BROOKHAVEN NATIONAL LABORATORY

Superconducting Magnet Division

IRON SHIMS OUTSIDE THE HELIUM VESSEL TO ADJUST FIELD QUALITY AT HIGH FIELDS*

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Abstract

This paper describes the development and demonstration of a novel technique of adjusting measured field quality. The technique is particularly attractive for achieving ultra-good field quality at high fields in superconducting magnets where the iron return yoke is saturated. The technique is based on placing iron shims of variable stack thicknesses, variable width and/or variable length on the outer surface of the stainless steel shell at strategic locations. Since the shims are placed outside the helium vessel, adjustments can be made without involving major operations such as opening the helium vessel. It is a simple and economical technique with a fast turn-around which is suitable for both short and long magnets. This allows one to reduce field errors well below the normal construction errors. The technique has recently been successfully applied in two magnets. This paper presents the design, measurement and adaptation of this technique which, when used in combination with the coil shims, produced near zero sextupole harmonic at the design field. The design was optimized to produce small harmonics throughout the range of operation.

Simple Method to Adjust Saturation of as-built Magnets

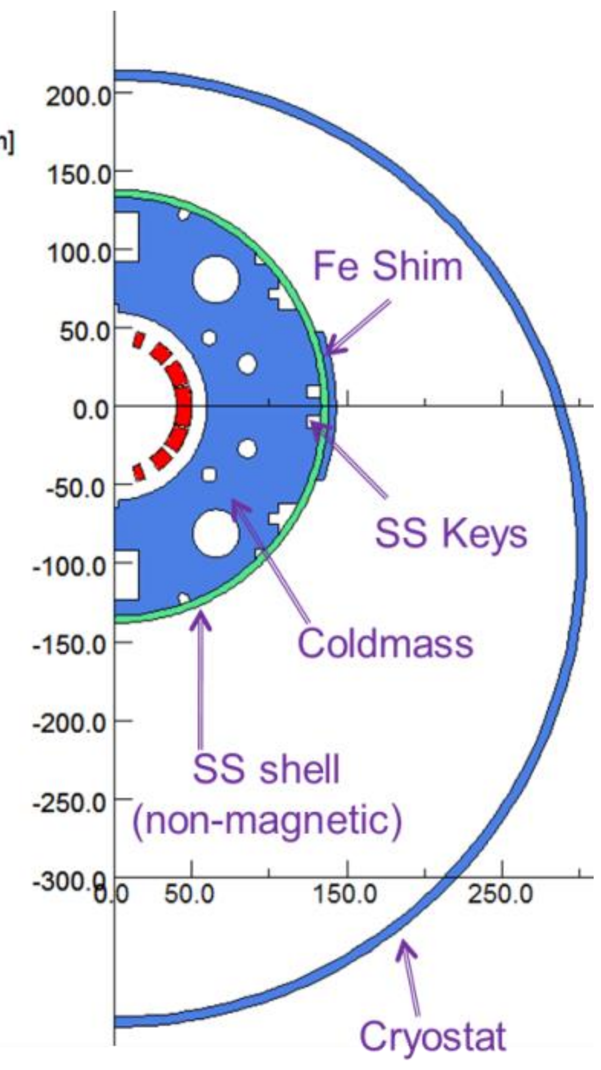
APUL

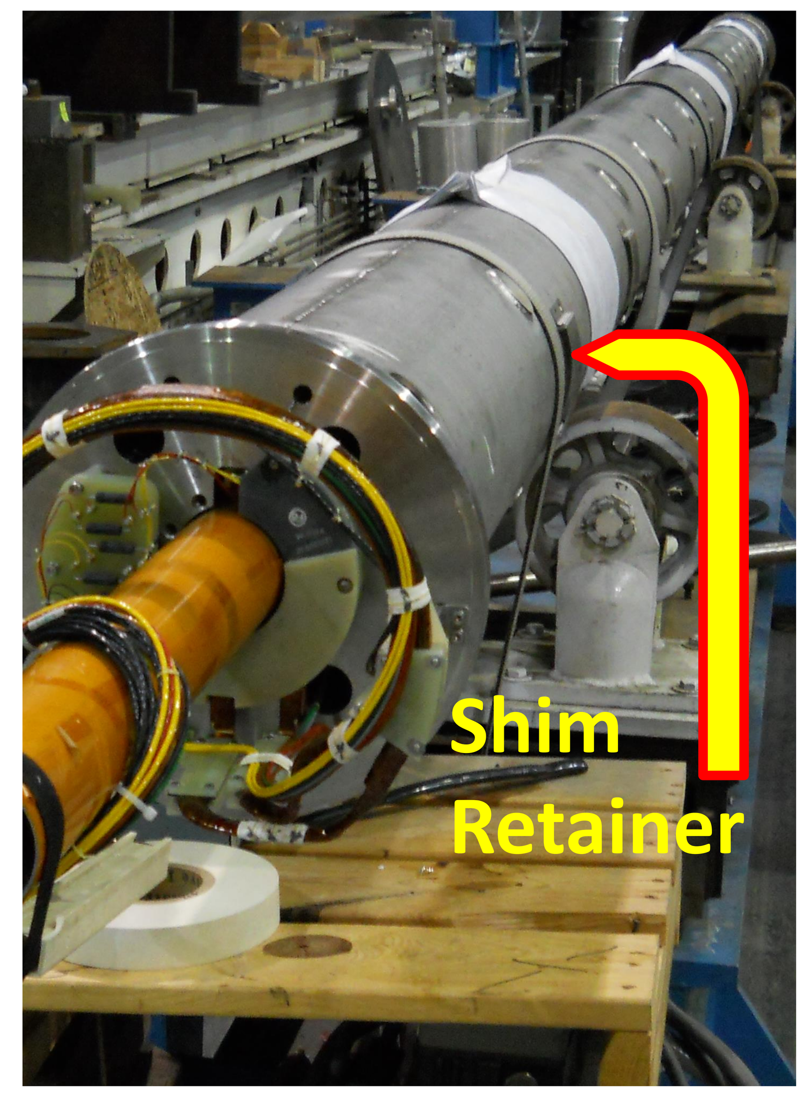
Installation of Saturation Control Iron Shims on SS Shell

(earlier method required cutting the weld to insert rods to adjust saturation control rods, this one does not)

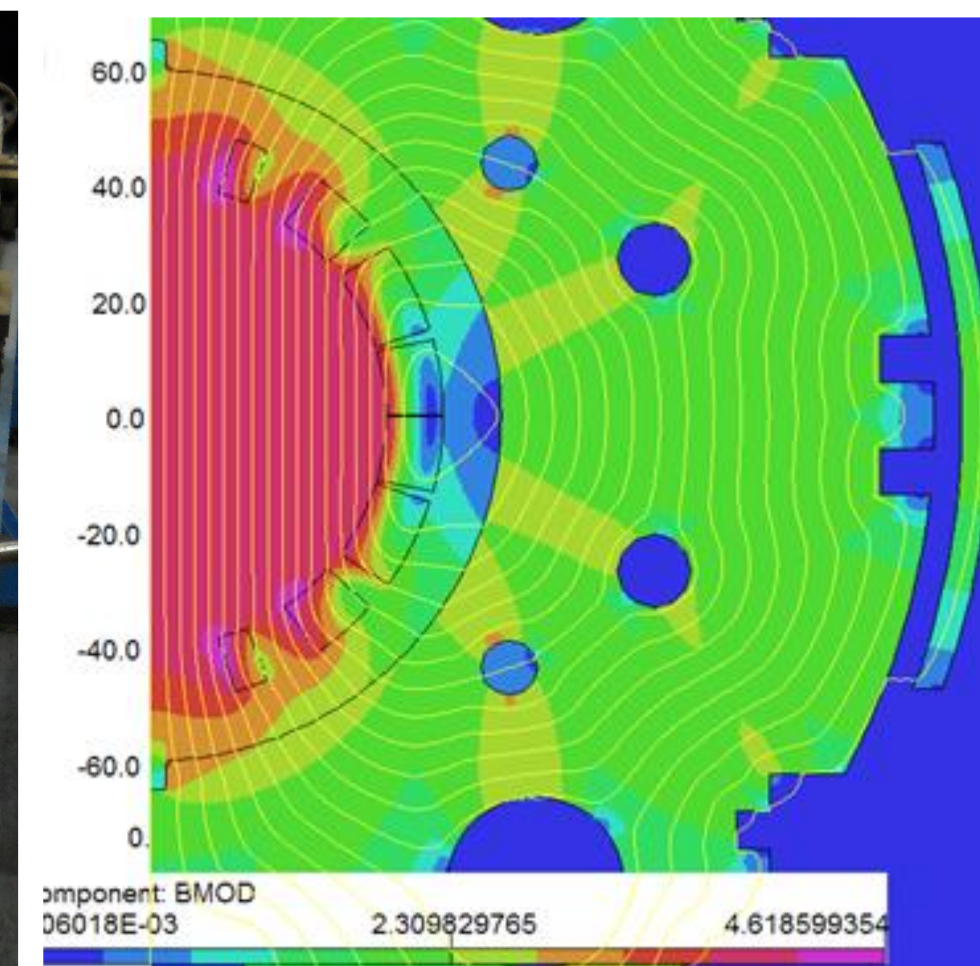
- Coldmass in cryostat gets connected to the feed-can for cold testing.
- The surface outside the stainless steel shell is open and hence some adjustments could, in principle, be made there without a major operation like cutting the weld of helium vessel, etc.
- We propose iron shims of nominal thickness attached to the shell with adjustment in the value to adjust b_3 saturation.

In the first magnet, the coldmass will anyway be taken out of the cryostat after the cold measurements before it is shipped to CERN. In the second coldmass, it will be taken out for this adjustment, if needed. In a large scale operation for other applications, one can setup a method where the shim thickness can be adjusted without taking coldmass out.





Magnetic model of the D1 magnet with the Iron Shim indicated and the actual magnet during the construction (shims will be placed in the Shim Retainer).



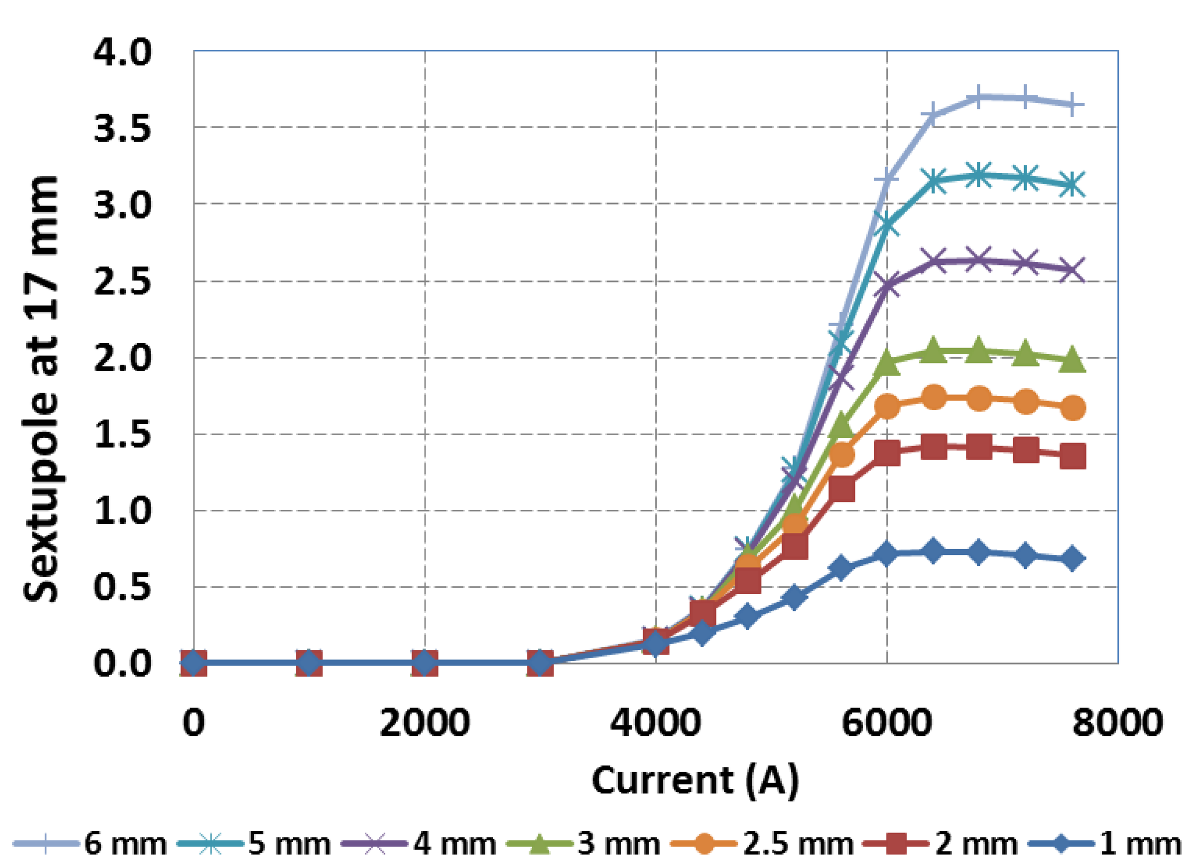
Field contour and field lines at 6000 A in the 2-d model of the D1 magnet (see iron shim on the right).

Before the final correction with the Iron Shims is applied, the following approach is used to remove the initial (geometric) errors in the sextupole and decapole harmonics (b_3 and b_5):

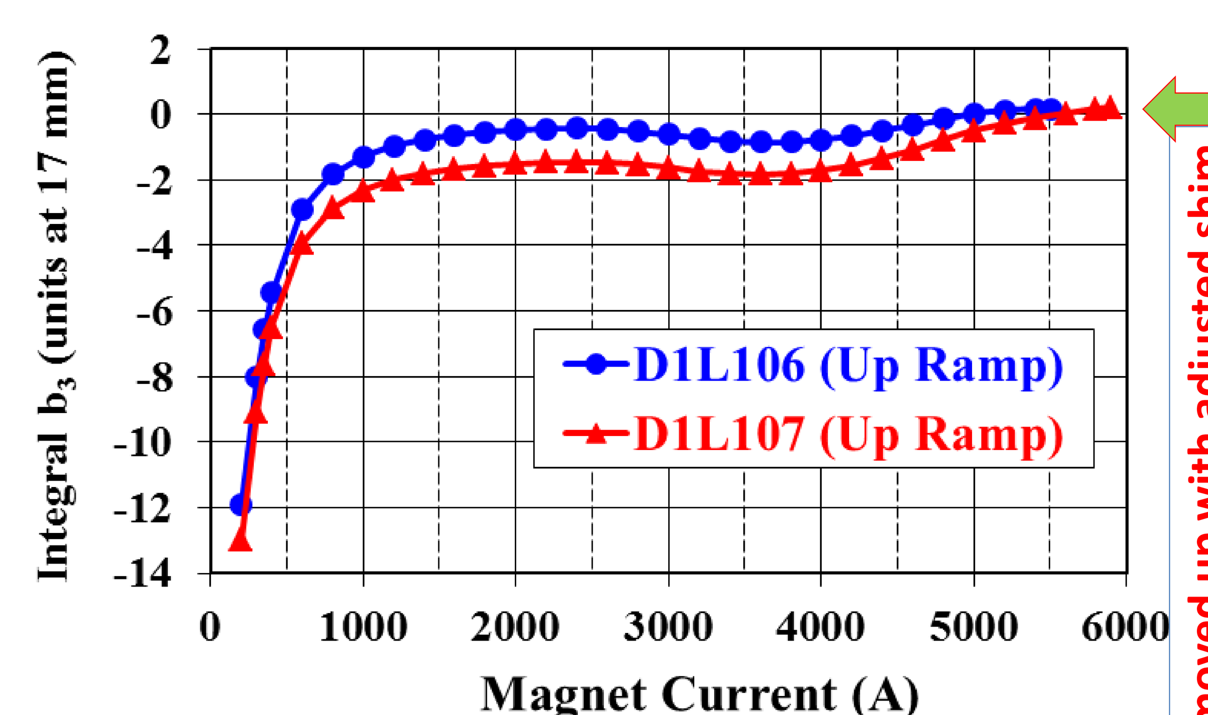
- Develop a flexible design that allows significant adjustability in two harmonics. The design has larger than minimum pole shims and midplane caps.
- Measure warm harmonics before the outer shell is welded.
- Use warm-cold correlations in previous magnets to estimate the b_3 and b_5 at the design field.
- If the expected harmonics are large, un-collar the coldmass, change the midplane and/or pole shims and measure harmonics again to verify the correction.

The following steps were envisioned to measure the influence of shims and determine the right size to minimize b_3 at the design field in magnets #106 and #107:

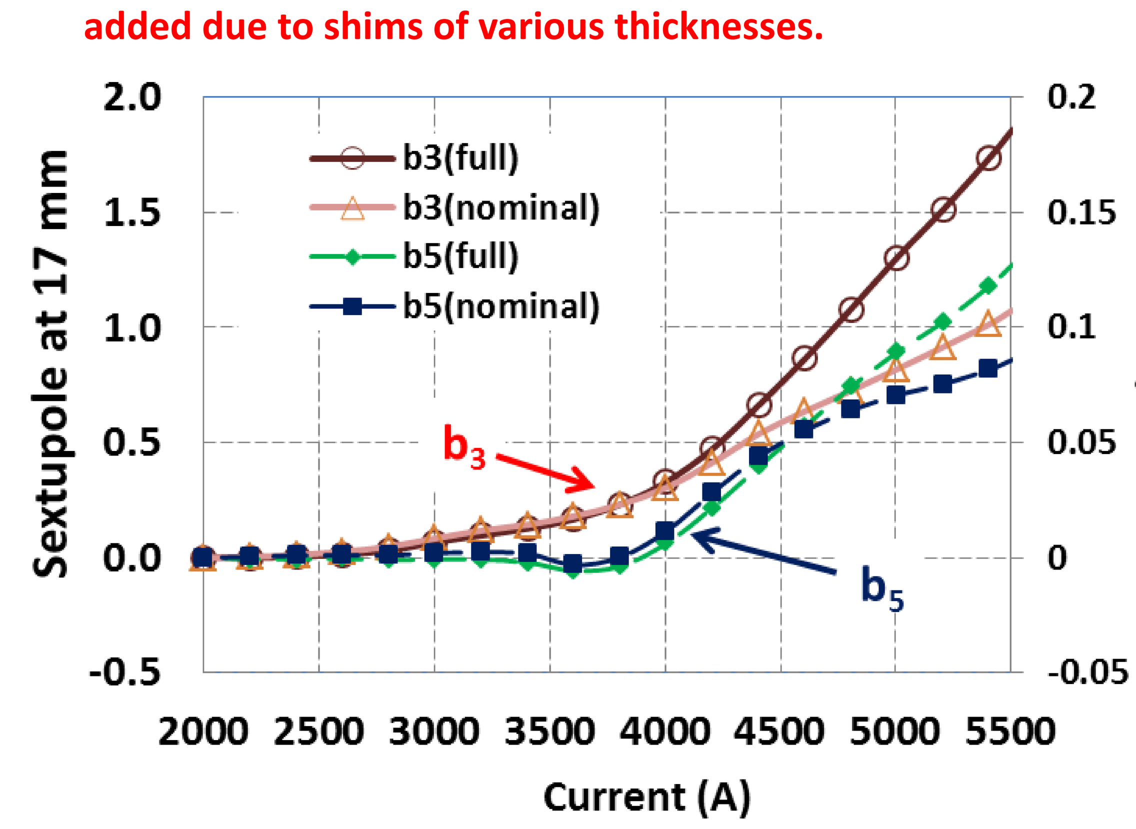
- Build coldmass #106 with (a) 1/3 length full size shim, (b) 1/3 length half (nominal) size shim and (c) 1/3 length no shim.
- Perform magnetic measurements as a function of current in coldmass #106 using a 1-meter long rotating coil in the entire length of the magnet to determine integral values of harmonics and to determine the measured change in b_3 due to the full size and half size shims.
- If b_3 at design field is outside the specifications in #106, change the thickness of Fe shim by taking the coldmass out, installing corrected shim and putting the coldmass back inside the cryostat. Perform the second set of cold measurements if the shims were changed.
- Build coldmass #107 using shims with optimized thickness, computed on the basis of warm measurements and shim calibration in #106. Do cold magnetic measurements. If b_3 is outside the specifications, change the shims and repeat the cold magnetic measurements.



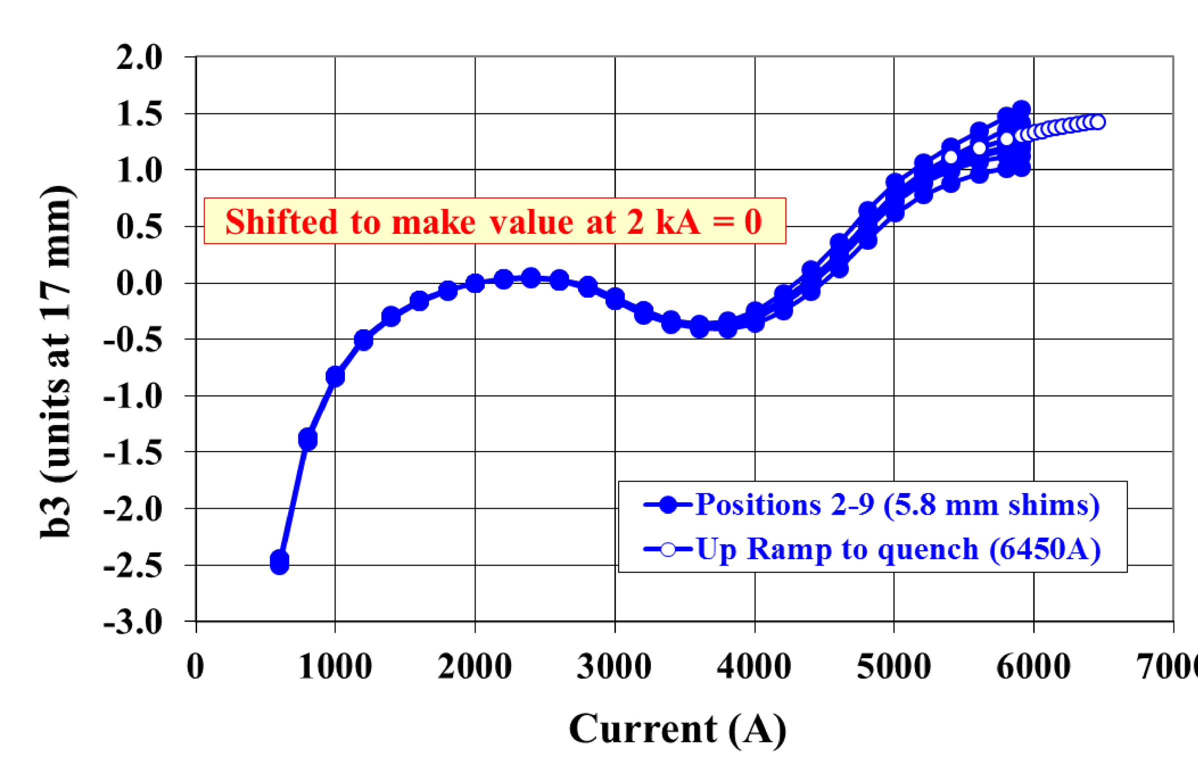
Computed sextupole harmonic (b_3) as a function of current added due to shims of various thicknesses.



Measured integral harmonics as a function of current in magnets #106 and #107.



Harmonics due to iron shims obtained by subtracting measured harmonics with full (or nominal) shim and without shim.



Measured b_3 as a function of current in eight 1 meter long sections in body of the magnet D1L107. The data are offset to make each zero at 2000 A.

Table 1: Measured integral harmonics at a reference radius of 17 mm in magnet #106 and 107

	#106 @5500 A		#107 @5600 A	
n	a_n	b_n	a_n	b_n
2	-3.42	-0.26	-1.05	-0.20
3	-0.41	0.16	-0.14	0.04
4	-0.30	-0.06	-0.33	-0.07
5	0.05	0.27	0.09	0.24
6	-0.01	-0.01	0.00	0.00
7	-0.01	0.17	0.00	0.17
8	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00

Program Goal: Sextupole < 2 unit @5600

(initial adjustment was made with pole shims)

Achieved: ~ 0.2 unit @5600 in both

Highlight of the New Technique:

- Adjustable iron shims outside Helium vessel moved sextupole to near zero
- Measurement at one position indicates that sextupole will remain near zero even at high currents

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