Staves and Petals: Multi-module Local Support Structures of the ATLAS ITk Strips Upgrade

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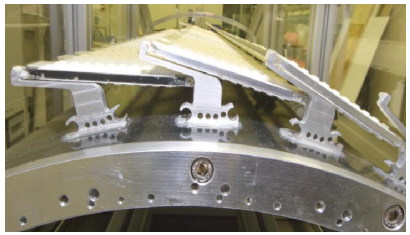
International Conference on Technology and Instrumentation in Particle Physics
Beijing, May 23rd 2017

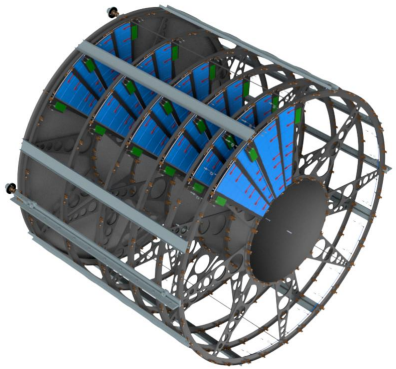
Outline

Introduction

- The ATLAS Experiment and the Strips ITk Upgrade were introduced in the previous talk.
- This talk focuses on the multi-module structures called **staves** and **petals**.
  - Made from a **core** and a **bus-tape**, with silicon detector **modules** glued on top.
  - Most results shown here are from the **Technical Design Report** published in April 2017.
- These are then mounted on their respective **global structures**: barrel cylinders and end-cap wheels.



Stave mounting on a barrel cylinder.



Petals mounted on end-cap wheels.

Local Supports

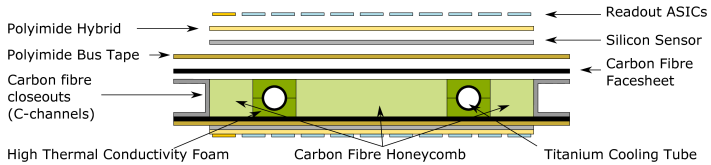
Introduction and Requirements

- Local supports provide **mechanical stability and services** to the modules.
  - Services are cooling, power and data input/output.
- General performance **requirements**:
  - Geometric **stability**.
  - **Cooling** performance.
  - **Power supply**: minimum current for low and high voltages.
  - **Data transmission**: minimum bandwidth, signal integrity and Bit Error Rate for point-to-point and multi-drop lines.

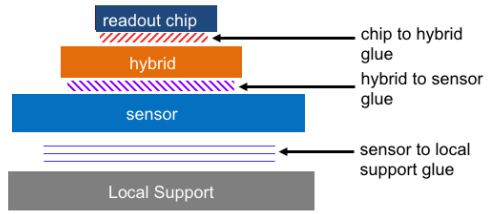
Local Supports

Design

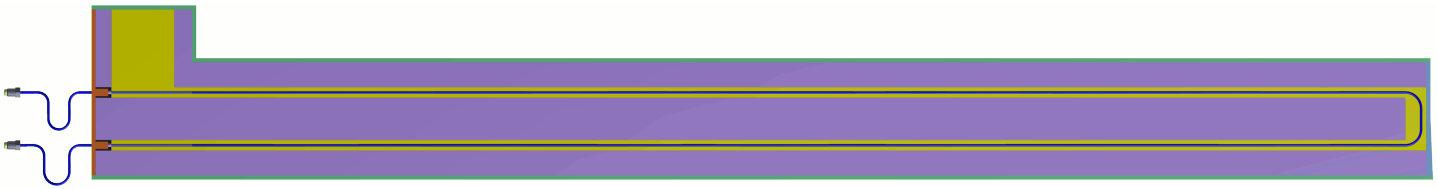
- Core is made of:
  - Low density carbon fibre **honeycomb**
  - Carbon fibre **facings** around it.
  - Titanium **cooling** pipes.
- Electric polyimide **bus-tape** glued on the core.
- **Modules** are glued on the bus-tape.
  - **Electrical connections** to the bus-tape via wire-bonds.



Cross section of the stave (excluding glues).



Stack-up of the glues for the whole assembly of modules on support.



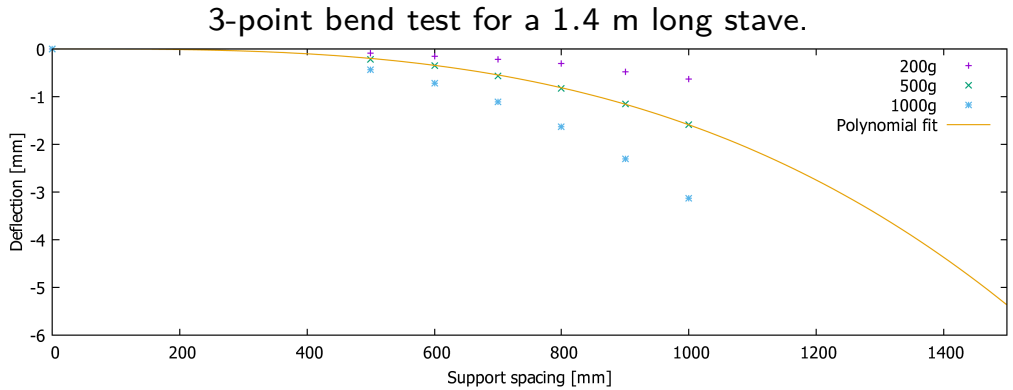
Local Supports

Thermal Performance

- **Coolant** is CO2.
- **Operation** of the local supports will be as **warm** as 20°C and as **cold** as −55°C (under fault conditions).
- Low temperature needed to avoid **thermal runaway of sensors** after irradiation.
- In addition, **TID peak** increases digital power consumption temporarily.

	Stave	Petal
Max. Module Power	10 W	12 W
EoS Power	12 W	6 W
Local support total power	300 W	130 W

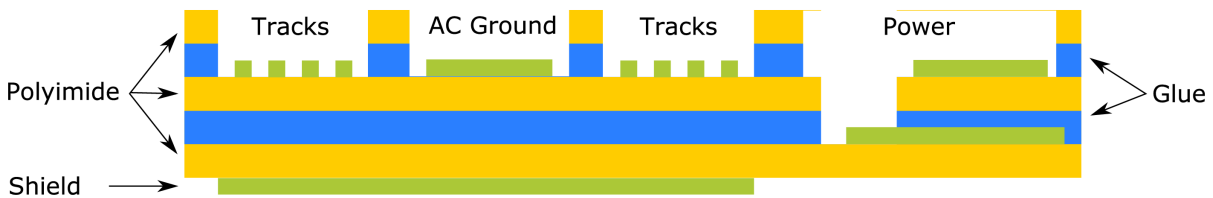
- **Dimensional changes** might occur due to the large temperature variation.
- **Mechanical stability** is required for the tracking performance.
- In operation, **displacements** have to be less than 2 µm over one day in the $R\phi$ direction
  - 5 µm over one month.
  - Less stringent requirement for less sensitive directions.



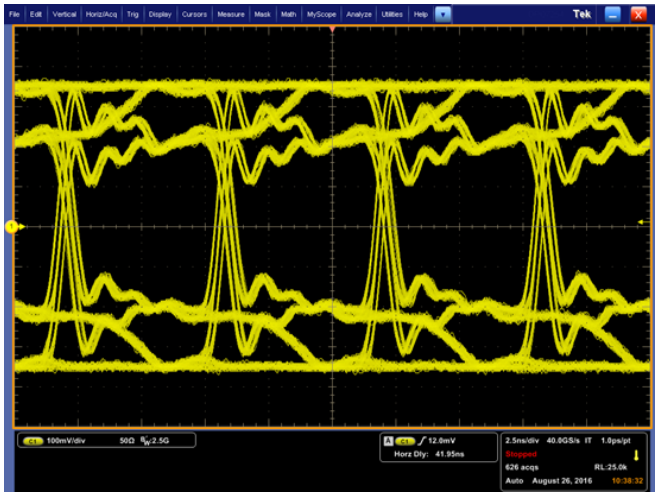
Power requirements:

- **Maximum current** specified in the worst case for the TID bump.
- Maximum **voltage drop** in the low voltage lines: 1 V.
  - For I2C lines: 200 mV in return lines.

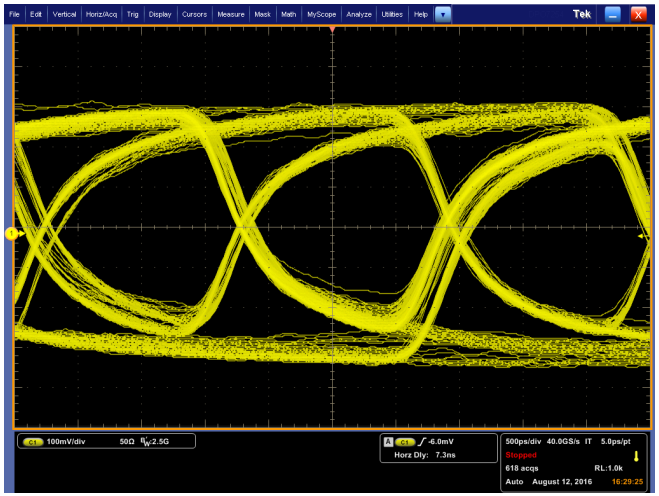
Supply	Minimum V	Maximum V	Maximum I
Stave Low Voltage	10 V	11 V	8.2 A
Stave High Voltage	-	750 V	100 mA
Petal Low Voltage	10 V	11 V	3.6 A
Petal High Voltage	-	750 V	70 mA



Stack-up of the bus-tape (not to scale).



Eye diagram of a PRBS pattern at 160 Mbps on a multi-drop (10) line.



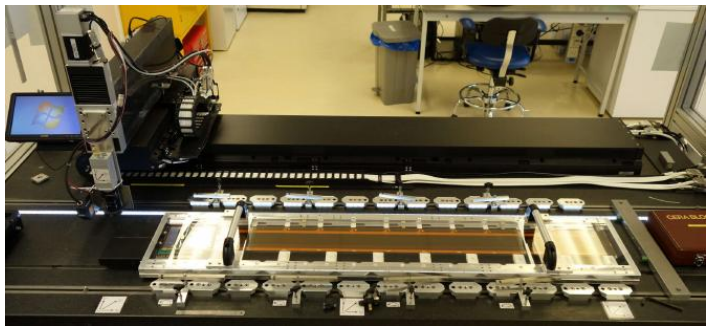
Eye diagram of an 8b10b pattern at 620 Mbps on a 1.4 m long bus-tape.

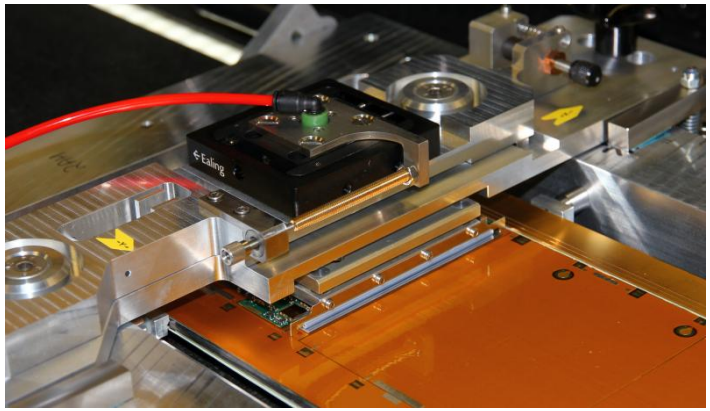
Data transmission requirements:

- **TTC** signals: 40 MHz clock and 160 Mbps lines.
  - **Multi-drop** lines with capacitive loads.
  - **Split into sections**: 2 to 10 HCC chips.
  - **BER** for 10 loads at 160 Mbps: $< 10^{-12}$.
- Data from HCC: 640 Mbps with 6b8b (or 8b10b) encoding.
  - **Point to point** links, differential pairs.
    - Staves require 28 links (short strips).
    - Petals require 14 links.
  - Measured at 620 and **777 Mbps**: BER$< 10^{-13}$.
- **Monitoring and slow control**: I2C, 400 kHz, single-ended.

Local Supports

Module Loading

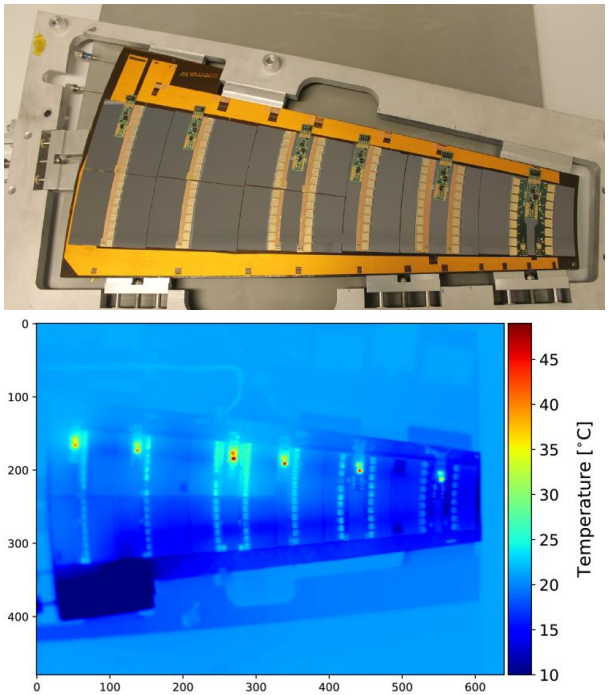


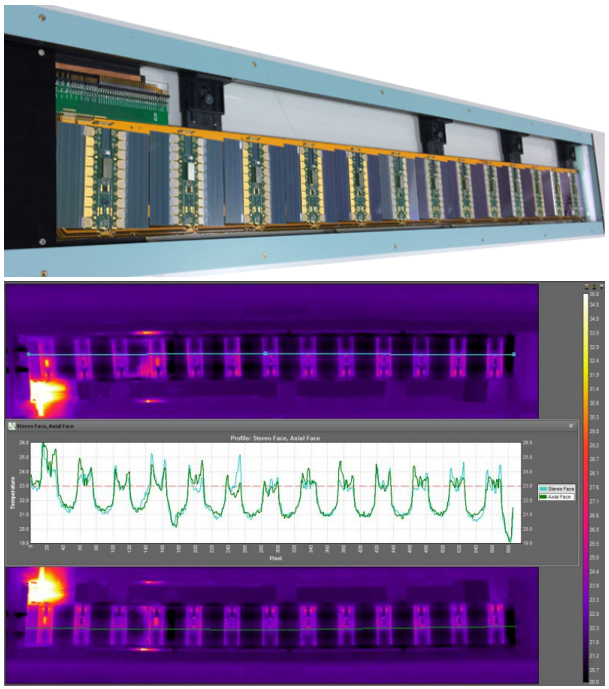


Module mounting system for the barrel.

- Module placement **precision** within 100 μm.
- Provide **good cooling connection** $\Rightarrow$ close contact between module backside and support structure.
- **Optical table** with a moving microscope.
- **Module loading bridges** to put down the modules at an adjustable location.
  - Used to hold the modules in place during glue curing.

- **Stave** and **Petal** thermo-mechanical prototypes built and measured.
  - Measurements in agreement with simulations.





Local Supports

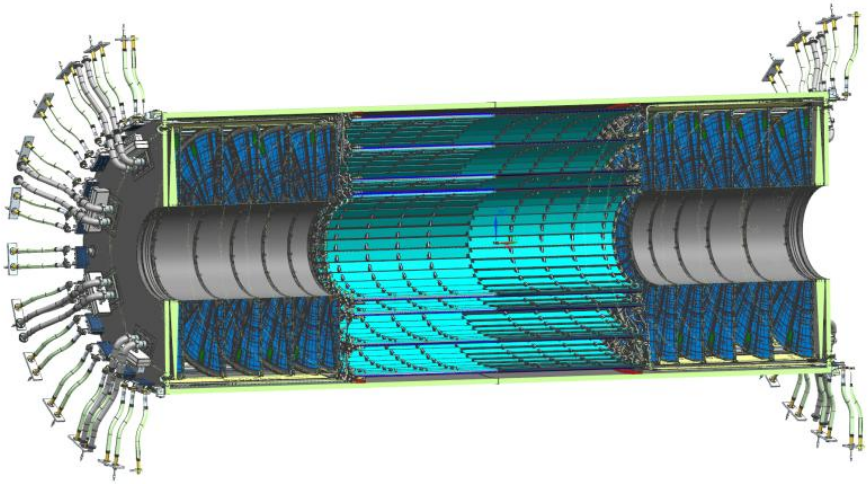
Radiation Length

- Estimations based on the current prototyping.
- **Current SCT** radiation lengths are 2.48% for barrel and 3.28% for end-caps.
- Lower radiation lengths achieved through **higher degree of sharing** of support, power and services.

Component	**Radiation Length**
Stave Core	0.48%
Stave Bus-tape	0.18%
Stave SS Module	1.08%
Module Adhesive	0.06%
Total Stave	1.80%
Petal Core	0.46%
Petal Bus-tape	0.23%
EC Module	1.04%
Module Adhesive	0.05%
Total Petal	1.78%

Global Supports

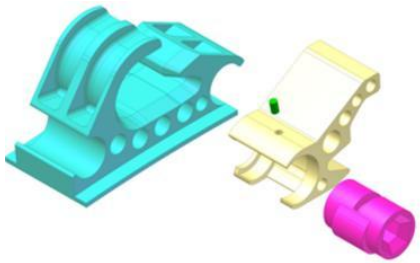
- Cylinders made of staves, wheels made of petals.
- Four concentric cylinders make up the **barrel**.
- Six wheels make one **end-cap**.

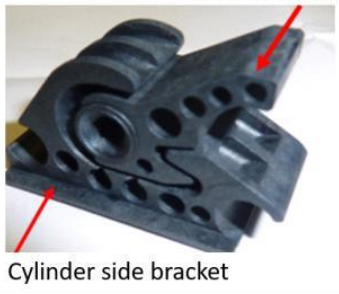


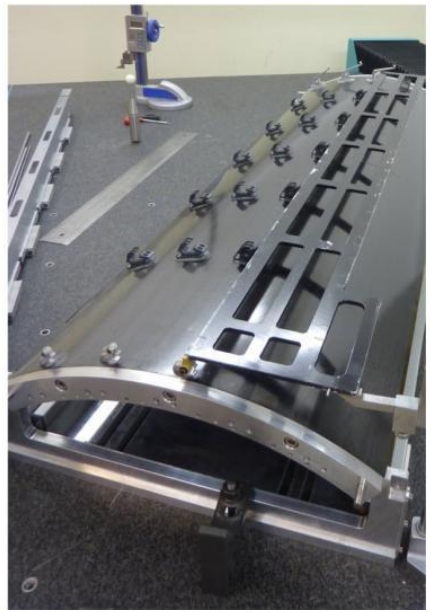
Global Supports

Barrel Global Supports

- Cylinders have lock points installed to fix the staves.
  - Five lock points per stave plus a unique point at $z = 0$.
  - Attached with a precision of 50 μm.
- Final structure built by connecting each cylinder with its neighbours by means of **interlinks**.
  - One interlink per stave $\Rightarrow$ 120 interlinks per end.



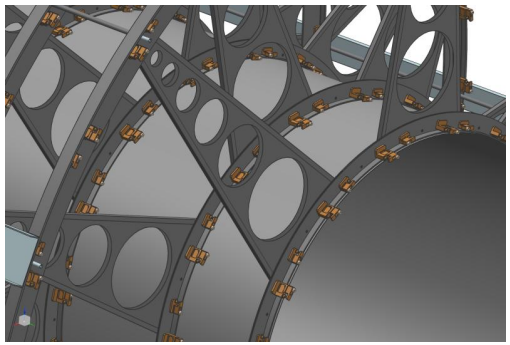


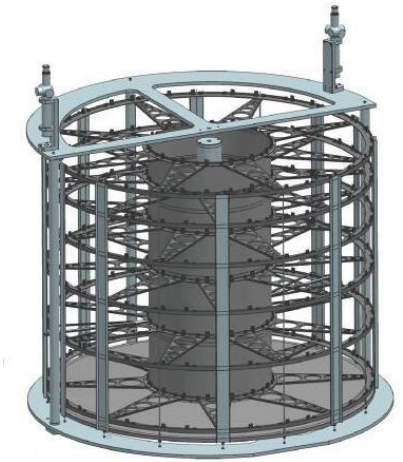


Global Supports

End-cap Global Supports

- Petals are mounted on **carbon-fibre wheel structures**.
- The wheels hold the petals in **accurate positions** and absorb mechanical stress.
- **Locking points** on the inner and outer rims of the wheels.
- Wheels are assembled into an end-cap on a super-structure.
- End-caps will be assembled at two different sites and transported to CERN.





Conclusions

- The engineering designs of the **stave and petal cores** are well advanced.
- The overall **performance** of these cores is adequate for the ITk design.
- The **electrical performance** of the first bus-tape designs exceed the requirements.
- The **global supports** design and prototyping is also in full swing.