High-precision timing detectors for HL-LHC

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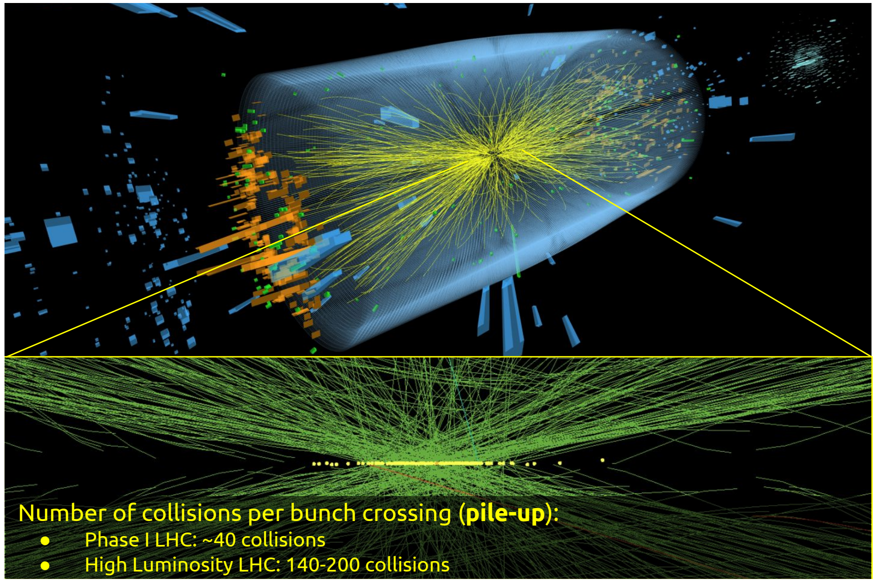
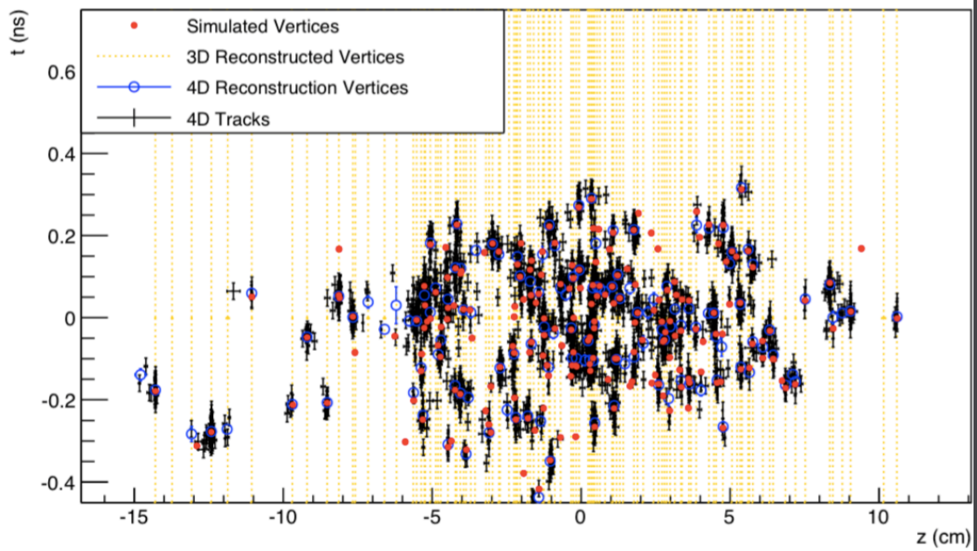
High-luminosity HL-LHC challenge



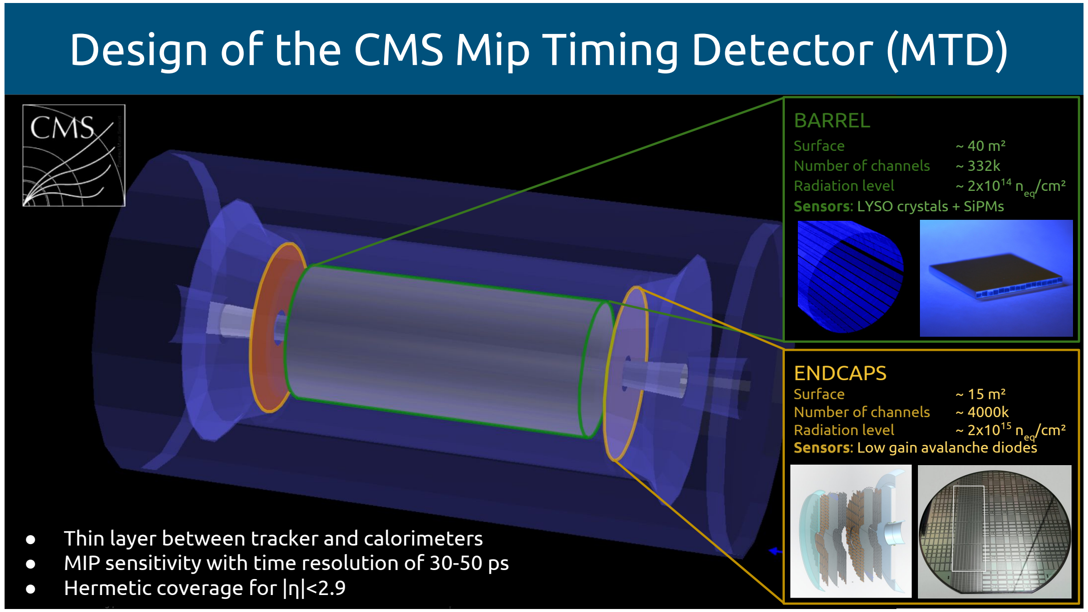
- HL-LHC targeted luminosity for CMS in phase-2 upgrade is (5-7.5)x10^{34} Hz/cm^2 (140-200 pileup events)
- This can degrade the identification and the reconstruction of the interaction

High-luminosity HL-LHC challenge

- Exploit the time spread of collision vertices to provide extra separation power against pileup collisions
- Time resolution of 30-50 ps for charge particles throughout the HL-LHC can be achieved with thin, large area and cost-effective detectors



BTL – Barrel Timing Layer



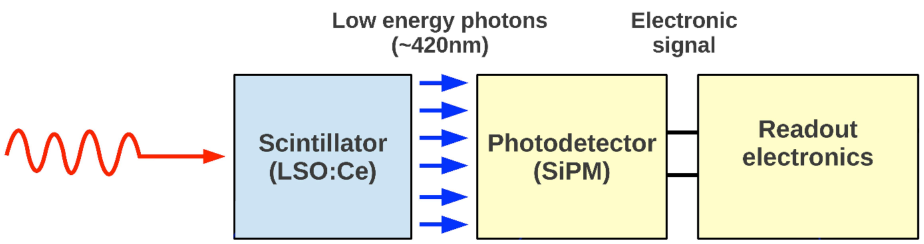
Sensors:

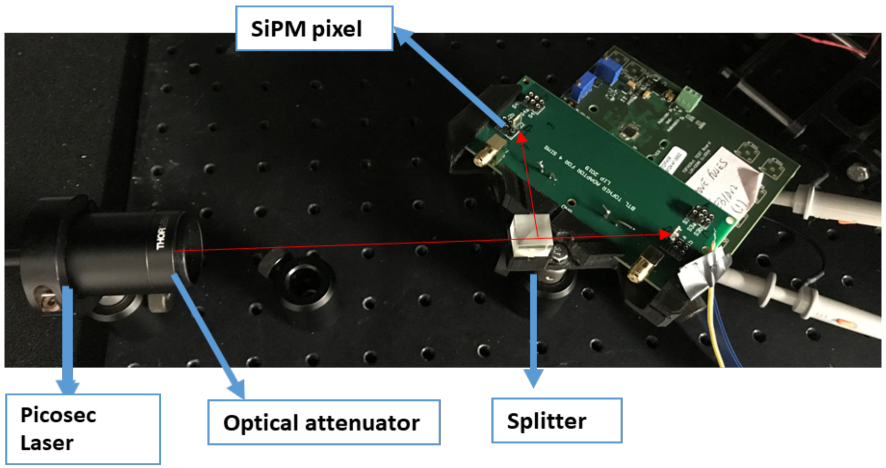
- LYSO:Ce scintillator crystal bars (~3x3x57 mm^2)
- SiPM readout (double ended readout)
- 332k channels

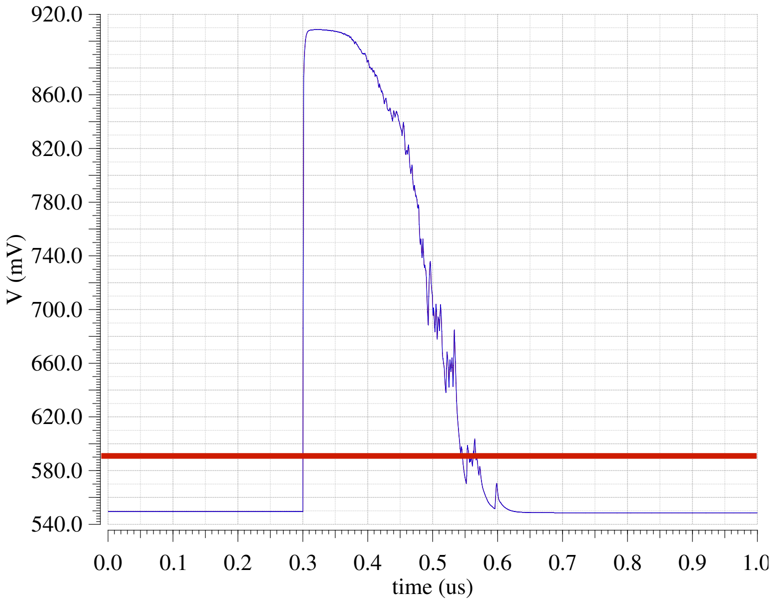
Readout electronics:

- TOFHiR ASIC
  - analog processing and digitization of SiPM signals

High-precision timing detectors







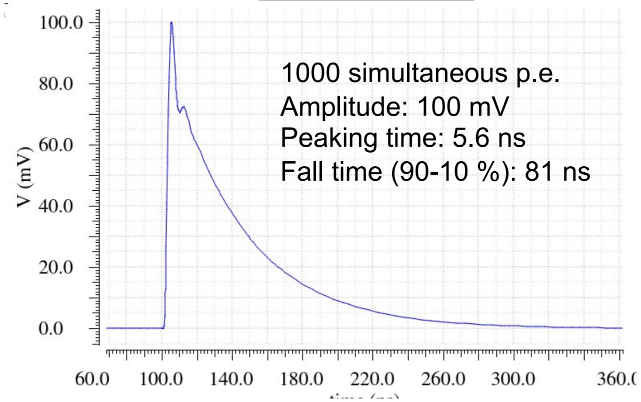
Pulse Height Comparison

nPe	Simulated Pulse Height (mV)	Measured Pulse Height (mV)	Optical Atenuators
100	9.68	8.75	NE20A+0.9
200	20.14	20.00	NE20A+0.6
300	28.79	31.25	NE20A+0.3+0.15
400	37.99	35.25	NE20A+0.4
500	48.18	45.25	NE20A+0.3
600	57.12	52.5	ND1+0.9+0.6+0.15
700	66.15	69.5	ND1+0.9+0.4+0.15
800	75.75	76.5	ND1+0.6+0.4+0.3+0.15
900	85.00	83.25	ND1+0.9+0.6
1000	95.05	102.5	NE20A

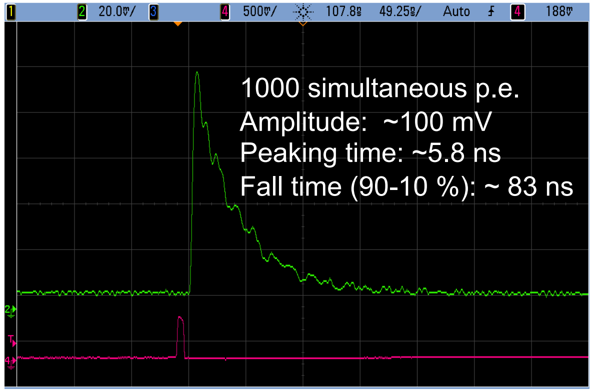
SiPM Direct Output: Simulation vs Measurement

- Comparing pulse shapes in simulation and measurement at the direct output of SiPM to estimate the number of photo-electrons
- Temperature is set to 18 °C
- Laser pulse width 50ps
- Scan a range of number of p.e. (200-1000 with)

Simulation

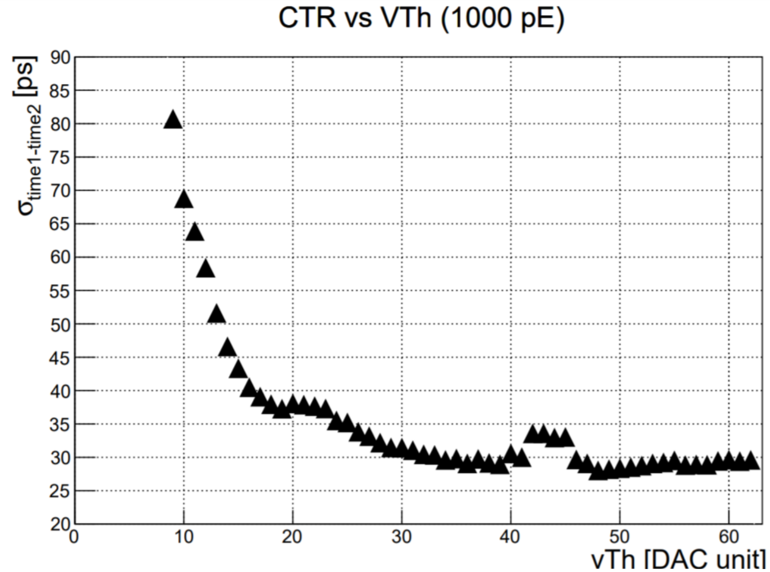


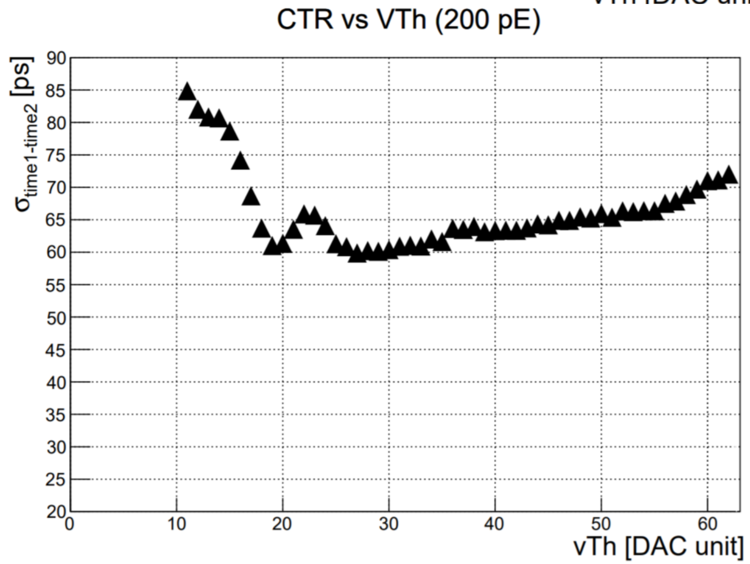
Measurement



Threshold Scan

- SiPM type: HDR2
  - OV: 4.99 V
- Laser shine at both SiPMs
  - Operation modes:
  - 2 SiPMs are connected to 1 TOFHiR test board
  - Trigger the laser through FPGA at (100kHz)
  - Temp : 18^{o}C
- LYSO/SiPM pulse is ~10k p.e.
  - Best threshold for timing 5-10 p.e.
  - 1 p.e. ~(10mV)

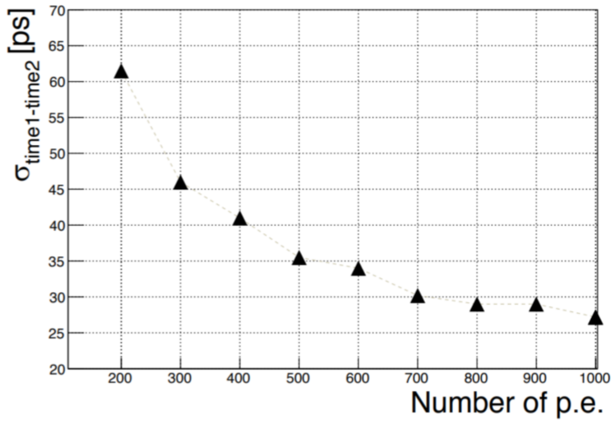




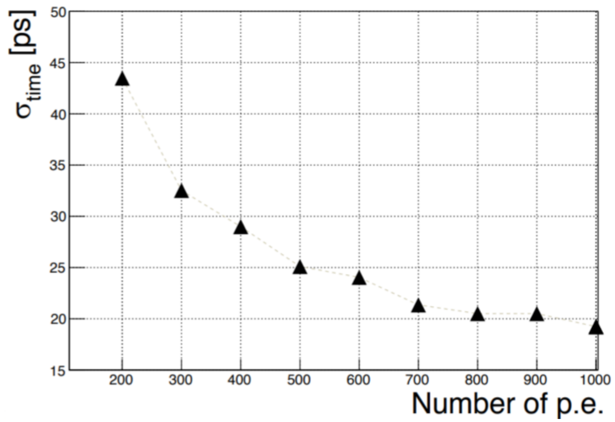
Number of photo-electron scan

- SiPM type:
  - HDR2
  - OV: 4.99 V
- Laser shine at both SiPMs
- Operation modes:
  - 2 SiPMs are connected to 1 TOFHiR test board
  - Trigger the laser through FPGA at (100kHz)
  - Temp : 18°C
- $\sigma^2_{time1-time2} = \sigma^2_{time1} + \sigma^2_{time2}$

Coincidence time resolution vs Number of photo-electron



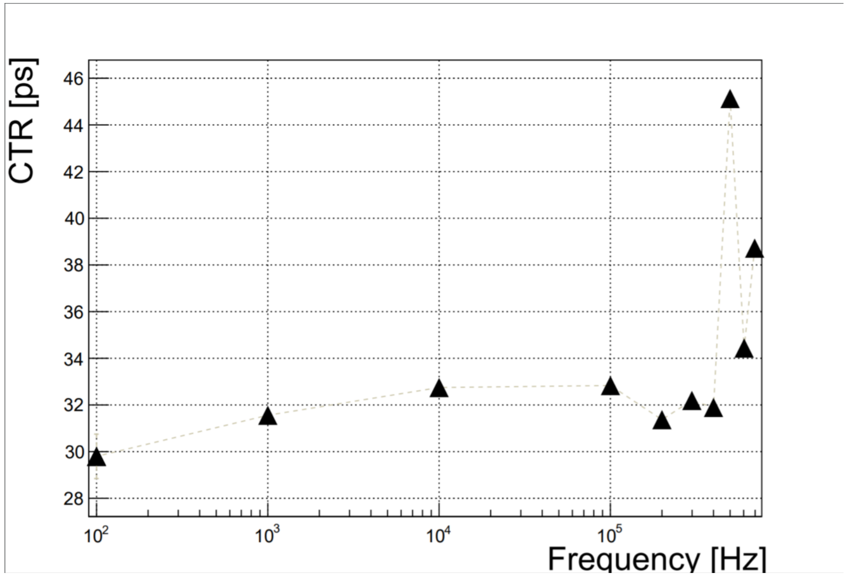
Time resolution per channel vs Number of photo-electron



Frequency Scan

- SiPM type
  - HDR2
  - OV: 4.99 V, corresponds to the gain of 5e5
- Laser shine at both SiPMs:
  - ~1000 p.e. per pulse on average
- Operation modes:
  - 2 SiPMs are connected to 1 TOFHiR test board
  - Temp : 18ºC
- Threshold in DAC unit set to 63 (139 mV over the baseline)

CTR vs frequency
100Hz-700 kHz



Summary and Conclusions

- Estimation of number of p.e. with laser pulses and attenuators based on simulation results
- Time resolution of laser pulse with BTL SiPMs has been measured at low thresholds
  - laser pulse 1 k p.e. (~10k p.e. LYSO pulse): 19 ps
  - laser pulse 200 p.e. (~2k p.e. LYSO pulse): 43 ps
- Time resolution is stable with frequency (up to 700 KHz)

Questions?