Alpha Natural Radioactivity in the Air: an Experiment for High-School Students (CERN Competition 2003)

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Abstract

For the Physics Teachers Competition at CERN 2003 a project has been carried out concerning some experimental aspects of natural radioactivity. The experimental activity, was based upon the use of a diffusion cloud chamber, which allowed us to measure the lengths of tracks left by elementary particles coming from natural decays. More than 500 tracks have been hand-measured by secondary school students and their lengths have been related to the energy loss in the chamber. This project, that won the first price at CERN, will be here described and the most important educational and experimental results will be presented.

Introduction

The project was planned by a group of 6 secondary school Physics teachers who granted the request made during the programme *Physics Teachers @ CERN 2003*: "Develop a piece of work on a particle physics topic at any level. Show some students' work to indicate the success of the work". The work involved 133 students, coming from 5 different secondary Italian schools (in the north area of Milan). Two researchers and a university teacher took part in the project allowing the use of a cloud chamber to realize the experimental activity.

1 Goals and expectations

The aims of the project were: a) to give the students the opportunity of realizing a first experimental approach to the methodology of revealing radiation using a cloud chamber; b) to introduce some basic radioactivity topic in Secondary School from an experimental point of view .

2 The cloud chamber

The chamber that is now at the Physics Department of the University of Milan , Fig. 1, was built about ten years ago by two of us (Giliberti M. and Labanca I.). It has a cylindrical shape: the radius of its base and its height are 15 cm. At the bottom there is a continuously sensible revelation zone, about 3 cm high, created by a layer of supersaturated alcohol vapour (cooled down to about 230 Kelvin degree by a block of dry ice). The passage of a ionising particle condenses the vapour into tiny droplets, producing a visible track.

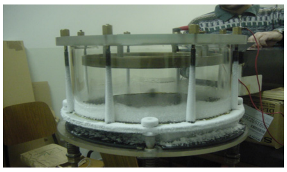

Figure 1: The cloud chamber

3 The activity at the University of Milan

In October 2003 a representative group of 50 students coming from all the schools involved in the project went to the Physics Department of the University of Milan to see the cloud chamber in action. More than 500 tracks were observed in a period of about 60 minutes. Some observations were made by the students. Oa) Two clearly different kinds of tracks could be seen; some tracks were broad and mostly straight, while others were very light and bended. Ob) The tracks were homogeneously and isotropically distributed in the sensible volume of the chamber. Oc) The α tracks were only some centimeters long.A video camera was placed on the top of the chamber to film the tracks. The video was recorded and distributed in every school, where the other students could see the film on a television set. Many discussions followed this laboratory activity In particular (see Oa)) students were told that the broad tracks were due to α particles and the others were caused by electrons. We mainly concentrated our attention on the former. The students were also driven to considerations of semi quantitative kind: first of all on the concept of stopping power with its rough dependence on the density of the medium crossed by the particles and, second, the idea that nearly all the of α particles coming from a given decay have the same energy. Students were also told that it is possible to obtain the energy of α particles, expressed in MeV, as a function of their ranges l in air, by means of two empirical formulas [1]:

$$E = \frac{l}{0.560} \quad \text{for } l < 2.2\,cm \qquad (1)$$

$$E = \frac{l + 2.62}{1.24} \quad \text{for } 2.3\text{cm} < l < 7.3\,cm \qquad (2)$$

In this way students could clearly see that (see Oc)) the energy of α particles have the order of magnitude of some MeV and that they were most probably produced inside the chamber (otherwise they should have been able to cross the thickness of 0.5 cm of glass which is about thousand time denser than a gas…).

4 The measurements

When the students began reasoning about the data they could get on television , they immediately faced with two crucial points: the scaling problem (all the measure on the screen must be scaled) and the geometrical problem (the camera gave us the images of the projections of the tracks on an horizontal plane). The first problem has been solved getting a scaling factor from the image of a metric paper approximately filmed at the same distance as the tracks. All the length of the tracks were proper scaled; only the tracks starting and finishing completely inside the filmed area were considered.

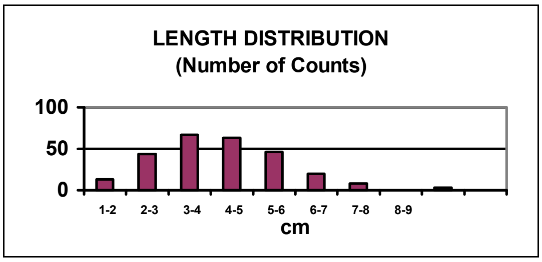

Figure 1.Distribution of the projection of α tracks

In the graph of Fig. 1we could distinguish a main distribution of values (lower than 8 cm) and a tail of very few number of measures between 9 cm and 10 cm (they are less than the 0.3%). We can make the assumption that the longer tracks are horizontal, so that their length is the real one. The isolated measures between 9 cm and 10 cm correspond to an energy of the particles (eq. (2)) between 9.3 MeV and 10.2 MeV. We can also see that the longer tracks of the main distribution lay between 7 cm and 8 cm, corresponding to energies between 7.7 MeV and 9.1 MeV. If we make the hypothesis that the distribution is mainly due to a predominant decay, so that the real tracks have almost the same length, we can try to argue, from the previous distribution, the real length of the track. We can work as follows. If x is the length of the track, d is the height of the active region of the chamber (3 cm) and z is the projection of the track on the vertical axis, some simple geometry consideration leads to the observed length y:

$$y(z) = \sqrt{x^2 - z^2} \qquad if \quad 0 \le z \le d \qquad (3)$$

$$y(z) = d\sqrt{\frac{x^2}{z^2} - 1} \qquad if \quad d \le z \le x \qquad (4)$$

These expressions should be integrated to obtain the average value previously described.

$$y = \frac{1}{d}\int_0^d \sqrt{l^2 - z^2}\,dz + \frac{1}{l}\int_d^x d\sqrt{\frac{x^2}{z^2} - 1}\,dz$$ The result is:

$$y = \frac{1}{2}x \arcsin\frac{3}{x} - \frac{3}{2}\sqrt{1 - \left(\frac{3}{x}\right)^2} - 3\log\left(\frac{x}{3} - \sqrt{\left(\frac{x}{3}\right)^2 - 1}\right)$$

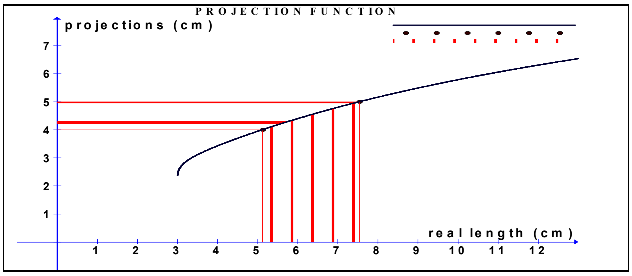

Figure 2 The graph represents the observed value y of the projection vs the real length of the tracks x.

The average value of the distribution is 4.2 cm; it is comprised between 4 cm and 5 cm (measured projections). From Fig. 2 we obtain the corresponding values for the real tracks which are about 5.1 cm and 7.5 cm. These values are the ranges of α particles with energy between 6.3 MeV and 8.1 MeV; which range agree with the range of the energy related to the horizontal tracks belonging to the main distribution. The experiment was done in a laboratory at the ground floor, and we know that in this condition the α decay of ^{222}Rn (7.74 MeV) can have a leading role; it is thus possible that our tracks come from α^{222}Rn.

Conclusions

From an educational point of view, the project was important for two main reasons: a) even if the experimental apparatus was not sophisticated, the students could assay a first, simple example of the methodology of revelation problem. (All the previous consideration agree with the hypothesis that the main radioactive α element present in the filmed area is ^{222}Rn) ; b) The students have had an opportunity to realize a project in collaboration with University and CERN.

References.

[1] KINSMAN, S. Radiological Health Handbook. US Government Printing Office, Washington, DC