Introduction and motivation

• HL-LHC will reach pileup of approximately 200 simultaneous interactions!
• CMS MIP Timing Detector Phase II Upgrade: provide 40 ps timestamp for every track, maintain detector performance in complex environment.

Physics impact of CMS MTD

• Reduce PU misassociation rate to Run II levels, critical for lepton isolation, b-tagging & MET resolution
• TOF particle ID for heavy ion/B-physics

ETL mechanical design

• Two layers provide ~1.7 hits per track, ~ω = 50 ps per hit = 35 ps per track.
• Stability and easy to assemble modules.

What are LGADs?

LGADs: novel ultra-fast silicon detectors
• Moderate internal gain (10-20): Large signals, but low noise
• Thin (50 micron depletion region): Uniform field, fast rise-time

LGAD sensors for CMS ETL

• Two main producers: Hamamatsu (HPK), Fondazione Bruno Kessler (FBK)
• Main R&D focus: improving radiation hardness & developing large, uniform arrays

CMS ETL fluence vs radius

- FWD, Barrel Timing Layer
- MTD 35 ps
- MTD 50 ps
- MTD 60 ps
- No MTD

CMS MIP Timing Detector Phase II Upgrade: provide 40 ps timestamp for

• FNAL 16-channel board enables measurements with large arrays for the first time!
• Series of measurements with HPK type 3.1 arrays (4x4 grid of 3x1 mm² pads)

CMS ETL setup at Fermilab Test Beam Facility

• Main Injector provides 120 GeV protons
• Strip telescope: track position (σ = 30-50 µm)
• Multi-channel plate: time reference (σ = 10 ps)

LGAD test beam results

- Grap and pixel telescope
- MCP time reference
- Calibration: 1 x 3 mm pads
- All pads 3 mm wide
- High fast bias
- High density input

Beta source LGAD characterization

• Beta source allows high-statistics sampling of sensors
• Complete characterization of 22 HPK 3.1 sensors: study wafer uniformity & prepare for systematic irradiation campaign.

Scanning laser uniformity studies

• Scanning laser enables detailed studies of spatial features without TB, in the comfort of the lab.
• Series of scans with increasing laser intensity
• High uniformity studies with probe CV
• Complete test beam characterization as anchor for all measurements.

Summary & conclusions

- Full exploitation of silicon detectors
- Improved detector performance in complex environment
- Improved radiation hardness & developing large, uniform arrays
- Detailed timing & irradiation studies with betasource
- Strong characterization capabilities lead towards promising future.