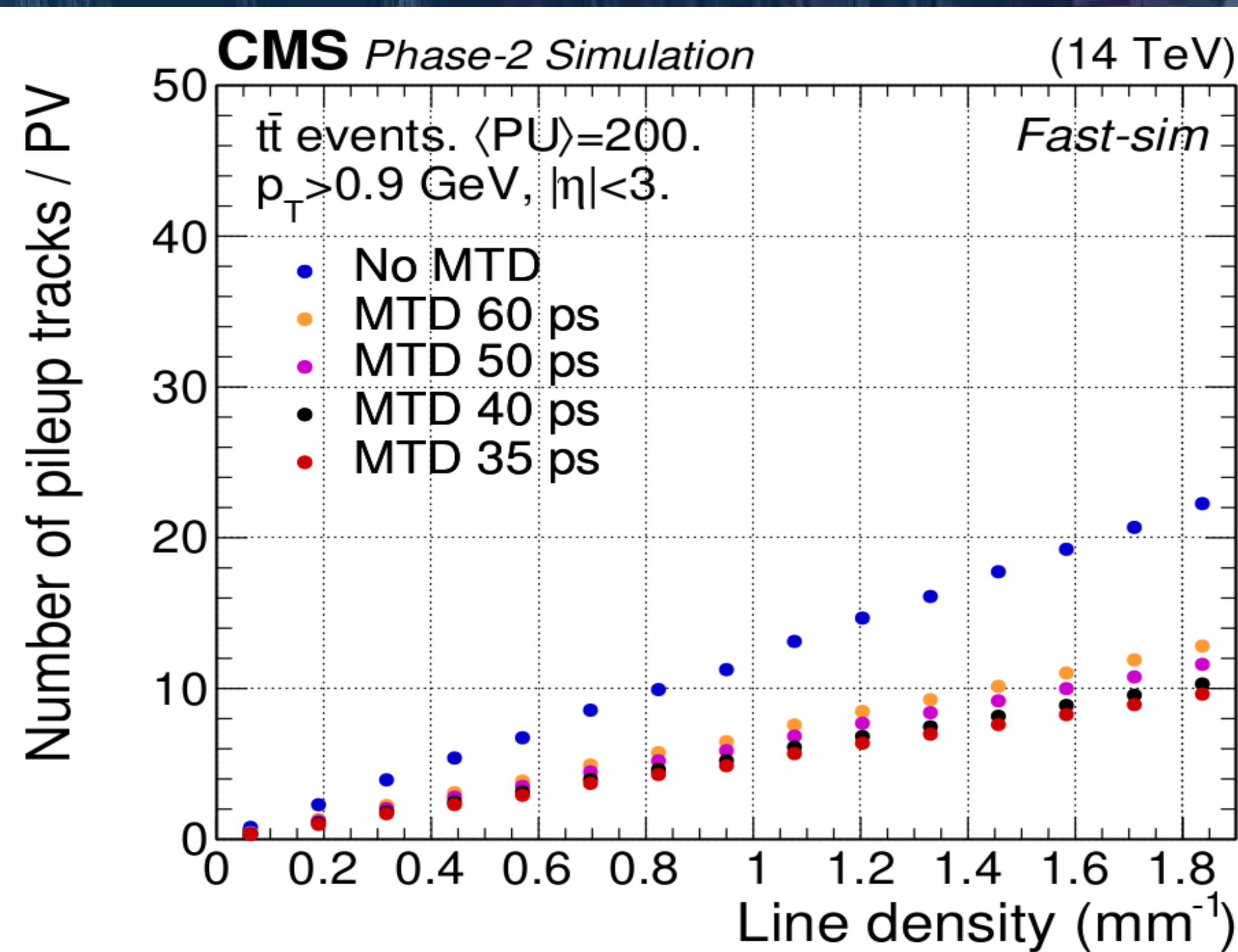# Precision Timing with the CMS MTD Barrel Timing Layer for HL-LHC

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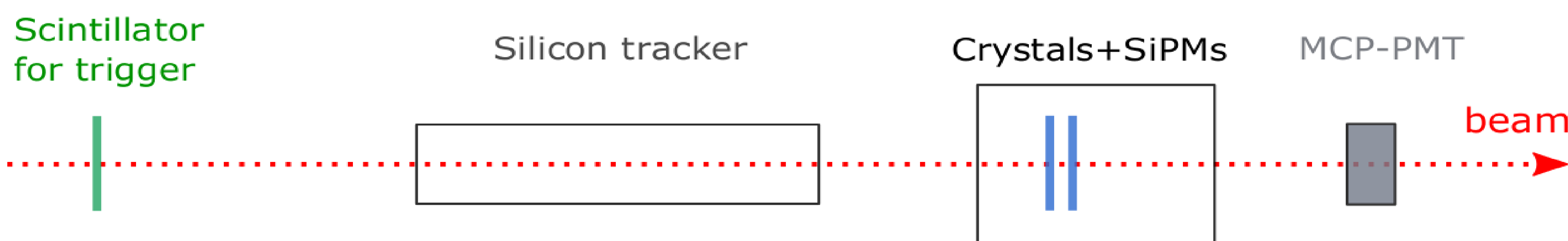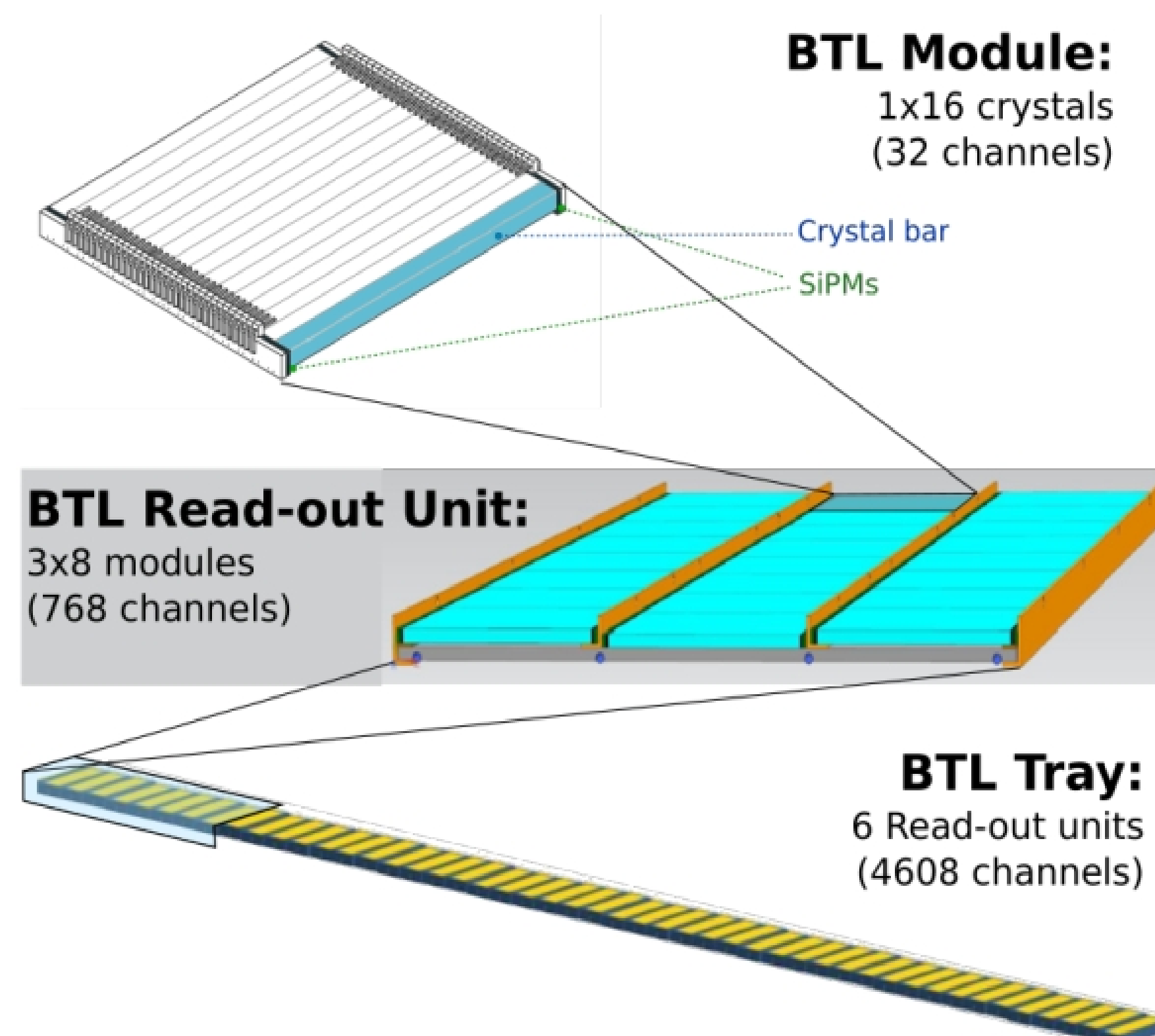CMS Phase-2 Simulation — (14 TeV) — t̄t events. ⟨PU⟩=200. p_T>0.9 GeV, |η|<3. — Fast-sim — No MTD, MTD 60 ps, MTD 50 ps, MTD 40 ps, MTD 35 ps — Number of pileup tracks / PV vs Line density (mm⁻¹)

- **High Luminosity LHC (HL-LHC)**
  - → Maximum luminosity of 2×10^{35} cm⁻² s⁻¹
  - → Average pile up: 140 (maximum 200)

- **Timing information of the tracks can be exploited**
  - → Reduce the impact of pile up on objects reconstruction and identification
  - → Mip Timing Detector (MTD): σ_t~30 ps (50-60 ps by the end of HL-LHC operations)

- **MTD Barrel Timing Layer [1]**
  - → LYSO:Ce bars + SiPM readout + TOFHIR ASICs front-end
  - → Operated at -30°C to reduce the dark current, induced by radiation
  - → Tracker/ECAL interface: ~ 40 mm thick, ~38 m²
  - → Mounted on the inner surface of the Tracker Support Tube
  - → 72 trays with 332k channels

BTL Module: 1x16 crystals (32 channels) — Crystal bar — SiPMs — BTL Read-out Unit: 3x8 modules (768 channels) — BTL Tray: 6 Read-out units (4608 channels) — 2 trays in z — BTL detector — 72 trays: 2(z) x 36(φ) — 332k channels

Scintillator for trigger — Silicon tracker — Crystals+SiPMs — MCP-PMT — beam

[2] accepted by JINST

LYSO-SiPMs pulse shape slope — slope (mV/ns) vs time (ns)

- **Study LYSO+SiPMs performance at Test Beam**
  - → 120 GeV protons
  - → Scintillator (trigger) + Silicon tracker (beam tracking) + LYSO bars (with unirradiated SiPMs) + MCP-PMT (reference)
  - → Customized electronic boards used to apply the bias voltage and perform the readout of the SiPMs

- **Test various crystal dimensions and SiPMs manifactures**
  - → 3x2x57 mm³, 3x3x57 mm³ and 3x4x57 mm³ crystals
  - → Hamamatsu (HPK) and Fondazione Bruno Kessler (FBK) SiPMs

- **Measure time resolution for various configurations**
  - → As a function of the MIP impact point and angle
  - → As a function of the most probable value (MPV) of the signal amplitude

- **Target time resolution for MTD with unirradiated SiPMs achieved: σ_t~30 ps**

time resolution (ps) vs amplitude (MPV)

$$f_1(A) = \frac{a}{A^\alpha} \oplus c$$

χ²/ndf	17.19 / 16
p0	23.4 ± 11.82
p1	0.8677 ± 0.1206
p2	13.95 ± 3.1

χ²/ndf	17.5 / 16
p0	18.41 ± 3.806
p1	16.15 ± 9.28
p2	11.88 ± 6.351

$$f_2(A) = \frac{s}{\sqrt{A}} \oplus \frac{n}{A} \oplus c$$