Status Of The CMS Pixel Detector

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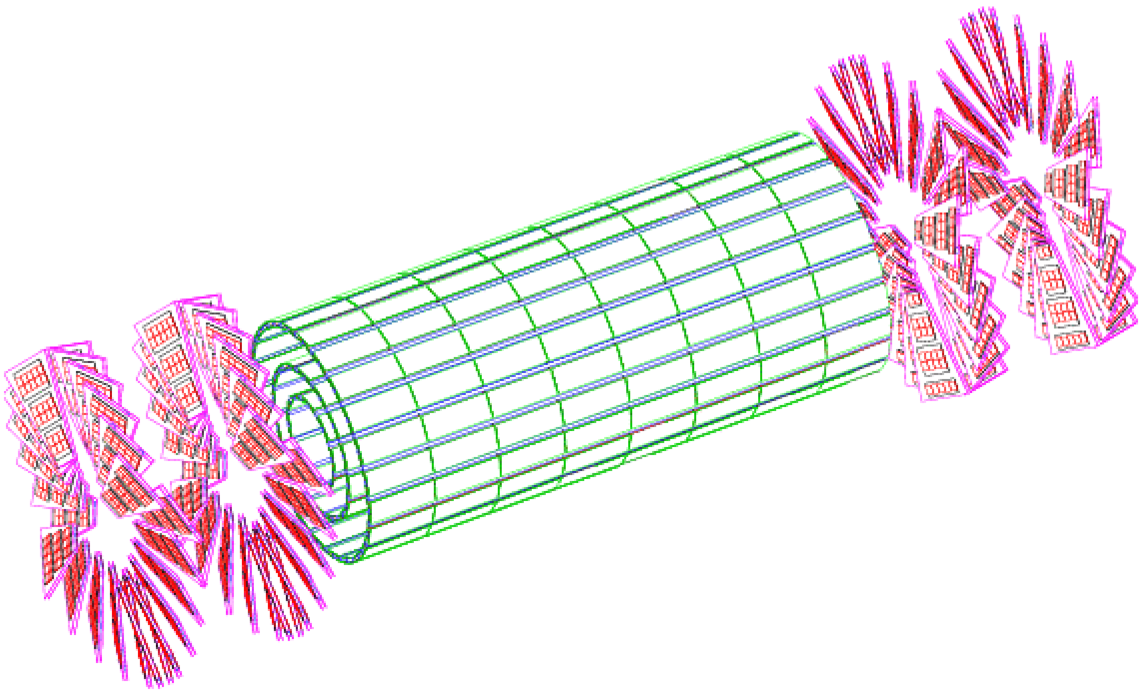
Pixel 2008

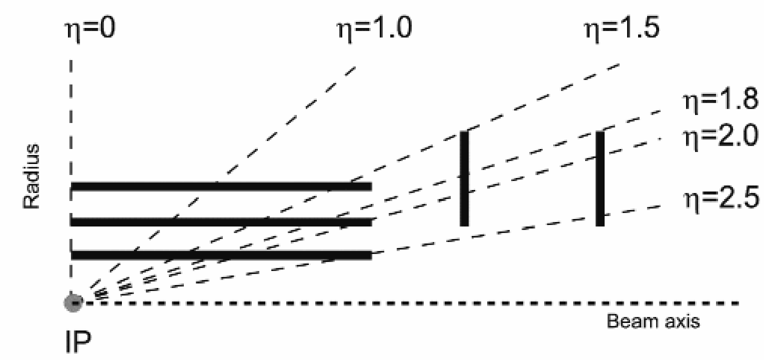
Fermilab, September 23, 2008

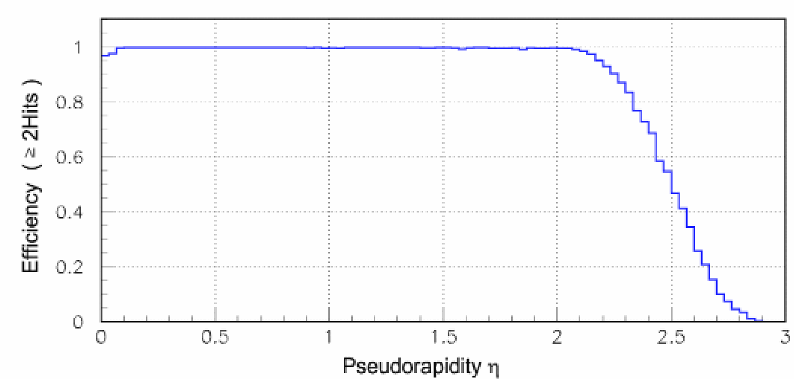
For more details see other CMS pixel talks:

Andrei Starodumov - Building of the CMS barrel pixel detector
Lea Caminada - Commissioning of the CMS barrel detector
Ashish Kumar - Commissioning of the CMS forward pixel detector
Christian Veelken - The control and readout of the CMS pixel detector
Valeria Radicci - CMS pixel upgrade program

The CMS Pixel Detector







The CMS pixel detector consists of:

(BPix) 3 barrel layers at 4.3, 7.2 and 11cm with 768 modules, 11520 ROCs, 48Mpixels

(FPix) 2 forward disks at z=35 and 45cm with 192 panels, 4320 ROCs, 18Mpixels.

Our Final Schedule

1994 - CMS Technical Proposal, pixels included
1998 - Tracker Design Report
1994-2005 - R&D, mostly readout chip (ROC) and sensor.
9/2005 - discovered a serious problem the PSI-46V2.2 ROC
11/2005 - submit PSI-46V2.3
3/2006 - final ROC arrives

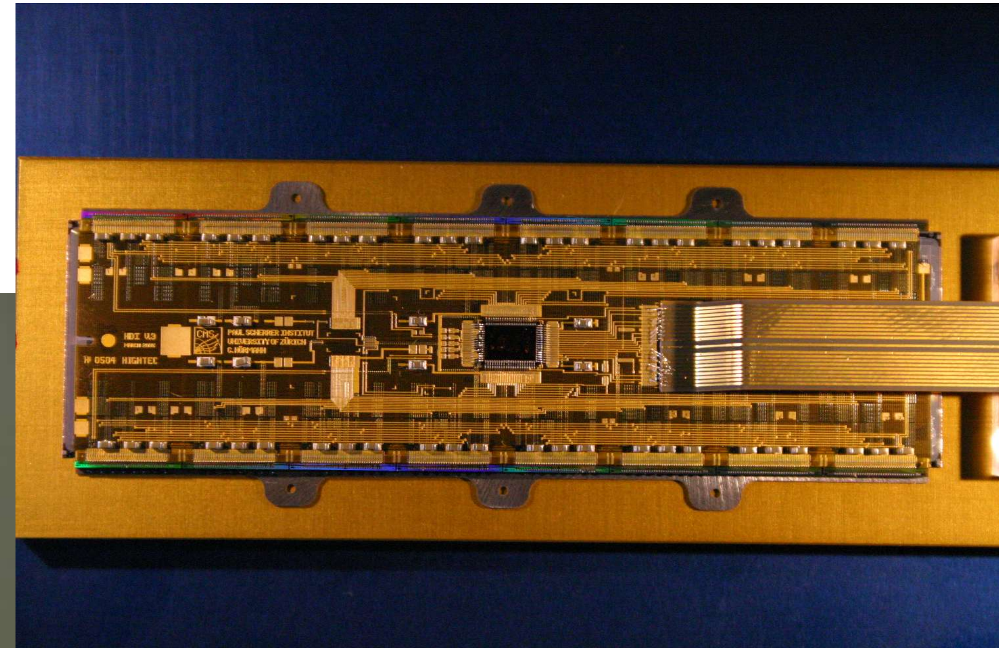
FPIX
6/2006-10/2007 -
plaquette & panel construction
2/2007-11/2007 -
disk assembly
4/2007-12/2007 -
delivery to from FNAL to CERN
1/2008-7/2008 - testing

BPIX
6/2006-12/2007 -
module production
1/2008-3/2008 -
module mounting on ladders
2/2008-4/2008 -
integration with the supply/service tubes
5/2008-6/2008 -
testing at PSI
7/2008 - delivery to CERN

July 23-24th 2008 BPix insertion
July 29-31st 2008 FPix insertion
August 7th 2008 loose all access to PP0 (our connection area)

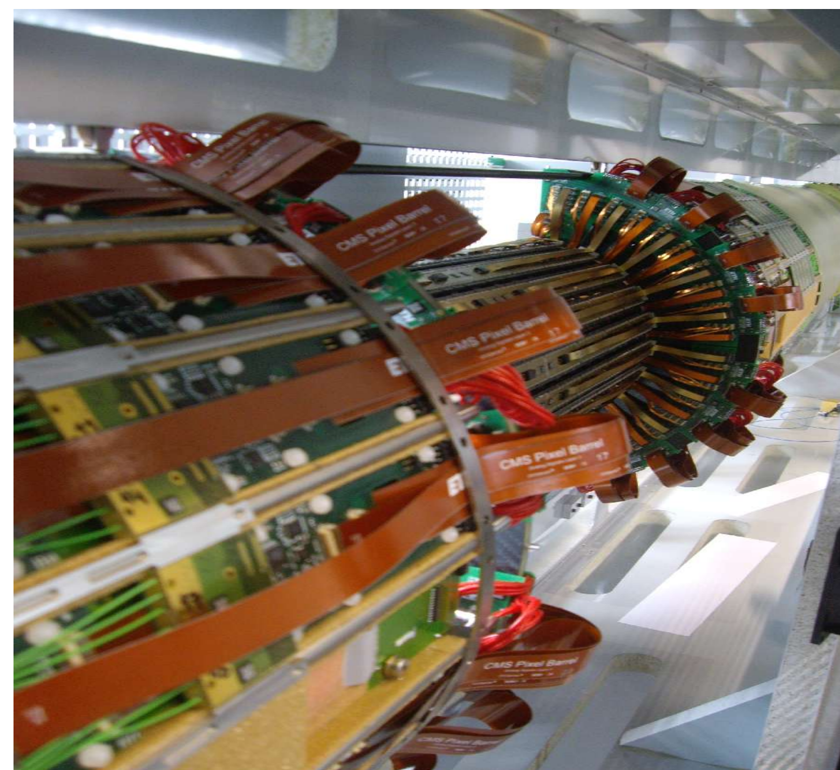
BPix Construction

A single module



The whole barrel

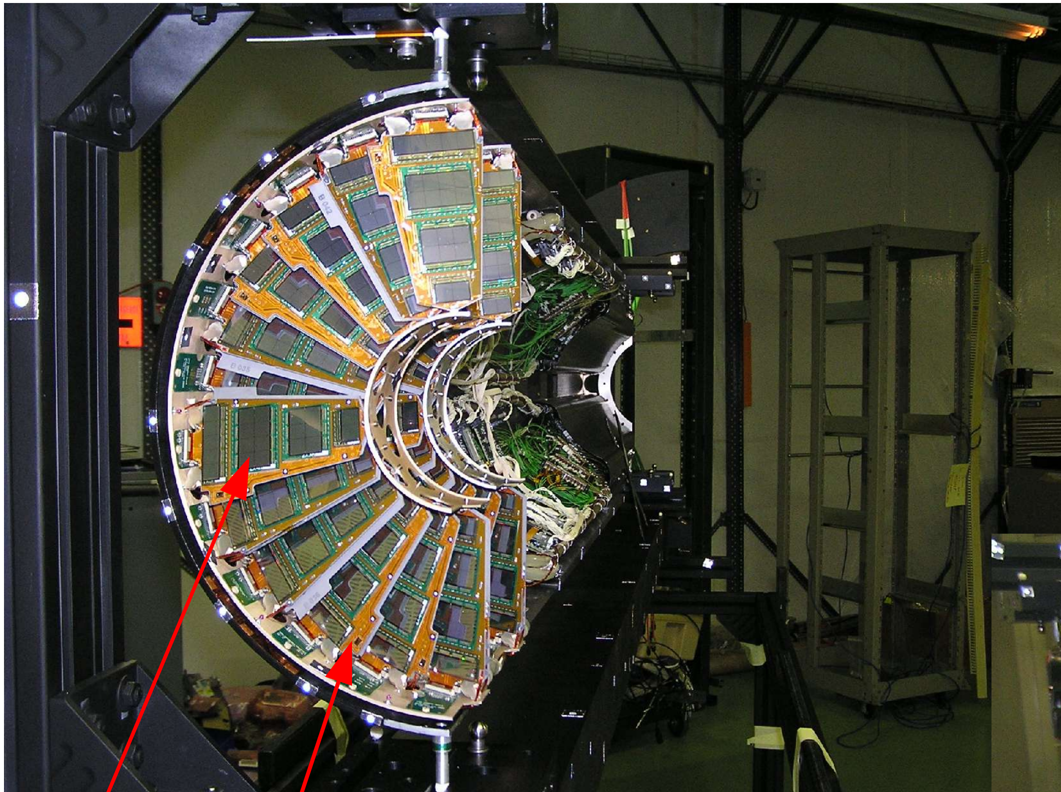
Barrel+Supply tubes



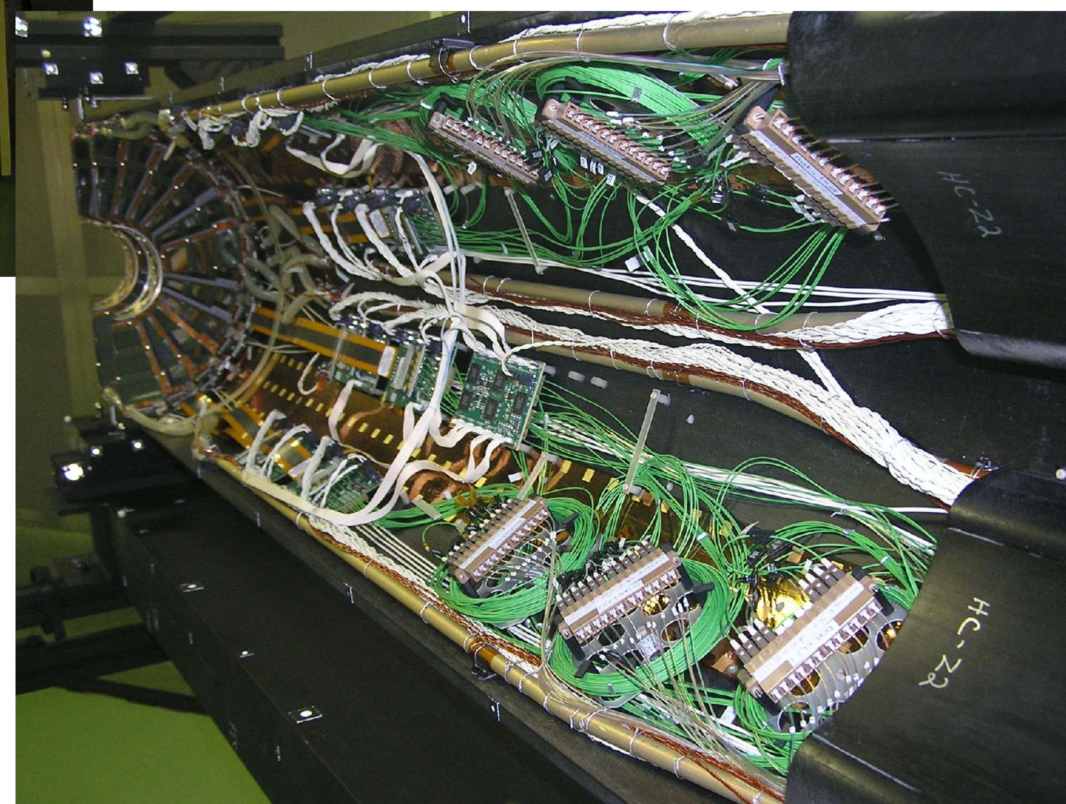
More details from Andrei Starodumov

FPix Construction

Half-disks



Half-shell + supply tube

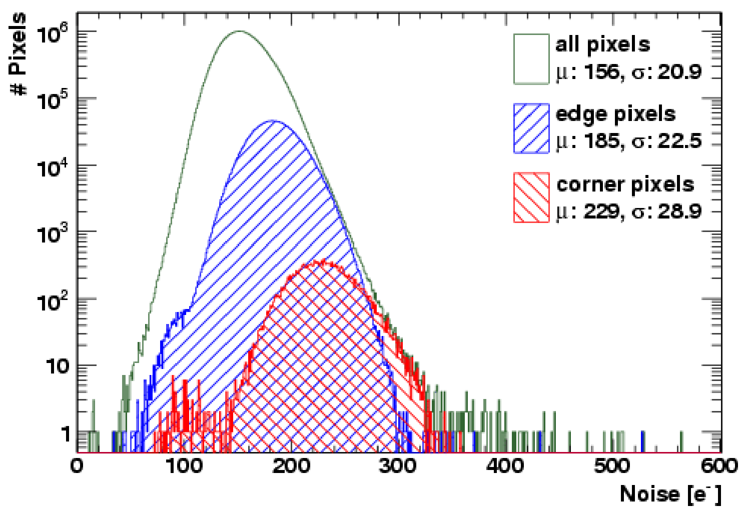


Module/Panel Production Quality & Yield

All modules (bpix) and panels (fpix) were extensively tested and thermal cycled. The tests included many steps starting from simple (dead pixels, missing bumps) to complex tests like trimming and pedestal spread of the analog signals.

We used a classification scheme with 3 classes A, B and C.
The production yield starting from good components was for the BPIX: 76%
16% lost after the "raw module" step, 8% classified as class C (reject).

For the FPIX production was split into:
plaquettes (like "raw" modules in the BPIX) - 80% yield for class A
panels (like modules) - almost 100%



An example of the module testing results. Noise measurement from all BPIX pixels.

Mean noise is 156 electrons.

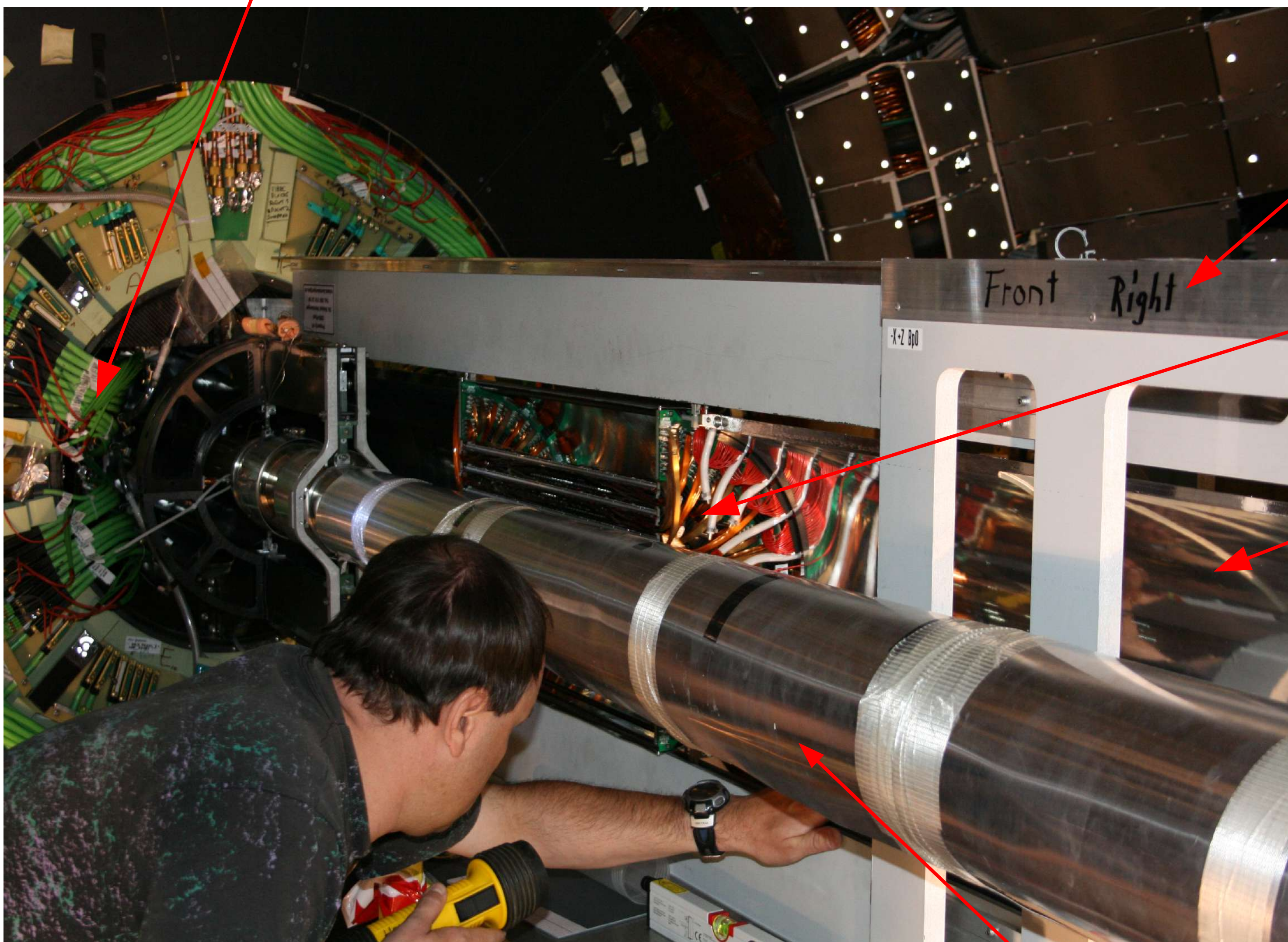
Barrel Installation In CMS

The left side of the detector already inside

The transport box

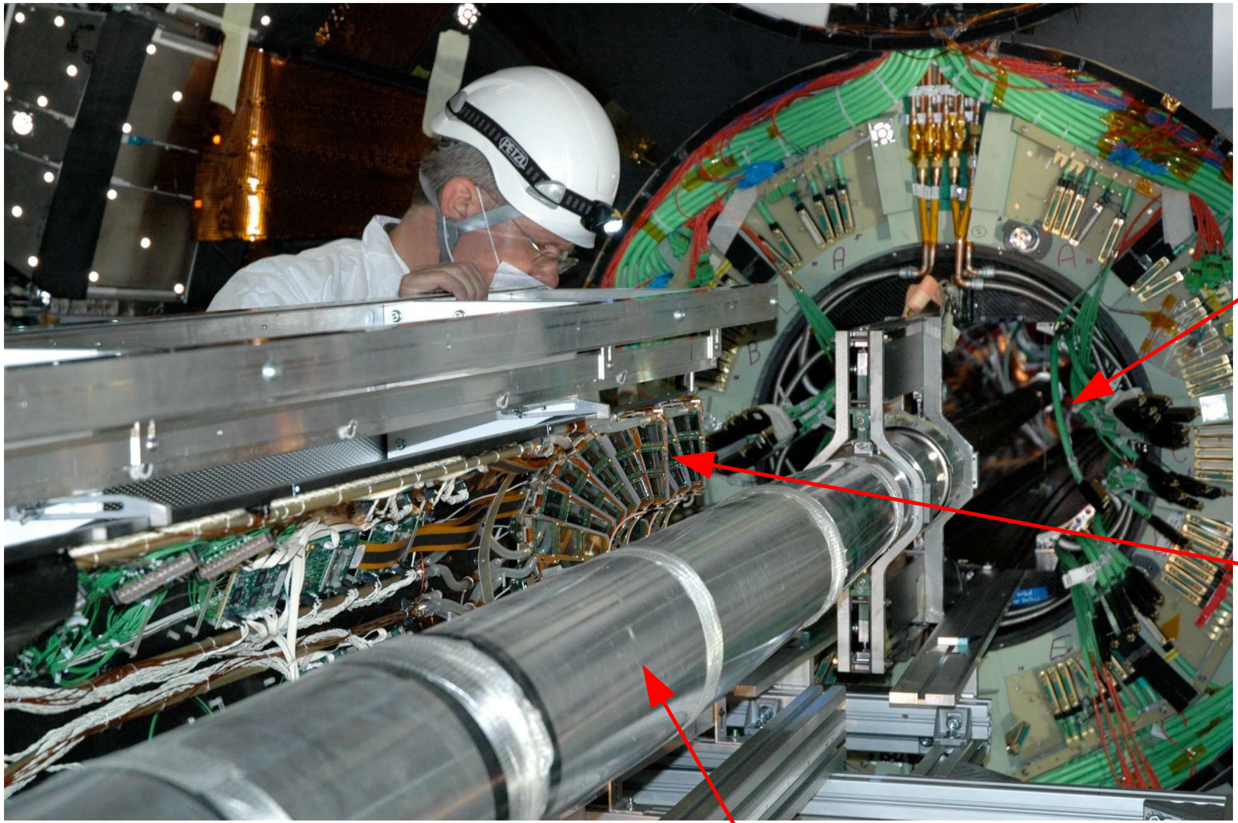
Pixel barrel layers

Supply tube



Beam pipe

Forward Disk Installation In CMS



BPix cables, fibers and cooling tubes

The FPix disks

Beam pipe

Final Defects

	Pixels	Lost on surface	Lost later	Total	Single Pixels
Barrel Layers	48M	0.35%	0.52%	0.87%	0.01%
Forward disks	18M	0.00%	6.00%	6.00%	<0.1%

The FPix 6% is dominated by a single power group which has developed a short just after installation.

Main reasons for lost modules:

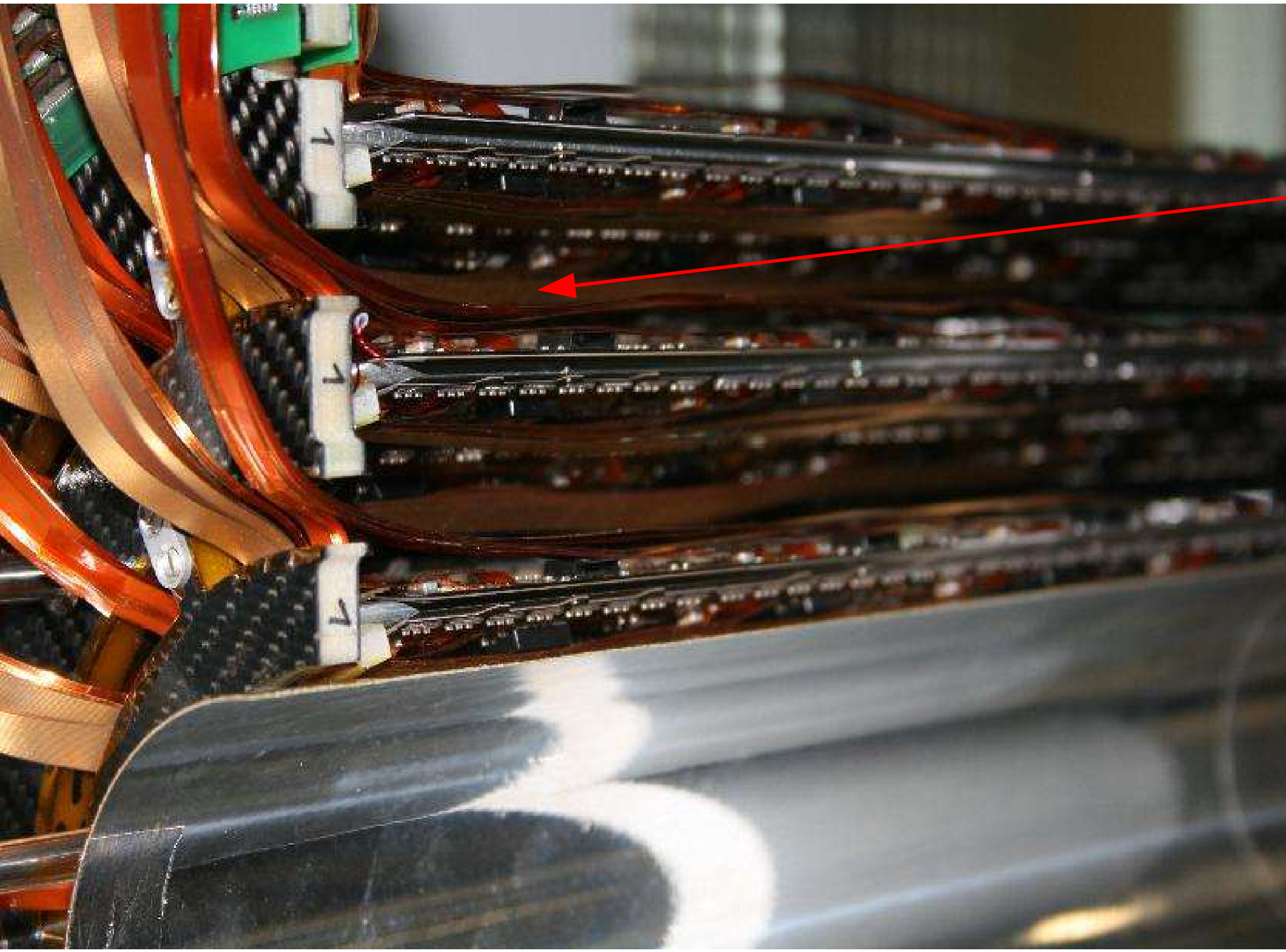
- Short circuits developed somewhere inside the detector volume
- Broken wire-bonds
- Bad contacts

Single pixel defects are dominated by the faulty bump-bonds.

Modules tend to be either broken or are very efficient.

More details in talks by Ashish Kumar & Lea Caminada

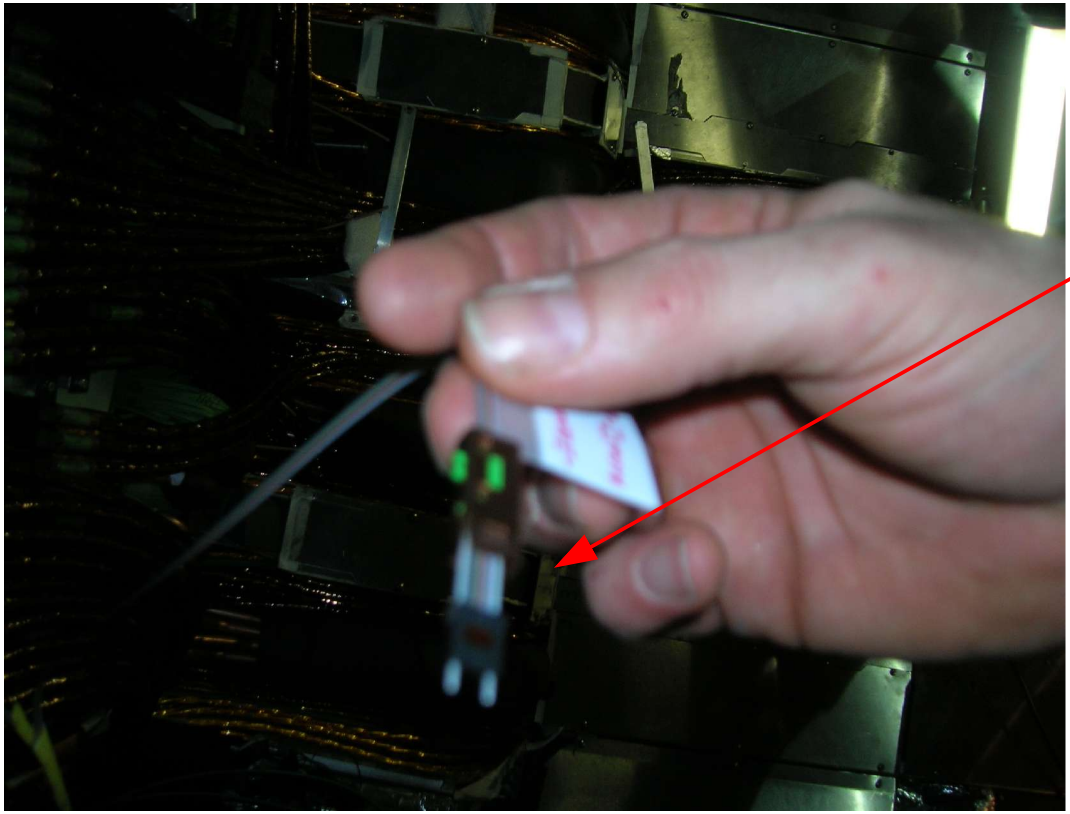
Why did the barrel pixel detector have bad modules already before installation?



Very dense!
To replace a single module the whole structure had to be disassembled.
We did it 3 times. Each time new defects were introduced

Optical Transmission & Connectors

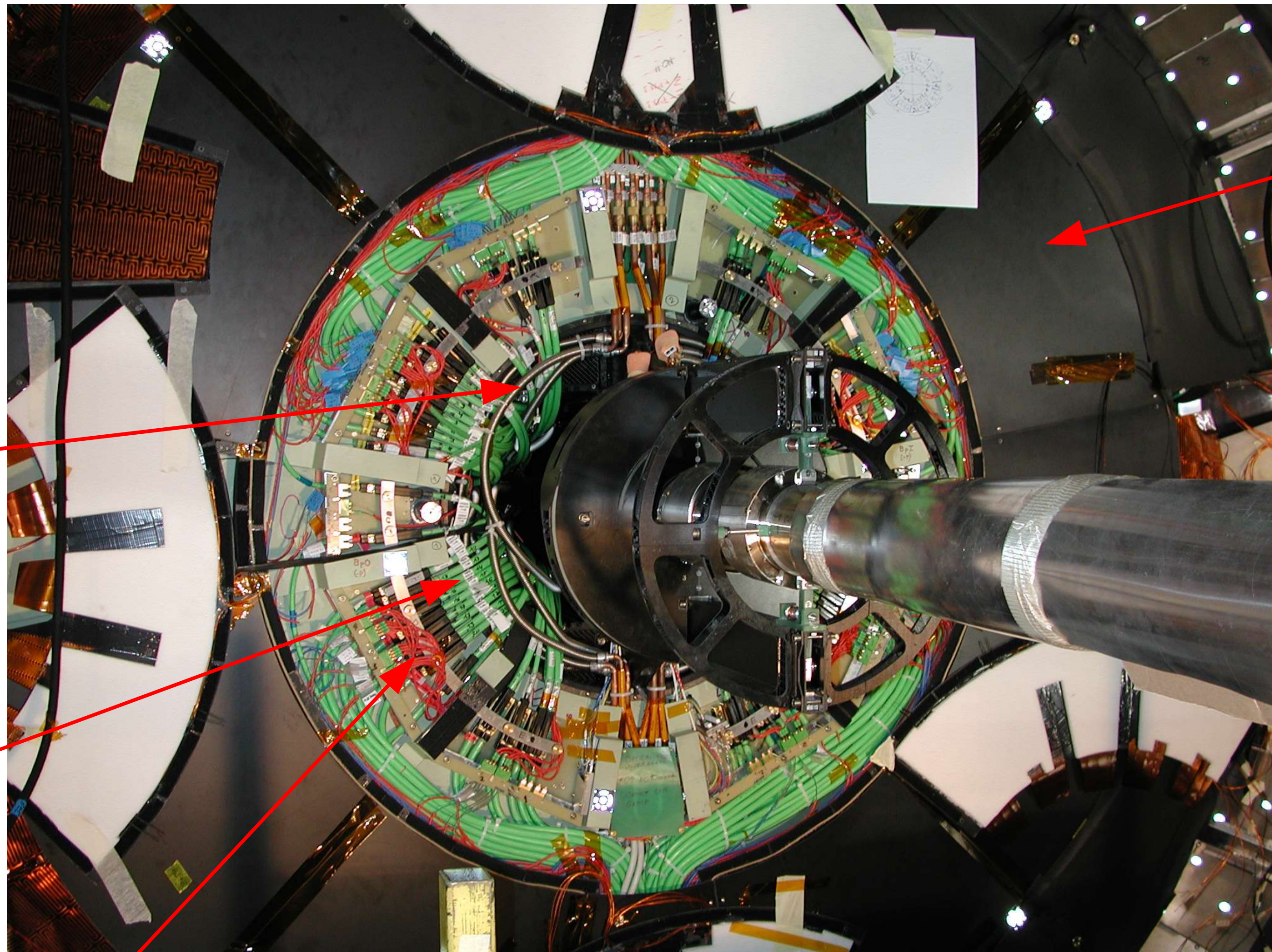
The layout of the fibers and the connections in the PP0/PP1 area were difficult.
It is a miracle that no fiber was completely broken.
We found 4 fibers with very low light transmission, had to be replaced by spare fibers.
Many other fibers had to be cleaned many times. The connectors get dirty after reconnecting them 2-3 times. Some signals are of a poor quality even after the cleaning.



Broken MPC connector at PP0.
Was fixed by splicing the fiber and installing a new connector.

Connection Nightmare! Our PP0 Area.

Everything installed ready to close

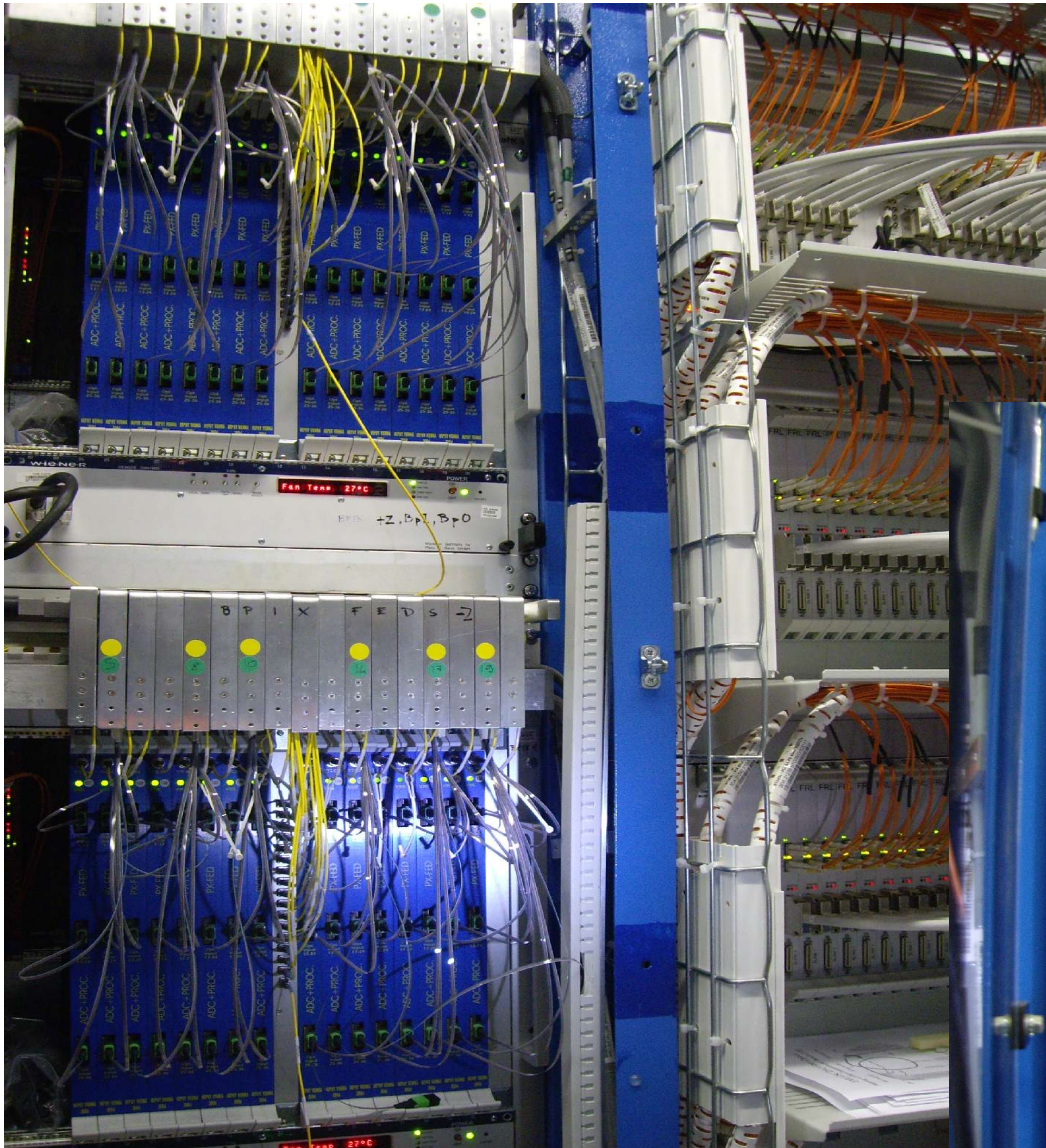


A warning for SLHC upgrades!

Readout & Control

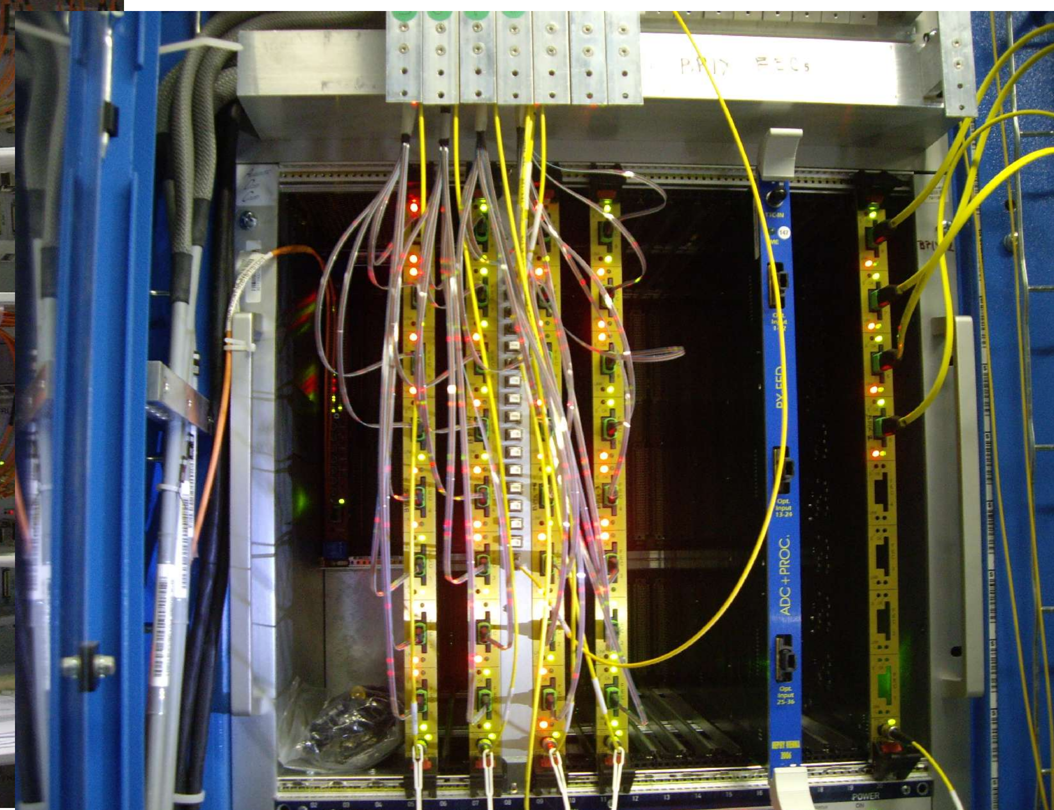
More details from Christian Veelken

FEDs – readout (bpix)

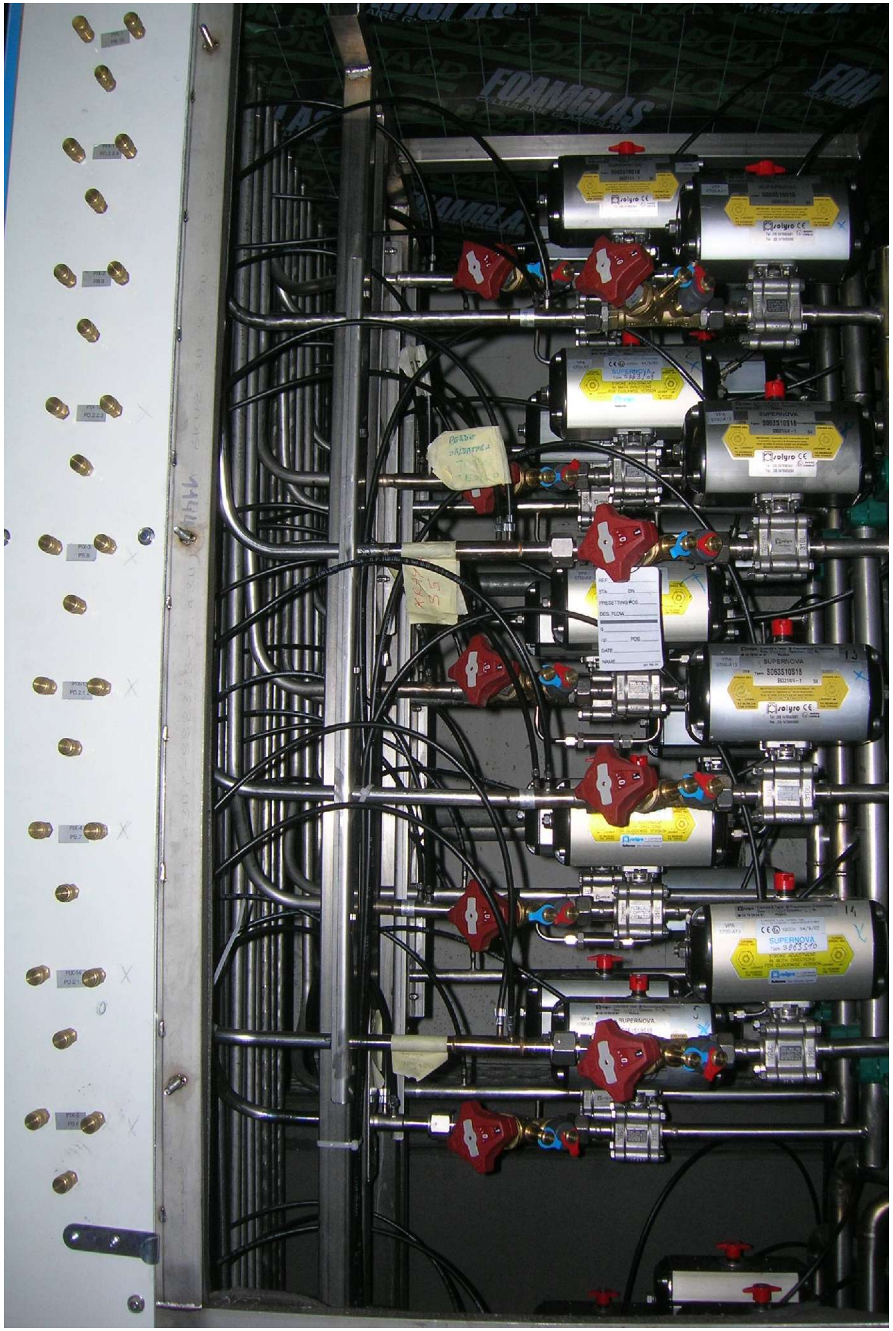


For the fpix there is in addition one more FED crate (8 modules) and one FEC crate (3 modules)

FECs – control (bpix)



Other problems



1) Cooling (C6F14 at 1.8bar)
The pixel detector uses the same design of the cooling plant as the strip and the pre-shower detectors.

The design and the quality of manufacturing was poor. Most problems were debugged by our strip colleagues who installed much earlier.

Nevertheless still o lot of hard work (3-4 weeks) was required by the pixel group to get the cooling running (mostly done by our US collaborators).

The cooling is running now at 11deg.
Most likely it will stay like this until then end of the year.

Other problems

2) Power (CAEN, EASY-series power supplies)
Our power supplies are in the experimental cavern. They were designed by CAEN to work in magnetic field and radiation. Similar units are used by the strip detector.
The quality is acceptable (10% broken units until now) but the delivery time was late.
We had/have a lot of mechanical problems with the connectors, bad contacts etc.
This is still an important issue for us.

Now, after the 1st beam, the replacement and repair procedure will be very complex.

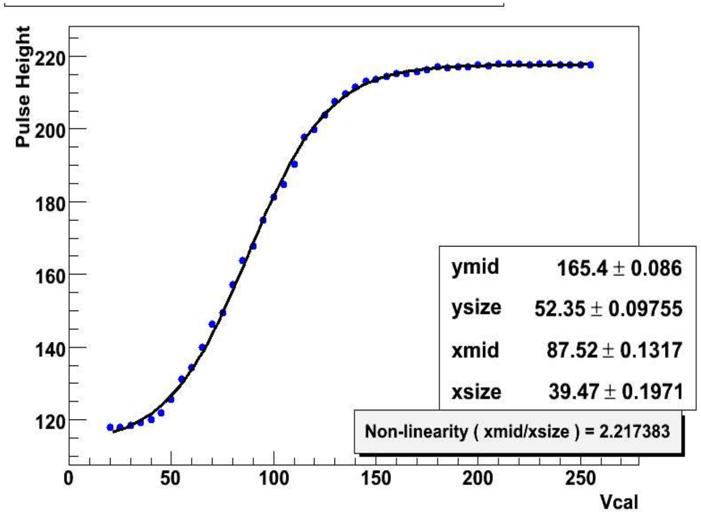
The backside looks much worse!

Some Design Issues

1) Front-End programming, use a 40MHz I2C like protocol.
For the START/STOP condition needs effective 80Mhz bandwidth.
Worked in the LAB. Seems to also work OK in the CMS environment with long kapton cables, optical fibers, optical converters.

2) Analog Readout
Improves our position resolution but is difficult to handle.
It worked very well in the LAB and in test beams but we have underestimated the thermal effects in the optical components.
Our AOH (analog optical hybrid) is very, very temperature sensitive, resulting in serious signal drifts (baseline and gain).

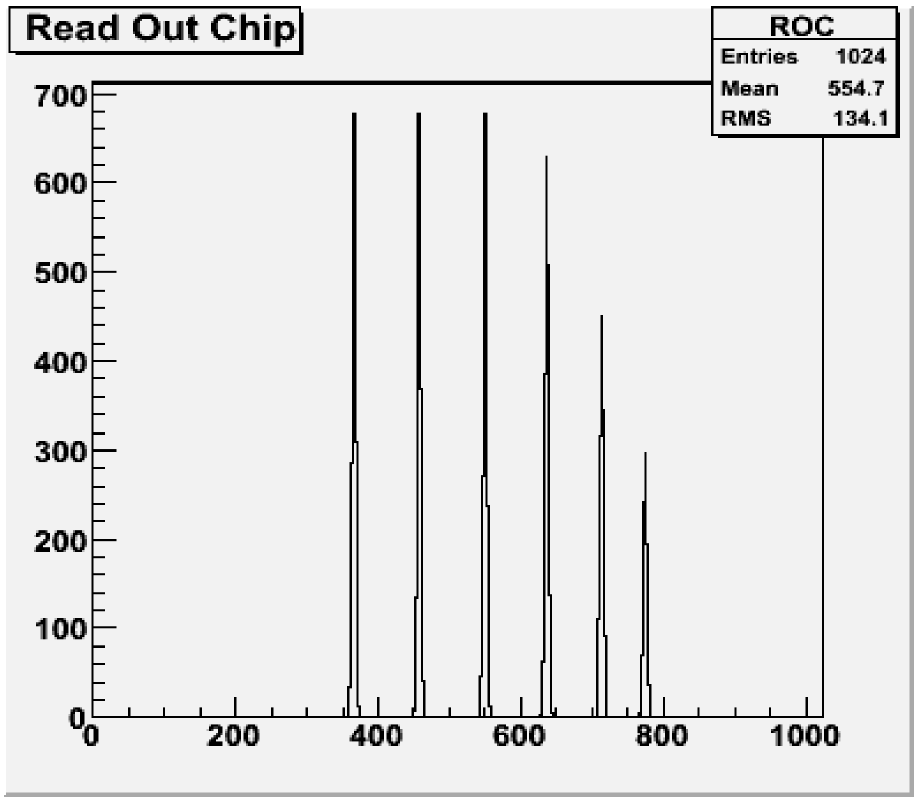
This means that in addition to the automatic offset adjustment we need to perform frequent base-line calibrations.



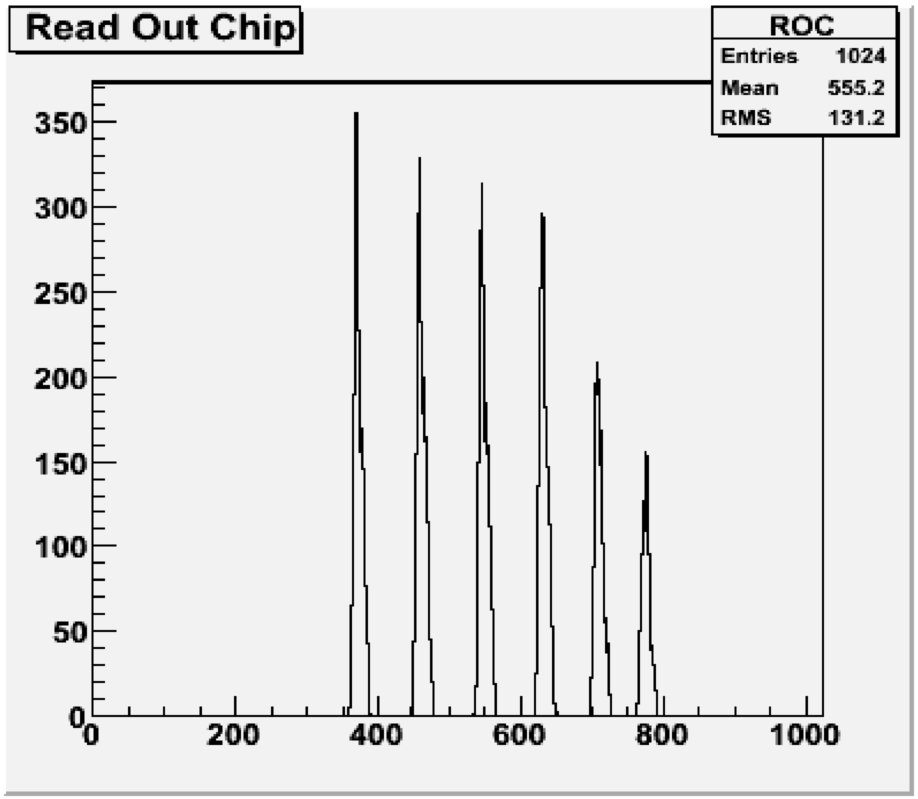
An example of the response of the pixel analog signal.

Analog Coded Pixel Addresses

Good case (rms ~2.5)



Worse case (rms >5)

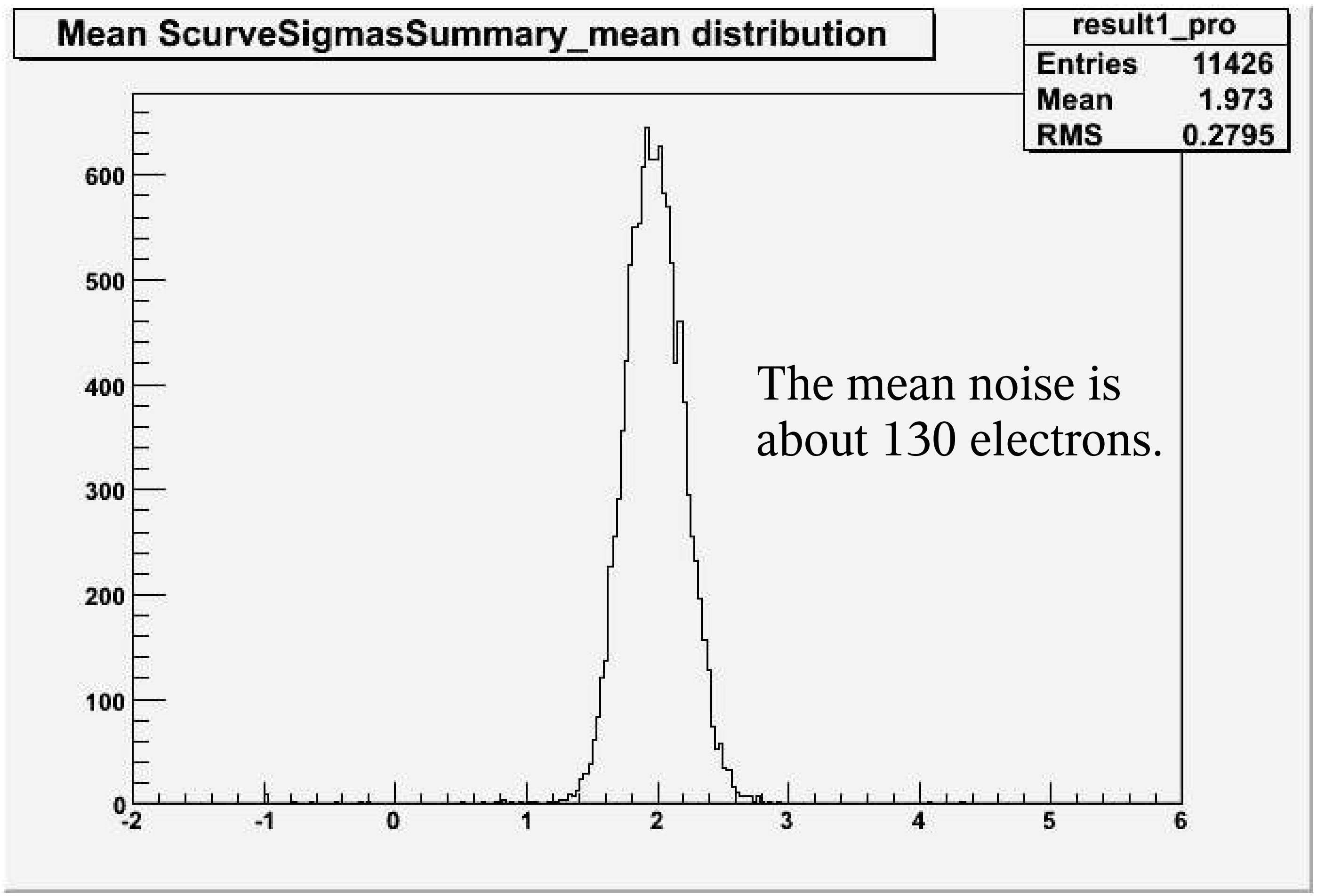


Can we maintain this through longer physics runs?

Still To Do

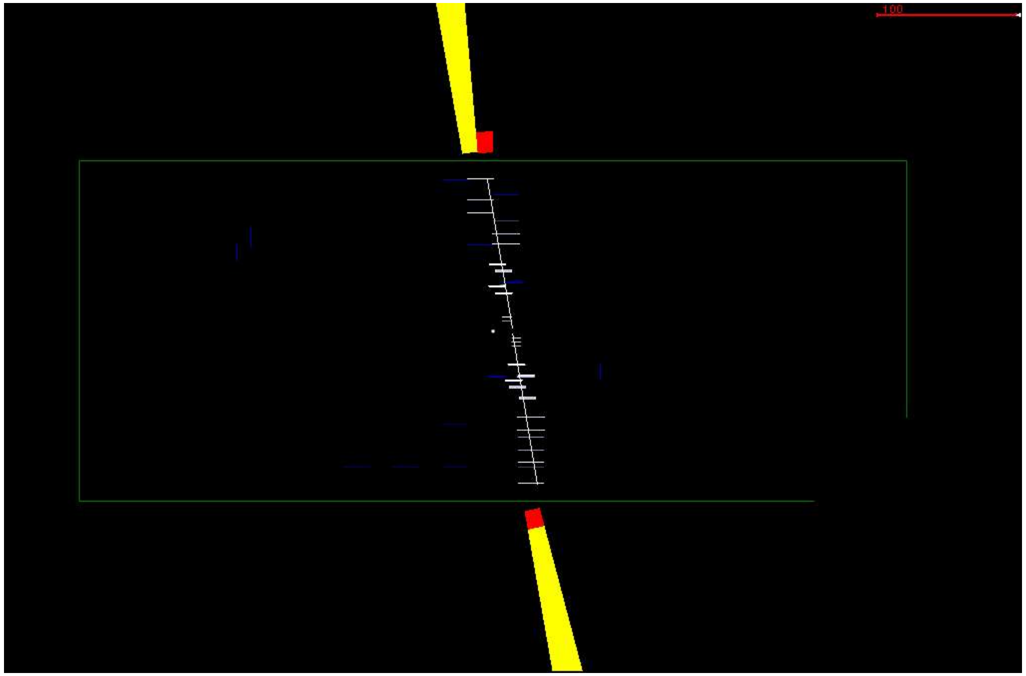
The detector is running but we only just started with serious detector calibrations. The analog signal needs a lot of attention to adjust the linearity, measure the gain calibration. We still need to finalize the trimming (threshold adjustment).

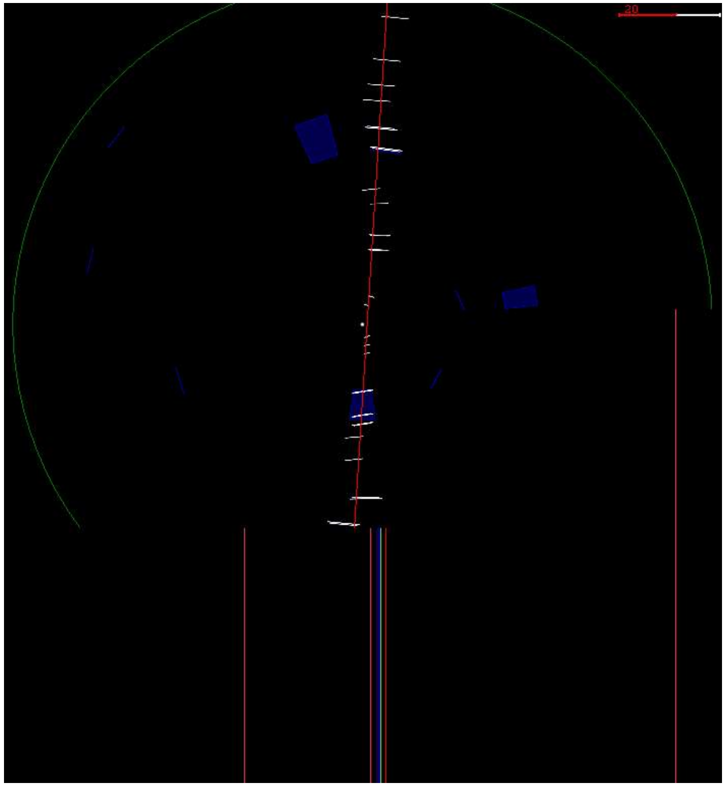
Average noise per ROC



Why is it lower than in the module testing?

First Cosmic Events





The CMS Pixel Collaboration

(for the last time split into bpix&fpix)

FPIX

FNAL, North-Western, Rutgers, Johns Hopkins, Purdue, UC Davis, Cornell, Colorado, Nebraska-Lincoln, Vanderbilt, Kansas, Puerto-Rico, Iowa, Rice, Mississippi
Milano

BPIX

PSI, Uni. Zuerich, ETH-Zuerich
HEPHY-Vienna
(Kansas, Nebraska)