NAL PROPOSAL # 226

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Coherent K_S Regeneration by Electrons

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TITLE: COHERENT K_S REGENERATION BY ELECTRONS

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BEAM REQUIREMENTS: Neutral Beam M-4

RUNNING TIME: 30 days (90 shifts)

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ABSTRACT

We propose to extend the use of the E-82 spectrometer in the neutral beam M4 to a determination of the amplitude for regeneration of K_S by electrons. This quantity is directly proportional to the rms neutral kaon charge radius, R^2. NAL is uniquely suited for such a determination, since the electron contribution to regeneration is ~ 7% at 100 GeV, and grows as the square root of the kaon momentum.

The K^o is neutral
albeit not quite
it shows its charge radius
to those who are bright.
A photon exchange, when properly done,
Will suddenly turn a K_2 into a K_1.
The regeneration, while admittedly rare,
Is obviously proportional to the kaon's R^2.
Where Zel'dovitch sweated, where Rubbia faltered,
the state of the art must clearly be altered.
We ask for no new beams, for no fancy device
Just give us 90 shifts of running
And that will suffice.

COHERENT K_S REGENERATION BY ELECTRONS

In our approved NAL proposal, E-82, we alluded briefly to our intention to study electron regeneration (p.6). In the present proposal we wish to spell out the details of the experiment that we would like to perform. Since we intend to use the apparatus and the beam of E-82 without modifications, the experiment proposed here could be carried out in the near future.

1. Theoretical background.

K^o and $\overline{K^o}$ have conjugate charge distributions, and will thus scatter from electrons with amplitudes $f^e, \overline{f^e}$ of equal magnitude and opposite sign. Hence there exists a regeneration amplitude

$$\rho_e = 2\pi i \ NL \ f_{21}^e /k \tag{1}$$

and f_{21}^e/k is proportional to R^2, the rms charge radius of neutral kaons, viz. $$f_{21}^e/k = - \alpha R^2/3 \tag{2}$$.

To predict the magnitude of K_s regeneration from electrons, one needs hence an estimate of R^2 ; conversely, a measurement of ρ_e (such as proposed here) serves essentially to determine R^2.

R^2 can be predicted from the observed rate of $e + \overline{e} \rightarrow K + \overline{K}$ (with some vector dominance and SU (3) assumptions), or from the "algebra of fields" considerations of Kroll, Lee and Zumino [1], who give

$$R^2(K^o) = - 0.76 \text{ mb}. \tag{3}$$

In either case, we expect regeneration by electrons to be less strong than predicted in the early work of Zeldovitch [2], corresponding to $R^2 \simeq 21$ mb.

An important fact underlying the experiment proposed here is that ρ_e is independent of k, the K_L momentum, whereas the corresponding (and dominant) nuclear amplitude ρ_N is expected to decrease as $k^{-1/2}$. Thus the relative importance of electron regeneration increases with k, making the experiment particularly suited for NAL.

2. Principle of the experiment.

The principle which we propose to adopt for measuring ρ_e is essentially the same as that used by the Aachen-CERN-Torino group in their experiment directed at the same goal [3] (for facilitating the reviewer's task, we enclose a copy of this reference). There are, however, certain important differences -- of method rather than of principle -- between our approach and that of Ref. 3; these will be discussed later on (see Section 3)

The so-called "transmission regeneration" amplitude ρ at the exit of a slab of number density N and thickness L (thin compared to the mean K_S decay length, $\Lambda(k)$) is given (per K_L) by

$$\rho = \rho_N + \rho_e = 2\pi i \; NL \left[f_{21}^N(0) + Z f_{21}^e(0) \right] / k \; , \qquad (4)$$

The intensity of transmission-regenerated K_S's is

$$N^{tr} = |\rho|^2 = \left(\frac{2\pi \; NL}{k}\right)^2 \left| f_{21}^N(0) + Z f_{21}^e(0) \right|^2 \; , \qquad (5)$$

where we have neglected attenuation in the slab, and CP-interference effects behind it. Since terms quadratic in f_{21}^e will always be negligible in practice, we can make the approximation

$$N^{tr} \simeq (2\pi \; N \; L)^2 \left| \frac{f_{21}^N(0)}{k} \right|^2 \left[1 + 2 \; \mathrm{Re} \, \frac{Z f_{21}^e(0)}{f_{21}^N(0)} \right] . \qquad (6)$$

The essential point is that $|f_{21}^N(0)/k|$ can be determined independently from the so-called <u>diffraction regeneration</u> extrapolated to $\vartheta = 0$. When momentum is transferred to the scattering centers, then these act incoherently among each other and lead (again neglecting attenuation and CP-effects) to the regenerated K_S intensity.

$$\frac{dN^{diff}}{d\Omega}(\vartheta) = NL\left\{|f_{21}^{N}(\vartheta)|^2 + Z^2|f_{21}^{e}(\vartheta)|^2\right\}$$
$$\simeq NL\,|f_{21}(\vartheta)|^2 , \tag{7}$$

again neglecting the electron term. In a more convenient notation, one has

$$\frac{dN^{diff}}{dt}(t) = \pi NL\,\left|\frac{f_{21}^{N}(t)}{k}\right|^2 \tag{8}$$

Extrapolation to t = 0 (see Fig. 1) yields dN/dt (0), and one can rewrite (6) in terms of observed quantities

$$\frac{1}{4\pi\,NL}\,\frac{N^{tr}}{(dN/dt(0))\Delta t} = 1 + 2\,\mathrm{Re}\,\frac{Z\,f_{21}^{e}(0)}{f_{21}^{N}(0)} \tag{9}$$

or $$R_{obs}/4\pi\,NL = 1 + \varepsilon\ ;$$

where $R_{obs} = N^{tr}/\Delta t\,\left[dN^{diff}/dt(0)\right]$ is the well-known "Good ratio" (for a thin slab), and ϵ the quantity to be determined. <u>Thus the experiment, in its idealized version, consists in measuring R_{obs}.</u>

At this point it is interesting to estimate numerically

$$\epsilon = 2\,\mathrm{Re}\,\frac{Z\,f_{21}^{e}(0)/k}{f_{21}^{N}(0)/k} \tag{10}$$

For Pb, $(f_e - \overline{f}_e)/k = 82 \times 3.65 \times 10^{-3} = 0.30$ mb according to Eqn. (2,3) (note that this quantity is real and momentum-independent); on the other hand, $(f^n - f^n)/k$ has at 4 GeV a modulus of 32 mb, and a phase of -135^o [3]. Thus

$$\varepsilon(\mathrm{Pb}\ ,\ 4\ \mathrm{GeV}) = -\frac{0.30\,\sqrt{2}}{32} = -1.4\% \tag{11}$$

It is anticipated that (see our proposal for E-82) the nucleon amplitudes $(f-\bar{f})/k$ fall as $k^{-1/2}$, and we assume that the nuclear regeneration exhibits the same momentum dependence (this assumption was borne out by detailed optical model calculations). Thus ϵ is expected to grow as $k^{1/2}$, yielding typically

$$\epsilon\,(\mathrm{Pb}\ ,\ 100\ \mathrm{GeV}) \simeq 7\%,$$

a <u>large effect</u>.

3. The actual experimental method.

In the idealized experiment described in the previous section, it is the departure of the observed Good ratio R_{obs} from its "theoretical" value which yields ϵ. In actual practice, some of the simplifying assumptions used in the derivation above do not hold, i.e.

(a) the slab thickness L may not be small in terms of $\Lambda(k)$, the mean decay length of K_S's;

(b) L may not be small in terms of $\mu = 1/N\,\sigma_T$; the mean free path for interactions in the regenerator;

(c) Instead of the regenerated K_s intensity, one has to consider the corresponding amplitude and CP interference effects downstream of the regenerator.

Of these, (a) is least relevant at our energies. $\Lambda(100\ \mathrm{GeV})$ is 500 cm, far greater than L for any practical regenerator.

Assumption (b) is most serious. Aside from attenuation (which is the <u>same</u> for K_L and K_S!) multiple scattering effects arise in a "thick" regenerator, affecting the Good ratio drastically. Piccioni and his collaborators [4] have presented an analytic approximation for the "modified" Good ratio, while Foeth et al. [3] have treated the same problem by Monte

Carlo techniques. In either case, the result depends on the nuclear parameters σ_T, σ_{22} and $d\sigma_{21}/dt$, and these must be well-known to make an adequately accurate prediction of the Good ratio possible.

Corrections due to CP interference effects are comparatively easy to handle. In a sense they are complementary to the multiple scattering effects, since they are easiest to apply to "strong", i.e. thick, regenerators.

Note that in the case of the Aachen-CERN-Torino experiment [3], for which Eqn. (11) predicts a net effect $\varepsilon \simeq -1.4\%$, the various corrections to the "ideal" Good ratio amounted to about 30%.

Our approach is to decouple ourselves as much as possible from the dependence of R_∞ (the Good ratio calculated for the convergent series corresponding to infinitely many possible scattering in the regenerator) on the nuclear parameters in question. In other words, we seek that "magic length" L_o for which R_∞ exhibits an extremum respect to these parameters.

It is convenient to measure the regenerator length in units of the interaction mean free path $\mu = 1/N\sigma_T$, i.e. $L/\mu = LN\sigma_T = x$. We find that the magic length is $x_o \simeq 2$. Note that since N_S, the intensity of coherently (tramsmission) regenerated K_S's, goes (for $L/\Lambda << 1$) as $x^2 e^{-x}$, $x_o = 2$ also corresponds to the maximum possible K_S intensity (per incident K_L).

To obtain this result, we first consider R_∞ in the absence of CP-violating interference effects (for $L/\Lambda << 1$) as given by Ref. 4.

$$R_o/R_\infty = \left[\sum_{n=1}^{\infty} \frac{(NL\,\sigma_{22})^n}{(n)!} G_n(\vartheta = 0) \left(\frac{n}{|f_{22}(0)|^2} + (N\lambda L)^2 + \frac{n(n-1)}{|f_{22}(0)|^2} - \frac{n\,NL\,\sigma_T}{|f_{22}(0)|^2} \right) \right] / NL\lambda^2 \quad (12)$$

where $G_n(=0) = \frac{|f_{22}(0)|^2}{n\,\sigma_{22}}$, $\lambda = \frac{2\pi}{K}$, and $R_o = 4\pi NL(1+\epsilon)$ is the Good ratio in the absence of multiple scattering and CP interference. This formula can be simplified by noting that $f_{22} = (f + \bar{f})/2$ is essentially purely imaginary at the energies of interest here. Thus

$$\sigma_T = \frac{4\pi}{k}\ \mathrm{Im}\ f_{22}(0) = \frac{4\pi}{k}\ f_{22}(0). \tag{13}$$

σ_{22}, the elastic scattering cross section, is given by $\int d\Omega |f_{22}|^2$, and it is useful to introduce the variable $\alpha \equiv \sigma_{22}/\sigma_T$. With these notations one has

$$R_o/R_\infty = \sum_{n=1}^{\infty} \frac{(\alpha\ x)^{n-1}}{(n-1)!}\ \left(1 - \frac{x}{2n}\right)^2 \tag{14}$$

Using the optical model and the measured charged kaon-nuclear total cross sections (extrapolated to 100 GeV) as input parameters, we have computed the relevant amplitudes and cross sections for Pb; our results are given in Table I. Since the charge averaged cross sections are, for $k > 20$ GeV/c, anticipated (at the 1% level) to be momentum independent, α is also expected to be so.

Fig. 2 shows a plot of R_∞/R_o as a function of x, calculated with $\alpha = 0.319$ (see Table I). Since α is k-independent, this curve is "universal". With $\mu = 13.1$ cm, L_o is 26.2 cm and $\ell \doteq L/\Lambda = 26.2/500 = 0.052$ for $k = 100$ GeV/c. As $\ell \ll 1$, the thin slab approximation is valid, and excludes any additional momentum dependence of L_o.

The prime question of interest is the sensitivity of R_∞ to the nuclear parameters σ_T and σ_{22} for $x = x_o$, since these are not too well-known a priori. We find that R_∞ changes by 2.0% for a 1% change in σ_{22}

and by 0.5% for a 1% change in σ_T. Before accepting the regenerator of "magic thickness", we have to remove the last simplifying assumption made above, i.e. we have to allow for CP interference effects downstream of the regenerator. As is well-known, interference between transmission regenerated K_S's and K_L decays yields the 2π-distribution:

$$I_{2\pi}^{trans} = C\,|\rho|^2 \left\{ e^{-t/\tau_S} + |\eta_{+-}/\rho|^2 e^{-t/\tau_L} + 2|\eta_{+-}/\rho|\, e^{-t/2\tau_S}\cos(\Delta m t - \phi) \right\} \quad (15)$$

which can be fitted to yield $|\rho/\eta_{+-}|$. ($\phi = \phi_\rho - \phi_{+-} \cong 90^\circ$) Similarly, the diffraction regenerated component has a distribution:

$$dI_{22}^{diff}(t)/dt = (C|\rho|^2/R_o) \sum_{n=1}^{\infty} \frac{(\alpha x)^{n-1}}{(n-1)!} \left\{ e^{-t/\tau_S}\left(\frac{x}{2n}-1\right)^2 + |\eta_{+-}/\rho'|^2 \frac{1}{n^2} e^{-t/\tau_L} + 2\left(\frac{x}{2n}-1\right)|\eta_{+-}/\rho|\,\frac{1}{n}\, e^{-t/2\tau_S}\cos(\Delta m t - \phi') \right\}$$

where $\rho = f_{21}(0)/f_{22}(0)$ and $\phi' = \phi_{21} - \phi_{22} - \phi_{+-} = 90^\circ$. Interestingly enough $\rho' = \rho$ for the "magic" thickness $x_o = 2$! Integration over m K_S proper lifetimes yields (with $m\,\tau_s \ll \tau_L$)

$$R_\infty/R_o = \frac{1 - e^{-m} + |\eta_{+-}/\rho|^2 m + 2|\eta_{+-}/\rho| \left[1 - e^{-m/2}(\sin m/2 + \cos m/2)\right]}{\sum_{n=1} \frac{(\alpha x)^{n-1}}{(n-1)!} \left\{ \left(\frac{x}{2n}-1\right)^2 (1-e^{-m}) + m|\eta_{+-}/\rho'|^2 \frac{1}{n^2} - 2\left(\frac{x}{2n}-1\right)\frac{|\eta_{+-}/\rho'|}{n}\left[1 - e^{-m/2}\left(\sin\frac{m}{2} + \cos\frac{m}{2}\right)\right] \right\}}$$

As seen in Fig. 3, if we integrate over a fixed distance in the lab, R_∞/R_o is practically momentum independent.

Thus, including CP-effects, $x_o \approx 2$ remains that "magic" slab thickness for which the predicted Good ratio R_∞ is particularly insensitive to nuclear parameters. We shall describe the requisite ancillary measurements of the latter in the next section.

There is one effect which we have not mentioned so far. In addition to K_S regeneration by transmission and by elastic diffraction, also inelastic regeneration can occur, i.e. the process K_L + nucleus $\to K_S$ + nucleus + hadrons (or $\to$ nuclear fragments + hadrons). This process which is due to the inelastic scattering of $K^o, \overline{K^o}$ on nucleons, has a vastly different t-dependence from that of ordinary diffraction regeneration [$\sigma_{21}(t)$ is governed by the nuclear size!] but nevertheless constitutes a background to the latter. Thus $dN^{diff}/dt(0)$ is "contaminated" by inelastic regeneration. This contamination" is hard to calculate theoretically, but could amount to ~10% [5]. Wanting to determine the Good ratio to 1%, it will hence probably be sufficient to determine this background experimentally to 10% accuracy; such a determination can be done (a) by exploiting the different t-dependence, (b) by suitable co-incidence or anticoincidence requirements [5] involving the unwanted secondaries.

It should also be pointed out that the transmission and diffraction regenerated events should have the same momentum (k) distribution (to the extent that the Good ratio is momentum independent), thus providing an easy check for the contamination in question.

4. Ancillary Measurements

a) Measurement of σ_T

The attenuation of K_L mesons is easily measured by standard "good geometry" transmission techniques, i.e. by inserting material in the K_S beam far upstream of the usual regenerator position. The transmitted K_L's can be detected either via their copious $K_{\ell 3}$ modes, or by using a thick regenerator as a "converter" (to $K_S \to 2\pi$), or even via the rare $K_L \to \pi^+\pi^-$ mode. In either case, 1% accuracy in σ_T is easily obtained. The "magic thickness" of the regenerator actually to be used in the experiment proper is also readily checked by transmission.

b) Measurement of σ_{22}

We recall that $\sigma_{22} = \int d\Omega |f_{22}(\vartheta)|^2$, and that $f_{22}(0)$ is essentially pure imaginary. Thus $|f_{22}(0)|$ is given directly by σ_T, while the angular (or t) dependence is most easily obtained from a measurement of σ_{21} and an appeal to the optical model. Table II, based on detailed calculations, shows that while σ_{21} and the differential cross section $d\,\sigma_{22}/dt$ vary with the nuclear shape parameters, ~~vary with the nuclear shape parameters,~~ the integral σ_{22} is very insensitive to the latter (which are, in the case of Pb, already rather well known[5]). Thus a measurement of σ_{21} basically constitutes a determination of σ_{22}.

There are also direct methods for determining σ_{22}, e.g. studying the diffraction of K_L's (detected via the $K_{\ell 3}$ mode) or of K_S's from a short-lived beam (such as built for E-8).

(c) Measurement of σ_{21}

This is readily done by measuring the diffraction regeneration $d\sigma_{21}/dt$ from a moderately thin regenerator (to keep multiple scattering effects down).

(d) Measurement of inelastic regeneration.

This can be done in a number of ways. The simplest is to see (with a moderately thin regenerator) how the minima of the diffraction regeneration distribution ($\sim d\sigma_{21}/dt$) get "filled in" by the inelastic events, and in fact to follow that distribution out to large t's where the elastic events should practically vanish. A more direct way is to trigger only on inelastic events, requiring a charged secondary from the regenerator in coincidence with the usual 2π-trigger. Finally, one can study regeneration free of inelastic events by a suitable anti-coincidence requirement. This requires a special run at very low neutral beam rates, since the anticoincidence would otherwise be constantly "on".

5. Organization of experiment and running times.

Since we expect a 7% effect, ε, at 100 GeV, we set ourselves the goal to measure R_{obs} to 1% at this energy and to be able to predict R_∞ to 1.5%, yielding a combined error of ~1.8% in ϵ. This prediction of R_∞ requires a determination of σ_T to 0.5% and of σ_{22} to 0.75%.

Of course, 100 GeV is just an arbitrarily chosen reference energy, since all K_L > 30 GeV are studied simultaneously. Fig. 4 shows the K_L spectrum predicted for our beam line, as well as the number of K_S's regenerated by a Pb block of "magic" thickness $L_o \approx 26$ cm and accepted by our spectrometer.

Assume that we require 10^5 regenerated 100 GeV events to measure R_{obs} to 1% (Note that in Ref. 3 80K events were collected to determine R_{obs} to 1%). At the time of writing, 0.5×10^{12} interacting protons/burst appear to be a reasonable estimate. This yields ~ 1 regenerated and detected K_S $\pi^+\pi^-$ events at (100 ± 10 GeV)/burst, or ~18K such events/day. Thus, we could, in <u>principle</u>, collect the main body of data in ~5 days (15 shifts) of running, achieving our stated statistical goals at 100 GeV and exceeding them at lower momenta. <u>In practice</u>, we may need more time. Under the running conditions stated above, we <u>predict</u> a total rate of detected 2π-events of ~<u>26/burst</u>. Whether we can handle such a <u>large</u> rate, depends on the number of unwanted triggers (neutron stars, unrejected leptonic decays, etc.), the length of the spill, the time-structure of the beam etc. It is clear that with a core-memory wire-spark chamber spectrometer such as currently operated by us and as described in our proposal (E-82), and a spill of 300 msec, one would be limited to $\lesssim$ 50 total events/burst, corresponding to perhaps 5 "good" events/burst. Thus one would have to run with a 5 times lower beam intensity (10 interacting protons/burst) for 25 days (75 shifts).

The ancillary measurements discussed in Section 4 would require, even with such a reduced beam, at most another 5 days (15 shifts).

Since our proposal E-82 was submitted (August, 1970), we have greatly improved our spectrometer. Hodoscopes and MWPC's have been added to act as roadmaking devices, and an elaborate on-line processing system (involving two Supernovas in addition to our standard processor, the ASI-6040), has been assembled. This is however not all: in view of the present (June 1973) status of the structure and length of the beam spill at NAL, we are currently building a full complement of MWPC's sufficient to <u>replace all the wire-spark chambers</u> in our initially proposed setup. These MWPC's will have been built and tested by the fall of 1973, and they should certainly be operational well before the experiment proposed here could be scheduled. The construction of these chambers and of the associated electronics is being greatly helped by the expertise gained by our supporting staff in connection with other NAL projects (e.g. E-98, Mo-p scattering).

References

[1] Kroll, Lee, and Zumino, P. R. 157, 1376 (1967).

[2] Y. B. Zel'dovich, JETP 36(9), 984 (1959).

[3] Foeth et al., Phys. Letters, 30B, 276 (1969).

[4] R. M. Good et al., Phys. Rev. 124, 1223 (1961).

[5] Foeth et al., Phys. Letters, 31B, 544 (1970)

TABLE I. Optical Model Calculations for Pb

Inputs: $\sigma_T(K^+p) = 18.2$ mb[a] $\sigma_T(K^+n) = 18.7$ mb[a]

55 GeV/c

$\sigma_T(K^-p) = 20.5$ mb[b] $\sigma_T(K^-n) = 19.5$ mb[b]

$f(K^-\mathcal{N})$ assumed pure imaginary.

$f(K^+\mathcal{N})$ have real parts chosen to yield $\phi_{21} = -135°$.

Extrapolation to 100 GeV:

$\sigma_T(K^+p) = 18.5$ mb $\sigma_T(K^+n) = 18.8$ mb

$\sigma_T(K^-p) = 20.2$ mb $\sigma_T(K^-n) = 19.4$ mb

Same assumptions for amplitudes.

Nuclear model: $\rho_p = \rho_n = C\left[1 + e^{(r - 6.6)/0.5}\right]^{-1}$ (r in fm.)

Output: 55 GeV/c: $(f - \bar{f})/k = 9.98$ mb $\sigma_T = 2329$ mb[c]

$\sigma_{22} = 742$ mb $\sigma_{21} = 0.631$ mb

100 GeV/c: $(f - \bar{f})/k = 7.41$ mb $\sigma_T = 2329$ mb

$\sigma_{22} = 742$ mb $\sigma_{21} = 0.348$ mb

$\mu = 1/N\sigma_T = 13.1$ cm $\alpha = \dfrac{\sigma_{22}}{\sigma_T} = 0.319$

[a] Phys. Lett. 36B, 415 (1971).

[b] Denisov et al., contributed paper No. 924 at the 1972 NAL Conference.

[c] At 9 GeV, Lakin et al. measure $\sigma_T = 2307$ (55) mb.

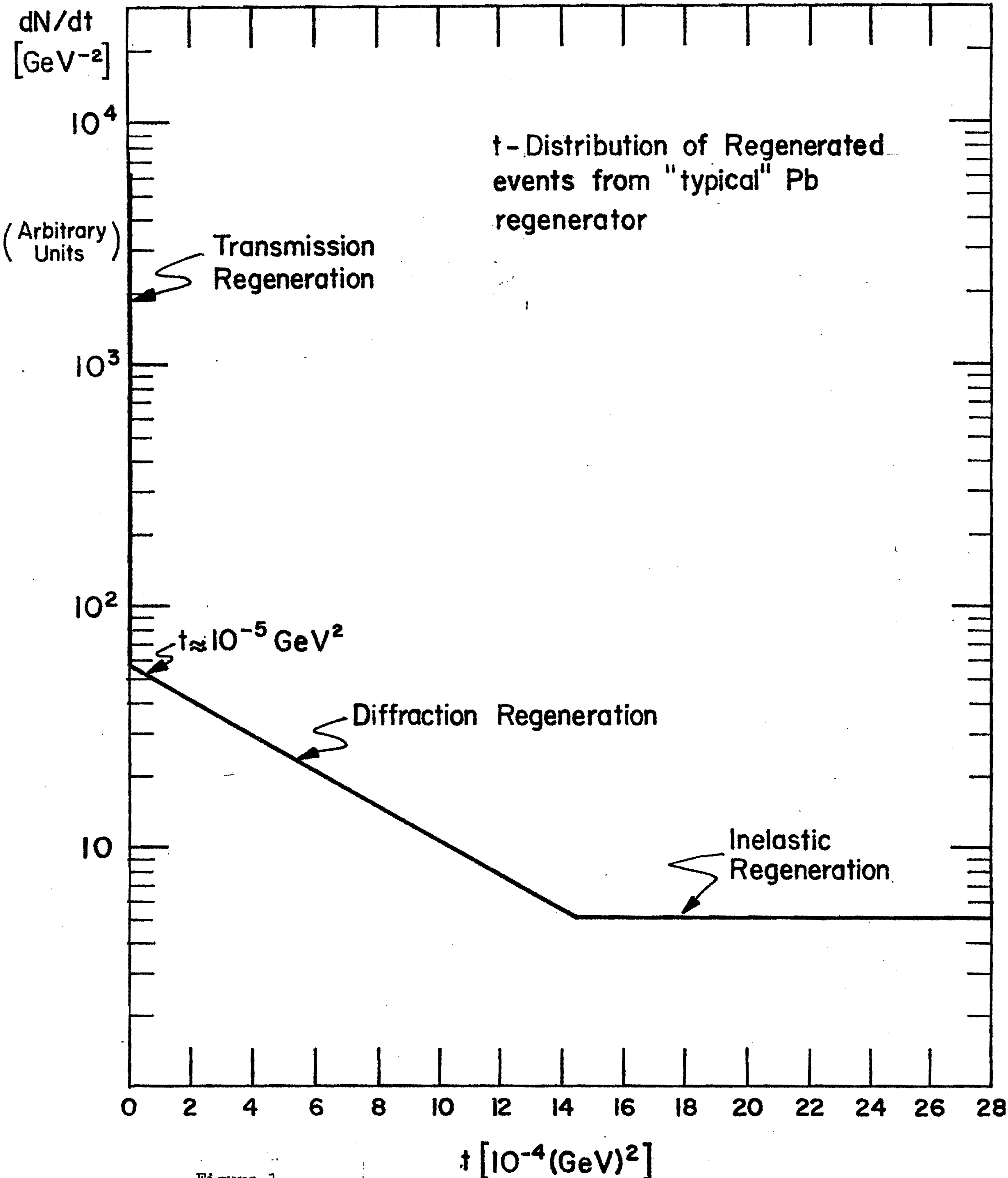
TABLE II. Dependence of Optical Model Results for Pb on Nuclear Parameters

(Input at 55 GeV/c as in Table I)

Nuclear Density Distribution $\rho_{p,n} = C \left[1 + e^{(r - r_{p,n})/a_{p,n}}\right]^{-1}$

r_p(fm)	r_n(fm)	a_p(fm)	a_n(fm)	σ_T(mb)	σ_{22}(mb)	σ_{21}(mb)	t_1^*(GeV)^2	t_2^*(GeV)^2
6.60	6.60	0.50	0.05	2329	742	0.631	-.0098	-.0378
6.60	6.60	0.50	0.68	2464	747	0.761	-.0092	-.0354
6.60	7.29	0.50	0.50	2378	736	0.678	-.0090	-.0333

* t_1, t_2 are the positions of the first and second diffraction minima in $d\sigma_{22}/dt$



dN/dt
[GeV^-2]
(Arbitrary Units)
10^4
10^3
10^2
10
t-Distribution of Regenerated events from "typical" Pb regenerator
Transmission Regeneration
t≈10^-5 GeV^2
Diffraction Regeneration
Inelastic Regeneration
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
t [10^-4 (GeV)^2]

Figure 1

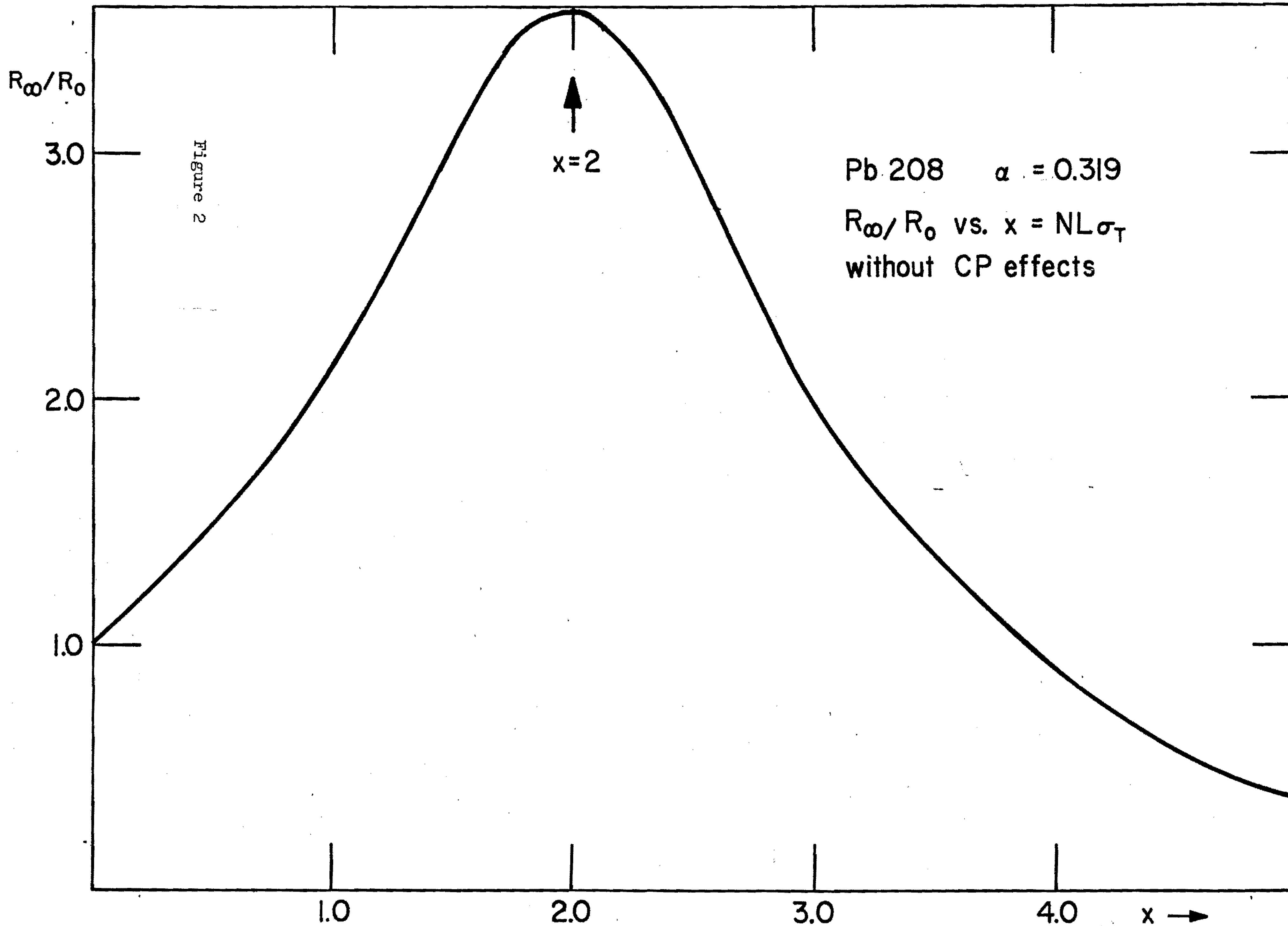
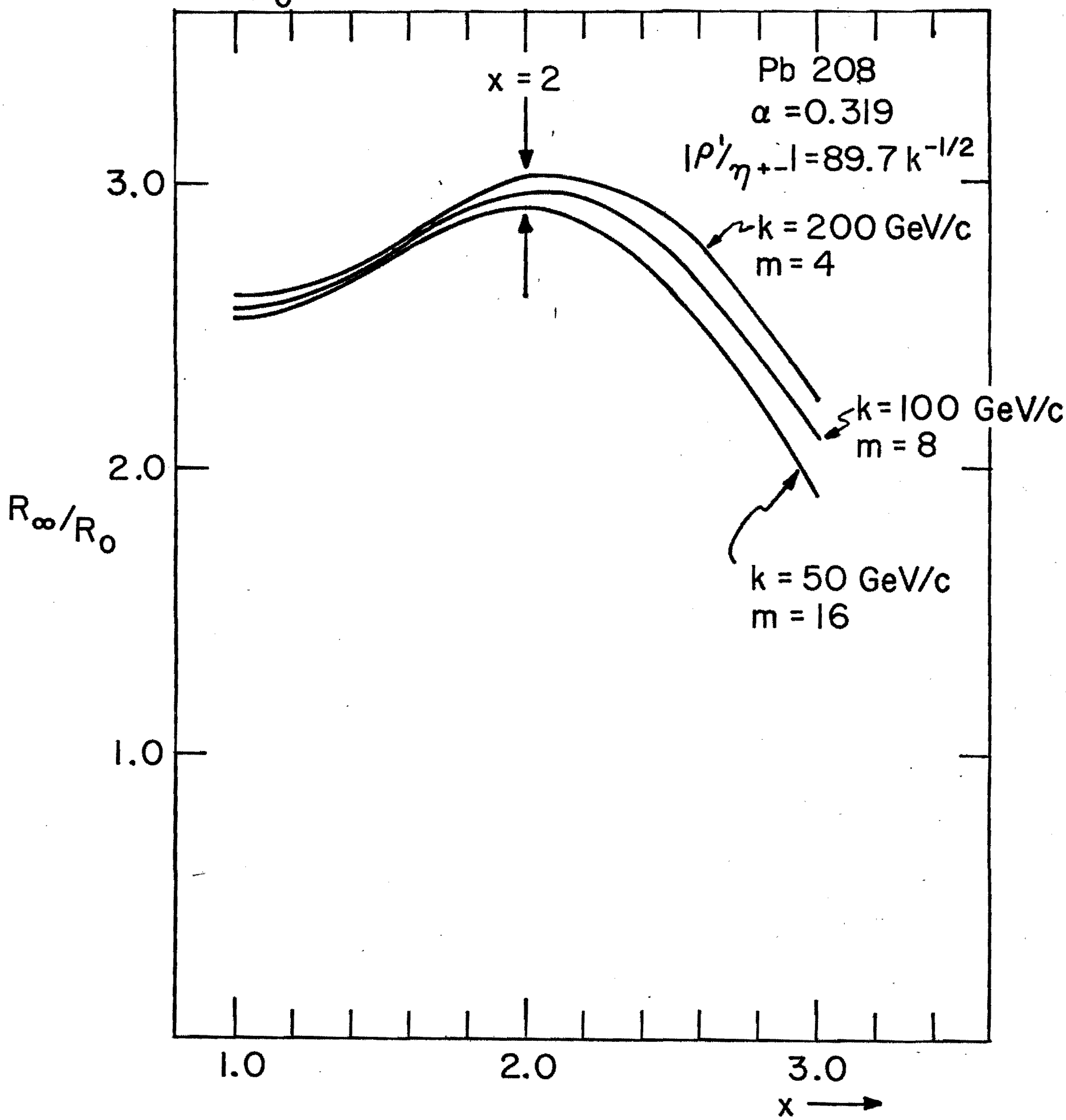

R_∞/R_0
3.0
2.0
1.0
x=2
Pb 208 α = 0.319
R_∞/R_0 vs. $x = NL\sigma_T$
without CP effects
1.0
2.0
3.0
4.0
x

Figure 2

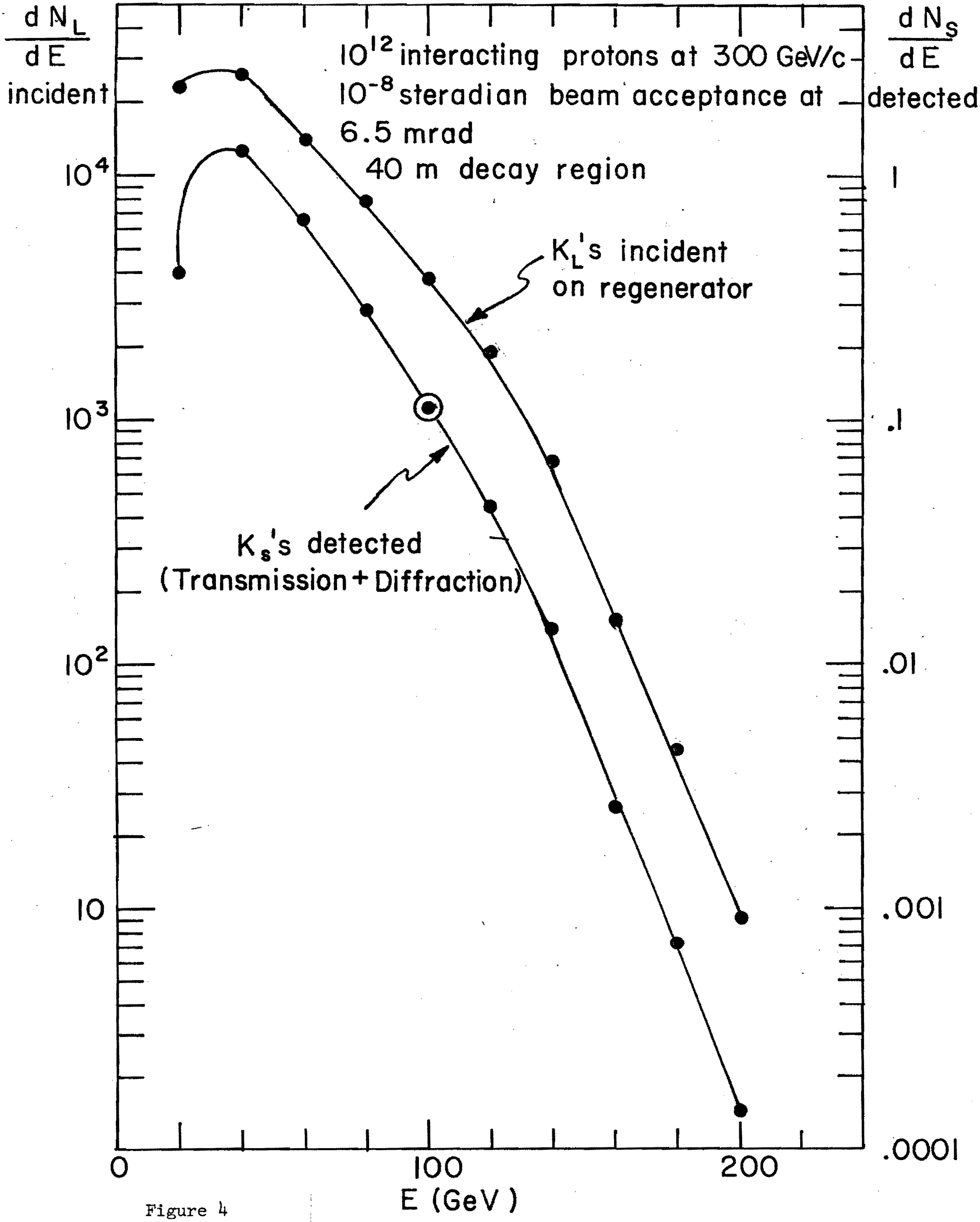
R_∞/R_0 vs x Including CP effects



Note: We integrate over fixed $z \simeq 40$ meters; thus

$$m \simeq \frac{40 \times 10^2 \mathrm{cm}}{k/m_k\, c\, \tau_S} = \frac{800}{k}$$ where k is in GeV/c

Figure 3



$\frac{dN_L}{dE}$ incident
$\frac{dN_S}{dE}$ detected
10^{12} interacting protons at 300 GeV/c
10^{-8} steradian beam acceptance at
6.5 mrad
40 m decay region
K_L's incident on regenerator
K_s's detected (Transmission + Diffraction)
10^4
10^3
10^2
10
1
.1
.01
.001
.0001
0
100
200
E (GeV)

Figure 4

Addendum to Fermilab Proposal #226

November, 1974

Since submitting the original proposal, we have refined the original estimates of the requisite running times. The major change is that the actual K_L fluxes in the M4 beam line, as determined in E-82, are significantly lower than those anticipated from a Hagedorn-Ranft type calculation (see Fig. 1). In addition, we improperly calculated the running time by scaling the number of transmitted events of Foeth et al., but in actuality it is the diffracted events which dominate the statistical accuracy of the experiment. These changes have led us to rethink our approach to determining the effect of the K_S regeneration off electrons.

As outlined in our proposal, we have set ourselves the goal of measuring the observed "M.L. Good" ratio to 1% for kaon momenta of 100±10 GeV/c. Since the ratio of transmission regenerated events to diffraction regenerated events in a small momentum transfer interval ($\Delta t \sim 200 \mathrm{MeV}^2/c^2$) is >>1, the statistical error in the "Good ratio" is determined by the number of diffraction regenerated events in this t interval. The minimum running time to collect a given number of such events occurs for x=1, i.e. a 1 interaction length regenerator. Fortunately, the dependence on the nuclear parameters σ_{22} and σ_{total}, as discussed in our proposal, is about the same as for the originally proposed regenerator, x=2. (This is because the increased dependence on x is compensated for by a decreased dependence on α - See Equation 14 of Proposal #226.)

Even with this rate optimization, the loss of flux leads to prohibitively long running times in M4, the 7.5 mrad neutral beam. It is, however, now experimentally known that in M3 (1 mrad beam) a much larger K_L flux is available, particularly around 100 GeV/c. Using the M3 beam, we propose to attain the goals of our proposal in 1600 hours. (We assume the use of 50cm of Al to decrease the n/K ratio in M3. This yields a factor of 10 more K_L flux at 100 GeV/c than presently available in M4, if we use the results of Longo et al.) An alternative scheme, which we have not yet fully explored, is to increase the solid angle acceptance of the M4 beam line.

The critical reader will now raise the point whether our spectrometer can stand the increased trigger rate (∿300/pulse) in M3. The answer is affirmative, based on the fact that we have been working on the full conversion to MWPC's for the past 2 years. The system, 5 planes (8000 wires), is about ready for testing and should be available for operation by the time we are to move into M3.

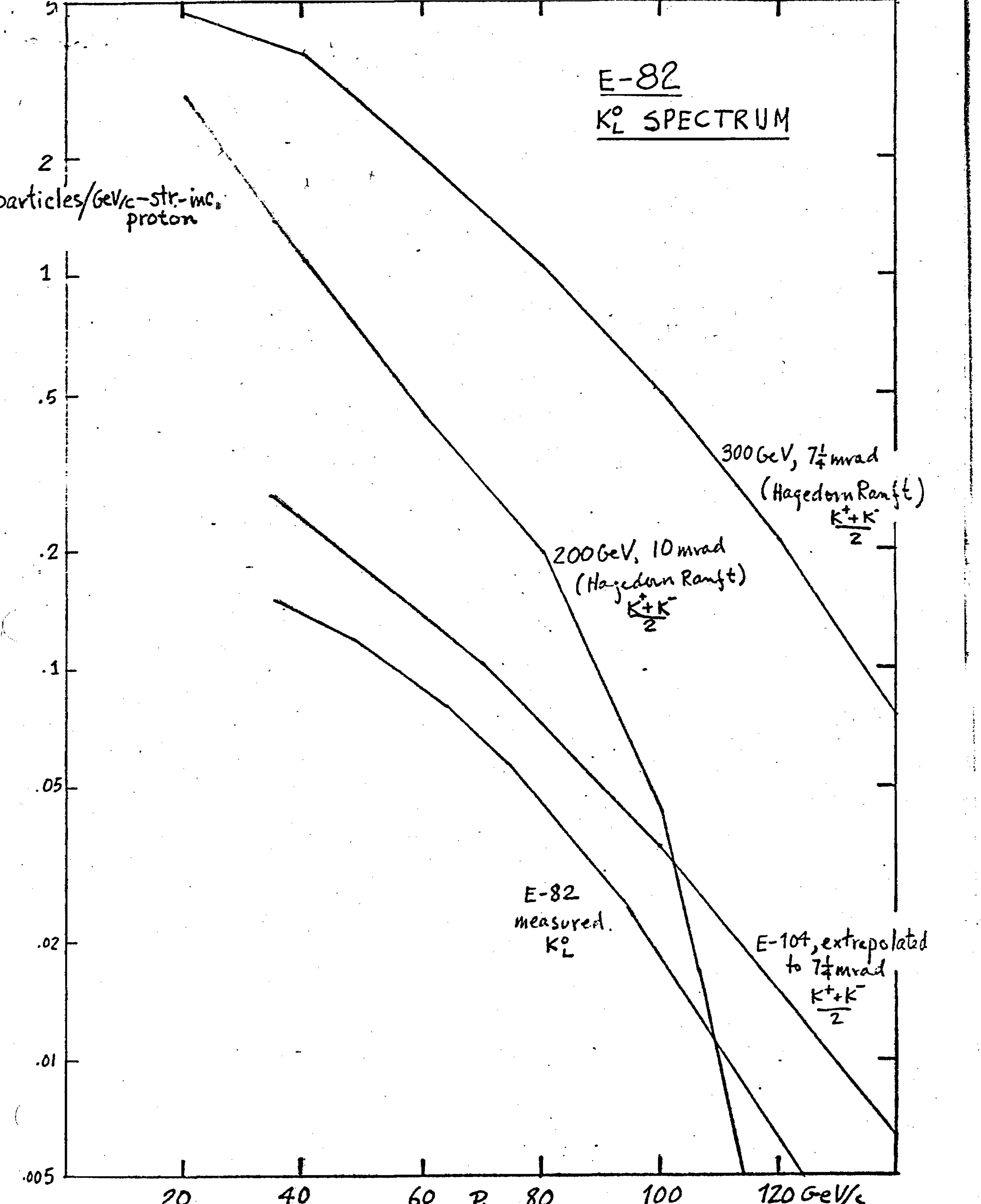
Many aspects of this experiment do not require the high flux of M3 and can be explored with the present flux in M4. These include determination of the nuclear parameters σ_T and σ_{22}, optimization of anticounter configurations near the regenerator used to suppress inelastic K_S regeneration and neutron induced events, and the study of our ability to clearly identify the diffraction regeneration events from a lead regenerator. The measurement of σ_T in M4 is expected to take about 200 hours with our present apparatus.

In summary, we would like to perform the experiment in two steps:

Phase I: Preliminary measurements and determination of some nuclear parameters, ∿500 hours in beam M4.

Phase II: Electron regeneration proper, 1600 hours in beam M3.

We note that we can begin Phase I with our present setup before the long hydrogen target needed to complete E-82 (our current effort) becomes available.



E-82
K^0_L SPECTRUM
particles/GeV/c-str.-inc. proton
5
2
1
.5
.2
.1
.05
.02
.01
.005
300 GeV, $7\frac{1}{4}$ mrad
(Hagedorn Ranft)
$\frac{K^+ + K^-}{2}$
200 GeV, 10 mrad
(Hagedorn Ranft)
$\frac{K^+ + K^-}{2}$
E-82
measured
K^0_L
E-104, extrapolated
to $7\frac{1}{4}$ mrad
$\frac{K^+ + K^-}{2}$
20
40
60
P_K
80
100
120 GeV/c

FIGURE 1