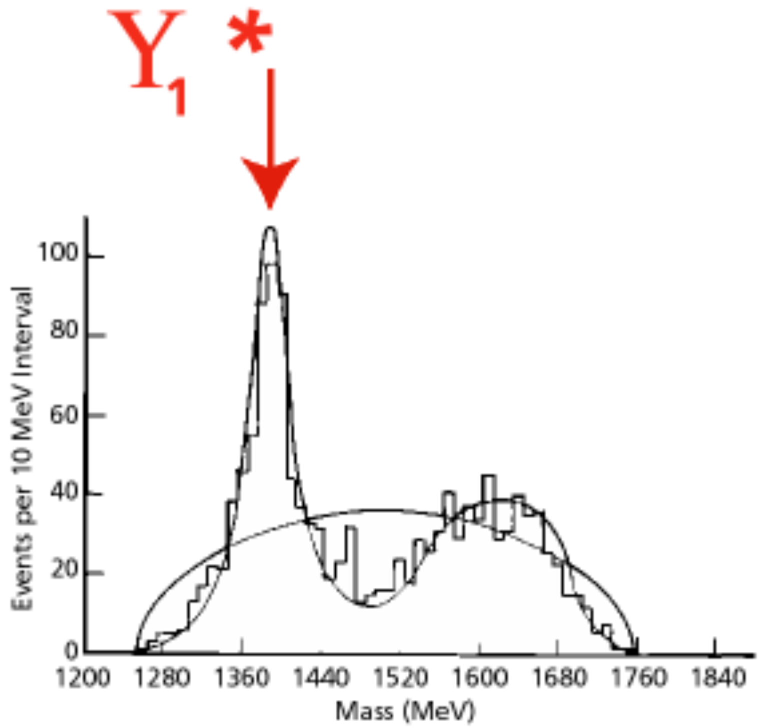
Name _______________

Date ________________

Particle physicists use graphs like the one shown on this page to look at the results of their experiments. By putting mass readings on a histogram, they can see that the peaks show separate particles or different versions of the same particle.



So, what do pennies have to do with particle physics? Pennies have an inner structure that you can discern without cutting them open, just like protons have quarks inside of them, which particle physicists can see from the results of scattering experiments.

Over the span of months, many of us let pennies pile up in a bowl, or on a shelf, or in several coat pockets. YOU might never think to measure the mass of each one, but WE have. However, you can go ahead and analyze the data. You'll find that the interior of pennies is a lot more visible on a histogram than when the penny is in the palm of your hand.

For this activity, you become a particle physicist studying the particles produced in a collision at Fermilab. You will fine-tune 150 pennies (particles) by the minting year. You will determine how many different particles were produced based on their differing masses. Design a data table that shows the year each penny was minted and its mass.

Get a sheet of graph paper and design a histogram that plots mass versus number of pennies with that mass.

Answer the questions on another sheet of paper. Show all calculations.

1. How many types of particles were produced in the collisions in this study? How can you tell?

2. During what year did pennies change mass?

3. When you include all of the minting years of pennies on the graph, how do the differing heights of the two peaks tell you which one is made of older pennies?

4. Assuming pennies were originally made of 100% copper, what metal could be sandwiched inside of a copper shell to account for the newer mass of pennies? Design a data table and procedure for finding the density of the newer penny. Use a density chart to identify the metal inside the penny.

5. Which year is represented by the most pennies? By the second most? By the third most? What would you graph instead of mass to make these answers immediately evident?

6. How many different “peaks” do you see in the histogram? What is your estimate for the average of each one?