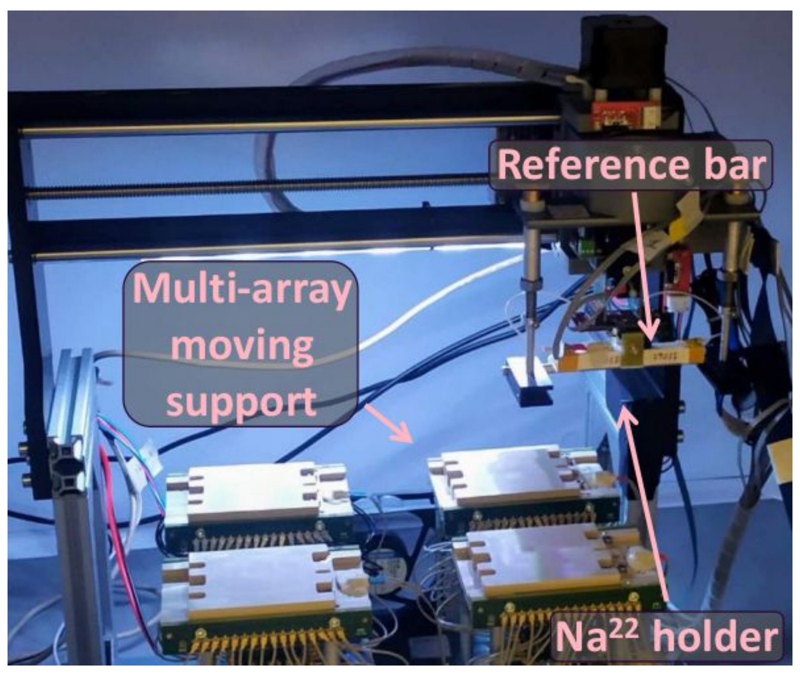
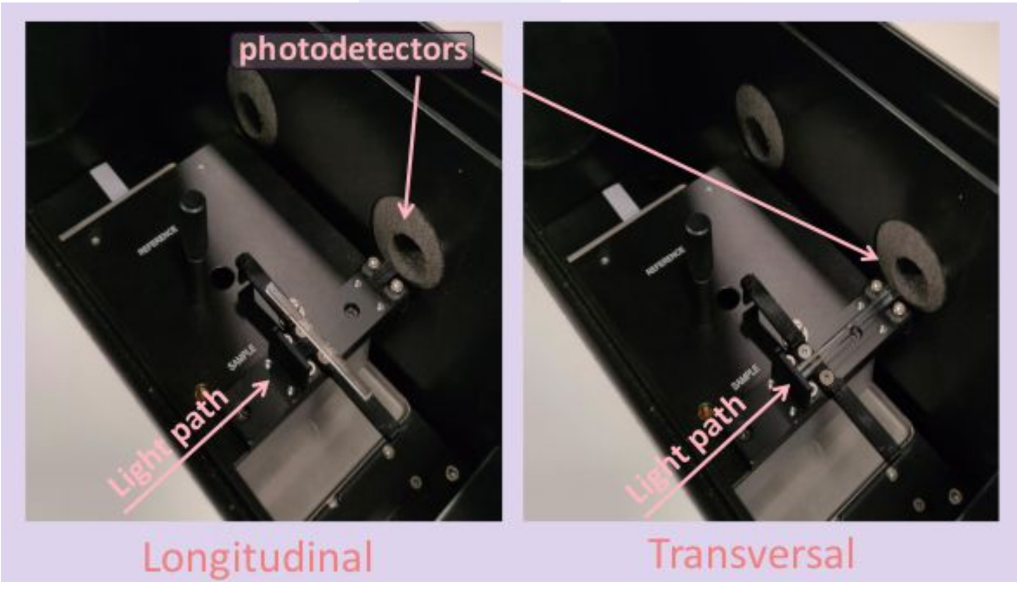
CMS Roma Group

LYSO Quality Assurance & Control

- Irradiated and non-irradiated **LYSO crystals tested** in INFN laboratory in Rome, to account for dose received during data-taking
- Study carried out on **time resolution**, **light output** (LO) & **transmittance**, **energy resolution** and **planarity** of the arrays
- Work on **test beams** to assess detector performance





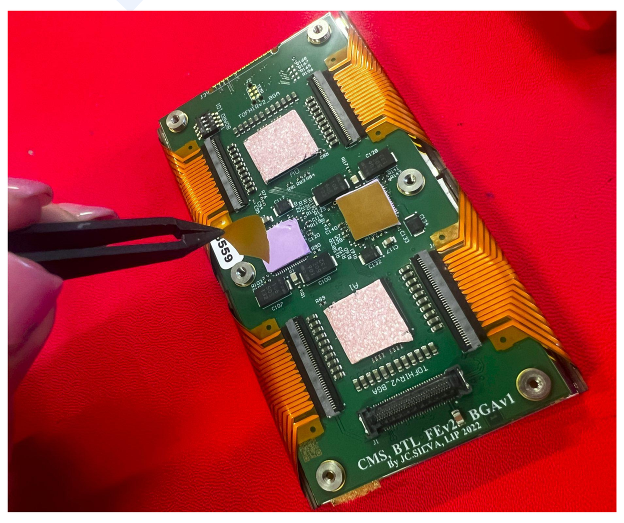
! **Very good validation rate, 99.7%** of the tested arrays **pass**. **0.01% discarded** for too large LO reduction after irradiation.

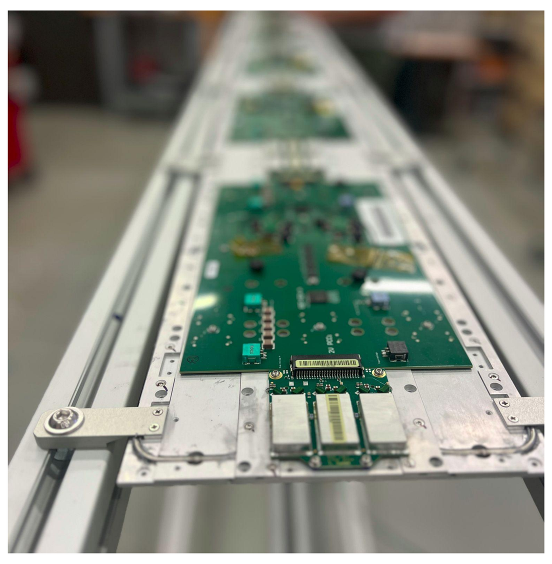
References: [1] CMS-TDR-020, "A MIP Timing Detector for the CMS Phase-2 Upgrade", [2] "Quality control of LYSO:Ce crystals for the CMS barrel MIP Timing Detector", ICHEP 2024

BTL tray assembly at CERN & Milan

- LYSO crystals are assembled in **sensor modules** (SMs, 16 crystals) and then mounted on trays composed by 144 SMs
- **Assembly is in full swing** in BTL Assembly Centers (**Milan**, Virginia, California, Peking)
- The trays will be **positioned inside the BTL-Tracker Support Tube (BTST) @ CERN** and then **integrated in CMS**

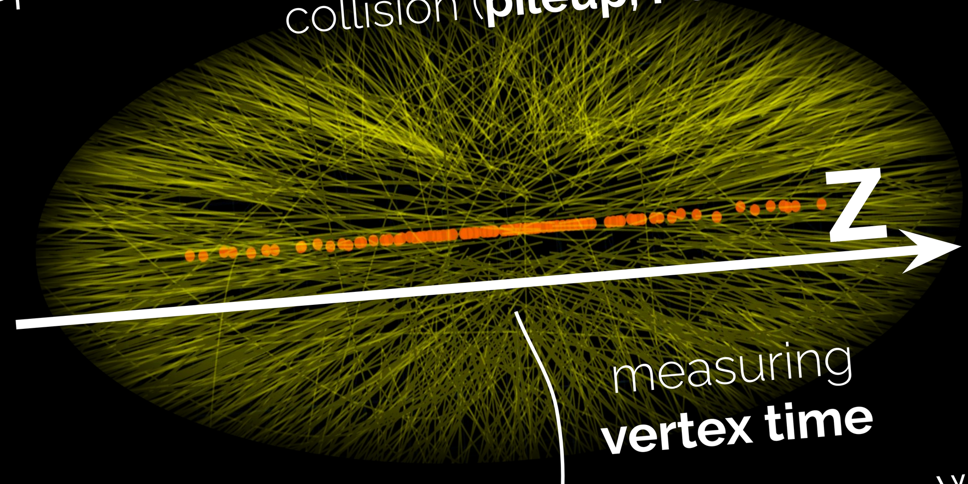
Pictures of assembly in Milan



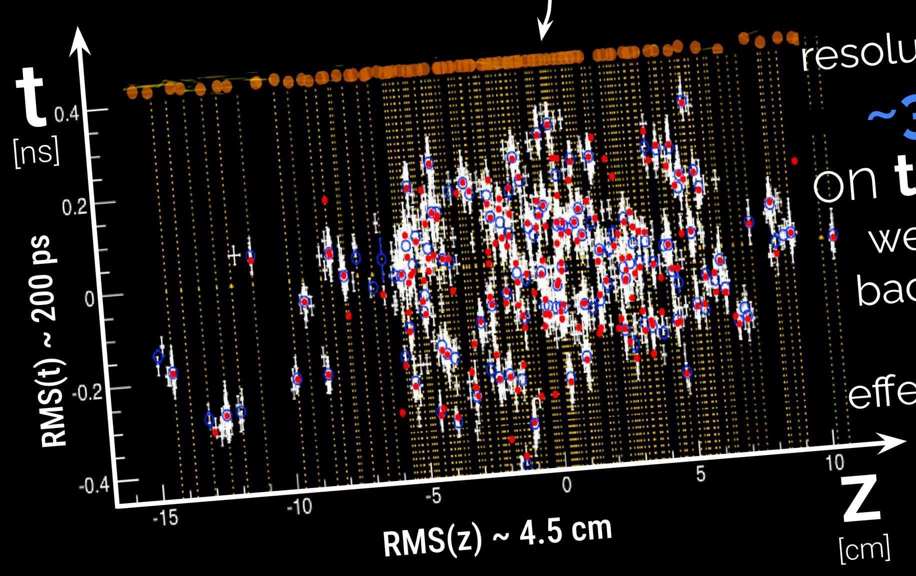


TOWARDS A PRECISE MEASUREMENT OF PARTICLES TIME WITH THE

During the High-Luminosity phase of LHC, we expect approximately **200 simultaneous interactions** per collision (**pileup, PU**)

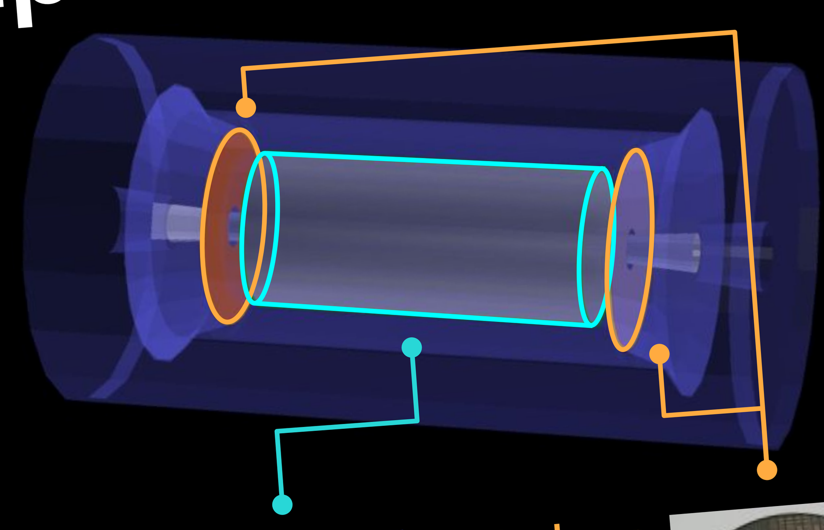


measuring **vertex time**



With a resolution of **~30 ps** on **tracks** we can go back to the current effective PU level

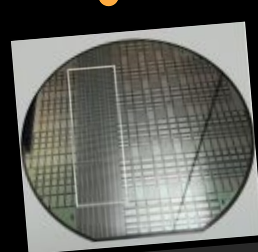
Mip Timing Detector



Barrel **T**iming **L**ayer

LYSO crystals + SiPM

Endcap **T**iming **L**ayer



Low Gain Avalanche Photodiodes

The CMS experiment will introduce the new MTD detector between the tracker and the electromagnetic calorimeter, measuring the **time of arrival of charged particles** with the required accuracy.

NEW MIP TIMING DETECTOR FOR THE CMS EXPERIMENT

Detector characterization and assembly...

Towards local & global reconstruction...

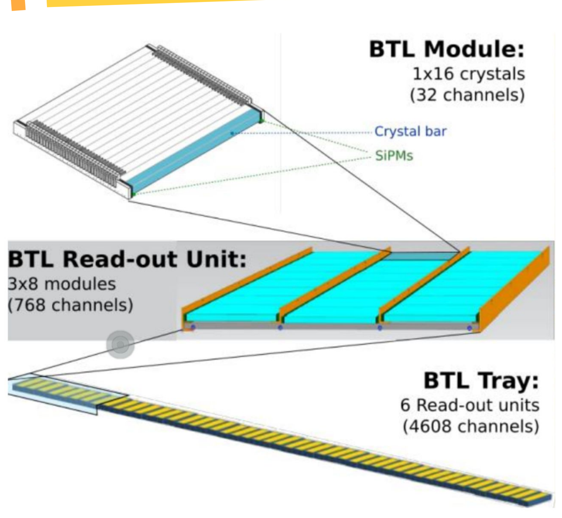
Essential to carry out physics analyses

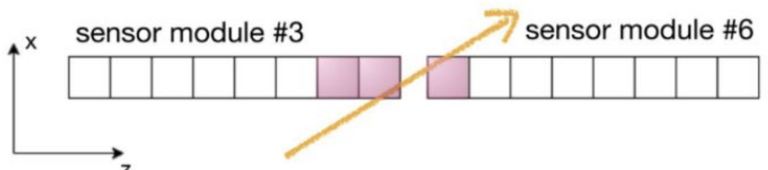
Still under development, other software efforts ongoing

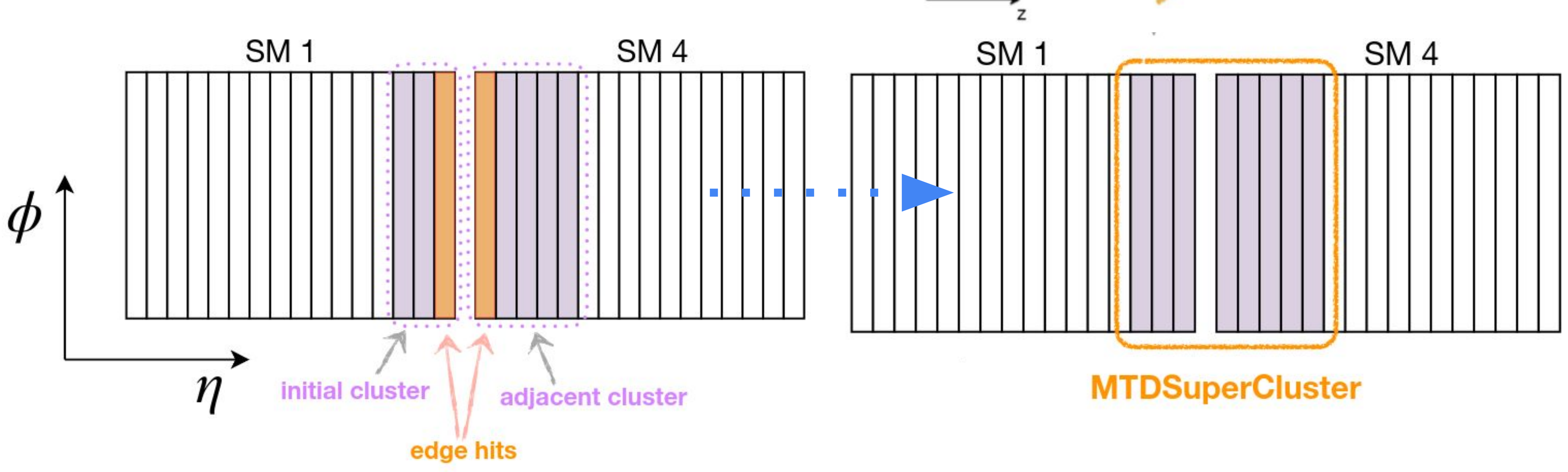
BTL clustering & reconstruction

For increased η, **signal can be shared across multiple bars** clustering required!

- Current algorithm does clustering within one 16 crystal module
  - **Need to redesign the algorithm** to allow for **cross-module clusters** → SuperClusters







In reconstruction, the track is **backpropagated** to the **beamline** by computing **time of flight** (TOF) under a **given mass hypothesis**:

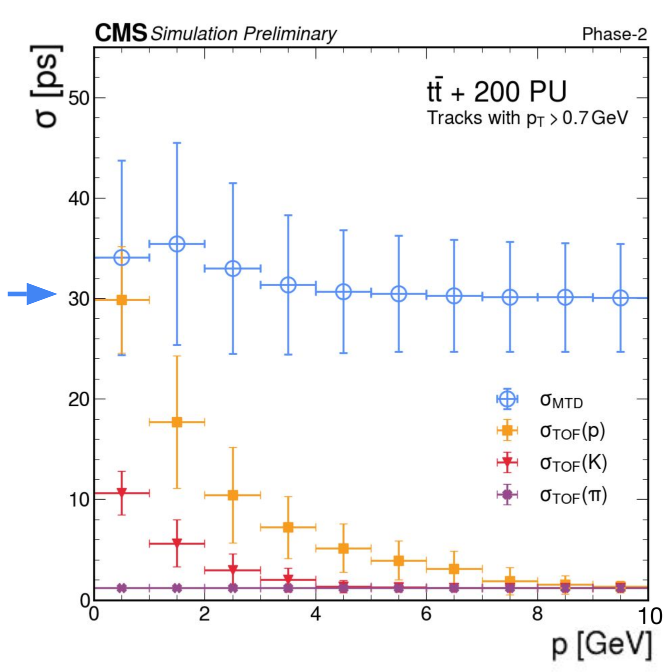
$$t_0(\pi, K, p) = t_{\mathrm{MTD}} - \mathrm{TOF}(\pi, K, p)$$

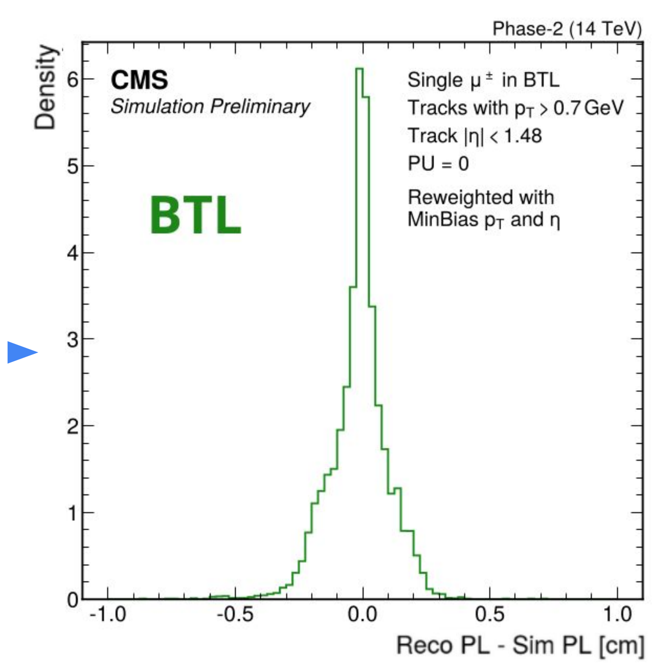
$$\mathrm{TOF}(\pi, K, p) \approx \frac{\ell}{\beta(\pi, K, p)c}$$

TOF uncertainty depends on:

- **Momentum uncertainty** propagated on velocity (depends on mass hypothesis)
- **Uncertainty on the track path length** (PL) measurement (below ~10 picoseconds)

! $\sigma_{TOF} \sim \mathcal{O}$ **(10 ps)** comparable to $\boldsymbol{\sigma(t_{MTD})}$ for **heavy**, **low momentum** particles (protons with p < 2 GeV).
PL resolution is **subdominant** when **compared to MTD time resolution**





References: [3] "Towards a precise measurement of particles time-of-flight with the new Mip Timing Detector for the CMS Experiment", ICHEP 2024, [4] CMS-DP-2024-048, "Improved use of MTD time in vertex reconstruction", [5] "Enhancing particle reconstruction with the MIP Timing Detector at CMS", EPS-HEP 2025, [6] CMS-DP-2025-037, "Track time uncertainties at the point of closest approach computed with MTD".