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ABSOLUTE MEASUREMENT OF ^{212}Po ALPHA PARTICLE ENERGY

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ABSTRACT: Using the one meter radius absolute magnetic spectrograph built in the Instituto de Física shop, we have measured the energy of ^{212}Po alpha particles. Since the experiment consists of measuring a distance and the frequencies that determine the effective magnetic field, the measurement is an absolute one. An optical method for obtaining small deformations of the optical bench is also described. The energy value obtained is 8784.85 ± 0.31 keV.

INTRODUCTION

The absolute measurement of alpha particle energies from some radioactive emitters like ^{210}Po, ^{212}Po and ^{241}Am is important because they are frequently used as secondary energy standards in nuclear laboratories. The measurement of ^{212}Po alpha particles is covered in this report. The instru-

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ment described was so designed as to be used also on line with an accelerator in order to measure nuclear reaction Q values.

I. APPARATUS DESCRIPTION

The one meter radius spectrograph is located in the experimental area of the Dynamitron Accelerator of the Instituto de Física, where temperature variations are very slow, providing favorable working conditions for the equipment. Figure 1 shows a view of the spectrograph.

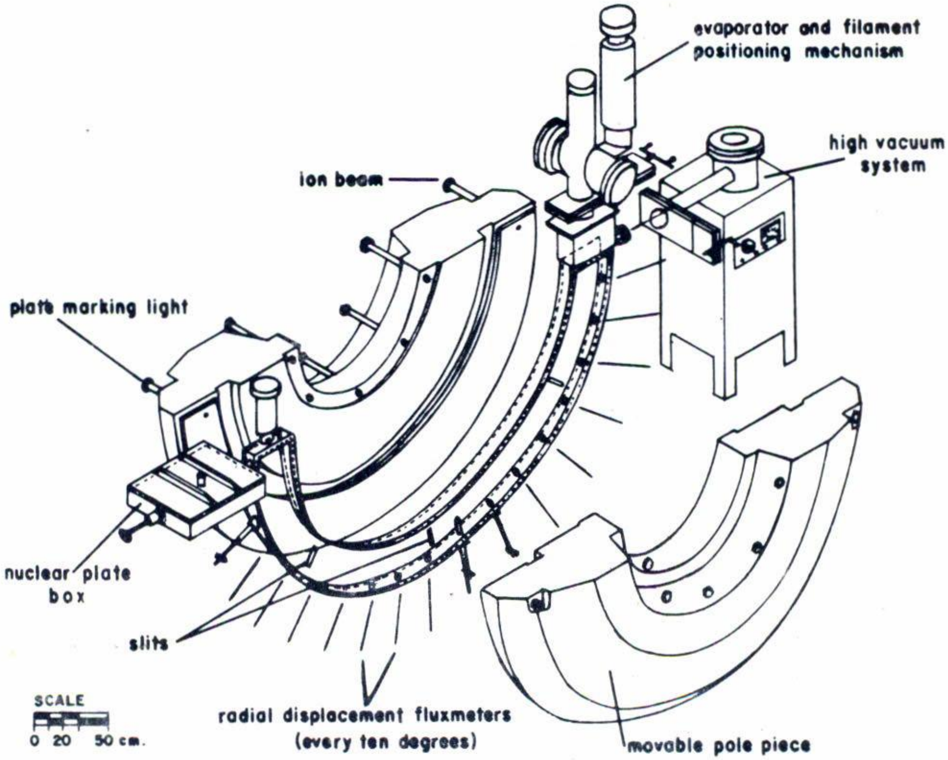

Fig. 1. Vacuum box with plate holder, filament positioning mechanism and radial displacement fluxmeters.

The vacuum chamber may be observed to have nuclear magnetic resonance fluxmeters every 10° whichmay be radially displaced without interfering with the vacuum. Thus the field may be mapped along the particle trajectories. The same figure shows the vacuum nuclear plate changer, for eight plates, as well as two bores, perpendicular to the pole faces; one for the particle beam, the other for the index marker that serves as reference for the radius of curvature determination. In addition, the vacuum system is pointed out, as well as the mechanism for introducing the radioactive sample without opening vacuum. Figures 2 and 3 show the optical bench for measuring distances, rigidly fixed to one of the pole pieces. The bench which is independent of the support, is used for levelingand aligning the spectrograph. For a more detailed description see references 1 and 2.

The slit that defines the solid angle in the trajectory radius direction of the field is at 135° and has an opening of 10 mm. At 45° there is an anti-scattering slit. All these slits are built of aluminum.

II. EXPERIMENTAL PROCEDURE

1.- Measuring Distance.

As mentioned earlier, the experiment requires measuring the distance (diameter) between the edge of the inside slit A (see figure 2), in front of the alpha particle emitter, and the index consisting of a cross of two fine hairs (B), used to mark the protographic plate, later, alpha particle track positions are measured with respect to this index. The distance is measured while there is vacuum in the spectrograph, that is, under the exact operating conditions, immediately before and after each exposure.

Two 99 cm Invar rods are used in the determination, Invar being chosen because of the ease in machining. These rods were calibrated against two standard quartz rods, whose lengths determined with an error of less than 0.001 mm by the Bureau International des Poids et Mesures, Pavillon de Breteuil, Sevres, France. Two rods were used instead of one because of ease in handling; the calibration of the Invar rods was undertaken one by one and also in pairs as they are placed on the optical bench, giving an error of 0.003 mm due to imperfect contact and alignment. Errors due to differences in temperature and contact pressure are negligible.

Figure 2 shows the two positions of the Taylor and Hobson telescope on the optical bench during the measurement. First it is made to coincide with the plate index marker and a reading is taken of its position with a

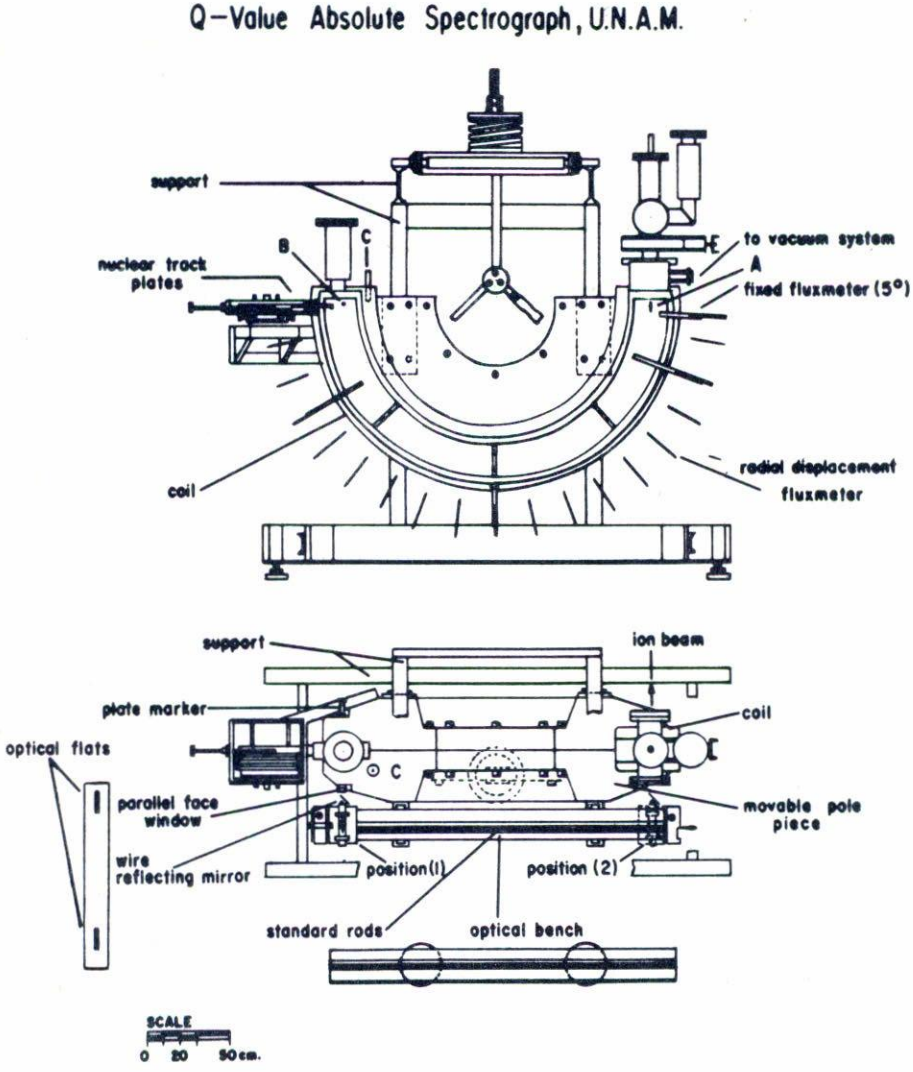

Fig. 2. Magnet Geometry.

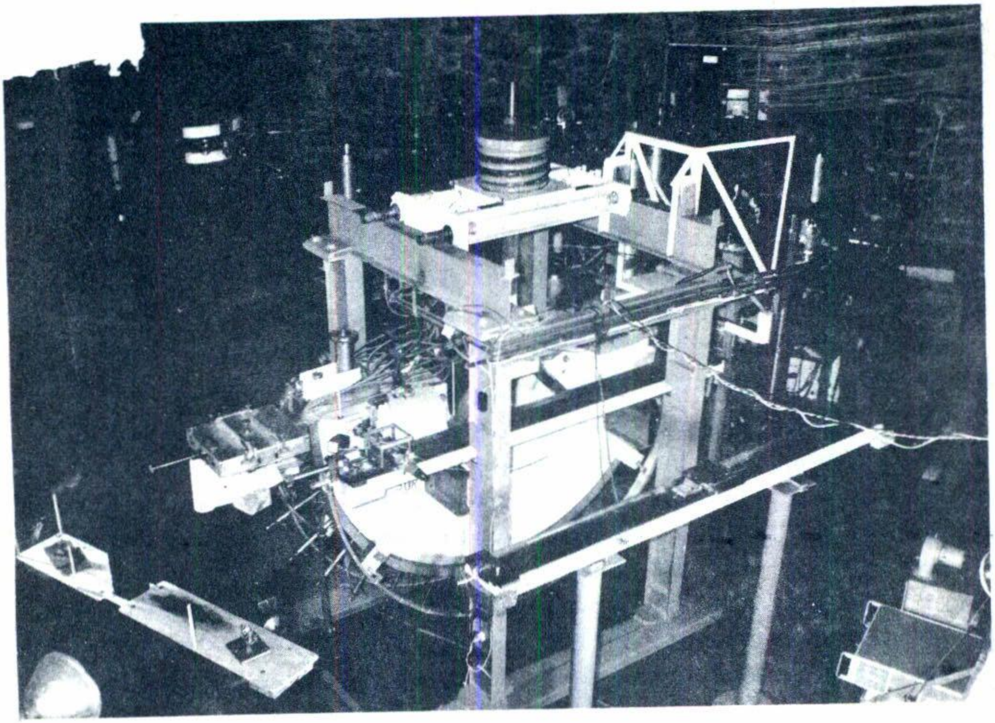

Fig. 3. Overall view of the equipment

micrometer on the bench. Next, it is moved to the source side to view the defining slit; the two Invar rods are placed between the micrometer and the telescope, and a new reading of the micrometer is taken. An error of ±0.010 mm is introduced due to the thickness of the telescope hair. After many measurements, it was noted that a one degree Centigrade change in the magnet temperature produced a separation between the two reference points of 0.024 mm, that is a linear thermal expansion coefficient of 12×10^{-6} per degree Centigrade, at room temperature. Several distance measurements are made just before and after each exposure, and in this time lapse, the temperature at point C changes less than 0.2° C, so that the correction for temperature variations is very small.

The following corrections for distance measurement are normally carried out:

a) The optical bench built in our shop was designed to be rigid, especially in the horizontal plane generated by the telescope axis as it changes positions. Machining difficulties, however, introduce a 20 second deviation from parallelism for the two positions of the telescope axis. Internal stresses and thermal variations in the optical bench also produce changes from one experiment to another of the order of 4 seconds. Therefore, these deviations must be measured before and after each run. The optical system used to determine the magnitude and direction of these deviations is shown in figure 2. A thin wire is fixed rigidly to the telescope, and its image is observed after reflection from an optically flat mirror. When the telescope is in position 1, the mirror is placed perpendicular to the telescope axis by aligning the wire, its image, and the telescope hair. Then the telescope is moved to position 2, where by viewing the image in the same mirror, the angle β is measured, and therefore the distance correction. Figure 4 shows the optics involved.

b) The reference slit and index marker are viewed through a glass window with optically flat and parallel faces. Because of construction, the windows are slightly inclined with respect to the viewing axis, so that a correction must be made. By observing with and without windows, the correction was found to be 0.010 mm.

The microscope used to scan the plates was adapted with a special plate holder, whose micrometer was calibrated against a a standard length, introducing a 0.010 mm error.

2. Measuring Magnetic Field.

The magnetic field is measured with proton magnetic resonance fluxmeters. As is shown in figures 1 and 5, the probes may be introduced to measure the field every 10° along the particle path. The field at each point is also measured just before and after each run. A fixed probe (at 5° and out of the particle path) helps to keep the field fixed during each mapping, and so its frequency will not interfere with those of the movable probes, the field at this point is deliberately slightly higher. During several hour runs, the field at any point is expected to vary differently from the 5° control position, this effect introducing an error mentioned in Table II as time dependent point - to - point variations. The Hartree correction is used to obtain the effective field.

The probes are at atmospheric pressure, the sensitive region within a copper tube,and this soldered to a stainless steel tube that provides the sliding vacuum seal for introduction into the field (see figure 5). Several materials were tested to find the one that least affected the measurements, and copper was therefore chosen to house the probe.

Castor oil was used in the probes; its diamagnetism was measured to differ from that of water by less than four parts per million. The probes

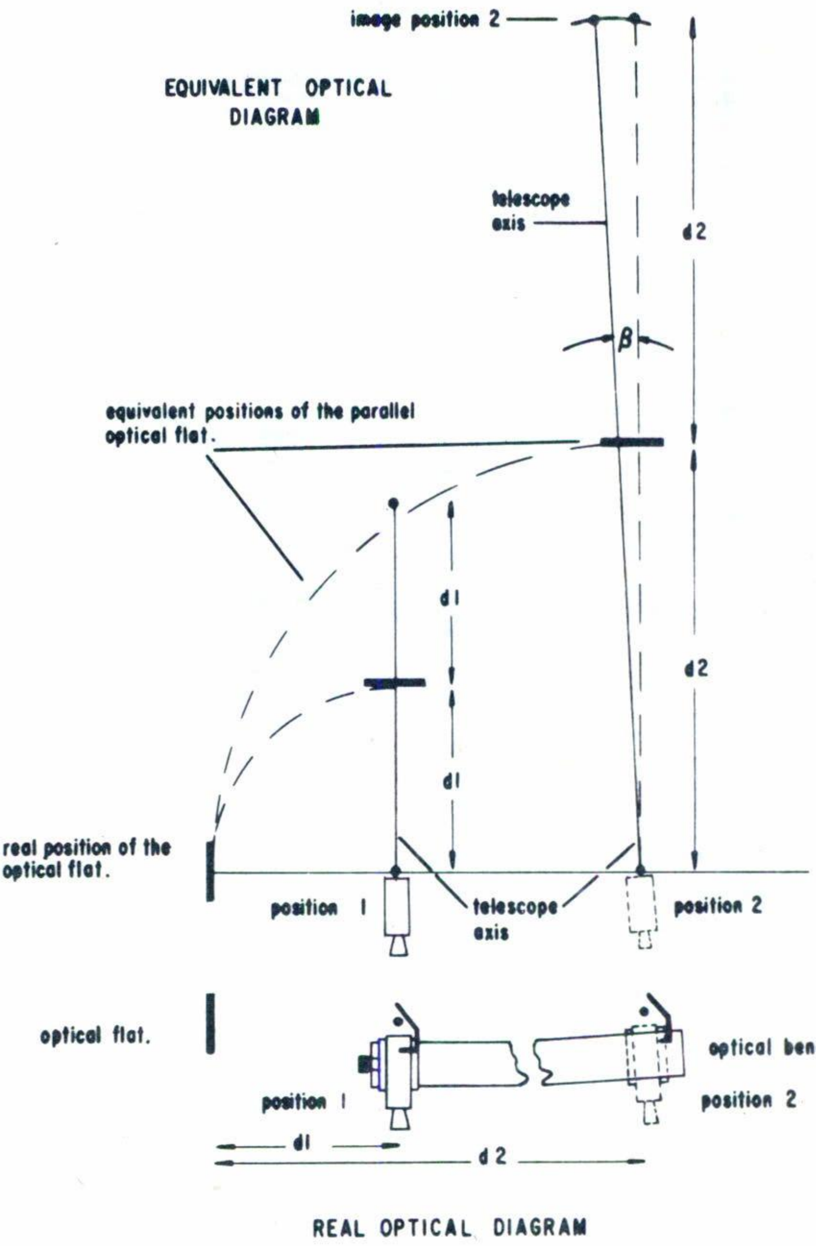

Fig. 4. Diagram of the optics involved in determining the bench deformation angle.

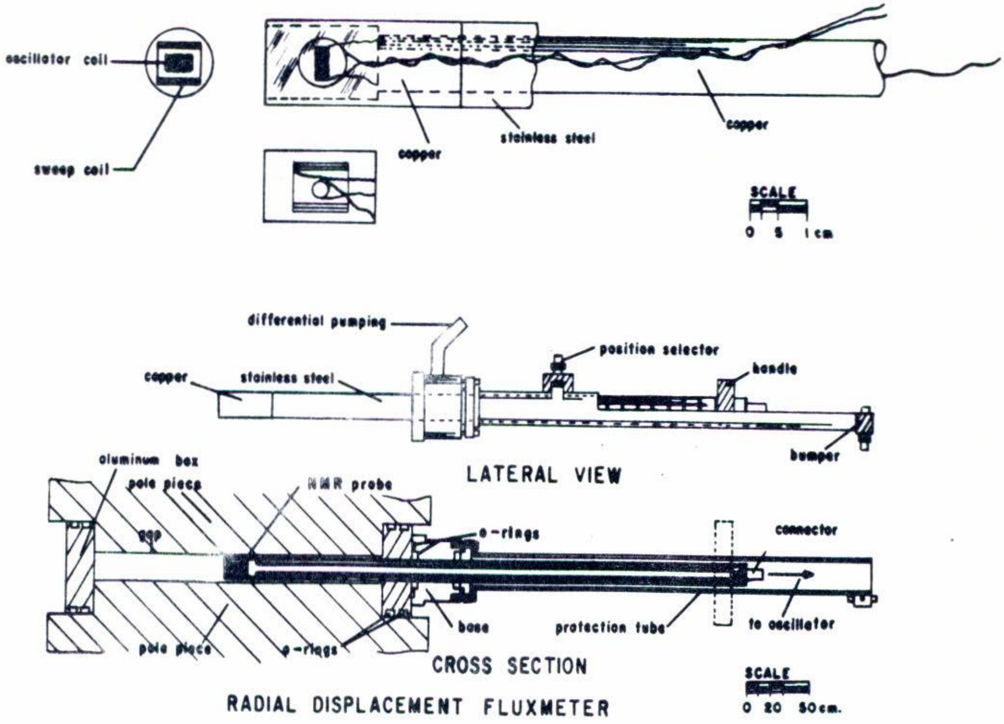

Fig. 5. Sliding seal N.M.R. fluxmeter probe showing detail of the sensitive area.

used cover a frequency interval of 5 to 45 ?&z, corresponding to magnetic fields between 1175 and 10570 Gauss.

The power supply control used is described in reference 3, to which a Varian V-3506 control was coupled, for correcting high frequency transients in the line, obtaining a regulation of one part in 200,000. In order to be sure of the stability, the magnet is turned on six hours before each experiment.

3. Preparing the Radioactive Source.

The ^{212}Po source was obtained in the following manner, starting from hydrated thorium-228 oxide, precipitated on hydrated iron oxide. This mixture is placed between two stainless steel filters, and nitrogen gass is passed through them; the nitrogen carries off the ^{220}Rn gas, leaving the ^{228}Th confined. The radon is collected electrically by a clean and polished platinum filament connected to a −300 volt supply. The filament is a small plate measuring 15 x 1.2 x 0.2 mm.

^{220}Rn decays until it reaches ^{212}Po. In this chain, the product with the longest half life is ^{212}Pb (10.6 hrs); therefore samples were activated during 20 hours and exposed for 10 hours.

4. Results and Error Estimates.

Figures 6a and 6b show the alpha particle distribution per 0.02 mm strip for one of the peaks, at the high energy side, on linear and $N^{2/3}$ scales respectively (see reference 4). A straight line was adjusted by least squares to the second case. The point where this line intersects the energy axis determines the maximum alpha particle energy. Results of the different runs are shown in Table I. The errors in each operation have been estimated and are shown in Table II. From the values in these tables the final energy is taken as 8784.85 ±0.31 keV. The constants used are:

γ_p = 26751.19 ± 0.08 rad $\cdot$ s^{-1} $\cdot$ Gauss^{-1} (reference 5)

F = 9648.682 ± 0.066 emu $\cdot$ Mole^{-1} (reference 5)

B = (Gauss) = (kHz)/4.257584

M_α = 4.0015058 ± 0.00000042 u (reference 6)

c = 2.997925 ± 0.000002 x 10^8 m $\cdot$ sec^{-1} (reference 7)

TABLE I

Results of the ^{212}Po alpha particle energy measurements

Run	Measured Energy keV
1	8784.63
2	8784.88
3	8785.08
4	8784.65
5	8784.99
Average Value	8784.85

TABLE II

ERROR ESTIMATES

	Estimate of standard errors
Distance measurement	.05 keV
Parallelism	.02 "
Energy curve fit	.05 "
Microscope	.07 "
Time dependent point - to - point variations	.25 "
Field reading	.10 "
Constants used	.12 "
Over-all standard deviation	.31 keV

Distribution of alpha particles at the high energy side of the peak

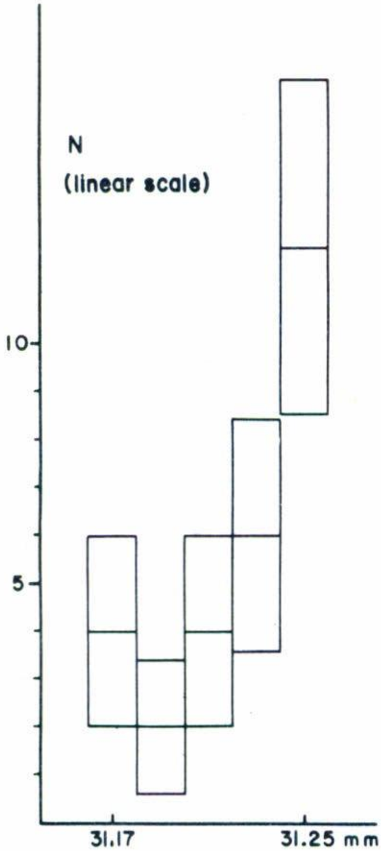

Fig. 6a

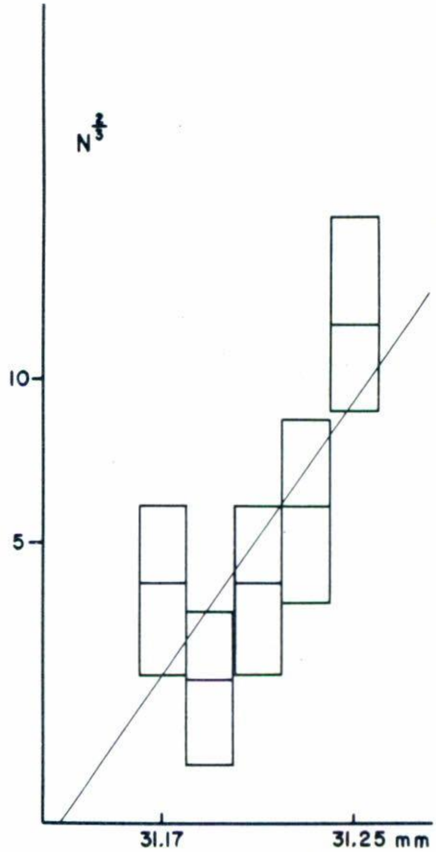

Fig. 6b

Figure 7 compares the present result with previous ones, see Rosenblum, Collins et al. and Rytz (references 8, 9 and 5 respectively).

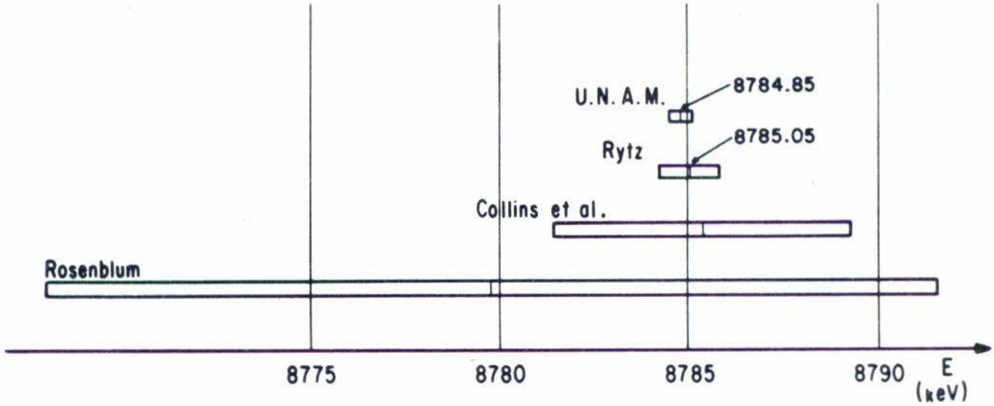

Fig. 7.

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RESUMEN

Empleando el espectrógrafo magnético absoluto de 180° y de un metro de radio, construido en los talleres del Instituto de Física, se ha medido la energía de las partículas alfa del ^{212}Po. Tal medida es absoluta, puesto que el experimento se reduce a medir una distancia y frecuencias que determinan el valor del campo magnético efectivo. Se describe un método óptico para medir las pequeñas deformaciones del banco óptico. El valor obtenido para la energía es 8784.85 ± 0.31 keV.