Endcap Modules for the ATLAS SemiConductor Tracker

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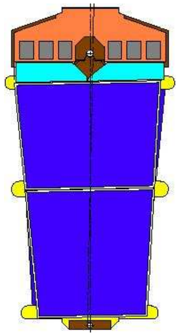
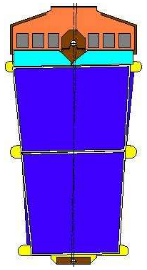
(For the ATLAS-SCT Collaboration)



The plan of this presentation



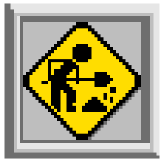
Introduction

The forward modules

Mechanical performance

Electrical performance

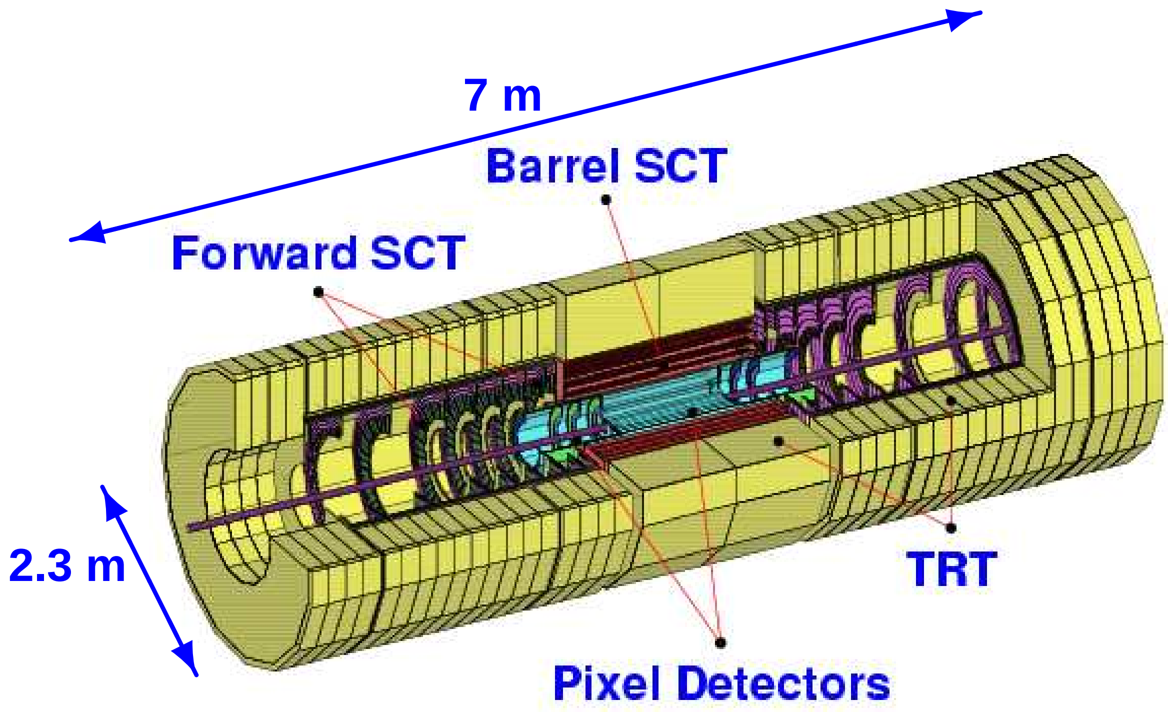
Test beam results



Status of module production

Conclusions and Outlook

The ATLAS inner detector



In this presentation, only the Semi Conductor Tracker will be discussed.

The Pixel Detector

— Radius 4.8 — 16 cm.
— 3 layers, 10 disks.
— $1.4 \cdot 10^8$ read-out channels.
— σ: $12\ \mu m$ ($R\Phi$) and $\approx 70\ \mu m$ (z/R).

The Semi Conductor Tracker

— Radius 27 — 52 cm.
— 4 layers, 18 disks
— $6.3 \cdot 10^6$ read-out channels.
— 4088 modules, 61 m^2 silicon
— σ: $16\ \mu m$ ($R\Phi$) and $580\ \mu m$ (z/R).

The Transition Radiation Tracker

— Radius 56 — 107 cm.
— 100 k / 320 k straws in barrel / end cap.
— 420 k read-out channels.
— Xe radiator for electron-detection.
— σ: $170\ \mu m$ / per straw.

The SCT forward part - how to build a module

Hybrid

A 6-layer copper-polyimid flex on a carbon substrate

Read-out chips

6 ABCD3T chips per side with binary read-out

Fixations

Precision 20 μm

Fan-ins

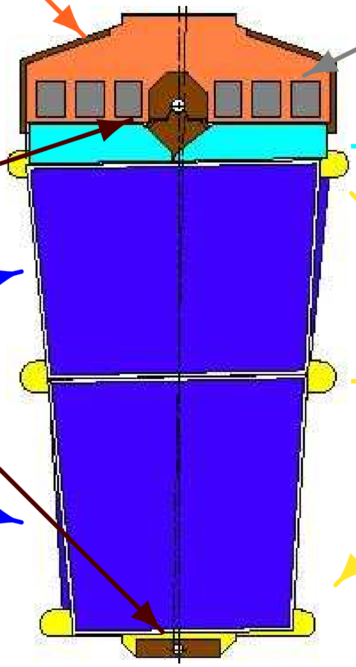
4/module, glass with Al-strips of 300 μm thickness

Si-wafers

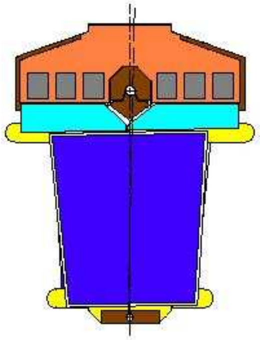
ca. 6x6x0.285 cm^3
768 single-sided p-type strips on n-type substrate with 50-90 μm pitch

Support-structure (Spine)

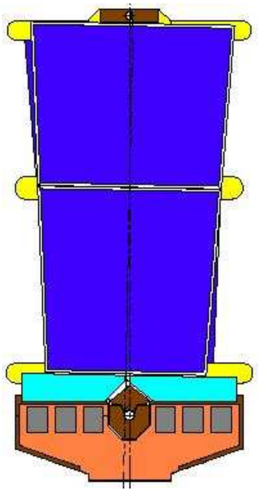
Thermal Pyrolytic Graphite thickness 500 μm, 1700 W/m/K



Middle module

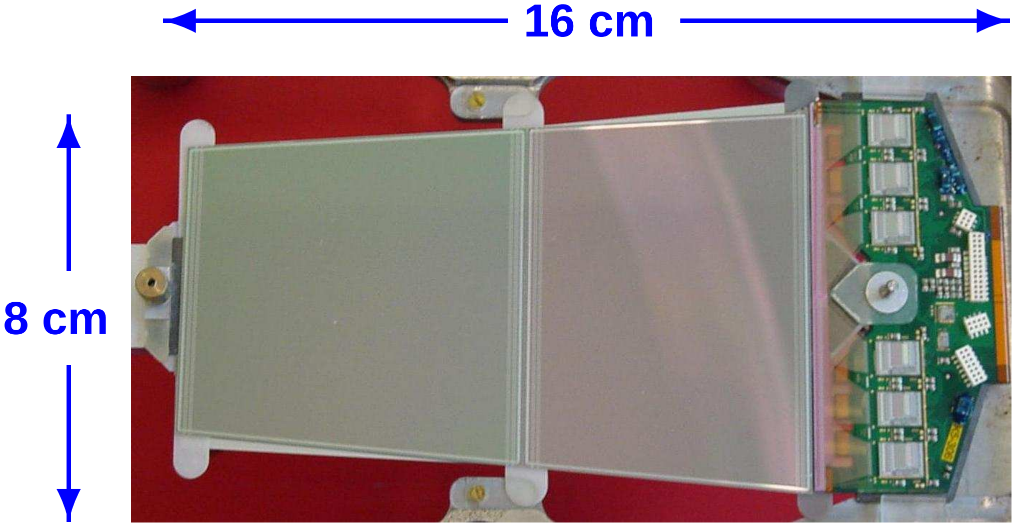


Inner module



Outer module

SCT forward modules - some design values

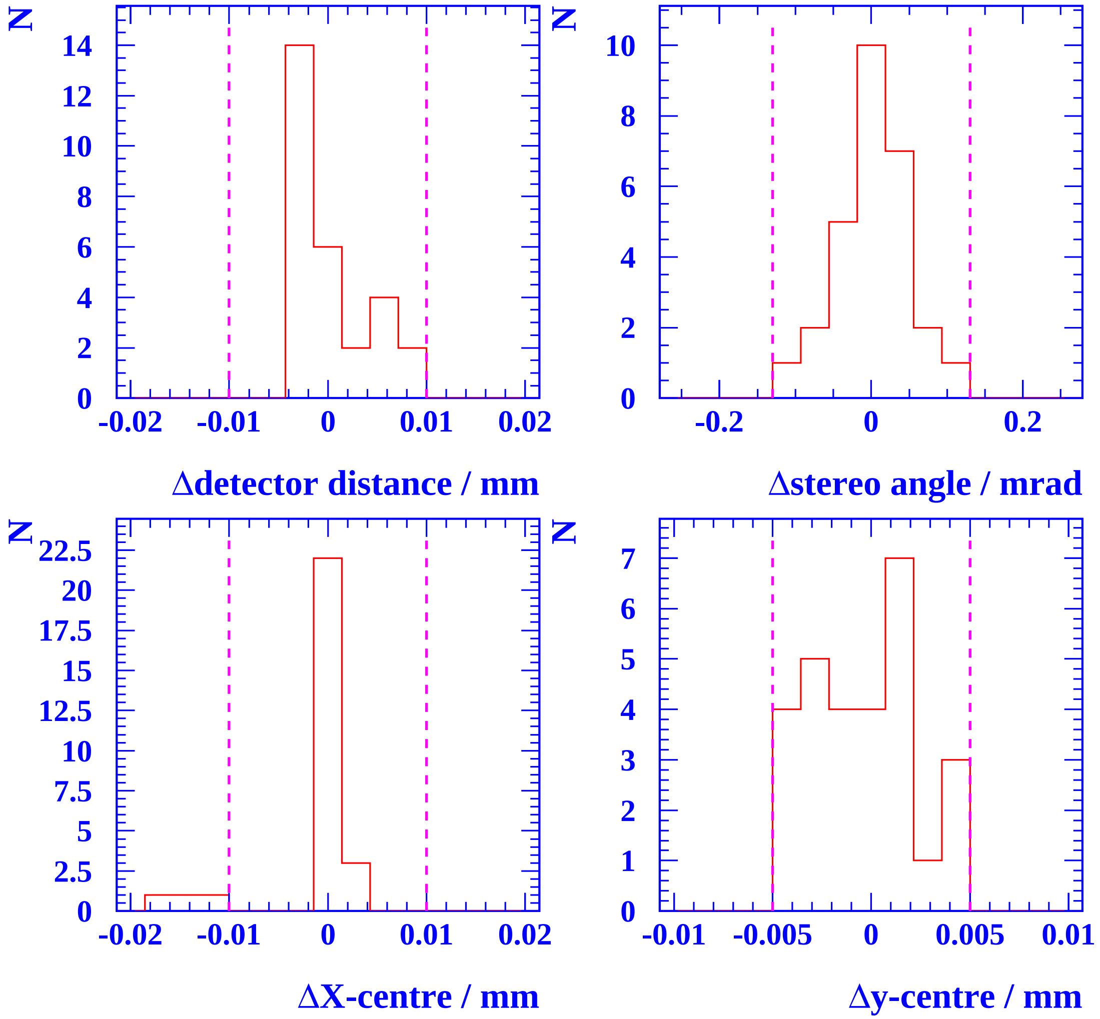


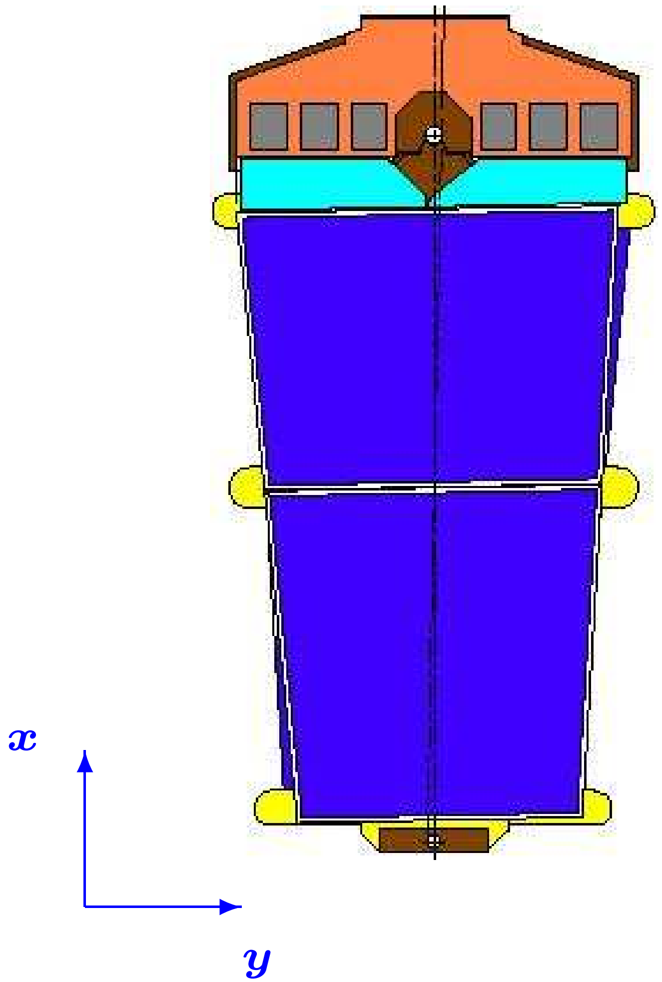
- **Bias voltage: < 500 V.**
- **Produced heat: < 7 W per module.**
- **Gain: 50 mV/fC.**
- **Linearity: better than 5%.**
- **Peaking time: 20 ns.**
- **Signal charge: 3.3 fC, $S/N > 10$.**
- **Noise: $< 1500(1900)$ e$^-$ ENC before (after) irradiation.**
- **Noise occupancy: $< 5 \cdot 10^{-4}$.**
- **Hit efficiency: $> 99\%$.**
- **Time walk: ≤ 16 ns, and bunch crossing resolution better than 99%.**
- $\sigma = 16(580)\ \mu m \perp (||)$ **to the strips.**
- **Two-track resolution: $200\ \mu m$.**

The SCT modules are very delicate objects that have to be built with great care.

The mechanical reproducibility

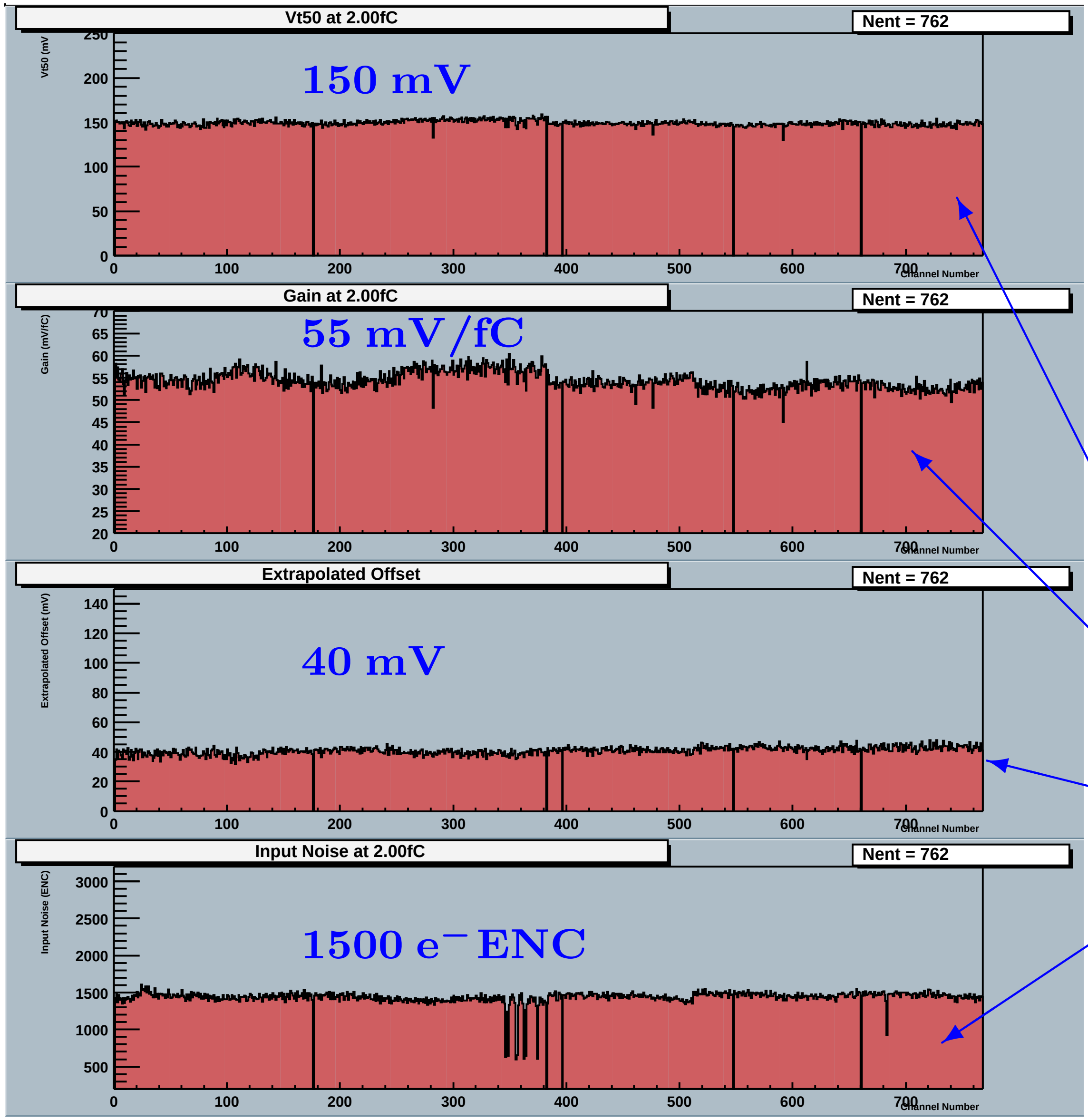
Results from 28 pre-series modules (- - - tolerances)





The modules can be built within specifications with high yield.

An example of the electrical performance



0 768

— Test of a non perfect hybrid (dead channels are visible as black lines). Shown are the results for one side of the hybrid ($6 \times 128 = 768$ channels), tested at 2 fC injected charge.

— The results are obtained by analyzing the S-curves from threshold scans.

The output signal.

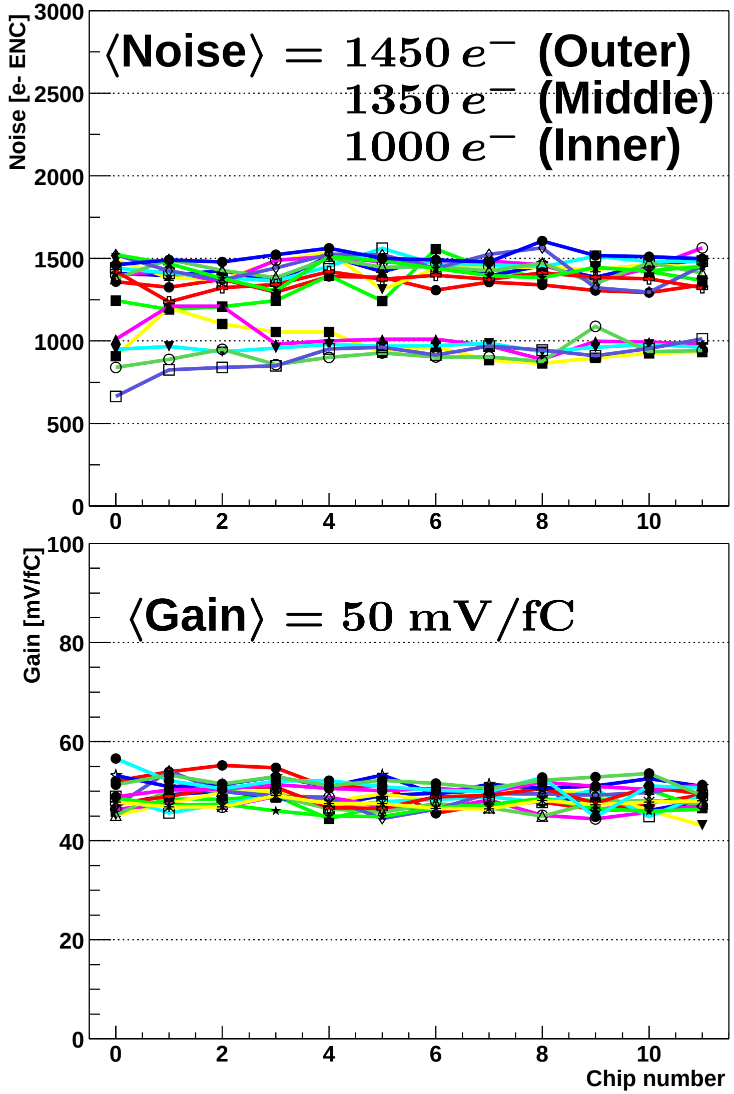
The calculated gain.

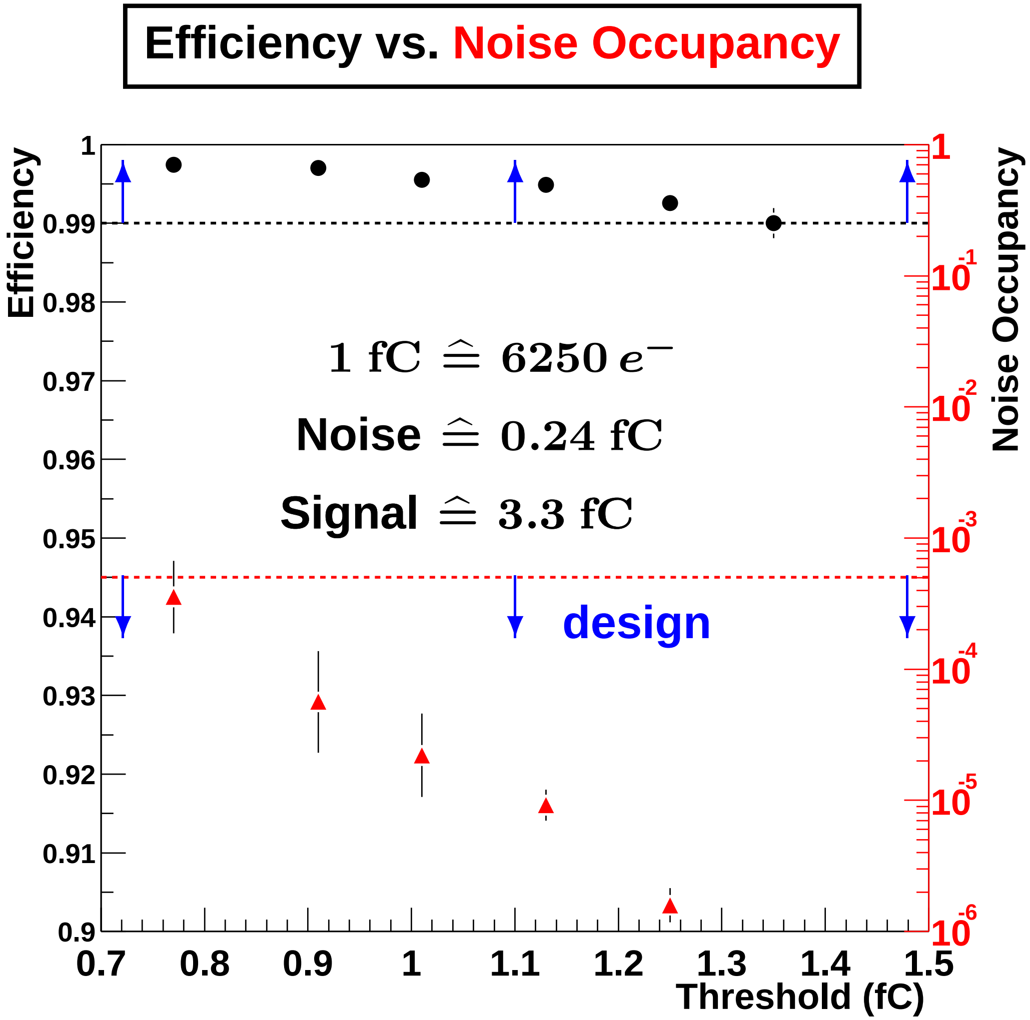
The extrapolated offset for 0 fC.

The noise in e^-ENC.

The channel to channel variations within a module are small.

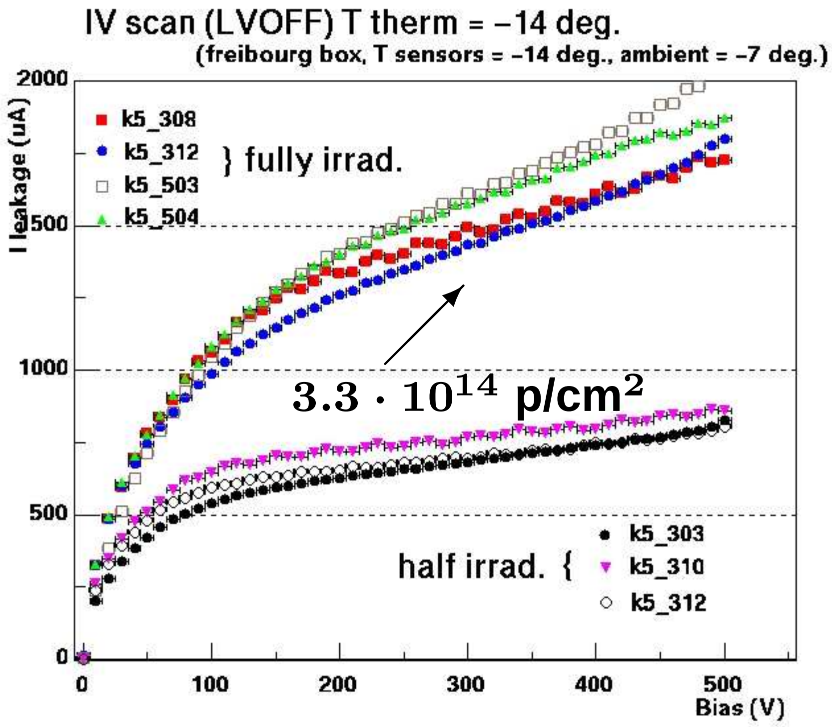
Some properties of non-irradiated modules



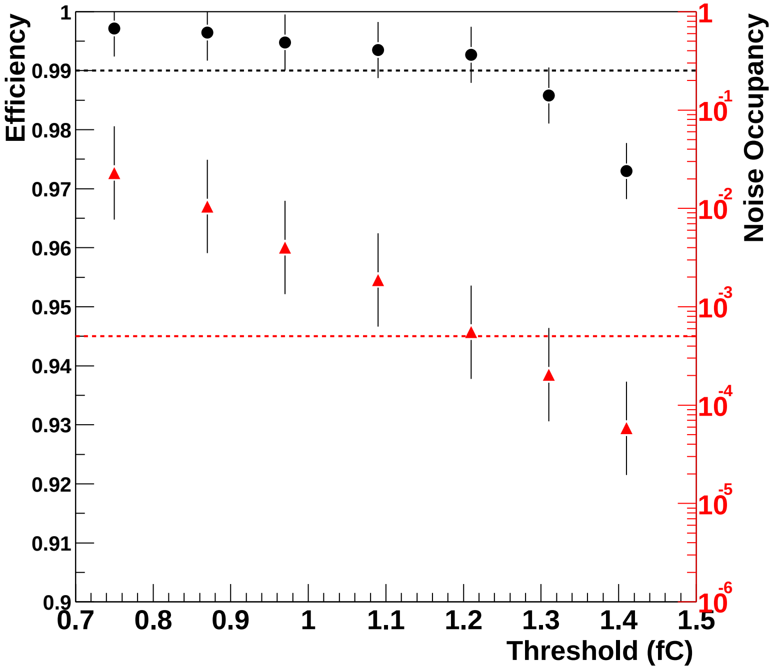


The non-irradiated modules are well within the design limits.

Performance degradation for irradiated modules



A module after full dose



– **Gain:** $50 \rightarrow 30$ mV/fC $\Rightarrow$ **Smaller signals.**

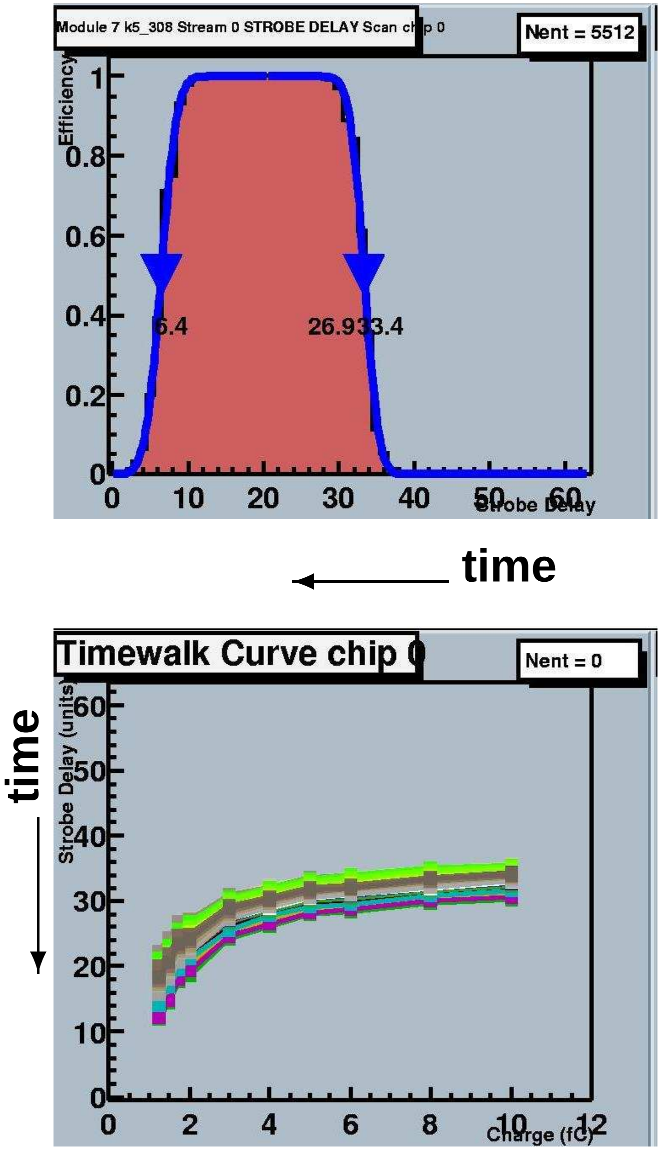
– **Noise:** $1500 \rightarrow 2100 - 2400$ e^- ENC $\Rightarrow$ **Worse S/N ratio.**

– **Temperature dependence:** $6 \rightarrow 20$ e^- ENC/$^\circ C$ $\Rightarrow$ **Higher temperature sensitivity.**

– **Threshold spread:** $160 \rightarrow 600$ e^- ENC $\Rightarrow$ **Increased noise.**

The operation margin for irradiated modules is rather narrow.

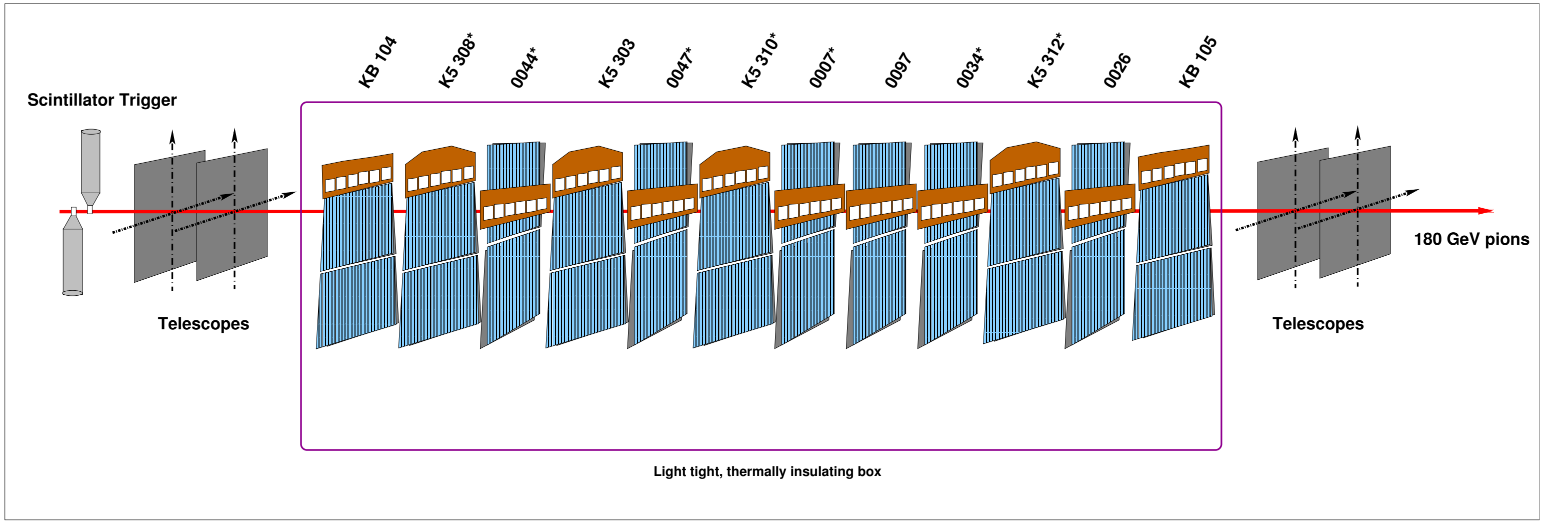
Lets do the time walk



- Efficiency vs. timing of clock and trigger signal at 1 fC threshold. The width corresponds to 25 ns.
- Timing per chip vs. injected charge. The timewalk is defined as the maximum difference in timing at 1 fC threshold for 1.25 to 10 fC injected charges.
- The chips get slower after irradiation. Peaking time: $20 \longrightarrow 30$ ns.
- The threshold will be crossed later after irradiation. Timewalk: $10 \longrightarrow$ more than 16 ns
- By increasing the Voltage for the analog part of the chip from 3.5 to 3.8 V, the timewalk can be brought within specifications for most of the channels.

The chips get slower and the timewalk increases.

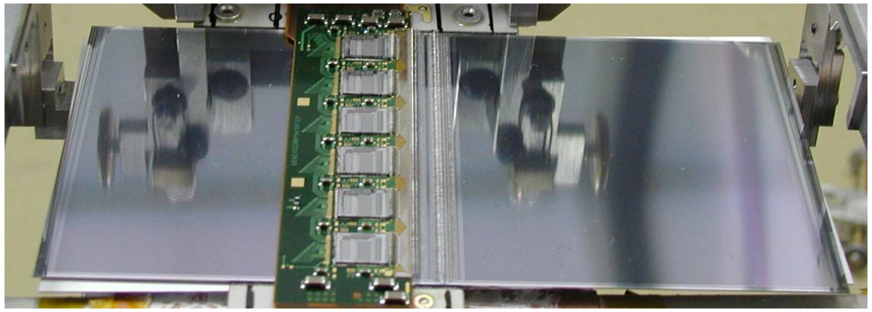
Tracking performance from test beam measurements



- Several fully irradiated modules, are placed at about the distances they will have in ATLAS.
- The tracking performance is studied, varying the noise occupancy via the threshold.
- The observed residuals of the space points per module are according to expectation from the geometry, about 17 (800) μm perpendicular (parallel) to the strips.
- For a track reconstructed from three modules, and at 1.2 fC threshold, an efficiency of more than 97$\%$ at about 10^{-3} fake rate is achieved. For four modules the efficiency is still larger than 97$\%$, however at lower fake rate, which is compatible with zero.

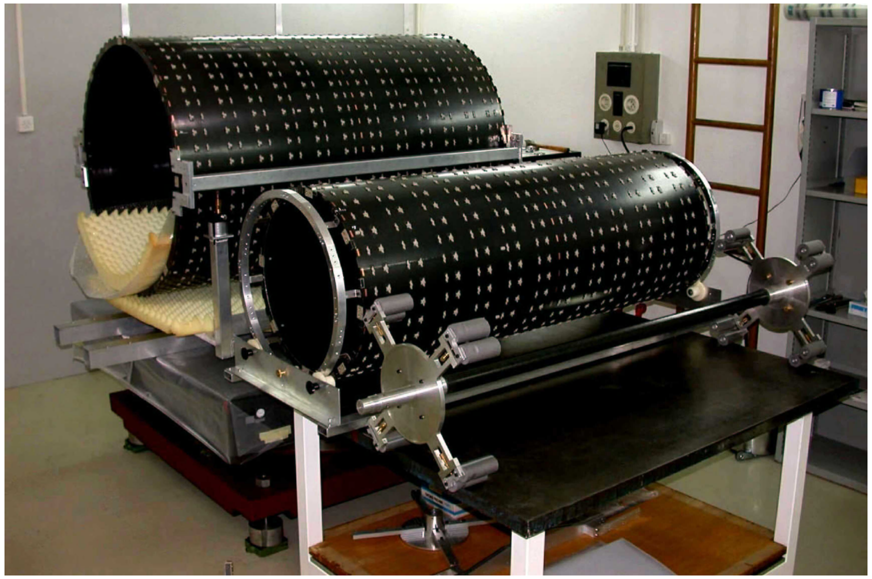
The fully irradiated modules still allow for tracking with high efficiency and low fake rate.

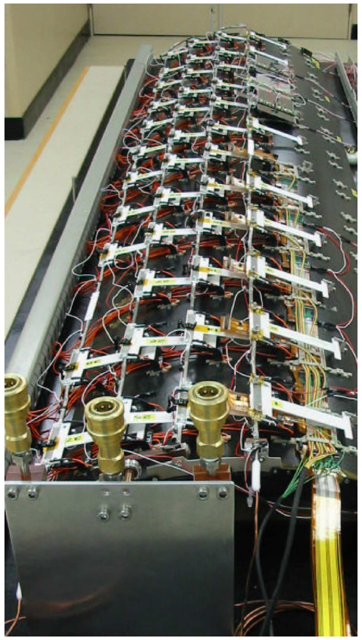
Status of the production - the barrel part



— Module production is distributed over the world. Production centers are at various institutes in Japan, Scandinavia, UK and the US. This means a complex logistics is needed.

— The module production is about 1/3 completed.



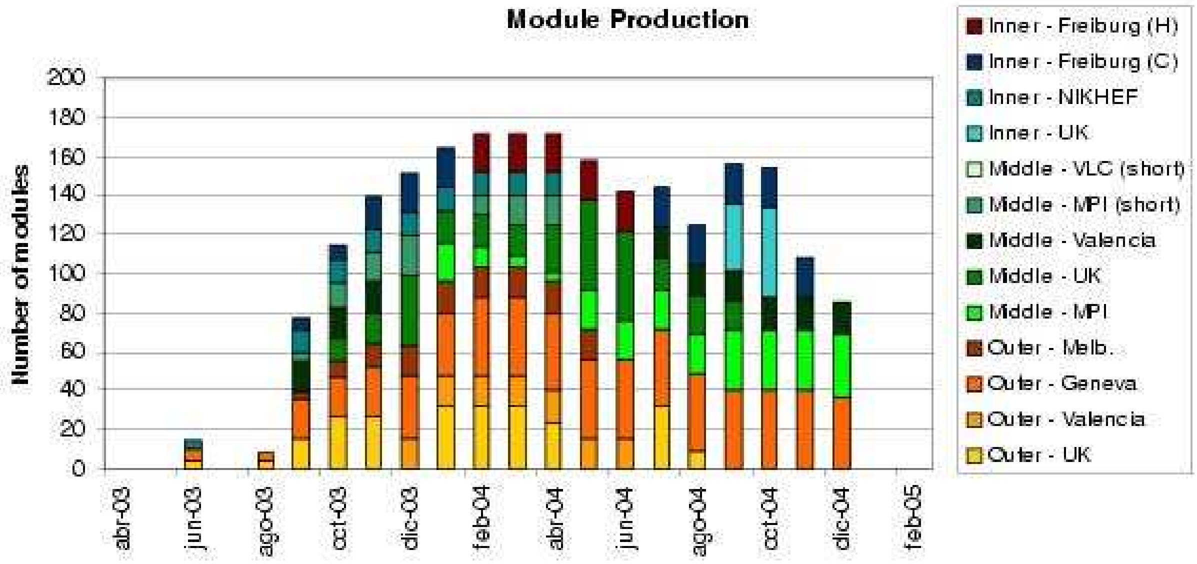


— Module to barrel mounting is done in the UK.

— Lots of services (cooling, cables, sensors for monitoring, . . .) have to be installed.

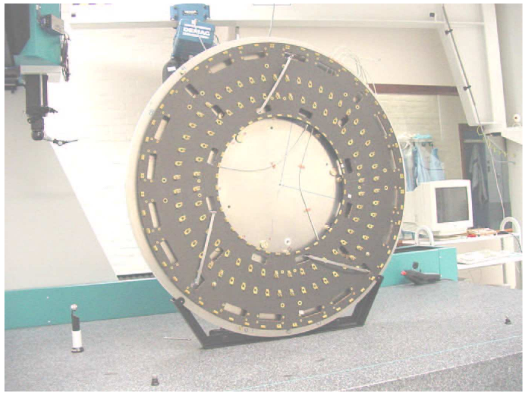
There is still much work ahead.

Status of the production - the forward part



— **The module production is distributed over various institutes in Europe and Australia. The existence of three different module types makes the logistics even more complex.**

— **Module production is about to start.**



— **Module to disk mounting is done at NIKHEF and Liverpool.**

— **Lots of services (cooling, cables, sensors for monitoring, . . .) have to be installed.**

The time schedule to complete the forward SCT is tight.

Conclusions ...

— A part of the ATLAS inner detector will be equipped with silicon microstrip detectors, the SCT.

— A number of prototype forward modules demonstrate that the mechanical requirements can be met with sufficient yield.

— The electrical performance of non-irradiated modules is according to the design.

— The electrical performance of irradiated modules only allows for a marginal operating flexibility after receiving the full LHC dose, i.e. in the year 2017.

— The series production is underway for barrel modules and about to start for forward modules.

... and Outlook

— In december 2004 the barrel part is expected to be ready for integration.

— In may 2005 the forward part is expected to be ready for integration.