The CMS Electromagnetic CALorimeter (ECAL)
Compact, homogeneous and hermetic high-granularity crystal e.m. calorimeter based on scintillating crystals:
- 61.2k (Barrel) + ~14.6k (Endcaps) PbWO4 crystals
- $t_{\text{typ}} = 25$ ns, $X_0 = 8.9$ mm, $r_{M} = 2.19$ cm

ECAL Barrel
- APD sensors readout
- 36 supermodules, 1700 crystals each
- 2448 readout units, made of 5x5 crystals
- 5 VFE cards/unit, 5 channels/VFE
- Multi Gain PreAmplifier (MPGA) x1, x6, x12 gain, CSA + 40ns RC-CR shaper
- 12-bit, 40 MS/s ADC, dynamic range 40 MeV – 1.5 TeV

Redesign of VFE, FE and off-detector electronics to cope with new CMS trigger and DAQ requirements:
- L1 trigger latency: 4.5μs $\rightarrow$ 12.5μs
- L1 trigger rate: 100kHz $\rightarrow$ 750kHz
- Trigger granularity: 5x5 crystals $\rightarrow$ one crystal

CATIA: Calorimeter Trans-Impedance Amplifier
Single sensor readout system chip based on Trans-Impedance Amplifier (TIA)
- Designed by CEA Saclay, 130 nm CMOS technology
- RCG input stage $\rightarrow$ very low $Z_{in}$ and 35 MHz bandwidth
- Dual gain: 10x and 1x $\rightarrow$ 50 MeV – 2 TeV dynamic range
- Test pulse injection for gain and linearity calibration
- Output differential buffers with pedestal control

LITE-DTU: Lisboa and Torino ECAL Data Transmission Unit
2x 12-bit, 160 MS/s ADCs
- IP block from commercial company
- time-interleaved 80 MHz SAR ADCs
- ENOB: 10.2 @ 50 MHz
- Lossless data compression
  - 6 bits for signals < 2.4 GeV
  - bw occupation: 2.08 Gb/s $\rightarrow$ 1.08 Gb/s
  - latency < 350 ns
- PLL block from lpGBT to generate 1.28 GHz clock
- 65 nm CMOS technology
- TID tolerance up to 20 kGy
- SEU-protected logic

Conclusions and Outlook
The challenging conditions of HL-LHC require a complete re-design of the CMS ECAL Barrel electronics
- Faster FE electronics (~4x bandwidth, 4x sampling rate) $\rightarrow$ “spikes” suppression
- L1 trigger hardware moved off-detector for maximum flexibility $\rightarrow$ single crystal granularity
- Very good performance already from ASICs prototype versions
- Full installation during LHC Long Shutdown 3 (2024-2026)