ATLAS Strip Tracker

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On behalf of ATLAS Collaboration

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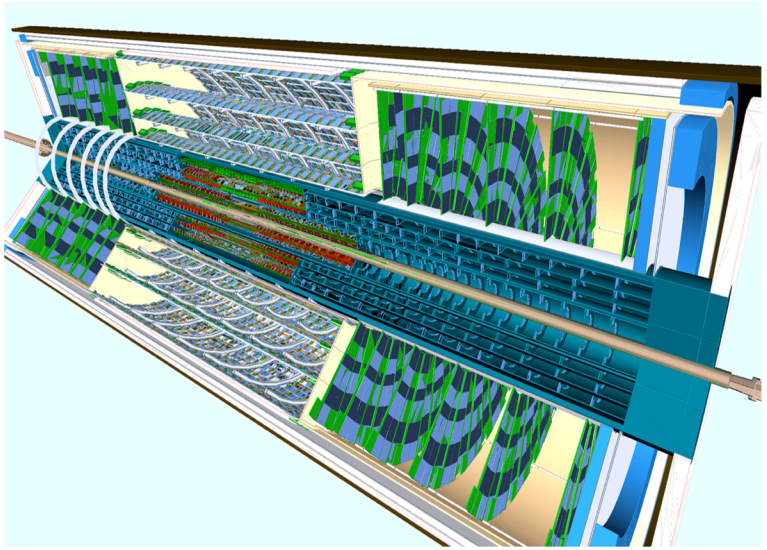
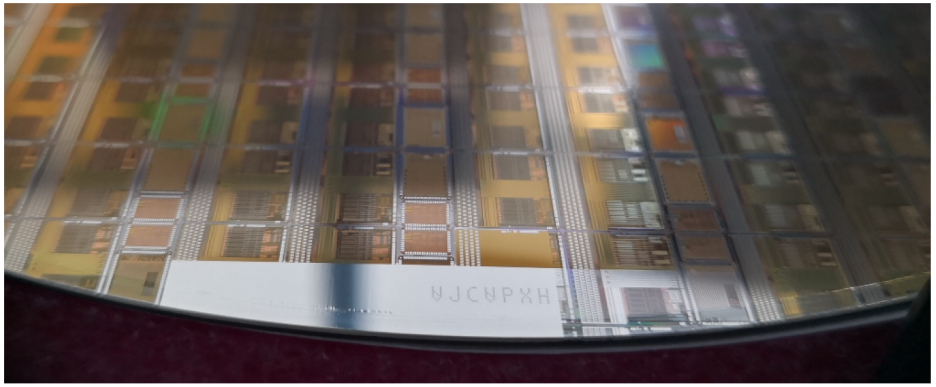
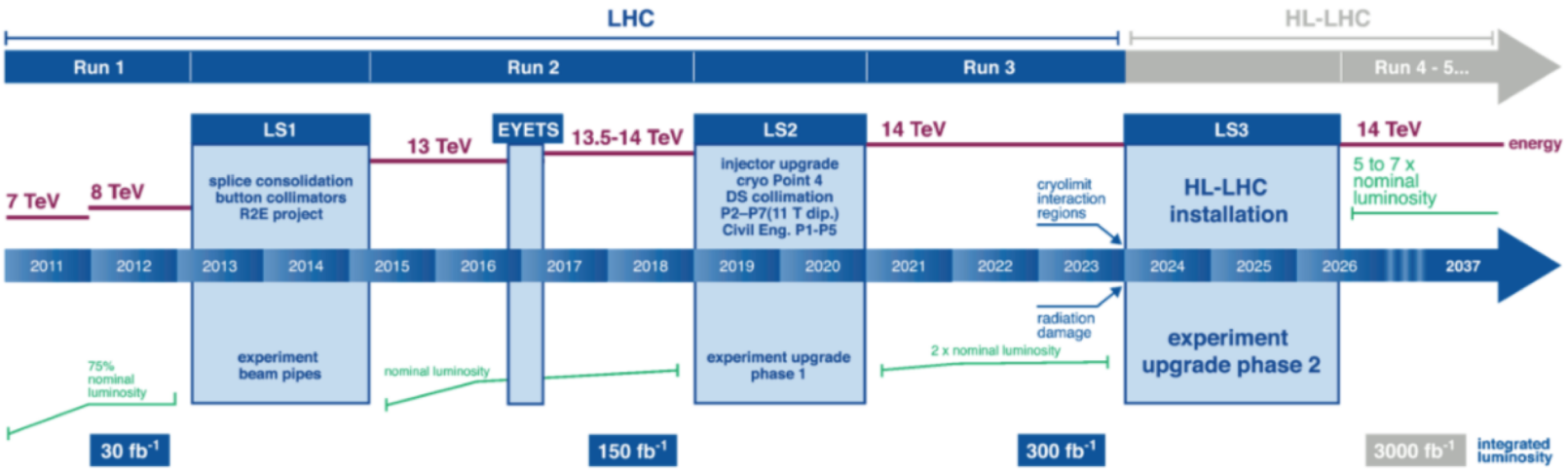
Outline

- Overview
  - ATLAS Upgrade for HL-LHC
  - The Inner Tracker (ITk)
  - ITk Layout
- ITk Strips
  - Sensors
  - Modules
  - Local Supports
  - Global Mechanics

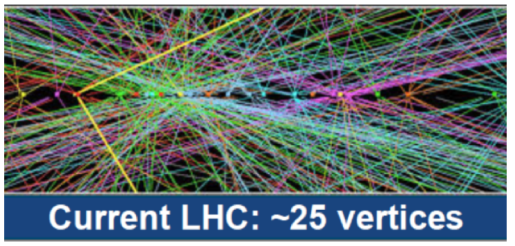


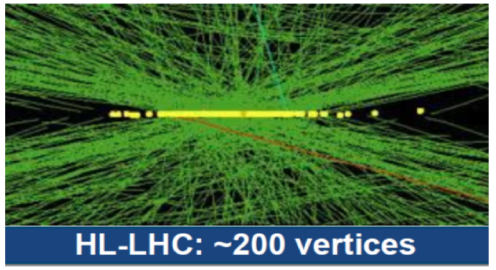


ATLAS Upgrade for HL-LHC



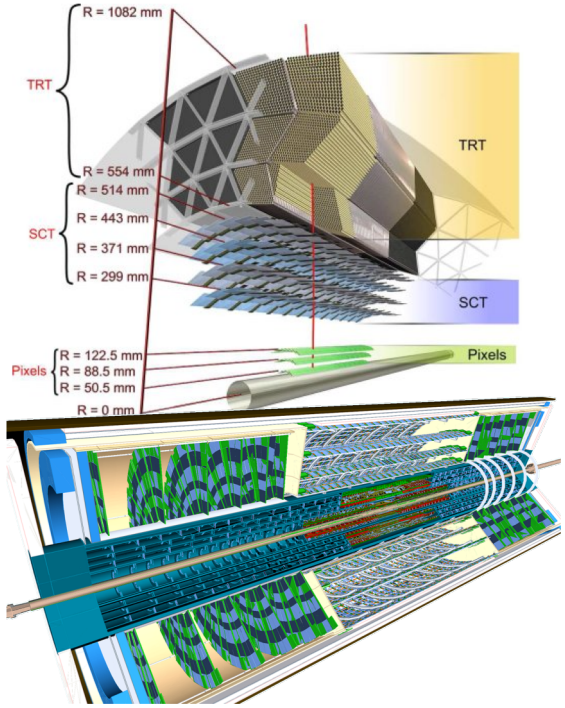
- High Luminosity-LHC (HL-LHC) is foreseen in 2026
- Instantaneous luminosity up to 7.5×10^{34} $cm^{-2}s^{-1}$
- Delivering an integrated luminosity of 4000 fb^{-1}
- Up to 200 collision per bunch crossing
- High particle fluences: radiation hardness of up to $1.3x10^{16}$ n_{eq}/cm^2 (Inner pixel layer)
- Low material budget

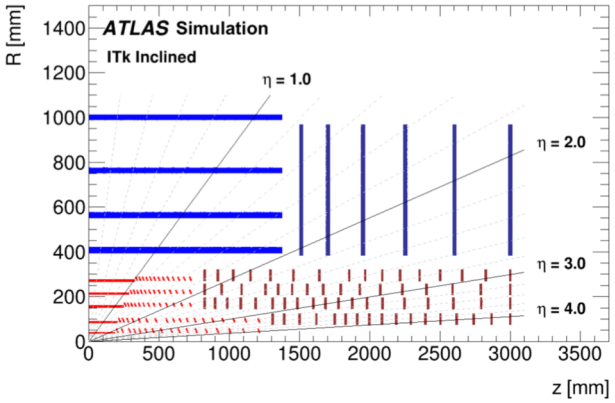




ATLAS Inner Tracker (ITk) upgrade

- The new inner tracker (ITk) will be an all Silicon tracker system
- 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
- Strip system consists of
  - ~18k Modules
  - ~60M channels
  - 165m^2 of Silicon
  - 50 institutes from 16 funding agencies (IHEP will contribute 1000 modules)





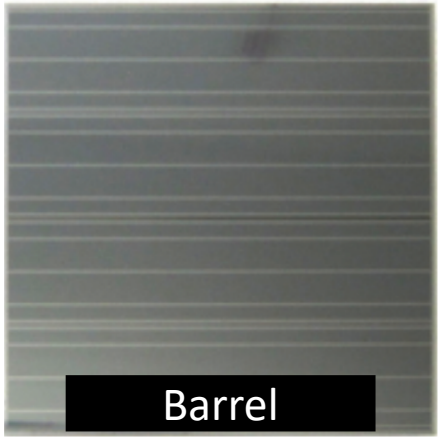
Strip detector comparisons	Current Inner strip tracker (SCT)	Future ITK strip tracker
Radial distance	300-560mm	400-1000mm
Channels	~8 millions	~100 millions
Modules	4 thousands	~20 thousands (165m^2 silicon)

ITk Strips R&D

- Strips TDR was approved early 2017
- Strips have begun transition from R&D phase into production preparation. However lot of work still going on
  - Sensor Characterization
  - UV Curing of Glues
  - First Modules built with ABC130 ASICs
  - Irradiation & Testing of Components
  - Electrical & Thermo-mechanical Stave/Petal test

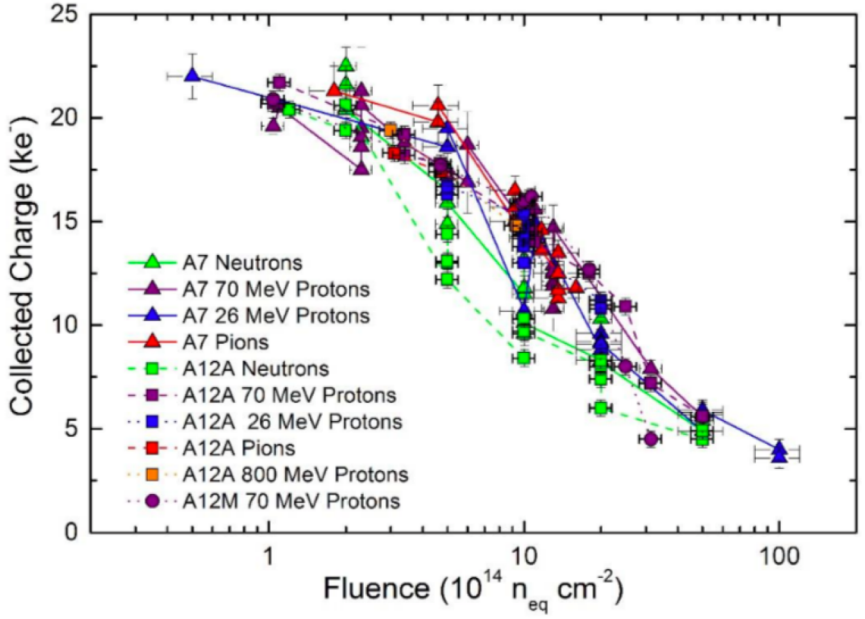
ITk Strip Sensors

- 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 75.4µm 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



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

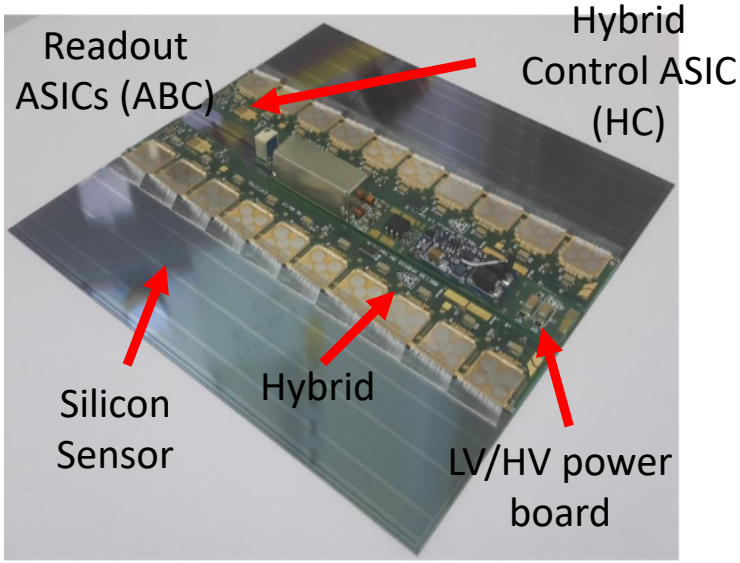


Poster by Yuzhen Yang

ITk Strip Modules

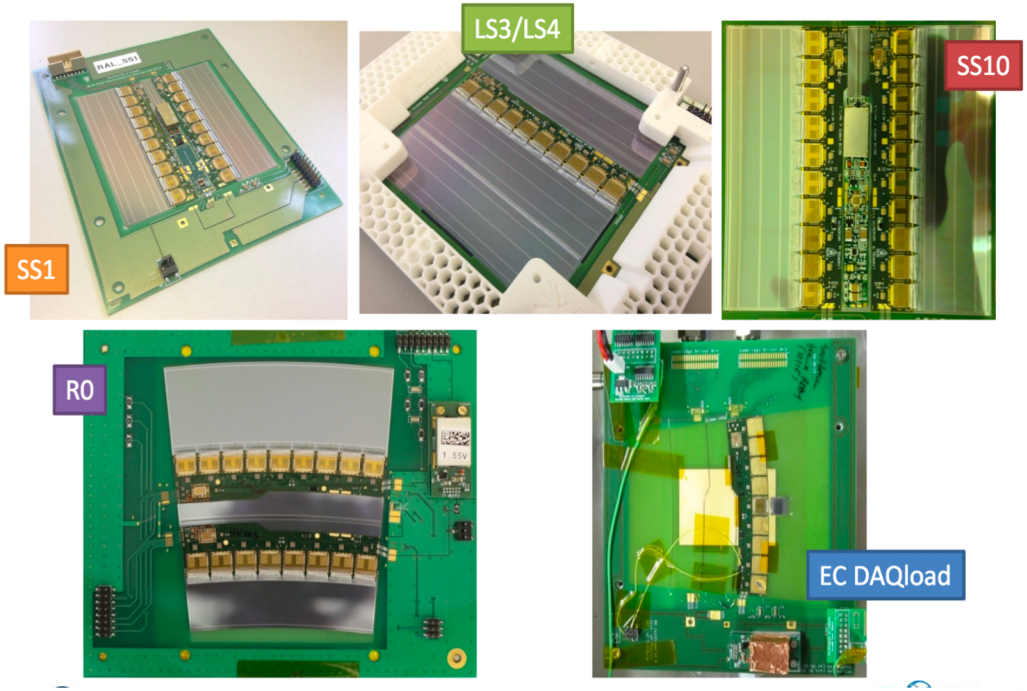
Silicon Modules consist of

- Binary readout chips (ABC) and hybrid controller chips (HCC)
  - Glued & wire bonded to a hybrid
  - Data transfer on hybrid at 32Mbit/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 – Electrical Tests

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



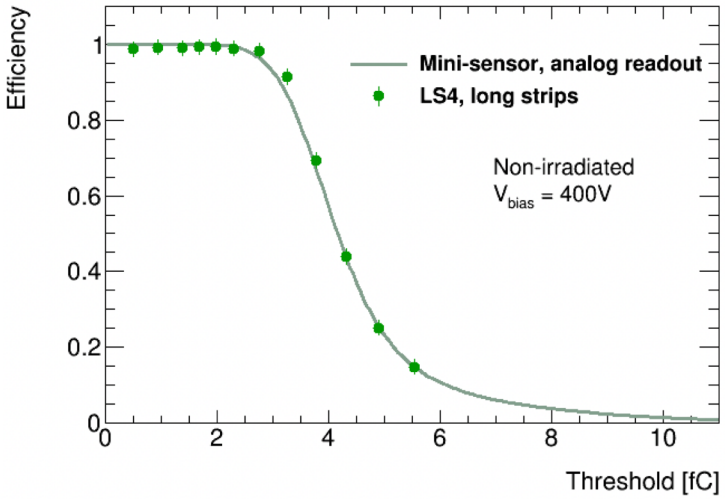
Test a binary readout using

Threshold Scans

- Have a known input signal

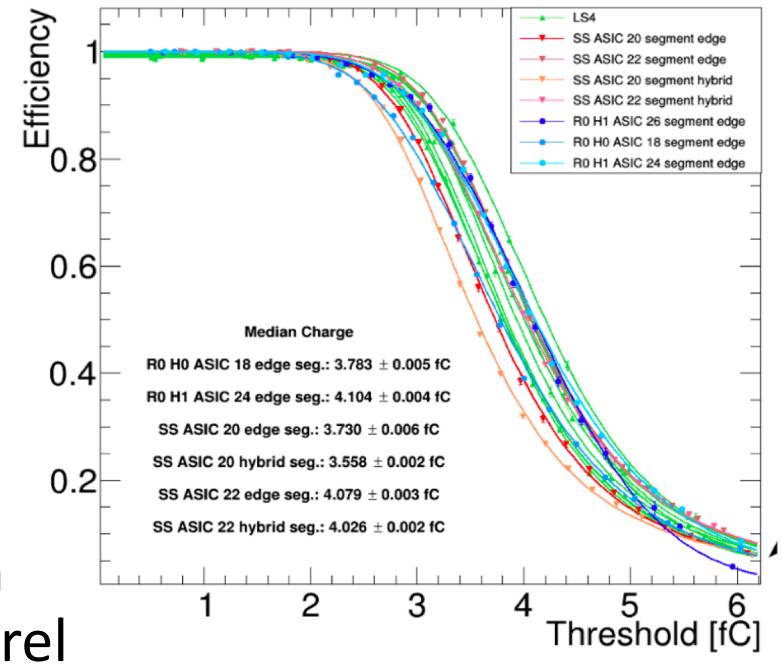
Loop

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

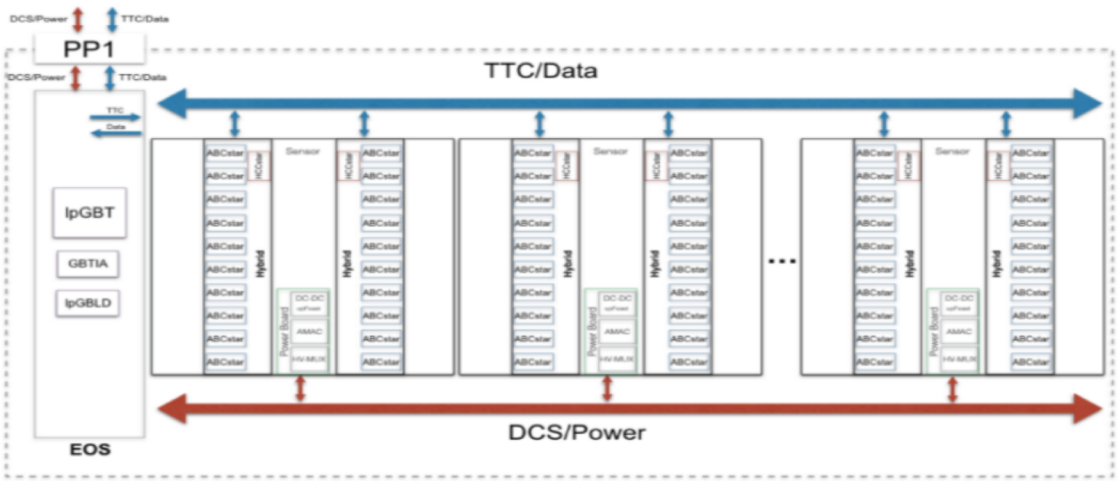


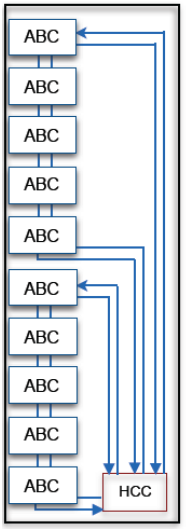
Modules - Testbeam

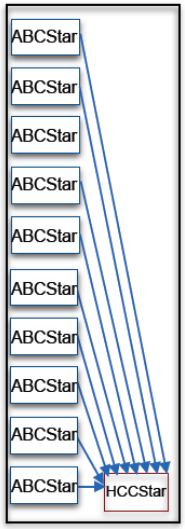
- Conducted a series of successful testbeam campaigns since 2015
  - Both pre and post irradiated Modules
- Latest studies conducted on Endcap R0 Modules
  - Track reconstruction more complex due to Radial Strips
  - However efficiency measurements seen to match well to previously studied Barrel Modules



ITk Strip Electronics





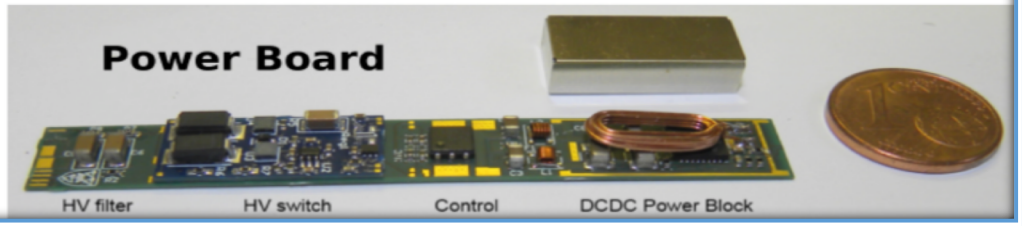


EOS
- lpGBTx (I2C interface) + VTRx+

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)

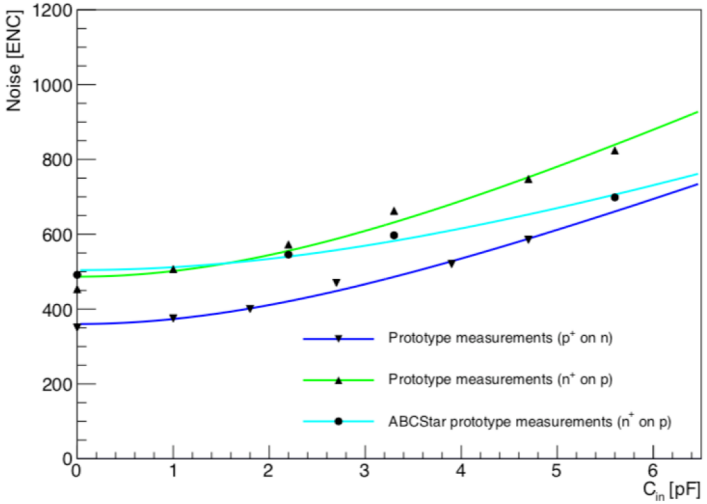
AMAC
- monitoring of LV and HV, temperatures and sensor bias current on module (1 sample / ms)

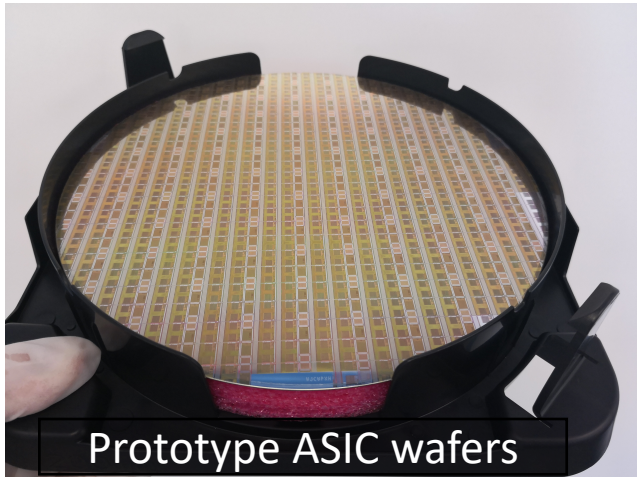
HV-MUX
- controlled HV switch,
- connection/disconection of module from HV,
- GaNFET or 3D Trench Vertical JFET transistor gate controled by HV multiplexer

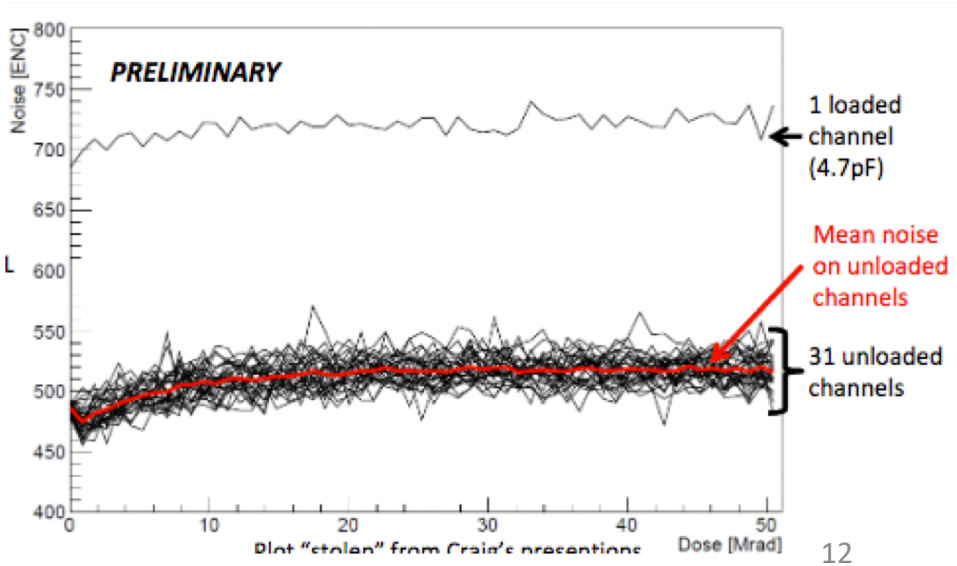


ABCstar Front End Prototypes

- 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) FE prototype has been tested to examine any noise increase after irradiation
  - Reduction in noise of Front End prototype compared to current ABC130 chips
- Full ABCstar prototype in hand. Irradiation tests to confirm expected performance by Jan 2019

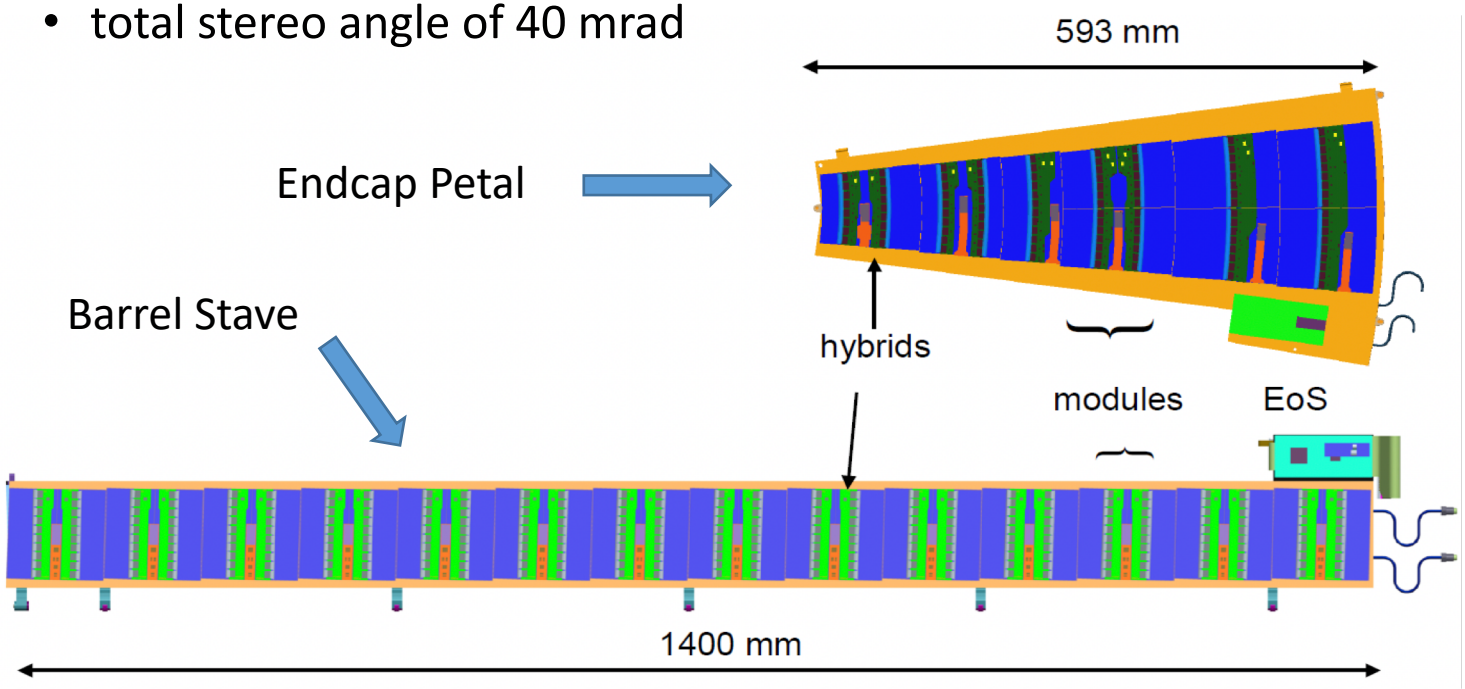






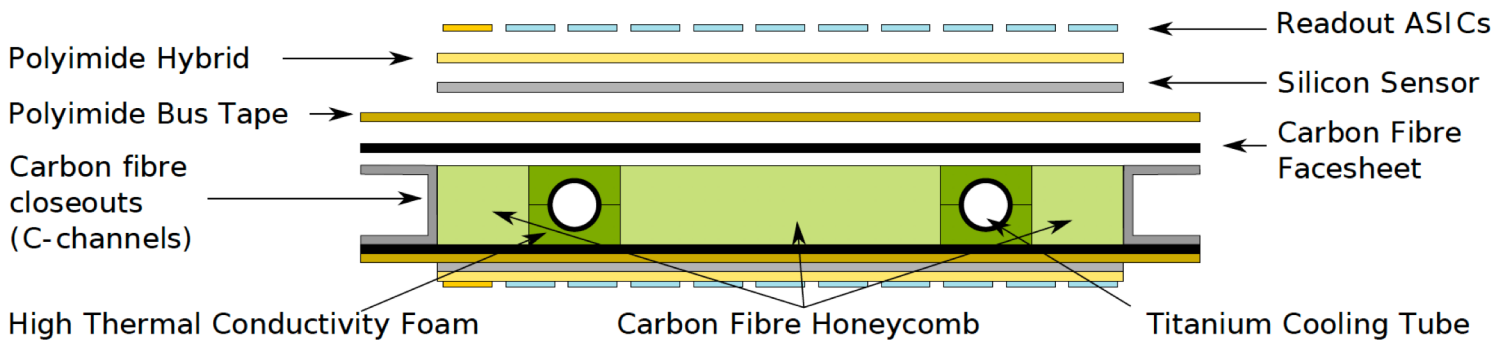
ITk Strip Local Supports

- 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

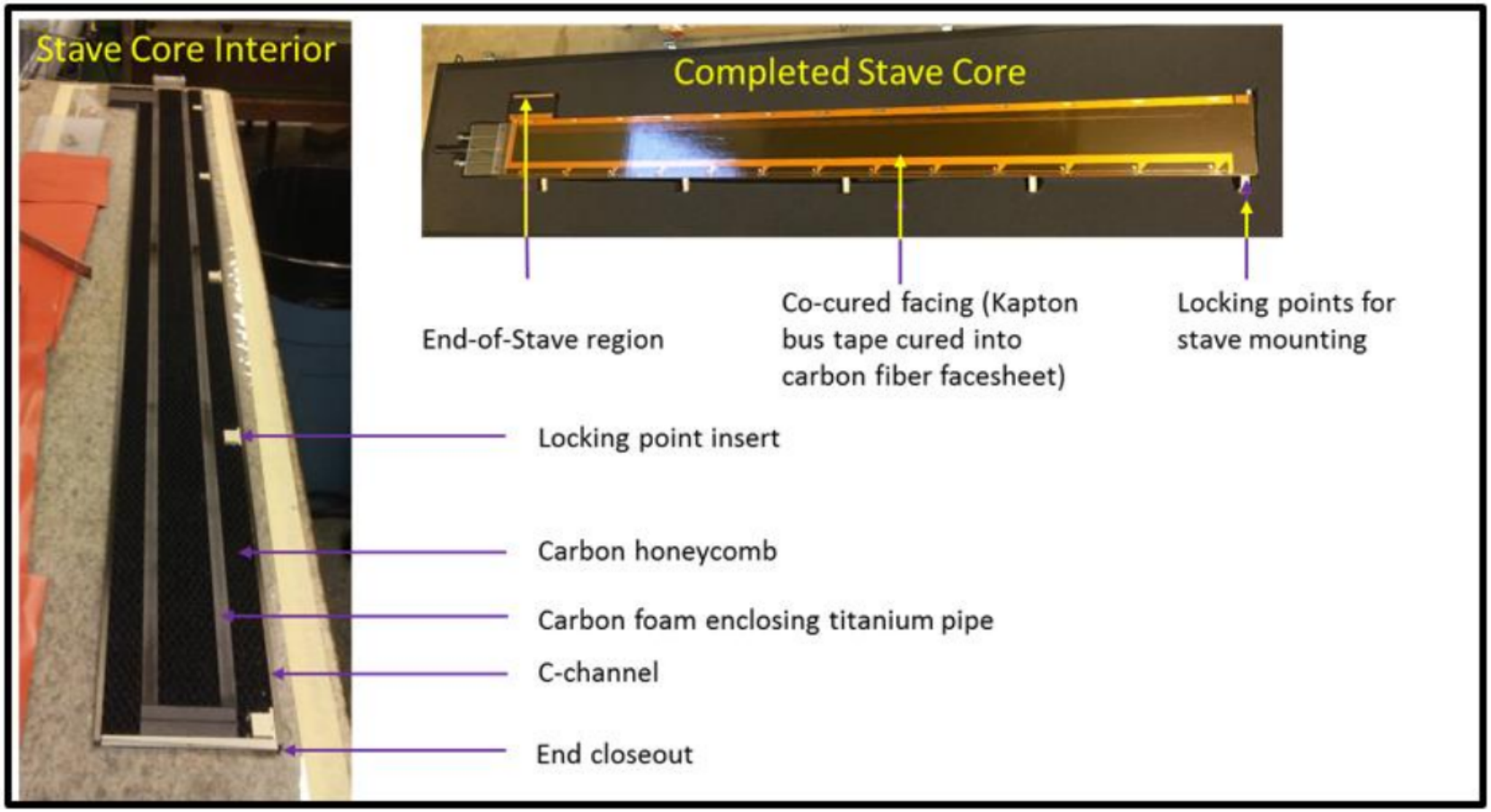


ITk Strip Local Supports

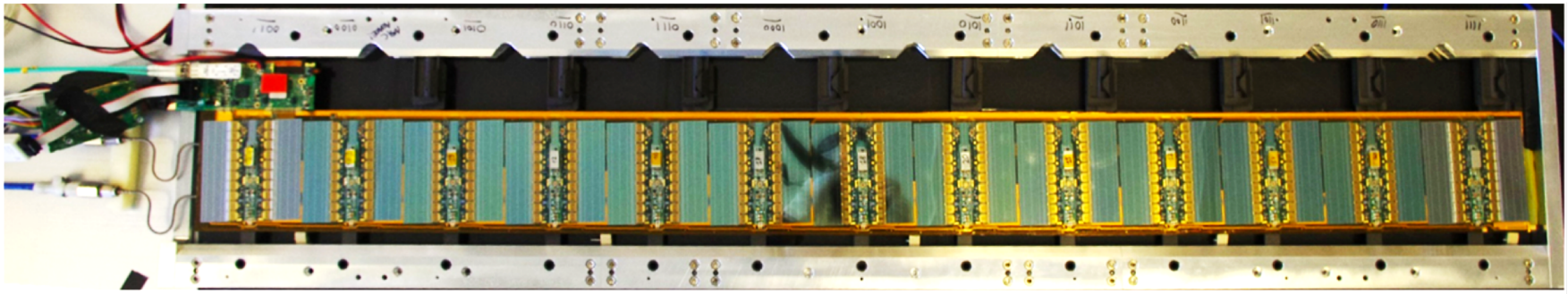
- Staves (barrel) and Petals (endcap) provides mechanical, geometric, thermal and electrical support to modules:
  - **Mechanical and Geometric**: local supports interface to global support structures through a series of position locators and locking points
  - **Thermal**: titanium cooling tubes connected to CO2 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

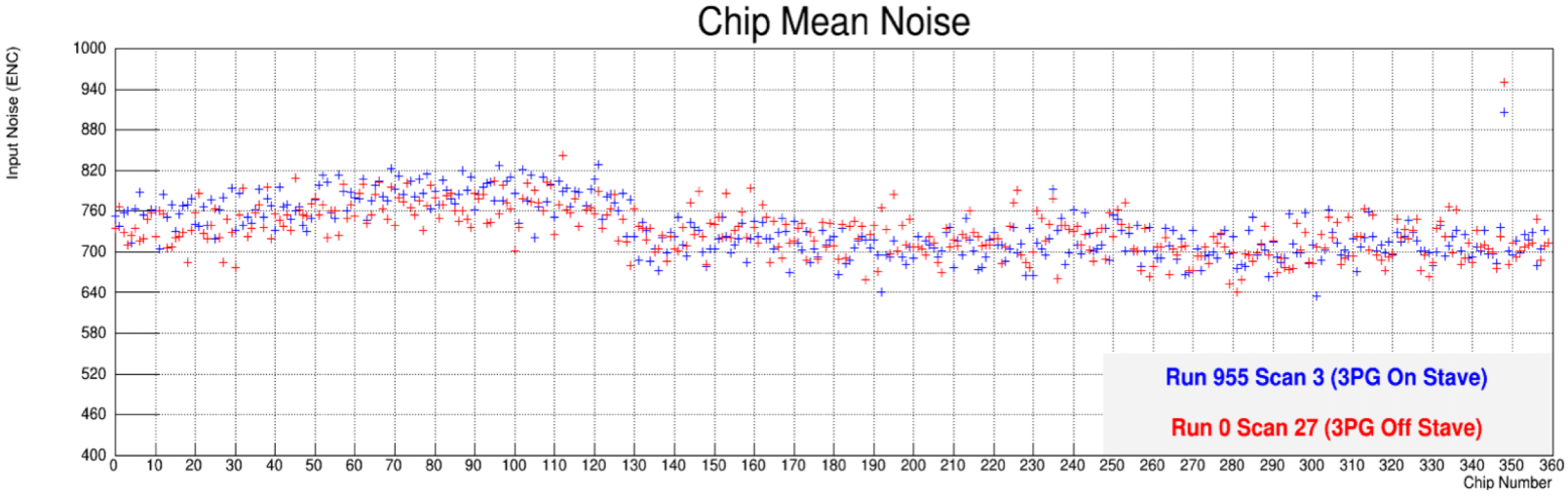


Electrical Stave tests

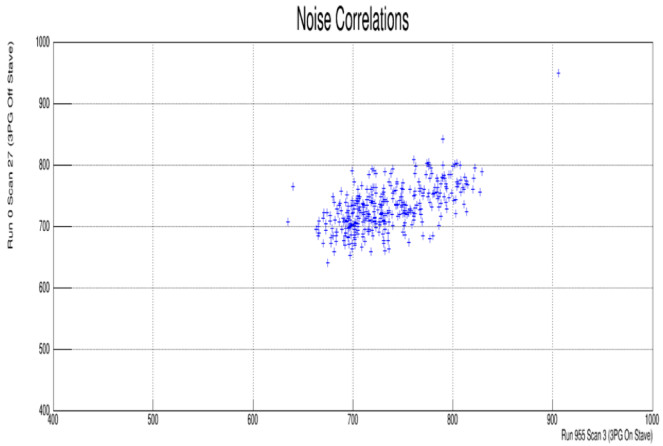


- Electrical Staves are being assembled at institutes in the UK (Rutherford Laboratories) and USA (Brookhaven National Labs)
  - BNL: 12 Electrical Short Strip modules
  - RAL: 2 real SS modules and 11 Electro-Mechanical SS modules (dummy sensor)
- In addition a 5 module ’Stavelet’ was assembled and fully tested
  - Comparison made of 3 point gain measurements before and after mounting to the stavelet

Comparison of Noise Results

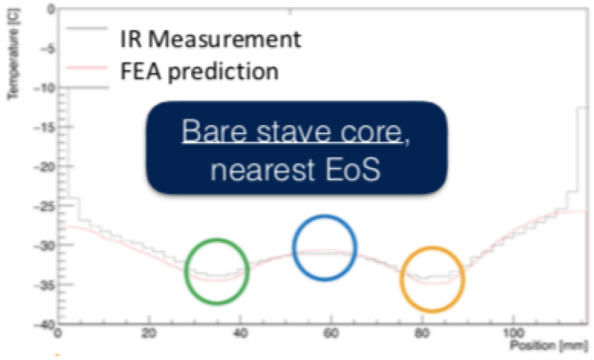


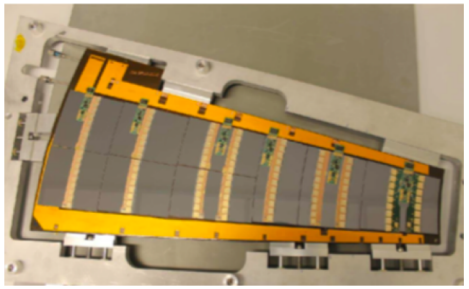
- On & Off Stavelet

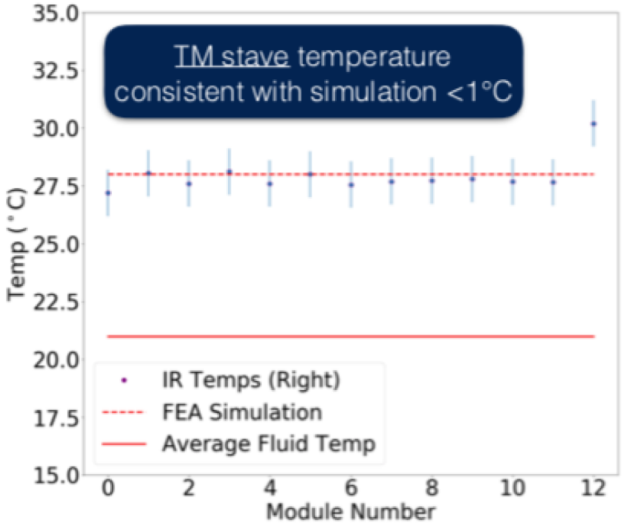


Thermal performance well-understood

- Thermo-Mechanical (TM) Staves and Petals match Finite Element Analysis (FEA) prediction and infrared temperature measurements



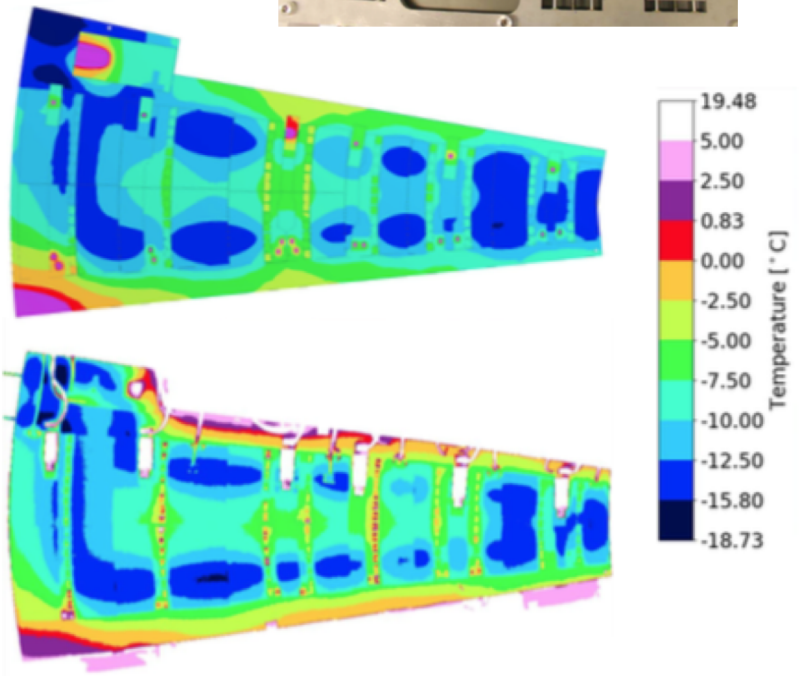




FEA setup
Fully powered
T_{CO2} = -21.7 °C
T_{amb} = 20.5 °C

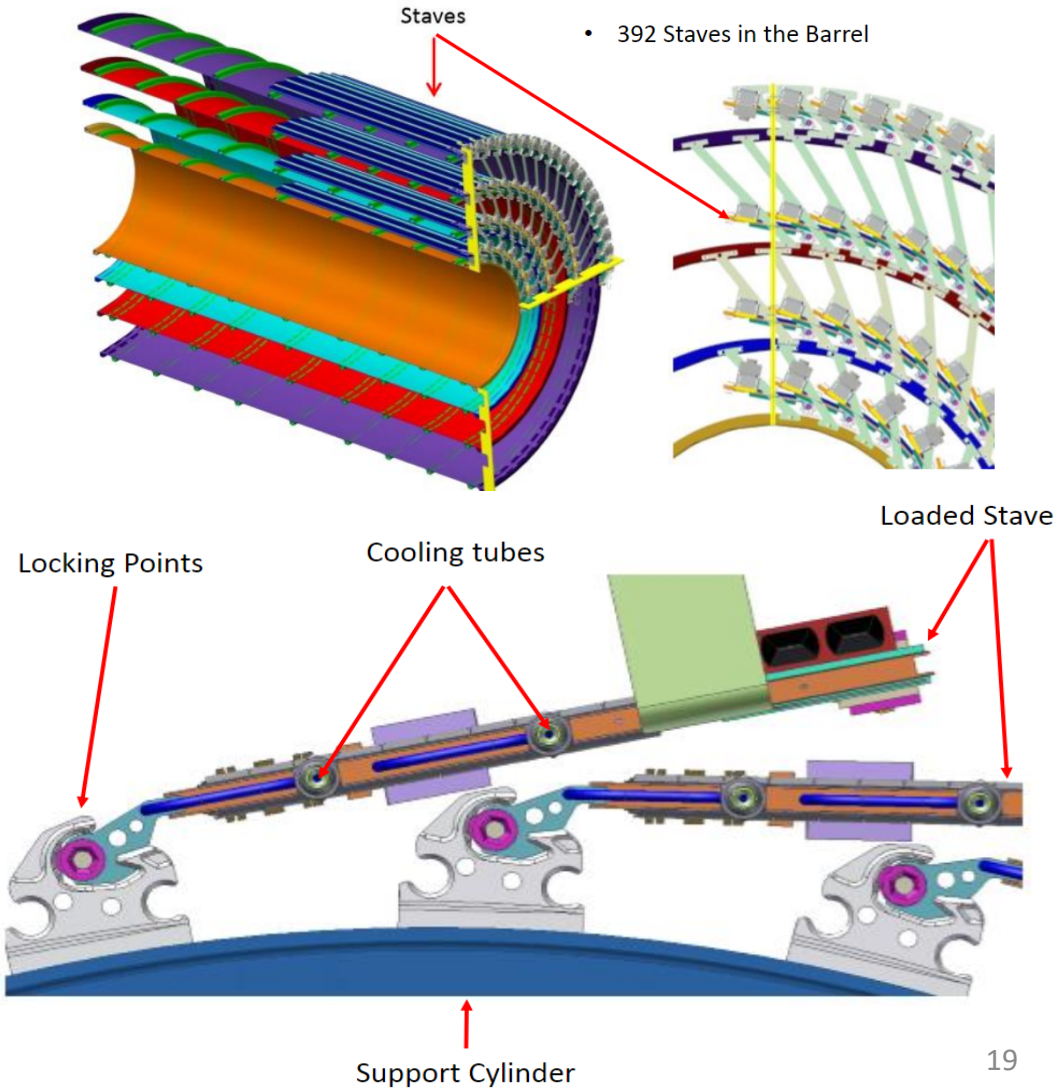
Measurement
Fully powered
T_{CO2} = -21.7 °C
T_{amb} = 20.5 °C

Horizontal orientation



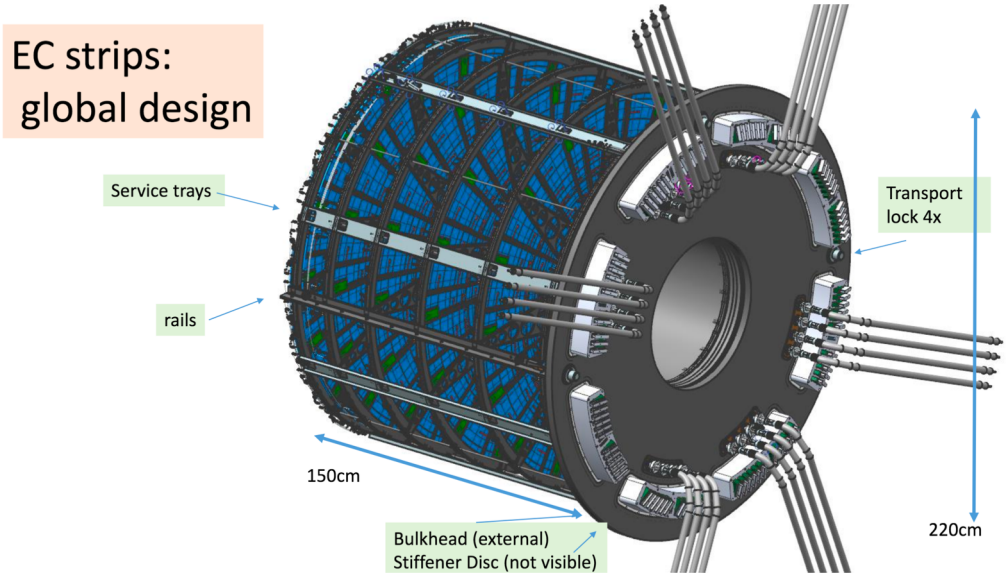
ITk Strip Global Structures

- 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



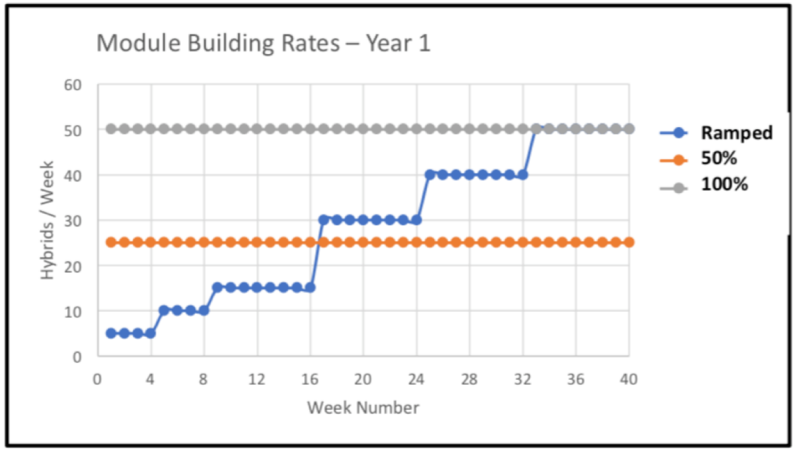
ITk Strip Global Structures

- 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



Transitioning to Production

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



Modelling the ramping of production rates for module building

Summary

- 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
- Now beginning the process of getting ready for production!

Lessons for CEPC as large trackers

(Thanks Tony Affolder!)

- Take design risks only when you need them for performance. Not just to be innovative.
- Settle on base design concepts early. Stability allows for more thorough development.
- For "light" detectors, minimizing overall system power and using modern powering concepts is critical. Services needs to be considered early in the design process.