Test facilities for phase-1 pixel upgrade at CERN

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5th Infieri workshop – Infieri at CERN – 27-29 April 2015

Introduction

Outline

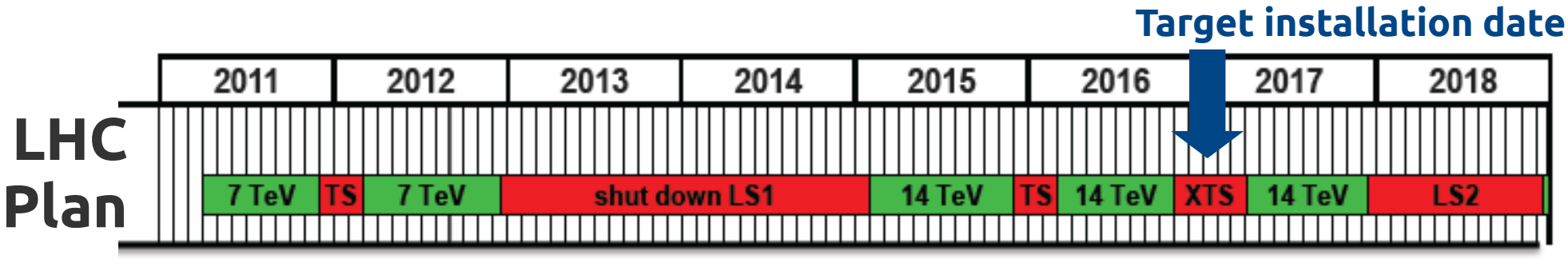
- CMS Pixel Phase-1 upgrade introduction
- Test systems @CERN (building 186)
  - Beam test preparation
  - Production/calibration measurements
  - Small system integration tests
  - Cooling plant
- Future activities @CERN (building 186)

Not covering:

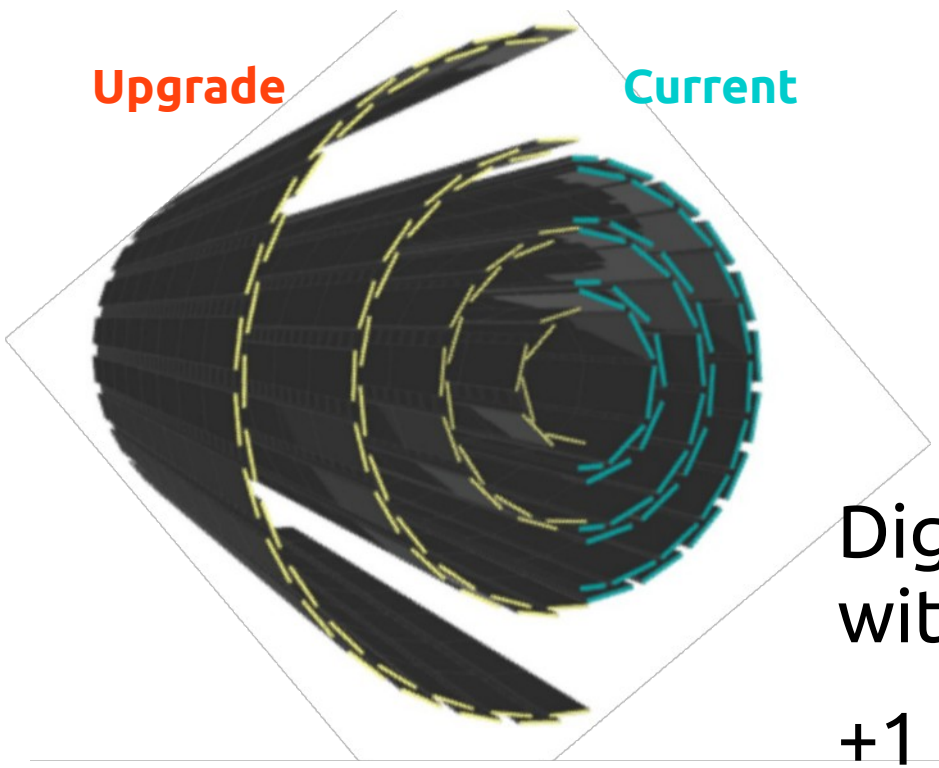
- Activities at the experiment site (P5)
  - Cooling
  - DAQ integration
- Optical links and DAQ hardware development and tests (PH-ESE)

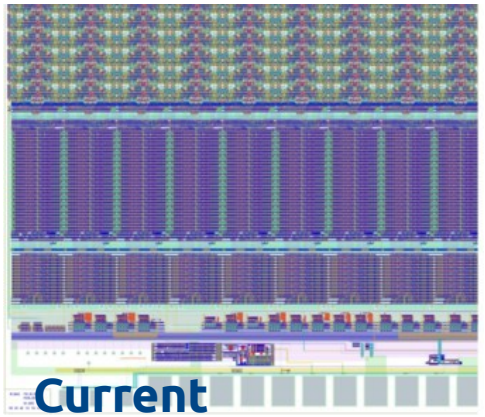
CMS Pixel Phase-1 upgrade

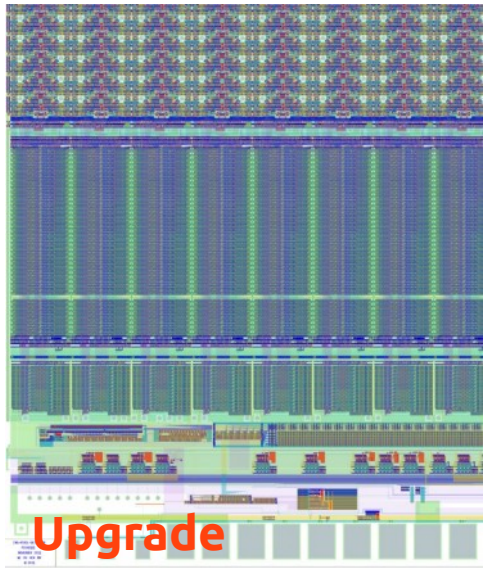
- Present detector :
  - Proposed in 1995 for max instantaneous L = 1×10^{34} Hz cm^{-2}
  - Good performance in Run 1: $\sigma_{r\Phi}$=10 μm , σ_z=20 – 40 μm, ε>99%
  - Possible high dead-time (~50% @ 2×10^{34} Hz cm^{-2} & 50 ns BX spacing)
- Upgrade detector
  - Lower dead-time (new ROC) & improved geometry
  - Baseline L=2×10^{34} Hz cm^{-2} & 25 ns (50 pileup) and tolerate same luminosity but 50 ns (100 pileup)
  - Serve integrated Luminosity of 500 fb^{-1} (250 fb^{-1} for L1)



CMS Pixel Phase-1 upgrade

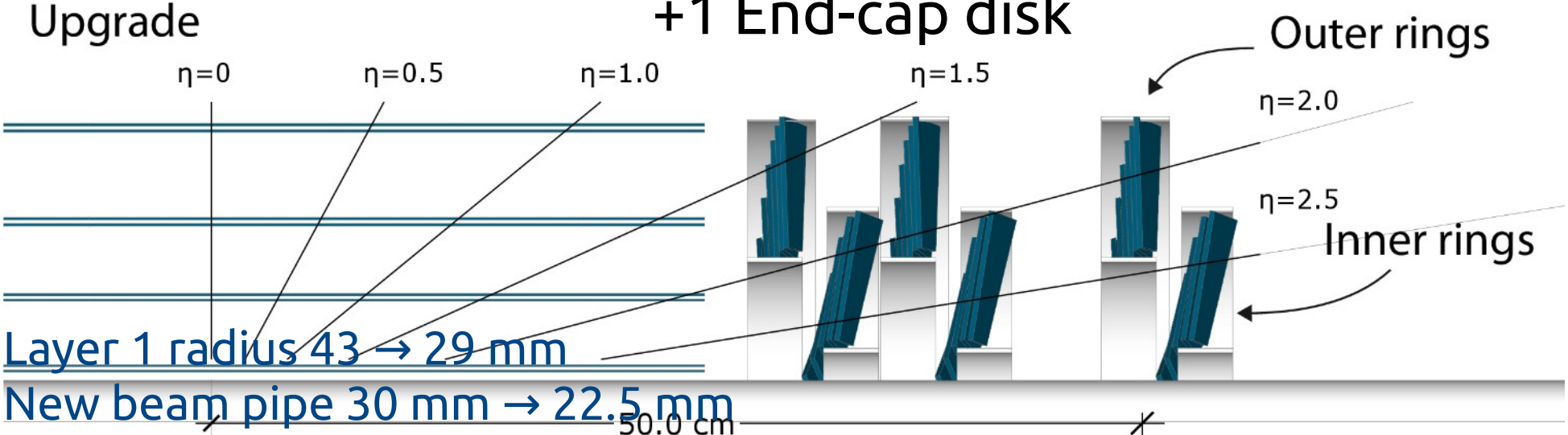






Digital Read-Out Chip
with increased rate capability

+1 Barrel layer
+1 End-cap disk



Layer 1 radius 43 → 29 mm

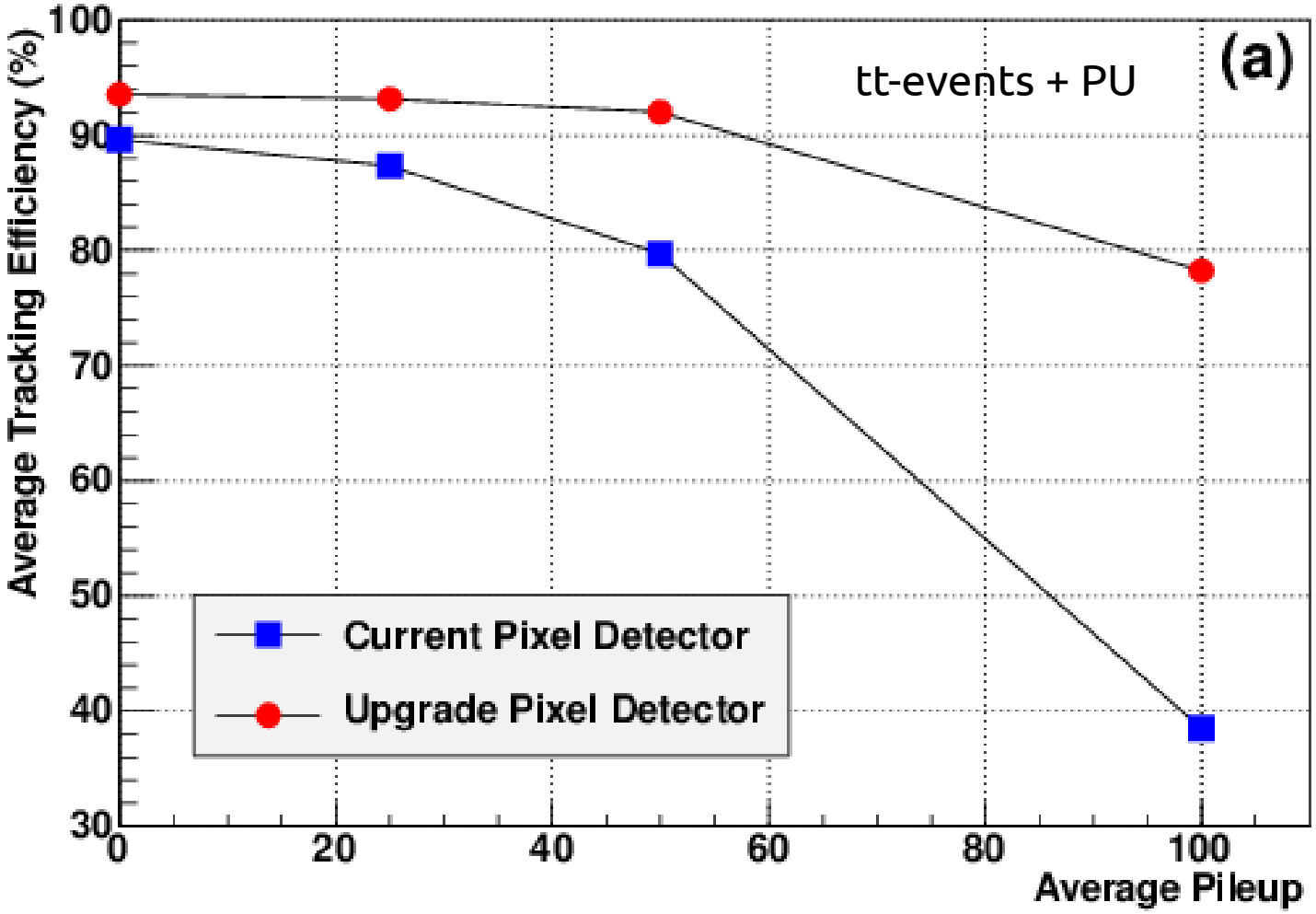
New beam pipe 30 mm → 22.5 mm

CMS Pixel Phase-1 upgrade

+1 detector layer

Improved Read-Out Chip

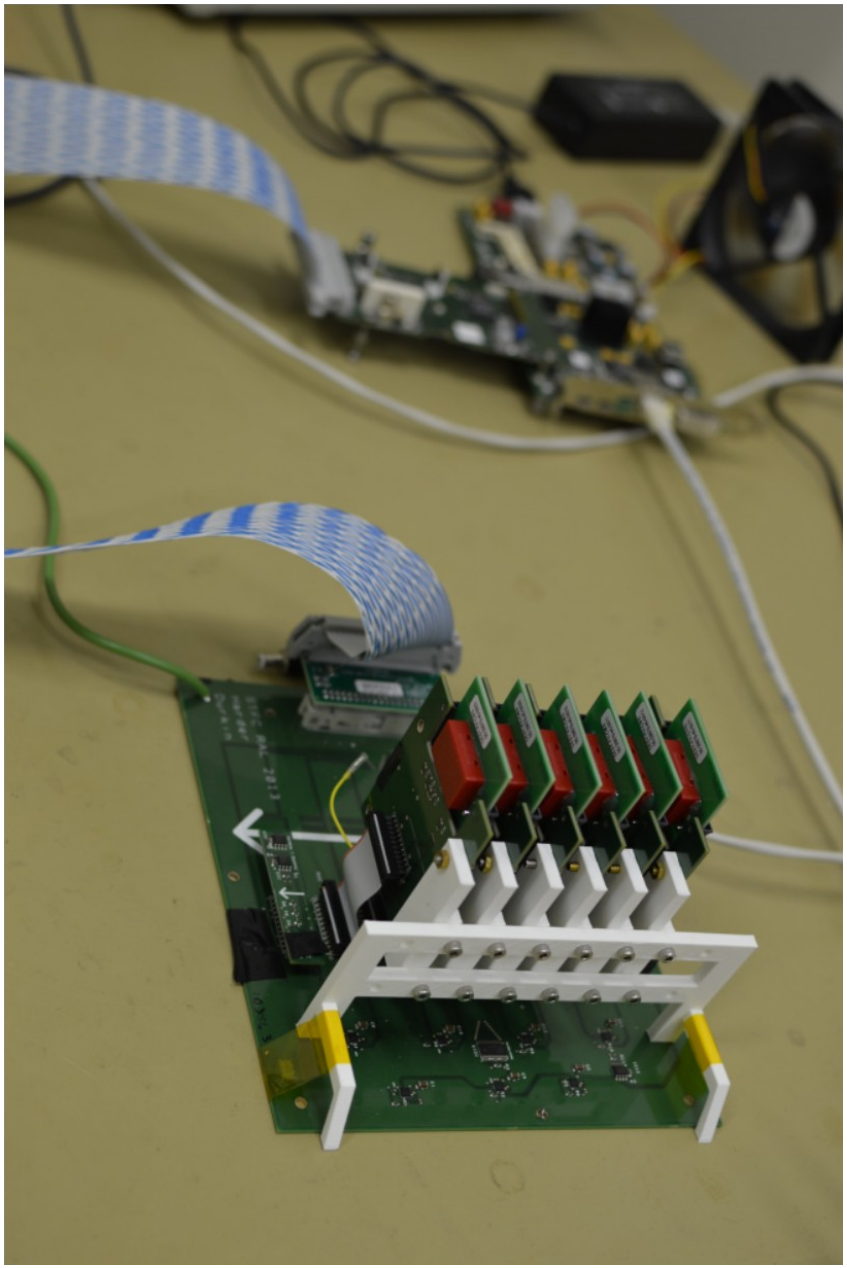
Greatly improved performance at high pile-up



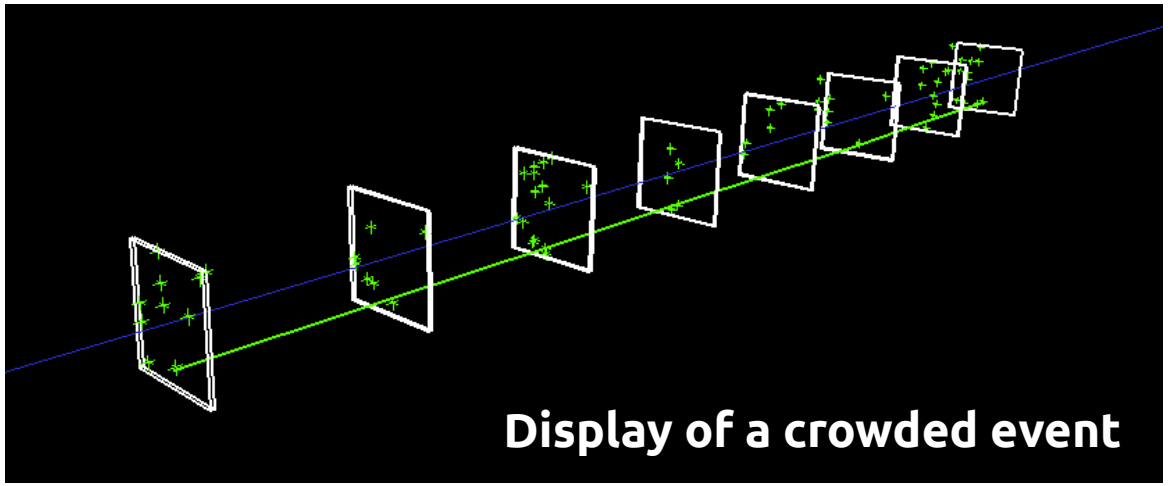
CMS Pixel Phase-1 activities at CERN

- Beam test to qualify the new read-out chip — Past
- Module construction — Present
  - Component testing
  - Mechanical assembly, wire-bonding
  - Functional tests (thermal cycling, calibration)
- System integration (small systems)
  - DAQ hardware
  - DAQ software
  - New components
- Cooling plant prototype — (Near) Future
- Large-scale integration test (towards final system)

Beam tests

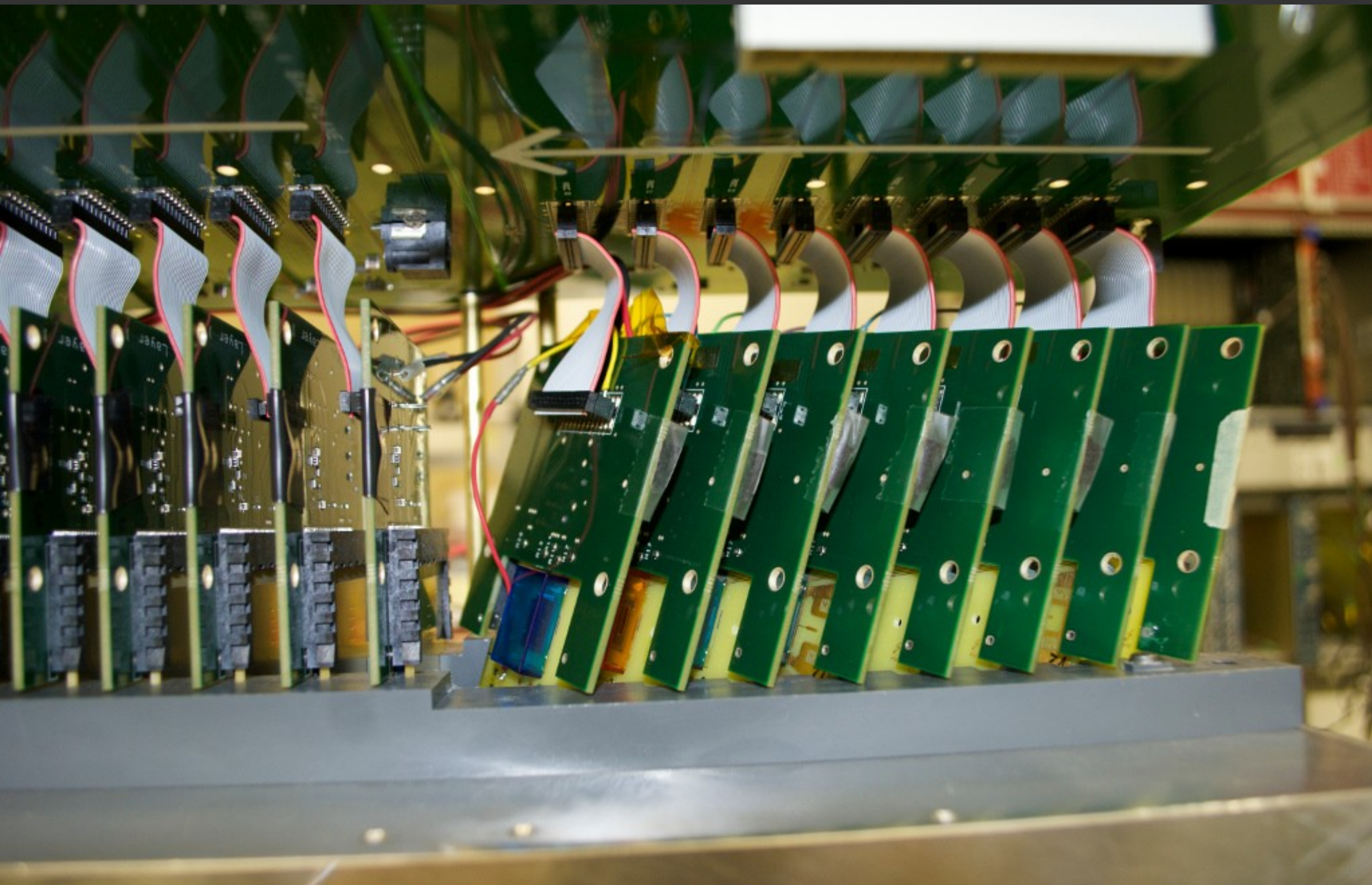


- NTU+RAL+CERN performed a series of beam tests (at PSI, FNAL & CERN) to assess the performance of the new Read-Out Chip in a high-rate environment
- An ad-hoc telescope made of PSI46dig ROC chips was built and the corresponding DAQ was set-up
- The DAQ is based on a Xilinx evaluation board and is read via IPBus (just like the local readout of the new µTCA back-end cards!)
- The set-up is still available and can be used as a telescope



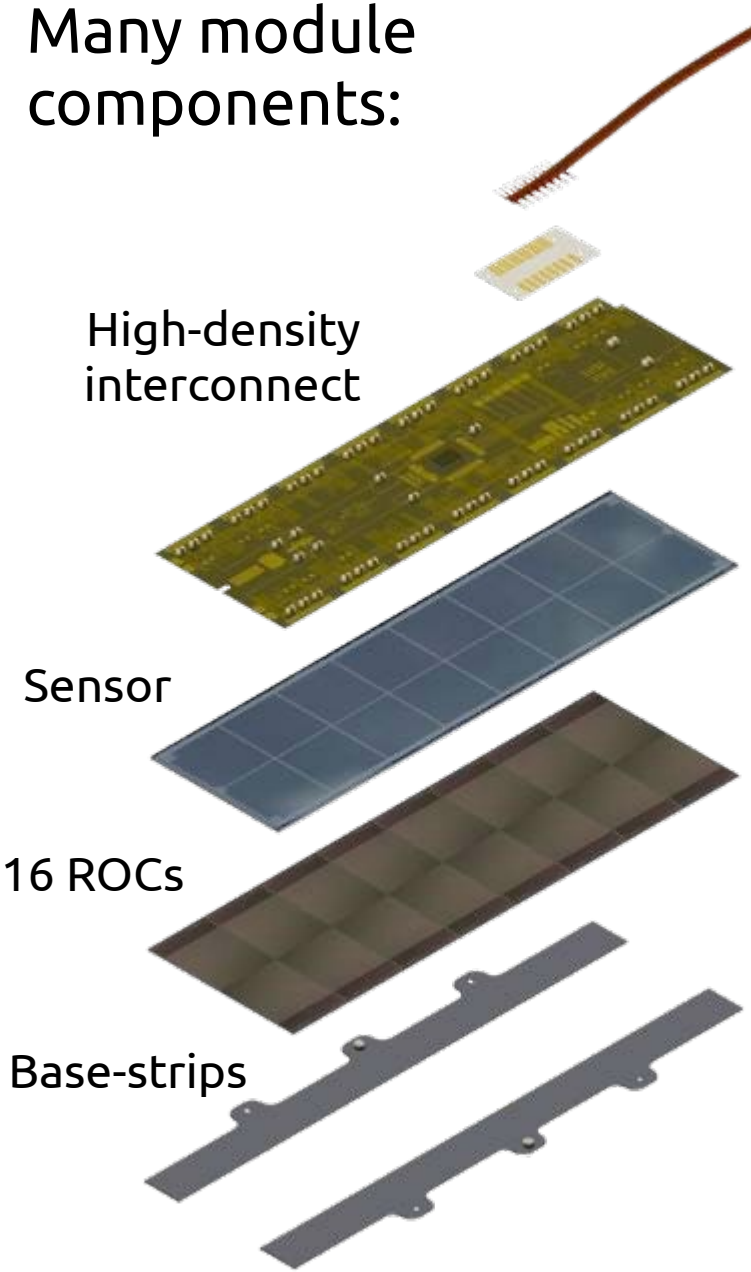
Display of a crowded event

Beam tests – telescope in action

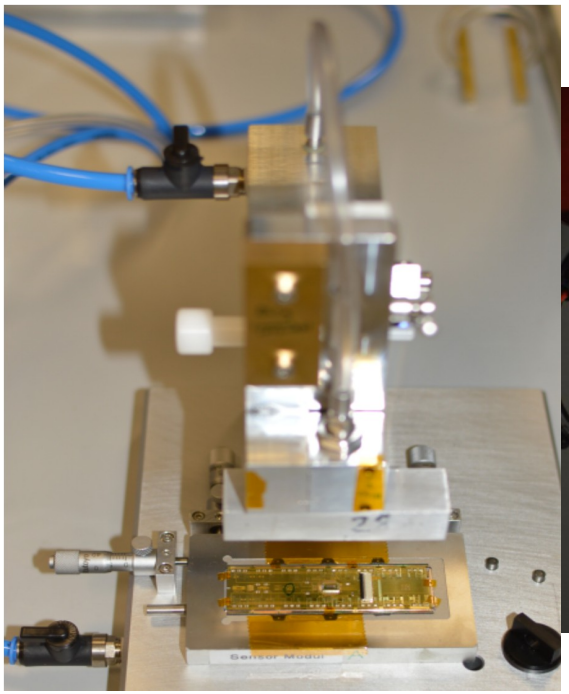


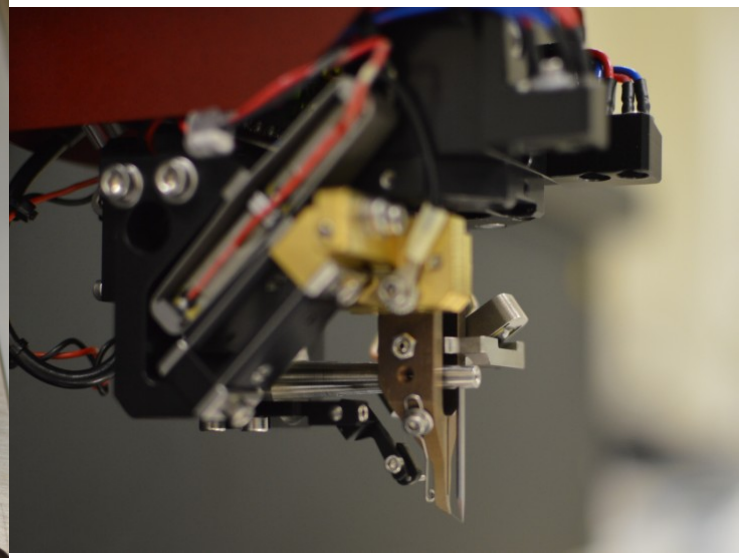
Module construction

Many module components:



- All components are tested upon reception (not covered here)
- Mechanical assembly & wire bonding





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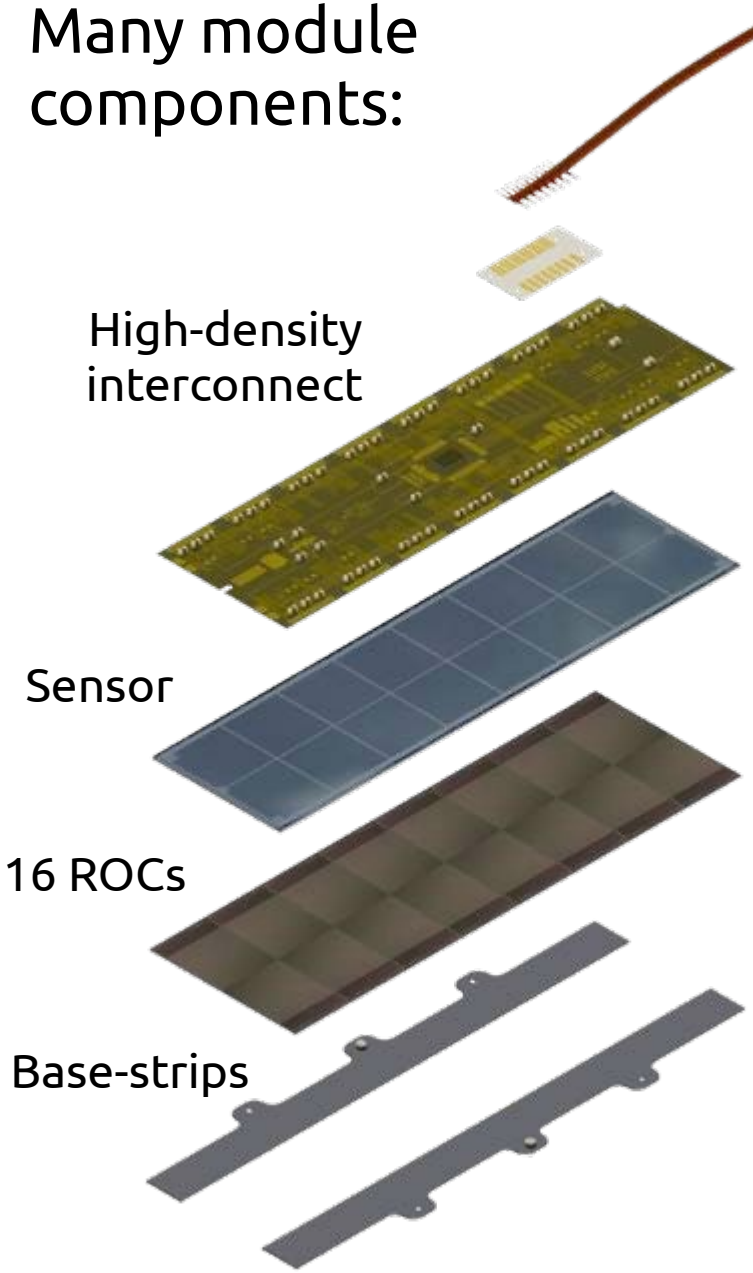
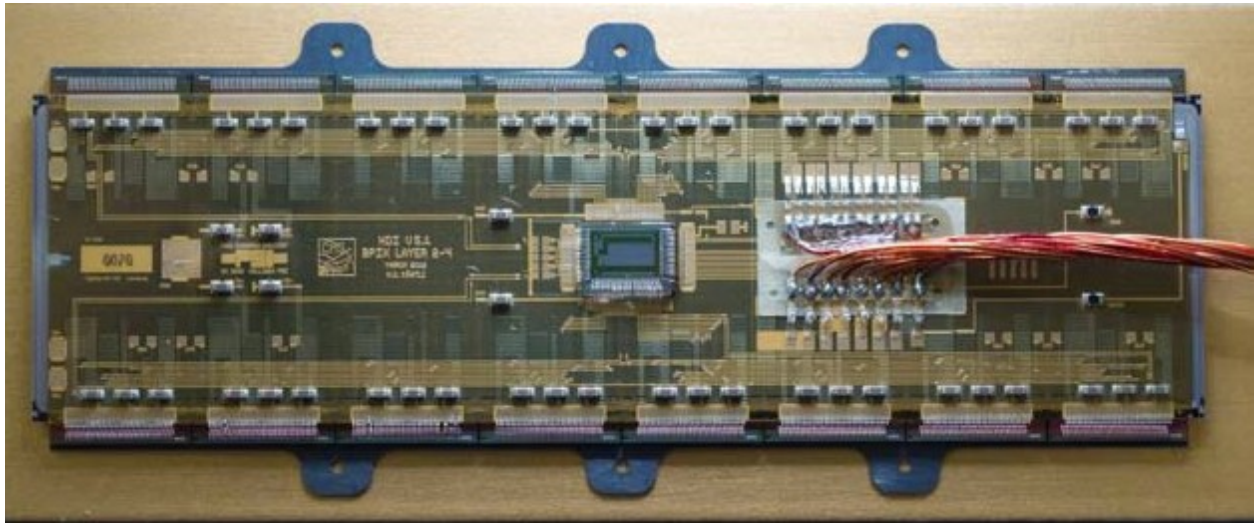


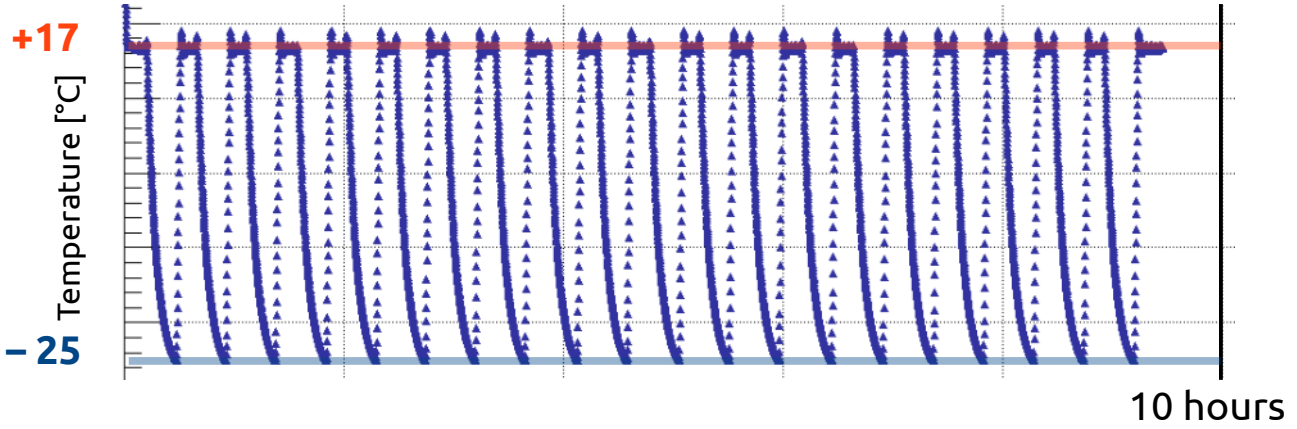
- All components are tested upon reception (not covered here)
- Mechanical assembly & wire bonding
- Each module undergoes full functional test after assembly



Thermal cycling

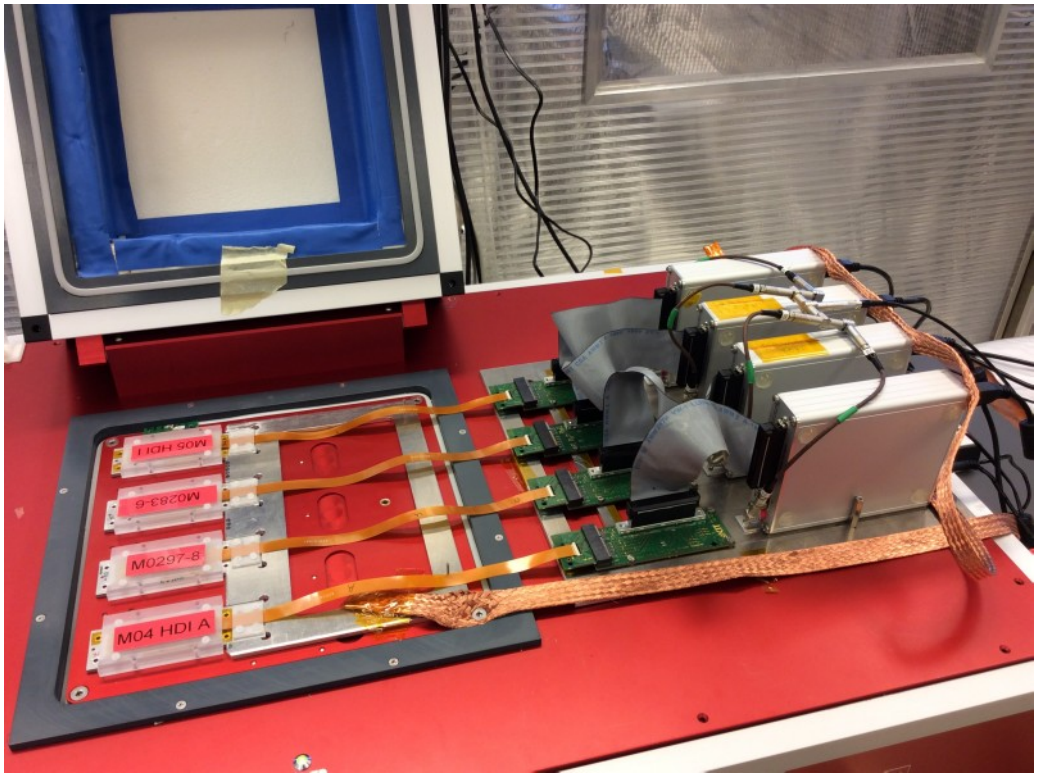
Operating temperatures:

- Sensor max = -5°C
- Cooling = -25°C



Thermal chamber with functional test:

- Thermal cycling (burn-in)
- Measurement of calibration constants at room temperature and -25°C



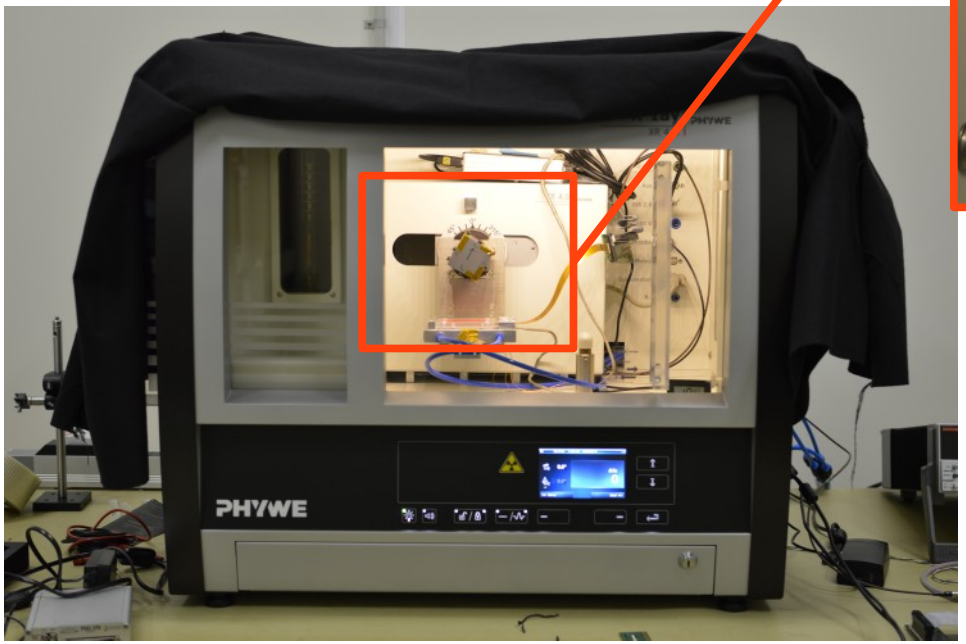
X-ray calibrations

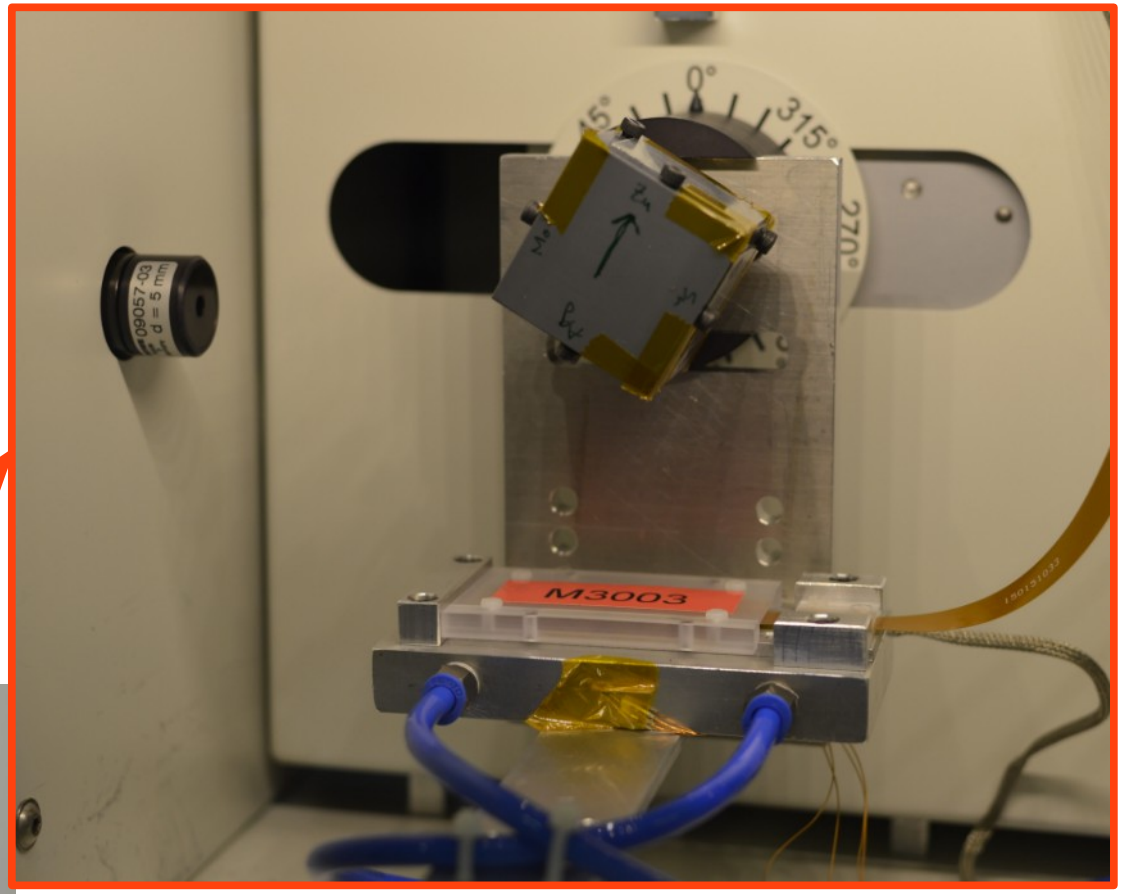
High-rate x-rays

- Tests if each pixel is responding

Secondary x-rays: fluorescent target

- Tests linearity of response
- Records calibration constants





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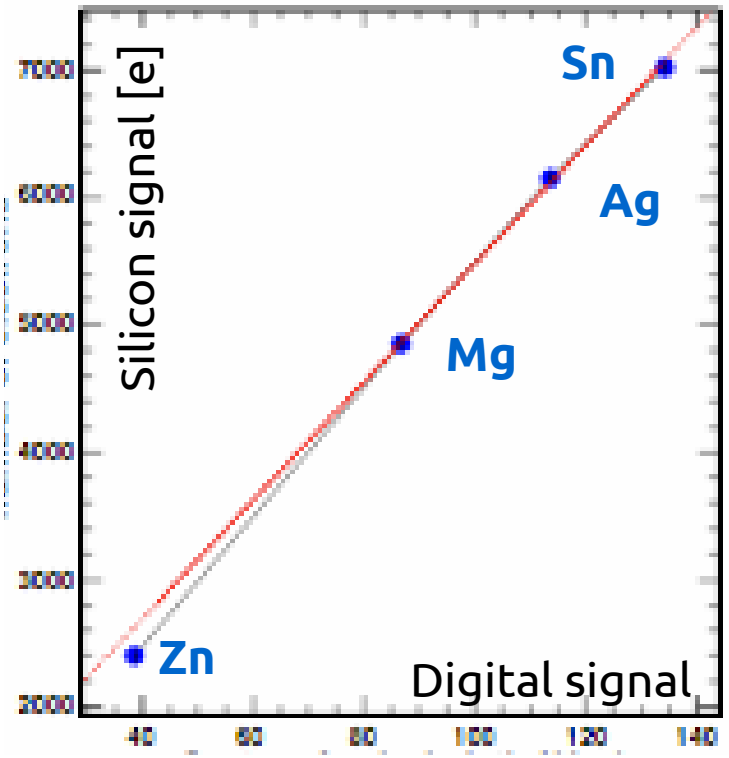
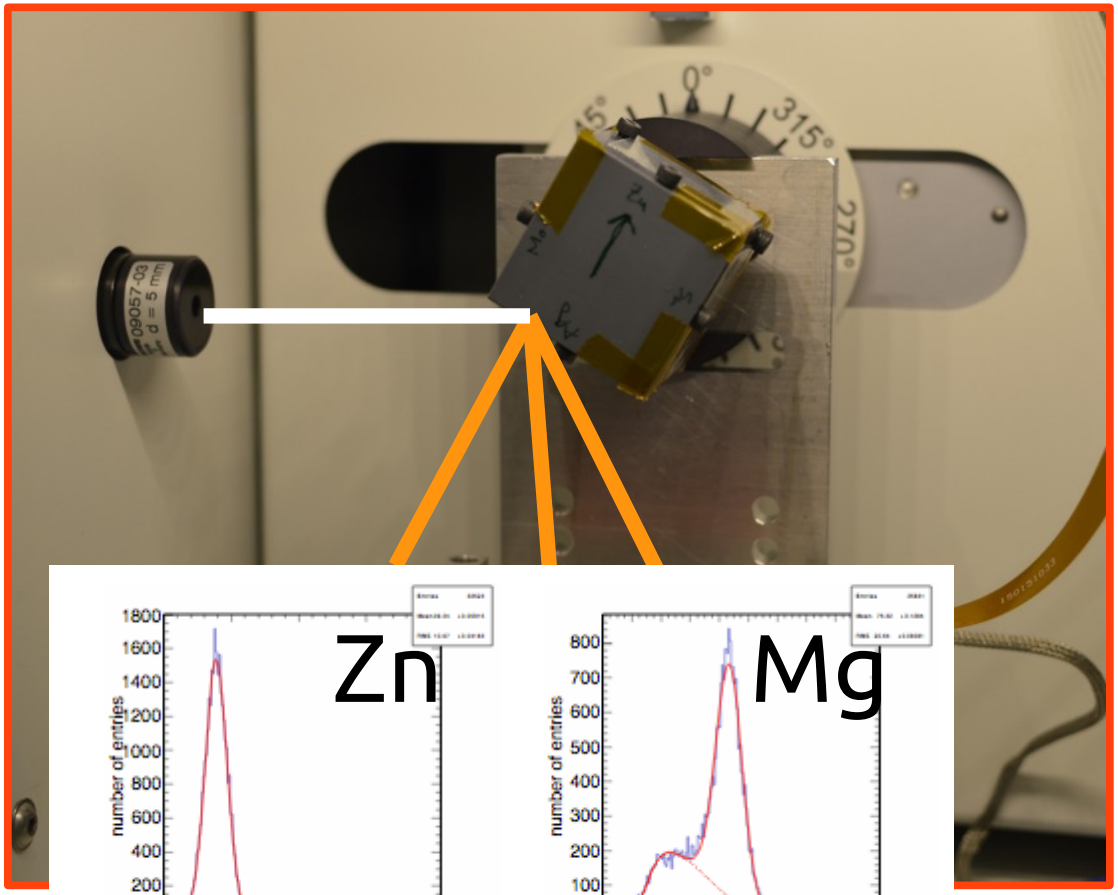
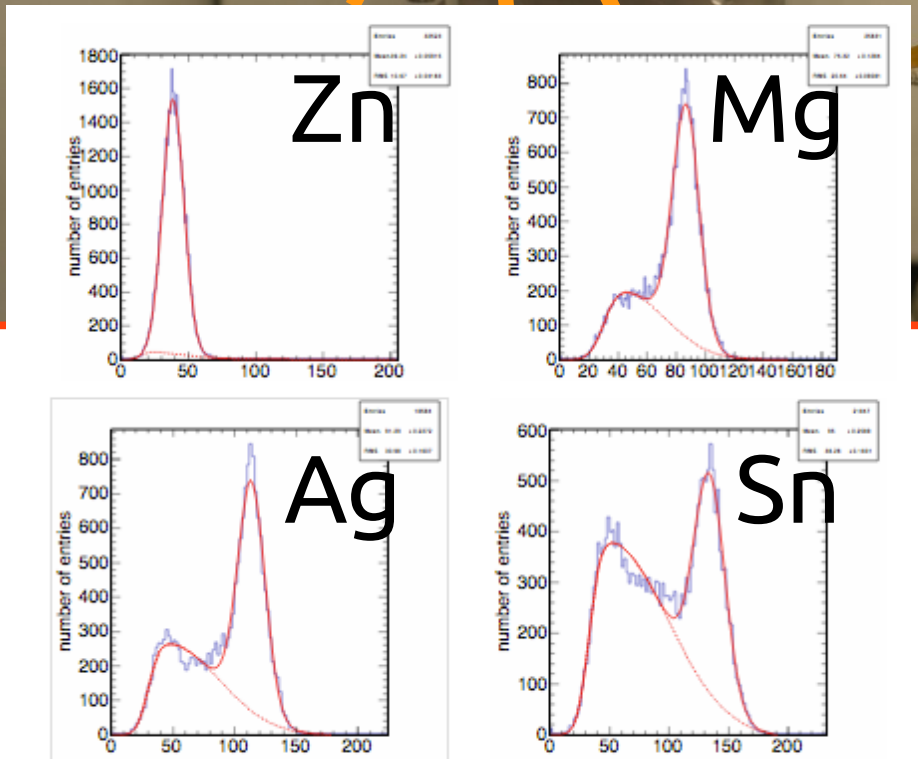




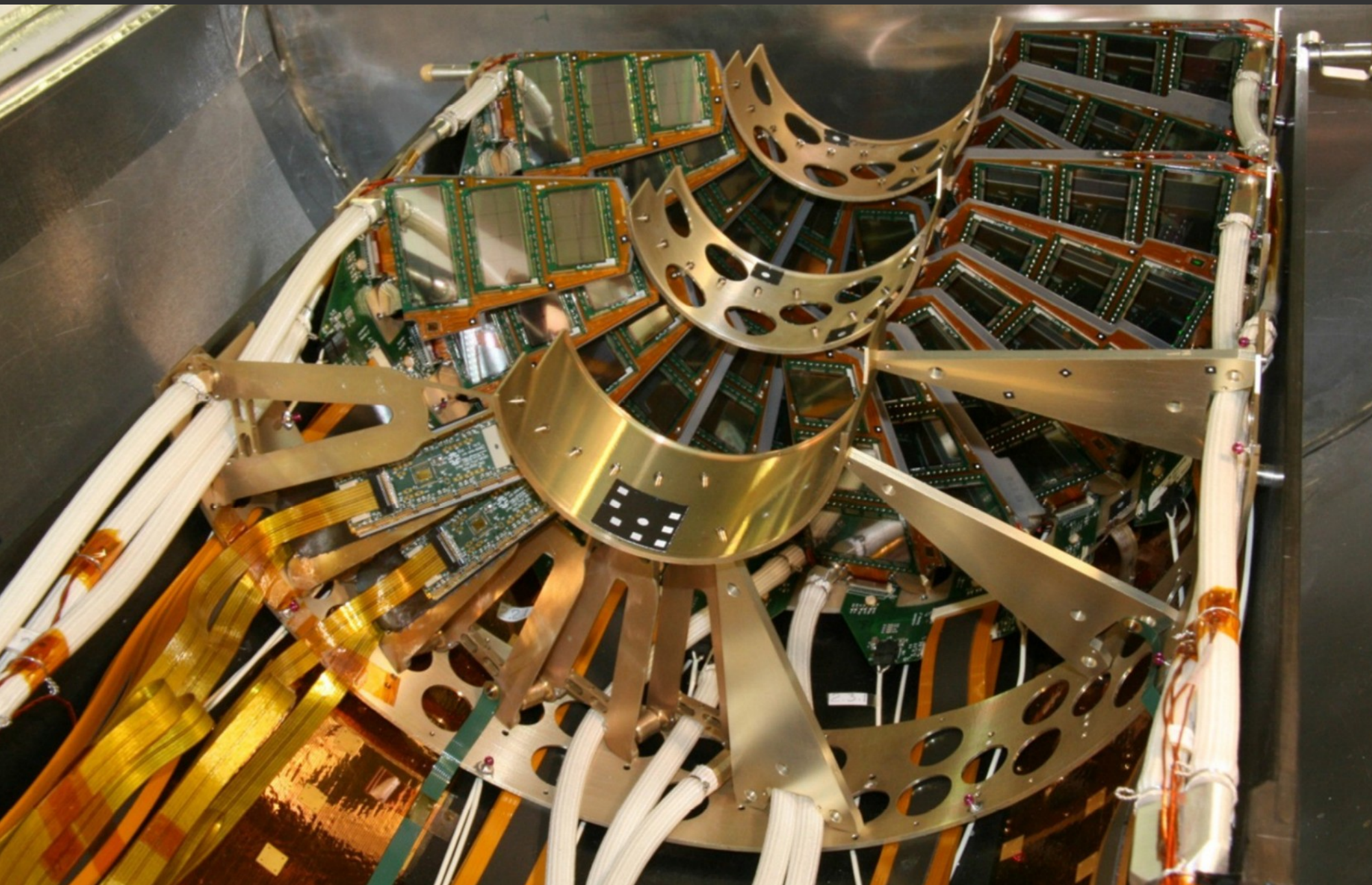


Integration test systems @CERN

- Inside CMS: pilot blade
  - A very realistic... beam test!
  - Small fraction of an upgraded endcap disk
  - Can test integration of DAQ with CMS

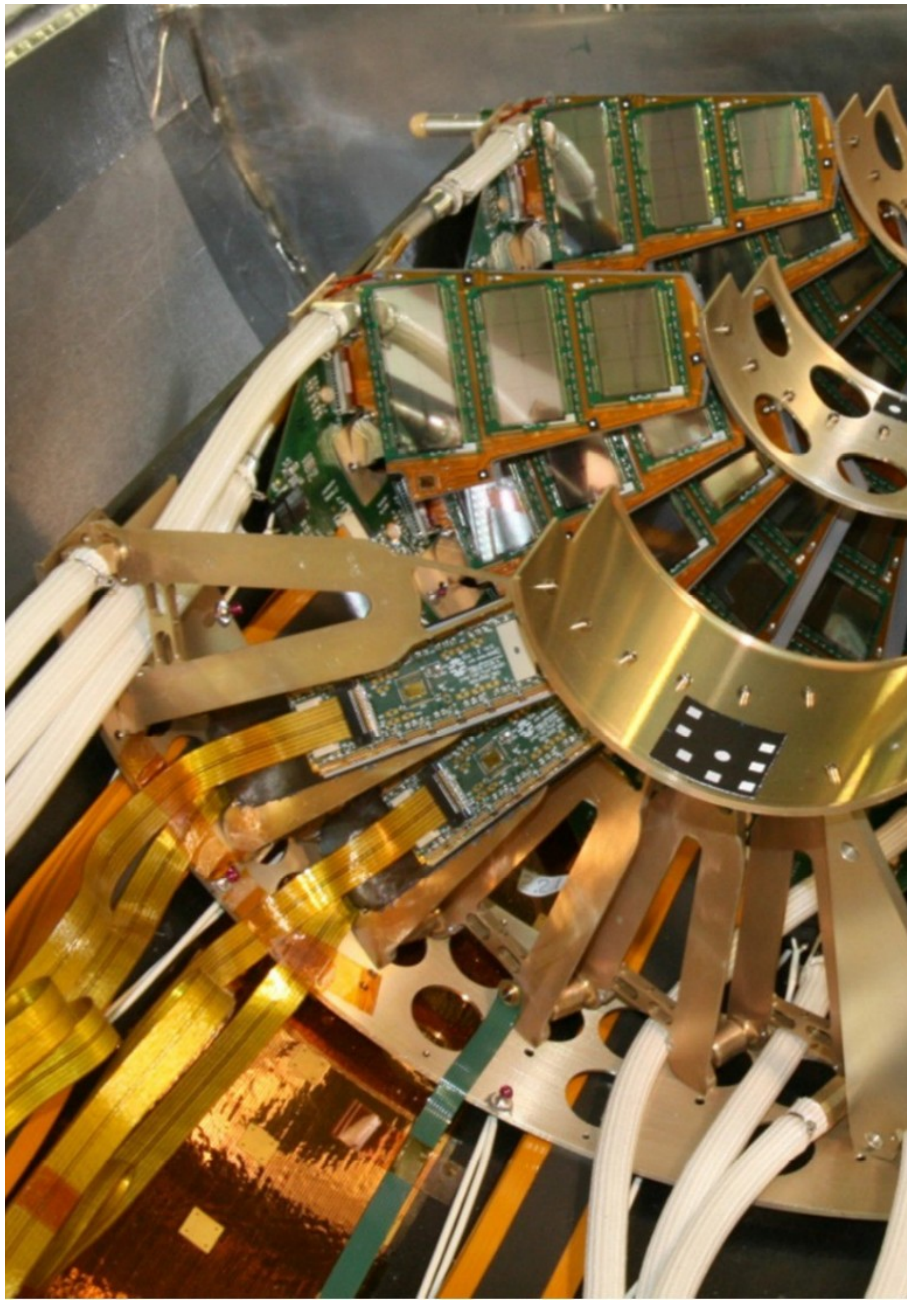
- Building 186 (Monday's visit)
  - DAQ intergation and testing
  - Table-system

Pilot system inside CMS

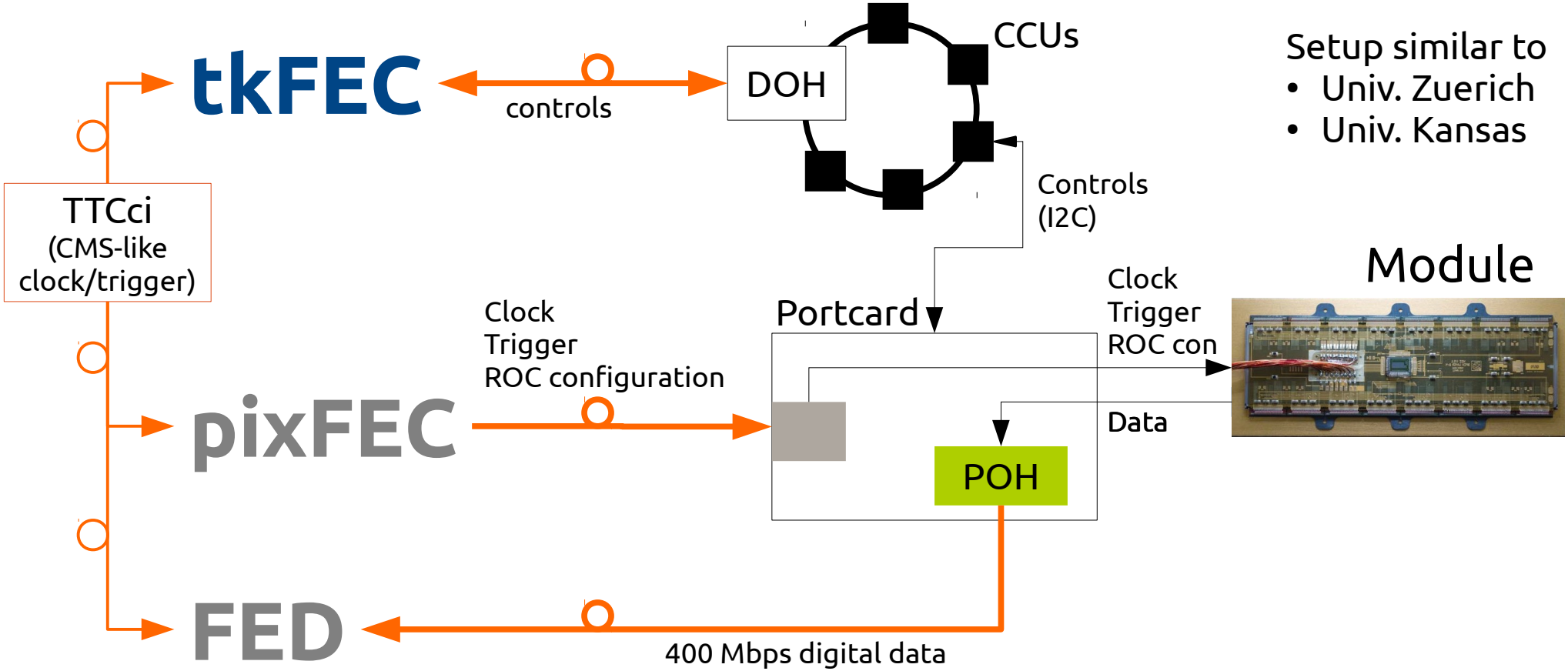


Pilot system

- Current Forward-PIX has room/services for 3 disks, but only 2 have been built
- 8 Phase-1 FPIX modules mounted on 3rd disk
- Exercise and develop detector operation (readout, control, DAQ integration)
- Crucial for seamless transition after upgrade



B186 integration test system



Setup similar to
- Univ. Zuerich
- Univ. Kansas

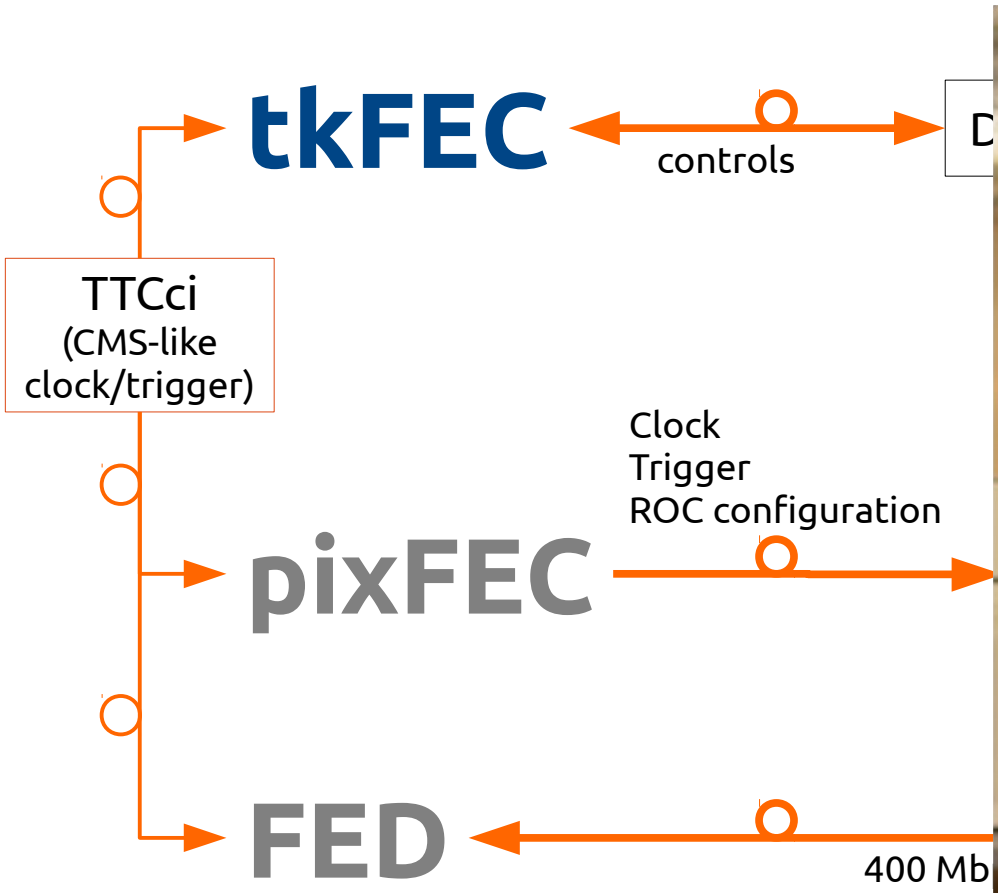
Current status

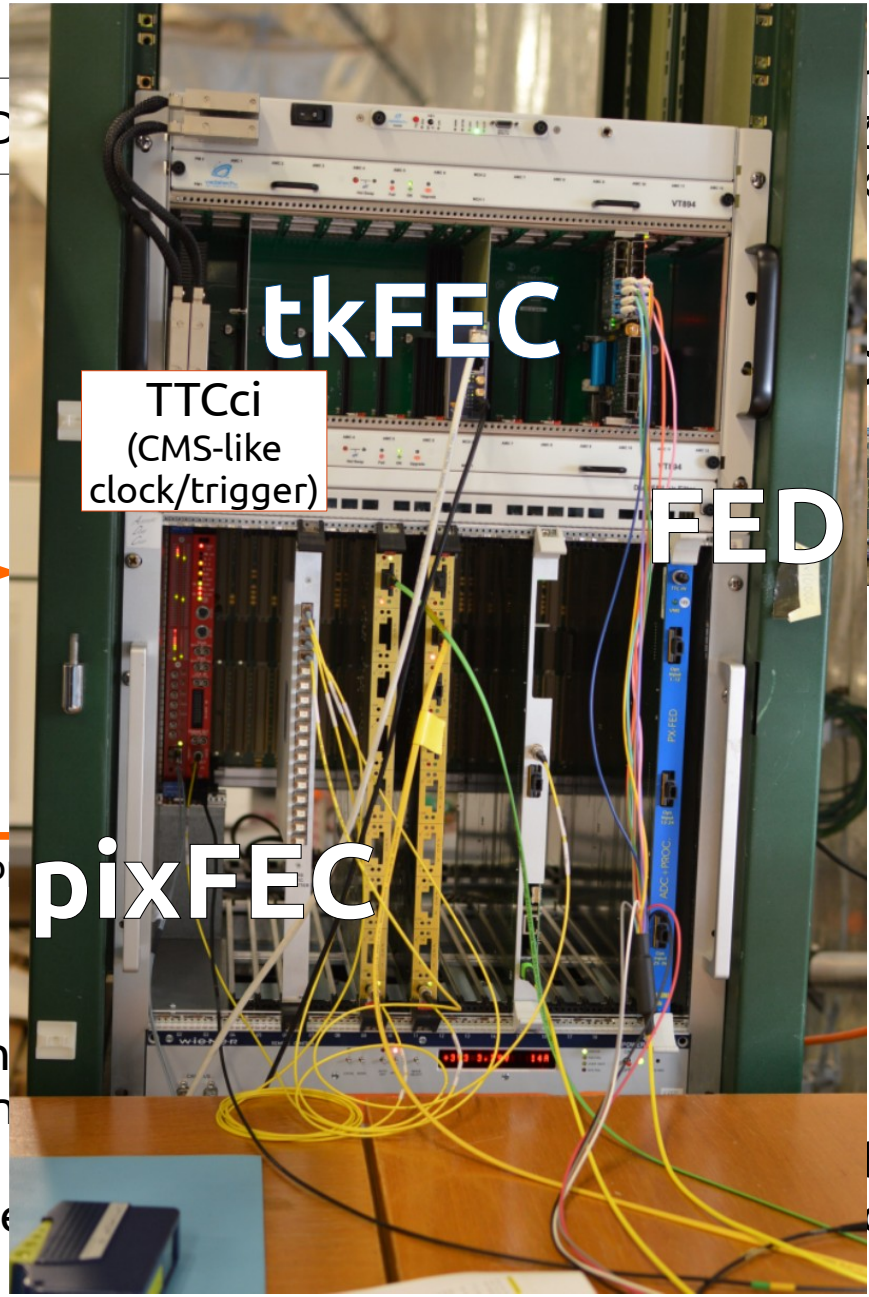
New: µTCA

Old: VME

Software integration tests
Firmware integration tests
Possible to debug the front-end with a scope & probe!
Software development to merge with CMS DAQ code

B186 integration test system





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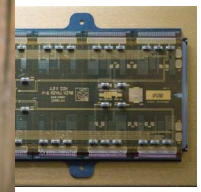

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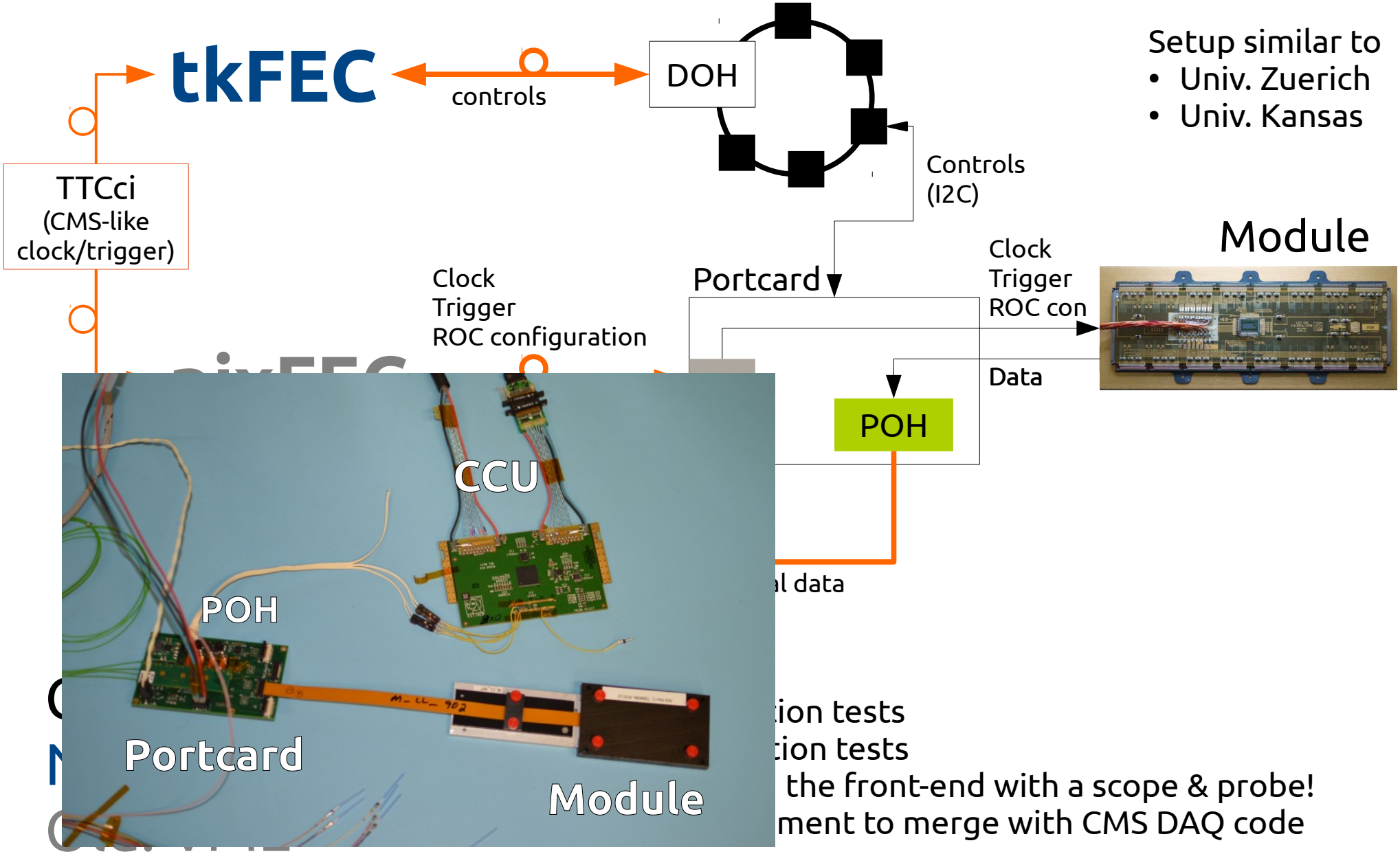

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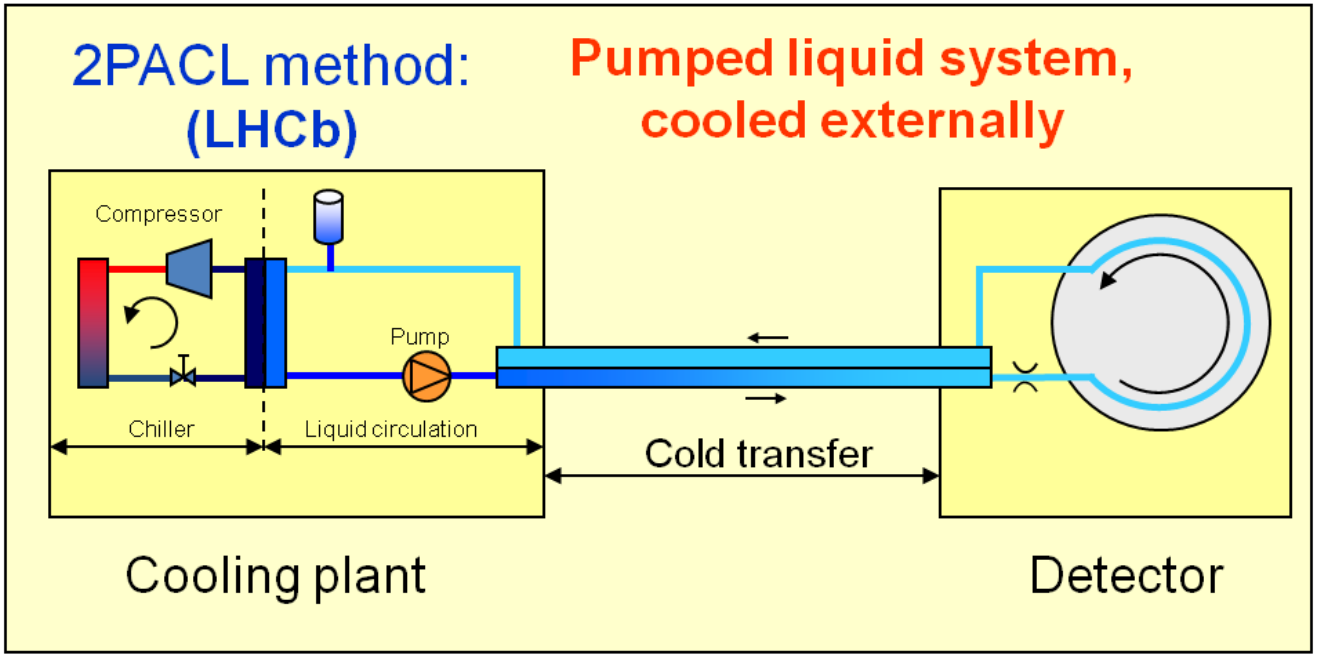
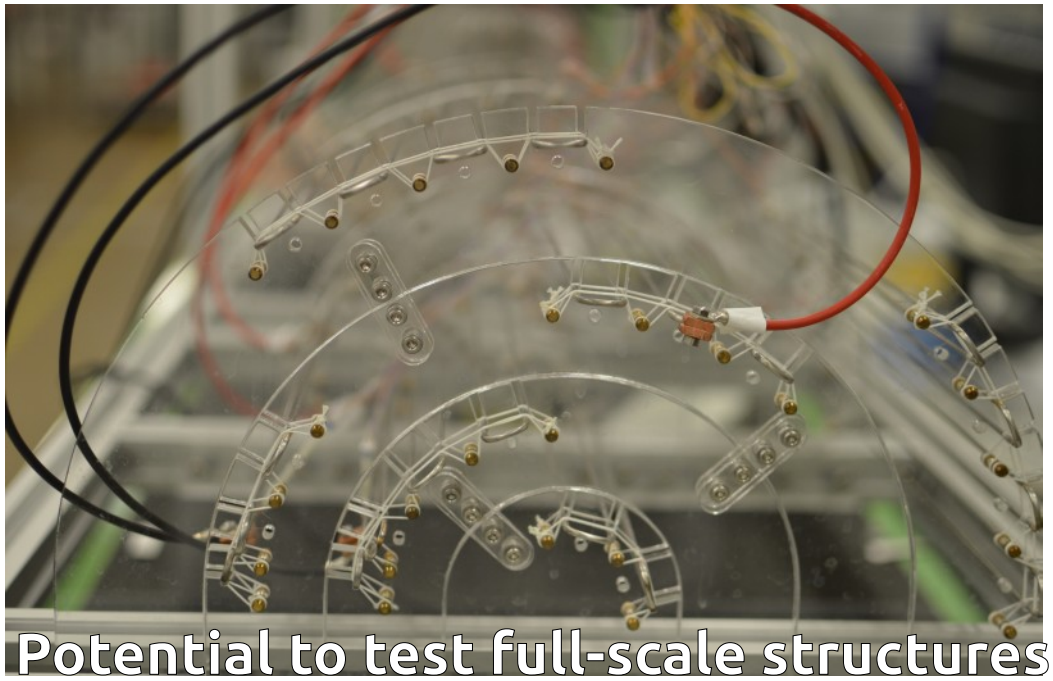
Cooling plant full-scale prototype

Several years of development & construction

- 15 kW plant
- CO_2 evaporative cooling
- Coolant T= -20 °C
- Thin cooling tubes in active region
  - 50 um wall (steel)
  - 80 bar





Next: testing of large structures

- As soon as possible, putting together a full shelf of µTCA boards
- Building the system control/monitoring/safety
- Assessing system stability over time
- Software integration with current DAQ & performance/scalability test

Whole system FED+FEC = ~100 new µTCA boards

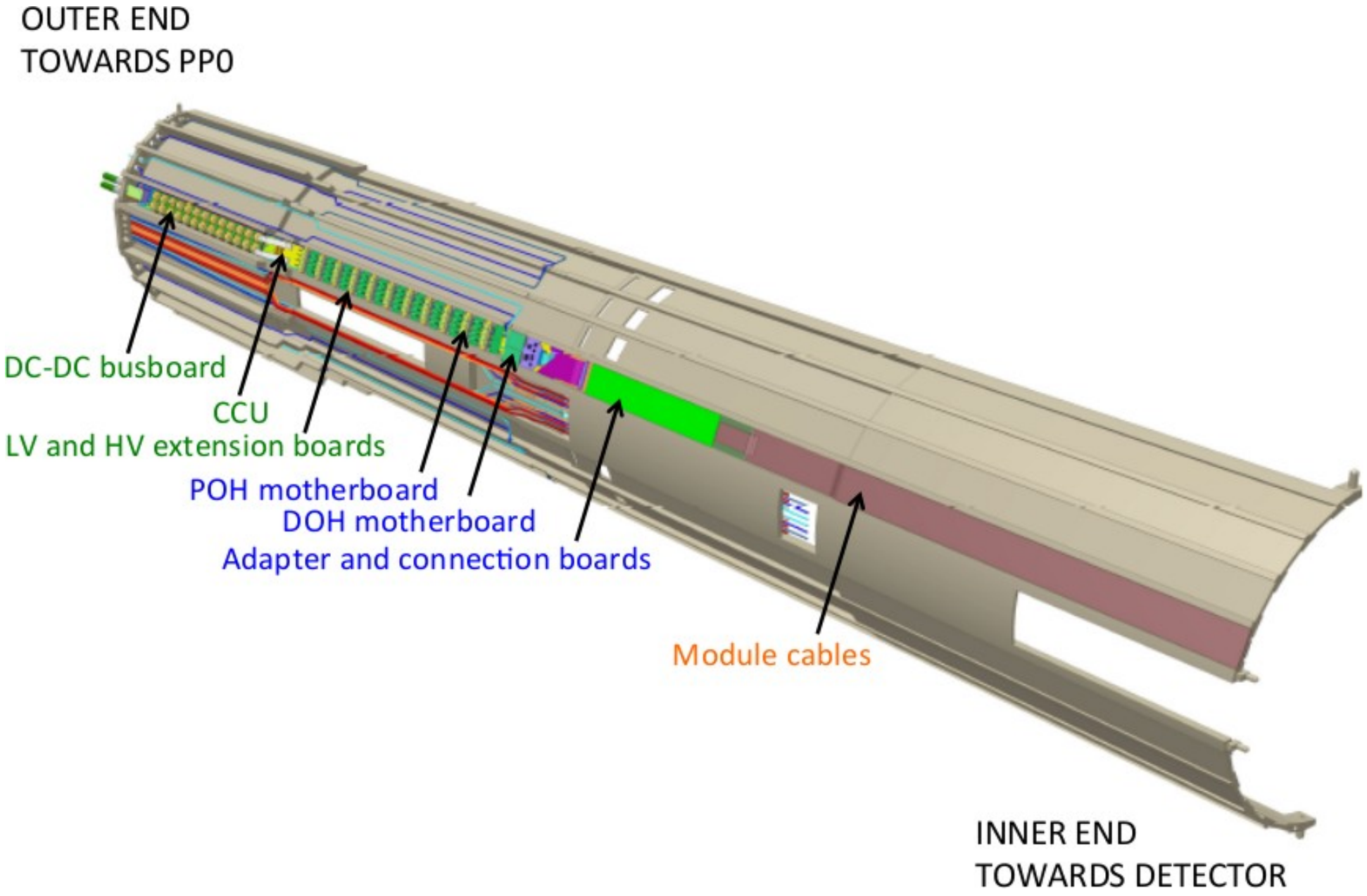
  - Long-term tests
  - Progressively integrate towards the full scale of final DAQ system

Conclusion and outlook

- CERN hosting a number of production/testing activities in Building 186:
  - Design and construction of cooling plants
  - Module assembly and qualification
  - Integration of DAQ systems
- In the near future, all these activities will converge towards:
  - Testing large-scale systems
  - Detector installation/commissioning at CMS

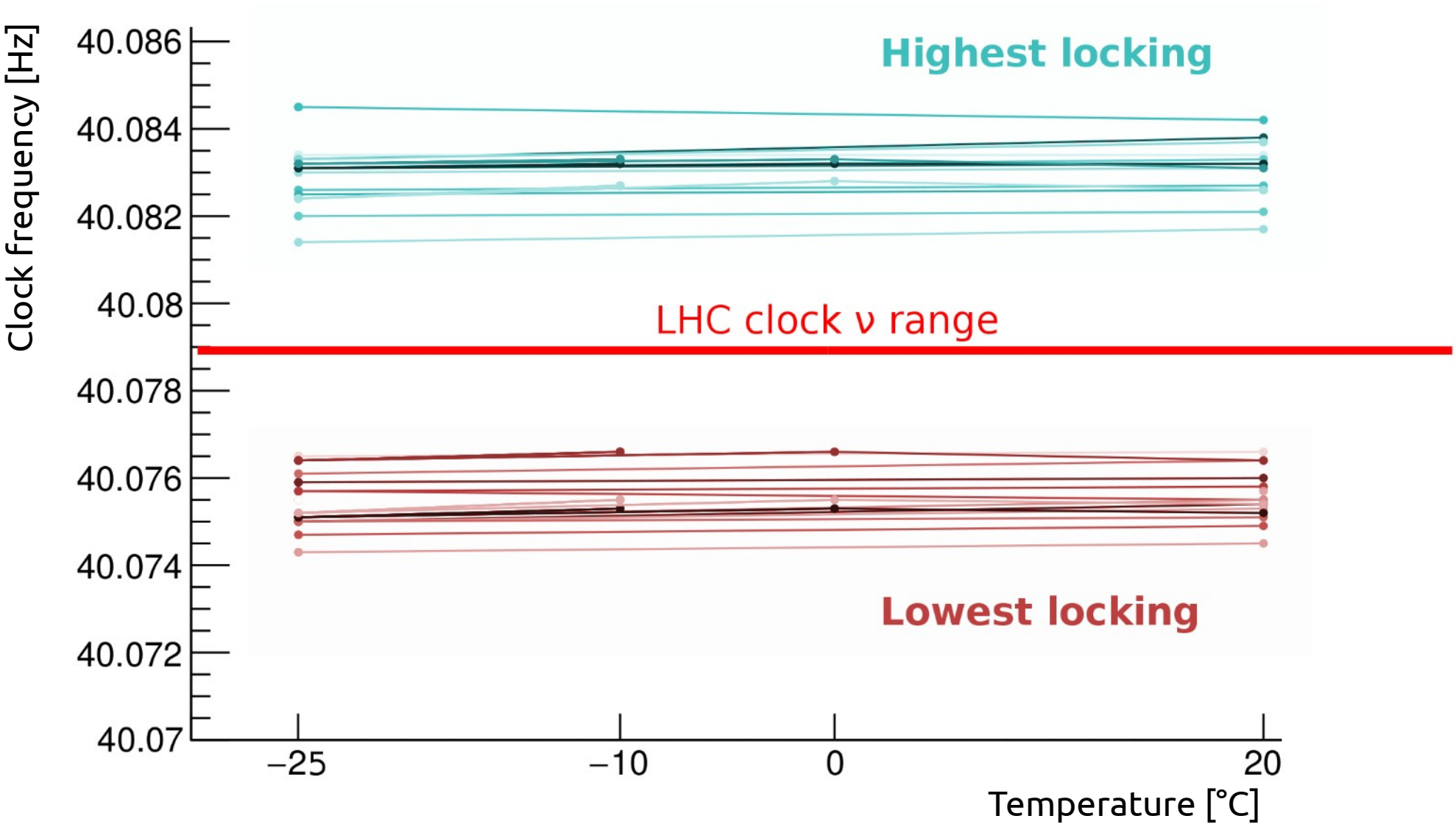
Questions?

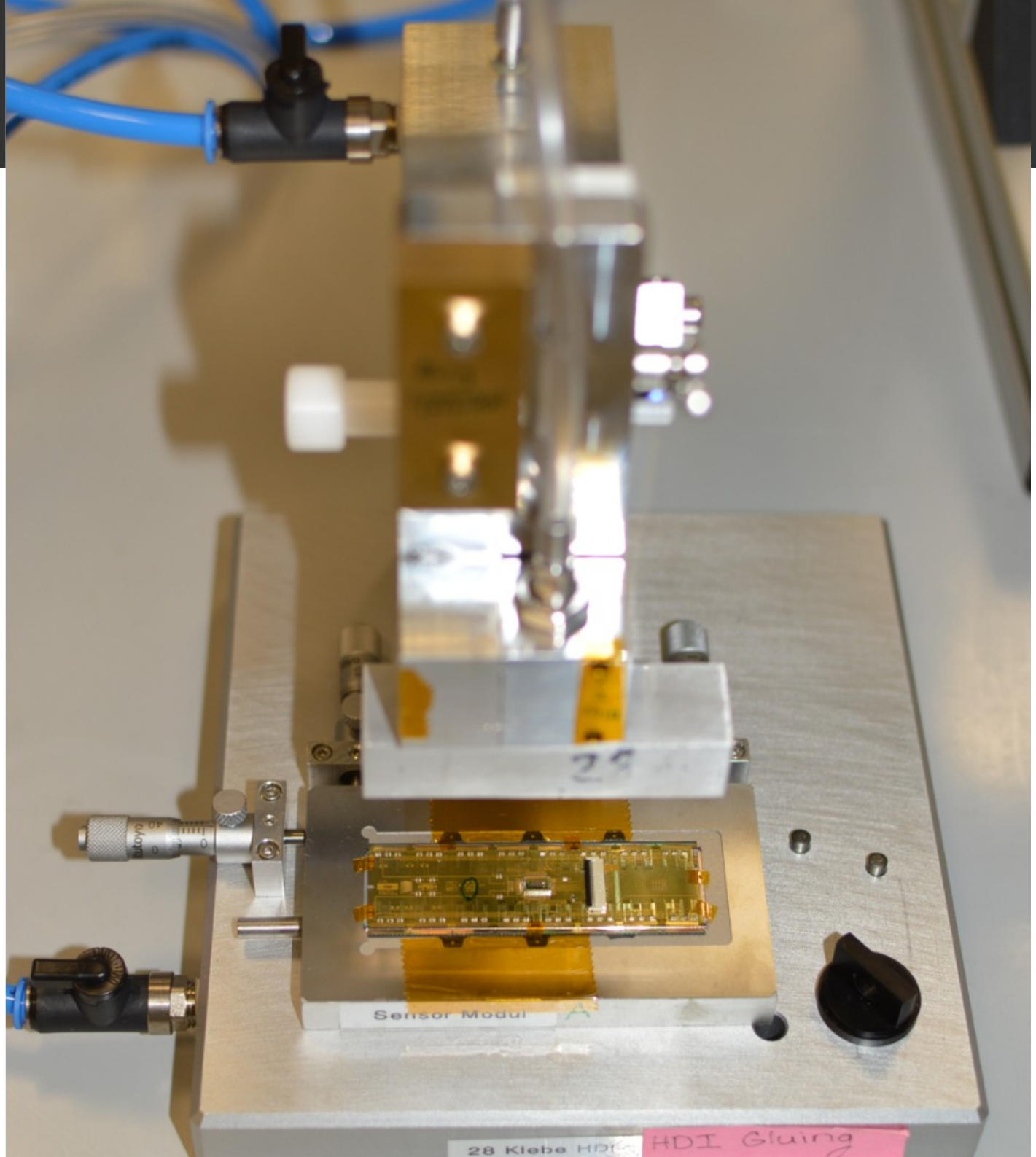
Backup slides



Q-PLL qualification: locking range

48 Q-PLLs, before irradiation




Sensor Modul
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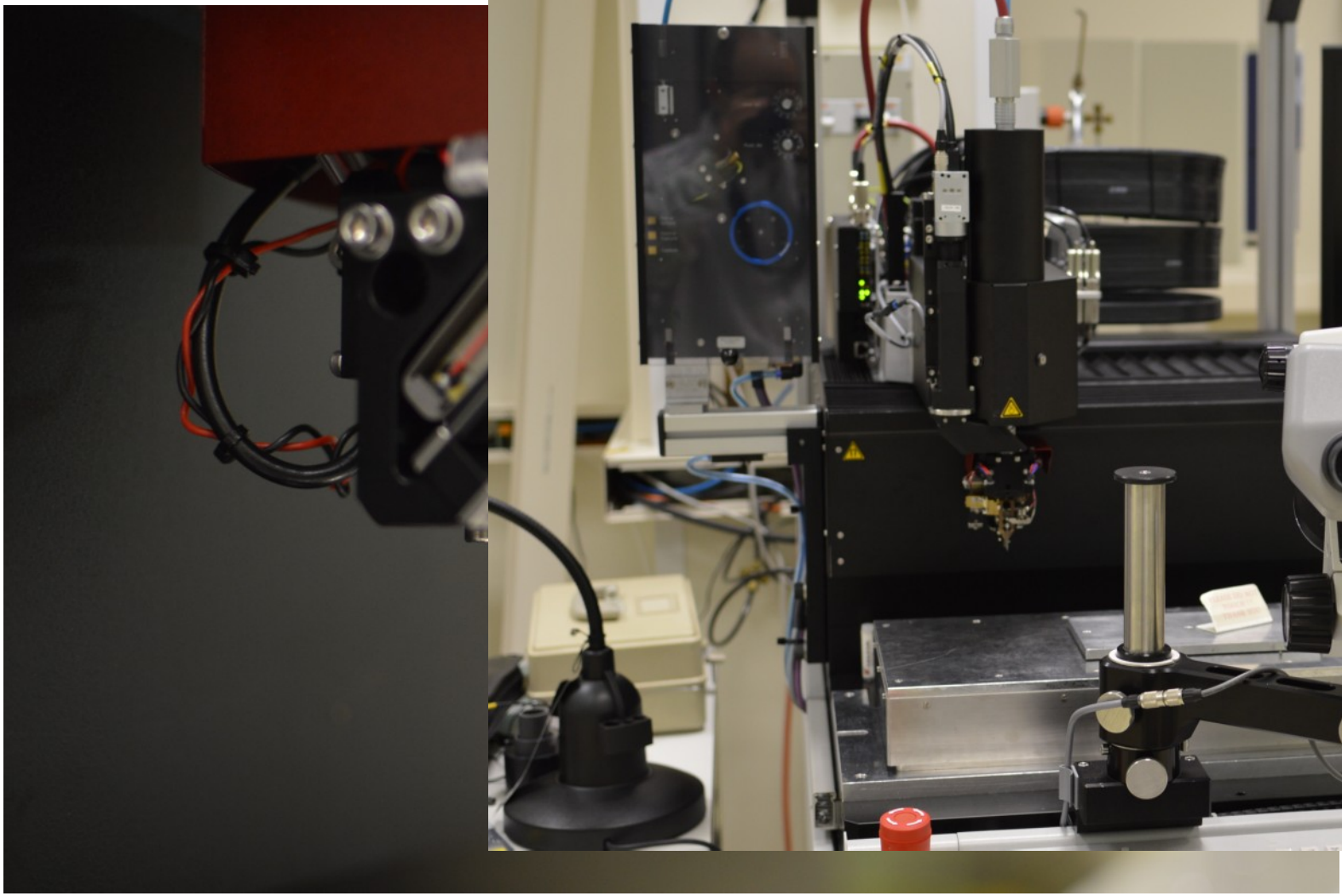
HDI Gluing



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