KARATE – A Setup for High Rate Tests of the CMS Outer Tracker 2S Module Readout Chain

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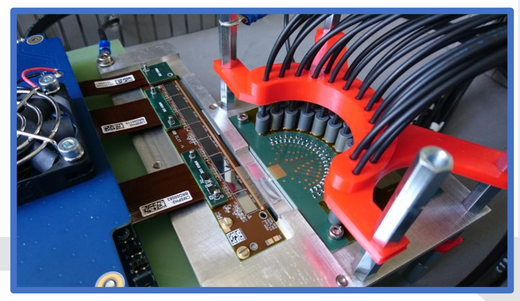
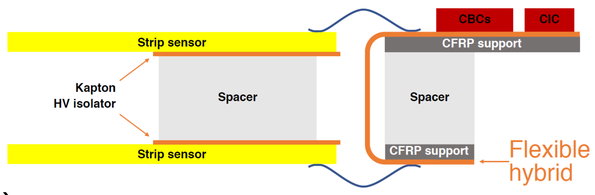
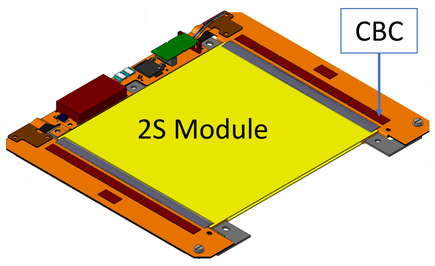
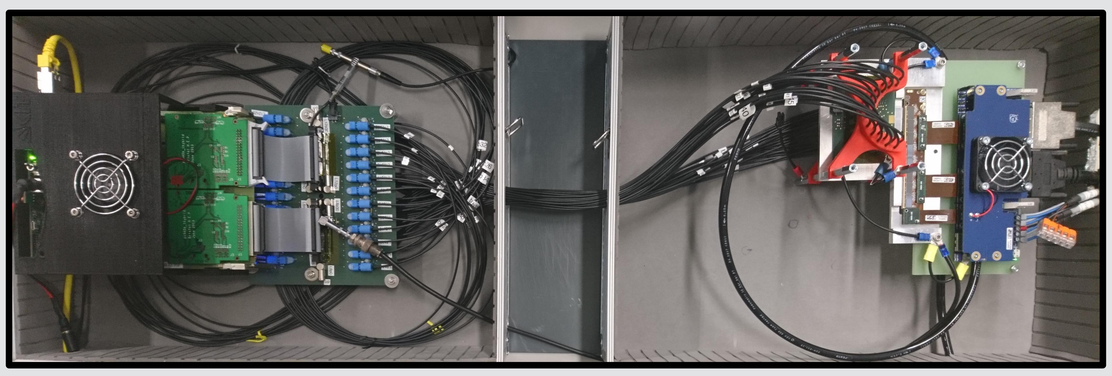


Phase-II Upgrade of the CMS Tracker

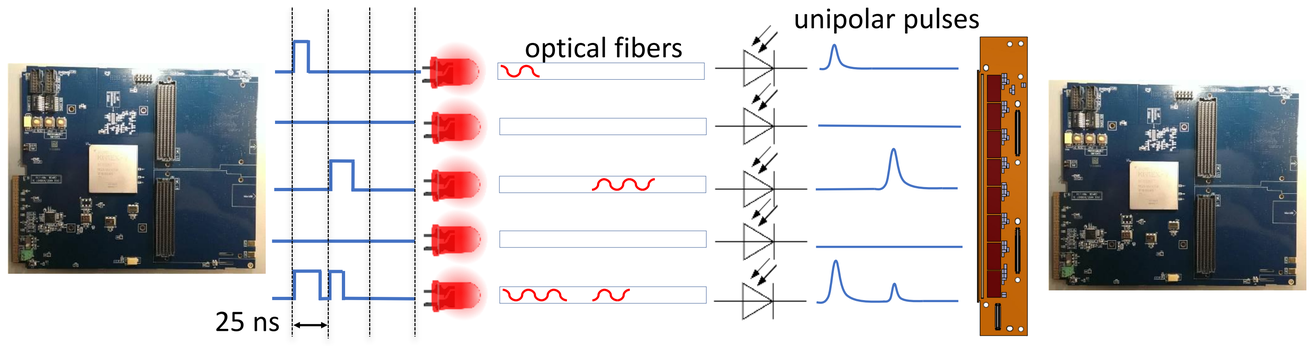
- New enhanced outer silicon tracker for HL-LHC
  - Double-sided p_T trigger modules
  - 2S module readout by 16 CMS Binary Chips (CBC Imperial College London)
- Usual tests below expected occupancy (~1%) and trigger rates (750 kHz)
- Need for setup to validate high rate functionality of readout chain: **CBC (avail.)** → CIC → LpGBT → VTRx+

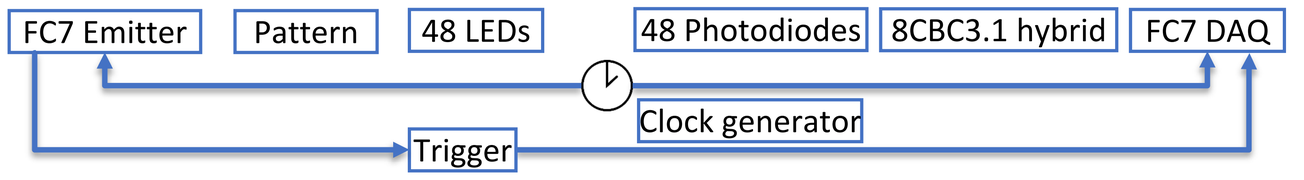




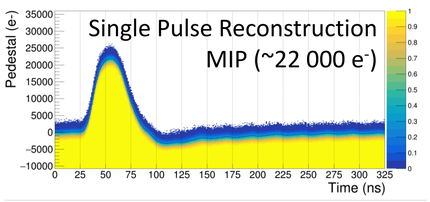


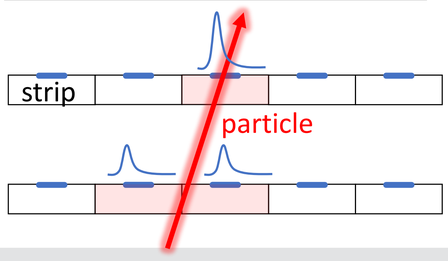
KArlsruhe high RAte TEst: KARATE





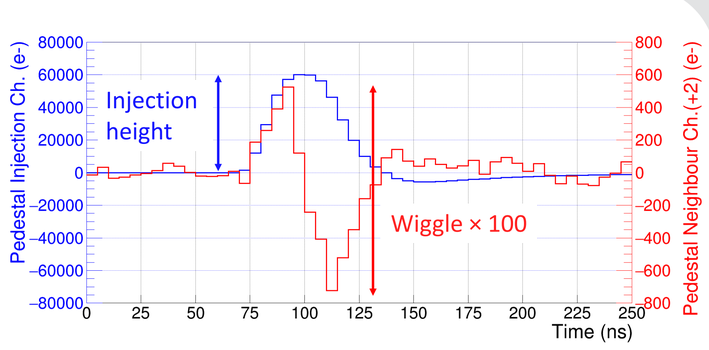
- Fast electrical, unipolar pulses injected in front-end channels
- Emulate sensor signals with variable charge injection on 2 × 24 CBC channels
  - Track-emulating pattern injection at **40 MHz**
  - Landau-distr. cluster signal, charge sharing
  - Variable occupancy and trigger rate
- Compare injection pattern with readout data

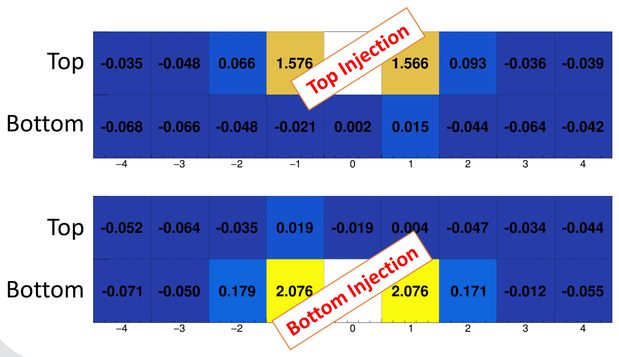




XTalk Measurements

- Single channel pulse injection
  - Injection rate: **400 kHz**
- Observe neighbours
- Repeat with increasing pulse height for all channels



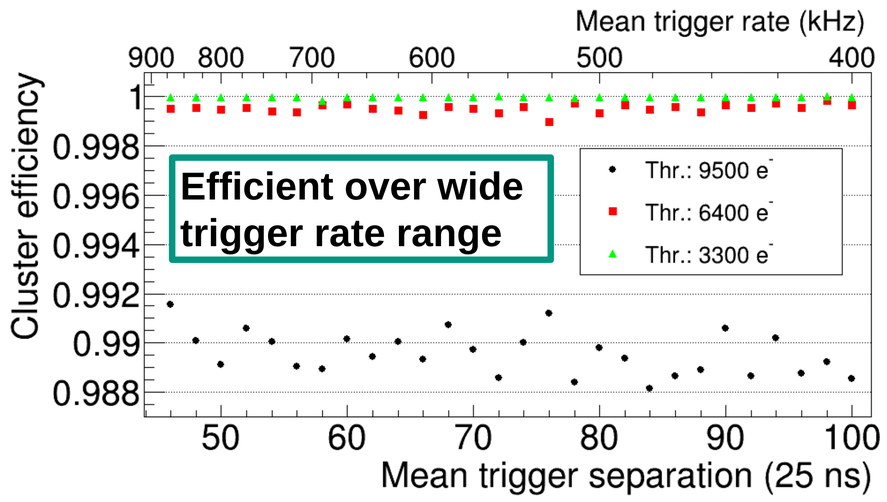


- Wiggle / Injection height
  - Top injection: 1.6 %
  - Bottom injection: 2.1 %

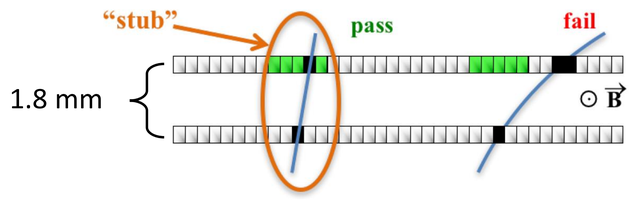
Bottom XTalk higher due to longer signal lines in hybrid fold over

Trigger Rate Scans

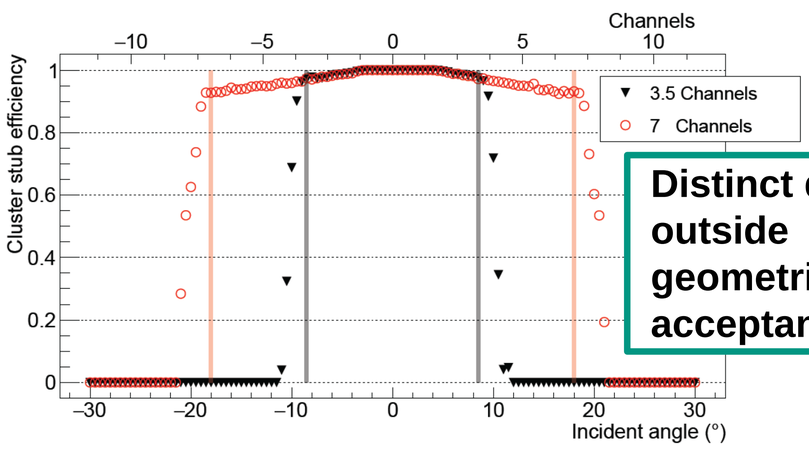
- Vary average trigger rate (Poisson-distr.)
- Cluster signal: 22 000 e⁻
- Track density: **10 MHz/cm²**



Track Inclination and Stubs



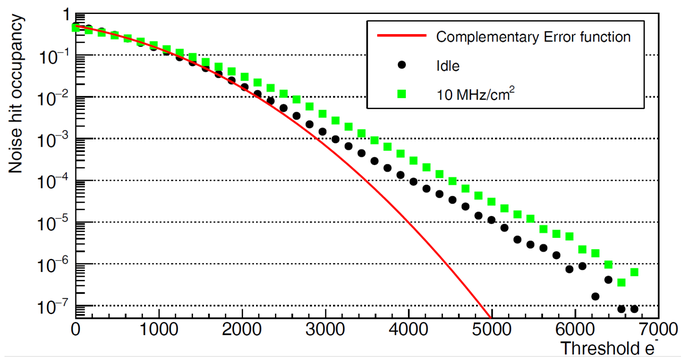
- Trigger rate: **750 kHz**
- Cluster signal: 22 000 e⁻ (0°)
- Track density: **10 MHz/cm²**

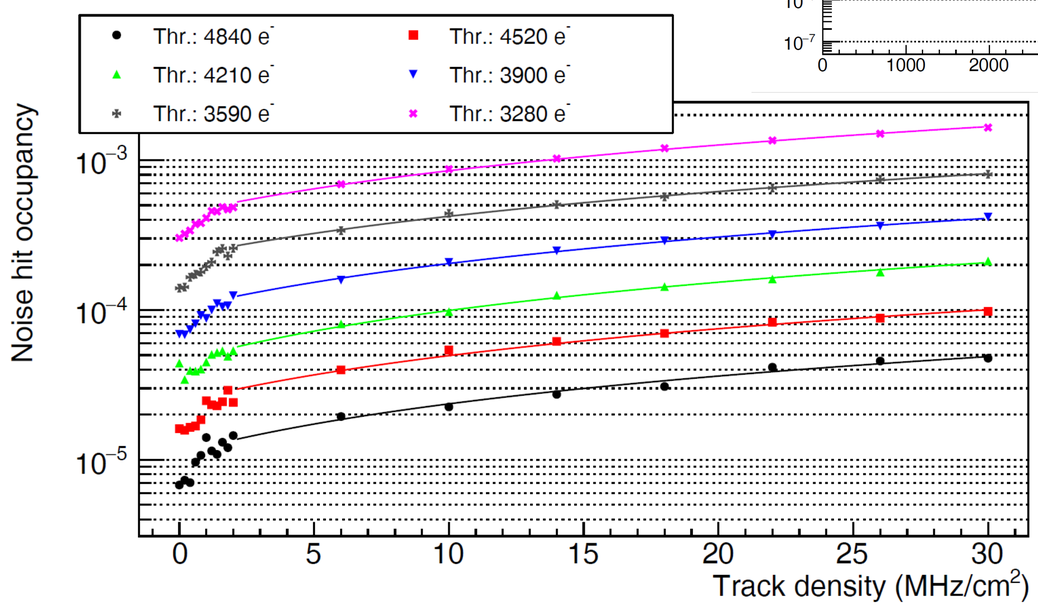


Distinct drop outside geometric acceptance

Noise Studies

- Compare noise: Idle ↔ Data taking
- Noise increases with occupancy
- Expected track density: ~10 MHz/cm²





- Trigger rate: **750 kHz**
- Cluster signal: 22 000 e⁻

Efficient module operation possible