CMS Pixel Barrel Detector Assembly and Insertion

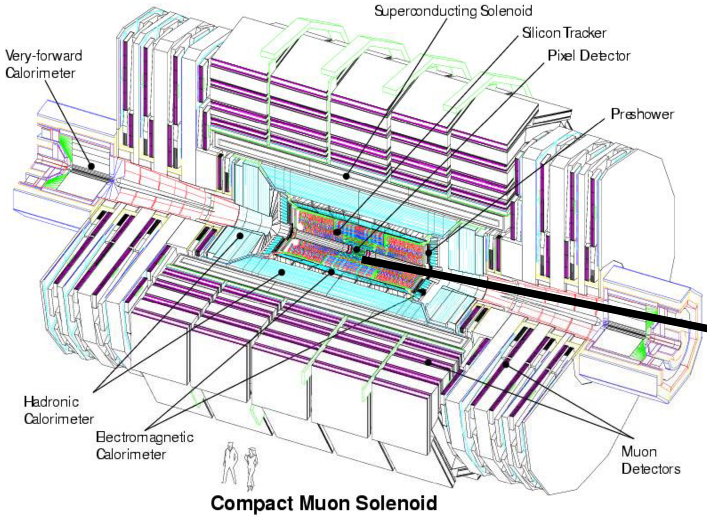
Hans-Christian Kästli, PSI

Vertex08, 28. 7. 2008

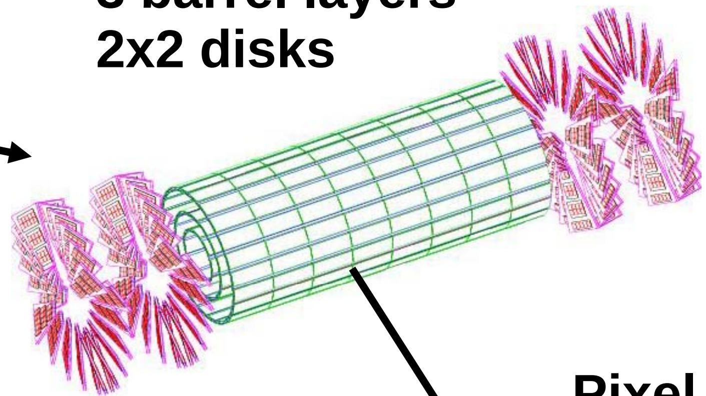
Contents

- Introduction, system overview
- Detector assembly
- Survey
- Service cylinder
- Transport and insertion
- Commissioning

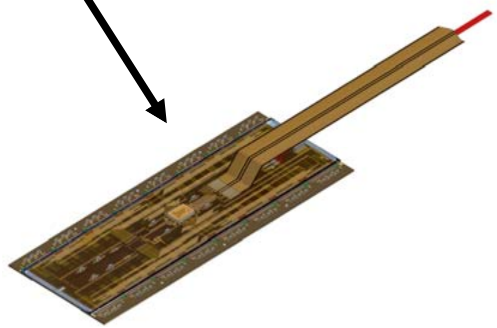
CMS Pixel Barrel Detector



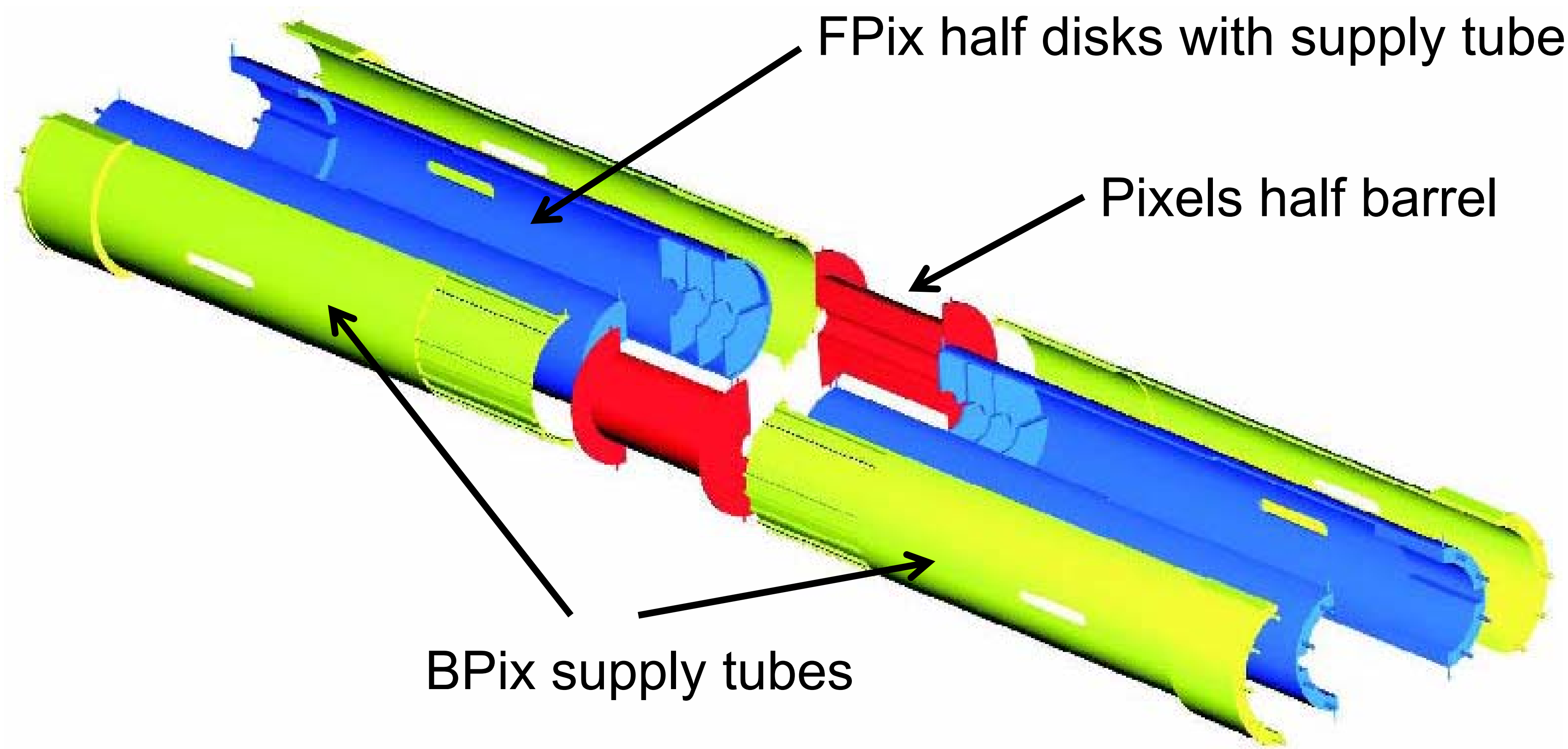
CMS Pixel Detector
3 barrel layers
2x2 disks



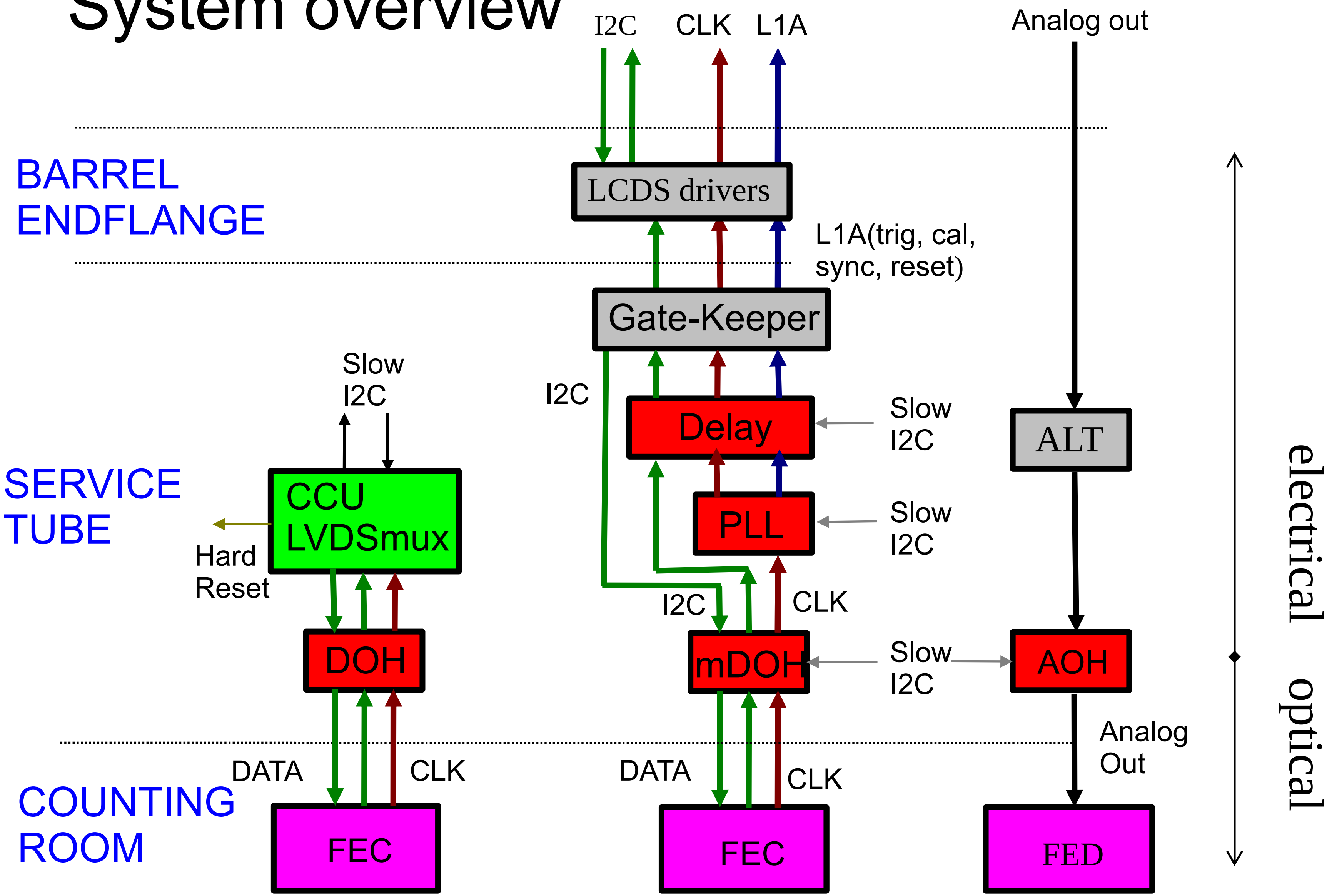
Pixel barrel Module



Radius [cm]	**# Modules**	**# Pixels [10^6]**	**Area [m^2]**
4	128 + 32	9.6	0.15
7	224 + 32	16	0.26
11	320 + 32	22.4	0.42
total	672 + 96	48	0.83

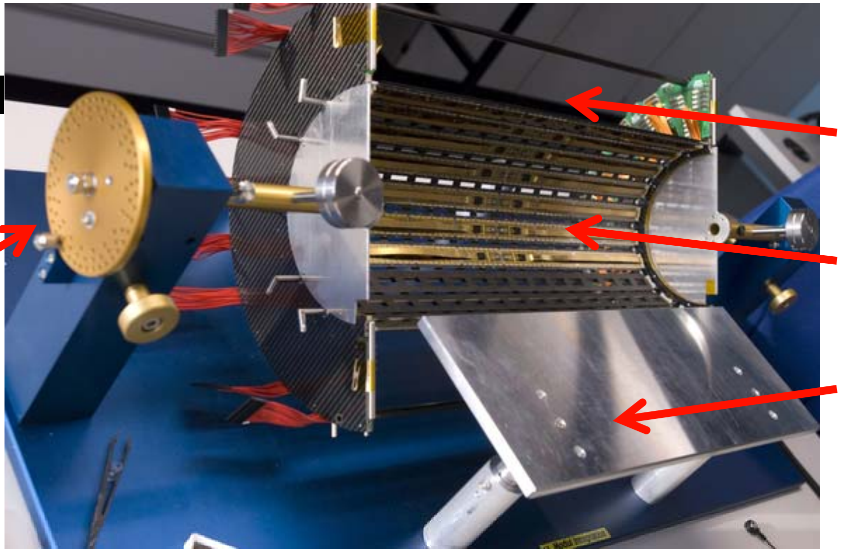

FPix half disks with supply tube
Pixels half barrel
BPix supply tubes

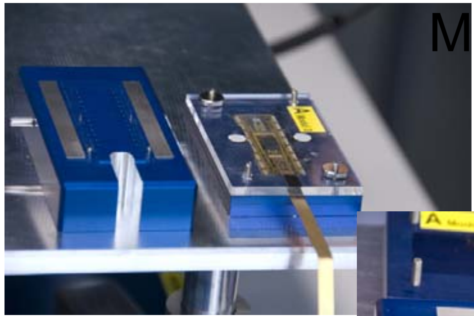
System overview



Detector Integration

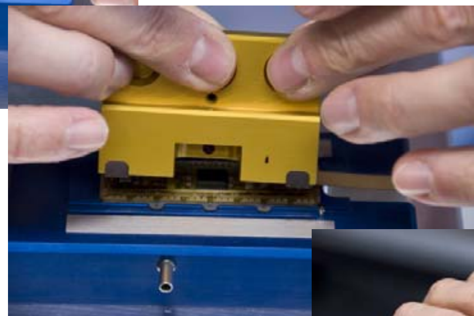
- ~800 modules to mount
- Can do manually if good tooling designed
- Turned out to be very efficient (up to 60 modules per day) and reliable. Only 3 modules destroyed, O(10) could be repaired (broken wire bonds, bad connector)



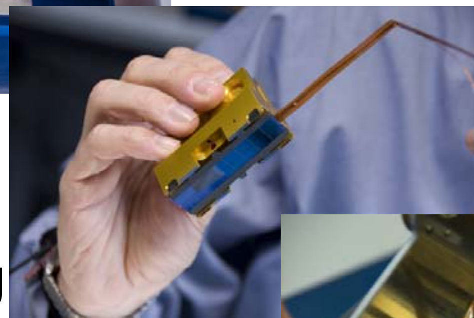


Module in protection box for safe handling while cutting+bending cables, soldering plugs

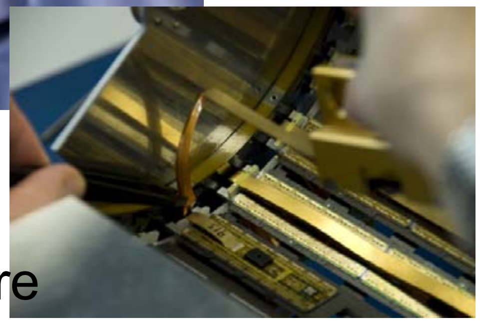
Transfer tool



Pick up with mounting clamp

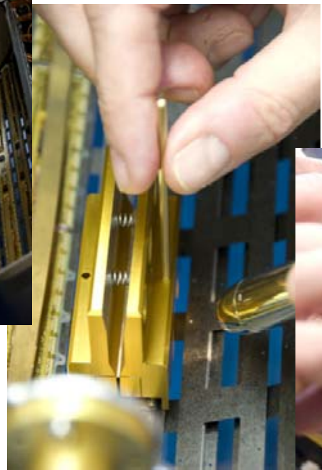


Module ready for mounting

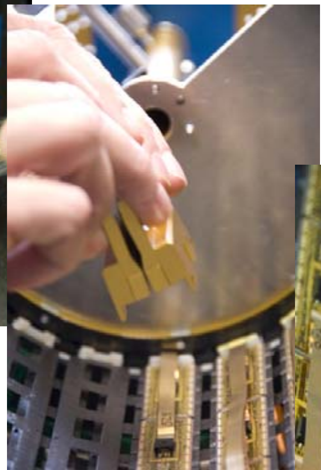


Put cables through support structure

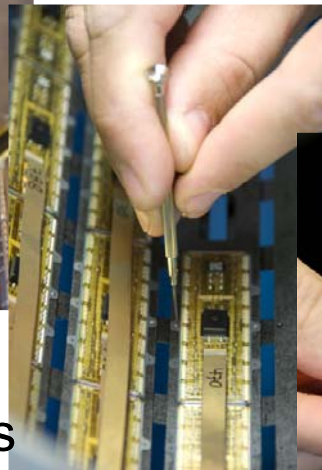
Putting module onto mechanics



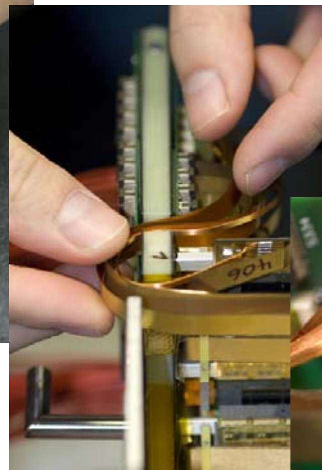
Put in screws through mounting clamp. Module still fully protected



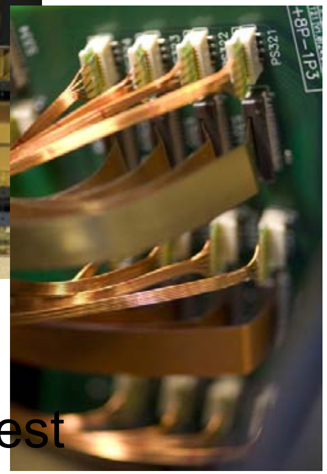
Remove mounting clamp



Tighten screws

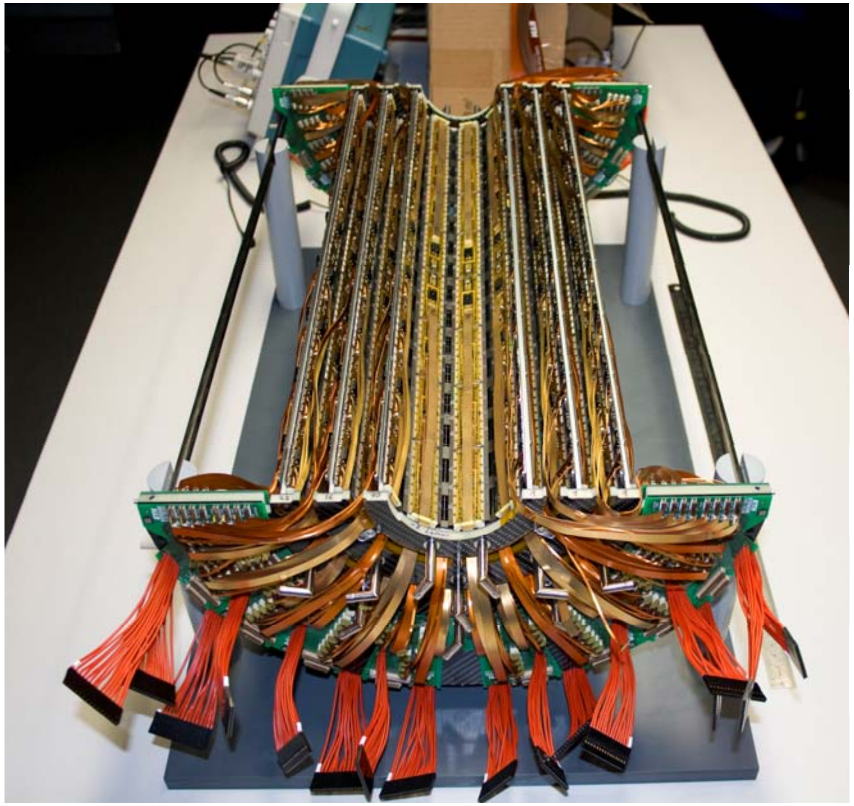


Bring cables in place



Plug in on end flange and test

Survey



Object very ‚crowded‘

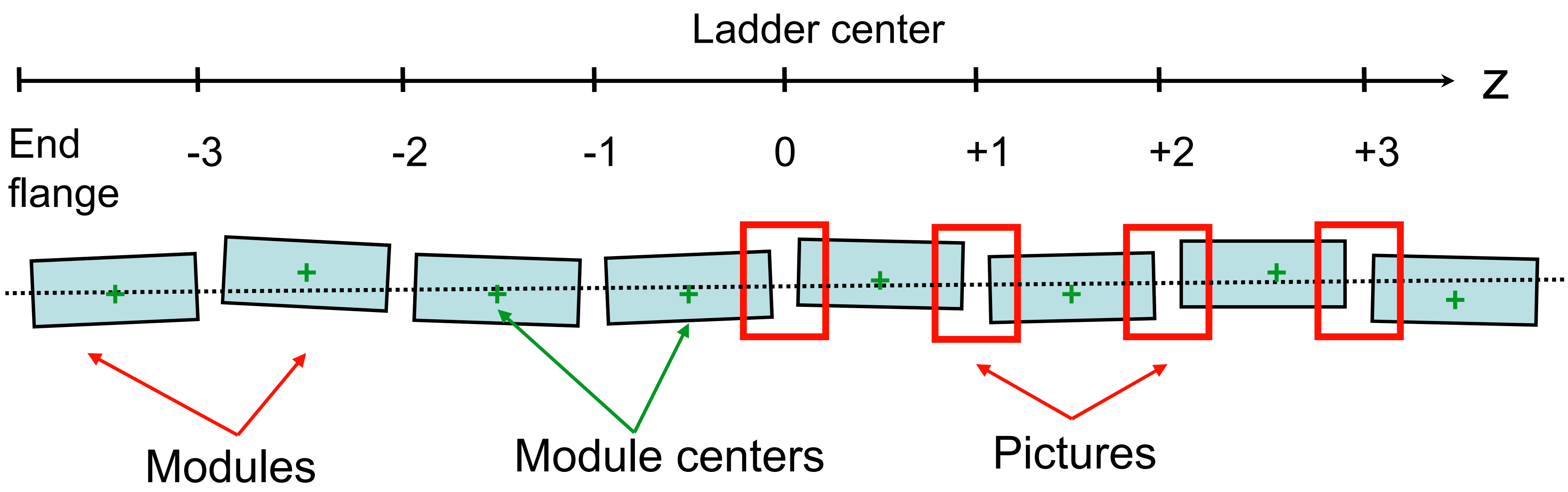
Difficult to survey

No fiducial points foreseen on mechanical structure

Decided to only survey module positions per ladder in 2D. No higher level structures.

- •Simple manipulations, no risk for damages
- •Fast and easy procedure with reasonable accuracy

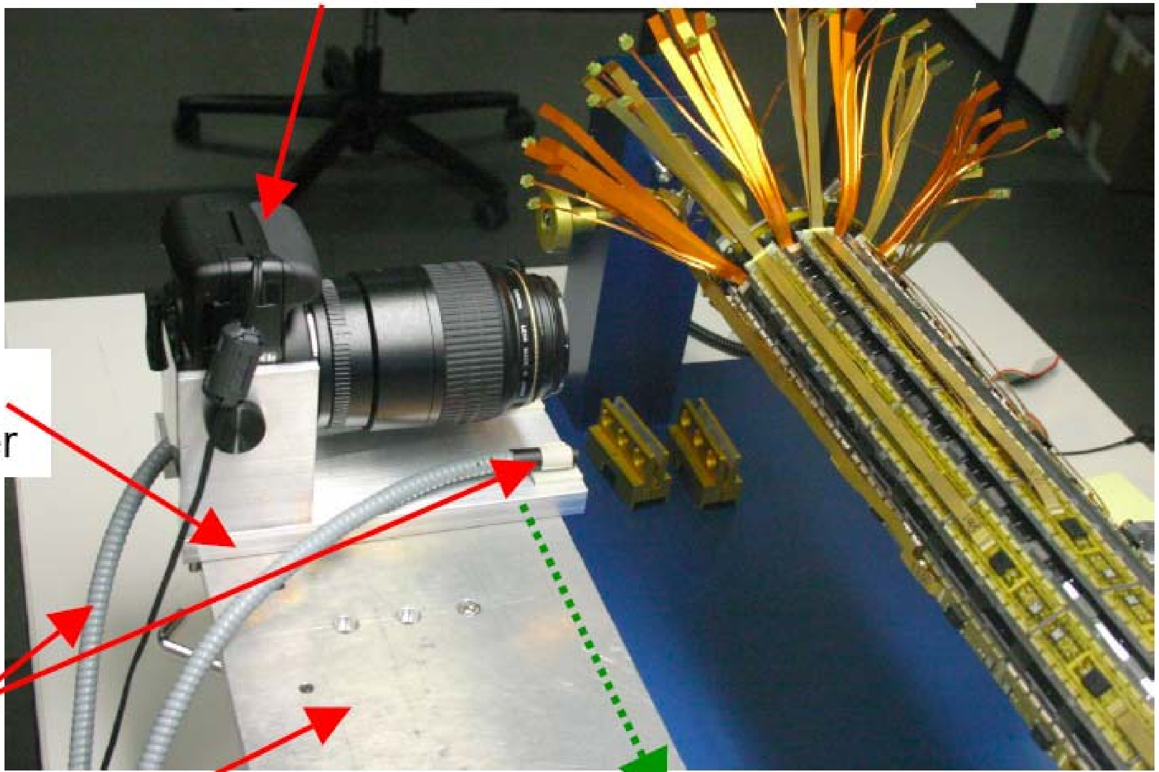
Principle of Survey



Take pictures of region where modules are facing each other.
Connect modules positions from center outward
For BPix a ladder is not a mechanically independent object
There are no fiducial points on a ladder
➔ Define ladder through its center of gravity (of all 8 modules) and the direction by fitting a line through the module centers

Photographic Survey

10 M pixel camera with macro lens
1.3:1 picture on 1 inch sensor → 9μm per pixel



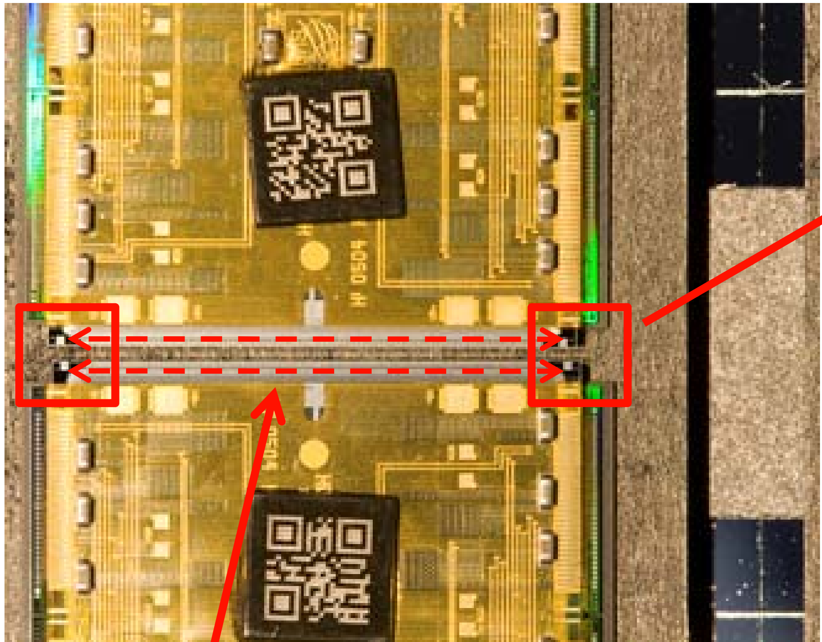
Movable
camera carrier

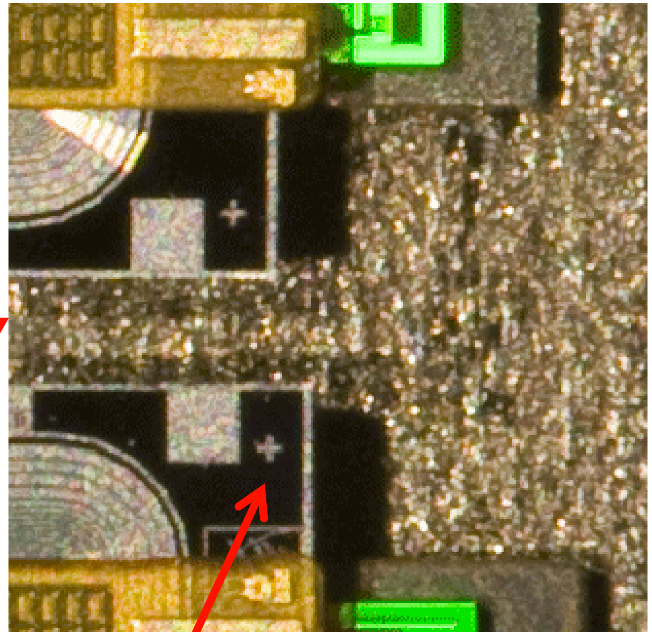
Illumination

Fixed table with edge guide
and stoppers

Camera movement

Example Picture

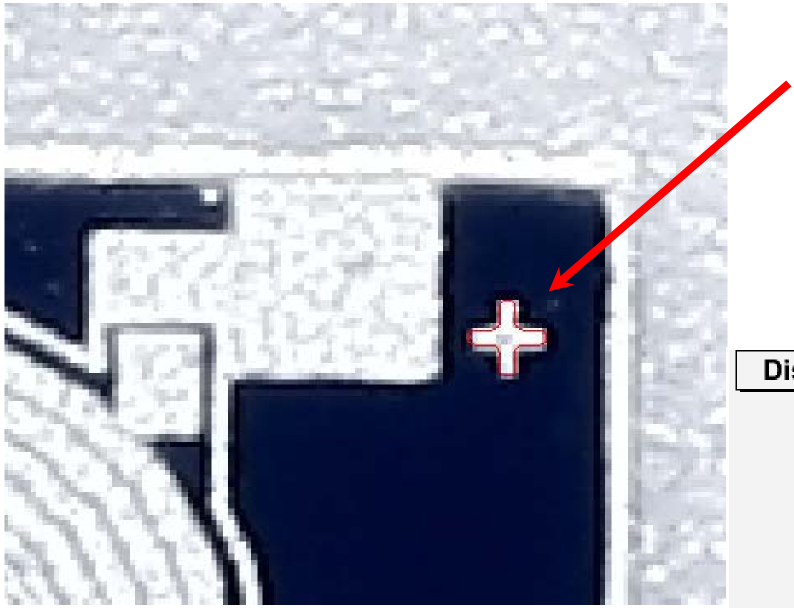




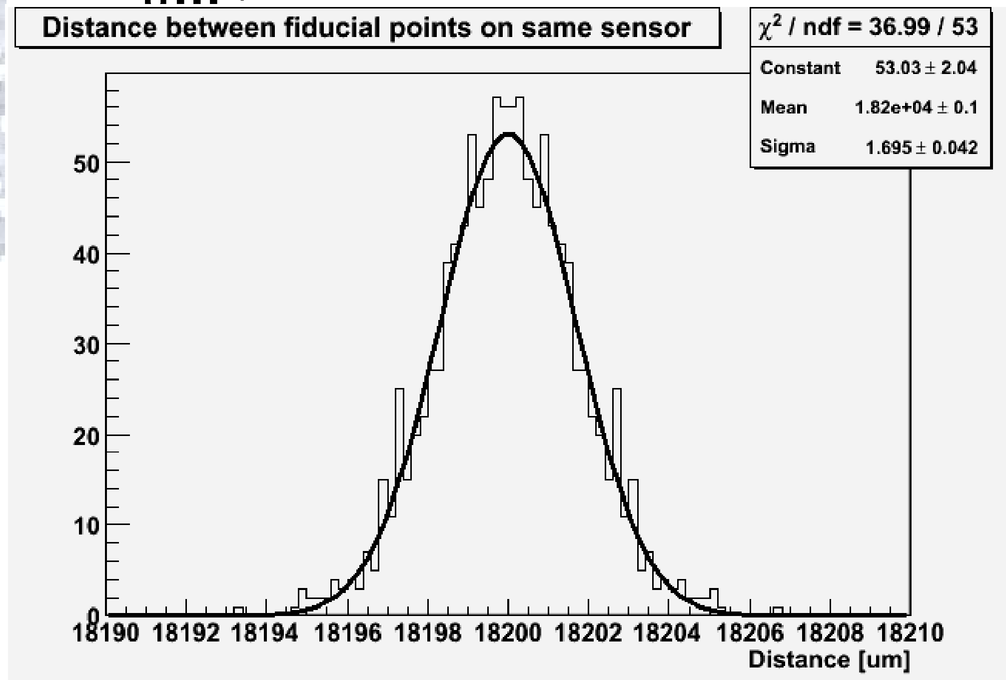
Alignmnet mark on active material, one at each corner
Size: 100µm

Known distance, used to get scale of picture

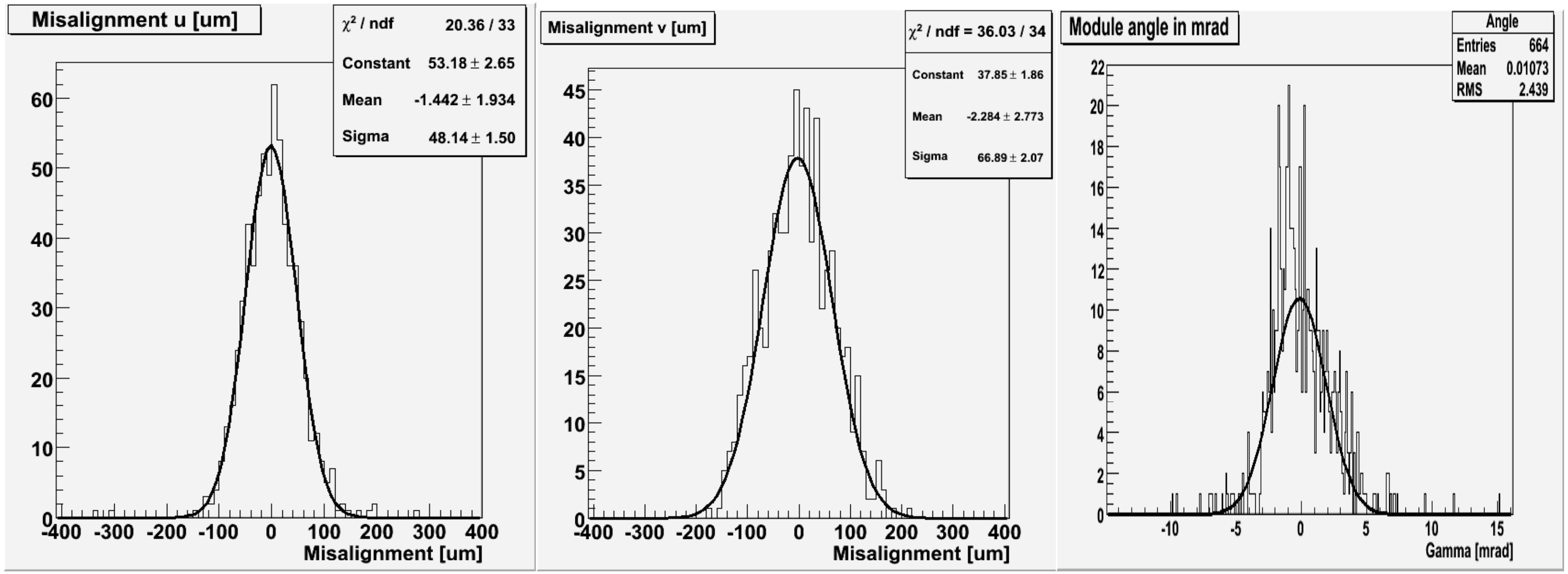
Position Measurement



- Use optical pattern recognition software
- Interpolation of brightness
- Pattern found with subpixel accuracy
- Very good resolution for single alignment marks: $\sigma = 1.7\mu m/\sqrt{2}$ = **1.2 µm !**



Misalignment



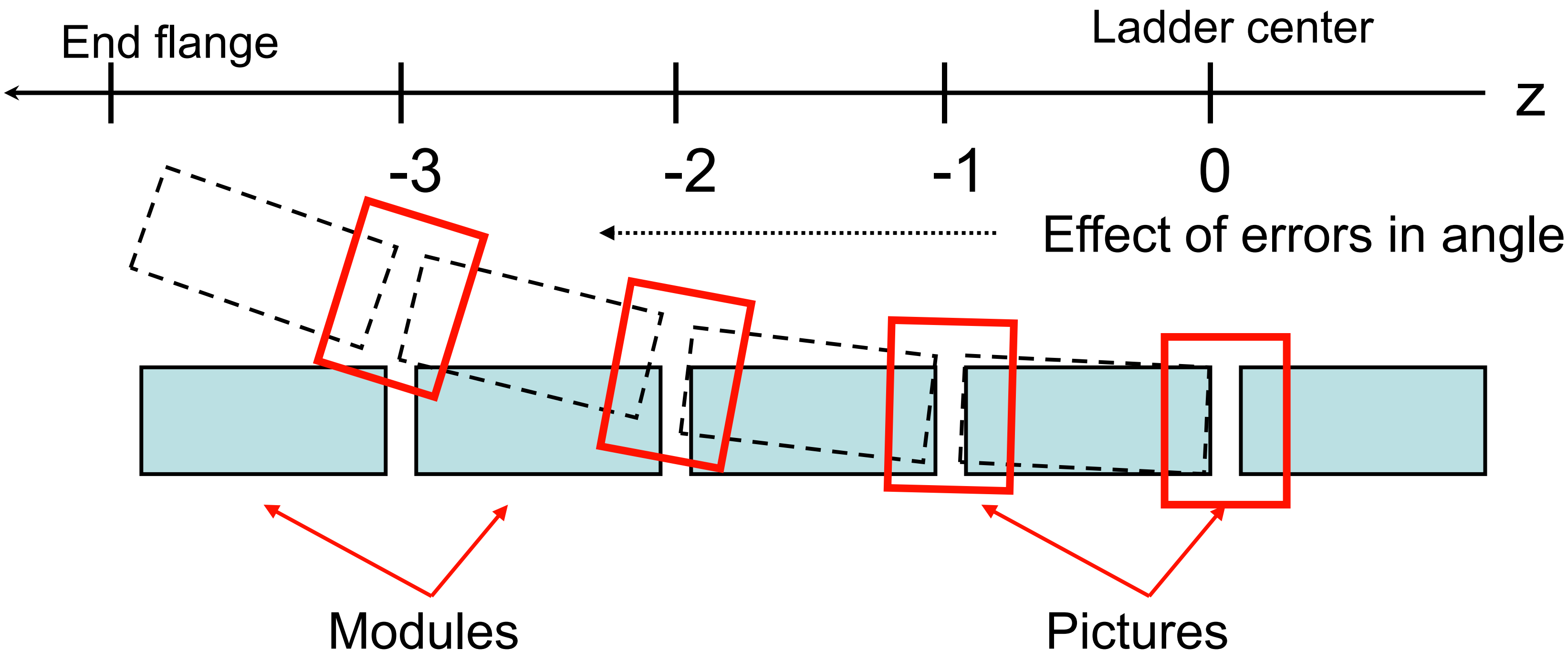
Shown is position and angle of module w.r.t. ideal position on ladder

Measured misalignments: 50μm in u=r-phi (gauss)

70μm in v=along beam axis (gauss)

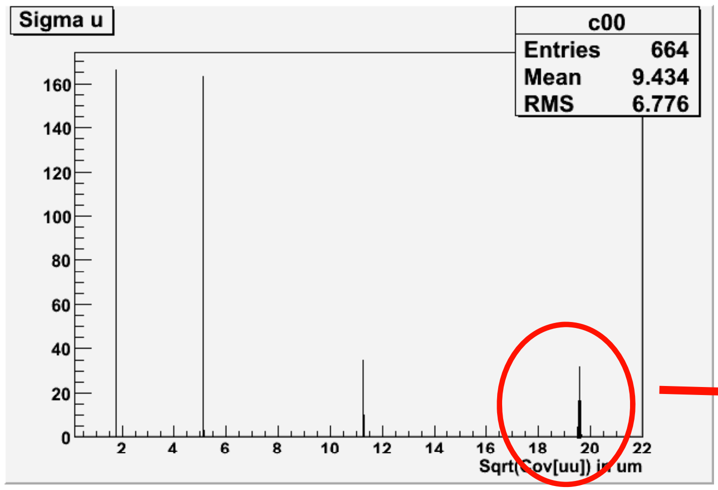
2.5 mrad in γ (~ gauss)

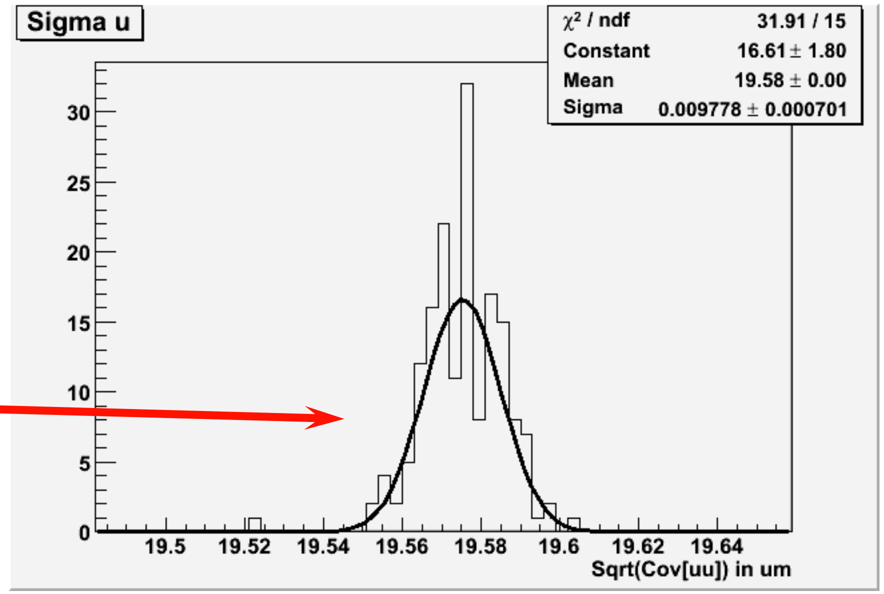
Error propagation



- Single pictures are very precise: O(1μm) resolution of fiducial points
- But: only relative measurement
  - Large (z-dependent) lever arm
  - Errors add up along z
  - Final error an order of magnitude larger at z=±4

Errors



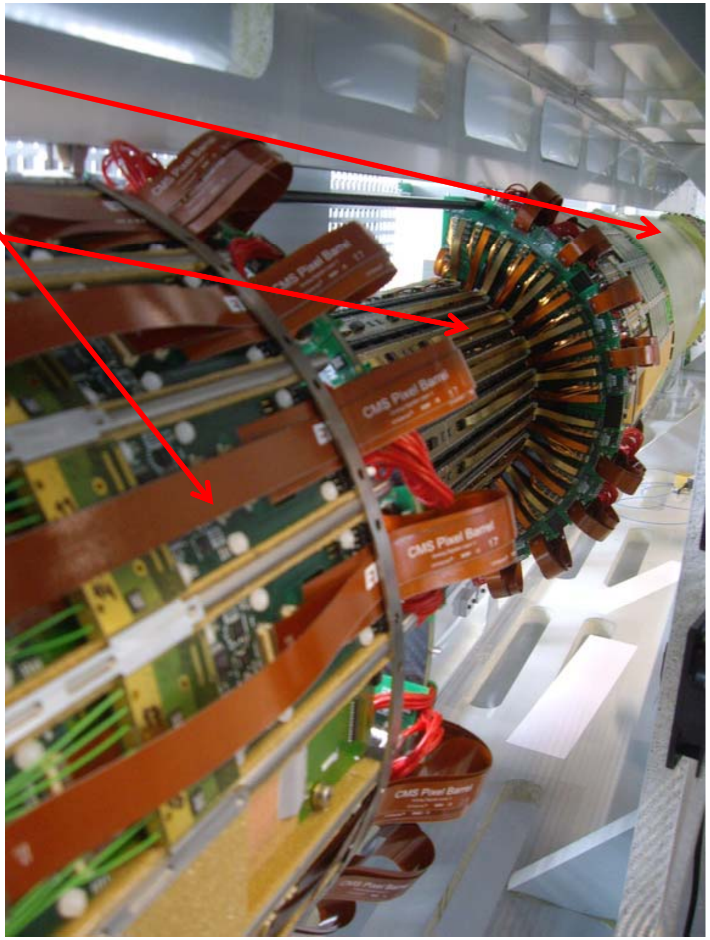


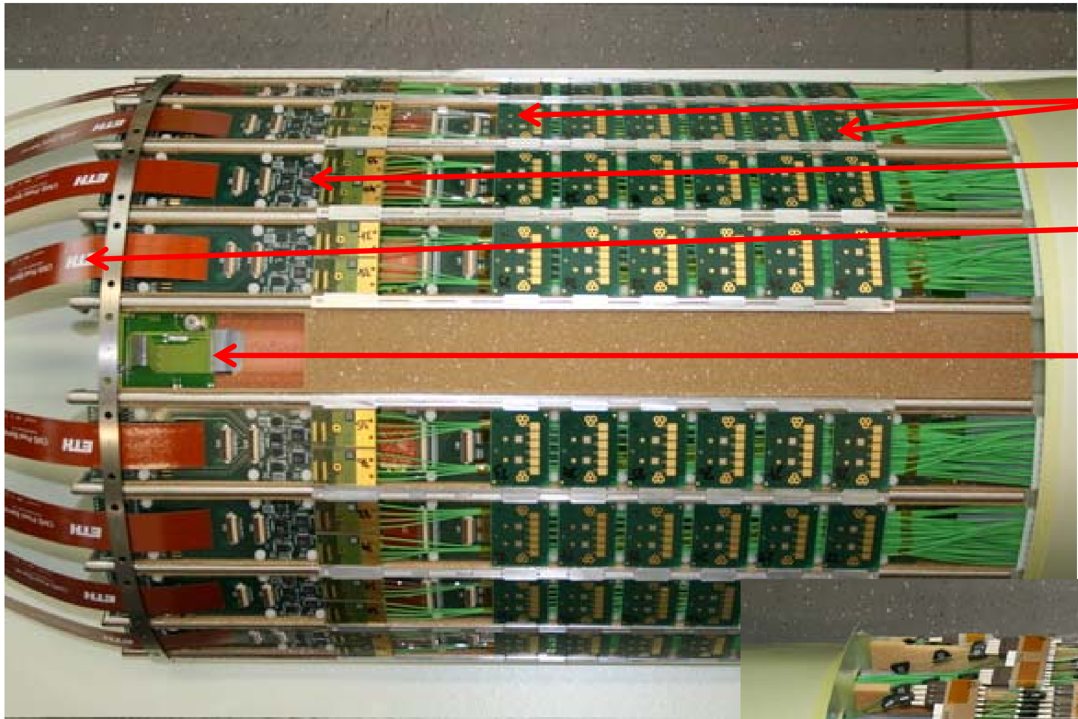
- Plotted is $\sqrt{\text{Covariance}(u,u)}$
- Error is z-dependent: each peak corresponds to position $\pm$n on the ladder. It gets bigger further away from the ladder center

Results:	**u (=r-phi)**	**v (along beam pipe)**	**γ**
Mean error	9.5μm	4.5μm	240 μmrad
Outermost modules	20μm	7μm	370 μmrad

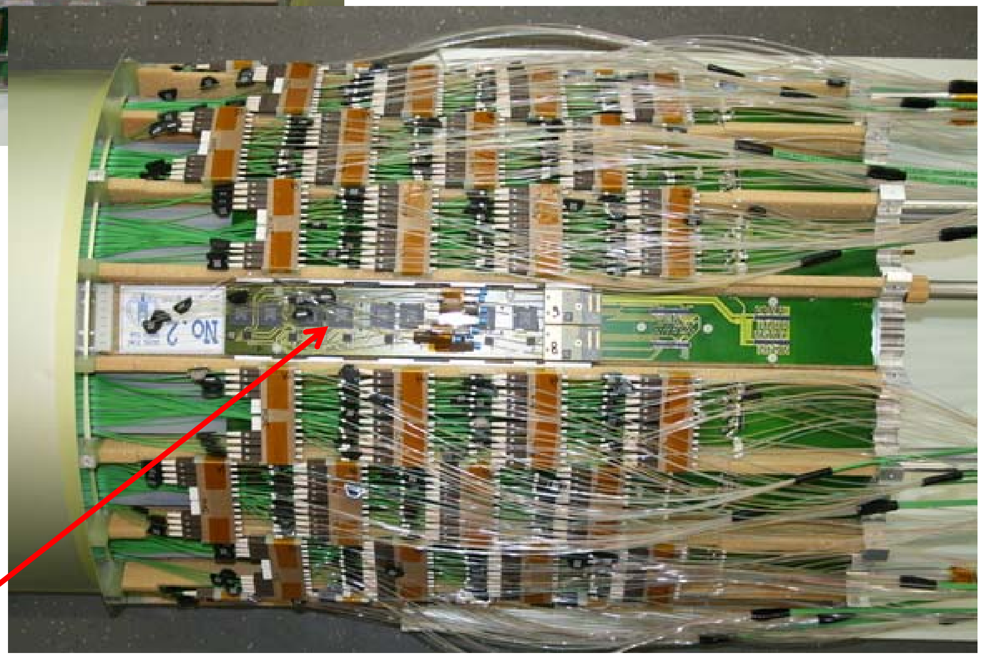
Supply tubes

- Two ~3m long supply tubes build independent system unit together with half of the BPix detector.
- Supply tube containes:
  - Opto hybrids for 1152 optical r/o links
  - Optical control links for FE programming
  - Optical control link for detector control
  - Boards for power distribution
  - Temperature and humidity sensors
- Half of BPix detector assembled in a special transport box
- Complete system assembled, debugged and tested at PSI
- Transported as a whole to CERN
- Retest after transport showed no damages





Detector side:
r/o optical drivers
sector control
electronics
Kapton cables to
detector end flange
Temp / humidity sensors

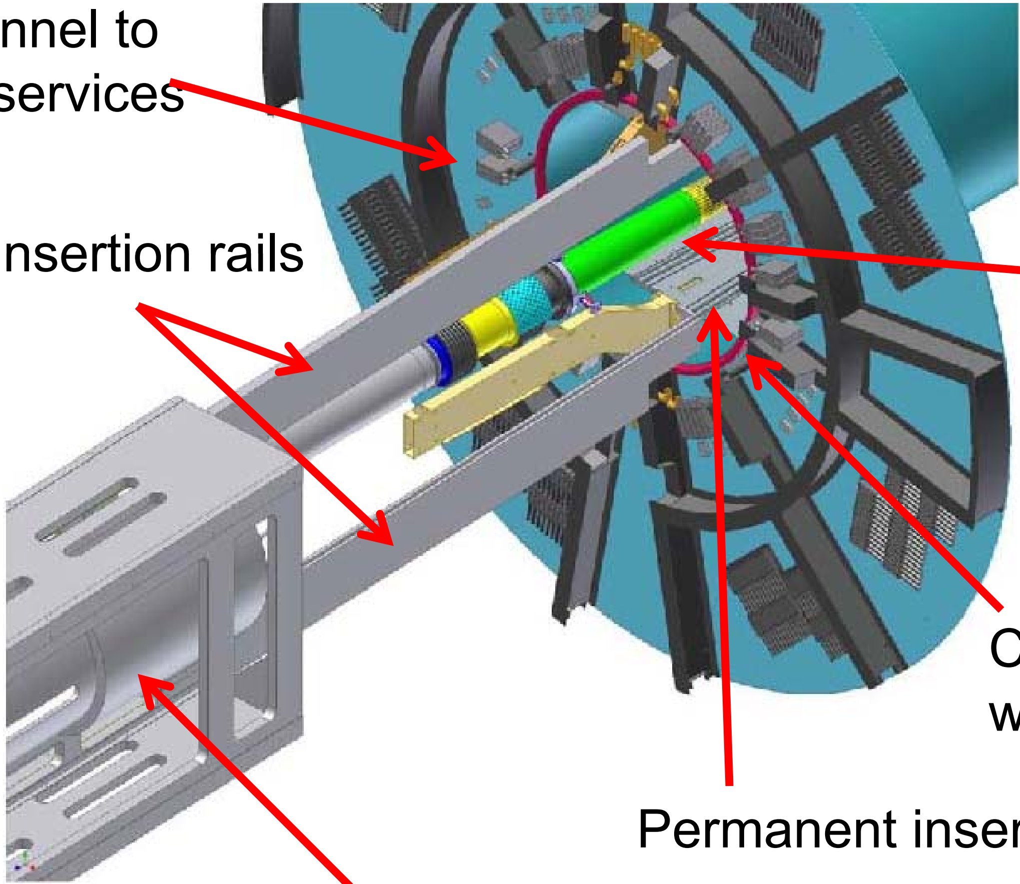


Off detector side:
Last cm^2 filled with optical
connectors and fibres
Painful slack management
Detector control electronics

Insertion

- CMS Pixel detector designed for fast insertion
  - Independent from rest of tracker
  - Pixel barrel and end disks independent systems
  - Replacement possible in O(1 week)
- Last subdetector to be installed in CMS
- Installation time: a few hours (first time a bit longer) + check out ~1 day

Insertion



System supply tube – detector – supply tube fully assembled and connected

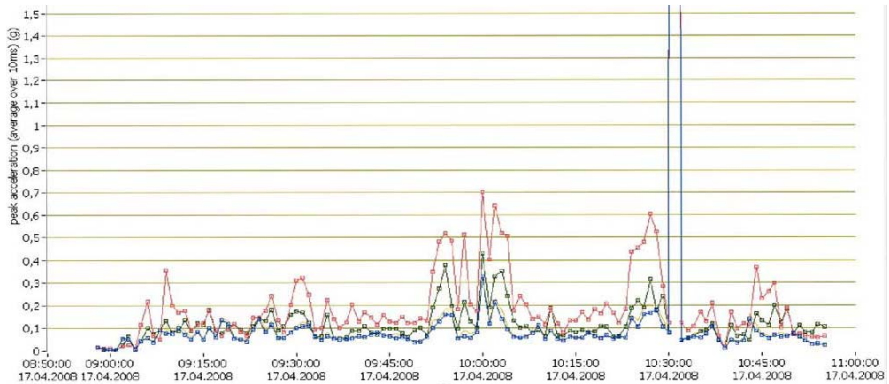
Tests before Installation

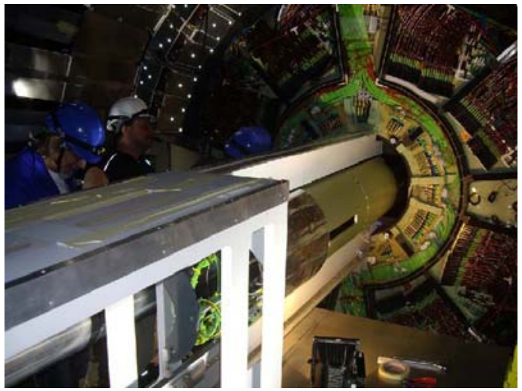
Clearance test with real detector and mockup rail system

Clearance between left/right halfs:1mm!

Problem with cable found and solved

Test transport of ‚commissioning system‘ from PSI to CERN with accelerometers





Insertion test with ‚commissioning system‘: true mechanical structure, prototype supplytube, only one sector (1/32) equipped with modules

Commissioning ongoing...

- Installation done July 23/24
- All cables and fibres connected
- Cooling is (finaly) working
- Lots of problems encountered (collision during insertion, wrong cabling, bad connections...) and solved thanks to outstanding effort of S. Streuli, R. Horisberger, W. Erdmann, T. Rohe, D. Kotlinski and others ! Still installed in 1.5 days!
- Checkout of -X side sucesfully done over weekend, 100% operational
- +X side under test now

Checkout Procedure (I)

- Phase I (now): Fast detector checkout . Check hardware after insertion and cabling
- Lasts about 1-2 days (and nights) per side.
- With standalone BPIX software (no XDAQ).
- Access to PP0 required.
- What is beeing checked?
  - power the full detector or its parts
  - can we talk to slow I2C devices e.g. DELAY25?
  - check if the clock present
  - are all devices drawing the correct current?
  - can we program ROCs/TBMs?
  - is the token passage complete?
- Completed for –x side, ongoing today for +x side

Checkout Procedure (II)

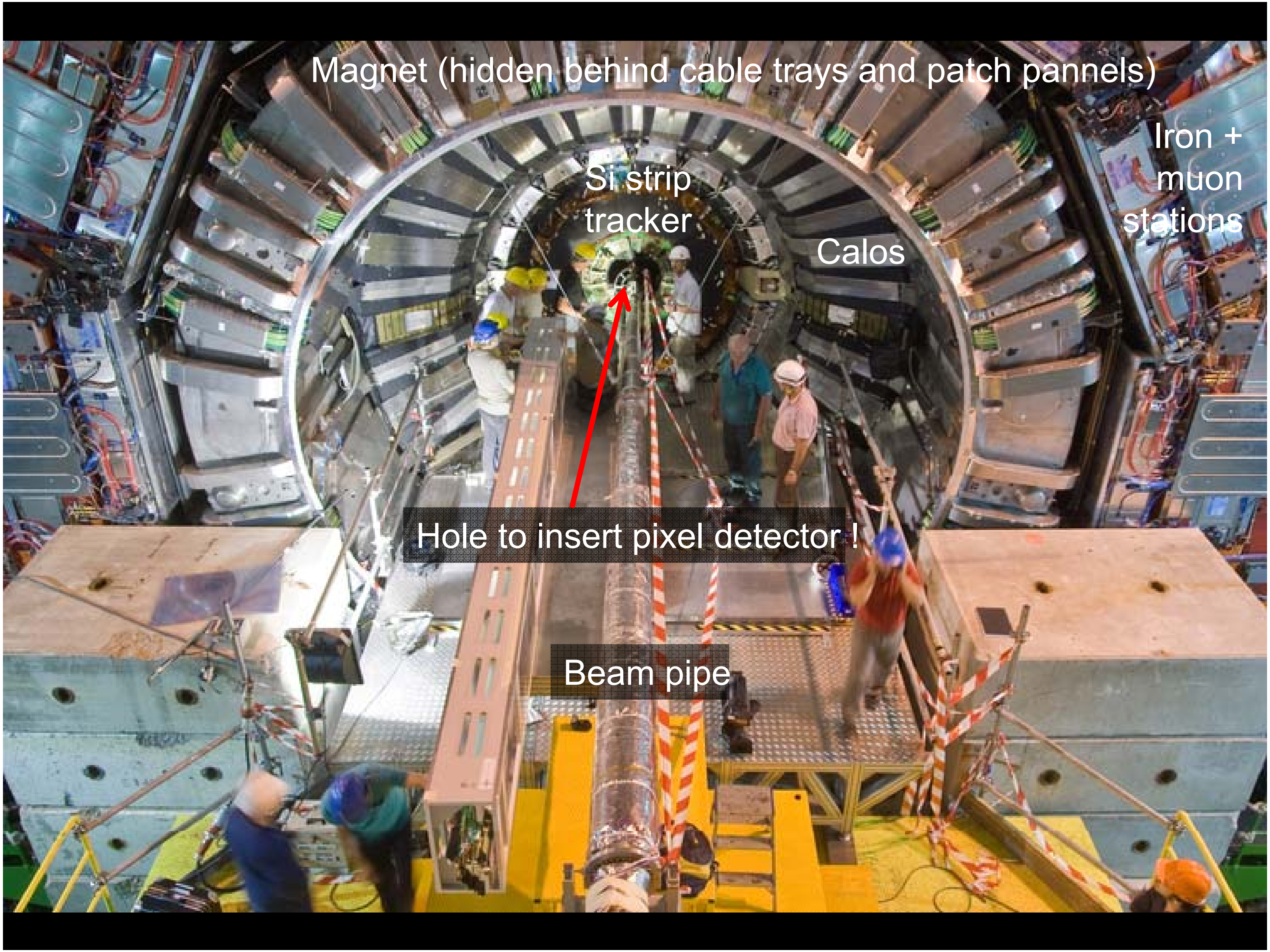
- Phase II: extensive detector testing and determining optimal settings
- Access to PP0 not needed anymore.
- Run full pixel test and setup software:
  - establish all working parameters (DELAY25, ROCs, FED, AOHs,..)
  - do the address level calibration
  - pixel alive and S-curves for a limited number of pixels per ROC.
  - HV test
- Done with the pixel XDAQ based software.
- Not done yet. Start this week (when fast check finished)
- Time estimate: about 3 weeks if everythings goes smooth

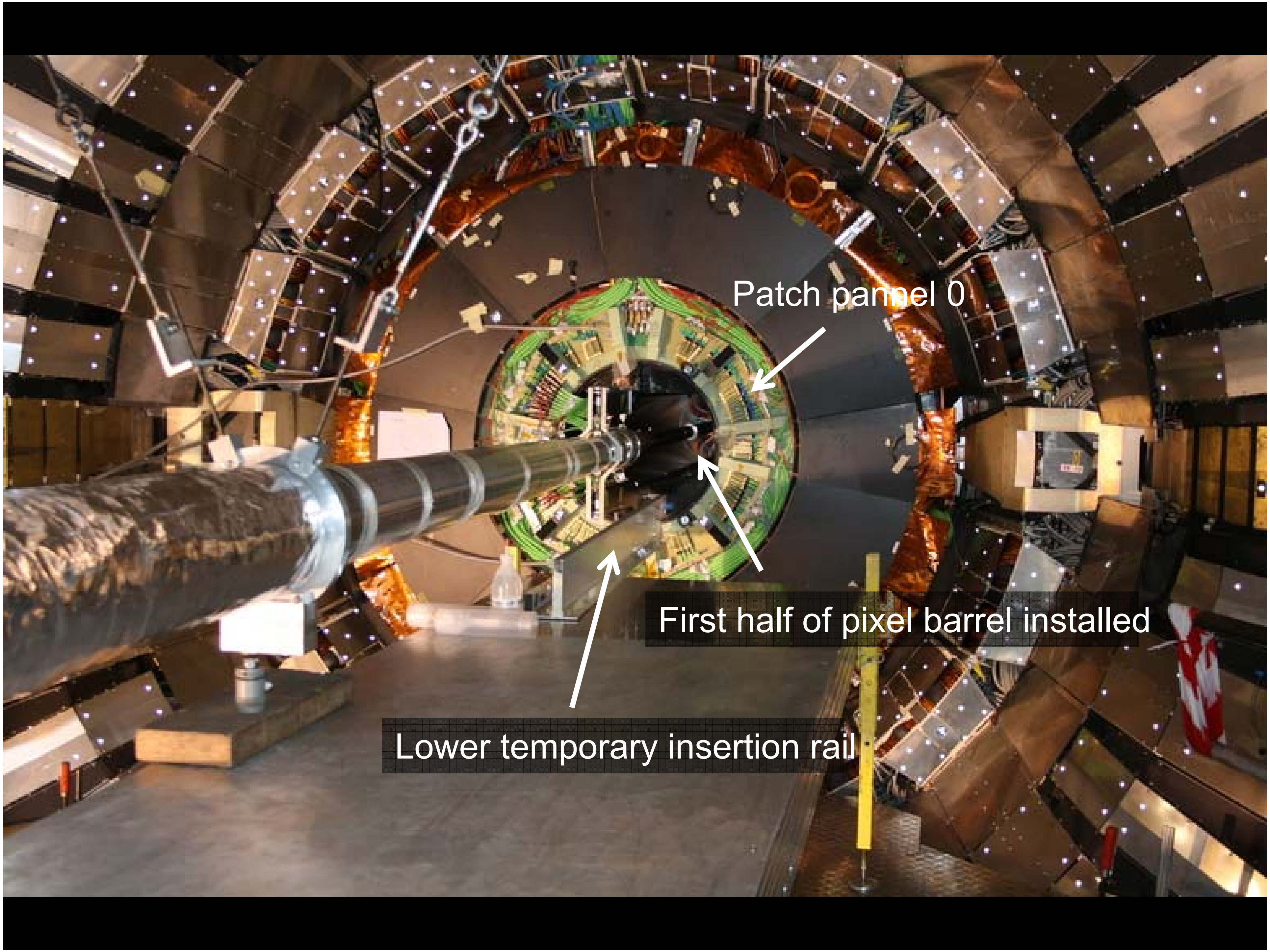
- Cannot participate in global runs before finished

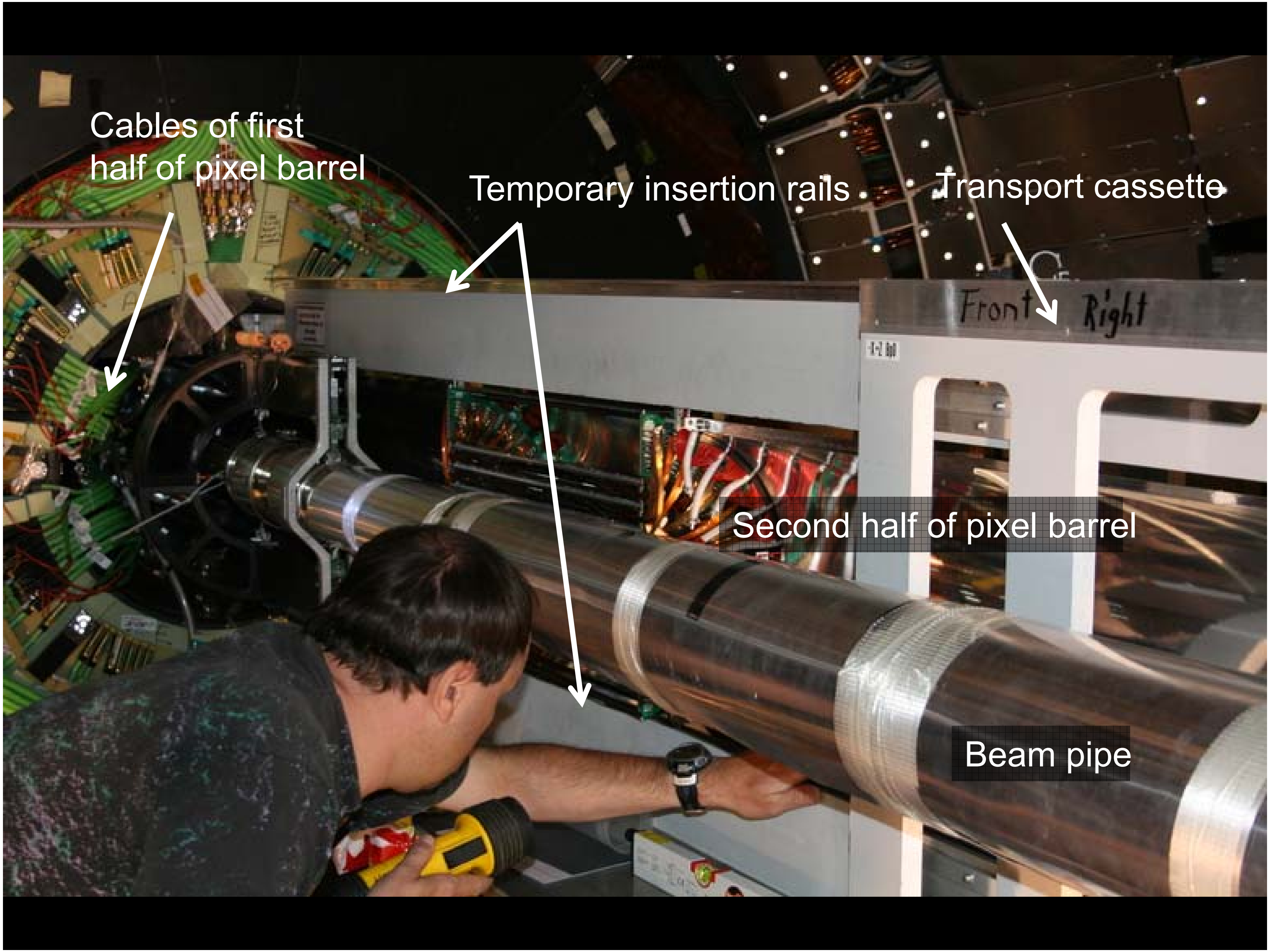
Recent Pictures from Installation 23 / 24. July 2008


Cassette for transport from PSI to CERN
ca 100kg, 6.5m long
Half of pixel barrel completely assembled and connected
Supply tube
detector
supply tube

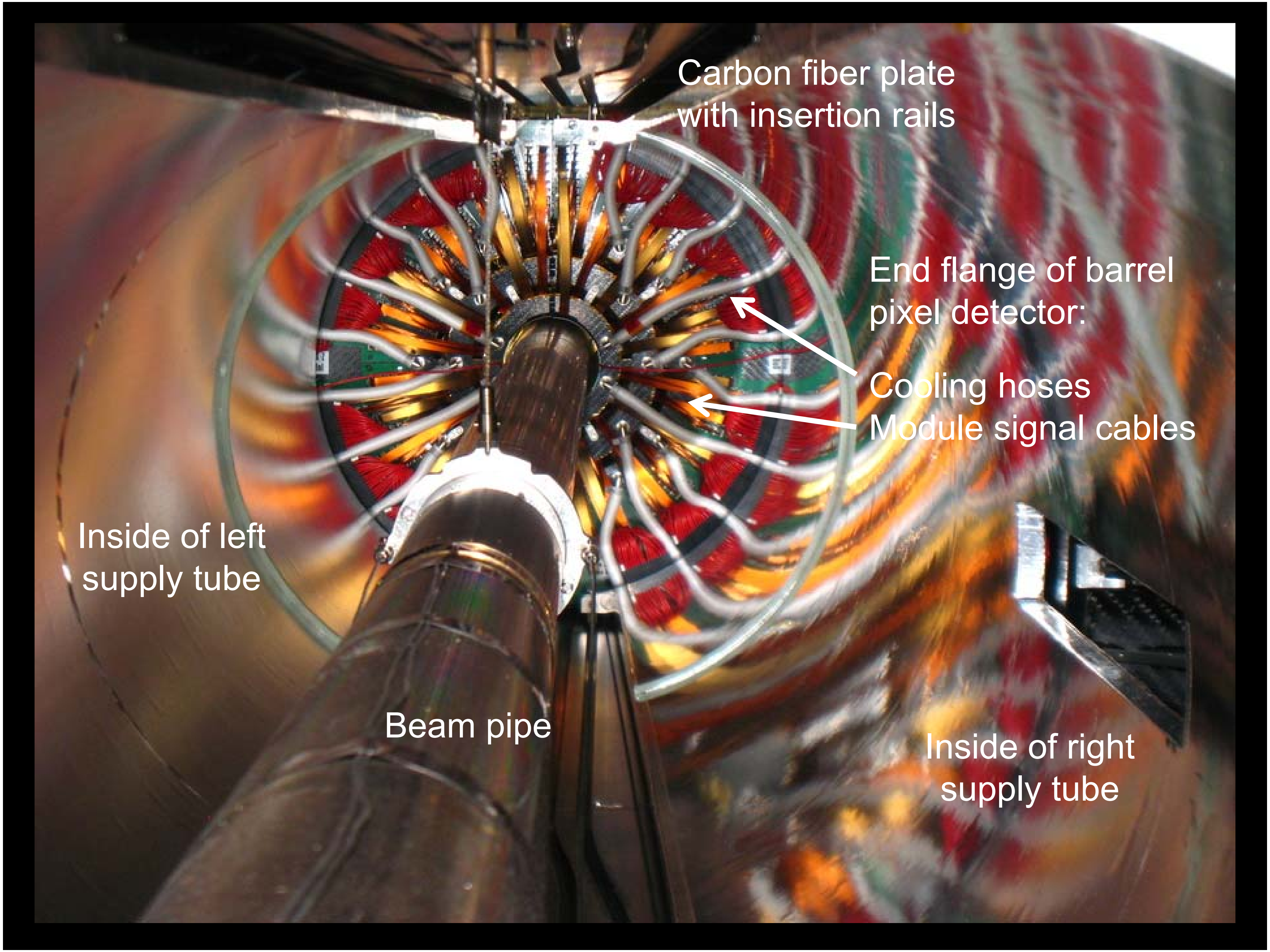
Lowering at P5


Magnet (hidden behind cable trays and patch pannels)
Iron + muon stations
Si strip tracker
Calos
Hole to insert pixel detector !
Beam pipe


Patch pannel 0
First half of pixel barrel installed
Lower temporary insertion rail



Cables of first
half of pixel barrel
Temporary insertion rails
Transport cassette
Front
Right
Second half of pixel barrel
Beam pipe



Carbon fiber plate
with insertion rails
End flange of barrel
pixel detector:
Cooling hoses
Module signal cables
Inside of left
supply tube
Beam pipe
Inside of right
supply tube

Summary

- Pixel barrel assembly finished
- Went pretty smooth and as expected
- System with detector and supply tubes assembled and fully tested at PSI
- Transported as a whole to CERN
- Installed in CMS last week
- Tests ongoing, everything looks good up to now
- Still much to do before we are ready for data takeing
- Many emotional moments in last weeks, but certainly much more to come...