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EXPERIMENTAL FACILITIES FOR KAON

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For the purposes of the Project Definition Study (PDS) the experimental facilities at the KAON Factory must be specified to sufficient accuracy that a reasonable estimate of costs can be established. As well, the impact of the production of these facilities on the Canadian industrial community needs to be evaluated. In order to achieve these goals a number of assumptions must be made regarding the types of facilities that will be required. In an attempt to assure that these assumptions are made as accurately as possible TRIUMF is seeking advice from physicists interested in experimenting at the KAON Factory by sponsoring a number of workshops (see Table I). The philosophy behind this approach is that it will help to ensure that the contents of the experimental areas are driven by the experimental needs as they are presently foreseen. It is important though that any scheme specified at this time be as flexible as possible in order to allow for modifications in response to changes in the physics priorities that will almost certainly occur between now and the achievement of beam at KAON.

Table I. Workshops 1989

	Local Organizer	Location	Atten.
KAON Workshop - May 1-5	Measday	Coimbra, Portugal	Open
Neutrino Workshop - May 14	Jennings	Montreal	Open
Hadronic Physics at the Kaon Factory - June 7-9	Haüsser	Bad Honnef, Germany	Open
Hypernuclear Physics - June 17-18	Gill	KEK, Japan	Open
Spin and Symmetries - June 30-July 2	van Oers	Vancouver	Open
KF Users Workshop - July 10-11	Page	Vancouver	Open
Nuclear Physics with Antiprotons	Kitching	Italy	Open

In order to begin the PDS Experimental Areas Definition Study a list of the desired facilities must be made. Table II is a list, extracted from a gaze into a crystal ball of some of the physics that will be undertaken at KAON. As stated above one of the purposes of the science workshops is to ensure that this list is as complete as possible. From this list (Table II) it is learned that channels providing charged particles, $K^{\pm}$'s ($\pi^{\pm}$'s, and $\bar{p}$'s) at all the possible energies would be desirable. As well there will be need for a neutral kaon beam, a neutrino beam, muon Spin Resonance (μSR) beams and an area for extracted polarized

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Table IIa Particle Physics

A. Very Rare Kaon Decays

   1. Muon number conservation ($K^0 \to \mu e$)
   2. Searches for new effects 4($K^+ \to \pi^+ X^0$)

B. Established Kaon Decays.

   1. CP violation
   2. Kobayashi-Maskawa angles
   3. Form factors

C. 1. $\nu_\mu(\nu_e?)$ e^- scattering.

   2. ν oscillations
   3. ν masses

D. Baryon Spectroscopy

   1. N and Δ resonances (πN scattering and reactions)
   2. λ and σ resonances (K^-N scattering and reactions)

E. Meson Spectroscopy

   1. $s\bar{s}$ states between 1 and 2 GeV/c^2
   2. Glueballs (or gluerings?)

F. Hyperon-Nucleon Interactions

   1. Direct scattering for Λn, ΣN, ΞN (tagged hyperons)
   2. Final-state interactions ($K^- d \to \gamma\Lambda$pn)
   3. Hyperonic atoms ($\Sigma^-, \Xi^-, \Omega^-$)

G. Antiproton Studies

   1. New charmonium states via $\bar{p}p \to \Psi$)
   2. Annihilation and baryonium
   3. $\bar{p}$ scattering on nuclei and 'hot spots'

H. Muon Physics

   1. New (g-2) with x20 precision

I. Polarization Studies

   1. Polarized proton beam and target
   2. Polarized effects in reactions such as $\pi^- p \to pn$

Table IIb Nuclear (or many-body) physics

A. Λ Hypernuclei

   1. Spectroscopy of excited states via (K^-, π^-), (π^+, K^+), (K^-, π at rest), (K^-, γ)
   2. Effective spin-orbit forces
   3. Binding energy anomalies (e.g. ${}^5_\Lambda$He)

4. Λ lifetime in hypernuclei

B. Σ Hypernuclei
   1. Why are states so long-lived?
   2. Spin-orbit forces ($^{7}_{\Sigma}$Li)
   3. Isospin violation

C. Double Hypernuclei
   1. Do they really exist? $\Lambda\Lambda$ or Ξ (via (K^-, π^+))
   2. Relation to possible S=-2 dibaryons

D. Neutron Radii in Nuclei
   1. K^+ and p nucleus scattering
   2. Kaonic and hyperonic atoms

E. Resonance Propagation
   1. $\lambda(1520)$ behaviour in nuclear matter

F. Miscellaneous
   1. Regenerative amplitudes
   2. Neutrino-nucleus interactions

proton studies. Some of these latter studies could be done using internal targets so an area for such must also be included in the considerations. This knowledge of what might be wanted reduces the problem to one of deciding how such a range of facilities could be constructed to optimize the use of the available accelerated protons.

Before proceeding with a description of a study undertaken to find this optimum layout it is instructive to ask if there are any considerations of the accelerator design that are significant to the experimental program. The KAON accelerator complex[1] consists of five rings, the Accumulator, Booster (to 3 GeV), Collector, Driver (to 30 GeV) and the Extender. It is possible to extract the beam from any of these rings; however present plans only envisage this occurring for experimental purposes from the D or E rings. This extraction can be made at any energy between 3 and 30 GeV for the purposes of polarized proton experiments. Thus the facilities for this purpose may need to be capable of dealing with proton beams over this extensive range. Experimentalists will also be able to select from amongst the available time structures of the extracted beams that are listed in Table III. The beam extracted from the D ring will have a duty cycle of .004% (3.6 μsec/100 msec) with a microstructure of 1 nsec wide pulses every 16 nsec. This would appear to be ideal for the neutrino and some parts of the μSR experimental programs. The beam from the E-ring will be slow-extracted beam and will be essentially DC ($\simeq$85% duty cycle) where the macroscopic variations will be at 10 Hz. The microscopic structure of this beam can have the 16 nsec structure due to the 63 MHz RF of the E-ring partially eliminated. This partially flattened mode is referred to as debunched and will

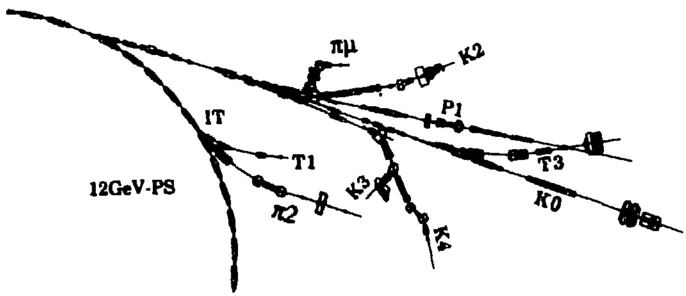
Table III. Time Structures of Available Extracted Proton Beams.

- Fast Extraction from D-Ring
  - Macrostructure .004% Duty Cycle(3.6 μsec/100 msec)
  - Microstructure Pulses every 16nsec (63 MHz RF)
- Slow extraction from E-Ring
  - Macrostructure 85% Duty Cycle (10Hz)
  - Microstructure - Two Modes Available
    1. Bunched 1nsec wide pulses every 16nsec
    2. Debunched $\geq$ 50% Micro Duty Cycle

have a micro duty cycle of better than 50%. The decision as to which of these various time structured extraction modes will be employed at a given time will be made on the basis of the requirements of the experiments on the floor, that is, it will be a scheduling committee task.

The considerations[2] to date of what the experimental facilities at KAON will look like have primarily concentrated on the secondary beams that will be produced using the full intensity (100 μ-amps) 30 GeV/c unpolarized proton beam. Figure 1 shows the layout of the areas that serve this purpose at KEK and at BNL. At both of these accelerators the primary beam is split between several proton lines some of which contain several production targets which in turn serve as sources for a number of secondary beam lines. There are various other schemes possible, for example, the one employed at all the pion factories is to place all production targets one after the other on a single proton line. It is necessary to devise a comparative scheme in order to determine which of the possible approaches is the most efficient way to employ the protons from the accelerator.

A straightforward way to make such a comparison of the many options is to begin with the ideal secondary channel and attempt to devise a scheme that compromises it as little as possible. All experimentalists will agree that the ideal channel is the only channel, thus it will receive all the protons, its production target can be of optimum length (Fig. 2 shows that this is ~6.5 cm), its takeoff angle can be at zero degrees (the smallest source for secondary particles) and its acceptance can be made as large as the optical requirements will allow. A comparison study can then consider how compromises, such as putting several production targets in a line, having several channels viewing the same production target and splitting the proton beam in varying proportions, would effect the efficiency of this ideal channel. A recent study along these lines by Beveridge and Doornbos[2] considered an experimental arena containing six (6) charged secondary channels and a neutral kaon channel. They started with ideal channels,



KEK-PS Beam Lines.

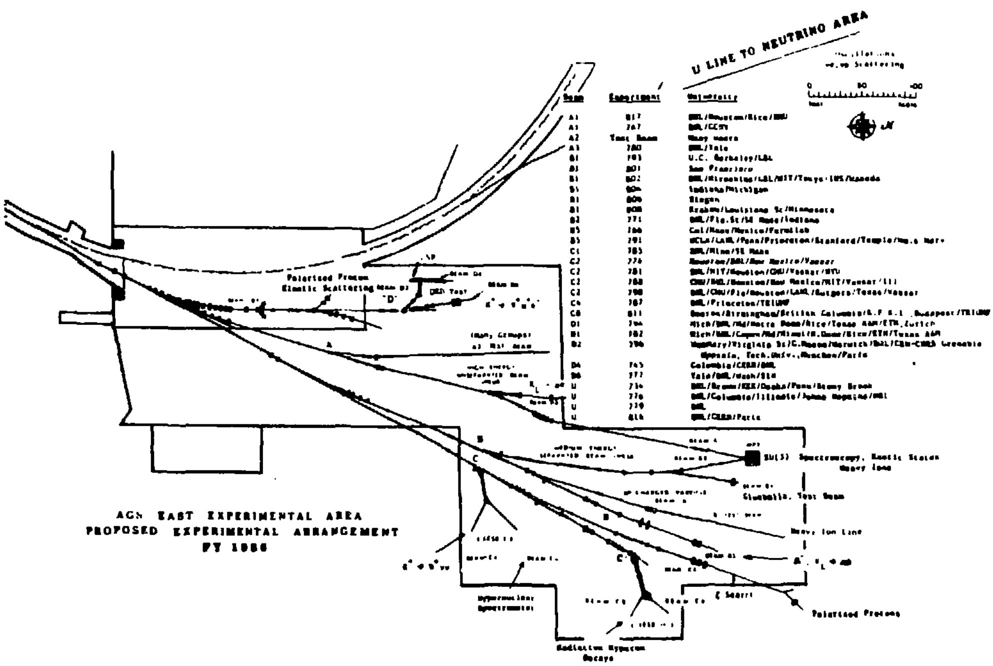


Fig. 1. KEK and BNL experimental areas

examples of which are shown in Fig. 3a for high energies, and Fig. 3b for low energies.

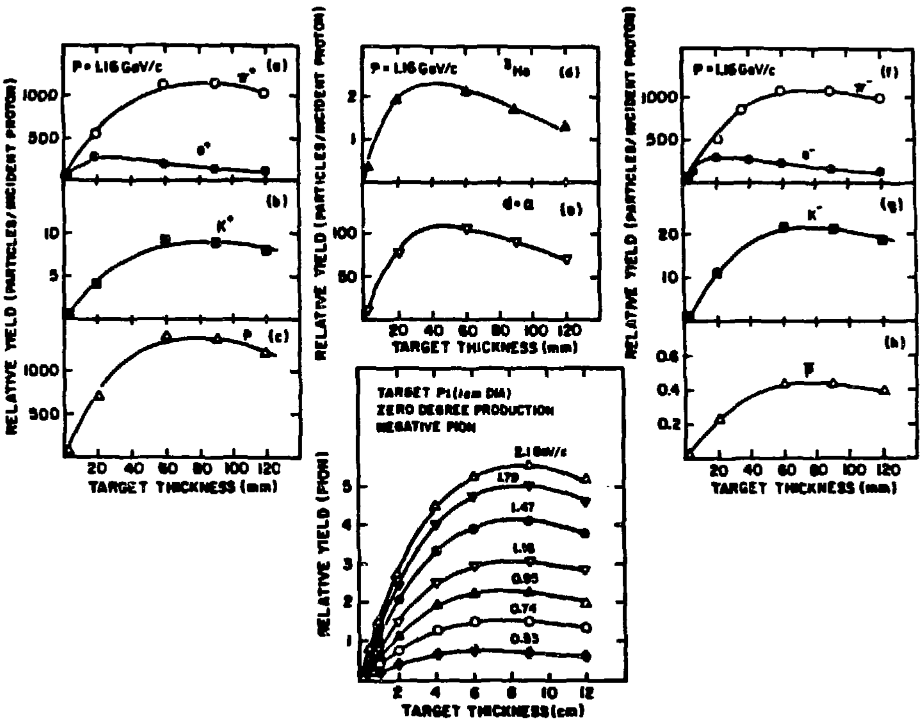


Fig. 2. Length versus yield from Yamamoto (Ref. 3).

Figure 4 shows several schemes for extracting low energy beams from a production target that will allow for the extraction of several other beams from the same target. All of these schemes compromise the acceptance of the channel as is documented in Table IV where the uncompromised version appears in the last column. The other major effect of these schemes is that the takeoff angles for the beams is no longer at zero degrees. This means that the source of the particles will be large in the horizontal direction, for example a 6.5 cm target viewed at 10° will be a 1 cm long object (in addition to the width of the proton beam). A possible solution to this problem is the vertical momentum analysis scheme employed at LAMPF but the need for electrostatic and RF separators may make such an approach prohibitively difficult.

Any experimental layout that places several production targets in the same proton beam must attempt to optimize particle production versus the

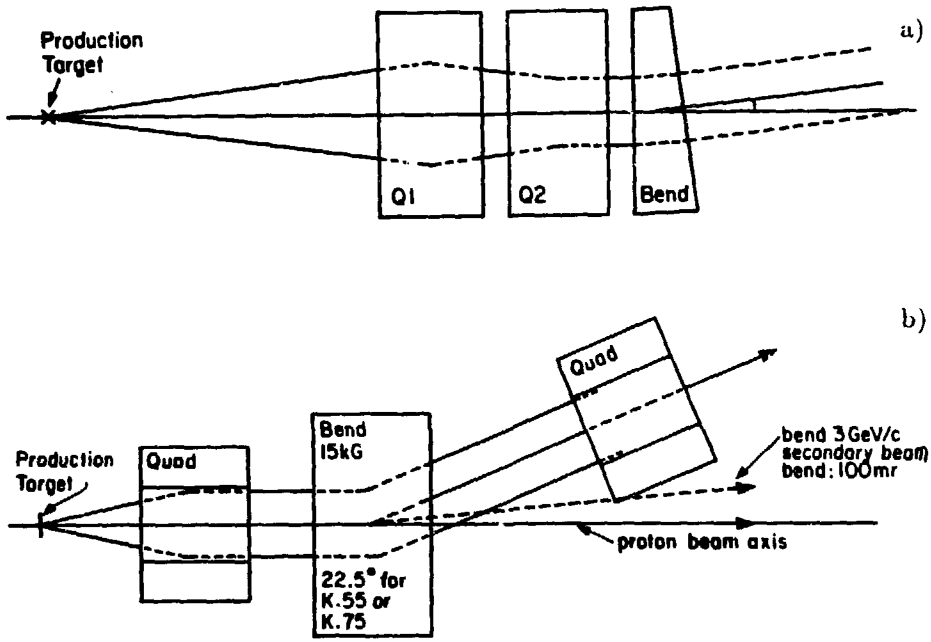


Fig. 3. a) High energy "ideal" channel and b) low energy "ideal" channel.

Table IV. Solid Angle Acceptance for Different Take-off Schemes

P Gev/c	Septum (msr)	Bend (msr)	Maxim (msr)	Semi-maxim (msr)	Quad at 0°
0.55	4.0	5.3	3.6	5.3	8.0
0.75	4.0	4.7	3.6	4.7	8.0
1.50	1.48	1.72	1.65	1.57	2.36
2.50	0.62	0.68	0.55	0.59	0.75

transmission of the primary beam through the upstream targets. The problem of reconstituting and transporting the beam after it has passed through one of these targets must also be taken into account. Beveridge and Doornbos[2] using the results of Yamamoto *et al.*[3] studied particle production versus transmission for the case in which a target of 6 cm length (approximately ideal) is preceded by

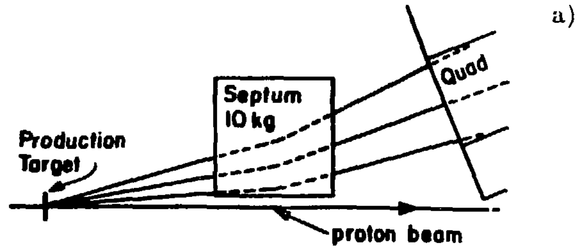
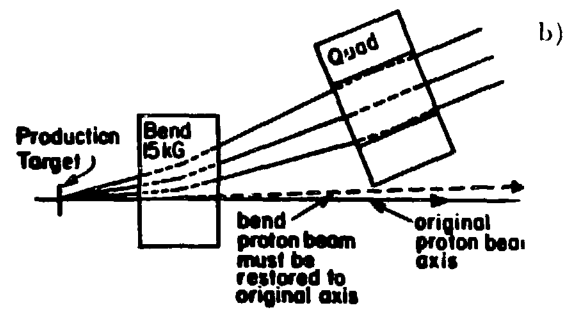
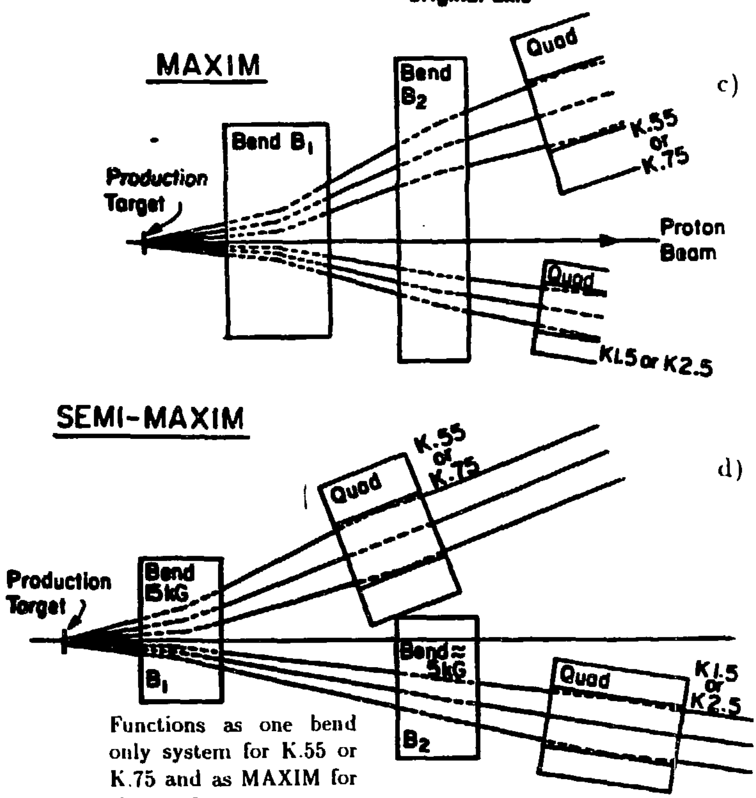


Fig. 4. a) Septum scheme for low energy channel; b) bend scheme for low energy channel; c) MAXIM scheme for two low energy channels; d) semi-MAXIM scheme for two low energy channels.





Functions as one bend only system for K.55 or K.75 and as MAXIM for K1.5 or K2.5.
The rays exiting B_2 seem to go straight through the production target.

another target. They determined that the efficiency of a pair of targets was best if the first target was approximately 3 cm in length. Assuming that the efficiency for restructuring the beam after such a target can be 100% they examined the three possible layouts of six charged and two neutral channels shown in Fig. 5.

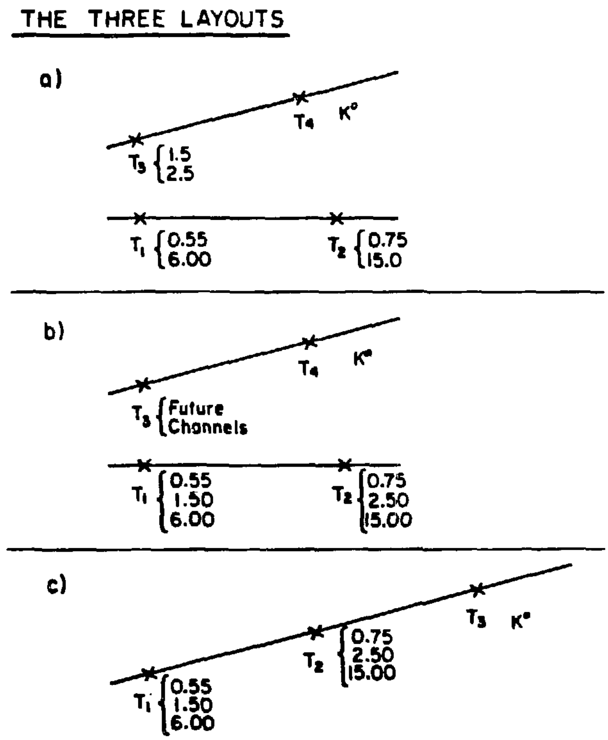


Fig. 5. Test layouts.

In Fig. 5a it is assumed that the primary proton beam is split two ways and that only two secondary channels will be taken from any of the production targets. This allows the takeoff angles for the .55 and .75 GeV/c beams to be at 0° when they are combined with the 6.0 and 15 GeV/c beams respectively. All these channels therefore meet the optimization requirements described above regarding solid angle and source size. In this study the 1.5 and 2.5 GeV/c beams are compromised by being combined in a MAXIM scheme.

In Fig. 5b it is again assumed that the proton beam is split two ways while in Fig. 5c it is not split. In both 5b and 5c the channels are combined as shown using a SEMI-MAXIM scheme for the lower energy channels. The targets for the charged particle channels in the case of Fig. 5c are both 3 cm in length. The arrangement of Fig. 5b has the advantage that future expansion at target 3 is possible while in the meantime the neutral kaon channels can be operated independently of the charged channels.

Table V lists the factors by which each of the channels has been compromised in order to achieve the arrangements shown in Fig. 5. Here, as compared to Ref. 2, the K1.5 and K2.5 channels in setup A are considered to be compromised relative to their ideal arrangement. Here also where targets have been shortened relative to the ideal case that factor has been included in the calculation of the efficiency of the channels viewing it. The product of these compromise factors is shown in the final column for each setup. The sum of the final efficiencies for each channel is the efficiency of that entire scheme. Of course in either of the split proton beam schemes the split factor can be varied in an attempt to maximize productivity. A 50/50 split has been assumed here and a decision to use any other ratio left, like that of selecting the time-structure of the beam extracted from the accelerator, as a task for the scheduling committee.

From Table V it appears that the arrangement in which the three targets are on a single proton line is the most effective way to employ the proton beam. However this efficiency advantage is not considered to be sufficient to overcome the fact that in this scheme these channels are far from ideal and the operational coupling between all the channels is maximized. It has therefore been decided that the layout shown in Fig. 5a, being the one with the largest number of ideal channels and the greatest flexibility, is the one that will be constructed. Fig. 6 shows how this scheme would appear and what the building to contain it will be.

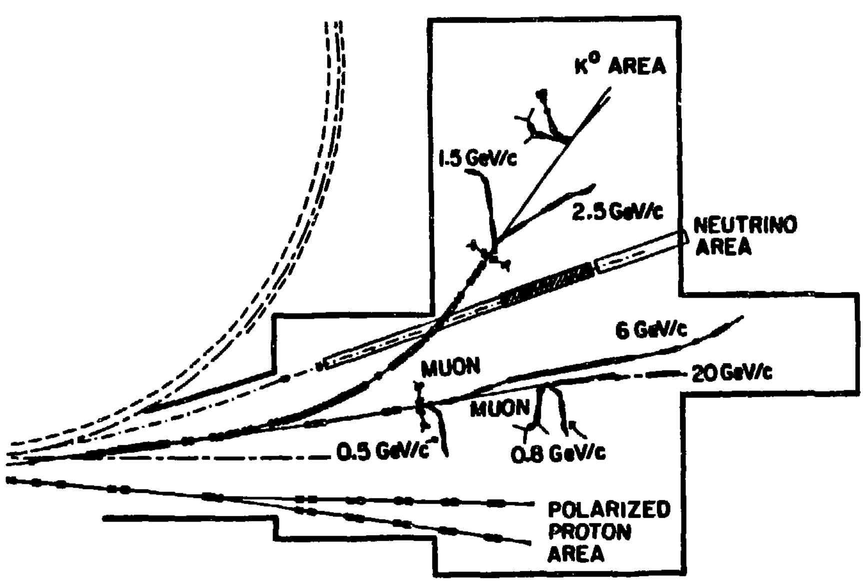


Fig. 6. KAON experimental facilities.

In conclusion a scheme for the layout of the secondary beams has been selected and the building sized. Cost estimating for the magnets, shielding,

Table V. Compromised Factors for Test Setups

Case A

Channel	Momentum Range	Ratio of Compromised Factors to Ideal Factors			
		Solid Angle	Target Length	I_p	Product
K(.55)	0.40 - 0.55	1.0	0.72	0.50	0.36
K(.75)	0.55 - 0 .75	1.0	1.0	0.28	0.28
K(1.5)	0.75 - 1.5	0.7	0.72	0.50	0.25
K(2.5)	1.5 - 2.5	0.73	0.72	0.50	0.26
K(6.0)	2.5 - 6.0	1.0	0.72	0.50	0.36
K(15.)	6.0 - 15.0	1.0	1.0	0.28	0.28
K^0		7.0	7.0	0.28	0.28
SUM					2.07

Case B

Channel	Momentum Range	Ratio of Compromised Factors to Ideal Factors			
		Solid Angle	Target Length	I_p	Product
K(.55)	0.40 - 0.55	0.66	0.72	0.50	0.24
K(.75)	0.55 - 0.75	0.59	1.0	0.28	0.16
K(1.5)	0.75 - 1.5	0.70	0.72	0.50	0.25
K(2.5)	1.5 - 2.5	0.73	1.00	0.28	0.20
K(6.0)	2.5 - 6.0	0.66	0.72	0.50	0.24
K(15.)	6.0 - 15.0	1.00	1.00	0.28	0.5
K^0	0.66	7.0	7.0	0.5	0.28
SUM	1.00				1.87

Case C

Channel	Momentum Range	Ratio of Compromised Factors to Ideal Factors			
		Solid Angle	Target Length	I_p	Product
K(.55)	0.40 - 0.55	0.66	0.72	1.00	0.48
K(.75)	0.55 - 0.75	0.59	0.72	0.55	0.23
K(1.5)	0.75 - 1.5	0.70	0.72	1.0	0.5
K(2.5)	1.5 - 2.5	0.73	0.72	0.55	0.29
K(6.0)	2.5 - 6.0	0.66	0.72	1.0	0.48
K(15.)	6.0 - 15.0	1.00	0.72	0.55	0.30
K^0		7.0	7.0	0.30	0.40
SUM					2.68

building and building services are now under way. The list of tasks related to defining the experimental facilities at KAON that are shown in Table VI still require a substantial amount of effort before the PDS can be declared complete. This list is extensive and there are many places where our colleagues interested in experimenting at KAON can help us. The workshops discussed above are one way in which people are encouraged to input their ideas but private communications are certainly welcome.

Table VI. Tasks Still Requiring Input

- Polarized Proton Beam Area
  - All Energies Needed?
  - Spectrometers
- Internal Targets
  - Site Definition
  - Spectrometers
- Neutrino Facility
  - Site Definition
  - Detector System
- Kaon Spectrometers and/or Detector Facilities
  - Floor Space Required
  - Compatability of Kaon and Hypernuclear Systems
  - High Resolution Versus Acceptance
- Production Targets
  - Radiation Hardening of Magnets etc.
  - Remote Handling Capability
- Proton Beams Downstream of Production Targets
  - Beam Reassembling Versus Bypass

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1. M.K. Craddock, (these proceedings).
2. J. Beveridge and J. Doornbos, TRI-DN-89-K19.
3. A. Yamamoto, Study on Low Energy Intense Kaon Beam K2, Thesis, KEK.