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Internal monitoring of the HL-LHC components

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The High-Luminosity Large Hadron Collider (HL-LHC) project at CERN aims to enhance the LHC's performance and expand its potential for discoveries beyond 2029. New components will be installed within the 220 meters before the collision points of the ATLAS and CMS experiments, including 16 NB3Sn quadrupoles to focus the beam before collision and 8 radio frequency crab cavities to allow beam tilting, thereby increasing number of collisions within experiments. Whether for quadrupoles or for crab cavities, the element consists of two distinct elements: the visible outer envelope (called the vacuum vessel for quadrupoles and the cryomodule for crab cavities) and the active element installed inside (called the cold mass for quadrupoles, and cavity for crab cavities).
The HL-LHC project requires the determination of the position of the inner element within the outer envelope with an accuracy of 0.1 mm (1σ). Until now, the position of the cold mass in a quadrupole was determined during construction and considered stable afterward in warm conditions and with a thermal contraction model in cryogenic conditions. However, due to the stringent HL-LHC requirements, the previous assumption is no longer be considered valid. To determine the position of the inner element inside the outer envelope in real time with 0.1 mm accuracy, the absolute distances between the two elements will be measured using multi-target Frequency Scanning Interferometry.
CERN has conducted tests on the first HL-LHC quadrupoles and crab cavities under both warm and cold conditions. For the crab cavities, the positions of the two cavities were monitored during the cool down. For quadrupoles, the positions of the mechanical axis of the cold mass in both conditions were compared with the behavior of the magnetic axis. This paper will describe the monitoring system and report on the results from these initial measurements.

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