Beam Abort and Collimation for a 3×3 TeV Hadron Collider

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1 Beam Abort System

Design of a 3 TeV beam abort system follows the 3 TeV UNK abort system [1, 2] designed in IHEP (Protvino, Russia) a few years ago. The SSC and LHC experiences [3] are taken into account.

In a baseline case, a 3 TeV beam abort system is located in a special 800 m long straight section (Fig. 1). It consists of a kicker-magnet, two septum-magnets, and a set of bump-magnets. First septum-magnet has 1 mm thick septa and low field that allows to decrease a kicker strength. A thickness of the second septum-magnet increases from 5 to 20 mm with the magnetic field.

During the accelerator cycle the circulating beam is kept close to the extraction magnet septa by a set of bump-magnets. A kicker magnet is needed to put the beam into the septum aperture. To minimize the beam loss at the septa, the kicker rise time must be shorter than the distance between bunches. Fast ramping septum-magnets are used to decrease electric power. With a rise time of 350 μs one can extract the beam from the accelerator in 5 turns after the abort signal. One of the septum-magnet modules is on at injection. It gives a possibility to extract the beam over one turn and eliminate the accelerator component damage in a case of very fast instabilities at injection. The aperture of the septum-magnet should be large enough to extract the beam without losses over the machine cycle. The abort system magnet parameters are presented in Table 1.

A long distance between central quads is required to bypass the machine quadrupoles at extraction. It was found both in the SSC and LHC designs that to shorten the system, one can send the extracted beam through the beam pipe buried through the quadrupole yokes without deterioration of their performance. In the considered case it will decrease the straight section length from 800 m to about 400 m. Certainly, more studies are needed to investigate this possibility.

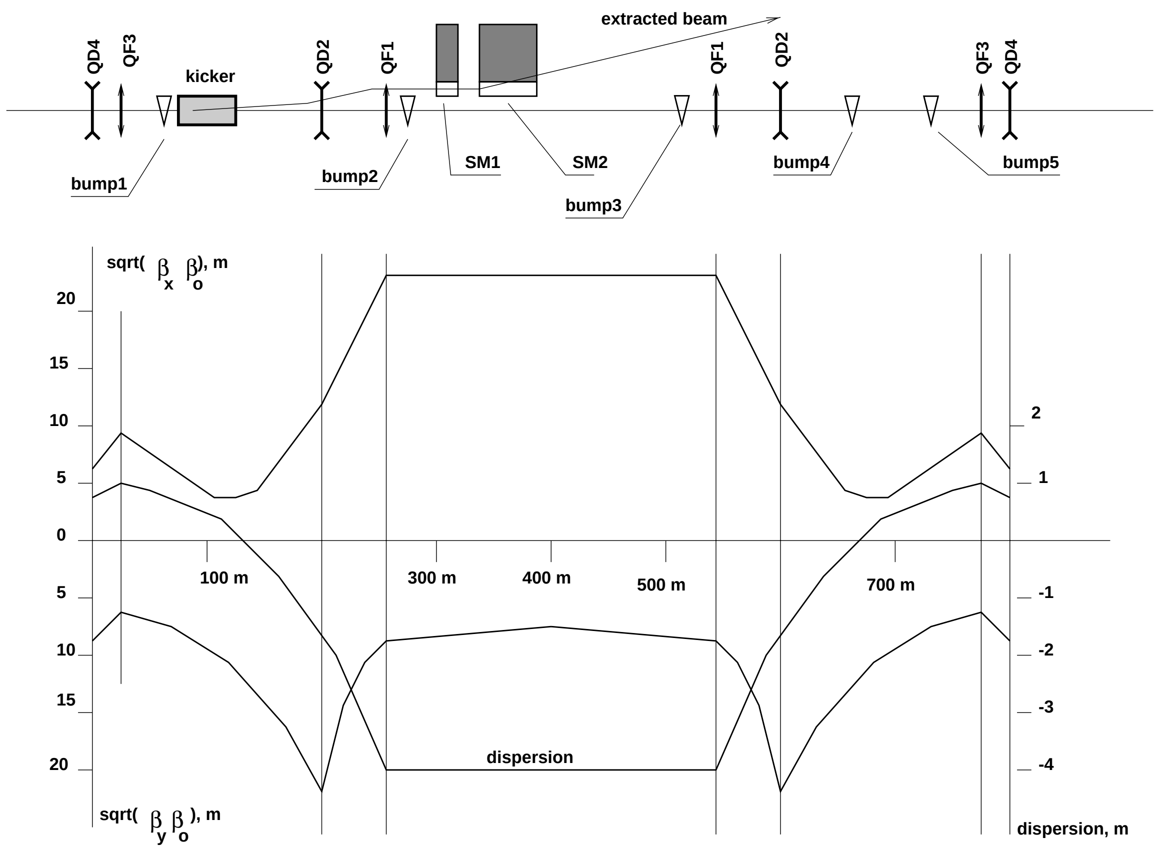

Figure 1: 3 TeV beam abort system layout.

2 Beam Collimation System

As in any other accelerator, some level of systematic beam loss is unavoidable in a 3 TeV machine certainly due to beam-gas scattering and slow diffusion processes (resonances, RF noise, ground motion, ...). This can cause quench of superconducting magnets, increased radiation levels and degradation of functional properties of the machine components. Significant fraction of beam loss can be localized in a few predetermined locations in the lattice with a dedicated beam cleaning system.

A two-stage beam collimation system can localize most of losses in the long straight section used for the abort system. System consists of a set of primary and secondary collimators (Fig. 2). A primary collimator, where a proton impact parameter is of the order of 1μm [7, 8], serves as a scattering target. As a result, the impact parameter on the thick downstream secondary collimators is drastically increased which results in significant increase of a scraping efficiency. Circulating beam is shaped in the horizontal and vertical plane by two separate primary collimators. A horizontal primary collimator is located upstream of the first thin septum-magnet of the abort system. A vertical

Table 1: Parameters of the abort system magnets.

Element	Length (m)	Magnetic field (T)
kicker	27	0.1
septum-magnet	9	0.1
septum-magnet	36	1.1
horizontal bump-magnet 1	2	1.2
horizontal bump-magnet 2	6	1.2
horizontal bump-magnet 3	6	1.2
horizontal bump-magnet 4	2	1.2
horizontal bump-magnet 5	2	1.2
vertical bump-magnet 1	3	1.2
vertical bump-magnet 2	12	1.2
vertical bump-magnet 3	15	1.2
vertical bump-magnet 4	15	1.2
vertical bump-magnet 5	6	1.2

primary collimator is placed downstream of the QD2 quadrupole at the beginning of the long drift. The primary collimators define the accelerator aperture at 6σ of the circulating beam in both directions.

Our studies show that at 3 TeV, a 5-mm thick tungsten target positioned at 6σ from the beam axis in both vertical and horizontal planes is a good choice. An optimal length of stainless steel secondary collimator is about 2 m. Each of them consists of a movable L-shaped jaw positioned at about 7σ from the beam axis in horizontal or vertical plane. The collimators are aligned parallel to the envelope of the circulating beam. A set of vertical and horizontal bump-magnets is used to keep the beam at the distance of 7σ from the secondary collimator jaws and to move the neutral and photon flux out of the superconducting coils.

3 Accidental Loss

A prefire of a single module of the abort kicker will result in a high amplitude coherent betatron oscillations of the beam. The disturbed beam can then hit a collimator jaw or other limiting aperture resulting in a significant component overheating or even damage. In a worst case, when a module prefire takes place just after the longitudinal abort gap, one needs to wait for the whole turn to extract the beam. For the SSC, two ways have been proposed [6] to mitigate the problem:

- start abort after a module prefire as soon as possible without synchronization with abort gap (asynchronous firing of beam abort kicker);

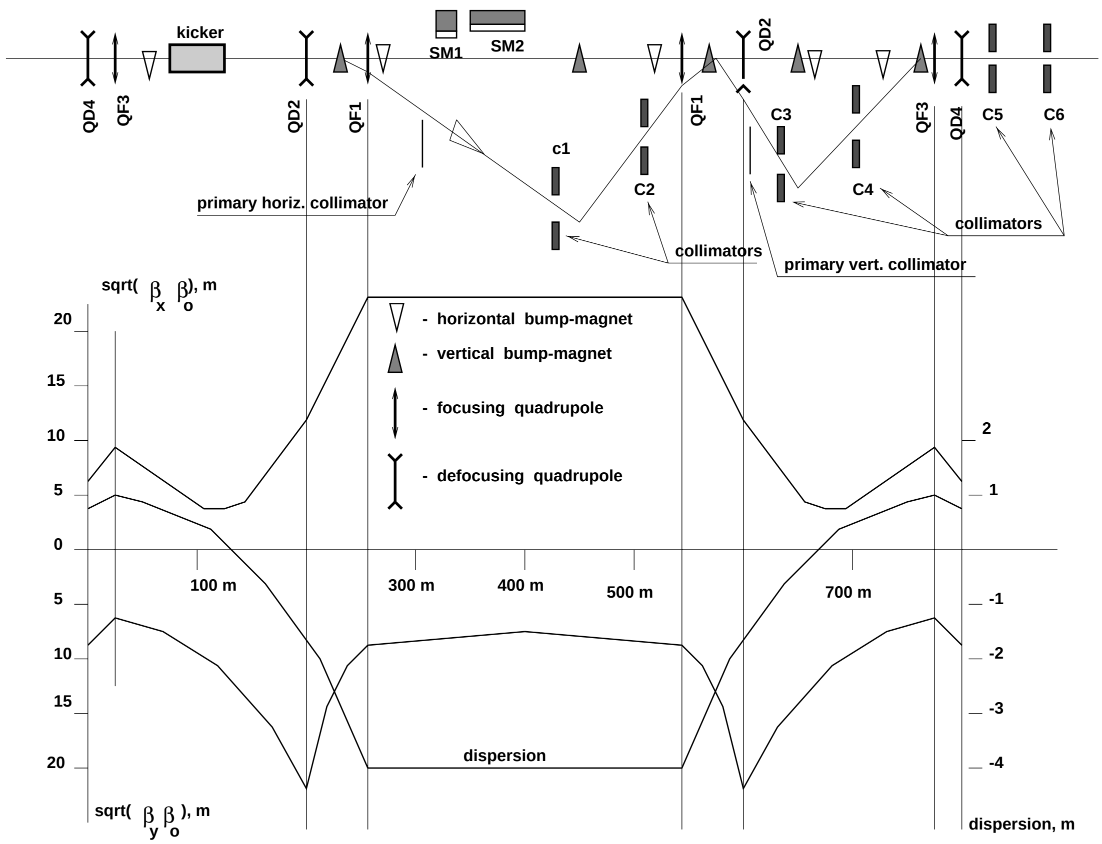

Figure 2: Beam collimation system layout.

- compensate a prefired module by a special module with the opposite magnetic field (antikicker). In this case the beam abort can be safely delayed until the gap comes, thus eliminating beam loss during the kicker rise time. The amount of beam loss depends on the delay between the moment of prefire and antikicker start.

The machine injection kicker misfire and prefire results in a coherent betatron oscillation of injected portion of the beam with pretty large amplitude causing the same problems [6] at injection. An asynchronous firing of the beam abort and beam injection kickers will spray the beam across the accelerator aperture (Fig. 3). Number of particles sprayed by the abort kicker is equal to $(\Delta t \times I)/t$. Here Δt - kicker rise time, T - revolution time, I - beam intensity. About half of this intensity will be sprayed across the abort beam line, and another half will come to the primary collimator (Fig. 3). Shadows (spoilers) can be used to protect collimators against overheating and damage. Pyrolytic graphite can be used as a material for shadows. This material can tolerate a temperature rise of $2500^o C$ before fracture. It can be coated with a conductive material to reduce the resistive wall wakes.

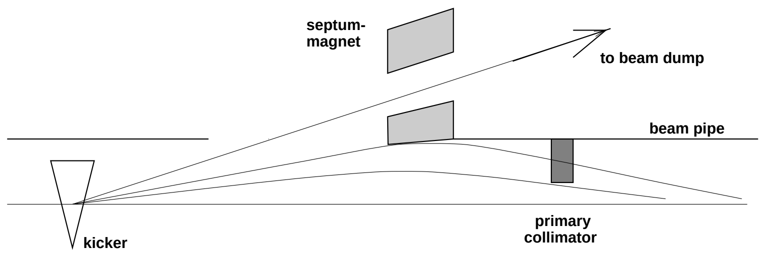

Figure 3: Asynchronous firing of beam abort kicker.

References

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