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THE TRIUMF KAON FACTORY PROJECT

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ABSTRACT

A 100 μA 30 GeV facility, named KAON, could soon be developed at TRIUMF using the present cyclotron as an injector. A wide variety of beams would be provided which would accommodate a very diversified physics program. A "flavour" of the experimental program will be given together with an outlook of the facilities currently planned for the initial program.

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1. INTRODUCTION

The basic aim of the KAON project is to accelerate 100 μA beams of protons to 30 GeV, an increase of two orders of magnitude over the intensities available in this energy domain. In Table 1 the characteristics of KAON are compared to other existing or planned facilities. To achieve this objective a complex of two synchrotrons and three storage rings will be added to the TRIUMF cyclotron$^{1)}$ (Fig. 1).

The 30 GeV energy will be reached in two steps: 20 msec worth of the 450 MeV beam from the TRIUMF cyclotron is first accumulated in the 216 m circumference Accumulator then accelerated to 3 GeV in a fast cycling (50 Hz) Booster synchrotron. The 3 GeV beam is injected over 5 periods into a 1 km circumference Collector which feeds the main accelerator, the Driver synchrotron, operated at 10 Hz producing 3.5 μsec bunches every 100 msec at 30 GeV. For slow extraction the beam is steered in a fifth ring occupying the same tunnel as the Collector and Driver synchrotron, generating essentially dc beams for coincidence experiments. Fast extraction is also available to feed neutrino beams, and special care has been taken to allow acceleration of polarized beams with less than 15% polarization losses.

The technical challenges in producing such high intensities at 30 GeV are related to the 3 MW power in the beam which must be controlled, with minimal losses at any stages, in particular at extraction, and must be dissipated in the targets and beam stops. While space charge densities are kept to what is found in existing machines, the higher current is obtained by faster cycling, putting much of the burden into the accelerator hardware: magnets, beam pipe, rf systems, magnet power supplies and kicker magnets.

Table 1. Comparison of high intensity proton accelerators.

	Energy (GeV)	Average Current (μA)	Rep. Rate (Hz)	Protons/ Pulse N ($\times10^{13}$)	Circulating Current I (A)
Fast Cycling					
Argonne IPNS	0.5	14	30	0.3	4.0
Rutherford ISIS	0.75	130(200)	50	1.6(2.5)	4.0(6.1)
AGS Booster	(1.5)	(20–40)	(7.5)	(1.8–3.5)	(4–8)
Fermilab Booster	8	7	15	0.3	0.3
SSC LEB	(11)	(8)	(10)	(0.5)	(0.5)
Slow Cycling					
KEK PS	12	0.32	0.6	0.4	0.6
CERN PS	26	1.2	0.38	2	1.5
Brookhaven AGS	28.5	0.9	0.38	1.6	0.9
– with Booster		(4)	(0.38)	(6)	(4)
Kaon Factories					
TRIUMF KAON	30	100	10	6	2.8
KAON Booster	3	100	50	1.2	2.7
Moscow KF	45	125	6.25	12.4	3.2
Moscow Booster	7.5	250	50	3.1	3.2

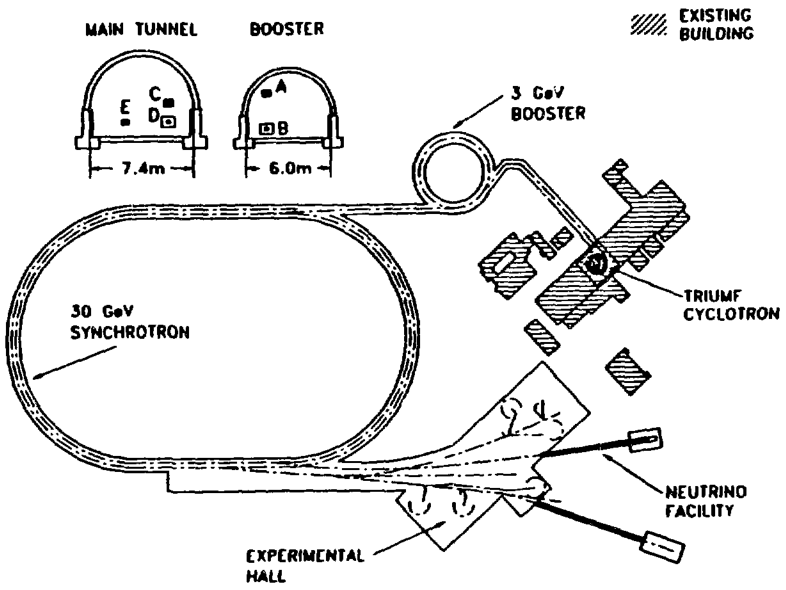

Fig. 1. Accelerator complex for KAON.

These critical items have all been prototyped during a feasibility study which demonstrated last May that technical solutions existed and that this machine could be built in 5 years for a cost of 700 M$.

I shall elaborate on the physics program which motivated this project and spend the last part of the talk on the proposed experimental facilities for KAON which had been determined by the initial physics program as expressed by the users community during 12 workshops held in the last 2 years.

2. PHYSICS OUTLOOK

KAON will produce a large variety of secondary beams and consequently the physics program is very broad in scope touching nuclear physics, particle physics, atomic and condensed matter physics. Beams of π, K, Hyperon, $\bar{p}$, ν, μ, $\vec{p}$ will be available. Table 2 lists a number of topics which will be part of the scientific program together with their required facilities – I shall briefly comment on several of these topics.

Table 2. Physics opportunities and requirements.

Rare Decays	**K^0, stopping K^+**
CP Violation	**few GeV/c K^0**
Neutrino Physics	**1–2 GeV neutrinos beam stop neutrinos?**
Meson Spectroscopy	**8–15 GeV/c $K^\pm$ up to 20 GeV/c $\pi^\pm$**
Baryon Spectroscopy	**0.5–2.5 GeV/c $\pi^\pm$ 1–6 GeV/c $K^\pm$**
Kaon-Nucleon Scattering	**0.3–2.5 GeV/c $K^\pm$**
Kaon-Nuclear Reactions	**0.3–1.0 GeV/c $K^\pm$**
Hypernuclei	**0.3–2.5 GeV/c $K^\pm$ 1.0–1.5 GeV/c $\pi^\pm$**
Spin Physics	**3–30 GeV/c $\vec{p}$**
Antiproton Physics	**0.5–10.0 GeV/c $\bar{p}$**
Low Energy Muon Physics	**Low energy $\mu^\pm$**

2.1. *Rare Decays and CP Violation*

K decays have been the source of many important discoveries and will continue to be a very fertile laboratory to study the so called Standard Model and its possible extensions.

One can distinguish three general types of studies:

- Searches for highly suppressed modes which are expected in the Standard Model (second order weak, GIM suppression). In this category, the studies of $K \to \pi\bar{\nu}\nu$, $K_L \to \mu\mu$ or $K_L \to \pi ee$ would be considered. Here, one tests the higher order calculation and the renormalization of the basic theory.

- Searches for decays forbidden in the minimal standard model but allowed in some of its extensions. In this category I shall consider $K_L^o \to \mu e$, $K \to \pi\mu e$ and the window they open on possible new physics.

- High precision studies which are mainly directed at elucidating the CP violation observed in the K system 30 years ago. Here, I shall describe measurements of μ polarization as signal for CP violation in $K_L \to \mu\mu$ or $K^+ \to \pi^o\mu\nu$.

Although great emphasis is given here to K decays, other processes are also considered like $\eta \to \mu\mu$ and $p\bar{p} \to \Lambda\bar{n}$ or $\Xi^+\Xi^-$.

For the first type of studies, the decay $K^+ \to \pi^+\nu\bar{\nu}$ is the best example of a highly suppressed branch which should be seen at the level of a few 10^{-10} branching ratio. Currently - and S. Smith is going to report in detail on this$^{2)}$ - an experiment at BNL is searching for this branch and should be seeing a few events before 1995. At that time KAON should take over and produce 100 of these events allowing a precision test of current theoretical estimates. In fact the new beam line presently being built at the AGS is a prototype of KAON's low energy kaon lines and TRIUMF is heavily involved in its design and implementation.

Increasing the number of incident kaons is not the only condition for improving the sensitivity of the current experiment. In fact, the bottleneck may be in the triggering capability and data rate for the acquisition systems. The raw increase in K flux will be used to get less π contamination and better optics. Major improvements in the detector will be required like:

- Improvement of the photon vetoing efficiency (active fast inorganic scintillator – CsI or BaF_2).

- Greater segmentation.

- High field solenoid.

- Fully instrumented detector with transient digitizers.

A sensitivity of $> 4 \times 10^{-12}$ should be achievable with no background which would yield several hundred events in the π spectrum above the $K\pi_2$ line.

In the second category are rare decays which are absolutely forbidden in the Standard Model such as $K_L^o \to \mu e$ and $K^+ \to \pi^+ \mu e$.

Such decays probe very high mass scales. For a particle H mediating this process with coupling strength g_H at the tree level the mass region probed can be expressed by the formula

$$M_H \approx 200 \quad \text{TeV} \left[\frac{10^{-12}}{\text{BR}} \right]^4 \frac{g_H}{g_w}. \tag{1}$$

One sees that the dependence on the branching ratio comes in the 4th power. This implies that new limits have to be improved by several orders of magnitude to significantly increase the region eliminated by an upper limit measurement. Since there is very little guidance as to where specific predictions are reliable, a program to improve the current round of experiments will be part of KAON scientific objectives. A combination of flux improvements and better instrumentation could lead to such a leap forward as has been accomplished at the meson factories. Table

Table 3. *Mass bounds from different processes.*

Process	**Higgs scalars (GeV/c²)**	**Pseudoscalar leptoquarks (TeV/c²)**	**Vector leptoquarks (TeV/c²)**	**Experimental Value**	
$\frac{\Gamma(K_L^0 \to \mu\bar{e})}{\Gamma(K_L^0 \to \mathrm{all})}$	11	8	149	$<8.5 \times 10^{-11}$	(a)
$\frac{\Gamma(K_L^0 \to \mu\bar{\mu})}{\Gamma(K_L^0 \to \mathrm{all})}$	4.7	3.6	62	7.6×10^{-9}	(a)
$\frac{\Gamma(K_L^0 \to e\bar{e})}{\Gamma(K_L^0 \to \mathrm{all})}$	8	2.6	108	$<11.6 \times 10^{-11}$	(*)
$\frac{\Gamma(K^+ \to \pi^+ \mu e)}{\Gamma(K^+ \to \mathrm{all})}$	1	0.5	39	$<2.1 \times 10^{-10}$	(d)
$\frac{\Gamma(\mu \to e\gamma)}{\Gamma(\mu \to \mathrm{all})}$	0.3	-	-	$< 4.9 \times 10^{-11}$	(e)
$\frac{\Gamma(\mu \to ee\bar{e})}{\Gamma(\mu \to \mathrm{all})}$	2.6	-	-	$< 1.0 \times 10^{-12}$	(f)
$\frac{\Gamma(\mu Z \to e\bar{A})}{\Gamma(\mu Z \to \nu Z')}$	22	22	118	$< 4.6 \times 10^{-12}$	(g)
$\Delta m(K_L^0 - K_S^0)$	150	-	-	3.6×10^{-15} GeV	(b)

(a) W.R. Molson, Proc, KAON Workshop (Vancouver, 1990)
(b) Particle data group, Phys. Lett. **170B**, 1 (1986)
(c) E. Jastrzembski *et al.*, Phys. Rev. Lett. **20**, 2300 (1988)
(d) A.M. Lee *et al.*, Phys. Rev. Lett. **64**, 165 (1989)
(e) R.D. Bolton *et al.*, Phys. Rev. Lett. **56**, 2461 (1986)
(f) U. Bellgardt, Nucl. Phys. **B299**, 1 (1987)
(g) S. Ahmad *et al.*, Phys. Rev. **38**, 2102 (1988)
* preliminary results

3 gives a summary of the sensitivity of different decays to new physics.

The final group in the trilogy of rare decays studies has to do with the study of CP violation and is of more direct relevance to this meeting.

Several decays have been predicted to have large amplitudes for the CP violating component but have yet to be observed. The decay $K_L^o \to \pi^o e^+ e^-$ is a good example. Figure 2 gives the two main diagrams contributing to the decay rate. However, the predicted branching ratio is in the region 10^{-11} to 10^{-12}, a formidable challenge for experimenters. Efforts to see this branch are mounted at KEK, BNL$^{3)}$ and Fermilab$^{4)}$ and the intensity of K_L produced at KAON may be crucial for seeing such decays.

Another avenue is offered by the measurement of the longitudinal polarization of the muon in the decay $K_L \rightarrow \mu\bar{\mu}$. Only a few hundred events have ever been seen from this decay level (B R $\sim$ 7.6 10^{-9}), yet it is conceivable to measure the polarization to a level of 10^{-3}, which could be expected from the Standard Model and could be much larger in other extensions.

Similarly an experiment has been proposed to measure the μ polarization in $K\mu_3 (K^+ \rightarrow \pi^o \mu \nu_\mu)$ using a rather straightforward extension of the apparatus currently envisaged for experiment 777 at BNL (Fig. 3). A similar apparatus could also measure the asymmetry of the branch $K^+ \rightarrow \pi^+\pi^-\pi^-$. 10^{10} events could be accumulated in this mode permitting statistical accuracies of order 10^{-5}.

K decays are not the only place where CP violation searches can be made at KAON. A search for $\eta \rightarrow \mu\mu$ and in particular the polarization of the μ can be conducted by using the high flux π beams. A different approach is to emulate the CP LEAR techniques and use $p\bar{p}$ annihilation to create pure, tagged K^o and $\overline{K}^o$ states.

Similarly a very clean signature of CP violation can be obtained by observing both the decay asymmetries and final state polarization in the reaction $p\bar{p} \rightarrow \Xi^+\Xi^-$. The decay of Ξ provides a self-analyzing signal since the polarization of the Λ produced can be measured.

The threshold for this reaction is 3 GeV, well matched by the energies of several beams at KAON. Figure 4 shows the characteristic signature for this decay.

This list is not exclusive and many more branches are accessible to make K decay a very prolific area which will be exploited at KAON.

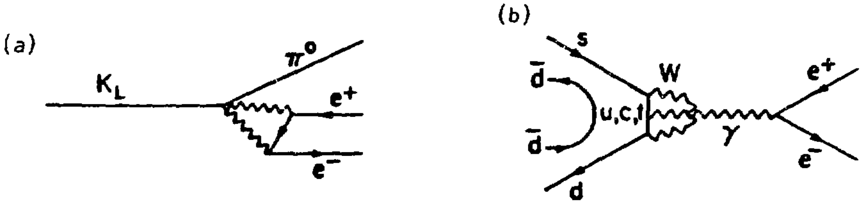

Fig. 2. Diagrams for $K_L^0 \to \pi^0 e^+ e^-$. (a) CP conserving two photon process; (b) CP violating penguin diagram.

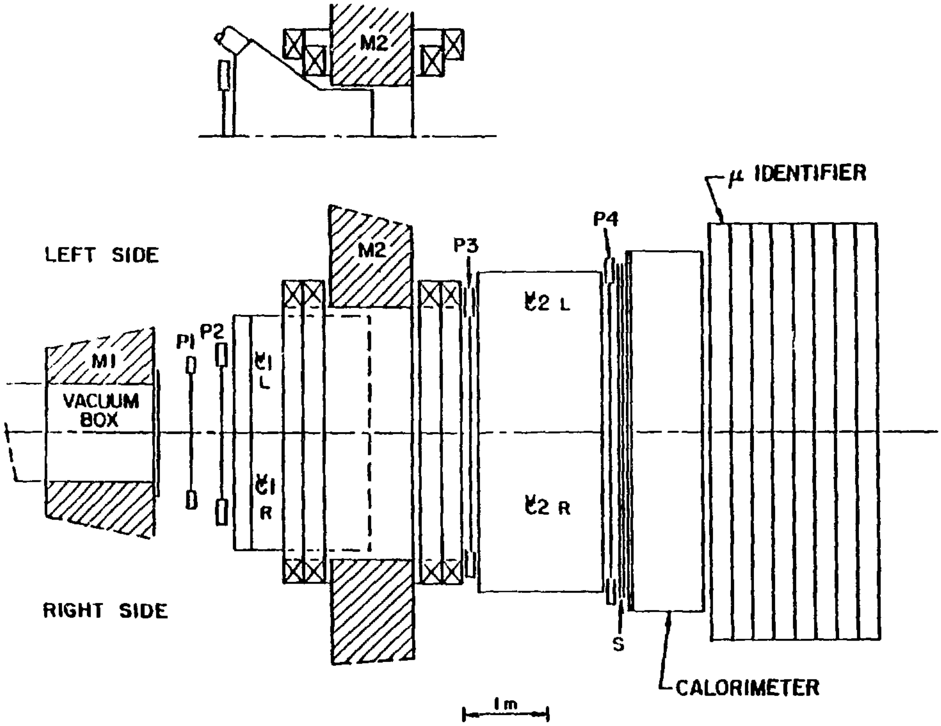

Fig. 3. E777 detection system.

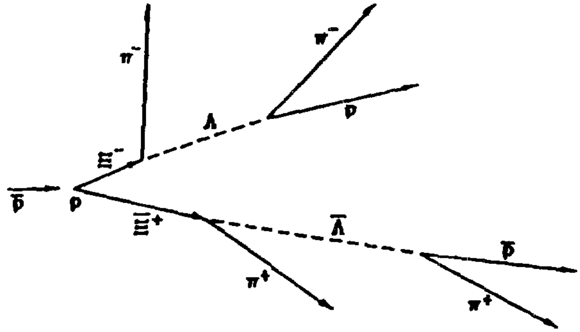

Fig. 4. An event $p\bar{p} \to \Xi^+\Xi^- \to \bar{\Lambda}\pi^+ \to \bar{p}\pi^+\pi^+ p\pi^-\pi^-$ generated at 3.5 GeV/c incident $\bar{p}$ momentum.

2.2. Neutrino Physics

If there is a domain where increased flux can be exploited immediately, it is in the neutrino physics. Here the 100 fold increase in proton intensity can be translated directly in a similar increase of ν flux.

A number of experiments have been looked at to determine which type of beams would be of most benefit and at the moment the consensus is that we should build a double horn decay in-flight channel, as was developed for the AGS neutrino facility and at CERN. Figure 5 gives an idea of the fluxes which could be delivered to the experiments. A stopped source is not excluded and could be based on the 3 GeV or the 30 GeV p beam.

I shall paint a very crude outline of a possible neutrino program and since we are going to focus also on detectors for Daphne, I shall describe a possible detector based upon scintillating fibre technology.

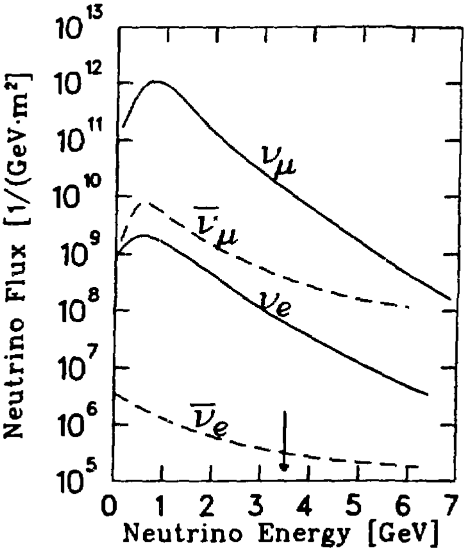

Fig. 5. Neutrino fluxes available at KAON.

The resolution of the solar neutrino puzzle seems further away since the new Ga detectors have started to produce results and one possibility rests with the phenomenon of neutrino oscillations. Evidence for neutrino oscillations would be extremely important in demonstrating that neutrinos have finite masses. A KAON Factory with 25 times more beam flux than the AGS after completion of the booster program would allow an oscillation search with a baseline of 100 km and could push the limit on δ_m in the few 10^{-4} eV^2 level, closing the window which presently exists between the experimental upper limits and the region which could explain the deficiency of ν_e flux from the sun as seen in R. Davies' experiment. This would represent a formidable technical challenge (and financial commitment).

A study of νe elastic scattering, in particular of $\overset{(-)}{\nu}_\mu$ e scattering could be mounted and the goal then would be to measure for the first time the neutral current differential cross section (3 events/hour would allow a precise measurement in a couple of years). The angular distribution, especially near the backward direction ($Ee/E\nu \sim 0$) is sensitive to non-V-A terms and also may allow an improved estimate of the neutrino magnetic moment to the level which has been predicted to explain again in a different way the deficiency of the number of ν_e emitted by the sun.

For the present upper limit obtained by a LAMPF experiment on $\nu_e e$ scattering of $8 \times 10^{-10} \mu_B$, an enhancement of a factor 2 in the rate would be seen near $y = 0.07$. With a lot of patience, an order of magnitude improvement could be obtained within 10 years of operation.

A less demanding experiment would focus on the precise measurement of the Q^2 dependence of $\nu_\mu p$ scattering. The physics objective here is to determine the axial vector form factor and determine the contribution of heavy quarks which would show up as a deviation from the predictions based on current values of g_A and g_V, the axial and vector coupling constants. By improving the angular and dE/dx measurement of the recoil proton, a high precision measurement of the Q^2 dependence over the range 0.05–1 GeV^2/c^2 is possible.

The program outlined above could be based on a detector capable of good tracking, good angular and vertex resolution, particle identification and good energy resolution.

A design based entirely on scintillating fibres is currently evaluated$^{5)}$ following recent implementation of such a detector in UA2.$^{6)}$

Figure 6 gives a visual impression of a modular section where each fibre is

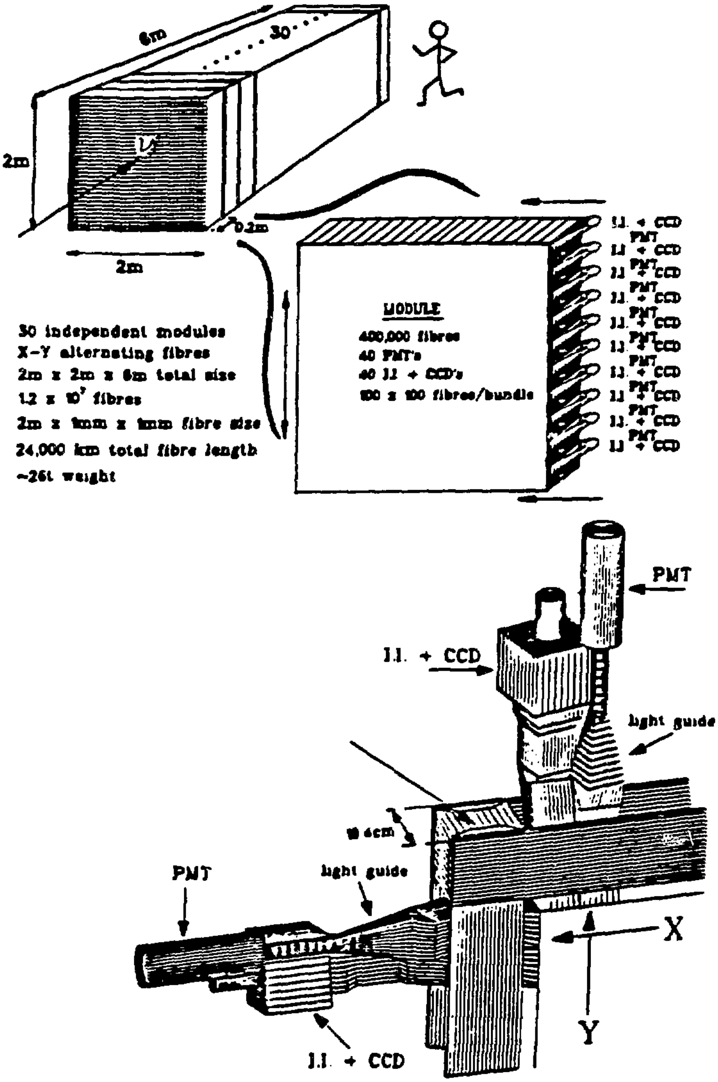

Fig. 6. A possible neutrino detector.

imaged on a CCD pixel via an image intensifier at one end while the other end is coupled to standard photomultipliers for the trigger decision on a group of 100 fibres.

The detector is made of 2 × 2 m^2 modules and would have 1.2 $\times 10^7$ fibres, 1200 CCD read-out channels and 1200 PMT's.

This represents a very cost effective and yet very powerful detector which is feasible with today's technology.

2.3. Nuclear Physics

KAON will be an ideal tool to study one of the most interesting questions today namely the connection between our picture of nuclear physics based on mesons and well identified hadrons and the more elementary picture involving quarks and leptons. Searching for evidence of quark degree of freedom in nuclei will be at the forefront.

2.3.1 Hadron Scattering

The positive kaon is an ideal probe of the nucleus. Because its $\bar{s}u$ structure prevents the formation of low-lying resonances, the basic K^+ nucleon interaction is very weak and K^+ could be the ideal strong probe with the added advantage of a strangeness tag. However, the data base on this fundamental process is still rather poor and better data, in particular polarization data, are desparately needed in the range $p < 1$ GeV/c before a comprehensive nuclear scattering program can be envisaged.

Figure 7 shows how a spin rotation parameter measurement could anchor solidly one of the phase shift solutions allowed by the cross section and polarization data. This program is very well matched to our current expertise in nucleon-nucleus studies at TRIUMF.

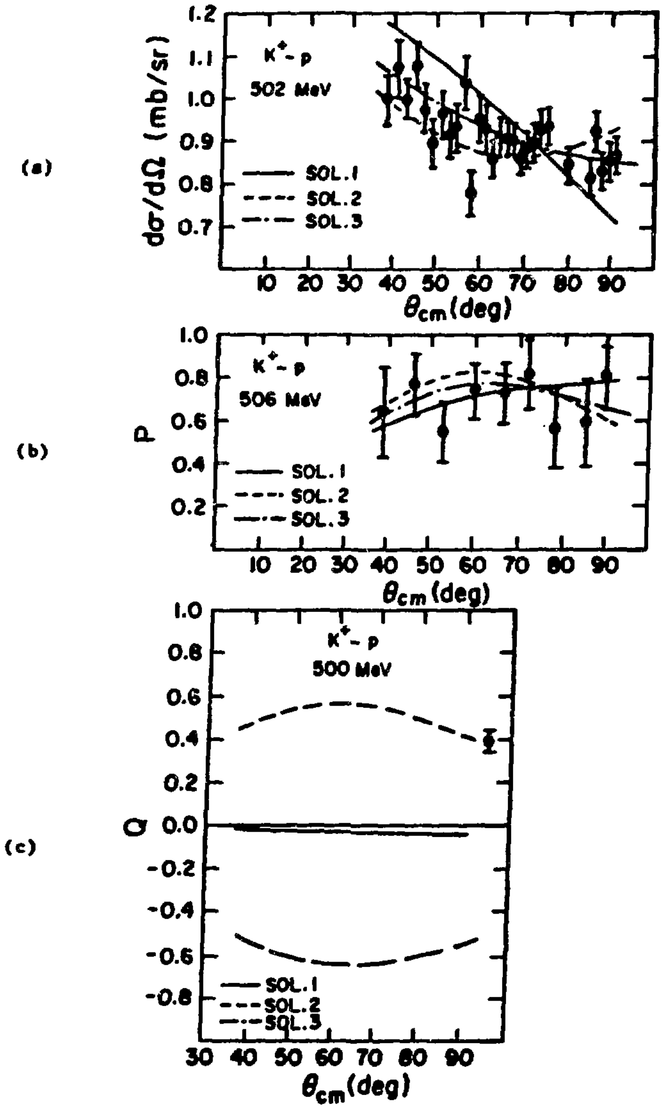

Fig. 7. Three allowed phase shift solutions for K^+P and measured values of (a) the differential cross section ($\frac{d\sigma}{d\Omega}$), (b) the analyzing power (P), and (c) the values of $Q = 2Re(\frac{f^*g}{d\sigma/d\Omega})$. Also shown is the estimated measurement error attainable in less than one day of running at the KAON Factory.

An example of the usefulness of the K^+ probe can be the derivation of neutron densities in nuclei, by using large angle K^+ scattering. Table 4 gives an outline of a possible systematic program along these lines at KAON.

2.3.2 Hyperon-Nucleon Reactions

The elementary baryon-baryon interaction is a very active and very interesting field of research. Since we now believe that baryons are made of quarks and gluons, one should eventually describe the strong force in terms of these constituents.

In the low and medium energy domain, where the residual interaction is too strong to be tested preturbatively, one relies on models to describe the baryon-baryon interaction.

Fifty years of nuclear physics have brought us a very good parametrization of the nucleon-nucleon force and one has learned about the spin-orbit component, the tensor piece, etc. Many models inspired by the quark gluon picture have also been developed to make the connection with the purely mesonic one (Skyrme, relativistic quark bags, non-relativistic quark cluster models).

Table 4. A possible K^+ experimental program.

System	Measure	Remarks
$K^+\vec{p} \to K^+p$	σPQ	
$K^+\vec{n} \to K^+n$	$\sigma P(Q)$	Use $\vec{d}(^3H\vec{e})$ target quasifree
$K^+\vec{d} \to K^+d$	$iT_{11}, T_{20}, T_{21}, T_{22}$	Test of "exact" calculations
$N = Z_{A(K^+,K^+)_{elastic}}$	σ	Test reaction mechanism
$A(K^+,K^+)_{elastic}$	σ	Deduce neutron distributions
$A(K^+,K^{+\prime})_{inelastic}$	σ	Deduce neutron transition densities, collective $2_1^+, 3_1^-$ surface peaked 2_2^+ peaked in interior

A quantitative understanding of the single baryon properties and of the nucleon-nucleon interaction has emerged. A more global approach should consider whether this success could be extended to other baryons namely the hyperon system, for which KAON would provide very high quality data.

Already some models have been extended to the hyperon-nucleon and hyperon-hyperon systems.

However, to confront theory and experiments, more comprehensive data are needed for these hyperon elementary processes.

1) ΛN force: One would like to achieve a full phase shift analysis of ΛN scattering data. KAON would allow production of tagged Λ and Σ beams and the study of their scattering off nucleons. Because Λ and Σ's are self-analyzing through their asymmetric weak decays, the spin observables are accessible.

Determination of the ΛN spin dependence is badly needed. From Λ hypernuclei, we have an indication that this dependence is small. The spin-orbit ΛN interaction could be studied by measuring elastic scattering and polarization in the p-wave region. The tensor component of ΛN force is totally unknown. Again a comprehensive partial wave analysis of Λp scattering data could help determine the s and d wave couplings induced by the tensor piece.

2) ΣN force: An analogous situation exists for the ΣN force. At low energy the ΣN interaction has a strong isospin dependence but one must also know the spin-spin component before one can predict the widths of Σ hypernuclear states and their isospin splitting. In contrast to the NN system, one-pion exchange is not allowed while one-kaon exchange allows testing of the one-boson exchange model.

A proposal is being worked out to measure hyperon-nucleon observables.

Tagged beams of Λ, Σ or Ξ are produced via $\pi^+p \rightarrow K^+\Sigma^+$ or $\pi^-p \rightarrow \Lambda K^o$

reactions at ~900 MeV, or $K^-p \to \Xi^-K^+$ reactions respectively. Using the πp reaction the Σ^+ is tagged by detecting a K^+ while the proton from Σ decay and the recoil proton in the Σ_p scattering process are detected in the toroidal magnet (Fig. 8, based on the present KEK design). With 3 $\times 10^{10}$ π^+/sec incident on a liquid hydrogen target and K^+ detected in the angular region 30°–60°, one can tag 10^5 Σ per sec and expect to identify about 5 $\times 10^3$ scattered events per day. Cross section, analyzing power and spin transfer coefficients could be determined with good statistical precision.

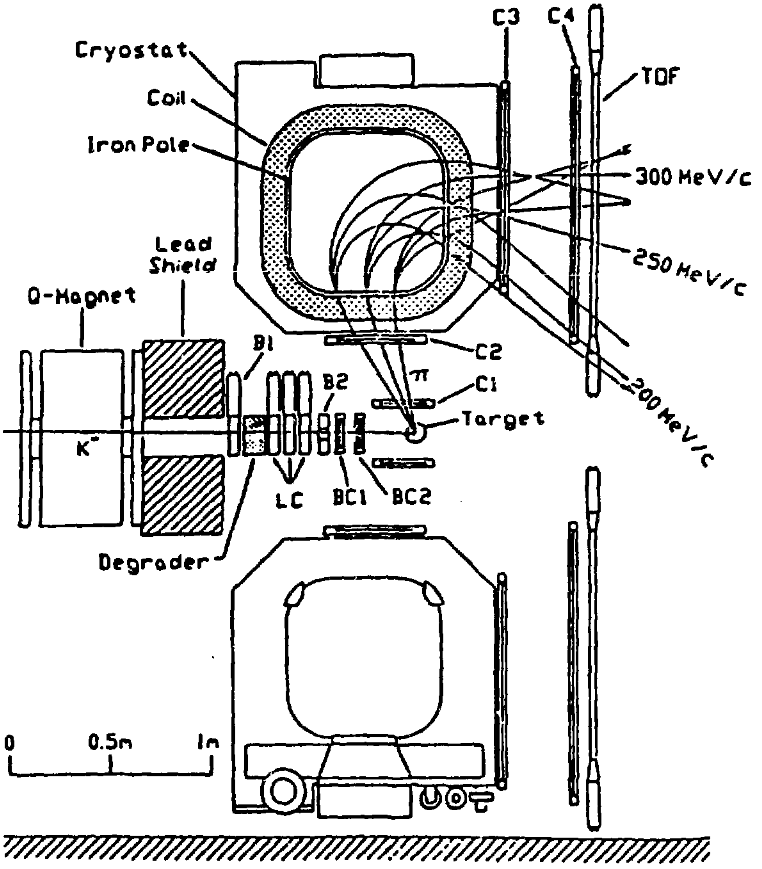

Fig. 8. Toroidal spectrometer for hyperon-nucleon studies.

By using a 1 GeV K^- at a rate of 10^6/sec, it is possible to conceive an experiment which would identify Ξp scattering events via its 5 charged particles final state.

$$\begin{array}{l} \Xi^- p \to K^+ \Xi^- \to \Lambda \pi^- \\ \quad \hookrightarrow p \quad \text{recoil} \hookrightarrow \pi^- p \end{array} \tag{2}$$

2.3.4 Hadron Spectroscopy

Quantum chromodynamics (QCD) is believed to be the theory of strong interaction and if it has had remarkable successes at very high energy where quarks can be viewed as free, it still has to be shown to produce the physical states we observe in nature. Because of the difficulties encountered in trying to solve QCD at distances where perturbation methods are no longer reliable and our lack of understanding of the confinement mechanism, one still has to rely upon models to explain the physics of hadrons.

There are numerous models of hadron structure on the market, and experiments have to provide the clues in building relativistic descriptions of the hadronic families. Because the quark models have been the most useful tool to understand hadron spectroscopy, one uses a classification of hadrons states into 2 categories – those states expected from the quark model are called ***conventional*** hadrons, those not expected at all in the quark model are called ***exotics***.

The strategy generally adopted consists of identifying all the predicted states of the quark model to isolate candidates which do not fit into the model and points to new degrees of freedom beyond the quark model: such are the hadrons made of glue (glueball) or hybrids made of multiple quarks and gluons.

The present situation7) is such that we are far from having established a solid picture of conventional hadrons. The baryons searches have concentrated on πN

and $\overline{K}N$ formation so that states coupling strongly to πN have been identified while the states which couple weakly have not. Other formation channels should be exploited like Kp or πp requiring higher energy beams (in the region of 6 GeV). These experiments will require very large statistical samples to disentangle the large number of expected states around 2 GeV excitation. The sss baryons are almost totally unexplored.

The meson sector is still very poorly known and many states are missing. This is due in part to the difficulty of forming the states, their broad width and isospin mixing. Extension of the LASS program at SLAC which has been mapping very effectively the $s\overline{s}$ meson using a 11 GeV K^- beam has been considered for KAON. The plan calls for rf separated beams in the range 6-20 GeV with typically 10^7 K's per spill.

Several spectrometers have been studied combining features from the LASS spectrometer and the crystal barrel experiment at LEAR. Large, uniform acceptances, large acceptance of neutrals with good energy resolutions and sophisticated forward tracking spectrometer are the ingredients required for such a program, not to mention a powerful data processing facility. The full program should encompass $\pi, K, \overline{p}$. Extension of the comprehensive searches at LEAR in $p\overline{p}$ annihilation is also considered with beams between 0.5 and 3 GeV/c to cover the region of 2 GeV excitation (see Fig. 9).

Polarization experiments are also envisaged and would capitalize on a new detector being assembled at TRIUMF for π physics with polarized target (CHAOS).

Having done a very complete survey of conventional states, one would then try to explain the extraneous states seen in terms of extensions of the quark model. The other approach is to focus on states whose quantum numbers are not possible

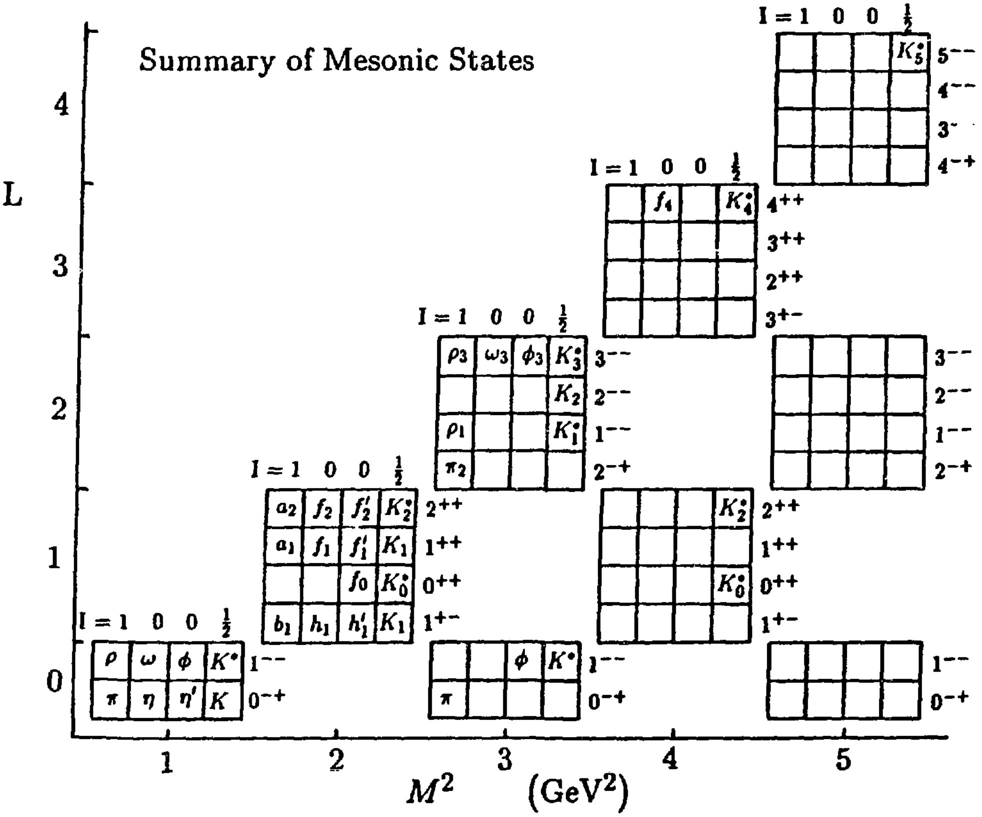

Fig. 9. Meson spectroscopy table.

within the quark model. These states tend to be at excitation energies greater than 2.5 GeV and are thus difficult to reach at LEAR. Using a device similar to the one proposed for the K^- beam spectroscopy (Fig. 10), a program to study resonances on a high flux $\bar{p}$ line at 3 GeV with $10^6\bar{p}$/sec could be effectively mounted.

2.4.5 Other Particles

TRIUMF has had a very active program in disciplines other than subatomic physics. It turns out that KAON will produce a very intense flux of muons and pions which have attracted our clientele of μSR physicists and pion therapists. Plans are included in the development of the facility to develop μ beams for our

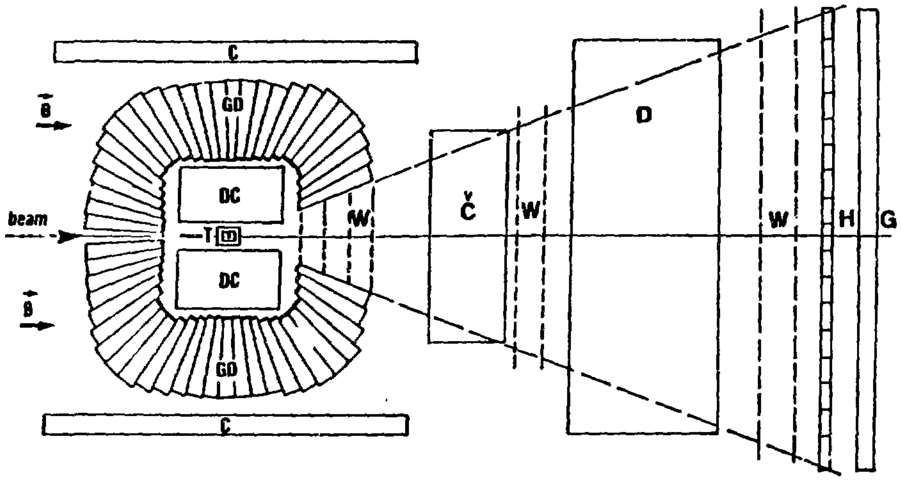

Fig. 10. $\bar{p}p$ or K^-p facility using the Crystal Barrel. (C – solenoid, DC – jet drift chamber, GD – CsI barrel, T – LH_2 target, W – PWC, Č – Čerenkov, D – dipole magnet, H – hodoscope, G – lead glass hodoscope or crystal detector).

condensed matter colleagues.

Similarly, attractive neutron sources could be considered with interesting time structure which have captured the imagination of neutron scatterers.

3. EXPERIMENTAL FACILITIES

Having defined the physics program envisaged for KAON, it is interesting to review the requirements in terms of beam lines and facilities for supporting the initial experimental program. Table 2 gave a synopsis of these requirements and Table 5 gives the specifications of the beam lines which have been studied.[8]

Figure 11 gives a view of the large experimental hall which would accommodate the thousands of users who would travel to Vancouver to exploit KAON.

4. CONCLUSION

The physics program of KAON is very rich, spanning particle physics, nuclear physics and some connected disciplines like condensed matter research, medical treatment and muonium chemistry. The critical components of the complex have

Table 5. Beam lines specifications.

Channel	Momentum GeV/c	Solid Angle msr	Momentum Acceptance $\Delta p/p$ in %	Length m	Type of Separation
K20	20 -6	0.1	1	160	RF, 3 cavities, 2.8 GHz
K6	6 -2.5	0.08-0.30	3	110	RF, 3 cavities, 1.3 GHz
K2.5	2.5 -1.25	0.5 -2.0	4	54	DC, 2 stages
K1.5	1.5 -0.75	2.0	4	30	DC, 2 stages
K0.80	0.80-0.55	6.0	5	18	DC, 2 stages
K0.55	0.55-0.40	8.0	6	14	DC, 1 stage, extra optics

Anticipated Beam Intensities[*]

Channel	P GeV/c	K^- $10^6/s$	K^+ $10^6/s$	π^- $10^9/s$	π^+ $10^9/s$	$\bar{p}$ $10^6/s$
K20	21	0.75	29	0.16	0.95	0.05
	18	2.4	43	0.35	1.05	0.35
	15	5.9	62	0.60	1.50	1.7
	12	9.2	52	0.90	1.90	5.0
	9	7.9	23	0.70	1.30	10.5
	6	2.3	4.2	0.78	1.20	11.5
K6	6	15	34	1.9	3.6	23
	3	2.5	4.5	3.2	5.0	43
K2.5	2.5	66	119	16	24	110
	2.0	39	76	21	30	91
	1.5	14	27	25	36	52
	1.25	5.4	9.7	27	37	26
K1.5	1.5	193	366	49	69	81
	1.2	52	93	36	49	25
	1.0	18	31	27	36	8.3
	0.8	3.7	6.3	18	23	1.9
K0.8	0.8	99	203	87	113	7.1
	0.65	32	59	63	80	2.6
	0.55	10	19	44	55	1.0
K0.55	0.55	41	80	80	101	1.5
	0.50	21	44	67	82	0.93
	0.45	9.2	21	50	61	0.53
	0.40	3.8	9.4	33	44	0.30

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[*] Intensities are for a 100 μA 30 GeV beam on a 6 cm Pt target.

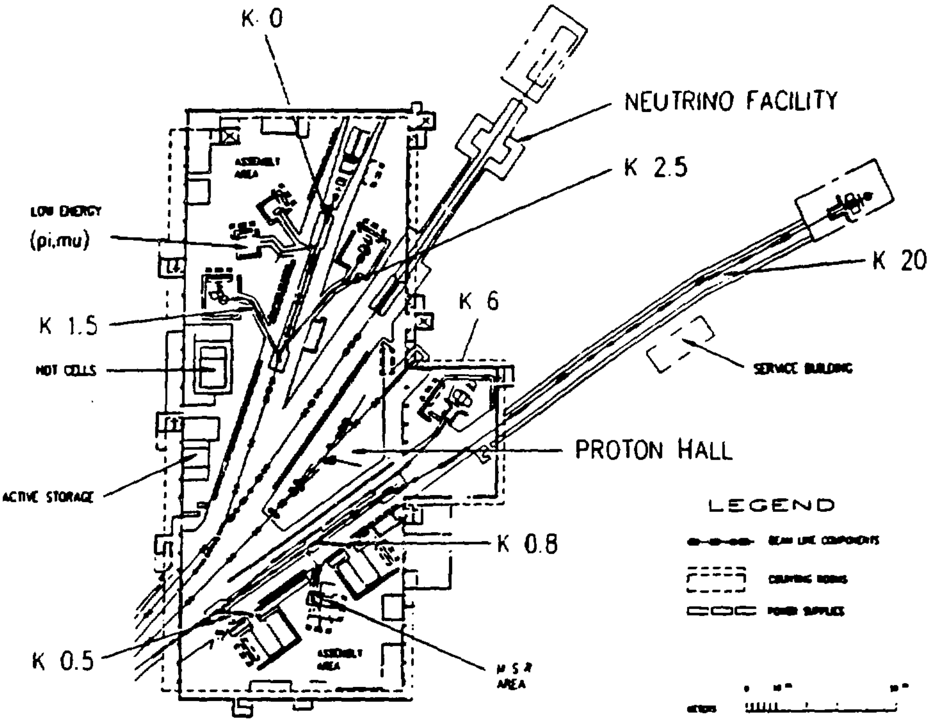

Fig. 11. Proposed layout of the experimental area for the TRIUMF KAON Factory.

been successfully prototyped during a feasibility study completed last year.

Two thirds of the funding for construction have been identified and we are eagerly awaiting the green light (and the green bills) from the Canadian government to proceed.

We are confident that within 6 years of the go-ahead signal, experimenters will be fighting for beam time at KAON. You are all invited to join the brawl.

References

1. M.K. Craddock, The TRIUMF KAON Factory, TRIUMF preprint TRI-PP-90-85.
2. A.J.S. Smith, these proceedings.

3. H. Geenlee, A search for flavour changing neutral current $K_L \rightarrow \pi^o e^+ e^-$, Proc. KAON Workshop (Vancouver, 1990).
4. A. Barker *et al.*, Phys. Rev. **D41**, 3546 (1990); and G.J. Block, Results from the FNAL E731 Experiment and future possibilities, Proc. KAON Workshop (Vancouver, 1990).
5. D. Frekers, High intensity neutrino beams at KAON, Proc. Int. Workshop on Application of Scintillating Fibres in Particle Physics (Blossin, Germany, 1990).
6. J. Alitti *et al.*, NIM **A279**, 364 (1989).
7. S. Godfrey, Summary of the workshop on hadron spectroscopy at the KAON Factory, TRIUMF report TRI-89-4.
8. J. Beveridge, Experimental areas at KAON, Proc. Workshop on Intense Hadron Facilities and Antiproton Physics (Torino, 1990) pg. 17.