analysis of the experimental angular distributions of elastic ($\pi^- p$) interactions at $E > 1$ Bev.‡

I am grateful to D. I. Blokhintsev for discussions.

*It was assumed here that, in the case of (πN) and (NN) collisions at $E > 1$ Bev, the cross section of diffraction ($\pi\pi$) scattering $\sigma_{\pi\pi}^{d} \simeq 1/3\sigma_{\pi\pi}^{in}$, where $\sigma_{\pi\pi}^{in}$ is the cross section of all inelastic ($\pi\pi$) interactions. Calculations have shown that the numbers in the table vary little with $\sigma_{\pi\pi}^{d}$.

†This question will be considered in detail in another paper.

‡Approximately half of the ($\pi^- p$) collisions occurs at impact parameters $\rho \gtrsim (0.5$ to $0.6) \times 10^{-13}$ cm, which can be explained only by assuming $r_\pi \sim r_N \sim 0.5 \times 10^{-13}$ cm, i.e. $\sigma_{\pi\pi} \sim 4\pi r_\pi^2 \sim \sigma_{\pi N}$ (see reference 5).

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DETECTION OF Eu^{++} *IONIZATION IN THE* SrS-Eu, Sm *PHOSPHOR BY THE PARAMAGNETIC ABSORPTION METHOD*

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IN the phosphor SrS-Eu, Sm (without flux) we discovered a decrease in the paramagnetic absorption of Eu^{++} upon excitation of this phosphor with light in the absorption band of Eu^{++} ($\lambda \sim 440$ mμ). This decrease was found to be dependent on the degree of the phosphor stimulation. At the moment of excitation the decrease of paramagnetic absorption is $\sim 15\%$, and ~ 10 minutes after cessation of excitation this decrease amounts to $\sim 8\%$. This agrees with the decrease in the self-absorption coefficient of Eu^{++} in phosphor during excitation. Measurements made some 10 — 20 minutes after cessation of excitation showed that the coefficient of activator absorption in the excited phosphor was less by $\sim 11\%$. At the same time, measurements of the total number of quanta emitted by the excited phosphor were made starting 10 — 20 minutes after cessation of excitation. The measurements yielded 6.5×10^{15} quanta, proving that not less than 4% of the Eu^{++} became ionized. Assuming that the quantum yield of the radiation at recombination is $\sim 1/2$ and that the full amount of the activator was used for the formation of luminescence centers (Eu^{++}) we can state that about 8% of the Eu^{++} ions became ionized.

Thus, three independent methods gave compatible results. This allows us to state that ionization of the activator ($Eu^{++} \rightarrow Eu^{+++}$) takes place upon excitation of the phosphor SrS-Eu, Sm.

The cause of the non-detection of ionization in the previous[1] work remains unclear. It is probably connected with the lower stability of the radiation spectroscope or with stray excitation of the luminophore in the resonator.

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SCATTERING OF A LOW-ENERGY ELECTRON BY A SHORT-RANGE POTENTIAL IN A STRONG MAGNETIC FIELD

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WE study the question of the scattering of an electron with energy E by a potential $V(\mathbf{r})$ in a homogeneous magnetic field $\mathbf{H}$, assuming that the radius of action of the scattering potential

$r_0 \ll \lambda = (2mE)^{-1/2}$ (the system of units is employed in which $\hbar = c = 1$).

The Hamiltonian of the electron without consideration of the scattering potential is $H_0 = (p - eA)^2/2m$, where curl $\mathbf{A} = \mathbf{H}$. Let $H_0\varphi_\alpha = E_\alpha\varphi_\alpha$, α is the total set of quantum numbers for an electron in a magnetic field. The exact wave function of the electron $\Psi(\mathbf{r})$ satisfies the integral equation[1]

$$\Psi_\alpha(\mathbf{r}) = \varphi_\alpha(\mathbf{r}) + \int G(\mathbf{r}, \mathbf{r}'; E_\alpha) V(\mathbf{r}') \Psi_\alpha(\mathbf{r}') d^3r', \tag{1}$$

$$G(\mathbf{r}, \mathbf{r}'; E) = \sum \varphi_\nu(\mathbf{r}) \varphi^*_\nu(\mathbf{r}') / (E - E_\nu + i\delta). \tag{2}$$

According to Lippmann and Schwinger, the scattering is completely determined by the matrix elements $T_{\beta\alpha} = (\varphi_\beta | V | \Psi_\alpha)$, i.e., for the solution of the problem, one needs to know the form of $\Psi_\alpha(r)$ at distances of the order r_0. Taking the vector $\mathbf{A}$ in the form $A_x = A_z = 0$, $A_y = Hx$, and summing, in (2) over the x coordinates of the center of rotation of the electron, we obtain

$$G(\mathbf{r}, \mathbf{r}'; E) = \Phi(\mathbf{r}, \mathbf{r}') S(\mathbf{r} - \mathbf{r}'; E),$$

$$S(\mathbf{r}, E) = \frac{\gamma}{4\pi^2} \int_{-\infty}^{+\infty} dk \exp(ikz - \gamma\rho^2/4) \sum_{n=0}^{\infty} \frac{L_n(\gamma\rho^2/2)}{E - E_n(k) + i\delta},$$

$$\Phi(\mathbf{r}, \mathbf{r}') = \exp\{i\gamma(x + x')(y - y')/2\}, \tag{3}$$

where

$$\rho^2 = x^2 + y^2, \qquad E_n(k) = [2\gamma(n + 1/2) + k^2]/2m, \qquad \gamma = eH;$$

$L_n(u)$ are the Laguerre polynomials normalized to unity.

We introduce the notation $E = (N + 1/2 - \epsilon)\gamma/m$, where $0 < \epsilon \leq 1$, and separate the first N terms from the sum over n in the formula (3). Then $S(\mathbf{r}, E) = S_N(\mathbf{r}) + S'(\mathbf{r})$, where

$$S_N(\mathbf{r}) = -i\gamma \frac{m}{2\pi} \sum_{n=0}^{N} k_n^{-1} L_n(\gamma\rho^2/2) \exp(ik_n z - \gamma\rho^2/4),$$

$$k_n = \sqrt{2\gamma(N - \varepsilon - n)}.$$

We note that the condition $r \ll \lambda$ now has the form $r \ll (2\gamma N)^{-1/2}$. It can be shown that for $r \ll \lambda$

$$S'(\mathbf{r}) = -(m/2\pi)(1/r + \eta_1\sqrt{2\gamma} + \eta_2 2\gamma N r),$$

where $|\eta_{1,2}| < 1$ for all ϵ. Thus the asymptotic solution of the Green's function G for $r, r' \ll \lambda$ has the form $(\Phi(\mathbf{r}, \mathbf{r}') \approx 1)$

$$G(\mathbf{r}, \mathbf{r}'; E) \approx S(\mathbf{r} - \mathbf{r}'; E) \approx -(m/2\pi)[|\mathbf{r} - \mathbf{r}'|^{-1} + iK(E)],$$

$$K(E) = \gamma \sum_{n=0}^{N} (k_n)^{-1}. \tag{4}$$

We now write down Eq. (1) in the region $r \ll \lambda$:

$$\Psi_\alpha(\mathbf{r}) = \varphi_\alpha(0) - \frac{m}{2\pi} \int \left(\frac{1}{|\mathbf{r} - \mathbf{r}'|} + iK \right) V(\mathbf{r}') \Psi_\alpha(\mathbf{r}') d^3r'. \tag{5}$$

It is easy to see that the solution of this equation has the form

$$\Psi_\alpha(\mathbf{r}) = \frac{\varphi_\alpha(0)}{1 + iKf} \Psi_0(\mathbf{r}), \tag{6}$$

where $\Psi_0(\mathbf{r})$ is determined by the equation

$$\Psi_0(\mathbf{r}) = 1 - (m/2\pi) \int |\mathbf{r} - \mathbf{r}'|^{-1} V(\mathbf{r}') \Psi_0(\mathbf{r}') d^3r',$$

$$f = (m/2\pi) \int V(\mathbf{r}) \Psi_0(\mathbf{r}) d^3r;$$

f represents the scattering amplitude of a free electron with zero energy in a potential V. It follows from (6) that

$$T_{\beta\alpha} = \frac{2\pi f}{m} \frac{\varphi^*_\beta(0)\varphi_\alpha(0)}{1 + iK(E_\alpha)f}. \tag{7}$$

With the aid of (7), it is easy to find the total scattering probability per unit time, averaged over the positions of the center of rotation of the electron in the initial state:

$$W(E) = \frac{4\pi}{\Omega} \frac{f^2 K'(E)/m}{(1 + K''f)^2 + (K'f)^2}; \tag{8}$$

We introduce here the notation $K = K' - iK''$, Ω is the normalized volume.

Let us investigate the expression (8) in the case $1 \ll N \ll 1/2\,\gamma f^2$. Here,

$$K'(E) = \sqrt{2mE} + \eta(\varepsilon)\sqrt{2\gamma/(1 - \varepsilon)},$$

where $|\eta(\epsilon)| \lesssim 1$ for all ϵ. If $K'f \ll 1$ and $K''f \ll 1$, i.e., $(1 - \epsilon) \gg \gamma f^2/2$ and $\epsilon \gg \gamma f^2/2$, then the formula (8) yields

$$W(E) = \frac{4\pi f^2}{\Omega} \sqrt{\frac{2E}{m}} \left[1 + \frac{\eta(\varepsilon)}{\sqrt{N(1 - \varepsilon)}} \right] \tag{9}$$

In the case $E \to (N + 1/2)\gamma/m$,

$$W(E) = \begin{cases} \dfrac{4\pi}{\Omega} \dfrac{1}{m\eta} \sqrt{\dfrac{1 - \varepsilon}{2\gamma}} & \text{for } (1 - \varepsilon) \ll \gamma f^2/2, \\[2ex] \dfrac{8\pi}{\Omega} \sqrt{\dfrac{2E}{m}} \dfrac{\varepsilon}{\gamma} & \text{for } \varepsilon \ll \gamma f^2/2. \end{cases} \tag{10}$$

Equation (8) for $W(E)$ has a maximum value for $K'f \sim 1$, i.e., for $(1 - \epsilon) \sim \gamma f^2/2$, whence

$$W_{max} \sim 2\pi f/\Omega m.$$

It follows from Eqs. (9) and (10) that the width of these resonant peaks is of the order $\Delta E = \gamma^2/4m^2E$.

The energy levels of the electron have a finite width Γ, and δ in Eq. (2) should be replaced by $\Gamma/2$. As a consequence, $K(E)$ is finite for all ϵ, and $W(E)$ does not vanish for any E. However, $W(E)$ will, as before, have resonance maxima if $\Gamma/2 \ll \Delta E$.

I express my gratitude to L. É. Gurevich for his constant attention to the work and also to V. N. Gribov, S. V. Maleev, and L. P. Pitaevskiĭ for useful discussions.

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CERTAIN EXPERIMENTS WITH METASTABLE LIQUIDS IN AN X-RAY BEAM

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To establish the sensitivity of metastable liquids to low-energy electrons and the extent of this sensitivity, and also to carry out test experiments on the photography in a beam of penetrating radiation with the aid of metastable liquids, we placed a 0.75-liter propane bubble chamber in the beam of the URS-70 x-ray structural-analysis apparatus. To reduce the absorption of soft x-rays, an inlet hole 5 mm in diameter was made in the wall of the bubble chamber and was covered with a bakelite layer 3 mm thick. Owing to the pulsations in the tube electrode voltage and to the short sensitivity time of the chamber (on the order of several milliseconds), several pictures were taken for each set of conditions, from which we selected the cases of maximum intensity of action and associated them with the maximum value of the current and voltage in the tube. We observed that bubbles were produced at 10 kev and above (see Figs. 1 and 2), but the sharp change in the penetrating ability and the spectrum of the x-ray beam at low tube voltages does not allow us to draw more definite quantitative conclusions concerning the electron threshold energy necessary to initiate bubbling.

We attempted to photograph an object in an x-ray beam penetrating to the side glass of the chamber. The use of an illuminated layer of metastable (superheated or gassed) liquid as a converter and registrator for the image of objects in the transmitted beam of penetrating radiation (x-rays, γ rays, or neutrons) is of interest because of the extremely high

FIG. 1. Formation of bubbles by x-ray beams at x-ray-tube voltage 10 kv and a current of 10 ma. The input window of the chamber was 30 cm from the anticathode of the tube.

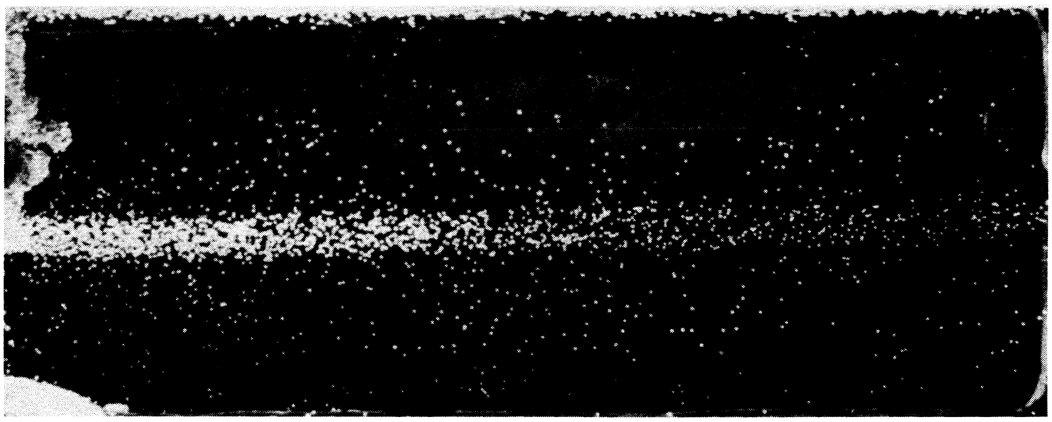

FIG. 2. The same at 30 kv and 1 ma, in the presence of a 9 cm paraffin n absorber in front of the entrance window of the chamber.