

ATLAS and CMS Operations and Upgrades

Elementary Particle and Astroparticle Physics at DESY

Helmholtz Program: Matter and the Universe (MU)

PoF III Topic: Fundamental Particles and Forces

DESY Research Unit: Experimental Particle Physics

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Center Evaluation DESY, 5 – 9 February 2018

HELMHOLTZ RESEARCH FOR
GRAND CHALLENGES



Detector Operations and Performance Studies

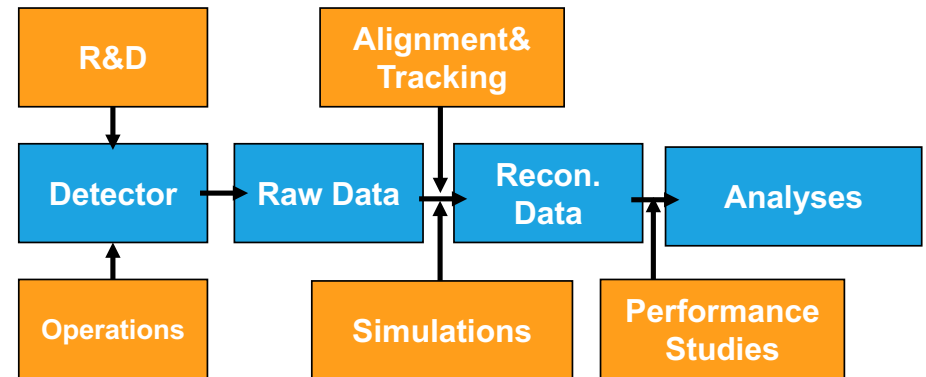
Successful operation of LHC Detectors

Unique opportunity to gather further experience

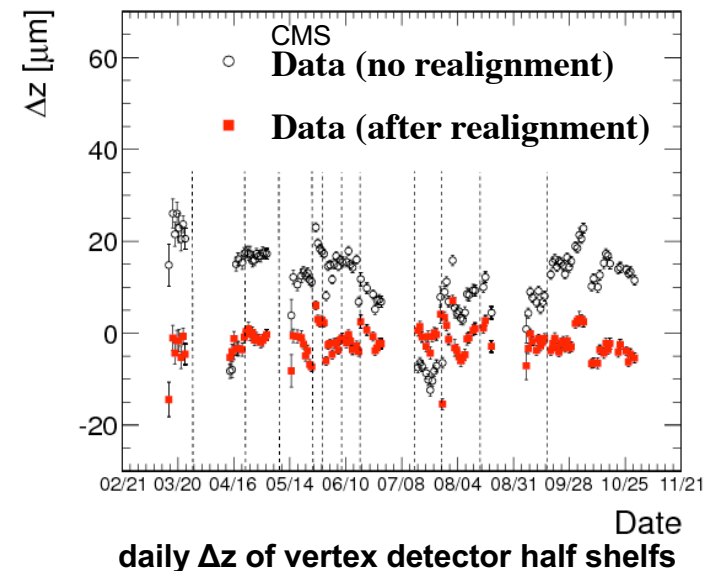
- CMS: fast beam condition monitor (BCM1F) for online measurement of luminosity constructed at DESY and group has a leading role in operation.
- ATLAS: responsibility for maintenance and further development of prompt calibration loop for the semiconductor tracker (SCT).

Key contributions to data analyses

- Involved in many performance studies required for successful data analyses:
 - from photon identification to Monte Carlos studies.
- CMS: pivotal role in alignment of CMS detector, handling about 200000 alignment parameters simultaneously.
- ATLAS: concentrating on tracking aspects for current and future tracking systems to adjust to ever increasing pile-up events.



Simplified path from raw data to physics results.



LHC Upgrades

Full exploitation of the LHC with up to 4000 fb⁻¹

Upgrades of machine and detectors are necessary to reach goal.

- Germany contributes significantly to phase 1 and phase 2 detector upgrades
 - BMBF: 90 MEUR for all LHC experiments
 - Helmholtz: 22 MEUR for ATLAS, CMS and ALICE

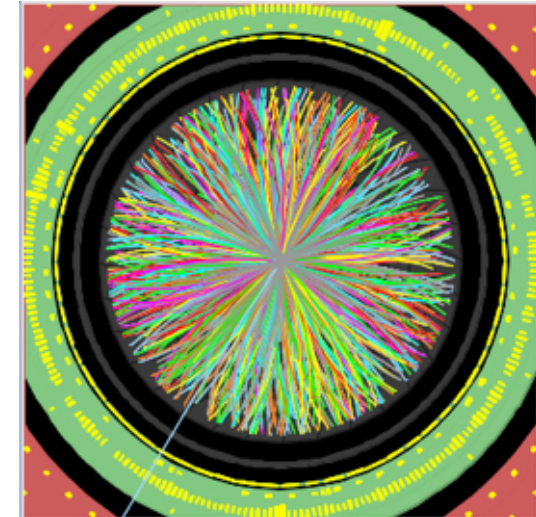
DESY is major player in building new tracking detectors

Phase 1:

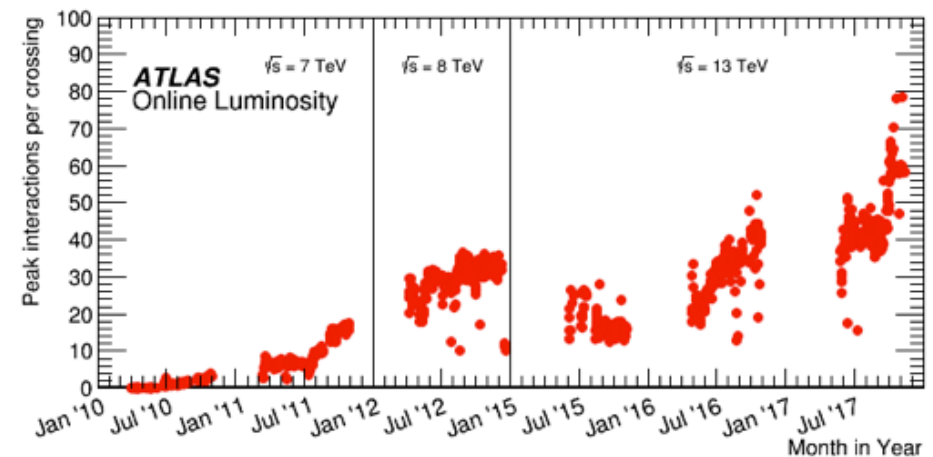
- ATLAS added innermost layer (IBL): DESY strongly contributed to detailed test beam studies (telescopes)
- CMS replacing pixel detectors: all modules for outer barrel layer built by DESY and German universities (~50% of new barrel).

Phase 2:

- One outer tracker end-cap each for ATLAS and CMS assembled by Germany with DESY as the hub.



ttbar event with 140 pile-up events (ATLAS simulation)



Peak interactions per crossing versus operation years as example for ATLAS.

Phase 1: CMS Pixel Detector

Module production at DESY

Outer pixel barrel modules built in Germany

- At DESY an in-house flip-chip bump-bonding process was established to ensure high module production quality.
- Significant R&D was required on bump-bonding material and process details.

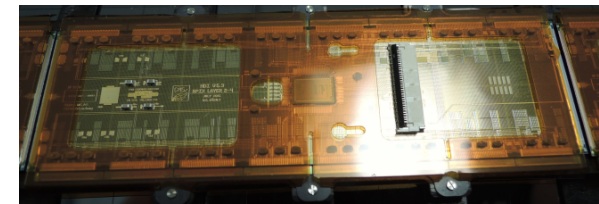
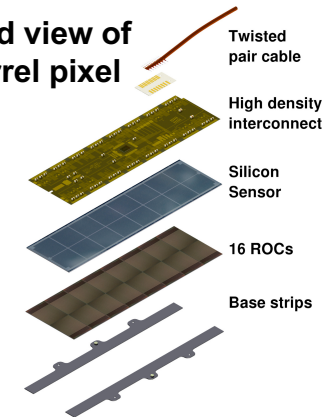
More details also see MT-DTS parallel session.

Completed production in time

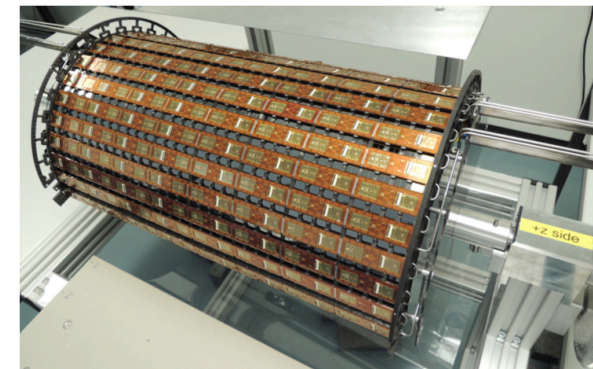
- 287 modules in 1.5 years
(~420 sensors, ~6700 ROCs, ~30million solder balls, ~224k wire bonds)
- Pre-commissioning at PSI winter 2016/17.
- Detector installed in CMS in spring 2017 and commissioned successfully.

Very successful collaboration between scientists and engineering groups at DESY.

Exploded view of CMS barrel pixel module.



Photograph of single CMS module



Fully assembled layer 4 barrel (half).

Phase 2: R&D for the Tracker Upgrades

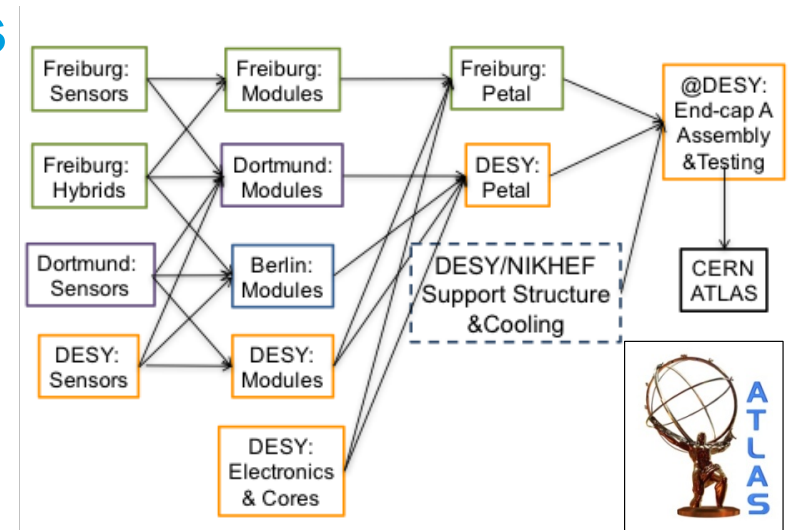
Next generation LHC Detectors build at DESY

ATLAS and CMS: significant upgrades for the HL-LHC phase

- Replace current inner tracking systems by more radiation-tolerant and granular silicon detectors.
- Coherent collaboration plan for all involved German universities and DESY: delivering one end-cap each.
- DESY groups play leading roles in the design and construction of tracking detectors.
 - Preparations started in 2010 with an extensive R&D program.

R&D from detector concept to production

- Covering many areas from simulation to mechanical construction.
- Supported by R&D performed within “Matter and Technologies”.
- Technical Design Reports indispensable milestones on way to production
 - TDRs approved in 2017 (ATLAS April, CMS December)
 - DESY members main authors of TDRs.



Planned workflow during production (example ATLAS)

	ATLAS	CMS
Radiation damage	X	X
Module design	X	X
Mechanical structures	X	X
Electronics/DAQ	X	X

DESY R&D involvement

Phase 2: The End-Caps

Delivering two end-caps to CERN has highest priority

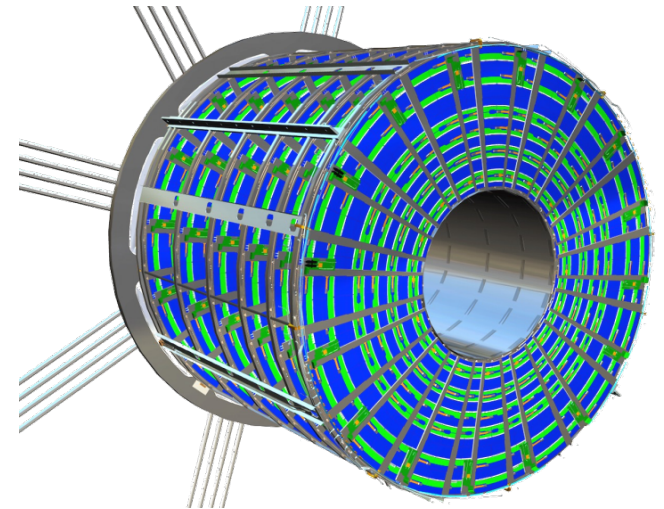
- Schedules in TDRs plan for end-cap deliveries to CERN end of 2024
 - Including about 3 years of module production.

ATLAS

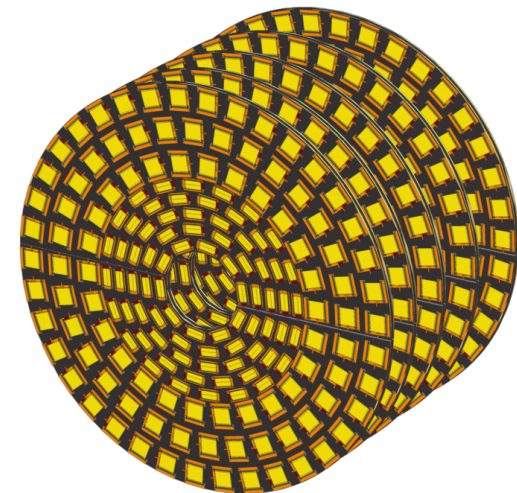
- Silicon strip end-cap assembled at DESY in strong collaboration with the universities of Berlin, Dortmund, and Freiburg.
- 2,000 modules with 20m² silicon area to be built at Hamburg and Zeuthen.
- Tested modules to be loaded on structures and into global mechanics. Full system test before shipping to CERN.

CMS

- New tracker end-cap will also be assembled at DESY, in strong collaboration with RWTH Aachen and KIT.
- DESY committed to build 1,000 modules – ~10 m² of silicon area.
- Responsible for the construction of the mechanical structures to locally support the modules necessary for one end-cap.



ATLAS ITk Strips Detector end-cap



CMS Outer Tracker end-cap.

Phase 2: R&D Highlights – Silicon Modules

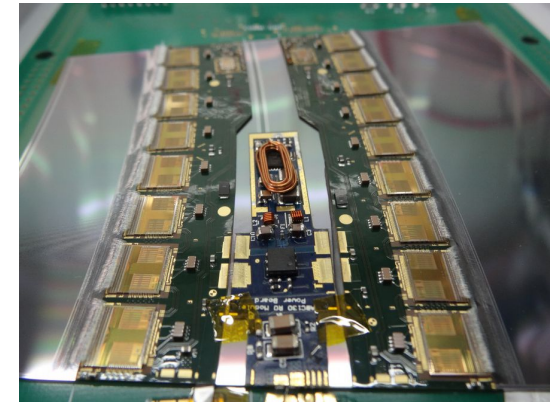
Next generation LHC Detectors build at DESY

Novel concepts developed for HL-LHC

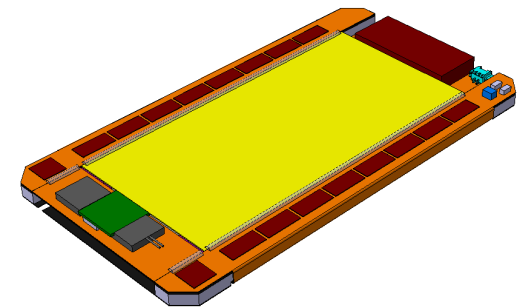
- ATLAS: silicon sensor directly glued onto structure providing cooling, power control, and data transmission.
- CMS: modules providing particle momentum information by correlation of hit signals in two closely spaced silicon sensors.
- DESY leading role in sensor studies and module designs: layout, material choices, thermo-mechanical properties, and production optimization.
- Performance studies: silicon sensors, full modules before and after irradiation
 - DESY test beam key for tracker developments.

From silicon modules to full detector

- Monte Carlo simulations to optimize tracking performance of the detector.
- Simulations and measurements of thermo-mechanical behavior: modules, petals, and the full system.



First end-cap module produced at DESY (Zeuthen).



Drawing of CMS PS-Module.

Phase 2: R&D Highlights – Mechanics & Electronics

Modules and mechanical structures

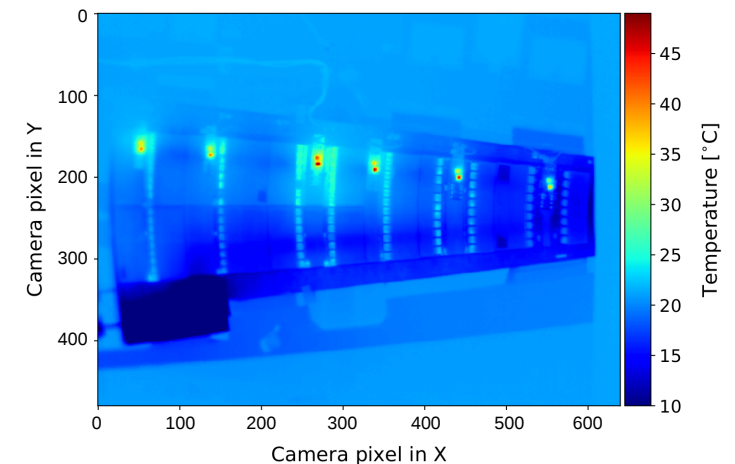
Design of mechanical structures

- Structures combine mechanical stability and embedded cooling pipes.
- Need to provide precise positioning of modules at minimum mass.
- Material choices by material machining tests, prototyping and extensive characterisation of prototype parts.
- Prototypes developed and constructed at DESY.
 - Petal for ATLAS and part of a Dee for CMS.
 - Focus on assembly sequence, mechanical stability, and scalability.
 - Measurement of thermo-mechanical properties.
- Full-system and integration aspects currently being followed up.

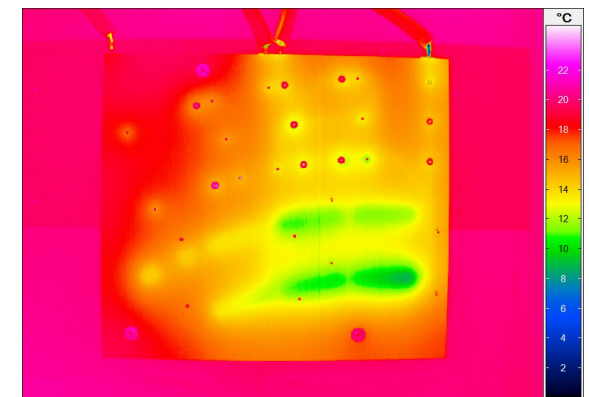
More details also see DTS parallel session.

Interface between on-detector and off-detector (ATLAS)

- DESY has responsibility for the electrical design of high speed interface card (10GB/s links).



Thermo-camera images of petal prototype and the Dee small prototype.



Detector Assembly Facility (DAF)

Infrastructure for LHC Upgrades

Detector assembly facility extremely important for upgrades

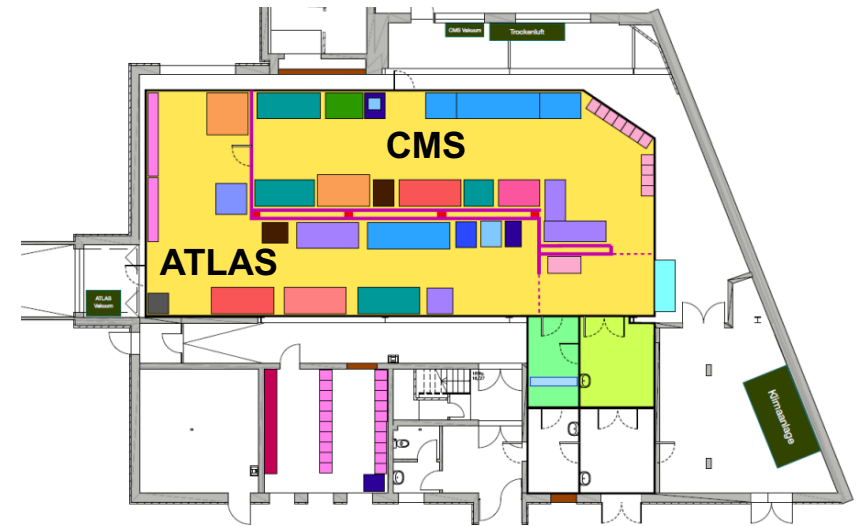
- Dedicated facility for detector development and construction to be used for HL-LHC tracking detectors.
- Strengthening DESY's position as national lab in Germany and beyond.
- Serving ATLAS and CMS needs with a common infrastructure

DAF layout

- Existing buildings 25c and 26; about 1000 m² clean rooms and 200 m² lab space.
- 10 MEUR from DESY for refurbishment and lab equipment.

DAF status:

- Clean rooms in 25c installed including technical building infrastructure.
- Now being commissioned; begin of operations middle 2018.
- Assembly hall: installation of clean rooms started in February 2018.
- DAF will be in use for LHC Upgrades until about 2025.



250 m² clean room infrastructure for module production of ATLAS and CMS



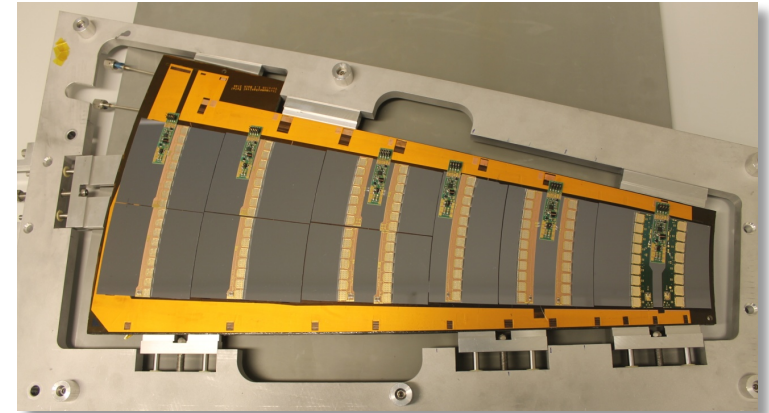
Assembly hall for the end-caps

Summary and Outlook

Essential detector operations, performance studies and upgrades

- DESY picked up relevant work packages in all areas which provide the basis for the data analysis efforts:
 - Detector operations
 - Performance studies
 - Alignment and tracking
 - Simulations
- In preparation for the detectors for HL-LHC assumed major responsibilities in ATLAS and CMS.
 - Supported by R&D performed within “Matter and Technologies”.
- The new DAF infrastructure is essential ingredient.
- Exploiting synergies with and resources of technical groups.

DESY will act as the system integration hub in Germany for one end-cap for the new tracking detectors of both experiments, ATLAS and CMS.



Thermo-mechanical petal prototype.



Clean room in building 25c.

Backup

Additional material for possible discussions

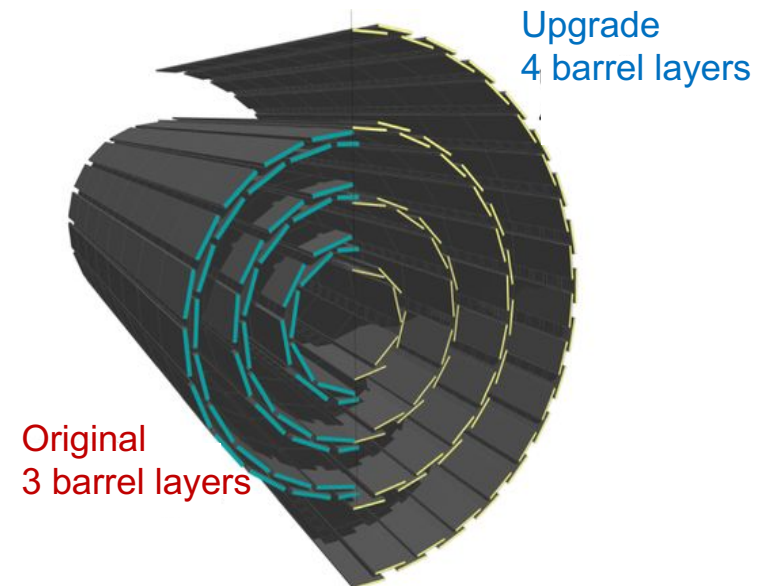
Phase 1: Improved Pixel Detectors

Four layer systems for ATLAS and CMS

Adding one pixel layer for efficient operation at increasing luminosities

- ATLAS added additional innermost layer (IBL)
 - DESY strongly contributed to detailed test beam studies (telescopes)
- CMS replaced complete pixel detector with new system adding an additional layer to the barrel and forward detectors
- CMS-Germany was responsible for producing modules for the 4th layer
 - one half from DESY and Hamburg University
 - one half from RWTH Aachen and KIT

**CMS pixel barrel:
comparison original and
Phase 1**



Phase 2: R&D Highlights

Next generation LHC Detectors build at DESY

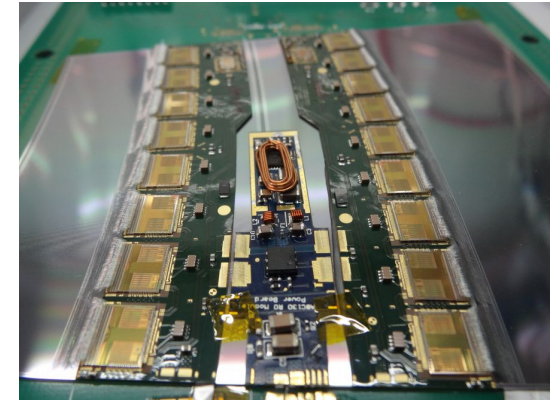
Examples of R&D towards the tracking detectors for HL-LHC

- silicon sensor directly glued onto structure providing cooling, power control, and data transmission (ATLAS).
- Performance studies: silicon sensors, full modules before and after irradiation
 - DESY test beam key for tracker developments.
- Structures combine mechanical stability, embedded cooling, precise positioning at minimum mass.
- Prototypes developed and constructed at DESY to study assembly sequence, mechanical stability, and scalability
 - Example on measurement of thermo-mechanical properties

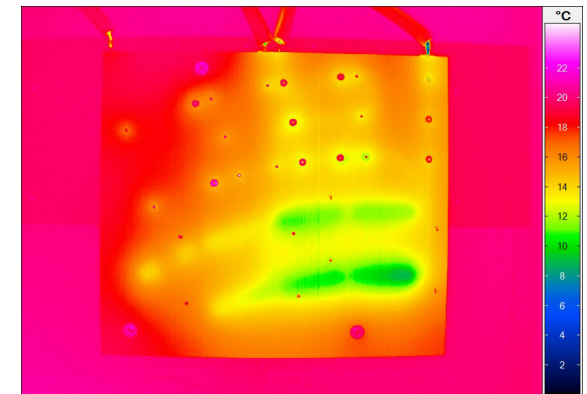
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Thermal images of the CMS Dee small prototype.