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Aligning the HL-LHC magnets with interferometry

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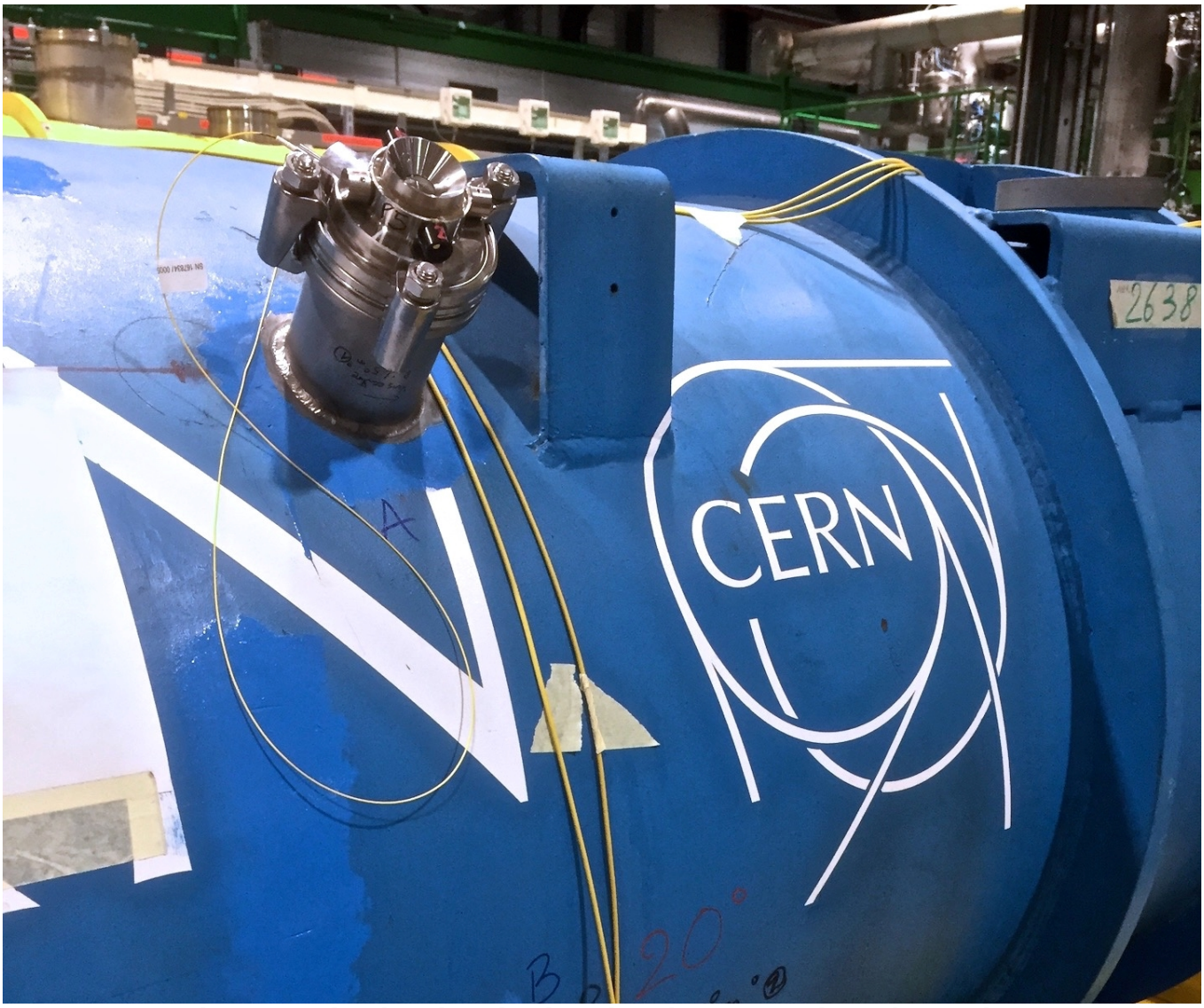
Metrology High-Luminosity LHC

CERN surveyors have developed a procedure based on interferometry to determine the position of cold masses inside the cryostats of the future HL-LHC.



A cryostat can be equipped with 12 laser heads such as the ones seen here (the two devices connected to yellow cables). Facing each laser head is a reflective target (not seen), which is attached to a cold mass inside the cryostat (Image: CERN)

CERN surveyors have just finalised a system that can determine, in real time, the position of certain components inside the (sealed) cryostats of the future High-Luminosity LHC (HL-LHC). Currently, only the position of the cryostats themselves can be measured, using sensors that perform continuous measurements. “This new system has been specially developed for the HL-LHC, to be able directly to determine the position of cold masses at the level of the inner triplets, located on either side of the ATLAS and CMS experiments, and the position of the crab cavities inside their cryostat,” says Hélène Mainaud Durand, in charge of alignment in the High-Luminosity LHC Project. “It will be a real plus to be able to monitor the alignment of these components continuously, especially during the accelerator’s cycles of heating and cooling.”

The new procedure is based on frequency sweeping interferometry (FSI), a distance-measurement method that simultaneously performs several absolute distance measurements between a measuring head and targets, and relates them to a common benchmark measurement. “Thanks to this technique, it will be possible to deduce the position of the cold mass to within a few micrometres relative to the cryostat by making 12 distance measurements between the cryostat and the cold mass,” says Mainaud Durand. Each cold mass will therefore be equipped with 12 targets, which are

reflective glass spheres that have been specially designed for this procedure. Opposite the targets are 12 laser heads, which are attached to the cryostat and connected by optical fibres to a laser acquisition system.

Even though FSI is commonly used in metrology, adapting it for use in a cryogenic environment has not been completely straightforward: “We have had to overcome several challenges posed by the extreme conditions inside the accelerators,” says Mateusz Sosin, the mechatronic engineer in charge of this development. “The first problem became apparent during a test carried out at the cryogenic temperature of 1.9 K (–271.3 °C) on one of the LHC dipoles fitted with the system. At this temperature, the cold masses contract and lose up to 12 mm, taking our interferometry targets with them, meaning the targets are no longer aligned with the laser heads.” To get around the problem, a divergent, or conical, laser beam has been developed, such that the source remains “in the spotlight” despite the movements caused by contraction and expansion.

The second problem is caused by condensation. At 1.9 K, the targets are covered by a fine layer of frost caused by the condensation of residual gases, which make them impervious to the laser beams. “Following the advice of our colleagues in the cryostat section, we decided to use the thermal radiation emitted by the vacuum vessel to heat up the targets,” explains Mateusz Sosin. “The radiation is ‘absorbed’ by an aluminium plate located under the target, keeping it at just the right temperature to avoid condensation. The plate is attached to an epoxy insulating support, which is in turn attached to the cold mass.”

Several tests have already been carried out, including on a crab cavity prototype installed in a special SPS test stand, as well as on an LHC dipole. The final tests, currently in progress, look very promising, and surveyors from other laboratories, notably DESY and Fermilab, have already shown great interest.

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