Construction of the CMS Forward Pixel Detector

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On behalf of the CMS Forward Pixel Collaboration

University of Colorado, Cornell University, UC Davis, FNAL, University of Iowa, John Hopkins University, Kansas State University, University of Milano, University of Mississippi, University of Nebraska, Northwestern University, Purdue University, Purdue University Calumet, University of Puerto Rico, Universidade do Estado do Rio de Janeiro (Brazil), SUNY Buffalo, Rutgers University, University of Tennessee, Vanderbilt University, University of Virginia

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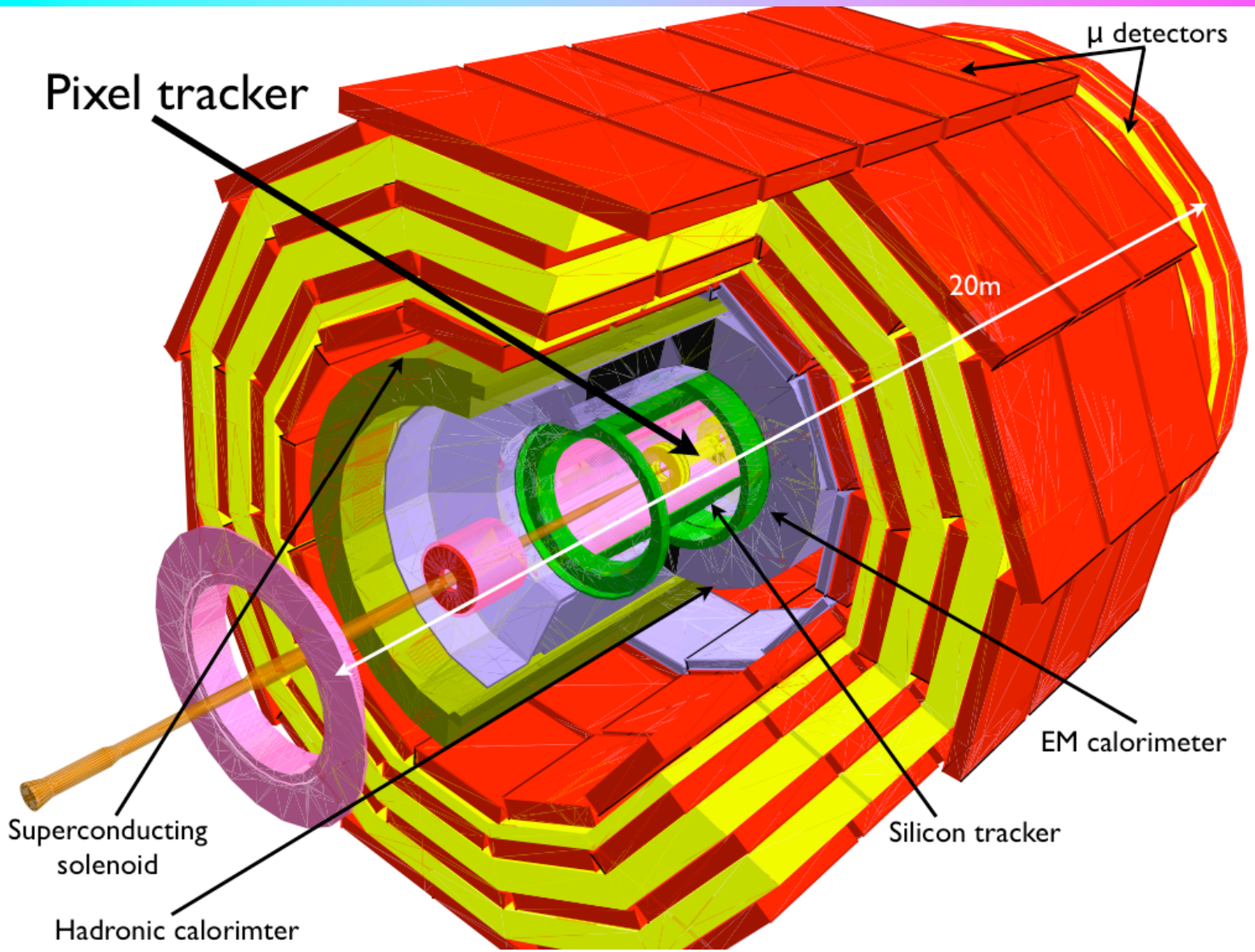
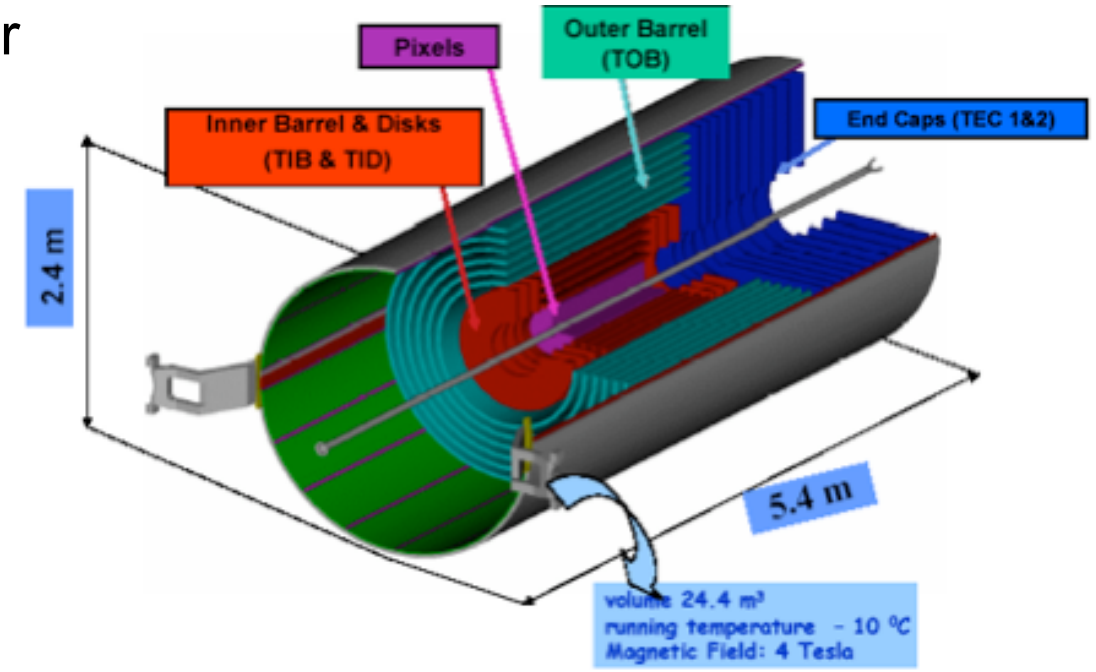
The CMS Detector



Pixels – At Core of CMS Tracker

- 5.4 m long x 2.4 m diameter
- Silicon sensor technology
- 17000 silicon modules
- 13 Barrel Layers
- 14 End Cap Disks



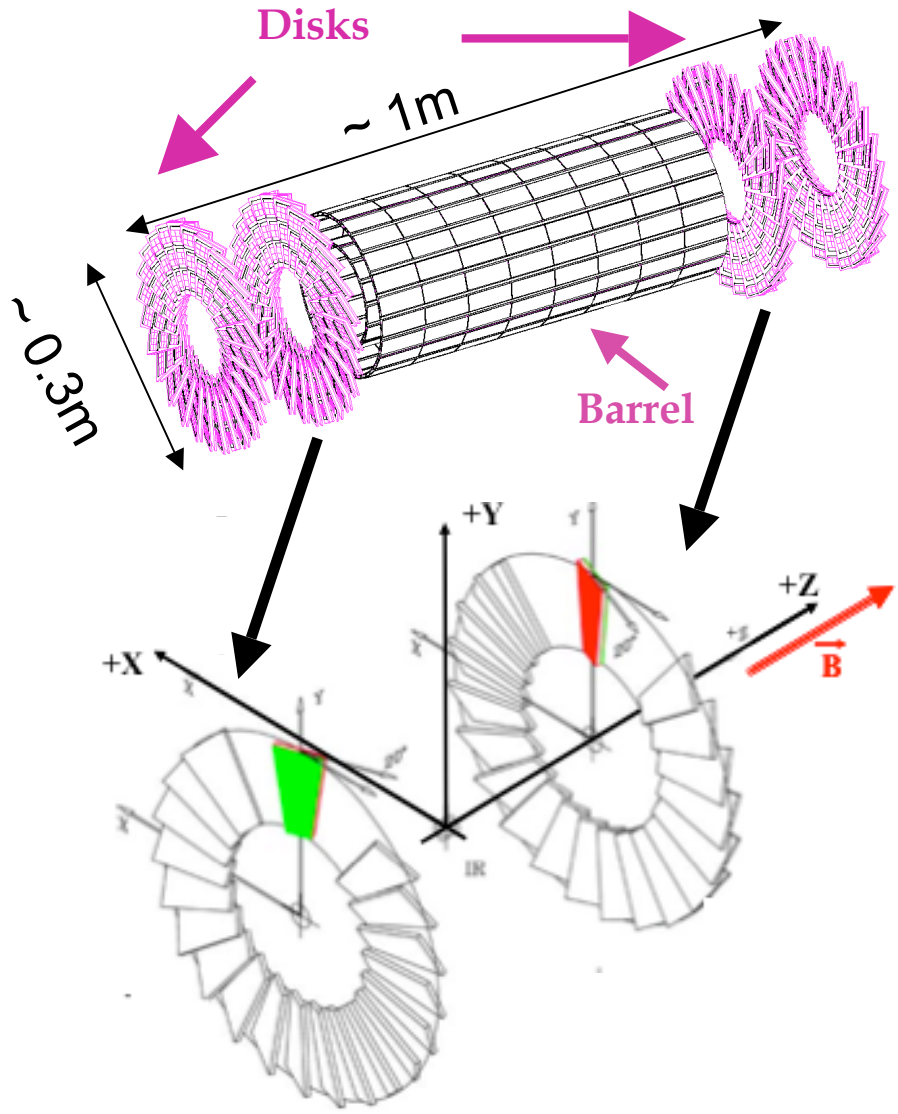
Divided into 3 subdetectors

- Pixel Detector based on silicon pixels
- Inner Tracker based on silicon microstrips
- Outer Tracker based on silicon microstrips

The Pixel design guarantee 3 pixel hits, up to a $|\eta|$ = 2.5, that are used for three main purposes:

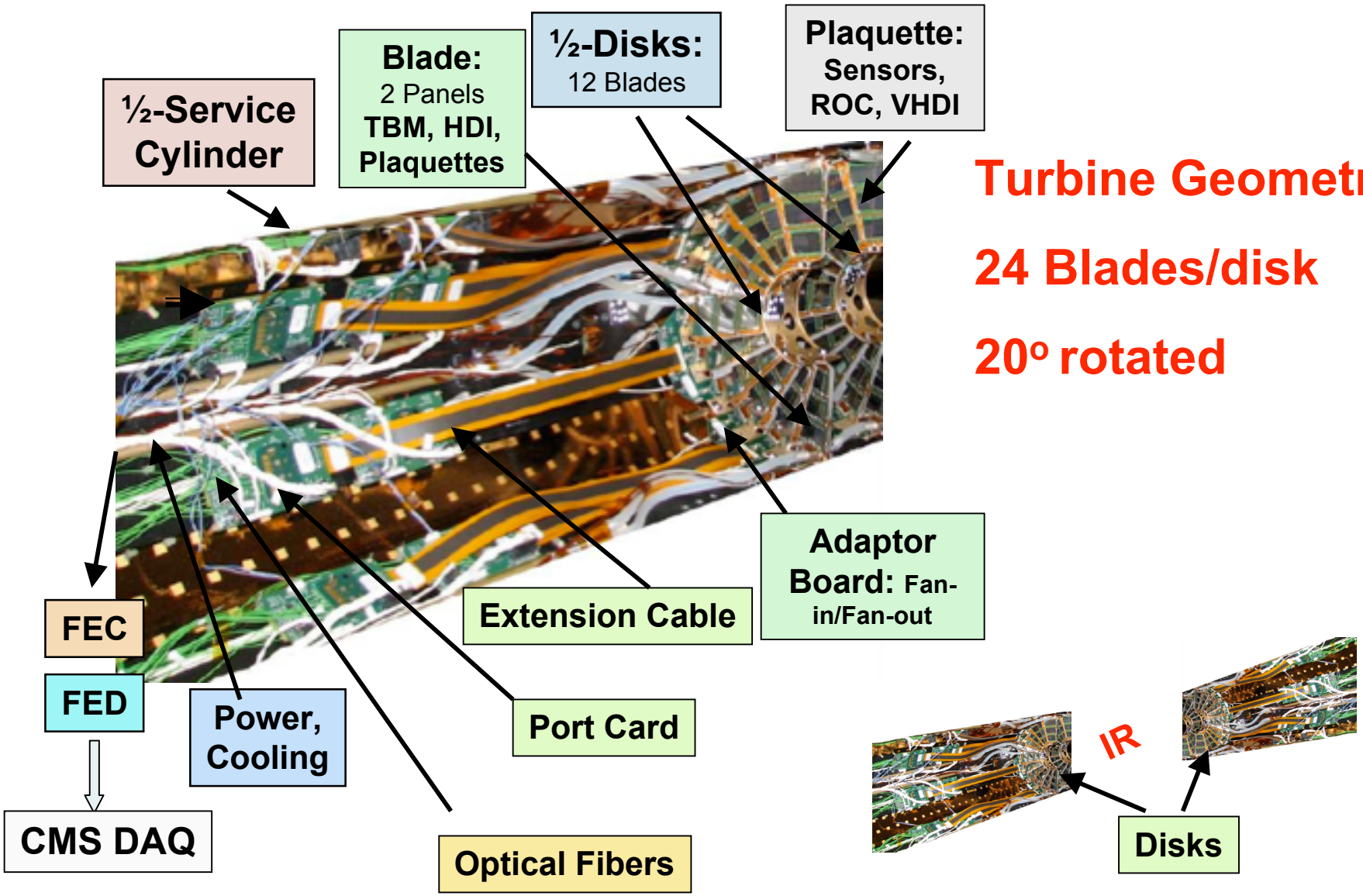
- seeds used for pattern recognition in all tracker
- improve the vertex resolution near the IP
- fast tracking and vertexing in the High Level Trigger using only the pixel info

The Pixel Detector – Facts



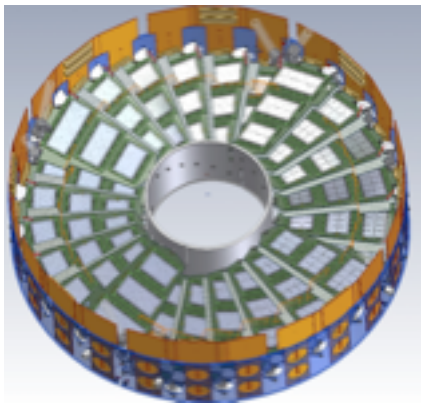
- Active area ~ 1m^2
- Operation at~ -10 ^{0}C in 4 Tesla B field
- 3 space points up to $|\eta| < 2.50$
- 100 × 150 μm^2 pixel size ⇒ excellent spatial resolution ≈10-20 μm
  - Charge sharing promoted by 4T B field and 20^0 tilt in FPix
- Barrel (BPix) - 3 barrel layers
  - r= 4.3, 7.2 and 11 cm
  - 672 modules,96 half modules
  - 11528 Readout Chips (ROCs), 48 million pixels
- Forward (FPix) - 4 disks
  - Z=±34.5 and ±46.5 cm (~ 6 cm above beam line)
  - 96 blades with 672 modules
  - 4320 ROCS, 18 million pixels

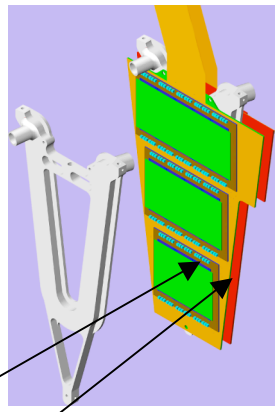
FPix Disks - Overview

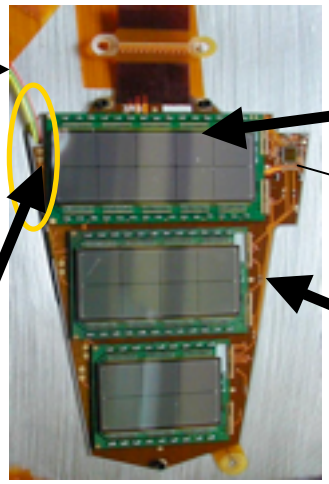


Disk – A Complex Structure

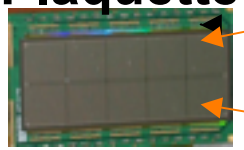
Disk (*turbine geometry,20⁰*) **Blade**(***24/disk***) **Panel**







Plaquette



VHDI

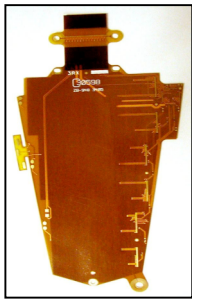
Bump bonded Module

(Sensor + ROC)

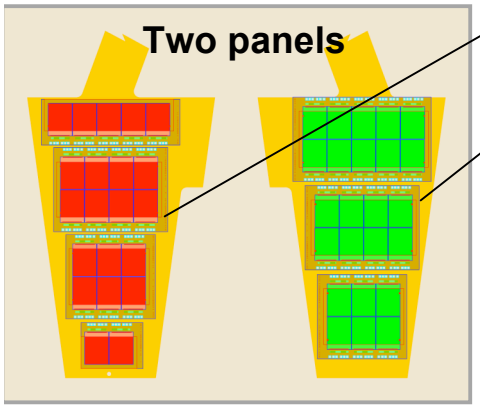
TBM chip

Be substrate

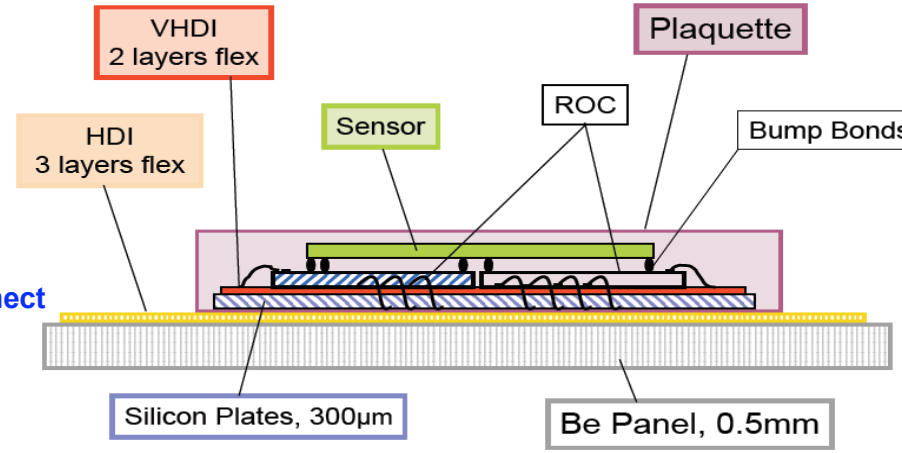
HDI



Two panels



Multi-layer structure



7 types of plaquettes

7 types of VHDIs

5 types of sensors

4 types of HDIs

4 types of panels

Terms:

VHDI: Very High Density Interconnect

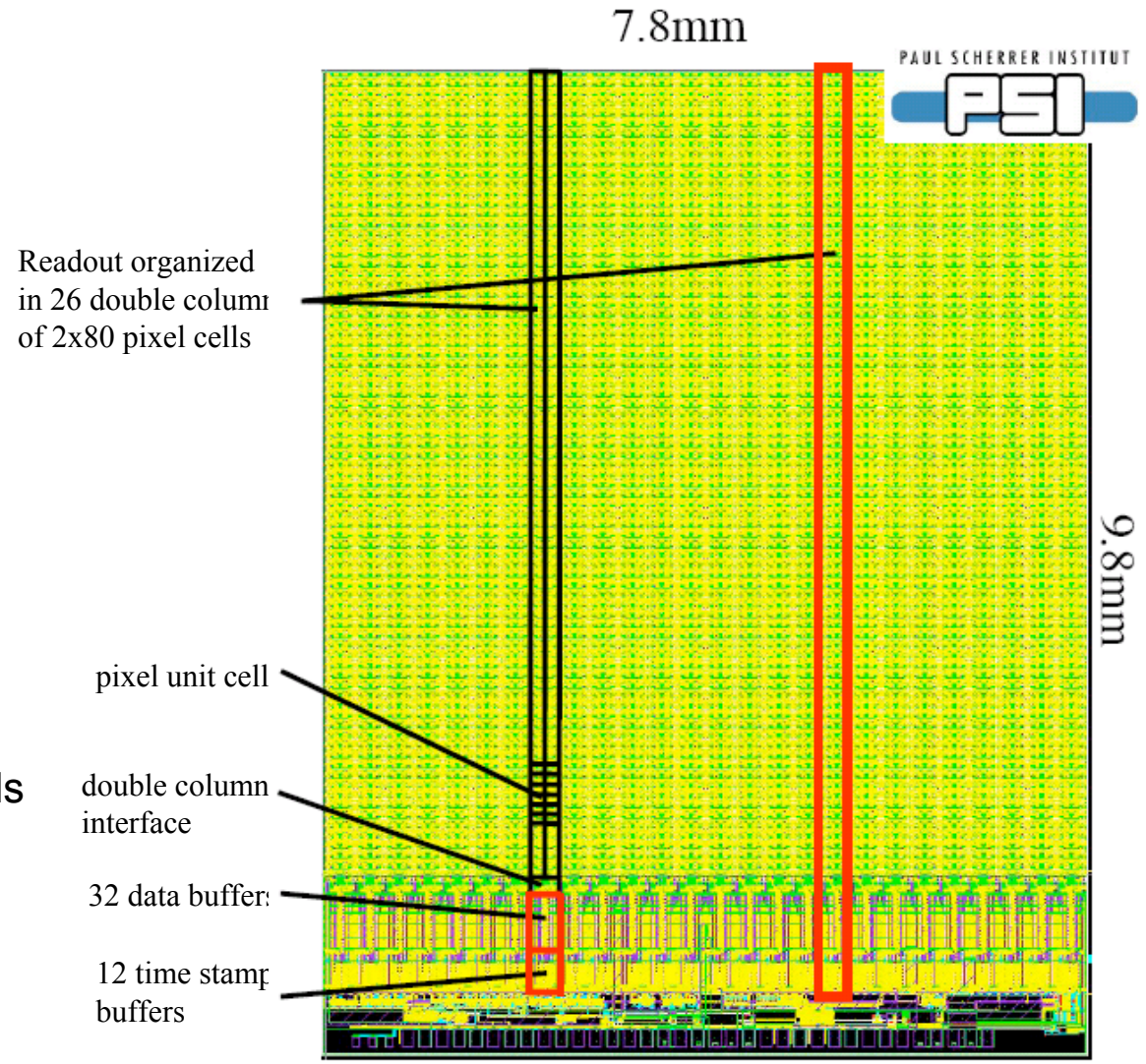
HDI: High Density Interconnect

TBM: Token Bit Manager Chip

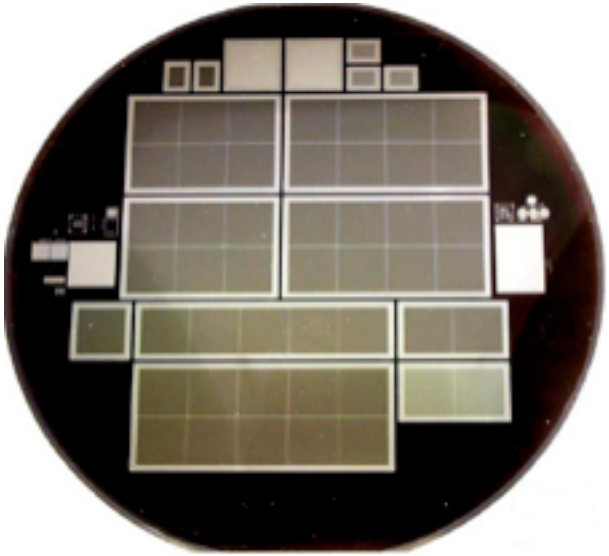
ROC: Readout Chip

The Readout Chip

- 0.25µm IBM CMOS rad hard technology
- 100x150 µm pixel cell size which provide a spatial resolution of ~10µm in rφ and ~20µm in z
- 52x80 cells organized in double columns
- 32 data and 12 time stamp buffers
- Data are encoded on 6 analog levels



The Sensor - *n*-on-*n*

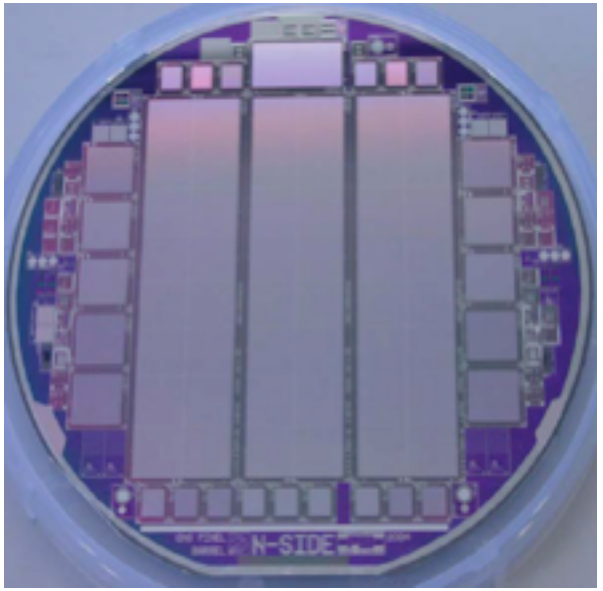


FPIX

- Sensors use partially open p-stop isolation and they are all in hand from Sintef
- They are bump bonded to the ROCs at two different vendors, RTI and IZM using PbSn

Barrel (BPIX)

- Sensors use p-spray isolation and they are all in hand from CIS
- They are bump bonded to the ROCs in house at PSI using indium



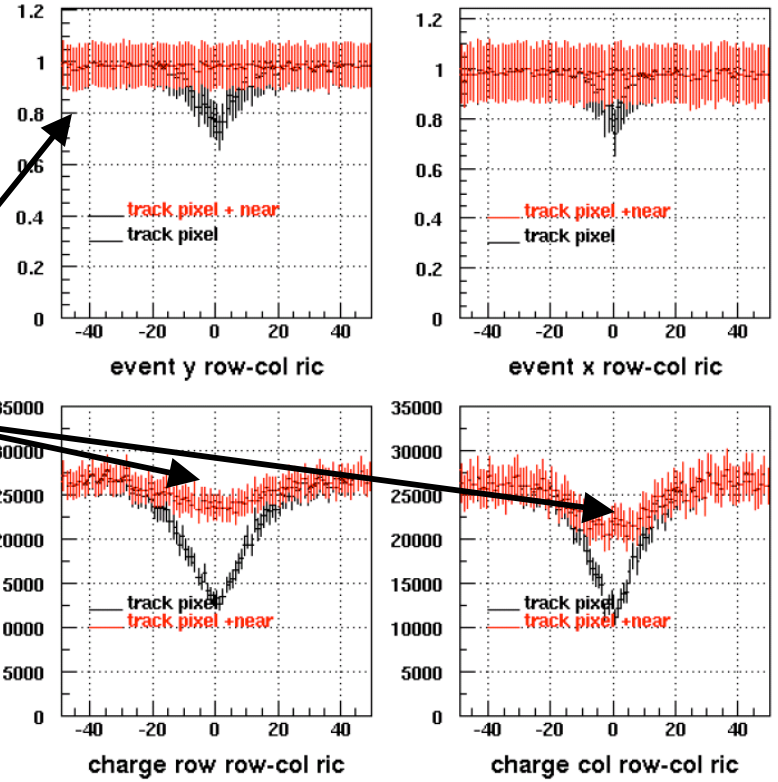
Charge Collection in Irradiated Devices (Prelim. Results)

Extensive studies have been done in the past years to guarantee high efficiencies for highly irradiated detector.

The track detection efficiency was measured for both technologies. After a fluence of 8×10^{14} neq/cm^2, above the goal of the CMS TDR, the detection efficiency is > 99% both for BPIX and FPIX.

FPIX testbeam 2006

- No evident loss in detection efficiency
- Some enhanced charge loss when compared with non irradiated devices
- Some asymmetry between row and column sharing



Plaquette Testing

- Plaquettes assembled at 6/day
- Undergo 10 thermal cycles -15 to +20
- Detailed performance tests at -15 C
    - HV breakdown, noise, bump bonds, DACs etc.

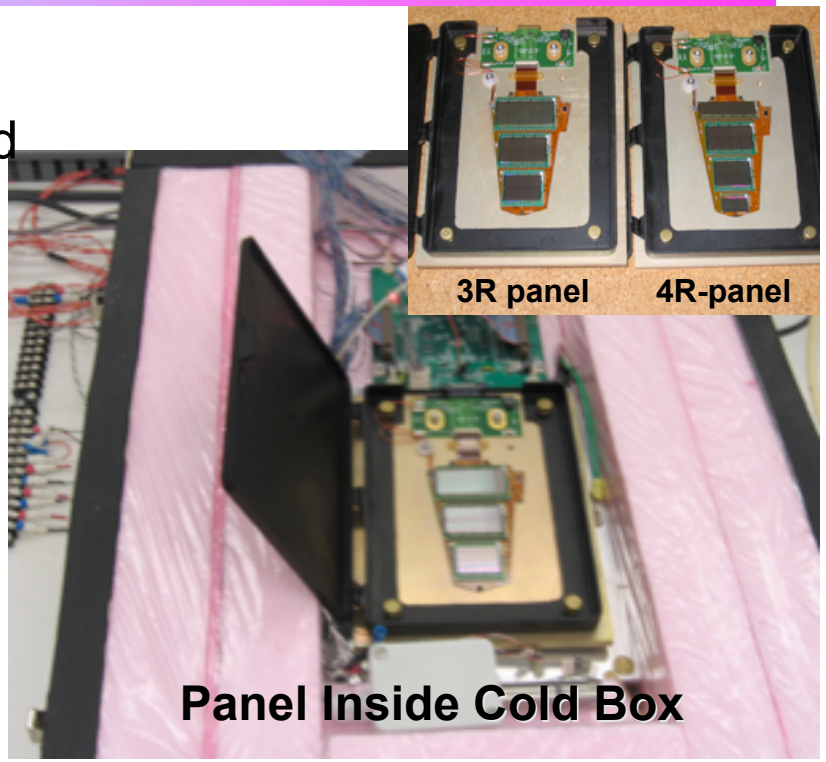
Test stand

Burn-in Box

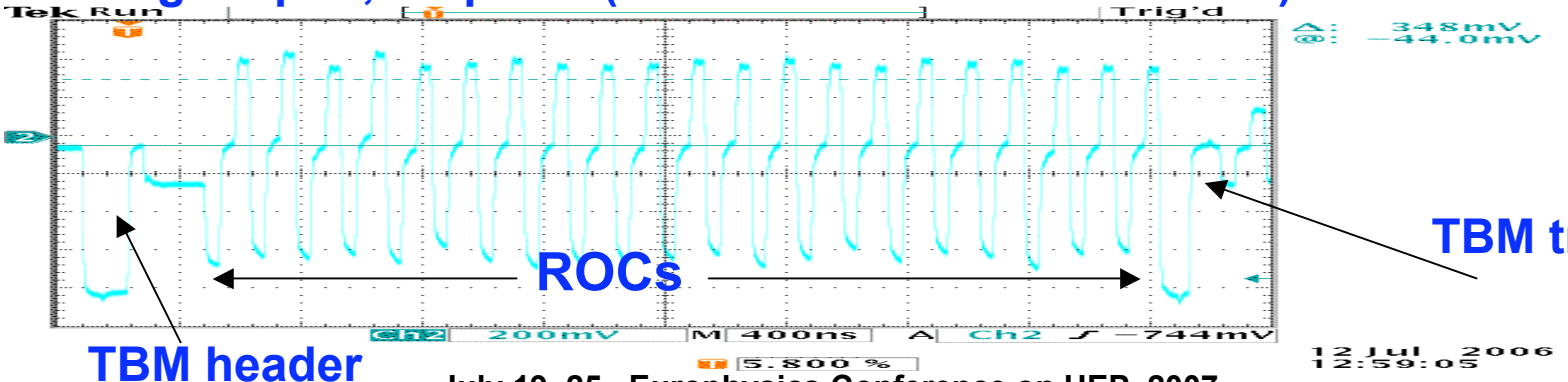
Plaquette Inside Cold Box

Panel Testing

- Bare panels (TBM, no plaquettes) are burned in
- Plaquettes are assembled on panels - 2/day
- Detailed performance tests of plaquettes on panels at -15 C
  - HV breakdown, noise, bump bonds, DACs etc.

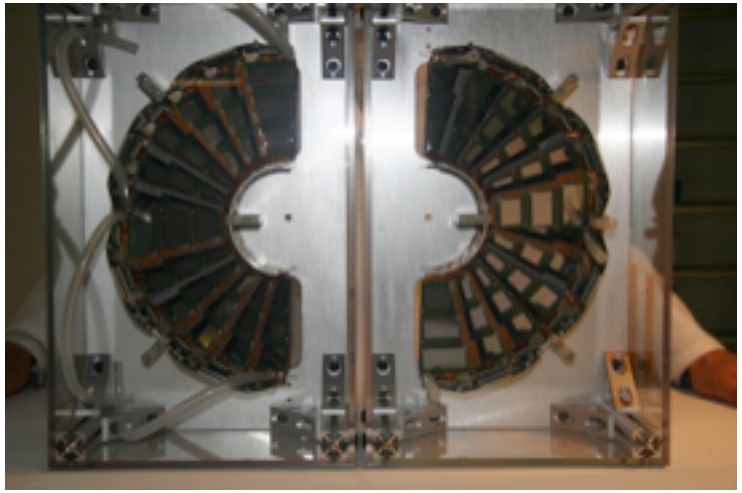


Analog output , 4R panel (21 ROCs = 1x5+2x4+2x3+1x2)



1/2-Disk and Service 1/2-Cylinder

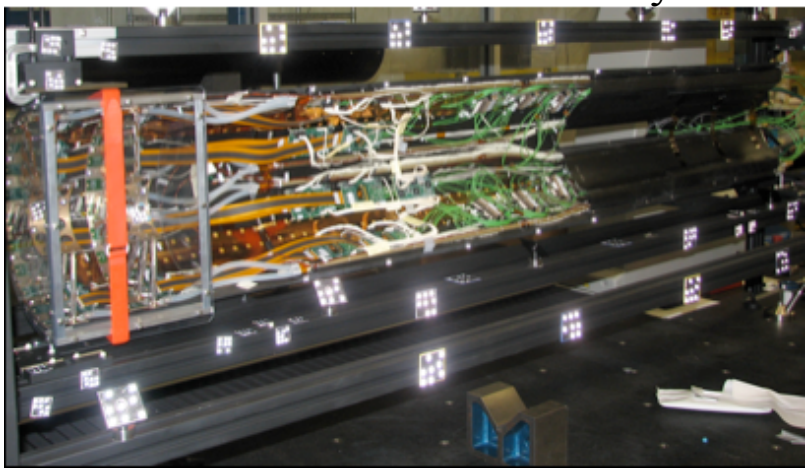
Panels are mounted on the 1/2-disks



Service 1/2-cylinder is assembled

- Panels are mounted on 1/2-disks
- Service 1/2-cylinder is populated with services - optic fibres, Port card, AOH, RTDs, cooling pipes etc.
- The two 1/2-disks are then mounted in the service 1/2-cylinder and tested with the final DAQ electronics
- Shipped to CERN

1/2-disks mounted on service 1/2-cylinder

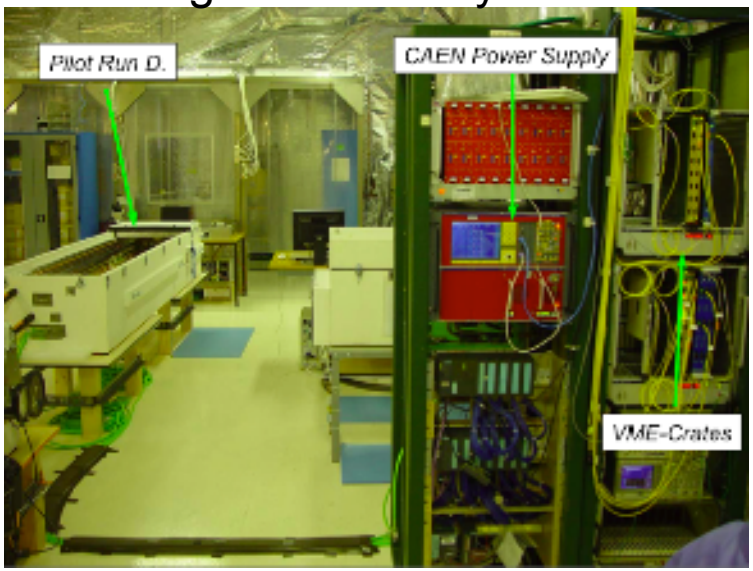


Test facility at CERN

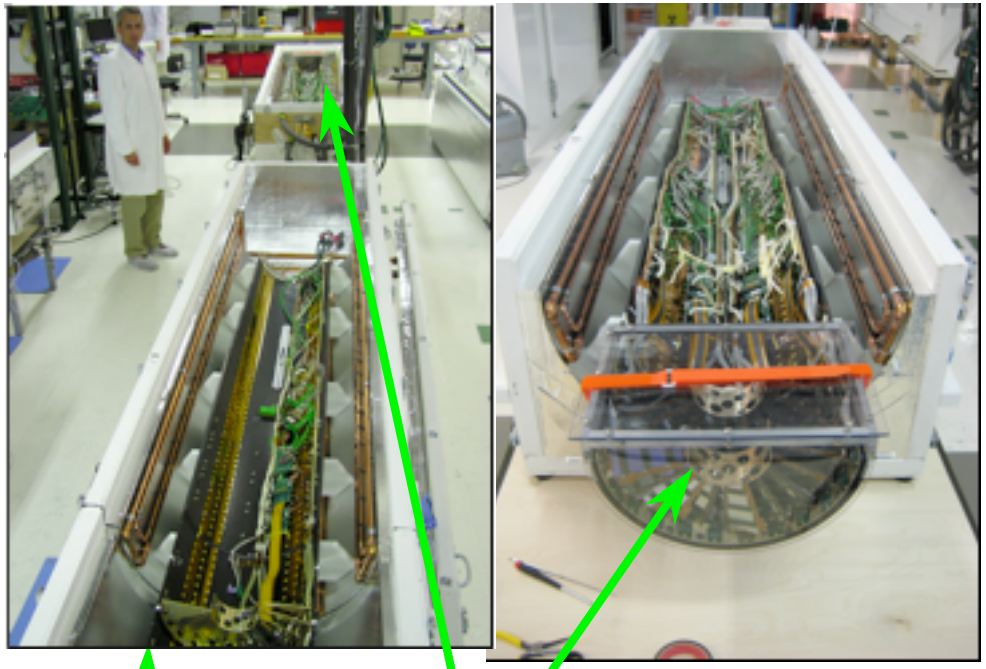
First two production 1/2-disks at CERN

- **Engineering Detector at CERN (September 06)**
  - **8 panels (4 on each 1/2-disk)**
- **Four (out of eight) 1/2-disks and two service 1/2-cylinders (out of four) at CERN**

Pixel Integration Facility at CERN



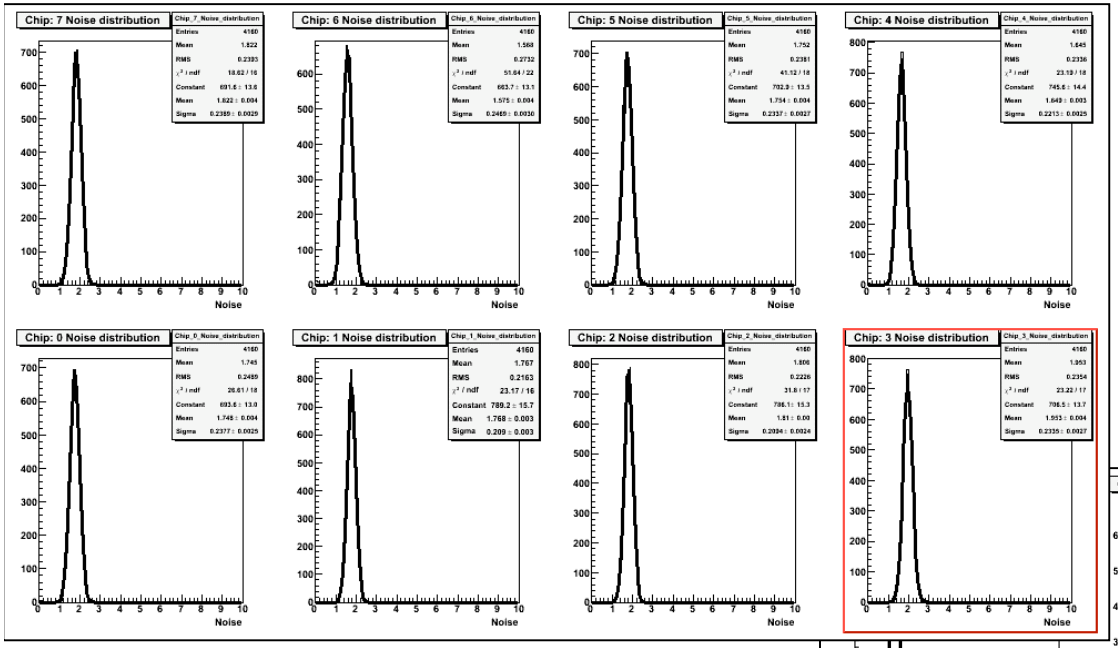
1/2-cylinder HC-Z1 **1/2-cylinder HC-Z2**



HC-Z1, HC-Z2 with two 1/2-disks each

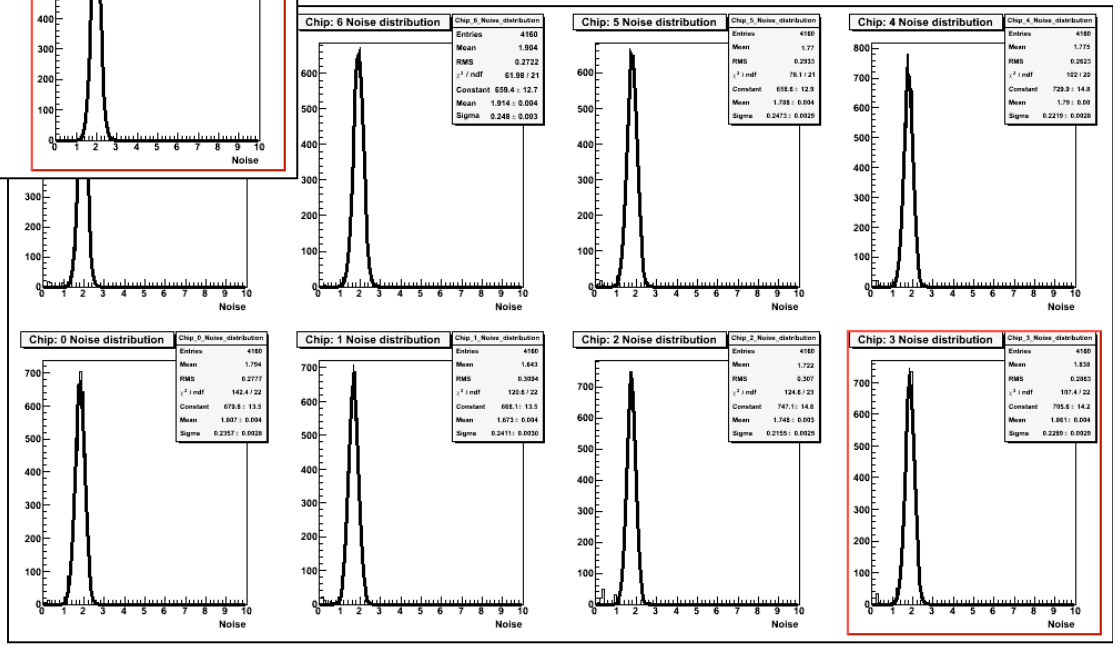
Engineering Run Detector

Noise Measurements (Engineering Run Detector)



Measured at FNAL at +15°C

- ~ 100 electrons

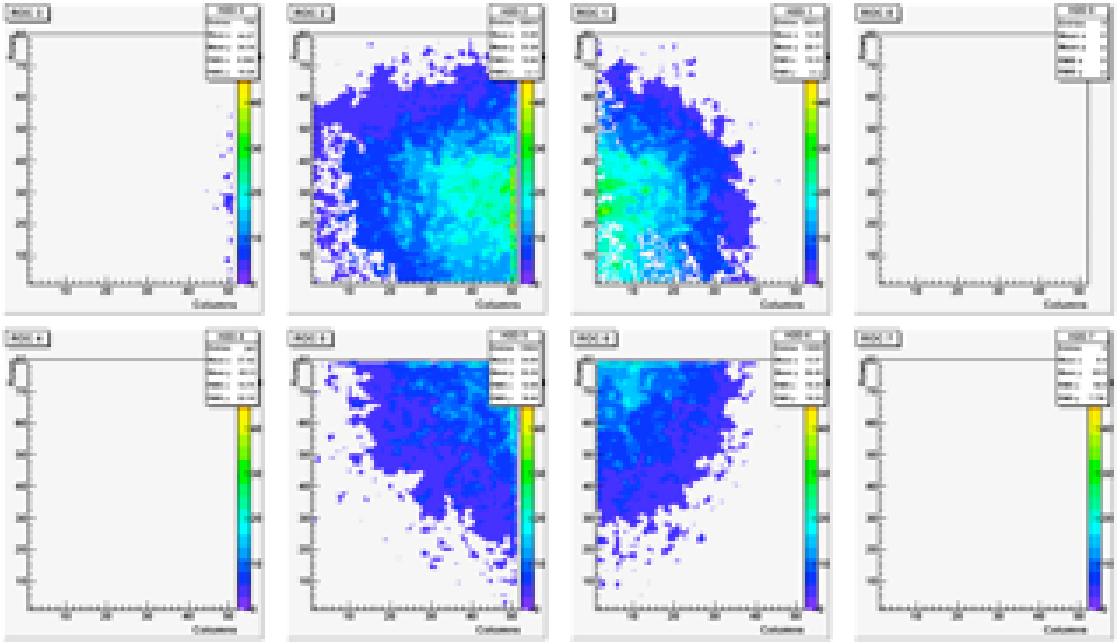


Measured at CERN at -10°C

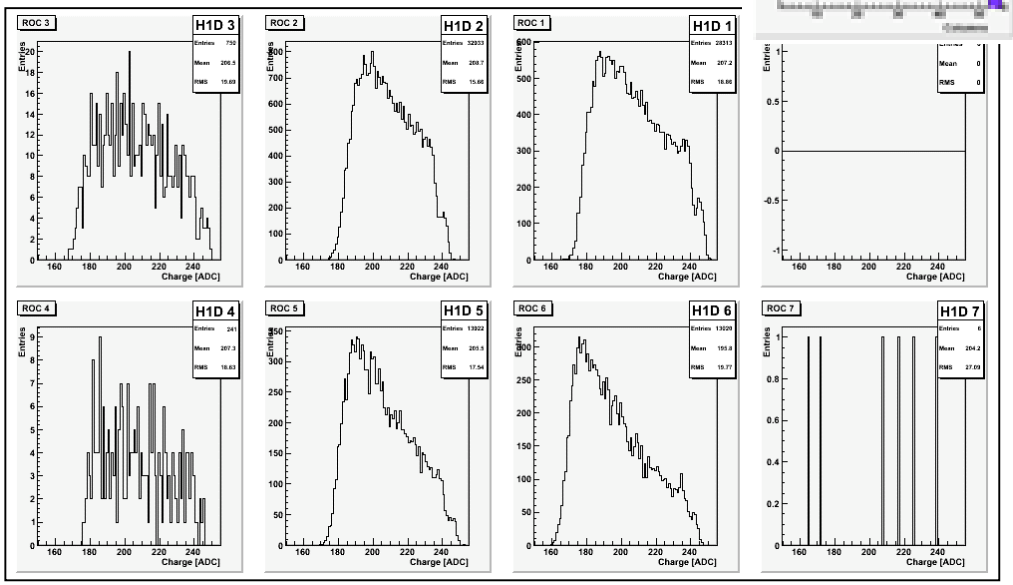
- ~ 100 electrons

Tests-Radioactive Source (Eng. Run Detector)

2x4 plaquette from 4R panel

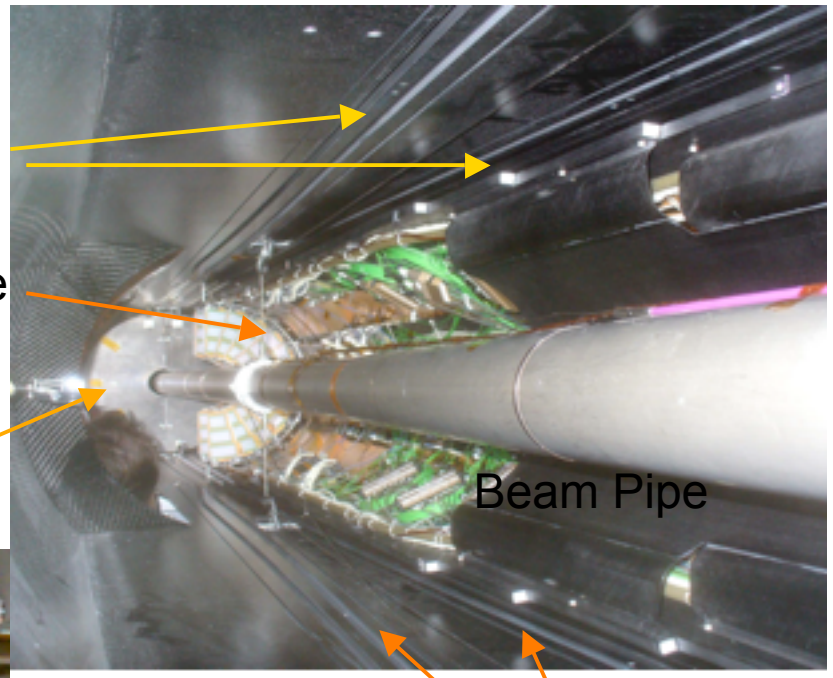


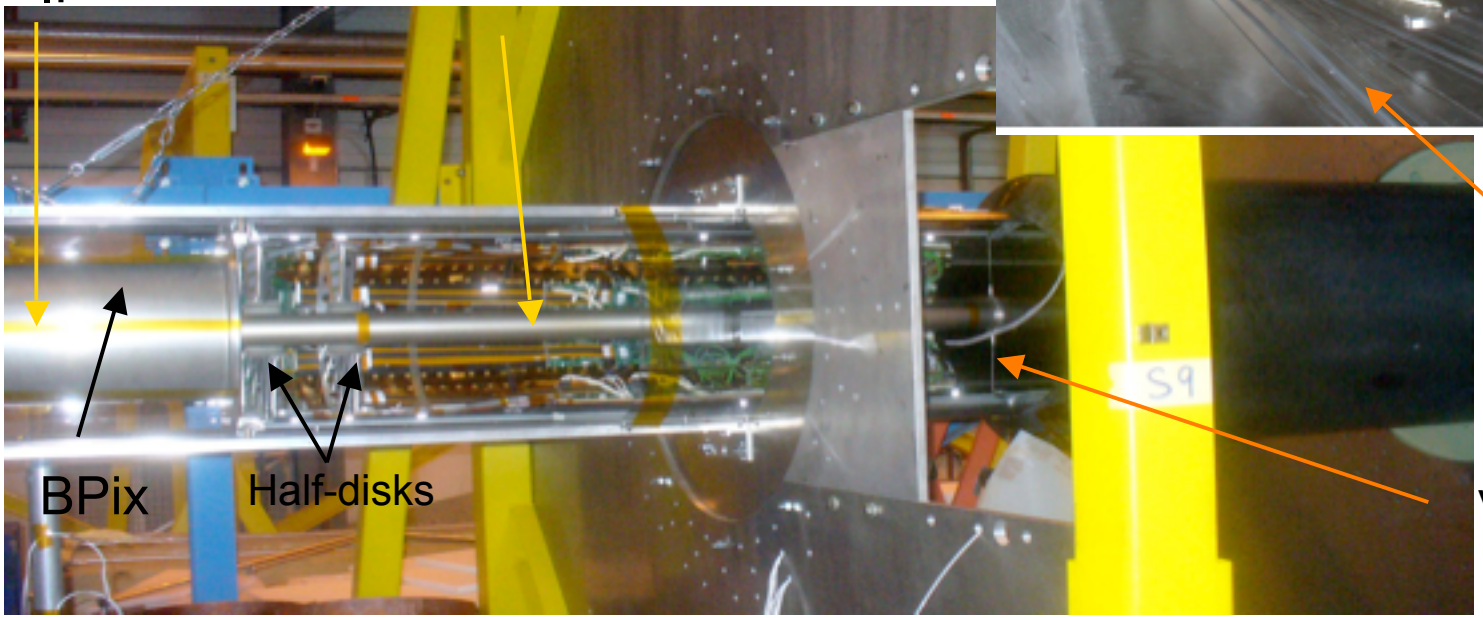
Spectra



Test of the FPix Installation (CERN,May 2007)

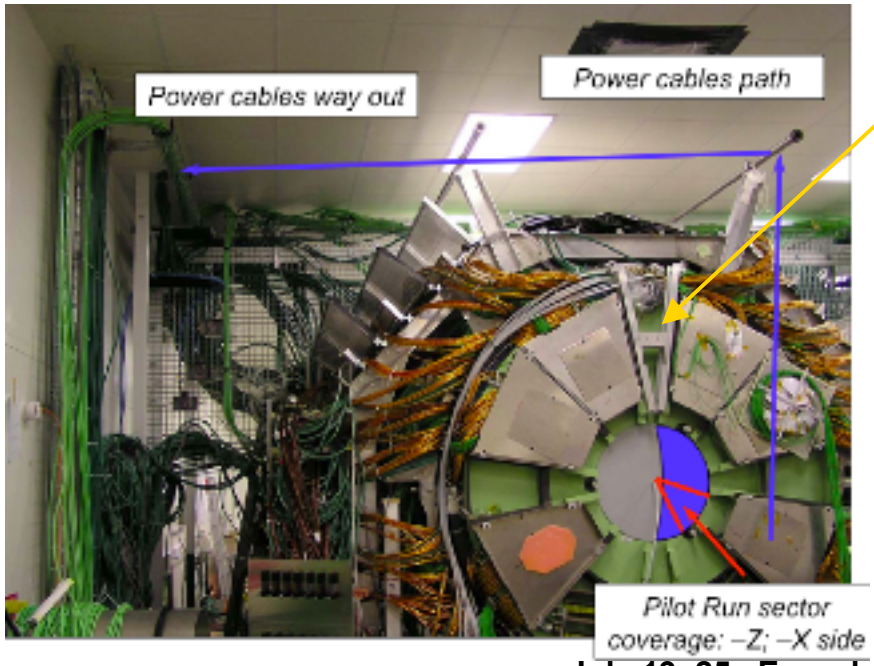
BPix and ½-FPix in Final Position





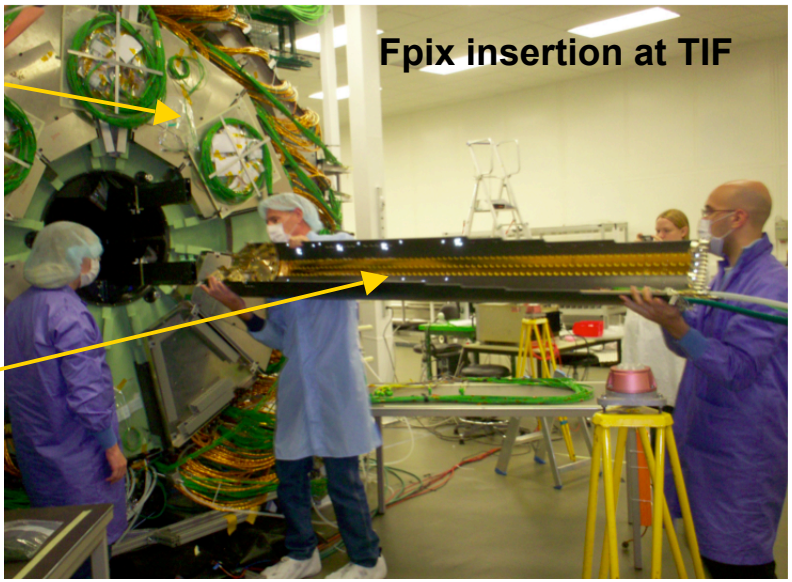
Pixel-Microstrip Integration Test (CERN, July 2007)

- Reality Check (only with Fpix, Engineering Run Detector), only chance before integration at P5
- Plan-
  - run the Pixels without grounding them to the tracker and with the TIB off
  - run the Pixels without grounding them to the tracker and with the TIB on
  - run the Pixels grounding them to the tracker and with the TIB off
  - run the Pixels grounding them to the tracker and with the TIB on
  - Might change the ground configuration and see if this changes the noise
- Around 1/4 of the inner most layer of the TIB will be powered



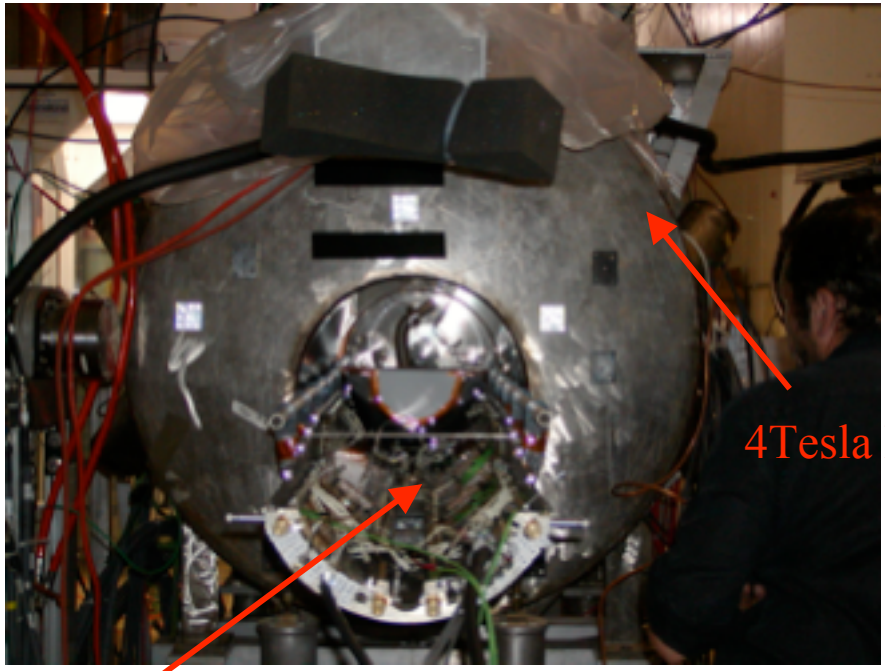
Tracker

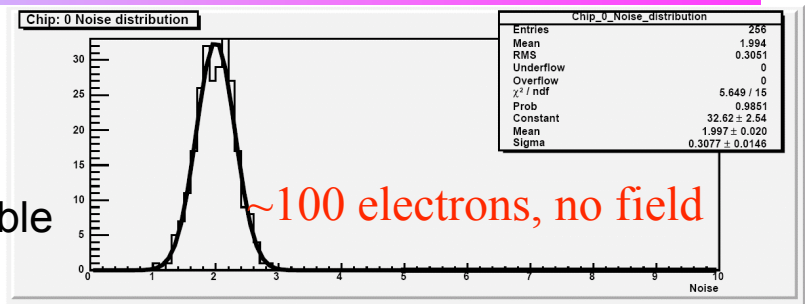
FPix

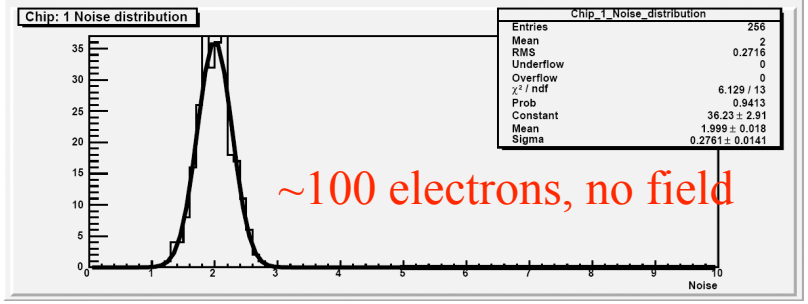


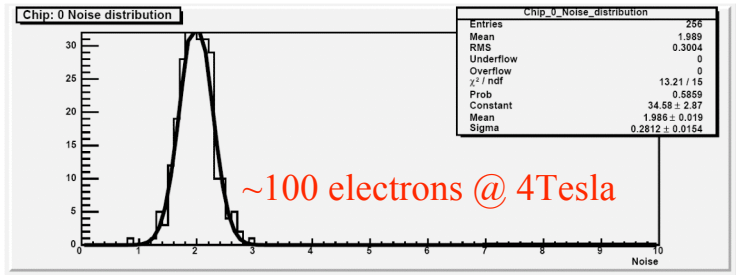
Fpix Magnet Test at FNAL (July 2007)

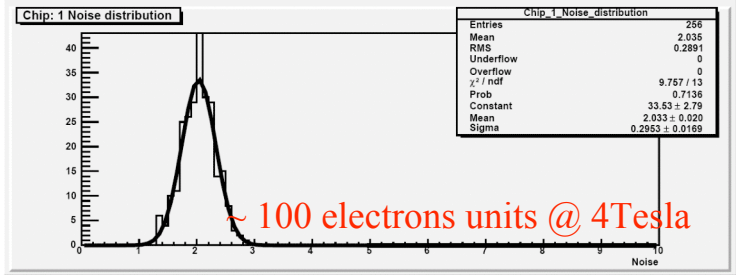
- How the detectors behave at 4T
- Differences in performance with or without B-field
- Forces on the cables, connectors etc. in case of variable loads, Turn on/off procedures
- Potential damages in case of magnet failure
- AOH wirebonds behavior





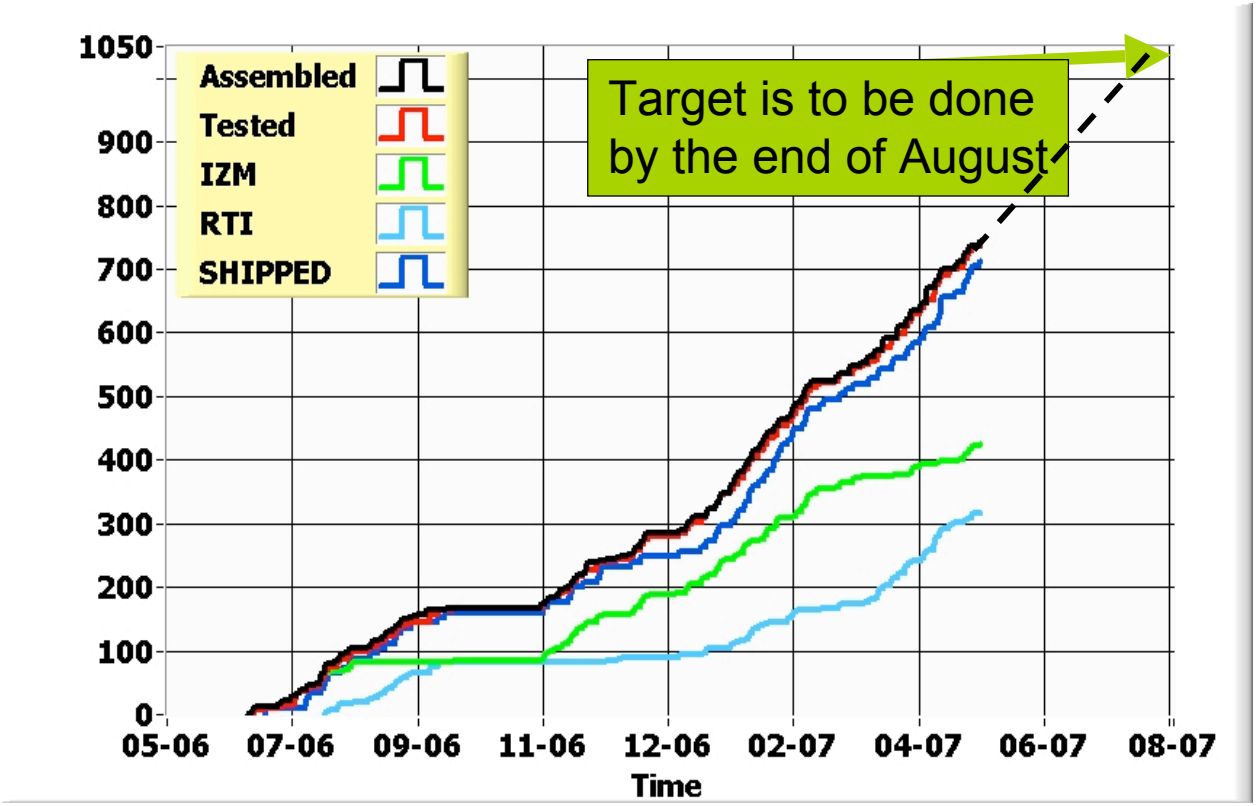






Sudhir Malik

Schedule - plaquette production



All bump modules in hand except the last 20 sets (140 plaquettes)

Conclusions

- The pixel production is running on schedule,extensive tests are performed at every stage of assembly for best quality
- 80% of the FPix modules done and 50% of the full detector assembled. (80% of BPix modules are also done).
  - the ’07 module (Engineering Run Detector) helped us debug our system and setup facility at CERN
  - four 1/2-disks and two 1/2-cylinders are at CERN already.
- Following are underway for FPix
  - integration of the Engineering run detector with the silicon strip tracker
  - test in a 4T magnetic field at Fermilab of a fully instrumented Fpix sector
- A mock installation exercise with the real service cylinder was successful at CERN (May 2007)
- We plan to finish production in September/October of ’07 and have pixel detector at CERN and ready to install by early February of ’08
- We want to install the pixel detector for the start of CMS and have the entire tracking system available for early physics