LHC Upgrade

Subtitle of Presentation

Helmholtz Program: Matter and the Universe (MU)

PoF III Topic: Fundamental Particles and Forces – Physics at the Large Hadron Collider

DESY Research Unit: Experimental Particle Physics

Ingrid-Maria Gregor
Center Evaluation DESY, 5 – 9 February 2018

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

DESY

Overview

First ideas for the talk

Mention:
Connection to MT
National and international collaborations

10 minutes on LHC Upgrade

- Introduction to LHC Detectors and Upgrades
- CMS Phase1 pixel – 2 slides
  - Overview on the project and what was done/developed at DESY
  - One slide on production, installation and commissioning with focus on DESY work
- R&D for ATLAS und CMS for HL-LHC – 2 slides
  - Overview that both groups are involved in many areas from sensor to full system
  - One slide with some highlights of the R&D of the recent years
- DAF – 2 slides
  - National hub for the production and construction of two end-caps with current status
- Current focus of both groups
  - Complete R&D (TDRs submitted and approved) and get ready for production
- Future
  - Delivery of two end-caps

~10 slides

LHC Upgrades

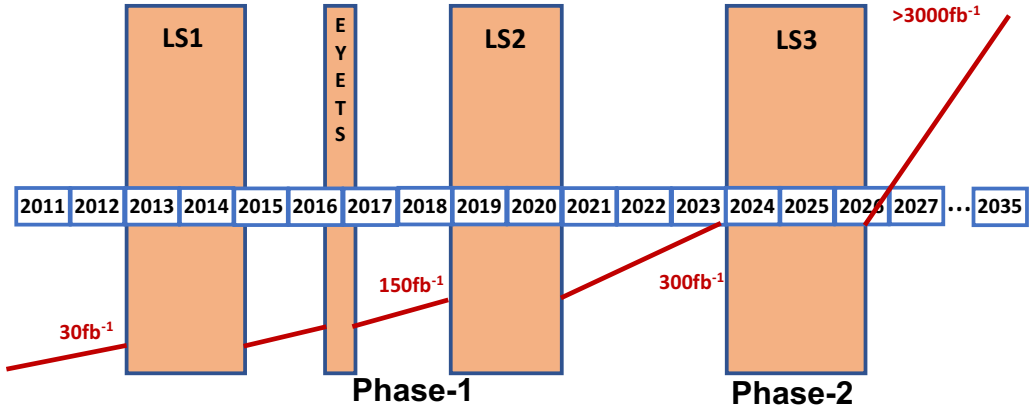
Next generation LHC Detector Components at DESY

Full exploitation of the LHC with up to 4000 fb^{-1}

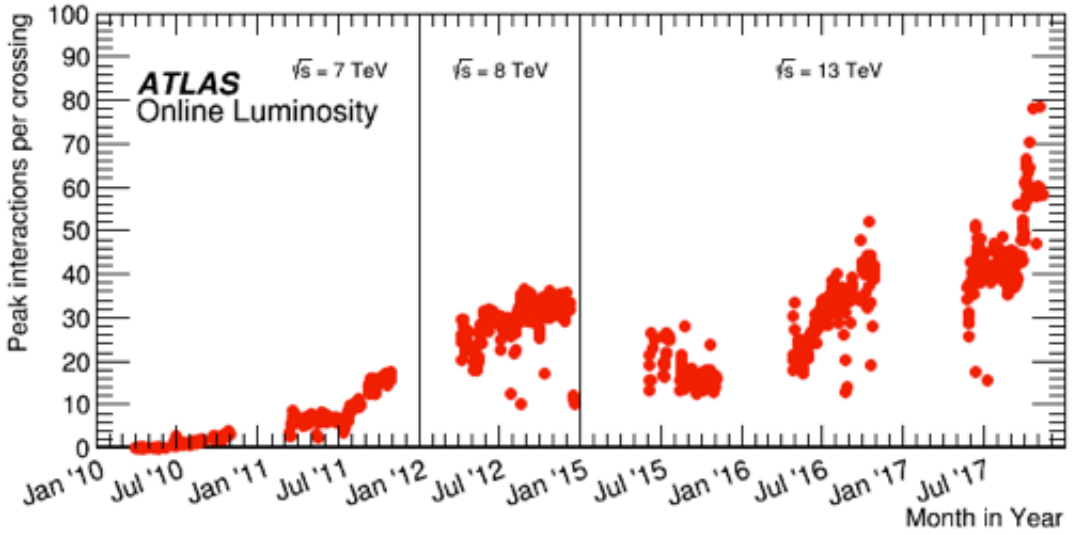
- LHC is exceeding expectations in many ways.
- ATLAS and CMS experiments in excellent shape.
- Upgrades of machine and detectors are necessary to reach goal of up to 4000 fb^{-1}
  - Detectors are ageing and suffering from radiation damage.
  - Increase in luminosity will require detector improvements.

DESY is strongly involved in building tracking detectors

- CMS Phase 1 Pixel Upgrade: outer layer was build and assembled at DESY
- For the high-luminosity phase of the LHC starting 2026 DESY will assemble each one outer tracker end-cap for ATLAS and CMS
  - Close collaboration with German and international partners



LHC schedule with long shutdowns for accelerator and machine interventions. Planned integrated luminosities are indicated in red.



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

Phase-1: CMS Pixel Detector

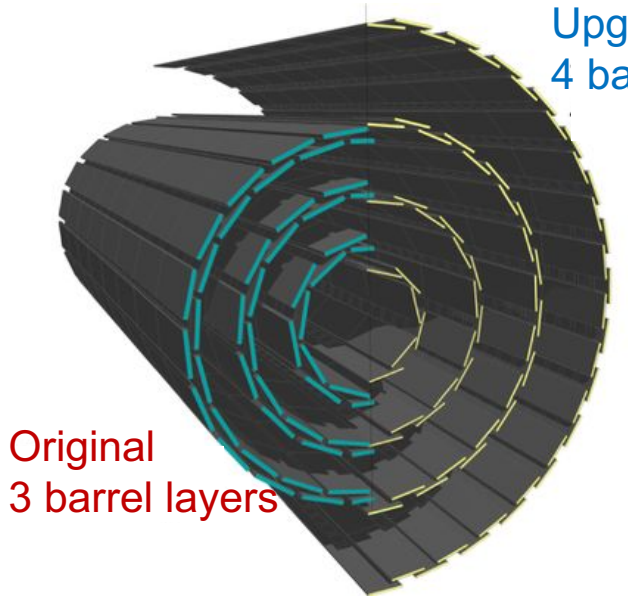
A four layer pixel detector for CMS

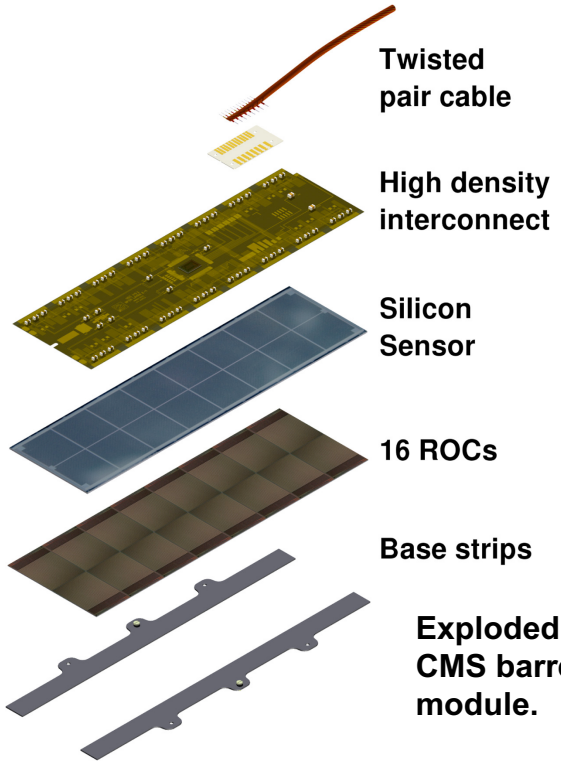
Optimisation of tracking capabilities by increasing number of pixel layers for efficient operation at increasing luminosities

- ATLAS added additional innermost layer (IBL)
  - DESY strongly contributed to detailed test beam studies (telescopes)
- CMS replaced the original 3 layer system by a new 4 layer pixel detector
  - CMS Germany was responsible for producing modules for the 4th layer – half from DESY and Hamburg University

Outer pixel barrel plane assembled at DESY

- New CMS pixel detector with four barrel layers and 3-disk forward system
- Featuring 4-hit coverage up to |eta|<2.5
- Reduced material budget, higher tracking efficiency
- At DESY an in-house flip-chip bump-bonding process was developed to ensure high module production quality.
  - Significant R&D required on used material and detailed process





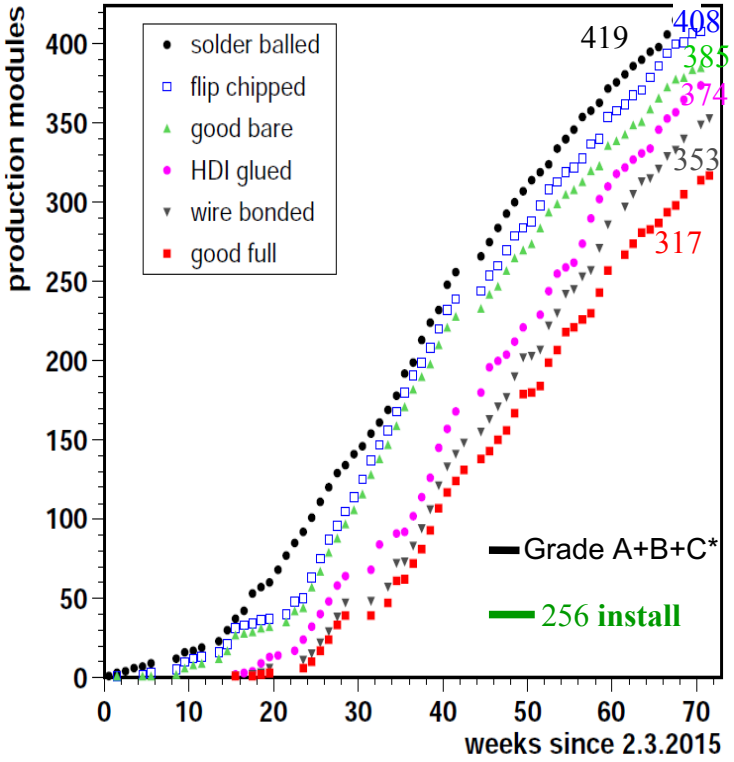
Exploded view of CMS barrel pixel module.

CMS Phase-1 Pixel Detector

Module production at DESY

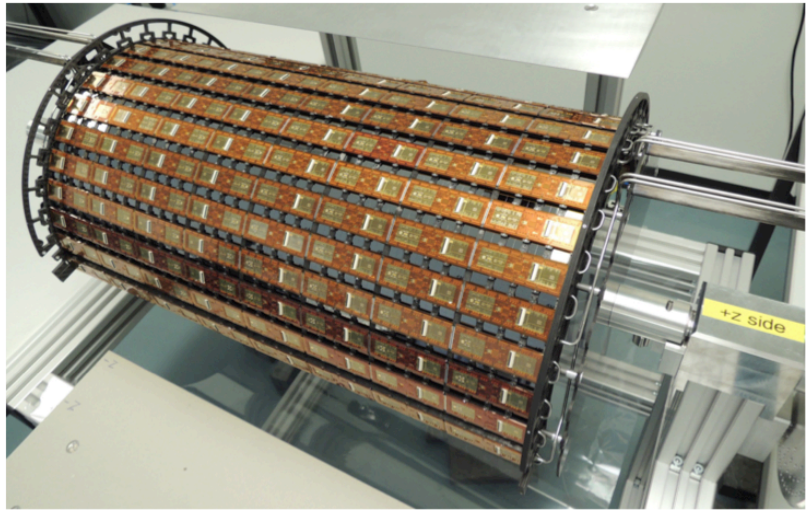
Flip-chip machine as central infrastructure

- DESY contributed 300 modules to one half of the fourth barrel pixel layer
- All together 419 silicon pixel sensors used
- Placed 29.3 million solder balls with the flip-chip machine
- Flip chip bonded 6528 readout chips with 94% yield
- Placed 224 k wire bonds, all good
- Full calibration and high rate X-ray test



Commissioning at PSI and CERN

- DESY delivered 287 modules to PSI in Switzerland
- Includes 12% spares
- **NOCH EIN BISSCHEN HIER ….**



Phase-2: Detector R&D (ATLAS&CMS)

Next generation LHC Detectors build at DESY

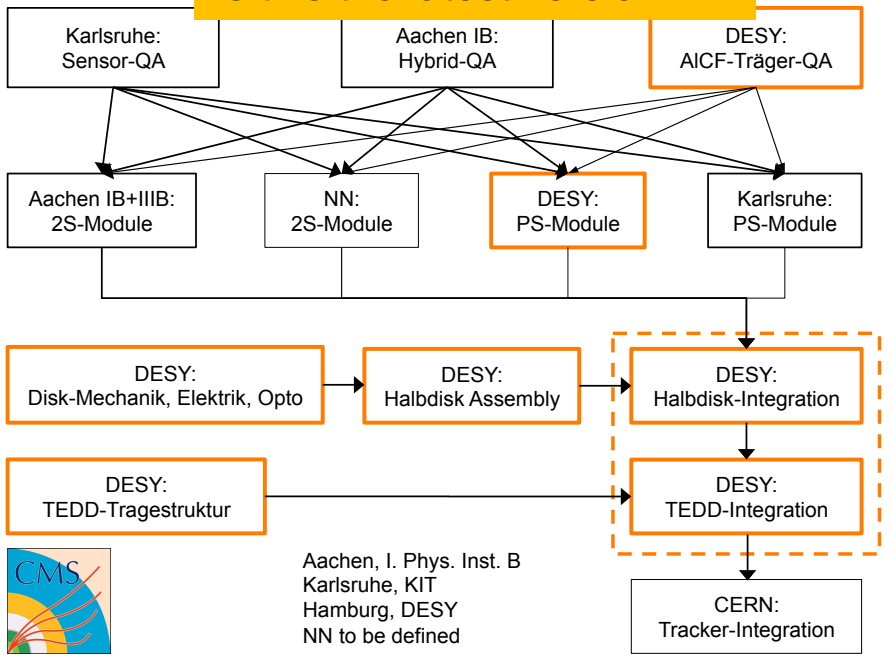
ATLAS and CMS: significant upgrades for the HL-LHC phase

- Both experiments will replace the inner tracker system by more radiation-tolerant and granular silicon tracking systems.
- DESY groups play leadings roles in the design and construction of tracker upgrades for ATLAS and CMS.
  - Follow a program to deliver one end-cap each for the HL-LHC trackers.
  - Preparations started in 2010 with an extensive R&D program.

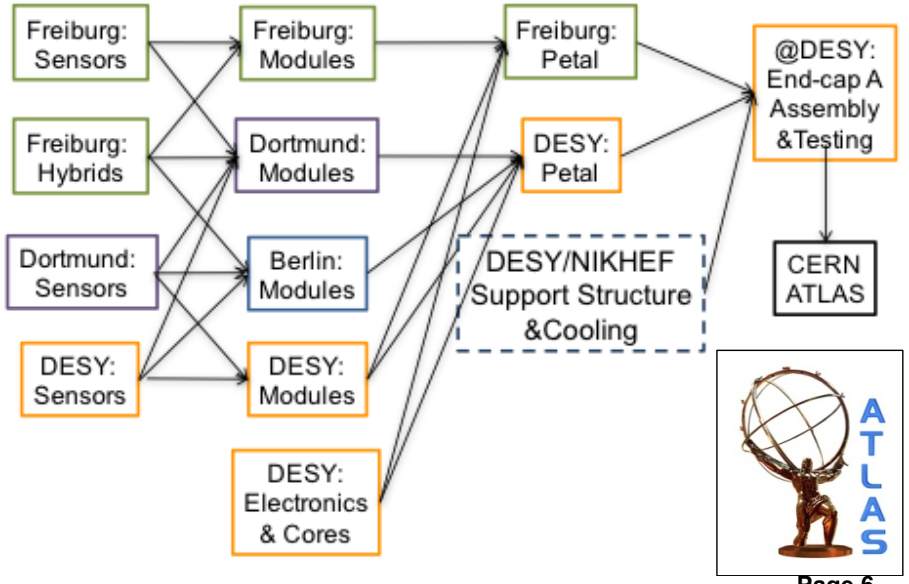
DESY groups strongly contributed to R&D phase for these

- Monte Carlo simulations for detector optimisation.
- Sensor developments and radiation tolerance studies.
- Module design studies, finite element analyses, prototype production, test beam studies.
- Design, prototyping and thermo-mechanical studies of mechanical structures (local and global).
- System tests and DAQ.
- Supported by R&D performed within “Matter and Technologies”.

Is this the latest version ??



Planned workflow during production



Phase-2: R&D Highlights - ATLAS

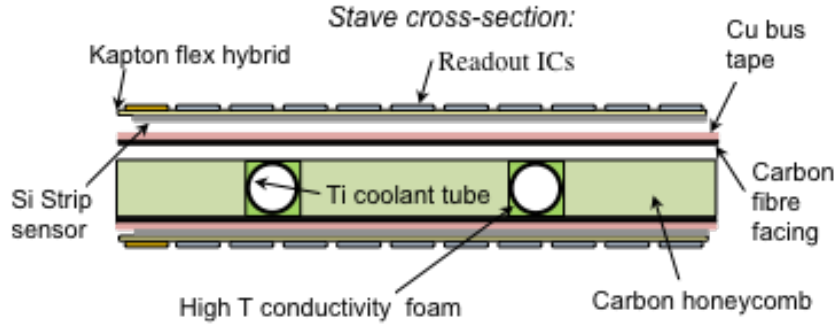
Next generation LHC Detectors build at DESY

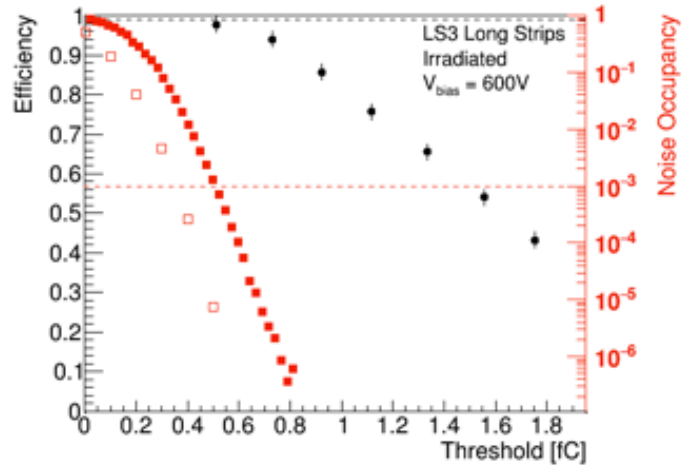
Sensors directly glued to surface

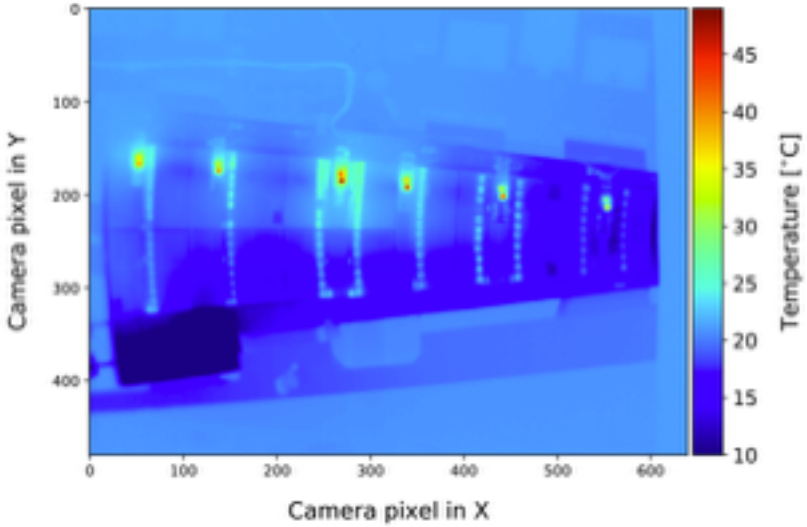
- Novel concept of silicon modules directly bonded to a cooled carbon fibre plate with services integrated into plate including power control and data transmission.
- DESY key role in module design: layout, material choices (UV glue), thermo-mechanical properties, and production optimisation.
- Performance characterisation of silicon sensors and full modules before and after irradiation (DESY test beam key for ATLAS Upgrade).

Full system aspects

- Monte Carlo simulations to optimise tracking performance of the detector.
- Sole institute to design and prototype production of petal local support structure.
- Finite element calculations and comparing measurement of thermo-mechanical petal.
- DESY took on the responsibility for the electrical design of the interface card between on-detector and off-detector electronics (using a 10Gbit/s radiation tolerant optical links).





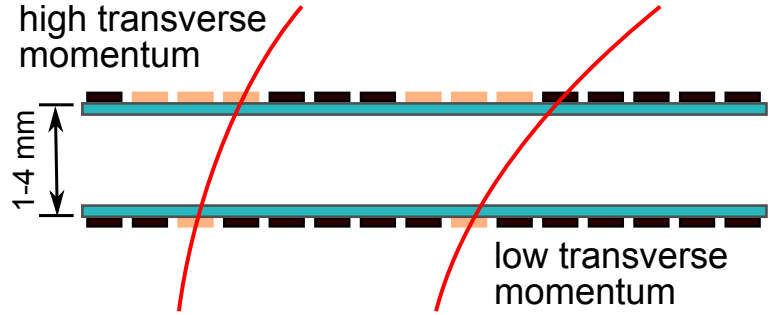


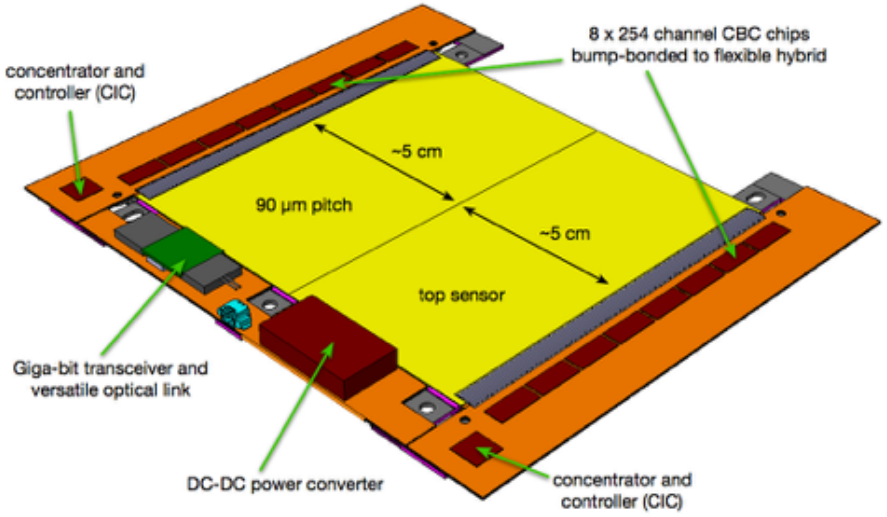
Phase-2: R&D Highlights - CMS

Modules and mechanical structures

CMS modules providing particle momentum information

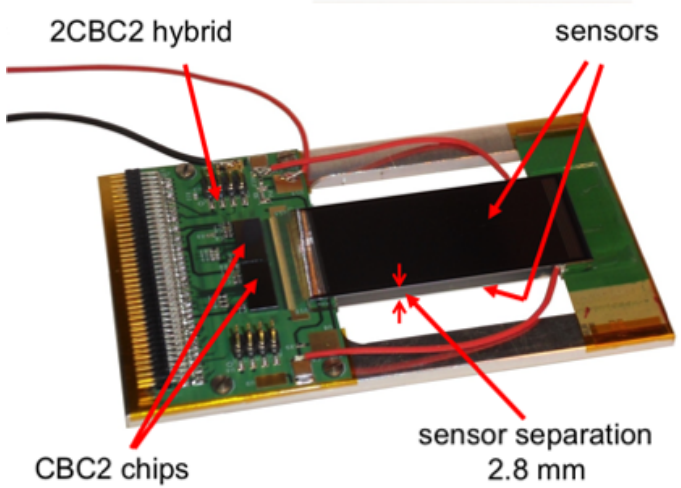
- Correlation of hit signals in two closely spaced silicon sensors.
- DESY has leading role in simulation studies to optimise mechanical stability, sufficient thermal performance and minimum amount of material.
- Material choices by material machining tests, prototyping and extensive characterisation of prototype parts.





Design of mechanical structures

- Structure combines mechanical stability, embedded cooling pipes.
- Needs to provide precise positioning of modules at minimum mass.
- Small scale prototypes developed and constructed at DESY.
  - Focus on assembly sequence, mechanical stability, and scalability to large-scale version.
  - Measurement of thermal-mechanical properties.
- Full-system and integration aspects currently being followed up.



Detector Assembly Facility (DAF)

LHC Upgrades at DESY

Detector assembly facility as valuable asset

- Dedicated facility for detector development and construction
- Now reserved for HL-LHC upgrades
- In future open for other large-scale projects
- Strengthening DESY's position in Germany and beyond.

DAF layout

- Buildings 25c and 26; about 1000 m^2 clean rooms (ISO-6 and ISO-7) and 200 m^2 lab space and storage
- 10 MEUR from DESY

DAF status:

- Clean rooms in 25c installed; currently installing technical building infrastructure. Begin of operations middle 2018.
- Tendering for building 26 done; installation of clean rooms starting soon.
- DAF will be in use for LHC until about 2025.

Not sure if I should discuss schedule …

DAF Schedule

Everything on time

Clean room for module production

- Correlation of hit signals in two closely spaced silicon sensors.
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Future

XXXX

XXXX

- wfrlkjerfoqer

YYYY

- wefiqjroqirvl

Summary

LHC Upgrade

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YYYY

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Backup

Additional material for possible discussions