EXPERIMENTAL STUDY OF THE SCATTERING OF 7.4 – MEV ELECTRONS INTERSECTING A FOIL AT AN ANGLE OF 5º – 60º TO ITS SURFACE

A.V. Koltsov, A. V. Serov , LPI, Moscow, Russia
I. A. Mamonov, MEPhI, Moscow, Russia

Abstract

Angular distributions of electrons incident of a planar target at a small angle to its surface have been measured. Electrons have been injected from a microtron with a particle energy of 7.4 MeV. The dependence of the characteristics of beams on the initial energy and direction of injection of particles, as well as on the material and thickness of the target, has been considered. The intersection and reflection of electrons in the target have been investigated. The angle between the trajectory of the particles and the surface of the target was varied in the range of 5º - 60º. Aluminum, lead, and copper foils have been tested. The thickness of the foils was varied from 50 μm to 600 μm.

INTRODUCTION

The solution of some applied problems implies the knowledge of the characteristics of the scattering of particles incident on the surface at an angle much smaller than a right angle. One of such problems is the problem of the excitation of transition radiation by electrons intersecting a dihedral angle [1] or a conical surface [2]. The transition surface can be a thin layer of a certain material (Mylar, metal). In this case, the characteristics of radiation should depend not only on the initial parameters of the beam but also on a change in these parameters when intersecting the thin layer, i.e., on the material and thickness of the intersected surface, as well as on the direction of motion of particles. The smaller the angle between the direction of motion of particles and the surface, the stronger the effect of the properties of the transition surface on scattering. The motion of beams injected at a small angle to the surface was studied in [3]. The aim of this work is to analyse the effect of the direction of injection of particles on the parameters of the beam intersecting metallic foils with various thicknesses.

SETUP OF THE EXPERIMENT

The layout of the experiment is shown in Fig. 1. The z axis is taken along the trajectory of particles and the x axis lies in the horizontal plane. The charge e_d intersecting the target leaved it at the angle of refraction θ_d with respect to the initial direction of motion, whereas the charge e_r reflected by the target moved at the angle φ_r to the plane of the target. The point x_b in Fig. 1 is the point at which a straight line in the plane of the target intersects the plane of the detector. The coordinate x_b is determined by the distance *L* from the target to the detector and the angle of injection α. According to the geometry of the experiment, the coordinates of particles e_d intersecting the target on the plane of the detector satisfy the condition $x > x_b$ and the coordinates of reflected particles e_r satisfy the condition $x < x_b$.

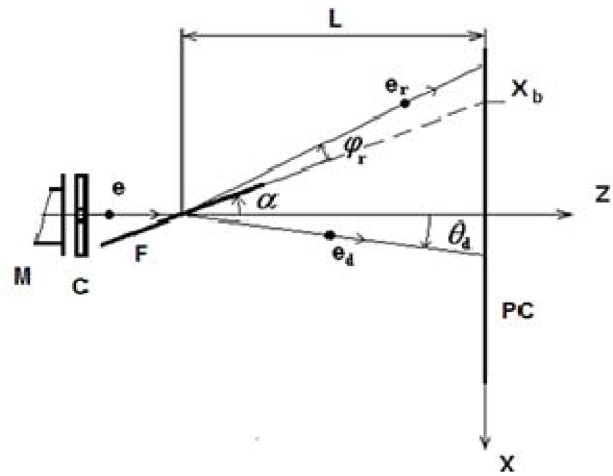

Figure 1: Geometry of the experiment.

In the experiments, it is used 7.4 MeV electron bunches from the microtron. Electrons were extracted to the atmosphere through a 100 μm aluminum foil on the flange of microtron M. Lead collimator C and foil F were placed behind the flange. The 50 mm thick collimator had a hole with a diameter of 3 mm. The foil was rotated with respect to the vertical (y) axis by the angle α. The distribution of electrons was measured by multiwire proportional chamber PC consisting of three 64 × 64 mm frames. The chamber allowed measurements of the distributions of particles in the horizontal (x) and vertical (y) directions. The chamber was located at a distance of L ~ 150 - 300 mm from the point of intersection of the foil by the beam. A signal from the proportional chamber was fed to an oscilloscope. Charged particles passing through the layer of the substance undergo numerous collisions; consequently, the spatial distributions of passed and reflected particles are approximated well by a Gaussian distribution. The direction at which the distribution has a maximum was taken as the motion direction of refracted and reflected beams of particles.

EXPERIMENTAL RESULTS

The typical oscillograms of the signals of the chamber are shown in Fig. 2. The first and second pulses of the oscillograms describe the horizontal and vertical distributions of particles, respectively. Figure 2 shows the distributions for the cases where (a) copper foil with a

ISBN 978-3-95450-170-0

thickness of $\delta = 50$ μm is placed behind the collimator at the angle of $\alpha = 90$ ° to the *z* axis and (b) the same with the $\alpha = 10$ °. The comparison of the figures shows that the intersection of the foil in case $\alpha = 10°$ leads to split of the beam to refracted and reflected ones and to the shift of the maximum of the horizontal distribution (Δx_d and Δx_r in Fig. 2b). This indicates that the intersection of the foil changes the direction of motion of a particles bunch relatively to the initial direction. The trajectory of the refracted beam deviates by an angle of $\theta_d = \mathrm{arctg}(\Delta x_d/L)$. The angle φ_r of reflected beam is $\varphi_r = \mathrm{arctg}(\Delta x_r / L) - \alpha$. The position of the maximum of the vertical distribution hardly changes. Therefore, the refraction of the trajectory occurs only in the horizontal plane.

The measurements were performed with a copper, aluminum and lead foils with a thickness from $\delta = 40$ μm to 600 μm. The angle α between the trajectory of injected particles and the surface of the foil varied in the experiments from 5° to 60°.

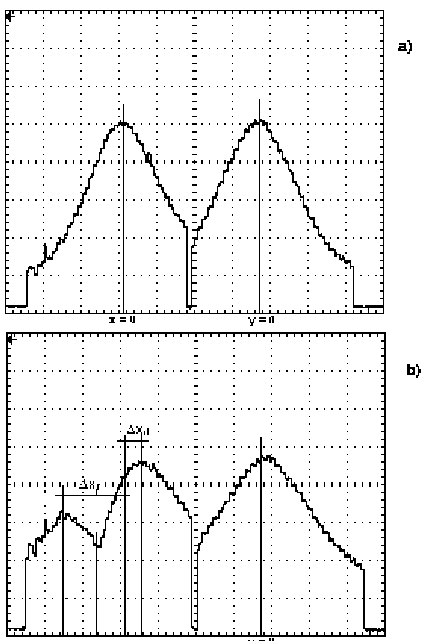

Figure 2: Transverse distributions of electrons intersecting a 50 μm cooper foil at an angle of $\alpha = 90°$ (a), 10° (b) to its surface. L = 100 mm.

The experiment results make it possible to plot the dependence of the angle refraction θ_d at a given angle of injection α. (Fig. 3). The measurement results for the copper foil with a thickness of $\delta = 50$ μm, for the aluminum foil with a thickness of $\delta = 600$ μm and the lead foil with a thickness of $\delta = 70$ μm are shown by squares, triangle and circles respectively. It can be seen that the angle refraction θ increases with a decrease in α.

There have been investigated dependences $\theta_d(\alpha)$ for different thicknesses of copper foil. These dependences are shown in the Fig.4. Increase of thickness of the target leads to increase of refraction angle θ_d. Moreover changes of thickness of the target influence the behaviour of curve $\theta_d(\alpha)$.

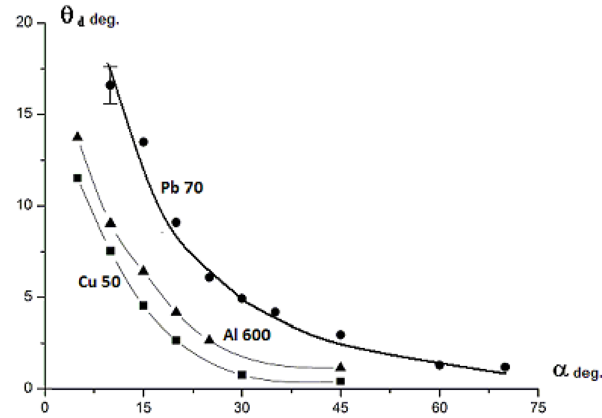

Figure 3: Angle of refraction of the trajectory θ_d versus the angle of injection α. 50 μm copper, 600 μm aluminum and 70 μm lead foils. Notes for curves indicate the foils materials and their thicknesses in microns.

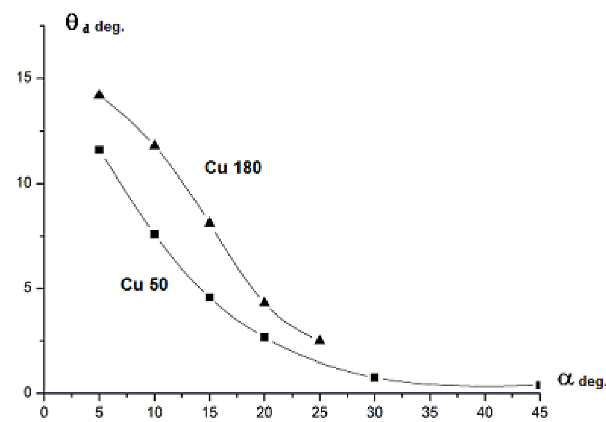

Figure 4: Angle of refraction of the trajectory θ_d versus the angle of injection α. 50 μm and 180 μm copper foils. Notes for curves indicate the foils materials and their hicknesses in microns.
t

It has been also analyzed the effect of the angle of injection on the direction of motion of reflected electrons. The results of the corresponding measurements are shown n Fig. 5. It can be seen that the direction of motion of reflected particles changes slightly in certain angular ranges ($\alpha \sim 12° -- 17°$).

Notice that for small foil thickness δ reflected angle φ_r is less than the injection angle α. Increase of thickness of the target leads to increase of reflected angle.

Figure 6 shows dependences of the angle of reflection of the beam φ_r on the thickness of the intersected foil δ at angle of injection $\alpha = 10°$. It can be seen that for $\delta < 300$ μm the reflection of the trajectory of the beam increases with the thickness of the target. For $\delta > 300$ μm the reflection of the trajectory of the beam changes slightly.

ISBN 978-3-95450-170-0

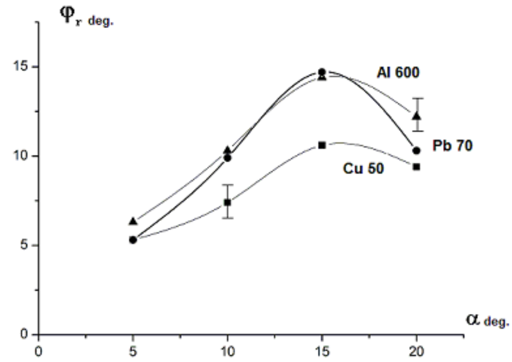

Figure 5: Angle of reflection of the trajectory φ_r versus the angle of injection α. 50 μm copper, 600 μm aluminum and 70 μm lead foils. Notes for curves indicate the foils materials and their thicknesses in microns.

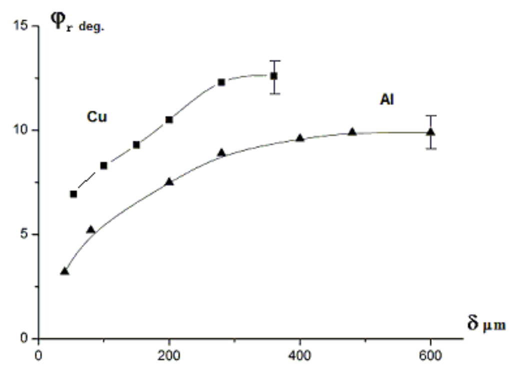

Figure 6: Angle of reflection of the trajectory φ_r versus the foil thickness δ. $\alpha = 10°$. Copper and aluminum foils.

The experimental data indicate that the intensity and direction of motion of the refracted and reflected beams can be changed by modulating the thickness of the target or the angle at which the plane of the target is intersected.

REFERENCES

[1] A. V. Serov, JETP. **108** (4), 593 (2009).
[2] A. V. Koltsov, A. V. Serov, JETP. **116,** (5), 732 (2013).
[3] A. V. Koltsov, A. V. Serov, JETP Lett. **99** (1), 1 (2014).

ISBN 978-3-95450-170-0