The CMS HGCAL: Possible use of DESY testbeams

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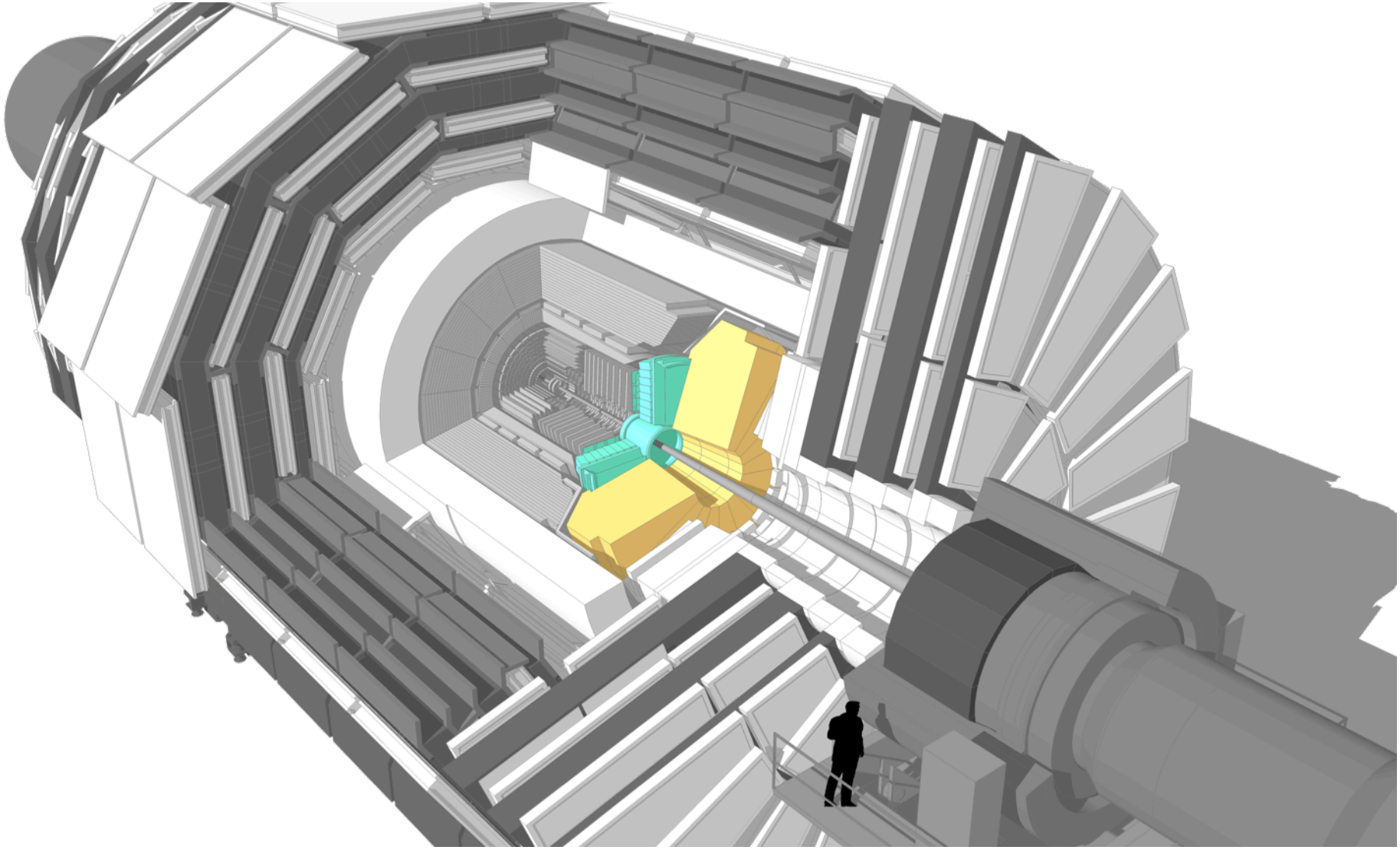
On behalf of the CMS Collaboration

All CMS Endcap Calorimetry will be replaced for HL-LHC, ~2024/25



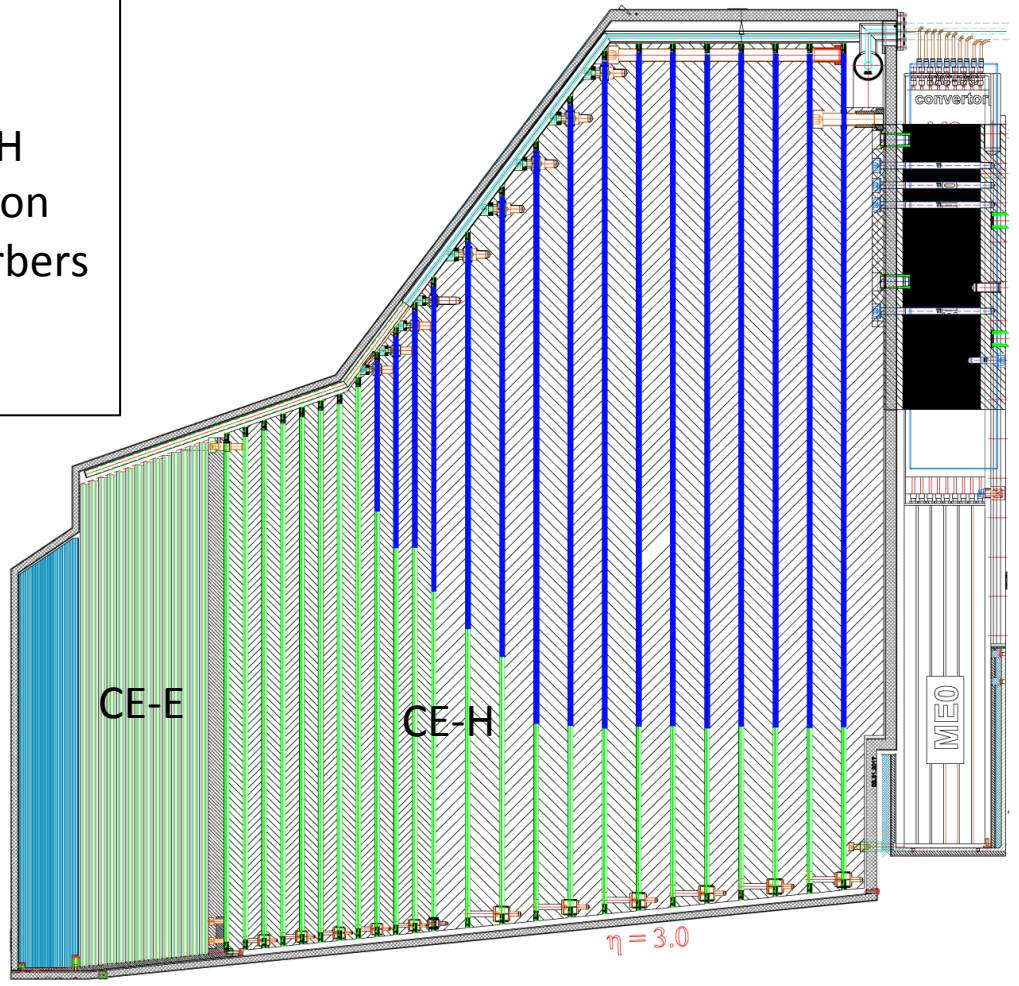
High Granularity Calorimeter (HGCAL)

Active Elements:

- Hexagonal modules based on Si sensors in CE-E and high-radiation regions of CE-H
- "Cassettes": multiple modules mounted on cooling plates with electronics and absorbers
- Scintillating tiles with SiPM readout in low-radiation regions of CE-H

Key Parameters:

- EC covers $1.5 < \eta < 3.0$
- Full system maintained at -30°C
- ~600m^2 of silicon sensors
- ~500m^2 of scintillators
- 6M si channels, 0.5 or 1 cm^2 cell size
- **~22000 si modules**
- Power at end of HL-LHC: ~60 kW per endcap

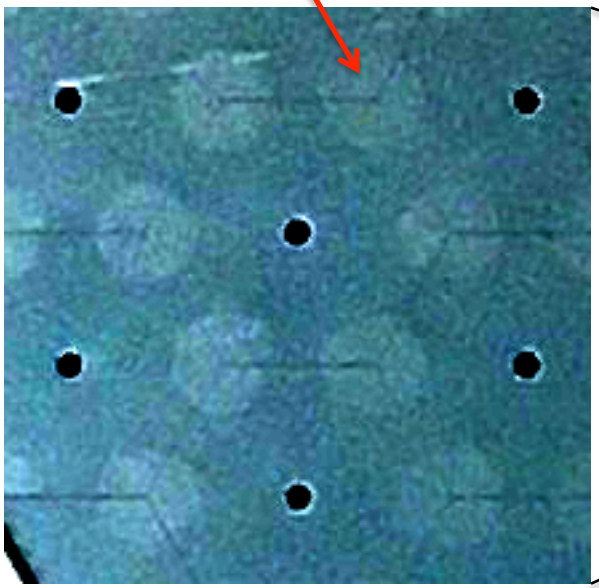


Electromagnetic calorimeter (C**E-E**): **Si**, Cu & CuW & Pb absorbers, 28 layers, 25 X_0 & ~1.3λ
Hadronic calorimeter (**CE-H**): **Si** & **scintillator**, steel absorbers, 24 layers, ~8.5λ

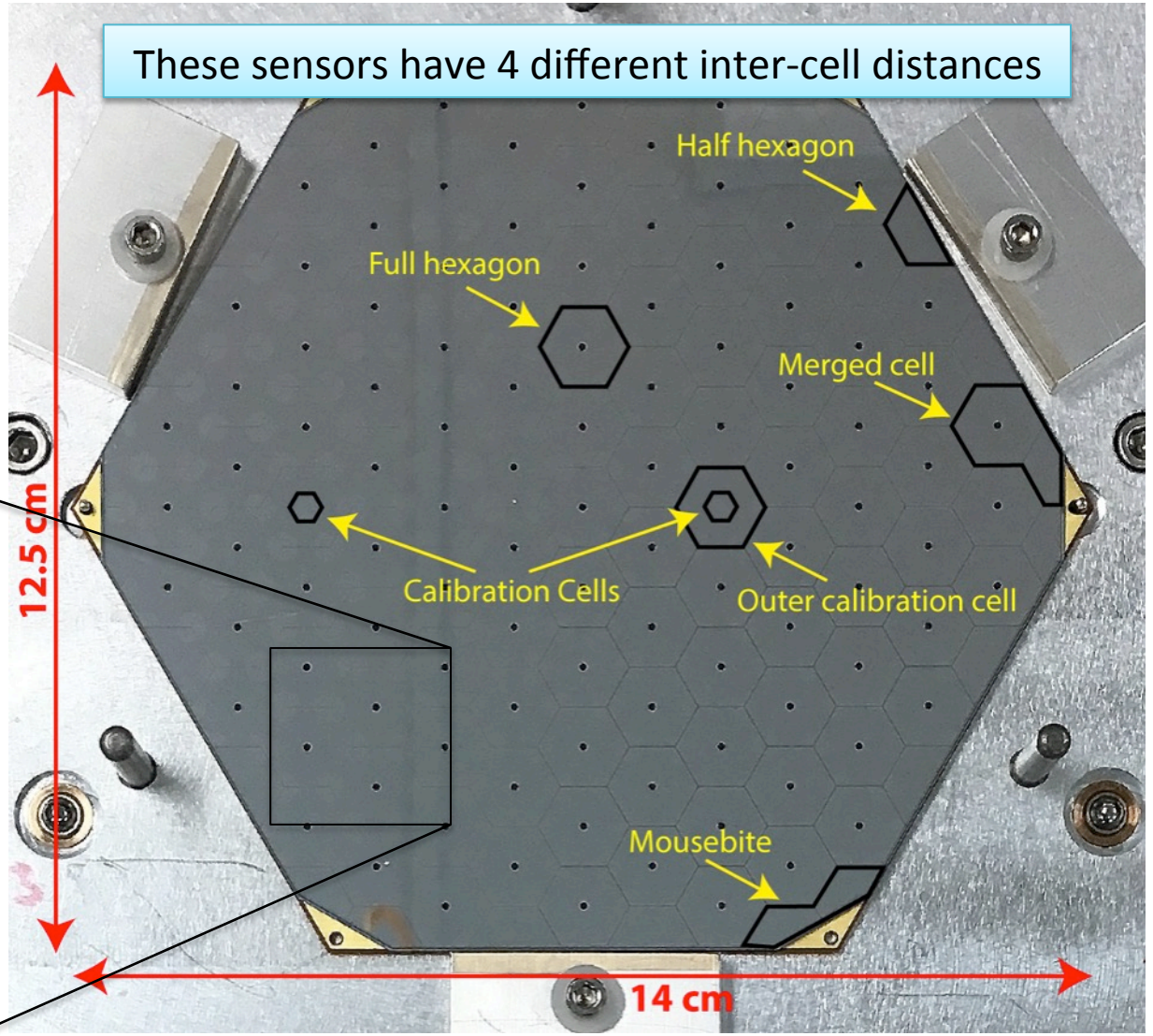
HGCAL Silicon Sensor Prototypes

2016 prototypes: Hexagonal sensor from 6” wafers, with 128 or 256 (mostly) hexagonal cells
Final baseline: 8” sensors

Bonding pads at each corner of each hexagon

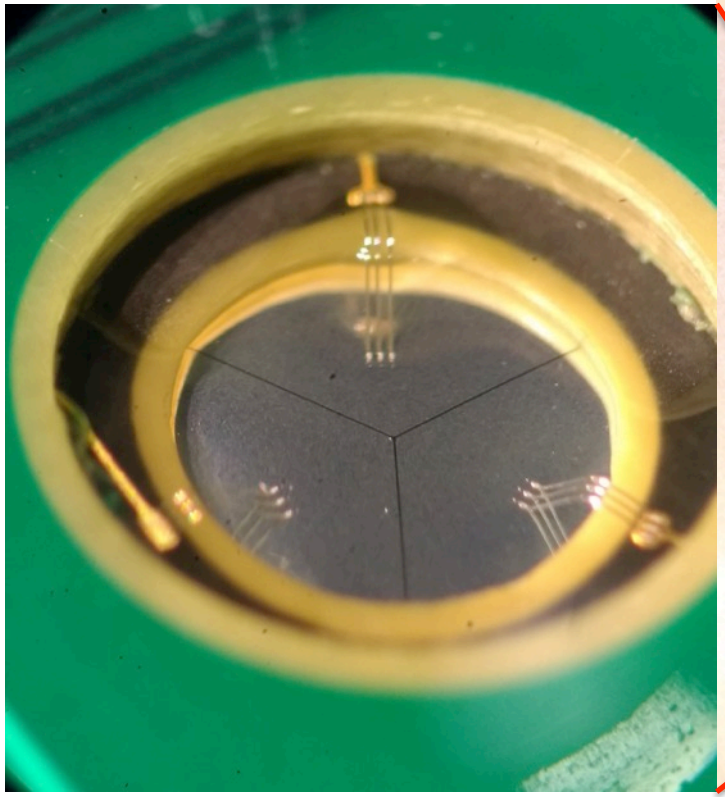


These sensors have 4 different inter-cell distances

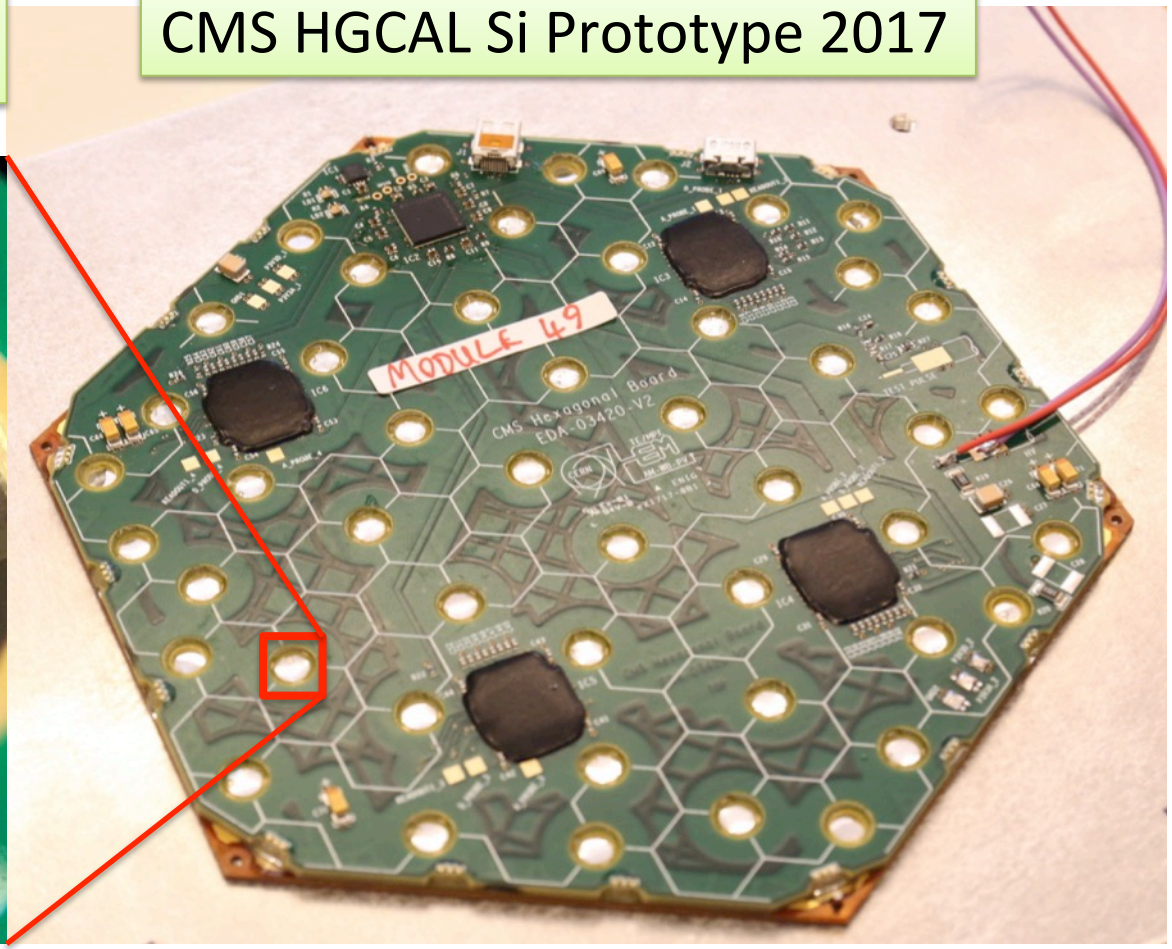


~22000 hexagonal Si modules

Wire bonds through holes in the PCB → works well, but reduction in PCB real estate

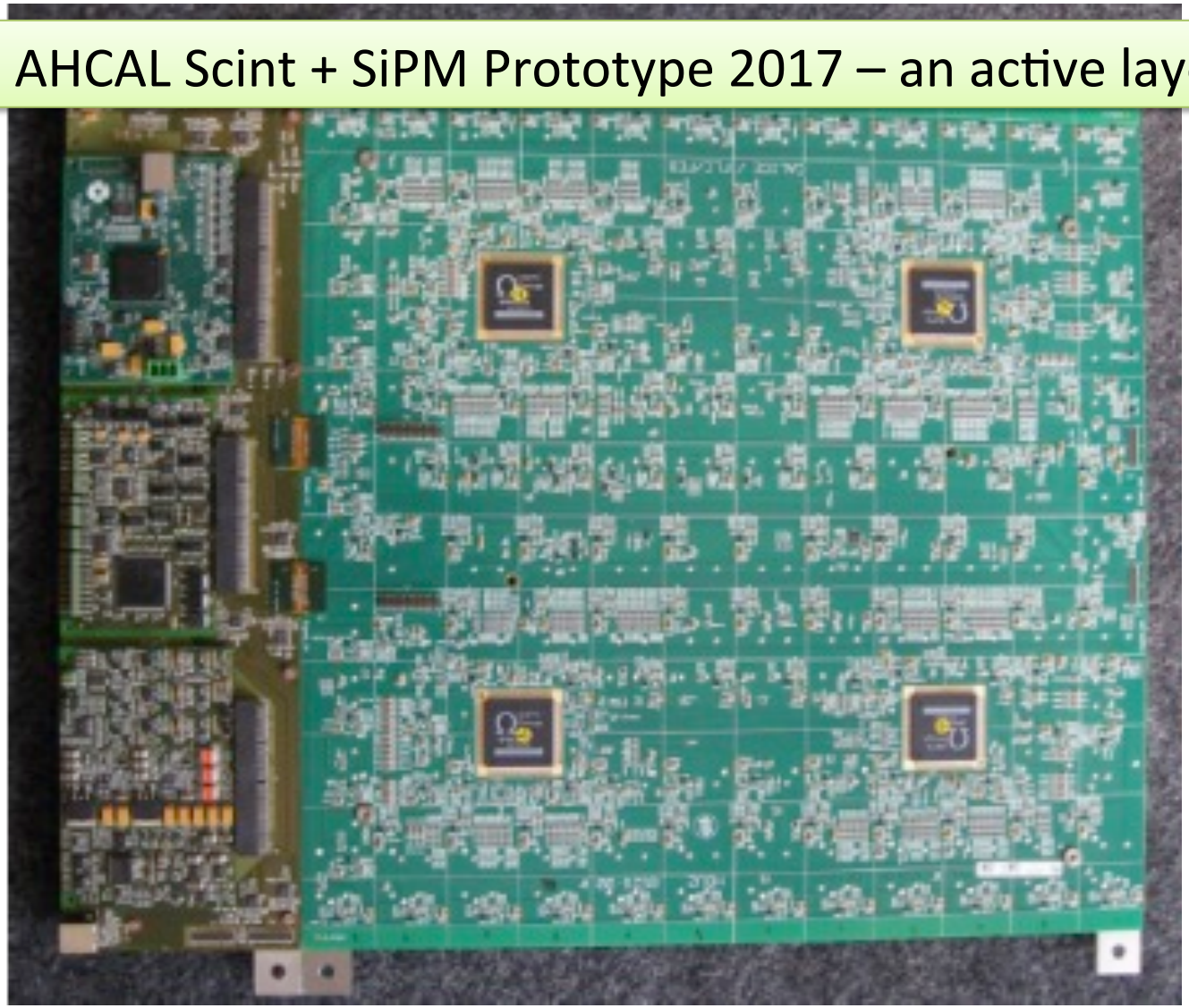


CMS HGCAL Si Prototype 2017

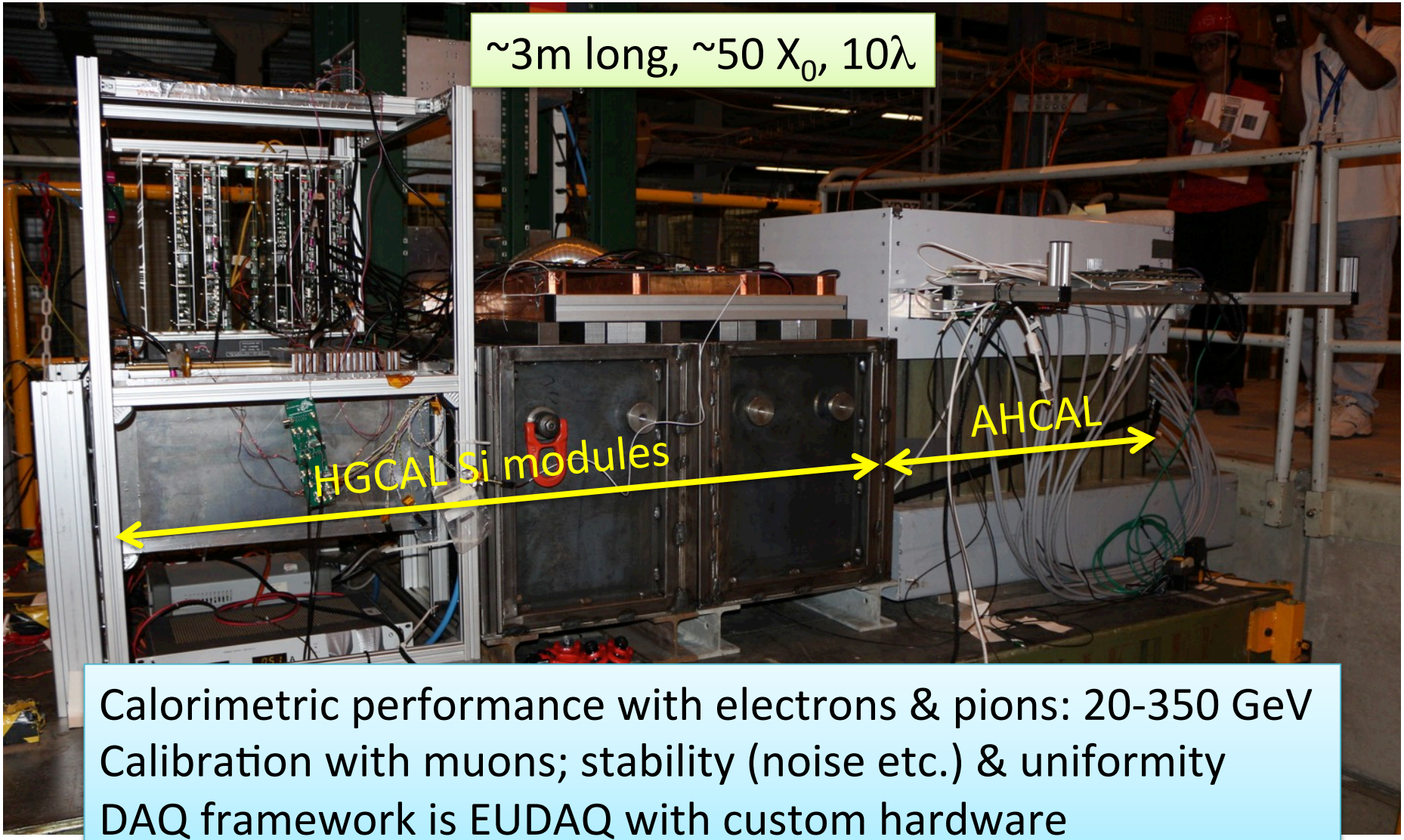


~500 m^2 scintillator + SiPM

CALICE AHCAL Scint + SiPM Prototype 2017 – an active layer

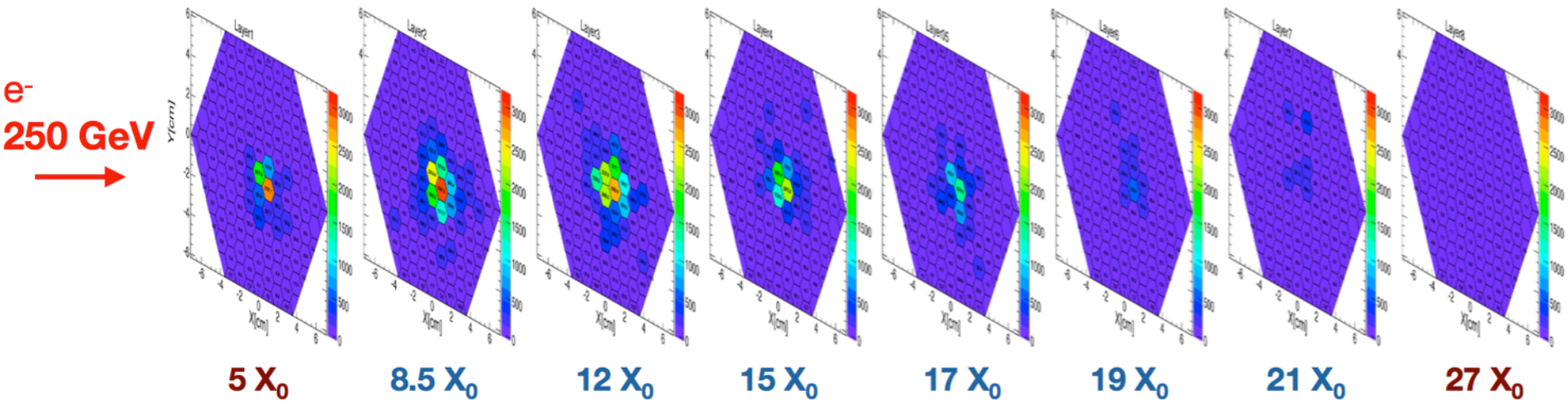


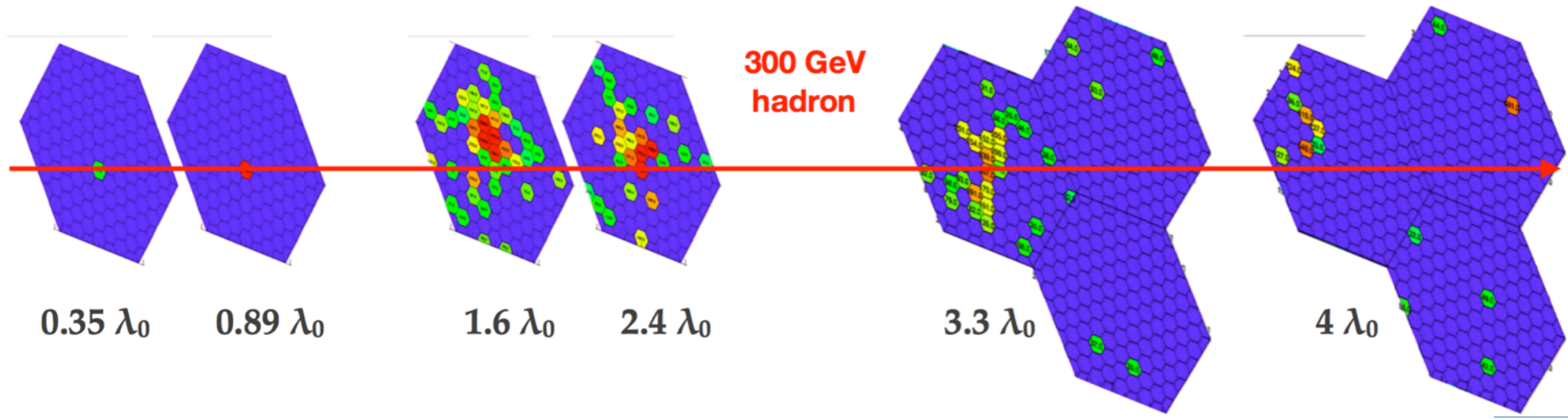
HGCAL+AHCAL test @ CERN



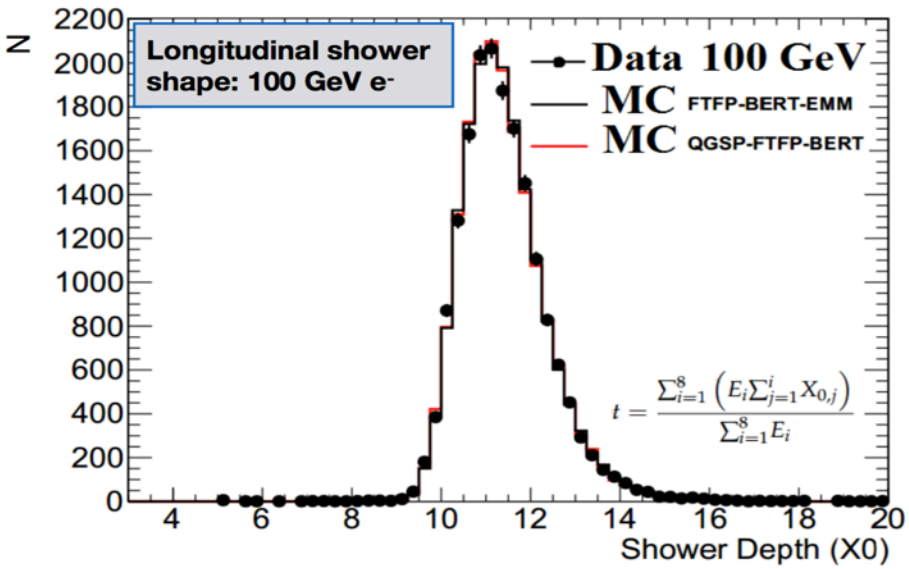
Calorimetric performance with electrons & pions: 20-350 GeV
Calibration with muons; stability (noise etc.) & uniformity
DAQ framework is EUDAQ with custom hardware

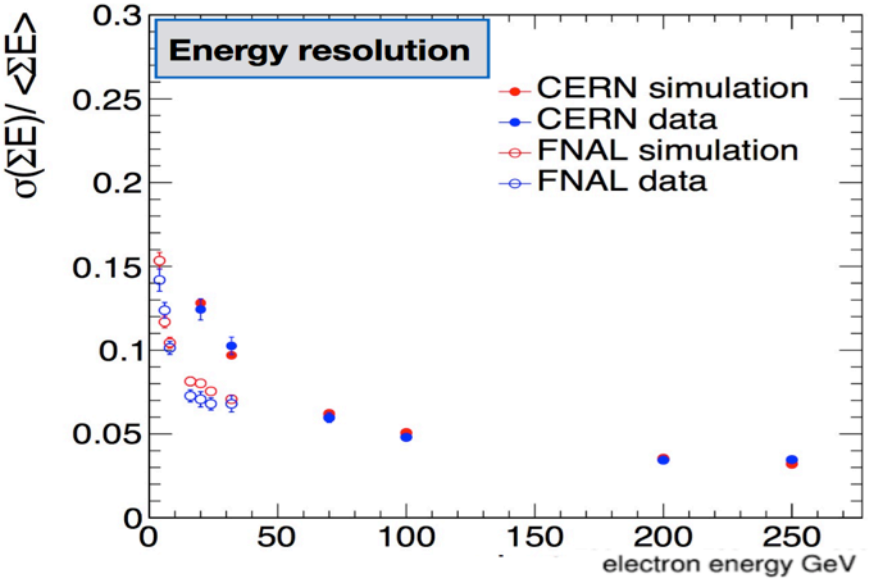
Typical Measurements @ CERN

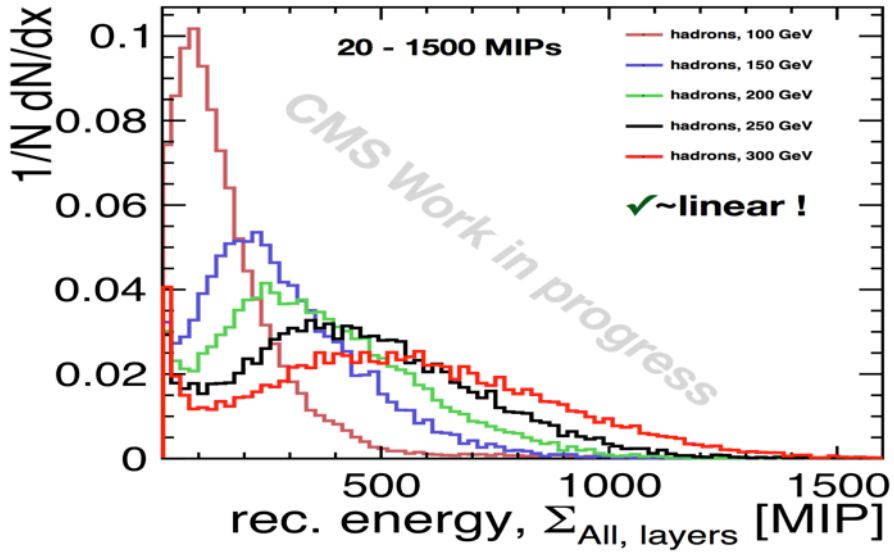


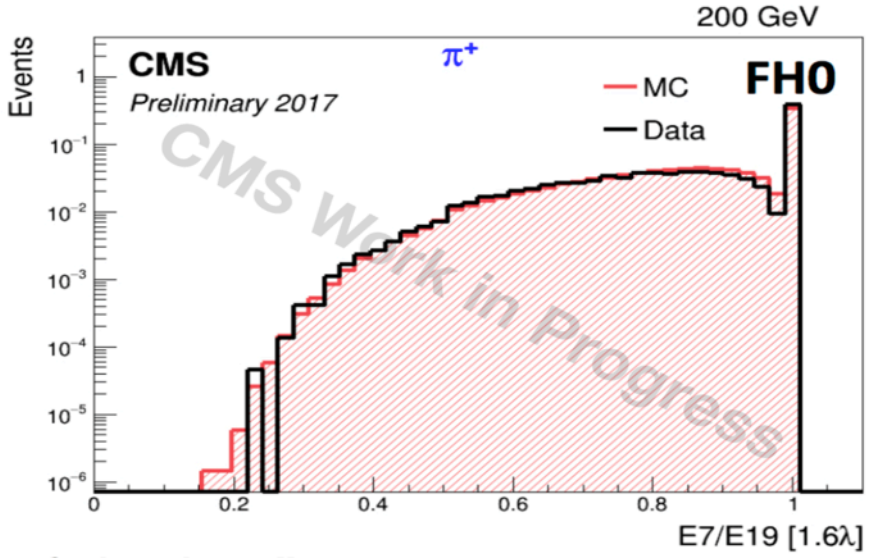


Typical Measurements @ CERN: comparisons with simulation

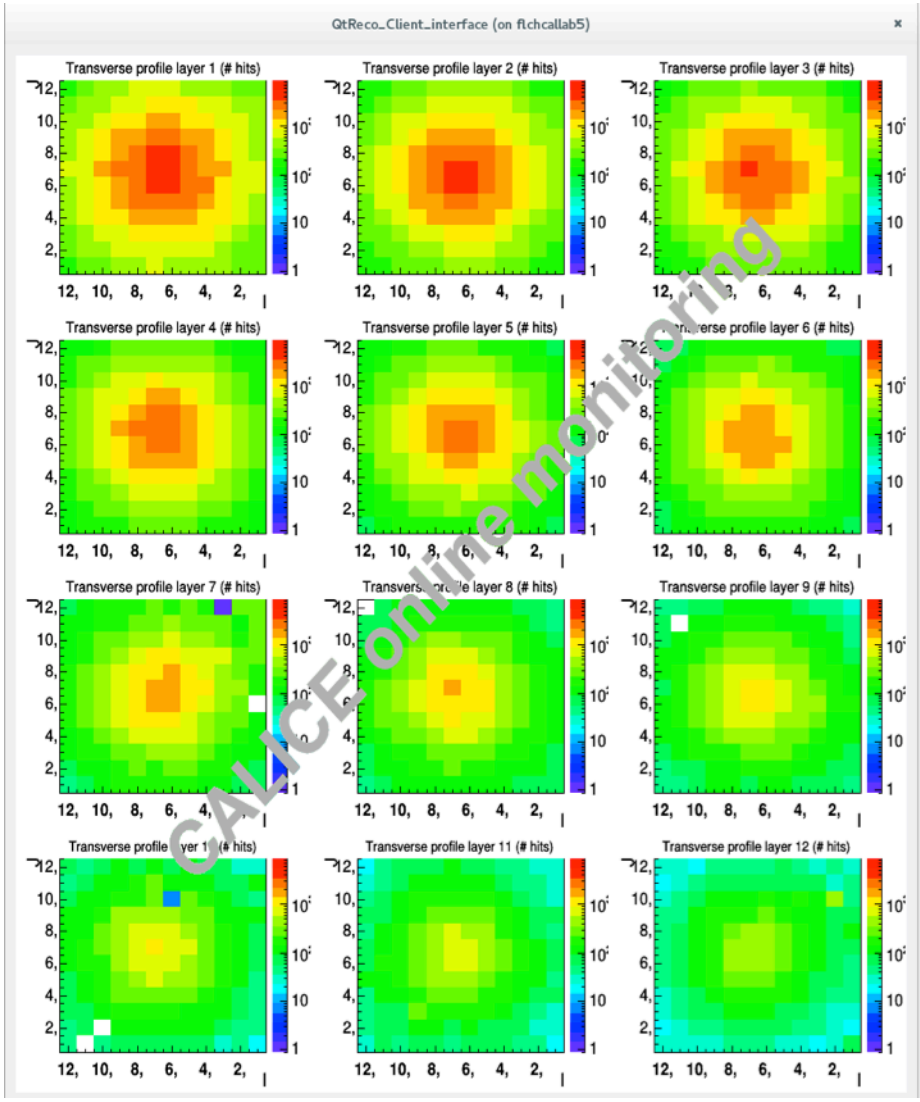


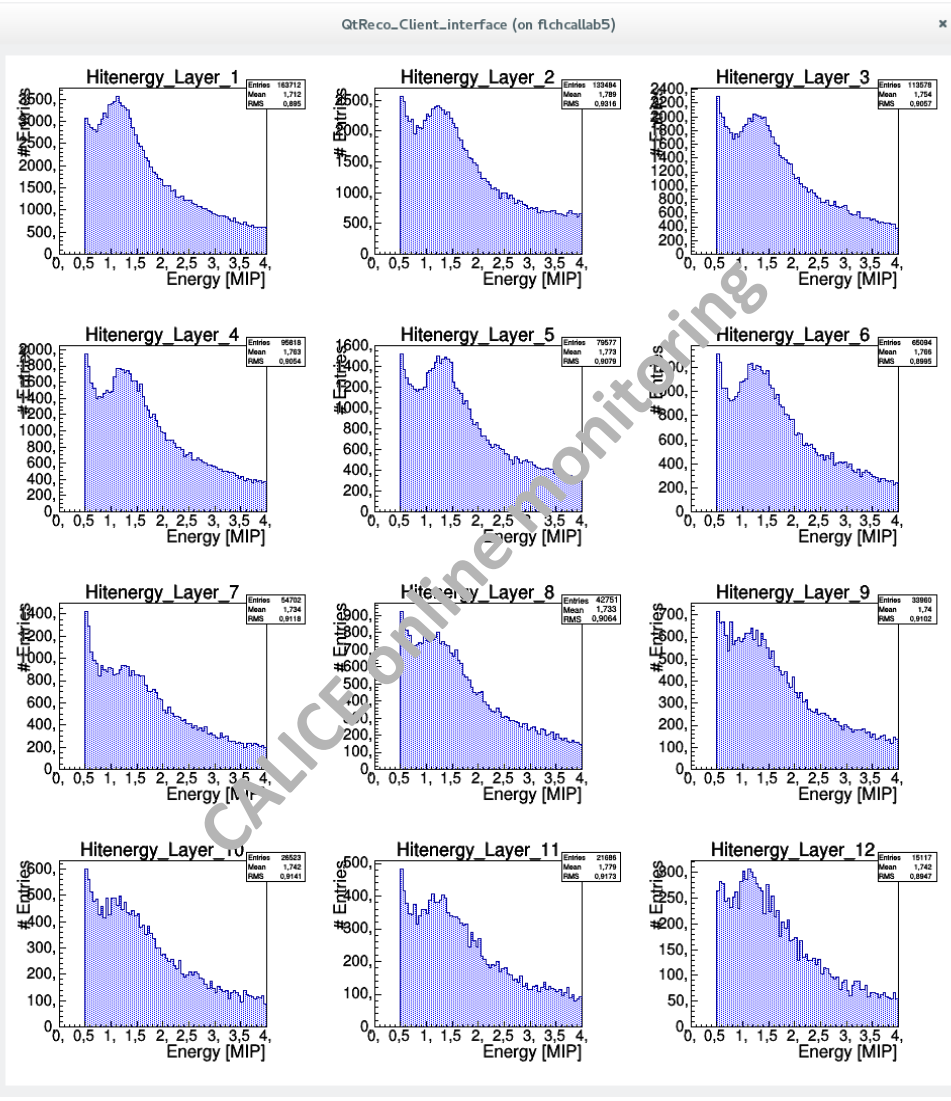




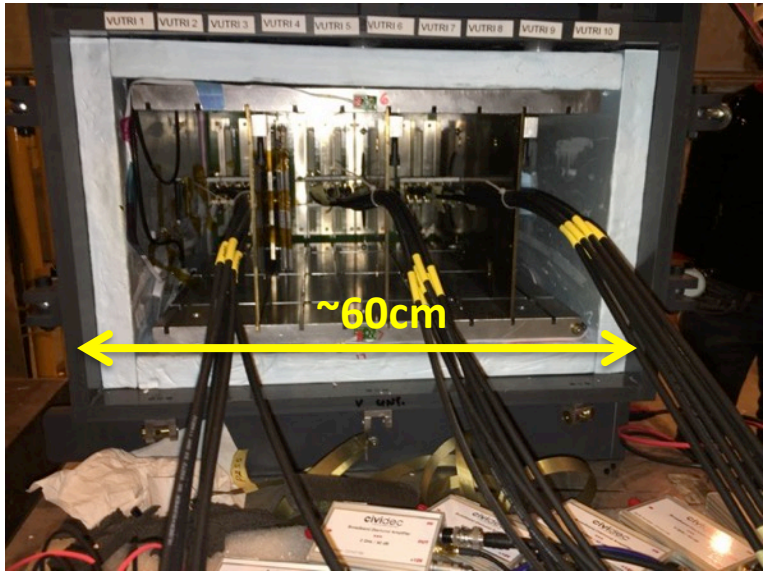


Typical measurements @ CERN: shower profiles and MIPs in AHCAL

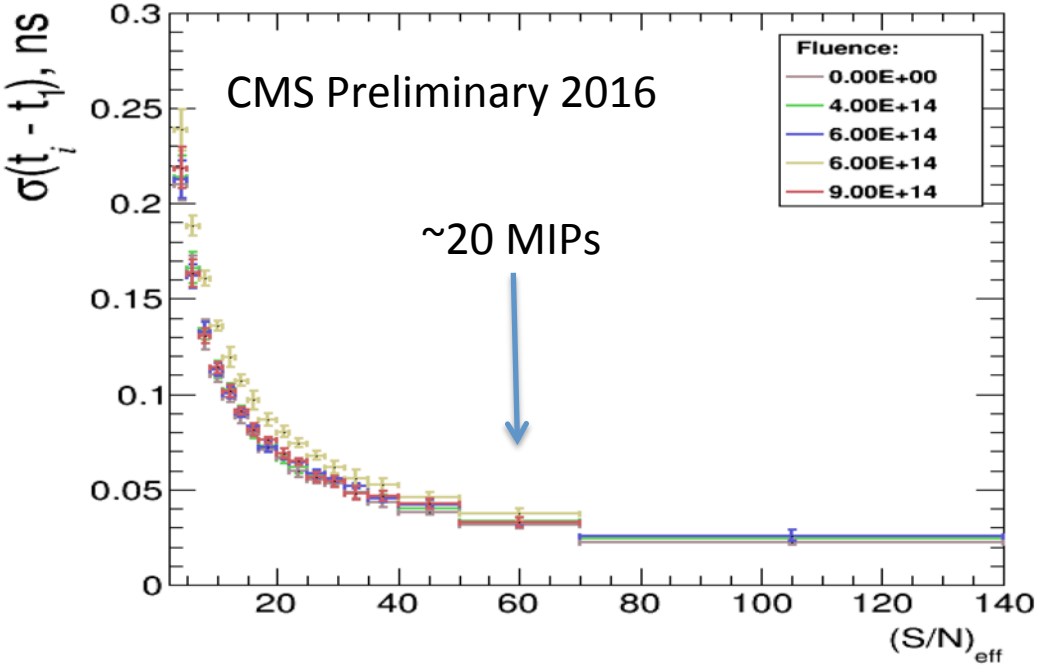




Also studied timing performance of silicon sensors (inc. irradiated)



- Stack of Si diodes irradiated to different fluences (up to 10^{16} n cm^{-2})
- CAEN digitizer
- Placed inside "Vienna box" for cooling to -30°C
- Absorbers to create EM showers
- Timing performance depends on signal size



Many very useful features @ DESY

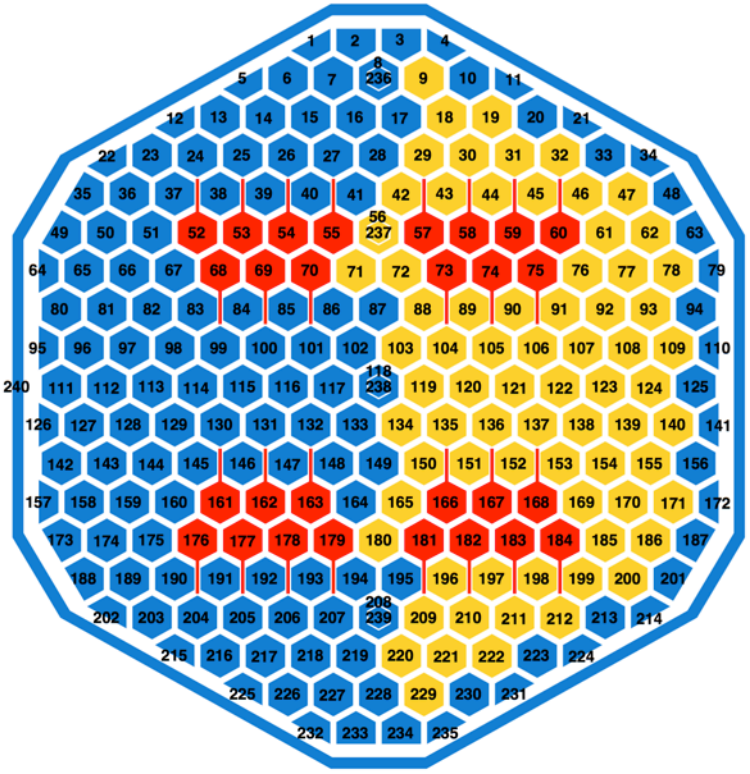
- ***Operational most of the year, all years***
  - LHC LS2 (2019/2020) comes at the critical part (end) of the HGCAL prototyping phase
    → final module qualification in electron beams (Si & scint +SiPM) with modest absorbers to get reasonably-high signals (10-30 mips should be possible)
    → including irradiated modules in cold-box
- ***High duty cycle***
  - Great for tests of stability etc. in a realistic environment
    - Perhaps observe rare, unexpected (unwanted!) occurrences in the sensors, SiPMs, ASICs etc.
    - Difficult to get >1 week of time @ CERN

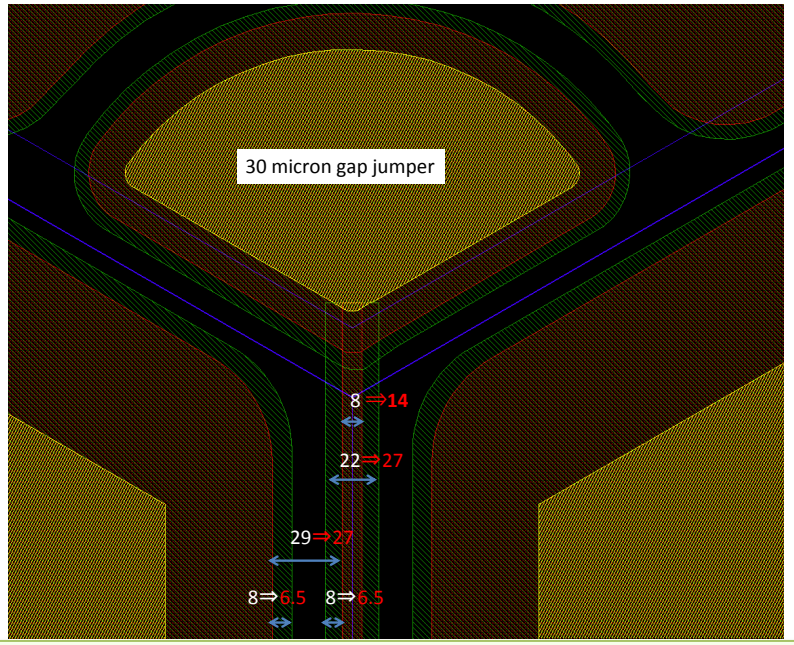
Many very useful features @ DESY

- ***6 GeV electrons can be very useful***
  - Without absorbers, can use to test and synchronize the DAQ for a number of layers (including both Si & Scint+SiPM)
  - Sufficient for precision timing studies of our full system with real front-end electronics, realistic clock distribution etc.
  - Low-energy performance and detailed shower shape for electrons
    - HGCAL is an imaging (particle flow) calorimeter – low energies are also important
- ***3 GeV electrons are also useful!***
  - Without absorbers, they are a good approximation to MIPs – the basic calibration method of HGCAL
- ***1.2T solenoid***
  - As above, but within a reasonable magnetic field
  - Can fit the Vienna cold box in the bore

Many very useful features @ DESY

- ***High-precision beam telescopes***
  - Can be useful for detailed studies of sensor structure
  - E.g. 256-cell 6” sensor uses on-silicon “jumpers” (**red lines** in left figure) to bring some bonding sites away from a hexagon, otherwise too many holes in the PCB





With 2-3μm precision, can study efficiency of these regions, as well as the inter-cell regions

A Couple of Suggestions

- Support the proposition from ATLAS for a ***common cold-box system***
  - 50x50cm^2 transverse size
  - Cool to -30^{o}C or below
  - Humidity & temperature control
- Support the desire from many to have a ***timestamp associated to the Mimosa tracks***
- ***Hadrons*** would be very nice to have (and muons)
- ***Precision-timing reference device***, e.g. MCP (<10 ps precision)
  - Would be useful to have a reference hardware integrated into EUDAQ
- Standard "***Detector Safety System***"
  - PLC with environment sensors & alarming (through SMS)
  - Integration of HV and LV systems if possible (apologies if all this exists already)