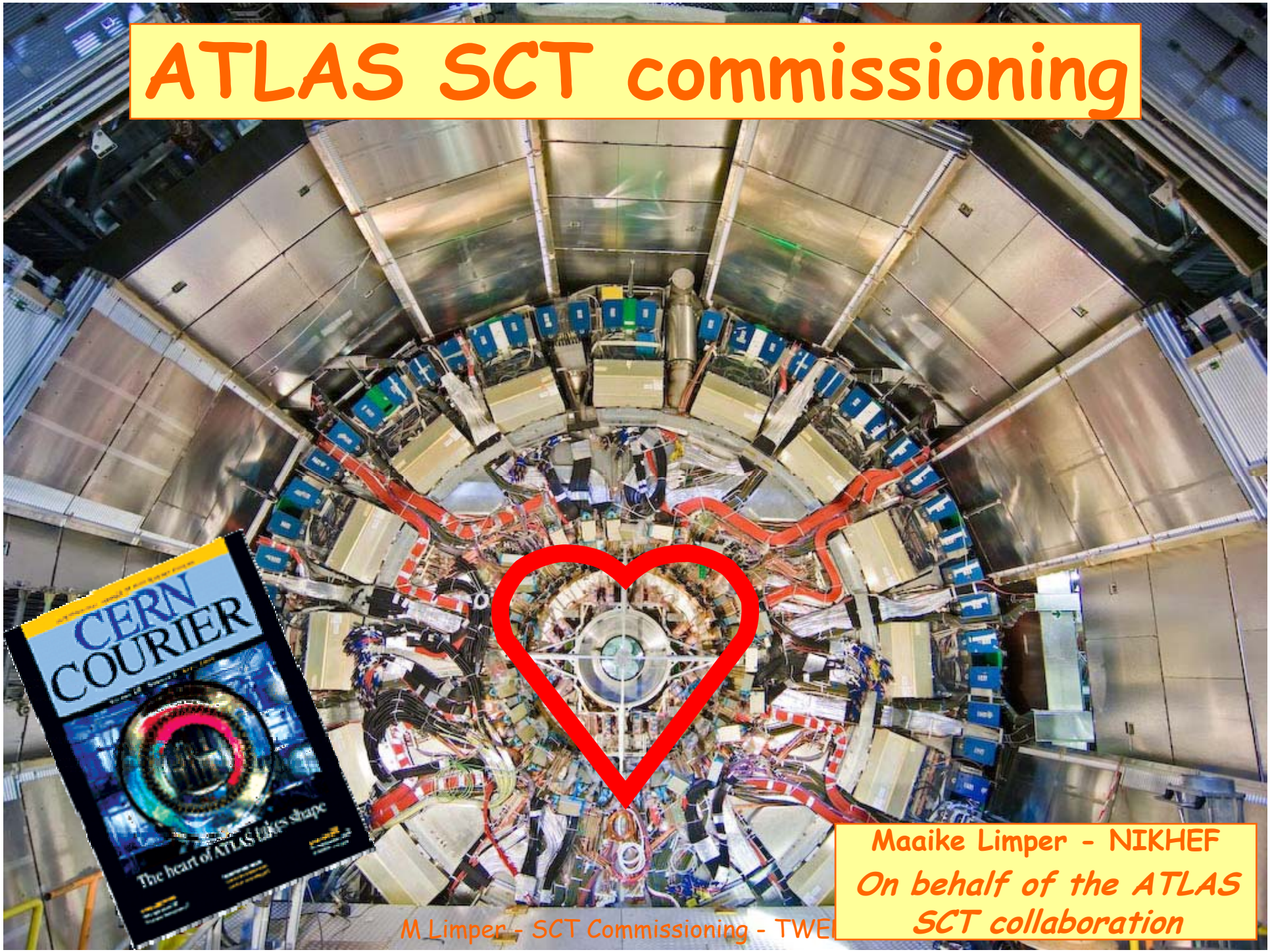
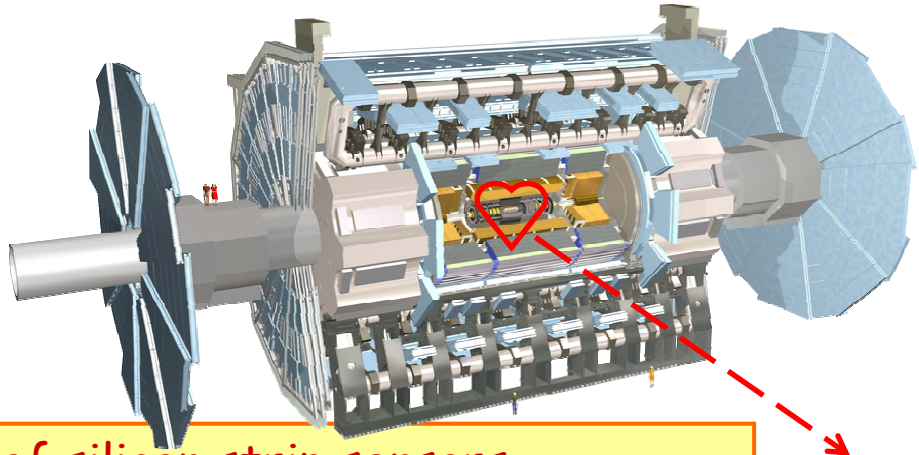
ATLAS SCT commissioning

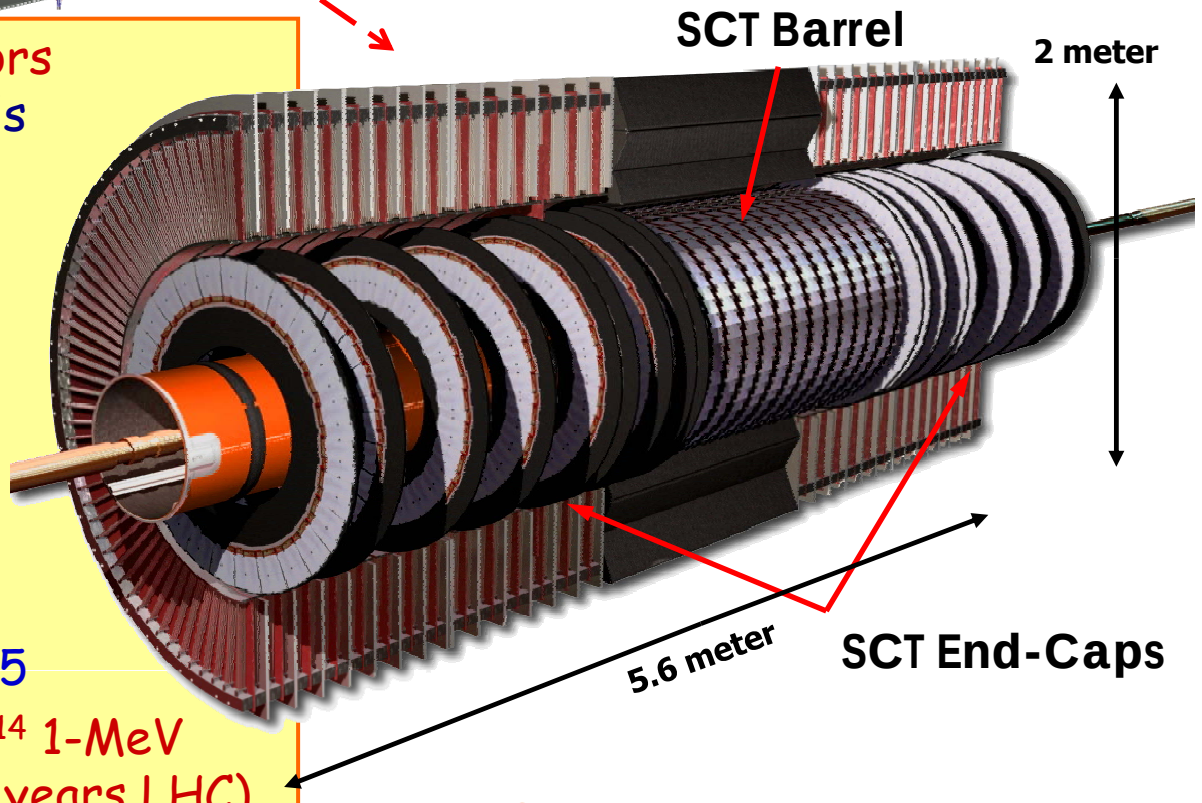


Maaike Limper - NIKHEF
On behalf of the ATLAS SCT collaboration

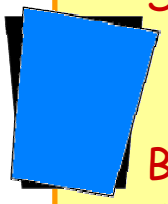
ATLAS Semi-Conductor Tracker



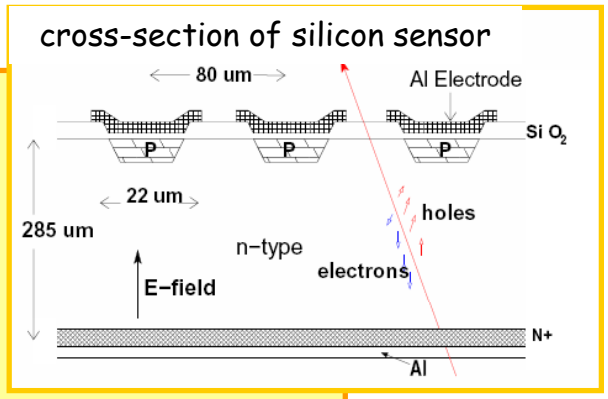
- 61 m^2 of silicon strip sensors
- 6.2 million readout channels
- Barrel
  - 4 cylindrical layers
  - 2112 modules
  - coverage $0<|\eta|<1.1\text{-}1.4$
- End-Caps
  - 18 discs
  - 1976 modules
  - coverage $1.1\text{-}1.4<|\eta|<2.5$
- Radiation hardness : 2×10^{14} 1-MeV neutron equivalent·cm^{-2} (10 years LHC)



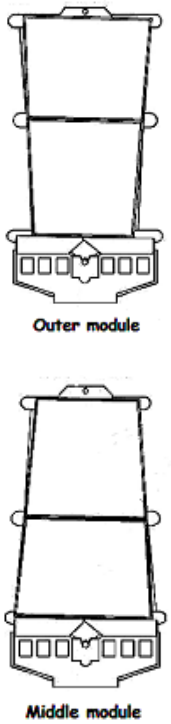
SCT modules

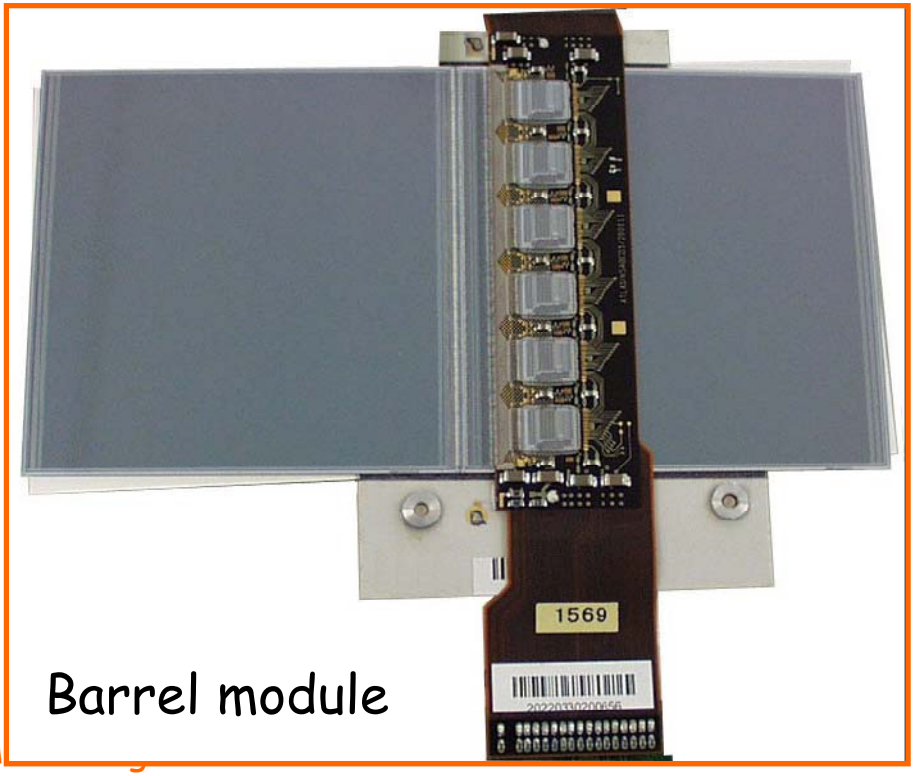


- Single-sided back-to-back p-on-n sensors
  - 40 mrad stereo-angle
  - 1536 channels per module (768 per side)
- Binary read-out
- Optical communication
- Up to 500 Volt bias voltage
- Power consumption : 5.6 W/module (10 W after 10 years of LHC)
- Sensors cooled at –10°C to improve lifetime



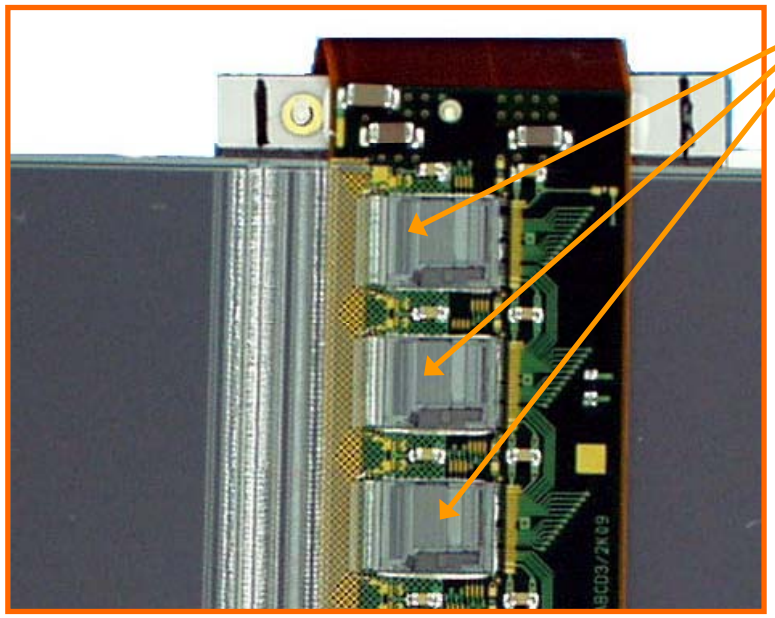
Endcap inner module





Barrel module

SCT modules



ABCD3TA chips

- **12 ABCD3TA chips per module (6 per side)**
- Each chip is wirebonded to 128 strips
- Strip signal is amplified and converted to **digital signal** (threshold for each channel)
- **Charge injection circuity** for calibration
- **Pipeline memory** stores hits for 132 bunch crossings

Optical communication with module via **opto-plugin:**

- One **p-i-n diode receives Timing, Trigger & Control**
  - TTC from neighbouring module in case of broken link
- **Two VCSELs* return data from each side of module**
  - broken VCSEL -> both side read-out through 1 VCSEL

DORIC4A chip
decodes and transmits signals from p-i-n to ABCD3TA chip

VDC chip
drives 2 VCSEL channels

Module test stages

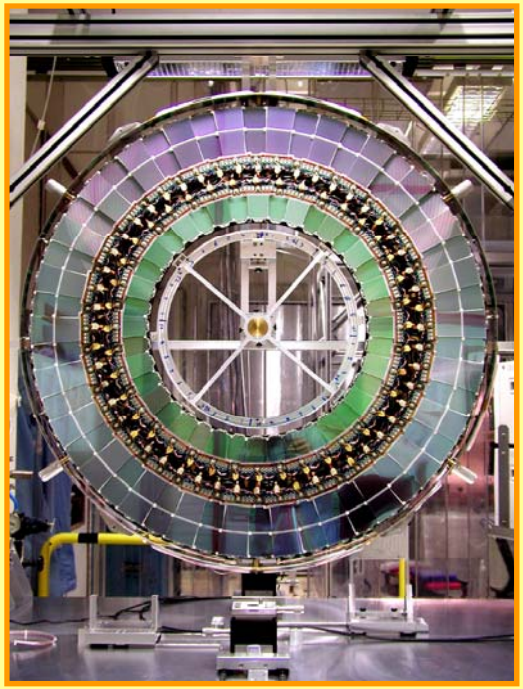
Modules are fully tested after:

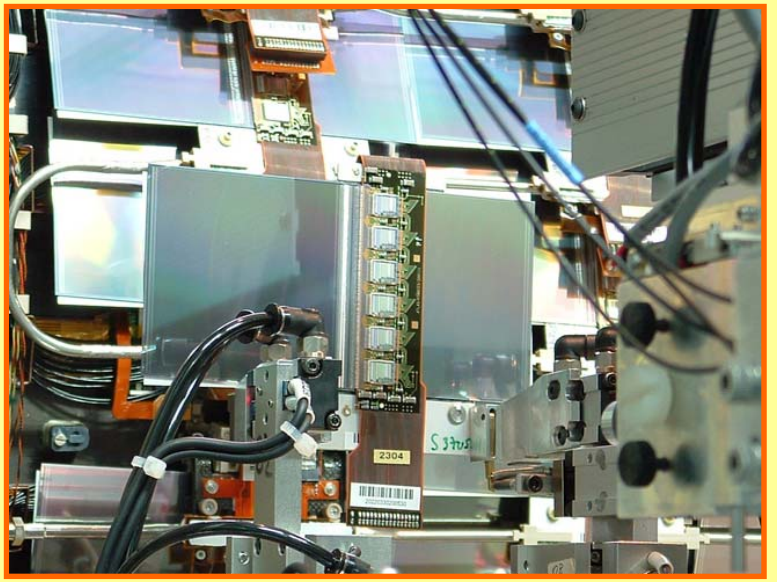
1. Production (at module assembly sites)
2. Reception at macro-assembly sites
3. Macro-assembly
4. Reception at CERN
5. Insertion in ATLAS detector (at CERN)

SCT assembly

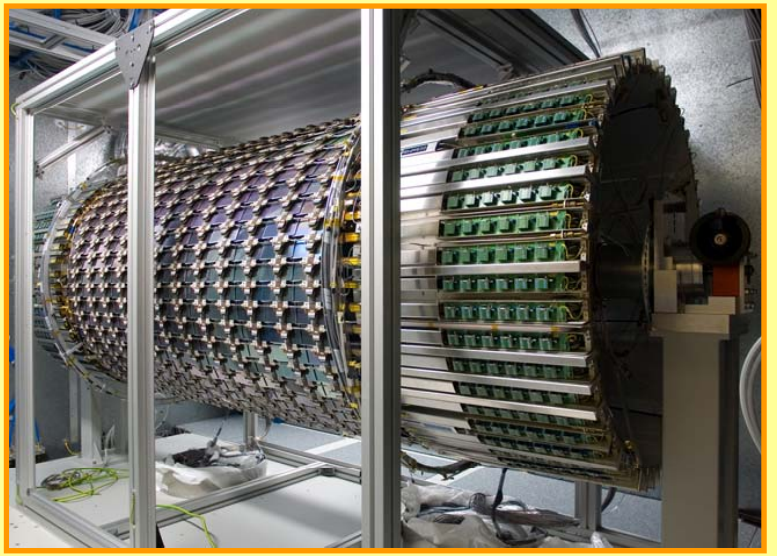
SCT modules were produced in 11 production sites and shipped to 3 assembly sites

End-Caps assembled in **NIKHEF** and **Liverpool**





All 4 barrels assembled in Oxford



At assembly mount and test services:

- cooling lines
- low mass tapes (power supply)
- Optical fibers
- FSI fibers (alignment)

Mount modules

Cool, power and test all modules in barrel/endcap at assembly site

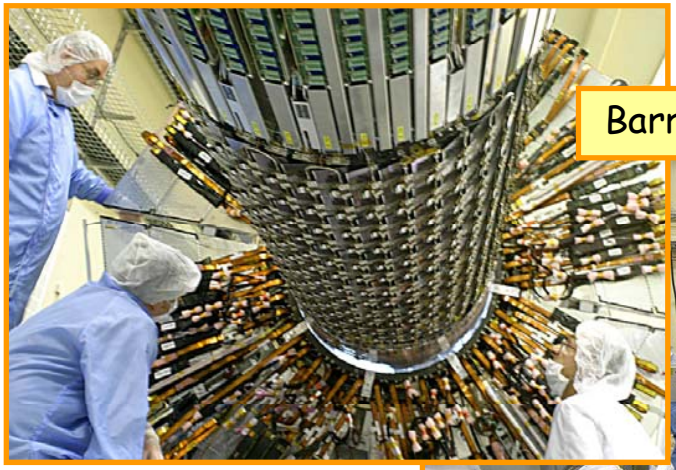
CERN Surface Tests

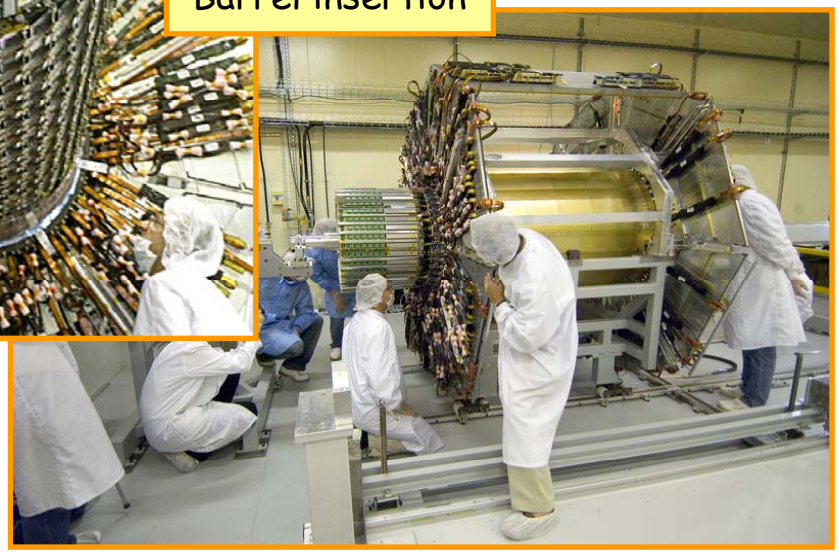
SCT Barrel

- first barrel arrived in january 2005
- last barrel arrived in august 2005
- 4 barrels assembled into one detector at CERN, september 2005

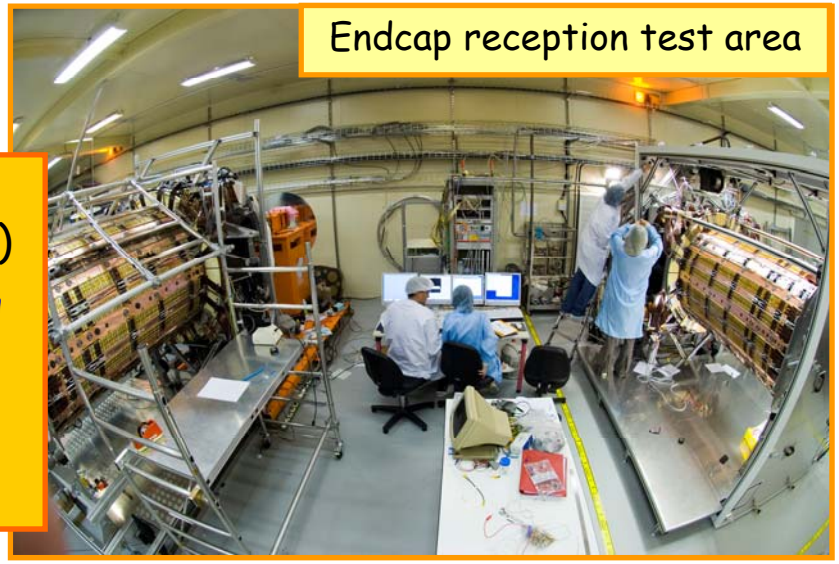
SCT endcaps

- endcap C arrived in february 2006
- endcap A arrived in april 2006





Barrel insertion



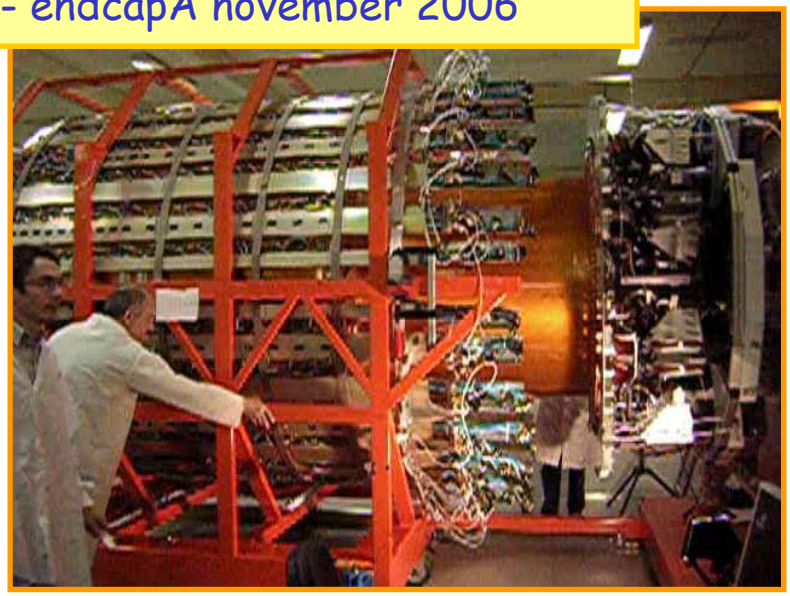
Endcap reception test area

The SCT barrel and endcaps were tested extensively in the the surface reception area (SR1)

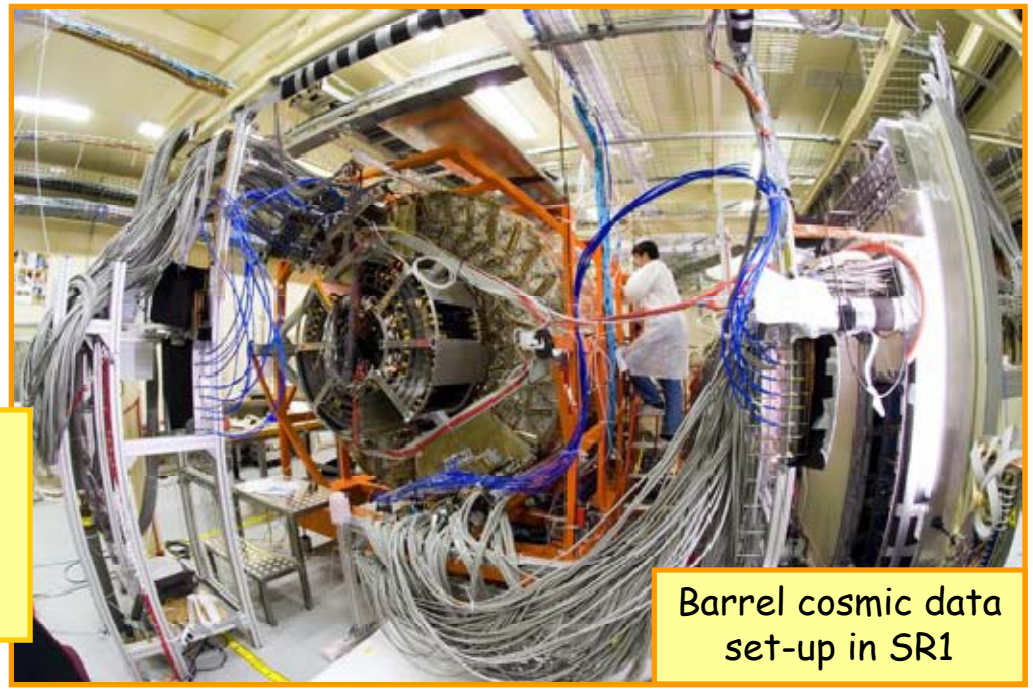
- C3F8 cooling setup similar to final ATLAS cooling
- All 4088 modules, cooled, powered and read-out
- DCS and DAQ software tested
- Prepared for integration with TRT

SCT+TRT integration

SCT+TRT endcaps integration:
- endcapC september 2006
- endcapA november 2006



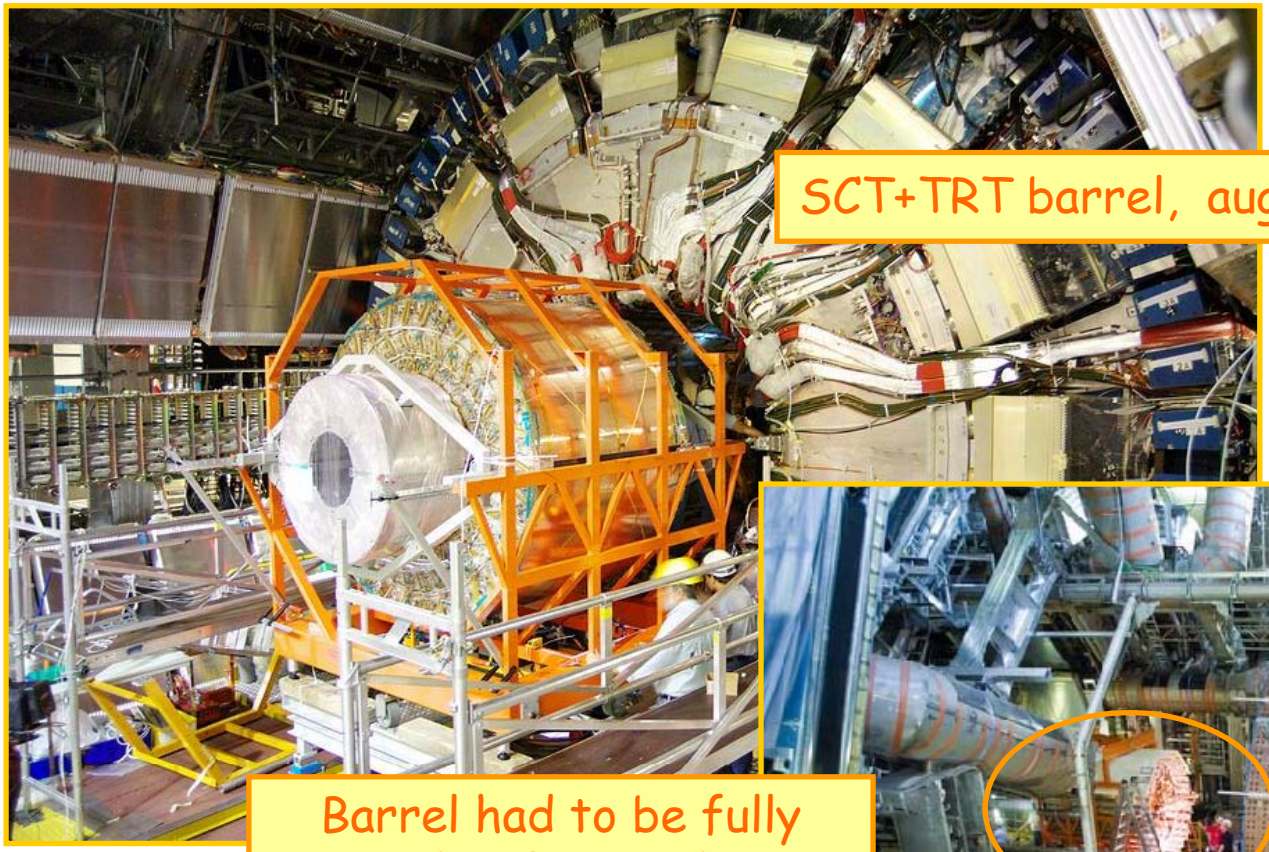
SCT + TRT barrel integration: february 2006



Barrel cosmic data set-up in SR1

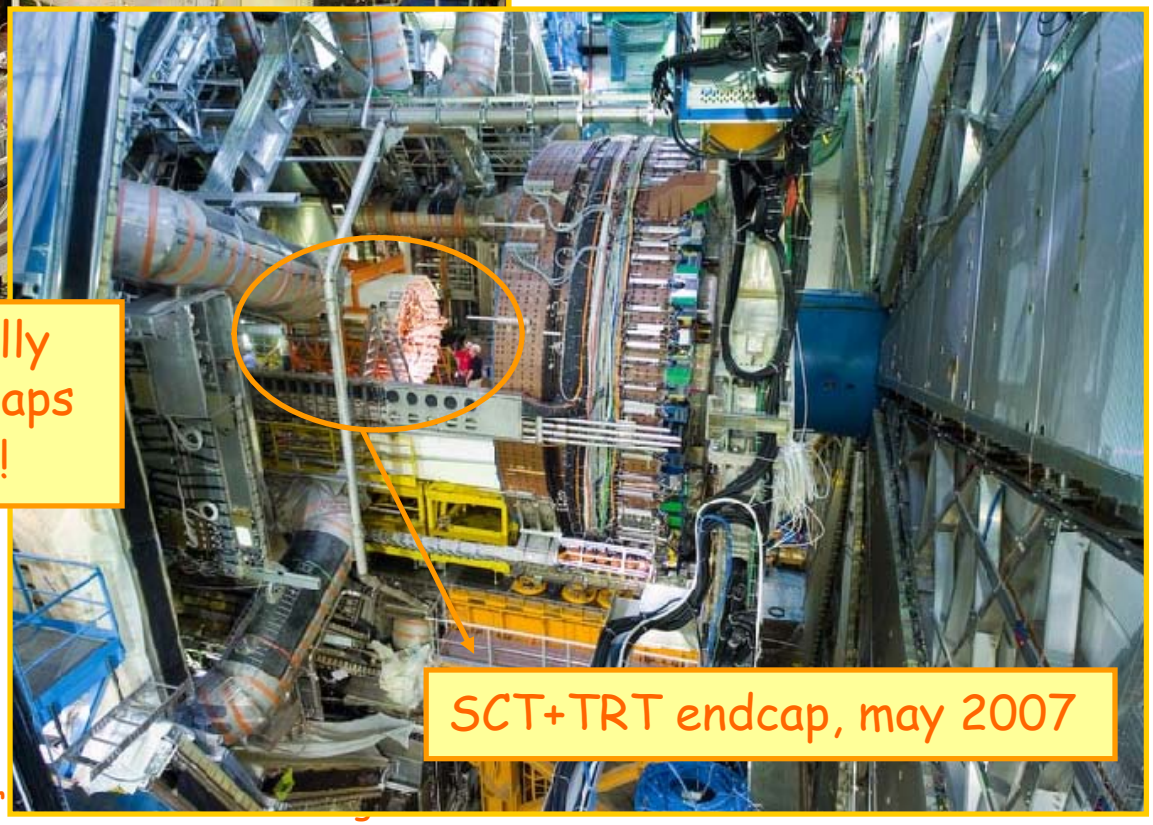
Cosmic data was taken at SR1 for the combined barrel and one of the combined endcaps, **see talk by H. Sandaker**

Installation in the ATLAS cavern



SCT+TRT barrel, august 2006

Barrel had to be fully tested before end-caps could be installed!



SCT+TRT endcap, may 2007

Final services

SCT detectors in cavern are using their final services as they will be used in the next years of LHC running!

- **Power supplies**
  - 88 power supply crates
  - HV and LV cards for 4088 channels
  - **Power cables for 4088 channels**
- **Off-detector electronics for optical communication:**
  - BOC Back-Of-Crate
    - Send and receives optical signals of up to 48 modules
    - Connect to BOCs:
      - 12 fibers in one ribbon
      - **354 Tx ribbons**
      - **708 Rx ribbons**
  - ROD – ReadOut Drive
    - generates command to BOC
    - interpretates data from BOC
  - 9 SBCs – Single Board Computer
    - Analyse test results
  - TIMs, Timing-Interval-Module
- **Cooling system:**
  - Evaporative cooling system using C3F8
  - Compressors shared with Pixel detector
  - Back pressure regulator to control temperature
- **DCS system**
  - Monitor temperatures, PS values, cooling
  - Interlocks

Commissioning so far

SCT Barrel commissioning

- Electric and optical connections tests finished:
  - optical connections after occasional cleaning all ok
  - low P-I-N current on many channels
  - where neccesary repairs were made for LMT connections
- March '07, all SCT Barrel modules were re-tested with evaporative cooling on
  - Module temperatures
  - Gain measurements
  - Noise occupancy
- Final versions of the DAQ and DCS software were also commissioned
- **Cooling problems prevented further testing!**

SCT End-caps commissioning

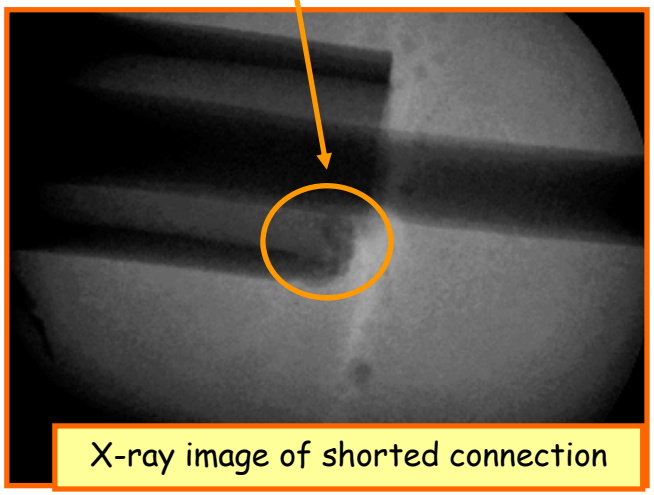
- May '07, both endcaps installed in pit
- July '07, started connections tests
- Electric and optical connections tested without cooling, "Dicing with Death"

Cooling problems

- The SCT is cooled down by an evaporative cooling system using C3F8 that has to remove up to 40kW of heat from the system
- Overall good performance of the cooling system for the barrel test in the ATLAS cavern, until...

Problem in the heaters:

- Heaters in the return lines evaporate and heat the remaining liquid above the cavern dew point
- **Short** in connection to heater element caused heater failure



X-ray image of shorted connection

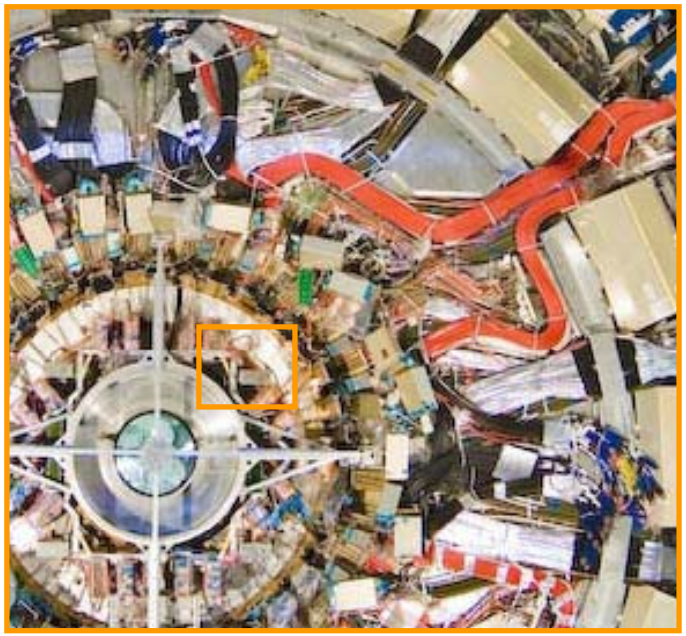
- **First fault in February**. The union of a heater blowed-up after few hours of operation.
- All non conformities (geometrical and permeability to moisture) found and corrected.
- **Another union failed on May 7** while testing Barrel SCT in the pit. This was a "golden" union, not a single non conformity and was in operation since 5 days.

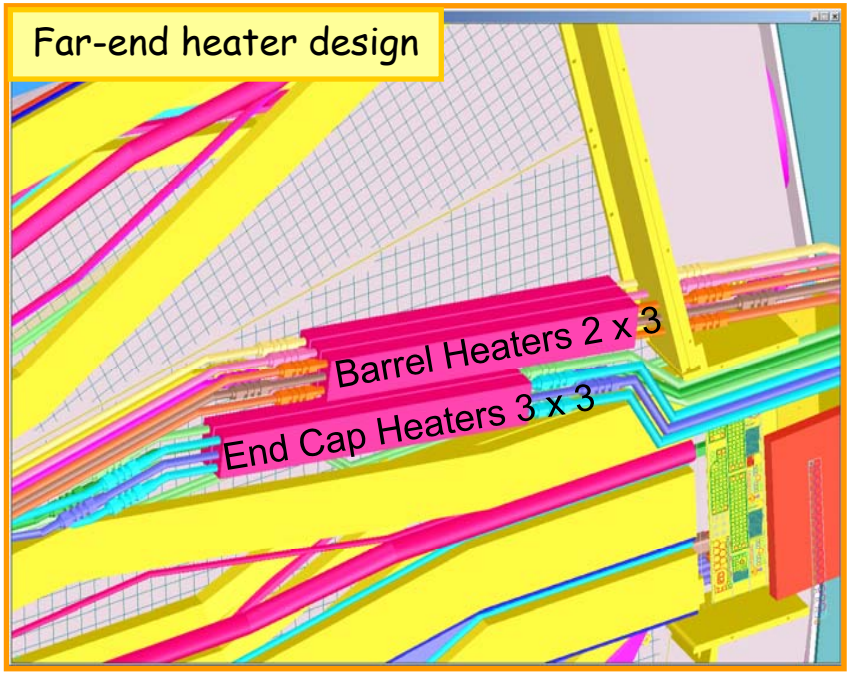
Cooling problems

Move all heaters to more serviceable area, on cryostat flange, behind SCT endcaps

- All **heaters were removed** from their original positions
- work on-going for new **"far-end heater" design**
- tests on-going for **improved heater connection**
- meanwhile **no heaters = no cooling!**

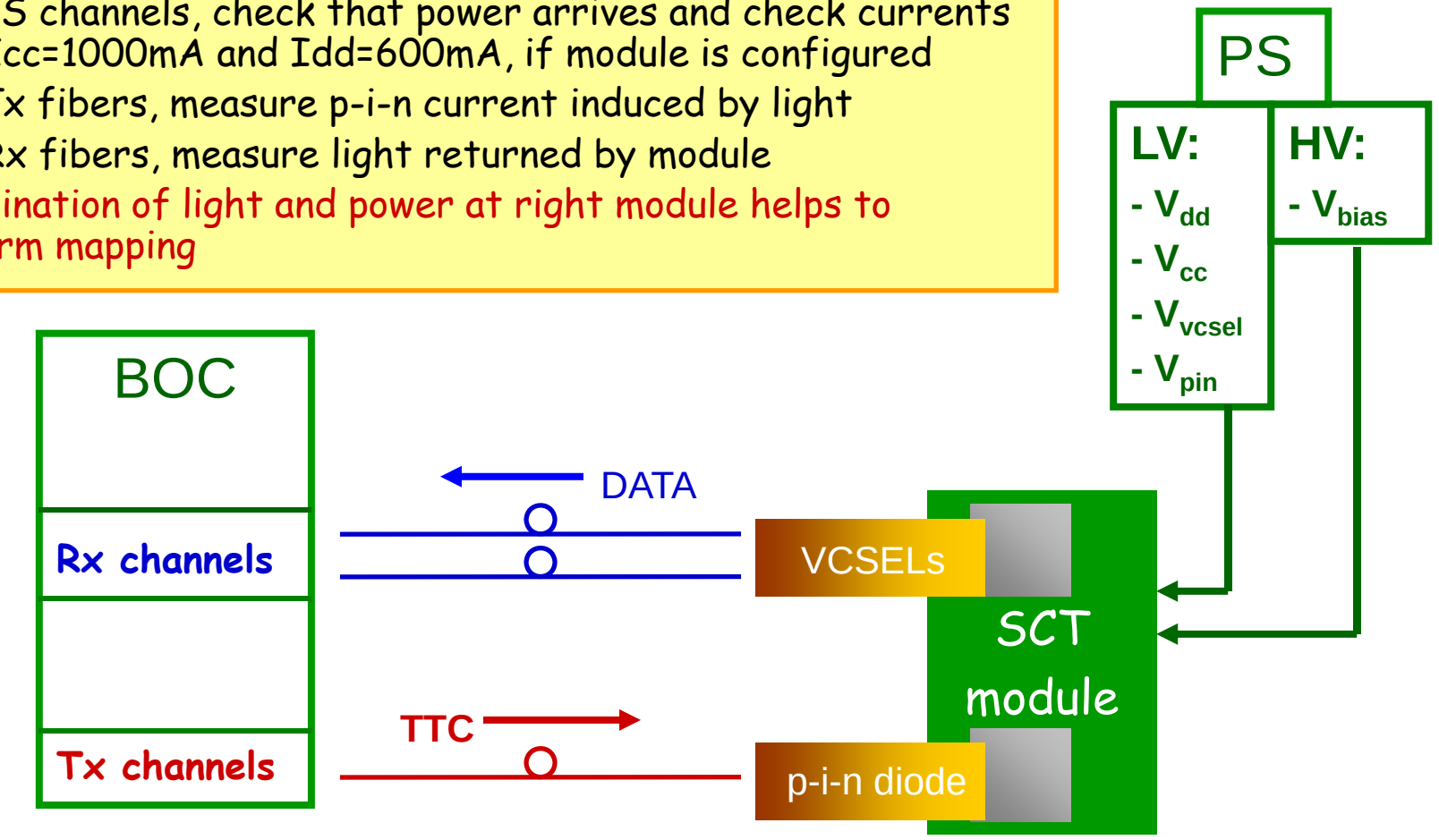
SCT cooling is expected to be operational again in october





Electric and optical connections

- Make full tests and repairs while access is possible
- Continuity test for all connection of PS cables
  - repairs shorts and broken lines
- Check electric and optical connections:
  - PS channels, check that power arrives and check currents Icc=1000mA and Idd=600mA, if module is configured
  - Tx fibers, measure p-i-n current induced by light
  - Rx fibers, measure light returned by module
- Combination of light and power at right module helps to confirm mapping

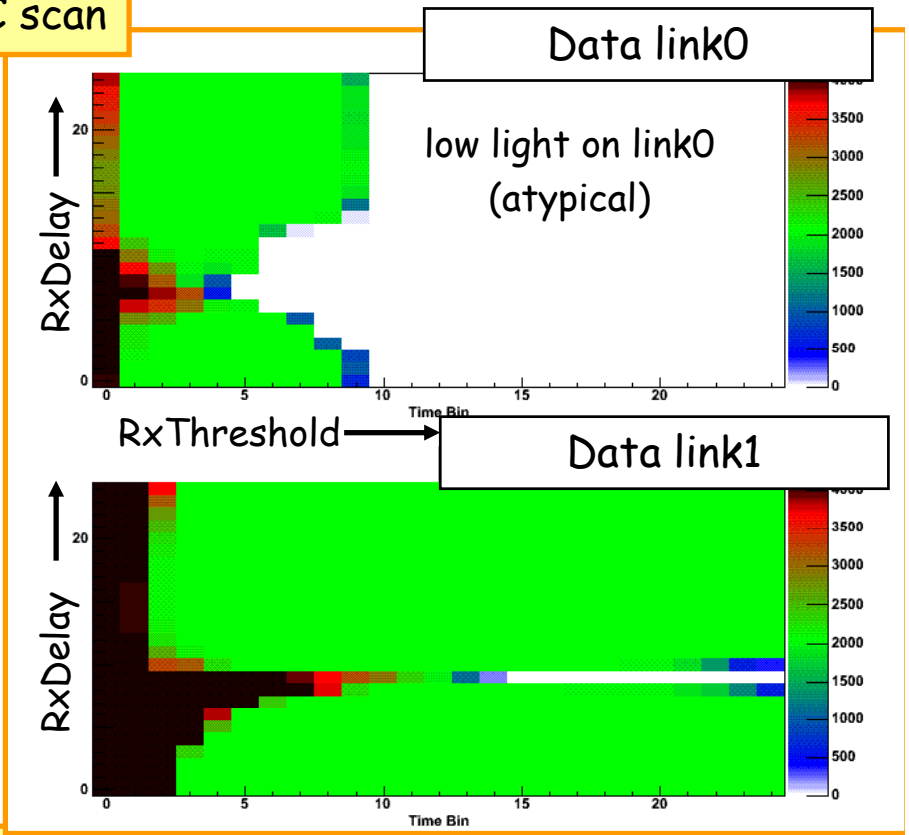


Electric and optical connections

"Dicing With Death", DwD tests
- without cooling,
- turn module on, test, and off again, module T < 30 ^{0} C
- software and firmware interlock will still turn off module gets too warm

Rx Fibers tested with 2D BOC scan:
- Finds optimum BOC settings within a few seconds

2D BOC scan

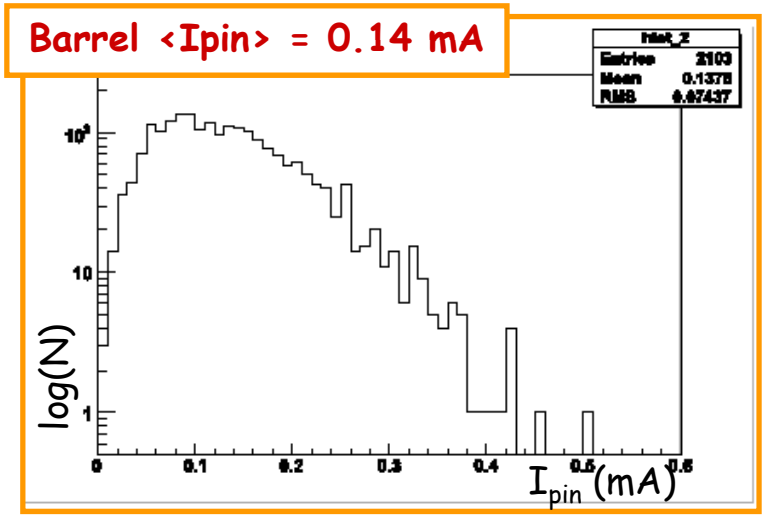


- So far, all modules are seen to return data
- Occasional cleaning or swapping fibre ribbons needed to solve problem
- Few problematic links, known from previous tests, can be read-out via other link

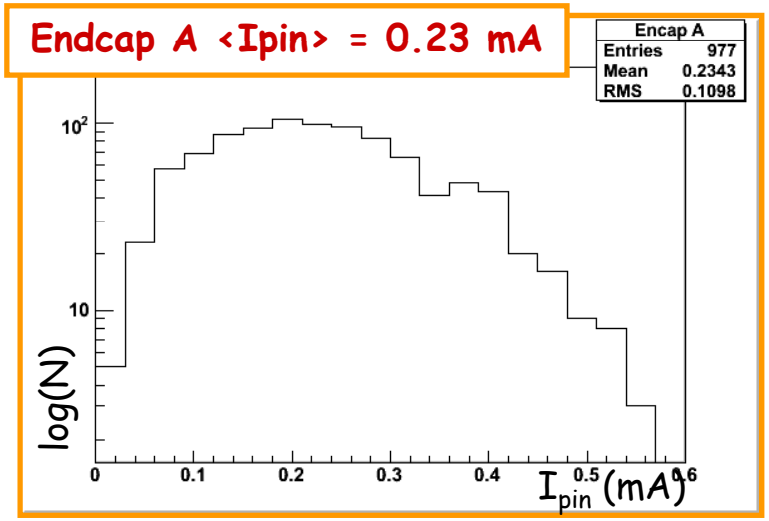
p-i-n currents

Current induced by light from BOC with V_{pin}=6 Volt

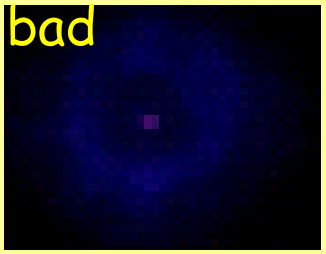
Barrel <Ipin> = 0.14 mA



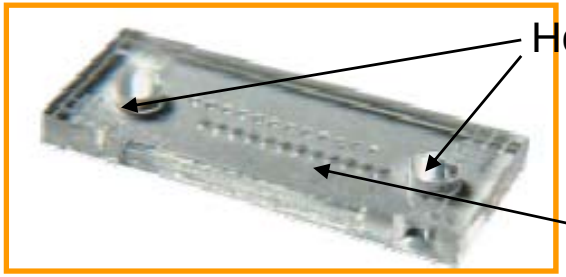
Endcap A <Ipin> = 0.23 mA



- All modules tested so far see clock and commands and are configured
- Few channels are close to threshold (0.02 mA)
- Many Tx channel with low Ipin
  - Require I_{pin} > 0.1 mA for module communication during high luminosity runs
- Light from bad Tx's typically more divergent:



- Tests on-going with Micro Lense Arrays to reduce beam divergence
- In the future all Tx's at BOC might be replaced



Calibration tests

Barrel was tested with cooling until cooling problems required moving of heater to far-end design

Endcap awaits cooling to start calibration tests

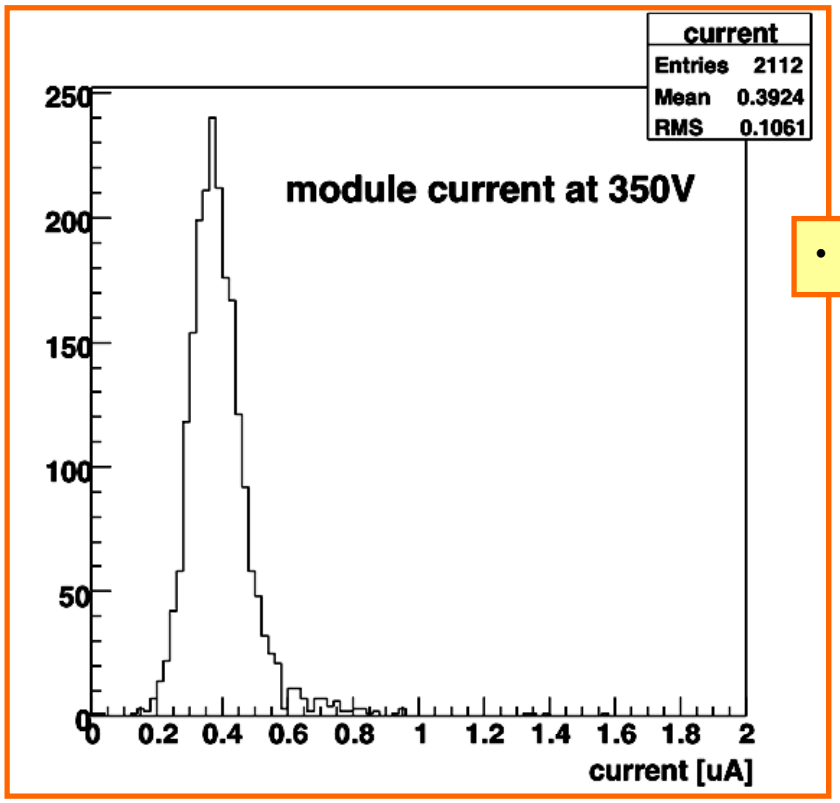
Barrel modules tested for:

- -Temperatures
- - High voltage on modules (350V)
- - Module ENC noise from gain measurments
- - Noise Occupancy

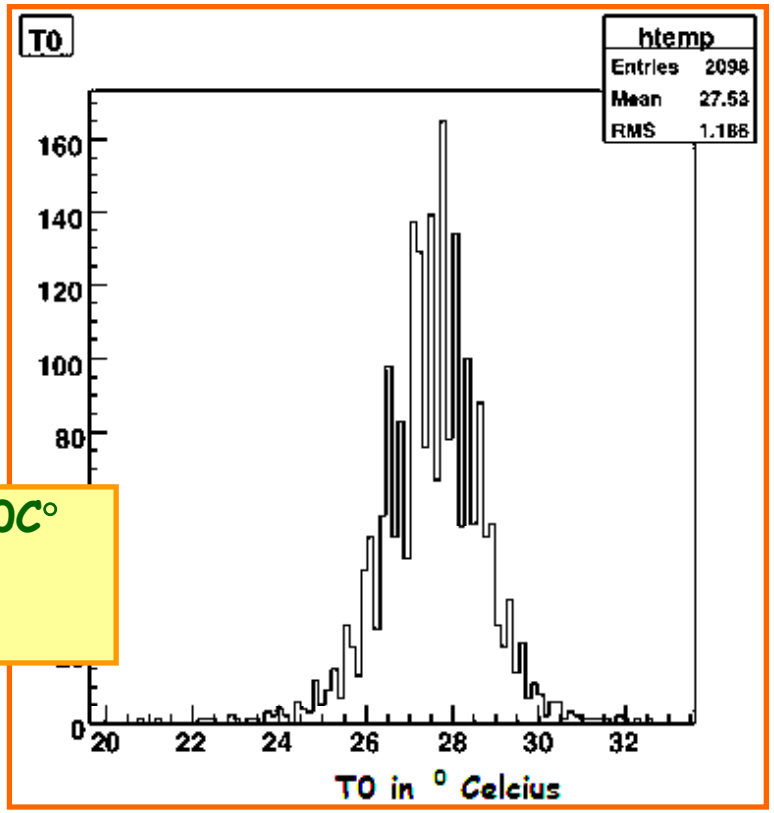
SCT barrel operated "warm":

- -T hybrid ~ 29°C,
- -T cooling pipes (SCT off) ~ 8°C,
- -T pipes (SCT on) ~ 15°C

Barrel test results



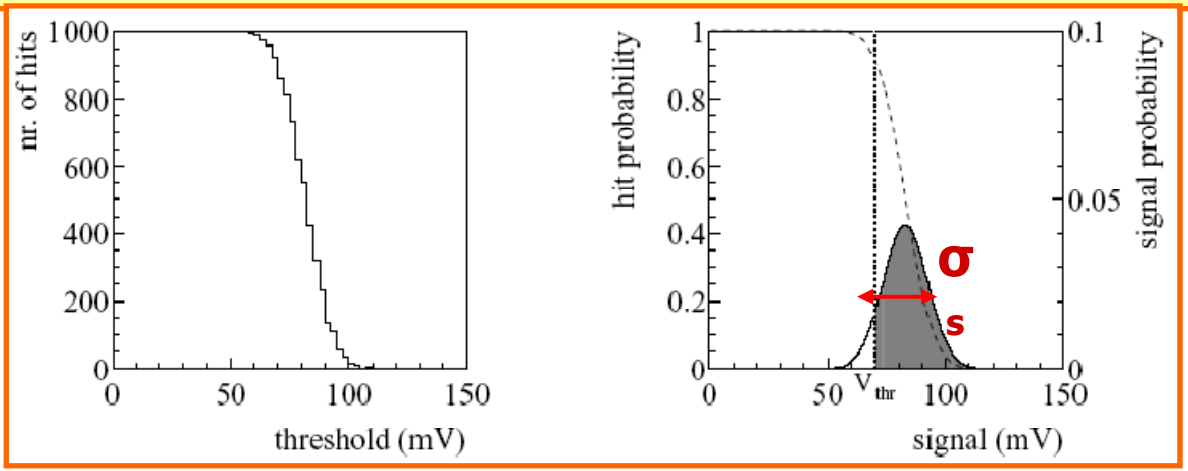
- Leakage current at 350 V, <Ibias> = 390nA

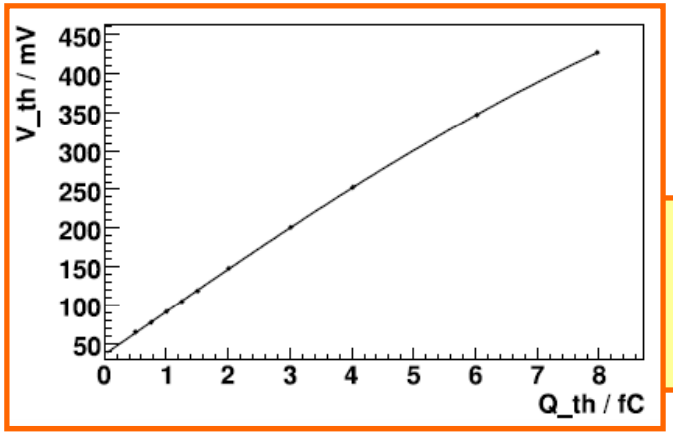


- **Hybrid temperatures uniform <T0>=27.6±1.0C°** for cooling back pressure at 6.3b
- At 6.0 b <T0> = 25.5±1.0C°

Analogue performance

- **Analogue performance** is evaluated by looking at the **S-curve** for each channel:
  - Inject known charge and read-out number of hits
  - Measure response at a range of thresholds
  - S-curve reveals **signal probability distribution** of each strip (ABCD channel)





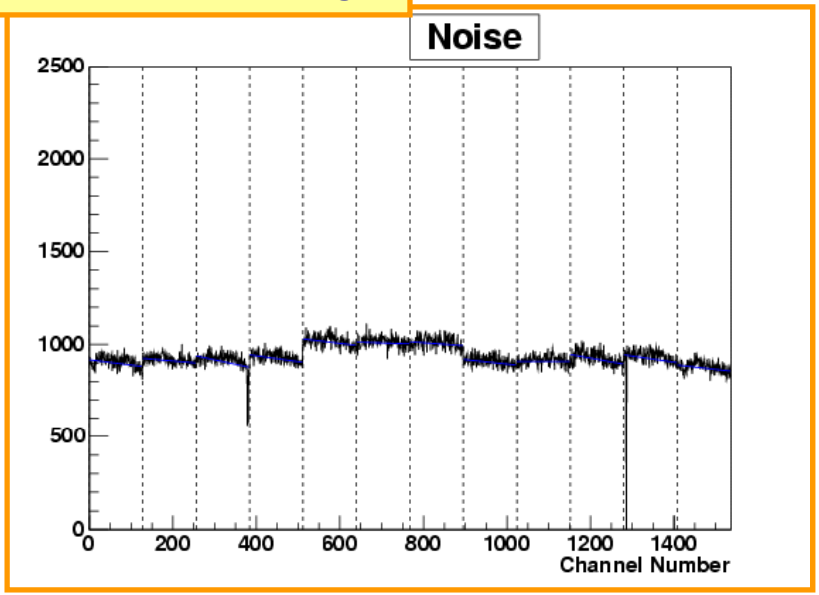
inject increasing values of charge and measure average output voltage to find **gain**
translate σ_s with gain into **input noise**

Analogue performance

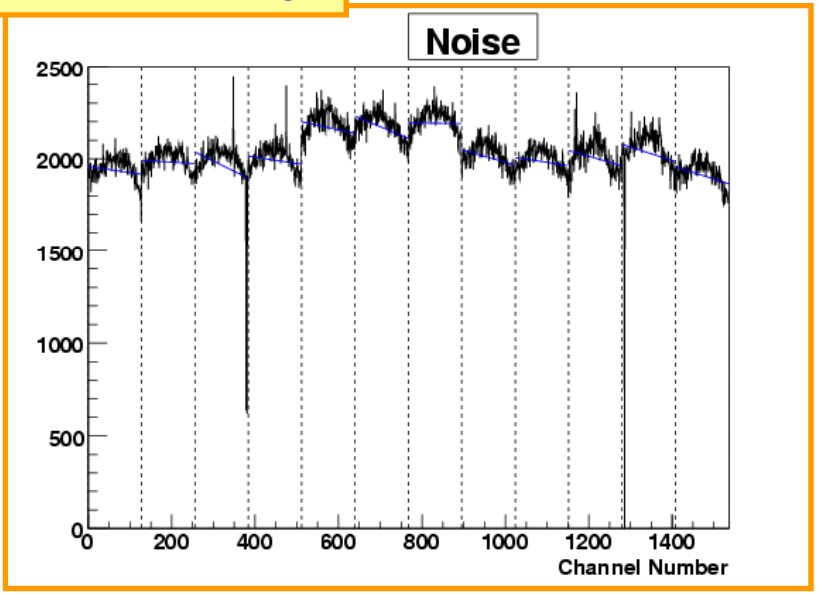
Input noise indicates **dead** and **unbonded** channels and possible problems with **bias voltage**

- Compare results with previous test results in module database to find possible new defects
- Defects gives unique fingerprint for each module, useful for mapping

with 150 V bias voltage



with no bias voltage



From CERN reception tests of all SCT modules:

- More then 99.7% of channels are performing to specification
- Well above ATLAS requirements of 99%

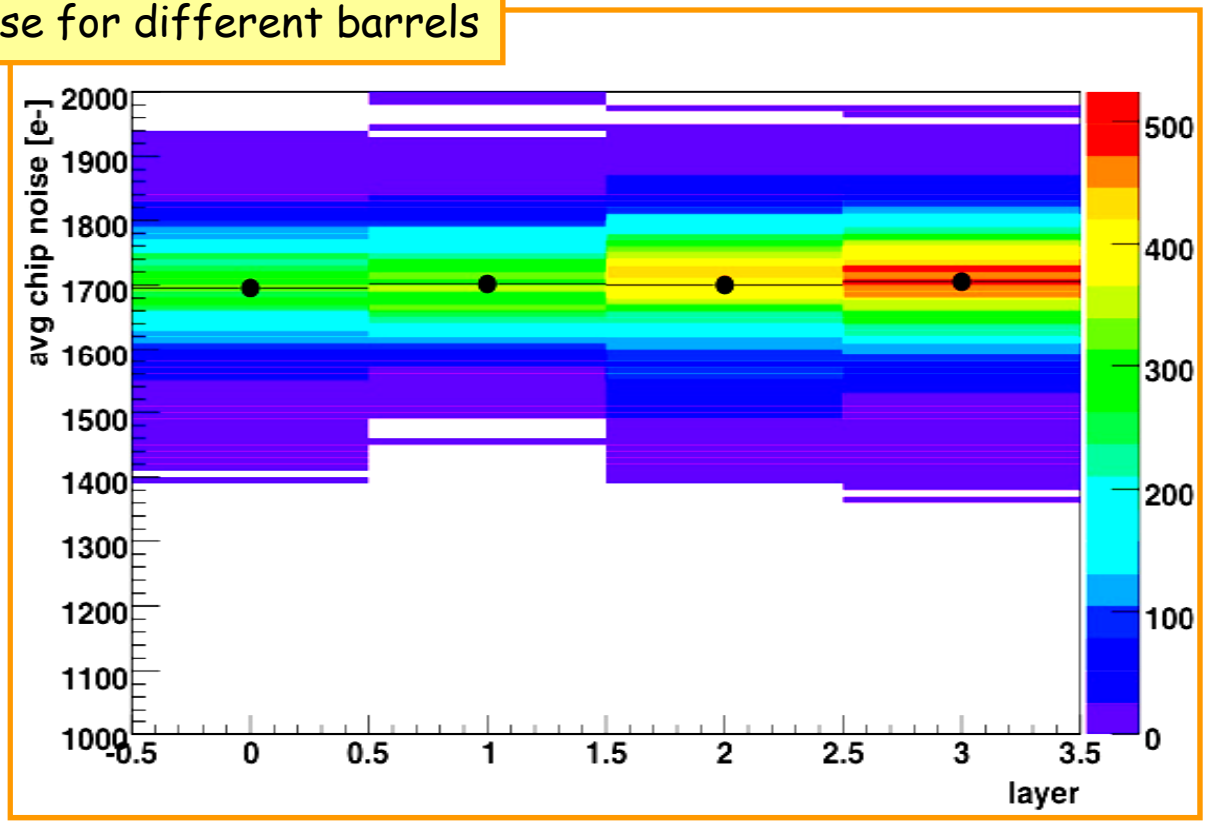
No significant increase in dead channels found in SCT barrel in-situ tests

Barrel performance

Barrel in-situ tests:

- Detector biased at 150V (for 30min to 7hrs before noise measurement)
- Plots based on chip averages of analysed scans for 2098 modules

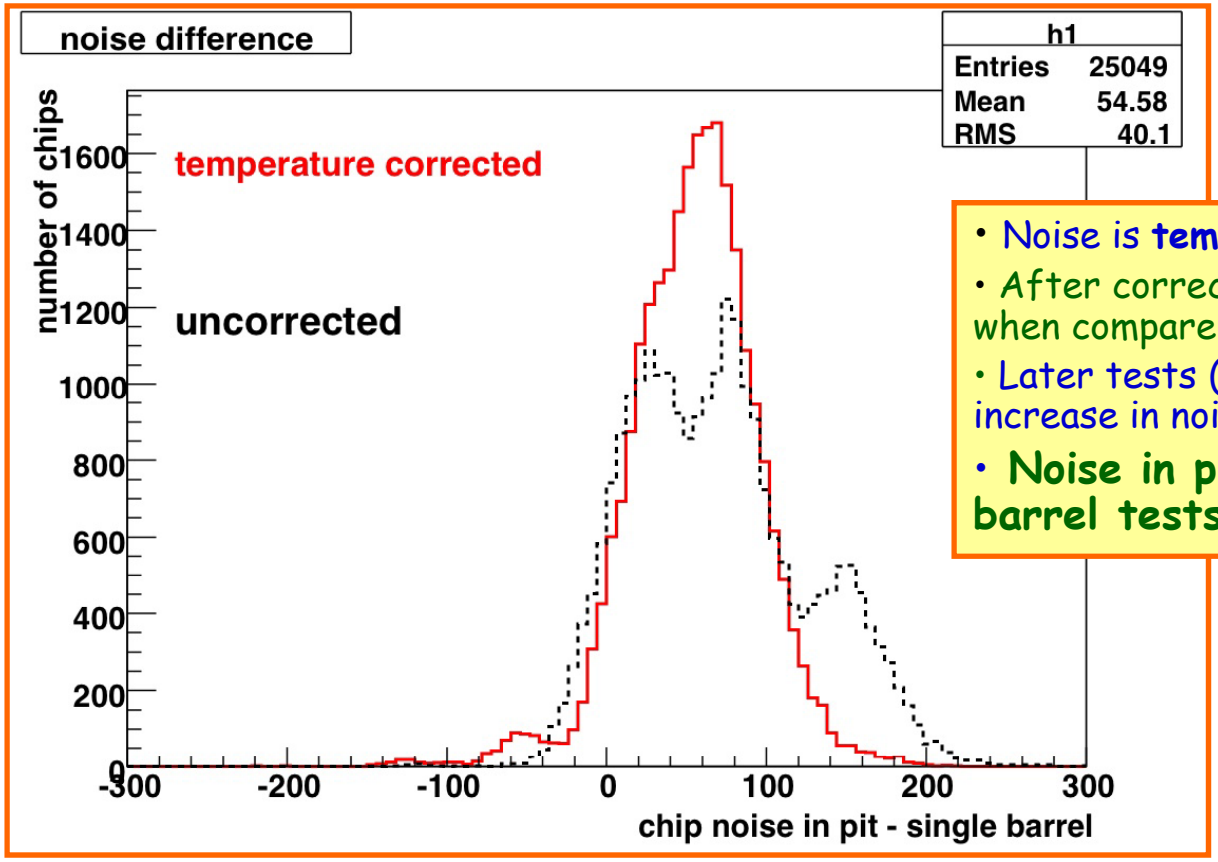
Average chip noise for different barrels



Barrel test results comparison

Reference data (chosen for similar test temperature and number of modules included)

- B3: SR1 reception test
- B4: Oxford warm final test
- B5: Assembly test
- B6: assembly test

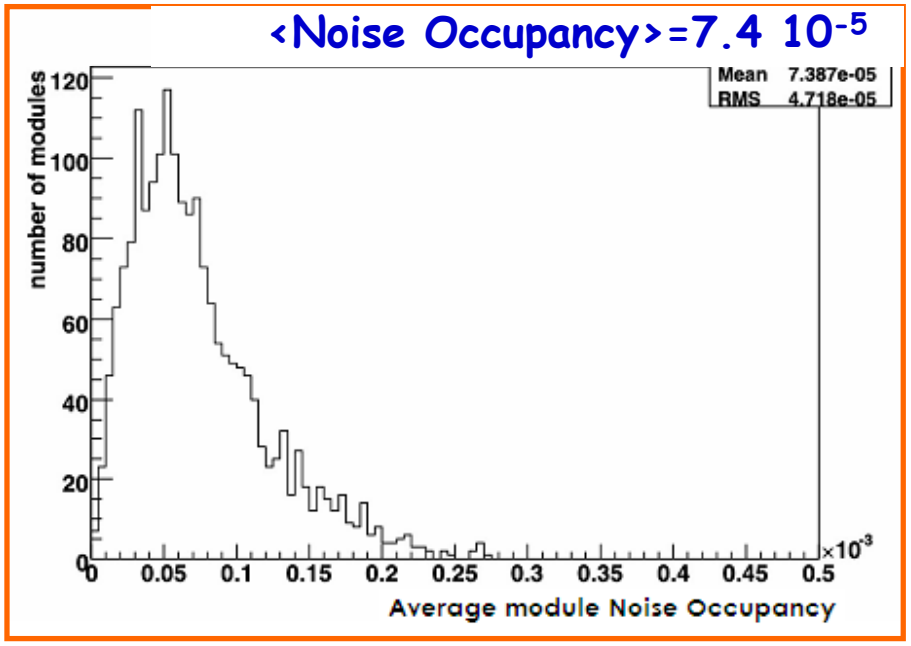


- Noise is **temperature dependent!**
- After correction average 60 electrons higher when compared to reference data
- Later tests (modules biased longer) show no increase in noise compared to reference data
- **Noise in pit comparable with single barrel tests**

Noise occupancy

Noise occupancy test

- Without charge injection, send triggers and measure hits over a range of thresholds
- Noise Occupany at threshold equivalent to 1 fC calibration charge
- ATLAS specification requires a **maximum noise occupancy of 5 x 10^{-4}**
- High noise occupancy channels will be masked off



- Results slightly higher than single barrel reference data <Noise Occupancy> 6.0 10^{-5}
- No difference with reference data for modules that were biased longer
- **Noise Occupancy still well within ATLAS specifcation**

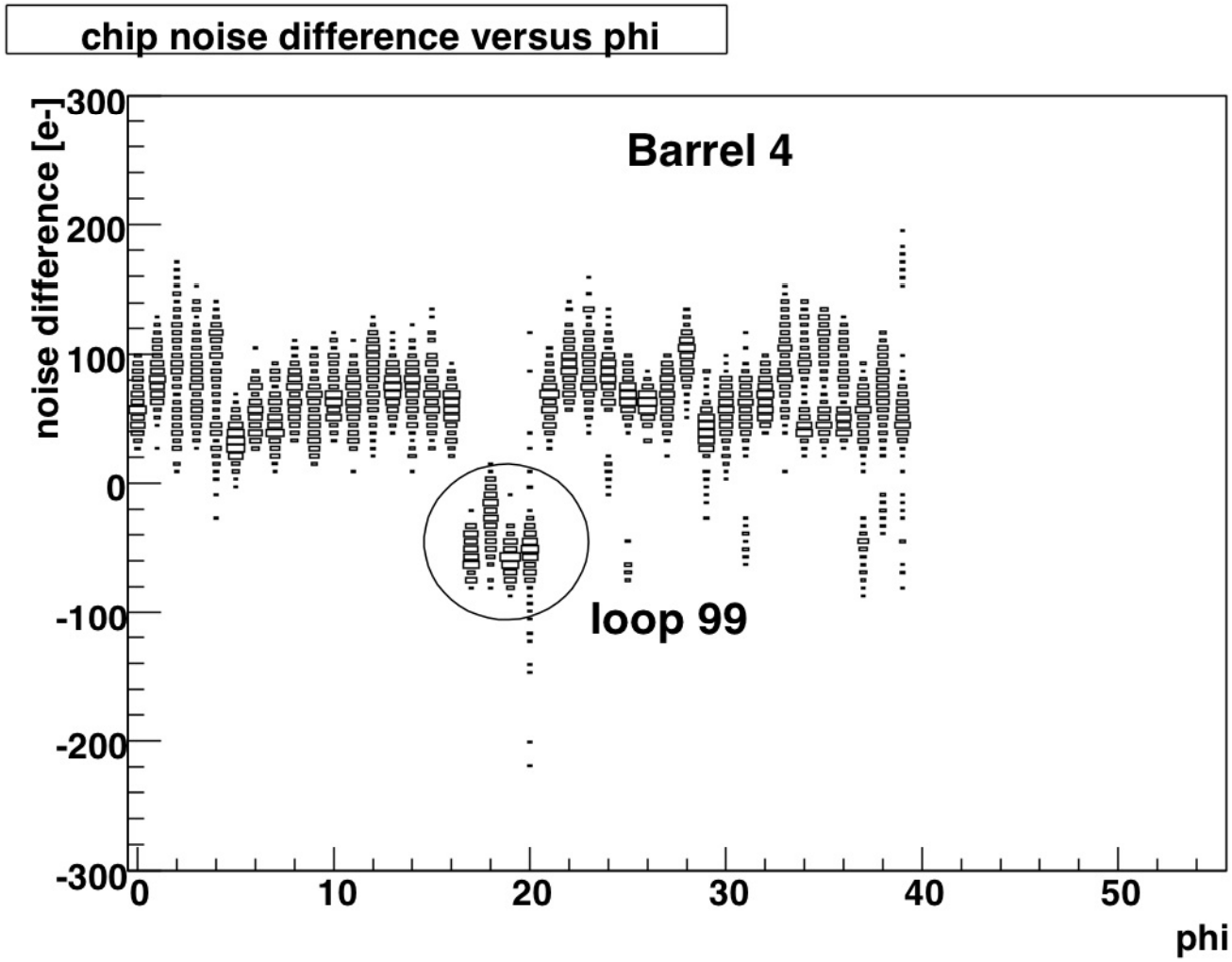
Conclusions & Outlook

- SCT barrel and both endcaps are installed in their final position in the ATLAS cavern
- SCT barrel has been fully tested both at surface reception and in cavern and performs well within ATLAS specification
- Cooling problems are currently limiting commissioning of the SCT endcaps but electric and optical connection tests are continuing
  - All tested modules receive clock & command
    - Low p-i-n currents might require new Tx channels in the future
  - All tested modules return data
- Cooling problems are expected to be solved in october:
  - Fully test one quadrant with cooling to sign off end-cap.
  - Prepare meaningful Barrel and Endcap detector sections to be available to join the ATLAS M5 cosmics run end of october
- Testing with final services and DCS and DAQ software allows the SCT to be well-prepared for LHC data taking in 2008
  - Thanks to the effort of many people participating in the SCT commissioning!

Backup

Barrel 4 in more detail

- ENC vs phi
- Loop 99 was tested in run1188 later than most other modules(run 1140)
- Not caused by temperature
  - Temperature was uniform across B4 and reference
- Signs of stabilization ?



Question of Stabilization?

- Noise Occupancy on B4
  - All loops except loop 99
  - Loop 99
- Noise Occupancy on loop 99 shows same picture as ENC
- Noise Occupancy at least as good as reference data