Multipole Polarities for the SNS Accumulator Ring

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Introduction

We document polarities of the magnet multipoles. In this paper we extend the definitions for the polarities given by [1]. For dipoles in the ring — which uses proton beam — a bend toward the right (in the negative **X** direction) has a **B** polarity. Note, the convention was established for the HEBT line which uses H^- beam. Furthermore, quadrupoles with with polarity **A** defocus the beam horizontally.

Field Layout

The magnetic field lines for the multipoles are shown in the following schematics. The skew multipoles are obtained by rotating regular multipoles in the clockwise direction. The coordinate systems is shown in Fig. 1, where *X* is the radial direction, *Y* is the vertical direction and *Z* is along the beam. Fig. 2 shows the regular and skew dipoles, Fig. 3 shows the quadrupoles, Fig. 4 shows the sextupole fields and finally, Fig. 5 shows the octupoles.

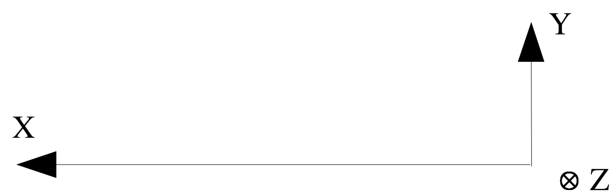

Figure 1: The coordinate system used. X is radial, away from the center of the ring. Z is into the paper in the clockwise direction around the accumulator ring.

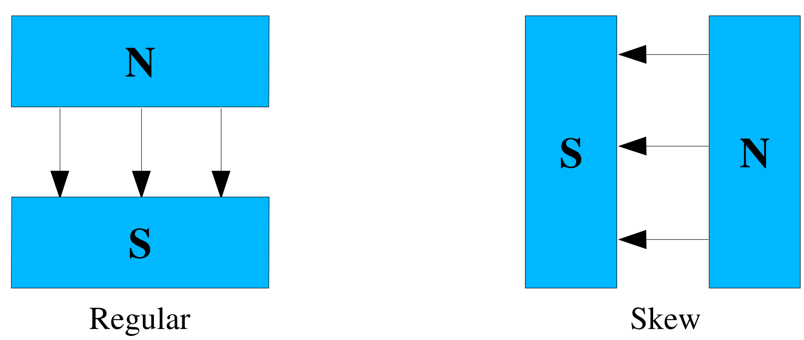

*Figure 2: The field directions for the Horizontal (regular) and Vertical (skew) bending dipoles when the magnet is powered with polarity **A**. Skew dipole: Clockwise rotation of 90°.*

*Figure 3: The regular and skew field lines for the quadrupoles in the accumulator ring. These field lines for polarity **A**. Skew quadrupole: Clockwise rotation of 45˚.*

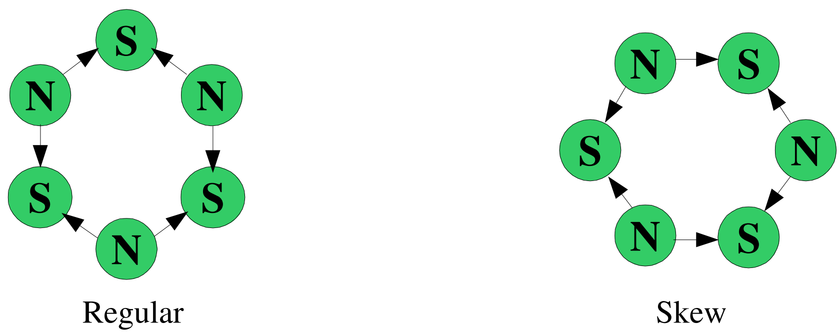

*Figure 4: Sextupole field lines for regular and skew magnets. As above, these field lines are for polarity **A**. Skew sextupole: Clockwise rotation of 30˚.*

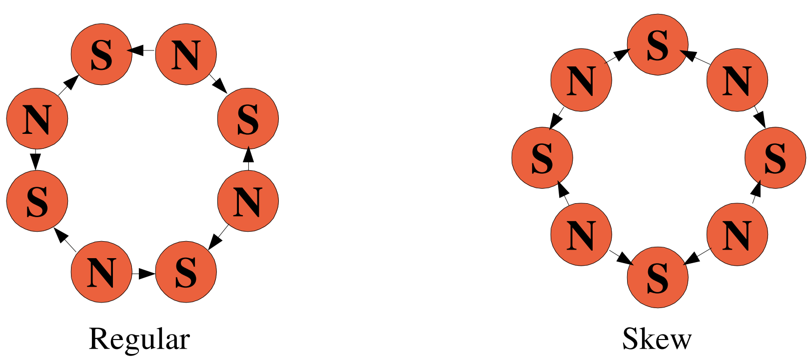

*Figure 5: The regular and skew field lines for the octupole correction magnets. These are the field lines for polarity **A**. Skew octupole: Clockwise rotation of 22.5˚.*

From the direction of the field lines given in the Figs. 2-5, the relation between the multipoles and the planar magnet field are as follows[2]:

$$\boldsymbol{B}_y(x,0,z) = -\sum_{n=0}^{\infty} B_n^{[SNS]}(z)\frac{x^n}{n!} \qquad \boldsymbol{B}_x(x,0,z) = \sum_{n=0}^{\infty} A_n^{[SNS]}(z)\frac{x^n}{n!}$$

where, $B_n^{[SNS]}(z)$ are the regular multipole strengths and $A_n^{[SNS]}(z)$ are the skew multipole strengths. Note, the negative sign for the regular multipoles, due to the choice of field directions. Next we will consider the field directions used in the optics design.

Optics Design

To find out the field directions for the multipoles in the MAD [3][1] program, a simple beam line with a drift space followed by the multipole (excited with a positive strength) then another drift space was created (see the Appendix). The closed orbit then is observed for a particle with an offset of +1*cm* through this line, to see in which direction the particle is shifted (For the dipole, use the survey command). From the direction of the shift, the field direction is deduced. The results are shown in Table 1.

	+X Bump (1 cm)			
Device	***X shift***	***Y shift***	***Field Direction***	***Polarity***
Dipole	-	0	↑	B
Skew Dipole	0	-	→	B
Quadrupole	-	0	↑	B
Skew Quadrupole	0	-	→	B
Sextupole	-	0	↑	B
Skew Sextupole	0	-	→	B
Octupole[2]	-	0	↑	B
Skew Octupole[2]	0	-	→	B

Table 1: Using MAD, an orbit bump in the ***X*** *direction was applied to each device (Col. 1) with a positive strength. The shift in the closed orbit is then determined: -, 0 or + (shown in Cols. 2 and 3). Assuming a proton beam, the field direction at the* ***+X*** *position is shown in Col. 4. From the field direction, we deduce the polarity in Col. 5.*

This leaves the relation between the MAD multipoles and the planar magnetic fields as:

$$\boldsymbol{B}_y(x,0,z) = \sum_{n=0}^{\infty} B_n^{[MAD]}(z)\frac{x^n}{n!} \qquad \boldsymbol{B}_x(x,0,z) = -\sum_{n=0}^{\infty} A_n^{[MAD]}(z)\frac{x^n}{n!}$$

1 MAD versions 8.22/12 and 8.23/0 gave these results. Other versions of MAD may be different.

2 For octupoles, use the MAD “MULTIPOLE” device. “OCTUPOLE” behaves differently.

Thus, we have $B_n^{[SNS]}(z) = -B_n^{[MAD]}(z)$ and $A_n^{[SNS]}(z) = -A_n^{[MAD]}(z)$. This can be expressed with following rule of thumb:"In the SNS accumulator ring, a positive strength (from MAD) for a regular or skew multipole has its power supply set to polarity B".

Appendix

Here is the MAD file used to check the multipole field directions:

```
title, "Simple Line"
beam, particle = proton, gamma = 108
oo : drift, l = 1.0
!
! ---- Skew
!bmultx : sbend, angle = 0.01, l = 0.1, tilt
!bmultx : quadrupole, k1 = 0.01, l = 0.1, tilt
!bmultx : sextupole, k2 = 10.0, l = 0.1, tilt
!bmultx : octupole, k3 = 1000.0, l = 0.1, tilt
!bmultx : multipole, k3l = 1000.0, t3
!
! ---- Regular
!bmultx : sbend, angle = 0.01, l = 0.1
!bmultx : quadrupole, k1 = 0.01, l = 0.1
!bmultx : sextupole, k2 = 10.0, l = 0.1
!bmultx : octupole, k3 = 1000.0, l = 0.1
bmultx : multipole, k3l = 1000.0

bline : line=(oo, bmultx, oo)
use, bline
   print, full
   survey
   twiss, x = 0.01, px = 0.0, y = 0.0, py = 0.0, betx = 1.0, bety = 1.0
```

Acknowledgments

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Bibliography

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[2] C. J. Gardner, BNL/SNS/053, November 19, 1998
[3] H. Grote, F. C. Iselin, CERN/SL/90-13 (AP) (Rev. 4), May 26, 1995