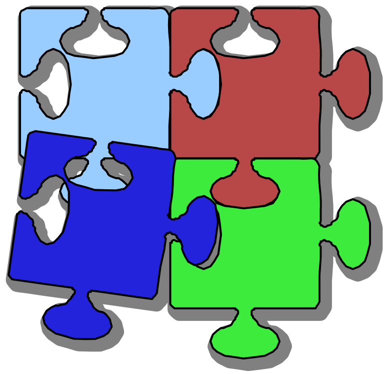
Integration



of the CMS silicon tracker

Stefano Mersi
on the behalf of the CMS Tracker

Frontier Science 2005
September 12-17

Outline

- The aim of this talk is to give a sketch on how single detectors are being assembled into more complex structures (sub detectors) in the CMS Silicon Strip Tracker
- During this talk I will shortly describe the structure of the CMS Silicon Strip Tracker, but I will not cover the assembly of sub detectors which will be performed at CERN
- This overview also shows how different are the designs of sub detectors
- I will also give a hint of the tests being performed during the assembly

Tracker sub detectors' structure

- The CMS tracker is entirely built with silicon detectors
- It is divided in 5 separate regions, each with a peculiar design approach:

Pixel vertex detector

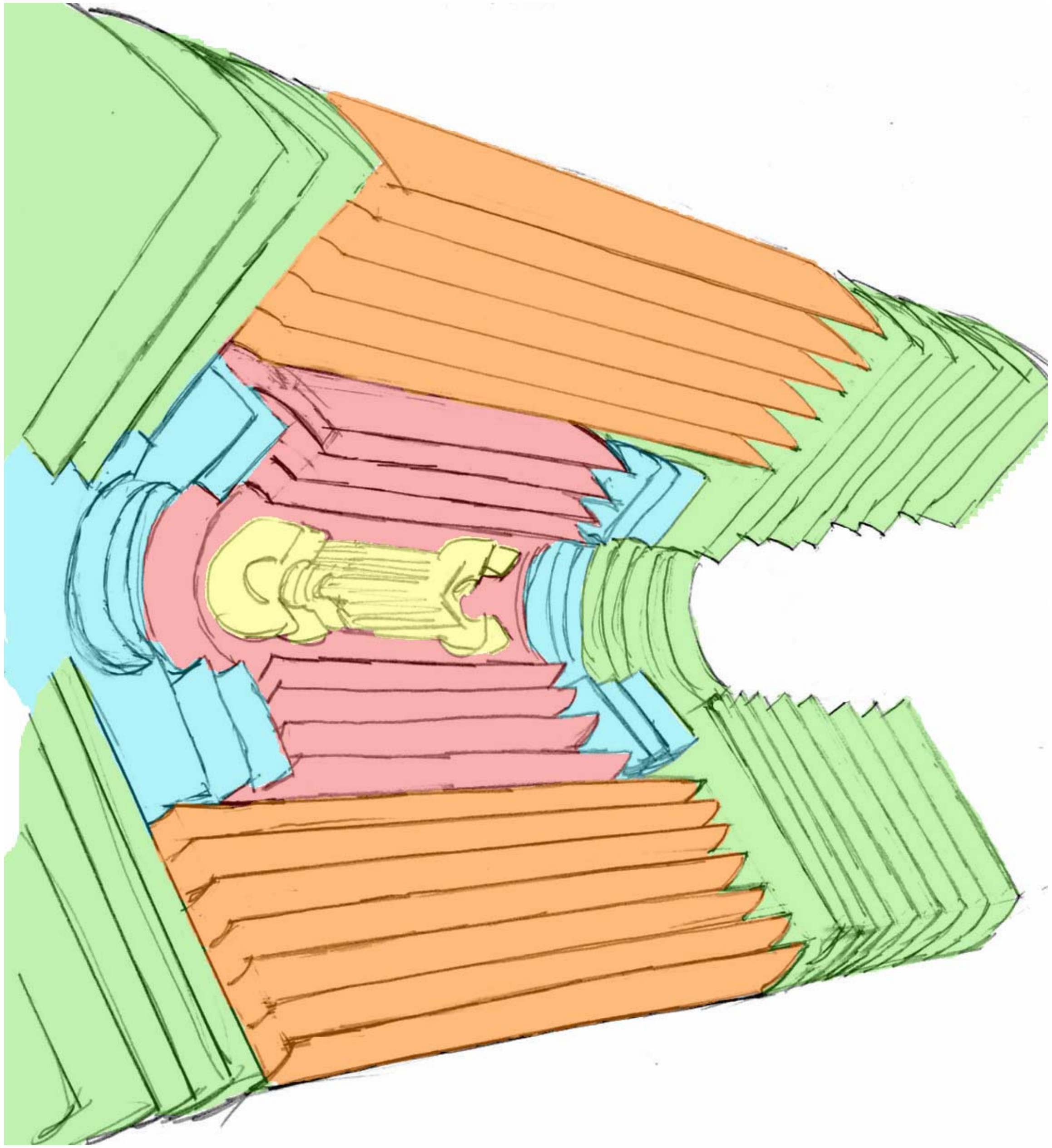
Silicon strip tracker

Inner Barrel (TIB)

Inner Disk (TID)

Outer Barrel (TOB)

End Caps (TEC)

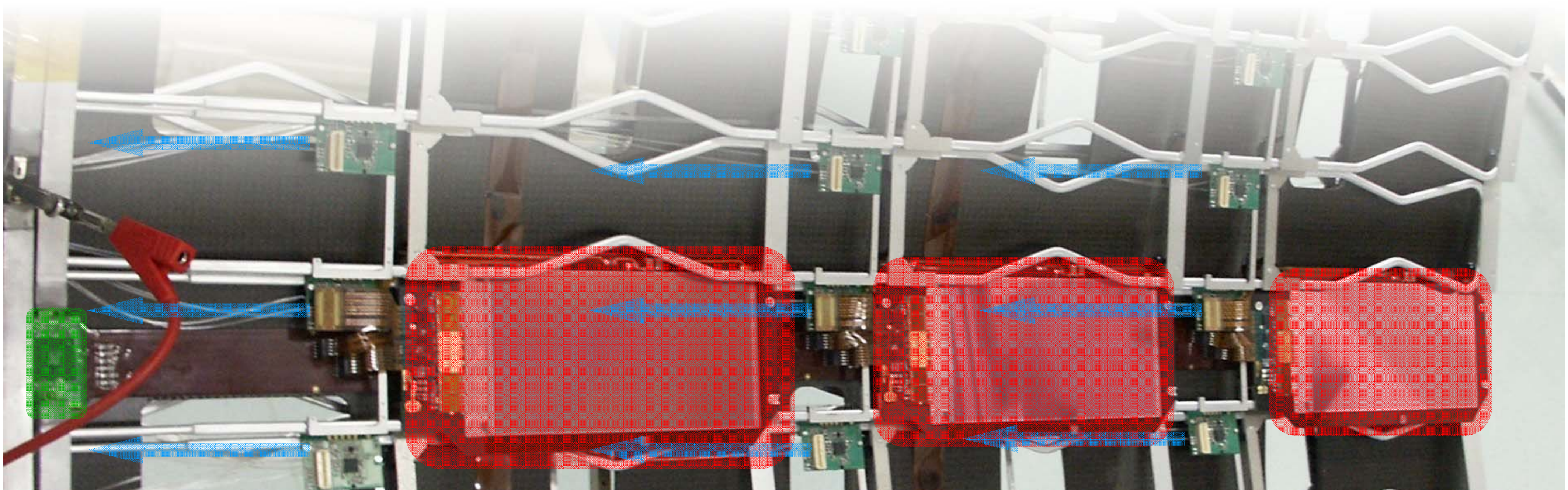


The technical challenge

- 10 years of operation
- Little or no chance for maintenance after LHC start-up
- There is no room for mistakes...

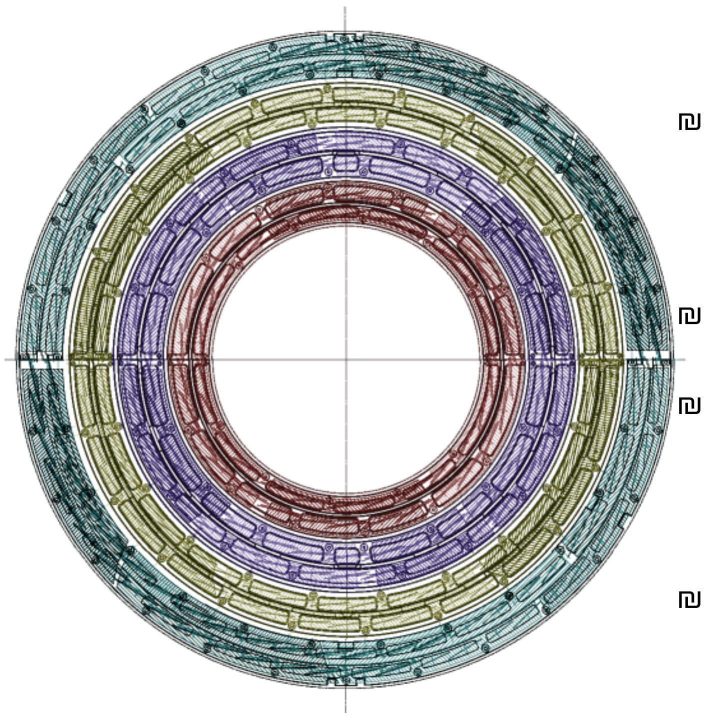
General DAQ structure

- A group of detector **modules** is driven by a control unit (**CCU**, which provides clock, trigger, monitoring, ...)
- A set of CCUs are linked in a token-ring configuration (*control loop*), which is controlled from outside the detector through optical fibres
- Also the analogue signal from the modules is routed optically, to be digitized far from the detector

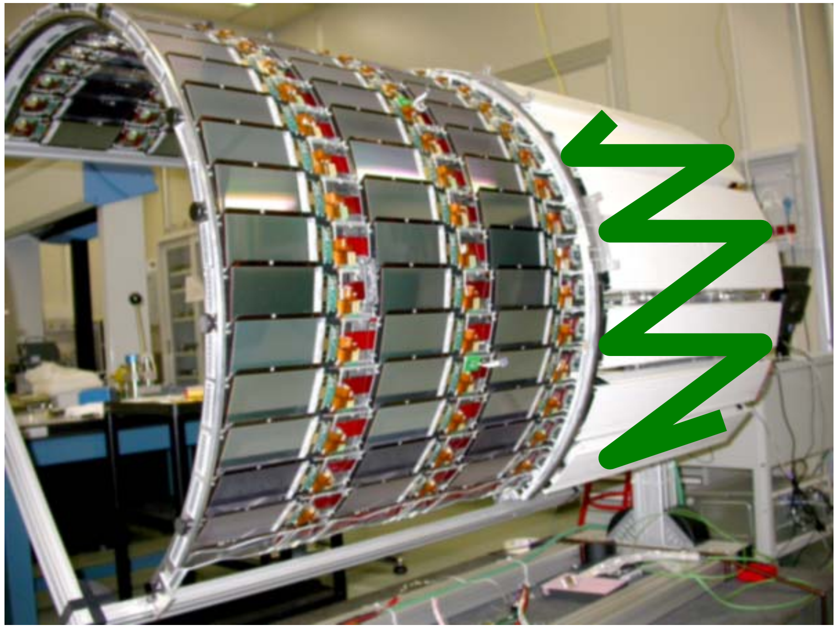


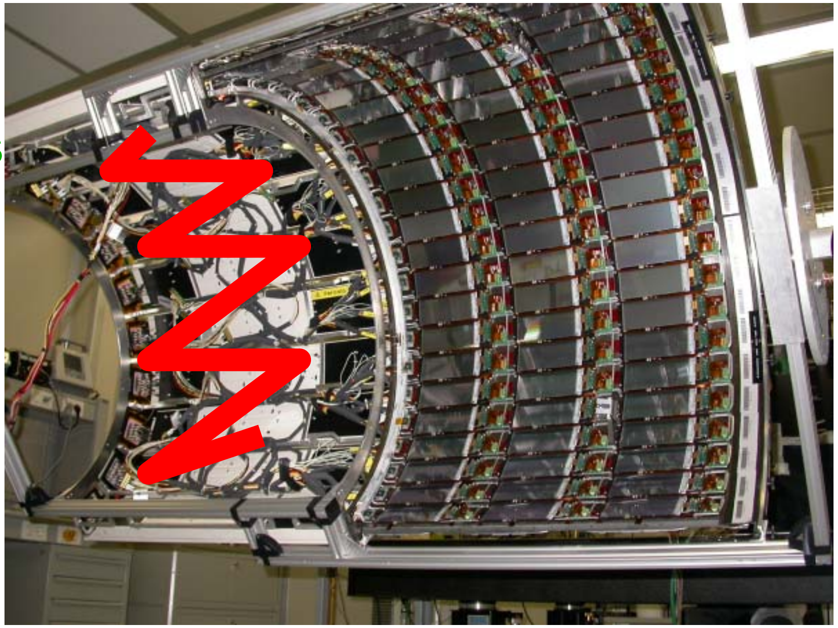
Tracker Inner Barrel

- It is made of 4 layers: L1 and L2 are filled with double sided detectors, L3 and L4 with single sided
- Each layer is divided into 2 symmetrical barrels (TIB+, TIB-) each divided in 2 semi-cylinders
- Each layer has modules both inside and outside



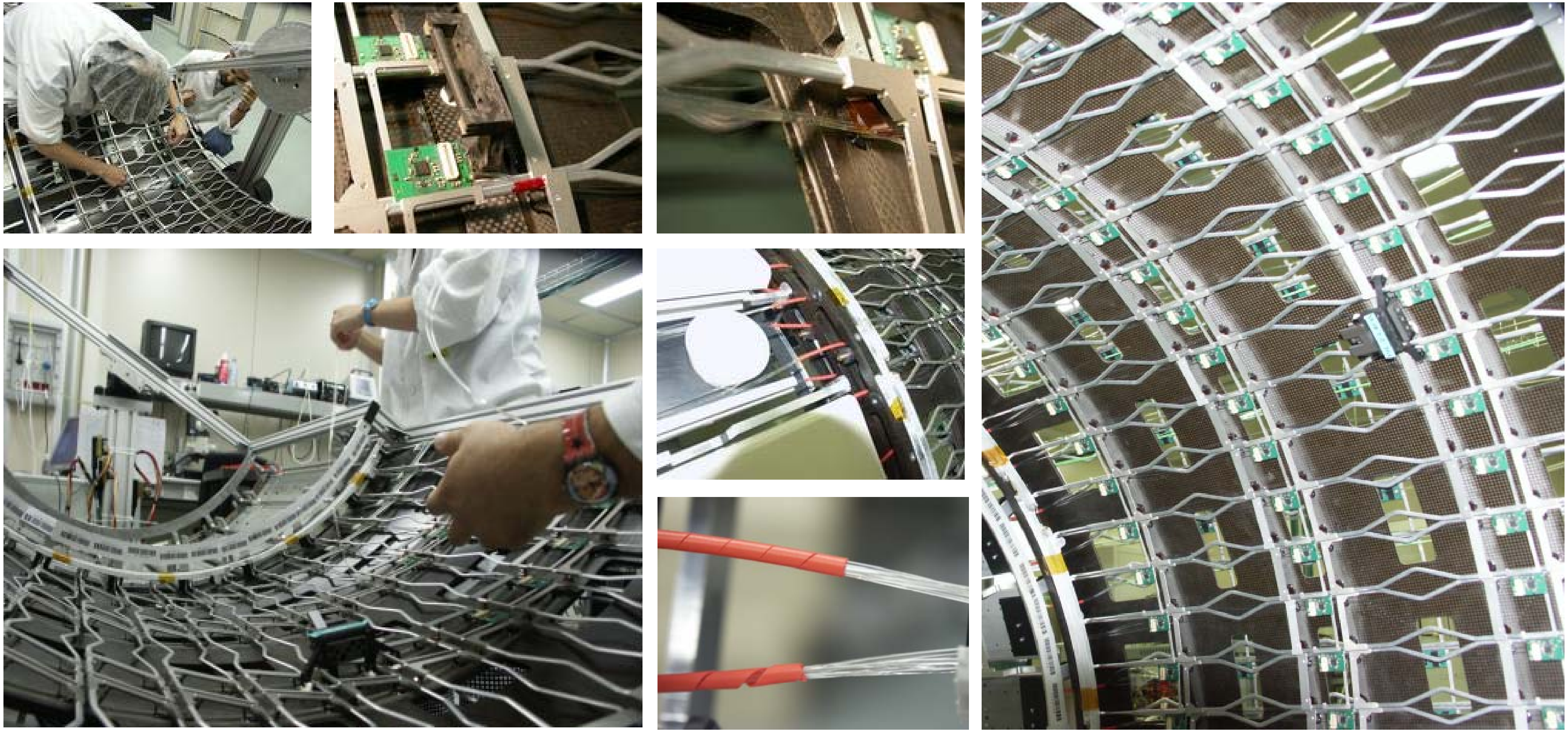
- Final routing of control cables
- Analogue Opto-Hybrids + temporary routing of optical fibres
- Modules (+tests)
- Temp. route power cables that will turn around TID
- Final tests





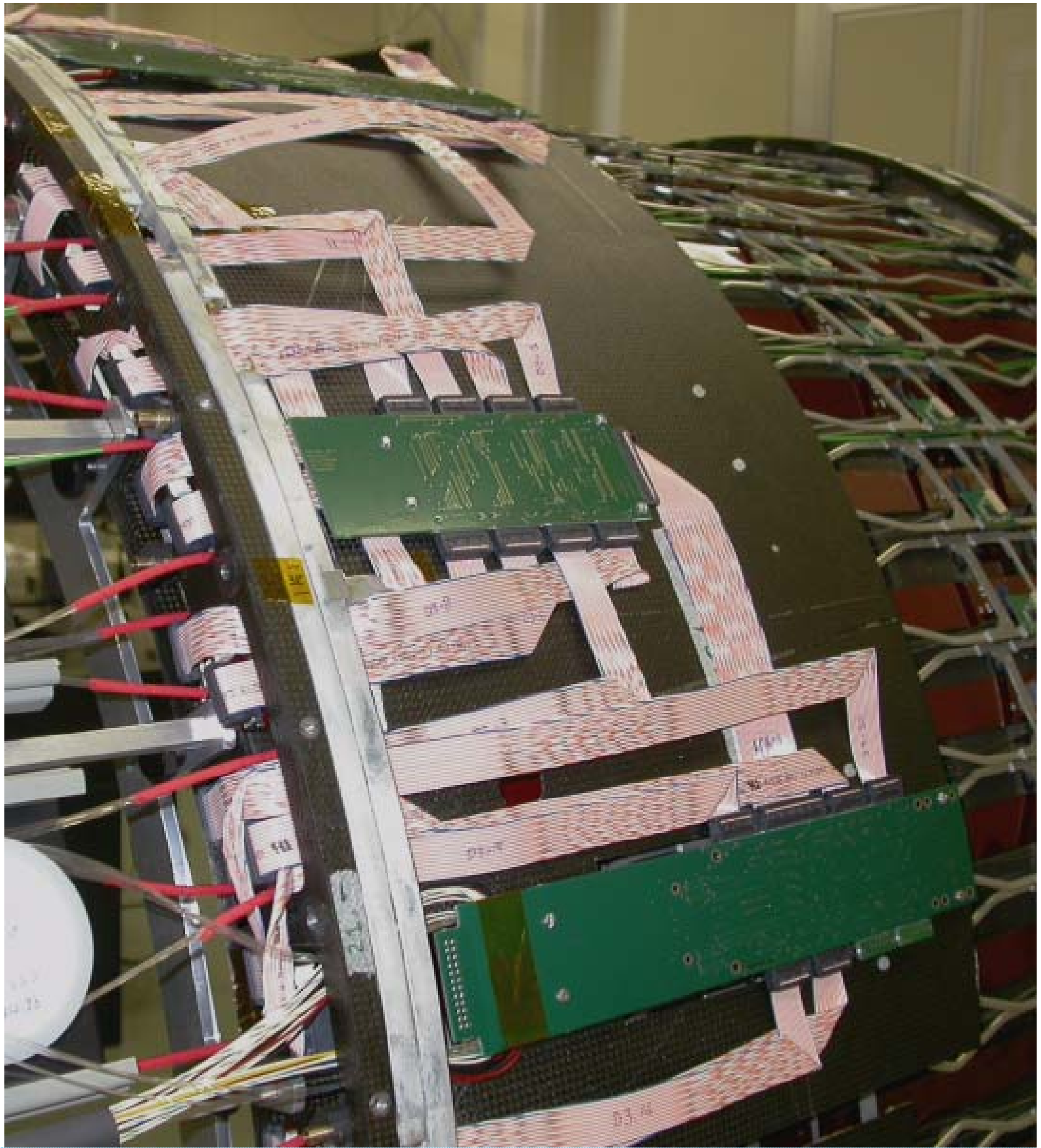
Routing optical fibres

- Every module has its own laser driver which sends the analogue signal out of the detector through optical fibres
- Fibres are held under the cooling pipes and protected from twists



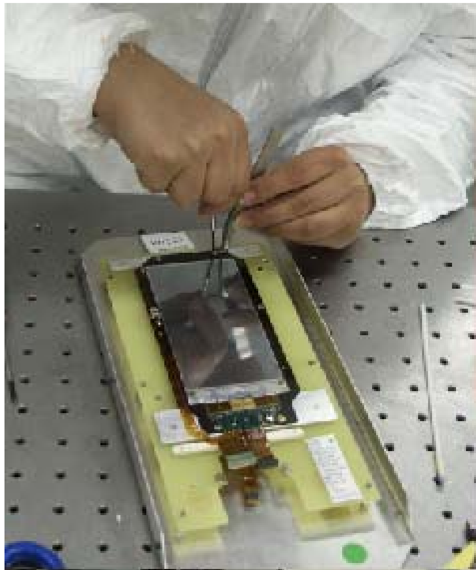
Routing the control loop cables

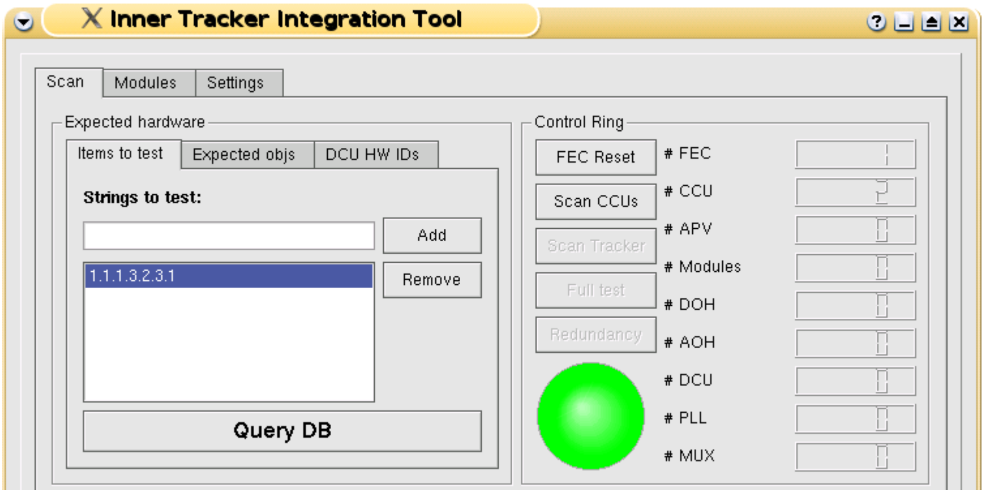
- Control loop cables are to be bent individually to fit in the structure
- A carbon fibre 'skin' had to be implemented to hold the cables and control boards in place and to provide a shielding
- Every control cable drives a logical group of 3 modules (called a *string*)



Mounting a module

- In TIB modules are removed from their handle support, cleaned, individually mounted on the structure and registered in the Tracker Construction Database
- As removing a module from the final structure is a risky operation, on each module the control logic is tested with a software that also x-checks the components' identity with the database
- This guarantees correct connections, module's functionality and reduces the probability of a further substitution

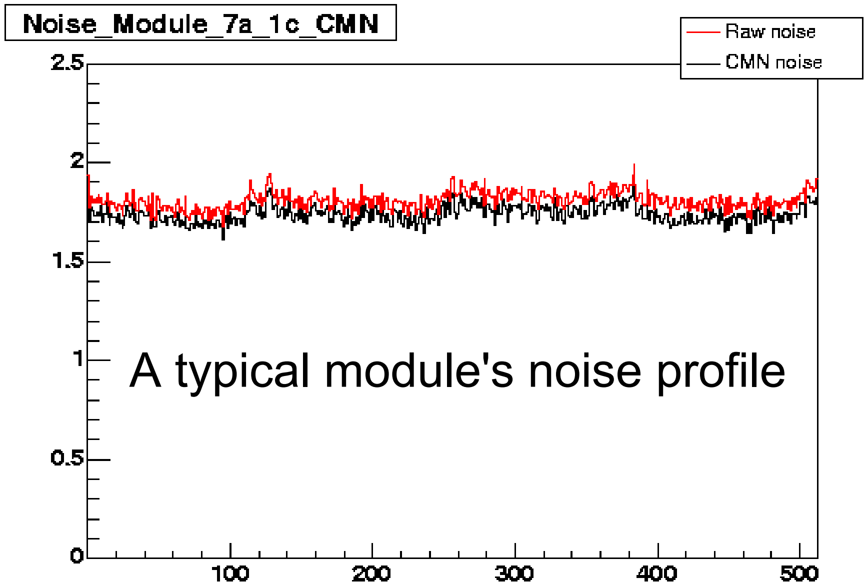




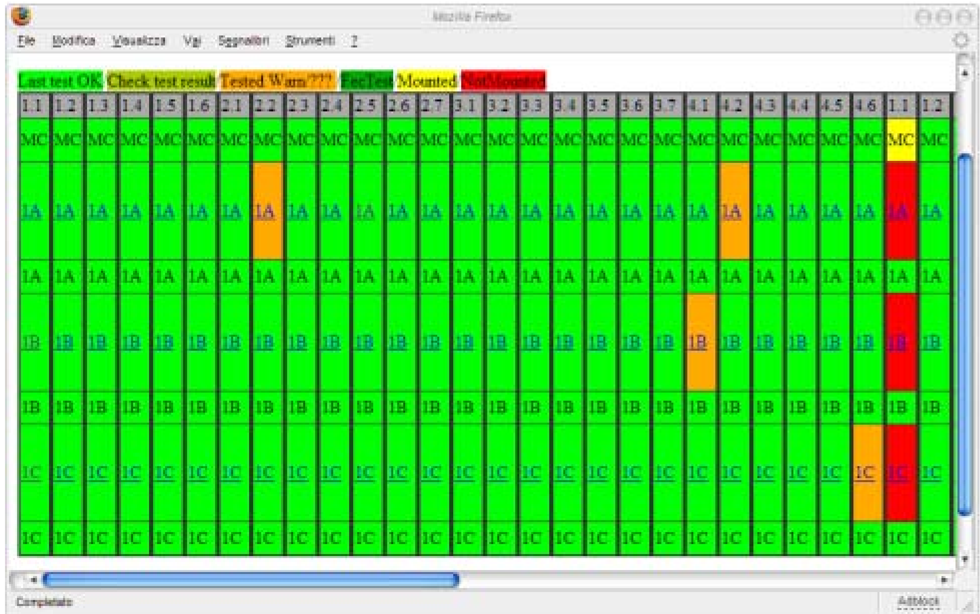
String-by-string measurements

- Each time a string is mounted the readout is tested by checking the noise and measuring the calibration signal
- This operation needs the bias voltage, and thus the room is to be darkened!
- This allows not only to check the modules' functionality, but also to test against possible noise sources in the chosen configuration

- The operator can put flags in the DB which has a quick web accessible overview and link to plots



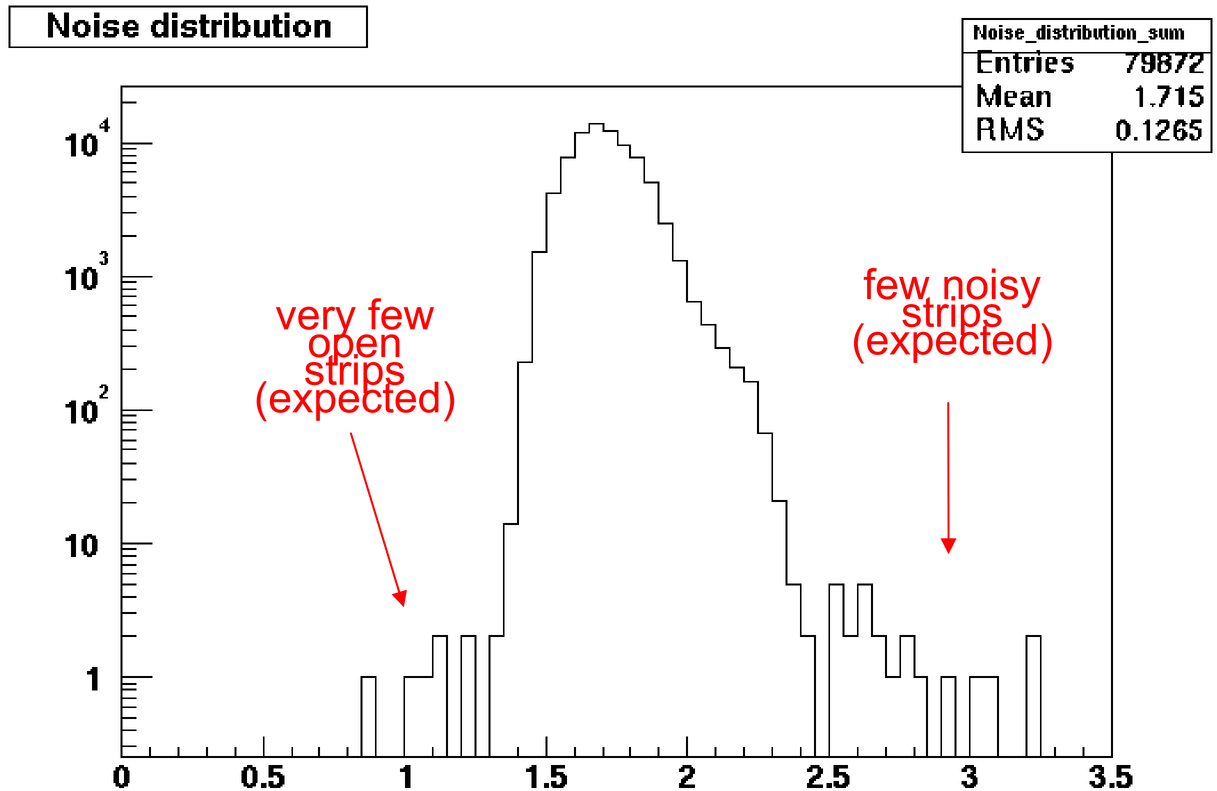
A typical module's noise profile



Overall noise/calibration

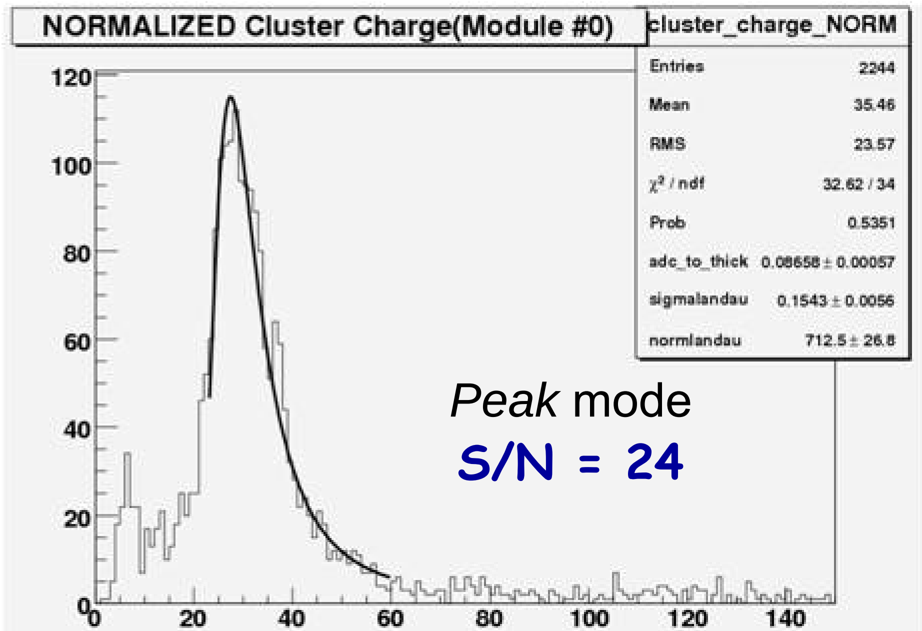
- With all the data stored it is easy to perform an integral analysis, such a the strip noise distribution

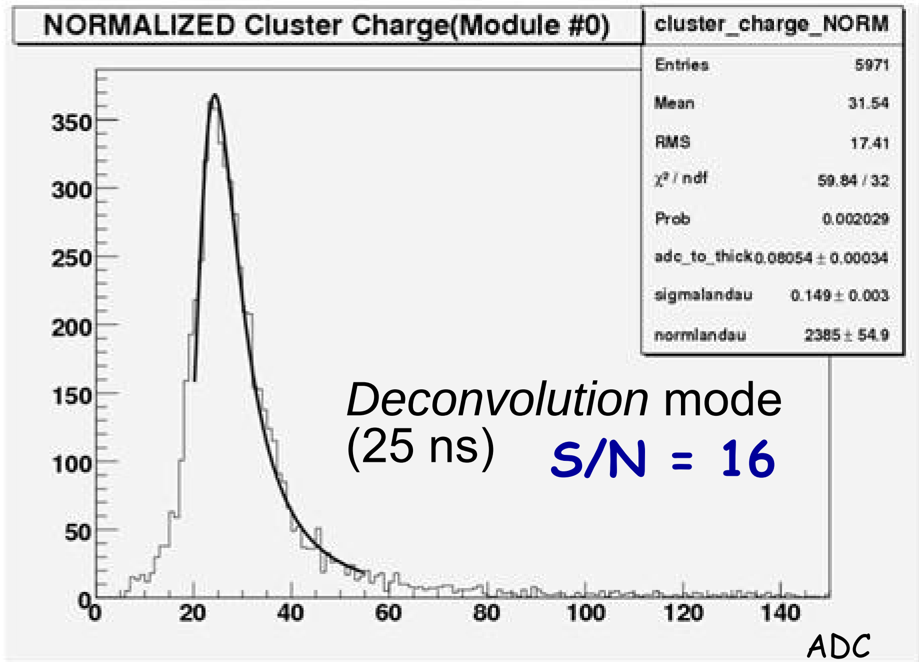
- This is useful to identify possible production problems

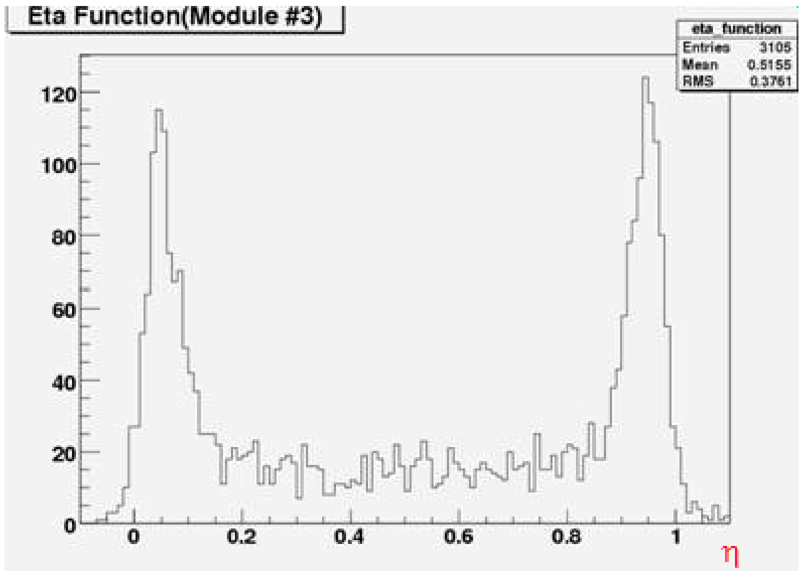


Cosmic test

- A cosmic muons test was performed by setting up a duplicate system
- Analysis confirms that a stable readout can be achieved with a good signal-to-noise ratio
- One can also reconstruct the strip to neighbour charge distribution function (eta function)

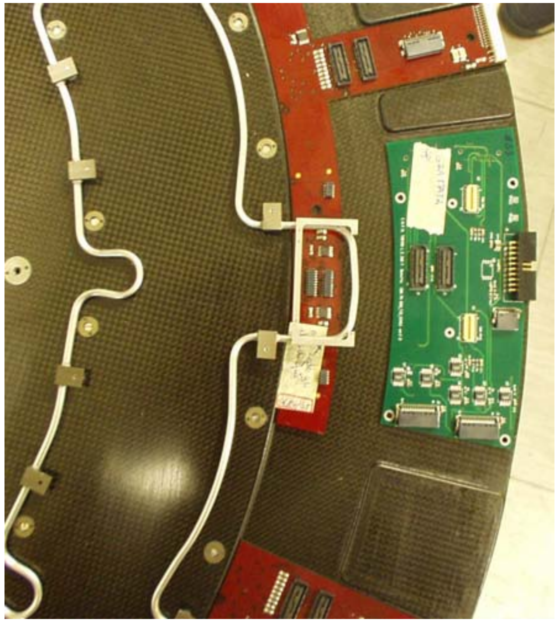


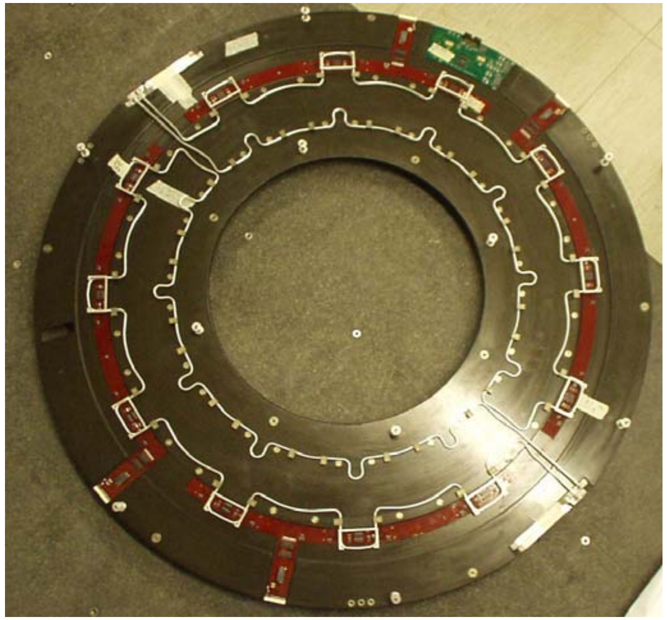




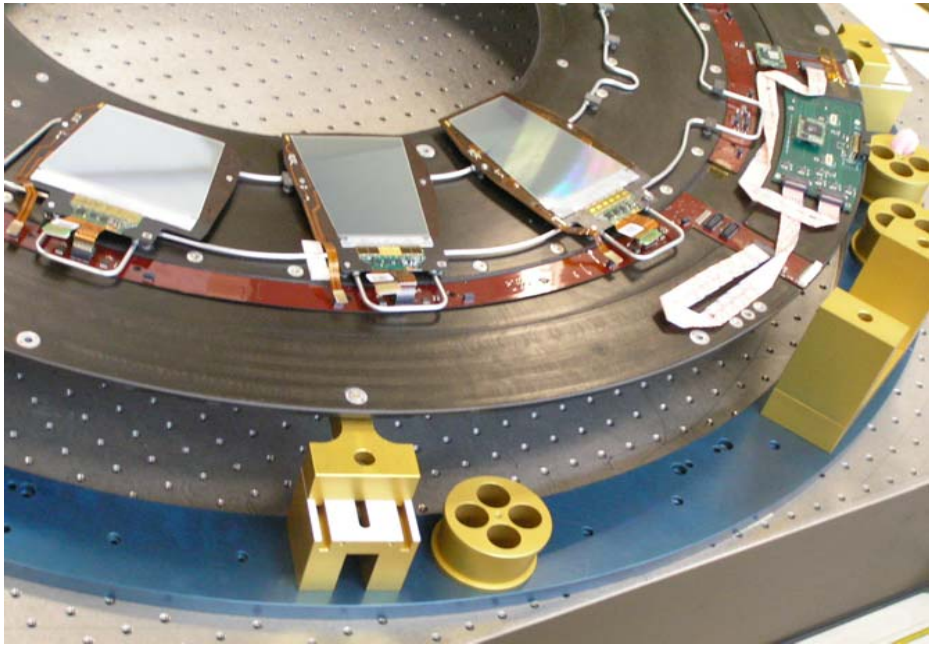
Tracker Inner Disk integration

- Also in TID modules are individually mounted onto disk support structures
- TID has fewer modules w.r.t. TIB, but they come in 7 different fashions
- Thus production of tooling and modules is more difficult, but integration will be quicker



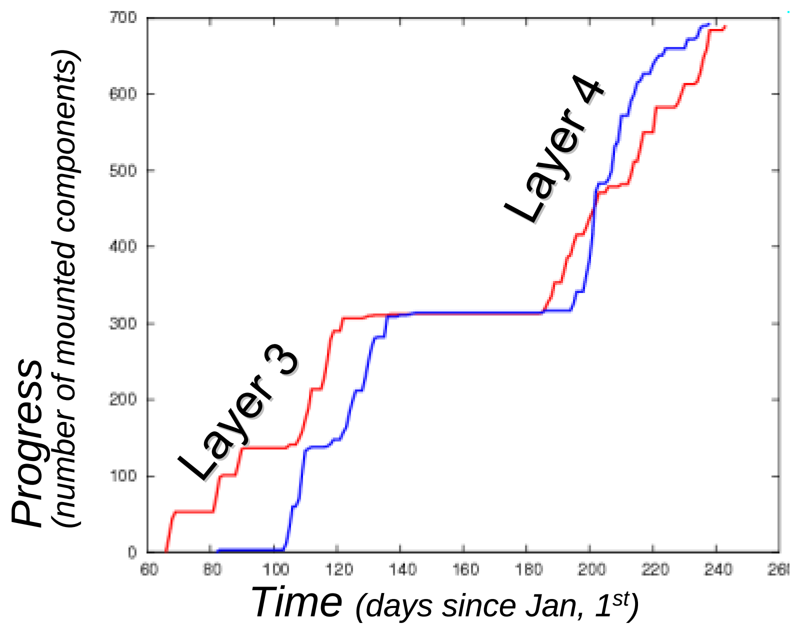


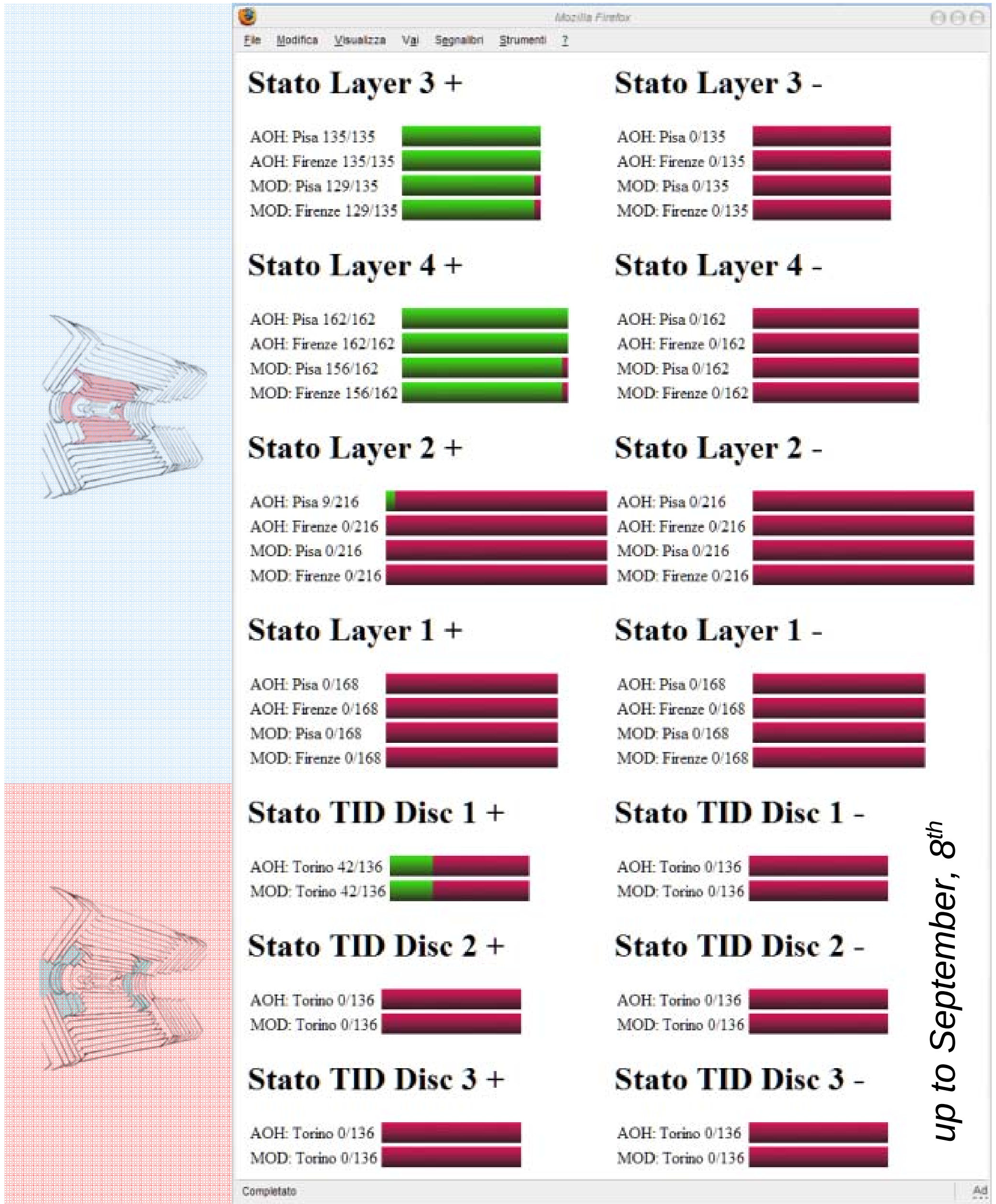
- Integration tooling has been qualified and the integration of the first disk is just started
- Like TIB, also TID will measure noise for every module and store the results on the on-line database



TIB & TID production control

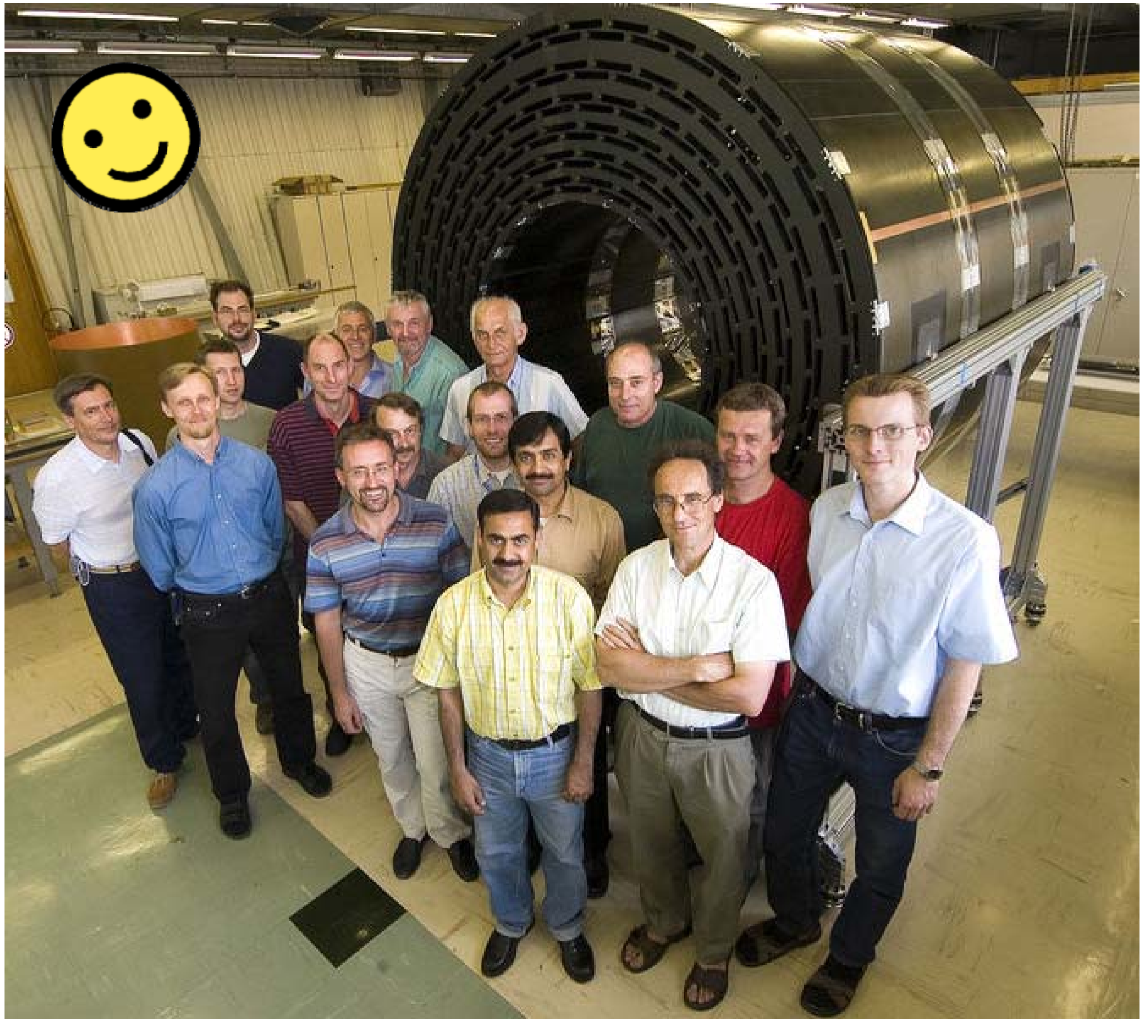
- TIB and TID progress can be monitored through this *big brother web page*
- *The integration process is flowing smooth, even if it can be bottlenecked by the production of specific tools and components, which are unique*





Tracker Outer Barrel

- The TOB is a cylinder of about 2.2 m length and 2.3 m diameter.
- It mounts on its inner surface the rails that support the Inner Barrel and the Inner Disks
- It's composed of 688 sub assemblies (**rods**), it is arranged in 6 concentric layers inside a supporting mechanical structure (**wheel**), mostly made of carbon fibre



The supporting wheel has been completed and measured

It has a precision better than 200 µm over its whole size

TOB integration

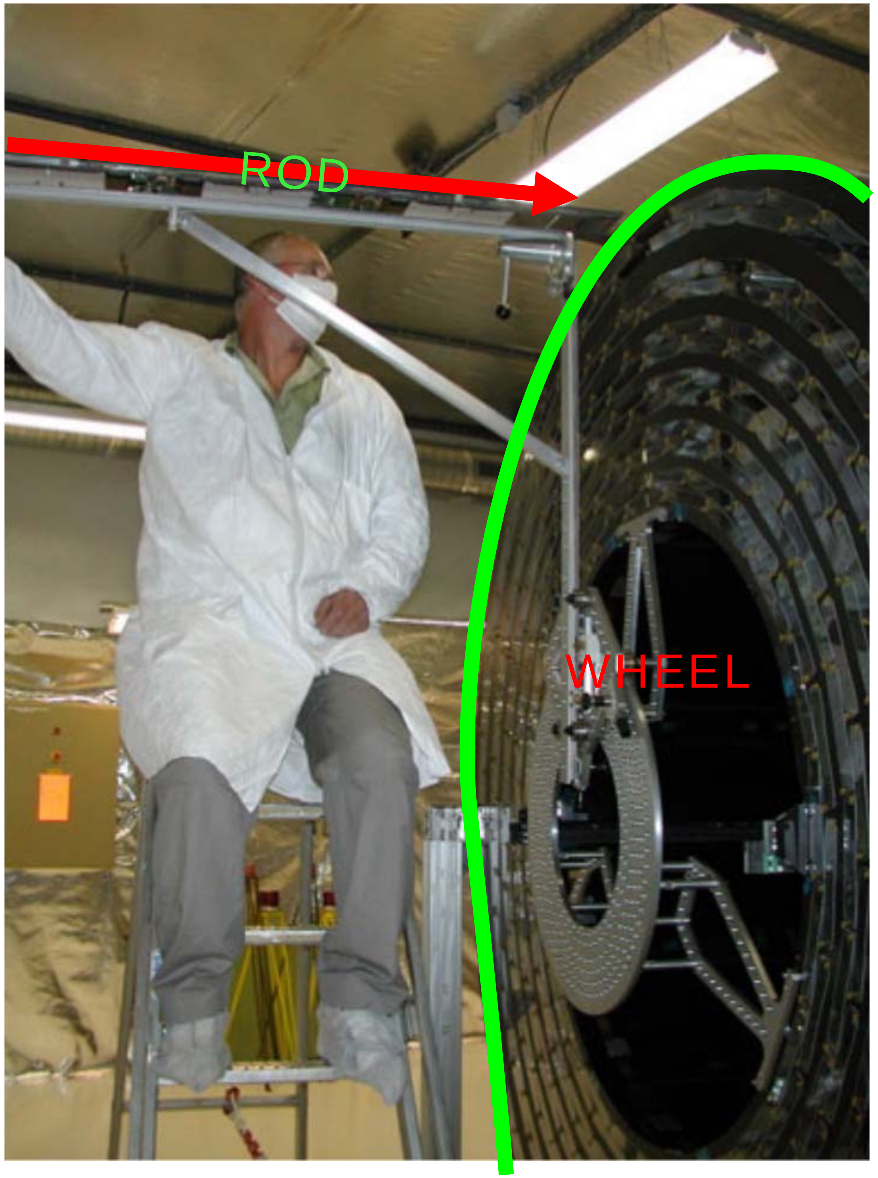
- A rod houses 6 or 12 silicon detectors, with all the interconnection electronics and the readout optical hybrids
- Rods are inserted in the wheel from both ends. The length of the TOB is covered by two rods overlapping in the centre (z=0).
- All rod frames are produced and individually measured (typical precision of inserts supporting the modules about 30 μm)
- Assembling of electronics boards & optical hybrids and validation at about 70% complete

TOB integration

- First rods populated with modules have been inserted in the wheel
- Installation procedures and tools finalized
- Quality control of completed segments of the TOB fully defined and being commissioned
- Integration procedure (a bit of...):

– Insert the rod in the wheel & register it in a DB
– Solder several connections and radial pipe
– Helium leak test + CF circulation + touching probes
– Attach cables, register all the connections in the DB

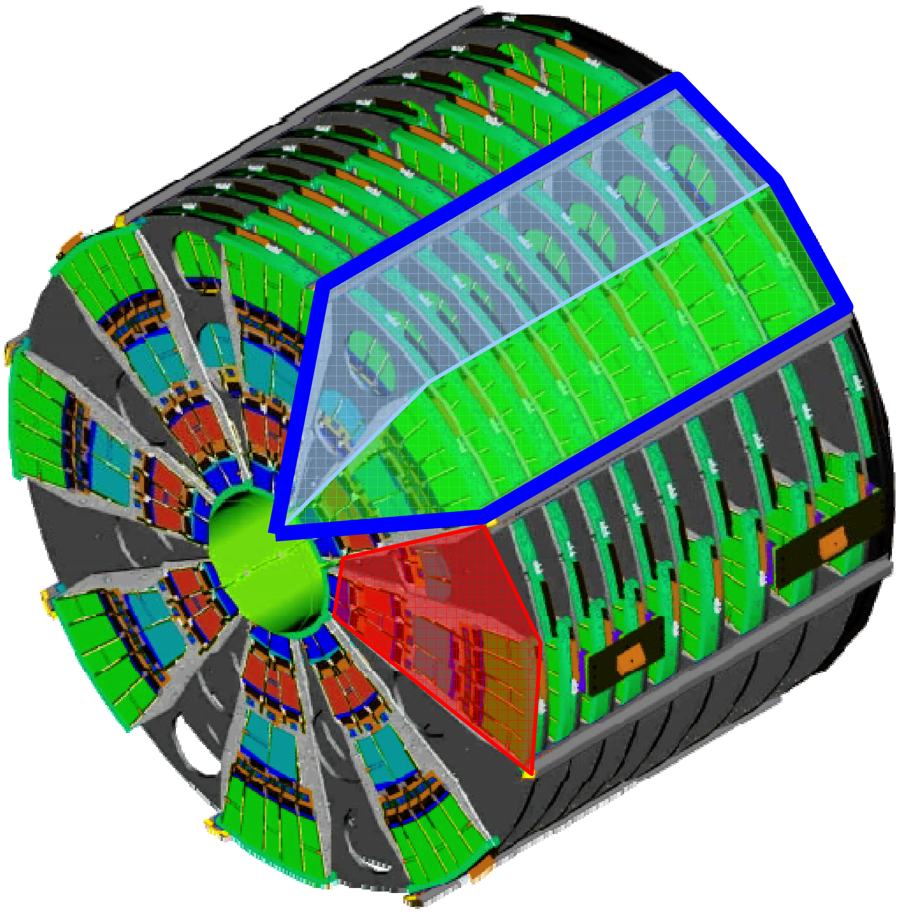
about (70' per rod!)



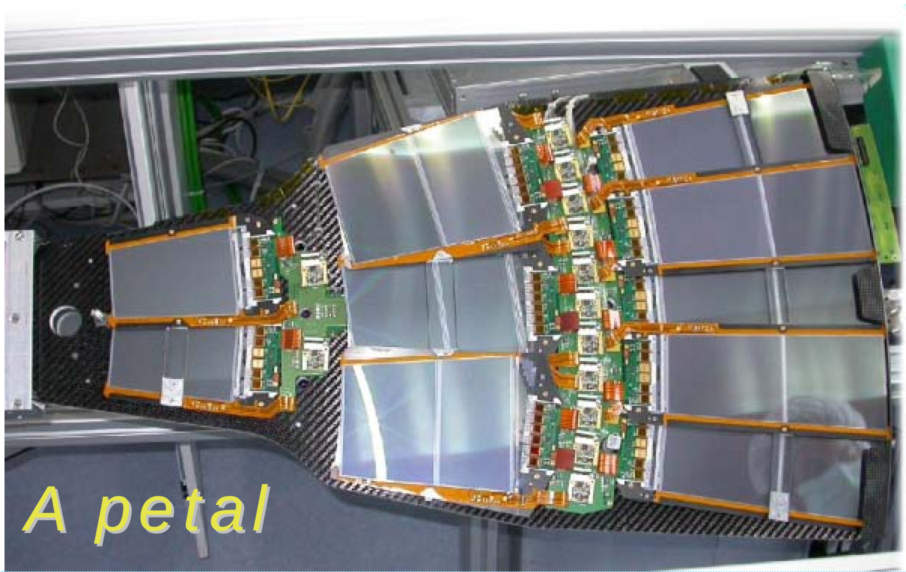
– A longer functional test (6h) follows when a sector is finished

Tracker End Cap

- **Modular structure: modules assembled onto petals, petals mounted onto disks.**
- **Total 288 petals with 6400 module**

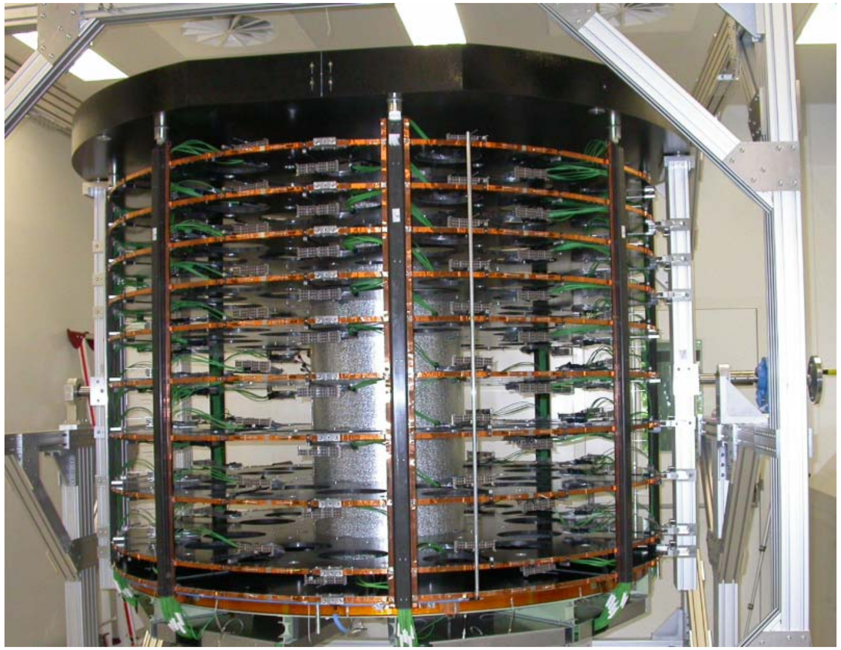


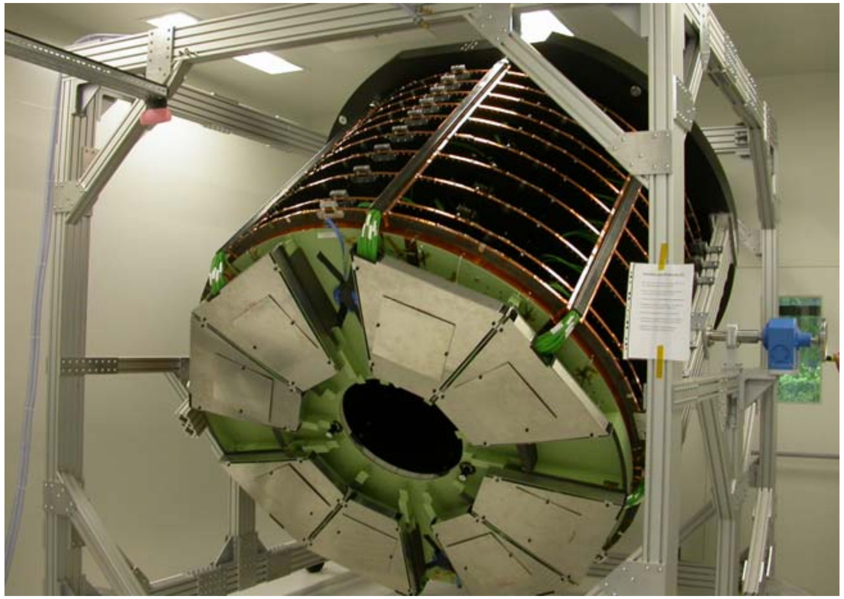
- **1 tower = 9 back or 9 front petals**
- **1 sector = 1 tower of BPs + 1 tower of FPs**
- **1 control loop = 1 BP and 1 FP**



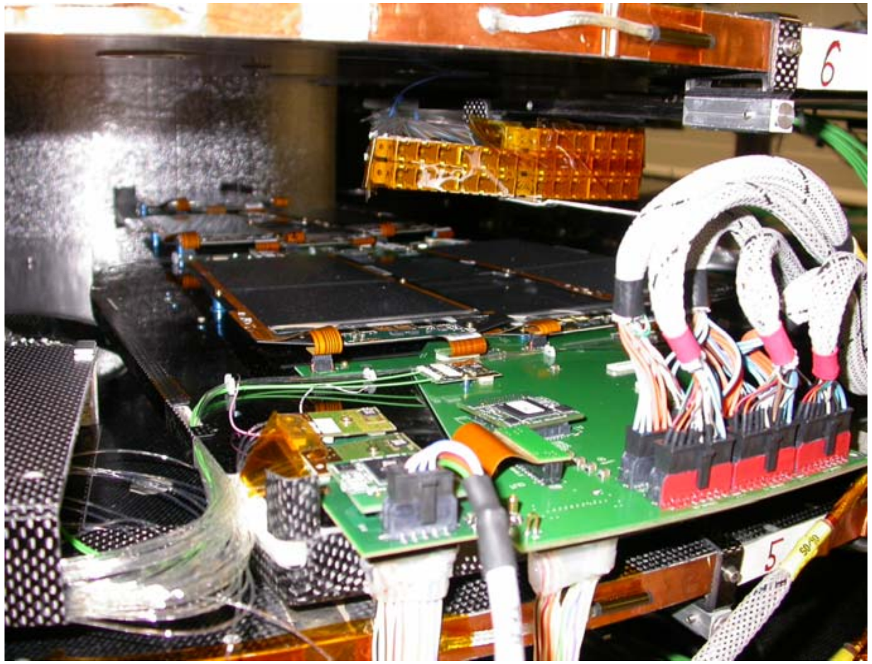
TEC status

- Both mechanical structures are ready, with optical ribbons for readout mounted
- Cooling pipes and power cables have to be mounted
- Petals for the first sector built and under test
- Integration of first TEC starts in October and will proceed sector by sector
- Cold test at CMS operating temperature planned for the first sector
- Grounding and shielding scheme will be studied



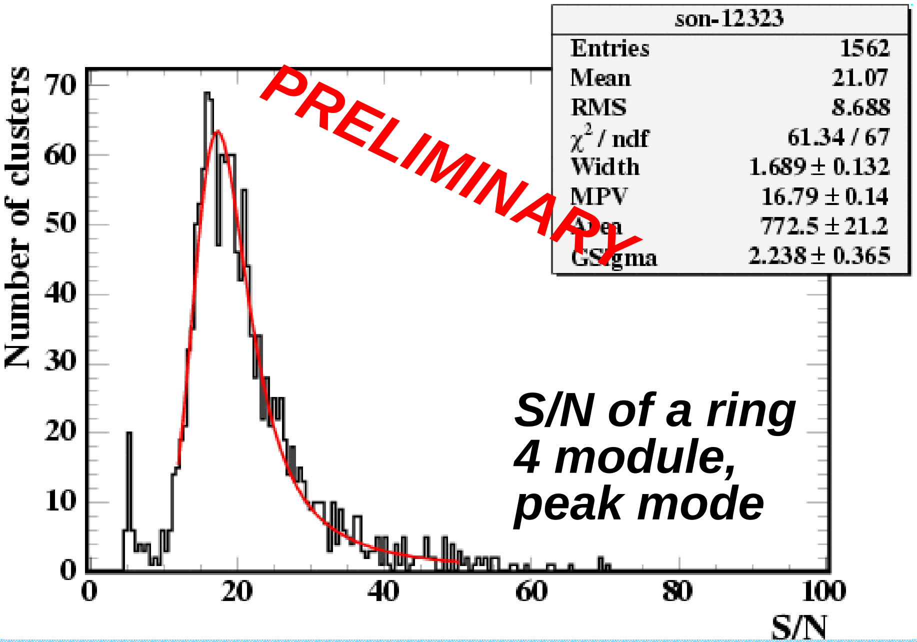


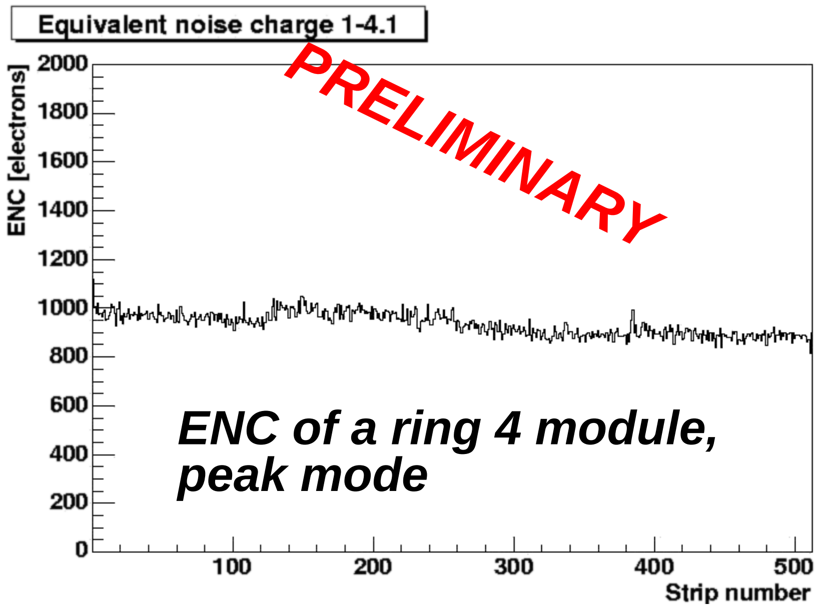
TEC integration exercise



Trial assembly of two petals in the TEC with full readout:

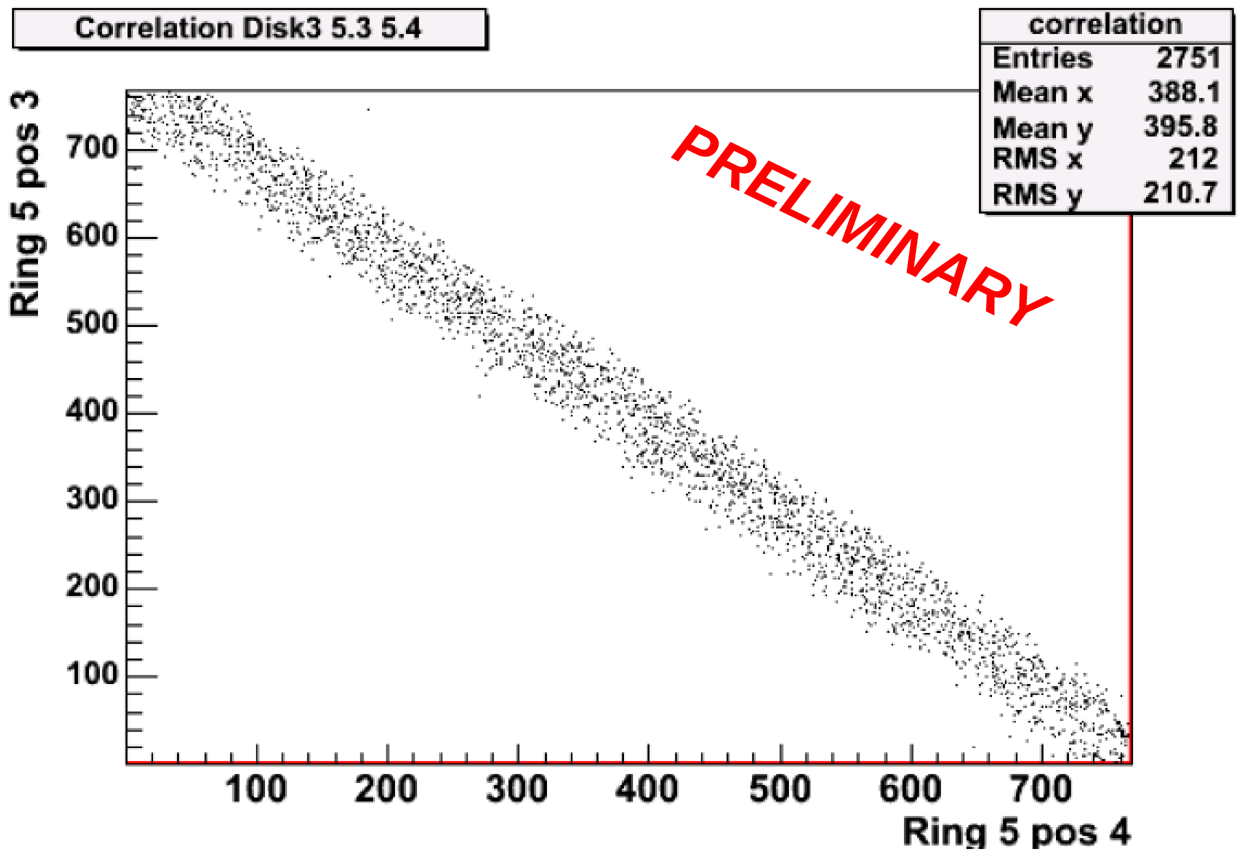
- Insertion procedure, cabling and handling of optical fibres exercised
- Experience with cosmic muon trigger gained
- Preliminary results: S/N and ENC similar to previous test beam results





TEC summary

- A stable readout was achieved
- Cosmic muons detected
- 2 additional test structures were produced to be partially filled with modules: 1 for a magnet test and 1 for DAQ test



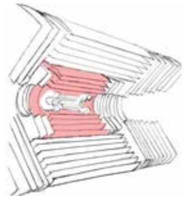
Conclusions

- Integration and commissioning of the Silicon Strip Tracker in time is essential for the construction of the CMS experiment
- The whole process' steadiness is sensitive to many details
- This work presents difficulties both because of the volume of work to be handled and because of its uniqueness
- Thus a step-by-step quality check is essential to spot any problem in time for implementing proper solutions
- A parallel work now in progress is the commissioning of a tracker's segment duplicate (with a limited subset of detectors) to check how these sub detectors will work together inside a magnet field and test its tracking capability

Some numbers

Table 1: Detector multiplicity for the inner barrel

Layer #	Avg. radius	Modules in phi	Total # of modules	APV / det	Pitch phi	Pitch stereo	Total # of APVs
TIB1	255	26-30	336	6 + 6	80	80	4032
TIB2	340	34-38	432	6 + 6	80	80	5184
TIB3	430	44-46	540	4	120	-	2160
TIB4	520	52-56	648	4	120	-	2592



The TIB is made of 1188 single modules and 768 double modules, for a total of 2724 detectors, 2724 6" wafers, and 13968 APVs.

Table 2: Detector multiplicity for the outer barrel

Layer #	Avg. radius	Modules in phi	Total # of modules	APV / det	Pitch phi	Pitch stereo	Total # of APVs
TOB1	608	42	504	4 + 4	183	183	4032
TOB2	692	48	576	4 + 4	183	183	4608
TOB3	780	54	648	4	183	-	2592
TOB4	868	60	720	4	183	-	2880
TOB5	965	66	792	6	122	-	4752
TOB6	1080	74	888	6	122	-	5328

The TOB is made of 3048 single modules and 1080 double modules, for a total of 5208 detectors, 10416 6" wafers, and 24192 APVs.

Some numbers

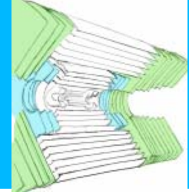
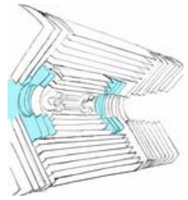


Table 3: Detector multiplicity for the inner disks.

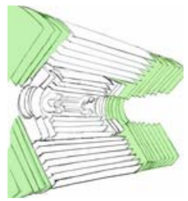
Ring #	Modules in phi	N of rings in z	Total # of modules	APV / det	P1/P2 phi	P1/P2 stereo	Total # of APVs
TID1	24	6	144	6 + 6	81/112	81/112	1728
TID2	24	6	144	6 + 6	113/143	113/143	1728
TID3	40	6	240	4	123/158	-	960



The TID is made of 240 thin single modules and 288 thin double modules, for a total of 816 thin detectors, and 816 thin 6" wafers.
The total number of APVs is 4416.

Table 4: Detector multiplicity for the endcap.

Ring #	Modules in phi	N of rings in z	Total # of modules	APV / det	P1/P2 phi	P1/P2 stereo	Total # of APVs
TEC1	24	6	144	6 + 6	81/112	81/112	1728
TEC2	24	12	288	6 + 6	113/143	113/143	3456
TEC3	40	16	640	4	123/158	-	2560
TEC4	56	18	1008	4	113/139	-	4032
TEC5	40	18	720	6 + 6	126/156	126/156	8640
TEC6	56	18	1008	4	163/205	-	4032
TEC7	80	18	1440	4	140/172	-	5760



The TEC is made of 1648 thin single modules and 432 thin double modules, for a total of 2512 thin detectors, and 2512 thin 6" wafers; 2448 thick single modules and 720 thick double modules, for a total of 3888 thick detectors and 7776 thick 6" wafers. The total number of APVs is 30208.