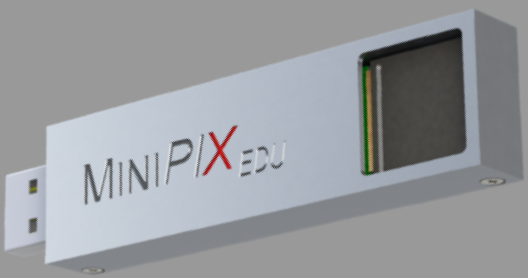
Queen Mary
University of London



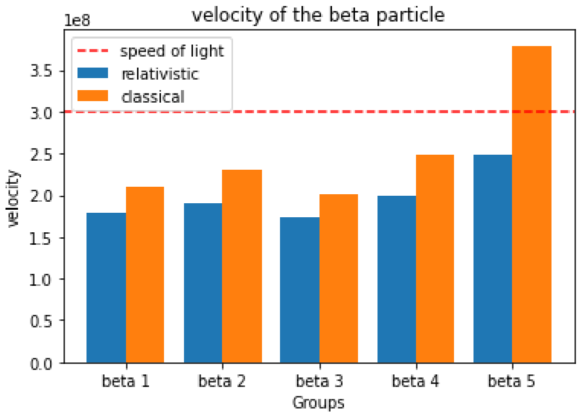
ANSWER BOOKLET

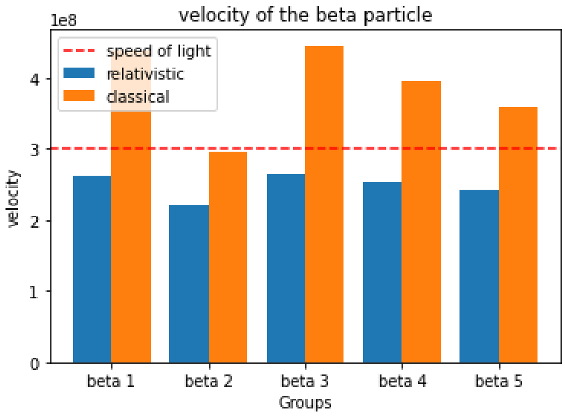
Particle Physics

Research Centre

Outreach Team

EXPERIMENT 1- examine the relationship between speed and kinetic energy for beta particles



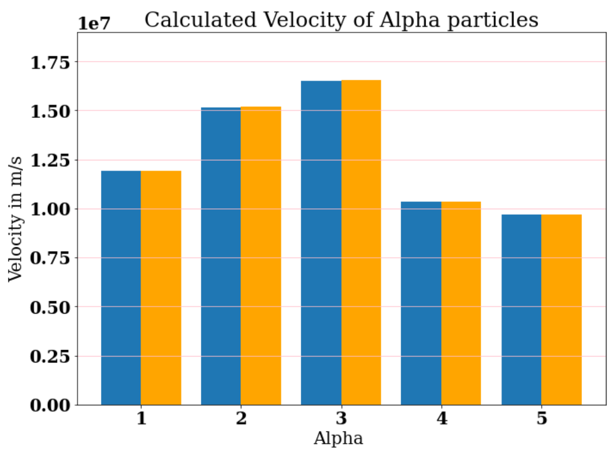


Data should look like this. (Left is particles in the room, right is particles from a thorium rod)

Q- Look at the data to determine the differences between the two predictions.
A- Classical mechanics is good for objects travelling at low speeds. Relativity is good for speeds close to the speed of light.

Q-Is classical mechanics a good prediction for particles close to the speed of light?
A- Classical mechanics is NOT good for fast-travelling particles as it predicts speeds that are faster than the speed of light, which we know is not allowed! This shows why we use relativity for particles travelling close to the speed of light, as it follows the laws of the world, where nothing can travel above the speed of light.

Q- Extension - Would you see a similar graph with alpha particles?



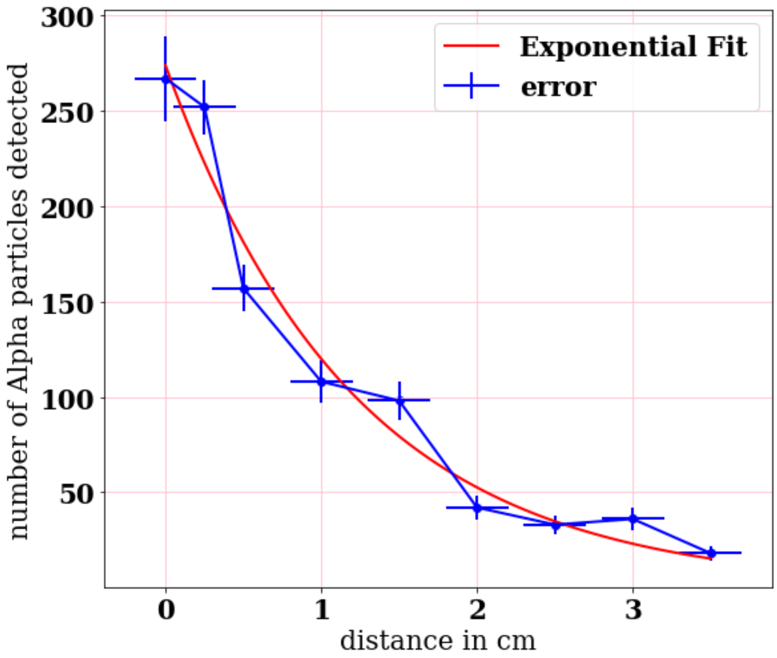
A- No, you wouldn't see a similar graph. Alpha particles have a helium nucleus, meaning that they are much heavier than an electron (beta decay). This means that they travel a lot slower than the electrons. The difference between classical mechanics and relativity is very small and not noticeable at this speed. This shows us that relativity is best at very high speeds, that are very close to the speed of light. (take note of the units of speed in this case, they are much lower than the beta)

Q- Extension- Compare the graph of electrons from a radioactive source vs ones in the room, what is the difference?

A- (graphs at top of page). Electrons from a source have much higher speeds than ones in the room. This is due to the 'expulsion' of the electrons from the radioactive source forcing them to be sent away at a higher velocity.

EXPERIMENT 2- Alpha radiation vs distance

The data should look something like this. I suggest using desmos or a similar simple graphing tool to plot the data.



Q- Taking the measurement from the centre of the detector, it is hard to get exact distances. Consider what the best point is to take measurements from on the detector (e.g. the end of the detector, the middle or the front?) How does this affect your results?

A- Aligning the detector in the middle of a measurement will cause a larger error in the distance compared to lining it up with the ends of the detector. But, as long as students consider this, then all three are fine to use for measurements.

Q- The graph displays the relationship between the distance from the radioactive source and the number of alpha particles detected. What is this relationship?

A- Negative exponential fit.

Q- What is the error on the distance?

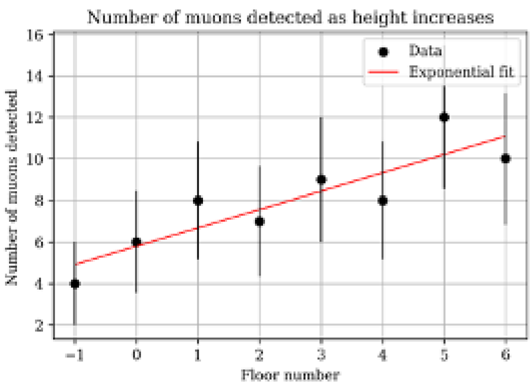
A- Due to the size of the detector, it would be expected to get around +-2mm of error on the distance.

Q- How can you work out the error on the alpha particles?
A- Taking the square root of the number of particles detected gives the error on the value (as a general rule in this case!)

EXPERIMENT 3- Detecting muons at different elevations

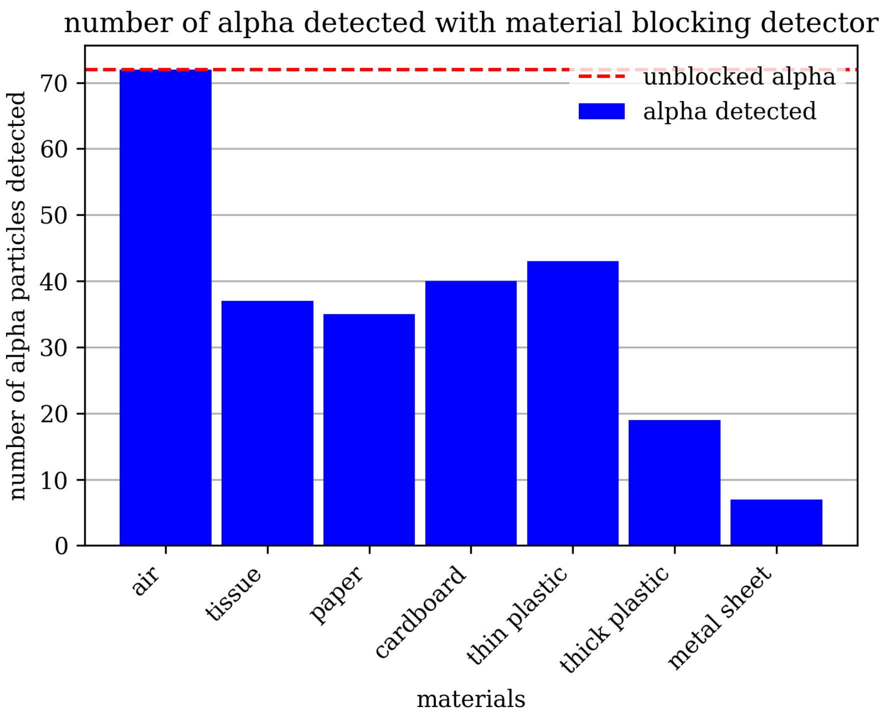
Q- Would you expect to see a difference at this small of a change in altitude? Why, why not?

A- To explain the relationship further, find attached a graph from an expanded version of this experiment, where data was taken on each floor of a 7 floor building. You'll notice that the total number of muons steadily increases as elevation increases, this is because the amount of overhead absorbing/scattering concrete (known as "Overburden") decreases as you move upwards. You can expect to see a small change due to this overburden.



EXPERIMENT 4- How much material is required to stop certain radiation

Q- Summarise the findings of the experiment and explain the most effective materials for stopping each type of radiation. Discuss any trends observed and potential applications of these materials in real-life scenarios.



A- tissue and paper were both too thin to stop most of the radiation. Cardboard was successful in stopping the majority of alpha, and plastic and metal stopped all radiation from getting through.

The thicker the material, the more radiation it stops. Alpha has a very short range and is easily stopped by a thin piece of cardboard.

Q- Design a safety outfit for a scientist entering a radioactive room containing an alpha source. Why have you chosen this material?

A- Several correct answers here:

Some may say that cardboard provides good protection, so a thin cardboard suit would work well.

Others may say that they want complete safety so opt in for plastic or metal.

Students might mention that layering clothing provides enough protection as alpha particles only travel a few cm in the air.

There are several correct answers which depend on the explanation.

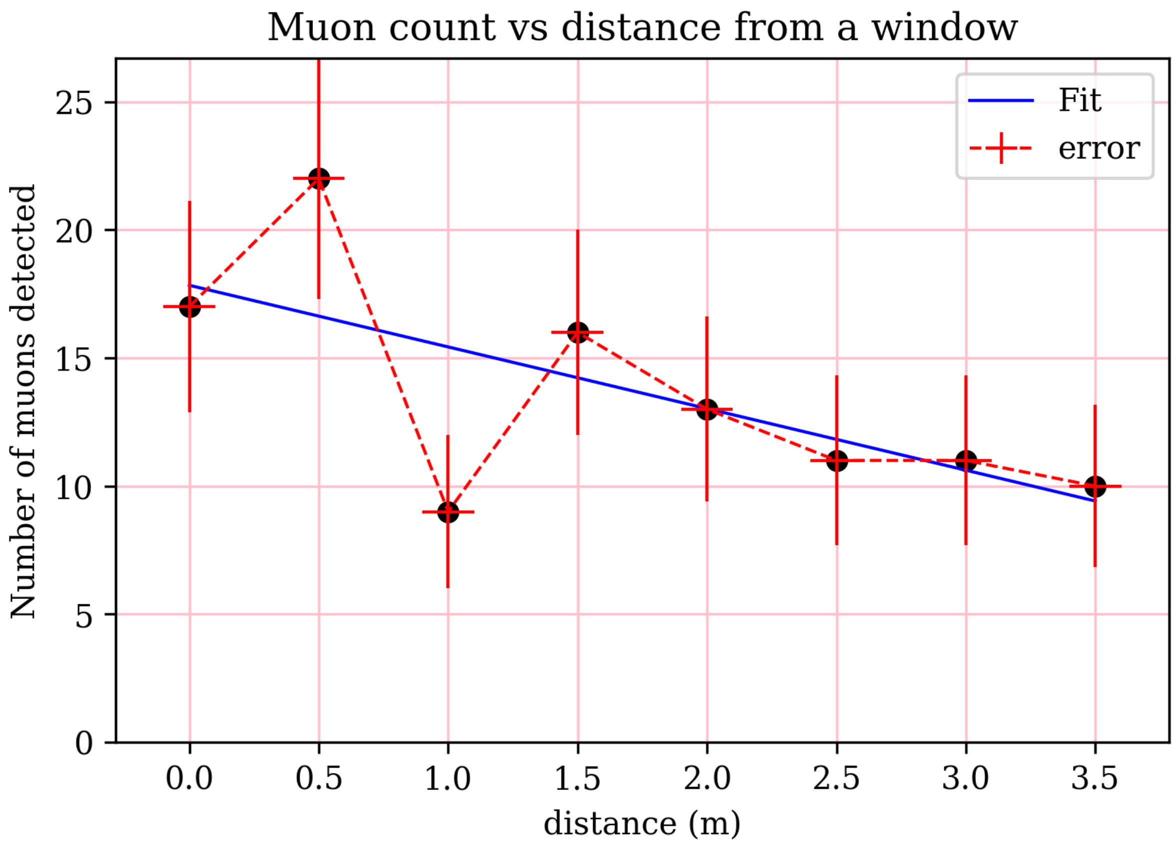
Q- What does this tell us about the importance of safety and storing sources when dealing with radiation?
A- Different sources require different amounts of caution. Alpha is very ionising but has a super short range so is relatively safe to handle. The findings tell us that a person handling an alpha source should not hold it close to themselves and that it should be stored in a box with metal walls to stop any

radiation from escaping. This eliminates any issues of people near the alpha source unknowingly becoming irradiated.

EXPERIMENT 5- Muon detection near/ far from the window

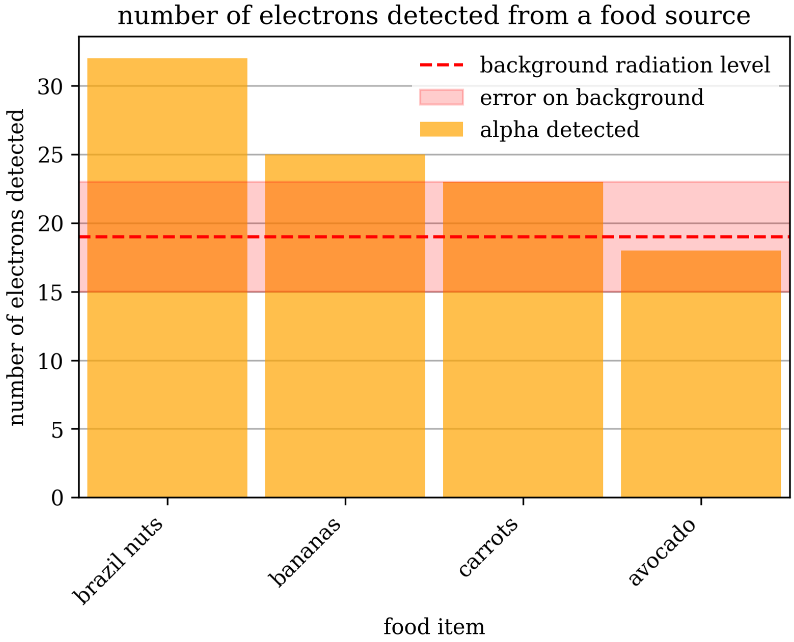
Q- Now compare your total muons detected close to the window, and the total muons detected far from the window. What do you notice? And why could this be?
A- Near the window had more muons- less concrete next to the window, so no absorption of the particles.

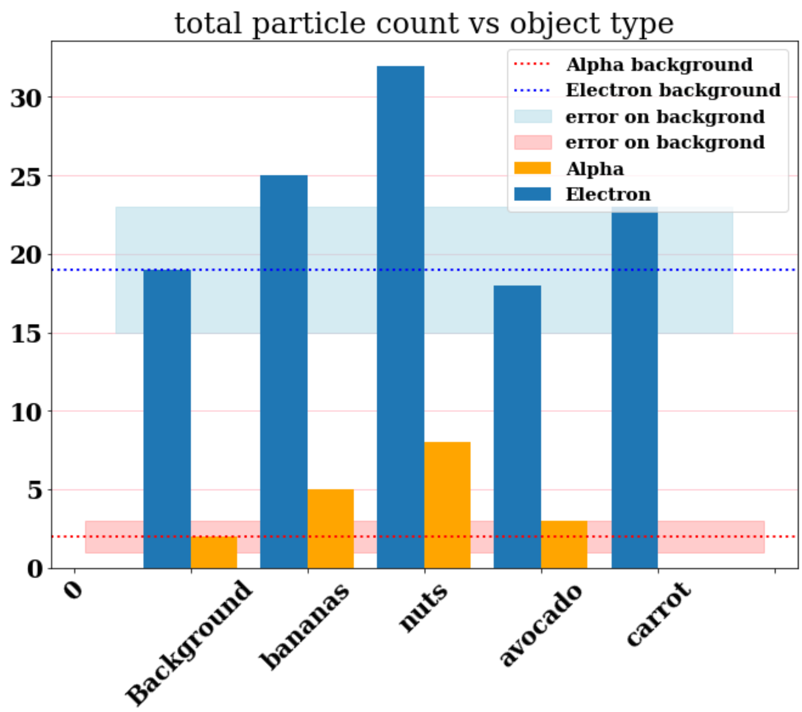
Q- Can you find the equation to the line you have? What is the relationship of this data?
A- Linear fit works best giving an equation y = mx + c where m = -2.4 & c = 17.8 (this will differ depending on the fit of students data!)



EXPERIMENT 6- Is it radioactive?

Q- Compare the radiation levels of each item with the background radiation measurement. What do you see?
A- This answer depends on what the students used- but items such as bananas and nuts will be higher than background levels.





Q- Discuss why some items may emit higher or lower levels of radiation than others.
A- Bananas and Brazil nuts are known to contain potassium and may emit slightly higher radiation levels due to the presence of naturally occurring radioactive isotopes. They contain radioactive levels which are so low that they would not cause any issues if eaten, but the detector is sensitive enough to see the increase.

Educational Insights: This experiment allows students to understand the concept of radiation, its sources, and its natural occurrence in certain everyday items. It also encourages critical thinking and analysis of data. Students can discuss the potential impact of such radiation and how exposure to natural radiation is a part of our daily lives.

EXPERIMENT 7- Cosmic Angles

Q- What do you notice in the data, any relationships or abnormalities-
A- You should see a peak at around 30-50° (hopefully!)

Q- Is there any difference between the angles 0° and 180° ?
A- Yes, while 0° does not have the maximum muon count, it does have more than 180°. This makes sense as we expect to see more muons from above compared to below.

Q-What does the data tell you is the best angle to take data from? What is the worst?
A- best angle = 40°, worst angle 90°

Q- Explain why the maximum muon count is not at its peak at 0°
A- The number of detected muons is higher between 30° to 50° compared to 0° and 180°. This finding seems odd but can be explained logically: muons are more prone to travel straight downwards. When muons travel straight down from the sky, they are less likely to be detected as distinct muon tracks and appear as dots on the detector. But when muons arrive at an angle, they become more detectable, giving a result of the best angle to measure muons being around 40 degrees. This peak is shown on the graph.