CMS Phase 2 upgrade: the MIP Timing Detector (MTD)

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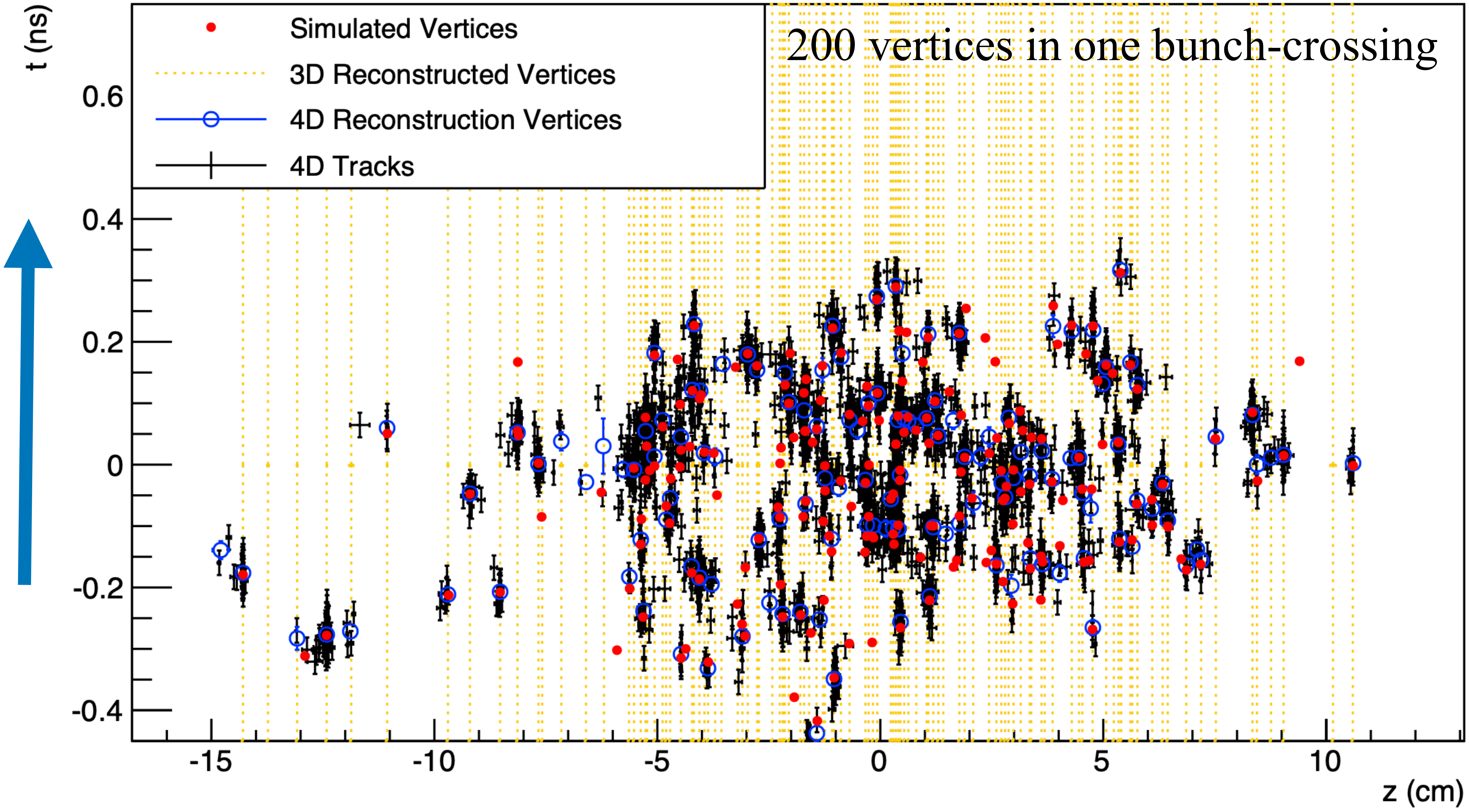
Introduction

- LHC will upgrade to high luminosity HL-LHC
  - Int. lumi will increases by x5 leading to much quicker data taking but also severe pileup that challenges the measurement precision
  - To deal with this dense environment, CMS planned and is building a new timing detector MTD expecting to improve the timing resolution by 3 orders of magnitude（25 ns → 30 ps）

MTD provides an additional dimension: time!

New dimension



MTD brings significant improvements in physics

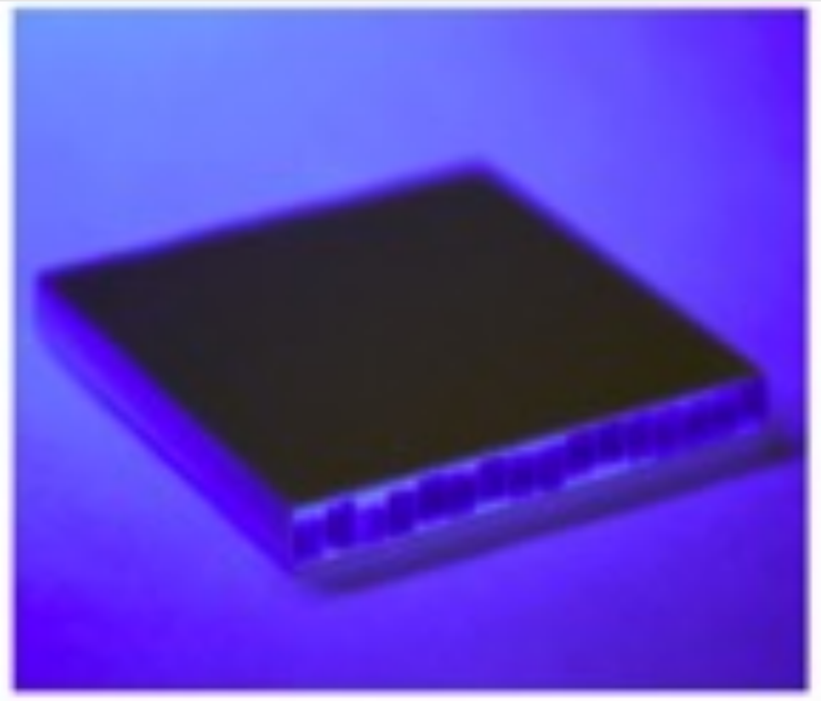
- MTD suppresses pileup effectively

Signal	Physics measurement	MTD Impact
H→γγ H→4leptons	**+25%** statistical precision on xsecs → Couplings	Isolation Vertex identification
VBF+H→ττ	**+30%** statistical precision on xsecs → Couplings	Isolation VBF tagging, MET
HH	**+20%** gain in signal yield → Consolidate searches	Isolation, b-tagging
EWK SUSY	**40%** reducible background reduction → +150 GeV mass reach	MET
Long Lived Particles (LLP)	Peaking Mass Reconstruction → Unique discovery potential	β_{LLP} from timing of displaced vertices

MTD overview

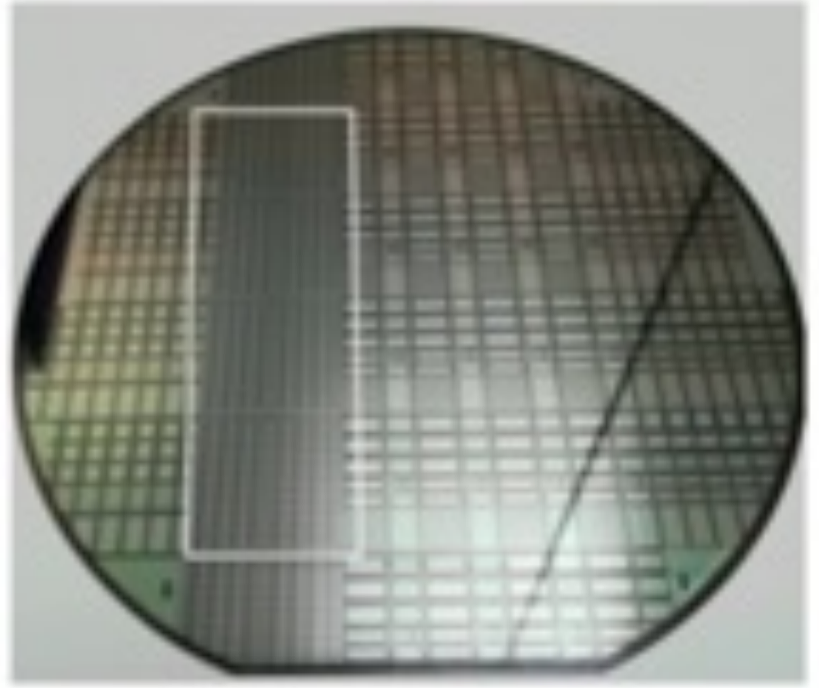
BTL: LYSO bars + SiPM readout:

- TK / ECAL interface: $|\eta| < 1.45$
- Inner radius: 1148 mm (40 mm thick)
- Length: ±2.6 m along z
- Surface ~38 m^2; 332k channels
- Fluence at 4 ab^{-1}: 2×10^{14} n_{eq}/cm^2

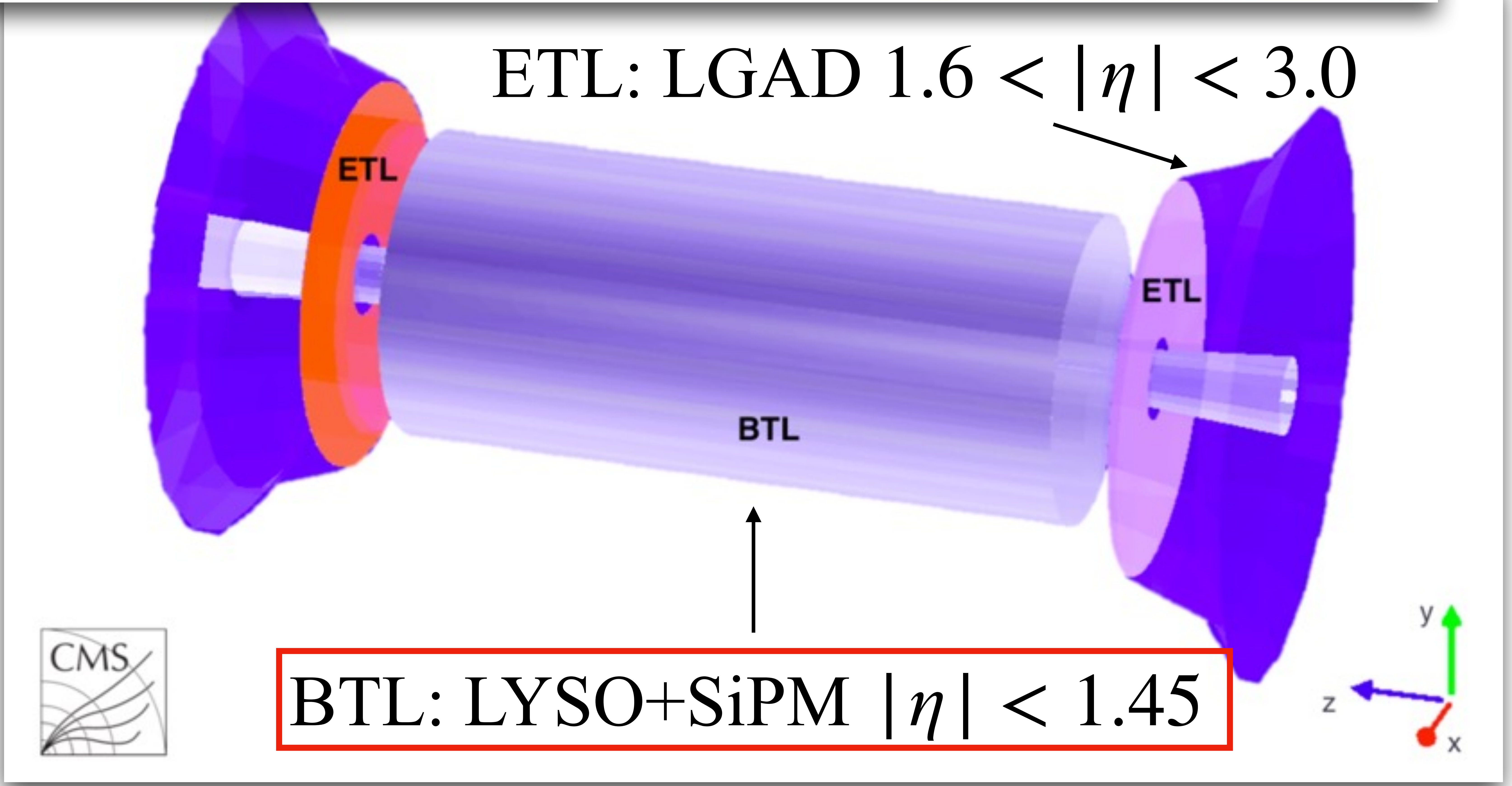


ETL: Si with internal gain (LGAD):

- On the CE nose: $1.6 < |\eta| < 3.0$
- Radius: 315 < R < 1200 mm
- Position in z: ±3.0 m (45 mm thick)
- Surface ~14 m^2; ~8.5M channels
- Fluence at 4 ab^{-1}: up to 2×10^{15} n_{eq}/cm^2

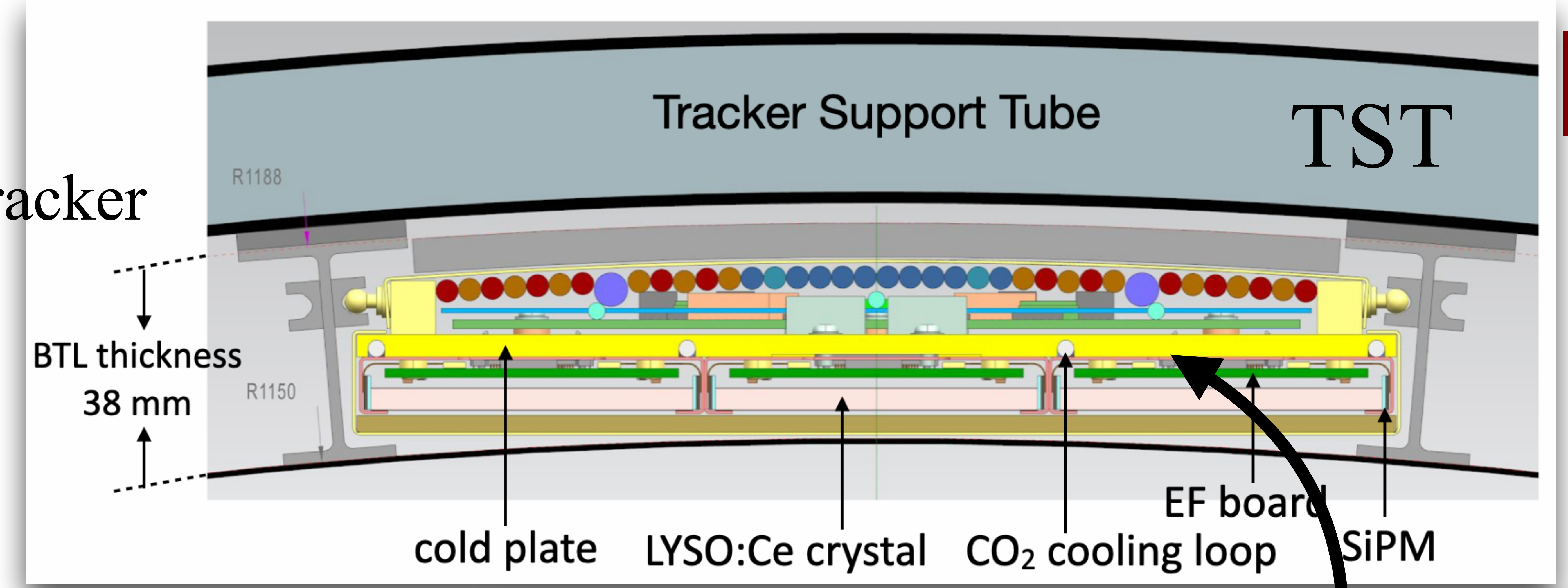


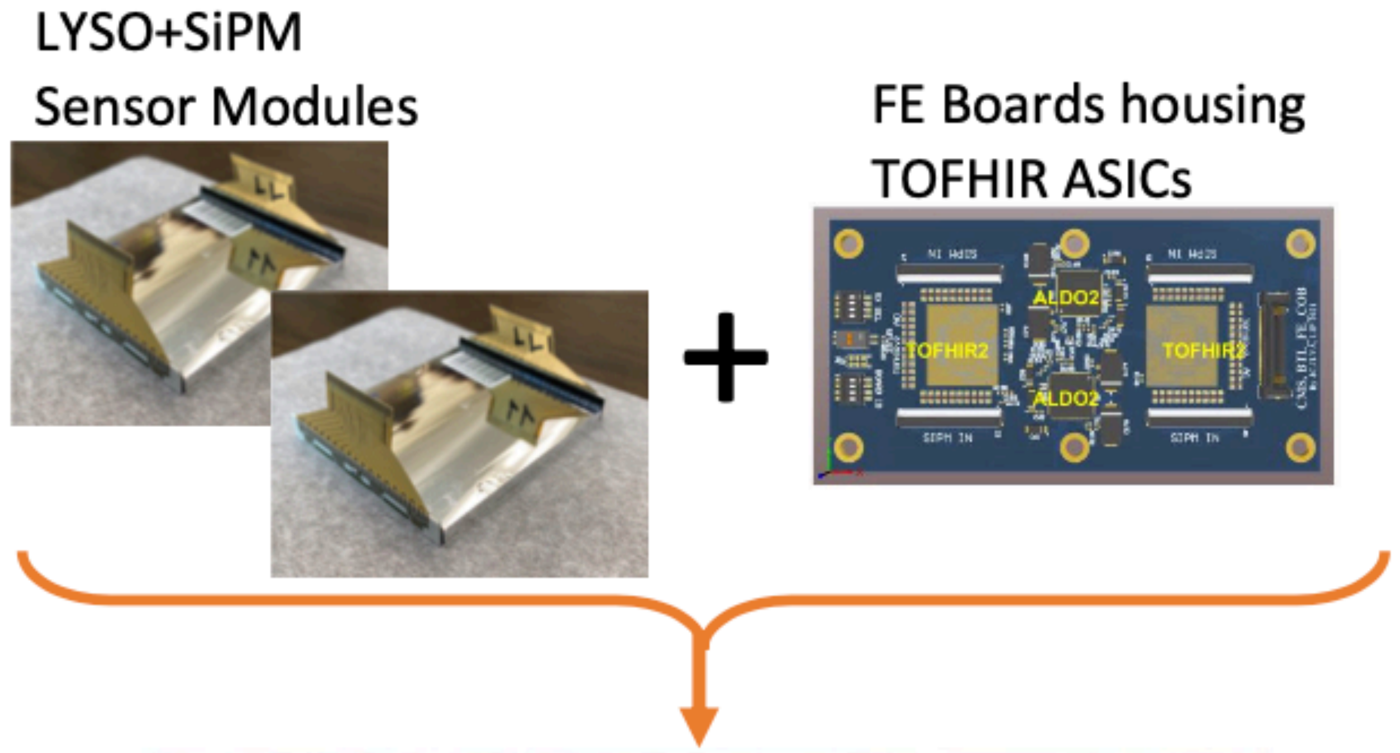
- This is an approved project and is well undergoing
- Given different radiation dose, two different technologies are taken
  - Barrel (BTL) uses LYSO:Ce + SiPM readout
  - Endcap (ETL) uses LGAD
- MTD TDR CMS-TDR-020

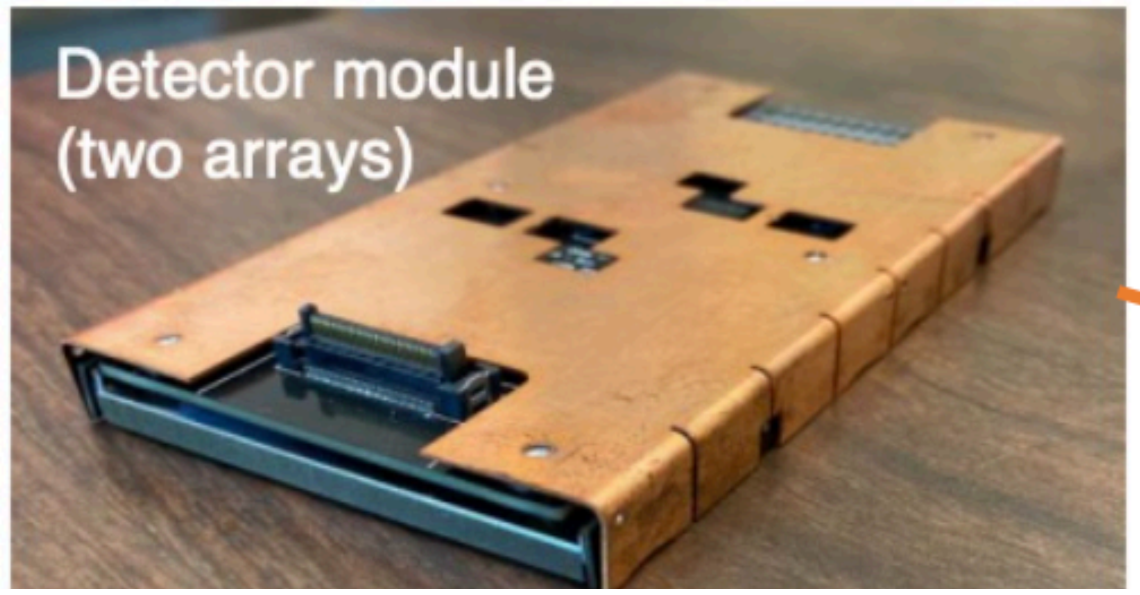


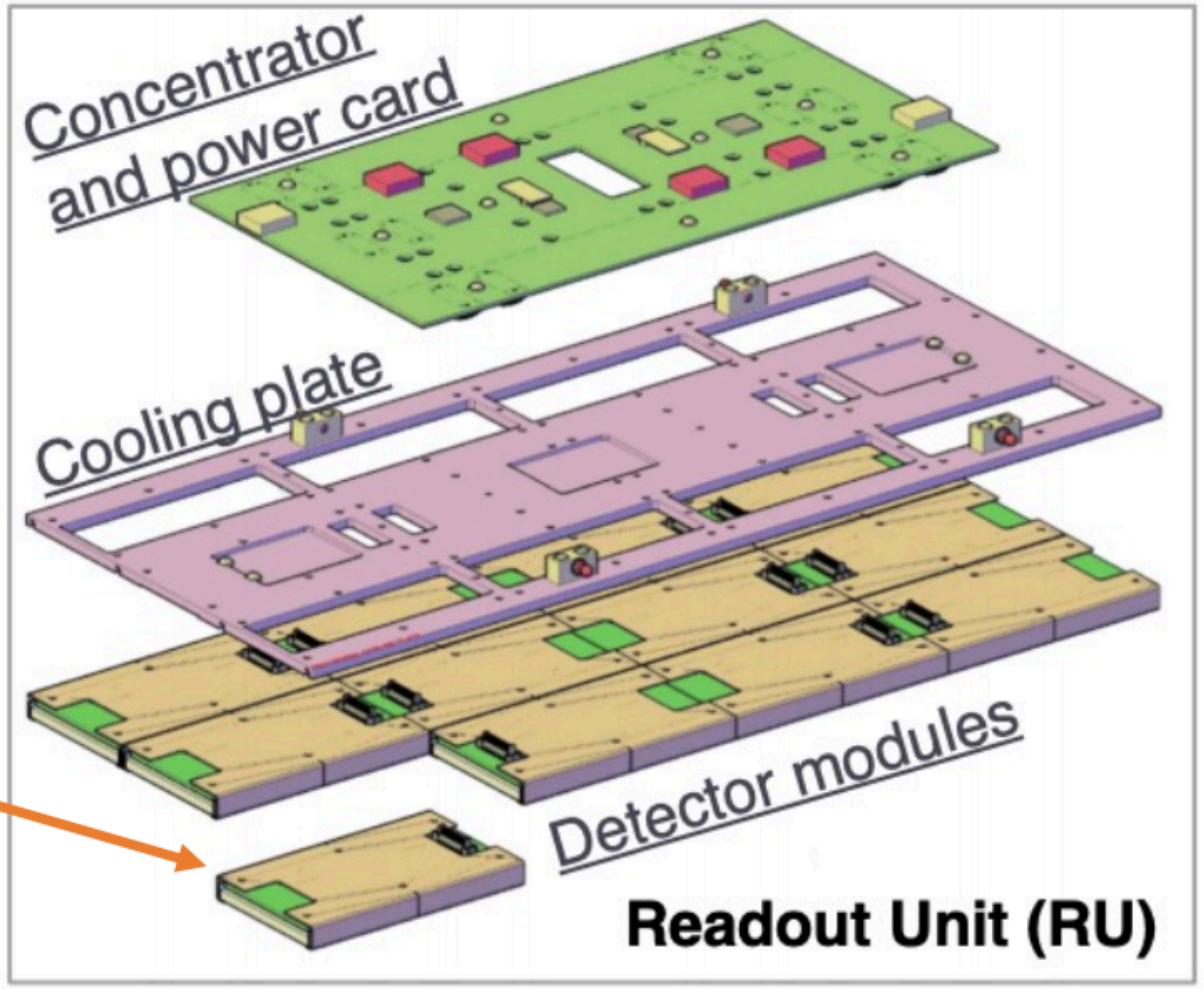
BTL design

- BTL detector mounted on inner surface of Tracker Support Tube (TST) and share the cooling
- LYSO+SiPM&TEC=Sensor Modules
- SMs+FE=Detector Modules
- DMs are grouped in Readout Units
- Mechanical support & CO_2 via cooling plate in a Tray

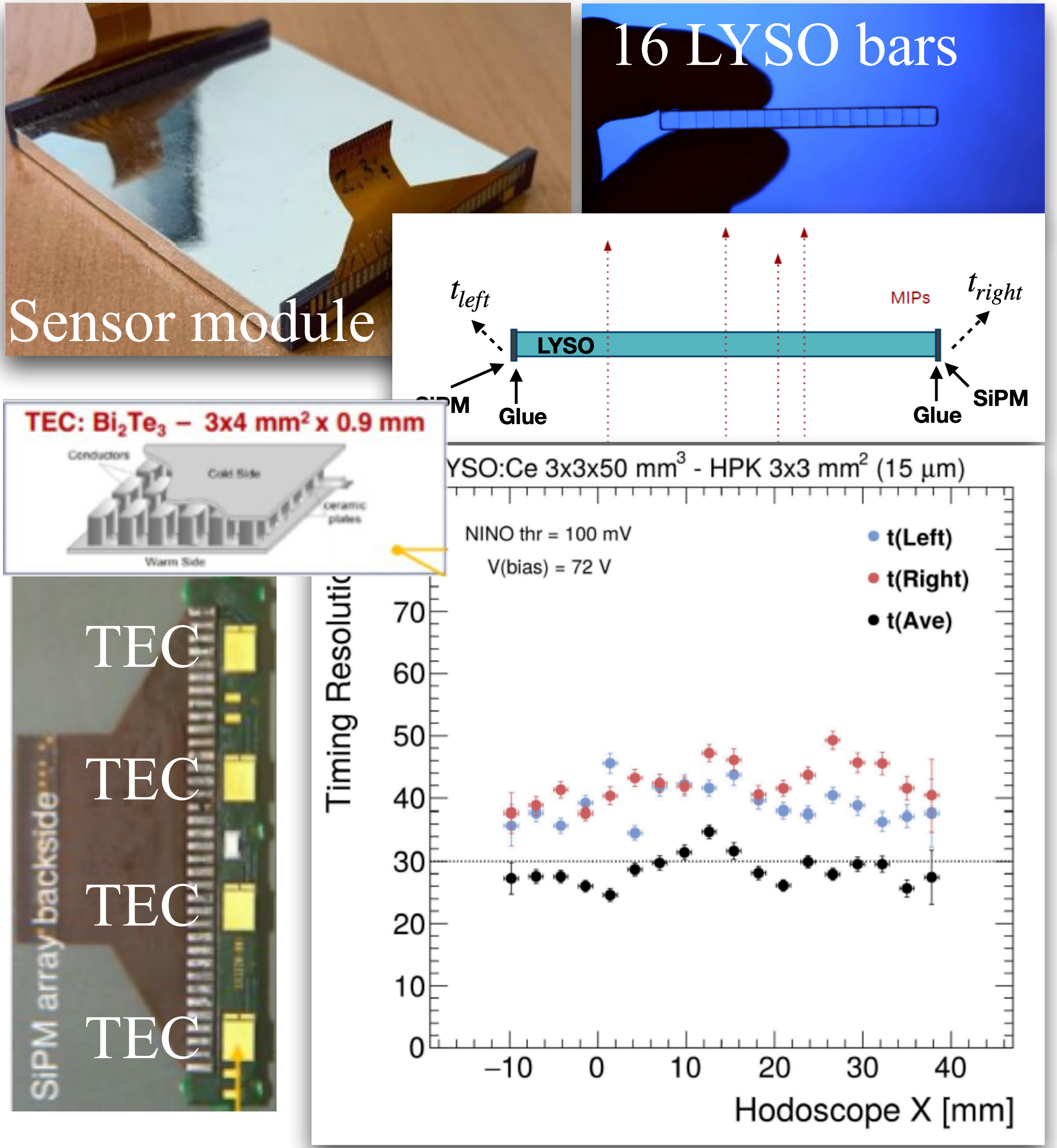








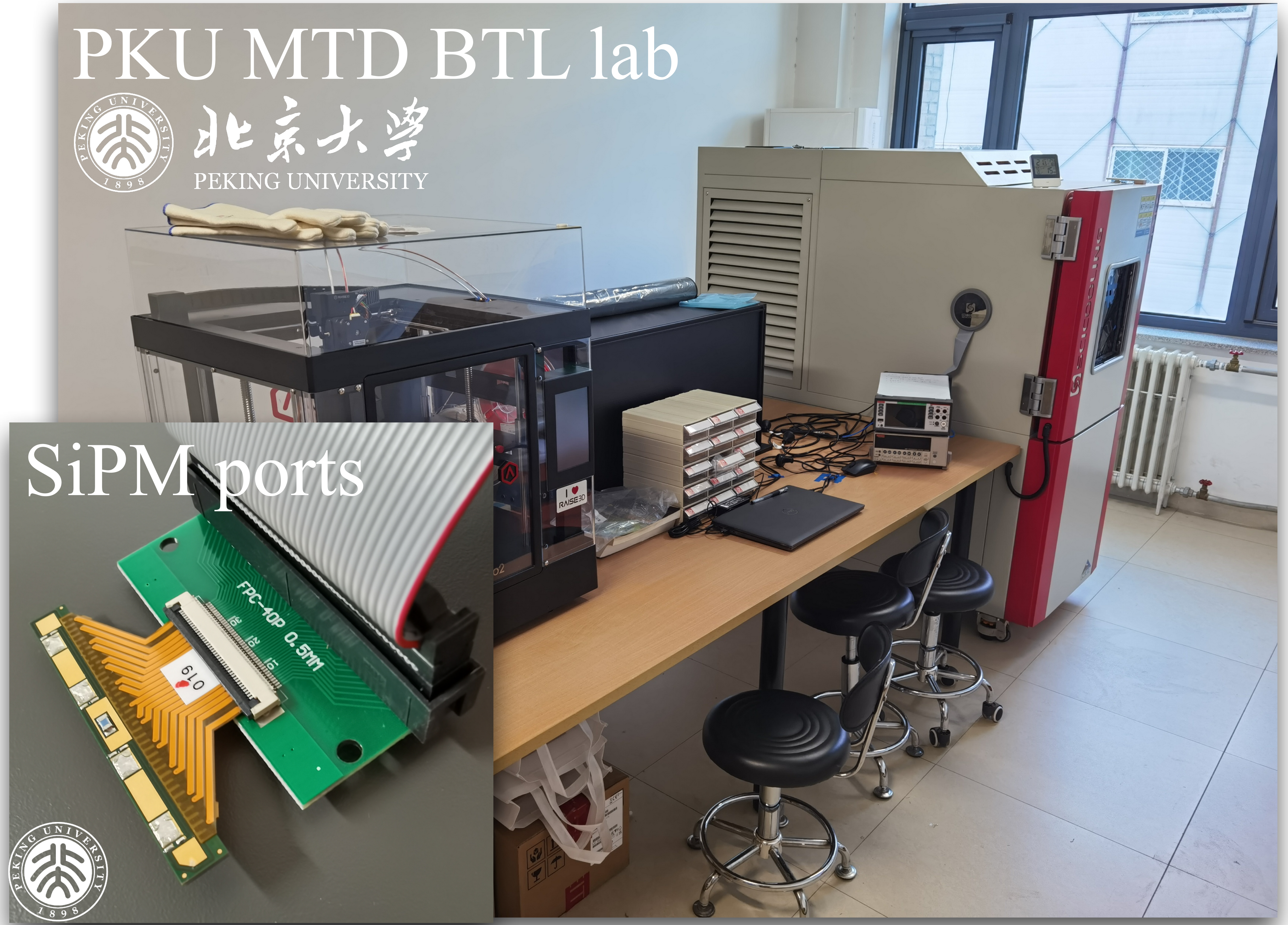
Sensor module

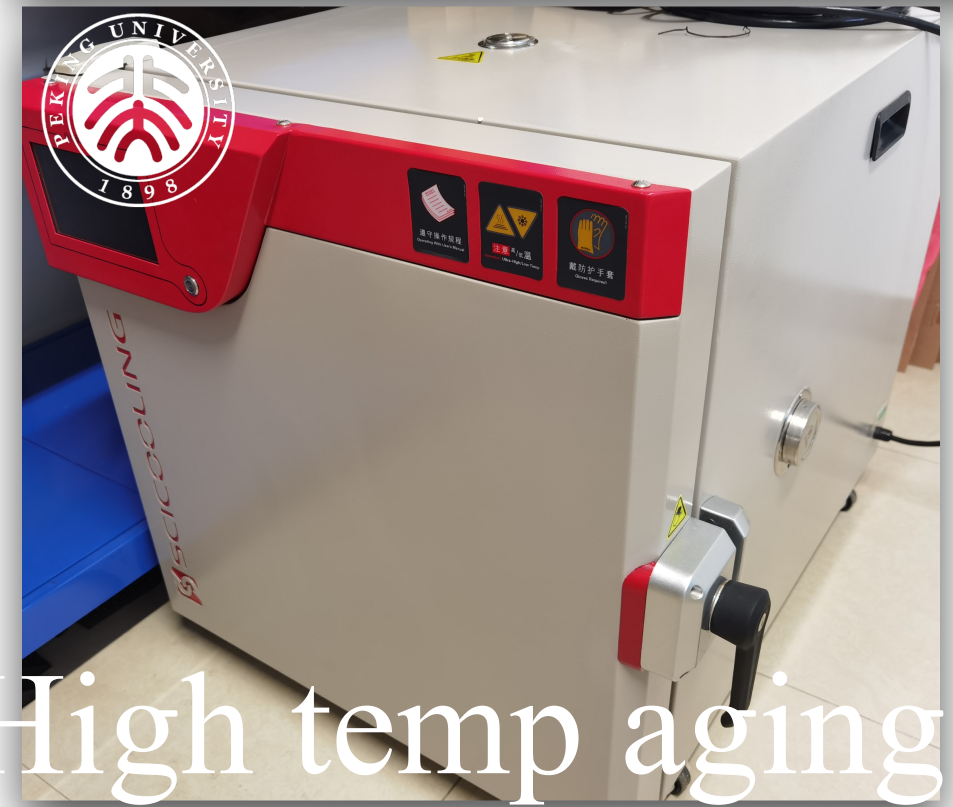


- Sensor module has 16 LYSO bars (3×3×57 mm³)
  - High light yield (~ 40000 photons/ MeV)
  - Fast scintillation rise time (< 100 ps)
  - Short decay time (~40 ns)
- Dual readout by 2 SiPM arrays
  - Photo-detection efficiency (PDE): 20-40%, with optimal cell size of 15 µm
  - Gain: 1.5-4×10⁵
  - Cooled to -35°C with CO2 and -10°C **with thermo-electric cooler (TEC)**
- The time resolution can reach 30 ps regardless of the position of inducing particles

Progresses at PKU

- In this half of year after we officially join the MTD BTL project, PKU has been actively working on SiPM tests and set up testing benches at the local lab



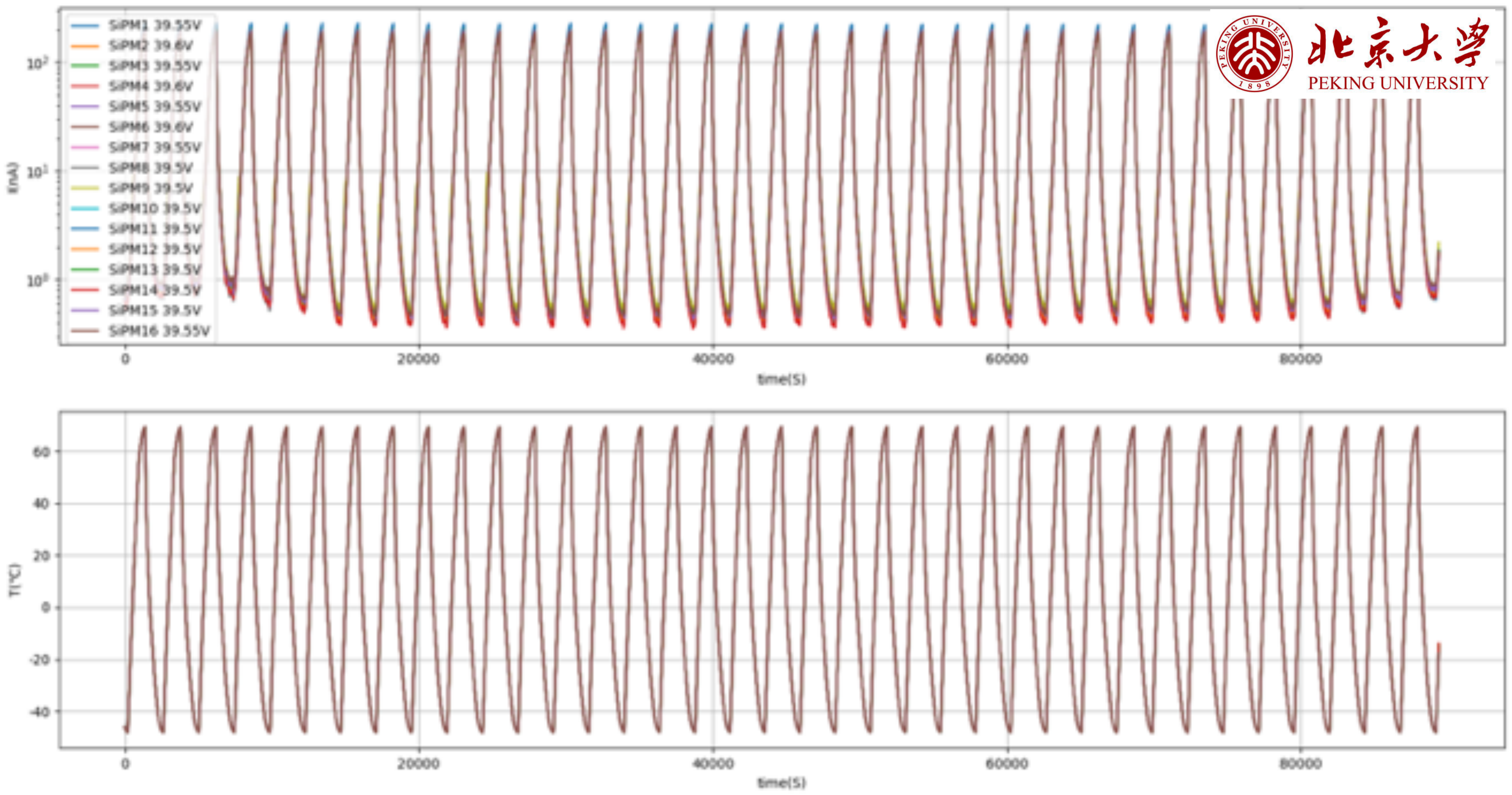


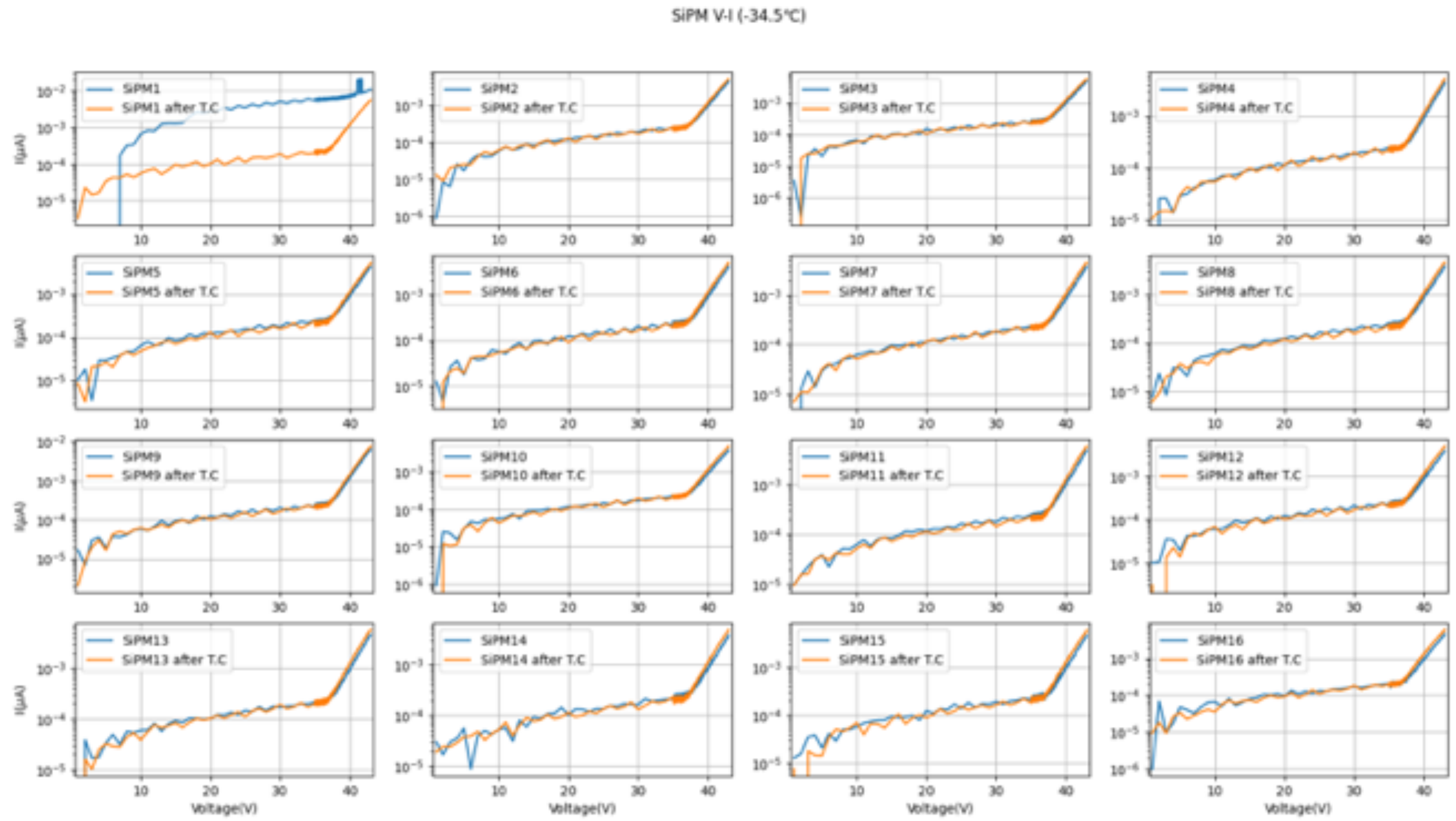
SiPM I-V

- I-V curves are measured for the SiPM potentially used in the MTD BTL sensor modules under different temperature and with/without lights
- The features are expected and satisfy the need of MTD BTL

Thermal cycling

- Reliability is of top priority for MTD BTL, because there is only one layer of this detector (no room for more) and it has to keep good performance for the whole HL-LHC
- Stress tests with 100 thermal cycles (for 10 years HL-LHC) are performed
- Temperature range provided by the climate chamber: -50 to 70 °C





I vs V (reverse) T≈ -35℃ no light

Summary

- In 2021 CMS China officially joined MTD efforts
  - PKU, BUAA and THU joined MTD barrel (BTL) project which uses LYSO+SiPM
  - USTC plans to join the MTD endcap (ETL) project which uses LGAD
- During this half year after we joined MTD, we actively communicated with the MTD collaboration, built local labs, set up preliminary testing bench, and already made contributions to SiPM testing etc.
- In next years, China MTD community will ramp up and make lots of important contributions
- General timeline for BTL:
  - Early 2022 wrap up technicalities of sensors and start procurement
  - 2023-2024 assemble sensor modules, detector modules and trays at assembly centers as well as the installation of MTD BTL in the tracker chamber at CERN
  - 2025 start testing on CMS

Backup

HL-LHC timeline

Detector module