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Tolerance Evaluation of BC1 in RHIC Lattice

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TOLERANCE EVALUATION of BC1 in RHIC LATTICE

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ABSTRACT

We analyze the effect of heavy-ion collision on the beam crossing dipole BC1. We found that the temperature increment is about .0007 per hour to the superconductor in the absence of cooling. The life time of the superconductor due to the nuclear reaction between the secondary particles and the Nb-Ti atom is about 4*10^14 hours!!.

1. Introduction

A collision of heavy ion particles produces tremendously many secondary particles, which may interact with the beam crossing dipoles BC1. These secondary particles have larger charge to mass ratios. Their trajectories will therefore spread onto the superconductors of BC1. It is of interest to investigate the effect of these secondary particles on the BC1. In this paper, we shall estimate the effect of these particles on the life time of the superconductor and the effect of the temperature rise on the superconductor.

2. Estimate of the effect for the STANDARD INSERTION LAYOUT.

Table 1 lists the luminosity of Au on Au at 100 GEV/nucleon from the RHIC proposal(ref.1).

TABLE 1. LUMINOSITY of AU + AU @ 100 GEV/nucleon

Initial Luminosity(α = 0)	9.2 *10 ^26 /cm^2/sec
Average Luminosity(α = 0)	4.4 *10 ^26 /cm^2/sec

The nuclear reaction cross-section is given by

$$\sigma = \pi *(1.25*(A_1^{1/3} + A_2^{1/3}))^2*10^(-26) \ cm^2 .$$

Therefore the number of central collision events(taken to be 5% of the total of collision events) per unit time is given by

$$dN/dt = L * \sigma * 5\% = 300/sec ,$$

where we use the initial peak luminosity for our estimate and we assume 95 % of reaction cross-section to be grazing or peripheral, thus they do not create a large number of particle showers.These peripheral collisions may cause some background radiation to the rest of the machine. Their effect to BC1 should be minimum. There are two problems in the effect of collision: (1) Temperature increase (2) Secondary interaction with the superconductors.

(1) Temperature increase:

Fig.1 shows the data of range and energy loss rate as a function of the particle momentum. For those particles in the fragmentation region, their rapidity being the same as the beam particles, we expect that dE/dx becomes nearly constant. The superconductor for BC1 has two layers of 1.007 cm each. Assuming 100% superconductors,we obtain the thickness of 17 g/cm^2 of superconductors. Assuming that the fragmentations are mostly singly charged, we obtain that the energy deposit on the superconductor would be

$$Es = \langle N \ ch\rangle * 17 * 1.5 \ MeV ,$$

where we assumed two layer superconductor of $17\ g/cm^2$ thickness and 1.5 MeV energy loss of dE/dx. The number of charged particles created depends on the temperature or the intrinsic excitation of the fragmentation volume. The number may vary from hundreds to thousands. If we take the number to be $\langle N_{ch} \rangle = 4000$, we obtain the effective energy deposit to be

$$dE/dt = dN/dt * Es = 4.8 * 10^{-6} \text{ Joules/sec} .$$

The energy is deposited in the superconductor of BC1, which has dimension of $2.007 \times 4 \times 330\ cm^3$. The effective area may be slightly smaller because of the majority of the particles will be spilled at the center of BC1. The effective mass of the superconductor is therefore about 6000 gm. The specific heat of Nb-Ti is about 4 mJ/gm/K at 4K. We have therefore obtained a temperature increase of

$$dT/dt = 1.4 * 10^{-7} \text{ degree/sec} = 7.2 * 10^{-4} \text{ degrees/hr.}$$

(2) Secondary interaction with the superconductors.

Another effect of these secondary particles is the nuclear reaction with the superconductors. The flux of the secondary particles is about

$$\text{Flux} \approx \langle N_{ch} \rangle * dN/dt .$$

These secondary particles have the cross-section of .66 barns with the superconductors. The superconductor has a thickness of 17 gm/cm^2 or $2 * 10^{23}$ $nuclei/cm^2$. The decay rate is therefore

$$\lambda = \text{Flux} * \text{cross-section}/(\text{effective surface area})$$
$$= 6 * 10^{-21}/\text{sec} .$$

The time for 1% loss of the superconductor is $4 * 10^{14}$ hours!. It is therefore not an important effect at all.

3. Estimate for the suggested fragmentation layout.

It was suggested by the fragmentation region experimental group that the BC1 is moved to a distance 1 m from the interaction point(IP). The experimental set-up is then located between BC1-BC2. The magnet BC1 has a sizable solid-angle, .31 radians out of 4π onto the superconductor parts of the magnets. Those particles which miss the superconductor are assumed to be of little importance. The central region would probably create mainly pions and some kaons, of less than 1 Gev/c . The energy loss onto the superconductor is therefore (see Fig.1)

$$dE/dt = dN/dt * \langle N_{ch} \rangle * 10 * 17 \text{ Mev/sec} * (\text{solid-angle}/4\pi),$$

where we have assumed $17\ g/cm^2$ thickness of superconductor and maximum of 10 $Mev/(gm/cm^2)$ of energy loss for these particles. With $\langle N_{ch} \rangle = 4000$ in the central region, we obtain

$$dT/dt = 3 * 10^{-8} \text{ degree/sec} = 1 * 10^{-4} \text{ degree/hour.}$$

Thus the effect is 5 times smaller then the fragmental contribution due to the smaller solid angle acceptance. Since the effect of the nuclear collisions is not important for the life time of the superconductors, we shall conclude the same thing holds true here in the present configuration.

4. Conclusion

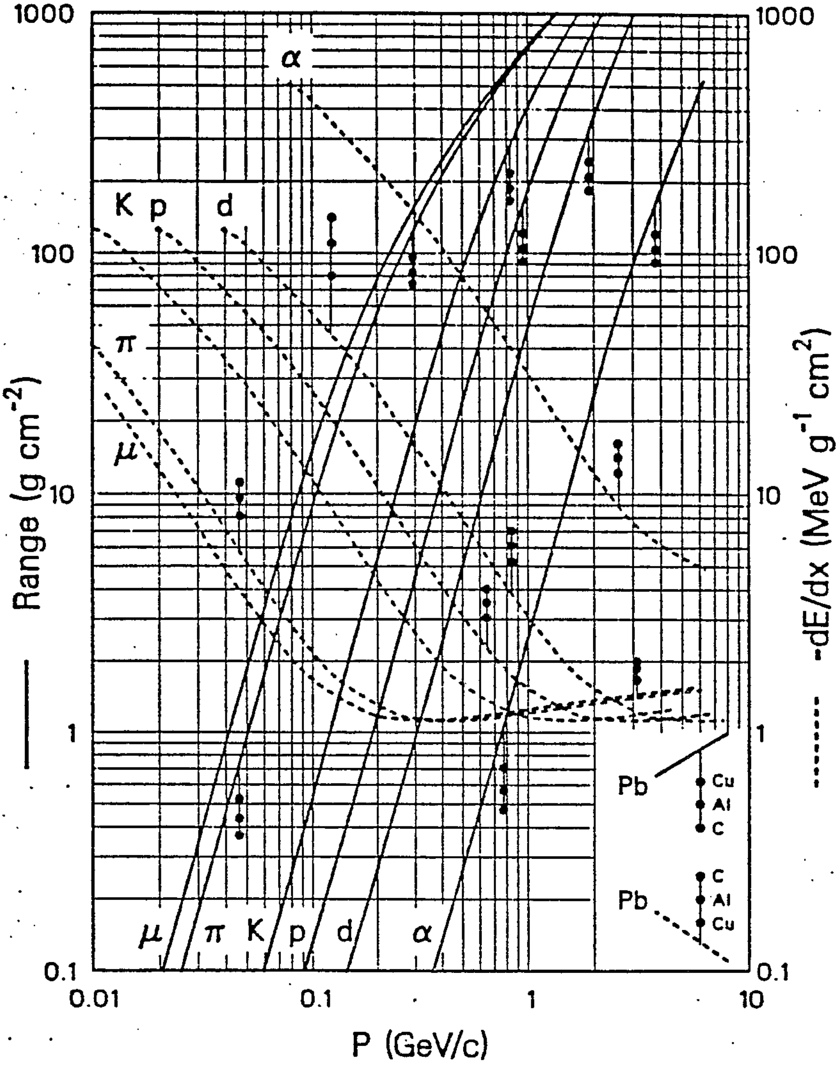
We have investigated the effect of the secondary particles from the heavy ion collisions on the performance limitation of the beam crossing dipoles. Our estimate should serve as an order of magnitude discussion. Since our calculation indicates that the BC1 has a huge safety margin against these damages, we can conclude that the effect of secondary particles poses no difficulties to the performance of BC1 at all.

Reference:

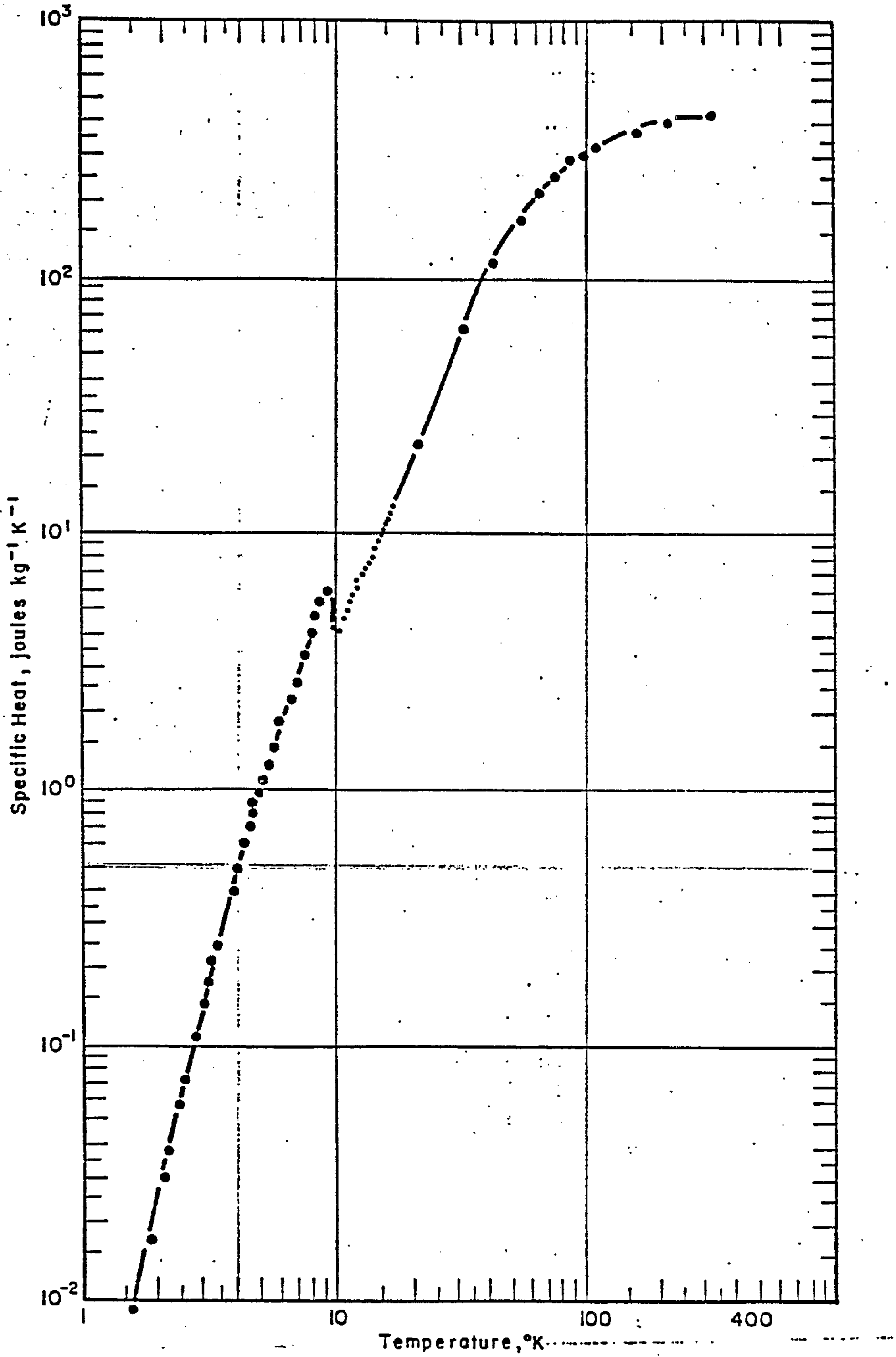
1. Proposal for a Relativisitic Heavy Ion Collider, BNL-51932,UC-28.

2. Selected cryogenic Data note-book, BNL-10200-R

MEAN RANGE AND ENERGY LOSS in Lead, Copper, Aluminum, and Carbon



Mean range and energy loss due to ionization for the indicated particles in Pb, with scaling to Cu, Al, and C indicated, using Bethe-Bloch equation [See Sec. (1) of Passage of Particles Through Matter] with corrections. Calculated by M.J. Berger, using ionization potentials and density effect corrections as discussed in M.J. Berger and S.M. Seltzer, "Stopping Powers and Ranges of Electrons and Positrons," (2nd ed.), U.S. National Bureau of Standards Report NBSIR 82-2550-A (1982). The average ionization potentials (I) assumed were: Pb (823 eV), Cu (322 eV), Al (166 eV), and C (78.0 eV). Figure indicates total path length; observed range may be smaller (by ~ 1 % - 2% in heavy elements) due to multiple scattering, primarily from small energy-loss collisions with nuclei. The functional forms have not been experimentally verified to better than roughly ± 1%. For higher energies refer to discussion by Cobb ["A Study of Some Electromagnetic Interactions of High Velocity Particles with Matter," University of Oxford Report HEP/T/55 (1973)] and by Turner ["Penetration of Charged Particles in Matter: A Symposium," National Academy of Sciences, Washington D.C. (1970), p. 48]. For lower energies both data and theory are not well understood. Scaling to other beam particles is, to a good approximation, described by the formula on the next page.



SPECIFIC HEAT VERSUS TEMPERATURE FOR NB 51 TI 49