CONF-791047--5

LA-UR -79-2137

MASTER

TITLE: REPORT ON THE LOS ALAMOS KAON FACTORY SEMINAR: PHYSICS

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SUBMITTED TO: 8th International Conference on High Energy Physics and Nuclear Structure, August 13-17, 1979, Vancouver, B. C.

University of California

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REPORT ON THE LOS ALAMOS KAON FACTORY SEMINAR: PHYSICS

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ABSTRACT

The motivations, discussions, and preliminary conclusions of the LASL Kaon Factory Seminar, which met 15 times in the Spring of 1979, are reported. It is technically feasible, but expensive, to build a kaon factory using LAMPF as an injector. Taking advantage of the increased beam intensity, excellent secondary beam lines could be built. While we continue further study of the physics justification for a kaon factory, we also propose to gradually increase LASL participation in kaon and antiproton physics.

INTRODUCTION

"A very important factor if one looks forward to a kaon factory," Louis Rosen remarked in a Physics Today article in 1966, is that a linac, such as the then-proposed LAMPF, could increase its energy by adding stages of acceleration. 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 to the LAMPF User's Group Long-Range Planning Committee,[1] 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 on 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.[2] 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.[3] 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 in December), 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 physical aspects (organized by R. R. Silbar and J. D. Bowman) and machine/facilities aspects (organized by R. J. Macek and A. A. Browman). 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. 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 in May, but we expect the KFWS to resume meeting in the fall.

In this talk I will briefly summarize the physics aspects of our discussions. You will hear tomorrow from Darragh Nagle more detail concerning our machine-related and experimental-facility-related deliberations. Also, tomorrow afternoon, Peter Herczeg will talk about what might be learned from a kaon factory regarding kaon and hyperon decays. This talk is an outgrowth from one that Herczeg gave in the KFWS in April.

The subjects I will discuss today will necessarily be treated somewhat cursorily. You should view what I say more as a report on our seminar's activities than as an in-depth discussion of these physics topics. In fact, most of these subjects will be dealt with in detail by other speakers in this Workshop or in the ICOHEPANS program. I will try to flag the connections to these talks when appropriate.

Although the kaon factory I am going to talk about would be a user-oriented facility, with user input at all levels of policy, much of what I will say has a strong LASL-centric flavor. Should Los Alamos get involved in proposing a kaon factory? Does it fit in with our laboratory-wide goals? Is it the natural extension of LAMPF, or is some other direction more appropriate for us to pursue? These questions were always in the back of our minds as we met.

To conclude these introductory remarks, let me state the major conclusions of our first half-year of the seminar:

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 experimental areas and facilities, is crudely estimated to be $150 M.

2.) It looks feasible to build improved beam lines to take advantage of the increase in primary beam intensity. Such beams would have both good 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 a number of the important topics of interest have now been identified, but they need critical study. Bear in mind, however, that some of the most interesting experimental programs being carried out at meson factories today were not dreamed of in the original justification.

4.) 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 the transport of high-intensity beams and with high-radiation-level target cells. 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.

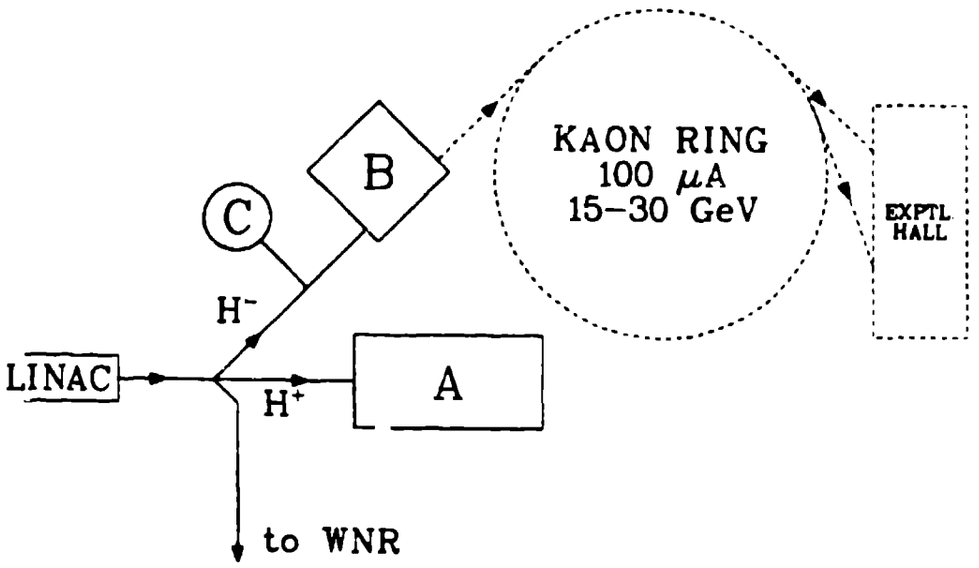

Fig. 1. A theorist's-eye view of a kaon factory at LAMPF.

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The fifteen sessions of the seminar, in summary, covered the following topics.

January 8

An organizational meeting, led by R. R. Silbar, which included 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 $^{40}Ca(K^+,K^+)^{40}Ca$ experiment, and generation of a list of 16 topics that might be studied or discussed in these seminars.

January 15

Remarks by A. A. Browman on what sort of kaon factory could be built, assuming LAMPF as an injector. As mentioned, this and other such subjects will be discussed in detail by Darragh Nagle. Also, 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 very important and must be faced if the full use of increased primary beam intensity is to be realized. In the course of the seminar we returned to this subject a number of times, as you will see, and we now feel this is a soluble problem.

January 29

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 for π-nucleus scattering. Glauber model predictions of elastic and inelastic scattering cross sections were presented.[4] The subject of K^+-nucleus scattering will be discussed by Eisenstein and Tabakin, the next two speakers, so I will not say more about this.

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. Hypernuclear physics has been reviewed at the ICOHEPANS session this morning by Povh, and will also be discussed by Dover on Friday afternoon.

February 12

C. M. Hoffman reviewed the BNL Workshop on the AGS Fixed-Target Research Program, held last November.[5] We have just heard of Brookhaven's plans in this regard from May. We also discussed at this time the CERN program on antiproton physics, which will be described in some detail tomorrow by Gastaldi.

February 26

R. L. Burman discussed the neutrino facility that will be proposed to take advantage of the proton shortage ring (PSR) at the LAMPF 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.

March 19, March 26, and April 2

Discussions by R. J. Macek, H. A. Thiessen, and E. Colton (Argonne National Laboratory), respectively, on the design of low-energy separated kaon beams. Based on experience, it is necessary to collimate at a secondary focus to improve the quality of such beams.

April 6

P. Herczeg reviewed the status of the CP-violation parameters in kaon 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 $K_L \to 2\pi$ 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. As mentioned, Herczeg will expand on this subject in his talk tomorrow.

April 16

H. A. Thiessen reported on a meeting held at BNL to discuss an improved kaon beam and spectrometer there. (See talks by May and Hungerford at this Workshop.) A. A. Browman then made a number of comments on a kaon facility at LAMPF and gave some rough cost estimates.

May 14

M. M. Sternheim (University of Massachusetts, Amherst) reviewed the physics of kaonic and exotic atoms. This subject will be discussed in the ICOHEPANS program on Friday afternoon by Dover.

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 experience 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,[1] 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. 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

Wrap-up session for Spring, 1979. R. R. Silbar discussed material he sent to P. D. Barnes for the preparation of the NUSAC Facilities Subcommittee report on 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 below.

SUBJECTS NOT YET DISCUSSED

In the coming year, after the KFWS resumes, a number of other physics topics will be dealt with more fully. These include:

1.) What can be learned in general from rare decays of kaons? (An extensive program investigating rare pion and muon decays has been underway at LAMPF for some time.)

2.) What neutrino experiments can only be done with kaon factory beam intensities? What are the requirements imposed on a neutrino experimental facility?

3.) How big are the advantages of studying pion-nucleus scattering at energies well above the (3,3) resonance?

4.) Are there novel nuclear chemistry experiments to be done at a kaon factory? For kaon-induced reactions, a severe problem could be the pion contamination in the beam.

PROPOSED CORE PROGRAM FOR LASL PARTICIPATION IN KAON AND ANTIPROTON PHYSICS

The following is a suggested program, developed together with J. D. Bowman and D. E. Nagle, for building up some LASL momentum in the direction of eventually building a kaon factory extension to LAMPF. The program is not yet official policy of the Los Alamos Scientific Laboratory management, nor is it even universally accepted by all the KFWS participants.

Near Term Projects

This means activities that would 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 in conjunction with further exploratory work on a kaon factory.

(a.) The LAMPF π^0 spectrometer could be easily transported 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. Our present knowledge corresponds to that 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 university user groups.

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 <u>really</u> 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 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 more detailed investigations of some of the subjects already discussed this last spring, as well as the subjects mentioned above as not yet having been touched. We also plan to look into a number of facilities-related questions.

4.) It is desirable to increase the participation of other LASL Divisions and the medium energy physics community in these discussions. One way of achieving the latter is to encourage long-term visits by university people on sabbatical leave. The visitor would devote more or less full time to consideration of one of the above-mentioned topics.

5.) If the suggested activity in Items 1.) - 4.) generates sufficient enthusiasm and momentum, we would begin to prepare a kaon factory proposal, presumably not unlike the "Blue Book" proposal for LAMPF in 1965. This might already begin three years from now and could involve perhaps 10 SMY of effort and extensive collaboration with the nuclear and high-energy physics communities.

<u>Long-Term Projects</u>

This refers to activities five to ten years hence and assumes we will have decided that a kaon factory is worth proposing (Item 5. 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.

CONCLUSIONS

To summarize our first semester of study in the KFWS at Los Alamos:

1.) A kaon factory at LAMPF is technically feasible, but expensive.

2.) There appear to be many interesting physics questions that can be addressed with such a machine.

3.) The important task before us is to decide if the physics to be learned warrants the expense and effort needed to build a kaon factory.

As a result of a rather encouraging five months, we at Los Alamos will continue to pursue this line of development. The KFWS will be meeting again in the fall.

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