# A Test Bench for the Warm Magnetic Measurement of the LHC Corrector Magnets in Industry

The LHC accelerator will be equipped with more than 6000 superconducting spool corrector magnets. CERN has awarded the contract for the series production and testing of these corrector magnets to Industry. Magnetic field measurements are done at the factory.

The measurements performed so far on the model corrector magnets allow to define the following strategy for the series measurements of the LHC correctors. A good correlation has been obtained between measurements at nominal strength in superfluid helium and on a dedicated bench for measurements at room temperature.

The benches described here have been designed to routinely control at room temperature the production in the magnet manufacturer's premises before and after systematic tests of the quench performance of the magnets at 4.3 K.

The benches allow to measure the strength of the main field, normal and skew harmonics, the magnetic axis position and orientation of the main field with respect to the mechanical reference points of the magnet, which can be dowel holes or keys.

The quality of the magnetic field and magnetic axis alignment depends on the precision of the magnet coils and their assembly in the yoke and casing, difficult to measure on a finished magnet assembly. Therefore a relatively simple magnetic field measurement at room temperature is done by the manufacturer to obtain these data and confirmation that the assembly is within tolerance. This test also detects gross errors like inversely connected coils, coils with a missing turn or interturn short circuits. The field quality is recorded and an acceptance or out-of-tolerance indication obtained.

The industry bench includes a mechanical bench on which the magnet is installed, and a rack containing the VME integrators, the bipolar power supply, a Sun/Labview data acquisition system, and a printer to easily record the main parameters of each measured magnets.

The measurement is based on the rotating coil principle. This method consists of taking the values of the flux linked with the coil at (equally space) angular positions. The coil angular position is read by an angular encoder. The signal (flux as a function of angle) is obtained from the measured coil voltage during the coil rotation by integration.

The measurement is repeated with both direction of rotation to correct for shaft twist and electronic drifts, and with both current polarities to correct for permanent magnetization and pick-up of external fields. Data are obtained from averages of 10 such measurement sequences. The results are then analyzed to generate the levels of the harmonics up to order 15, the position of the magnetic axis and orientation of the field. These measurements are then compared with the acceptable levels, and if the tolerance is exceeded anywhere it is highlighted on the screen. The LabView/Sun based MMP program used for the magnetic measurement of all the LHC magnets has been tuned to reduce to a minimum the man-machine interface.

The axis of rotation of the coils is not perfectly centered with respect to the mechanical reference points of the bench. A calibration corrects the resulting systematic error. A reference magnet is measured in three different positions : rotated by 180° with respect to the normal position to measure X-Y offset ($\Delta_{xBench}$, $\Delta_{yBench}$), and turned end to end to measure the angular offset ($\Delta\theta_{Bench}$).

The LabView application calculates the three values ($D_{xBench}$, $D_{yBench}$, $\Delta\theta_{Bench}$), with the difference between coil rotation axis and magnetic axis. Now by this procedure the right deviation of the magnetic axis with respect to the mechanical axis ($\Delta_{xMagnet} = {}_{xmeas} + \Delta_{xBench}$ ; $\Delta_{yMagnet} = {}_{ymeas} + \Delta_{yBench}$ ; $\Delta\theta_{Magnet} = \Delta\theta_{meas} + \Delta\theta_{Bench}$) can be generated.

7 benches have been already built and sent to the industry. 15 others will follow.