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Title: Scattering Experiments in Particle Physics

Synopsis

Participants will explore the process by which particle physicists learn about fundamental particle interactions. Three ramps will be available with a section obscured from view, each with a different obstacle. Participants will roll marbles down the ramp and observe where they emerge from the covered section. With this information they will make inferences about the shape of the covered section of ramp (i.e. bulged, sunken, flat, etc.).

Audience

General public, preferably age 13+.

Learning Goals

- Teach the audience the general principles of science and how we can gather knowledge about processes we cannot directly observe.
- Learn about scattering experiments, and how we can use this procedure to learn about forces acting on fundamental particles, which we cannot see.

Concepts

The fundamental concept of this activity is the process of science. Developing a theory out of incomplete information, testing it, and then revising the theory based on new information. The interested participant will learn about the fundamental concepts of scattering experiments and perhaps gain some understanding of how different types of particle interactions can be distinguished.

Materials

- 2-3 prepared ramps with different geometries.
- Marbles (approx. 10-20).
- Sheet of paper and pencil, or computer.

Preparation and Set-up

The ramps will be constructed by insetting a 3D printed obstacle into a wooden board. The scatterers will be rubber coated metallic balls such as those available at http://www.alibaba.com/product-gs/631374644/High_quality_NBR_Nitrile_rubber_ball.html. The coverings will be constructed out of wood or plastic sheet, whichever is more economical and the ”detector” side will be a wood semi-circle will balsa or paper siding. The preparation region will have metal railings attached to it so that consistent initial conditions can be achieved.

Guiding Questions

- See what you can learn about the target “particles” on these ramps by rolling balls down them!
- Perhaps they look like they are the same at first, but they are different, can you tell how? Try drawing a picture of each of them.
- What does this particular method allow you to test? (think about what it is we can measure with this setup, how accurately can we measure it?)
- What can’t it test? (are there limitations based on what we can measure, or how accurately we can measure it?)
- What are other properties things can have and how could we test them? (It can test general shape i.e. attractive or repulsive.)
- What are properties of matter that you might want to test this way and how would you do it, what would you try to measure? (charge/magnetism, mass, size, hardness etc—can measure charge by throwing things with different charges or magnets at the target, and can measure size, mass and hardness by making careful measurements of the final position and momentum of the scatterer.)

Activity Description

1. The facilitator will invite the participant to "take data" from the ramps and proceed to explain that there is something in the boxes, and the only way to get information about it is by rolling marbles down the ramp and seeing where they come out.
2. The participant will be provided with marbles and asked to record where they put them in, and where they came out. Ideally there will be a computer with a spreadsheet open so that data taken by participants can be recorded and displayed.
3. Once the participant has rolled a few marbles (if they stay that long) the facilitator might ask leading questions such as "what do you think is under the boxes?" or "are the two boxes different?"
4. If time and interest allows, now would be an appropriate time to ask the participant to make a prediction to test based on the data they have already taken and the theory they came up with before.
5. Finally, the especially interested participant can be told about how this experiment emulates Rutherford scattering, and how this relates to modern particle physics experiments.

Science Content Background and Additional Resources

The basic process of a scattering experiment includes two particles, the target and the scatterer. The scatterer is accelerated to some known momentum and directed towards the target. After a collision occurs, the momentum of the scatterer is detected. Using the initial and final momentum of the scatterer over multiple trials, we gain information about the target's properties.

Scattering experiments are how we gather knowledge about the fundamental physics of the universe. They are currently our best probes into the subatomic world. This basic method is used to learn everything we know about elementary particles. This is how scientists discovered the Higgs Boson, Antimatter, W and Z bosons, quarks and everything else. Using these methods we can find the mass, the charge, the strength of interaction between various particles.

Activity Extension

Including more ramps with more complicated geometries could easily extend this activity. In addition, if metallic balls, or magnets were used that could be utilized to give different types of interactions. Finally, some of the ramps would be equipped with sufficiently deep indentations that ”bound states” could arise, in which the marble does not emerge from the ramp. An additional extension would be to place spheres of a different size inside the potential well of one of the ramps, so that if a marble is dropped at the correct location it hits these balls and knocks them out of the ramp, simulating an inelastic scattering process.