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8/29/79
LA-7930-C

Conference Proceedings

Lh. 3073

Report on Kaon Factory Working Seminar

Spring 1979

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

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REPORT ON KAON FACTORY WORKING SEMINAR
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by

R. R. Silbar and J. D. Bowman

ABSTRACT

We report the motivations, discussions, and preliminary conclusions of the LASL Kaon Factory Working Seminar, which met 15 times in the Spring of 1979. It is technically feasible, but expensive, to build a kaon factory using LAMPF as an injector. Taking advantage of the increased beam intensity, better secondary beam lines can then be built. The physics justification for a kaon factory requires further study, however. We outline a proposed program for gradually increasing LASL participation in kaon and antiproton physics.

I. OVERVIEW

In a Physics Today article in 1966 discussing meson factories, Louis Rosen remarked that a linac, such as the proposed LAMPF, could increase its energy by adding stages of acceleration, "a very important factor if one looks forward to a kaon factory." In the time since then we have been building and learning how to use LAMPF, and this suggestion has lain more or less dormant. This last summer, however, it became clear that the question of a kaon factory was now ripe for consideration. This resulted in a report by J. D. Bowman, P. C. Gugelot, and D. E. Nagle, to the LAMPF User's Group Long-range Planning Committee (September, 20, 1978), which discussed a possible configuration for a kaon factory extension of LAMPF and the kinds of physics questions that could be addressed by such a facility. In this report it was suggested that a working group be formed to study technical and scientific issues in more detail.

In the Fall of 1978 we began discussing formation of such a group. We were spurred in this regard by the realization that people at TRIUMF, our Canadian counterpart, had already presented preliminary design studies of a kaon factory extension for TRIUMF at the Cyclotron Conference in Bloomington,

Indiana. Further, in conversations with V. M. Lobashov (Inst. for Nucl. Res., Moscow), it also became apparent that our Soviet colleagues in Krasnaya Pakhra may have intentions of converting as soon as possible the meson factory under construction into a kaon factory. [See Yu. G. Basargin et al., Sov. Phys. Dokl. 18, 229 (1973).] Also, the LAMPF Technical Advisory Panel had urged the LAMPF management to direct some effort to long-range studies along this line. Thus, with the encouragement of Rosen and under the general guidance and prodding of Darragh Nagle (a preliminary organizational meeting was held in his office on December 8), the Kaon Factory Working Seminar (KFWS) began its meetings on January 8, 1979.

The structure of the KFWS was broken down into two intermeshing subtopics --the physics aspects (organized by R. R. Silbar, T-5, and J. D. Bowman, MP-4) and machine/facilities aspects (organized by R. J. Macek, MP-13, and A. A. Browman, MP-D0). LASL divisions participating were MP, T, and, to a lesser extent, CNC, P, and AT. About ten persons were regular attendees, but up to 20 people were at times present for a particular session. The seminar met 15 times during the Spring of 1979, usually on Mondays at 1:30 p.m. in Room A-234 of the LAMPF Lab-Office Building. In many respects it was a learning experience for most, if not all, of us. The last meeting before a long summer break was held on May 29, but we expect the KFWS to resume meeting in the fall.

This report summarizes the deliberations of the KFWS and presents a proposed program of future LASL effort in kaon factory physics. Our major conclusions are these:

(1) It is technically feasible to build a kaon factory using LAMPF as an injector (see Fig. 1). A reasonable energy for such a proton accelerator would be 15 to 30 GeV with a beam current of 100 μ amps, some 100 times more intensity than is available at the Brookhaven AGS accelerator. The cost of such a machine, together with all contemplated areas and facilities, is crudely estimated to be \$150 M. Some savings could be realized by not building some experimental facilities.

(2) It looks feasible to build improved beam lines to take advantage of the increase in primary beam intensity. Such beams would have both better purity and flux.

(3) The largest remaining question is whether the physics to be done with such a kaon factory is worth the cost and effort. We believe the important topics of interest have now been identified, but they still need critical study.

A kaon factory need not necessarily be built at Los Alamos, but there are certain advantages to doing so. LAMPF can be used as an injector and there is a reservoir of experience in dealing with highly radioactive beam handling systems. LAMPF itself would continue to be available for pursuit of physics and applications with the 800 MeV beam. At the time the kaon factory would become operative, however, many of the physics activities and experimental facilities would probably be diverted to dealing with kaons and antiprotons.

II. SUMMARIES OF SEMINARS, SPRING 1979

January 8

Organizational meeting led by R. R. Silbar: Discussion of competing projects at other national laboratories, review of previous kaon factory studies and workshops on "kaon physics," an example of how increased intensity would help in a $^{40}\text{Ca}(K^+, K^+)^{40}\text{Ca}$ experiment, and generation of a list of 16 topics that might be studied or discussed in these seminars.

January 15

A. A. Browman remarked on what could be built, using conventional technology, assuming LAMPF as an injector and only one ring tunnel. There is space available on the mesa for a ring of 150 m diameter, which could be used for acceleration to 30 GeV. Space charge limits imply an intensity up to 10^{14} protons per pulse. Fast cycling at, say, 12 Hertz might reduce AC energy losses. (12×10^{14} ppp means 200 μA beam current.)

E. W. Hoffman reviewed what is presently achieved in kaon and antiproton secondary beams. The fluxes obtained depend upon primary beam energy, but there are "knees" in the production cross sections for low-energy K^- 's around 10 GeV and for $\bar{p}$'s around 25 GeV. It was emphasized that present day kaon beams are strongly contaminated by other particles, mostly pions, even after one stage of mass separation. This problem of beam purity is one which must be faced if the full use of increased primary beam intensity is to be realized.

January 29

R. R. Silbar suggested two homework problems (there were no takers) and noted the possible interference of a second, energy-variable proton storage ring under discussion in the LAMPF long-range planning committee.

D. D. Strottman reviewed K^+N and K^+ -nucleus physics. The situation with respect to "exotic" K^+N resonances is experimentally murky, but there

are theoretical grounds for believing such resonances exist, in bag models or otherwise. For K^+ -nucleus scattering, the weak K^+N interaction suggests multiple scattering approaches are better founded than, say, π -nucleus scattering. Glauber model predictions of elastic and inelastic scattering cross sections were presented.

February 5

B. F. Gibson reviewed the status of hypernuclei, a form of nuclear matter in which one nucleon is replaced by a Λ (or Σ) hyperon. Several possible reactions for producing hypernuclei were discussed; the (K^-, π^-) reaction is currently of most interest. Physics to be learned from hypernuclei includes hypernuclear matter itself, aspects of the hyperon-nucleon interaction, and perhaps properties of ordinary nuclear matter from use of the Λ as a "test probe" unaffected by the Pauli principle. The reaction mechanism of recoilless Λ production, in (K^-, π^-) , is somewhat controversial, but good experiments at the "magic" beam momentum of 500 MeV/c are yet to be done. There are some very recent indications of the existence of Σ -hypernuclear states. The corresponding "magic" momentum for Σ -states is 300 MeV/c; presently no channel can provide such low-energy kaons.

February 12

R. R. Silbar reported a discussion he had with R. Richardson (UCLA and TRIUMF) on the Canadian plans for a kaon factory.

C. M. Hoffman reviewed the BNL Workshop held in November, 1978, on the AGS Fixed-Target Research Program. (The workshop proceedings are published as BNL report 50947.) Basically, there may be only eight years of low-energy kaon research remaining, since, when ISABELLE becomes operative, this sort of physics may die in the U.S. unless something like a kaon factory is built. In Europe the present emphasis in "medium energy physics" seems to be on antiprotons rather than kaons.

February 26

R. L. Burman discussed the neutrino facility that will be proposed to take advantage of the proton storage ring (PSR) at the WNR facility. Such a short duty factor use of the PSR is very compatible with the neutron time-of-flight program of solid state investigations. (A written proposal will soon become available.)

March 19

R. J. Macek presented a number of his ideas on how to make purer low-energy kaon beams. He discussed both D.C. and R F. separators, use of degraders, and time-of-flight techniques. Putting separators inside bending magnets would help to reduce beam length, as would some cleverer choices of shielding around the target cells. Far better separation is achieved with more than one separator and a collimated intermediate focus. Likewise, given an appropriate bunch time-structure in the primary proton beam, there are big advantages to using R.F. separators. Such a time-structure (1 ns bunches separated by 20 to 30 ns) would also be useful for TOF discrimination. Given the LAMPF time-structure of 5 ns bunches, this would require the beam in the synchrotron ring to be debunched and then rebunched, all without significant beam loss.

March 26

H. A. Thiessen continued in a similar vein, giving his views on how to improve low-energy kaon beams, but together with whatever spectrometer would be necessary to do elastic or inelastic scattering measurements. Reactions of interest were discussed, particularly with respect to requirements imposed on experimental technique. It is easiest (cleanest) to detect the heaviest particle last, as in a (π^+, K^+) reaction. In contrast, (K^-, π^-) is difficult, as resolution requirements discourage using counters in the beam. A kaon factory, with clever beam design, could achieve kaon rates comparable to the pion rates now available at the SIN SUSI spectrometer.

Regarding beam design, Thiessen emphasized 0° production from the target, beam length, shielding, material (such as counters) in the beam, and use of two separators. A preliminary look at costs indicates that such a kaon channel and spectrometer ought not be grossly different from EPICS (perhaps \$4 M in 1984 dollars.)

April 2

E. Colton (Argonne National Laboratory) reviewed kaon beams further and presented his views of what improvements could be made. The K to π ratio improves with increasing primary proton energy. (Unfortunately, shielding costs also go up.) The ideal production target should be short and dense (e.g., Ir), and a non-zero production angle is better from the standpoint of kaon yield, worse from the standpoint of source size (Thiessen's reason for preferring 0°). For beam purity it was emphasized that one intermediate

focus was not enough, and that solid angle and momentum bite work against you. Colton concluded that, even by only moving an already "existing" beam (such as LBL 34) to a kaon factory, one could get 10^8 K^+ /sec with a π^+/K^+ (impurity) ratio as low as 1, approximately the limit imposed by kaon decay in the channel.

April 9

P. Herczeg reviewed the status of the CP-violation parameters in $K_L \rightarrow 2\pi$ decays. There is renewed interest in this subject because of gauge theories which have natural CP-violation built in. Of the "classical" suggestions for the origin of CP-violation, the $K_L \rightarrow 2\pi$ parameters, together with the limit on the neutron dipole moment, tend to rule out all but the "superweak" model. The differences between the Kobayashi-Maskawa gauge model and the superweak theory are small, but might be measurable in the future.

April 16

H. A. Thiessen reported on a meeting held at BNL to discuss a new, improved low energy K and $\bar{p}$ beam line there.

A. A. Browman then made a number of comments on a facility layout and rough cost estimates. There are questions to settle which have a big impact on machine design and cost: how many experimental beams will there be and how will they be utilized? Multiple experimental areas? It was pointed out that two rings in the same tunnel--one for acceleration and the other for storage and spill--might be more cost effective than one expensive ring that can handle both functions. Scaling costs of similar projects to one of this size gives a rough cost estimate of \$150 M.

May 14

M. M. Sternheim (University of Massachusetts, Amherst) reviewed physics of kaonic and other exotic atoms, a presently moribund subject. Beam requirements for such experiments are quite different from those for scattering experiments. It is not clear that much more can be, or need be, done in this field, although more data would certainly be acquired if better stopping kaon beams were available.

May 17

B. Povh (Max Planck Institute, Heidelberg) spoke informally on a number of subjects of interest to him, mostly in response to questions from the floor. His recent experiences in $\bar{p}$ experiments was emphasized.

May 21

An informal discussion of where we are and what we should do. R. L. Burman discussed other proposals from other laboratories that are likely to be coming soon before NUSAC for consideration. G. H. Sanders presented, at some length, reasons why we at LAMPF should not build a kaon factory. Arguing from the physics program outlined in the Bowman-Gugelot-Nagle report to the TAP (September, 1978), he pointed out that other, present-day facilities can satisfy many of the stated needs, at least for the nuclear physics problems posed. He then asked if there is an alternative future project for LAMPF that might be more interesting, manageable, and saleable. One possibility might be a second proton storage ring, possibly with variable energy, for reinjection into Area A. H. A. Thiessen also mentioned some possible smaller projects, such as additional experimental areas for LAMPF.

May 29

R. R. Silbar discussed material he had sent to P. D. Barnes for the preparation of the NUSAC Facilities Subcommittee report on the subfield of kaons and antiprotons. This was a somewhat personal distillation of the work of this seminar, particularly as it relates to the formulation of a core program for future work (at LASL, or elsewhere) in this subfield. This material forms the basis of the recommendations given in the next section of this report.

Additional, Related Activities

At the Second International Conference on Meson-Nuclear Physics, held in Houston in March, 1979, D. E. Nagle presented an invited talk, "Physics Uses of Intense Proton Beams at 10-20 GeV."

The following MP-Division Colloquia were of direct interest to the subject of the KFWS:

- (1) "Hypernuclear Studies at CERN," March 15, by R. Bertini of CERN and Saclay.
- (2) "Novel Insights from Hyperons in Nuclei," May 16, by B. Povh of the Max Planck Institute in Heidelberg.
- (3) "Recent Results in Kaon-Nucleus Scattering," June 20, by R. Eisenstein, Carnegie-Mellon University.

III. OUTLINE OF A PROGRAM FOR LASL PARTICIPATION IN KAON AND ANTIPROTON PHYSICS

Near Term Projects

This means activities that can be undertaken in the next five years.

(1) It is quite likely that a new low-energy kaon beam will be commissioned and built relatively soon at the Brookhaven AGS. This would presumably optimize flux and purity to the extent possible at given present AGS intensity. It would be reasonable for LASL to participate in the design, but not the construction, of this new beam. This would naturally fall under activity of group MP-10; in fact, H. A. Thiessen has already been involved in preliminary discussions of this beam (see seminar precis for April 16). Perhaps as much as 0.5 SMY (Staff Member Year) could be invested by LASL in such advisory work.

(2) In the next two years it would be useful for LASL to become involved in user-group experiments with kaons and antiprotons at other facilities, such as BNL. Two experiments come to mind as natural extensions of LAMPF work and in conjunction with further exploratory work on a kaon factory:

(a) The LAMPF π^0 spectrometer could be easily taken to BNL and applied to study the interesting strangeness-changing, charge-exchange reaction (K^-, π^0) on nuclei.

(b) Production cross sections of $K^\pm, \bar{p}$ (and also $\pi^\pm$) as a function of beam energy, laboratory production angle, and atomic number (target) are only roughly known at present. This situation corresponds to the one at LAMPF energies before we carried out the (much-cited) LASL experiment in 1969 to measure $\pi^\pm$ production in detail at 730 MeV at the Berkeley 184" Cyclotron. It would be useful for future beam design studies to do the same for K 's and $\bar{p}$'s.

An estimated level of effort for the two experiments would be about 5 SMY's each. Perhaps some of the work can be shared with one or more of the university user groups working at LAMPF.

(3) The "preproposal study" of kaon factory physics, as represented by this Seminar, should be continued. The basic question to be answered is whether the higher intensity of a kaon factory is really needed to do interesting nuclear and particle physics with K 's and $\bar{p}$'s. It will soon be necessary, however, for some members of the Seminar, to participate using

more than bootlegged time. To this end proposals to the Associate Director of Research for LASL Institutional Supporting Research funds have been submitted by both MP and T divisions, each asking for 1 SMY of support in FY 80. Physics topics to be studied next year should include:

- (a) Rare kaon decay modes, including those showing CP-violation.
- (b) K^+ and K^- -nucleus scattering and hypernuclei.
- (c) Neutrino experiments that can (only) be done with higher intensities.

We also plan to look further into a number of facilities-related subjects, including:

- (a) Considerations of accelerator and experimental facility design.
- (b) Intense K^+ , K_L^0 beam designs.
- (c) Preliminary kaon spectrometer designs.
- (d) Neutrino facility requirements.

It is desirable to increase the participation of AT and P Divisions and the LAMPF Users community in these discussions. One way of achieving the latter is to encourage long-term visits by university people on sabbatical leave, where the visitor would devote more or less full time to consideration of one of the above-mentioned topics.

(4) If the suggested activity in Items (1)-(3) generates sufficient enthusiasm and momentum, we would begin to prepare a kaon factory proposal, presumably not unlike the "Blue Book" that proposed LAMPF in 1965. This might already begin three years from now, and could involve perhaps 10 SMY of effort.

Long Term Projects

This refers to activities five to ten years hence and assumes we will have decided that a kaon factory is worth proposing (Item (4) above).

The design and proposal would be completed, and enlisting community support would begin. A political question to be answered is whether the expense of such a large project could be shared with some other country, such as Canada. If the project is authorized, many people will be involved in the construction of the ring and experimental facilities for many years. During this time, however, it would be useful for LASL to continue doing kaon and antiproton experiments in the user-group mode at other facilities. One experiment every two years might be a reasonable level of effort. This would be valuable experience that would ease the transition to doing physics at the kaon factory.

IV. PARTICIPANTS

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B. Gibson, T-5
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C. Hoffman, MP-4
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