DIY FRAGMENTATION BOX

Learn Nuclear Science

with Marbles

A JINA/NSCL outreach service by Zach Constan

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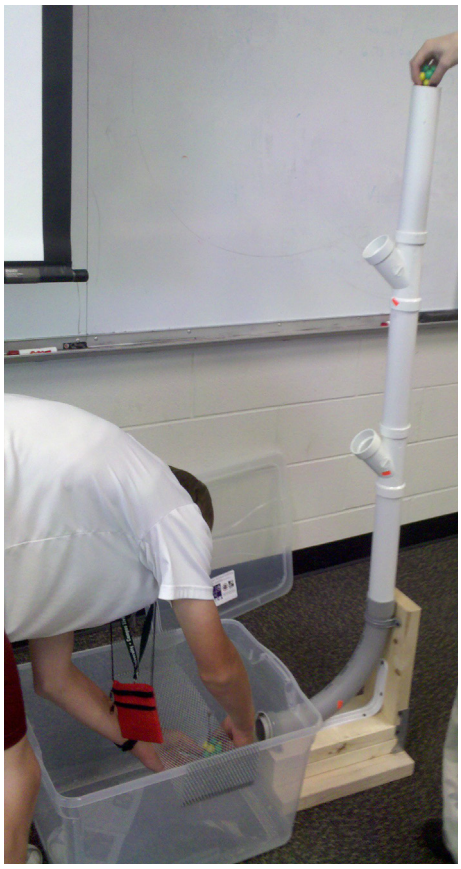


This document contains step-by-step instructions on how to construct a "fragmentation box" demonstration that is useful for smashing model marble nuclei into each other at high speeds, simulating the method by which the National Superconducting Cyclotron Laboratory (NSCL) creates rare isotopes (and how carbon-14 is made in the atmosphere, and the process of stellar fusion, etc.).

Gravity performs the acceleration when a nucleus is dropped in the top, so by inserting the bottom end of the pipe into your box, the fast nucleus can collide with the suspended target nucleus. The tube's many openings let you drop the nucleus from various heights, giving it different energies.

The box and accelerator design described herein differs radically from the original design used at NSCL, which took advantage of the resources and capabilities of the lab's machine shop as well as the JINA outreach budget. The design described herein follows three rules:

- It must be *inexpensive*, lowering the cost of entry for educators who build their own. (there are even cheaper options on the last page!)
- It must be *portable*, making it convenient to use anywhere.
- It must be *easy to build*, using commonly-accessible materials and requiring no special skills to assemble.

With that in mind, the following detailed instructions should make it possible for you the reader to "do it yourself" and reproduce the fragmentation box. It is recommended you read through it before starting.

Tools you need: hammer, drill, screwdriver (or equivalent drill bit), clamps (if desired, >6"), 2.5-inch hole saw.

Building a fragmentation box for your marble nuclei

Co-developed by Jonathan Delauter

This is part of a series of documents related to the Marble Nuclei Project, downloadable from:

https://www.jinaweb.org/educational-outreach/marble-nuclei-lessons

Send your notes and suggestions for the following activities, or any other marble nuclei exercises to constan@nscl.msu.edu, and thanks in advance.

Would you like video instructions? PAN 2009 alum Tiberiu Dragoiu-Luca has posted some similar instructions on YouTube: https://www.youtube.com/watch?v=QVGT8yfRcDI

Step 1
Purchase materials

The following list contains all the materials you'll need to build your own fragmentation box demo, including where to find each part and approximate cost (in summer 2010). Total expected cost: less than $50.

NOTE: Sometimes, if you submit a list of materials to a home improvement store and explain how you'll be using them at school for students, they may give you the materials for free or at reduced cost!

Box

The box itself (where the target nucleus will be suspended, and the accelerator will feed beam nuclei) should be:

- large enough to contain all the other parts of the demo
- be of clear plastic so observers can see fragmentation events inside
- deep and long enough that fragments don't immediately recombine

Recommended: Rubbermaid 70-quart clear plastic tote ($10.97, Menards storage department)

Also useful: Sterilite 66-quart clear plastic tote ($9.74, Home Depot storage department)

Base

The base for the accelerator needs to be heavy and broad enough to keep it from tipping, but small enough to fit in the box and not TOO heavy.

Recommended: 2x10 board, 1 piece cut to 13" ($7.89, Home Depot lumber)

Recommended: 2x6 board, 2 pieces cut to 13" and 1 piece cut to 11" ($4.48, Home Depot lumber)

Note: home improvement stores may be able to cut these for you!

Recommended: 2.5-inch wood screws.

Base hardware

The brackets that will hold together the horizontal and vertical parts of the accelerator base should be metal and have several points for inserting screw/nails. At the same time, they can't be too large or they'll get in the way of the accelerator tube.

Recommended: 8" Magnum shelf bracket (top picture, $2.48, Menards shelving/storage)

Recommended: A35Z Angle frame anchor (middle picture, $0.80, Home Depot decking)

Recommended: 1-inch wood screws

Accelerator bend

The nuclei will need to make a 90-degree turn to enter the box after falling.

Recommended: 2" conduit 90-degree bend ($2.69, Home Depot electrical)

Note: You can also find similar parts in plumbing, but the electrical materials are cheaper.

Accelerator tube

The nuclei will fall through this tube to accelerate, so it needs to be wide enough (two inches) and long enough to allow the nuclei to gain significant energy.

Recommended: 2" conduit schedule 40, 3 pieces cut to 12" ($3.58, Home Depot electrical)

Note: if you don't have to fit your accelerator in the box, the tube lengths are somewhat arbitrary. If you make your accelerator too tall, however, the base will need to be larger to remain stable.

Note: home improvement stores may be able to cut these for you!

Entry ports

In between sections of accelerator tube, you can insert extra "entry ports" that allow you to drop the nuclei from a variety of heights (and thus, energies).

Recommended: 2x 2" 45-degree Wye piece ($2.53, Home Depot plumbing)

Recommended: To complete the assembly of these parts, you'll also need assorted 2.5-inch wood screws, 1-inch wood screws, and wood glue. Useful tools are hammer, drill, and clamps.

Tube mount hardware

To attach the 90-degree accelerator bend to the base, you'll need some brackets. There are actually some made for the purpose.

Recommended: 2x 2" galvanized pipestrap - two hole ($0.51, Home Depot plumbing). You'll need two to affix the 90-degree pipe bend onto the wood base!

Also useful: PVC "conduit clamp" brackets, package of 5 ($2.18, Home Depot plumbing)

Recommended: 1-inch wood screws

Also useful: washers (in case the screw heads are smaller than the bracket holes)

Target suspension

To hold the target nucleus suspended in the box near the exit of the accelerator, you'll need a stiff but bendable material that can span your box and hold up the marbles, while at the same time being adjustable for different positions. The nucleus itself will hang from a long nail or screw that is inserted through a hole in the gutter guard.

Recommended: 3-foot gutter guard ($1.94, Home Depot building materials)

Recommended: narrow 3-inch machine screws (flat end) or nails with the tip cut off

Step 2

Building the demo

Assemble the base

Note: these instructions are based on the steps we performed at NSCL, and are just a suggestion.

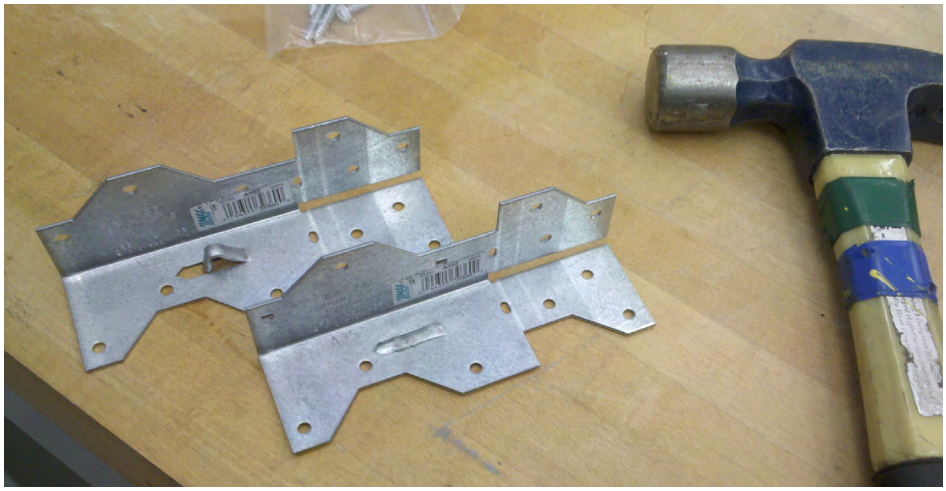
Your base is made from four pieces of wood:

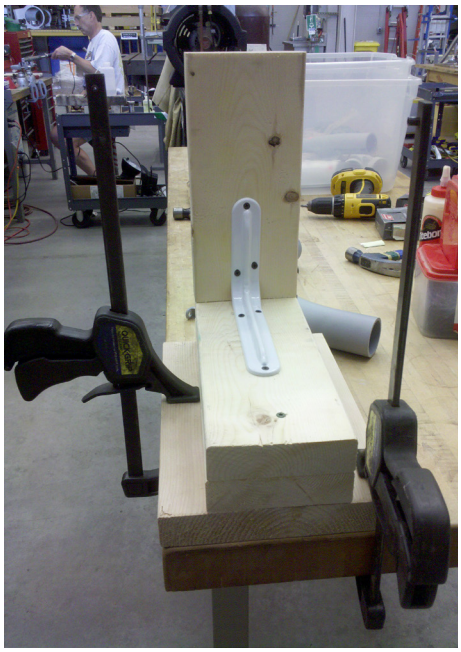
- One 13″ piece of 2x10
- Two 13″ pieces of 2x6
- One 11″ piece of 2x6

Put glue on one side of a 13″ piece of 2x6 board, the stick it (approximately centered) onto the 2x10 (top picture).

Drive four 2.5-inch wood screws through the 2x6 into the 2x10 (middle picture) near the four corners of the board, but not too near! We used a drill with a Phillips head to drive the screws into the wood, and it saved a lot of time and energy. Note that we also used a clamp to hold the 2x10 in place.

Glue the second 2x6 on top and drive three 2.5-inch wood screws down the center of the board (bottom picture). Putting them in the center helps you avoid the corner screws. You could reverse the order (center screws in first board, corner screws in second).





The vertical part of the base must be very stable, since it will hold up a long tube extending above it.

If your angle frame anchor has a protruding metal tab, hammer it flat (top picture, compare the two anchors).

Set the vertical part (the 11” 2x6 board) on its end, resting on one end of the three-board base (middle picture). Use 1-inch screws to attach the anchor to both, making sure to have at least two screws in the vertical and horizontal parts.

The shelf bracket can fit inside the “L” formed by the vertical and horizontal parts, and attached with 1-inch screws (bottom picture).

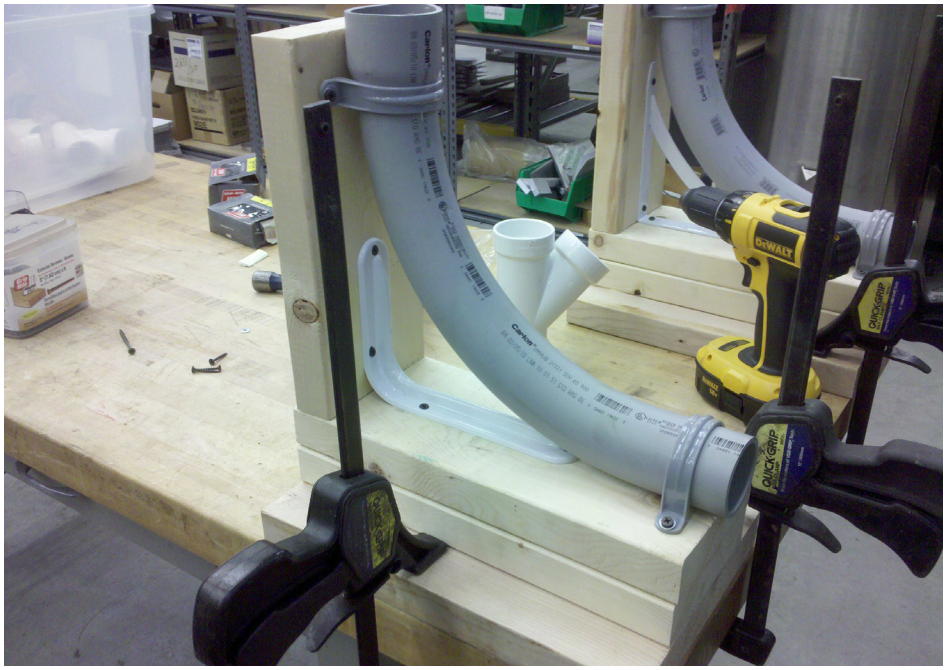
The easiest way is to screw the bracket down into the base first, then turn the base on its side so you can screw the bracket down into the vertical piece.

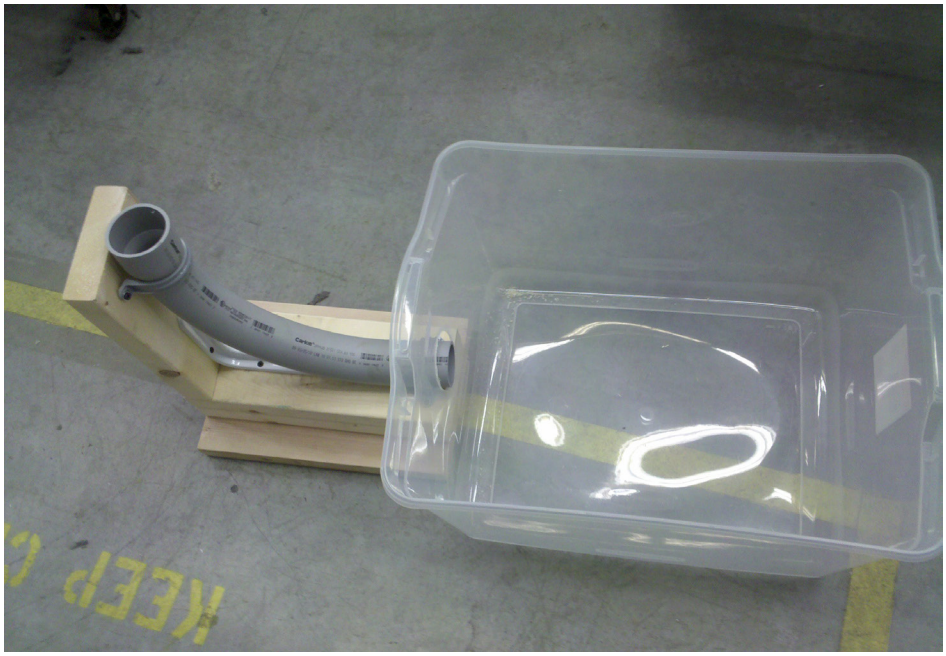
Attach the tube

Use the conduit clamps and 1-inch screws to attach the 90-degree bend to the wooden base as shown in the top picture.

Note: the pipe should extend somewhat beyond the wood at each end, and the clamp should be placed about one inch from the end of the wood (middle and bottom pictures).

Again, the easiest way is to screw the lower bracket into the base first, then turn the base on its side so you can screw the other bracket down into the vertical piece.





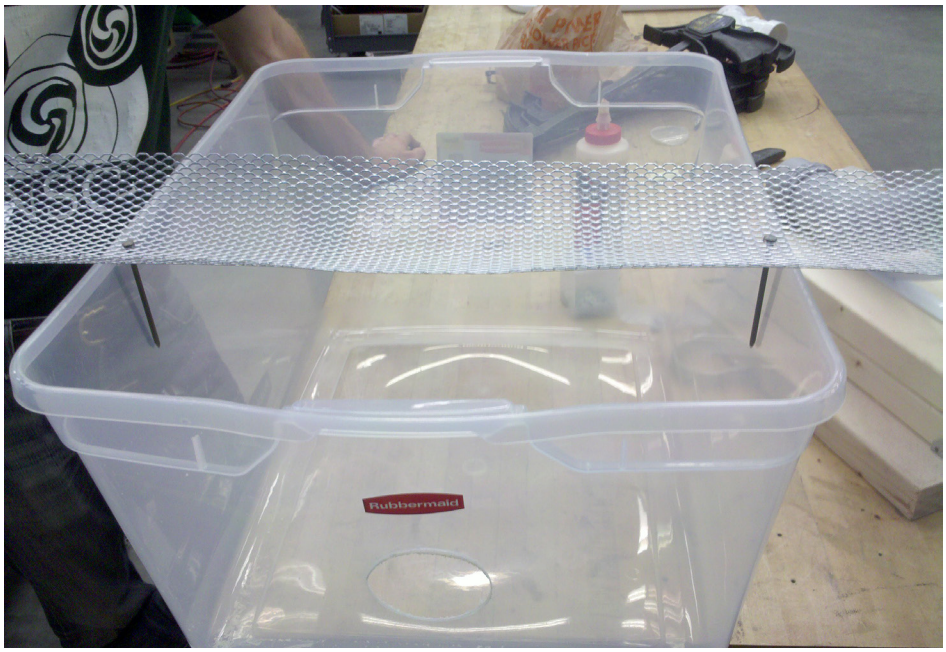
Make an opening

Place the base next to your clear tote box to see where the tube should be inserted. It should be up against one of the short sides of the box. Looking through the clear plastic, mark the center of the tube on the side of the box (top picture).

Use a 2.5-inch hole saw (middle picture) to drill through the box wall, centering on the point you marked. This should make a hole big enough and properly positioned for the accelerator base to insert the tube into the box.

Note: the hole saw is probably not something you have on hand, but could borrow or even buy ($10-$20)

Note: If desired, add a soft material inside the box to stop the marbles from rolling around and recombining.



Create suspension

You will now shape the gutter guard so it fits over the sides of the box and provides a sturdy suspension for your target nucleus.

Place the guard across the top of the box (oriented along the short dimension of the box) so it overlaps equally on both sides. Insert 3-inch nails or screws through the holes in the guard, searching for the holes where the bottom tip of the nail just barely touches the side of the box. Mark a line across the guard where the nailhead lies.

Bend the guard

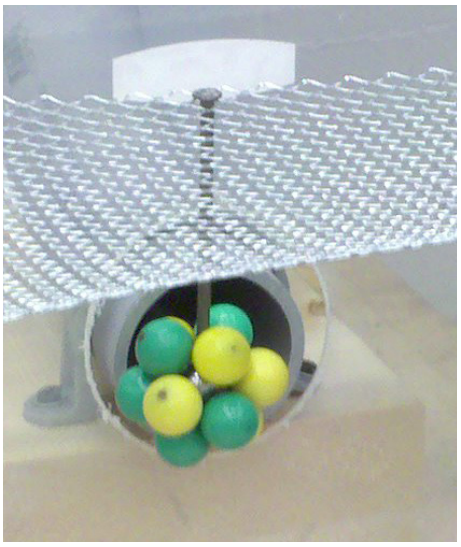
We actually made bends in the guard using a professional apparatus (middle picture), but you can do it with two pieces of wood and a hammer.

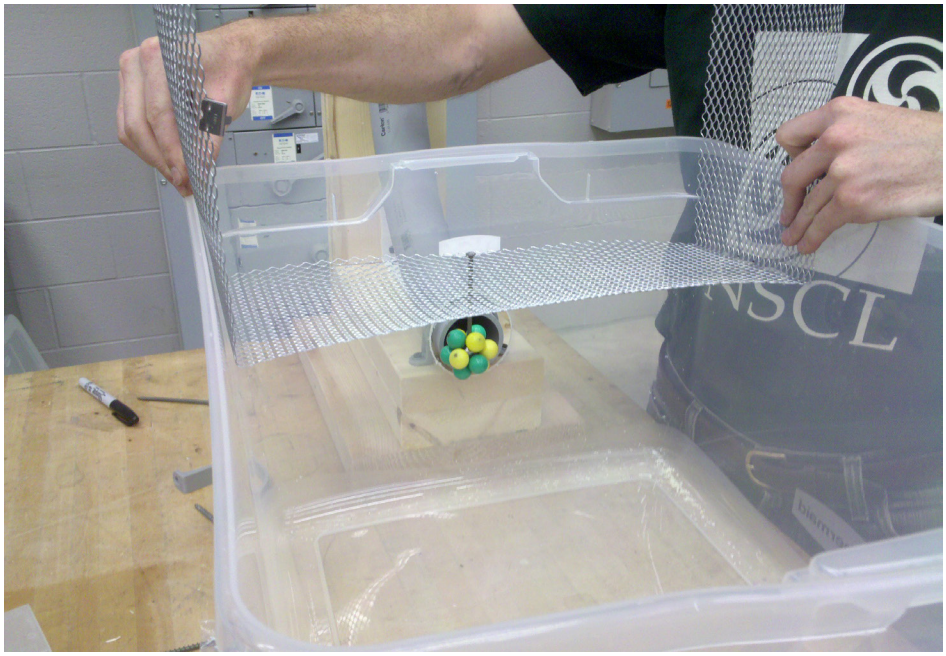
Place the gutter on a hard floor. Align one piece of wood with the mark you drew showing where to bend the gutter (based on the position of the hanging nail). Hold that wood down with one foot, and pull up the gutter so it is bending along the line you marked. Scoot the other piece of wood up against the guard (bottom picture) and use the hammer to tap it into the guard and wood. This will create a 90-degree bend in the guard. Bend both sides of the guard up in this way so it forms a "U".

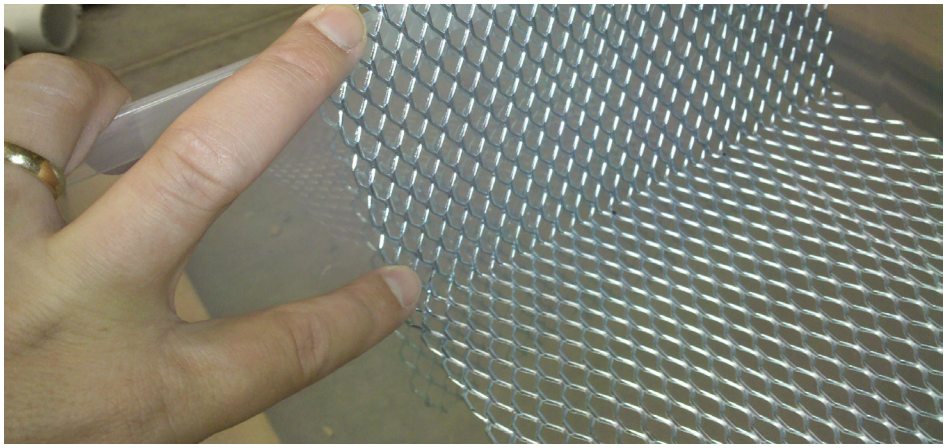
Suspend the target

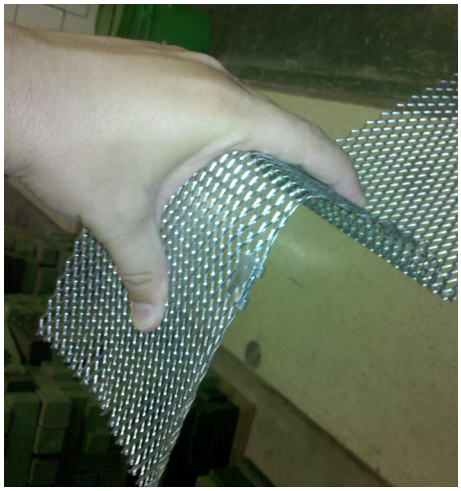
File down or cut the end off of a 3-inch nail, or just use a 3-inch machine screw with a flat end.

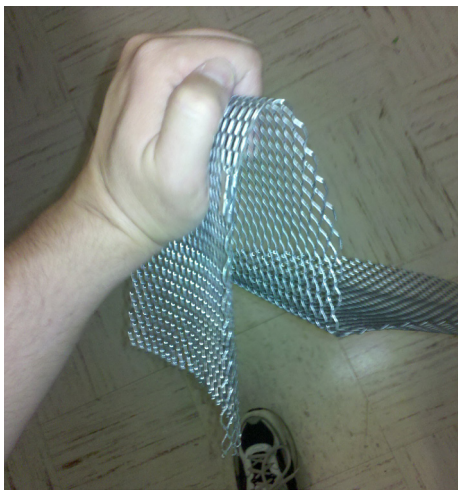
The smooth surface on the end will stick to the neodymium magnet at the center of a marble nucleus (left picture). You can thus suspend a target by inserting the nail through the gutter guard (right picture) and attaching the nucleus.











Find your depth

Suspend a marble nucleus from the middle of the gutter. Lower the gutter into the box until the nucleus is level with the pipe entering the box; this is the depth you want (top picture).

Mark the gutter on both sides where the top of the box is, so you know where to bend the guard. Definitely make sure the suspension is level by counting the number of holes to the top on both sides (middle picture). That way, when you bend the gutter, both sides will be the same length.

To make the bend at those two markings, you can do it by hand (bottom pictures). Now, both sides of the gutter can fit over the sides of the box, leaving a "bridge" across that you can use to suspend your target nucleus and move closer to and farther from the accelerator tube.

Play!

An example of the assembled product is shown in these pictures.

Your new accelerator is just what you need to do the "Fragmentation Box" section of the Learn Nuclear Science with Marbles Activities. The instructions on the student worksheet detail how to explore many variables involved in the collision:

- mass of beam/target nuclei,
- beam velocity
- types of isotopes created
- "impact parameter" can also be changed by moving the target horizontally or vertically.

Altering these variables can result in scattering, fusion, or fragmentation, which may not match the physical reality of nuclear interaction.

As an alternative, you could just as well dangle the target nucleus from a ring stand and catch/contain the fragmented marbles in one of several ways:

- Lay out a shallow box of sand on the floor in front of the accelerator.
- Use a large but shallow partitioned box (like a fishing tackle box). When the marbles fall in, each partition is like one "detector"
- Have students stand in the path of the marbles and catch them, acting as "detectors" themselves!

In each case, knowing where the marbles went after fragmentation tells one about the original beam and target nuclei and how they collided.