Systematical Analysis on Angular Distribution of Bremsstrahlung Radiation in Microtron MT-22

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Abstract: The systematic analysis has been made the measurement results of the relative angular distribution of gamma quantium with 11-22 MeV energy which is induced by bremsstrahlung within $2-3\ g/cm^2$ optimal geometrical region of target nucleus. We are shown that relative intensity distribution of gamma radiation with energy 11-22 MeV, induced by stopped electrons with various thicknesses at heavy and lighter target nucleus as an exponential form within angular region 0^o-14°.

Key words: optimal geometry of target nucleus, giant resonance region
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INTRODUCTION

Electron accelerator Microtron MT-22 at Nuclear Research Center was began to be used in its full capacity since the end of 1990. Research using gamma channel of bremsstrahlung radiation with energy 22 MeV became the new direction for Mongolian specialists.

In other hands, research work on spatial distribution of gamma radiation induced from the various targets is rare. Because of electron cyclic accelerator Microtron MT-22 is not widespread in the world.

Hence there is a need to develop systematic analysis of optimal geometrical region within $2-3\ g/cm^2$ based on the experimental measurement results [1, 2] of gamma distribution with 11-22 MeV energy induced from Ti, Cu, Mo, Ta, W targets which is commonly used in practices.

As a result of the research, the matter on selection of irradiation optimal geometry at gamma channel in Microtron MT-22 depending on charge number and thickness of target nucleus will be resolved.

SELECTION OF REACTION AND BOUNDARY CONDITION

Electron cycle accelerator is called Microtron. Electron accelerator Microtron is generally divided into two types - MT-17 and MT-22. The numbers, 17 and 22 are the maximum value of electron energy from the accelerator. Microtron MT-22 accelerates electrons up to 22MeV energy.

The maximum energy of bremsstrahlung radiation is defined by the energy of incident electron.

When Z atomic number of target nucleus in where accelerated electrons incident increases, cross section of bremsstrahlung radiation increases. Therefore atomic numbers of target nucleus have to be selected properly in order to increase intensity of bremsstrahlung radiation. In other hands, radiation intensity and angular distribution of induced bremsstrahlung radiation depend much on charge number and thickness of nucleus. The optimal thickness of target nucleus is determined as $2-3\ g/cm^2$ [4]. It is clear that the determined region is different in centimeter units depending on the density of element.

Electrons accelerate up to 22 MeV energy in Mictrotron MT-22 and its spectrum of bremsstrahlung radiation is corresponded to 0-22 MeV energy [3].

Nuclear reactions interact with gamma quantum are termed threshold reaction and as well as interaction of Giant resonance is induced for all nuclei in energy region 13-20 MeV. Therefore, study on systematic analysis of distribution of bremsstrahlung radiation with energy corresponding to Giant resonance region within optimal geometry of target nucleus, is important to select the geometry of sample for the further research.

We have fitted data on measurement of intensity of gamma radiation induced from electron in targets Ti, Cu, Mo, Ta, W, commonly used in Microtron MT-22, with various thicknesses using by photo-nuclear reaction $^{63}Cu(\gamma,n)^{62}Cu$ [1]. Angular distribution of radiation corresponds to the energy region 11÷22 MeV because of the threshold energy of reaction 11 MeV. Obviously, our selected nuclear reaction fully provides the above mentioned condition.

SYSTEMATIC ANALYSIS ON ANGULAR DISTRIBUTION OF BREMSSTRAHLUNG RADIATION

In Figures 1-5 presents that relative intensity distribution of gamma radiation with energy 11-22 MeV, induced by stopped electrons with various thicknesses, we have taken by $^{63}Cu(\gamma,n)$ reaction, on the basis of detection for 1174 keV energy gamma quantum within the angular region 0÷14, produced from $^{62}Cu(T_{1/2}=9.7\ min)$

From the graphs, the angular distribution and correlation coefficient, we can express the relative angular distribution of bremsstrahlung radiation as an exponential form for the any target.

$$I(\alpha, t) = e^{(-\alpha/\alpha(t,z))} \quad (1)$$

Where: $\alpha(t,Z)$ –output average angle
t – Target thickness,
Z - Charge numbers of target.

Average output angle is:

$$\overline{\alpha} = \frac{\int \alpha \cdot e^{-\frac{\alpha}{\alpha(t,Z)}} d\alpha}{\int e^{-\frac{\alpha}{\alpha(t,Z)}} d\alpha} = \alpha(t,Z)$$

$$\Rightarrow \ I(\alpha, t) = e^{-\frac{\alpha}{\overline{\alpha}}}$$

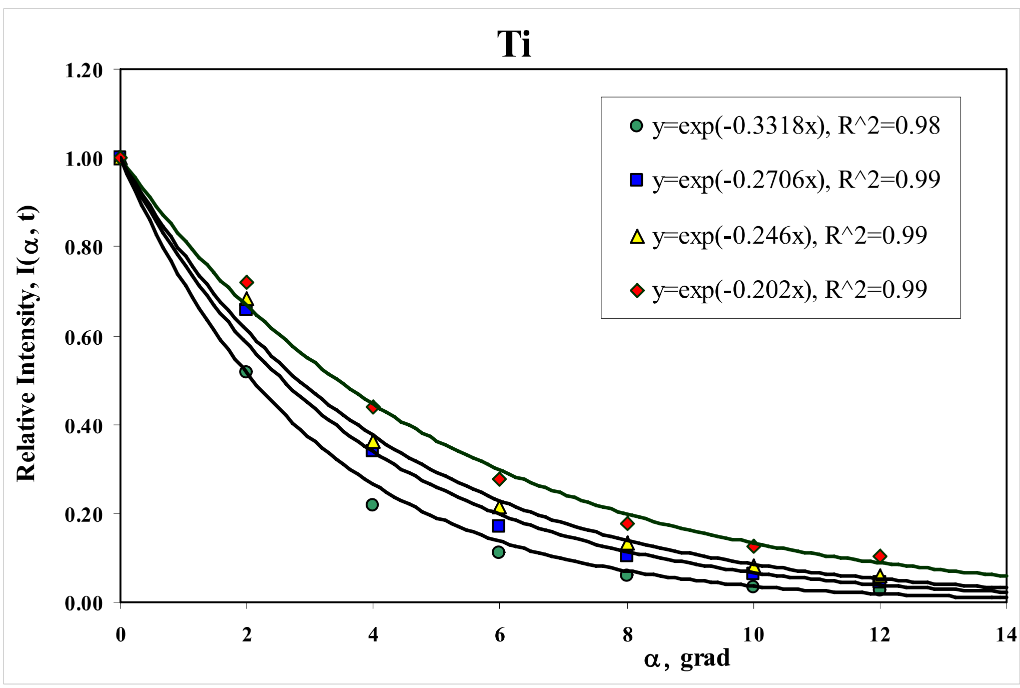
Dependence of $\overline{\alpha}$ width at half height of relative distribution and output average angle $\alpha(t,Z)$ is:

$$\alpha(t,Z) = \frac{\alpha_{ave}}{Ln\,2}$$

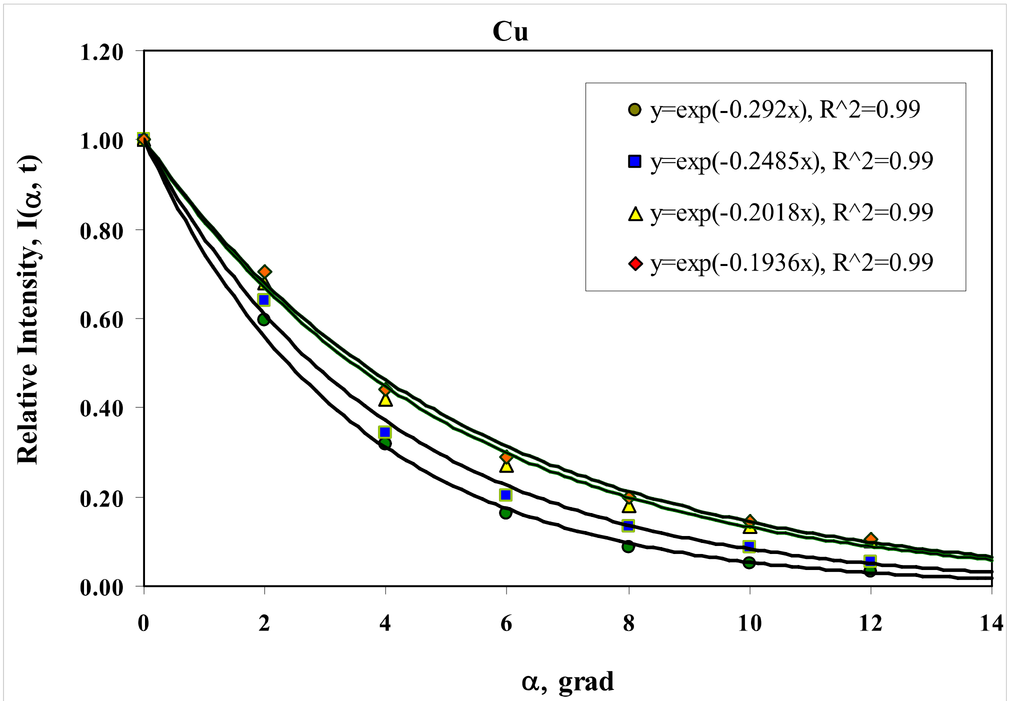
Hence Eq.1 will be the following form.

$$I(\overline{\alpha},t) = e^{-\left(\frac{Ln2}{\overline{\alpha}}\right)\alpha} \quad \textbf{(2)}$$

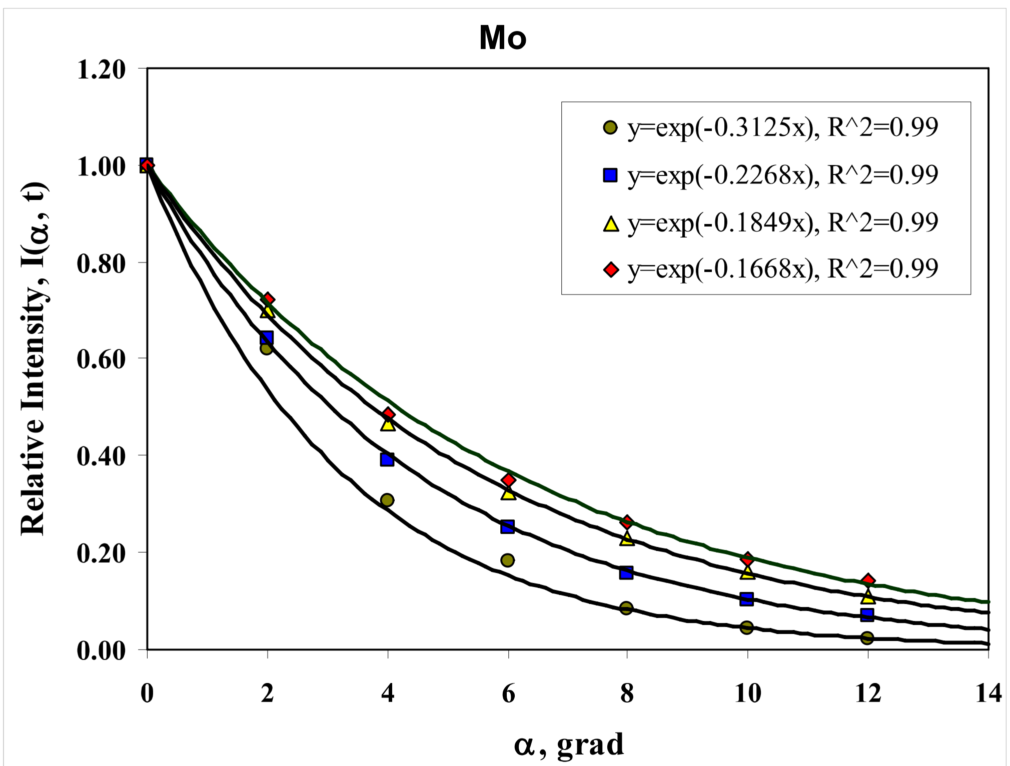
Where: $\overline{\alpha}$ - width at half height of angular distribution $I(\alpha,t)$ and it depends on electron energy, thickness of target and charge number.



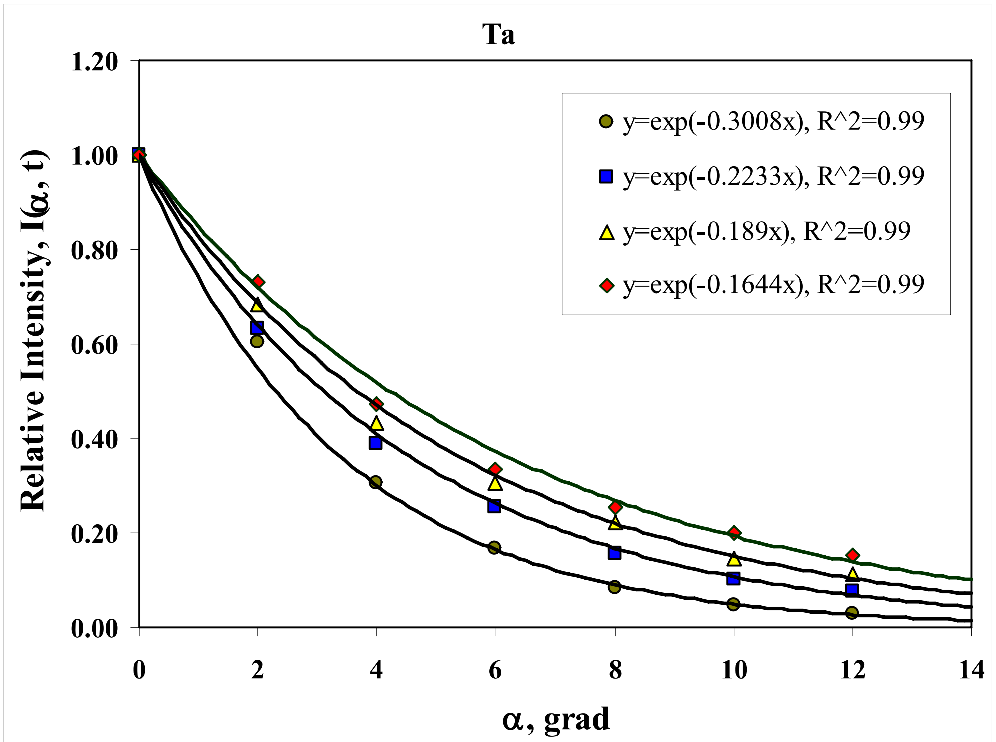
Graph.1. *Angular distribution of bremsstrahlung radiation for Ti target with various thicknesses*



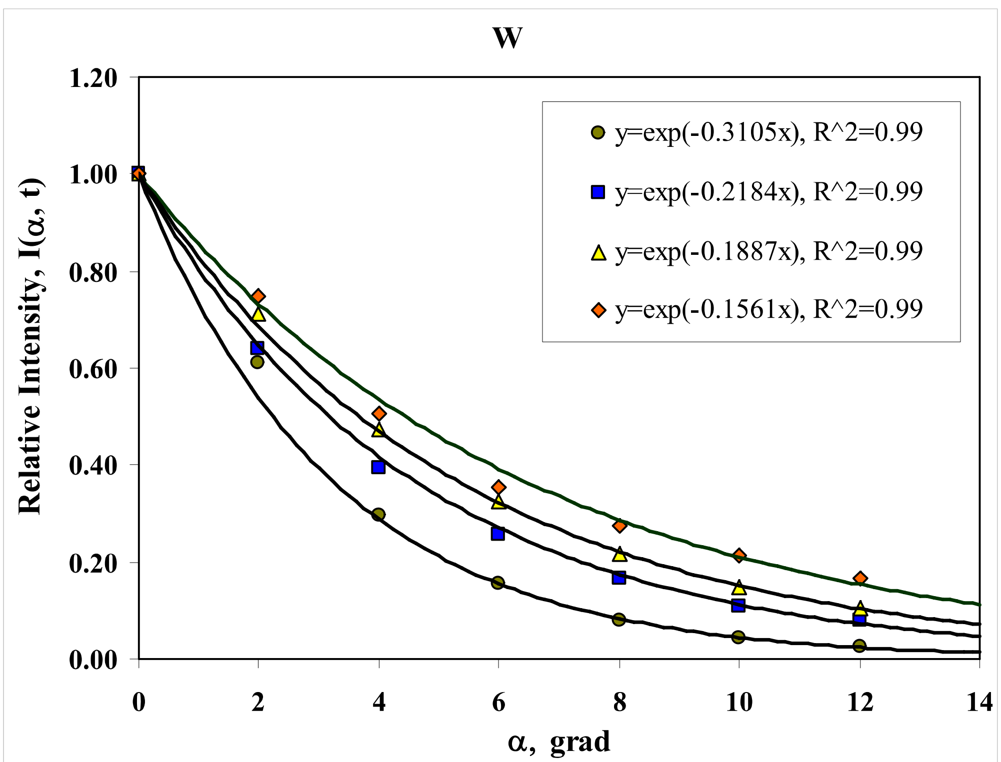
Graph.2. *Angular distribution of bremsstrahlung radiation for Cu target with various thicknesses*



Graph.3. *Angular distribution of bremsstrahlung radiation for Mo target with various thicknesses*



Graph.4. *Angular distribution of bremsstrahlung radiation for Ta target with various thicknesses*



Graph.5. *Angular distribution of bremsstrahlung radiation for W target with various thicknesses*

DEPENDENCE OF THICKNESS α_{ave} AND CHARGE NUMBER OF THICK TARGET

As a previous mentioned, in table 1 shown that optimal thickness t_{op} and covered region in research is corresponded to the most optimal thickness $2-3$ g/cm^2 of the target nucleus.

***Table 1**. Optimal thickness of target nucleus and thickness region used for calculation*

No	Target nuclei	Optimum thickness region of target nuclei t_{op}, cm	Thickness region t, cm	$1/t$, cm^{-1}
1	Ti	0.44 - 0.67	0.11 - 3.90	0.25 - 9.10
2	Cu	0.22 - 0.33	0.10 - 1.97	0.50 - 10.0
3	Mo	0.20 - 0.30	0.09 - 1.20	0.83 - 11.10
4	Ta	0.12 - 0.18	0.03 - 0.70	1.42 - 33.33
5	W	0.10 - 0.16	0.03 - 0.70	1.42 - 33.33

From table 1 we can see that the optimal thicknesses (t_{op}) were fully covered in selected thickness region (t) for the target nucleus.

However, in Figure 1, 2 shown that the results of dependence of width (α_{ave}) on thickness (t) in the above selected regions.
From following figures we can see that width at half height α_{ave} relative intensity of bremsstrahlung radiation for angular distribution in our geometrical region is expressed by linear form.

Obviously,

$$\alpha_{ave} = \alpha_0 + A(z)\left[1 - B(z)/t\right], \quad grad \qquad \textbf{(3)}$$

Where: $\alpha_0 = 57.28\, m_0c^2 / E$;
$m_0c^2 = 0.511\, MeV$;
E – electron energy, MeV;
t – target thickness;
$A(z)$, $B(z)$ –parameters depending on charge number of target nucleus.

However, in case of $t = B(z)$, this value is the begining region for the thickness of the target nucleus could understand as infinite thin form. Because in this case $\alpha_{ave} = \alpha_0$ and the width at half height will only depend on initial energy of incident electron on target.

In Figures 3 and 4 are shown that dependence between $A(z)$, $B(z)$ parameters and charge number of nucleus based on linear form as in Fig.1 and 2.

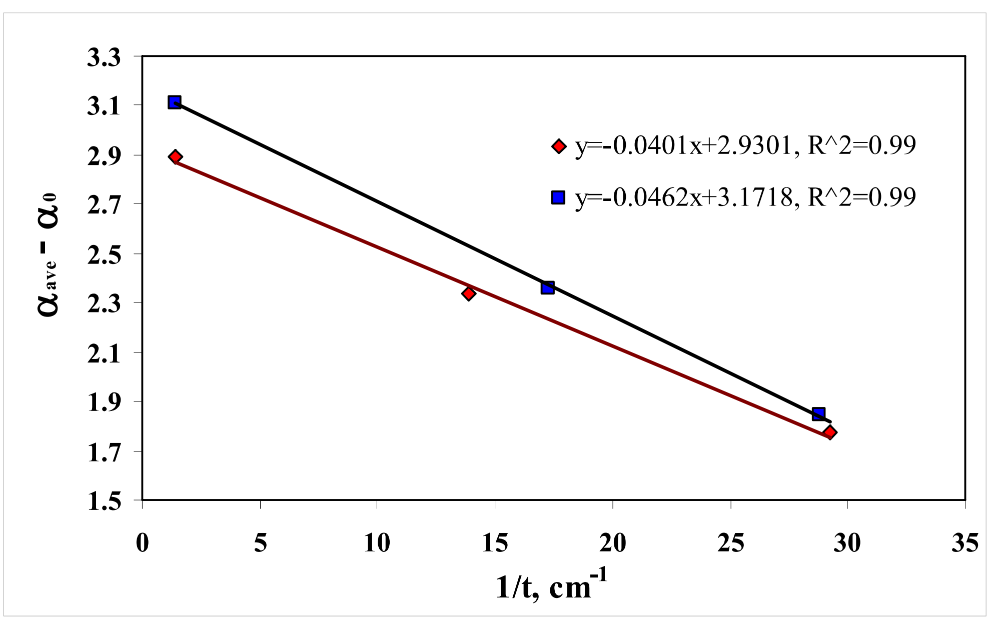


***Fig.1.** Dependence of width α_{ave} and thickness t for Ta, W target nucleus*

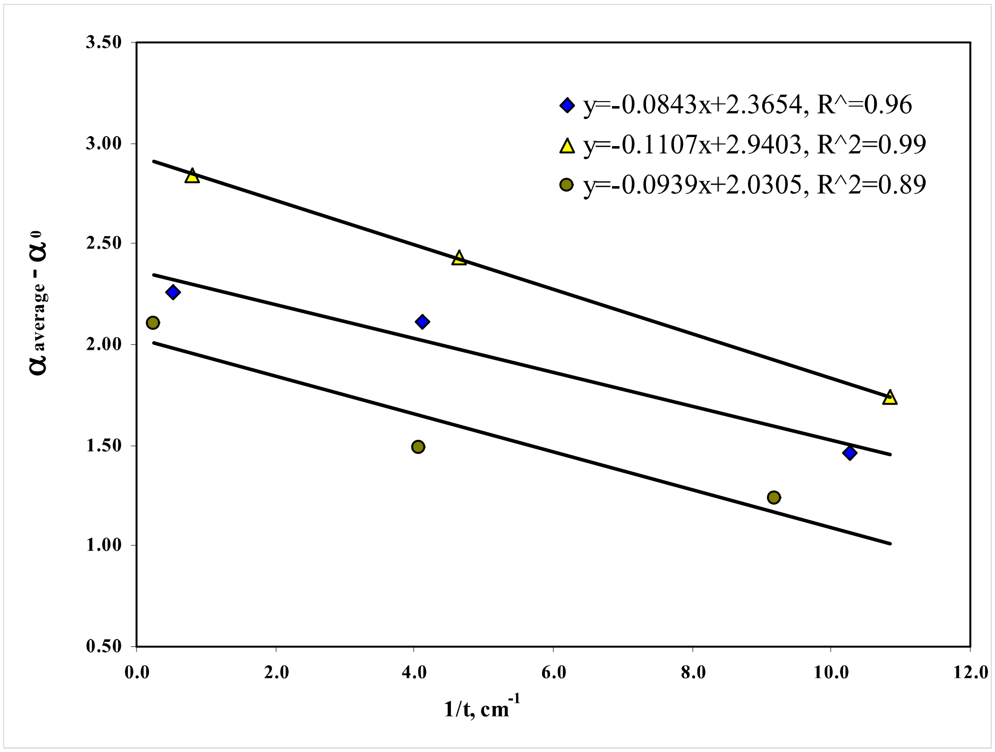


Fig.2. *Dependence of width* α_{ave} *and thickness* t *for Ti, Cu, Mo target nucleus*

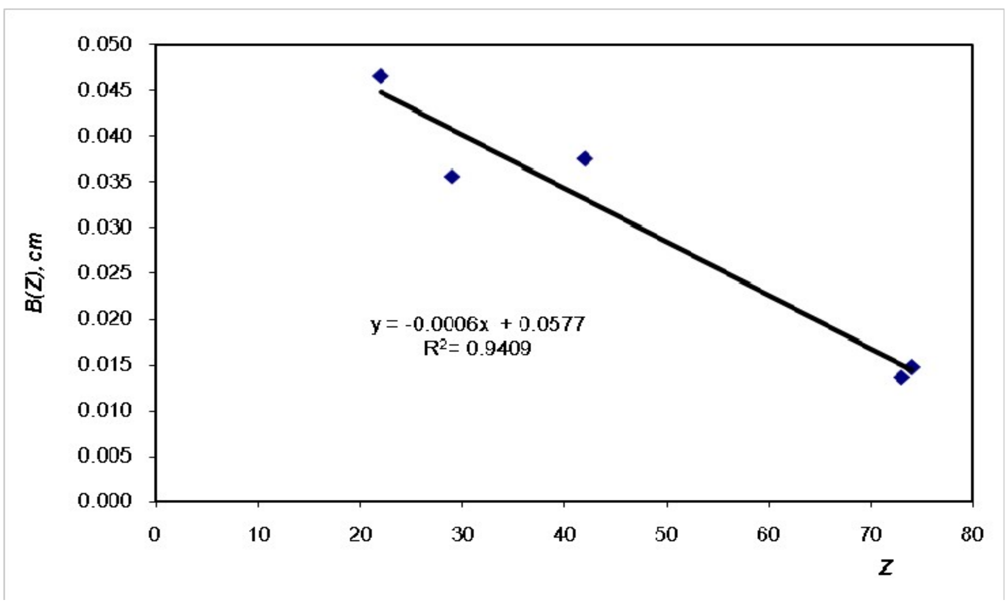


Fig.3. *Dependence of parameter* $B(Z)$ *and charge number of target*

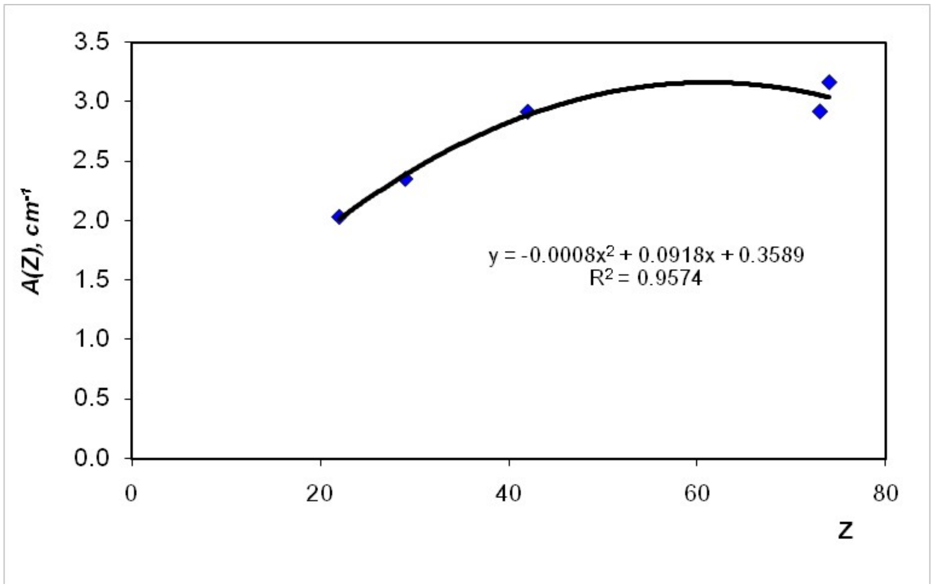


Fig.4. *Dependence of parameter* $A(Z)$ *and charge number of target*

CONCLUSION

1. On the basis of systematic study, we are shown that relative intensity distribution of gamma radiation with energy 11-22 MeV, induced by stopped electrons with various thicknesses at heavy and lighter target nucleus as an exponential form within angular region 0°-14°.
2. The width of angular distribution for relative intensity at half height within the $2-3\ g/cm^2$ region is shown that dependence between electron energy, charge number and thickness of the target nucleus as an linear form.
3. For the widely used target at Microtron MT-22, angular distribution of bremsstrahlung radiation within the Giant resonance region is depended on charge number and thickness of the target nucleus.
4. This research has both practical and theoritical importance for optimal selection of experimental geometry by the photo-nuclear reaction at Microtron MT-22 depending on a charge number and thickness of the target nucleus.

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Бай цөмийн хамгийн тохиромжтой $2-3\ г/см^2$ *геометрийн мужид, электроны тормозоор үүсэн 11-22 МэВ энергитэй гамма квантын өнцгөөрх харьцангуй түгэлтийн зүй тогтолыг судалсан. (Энэ жил”Цөмийн хавсрага судалгаа” сэдвийн дагуу хийгдэв.*