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KP AND KP INTERACTIONS FROM $\sim$ 20 - 60 GeV/c IN A LARGE LIQUID HYDROGEN BUBBLE CHAMBER

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ABSTRACT

We propose to study Kp and $\bar{K}$p interactions in the energy regions immediately above those now accessible by exposing the NAL large liquid hydrogen bubble chamber to a neutral K_L^o beam.

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PHYSICS JUSTIFICATION

We propose a systematic investigation of $K^o p$ and $\bar{K}^o p$ interactions in a large liquid hydrogen bubble chamber long before separated K^+ or K^- beams in this energy region will be available for bubble chamber experiments at NAL. We will outline briefly some of the important physics results anticipated from this experiment.

1. $K_L^o p \rightarrow K_S^o p$

From charge-independence the amplitude $A(K_L^o p \rightarrow K_S^o p)$ can be related to $K^{\pm} n$ processes as follows:

$$A(K_L^o p \rightarrow K_S^o p) = \tfrac{1}{2} \left[A(K^+ n \rightarrow K^+ n) - A(K^- n \rightarrow K^- n)\right]$$

Therefore this reaction probes the difference between the two elastic cross sections. Experimentally, the Serpukhov data for $\sigma(K^- p)_{TOT}$ suggests that $\sigma(K^- p)_{TOT}$ and $\sigma(K^+ p)_{TOT}$ may have a rather constant difference out to 70 GeV/c.[(1)] Studying the energy dependence of the cross section as well as the behavior of the differential cross section of the process $K_L^c p \rightarrow K_S^o p$ can shed light on the apparent constant difference between the $K^+ p$ and $K^- p$ total cross sections. Since the $K^{\pm} p$ cross sections are not changing drastically between 5 and 20 GeV, a cross section of $46 \pm 10\,\mu b$[(2)] for this process at $\sim$5 GeV/c should serve as an upper limit estimate at $\sim$60 GeV/c.

2. Particle and Antiparticle Cross Section Comparison

If the diffractive processes are dominated by the Pomeranchuk exchange, the cross sections of these processes induced by particle and anti-particle should be exactly equal. To be more specific, we can compare processes such as:

$$\frac{K^o p \rightarrow Q^o p \rightarrow K^{*+} \pi^- p \rightarrow K^o \pi^+ \pi^- p}{\bar{K}^o p \rightarrow \bar{Q}^o p \rightarrow K^{*-} \pi^+ p \rightarrow \bar{K}^o \pi^- \pi^+ p}$$

Any deviation from unity of this ratio can suggest that additional trajectories are necessary to describe so-called "diffractive processes". The energy variation of this dependence is of crucial importance, since it can provide some insight as to how fast these "diffractive processes" approach the asymptotic region. Since the cross sections for $K^{\pm}p \rightarrow K^{\pm}\pi^+\pi^- p$ are well known at low energy, we estimate that $K^o_L p \rightarrow K^o_S \pi^+\pi^- p$ in the 20-60 GeV/c region should have a visible cross section of at least about 100 μb assuming the "diffractive process" does not have a strong energy dependence.

3. Test of One-Pion-Exchange in High Energy

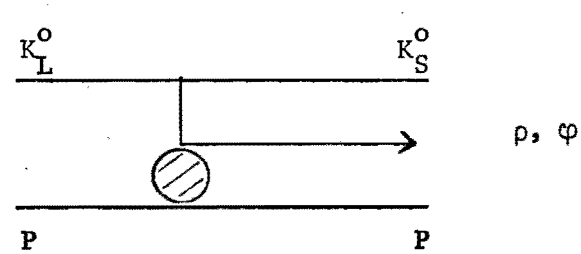
The double resonance production:

$$K^o_L p \rightarrow K^{*+} \Delta^o \rightarrow K^o \pi^+ \pi^- p$$
$$K^o_L p \rightarrow K^{*-} \Delta^{++} \rightarrow \bar{K}^o \pi^- \pi^+ p$$

would be expected to be dominated by π-exchange. By studying and comparing the differential cross sections, decay angular distributions and energy dependence of the cross sections, a good test of the OPE model at very high energies could be made.

4. Test of Double-Regge-Exchange

Three-body production of the processes such as $K^o_L p \rightarrow K^o_S \rho p$ and $K^o_S \varphi p$ are expected if the double-Regge-exchange diagram, shown below, dominates:



In the context of this production scheme, we do not expect strong production of final states such as $K^o_S A_2 p$ and $K^o_S f^o p$ since A_2 and f^o do not couple with K^o_L K^o_S due to charge conjugation.

5. Test of (K^*, K^{**}) Exchange Degeneracy

From the absence of exotic states coupled with the duality hypothesis, one can relate the K^* and K^{**} trajectories. This conjecture of exchange degeneracy has been tested experimentally without success in the low energy region. It is extremely important to extend this test to higher energies. From this experiment, we can obtain the reaction $\bar{K}^o p \to \pi^+ \Lambda$ and the Λ-polarization to compare with the crossing reaction, namely $\pi^- p \to K^o \Lambda$. From the "weak" exchange degeneracy, one expects the differential cross sections to be identical. The Λ-polarization, however, should be equal in magnitude but opposite in sign. We expect the observable cross section of this process to be about one μb.

6. Search for New Particles

New neutral particles may be produced in the target. They then could be detected in the bubble chamber by their decay into charged secondaries. In conclusion, it is impossible to anticipate what may be the most interesting discoveries in this high statistics experiment in a new energy region.

EXPERIMENTAL ARRANGEMENT

The beam requirement is simple for this experiment as shown in the appendix. Because the flux requirement for this beam is about 10^{10} protonsper pulse, it seems to be an ideal experiment to run in parallel with ν experiments provided Fowler's double-pulse dual camera system is implemented. To obtain $\sim$4000 events of $K_L^o p \rightarrow K_S^o p$ (excluding the regeneration process) from this energy range, assuming $\sim$40 K_L^o's per picture in the NAL large liquid hydrogen chamber, we would require a total of one million pictures. To measure the momentum distribution of the K_L^o's, we require tantalum plates at the end of the bubble chamber to analyze the $K_L^o \rightarrow \pi^+\pi^-\pi^o$ and $K_{\ell 3}$ decays. This analysis of the momentum will give an absolute normalization to the cross sections. The tantalum plates will also be necessary to distinguish events with a fast forward π^o from the required 3-constraint events in this experiment.

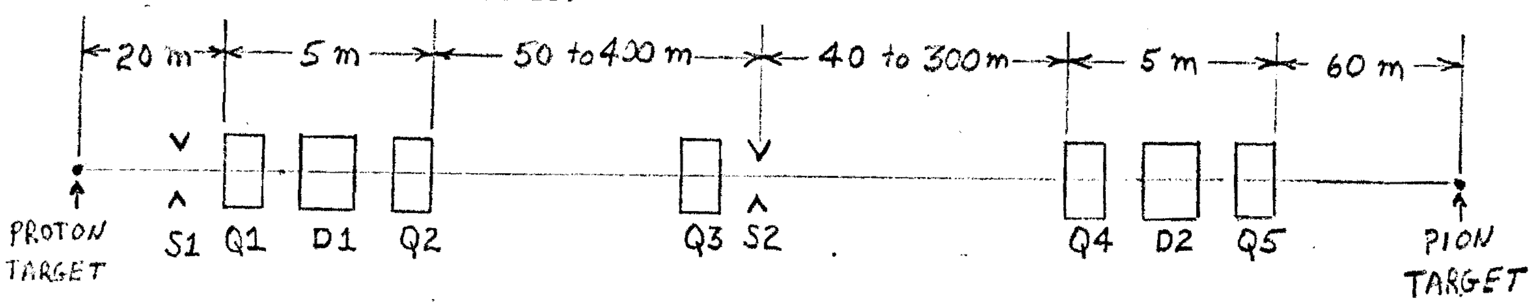
APPARATUS

We require the large NAL liquid hydrogen bubble chamber with tantalum plates at the downstream end. The film will be scanned and measured at BNL with the Flying Spot Digitizer and at Florida State University. Florida State University will have two graduate students doing their thesis work with this experiment. Analysis will be done in all three laboratories. The group at the Vanderbilt University will undertake the main responsibility for further detailed design of this beam.

Appendix - Beam for the K_L^o bubble chamber experiment

There are two distinct parts of the beam required for this experiment. The first is a moderately high flux negative beam and the second is the magnet, collimator, and photon converter required to clean up the K_L^o beam produced in the secondary target.

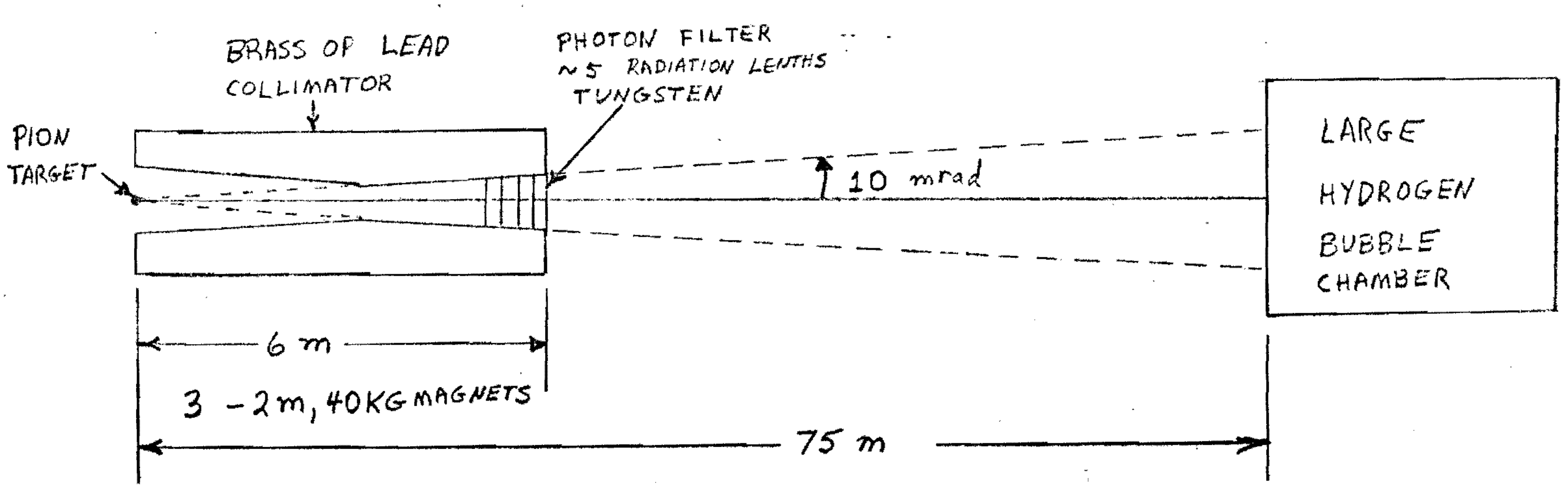
70 GeV/c pion beam - A simple pion transport beam is sketched below. We wish to emphasize the flexibility of the pion transport system and our desire to modify the design in order to make use of whatever primitive beam facilities could be made available during the early stages of operation of the large chamber. In particular the crude momentum resolution requirement implies the need for only two bending magnets and the length of the beam can be varied from about 180 to 800 meters.



All quadrupoles are 8Q48 type conventional iron magnets. Both deflecting magnets are 40KG superconducting magnets 2 meters long and 6 inches high. The horizontal optics are simply an intermediate focus at S_2 for crude momentum, analysis of a few per cent and then recombination at a second focus on the pion target. Q_3 is a horizontally focusing field lens. Q_2 and Q_4 are both vertically focusing and together produce a single vertical focus at the pion target. S_1 is the aperture slit. The horizontal and vertical acceptance semi-angles of such a beam are 4 and 1.5 mrad, respectively, and the momentum bite of the beam is ±3%. Hence we obtain about 2 x 10^7 beam pions per 10^{11} protons on our target at 200 GeV.

Neither vacuum nor helium bags would be required for the shorter possibilities of beam considered here, but lengths greater than about 500 meters would require helium bags along most of the path.

K_L^o part of beam - This part of the beam is simply a collimator and a vertical deflecting magnet to sweep all charged particles from the beam.



Flux - The Zadonis report (SS-29-2256, p. 187, Vol. 1, 1969, Summer Study) gives an estimate K_L^o production by decay of diffractively-produced resonances. The flux predicted is 10^{-5} K_L^o per beam pion with a comparable flux from the negative K mesons in the beam. The nondiffractive processes listed by Zadonis lead to a peak in the K_L^o momentum spectrum. Such a peak was not seen in the BNL-Yale bubble chamber experiment at 7 GeV. Since the relative importance of these nondiffractive processes is expected to be much less at this higher energy, we neglect this contribution to the cross section and expect a fairly flat spectrum ranging from 10 to 60 GeV for the K_L^o and an intensity of about 2K per 10^5 beam pions. The angle subtended by the bubble chamber is 10 mrad, rather small for this low an energy and we thus expect to lose a factor of about 2 from Zadonis' estimate. The desired intensity of 40 K_L^o per pulse in the bubble chamber thus requires about 10^5 beam pions and hence fewer than 10^{10} protons on the primary target.

REFERENCES

1. See for example D.R.O. Morrison, Proceedings of the Lund Conference, p. 237, (1969).

2. A. Firestone, et al., Phys. Rev. Letters 16, 556 (1966).

ADDENDUM TO PROPOSAL #65
September 1975

Beam Design

With slight modification to the existing arrangement, the N5 beam at Fermilab can function as a neutral beam facility. This fact was pointed out by Pruss[1] and discussed by Albright[2]. In order to produce a beam of K_L^0 mesons the scheme in Fig. 1 can be used. The primary proton beam is brought to focus on a target in Enclosure 100. A beam of negatives - almost all π^- - can then be brought to a second double focus on a target at the upstream end of Enclosure 113. The production of the K_L^0 in the neutral beam takes place here, aimed straight toward the 15-foot bubble chamber. The rest of the equipment is used to sweep away various impurities so that the beam will be mostly K_L^0 .

We consider the impurities separately.

a) Charged particles from the second target. These are swept by a 20-foot dipole downstream from the target. They can be dumped onto the steel of an existing quadrupole magnet.

b) Photons from the second target. At the downstream end of Enclosure 113 we need to place several radiation lengths of Pb, followed by another 20-foot dipole to sweep away the electrons.

c) Strange particles (K_S^0 and Λ) from the second target. There will be a drift space between the second target and the Pb radiator to allow the K_S^0 and Λ to decay. The second dipole will sweep their decay products.

d) Neutrons. It is expected that by limiting the neutral beam to angles very close to the forward direction we shall reduce greatly the number of neutrons relative to K_L^0 . If the absolute kaon flux is large enough, we can add some polyethylene absorber near the Pb radiator to help get rid of neutrons.

e) Negative muons. The π^- beam between the two targets will undergo a certain amount of decay in flight (about 10% for p_π = 140 GeV/c) producing a large number of incoherent μ^-. The best way to prevent them from reaching the chamber would be to use the large toroidal magnets in Lab E to deflect them away. The small hole in the center of the toroids will also serve to define the aperture of the neutral beam.

Equipment Needed

1. Two 20-foot dipoles in Enclosure 113.
2. Target station in Enclosure 113.
3. Pb radiator.
4. $(CH_2)_n$ filter.
5. Vacuum pipes and He bags.
6. Possibly some radiation shielding in Enclosure 113.
7. Toroidal magnets in the N5 line for sweeping muons.
8. Collimators, including some sort of plug for air gaps around the windings of the toroids.
9. Counters for measuring beam intensity downstream of the second target. It would be useful to have a calorimeter to measure the hadronic momentum spectrum; it would also be well to have a lead-glass scintillator to count γ rays.

Testing Time

In order to find out what the yields really are, it is important that some testing time be made available to try out the neutral beam. For instance, it is important to know how much Pb will be needed to get the γ flux to acceptably low levels. It appears that the shape of the momentum spectrum should enable us to determine whether the neutron flux in the forward direction is acceptably low or whether we shall need the $(CH_2)_n$ absorber. At least some of the testing time should involve taking a few pictures with the bubble chamber to see whether things are indeed going properly. For this purpose it might be useful (although not essential) to have some neon in the chamber. The neon tends to make the chamber function more like a calorimeter. It could help to facilitate the distinguishing of K_L^0 from neutrons. In the absence of neon the EMI could be of use for tagging candidates for $K_{\mu 3}^0$ decay in the chamber.

References:

1. S. Pruss, "Conceptual Design of Neutral Beam Facility for 15-foot Bubble Chamber" (April 1975).
2. J.R. Albright, TM-604, Fermilab (August 1975)

Figure 1

Schematic of the neutral kaon beam for the 15-foot chamber. Not drawn to scale.