Studies of uniformity of 50 μm low-gain avalanche detectors at the Fermilab test beam
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High Luminosity LHC & Future Colliders
- Precision timing is the “Last Great Frontier” in reconstruction
- Pileup reduction: ~200 at HL-LHC, and up to 2,000 at FCC
- Long-lived particles, displaced vertices, GMSB, many others

Timing detector for High Luminosity LHC
- Equip upgraded CMS detector with precision timing MIP detector
- LGADs in the endcap region: radiation hard, with small pixels
- Key challenges in sensor R&D:
  - Radiation tolerance up to 2x10^{15} n_{eq}/cm^2
  - Large area sensors to reduce module multiplicity
  - Maintain uniform gain across irradiated, large sensors
  - Large fill-factor: greater than 95%
  - Fast readout board for 4-channel LGAD sensors

Sensor uniformity and time resolution
- Signals digitized with CAEN V1742 VME board.
- 100% detection efficiency across the sensor area
- CNM and HPK sensors show excellent uniformity of size over the sensor area.
- Time resolution measured with respect to a fast Photek 240 MCP-PMT.
- Uniform time resolution at about 40 ps for the HPK50D, and 60 ps for the CNM.

Tests of irradiated sensors
- Irradiated CNM sensor shows distinct regions with different gains.
- Irradiated HPK sensor has a uniform gain.

Excellent uniformity of signal across the irradiated HPK sensor area, better than 40 ps time resolution

Summary
- The signal size uniformity of measured LGAD sensors before irradiation has a spread of ~2%
- Efficiency of 100% over the whole surface, and timing resolution of 30-40 ps for pixels with 3x3 mm^2 size.
- The “no-response” region between pixels was measured to be about 70 μm for CNM sensors and 110 μm for HPK.
- CNM sensor exhibits a large gain variation over its surface area after a neutron fluence of 6x10^{14} n_{eq}/cm^2
- Irradiated CNM and HPK sensors achieve < 40 ps time resolution