The CMS ECAL is:

- a homogeneous calorimeter made of 75,848 PbWO₄ scintillating crystals
- compact, hermetic, fine-grained and with excellent energy resolution

**ECAL Barrel (EB):**

- divided into 36 super-modules of 1700 crystals
- scintillation light read out by avalanche photodiodes (APDs)

**Current EB On-Detector Electronics:**

- Trigger Tower
- Very-Front-End (VFE)
- Front-End (FE)
- Readout

**ECAL Endcaps (EE):**

- 7,324 crystals for each of the 2 endcaps

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**Towards High-Luminosity LHC...**

**HL-LHC main feature & drawbacks:**

- higher instantaneous and integrated luminosity
- much higher level of overlapping events: the Pile-Up (PU) will increase from ~40 to ~140
- radiation levels will be 6 times higher than for LHC

**EB will be upgraded to:**

- allow higher trigger rates
- mitigate PU from previous and following bunch crossing
- mitigate signal contamination from concurrent interactions in the same bunch crossing (through timing)
- mitigate the noise effect from APD leakage current, increased by long exposure to radiation
- identify the vertex of origin of the photons

**EE will be replaced by a different detector**

**New VFE boards with fast trans-impedance amplifier and 160 MHz ADC sampling, characterized by 2 gains per channel (i.e. two ADCs)**

**New streaming Front End (FE) card**

**New low voltage regulator**

**Off-detector transmission for all samples and off-detector trigger formation**

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**Electron beam** from CERN H4 test line:

- 20, 50, 100, 150, 200 GeV

**Reference time** defined by a Multi-Channel-Plate Detector (MCP), used to measure the electron time of arrival. Time resolution: 25 ps

**EB prototype setup:** 6x5 matrix of PbWO₄ crystals + APD

**Test Beam Setup (Summer 2016):**

- Top of the crystals
- Bottom of the crystals with 0.6 mm PMMA
- UV LED
- Test pulse
- Test signal

The time of arrival of the electrons is measured at the test beam using a **template fit.** The known signal shape is used as a template that is superimposed to the acquired signal and shifted in time until the best fit is obtained. Timing resolution is obtained by studying the distribution of the estimated arrival times using the time measured by the MCP as a reference. At each available energy ~10⁴ events are collected. Various possibilities for the **sampling frequency** are explored: 5 GHz, the maximum frequency of the digitizer used in the test setup, 160 MHz and 80 MHz. At 80 MHz, two choices of phase are investigated: top and edge sampling. At 80 MHz, a good timing resolution is reached only for edge sampling: lowering the sampling frequency requires a precise knowledge of the signal phase. Experimental data are fitted with the function:

\[ N = a \frac{1}{\sqrt{\sigma}} + b \]

where \( N \) and \( C \) represent the free parameters. It is evident that, for high signal amplitudes, the **timing resolution** is well below 30 ps.