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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-5-23. Comments on Standpoint for Analyses of Hard Showers by μ-mesons

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We want to make two theoretical comments.

The first is that the total cross section of hard showers produced by a muon-nucleon or an electron-nucleon collision is limited up to two unknown functions by using only Lorentz invariance and Gauge invariance, like Eq. (1).

$$\sigma=\frac{\alpha}{8\pi^2}\frac{1}{|P_1|^2}\int\frac{d\varepsilon dq^2}{q^4}\Big[L\Big\{(E_1^2+E_2^2)q^2-2m^2\varepsilon^2-\frac{1}{2}q^4\Big\}+L'(2m^2-q^2)q^2\Big], \quad (1)$$

where α is the fine structure constant, ε is the transferred energy from a muon, q^2 is the square of the four dimensional transferred momentum and m is the mass of incident muon or electron. The other notations of momenta are same as those presented in our paper submitted the ordinary session. L and L' are the above mentioned unknown functions of which arguments are q^2, $pq=-M\varepsilon$, and $p^2=-M^2$. The regions of the integrations over ε and q^2 are determined by kinematics and the upper limit of q^2 is given by

$$q^2_{\rm kin}=\mathrm{Min}\{2M(\varepsilon-\kappa)-\kappa^2,\ -2(|P_1||P_2|-E_1E_2+m^2)\} \quad (2)$$

where κ is the pion mass.

We can write down the cross section of the corresponding process by a real photon in the similar way, *i.e.*,

$$\sigma_{h\nu}=\frac{1}{4\pi}\Big(L\varepsilon-L'\frac{q^2}{\varepsilon}\Big)\Big|_{q^2=0} \quad (3)$$

From Eq. (3), we can see that roughly speaking, the contribution from transverse photons is given by L.

The second point of our comments is as follows: theoretical analyses so far performed are based on special assumptions as to L and L'. Assuming the q^2-dependences of L and L', after the integration over q^2 we obtain $d\sigma/d\varepsilon$ which is able to be compared with these analyses. The table shows the forms of L and L' on which these theories are based.

At present, our knowledge about the strong

Table I.

	W—W[1]	M—U[2]	K—K[3]	(a)
$N(\varepsilon)\sim$	$\frac{1}{\varepsilon}\log\frac{E_1}{\varepsilon}$	$\frac{1}{\varepsilon}\log\frac{\chi}{m}\frac{E_1}{\varepsilon}$	$\frac{1}{\varepsilon}\log\frac{E_1}{m}$	$\frac{1}{2\varepsilon}\log\frac{ME_1E_2}{m^2\varepsilon}$
L'	0	0	1	0
$\frac{L}{(4\pi\sigma_{h\nu}/\varepsilon)}$	$\frac{\Lambda^2}{q^2+\Lambda^2}(\Lambda\sim m)$	$\frac{\Lambda^2}{q^2+\Lambda^2}(\Lambda\sim\kappa)$	1 $q^2{}_{\max}=\frac{E_1}{E_2}\varepsilon^2$	1 $q^2{}_{\max}=q^2{}_{\rm kin}$

$N(\varepsilon)$ is the main part of the spectrum of photons accompanying incident muon or electron. In K—K, the upperlimit of q^2 integration ($p^2{}_{\max}$) is larger than the kinematical limit for large ε. Putting $q^2{}_{\max}=q^2{}_{\rm kin}$, we obtain the spectrum given in the last column. The last case corresponds to the case (a) (c.f. our paper in the ordinary session).

interaction is not enough to determine which theory is good. Even there may be the possibility that all of these theories are wrong. In other words, we must determine the L and L' from experiments on hard showers produced by a muon or an electron. Then we will obtain some new information about the character of strong interaction.

References

1) E. J. Williams: Kgl Dansk. Vid. Selsk. **13** (1935) 4.
2) T. Murota and A. Ueda: Prog. Theor. Phys. **16** (1956) 497.
3) D. Kessler and P. Kessler: Nuovo Cimento **4** (1956) 601. P. Kessler: Nuovo Cimento **17** (1960) 809.

Discussion

Yamaguchi, Y: I would like to know the experimental distribution of q^2.

Kobayakawa, Y: I would like to answer Prof. Yamaguchi question. I will show the integral spectrum of q^2 in our slide.

Messel, H.: I would like to assume members present that there exists a real question problem in regard to the question of the interaction of μ-mesons at high energies, and one which will have to be resolved both on the theoretical and experimental front.

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III-5-24. Deep Underground Studies of Muon Intensities and Investigations on the Interactions of Muons

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In this report I shall deal with the present status of our knowledge concerning the intensities of μ-mesons at various depths deep undergound, as also the situation concerning the interactions of μ-mesons.

Miyake, Narasimhan and Ramanamurthy[1] have reported new measurements from an experiment, which is in progress in the Kolar Gold Fields in South India, on μ.meson intensities deep underground. These constitute the best, directly obtained, data available thus far at the deepest depths considered, >3000 mwe. A telescope, of area $\sim$1.5 m^2, consisting of scintillators in coincidence, was used by them to measure intensities at depths of 816, 1812, 3410 and 4280 mwe. Details of the experiment are contained in the paper of Miyake *et al*[1]. Valuable data on intensities at great depths is also available from a recent experiment carried out by Barton[2].

The available information on μ-meson intensities at various depths underground is shown in Fig. 1. This figure is based on: the data as summarized by Barrett *et al*[3], some earlier measurements by Sreekantan *et al*[4] in the Kolar Gold Fields, the recent observations of Barton[2], the intensities derived by Bollinger, as reported by Pine *et al*[5], and the most recent work of Miyake *et al*[1]. It can be seen that there is good agreement throughout between the various determinations. There does appear to be a scatter of points at the greatest depths investigated. This is mainly due to the fact that the data of Bollinger, (obtained from angular distribution measurements at 1500 and 1840 mwe), are first shown as values *uncorrected* for decay effects; the values corrected for decay effects are in good agreement with the re-