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June 11, 1982

Dr. Leon Lederman
Director
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Batavia, Il. 60510

Dear Leon:

This is a letter of intent regarding a proposed experiment which addresses that persistent enigma CP violation. A ten year old draft of a B.N.L. proposal that was never pursued and submitted is enclosed. As a result of discussions with T. Yamanouchi and D. Buchholz, we came to realize that the conditions for executing this experiment in P-West were far superior to those at the A.G.S.

It would be nice if you and your advisors could very briefly acquaint yourselves with this proposition and ruminate upon the physics. Perhaps you will conclude that this is outrageous foolishness or that information already in hand (of which I am unaware) refutes the issues raised. A detailed proposal and a fully developed collaboration would then be pointless. If you and your advisors are unenthused, potential collaborators are likely to be even more so.

The proposition is this:

A 200 GeV $\bar{p}$ beam, 10^6 particles/sec, enters a 0.5m hydrogen target. Beam π^- are also tagged. A large area K_L° beam is prepared (± 30 mrad vertical, ± 60 mrad horizontal and with a conical plug obliterating a region centered on the beam axis and with cone half angle ≃10 mrad). A large aperture powerful sweeping magnet is required - it is already in position! Ten meters from the hydrogen target, there will emenate from a 3 meter decay region, vee decays of the K_L°. These will be recorded using the virtually unmodified spectrometer system of Brad Cox and his colleagues. We assume that both the spectrometer and the $\bar{p}$ beam will be operational at the outset of this experiment.

After a few weeks something like 10^5 vee decays in the K_L° momentum range (3-8) Gev/L (surrounding x = 0) will be accumulated. Should this sample <u>not</u> contain 200 $\pi^+\pi^-$ CP violating decays, it will be very exciting. Pion tagged events will serve as a control. A portion of the beam aperture will have a regenerator target as well.

Organizationally, the situation is largely undeveloped. T. Yamanouchi has agreed to participate. Northwestern personnel includes Buccholz, Gobbi and Rosen. Buchholz has agreed to serve as spokesman. We have had discussions with Brad Cox. Brad has been receptive and has K_L° beam experience. No committment can be made on his part without extensive exchanges with his colleagues.

We look forward to hearing from you.

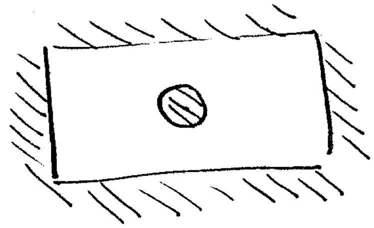
Sincerely,

Jerry Rosen

J. Rosen
Professsor of Physics
& Astronomy

JR/kmv

Beam profile



Decay path (10–13) m

Spectrometer magnet – 15 m

Some numbers

10^5 interacting $\bar{p}$ / sec

We use

$$\overline{E \frac{d^3\sigma}{dp^3}} \sim 3 \text{ mb}/(\text{GeV}/c)^2 \quad K_L^0 \text{ production}$$

$$\bar{p} \approx 5 \text{ GeV}/c$$

$$\begin{cases} \Delta p_x = 0.6 \\ \Delta p_y = 0.3 \\ \Delta p_z = 5 \end{cases}$$

$\rightarrow$ Yield $\sim \frac{0.15 \text{ mb}}{30 \text{ mb}} \sim 5 \times 10^{-4}$ useful K_L^0 / $\bar{p}$ interaction

$\downarrow$

50 K_L^0 / sec

Decay fraction $= \frac{3\text{m}}{150\text{m}} = 2\%$

Spectrometer acceptance $\gtrsim 50\%$

} 1%

$\rightarrow$ 0.5 Detected V / sec (+ trigger bkgd of course)

$\downarrow$

10^5 V's in ~10 days

$\hookrightarrow$ implies 200 CP violating $\pi^+\pi^-$

A Possible CP Violation Experiment at the A.G.S.

J. L. Rosen

July 1972

Abstract

The phenomena of CP violation in K_L^o decay has been convincingly demonstrated and intensively studied. Neither a fundamental understanding of the problem nor a program of definitive or incisive experiments appears at hand. It may be appropriate to probe fundamental assumptions. We note that the neutral kaons used for all experiments are produced in material targets which are not CP eignestates. We ask: Are the decay properties of the K_L^o completely independent of the manner in which they are produced? We are led to explore the feasibility of verifying the CP violation properties of K_L^o produced by particle interactions which are CP eigenstates (or ensembles of CP eigenstates).

The totality of CP Expermentation to date indicates that:

(1) There is no evidence for CP violation anywhere exclusive of K_L^o decays.

(2) Within present experimental accuracy, all CP data requires only one dimen ionless quantity ε appearing in the equation

(1) $$|K_L^o> = \frac{1}{\sqrt{2}}[\ (1+\varepsilon)\,|K^o> - (1-\varepsilon)\,|\overline{K^o}>\ ]$$

The phase of ε is given by $\arg[\varepsilon] = \tan^{-1}[2(m_L-m_S)/\Gamma_S] = 43^o$ where m_L-m_S is the K_L-K_S mass difference and Γ_S is the decay rate of the K_S^o.

$$|\varepsilon| \approx 2 \times 10^{-3}$$

Thus the K_L^o has a small excess of K^o component relative to $\overline{K^o}$. The K_S^o has a similar excess of K^o but this fact has not been directly verified.

We may ask: why does there not exist a particle (call it $K_L^{o\prime}$) which has a conjugate mix of K^o and $\overline{K^o}$?

(2) $$|K_L^{o\prime}> \equiv \frac{1}{\sqrt{2}}[\ (1-\varepsilon)\,|K^o> - (1+\varepsilon)\,|\overline{K^o}>\ ]$$

$$= -\ |\overline{K_L^o}>$$

$$= |K_L^o>_{\varepsilon\to-\varepsilon}$$

A certain level of symmetry would be restored to the world if $K_L^{o\prime}$ existed. The implications of such a state would be very deep. Presumably, the existence of $K_S^{o\prime}$, $K^{o\prime}$, $\overline{K^{o\prime}}$ would necessarily follow. Possibly other particle states as well would manifest this kind of superfine structure. We do well to remember that the CP violation phenomena is extremely weak even on the scale of weak interactions.

If $K_L^{o\prime}$ exists, it seems reasonable to assume that we are not making them in detectable amounts. Perhaps this is related to the fact that in all experimentation to date, neutral kaons have been prepared by production processes which are not CP eigenstates. Perhaps kaon production by $\overline{p}$ incident on an anti Berylium target results in $K_L^{o'}$ production excluding or dominating K_L^o production.

At the present stage of understanding, it may be wise to check that the apparent phenomena of CP violation is unchanged if the long lived neutral kaons are produced in CP self conjugate collisions.

Admittedly, we do not have a model mechanism for describing the fashion in which matter uniquely sets up some kind of metastable excitation of the kaon which persists through its lifetime.

We ~~are~~ speculating that a coherent superposition of K_L^o and $K_L^{o'}$ would result in a cancellation of apparent CP violation.

Description of the Experiment

We would prefer to use $\overline{p}p$ annihilations at rest but there are three serious technical drawbacks.

1. Stopping $\overline{p}$ beams are not very intense.
2. Kaons emerge isotropically.
3. Kaon decay opening angles are large and this, together with point 2, makes efficient detection difficult.

The use of $e^+ e^-$ collisions does not yet appear feasible.

We envision the use of $\overline{p}p$ interactions in flight. Then the K_L^o are peaked forward and are more conveniently detected.

We need two key ingredients

1. Very large Wire Chamber Spectrometer.
2. High flux (~10^5/pulse) separated $\overline{p}$ beam - momentum ~7 GeV/c.

Both are under construction at B.N.L. and are scheduled to become operational in the summer 1973. The B.N.L. M.P.S. dectector will feature a magnet with transverse aperture 4'×6' and 15' long.

The use of $p\overline{p}$ in flight introduces a qualification. Perhaps the K_L^o and $K_L^{o\prime}$ angular distributions with respect to the beam axis are not identical. Then perfect cancellation would be expected only for kaon emission corresponding to 90° in the C.M. i.e. $(x \approx 0)$

C.M.		Lab
$p_L=0$	$\rightarrow$	$p_L = \gamma_{CM}\beta_{CM}(m_K^2+p_o^2)^{1/2}$
$p_t=p_o$		$p_t = p_o$

For 7 GeV/c $\overline{p}$, γ_{CM}= 2.0 and $p_L \approx 1$ GeV/c. Such a kaon has typically, a 45° decay opening angle.

We will concentrate on kaon decays $\geqslant$ 3m from production and with

$0.7 < p < 1.5$ GeV/c.

There are many technical problems to consider which we will not go into here. viz.

False triggers produced by n, $\overline{n}$, γ.

Small K_S^o regeneration effects.

We believe these are soluble.

Rough Rate Estimates

	Number/pulse
$\bar{p}$ flux	10^5
	$\downarrow$
$\bar{p}p$ interactions (σ = 60mb, 50 cm target)	1.3×10^4
	$\downarrow$
$\bar{p}p$ annihilations (σ = 25 mb)	5×10^3
	$\downarrow$
Number of K_L^o produced	1.3×10^2
	$\downarrow$
Number of K_L^o in range (0.7 - 1.5) GeV/c	50
	$\downarrow$
Number of Detected V's (K_L^o m.f.p. for decay = 30 m, $\Delta\Omega$ cuts etc.)	0.5

$\rightarrow$ 60k V's/100 hours

60k V's implies 100 Fitch-Cronin CP violating decays $K_L^o \rightarrow \pi^+ + \pi^-$

Feasibility Study

A short run looking at $\bar{p}\, p \rightarrow (K_S^o + \text{any})$ would be useful. This is pretty much what the Lindenbaum-Ozaki group will be doing in the first approved experiment for the M.P.S.

MOMENTUM DISTRIBUTION OF K_1°

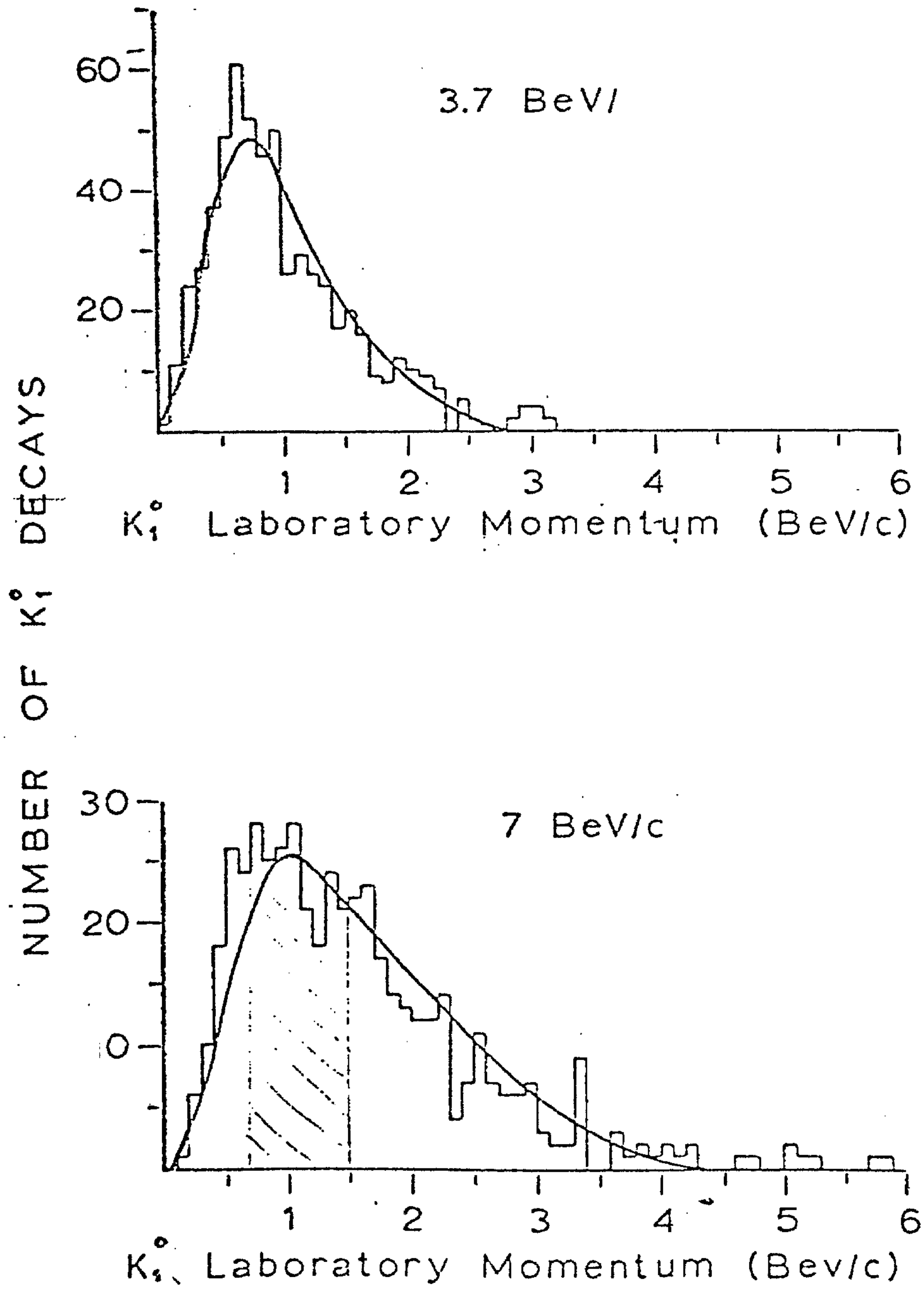


Figure 19. Laboratory momentum spectra of K_1^0-particles produced at 3.7 and 7 BeV/c. The smooth curves represent statistical model expectations on the basis of 6-body final state for 3.7 BeV/c and 7-body final state for 7 BeV/c.

Noel Kuei-Eng Yeh.
Yale University 1966

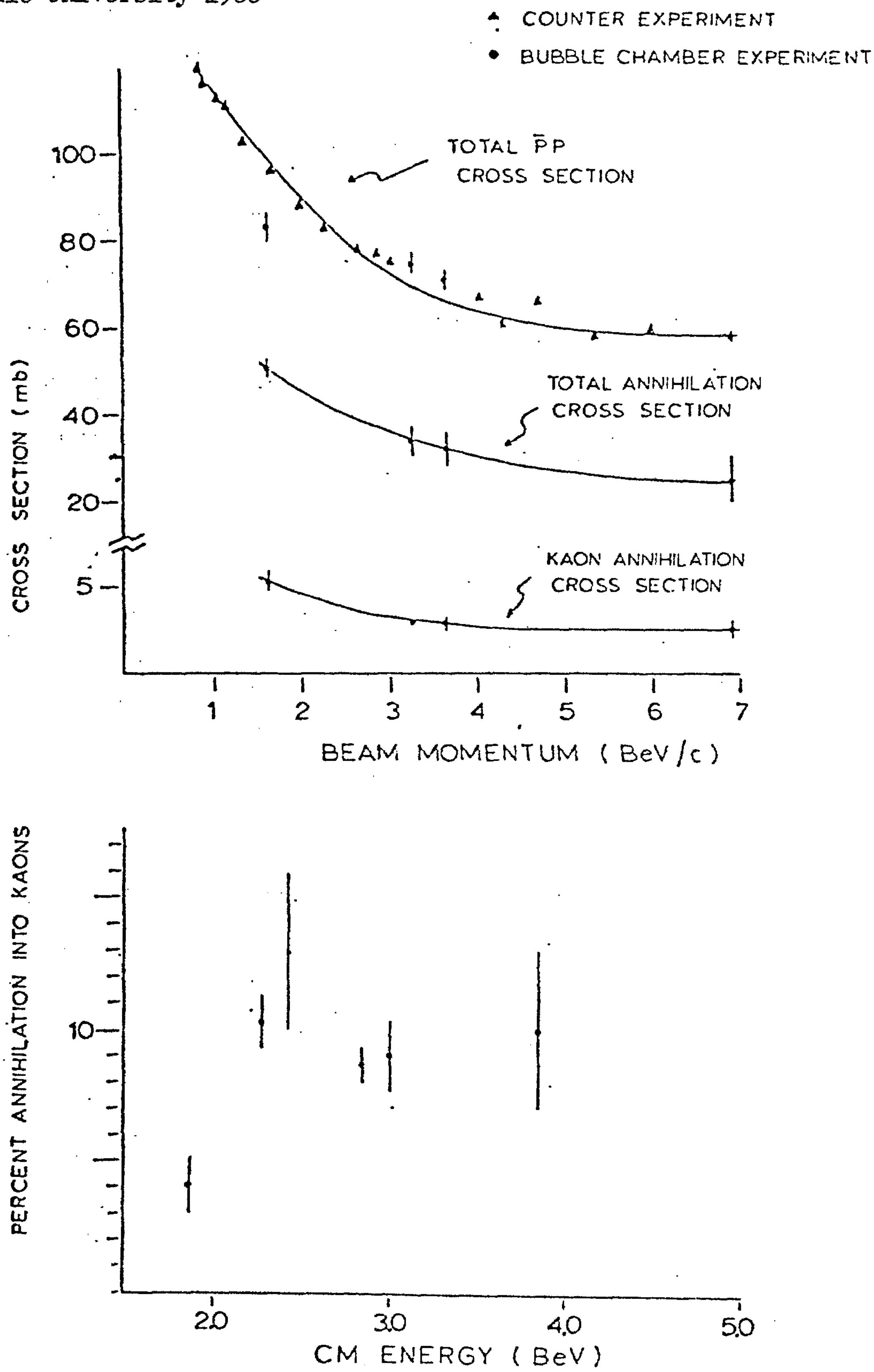


Figure 18. Variation of cross section with incident antiproton momentum.

The K^0-$\bar{K}^0$ System in p-$\bar{p}$ Annihilation at Rest.

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In $\bar{p}$-p annihilation, detection of a charge asymmetry in the decay $K_L \to \pi l \nu$ would be a *direct* proof of *CP* violation, *independent* of the usual theoretical analysis of the time dependence of the K^0-$\bar{K}^0$ complex, since the initial particles producing the K_L (*i.e.* $p\bar{p}$) are their own *CP* conjugates. (In contrast, the usual charge asymmetry experiments [5] examine K_L produced in hadronic collisions not involving antinuclei. They therefore demonstrate *CP* violation only if one accepts the analysis that the K_L observed are the same whether they are produced in *CP* self-conjugate collisions or not. While this analysis is in all probability correct, there is an explicit advantage [6] in a direct experimental demonstration of the important phenomena of *CP* violation without having to use such an analysis.) The experiment can only be successful, however, if one observes $\sim 10^7$ or more K_L decays.

The paragraph reproduced above has been taken from the body of the Goldhaber and Yang paper. We thank Dr. Goldhaber for bringing this to our attention.

It does not appear technically feasible at this time to plan a charge asymmetry measurement using K_L^0 produced in CP self conjugate collisions as it requires ~ 10^7 observed K_L^0 decays. However, a statistically significant measurement of the Fitch-Cronin decay $K_L^0 \to \pi^+\pi^-$ requires ~ 10^5 observed K_L^0 decays.

Since experiment indicates that both phenomena, $K_L^0 \to \pi^+\pi^-$ and charge asymmetry have the same origin, namely a skewness in the neutral kaon mass matrix (characterized by ε), it is difficult to conceive of a mechanism negating one but not the other.

APPENDIX A

Matter vs. Anti-Matter

These ruminations were triggered by a consideration of the classic cosmological question. Does our universe contain galaxies, however remote, which are constituted of anti-matter (anti nucleons, positrons etc) in the same sense as our region is constructed predominantly of matter (nucleons, electrons etc.)? The question remains unanswered. However, the phenomena of CP violation has added an interesting twist to the speculative aspects of the problem.

Imagine communicating with a remote galaxy and attempting to establish, in the course of these exchanges, the matter or anti-matter nature of this galaxy. Let us further specify that we exchange only "pure" information via radio waves.

In the absence of CP violation, it is well known that any attempt to communicate the primacy of matter or anti-matter in the other galaxy would fail. This is because there are two ambiguities which must be communicated rather than only one - the definition of matter and a specification of a sense of handedness. Any attempt to communicate a sense of charge (or "particle ness") would be neatly and exactly refuted by switching the definition of left and right handedness. This is the import of CP conservation.

But CP is violated. Let us describe a simple example of how CP violation allows a resolution of the matter anti-matter ambiguity. In our world, K^0_L contains a small excess of positive strangeness kaon (K^0) as opposed to negative strangeness kaon ($\overline{K^0}$).

(1) $$K_L^o = \frac{1}{\sqrt{2}}\left[(1+\varepsilon)\,K^o - (1-\varepsilon)\,\overline{K^o}\right]$$

where $\varepsilon = (2 \times 10^{-3}) \exp(i\, 43^o)$

It follows from the $\Delta S = \Delta Q$ rule that

$K^o \rightarrow \pi^- e^+ \nu$ $\qquad\qquad$ $\overline{K^o} \rightarrow \pi^+ e^- \bar{\nu}$

$\not\rightarrow \pi^+ e^- \bar{\nu}$ $\qquad\qquad$ $\not\rightarrow \pi^- e^+ \nu$

In other words, the e^- to e^+ ratio reflects the ratio of the S = -1 to S = +1 composition of K_L^o.

Hence the number of K_L^o decays producing e^- is <u>less</u> than the number of decays producing e^+. Rephrased: the light, charged lepton produced least copiously in K_L^o decay is the same as the lepton in a hydrogen atom.

As a result of all this, we can communicate the following instructions to the remote galaxy.

1. Make a K_L^o beam

2. Carry out an electron-positron charge asymmetry measurement.

3. Answer the question: Is the less copiously produced of the two leptons (electron-positron) the same lepton as in your hydrogen atom? Yes (No) means you are, by our definition, matter (anti-matter).

However, if the anti-matter creatures produced the $K_L^{o\prime}$ particle we have hypothesized, then the charge asymmetry measurement would be reversed and a kind of macroscopic CP symmetry will have been restored.

Fermilab Proposal No. 721

Scientific Spokesman: D. Buchholz
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CP VIOLATION

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Introduction

Fifty years have elapsed since the discovery of the first particle of anti-matter, the positron, by C. W. Anderson. This confirmed the brilliant prediction of P. A. M. Dirac. In subsequent years, many other species of anti-particles were observed, up to and including the anti-particle versions of the heavier hydrogen isotopes. Three decades of physics revealed a complete microscopic symmetry between matter and anti-matter in juxtaposition to an awesome macroscopic asymmetry. Our galaxy is hostile to any extended intrusion of anti-matter. Are there remote galaxies formed of anti-matter? There is no really hard evidence to exclude this possibility, although speculative theoretical arguments have been advanced against it.

Eighteen years ago, the Fitch-Cronin[1] group uncovered the first evidence for a small but significant microscopic matter-antimatter asymmetry in the phenomena of CP violation as exhibited in the decay properties of the neutral kaon system. Although subsequent measurements have refined and extended our qualitative knowledge concerning this curious and incompletely understood phenomena, CP violating effects have not been revealed in any other type of particle physics reaction. We do understand, however, that the neutral kaon system is a virtually unique laboratory for examining CP violation. While the $D^\circ - \overline{D}^\circ$ system should, in principle, exhibit much the same phenomena, flux availability, decay time scale and other considerations have made it an impractical possibility.

During the eighteen year period since the discovery of CP violation, other advances have been made. The composite nature of the hadrons has been revealed, leading to the still evolutionary Q.C.D. theory. Kobayashi and Maskawa[2] have built CP violation into the weak interaction quark sector. CP violation remains a phenomenologically postulated effect. One can choose to be alternately puzzled by its smallness, as well as by its very existence. It is ironic that one measure of support for the theory rests on its cosmological implications. Although in the present world CP violation is a minute phenomena, weak even on the scale of weak interactions, it is speculated that during the "big bang," when energy densities were unthinkably large, bosons abounded and CP violation was large.

Hence, the cosmological asymmetry between matter and anti-matter has been attributed to CP violation during the first moments of creation! This is the barest outline of the role of CP violation in modern cosmology. It should be possible to concede, then, that any experiment which could shed new light on CP violation should be examined with the utmost seriousness. None of the following speculations should be precipitously rejected as "far out." CP violation is inherently "far out!"

Let us get down to cases. What if CP violation is not "real?" Several alternate explanations were put forth immediately after the CP violation discovery. Generally, this type of alternative involves some kind of long range interaction or a very high density sea of neutrinos (or neutrino like particles). The basic idea is that propagating kaons continuously regenerate in flight. Generally, the wrong phase for CP violation, marked energy dependence (γ^{2J} where $\gamma = E_K/m_{\circ K}$, J = spin of exchange field), or both is predicted. Maybe some modified form of these vacuum regeneration theories can be revived but this is not the thrust of this proposal. Suppose (apparent) CP violation is an artifact of the manner in which the K°_L beam is prepared.

It has always been <u>assumed</u> that all K°_L are interchangeable and that their subsequent decay has nothing whatever to do with the manner in which they are prepared. There is nothing CP symmetric about the production process. Most commonly, high energy protons strike a Berylium target. We cannot be be sure what would happen if anti-protons strike an anti Be target ($\overline{p} + \overline{Be} \rightarrow K^\circ_L + X$).

Interestingly, CP measurements have converged with impressive accuracy on the so-called superweak theory--described by a single parameter (ε). Simply stated, the K°_L is an asymmetric mixture of K° and $\overline{K}^\circ$.

$$|K^\circ_L\rangle = |K^\circ_2\rangle + \varepsilon|K^\circ_1\rangle$$

where

$$|K^\circ_2\rangle = \frac{|K^\circ\rangle - |\overline{K}^\circ\rangle}{\sqrt{2}} \qquad CP = -1$$

$$|K^\circ_1\rangle = \frac{|K^\circ\rangle + |\overline{K}^\circ\rangle}{\sqrt{2}} \qquad CP = +1$$

$$|\varepsilon| = 2.27 \pm 0.02 \times 10^{-3} \quad \text{(experiment)}$$ [3]

and its measured phase to a few degrees accuracy

$$\phi_\varepsilon = \tan^{-1} \frac{\Gamma_S/2}{M_S-M_L} = (44.6 \pm 1.2)^\circ.$$

Note also, that the superweak theory preserves TCP invariance. Perhaps if we could produce long lived kaons by ($\overline{p} + \overline{Be} \rightarrow K^\circ_L + X$), we would produce a <u>different</u> K°_L.

$$|K^\circ_L{}'\rangle = |K^\circ_2\rangle - \varepsilon|K^\circ_1\rangle$$

That is, ε would apparently change sign. Suppose we actually produced kaons in a collision process which was a CP eigenstate, e.g.,

$$\overline{p} + p \rightarrow K^\circ_L + \ \ldots.$$

More precisely, it would suffice to have an <u>ensemble</u> of CP eigenstates. We speculate that a mixture of $|K^\circ_L\rangle$ and $|K^\circ_L{}'\rangle$ would be produced, and a cancelation would take place such that <u>pure</u> $|K^\circ_2\rangle$ would result and CP violation would disappear! One caveat, if the $\bar{p}\,p$ system annihilated at rest, the speculated cancelation would be complete. If the $\bar{p}$ beam interacted in flight with a fixed hydrogen target, total cancelation could only be assumed for $x \approx o$, i.e., K°_{L} production in the vicinity of 90° in the C.M.

Let us comment further on this speculated schizoidal behavior of K°_{L}. We now believe that kaons are not simply produced in an instant of time. Rather, strange (or anti-strange) quarks are ejected from the collision region and the curious process known as hadronization ensues.

Hadronization is a collective phenomena. It involves the residual hadronic matter as well as the accelerated or created $s(\bar{s})$. We speculate that there exists some kind of hyperfine or metastable structure in hadronic states. An asymmetric population of these states could result as a consequence of the asymmetry of the residual hadronic matter. One obvious asymmetry is the quark excess.

$$\frac{n_q - n_{\bar{q}}}{n_q + n_{\bar{q}}} \geq 10\%$$

Beyond these observations, we have not developed a theoretical model.[4,5] The idea of hyperfine structure should not be as readily dismissed as totally fanciful as it was a decade ago. Modern Q.C.D. is built upon the theoretical perception of a new hidden quantum number--color. Further surprises should not be rejected out of hand.

The above suggestions are purely speculative but they are motivated by the fact that CP violation is still an experimental observation without a good theoretical foundation. Aside from the "conventional" CP ideas like superweak interactions and mixing angles between quark states, there have been several recent speculations about CP violations. In a series of preprints and articles[6] it has been suggested that there is experimental evidence that the K°_L- K°_S mass difference, Δm, the K°_S lifetime, τ_S, and the CP-nonconserving parameter, η_{+-} have an anomalous energy dependence. As they point out this "dependence of quantities determined in the K° rest frame on the K° laboratory energy, could arise from the motion of the kaons with respect to some external field or medium." Some of this same data has been looked at differently[7] by splitting the data into pre-1971 and post-1971. Analyzed this way it appears that there is a time dependence to the CP-violating parameter η_{+-}.

We now turn to the questions of experimental strategy. Since e^+e^- collisions or $\overline{p}\,p$ annihilation at rest are CP symmetric states, they should provide a very different framework for demonstrating CP violation initiated in the decays of K°_L. A reasonably high flux $\overline{p}$ beam ($\sim 10^6$ $\overline{p}$ /sec at 200 GeV/c), colliding with a hydrogen target, is technically advantageous. The x = o K°_L's produced have a laboratory momentum of approximately 8 GeV/c. K°_S decays can be avoided by the conventional approach--decay distance > (10-20) K°_S lifetimes and sweeping magnet. Further, the opening angle of the sought after $K^\circ_L \to \pi^+\pi^-$ decay is conveniently small. A conventional large angle magnetic spectrometer with rectangular PWC planes can be employed.

Except for the fact that the solid angle of the K°_L beam is substantially larger than normally employed, the resulting experimental configuration is little different conceptually from the "standard" K°_L experiment carried out at the A.G.S. or the P.S. ~10 years ago.

Experimental Apparatus

We propose to use the E705 spectrometer to look for the CP violating decay

$$K^\circ_L \rightarrow \pi^+\pi^-$$

Figure 1 shows the proposed layout. The K°_L would be created in the collision of 200 GeV $\bar{p}$'s impinging on a 13% interaction length liquid H_2 target. The target would be followed by a dipole magnet (presumably the E615 magnet) to sweep all charged particles out of the beam. A 10 mrad conical collimator fills the center of this magnet to remove small angle K°_S's. A 3 meter decay volume follows the sweeping magnets to allow for K°_L decays. This is followed by the E705 spectrometer except that its target and first few PWC's have been removed. The area from the target to the first set of drift chambers would be filled with a He bag (similar to the original Cronin-Fitch experiment)[1] to minimize K°_S regeneration.

A Monte Carlo program was written to calculate the acceptance of this apparatus. The K°_L were generated according to $e^{-5p\perp}$ and an experimental y distribution measured in pp collisions at $\sqrt{S}$ = 63 GeV.[8] The K°_L are allowed to decay isotropically to $\pi^+\pi^-$ in the K center of mass but distributed in z according to the K°_L decay probability. These π's are then weighted by their proper decay probability and traced through the spectrometer for acceptance. The σ_{tot} for $p\bar{p} \rightarrow K^\circ_L X$ at p_{lab} = 200 GeV was taken from a plot of $p\bar{p} \rightarrow K^\circ_S X$[9] and assuming $\sigma_{K^\circ_S} = \sigma_{K^\circ_L}$. The decay estimates and assumptions are listed in Table I. The acceptance includes a cut on x ($|x| < 0.03$).

Figure 2 illustrates how the successive cuts are made. This figure shows the laboratory momentum distribution of the K°_L as they are produced at the H_2 target. The histograms in this figure follow the K°_L as they are removed by the requirements. These requirements are

1) the aperture of the sweeping magnet,

2) collimate the central 10 mrad of the produced K°_L,

3) the K°_L make it to the 3m decay region and decay,

4) if they decay within the decay region into $\pi^+\pi^-$, both π's are accepted within the fiducial region of the downstream spectrometer (this does not include branching ratios yet), and

5) require that $|x| < 0.03$,

The integrals for each of these histograms are listed in figure 2. These integrals correspond to the rates per second as listed in Table I except that the branching rate for $K^\circ_L \to \pi^+\pi^-$ has not been multiplied by the numbers on Figure 2. Table II lists the daily rates for K°_L and K°_S decays into $\pi^+\pi^-$. This table also shows how rates vary according to restrictions on the production angle and range of x accepted. This demonstrates how collimating the central 10 mrad of production removes a much larger fraction of K°_S decays than K°_L decays. Table III gives the expected trigger rates for all the K°_L and K°_S decays which would satisfy a charged 2 body trigger. The important numbers from this table are the total daily trigger rate of almost 200,000 and the daily rate of 180 $K^\circ_L \to \pi^+\pi^-$ before x cuts if there are no CP surprises. Figure 3 shows the laboratory momentum of the K°_L and K°_S's that decay into $\pi^+\pi^-$ and are accepted by the apparatus. This figure includes the relative branching ratios and shows how the K°_L decays are separated from the K°_S decays by the x cut.

The $\bar{p}$ beam includes an appreciable number of π^- particles which must be tagged. The π's are covenient in that they provide a simultaneous control experiment. Presumably K°_L's produced by π^-'s are "conventional" in that they decay into $\pi^+\pi^-$ with the measured CP violating rate. By triggering on 2 particle decays of K°_L's tagged with incident π^-'s, we have a built in simultaneous normalization experiment. If time permits, some dedicated incident p running might become necessary. This would allow a direct comparison of K°_L's from pp versus $\bar{p}$ p. The positive beam allows a check of π^+ production of K°_L and decays simultaneously with the tagging scheme.

The measured rate of $K^\circ_L \rightarrow \pi^+\pi^-$ can be normalized to the rate of $K^\circ_L \rightarrow \pi^\pm e^\mp \nu$. Both of these decays can be triggered with 2 charged particle triggers. The triggering scheme has not been completely worked out yet but it will involve a check that the particle multiplicity has increased by two from the start to the end of the decay region. It may be necessary to construct a segmented veto wall or a fast PWC at the start of the decay region. The particle multiplicity could thus be checked here and compared with the multiplicity behind the spectrometer magnet.

Conclusions

The questions of CP violation in the K°_L system is still an experimental area. This experiment will look at an untested aspect of CP violation. With a total time period of approximately 3 weeks (10 days of steady running and another 10 days of set up) this experiment would expect to see 400 CP violating decays if there are no surprises. If, as is suggested in this proposal, there are new eigenstates of K°, then one would expect that the observed rate of CP violations would be decreased. With a relatively short amount of running time this experiment could test out a total new area of K° CP violations. We would hope to take data for this experiment during the next E705 running period which starts in late 1984.

Table 1

Running Conditions

$\bar{p}$/spill at 200 GeV	1×10^7 $\bar{p}$/spill
10 sec beam spill each minute	10^6 $\bar{p}$/sec
$\sigma_{tot}(p\bar{p} \to K^\circ X)$	5 mb
$\rho(H_2)$	0.07 gm/cm^2
target length	100 cm
K°/sec	20,000 K°/sec
Beam conditions	60 spills/hour
	20 hours/day
	10 sec/spill

Giving 12,000 sec of beam/day

Or 2.4×10^8 K°/sec

Table II

Daily Rates For K°_L and K°_S Decay to $\pi^+\pi^-$

"Accepted Events" have:

1) decay occurs in 3m decay region

2) both π's are within fiducial region of last drift chamber

Extra Requirement	$K^\circ_S \rightarrow \pi^+\pi^-$/day	$K^\circ_L \rightarrow \pi^+\pi^-$/day
none	732,000.	300.
$\theta_{prod} > 10$ mrad	120,000.	180.
$\theta_{prod} > 20$ mrad	9,600.	72.
all θ, $\lvert x\rvert < 0.03$	0.035	52.
$\theta_{prod} > 10$ mrad, $\lvert x\rvert < 0.03$	0.032	39.
$\theta_{prod} > 20$ mrad $\lvert x\rvert < 0.03$	0.026	22.

Table III

Approximate Trigger Rates for θ prod>10mrad, no x cuts

Decay	Branching Rate	Trigger Rate / 20,000 K°	Trigger Rate / 10 sec spill	Trigger Rate / day
$K^\circ_L \rightarrow \pi^\circ\pi^\circ\pi^\circ$	(.215)	0.019	0.19	228
$Le^+e^-\gamma$	(.01213)			
$\rightarrow \pi^+\pi^\circ\pi^\circ$	(.1239)	0.92	9.2	11,040
$\rightarrow \pi^1\mu^\mp$	(.271)	2.0	20.	24,000
$\rightarrow \pi^\pm\mu^\mp$	(.381)	2.0	29.	34,000
$\rightarrow \pi^+\pi^-$	(.00203)	0.015	.15	180
			Subtotal	70,000
$K^\circ_L \rightarrow \pi^+\pi^-$	(.686)	10.	100.	120,000
$\rightarrow \pi^\circ\pi^\circ$	(.3139)	.056	.56	666
$Le^+e^-\gamma$	(.01213)			
			Subtotal	120,666
	Totals	15.9	159	190,666

Of the 180 $K^\circ_L \rightarrow \pi^+\pi^-$/ day, 40 remain after making the desired $|x| < 0.03$ cut.

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SPECTROMETER

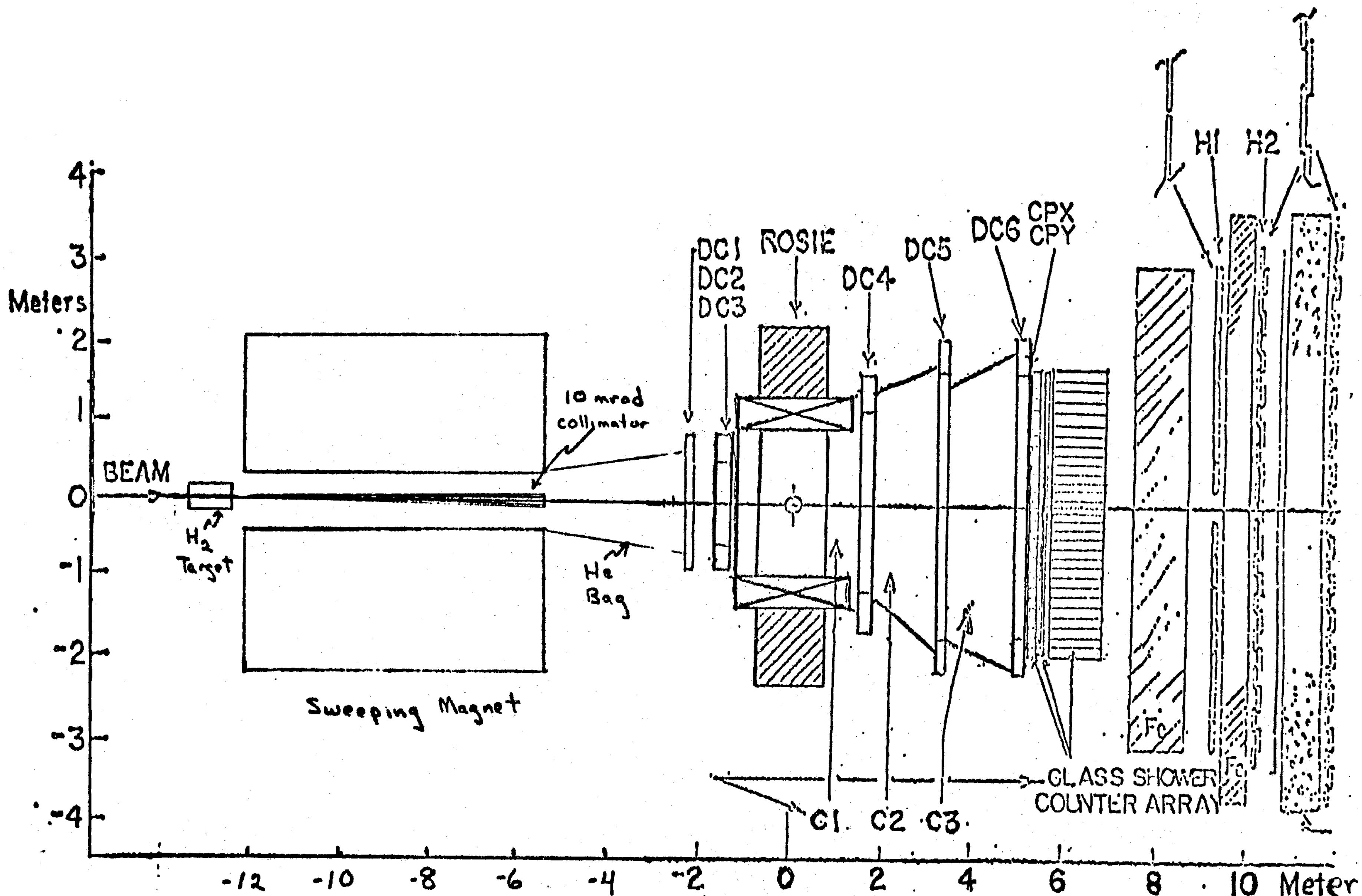
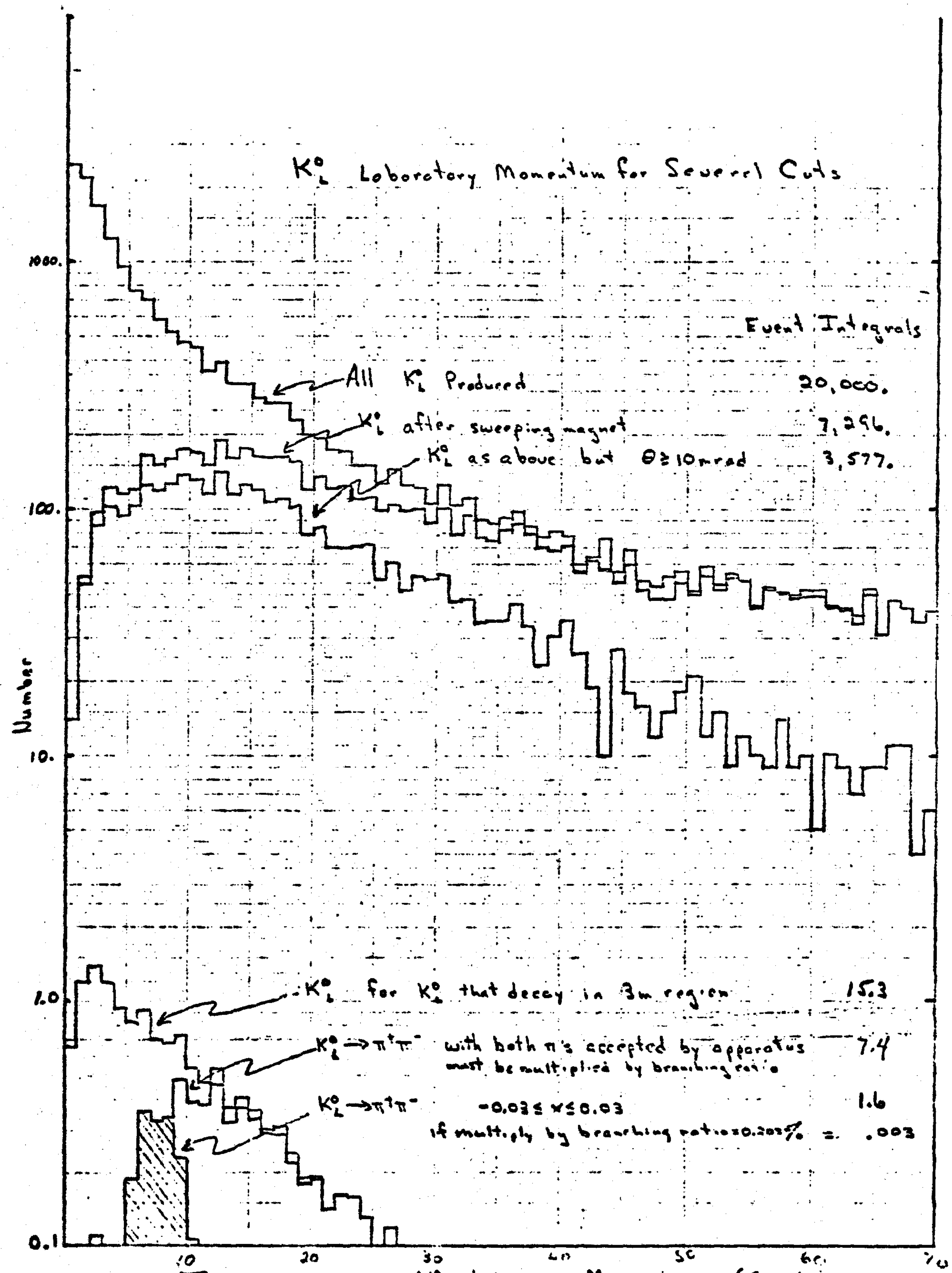


Figure 1



K^0_L Laboratory Momentum for Several Cuts
Event Integrals
All K^0_L Produced 20,000.
K^0_L after sweeping magnet 7,296.
K^0_L as above but $\theta \geq 10$ mrad 3,577.
K^0_L for K^0_L that decay in 3m region 15.3
$K^0_L \to \pi^+\pi^-$ with both π's accepted by apparatus 7.4
must be multiplied by branching ratio
$K^0_L \to \pi^+\pi^-$ $-0.03 \leq x \leq 0.03$ 1.6
if multiply by branching ratio = .003
Number
1000.
100.
10.
1.0
0.1
10
20
30
40
50
60
70
K^0_L Laboratory Momentum (GeV/c)

Figure 2

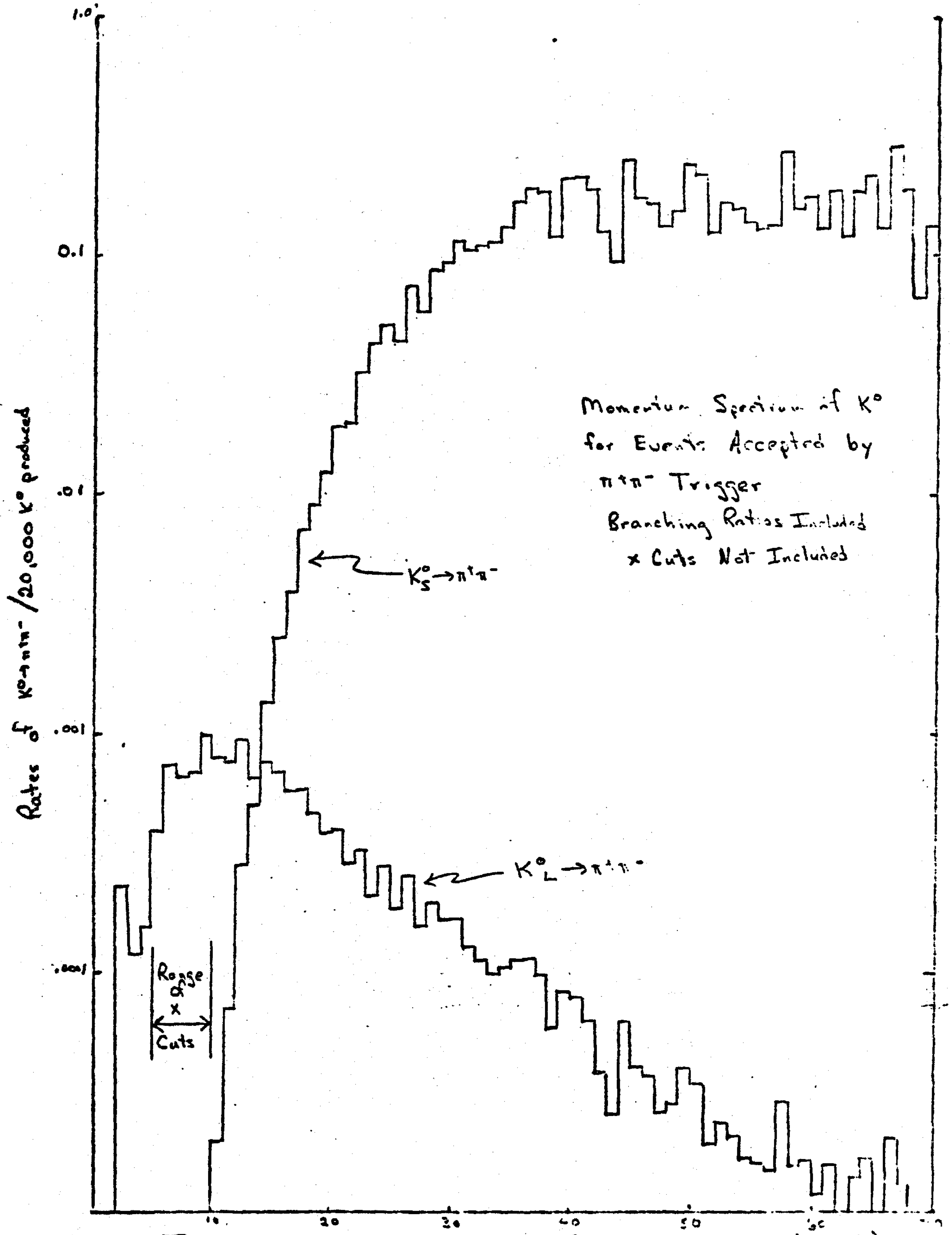


Figure 3 K^0_S and K^0_L Laboratory Momentum (GeV/c)