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PRODUCTION OF MUON PAIRS IN INTERACTIONS OF HADRONS OF HIGH ENERGY

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In recent experiments of the CERN group [1] they measured the cross section for the production of muon pairs following absorption of protons in uranium. It is customarily assumed that this process follows the scheme of Fig. 1 [2]. However, an important competitor is the purely electromagnetic process of the type shown in Fig. 2. With increasing effective mass of the produced muons, this process becomes the principal one. Let us compare the cross sections of both processes, substituting for simplicity a proton for the uranium. The cross section of the process of Fig. 1 is estimated in accord with vector-dominance scheme [2]. In terms of the effective mass of the pair of produced muons, we have in order of magnitude, in accord with Fig. 1b (cf.

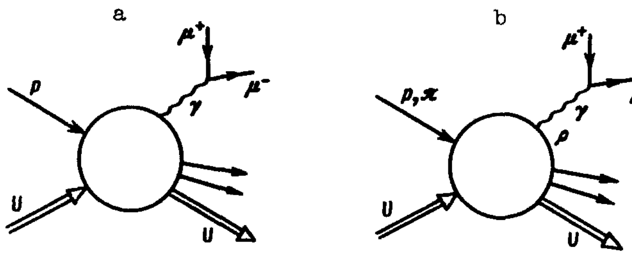

Fig. 1

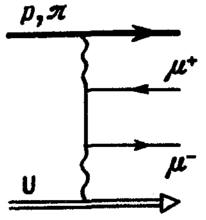

Fig. 2

[2]):

$$\frac{d\sigma^{(v)}}{dM^2} = \frac{\alpha}{3\pi}\frac{1}{M^2}\frac{\alpha m_V^4}{4}\frac{4\pi}{\gamma_V^2}\frac{1}{M^4}\sigma^V(s) \sim \frac{\alpha^2}{12\pi}\frac{m_\rho^2}{M^6}\,. \tag{1}$$

The factor $\alpha/3\pi M^2$ is due to the photon propagator and the muon trace, $\alpha m_V^4 4\pi/\gamma_V^2$ is the square of the coupling constant of the vector meson V with the photon, M^{-4} is the square of the V propagator, and $\sigma^V(s)$ is the total cross section for the production of the vector meson in the pp collision, $\sigma^V(s) \sim m_V^{-2}$. Since the largest of all the $4\pi/\gamma_V^2$ is $4\pi/\gamma_\rho^2 \sim 1$, we assume in the estimate that $m_V = m_\rho$. Landau and Lifshitz [3] calculated the cross section for the production of e^+e^- pairs in collisions of fast particles (in accordance with the scheme of Fig. 2) by the method of equivalent photons. A very simple modification of their results allows us to write down the cross section of the process of Fig. 2 for the production of $\mu^+\mu^-$ pairs with large effective mass:

$$\frac{d\sigma^{(e)}}{dM^2} \sim \frac{4\alpha^2}{\pi}\frac{\alpha^2}{M^4}\ln^2\gamma\left(\ln\frac{M^2}{m_\mu^2} - 1\right)\ln\frac{s}{2M^2} \tag{2}$$

Here γ is the Lorentz factor of the incident proton or pion, $\gamma = s/2m_1m_2$. Thus,

$$\frac{d\sigma^{(e)}}{d\sigma^{(V)}} \sim 48\alpha^2\left(\frac{M}{m_\rho}\right)^2\ln^2\gamma\,\ln\left(\frac{M^2}{m_\mu^2} - 1\right)\ln\frac{s}{2M^2}\,. \tag{3}$$

The value of the right-hand side is of the order of unity when $M \sim M_0 \sim 3 - 4$ GeV. A plot of $d\sigma/dM$ should therefore have a kink of the form shown in Fig. 3 at $M \simeq M_0$. With increasing proton energy E, the value of M_0 decreases, i.e., the kink shifts to the left. At $M_0 \sim 4$ GeV, we should have, according to both estimates

$$d\sigma/dM \sim 6\cdot 10^{-37}\ \text{cm}^2/\text{GeV}. \tag{4}$$

The actual situation may turn out to be much more complicated, since the experiment was performed on uranium and the fraction of the purely protonic contribution in it, estimated in (1 - 4), is unknown. For scattering by a nucleus of mass $A \gg 1$ with charge Z, the cross section (1) is larger by $\sim A^{2/3}$ times and the cross section (2) is larger by Z^2 times, i.e., the ratio (3) increases by $Z^2/\pi A^{2/3} \sim 60$ times (for uranium). There is a corresponding large shift of the kink to the left. However, in the experiment of [1] they registered only muons with a momentum larger than 6 GeV/c. Allowance for this limitation decreases both estimates

$$\frac{d\sigma_A^{(e)}}{dM} \sim \frac{8}{\pi}\frac{\alpha^4 Z^2}{M^2}\ln^2\gamma\left(\ln\frac{M^2}{m_\mu^2} - 1\right)\ln\frac{s}{2M^2}\,. \tag{5}$$

The measured value of $d\sigma_A^{(e)}/dM$ is smaller by approximately three orders of magnitude than that given in [5]. The measured value of $d\sigma_A^{(V)}/dM$ is also smaller than in (5) by three orders of magnitude. As a result, the relation (3) remains practically unchanged, i.e., the kink remains as before at $M \sim M_0 \sim 4$ GeV.

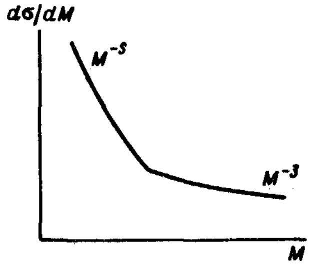

Fig. 3

The measured cross section at the kink does not differ strongly from (3), amounting to $\sim 10^{-36}$ cm^2/GeV. The preliminary data [1] lie between this value and that given in (4).

We thank R.M. Muradyan, whose report of the experiment of [1] stimulated this work, and N.N. Achasov, B.V. Serebryakov, L.D. Solov'ev, G.N. Shestakov, and D.V. Shirkov for useful discussions.

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STIMULATED MANDEL'SHTAM-BRILLOUIN SCATTERING IN THE REGION OF THE CRITICAL LAMINATION POINT OF SOLUTIONS

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We have obtained, for the first time, stimulated Mandel'shtam-Brillouin scattering (SMBS) near the critical lamination point of a solution (Fig. 1a). We investigated a solution of 0.4 molar fractions of nitrobenzene in normal hexane, having an upper lamination temperature $t_c = 20 \pm 0.05°C$.

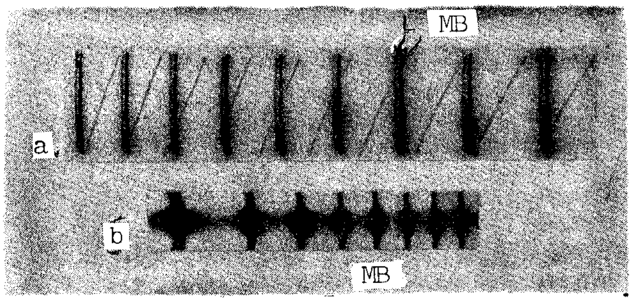

Fig. 1. Interference spectra of stimulated (a - interferometer dispersion region $\delta\nu = 2.5$ cm^{-1}) and thermal (b - $\delta\nu = 0.5$ cm^{-1}) Mandel'shtam-Brillouin (MB) scattering in a solution of 0.4 molar fractions of nitrobenzene in n-hexane at $(t - t_c) = 0.1°C$. L - laser emission line.

The SMBS method has advantages over the method of thermal Mandel'shtam Brillouin scattering (TMBS) in the study of the velocity of hypersound near the critical point of solutions, and also of pure substances[1]. The SMBS spectra can be registered within a time $\sim 10^{-8}$ sec, whereas in TMBS the exposure lasts from several minutes to several hours. In TMBS near t_c the error in the measurement of the positions of the MB components is usually much larger, owing to the increased intensity of scattering at the unshifted frequency [1, 2]. It is obvious that the position of the SMBS components under the same conditions can be measured without loss of accuracy (cf. Figs. 1a and b). In the direct vicinity of the critical point, owing to the decrease of the temperature conductivity, there should be no stimulated

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[1] Tuberman and Morozov [3], following a suggestion by I.L. Fabelinskii, were the first to obtain SMBS near the critical point of a pure substance (CO_2).