LARP-HiLumi CM18 working group (test results and future plans) discussion summary
Fermilab, 16:00 – 18:00, May 8, 2012

Participated by:
CERN: H. Bajas, E. Todesco;
FNAL: G. Chlachidze, J. DiMarco, G. Velev, R. Yamada;
LBNL: H. Felice, M. Marchevsky, T. Salmi, X. Wang;
with suggestions from L. Bottura and G. Sabbi.

Summary:
The discussion had two topics, magnetic measurements (1.5 hours) and protection studies of HQ01e and HQM (0.5 hours). The proposed items for discussion can be found at the CM18 website. Suggestions, comments and discussions are welcome.

1. Test of HQ01e at CERN after the warmup.
    - The assembly of HQ02 is a time constraint for the proposed second cold test.
    - Warm magnetic measurement. Magnet axis measurement.
    - Protection study of HQ01e. A summary of the discussion was prepared by T. Salmi and will be circulated.
    - Cold magnetic measurements:
        i. Repeat selected measurements interfered with mechanical issue at 4.4 K and 1.9 K.
        ii. Measure the field spike at an intermediate temperature between 1.9 K and 4.4 K.
    - Magnetic measurement of HQ01e at FNAL was proposed to confirm and characterize the field spike behavior.

2. Discussion of existing measurements and the field quality requirements.
    - The current field error table from the dynamic aperture analysis (presented by Y. Cai at CM18) may require more iterations before being used as a performance requirement. We decided to skip the proposed discussion on the observed multipoles.
    - The following analysis regarding the decay behavior and field spikes were proposed:
        i. Response of a current step performed at CERN. How does it compare to the decay behavior shown in the magnetic measurements?
        ii. Averaged cable contact resistance based on CERN's AC loss measurements. Is it consistent with the HQ cable contact resistance obtained based on magnetic measurements?
        iii. TQ, LQ contact resistance analysis based on magnetic measurements, if ramp-rate and stair-step measurements were performed. Compare to HQ results.

3. Instrumentation.

- A resolution of at least 0.1 units at the injection level is considered minimum for rotating coils for inner triplet field quality study (reference radius at 1/3 coil aperture, multipole order ≥ 6).
- Resolution of the existing LARP setup should be checked at the physical probe diameter.
- Probe resolution can be improved by increasing wire turns without increasing the probe size but appropriate probe size is the preferred choice.
- Limited by the current top plate, maximum FNAL probe diameter is ~ 65 mm and 43 mm for LBNL probe diameter. The resolution may not be high enough for magnet with an aperture of 140 – 150 mm even for low order field errors. If this is the case, plans should be made for facility upgrade to enable appropriate measurement without delay.

4. Plans and suggestions for future magnetic measurement.
    - Please see the appendix for the proposal of standard cold magnetic measurements.
    - For LQS03, the following were proposed:
        i. Standard cold measurements.
        ii. AC loss measurements.
        iii. Magnetic axis survey (with magnet horizontally positioned).
    - Integral field quality is important for accelerator operation. This can be measured by scan the field quality along the bore.
    - A warm-cold measurement and correlation of multipoles is suggested. For LARP (LBNL test facility), this requires a larger probe for warm measurement without anticryostat.

5. Collaboration and data sharing.
    - Raw data was suggested to be maintained at the local test team level.
    - Reduced data presented in excel data files was proposed to be made accessible by collaborators. The excel files contain the numbers and plots for the data set including the time stamp, current, main field, and multipoles, accompanied by a brief summary of the measurement, probe location, reference radius and other relevant information. LARP magnet data can be uploaded to LARP plone website. HQ data can in addition be uploaded to Hi-Lumi WP3 website.
    - Problem-driven instead of regular meeting for magnetic measurements and analysis is preferred.

Appendix – Draft proposal of standard cold magnetic measurements

The following measurements are proposed to be performed as standard cold magnetic measurements for LARP model magnets, listed in the test sequence. (These are different from those used for the production magnet at FNAL.)

1. Machine-cycle measurement at the magnetic center. The machine cycle is composed of a precycle and a measurement cycle. The measurement cycle consists of an injection plateau and a collision plateau. The measurement should include a few ($\geq$ 3) measurement cycles to study the field reproducibility. The magnet memory is cleared before the precycle. No specific ramp smoothing is required when changing ramp rates from 0 to 13 A/s or vice versa.
    - Basic rule for the cycles from E. Todesco:
        i. Operational (top field) is 80% of short sample limit (SSL).
        ii. Injection field for a magnet to be in the LHC has to follow the machine energy, i.e., one multiplies the top field by 450/7000, then we find the corresponding current.
        iii. Ramp rate: the time of ramping must be the same of the main dipoles. They make from 760 A to 11850 A at 10 A/s so the ramp takes about 1100 s. Or equivalently one takes the top current divide by top dipole current and multiply by 10 A/s. For example, HQ at 1.9 K, 15 kA/11.8 kA*10 A/s=13 A/s.
    - Ramp rate: 13 A/s, as defined for the inner triplet quadrupoles.
    - Nominal peak current for precycle: 80% of SSL. Dwell time: 600 s (can be changed based on the decay behavior at this current level).
    - Current at the end of precycle: 100 A. Dwell: 60 s.
    - Injection level current: 950 A (450 GeV injection level and 7 TeV collision level). Dwell: 1200 s.
    - Nominal peak current for the measurement cycle: same as precycle.

2. Load-line measurements at the magnetic center.
    - Precycle: defined in the machine-cycle.
    - Ramp rate: same as the accelerator cycle measurement.
    - Step: 1 kA.
    - Dwell time at each step: 7 times of the decay time constant observed from the machine-cycle measurement.
    - Both up and down ramp.

3. Ramp-rate dependence measurements at the magnetic center.
    - Cleansing quench (pre-cycle optional).
    - 3 – 4 ramp rates acceptable. The highest ramp rate used should be compatible with the probe rotation speed and the quench current.

4. Optional cold measurements, for example,
    - Z scan typically performed Z scan at the injection level.
    - Z scan at both up and down ramps at certain current levels.

- AC loss measurements for the averaged cable contact resistance estimation.
- Measurement during the ramp at various positions.
- Fixed coil measurements.
- …

Change log:

1. 19 June 2012, 8:24 am.
    - Included the basic rule on the current profile for an accelerator cycle measurement as explained by E. Todesco.
    - Included the change log.
2. 9 May 2012, 8:30 am, created.