FRONTIER DETECTORS FOR FRONTIER PHYSICS
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Silicon strip tracking detector development and prototyping for the Phase-2 Upgrade of the ATLAS experiment

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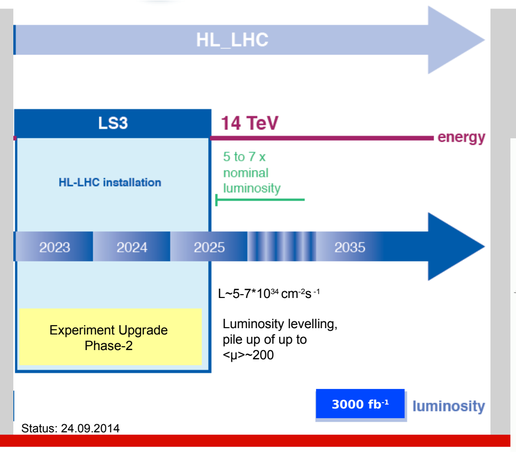
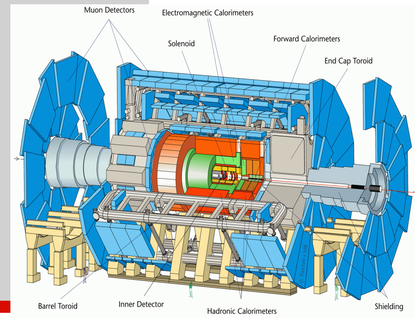
Introduction

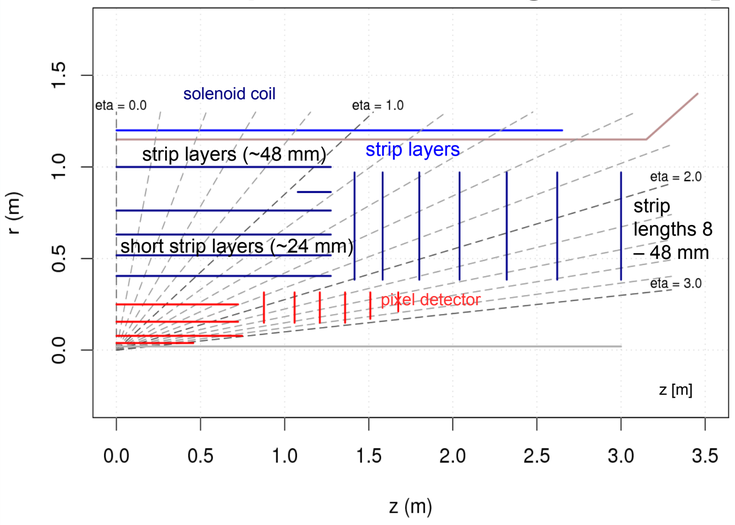
- Current silicon strip tracker of the ATLAS experiment performing very well.
- For ~2024 upgrade of LHC to HL-LHC planned: Increase by ~7x nominal luminosity at 14 TeV
  - Physics aim with 3000 fb^{-1}: measure Higgs boson properties (couplings to 2-10% precision, self-couplings) and extend mass reach for new physics (+30-50% compared to 300 fb^{-1}).
  - Increased luminosity results in: high radiation damage (fluences of up to $2*10^{16}$ Neq/cm^2), high rate, high occupancy
- Replacement of inner detector required to keep performance of current tracker.
- A lot of R&D ongoing for prototyping and layouting of the new silicon strip tracker → TDR in 2016





The new inner tracker: ITk

Pixel and strip silicon tracking detector [1]



Requirements

- Radiation hardness
- High granularity to keep occupancy at 1 %- level and resolve vertices
- Low material (X_0 < 0.7% in central region) to improve low-p_T tracking
- Implementation in existing detector
- Cost and mass production

Detector	Area [m^2]	Layers (B+EC)	Channel [10^6]
Pixel	8.2	4 + 6	638
Strip	193	5 + 7	74

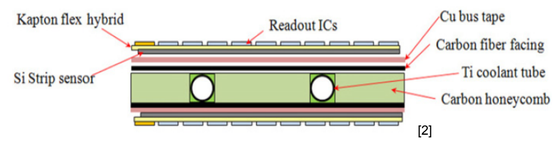
Deploy
- Fast data transmission with low power giga-bit transmitter
- CO_2 cooling (thinner pipes)
- Triggering at L0 with 1 MHz and at L1 300/400 kHz

Acceptance increase to |η|~4 under evaluation

The upgrade silicon strip tracker

Design concept: modularity

- Modularity for easier final assembly, multiple site production, early system tests
- Sensors: N-in-p FZ silicon 320 µm thick
- Modules: Sensors with binary readout electronics (130 nm CMOS ASICs) glued on top
- Stave/Petals: Modules glued double-sided with 40 mrad stereo on carbon and cooling structure

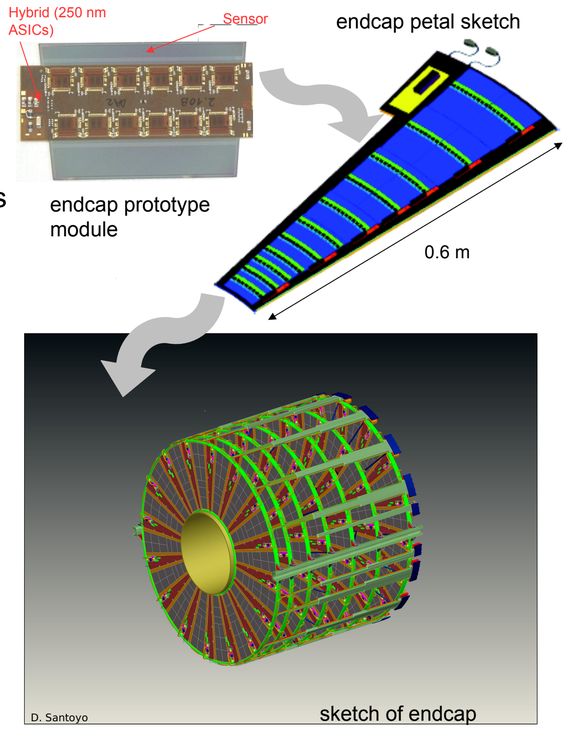


[2]

- Stave/Petals mounted on support structure including services in panels integrated
- DC-DC conversion baseline


DC-DC converter

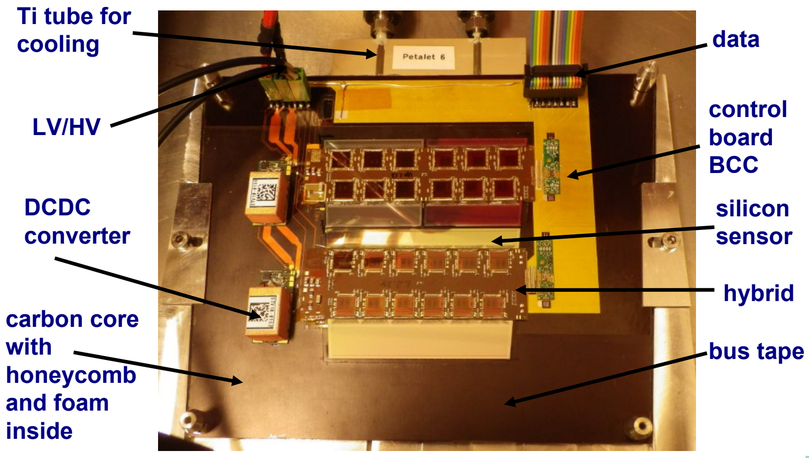
In total 446 petals (~9,000 modules) and 472 staves (~13,000 modules)



Developments and prototyping

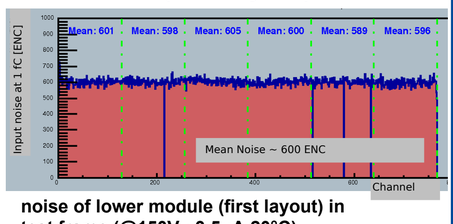
Prototyping of the forward region: Petalet project [3]

- Test production, assembly and readout layouts on smaller scale and with 250 nm CMOS ASICs

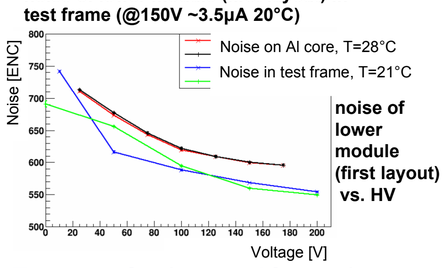


→ **~40 electrical good and precisely built modules and 9 cores for assembly with modules**

Test results (first layout):

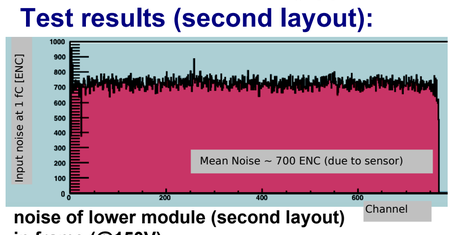


noise of lower module (first layout) in test frame (@150V ~3.5µA 20°C)



noise of lower module (first layout) vs. HV

Test results (second layout):

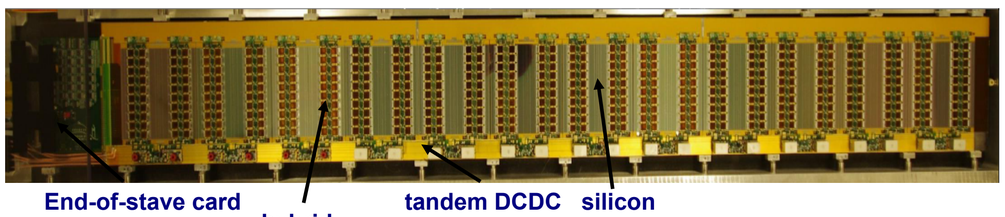


noise of lower module (second layout) in frame (@150V)

Prototyping of full-size objects: Staves and Petals

- Full-size staves built and successfully tested
  - Input noise at 1 fC is 600 - 670 ENC
- Thermo mechanical petal in preparation

Barrel stave with 13 modules using DC-DC powering, ~1.3 m long

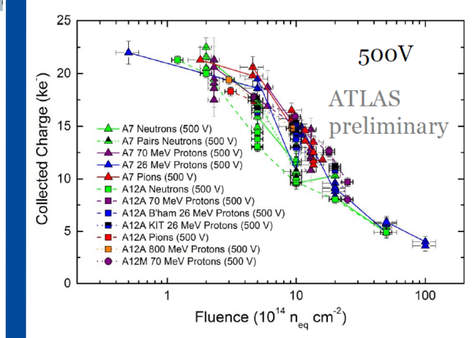



full-size endcap petal bus tape (for thermo-mech.)

Results for sensors and new readout ASICs

N-in-p FZ mini sensor study

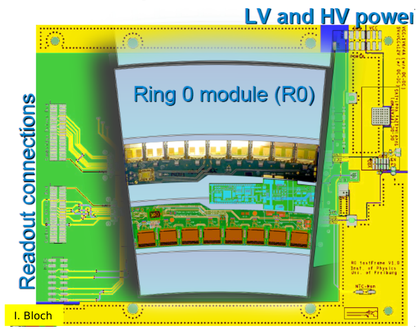
- Extensive tests of many HPK sensors irradiated with neutrons, gammas or protons → show their radiation hardness.



collected charge of irradiated HPK n-in-p mini strip sensors 300/320 µm thick, biased to 500 V

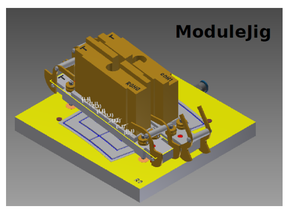
Binary 130nm CMOS ASICs

- 256 channels for lower power (~3 W per module (20 ASICs))
- First hybrid prototype for barrel and forward region including new Hybrid Control Chip (HCC) assembled
- First test show expected performance
- More assembly, testing and SEU und TID tests ongoing
- Test beam just finished



sketch of inner most module for forward region and first hybrid

Tools for assembly:



Results and Outlook

- ~70 barrel and ~40 endcap prototype modules produced, production and properties well controlled, low noise measured
- Stave with modules assembled and successfully tested, petalet under test
- N-in-p strip sensors with ~300 µm thickness withstand doses of $2*10^{15}$ Neq/cm^2
- Prototyping towards full-size objects and mass production ongoing
- Design of support structure, service modules approaching maturity
- New ASICs 130 nm under test and first hybrid results encouraging
- Many more fields of R&D like cores, module mounting, power boards, cabling ...

→ **Prepare TDR until end of 2016**

References:
[1] CERN-LHCC-2012-022, LHCC-I-023
[2] NIM A 699(2013)93–96
[3] NIM A 730(2013)210-214

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