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CMS DP -2024/049

The Compact Muon Solenoid Experiment

CMS Performance Note

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10 July 2024

Barrel Timing Layer Performance Plots

CMS Collaboration

Abstract

This note presents performance plots of Barrel Timing Layer sensor modules from recent test beam campaigns.

Barrel Timing Layer Performance Plots

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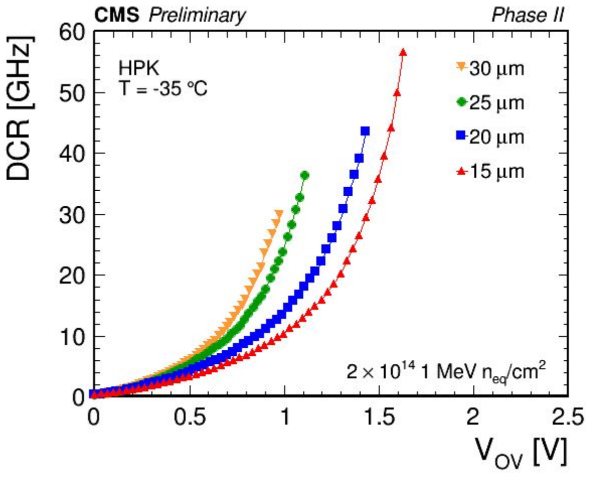
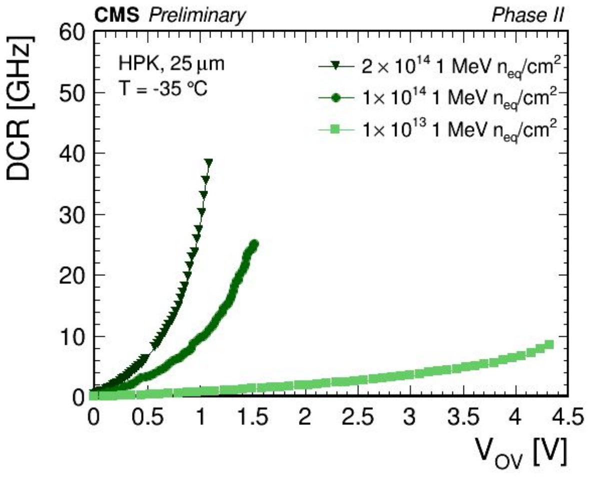
DCR plots

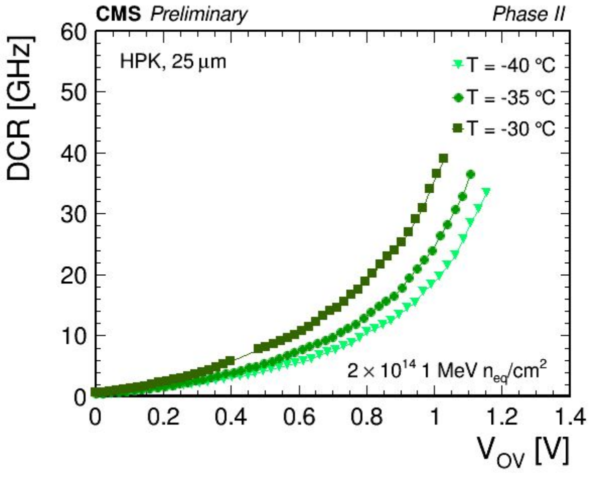
Per SiPM dark count rate (DCR) as a function of the SiPM over-voltage (V_{ov}) for different configurations tested: (a) type 2 modules (3 x 3 x 54.7 mm^3) with Hamamatsu Photonics (HPK) SiPMs of different cell size (15, 20, 25, 30 μm) irradiated to 2×10^{14} 1 MeV n_{eq}/cm^2; (b) type 1 modules (3.75 x 3 x 54.7 mm^3) with 25 μm cell-size HPK SiPMs irradiated to different fluences (1×10^{13}, 1×10^{14}, 2×10^{14} 1 MeV n_{eq}/cm^2); (c) type 2 module (3 x 3 x 54.7 mm^3) with 25 μm cell-size HPK SiPMs irradiated to 2×10^{14} 1 MeV n_{eq}/cm^2 for different operating temperatures. All the SiPM arrays underwent an annealing sequence of 40 minutes at 70 °C, three days at 110 °C and four days at 120 °C. In the (b) and (c) plots, anomalous current readings due to multimeter glitches have been removed.



(a)



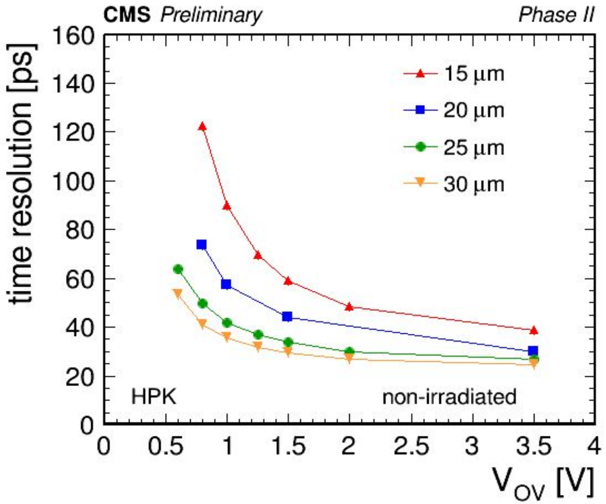
(b)

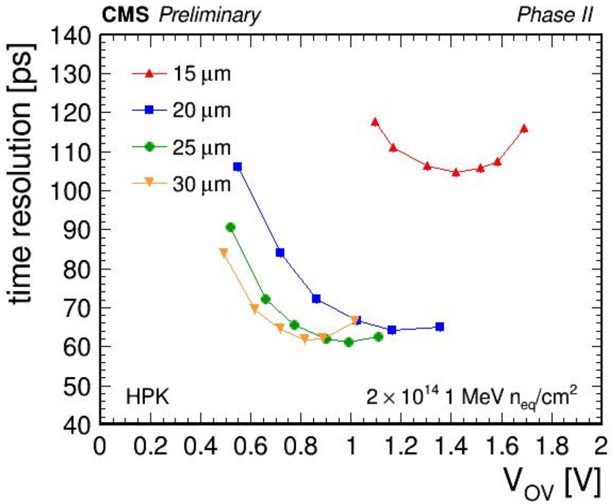


(c)

Performance with different cell-size

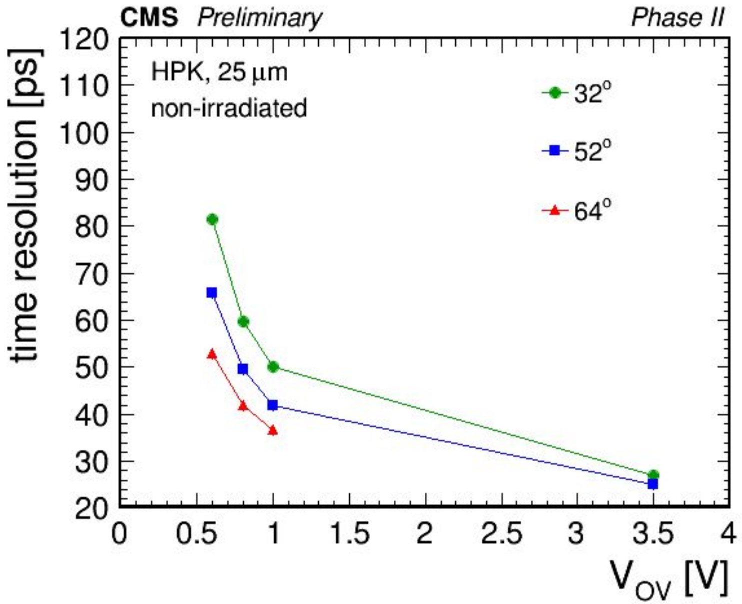
Time resolution as a function of the SiPM over-voltage (V_{OV}) for different module prototypes made of LYSO:Ce bars (type 2, 3 x 3 x 54.7 mm^3) coupled to non-irradiated (left) and irradiated to 2 × 10^{14} 1 MeV n_{eq}/cm^2 (right) Hamamatsu Photonics (HPK) SiPMs with different cell size dimensions (15, 20, 25, 30 μm). Modules with irradiated SiPMs are representative of the performance expected at the end of the BTL operation (assuming SiPM annealing at 60 °C and in-situ operation at -45 °C). The time resolution is estimated from test beam data as the average over all the module bars. Results are obtained using the TOFHIR2C readout ASIC [1]. The higher gain and Photon Detection Efficiency (PDE) featured by SiPMs with larger cell sizes enable the operation at a lower over-voltage, where the contribution of various terms to the time resolution (mostly DCR and electronics noise) is much smaller. For the production of 20, 25, 30 μm SiPMs the manufacturer used a wafer technology with improved PDE relative to 15 μm SiPMs. When exposed to a fluence of 2 × 10^{14} 1 MeV n_{eq}/cm^2, 15 μm SiPMs show 30% reduction in signal amplitude (gain x PDE), while for larger cell size SiPMs only about 15% signal loss was estimated. The increase in time resolution of 30μm SiPMs after reaching 0.8 V can be attributed to the growth of one of the dominant terms contributing to the time resolution, the DCR, with increasing overvoltage.

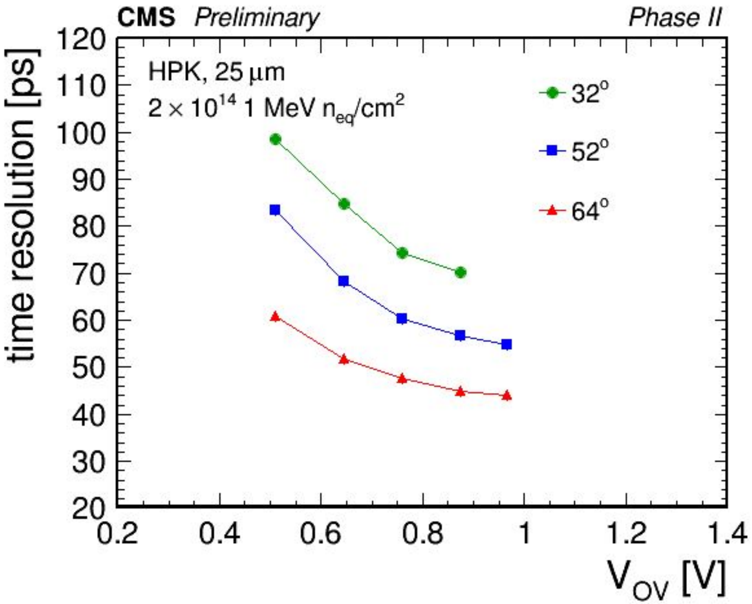




Performance at different angles

Time resolution as a function of the SiPM over-voltage (V_{OV}) for modules tilted at different angles with respect to the beam line, emulating the energy deposition of a MIP in the LYSO crystals in different pseudorapidity regions of the BTL detector [2]. On the left, a module made of LYSO:Ce bars (type 1, 3.75 x 3 x 54.7 mm^3) coupled to non-irradiated Hamamatsu Photonics (HPK) SiPMs; on the right, a module made of LYSO:Ce bars (type 1, 3.75 x 3 x 54.7 mm^3) coupled to HPK SiPMs irradiated to 2×10^{14} 1 MeV n_{eq}/cm^2 . Modules with irradiated SiPMs are representative of the performance expected at the end of the BTL operation (assuming SiPM annealing at 60 °C and in-situ operation at -45 °C). The time resolution is estimated from test beam data as the average over all the module bars. Results are obtained using the TOFHIR2C readout ASIC [1].





References

[1] E. Albuquerque *et al.* , TOFHIR2: the readout ASIC of the CMS barrel MIP Timing Detector, Journal of Instrumentation, 19 (05) (2024) P05048, DOI 10.1088/1748-0221/19/05/P05048

[2] CMS Collaboration, A MIP Timing Detector for the CMS Phase-2 Upgrade, CERN-LHCC-2019-003; CMS-TDR-020