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Design of Slow Extraction Beam Line at 50-GeV PS in High Intensity Proton Accelerator Facility

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Abstract

A high intensity proton accelerator facility will be jointly constructed by High Energy Accelerator Research Organization (KEK) and Japan Atomic Energy Research Institute (JAERI) at the Tokai campus of JAERI. In this project, we are in charge of design, construction and operation of the slow extraction beam (SEB) line at the 50-GeV Proton Synchrotron. Since high power beam of 750 kW will be transported through the SEB line, we will deal with much heat and radiation which will be generated in the SEB line. Therefore, we have to establish the efficient cooling system and the tight radiation shield for elements in the beam line. In this paper, schematic view of the radiation shield and a mock up of the SEB line are described.

1 INTRODUCTION

The present project aims to pursue frontier sciences in particle physics, nuclear physics, materials science, life science, and nuclear engineering with utilizing variety of intense secondary beams such as muons, neutrons, kaons, pions, antiprotons, and neutrinos produced by high intensity proton beams. In the fields of nuclear and particle physics, further developments of multi-strangeness hypernuclear spectroscopy, CP violation of the kaon decay, and long baseline neutorino oscillation are expected by means of high intensity secondary beam.

The accelerator complex of this project consists of a 400-MeV proton linear accelerator, a 3-GeV rapid cycle booster synchrotron, and a 50-GeV main synchrotron (50-GeV PS) as illustrated in Fig.1. The 50-GeV PS would have cycle time of approximately 3.4 seconds with 0.7 second of slow extraction period. The intensity of the extracted protons will reach 3.0×10^{14} particles per pulse (ppp), i.e. 15 μA, being the beam power of 750 kW [1].

Schematic view of the slow extracted beam (SEB) lines from 50-GeV PS to the experimental hall (K-hall) is shown in Fig.2. This facility is designed for the use of intense pions, kaons, and other secondary particles. Two primary beam lines (A and B) will be constructed. The A line has three primary target stations, T0, T1, and T2. A thin target will be placed at T0 to serve secondary beams for test experiments. Thick targets will sit at T1 and T2 to produce intense secondary beams. Two secondary beam channels, K1.8 and πμ, will be constructed from T1. Another secondary beam channel, K1.1, will be connected to T2. The second primary beam line, B, is designed for the production of neutral kaon beam and other uses of the primary beam.

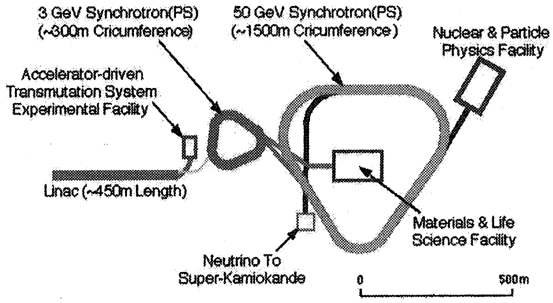

Fig.1: Layout of the accelerator complex [1]

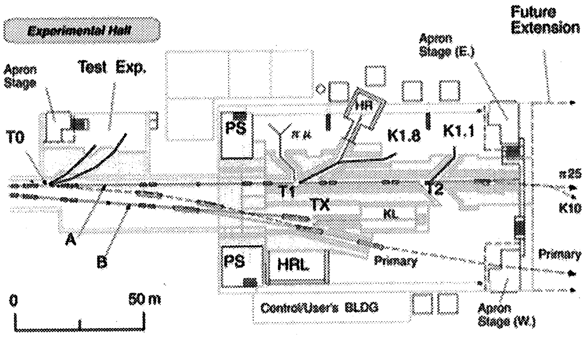

Fig.2: Plan view of the SEB line and K-hall [1]

2 DESIGN CONCEPT

The important issues in the design of the present beam lines are to avoid or solve many problems expected to be arisen from heat deposit and radiation on the beam line equipment induced by the high intensity beam. In order to realize easy and safe maintenance, based on the experience of the construction of North Counter Hall in KEK 12 GeV PS [2], it is crucial to construct beam line tunnels and service tunnels separately. Service tunnels help easy access to beam line elements and are important to maintain them for a long term.

Since people frequently access to the service tunnels, those areas must be shielded to keep the residual-radiation level reasonably low. We have to optimize the shape and thickness of the shielding materials with taking easy maintenance into account. It is also necessary to establish how to handle beam line magnets and support systems, to align magnets, and to maintain them as soon as possible. Therefore, we are building a mock-up to simulate the 50-GeV primary beam line in the East Counter Hall of the KEK 12-GeV PS.

3 COOLING AND SHEILDING

Since the power of the 50-GeV proton beam will reach more than 100 times stronger than that of KEK 12-GeV PS [3], special attentions should be paid for the construction of the new beam line in order to fulfil the requirements by ongoing environmental laws of radiation safety, air pollution, and so on. The overall study of radiation safety are made with considerations of the soil activation and the radiation levels in K-hall, at the boundaries of facilities and site. The thickness of the beam line shield is estimated based on Moyer's formulas, as listed in Table 1 [4].

The losses of the primary proton beam at T1 and T2 are assumed to be at maximum 30 % of full beam intensity, respectively. Namely, it is expected that the beam power of 225 kW would be released at T1 or T2. Therefore, the production target and peripheral materials must be designed to handle such high power deposit. The detailed description about the design of the target system can be found elsewhere [5]. Large portion of the released energy is directly deposited to magnets, beam pipes, shielding materials, and other beam line instruments placed downstream of the target. Particularly, the magnet, beam pipe, and collimator located in the closest downstream of the target are found to need the water cooling system. Detailed study is undergoing using the simulation code, MARS [6].

Since the beam line equipments near the production target are highly activated by the beam irradiation, one can never access close to them for maintenance. When such a highly-activated magnet or other instrument is necessary to be removed or replaced, we need to do it remotely in principle. Electric power, cooling water, compressed air, monitor gases, signal lines, and vacuum pipes to/from the beam line equipments have to be able to be disconnected or connected at behind the radiation shield, where the induced radiation level must be kept reasonably low so that one can stay there to complete such relatively-simple works. It is therefore vital to optimize the configuration and the thickness of shielding materials. The MARS code is employed also for this purpose.

4 MOCK-UP OF THE BEAM LINE

As mentioned in Section 2, we are building a mock-up in order to simulate the primary beam line tunnel, particularly near to the production target. The plan and cross sectional views of the mock-up shield are shown in Fig. 3.

Table 1: Shield thickness

Position	Shield thickness [cm]		
	Concrete	Iron	Soil
T0 target upper	230	50	620
T0 target lower	300	50	
Second split upper	310	50	810
Second split lower	370	50	
K-hall upper	550	100	
K-hall lower	240	0	
T1 target upper	550	250	
T1 target lower	200	200	
Beam dump upper	450	300	
Beam dump lower	170	250	

The mock-up shield is constructed with concrete blocks. Iron plates are placed on the beam line tunnel floor, as indicated by hatched area in the figure. A beam-line magnet will be installed on the iron plates. A trench lying under the floor along the beam line is necessary in order to circulate air in the beam line tunnel smoothly.

At first, we will install a dipole magnet, named 8D216MIC, in the mock-up. Fig.4 shows 8D216MIC. The outer dimensions of this electromagnet is 1060 × 850 × 800 mm^3. The weight is 6.1 ton. The magnet gap, pole width and pole length are 100 mm, 400 mm, and 800 mm, respectively. The maximum current and voltage are 3000 A and 33.1 V. The field strength of 1.4T can be generated. The coils of 8D216MIC are used mineral insulation cables (MIC). MIC is indispensable in high radiation environment.

Aluminium plates of 77 cm thick in total are attached on the top of the magnet so as to function as another radiation shield. When we install the magnet, the top of the aluminium plate comes to the same level (height) of the top of the present mock-up shield. Behind the aluminium shield, on the top of the mock-up shield, a service area will be constructed. Maintenance works will be done in the area. Thus, the thickness of the aluminium should be optimized depending on the radiation environment. If necessary, extra iron plates will be inserted between the magnet and the aluminium plates in order to increase the shielding power. The upper part of the shield should be light material such as aluminium or concrete in order to reduce residual radiation.

Manifolds for cooling water and bus bars for electric power are placed above the aluminium shield. Cranked paths through which the water pipes and conductors are connected to the coils are made in the aluminium shield with keeping the shielding power.

Now, we are ready to install the magnet to the mock-up shield. We will drive the magnet after the cooling water, electric power, and other signal lines are connected. Through this test drive, we will check if unexpected problems take place. We will study many expected problems. For example, remote connection or disconnection of the vacuum pipe has yet to be solved.

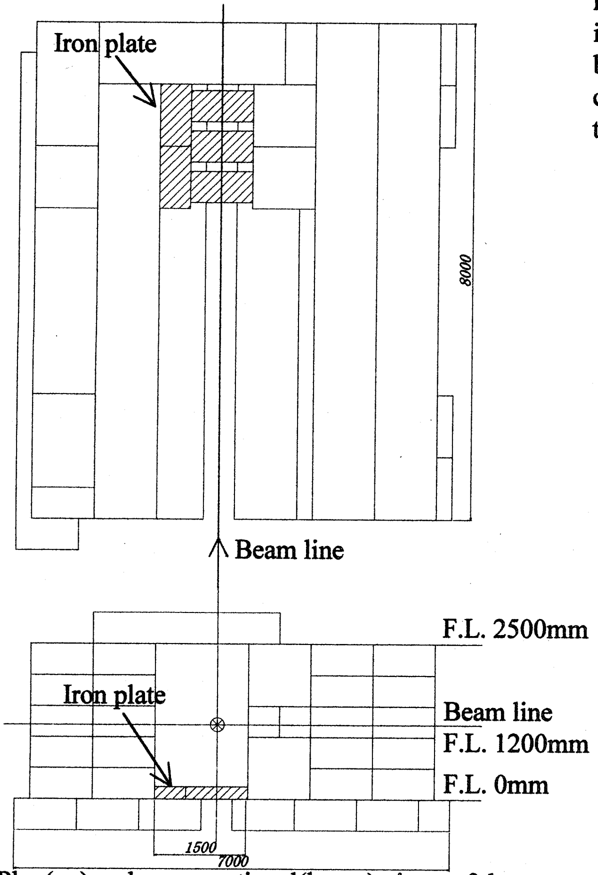

Fig.3: Plan(up) and cross sectional(lower) views of the mock-up shield

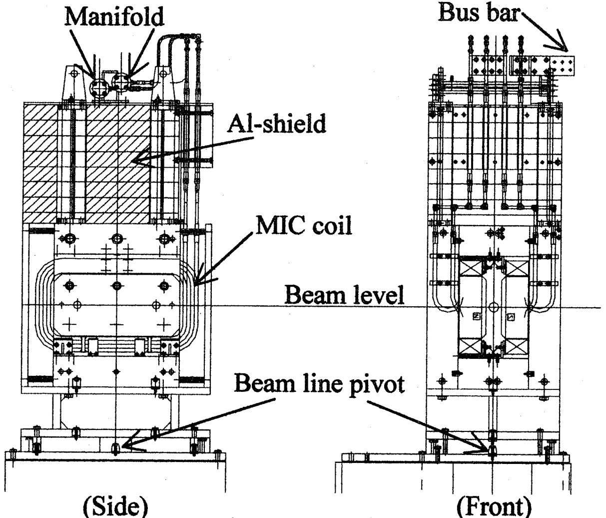

Fig.4 8D216MIC

Alignment of the beam-line magnets and other instruments will be done with referring an array of pivots along the beam line. The pivots are aligned and their positions are measured in advance. Then, a support frame with holes to fit the pivots is prepared. The magnet (or other beam-line instrument) and the support frame can be fabricated so as to align the magnet center to the holes before installation in the beam line. The beam line height can be adjusted in advance by inserting proper spacers between the magnet and frame. However, re-measurement of the alignment of the beam-line instruments and/or the pivots after many years of the beam delivery may be possibly required. It should be considered how to realize. Ideas expected to resolve these problems can be tested with this mock-up.

5 SUMMARY AND PROSPECT

- Layout and basic specifications of SEB and target stations in High Intensity Proton Accelerator Facility were briefly introduced.
- Conceptual design of SEB was discussed and requirements for the radiation shield, remote maintenance and operation of the beam-line equipments were summarised.
- Current status of the study for radiation protection and cooling system based on various model calculations was reported. Further study for detailed design is under way.
- Actual configuration of a beam line magnet, shielding materials and peripheral devices was described in detail. Construction of the mock-up will be completed by the end of November 2001, and a test operation of the magnet will start soon.
- We expect to obtain a lot of experience through building up and operating a mock-up of beam line magnet, and will be completely ready for the real construction of SEB in the present project.

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