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$f = 2.18 \times 10^{-13}$ cm $U_+ = 32.5$ MEV $U_- = 11.0$ MEV

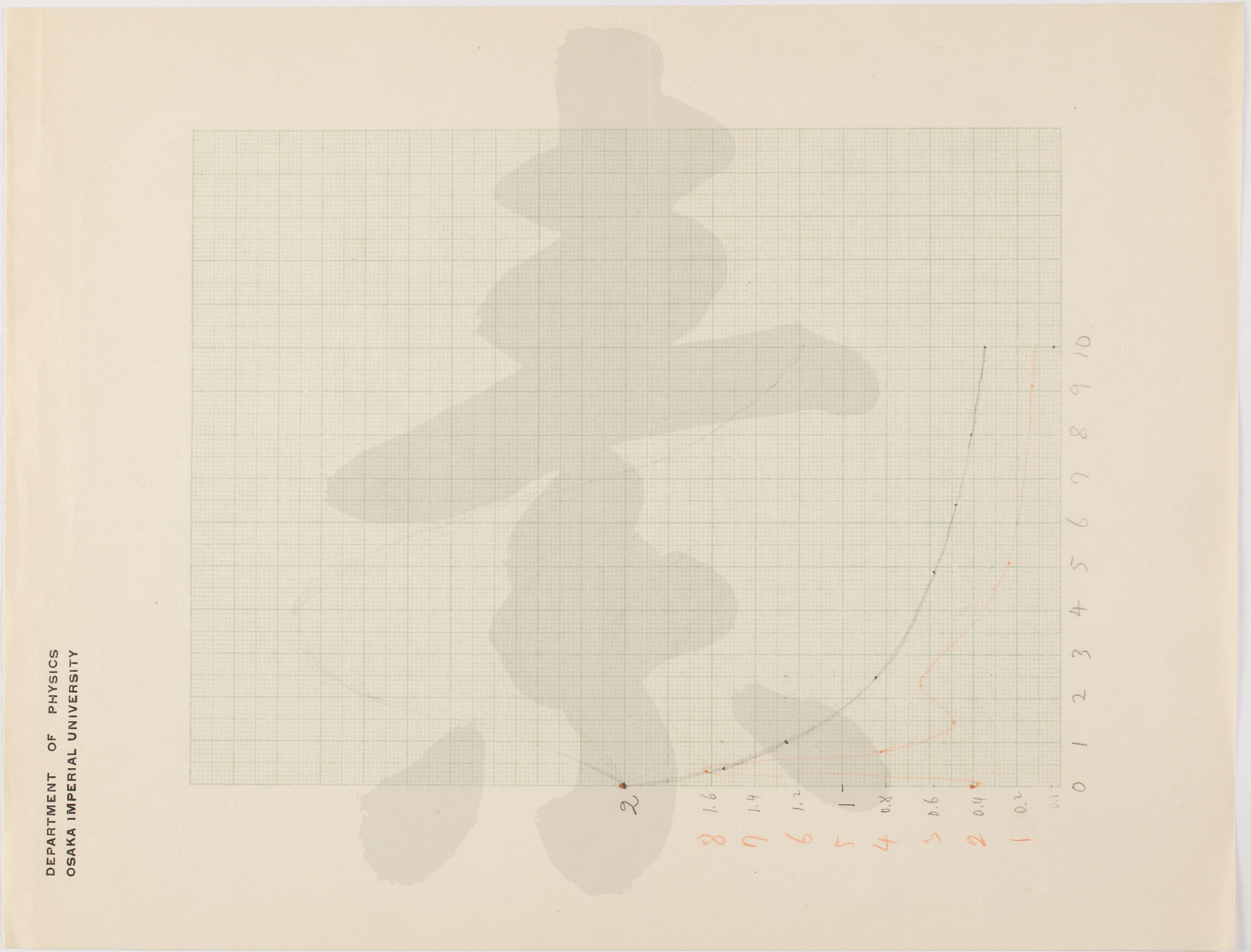
E_0	0	0.4	1	2.5	4.9	6.4	8.1	10	40
$\sigma_+(S)$	1.46	1.39	1.32s	1.07	0.85	0.74	0.65	0.54	0.11
$\sigma_+(P)$	0	0.0003	0.0011	0.003	0.024	0.042	0.039	0.11	0.30
$\sigma_-(S)$	2.18	1.60	1.24	0.785	0.48	0.38	0.34	0.25	0.0049
$\sigma_-(P)$	0	0.0000	0.0004	0.0022	0.0018	0.002	0.002	0.003	0.02
σ	2	1.55	1.26	0.85	0.58	0.48	0.40	0.35	0.12

E_0	0	0.09	0.2	0.365	0.57	0.82	1.12
σ	2	1.895		8.22		4.105	

E_0	1.46	1.85	2.28	5.13	9.12
σ	2.43		3.225	1.15	0.66

0.65

0.253
3
0.75
0.65
4)1.40
0.35



$\frac{d}{dx}(\arctan x) = \frac{1}{1+x^2}$ $\quad x - \frac{x^3}{3} + \cdots$

$1 = \frac{x^2}{x^2}$ $\quad 1 - \frac{2}{x^2}$

$-\frac{2x}{(1+x^2)^2}$

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$+\frac{2x^2}{(1+x^2)^3} - \frac{2}{(1+x^2)^2} = \frac{}{1}$

$\delta_0 = \tan^{-1}\left(\frac{k}{k'}\tan k'a\right) - ka$

$= \frac{k}{k'}\tan k'a - \frac{1}{3}\left(\frac{k}{k'}\tan k'a\right)^3 + \cdots$

$-ka = ka\left(\frac{\tan k'a}{k'a} - 1\right)$

$\sin^2 \pi a^2 \left(\frac{\tan k'a}{k'a} - 1\right)^2$

$E_0 = \frac{3}{2}(E' + E_D)$

$\Delta F + \frac{4M}{3\hbar^2}(E' + E_D - U_\pm)F = 0$

$\frac{4M}{3\hbar^2}(E' + E_D) = k^2 \quad -\frac{4M}{3\hbar^2}U_\pm = \kappa_\pm^2$

$\Delta F + (k^2 + \kappa_\pm)F = 0.$

$\sigma = \frac{4\pi}{k^2}(\sin^2\delta_0 + 3\sin^2\delta_1)$

$F = \frac{\sin \lambda r}{r}$ $r < b$ $\quad \lambda = \left\{\frac{4M}{3\hbar^2}(E' \pm E_D - U_\pm)\right\}^{\frac{1}{2}}$

$= \frac{Ae^{-\mu r}}{r}$ $r > b$ $\quad \mu = \frac{4M}{3\hbar^2}(E' \pm E_D)^{\frac{1}{2}}$

$\tan \lambda b = -\frac{\lambda}{\mu}$.

$J_{n+\frac{1}{2}}(ka)$

$\delta_n = \arctan(-1)^n \frac{k J_{n-\frac{1}{2}}(ka) J_{n+\frac{1}{2}}(k'a) - k' J_{n+\frac{1}{2}}(k'a) J_{-n-\frac{1}{2}}(ka)}{k J_{-n+\frac{1}{2}}(ka) J_{n+\frac{1}{2}}(k'a) + k' J_{n-\frac{1}{2}}(k'a) J_{-n-\frac{1}{2}}(ka)}$

$J_{\frac{1}{2}} = \sqrt{\frac{2}{\pi x}}\sin x \qquad J_{-\frac{1}{2}} = \sqrt{\frac{2}{\pi x}}\cos x$

$J_{\frac{3}{2}} = \sqrt{\frac{2}{\pi x}}\left\{\left(\frac{3}{x^2} - 1\right)\sin x \cdot \frac{\sin x}{x} - \cos x\right\} \qquad J_{-\frac{3}{2}} = -\sqrt{\frac{2}{\pi x}}\left(\sin x + \frac{\cos x}{x}\right)$

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$\frac{4M}{3\hbar^2}(E' + E_D) = \frac{8ME_0}{9\hbar^2} = k^2$

$M = 1.66 \times 10^{-24}$

$\hbar = 6.55 \times 10^{-27} / 2 \times 3.1416$

1.042

6.283) 6.550
6283
26700
25132
15680

1.042
1.042
2084
4168
1042
1.085

$\times 10^{-54}$

1.53
1.085) 1.660
1085
5750
5425
3250

1.53
9) 13.77
9
47
45
27
27

1.36
9) 12.24
9
32
27
54
54

1.36

$\frac{10^{-29}}{10^{-54}} = 10^{30}$

1.59×10^{-6}
$\times 10^{30}$

$k^2 = \frac{1.36 \times 10}{1.36}$ /MEV

2.1624
$= 1.36 \frac{1.59}{1.36} \times 10^{24}$ /MEV $= 1.17 \times 10^{29}$ /MEV

cm^{-2}

1.17
1.36) 1.59
136
230
136
940

$k^2 = 1.08 \times 10^{12} \times \sqrt{E_0}$ cm^{-1}
$2.65 \times 10^{24} \times E_0$ cm^{-2}

1.17
1.08
1.08
1.08
8677

1.59
1.36
954
477
159
2.1624

$1.08 \times 10^{12} \times \sqrt{13.8 \times \frac{3}{2} \times 4.5 \times 10^{-13}} = 2.94 = 3.00$
1.47

2.1624
4.65
1.47

6.9
3
20.7

20
4.55

1.47204
2.94
588
3.00

$k = 1.47 \times 10^{12} \sqrt{E_0}$ cm^{-1}

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$k = 1.47 \times 10^{12} \sqrt{E_0}\ cm^{-1}$.

$\sigma_{k=0} = 4\pi b^2 \left(\frac{\tan kb}{k'b} - 1\right)^2$

$\frac{\tan kb}{kb} = -\frac{1}{\mu b}$

$\lambda^2 + \mu^2 = \frac{4M}{3\hbar^2} U_0 = 2.1624 \times U$ (in MeV) $\times 10^{24}$

$(\lambda b)^2 + (\mu b)^2 = 2.1624$

$b = 2.18 \times 10^{-13}$

$(\lambda b)^2 + (\mu b)^2 = 2.1624 \times (2.18)^2 \times \frac{3}{2} \times 10^{-2} \times U$

$= 0.1554 \times U$

$\frac{\tan y}{y} = -\frac{1}{x}$

$x^2 + y^2 = a^2$.

$8.3 - 2.2 = 6.1$

$6.1 \times \frac{3}{2} = \frac{18.3}{2} = 9.15$

$\mu b = 1.47 \times 10^{12} \sqrt{9.15} \times 2.18 \times 10^{-13} = 0.9694 = \frac{1}{1.0316}$

1.47 0.16732
2.18 0.33846
$\sqrt{9.15}$ 0.48071
0.98649 1.97298
0.9694 0.9397
0.01351

2.1624 0.33494
$(2.18)^2$ 0.67752
1.5 0.17609
1.18855
1.554

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$\frac{\text{Lamb}}{y} = -1.0326$ $\quad y = 2.02$

$x^2 = (0.9694)^2 + (2.02)^2 = 0.9397 + 4.08 = 5.02$
$= 0.1554 \times U$

$U_+ = 32.5$ MEV

0.70070
1.18855
1.51215

$(k'b)^2 - (kb)^2 = 5.02 \left(= \frac{4M_p}{\hbar^2} U \times b^2\right)$

$k = 0$. $\quad k'b = \sqrt{5.02} = 2.24$

$\frac{\tan k'b}{k'b} = -0.5644$

$(1.5644)^2$ 0.38880 0.19440
$b^2 \times 10^{26}$ 0.67752
4π 1.09921
2.16553

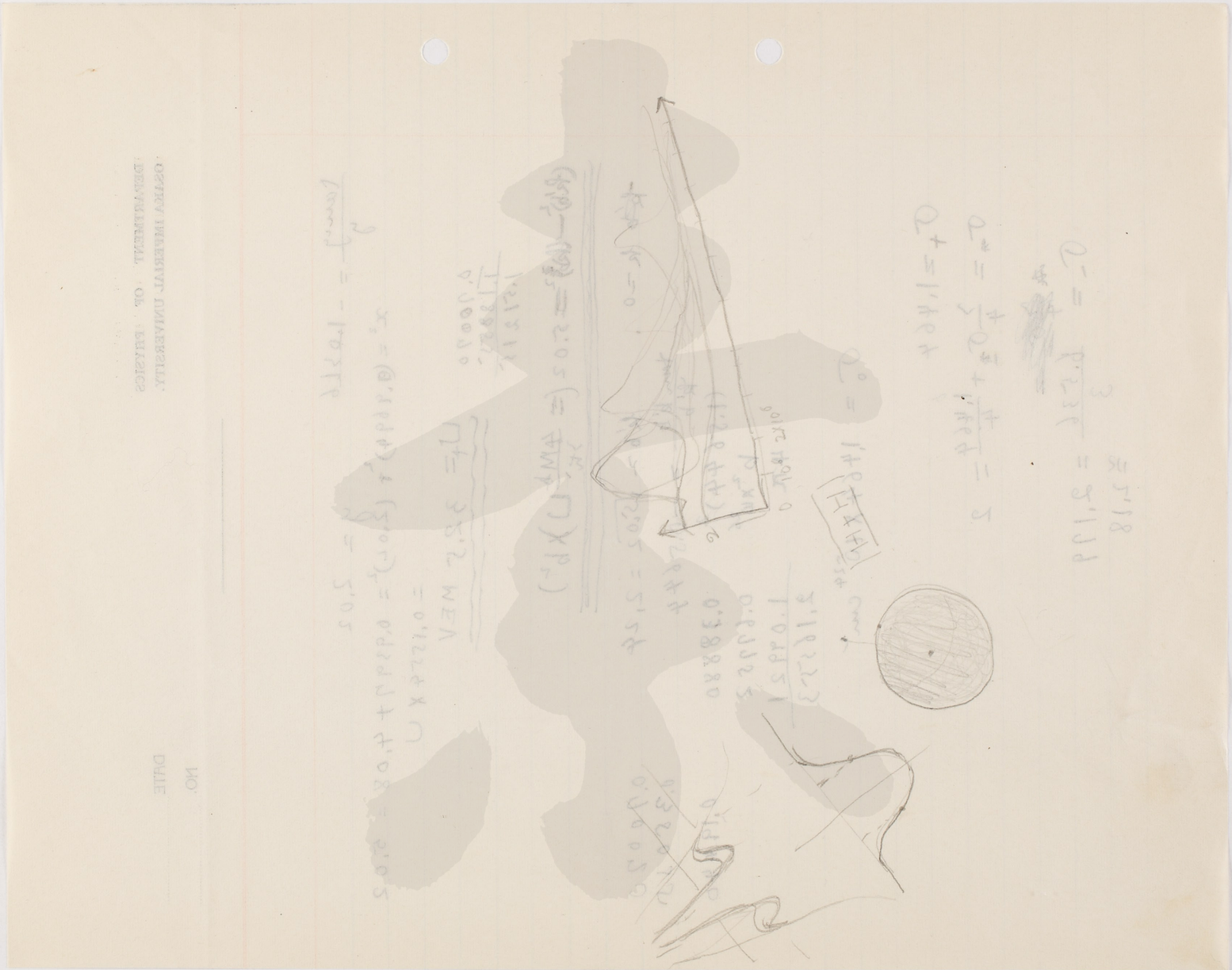
0.70070
0.35035

$\sigma_0 = 1.464 \times 10^{-24}\ \text{cm}^2$

$\sigma_+ = 1.464$

$\sigma_{\text{singlet}} = \frac{3}{4}\sigma_{\pm} + \frac{1.464}{4} = 2$

$\sigma_- = \frac{6.536}{3} = 2.179$
$\simeq 2.18$



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$$\sigma = 4\pi b^2 \left(\frac{\tan k'_-b}{k'_-b} - 1\right)^2 \qquad 4\pi b^2 \quad 1.77673$$

(598)

~~2,18 = 0,598~~

$$\log\left(\frac{\tan k'_-b}{k'_-b} - 1\right)^2 = 0,56173$$

$$\log\left(\frac{\tan k'_-b}{k'_-b} - 1\right) = \pm 0,27087$$

$$\frac{\tan k'_-b}{k'_-b} - 1 = \pm(1,866)$$

$$\frac{\tan k'_-b}{k'_-b} = \begin{cases} 2,866 \\ -0.866 \end{cases}$$

$$k'_-b = \begin{cases} 1.31 \quad !! < \frac{\pi}{2}. \\ 2.08 \end{cases}$$

$$0,1554 \times U_- = \begin{matrix} (1,31)^2 \\ (2.08)^2 \end{matrix} = \begin{matrix} 1,716 \\ 4,326 \end{matrix}$$

$$U_- = \begin{cases} \text{~~17.5 MEV~~ } 11,04\,\text{MEV}. \\ 27.8\,\text{MEV} \times \end{cases}$$

0.33846
0.77673
0.56173

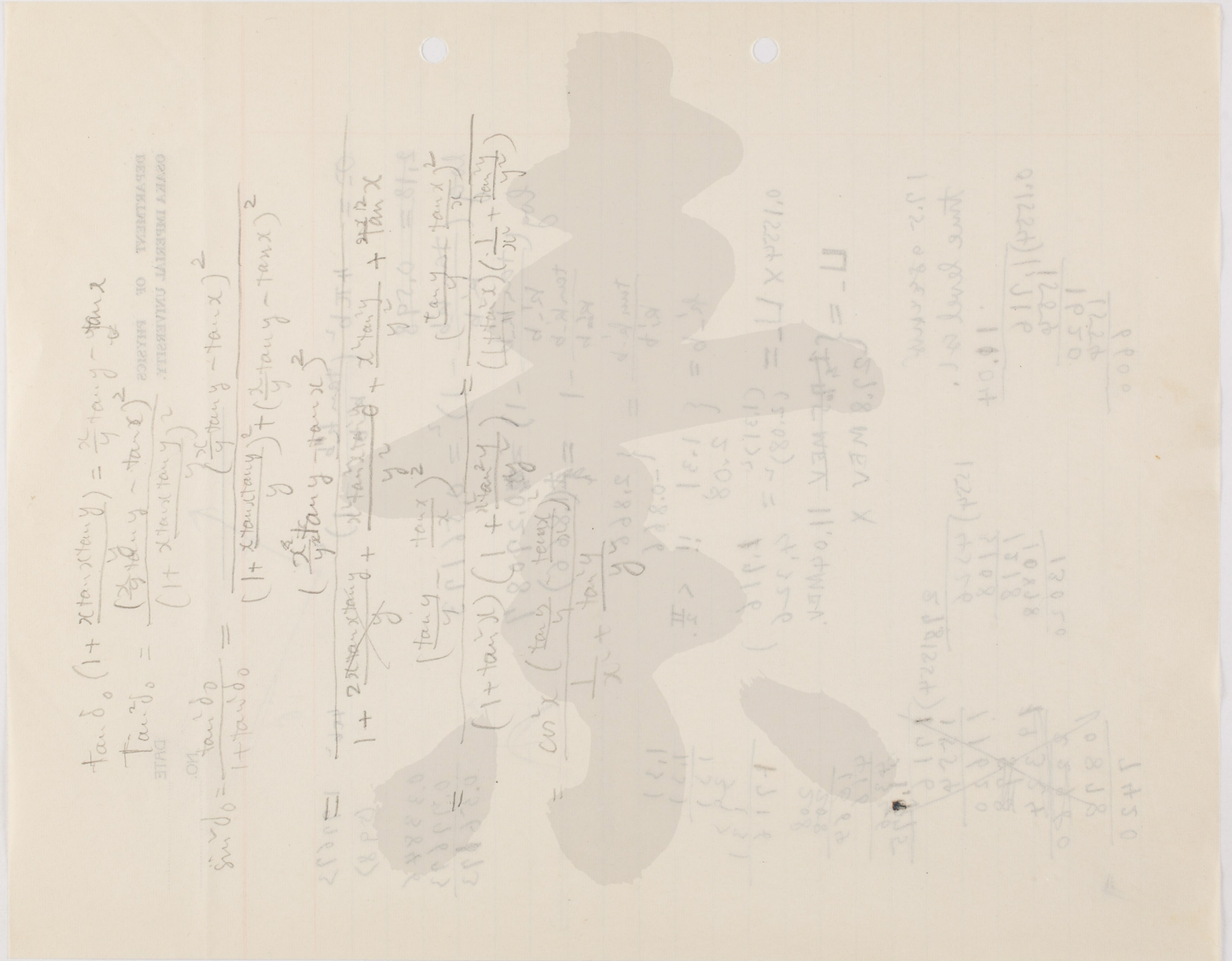
1.31 × 1.31 = 1.716
2.08 × 2.08 = 4.326

17.5 [illegible]
true level [illegible].

0.1554)1,716 = 11.04
1554
1620
1554
6600

1554)4326 = 2.78
3108
1218
10878
13020

1554)1,716 ...
1554
1620
[illegible]
324
2960
10878
7420



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$\tan(\delta_0 + kb) = \frac{k}{k'b} \tan k'b$

$\tan(\delta_0 + x) = \frac{x}{y} \tan y$

$\frac{\sin\delta_0 \cos x + \cos\delta_0 \sin x}{\cos\delta_0 \cos x - \sin\delta_0 \sin x} = \frac{x}{y} \tan y$

$\frac{\tan\delta_0 + \tan x}{1 - \tan\delta_0 \tan x} = \frac{x}{y} \tan y$

Energy Dependence (J+)
S-scattering $(10^5 eV)$ $10^6 eV$ $10^7 eV$

$\delta_0 = \tan^{-1}\left(\frac{k}{k'} \tan k'b\right) - kb.$

$E_0 = 10^6 eV$ $kb = 1.47 \times 10^{12} \times 2.18 \times 10^{-13}$

$= 0.3205$

0.50578
3205

$k'b = 0.3205 \times \sqrt{(32.5 \times \frac{3}{2}) + 1}$

32.5
97.5
48.75
49.75
7005
2005
4985
35

$= 0.3205 \times 7.005 = 2.245$

.3205
7.005
16025
22435
2245 1025

$= -0.557$

$\delta_0 = \tan^{-1}(-0.557 \times 0.3205) - 0.3205$

0.3205
0.557
22435
16025
16025
−0.17851 85

$= 2.965 - 0.3205$
$= 2.6445$
$\sin\delta_0 = \sin 151° 30'$
$= \sin 28° 30'$
$= 0.4772$

60.45
60.75

10° 7′
10.12
169.88 × π/180
57.2957

2.23019
1.75812
0.47207

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$0.598 \times (0.4772)^2 \times \left(\frac{1}{0.3205}\right)^2 =$

$\bar{1}.77673$
1.35732
$\bar{2}.98834$
1.12239

0.67866
2
50583
$\bar{1}.49417$

$E_0 = 1\text{MEV}$ $\sigma_+ = 1.325 \times 10^{-24}\ \text{cm}^2$.

$E_0 = 10\text{MEV}$. $k'b = 0.3205 \times \sqrt{10} = 1.0135 = 58°4'$

$k'b = 0.3205 \times \sqrt{48.75 + 10}$

$= 2.457$

$\sqrt{58.75} =$

$\bar{1}.50583$
0.5
0.00583

1.76901
0.88451
$\bar{1}.50583$
0.39034

$\delta_0 = \tan^{-1}(1.0135 \times (-0.33))$

$-2.457 = 2.82$
$-2.457 = 0.363$

$\log(\sin 76°34') = \bar{1}.98189$
$\log(4\pi b^2) = \bar{1}.77673$
$\log(\sin^2 76°34') = \bar{1}.96378$
$\log 4\pi b^2 = \bar{1}.77673$
$\log (kb)^{-2} = \bar{1}.98834$

$\log(\sin^2 \delta_0) = 2(\bar{1}.54769) = \bar{1}.09538$
$\log (kb)^{-2} = 2(\bar{1}.99417) = \bar{1}.98834$
$\log 4\pi b^2 = \bar{1}.77673$
$\bar{2}.86045$

$\sigma_+(10^7\text{eV})$ $\bar{1}.72885$
$= 0.53566 \times 10^{-24}\ \text{cm}^2$

$\sigma_+(10^7\text{eV}) = 0.07252 \times 10^{-24}\ \text{cm}^2$

$\delta_0 = \sin(0.363) = \sin(20°40') \sin(105°26') = \sin(76°34')$

30405
30405
-0.33445
$18°30'$
$161°30'$
2.82

$161°30'$
$58°4$
$105°26'$

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10^6 eV.
$0.7\,mc^2$ $0.35\,mc^2 \times 10^6$ eV

$E_0 = 10^8$ MEV. $\delta_0 = \tan^{-1}$ $kb = 3.205$

$kb = 0.3205 \times \sqrt{48.75 \times + 100}$
$= 3.909$

$\delta_0 = \tan^{-1}\left(3.205 \times \frac{\tan 3.909}{3.909}\right)$

148.75

2.17245
1.08623
T.50583
0.59206

3.909
3.1416
0.767

44°

3.205
3.1416
0.063

(3.205) T. 0.50583 1.01166
$(3.909)^{-1}$ 1.40794 2.98834
(tan 44°) T.98494
T.89861 → 0.67 ← 38°22′
7918
0.67 — 3.205 → 3°40′

$\sin^2\delta_0 = \sin^2 34°42'$ log. T.75533
$= 0.3241$ → log T.51066
→ log 2.98834
→ log T.77673
2.27573

$4\pi b^2 \times \frac{0.3241}{(3.205^-)^2}$

$\sigma_+(10^8 eV) = 0.0{,}1887 \times 10^{-24}\,cm^2$

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δ_+.

P-scattering

$$\delta_1 = \arctan - \frac{k J_{\frac12}(kb) J_{\frac32}(k'b) - k' J_{\frac12}(k'b) J_{\frac32}(kb)}{k J_{-\frac12}(kb) J_{\frac32}(k'b) + k' J_{\frac12}(k'b) J_{-\frac32}(kb)}$$

$$\left\{\Delta + \frac{4M}{3\hbar^2}\left(\frac{3}{2}E_0 - U_+\right)\right\} F = 0 \qquad (\Delta + k^2) F = 0$$

k^2

$F = P_n(\cos\theta) f_n(r)$ $\qquad \frac{1}{r^2}\frac{d}{dr}\left(r^2 \frac{df_n}{dr}\right) + \left(k^2 - \frac{n(n+1)}{r^2}\right) f_n = 0.$

$n=1$, $\qquad f_1 = \frac{1}{kr}\left(\frac{\sin kr}{kr} - \cos kr\right)$

$$f_n = \frac{1}{r^2}\frac{d}{dr}\left(r^2 \frac{df_n}{dr}\right) - \left(\mu^2 + \frac{2}{r^2}\right) f_1 = 0$$

$$f_1 = e^{-\mu r}\frac{e^{-\mu r}}{r}\left(1 + a\frac{a}{r} + \cdots\right)$$

$$\left(1 + \frac{a}{r}\right).$$

$$\frac{df_1}{dr} = -\mu\frac{e^{-\mu r}}{r}\left(1 + \frac{a}{r}\right) - \frac{e^{-\mu r}}{r^2}\left(1 + \frac{2a}{r}\right)$$

$$\frac{d}{dr}\left(r^2 \frac{df_1}{dr}\right) = \frac{d}{dr}\left(\mu r e^{-\mu r} + \mu a + 1 + \frac{2a}{r}\right) e^{-\mu r}$$

$$= \left\{\left(\mu - \frac{2a}{r^2}\right) + \mu\left(\mu r + \mu a + 1 + \frac{2a}{r}\right)\right\} e^{-\mu r}$$

$$-\frac{2a}{r^2} + \mu^2 r + \mu^2 a + \frac{2\mu a}{r} + \frac{2a}{r^2} = \left(\mu^2 + \frac{2}{r^2}\right)(r + a)$$

$$= \left(\mu^2 - \frac{2}{r^2}\right)(r + a) = \mu^2 r + \mu^2 a + \frac{2}{r}$$

$$+\frac{2a}{r^2}$$

$$a = \frac{1}{\mu}$$

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$$f_1 = \frac{e^{-\mu r}}{r}\left(1+\frac{1}{\mu r}\right)$$

$$\frac{1}{kr}\left(\frac{\sin kr}{kr} - \cos kr\right) \qquad \frac{Ce^{-\mu r}}{r}\left(1+\frac{1}{\mu r}\right)$$

$$\frac{1}{kb}\left(\frac{\sin kb}{kb} - \cos kb\right) = C\frac{e^{-\mu b}}{b}\left(1+\frac{1}{\mu b}\right)$$

$$\frac{1}{kr}\left(\frac{k\cos kr}{kr} - \frac{\sin kr}{kr^2} + k\sin kr\right)$$

$$\frac{1}{kr^2}\left(\frac{\sin kr}{kr} - \cos kr\right)$$

$$= \frac{1}{kr}\left(\frac{2\cos kr}{r} - \frac{2\sin kr}{kr^2} + k\sin kr\right)$$

$$C\left\{-\mu\left(\frac{1}{r}+\frac{1}{\mu r^2}\right) - \frac{1}{r^2} - \frac{2}{\mu r^3}\right\}e^{-\mu r}$$

$$= -C\left\{\frac{\mu}{r} + \frac{2}{r^2} + \frac{2}{\mu r^3}\right\}e^{-\mu r}$$

$$\frac{1}{kb}\left(\frac{2\cos kb}{b} - \frac{2\sin kb}{kb^2} + k\sin kb\right)$$

$$= -C\left\{\frac{\mu}{b} + \frac{2}{b^2} + \frac{2}{\mu b^3}\right\}e^{-\mu b} \quad !!!$$

$$\frac{\dfrac{2\cos kb}{b} - \dfrac{2\sin kb}{kb^2} + k\sin kb}{\dfrac{\sin kb}{kb} - \cos kb} = \frac{-\left(\mu + \dfrac{2}{b} + \dfrac{2}{\mu b^2}\right)}{\left(1+\dfrac{1}{\mu b}\right)}$$

$kb = y$
$\mu b = x$

$$k\,\frac{\dfrac{2}{y} - 2\dfrac{\tan y}{y^2} + \tan y}{\dfrac{\tan y}{y} - 1} = -\mu\,\frac{\left(x+2+\dfrac{2}{x}\right)}{x+1} = -\mu\,\frac{x^2+2x+2}{x^2+x}$$

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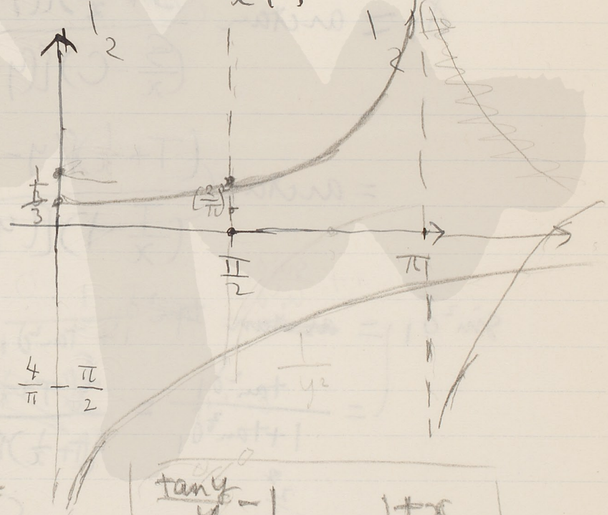
$$\frac{\tan y}{y}$$

$$\frac{2-2\frac{\tan y}{y}+y\tan y}{\frac{\tan y}{y}-1}=-\frac{x^2+2x+2}{x+1}$$

$$\frac{2\frac{\tan y}{y}-2-y\tan y}{\frac{\tan y}{y}-1}=\frac{x^2+2x+2}{x+1}$$

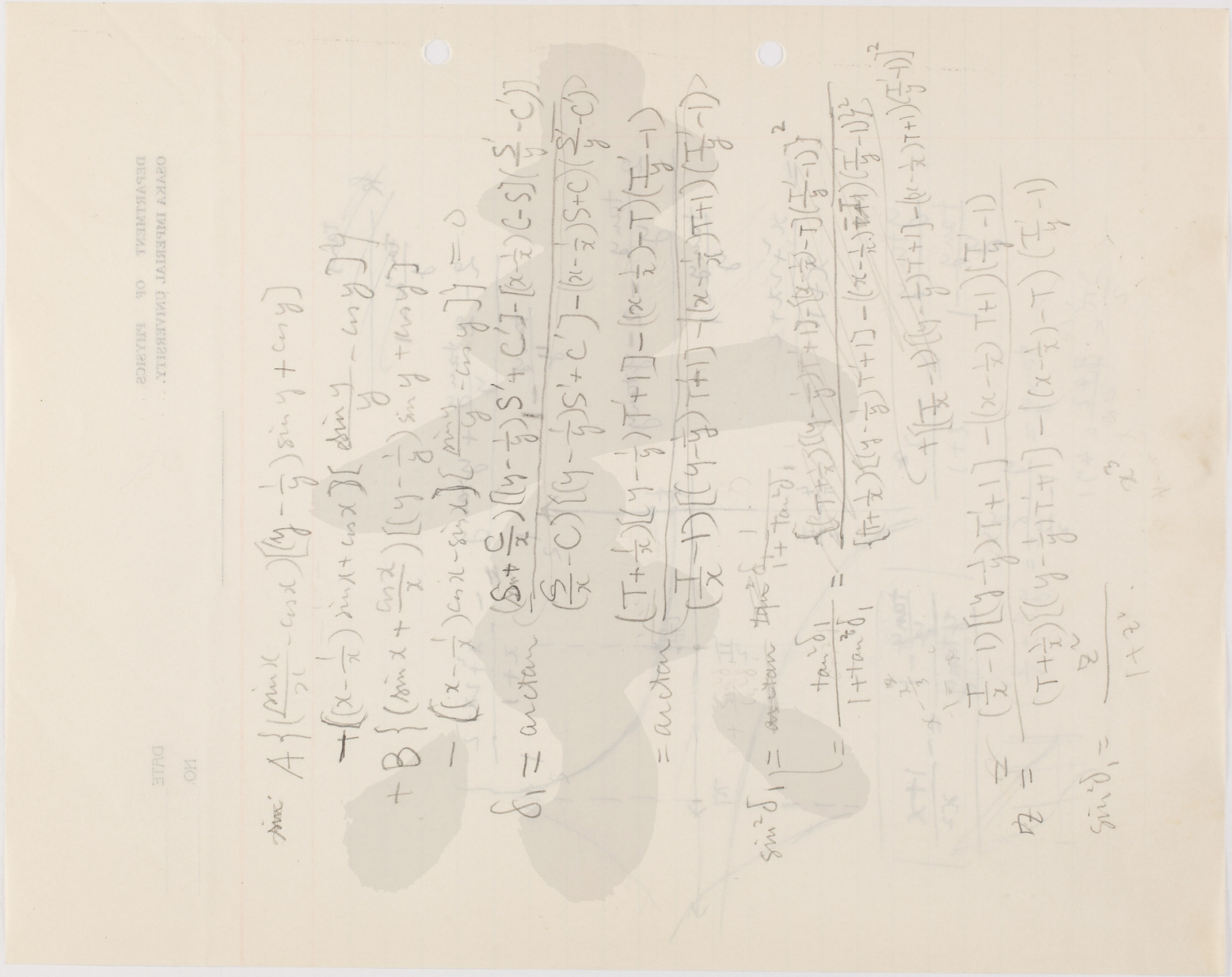


$$\frac{y\tan y}{\frac{\tan y}{y}-1}=-\frac{x^2}{x+1}$$

$$\frac{\frac{\tan y}{y}-1}{y\tan y}=-\frac{1+x}{x^2}$$

$$\tan y=\frac{y-\frac{y^3}{6}}{1-\frac{y^2}{2}}=y\left(1+\frac{y^2}{3}\right)$$

$$\frac{3\pi}{2}=\frac{9.42}{4.2}=4.71$$



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$-A\cos kr + B\sin kr$

$= C\sin\delta_1 \cos kr + C\cos\delta_1 \sin kr$

$= C\sin(kr+\delta_1)$

$\tan\delta_1 = \left(-\frac{A}{B}\right)$ cos

$= -C\cos kr\cos\delta_1 + C\sin kr\sin\delta_1$

$\tan\delta_1 = \frac{\sin\delta_1}{\cos\delta_1} = \frac{B}{A}$

$\frac{1}{kr}\left(\frac{\sin kr}{kr} - \cos kr\right)$ $\quad \frac{1}{kr}\left(\frac{\cos kr}{-kr} + \sin kr\right)$

$f = \frac{\varphi}{r}$ $\quad \frac{df}{dr} = \frac{1}{r}\frac{d\varphi}{dr} - \frac{\varphi}{r^2}$ $\quad \frac{1}{r}\frac{d}{dr}\left(r^2\frac{df}{dr}\right) = \frac{1}{r^2}\frac{d}{dr}\left(r\frac{d\varphi}{dr}\right)$

$-\frac{1}{r}\frac{d\varphi}{dr} = \frac{1}{r}\frac{d\varphi}{dr}$

$\frac{d^2\varphi}{dr^2} + \left(k^2 - \frac{n(n+1)}{r^2}\right)\varphi = 0$

$\frac{d}{dr}\left(\frac{\sin kr}{kr} - \cos kr\right) = \frac{d}{dr}\left(\frac{k\cos kr}{r} - \frac{\sin kr}{kr^2} + k\sin kr\right)$

$= \frac{-k^2\sin kr}{kr} - \frac{2\cos kr}{r^2} + \frac{2\sin kr}{kr^3} + k^2\cos kr$

$\frac{d}{dr}\left(\frac{\cos kr}{kr} + \sin kr\right) = \frac{d}{dr}\left(\frac{-k\sin kr}{kr} - \frac{\cos kr}{kr^2} + k\cos kr\right)$

$= -\frac{k^2\cos kr}{kr} + \frac{2\sin kr}{kr^2} + \frac{2\cos kr}{kr^3} - k^2\sin kr$

$\frac{\sin k'b}{k'b} - \cos k'b = A\left(\frac{\sin kb}{kb} - \cos kb\right) + B\left(\frac{\cos kb}{kb} + \sin kb\right)$

$k'b\left\{\frac{\cos k'b}{k'b} + \sin k'b\left(1 - \frac{1}{(k'b)^2}\right)\sin k'b\right\}$

$= kb\left\{A\left(\frac{\cos kb}{kb} + \left(1 - \frac{1}{(kb)^2}\right)\sin kb\right\}\right.$

$\left. + B\left\{\cos kb - \left(1 - \frac{1}{(kb)^2}\right)\cos kb - \frac{\sin kb}{kb}\right\}\right]$

$k'b = y \qquad kb = x$

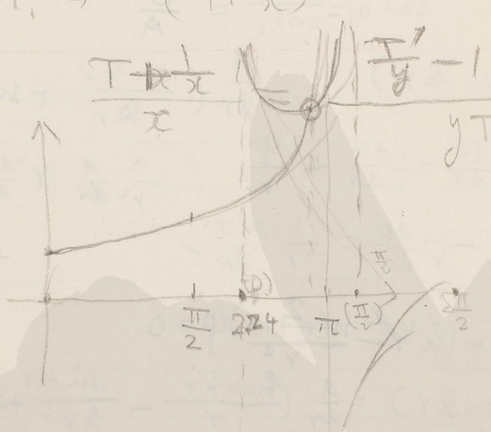
$\frac{\sin y}{y} - \cos y = A\left(\frac{\sin x}{x} - \cos x\right) + B\left(\frac{\cos x}{x} + \sin x\right)$

$\left(\frac{1}{y} - \frac{1}{y}\right)\sin y + \cos y = A\left\{\left(\frac{1}{x}\right)\sin x + \cos x\right\} + B\left\{\left(x - \frac{1}{x}\right)\cos x - \sin x\right\}$

$$\frac{(x-\frac{1}{x})-T}{(T+\frac{1}{x})} = \frac{(y-\frac{1}{y})T'+1}{\frac{T'}{y}-1}$$

$\sin y_1 = 1 \rightarrow$

$$\frac{T+\frac{1}{x}}{x} \qquad \frac{\frac{T'}{y}-1}{yT'} \quad !!!$$



$$\frac{T+\frac{1}{x}}{x} = T'$$

$$z = \frac{(\frac{T}{x}-1)(1-\frac{T'}{y})+y\frac{T'}{x}-1)+(\frac{T}{x}-1)(\frac{T'}{y}-1)-xT(\frac{T'}{y}-1)}{(T+\frac{1}{x})(1-\frac{T'}{y})+y\frac{T'}{x}(T+\frac{1}{x})+(\frac{T}{x}+1)(\frac{T'}{y}-1)-x(\frac{T'}{y}-1)}$$

$$= \frac{y\frac{T'}{x}-1)-xT(\frac{T'}{y}-1)}{y(T+\frac{1}{x})+(1+\frac{1}{x})(T+\frac{1}{x})}$$

$$(-x-T-\frac{1}{x})(\frac{T'}{y}-1)$$

$$yT'(T+\frac{1}{x})-x(\frac{T'}{y}-1)$$

$$\delta = \arctan \frac{y(\frac{T}{x}-1)-xT(\frac{T'}{y}-1)}{yT'(T+\frac{1}{x})-x(\frac{T'}{y}-1)}$$

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$4\pi b^2 = 0.598 \times 10^{-24} cm^2$

$\sigma_+(P) = 4\pi b^2 \frac{3 \sin^2\delta_1}{k^2 b^2}$

$E_0 \leq 0$, $\sigma_+(P) = 0$.

$E_0 = 10^6 eV$. $x = kb = 0.3205$ $y = 2.245$

$T = \tan x = \tan 18°22' = .3320097$ $T' = \tan y = \tan 51°22' = -1.2511848$

$\frac{T}{x} = 1.036$

$\frac{T'}{y} = 0.5573$

$y(\frac{T}{x} - 1) = 0.08082$

$-xT(\frac{T'}{y} - 1) = 0.16571$

$= 0.24653$

$y T'(T + \frac{1}{x}) = -9.698$

$-x(\frac{T'}{y} - 1) = 0.4991$

$= -9.199$

$z = \frac{-0.24653}{9.199} = 0.02680$

$z^2 = 0.0007181$

$1 + z^2 = 1.0007181 \approx 1$.

$\frac{1}{x} = 3.1201$

$T = 0.3320$

$T + \frac{1}{x} = 3.4521$

$\sin^2\delta_1 = \frac{0.035344}{1.035344}$

0.3205	$\bar{1}.50583$
0.3320	$\bar{1}.52118$
1.5573	0.19237
←	$\bar{1}.21934$

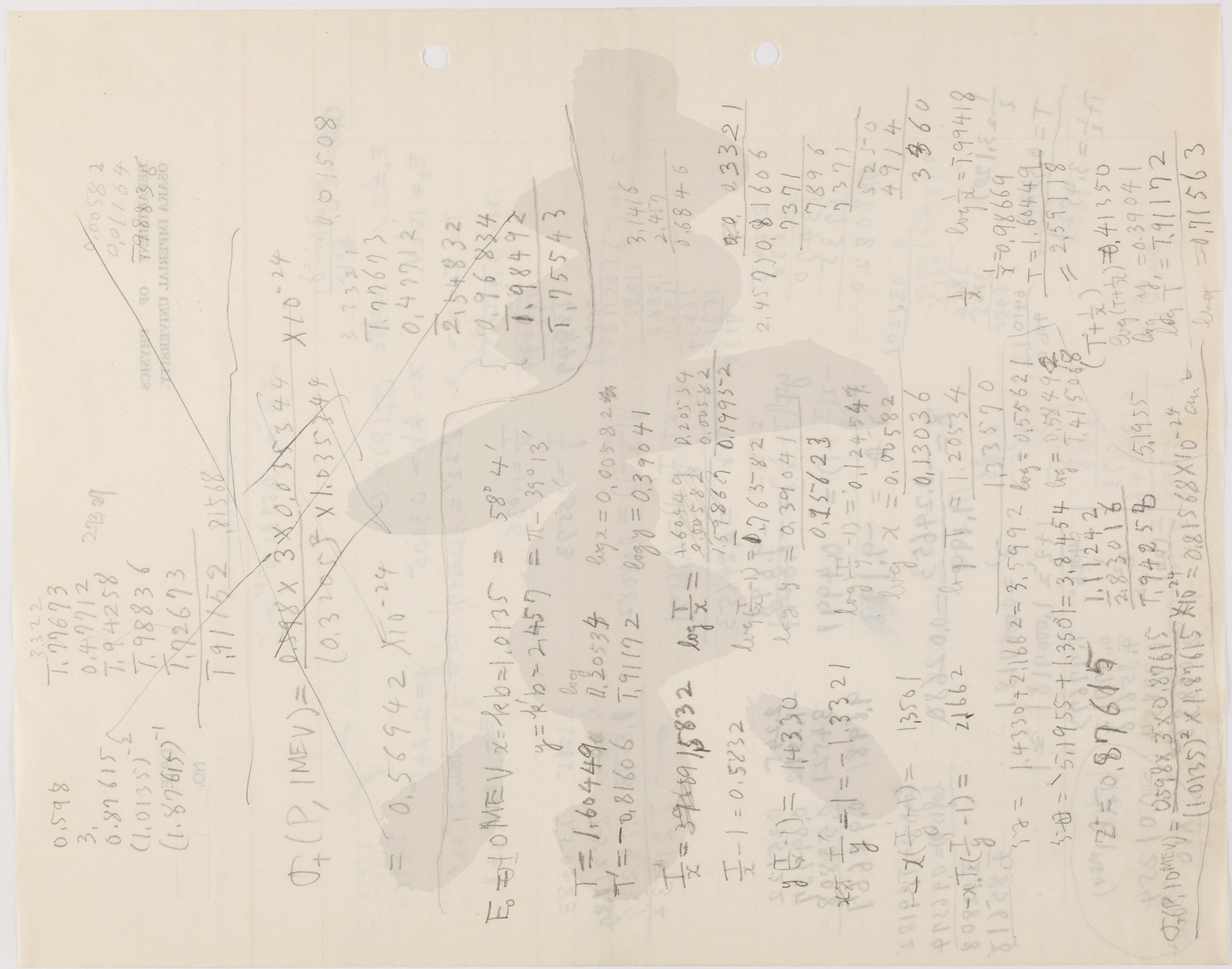
2.245	0.35122
-1.2512	0.09737
3.4521	0.53808
9.8981	0.98667

$\log(\ldots) = \bar{1}.39182$
$\log(9.199) = 0.96374$
$\bar{2}.42808$
$\bar{4}.85616$

$4\pi b^2$	$\bar{1}.77673$
3	0.47712
z^2	$\bar{4}.85616$
$(kb)^{-2}$	0.98834
	$\bar{2}.09835$

$\sigma_+(P, 1 MeV) = 0.01254 \times 10^{-24} cm^2$

3.1416
2.245
0.8966



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11.04
3
2)33.12
16.56

(1) S-scattering

$E_0 = 10^6$ eV $x = kb = 0.3205$ $\log x = \bar{1}.50583$

$y = k'b = 0.3205 \times \sqrt{17.56} = 1.343$

$\bar{1}.50583$
0.62226 1.24452
0.12809

$\delta_0 = \tan^{-1}(0.3205 \times 3.213) - 0.3205$
$= 45°50' - 18°22'$
$= 27°28'$

$\log \sin \delta_0 = \bar{1}.66392$ $\bar{1}.32784$
$\log(4ab^2) =$ $\bar{1}.77673$
$\log 0.3205 = \bar{1}.50583$ $\bar{1}.98834$
$\bar{1}.01166$ 0.08291

$3.176 \quad 124$
$372 \quad 3$
$3.213 \quad 372$

34
1.70

0.3205
3.213
9615
3205
6410
9615
1.0297665

$\sigma_-(5.1\,\mathrm{MEV}) = 1.239 \times 10^{-24}\,\mathrm{cm}^2$

17.56

$E_0 = 10^7$ eV $x = kb = 1.0135$

$y = k'b = 0.3205 \times \sqrt{27.56}$
$= 1.665 = 95°16'$ 1.430281 $\bar{1}.71514$
0.22097

$\delta_0 = \tan^{-1}(1.0135 \times 0.516) - 1.0135$
$= 180° - 81°23' - 58°4'$
$= 40°33'$

$\log(\sin \delta_0) = \bar{1}.81299$ $\bar{1}.62598$
$\log(4ab^2) =$ 1.77673
$\log(1.0135) = 0.0058238$ $\bar{1}.98835$
$\bar{1}.39106$

1.0135
0516
60810
10135
50675
60810
6.6039660

1663
-6.735
-6.016
0.719
0.7
0.5033

$\sigma_-(5.10\,\mathrm{MEV}) = 0.2461 \times 10^{-24}\,\mathrm{cm}^2$

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(1) P-scattering

$$\sigma_- = 4\pi b^2 \frac{3\sin^2\delta_1}{k^2 b^2}$$

$$\sin^2\delta_1 = \frac{z^2}{1+z^2} \qquad z = \frac{y(\frac{T}{x}-1) - xT(\frac{T'}{y}-1)}{yT'(T+\frac{1}{x}) - x(\frac{T'}{y}-1)}$$

$E_0 = 1\,\mathrm{MEV}$. $x = kb = 0.3205$ $y = k'b = 1.343$

$\frac{T}{x} - 1 = 0.0357$ $\frac{T'}{y} - 1 = 2.213$ $xT = 0.107$ $yT' = 5.79$

1.343 × 0.0357 = 9401 + 6715 + 4029 = 1.047945 1

2.213 × 0.107 = 15491 + 2213 = 0.236791

+0.047945 − 0.188846

$\delta' z = -0.189$

$T = \tan 18°22' = 0.3320$

$\frac{1}{x} = 3.12$

0.3205) 1.0000 (3.12
9615
3850
3205
6450

$T + \frac{1}{x} = 3.452$ × 5.79 = 31068 + 24164 + 17260 = 19.98708 + 0.01174 = 19.99564

0.0357 × 0.3205 = 1785 + 714 + 1071 = 0.011441 85

$z = -\frac{0.189}{19.976}$

$\log 1.29646 - \log 1.30051 = \log 3.97595 - \log 5.95090$

29

$z^2 = 3.899$

$1 + z^2 = 1.00003899$

$\frac{4\pi b^2}{3(k^2b^2)^{-1}} = 0.0001584$

5.95090 + 1.77673 + 0.47912 + 0.98834 = 9.19309

1.50583 × 2 = 2.01166

$\sigma_-(P, 1\,\mathrm{MEV}) = 0.00156 \times 10^{-24}\,\mathrm{cm}^2$.

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$E_0 = 10$ MEV. $x = kb = 1.0135 = 58° 4'$ $T = 1.6045$

$y = k'b = 1.663$ $T + \frac{1}{x} = 2.5912$

$\frac{T}{x} = 1.583$ $\frac{T}{x} - 1 = 0.583$ $xT = 1.627$ $\frac{1}{x} = 0.98677$

$\frac{T'}{y} = -6.5193$ $\frac{T'}{y} - 1 = -7.5193$ $yT' = 18.026$

$y(\frac{T}{x} - 1) = 0.9695$

$xT(\frac{T'}{y} - 1) = -12.2350$

$s^2 = 13.2045$

$yT'(T + \frac{1}{x}) = 46.6977$

$-x(\frac{T'}{y} - 1) = +7.6215$

54.3192

-39.0962

$\log(s \cdot z) = 1.12072$

$\log(s \cdot \bar{z}) = 1.73495$

$\log(z) = \bar{1}.38577$

□ $\log(z^2) = \bar{2}.77154$

$z^2 = 0.05909$

$1 + z^2 = 1.05909$

⊠ $\log(1 + z^2) = 0.02494$

− ▷ $\log(1 + z^2)^{-1} = \bar{1}.97506$

1,663
0.583
4989
13304
8315
0.969529

1,627
7,52
3254
8135
11389
12.23504

18.026
2,59
16227
9015
3606
46.6977

18.56
16.779
1.789
7
12467
16.779
18.026

6.735
6.016
719
7
5033
6.016
6.5193

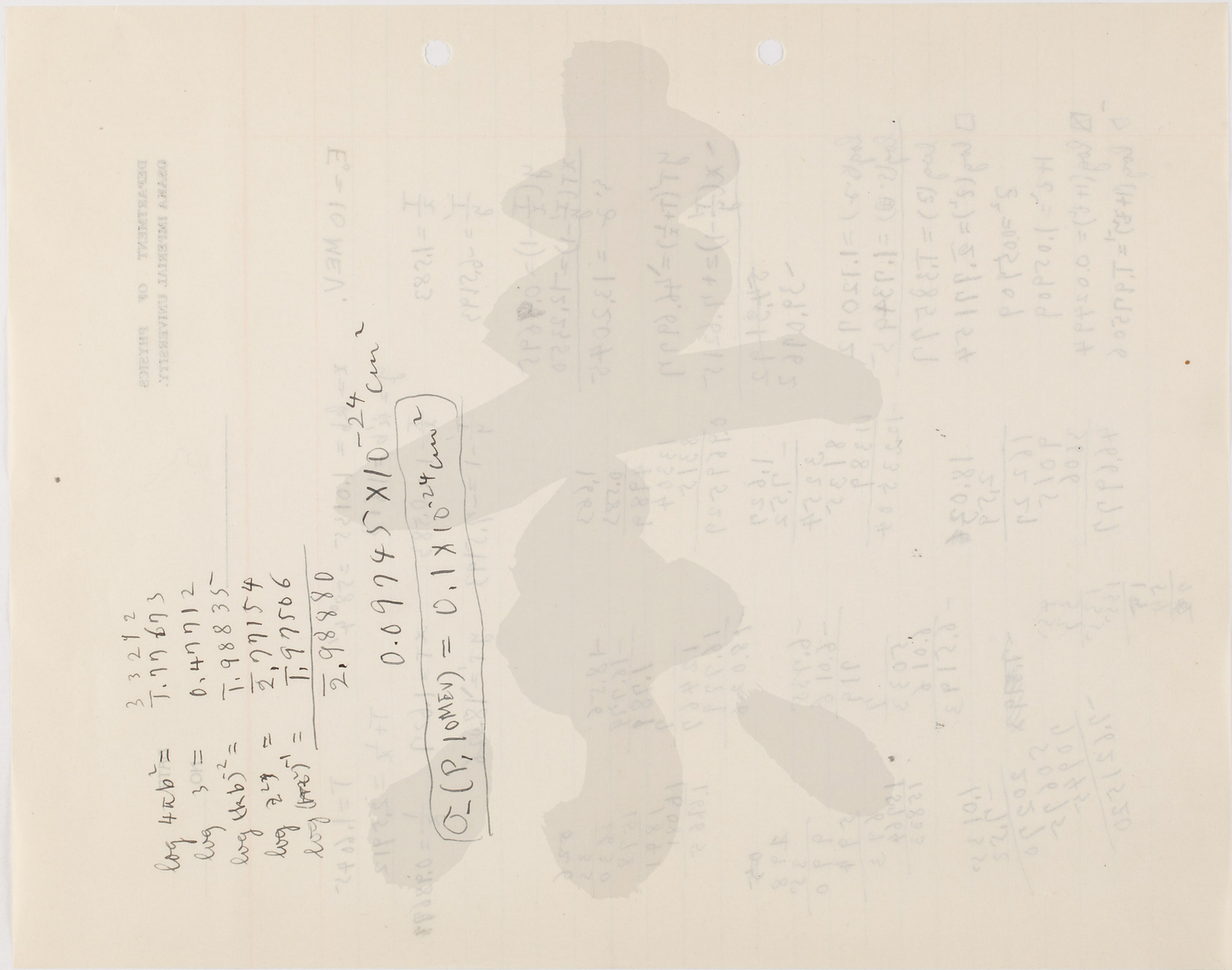
7.5193

45
33
135
135
15
54
2

526
35
2630
1578
1841
1.6081
1.6165

05
198
35
990
594
693
15764
15833

1.0135
7.52
20270
50675
70945
7.621520



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$4\pi b^2 \frac{\sin^2\delta_0}{(kb)^2}$

σ_+ (S-scattering)

$E_0 = 2.5$ MEV $\quad kb = 0.3205 \times \sqrt{2.5} = 0.3205 \times 1.581 = 0.50671$

$k'b = 0.3205 \times \sqrt{48.75 + 2.5} = 2.294$

$\delta_0 = \frac{\pi}{1+\varepsilon^2} \tan^{-1}\left(\frac{kb}{k'b}\tan k'b\right) - kb$

$= \tan^{-1}(0.506 \times 0.4914) - 0.5067$

$= \pi - 0.2491 - 0.5067$

$= 2.3928$

$\sin\delta_0 = 0.6777$ $\quad \log \bar{1}.8311$

$4\pi b^2 \quad 1.77673$
$\sin^2\delta_0 \quad 1.6622$
$(kb)^2 \quad 0.59050$

0.02943

$\sigma_+(S, 2.5\text{MEV}) = 1.0701 \times 10^{-24}\,\text{cm}^2$

σ_+ (P-scattering) $= 29°21'$

$x = 0.5067$ $\quad \frac{I}{I^x} = 1.0955$ $\quad Tx = 0.2781$

$y = 2.294$ $\quad \frac{I'}{I^y} = -0.4939$ $\quad T = 0.5543$

$\frac{I}{I^x} - 1 = 0.0955$ $\quad \frac{I'}{I^y} - 1 = -0.5086$ $\quad \frac{1}{x} = 1.97436$

$T + \frac{1}{x} = 2.8535279$ $\quad \frac{I'}{I^y} - 1 = -1.4939$

$yT' = -2.599$

$0.4987 - 0.4866 = 0.0121$

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$y(\frac{T}{x}-1) = 0.2191$
$-xT(\frac{T'}{y}-1) = 0.4154$
$\xi'\delta = 0.6345$
$\log = \bar{1}.80243$
0.76422

$\log z = \bar{1}.03821$
$\log z^2 = \bar{2}.07642$
$\log(1.01192) = 0.00514$

$yT'(T+\frac{1}{x}) = -6.5676$
$-x(\frac{T'}{y}-1) = 0.7570$
$\xi'\theta = -5.8106$
$\log = 0.76422$

$z^2 = 0.01192$
$(1+z^2) = 1.01192$

2.294
0.0955
11470
1147
20646
0.2190770

−1.4939
0.278
14939
119512
104573
29878
0.4154453 59

$4\pi b^2$	$\bar{1}.77673$
3	0.47712
z^2	$\bar{2}.07642$
$(1+z^2)^{-1}$	$\bar{1}.99486$
x^{-2}	0.59650
	2.91563

$\sigma_+(P,2.5) = 0.08234 \times 10^{-24}\,cm^2$

2.5279
2.599
2.526
2.6
15156
5052
6.5676

σ_- S-scattering, $kb = x = 0.5067$
$\frac{\tan k'b}{k'b} = 4.141$
$k'b = y = 0.3205 \times \sqrt{16.56+2.5}$
$= 0.3205 \times \sqrt{19.06} = 1.399$

$\delta_0 = \tan^{-1}(2.0982) - 0.5067$
$= 64°32' - 29°2'$ $= 1.4$
$= 35°29'$

$\log(\sin\delta_0) = \bar{1}.76378$

$\bar{1}.76378$
2
$\bar{1}.52756$

4.141
0.5067
28987
24846
20705
2.0982447

43.66
0.3205
21830
8732
13098
1.3993030

−1.4939
0.5067
104573
89634
74695
0.75695913

$4\pi b^2$ 1.77673
$\sin^2\delta_0$ 1.52756
$(kb)^{-2}$ 0.59050
1.89479

$\sigma(5.25^{MeV}) = 0.7849 \times 10^{-24}\,cm^2$

P-scattering $\frac{1}{x} = 1.97436$ $T = 0.5543$

$x = 0.5067$

$y = 1.4$

$\frac{I}{x} - 1 = 0.0955$ $T + \frac{1}{x} = 2.5279$ $Tx = 0.2781$

~~$\frac{I'}{y} - 1 = 1.4930$~~

$\frac{I'}{y} = 4.141$ $T'y = 8.117$

$y(\frac{I}{x} - 1) = 0.1337$

$-xT(\frac{I'}{y} - 1) = 0.8735$

$S_{\pi\pi} = -0.7398$

$\log(S_{\pi\pi}) = \bar{1}.86911$

$\log(S_{\pi\pi}) = 1.27709$

1.40798

$\bar{2}.59202$

2

① $\log(\frac{\sigma}{4\pi}) = 3.18404$

$z^2 = 0.001528$

$1 + z^2 = 1.001528$

$\log(1+z^2) = 0.000658$

② $\log(1+z^2)^{-1} = 1.99935$

3 4211

$4\pi b^2$ 1.77673

z^2 3.18404

$(1+z^2)^{-1}$ 1.99935

$(kb)^{-2}$ 0.47712

0.59050

$\bar{2}.02774$

0.01066

$yT'(T + \frac{1}{x}) = 20.5190$

$-x(\frac{I'}{y} - 1) = 1.5915$

$S_{\pi\pi} = 18.9275$

~~$\log S_{\pi\pi}$~~

2.5279
0.5067
0.5067
3.141
5067
20268
50671
15201
1.5915447

23
7
17.
12
709

0.0955
1.4
3820
955
0.13370

~~3.141~~
~~2.98~~

0.2781
3.141
2781
11124
2781
8343
0.87351 21

2.5279
8.117
17 6953
25279
25279
20223 2
20.51896 43

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$E_0 = 6.4^{MEV}$ $kb = x = 0.3205 \times \sqrt{6.4} = 0.8109$

σ_t $k'b = y = 0.3205 \times \sqrt{48.15 + 6.4} = 2.3801$

0,3205
2,550
9615
16025
6410
80865

S-scattering

$\delta_0 = \tan^{-1}(0.8109 \times (+0.4006)) - 0.8109$

$= 162^\circ - 46^\circ 28'$

$= 115^\circ 32' = 180^\circ - 64^\circ 28'$

55, 15

$\log(\sin\delta_0) = \bar{1}.95537$

$\log(\sin^2\delta_0) = \bar{1}.91074$

$\log(4\pi b^2) = 1.77673$

$\log(kb)^{-2} = 0.18206$

$\bar{1}.86952$

$\bar{1}.90897$
2
$\bar{1}.81794$
0.18206

7.4263
0,3205
32131 5
148526
222789
238012915

$\sigma_t(6.4^{MEV}) = 0.7405 \times 10^{-24} cm^2$

0.8109
0,4006
48654
32436
(-)0.3248654

P-scattering.

$x = 0.8109$ $\frac{1}{x} = 1.2332$

$\delta = 46^\circ 28'$ $T = 1.053$

$xT = 0.8534$ $\frac{T}{x} = 1.2978$

$180^\circ - 18^\circ = 162^\circ$

279
9
2511
8509
8534

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計算

P-scattering

$E_0 = 1$ MEV. σ_+.

$x = 0.3205$ $y = 2.245$

$T = 0.3320$ $T' = -1.2512$

$\frac{T}{x} = 1.036$ $\frac{T'}{y} = -0.5573$

$yT'(\frac{T}{x}-1) = -0.10112$

$-xT(\frac{T'}{y}-1) = 0.16571$

$\xi \delta = 0.06459$ log $= \bar{2}.81017$

$\xi \oplus = -9.199$. log $= 0.96374$

$z^2 = 0.00004930$ log $z = \bar{3}.84643$

2 log z = ~~0.0070215~~ $\bar{5}.69286$

$4\pi b^2$ $\bar{1}.77673$
3 0.47712
z^2 ~~4.85616~~
$(kb)^2$ ~~0.98834~~

z^2 $\bar{5}.69286$ (5)
$(kb)^{-2}$ 0.98834
$\bar{3}.03505$

$\sigma_+(P, 1 MEV) =$
$0.001084 \times 10^{-24} cm^2$

1251
0.08082

−1.2512
0.08082
25024
100096
100096
0.1011121984

σ_-. $x = 0.3205$ $y = 1.343$.

$\frac{T}{x} - 1 = 0.0357$ $xT = 0.107$ $T = 0.3320$

$\frac{T'}{y} - 1 = 2.213$ $yT' = 5.79$ $\frac{1}{x} = 3.12$

$yT'(\frac{T}{x}-1) = 0.2067$ $z^2 \ll 1$.

$-xT(\frac{T'}{y}-1) = -0.2368$

$\xi \delta = -0.0301$ log $= \bar{2}.47857$

$\xi \oplus = 19.976$ log $= 1.29051$

0.0357
5.79
3213
2499
1785
~~1785~~
0.206703

$4\pi b^2$ 3.33322 $\bar{1}.77673$
3 0.47712
$(kb)^{-2}$ 0.98834
$(\varsigma\cdot\gamma)^2$ $\bar{4}.95714$
$(\varsigma\cdot\theta)^{-2}$ $\bar{3}.41998$
$\bar{5}.61931$

$\bar{2}.47857$ × 2 = $\bar{4}.95714$

1.29051 × 2 = 2.58102
$\bar{3}.41998$

$0.00000\,4162 \times 10^{-24}\,cm^2$

$0.0000042 \times 10^{-24}\,cm^2$

$E_0 = 10$ MEV σ —

$x = 1.0135$
$y = 1.663$

$\frac{T}{x} = 1.583$ $\frac{T}{x} - 1 = 0.583$ $xT = 1.627$ $T + \frac{1}{x} = 2.59142$

$\frac{T'}{y} = -6.5193$ $\frac{T'}{y} - 1 = -7.5193$ $yT'^2 - 18.026$

$yT'(\frac{T}{x} - 1) = -10.5092$
$-xT(\frac{T'}{y} - 1) = +12.2350$

$\varsigma\cdot\gamma$ = + 1.7258 log = 0.23704
$\varsigma\cdot\theta$ = − 39.0762 log = 1.59191

log z = $\bar{2}.64513$
log z^2 = $\bar{3}.28026$
log$(1+z^2)$ 0.000 8244

18.026
0.583
54078
144208
~~1496158~~
9.0130
10.509158

log $z^2 = 0.001907$
$1 + z^2 = 1.0019$

$4\pi b^2$ 3.4312 $\bar{1}.77673$
3 0.47712
$(kb)^{-2}$ $\bar{1}.98835$
z^2 $\bar{3}.28026$
$(1+z^2)^{-1}$ $\bar{1}.99918$
$\bar{3}.52164$

σ_3(P, 10 MEV)
$= 0.003324 \times 10^{-24}\,cm^2$

7.5193
1.627
526351
150386
451158
75193
12.2339011

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$E_0 = 10$ MEV. σ_+ $x = 1.0135$ $y = 2.45^-7$

$\frac{T}{x} = 1.5832$ $T = 1.6045$

$\frac{T}{x} - 1 = 0.5832$ $T + \frac{1}{x} = 2.5912$

$\frac{T'}{y} - 1 = -1.3321$ $yT' = -2.006$

$yT'(\frac{T}{x} - 1) = -1.1699$

$-xT(\frac{T'}{y} - 1) = 2.1662$

$g_T = -0.9963$ log $= \bar{1}.99839$

$g_0 = 3.8454$ log $= 0.58492$

$Z^2 = 0.06713$ $\bar{1}.41347$

$1 + Z^2 = 1.06713$ $\bar{2}.82694$

0.02821

$\bar{1}.77673$
0.47712
$\bar{1}.98835$
$\bar{2}.82694$
$\bar{1}.99179$
$\bar{1}.04093$

$\sigma_+(P_1\ 10\text{MEV}) = 0.1099 \times 10^{-24}\ \text{cm}^2$

$0.11 \times 10^{-24}\ \text{cm}^2$

$yT'(T + \frac{1}{x}) = 5.1979$

$-x(\frac{T'}{y} - 1) = +1.3501$

3.8478

0.5832
− 2.006
34992
116644
1.16999

33
7
231
29
23
6

−1.3321
1.0135

2.5912
− 2.006
155432
5824
5.197 9432

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E_{in} MEV	0	0.4	1	2.5	4.9	6.4	8.1	10	10^2
$\sigma_+(S)$	1.46		1.325	1.09	0.86	0.74		0.536 ~~0.0725~~	0.0189
$\sigma_+(P)$	0		~~0.0254~~ ~~0.57~~	0.082				0.82	
$\sigma_-(S)$	2.18		1.24	0.985	0.94			0.25	
$\sigma_-(P)$	0		0.0016	0.0107				0.1	

$U_+ = 32.5$ MEV
$U_- = 11.0$ MEV