Testing the new electronics of the CMS phase I upgrade pixel detector

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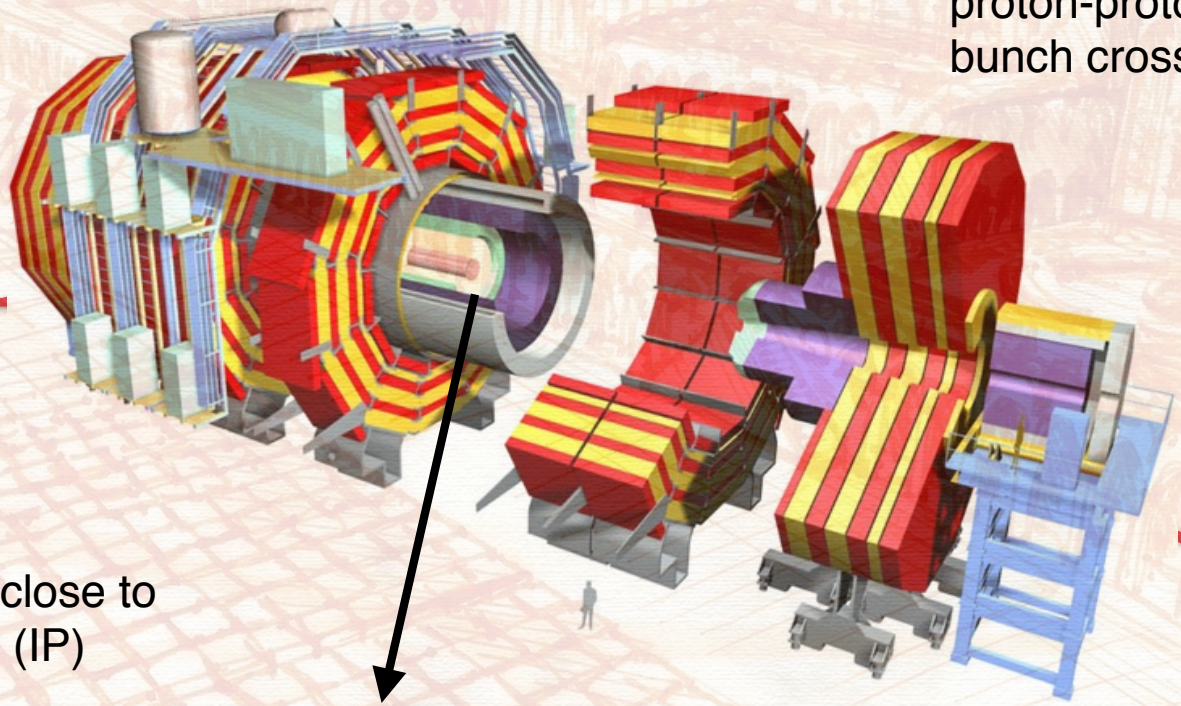
PhD seminar 24 November 2016

LHC and CMS

p-p collision
13 TeV at nominal luminosity
25 ns bunch spacing

expected average of ~ 25 proton-proton collisions per bunch crossing (pileup)



proton beam

proton beam

High particle fluxes close to the interaction point (IP)

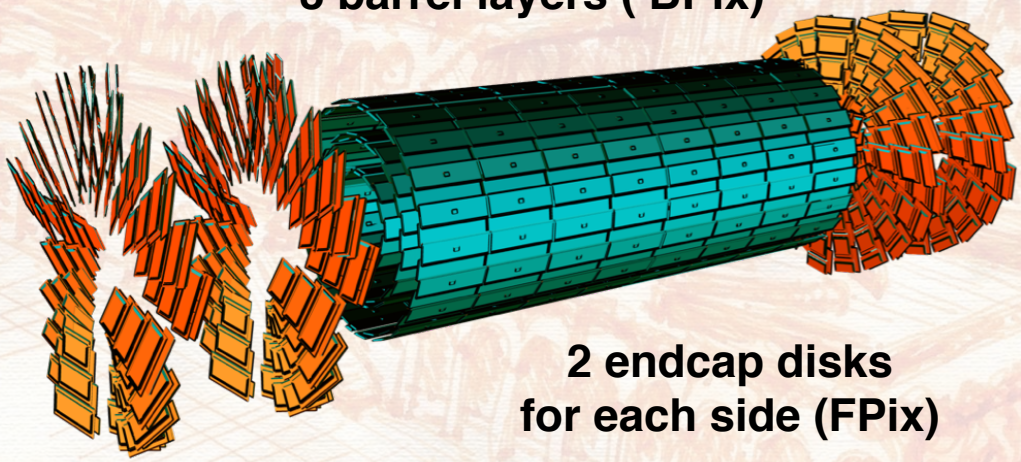
The Pixel Detector is the innermost detector

CMS Pixel Detector

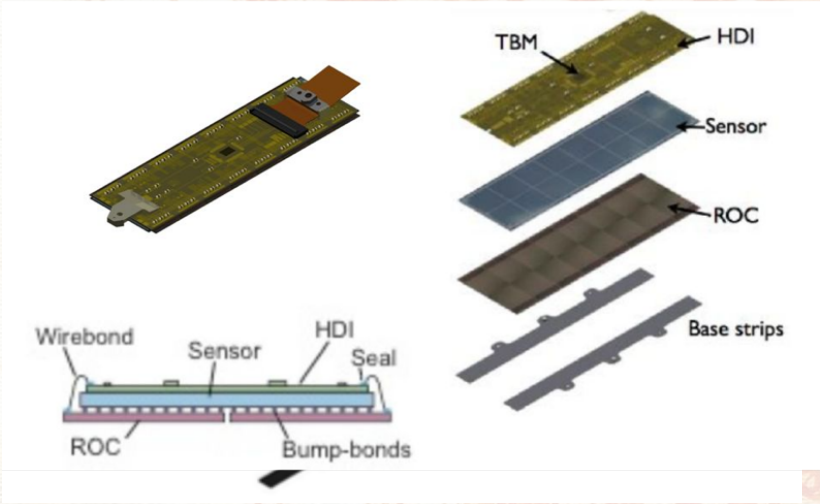
Feature and purpose:

- Reconstruct the track of particles with high precision(res ~10μm)
- High tracking efficiency
- Efficient tagging of long lived particle
- Primary vertex and impact parameter measurement
- Provide seeds for track reconstruction

3 barrel layers (BPix)



2 endcap disks for each side (FPix)



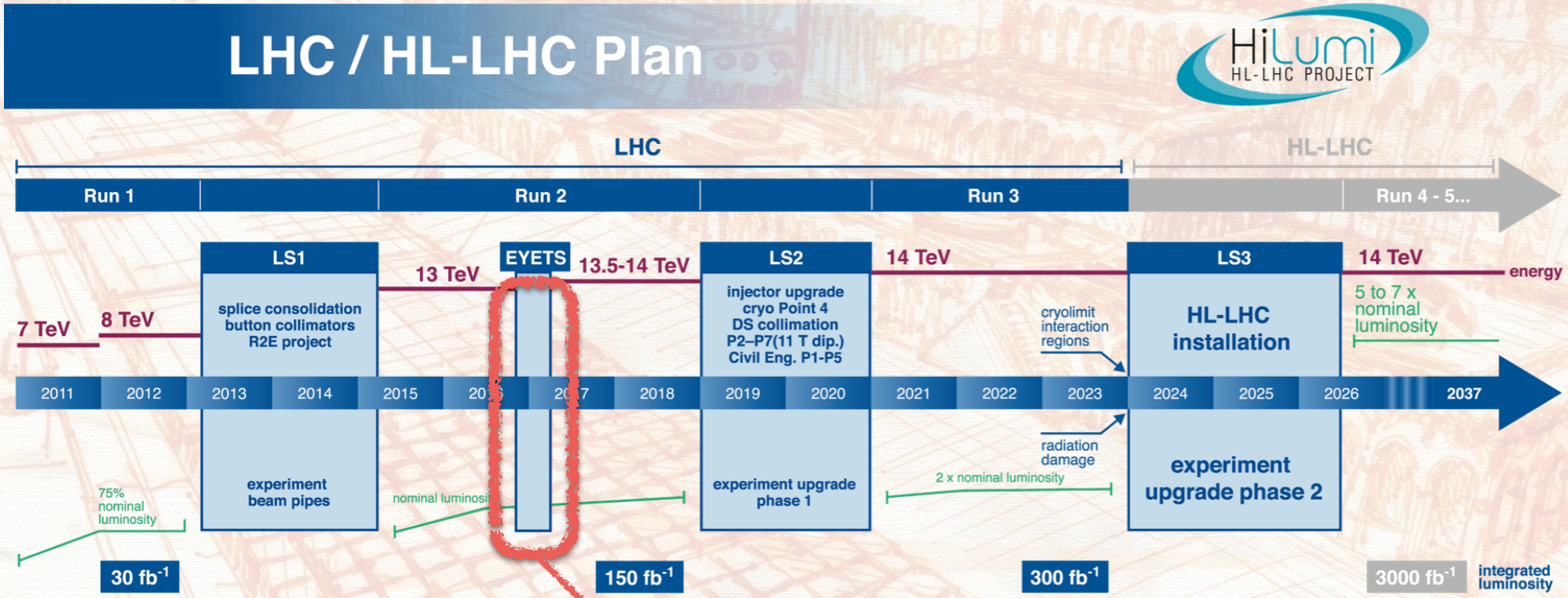
Layout:

- 3 layer in the barrel region (r: 4 - 7 - 11 cm)
- 2 disk for each side in the forward region

Pixel Module Sensor:

- n+ on n silicon bulk 100μm x 150μm
- 16 Read Out Chips (ROC) per module
- Each ROC serves a 52x80 pixel matrix
- 56 millions pixel

LHC/HL-LHC Plan

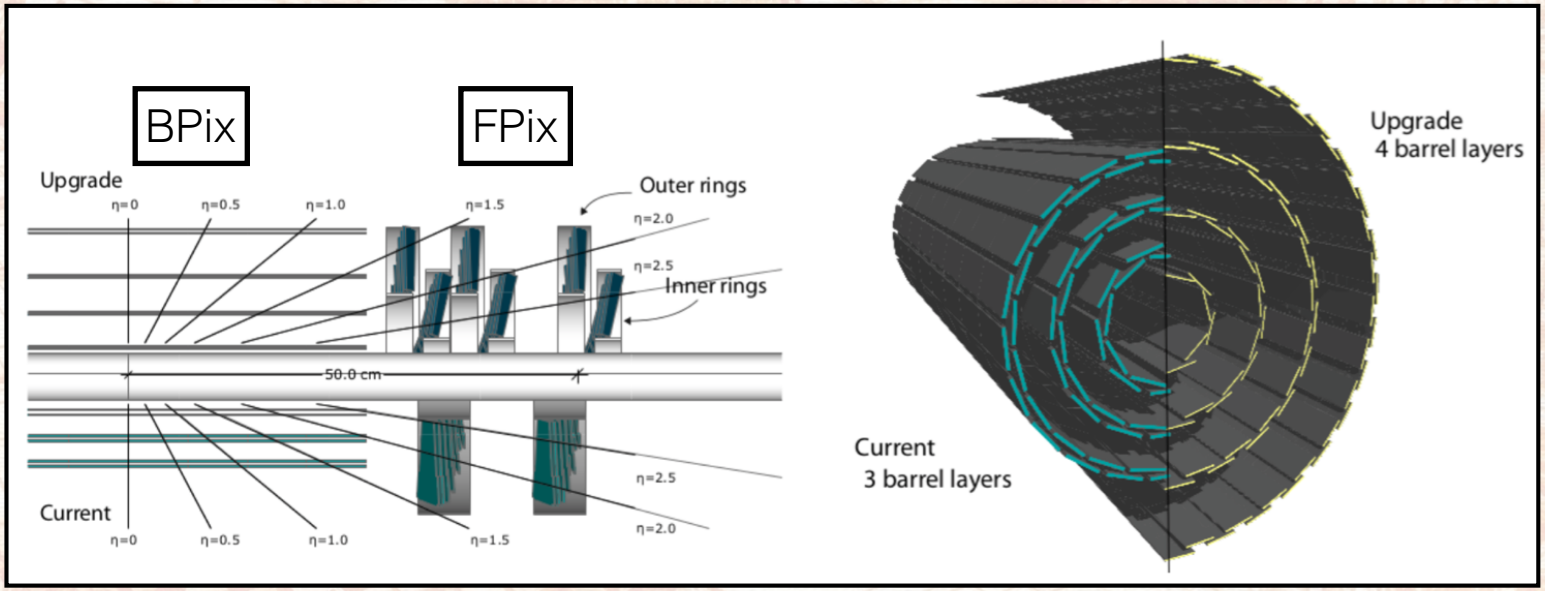


Run 1: excellent performance	2016 13 TeV $L=(1x10^{34}cm^{-2}s^{-1})$	Exceed nominal luminosity Hit nominal energy	Plan to double it <PU> ~50

CMS Pixel Phase I Upgrade

Will allow to maintain the current level of performance under high luminosity conditions.

The pixel detector upgrade



New digital readout :

- 40MHz → 400Mbit/s
- increased buffer size

Layout upgrade:

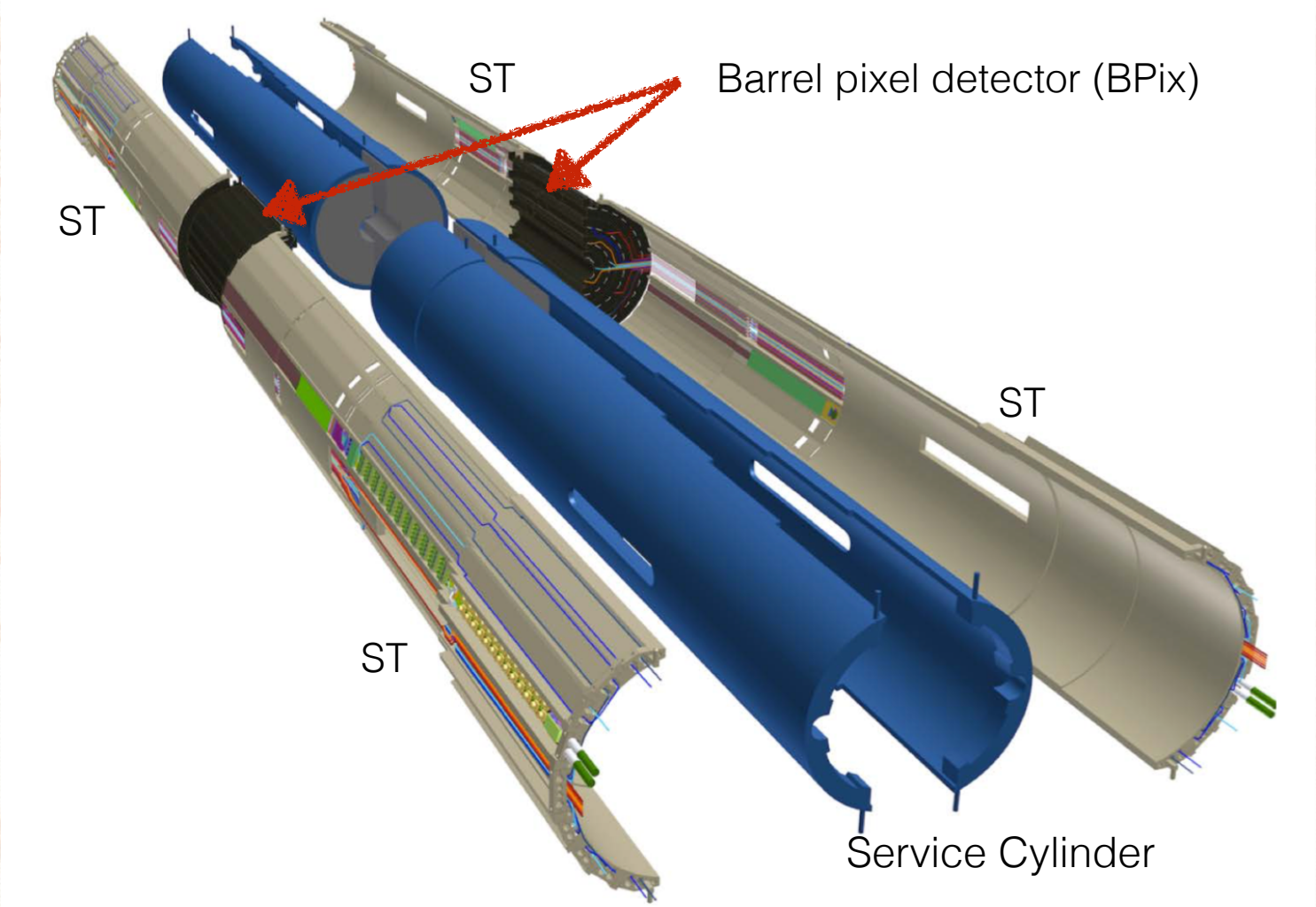
- 4th pixel layer and 2 extra disc for FPIX
- BPix module 768 → 1184
- BPix pixel 48M →79M

Improved material budget:

- moved electronic to higher η
- lighter mechanic
- CO2 cooling

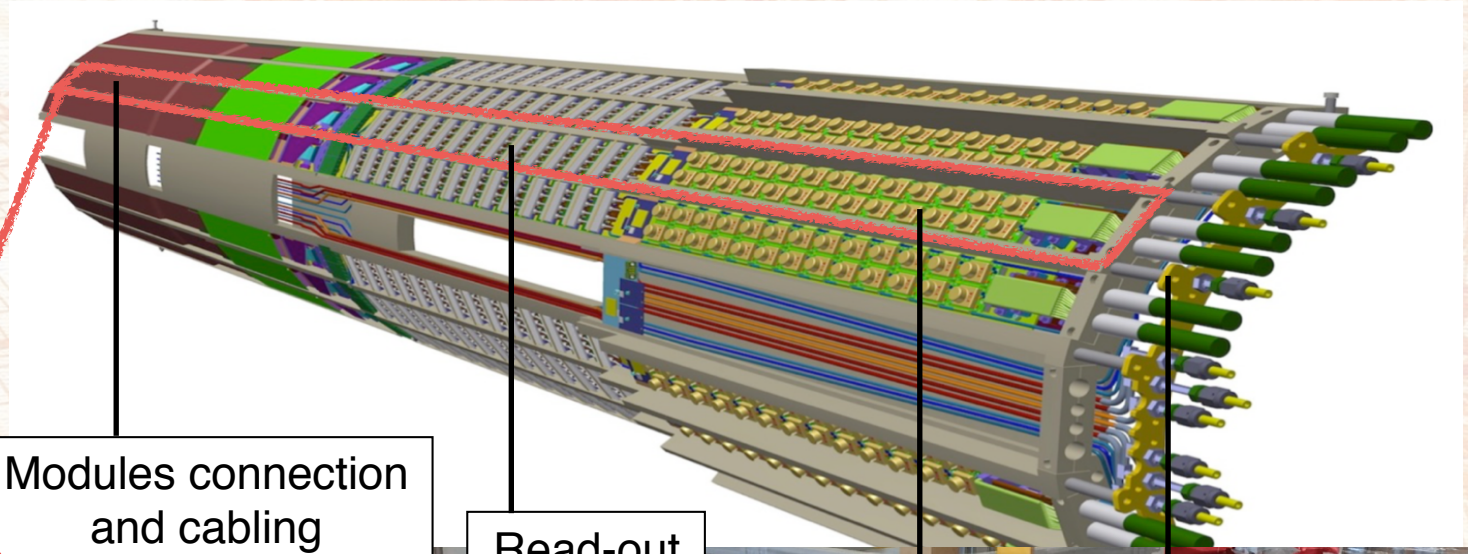
- Reduced dead time and data loss
- Improved track seeding and vertex reconstruction for large pile-up
- Improved IP resolution
- Less multiple scattering and photon conversion

Supply Tube



The supply tubes allow the data readout and the programming of the modules and supply power and cooling.

Supply Tube



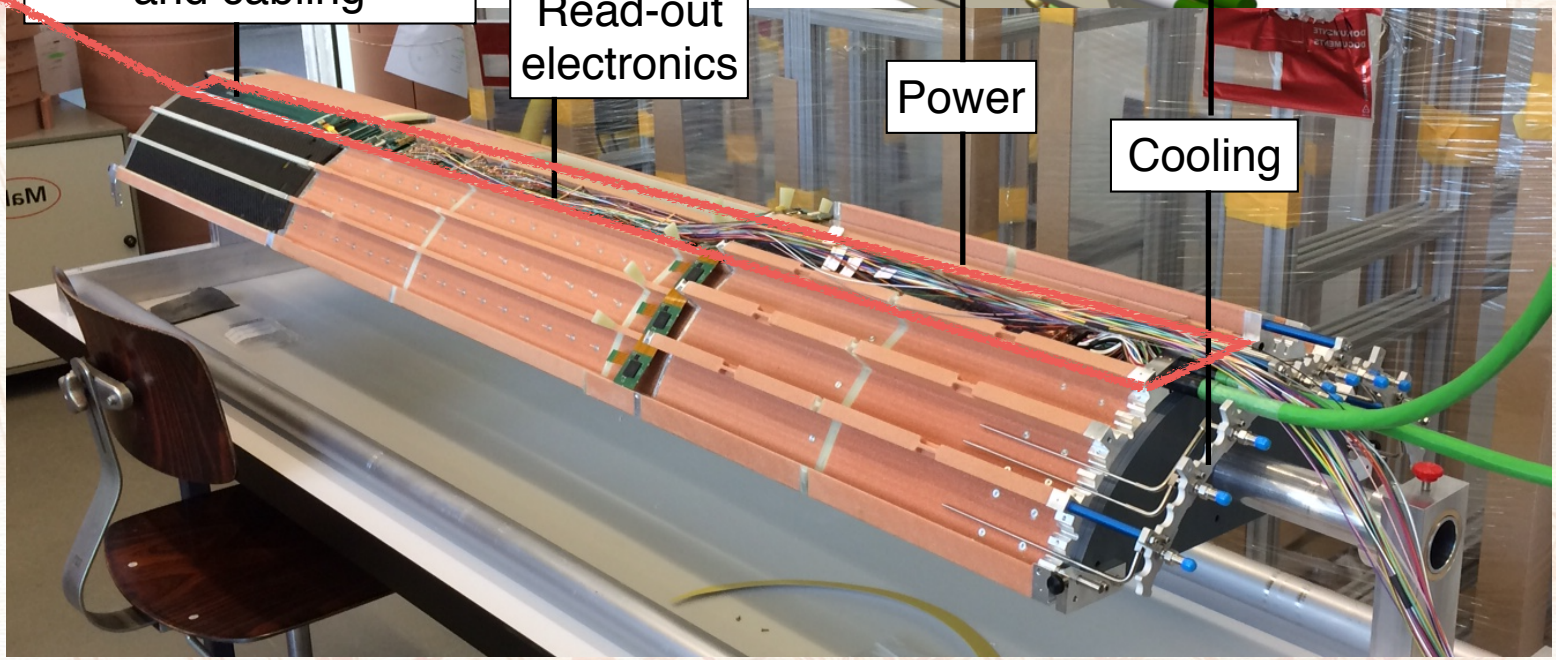
Sector

Modules connection and cabling

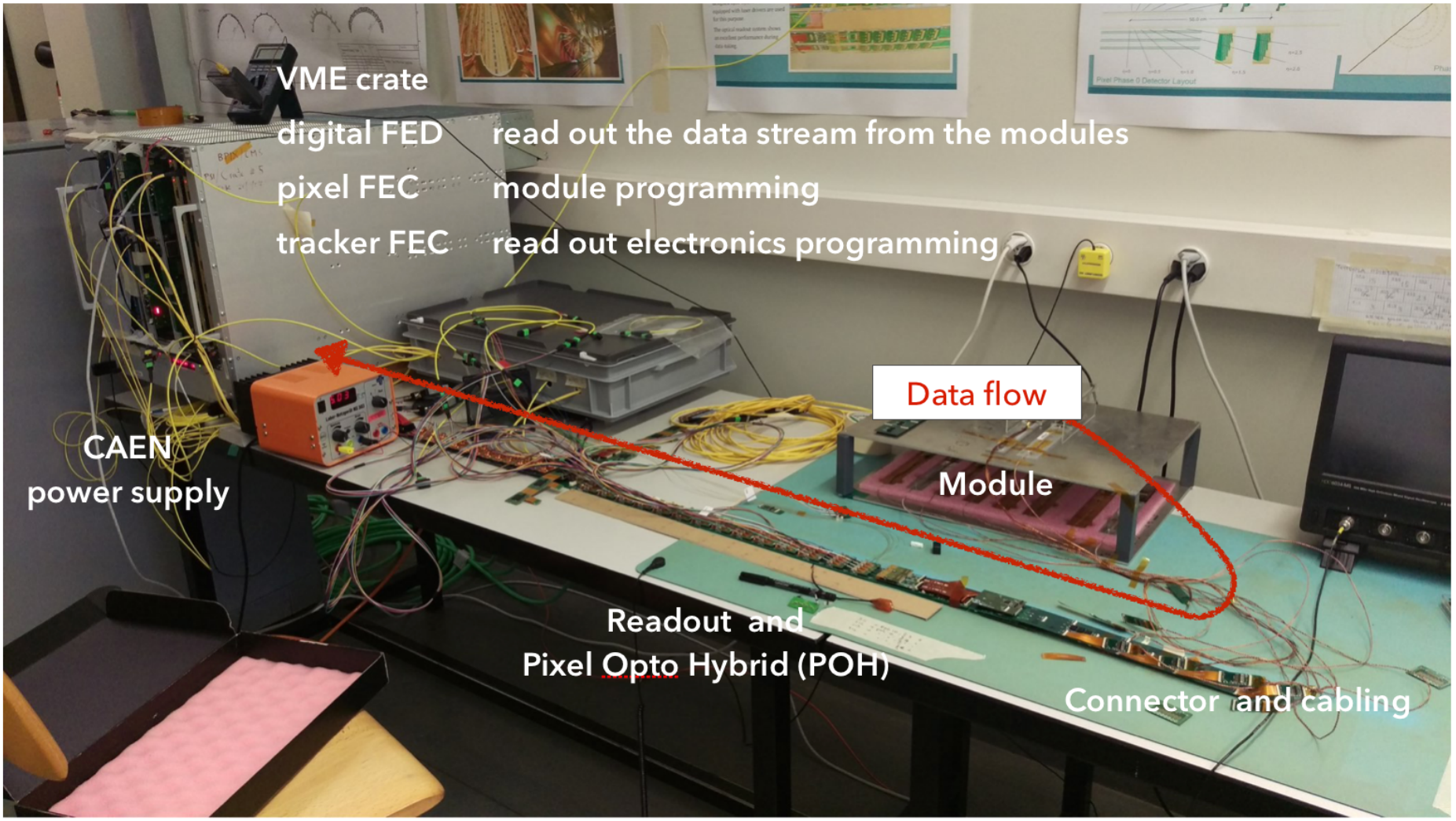
Read-out electronics

Power

Cooling

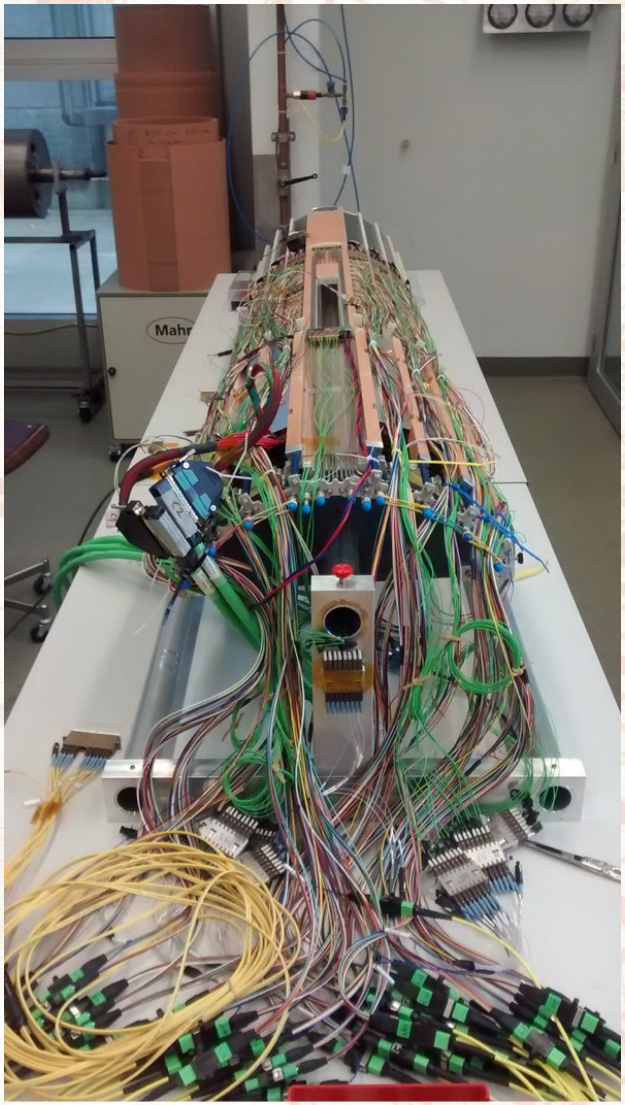


Test bench at UZH



The test stand includes a slice of the CMS pixel DAQ system and all components of the upgraded readout chain together with a number of detector modules.

Supply Tube



Testing procedure (room temperature)

High and low voltage distributions

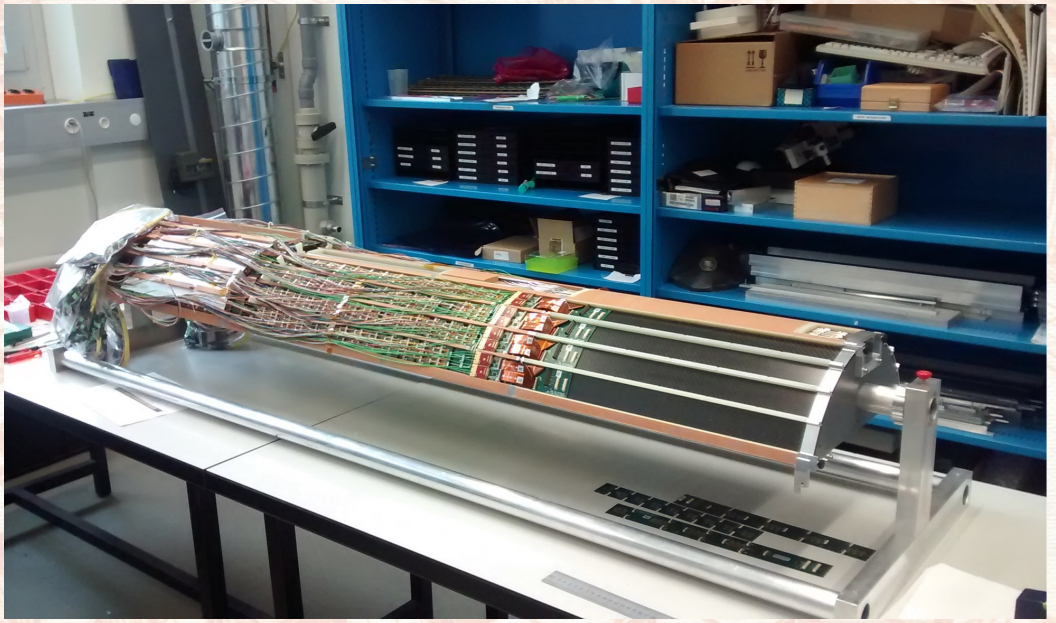
Devices programming and registers readout, functionality tests

POHs laser functionality and fiber connections quality

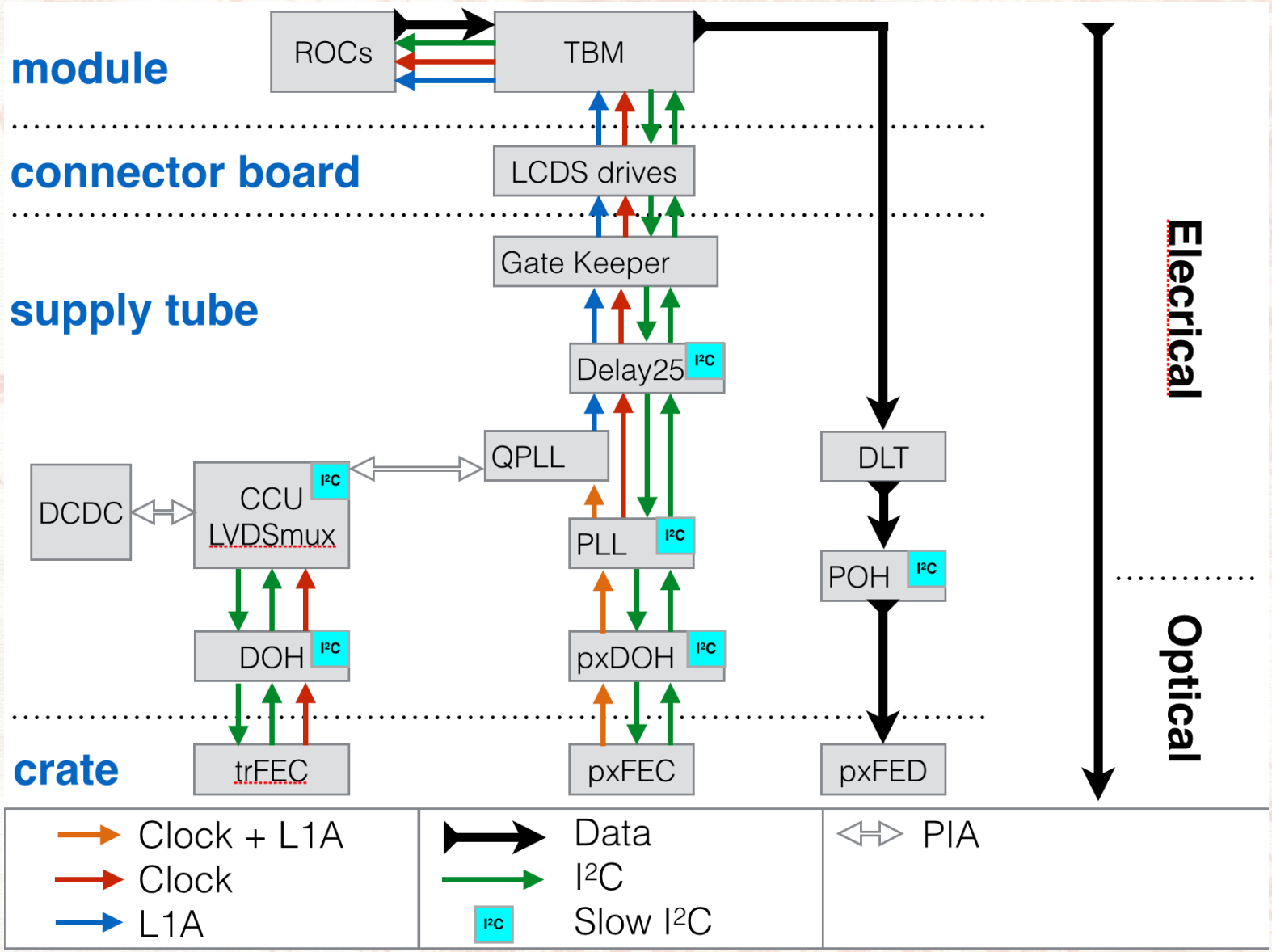
Communications and programming the modules

Data stream readout

Cold box test



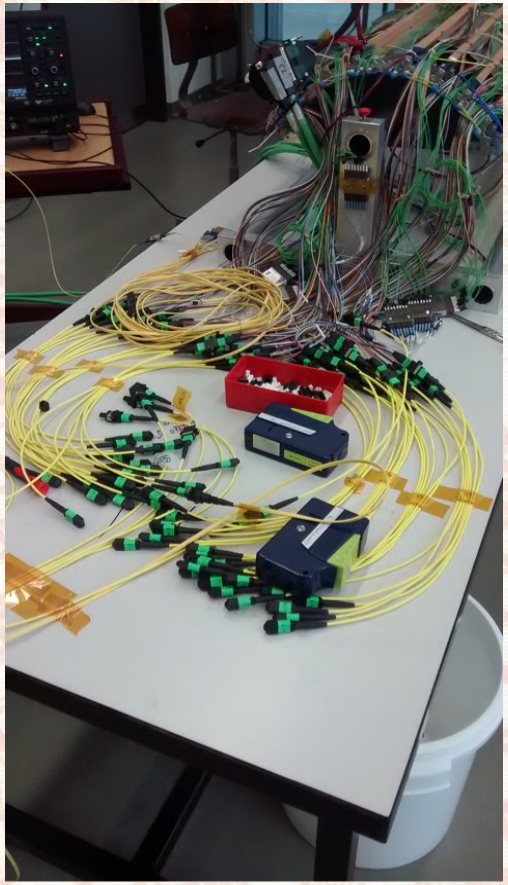
Supply Tube Diagram

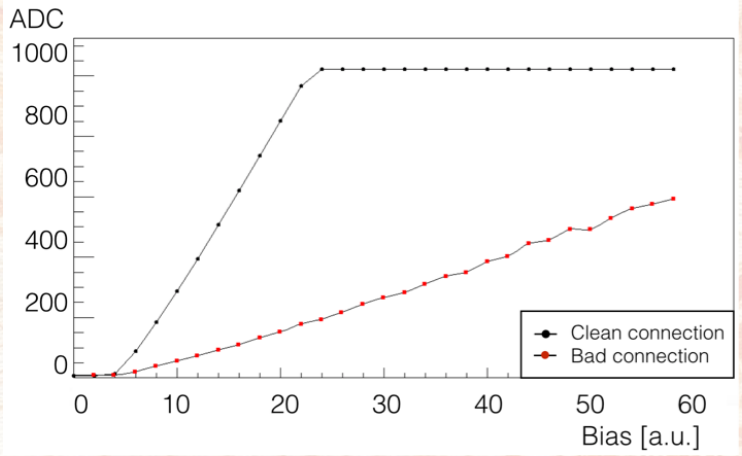


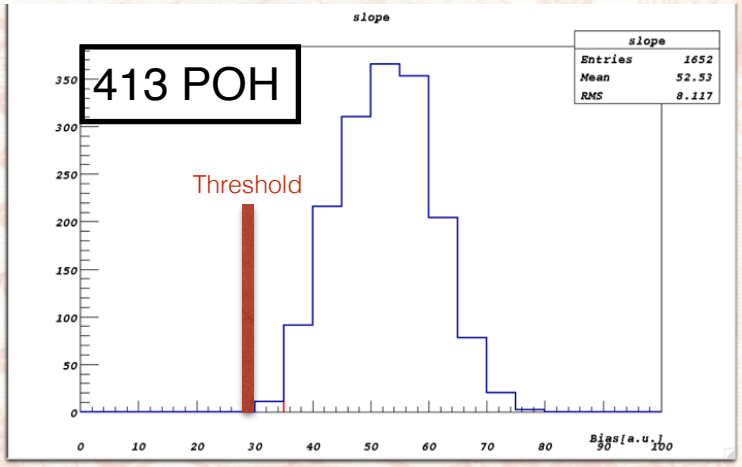
- **Three main rows:**
  - Module
  - Supply tube
  - Crate/ Counting room
- **Three main columns:**
  - trFEC
    (supply tube devices COM and programmig)
  - pxFEC
    (Modules COM and programmig)
  - pxFED
    (Data readout)

Test POH and optical fiber connections

This test aims to check the functionality of the Pixel Opto Hybrid (POH) laser, the quality of the optical fibre connections and the performance of the digital data transmission. The digital data stream coming from the module is converted from an electrical to an optical signal by the POH.

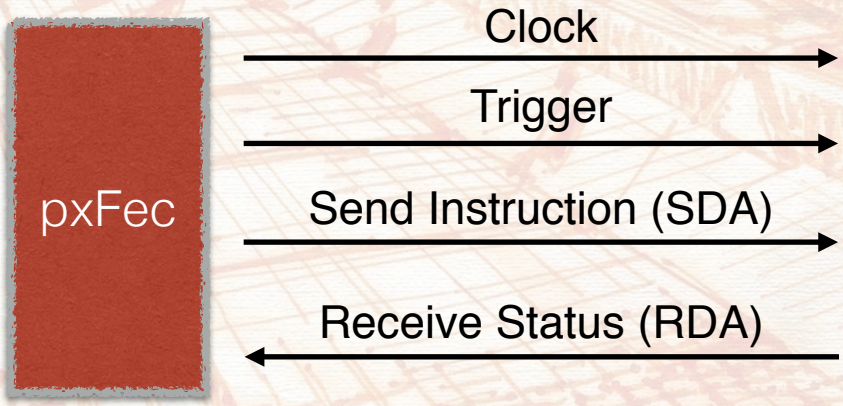


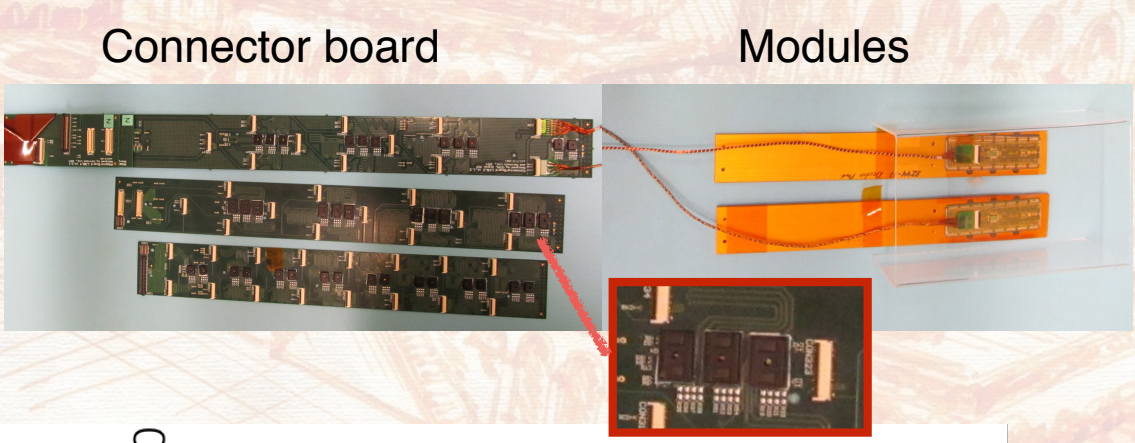


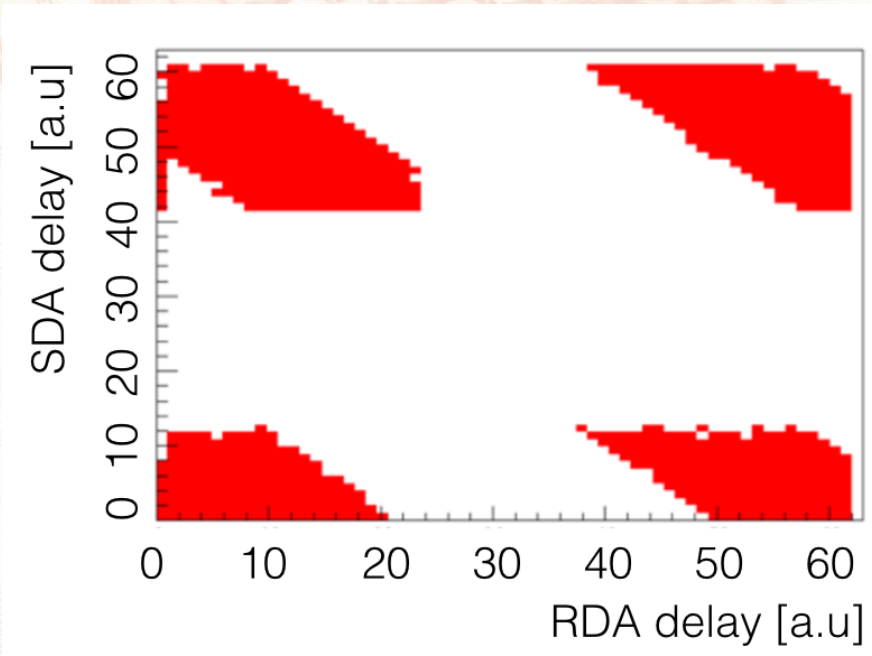


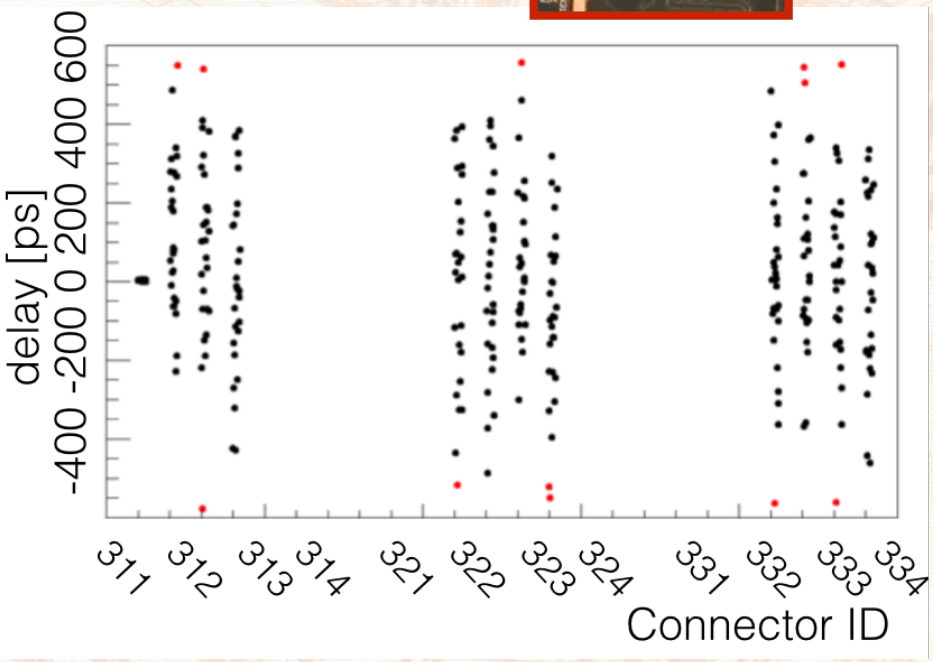
Test Module Programming and trigger delay

First one checks the communications and programming of the modules, then the trigger signal delay among different modules is tuned depending on the module layer, the pseudo- rapidity and cable length.

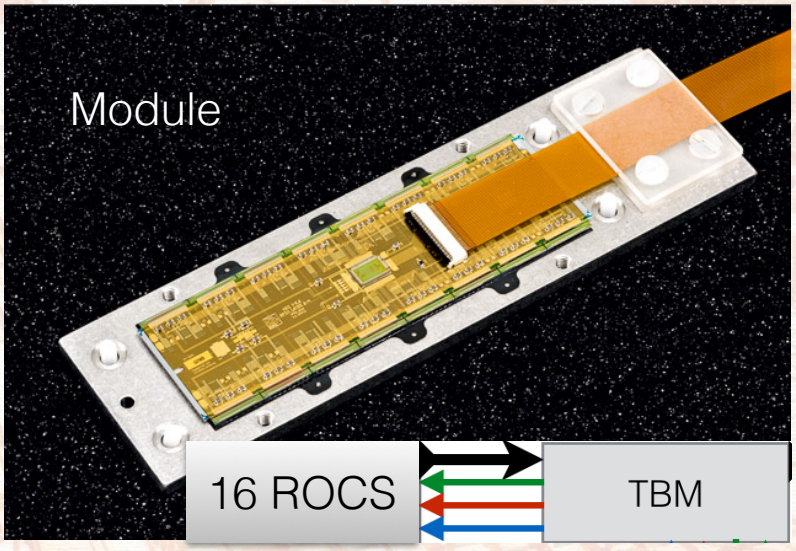


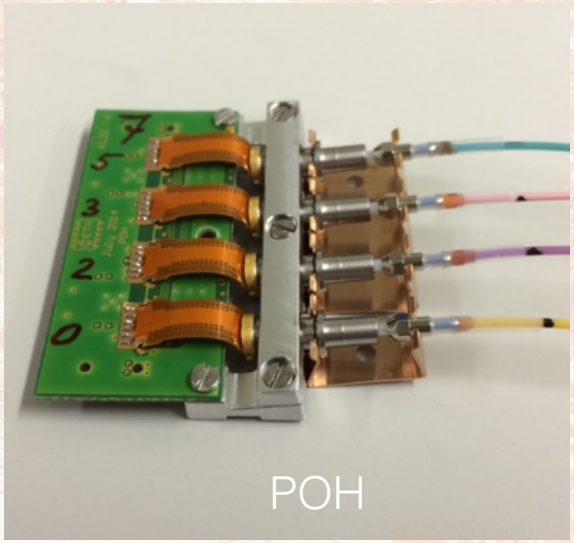


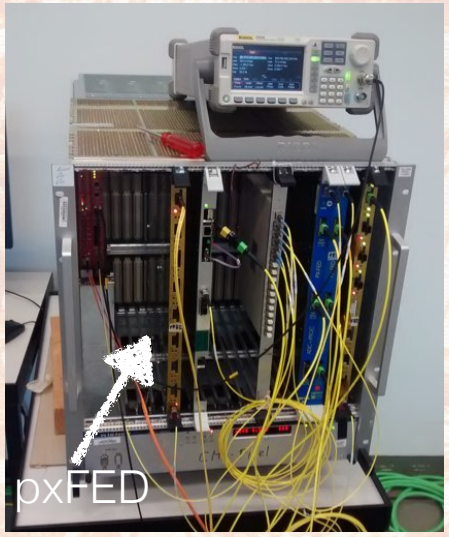


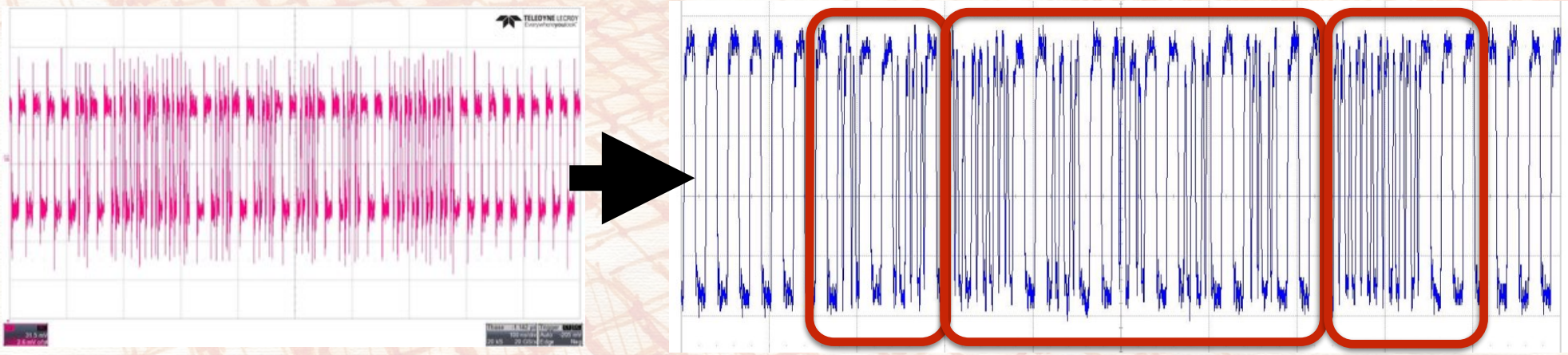


Test data transmission





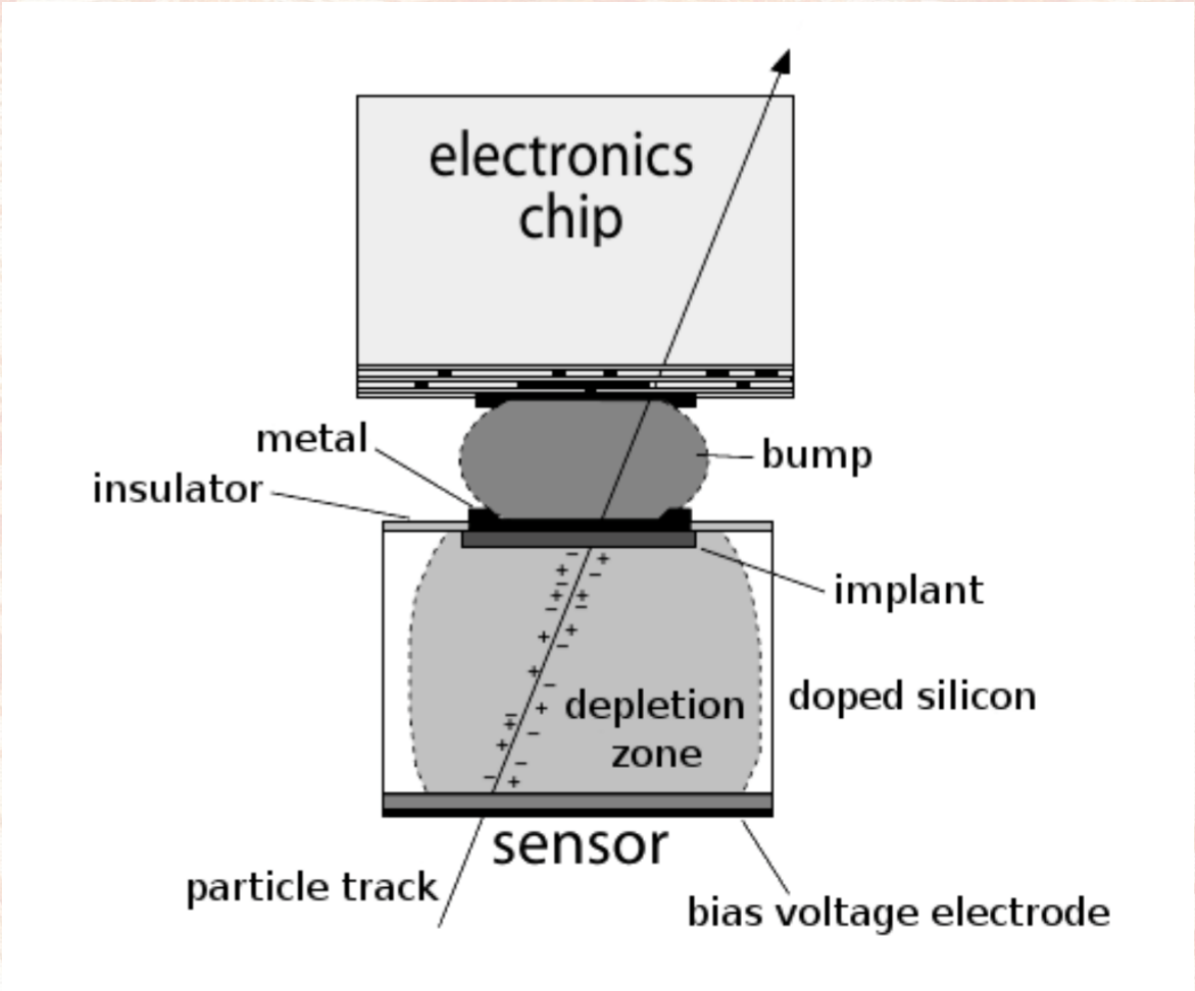




Data (electrical) → Data (optical) TBM header ROC header TBM trailer

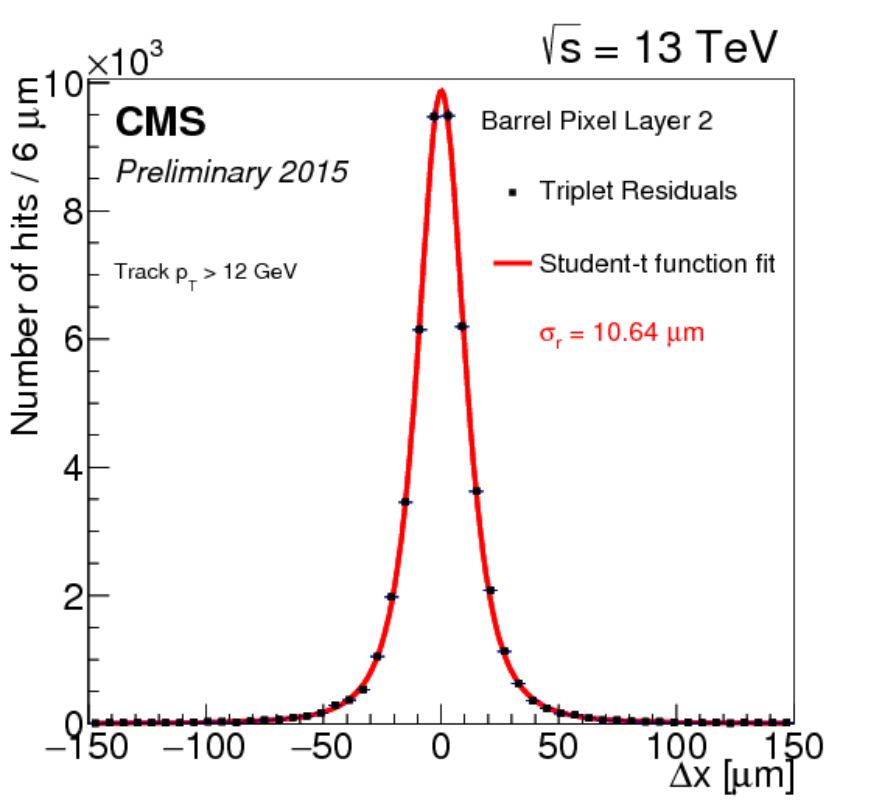
Thanks!

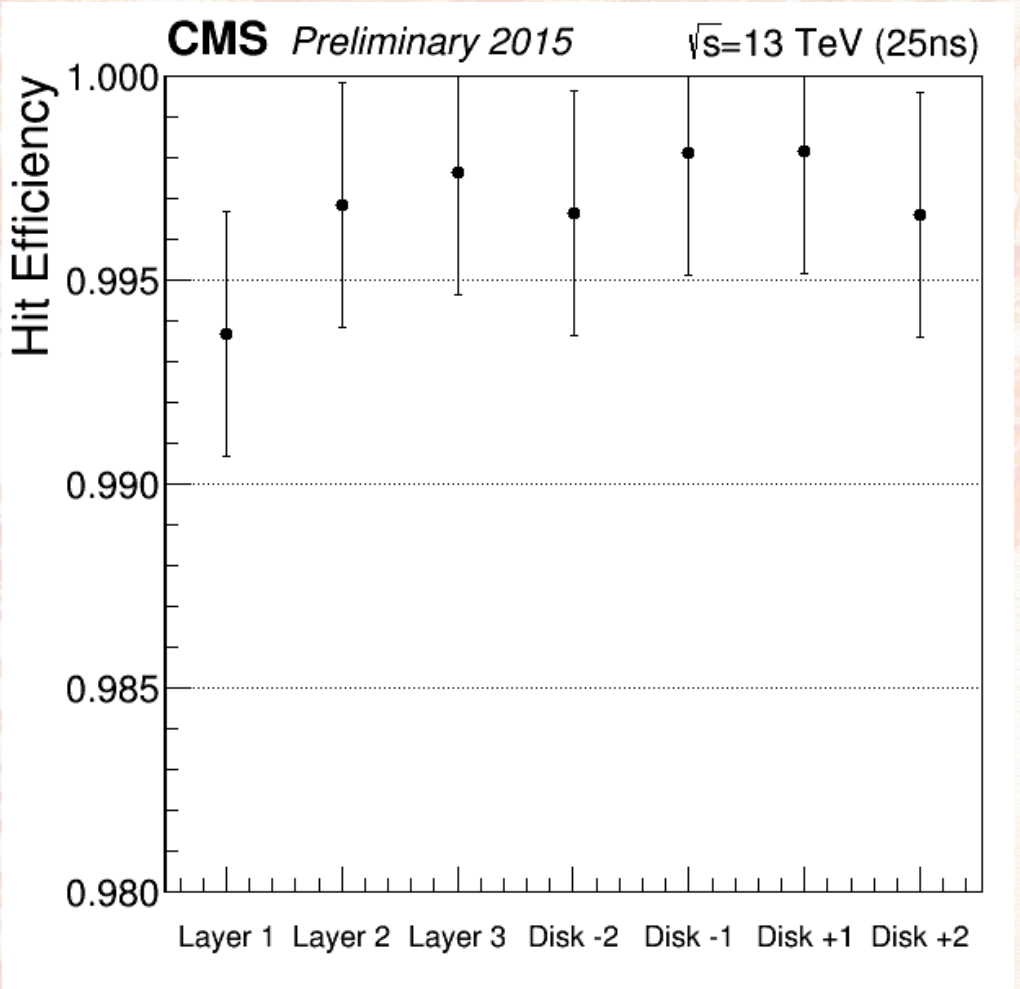
Backup Slides



Backup Slides

Hit efficiency and transverse resolution





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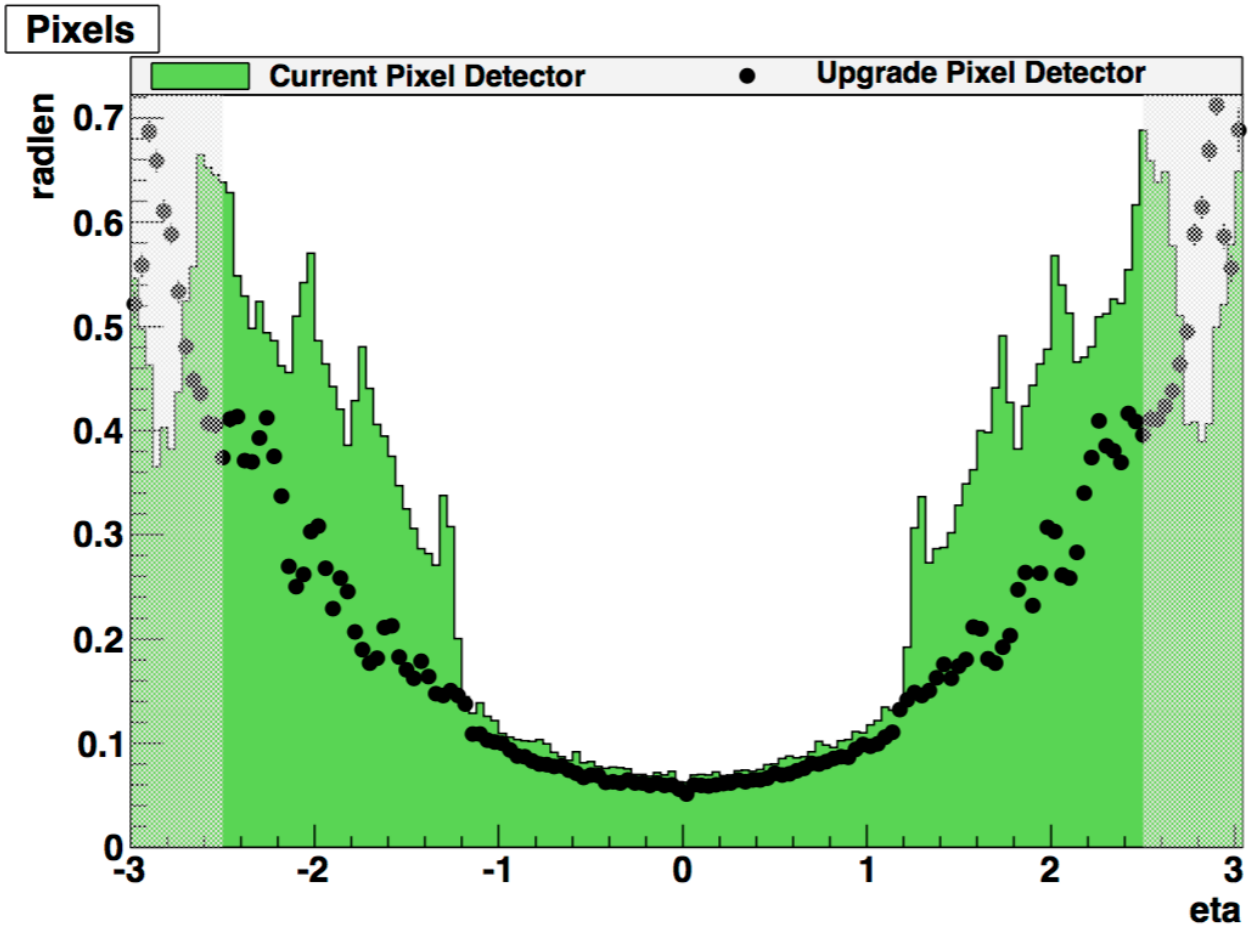


Material : rad len vs η

Backup Slides

Sample and Conditions		Tracking Efficiency (%)		Track Fake Rate (%)	
Sample	PU/DL/Cuts	Current	Upgrade	Current	Upgrade
Muon	0/No/Cleanup	97.4	98.1	0.0	0.0
Muon	0/Yes/Cleanup	93.9	97.9	0.0	0.0
Muon	50/No/Cleanup	90.1	94.9	0.22	0.17
Muon	50/Yes/Cleanup	81.5	94.4	0.23	0.17
$t\bar{t}$	0/No/Default	89.6	93.5	0.71	0.40
$t\bar{t}$	0/Yes/Default	85.6	93.2	0.68	0.41
$t\bar{t}$	50/No/Default	84.9	92.2	8.72	5.09
$t\bar{t}$	50/Yes/Default	79.7	92.0	9.49	5.13

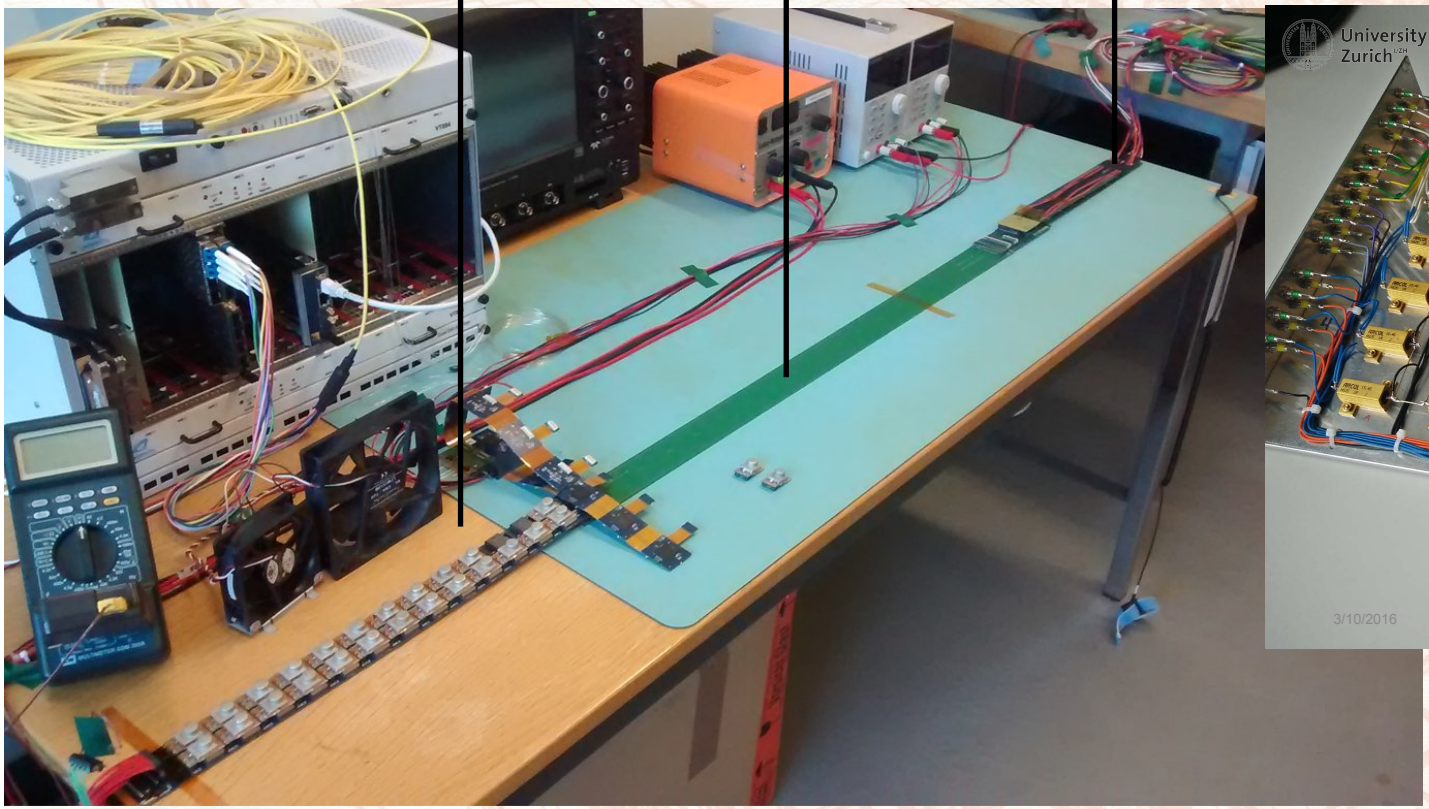
Eff/Fake rate for actual and phase I pixel detector w/wo pile up and ROC dynamic data loss

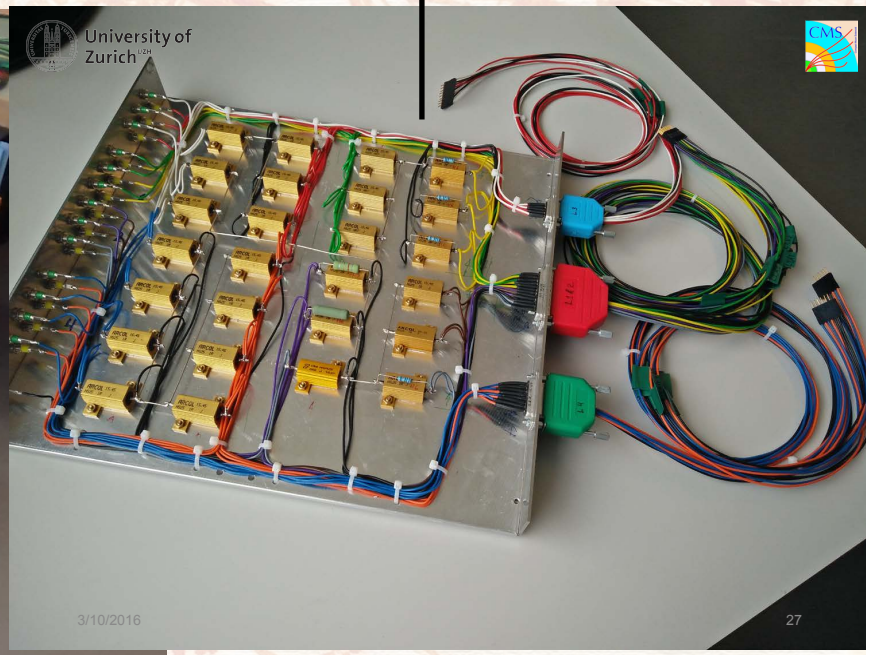
Supply Tube Testing

Two independent setups: Electronic test and Power test

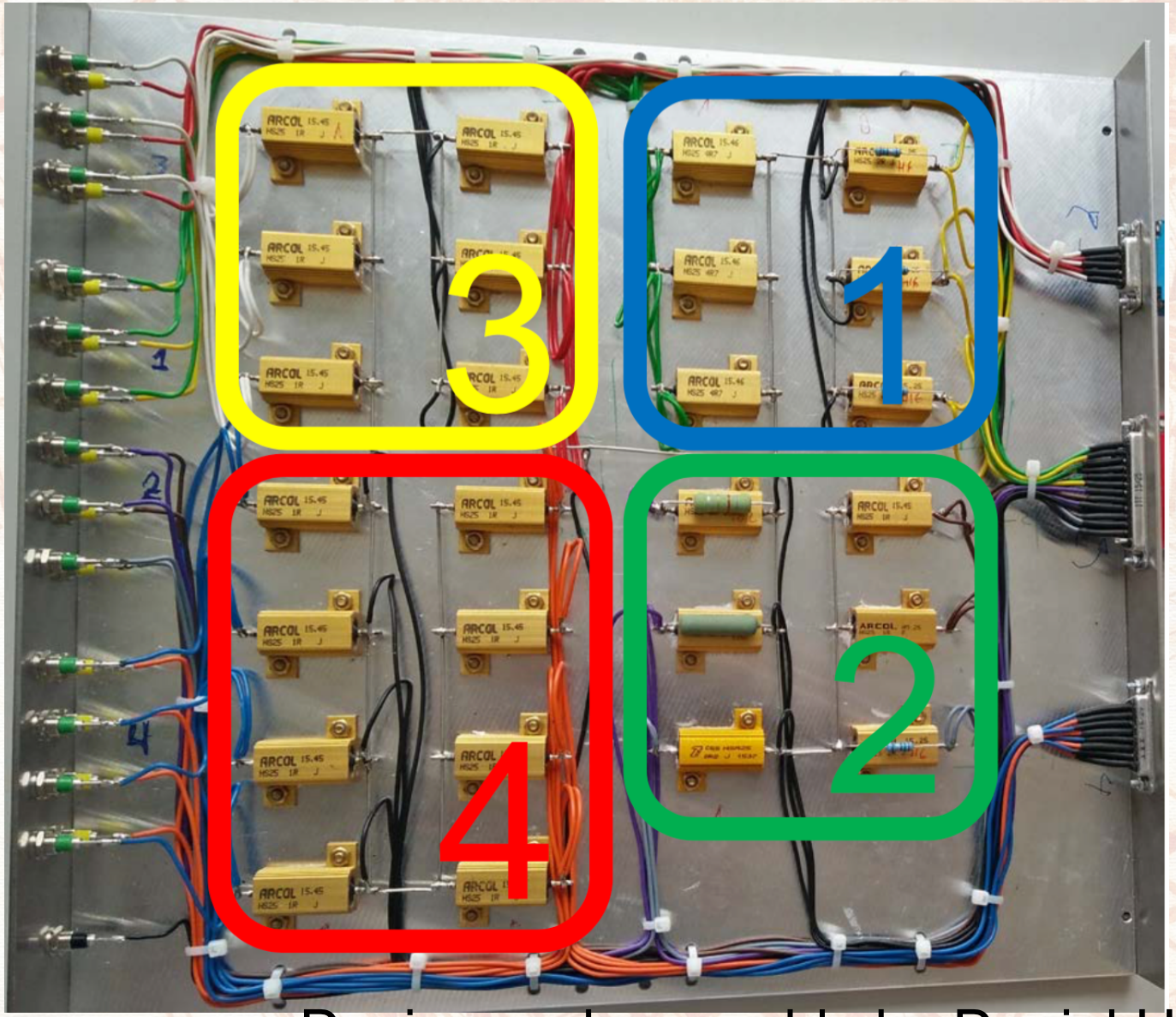
Power Distribution Test

DCDC - Extension Board - Connector Board - Load Board





Load Board



Layer	Mod.	DCDC Pairs
L1	3	3
L2	8	3
L3	12	3
L4	16	4

Design and assembly by Daniel Hernandez Garland

Mechanic on the mandrel