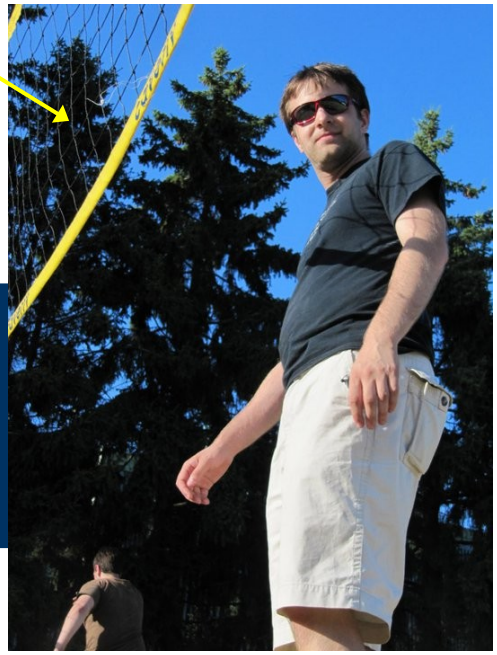
TRIUMF volleyball net
circa 2011



The ATLAS ITk Strip Detector System for the Phase-II LHC Upgrade

Karol Krizka

on behalf of the ITk Strips Collaboration

May 27, 2021

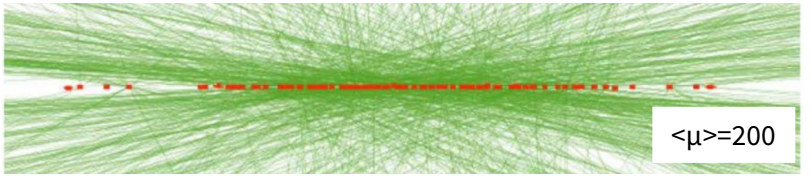
ATLAS ITk

BERKELEY LAB
Lawrence Berkeley National Laboratory

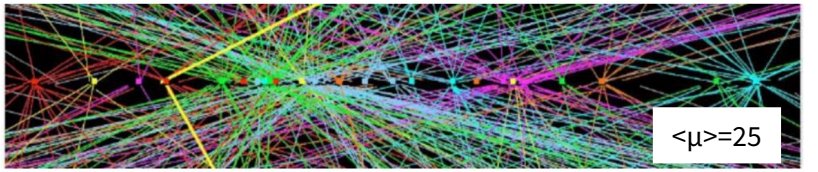
TIPP2021

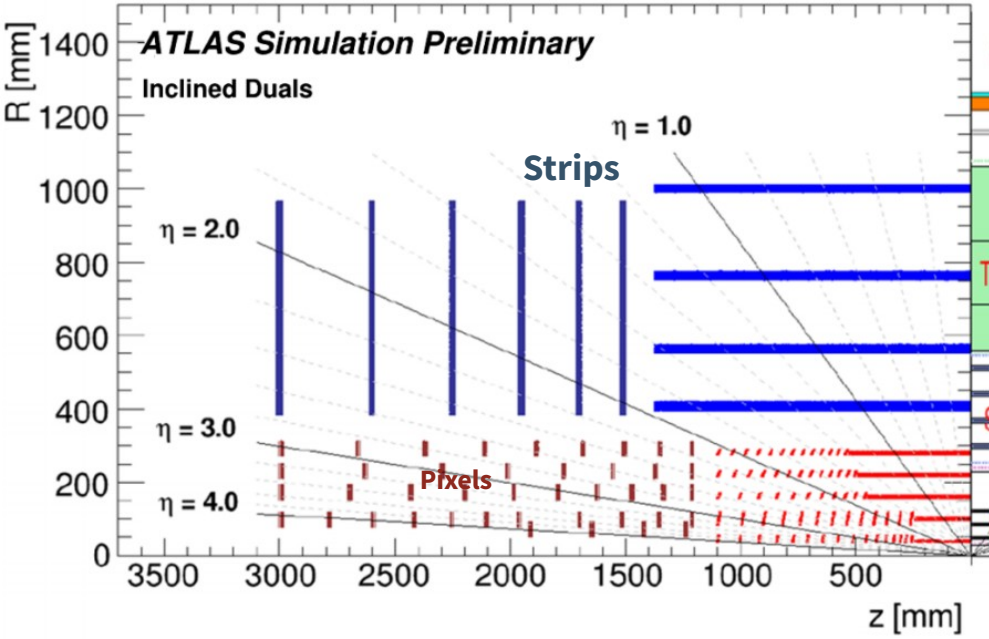
ITk Detector Overview

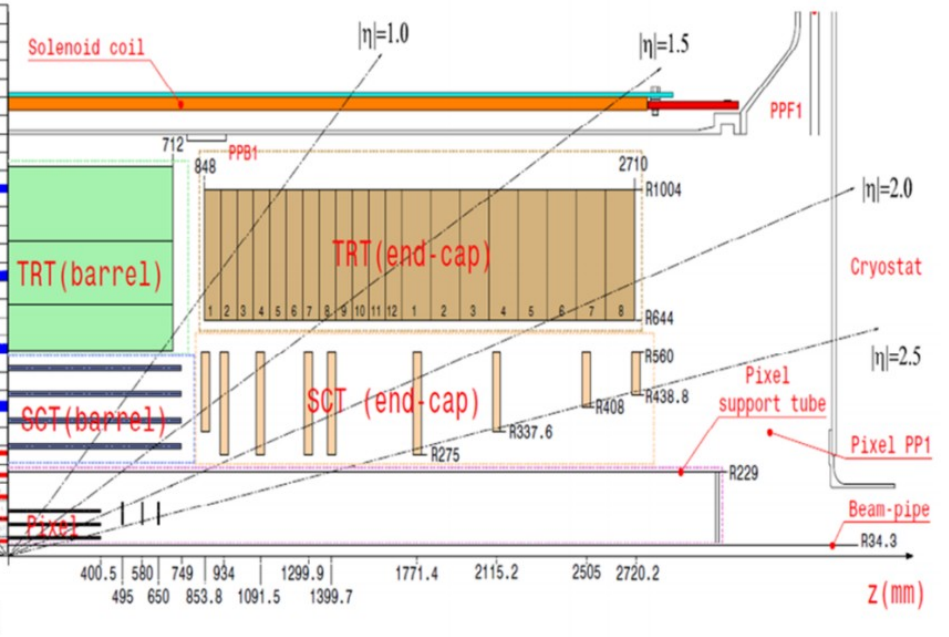
The **I**nner **T**rac**k**er (HL-LHC ATLAS)



The current detector





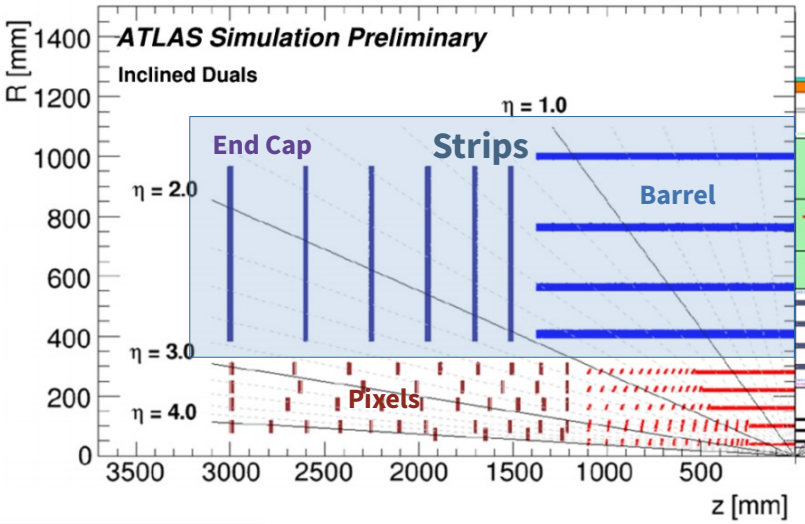


- **All silicon replacement for current tracker**
  - Higher granularity, larger radiation tolerance
  - Extends |η| coverage from 2.5 → 4.0

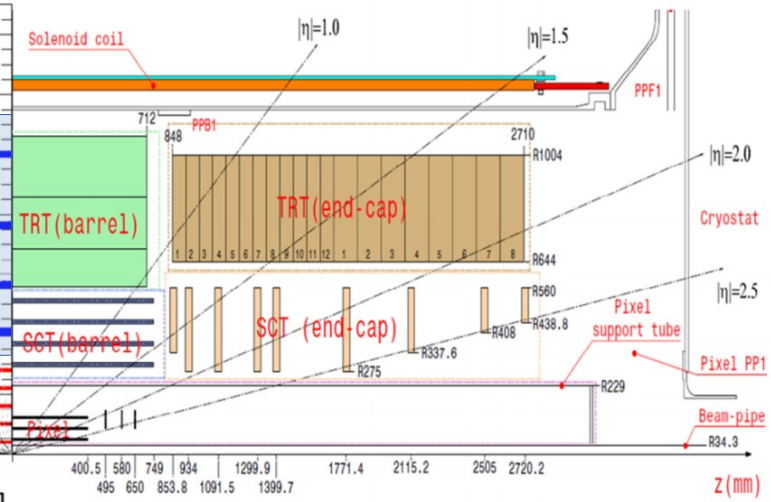
ITk Strips Detector Overview

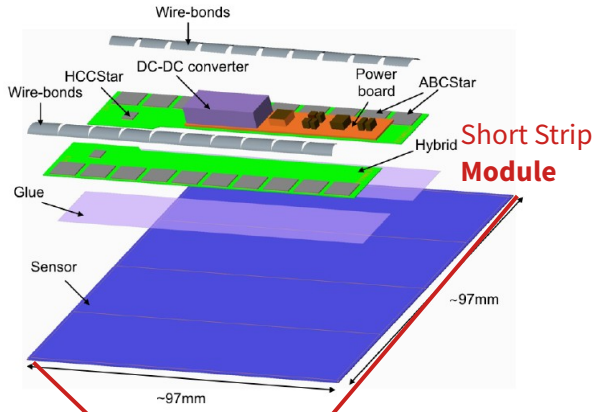
	Module Count
SCT	4088
ITk Strips	17888

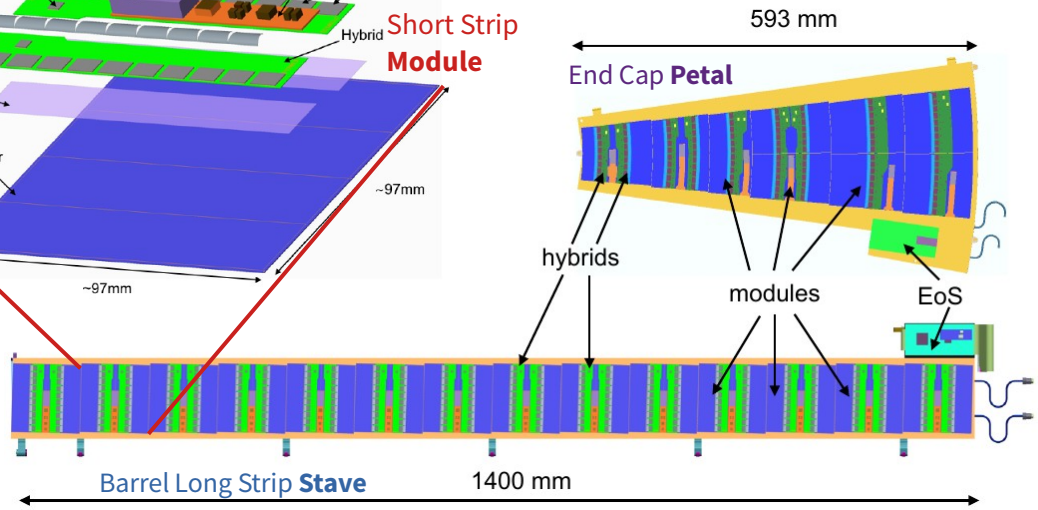
The **I**nner **T**rac**k**er

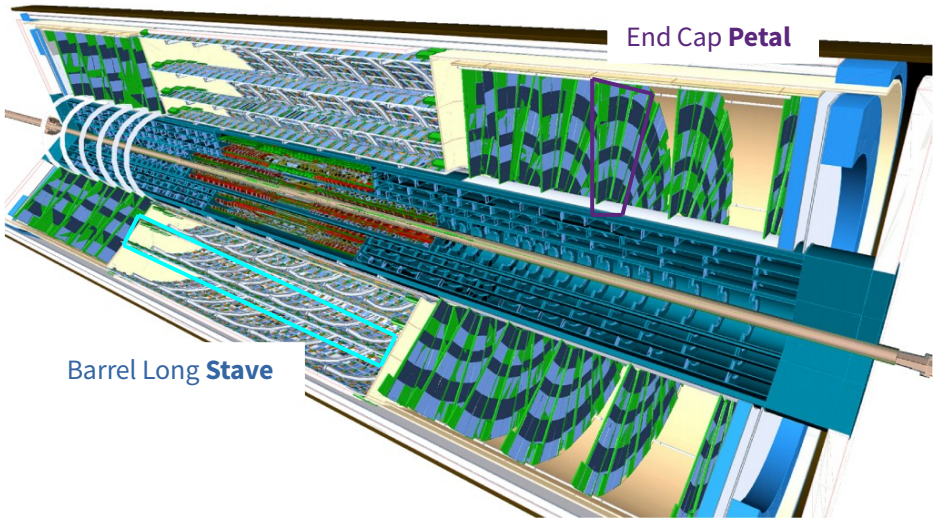


The current detector









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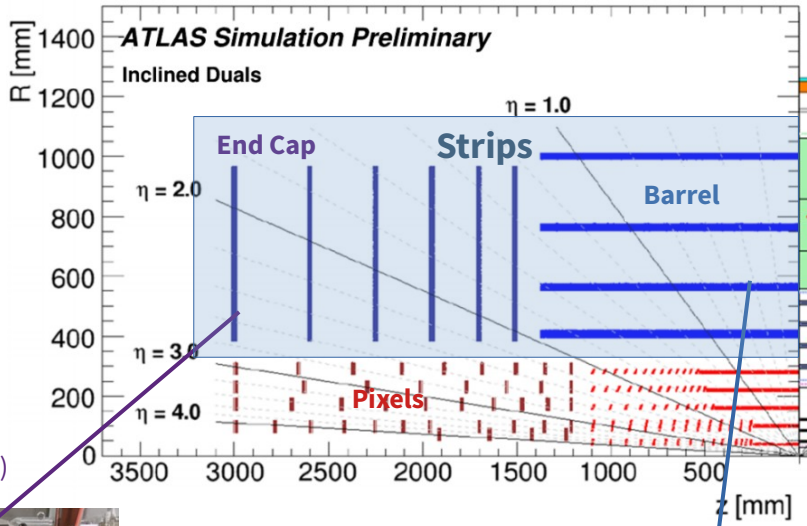
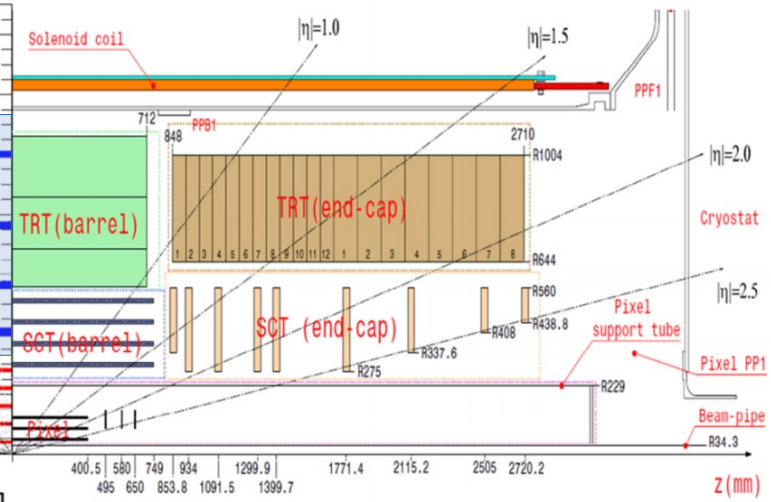
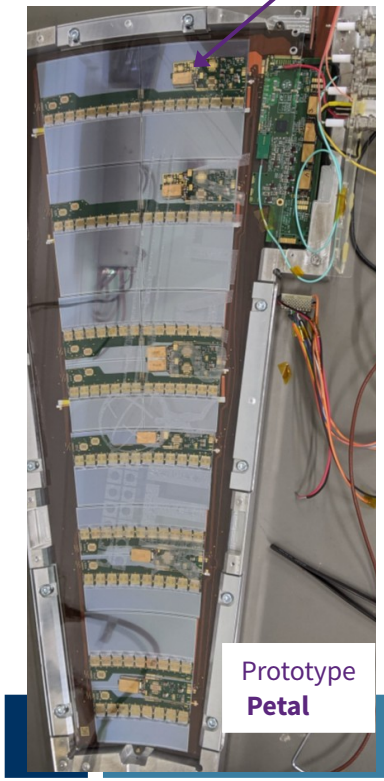
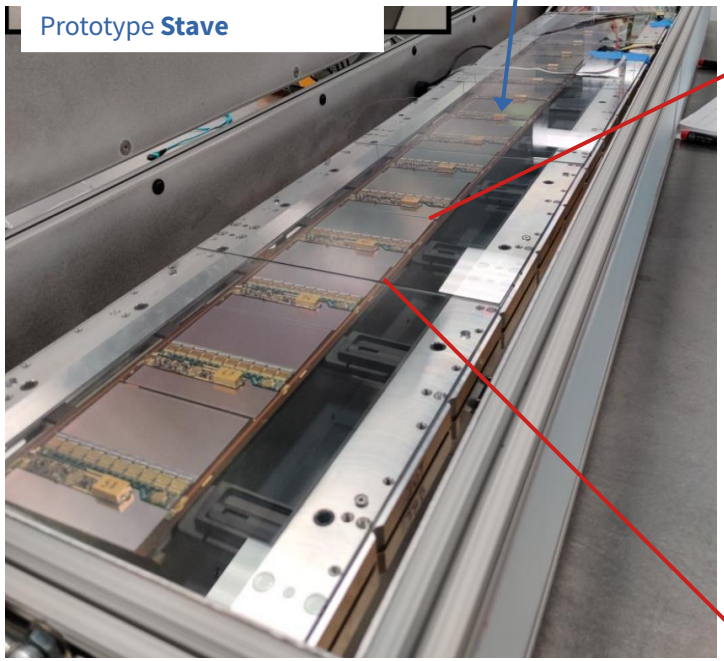


The current detector

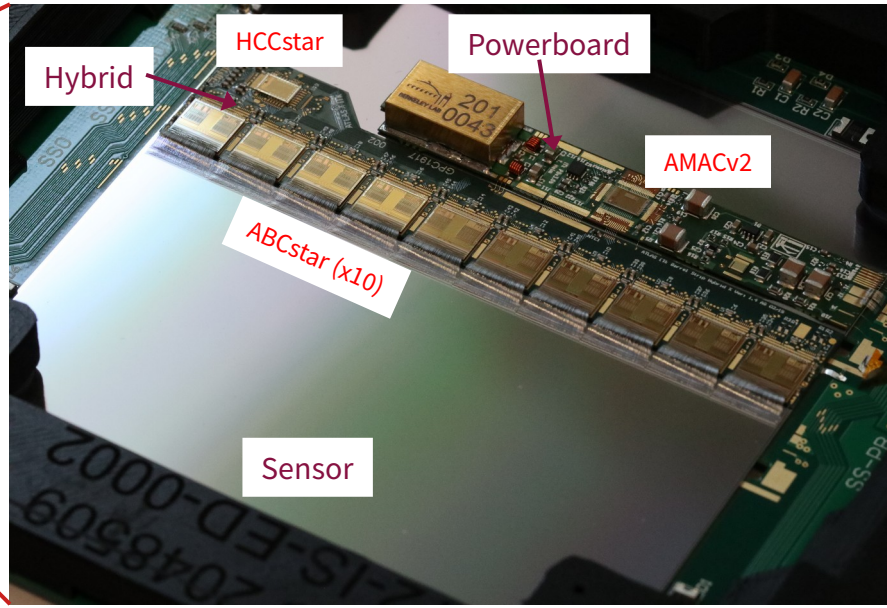


End Cap
(ring geometry)



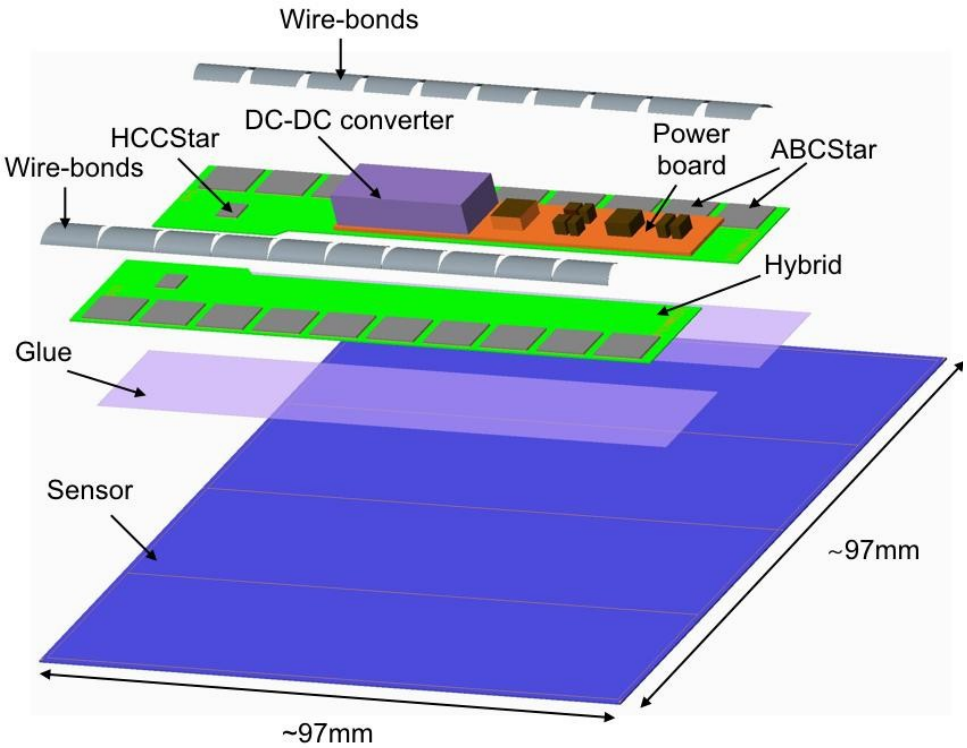


Prototype **Module**



ITk Strips Module

- **Basic building block**
  - Variations based on sensor geometry
  - Barrel/endcap difference is shape
- **2560 or 5120 channels/module**
- **Parallel powering scheme**
  - ~14 modules per LV channel
    - 11V → 1.5V on-module DC/DC conversion
  - ≤4 modules per HV channel
  - On-module power control and monitoring



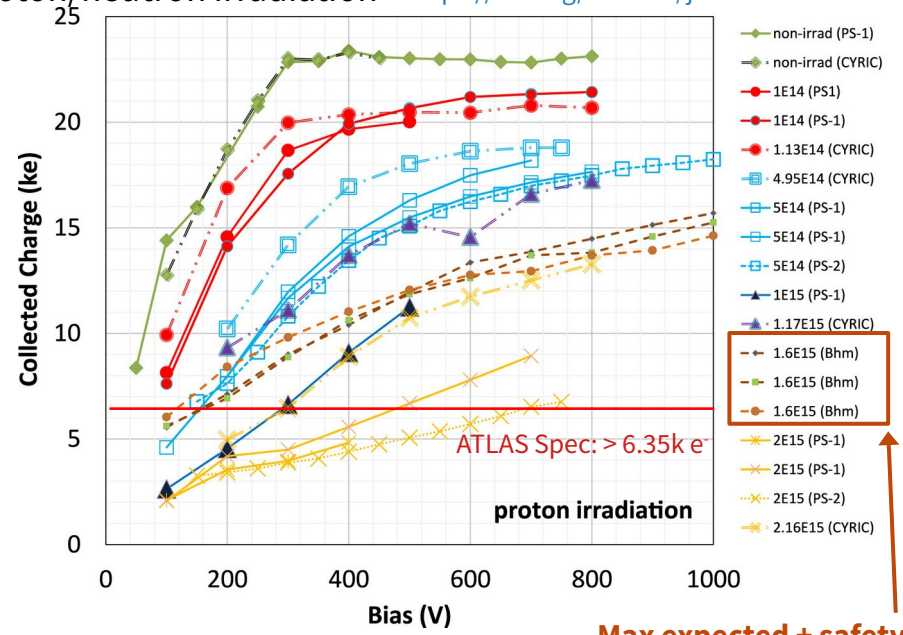
Assembly includes:

- Precision placement and gluing of ASIC-to-PCB and PCB-to-sensor
- Wirebonding: each FE ASIC has 256 bonds in four rows (x10/20 FE's per module)

Sensors

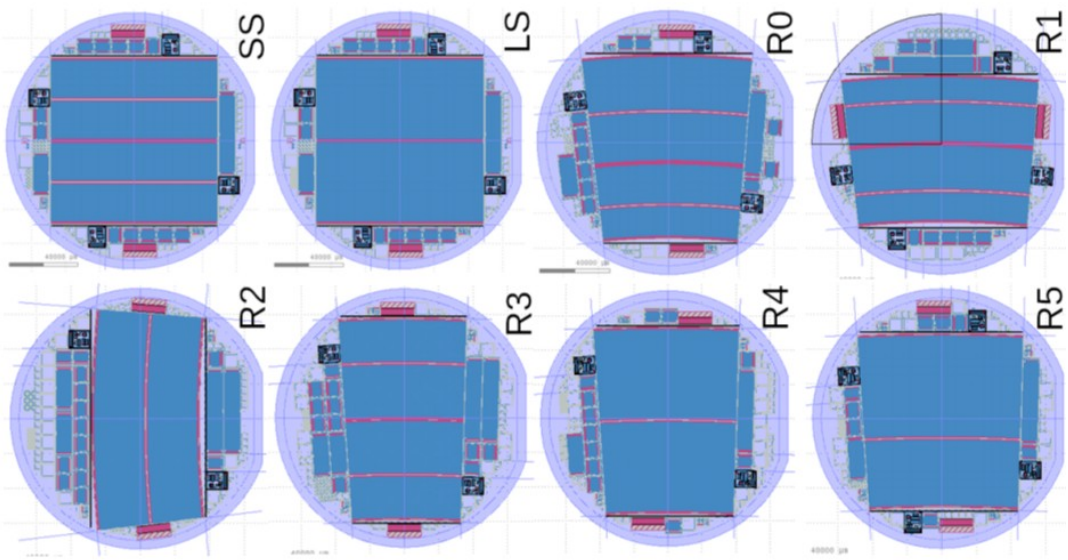
- 320µm thick silicon, n^+-in-p doped
- 75.5 µm strip pitch
- One sensor / wafer
  - Surrounded by mini-sensors for R&D
- bias voltage: -100V to -500V

Proton/neutron irradiation https://doi.org/10.1016/j.nima.2020.164422



Max expected + safety:
1.6×10^{15} n_{eq}/cm^2

SS, LS are barrel, R# are end-cap



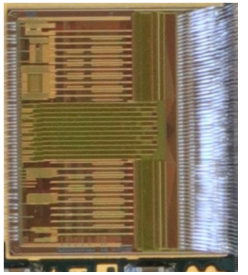
ATLAS reviews passed.

Production order made!

Status of ITk Strips ASIC's

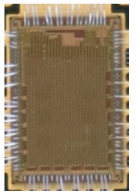
ABCstar (Front End Chip)

- Binary readout
- v1 (pre-production) available



HCCstar (FE Interface Chip)

- Connects 10x ABC to stave
- v0 (prototype) available
- v1 (pre-production) design being finalized
  - Heavy redesign due to SEE mitigations



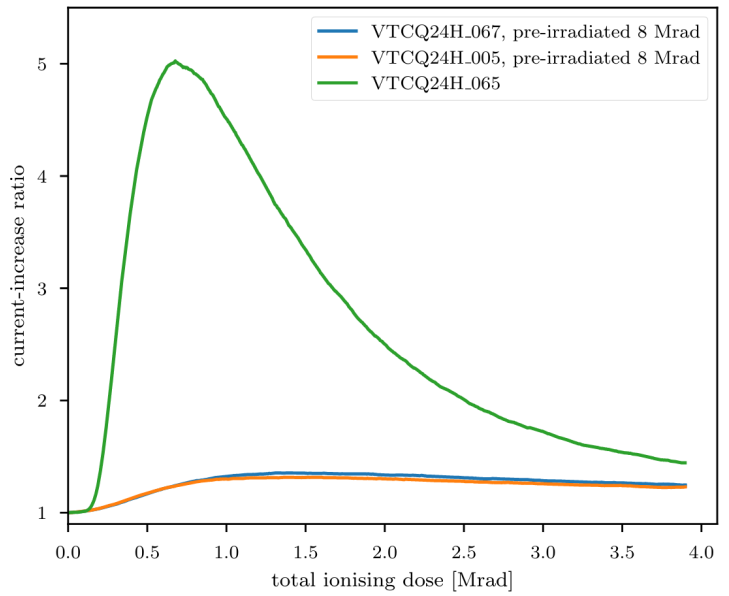
AMACstar (Power Control and Monitoring)

- v2a (prototype) available
- star (pre-production) design done
  - Tied to HCCstar production: same wafer

- **All chips made in 130 nm at Global Foundry**
- **Functionality of chips validated up to stave/petal system level**
- **Extensive testing in simulation for all chips**
  - Includes SEE-injection testing and "module" level tests

ITk Strips ASIC Radiation Hardness

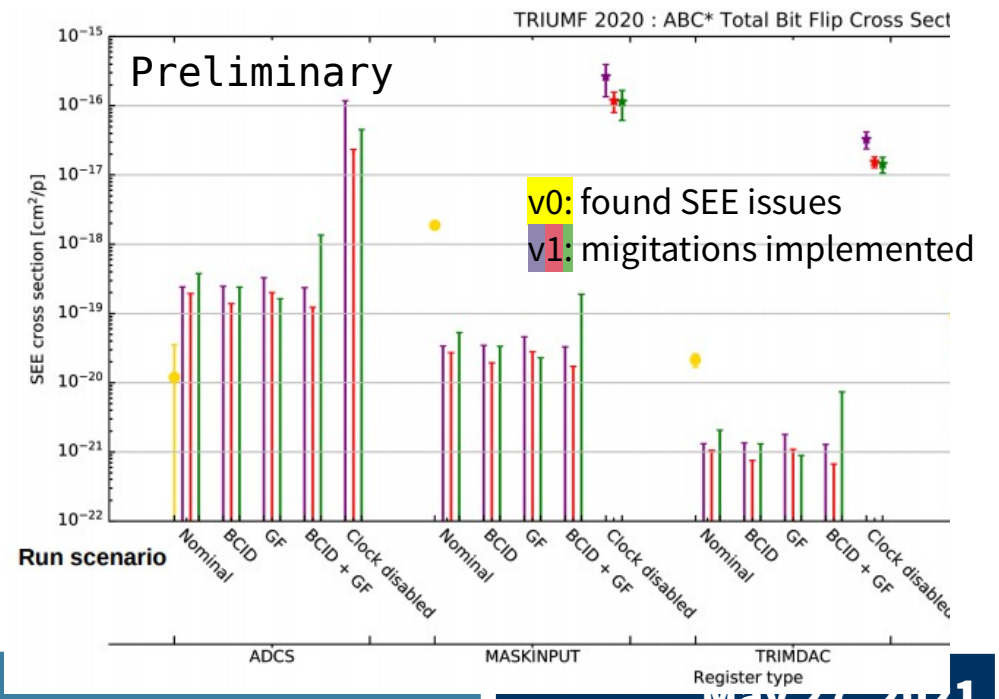
TID Peak (Details)



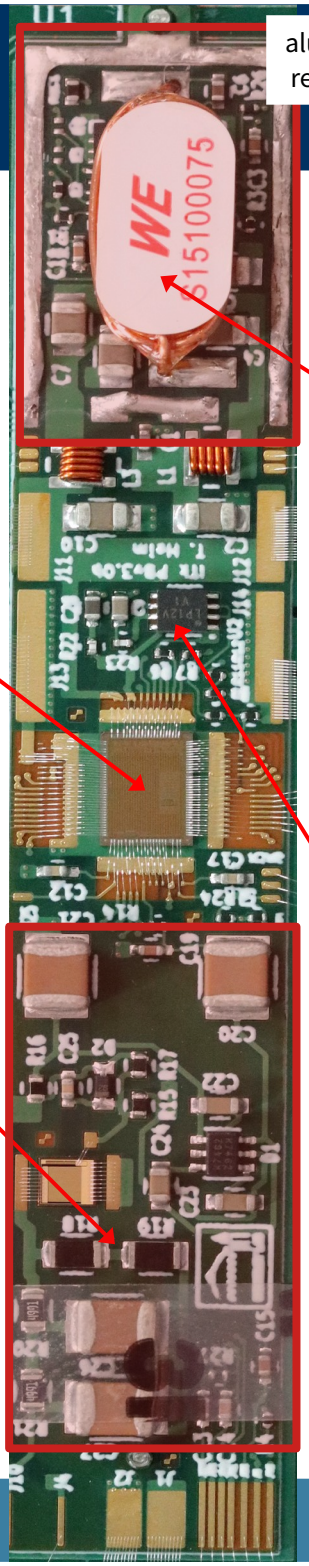
- Power usage increase vs ionizing dose known feature of 130nm chips
- Current design can handle the expected "peak"
- Pre-irradiating the ASIC's removes the peak
  - Current plan is to do a passive irradiation at a Co60 facility

Single Event Error Mitigations

- Effect of SEE's on operation
  - FE chips: data corruption
  - AMAC: power switching of module ← bad
- Tested in all chip versions with proton and heavy ion irradiation



Powerboard



AMAC (The Brain)

- Control/measurement
- Run-time calibration
- Interlock functionality
- Custom ITK Strips ASIC

bPOL12V (The Heart)

- Rad-hard Buck converter
- We use an air-core coil
- 0.1mm Al shield-box to prevent EM noise leakage to sensor
- ASIC designed at CERN

HV Switch

- GaNFET with source at -500V
- Enabled using 100 kHz clock connected to a charge pump
- Commercial chip

linPOL12V

- Rad-hard linear regulator
- 1.5V for AMAC digital logic
- 3.3V for HV switch enable
- Low output current
- ASIC designed at CERN

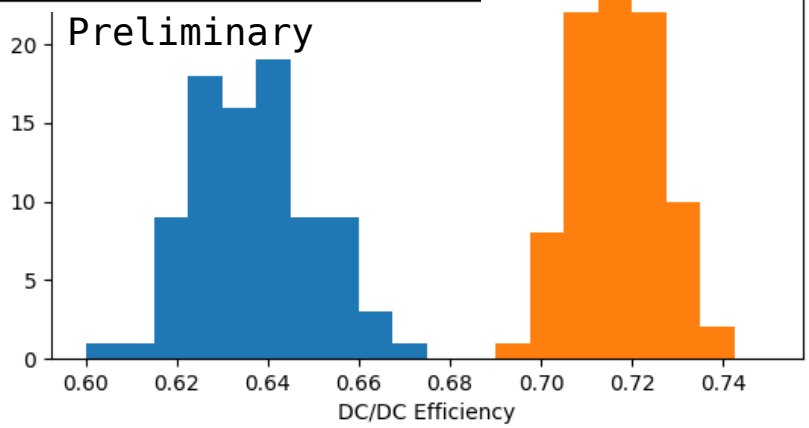
Powerboard Results

Details @ TWEPP2019

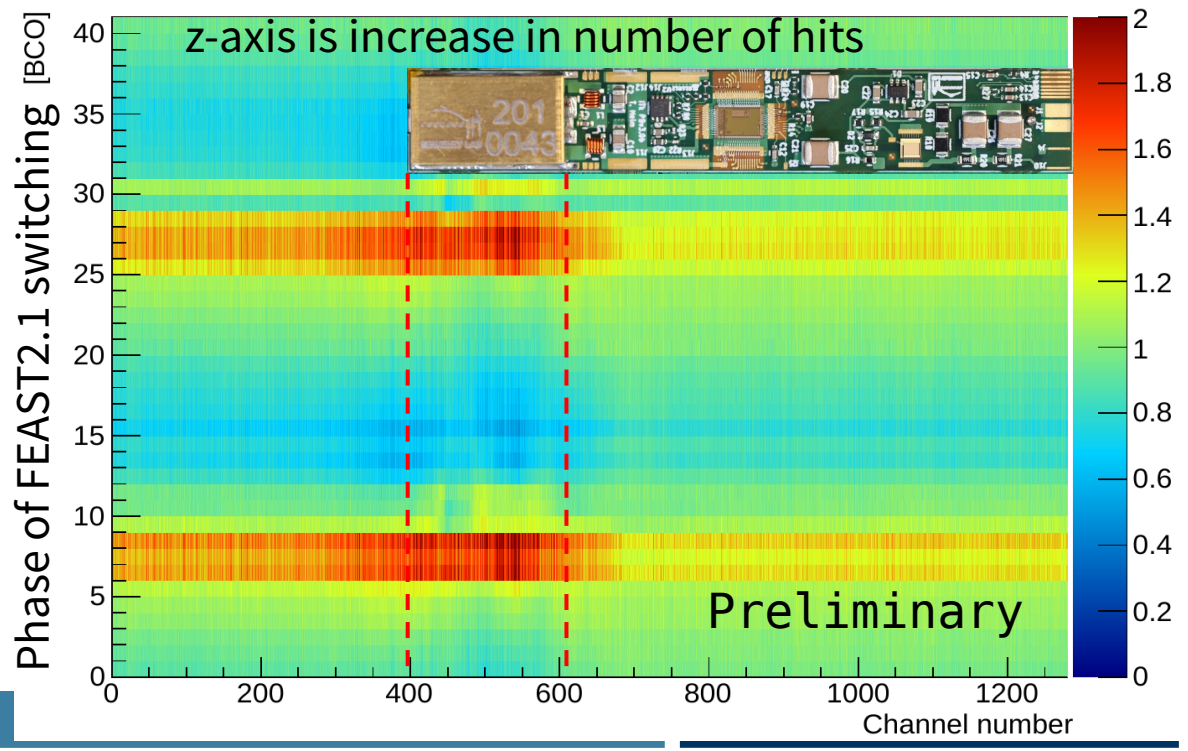
- **Extensive testing for reliability → can be a single point of failure**
  - Follow closely the development and testing of bPOL12V at CERN

Data for 87 PBv3's

Power [W]	SS	LS
No TID	4.72	2.42
TID	5.64	2.88

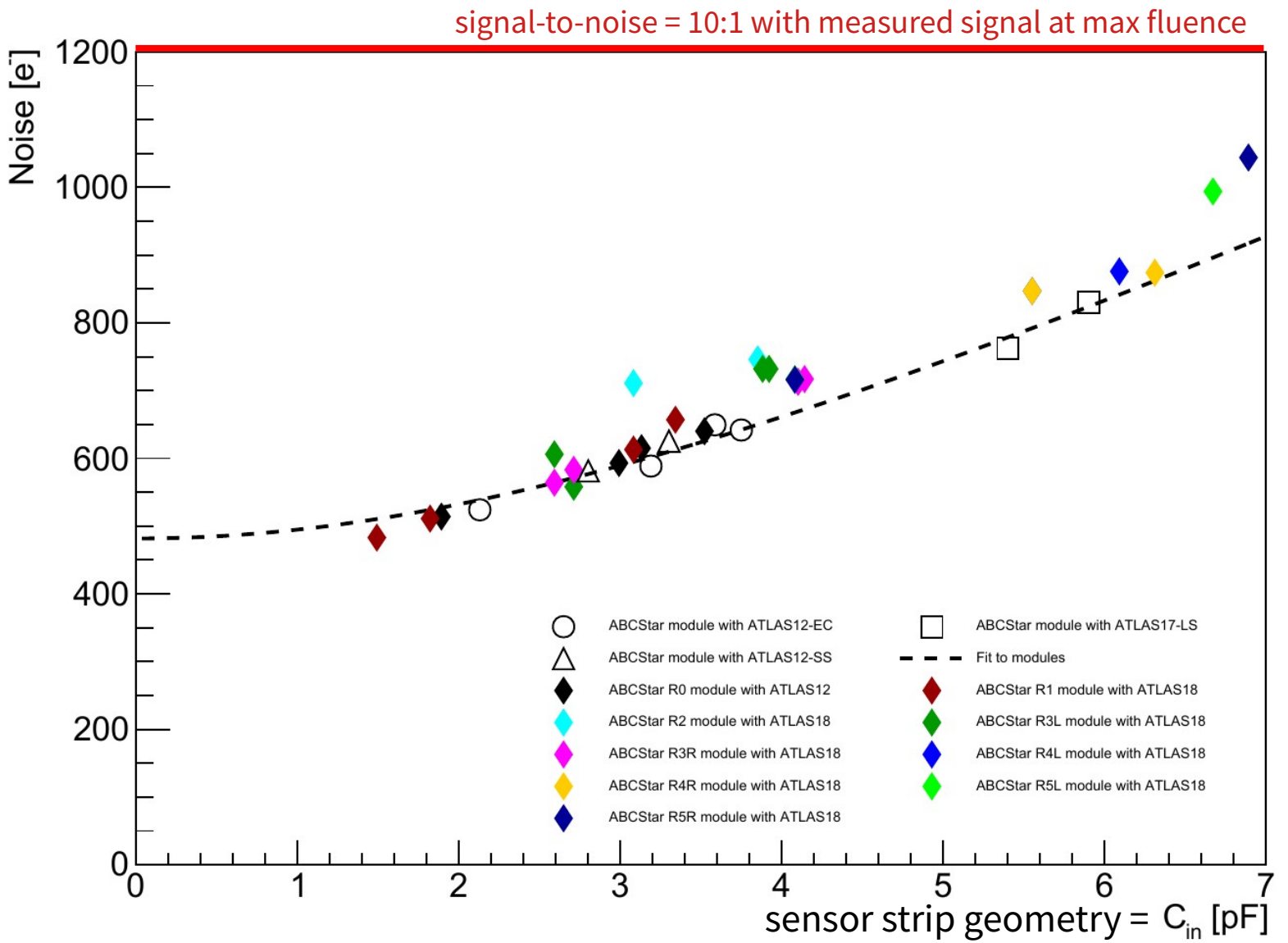


- **Can trigger on emitted EM-field phase to study effect of EMI radiation**
  - Mainly a tool, EMI not an operational issue



Module Results

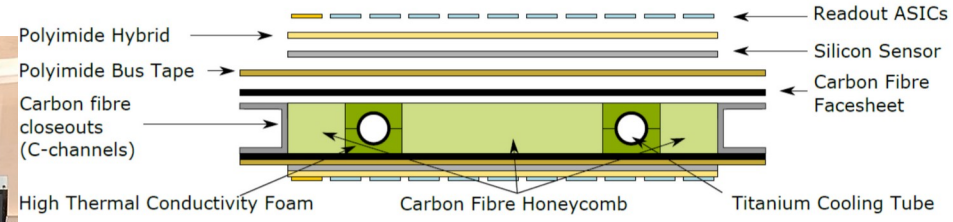
Poster: Testbeam Results by M. Valente

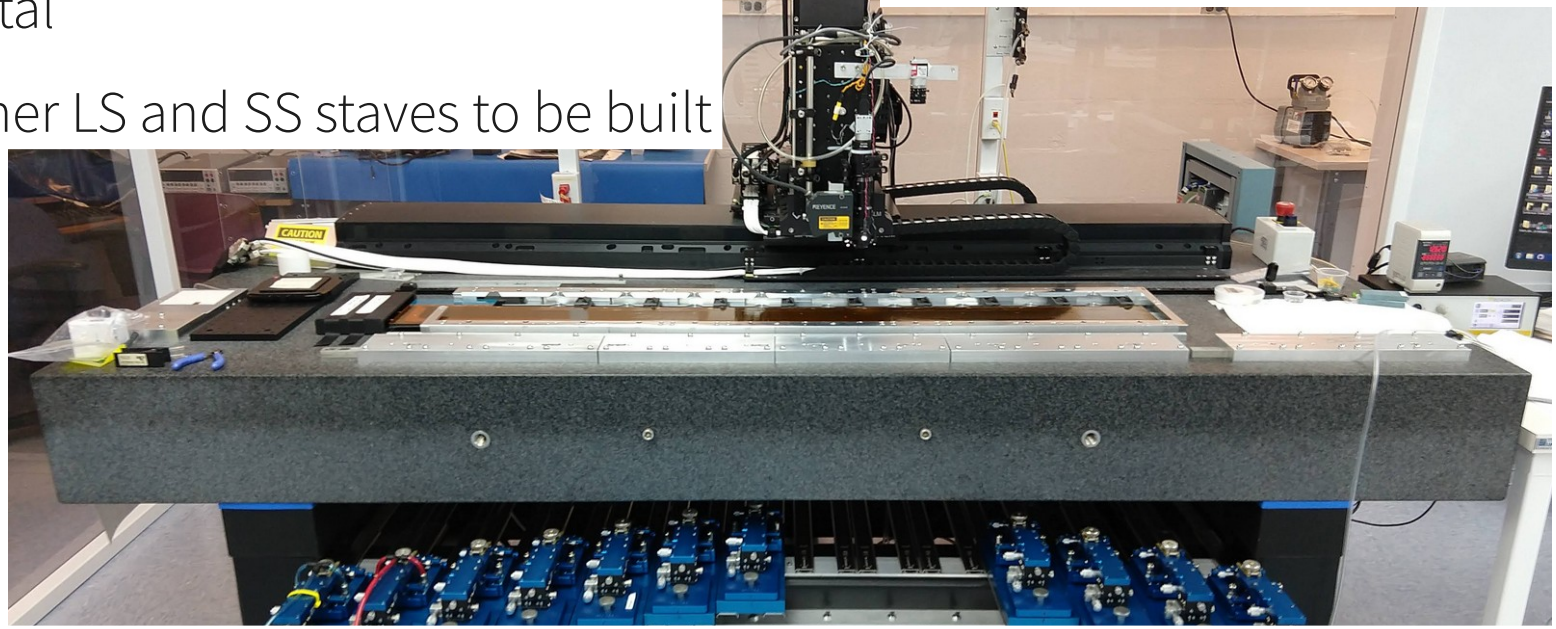


Staves and Petals

Petal Assembly on YouTube

- **Existing prototypes:**
  - 1x LS stave, 1x SS half-stave
  - 1x petal
  - another LS and SS staves to be built

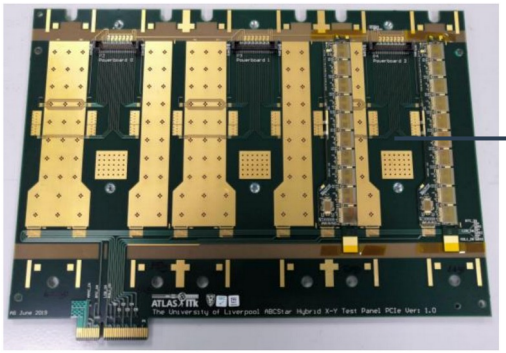




- **Assembly automated via a custom robot**
  - Image recognition used for precise placement of modules
- **Very useful for understanding and fixing system level issues**

Quality Control Systems

Hybrid Burn-in Crate



Powerboard Burn-in + Thermal Cycling Crate

Module Thermal Cycling Box

All systems for large scale testing being commissioned.

Module Pre-Production

Poster: Assembly Lab Monitoring by M. Sýkora

- **Pre-production will demonstrate we can produce 18000 modules**
  - Pre-production: Defined 10% of the actual production
  - A global effort: ~20 assembly sites across 4 continents
- **Two stage process due to part availability**
  - Pre-production A: ~20% of pre-pro
  - Pre-production B: use final components
- **Currently starting Site Qualification**
  - Detailed procedure documents written
  - Videos and measurements to demonstrate build quality
  - Complicated by COVID travel restrictions

	pre-pro A	pre-pro B
Sensors		
ABCstar		
HCCstar	v0	v1
Hybrid		
AMAC	v2a	star
bPOL12V	v4	750 x v4, 100 x v6
linPOL		
Powerboard	Prototype ASIC's	

Conclusion

Completed: No show stoppers found when testing prototypes

Next Step: Prove we can build entire detector (pre-production)

BACKUP

High Luminosity LHC

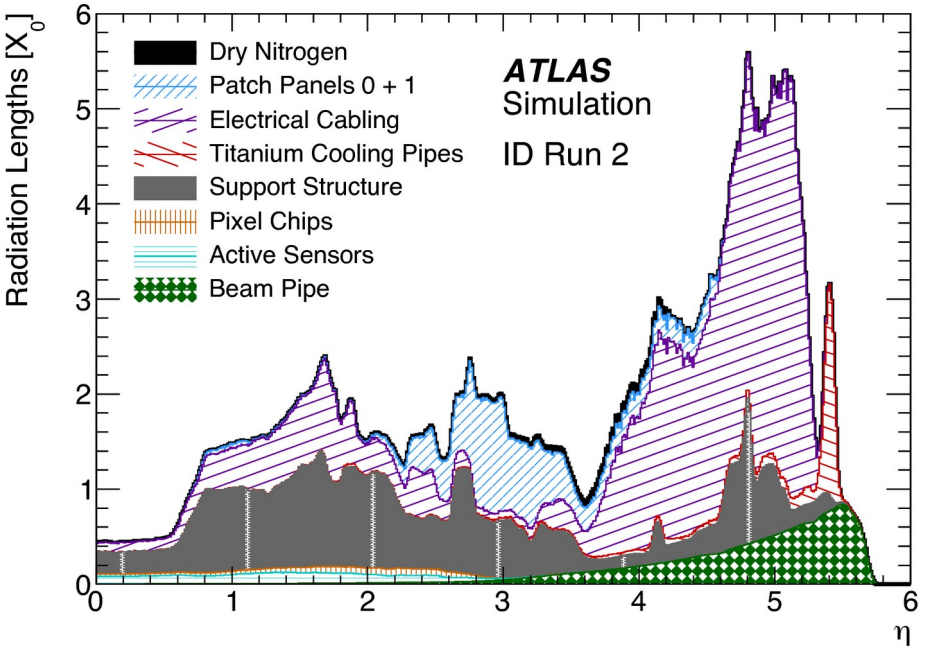
Installation of **major upgrades** to accelerator and detectors.

Start of **HL-LHC**

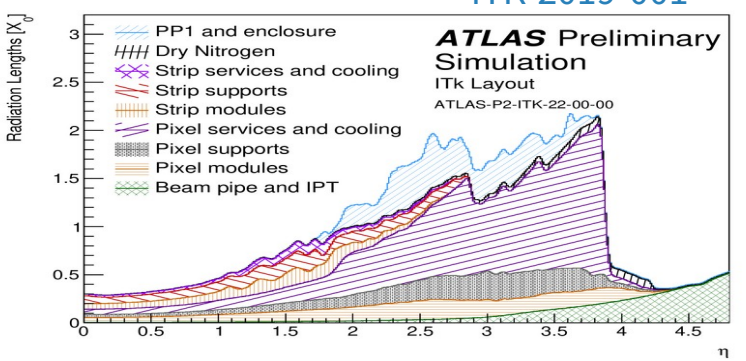
Shutdown/Technical stop
Protons physics
Ions
Commissioning with beam
Hardware commissioning/magnet training

	LHC (Run 2+3)	HL-LHC
Integrated Luminosity	300 fb^{-1}	4000 fb^{-1}
Instantaneous Luminosity	2×10^{34} cm^{-2} s^{-1}	up to 7.5×10^{34} cm^{-2} s^{-1}
Average # of Interactions Per Bunch Crossing	**50**	**200**

Material Budget



ITK-2019-001



COVID Related Impacts

- **Limited access to laboratories**
  - General delay in getting everything setup
- **Virtual collaboration meetings**
  - No informal interaction, split across timezones
- **No site-visits for Site Qualification**
  - Replaced by videos, but those can always miss something
- **Limited travel for test beams**
  - Means limited person power available and remote experts
- **The Great Silicon Shortage**
  - Test boards have to be redesigned as parts go out of stock
  - Purchasing production quantities of certain components now
  - FlexPCB material also impacted
  - Currently no impact on manufacturing of ASIC's