Note on Meson Production

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IN an earlier paper,[1] formulas were derived, on the basis of the pseudoscalar meson theory, which describe the multiplicity and angular distribution of mesons produced in nuclear collisions involving extremely high energies. It is the purpose of this note to rewrite these formulas in such a way that they can somewhat more justifiably be applied to the region of intermediate primary energies (5–15 Bev). In this connection, we have in mind, in particular, comparison with the cloud-chamber experiments of Fretter.[2]

In this range one must consider the difference between γMc^2, the energy of the primary nucleon in the center of mass system, and ϵ, the largest energy it can lose in that system through meson production (called ϵ_{max} in M). We take $\epsilon=(\gamma-\alpha)Mc^2$, where α is a parameter which must probably be chosen between 1 and 2, and which represents, roughly, the energy below which a nucleon ceases to radiate mesons effectively. The only reason for the appearance of such a parameter is the high energy approximation made in M, and one can expect that a more careful theoretical calculation, expressly intended for the intermediate energy region, should serve to determine the best value of α, in the approximation in which one can make the cut-off in this crude way.

The multiplicity is, then, proportional to $\epsilon^{\frac{1}{2}}$, hence to $[(1+\gamma_0)^{\frac{1}{2}}-2^{\frac{1}{2}}\alpha]^{\frac{1}{2}}=F(\gamma_0)$, where γ_0Mc^2 is the energy of the primary nucleon in the laboratory system.* To obtain the multiplicity, one must multiply this by a factor estimated in M to be about 4, and whose explicit expression is given there. $F(\gamma_0)$ is plotted in Fig. 1,

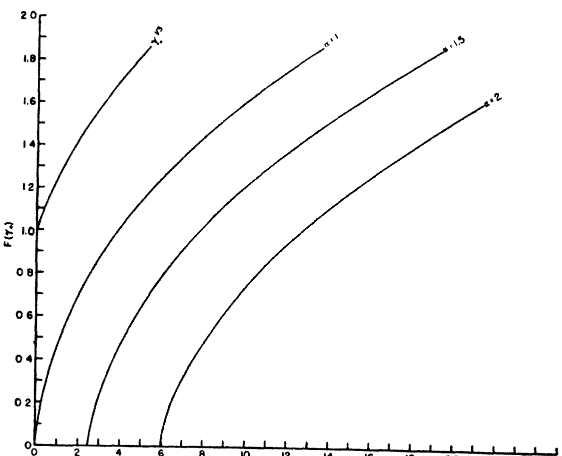

FIG. 1. $F(\gamma_0)$ as a function of primary kinetic energy. The most probable multiplicity is $\sim 4F(\gamma_0)$.

for three values of α, along with the asymptotic form $\gamma_0^{\frac{1}{4}}$. The failure of the asymptotic approximation, even for moderately high primary energies, should be noted.

The calculation of the mean square angular spread of the mesons leads to a number of superficial complications in integration. One can, however, obtain a rough estimate without undue effort, and finds $\overline{\vartheta^2}\approx 2/(1+\gamma_0)[1+\ln 2\gamma_0]$, with an accuracy of around 25 percent. An interesting feature of this result is its independence (to this approximation) of ϵ, and of the multiplicity, hence of α. One must be careful in applying this to a practical case, since the major contribution to the angular spread comes from slow mesons. Thus, for $\gamma_0=5$, if one were to leave out the contributions from mesons with kinetic energy below around 125 Mev, the factor in square brackets would be reduced to unity. This should be considered in the interpretation of an experiment.

It does not seem worth while to carry these calculations any further, particularly since the formulas given in M were not intended for the intermediate energy region, but also because of the inherent uncertainty of the underlying theory.

* $\gamma_0=2\gamma^2-1$.

[1] Lewis, Oppenheimer, and Wouthuysen, Phys. Rev. **73**, 127 (1948) hereinafter referred to as M.
[2] W. B. Fretter, Phys. Rev. **76**, 511 (1949).

Proximity Effects in the Measurement of Magnetic Susceptibility

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EXPERIMENTS have been performed to determine the effect of interaction between particles in measuring the magnetic susceptibility of suspensions containing superconducting spheres. The susceptibility was determined from the changes produced in the self-inductance of an air-core measuring coil when the suspension was introduced into the coil. The specimens were prepared from four different size-ranges of lead spheres (purity 99.9+ percent) dispersed in vaseline to give lead concentrations ranging from 1.7 percent to 9.3 percent by volume. All the samples were contained in Pyrex test tubes 5 cm long and 0.6 cm i.d. The magnetic field of the coil was parallel to the axis of the test tube in all cases. The diameter of the lead spheres ranged from 4.9×10^{-2} to 17.5×10^{-2} cm, so that the effect of penetration depth could be neglected.

The results are shown in Fig. 1, where χ/χ_0 is plotted as a

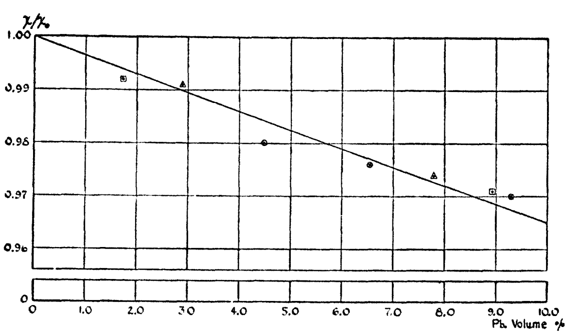

FIG. 1. Relation between χ/χ_0 and volume concentration. The points ⊡, △, ⊗ and ⊙ correspond to samples in which the diameter of the spheres ranged from 4.9 to 7.1×10^{-2} cm; 7.1 to 8.4×10^{-2} cm; 8.4 to 10.0 $\times10^{-2}$ cm; and 16.5 to 17.5×10^{-2} cm, respectively.

function of the lead volume concentration. χ is the apparent susceptibility of the lead spheres as obtained from the changes in self-inductance of the coil and χ_0 is the susceptibility of an ideal spherical superconductor when interaction is negligible.[1] It is to be noted that the line in Fig. 1 was made to pass through $\chi/\chi_0=1$ for zero percent volume, since this is a requirement for any curve relating these quantities. The deviation of each point from the line *drawn* in Fig. 1 is smaller than the over-all uncertainty in the corresponding experimental observations.

The relation between χ/χ_0 and concentration seems to be independent of the size of the spheres over the range used. Thus, it should be possible to utilize these results to correct the susceptibility measurements on samples containing much smaller spheres. For example, if the radius of the spheres was of the order of λ, the penetration depth, an appropriate correction could be made by determining the "effective" volume concentration. This "effective" concentration could be estimated by means of the London theory[2] if the radius of the spheres, R, and the order of the magnitude of λ are known.

[1] See D. Shoenberg, Proc. Roy. Soc. **A175**, 49 (1940).
[2] F. London, Physica **3**, 450 (1936).