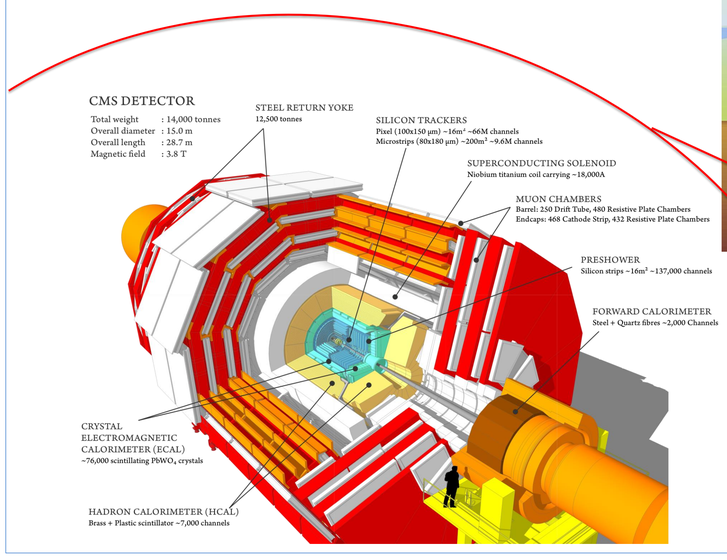
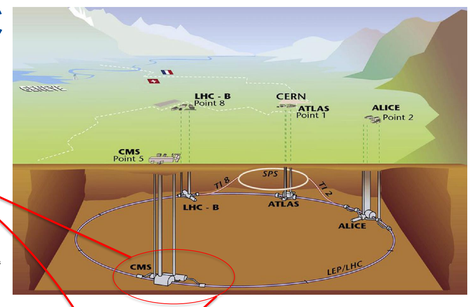
Precision timing with silicon photomultipliers

Irene Dutta, California Institute of Technology
On behalf of the CMS collaboration

The CMS Detector at the LHC





p-p collisions at a center of mass energy of 13 TeV!

High Luminosity (HL-LHC) : The new future

- Upgrade luminosity to 7.5 x10^{34} $cm^{-2}s^{-1}$ → more collisions at the same energy.
- Advantages:
  - Higgs and other precision SM measurements.
  - Beyond the standard model (BSM) searches .
- Challenges (due to increased PU):
  - Spurious track-PV association.
  - Resolution of missing transverse momentum, jet energies.
  - Acceptance of isolated objects.

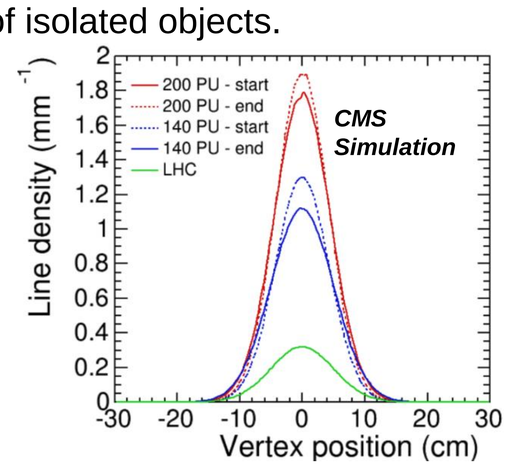


Fig 1. Line density (Number of pp collisions per unit length of beam axis) as a function of the vertex position in different luminosity eras [1].

The new MIP Timing Detector for CMS

- Time of arrival measurement - separate collisions very close in space but separated in time.
- Slice bunch crossing in exposures of 30 ps.
- PU levels drop to current LHC levels.

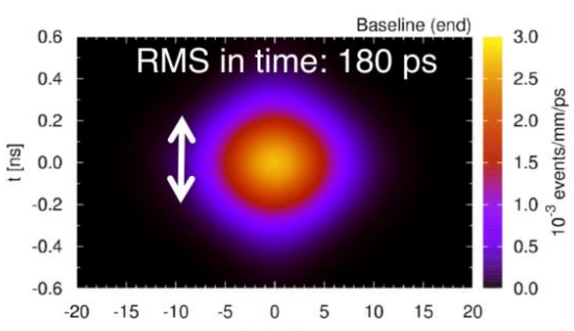


Fig. 2: Spread of the beam spot along the collision axis plotted against time.

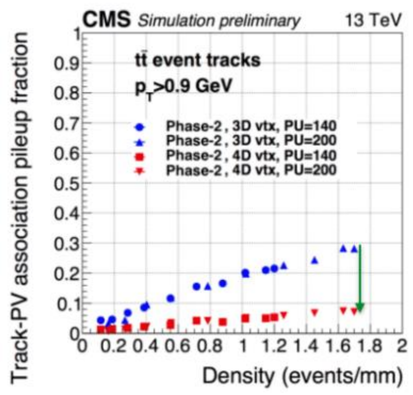


Fig. 3: Fraction of pile-up tracks that get falsely associated to the primary vertex greatly reduces with the timing information.

Physics impact of the Timing Layer

- Improvement in signal yields for several Higgs decay channels.
- Improved MET resolution almost overcomes the increased pileup effect → good for BSM searches.

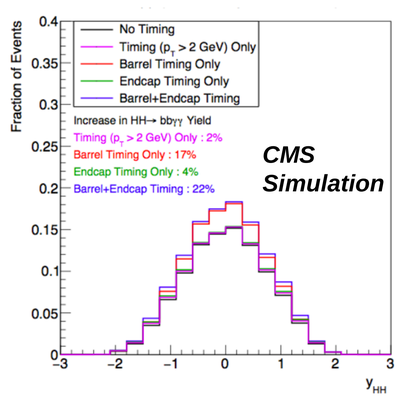


Fig. 4: Increase in the signal yields of HH→bb$\gamma\gamma$ with the MTD.

Design of the MTD

	Barrel	Endcap (LGAD)
Technology	Silicon Photomultiplers (SiPM) with LYSO crystal	Ultra Fast Silicon Detectors with low gain (LGAD)
Region	|η|<1.5	1.6 <|η|< 3.0
Surface Area	36.5 m^2	12 m^2
Radiation Dose	2x10^{14} n_{eq}/cm^2	2x10^{15} n_{eq}/cm^2

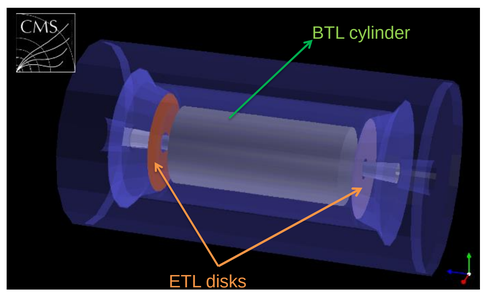


Fig 5. Schematic of the MTD. The timing layer will be placed in between the tracker and the ECAL [1].

BTL Technology

- Low operating voltages, immune to magnetic fields and radiation tolerant.
- Proven to achieve timing resolution of ~30 ps.
- Readout ASIC: Time-of-Flight High input rate (TOFHIR).

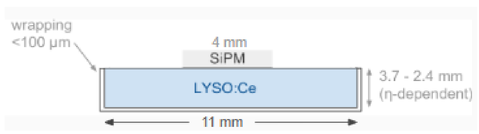


Fig. 6: Schematic of the SiPM + LYSO module

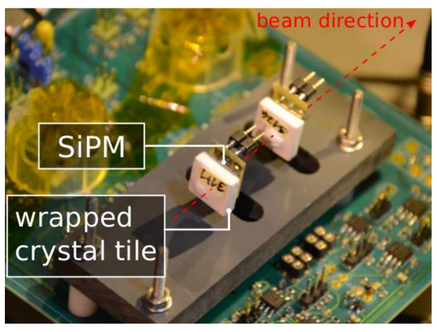


Fig. 7: Setup of the BTL module in a test beam [1]

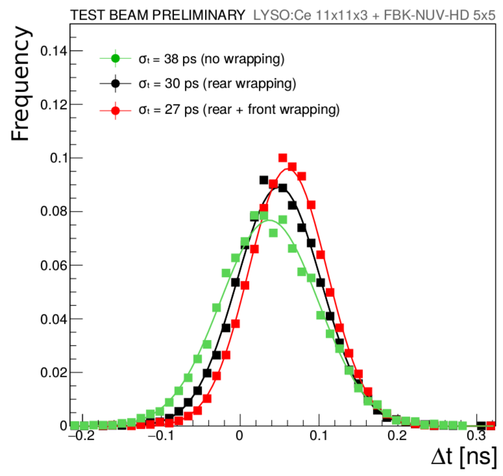


Fig. 8: Effect of the wrapping on time resolution [1].

Summary

- CMS MTD is important for an expanded physics reach : we expect 20-25% effective luminosity increase in crucial precision Higgs measurements.
- Our project is significantly advanced – the sensor performance is close to specification.
- We are heavily involved in efforts to ensure 30 ps time resolution for sensors throughout the HL-LHC run.

References

[1] CERN-LHCC-2017-027/LHCC-P-009