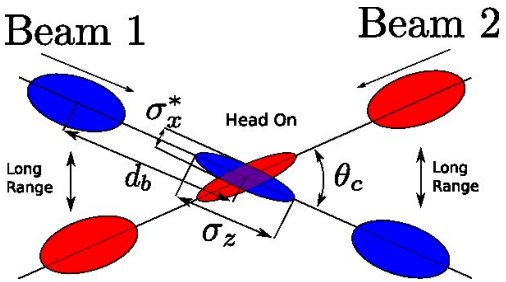
CMS Barrel Timing Layer

Ujvári Balázs

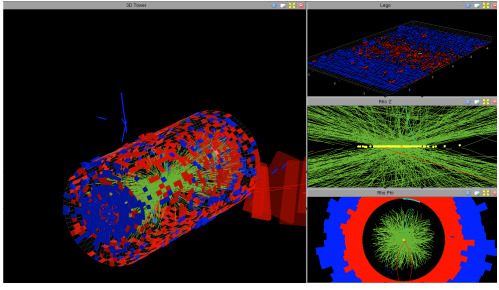
ujvari.balazs@inf.unideb.hu

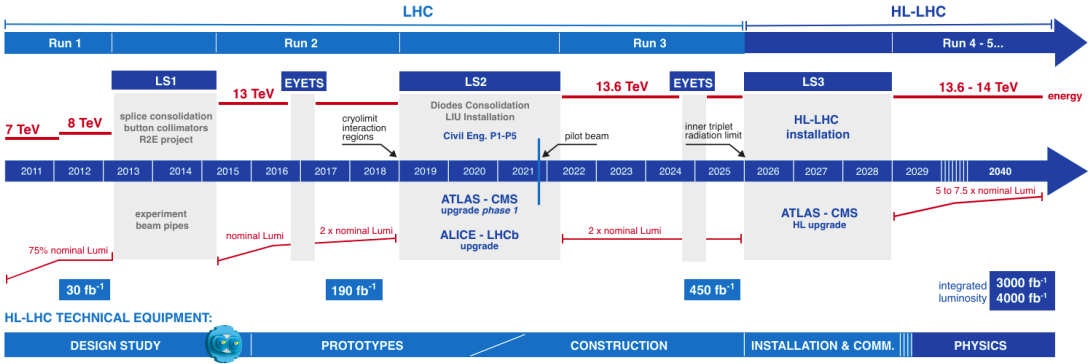
DEBRECEN



Every time these bunches (10^{11}) cross one another, more than one proton-proton collision takes place; this is known as pile-up. CMS has to observe the decay products of various particles produced in these collisions and work backwards to determine which collision interactions produced which particles.

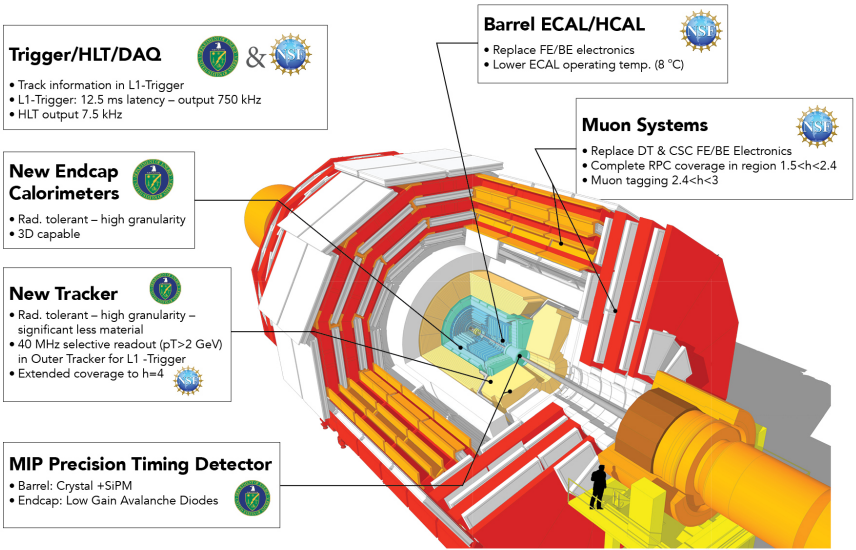
When CMS was designed and built, it was expected an average pile-up of around 25 interactions per crossing, with the proton bunches crossing inside CMS every 25 ns. Maximum: 78!

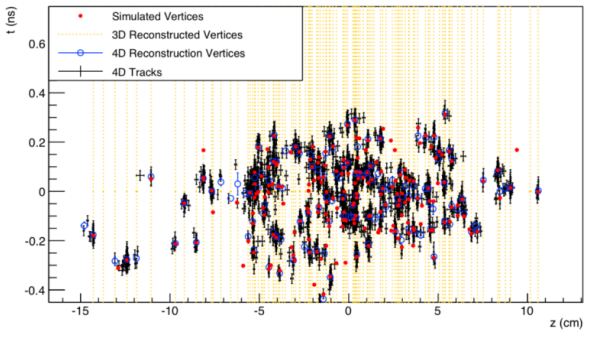


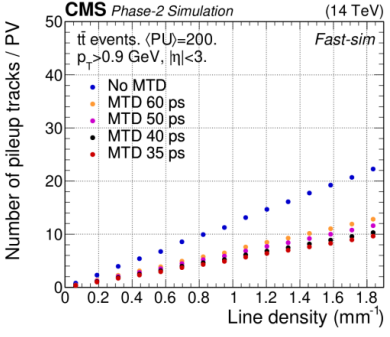


The High-Luminosity Large Hadron Collider (HL-LHC) project aims to crank up the performance of the LHC, 10^{12} instead of 10^{11} protons per bunch, in order to increase the potential for discoveries after 2029.

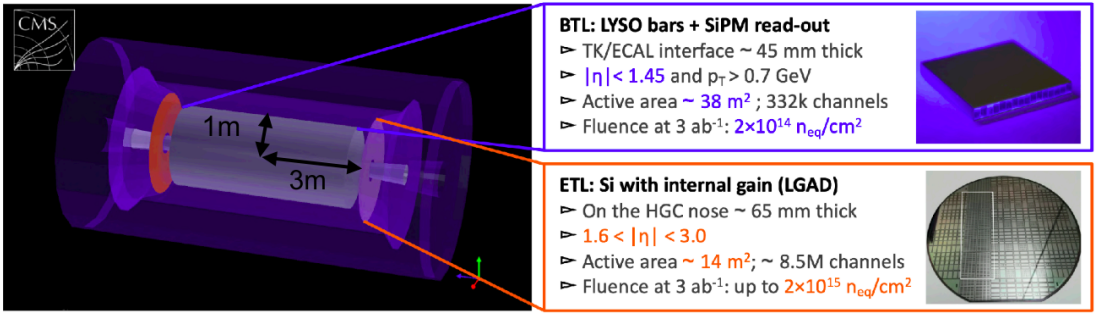
Summary of CMS HL-LHC Upgrades





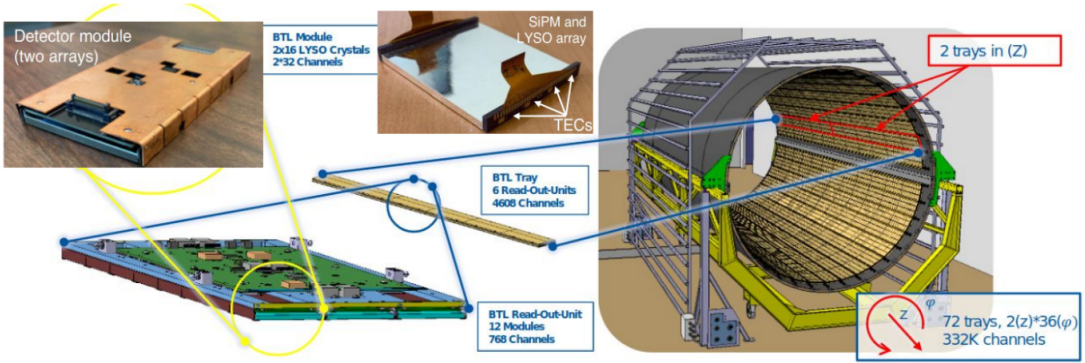


200 pileup interactions assuming a MIP timing detector with 30 ps time resolution. The red dots = no use of timing information the black crosses and the blue open circles represent tracks and vertices reconstructed using a method that includes the time information (referred to as "4D"). Number of pileup tracks incorrectly associated with the hard interaction vertex as a function of the collision line density for different time resolutions.

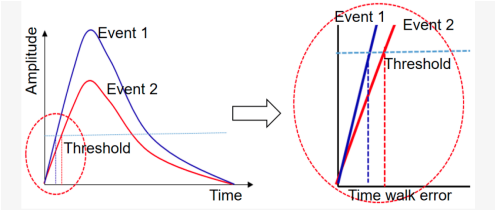


- MTD: MIP Timing Detector, reduce fals tracks + ToF for PID
- BTL: LYSO + SiPM + TOFHIR
- ETL: Low Gain Avalanche Diodes + ETROC

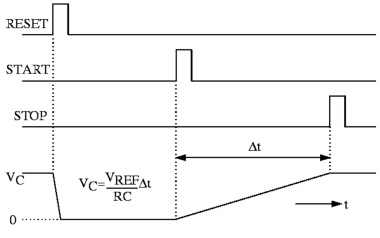
MTD with 30–40 ps precision + 200 pile-up = 80 pile-up today
3.6 - not great, not terrible.



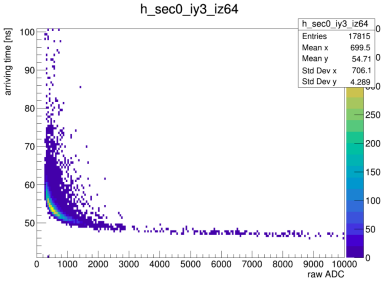
- LYSO crystals as scintillator: Radiation tolerance, fast
- SiPM: magnetic field, dynamic range, PDE, rad tol.
- Dedicated readout ASIC (TOFHIR) is being developed for BTL, improves time resolution by about a factor 2 at EOL
- Thermoelectric Coolers (TEC) coupled to SiPMs, op. temp + annealing

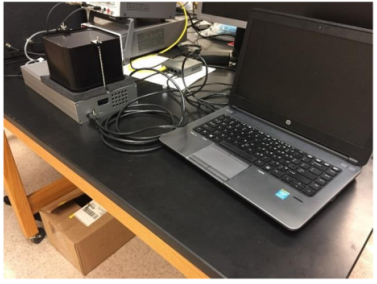


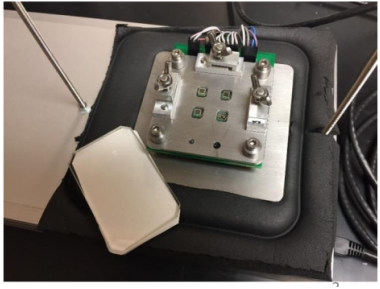
ToA, ToT uses threshold (high enough to avoid random signal from noise, 3-5 sigma),



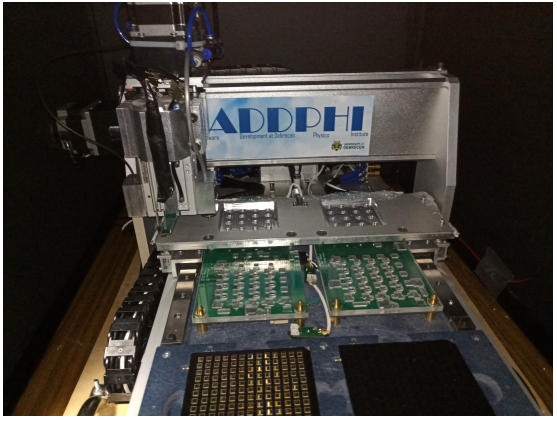
the signal exceeds the preset value (8-10bit DAC), read out the clock (ASIC), or a dedicated electronic starts charging a capacitor and read out in preset time. TOFHIR2 $\neq$ HGCROC, one 10bit 40MHz ADC for 32 channels, we can measure only the integral, trigger $\rightarrow$ charge a capacitor $\rightarrow$ read out with this ADC



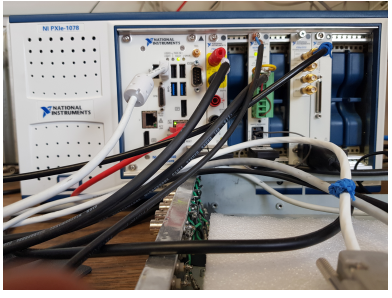


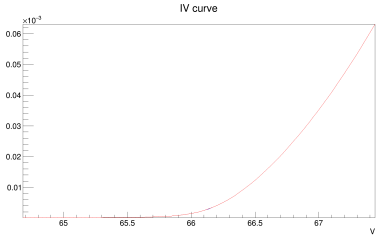


- Six days to test 1428 SiPMs
- Measure 4 SiPMs per turnover
- Automated root file management
- Next testing device prototype will be even faster 8x8 matrix
- Need to incorporate robots in the full production sorting plan
- database for result
- 10mV $\rightarrow$ 1-2mV precision in V_{br}



- 20k in 9 months
- IV + SPS
- Automated root file management + DB





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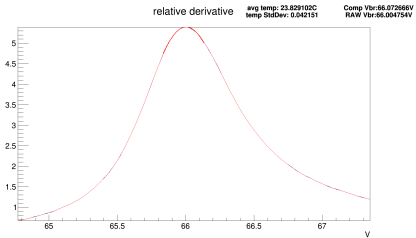
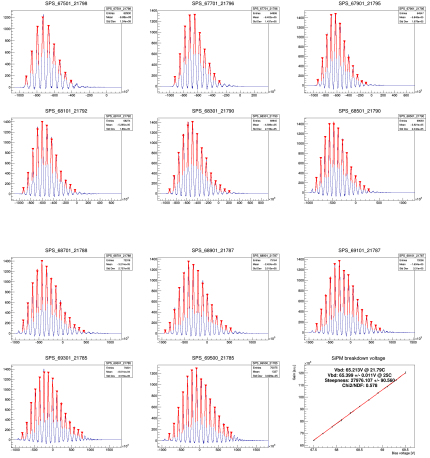
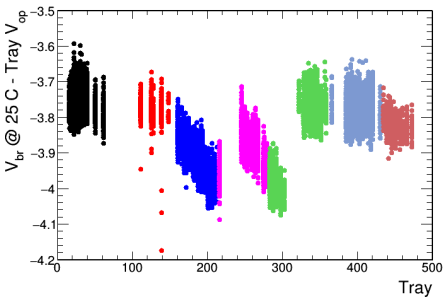
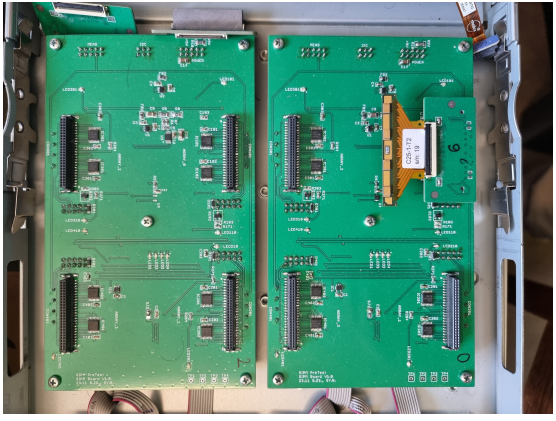




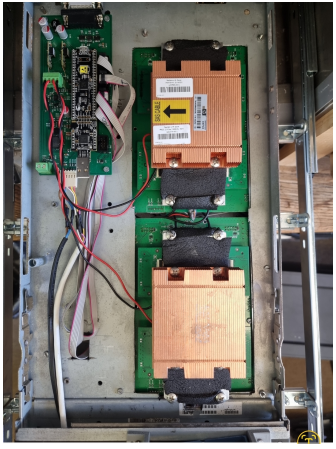
- Company may change the raw material
- Its calibration is different
- For calorimeters we need to test better



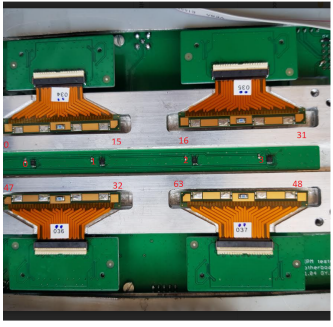


- Pt1000 thermometer
- Thermo Electric Cooler test
- Break test in electronic circuit
- DB, QC, send back to company

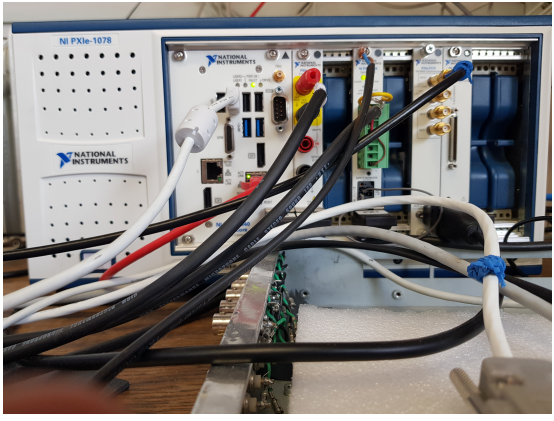
10-20% of the test have to do in a feezer -40°C, to check the tempareture coefficient (3.7mV/°C)



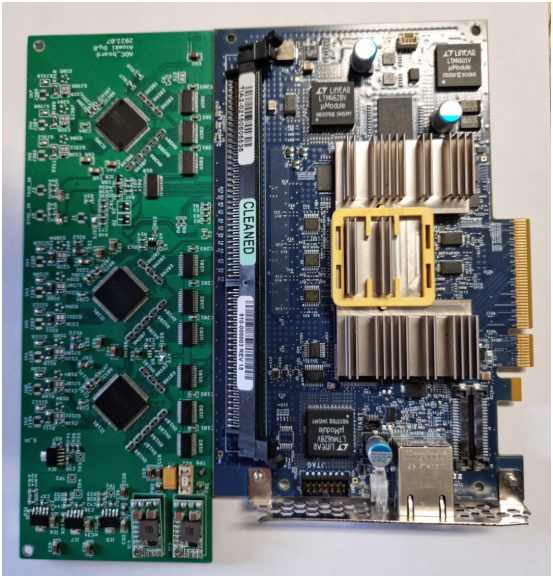
The temperature in the feezer is -37°C, heat sink + big TEC we set to -40°Cand keep it with 0.1°Csigma



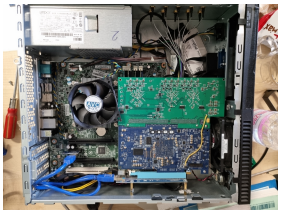
Place the arrays and start the test. IV low intensity light and dark, Single Photon Spectrum with pulses, plexi + optical cable under the SiPMs

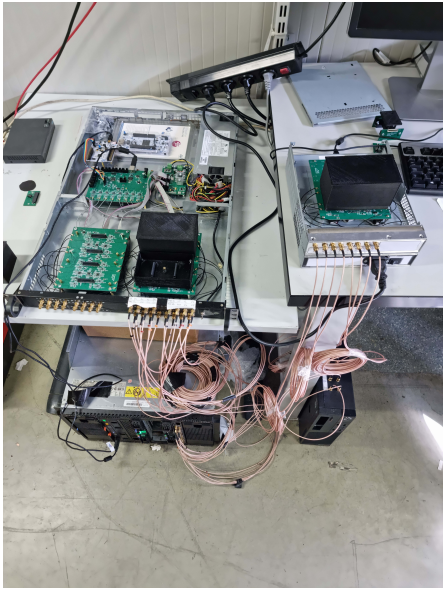


- PXIe-1078 chassis
- PXIe-4139 SMU pA-μA
- PXIe-4081 DMM 0-100V 1.25mV precision
- PXIe-5172 Digitizer 14bit 250MSPS 4ch
- IV 4sec
- SPS 11$\times$ 10 sec (100k pulses)
- SPS is too long



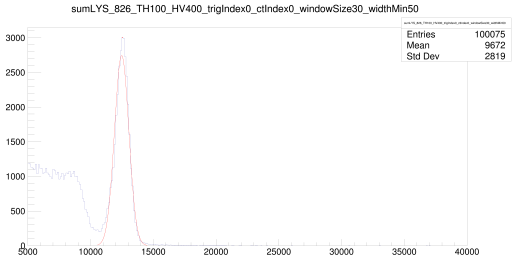
- 100 MSPS 10bit 8channels
- 1M pulses is 5sec for all channels
- At least 100*times* faster
- Custom designed PCB, Custom FPGA code
- Huge amount of data, dedicated server in the background



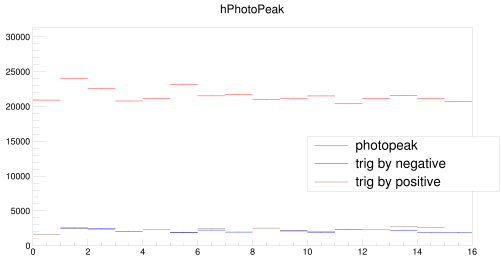


32 channels measures 4 modules, ready for mass test

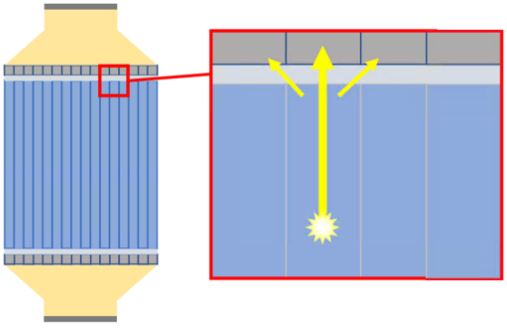
- Place a source (Cs-137)
- Analyse waveforms
- Reconstruct spectum
- Optical crosstalk measurement
- Using the gain from SiPM test calculate the light yield of the LYSO scintillator



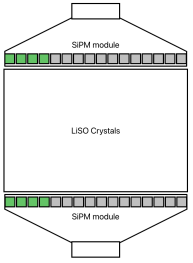
The spectrum of our tester can be used to measure photopeak, using the gain the number of photons $\rightarrow$ photon yield of the LYSO

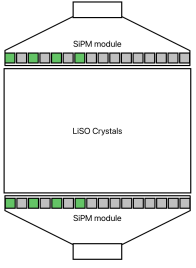


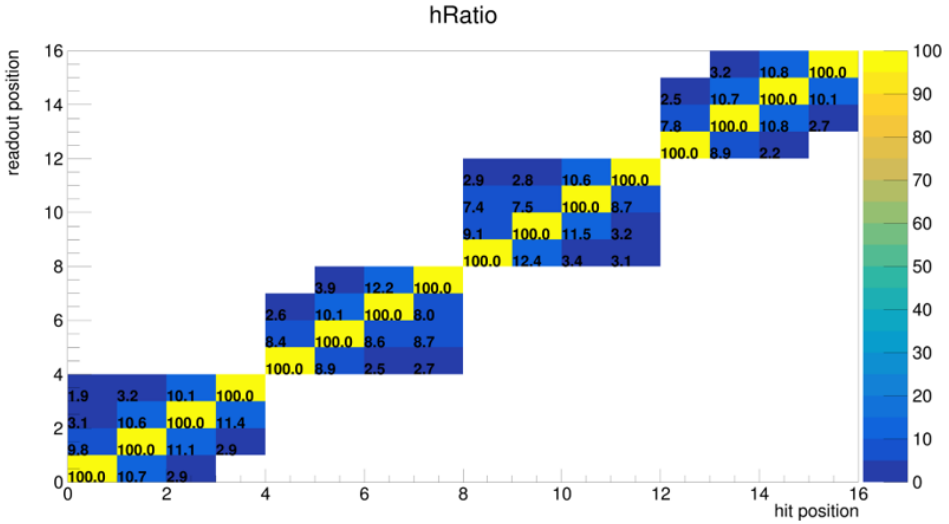
Modul (16 independent detectors) inhomogeneity can be measured with high precision



The pattern of crosstalks indicates the quality of the bonding!







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