SLAC-21
UC-28, Particle Accelerators and High-Voltage Machines
UC-34, Physics
TID-4500

PION PHOTOPRODUCTION IN HYDROGEN AND BERYLLIUM

October 1963

by

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Technical Report
Prepared Under
Contract AT(04-3)-400
for the USAEC
San Francisco Operations Office

Printed in USA. Price $1.25. Available from the Office of Technical Services, Department of Commerce, Washington 25, D.C.

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ERRATA -- SLAC-21

Page	Line	
2	Eq. 4	Insert "dpdΩ" after "S(P,B)."
12	6	"velocity B" should be "velocity β."
15	horizontal axis	Numbers "1,2,3,4" should be "0.1,0.2, 0.3, 0.4."
38,39	2	Add "in BeV" after "F(P,θ)."
40,41,42,43	2	Add "in mb BeV^{-2}" after "observation."
44	two places on left margin	"ρ" should be "P in BeV/c."

PION PHOTOPRODUCTION IN HYDROGEN AND BERYLLIUM

INTRODUCTION

Some numerical evaluations of the Drell cross section for pion production are presented in this report. The construction of a number of tables and graphs for determining pion production rates is discussed in the first three sections. The remaining sections are devoted to the discussion of some corrections to these basic rates.

I. CONSTRUCTION OF THE BASIC TABLES

The cross section for observing a photo-produced pion in a momentum interval dp about p (total energy E) and in a solid angle $d\Omega$ about θ is given by[1]

$$d^2\sigma' = dp d\Omega \frac{\alpha}{8\pi^2} \cdot \frac{\gamma^4 \ p \sin^2\theta \ (1 + \beta \cos \theta)^2}{(1 + \beta^2\gamma^2 \sin^2\theta)^2} \cdot \frac{K - E}{K^3} \cdot \sigma \ (K - E - m) \qquad (1)$$

where K is the photon energy, β and γ are the usual kinematic parameters of the pion, $\sigma(\epsilon)$ is the total pion-nucleus cross section at lab kinetic energy ϵ and m is the pion mass. If the photons are not monochromatic, we must integrate over a photon spectrum. In the case of thin target bremsstrahlung coming from a radiator of T radiation lengths the average number of photons of energy K emitted by an electron of energy B is given by the approximate expression

$$\Phi \ (K) \ dK = T \frac{dK}{K} \left[\frac{4}{3} \left(1 - \frac{K}{B}\right) + \left(\frac{K}{B}\right)^2\right] \qquad (2)$$

Combining (1) and (2) for the average pion-production cross section per incident electron, we obtain

$$d^2\sigma = \int_{E+m}^{B} dK\ \Phi(K)\ d^2\sigma' \tag{3}$$

$$= T \cdot F(P,\theta) \cdot S(P,B) \qquad dp\,d\Omega \tag{4}$$

where

$$F(P,\theta) = \frac{\alpha}{8\pi^2} \cdot \frac{p\ \gamma^4 \sin^2\theta\ (1 + \beta \cos\theta)^2}{(1 + \beta^2 \gamma^2 \sin^2\theta)^2} \tag{5}$$

and

$$S(P,B) = \int_{m+E}^{B} \frac{dK}{K^3}\ (K - E)\ \frac{\Phi(K)}{T}\ \sigma(K - E - m) \tag{6}$$

In case a single medium is used for both photon and pion production, a factor of 1/2 should be inserted in (4).

When sufficiently high energies are involved so that there is a region of integration in (6) where $\sigma(K - E - m)$ is a constant, this part may be integrated analytically. Let ϵ_o be the energy above which $\sigma(\epsilon)$ is a constant and let $L = \epsilon_o + m + E$. Then we have

$$S(P,B) = \int_{m+E}^{L} \frac{dK}{K^3}\,(K - E)\,\frac{\Phi(K)}{T}\,\sigma(K - E - m)$$

$$+ \sigma(\epsilon_o)\left[\frac{7}{9}\ \frac{E}{B^3} + \left(\frac{2}{3} - \frac{E}{L} + \log\frac{B}{L}\right) \cdot \frac{1}{B^2} \right.$$

$$\left. + \frac{2}{3}\left(\frac{E}{L} - 2\right) \cdot \frac{1}{BL} + \frac{2}{3}\left(1 - \frac{2}{3}\frac{E}{L}\right)\frac{1}{L^2}\right] \tag{7}$$

Since the observed cross section separates into a product according to (4), a relatively concise tabulation is possible. For each type of target nucleus a two-dimensional table can be constructed giving $S(P,B)$. Another two-dimensional table can be constructed for $F(P,\theta)$, and cross sections are obtained from the tables by using (4). In this report we make tables of $S(P,B)$ for both hydrogen and beryllium targets.

II. DETERMINATION OF $\sigma(\epsilon)$

We first list some methods for obtaining values of $\sigma(\epsilon)$ for complex nuclei:

1. Experimental values of the pion-nucleus cross section may be available. In the case of Be^9, experimental information is rather scarce. The information is fortunately concentrated around the 3,3 resonance region but there is no data for the higher resonances and very little for the high energy asymptotic region.

2. The cross sections can be derived on the basis of an optical model calculation in which experimental values of the pion-nucleon total cross sections and phase shifts are used as input.[2,3]

3. The $\pi^{\pm}$ - p total cross sections can be linearly combined according to the isotopic spin combinations and multiplied by $A^{2/3}$. Thus for negative pion observation,

$$\sigma_A^- = A^{2/3}\left[\frac{A - Z}{A}\,\sigma^+ + \frac{Z}{A}\,\sigma^-\right] \qquad (8)$$

where $\sigma^{\pm}$ is the total $\pi^{\pm}$ - proton cross section. Instead of the choice $A^{2/3}$ as in (8), one may multiply by a factor that best fits the experimental data. It is found, in fact, that $A^{2/3}$ is too small in the case of light elements.

4. If considerable information about σ is available for a nucleus, e.g., carbon, other than the nucleus under consideration, we may apply some rule to transform this information to the unknown nucleus. For example,

a. $\frac{\sigma'}{\sigma''} = \left(\frac{A'}{A''}\right)^{2/3}$

b. $\frac{\sigma'}{\sigma''}$ = some constant chosen to fit any available data

Sternheimer's method,[3] a particularly simple optical model approach, is used in this report for constructing the S(P,B) tables for beryllium. The method assumes that a nucleus is characterized by a square-well potential of uniform complex-valued depth. Refraction of the incident pion wave at the nuclear surface is neglected. The change k_1 in wave number as the pion enters the nucleon volume and the reciprocal mean free path k_2 are related to the elementary pion-nuclear scattering by

$$k_1^{\pm} = 2\pi\rho \left[Z\ D_{\pm} + (A - Z)\ D_{\mp}\right] \Big/ kA \qquad (9)$$

$$k_2^{\pm} = \rho \left[Z\ \sigma^{\pm} + (A - Z)\ \sigma^{\mp}\right] \Big/ A \qquad (10)$$

where

ρ = nucleon density = $\frac{1}{4/3\ \pi r_o^3}$

r_o = nuclear radius (generally $r_o = 1.4f$)

k = free pion wave number

$D_{\pm}$ = real part of forward scattering amplitude for $\pi^{\pm} - p$ scattering

$\sigma^{\pm}$ = total $\pi^{\pm} - p$ cross section

Upper and lower signs on k_1 and k_2 refer to π^+ and π^- - nucleus scattering, respectively.

We then have for the $\pi^{\pm}$ - nucleus total cross section,[4] with $\pm$

signs suppressed on k_1 and k_2:

$$\sigma_A^{\pm} = 2\pi R^2 - \frac{\pi}{\left[\frac{1}{4}k_2^2 + k_1^2\right]^2} \left\{ \left(\frac{1}{4}k_2^2 - k_1^2\right) + \right.$$

$$+ e^{-k_2 R}\left[2k_1 R\left(\frac{1}{4}k_2^2 + k_1^2\right) + k_1 k_2\right] \sin 2k_1 R + \tag{11}$$

$$\left. - e^{-k_2 R}\left[\frac{1}{4}k_2^2 - k_1^2 + k_2 R\left(\frac{1}{4}k_2^2 + k_1^2\right)\right] \cos 2k_1 R \right\}$$

where

$$R = A^{1/3} r_o$$

III. EXPLANATION OF TABLES AND GRAPHS

Table I contains $\pi^{\pm}$ Be^9 experimental total cross sections.

Values of $D_{\pm}$ were read from the curves computed from dispersion relations by Sternheimer[3] and are reproduced in Table II. For $\epsilon \geq 2.4$ BeV we set $D_+ = -0.31f$ and $D_- = -0.36f$.

Table III gives the total $\pi^{\pm}$ - proton cross section $\sigma^{\pm}$ obtained by reading values from the curves given in several sources.[5,6,7] For $\epsilon \geq 6.0$ BeV we always set $\sigma^+ = 26.7$ mb and $\sigma^- = 28.6$ mb.

Figures 1A and 1B show the total $\pi^{\pm}$ - beryllium cross section as computed by Eq. (11) with $r_o = 1.4f$ and with $r_o = 1.733f$. The latter value of r_o gives cross sections which are in good agreement with the experimental values, also shown in Fig. 1, and which are the ones used in evaluating S(P,B) in all the tables and figures for beryllium. The data of Ref. 12 was ignored in determining this best fit because it seemed quite inconsistent with the other data. For $\epsilon \to 0$, according to Eq. (11), $\sigma_A^{\pm}$ rises sharply to 816 mb (with $r_o = 1.733$). To avoid the use of an unusually fine integration mesh to handle this behavior, we arbitrarily let $\sigma_A^{\pm}$ go to 0 at $\epsilon = 0$. This procedure is justified since the final results for pion yields are insensitive to the behavior of $\sigma_A^{\pm}$ near $\epsilon = 0$. While Eq. (11) does not give a constant cross section as a function of energy even if $\sigma^{\pm}$ and $D^{\pm}$ are taken as constants, in calculating $S(P,B)$ we set $\sigma_A^{\pm}(\epsilon) = \sigma_A^{\pm}(6.0 \text{ BeV})$ for $\epsilon \geq 6.0$ BeV and thus made use of Eq. (7). These computed high energy values of the pion-beryllium cross section are $\sigma_A^{+} = 212$ mb and $\sigma_A^{-} = 210$ mb.

Table IV gives values of $F(P,\theta)$.

Tables V and VI respectively give values of $S(P,B)$ for observing negative and positive pions from a proton target.

Tables VII and VIII respectively give values of $S(P,B)$ for observing negative and positive pions from a beryllium target.

The negative pion yield in 1/2-inch of beryllium produced by thin-target bremsstrahlung normalized to 10^{10} BeV is given in Table IX. The angles and energies are specialized for the case of the CEA experiment.

Figures 2 through 9 give the number of pions produced by thin-target bremsstrahlung passing through 10 cm of liquid H_2. The bremsstrahlung is produced by 10^{10} electrons of energy B passing through 0.1 radiation lengths. The number written above each curve is B in BeV, the horizontal scale is θ in degrees, and the vertical scale is $10^{-5} \times$ the pion yield. The pion momentum in BeV/c and its charge are indicated at the bottom of each figure.

Figures 10 through 13 give the number of positive pions produced in 1/2-inch of beryllium. The rest of the description of these curves is the same as for Figs. 2-9 above. Numbers for negative pions are slightly smaller but are so nearly the same as those of positive pions that separate curves were not drawn.

IV. THICK RADIATOR CORRECTIONS

In case the thin-radiator bremsstrahlung approximation is unrealistic, it would be useful to have a quick rule for converting pion yields determined in this report to yields from thick radiator bremsstrahlung.

We consider two different geometrical arrangements:

A. First suppose that a bremsstrahlung beam is produced by monoenergetic electrons passing through a thick target. All particles other than photons are swept out of the emerging beam in a matter-free space and pions are then photo-produced in a second medium.

A simple analysis, after Ballam,[13] of the first generation photons is as follows:

The probability that an electron initially of energy B has an energy E in the interval dE at depth t is given by

$$P(E)\ dE \approx \left(\log \frac{B}{E}\right)^{\frac{t}{\log 2} - 1} dE$$

With E not much smaller than B we have approximately

$$P(E)\ dE \approx \left(1 - \frac{E}{B}\right)^{\frac{t}{\log 2} - 1} dE$$

which, when normalized to unit incident beam, is

$$P(E)\ dE = \frac{t}{B \log 2} \left(1 - \frac{E}{B}\right)^{\frac{t}{\log 2} - 1} dE$$

The number of photons of energy K in interval dK emitted in interval dt is then

$$\frac{dK}{K}\int_K^B dE \frac{t}{B \log 2}\left(1 - \frac{E}{B}\right)^{\frac{t}{\log 2}-1} = \frac{dK}{K}\left(1 - \frac{K}{B}\right)^{\frac{t}{\log 2}} dt$$

Integrating over t and including the probability, $e^{-7/9(T-t)}$, that these photons leave the radiator, of total thickness T, we obtain for the first generation photon spectrum

$$\Phi''(K)\, dK = T\,\frac{dK}{K}\, e^{-7/9T}\, f(z)$$

where

$$f(z) \equiv \frac{e^z - 1}{z}$$

$$z \equiv T\left[\frac{\log(1 - x)}{\log 2} + \frac{7}{9}\right]$$

$$x \equiv \frac{K}{B}$$

For comparison, the thin target spectrum is

$$\Phi'(K)\, dK = T\,\frac{dK}{K}$$

Let us now define a correction factor to be applied to pion yields or cross sections determined by the thin target approximation with the simplification $m \to 0$ and $\sigma(K - E - m) \to$ constant σ_o:

$$C_A(R, T) = \frac{\int_P^B dK\, \Phi''(K)\, d^2\sigma'}{\int_P^B dK\, \Phi'(K)\, d^2\sigma'}$$

with $R = \frac{P}{B}$.

Removing factors which are unaffected by the integrations we have

$$C_A(R, T) = \frac{e^{-7/9T} \int_R^1 \frac{dx}{x^4} (x - R) f(z)}{\int_R^1 \frac{dx}{x^4} (x - R)}$$

$$= \frac{6R^2}{(1 - R)^2 (1 + 2R)} e^{-7/9T} \int_R^1 \frac{dx}{x^4} (x - R) f(z)$$

Thus the rule for arrangement A is to calculate the pion yield or cross section according to Eq. (4) and then to multiply by the factor $C_A(R, T)$.

In Fig. 14, we have plotted $C_A(R, T)$ as a function of R for a number of values of T.

B. As a second arrangement, one in fact proposed for producing neutrinos, a single medium is used for producing both photons and pions. We will also consider the attenuation of pions by nuclear interaction by introducing a pion mean free path λ.

A simple analysis analogous to that of arrangement A is as follows: The $dtdN = dK/K\ (1 - K/B)^{t/\log 2}\, dt$ photons radiated at depth t will reach a further depth S with probability $e^{-7/9S}$ where pions will be produced with probability $\sigma(K)\, ds$. The probability that the pions will leave the medium without nuclear interaction is then $e^{-(T-S-t)/\lambda}$.

We thus obtain a correction factor

$$C_B(R, T, \lambda) = \frac{\int_E^B dK \int_o^T dt \int_o^{T-t} ds \frac{\left(1 - \frac{K}{B}\right)^{\frac{t}{\log 2}}}{K} e^{-7/9S}\, \sigma(K)\, e^{-\frac{(T-S-t)}{\lambda}}}{\int_E^B dK \frac{\sigma(K)}{K} \int_o^T dt \int_o^{T-t} ds}$$

The dsdt integrations give

$$C_B(R, T, \lambda) = \frac{\int_E^B dK\ \sigma(K) \cdot N}{\int_E^B dK\ \sigma(K)}$$

where

$$N = 2\ \frac{-\left(\frac{1}{\lambda}\right)^2\left(x + \frac{7}{9}\right) g\left(-\frac{T}{\lambda}\right) + \left(\frac{7}{9}\right)^2\left(x + \frac{1}{\lambda}\right) g\left(-\frac{7}{9}T\right) + x^2\left(\frac{7}{9} - \frac{1}{\lambda}\right) g\left(Tx\right)}{\left(\frac{7}{9} - \frac{1}{\lambda}\right)\left(x + \frac{7}{9}\right)\left(x + \frac{1}{\lambda}\right)}$$

$$x = \frac{\log\left(1 - \frac{K}{B}\right)}{\log 2}$$

$$g(z) \equiv \frac{e^z - 1 - z}{z^2}$$

As in A, we let $\sigma(k) \to$ constant and $k = E/B$ to obtain

$$C_B(R, T, \lambda) = \frac{6R^2}{(1 - R)^2\ (1 + 2R)} \int_R^1 \frac{dz}{z^4}\ (z - R) \cdot N$$

In Fig. 15 we have plotted $C_B(R, T, \lambda)$ as a function of R for $\lambda = 0.94$ radiation lengths (approximately the value for hydrogen) and for several values of T.

V. NUCLEON RECOIL EFFECT

In a realistic pion production calculation some of the energy of the photon is carried off by the recoiling nucleon. The lower limit on the integral over the photon energy becomes dependent on θ and a separation of the cross section into a product (Eq. 4) is not possible.

Several examples are presented here to give an idea of the magnitude of the effect. The photon energy threshold K_L in the process

$$\gamma + N \rightarrow \pi + (N + \pi)$$

is

$$K_L = \frac{E + m}{1 - \frac{E - p\cos\theta}{M}}$$

where E, p, and m are pion energy, momentum, and mass, respectively, and M is nucleon mass.

Figures 16 through 20 show the pion rates in hydrogen as a function of angle in degrees with $M = \infty$ for the upper curves and $M = 0.938$ BeV for the lower curves. Pion momentum P and maximum photon energy B in BeV are indicated in each graph. The vertical scale is in arbitrary units.

Note that from 0° to the position of the Drell peak the effect is clearly negligible in the examples chosen. Only at angles large in comparison to the Drell angle and at P close to B is the effect significant.

VI. EFFECT OF NUCLEAR FERMI MOTION

It has been suggested that the internal motion of nucleons within a complex nucleus could have the effect of washing out the predicted form of the Drell cross section. We present purely kinematical arguments here to show that the effect should be negligible. Consider a photoproduction process

$$\gamma + A \to \pi + B$$

where B is allowed to have a continuum of masses. Given the functional form of the cross section $d^2\sigma(\theta, p, K)/d\Omega dp$ for production of the π in the c.m. system of A, we ask what the form of the cross section in the lab system is where A is moving with a velocity $\vec{\beta}$ perpendicular to the photon direction. θ and p denote the pion angle and momentum, respectively, while K is the photon energy.

Upon carrying out this kinematical calculation for the Drell form of the cross section, the details of which we omit, we obtain some rather surprisingly small results:

1. The position of the forward zero is shifted by an angle $\approx \frac{1}{2} \beta\, \theta_D^2$ where θ_D is the characteristic angle of production (m/p). The exact result for $\beta \to 1$ is

$$\frac{1}{2} \sin^{-1} (\theta_D^2)$$

2. The angular shift of the peak is again of the order $\beta\theta_D^2$.

3. The differential cross section in the forward direction averaged over different velocities of the nucleus, while no longer zero, is down by a factor of the order θ_D^2 times the Drell maximum differential cross section.

Thus we have taken the extreme case where the nucleus as a whole has an arbitrary velocity perpendicular to the photon direction, and have found the resulting distortion in the functional form of the cross section to be generally negligible in the sense that θ_D^2 is negligible in comparison to θ_D. This strongly suggests that internal motion of individual nucleons in a nucleus also ought to cause a negligible distortion. While the first result listed depends only on the fact that the cross section has a forward zero and is otherwise form independent, the second and third are dependent on the peculiar form of the Drell cross section and are not general results applicable to production processes.

The analytic results listed above were verified by a machine calculation that plotted the differential cross section as a function of angle in the lab system for several values of β.

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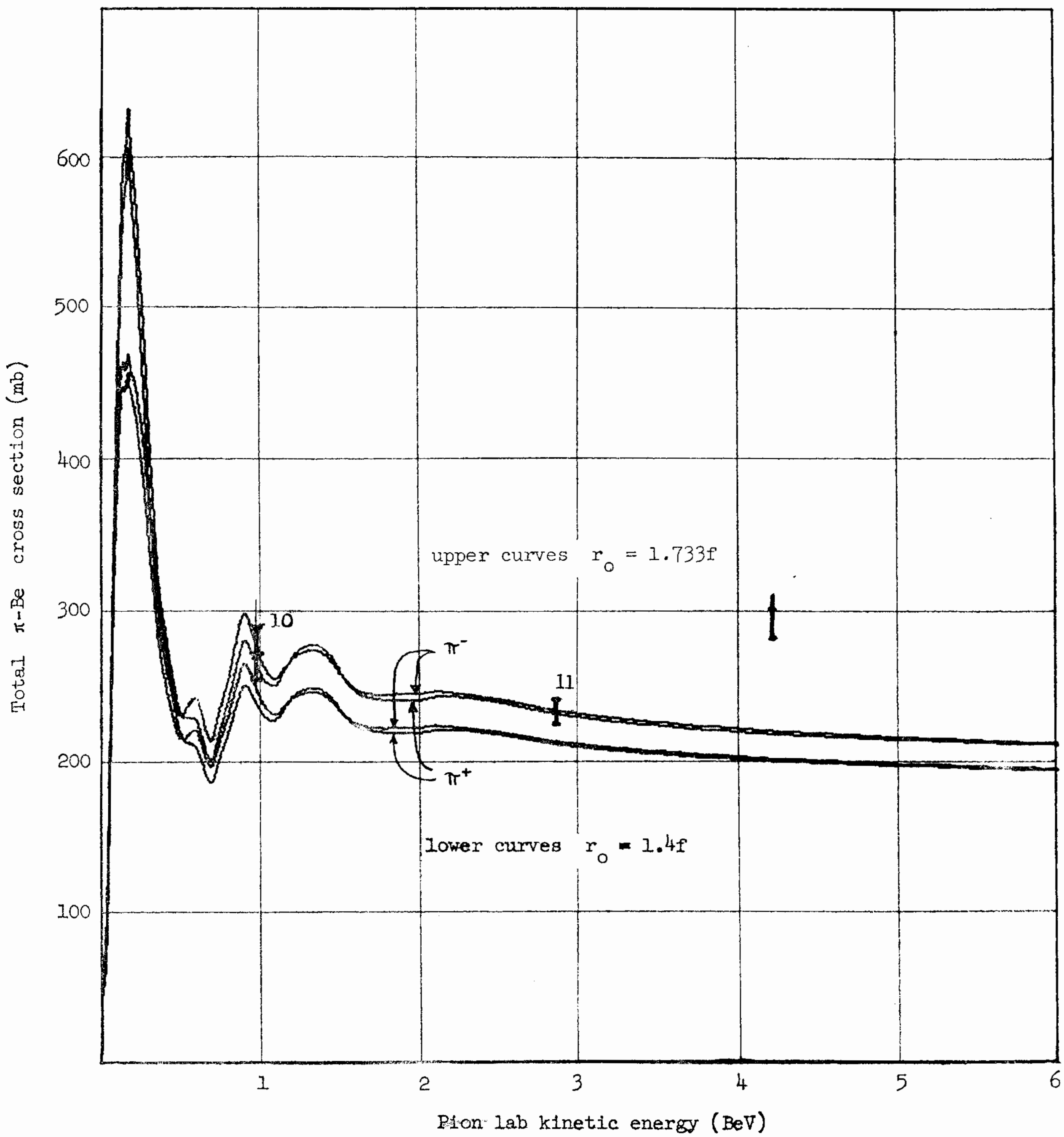
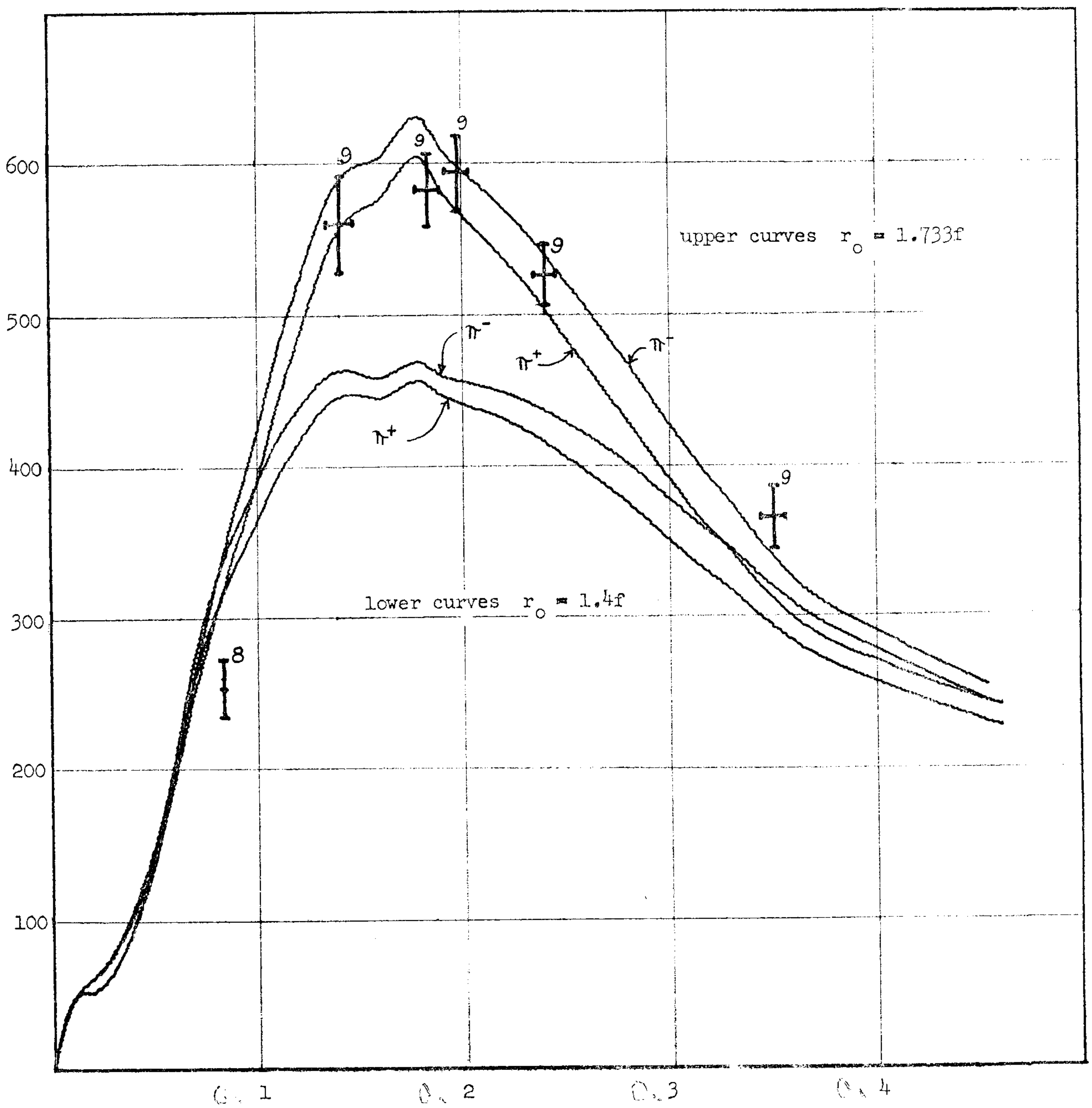
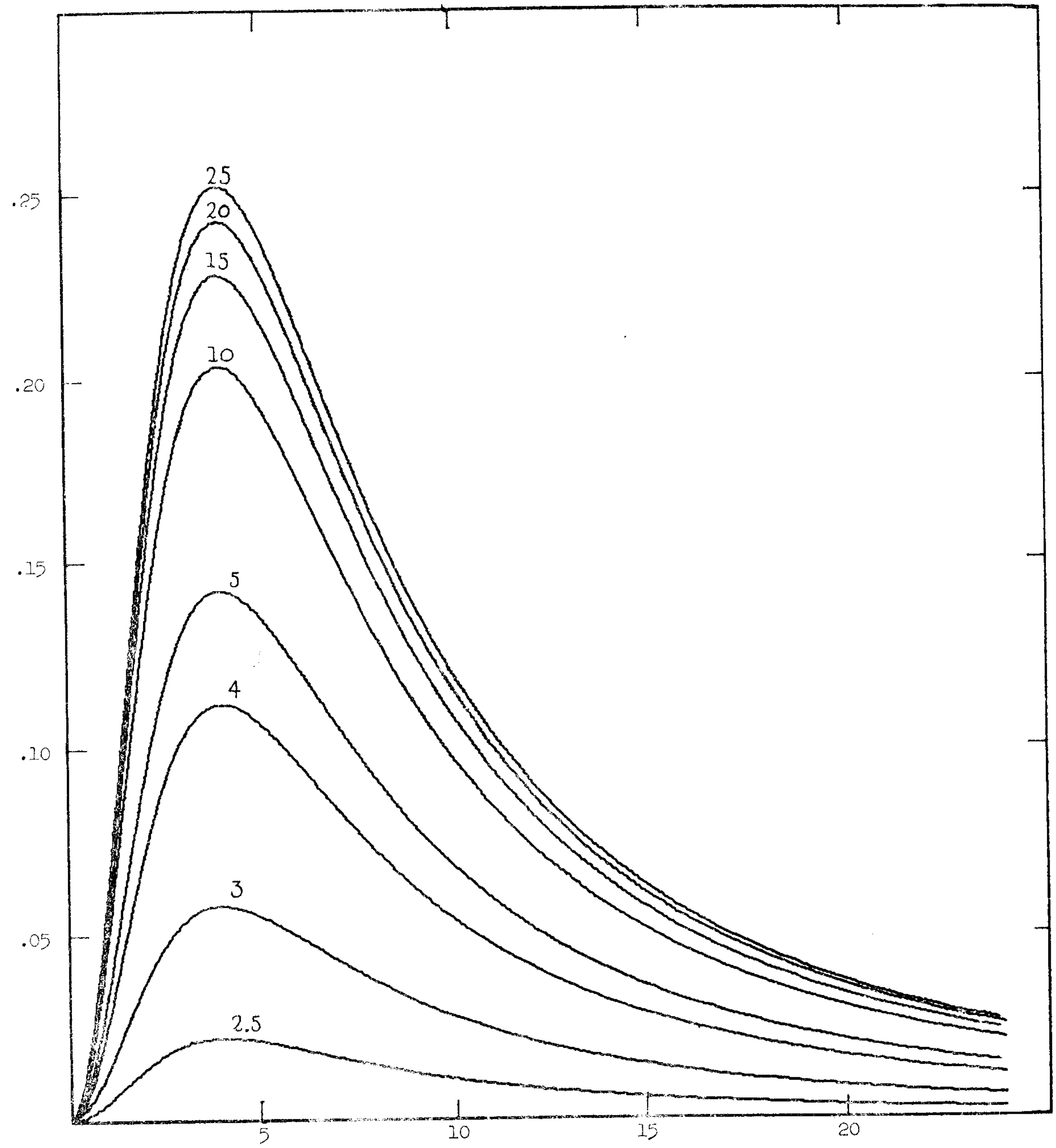

Total π-Be cross section (mb)
600
500
400
300
200
100
upper curves r_o = 1.733f
10
π^-
11
π^+
lower curves r_o = 1.4f
1
2
3
4
5
6
Pion lab kinetic energy (BeV)

FIG. 1A



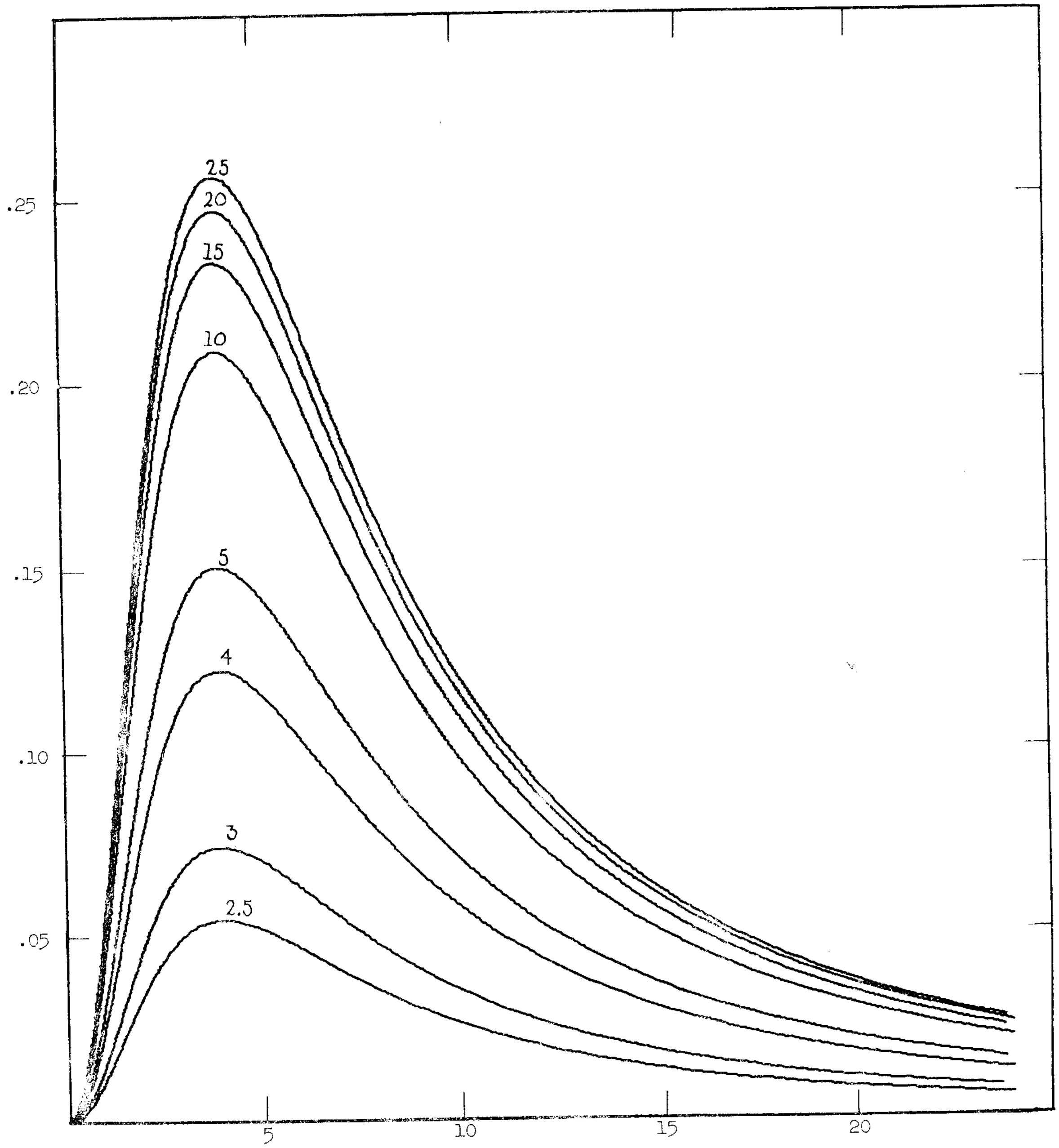
600
500
400
300
200
100
0.1
0.2
0.3
0.4
upper curves r_o = 1.733f
lower curves r_o = 1.4f
π^-
π^+
π^-
π^+
9
8

FIG. 1B



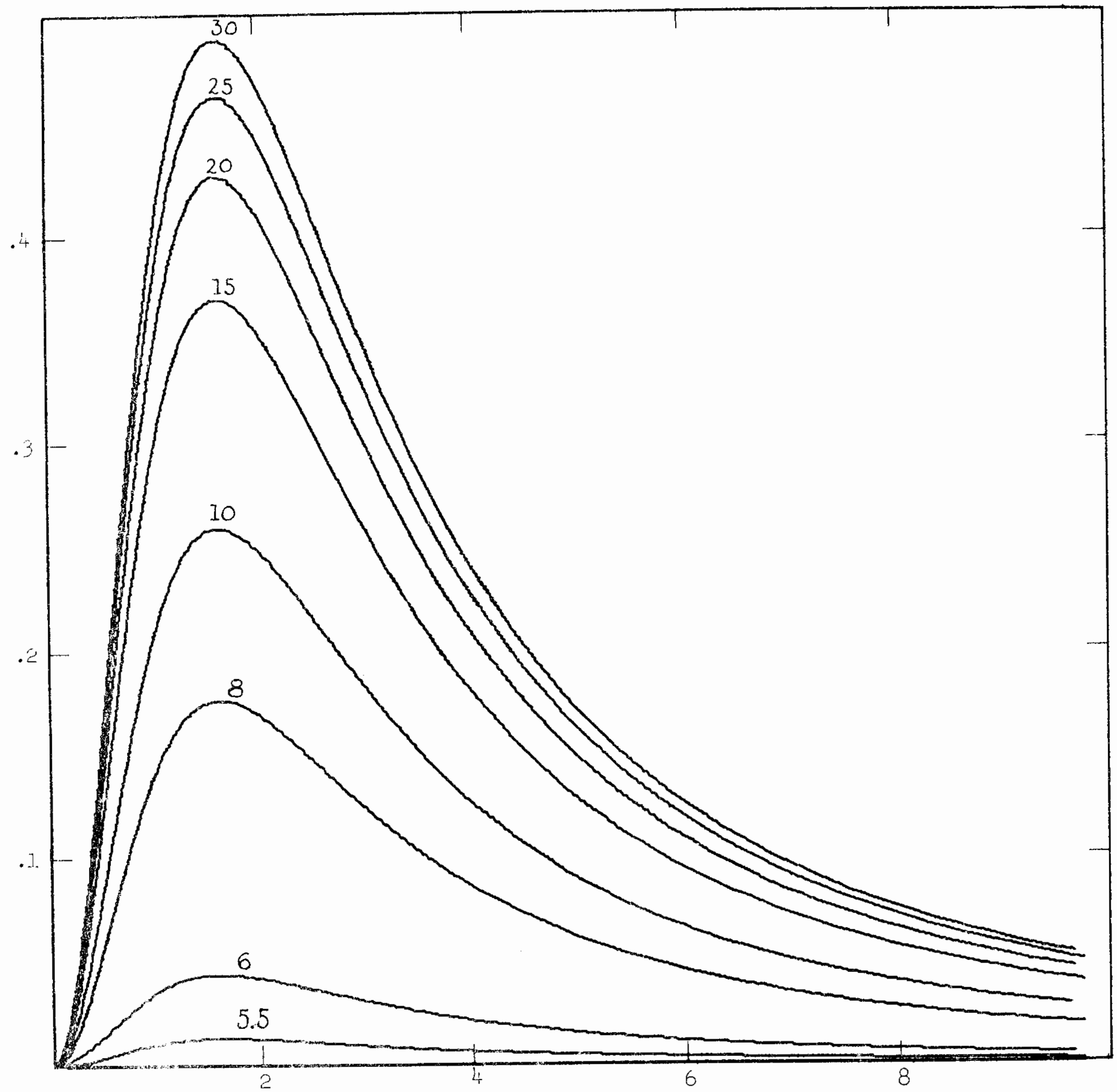
π^+
P = 2.0

FIG. 2



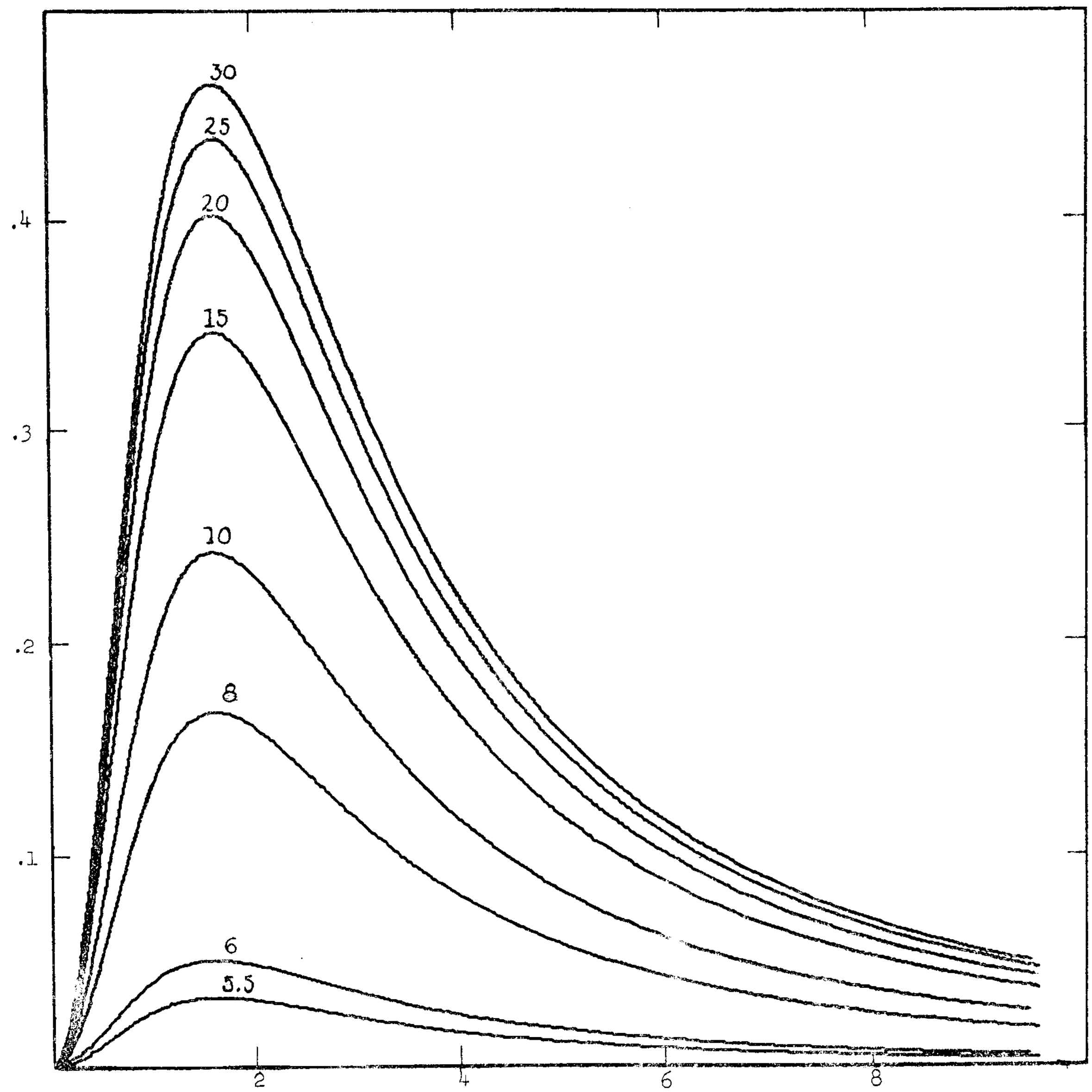
π^-
P = 2.0

FIG. 3



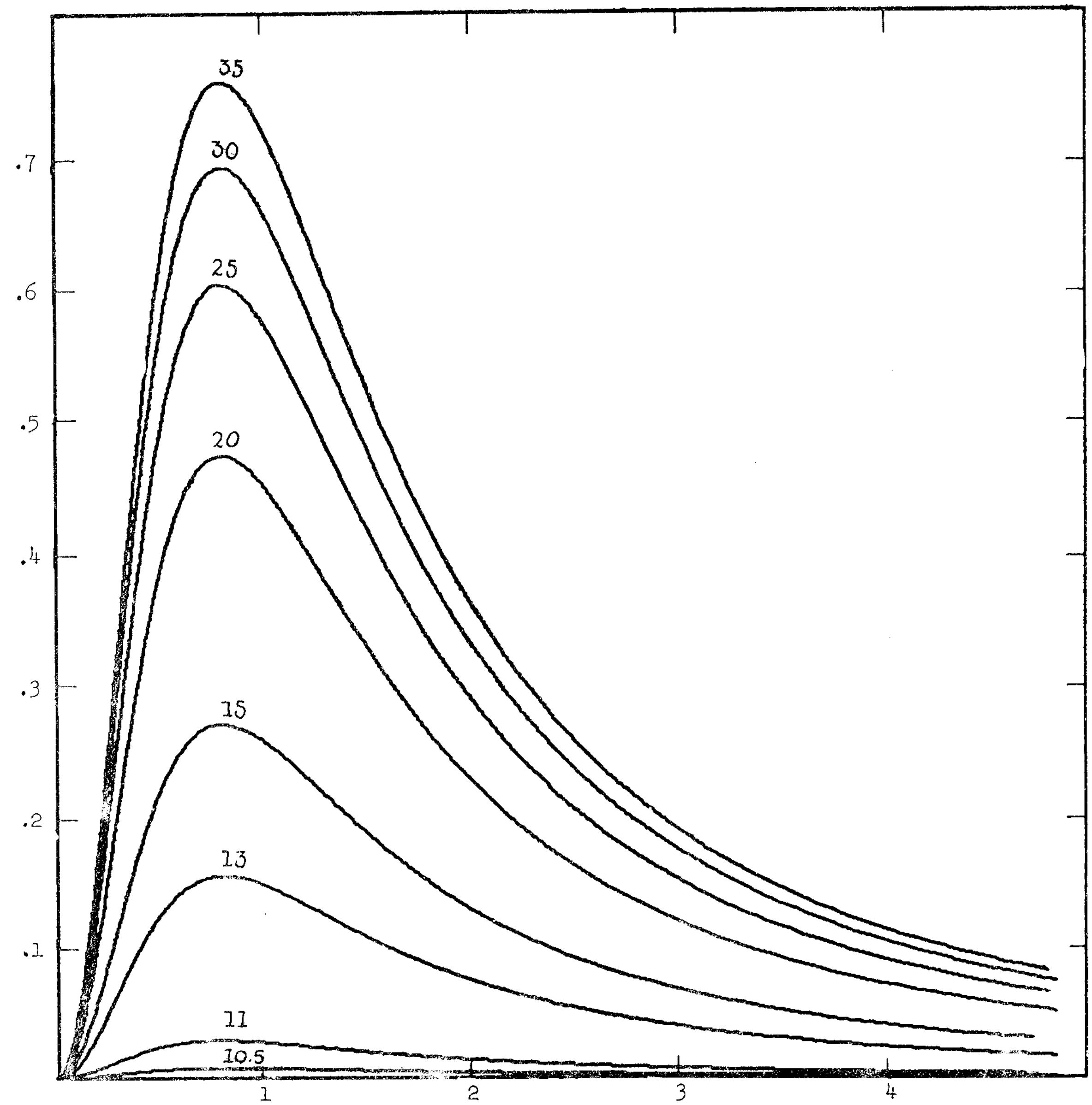
π^+
P = 5.0

FIG. 4



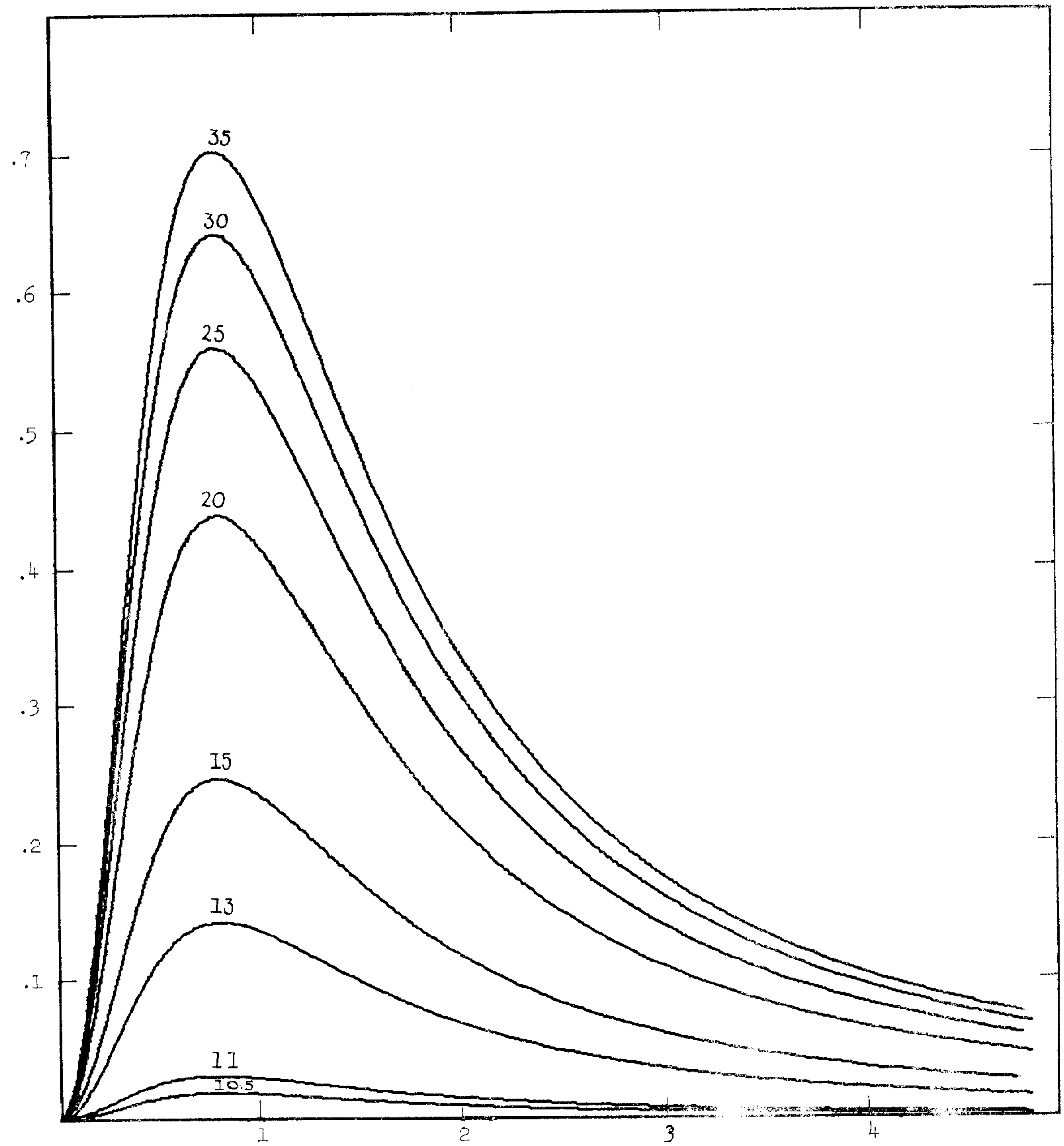
π^-
P = 5.0

FIG. 5



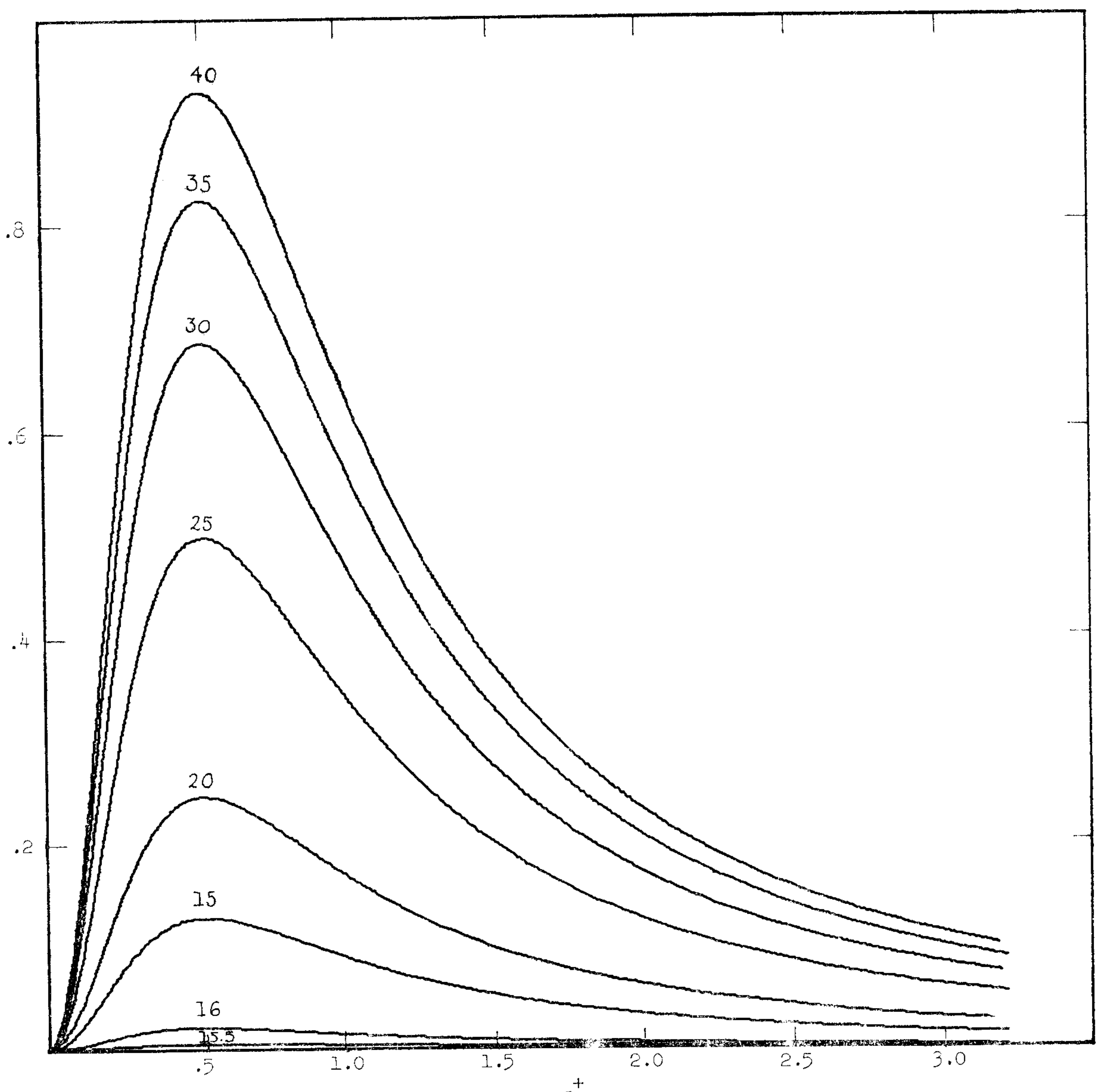
π^{+}
P = 10.0

FIG. 6



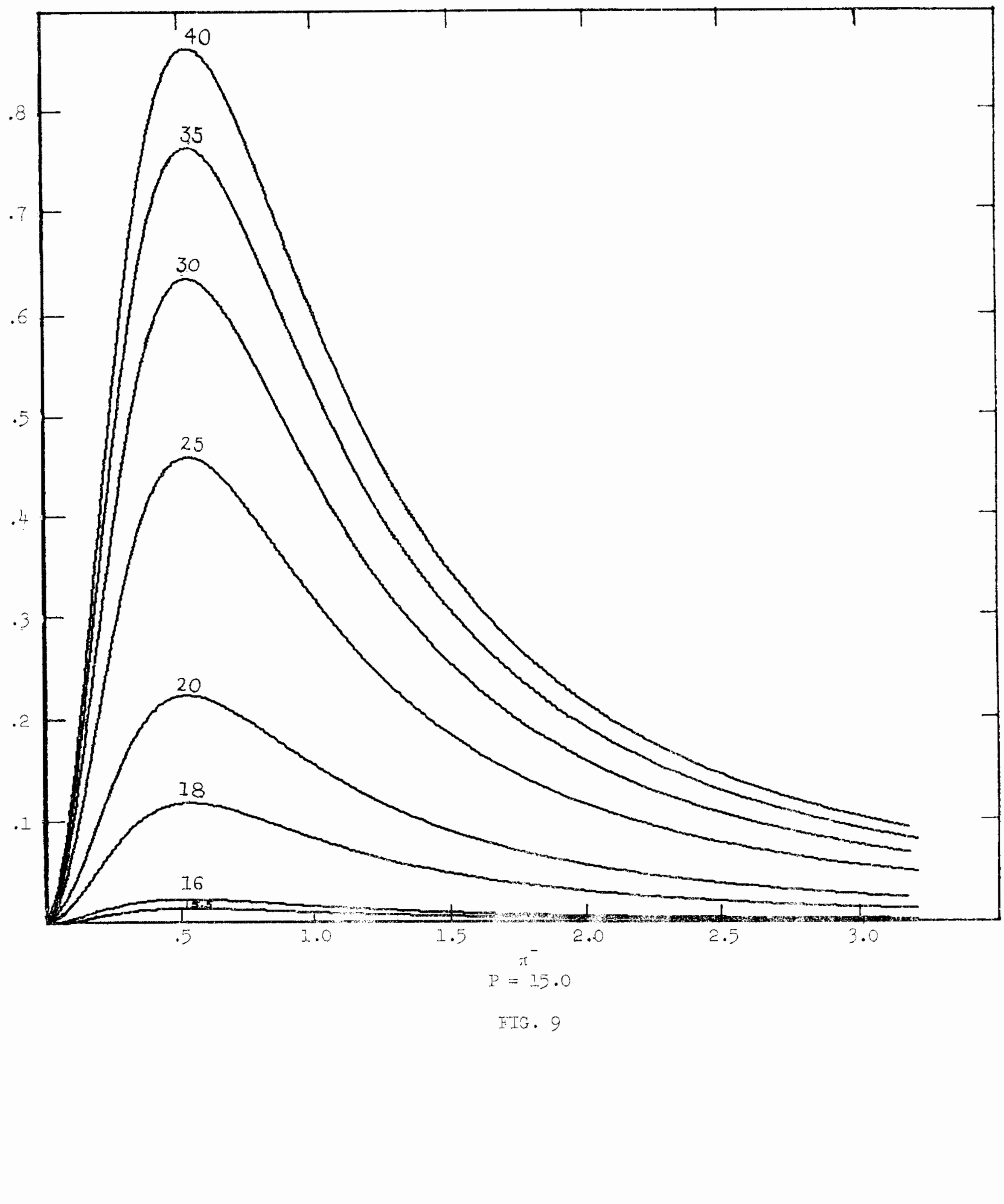
π^-
P = 10.0

FIG. 7



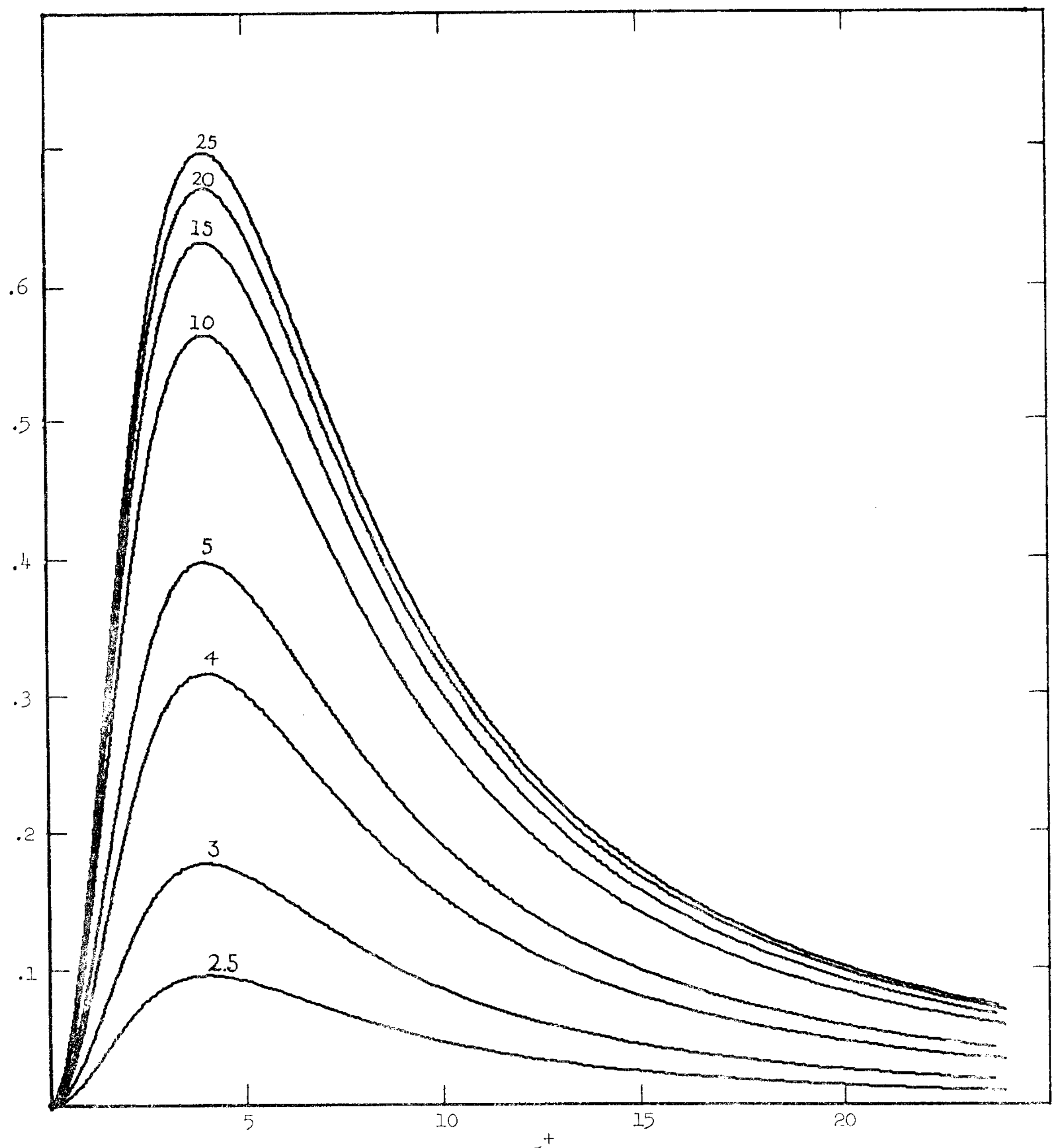
P = 15.0

FIG. 8



P = 15.0

FIG. 9



P = 2.0

FIG. 10

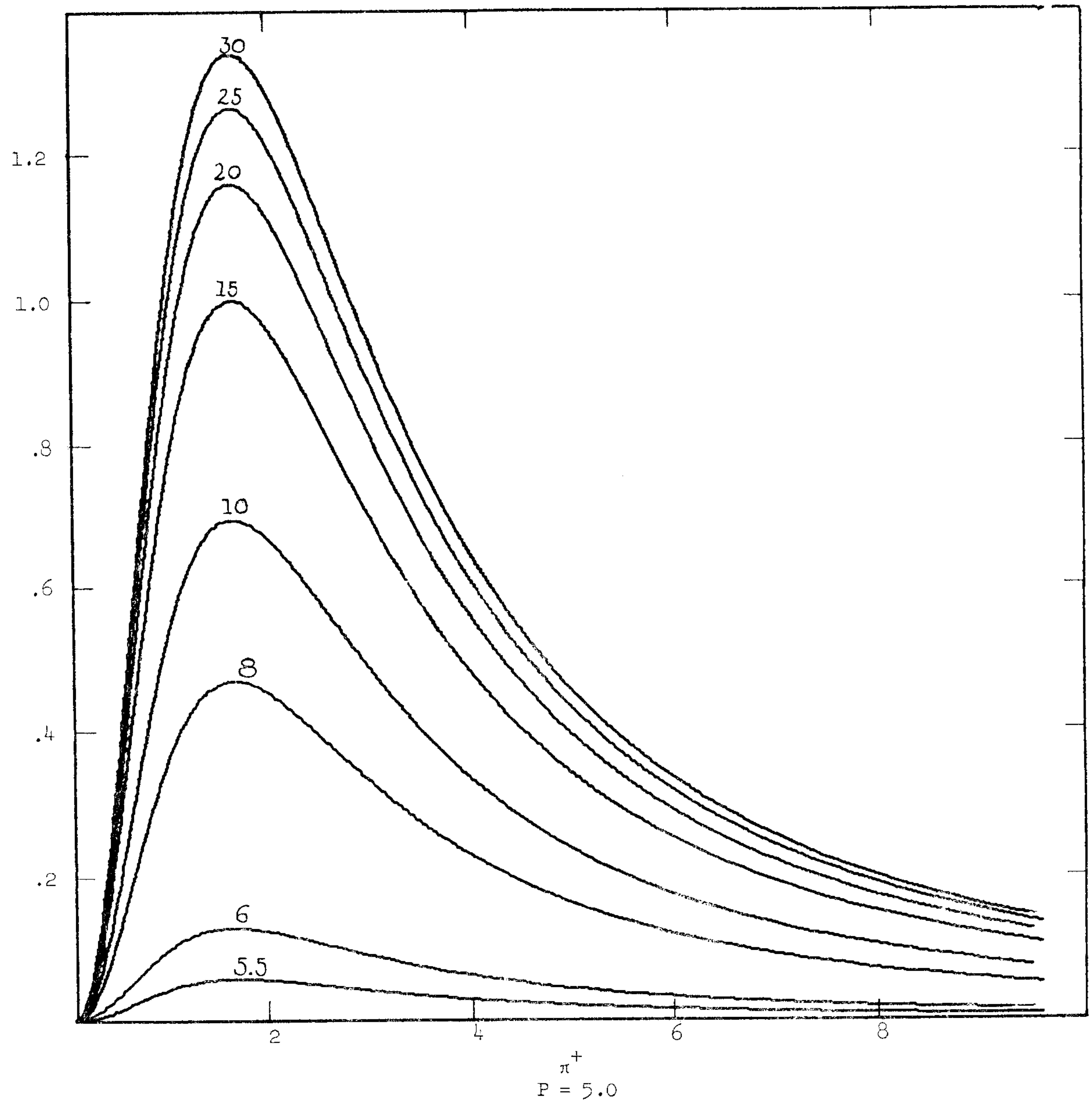


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FIG. 11

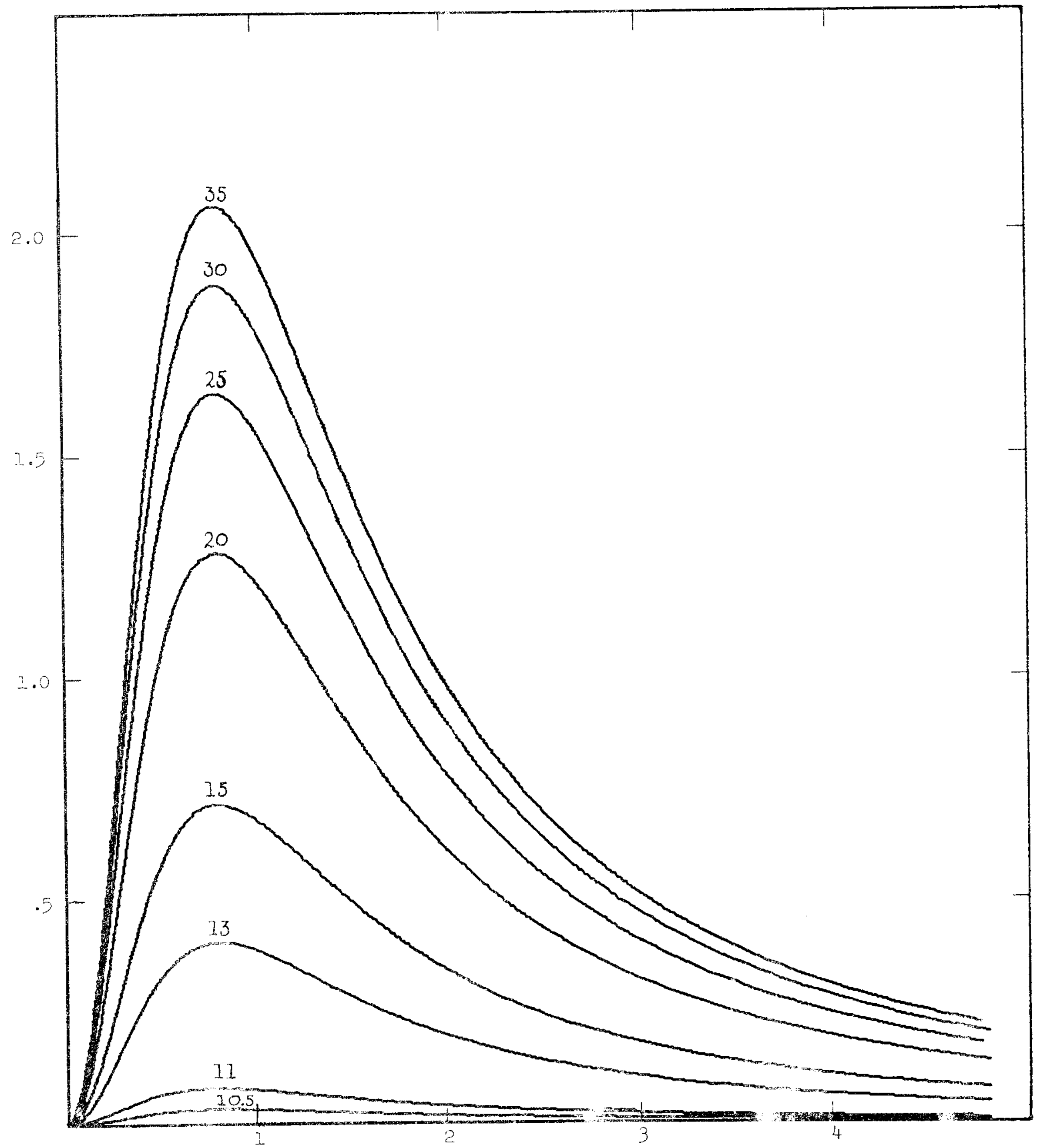

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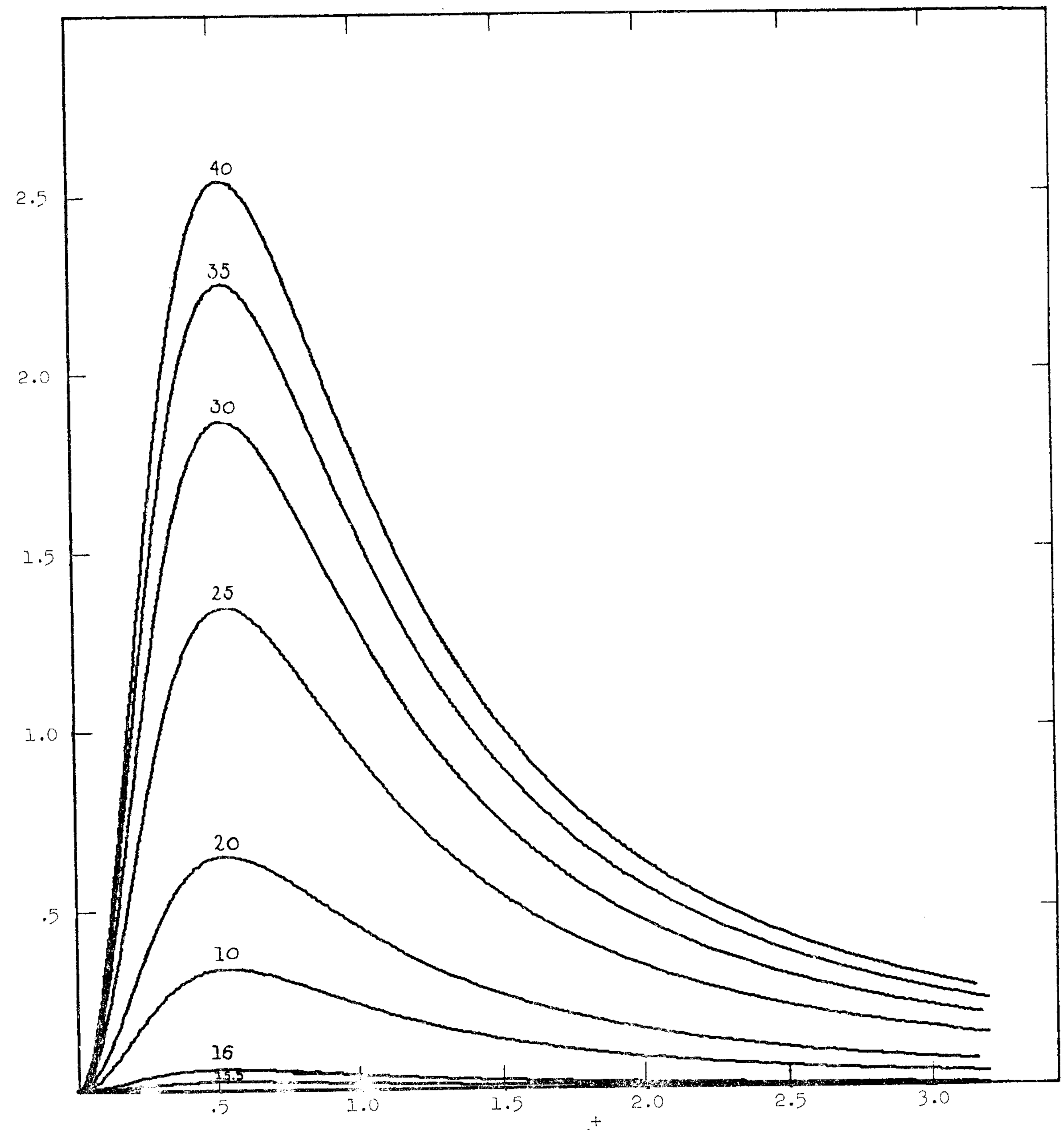
FIG. 12



P = 15.0

FIG. 13

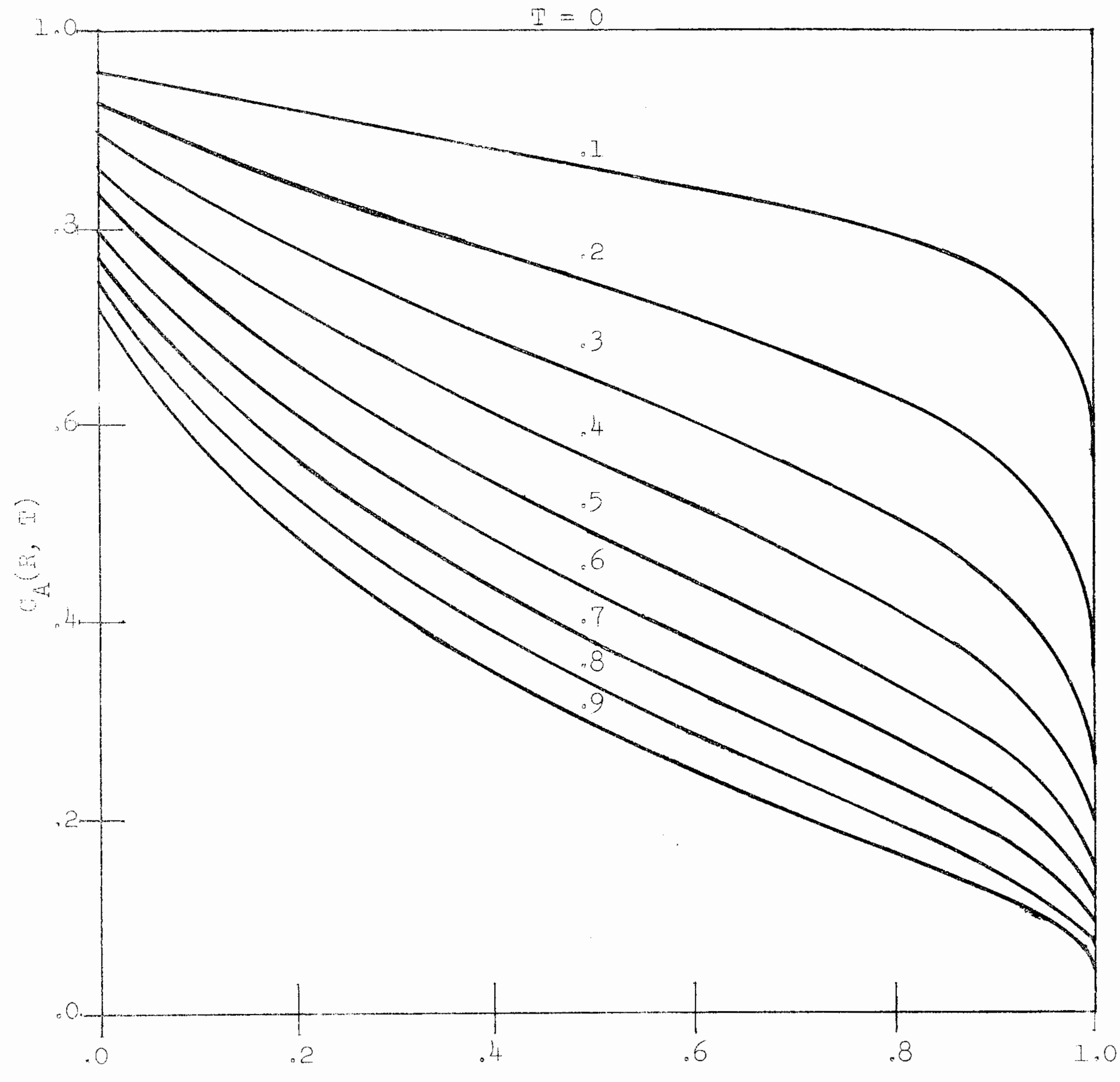
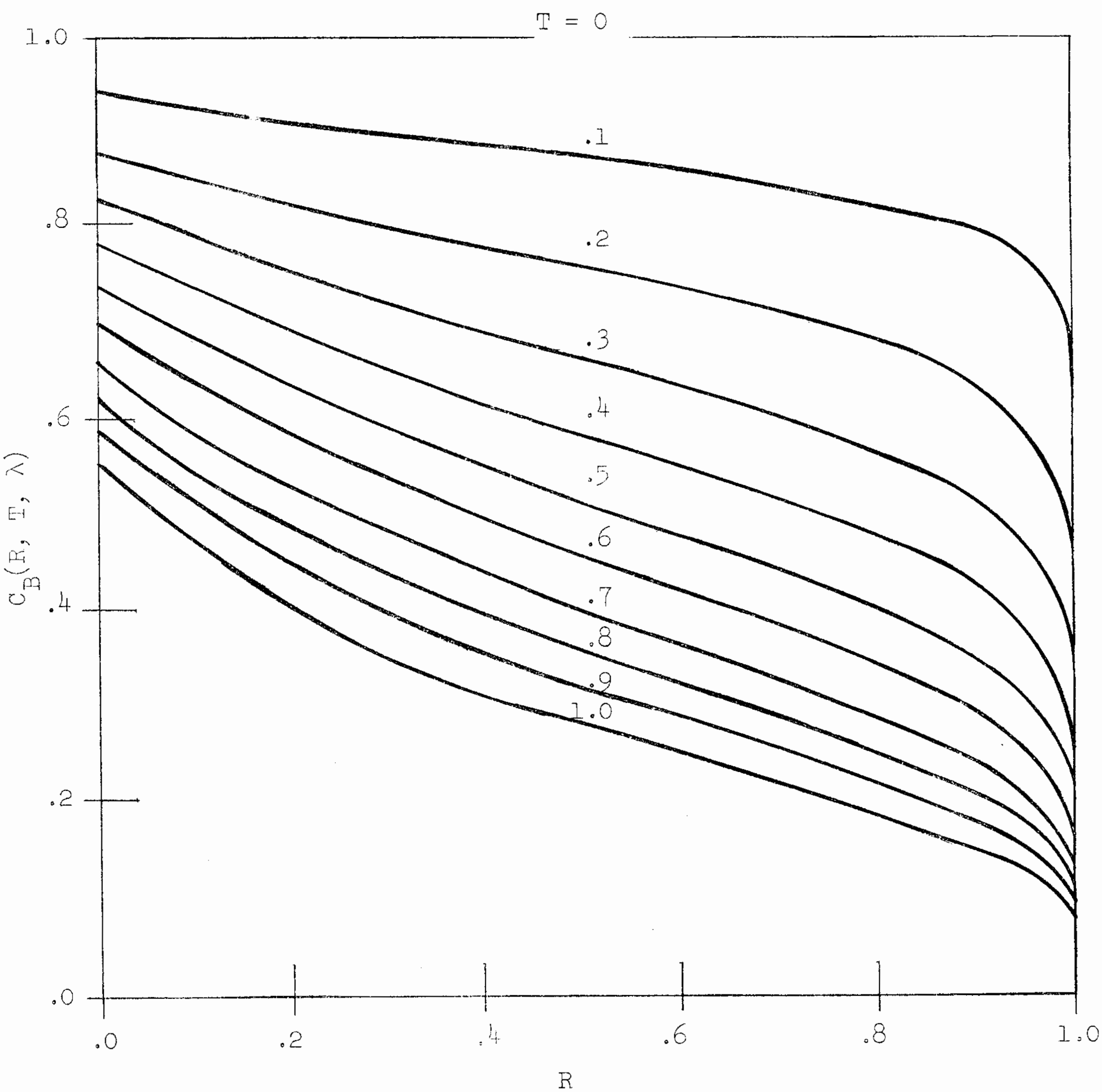
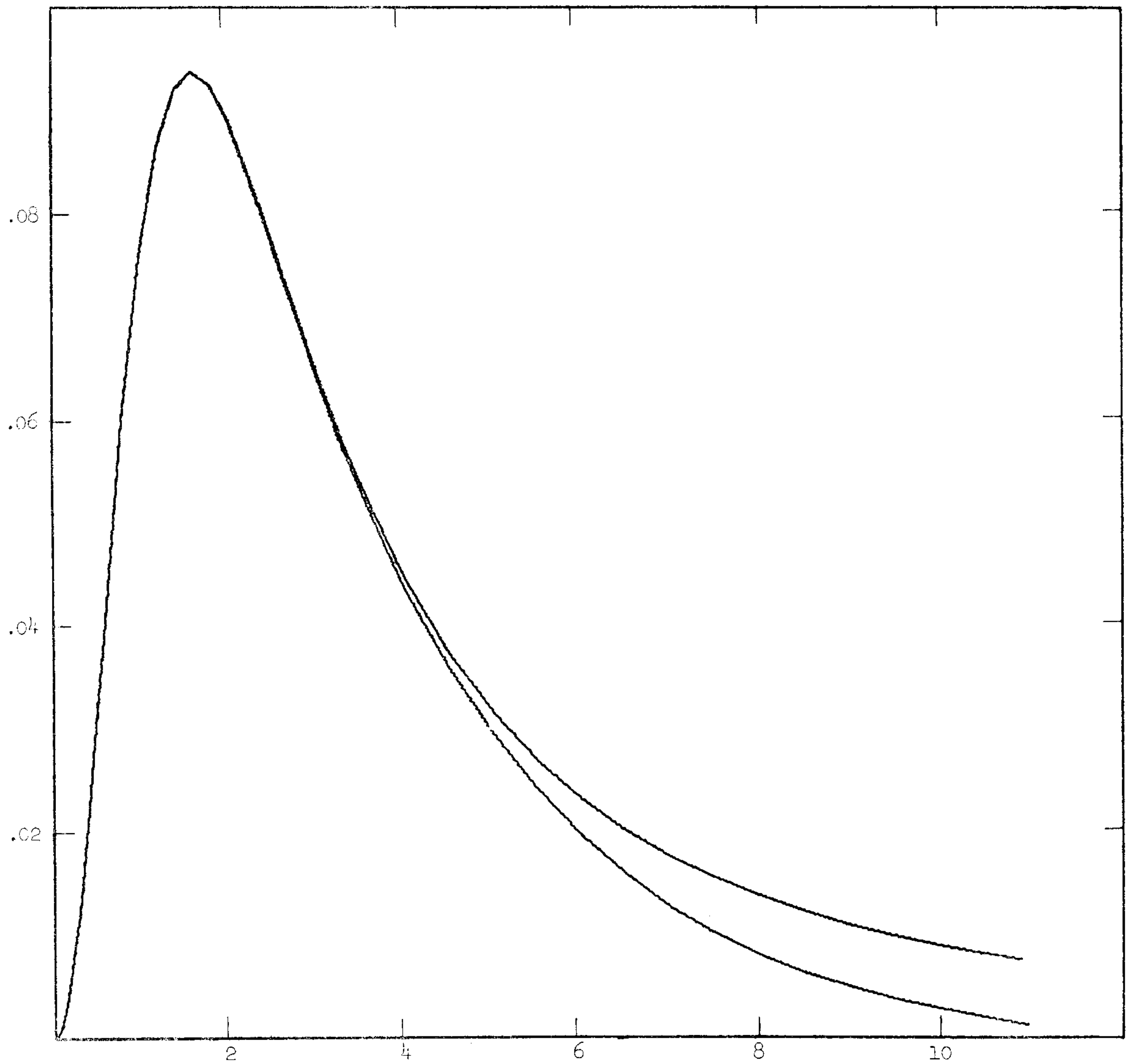


FIG. 14: Arrangement A



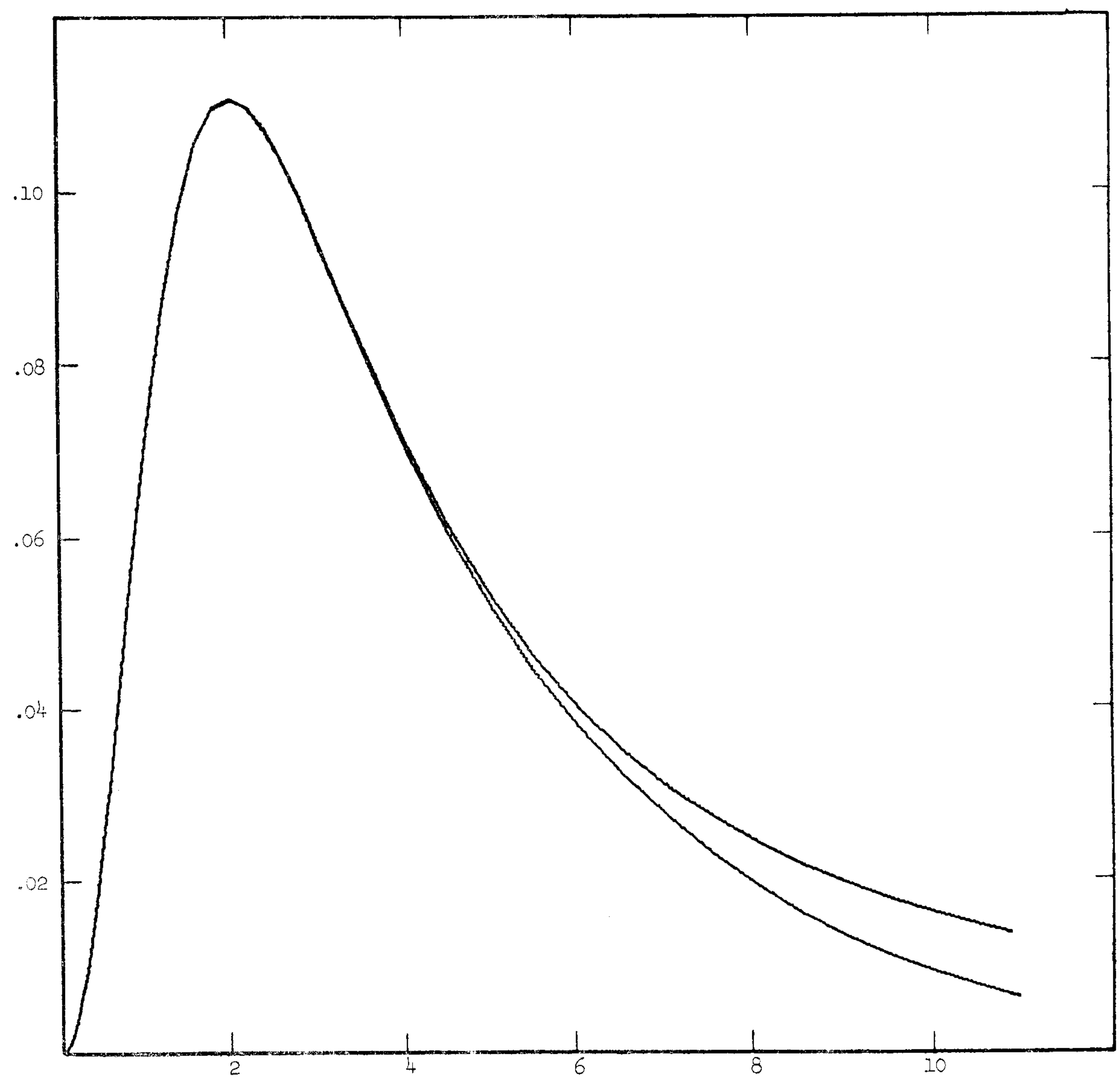
$\lambda = .94$

FIG. 15: Arrangement B



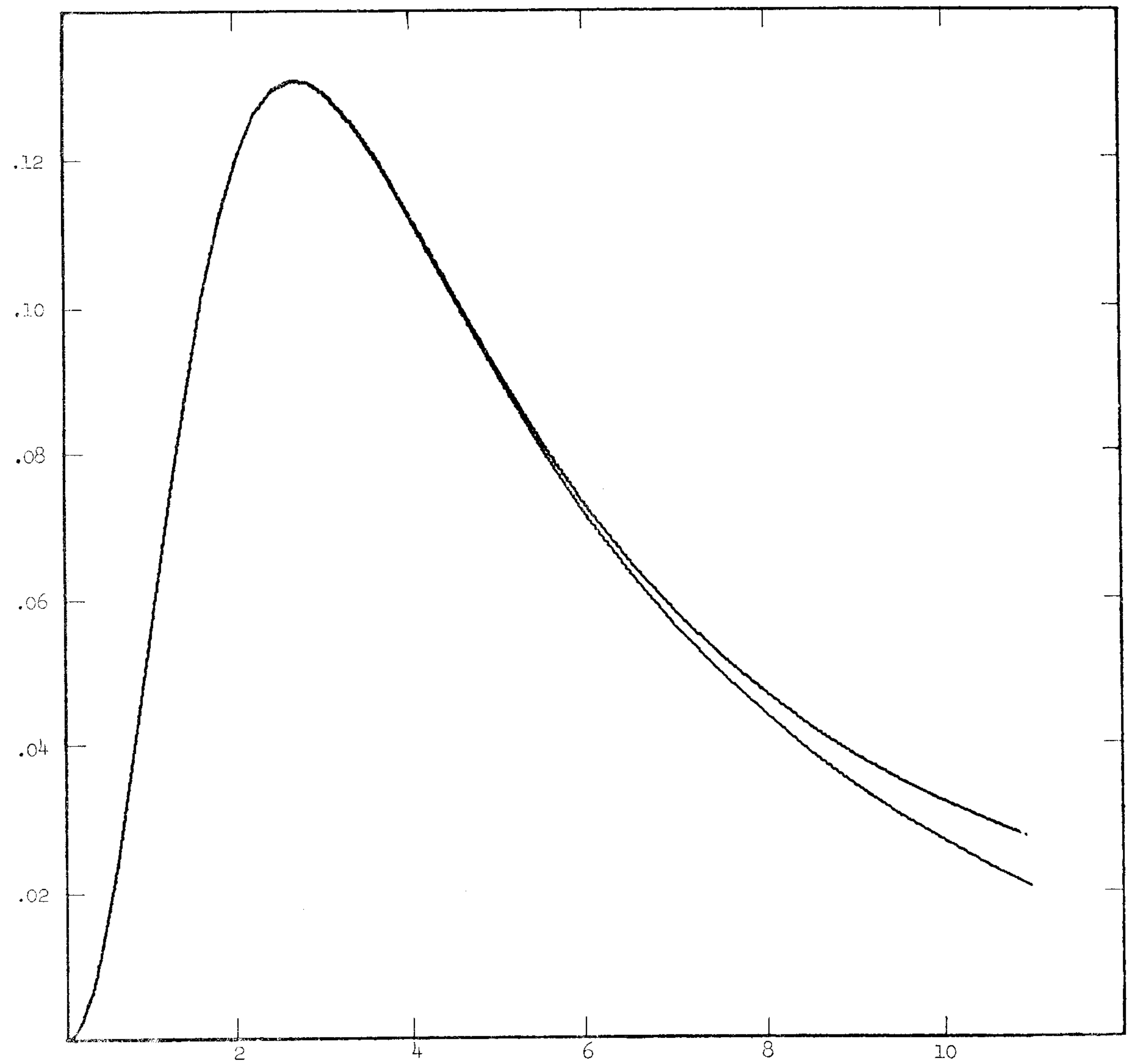
P = 5
B = 5.85

FIG. 16



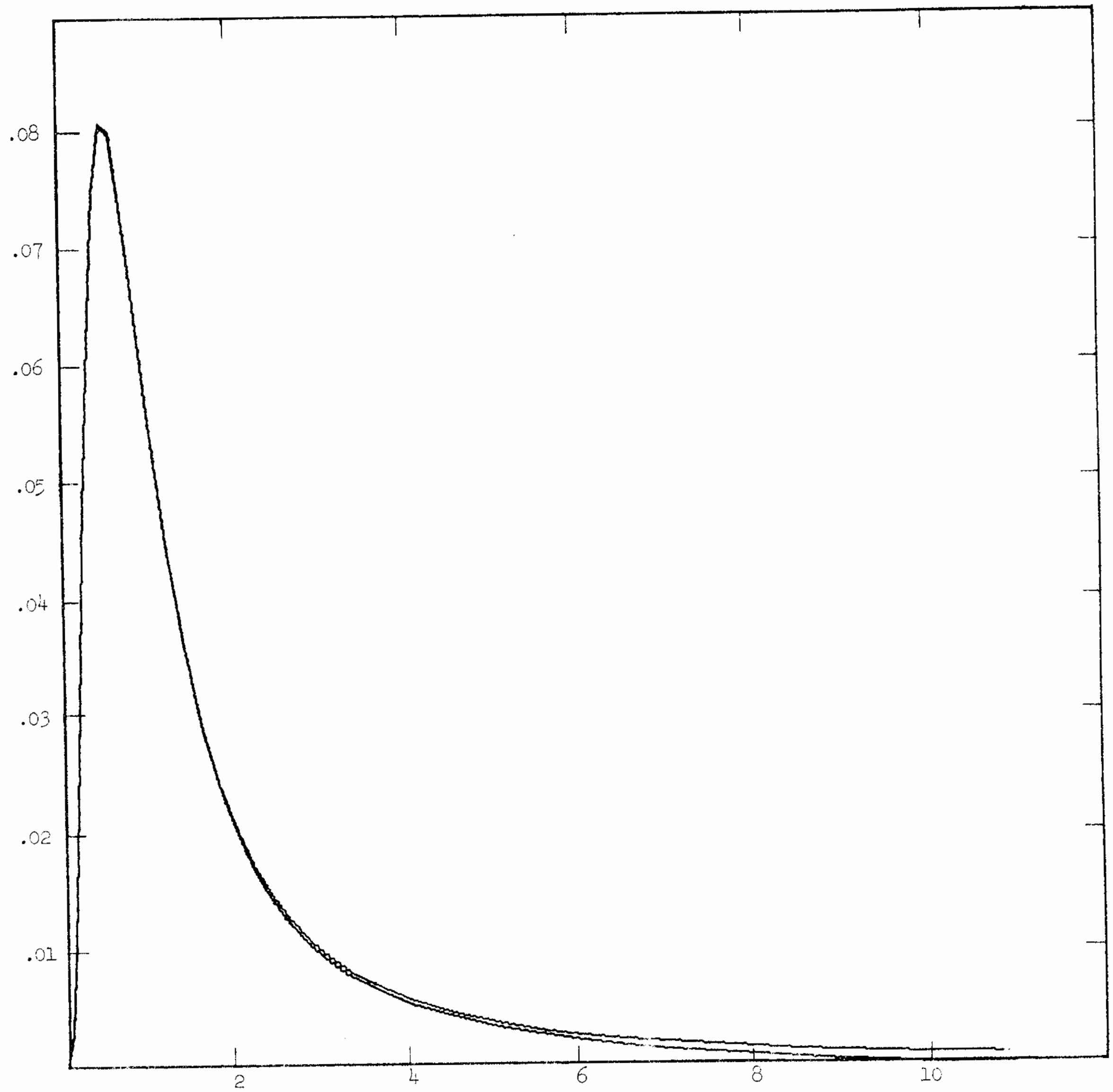
P = 3
B = 3.88

FIG. 17



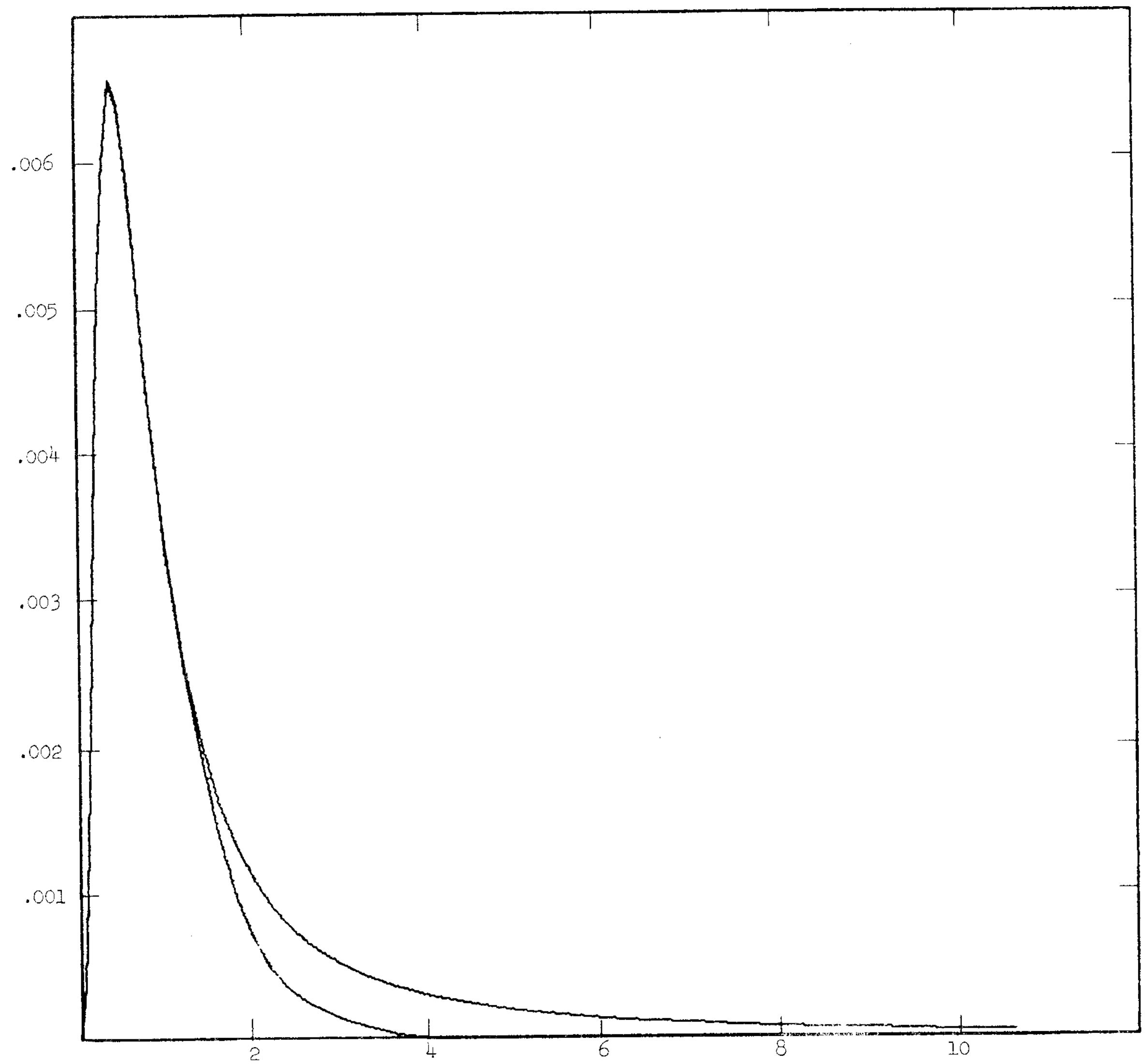
P = 4
B = 4.85

FIG. 18



P = 15
B = 20

FIG. 19



P = 19
B = 20

FIG. 20

TABLE I

EXPERIMENTAL VALUE OF π-BERYLLIUM CROSS SECTION

Lab. Kinetic Energy (BeV)	Total Cross Section (mb)	Charge of Pion	Reference
0.085	253 ± 20	-	8
0.140 ± 0.007	560 ± 32	-	9
0.184 ± 0.007	583 ± 24	-	9
0.197 ± 0.007	594 ± 26	-	9
0.240 ± 0.007	526 ± 20	-	9
0.350 ± 0.007	368 ± 21	-	9
0.970	273 ± 18	-	10
2.86	233 ± 9	+	11
4.2	302 ± 20	-	12

TABLE II

TABLE OF VALUES OF $D_{\pm}$

Lab kinetic energy of pion = ϵ in BeV;
$D_{\pm}$ is in fermis.

ϵ	D_+	D_-	ϵ	D_+	D_-	ϵ	D_+	D_-
.00	-.16	.12	.01	-.15	.14	.02	-.12	.15
.03	-.07	.15	.04	.00	.15	.05	.10	.16
.06	.22	.18	.07	.36	.21	.08	.47	.23
.09	.56	.24	.10	.65	.25	.11	.74	.27
.12	.82	.29	.13	.90	.31	.14	.93	.32
.15	.82	.30	.16	.47	.22	.17	.22	.08
.18	-.08	-.04	.19	-.47	-.12	.20	-.80	-.19
.21	-.98	-.24	.22	-1.07	-.28	.23	-1.14	-.30
.24	-1.20	-.30	.25	-1.25	-.30	.26	-1.28	-.30
.27	-1.30	-.30	.28	-1.31	-.30	.29	-1.31	-.30
.30	-1.31	-.29	.31	-1.32	-.28	.32	-1.33	-.26
.33	-1.34	-.25	.34	-1.35	-.23	.35	-1.35	-.21
.36	-1.35	-.19	.38	-1.35	-.14	.40	-1.34	-.09
.42	-1.32	-.05	.44	-1.29	-.01	.46	-1.24	.04
.48	-1.16	.09	.50	-1.09	.12	.52	-1.00	.16
.54	-.93	.20	.56	-.86	.24	.58	-.79	.28
.60	-.73	.30	.62	-.67	.31	.64	-.61	.31
.66	-.55	.30	.68	-.51	.29	.70	-.47	.27
.72	-.42	.24	.74	-.38	.19	.76	-.34	.13
.78	-.31	.07	.80	-.29	.01	.82	-.27	-.04
.84	-.24	-.10	.86	-.22	-.16	.88	-.20	-.21
.90	-.17	-.26	.92	-.15	-.33	.94	-.13	-.38
.96	-.10	-.41	.98	-.08	-.42	1.00	-.06	-.44
1.05	-.02	-.65	1.10	.01	-.70	1.15	-.01	-.71
1.20	-.07	-.69	1.25	-.15	-.64	1.30	-.21	-.57
1.35	-.27	-.52	1.40	-.31	-.50	1.45	-.35	-.48
1.50	-.36	-.47	1.55	-.36	-.45	1.60	-.37	-.44
1.65	-.37	-.43	1.70	-.37	-.41	1.75	-.37	-.39
1.80	-.37	-.38	1.85	-.37	-.35	1.90	-.37	-.33
1.95	-.37	-.32	2.00	-.36	-.32	2.10	-.35	-.35
2.20	-.34	-.36	2.30	-.32	-.36	2.40	-.31	-.36
2.50	-.31	-.36	2.60	-.31	-.36	2.70	-.31	-.36
2.80	-.31	-.36	2.90	-.31	-.36	3.00	-.31	-.36
3.10	-.31	-.36	3.20	-.31	-.36	3.30	-.31	-.36
3.40	-.31	-.36	3.50	-.31	-.36	3.60	-.31	-.36
3.70	-.31	-.36	3.80	-.31	-.36	3.90	-.31	-.36
4.00	-.31	-.36	4.20	-.31	-.36	4.40	-.31	-.36
4.60	-.31	-.36	4.80	-.31	-.36	5.00	-.31	-.36
5.20	-.31	-.36	5.40	-.31	-.36	5.60	-.31	-.36
5.80	-.31	-.36	6.00	-.31	-.36			

TABLE III

TABLE OF VALUES OF $\sigma^{\pm}$

Lab kinetic energy of pion is ϵ in BeV,
$\sigma^{\pm}$ is in mb.

ϵ	σ^+	σ^-	ϵ	σ^+	σ^-	ϵ	σ^+	σ^-
.00	3.0	5.5	.01	3.0	7.0	.02	4.0	8.5
.03	5.5	10.00	.04	8.5	12.0	.05	13.0	14.0
.06	19.0	16.5	.07	26.5	18.5	.08	35.0	21.5
.09	47.0	24.5	.10	60.5	28.0	.11	79.0	32.0
.12	97.5	37.0	.13	117.0	44.0	.14	138.5	52.0
.15	158.0	59.0	.16	180.0	66.0	.17	203.5	71.5
.18	214.5	74.0	.19	190.0	67.5	.20	170.0	61.5
.21	154.0	57.0	.22	142.5	52.5	.23	132.0	48.5
.24	122.0	44.5	.25	112.5	40.5	.26	104.0	37.5
.27	96.0	35.0	.28	88.0	33.4	.29	80.5	32.0
.30	74.0	30.5	.31	67.5	29.2	.32	62.0	28.7
.33	56.5	28.5	.34	51.0	28.0	.35	46.0	28.0
.36	42.3	28.0	.38	37.7	28.2	.40	35.5	28.6
.42	32.6	29.0	.44	30.1	29.6	.46	27.9	30.4
.48	25.8	31.5	.50	24.0	33.0	.52	22.6	35.4
.54	21.5	37.9	.56	20.4	40.4	.58	19.4	42.4
.60	18.5	43.5	.62	17.9	42.4	.64	17.6	40.5
.66	17.5	38.4	.68	17.6	36.7	.70	18.0	35.8
.72	18.9	37.0	.74	19.9	39.0	.76	21.0	40.6
.78	22.1	41.8	.80	23.0	43.3	.82	23.7	45.8
.84	24.3	48.6	.86	24.7	51.5	.88	25.1	54.2
.90	25.5	55.7	.92	26.1	54.3	.94	26.7	51.7
.96	27.3	48.9	.98	27.7	46.4	1.00	28.2	44.0
1.05	29.5	39.4	1.10	31.5	36.5	1.15	35.5	35.5
1.20	38.1	35.2	1.25	39.7	35.2	1.30	40.8	35.0
1.35	41.2	34.8	1.40	40.6	34.6	1.45	38.6	34.5
1.50	36.0	34.4	1.55	33.8	34.3	1.60	32.1	34.3
1.65	31.2	34.3	1.70	30.7	34.4	1.75	30.1	34.8
1.80	29.6	35.2	1.85	29.3	35.6	1.90	29.1	35.9
1.95	29.1	36.0	2.00	29.2	35.9	2.10	30.0	35.7
2.20	30.9	34.7	2.30	31.3	34.0	2.40	31.0	33.8
2.50	30.8	33.5	2.60	30.4	33.2	2.70	30.0	32.9
2.80	29.6	32.6	2.90	29.2	32.4	3.00	29.0	32.2
3.10	28.7	32.0	3.20	28.5	31.8	3.30	28.4	31.6
3.40	28.2	31.4	3.50	28.1	31.3	3.60	28.0	31.1
3.70	27.8	30.9	3.80	27.7	30.8	3.90	27.7	30.7
4.00	27.6	30.5	4.20	27.4	30.2	4.40	27.3	30.0
4.60	27.2	29.8	4.80	27.1	29.6	5.00	27.0	29.3
5.20	27.0	29.2	5.40	26.9	29.0	5.60	26.8	28.8
5.80	26.7	28.7	6.00	26.7	28.6			

TABLE IV (Page 1 of 2)

VALUES OF F(P, THETA)
(THETA IS IN DEGREES. P IS IN BEV/C.)

THETA	MOMENTA 1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
.10	3.05,-06	9.55,-05	7.21,-04	3.03,-03	9.21,-03	2.28,-02	4.92,-02	9.54,-02	1.71,-01	2.88,-01
.20	1.22,-05	3.81,-04	2.86,-03	1.19,-02	3.60,-02	8.84,-02	1.88,-01	3.60,-01	6.35,-01	1.05, 00
.30	2.74,-05	8.51,-04	6.35,-03	2.62,-02	7.80,-02	1.88,-01	3.93,-01	7.37,-01	1.27, 00	2.05, 00
.40	4.86,-05	1.50,-03	1.11,-02	4.50,-02	1.32,-01	3.11,-01	6.34,-01	1.16, 00	1.94, 00	3.04, 00
.50	7.58,-05	2.32,-03	1.69,-02	6.74,-02	1.93,-01	4.44,-01	8.79,-01	1.56, 00	2.53, 00	3.84, 00
.60	1.09,-04	3.29,-03	2.36,-02	9.22,-02	2.57,-01	5.75,-01	1.10, 00	1.89, 00	2.98, 00	4.38, 00
.70	1.47,-04	4.41,-03	3.10,-02	1.18,-01	3.20,-01	6.95,-01	1.29, 00	2.15, 00	3.27, 00	4.66, 00
.80	1.92,-04	5.66,-03	3.90,-02	1.45,-01	3.80,-01	7.99,-01	1.44, 00	2.31, 00	3.42, 00	4.75, 00
.90	2.41,-04	7.02,-03	4.72,-02	1.70,-01	4.34,-01	8.83,-01	1.54, 00	2.40, 00	3.46, 00	4.68, 00
1.00	2.96,-04	8.47,-03	5.56,-02	1.95,-01	4.80,-01	9.46,-01	1.60, 00	2.43, 00	3.41, 00	4.52, 00
1.20	4.21,-04	1.15,-02	7.20,-02	2.37,-01	5.47,-01	1.01, 00	1.62, 00	2.35, 00	3.17, 00	4.04, 00
1.40	5.63,-04	1.49,-02	8.71,-02	2.69,-01	5.83,-01	1.02, 00	1.56, 00	2.17, 00	2.83, 00	3.52, 00
1.60	7.23,-04	1.82,-02	1.00,-01	2.90,-01	5.94,-01	9.92,-01	1.46, 00	1.96, 00	2.49, 00	3.04, 00
1.80	8.96,-04	2.14,-02	1.11,-01	3.01,-01	5.86,-01	9.38,-01	1.33, 00	1.75, 00	2.18, 00	2.61, 00
2.00	1.08,-03	2.45,-02	1.18,-01	3.04,-01	5.65,-01	8.74,-01	1.21, 00	1.56, 00	1.91, 00	2.26, 00
2.50	1.58,-03	3.09,-02	1.28,-01	2.89,-01	4.89,-01	7.07,-01	9.31,-01	1.16, 00	1.38, 00	1.60, 00
3.00	2.11,-03	3.52,-02	1.27,-01	2.59,-01	4.09,-01	5.65,-01	7.20,-01	8.74,-01	1.03, 00	1.18, 00
3.50	2.63,-03	3.75,-02	1.19,-01	2.26,-01	3.39,-01	4.54,-01	5.67,-01	6.78,-01	7.87,-01	8.95,-01
4.00	3.12,-03	3.82,-02	1.09,-01	1.94,-01	2.82,-01	3.69,-01	4.54,-01	5.38,-01	6.20,-01	7.01,-01
4.50	3.55,-03	3.75,-02	9.87,-02	1.67,-01	2.36,-01	3.04,-01	3.70,-01	4.35,-01	5.00,-01	5.63,-01
5.00	3.93,-03	3.63,-02	8.84,-02	1.44,-01	2.00,-01	2.54,-01	3.07,-01	3.59,-01	4.10,-01	4.61,-01
5.50	4.24,-03	3.45,-02	7.90,-02	1.25,-01	1.71,-01	2.15,-01	2.58,-01	3.01,-01	3.43,-01	3.85,-01
6.00	4.47,-03	3.25,-02	7.06,-02	1.09,-01	1.47,-01	1.84,-01	2.20,-01	2.55,-01	2.90,-01	3.25,-01
6.50	4.65,-03	3.03,-02	6.32,-02	9.59,-02	1.28,-01	1.59,-01	1.89,-01	2.19,-01	2.49,-01	2.78,-01
7.00	4.76,-03	2.82,-02	5.67,-02	8.46,-02	1.12,-01	1.38,-01	1.64,-01	1.90,-01	2.16,-01	2.41,-01
7.50	4.82,-03	2.62,-02	5.10,-02	7.52,-02	9.86,-02	1.2[illegible],-01	1.44,-01	1.66,-01	1.88,-01	2.11,-01
8.00	4.84,-03	2.43,-02	4.61,-02	6.71,-02	8.75,-02	1.08,-01	1.27,-01	1.47,-01	1.66,-01	1.85,-01
8.50	4.82,-03	2.26,-02	4.17,-02	6.02,-02	7.82,-02	9.58,-02	1.13,-01	1.30,-01	1.48,-01	1.65,-01
9.00	4.76,-03	2.09,-02	3.79,-02	5.43,-02	7.02,-02	8.58,-02	1.01,-01	1.17,-01	1.32,-01	1.47,-01
9.50	4.69,-03	1.94,-02	3.46,-02	4.92,-02	6.34,-02	7.73,-02	9.12,-02	1.05,-01	1.19,-01	1.32,-01
10.00	4.59,-03	1.83,-02	3.17,-02	4.47,-02	5.75,-02	7.00,-02	8.25,-02	9.48,-02	1.07,-01	1.19,-01
11.00	4.36,-03	1.55,-02	2.68,-02	3.74,-02	4.79,-02	[illegible].82,-02	6.84,-02	7.85,-02	8.86,-02	9.87,-02
12.00	4.10,-03	1.36,-02	2.29,-02	3.17,-02	4.04,-02	4.90,-02	5.76,-02	6.61,-02	7.46,-02	8.30,-02
13.00	3.82,-03	1.19,-02	1.97,-02	2.72,-02	3.46,-02	4.19,-02	4.91,-02	5.64,-02	6.35,-02	7.07,-02
14.00	3.56,-03	1.05,-02	1.72,-02	2.36,-02	2.99,-02	3.62,-02	4.24,-02	4.86,-02	5.48,-02	6.10,-02
15.00	3.30,-03	9.34,-03	1.51,-02	2.06,-02	2.61,-02	3.15,-02	3.69,-02	4.23,-02	4.77,-02	5.31,-02
16.00	3.05,-03	8.33,-03	1.33,-02	1.82,-02	2.30,-02	2.77,-02	3.25,-02	3.72,-02	4.19,-02	4.66,-02
17.00	2.83,-03	7.47,-03	1.19,-02	1.61,-02	2.04,-02	2.46,-02	2.87,-02	3.29,-02	3.71,-02	4.12,-02
18.00	2.62,-03	6.73,-03	1.06,-02	1.44,-02	1.82,-02	2.19,-02	2.56,-02	2.93,-02	3.30,-02	3.67,-02
19.00	2.43,-03	6.08,-03	9.55,-03	1.29,-02	1.63,-02	1.96,-02	2.30,-02	2.63,-02	2.96,-02	3.29,-02
20.00	2.25,-03	5.52,-03	8.63,-03	1.17,-02	1.47,-02	1.77,-02	2.07,-02	2.37,-02	2.67,-02	2.97,-02

TABLE IV (Page 2 of 2)

VALUES OF F(P, THETA) in BeV
(THETA IS IN DEGREES. P IS IN BEV/C.)

THETA	MOMENTA 11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
.10	4.60,-01	7.05,-01	1.05, 00	1.50, 00	2.10, 00	2.88, 00	3.86, 00	5.08, 00	6.58, 00	8.41, 00
.20	1.65, 00	2.49, 00	3.61, 00	5.07, 00	6.93, 00	9.25, 00	1.21, 01	1.55, 01	1.96, 01	2.43, 01
.30	3.14, 00	4.60, 00	6.47, 00	8.83, 00	1.17, 01	1.51, 01	1.92, 01	2.38, 01	2.91, 01	3.50, 01
.40	4.51, 00	6.39, 00	8.71, 00	1.15, 01	1.48, 01	1.85, 01	2.27, 01	2.74, 01	3.25, 01	3.80, 01
.50	5.51, 00	7.56, 00	9.99, 00	1.28, 01	1.60, 01	1.94, 01	2.32, 01	2.73, 01	3.16, 01	3.61, 01
.60	6.09, 00	8.11, 00	1.04, 01	1.30, 01	1.58, 01	1.88, 01	2.20, 01	2.53, 01	2.88, 01	3.24, 01
.70	6.31, 00	8.18, 00	1.03, 01	1.25, 01	1.49, 01	1.74, 01	2.00, 01	2.27, 01	2.54, 01	2.82, 01
.80	6.26, 00	7.94, 00	9.74, 00	1.17, 01	1.36, 01	1.57, 01	1.78, 01	2.00, 01	2.21, 01	2.43, 01
.90	6.04, 00	7.51, 00	9.05, 00	1.07, 01	1.23, 01	1.40, 01	1.57, 01	1.74, 01	1.92, 01	2.09, 01
1.00	5.72, 00	6.99, 00	8.31, 00	9.67, 00	1.10, 01	1.24, 01	1.38, 01	1.52, 01	1.67, 01	1.81, 01
1.20	4.96, 00	5.91, 00	6.88, 00	7.85, 00	8.82, 00	9.80, 00	1.08, 01	1.17, 01	1.27, 01	1.37, 01
1.40	4.23, 00	4.94, 00	5.66, 00	6.38, 00	7.09, 00	7.80, 00	8.51, 00	9.21, 00	9.90, 00	1.06, 01
1.60	3.59, 00	4.13, 00	4.68, 00	5.22, 00	5.76, 00	6.30, 00	6.83, 00	7.36, 00	7.88, 00	8.41, 00
1.80	3.05, 00	3.48, 00	3.91, 00	4.33, 00	4.75, 00	5.17, 00	5.58, 00	5.99, 00	6.40, 00	6.81, 00
2.00	2.61, 00	2.95, 00	3.29, 00	3.63, 00	3.97, 00	4.30, 00	4.63, 00	4.96, 00	5.29, 00	5.61, 00
2.50	1.82, 00	2.03, 00	2.25, 00	2.46, 00	2.67, 00	2.87, 00	3.08, 00	3.29, 00	3.49, 00	3.69, 00
3.00	1.32, 00	1.47, 00	1.62, 00	1.76, 00	1.90, 00	2.04, 00	2.18, 00	2.33, 00	2.47, 00	2.60, 00
3.50	1.00, 00	1.11, 00	1.21, 00	1.32, 00	1.42, 00	1.52, 00	1.63, 00	1.73, 00	1.83, 00	1.93, 00
4.00	7.82,-01	8.62,-01	9.41,-01	1.02, 00	1.10, 00	1.18, 00	1.25, 00	1.33, 00	1.41, 00	1.49, 00
4.50	6.26,-01	6.89,-01	7.51,-01	8.13,-01	8.74,-01	9.36,-01	9.97,-01	1.06, 00	1.12, 00	1.18, 00
5.00	5.12,-01	5.62,-01	6.12,-01	6.62,-01	7.12,-01	7.61,-01	8.11,-01	8.60,-01	9.09,-01	9.58,-01
5.50	4.26,-01	4.67,-01	5.08,-01	5.49,-01	5.90,-01	6.31,-01	6.72,-01	7.12,-01	7.53,-01	7.93,-01
6.00	3.60,-01	3.94,-01	4.29,-01	4.63,-01	4.97,-01	5.31,-01	5.66,-01	6.00,-01	6.34,-01	6.68,-01
6.50	3.08,-01	3.37,-01	3.66,-01	3.96,-01	4.25,-01	4.54,-01	4.83,-01	5.12,-01	5.41,-01	5.69,-01
7.00	2.66,-01	2.91,-01	3.17,-01	3.42,-01	3.67,-01	3.92,-01	4.17,-01	4.42,-01	4.66,-01	4.91,-01
7.50	2.32,-01	2.54,-01	2.76,-01	2.98,-01	3.20,-01	3.41,-01	3.63,-01	3.85,-01	4.07,-01	4.28,-01
8.00	2.05,-01	2.24,-01	2.43,-01	2.62,-01	2.81,-01	3.00,-01	3.19,-01	3.38,-01	3.57,-01	3.76,-01
8.50	1.82,-01	1.99,-01	2.16,-01	2.32,-01	2.49,-01	2.66,-01	2.83,-01	3.00,-01	3.17,-01	3.34,-01
9.00	1.62,-01	1.77,-01	1.92,-01	2.07,-01	2.22,-01	2.37,-01	2.53,-01	2.68,-01	2.83,-01	2.98,-01
9.50	1.46,-01	1.59,-01	1.73,-01	1.86,-01	2.00,-01	2.13,-01	2.27,-01	2.40,-01	2.54,-01	2.67,-01
10.00	1.32,-01	1.44,-01	1.56,-01	1.68,-01	1.80,-01	1.92,-01	2.05,-01	2.17,-01	2.29,-01	2.41,-01
11.00	1.09,-01	1.19,-01	1.29,-01	1.39,-01	1.49,-01	1.59,-01	1.69,-01	1.79,-01	1.89,-01	1.99,-01
12.00	9.14,-02	9.99,-02	1.08,-01	1.17,-01	1.25,-01	1.34,-01	1.42,-01	1.50,-01	1.59,-01	1.67,-01
13.00	7.79,-02	8.51,-02	9.22,-02	9.94,-02	1.07,-01	1.14,-01	1.21,-01	1.28,-01	1.35,-01	1.42,-01
14.00	6.71,-02	7.33,-02	7.95,-02	8.56,-02	9.18,-02	9.79,-02	1.04,-01	1.10,-01	1.16,-01	1.23,-01
15.00	5.84,-02	6.38,-02	6.92,-02	7.45,-02	7.99,-02	8.52,-02	9.06,-02	9.59,-02	1.01,-01	1.07,-01
16.00	5.13,-02	5.60,-02	6.07,-02	6.54,-02	7.01,-02	7.48,-02	7.95,-02	8.42,-02	8.89,-02	9.35,-02
17.00	4.54,-02	4.95,-02	5.37,-02	5.79,-02	6.20,-02	6.62,-02	7.03,-02	7.44,-02	7.86,-02	8.27,-02
18.00	4.04,-02	4.41,-02	4.78,-02	5.15,-02	5.52,-02	5.89,-02	6.26,-02	6.63,-02	7.00,-02	7.37,-02
19.00	3.62,-02	3.95,-02	4.29,-02	4.62,-02	4.95,-02	5.28,-02	5.61,-02	5.94,-02	6.27,-02	6.60,-02
20.00	3.26,-02	3.55,-02	3.86,-02	4.16,-02	4.46,-02	4.75,-02	5.05,-02	5.35,-02	5.65,-02	5.95,-02

TABLE V

VALUES OF S(P, B) FOR NEGATIVE PION OBSERVATION FROM PROTON TARGET (P AND B ARE IN BEV/C) in mb BeV^{-2}

B	MOMENTA 1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
4.00	5.74, 00	7.60,-01	1.20,-01							
5.00	6.19, 00	9.35,-01	2.29,-01	4.44,-02						
6.00	6.52, 00	1.05, 00	3.03,-01	9.36,-02	2.00,-02					
7.00	6.77, 00	1.13, 00	3.54,-01	1.31,-01	4.55,-02	1.03,-02				
8.00	6.97, 00	1.20, 00	3.93,-01	1.59,-01	6.68,-02	2.49,-02	5.86,-03			
9.00	7.14, 00	1.25, 00	4.23,-01	1.81,-01	8.37,-02	3.79,-02	1.47,-02	3.57,-03		
10.00	7.27, 00	1.30, 00	4.47,-01	1.98,-01	9.71,-02	4.87,-02	2.32,-02	9.30,-03	2.30,-03	
11.00	7.39, 00	1.34, 00	4.68,-01	2.12,-01	1.08,-01	5.76,-02	3.04,-02	1.50,-02	6.16,-03	1.54,-03
12.00	7.49, 00	1.37, 00	4.86,-01	2.24,-01	1.18,-01	6.52,-02	3.67,-02	2.01,-02	1.01,-02	4.24,-03
13.00	7.58, 00	1.40, 00	5.02,-01	2.35,-01	1.25,-01	7.17,-02	4.20,-02	2.45,-02	1.38,-02	7.10,-03
14.00	7.66, 00	1.43, 00	5.16,-01	2.44,-01	1.32,-01	7.72,-02	4.67,-02	2.85,-02	1.71,-02	9.82,-03
15.00	7.73, 00	1.45, 00	5.28,-01	2.52,-01	1.38,-01	8.21,-02	5.08,-02	3.20,-02	2.01,-02	1.23,-02
16.00	7.79, 00	1.47, 00	5.39,-01	2.59,-01	1.44,-01	8.65,-02	5.44,-02	3.51,-02	2.27,-02	1.46,-02
17.00	7.85, 00	1.49, 00	5.49,-01	2.66,-01	1.49,-01	9.03,-02	5.77,-02	3.79,-02	2.52,-02	1.67,-02
18.00	7.90, 00	1.51, 00	5.58,-01	2.72,-01	1.53,-01	9.38,-02	6.05,-02	4.03,-02	2.73,-02	1.86,-02
19.00	7.94, 00	1.52, 00	5.66,-01	2.77,-01	1.57,-01	9.69,-02	6.31,-02	4.26,-02	2.93,-02	2.03,-02
20.00	7.99, 00	1.54, 00	5.74,-01	2.82,-01	1.61,-01	9.97,-02	6.55,-02	4.46,-02	3.10,-02	2.19,-02
21.00	8.02, 00	1.55, 00	5.81,-01	2.87,-01	1.64,-01	1.02,-01	6.76,-02	4.64,-02	3.27,-02	2.33,-02
22.00	8.06, 00	1.56, 00	5.88,-01	2.91,-01	1.67,-01	1.05,-01	6.96,-02	4.81,-02	3.41,-02	2.46,-02
23.00	8.09, 00	1.57, 00	5.94,-01	2.95,-01	1.70,-01	1.07,-01	7.14,-02	4.97,-02	3.55,-02	2.58,-02
24.00	8.12, 00	1.58, 00	6.00,-01	2.99,-01	1.72,-01	1.09,-01	7.31,-02	5.11,-02	3.67,-02	2.69,-02
25.00	8.15, 00	1.59, 00	6.05,-01	3.02,-01	1.75,-01	1.11,-01	7.46,-02	5.24,-02	3.79,-02	2.79,-02

B	MOMENTA 11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
12.00	1.08,-03									
13.00	3.02,-03	7.72,-04								
14.00	5.13,-03	2.21,-03	5.69,-04							
15.00	7.18,-03	3.80,-03	1.65,-03	4.28,-04						
16.00	9.11,-03	5.38,-03	2.88,-03	1.26,-03	3.28,-04					
17.00	1.09,-02	6.88,-03	4.11,-03	2.22,-03	9.77,-04	2.56,-04				
18.00	1.25,-02	8.30,-03	5.31,-03	3.20,-03	1.74,-03	7.70,-04	2.03,-04			
19.00	1.41,-02	9.62,-03	6.44,-03	4.16,-03	2.52,-03	1.38,-03	6.15,-04	1.62,-04		
20.00	1.55,-02	1.09,-02	7.52,-03	5.08,-03	3.31,-03	2.02,-03	1.11,-03	4.97,-04	1.32,-04	
21.00	1.67,-02	1.20,-02	8.53,-03	5.97,-03	4.07,-03	2.66,-03	1.64,-03	9.04,-04	4.06,-04	1.08,-04
22.00	1.79,-02	1.31,-02	9.48,-03	6.81,-03	4.80,-03	3.29,-03	2.17,-03	1.34,-03	7.43,-04	3.35,-04
23.00	1.90,-02	1.40,-02	1.04,-02	7.60,-03	5.50,-03	3.91,-03	2.70,-03	1.79,-03	1.11,-03	6.17,-04
24.00	2.00,-02	1.49,-02	1.12,-02	8.34,-03	6.17,-03	4.50,-03	3.21,-03	2.23,-03	1.48,-03	9.24,-04
25.00	2.09,-02	1.58,-02	1.19,-02	9.03,-03	6.79,-03	5.06,-03	3.72,-03	2.67,-03	1.86,-03	1.24,-03

TABLE VI

VALUES OF S(P, B) FOR POSITIVE PION OBSERVATION FROM PROTON TARGET (P AND B ARE IN BEV/C) in mb BeV^{-2}

B	MOMENTA 1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
4.00	4.58, 00	6.96,-01	9.92,-02							
5.00	4.99, 00	8.88,-01	2.22,-01	3.79,-02						
6.00	5.29, 00	1.01, 00	3.05,-01	9.35,-02	1.75,-02					
7.00	5.52, 00	1.10, 00	3.62,-01	1.36,-01	4.62,-02	9.18,-03				
8.00	5.70, 00	1.16, 00	4.03,-01	1.67,-01	7.03,-02	2.55,-02	5.27,-03			
9.00	5.85, 00	1.22, 00	4.35,-01	1.90,-01	8.90,-02	4.02,-02	1.52,-02	3.24,-03		
10.00	5.98, 00	1.26, 00	4.60,-01	2.09,-01	1.04,-01	5.22,-02	2.47,-02	9.64,-03	2.10,-03	
11.00	6.08, 00	1.30, 00	4.82,-01	2.24,-01	1.16,-01	6.20,-02	3.28,-02	1.61,-02	6.40,-03	1.42,-03
12.00	6.18, 00	1.34, 00	5.01,-01	2.37,-01	1.25,-01	7.02,-02	3.97,-02	2.17,-02	1.09,-02	4.42,-03
13.00	6.26, 00	1.37, 00	5.17,-01	2.48,-01	1.34,-01	7.70,-02	4.54,-02	2.66,-02	1.50,-02	7.66,-03
14.00	6.33, 00	1.39, 00	5.32,-01	2.58,-01	1.41,-01	8.30,-02	5.04,-02	3.09,-02	1.86,-02	1.07,-02
15.00	6.40, 00	1.42, 00	5.45,-01	2.66,-01	1.48,-01	8.82,-02	5.48,-02	3.46,-02	2.18,-02	1.34,-02
16.00	6.46, 00	1.44, 00	5.57,-01	2.74,-01	1.54,-01	9.28,-02	5.87,-02	3.79,-02	2.47,-02	1.59,-02
17.00	6.51, 00	1.46, 00	5.67,-01	2.81,-01	1.59,-01	9.70,-02	6.21,-02	4.09,-02	2.72,-02	1.81,-02
18.00	6.55, 00	1.47, 00	5.77,-01	2.87,-01	1.63,-01	1.01,-01	6.52,-02	4.35,-02	2.95,-02	2.01,-02
19.00	6.60, 00	1.49, 00	5.86,-01	2.93,-01	1.68,-01	1.04,-01	6.80,-02	4.59,-02	3.16,-02	2.20,-02
20.00	6.64, 00	1.51, 00	5.94,-01	2.98,-01	1.71,-01	1.07,-01	7.05,-02	4.81,-02	3.35,-02	2.37,-02
21.00	6.67, 00	1.52, 00	6.01,-01	3.03,-01	1.75,-01	1.10,-01	7.28,-02	5.01,-02	3.53,-02	2.52,-02
22.00	6.71, 00	1.53, 00	6.08,-01	3.08,-01	1.78,-01	1.12,-01	7.49,-02	5.19,-02	3.68,-02	2.66,-02
23.00	6.74, 00	1.54, 00	6.15,-01	3.12,-01	1.81,-01	1.15,-01	7.69,-02	5.35,-02	3.83,-02	2.79,-02
24.00	6.76, 00	1.56, 00	6.21,-01	3.16,-01	1.84,-01	1.17,-01	7.87,-02	5.51,-02	3.96,-02	2.91,-02
25.00	6.79, 00	1.57, 00	6.26,-01	3.20,-01	1.87,-01	1.19,-01	8.03,-02	5.65,-02	4.09,-02	3.02,-02

B	MOMENTA 11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
12.00	9.92,-04									
13.00	3.15,-03	7.15,-04								
14.00	5.54,-03	2.31,-03	5.29,-04							
15.00	7.83,-03	4.11,-03	1.73,-03	3.99,-04						
16.00	9.94,-03	5.87,-03	3.12,-03	1.32,-03	3.07,-04					
17.00	1.19,-02	7.52,-03	4.49,-03	2.40,-03	1.03,-03	2.40,-04				
18.00	1.36,-02	9.05,-03	5.80,-03	3.49,-03	1.89,-03	8.09,-04	1.90,-04			
19.00	1.52,-02	1.05,-02	7.03,-03	4.55,-03	2.76,-03	1.50,-03	6.47,-04	1.53,-04		
20.00	1.67,-02	1.18,-02	8.18,-03	5.55,-03	3.62,-03	2.21,-03	1.21,-03	5.23,-04	1.24,-04	
21.00	1.81,-02	1.30,-02	9.26,-03	6.49,-03	4.44,-03	2.92,-03	1.79,-03	9.83,-04	4.28,-04	1.02,-04
22.00	1.94,-02	1.41,-02	1.03,-02	7.39,-03	5.22,-03	3.60,-03	2.38,-03	1.47,-03	8.09,-04	3.53,-04
23.00	2.05,-02	1.52,-02	1.12,-02	8.23,-03	5.97,-03	4.25,-03	2.95,-03	1.96,-03	1.21,-03	6.71,-04
24.00	2.16,-02	1.61,-02	1.21,-02	9.03,-03	6.68,-03	4.89,-03	3.50,-03	2.44,-03	1.63,-03	1.01,-03
25.00	2.26,-02	1.70,-02	1.29,-02	9.77,-03	7.36,-03	5.49,-03	4.04,-03	2.91,-03	2.03,-03	1.36,-03

TABLE VII

VALUES OF S(P, B) FOR NEGATIVE PION OBSERVATION FROM Be^9 TARGET (P AND B ARE IN BEV/C) in mb BeV^{-2}

B	MOMENTA 1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
4.00	3.62, 01	5.21, 00	7.76,-01							
5.00	3.93, 01	6.57, 00	1.63, 00	2.92,-01						
6.00	4.16, 01	7.46, 00	2.22, 00	6.78,-01	1.34,-01					
7.00	4.33, 01	8.10, 00	2.62, 00	9.78,-01	3.34,-01	6.97,-02				
8.00	4.47, 01	8.59, 00	2.92, 00	1.20, 00	5.04,-01	1.83,-01	3.98,-02			
9.00	4.58, 01	9.00, 00	3.16, 00	1.37, 00	6.38,-01	2.87,-01	1.09,-01	2.44,-02		
10.00	4.68, 01	9.33, 00	3.35, 00	1.51, 00	7.46,-01	3.74,-01	1.76,-01	6.91,-02	1.57,-02	
11.00	4.76, 01	9.62, 00	3.51, 00	1.62, 00	8.33,-01	4.45,-01	2.35,-01	1.14,-01	4.59,-02	1.06,-02
12.00	4.83, 01	9.87, 00	3.65, 00	1.72, 00	9.06,-01	5.05,-01	2.84,-01	1.55,-01	7.76,-02	3.17,-02
13.00	4.89, 01	1.01, 01	3.77, 00	1.80, 00	9.69,-01	5.56,-01	3.27,-01	1.91,-01	1.07,-01	5.45,-02
14.00	4.95, 01	1.03, 01	3.87, 00	1.87, 00	1.02, 00	6.00,-01	3.64,-01	2.22,-01	1.33,-01	7.62,-02
15.00	5.00, 01	1.05, 01	3.97, 00	1.93, 00	1.07, 00	6.39,-01	3.96,-01	2.50,-01	1.57,-01	9.62,-02
16.00	5.04, 01	1.06, 01	4.05, 00	1.99, 00	1.11, 00	6.73,-01	4.25,-01	2.75,-01	1.78,-01	1.14,-01
17.00	5.08, 01	1.08, 01	4.13, 00	2.04, 00	1.15, 00	7.03,-01	4.51,-01	2.96,-01	1.97,-01	1.31,-01
18.00	5.11, 01	1.09, 01	4.20, 00	2.09, 00	1.19, 00	7.31,-01	4.73,-01	3.16,-01	2.14,-01	1.46,-01
19.00	5.15, 01	1.10, 01	4.27, 00	2.13, 00	1.22, 00	7.55,-01	4.94,-01	3.34,-01	2.30,-01	1.60,-01
20.00	5.18, 01	1.11, 01	4.33, 00	2.17, 00	1.24, 00	7.77,-01	5.12,-01	3.50,-01	2.44,-01	1.72,-01
21.00	5.20, 01	1.12, 01	4.38, 00	2.20, 00	1.27, 00	7.98,-01	5.29,-01	3.64,-01	2.57,-01	1.83,-01
22.00	5.23, 01	1.13, 01	4.43, 00	2.23, 00	1.29, 00	8.17,-01	5.45,-01	3.78,-01	2.68,-01	1.94,-01
23.00	5.25, 01	1.14, 01	4.48, 00	2.27, 00	1.32, 00	8.34,-01	5.59,-01	3.90,-01	2.79,-01	2.03,-01
24.00	5.27, 01	1.15, 01	4.52, 00	2.29, 00	1.34, 00	8.50,-01	5.72,-01	4.01,-01	2.89,-01	2.12,-01
25.00	5.29, 01	1.16, 01	4.56, 00	2.32, 00	1.36, 00	8.65,-01	5.85,-01	4.11,-01	2.98,-01	2.20,-01

B	MOMENTA 11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
12.00	7.42,-03									
13.00	2.26,-02	5.34,-03								
14.00	3.94,-02	1.65,-02	3.94,-03							
15.00	5.59,-02	2.92,-02	1.24,-02	2.97,-03						
16.00	7.12,-02	4.19,-02	2.21,-02	9.43,-03	2.28,-0[illegible]					
17.00	8.54,-02	5.39,-02	3.20,-02	1.71,-02	7.32,-03	1.78,-03				
18.00	9.85,-02	6.52,-02	4.16,-02	2.49,-02	1.34,-02	5.78,-03	1.41,-03			
19.00	1.11,-01	7.57,-02	5.07,-02	3.26,-02	1.97,-02	1.06,-02	4.62,-03	1.13,-03		
20.00	1.22,-01	8.54,-02	5.92,-02	4.00,-02	2.60,-02	1.58,-02	8.57,-03	3.73,-03	9.21,-04	
21.00	1.32,-01	9.45,-02	6.72,-02	4.70,-02	3.20,-02	2.09,-02	1.28,-02	6.98,-03	3.05,-03	7.55,-04
22.00	1.41,-01	1.03,-01	7.47,-02	5.36,-02	3.78,-02	2.59,-02	1.70,-02	1.05,-02	5.74,-03	2.52,-03
23.00	1.50,-01	1.11,-01	8.16,-02	5.99,-02	4.34,-02	3.08,-02	2.12,-02	1.40,-02	8.66,-03	4.77,-03
24.00	1.57,-01	1.18,-01	8.81,-02	6.57,-02	4.86,-02	3.55,-02	2.53,-02	1.76,-02	1.17,-02	7.22,-03
25.00	1.65,-01	1.24,-01	9.41,-02	7.12,-02	5.36,-02	4.00,-02	2.93,-02	2.11,-02	1.47,-02	9.77,-03

TABLE VIII

VALUES OF S(P, B) FOR POSITIVE PION OBSERVATION FROM Be^9 TARGET (P AND B ARE IN BEV/C)   in mb BeV^{-2}

B	MOMENTA 1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
4.00	3.68, 01	5.24, 00	7.90,-01							
5.00	3.99, 01	6.60, 00	1.63, 00	2.97,-01						
6.00	4.22, 01	7.48, 00	2.21, 00	6.78,-01	1.36,-01					
7.00	4.40, 01	8.12, 00	2.62, 00	9.75,-01	3.33,-01	7.06,-02				
8.00	4.54, 01	8.61, 00	2.92, 00	1.20, 00	5.01,-01	1.83,-01	4.03,-02			
9.00	4.65, 01	9.01, 00	3.15, 00	1.37, 00	6.35,-01	2.86,-01	1.09,-01	2.46,-02		
10.00	4.75, 01	9.35, 00	3.34, 00	1.50, 00	7.41,-01	3.71,-01	1.75,-01	6.89,-02	1.59,-02	
11.00	4.83, 01	9.63, 00	3.50, 00	1.61, 00	8.28,-01	4.42,-01	2.33,-01	1.14,-01	4.57,-02	1.07,-02
12.00	4.90, 01	9.88, 00	3.64, 00	1.71, 00	9.01,-01	5.02,-01	2.82,-01	1.54,-01	7.71,-02	3.15,-02
13.00	4.96, 01	1.01, 01	3.76, 00	1.79, 00	9.63,-01	5.52,-01	3.25,-01	1.90,-01	1.06,-01	5.41,-02
14.00	5.02, 01	1.03, 01	3.86, 00	1.86, 00	1.02, 00	5.96,-01	3.61,-01	2.21,-01	1.32,-01	7.57,-02
15.00	5.07, 01	1.05, 01	3.96, 00	1.92, 00	1.06, 00	6.35,-01	3.94,-01	2.48,-01	1.56,-01	9.55,-02
16.00	5.11, 01	1.06, 01	4.04, 00	1.98, 00	1.11, 00	6.69,-01	4.22,-01	2.73,-01	1.77,-01	1.13,-01
17.00	5.15, 01	1.08, 01	4.12, 00	2.03, 00	1.14, 00	6.99,-01	4.48,-01	2.94,-01	1.96,-01	1.30,-01
18.00	5.19, 01	1.09, 01	4.19, 00	2.07, 00	1.18, 00	7.26,-01	4.70,-01	3.14,-01	2.13,-01	1.45,-01
19.00	5.22, 01	1.10, 01	4.25, 00	2.12, 00	1.21, 00	7.50,-01	4.91,-01	3.31,-01	2.28,-01	1.58,-01
20.00	5.25, 01	1.11, 01	4.31, 00	2.15, 00	1.24, 00	7.72,-01	5.09,-01	3.47,-01	2.42,-01	1.71,-01
21.00	5.27, 01	1.12, 01	4.36, 00	2.19, 00	1.26, 00	7.93,-01	5.26,-01	3.62,-01	2.55,-01	1.82,-01
22.00	5.30, 01	1.13, 01	4.42, 00	2.22, 00	1.29, 00	8.11,-01	5.41,-01	3.75,-01	2.66,-01	1.92,-01
23.00	5.32, 01	1.14, 01	4.46, 00	2.25, 00	1.31, 00	8.29,-01	5.55,-01	3.87 -01	2.77,-01	2.02,-01
24.00	5.34, 01	1.15, 01	4.51, 00	2.28, 00	1.33, 00	8.45,-01	5.68,-01	3.98,-01	2.87,-01	2.10,-01
25.00	5.36, 01	1.16, 01	4.55, 00	2.31, 00	1.35, 00	8.59,-01	5.81,-01	4.09,-01	2.96,-01	2.18,-01

B	MOMENTA 11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
12.00	7.49,-03									
13.00	2.25,-02	5.39,-03								
14.00	3.92,-02	1.64,-02	3.98,-03							
15.00	5.54,-02	2.90,-02	1.23,-02	3.00,-03						
16.00	7.07,-02	4.16,-02	2.20,-02	9.39,-03	2.30,-03					
17.00	8.48,-02	5.35,-02	3.18,-02	1.70,-02	7.29,-03	1.80,-03				
18.00	9.77,-02	6.47,-02	4.13,-02	2.47,-02	1.33,-02	5.75,-03	1.42,-03			
19.00	1.10,-01	7.51,-02	5.03,-02	3.24,-02	1.95,-02	1.06,-02	4.60,-03	1.14,-03		
20.00	1.21,-01	8.48,-02	5.87,-02	3.97,-02	2.57,-02	1.56,-02	8.51,-03	3.72,-03	9.28,-04	
21.00	1.31,-01	9.38,-02	6.67,-02	4.66,-02	3.18,-02	2.07,-02	1.27,-02	6.93,-03	3.04,-03	7.61,-04
22.00	1.40,-01	1.02,-01	7.41,-02	5.32,-02	3.75,-02	2.57,-02	1.69,-02	1.04,-02	5.70,-03	2.51,-03
23.00	1.48,-01	1.10,-01	8.10,-02	5.94,-02	4.30,-02	3.06,-02	2.11,-02	1.39,-02	8.59,-03	4.73,-03
24.00	1.56,-01	1.17,-01	8.75,-02	6.53,-02	4.83,-02	3.52,-02	2.51,-02	1.74,-02	1.16,-02	7.16,-03
25.00	1.64,-01	1.23,-01	9.35,-02	7.07,-02	5.32,-02	3.97,-02	2.91,-02	2.09,-02	1.46,-02	9.69,-03

TABLE IX

B = 5.0 BeV

θ

p in BeV/c	1°	2.23°	3.17°	5.1°	8°	12°
2	1.76,4	5.74,4	7.52,4	7.47,4	5.05,4	2.83,4
3	2.86,4	6.41,4	6.42,4	4.45,4	2.37,4	1.18,4
4	1.80,4	2.78,4	2.29,4	1.30,4	6.20,3	2.93,3
4.5	8.35,3	1.09,4	8.31,3	4.41,3	2.04,3	9.53,2

B = 6.0 BeV

θ

p in BeV/c	1°	2.23°	3.17°	5.1°	8°	12°
2	1.66,4	5.43,4	7.11,4	7.06,4	4.78,4	2.68,4
3	3.24,4	7.26,4	7.27,4	5.05,4	2.69,4	1.33,4
4	3.48,4	5.37,4	4.42,4	2.51,4	1.20,4	5.67,3
4.5	2.81,4	3.65,4	2.80,4	1.48,4	6.87,3	3.20,3
5	1.69,4	1.88,4	1.35,4	6.82,3	3.08,3	1.43,3

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