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UNCONVENTIONAL NEUTRAL KAON BEAMS AT LAMPF II

by

C. M. Hoffman

ABSTRACT

Several methods of producing neutral kaon beams with reduced neutron contamination at LAMPF II are discussed. In addition, a possible K_S^0 beam design is presented.

I. INTRODUCTION

Two challenges to be addressed by LAMPF II are to improve our knowledge of the parameters of CP violation so as to understand the underlying source of this phenomenon, and to search with increased sensitivity for various rare decay modes of K mesons to stringently test present theoretical models. The vastly increased intensities of LAMPF II will certainly allow higher precision measurements to be made. To utilize the full power of LAMPF II, it will also be necessary to reduce systematic uncertainties and unwanted backgrounds. In most cases, this will be greatly facilitated by improvements in beam quality and purity.

In this report I discuss several unconventional methods of producing K^0 beams that have significantly lower neutron contamination than beams to date. These methods would be impractical at lower intensity accelerators; in a sense, I discuss several methods of trading some of the potential K^0 intensity for beam purity. The methods discussed are

1. K^0 production in p-nucleus collisions at large angles,
2. K^0 production in π -nucleus collisions,
3. Preferential neutron absorption in a neutral beam, and
4. $\bar{K}^0$ production by charge exchange.

II. K^0 PRODUCTION IN p-NUCLEUS COLLISIONS AT LARGE ANGLES

Neutron production in proton interactions peaks sharply at 0° . This is illustrated in Fig. 1, which shows proton production from 18.8 GeV/c proton-proton collisions at 0 and 100 mrad.^{1,2} Neutron production should be very similar to proton production except for the highest possible secondary momenta, where the neutron flux should drop to zero while the proton flux is a maximum. The K^0 flux is not such a strong function of production angle. Assuming that K_L^0 production cross section can be characterized by the average of the K^+ and K^- production cross sections, the K_L^0 production is shown^{1,2} in Fig. 2. Table I shows the integrated K_L^0 and neutron fluxes above 1 GeV/c for various production angles. The need to avoid 0° is obvious. It is also evident that the K_L^0/n ratio improves as the production angle increases, at the price of some reduction in the K_L^0 flux.³ An examination of Fig. 2 shows that the average kaon momentum decreases quite rapidly with increasing production angle.

The lesson to be learned here is that K_L^0 beams should be produced at small, nonzero angles to avoid the very large neutron flux at 0° . The improvement in the K/n ratio is most significant for angles up to 100 mrad. The K_L^0 flux decreases monotonically and the momentum spectrum softens as the production angle increases. It thus appears that 100 mrad is about the largest practical production angle. The K/n ratio cannot be made larger than about 1:10 by this technique.

III. K^0 PRODUCTION IN π -NUCLEUS COLLISIONS

It has been suggested* that a higher quality K^0 beam would result from pion-nucleus interactions. The rationale for this scheme is that, in proton-proton collisions, the secondary baryons tend to take up most of the incoming momentum, whereas in meson-nucleon collisions the secondary mesons emerge with most of the momentum. Data for $\pi^\pm p \rightarrow K^0 + \text{anything}$ exist at 6, 11.2, 15, and 16 GeV/c.⁴⁻⁷ These data indicate that K^0 production is peaked at small angles and has a broad momentum spectrum; Fig. 3 shows the cross section for 16 GeV/c at several angles. Figure 4 shows the kaon yields integrated over angles. Also shown in Fig. 3 is the cross section

* This information was supplied by D. Jensen, 1982.

Fig. 1. Cross section for $p + p \rightarrow p + X$ at 18.8 GeV/c.

Fig. 2. Cross section for $p + p \rightarrow K_L^0 + X$ at 18.8 GeV/c.

TABLE I

 K_L^0 AND PROTON PRODUCTION CROSS SECTIONS

IN p-p COLLISIONS AT 19 GeV/c

Production Angle	$\frac{d\sigma_p}{d\Omega}$ (mb/sr) (1-12 GeV/c)	$\frac{d\sigma_{K_L^0}}{d\Omega}$ (mb/sr) (1-12 GeV/c)	$\frac{\sigma(K_L^0)}{\sigma(p)}$
0 mrad	1020	18.8	0.02
50 mrad	300	13.8	0.05
100 mrad	85	9.4	0.11
200 mrad	25	2.9	0.12

Fig. 3. Cross section for $\pi^+p \rightarrow K^0 + X$ at 16 GeV/c for $0 < \theta_{lab} < 0.1$ rad, $0.1 < \theta_{lab} < 0.2$ rad, and $0.2 < \theta_{lab} < 0.3$ rad. The dashed curve shows the cross section for $\pi^+p \rightarrow \Lambda + X$ for $0 < \theta_{lab} < 0.2$ rad.

Fig. 4. Cross section for $\pi^- p \rightarrow K^0 + X$ at 11.2 GeV/c and 6 GeV/c integrated over production angle.

for Λ production at 16 GeV/c. K^0 's produced at forward angles tend to emerge with higher momenta than Λ 's. The data on inclusive proton production at 11.2 GeV/c (Ref. 8) indicate that the K_L^0/n ratio will be larger than 0.1 in the forward direction.

To estimate the K_L^0 fluxes, I will assume a pion channel with an acceptance of 1 msr, $\frac{\Delta p}{p} = 5\%$, and 20 μA (1.2×10^{14} p/s) incident on a 3-in. platinum target. These specifications are similar (except for the incident proton flux) to those of the high intensity pion beam C1 at the AGS.⁹ Scaling from the pion yields obtained there, one would expect $\sim 2 \times 10^{10}$ π^+ /s at 6 GeV/c. I shall assume that kaon production scales as $A^{2/3}$ where A is the atomic number.¹⁰ The number of K_L^0 's produced is then

$$\begin{aligned}
N_{K_L} &= \frac{d^2\sigma}{d\Omega dp} (N_{Av})(\rho)(L) \frac{A^{0.67}}{A} N_{\pi}(\Delta p) \Delta\Omega \\
N_{K_L} &= (2 \times 10^{-27} \frac{\text{cm}^2}{\text{Sr-GeV}}) (6 \times 10^{23}) (19) (7.5) \frac{1}{(195)^{0.33}} 2 \times 10^{10} \Delta p \Delta\Omega \\
&= 6 \times 10^8 \Delta p \Delta\Omega .
\end{aligned}$$

The K_L^0 momentum distribution is fairly flat from 1 to 4 GeV/c. If the K_L^0 channel has a 1-msr acceptance, we would expect

$$N_{K_L} = 2 \times 10^6/\text{s with } 1 \text{ GeV/c} \leq p_K \leq 4 \text{ GeV/c} .$$

This beam would be comparable with existing K_L^0 beams. The flux would be slightly inferior to beam A_3 at the AGS, the momentum spread would be somewhat smaller, and the neutron contamination would be somewhat less. The beam design might be similar to Beam B_5 at the AGS, the short (2.6-m) neutral beam.

Although the K_L^0 yield of this beam is similar to other beams, it is probably a superior source of K_S^0 . Traditional sources of K_S^0 have been regeneration from a K_L^0 beam and a very short neutral kaon beam. For a regenerated K_S^0 beam, a thick regenerator is preferred to maximize the K_S^0/K_L^0 ratio; the regenerator thickness is limited by the probability for K^0 absorption, which is proportional to $\exp(-N_{Av}L\sigma_{\text{tot}})$. A practical limit is $K_S^0/K_L^0 \lesssim 10^{-2}$ when the total K^0 intensity is decreased by a factor of 10 from absorption in the regenerator.¹¹ Thus, $\sim 10^3 K_S^0/\text{s}$ along with $\sim 10^5 K_L^0/\text{s}$ could be obtained. In addition, backgrounds induced by K^0 and n interactions in the regenerator and the problems associated with incoherent K^0 regeneration appear.

The design of a short K_S^0 beam is limited by the short decay path ($C\tau = 2.7 \text{ cm}$) and the need to shield the experiment from the production target. At Brookhaven the short neutral beam is 2.6 m long and yields $\sim 350 K_S^0/10^{10}$ protons incident on a 3-in. iridium target.⁹ An incident beam of 2×10^{10} pions at 6 GeV/c would certainly allow shorter shielding than a similar intensity of 28 GeV/c protons. A 2-m-long beam would result in $\sim 300 K_S^0/\text{s}$ while a 1.75-m-long beam yields $\sim 700 K_S^0/\text{s}$. Raising the incident

pion momentum increases the K_S^0 flux. The π^+ flux at 8 GeV/c is about 65% of the flux at 6 GeV/c, but the higher survival probability of the higher energy K_S^0 would result in ~ 1500 K_S^0 /s for a 2-m-long channel. The optimum occurs for an incident π^+ momentum of between 9 and 10 GeV/c where ~ 3000 K_S^0 /s would be available.

IV. PREFERENTIAL NEUTRON ABSORPTION IN A NEUTRAL BEAM

For the energy region in which we are interested $\sigma_{\text{tot}}(nN) > \sigma_{\text{tot}}(K_L^0 N)$ (Ref. 12): $\sigma_{\text{tot}}(np) \approx 40$ mb and $\sigma_{\text{tot}}(K_L^0 p) = 1/2 [\sigma_{\text{tot}}(K^+ p) + \sigma_{\text{tot}}(K^- p)] = 24$ mb above 1 GeV/c. Thus, putting a long absorber in a neutral beam will absorb more neutrons than kaons. This technique has been used with success at Fermilab,* although the need for kaon flux limited the improvement to roughly a factor of 2 in the K_L^0/n ratio. The very large K_L^0 flux available at LAMPF II would allow use of a much longer absorber.

A conventional neutral beam produced at 100 mrad from the interaction of 2×10^{14} protons/s with a 4-in. platinum target would yield 8×10^8 K_L^0 /s (Ref. 9). I assume a channel acceptance of 0.1 msr. The neutrons are about 10 times more numerous. An absorber long enough to reduce the K_L^0 flux by a factor of 10 would reduce the neutron flux by a factor of 50. This would require 23 m of liquid hydrogen or 2.5 m of graphite if the total cross sections scale as $A^{0.67}$. The resulting beam would have 8×10^7 K_L^0 /s and $\sim 1.5 \times 10^8$ n/s. Some experiments that are limited in their sensitivity by the neutron contamination in the beam** might be substantially improved in this manner.

V. $\bar{K}^0$ PRODUCTION BY CHARGE EXCHANGE

A $\bar{K}^0$ beam produced by $K^- p \rightarrow \bar{K}^0 n$ at 1050 MeV/c has already been discussed.¹³ For a 1.2-m-long liquid hydrogen target and a 1-msr $\bar{K}^0$ beam, we would expect 10^5 $\bar{K}^0$ /s. The advantages of such a beam are the following.

* This information was supplied by Gordon Thompson, 1982.

** Examples of such experiments are measurements of muon polarization in $K^0 \rightarrow \pi^- \mu^+ \nu$ and charge asymmetry in $K^0 \rightarrow \pi \mu \nu$. For $K^0 \rightarrow \pi^0 \pi^0$, the reduced neutron flux would enable the apparatus to have a smaller hole (dead region) along the beam line. This would imply a larger acceptance and smaller systematic uncertainties.

1. The $\bar{K}^0$ have a momentum spread of several percent.
2. $\bar{K}^0/n \approx 1$.
3. The initial state of the beam is purely $\bar{K}^0$; there is no K^0 contamination.

The extra constraint of the $\bar{K}^0$ energy would be especially useful in experiments such as $\bar{K}^0 \rightarrow \pi^0 \pi^0$ and $\bar{K}^0 \rightarrow \pi e \nu$.

VI. CONCLUSIONS

The very large K^0 rates potentially available at LAMPF II allow one to consider several unorthodox schemes for reducing the neutron contamination in a neutral beam. Two of these schemes, preferential neutron absorption and $\bar{K}^0$ production by charge exchange, offer the possibility of kaon-to-neutron ratios ≈ 1 . Kaon production by π -nucleus interactions appears to hold no great advantages for K_L^0 production, but it might result in the most intense K_S^0 beam possible.

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REFERENCES

1. D. Dekkers et al., Phys. Rev. 137B, 962 (1965).
2. J. V. Allaby et al., CERN-805 (1968).
3. J. Doornbos, "Neutral Kaon Beams at a Kaon Factory," 1981 TRIUMF Kaon Factory Workshop, Vancouver, B.C., Canada (1981).
4. D. J. Crennell et al., Phys. Rev. Lett. 28, 643 (1972).
5. P. Borzatta, L. Liotta, L. Tallone Lombardi, S. Ratti, O. Goussu, and M. A. Vincent, Lett. Nuovo Cimento 7, 641 (1973).
6. F. Barreiro et al., Phys. Rev. D17, 669 (1978).
7. P. Bosetti et al., Nucl. Phys. B94, 21 (1975).
8. P. Borzatti, L. Liotta, S. Ratti, P. Daronian, and A. Daudin, Nuovo Cimento 15A, 45 (1973).
9. G. M. Bunce, "AGS Beams - May 1978," BNL-50874 (1978).
10. A. Kosumegi, Y. Watase, and Y. Yoshimura, "High Energy Physics Program of KEK Proton Synchrotron in FY1980," KEK-EPC-81-02 (1981), p. AII-16.

11. M. Banner, J. W. Cronin, C. M. Hoffman, B. C. Knapp, and M. J. Shochet, Phys. Rev. Lett. 28, 1597 (1972).
12. For example, see Particle Data Group, Reviews of Mod. Phys. 52, No. 2 (1980).
13. C. M. Hoffman, "A Monochromatic Neutral Kaon Beam," Los Alamos Scientific Laboratory report LA-8444-MS (1980).

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