The CMS Tracker End Caps integration

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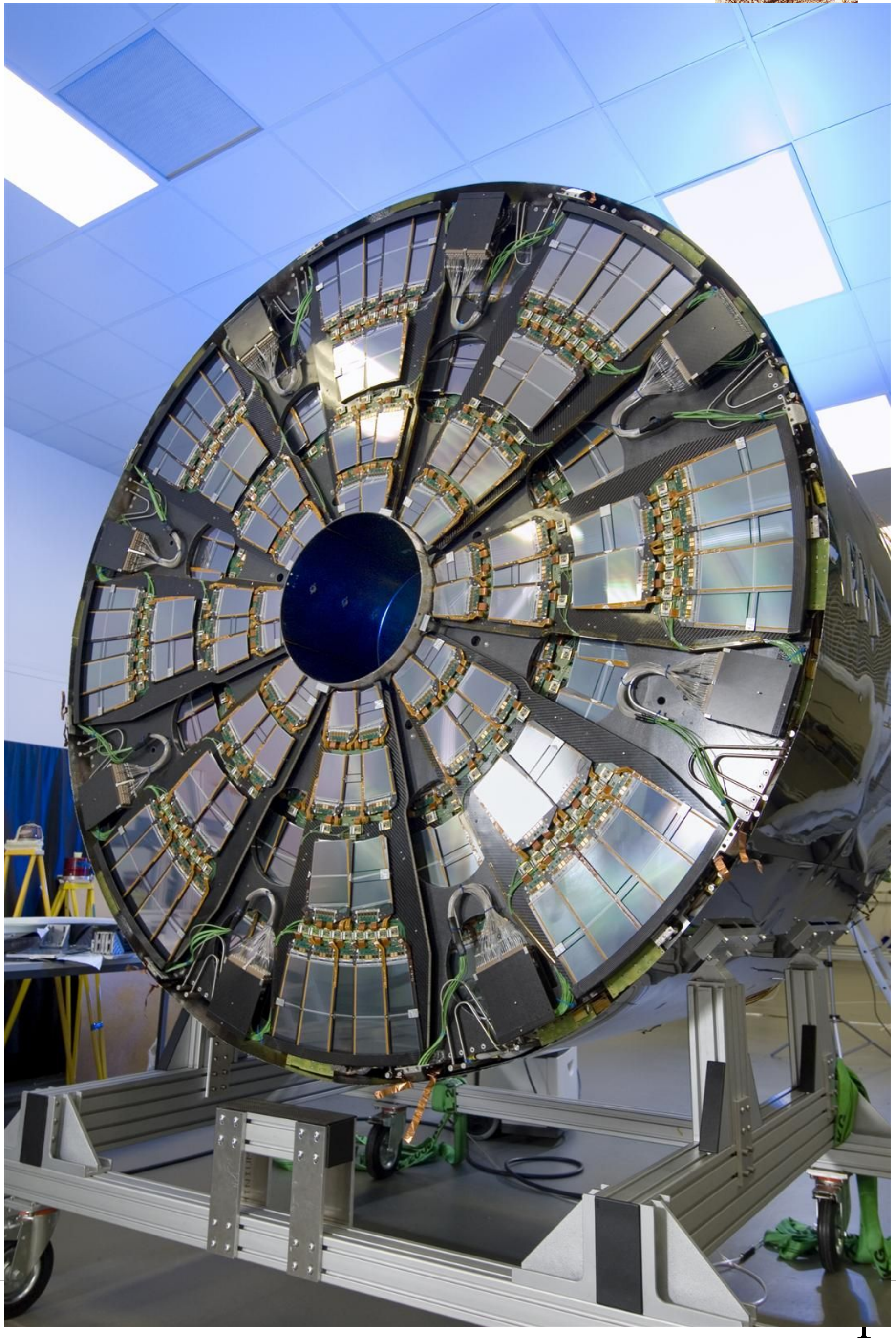
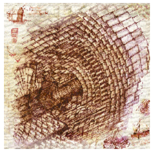
for the CMS Tracker collaboration

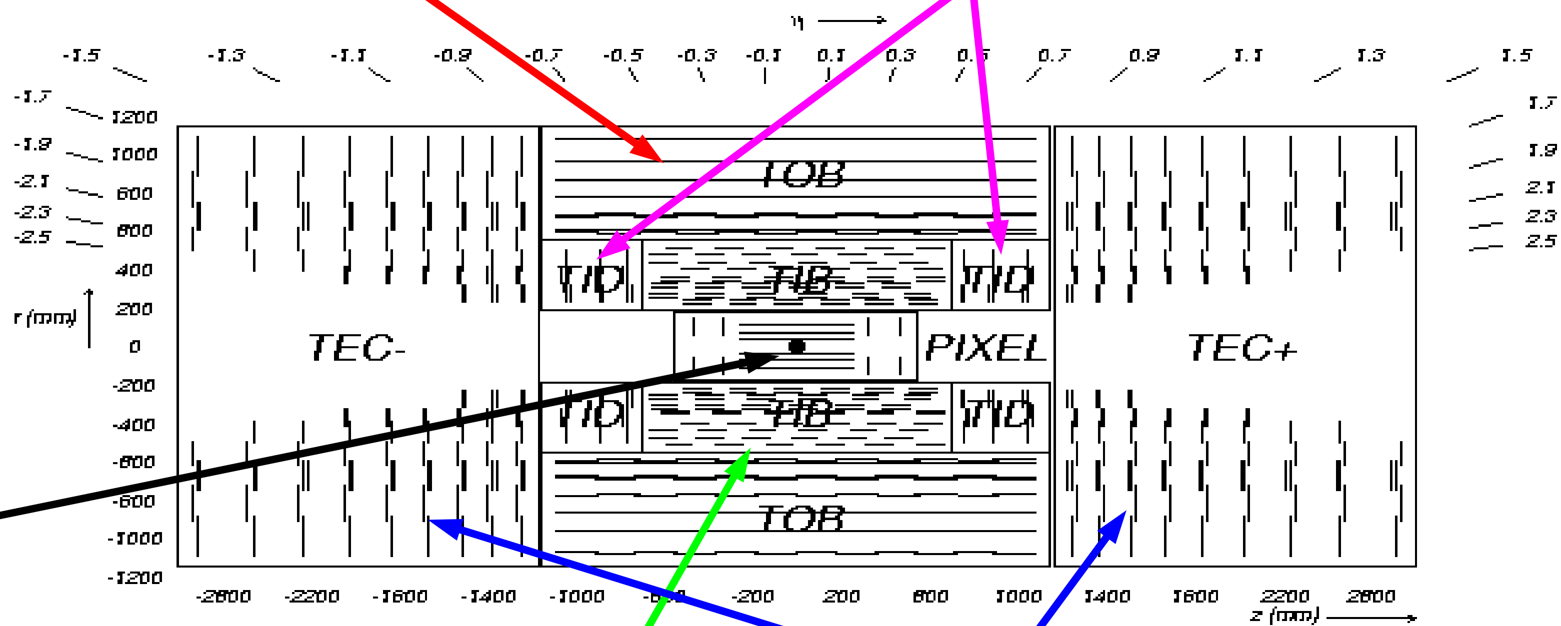


The CMS Silicon Strip Tracker



Tracker Outer Barrel
6 layers
5208 modules

Tracker Inner Disk
2 x 3 disks
816 modules



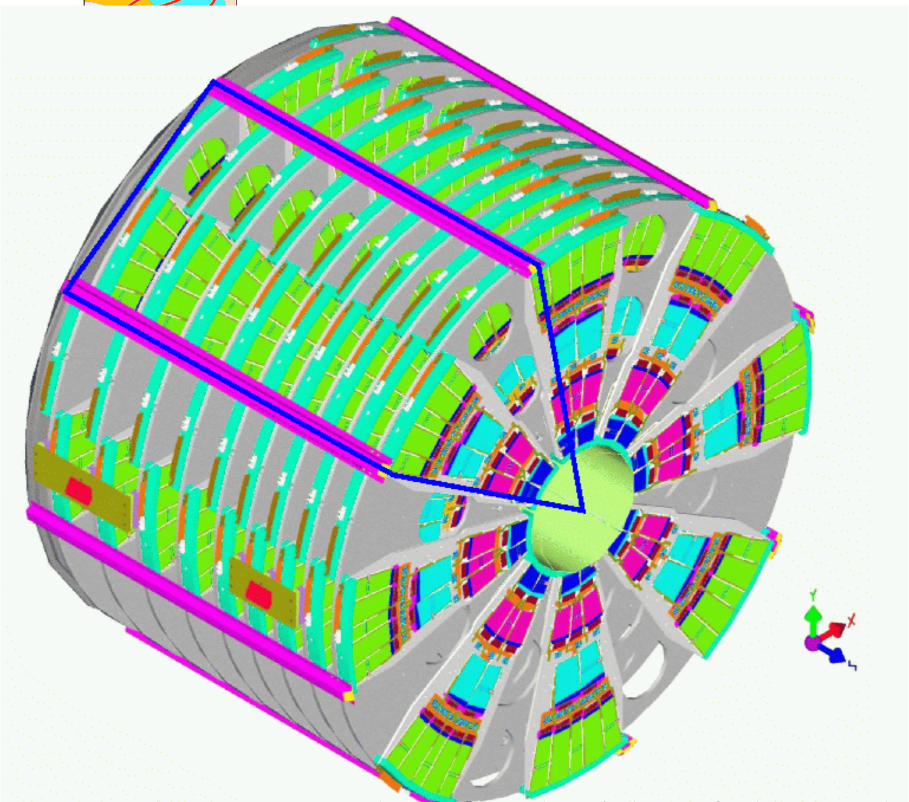
interaction point

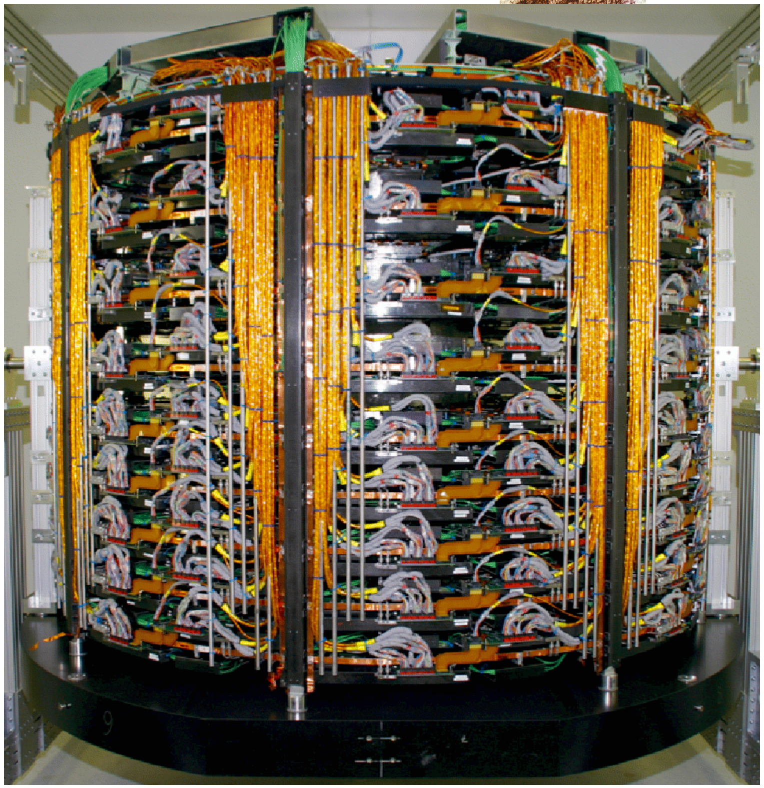
Tracker Inner Barrel
4 layers
2724 modules

Tracker End Cap
2 x 9 disks
6400 modules

⇒ TEC comprises 42% of the modules of the tracker = 82 m^2 active silicon area

The CMS Tracker End Caps





•8 petals mounted on each side of the carbon fiber disks, 9 disks per end cap

• Both mechanical structures built by AachenC 1B, precision (CERN photogrammetry) < 200μm

• All optical ribbons integrated (Karlsruhe)

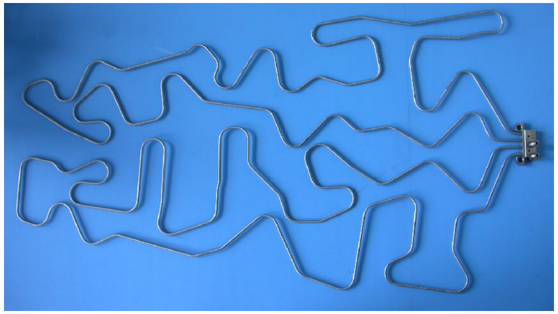
• Design and installation of the services (Lyon)

• One end cap ("TEC+": +z direction) integrated in AachenC 1B

• Second end cap integrated at CERN by Lyon group

Petal mechanics

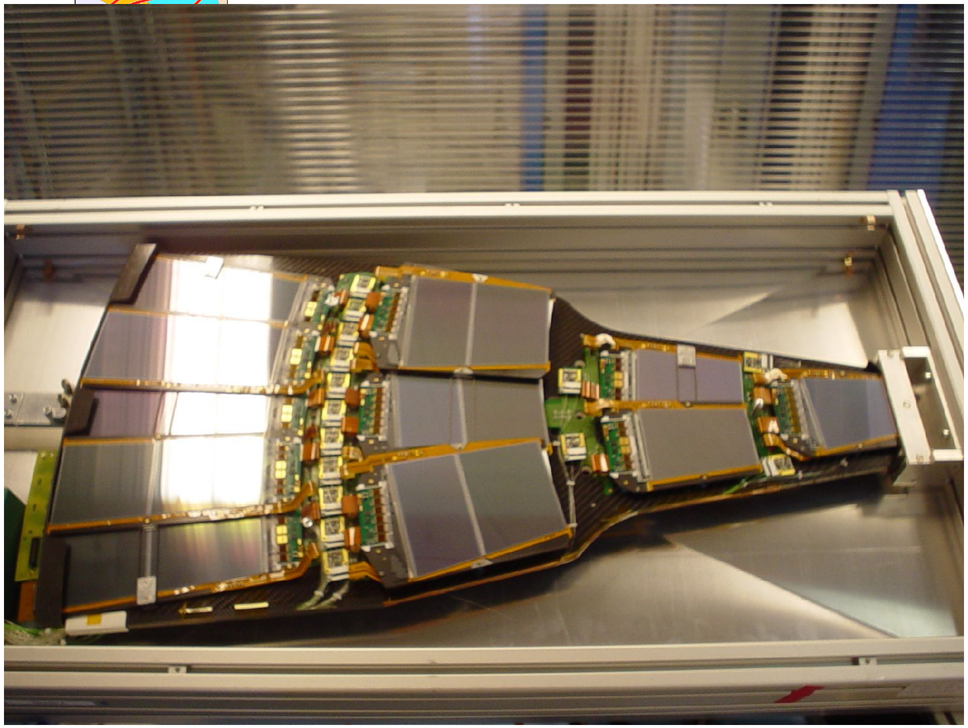
- Honeycomb plate with CF skins: light but stiff
- Each module mounted onto 4 aluminum precision inserts (relative precision in plane: 20µm)
- 7m long titanium cooling pipe embedded inside the petal; thermal contact to modules and AOHs via inserts



Many technological challenges:

- Mechanical precision, provided by milling of inserts
- Laser welding of manifold to pipe
- Electrical insulation (anodization) between inserts and pipe, necessary to avoid ground loops
- Throughput (2 petals were built per day)

Petal qualification



- "Burn-in" of components & connections at level of petal
- 6 cooling cycles between room temp. and -20˚C → 3 days in total
- In-depth qualification of petals
- Grading
- **Quality of petals produced is very good: 1-3 ‰ of bad strips**

TEC: Silicon modules are assembled onto carbon fiber plated honeycomb **"petals"**, petals are mounted into the end caps

The silicon modules, AOHs and CCUMs on the petals are connected to motherboards, called InterConnect Boards or ICBs, which are mounted on both sides of the petal.

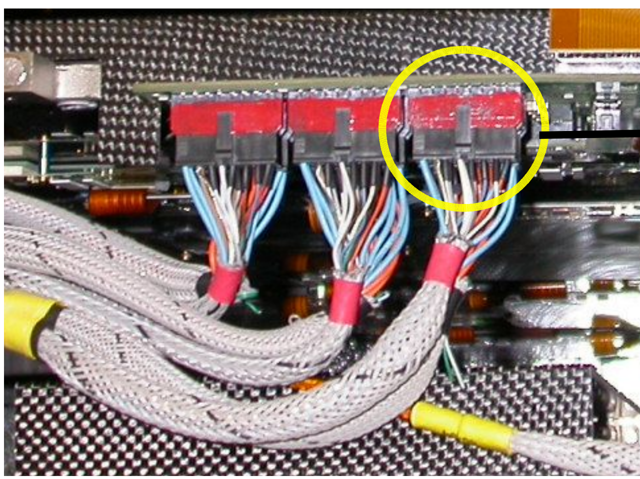
Advantage of this approach:
single substructures can be exchanged either during the integration or during shutdowns

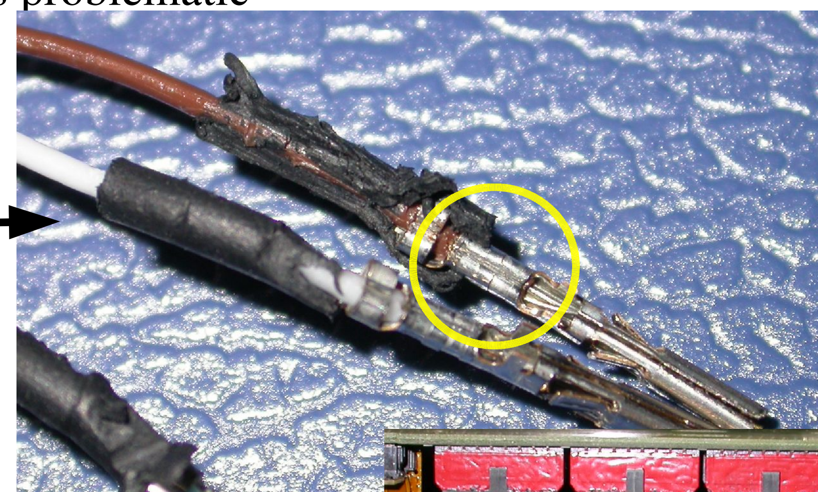
TEC cables problem

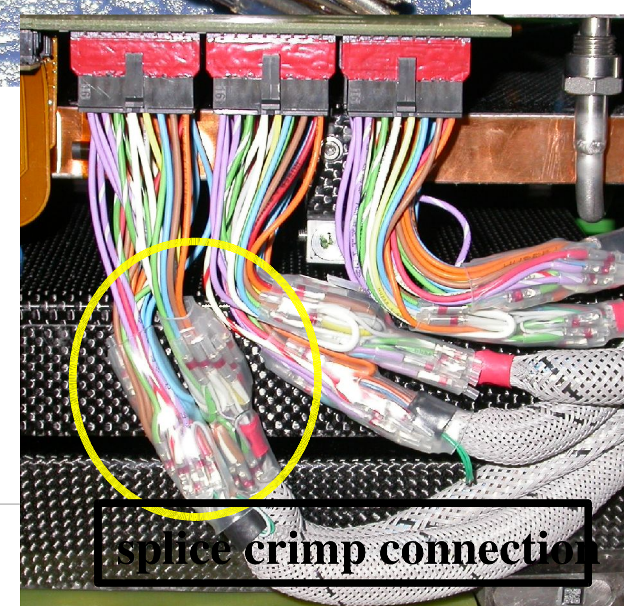
During the test of sector 7 (4th sector tested inAachen) unreliabilities observed on LV connection
symptom: very low or very large noise on one power group
finally traced back to bad crimp contact (July 6th)
many connectors opened and visualy inspected

Optical inspection: bad crimp contacts

- insulation material below conductor crimp
- automatic stripping/crimping of thin rad hard wires problematic







⇒ all connectors to be exchanged (26 000 contacts)

- company produces new pigtails (thicker wires, better QA)
- splice crimp connection to cable proven to work well

Leak testing of cooling system

- All sectors pressurized (N_2) to ~12 bar, pressure monitored over ~15 hours
- All circuits filled with He at ~10 bar and all joints (288 + 64) sampled with sniffer
- Vacuum in all circuits and all joints tested with He injection
- N_2 test revealed 2 suspicious sectors
- Problem localized (with He tests) to leaky petal in each case
  - Leak comes from *inside* petal, in each case
  - Two petals removed from TEC and replaced
- N_2 test performed *during* thermal cycles, 7 and 21 Feb. (pipes at -20^{o}C)

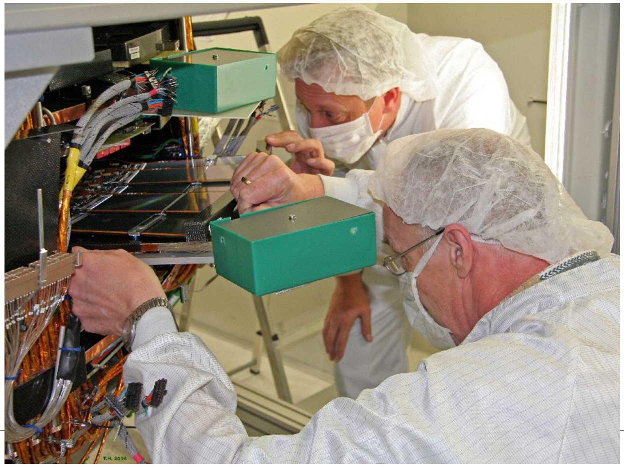
Integration procedure

- Integration sequence
  - insertion & cabling of 9 (18) back petals
  - rotation
  - insertion & cabling of 9 (18) front petals
  - connection of power, cooling, readout
  - readout test

- 1 sector (1/8 tec)
  - 9 back and 9 front petals
  - 4 cooling loops
  - 400 modules
  - 944 optical channels
  - 1888 APVs
  - 241664 silicon strips

Due to modular design, exchange of single petals “easily” possible (even if the environment is very dense...)

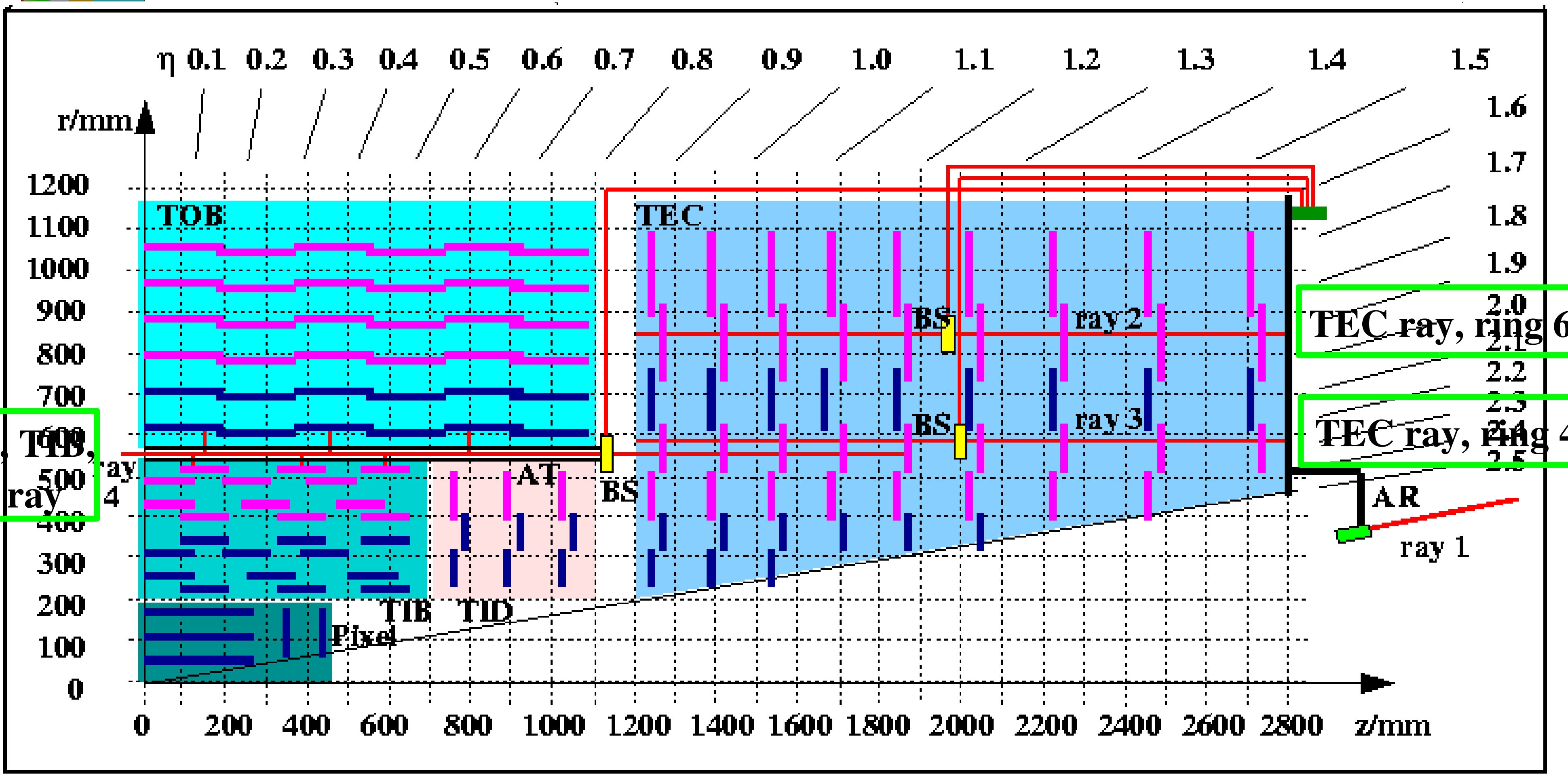
However: due to details of fixation, back petals can only be removed after the “neighbour” front petal is extracted (rotation!)



Test procedure

- Test of control ring functionality
- Test of i2c communication
- Connection run : debugging of missing optical connections
- Timing run
- Gain scan
- Long timing run: debugging of low gain fibers
- HV test up to 450V
- Pedestal with and without HV in peak and deconvolution mode
- Readout of DCUs
- Laser alignement run

Laser Alignment



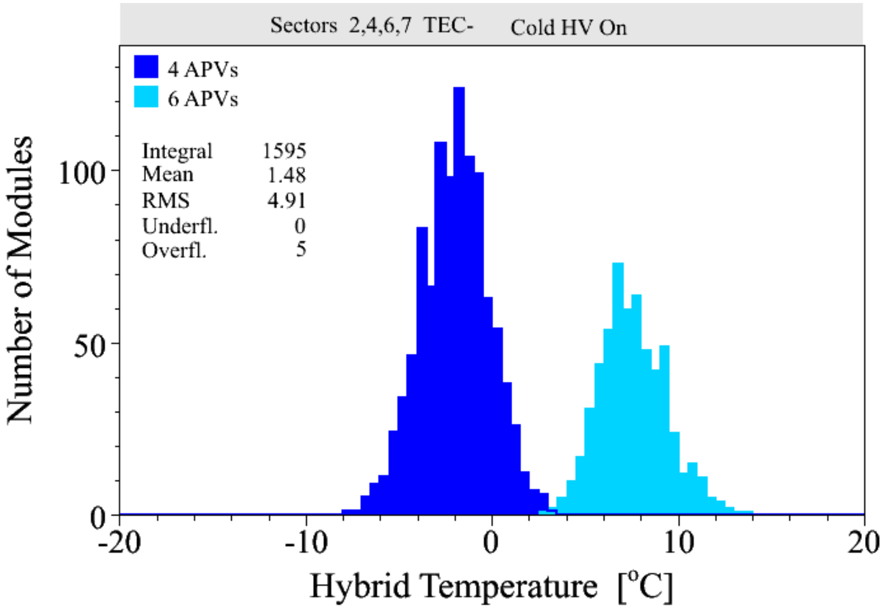
- First coarse alignment with laser beams
- Alignment of TOB, TIB and TEC with respect to each other
- TEC internal alignment: displacement of large structures (disks & petals)
- Design goals: absolute precision of 100 μm, relative precision of 10 μm

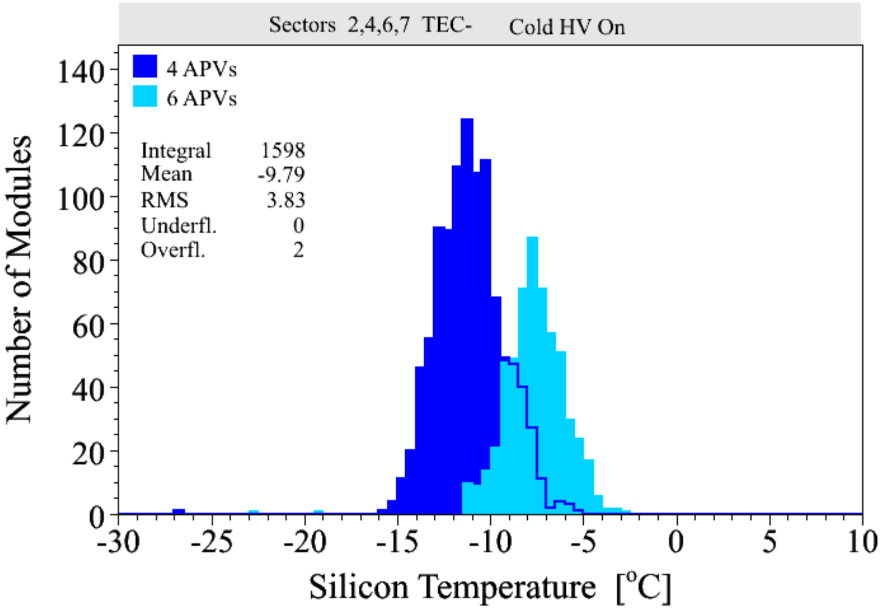
Cold test: Cold room, chiller, setup

Lyon cold room

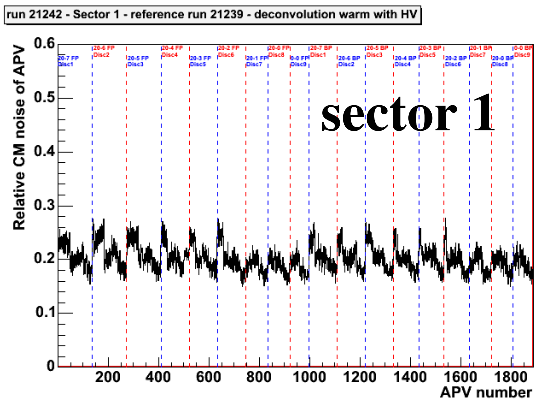
12 kW power can cool down to -20ºC . No active heating

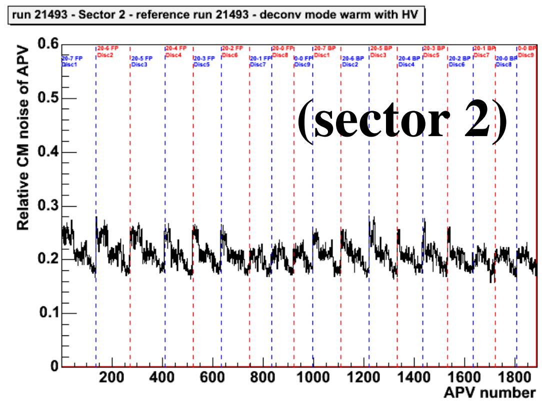
- Three electrical heaters in cold room to speed up the warmup phase
- TEC itself cooled with C_6F_{14}, using dedicated chiller
- Dry air supply flushing TEC volume and cold room itself . Flow ≈ 30m3/h, dew point 70ºC connected to UPS . second dry air unit can be connected in case of problems

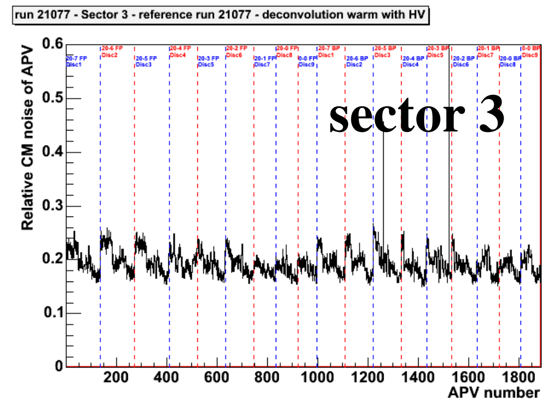


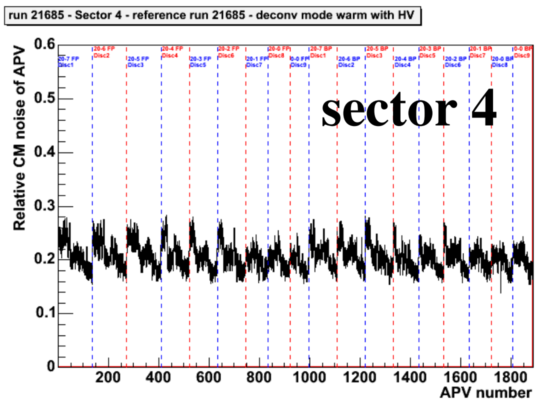


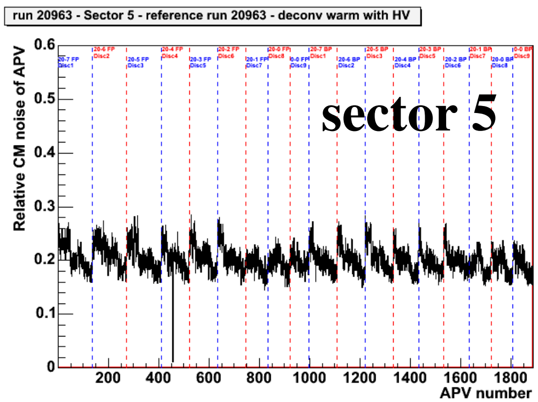
COMMON MODE NOISE (TEC+)

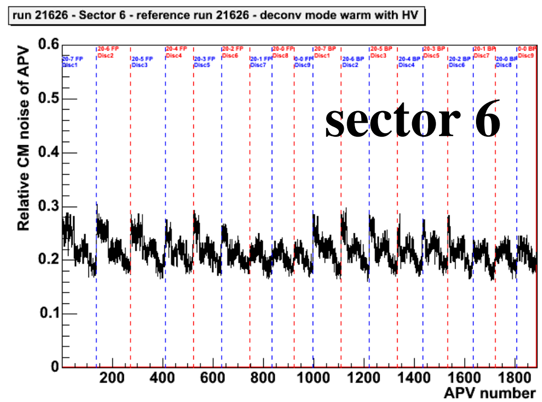




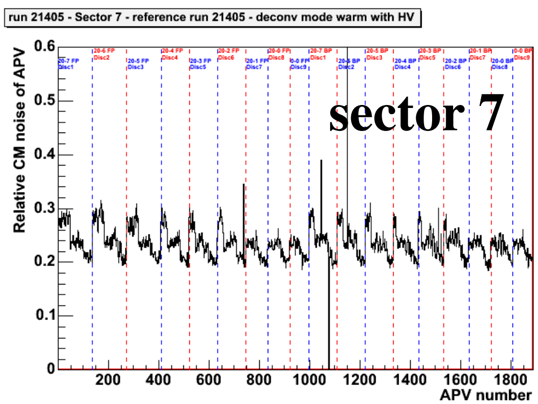


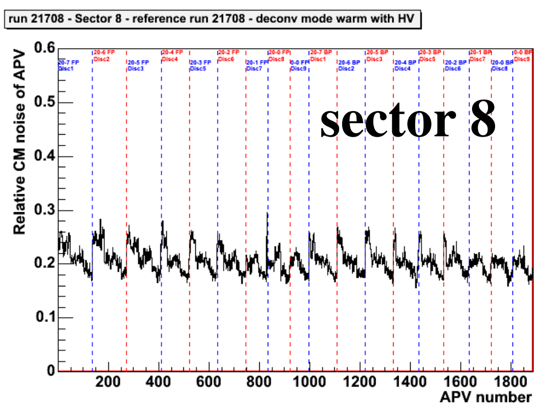




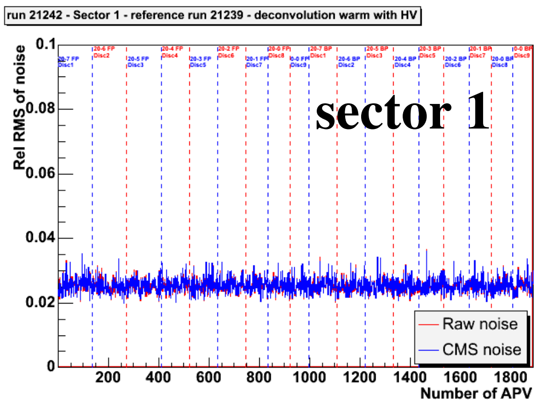


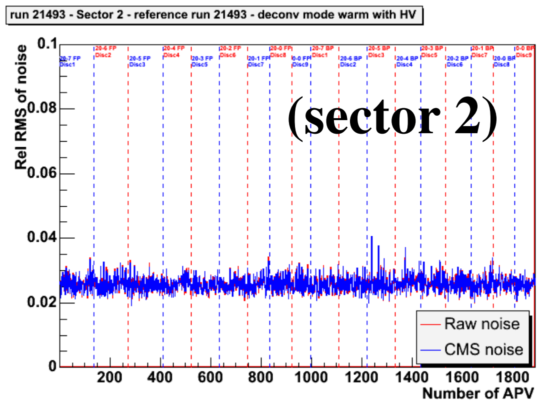
deconvolution mode

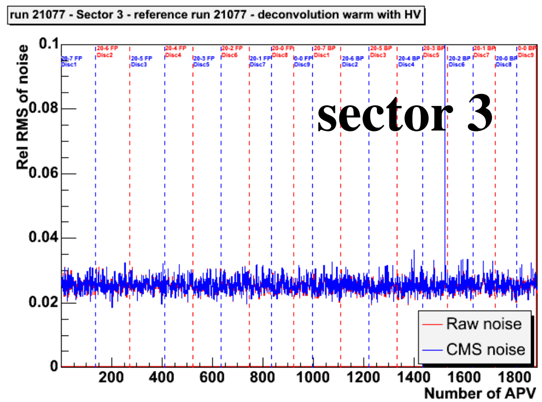


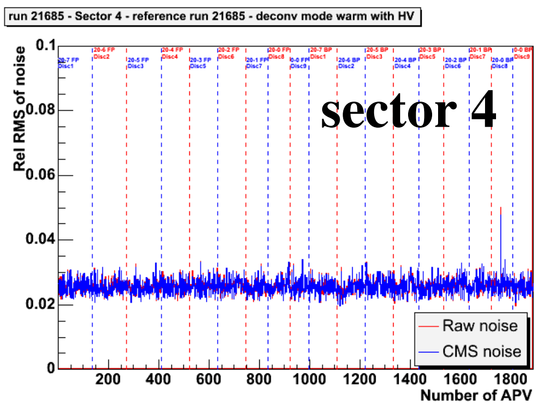


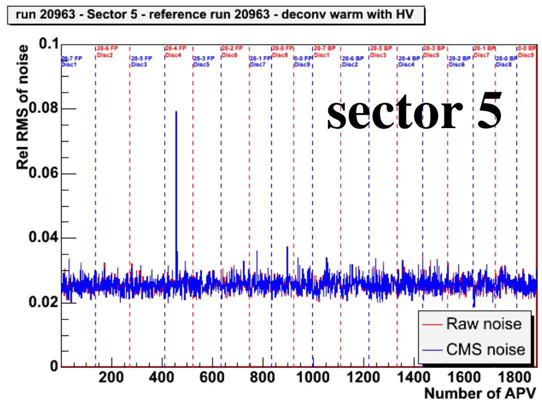
Noise flatness (TEC+)

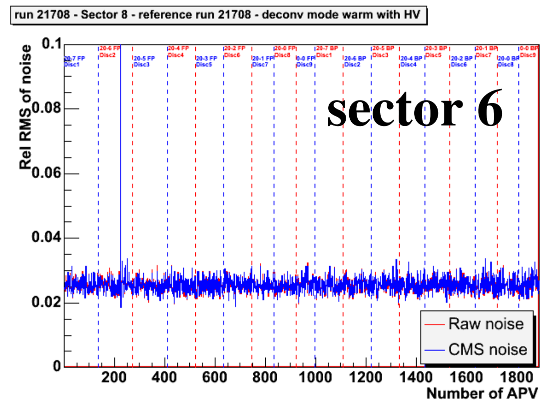




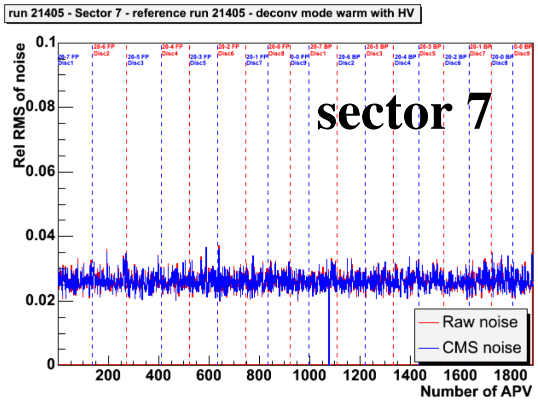


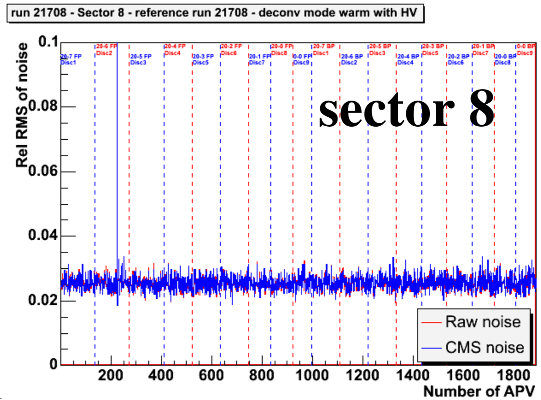




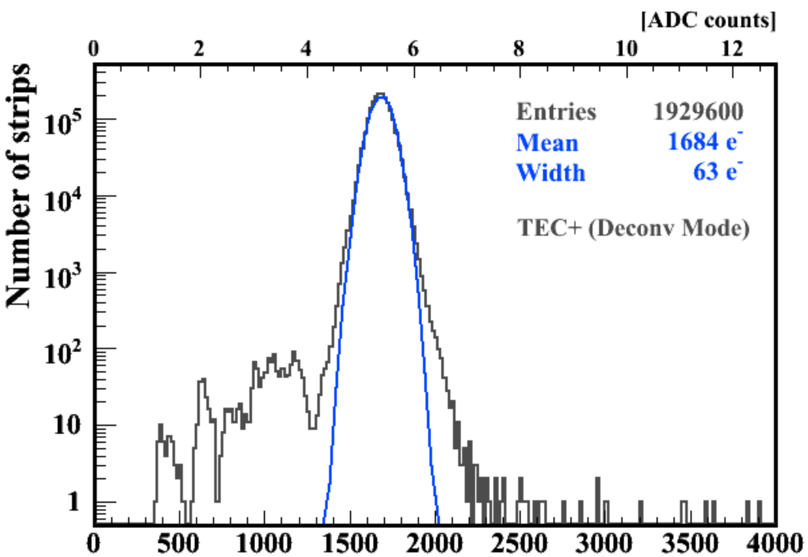


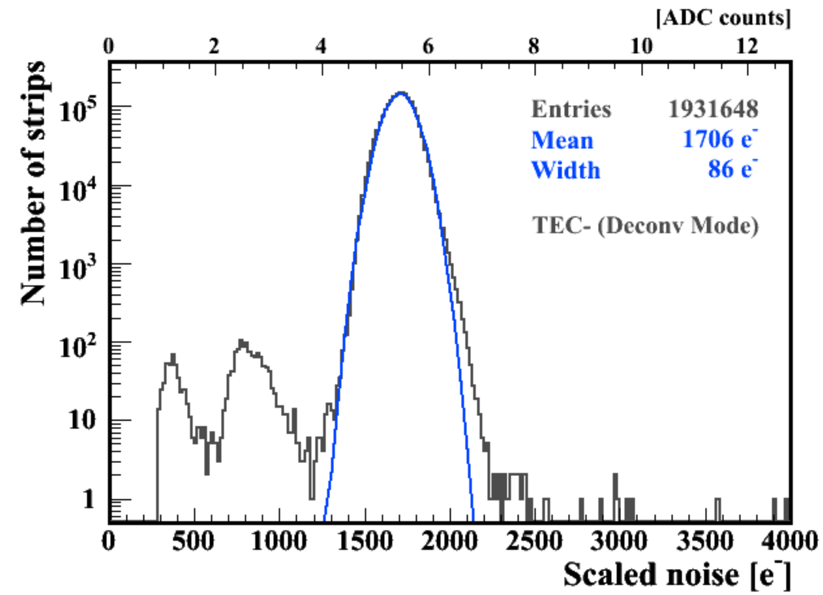
deconvolution mode

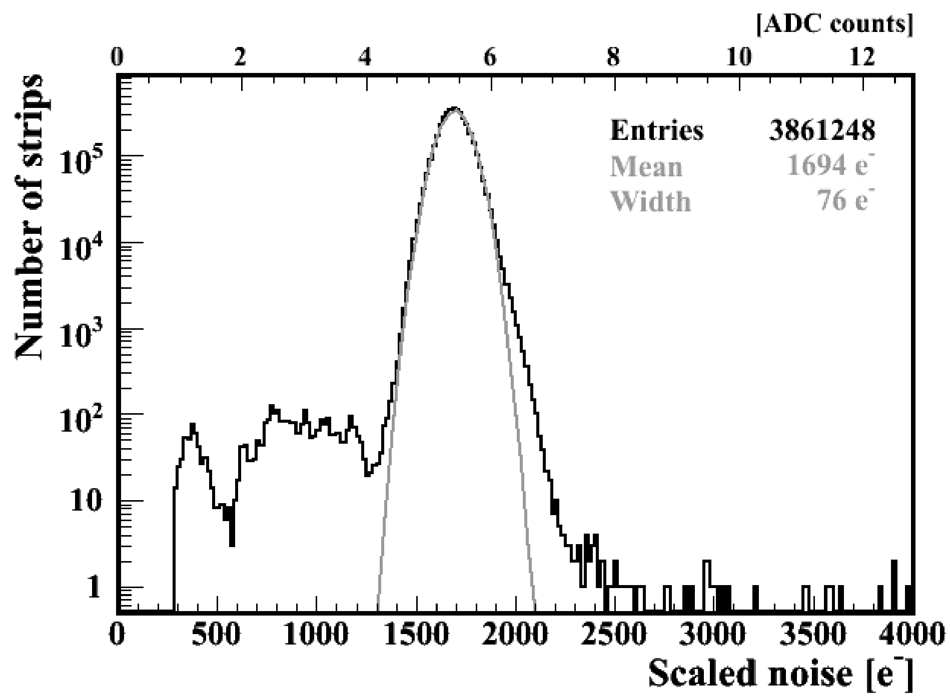




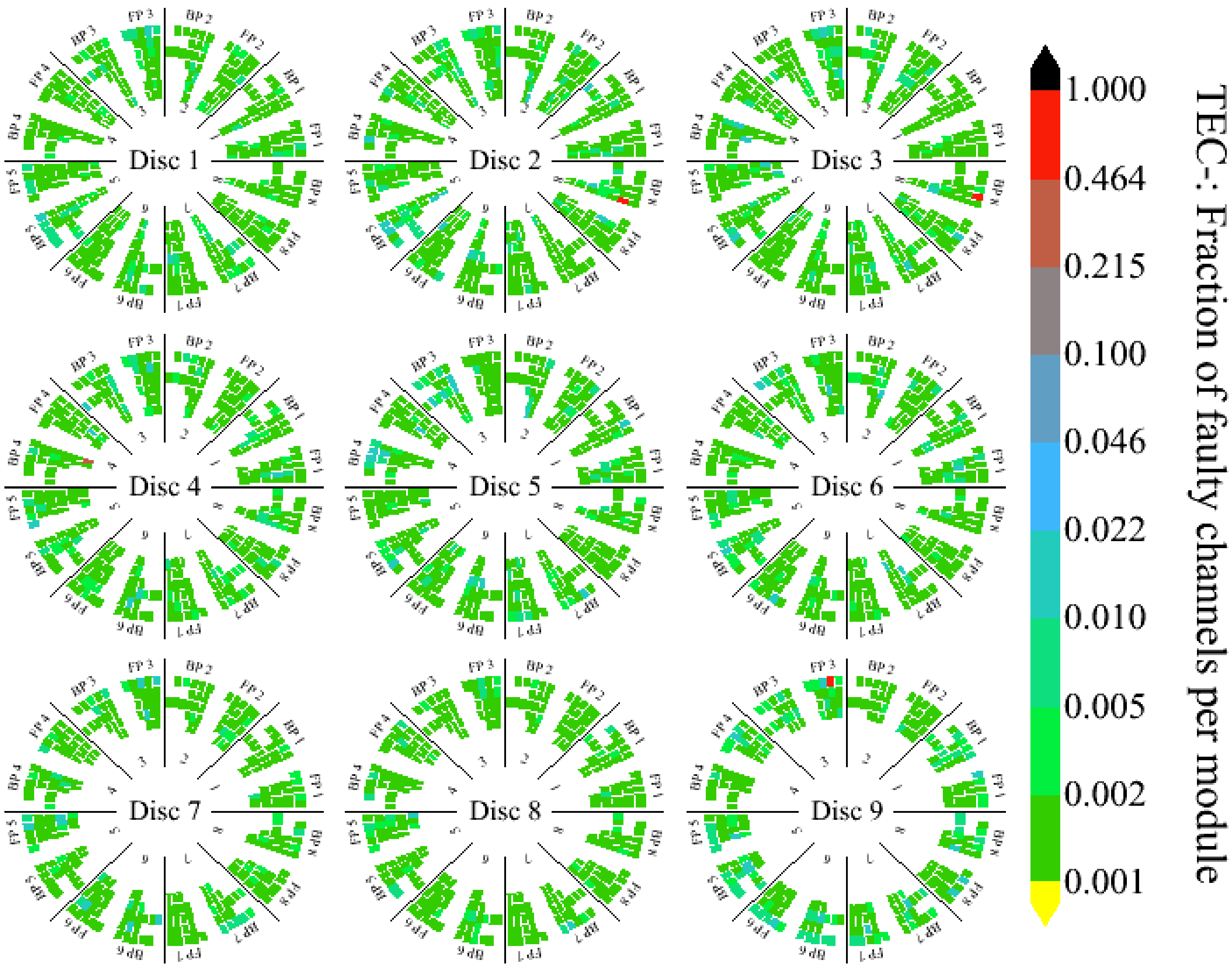
Normed single strip noise distribution for both TECs







Geometrical Distribution of Fraction of Bad Channels (TEC -)



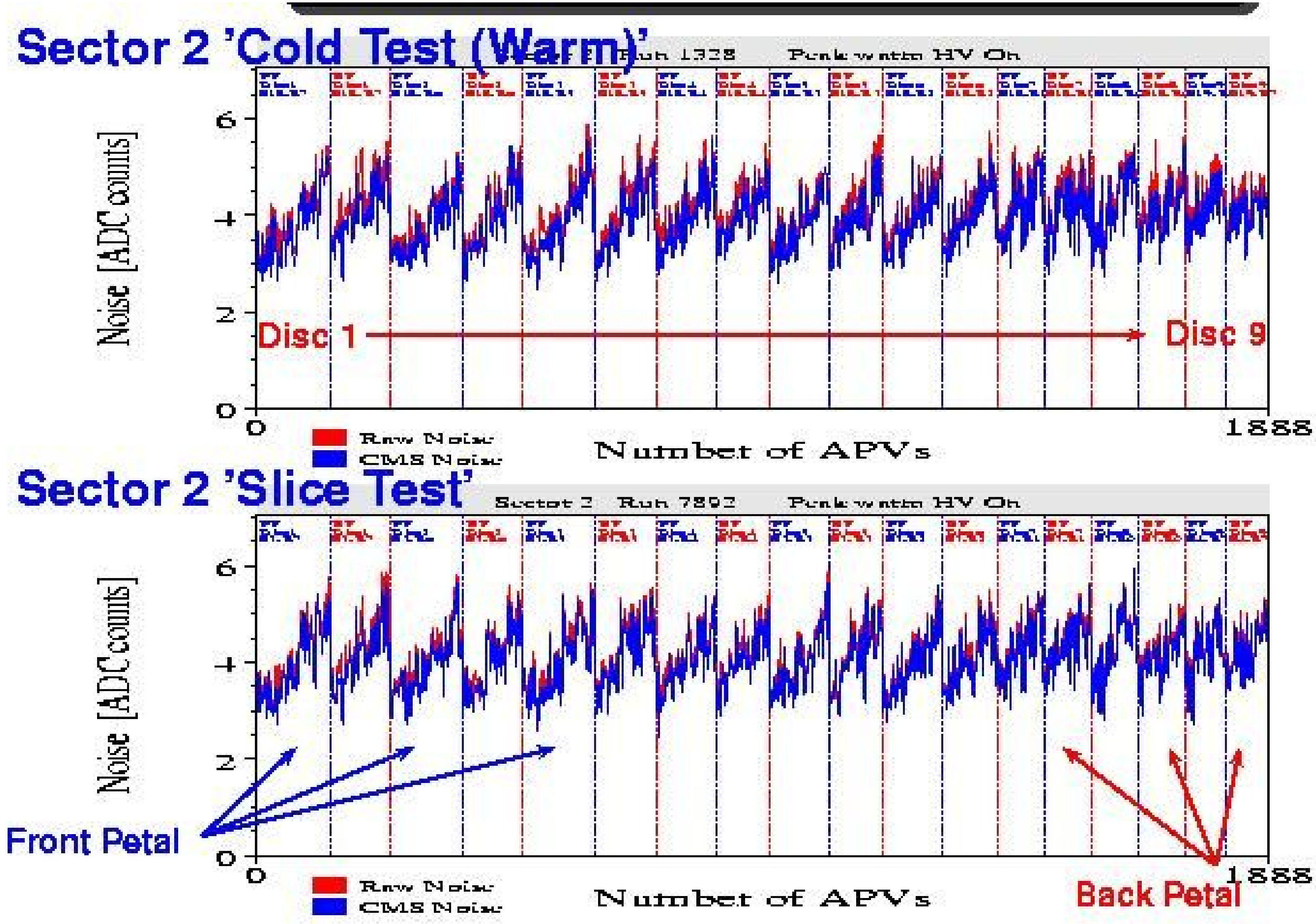
Summary of the numbers of defectives channels

Structure	Channels	Dead/noisy strips	Defects	Total bad strips	Dead/noisy strips	Defects	Total bad strips
		TEC+			TEC-		
Sector 1	241664	278	1 module with I^2C problem	1046 (0.43%)	512	-	512 (0.21%)
Sector 2	241664	284	-	284 (0.12%)	591	-	591 (0.24%)
Sector 3	241664	234	2 bad APVs	490 (0.20%)	680	1 dead fiber	936 (0.39%)
Sector 4	241664	305	1 dead fiber	561 (0.23%)	304	1 bad APV 1 dead fiber	688 (0.28%)
Sector 5	241664	276	1 module with I^2C problem 2 modules without HV	1812 (0.75%)	725	-	725 (0.30%)
Sector 6	241664	373	1 bad APV	501 (0.21%)	604	-	604 (0.25%)
Sector 7	241664	391	1 dead fiber 1 bad APV	775 (0.32%)	345	-	345 (0.14%)
Sector 8	241664	296	-	296 (0.12%)	360	2 dead fibers	872 (0.36%)
All sectors	1933312	2437		5765 (0.30%)	4121		5273 (0.27%)

Insertion of the TEC- inside the tracker tube

A slice of the tracker containing approximately 10% of readout channels has been operated to test system performance, and was commissioned using cosmic triggers.

TEC+ Noise Comparison inside-->outside TST



Conclusion and outlook

- **Excellent performance of TEC petals during integration**
- **It was a rocky way: many problems identified, investigated and solved**
- **TECs are now in the tracker tube, noise performances unchanged, laser alignment, cosmic data analysis in progress**
- **Transportation of the tracker to P5 (CMS cavern) expected in September**