Letters to the Editor

NEW DATA ON THE PRODUCTION OF NEUTRAL PIONS IN THE COULOMB FIELD OF THE NUCLEUS

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In our earlier work[1] we undertook the experimental observation and investigation of one particular case of coherent interaction between particles in a nucleus, wherein the primary particle, the pion, dissociates into two particles in accordance with the reaction

$$\pi^- + {}_ZN^A \rightarrow \pi^- + \pi^0 + {}_ZN^A. \quad (1)$$

The reaction (1) is possible only as the result of the interaction between the pion and the Coulomb field of the nucleus ${}_ZN^A$. This reaction was previously investigated[1] for the xenon nucleus with negative-pion momentum 2.8 BeV/c. A method was developed for identifying the reaction

$$\pi^- + \text{Xe} \rightarrow \pi^- + \pi^0 + \text{Xe} \quad (2)$$

from observations in a xenon bubble chamber. The background of reaction (2), due to the nuclear interaction, was determined from measurements in a Freon bubble chamber. About 10,000 stereophotographs of the xenon chambers were scanned, and 25 events selected, pertaining to the reaction (2) (including the background).

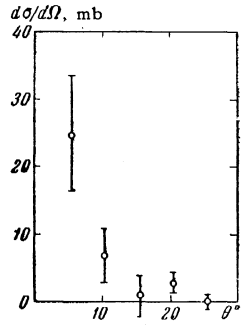
In the present work we subjected to a four-fold independent scanning approximately 15,000 more stereophotographs, so that the total number of scanned photographs from the xenon chamber now amounted to 24,474, with a total of 23,400 inelastic interactions. The total number of obtained events of reaction (2), passing through the kinematic selection in accordance with the previously developed method, now amounted to 53. The distribution of the events over the π^--meson emission angles θ, is given in the table.

The true number of events, n, was calculated as before by means of the formula

$$n = n_1/\eta_1 - n_2N_1/\eta_2N_2,$$

where n_1, η_1, and N_1 are respectively the obtained number of the events, the efficiency of registering the two gamma quanta from the decay of one neutral pion, and the number of all the inelastic interactions on the scanned photographs for xenon, while n_2, η_2, and N_2 are the analogous quantities for freon. In calculating the differential cross section $d\sigma/d\Omega$ it was assumed that the cross section of inelastic interaction of the negative pions with momentum 2.8 BeV/c in xenon amounts to 12,000 mb.

The angular dependence of the cross section $d\sigma/d\Omega$ is shown in the figure. As can be seen from the figure, the yield of reaction (2) at negative-pion emission angles $\gtrsim 15°$ is very small, as follows from the theory. In the entire investigated interval of angles of pion emission, 3—30°, the ratio of the reaction (2) to the total number of inelastic interactions is $n/N_1 = (2.21 \pm 0.75) \times 10^{-3}$. Assuming $\sigma_{\text{inel}} = 1200$ mb, we find that the cross section of the reaction $\pi^- + \text{Xe} \rightarrow \pi^- + \pi^0 + \text{Xe}$ in the 3—30° interval is $\sigma_C = 2.65 \pm 0.90$ mb. This quantity confirms, within the limits of errors, the previously obtained value[1].



Dependence of the cross section for production of π^0 mesons in the Coulomb field of a xenon nucleus (the reaction $\pi^- + \text{Xe} \rightarrow \pi^- + \pi^0 + \text{Xe}$) on the π^- meson emission angle θ.

The cross section for the production of particles in the Coulomb field of the nuclei can be

θ, deg	n_1	n_2	n_1/η_1	n_2N_1/η_2N_2	n	$d\sigma/d\Omega$, mb/sr
3— 8	18	2	31,6	6.4	25.2	24.8±8.4
8—13	13	3	22.8	9.6	13.2	6.8±4.3
13—18	9	4	15.8	12.8	3.0	1.1±3,0
18—23	8	1	14,0	3.2	10.8	2.9±1.6
23—30	5	3	8.8	9.6	—0.8	—0.1±0.8

related with the cross section of the corresponding photoprocesses. In particular, a study of the reaction (2) yields an estimate of the cross section of the reaction

$$\gamma + \pi^- \rightarrow \pi^- + \pi^0. \quad (3)$$

If w is the total energy of the two pions produced in reaction (2) in their c.m.s., and m is the pion mass, then, as shown earlier[1], we have for the xenon nucleus and our energy $\bar{\sigma}_p \cong \sigma_c/7.5$, where $\bar{\sigma}_p$ is the average value of the cross section of the reaction (3) in the interval $4m^2 \leq w^2 \leq 21m^2$. Then using the measured value of σ_c we find that $\bar{\sigma}_p = 0.35 \pm 0.12$ mb.

[1] Barmin, Krestnikov, Kuznetsov, Meshkovskiĭ, Nikitin, and Shebanov, JETP 43, 1223 (1962), Soviet Phys. JETP 16, 866 (1963).

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PARAMAGNETIC COUNTER OF ELEMENTARY PARTICLES

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THE methods of quantum electronics and optics of coherent sources of light make it possible to control various degrees of freedom of solids and liquids which, interacting with weak external perturbations, display a high selectivity and give strong response signals. A sufficient lowering of the temperature of the substance of such a quantum device leads to a strong reduction in the noise and provides the unusual sensitivity of the arrangement. A special place is occupied by devices (quantum counters)[1] containing unexcited molecules, and, consequently, having no noise background from spontaneous emission. Hence, together with an unlimited lowering of the temperature, the sensitivity of such a device increases without limit.

The possibility of detecting individual photons and phonons by a quantum counter has already been discussed in the literature.[2,3] In the present work, we investigate the prospects of using paramagnetic crystals to study the magnetic properties of elementary particles and to detect their presence by means of their magnetic interaction with the counter. As an example, we estimate the efficiency and sensitivity of a paramagnetic neutron counter (PNC).

The main scheme of the PNC is as follows. A crystal containing magnetic ions is placed in the path of a neutron flux. The energy spectrum of the magnetic ions has the levels $E_1 < E_2 < E_3$, where E_1 corresponds to the ground-state level. The crystal is cooled to a temperature $T \ll (E_2 - E_1)/k$ at which the levels E_2 and E_3 are unpopulated. The magnetic scattering of the neutrons on the ions produces the transitions $E_1 \rightarrow E_2$, which are detected by the excitation produced by the light from the transitions $E_2 \rightarrow E_3$, and the phototube counts of spontaneous-emission transitions $E_3 \rightarrow E_{2,1}$.

Under stationary operation, the efficiency of the PNC is determined by the ratio of the number of $E_1 \rightarrow E_2$ transitions produced by neutrons to the number of neutrons passing through the counter:

$$B = Nl\sigma_{12} \sim (10^{-2} - 10^{-4})\, l, \quad (1)$$

where l is the length of the crystal along the direction of the neutron flux, σ_{12} is the cross section for the scattering of a neutron on the magnetic system with a transition of the magnetic particle $E_1 \rightarrow E_2$, and $N \sim 10^{22}$ is the number of magnetic particles in a unit volume. If the phototube records individual photons, then the limit of sensitivity of the PNC is determined by the value of I_{min} of the neutron flux giving rise to the $E_1 \rightarrow E_2$ transitions with a probability $W_{12\,min}$ comparable in magnitude with the probability v_{12} of a $E_1 \rightarrow E_2$ relaxation transition. The value of $W_{12\,min}$ should also be compared with the transition probabilities q_{12} and q_{13} under the action of the light pumping. Here, the probability of light pumping q_{23} should exceed the probability v_{21} of the relaxation transition. We thus have

$$W_{12\,min} = \sigma_{12} I_{min} \sim v_{12},\ q_{12},\ q_{13}, \qquad q_{23} > v_{21}. \quad (2)$$

In paramagnetic crystals, the relaxation transitions $E_1 \rightarrow E_2$ are due to cross relaxation[4] and the spin-phonon interaction.[3] The first mechanism is described by the formula

$$v \sim \exp\left\{-\frac{\hbar\omega_{12}}{kT} - \frac{\omega_{12}^2}{\langle\Delta\omega^2\rangle}\right\}, \quad (3)$$

and is not very effective for spectral lines with a small relative width $\langle\Delta\omega^2\rangle^{1/2}$ of the energy split-