CMS MIP timing detector

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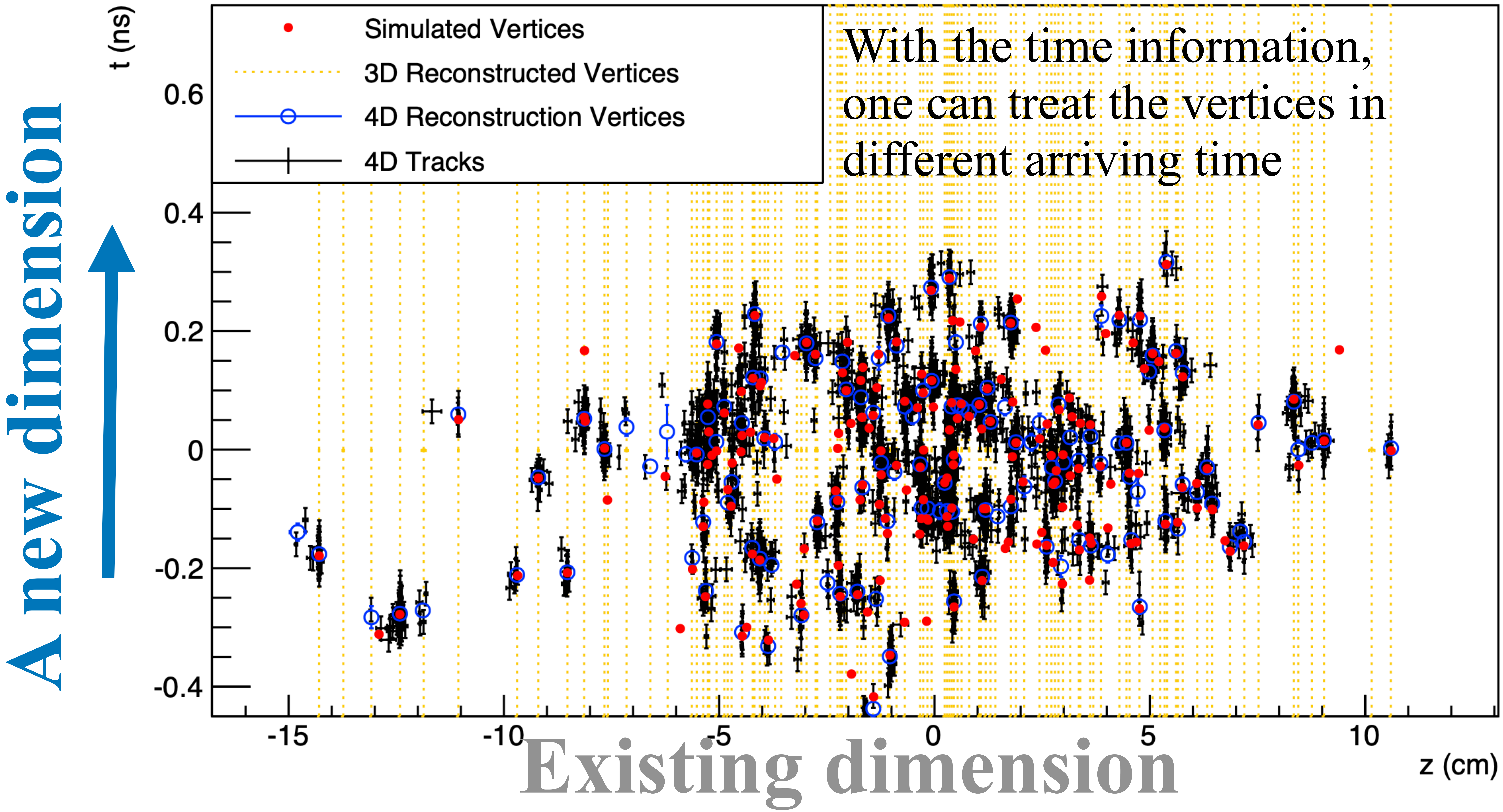
LHC → HL-LHC

- The LHC will be upgraded to HL-LHC in years
  - 3-4x higher instantaneous luminosity, severe pileup (from 40~60 at LHC to 140~200 at HL-LHC), challenging both the precision measurements and the probe of new physics
  - To deal with this dense collision environment, a novel timing detector is proposed, MIP timing detector (MTD) for CMS, with an aim to reach 30 ps time resolution

RUN 2: 40-60 vertices per bunch crossing

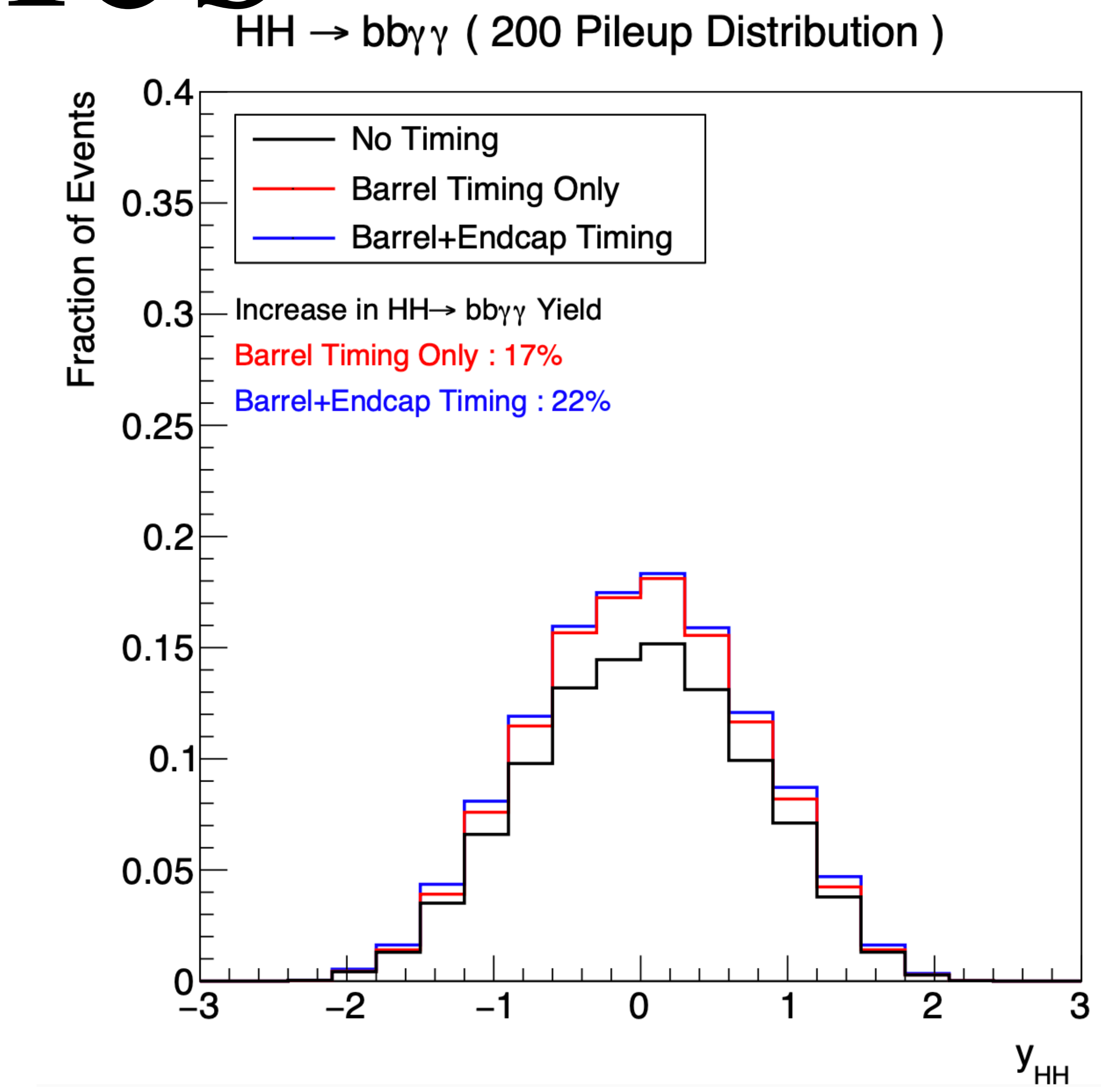
HL-LHC: 140-200 vertices per bunch crossing

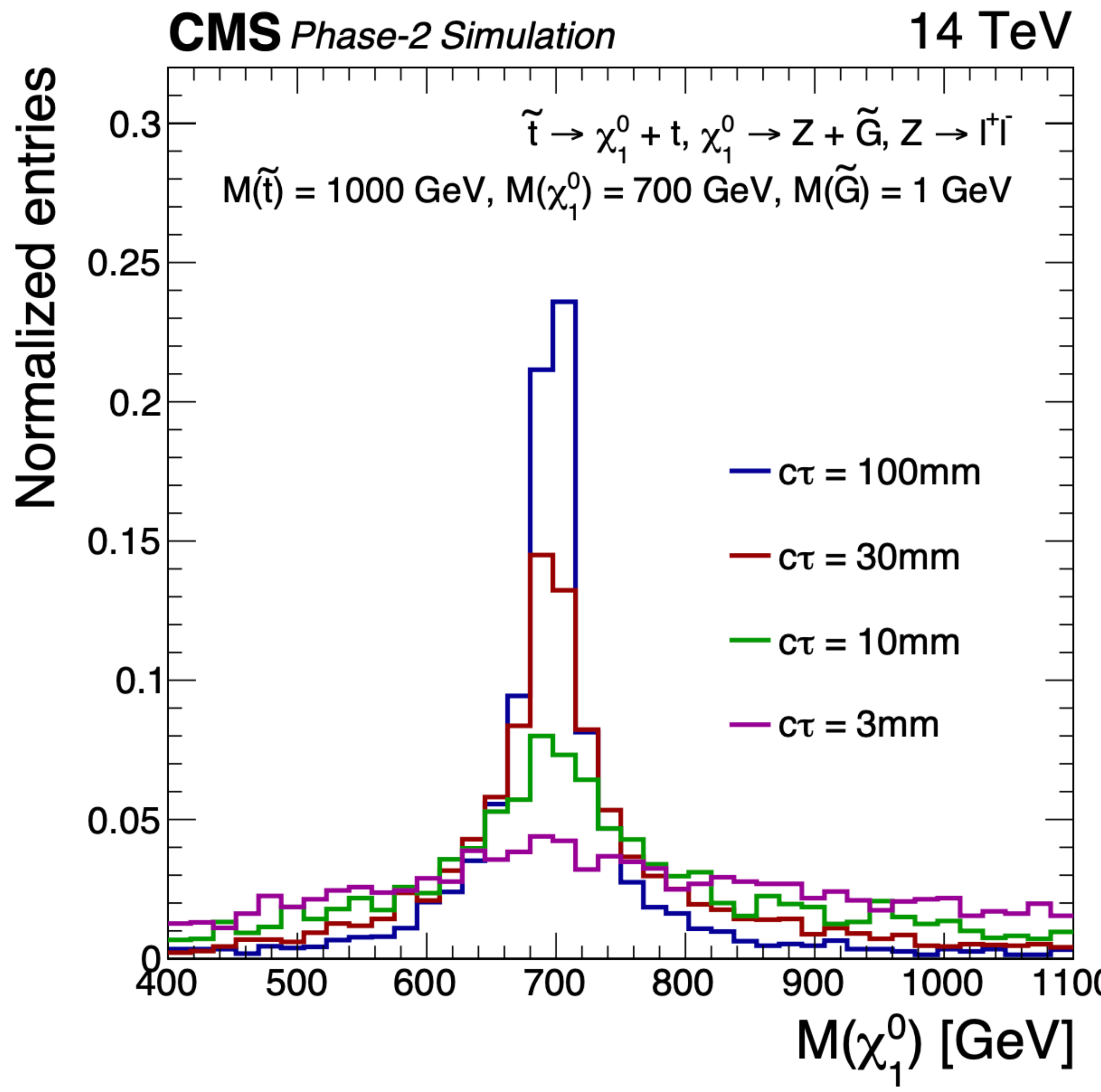
MTD brings a new dimension



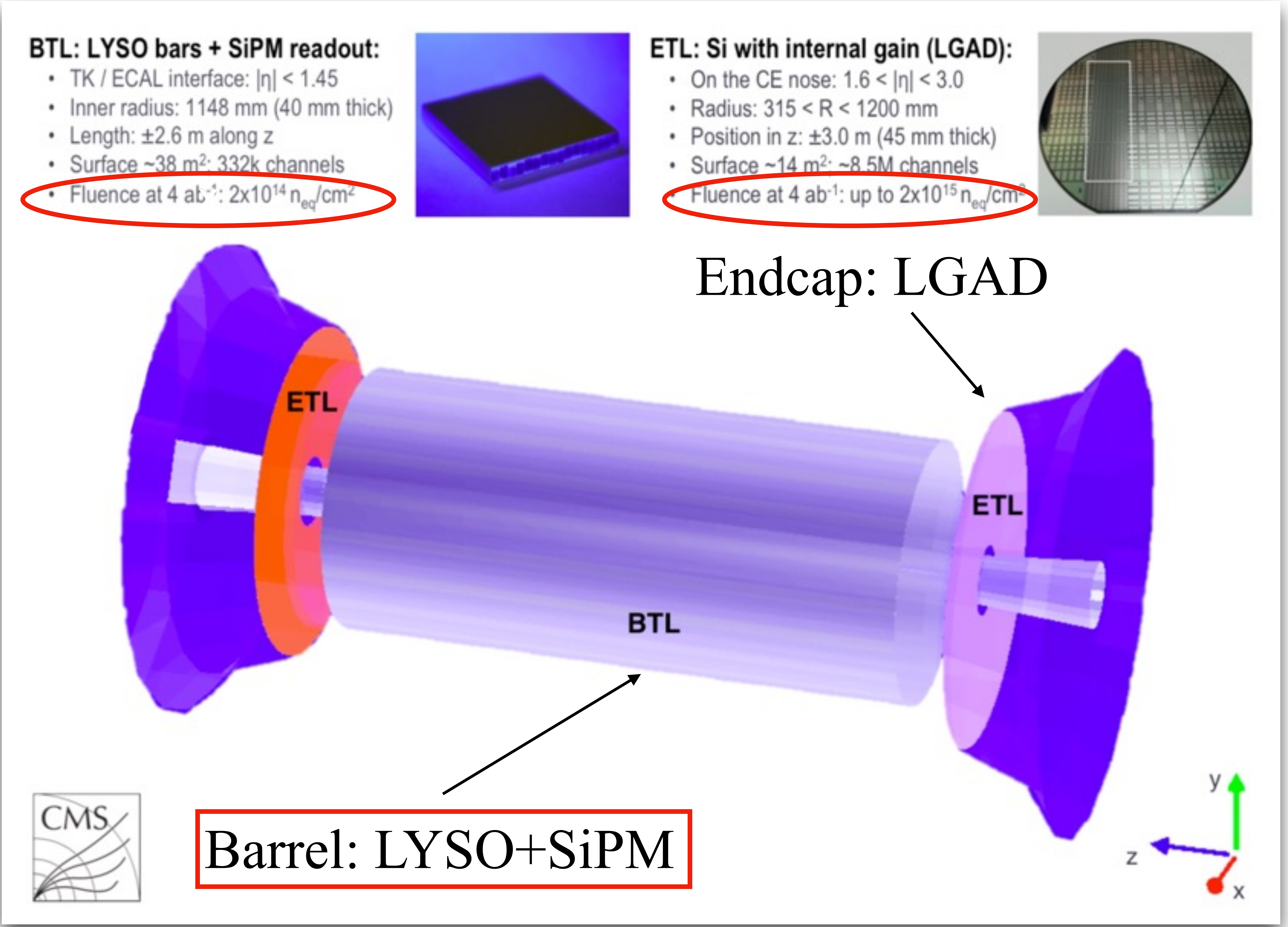
MTD potential in physics

- MTD will effectively suppress the pileup effect and even bring new functionalities
  - Increase the HH signal acceptance by 20%
  - Improve the single Higgs precision by 20-30%
  - Suppress reducible background in SUSY by 40%
  - Open a new avenue in searches for neutral LLPs





Layout

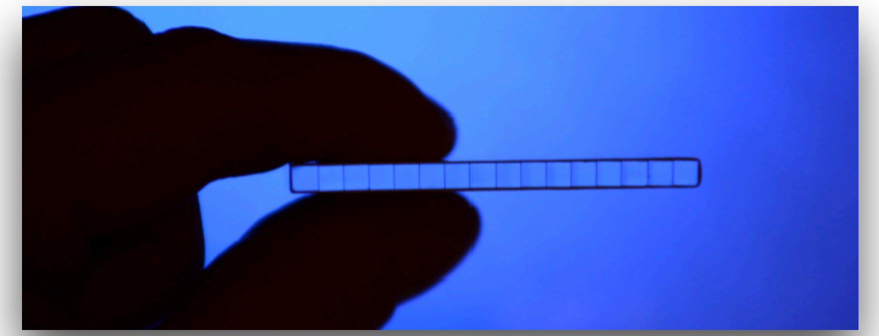


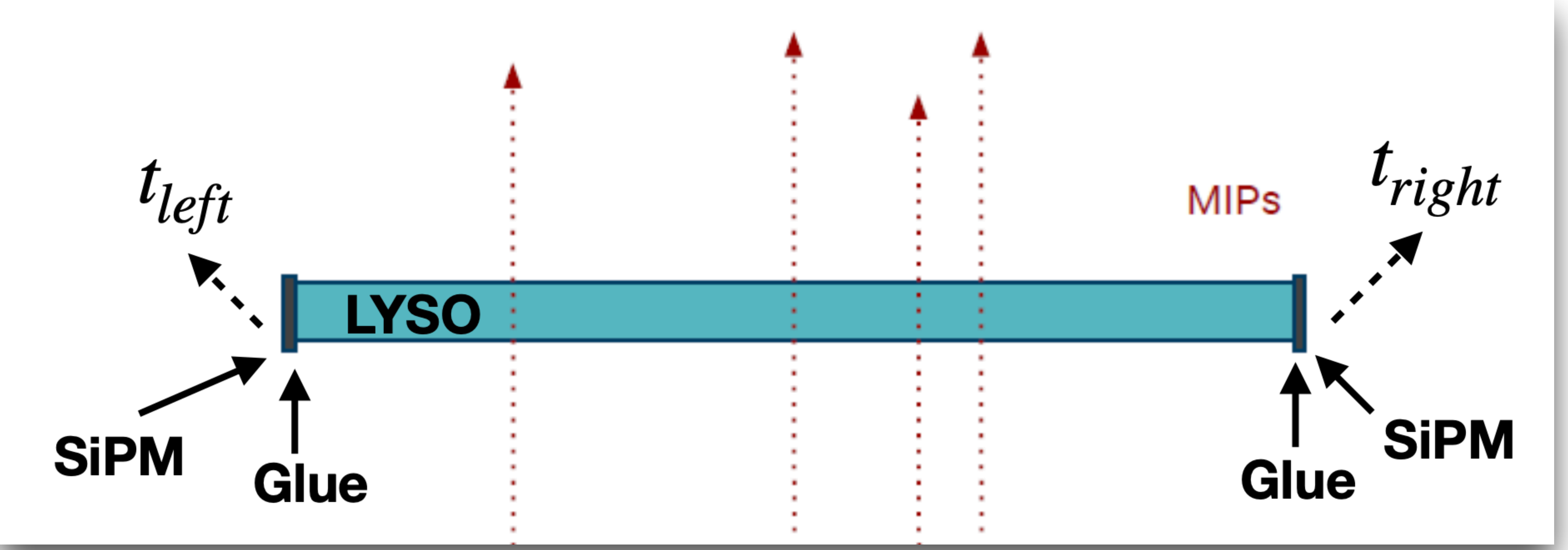
- In the barrel, LYSO+SiPM is adopted
- In the endcap, LGAD is adopted
- Very different radiation dose and different price of the sensor materials
- This talk will focus on MTD BTL

MTD BTL is here

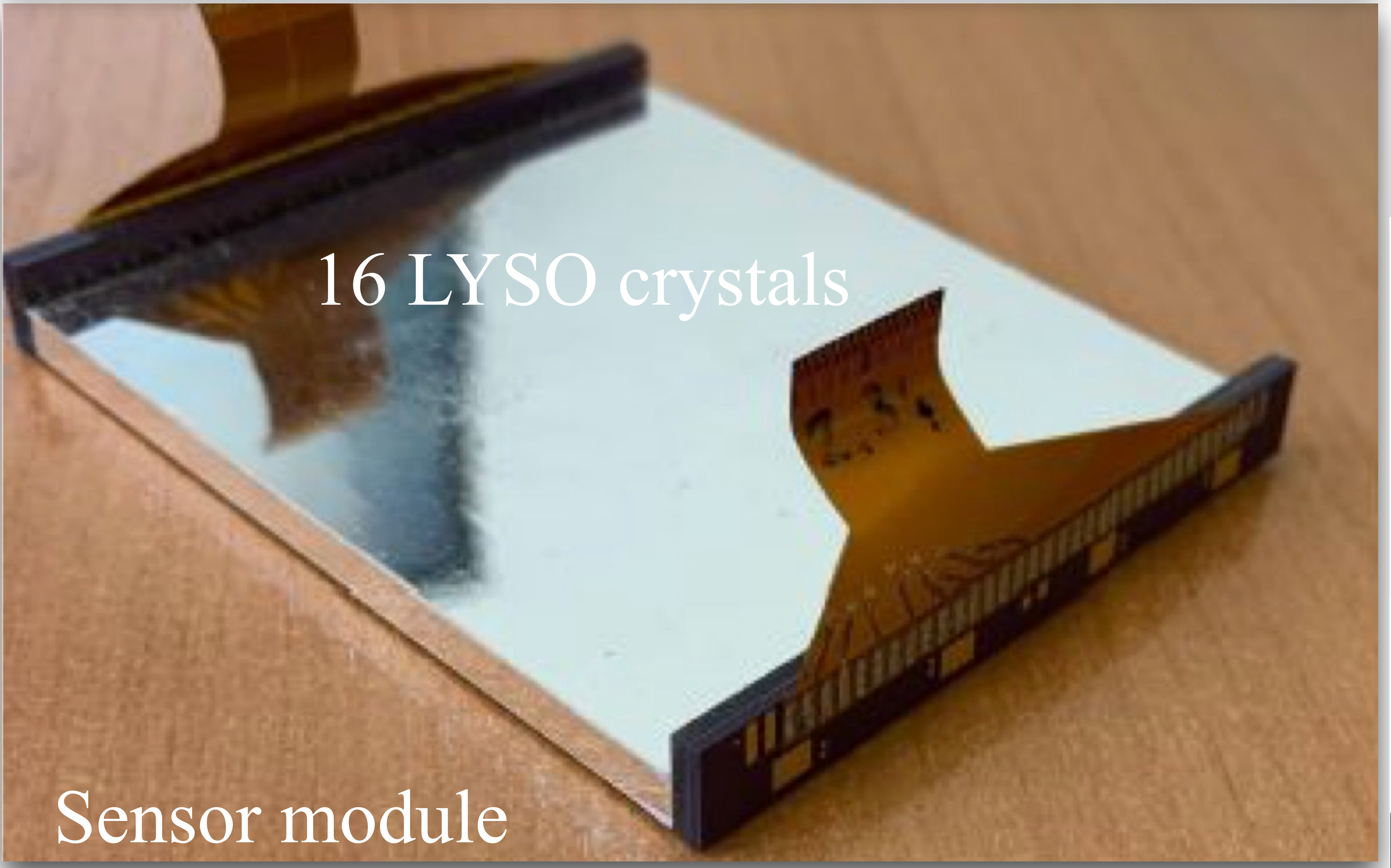
- MTD BTL share the dry/cold volume with the tracker
  - Keep below 4cm thickness
  - Minimal changes to the current tracker
- BTL with less than $0.4X_0$ (radiation length), compared to $25.8X_0$ in ECAL, has negligible impact to the downstream calorimetry

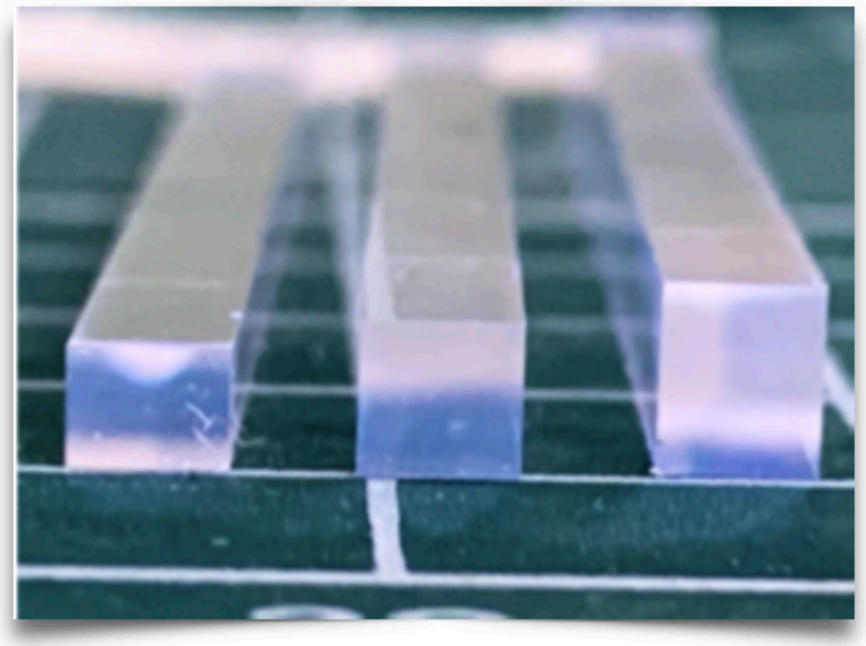
Sensor: LYSO





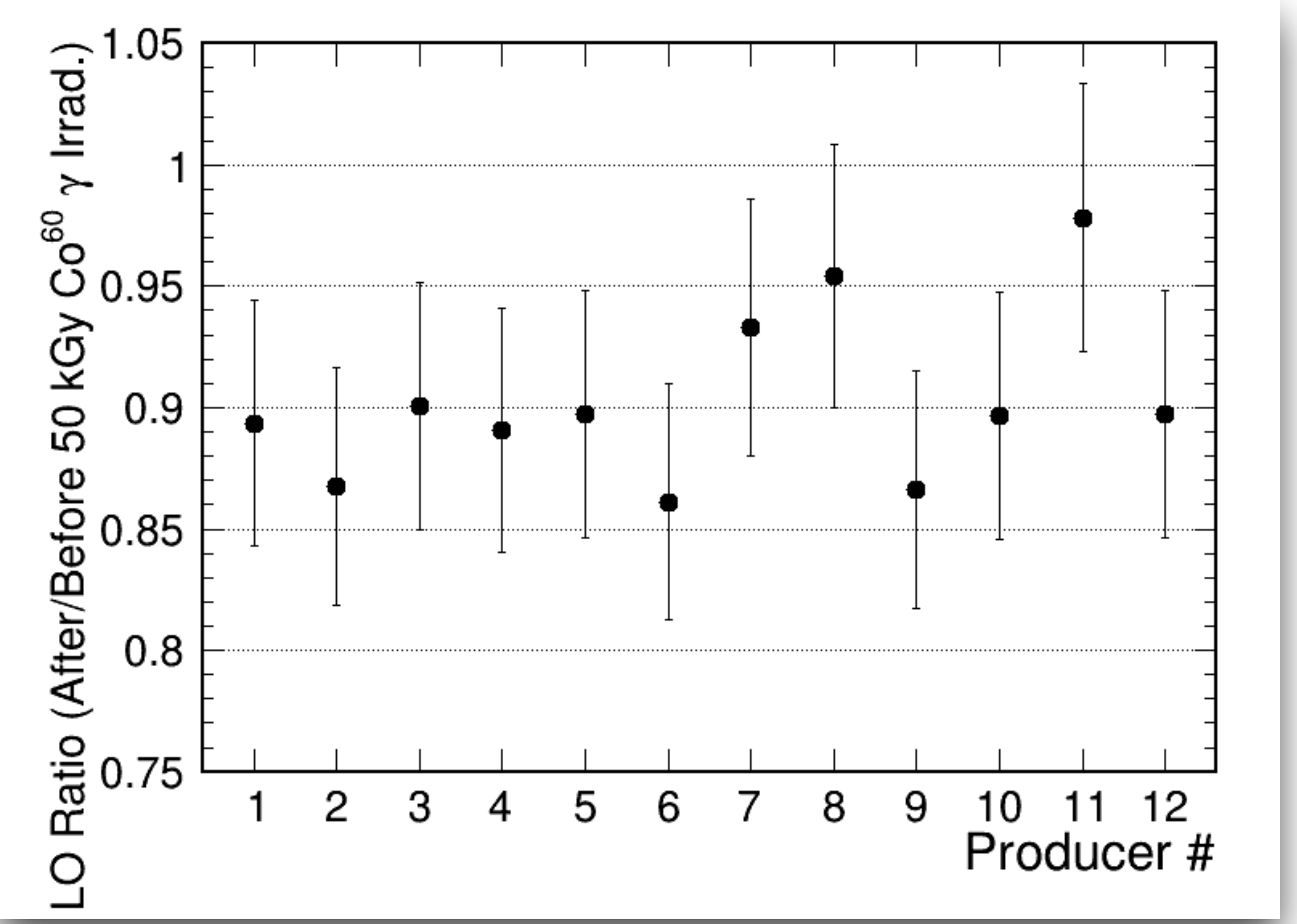
- Each sensor module contains 16 LYSO:Ce crystals placed in parallel, with a cross-section of ~3×3 mm^2
  - Fast rising (~100 ps) and decay time (~40 ns)
  - High light output: 40000 gamma/MeV
  - Radiation hard, proven up to 50 kGy with gamma radiation from ^{60}Co and 3×10^{14} N_{eq}/cm^2 with 1 MeV neutron
  - Mature technology in industry (PET)



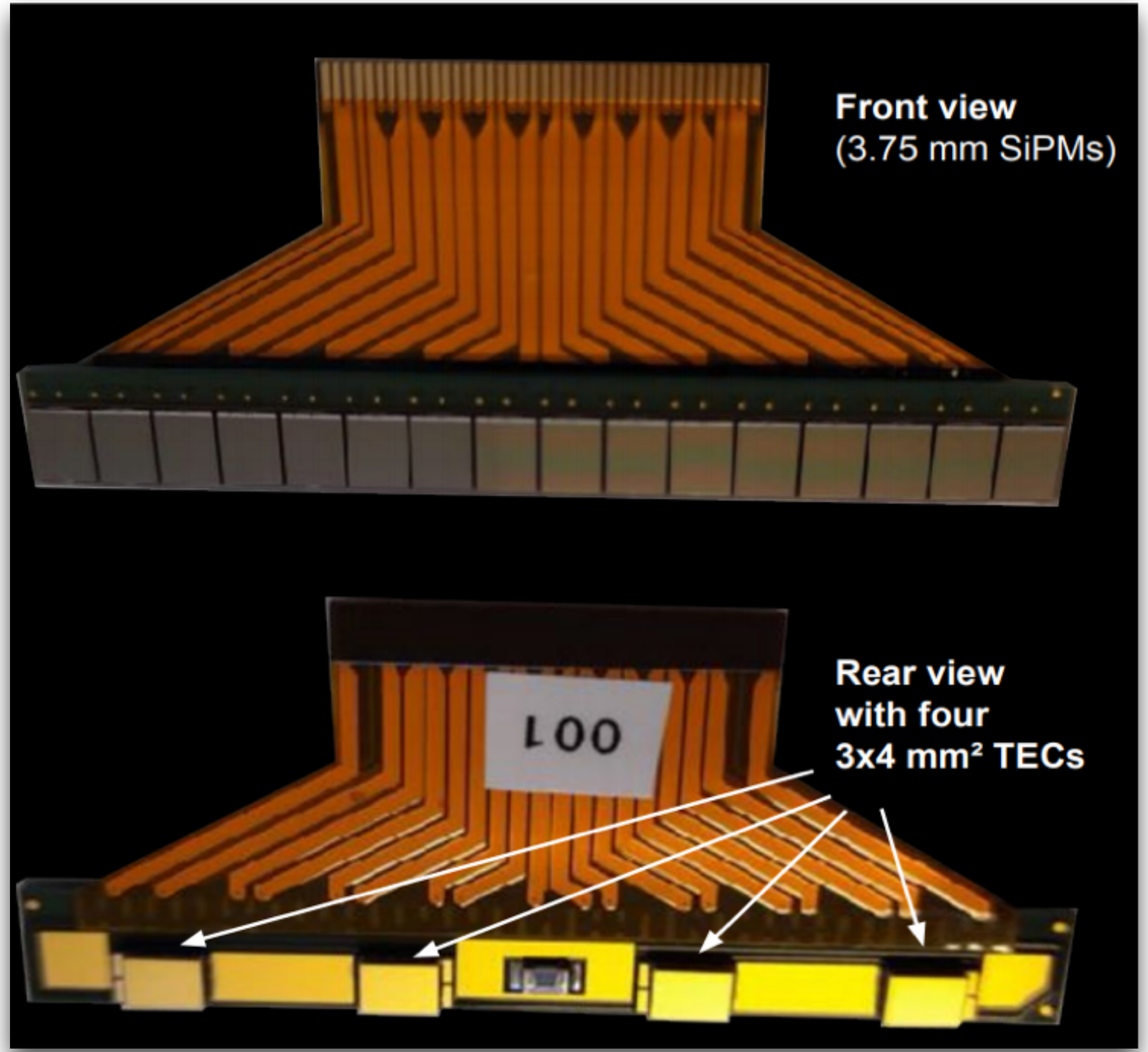


Type	t (mm)	|Eta|
1	3.75	0-0.7
2	3	0.7 - 1.1
3	2.4	1.1 - 1.5

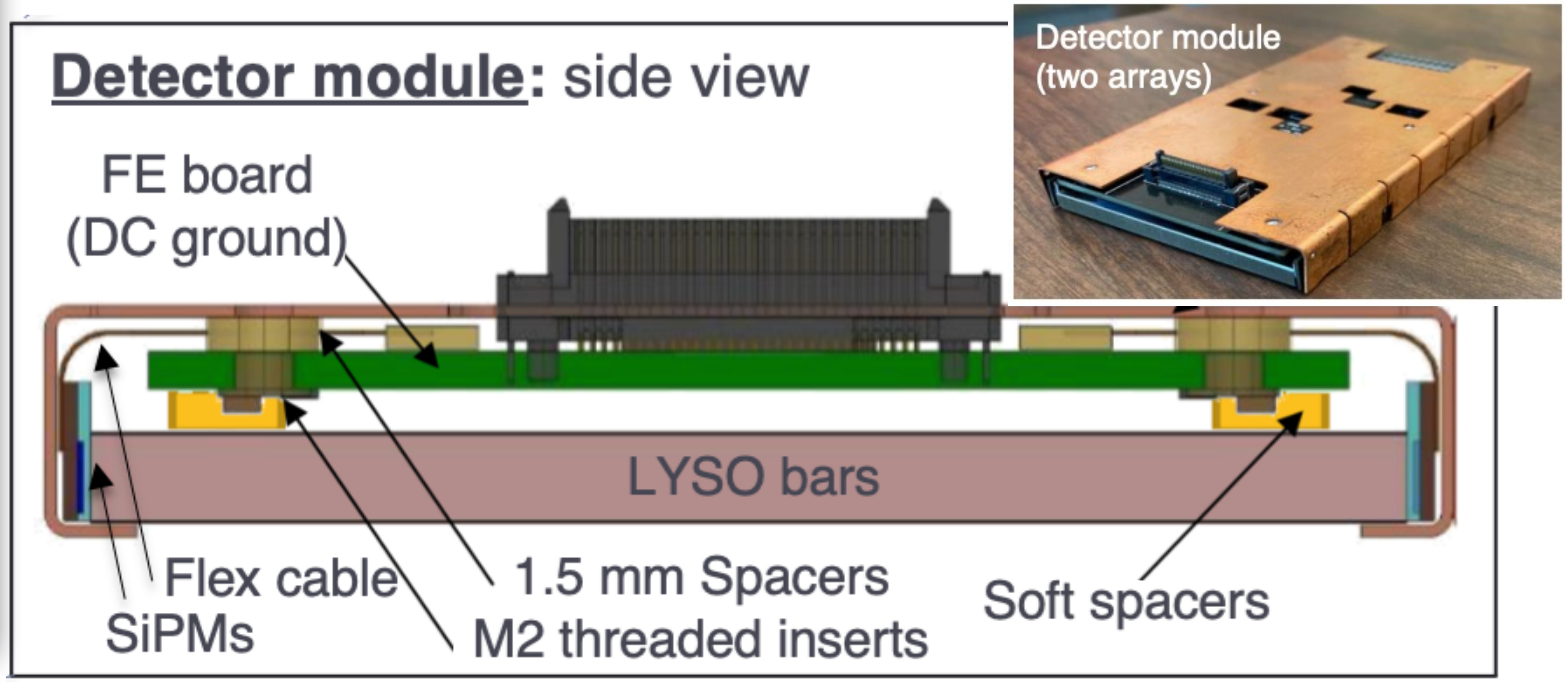
L=56.2 mm. w=3.12 mm



Sensor: SiPM

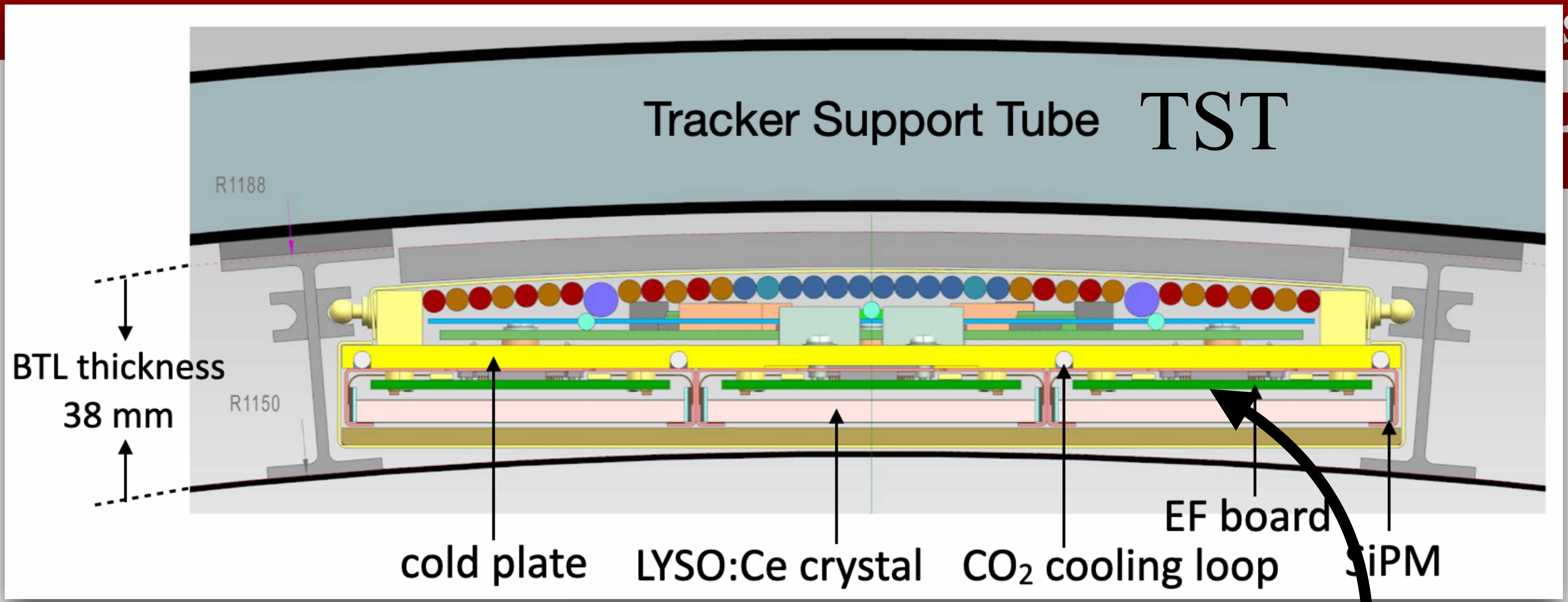


- Each sensor module contains 32 SiPM, with the effective area of ~3×3 mm^2
  - Compact in size, insensible to magnetic fields
  - Fast recover time < 10 ns, high gain ×10^5
  - PDE@LYSO emission peak 20-40%
  - Cooled by the cooling chamber of the tracker and further by TECs 3x4 mm^2 x 0.9 mm



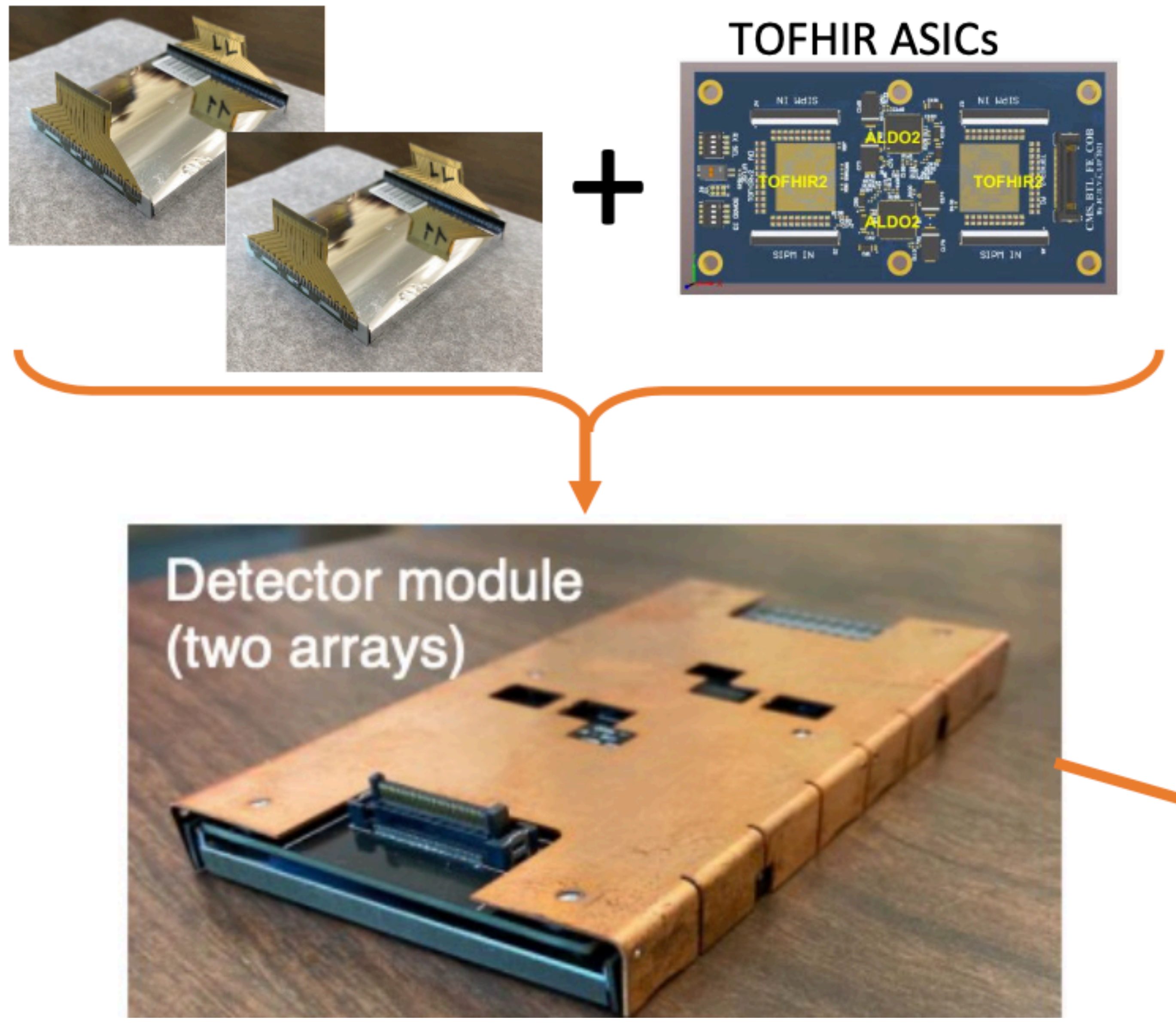
MTD BTL

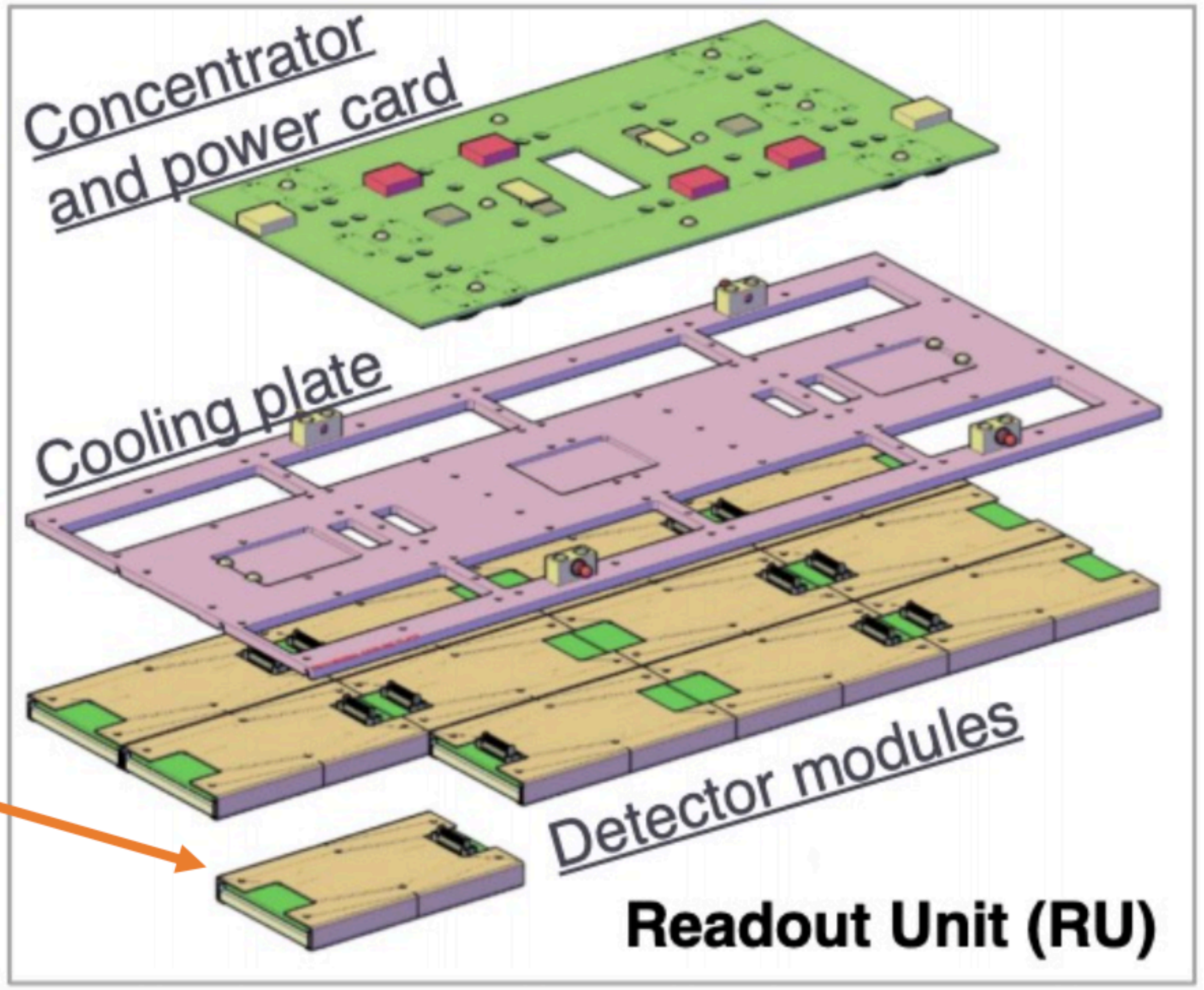
- Sensor Module: LYSO×16, SiPM×32
- Detector Module: sensor module × 2, ASIC × 2, copper housing
- Readout Unit: detector module × 12, concentrator cards, power converter cards, cooling plate
- Tray: readout unit × 6, cooling pipes



LYSO+SiPM
Sensor Modules

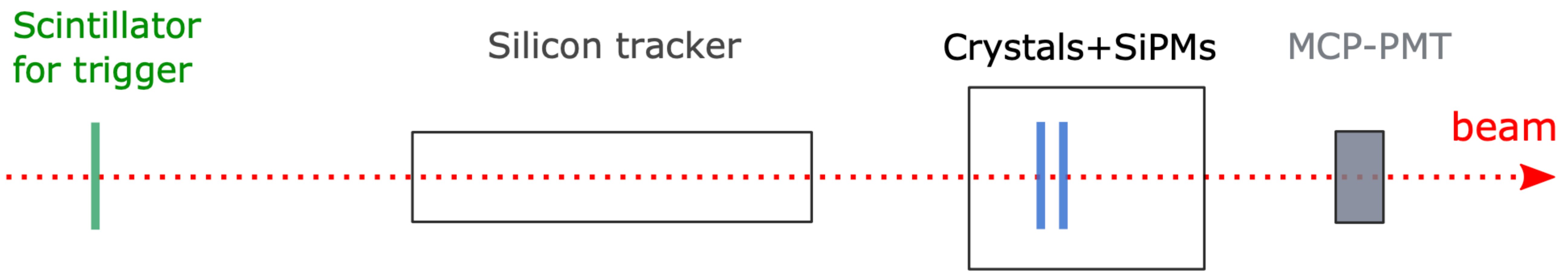
FE Boards housing
TOFHIR ASICs

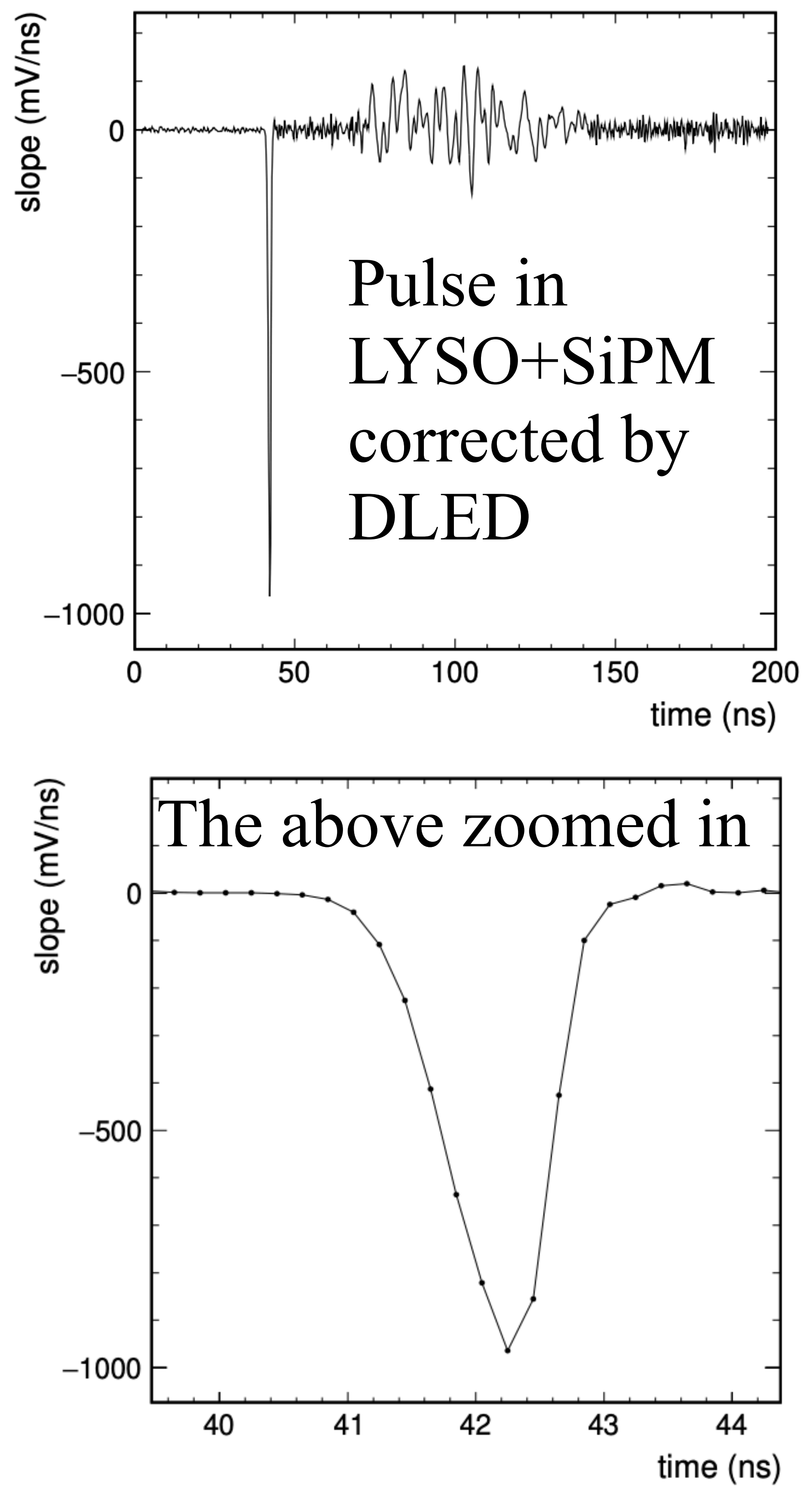


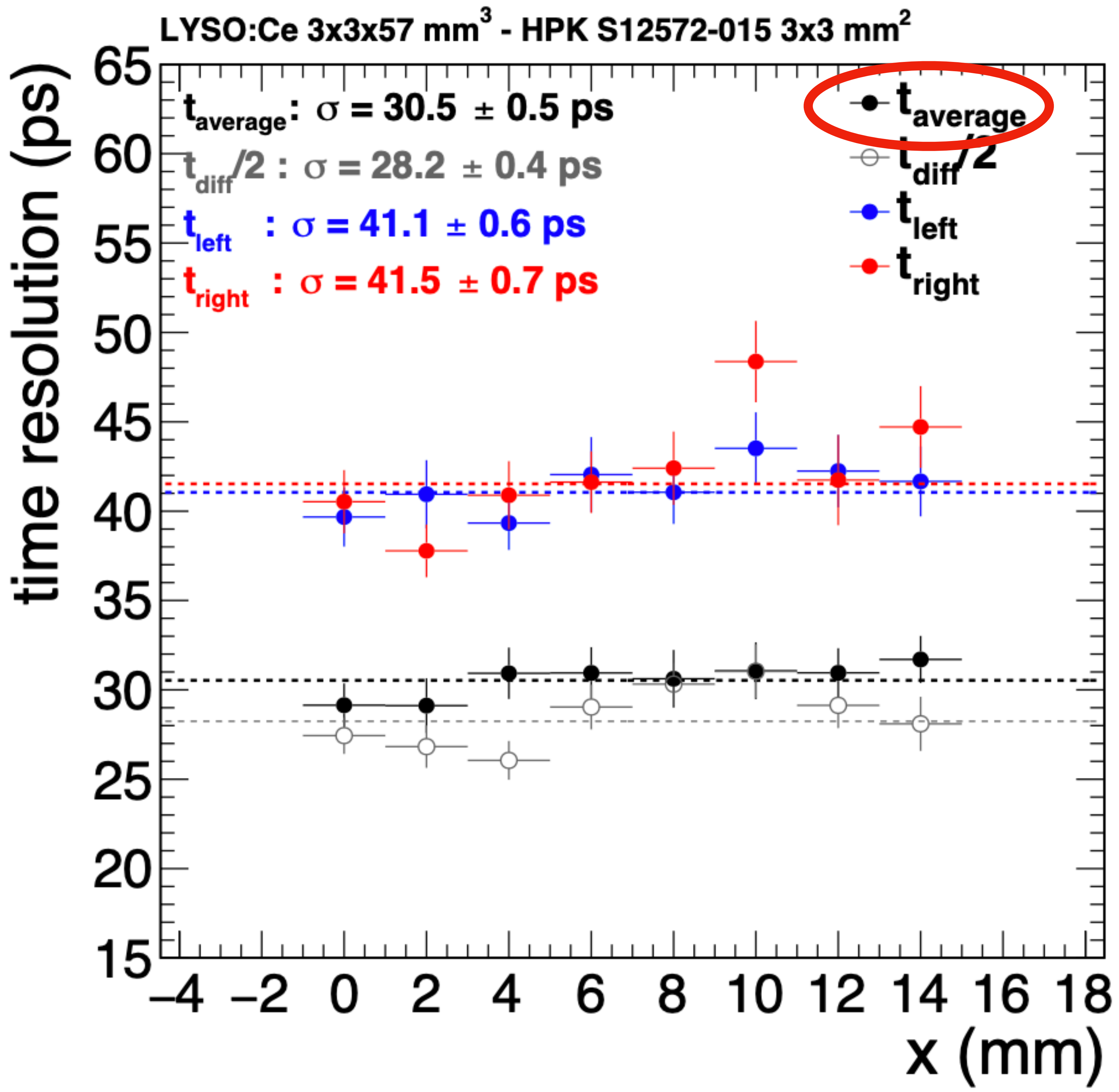


Test beam

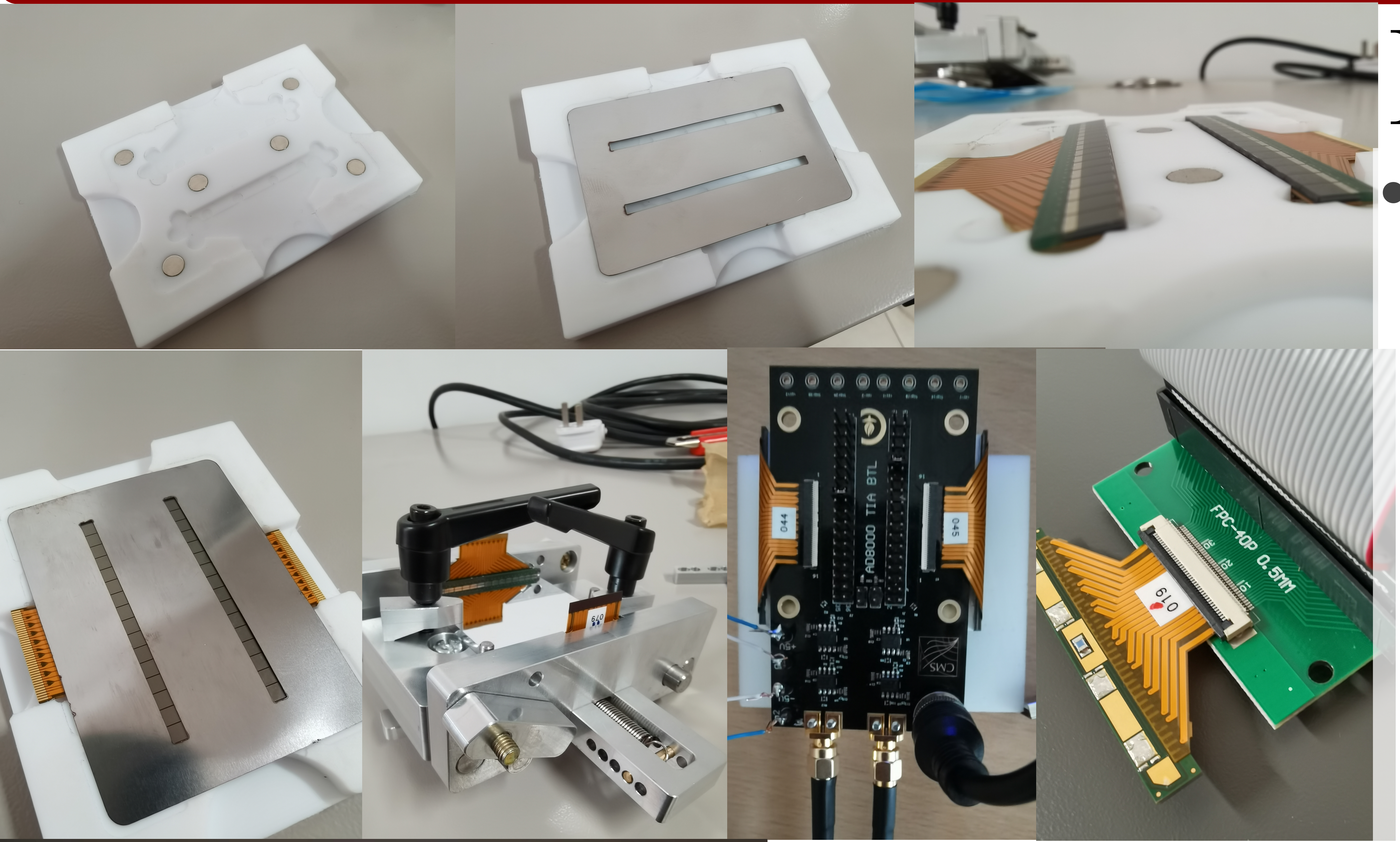
- Prototype was tested with 120 GeV proton beam @ FNAL
  - Silicon tracker to identify the position
  - MCP-PMT used as a time reference
- Pulse in LYSO+SiPM corrected by the differential leading edge discriminator (DLED) method
- A time resolution of 30 ps independent of the incoming position can be reached



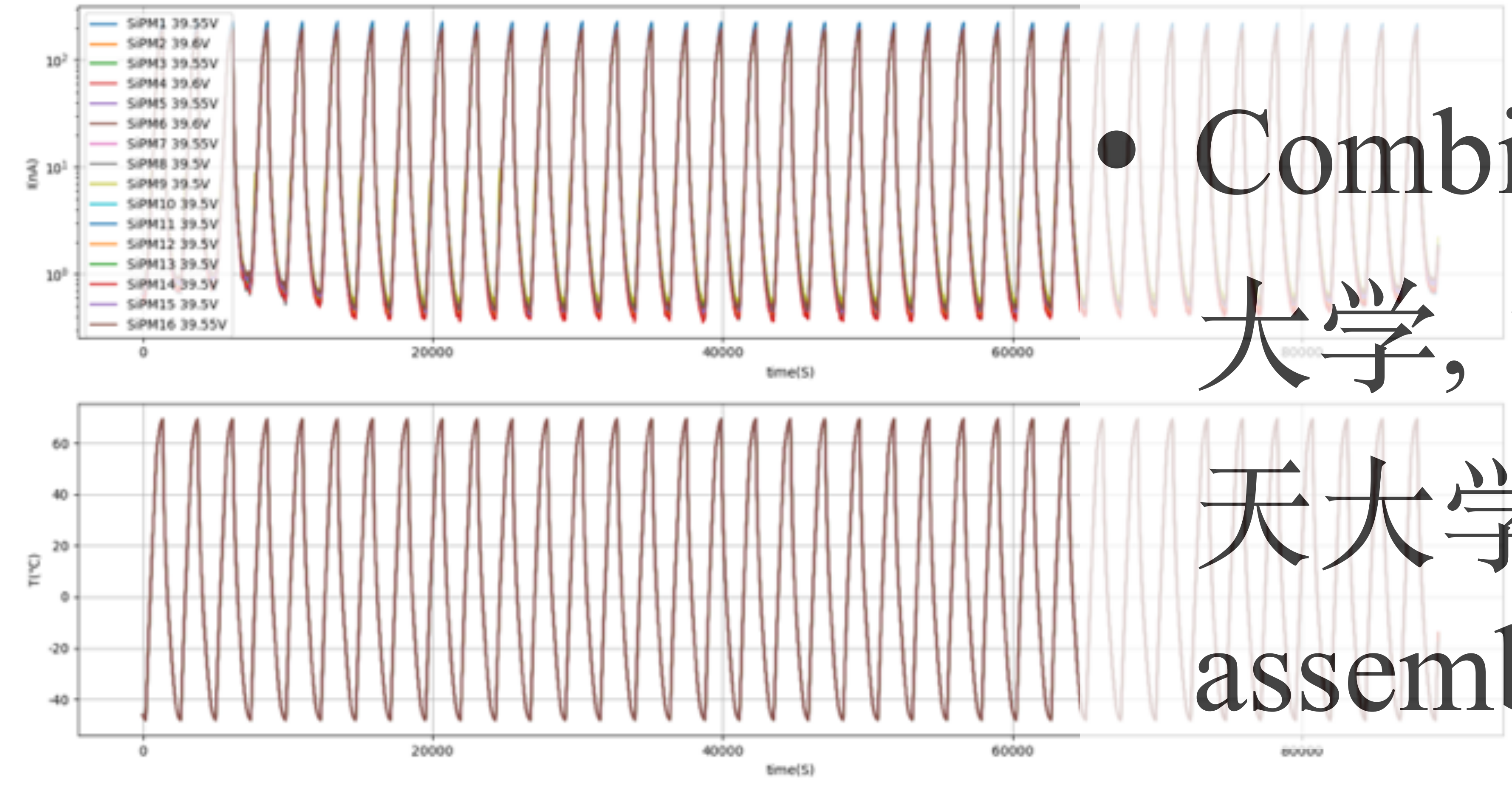




Local activities



- Many actives are ongoing locally, including
  - SiPM tests and R&D
  - The coupling between LYSO and SiPM
  - Assembly preparation
  - QA/QC design



- Combining the efforts from 北京大学, 清华大学 and 北京航空航天大学, we are building an assembly center at Beijing

Summary

- MTD is special timing detector that is designed to deal with ~200 pileup vertices and to keep the physics sensitivity of CMS during HL-LHC operations
  - First time on CMS to have a dedicated timing detector and to reach a time resolution of 30 ps, very promising
- Sensor design with LYSO+SiPM for the MTD barrel is proven to reach the expected time resolution using radiation sources and test beams
  - These two sensor materials have mature technology and can be provided by the industry
- R&D is close to the end and the assembly is going to start in middle 2023