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HIGH VELOCITY PARTICLE RANGES IN EMULSION

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An experimental program to determine the range-momentum relation for emulsion at high particle velocities has been undertaken because of the current and continuing need for such information. Ranges of five groups of mesons in Ilford G-5 emulsion have now been determined. The independent parameter was the particle momentum which was measured to better than one part in 1000 by bending the particles through $\approx 180^{\circ}$ in the magnetic field of the 184" cyclotron and computing the momentum of individual orbits by the method of Barkas, Birnbaum and Smith.[1]

The emulsion as received from the manufacturer was stored in a closed container for several weeks to attain uniform equilibrium[2] with a definite content of water. The specific gravities of 17 samples (1-2 gm) of the emulsion were then determined by weighing in air, in CCl_4, and again in air. By Archimede's principle we obtained a specific gravity of 3.8225, and the standard deviation was 0.0062. The deviations are real and must correspond to fluctuations in the local density of the emulsion in excess of the expected statistical variance.[3]

For the measurements we exposed four emulsion stacks. They were located at various radial distances from a small polyethelene target bombarded by the internal proton beam of the cyclotron. Location of a considerable amount of heavy element shielding as indicated by previous experience[1] proved effective in eliminating confusable tracks. The data were entirely free of background, and the range straggling[3] was as expected on the assumption that each orbit originated in the target, allowance being made for the target dimensions. Measurements of the magnetic field in vacuum were made to a few parts in 10,000, and the distances from the target to fiducial points in the emulsion were determined with similar accuracy. The position and angle of entry of each track into the emulsion was recorded.

The rectified ranges were measured by breaking up each track into many straight segments. By determining the emulsion thickness before and after processing, the shrinkage factor was obtained. Before exposure each stack of pellicles was clamped firmly between bakelite boards. The edges were then machined flat in a milling machine. It was found on releasing the clamping pressure after exposure that the area of each sheet decreased. Range corrections for this deformation varying from two to five tenths of a percent were required. The magnitude of this type of deformation is of sufficient importance so that cognizance should be taken of it in other experiments.

For the analysis of the results we introduced as a "standard range curve" that of Barkas and Young.[4] Taking the positive pion to proton mass ratio[1] to be 0.14887, a range-momentum relation is predicted for pions. If the measured range of a pion of momentum p is R and the standard range is R_o, then the quantity $u = (R - R_o)/R_o$ is expected to have approximately a gaussian distribution when the R_o are limited to a small interval. The mean value of u measures the deviation of the experimental result from the standard curve, and $\sigma^2 = \langle u^2 \rangle - \langle u \rangle^2$ measures the range variance. The quantities $\langle u \rangle$ and σ are slowly varying functions of the velocity. In Table I the ranges at particular values of the velocity are derived from the standard curve and the local values of $\langle u \rangle$. Since the standard range is calculated for emulsion of specific gravity 3.815, a slight correction is necessary for the difference in emulsion densities. Table I includes a point derived from the ranges of 100 muons produced by the decay of pions in the emulsion.

Many range measurements for particles of low velocity are to be found in the literature, but in almost no case has the emulsion density been measured or was it known to be independent of depth below the emulsion surface.[2] As part of this investigation we have obtained a considerable amount of range data at low particle velocities while attempting to keep the emulsion density uniform and known, but, because of the added complexity and the difficulty of these measurements, a complete report will be deferred until further checks are made. It can be stated, nevertheless, that existing range curves for slow particles are incorrect by several percent if applied to emulsion having the density usual in stacks.

This work was done under the auspices of the U. S. Atomic Energy Commission.

TABLE I

Measured Momenta and Ranges

Particle	μ^+	π^+	π^+	π^+	π^+
Measured Momentum (Mev/c)	29.80	95.94	129.2	172.0	199.9
Measured Particle Mean Range (cm)	0.06013 ±0.00025	1.5235 ±0.0088	3.655 ±0.018	7.759 ±0.048	11.008 ±0.059
Mean Range (cm) Adjusted to Standard Density	0.06022 ±0.00025	1.526 ±0.009	3.661 ±0.018	7.771 ±0.048	11.025 ±0.059
Equivalent Proton Energy (Mev)	36.55	200	340	550	700
Equivalent Proton Range (cm)	0.5344 ±0.0022	10.25 ±0.06	24.59 ±0.12	52.20 ±0.32	74.06 ±0.40
Percent Straggling (100 σ)	4.1 ± 0.4	3.9 ± 0.4	2.7 ± 0.4	2.8 ± 0.5	2.5 ± 0.4
Theoretical Straggling[3]	4.1	3.0	2.8	2.6	2.6

REFERENCES

1. Walter H. Barkas, Wallace Birnbaum, and Frances M. Smith, Phys. Rev. (in press) 1956.

2. A. Oliver, Rev. Sci. Instr. 25, 326 (1954).

3. Walter H. Barkas, Frances M. Smith, and Wallace Birnbaum, Phys. Rev. 98, 605 (1955).

4. Walter H. Barkas and D. M. Young, University of California Radiation Laboratory Report No. UCRL-2579 Rev. (unpublished).