DESIGN OF THE BEAM TRANSPORT LINES OF THE JAPANESE HADRON PROJECT

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ABSTRACT

We describe the design of the beam transport lines of the Japanese Hadron Project. The beam optics parameters are calculated and the gaps, the lengths and the magnetic fields of the transport magnets are estimated. This design will match the requirement with the transport of a high current beam.

INTRODUCTION

The proposed Japanese Hadron Project consists of the 1GeV Proton Linear Accelerator[1], the Compressor/Stretcher Ring[2] and three experimental arenas; Exotic Nuclei Arena with the Heavy Ion Linear Accelerator, Meson Arena and Neutron Arena. The layout of the facility is shown in Fig.1. The transport lines consist of the four lines; (1) the injection line from the linear accelerator to the Compressor/Stretcher Ring, (2) the line to Exotic Nuclei Arena on the way to the ring , (3) the fast extraction lines from the ring to Meson and Neutron Arenas and (4) the slow extraction line to Meson Arena. In this report, we describe the characteristics of three beam transport lines (1)-(3). The design was done by using the computer program "MAGIC"[3].

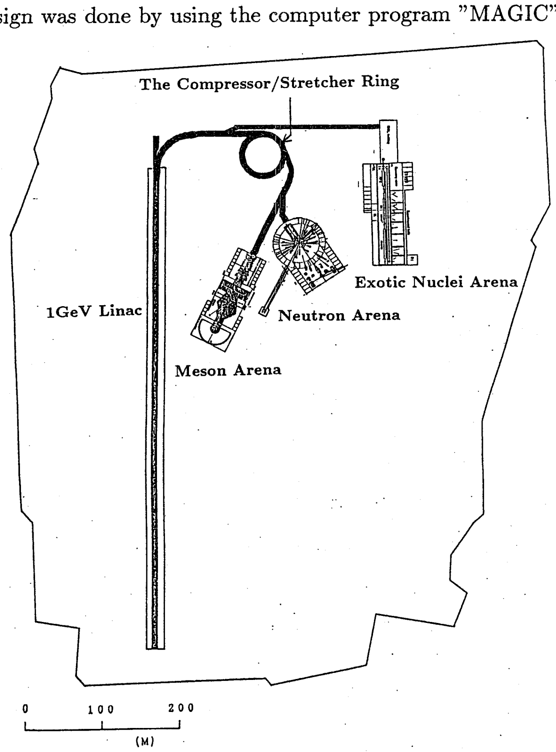

Fig.1. The layout of the Japanese Hadron Project.

1. THE INJECTION LINE FROM THE LINEAR ACCELERATOR TO THE RING

The injection line consists of a matching section, a bending section and a long straight section as shown in Fig.2. At the matching section, the beam optics is changed from the FDO type in the linear accelerator to the FODO type in the transport line.

The bending section consists of 16 bending magnets of rectangular type and 5 quadrupole magnets. The length and bending angle of a bending magnet are 2m and 5.625 degrees, respectively, and total angle of the bending section is 90 degrees. The magnetic field is chosen as 3kG in order to prevent stripping electron from H^-. As the emittance of the accelerated beam is small; $\epsilon_x = 1.2$, $\epsilon_y = 1.4\pi mm \cdot mrad$, the magnet gap is chosen less than 35mm. Figure 3 shows the betatron and dispersion functions. Four thin foil scrapers of horizontal and vertical emittance halo are set in the bending section. H^- particles are converted to protons by the scrapers and the protons are led to beam dumps. Large dispersion is produced at the center of the bending section to scrape the momentum halo with a thin foil scraper, for the injection of a small momentum spread beam to the ring. A simulation by the program TURTLE of scraping the momentum halo has been made and its result is shown in Fig.4. A pulse magnet(K1) is also set to transport the beam to the existing KEK 12GeV proton synchrotron. The long straight section is dispersionless and consists of the simple FODO cells and two matching sections at both ends.

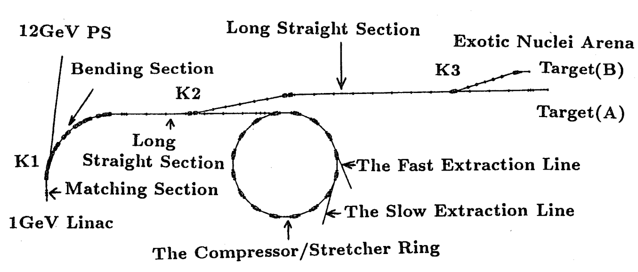

Fig.2. The beam transport line from the 1GeV linac.

2. THE BEAM TRANSPORT LINE TO EXOTIC NUCLEI ARENA

In the long straight section of H^- injection line, a pulse magnet(K2) is set to deflect the beam for Exotic Nuclei Arena(Fig.2). The magnetic field of the pulse magnet as well as the bending magnets is chosen as less than 3kG and the bending angles of all magnets are 5 degrees. The separation between the beam line and the injection line is required to be larger than 6m for shield-

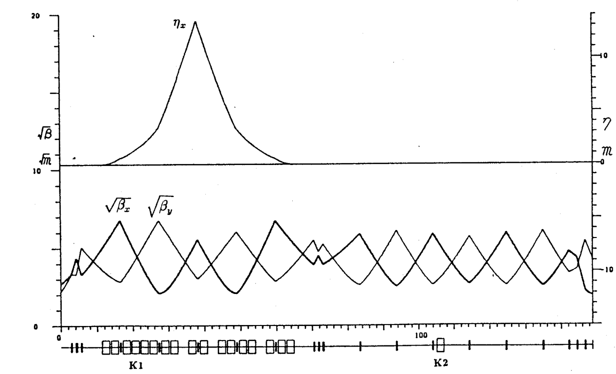

Fig.3. The betatron and dispersion functions at the H^- injection line. η_x is the horizontal dispersion function. $\sqrt{\beta_x}$ and $\sqrt{\beta_y}$ are square roots of the horizontal and vertical betatron functions, respectively.

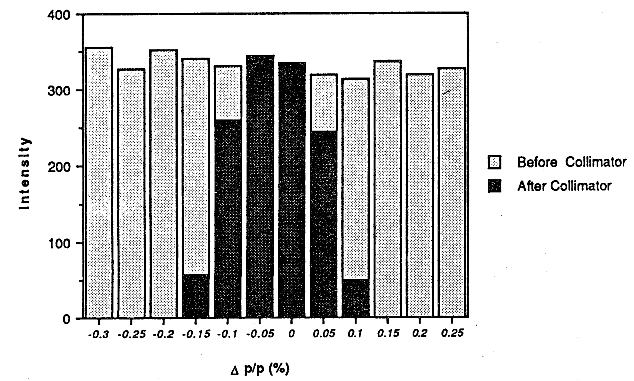

Fig.4. The result of scraping the momentum halo by the scraper at the center of bending section(Fig.2). The beam of $\epsilon_x = 1.2\pi mm \cdot mrad$,$\epsilon_y = 1.4\pi mm \cdot mrad$ and $\Delta p/p = 0.3\%$ can be scraped as $\Delta p/p = 0.1\%$.

ing the radiation from the injection point of the ring. The front end of the line to Exotic Arena is a 58m achromatic section which consists of five quadrupole magnets and four bending magnets. Figure 5 shows the betatron and dispersion functions in this beam line. Before the last bending magnet of the achromatic section, a foil is set for charge exchange, since proton beam can be deflected with a high magnetic field and transport easier than H^- beam. A 100m straight section with simple FODO cells links the achromatic section to the quadrupole triplet which matches the beam profile to the target(A) of Exotic Nuclei Arena. The K3 magnet located on the way ot the target(A) is set to share the beam to another target(B).

3. THE FAST EXTRACTION LINE

The beam injected to the ring is accumulated for 500 μs by the H^- injection method. The ring consists of 16 FODB cells. The beam emittance in the ring is 30 $\pi mm \cdot mrad$ while the aperture is 120 $\pi mm \cdot mrad$. The momentum aperture is 1.5%. The beam is vertically extracted from the ring with kicker and septum magnets(Fig.6) and the beam height of the extraction line is put back to the level of the ring(Fig.6-a) by three vertical bending magnets (B=8kG, L=2m). This vertical bending section forms an achromatic bend, as shown in Fig.7-a. In the bending magnets, the maximum horizontal betatron and dispersion functions are 28.9m and 0.4m, respectively, and the 130mm gap of the magnet is necessary for the acceptance of $120\pi mm \cdot mrad$ and $\Delta p/p = 1.5\%$.

Horizontal dispersion is reduced to zero(Fig.7-a) and the beam is directed straight to Meson Arena(Fig.6), by using three horizontal bending magnets(B=2.5-8kG, L=2.777m). Maximum vertical betatron function in the horizontal bending magnets is 26.1m and the 120mm gap of the magnet is necessary. On the way to Meson Arena, the beam is deflected to Neutron Arena by a pulse magnet(K4) and a bending magnet (B=8kG, L=2.777m) which make the optics achromatic together with three quadrupole magnets(Fig.6 and Fig.7-b).

In Neutron Arena, the beam is vertially deflected by four

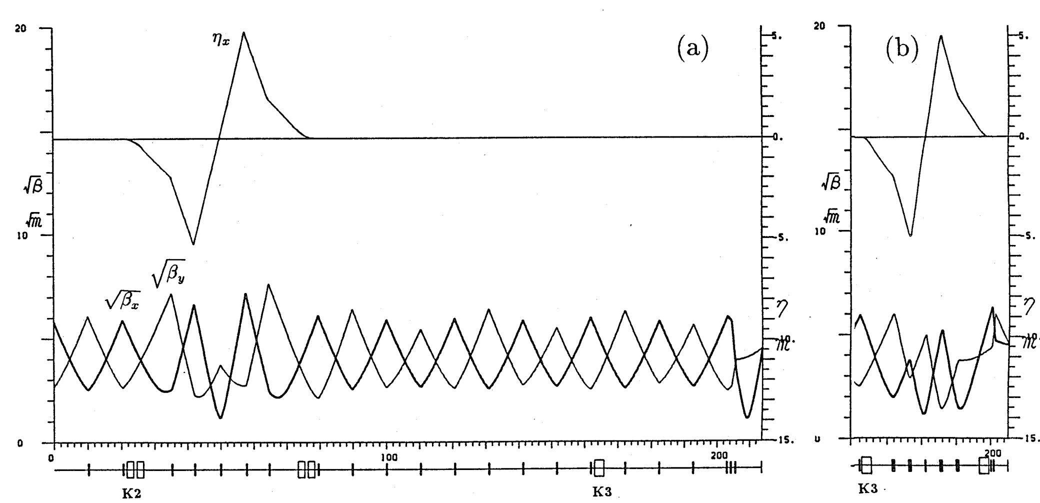

Fig.5. The betatron and dispersion functions at the transport line to Exotic Nuclei Arena. Figure 5-a shows the functions between K2 magnet and the target(A) of Exotic Nuclei Arena. Figure 5-b also shows the functions between K3 magnet and target(B).

bending megnet to the neutron target(Fig.6-c), in order to prevent the beam line from pushing the detectors and set the experimental set up all over the around. The vertical bending section is also made achromatic(Fig.7-b). Characteristics of this vertical bending section are listed in Table 1. The gap of the bending magnet of 90mm is accomodated to an acceptance of $120\pi mm \cdot mrad$. Slow extraction line connects the slow extraction point in the ring and Meson Arena.

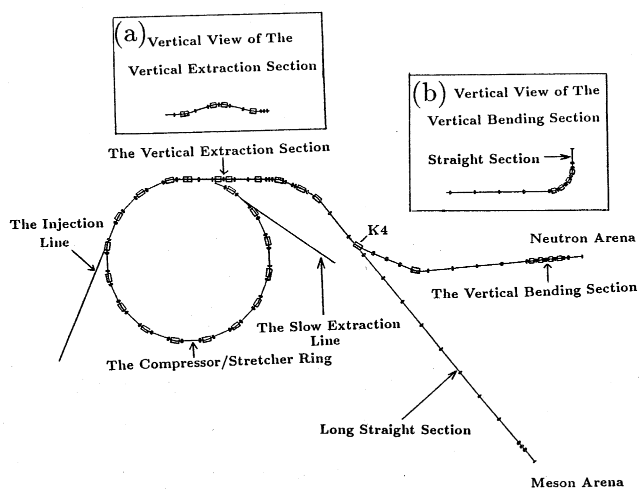

Fig.6. The fast extraction line to Meson and Neutron Arenas. The box denoted by (a) and (b) show the vertical views of the vertical extraction section from the ring and of the vertical bending section under Neutron Arena, respectively .

Table 1
Characteristics of the vertical bending section

Length of the magnet	1.5m
Gap of the magnet	100mm
Magnetic field	1.5T
Maximum β_x in the magnet	14.0m
Bending Angle per magnet	22.5degrees

CONCLUSION

The first round design of the beam line optics of the Japanese Hadron Project has been completed. We made the conceptial design of the magnets. The simulation result of scraping the momentum halo with a scraper has been calculated.

REFERENCES

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[3] A.S.King, M.J.Lee and W.W.Lee, SLAC-183 "MAGIC A COMPUTER CODE FOR DESIGN STUDIES OF INSERTION AND STRAGE RING ".

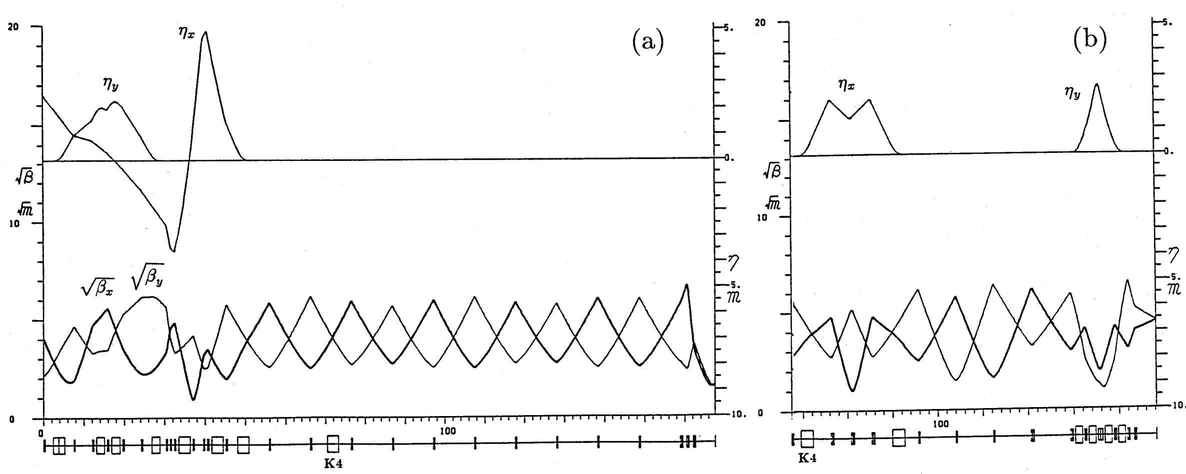

Fig.7. The betatron and dispersion functions of the fast extraction line to Meson Arena(Fig.7-a) and to Neutron Arena(Fig.7-b). The long straight section and the straight section near the target of Neutron Arena are dispersionless.