Experience of Commissioning the CMS Silicon Strip Tracker

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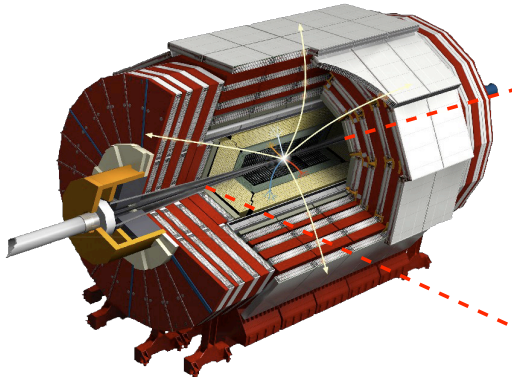
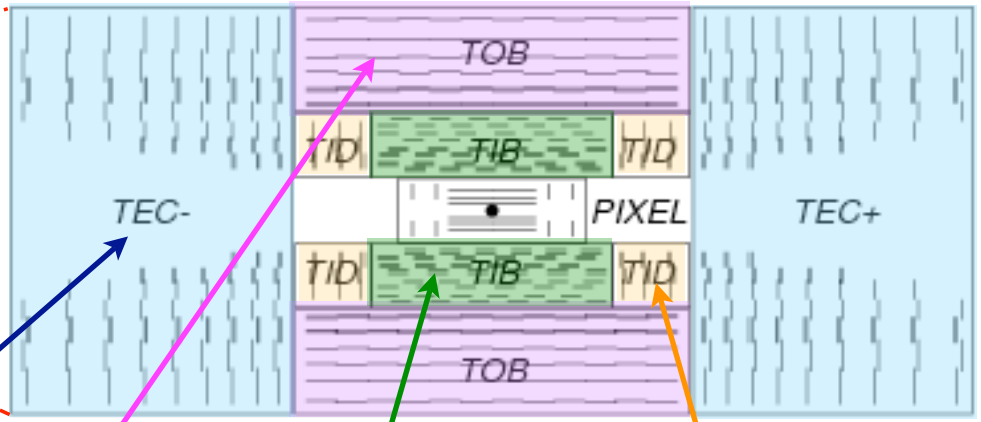
On behalf of the CMS Collaboration

28th July 2008

- Introduction to the CMS Silicon Strip Tracker (SST)
- Integration to commissioning: The story so far …
- The commissioning procedures
  - Preliminary results from the first round of commissioning
- Outlook

The CMS tracking system





TEC - Tracker EndCaps
2x9 disks, 6400 modules

TOB - Tracker Outer Barrel
6 layers, 5208 modules

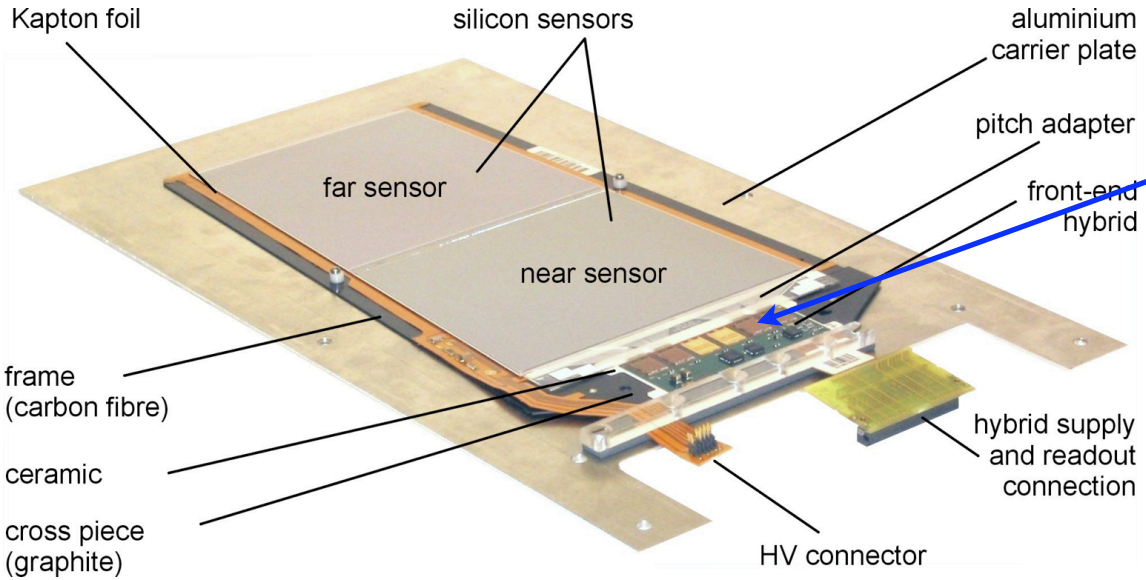
TID - Tracker Inner Disks
2x3 disks, 816 modules

TIB - Tracker Inner Barrel
4 layers, 2724 modules

5.4m x 2.4m
210m^2 of active silicon
15148 modules
75000 APV FE chips
9.6M readout channels

Only Strip Tracker considered here
See talk from Anders about Pixels

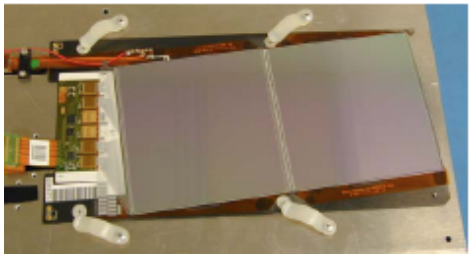
Modules



Each module includes analogue readout chips (APV25)

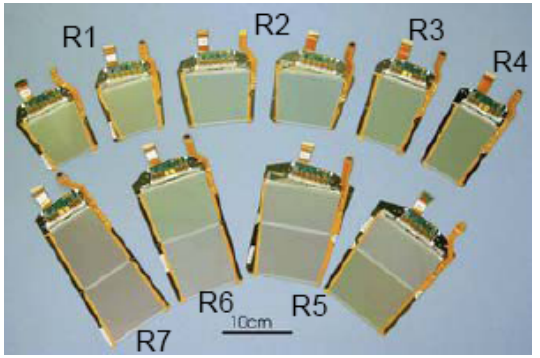
27 different types of modules

TOB stereo module (100 mrad stereo angle)

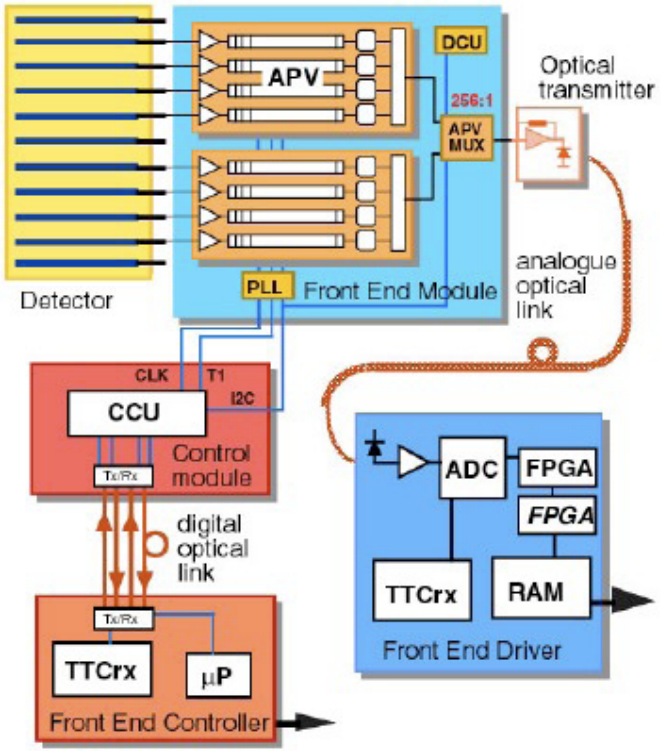


TIB module

TID/TEC modules



Readout and DAQ Architecture



- FE does analogue pulse shaping & optical transmission
- FEDs → Process data & send to central DAQ
  - Pedestal & noise suppression
  - Cluster finding
- FECs → Clock/trigger distribution & FE control

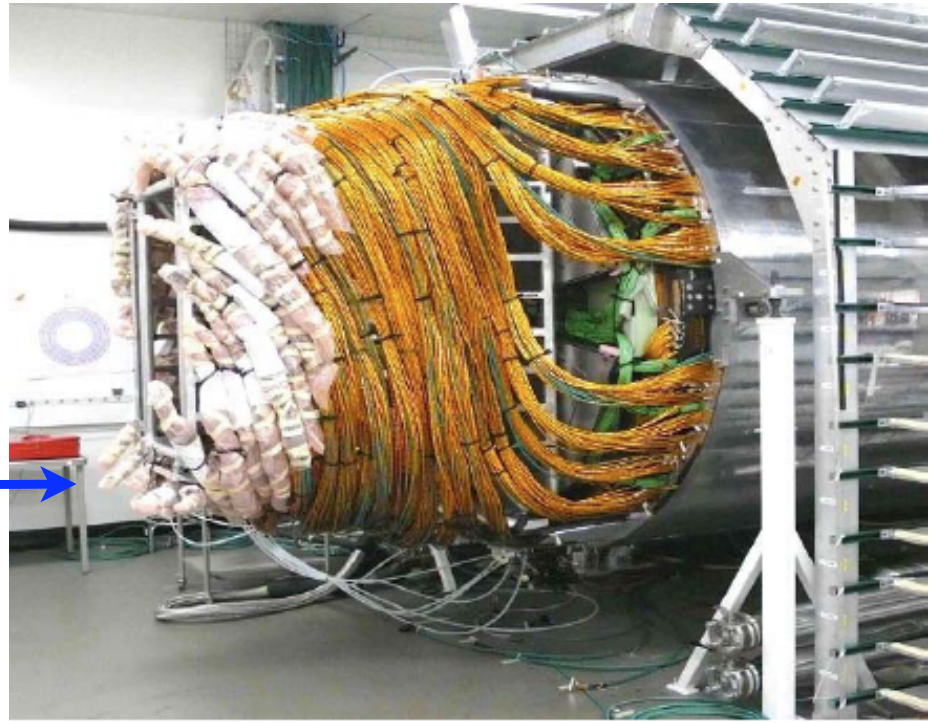
Use copy of CMS DAQ for "local" runs:

- ➡ Reconstruct full events (readout units)
- ➡ Process the events as they are taken (Builder/Filter units)
- ➡ Raw data as well as specialised tracker root files written out to disk (Storage Manager)

The SST in pictures

SST integration at CERN main site

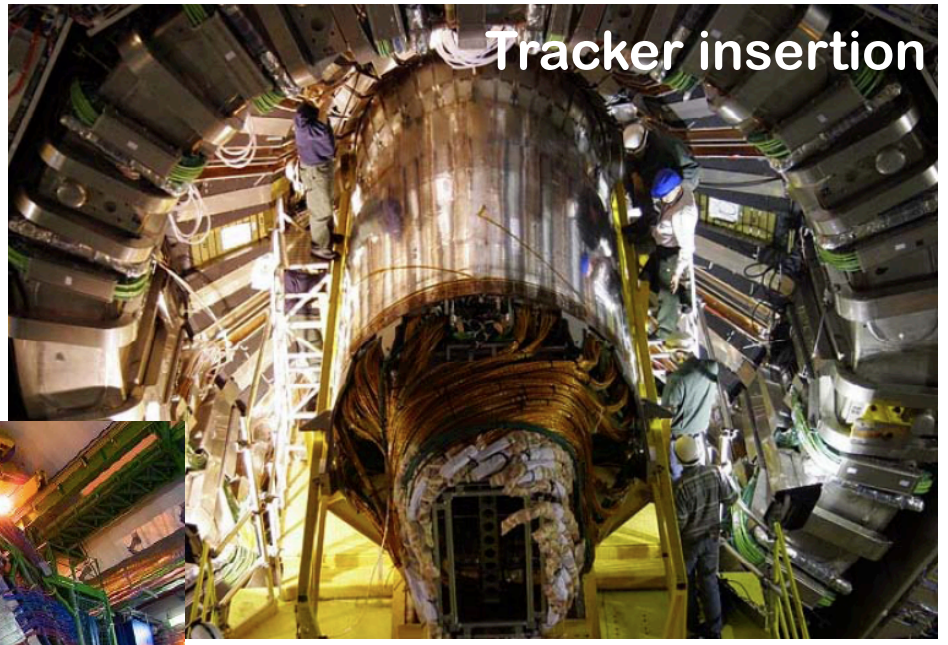
The SST ready for transport to CMS (20km journey)

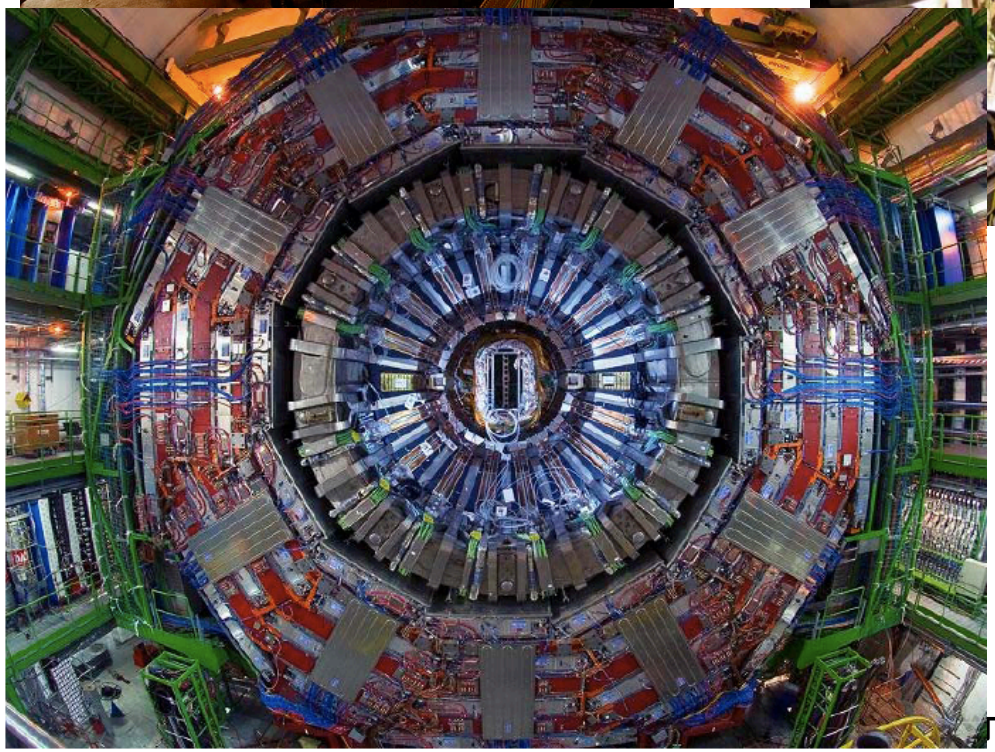


From Integration to Commissioning

- Summer 06 - MTCC - first experience of running CMS
- November 06 - July 07
  - Integration & operation at "Tracker Integration Facility"
  - 15% of tracker operated warm and then cold (down to -15˚C coolant temperature)
    - Huge amount of experience gained
- July - November 07: Cabling of central CMS section ("YB0")
  - A mammoth task!
- December 07: SST installed in CMS
- January - March 08: Connection & checking of tracker services
- March - April 08: First test of commissioning procedures with temporary cooling
- June 08 - Present
  - First round of checkout & commissioning with final cooling plant
  - Preparation for inclusion of SST in Global Run (7th July)
  - Cover only the results from this period here

Installing the SST underground

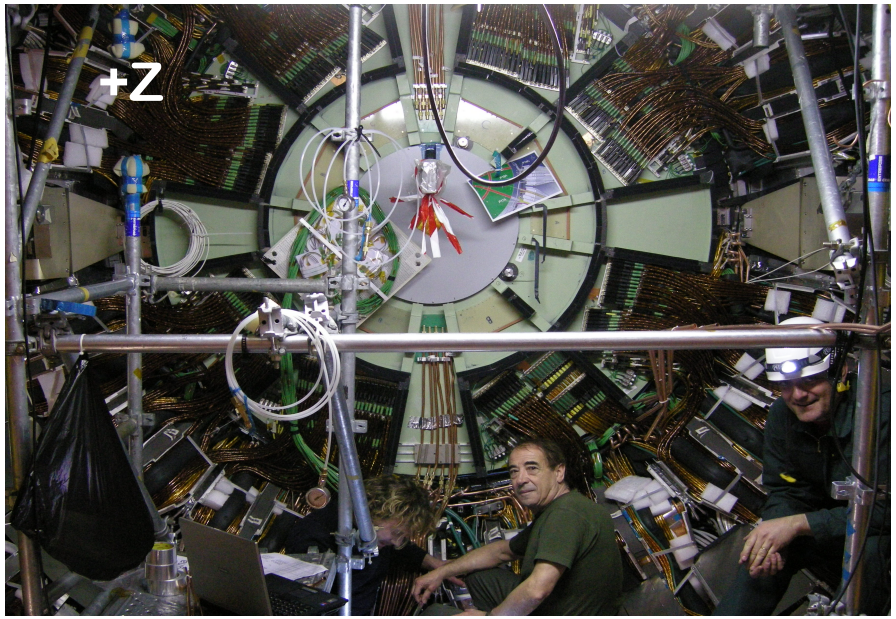




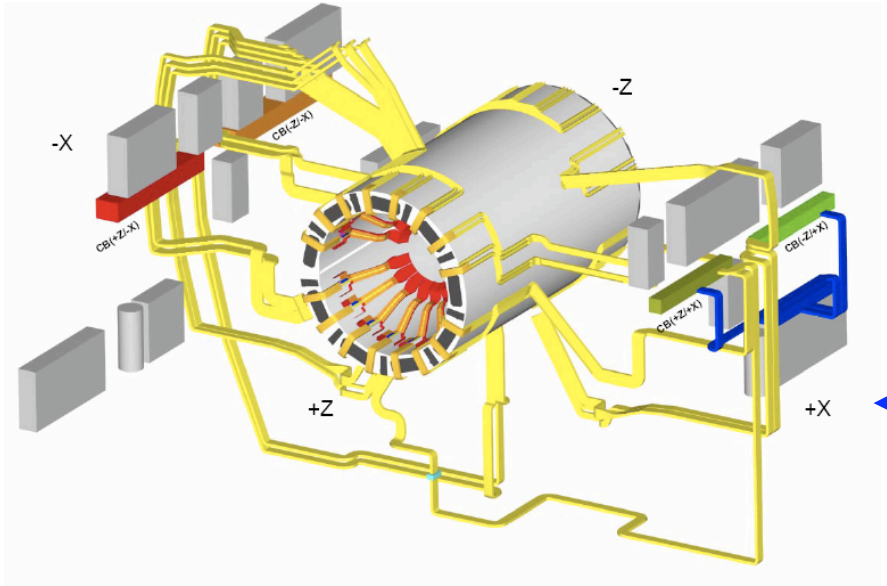
Safe arrival of the SST in CMS!

Connecting up the SST

- A major achievement!
- 980 pipes
- 1080km fibres
- 80km power cables



Cabling of +Z end - March 2008

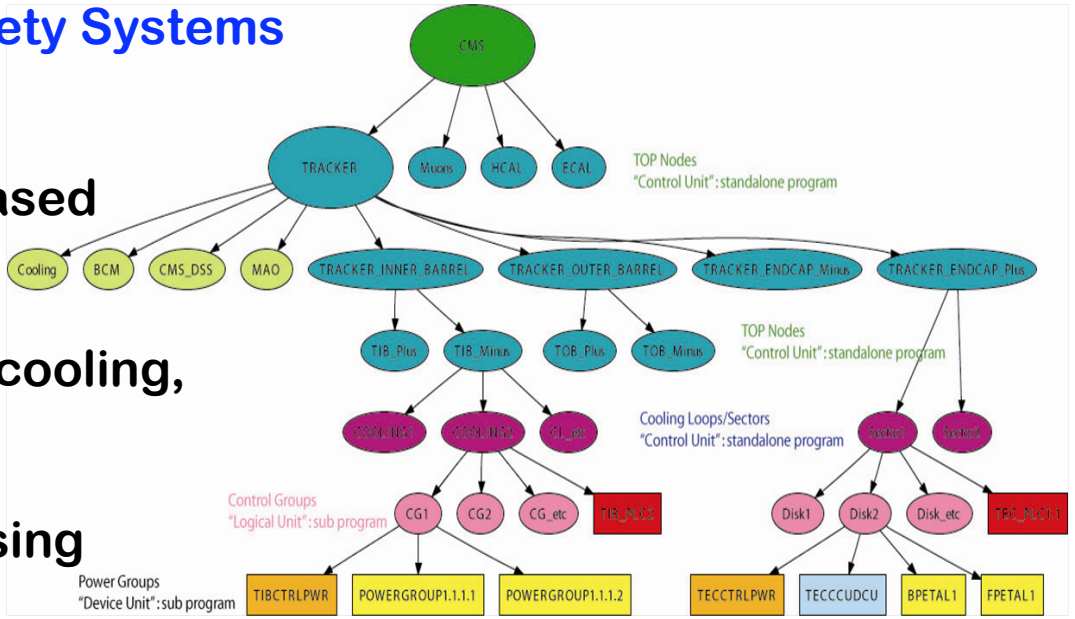


Power cabling layout for SST

How to commission the SST (I)

Step 1: Provide tracker with cooling, power & safety interlocks:

Tracker Control & Safety Systems



Safety: Hardware system based on PLCs
➜ Provide interlocks in case of problems (temperatures, cooling, trips etc.)

Control: Software system using PVSS
➜ Power on/off tracker
➜ Monitor environmental conditions; attempt to shutdown SST nicely (ie. BEFORE hardware) in case of problems

- **72 TIB/TID cooling loops**
- **44 TOB cooling loops**
- **16 TEC sectors**

How to Commission the SST (II)

- Control - PSU map
  - Identify connections between control and power supply systems
- Control - Readout map
  - Identify connections between control and readout systems
- Internal timing
  - Synchronization of all channels
- Optical Gain Scan
  - Optimal bias & gain settings for FE laser devices
- Analogue baseline tuning
- Tuning APV pulse shape
- Pedestal and noise (needed for physics)
- APV latency scan
  - Synchronize tracker with LHC clock
- Fine tuning of pulse shape sampling
  - Tune to 1ns (account for time-of-flight etc.)

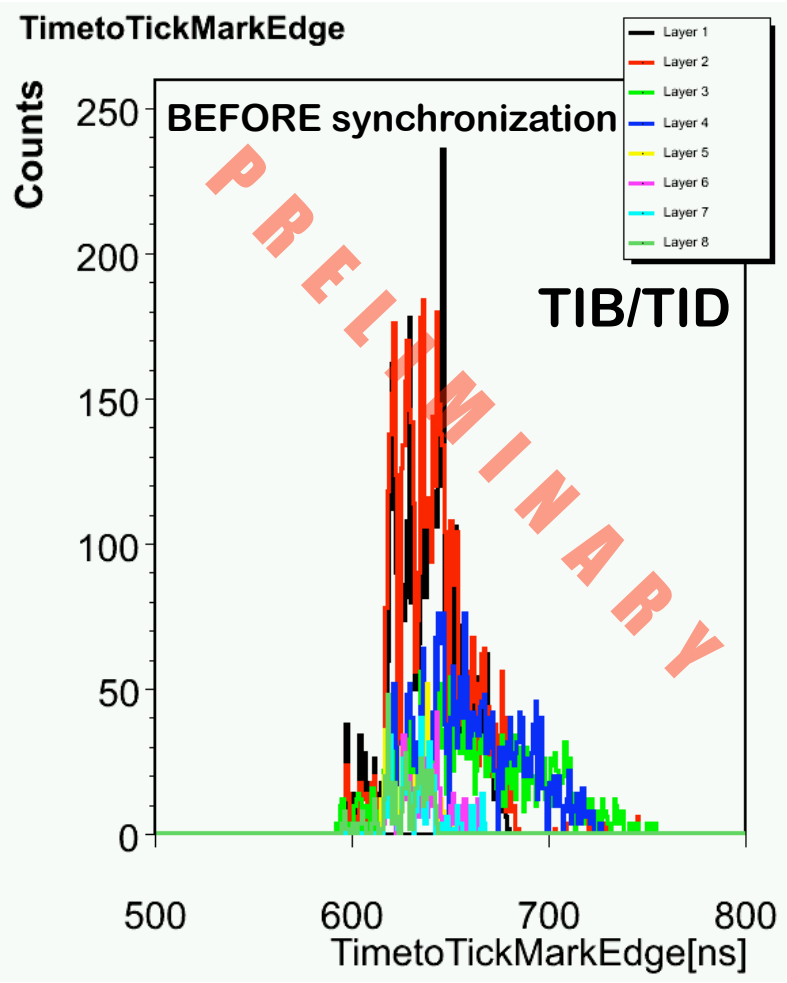
Checkout procedures

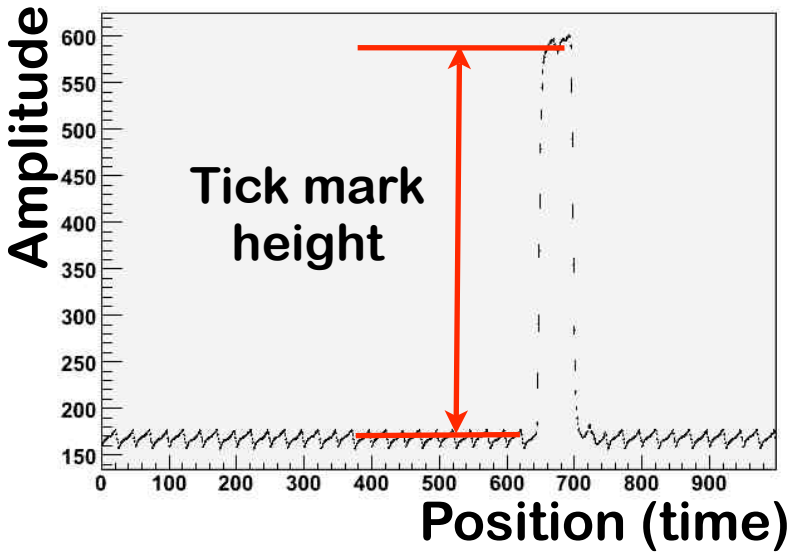
Checkout results

- These results are Preliminary - first round of commissioning
  - Aim was to validate commissioning procedures and to include SST in Global Run in early July
  - Excluded anything that was not completely understood
    - Deliberately conservative approach

- Second round of commissioning now underway
  - Systematic investigation of all channels not previously included
  - Large scale testing of all commissioning procedures not yet performed

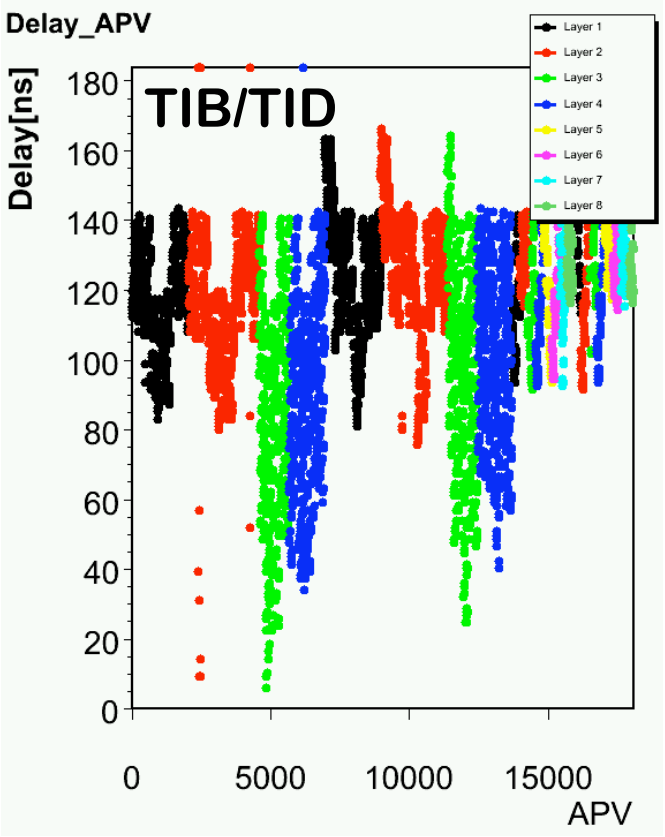
Synchronization (I)



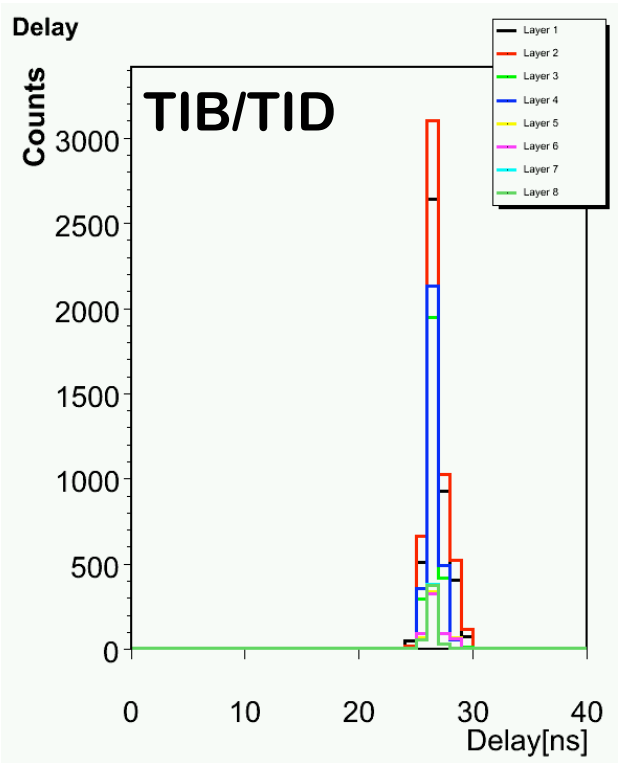


- APV synchronization pulses:"tick marks"
- Use tick marks to synchronize the SST internally
- Account for different cable lengths etc.
- Adjust programmable "Phase Lock Loop" chip on each module

Synchronization (II)



PRELIMINARY

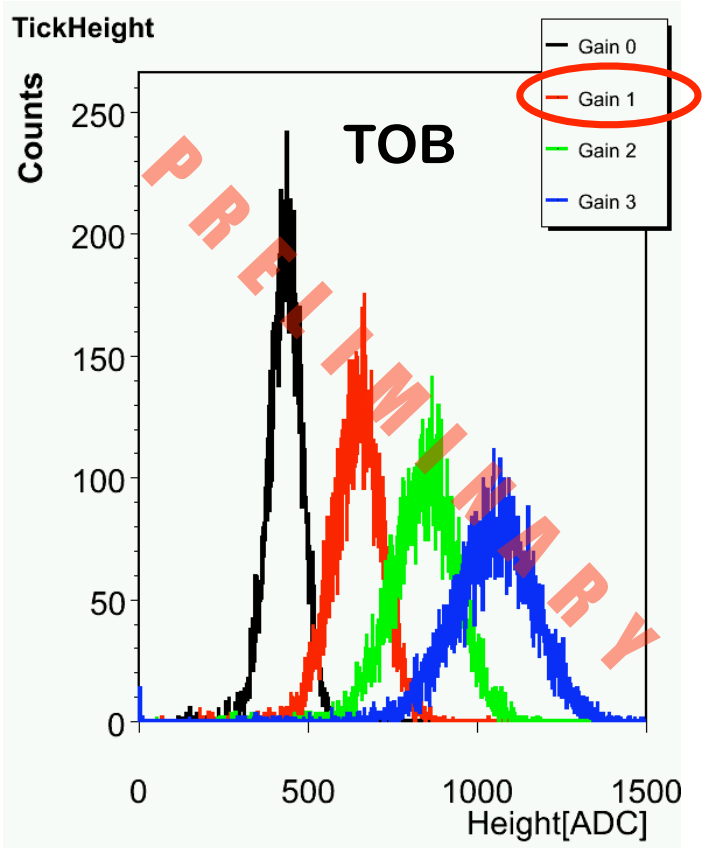


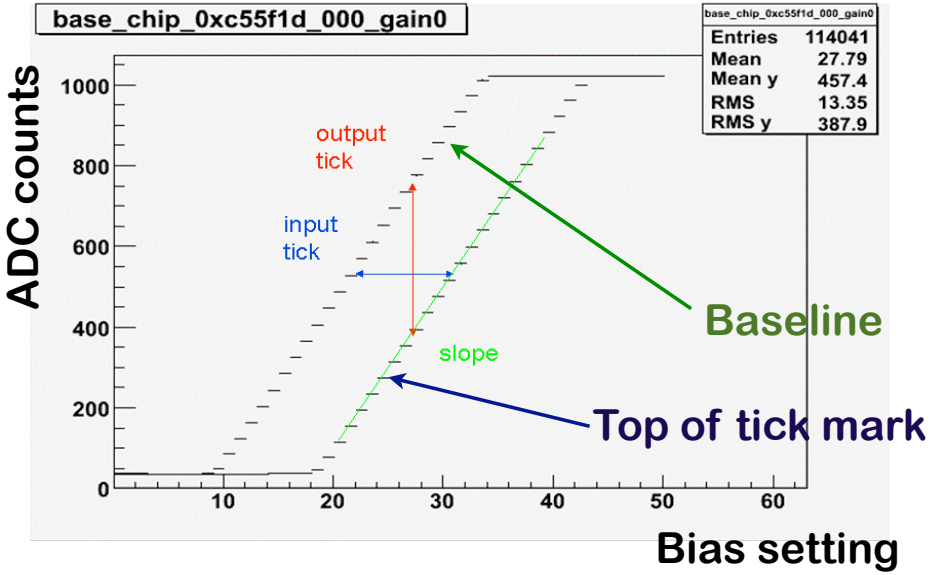
BEFORE: Cabling structure clearly visible

AFTER: All channels aligned

Opto-Gain Scan

- Optimize use of available dynamic range of analog opto-hybrid (AOH)
  - Laser bias
  - input scale factor (gain)





- Laser diode output scales linearly with input current above threshold
  - Monitor slope, threshold
  - Monitor output tickmark seen at FED
  - Monitor estimated input tickmark to LLD
- Note: Temperature dependence!

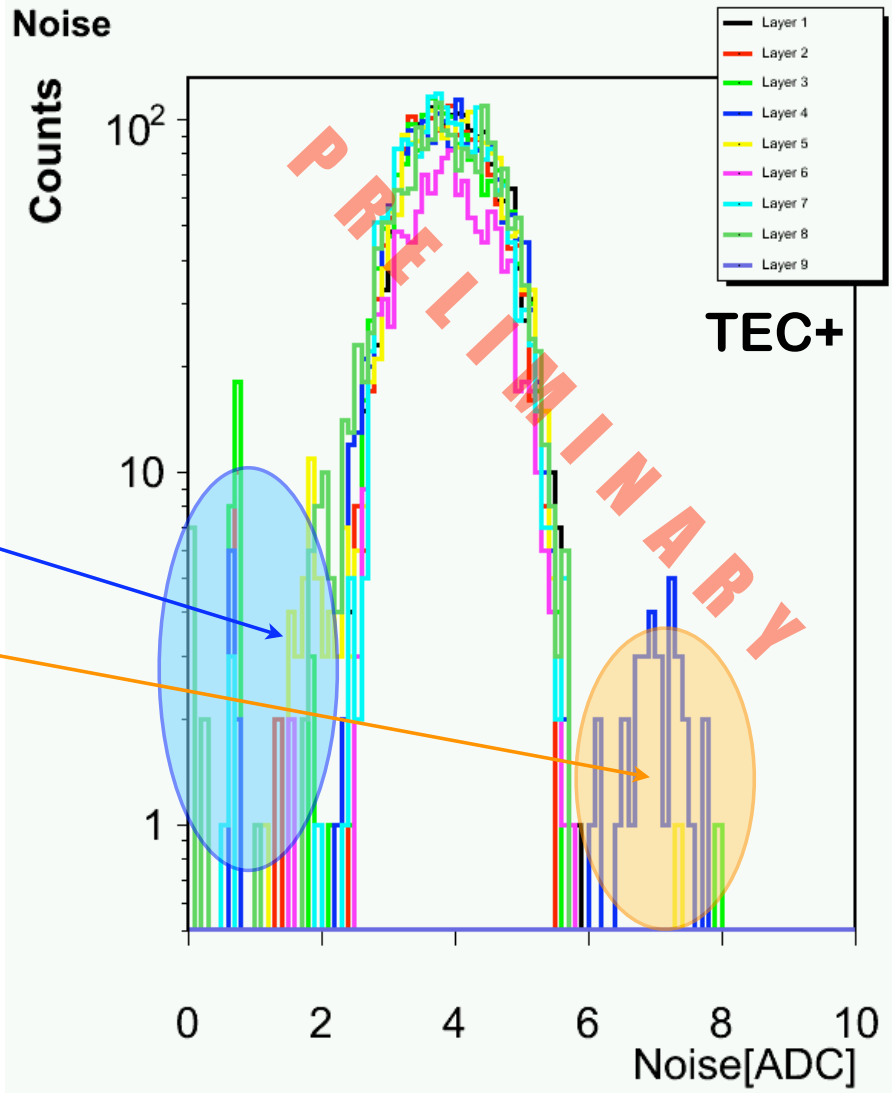
Pedestals & Noise

- Quality of the SST is excellent
- Example: TEC+
- Preliminary results from first round of checkout:

Number of dead strips << 1 % ✔

Number of noisy strips < 1 % ✔

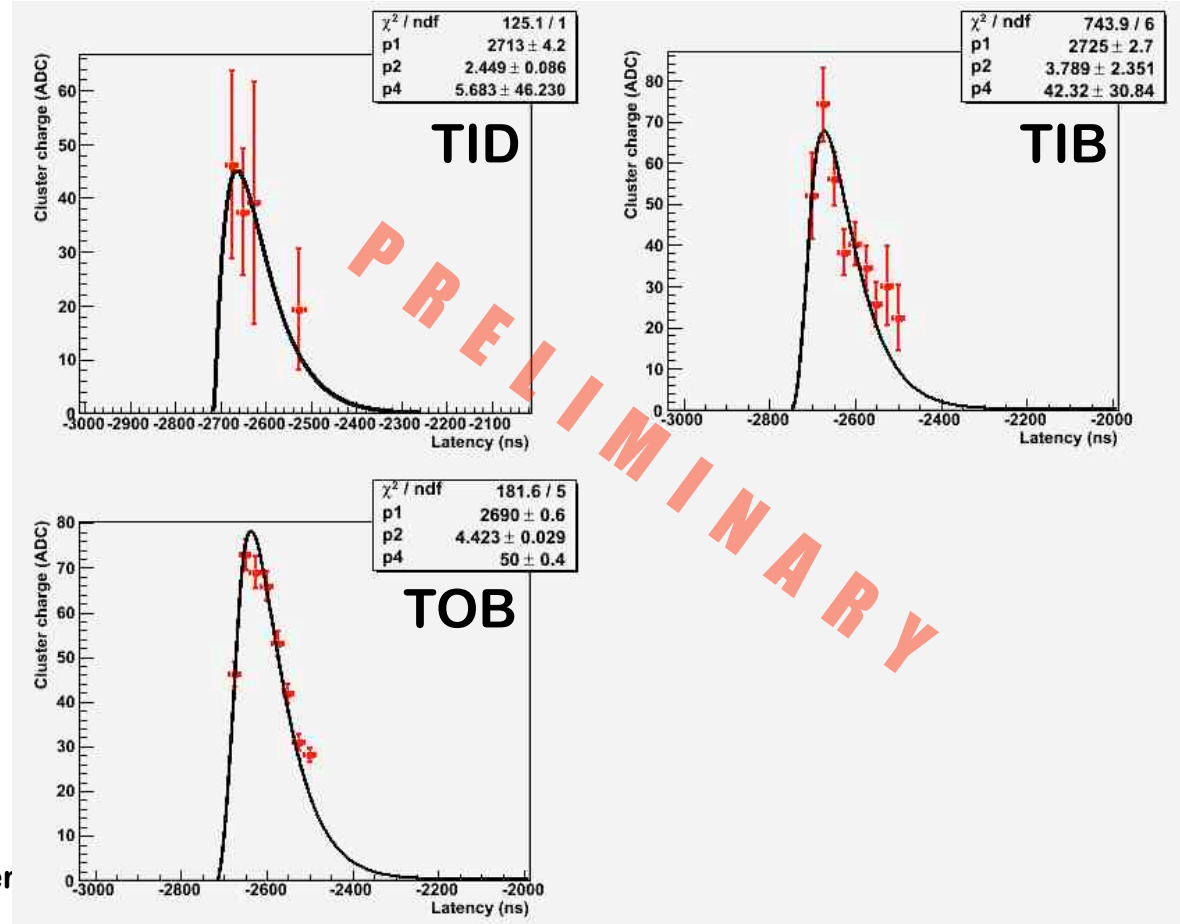
Mean noise < 2000 e-/strip ✔



Latency scan

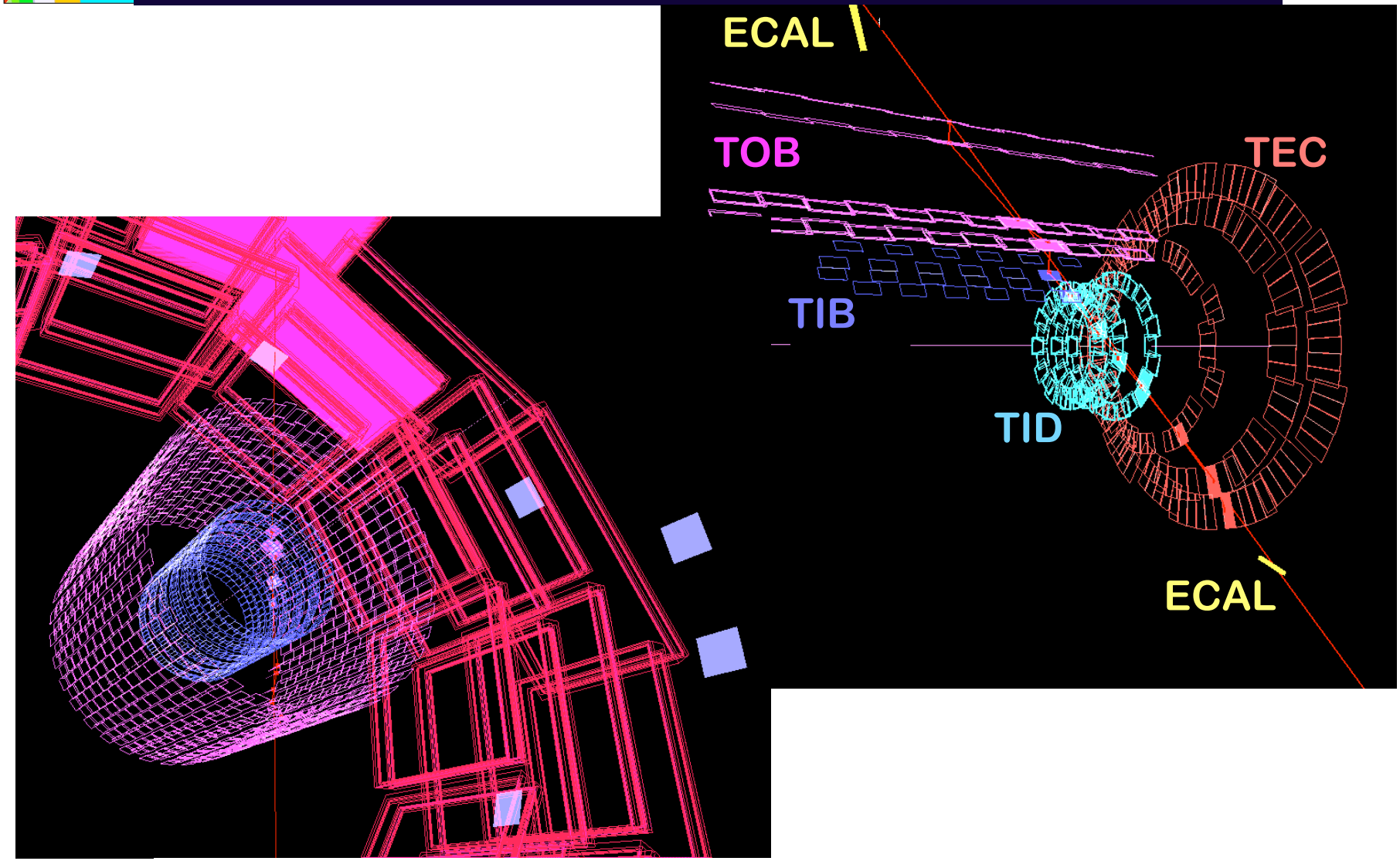
- Synchronization of tracker with external trigger
  - APV latency set in steps of 25ns
  - Determine optimal latency by reconstructing pulse shape
    - Choose working point closest to maximum

First large scale test of procedure
Very limited statistics



Based on these results, TIB/TID, TOB (and later TEC+) entered Global Run in early July! ☺

First tracks in CMS!



First round of commissioning

- First round of commissioning - all subdetectors checked out!
- Quality of connections is excellent:
  - 97% of TOB channels ✔
  - 97% of TIB/TID channels ✔
  - 95% of TEC+ channels ✔
  - 81% of TEC- channels ✔ (one sector excluded)
- TIB-TID-TOB participated in full global run
  - TEC+ joined later

A GREAT SUCCESS!!

Summary & Outlook

- First round of SST commissioning complete
  - Most commissioning procedures validated
  - TIB,TID, TOB and TEC+ participated in CMS global run in early July
- Quality of the SST is impressive
  - Vast majority of channels passed checkout first time
  - First look at performance looks good!
- Second round of commissioning underway
  - Large scale testing of remaining commissioning procedures
  - Systematic investigation and repair of channels excluded during the first round

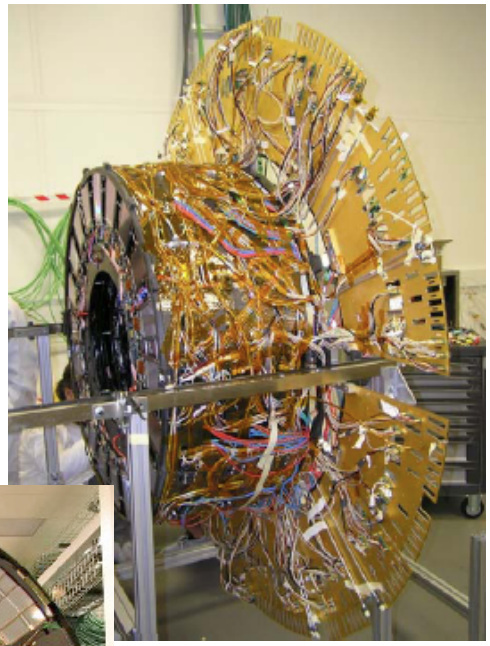
Thanks to Phil Harris & Christophe Delaere for the plots!

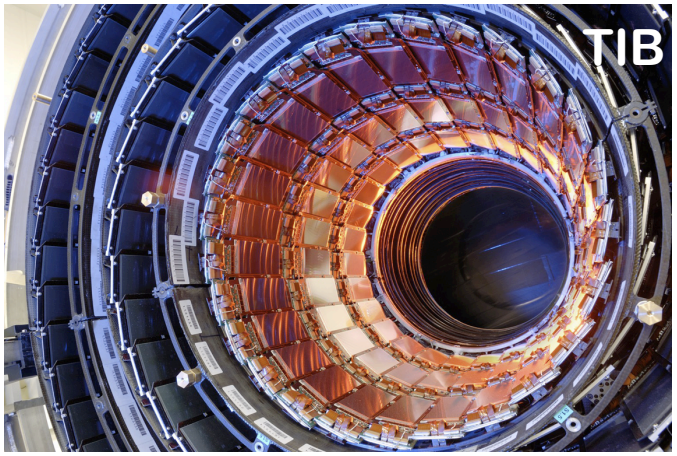
Extras

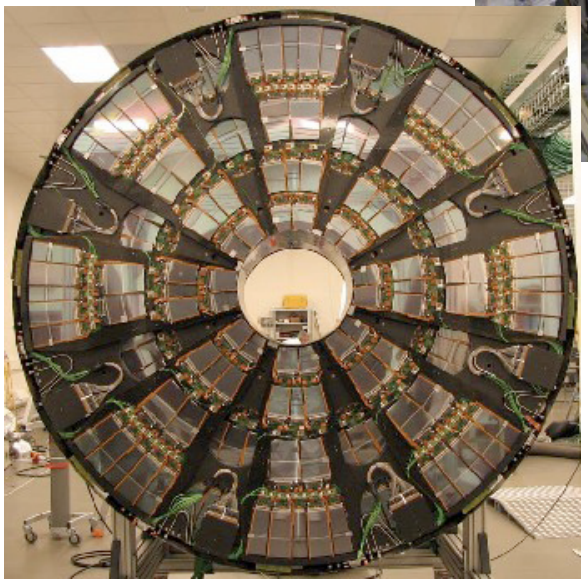
The subdetectors in pictures

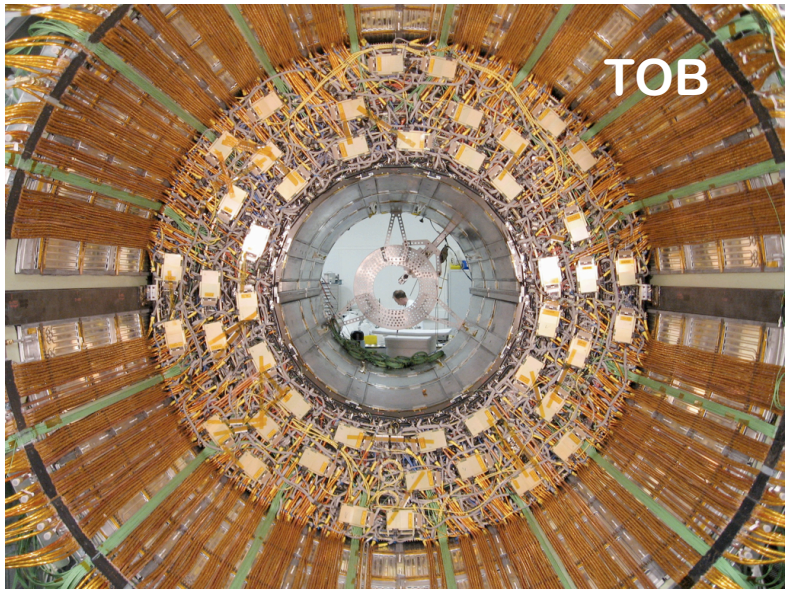
TID

TEC

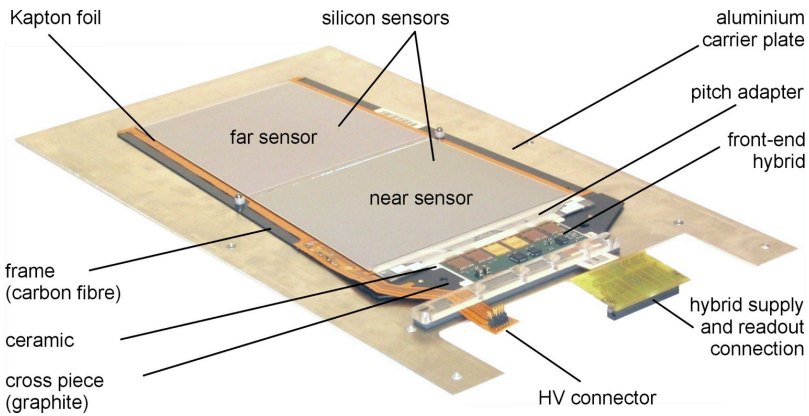


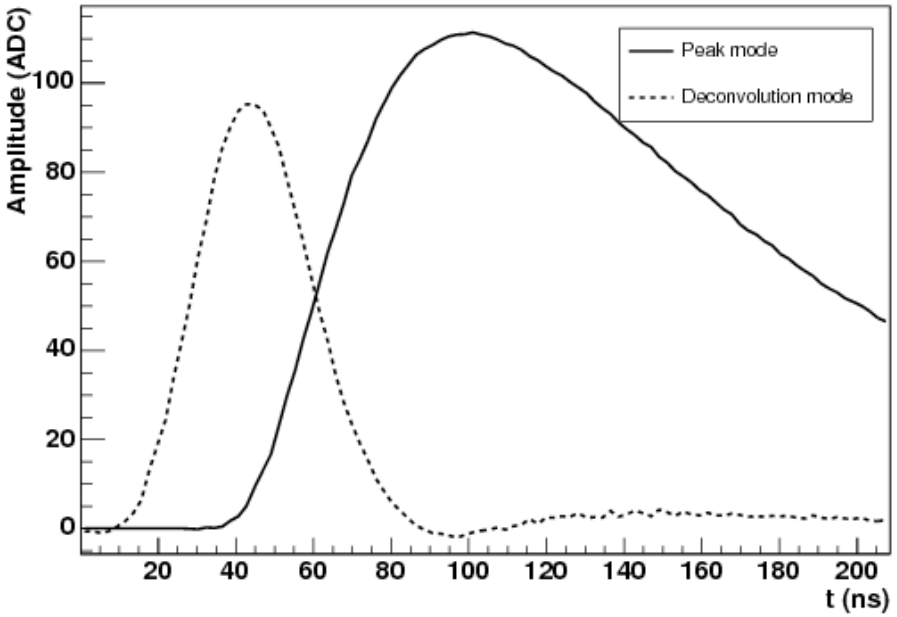






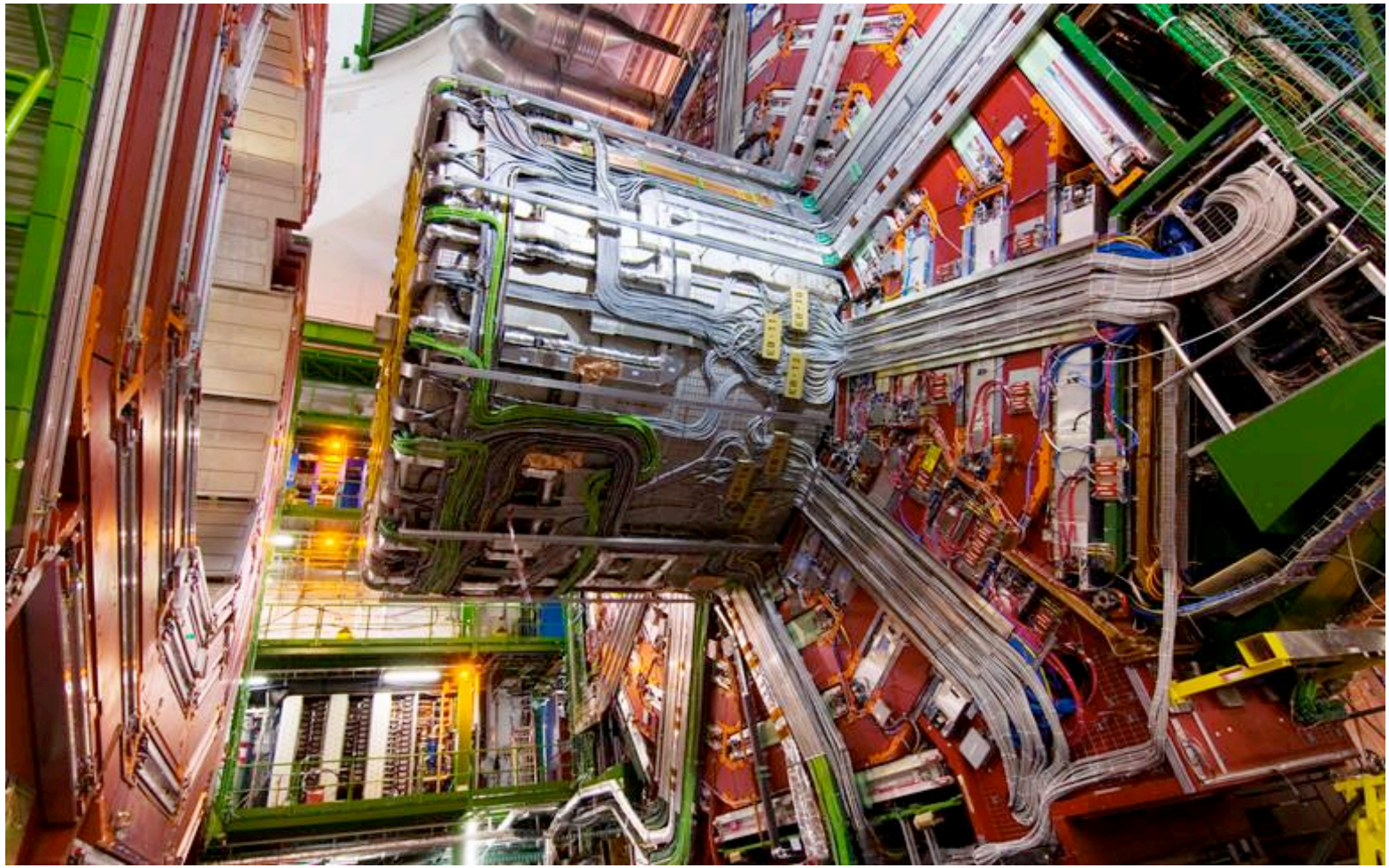
APV25





- Each module includes analogue readout chips → APV25
- Two readout modes:
  - Peak mode → signal lasts > 100ns
  - Deconvolution mode → signal lasts 25ns
    - Necessary for high luminosity running

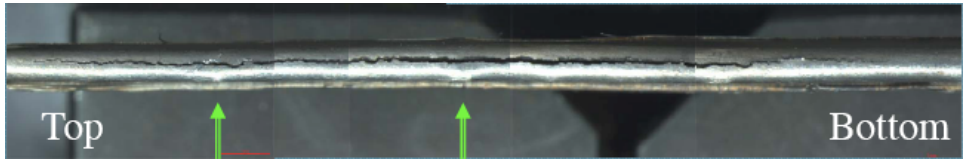
YB0 cabling

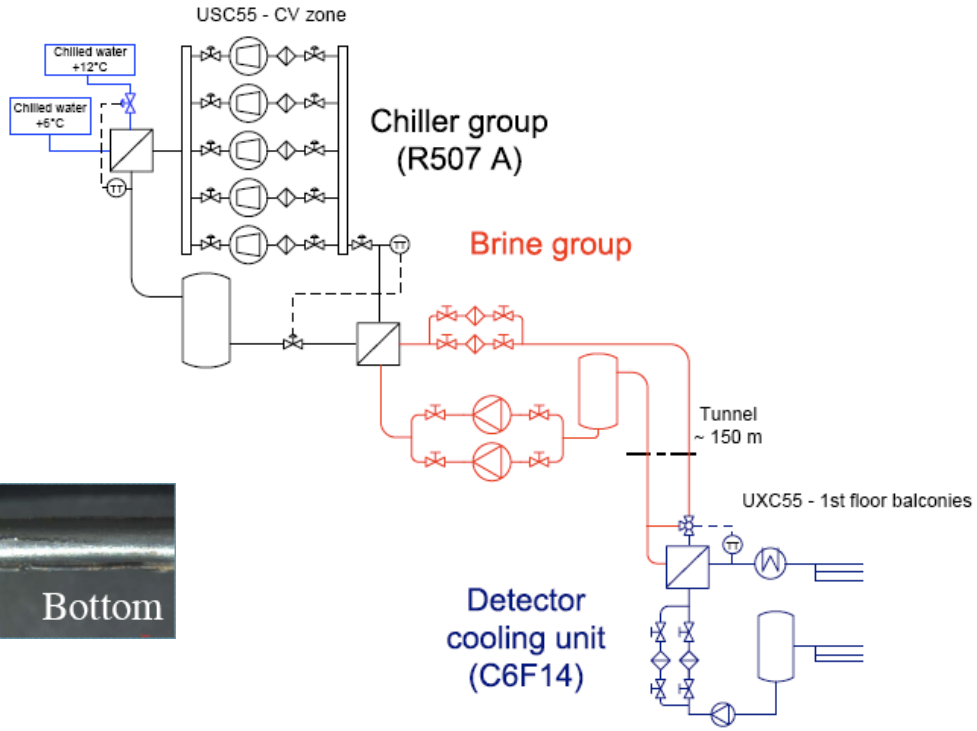


Tracker Cooling

Failure of heat exchanger in one of two tracker cooling stations (late November 2007)

Brine leaked in C_6F_{14} and contaminated the system

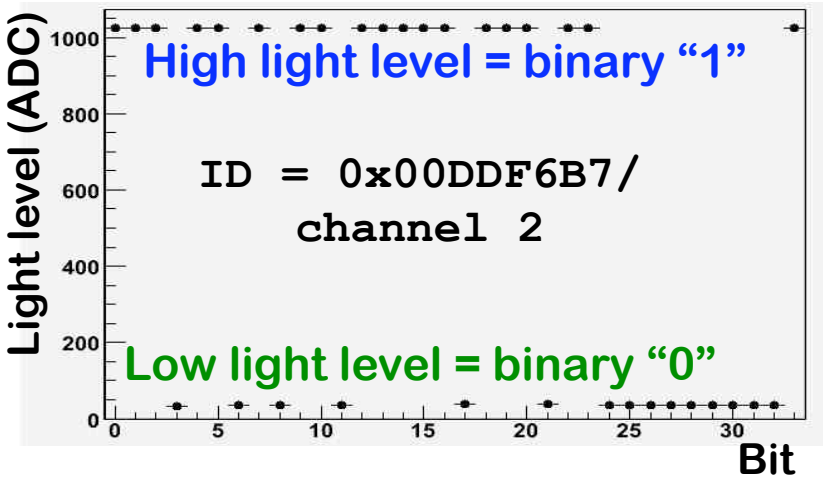


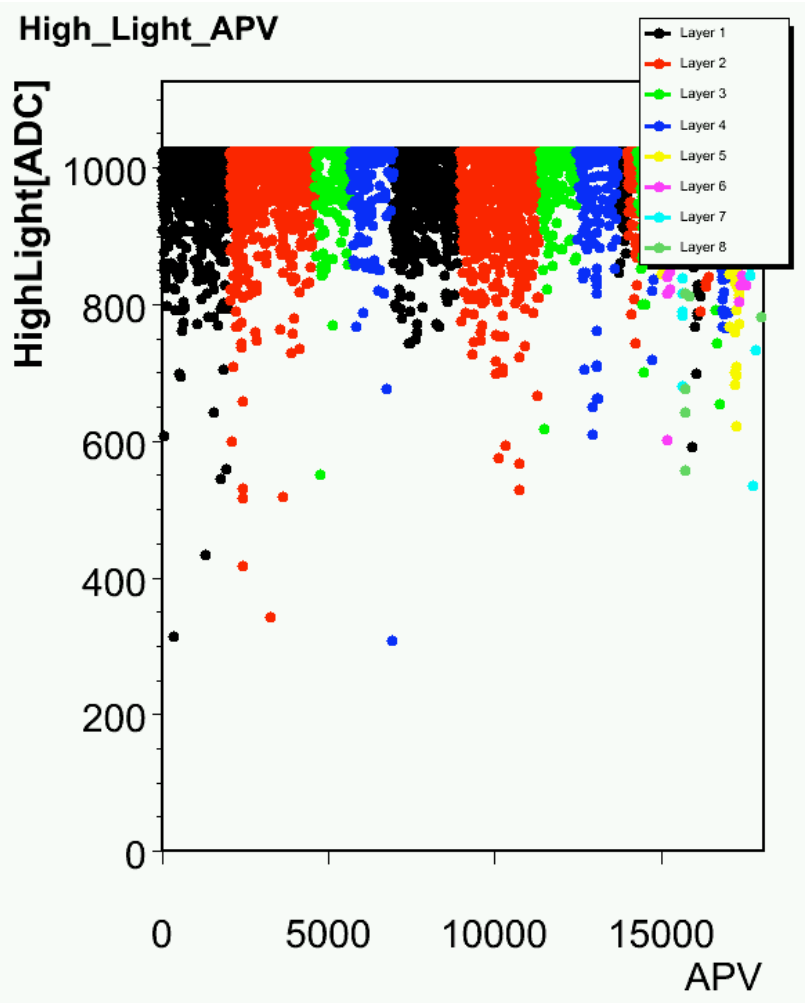


- Full cleaning procedure rapidly developed and carried out
- Tracker to be operated at room temperature this year
  - Use C_6F_{14} instead of brine
- Longer term: Replacement of all heat exchangers

Control - Readout Map

- Connects APVs to FED channels
- ID information from hybrid sent as bit pattern to FEDs





- Identify any missing connections
- Also spot any "grey" connections