PETRA IV.
NEW DIMENSIONS

CAD Integration for PETRA-IV.

Preparing an integrated CAD model for a complete synchrotron radiation facility

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DESY

MEDSI 2020

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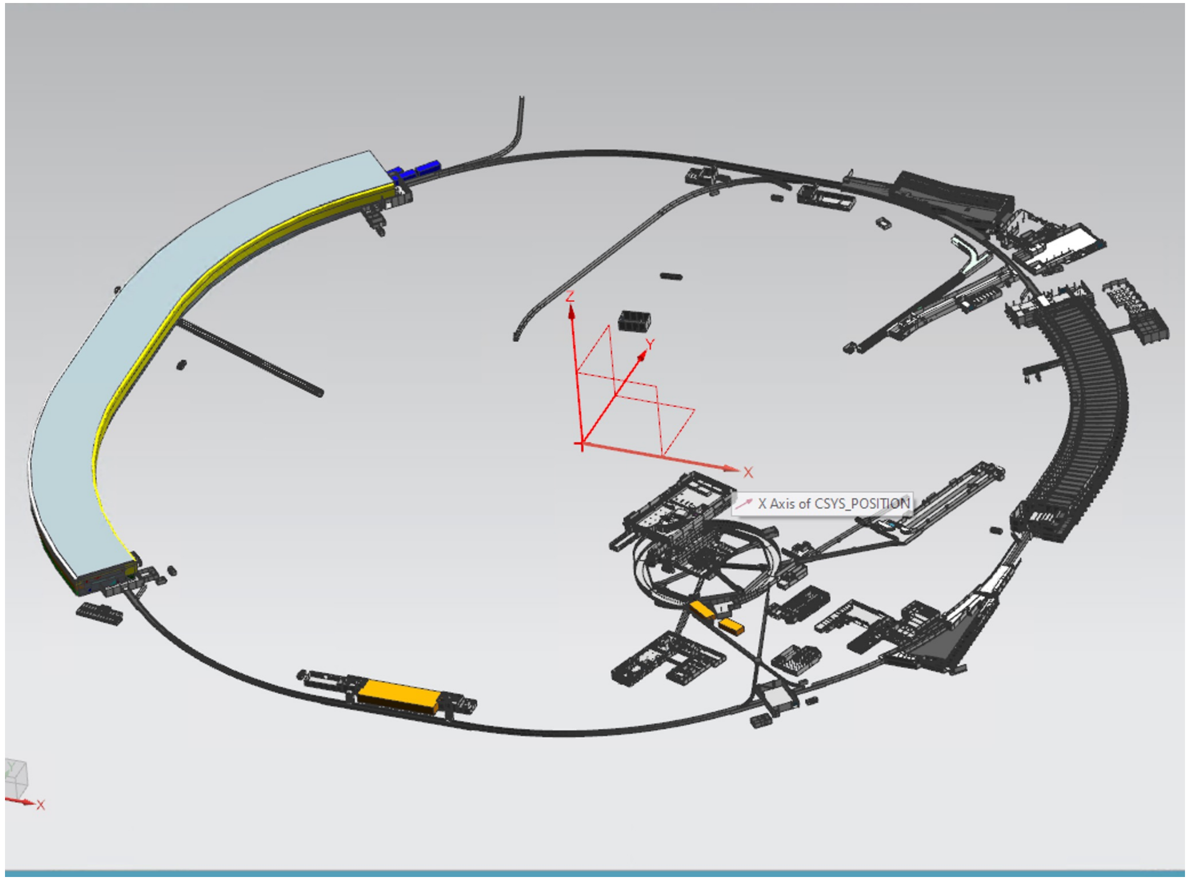
DESY.

Plan of the talk

- Introduction: the PETRA-IV projects
- The CAD model and its role in the project lifecycle
- Tasks in facility design
- Approach at the PETRA-IV Integration Model
    - Structure
    - Levels of detail
    - Modularisation
    - Configurations
    - Placing beamline components from the lattice
- Summary and Conclusions

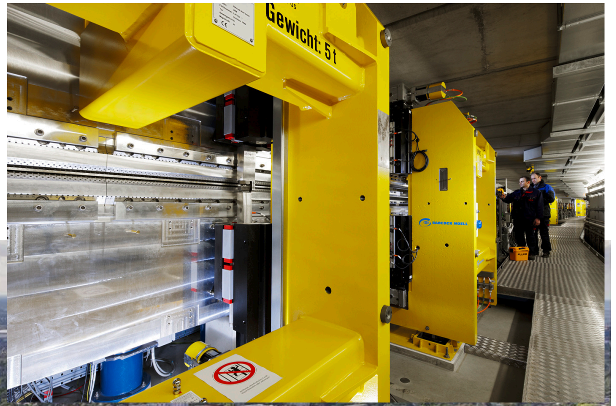


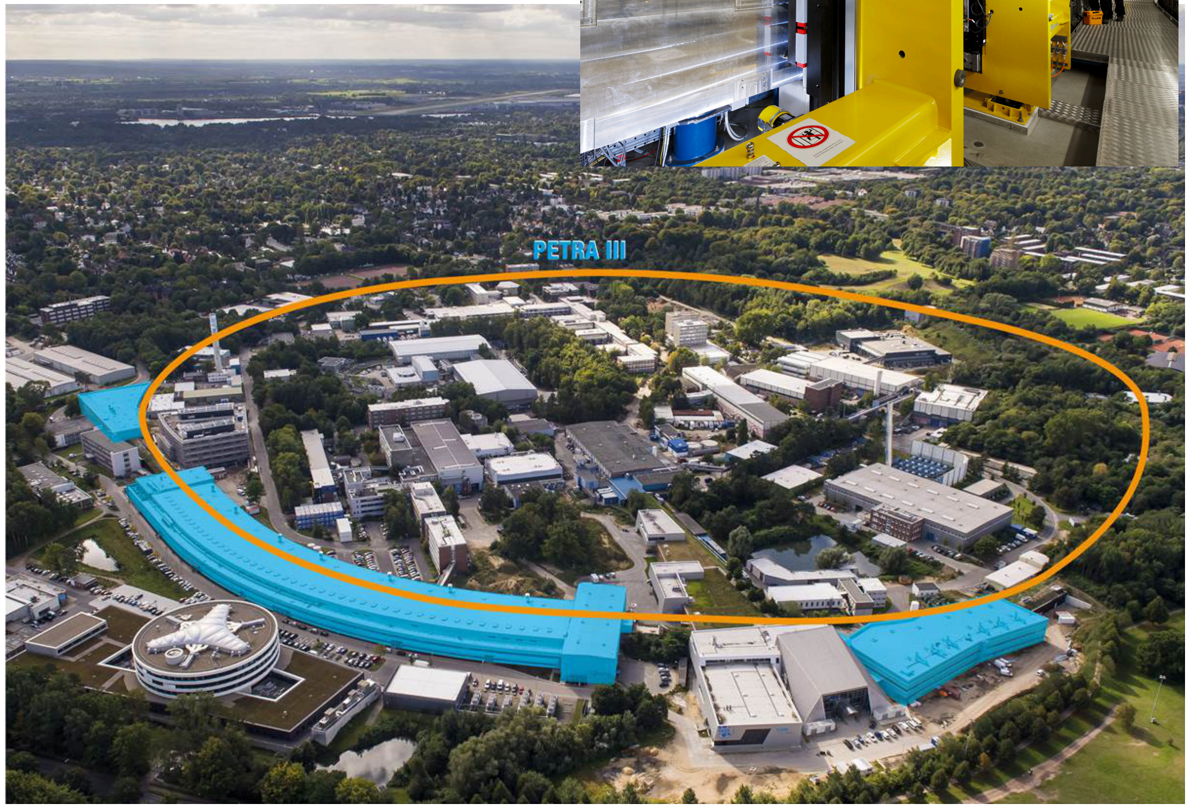
Introduction

A short history of PETRA

- 1978 PETRA: Storage ring for high energy physics
  - Built in 1976-1978, refurbished 1990 as HERA injector
  - 2304 m circumference, 8 octants
- 2007/08 PETRA-III: Synchrotron radiation facility
  - One octant refubished with undulators
  - Max von Laue Hall hall with 14 beamlines
  - 6GeV beam energy, 100mA current
  - Hor. emittance: 1300 pm rad
- 2016 PETRA-III Extension:
  - 2 more halls, 7 beamlines
- PETRA-IV:
  - Completely new accelerator with latest technology
  - Hor. emittance: 20 pm rad

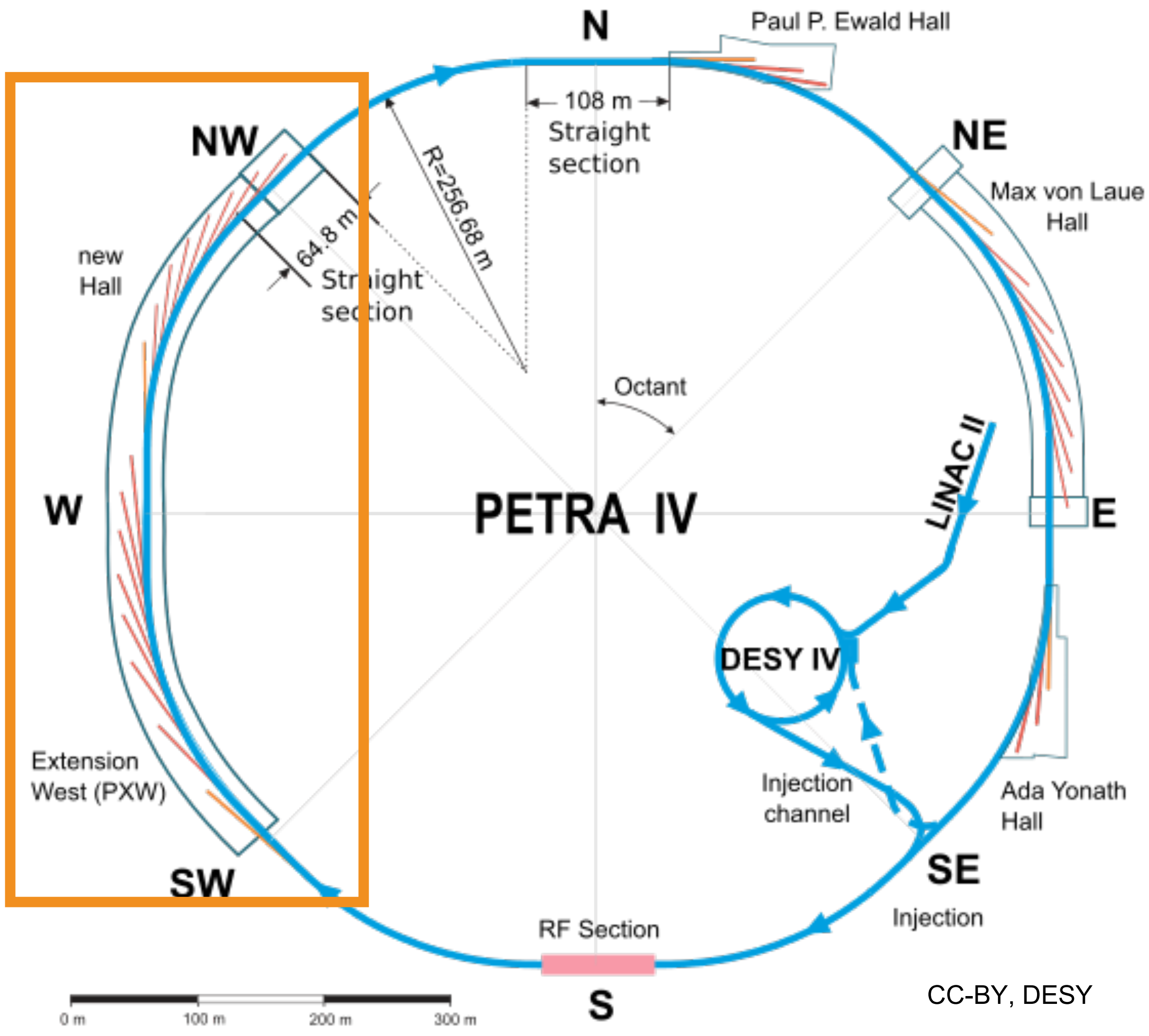
PETRA IV.
NEW DIMENSIONS





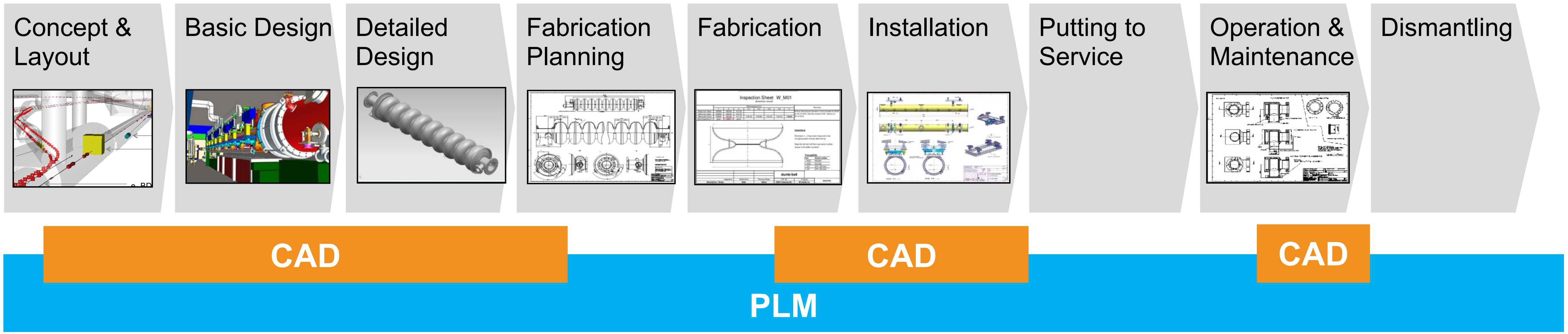
The PETRA-IV Project

- Build completely new accelerator
  - Hybrid Multi Bend Achromat (HMBA) lattice
  - Achieve fully coherent X-rays (diffraction limited) up to 6-7 keV
- …within the existing tunnels/halls
  -> severe space constraints
- Move existing beamlines to new locations
- Build new 600m long hall PXW
- New Pre-accelerator DESY IV
- Limit dark time (no beams) to 2 years
  -> time constraints



CAD in the Project Lifecycle

Different lifecycle phases pose different requirements and emphasis on CAD



schematic, simplified

- Teamcenter is a “Product Lifecycle Management” (PLM) system which digitizes (all) information and process across an entire product lifecycle.
- NX is a mechanical CAD system for authoring and updating mechanical engineering design models of products in the course of their lifecycles.

“PLM” suggests the data content & functionality:

- Product → Structures, e.g. PBS (→ E/M/SBOM)
- Lifecycle → Information, e.g. Requirements, CAD, documents, work instructions, inventory …
- Management → Workflow, e.g. review, approve …

All information & workflows are cross-referenced, version controlled, essential history is logged

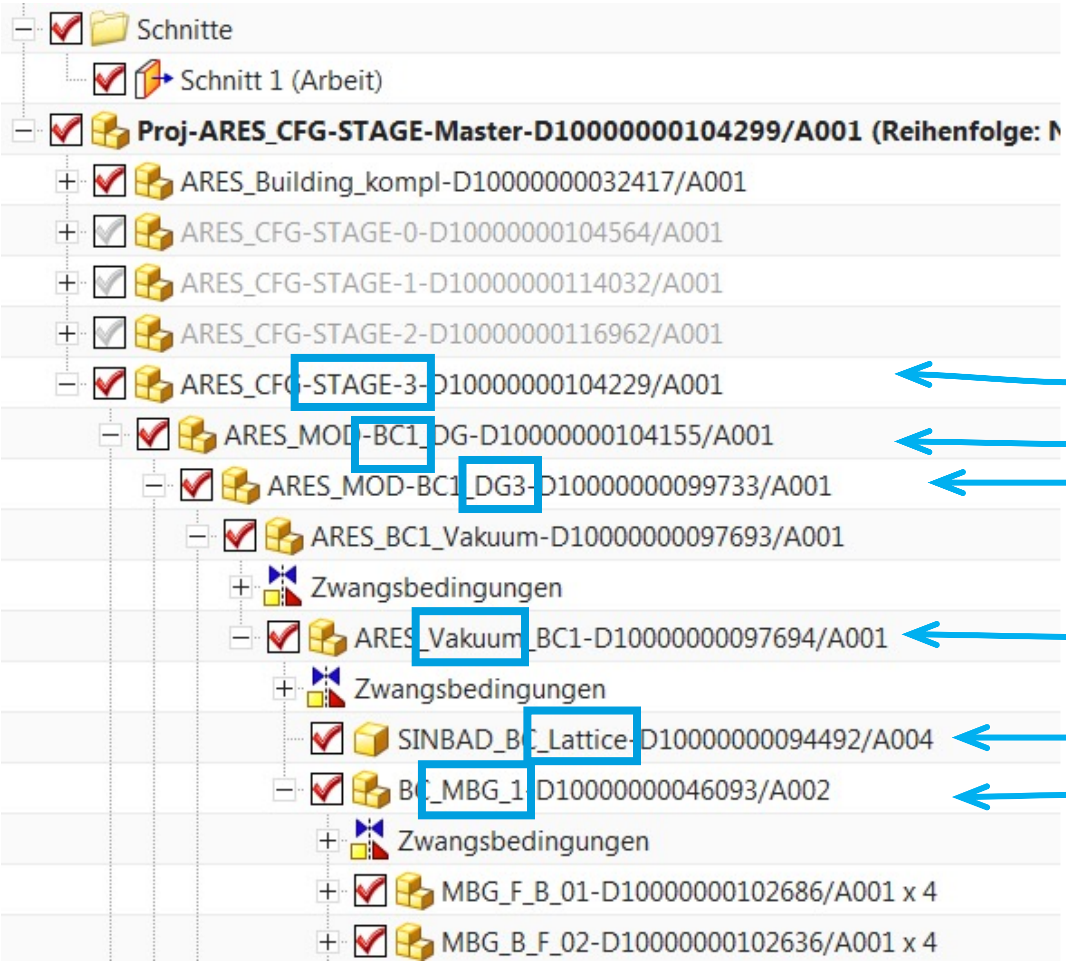
Tasks in Facility Design

What tasks and processes are supported by the integration model?

- **Handling of large assemblies**
  - Efficient & performant editing
  - Context: Place, section, system, component
- **Design process**
  - A model, purposeful and associative, for all lifecycle phases: concept, layout, detailed design, integration, installation…
- **Collaboration across groups and trades**
  - Data ownership by responsible group
  - Subassemblies marked according to trade or group
  - Minimize side effects from changes
- **Collaboration with suppliers**
  - Support context free work: provide interface geometry, space, insertion point
  - Space reservation for later import
- **Modelling of the accelerator**
  - Associativity with lattice
  - Automated updates after lattice changes
  - Modelling of facility structure (girder, section…)
  - Identification of interfaces between trades
  - Handling of large and complex systems (vacuum)
- **Modelling of buildings**
  - Transfer of buildings from civil engineering CAD
  - Sectioning according to building lots
  - Reservation of space
  - Requests for changes: penetrations, modifications…
- **Modelling of infrastructure**
  - Relation between infrastructure and building
  - Relation between infrastructure and accelerator
  - Segmentation into buildings, lots, sections

Model Structure

How the model structure reflects decisions in the project



Definition of project stages

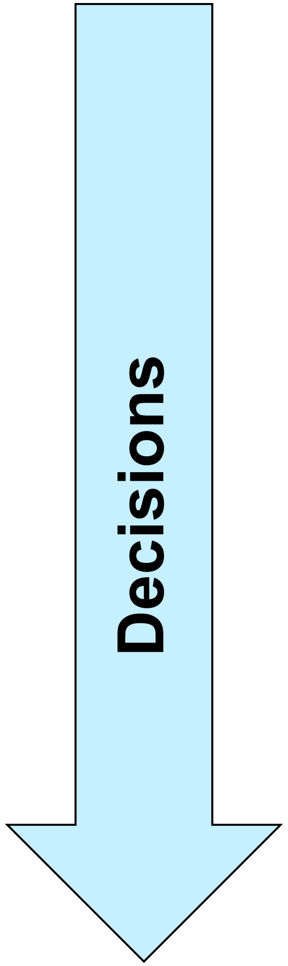
Definition of functional unites (modules)

Definition of detail levels – design lifecycle

Responsibility – trade / group / work package

Parametrisation (lattice)

Component (new/reused)

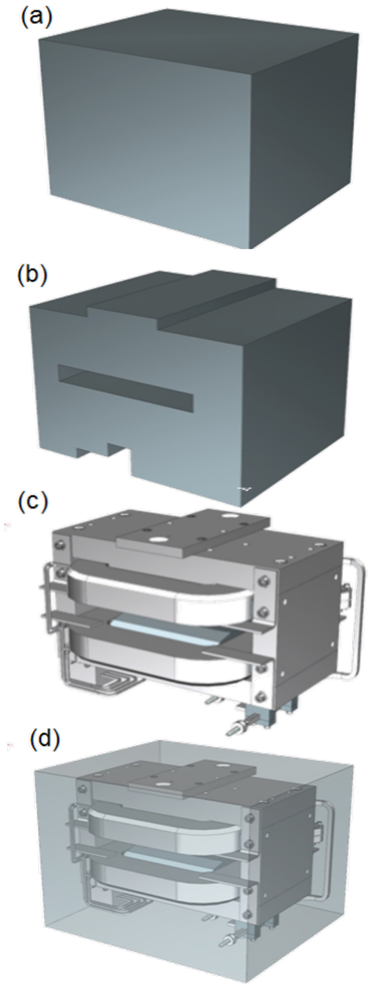


Example from the ARES accelerator test facility

Concept: Different Levels of Detail

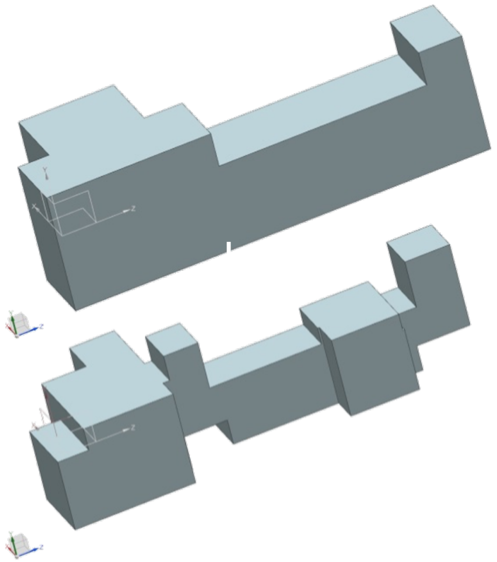
Examples how to use different levels of detail in the integration model

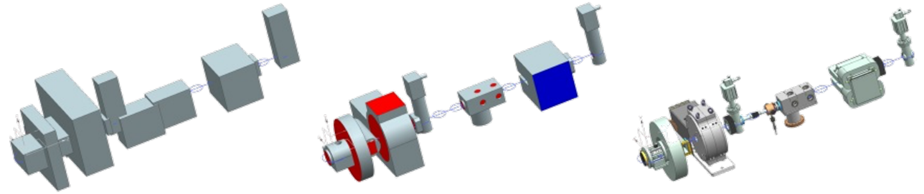
Single component



- Model in three levels of detail (DG: detail grade):
  - 1: rough space (concept)
  - 2: space reservation and interfaces (layout)
  - 3: inner structure (engineering design)
- Create separate items for DG1 / 2 / 3:
  - Freeze & release item if design is stable (phase is finished)
  - Load only desired level of detail
- Combine all available levels in one mother (“DG assembly”):
  - One model of a component, one source of truth
  - Verification (consistency checks) of different models
  - Switch between LOD’s
- Employ NX mechanism of “reference sets” and “load options” to select desired level of detail

Beamline





DG1 Space

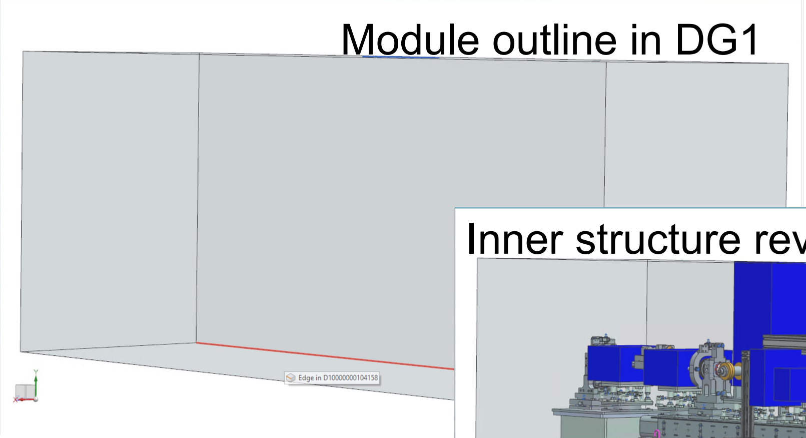
DG2 Interfaces

DG3 Detailed design

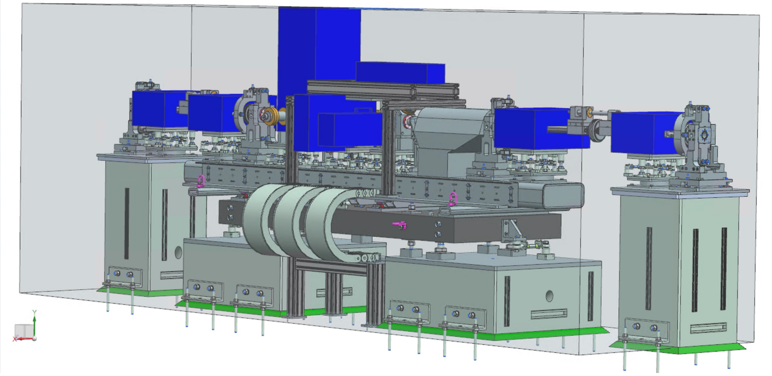
Modularisation

How modules form the building blocks of the integration model

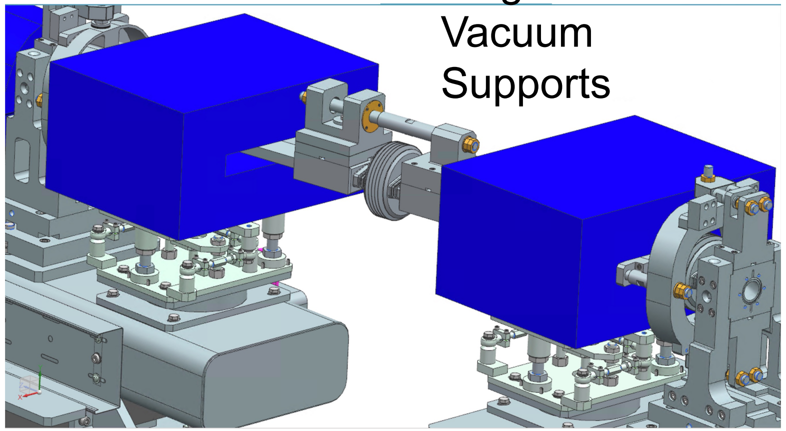
- Module:
  - Functionally and spacially coherent entity
  - Has limited interface (if possible)
  - Owns space: any geometry within owned space must be contained in module assembly structure (nothing peeks in, nothing peeks out)
  - Reserves space: DG2 sufficient for collision checks
  - Can contain other modules (nesting), and / or geometry too complex for simplification



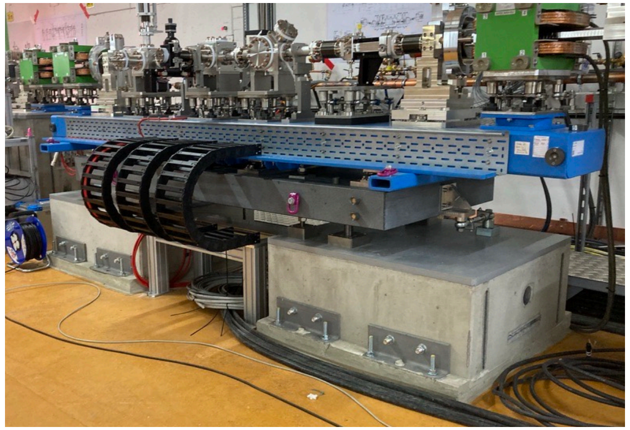
Module outline in DG1

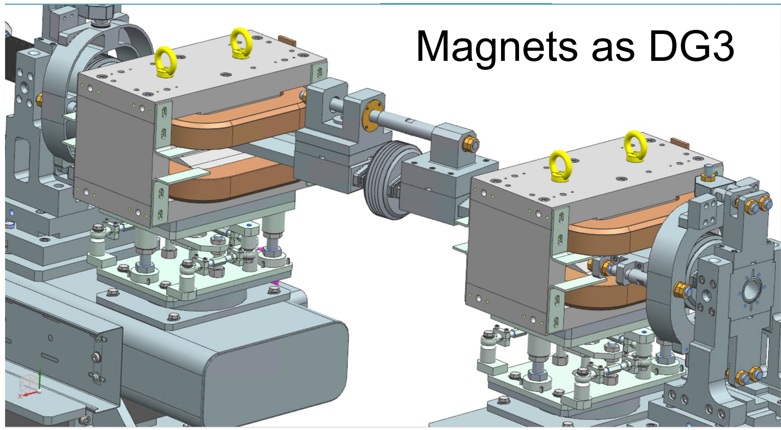


Inner structure revealed: DG1 and DG3



Magnets
Vacuum
Supports



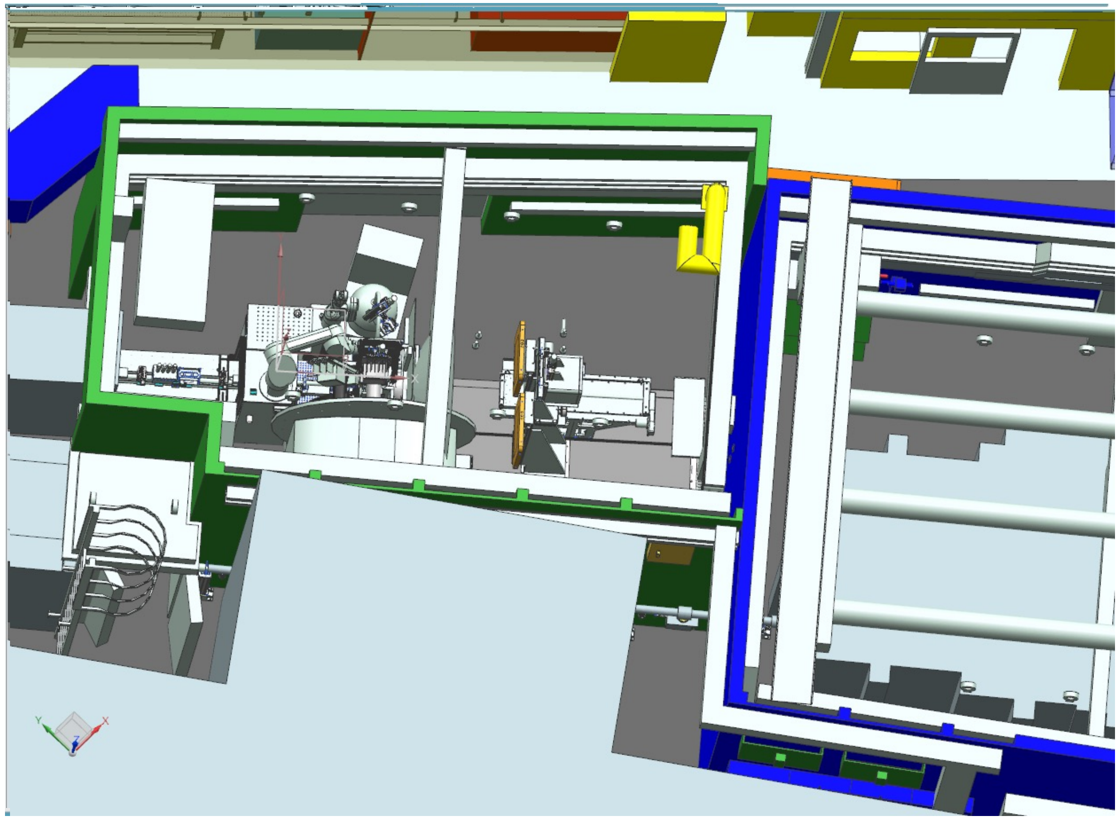


Magnets as DG3

Nested Modules

A complex example: The complete experimental hall “Max von Laue”

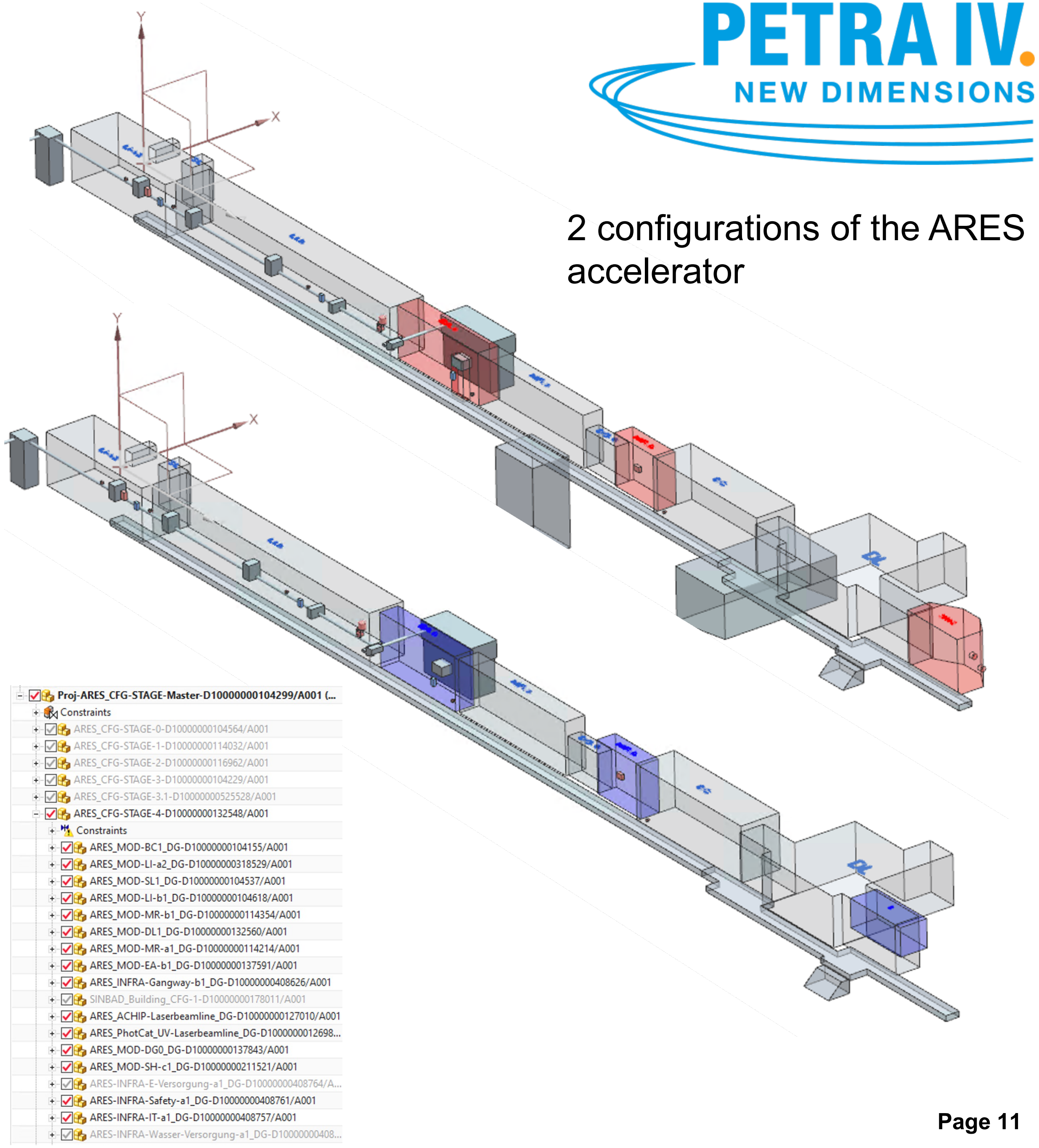
- Modular units are used to segment space
- Modularisation on different levels
  - Sector
    - Hutch
      - Beamline components / experiment
- Build integration model of existing experimental hall (“Max von Laue”) to demonstrate scalability of approach
- Within a module (e.g. a hutch), detailed geometry without simplification can be combined with sub-modules, e.g. for an experiment



Configurations

Modelling different states

- Configuration:
  - *„the particular arrangement or pattern of a group of related things"* (Oxford English dictionary)
  - Represents the modelled entity in a specific state:
    - state at a specific time,
    - a design variant
- A "configuration master" assembly collects all available configurations of the same entity
- Use modules for the configurable items, assemble configuration from these modules
- Configurations can be nested
- Configurations can be added or removed (e.g. after a downselect of design options)

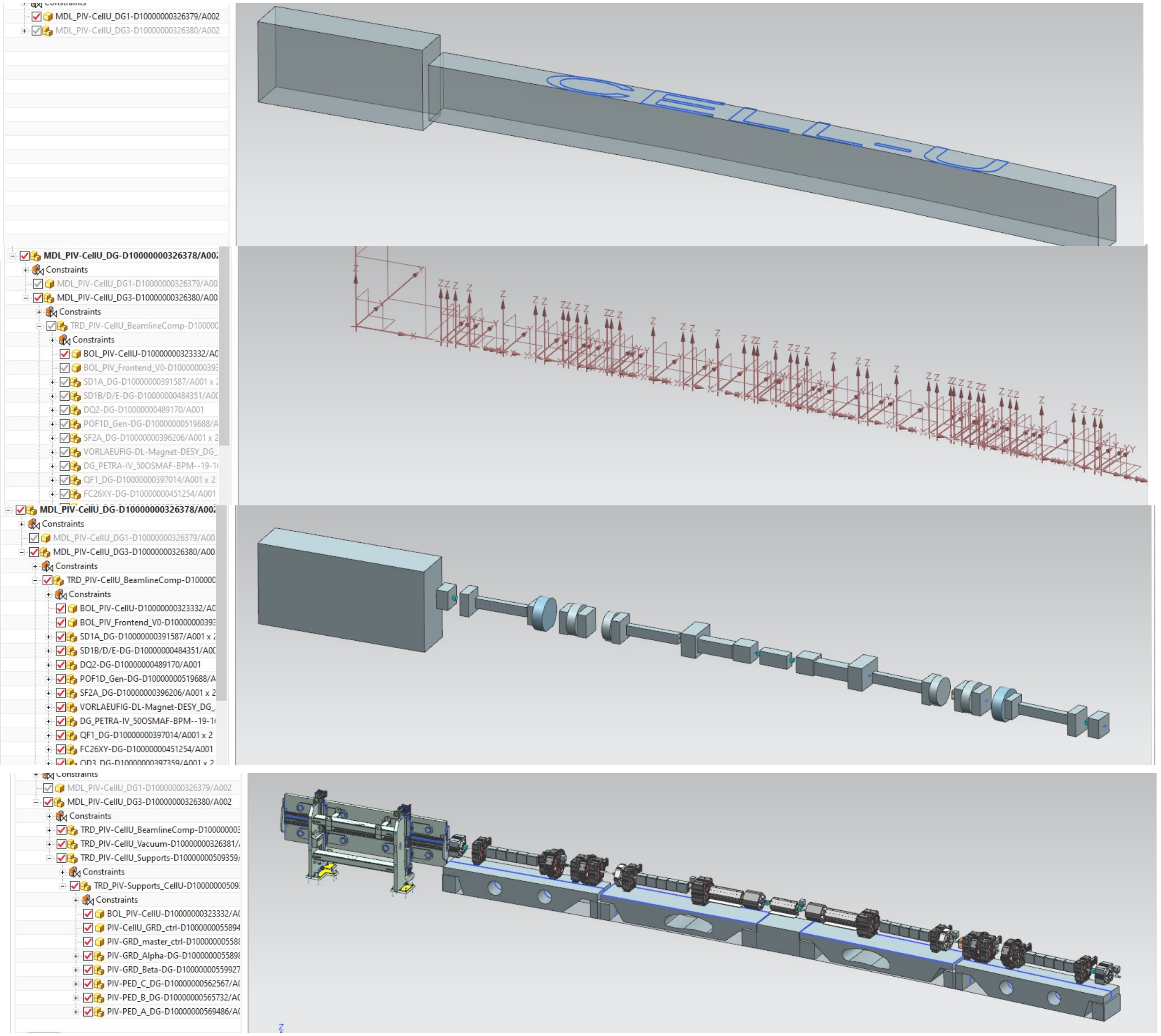


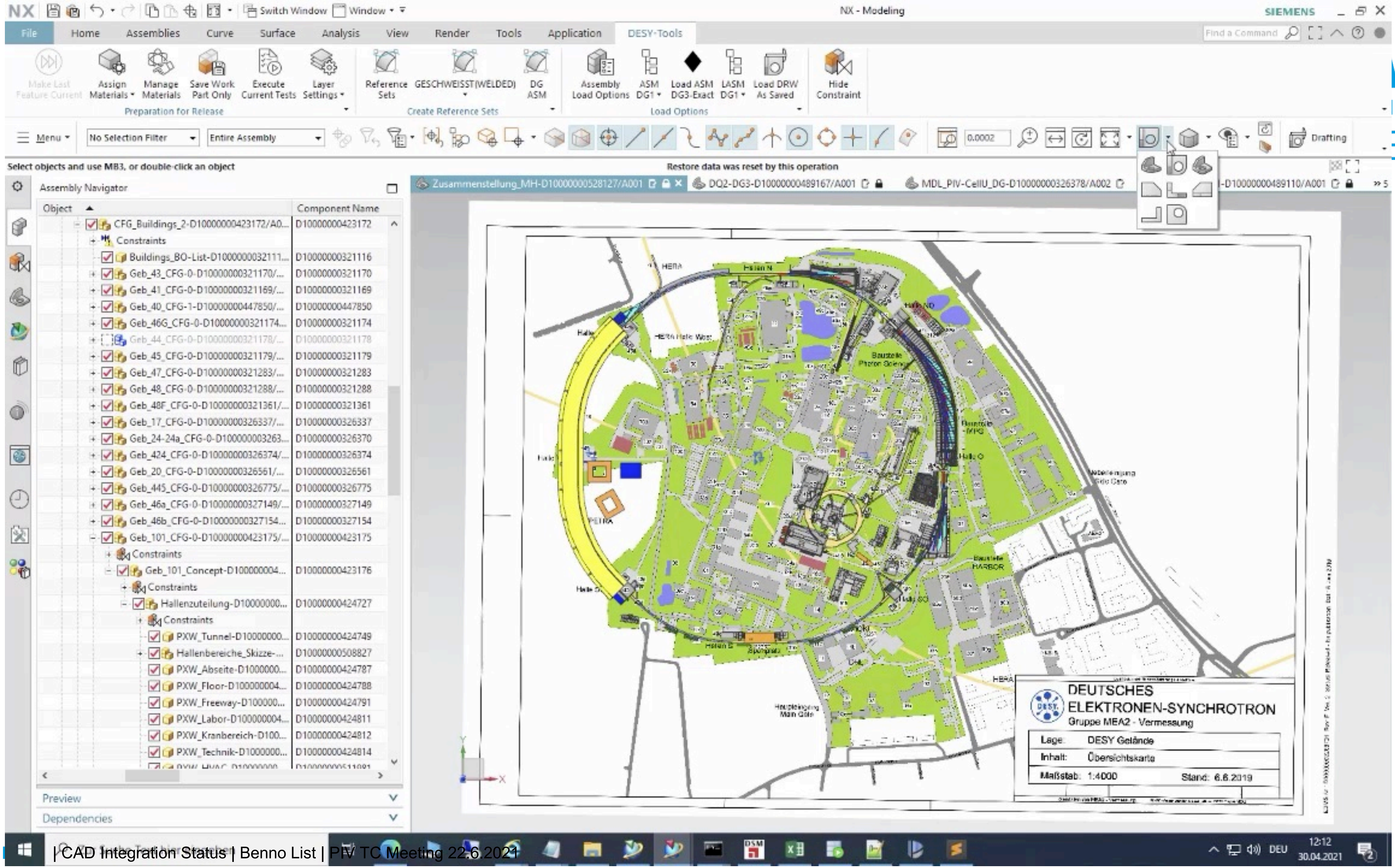
2 configurations of the ARES accelerator

Positioning of accelerator components

Example: Unit arc cell of PETRA-IV

- Accelerator lattice represented by one NX part with coordinate systems at component centers
  - Associative positioning via expressions
  - Read directly from TC-managed Excel™ spreadsheet
  - Creation of expressions automated by Python script
  - This lattice part may be used everywhere for positioning of parts
- All lattice-related components are inserted at coordinate system positions
- All components assemblies should have different levels of detail
- Benefits:
  - Fast and faithful translation from lattice to real geometry
  - Realistic geometry available in early design phases





NX
Switch Window
Window
NX - Modeling
SIEMENS
File
Home
Assemblies
Curve
Surface
Analysis
View
Render
Tools
Application
DESY-Tools
Find a Command
Make Last Feature Current
Assign Materials
Manage Materials
Save Work Part Only
Execute Current Tests
Layer Settings
Preparation for Release
Reference Sets
GESCHWEISST(WELDED)
DG ASM
Create Reference Sets
Assembly Load Options
ASM DG1
Load ASM DG3-Exact
LASM DG1
Load DRW As Saved
Load Options
Hide Constraint
Menu
No Selection Filter
Entire Assembly
0.0002
Drafting
Select objects and use MB3, or double-click an object
Restore data was reset by this operation
Assembly Navigator
Object
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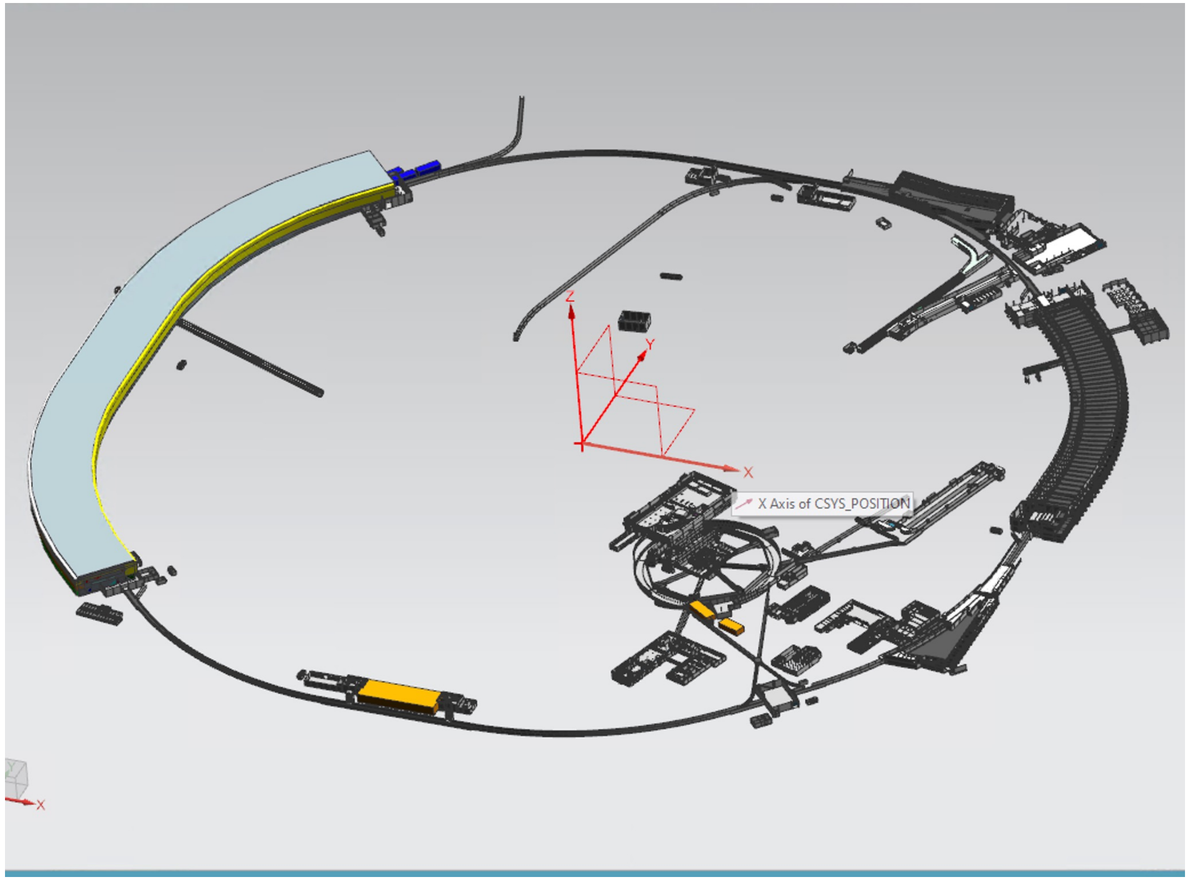
MDL_PIV-CellU_DG-D10000000326378/A002
-D10000000489110/A001
HERA
PETRA
DEUTSCHES
ELEKTRONEN-SYNCHROTRON
Gruppe MEA2 - Vermessung
Lage: DESY Gelände
Inhalt: Übersichtskarte
Maßstab: 1:4000
Stand: 6.6.2019
DEU
12:12
30.04.2021

Summary and Conclusions

- Integration model for PETRA-IV has been set up
- Model Structure reflects project decisions
- Different levels of detail decouple design phases and increases performance
- Modularisation makes manage complexity
- Configurations show specific states
- Automated placement of accelerator components from lattice supports fast design turnaround



Thank you for your Attention

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