Fermilabyrinth

- Fermilabyrinth : Entrance

Ghostbustin'

- Fermilabyrinth : Ghost Bustin'
- Story: Tools: Detectors
- Detector Detail
  - Introduction: Calorimeter
    - Detector Component
    - Calorimeter Cake
    - Recording a Shower
    - Calorimeter Recipe
    - Assembling
    - Making 3D Plots of Shower Shapes
    - Choosing the Right Materials
  - Particles
    - Electron
    - Muon
    - Jets
    - Practice Your Skills
  - Events
    - Z->e e
    - Z->jet jet
    - Z->mu mu
    - Practice Your Skills
  - Calorimetry
- Particle Countin'
  - Particle Countin' (Shockwave)
  - Particle Countin' test
  - Particle Countin' feedback
- Particles Trappin'
  - Particles Trappin' Intro 1
  - Particles Trappin' Intro 2
  - Particles Trappin' Intro 3

- Particles Trappin' Intro 4
- Particles Trappin' Intro 5
- Particles Trappin' Intro 6
- Particles Trappin' Intro 7
- Particles Trappin' Assignment
- Particle Trappin' Shockwave
- Test Your Knowledge of Particle Trappin'
- Response
- Show Einstein Bucks

Students* - *Educators* - *Lederman Science Center

Security, Privacy, Legal


Ghost Bustin'
TOOLS: Detectors Reveal Invisible Particles and Forces
Warp Speed
Law 'n Order
New Player
Code Crackin'
Diggin' Deeper
PARTICLE COUNTIN'
PARTICLE TRAPPIN'
DETECTOR DETAIL
Read the Story
PLAY
PLAY
PLAY
Read the Story

<

Detectors Reveal Invisible Particles and Forces

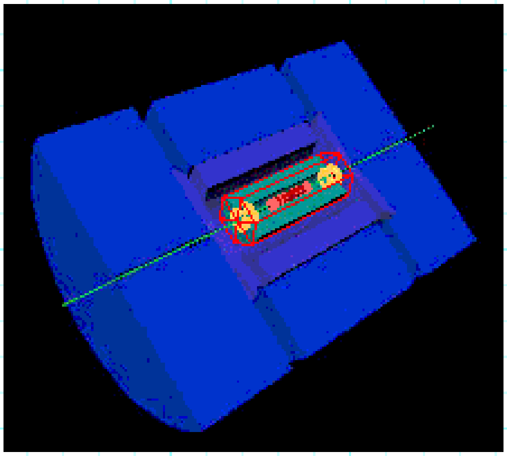
D0 Detector

CDF Detector

The particles scientists want to study are so small that they cannot be seen by the human eye or the most powerful microscope. So physicists build huge detectors to track the particles as they move outward from a collision. Scientists need computers to collect, store and analyze the information. They need computers because the experiments create a lot of data over a very short period of time and because many of the newly created particles live for only an instant. Computers also allow scientists to use the data to reconstruct events in a collision. Subatomic particles behave like waves. Understanding the properties of waves helps scientists design their experiments and interpret the results.

Ghost Bustin'

Welcome to the Detector Design Group at Fermilab. Our job is to design a calorimeter for a new particle detector.
To get up to speed, please complete the following assignments:



- Investigate how particles look in the D0 Calorimeter.
- Identify shower shapes of three particles.
- Identify those particles in collision debris (events).
- Learn about Calorimetry.

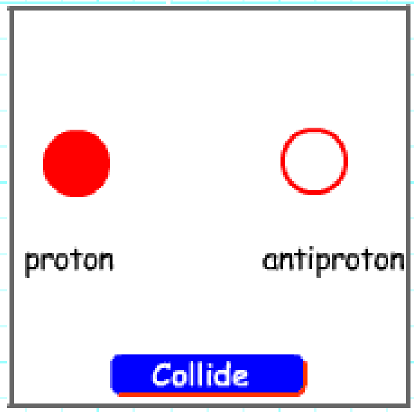
Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

Intro: Calorimeter - a Detector component

Calorimeters capture the energy of particles - the debris from high-energy collisions. Click **Collide** (flash-only) to see the particle debris from a collision of a proton and antiproton. Then click the arrow to continue.



Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

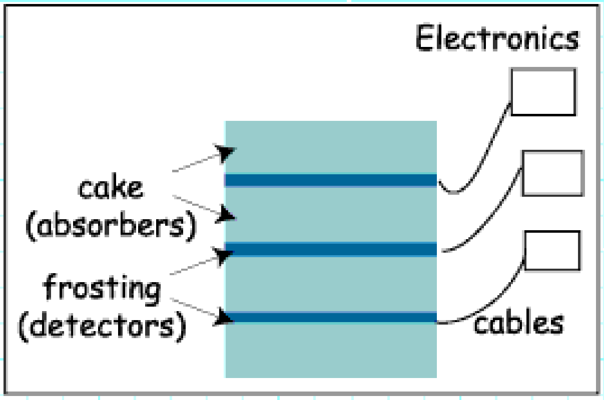
Double Your Bucks and Quit Detector Detail

Intro: Calorimeter Cake

A calorimeter - made up of layers of material, like a birthday cake.

Cake - **absorbing** material of the calorimeter

frosting - **energy detectors** with electronic readout devices



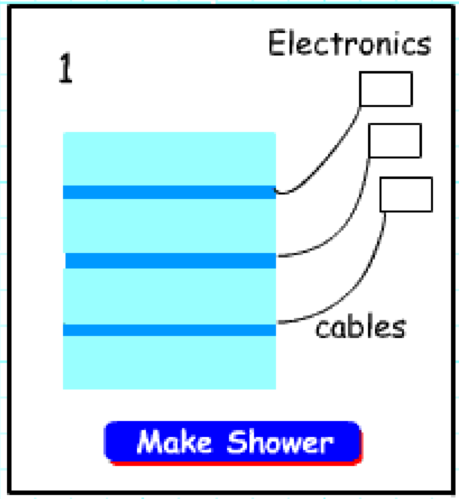
Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

Intro: Calorimeter - Recording a Shower

Click **Make Shower** to the right to see
1 - a debris particle enters the calorimeter and
2 - interacts with material creating a shower of new particles.
3- Electronics records the trail of energy deposited in each layer of material.



Introduction | Particles | Events | Calorimetry

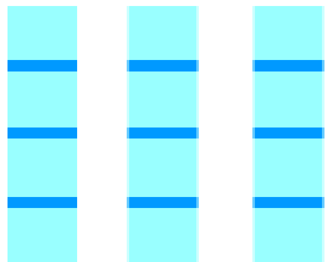
500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

Intro: Calorimeter Recipe

Recipe for a Calorimeter
1 - Slice into pieces like cake
2 - Assemble the slices around the central collision point to capture all the particles.

Calorimeter Cake
Cut in Slices



Assemble Slices

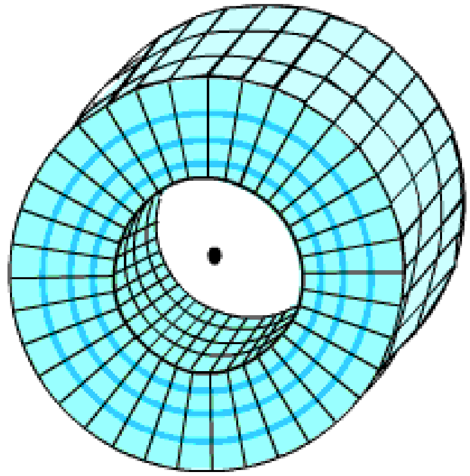
Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

Intro: Calorimeter - Assembling

Many rings of slices surround the central collision point so the calorimeter can trap particles coming out in all directions.



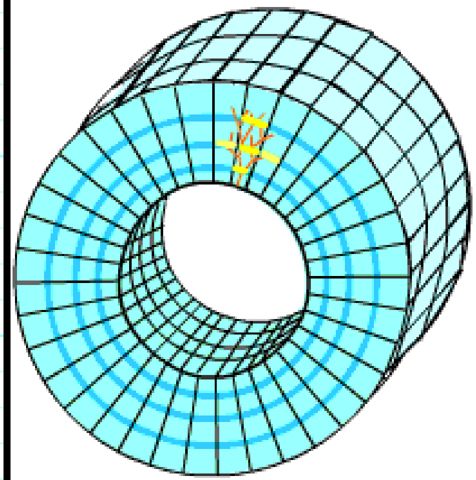
Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

Intro: Making 3D plots of shower shapes

For each slice in which energy was deposited by the shower of particles, add up all the energy captured in its layers. Make a 3 D plot of all these slices using color to indicate the amount of energy. Include the central collision point. The lengths and colors of the slices in the plot tell us which particle created the shower.



Make Shower

Show Slices Hit

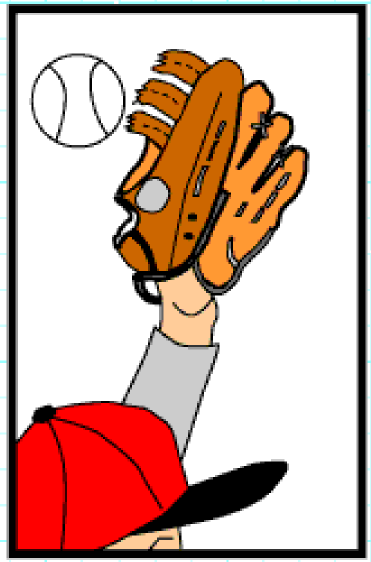
Shower Shape

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

Intro: Choosing the Right Materials

We choose the materials and their thickness very carefully to be sure we capture as much as possible of the the energy of the particles. If we goof and don't choose the right materials, it is something like making a baseball glove out of paper. The ball would just sail through without being caught.

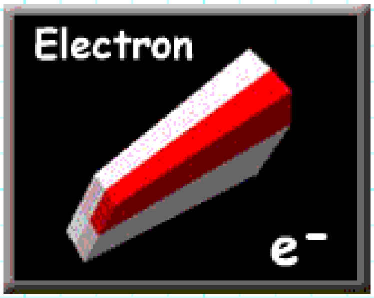


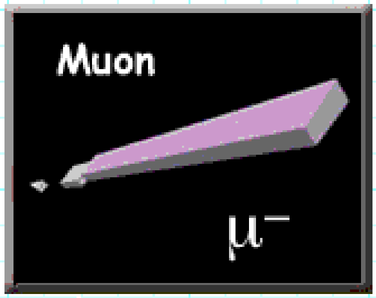
We might be able to catch a ping pong ball, but not a baseball!

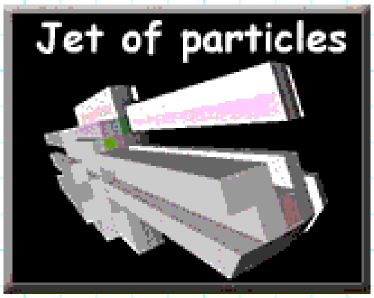
500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

Particles







Practice your skills!

Click on any of the particles to the left to see how they look in a calorimeter. Particles are identified by the shape and color of their shower. Color is used to indicate the amount of energy. Red is lots of energy, green is some energy and light purple is very little energy.

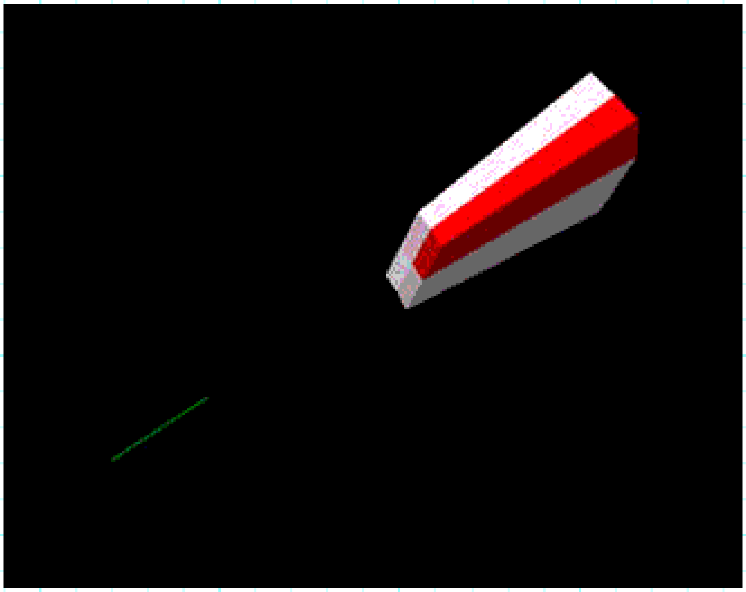
Try testing your recognition ability. You will need this knowledge to move on to the next level.

Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

An Electron

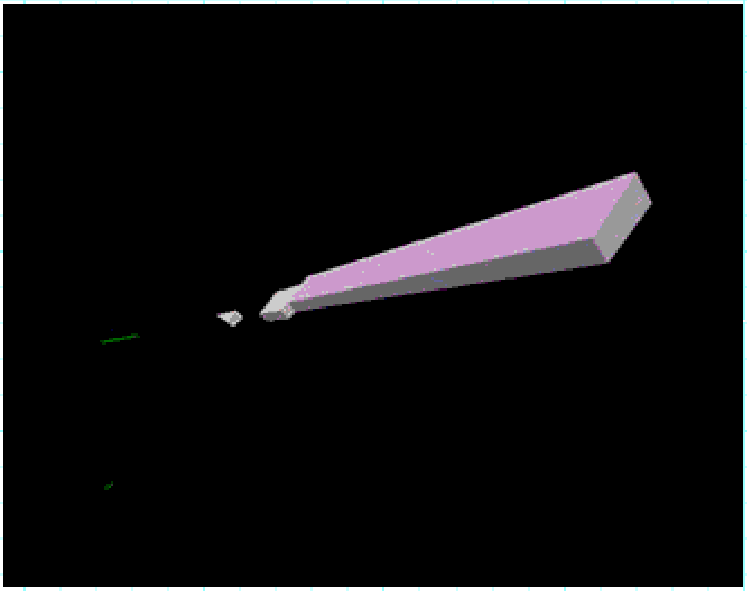


As an electron moves through the calorimeter it produces photons which in turn make more electrons until the particles runout of energy. The shower occurs over a short distance and is narrow. The "shower shape" of the electron is a single tower with lots of energy surrounded by a few towers with little energy. The shower shapes vary depending on how energetic the original electron was. Watch this shower shape rotate with an Animated Gif or Quicktime Movie.

Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail



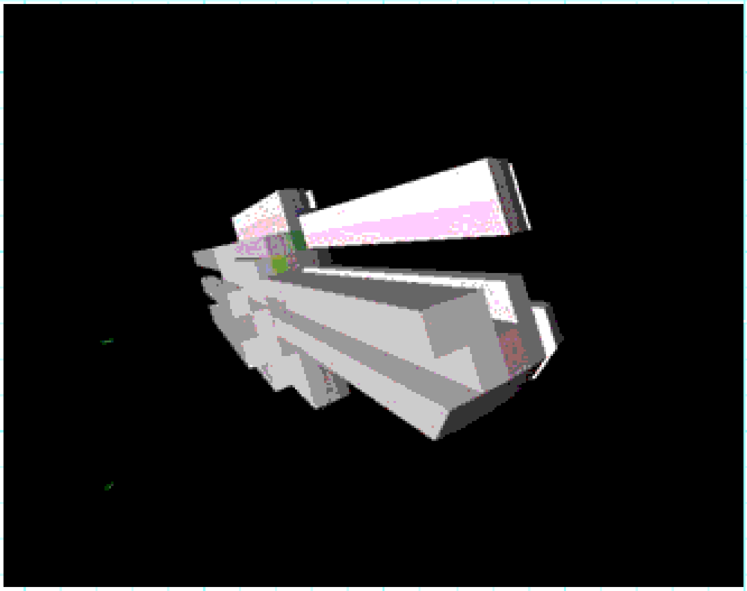
A Muon

Muons are detected by charged particle detectors that are outside the calorimeter. They interact only a little with the material in a calorimeter leaving a small amount of energy all along the path they take. Their "shower shape" is one tower wide and light in color. Watch this show shape rotate with an **Animated Gif** or **Quicktime Movie**.

Introduction **Particles** **Events** **Calorimetry**

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail



Jet of Particles

Jets are composed of a spray of particles. Because lots of particles start the shower, the"shower shape" is typically very broad and has many towers with different energies displayed as different colors. The shower extends deep into the calorimeter, and so the towers are much longer. Watch this shower shape rotate with an **Animated Gif** or **Quicktime Movie**.

Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

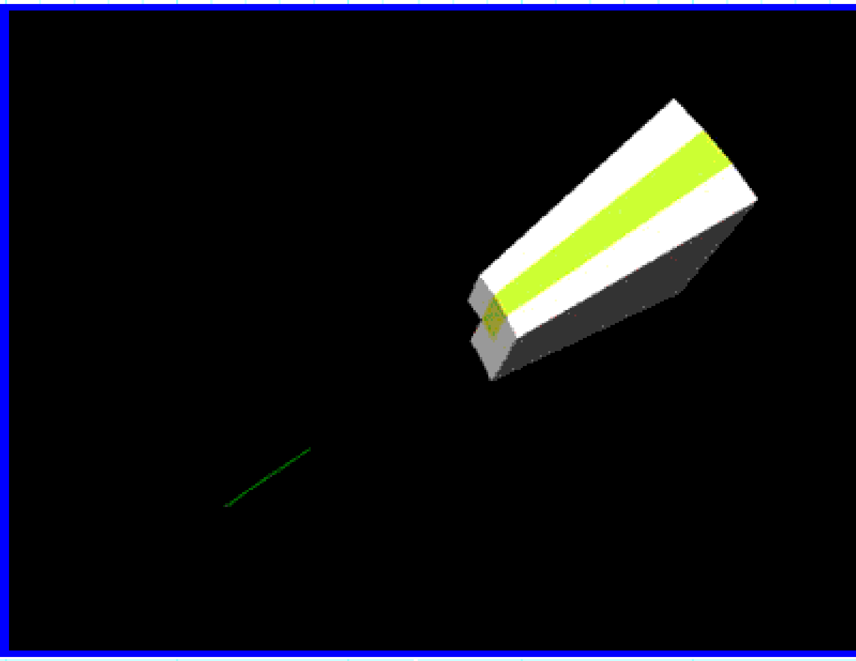
Double Your Bucks and Quit Detector Detail

See how many of the 16 shower shapes on the right you can recognize.

Electron | Jet | Muon

New Shower Shape.
Click Electron, Muon, or Jet.

Right: 2 Wrong: 2

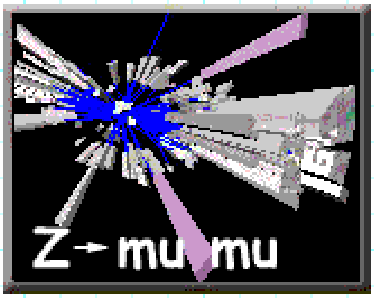


Introduction | Particles | Events | Calorimetry

750 Einstein Bucks

Double Your Bucks and Quit Detector Detail

Events



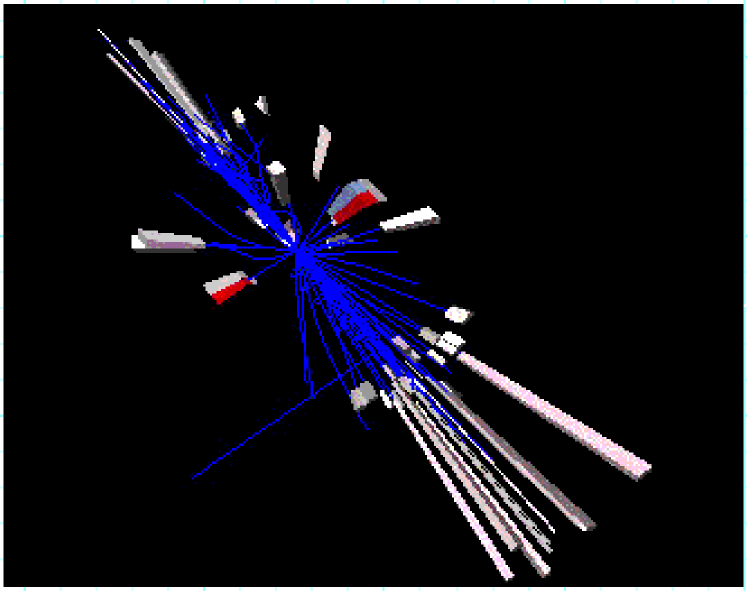
Practice your skills!

An event is a record of what happens in a collision. The 3D plot shows the towers of the D0 calorimeter in which particles deposited energy. This is a record of the final collision debris, the offspring of particles made immediately after the collision. By studying 3D plots, physicists try to discover what happened in the event. The plots you will see show the offspring from the decay of a Z particle. You may find the shower shapes of a pair of electrons, a pair of muons, or two jets.

Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail



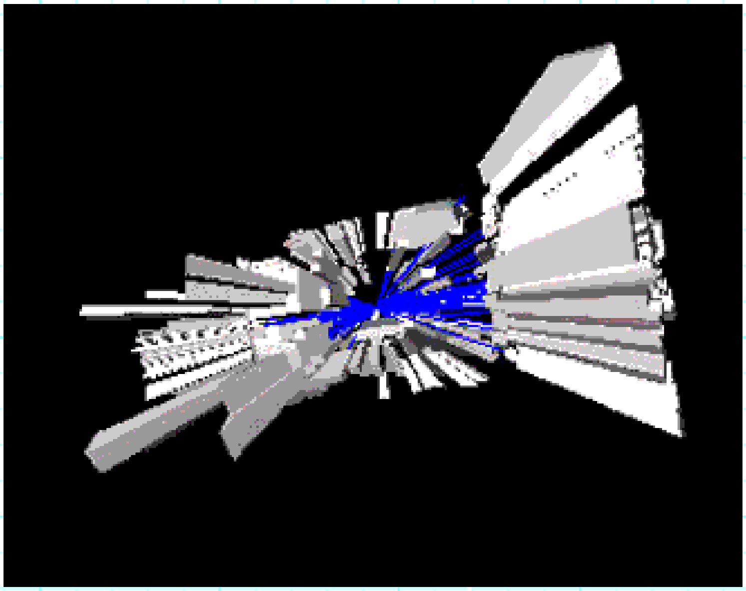
Z -> e e

A Z particle can decay to an electron and an anti-electron (also called a positron). Positrons have the same shower shape as electrons. In this display, you can find the two electron shower shapes by rotating the event. It may not be possible to see both the electron and the positron at the same time.
Rotate the event with an Animated Gif or Quicktime Movie.

Introduction | Particles | Events | Calorimetry

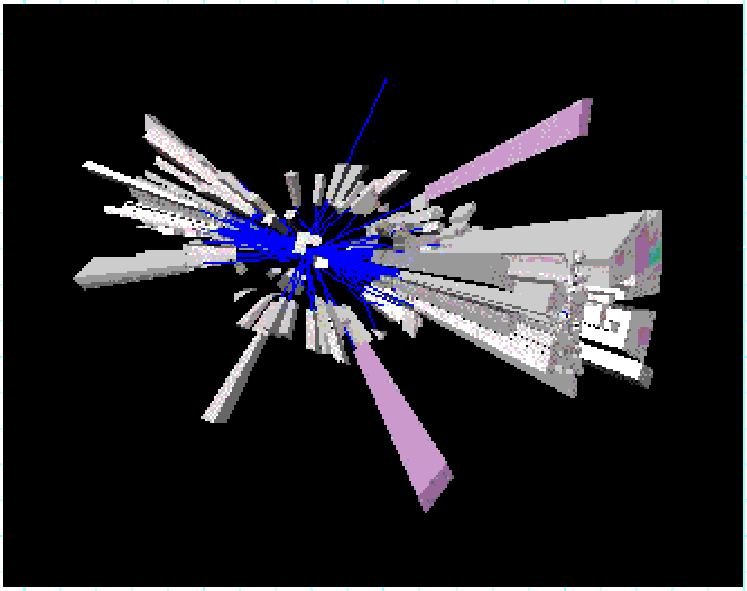
500 Einstein Bucks   Double Your Bucks and Quit Detector Detail

Z -> jet jet



A Z particle can decay to a quark and antiquark, and the quarks produce jets. Jets are sprays of particles and do not have as consistent a shower shape as do electrons and muons. The best way to look for jets is to look for concentrations of energy in the event. Towers with a lot of energy (the jet core) surrounded by many other towers with less energy indicates a jet while lots of towers with low energy indicates debris that is not from the Z decay. Watch this event rotate with an Animated Gif or Quicktime Movie.

Z -> mu mu



A Z particle can decay to a muon and an anti-muon. It is very difficult to find the muons in this display. Physicists do not rely solely on calorimeters for muon identification. Since the muons keep most of their energy as they go through the calorimeter, there are tracking chambers outside it where the muons leave a trace. Physicists match that trace with the calorimeter muon shower shape to confirm the presense of a muon. Watch this event rotate with an Animated Gif or Quicktime Movie.

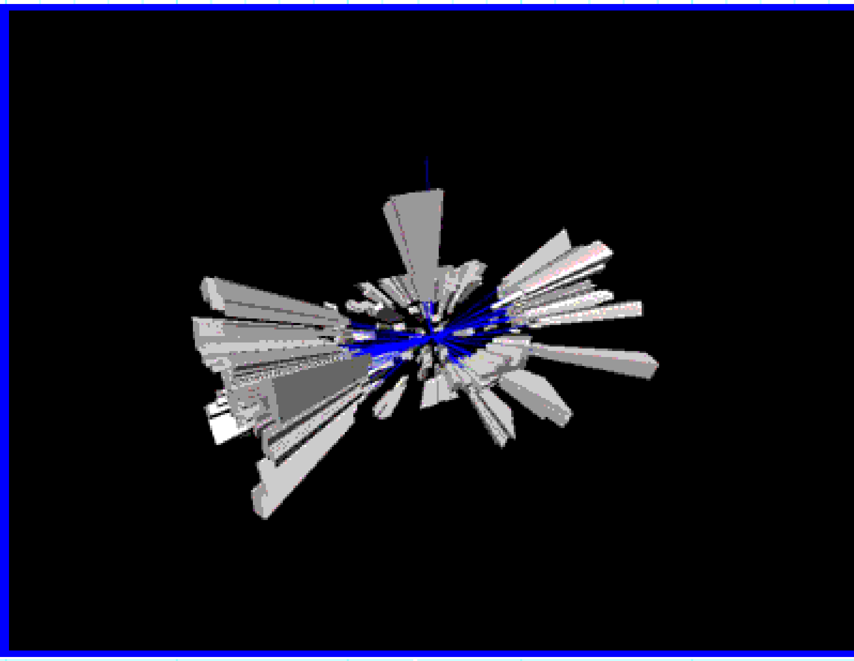
500 Einstein Bucks

See how many of 8 events on the right you can recognize.

Z → e e | Z → jet jet | Z → mu mu

New Event
Click on Z -> e e , Z -> jet jet or Z -> mu mu.

Right: 0 Wrong: 0

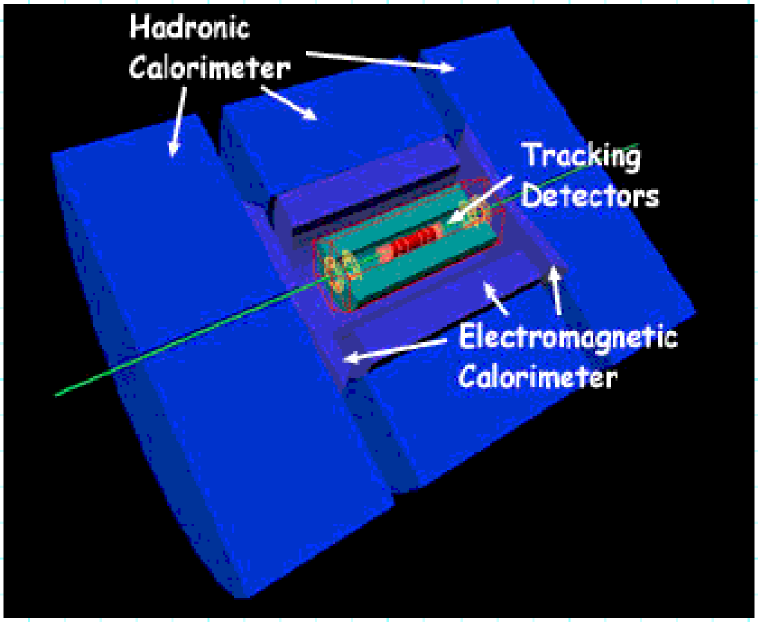


Introduction | Particles | Events | Calorimetry

500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

Calorimetry



In this 3D rendering of half of the detector, the blue calorimeter surrounds the inner tracking detectors. The electrons leave energy in the inner blue section, the electromagnetic calorimeter, and particles called hadrons leave energy in the outer blue section, the hadronic calorimeter. Hadrons are particles made of quarks. Muons leave only very little energy in both parts of the calorimeter.
Zoom into the detector with an

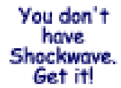
Animated Gif or **Quicktime Movie**.

Introduction | Particles | Events | Calorimetry

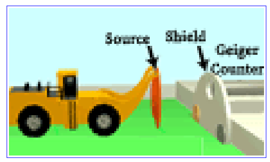
500 Einstein Bucks

Double Your Bucks and Quit Detector Detail

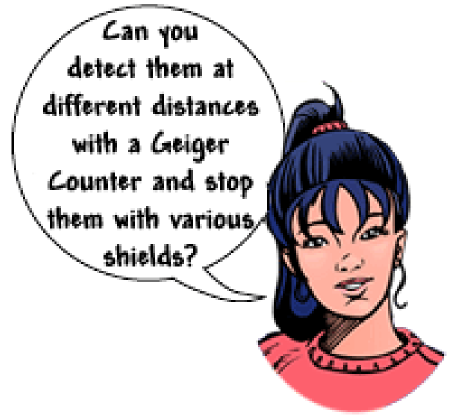
Detect Invisible Bullets with a Geiger Counter



This activity needs Shockwave. If you don't see the animation above, click GET SHOCKWAVE



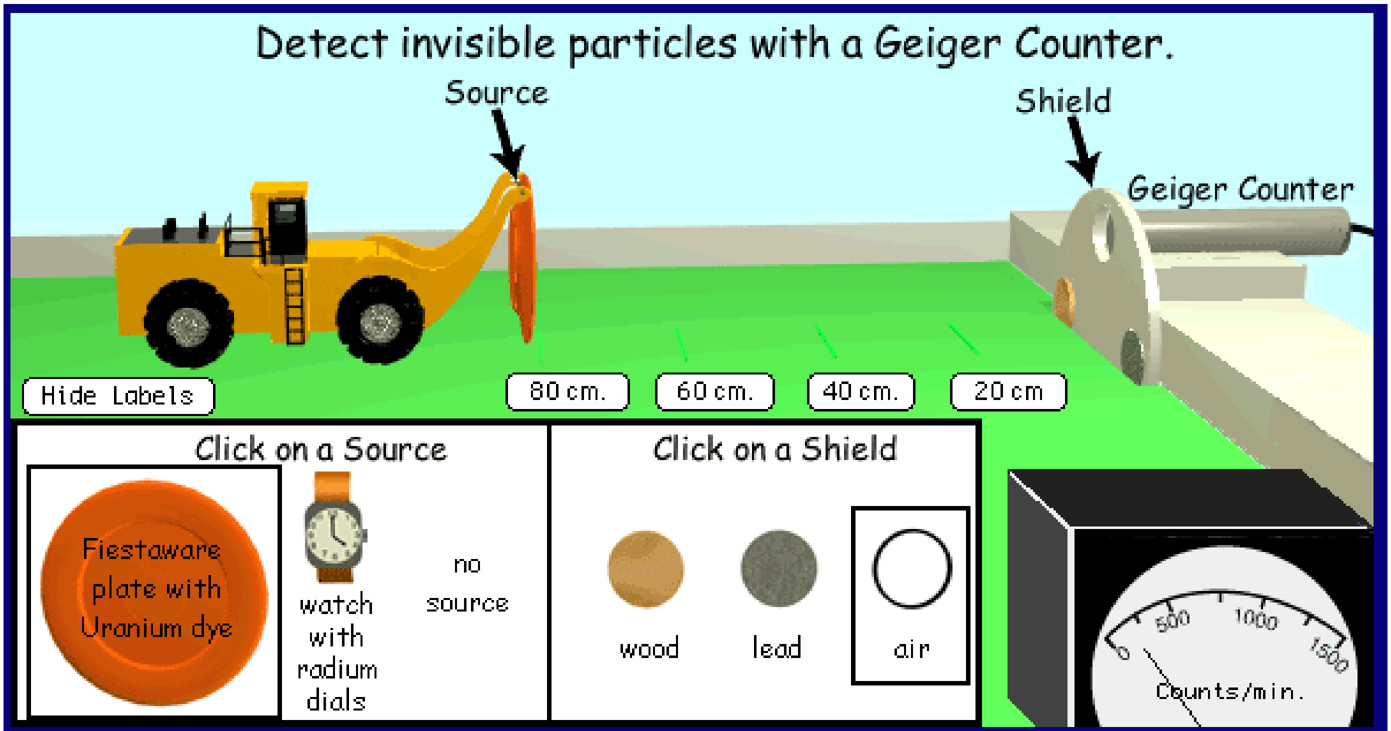
[Go to Game]



Be sure to turn up your sound!

[Ghost Bustin']

Web Maintainer: ed-webmaster@fnal.gov
Last Update: Mar.1,1999
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/geiger_counter/activity.html



[Ghost Bustin'](http://www-ed.fnal.gov/projects/labyrinth/games/ghostbustin/) - [Earn Einstein Bucks]()

Web Maintainer: ed-webmaster@fnal.gov
Last Update: Feb. 19, 1999
http://www-ed.fnal.gov/projects/labyrinth/games/ghostbustin/geiger_counter/geiger.html

Particle Countin' - Test What You Learned

Earn Einstein Bucks by answering the questions below. Remember you can always go back to the Particle Countin' Game. After you are done, click on the "Click to Print Bucks" Button at the bottom of the page. You'll get more Einstein bucks if you fill in the explanations.

Both the fiesta ware and the watch are radioactive; this means that very small particles, too small to see, shoot out of them. The Geiger Counter counts how many particles come from each object. The shields may stop some of the particles.

- Question 1: Which object seems to have the most particles coming out?

  ○ Fiestaware Plate ○ Watch

- Question 2: Does the Geiger counter count more particles when objects are close by or when they are far away? Explain your answer in the box below.

  ○ Close by ○ Far away

- Question 3: Which shield does the best job stopping the particles?

  ○ Wood ○ Lead ○ No Shield

- Question 4: Why do you think the Geiger counter can still count particles even though you put a shield in the way?

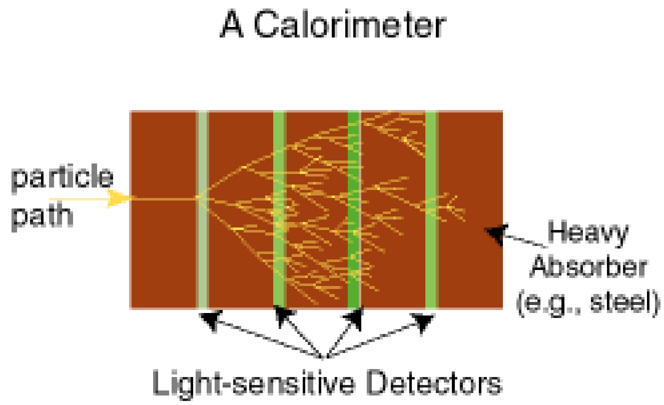
- Question 5: Why do you still hear some clicks on the Geiger Counter when you have no source?

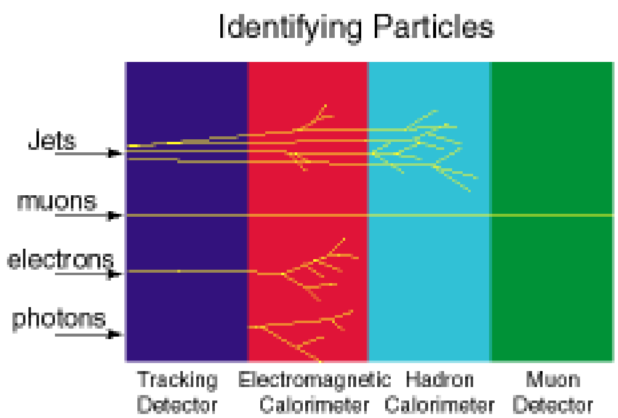
- Question 6: Physicists at Fermilab build their detectors with layers of different materials to trap the particles. These type of detectors are called **Calorimeters**. If you were going to trap all these particles with a layer of material, which would you use?

  ○ Wood ○ Lead

Double Your Bucks by reading about detectors and answering the question correctly:

Calorimetric ("energy-measuring") detectors absorb the energy of a particle and convert it into light which can be observed by light-sensitive detectors. The amount of light observed measures the energy of the particle. Absorbing high-energy particles requires a lot of material, typically many feet of steel or lead. The calorimeter surrounds the point of interaction in a collider detector.





In calorimeters different particles travel different distances before being absorbed. Photons and electrons lose energy very quickly and stop in the first layers of a calorimeter. Muons, by contrast, can pass through many feet of steel before losing their energy. Jets from quarks have an intermediate range. Physicists use the distance a particle travels in a calorimeter to identify the particle.

- Question 7: In which layer would photons be trapped?

○ Tracking ○ Electromagnetic ○ Hadron ○ Muon

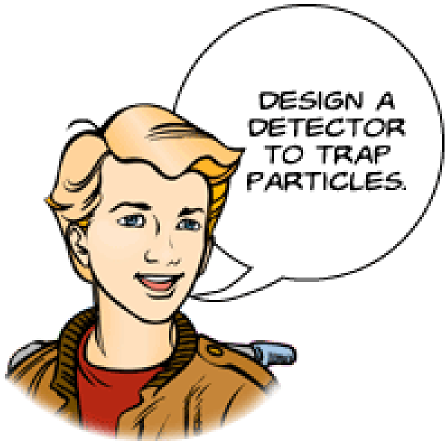
Web Maintainer: ed-webmaster@fnal.gov
Last Update: Mar.1,1999
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/geiger_counter/test.html

Feedback on Karin Fuchs's Answers to Particle Countin'

- Question 1: Sorry, the FiestaWare Plate is the best source.
- Question 2: No, the closer the source, the higher the count.
  You missed earning 200 Einstein bucks by not explaining why.
- Question 3: No, the best shield is made from lead.
- Question 4: You missed earning 200 Einstein bucks by not answering.
- Question 5: You missed earning 200 Einstein bucks by not answering.
- Question 6: No, the best material of the two to trap particles is lead.
- Question 7 to Double Your Bucks: Sorry, you did not double your bucks; the photons are stopped in the Electromagnetic Calorimeter.

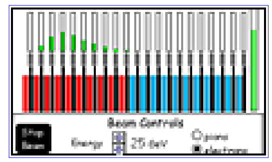
Click to Print Bucks

Particle Trappin'



This activity needs Shockwave. If you don't see the animation above,

click GET SHOCKWAVE



Go to Game

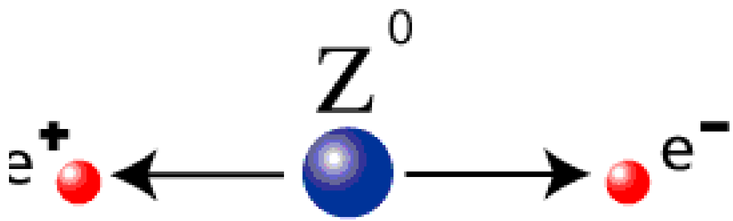
Be sure to turn up your sound!

Ghost Bustin'

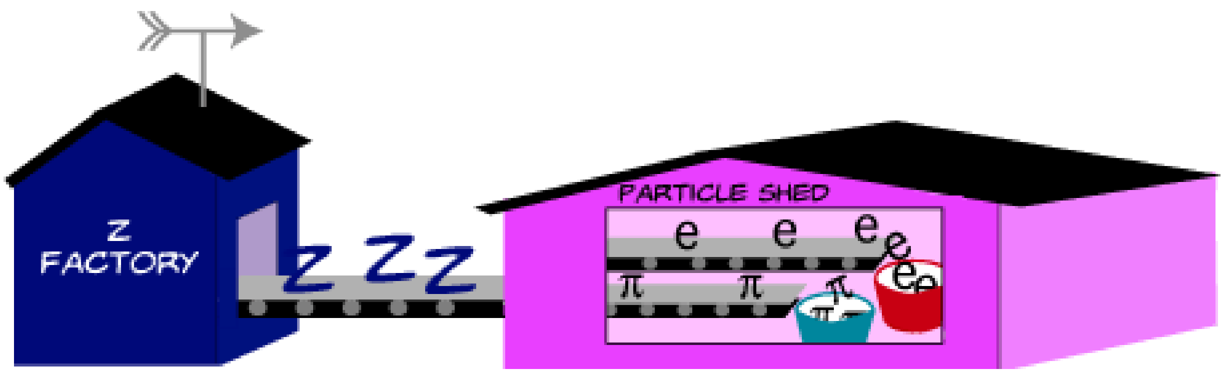
Web Maintainer: ed-webmaster@fnal.gov
Last Update: June 12, 2000
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/activity.html

Particle Trappin' - Join the Team

Welcome to our experimental team. We want to measure the mass of the Z particle. Zs don't live long so we can't trap them, but we can trap the particles they decay into. If we measure the energies of the particle children of the Z, we can calculate its mass. Check out the animation of **some, but not all** of the ways the Z decays into its particle children.



Did you notice two particle children are the electron (**e**) and the pion (π)? Your job is to help build the "Particle Shed" below to trap electrons and pions and to measure their energy. We will be getting the Zs from a Z factory.
[How can you trap particles?]

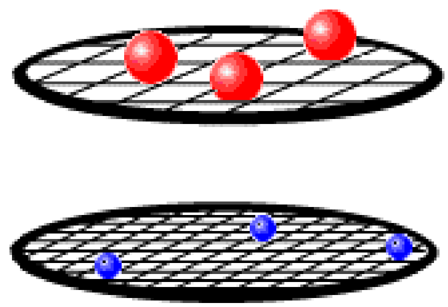


[Ghost Bustin']

Web Maintainer: ed-webmaster@fnal.gov
Last Update: June 26, 2000
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/intro1.html

Particle Trappin' - A Sieve

First, you need to build a device to distinguish between pions and electrons, a sort of sieve that traps each in a different section.



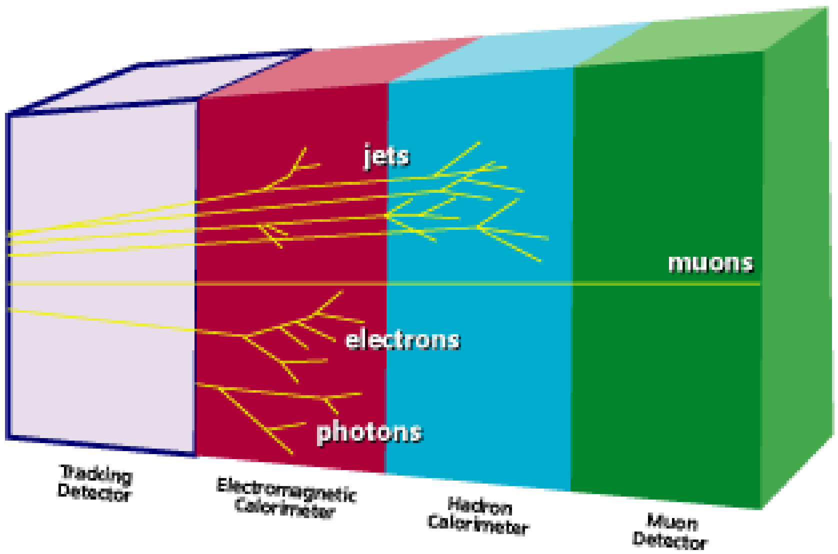
What do physicists use?

Ghost Bustin'

Web Maintainer: ed-webmaster@fnal.gov
Last Update: June 26, 2000
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/intro2.html

Particle Sieve - Identifying Particles

First, you need to build a device to distinguish between pions and electrons. Physicists line up different metals (shown in red, light blue and green). Each metal traps different types of particles and allows other types to pass through. You will be building the red and light blue sections, labeled calorimeters. Show me more about calorimeters.

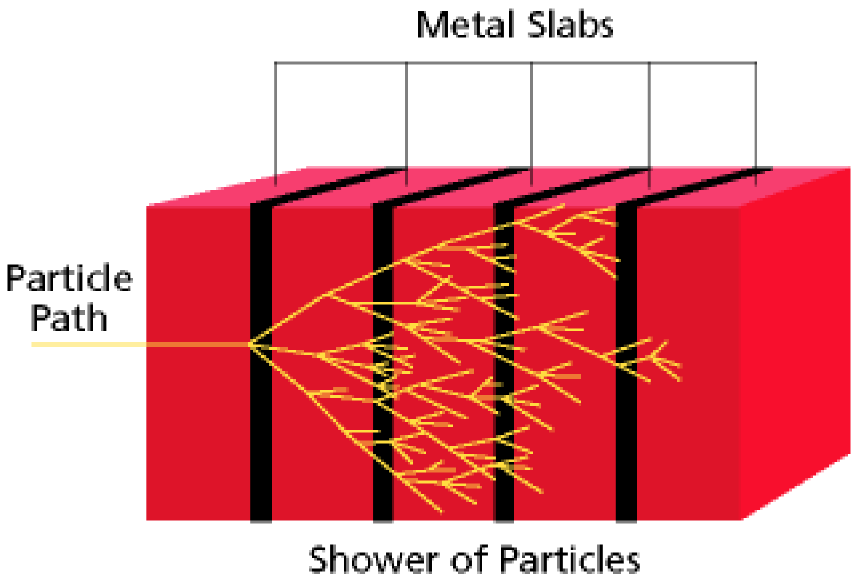


Ghost Bustin'

Web Maintainer: ed-webmaster@fnal.gov
Last Update: June 26, 2000
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/intro3.html

What's a Calorimeter?

Calorimeters measure the trapped energy of the incoming particle. A calorimeter is a layer cake of metal slabs and detectors. When a particle enters the metal, it causes a shower of particles, somewhat like lightning moving through the atmosphere. The shower of particles loses energy as it goes through the metal. How do physicists measure the energy lost in the slabs?

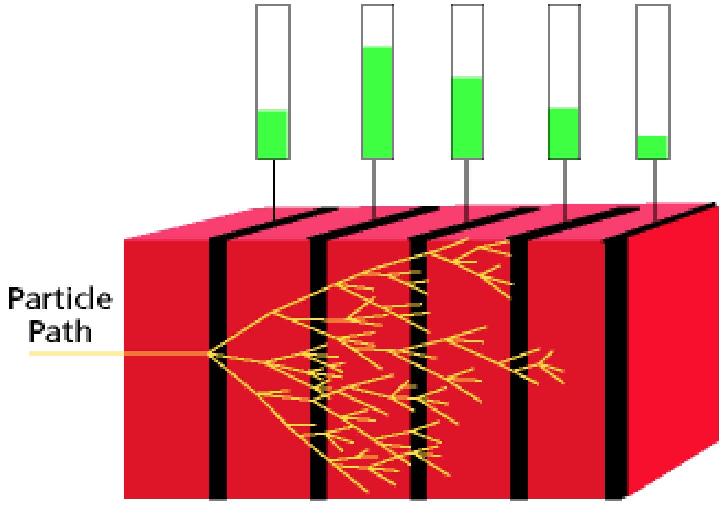


Ghost Bustin'

Web Maintainer: ed-webmaster@fnal.gov
Last Update: June 26, 2000
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/intro4.html

Measuring Energy Lost in Each Slab

By placing detectors between each metal slab, physicists measure the energy lost in each slab. The green bars indicate how much energy was lost in each slab. The energy is spread out over a number of layers depending how deep the shower goes. The green bars start out small, get quite tall, and then drop off. **WARNING: If you do not have enough layers, you may miss some of the energy.** How do they get the total energy?

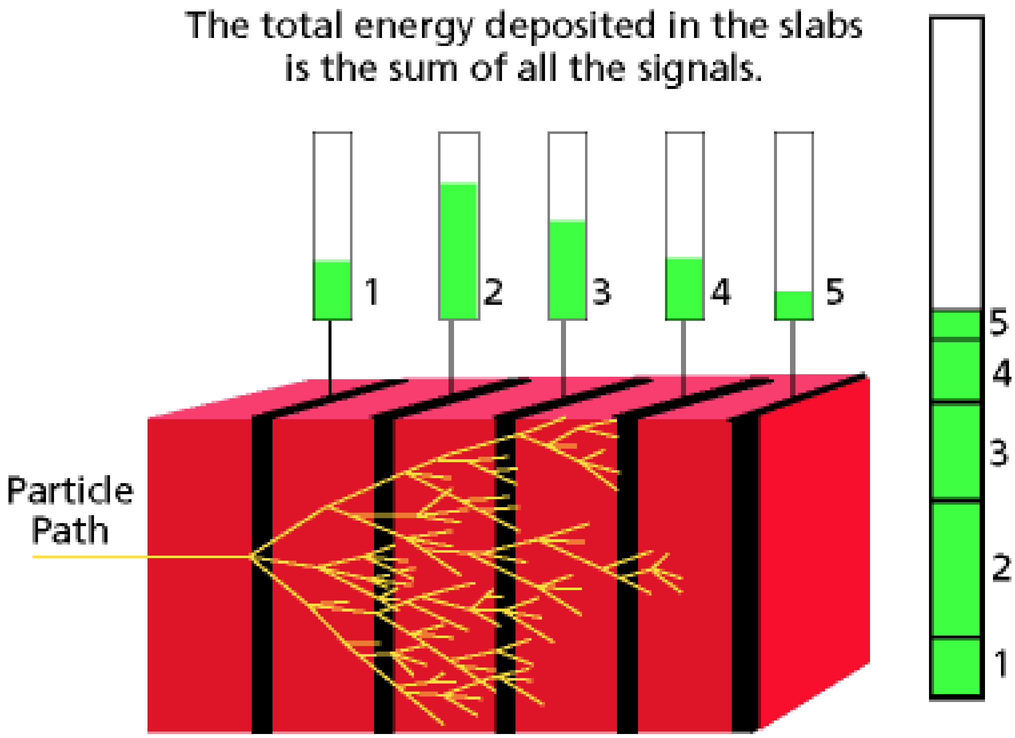


Ghost Bustin'

Web Maintainer: ed-webmaster@fnal.gov
Last Update: June 26, 2000
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/intro5.html

Measuring the Total Energy Deposited in the Calorimeter

Physicists add up the energy in all the detectors to get the total energy deposited in the calorimeter by the particle.



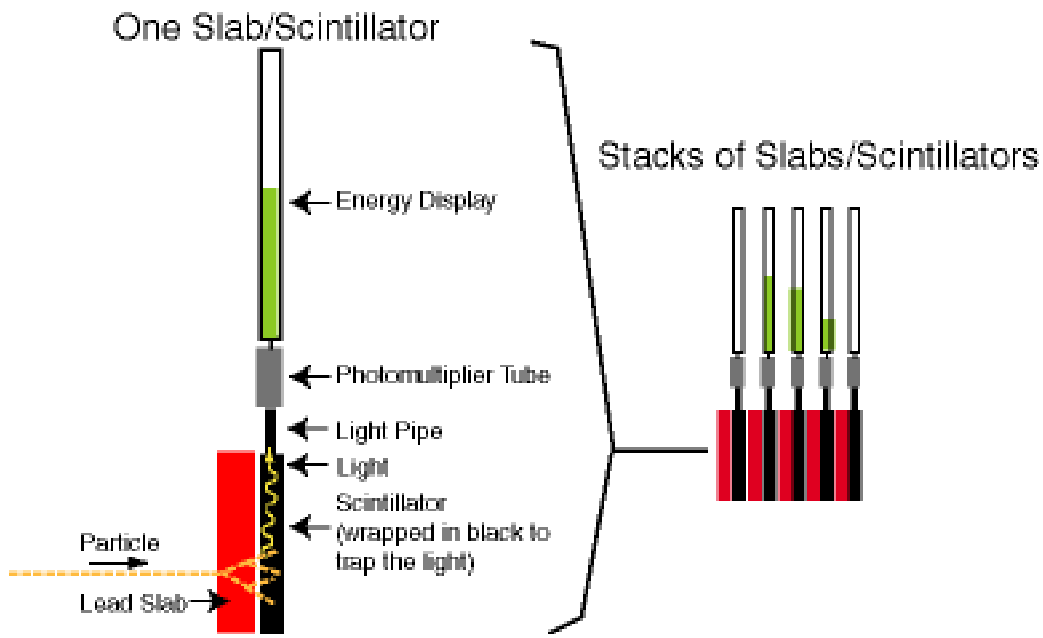
Now you know how to identify your particles and measure their energy. Find out your assignment or if you are really curious, more about the detectors.

Ghost Bustin'

Web Maintainer: ed-webmaster@fnal.gov
Last Update: June 26, 2000
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/intro6.html

Optional: How the Detector Works

Physicists install light-sensitive detectors called scintillators in between the slabs of metal. The amount of light collected in the scintillator tells the amount of energy lost. The light travels through the light pipe into the photomultiplier tube which enhances the green LED signal in the Energy Display.



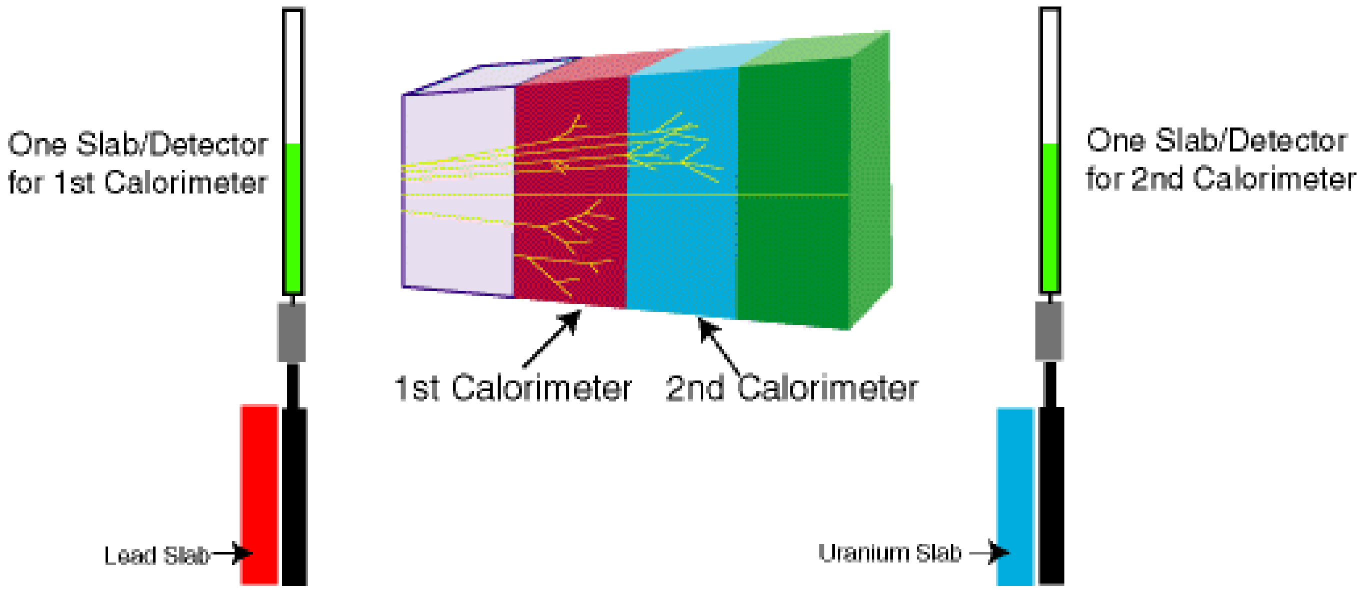
[What's your assignment?]

Ghost Bustin'

Web Maintainer: ed-webmaster@fnal.gov
Last Update: June 26, 2000
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/intor7.html

Your Assignment

Your job is to build two calorimeters back to back. One will detect pions and the other electrons. The metals you will use are lead and uranium. Here are the basic components of each of your calorimeters.



You have to experiment with your calorimeters in a test beam to see that they

- trap pions in one calorimeter and electrons in the other for all possible beam energies.
- each have enough slabs to capture all the energy for particles in the test beam.
- do not have more slabs than you need because we cannot go over budget. These slabs and detectors are expensive!

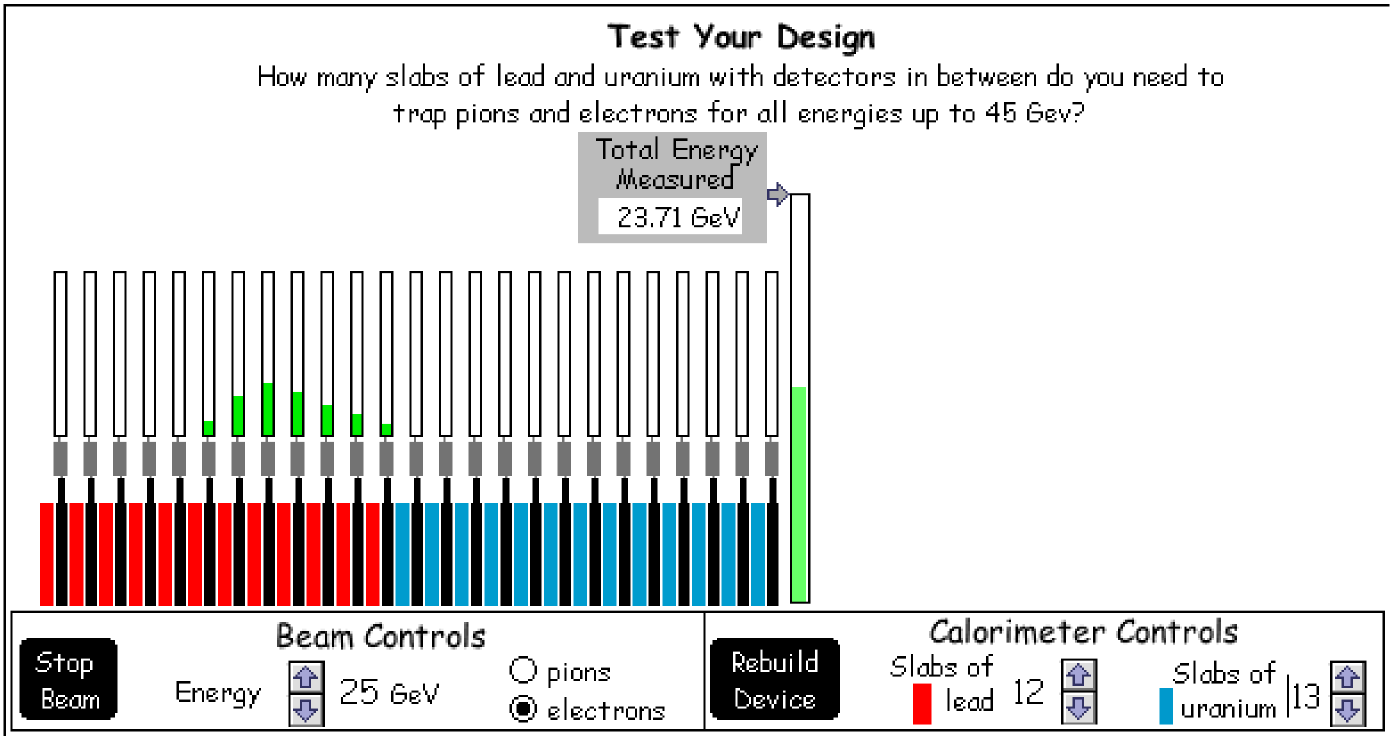
When you are done, answer these questions for your report and you can earn Einstein bucks!

Go to the Lab with the Test Beam.

Ghost Bustin'

Web Maintainer: ed-webmaster@fnal.gov
Last Update: July 2, 2000

http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/assignment.html


Test Your Design
How many slabs of lead and uranium with detectors in between do you need to trap pions and electrons for all energies up to 45 Gev?
Total Energy Measured
23.71 GeV
Stop Beam
Beam Controls
Energy
25 GeV
pions
electrons
Rebuild Device
Calorimeter Controls
Slabs of lead
12
Slabs of uranium
13

Particle Trappin'

Earn Einstein Bucks. Fill in the form below. You can always go back to the window with the calorimeter to check how it works.

Particles trapped in lead: ○ pions ○ electrons

Particles trapped in uranium: ○ pions ○ electrons

Least number of slabs of lead needed to measure 45 Gev particles:

☐

Least number of slabs of uranium needed to measure 45 Gev particles:

☐

To double your bucks, answer the following:

Each Z can decay into two pions **or** two electrons.
Each pion or electron has an energy of about 45 GeV.

About how much do you think the mass of the Z is? ○ 45 ○ 90 ○ 180

Web Maintainer: ed-webmaster@fnal.gov
Last Update: July 2, 2000
http://www-ed.fnal.gov/projects/fermilabyrinth/games/ghostbustin/calorimeter/test.html

Feedback on Marilyn Fox's Answers to Particle Trappin'

- Question 1: Yes, the lead traps electrons.
- Question 2: Yes, the uranium traps the pions.
- Question 3: You used too few slabs of lead; You'll miss some electrons!
- Question 4: You used too few slabs of uranium; you'll miss some pions!
- Doubling Your Bucks:
- Doubling Your Bucks: Sorry, you didn't double your bucks; all the mass of the Z is converted into the energy of two pions or electrons when it decays. If the energy of each pion or electron is 45 GeV, then the mass is 90.

Click to Print Bucks

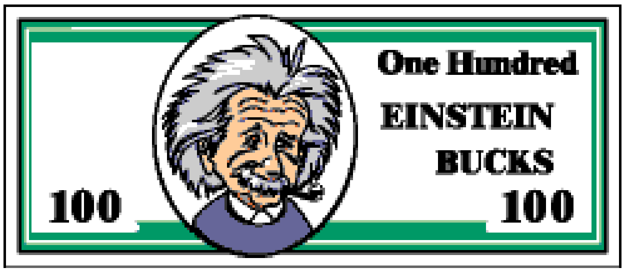
Fermilabyrinth
Batavia,IL 60510

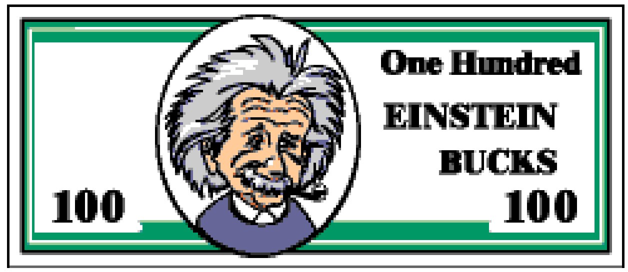
10/4/101

Pay to the order of: Marilyn Fox

200 Einstein Bucks

For: Particle Trappin





See The High Scores

If you do not see your name on the check, try resizing the window. Close this window when you have printed out your Einstein bucks or have looked at the high scores.