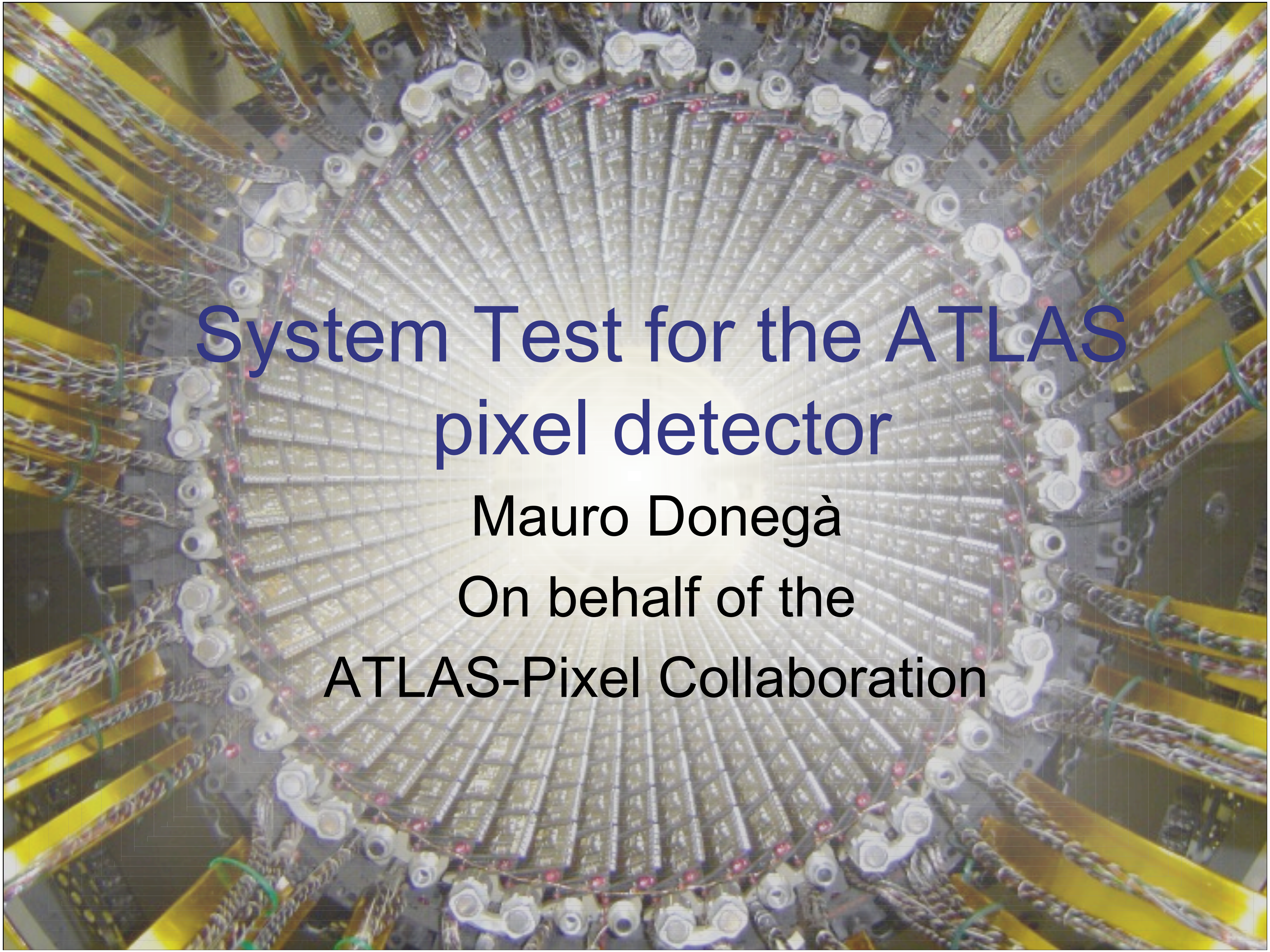


System Test for the ATLAS pixel detector

Mauro Donegà
On behalf of the
ATLAS-Pixel Collaboration

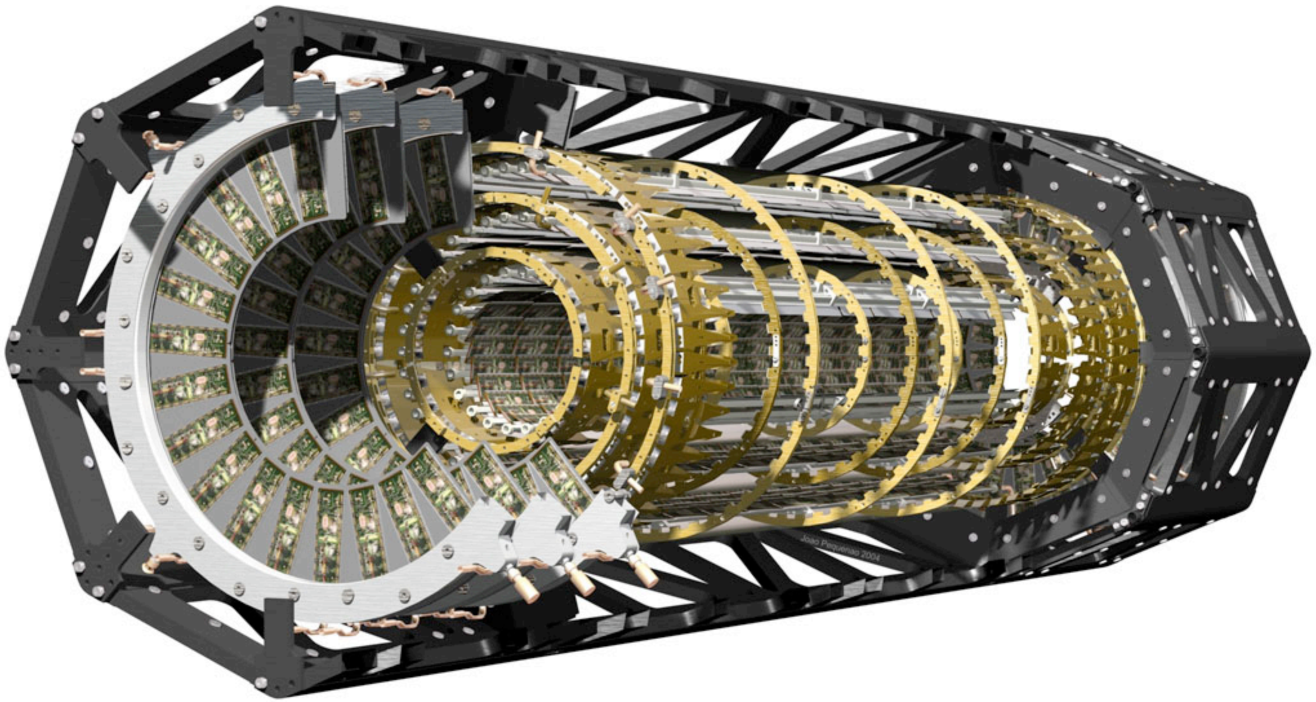
Outline

- ATLAS Pixel Detector Overview
- System Test Setup
- Calibration runs
- Data taking runs
- Cosmics data analysis
- Conclusions

ATLAS Pixel Detector

Pixel Detector design constraints from LHC timing / event-environment physics, ATLAS design

- Tracking in high multiplicity environment → high granularity
  (22 interactions ~1200 tracks per BC)
- Good impact parameter resolution → high granularity + low mass
  ($\sigma(d_0)$~12 µm)
- Distinguishing hits 25ns apart → fast preamp rise time
- 3.2 µs trigger latency (LVL2) → on detector buffering of hits
- High radiation dose 10^{15} n_{eq}/cm^2 (niel) → low temp., high radiation tolerance
  60 Mrad



ATLAS Pixel Detector

Some numbers:

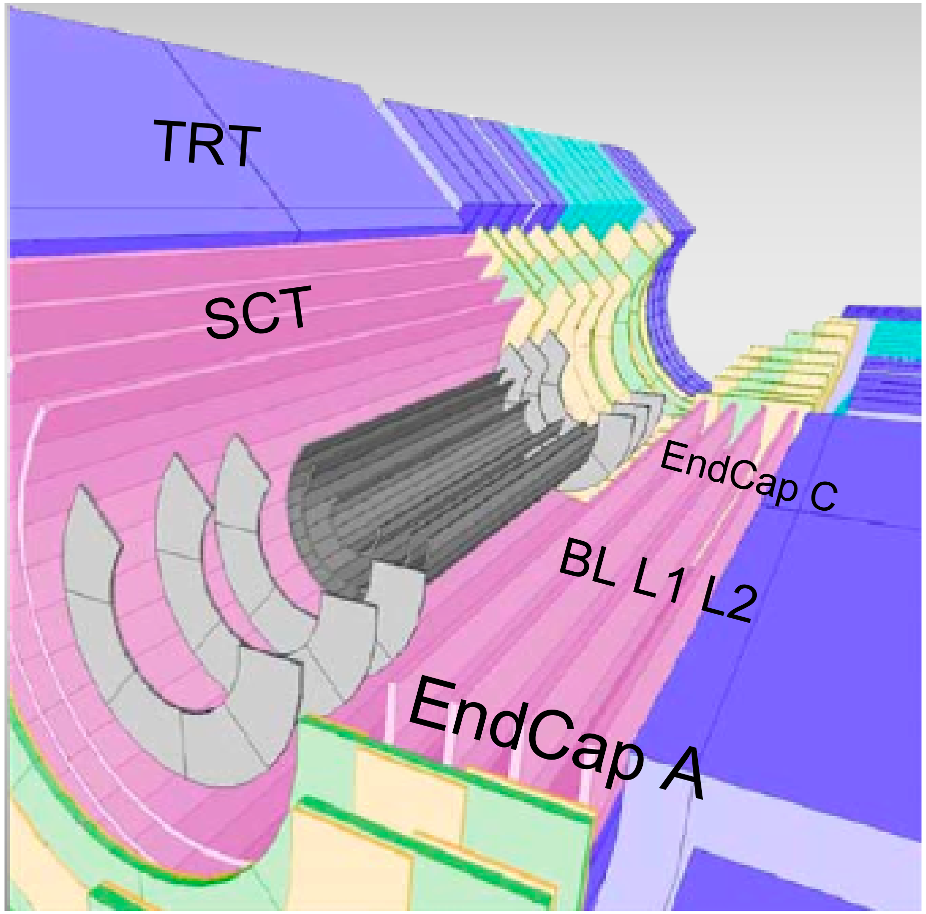
- 3 space points for $|\eta|<2.5$
- 3 barrel layers at r = 5, 9, 12 cm
- 2 endcaps with 3 layers
- 80 million channels
- Area 1.8 m^2
- Total mass is 10% X_0 normal to beam

– ~10 kW operating power in active volume

– Detector will operate at ~ -7°C

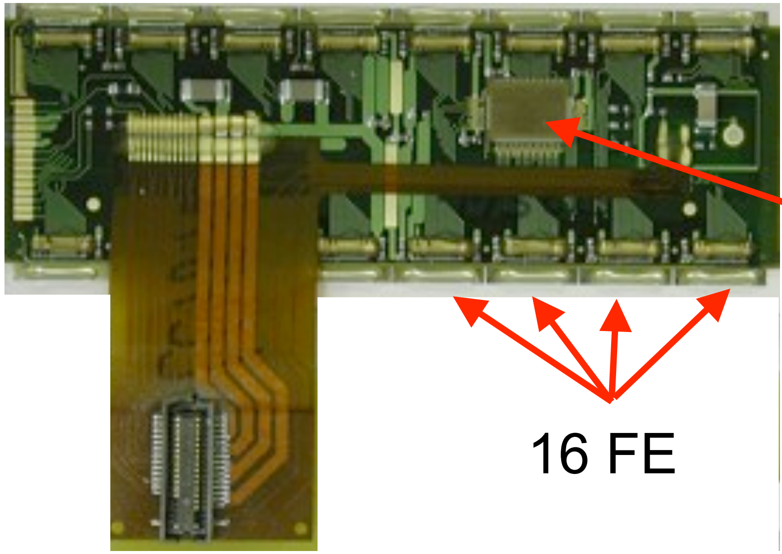
– Cooling integrated in local support structure

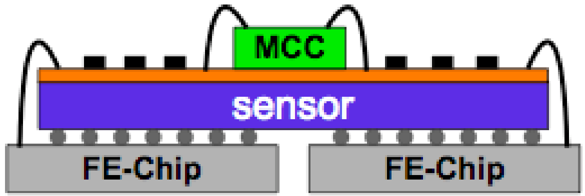
– C_3F_8 evaporative cooling

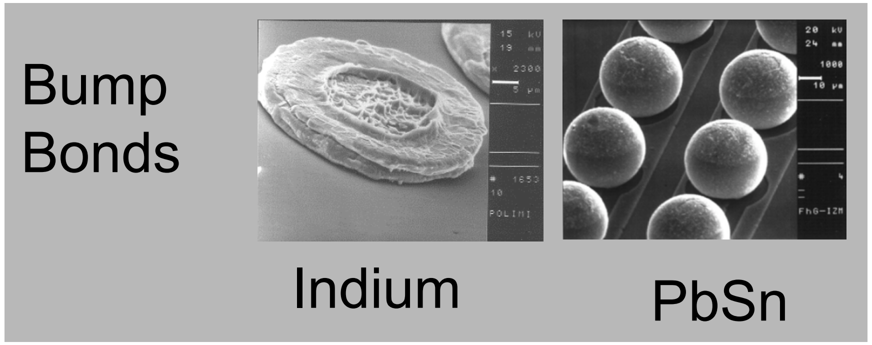


Will be first large-scale active pixel device in operation

ATLAS Pixel Detector

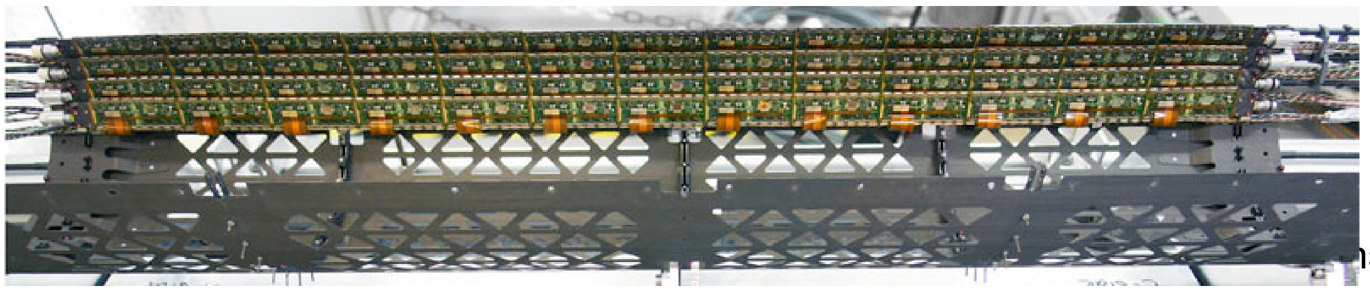


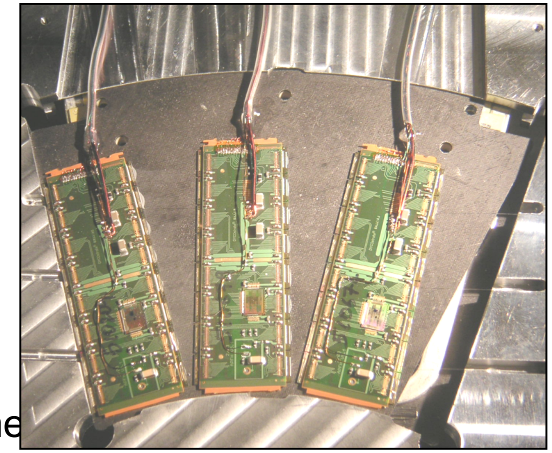


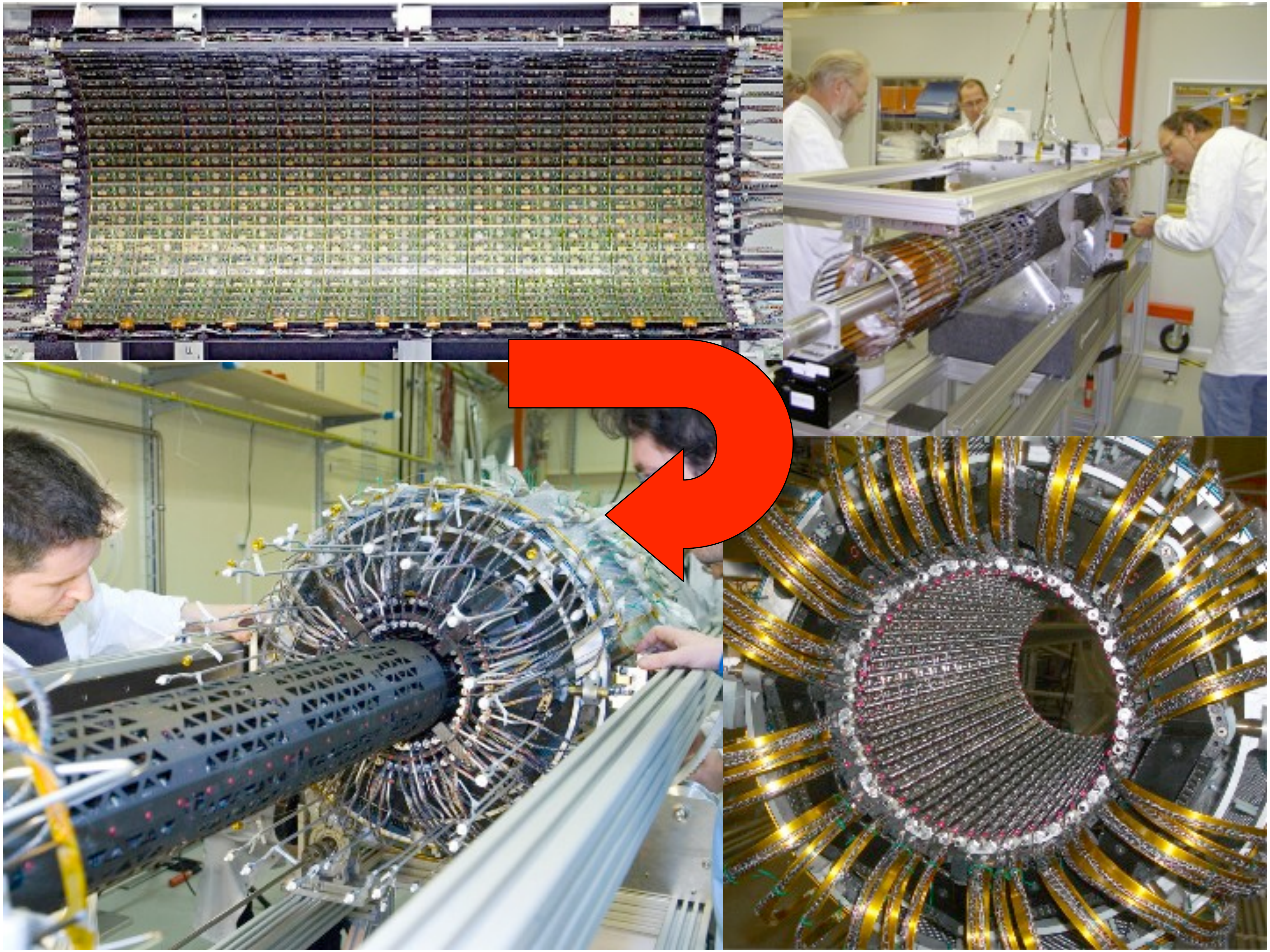


Pixel = 50 x 400 μm^2
2880 pixels x 16 FE = 46080 pixels
1744 modules x 46080 pixels ~ 80 million channels

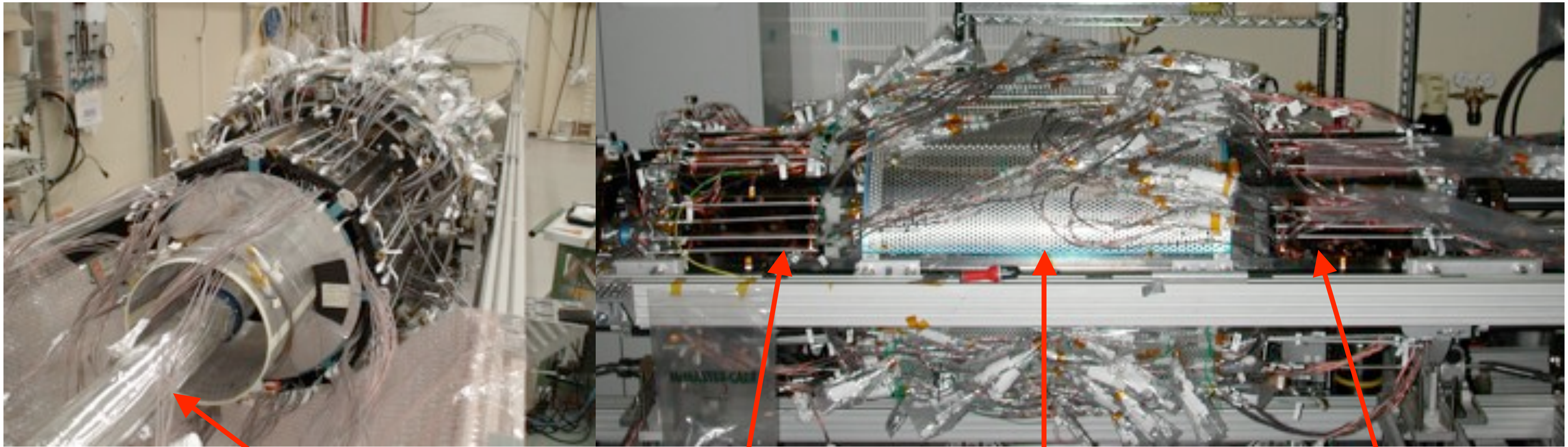
Barrels and Disks mount identical modules







ATLAS Pixel Detector

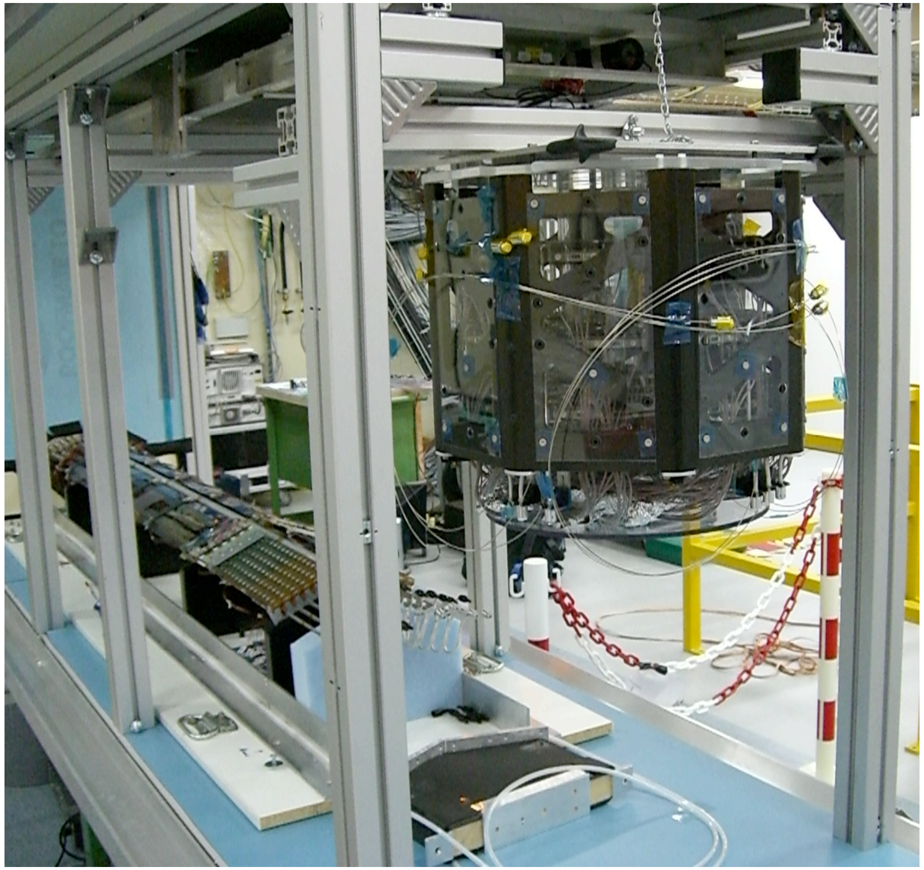


- Integration is well advanced
- EndCaps and Barrels mounted on the beam pipe
- Next steps: service quarter panels integration and connectivity test
- Ready to lower the detector in early June

System Test: Oct 06- Jan 07

Verify the performance of the detector using production items

Test the complete infrastructure (HW+SW) on 10% of the entire detector



End Cap A :144 modules

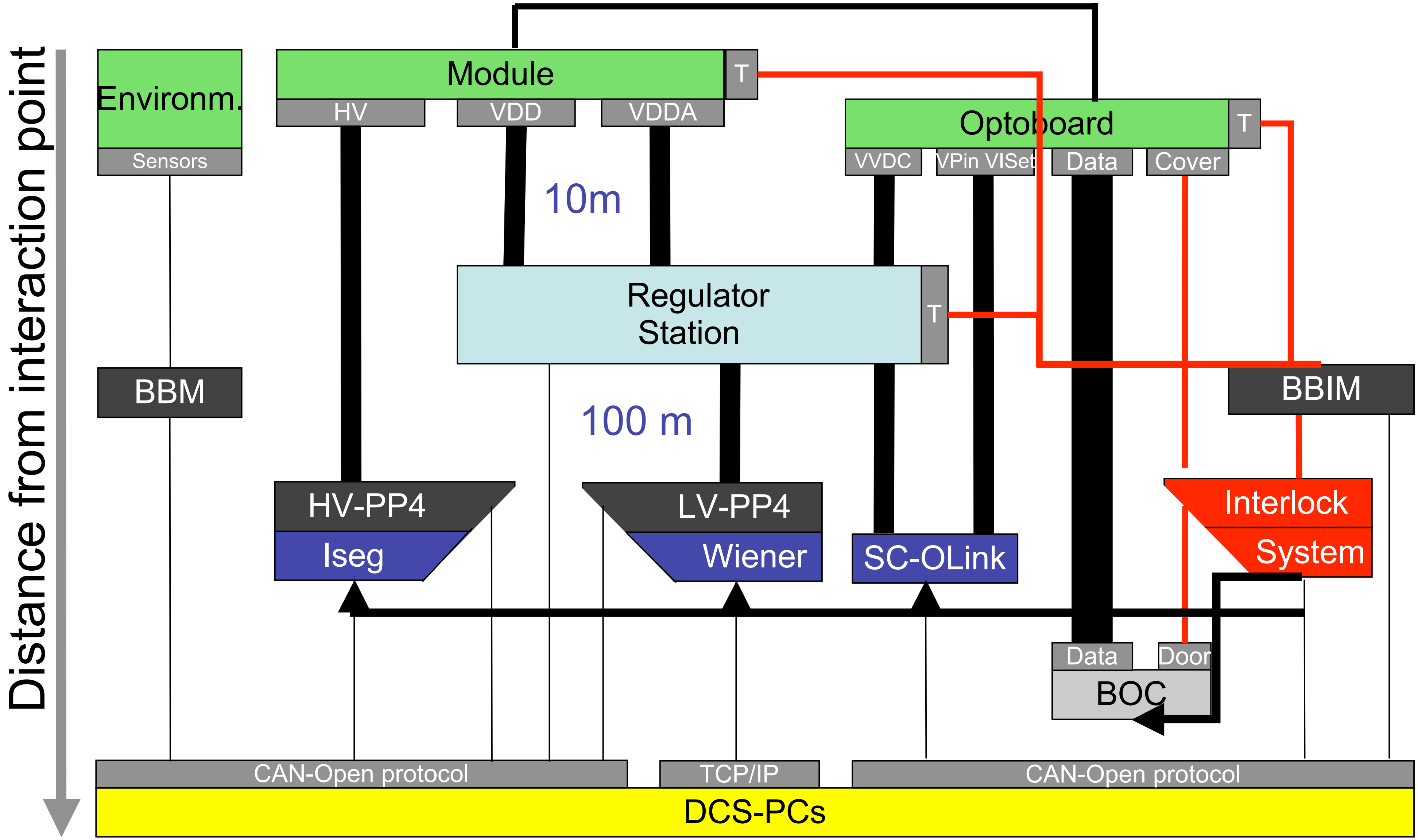
Optical Readout:
24 optoboards (LVDS ↔ optical converters)

Power Supplies:
24 HV ISEG modules
4 LV Wiener power supplies (Digital + Analog)
24 LV Regulators Channels (custom)
12 SC-OLinks (Optolinks custom power supplies)

Interlock System monitoring:
Temperaures (modules, optoboards, regulators)
Currents (modules, optoboards)

ReadOut:
16 Read-Out-Drivers
16 Back-Of-Crate
(opto/electrical conversion + routing)

Detector Control System (DCS)



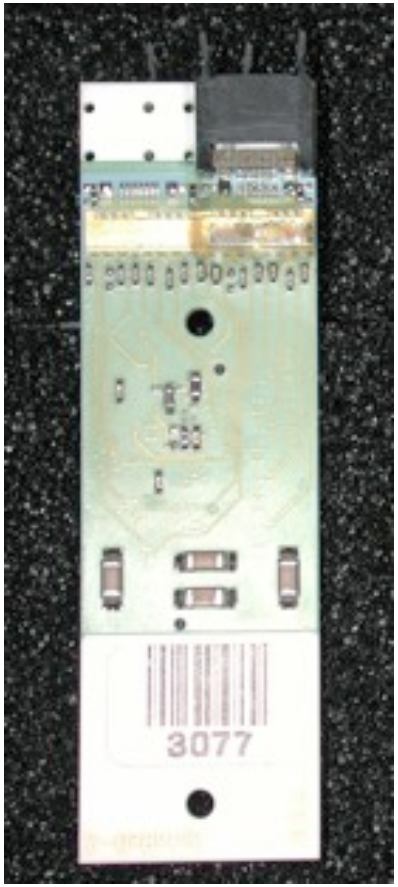
Services Performance

- The complete services chain has been tested
- Intense debug has been done on many different items giving precious feed back
- Big step forward in DCS software

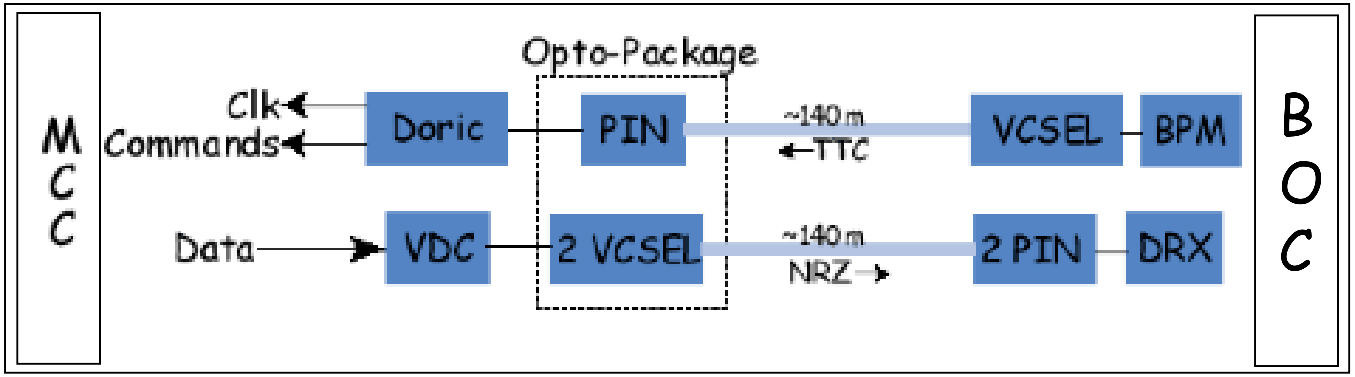
  (Detector Status, Finite State Machine)

All services are fulfilling the detector requirements

OptoLinks



- Optoboards: LVDS signals ↔ optical
- Radiation Hard
- Different data bandwidth: 40 Mbit Layer2
  80 Mbit Layer1, disks
  160 Mbit B-layer
- Signals: Clock, Data IN, Data OUT

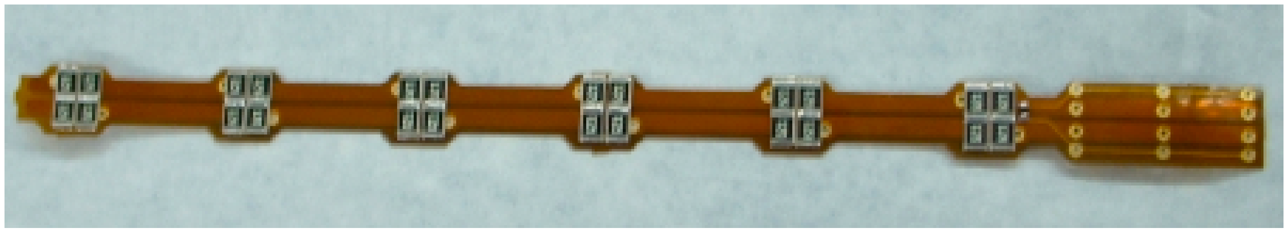


Needs matching between Optoboards and BOC:
0/1 discriminating threshold, delays

OptoLinks Tuning

- We observed that the light output and the channel to channel light spread depends significantly on the optoboard temperature, resulting in non-tunable channels below 5°C
- Increasing driving currents (VISet) does not fix the problem
- We observed that all optoboards are well behaving at ~20°C

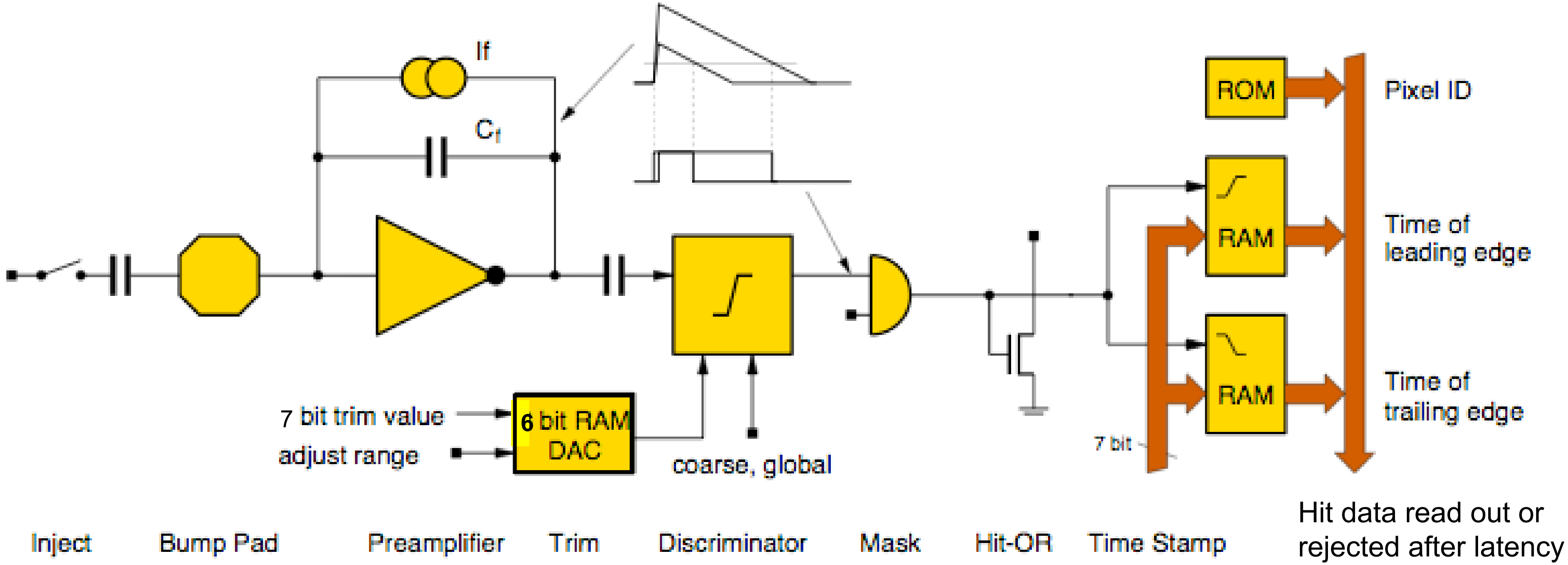
- Optoboards have been equipped with heaters
- Thermal management: PID controller for cooling loops and heaters
- Heaters prototype produced and tested



100% tunable channels in the System Test

Calibration Runs: Module tuning

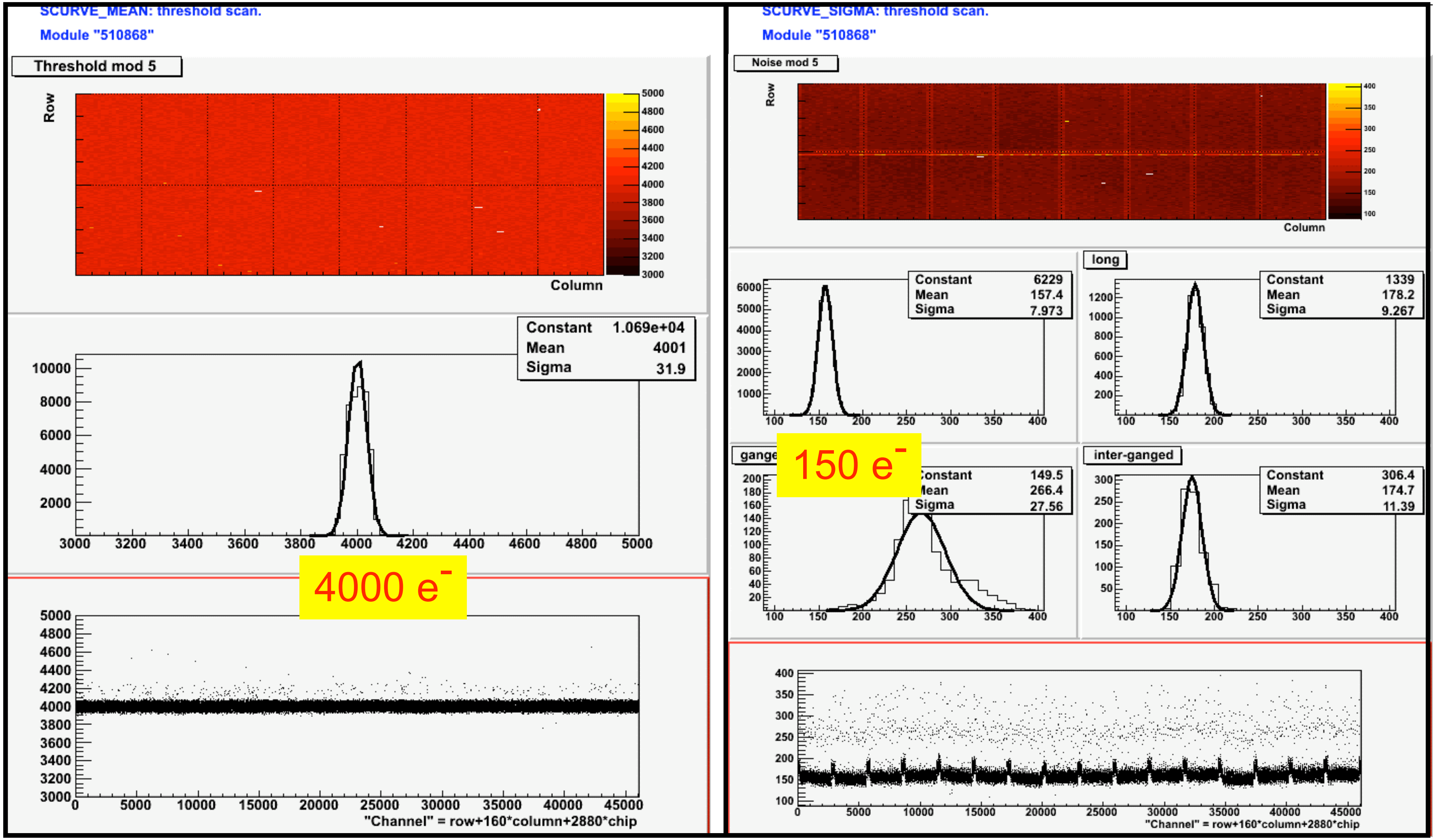
Front End Schematics



FE chip can be tuned using several DACs among which:

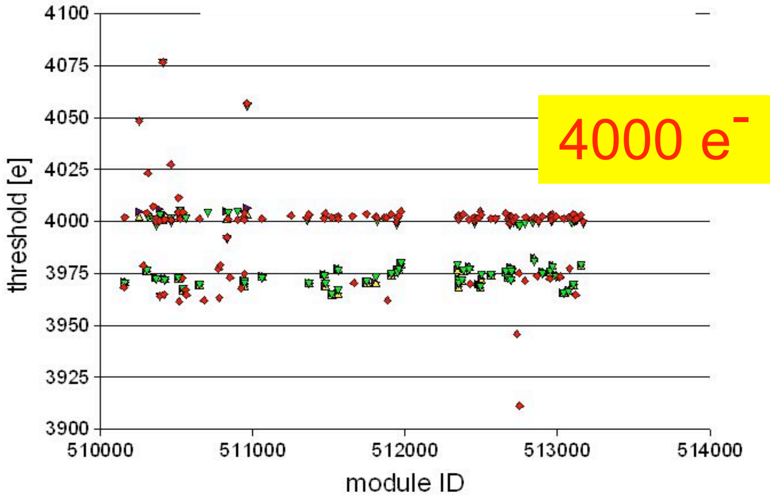
- Coarse and fine tune Discriminator Threshold
- PreAmp Feedback current: tune Time over Threshold (TOT)

Tuning Performance



Tuning Performance

Tuned Thresholds



MIP: ~ 20000 e^- in 250 um silicon

~ 13000 e^- including charge sharing

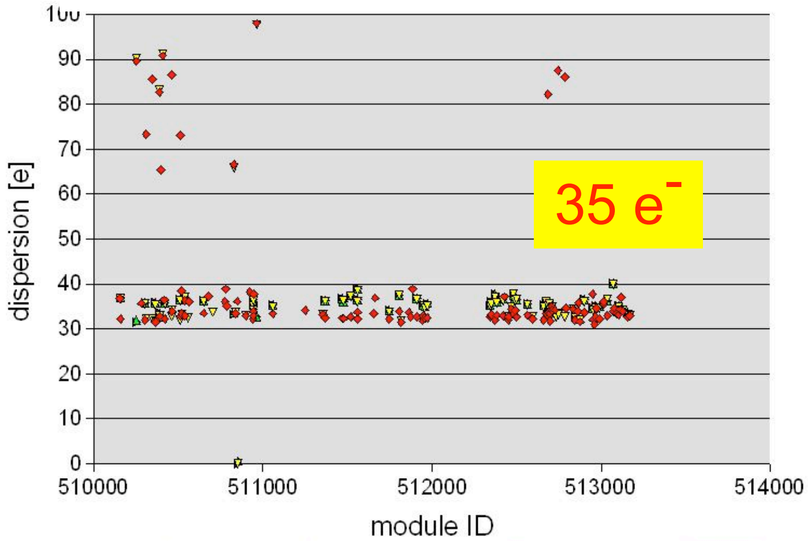
~ 6000 after 10 years at the LHC

Typical Noise ~ 150 e^-

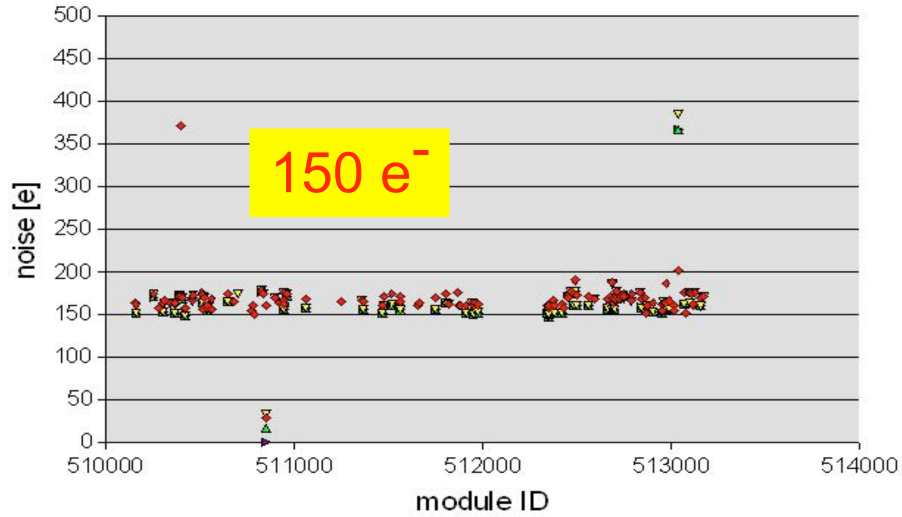
~ 200 e^- after 10 years at the LHC

S/N > 30 throughout the LHC lifetime

Tuned Thresholds dispersion

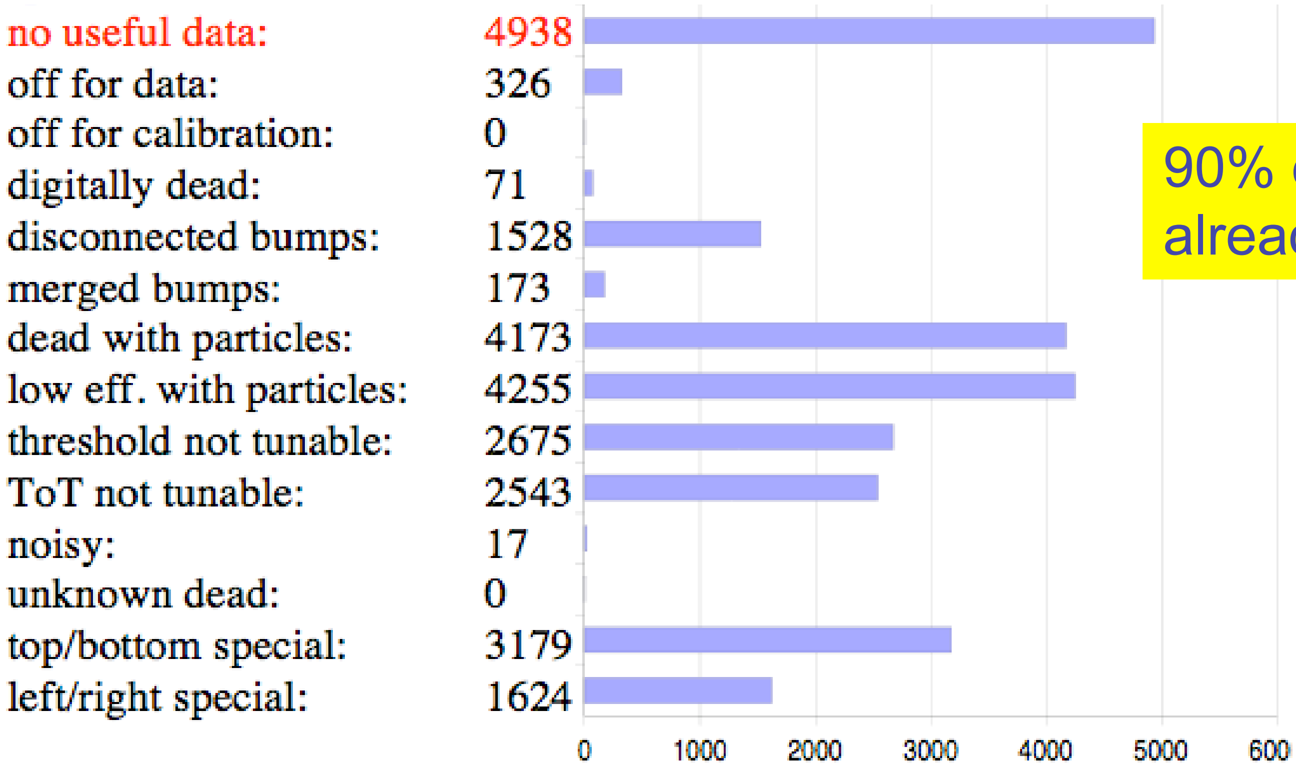


Noise



Random Trigger Data

"Special Pixels"



0.074%

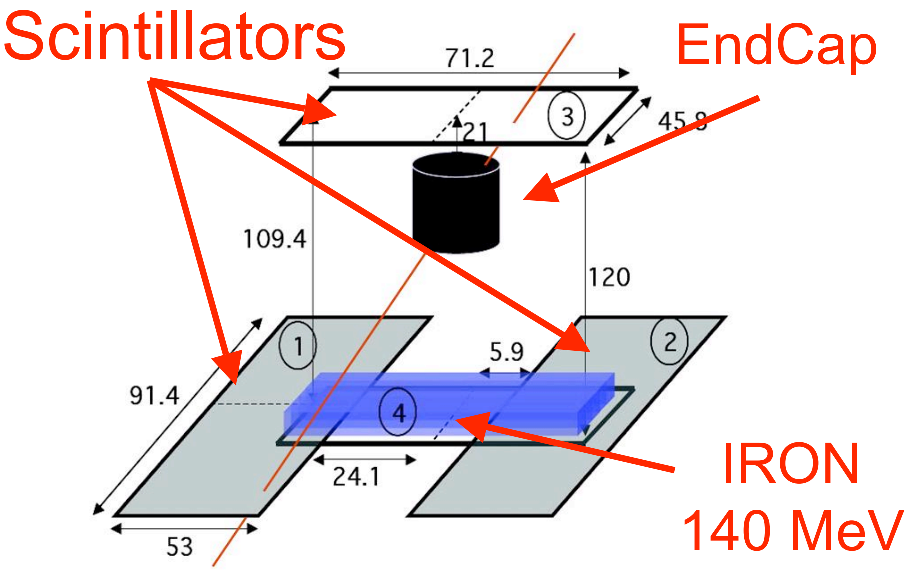
90% of "special pixels" were already spot during production

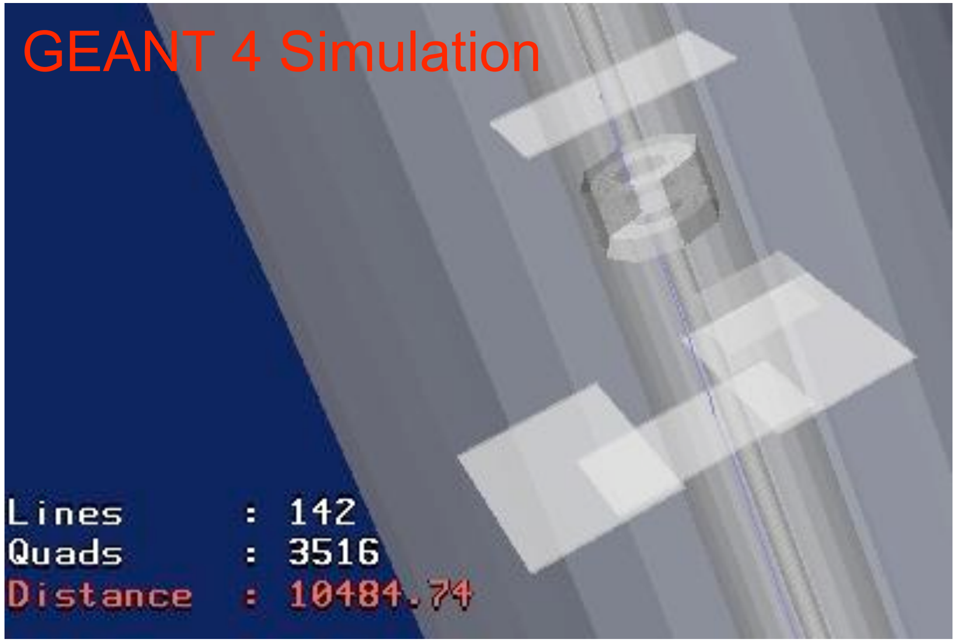
30 10^6 noise events analysed:

~ 2 10^{-7} averaged occupancy

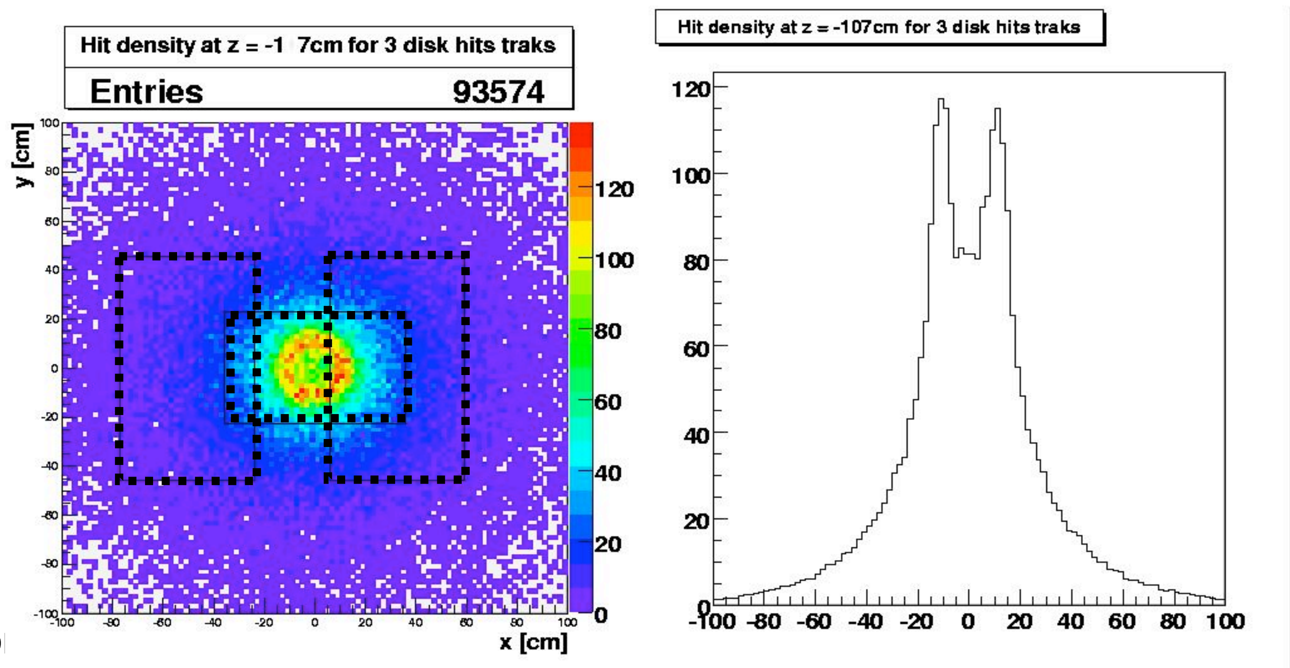
~ 90% of the noisy pixels are classified as "special"

Data Taking Runs: Setup

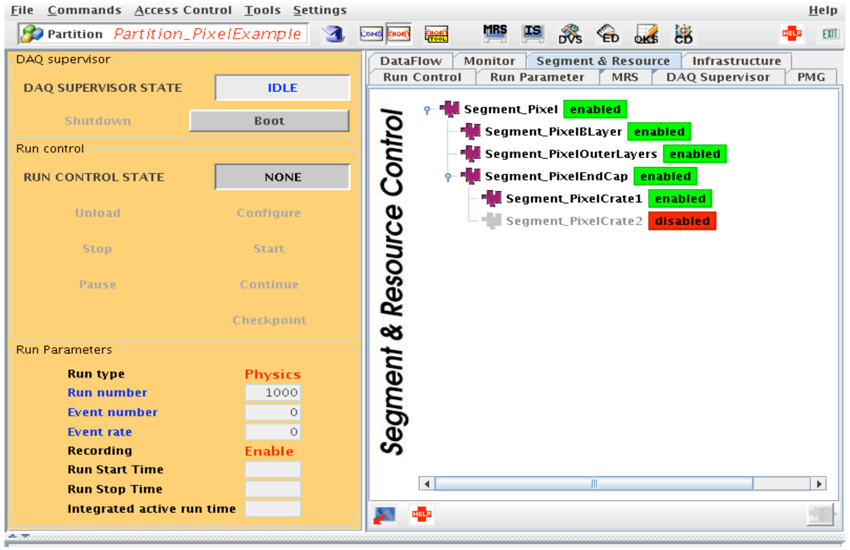




29 modules disabled out of 144
Measured count = 15.7 Hz Full simulation ~ 18 Hz ~10% reco efficiency



Data Taking Runs



Cosmics data taking represents a realistic test bench to test the complete data acquisition chain before lowering the detector in the pit.

The main Pixel Software application is the crate run controller developed in the framework of the common ATLAS DAQ infrastructure.

The detector is described as a hierarchy of segments and partitions
Each segment corresponds to a controller application each implementing a common set of state transition.

In particular the controllers managing VME crates are implemented in the ROD Crate DAQ (RCD) framework, providing interfaces to the DAQ software infrastructure (configuration DB, messages, OH…)

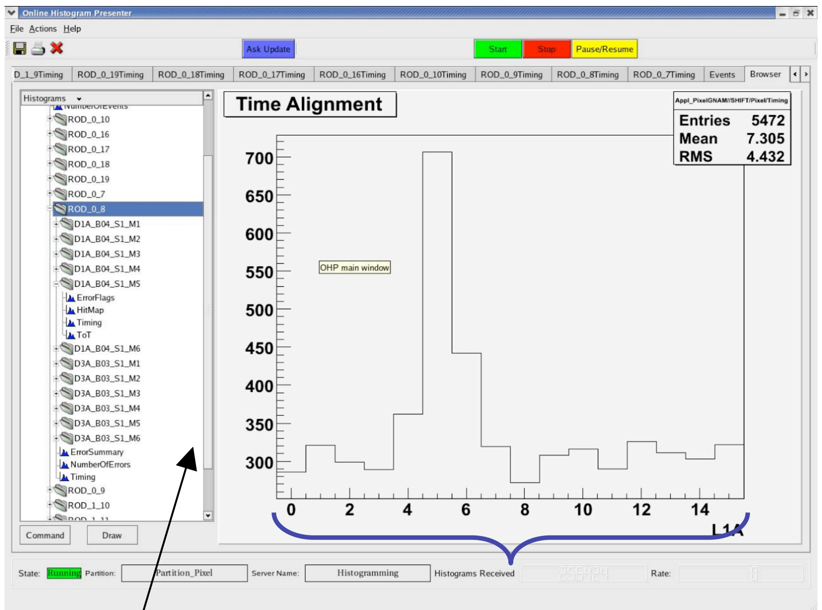
The detector specific developers must provide plugins to control the HW components (RODs, TIM…) and the RCD propagates the state transitions to the plugins

First Evidence of Cosmics…

Modules Timing

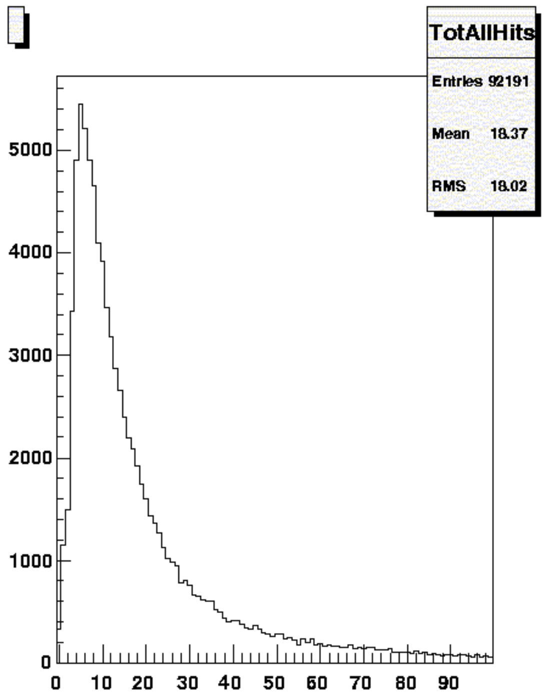
Random Triggers

Cosmics Triggers

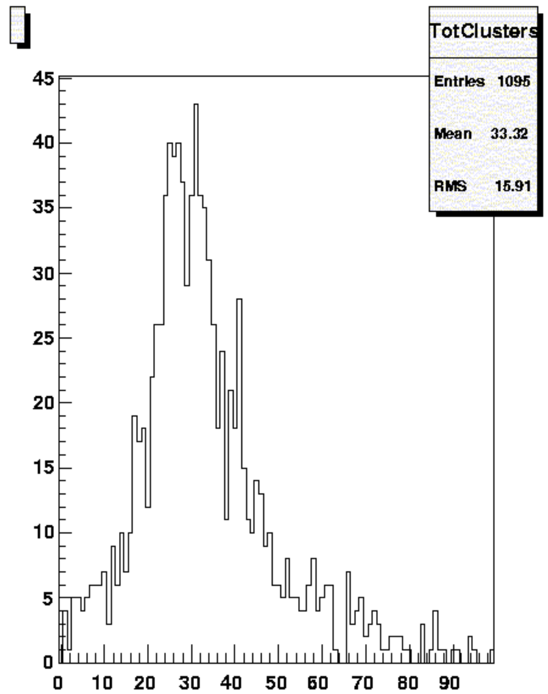


16 consecutive L1A trigger

Online monitoring

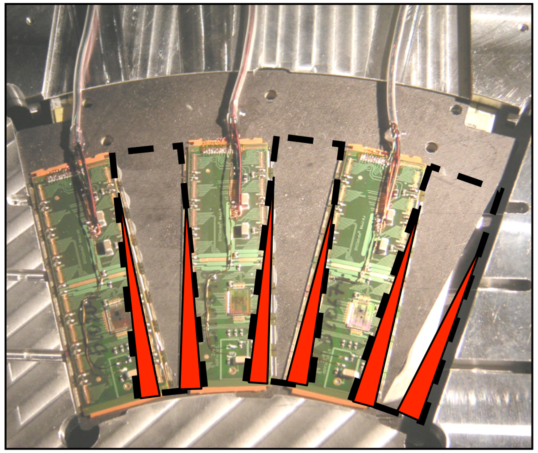


TOT units

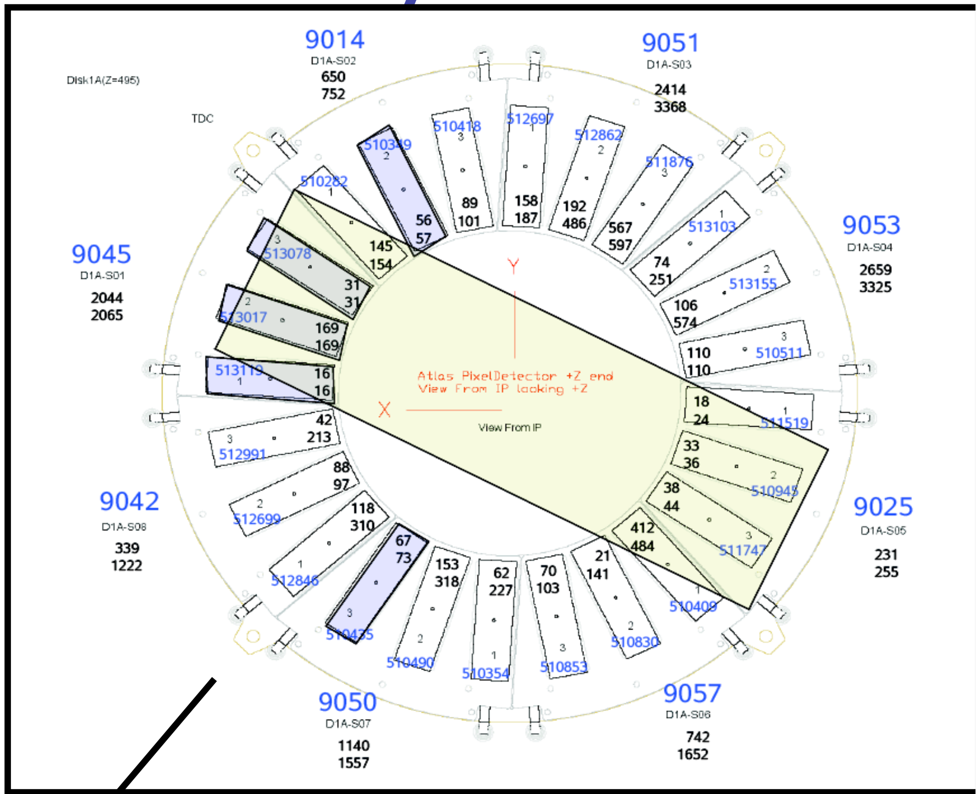


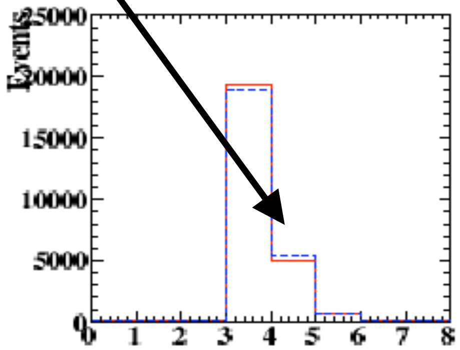
TOT units

Cosmics Data Analysis

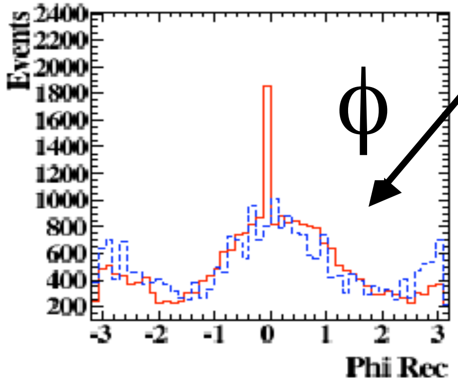


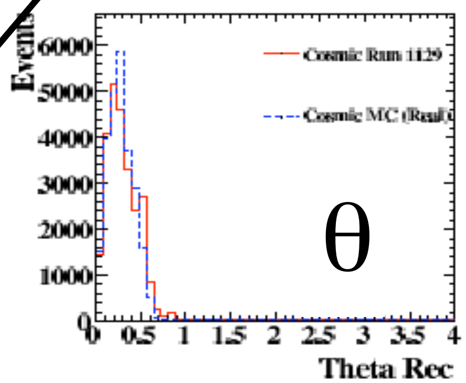
Overlap regions





#clusters on track





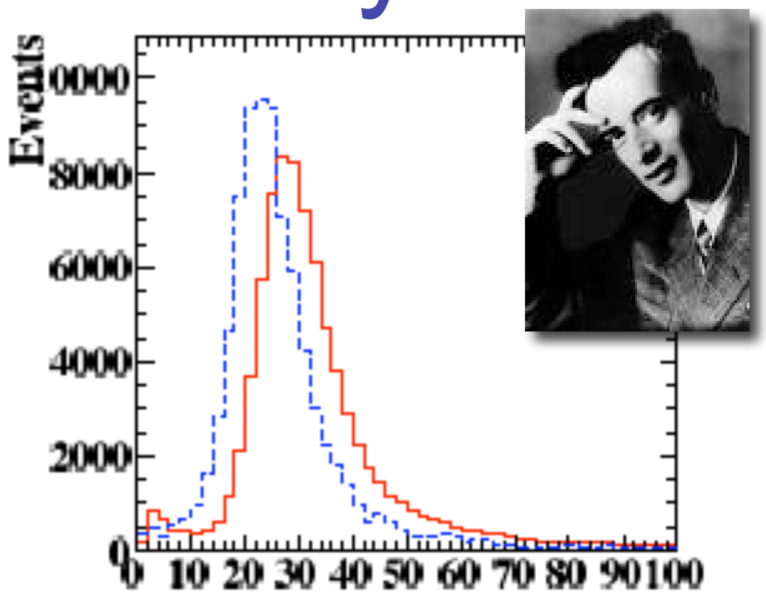
MC

Data

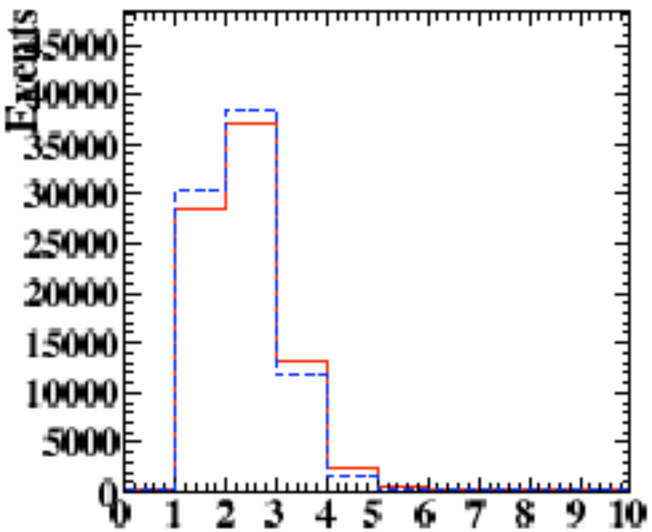
Cosmics Data Analysis

TOT distribution:
MC tuned on Test Beam
Correct shape: TOT calibration OK
Shift under investigation probably
different threshold

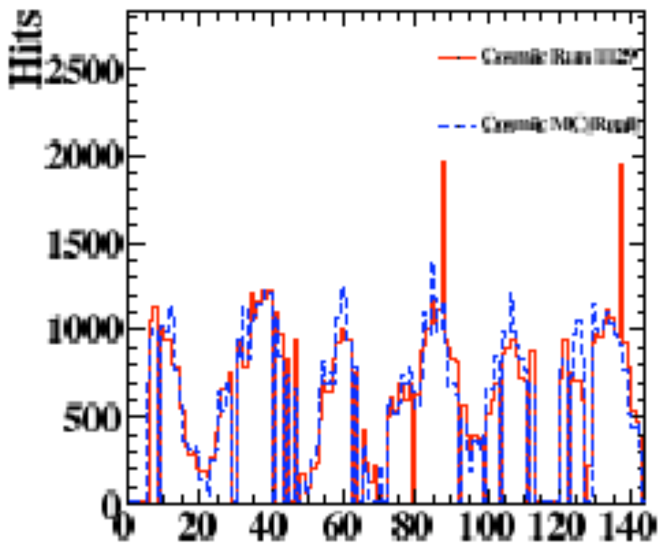
MC
Data



TOT charge on track

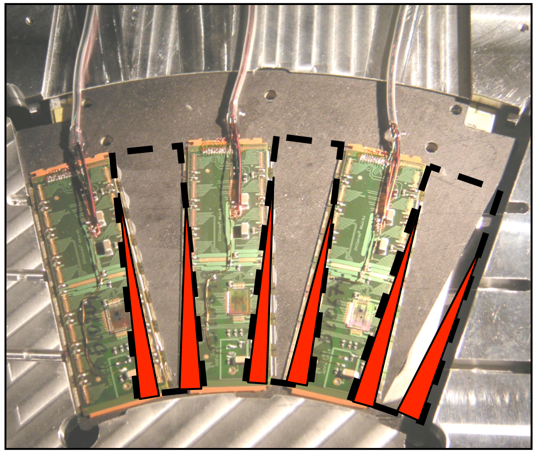


Cluster width on track



Hits on track vs Module

First Alignment Studies



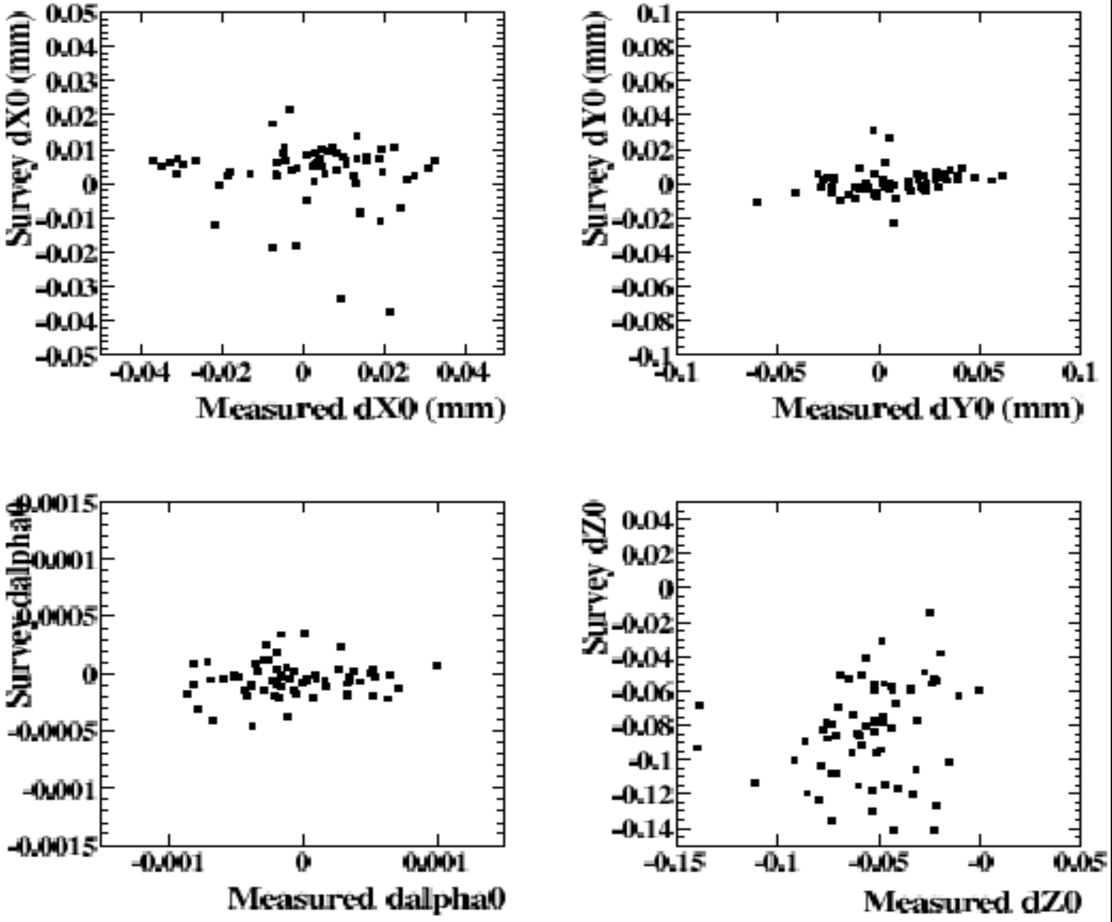
Use the overlap between adjacent modules
to derive the relative alignment between modules.

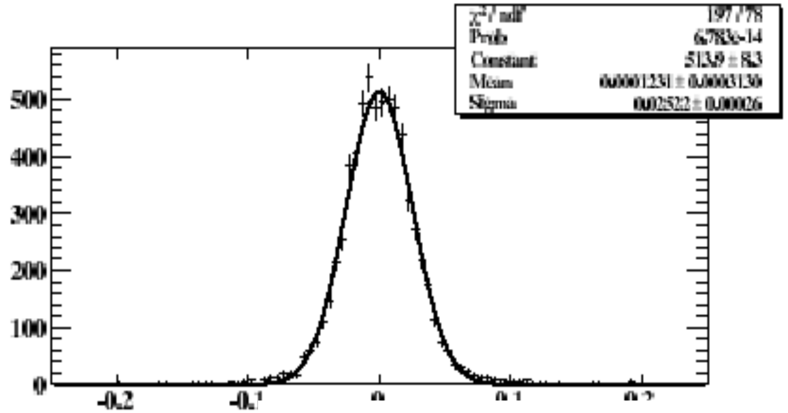
There are > 10% overlap between adjacent modules
with dz = 4.2 mm. The extrapolation in z produces a negligible error
(<1μm in x and < 5 μm in y)

The module is described as a rigid body in the disk plane:
- Shift in X_0 in local X
- Shift in Y_0 in local Y
- Shift in Z_0 in local Z
- Rotation α_0 along Z axis

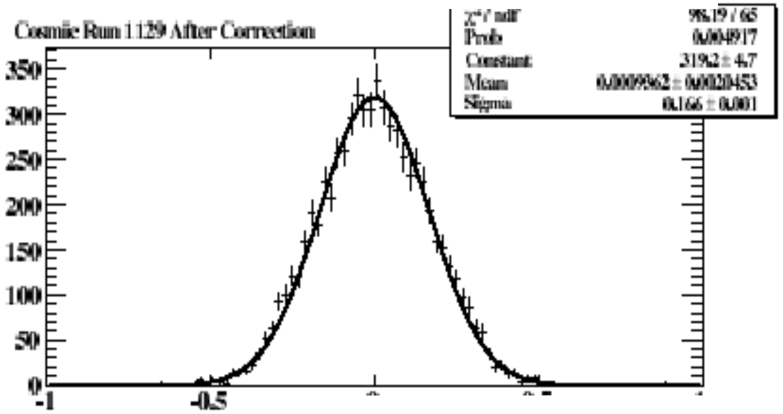
First Alignment Studies

Survey Alignment vs Cosmics Alignment
For modules with more than 50 hits in the overlapping regions





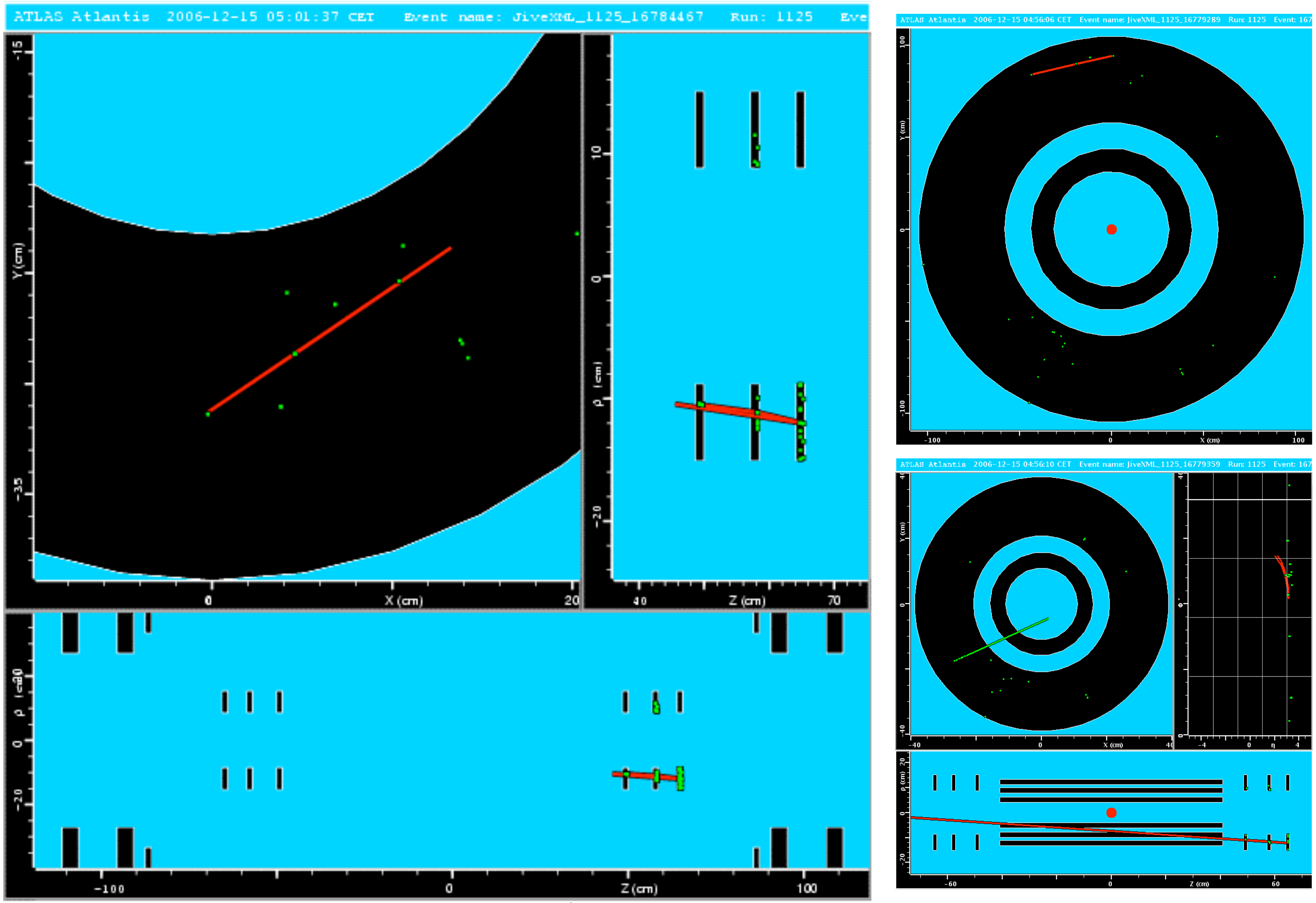
Residuals dLocX



Residuals dLocY

Resolution
X : 17.8 μm (MC 15.8 μm)
Y : 117 μm (MC 117 μm)

ATLANTIS event display



Conclusions

System Test:

- The system test on 10% of the detector is completed
- Intense debug has been done on many different items giving precious feed back
- DCS, calibration and data taking software are well advanced
- The preliminary studies on cosmics data confirm MC expectations

The dedicated effort of many persons made the system test a SUCCESS

Detector status:

- Integration is well advanced
- EndCaps and Barrels are mounted on the beam pipe
- Next steps: service quarter panels integration and connectivity test

We will be ready to lower the detector in early June

BACKUP

40 Mbit optolink tuning

Phase space:

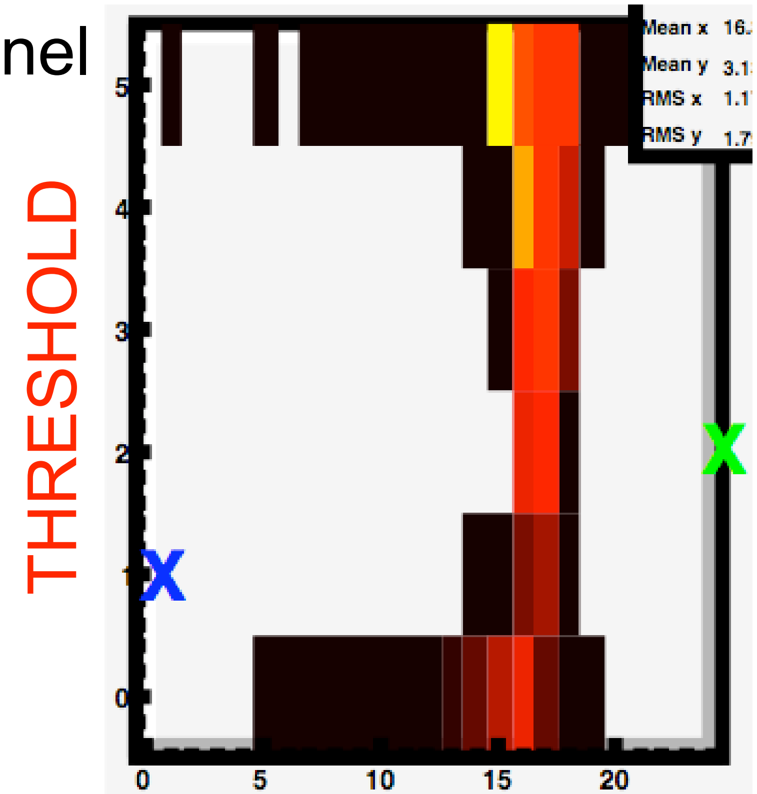
[VISet]x[Threshold]x[RXdelay]x[MSR]x[temperature]

Procedure:

•THR_RXdel_scan at different VISet -> find best VISet

VISet one value /optoboard looking at EFR area

•Find the best THR/Rxdel for each channel



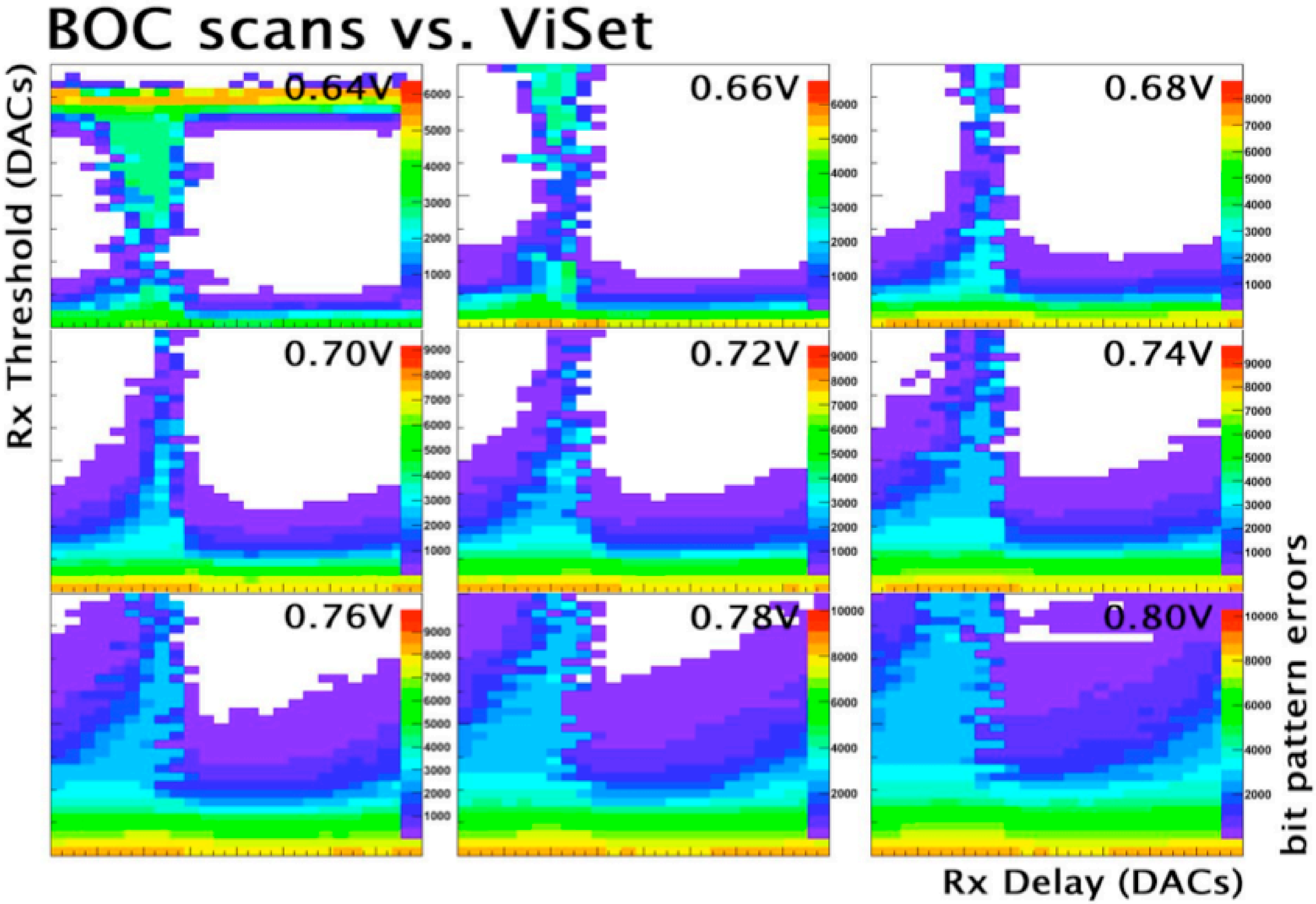
Two scanning engines:

•Pseudo-Random

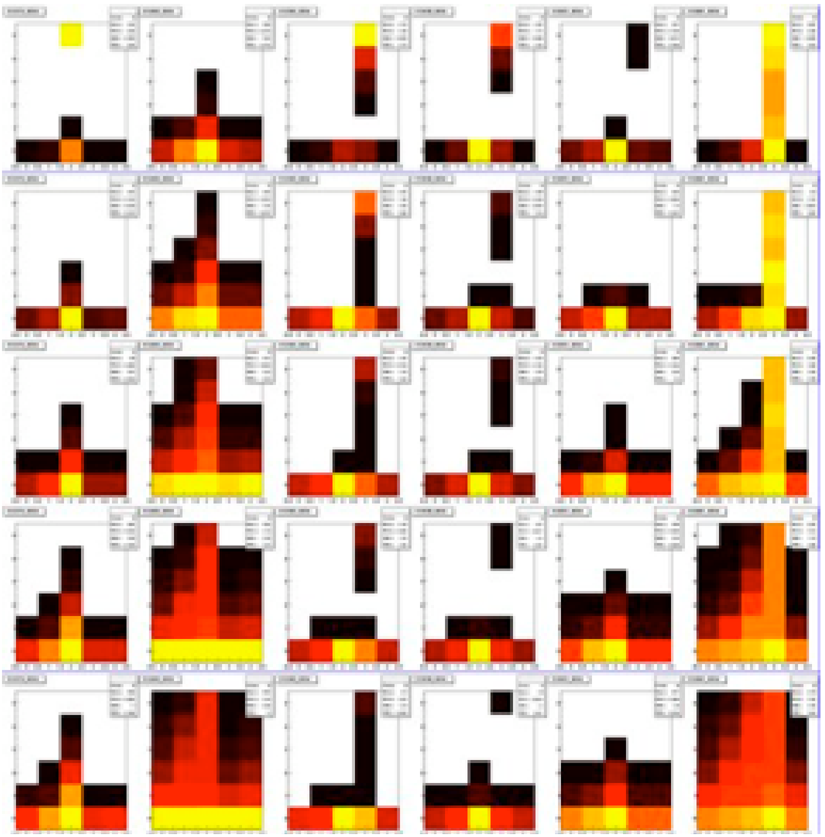
(sensitive to slow turn on effects)

•Periodic

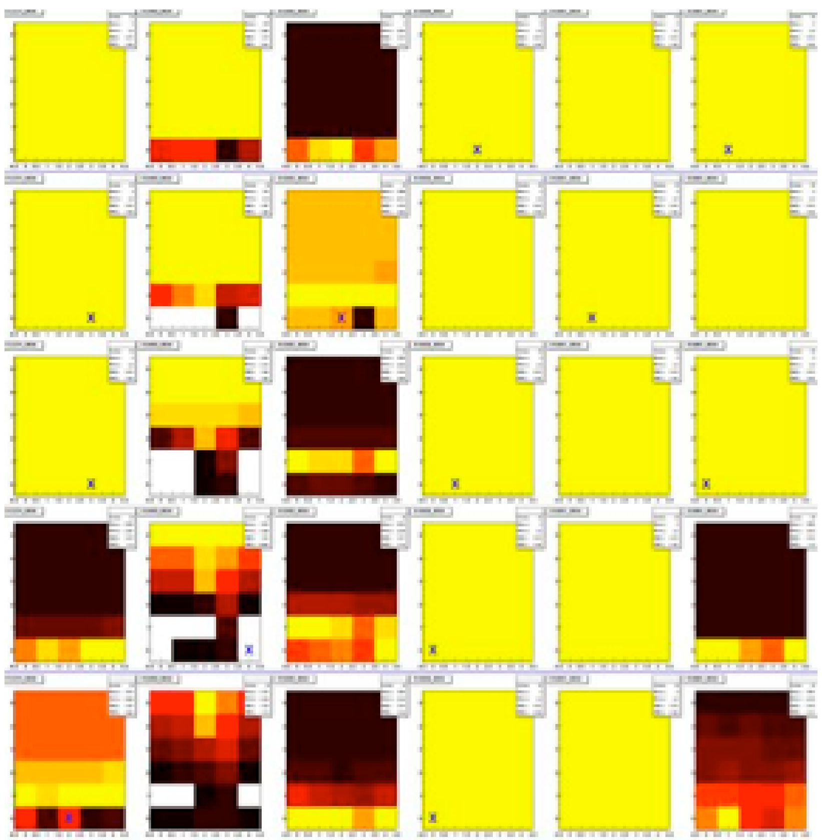
VISet BER dependence



Temperature dependence

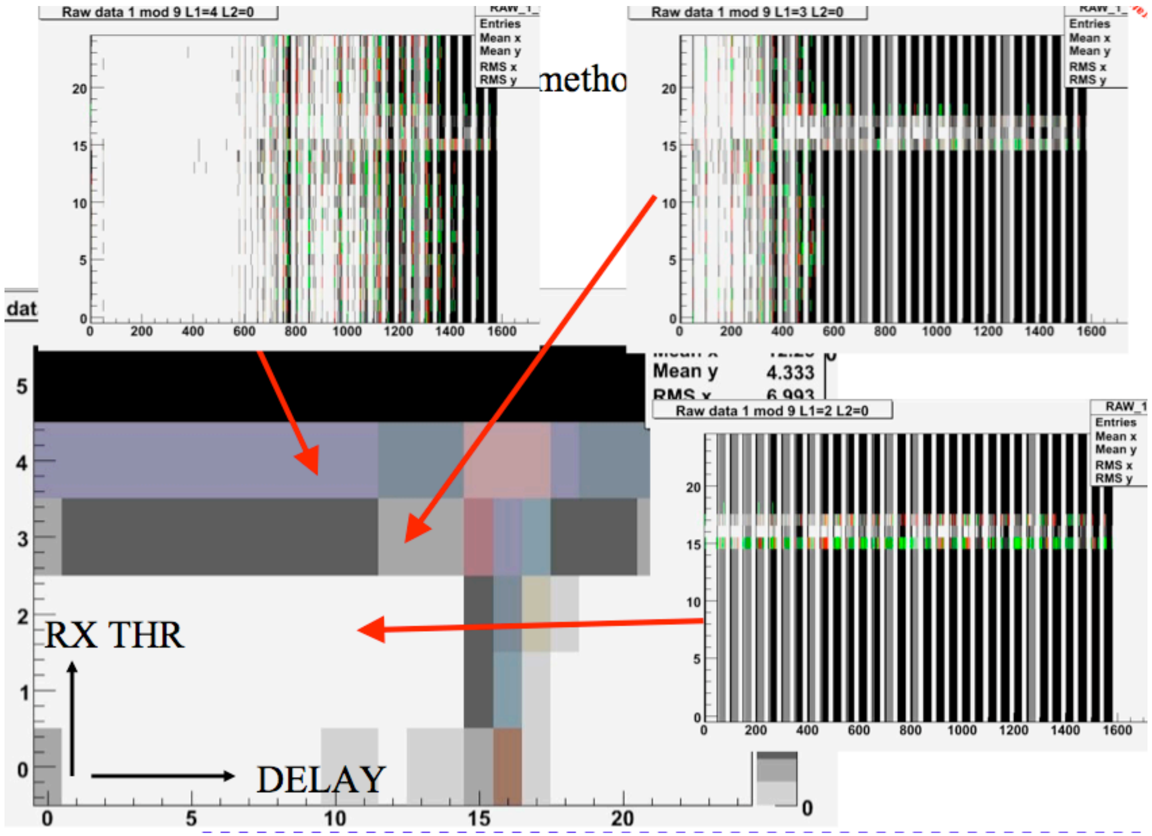


T = + 10 C



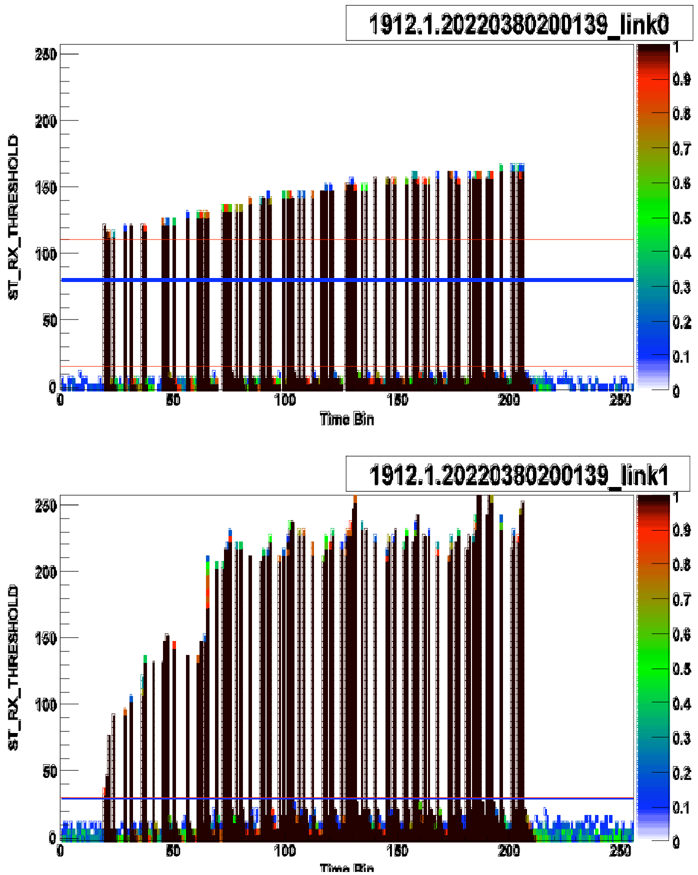
T = -10 C

VCSel Slow Turn On



Transmission BER

RX amplitude



80 Mbit optolink tuning

Phase space:

[VISet]x[Threshold]x[RXdelay]x[V0]x[MSR]x[temperature]

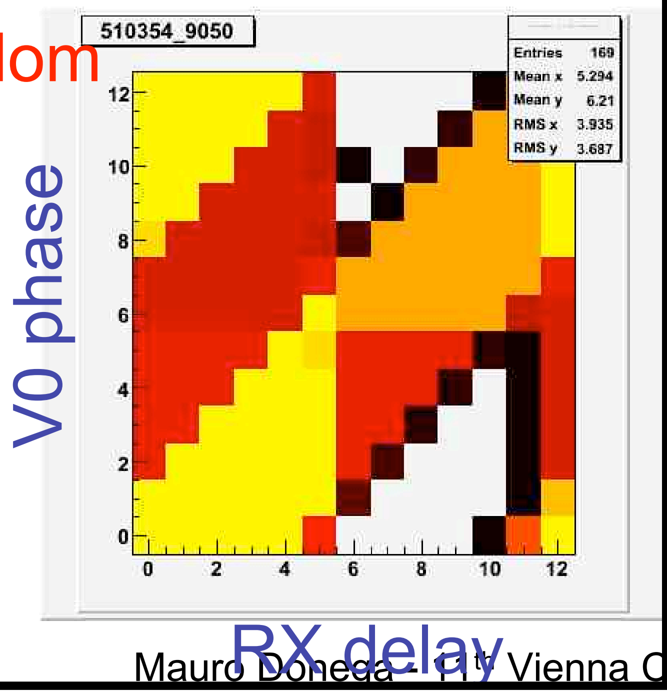
Procedure:

•Fix best VISet/threshold (40 Mbit tuning)

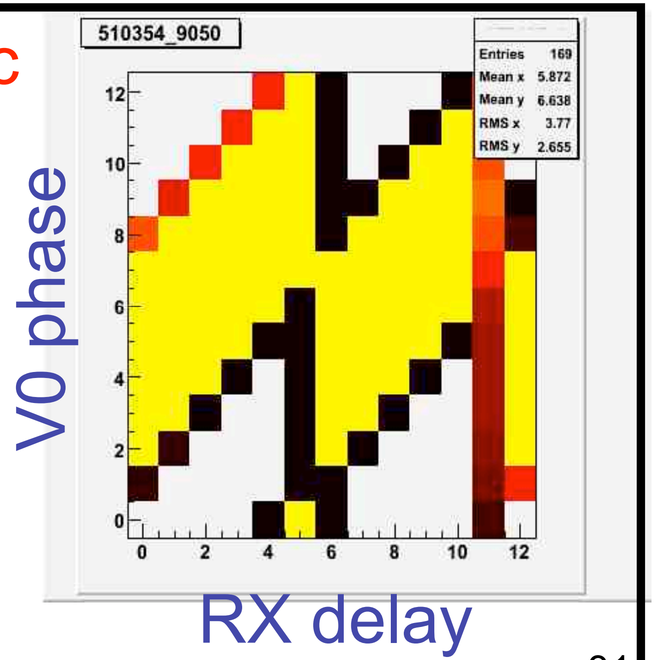
•Scan V0_RXdelay find the optimal point

•V0=0 is typically the optimal value (V0 is one value /BOC)

Pseudo-random



Periodic



Example of problematic channels at 80 Mbit