# THE RHO-PHOTON COUPLING CONSTANT AND THE RHO-NUCLEON SCATTERING AMPLITUDE

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Some recent data on the $\varrho^0$ photoproduction on nuclei were analysed in terms of the Glauber model of multiple scattering in order to calculate the value of the rho-photon coupling constant. The numerical results depend on the assumed value $\alpha_{\varrho N}$ of the ratio of the real to imaginary part of the elementary rho-nucleon scattering amplitude. For $|\alpha_{\varrho N}| = 0.2$, which is a reasonable assumption, we get results consistent, within the limit of error, with the value of $\gamma_\varrho^2/4\pi = 1.0$, obtained at SLAC from the different analysis of the same data.

In this paper some recent data on the $\varrho^0$ photoproduction on nuclei were analysed using the Glauber model of multiple scattering. We used only the SLAC data [1], because other laboratories [2, 3] did not publish their differential cross-sections for a wide range of momentum transfer.

The previous analyses of the data were made in terms of the optical model of the scattering on nuclei. To get the value of the $\gamma-\varrho$ coupling constant the vector-dominance model (VDM) was used at $\theta = 0^0$ (*i. e* in the forward direction), together with the optical theorem and the assumption of the purely imaginary photoproduction amplitude. A necessity arose to extrapolate the measured differential cross-section to $\theta = 0^0$, where the appropriate formulae could be used. The extrapolation was done with the same optical model formula that served to evaluate the elastic scattering cross-section. This is the most uncertain part of the method, especially because the experimental cross-sections show a tendency to decrease near the forward direction, while neither the optical nor the Glauber model is able to reproduce such an effect.

To avoid this difficulty we analysed the SLAC data for momentum transfers in the range $0.003 \leqslant |t| \leqslant 0.03$ $(\mathrm{GeV}/c)^2$, *i. e.* in the first diffractive maximum. In this range we expect that the results are independent of the assumed nuclear model. For larger momentum transfers the differential cross-section has a distinct structure, which is very sensitive to the detailed shape of nuclear wave functions [4]. In our range of $t$ we do not need any extrapola-

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tion and use only the directly measured differential cross-section. This is the main asset of our method, provided we take for granted the validity of VDM for the momentum transfers between 0.003 (GeV/c)$^2$ and 0.03 (GeV/c)$^2$.

We consider the process

$$\gamma + A \to \varrho^0 + A', \tag{1}$$

where $A'$ may be any exited state of the original nucleus.

Let us start with the direct VDM relation

$$\frac{d\sigma}{dt}(\gamma + A \to \varrho^0 + A') = \frac{\alpha}{4}\left(\frac{\gamma_\varrho^2}{4\pi}\right)^{-1}\frac{d\sigma}{dt}(\varrho^0 + A \to \varrho^0 + A'). \tag{2}$$

The left-hand side of the equation is the directly measured $\varrho^0$ photoproduction differential cross-section for any $t$ from our considered range. The right-hand side consists of the sought coupling constant and the differential cross-section for $\varrho^0$-$A$ elastic scattering. This is built in the framework of the Glauber model [4, 5] from the elementary $\varrho^0$-nucleon scattering amplitude of the form

$$f(\varrho^0 + N \to \varrho^0 + N) = \frac{k}{4\pi}\sigma_{\varrho N}(i + \alpha_{\varrho N})e^{\frac{B}{2}t}, \tag{3}$$

where $\sigma_{\varrho N}$ is the total cross-section for elementary $\varrho^0$-$N$ scattering, $\alpha_{\varrho N}$ — the ratio of the real to imaginary part of the elastic $\varrho^0$-$N$ scattering amplitude, and $B$ is the slope of the diffractive peak in the elastic $\varrho^0$-$N$ differential cross-section; $k$ denotes the c. m. momentum in $\varrho^0$-$N$ scattering. We assume a simple model for the nucleus, with a gaussian density distribution of the nuclear matter

$$\varrho(A) \sim \prod_{j=1}^{A}\exp(-r_j^2/R^2). \tag{4}$$

The values of the nuclear radii $R$ were taken from the electromagnetic form-factors.

Our calculations were done with the differential cross-section of the form [5]

$$\frac{d\sigma}{dt}(\varrho^0 A \to \varrho^0 A') = \frac{\pi}{4}(R^2+2B)^2 \sum_{j=1}^{A}\sum_{\substack{l=0\\ l+k>0}}^{A-j}\sum_{k=0}^{j}(-1)^{j+k+l}\times$$
$$\times\left\{\left[\binom{A}{j}\binom{j}{k}\binom{A-j}{l} - k\right]e^{t_{\min}\cdot\frac{R^2}{2}} + k\right\}(1-i\alpha_{\varrho N})^j(1+i\alpha_{\varrho N})^{k+l}\times$$
$$\times\left[\frac{\sigma_{\varrho N}}{2\pi(R^2+2B)}\right]^{j+k+l}\left[\frac{1}{4B}\frac{(R^2+2B)^2}{R^2+B}\right]^k\left[(j-k)l + k(j+l)\frac{1}{4B}\frac{(R^2+2B)^2}{R^2+B}\right]^{-1}\times$$
$$\times\exp\left\{\frac{1}{4}t(R^2+2B)\left[j+l+k\frac{B}{R^2+B}\right]\left[(j-k)+k(j+l)\frac{1}{4B}\frac{(R^2+2B)^2}{R^2+B}\right]^{-1}\right\}. \tag{5}$$

This formula follows directly from the closure approximation [4, 5], which takes into account all possible final states of the target nucleus, so the right-hand side of Eq. (5) does not depend on $A'$. It is safer to use this approximation, because the large width of the experimental photon beam does not guarantee full knowledge of the final state of the target nucleus.

We also take into account the correction for the longitudinal momentum transfer $t_{\min} = -\left(\frac{m_\varrho^2}{2\,p_{\text{lab}}}\right)^2$ to the nucleus which occurs in the photoproduction process. The way of introducing this contribution in the framework of the Glauber theory was shown in [4]. The magnitude of the correction changes from 3% for $^9$Be to 12% for $^{64}$Cu.

The $\gamma-\varrho$ coupling constant is thus expressed as follows

$$\frac{\gamma_\varrho^2}{4\pi} = \frac{\alpha}{4}\,\frac{\left.\frac{d\sigma}{dt}\right|_{\text{theor}}(\varrho^0 A \to \varrho^0 A')}{\left.\frac{d\sigma}{dt}\right|_{\text{exp}}(\gamma A \to \varrho^0 A')}. \tag{6}$$

We performed our numerical calculations for the SLAC data at 8.8 GeV incident photon energy for four nuclei: $^9$Be, $^{12}$C, $^{27}$Al and $^{64}$Cu. Three free parameters: $\sigma_{\varrho N}$, $\alpha_{\varrho N}$ and $B$ appeared in our formula. We considered only two values of $\sigma_{\varrho N}$: 30 mb and 26 mb. The first one is the value obtained in the SLAC analysis of the same data; the second was calculated from the analysis of other experiments of the same type [2, 3], and it is also strongly suggested by the quark model [6]. For the second parameter we took $|\alpha_{\varrho N}| = 0$, 0.2 and 0.6 (the differential cross-section given by the formula (5) is not sensitive to the sign of $\alpha_{\varrho N}$).

If we believe in the VDM for the elementary photoproduction process

$$\gamma + N \to \varrho^0 + N, \tag{7}$$

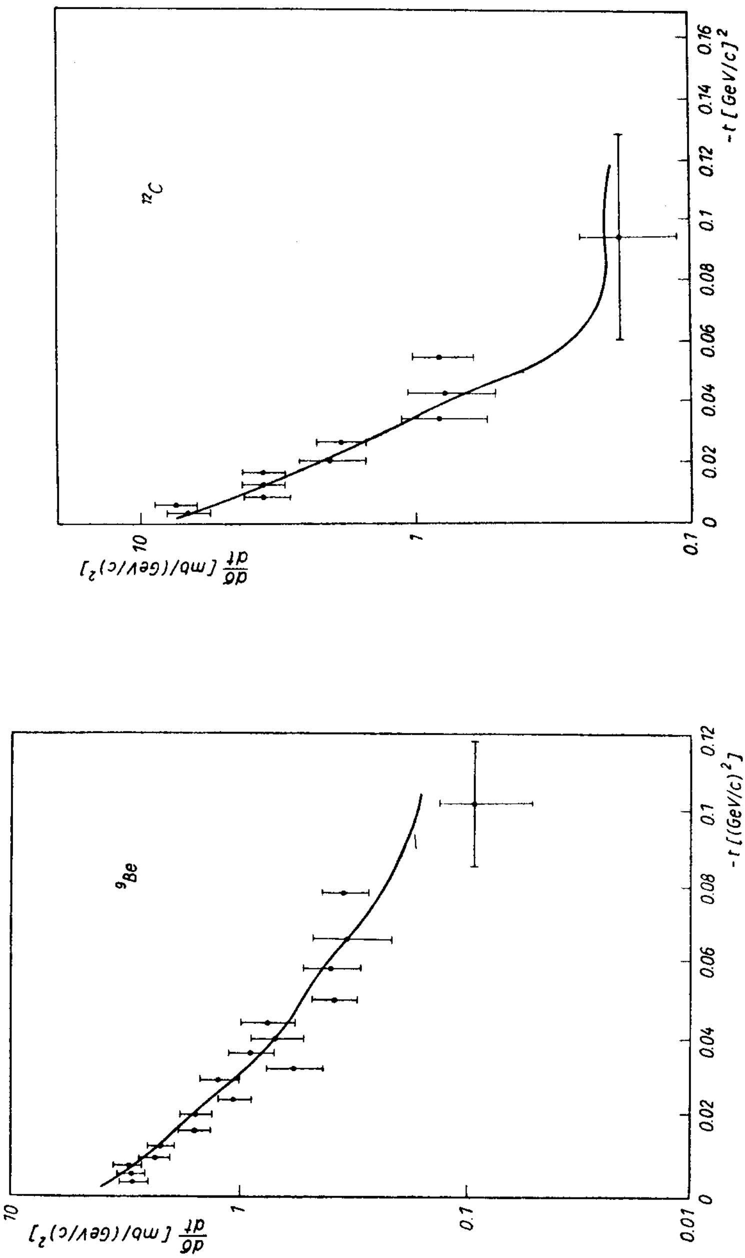
we expect that our slope $B$ is equal to the slope for the reaction (7). Hence, we take, according to the experimental values [8], $B = 8(\text{GeV}/c)^{-2}$ for $^9$Be, $^{12}$C and $^{27}$Al. For $^{64}$Cu, however, in order to obtain the $t$-independence of $\gamma_\varrho^2/4\pi$ in the considered range of momentum transfer, we had to put $B < 3(\text{GeV}/c)^{-2}$. This stems from the fact that the used gaussian density (4) fails to describe larger nulei.

The numerical results are presented in Table I and partly in Fig. 1.

TABLE I

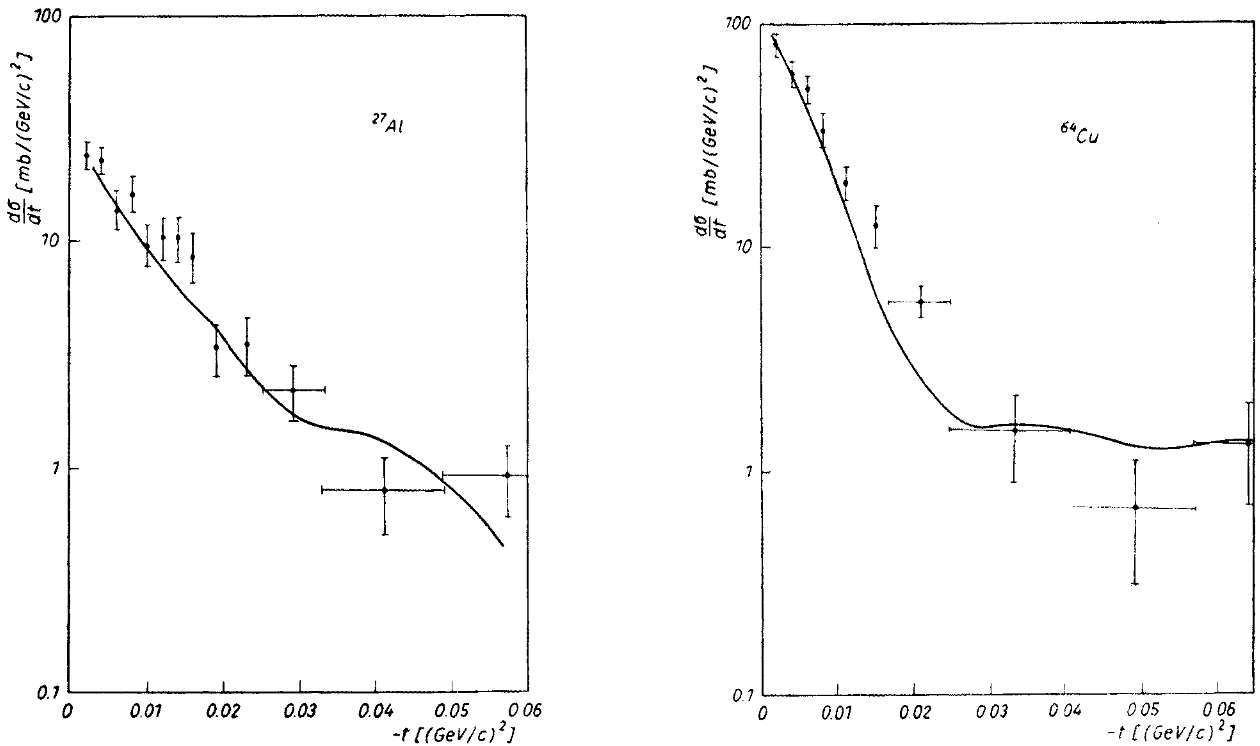
| Nucleus | | $\gamma_\varrho^2/4\pi$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $\sigma_{\varrho N} = 26$ mb | | | | $\sigma_{\varrho N} = 30$ mb | | | |
| | $R$ [fm] | $\alpha_{\varrho N} = 0$ | $\|\alpha_{\varrho N}\| = 0.2$ | $\|\alpha_{\varrho N}\| = 0.6$ | SLAC results[1] for $\alpha_{\varrho N} = 0$ | $\alpha_{\varrho N} = 0$ | $\|\alpha_{\varrho N}\| = 0.2$ | $\|\alpha_{\varrho N}\| = 0.6$ | SLAC results[1] for $\alpha_{\varrho N} = 0$ |
| $^9$Be | 1.8 | 0.85±0.1 | 0.9±0.2 | 1.10±0.2 | 1.0±0.1 | 1.05±0.2 | 1.10±0.2 | 1.40±0.2 | 1.25±0.1 |
| $^{12}$C | 1.95 | 0.65±0.1 | 0.75±0.2 | 0.80±0.2 | 0.80±0.1 | 0.80±0.2 | 0.85±0.2 | 1.0±0.2 | 1.0±0.1 |
| $^{27}$Al | 2.45 | 0.75±0.1 | 0.8±0.2 | 0.95±0.2 | 0.80±0.1 | 0.90±0.2 | 1.0±0.2 | 1.15±0.2 | 1.10±0.2 |
| $^{64}$Cu | 3.3 | 0.70±0.1 | 0.8 ±0.2 | 1.10±0.2 | 0.95±0.1 | 1.0±0.2 | 1.05±0.2 | 1.30±0.2 | 1.20±0.2 |
| average value of $\gamma_\varrho^2/4\pi$ | | 0.75±0.1 | 0.8±0.2 | 1.0±0.2 | 0.90±0.1 | 0.90±0.2 | 1.0±0.2 | 1.20±0.2 | 1.10±0.2 |

[1] These values were read from the diagrams published in [1].




b

a




c d

Fig. 1. The differential cross-sections for the process $\gamma + A \to \varrho^0 + A'$, compared with the SLAC data [1]. The theoretical curves are drawn for $\gamma_\varrho^2/4\pi = 0.8$; this corresponds to $\sigma_{\varrho N} = 26$ mb and $|\alpha_{\varrho N}| = 0.2$

For $\alpha_{\varrho N} = 0$ our values of $\gamma_\varrho^2/4\pi$ are lower than in [1]. However, within the limits of error, they are still consistent with 1.0 rather than with 0.5, especially when we depart from the assumption of purely imaginary $\varrho^0-N$ scattering amplitude and take the more realistic value of $\alpha_{\varrho N}$. We conclude that our analysis of the SLAC data [1] alone indeed gives $\gamma_\varrho^2/4\pi$ close to 1.0.

We notice that for $|\alpha_{\varrho N}| \neq 0$ the value of $\gamma_\varrho^2/4\pi$ increases with the increase of $|\alpha_{\varrho N}|$. An opposite effect was found in the recent analysis of the Cornell data [7], where adding the real part to the elementary $\varrho^0-N$ scattering amplitude diminished the resulting value of $\gamma_\varrho^2/4\pi$. It is easy to see the source of this discrepancy. In our work $\alpha_{\varrho N}$ enters only into $\left.\frac{d\sigma}{dt}\right|_{\text{theor}}$, increasing its value, while $\left.\frac{d\sigma}{dt}\right|_{\text{exper.}}$ in the denominator of the right-hand side of Eq. (2) is purely the experimental value. On the other hand, in [7] the experimental values of $\frac{d\sigma}{dt}$ were extrapolated to $\theta = 0^0$ with a theoretical formula that was also affected by introducing $\alpha_{\varrho N}$.

After this work was completed the new data on $\varrho^0$ photoproduction on various nuclei, coming from the DESY experiment of high accuracy, appeared [9]. An optical model analysis of the data yielded the value of $\gamma_\varrho^2/4\pi = 0.57 \pm 0.10$ for $\sigma_{\varrho N} = 26$ mb and $\alpha_{\varrho N} = -0.2$. We repeated our calculations for DESY experimental cross-sections, for the same four nuclei as before and taking the values of $\sigma_{\varrho N}$ and $\alpha_{\varrho N}$ from [9]. We get $\gamma_\varrho^2/4\pi = 0.55 \pm 0.15$, hence, complete consistency with the DESY value is achieved.

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