The Construction of the CMS Silicon Tracker Inner Barrel and Disks

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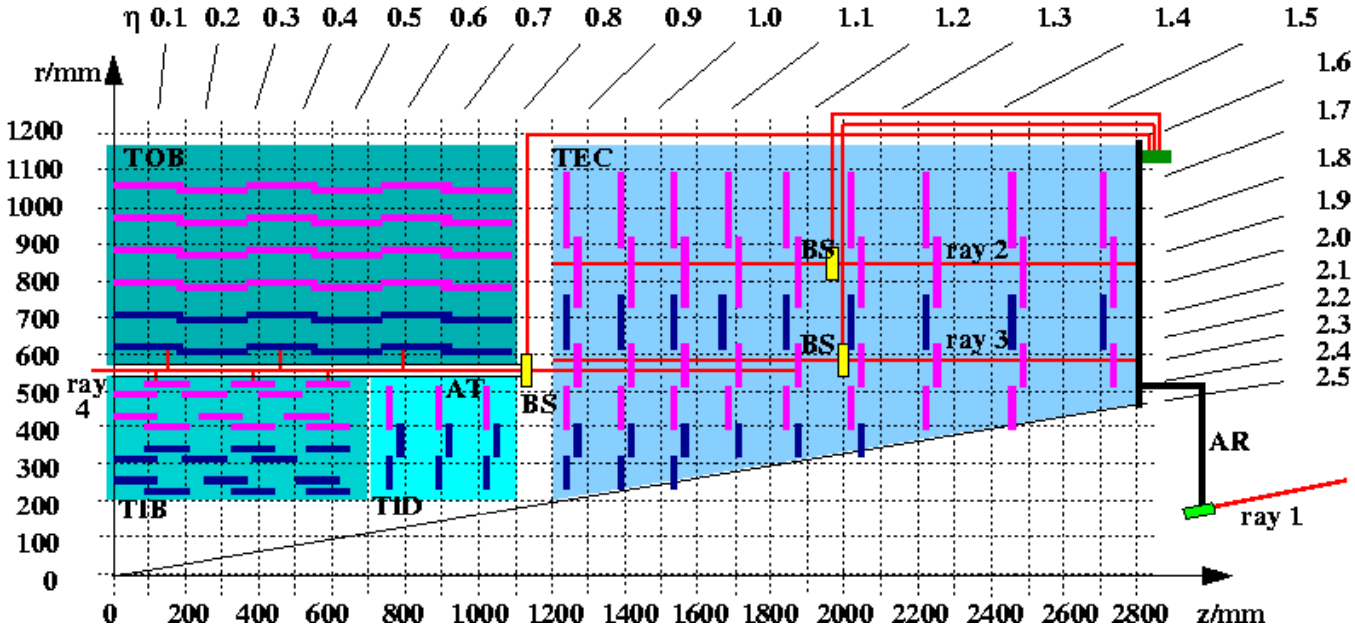
on behalf of:
CMS SiTracker Collaboration and INFN TIB/TID Consortium

CMS SiStrip Tracker

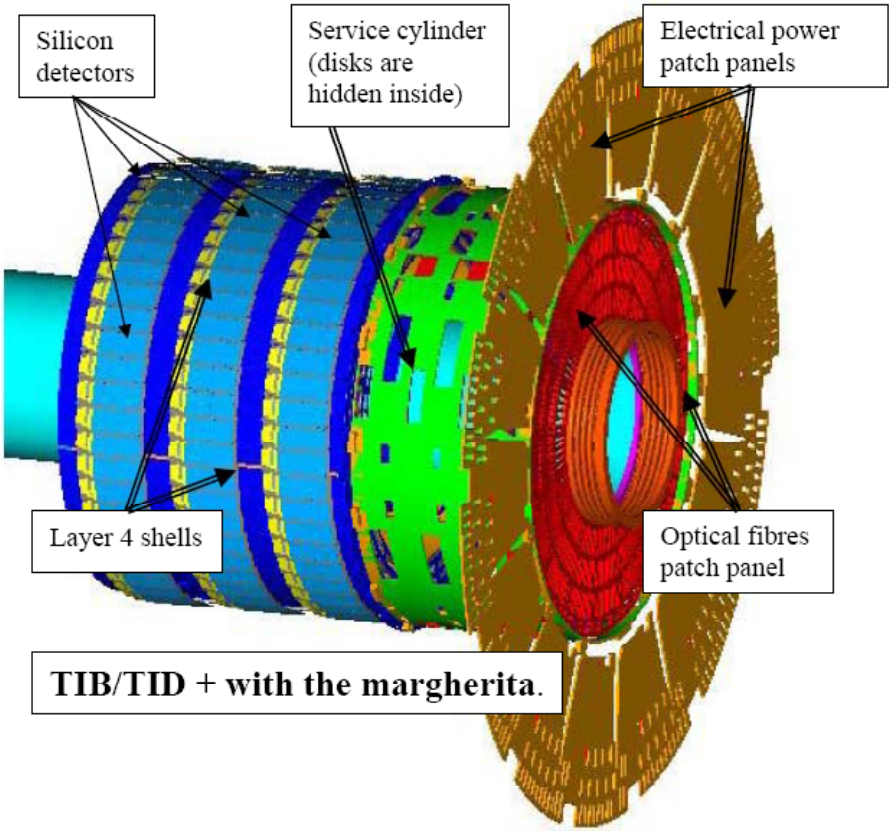
- Charged track reconstruction in LHC collisions:
  - 40 MHz collisions
    - ~1000 particles/xing (high lum.)
- Pixel + SiStrip
  - B = 4 Tesla
  - $T_{cooling}$ ~ -10 / -25 C
  - Resolution: $\Delta pt/pt$ ~ 1-2% ($\eta<1.6$)
    - i.p.: σ~ 10-100 μm
  - Tracking efficiency: ε~99% (μ)
    - ~90% hadrons

- SiStrip Tracker
  - ~9M strips
    - pitch: 80μm – 200 μm
    - length: 85 mm – 200 mm
  - surface 198 m2
    - 15148 modules
      - many with two sensors (~24k)
  - ~10 hits per track (~4 3D hits)
    - occupancy ~1-2% (high lum.)



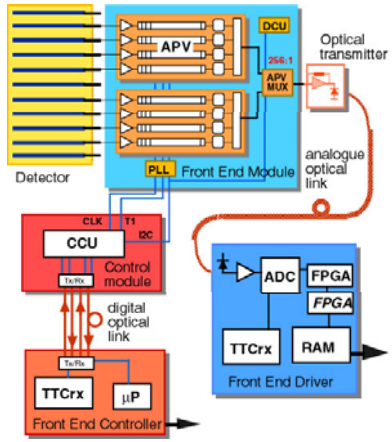
CMS TK Inner Barrel and Disks

- Two symmetric parts:
  - forward and backward
- Barrel: 4 layers
  - two layers 3D
  - radii: 200 to 550 mm
- Disks: 3 disks with 3 rings
  - two rings 3D
  - 750 to 1050 mm from IP
- Channels:
  - 3540 modules
    - 320 μm thick, 80-120 μm pitch
  - 2353152 strips
  - power: ~13 kW
    - >50% from modules
- Build by INFN Consortium:
  - Bari, Catania, Firenze, Padova, Perugia, Pisa and Torino

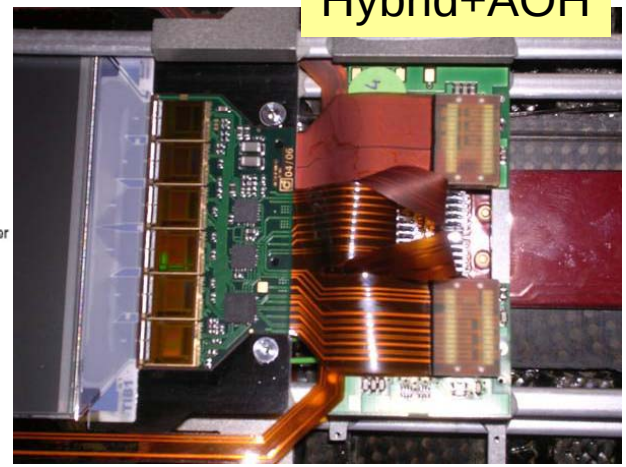


System Components

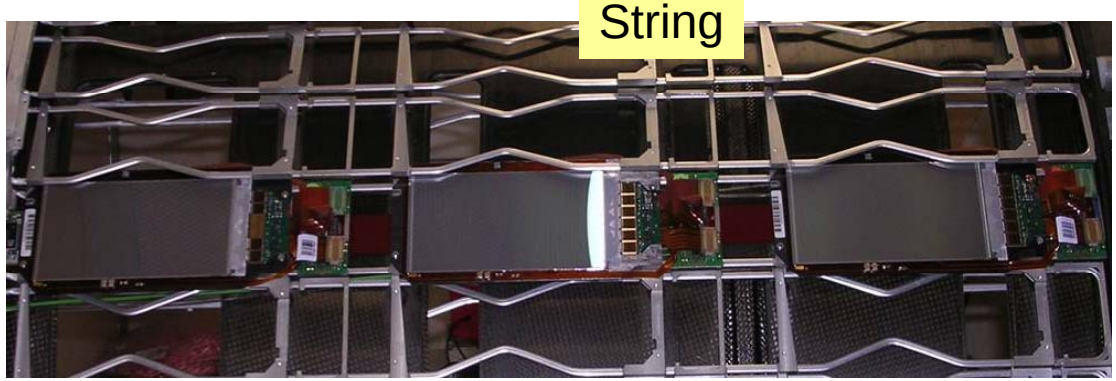
- Module
  - Sensor + FE Hybrid
    - chip: APV25 (128 strips) - analog
- Optical converter (AOH)
  - one laser/fiber = 256 strips
- Controls/Clock/Trigger
  - Control chip (CCU)
    - I2C protocol with modules
    - rings of CCUs
  - Digital optical converted (DOH)
    - optical link to VME controller (FEC)



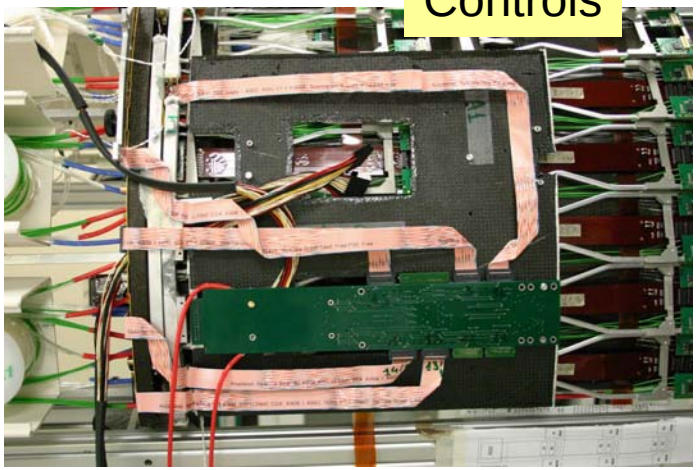
Hybrid+AOH



String

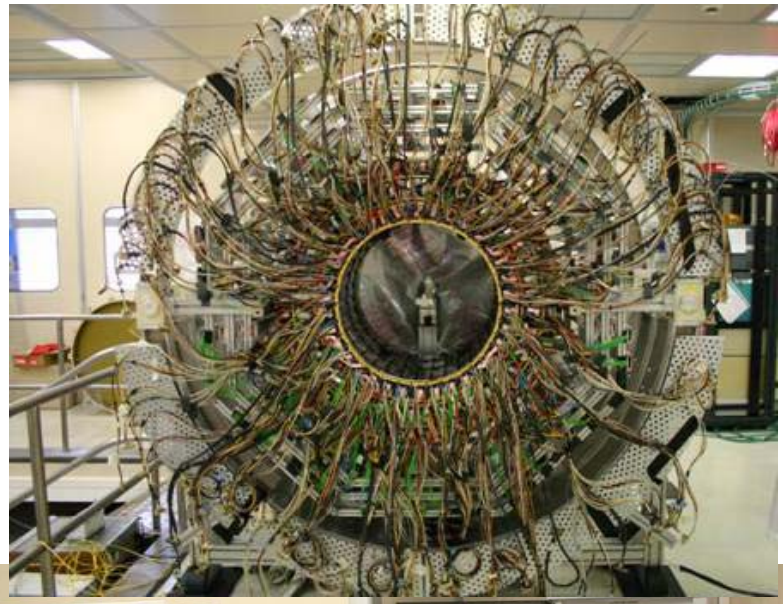


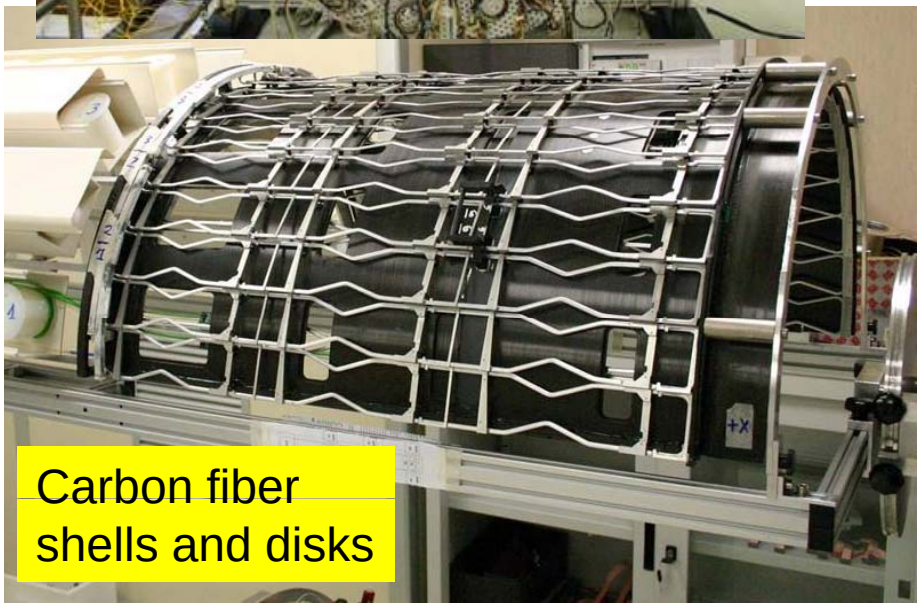
Controls



System Components (II)

- Power
  - LV: 2.5V – 1.25V
    - one channel: ~ 6-12 modules
  - HV: ~400 V
    - one channel: ~3 modules
- Cooling
  - Aluminum pipes/ledges
    - 300μm thick walls
  - C6F14
  - T ~ -25 C
    - keep sensor T < 0 C
- Statistics:
  - 9192 (analog) + 960 (dig.) fibers
  - 608 LV/HV channels/cables
  - 148 cooling manifolds
  - 120 Control Rings



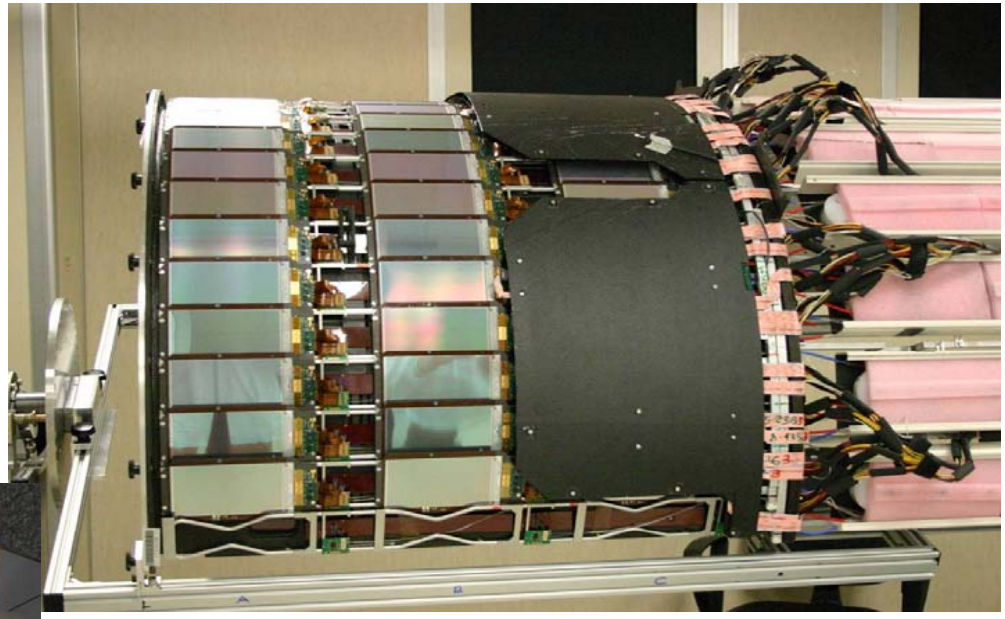


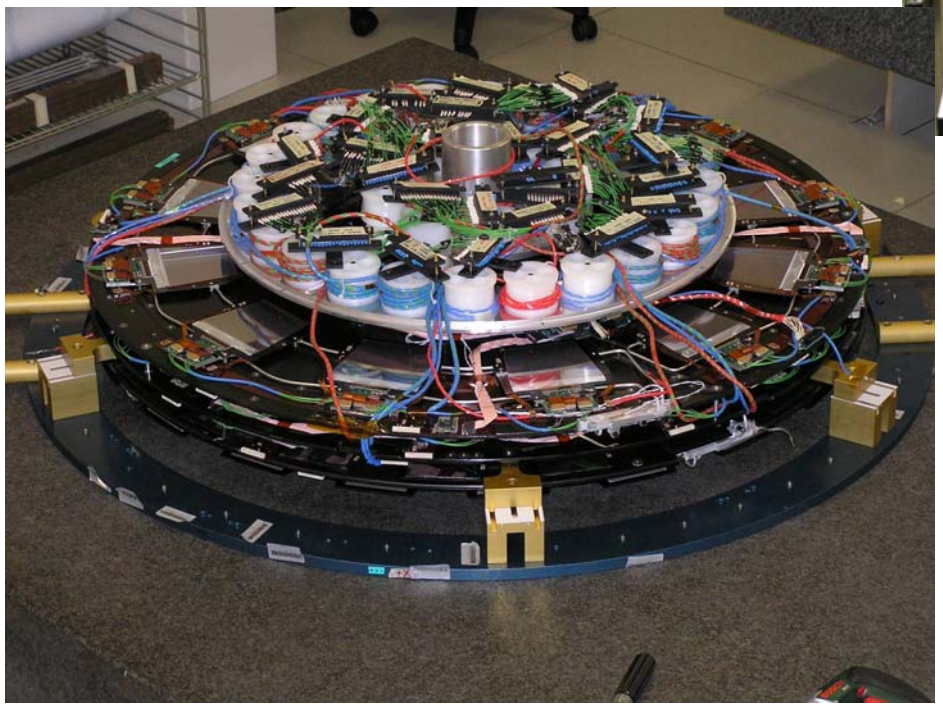
Last (two?) year(s) activities

- Two halves integrated and assembled in sequence with some overlap to optimize the schedule:
  - Module/AOH integration on mechanics
    - Forward: Mid 05- Apr 06, Backward: Apr 06 – Aug 06 (10 + 4 months)
  - “Final” complete test: Burn-in
    - Forward: Oct 05 - May 06, Backward: Jun – Sept 06 (8 + 4 months)
  - Assembly
    - Forward: Jun 06, Backward: Sept – Oct 06 (1 + 1 months)
  - Shipping to CERN
    - Forward: June 06, Backward: October 06
  - Reception and Services “dressing”
    - Forward: Jun - Oct 06, Backward: Nov 06 - Jan 07 (4 + 3 months)
  - Insertion in CMS Tracker and Final external connections
    - Forward: Dec 06, Backward: Feb 07
  - (Part of) CMS Tracker Cosmic run
    - Feb - Jun 07

SubStructure integration

- Half layers and Disks shipped to Pisa for final tests after module/AOH integration
  - 10 half layers from Firenze
  - 6 half layers from Pisa
  - 6 disks from Torino

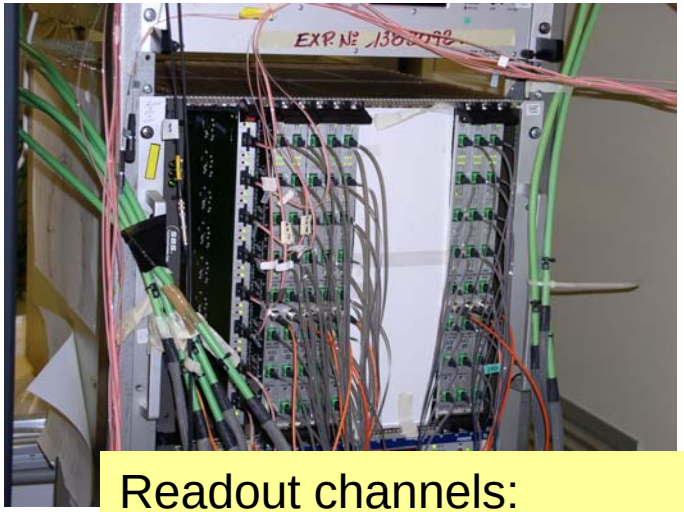




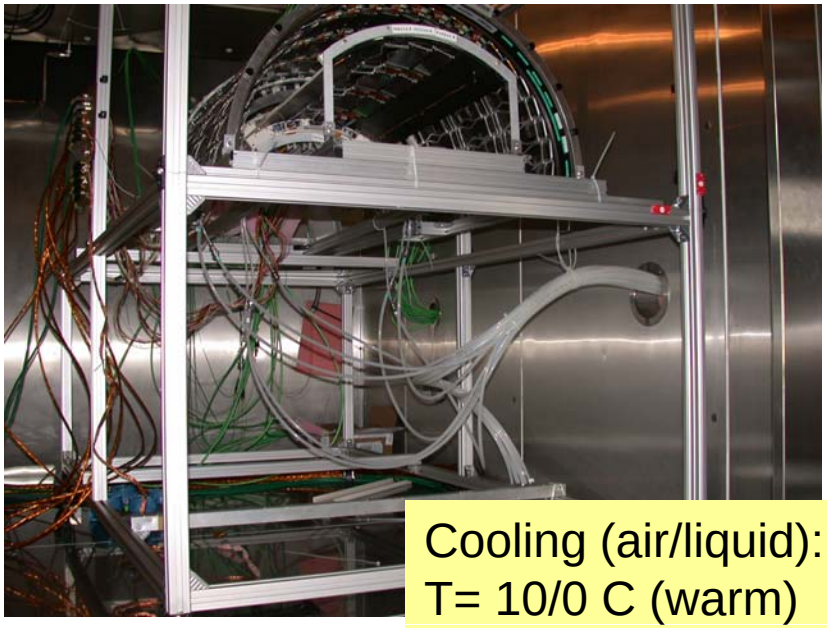
- Each component tested individually before and during assembly

Sub-Structures burn-in

- Test of (part of) the final components on the final structure
  - electrical/optical performances
  - cooling performances
  - noise performance: grounding scheme



Readout channels:
max ~200 modules: half layer

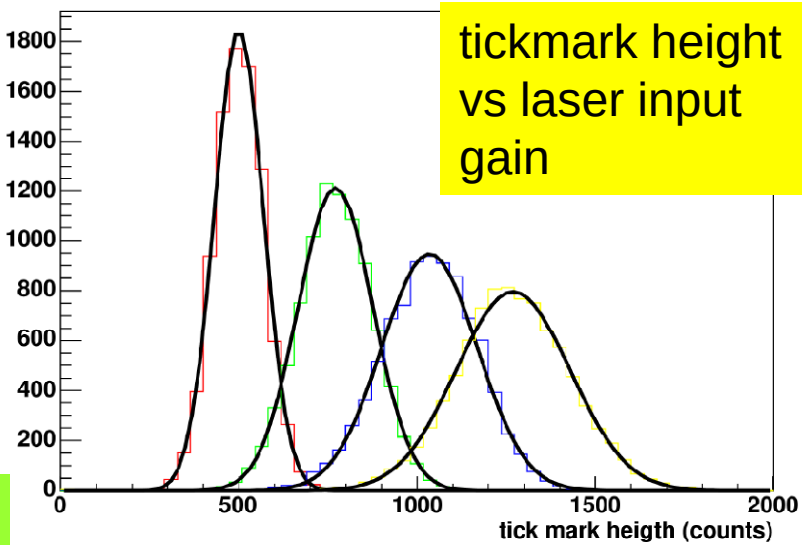


Cooling (air/liquid):
T= 10/0 C (warm)
T= -10/-25 C (cold)

“Final” optical fanout and cables
but not “The Final” ones !
To be installed after full assembly

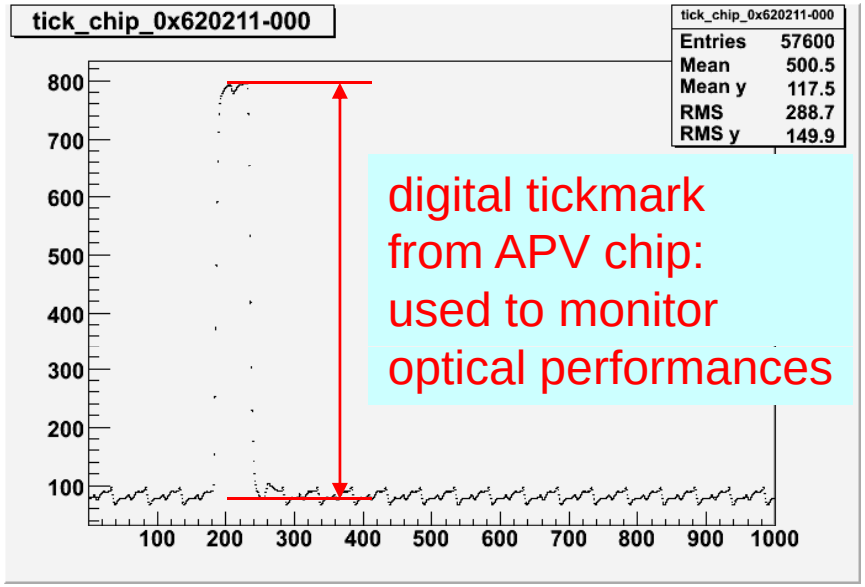
Burn-in Measurements

- "Commissioning" runs
  - chip parameter setting
  - ⇒ electrical / I2C / optical performances
- Pedestal/Noise run (HV bias 400 V)
  - "Peak" and "Deconvolution" APV25 mode
- Temperature measurements



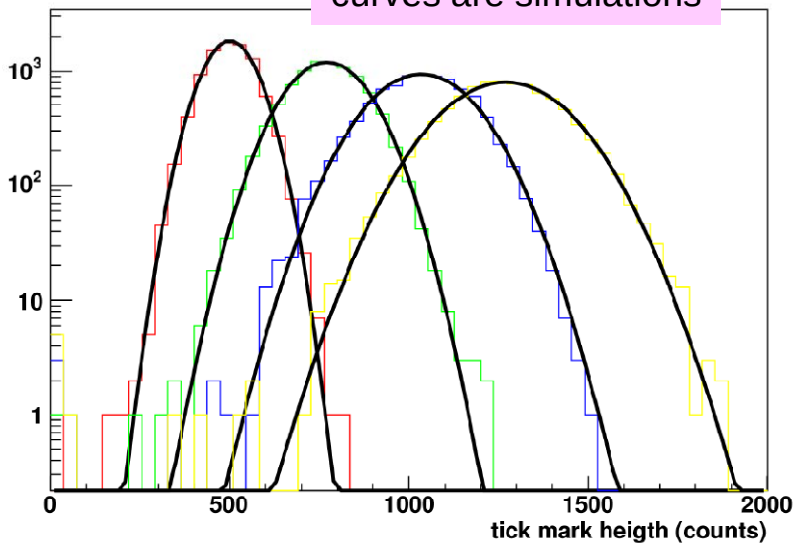
tickmark height vs laser input gain

Optical performances



digital tickmark from APV chip: used to monitor optical performances

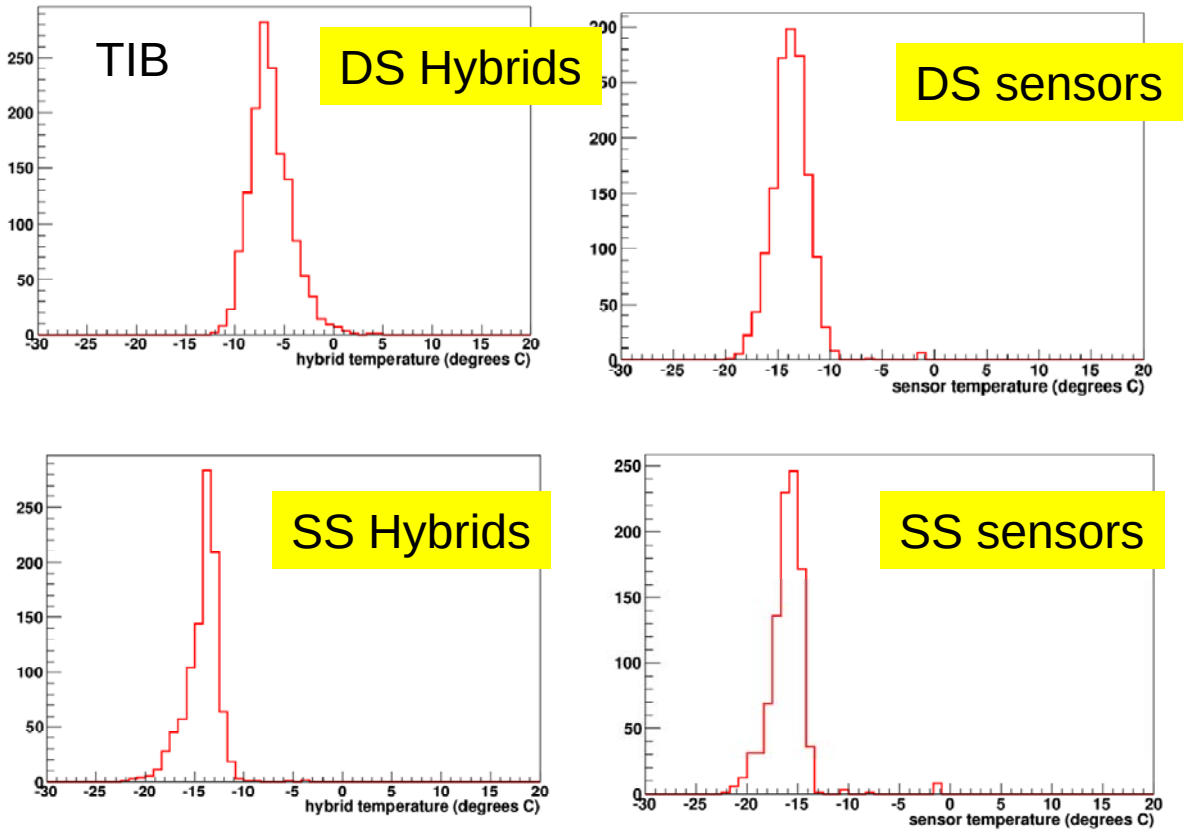
curves are simulations



Thermal/cooling performances

- Hybrid and Sensors temperatures from chip on modules (DCU)
  - Different air and liquid temperature settings to separate the effects
  - Two poor cooling loops detected: one has to be replaced

T_{liq} = -25 C T_{air} = -10 C



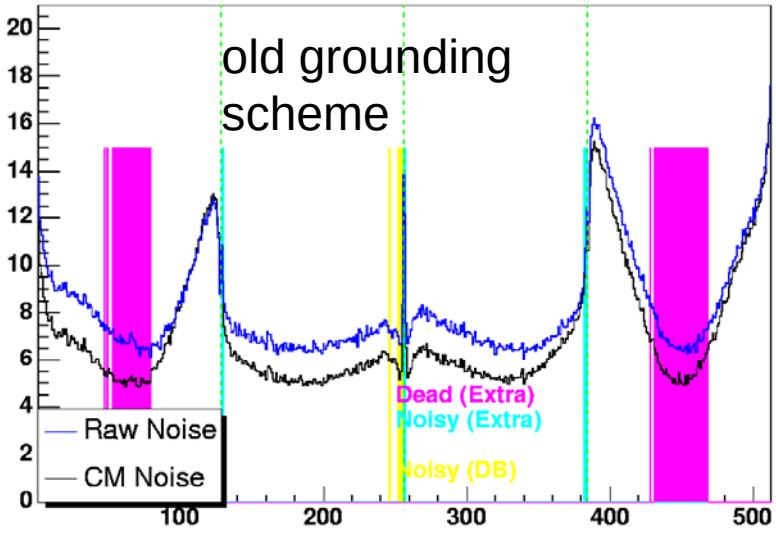
Double sided modules:
6*2 chips
Hybrids ~ -5 C
Sensors ~ -14 C

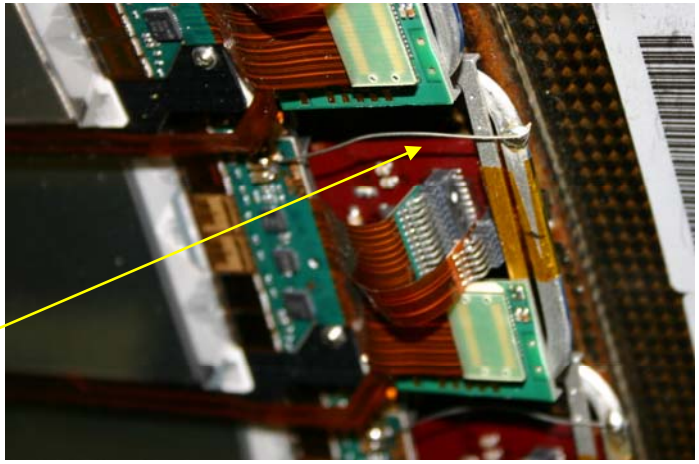
no heating from leakage current

Single sided modules:
4 chips
Hybrids ~ -13 C
Sensors ~ -16 C

Grounding scheme studies

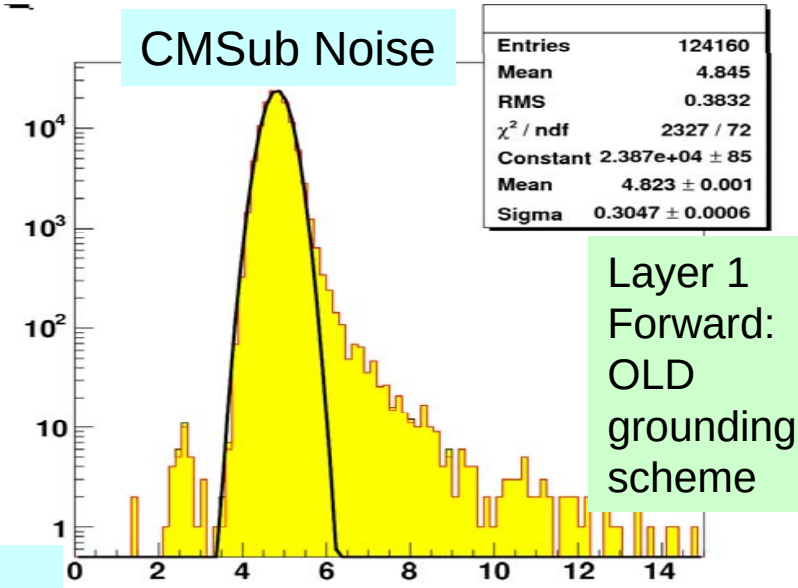
- Noise tails carefully investigated
- Pick-up from control lines found
- Grounding scheme modified to reduce it





New Ground connection

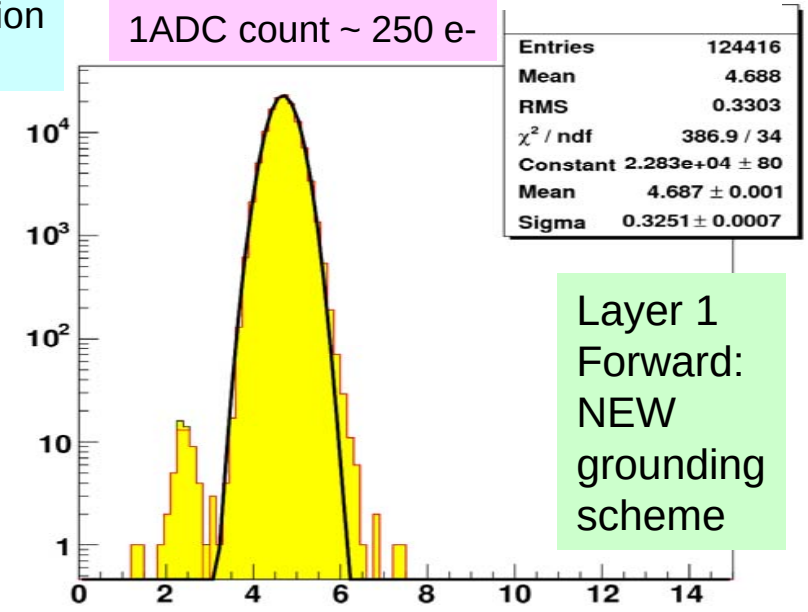
CMSub Noise



Layer 1 Forward: OLD grounding scheme

APV25: Deconvolution mode

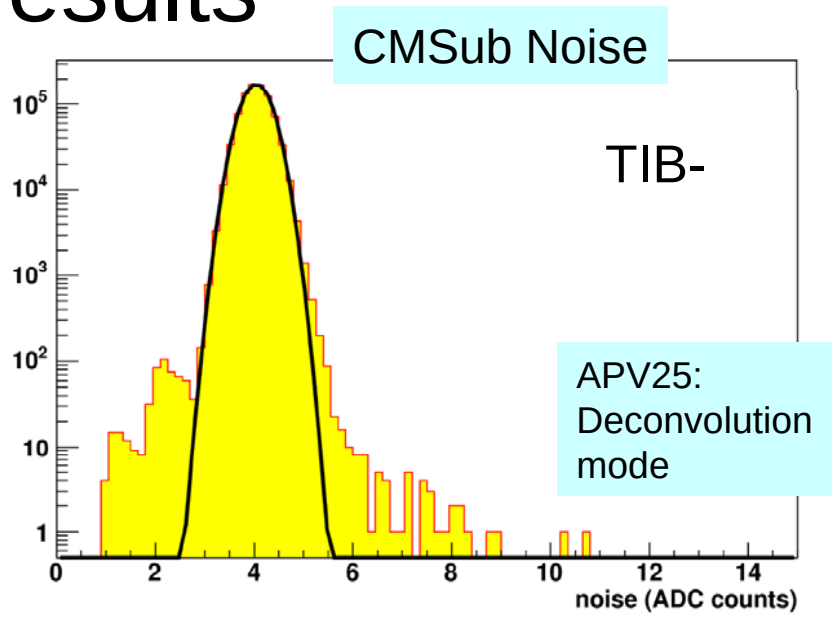
1ADC count ~ 250 e-

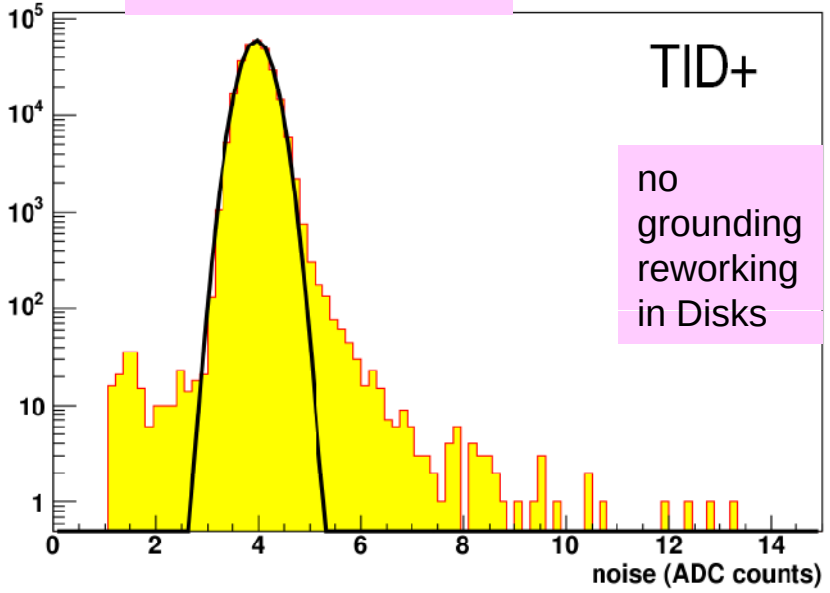


Layer 1 Forward: NEW grounding scheme

Burn-in results

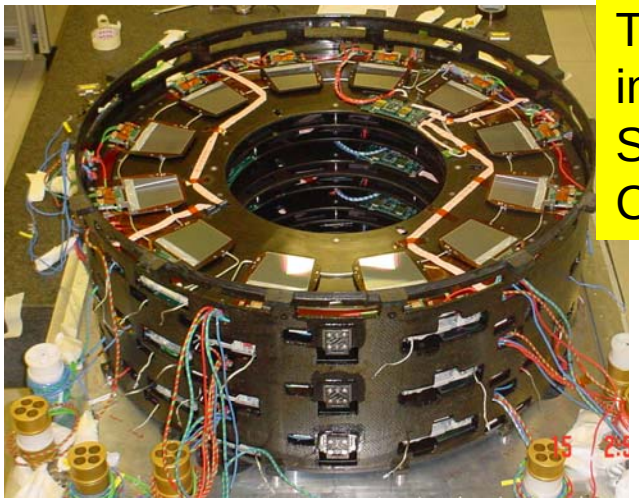
- Full Detector Performance map
- Improved understanding of “features” (and workarounds)
- Improved grounding scheme
- Bad component replacements:
  - Last Chance !!
  - one cooling loop
  - few modules, AOHs, electrical buses
- Bad channels status:
  - no broken component
  - Strips:
    - dead: < 0.1 %
    - “noisy”: < 0.1 %
- But...still a long way to do before assembly completion !!
  - with limited testing capability





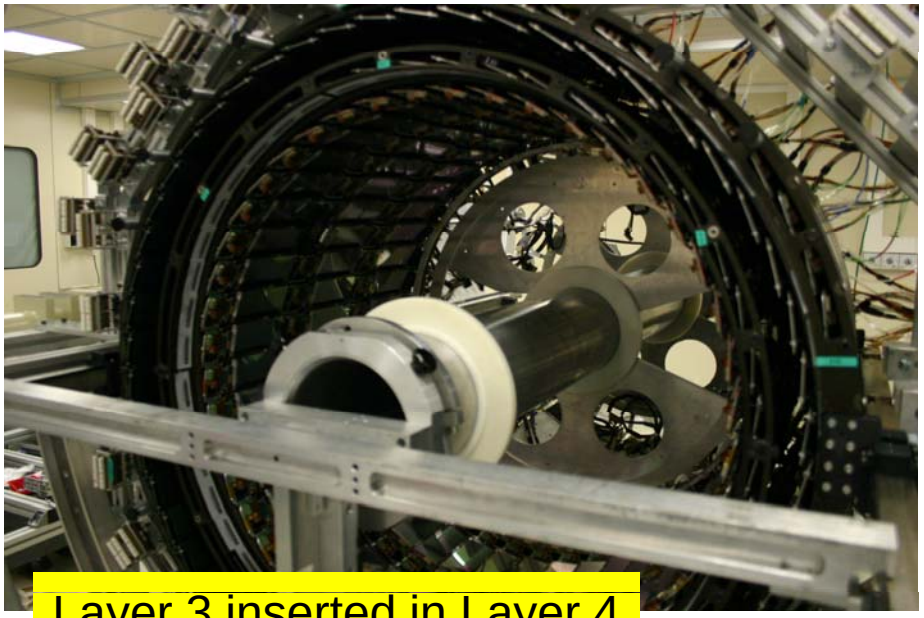
Structure Assembly

- Layers and Disks Assembly
  - each half separately
- Cables, fibers and pipes routing
  - components and connections less and less accessible
  - (only) LV electrical tests at each step

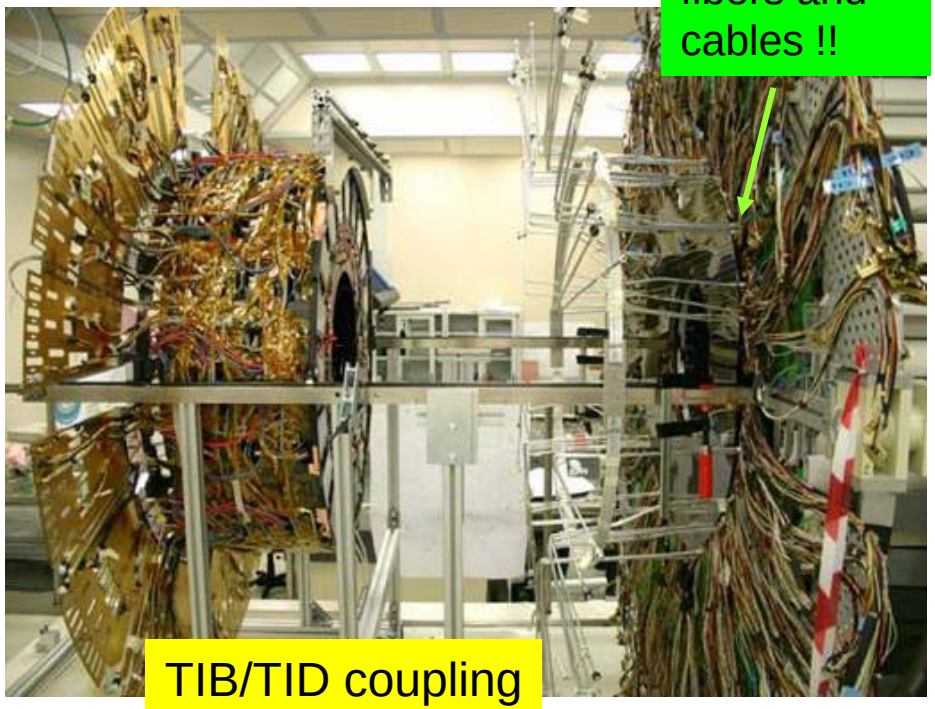


TID disks in the Service Cylinder

20 mm thick envelope for all TIB fibers and cables !!



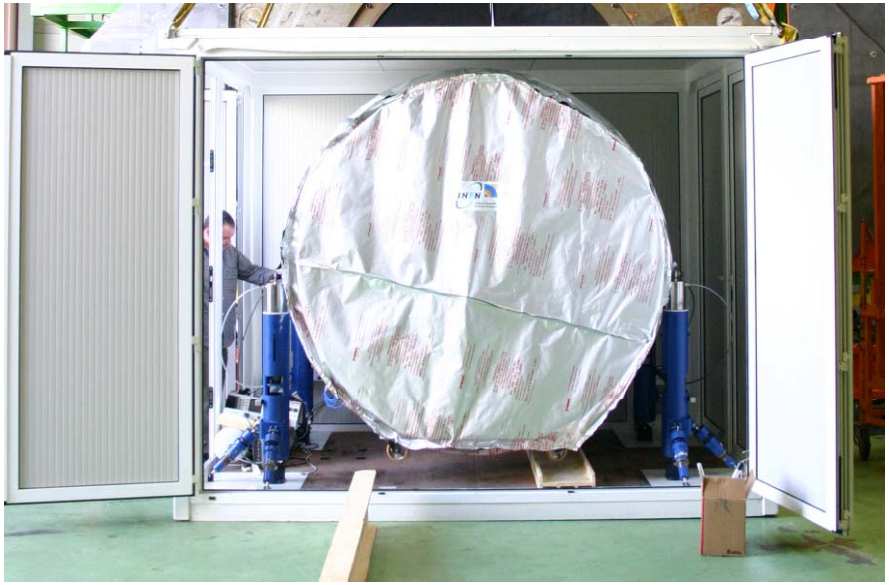
Layer 3 inserted in Layer 4

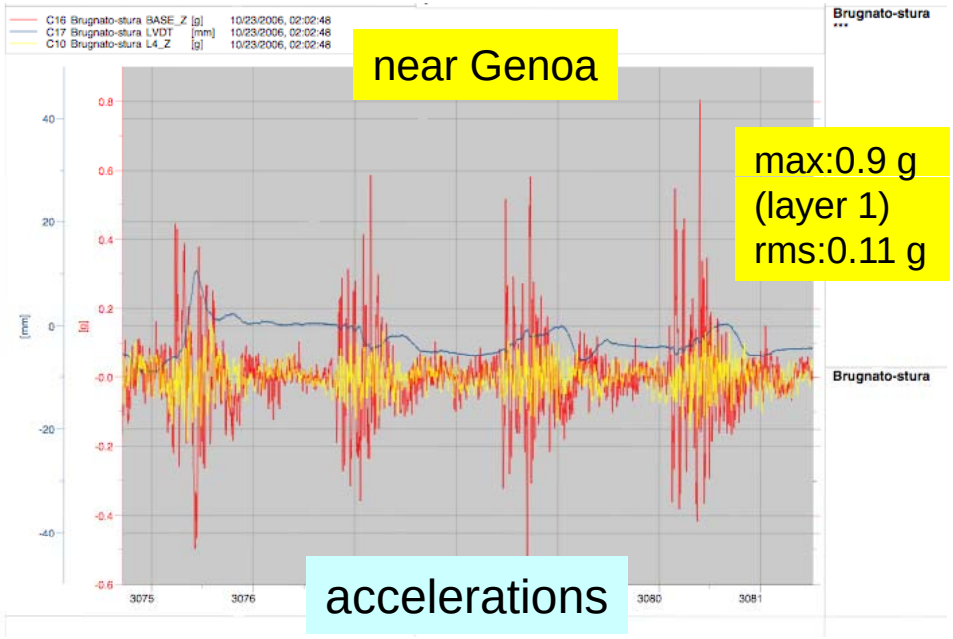


TIB/TID coupling

Shipping to CERN

- Support “cradle” on a dumping system in a box loaded on a truck
  - online acceleration monitoring
    - WIFI connection to a following car
  - low speed: ~12 hours trip
- Eventually no problem

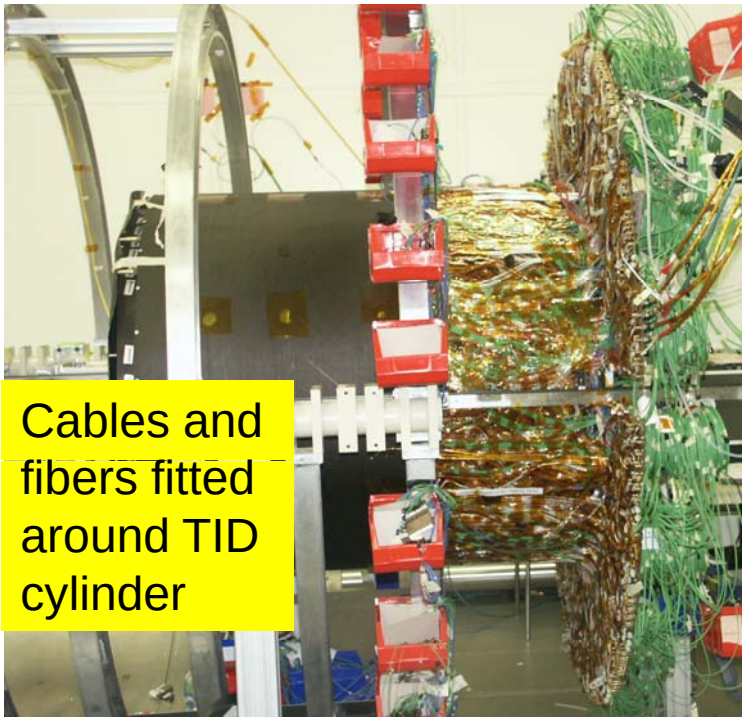




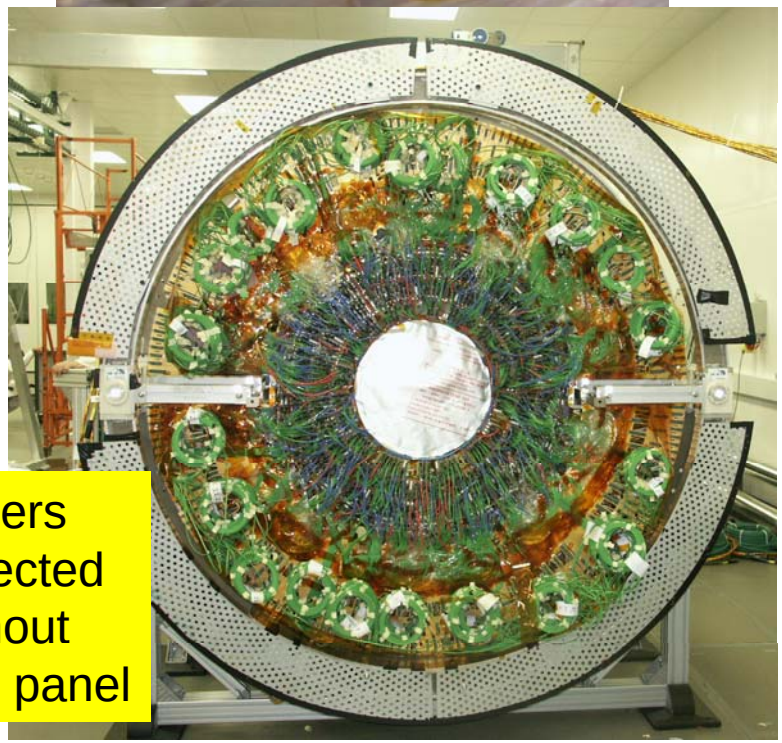
Service routing: fitting the envelope

- Routing cables, fibers and pipes to patch panels
  - fit in a tight envelope (2-3 cm thick)
- Install final 12-fold fibers: “ribbons”
- Final fiber connections
  - ~10.000 fibers/connections

12-fold fibers fanout “ribbon” on patch panel



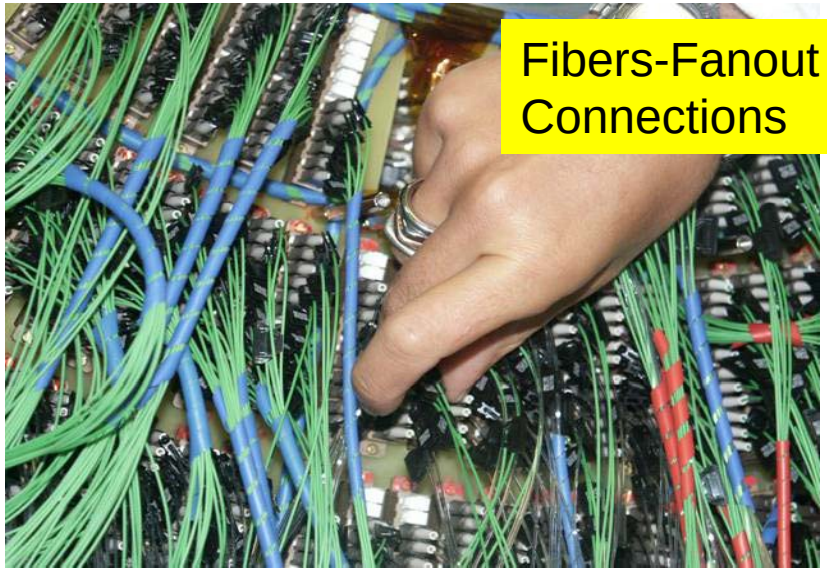
Cables and fibers fitted around TID cylinder

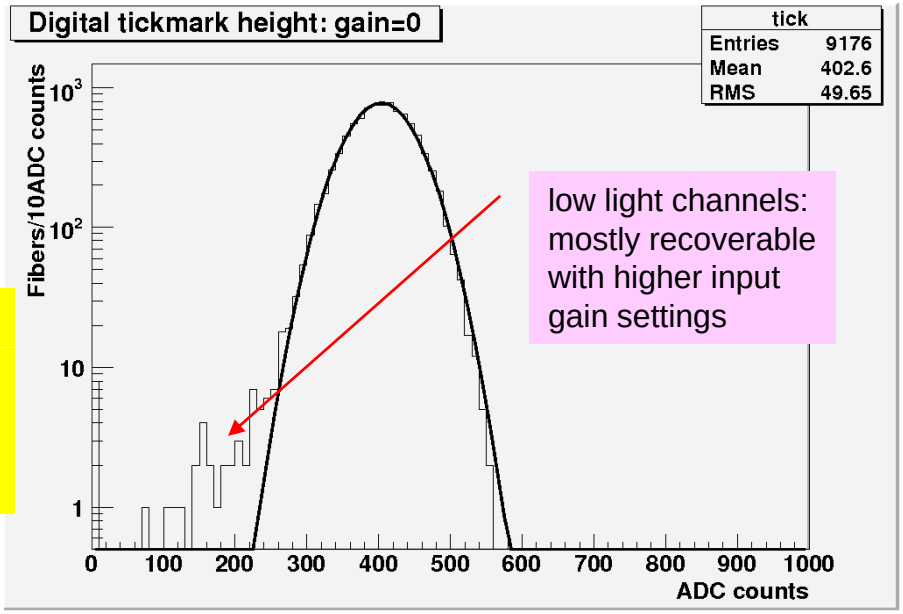


All fibers connected to fanout patch panel

Optical connection checks

- Last chance to clean/fix these connections
- Light yield tested as in burn-in
- Low light/no light channels investigated
  - repaired and/or cleaned if possible
- Statistics:
  - 7 broken fibers (0.08 %)
  - ~20-30 low light (0.3%) (usable)
  - 8 missing modules (no comm.) (0.2%)

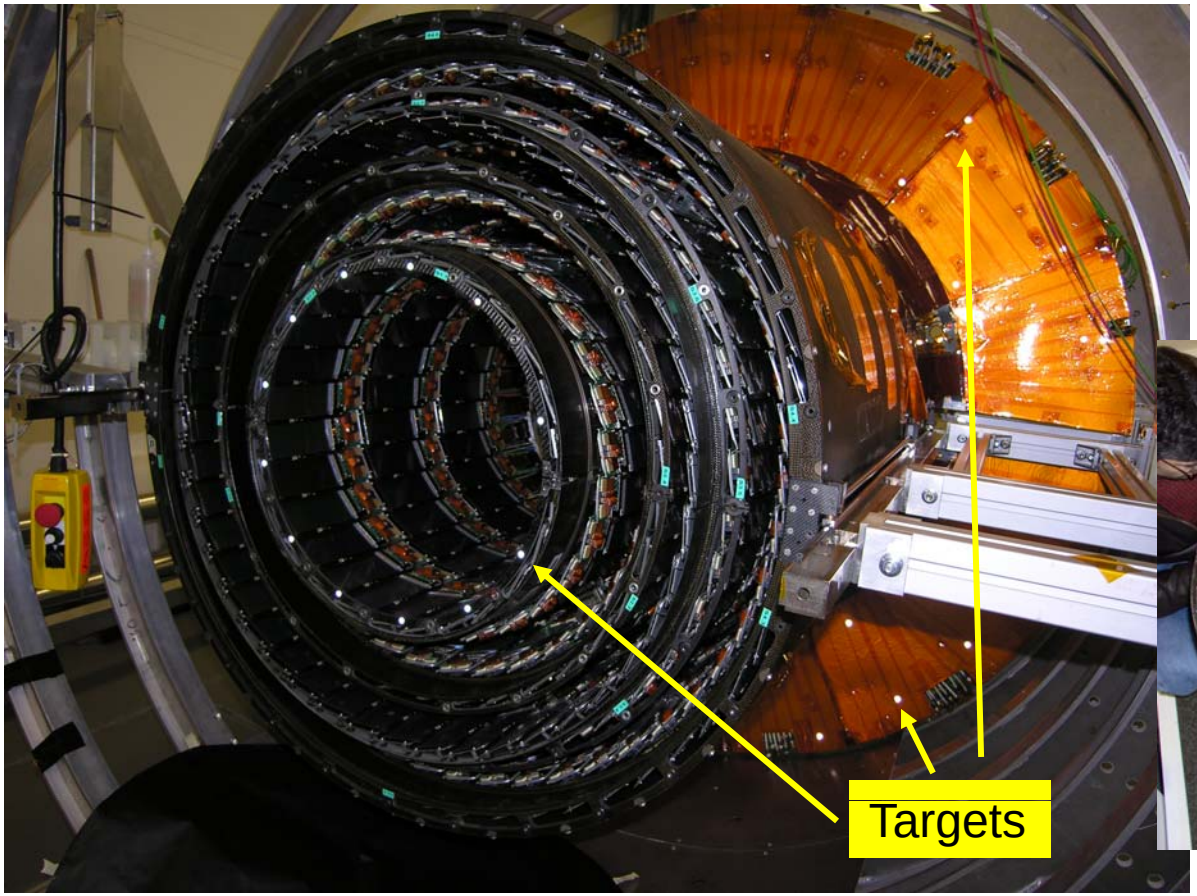




Optical connection estimator: digital tickmark height with fixed laser input gain

Surveys

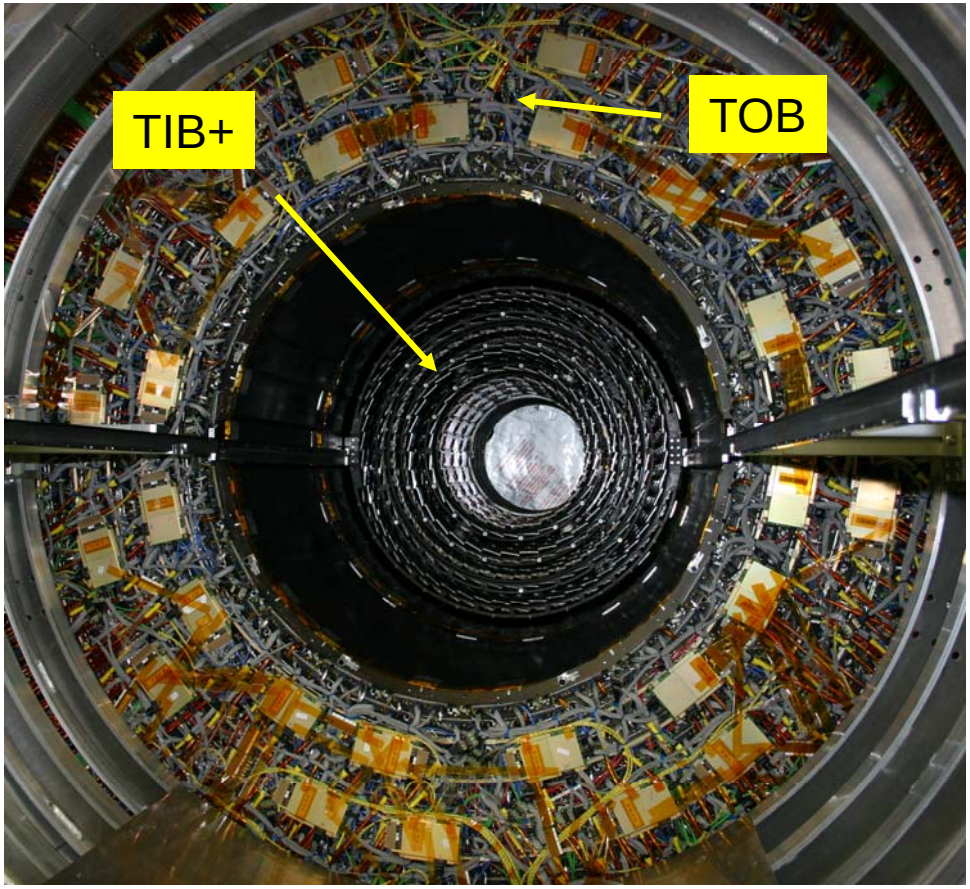
- 3D survey with photogrammetry of the full structure
  - w.r.t. insertion rails
  - envelope check

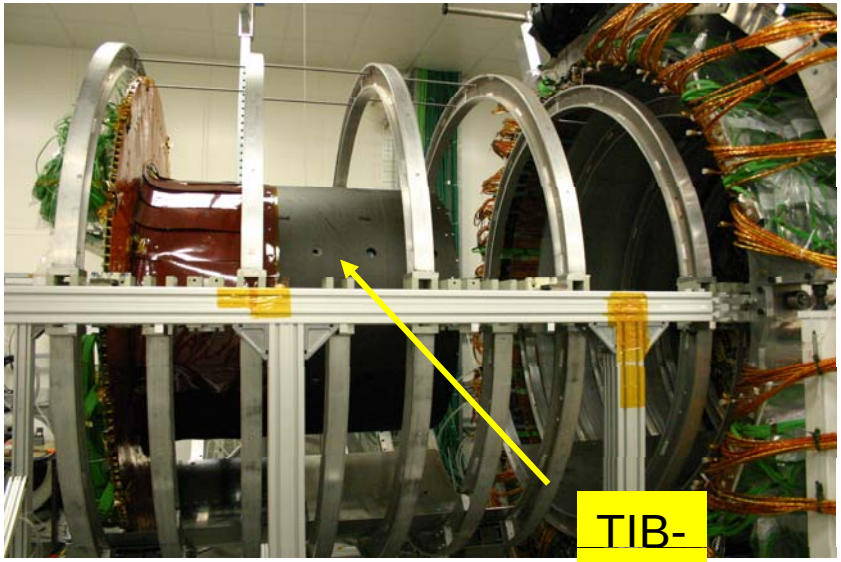


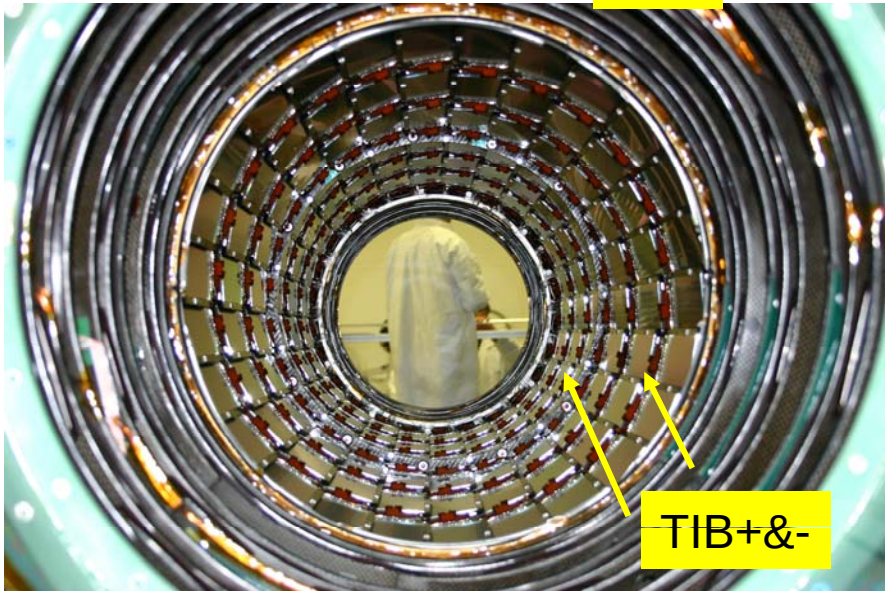
- layers survey to be combined with module fixation (ledges) survey
  - tracking alignment

Insertion in Tracker Support Tube

- TIB+ and TIB- inserted in Outer Barrel (TOB)
  - 1.5 mm overlap at z=0

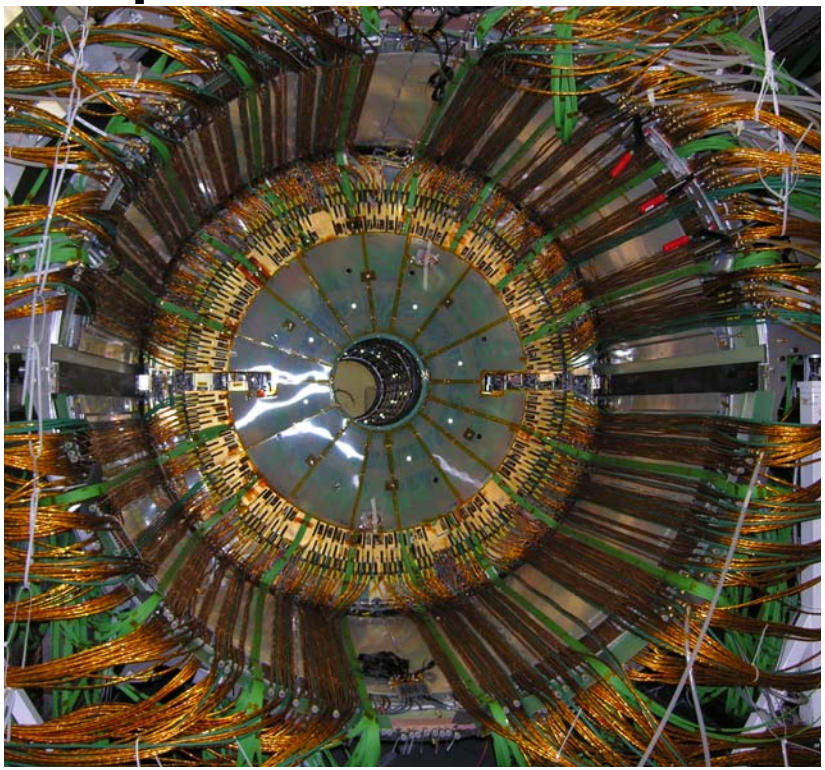


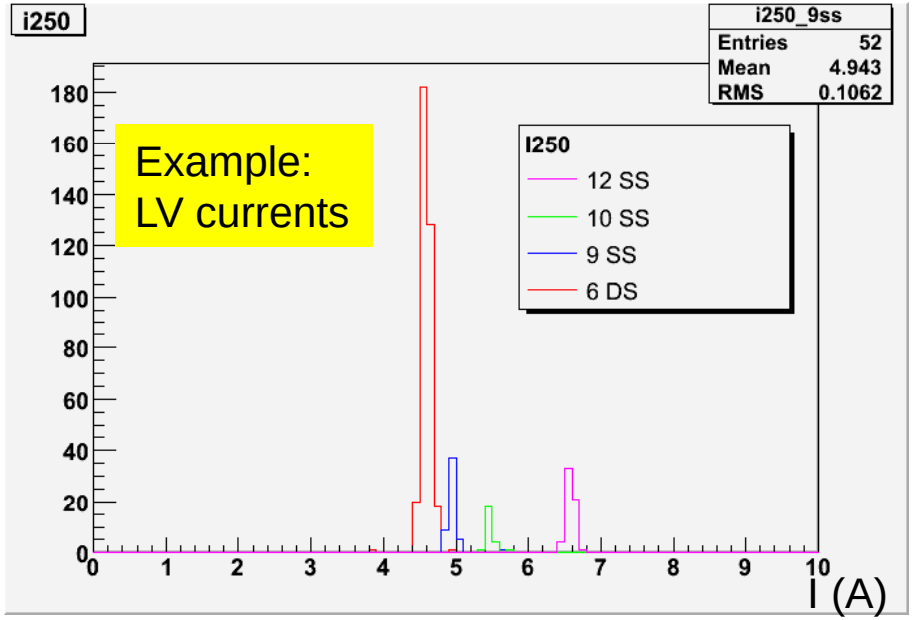


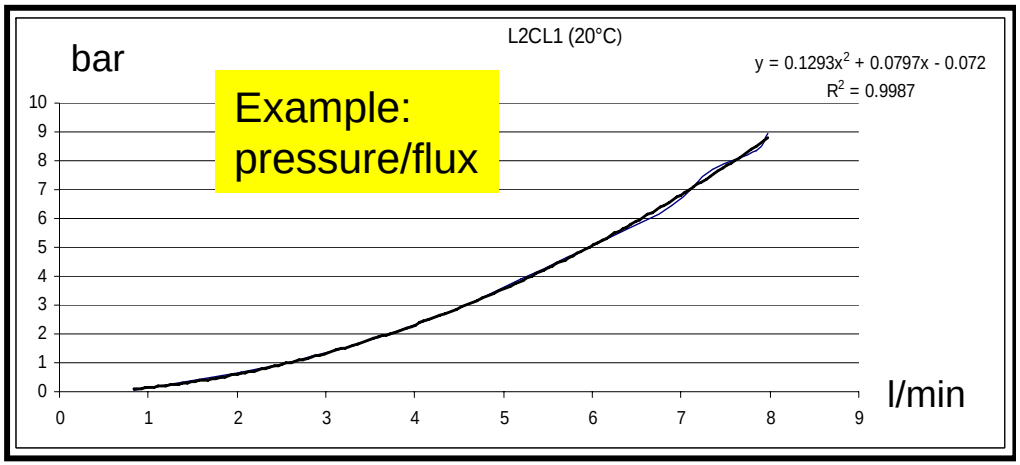


Cables and Pipes

- Electrical and cooling lines extended to the TK boundaries
  - 608 final cables (mostly Al)
  - 144 copper pipes
- Tests
  - pressure test: 12 bar (He)
  - pressure/flux curves
  - LV, HV, temperatures
    - 12 modules (4 channels) with HV bias problems (~0.6%)

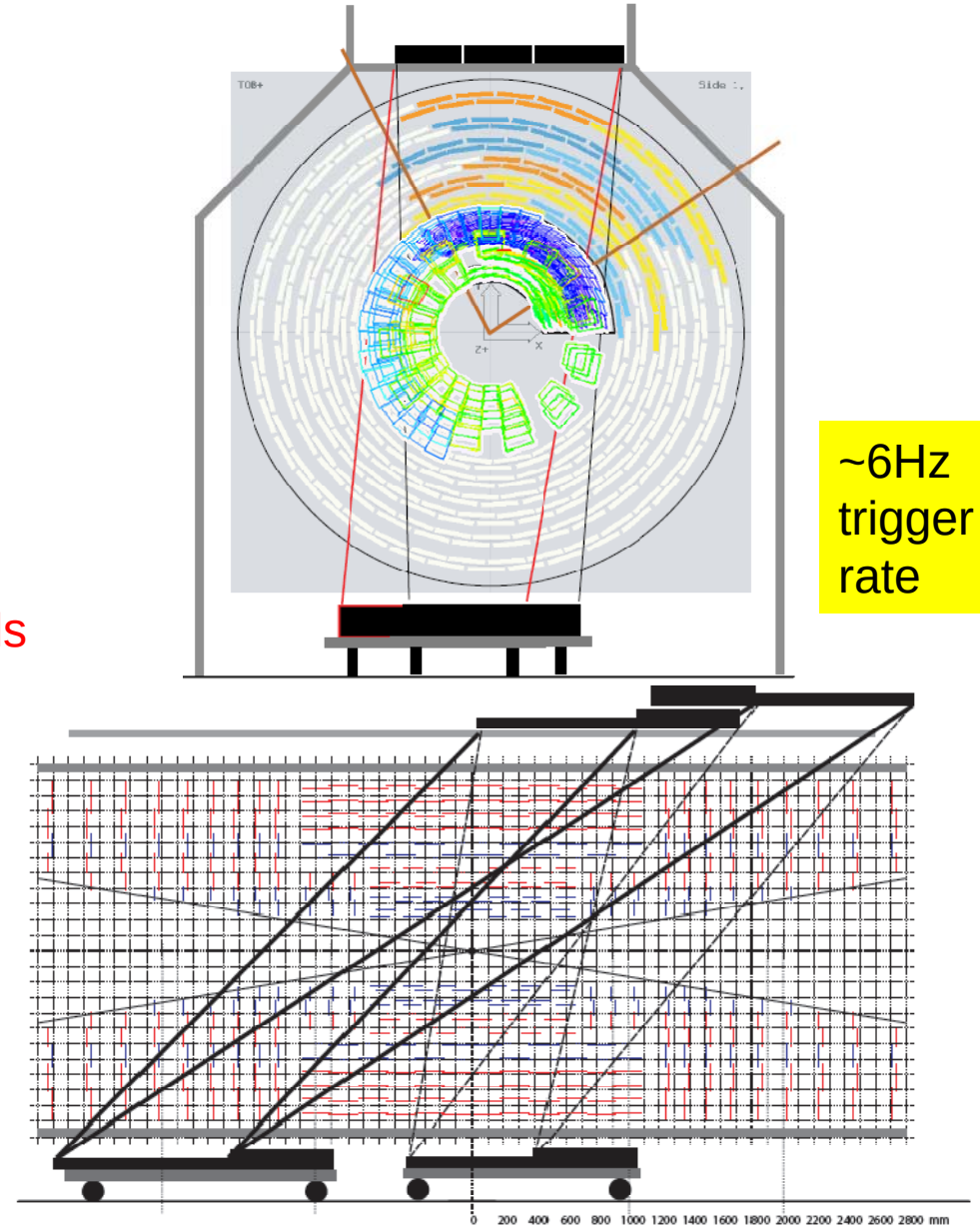






CMS Tracker Sector Test

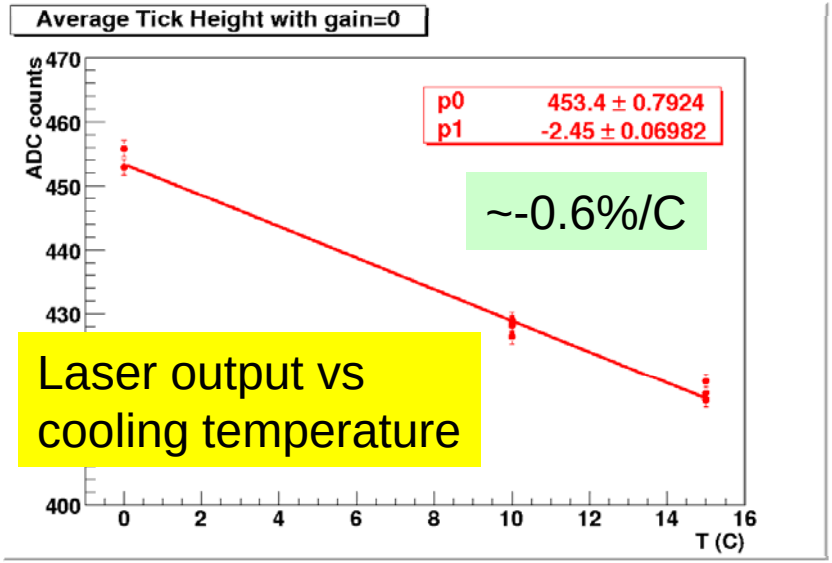
- ~15% full Tracker being tested with a Cosmic trigger
  - since Feb 2007
  - follow P.G. Lenzi's talk
- TIB/TID: 22 control rings, 642 modules (~18%)
  - already tested in Nov06 before insertion with Cosmic trigger
- Results are very preliminary
  - very recent and a lot of channels
- Motivations:
  - noise performance in fully integrated Tracker
  - long(er) term (in)stability
    - work in progress
  - operation at different temperatures
    - 15C, 10C, 0C, -10C
  - Tracking with real data

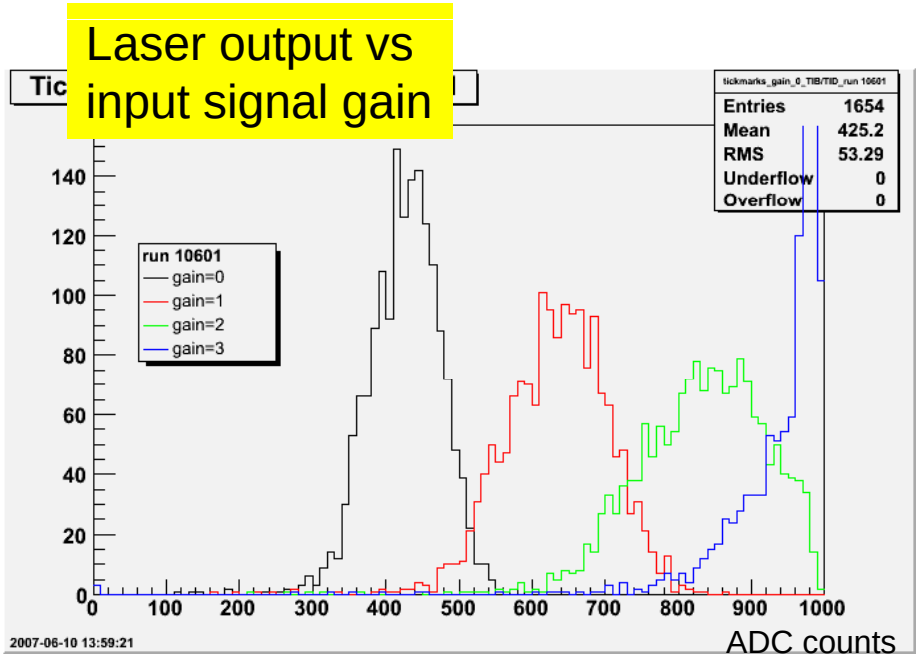


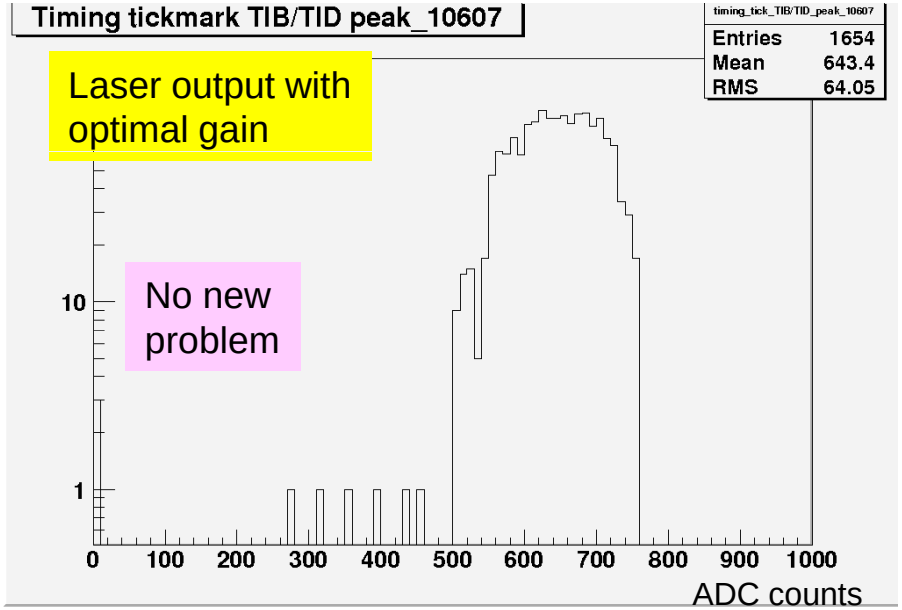
~6Hz trigger rate

Preliminary TIB/TID performances

- Electrical/Optical links
  - stable performances
  - one LV channel successfully patched
- Noise Performance:
  - no degradation in the full Tracker environment: HV bias ~ 290 V

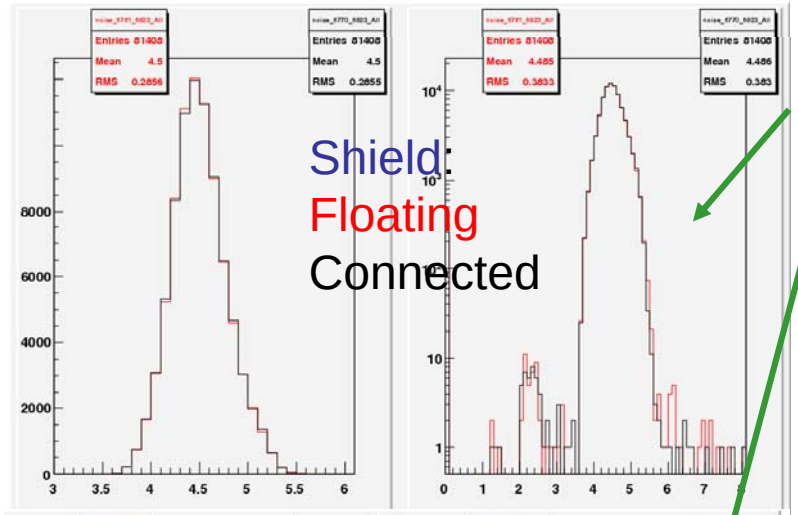


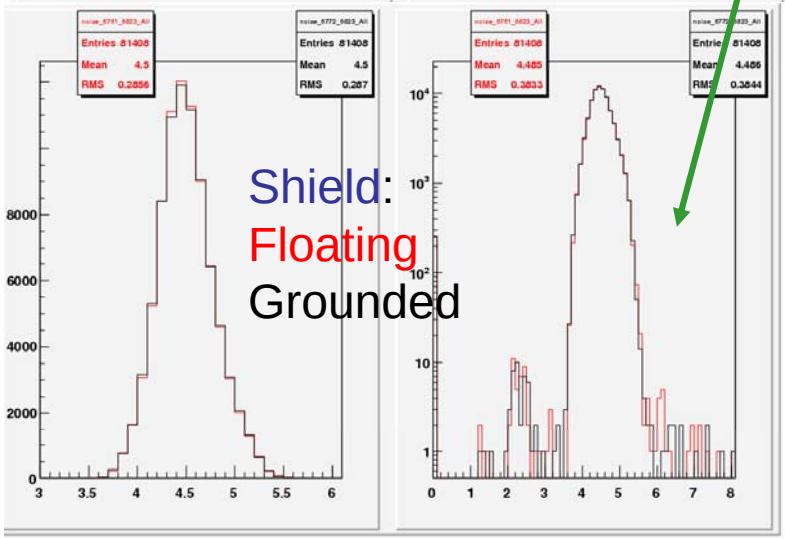




TK Sector Test: TIB/TID noise tests

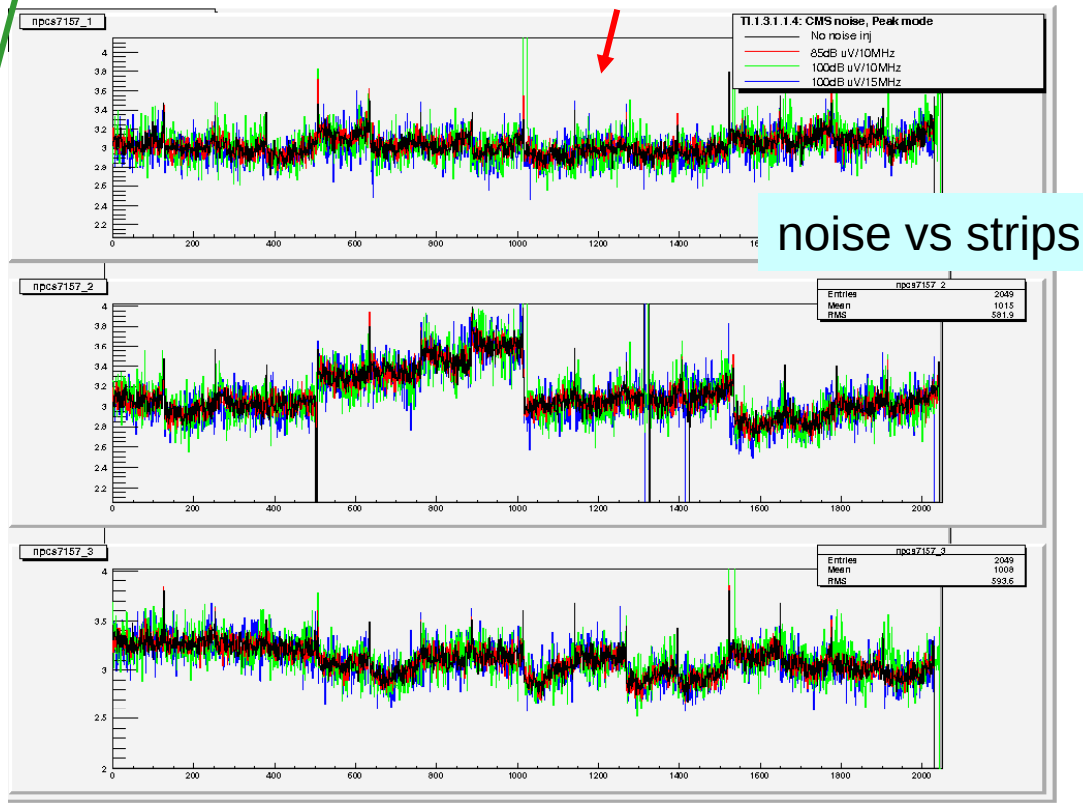
- Noise Performance
  - dedicated tests show small sensitivity to setup changements
- Tests:
  - grounding scheme at patch panel
  - noise injection in power cables





Changes in cable shields connections: NO EFFECT

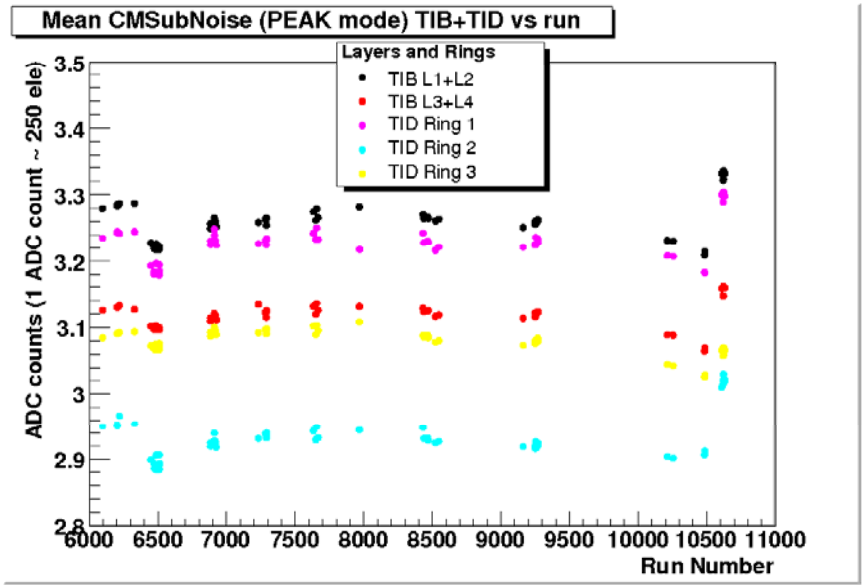
Noise injection:
10-15 MHz
85-100 dBµV (4-20 mA)

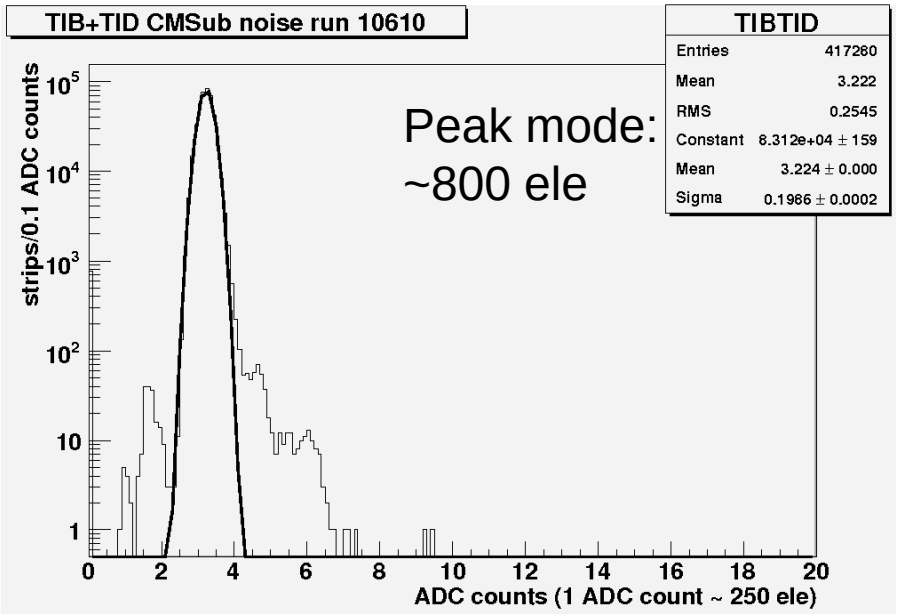


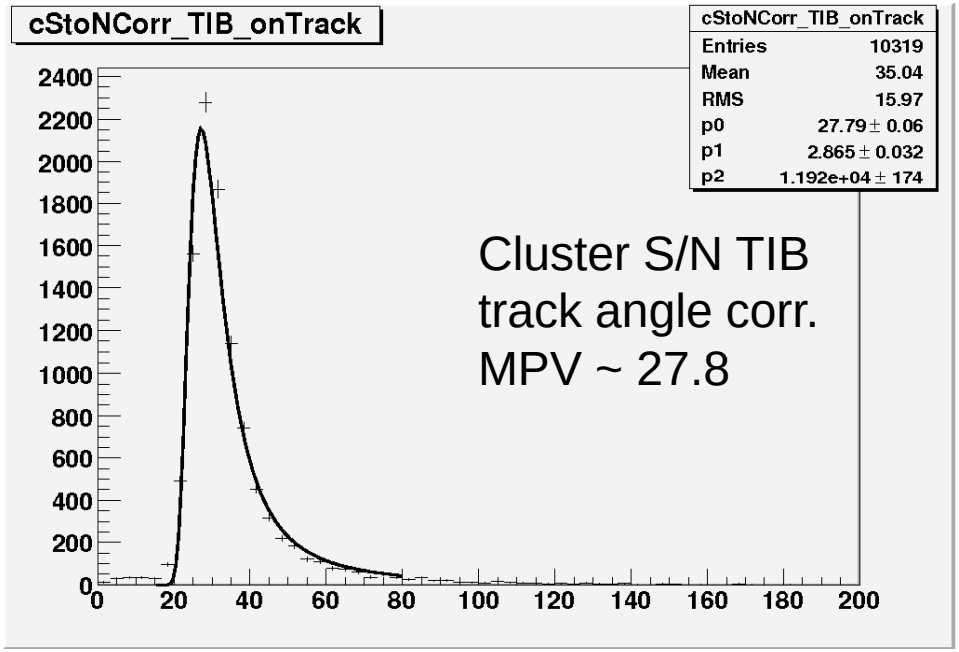
noise vs strips

Sector Test: TIB/TID noise performances

- Strip noise stability is under control
  - ~0.5% spread in stable conditions
  - S/N stability being studied
  - individual chip/module stability under investigation
  - bad strip statistics is stable
    - detailed comparison to be done
- TIB/TID S/N ~ 28 (PEAK mode)







Conclusions

- Inner Barrel and Disks fully integrated in CMS Tracker
- ~15% of Tracker continuously tested since Feb 2007
- Performances are good and well within specs: S/N ~ 28 (Peak)
  - S/N ~ 17 (Deconvolution) (?)
  - bad channels ~0.3 % + 0.6% (HV)
- Ready to switch on the full Tracker in the cavern in CMS:
  - likely October 2007