# Facility Impact and Funding Committee (FIFC) Report

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J. Haba, M. Ieiri, J. Imazato, R. Itoh, T. Kamitani, M. Kikuchi, H. Kobayashi, T Minura, K. Nishikawa, M. Nozaki, K. Sato, M. Takasaki, M. Tanaka, T. Tauchi and Y. Unno

## 1. INTRODUCTION

To evaluate validity and feasibility of the experiments planned in the Hadron Experimental Hall of J-PARC, the Facility Impact and Funding Committee (FIFC) of the Institute of Particle and Nuclear Physics (IPNS) was set up in the fall 2006.

Following the charges imposed by the IPNS director to the committee, the review is being made in the viewpoints as follows:

1) Technical validity and feasibility of the experiment and the detector.
2) Validity and feasibility of the requested beam.
3) Safety.
4) Validity of the cost estimate and the budget plan.
5) Validity of the human resource and the group organization.
6) Support requested to IPNS.

Those discussed and evaluated in the three meetings held in October, November and December 2006 were the two experiments approved for stage-2 (E05 and E13) and the four experiments approved for stage-1 (E07, E15, E17 and E19) in the last PAC meeting. The beam lines K1.8 and its branch line (K1.8BR) and the SKS spectrometer to be used by these experiments were also reviewed as major facilities at the Hadron Experimental Hall of J-PARC. In summary the followings subjects were investigated here.

- Beam lines K1.8 and K1.8BR
- SKS spectrometer
- E05: "Spectroscopic Study of $\Xi$-Hypernucleus, ${}^{12}_{\Xi}$Be , via the $^{12}$C($K^-$,$K^+$) Reaction"
- E13 : "Gamma-ray spectroscopy of light hypernuclei"
- E19: "High-resolution Search for $\Theta^+$ Pentaquark in $\pi^- p$ -> $K^- X$ Reactions"
- E07: "Systematic Study of Double Strangeness Systems with an Emulsion-counter Hybrid Method"
- E15: "A Search for deeply-bound kaonic nuclear states by in-flight $^3$He($K^-$, $n$) reaction"
- E17 : "Precision Spectroscopy of Kaonic $^3$He 3d -> 2p $X$-rays"

2. BEAMLINES K1.8 AND K1.8BR

The committee evaluated the designs of the K1.8 and K1.8BR beamlines. The K1.8 beamline is for experiments using $K^-$ beam of 1.8-GeV/*c* momentum with the front end which includes a production target and an initial beam collimator, two stages of electrostatic $K/\pi$ separation and a final focusing section. The K1.8BR is a beamline branching after the first-stage electrostatic separator off the K1.8 line and it has an independent final analyzing section. It is for experiments using a $K^-$ beam with lower momentum (0.8-1.1 GeV/*c*). The primary purpose of both beamlines is to supply high-intensity separated $K^-$ beams with low pion contamination with high momentum resolution. The structure of the beamlines, their beam optics and beam qualities were checked. In particular an external reviewer, Dr. J Doorndos, performed an independent beam simulation calculation and confirmed the validity of the optics and the expected performance of the beams basically. His report is attached at the end of this report. In regard to the beam tracking chamber system which is essential for beam particle momentum analysis, a review summary is given in a separate section later.

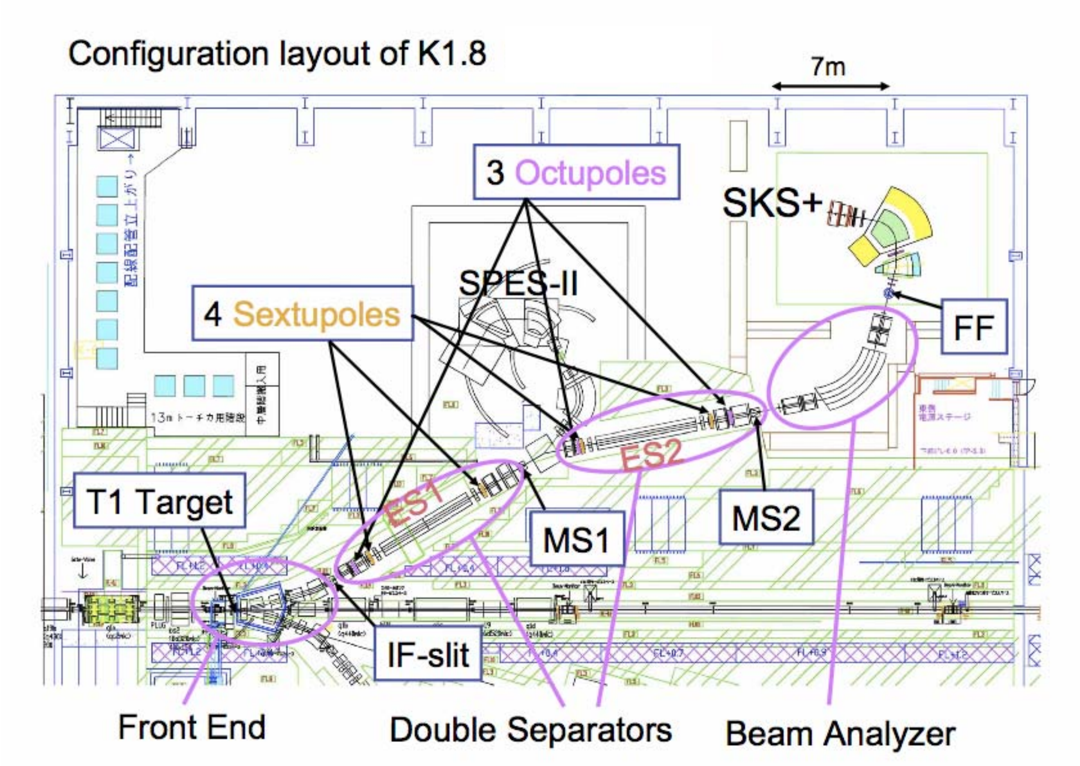


Fig. 2.1 Layout of K1.8 beam line

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## 2.1 K1.8 beam line

(1) Front end part

According to the full specification of the J-PARC accelerator, a proton beam with 750-kW power (15 μA×50 GeV) irradiates a 54-mm thick nickel target to produce a *K*-beam. In the initial stage of Phase-1 operation, however, the power is expected to be 270 kW (9μA×30 GeV). The beam extracted at 6° is collimated with a 200-mm thick copper block and is bent and focused by a dipole and quadrupole magnets, respectively. These magnets are placed in a huge vacuum chamber to avoid vacuum ducts which would be excessively heated by beam deposition. The chamber is separated from the downstream high-vacuum beam line by a 50-μm thick stainless steel window. The beam is vertically focused (IF) onto the window into a small spot size in order to reduce the additional aberration due to multiple scattering at the window. The target, the collimator and the magnets are designed with special care for less heating by the beams, better cooling and stringent preventions against water leakage. The committee does not find any essential problems in these hardware designs.

(2) Electrostatic separator and mass slits

Kaons are separated from pions by the two stages of 6-m long electrostatic separators with an 8 MV/m field. While a reused separator from KEK-PS will be applied at the 2$^{nd}$ stage, the 1$^{st}$ stage will be equipped with the newly designed separator for improved radiation tolerance. Several R&D and tests of the new separator is now going on. Mass slits (MS1, MS2) are placed to intercept pions at each end of the two separators. Shapes and materials of the slits will be optimized further for a higher $K/\pi$ ratio.

The committee foresees no significant concern about its performance. It is remarked that the experience at KEK-PS should be very useful and important in the operation of these separators.

(3) Final analyzing and focusing system

The beam coming out the 2$^{nd}$ electrostatic separator is momentum-analyzed by the system with a 64-degree bending magnet of 4-m radius and quadrupoles and focused onto the final focus (FF). Tracking chambers with 0.2-mm spatial resolution are placed in at the entrance and the exit of the final analyzer section to determine the orbit and the momentum of each particle with a momentum resolution of $\Delta p/p = 1.4\times10^{-4}$. The design of the beam analyzer section is similar to that of the KEK-PS K6 beamline.

The committee was convinced with this performance of momentum resolution from the beam optical point of view. However, in order to realize this performance, it is essential for the tracking chamber to work properly in the high hit-rate environment.

(4) Beam optics design and *K*/π separation

The beam optics of the K1.8 beam line is designed using the TRANSPORT code. The beam is focused vertically on the slits to eliminate pions. Four sextupoles are used to cancel the second order chromatic aberration. Three octupoles are added to cancel the third order effect to improve *K*/π ratio. The DECAY TURTLE code was used for particle tracking simulation to estimate the *K*/π separation performance. The simulation includes (a) the higher order aberration of the beamline up to the third order, (b) the effects of multiple scattering, nuclear elastic scattering, nuclear absorption in the slit materials and (c) the kaon decay in flight. The expected beam intensities are, $6.6 \times 10^6$ $K^-$/pulse, $0.83 \times 10^6$ pions/pulse with the *K*/π ratio of 7.9 at FF for the case of the full-intensity proton beam. More details are described in the table below. The values in the parenthesis are for the case of the 270 kW proton beam in the initial stage. The $K^-$ intensity and the *K*/π ratio are sufficiently large for the requirements from the experiments.

The committee agrees with the presented performance as a whole, although it wants to reserve some uncertainty in the estimate of *K*/π ratio. The counting rates in the tracking chambers are expected to be very high, especially at MS2. For the case of full-intensity operation some improvements on the tracking chambers should be necessary. This will be discussed more in the section 10.1.

| 1.8GeV/c (distance from target) | @MS1 (19.800m) | @MS2 (34.185m) | FF (45.853m) |
|---|---|---|---|
| K- ($\times 10^6$/pulse) | 68.2 (12.4) | 17.3 (3.2) | 6.6 (1.2) |
| π- ($\times 10^6$/pulse) | 1356 (284) | 15.6 (3.3) | 0.83 (0.17) |
| K/π | 0.05 (0.04) | 1.1 (0.96) | 7.9 (6.9) |

## 2.2 K1.8BR beamline

The K1.8BR line for lower momentum (0.8-1.1 GeV/*c*) $K^-$ beam is branched off after the first electrostatic separator into the opposite direction. There is no second electrostatic separator for this beam line. A final focusing system consisting of a dipole and quadrupole doublet comes just after the branching point. A sextupole is added to cancel the second order chromatic aberration. The design and performance estimate of this branch line are performed in the similar manner as the K1.8 line. The expected beam intensity is, $5.5 \times 10^6$ $K^-$/pulse with a $K/\pi$ ratio of 7.0 at the final focusing point for full-intensity proton beam. The intensity and the $K/\pi$ ratio are sufficiently large for the requirements from the experiments. An operation of the K1.8BR line needs time sharing with that of the K1.8 beam line.

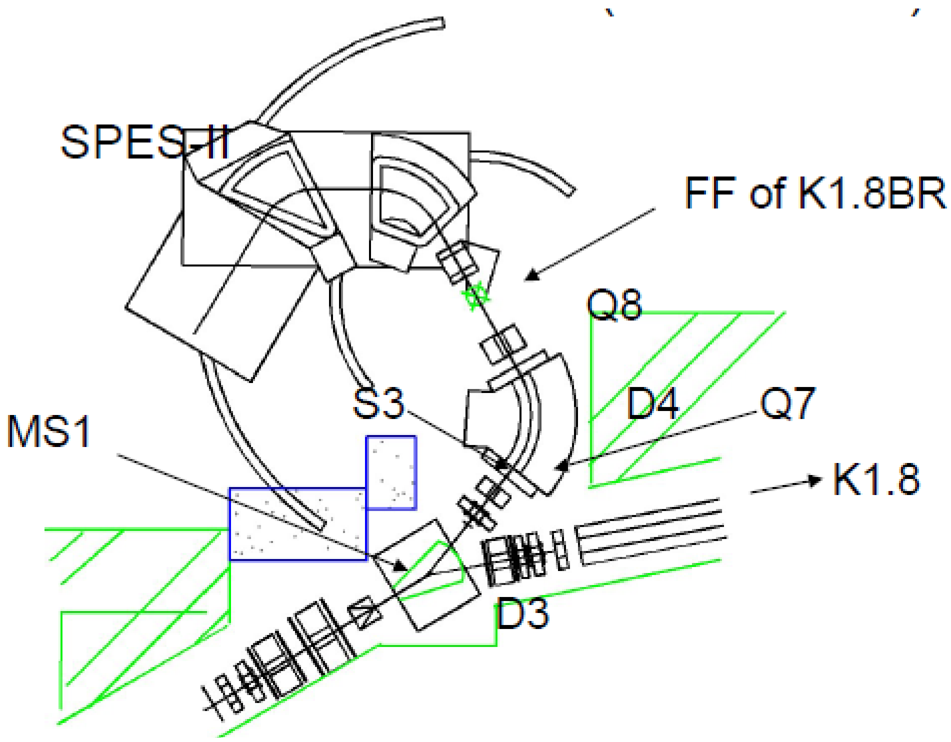



Fig. 2.2 Layout of K1.8BR.

The committee accepts the proposed performance of this branch up to the $K/\pi$ ratio which had better to be regarded with some ambiguity ( more than K1.8). As was pointed out in the simulation calculation by Dr. Doornbos, the committee was concerned about the muon contamination in the beam, since it could influence on the experimental conditions and thus the detector design significantly. The committee recommends both the beamline designers and the users to evaluate it seriously soon.

## 2.3 Conclusion

Based on the presented (a) beam line optics, (b) channel structure, (c) components design and (d) the status prototype test, the committee found no problem in the prospect that the K1.8 and K1.8BR beamlines will be operational with sufficient performance for the experiments, in general. It is remarkable that the high $K/\pi$ ratio presented by the designer in the simulation study has been supported by the independent check by the external reviewer (Dr. Doornbos). However, the ambiguity of the estimate has to be taken to be large. The experiment groups should take this ambiguity into the design and planning of their experiment reasonably.

## 3. SKS SPECTROMETER

### 3.1 Spectrometer system

The SKS spectrometer was used in KEK-PS from 1992 to 2005 with a successful operation history. A reuse of it at the K1.8 beamline of the J-PARC Hadron Hall is intended for the E05, E13 and other experiments. Here is a summary of the evaluation of the proposal.

1)Good experience with the SKS magnet has been accumulated in the KEK-PS and no problems are foreseen in its reuse. The operation mode "SKS-minus" in which the magnet is operated at a reduced field also shows no problem.

2) The addition of the new "D" magnet for the E05 experiment is planned in the “SKS-plus” mode to focus the beam onto the chambers in the down stream whose resolution is $\sigma$~300 μm. The committee discussed the possibility to realize a similar performance without the addition of "D" magnet by replacing DC3 and 4 with higher

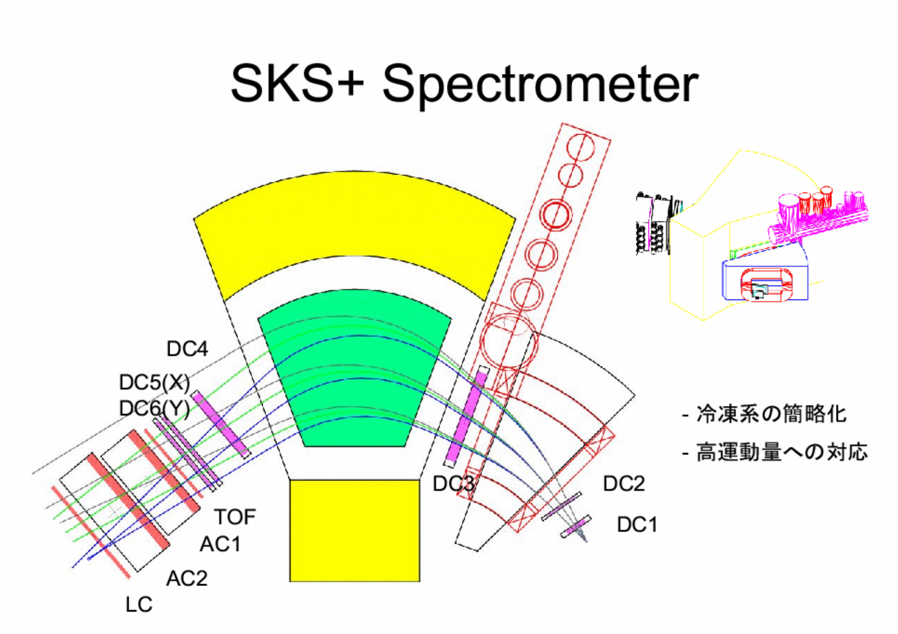



Fig. 3.1 SKS Spectrometer.

resolution ($\sigma$~100 μm) chambers as proposed in E13. This was checked to be possible by the E05 group themselves using an improved simulation. However, the size of the chambers must be wider because the beam would be focused weakly, and it seems difficult to keep the original resolution of $\sigma$~100 μm for a long time over such a wide area. Therefore, the committee endorses the original plan with the addition of the "D" magnet.

3) The committee highly evaluates the adoption of small GM-JT refrigerators for superconducting magnet cooling, which enables much easier operation and maintenance of the cryogenic system and larger mobility of the spectrometer setup in the area. The committee anticipates good results of this cooling scheme to be tested soon.

### 3.2 Sharing instrumental setup among experiments

The committee examined experimental setups with the SKS magnet proposed by several experiments and found that a large part of the instruments can be common among them. For example, the MWPCs and drift chambers in the up- and downstream of the SKS magnet are commonly used by various experiments although the requirements to the resolution and size are different. The committee asked those experiment group why not they will try to have a common instrumentaton in the SKS spectrometer. Their answer were two fold; 1) they like to apply their existing instruments previously used in KEK-PS experiments, and 2) there were no particular discussions about the sharing of instruments among experiments at the time of planning the experiments.

The committee considers the possible sharing of the instruments can reduce the total cost of experiments and demand on the human resource. Therefore the committee suggests to equip the SKS magnet and nearby instruments together as the "SKS facility" which is maintained under the responsibility of IPNS. The optimal design of instruments should be drawn by the "core" team which runs the experiments with the SKS magnet. The reorganization of the existing group which is responsible for the SKS magnet to pursue this possibility is highly appreciated.

### 3.3 Safety

The cryogenic system has to obey the refrigerator regulation of the Japanese high-pressure gas safety law. The system including new GM refrigerator units has already been proven to clear necessary conditions by the authority and therefore the cryogenic equipment is secure.

## 4. E05 "SPECTROSCOPIC STUDY OF Ξ-HYPERNUCLEUS, $^{12}{}_{\Xi}Be$ , VIA THE $^{12}C(K^{-},K^{+})$ REACTION"

### 4.1 Detector system

(1) Outline of the system

The E05 detector system is to measure the binding energy and decay width of the bound state of the Ξ hyper nucleus. The experiment requires high intensity and pure $K^-$ incident particles from the K1.8 beam line and the high precision SKS-Plus spectrometer system to measure the $K^+$ particles that are decaying from the Ξ hyper nuclei.

The incident $K^-$ particles are assumed to be 1.8 GeV/*c* with the intensity of $1.4\times10^6$ /spill (spill=0.7s) and the *K*/π ratio of 6.9 of the design of the Phase–1 runs (30 GeV× 9μA). In the K1.8 beamline the spectrometers are made of BC1 and BC2 chambers in the upstream and BC3 and BC4 in the downstream of the analyzing magnets of Q10-Q11-D1-Q12-Q13 system. The BC1 and BC2 chambers are to be MWPC's with the wire spacing of 1 mm and BC3 and BC4 are drift chambers with the anode wire spacing of 3 mm. The MWPC's and the drift chambers are read with the SONY ASD chips with a shaping time constant of 80 ns. The high rate capability of the chamber and the readout will be evaluated in beam-tests in next year by using the completed 3 planes of the MWPC's.

The SKS-Plus spectrometer is to be equipped with the DC1 and DC2 chambers in the upstream and DC4, DC5, and DC6 in the down stream of the SKS-plus magnets. As the incident particles pass through, the DC1 and DC2 chambers are the drift chambers with the same anode wire spacing of BC3 and BC4, and with the same ASD readout chips, but with multi-hit TDC system. The DC4 and others do not require high rate capability and the drift chambers of the previous SKS experiments will be used with wide anode spacing and with a 16-ch hybrid-IC preamplifier with a single-hit TDC system.

The DC3 chamber is to be placed between the SKS and the D-magnet to understand spectrometer optics. This is a newly build drift chamber with hexagonal cells with anode-wire spacing of 10-20 mm, which is thin to minimize multiple scattering. In case the multiple scattering is to become an issue, it will be removed once the optics has been understood.

(2) Chamber rate performance

As examined in 10.1, the rate at the BC1 is barely acceptable without any headroom. By considering the particle distributions in the chambers, especially at BC1, BC4 or DC1, the highest hit rate per wire could reach at 0.2-0.3 MHz. This is at the edge of the proven experience where analysis efficiency has been maintained. Accordingly, all the BC detectors are required to be upgraded drastically for the Phase-2 run.

Due to the space charges, the gas gain of BC1 and BC2 (MWPC's) are expected to decrease to be about 60% at the wire-hit rate of 100 kHz. The threshold of the ASD can be adjusted to lower thresholds to recover the efficiency. The new ASD being developed by the KEK electronics group has shorter shaping time and pole-zero cancellation. This new chip can have a higher gain to compensate the loss of the gas gain.

Extrapolating to the E05 experiment, the life of the chambers are, about 5 yrs for BC1 and BC2, 5-10 yrs for BC3, BC4, DC1, and DC2 and no limit foreseen for DC3, DC4, DC5, and DC6. The scintillation counters in the upstream of the K1.8 beam line should be replaced in 5-10 yrs.

(3) Conclusion

In summary, the detector system, especially the position sensitive chambers, is well considered for the intensity in the Phase-1 runs. For the Phase-2 run, those chambers such as BC1, BC2, BC3, BC4, DC1, and DC2 require a significant upgrade for the expected higher rates. In addition, those such as BC1 and BC2 may have come to the end of life within 5 yrs in the Phase-1 runs. For the foreseen Phase-2 runs in 5-10 yrs timescale, the new chambers with higher rate capability and longer life will be required. A prompt development of such chambers would be needed no later than the initial run has been completed in Phase-1.

## 4.2 Safety

The chamber gases are inflammable. An exhaust-gas control and a gas leak detector should be equipped. Inspection and a check are required before its use.

### 4.3 Experimental cost

The experiment group has estimated the cost of the beamline instruments and the SKS spectrometer together with related electronics to be 1.6 oku-yen, which will be covered by the Grant-in-Aid for Scientific Research (Tokutei-Ryouiki). The grant will continue until the end of JFY2009. We find no problem about the funding of this experiment. However, it should be noted that the cost of refurbishment and transport of the SKS superconducting magnet, which is calculated to 2.3 oku-yen, is not included in the above budget. Considering the current tight funding situation, the experiment group is encouraged to reduce the cost as much as possible.

### 4.4 Human resource

There seems to be no big problem in group organization and man-power of this experiment. Some general comments are found in **10.4**.

## 5. E13 "GAMMA-RAY SPECTROSCOPY OF LIGHT HYPERNUCLEI"

### 5.1 Detector system

(1) <u>Ge detectors</u>

The experimental group has conducted experiments with gamma-ray spectroscopy of hypernuclei by employing Germanium gamma (Ge-gamma) detectors at KEK-PS and BNL. This experiment (E13) will double the number of Ge-gamma detectors from the previous experiments which have used 14 Ge-gamma detectors, each of which consists of a crystal with a 7cm diameter and 7cm length. Therefore, the enlarged detector system can be well managed within their capability based on good experiences.

The group proposed (1) an operation of the Ge-gamma detectors at lower temperature than previous experiments, i.e. below 85K, to increase radiation hardness for higher intensity beam at JPARC, and (2) replacement of background veto detectors from BGO crystals to PWO ones to have sufficient alive time under the intense background with a faster time response. These two issues should be reviewed.

The radiation hardness is very important to have good energy resolution in E13. However, it seems that an experimental effort is not sufficient in quantitative understanding between the operational temperature and the hardness. The group is developing a cryogenic system for lower temperature operation in collaboration with the KEK cryogenic group. At present, a vibration caused by the cryogenic system attached directly to the detector cryostat affects the electronics of Ge-gamma detectors which prevents from having a good energy resolution. The committee encourages the group to overcome this problem.

(2) PWO

The group showed that the light yield of PWO is about 1/15 of BGO, which can be doubled by doping. Even with the doped PWO crystal with the light yield of 3.9 photo-electrons/100 keV, a single photo-electron detection must be necessary for sufficient gamma-veto. The committee concerns whether the performance of PWO detectors is enough or not.

(3) Conclusion

We understand that the proposed modification of SKS spectrometer is matched to the experimental purpose. Since the SKS spectrometer can be a facility together with K1.8 beam line, the spectrometer is expected to be common to E05 experiment. Also, data acquisition system could be standardized. We would like to encourage the experimental groups to extend effort towards the common facility and the standardization.

The committee appreciates the international contribution especially to the large drift chambers and PWO crystals. Such in-kind contributions are encouraged for international collaboration.

As explained in (4)-2) below, the E13 experiment does not need lower temperature operation of Ge detectors at any cost. However, the committee encourages the group to continue the development of refrigerator for better performances as well as for future experiments. Also, the committee suggests to operate doped or undoped PWO at a reduced temperature (0 $^{o}$C or -20 $^{o}$C, respectively), for the same performance as the BGO.

(4) Questions to and answers from the group

1) *Radiation damage data of 14 Ge-gamma detectors in previous experiments, e.g. energy resolution as a function of radiation dose, which may have recovery with*

*annealing:*

In general, a radiation damage of n-type Germanium detector will appear after exposing with neutron flux of O($10^9$ n /cm$^2$) and it will be permanently damaged with O($10^{10}$ n /cm$^2$). The group estimated the neutron flux by a GEANT4 simulation. The estimations agree with those calculated by an empirical formula within 30% error. Since a Ge detector of the Hyperball has total surface area of 39 cm$^2$, the damage will appear with about $4\times10^{10}$ n/detector. The 14 Ge detectors have been used at experiments of E419/KEK, E930/BNL and E509/KEK for 1998-2002. The total neutron flux was estimated to be $1.9\times10^{10}$ n/detector. The energy resolution (FWHM) has degraded from 3keV to 4 keV for 1.33MeV gamma. After all the Ge detectors were warmed up at room temperature, they were cooled down for the energy resolution measurement. The measured FWHMs ranged from 5 to 20 keV. After annealing at 100$^{o}$C for 24 hours, their resolutions were recovered to 3keV but with tails. Then the detectors were used at E518/KEK and E566/KEK with neutron flux of $1.1\times10^{10}$ and $1.3\ \times10^{10}$, respectively. The detectors have to be annealed with much more time for the 3keV energy resolution. The group concluded that the Ge detectors must be annealed after every 2 x $10^{10}$ n/detector.

*2) Tolerance of the radiation damage and expected value at the full-intensity, J-PARC:*

The group estimated that the first annealing must be necessary after 120 days with full beam intensity at E13, J-PARC. Since the E13 machine time is 54 days with a full intensity, the annealing will not be necessary. In a future experiment at K1.1 beam line, the annealing will be needed in every 14 days with a *K* intensity of $0.6\times10^7$ /spill. Taking account of the permanent damage limit and practical annealing time, the maximum number of times of of annealing is estimated to be 10/detector. If the detectors are cooled down at less than 85K while they have been operated at 96K, the damage limit would increase significantly.

*3) Radiation damage data at 85K and the theoretical values:*

The group showed a published data on measurements of the energy resolution as a function of temperature after exposure of $3.2\times10^8$ n/cm$^2$ with 1.33 MeV gamma at 72 K, where the neutron flux corresponds to $1.2\times10^{10}$/detector in this experiment. The FWTM becomes worse at 75K, while the FWHM varies slower than the FWTM. There seems to be no critical point at 85K, where the FWHM crosses 3.0% from the beginning of 2.5%. The data show that the damage is less at lower temperature, and the committee suggests the operation at less than 75K. The group will reproduce the above measurement with the pulse tube refrigerator being developed at KEK.

*4) Simulation results of background suppression with BGO and PWO crystals, also experimental performance with BGO crystals:*

A gamma with the energy less than 1MeV shows different suppression capabilities of PWO and BGO. First, the group showed simulation results of the suppressions with PWO at 20 $^{o}$C, 0 $^{o}$C, -20 $^{o}$C and BGO for 1MeV gammas, where the PWO is doped with $La_2O_3$. The PWO performances of less than 0$^{o}$C are very similar to BGO. The group showed measurements on the suppression by undoped PWO at ±20 $^{o}$C and BGO with 1.33 MeV gammas from $^{60}$Co. The measurements show the same suppression with undoped PWO at -20 $^{o}$C and BGO.

Assuming that doped and undoped PWO have the same suppression at 0 and -20$^{o}$C, respectively, the simulation agrees with the measurement. Also, the group shows the measurements with undoped PWO (T536) at room temperature with similar setup to the hypernuclear experiment at K6, KEK. The PWO has less suppression by about 50% than the BGO in the gamma energy of less than 0.7 MeV, while both crystals have the same suppression above 0.7 MeV.

5.2 Safety

The chamber gases are inflammable. An exhaust gas control and a gas leak detector should be equipped. Inspection and a check are required before its use.

5.3 Experimental cost

There seems to be no major matter in the budget of E13. According to the E13 group, the construction cost of Hyperball-J is 3.15 oku-yen, including the central germanium detectors, the PWO calorimeter, and the SksMinus spectrometer system. A total of 2.9 oku-yen will be appropriated by the Grant-in-Aid for Scientific Research (Tokutei-Ryouiki) that will be continued until the end of JFY 2009. The foreign collaborators are expected to cover the rest of the apparatus such as various counters for the SksMinus spectrometer. The group is also considering the possibility to utilize used counters as a backup.

5.4 Human resources

There seems to be no big problem in group organization and man-power of this experiment. Some general comments are found in **10.4**.

# 6. E19: "HIGH-RESOLUTION SEARCH FOR $\Theta^+$ PENTAQUARK IN $\pi^- p$ -> $K^- X$ REACTIONS"

6.1 Detector system

E19 proposes an experiment to search for a pentaquark resonance by $p$ ($\pi^-$,$K^-$) reaction at the K1.8 beam-line in the Hadron Hall. E19 expects a higher sensitivity than KEK-PS E522 because of higher beam intensity and better mass resolution using the SKS spectrometer. Beam-line setup is the same as E05 and E13 except target area. E05 intends to modify beam line by adding a dipole magnet before SKS spectrometer. If E19 use the same instrumentation, the acceptance is 4 times smaller than those without the dipole magnet. E13 also intends to add Ge detectors (Hyperball-J) around the target area. E19 may try to keep compatibility with E13, with one or two weeks for rearrangement of the SKS downstream detectors due to a different SKS magnetic field. Since E19 uses $p$ ($\pi^-$,$K^-$) reaction, a high intensity pion beam goes through the beam-line to the target instead of $K$ beam. Typical pion beam intensity is predetermined by the capability of the beam-line chambers. As described in 10.1, the maximum allowable counting rate is expected for standard wire chambers to be 0.3 MHz/wire and therefore the beam rate would be limited to $1.3 \times 10^7$ $\pi$/sec for BC1 with a 1mm spacing MWPC.

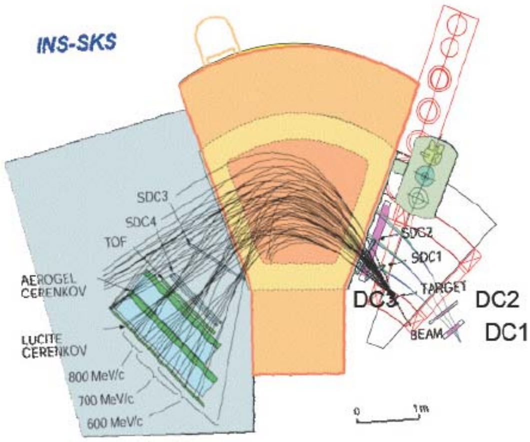


Fig.6.1 Layout of E19 experiment

The expected sensitivities for the requested beam time with the above mentioned beam rate are 75 nb/sr for Γ< 2 MeV or 150 nb/sr for Γ =10 MeV. Fig. 6.2 shows the dependence of sensitivity on statistics for Γ< 2 MeV.

In summary this experiment has sufficient feasibility with a rather low intensity beam at the early stage of J-PARC.

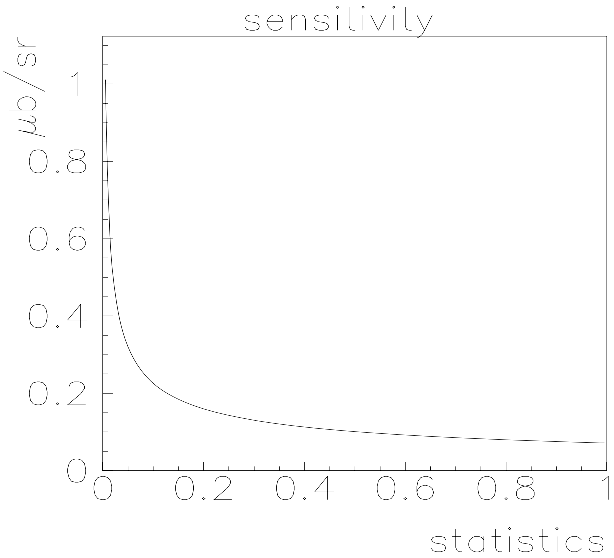



Fig. 6.2 Sensitivity dependence on statistics. The *x*-axis shows ratio to statistics at the Phase I full intensity beam condition

6.2 Safety

1) The committee checked the safety issues of the proposed hydrogen target. The hydrogen target would be secure, because the E19 group will use the same equipment used in the previous experiment at KEK-PS. However, it might be subject to safety regulations at J-PARC yet to be settled along with other high pressure gas equipments. For example, the setting pressure of a safety valve etc. should be inspected before its use under the regulation in J-PARC.

2) The chamber gases are inflammable. An exhaust gas control and a gas leak detector should be equipped. Inspection and a check are required before its use.

6.3 Experimental cost

The E19 group needs no new detectors for the baseline experiment and the expenditure will be covered by RIKEN even if the group failed to acquire a new fund. However, an additional fund is needed to build the new beamline drift chambers that are recommended in the previous section.

6.4 Human resources

There seems to be no big problem in group organization and man-power of this experiment. Some general comments are found in **10.4**.

6.5 Conclusion

There are no major issues other than the following comments. The committee regards that E19 is feasible at an early stage of J-PARC experiment.

1) Collaboration among the users at K1.8 beam-line (especially E05, E13 and E19) to develop a high-rate beam line chamber should be encouraged since it is essential for all those experiments to stand the high rate beam of J-PARC and it also helps the group to save any resources of the experiments.

2) Optimization of statistics and feasibility should be considered in a reasonable manner. As shown in the figure above, a significant sensitivity would be achievable with rather low statistics (namely low beam intensity). The reasonable goal of the experiment should be discussed in PAC.

## 7. E07: "SYSTEMATIC STUDY OF DOUBLE STRANGENESS SYSTEM WITH AN EMULSION-COUNTER HYBRID METHOD"

### 7.1 Detector system

E07 is the experiment to acquire ~$10^4$ $\Xi$ stops in the emulsion which is 10 times more than that of the previous experiment E373 at KEK-PS, and to observe an order of $10^2$ S=-2 nuclei. The experimental setup is inherited from E373, but silicon trackers are newly added in front of and behind the emulsion stack for the better reconstruction efficiency.

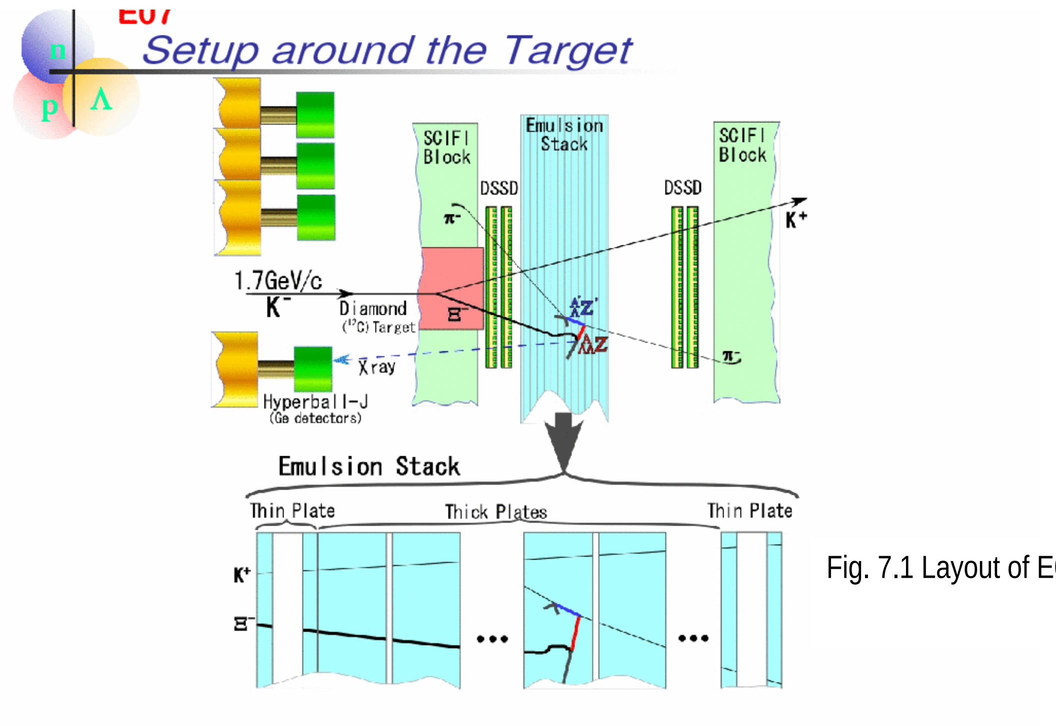



Fig. 7.1 Layout of E07 experiment.

The committee does not foresee any technical problems in this setup and basically endorses the original design of the experiment. However, there are two concerns raised. One is related to the choice of a spectrometer magnet. The use of the SKS magnet instead of the originally proposed KURAMA would reduce the acceptance by a factor 2. This reduction will reflect directly to the total amount of the emulsion. Apparently there is no strong reason to use SKS unless a technical difficulty to remove SKS or to let KURAMA coexist with SKS is encountered. Therefore the committee favors the use of KURAMA for this experiment.

Another concern is on the method to align two DSSDs and the emulsion stack. It is normally achieved using a high statistics beam data. However, it might be difficult to use tracks recorded in the emulsion for this purpose since the stack is frequently replaced and number of tracks used for the alignment is limited. Since the question has not yet answered to by the experiment, the committee expects to hear the strategy on this issue from the group at the coming PAC.

7.2 Safety

The chamber gases are inflammable. An exhaust gas control and a gas leak detector should be equipped. Inspection and a check are required before its use.

7.3 Experimental cost

The E07 group has estimated the emulsion related cost to be about 1 oku-yen, of which 3,500 man-yen has already been spent to purchase half the emulsion necessary for the KURAMA option. Although the group is applying to a grant for the tools and chemicals for development, they have no plan to secure the remaining half of the emulsion. The microscopes for scanning will be provided by collaborators. The detectors other than emulsion will supplied from other experiment groups.

7.4 Human resources

There seems to be no big problem in group organization and man-power of this experiment. But the comment in **10.4** is referred.

## 8. E15 “A SEARCH FOR DEEPLY-BOUND KAONIC NUCLEAR SYSTEM BY IN-FLIGHT $^3$He(K$^-$, n) REACTION”

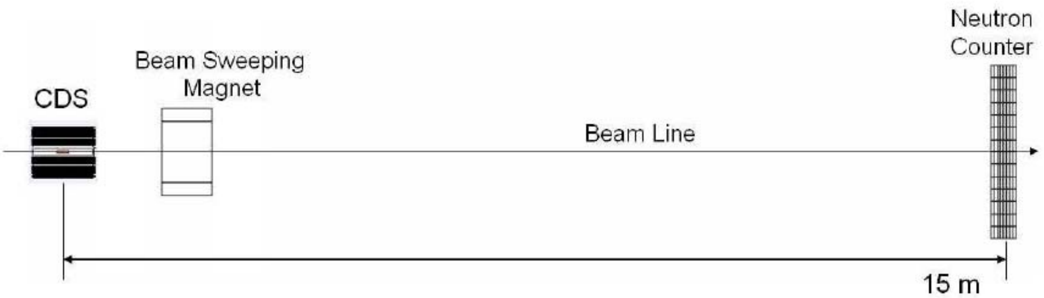



Fig.8.1: Global setup of the E15 experiment

### 8.1 Detector system

(1) Outline of the system

The E15 experiment aims to measure *K*-mesic nuclei by measuring simultaneously the neutrons and decay particles in the reaction of $K^-$+$^3$He to ($K^-pp$)+$n$. The neutrons are measured with a neutron counter set at zero-degree. One observable is the missing-mass by using the momentum of the incident $K^-$ particles and that of the neutrons. The other is the invariant mass of the $K^-pp$ system by reconstructing the Λ particles that decay into p and π particles. In order to maximize the yield and the resolution of missing-mass, the momentum of $K^-$ is chosen to be 1.0 GeV/*c* from the K1.8BR beamline. The momentum resolution of the beamline, $\delta p/p$, is estimated to be 0.02% (rms). This contribution to the resolution of missing-mass is much smaller than that of the time-of-flight resolution of the neutron counter.

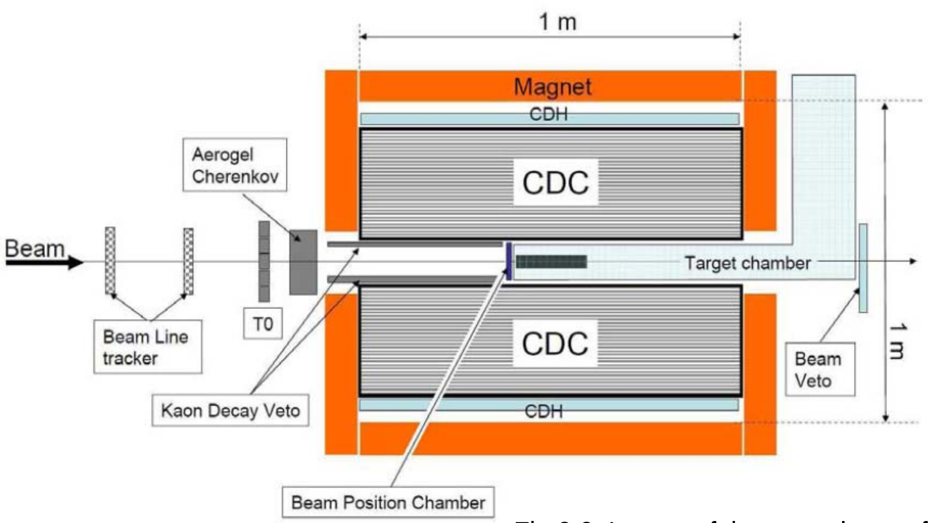



Fig.8.2: Layout of the central part of the E15 detector

(2) Chambers

The singles rate of the Day-1 runs (30 GeV×9 μA, 0.7-s flat top) is 2.8 MHz/plane at VI and 1.1 MHz/plane at FF. The peak rates after the particle distribution in the planes is estimated to be 140 kHz/0.5cm. The readout of the beamline chambers is designed to cope with the rate.

The beamline chambers are recycled from the previous experiments: BLC1 at VI is a drift chamber with a cell size of 5 mm (drift length of 2.5 mm) and BLC2 at FF of an 8 mm cell (4.0 mm drift length). Both chambers are to be read with the new preamp-shaper-discriminator ASIC (ASD chip) being developed by the KEK electronics group. The ASD chip has a short shaping-time constant and a pole-zero cancellation that enable multi-hit separation. The ASD board will be prototyped in the beginning of 2007 when the ASD chip will be available.

(3) Other counters

To identify the incident kaons, an aerogel Cherenkov-counter will be used between the VI and FF in the beamline at the entrance of the Cylindrical Detector System (CDS). The neutrons in the forward direction are emitted at 1.3 GeV/*c* and to be measured with the forward spectrometer that utilizes the time-of-flight (TOF) method. With the time resolution of 150 ps(σ) and the momentum resolution of the incident particles of $\delta p/p$=0.1% (while the expected resolution of the K1.8BR beamline is 0.02%), it is expected to achieve the missing-mass resolution of $\sigma$ = 12 MeV/$c^2$ (i.e., FWHM=28 MeV/$c^2$) with the possible longest distance of 12 m in the experimental hall.

The unreacted $K^-$ particles of the incident beam need to be swept away by a sweeping magnet with a magnetic field strength of > 0.6 Tm. The magnet available for the purpose is KURAMA, USHIWAKA or SHIZUKA, with an existing power supply.

In order to reconstruct the decay particles (Λ and p) from the $K^-pp$ bound state with high efficiency, the target is covered with the CDS that is made of a solenoid, a cylindrical drift chamber (CDC), a trigger hodoscope surrounding the CDC, and a scintillator inside the CDC that vetos the particles from kaons.

(4) Required performance etc.

The design goal for the reconstructed mass resolution is set to be FWHM = 40 MeV/$c^2$

in order to resolve the mass difference of 74 MeV/$c^2$ between the background process of $K^-pp \rightarrow \Sigma^0 p$ and the $\Lambda p$ with the mass resolutions of 2 MeV/$c^2$ for $\Lambda$'s. After analyzing the reconstructed mass resolution with the magnetic field strength (B) and the momentum resolution that is governed by the position resolution of 250 μm and the length of lever-arm (L), the resolution of 40 MeV/$c^2$ is achieved with the $BL^2 > 450$ Tcm$^2$ that leads to the choice of B = 0.5 T and L = 30 cm. The uniformity of the magnetic field is calculated to be within +/- 1.5%. The solenoid is to utilize an existing power supply of >1,000 A.

The CDC will be built newly and has a length of 86 cm, an inner radius of 15 cm, and an outer radius of 48 cm. The endplates are made of aluminum of 2-cm thickness and the outer and the inner cylindrical walls are to be made of carbon-fiber whose thickness is being optimized. The cell structure of the drift chamber is hexagonal of a size of 1.5 cm x 1.5 cm that enables the circular approximation for the drift field. The total number of layers is 17 that are split into 3 super-layers of axial layout (A) made of 3 axial layers each and 2 super-layers of stereo layout (U or V) made of 2 stereo layers each. The He-Ethane 50%-50% gas is to be used in order to minimize the amount of material in the tracking volume. The drift time has been analyzed with the GARFIELD program. The signals are to be read out with the ASD board using the same ASD chips as the BLC chambers.

The inner scintillator is to veto the $K^- \rightarrow \pi^- \pi^0$ or $\mu^- \nu$ decays in the decay volume between the aerogel counter and the target. This veto counter is critical for suppressing the background in the trigger level.

The DAQ system is to utilize the COPPER system that is being developed by the KEK online group.

(6) Conclusion

In summary, the detector system is well designed for the goal of the experiment. The experiment utilized a number of external devices: the sweeping magnet and its power supply, the power supply for the CDS solenoid, the ASD chips, and the DAQ system. The availability and the choice of the sweeping magnet and power supplies are to be discussed with the J-PARC facility group. The USHIWAKA may be applicable with a slight modification to restore its original gap. The SHIZUKA may be readily available, however, the size of its gap has to be confirmed. The power supply with the current of

1250A should be available for the solenoid. The development of the ASD chips and the prototyping of the ASD boards are done in collaboration with the electronics development group of KEK. The DAQ system is with the online group of KEK. The committee appreciates the already-existing communication with those groups and recommends reinforcing it further for smooth preparation and execution of the experiment.

### 8.2 $^3$He target

The committee consulted with Dr. T.Haruyama of the IPNS cryogenics group about the feasibility of the $^3$He target. The technology of the $^3$He target designed for E15 utilizes the gas condensation through a heat exchange with 1.25 $^o$K Liq. $^4$He. The system will be constructed by modifying the previous super-fluid $^4$He target used for the KEK-PS experiments. This technique for $^3$He should be feasible for the project, if a few technical key-points will be clarified. They are: 1) uncertainty of the temperature of the $^3$He target and 2) pressure tolerance at Be and stainless-steel connection in $^3$He target vessel

For the point 1), an experiment with $^4$He is planned to estimate so-called Kapitza heat conductance between $^4$He and a Cu surface at the condenser. The result can be applied for the estimation of the conductance between $^3$He and Cu surface, which is known with a good precision relative to that of $^4$He (an order of magnitude lower). Just in case of much lower heat conductance than expected, an additional improvement, such as increasing the total surface of the heat exchanger, should be effectively applicable. For the second point 2), so far, a pressure test was done by an all-stainless steel target vessel. Since the real experimental target will use Be and stainless-steel connection, further follow-up reports on this point will be desirable.

### 8.3 Safety

The gases are inflammable. An exhaust gas control and a gas leak detector should be equipped. Inspection and a check are required before its use.

### 8.4 Experimental cost

All the expenditure, which was estimated to be 1.95 oku-yen, will be provided by the Grant-in-Aid for Scientific Research (Tokutei-Ryouiki) that will continue until the end of JFY 2009.

### 8.5 Human resources

There seems to be no big problem in group organization and man-power.

## 9. E17 "PRECISION SPECTROSCOPY OF KAONIC $^{3}$He 3d → 2p X-RAYS

### 9.1 Detector system

This experiment (E17) is a descendant of E570 at KEK-PS. The target is changed to liquid $^{3}$He (500 cc) at 1.4 K. They upgraded various techniques such as the beryllium target window, two clustered SDDs, two calibration foils and pre-amplifiers in vacuum. The trigger logic will be unchanged.

There are issues to be reviewed in the technical aspect as follows.

1) Trigger rate will be too high, if the beam intensity is design value.

2) Charged particle backgrounds from beam halo at SDD, e.g. SDD have been reset at several 100 Hz for the background at E570 in KEK-PS.

3) SDD had gain drift of about 10eV during a shift for unknown reasons at E570.

4) How much is a systematic error in the *X* ray energy measurement while the experimental goal of statistical error is 2 eV ?

The E17 group suggests an experiment with lower beam intensity unless the group can reduce the trigger rate with charged-particle veto counters etc. This sounds reasonable since the requested beam time is 2-3.5 days with full intensity (30 GeV×9 μA) along with a commissioning of 10 days for the beam line.

The committee understood that SDD is the best *X* ray detector for better energy resolution with a larger acceptance. The committee would like to ask the group for the tolerable hit rate of the charged particles at SDD and the estimation at E17. Especially, the committee is interested in the acceptance of the foils which extend to SDD. Also, the beam profile with halo should be shown in the target region. The existence of muon contamination with halo which amounts 1.75 times of the total kaon flux was pointed out in the course of the K1.8-BR beamline review. The committee recommends that its influence should be worked out.

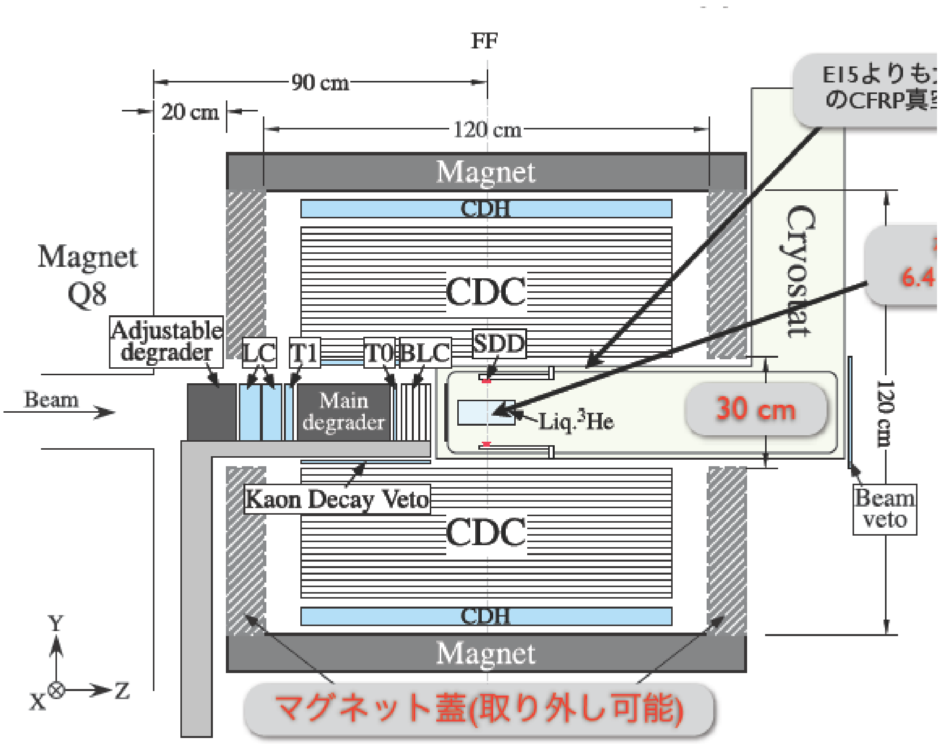



Figure: The Detector of E17

Since the gain can be calibrated real-time by in-situ energy calibration, the drift may not have a relevant error. However, the committee would like to encourage the group for detailed investigation of the systematic errors originated from gain variations. E570 has already shown the performance of discriminating 40eV energy shift. To examine the shift of less than 10 eV from the recent theoretical calculation, E17 must have the systematic error similar to the statistical one as small as 2 eV. The committee may suggest both measurements with $^4$He and $^3$He for enhancing signals to see consistent results. Therefore, the cmmittee would like to ask the group to report the detailed evaluation of the systematic errors of E17 and the error estimated at E570 to PAC.

9.2 Safety

The chamber gases are inflammable. An exhaust gas control and a gas leak detector should be equipped. Inspection and a check are required before its use.

9.3 Experimental cost

A part of the apparatus is in common with the E15 experiment and the common part will be provided by the E15 group. The rest of the apparatus including X-ray detectors, target system, beamline tracking chambers, and DAQ system amounts to 27 million yen, of which grant will be applied.

### 9.4 Human resources

There seems to be no big problem in group organization and man-power.

## 10. GENERAL REMARKS

### 10.1 Performance of beamline chambers

<u>Experience with high count rate environment</u>

Fig. 10.1 shows the downstream part of the K1.8 beam-line. Five gas detectors (BC1, BC2 BC3, BC4 and DC1) will be operated under a high intensity beam condition. BC1 and BC2 are installed around MS2, and BC3, BC4 and DC1 are installed around FF. The tracking efficiency with those detectors should be kept as high as possible even under the high count rate beam condition. Here we concentrate on the discussion of

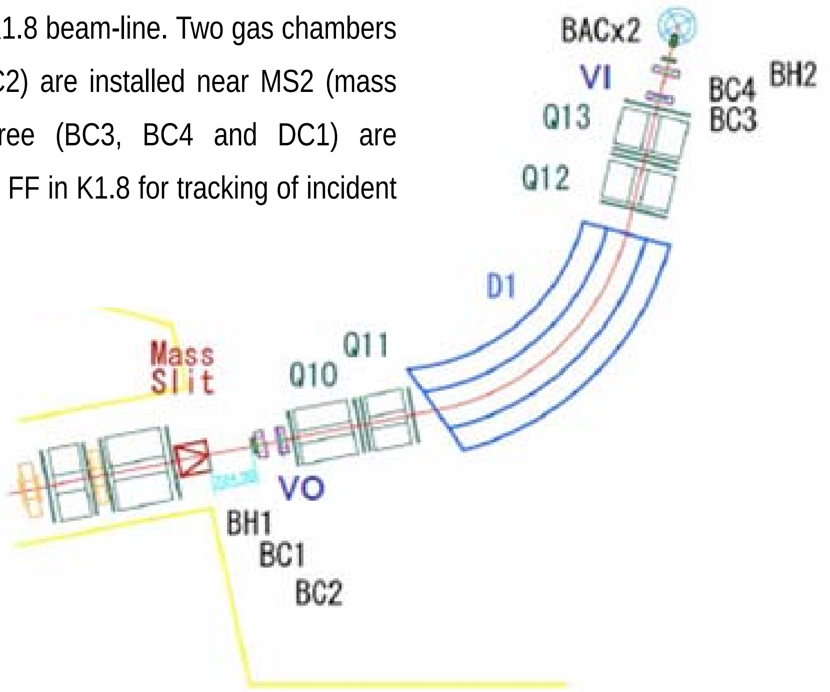



Figure 10.1 K1.8 beam-line. Two gas chambers (BC1 and BC2) are installed near MS2 (mass slit) and, three (BC3, BC4 and DC1) are installed near FF in K1.8 for tracking of incident particle.

BC1, BC4 and DC1 operation where the beam profile is expected to be smaller than those on BC2 or BC3.

To see the practical limitation of the typical wire chamber used in the KEK-PS experiments, some numbers given by the experimental groups summarized here.

Drift chambers with 5mm anode wire pitch were used at the K6 beamline together with the preamplifier of time constant of 30 ns. Since there is no big difference of the beam size distribution between the PS-K6 and J-PARC K1.8, the following discussion will be done using the total (integrated) flux. In the normal case of 4.0-s duration with 2.2-s flat-top and 1.9-s extraction width, the experimental group were able to use pion beam with 3.3~$3.6\times10^6$ /spill on target at PS-K6 with an analysis efficiency of greater than 95%. Counting rate at the upstream of the spectrometer was twice more than that at the downstream. Taking positron contamination of about 10% into account, the rate was calculated to be,

$2.1\times10^6$ /sec. at the downstream

$4.2\times10^6$ /sec. at the upstream.

On the other hand the experimental group operated their detectors under the condition of 2.67-s duration and 0.57-s extraction to fit the request by the other experiment. They managed $2.0\times10^6$ pions/spill on target as an upper limit. Thus the beam intensities were,

$3.9\times10^6$ /sec. at the downstream

$7.9\times10^6$ /sec. at the upstream

Some degradations of the tracking efficiencies and the position resolution were clearly observed in this case, although the figure of merit (efficiency×intensity) was still good. Accordingly, the maximum intensity without any degradation of performances will be around $5\times10^6$ /sec. as a total flux. Considering the beam profile and the wire spacing (3mm), the maximum counting rate per wire were also estimated to be $3\times10^5$ /s/wire for the chambers with the electronics used in the KEK-PS experiment.

Consideration of gas detector operated under high count rate

(1) Gain degradation due to space charge

Early studies using a high intensity beam (ex. NIM A446 (2000) 435) report a gas gain degradation due to space charge in a gas detector. According to this study, the wire chambers would have a gas gain drop to 60 % at the hit rate of a few hundred kHz.

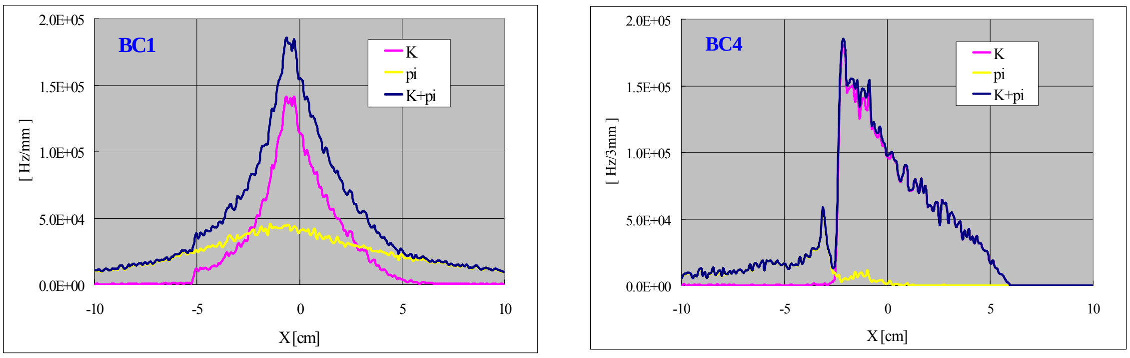
(2) Operation life time of chambers limited by carbon polymerization

A life time of several beam-line chambers in KEK-PS SKS experiment was found to be about ten years. The total accumulated charge was estimated to be ~2 Coulomb/year as,

$$I_{beam} \times Q_{1st} \times G_{gas} \times 3600 \times 24 \times 365 \sim 3 \times 10^{19} \text{ e}$$

where $I_{beam}$ (beam intensity/wire) is $10^6$/4sec, $G_{gas}$ (gas gain)=$10^5$, $Q_{1st}$ (number of ion electron pairs) ~ 50.

Based on SLAC-PUB-3882 (J.Va'vra, Review of wire chamber aging) they observed gain degradation of wire chamber started after the charge accumulation of ~1 Coulomb/cm. Since the beam size at SKS beam-line was about 1cm, the observation in the SKS group is consistent with this report.



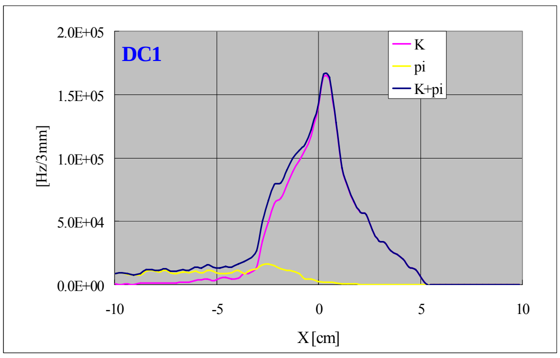




Figure 10.2 Beam profiles at BC1, BC4 and DC1 for E05. Vertical axis indicates the beam counting rate per wire.

<u>Expected charged particle hit rate</u>

The beam conditions for the J-PARC hadron beamlines and the characteristics of the critical beam line chamber are listed for each experiment in Table 10.1. Total charged particle hit rates in phase I and phase II are taken from the estimations by the hadron beam-line construction group. $K/\pi$ ratio and flat top period are assumed to be 6.9 and 0.7 sec, respectively, in this case. The peak hit rates in the table are estimated based on the beam profile shown in Figure 10.2. For the upstream chambers (BC1 and BC2) the new MWPCs with wire spacing of 1mm are assumed to be installed for all the experiments. Construction of the same type of chambers is also planned for BC4 and DC1 in E19.

It can be seen from the table that the rates in the upstream chambers will be just below the supposed maximum level for E05 and E13 in Phase I, although there are no sufficient headroom. The MWPCs with 1mm spacing being developed by the K1.8 beam-line user groups seems functional, just to start their experiments in time. For E19, the proposed beam rate exceeds the nominal upper limit and some reduction of the beam intensity is necessary. To restore the possible gain drop, the K1.8 user groups are planning to use a larger gain amplifier/discriminator (ASD) with lower threshold, which is under development in the KEK electronics group

It should be remarked that the charged particle rates could increase rapidly when the $K/\pi$ ratio would be worth within the possible ambiguity as mentioned in the section 2. New tracking detectors with sufficient high-counting capability and longer life time have to be installed within five years for the Phase II experiment or earlier.

Remarks for R&D of high rate detector

Even for the detectors to be used only in the Day-1 experiment, a serious test is needed to confirm the expected performance/rate capability before mass production. The fabrication of a stable MWPC with 1mm spacing or development of the faster ASD chip might not be easy. Thus, the progress of the developments have to be reported regularly to the committee.

Along with this effort an extensive development of the beam line detector system should also be made for much higher rate environment. The first objective is to develop the beam tracking detector system functional under high-beam-rate condition up to several MHz/mm. This effort is important to carry out E05, E13 and their future extensions successfully, because a high and stable detection efficiency should be kept during these experiments for Phase II.

The lifetime of the detector is another issue. The lifetime of the proposed beam chambers is expected to be around 5 years for phase I period as described above. Although the operation of a wire chamber at lower gas gains can be an easy and quick remedy for a while, it must be insufficient for the coming full intensity operation of J-PARC.

Considering the common features of the detectors required by E05, E13 and E19 (especially beam-line gas chambers working under high-intensity beam), the committee encourages to form a collaboration among the relevant experiment groups to develop the detector system including its electronics and DAQ which can work reliably under the very high counting rate environment as happen in the J-PARC phase II. It would be very effective not only to save the resources but also to complete the best system in the shortest period. Needless to mention, such a system is essential to take full advantage of the high intensity beam of the J-PARC.

| Experiment | E05 | E13 | E19 |
|---|---|---|---|
| Beam | 1.8GeV/c $K^-$ | 1.5GeV/c $K^-$ | 2.0GeV/c $\pi^-$ |
| Toatl charged particle@FF<br>Peak hit rate(Phase I K/pi:6.9)<br>Peak hit rate(Phase I K/pi:3)<br>Peak hit rate(Phase II K/pi:7.9) | >1.4x$10^6$ /spill<br>~0.18MHz/3mm<br>~0.2MHz/3mm<br>~1MHz/3mm | 0.5x$10^6$ /spill<br>~0.063MHz/3mm<br>~0.075MHz/3mm<br>~0.36MHz/3mm | 1x$10^7$ /spill<br>~0.4MHz/mm<br>~0.4MHz/mm<br>NA |
| Chamber around FF<br>Wire spacing(mm) | BC4,DC1<br>3 (MWDC) | BC4,DC1<br>3 (MWDC) | New BC4&DC1<br>1 (MWPC) |
| Total charged particle @MS2<br>Peak hit rate(Phase I K/pi:6.9)<br>Peak hit rate(Phase I K/pi:3)<br>Peak hit rate(Phase II K/pi:7.9) | >7.5x$10^6$ /spill<br>~0.18MHz/mm<br>~0.3MHz/mm<br>~0.9MHz/mm | NA<br>~0.18MHz/mm<br>~0.3MHz/mm<br>~0.9MHz/mm | (1.1x$10^7$ /spill)<br>~0.5MHz/mm<br>~0.5MHz/mm<br>NA |
| Chamber around MS2<br>Wire spacing(mm) | BC1,2<br>1 (MWPC) | BC1,2<br>1 (MWPC) | BC1,2<br>1 (MWPC) |

Table 10.1 beam intensity and hit rate at J-PARC Phase I

## 10.2 Experiment support

Each experimental group requires the area equipped with water, electricity and/or crane etc. for preparation. On the Tokai campus, however, such areas are not prepared at present. Taking the plan of each group into consideration, KEK should build or arrange the required area etc. on the Tokai campus soon, so that each group can prepare and start the experiment without delay. On the Tsukuba campus, at the same time, KEK should make proper arrangements with the existing facilities for the requirements.

## 10.3 Early beam tuning and beam time scheduling

The requirements to the quality of a beam such as the size or a $K/\pi$ ratio of a beam, the reduction of beam halo etc. are different for each experiment. Secondary beams will be tuned by the hadron beam line group which designed and constructed the beamlines. Prior to beam tuning, each experimental group should take close contact with the hadron beam line group for preparations. In order to start the experiment efficiently, the experimental group should provide detectors necessary for beam diagnosis from the early stages of beam tuning.

### 10.4 Human resources

E06,13,19,,07 collaborations consist of reputable physicists who have performed many experiments at KEK-PS. We believe each experiment will be performed as proposed. However, many physicists have signed up for more than one proposal. The committee feels comfortable if the actual commitment of each participant becomes clear.
Please report to the PAC in term of person-year of each participant.

### 10.5 Necessity for early start of experimental program coordination

In the early stage of the beam time, experiments should be scheduled considering the following factors; available beam intensity from the accelerator, progress of the construction of the K1.8 and K1.8BR beam lines, and readiness of each experiment. For efficient use of the beam, and early and good physics results, experimental program coordination is required. A section manages beam time for the experiments. This section control the transition from beam tuning phase to the data acquisition. The section should be also responsible to check used beam time of each group by receiving reports from the experimental group and also from the hadron beam line group.

# Report to the FIFC committee of an investigation of the beam optics and expected performance of the proposed K1.8 beamline at J-PARC

J. Doornbos, TRIUMF

October 24, 2006

## Contents

# 1 Introduction

An investigation was done for the beam on the basis of the provided TRANSPORT tunes and the design report of Dr. Noumi of October 2006.

The purpose of the beam line is to deliver a momentum analyzed kaon beam without significant contamination by other particles. The beam contains sextupoles and octupoles for the correction of higher order aberrations. There are three defining slit systems, namely slit IF immediately after the second bend, at MS1 after the first separator and at MS2 after the second separator. The separation stage is followed by a momentum analyzing stage.

The beam design group has extensive experience with momentum analysis. Therefore, I have restricted myself to a consideration of the cleanliness of the beam at the final focus position. I have done extensive calculations for the main K1.8 beam, followed by a less elaborate check of the 1.1 GeV/c branch line.

In calculating the negative kaon to negative pion ratio at 1.8 GeV/c, I have assumed that there are, taking into account decay, 570 times as many pions as negative kaons in the 45 m long beam line, when the separators are switched off. This is based on some old numbers combining cross sections for a 24 GeV proton beam at zero degrees fitted from some data with so called kinematic reflection and ratios of non zero degree to zero degree cross sections. In other words, a not so sure normalization factor between pions and kaons.

For the 27 m long 1.1 branch, I assumed that there are 1,200 times as many negative pions as kaons if the separators are switched off. This implies that a pion transmission of 0.1 percent corresponds to a pion rate in the final beam which is 1.2 times the kaon rate.

The proposed layout will give a clean 1.8 GeV/c kaon beam with a total angle and momentum acceptance of about 1.4 msr.percent. It can be arranged that the kaon rate is three times as high as the pion plus muon rate, possibly better.

The acceptance of the branch line at 1.1 GeV/c is about 2.0 msr.percent. Because of the unfavourable ratio between the production cross sections, the cleanliness is probably not as good as in the 1.8 GeV/c branch, but a kaon to pion ratio of 2.0 seems achievable, possibly better. Unfortunately, there seems to be a muon contamination which is 1.75 times the kaon rate.

## 2 Some details for the main 1.8 GeV/c beam

In all calculations for the K1.8 beam I assumed a separator voltage of 750 kV over the 10 cm vertical gap.

The contamination in a kaon beam is due to a number of factors.

- DIRECT PIONS from the production target can pass through the mass slits if the separation is insufficient, or the beamspot has higher order tails. In the K1.8 case the pion to kaon separation is 3.4 mm at MS1 and 7.6 mm at MS2. I assumed a sigma of 1.3 mm for the vertical beam spot on the production target, a number obtained from a talk by Dr. Noumi at NP04 in 2004. Taking into account the vertical magnification at the mass slits, the beam spot should have a sigma of 0.65 mm at MS1 and 1.0 mm at MS2. This is confirmed by the higher order Monte Carlo calculations. Due to the higher order corrections only a negligible number of pions passes through the mass slits, corresponding to a kaon fraction of less than 0.1 of the kaon rate at the final focus, even with the octupoles switched off. Calculations with a 1.5 times as large initial sigma, namely 1.95 mm, while the octupoles are switched off gave a pion contamination which is a fraction of 0.4 of the kaon rate, if only MS1 and MS2 are used. When slit IF is also closed the pion rate reduces to a fraction of 0.2.

- CLOUD PIONS result from the decay of neutral kaons and other particles near the production target. In the case that only slit MS2 is used, a substantial fraction reaches the end of the beam line. Closing also MS1 reduces the rate by a factor 5, and closing also slit IF gives an additional reduction of a factor 3. Therefore, the system of slits takes sufficiently care of the cloud pion problem.

- MUONS from pion decay in the channel can contaminate the kaon beam. MS1 stops most of the pions. Therefore only a small number of muons is generated after MS1, The muons that were generated before MS1 and pass through MS1 are mostly stopped by MS2. Slit IF is not needed in this case. The muon contamination is less than a fraction of 0.1 of the kaon rate.

- SLIT SCATTERING OF PIONS can give a serious contribution to the contamination. The beamline at J-PARC has the unique feature of a vertical focus in the beginning of the beam, before the first separation stage. At this point, the beam line sees a large momentum bite and a fairly large horizontal and vertical angle acceptance. Therefore, there are many pions that scatter on a long slit at this location. Beam lines without such an extra focus do not have this problem. In the J-PARC case the problem is reduced by two special features of the beam line, namely the existence of two mass slits after slit IF, and the fact that the separation at the mass slits is large due to the long length of 6 m each of the separators, which can also run at the high voltage of 750 kV. It turns out that therefore the slit scattering problem can be managed in a satisfactory way. The pion intensity from this process is at most a fraction of 0.2 of the kaon rate.

# 3 The 1.1 GeV/c branch

I have not yet spent much time on the 1.1 GeV/c branch line.

It is expected that the direct pion contamination will be negligible because the large separation of 7.6 mm at MS1, compared to the vertical beam size which has a sigma of 0.65 mm, and taking into account the correction of higher order aberrations, which limit the tails of the beam spot at MS1.

The cloud pion contamination can most probably be reduced by an order of magnitude by using slit IF in addition to the MS1 slit.

I used a separator strength of 500 kV over the 10 cm separator gap to do Monte Carlo calculations of the slit scattering problem. The result was a pion contamination which is at most a fraction of 0.3 of the kaon rate. This is a good result, which can be attributed to the fact that the vertical source of the scattered pions at slit IF is small, and the separation at MS1 is large.

Unfortunately, Monte Carlo calculations showed that there is a large muon component in the beam at the final focus, which is 1.75 times the kaon rate. This contamination is not very sensitive to the settings of the slits, and to the strength of the separator. The muon spot at the final focus is however larger than the kaon spot, and half of the muons are outside a $\pm$ 2 cm horizontal area. Furthermore, muons are only weakly interacting. Therefore, they may not be a problem for the experiments.

# 4 Conclusions

The optics for the 1.8 GeV/c beam was checked, and Monte Carlo calculations were done to determine the level of contamination from various processes, as indicated in section 2.

The pion to kaon separation at the mass slits is large due to the 6 m long separators at a high 750 kV voltage over the 10 cm separator gap. The beam line has sufficient higher order correction elements to limit the tails on the beam spots at the two mass slits. An additional focus in the beginning of the beam line at the slit IF helps with the reduction of the cloud pion contamination.

The individual contributions to the contamination from the various mechanisms are each at most at the level of a pion to kaon ration of 0.1 to 0.2, depending on the slit settings. Therefore, it is possible to obtain a kaon to pion ratio at the final focus of 3.0 or better for a total angle and momentum acceptance of 1.4 msr.percent.

The 1.1 GeV/c branch has only one separator stage, but the vertical pion to kaon separation at MS1 is 7.6 mm compared to a beam width with a sigma of 0.65 mm. The beam spot is well corrected with higher order optical elements. Most contaminating processes will only give a small pion rate. Therefore, a pion to kaon ratio at the final focus of better than 2.0 looks possible. Nevertheless, a way has to be found to deal with the large muon intensity which is 1.75 times the kaon rate. The angle momentum acceptance is 2.0 msr.percent.