## SLAC Magnetic Measurement Plan for LCLS-II BX31B/BX32B Dipole Magnets (1.06D103.3T)

(Sept. 4, 2019)

This magnetic measurement plan is intended to cover reception, preparation, mechanical fiducialization, and magnetic measurements of the two LTUS dog-leg dipole magnets. These magnets are 2.656 m long and have MAD designations of: BX31B and BX32B. Each magnet has trim coils. Magnet requirements are listed in LCLS-II-2.4-PR-0081.

**Receiving:**

The following information is to be noted upon receipt of the magnets by the SLAC MM group:

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| Received by (initials): | SDA |
| Date received (dd-mmm-yyyy): | 9/17/2019 |
| SLAC barcode number: | 4509 |
| Vendor serial number from magnet label: | 16101 |
| SLAC approved electrical safety covers? (Y or N): | N |
| SLAC drawing number (enter number): | LCL0351-006802 |

**Preparation:**

A beam direction arrow, with text “beam direction”, is to be applied to the top and/or tunnel aisle side of the magnet with a sticker supplied by LCLS II. The beam direction should point toward the end without the terminals.

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| Beam-direction arrow in place (initials): | SDA |

**Fiducialization:**

Fiducialization may be done before or after magnetic measurements. The magnet is to be fiducialized by the CMM group. This will require the installation of removable tooling balls, location of the geometric axis of the poles of the magnet, and location of tooling balls with respect to the center of this geometric axis when the poles are aligned precisely horizontal.

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| CMM technician (initials): | HI |

URL of on-line CMM fiducialization data (please modify or correct if necessary):

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| http://www-group.slac.stanford.edu/met/MagMeas/MAGDATA/LCLS-II/Fiducial Reports/ |

**Magnetic Measurements:**

1. Verify that the magnets are complete and undamaged, including wiring connections.

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| Incoming inspection OK (initials): | SDA |
| Date of arrival to mag. meas.(mm-dd-yyyy): | 9/10/2019 |

Enter URL of on-line magnetic measurements data (please modify or correct if necessary):

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| http://www-group.slac.stanford.edu/met/MagMeas/MAGDATA/LCLS-II/Dipole/4509/ |

1. Mark each magnet as BX31B *or* BX32B. By choosing the magnet location initially, they will be tested in their proper polarities; since one is “positive” and the other is “negative” (see below for definition).

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| Magnet marked as (BX31B *or* BX32B): | BX32B |

1. Determine the main-coil connection polarity (with main supply outputting positive current) which produces a “positive” field polarity for BX31B (below left), but a “negative” field polarity for BX32B (below right), as shown below:



**Figure 1**. BX31B is “positive” (left), while BX32B is “negative” (right).

1. Mark the polarity near the **main** magnet leads with clear “+” and “” labels as shown above.

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| **Main** coil polarity chosen from Fig. 1 is (P or N): | N |

1. Also mark the **trim** leads with clear “+” and “” labels such that, with the trim supply outputting positive current, the trim coil *increases* the absolute value of the magnetic field established by the main coil. This will set the trim polarity as “positive” for BX31B, and “negative” for BX32B, as described in LCLS-II-2.4-PR-0064 (https://docs.slac.stanford.edu/sites/pub/Publications/Polarity.pdf).

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| **Trim** coil polarity chosen from Fig. 1 is (P or N): | N |

1. Connect the **main** magnet terminals (not the trims), in the correct polarity as established above, to a unipolar power supply with maximum current *I* ≥ 200 A. Leave the trim coil disconnected for now.
2. Connect magnet to LCW supply. Adjust supply pressure to a delta P of ~100 psi to achieve a flow rate of 1.76 gpm. Run the magnet up to 200 A for ~1 hour to warm it up (record, delta P, flow rate, and temperature).

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| LCW delta P (psi) | 118 psi |
| LCW flow rate (gpm) |  2.3 gpm |
| LCW delta T (°C) | 3.2 °C |
| Ambient temperature (°C): | 23.1 °C |
| Final magnet temperature (°C): | 28.7 °C |

1. Standardize the magnet, starting from zero to 200 A and back to zero, through three full cycles, finally ending at zero, with a flat-top pause time (at both 0 and 200 A) of 10 seconds. Use a Cosine ramp type, with a ramp rate of 5 A/sec, and record the ramp type, rate, and settle time used. Also, use these ramp parameters for setting the current.

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| Standardization complete (initials): | SDA |
| Ramp type, ramp rate (A/sec), and settle time (s): | Cosine, 5 A/sec, 10 sec |

1. Maintaining this cycle history, measure the length-integrated vertical dipole field, ∫*Bydl*, from 0 to 200 A in 10 A steps, including zero. Also include a measurement at 126.4349 A, which is the nominal current at the maximum beam energy of 10 GeV for these magnets because they are on the BYDB string (22 ‘up’ measurements). Please record (below) the current necessary to achieve 6.2154 kG-m (10 GeV requirement). Then, still maintaining the cycle history, measure ∫*Bydl* back down from 200 A to 0 in 20 A steps, including zero (11 ‘down’ measurements).

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| Main coil excitation current at 6.2154 kG-m: | 126.6095 Amps |
| Filename & run number of ∫*Bydl* up & down data: | Wiredat.ru1, wireplt.ru1 |

1. With the **main** coils still hooked up, connect the **trim** coil to a bipolar 6 A (MCOR6) supply with proper trim polarity as determined above, so that a positive current on the trim adds to the main field. Please note the ramp type, ramp rate, and settle time used for the trim.

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| Ramp type, ramp rate (A/sec), and settle time (s): | LINEAR, 1 A/sec, 10 sec |

1. Standardize the **main** coil, then set *I*main = 126.4349 amps. Measure ∫*Bydl* as a function of **trim** coil current from 0 to 6 in 0.5 A steps, including zero (13 ‘down’ measurements), and again from 6 to 6 A in 0.5 A steps (24 ‘up’ measurements). Finally, set the **trim** current to 0.

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| Filename & run # of ∫*Bydl* **trim** data at *I*main = 126.4349: | Wiredat.ru2, wireplt.ru2 |

1. Standardize the **main** coil, then set it to 0 amps. Measure ∫*Bydl* as a function of **trim** coil current from 0 to 6 in 0.5 A steps, including zero (13 ‘down’ measurements), and again from 6 to 6 A in 0.5 A steps (24 ‘up’ measurements). Finally, set the **trim** current to 0.

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| Filename & run # of ∫*Bydl* **trim** data at *I*main = 0: | Wiredat.ru2, wireplt.ru3 |

1. For each magnet, with stretched wire, measure the ∫*Bydl* over a horizontal span of ±30 mm, at each 3-mm interval, at the following **main** and **trim** coil current settings.
* *I*main = 126.4349 A, and *I*trim = 0

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| Filename & run # of ∫*Bydl* vs. *x* data at 126.4349, 0 A: | Wirevsx.ru1 wirepltvsx.ru1 |

1. **For the BX32B magnet only**, and at a **main** current of 126.4349 A, with **trim** current at zero, measure the vertical magnetic fringe field component, *By*, at *x* = *y* = 0, as a function of the longitudinal beam-direction coordinate, *z* (from 10 cm to +30 cm in 1-cm steps, where *z* = 0 is defined at the iron edge), at the *one* end of this one magnet. Please also measure the background field at *z* = +30 cm with magnet switched off (separate file).

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| Filename of *By* vs. *z* data for BX32B exit edge: | Not measured due to time constraints |
| Background filename of *By* (*z* = 30 cm), magnet OFF: | Not measured due to time constraints |

1. Measure the inductance and resistance of the **main** and **trim** magnet coils for each magnet:

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| Inductance of **main** coil (mH): | 1.504 mH |
| Resistance of **main** coil (Ohms): | 0.0690 Ohm |
| Inductance of **trim** coil (mH): | 1.4124 mH |
| Resistance of **trim** coil (Ohms): |  0.7130 Ohm |

1. Measure pole tip field of the main at 200 amps, then Main at 0 and Trim at 6 A

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| Pole Tip Field and Current with Main at 200 A | 0.366 Tesla at 199.93214 Amps |
| Pole Tip Field and Current with Main at 0 A, Trim = 6A | 0.00944 Tesla at 6.00382 Amps |

1. Upon completion of tests, send data link to Mark Woodley who will produce a data analysis file. Place data analysis file in magnetic measurements data directory.

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| Magnet data accepted and data analysis file produced | SDA |

Enter URL of on-line magnetic measurements data and analysis:

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| http://www-group.slac.stanford.edu/met/MagMeas/MAGDATA/LCLS-II/Dipole/4509/ BX32B.pptx |