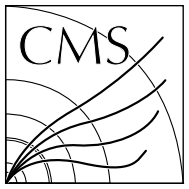
Available on CMS information server

CMS DP -2024/035



The Compact Muon Solenoid Experiment

CMS Performance Note

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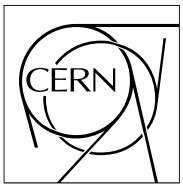


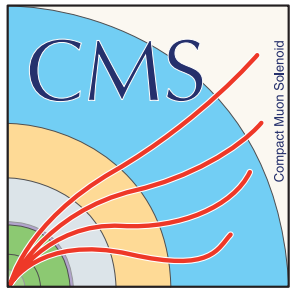
29 May 2024 (v2, 15 June 2024)

Test Beam Characterization of 16$\times$16 LGADs for MTD ETL

CMS Collaboration

Abstract

The document present charge collection and timing resolution of LGAD sensors tested with beta source and on beam, to test performance of the LGADs for the MTD Endcap Timing Layer.



Test Beam Characterization of 16x16 LGADs for MTD ETL

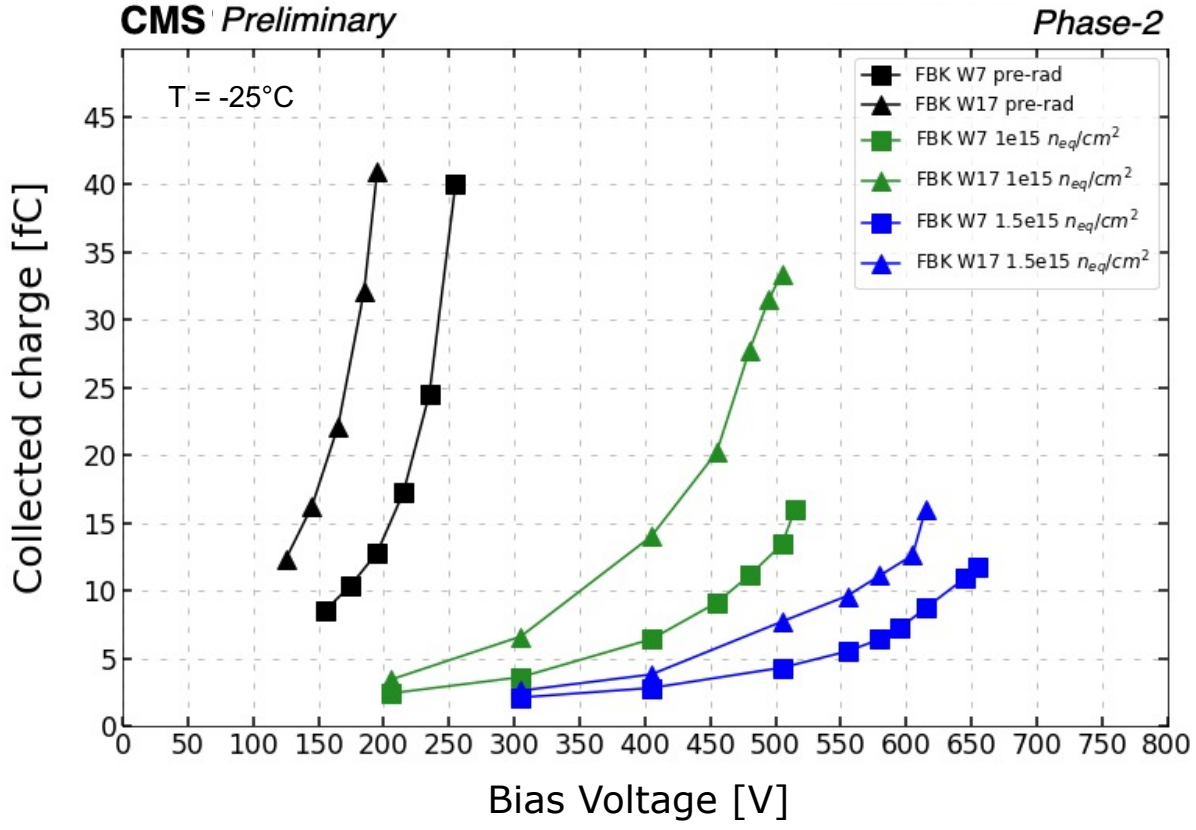
CMS collaboration

cms-dpg-conveners-mtd@cern.ch

FBK new and irradiated – Collected Charge at Beta-Source setup

Experimental setup for Low Gain Avalanche Diodes (LGADs) testing:

- **One 2x2 LGAD device tested per time** and held by a 3D-printed structure placed within a climate chamber (T = -25°C)
- Sensors glued on Santa Cruz (SC) boards (analogic boards with discrete components)
- **MCP** (Microchannel plate) **used as trigger** and placed behind the Device Under Test (DUT)
- Only one pad read-out, all the others grounded
- **Sensor performance evaluated with a ^{90}Sr Beta source and measured each device for ~1 day**



Devices and Performed tests:

- Evaluation of the Collected charge against Bias Voltage of non-irradiated and irradiated LGADs (up to 1.5e15 n_{eq}/cm^2) produced by Fondazione Bruno Kessler (FBK)
- Two samples for each irradiation fluence, one belonging to Wafer7 (W7), one belonging to Wafer17 (W17) (a Wafer is a batch of sensors with a characteristic design)
- LGAD charge [fC] = LGAD signal area [pWb] / 4700 Ω (4700 Ω is the SC board trans-impedance)
- **All devices showed a collected charge greater than 8 fC** (threshold requested by CMS specification)

FBK new and irradiated –Time Resolution at Beta-Source setup

Experimental setup for Low Gain Avalanche Diodes (LGADs) testing:

- **One 2x2 LGAD device tested per time** and held by a 3D-printed structure placed within a climate chamber (T = -25°C)
- Sensors glued on Santa Cruz (SC) boards (analogic boards with discrete components)
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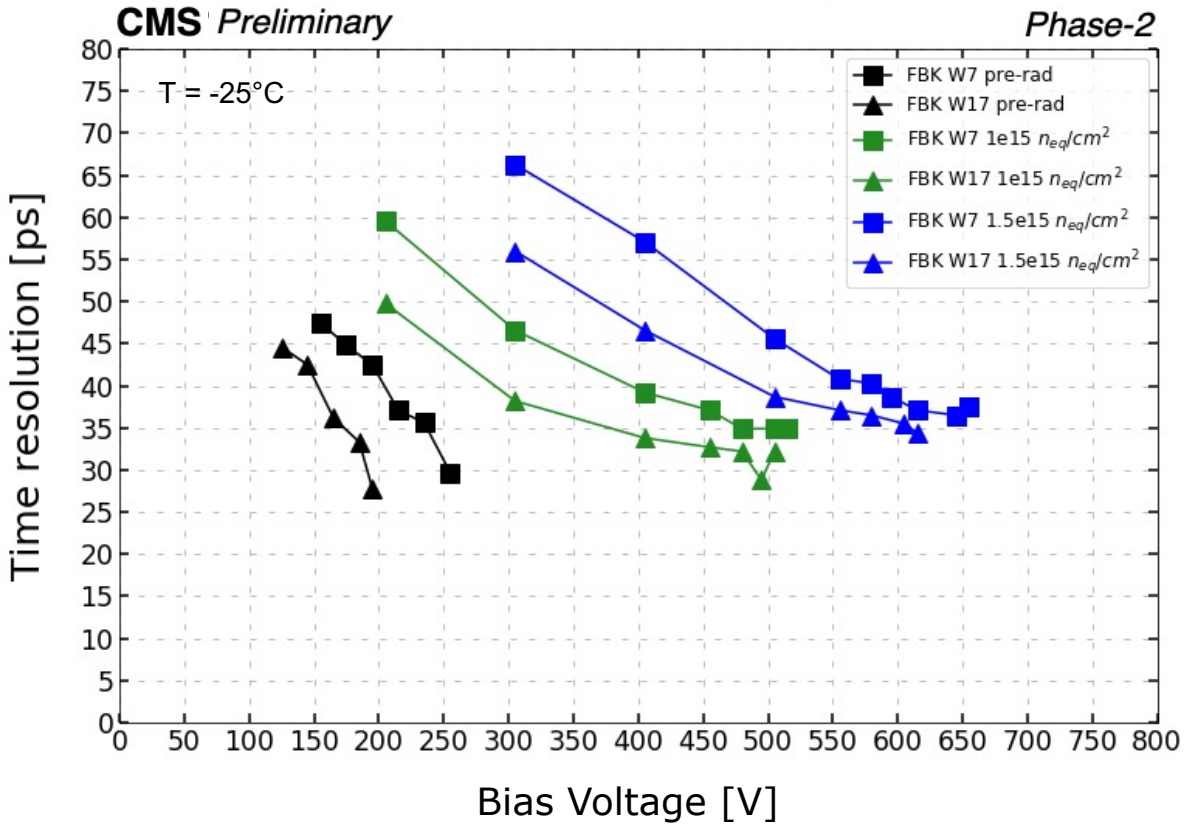


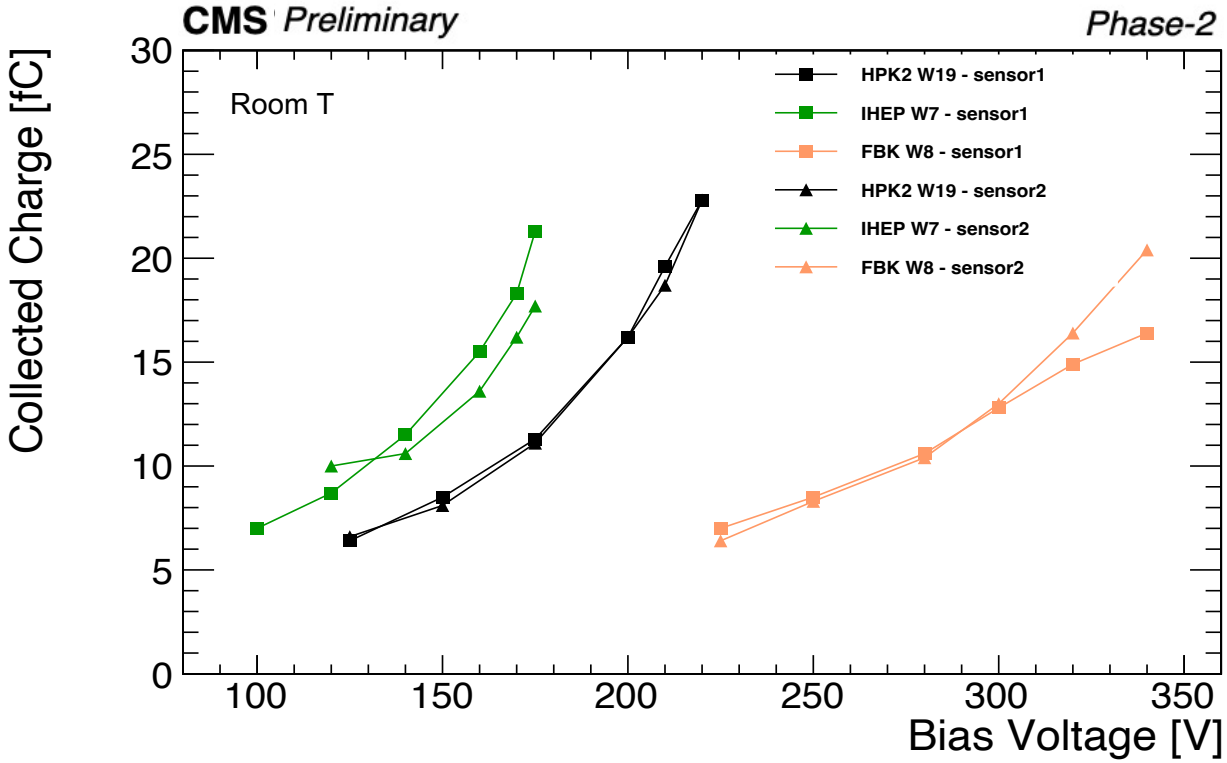
Devices and Performed tests:

- Evaluation of the Time resolution against Bias Voltage for the same LGAD devices that underwent the collected charge evaluation
- $\sigma_{tot} = \sigma$ of the distribution of the difference between the DUT ToA and the Trigger ToA (where ToA stands for Time of Arrival, namely the time at which the LGAD signal crosses the 20% of its maximum amplitude)
- $\sigma_{DUT} = \sqrt{\sigma_{tot}^2 - \sigma_{trg}^2}$ with σ_{trg} = 15ps
- **All devices showed a Time resolution lower than 40 ps** (threshold requested by CMS specification)

FBK, HPK & IHEP – Collected Charge at test beam

Experimental setup:

- **Three 16x16 LGADs tested simultaneously** and held by a 3D-printed structure (room temperature for all the measurements)
- Sensors glued on SC boards with a modified layout to host 16x16 arrays (SC-UZH boards, which feature the same electronic characteristics of the regular SC boards)
- **MCP used as trigger and** placed behind the DUTs
- Only one pad read-out, all the others grounded
- **Electron beam with an energy set at 4-5 GeV and measured each batch for ~1.5 day (one batch = three LGADs)**



Devices and Performed tests:

- Evaluation of the Collected charge against Bias Voltage of non-irradiated LGADs produced by Fondazione Bruno Kessler (FBK), Hamamatsu Photonics (HPK) and Institute of High Energy Physics of the Chinese Academy of Sciences (IHEP)
- Two identical samples for each producer (a Wafer is a batch of sensors with a characteristic design)
- LGAD charge [fC] = LGAD signal area [pWb] / 4700 Ω (4700 Ω is the SC-UZH board trans-impedance)
- **All devices showed a collected charge greater than 8 fC** (threshold requested by CMS specification)

FBK, HPK & IHEP –Time resolution at test beam

Experimental setup:

- **Three 16x16 LGADs tested simultaneously** and held by a 3D-printed structure (room temperature for all the measurements)
- Sensors glued on SC boards with a modified layout to host 16x16 arrays (SC-UZH boards, which feature the same electronic characteristics of the regular SC boards)
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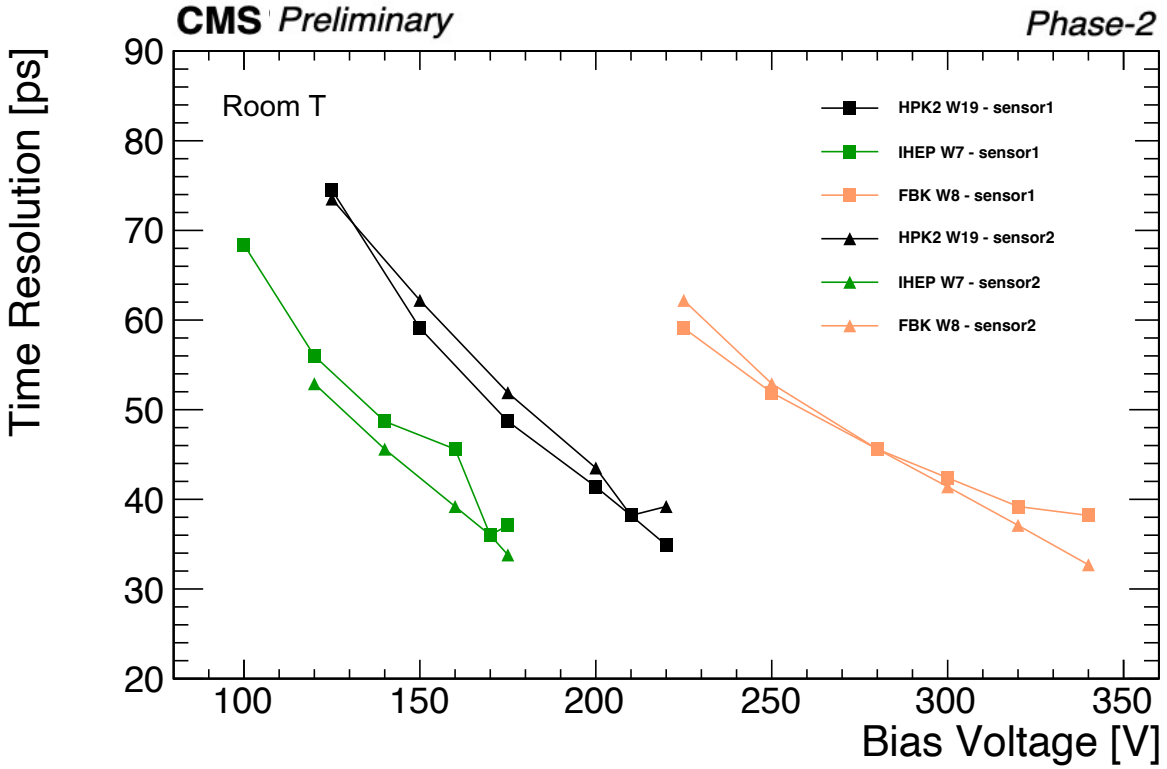

Devices and Performed tests:

- Evaluation of the Time resolution against Bias Voltage of same non-irradiated LGAD devices that underwent the collected charge evaluation
- Two identical samples for each producer (a Wafer is a batch of sensors with a characteristic design)
- $\sigma_{tot} = \sigma$ of the distribution of the difference between the DUT ToA and the Trigger ToA (where ToA stands for Time of Arrival, namely the time at which the LGAD signal crosses the 20% of its maximum amplitude)
- $\sigma_{DUT} = \sqrt{\sigma_{tot}^2 - \sigma_{trg}^2}$ with σ_{trg} = 15ps
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