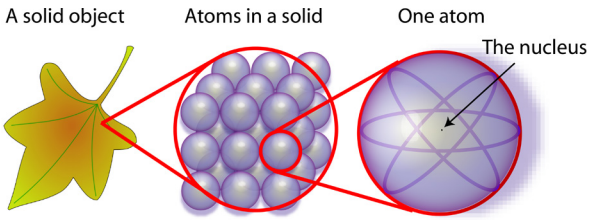
Shadow Nuclei

Seeing the Invisible



Normal matter (like you, your house, a tree, and air) is made of tiny particles called atoms. Your fingernail is about 100 million atoms across! And yet, the atom is made of even smaller things. At its core is the **nucleus**, which is 10,000 times smaller.

Scientists at the **Facility for Rare Isotope Beams (FRIB)** on the campus of Michigan State University study nuclei every day... but how do we measure them, or even know they exist?

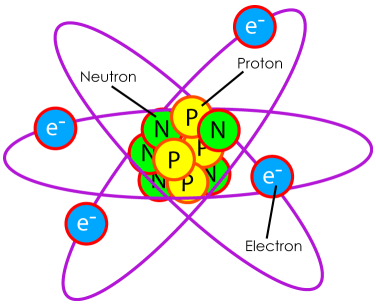
Materials needed for each student (working with a partner/parent)

- A blank sheet of paper • Paper clip • Light source (lamp, etc.)
- 5 different small objects (game pieces, cereal, coins, etc.)
  - Should be light enough to be held up by a piece of paper
  - Keep these objects secret from your partner

What's in the atom

Imagine that an atom is the size of the room you are in (that's one big atom)! The atom has a nucleus made of protons and neutrons (in the center of the room), plus some electrons around the outside.

Look at the thickness of your paper clip – that's about the right size for the nucleus in your room-sized atom. The electrons (smaller than the tip of your paper clip) would be somewhere near the walls.



A model atom (not to scale)

Discuss with your partner: how much space inside the atom is full of particles? How much space inside the atom is empty?

A reaction you see

But how can we know about the atom, much less the nucleus, when it's too small to see? Actually, you "see" something invisible every day: moving air!

Partners should take turns dangling a piece of paper from their fingers. Then they can either blow on it (gently but firmly) or pretend to blow on it. The other partner guesses whether they actually did blow.

Discuss with your partner: how can you see whether air came out of your partner's mouth? Did you use any other senses as well? Another name for moving air is "wind"… how can you "see" wind outside?

Counting invisible things

Knowing that the nucleus is there can simply be a matter of seeing how it **affects something else** (like how moving air affects the paper). The material or equipment that reacts to a nucleus is called a "detector." Some detectors can actually measure the shape of a nucleus!

See if you can measure the shape of an invisible object: *partners should take turns putting their hand under the piece of paper to hide it, then hold up some number of fingers. The other partner guesses how many fingers are up.*

With no way to observe or measure your partner's hand, you can only guess at a number! You need some way to detect their fingers.

Next, partners should take turns putting their hand behind the piece of paper and moving it in front of a light (like the overhead lights), then holding up some number of fingers by touching them to the paper. The other partner guesses how many fingers are up.

Discuss with your partner: is the hand "invisible" (like a nucleus) in both cases? How can you "see" the invisible fingers? What is the hand affecting (blocking, in this case)? Are there other ways you can think of to "see" something invisible by how it affects something else?

Nuclear shapes

Let's see if you can use your "detector" (light shining behind a piece of paper) to measure the shapes of other objects.

Put the paper clip onto the piece of paper and hold it up to an overhead light. Can you see the shadow of the paper clip? Is it easy to tell what object is on the other side of the paper?

Because the paper clip lays flat and has a very recognizable shape, its shadow is easy to identify. When you're trying to measure a nucleus with an unknown shape, it's definitely more difficult!

While one partner has their eyes closed or is turned away, the other should put one of their secret small objects on the paper and hold it up to the light, making sure they can see the paper and not the object. Can the other partner tell what the object is?

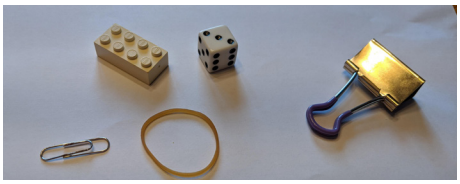
Take turns putting your small objects on the paper up to the light and trying to guess what they are, but ***keep them secret for now****!*

If you find an object that is hard to identify from its shadow on the paper, this is the challenge that nuclear scientists have in trying to understand what a detector tells them. Just seeing how the detector reacted (in this case, a shadow) isn't necessarily enough to understand the invisible thing we're measuring.

Models to the rescue

Nuclear theorists make "models" of a nucleus, calculating the ways a nucleus might look or act based on what we know about it. After an experiment, a researcher might compare their detector information to see if it could be explained by a model.

Partners can now take turns revealing their 5 small secret objects to each other. Now that they can see what shapes might have been on the paper, can they correctly identify which one(s) cast the shadow(s) they saw? Is it easier to understand the shadow's shape when you have some idea of the object casting it? This is why modeling is important!



What's Next?

There is much more to discover about nuclear science at MSU's Facility for Rare Isotope Beams!

Lots of YouTube videos, a virtual lab tour, and the Isotopolis video game: https://nscl.msu.edu/public/learning