Readout electronics and test bench for the CMS Phase I pixel detector

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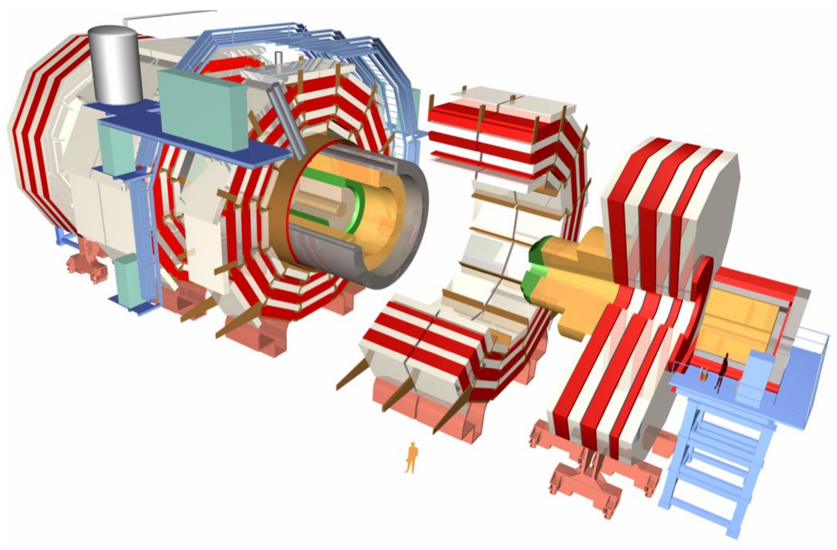
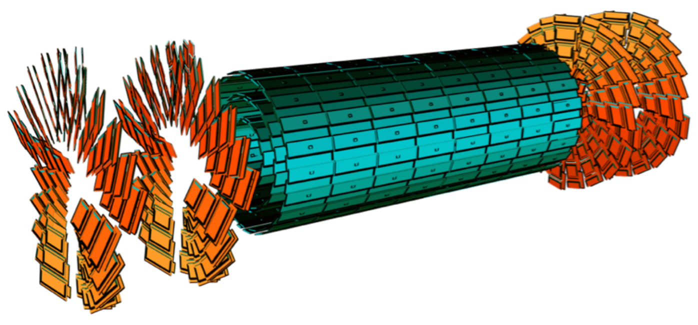
CMS and the pixel detector phase I upgrade



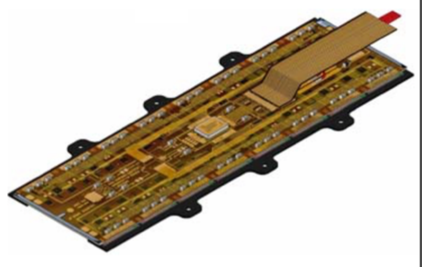
CMS detector

CMS is a complex detector comprising different sub-systems, each designed to perform a specific task. The innermost of them is the pixel detector, which provides spatial information with high resolution close to the interaction point (IP). The chosen technology to work in such a harsh environment is silicon detector. With 66 millions channels, the detector has shown excellent performance during Run I.



Current CMS pixel detector. In orange the forward region (FPix) and in blue the barrel region (BPix).

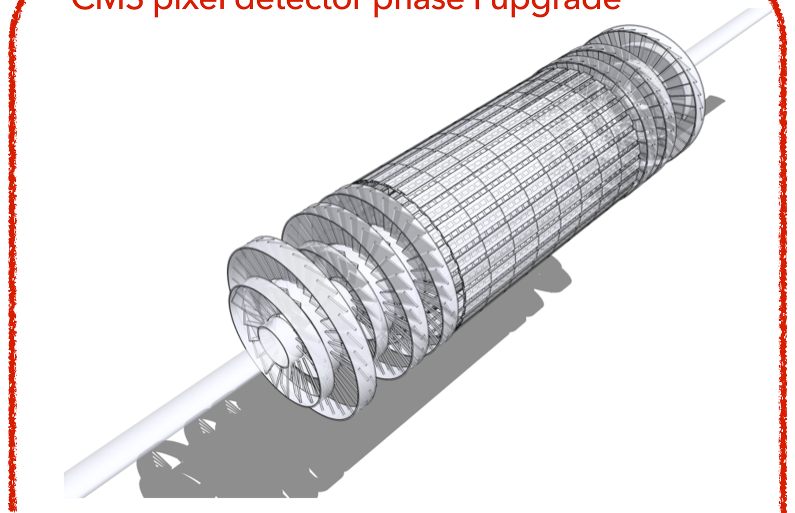
Beam pipe and half of the pixel detector

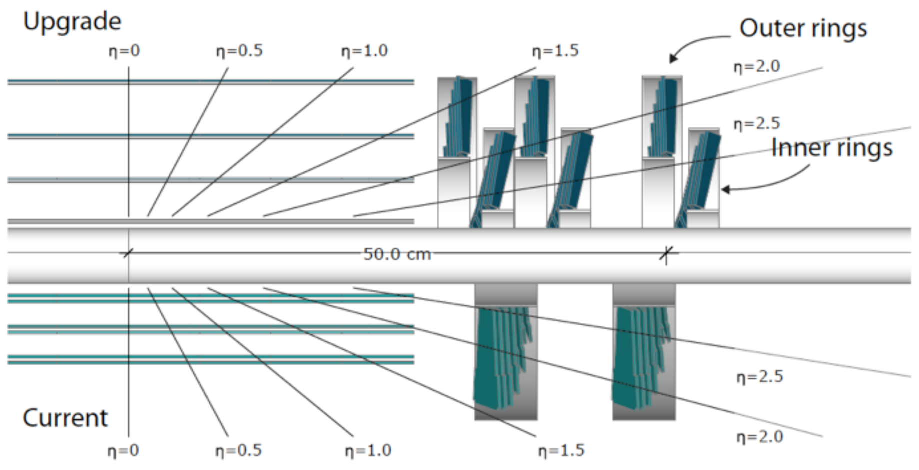


Pixel module

During Run II LHC reached 13 TeV centre of mass energy and a luminosity above the design value of $1.0 \cdot 10^{34}$ $cm^{-2}s^{-1}$. During Run III LHC plan is to double the luminosity. By the end of this year there will be a technical shut down, in this period the new pixel detector will be installed to maintain the excellent level of performance under the new beam parameter.

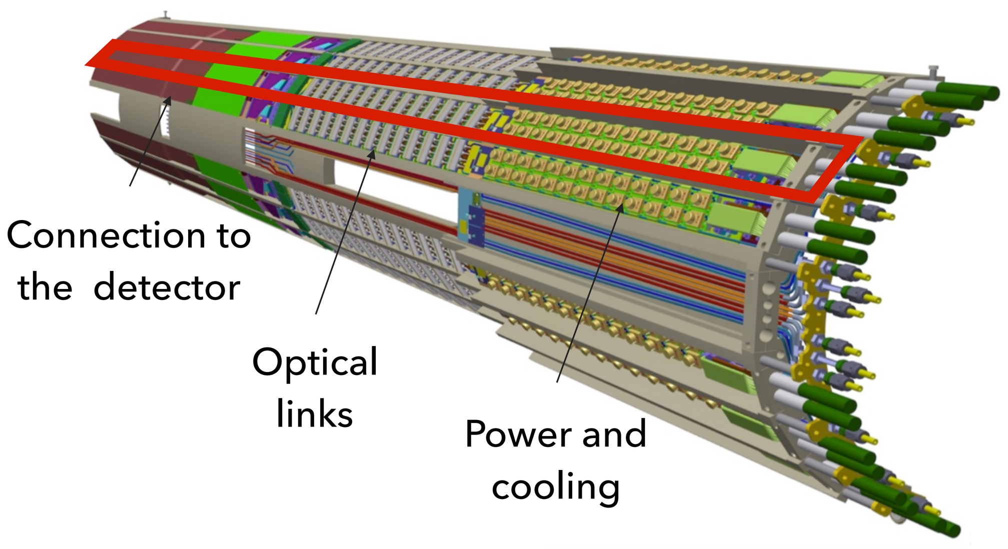
CMS pixel detector phase I upgrade





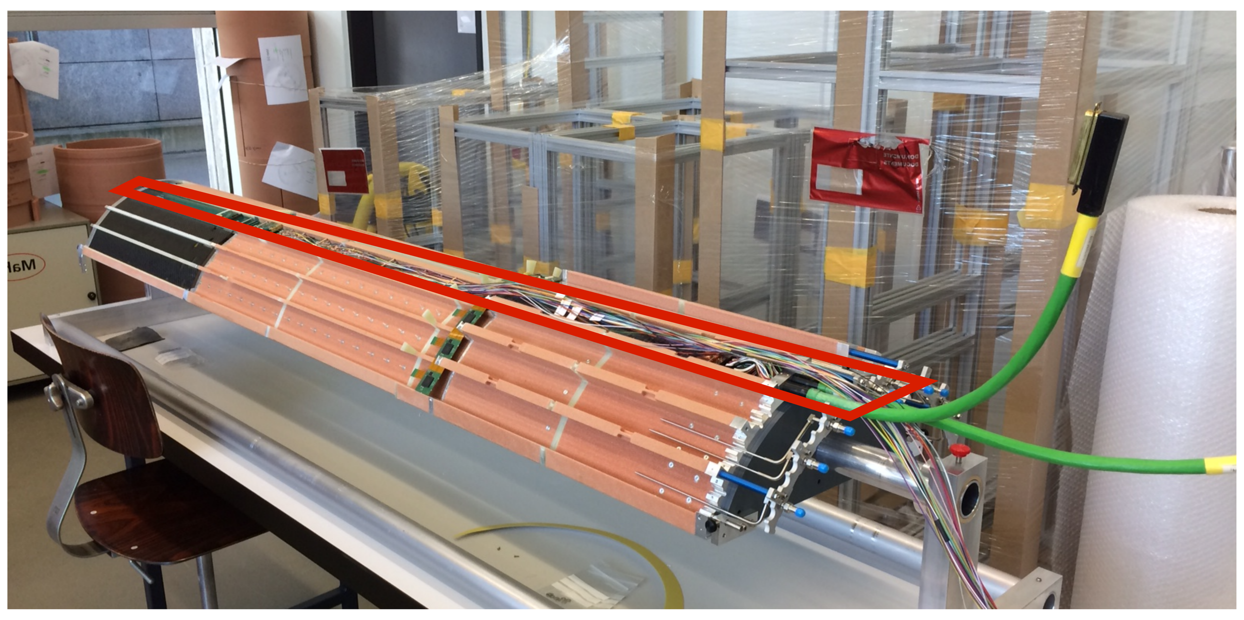
Pixel detector layout: current and upgrade

- 3 → 4 barrel layers
- 2x2 → 2x3 endcap disks
- Robust vertex reconstruction at large pileup
- Improved track seeding



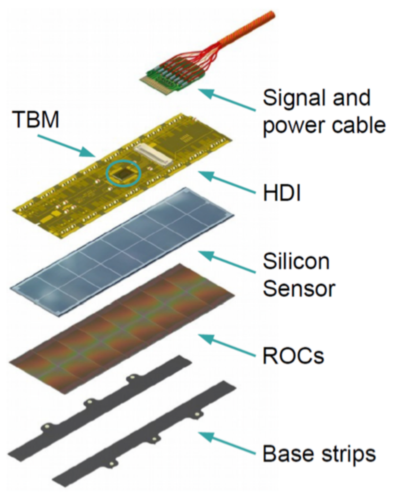
New read out electronic for the barrel layers on one of the four supply tube (ST). Each ST is divided in 8 sector, marked in red.

- New read out electronics moved to higher η
- Ultra-light mechanical support structure
- New CO2 cooling system
- Less multiple scattering
- Less photon conversion
- Improved impact parameter resolution



Supply tube with one sector equipped with electronics and fiber, UZH

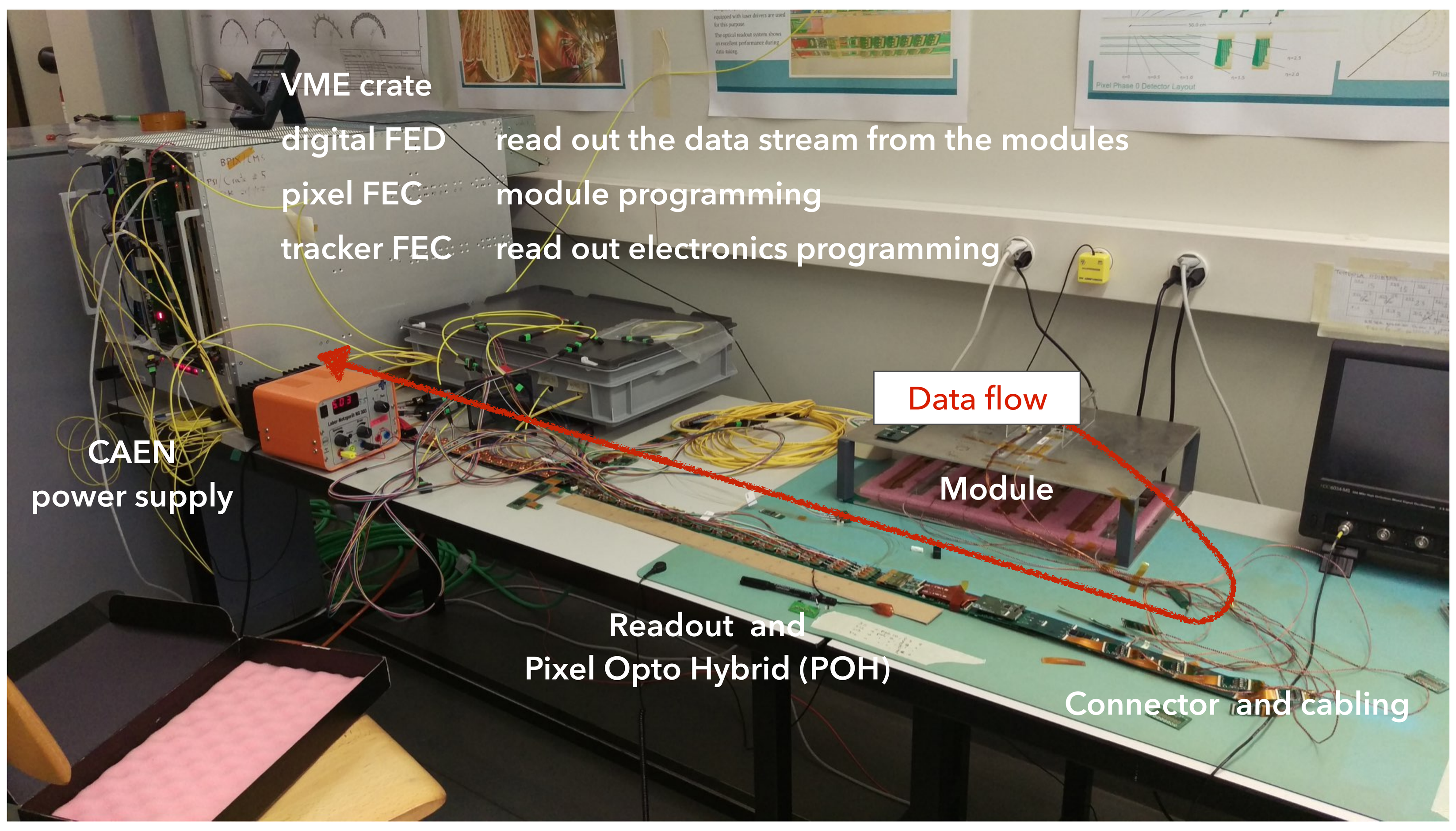
Pixel module



Pixel module exploded

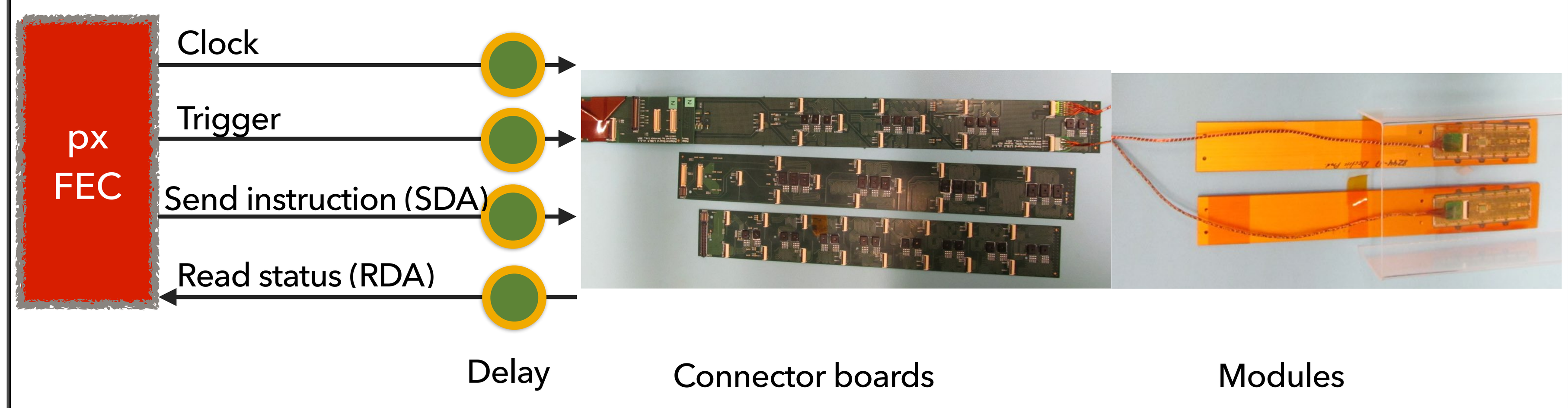
- New digital readout chip
- Faster readout (400 Mbit/s)
- Increased buffer size
- Reduced dead time
- Reduced dynamic data loss

Test bench and testing procedure

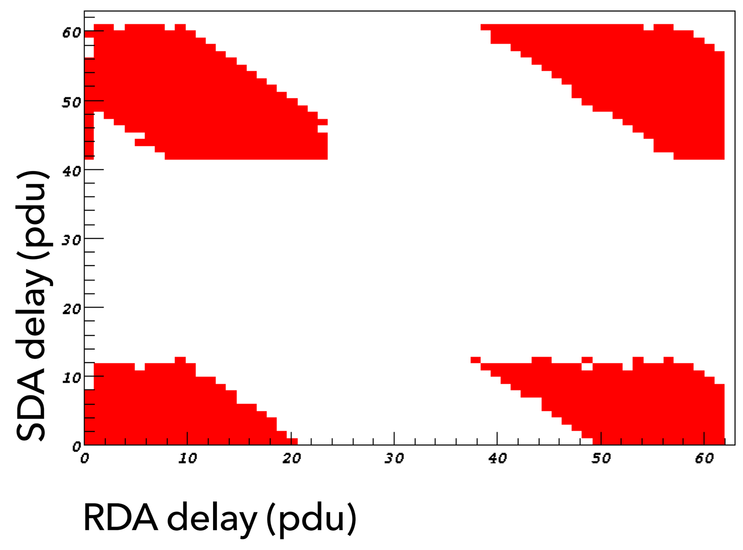


Test bench at UZH. The setup consist in one sector equipped with the readout electronic and a number of modules, the power supply and the control system . Up to 39 modules from 4 different layers can be connected on a single sector.

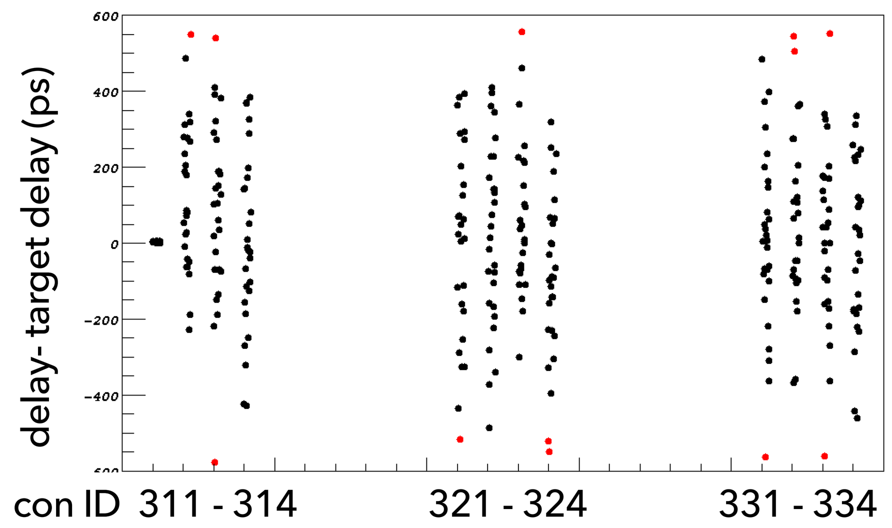
TEST: module programming and trigger timing



It is possible to adjust the delay between the clock, the SDA and RDA channels to find a range in which we can program the module. The trigger delay among different connectors is measured and adjusted with a maximum tolerance of 500 ps.



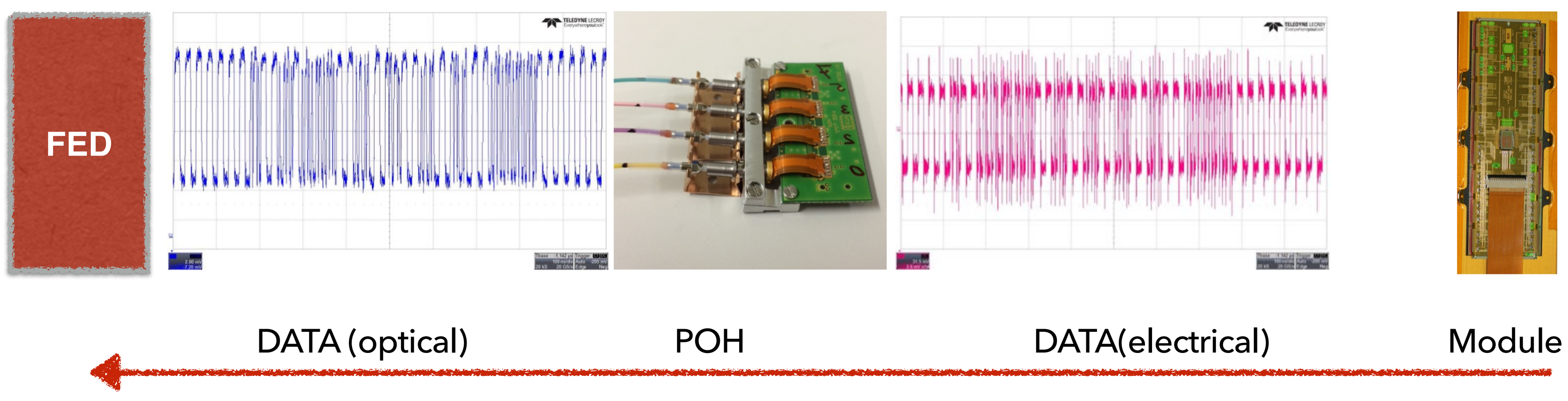
SDA RDA delay scan, the regions in red allow a correct programming of the module.



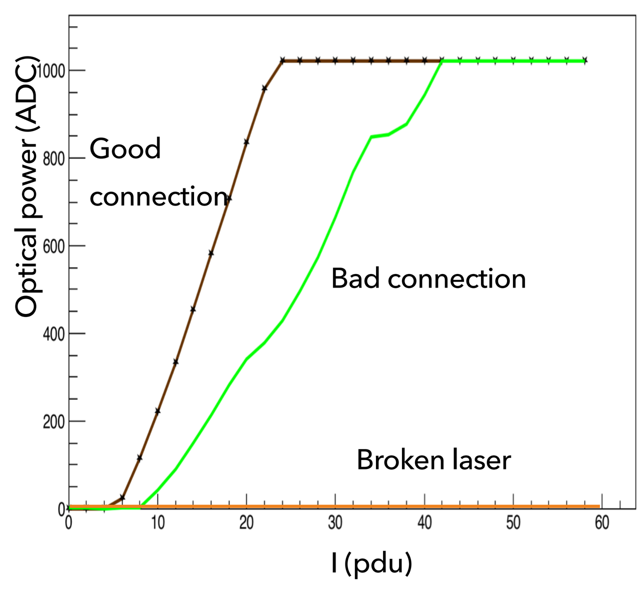
Trigger delay minus target time for 28 layer 3 boards with 12 connectors. In red the connectors that need to be adjusted.

TEST: data transmission

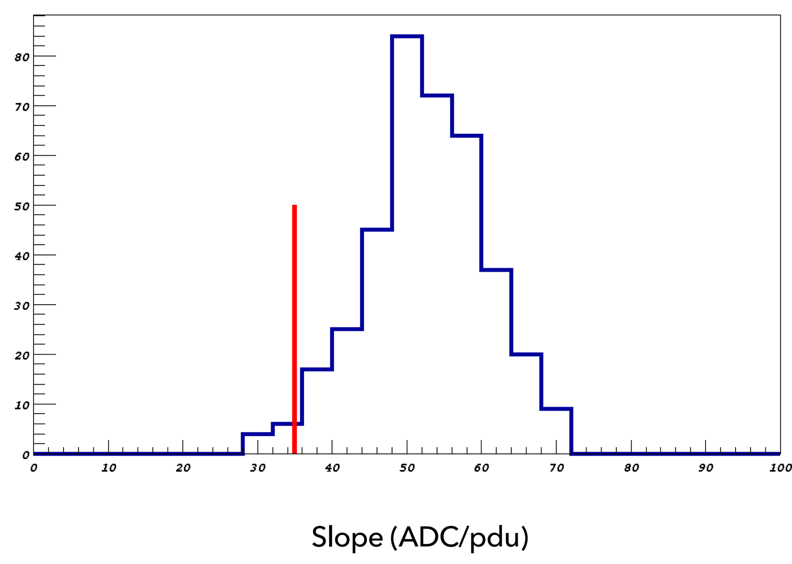
Each POH hosts four laser diodes and converts the signal from electrical to optical.



Measuring the laser optical power as a function of the supply current allow us to test:
diodes functionality   optical fibres   quality of optical connections
After that we test the digital data transmission using real data from the module



Laser optical power as a function of the supply current for three different cases.



Slope distribution for 96 POH's. In red the minimum slope cut-off is shown.

Conclusion

The new pixel detector will maintain the current excellent performance with increased luminosity. The testing setup is allowing a smooth and reliable testing procedure before the final installation, with a number of different tests for all the elements of the readout chain. The testing is ongoing and until now the performance of the tested electronics matches the expected standard with a low rejection rate and an excellent resiliency to handling.

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