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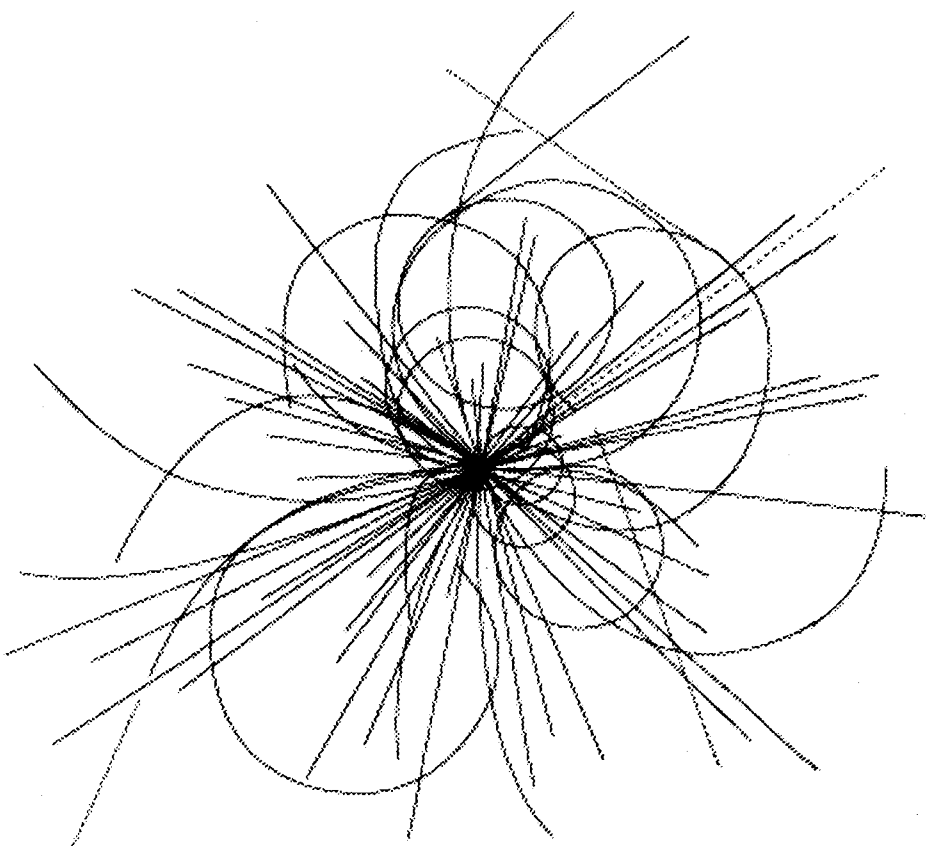

Superconducting Super Collider Laboratory

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2 TeV HEB Beam Abort at the SSCL*

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2 TeV HEB Beam Abort at the SSCL

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Abstract

The High Energy Booster (HEB) of the Superconducting Super Collider Laboratory (SSCL) will require a full aperture beam abort over a dynamic energy range of 200 GeV to 2 TeV. Since the HEB is a bi-polar machine, both clockwise (CW) and counter-clockwise (CCW) beam aborts are required. Also, the stored beam energy of 6.55 MJ in the superconducting HEB imposes upon the full aperture requirement. In this report, we describe the abort channels in the HEB utility straight sections, aperture restrictions, mechanical interferences and solutions, kicker misfires, and a 2 TeV beam absorber.

I. INTRODUCTION

The description of the HEB Abort consists of two major parts: 1.) the abort channel, common to the HEB ring, and 2.) the absorber, which lies in a gallery on a line of tangency (Fig. 1) from the HEB ring. Each part challenges the design of the 2 TeV beam abort. We shall describe the "top level" requirements first, and then show how the major parts, and their components, meet these requirements.

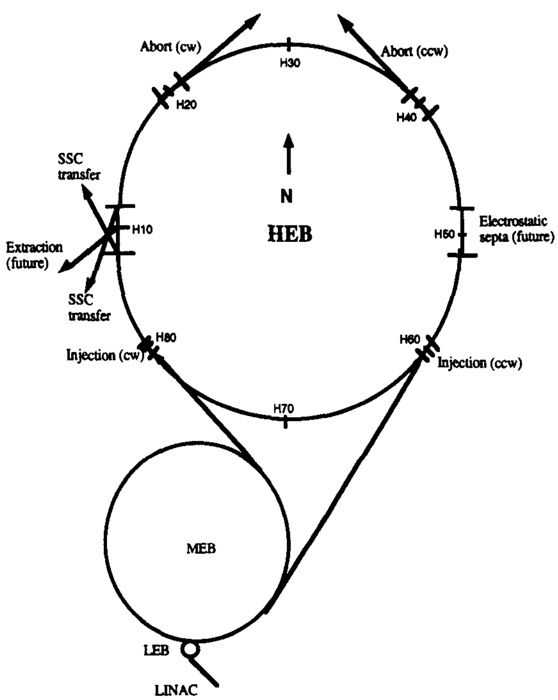

Figure 1. HEB Ring Plan View

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II. TOP LEVEL REQUIREMENTS

Table 1 lists the conditions or requirements which are imposed on the abort system. These requirements drive what the abort hardware will look like. The most difficult requirements to satisfy are those relating to beam energy and power. This is true, since any HEB ring component could be melted if the aborted beam were to strike a limiting aperture in the machine, before being aborted, within three turns, to the graphite absorber.

Table 1. HEB Abort System Top Level Requirements

Parameter	Requirement
Beam Power: Collider Injection Test Beam(future upgrade)	 192 GW @10^{10}/bunch 960 GW @5 x10^{10}/bunch
Beam Stored Energy: Collider Injection Test Beam(future upgrade)	 6.55 MJ 32.75 MJ @ 5x10^{10} /bunch
Proton Energy Range	0.2 to 2.0 TeV
Number of Protons	1 x 10^{14} @ 5x10^{10} /bunch Max
Number of protons per year	1.8 x 10^{19} Max @ 5x10^{10}/bunch
Abort Kicker Risetime	Current Rise to Maximum within abort Gap time =1.7 μs
Abort Kicker Flat Top	One full Ring Circumference to abort all beam= 36.1 μs
Abort Control	Automatic & Manual
Delay Time	Beam removed within three turns from when any of the permits is removed or from when an abort condition is detected
Kicker Prefire/Misfire	The abort system shall successfully abort beam within a 10 mm offset from the closed orbit with any one kicker misfiring or prefiring.
Muon Vector	The Muon vector after the backstop shall fall within the stratified fee site boundaries

III. ABORT CHANNEL

The HEB beam may need to be aborted because of either high beam loss, large (> 3 mm) "free" β oscillations due to kicker misfires, large transverse injection errors, or other technical reasons, such as vacuum leaks, refrigeration plant failure, quench detection, etc. When such adverse conditions are detected, then the abort kicker magnets are triggered and fire with a risetime of 1.7 μs, synchronously at the beginning of the abort gap. The kickers move the aborted beam vertically into the field region of the Lambertson magnets. The field of the Lambertson's is such that the beam is bent horizontally "out of" the HEB ring. The kicker magnet waveform has a ±10% droop, such that vertical "painting" of ±25 mm is seen at the face of the graphite beam absorber ≈ 400 m from the utility straight section. This ±10% droop is consistent with Lambertson apertures (Figs. 3,4) and allows the HEB beam absorber to be placed "close" to the HEB ring, and therefore, far from site boundaries where "μ vectors" are a concern. We will address this concept in another section. The Lambertson magnets will be placed in series on the main power bus along with the dipoles and quadrupoles of the HEB ring. This is done to take advantage of the large inductance, and therefore, time constant, $\tau = L/R \approx 30$ sec. This allows the aborted beam to be extracted from the HEB ring in a "fail-safe" way even with a shorted or "ground faulted" bus, since the orbit will only decay by ≈ 4 mm in the nominal three turns before the beam abort is completed.

It should be noted that the criterion of a "full aperture" abort is satisfied in the following way. The dynamic aperture has a radius of ≈ 7-8 mm, and the beam abort provides a radius of 10 mm, thus allowing for all the accelerated beam, that normally survives field and alignment errors, to be aborted cleanly to the absorber, even with a single kicker misfire.

It should also be noted that the present abort scheme has a beam trajectory which offers a mechanical design challenge for the two superconducting quadrupoles, QS3 and QS2 (Fig. 2), and associated spool pieces which are directly downstream of abort Lambertson magnets. This is true since the present design minimizes the number of abort kickers and Lambertson magnets by passing aborted beam through the side of cryostats for the two superconducting quadrupoles, and spool pieces. Conceptual design for these special cryostats presently exists.

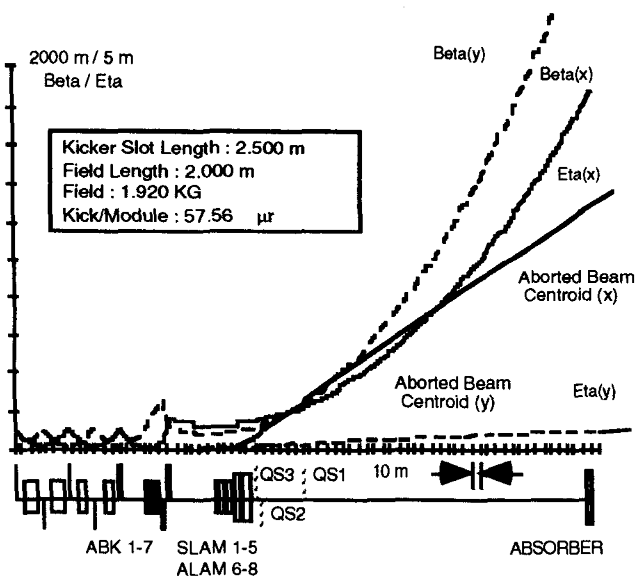

Figure 2. HEB Abort Channel

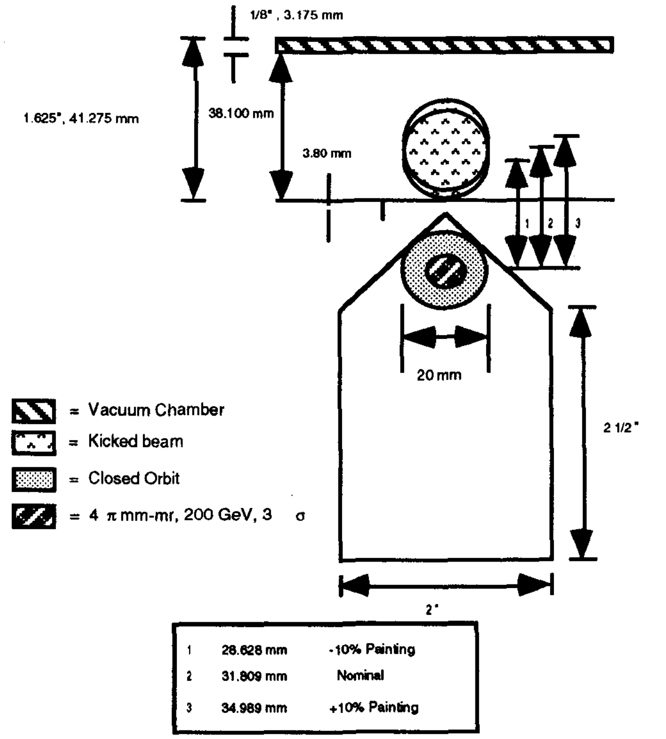

Figure 3. First Symmetric Lambertson Aperture of Abort Channel, Upstream End

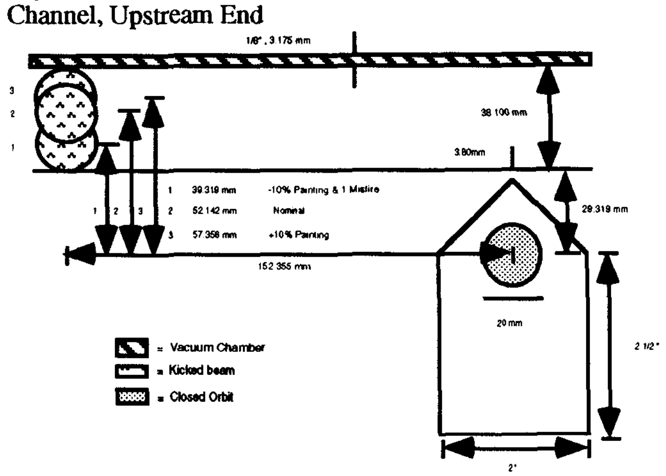

Figure 4. Last Asymmetric Lambertson Aperture of Abort Channel, Downstream End

IV. BEAM ABSORBER

The location of the HEB absorber relative to the ring is constrained by two boundary conditions (Fig. 8). First, the "μ vector" at the site boundary, and second, the ΔT, or instantaneous temperature rise of the graphite core of the beam absorber. The first constraint would allow for a design that would place the absorber far from site boundary, or close to HEB ring. A 2 TeV μ vector is defined as a 10 mrem/year isodose contour, assuming that aborted beam is attenuated only through natural earth shield (ie. Austin Chalk). The aborted beam is absorbed in a graphite and steel absorber, and the resultant μ vector, as calculated by N. Mokhov, is found to be 1625 m [1]. The HEB absorber is tentatively placed some 1900 m from the site boundary. The second constraint, of ΔT, would allow for a design that would place the absorber far from the HEB ring, in order to allow natural beam spot to become larger, and energy deposition and ΔT, to become smaller. These two constraints are clearly in conflict. The resolution is to force the "natural droop" of the kicker flat top to be as large as 20% (ie. ±10%) and still fit through Lambertson magnets, in order to "paint" a 50 mm vertical stripe on the face of the graphite absorber core. This allows the core to reach a maximum temperature of ≈ 900 °C, and ≈ 1,100 °C [1] with a single kicker misfire (Fig. 7). The choice of graphite as core material is such that the ionization shower is spread out over a large volume and minimizes growth of instantaneous temperatures.

The absorber, as well as absorbing 6.55 MJ of beam energy, must also protect the environment from ground water activation. This, in large part, is the role of the iron shield surrounding the graphite core (Figs. 5 and 6). J. Bull has calculated [2] the required amount of iron shielding assuming a maximum of 20% of all accelerated beam is aborted per year.

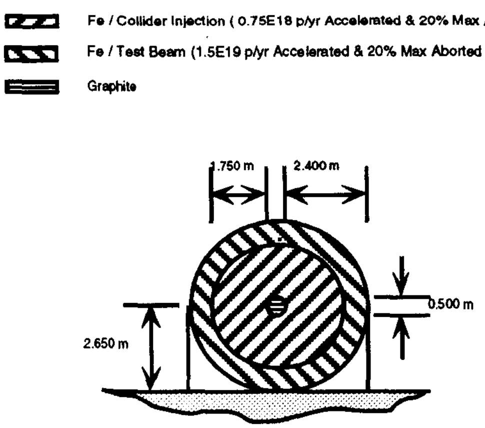

Figure 5. HEB Absorber / Cross Section

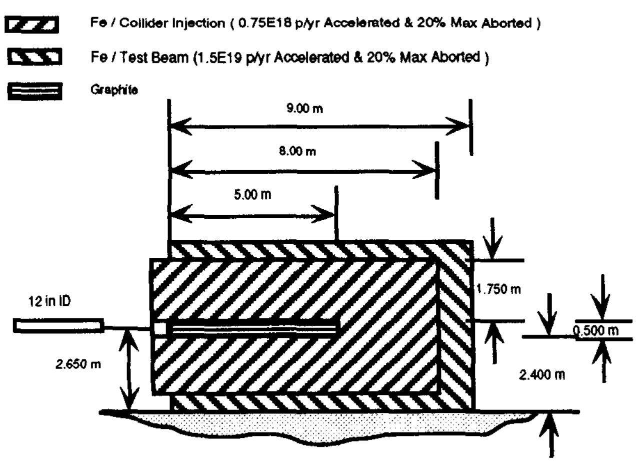

Figure 6. HEB Absorber / Lengthwise Section

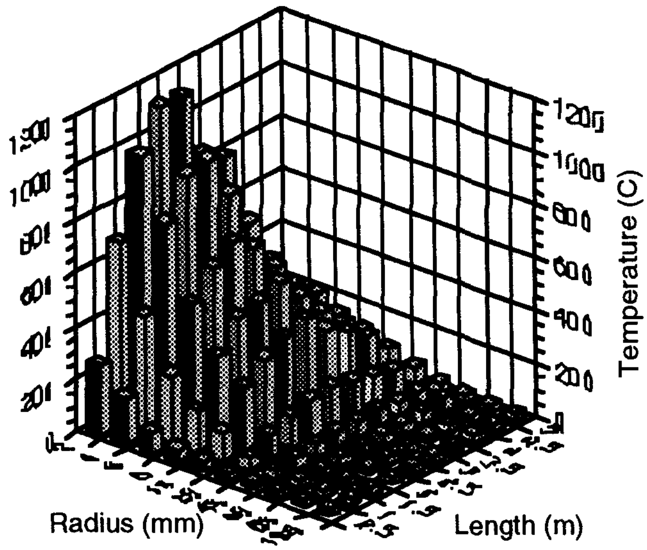

Figure 7. HEB Absorber Core Temperatures / Single Misfire

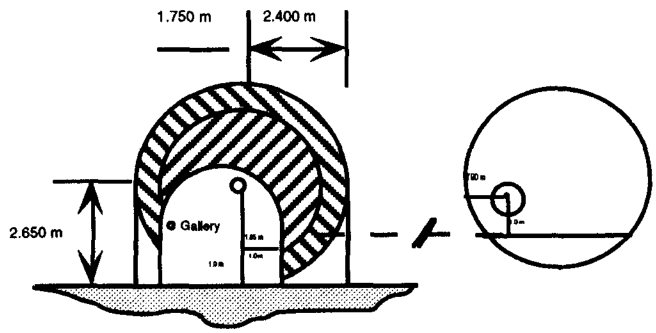

Figure 8. HEB Ring / Absorber Tunnel Relative Orientation

It should be noted that between the abort channel and the absorber there is only a vacuum beam pipe which telescopes to 12 in. I.D. to accommodate magnification of 10 mm "off axis" aborted beam, and single kicker misfire.

V. SUMMARY

In conclusion, a conceptual design exists for a full aperture HEB abort and absorber which addresses all top level requirements and related safety issues.

VI. ACKNOWLEDGMENTS

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VII. REFERENCES

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[2] A. Van Ginneken, CASIM "Program to Simulate Transport of Hadronic Cascades in Bulk Matter", FN-272, Fermilab, 1975.