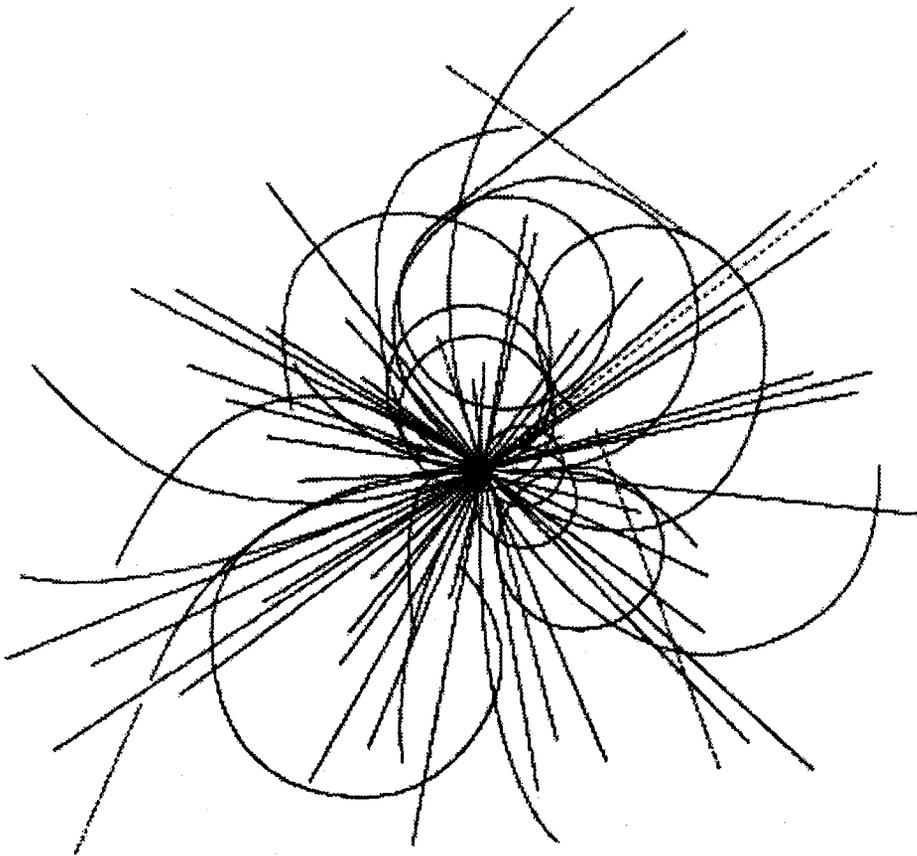


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Dealing with Abort Kicker Prefire in the Superconducting Super Collider



**Superconducting Super Collider
Laboratory**

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Dealing With Abort Kicker Prefire in the Superconducting Super Collider

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Abstract

The Superconducting Super Collider uses a single-turn extraction abort system to divert the circulating beam to a massive graphite absorber at normal termination of the operating cycle or in case of any of a number of predefined fault modes. The Collider rings must be designed to be tolerant to abort extraction kicker prefires and misfires because of the large circulating beam energy. We have studied the consequences of beam loss in the accelerator due to such prefires and misfires in terms of material heating and radiation generation using full scale machine simulations and Monte-Carlo energy deposition calculations. Some results from these calculations as well as possible protective measures for minimizing the damaging effects of kicker prefire and misfire are discussed in this paper.

I. INTRODUCTION

The Superconducting Super Collider beam[1,2] contains approximately 420 MJ of circulating beam energy per ring at the operating design point, proton momentum equal to 20 TeV/c and a circulating current of 70 mA. This amount of circulating beam energy is equivalent to about 100 kg of high explosives and must be dealt with by a reliable abort system.

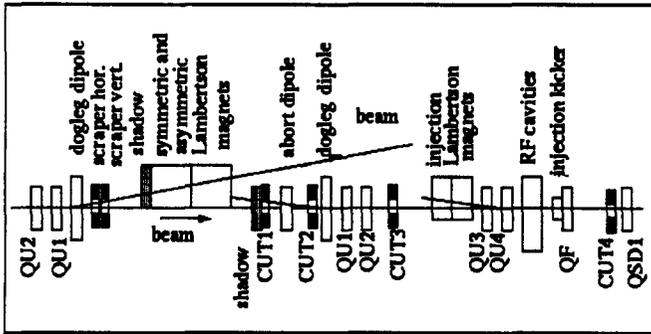


Figure 1. Collimators Locations in the West Utility

The abort system consists of 24 pulsed kicker magnets which direct the beam through the field free region of a series of Lambertson magnets on to a massive graphite absorber[3,4,5]. The abort kickers have a risetime of about $3\mu\text{s}$. Normally this system is triggered during the $4\mu\text{s}$ abort gap in the circulating beam and takes $290\mu\text{s}$ to extract

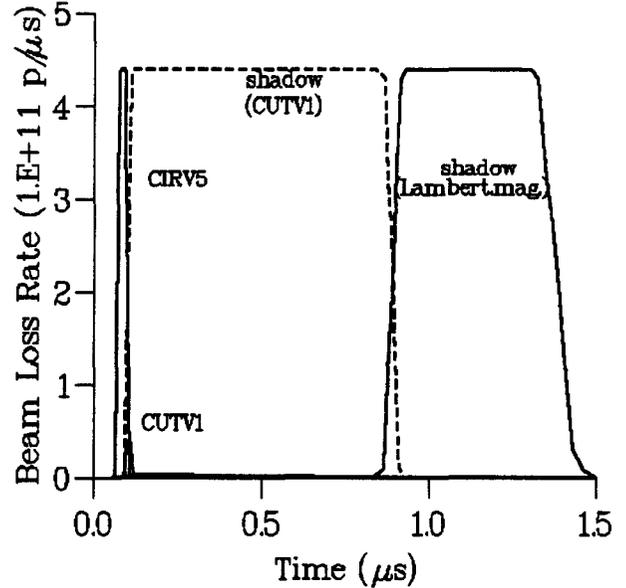


Figure 2. Beam Loss During the $3\mu\text{s}$ Kicker Rise Time

beam from the full 87 km circumference of the Collider. If one or more kicker module either prefires or misfires, some fraction of the beam may not reach the absorber. The consequences of such a beam loss on accelerator components are discussed in the next section. In this paper particle tracing is done with STRUCT program[6]. Beam loss induced cascades and corresponding temperature rise is simulated with MARS12 code[7].

II. ABORT PREFIRE PROBLEM

An abort kicker prefire causes large amplitude coherent betatron oscillation of the beam and results in halo particles being intercepted by the collimators positioned around the ring. These particles can induce overheating of the collimator jaws up to hundreds of degrees. The most severe situation takes place at 20 TeV/c before or during collisions.

Simulations of this process have been done for the following assumptions. We assumed that the circulating beam is cleaned to the 10σ level by a scraper which leaves 99% of the circulating beam inside of 4σ and 1% of the beam between 4 and 10σ . Collimators are located in West Utility, as shown in Figure 1 and in the Interaction Region (IR) of the Collider (not shown) to protect low-beta quadrupoles against irradiation. For our initial simulations we assumed

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that these collimators are placed 4σ inside the physical aperture of Collider. With an admittance of machine of 729 mm.mrad or 27σ of the circulating beam at top energy, the collimators were therefore positioned at 23σ with respect to the Collider closed orbit.

For the worst case, when abort kicker prefire takes place just after the longitudinal abort gap passes, one needs to wait one full turn to resynchronize with the abort gap in order to cleanly remove beam from the Collider. For this case the overheating of IR collimator CIR5 considerably exceeds the melting point of iron. In order to avoid overheating this collimator one could arrange to immediately fire the next 23 kickers; however, according to our simulations one would have to limit the interval of time between the prefire and the start of the rest of the kickers to be less than about $5\mu\text{s}$. Unfortunately the full abort kicker pulse is unlikely to be contained within the abort gap and one has an unsynchronized abort. Results of a simulation of beam loss around the Collider during the $3\mu\text{s}$ kicker rise time are presented in Figure 2. At low kicker field levels, halo particles are intercepted by a collimator in the IR and by the first collimator in West Utility. The temperature rise of these collimators are 400°C and 40°C respectively

At the level of about 10% of full kicker strength the deflected beam is intercepted by the first collimator in the West Utility. We must protect this collimator by a graphite shadow and temperature rise in shadow is 250°C . At the level of about 40% of kicker strength the beam is intercepted by the graphite shadow of Lambertson magnet[8] and the shadow overheating is a tolerable 800°C .

III. PREFIRE PROTECTIVE MEASURES

There are two ways we have investigated to avoid overheating of collimators and shadows:

- decreasing of the abort kicker rise time from $3\mu\text{s}$ to $1\mu\text{s}$ and
- compensating a prefired kicker by another kicker with opposite magnetic field (antikicker).

Decreasing the abort kicker rise time yields a three fold decrease in heating. For sufficiently short antikicker delay the full beam abort can be delayed until synchronization with the abort gap and thereby eliminating beam loss during the kicker risetime.

Recent simulations[9] suggest that the dynamic aperture of Collider at the top energy is around 12σ and the lifetime of the particles with large betatron amplitudes, from 12 to 20σ , varies from 50 to 2 turns. The lifetime is less than one turn for amplitudes greater than 20σ . For this case collimator jaws would have to be installed between 16 – 20σ from the circulating beam axis to protect superconducting magnets irradiation and the collimator jaws would then intercept a more dense part of the circulating beam. This closer position would lead to an additional overheating about 20 times greater than for the 23σ positions. The overheating of the collimator CIRV5 jaw during an unsynchronized abort increases to an inadmissible 900°C . The

first method of overheating reduction is ineffective in this case and only via an antikicker is it possible to eliminate the danger of collimator and shadows damage.

The collimator jaw overheating is also strongly dependent upon the delay between prefire and start of antikicker. The resulting kick and beam loss versus time for different delays ($1.2\mu\text{s}$ and $1.65\mu\text{s}$) are presented in Figure 3,4. At $1.8\mu\text{s}$ delay the result kick exceeds 75% of one kicker strength and collimator CIRV5 overheating exceeds melting point. Collimator jaws overheating versus antikicker delay is shown in Figure 5. An acceptable level of temperature rise of about 300°C is exceeded at $1.5\mu\text{s}$ delay between prefire of abort kicker and start of antikicker. Providing a short ($< 1.5\mu\text{s}$) delay is an important antikicker design requirement.

IV. CONCLUSIONS

Our simulations show that for large ($> 20\sigma$) Collider collimators settings an unsynchronized abort is allowed if graphite shadows are used upstream of the first abort Lambertson magnet and at a few critical collimator locations. For smaller collimator settings (between 14σ and 20σ) an antikicker with less than $1.5\mu\text{s}$ delay appears to be needed to limit Collider equipment overheating to tolerable levels; however, further study is required in order to understand multi-kicker prefire and other failure scenarios.

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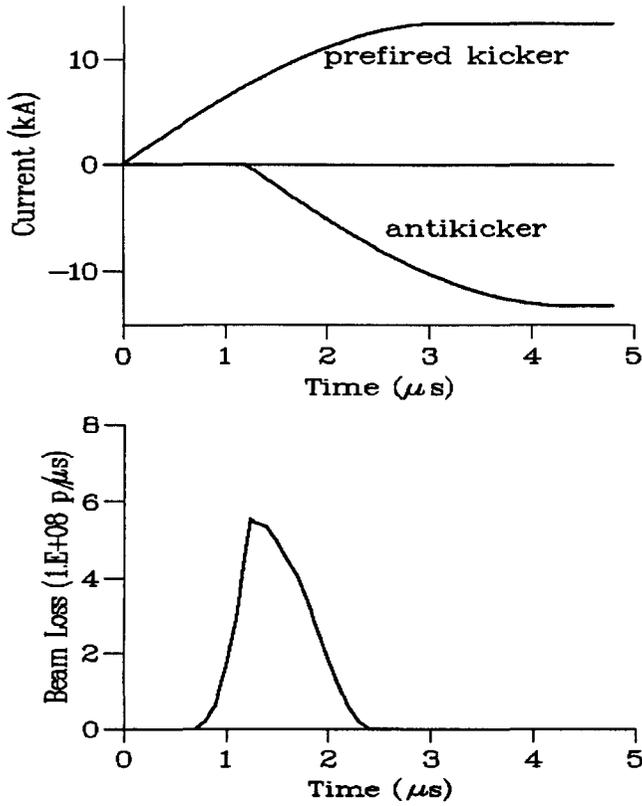


Figure 3. Kicker/Antikicker Pulse Shape (top) and Beam Loss Versus Time (bottom) for 1.2 μs Delay

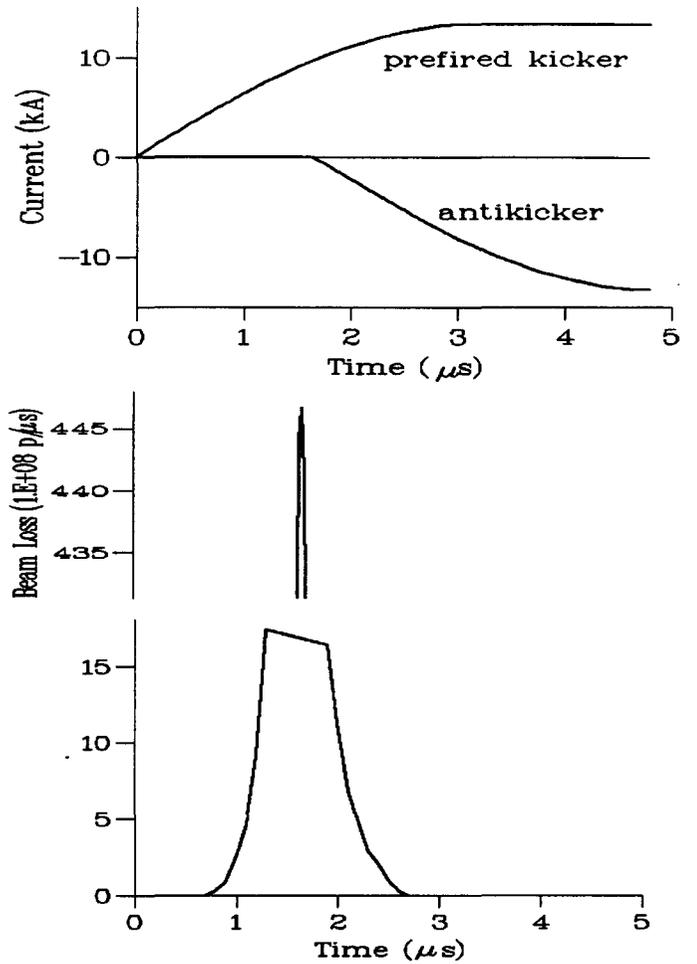


Figure 4. Kicker/Antikicker Pulse Shape (top) and Beam Loss Versus Time (bottom) for 1.65 μs Delay

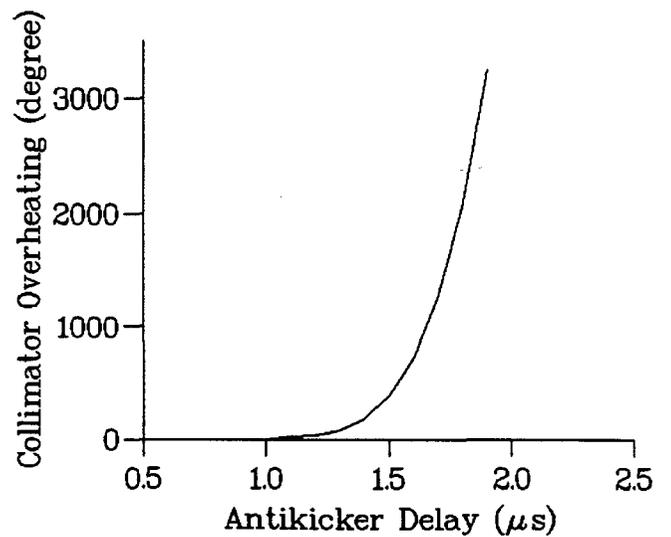


Figure 5. Collimator Jaws Overheating Versus Antikicker Delay