BEAM HALO COLLECTION FOR THE JHF 3-GEV SYNCHROTRON

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Abstract

The JHF 3-GeV synchrotron is designed to supply 200 microamps proton beam at 25 Hz repetition. In order to allow hands-on-maintenance for most area, beam loss is localized by a lost beam/halo collimation system. The computer code STRUCT is used to simulate the distribution of the beam losses around the ring, and then the shield requirement around the collimator is estimated by the computer code MARS.

1 INTRODUCTION

From experience of the KEK-PS operation[1], the average beam loss should be kept at an order of 1 Watt/m for hands-on-maintenance. The ratio of the beam loss is then as low as 10^{-3} compared to the 600 KWatts output of the JHF 3-GeV ring[2]; the circumference of the ring is 340 m. The only measure we can take against such losses is to localize them at a restricted area, where deliberate modules should be provided for quick coupling and remote handling in order to mitigate the personnel doses. In the rest part of the machine, the beam losses are expected to be an order of 1 Watt/m. Since the 3-GeV ring is installed in the present KEK 12-GeV ring vault, dose rate is another important issue.

2 COLLIMATION SYSTEM

The collimation system comprises a primary collimator and a secondary collimators located approximately at θ and π-θ downstream in the collimation plane, and $\pi/2$ downstream in the orthogonal plane. The θ is 10~30 degrees. In a horizontal plane the system collects an untrapped beam out of the RF bucket as well as a beam halo which is created in any kind of instabilities. The location of the primary collimator is determined so that the normalized dispersion has its maximum value [3]. The condition is given as

$$\frac{1}{\eta_x}\frac{d\eta_x}{ds} = -\frac{\alpha_x}{\beta_x},$$

where η_X is the horizontal dispersion function. The slope of the beam envelope at this point is then independent of the momentum, which is given by

$$\frac{1}{x}\frac{dx}{ds} = -\frac{\alpha_x}{\beta_x}. \qquad (1)$$

Fig. 1 shows the layout of the collimators. The primary collimators in the horizontal and vertical planes are denoted by HPRI and VPRI, respectively. The phases of the subsequent collimators are listed in Table 1. The aperture of the collimators is set to intercept the beam having an emittance larger than 312π mm mrad in both planes[4].

Table 1: Phase advance of collimators measured from the primary ones. Units are in degrees.

plane	HPRI	H15	HV62	HV90	H160
horizontal	0	15.2	—	—	159.8
vertical	0	—	62.4	90.0	—

plane	VPRI	V17	VH89	V162
horizontal	0	—	89.4	—
vertical	0	16.8	—	161.8

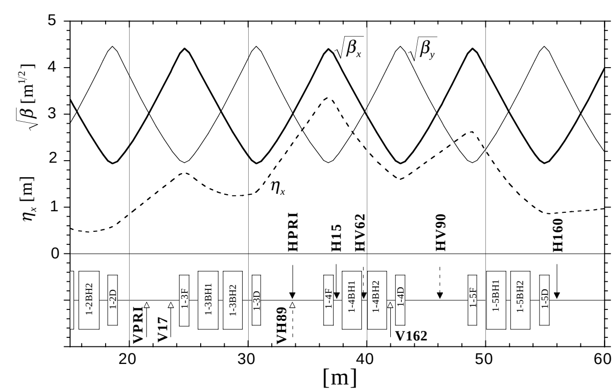

Figure 1: Layout of the lost beam/halo collimation system in the superperiod I.

3 SIMULATIONS

3.1 STRUCT calculation

The Monte-Carlo simulation code STRUCT[5] was used to calculate the beam-loss distribution around the ring. Since the collimator system intercepts the penumbra of the circulating beam, the initial distribution of protons is given in such a way that the particles only exist outside the maximum emittance (312π mm mrad), the density of which is inversely proportional to the distance from the phase-space origin. The momentum spread is also included with a 3-σ spread of ±0.5%. Fig. 2 shows the input distribution of 200 MeV protons at the upstream-end of the superperiod I. The material of the collimator is iron and the azimuthal length is 150 mm, which is long enough to stop protons at 200 MeV (4.7 cm). As for the primary collimator, a tungsten scraper of 1mm thick is attached to the front edge in order to increase the scattering angle. The height of the scraper from the collimator surface is 0.2 mm. The collimator surface is positioned so that the scraper edge just touches the beam envelope of the maximum emittance with 0.5% momentum deviation, and its slope is given by eq. (1). The surface of secondary collimators is positioned at a distance of 2 mm from the beam envelope. The effect of a closed orbit distorsion or a space charge tune-shift is not taken into account.

The number of traced particles is 5000 to simulate 10% of the total beam, i.e. 5×10^{12} protons. A STRUCT calculation shows that 89% of the traced beam is lost around the ring after 50 turns. The energy deposition per meter at each element is shown in Figs. 3 and 4, where the loss is assumed to occur at 200 MeV at 25 Hz repetition. The breakdown of the losses is that 2.85 kW is lost at a collimator area of 40 m long, and 700 W is distributed over the remaining part. The average loss is then given by 2.3 Watt/m for a hands-on-maintenance area.

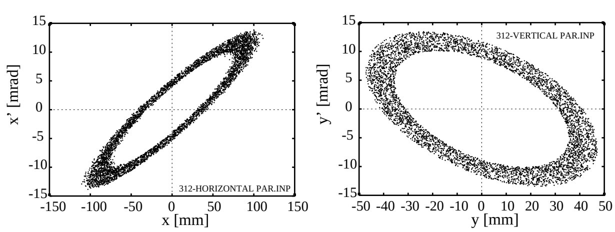

Figure 2: Initial particle distributions for the STRUCT calculation in the horizontal (left) and the vertical (right) plane.

3.2 MARS calculation

Unlike to the STRUCT code, the MARS Monte-Carlo code[6] treats a magnet as not only an optical element but also a scattering object of protons. Allocations of the three-dimensional magnets, vacuum chambers and collimators in the synchrotron room are then the input data to MARS. Since it takes a long cpu time to calculate over an entire ring for many turns, a short run was performed only for the collimator area in order to estimate the dose rate. The data of initial proton distributions is given by the STRUCT output. The peak dose is given by 175 Sv/h at 1m distance from the beam center.

- Soil-activation: the dose limit at the boundary of concrete shielding wall and soil is that which produces 3.7 Bq/gr of the sum of saturated activities in soil, corresponding to 23 mSv/h[7]. Then, 59 cm-thick iron shield is necessary between the collimator and the nearest concrete wall (Fig. 5).
- Site-boundary: the nearest site boundary is located 400 m apart from the beam in Fig. 5. If we assume a yearly opeartion period to be 4,000 hrs, the dose rate is then given by 0.018 μSv/y, which is far below the regulation to the 3-GeV ring (5 μSv/y).

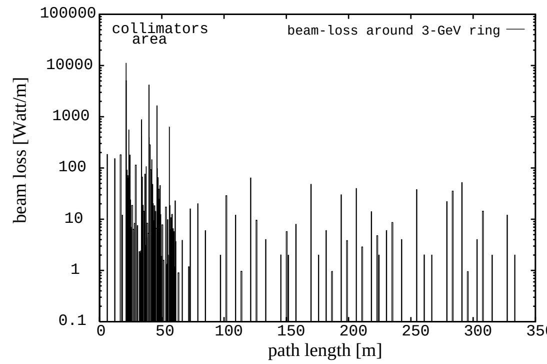

Figure 3: Beam-loss distributions around the ring where 18 μA is assumed to be lost at 200 MeV. Energy deposition on each element is normalized by its length.

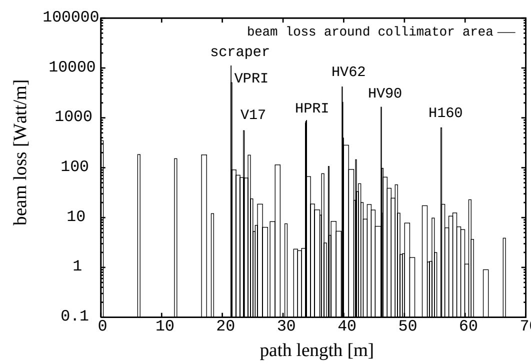

Figure 4: Beam-loss distributions around the collimator area; a part of Fig. 3 in a magnified scale.

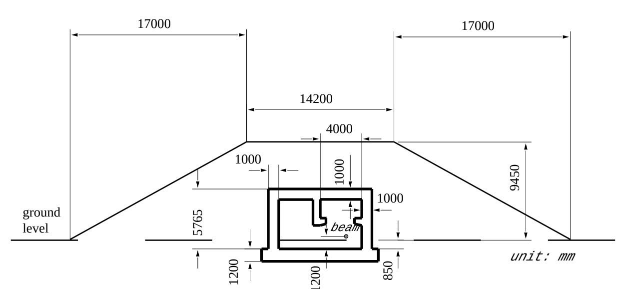

Figure 5: Cross-sectional view of the 3-GeV synchrotron room near to the collimators, which is the present KEK 12-GeV ring vault.

4 CONCLUSIONS

Collimation system for the lost beam/halo is simulated at the injection energy of the JHF 3-GeV ring by using the Monte-Carlo codes, STRUCT and MARS. Beam loss distribution around the hands-on-maintenance area is 2.3 Watt/m if 18 μA is lost at 200 MeV. As for a dose limit, 59 cm-thick iron shield should be reinforced between the collimator and the existing concrete wall against soil activation. The dose rate at the site-boundary is far below the regulation.

REFERENCES

[1] I. Yamane, private communications, October 1996.

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[3] P. Bryant and E. Klein, “The design of betatron and momentum collimation system”, CERN SL/92-40 (AP), August 1992.

[4] Y. Irie et al, "H^- Painting Injection for the JHF 3-GeV Synchrotron", this proceedings.

[5] I. Baishev, A. Drozhdin and N. Mokhov, “STRUCT Program user’s reference manual”, SSCL-MAN-0034, February 1994. This code calculates the interaction of protons with scattering elements such as a scraper, a collimator and an extraction septum, and creates a file of outgoing particles with energy higher than some limit, $E > 0.7\ E_{0,}$ in the present version, where the E_0 is the initial energy. The particles are then projected through each lattice element sequentially. Aperture check is performed in each element and the particle distributions at the loss point are recorded. The RF acceleration is not taken into account.

[6] N. Mokhov, “The MARS code system user’s guide, version 13(95)”, Fermilab-FN-628. This code performs fast inclusive simulations of three-dimensional hadronic and electromagnetic cascades, muon and low energy neutron transport in shielding and in accelerators.

[7] T. Shibata, "JHF Accelerator Design Study Report”, ibid, Chap. 6.