Design validation of the CMS MTD Barrel Timing Layer

The High Luminosity phase of the Large Hadron Collider (HL-LHC), slated to start in 2029, will provide an unprecedented integrated luminosity of about 3000 /fb over 10 years of operations, and thus constitutes a unique opportunity for the experiments to perform precision measurements and search for rare processes. Such a large proton-proton collision dataset will be collected at the price of harsh experimental conditions, namely a large number of interactions per bunch crossing - up to 200 - and extremely high radiation levels, posing a challenge for the detectors' survivance. To mitigate the adverse effects of pileup, the CMS Experiment Upgrade will include a novel detector, the Mip Timing Detector (MTD), to facilitate the association of each particle with its interaction vertex through precision timing measurements. Its barrel section, the Barrel Timing Layer (BTL), will make use of scintillating LYSO crystals coupled to Silicon photomultiplier as sensor technology to measure charged particles with a precision of ~30 ps at startup, degrading to ~70 ps at the end of operation due to the SiPMs radiation damage. In this talk, the BTL layout will be presented, focusing on the optimization of the sensor design from the publication of the detector's Technical Design Report in 2019 to the current, final one. The validation of the detector performance will be discussed presenting recent results of laboratory and beam tests of final module prototypes, both unirradiated and after exposure to a neutron fluence of 2E14 1MeV_eq/cm^2, as expected by the end of HL-LHC operations. The completion of the detector validation phase marks the transition to the production and installation phase, which is scheduled to start in early 2024.