BROOKHAVEN NATIONAL LABORATORY

BNL-102623-2013-IR

Settings of the NSLS II BSR magnets for energy interlock

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November 19, 2013

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DOE Office of Science

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1 Introduction

It was determined [1] that for the commissioning purposes energy range of the beam reaching the NSLS-II storage ring (SR) is allowed to be 2 GeV - 3.15 GeV. The Booster to SR (BSR) bends B1 and B2 interlocked at their nominal 3 GeV settings with +-5% window provide the required “energy filter” [2].

Another scenario of Booster operation suggests extracting the beam from the Booster to the BSR phase 1 line (or dump line). Under these circumstances the bend B2 is turned off. An adequate shielding is planned in BSR phase one line [3] for B1 set within the boundaries of its 2 GeV nominal setting minus 5% and its 3 GeV setting plus 5 %.

The goal of this exercise is to find the proper settings of respective bends PS currents, which will realize described interlock.

2 Magnetic field data

For each BSR dipole the field profile was measured on the designed beam trajectory, with a 5 mm step, at four different currents, 222 A, 279 A, 301 A and 320 A (see Fig. 1) [4-11]. Additionally, an excitation curve (Fig. 2) was measured for each dipole in 190-350 A range with 20 A steps, and with the Hall probe placed at the center of the magnet [12, 13].

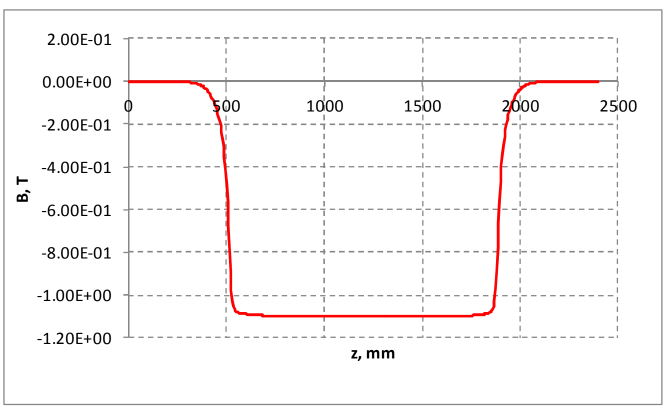

Figure 1: Magnetic field of BSR dipole B1 (BST-9035-SN002) on the designed beam trajectory measured at 301 A.

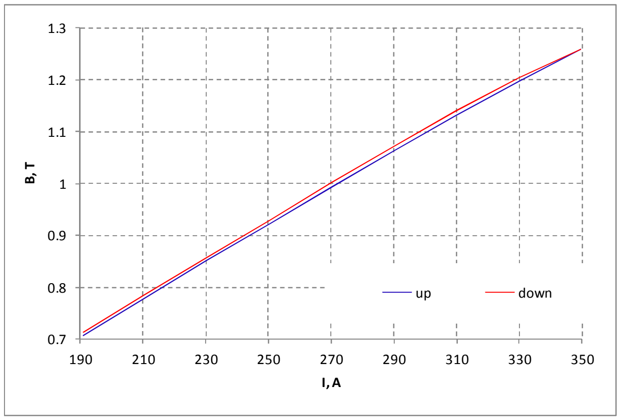

Figure 2: B2 (BST-9035-SN 001) excitation curve. The current was first increased from 190 A to 350 A (blue "up" curve), then lowered back to 190 A (red "down" curve).

We calculated field integral (BL) at four currents from measured dipole field profiles. We also estimated field integral at the currents of excitation curve measurements by assuming that BL is proportional to the field (B) at the center of the dipole: $BL_1=BL_0*B_1/B_0$. We estimate (by applying this formula to measured field profiles) that the precision of such field integral calculation is about 0.1%. Figure 3 shows both calculated and estimated field integrals at various dipole currents.

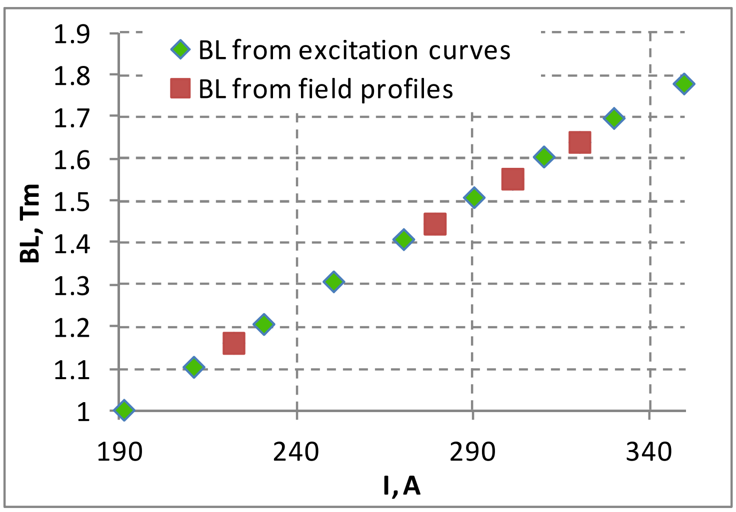

Figure 3: Field integrals at various B1 currents calculated from dipole field profiles (red squares) and estimated from excitation curve data (green diamonds).

3 Dipoles current settings

The designed angles for B1 and B2 are 0.1148 rad and 0.154 rad respectively. This provides nominal field integrals BL_{B1}=1.15 Tm and BL_{B2}=1.54 Tm. The +-5% interlock window on B1 and B2 means that the current interlock shall provide 1.09 Tm lower boundary field integral and 1.21 Tm higher boundary field integral for B1, and 1.46 Tm and 1.62 Tm lower and higher boundary field integrals for B2.

The nominal and interlock boundaries field integrals for B1 are near BL measured for 222A. This current region was not well measured. We estimate (from interpolating currents that would provide the measured field integral) that interpolating the currents for B1 interlock from 222 A and 279 A data would give current precision of about 0.2%. Therefore, it makes sense to use data for field integrals calculated from excitation curve. The resulting B1 interlock currents are: I_{low}=208.0 A, I_{nom}=219.3 A and I_{high}=230.3 A.

For B2 the required interlock field integrals are conveniently close to the measured field integrals. So we can interpolate the required interlock currents from the data for measured field profiles. The B2 results are: I_{low}= 282.1 A, I_{nom}= 298.0 A and I_{high}= 314.5 A.

It was decided that the interlock boundaries will be set with 0.6% precision; therefore we suggest that high and low current settings shall be moved towards nominal dipole current by 1%. Such set-up automatically guarantees that dipole bending angle will never be out of +-5% window. The finalized dipole interlock settings are given in Table 1.

	B1	B2	units
I_{low}	210.1	285.0	A
I_{nom}	219.3	298.0	A
I_{high}	228.0	311.4	A

Table 1: Results for the BSR B1 and B2 current interlocks.

For the case of extracting beam into the dump line, the nominal 2 GeV field integral for B1 is 0.77 Tm. Therefore the B1 lower bound field integral is 0.73 Tm. This value is much less then any measured field integral. We find the required current to be I_{low}= 137.6 A by using closest to 0.73 Tm field integrals calculated from excitation curves. We estimate the error on obtained current value to be within 1%. Furthermore, we suggest that moving the found current setting up by 2% guarantees that B1 bending angle will never be out of the boundary of nominal 2 GeV -5% angle. The dipoles settings for beam extraction into the dump line are given in Table 2.

	B1	B2	units
I_{low}	140.4	0.0	A
I_{nom}	N/A	0.0	A
I_{high}	228.0	0.0	A

Table 2: Results for the BSR B1 and B2 current settings for extraction into BSR phase 1 beamline.

Conclusion

We found the dipole current settings for the BSR energy interlock. The finalized results are presented in Table 1. Setting B1 and B2 interlock with these values guarantees that +-5% windows on these dipole angles are never exceeded, provided that the precision of setting the dipole current is better than 1%.

In addition to that, we specify the current settings suitable for beam extraction to BSR phase 1 beamline. The dipole current values provided in Table 2 guarantee that any possible beam losses associated with operating BSR phase 1 line are adequately shielded.

References

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