MATTER AND THE UNIVERSE

The detector Upgrades for HL-LHC at DESY

Sergio Díez Cornell (DESY)

MU days
DESY, 12-13 December 2024

HELMHOLTZ

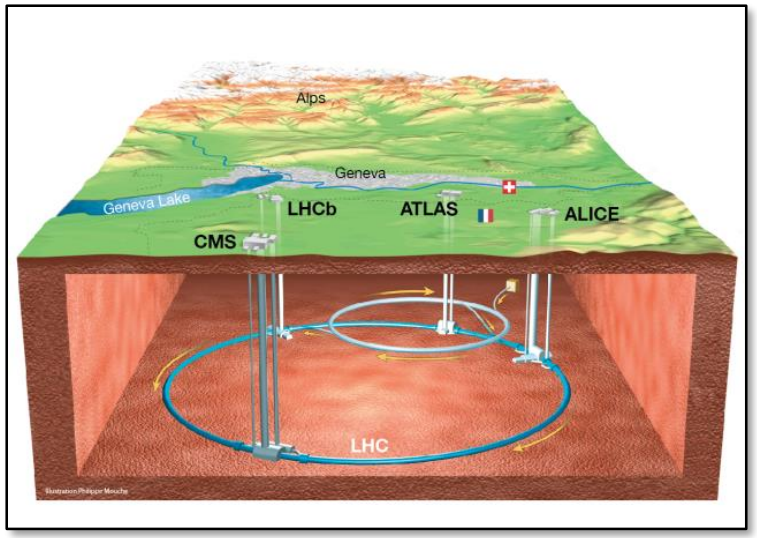
DESY.

Introduction

Leading the effort in instrumentation

DESY keeping his commitment driving collider physics

- Contributing to the major international collaborations as one of the main players
  - Full exploitation of ATLAS and CMS experiments
  - Crucial in the most ambitious upgrade projects within the detectors: Trackers and HGCAL (endcap calorimeter)
- Maintaining the leading role of DESY in particle physics instrumentation
  - In-house experience and **competence in** construction of **detector systems**
  - Strong, multidisciplinary **engineering** teams
  - State-of-the-art **facilities**
  - **German "hub"** for universities and institutions

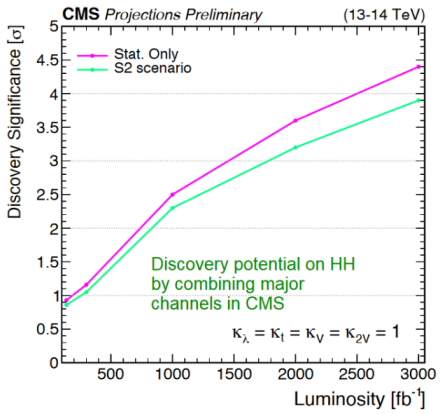


The HL- LHC Upgrade

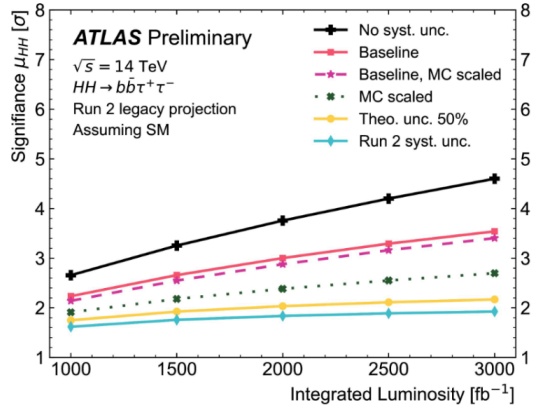
Exploring the limits of the World's biggest collider

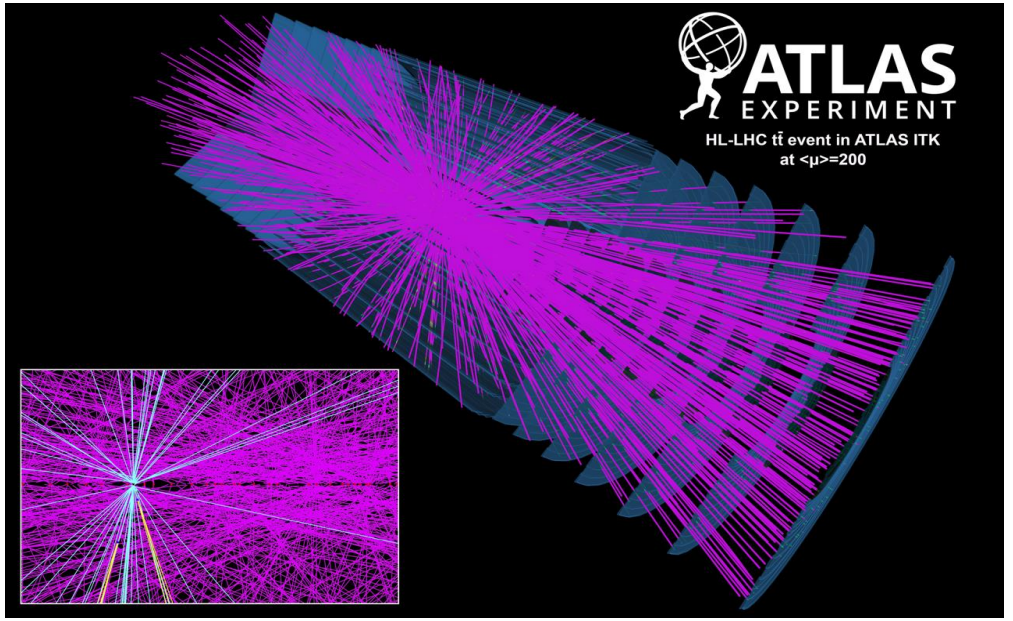
- **Main measurement:** measurement at 4sigma (or better) of the Higgs self-coupling mechanism, by combining ATLAS and CMS
- **Main challenges:** 5-7x higher instantaneous luminosity (7.5×10^{34} $cm^{-2}s^{-1}$) and 10x more pile-up events ($\mu = 200$) in the detectors
- **Main design goal**: Maintain or improve resolution and particle identification performance of current detectors

CMS-PAS-HIG-20-011



ATLAS-PHYS-PUB-2024-016





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High granularity | High speed | Radiation tolerant

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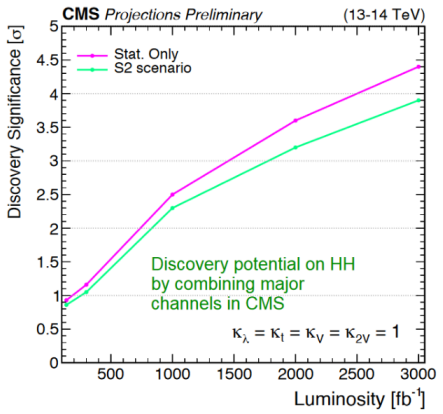

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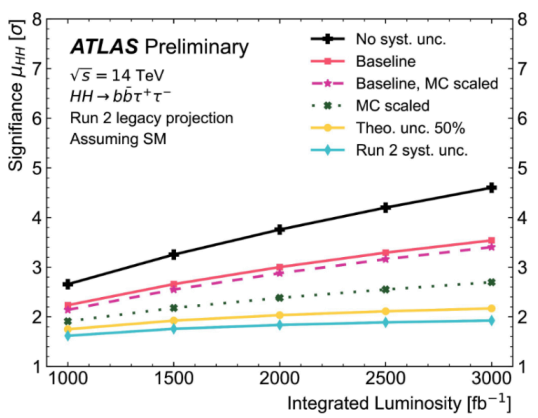

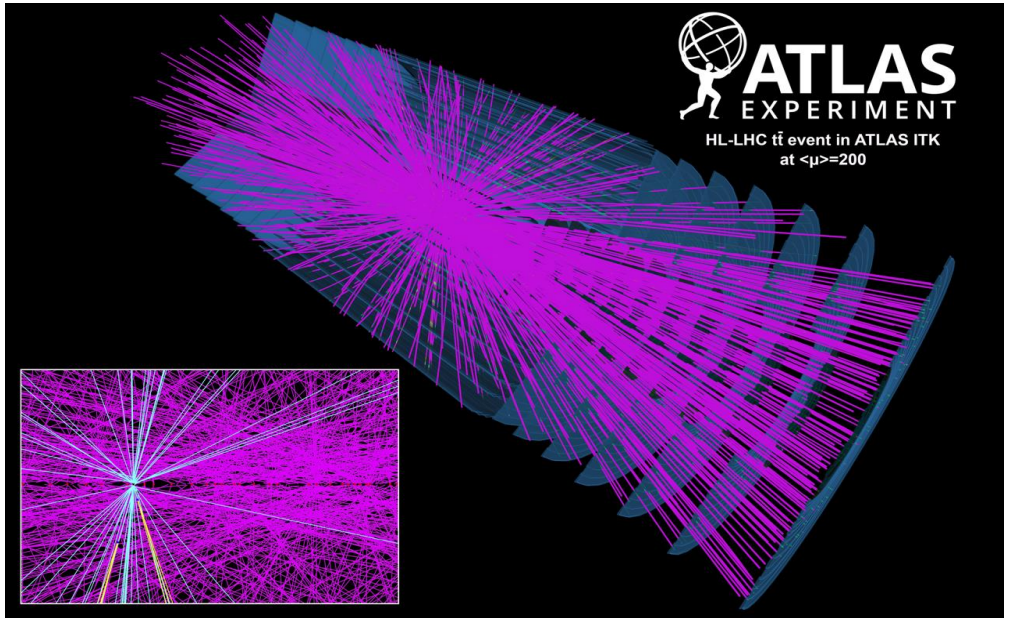

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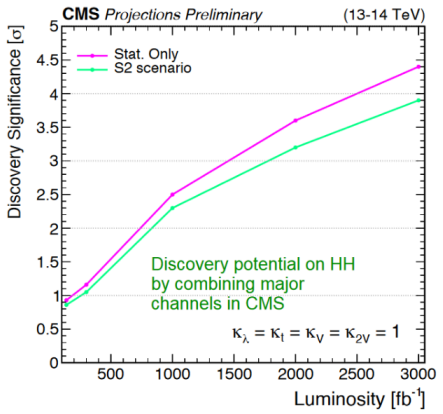
⇧	High granularity	High speed	Radiation tolerant
⇩	Low power	Low mass	Low cost

CMS-PAS-HIG-20-011



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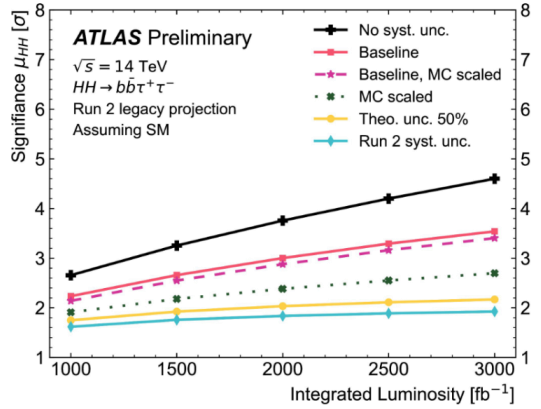
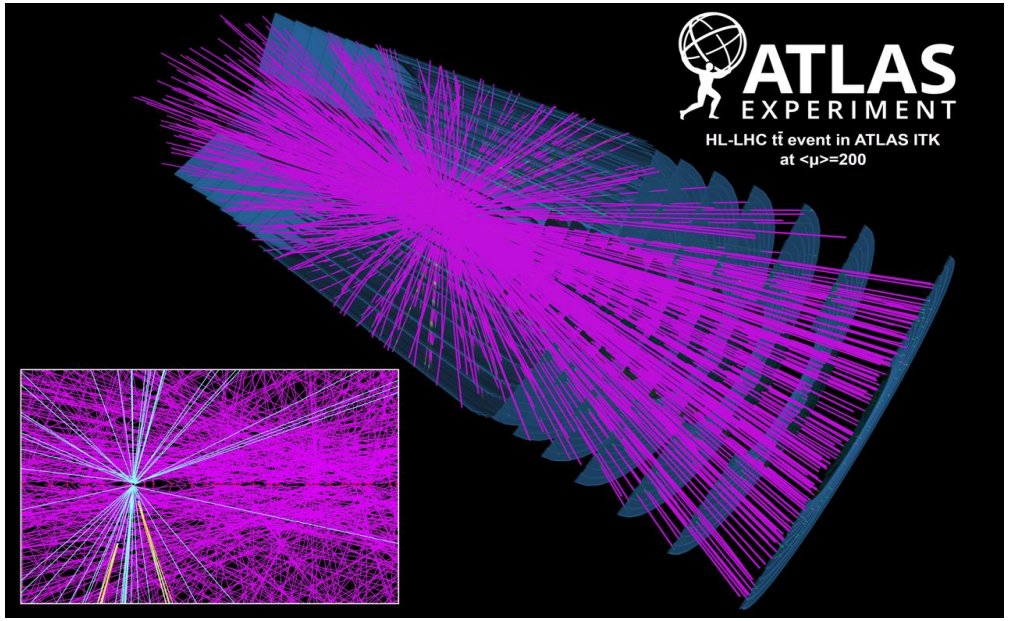
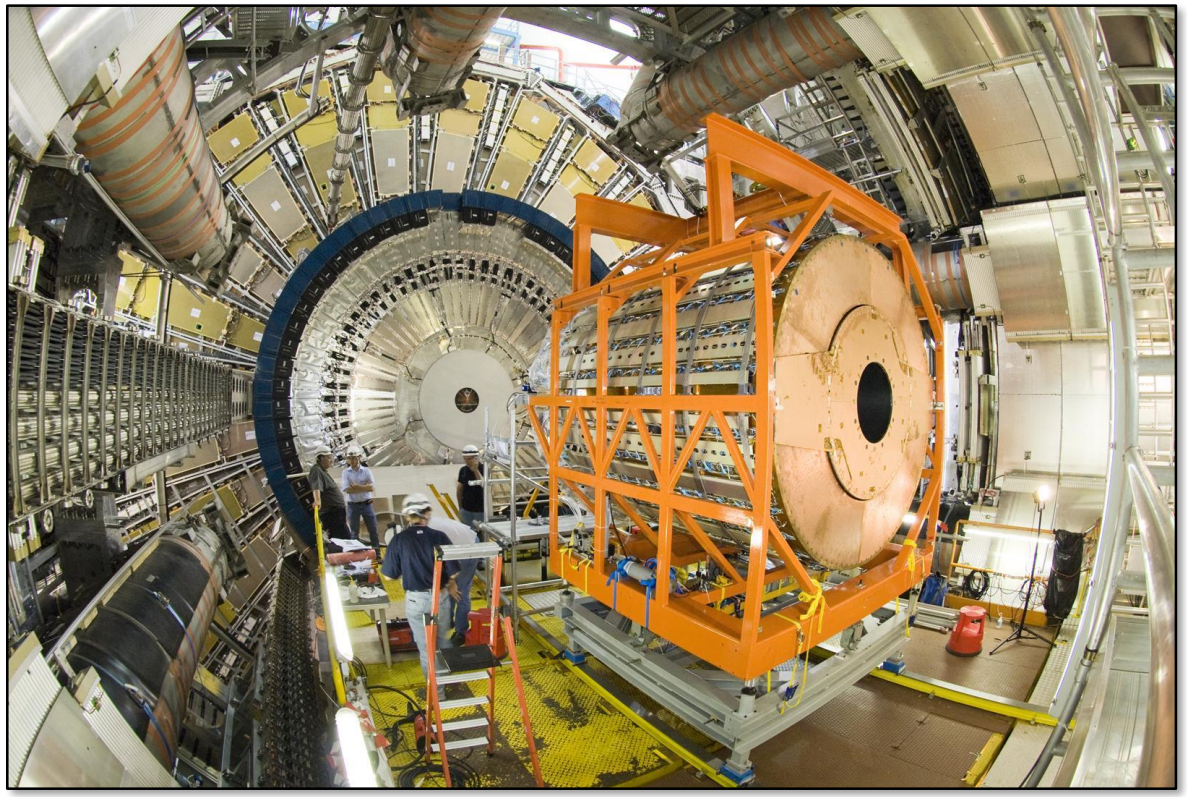




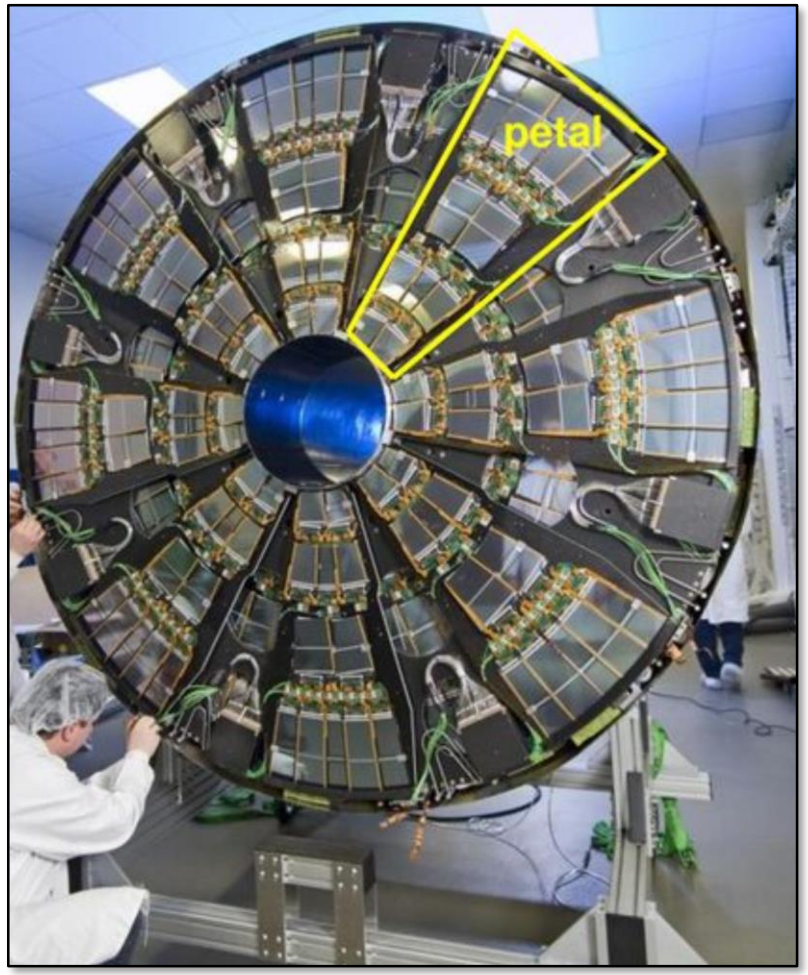
Replacing the old trackers

After more than a decade of excellent performance

ATLAS Inner Detector End-cap

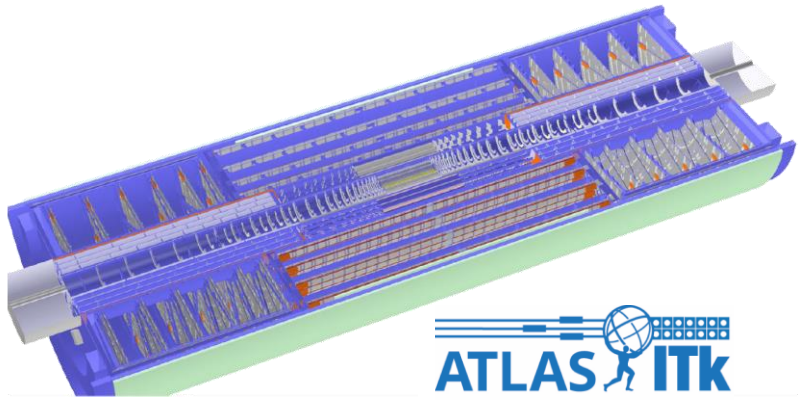


CMS strips tracker End-cap



The new CMS and ATLAS trackers

A whole new scale for silicon detectors

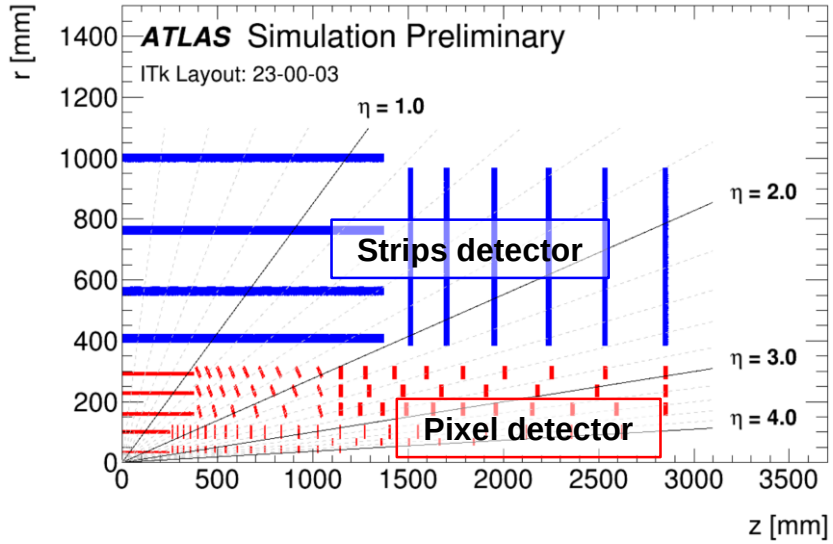


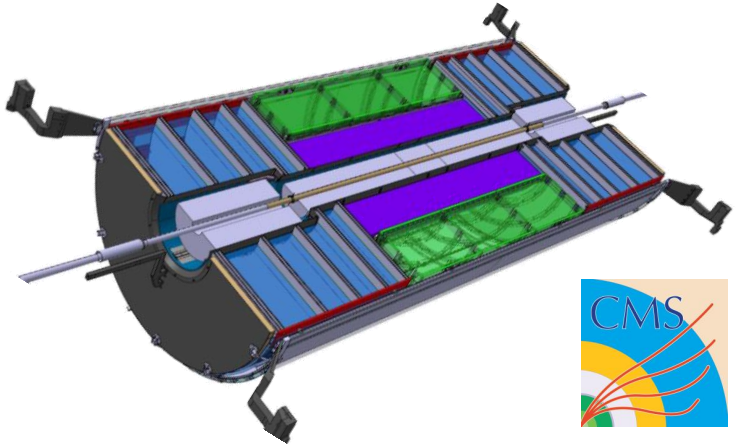
179 m2 of silicon

Pixel detector: 5x10^9 readout channels

Strips detector: 50x10^6 readout channels

ATLAS Inner Tracker (ITk)



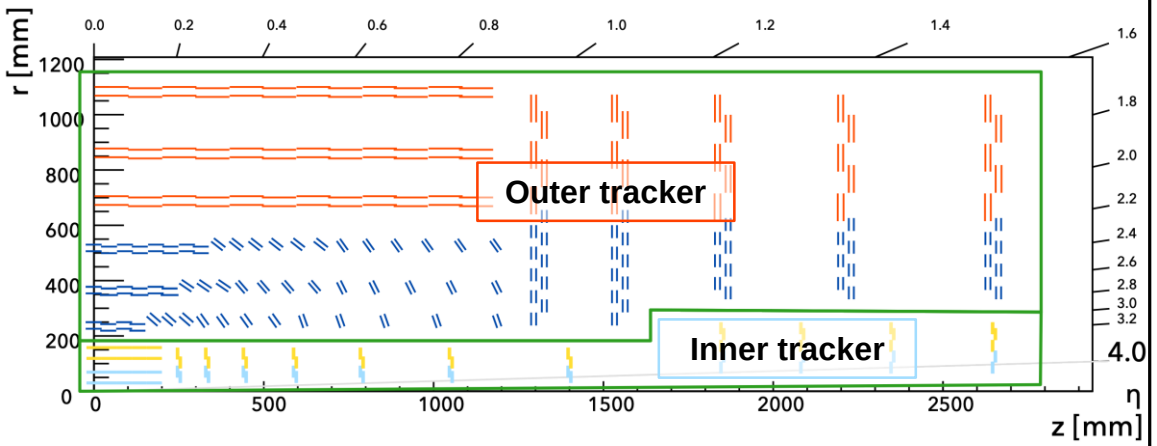


204 m2 of silicon

Pixel tracker: 2x10^9 readout channels

Strips tracker: 200x10^6 readout channels

CMS Phase-II Tracker



The new CMS and ATLAS trackers

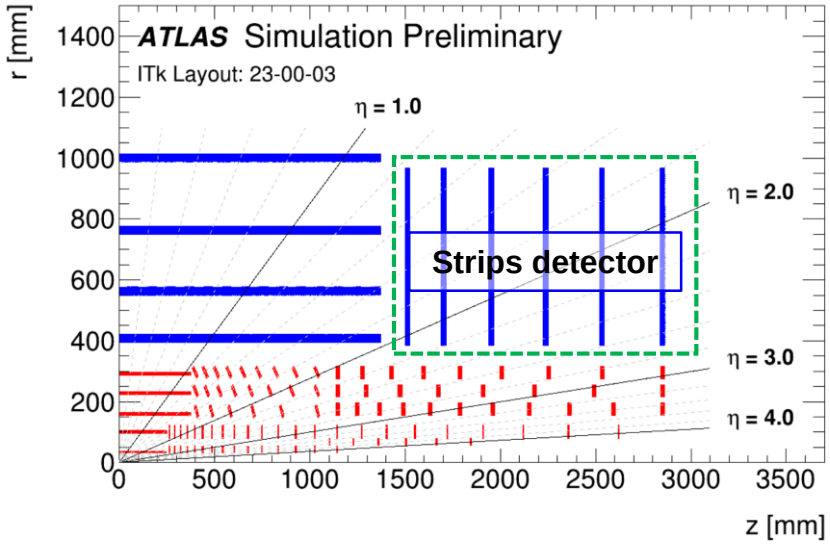
The role of DESY

ATLAS ITk strips End-cap

2000 end-cap modules

100 “petals”

One fully instrumented end-cap

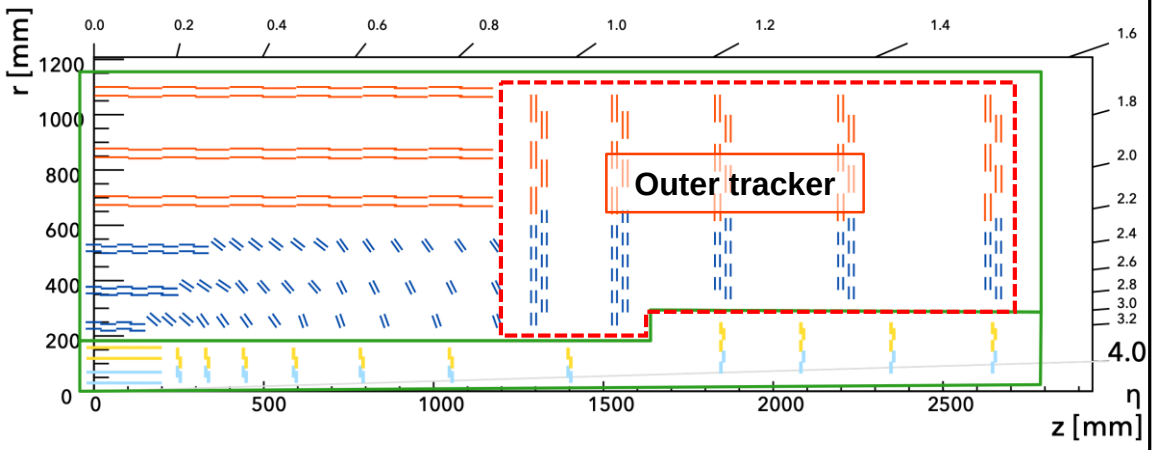


CMS Outer End-cap

1120 PS modules

16 Integrated “Dees”

One fully instrumented end-cap



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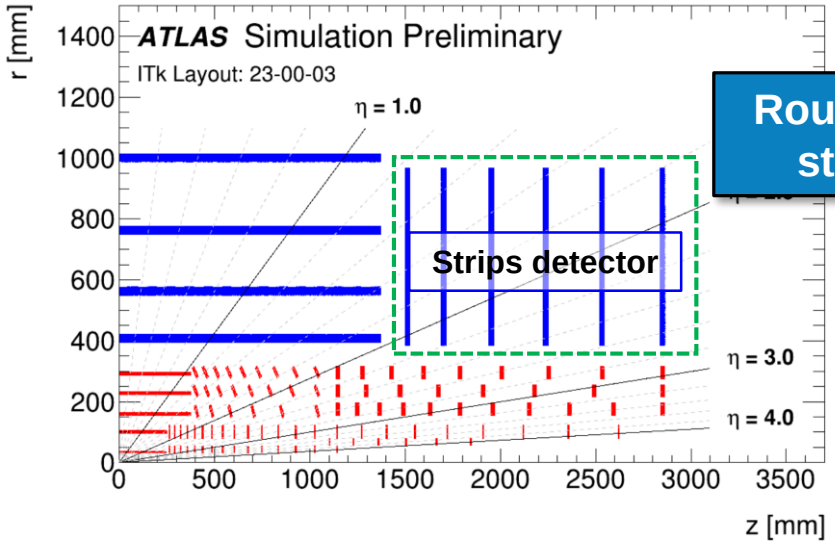

Roughly 1/4 of the Outer Tracker and the strips ITk are responsibility of DESY

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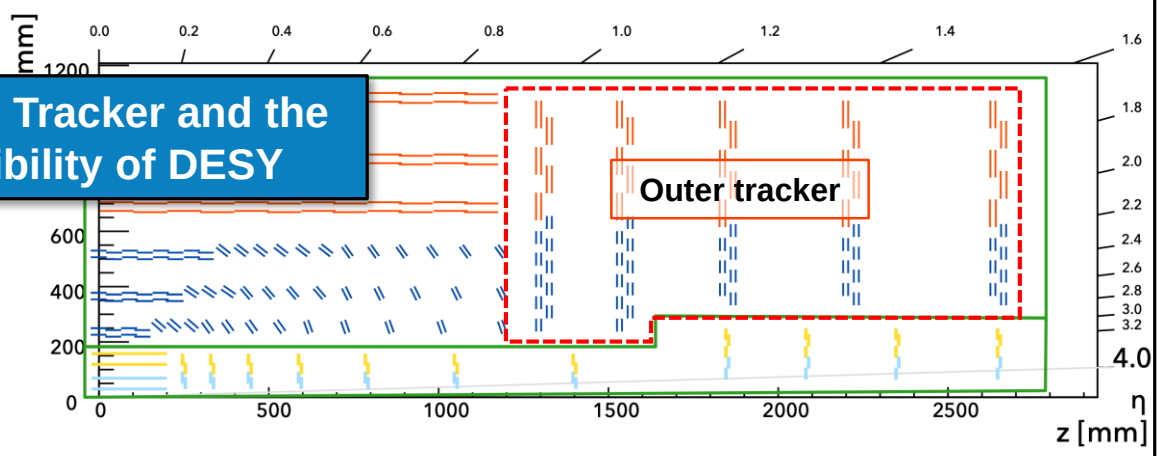


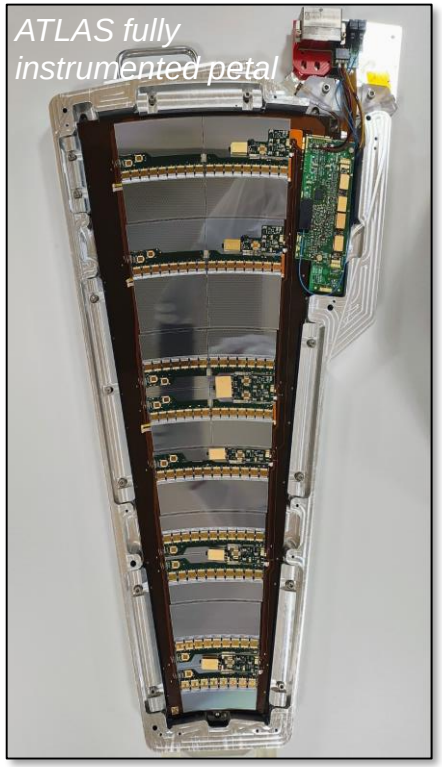
Covering the full spectrum

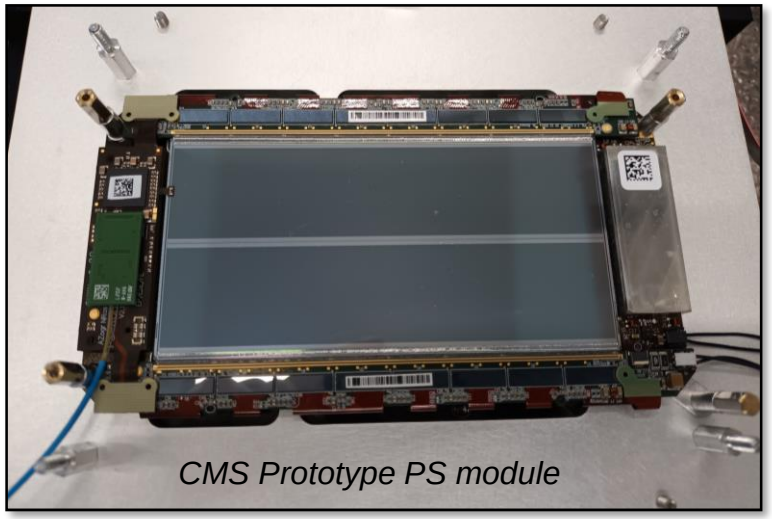
From the smallest sensing units to the biggest structures

Covering the whole range of the detectors design, assembly, and test from the start

- Silicon sensors and modules
- (Instrumented) support structures and its electronics
- Global structures
- Integration of sub-detectors
- System testing

- Know-how expertise present at DESY for integration, installation and commissioning of detector systems instrumental for their success


ATLAS fully instrumented petal


CMS Prototype PS module


CMS Pre-productionP "Dees" mounted on arc frames

Systems engineering

Tooling for assembly, QC and integration

Exploiting the strong and multidisciplinary engineering expertise at DESY

- Leaders in production of custom-built tooling and setups for components assembly, quality control (QC), and detector integration
  - Module and instrumented supports **assembly**
  - **Thermal QC**
  - **Electrical QC**
  - **Integration tooling** and tests
  - **Dual-phase CO_2 cooling** machines

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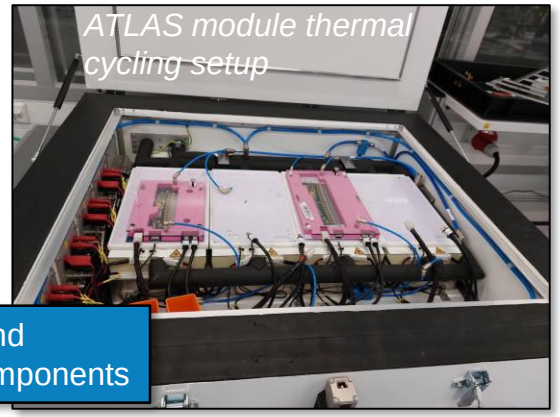
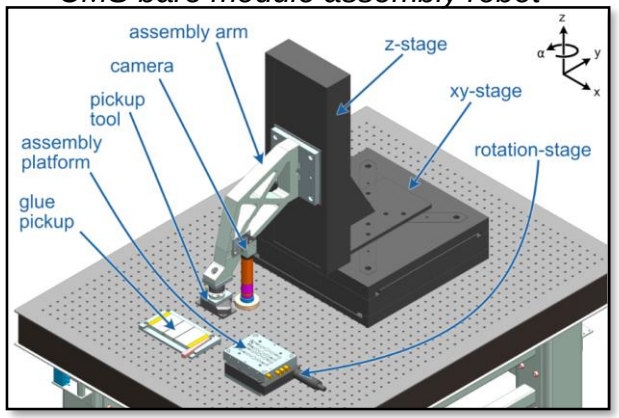


Modules and module components

CMS bare module assembly robot



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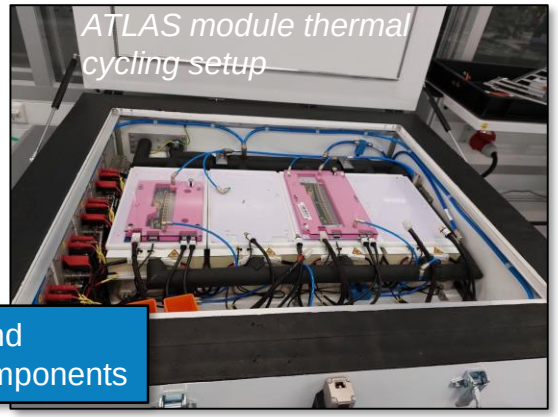
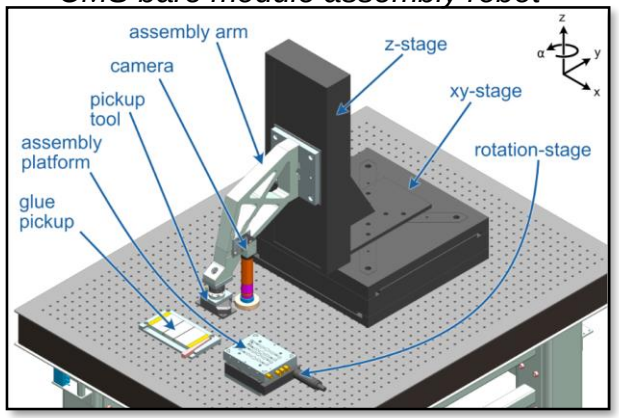
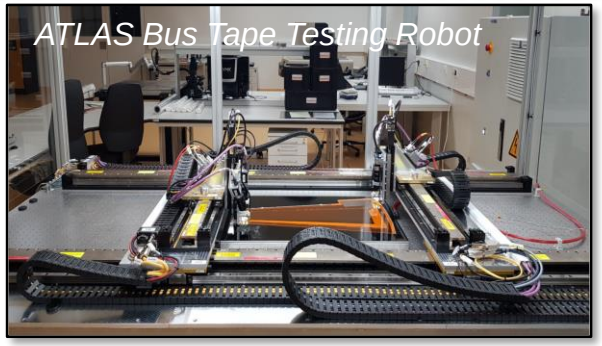


CMS bare module assembly robot



Instrumented supports



Systems engineering

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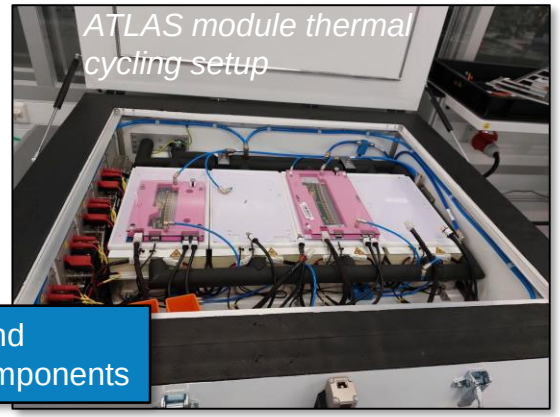
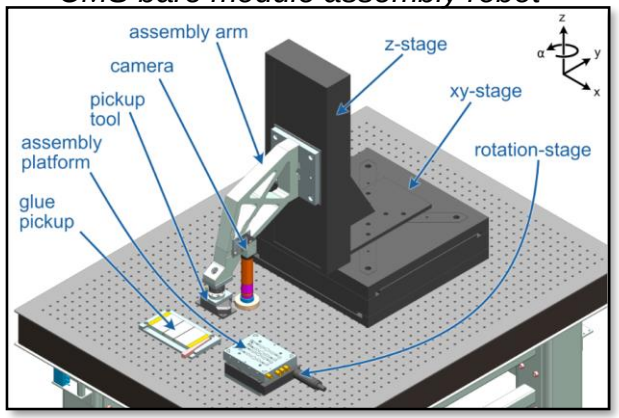
  - Module and instrumented supports **assembly**
  - **Thermal QC**
  - **Electrical QC**
  - **Integration tooling** and tests
  - **Dual-phase CO_2 cooling** machines
- Produced and delivered most of these tools to the ATLAS and CMS Collaborations

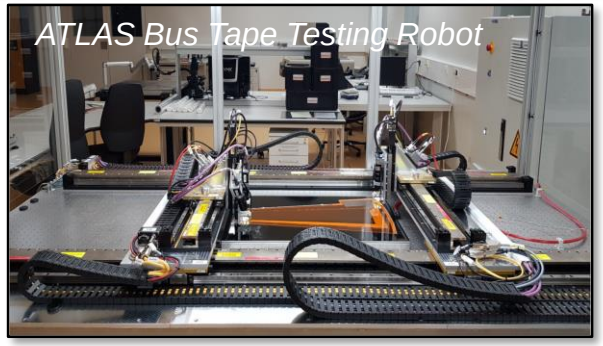
Modules and module components



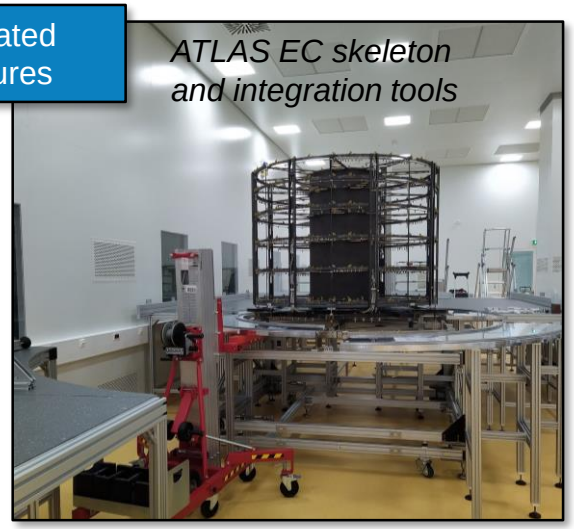
CMS bare module assembly robot

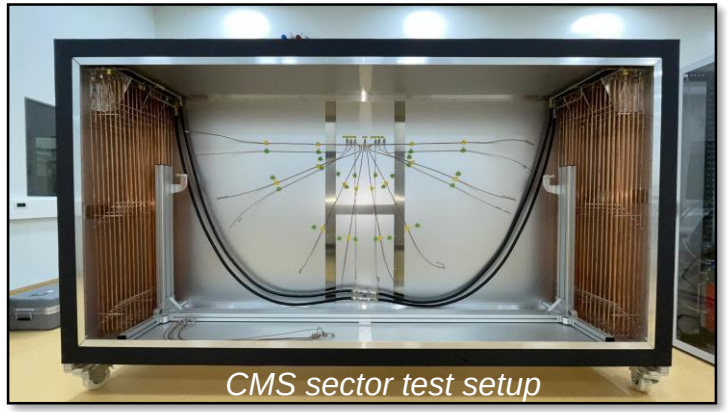


Instrumented supports



Integrated structures





Detector Assembly Facility (DAF)

New clean rooms for new detectors

DESY laboratories for integration

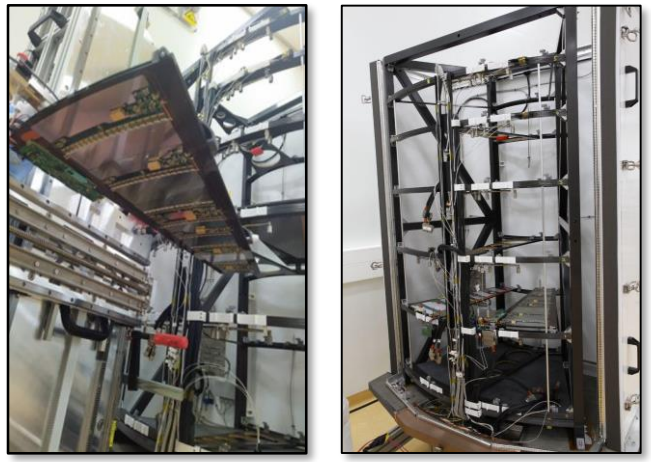
- Detector Assembly Facility, constructed for the assembly and integration of the new CMAS and end-cap trackers
- ISO-6 and ISO-7 clean rooms
- More than 600sqm of laboratory space

Approaching production phase

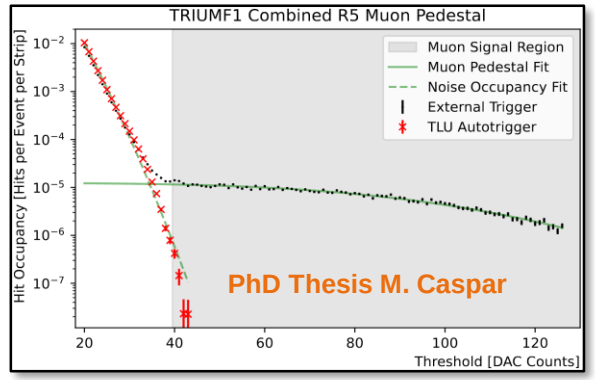
First steps into final assembly of components

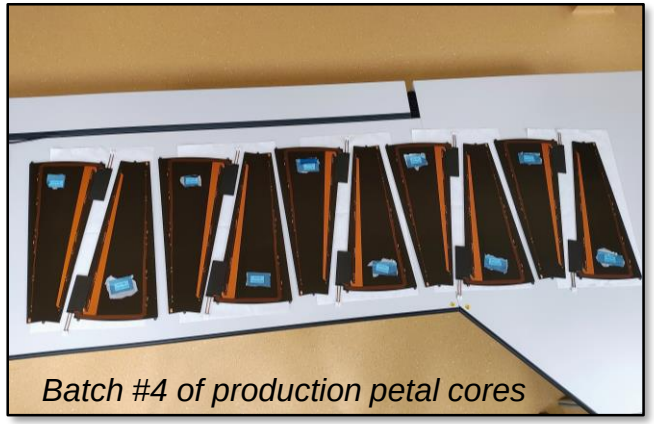
Recent milestones: ATLAS

- Qualified as module and instrumented support sites
  - More than 55 pre-production modules and three fully instrumented petals built and QCed during pre-production
- First cosmic tests performed on system test setup
- Multiple DESY components in production
  - Local supports (“**petal cores**”)
    - ~ 20% of cores received and tested
  - Back-end electronics boards (“**EoS**”)
    - >50% of production assembled and tested
  - Rapidly approaching production on modules (est. March 2025)
- Recent **arrival of endcap global structure**, ready for integration
  - End-cap integration already exercised on system test setup



ATLAS system test setup





Batch #4 of production petal cores

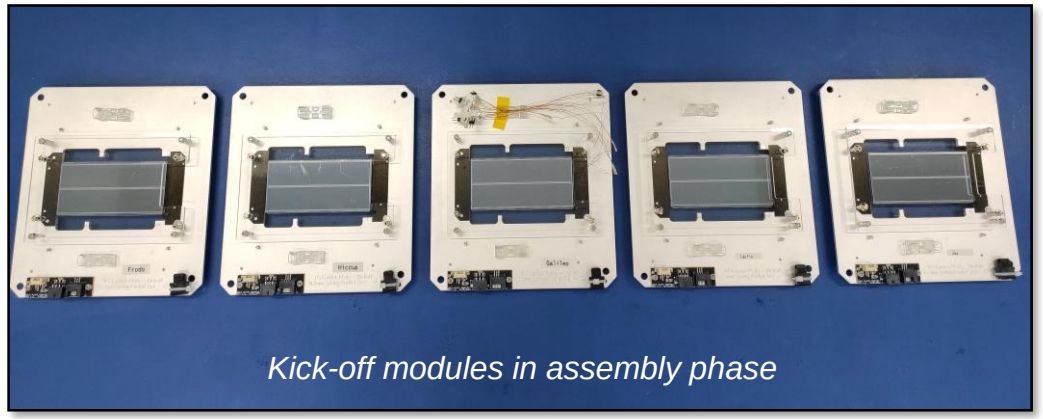
Endcap skeleton in super frame

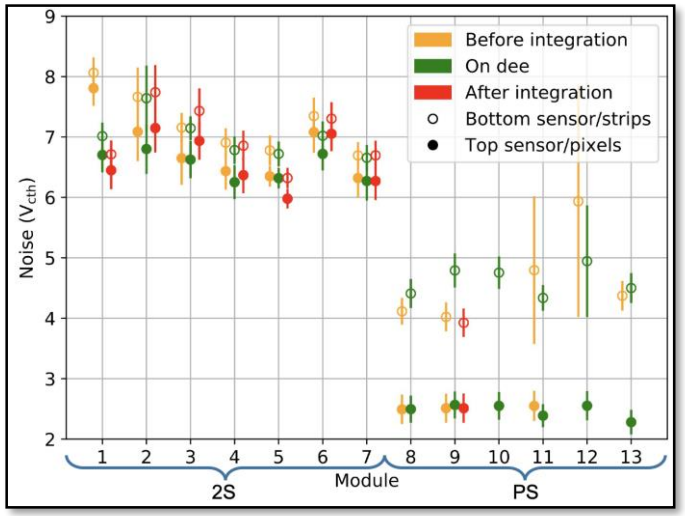
Approaching production phase

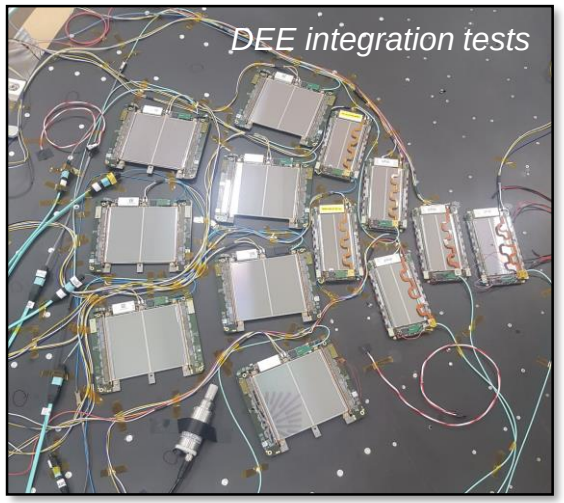
First steps into final assembly of components

Recent milestones: CMS

- Pre-production gaining traction
  - First 5 pre-production modules in fabrication, expected O(25) by Feb 2025
  - First two pre-production supports (“DEEs”) in-hand, a total of four by Feb 2025
  - DEE integration exercise took place at DESY in June 2024
    - 13 prototype modules mounted on prototype Dee and operated in parallel with final services routing
- Moving towards production
  - DEE production recently started (Dec 2024), first objects expected by Q2 2025
  - Module production aiming for Q3 2025



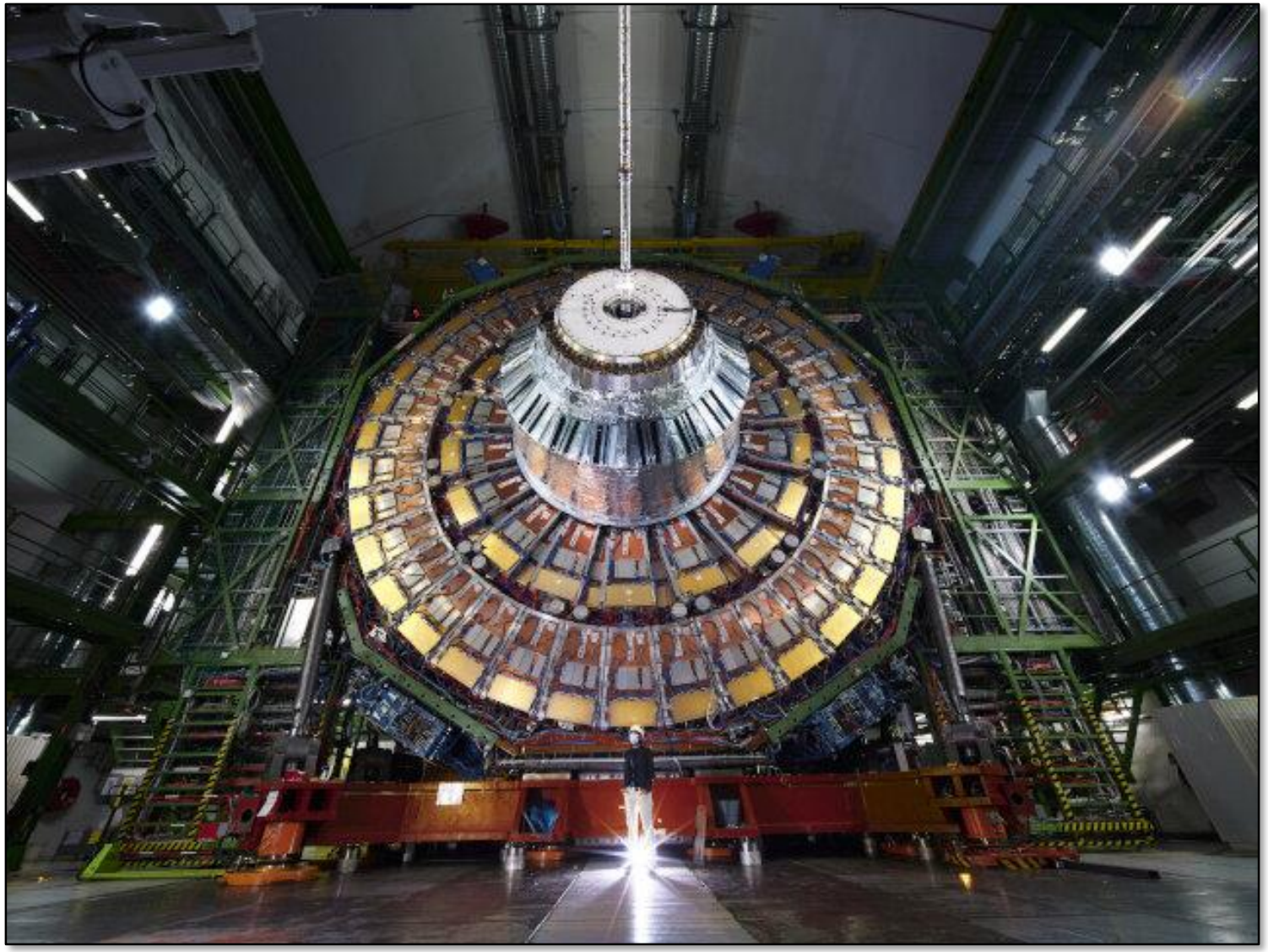




A new Endcap Calorimeter for CMS

Replacing pre-shower, ECAL and HCAL

Current CMS endcap Calorimeter



A new Endcap Calorimeter for CMS

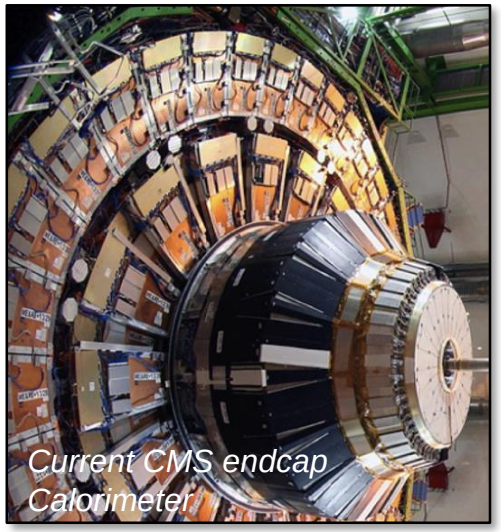
High Granularity Calorimeter (HGCAL)

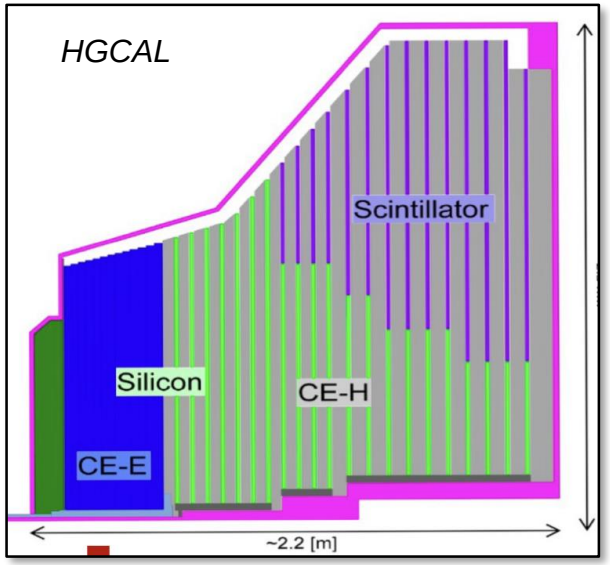
High Granularity Calorimeter (HGCAL)

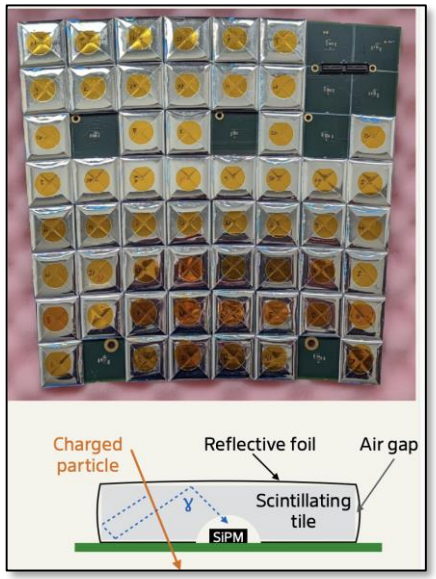
- Silicon and SiPM-on-Tile readout
- **SiPM-on-Tile**: Developed at DESY
  - Originally developed for future e+e- colliders
  - Scintillator part: 3700 m^2, 280k SiPMs

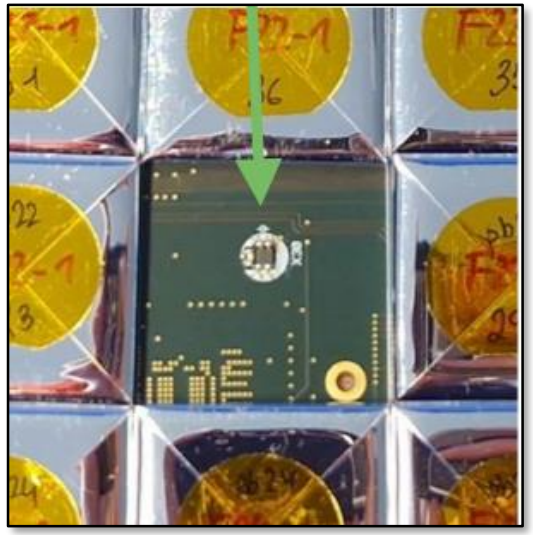
DESY contributions

- Development and production of 2000 Tilemodules
- Automated production techniques
- Mapping and calibration software









HGCAL SiPM scintillator tiles

CMS HGCAL Status

Approaching production

Production techniques proven

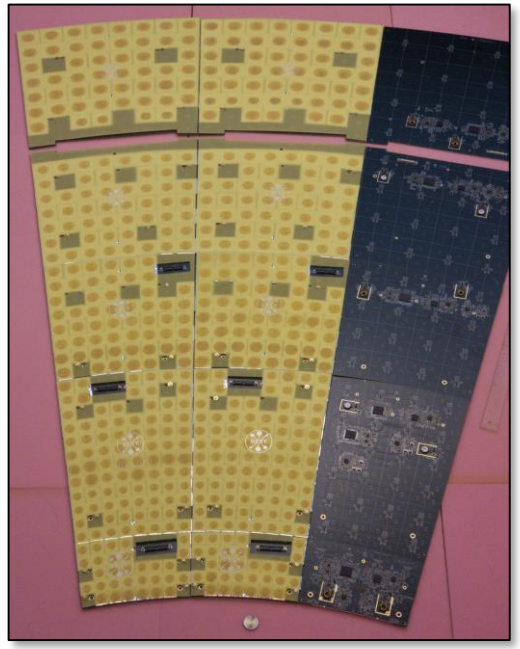
- Scintillator tile wrapping: DESY development
  - Reproduced at 2nd site (FNAL)
- Tilemodule assembly: adaptation of industrial pick & place technology

Quality control procedures in place

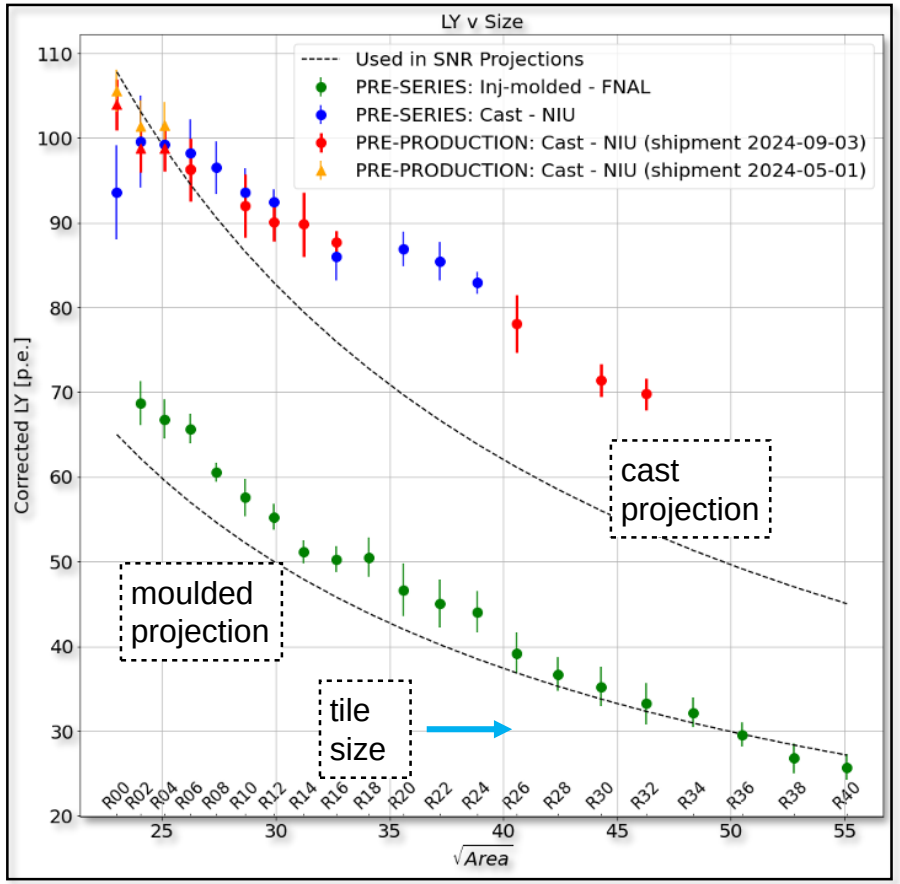
- Tile dimensions, light output, tilemodule response to particles (beam, cosmics)
  - Throughput matches production requirements
  - Results according to specs

Pre-series module production complete

- Close-to-final components
- Final production techniques



Populated HGCAL scintillator sector



CMS HGCAL Outlook

System testing and production start

2025-26: Tilemodule production and test

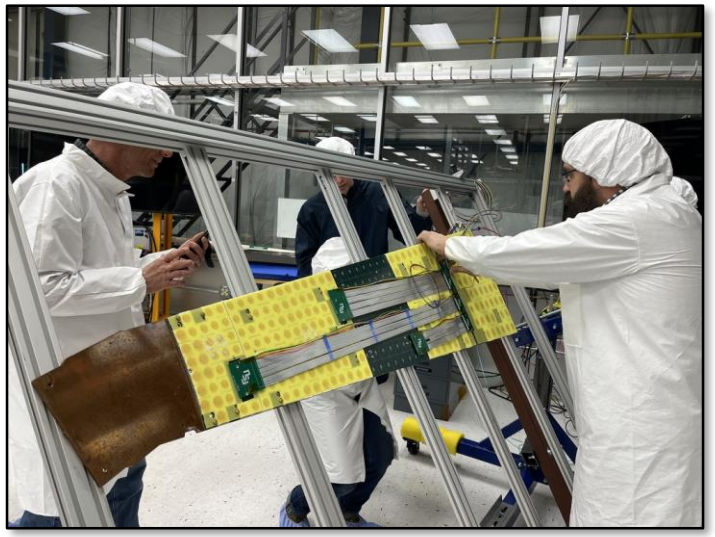
- Tile wrapping, electrical assembly, placement of tiles
- Tests of tiles, electronics and full modules

System tests and software development

- In cooperation with KIT
- Build up expertise for integration, commissioning
- Testbed for software: machine learning for calibration, simulation,…

Future developments

- Prepare for scalability and integration challenges
- High-granularity calorimeter for future Higgs factory



First 10-degree sector test

Beam test in 3T field

In summary

DESY background and workforce provides a strong **systems and commissioning competence**

State-of-the-art **facilities**

Well regarded as a “**German instrumentation hub**” for universities and institutes

Multiple **successful projects** completed or in production

Ambitious goals for instrumentation in future experiments in HEP

Thank you

Contact

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