Nscl cOsmlc rAy experlment

How the detector works

A **scintillator** is a material that gives off light when struck with a charged particle, such as a nucleus. Believe it or not, the scintillators on the cosmic ray detector are made of plastic that has been mixed with special scintillating material. They are wrapped in layers of aluminum foil, construction paper, and finally the electrical tape to that you see on the outside. When a cosmic ray strikes the plastic, it **excites** (or gives energy to) an electron in one of the atoms. The excited electron wants to give up its energy, so it emits a **photon** (you can think of it as a particle of light). This is an **interaction**.

Photons can come from other sources, like fluorescent bulbs and the sun. The electrical tape and construction paper are necessary to keep stray light from getting into the scintillator. This way, the only light in the scintillator is due to cosmic rays. The aluminum foil helps keep stray light out and reflects light from interactions with cosmic rays back into the scintillator. This light eventually (and by "eventually" I mean "in less than a microsecond") bounces into the **photomultiplier tube**.

Inside the photomultiplier tube, the photon strikes an electron and gives it enough energy to leave its atom. Then, the negatively charged electron gets pulled toward a plate of positively charged metal. Once it hits the metal, it frees other electrons. These electrons hit the next piece of positively charged metal, which frees even more electrons. This process continues until there are around a million electrons. They strike the last metal plate, which registers the electrical signal as a single count.

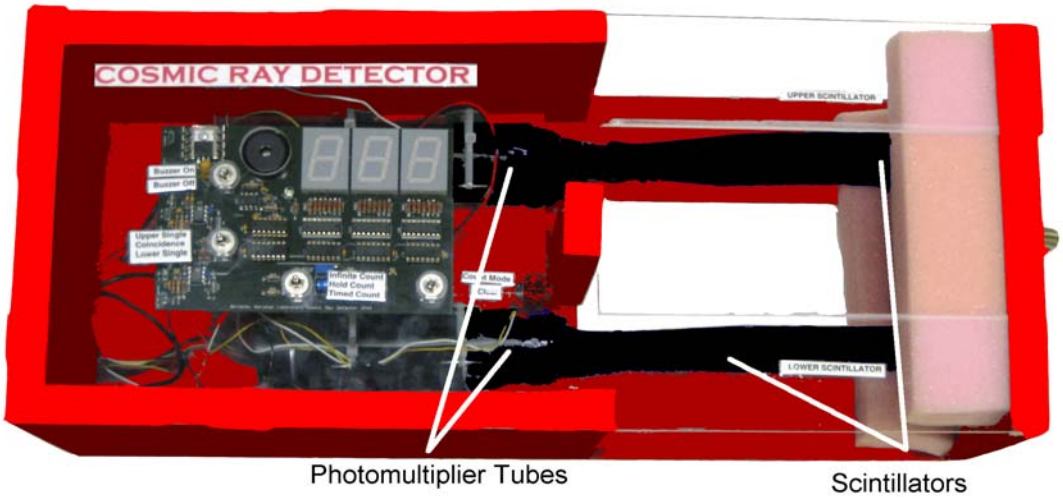


Figure 1 Shows scintillators and photomultiplier tubes of a detector similar to the one that you will use!

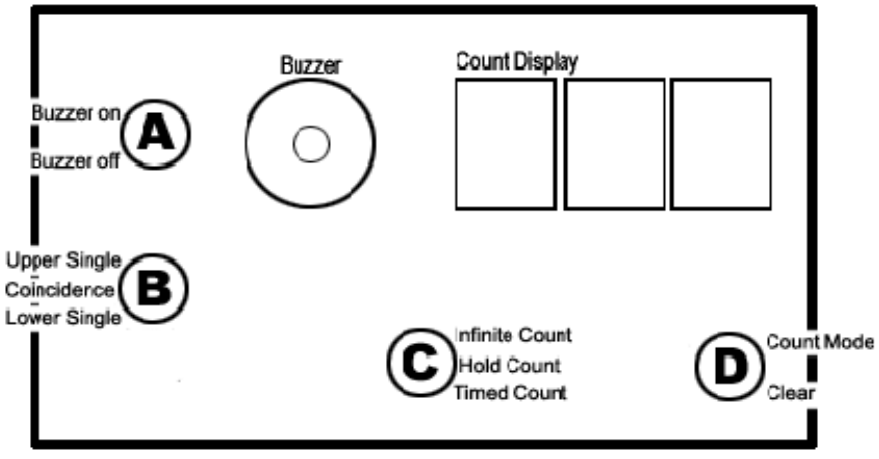
You'll notice that the detector has two scintillators, not just one. This allows you to control the direction of the cosmic rays that you are counting. If you use only one scintillator, the cosmic rays may come from any direction. If you set the detector to "coincidence," the detector will only count the rays that pass through both scintillators. The rays that it detects will come in at an angle roughly perpendicular to the scintillator paddles. When a cosmic ray strikes the scintillator(s) and results in a count, we call it an **event**.

Operating the Cosmic Ray Detector

1. Plug it in! You may need an extension cord. It should turn on immediately.

2. There are four switches that you will be using.
    a. Switch A, as shown in the diagram, controls the buzzer – whether or not the machine beeps every time it counts a ray.
    b. Switch B controls what events the detector will report as a count. Do you want rays that hit the top scintillator, the bottom scintillator, or **coincidence** (both scintillators)?
    c. Switch C controls the count mode. Do you want it to just keep counting without stopping (infinite), to count for one minute and then shut off (timed count), or stop counting while still displaying the current count (hold count)?
    d. Switch D clears the count. Most of the time, D will be positioned on "count," which lets the detector work, but sometimes you will turn the switch to clear and reset the count.

Figure 2 Controls of the cosmic ray detector



cOsmIc rAy experIment

(with Real Nuclei from Outer Space!)

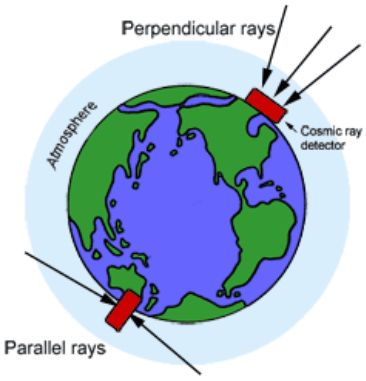


Figure 3 Cosmic rays approaching rectangles that represent the detectors you will work with.

Materials:

You Provide:	**NSCL Provides:**	**Universe Provides:**
Pencil or Pen	Cosmic Ray Detector	Cosmic Rays
Notebook	Protractor	
	Plumbob	
	String	
	Supportive materials	
	Stopwatch	
	Calculator	
	Rulers	

Objective: Find out how the frequency of cosmic ray events changes with the angle between the detector and the earth's surface.

Hypothesis: From which direction do cosmic rays reach the earth's surface? Do you think they come in perpendicular to the earth, or parallel to the earth? Write down your hypothesis.

Prediction: How do you think the angle will affect the cosmic ray count rates? Do you think the detector will report more counts when it is horizontal (catching rays perpendicular to the earth's surface) or vertical (catching rays parallel to the earth's surface)? ** Write down your prediction.

****For this experiment, the words *horizontal* and *vertical* refer to the detector while *parallel* and *perpendicular* to the earth's surface refer to the cosmic rays.

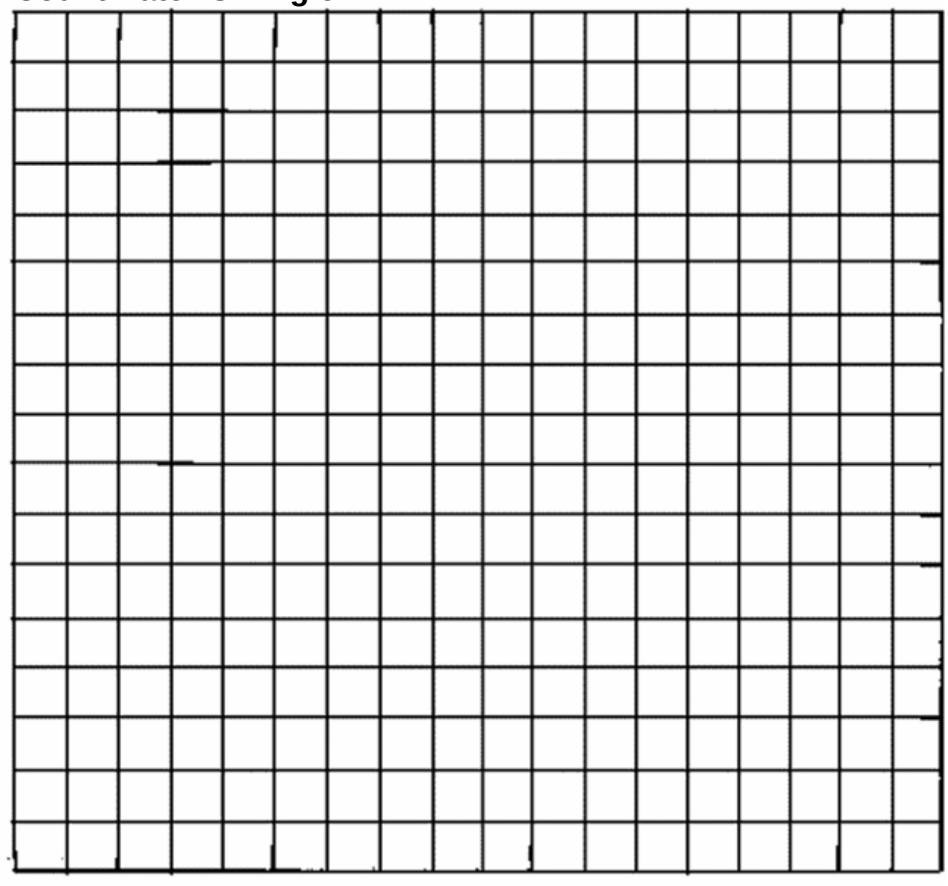
Procedure:

1. Set the switches on the cosmic ray detector so that the buzzer (switch A) is off and coincidence events are counted (switch B). Set the switch C to "hold count." Clear the count by moving switch D to "clear" and then moving it back to "count."
2. Set the cosmic ray detector on its end (vertical position) so that it catches rays coming in parallel to the earth's surface. You will have to hold it in this position.
3. You and your partner should start the stop watch and switch the count mode to "infinite" at the same time.
4. Let the cosmic ray detector count for 180 seconds (3 minutes).
5. Stop your watch, switch the count mode to "hold count," and record the count in the table under 90 degrees.
6. Using the protractor, string, and plumbob, set up your cosmic ray detector so that it is at an angle of 75 degrees from the ground. Use the supports provided to hold it there.
7. Move switch D to "clear" and switch C to "hold count. Then put switch D back to "count."

8. Simultaneously put switch C back on "infinite count" and start the stopwatch, again counting for 180 seconds.
9. Repeat the process until you have recorded times for 90˚, 75˚, 60˚, 45˚, 30˚, 15˚, and 0˚. At zero degrees, the detector should be in the horizontal position, catching rays perpendicular to the earth's surface.

Angle (degrees)	90	75	60	45	30	15	0
Number of counts							
Count Rate (counts/second)							
Error in Count Rate							

Count Rate vs. Angle



Analysis:

In your table, you have recorded the number of cosmic rays that struck the detector in a three minute interval. We are interested in how often an event occurs, so we calculate a count rate. Divide the counts by 180 seconds to get the count rate and record it in the table. Do this for each angle. Next, record the error in your count rate. The error is given by the following formula:

$$\sigma_{CR} = \frac{\sqrt{N}}{t}$$ where σ_{CR} is the error in count rate, N is the number of counts, and t is the time (180 seconds).

Now that you have the count rates, plot them on a rough graph. The x-axis should be the angles and the y-axis should be the count rate. Make error bars for the count rate by drawing lines in the positive and negative y direction on each of your points. The length of the each line should be the size of your error for that point. Then, answer the following questions.

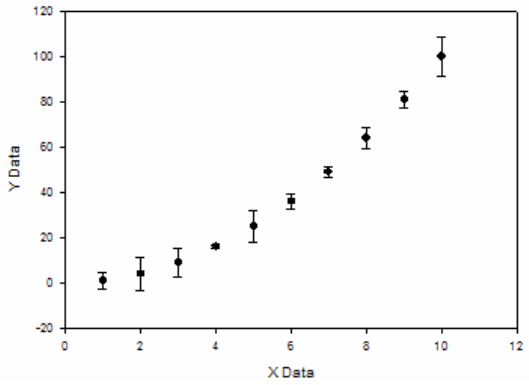


Figure 4 A chart with error bars for the y-variable.

1. Does the curve look like any other graphs you've seen? Sketch a continuation of the graph from 90˚ to 180˚, guessing what the count rates would be like if you had measured them for these angles.

2. Are count rates higher for angles close to 0˚ or angles close to 90˚?

3. From which direction are the cosmic rays coming most often? Perpendicular to the earth, or parallel?

4. Was your prediction correct? Does the data support your hypothesis?

5. Why do you suppose they would come from that direction? Hint: what are the effects of the atmosphere?