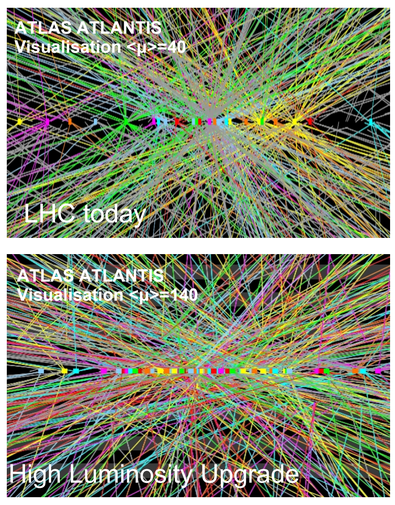
ATLAS Silicon Strip Tracker Upgrade

Activities of the DESY ATLAS group

ATLAS Tracker Upgrades for Phase II

High-Luminosity LHC (2022-)

Proton-proton collision energy √s=14 TeV
Instantaneous luminosity of L=5x10^{34} cm^{-2}s^{-1}
Average number of 'pile-up' collisions per event <μ> = ~130
Integrated luminosity 3000 fb^{-1} over entire run



ATLAS Phase II Upgrade
The High luminosity Upgrade is broadening and enhancing the possibilities for physics measurements, but also has very significant experimental challenges. The current ATLAS Inner Detector, responsible for tracking the trajectory of charged particles, will not be suitable for operation in such an environment due to the high occupancy and the radiation damage.

A new all-silicon tracker, comprising pixel and microstrip technologies, is planned as its replacement.

Design Considerations

The following factors are amongst those taken into account when designing a detector for HL-LHC conditions:

Granularity: Good impact parameter resolution and separation of tracks/ vertices

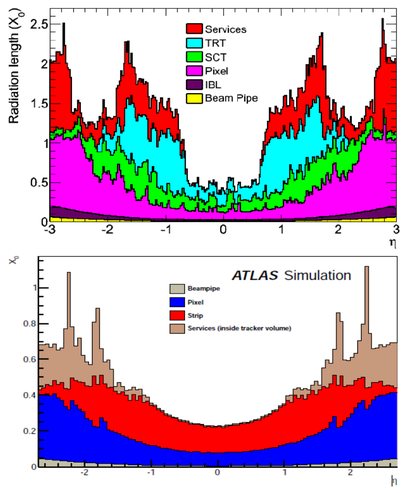
Material: Minimize multiple scattering and bremsstrahlung

Occupancy: Avoid dead time

Hit Coverage: High track efficiency with good rejection of combinatorial fakes

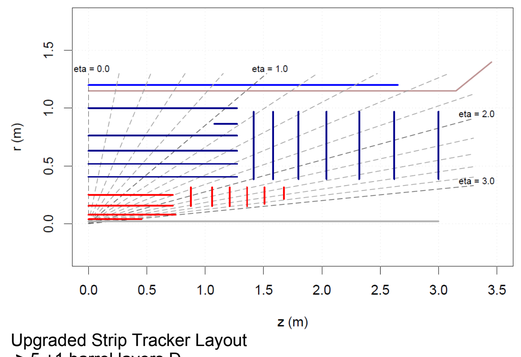
Detector Acceptance: Match coverage to other ATLAS subdetectors and Physics aims

Momentum Resolution: Maximize lever arm and uniformity



Material budgets in radiation lengths (X_0) for the ATLAS Inner Detector (top) and the HL-LHC ITK design (bottom), demonstrating a significant reduction in detector material within acceptance.

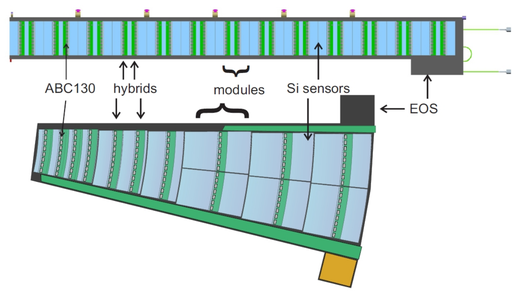
Strip Tracker Layout



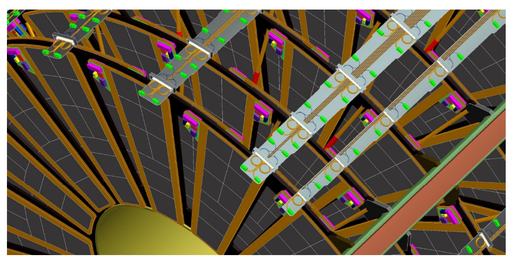
Upgraded Strip Tracker Layout
> 5 +1 barrel layers D
> 7 endcap layers

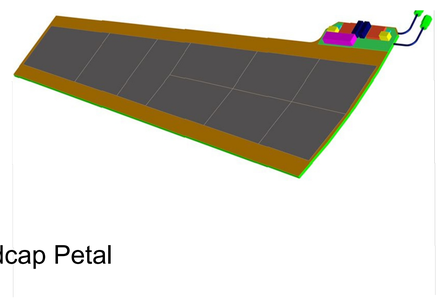
Tracker barrel built from **Staves**
Tracker endcap from **Petals**

Staves and Petals



Endcap Design

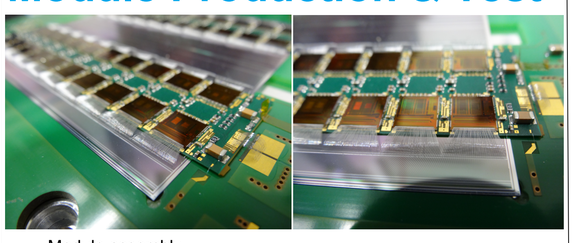




Endcap Petal

The endcap in numbers:
> 7 disks on each endcap
> 32 petals/disk (16 on each side)
> Petal surface: 830 cm^2
> 116 readout kcalcchips/petal
Total endcap:
> 224 petals
> 25984 readout chips
> 18.6 m² silicon

Module Production & Test



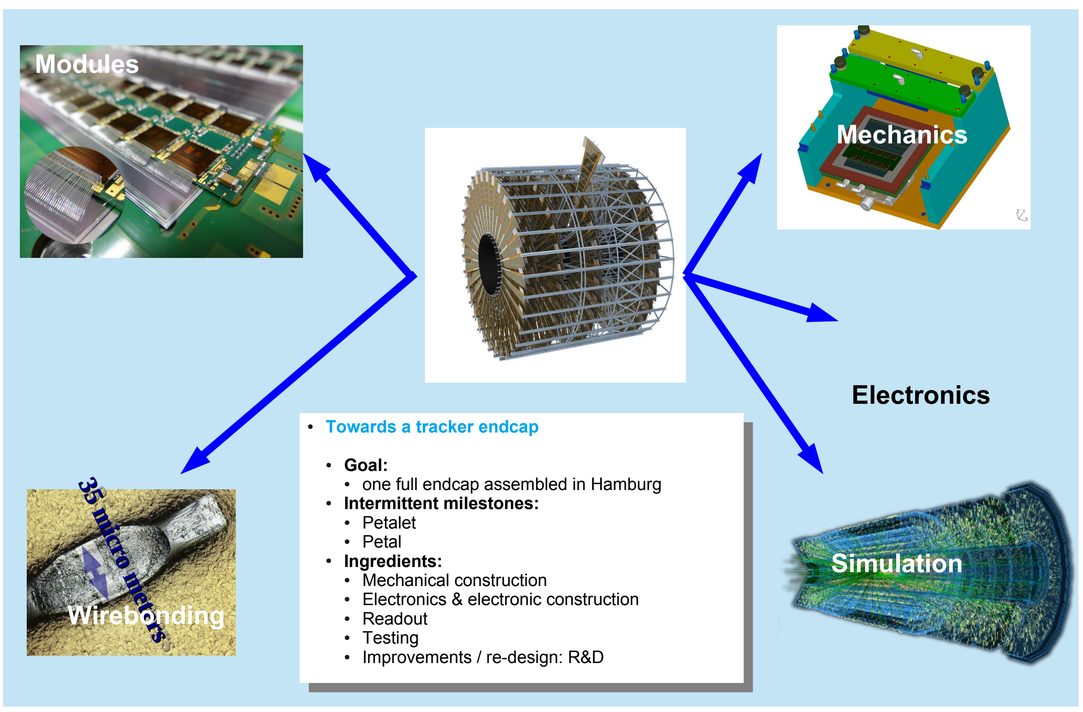
Module assembly

Complete prototype production in place:

Sensor testing
> Hybrid assembly
> Readout chip bonding
> Module assembly
> Module bonding

Module testing
> Connectivity, noise performance, thermal tests

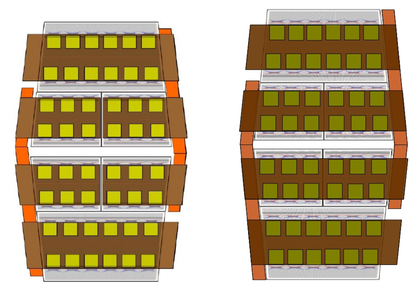
Towards a Tracker Endcap at DESY



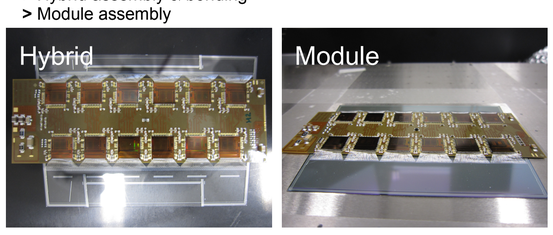
The Petalet Project

With the petalet we plan to address specific challenges posed by the petal design

> High strip density → high ASIC density
> Sensors too large to fit on one wafer, so have to be split up
> Distribution of services



The first petalet module shape recently been assembled at DESY
> Hybrid assembly & bonding
> Module assembly

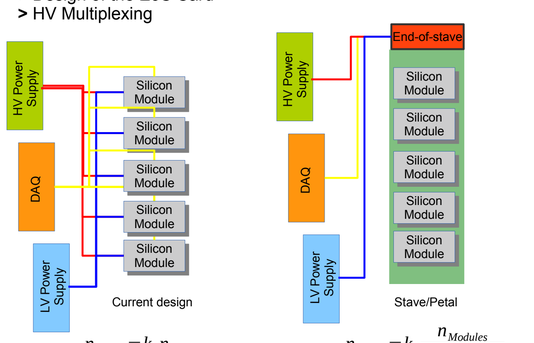


Petal/Stave Electronics

The petal/ stave approach significantly reduces the number of cables/ services for the detector.

All electrical services are now routed through the EoS Card. DESY drives two key areas:

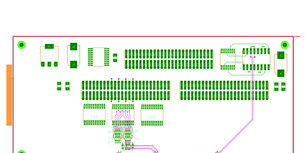
> Design of the EoS Card
> HV Multiplexing

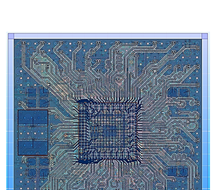


$$n_{Cables} = k \cdot n_{Modules}$$

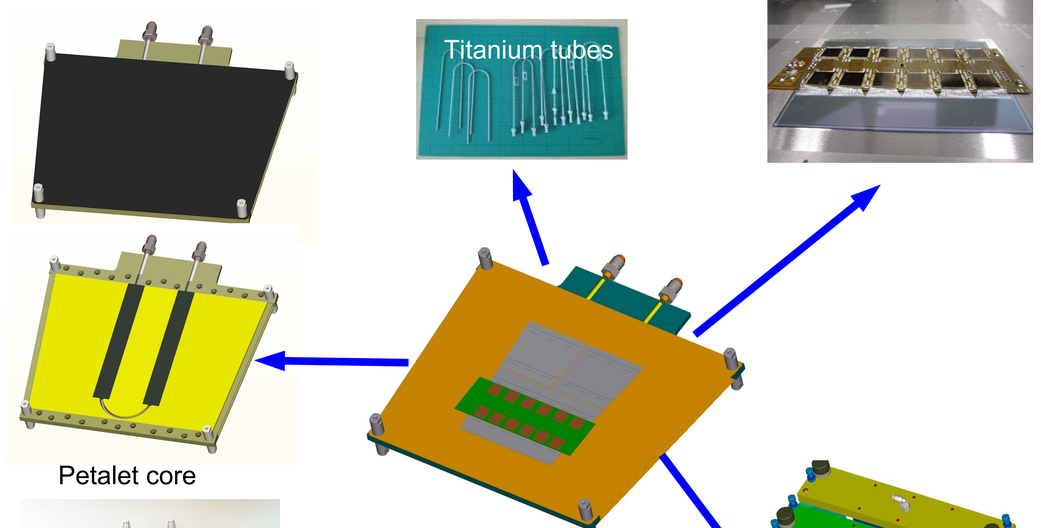
$$n_{Cables} = k \cdot \frac{n_{Modules}}{n_{Modules,Stave}}$$

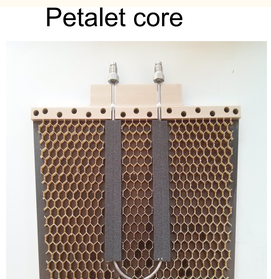
EoS („End of Stave“) Card Design
> High reliability
> LV/HV multiplexing (radiation-hard)
> 10 Gbit/s opitcal links



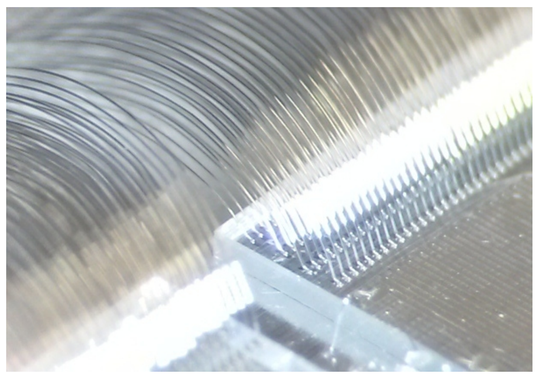


Petalet/Petal Assembly at DESY



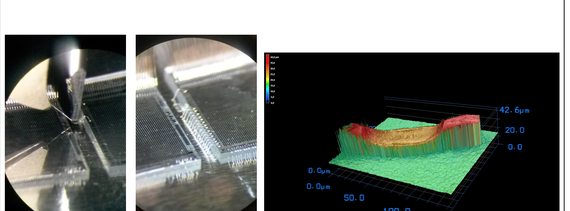


Wire-Bonding R&D



Choice of bond wedge is crucial for module production
> Issues with narrow pads and collisions of heel with lower rows

DESY solution
> Narrow width wedge with custom made „raised heel“



HELMHOLTZ GEMEINSCHAFT