Photoproduction of η mesons on nuclei in the region of the S_{11} (1535) resonance

G. N. Dudkin, V. N. Eponeshnikov, and Yu. F. Krechetov

Research Institute for Physics, Electronics, and Automation at the Tomsk Polytechnic Institute
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We measured the differential cross section of incoherent photoproduction of η mesons on the nuclei C, Cu, Ag, and Pb. Using the dependence of the cross sections on the mass number A, we determined the dipole and elastic cross sections of the ηN interaction for η-meson kinetic energies 80, 150, and 230 MeV. These data yielded the mass of the S_{11} (1535) resonance and its width.

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To determine the total cross section of ηN interaction in the region of the S_{11}(1535) resonance, we measured the differential cross section of incoherent photoproduction of η mesons on nuclei as functions of the mass number A. The measurements were made on the nuclei C, Cu, Ag, Pb at maximum bremsstrahlung beam energies $E_{\gamma_{max}}$ equal to 900 and 850 MeV. The kinematic characteristics of the reactions were the following: kinematics I—total reaction energy and emission angle of the η meson in the c.m.s. respectively $E^* = 1540 \pm 30$ MeV and $\theta^*_\eta = 103 \pm 10°$; kinematics II—$E^* = 1605 \pm 50$ MeV and $\theta^*_\eta = 90 \pm 15°$, $T_\eta = 150 \pm 25$ MeV; kinematics III—$E^* = 1580 \pm 50$ MeV, $\theta^*_\eta = 50 \pm 15°$, $T_\eta = 230 \pm 30$ MeV.

The η mesons were detected by registering the two quanta from the $\eta \to 2\gamma$ de-

TABLE 1. The photoproduction cross sections for the second and third kinematics are given in units of 10^{-30} cm²/sr.

Kinem. \ Nucleus	C	Cu	Ag	Pb	H
I	1.57 ±0.16	4.9 ±0.7	6.87 ±0.9	10.5 ±1.5	–
II	1.11 ±0.14	4.35 ±0.56	5.1 ±0.7	8.8 ±1.2	0.23 ±0.03
III	1.71 ±0.23	6.54 ±0.82	8.1 ±1.2	13.7 ±1.9	0.24 ±0.05

Note: The photoproduction cross sections for the second and third kinematics are given in units of 10^{-30} cm²/sr.

cay with two Cerenkov total absorption spectrometers. The recoil nuclei were not registered. The description of the apparatus and of the method of separating the reaction channel are given in[1,2].

Table 1 shows the differential cross sections of η-meson photoproduction on nuclei and hydrogen in the c.m.s. for the second and third kinematics in the decay mode $\eta \to 2\gamma$. The cross sections for hydrogen were taken from[3] and averaged with allowance for the energy resolution of the apparatus. The total errors are indicated. For the third kinematics are given the η-meson yields per equivalent quantum and per nucleus. The reason is that threshold effects that are difficult to account for manifest themselves in this kinematic region. We have therefore decided to analyze the results for the third kinematics, using normalization to carbon. It was assumed here that the threshold effects vary little from nucleus to nucleus.

The differential cross section of incoherent η-meson photoproduction on a nucleus can be written in the impulse and eikonal approximations and in the completeness approximation in the form[4]

$$\frac{d\sigma(A)}{d\Omega^*} = A < \frac{d\sigma}{d\Omega^*} >_N [1 - G(q)]\, f(A; \sigma_{\eta N}^{tot}), \quad (1)$$

where A is the mass number; $\langle d\sigma/d\Omega\rangle_N$ is the differential cross section for the production on a free nucleon, averaged over the momentum distribution of the nucleons in the nucleus; $G(q)$ is an inelastic nuclear form factor that depends on the momentum transfer q; $f(A, \sigma_{\eta N}^{tot})$ is a coefficient that takes into account the interaction of the produced mesons with the nucleons of the nucleus.

In the optical model we have

$$f\left(A; \sigma_{\eta N}^{tot}\right) = \frac{2\pi}{\sigma_{\eta N}^{tot} A} \int_0^\infty b\,db \left[1 - \exp\left(-A\sigma_{\eta N}^{tot} \int_{-\infty}^{\infty} \rho(b, z)\,dz\right)\right] \quad (2)$$

where $\rho(b,z)$ is the density function and b is the impact parameter. The inelastic nuclear form factor is $G(q) = 0$ for all three kinematics. The distribution of the nuclear density was chosen in the form of a Woods-Saxon distribution with parameters $a = 0.54$ F and $C = 1.14A^{1/3}$ F.

The unknown parameter $\sigma_{\eta N}^{tot}$ was obtained by a least-square fit of the function $f(A;\sigma_{\eta N}^{tot})$ to the experimental points. The cross sections obtained from the fit are certain effective cross sections, since it is necessary to take into account the Pauli principle and the fraction of the mesons that undergo elastic scatter-

TABLE 2

σ, mb \ Kinem.	I	II	III
$\sigma^{in}_{\eta N}$	35.0 ± 4.0	20.2 ± 2.1	10.8 ± 1.2
$\sigma^{el}_{\eta N}$	$44 \pm^{28}_{18}$	$42.2^{+8.4}_{-6.7}$	21.6 ± 4.3
$\sigma^{tot}_{\eta N}$	79^{+50}_{-32}	62^{+12}_{-10}	32.4 ± 6.5

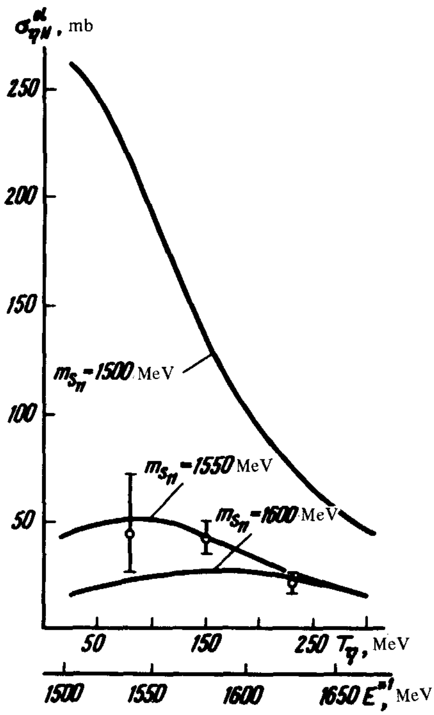
ing by the nucleons of the nucleus and are not knocked out of the registration. Assuming that the main contribution to the total ηN-interaction cross section is made by the processes

$$\eta N \to \pi N, \tag{3}$$

$$\eta N \to \eta N \tag{4}$$

we write

$$\sigma^{\text{eff}}_{\eta N} = \sigma^{in}_{\eta N} + K\xi\sigma^{el}_{\eta N}, \tag{5}$$



where $\sigma_{\eta N}^{in}$ is the total inelastic-interaction cross section, $\sigma_{\eta N}^{el}$ is the total elastic-scattering cross section, ξ is a coefficient that takes the Pauli principle into account, and $0 < K < 1$ is a coefficient that takes into account the scattered mesons not knocked out of registration. It was calculated for all the kinematics by the Monte Carlo method under the assumption that reaction (4) has angular isotropy. The total cross section $\sigma_{\eta N}^{in}$ of the inelastic interaction was determined from the cross sections of the reaction $\pi N \to \eta N$[5,6] by the detailed balancing method. Table 2 lists the values of $\sigma_{\eta N}^{in}$, $\sigma_{\eta N}^{el}$, and $\sigma_{\eta N}^{tot}$ obtained in this manner.

The amplitudes of the processes (3) and (4) were obtained in[7] assuming that the resonance S_{11} plays the predominant role, and with account taken of the contribution of the nucleon pole.

The figure shows the theoretical plots of $\sigma_{\eta N}^{el}$ against the η-meson energy (total energy $E^{*\prime}$ of the ηN system) for three values of the resonance mass. The figure shows also our experimental points. The fit of the theoretical curve (where the free parameters were the resonance mass $m_{S_{11}}$ and its width Γ) to the experimental values of $\sigma_{\eta N}^{el}$ has enabled us to determine these quantities, namely $m_{S_{11}} = 1550^{+25}_{-15}$ MeV and $\Gamma = 160^{+40}_{-30}$ MeV. It must be noted that our results depend strongly on the models developed in[4,7]. Therefore, to extract more exact data from experiment, it is necessary to refine these models.

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