University of Glasgow | Department of Physics & Astronomy

ATLAS ITk

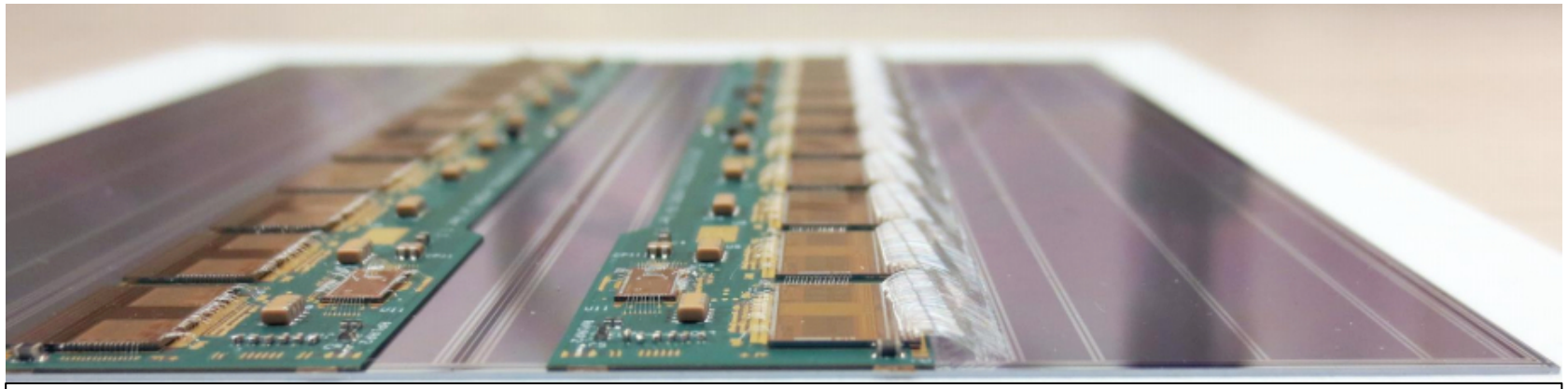
ATLAS ITk Strip Detector for High-Luminosity LHC

Andy Blue, University of Glasgow

On behalf of the ATLAS Collaboration

Outline

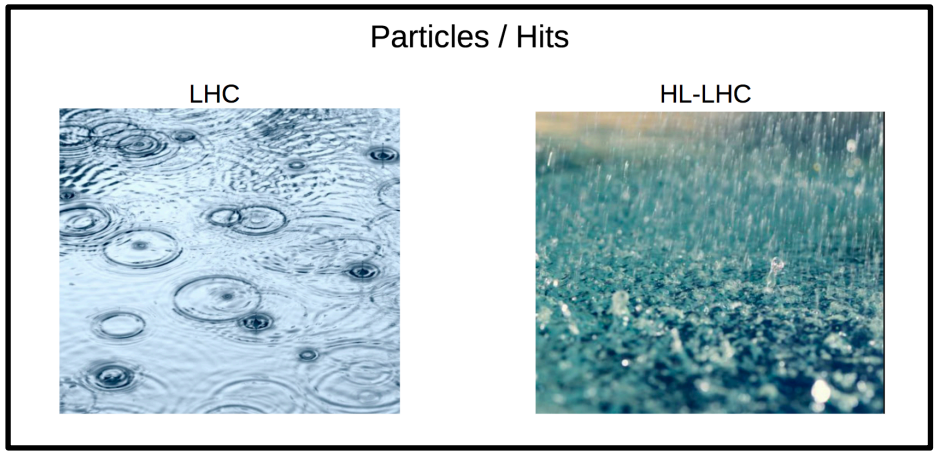
- Overview
  - ATLAS Upgrade For HL-LHC
  - The Inner Tracker (ITk)
  - ITk Layout
- ITk Strips
  - Sensors
  - Modules
  - Local Supports
  - Global Mechanics
- Current R&D
- Looking ahead

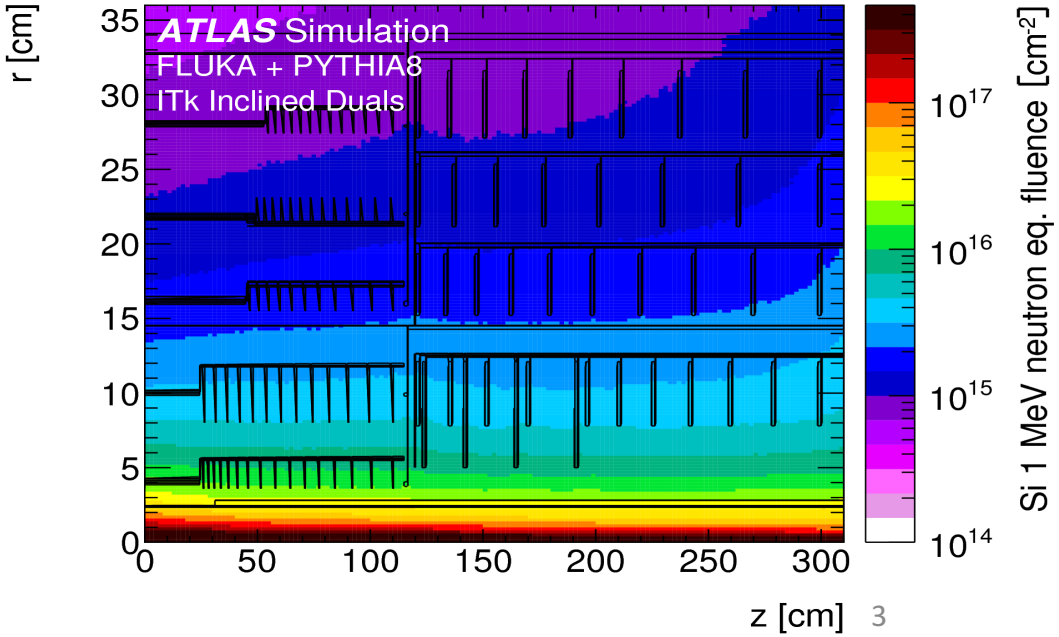


Fully Bonded Electrical Short Strip Barrel Module

ATLAS Upgrade for HL-LHC

- An Upgrade of the Large Hadron Collider (LHC) to the High Luminosity-LHC foreseen in 2026
- Instantaneous luminosity of up to **$7.5 \times 10^{34} cm^{-2} s^{-1}$**
  - Triggering with high rate & increased event sizes
- Delivering an integrated luminosity of **4000 fb^{-1}**
- Up to **200** simultaneous interactions per bunch crossing
  - Limit occupancy to 1%
- High particle fluences
  - Radiation hardness of up to **$1.3 \times 10^{16} neq/cm^2$** (Inner pixel layer) required
  - x1.5 Safety factor
- Low material budget
  - Reduction in scattering & fluences from secondary interactions



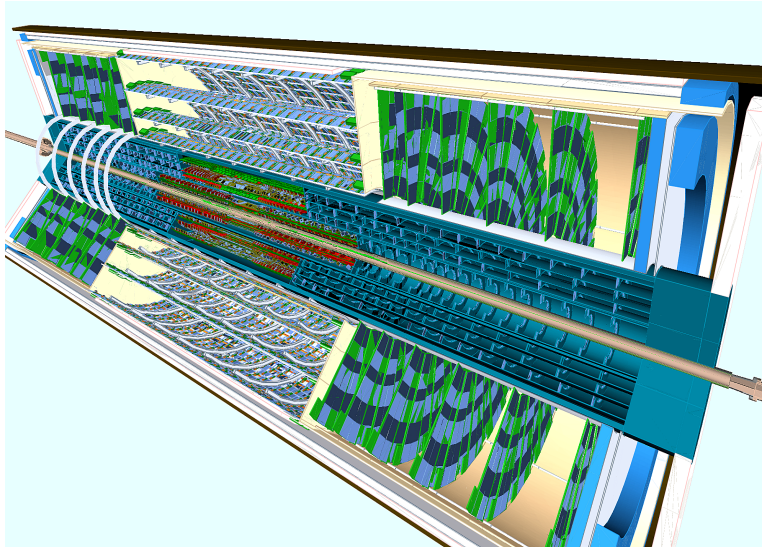


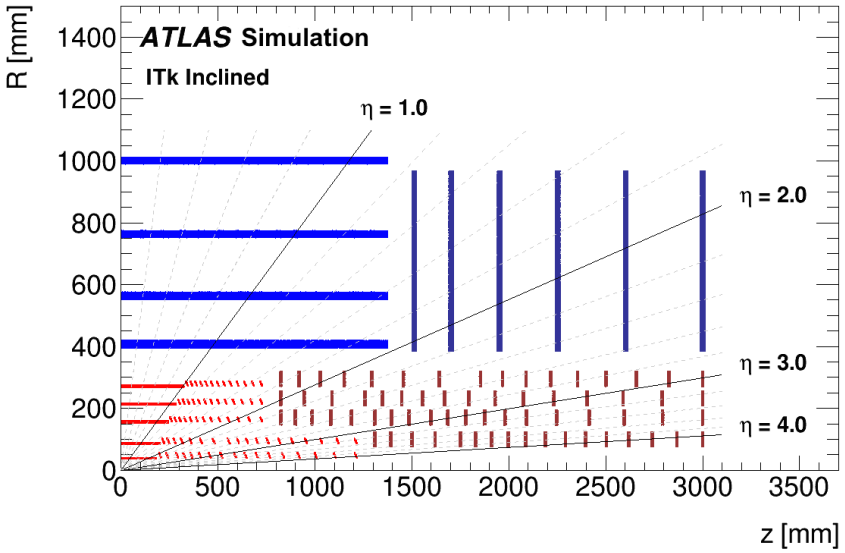
Inner Tracker System

- The new inner tracker (ITk) will be an all Si Tracker system
  - Will replace the current ID (Pixels, SCT + TRT)
  - 'All Silicon' -> no TRT
- 2T magnetic field, ~6m long, ~1m radius & up to |η|=4
- 5 Central and multiple Forward Pixel layers
- 4 Central and 6 Forward Strip layers

- Strips system consists of
  - **~18k Modules**
  - **59.87 million channels**
  - **165 m² of Silicon**

101 Institutes from 22 countries

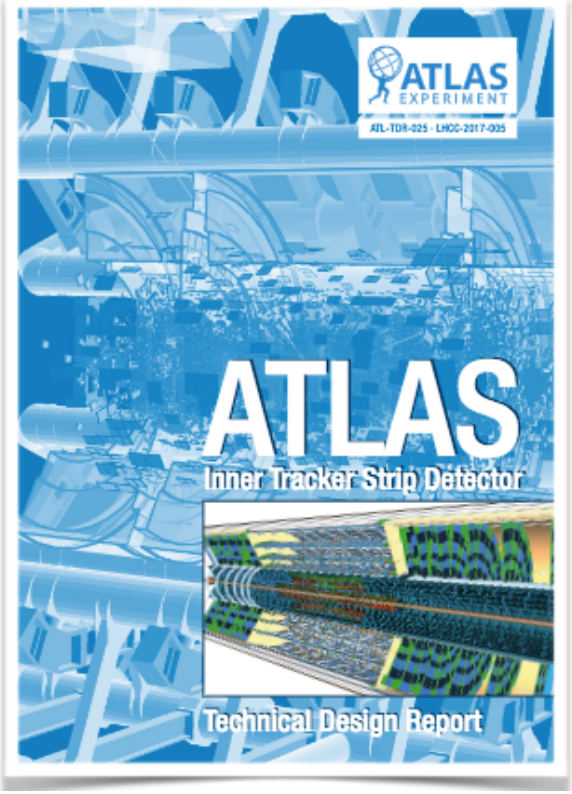




R&D - Strips

- Strips TDR was approved early 2017

- Strips have began transition from R&D phase into production preparation. However lot of work still going on
  - Sensor Characterisation
  - UV Curing of Glues
  - First Modules built with ABC130 ASICs
  - Irradiation & Testing of Components
  - Electrical & Thermo-mechanical Stave/Petal tests



Poster by Cristoph Klein

ITk Strip Sensors

- Silicon used by ITk strips are 320μm thick n-in-p float zone Si sensors
- n-in-p sensors allow for
  - Improved tolerance against radiation damage (no p-bulk type conversion)
  - Collection of electrons (fast charge carriers)
  - Single sided processing (easier processing, handling and cost)

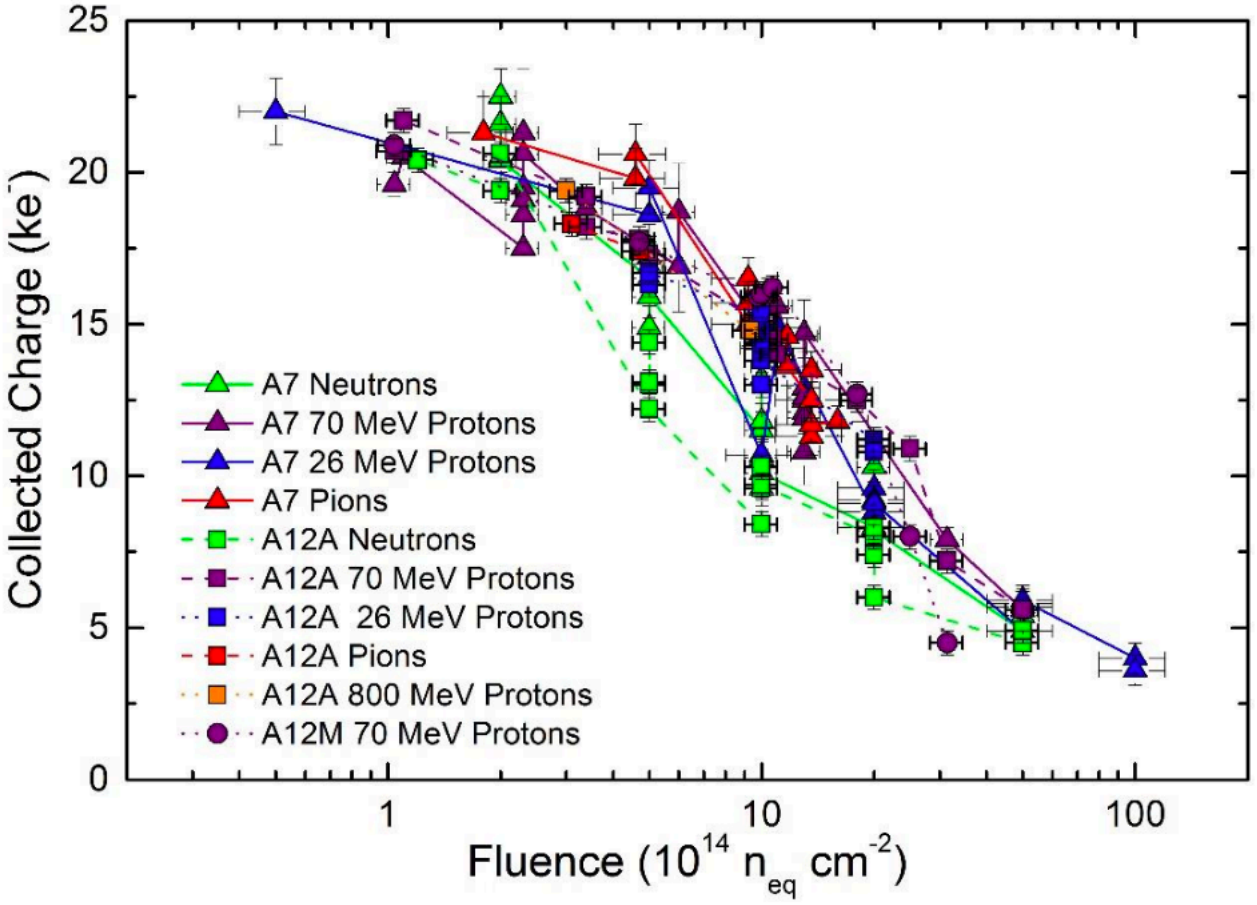
- The Central region (barrel) has 1 sensor shape with 74.5um strip pitch, and with strip lengths of 23.9mm & 47.75mm (Short & Long Strips)
- The Forward regions (Endcap) has 5 sensor shapes with strip lengths from 8.1mm to 49.9 mm

R0 Sensor – Innermost sensor for the Endcap (forward) region

Sensor Evaluation

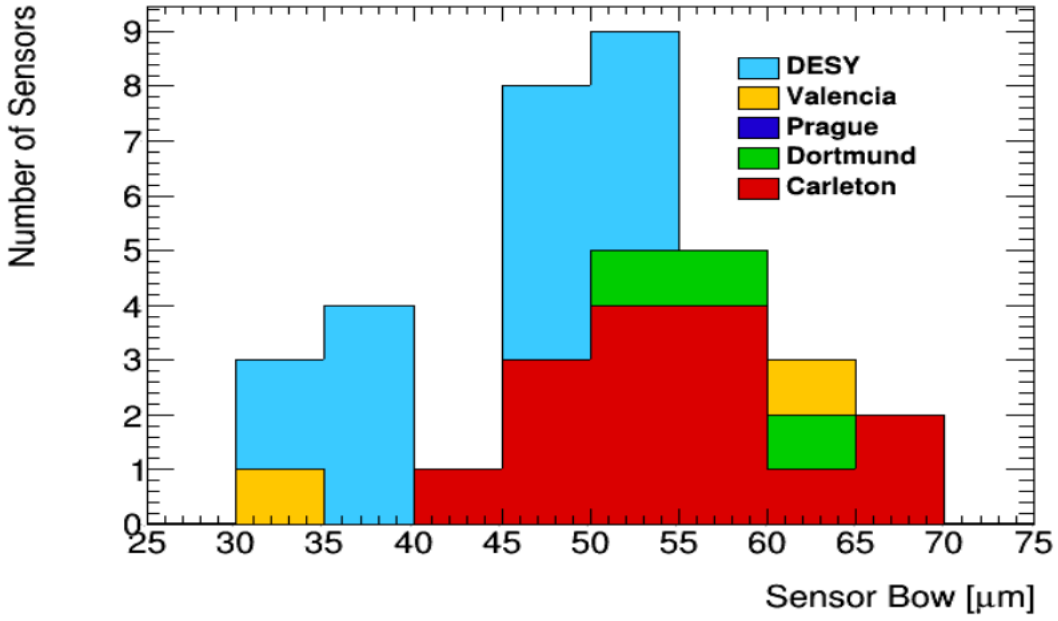
- Community has tested several iterations of sensors
  - Barrel Long Strip & Short Strip
  - Endcap R0 (innermost sensor of the petal)

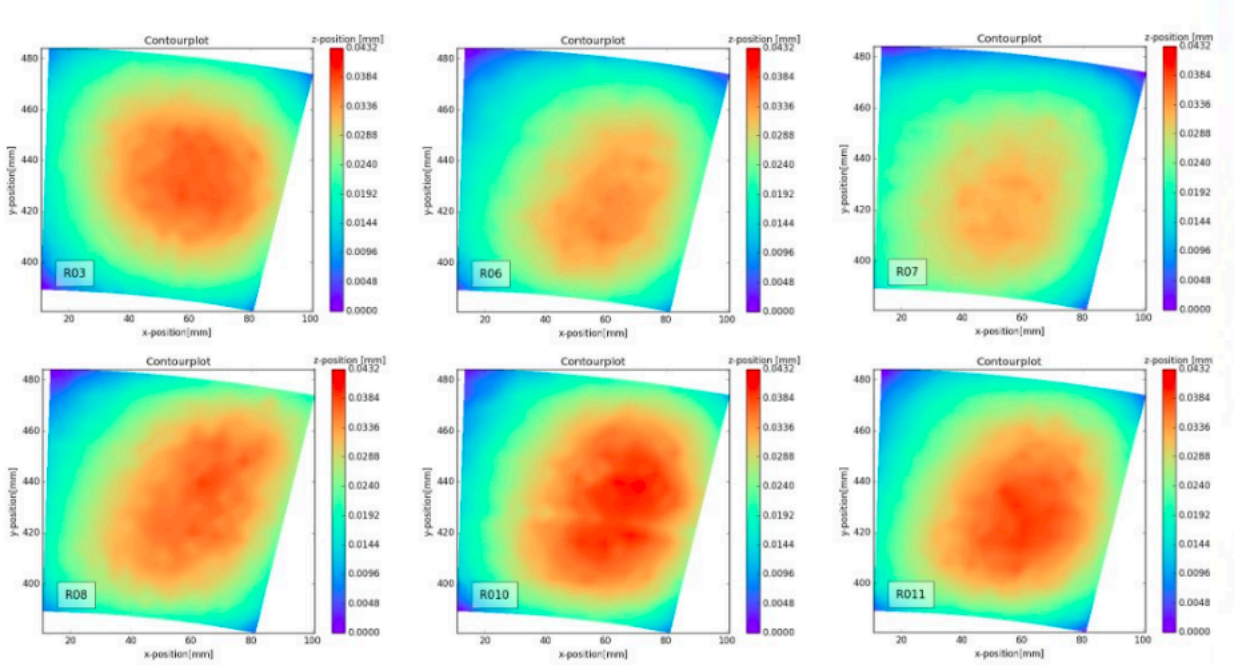
- Measured expected signal from Alibava system (Sr-90 source)
  - Consistent with previous measurements
  - Over a range of irradiation sources and fluencies



Sensor Evaluation

- As well as electrical characterisation, mechanical properties look consistent across batches
- All R0 sensors measured have a total bow (max minus min point) below 70 μm, which is within specification of 200 μm



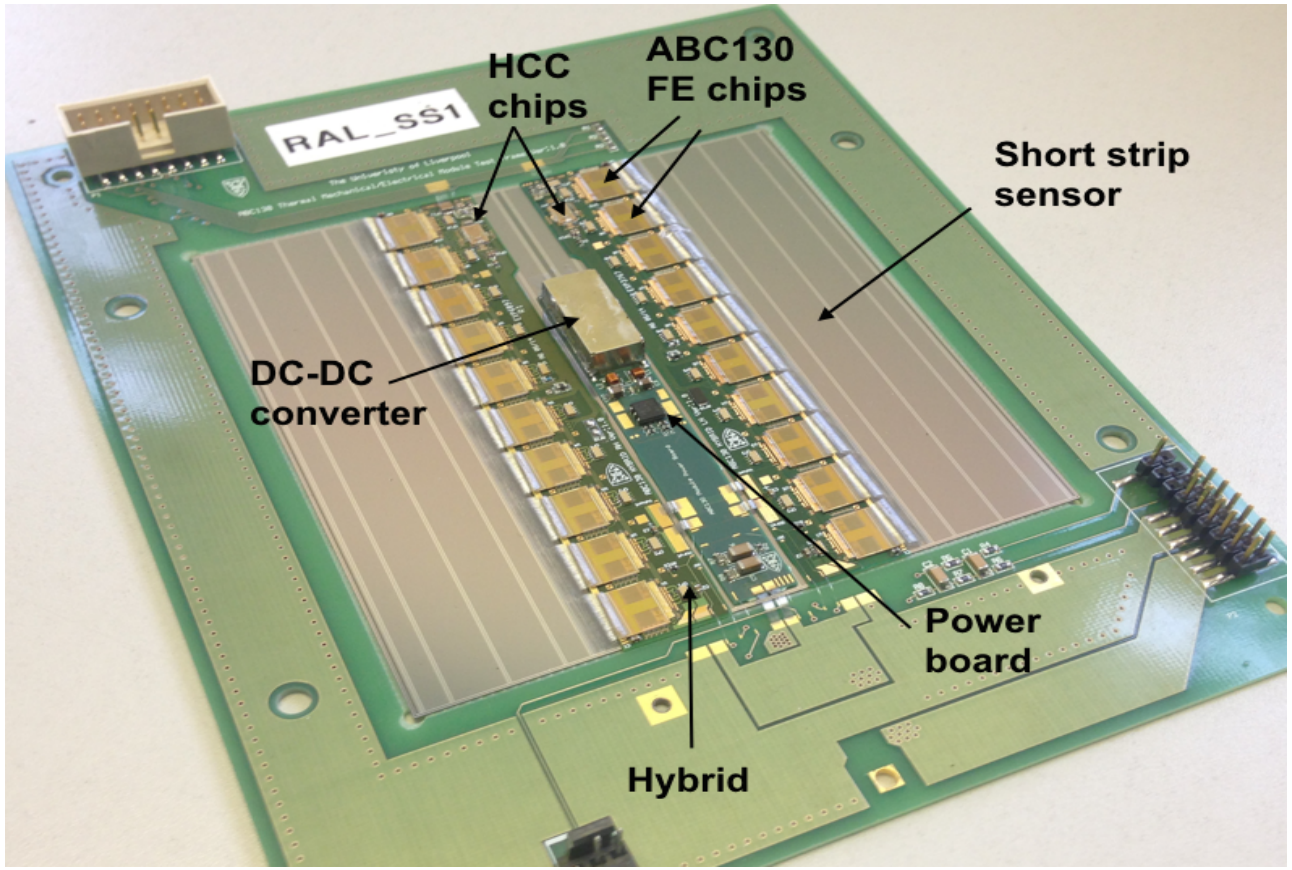


Poster by Martin Sykora

ITk Strip Modules

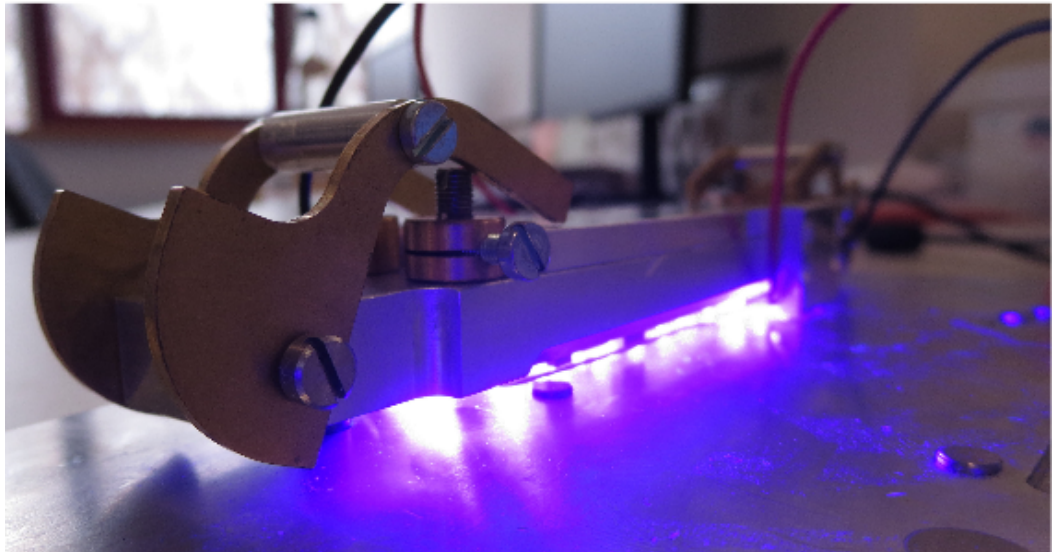
Silicon Modules consist of:

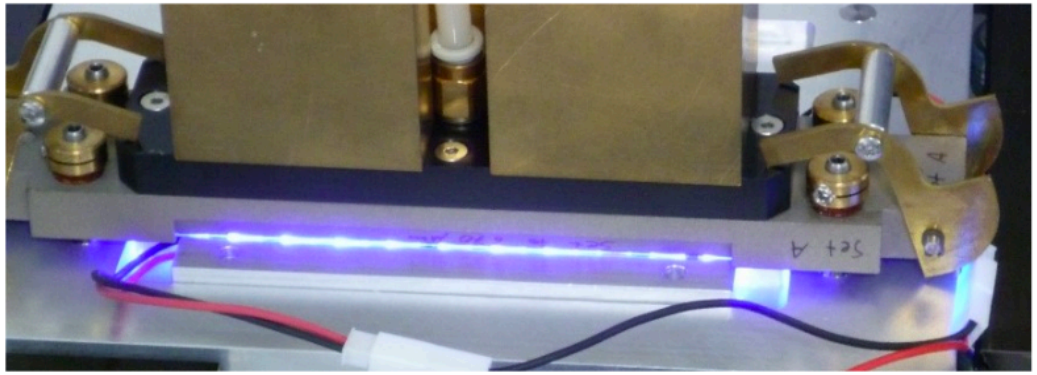
- Binary readout chips (ABC) and hybrid controller chips (HCC)
  - Glued & wire bonded to a hybrid
  - Data transfer on hybrid at 320 Mbit/s
- Hybrids are glued to the surface of the Si sensor
  - Wire bonds connect Front End ABC channels to Si strips
  - ~5200 wire bonds /module
- DC-DC powering allows powering of all modules
  - Unlike SCT each module cannot have own Voltage Cables



Modules – UV Curing

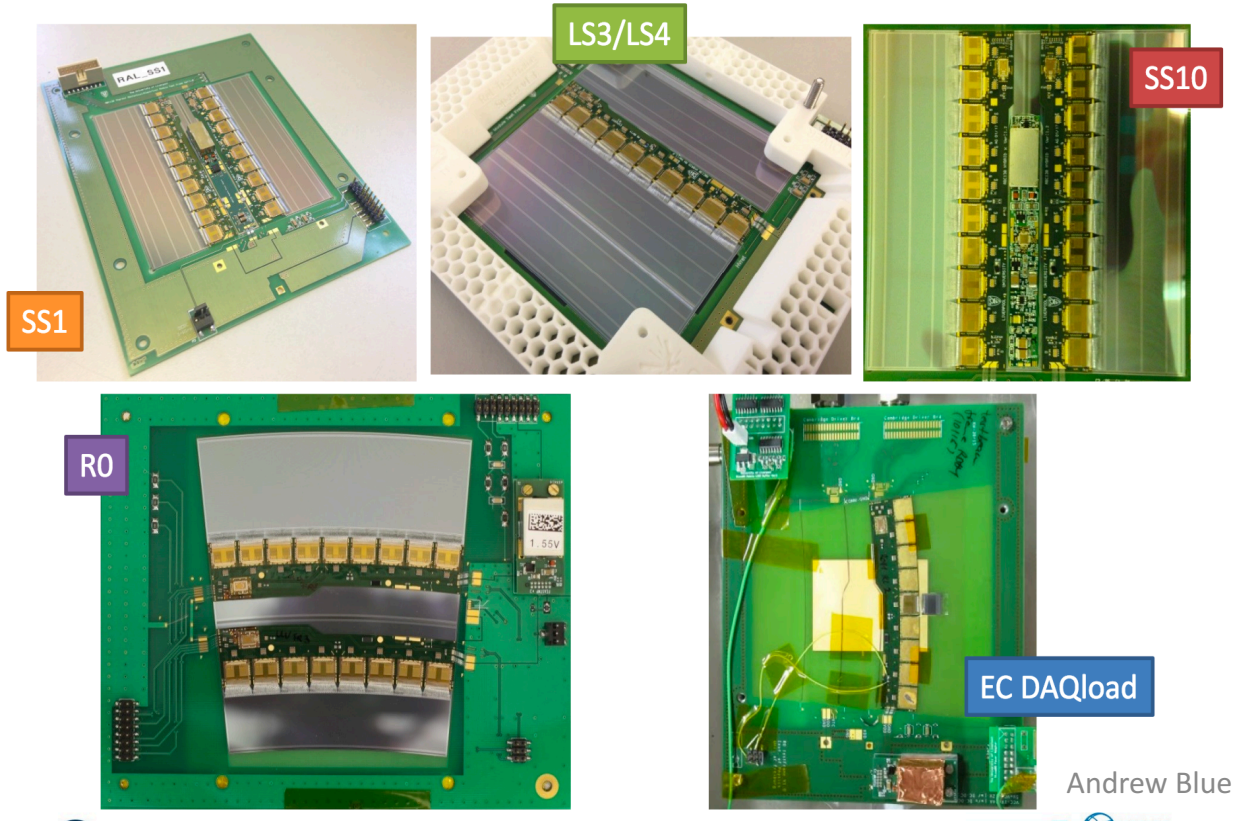
- With the high throughput of modules needed for the ITk, it is necessary to optimise the build time
  - Module Count - SCT: **4088** v ITk: **17,888**
- Strips have baselined the use of UV Cure glues
- For glue between ASICs and Hybrids
- Glues exposed to UV light will cure within 6 minutes
- Conventional glue takes > 12hrs





Modules – Electrical Tests

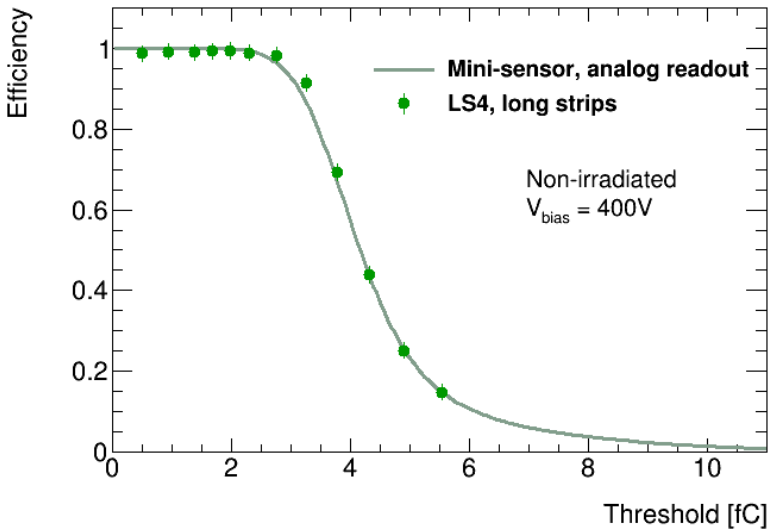
- Fully functioning electrical modules have been made by many of the assembly sites (for both Barrel and Endcap)



We test a binary readout using **Threshold Scans**

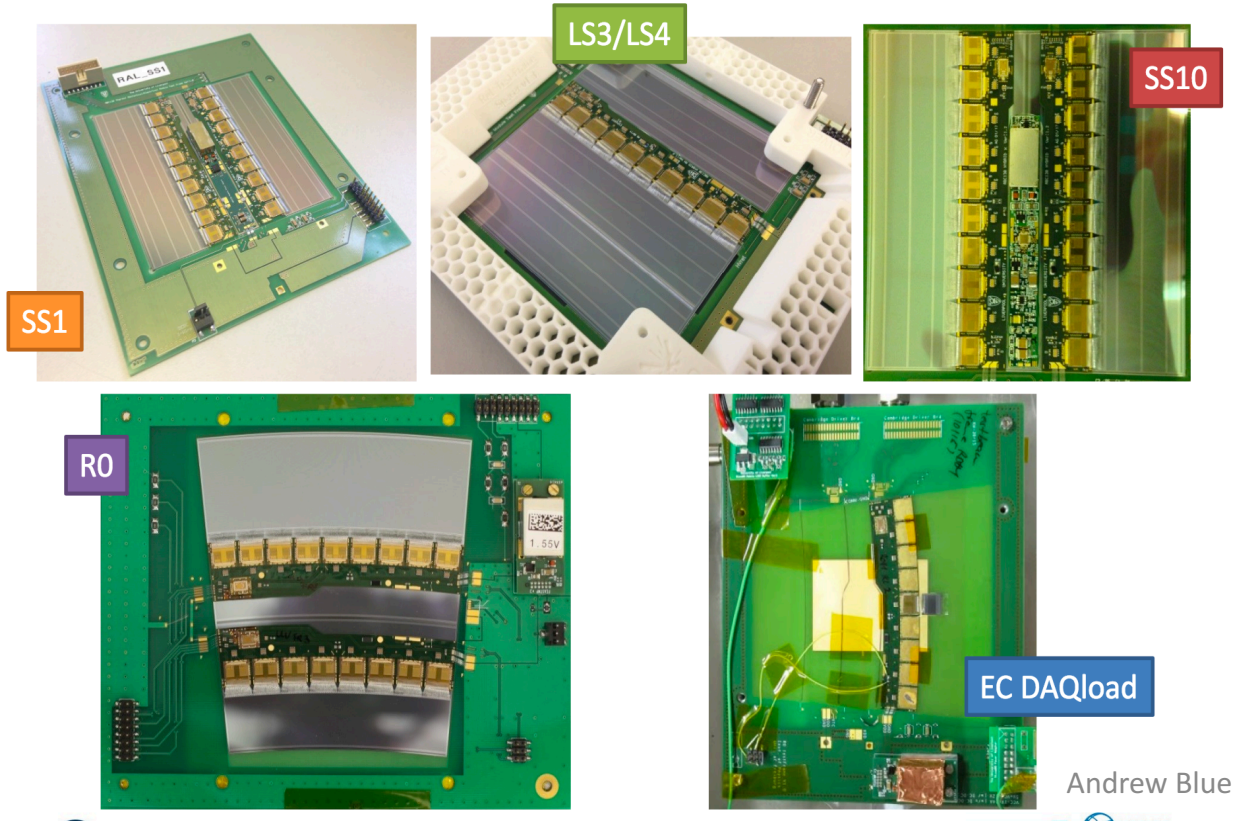
- Have a known input signal
  - Set low threshold
  - Apply signal x n(200)
  - Count the number of recorded hits
  - Increase threshold
  - Apply signal x n (200)
  - Count hits

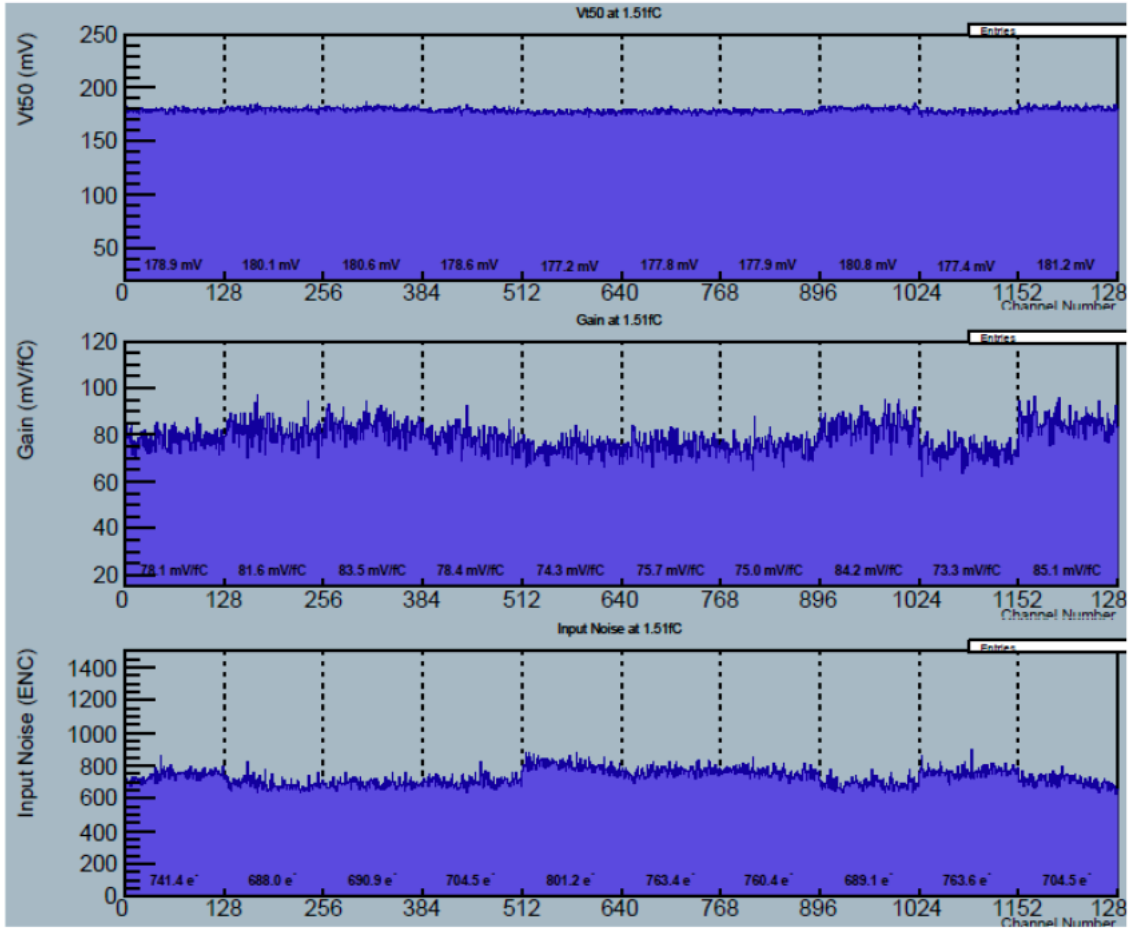
Loop



Modules – Electrical Tests

- Fully functioning electrical modules have been made by many of the assembly sites (for both Barrel and Endcap)

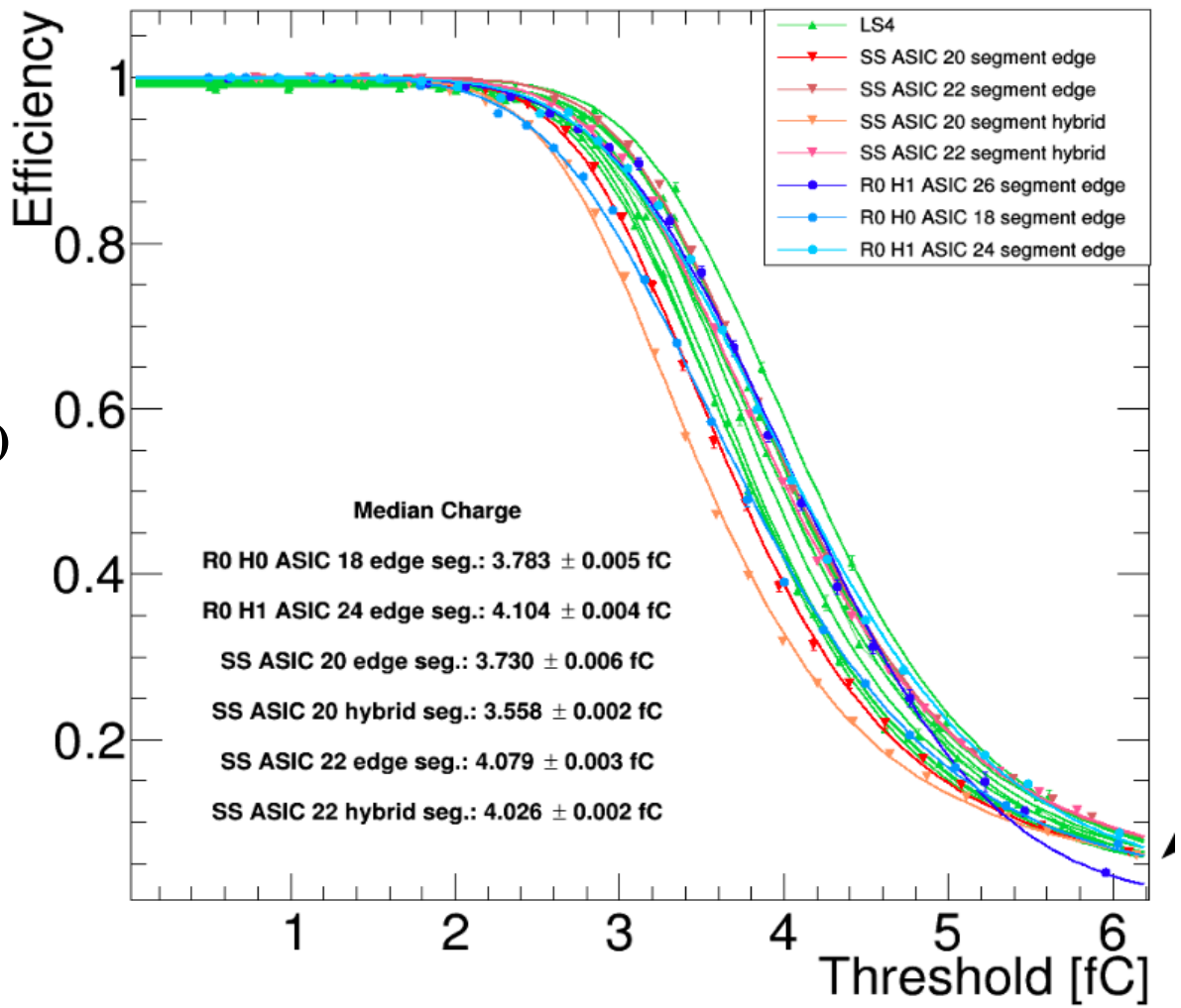




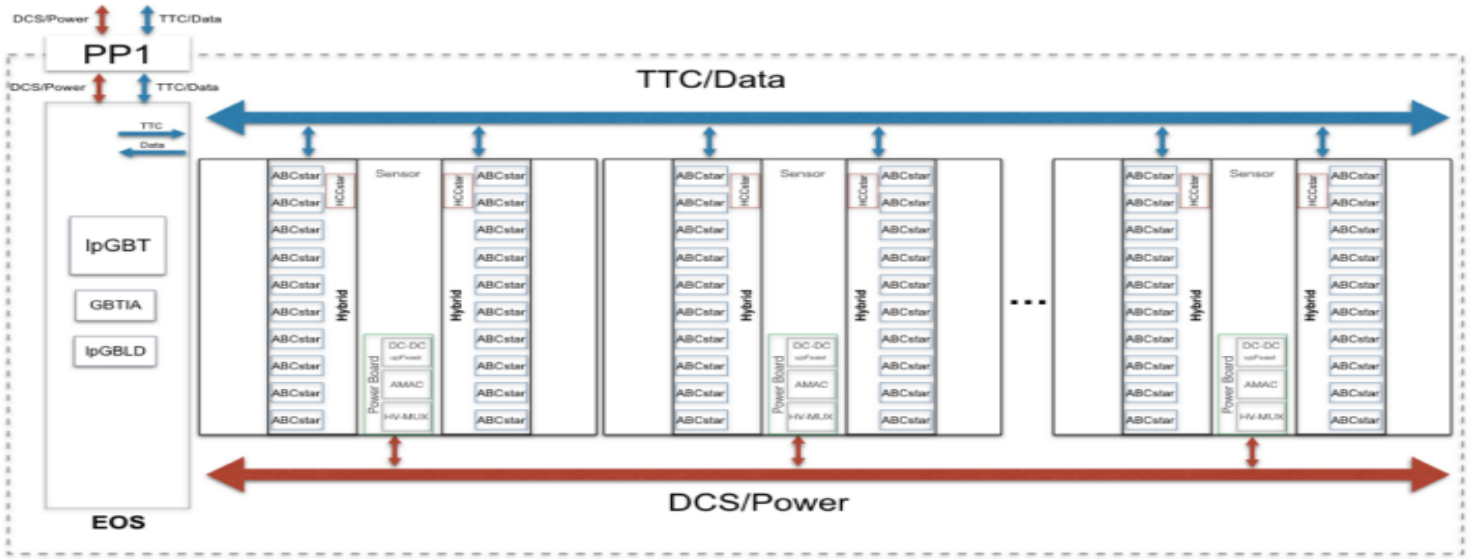
A Barrel Module operated at 400 V bias.
The average noise on hybrid is 710e⁻
The row of strips under the hybrid has higher noise by 41e⁻

Modules - Testbeam

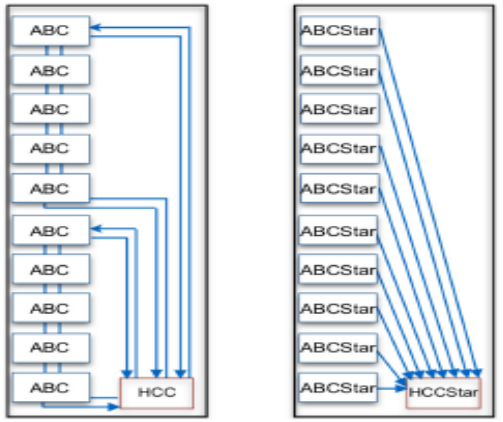
- Conducted a series of successful testbeam campaigns since 2015
  - Both pre and post irradiated Modules
- Latest studies conducted on Endcap R0 Modules
  - Track reconstruction more complex due to Radial Strips
  - However efficiency measurements seen to match well to previously studied Barrel Modules



ITk Strip Electronics



Comparison of daisy chain signal routing of prototype ABC ASICs and new ABCStar design.

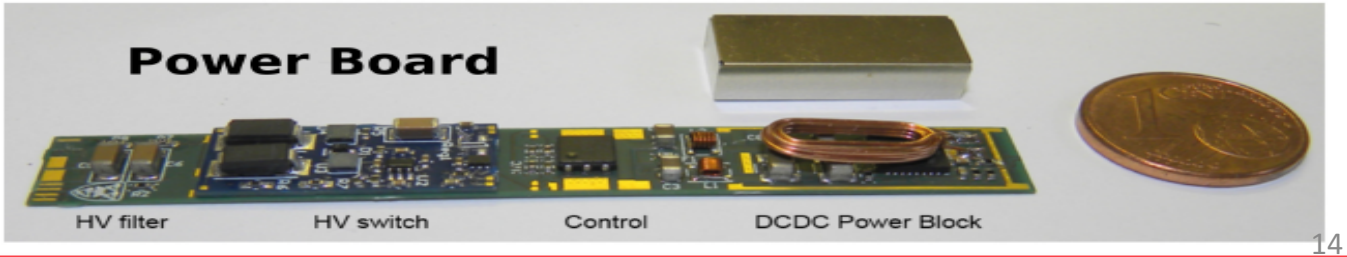


EOS
- lpGBTx (I2C interface) + VTRx+

DC-DC converter
- built around a buck converter **upFEAST chip**
- distribution of LV to module (5-12 V -> 0.6-5 V with FAEST2.1)

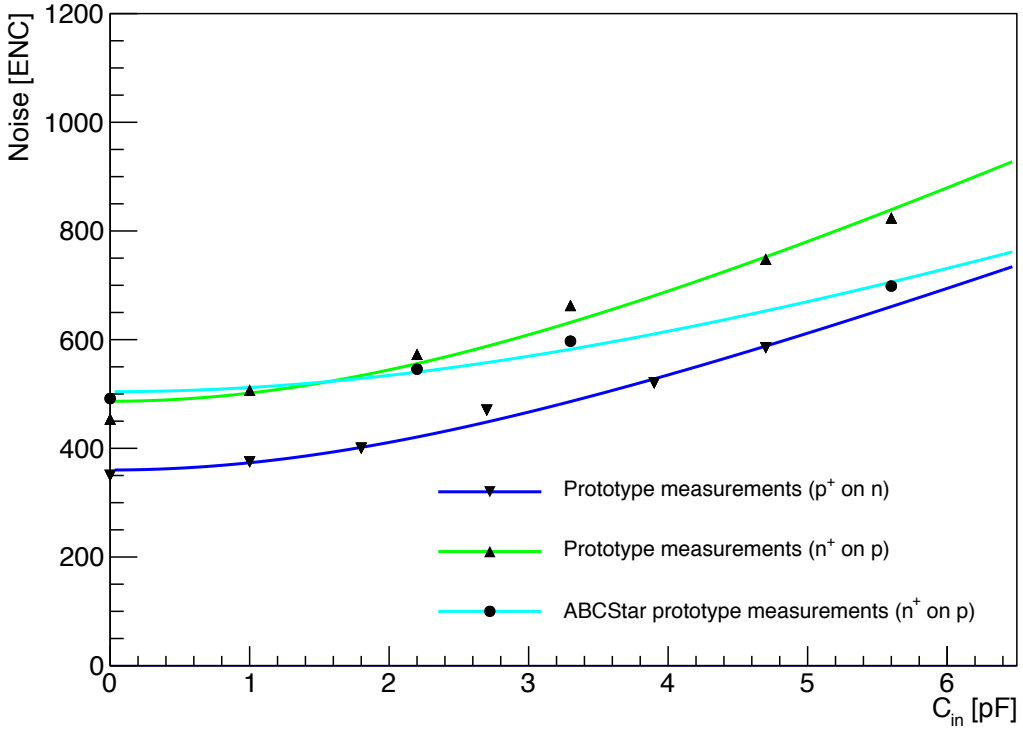
AMAC
- monitoring of LV and HV, temperatures and sensor bias current on module (1 sample / ms)

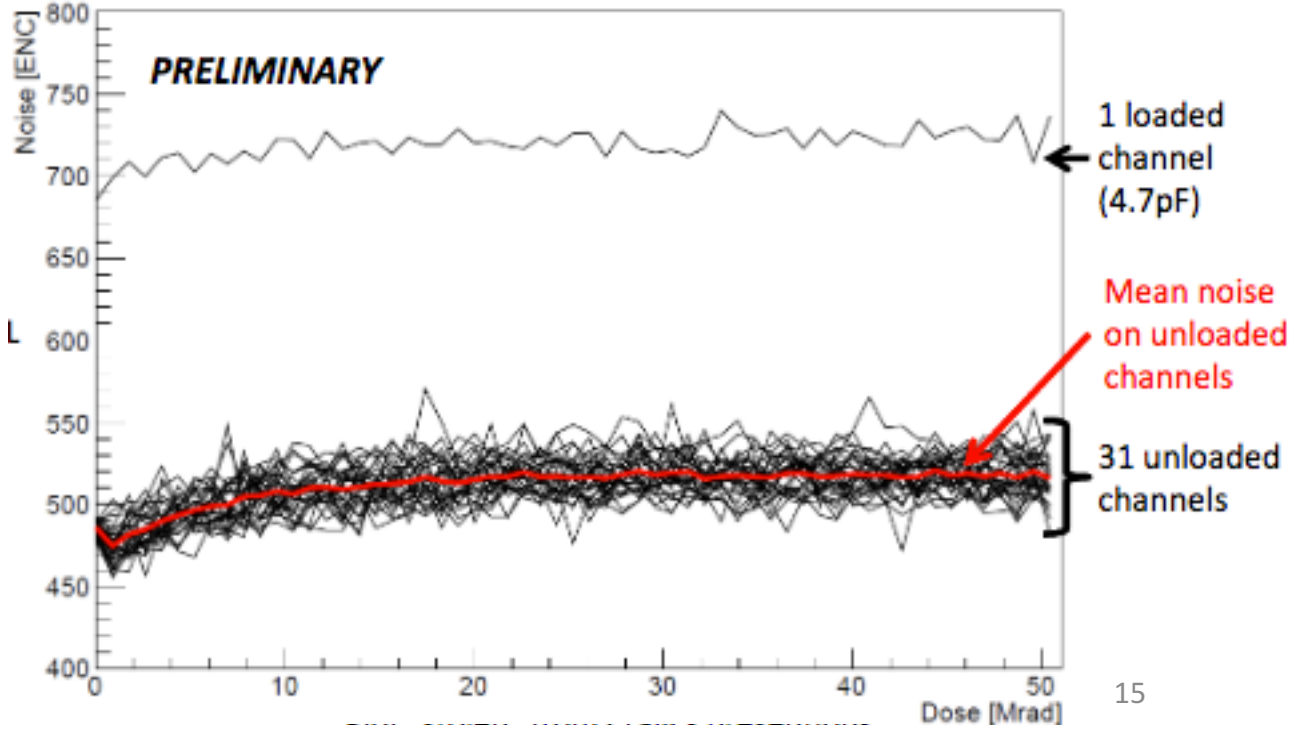
HV-MUX
- controlled HV switch,
- connection/disconection of module from HV,
- GaNFET or 3D Trench Vertical JFET transistor gate controled by HV multiplexer



ABCstar Front End Prototypes

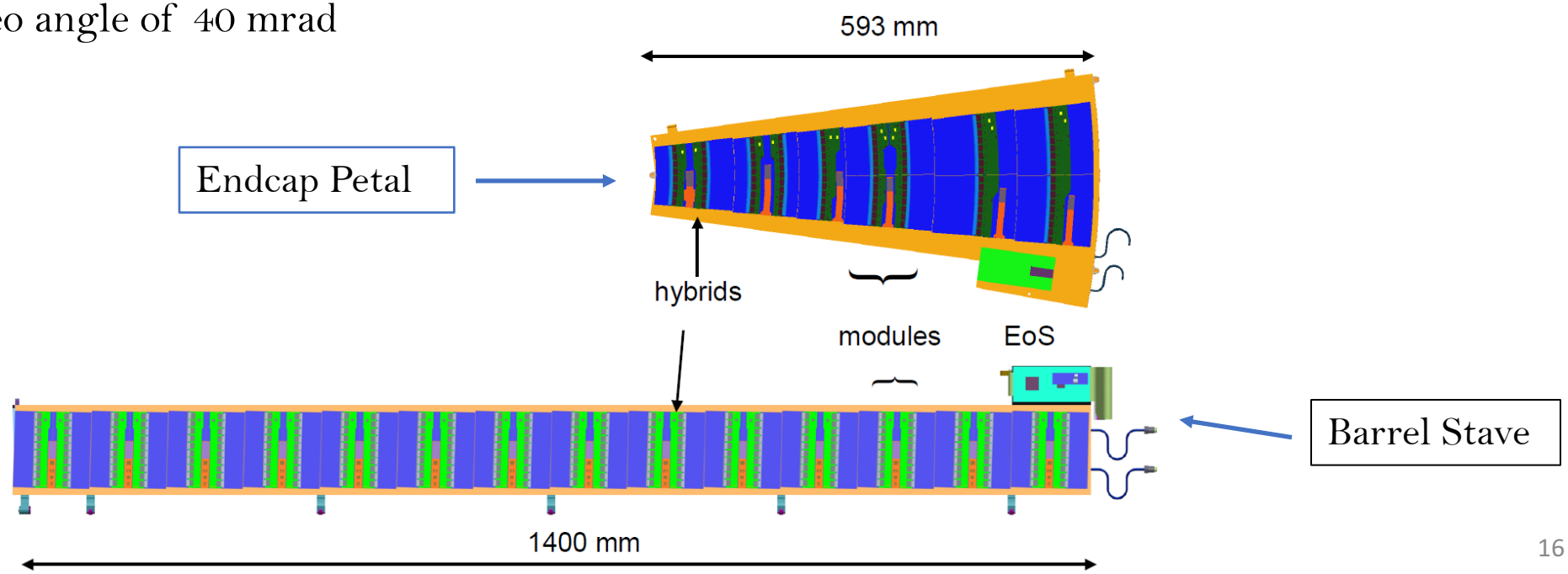
- Important to demonstrate all components used are radiation hard to the expected end of life dose of the HL-LHC
- The new readout chip (ABCstar) has been tested to examine any noise increase after irradiation
  - Reduction in noise of Front End prototype compared to current ABC130 chips





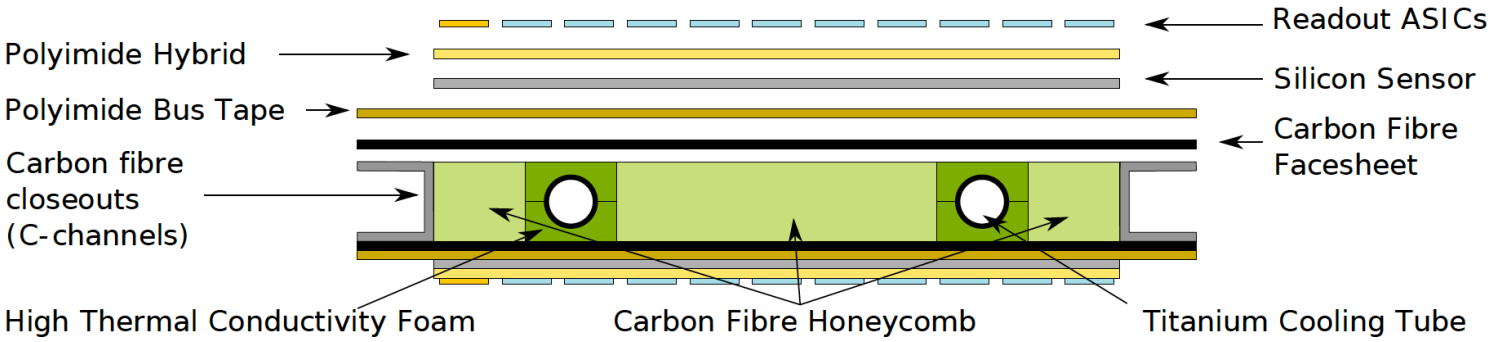
ITk Strip Local Supports

- There are **28** barrel modules on each stave (14 modules per side)
  - Modules on each side of the stave are rotated with respect to the beam line by 26 mrad
    - A total rotation of 52 mrad
- There are **18** endcap modules on each petal (9 modules per side, rings R0 - R5)
  - stereo angle of 20 mrad directly implemented in sensor geometry
    - total stereo angle of 40 mrad

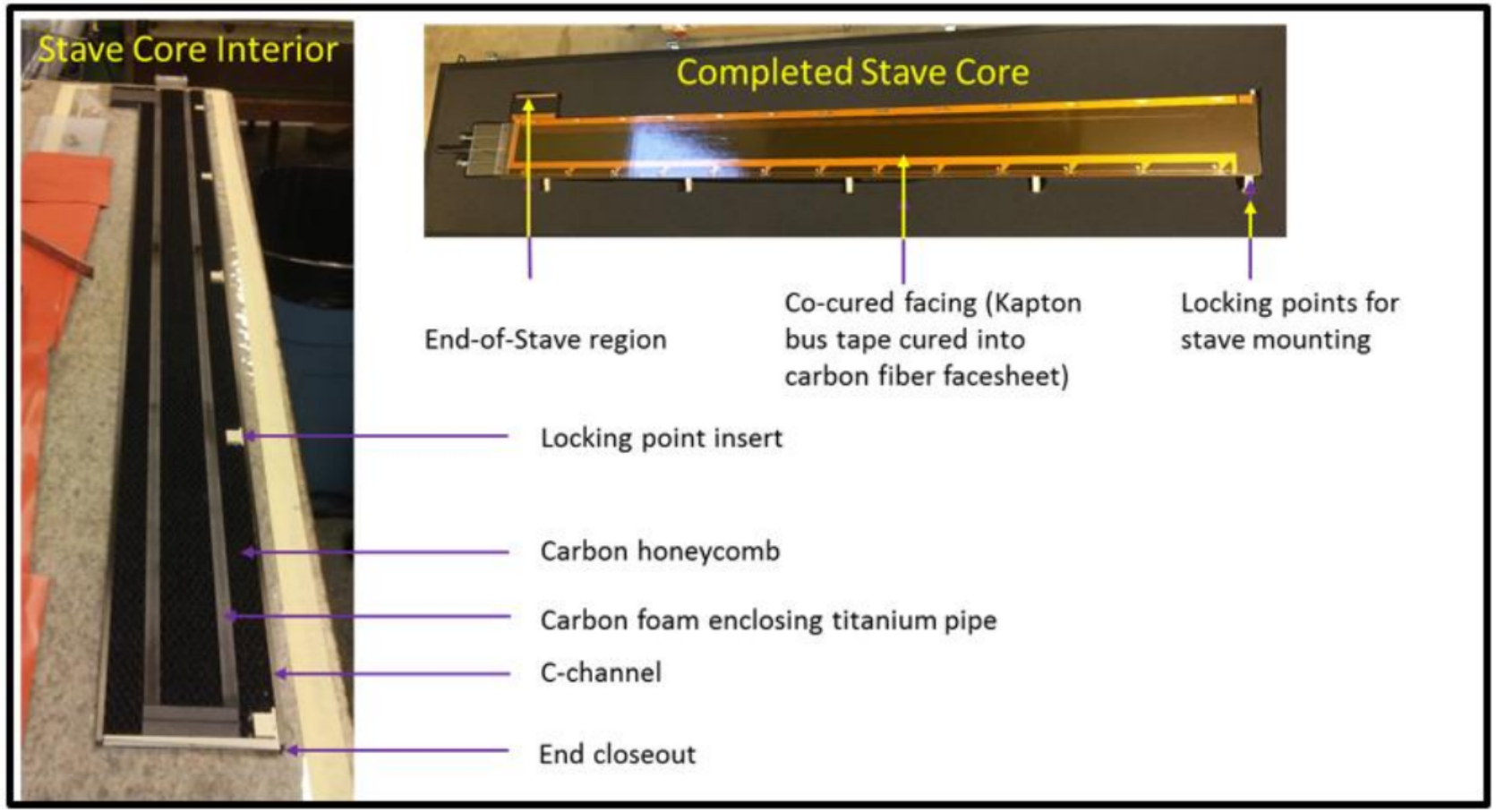


ITk Strip Local Supports

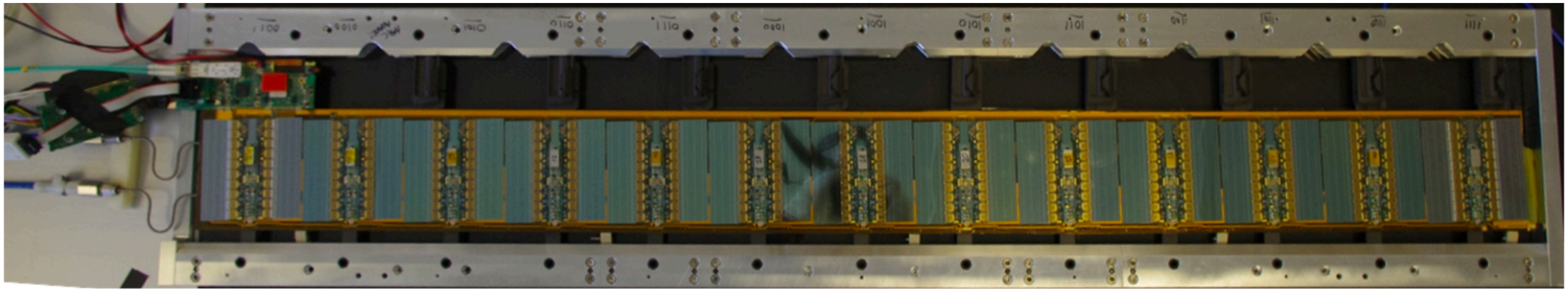
- Staves (barrel) and Petals (endcap) provides mechanical, geometric, thermal and electrical support to modules:
  - **Mechanical and Geometric**: local supports interface to global support structures through a series of position locators and locking points
  - **Thermal**: titanium cooling tubes connected to CO^2 cooling system working with temperatures between +20C and - 40C
  - **Electrical**: electrical power (LV and HV), TTC (Timing, Trigger and and Control) data, DCS (Detector Control System) data and measured data transfer services required by the modules are carried by a copper/kapton bus tape mounted on both sides of structure and operated by EoS (End of Substructure) card



Local Supports – Prototype Staves



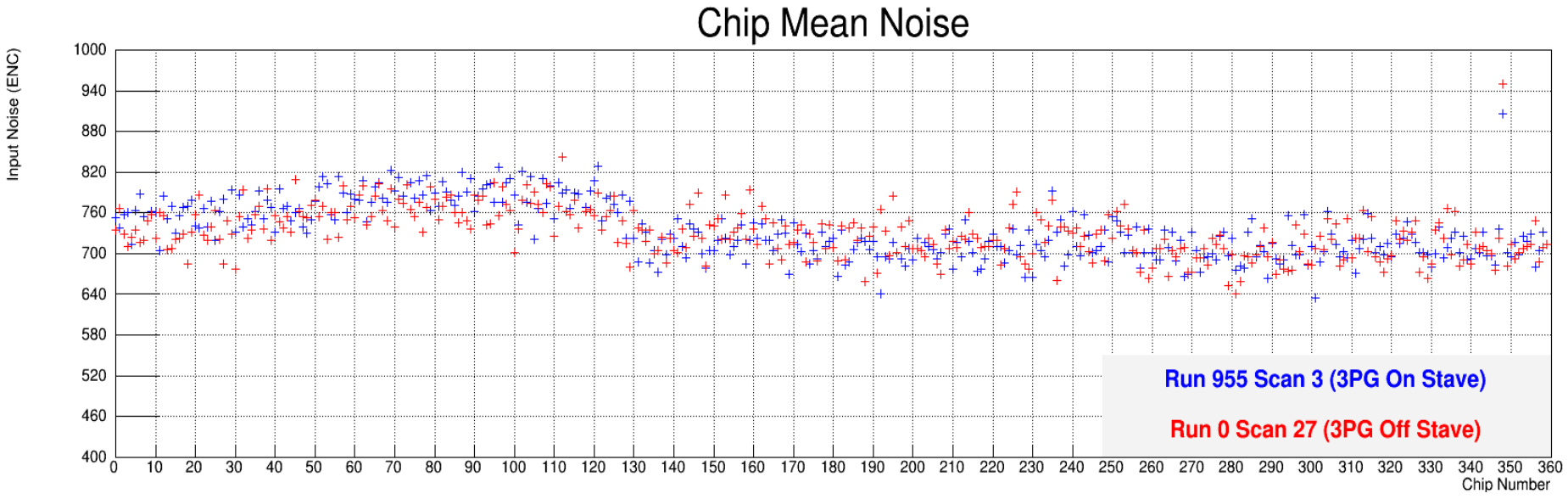
Electrical Stave tests

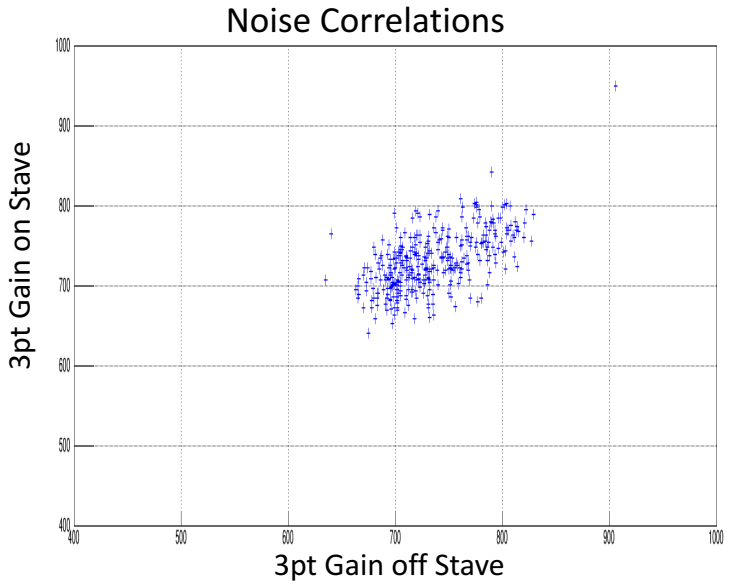


- Electrical Staves are being assembled at institutes in the UK (Rutherford Laboratories) and USA (Brookhaven National Labs)
  - BNL: 12 Electrical Short Strip modules
  - RAL: 2 real SS modules and 11 Electro-Mechanical SS modules (dummy sensor)

- In Addition a 5 module 'Stavelet' was assembled and fully tested
  - Comparison made of 3 point gain measurements before and after mounting to the stavelet
    - Do we see an electrical noise increase?
    - Early systems test

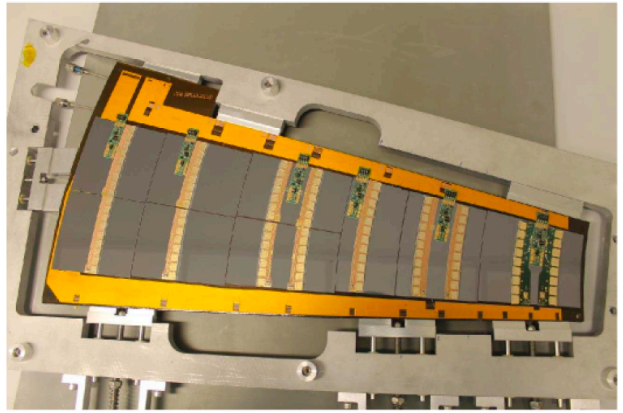
Comparison of Noise Results: On & Off Stavelet

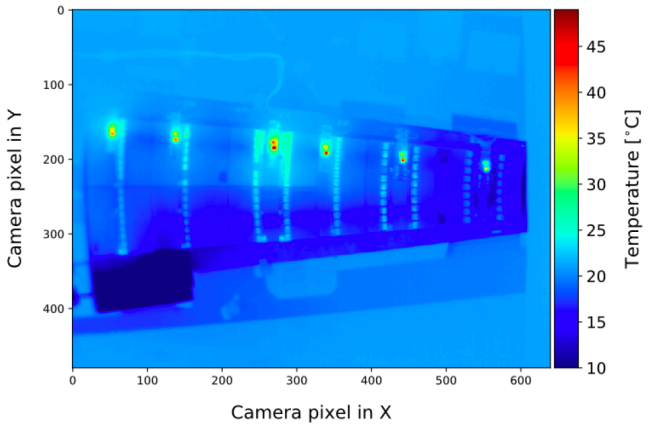




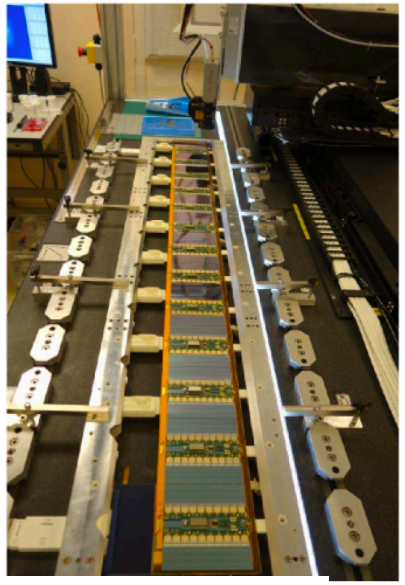
Thermo-Mechanical Local Supports

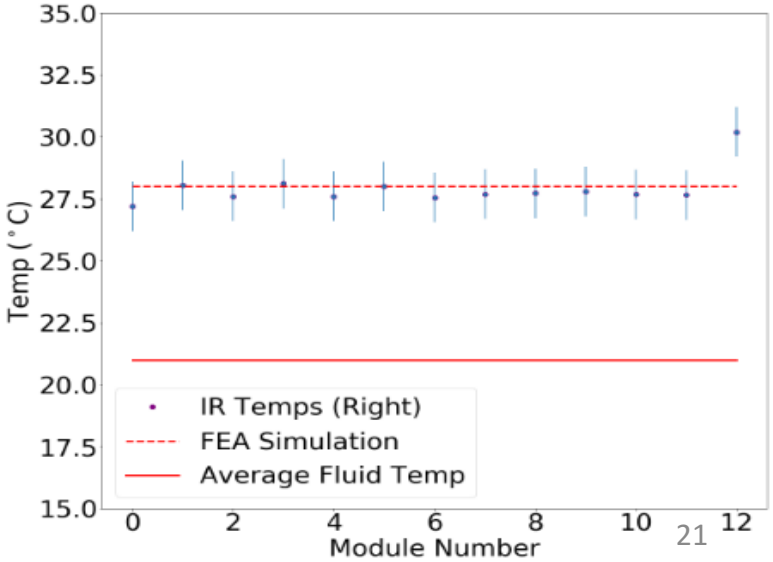
- Thermo-Mechanical Staves and Petals have been assembled
  - Using dummy module with same dimensions and thermal outputs as electrical modules





- Performance can then be compared to Finite Element Analysis (FEA) simulations
- For Barrel TM Stave, measured difference from simulation **~0.2°C**



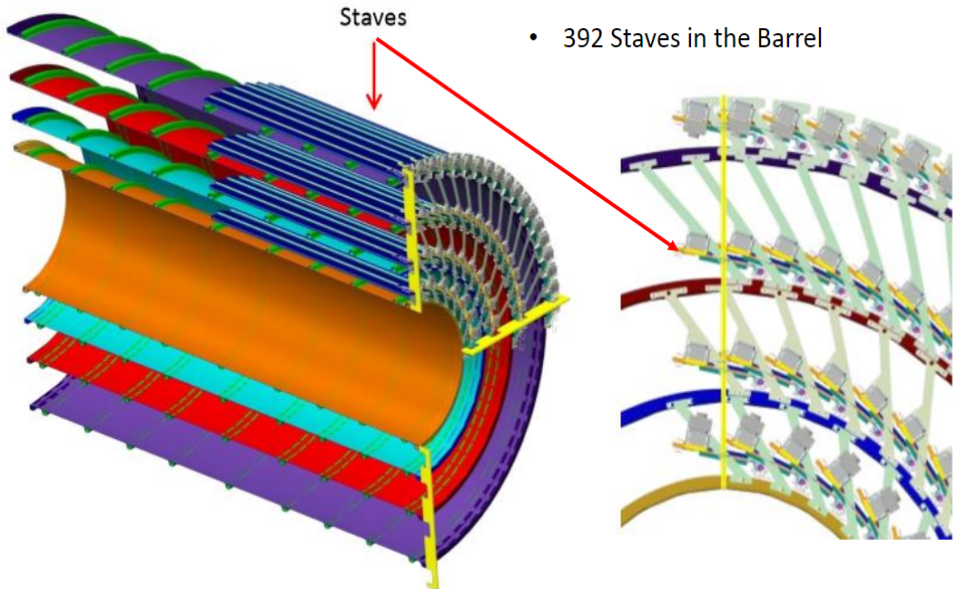


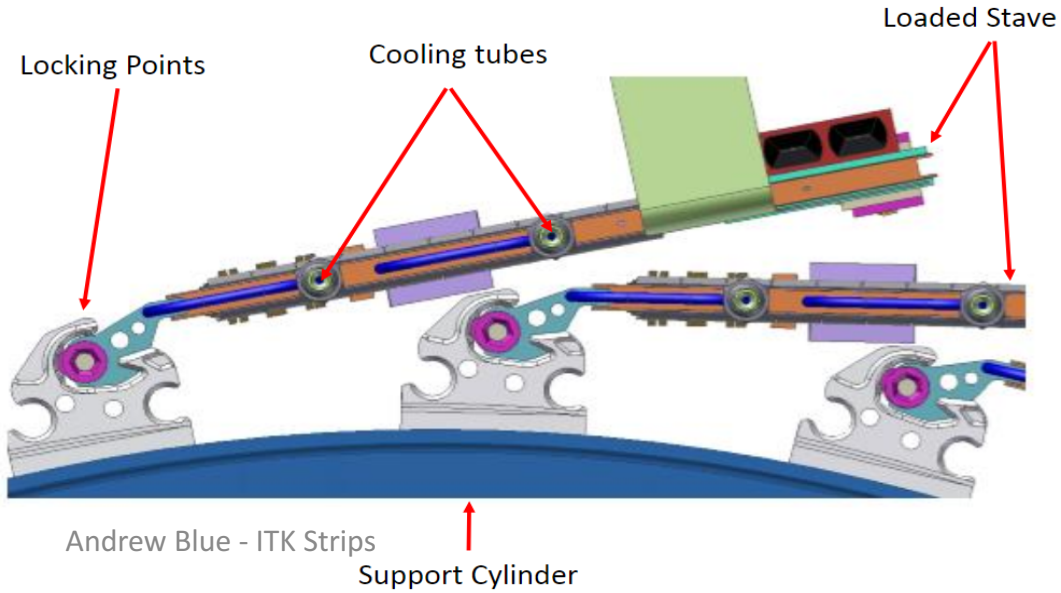
ITk Strip Global Structures

The Barrel is constructed from

- 4 Layers (392 Staves in total)
  - Outer 2 Layers have Long Strip Modules
  - Inner 2 layers have Short Strip Modules

Barrel Cylinder





ITk Strip Global Structures

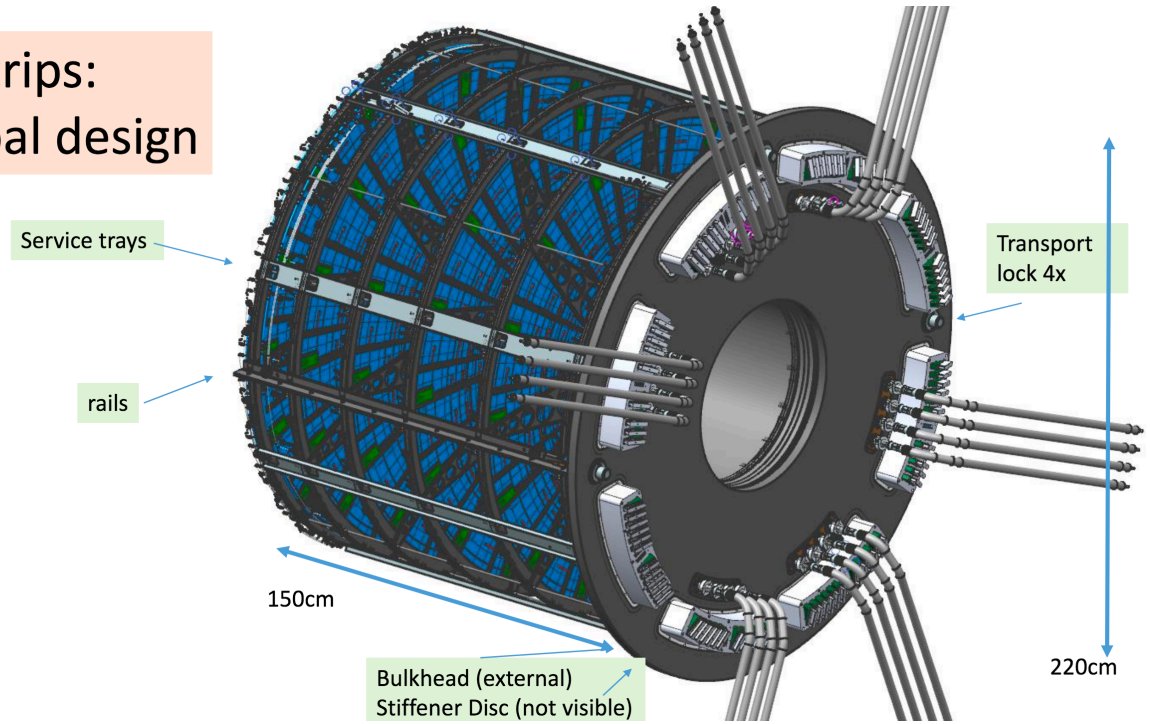
The Barrel is constructed from

- 4 Layers (392 Staves in total)
  - Outer 2 Layers have Long Strip Modules
  - Inner 2 layers have Short Strip Modules

The Endcaps are constructed from

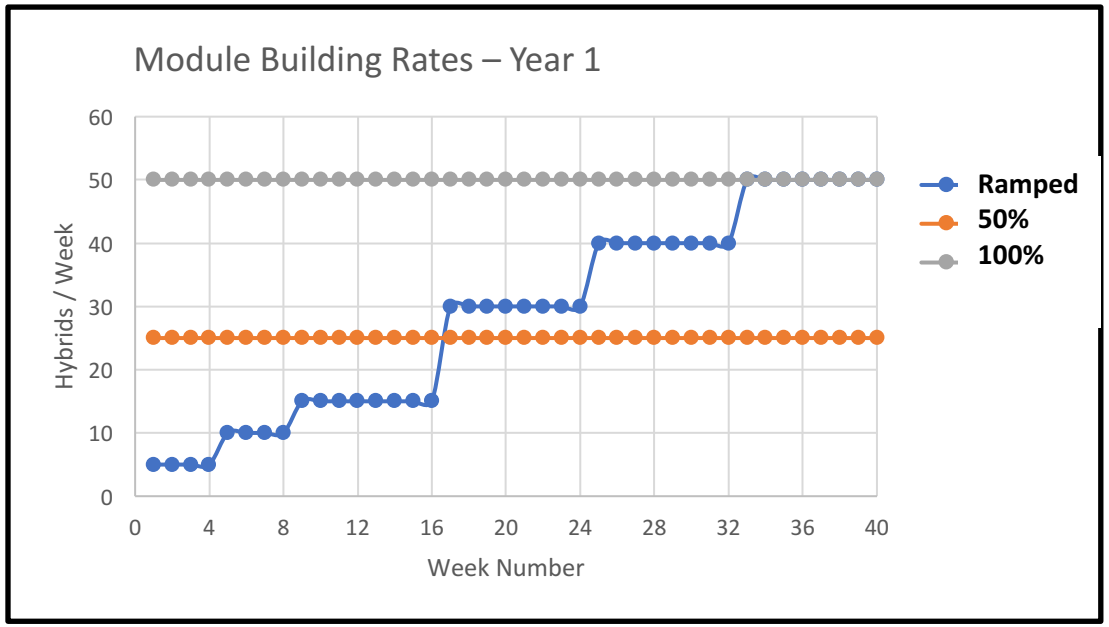
- 32 petals per disk
- 6 disks per Endcap

EC strips:
global design



Transitioning to Production

- As well as finalisation of the prototyping of components, ITk Strips is making the transition through to the production phase
  - Internal Technical Reviews (8 this year alone)
  - Organisation of procurements
  - Understanding production rates and part flow
  - Preparing for site qualification (Late 2019)



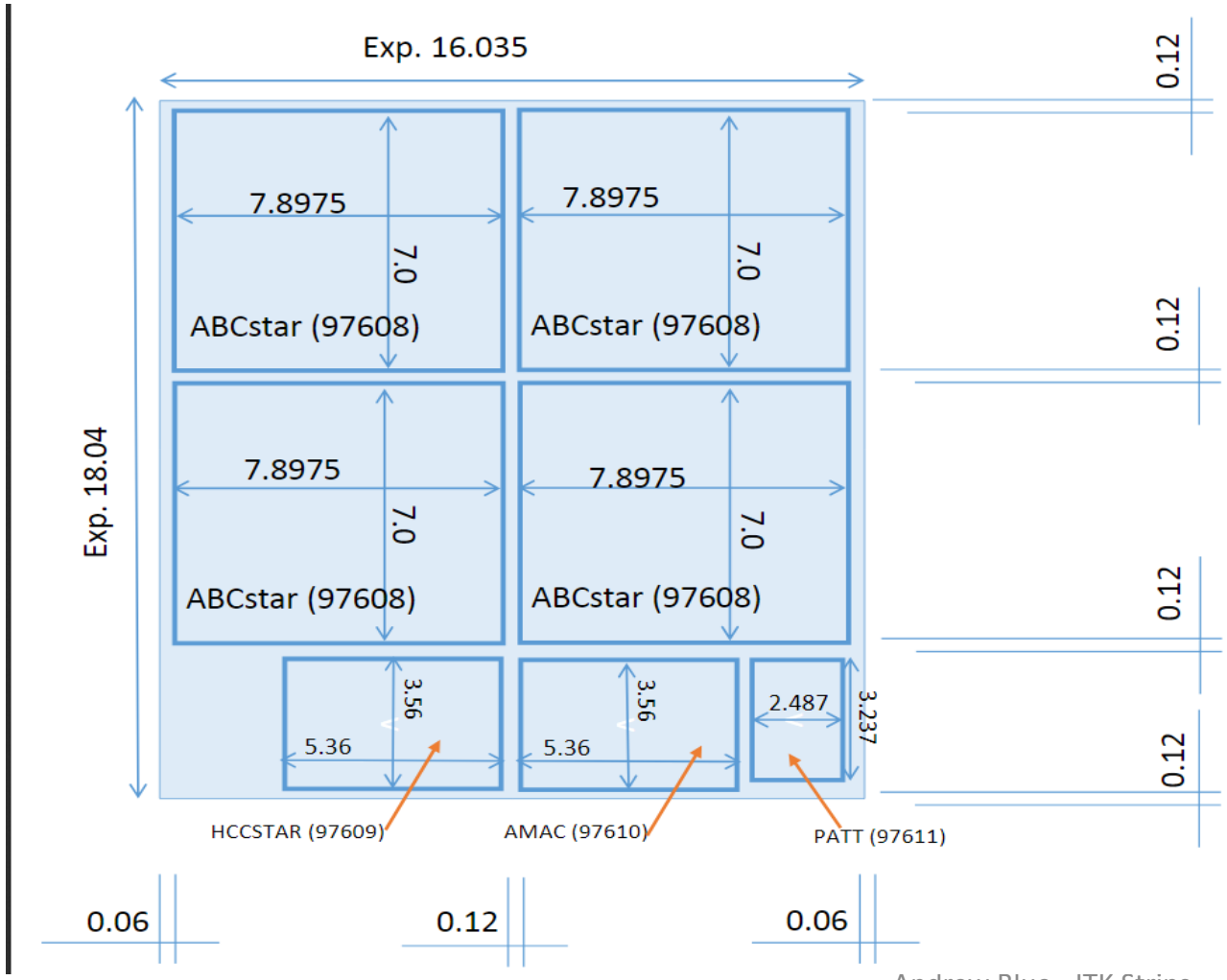
Modelling the ramping of production rates for module building

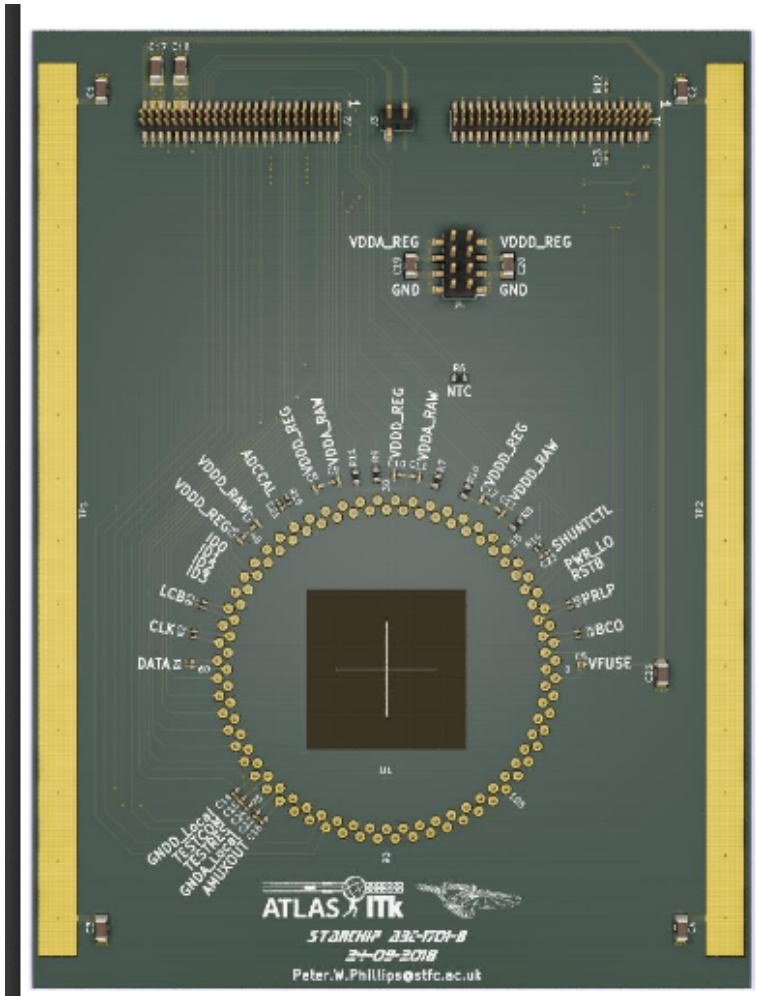
Conclusions

- The HL-LHC will be a challenging but exciting new stage for the LHC
- The ITk is making the transition from R&D to a pre production phase
- ITk Strips are continuing to finalise the prototyping of components from Sensors -> Global Structures
- Now beginning the process of getting ready for production!

Backup

Star Chipset Submissions





FRONT