ANGULAR DEPENDENCE OF THE LIGHT BARE ION ENERGY LOSS IN THIN GOLD FOIL

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This work is carring out in the frames of collaboration of the two laboratories: lab, of the ion interaction with matter., Institute of nuclear physics, Moscow state university and nuclear solid state physics lab., Material science center, University Groningen (Netherlands). The aim of this investigations is to check the correlation between the high order corrections to the Z_1^2 dependence of the energy loss (Barkas and Bloch efects) and the impact parameter of the ion-atom collision. The setting up of the experiment and some preliminary results are discussed here.

As it is known [1,2] the physical reason of the correction existance is the shift of the matter electron in the process of the collision with a swift charged particle that is the second order effect in comparing with the energy transfer to the rest electron. The information about the magnitudes of the higher order corrections in close and distant collisions as so as in collisions with core and valent electrons is important for the stopping theory. The knowlege of the dependence of the higher order corrections on the impact parameter in the ion-atom collision would clarify these questions. It has been revealed recentely by V.A.Khodyrev [1] and N.M.Kabachnik [2] that the magnitudes of the Z_1^3 and Z_1^4 corrections as soon as their contributions to the stopping functions increas with the impact parameter decreasing. It is interesting that the Barkas correction has different sign for the core and valent electrons.

The Z_1^3 and Z_1^4 corrections in close and distant collisions have been investigated in the channeling experiments . It is known also that the impact parameter dependence of the energy loss is responsible for the angular dependence of the energy loss (ADEL) in the scattering experiments with thin amorphous foils [3,4] and gases [5]. It would be useful to check the correlation between the higher order corrections to the Z_1^2 scaling of the stopping power and the impact parameter on the basis of the ADEL experiment.

The experiment was carried out with beams of H^+, D^+, He^{++}, Li^{2+} and Li^{3+} ions at the initial energies E_0 = 0,5 and 1 MeV/amu. The selfsupporting polycrystalline gold foils of the 200Å thickness were used as the targets. The thickness nonuniformity was about ±10% that has been evaluated from the measurement of the energy spread of the scattered particles. The preparation and test procedures of the foils were described previousely [4]. The targets were mounted on the grids with the cell size 0,5 mm, the beam diameter was 0,2 mm. The measurements were performed in the Van-der-Graaf Laboratory of the University Utrecht (Netherlands). The accelerator was the Tandemgenerator with maximum voltage 6,5 MeV and energy spread about 10^{-3}. The analysis of the scattered particle flow was performed with the magnetic spectrograph which enables ones to obtain the twodimension (energy-angle) distribution simultaneousely in one set (fig.1,2) The ranges of arguments of the measured in the such a manner distribution function were $10\%E_0$ and ±2,5 degrees with respect to the energy and the scattering angle. The resolutions were equal to 10^{-3} and 0,1 degree respectively. This device is composed of the quadrupole lens. Win filtre, dipole 90-degree magnet and the position sensitive detector based on the chevron assemble of the 3 microchannel plates. Vacuum in the system was 10^{-8} torr, beam current was equal tou fraction of picoampere.

The projection of the two-dimensional distribution is presented at the flg.3 as an example. Here the absciss and ordinate are the energy and angle respectively, the scales are concerned with the above mentioned ranges. The points at this map correspond to the individual events, the contoure lines are concerned with the logarithmic scale of intensity with the step of *e* times. The horizontal tale corresponds to the relatively rare events of the extremely high energy loss at the small scattering angles. The vertical cross sections of the three-dimensional graph of the measured distribution depict the angular distributions and the energy spectra of the scattered particles. Fig.4 presents the example of the proton spectra. Solid and dashed lines correspond to the incident beam and the scattered particles at the angles 0 and 0,5 degree. The peak displacement to the higher energy loss for the large angle scattering is visible at this graph. The ADEL function for 1 MeV protons is presented at the top picture of the fig.4. The mean values of the respective peaks in energy spectra were used for the energy loss $\Delta E(\Theta)$ obtaining. Dashed and black solid lines exhibit the experimental values, their spread is depicted by the unsmoothness of the curves. The grey line depicts the ADEL function that was calculated with the Monte-Karlo method of trajectory simulation for the somewhat different conditions. The used in this calculation impact parameter dependece of the energy loss $\Delta E(b)$ has been odtained in semiclassical approximation with quasiclassical wave functions of the high excited atomic states [6]. The same function but multiplicated by Z_1^2 was used for the Monte-Karlo simulation in the cases of He^{++} and Li^{3+} ions (fig.5). Some difference in the agreement between the experimental and theoretical ADEL functions for the different ions would give the indication on the violation of the Zi_1^2 scaling in the $\Delta E(b)$ dependence.

The relative behaviour of the experimental and theoretical ADEL functions displays the considerable difference at the energies which are distinguished by 2 times that is visible at the example of the He ions (flg.6).

Probably, the explanation of this result should be found in the theoretical underestimation of the atomic inner shell contribution to the stopping power at the small impact parameters which correspond to the large scattering angles.

The experiment and calculations are continued now and more reliable conclusions may be done in the near future.

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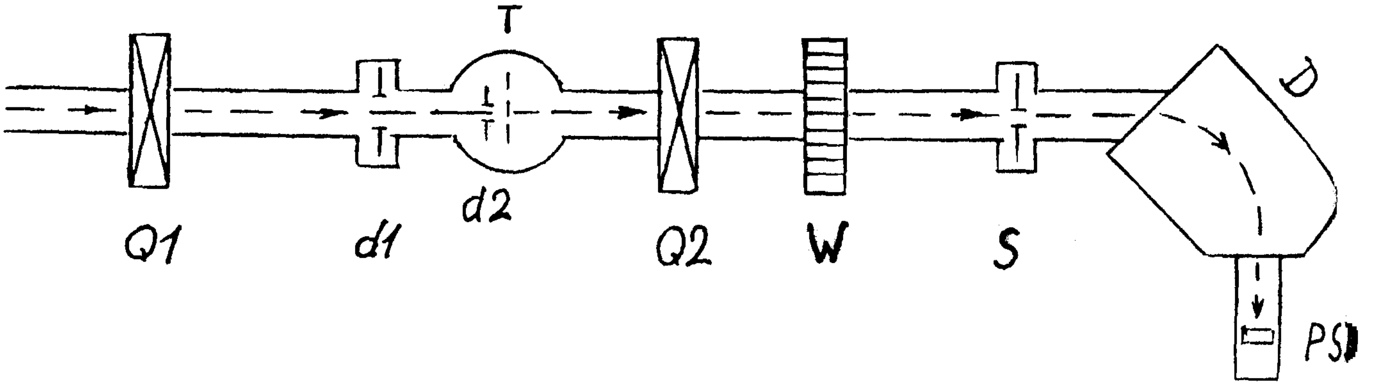


Fig.1.

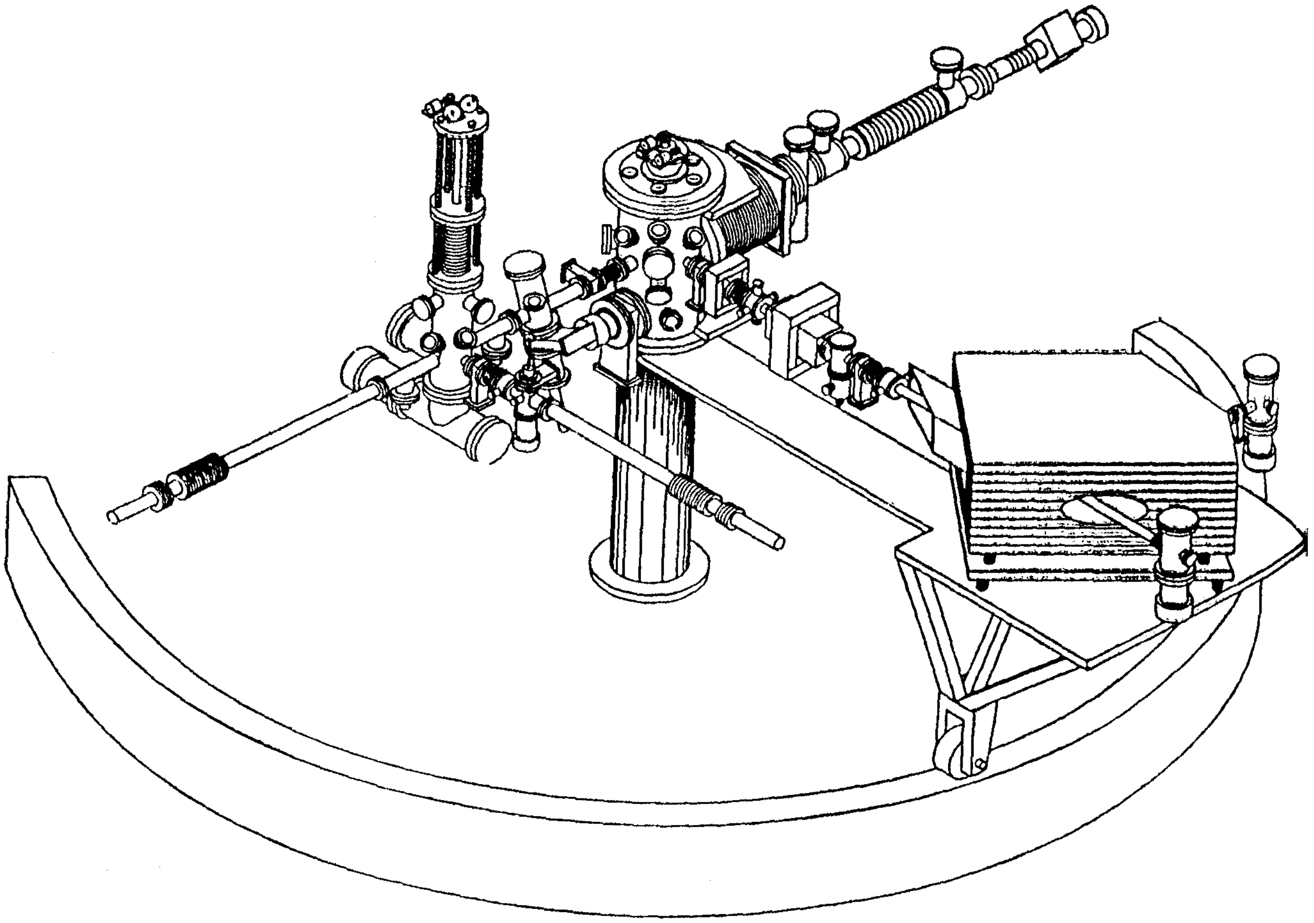


Fig.2.

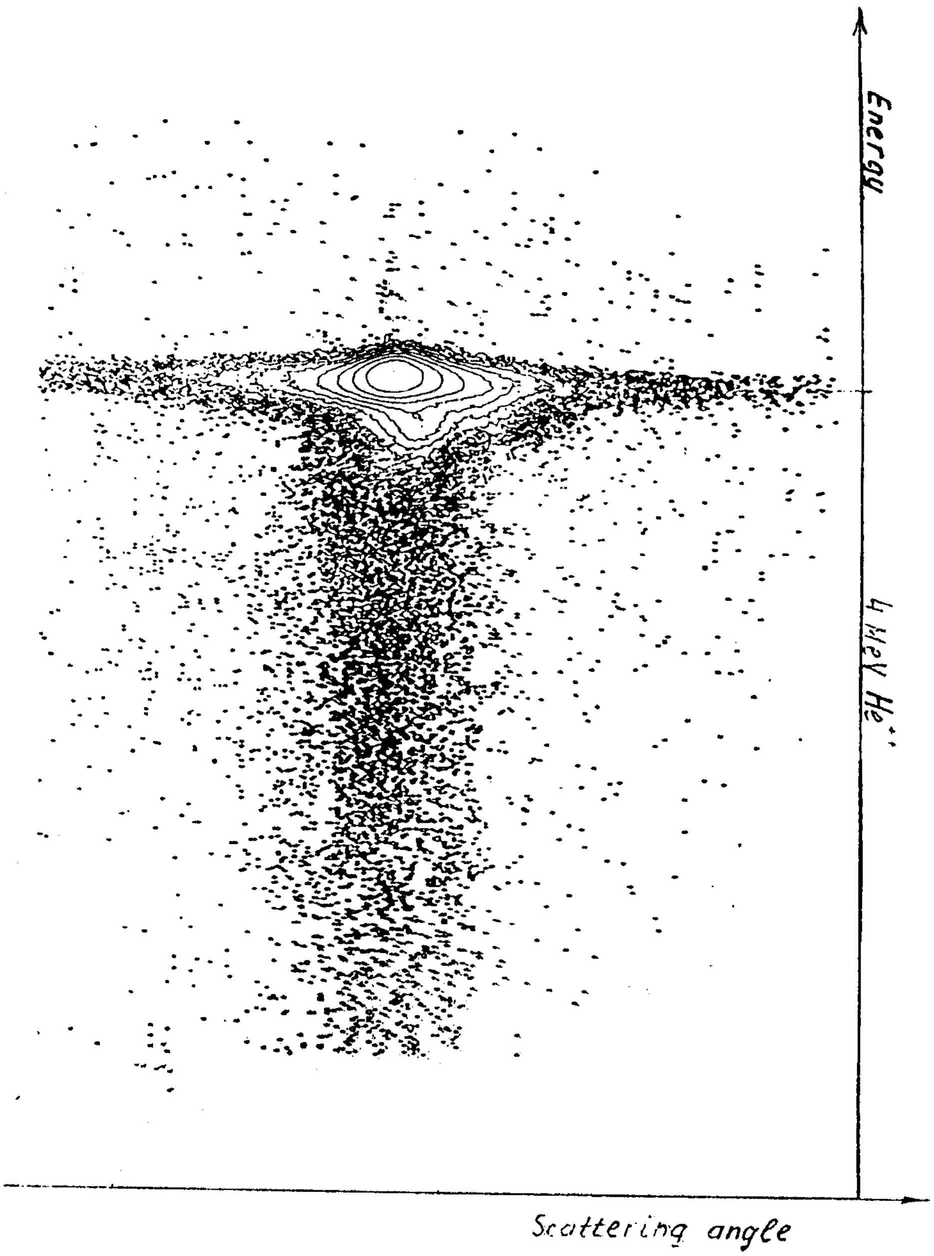


Fig.3.

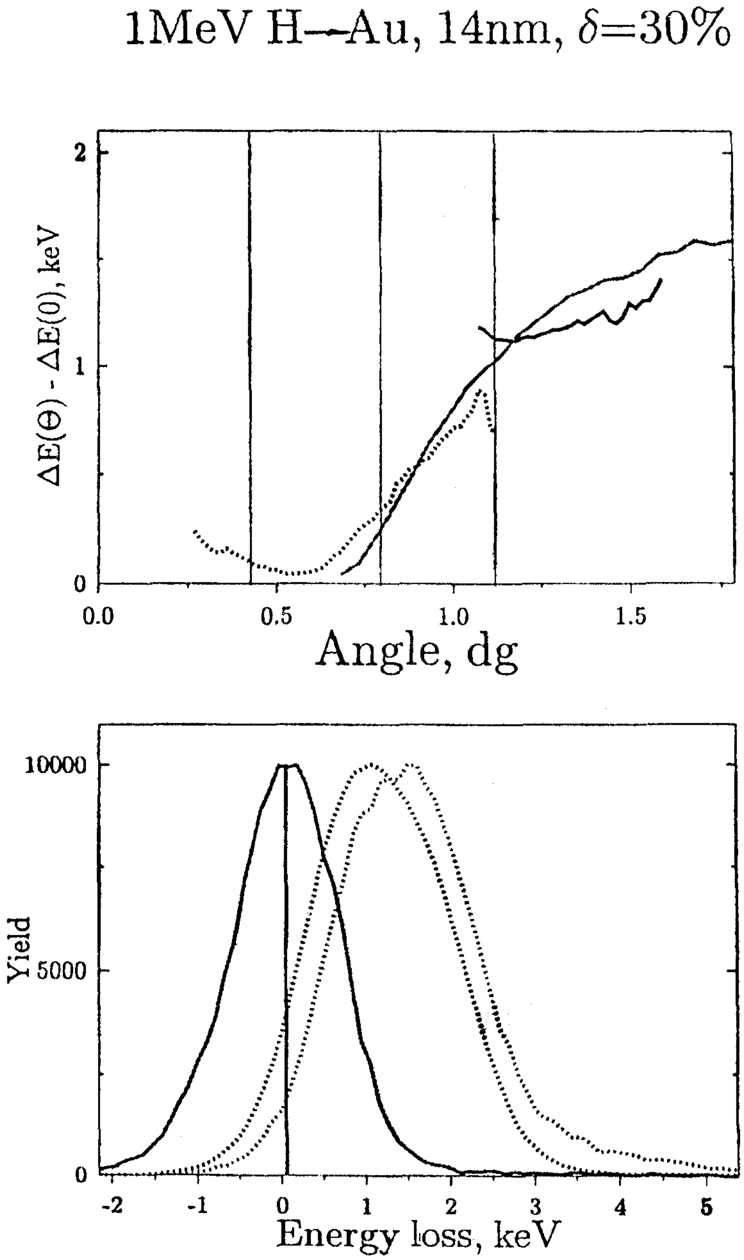
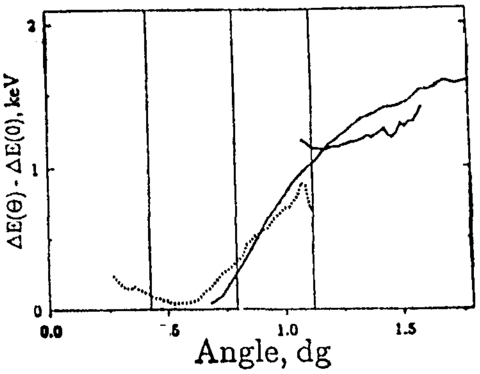
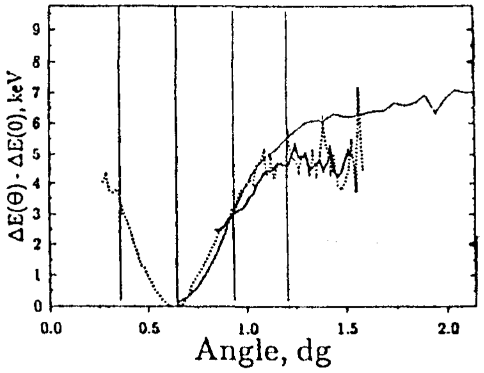

1MeV H→Au, 14nm, δ=30%
ΔE(Θ) - ΔE(0), keV
0
1
2
0.0
0.5
1.0
1.5
Angle, dg
Yield
0
5000
10000
-2
-1
0
1
2
3
4
5
Energy loss, keV

Fig.4.

1MeV H—Au, 14nm, δ=30%



4MeV He—Au, 14nm, δ=30%



7MeV Li—Au 14nm, δ=30%

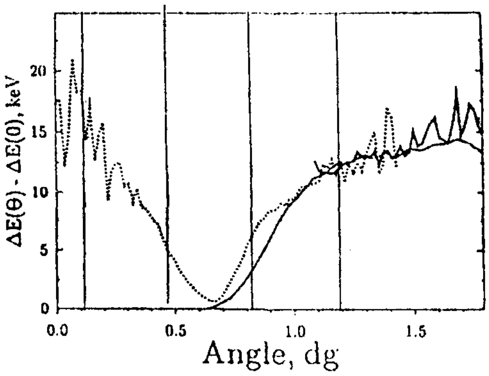
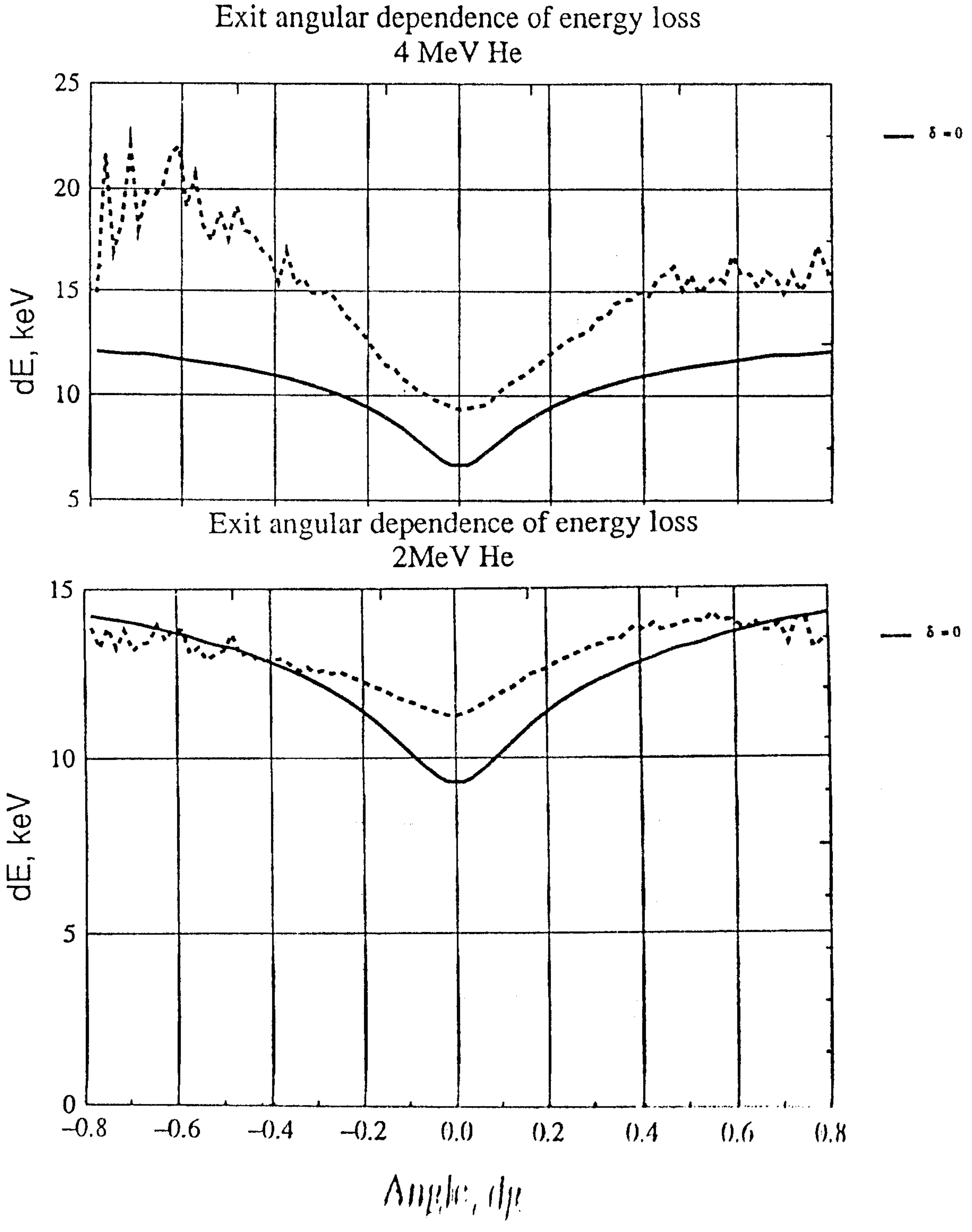


Fig.5.



Exit angular dependence of energy loss
4 MeV He

Exit angular dependence of energy loss
2MeV He

Fig.6.