# ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

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# ON THE ELASTIC SCATTERING OF $\gamma$ -RAYS BY NUCLEI

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**Summary**

*The energy dependence of the elastic cross section of $\gamma$ rays by nuclei near the threshold of photonuclear reactions is studied with the help of the dispersion relation for forward scattering. The first maximum in the cross section is shown to be connected with the dispersion effects. Further experiments which are necessary for a more detailed analysis are discussed.*

# I

In a recent paper on $\gamma$ -d scattering/1/ by using the dispersion theory it is shown that in a wide energy range up to about 100 MeV the phonuclear processes have a great influence on the behaviour of the elastic scattering cross section.

In the present work the scattering of low energy $\gamma$ -quanta on nuclei is discussed.

Fuller and Hayward/2/, Penfold and Garwin/3/ have already applied the dispersion relation to the analysis of the elastic scattering of $\gamma$ -quanta on nuclei. However, they have studied the scattering only above the threshold of the ( $\gamma - n$ ) reaction.

The consideration of the particle production in S-state leads to the appearence of the well known energy anomalies near the threshold of $\gamma$ - N reaction. The dispersion technique is useful not only for the study of the Wigner–Baz' effect but also for the investigation of the general influence of the inelastic processes on the energy dependence of the elastic scattering amplitude in a wide energy range.

In the present paper we shall consider the energy dependence of the scattering amplitude and the cross section for the $\gamma$ -nucleus scattering near the threshold of $\gamma$ - N reaction.

We are convinced in the framework of the dispersion theory that the first maximum in the scattering cross section of $\gamma$ - quanta/2/ is naturely connected with the threshold effects.

We shall confine ourselves to the forward scattering. In the dipole approximation, which seems to be not in contradiction with the experimental data for the absorption of $\gamma$ - quanta by nuclei up to about 30 MeV/3/, our results will be correct also for other angles and for the total elastic cross section

# II

The amplitude for the scattering of $\gamma$ -quanta has the form:

$$T = R_1(\vec{e}'\cdot\vec{e}) + R_2(\vec{s}'\cdot\vec{s}) \quad , \quad \begin{matrix} \vec{s} = \vec{K}\wedge\vec{e}, \\ \vec{s}' = \vec{K}'\wedge\vec{e}'. \end{matrix} \qquad (1)$$

for spinless nucleus, and

$$T = R_1(\vec{e}'\vec{e}) + R_2(\vec{s}'\vec{s}) + iR_3(\vec{\sigma}\cdot[\vec{e}'\vec{e}]) + iR_4(\vec{\sigma}\cdot[\vec{s}'\vec{s}])$$
$$+ iR_5[(\vec{\sigma}\vec{K})(\vec{s}'\vec{e}) - (\vec{\sigma}\vec{K}')(\vec{s}\vec{e}')] + iR_6[(\vec{\sigma}\vec{K}')(\vec{s}'\vec{e}) - (\vec{\sigma}\vec{K})(\vec{s}\vec{e}')]$$

for the nucleus with spin ½ . For the nucleus with other spins more complicated expressions will be obtained. In the dipole approximation only $R_1$ is different from zero. Dispersion relations can be written for all the scalar amplitudes $R$ . The imaginary part of the amplitude is connected with the absorption cross section of $\gamma$ -quanta by using unitarity conditions. Thus, the real and imaginary parts of all the scattering amplitudes $R_I$ can be evaluated from the data on the photonuclear processes with the help of the dispersion relations and the unitarity conditions. However, at present there is no detailed analysis of the photonuclear processes. Therefore, we shall consider only the dispersion relations for the amplitude $R_I + R_2$ in the forward direction which has the simple form:

$$\mathrm{Re}\left[R_1(\nu, \theta=0) + R_2(\nu, \theta=0)\right] = -\frac{Z^2e^2}{M_A} + \frac{\nu^2 P}{2\pi^2}\int_{\nu_t}^{\infty}\frac{d\nu'\,\sigma_t(\nu')}{\nu'^2-\nu^2} \qquad 3)$$

We have not found in literatures/4/ available for us detailed informations on the energy dependence of the cross section of the photonuclear processes. Except deuterons the cross section of photodisintegration is known only for $He$/4/5/ in a wide energy range. In a recent paper by Mihailovic and others/6/ the total cross section $\sigma_t(\nu)$ for Al is obtained up to about 30 MeV. These authors have found some indication of the fine structure on the energy dependence in the giant resonance region. Data in the threshold region is still absent.

Smoothing out these experimental data we get the scattering amplitude with the help of ( 3 ). Schematically it is shown in Fig. 1. It seems to us that the form of the curve shown in Fig. 1 is characteristic for a series of nuclei for which the total cross section $\sigma_t(\nu)$ is large in the giant resonance region.

In the threshold region the photodisintegration of deuterons leads to a decrease of the scatterin amplitude in comparison with the Thompson amplitude. But for other nuclei with great absorption cross section the situation is completely altered.

Since the amplitude changes from negative to positive at a certain energy below $\nu_t$ and then becomes negative at an energy above $\nu_t$, the energy dependence of the scattering cross section will have in general the form shown in Fig. 2 which agrees with the general tendency of the experimental data.

For the nucleus Al the magnitude for the scattering cross section in the region of the first maximum attains the value $\sigma_s(\nu) = 2 \cdot 10^{-28}$ cm$^2$, which is very near to the experimental ones.

It is clear that the first maximum will be absent if the dispersion effect is not great enough to change the sign of the real part of the scattering amplitude in the threshold region.

The amplitudes of the first maximum for different nuclei are determined by the relative weight of the absorption cross section in the threshold region and in the giant resonance region. The contribution of the dispersion integral from the giant resonance region greatly enlarges the pick in the maximum. For Al the width of the maximum is greater than 2 MeV.

In our consideration the effects connected with the different places for the $(\gamma p)$ and $(\gamma n)$ thresholds are neglected. The error inherent in the data used is not analysed. We think that the general trend will not be changed in a more detailed analysis.

## III

Therefore, the explanation of the energy dependence of the $\gamma$-nucleus scattering cross section pointed out earlier/7/ seems to be correct.

The relatively inaccurate and poor experimental data on the absorption cross section for a series of nuclei makes it impossible to try a reliable analysis of the scattering cross section.

The data on the absorption cross section in a wide energy range is also useful for the estimation of the polarizability of the nucleus. For Al the polarizability

$$\alpha = \left[\frac{d}{d\nu^2}(R_1 + R_2)\right]_{\nu=0} = \frac{1}{2\pi^2} P \int_{\nu_t}^{\infty} \frac{\sigma_t(\nu)\, d\nu}{\nu^2}$$

which is approximately equal to $\simeq 2 \cdot 10^{-39}$ cm$^3$ ( with an error of about 50%). For $He_2^4$, $\alpha \simeq (0.70 \pm 0.05) \cdot 10^{-40}$ cm$^3$

It seems to us that more experimental work on this field will be very interesting. It is necessary at first to obtain the energy dependence of the photoabsorption cross section both in the threshold region and in the higher energy region. For heavy nuclei like U and Th the cross section for the photofission process is also desirable. The photoproduction of pions will also be important in the region of 120–150 MeV and at high energies.

More detailed phenomenological analysis of the photonuclear processes in a wide energy range is necessary in order to get the spin dependent amplitudes for the $\gamma$ -nucleus scattering.

On the other hand with the help of the dispersion relation and the unitarily condition it is possible to obtain some information on the absorption cross section from the experimental data on the elastic $\gamma$ -nucleus scattering. For this purpose the inverse dispersion relations seem to be an useful tool.

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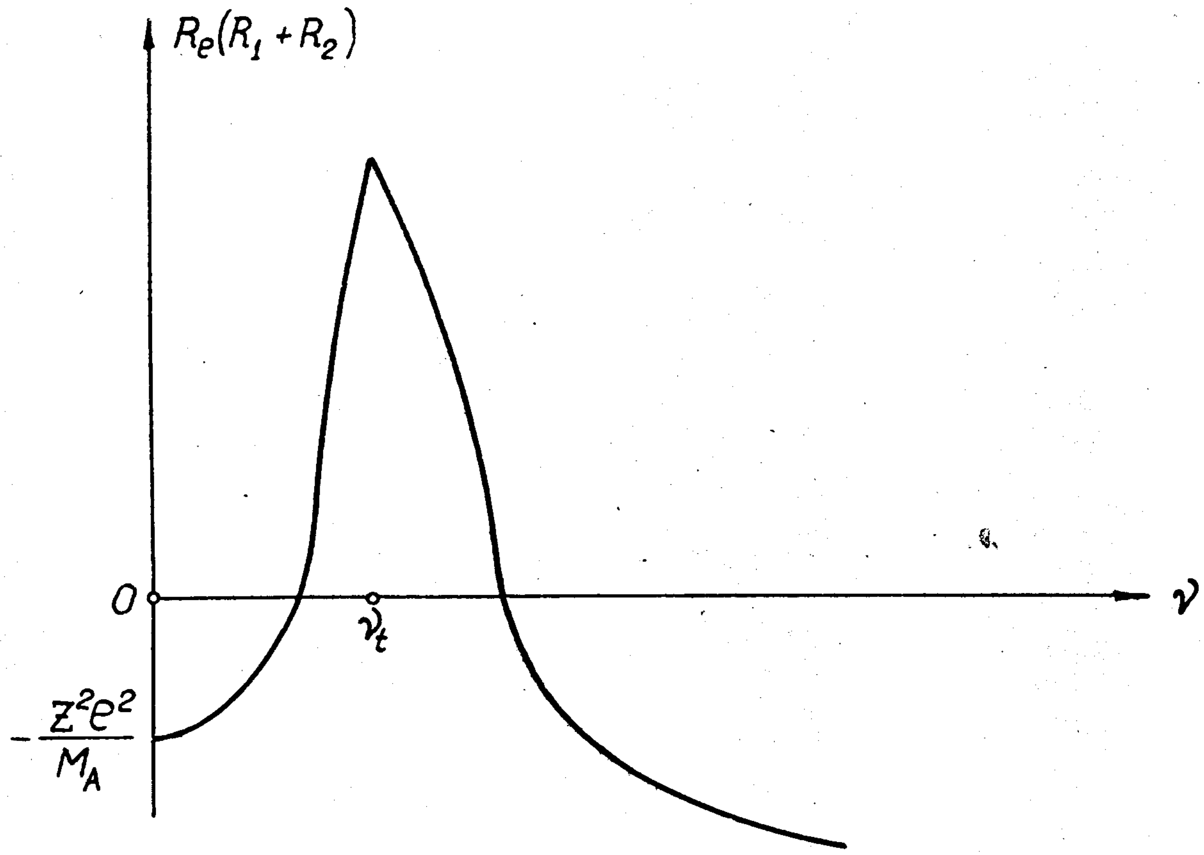


Fig. 1

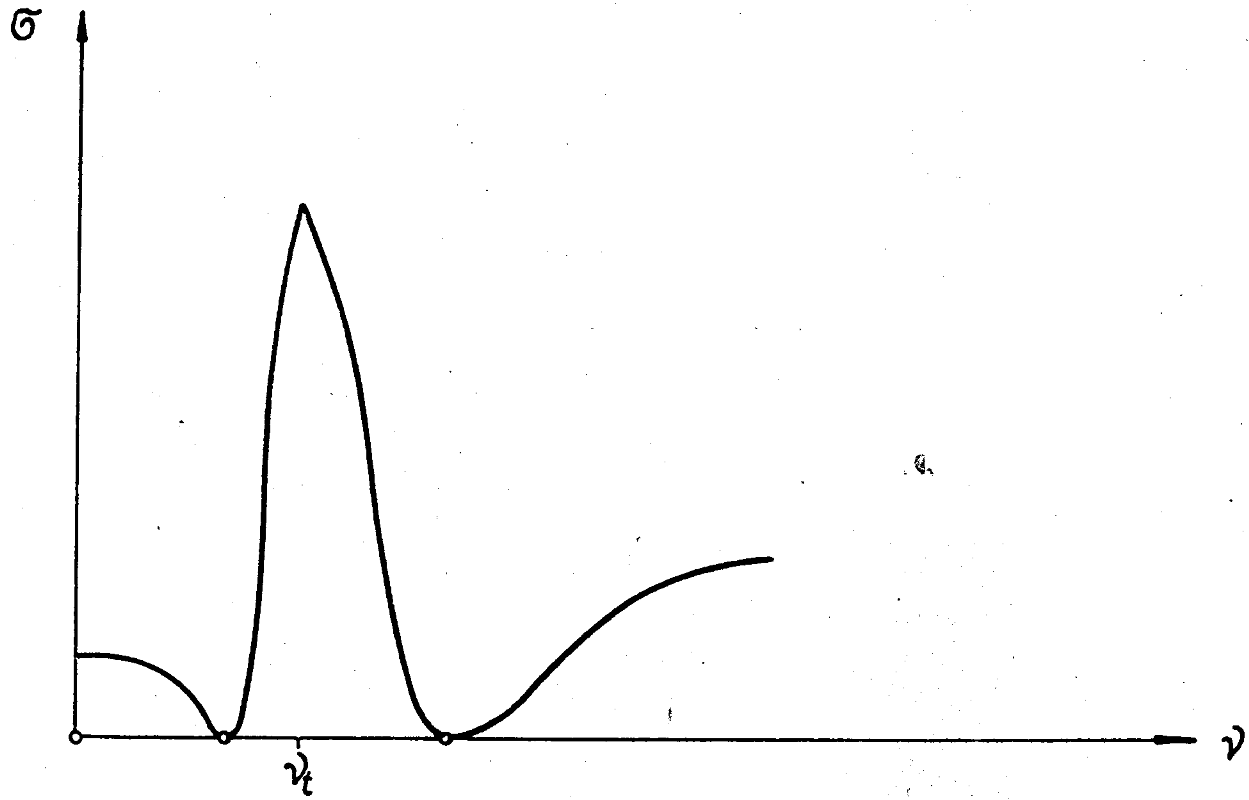


Fig. 2