PETRA IV.
NEW DIMENSIONS

PETRA IV Projekt Infos

KITE. 11th DESY Engineering & Innovation Day, 20 Juni 2024

Harald Reichert

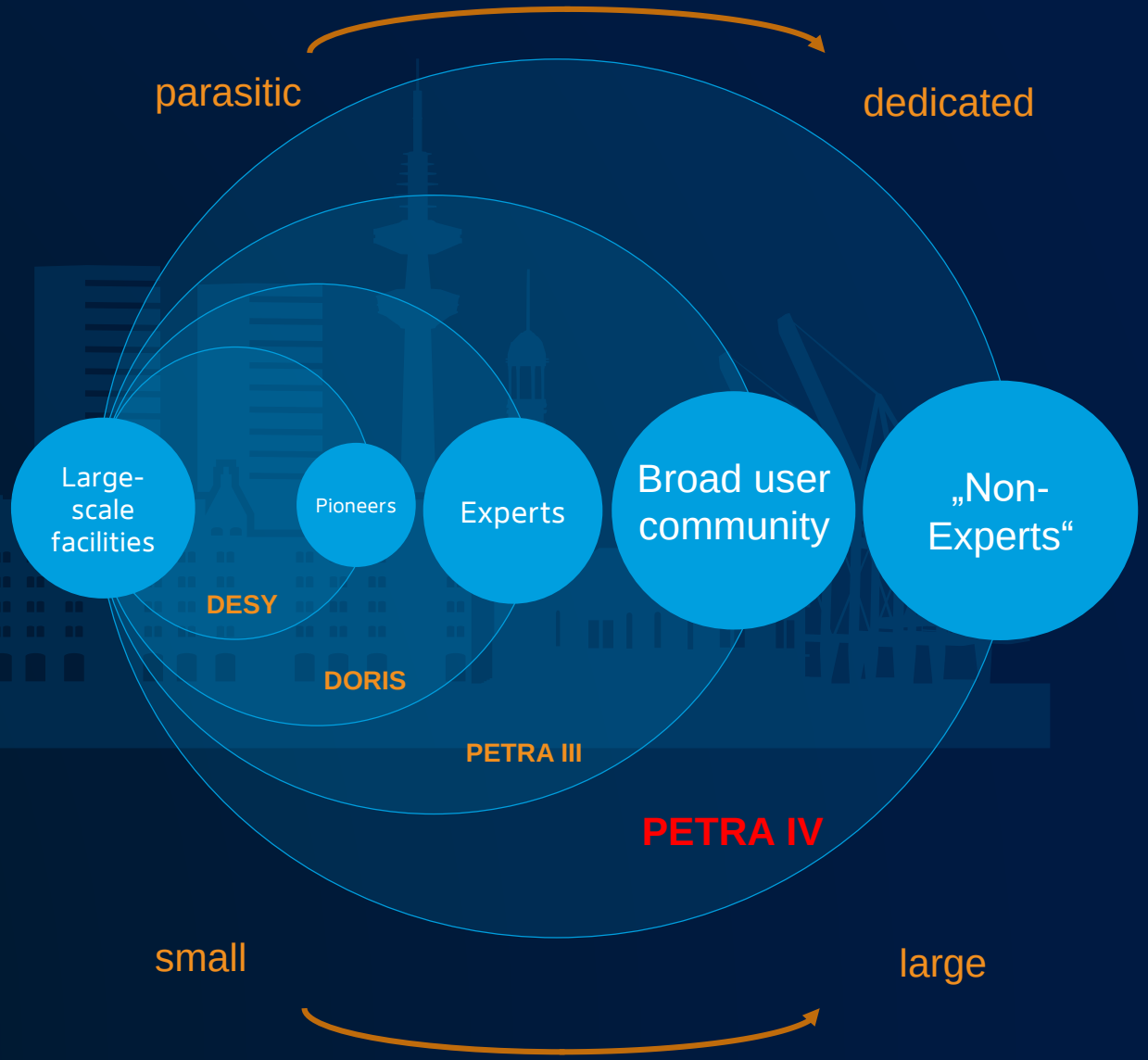
(on behalf of the entire PETRA IV team)

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

60 Years of Synchrotron Radiation at DESY

From basic science to broad application – a swiss army knife for science



PETRA III – One of the Core Facilities at DESY

~ 6500 h/year operation – serves thousands of users every year

Ada Yonath Hall
Extension Hall East

The PETRA IV project is the transformation of PETRA III into the synchrotron radiation source with highest brightness worldwide

Max von Laue Hall

Paul Peter Ewald Hall
Extension Hall North

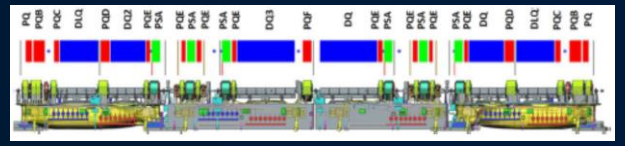
The PETRA IV Project

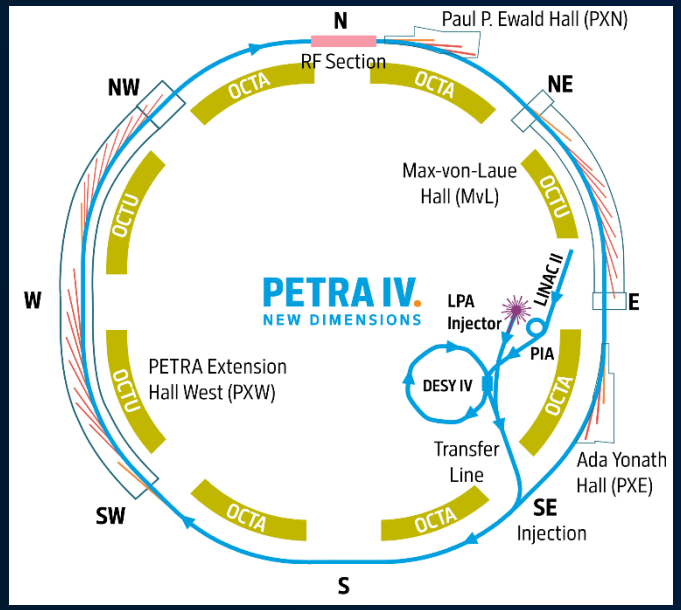
Extension/Refurbishment of the existing infrastructure, accelerator complex, and experimental facilities

Baseline design is fixed and costs have been assessed and reviewed on that basis

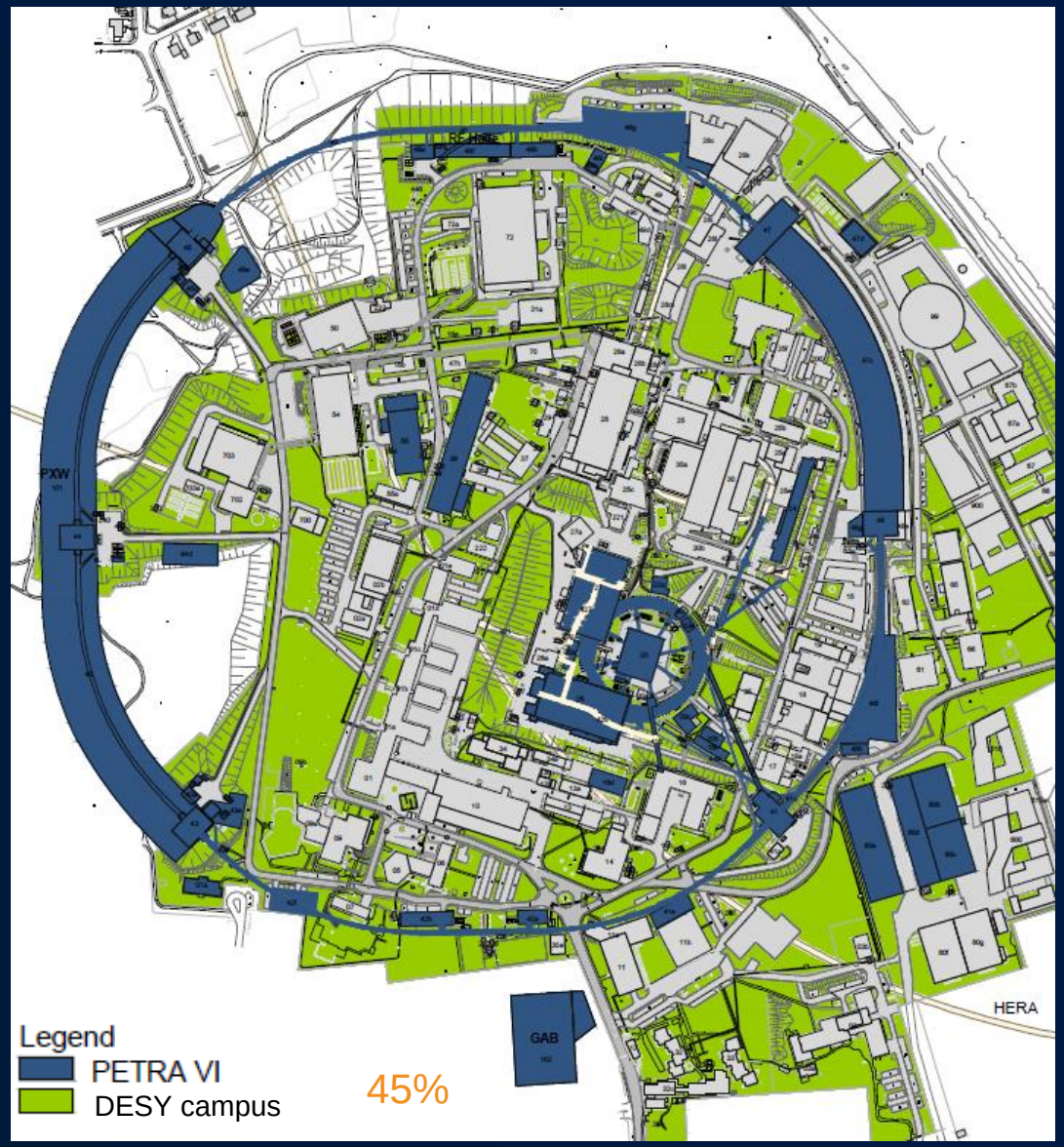
Increase in performance by a factor of 500

25%





30%

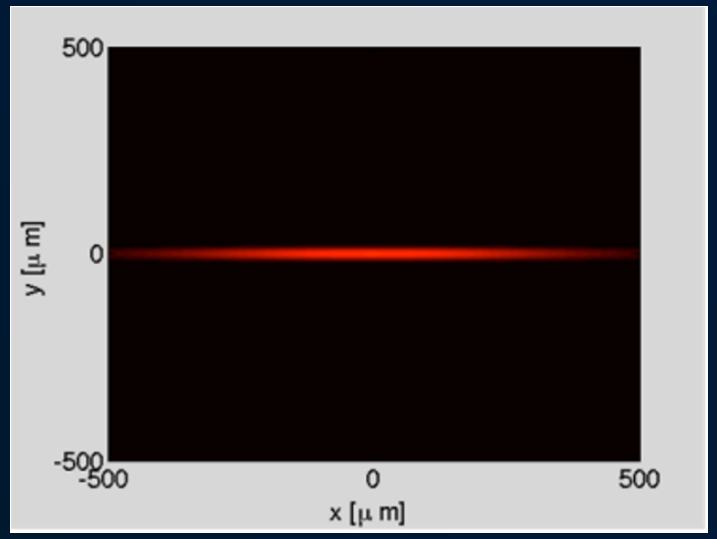


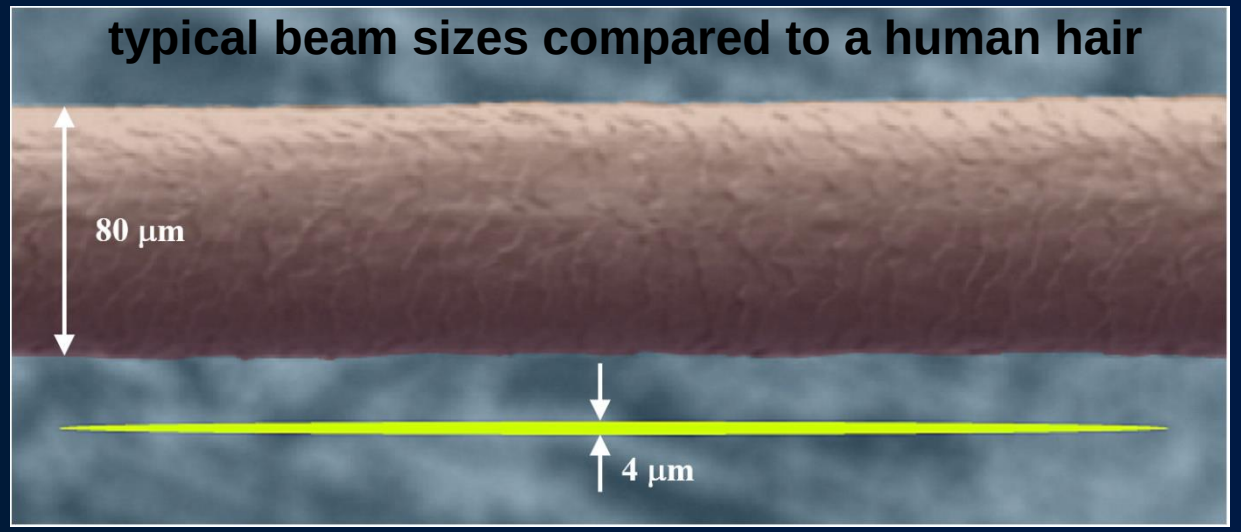
45%

From PETRA III to PETRA IV

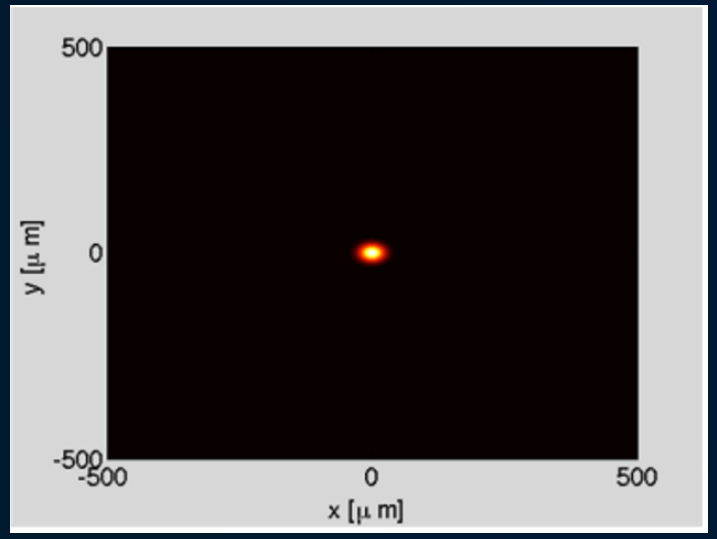
Smaller electron beam produces smaller photon beam until the diffraction limit is reached

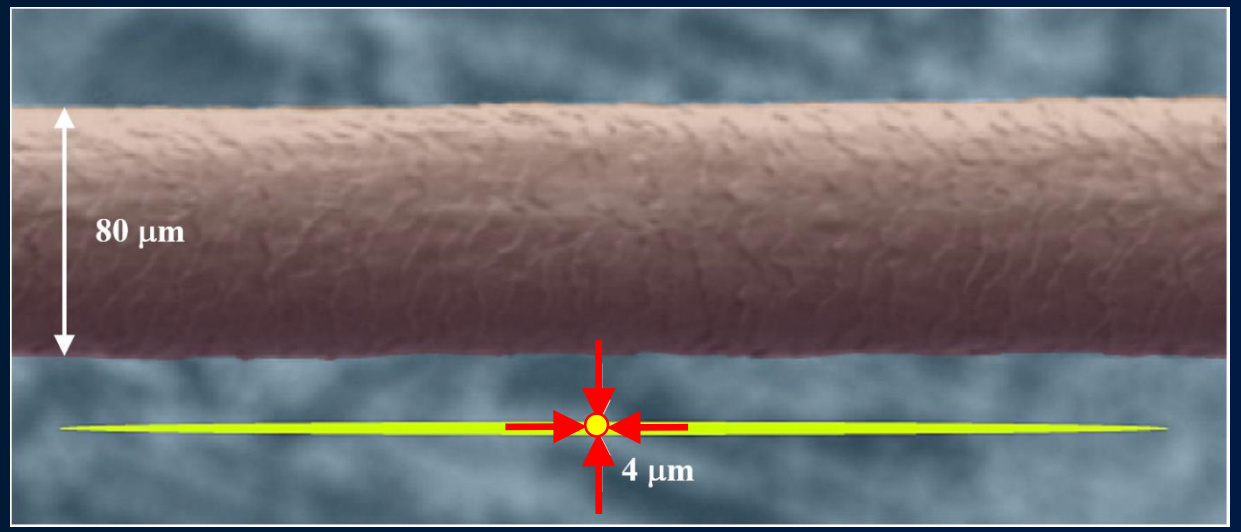
3rd generation light sources





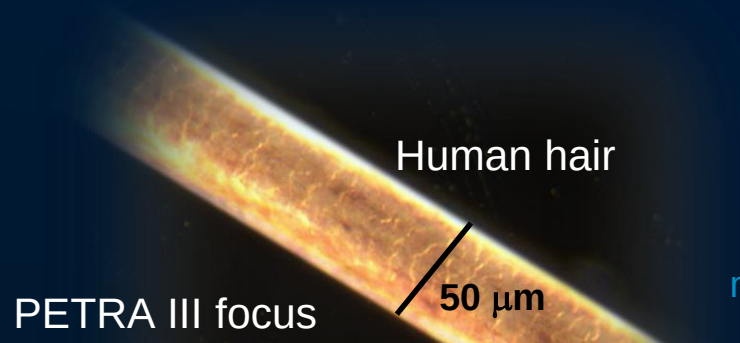
4th generation light sources



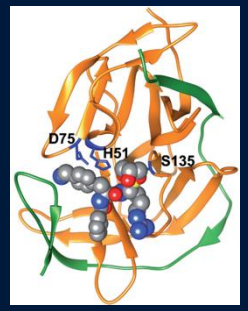


PETRA III / IV

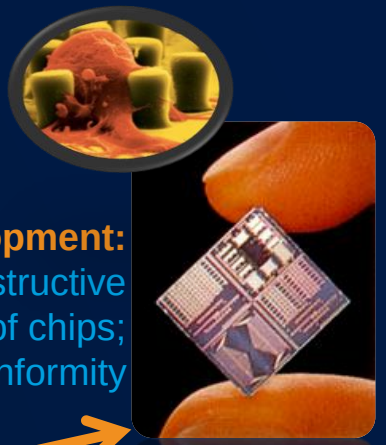
X-Ray analytics for a broad field of applications



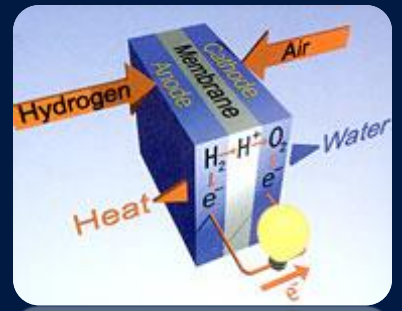
Health: Hierarchical imaging and functional analysis from molecules to whole organs



Chip development: nondestructive analysis of chips; quality & conformity



Renewable Energy: Analytics for the development of new materials for energy production, storage and conversion



27 beamlines operating in parallel with more than 62 endstations

Transport: Precise 3D-anlaysis of entire devices under operating conditions

PETRA IV Project Status

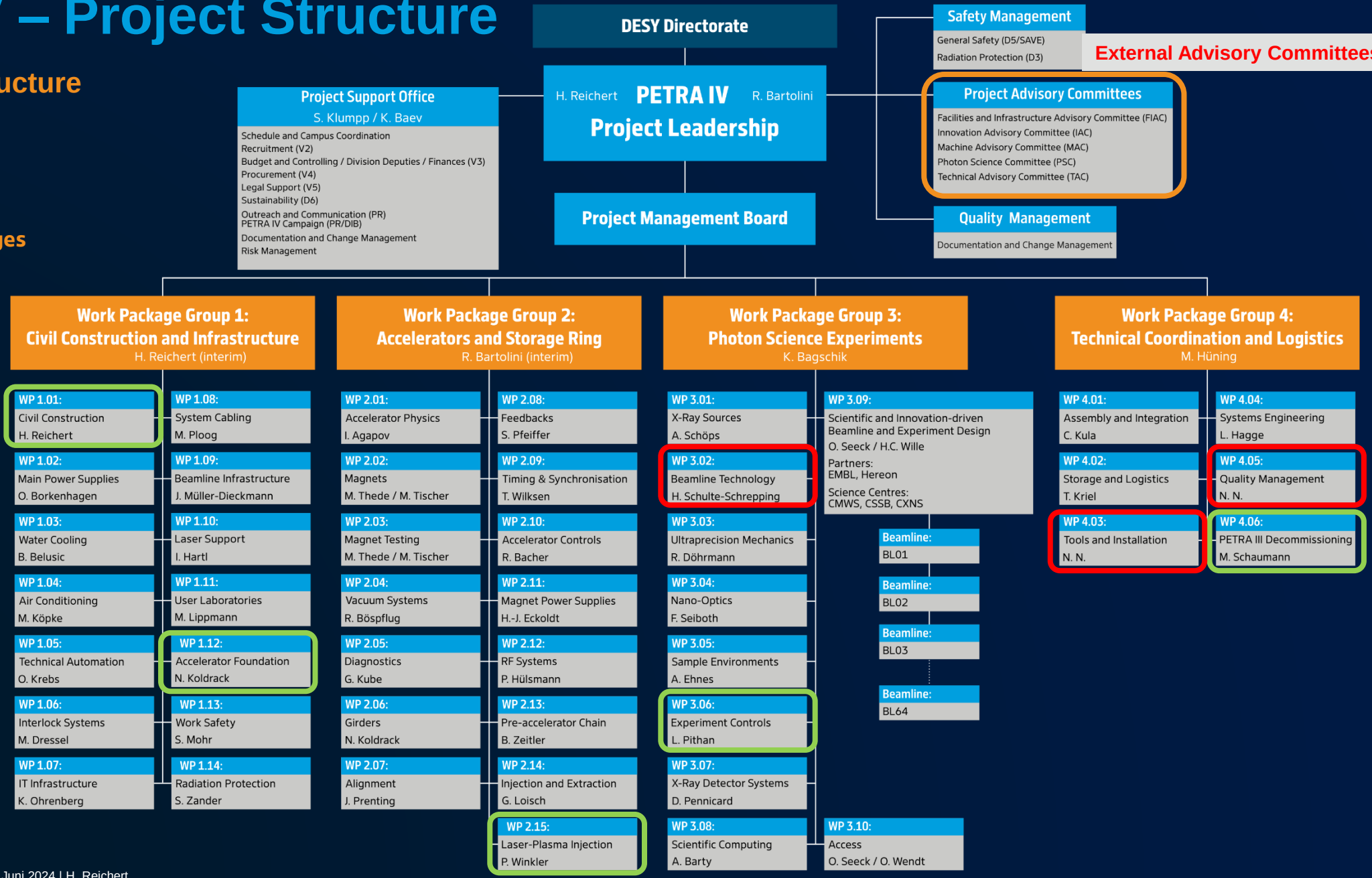
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

PETRA IV – Project Structure

Work package structure

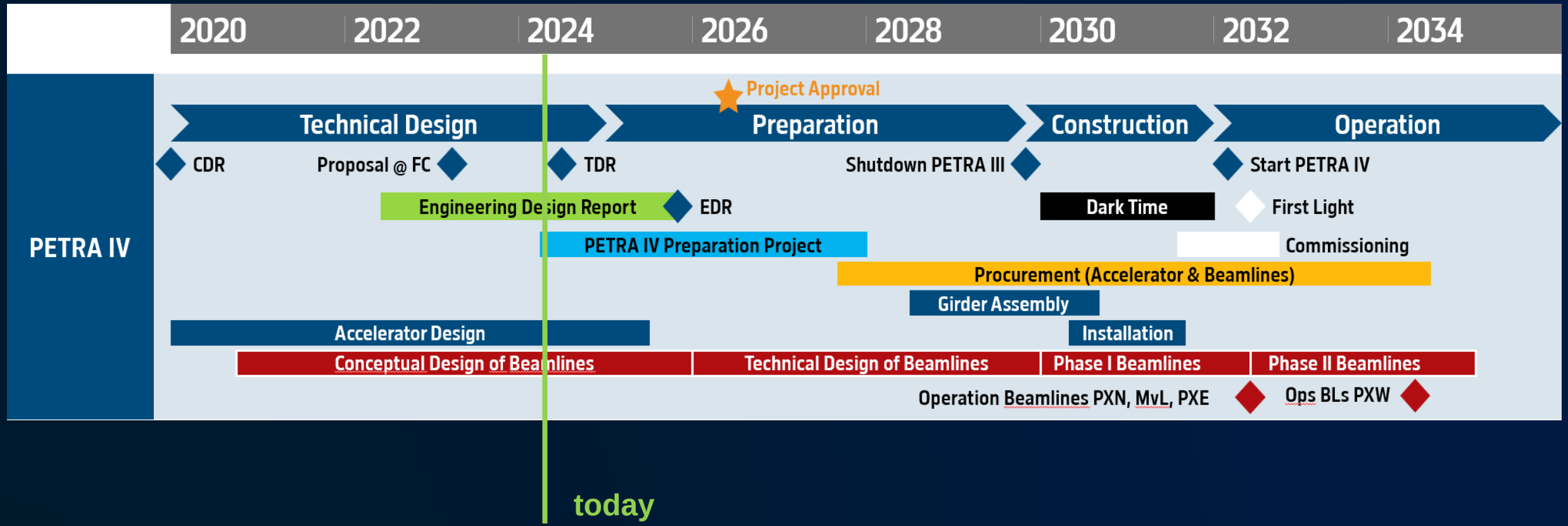
- 45 Work Packages



PETRA IV – Revised Schedule 2024 (Optimum)

Project fixed by (external) boundary conditions

- Start of operation Q2/2032 with 19 BLs
- Shutdown of 2 – 2.5 years (2030/2032)
- Project duration: 9 years (2025-2033)



PETRA IV – The clock is ticking……

Worldwide competition

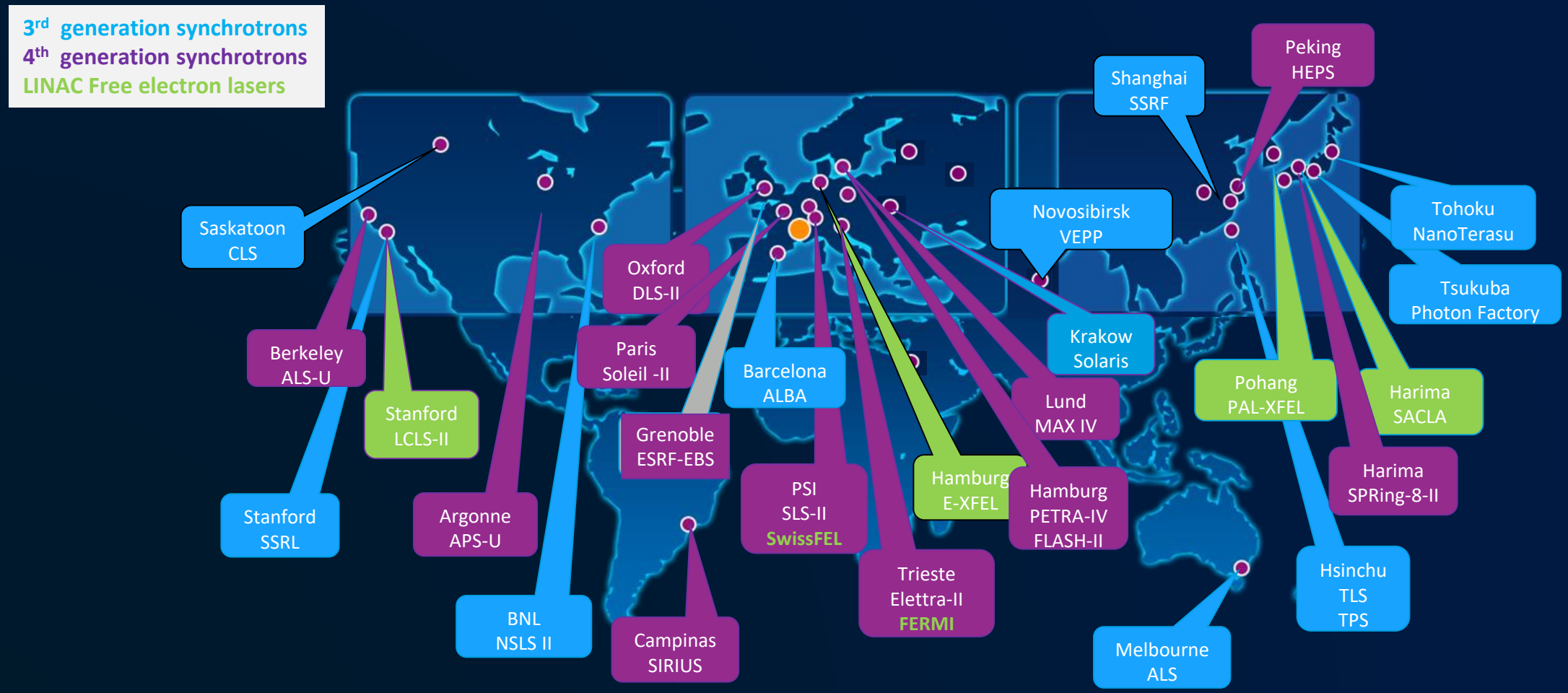
Performance 4th generation

Performance 3rd Generation

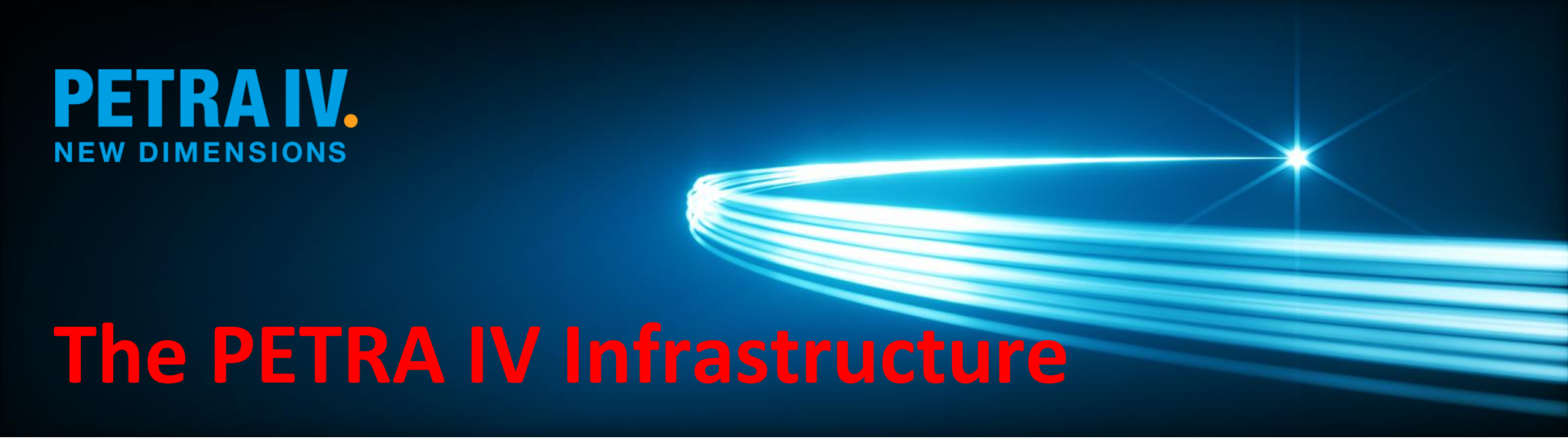
Start of operation 4th Generation	2020	2024	2024	2028	>2030
Standort	ESRF-EBS Grenoble	APS-U Chicago	HEPS Beijing	Spring-8-II Hyogo	**PETRA IV Hamburg**

Worldwide Race for 4th Generation X-ray Sources

Many big projects in X-Ray science: >10 running or planned projects



PETRA IV.
NEW DIMENSIONS

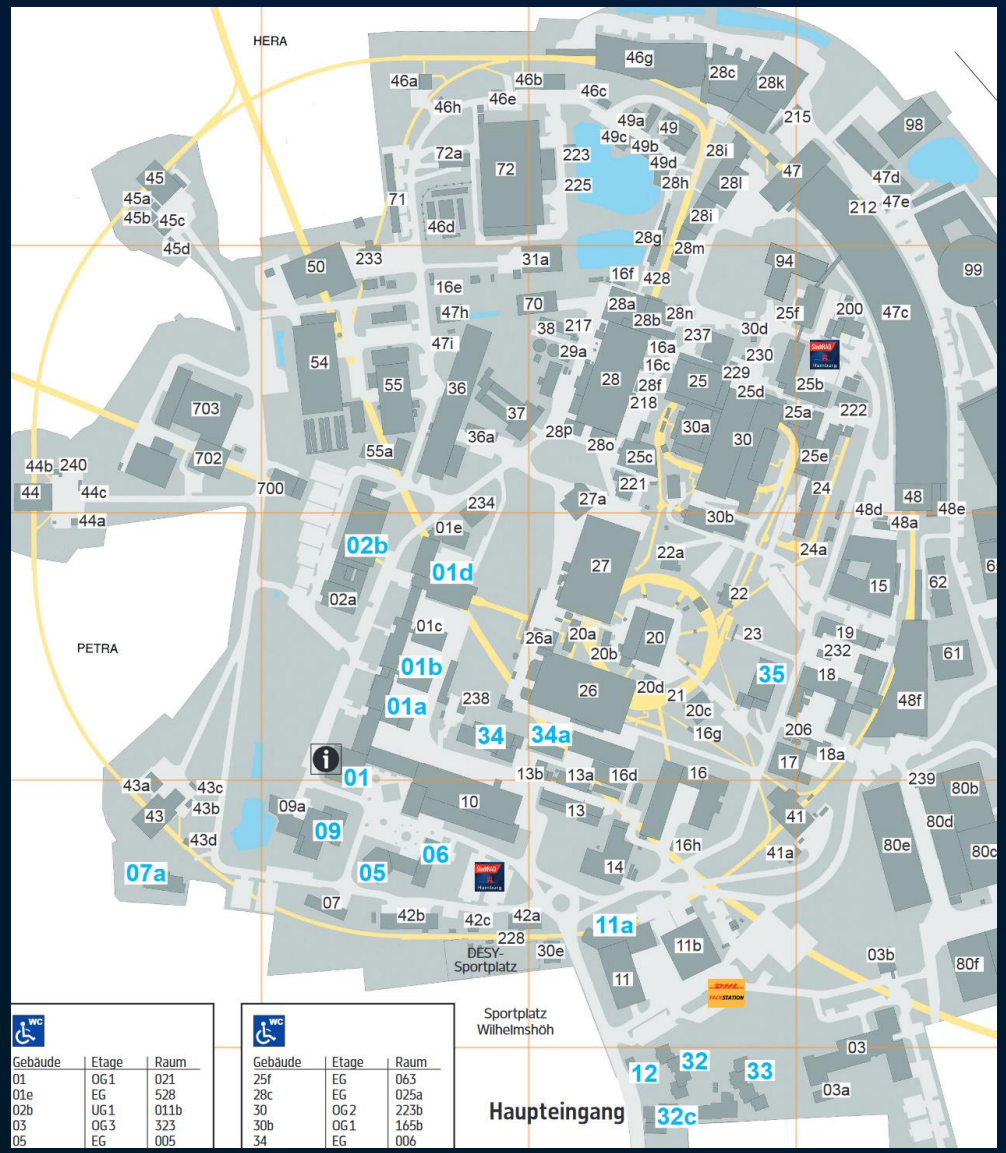


The PETRA IV Infrastructure

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

WP 1: PETRA IV – Infrastructure



Demolition

Gebäude-nummer	Bezeichnung
7a	Gästehaus
40	PETRA Tunnel
43	PETRA Halle
43a	Büro/Werkstatt
43b	Heizzentrale
43c	Trafostation
43d	Büro & Serverraum
44	PETRA Halle W
44a	Ölsammelgrube & Trafos
44b	Pumpenhaus
44c	Trafostation
45	PETRA Halle
45a	Heizzentrale
45b	Lager
45c	Werkstatt
45d	Trafostation
46a	PETRA Halle N
46b	PETRA Halle N
46c	Senderstromversorgung
46h	Heizstation
240	Container
448	E-Weg
449	P-Weg
446	PR Weg
102	Vereinsgebäude
102	Vereinsgebäude
102	Vereinsgebäude
46e	Trafostation

Construction

Gebäude-nummer	Bezeichnung
101	Umverlegung Biotope im Vorfeld
	PXW
	Medientunnel unter PXW
	Fläche für Kryopumpen (2 Stck / 30.000L)
	Gefahrstoffcontainer
	Neugestaltung Lise-Meitner-Park (12,9ha)
	Ausgleichsmaßnahmen außerhalb des Parks
	Sportplätze Stiefmütterchenweg
45e	Büro PIV N
	Verbindung PXW & 45e
	Fußgängertunnel Büro Nord - PXW
43e	Büro PIV S
	Verbindung zwischen PXW & 43e
44d	Technikzentrale Kältetechnik - Pumpenhaus
	Medientunnel Pumpenhaus - PXW
	Fläche für Kühltürme (8 Stck)
46f	RF Halle
	Einspeisegebäude RF Halle
	Tunnelzugang RF
	Fläche für Kühltürme RF (4 Stck)
40a	PETRA Tunnel
40b	PETRA Tunnel
102	GAB
	GAB - Umkleiden
	GAB - Gastro
46i	Versorgung NNO
	Tunnelzugang 46i NNO NOL110
	Medientunnel 46i NNO NOL110 zu PETRA
	Medienbrücke NNE
48g	Versorgung O
48h	Versorgung OSO
	Tunnelzugang 48h OSO SOL110
41e	Versorgung SSO
	Tunnelzugang 41e SSO SOR101 (Notausgang)
	Medientunnel 41e SSO SL98 zu PETRA
	Medienbrücke SSO
	Tunnelzugang 41e SSO SL98
42f	Versorgung SSW
	Tunnelzugang 42f SSW SR98 (Notausgang)
	Medientunnel 42f SSW SR98 zu PETRA
	Medienbrücke SSO
16i	Hauptstation A
	Versorgungsschacht Hauptstation A
	Medienbrücke zum Geb. 20c
	Tunnel von 20c zum Geb. 20
420	D- Weg
16 / 16d	Versorgungstunnel/ - brücke für DESY
16	Schachtbauwerk am Geb. 16

Refurbishment

Gebäude-nummer	Bezeichnung
20	Synchrotron Ringtunnel
26	Experimentierhalle I
40	PETRA Tunnel
41	PETRA Halle SO
42a	PETRA Halle Süd
42b	PETRA Halle Süd
47	PETRA Halle NO
47d	Kühlstation
48	PETRA Halle Ost
80e	Reemtsma
416	DESY Verbindungstunnel

PETRA IV – Infrastructure

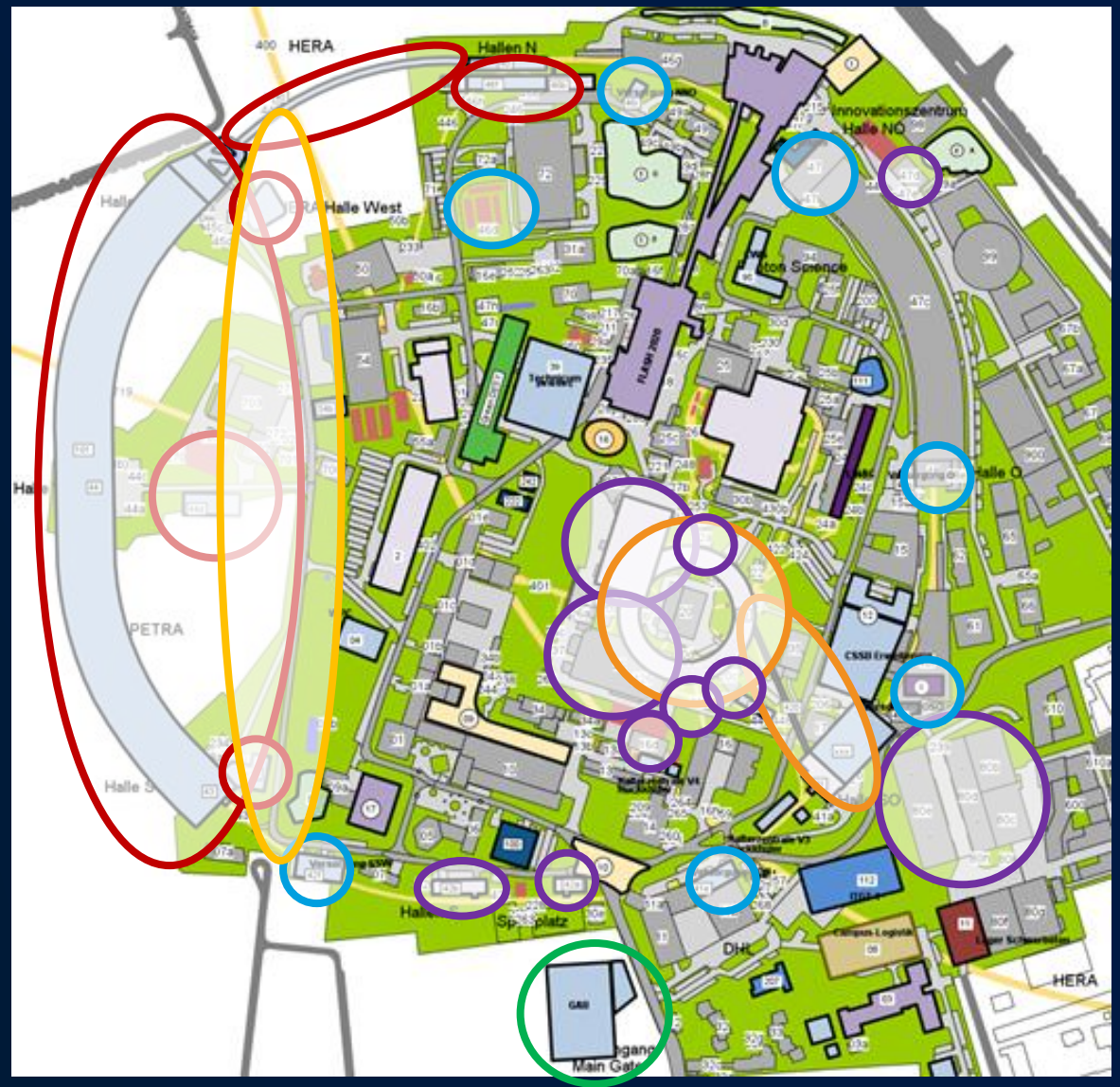
Civil construction programme (status end of January 2024)

organised in 11 packages

- GAB
- PXW, Tunnel NWN, RF Sector (TP2)
- DESY Complex
- Supply Buildings
- Building Refurbishments
- Tunnel refurbishment (old sections)
- Underground Networks (Heating, Cooling, IT, etc.)

+ preparatory works

- Relocation of the biotopes
- Replacement of sports facilities
- Reconstruction Lise-Meitner-Park



PETRA IV Preparation – WPG1 Critical Path for Infrastructure

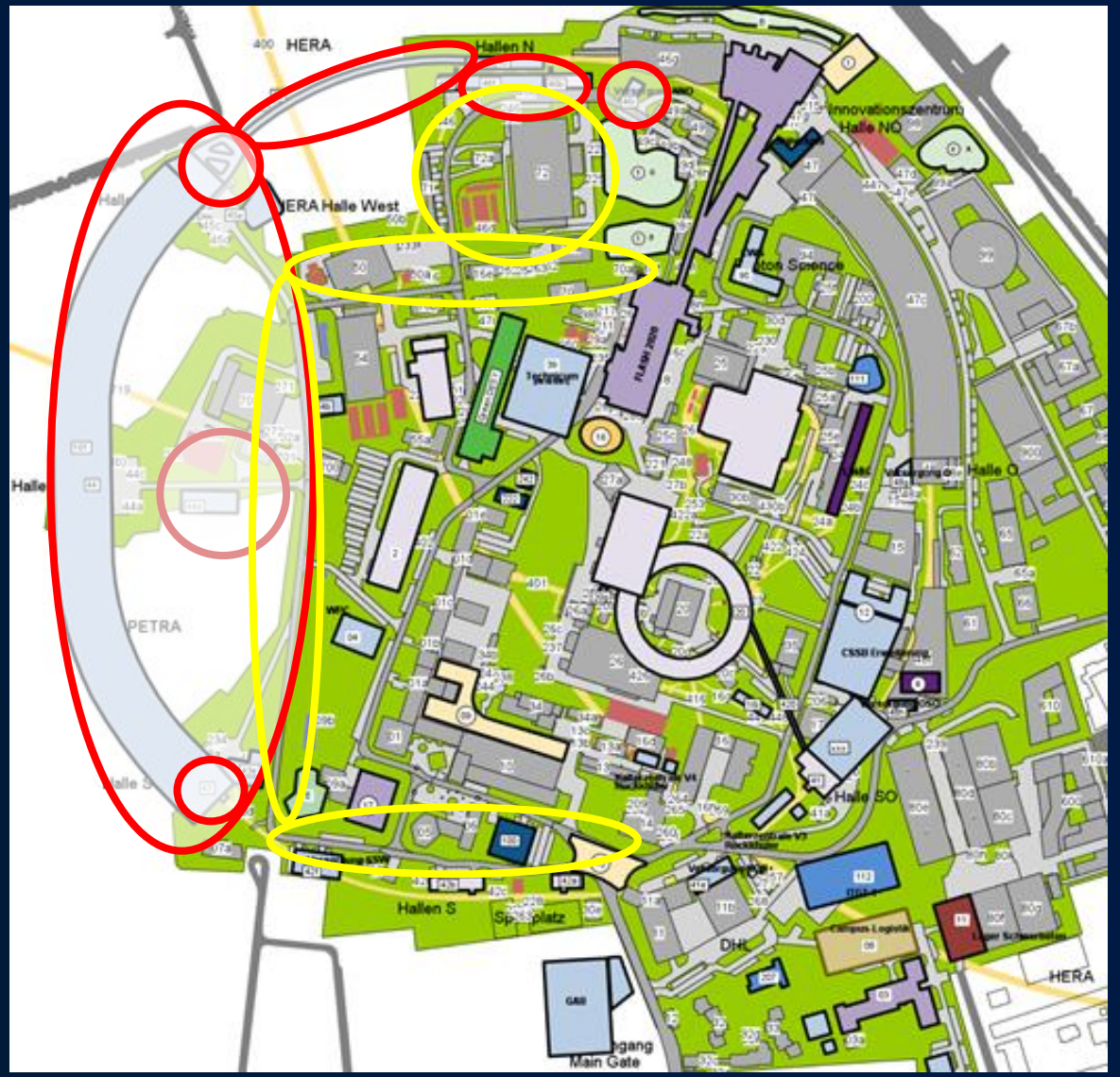
Planning for civil construction & technical infrastructure

Zeitkritische Baumaßnahmen

- Endcap South
- PXW
- Supply Building West
- Endcap North
- Tunnel NNW
- RF Hall
- Supply Building NNE

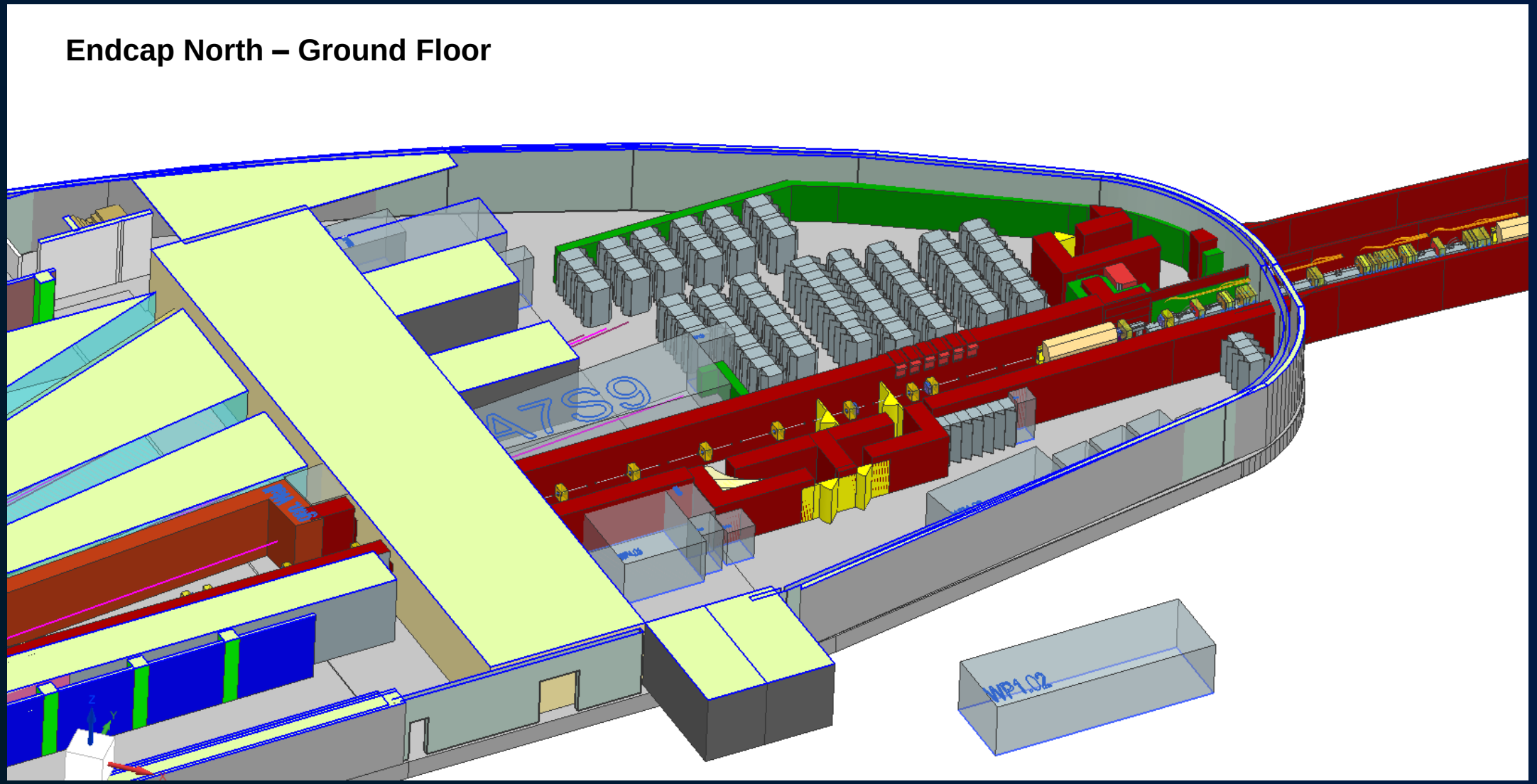
} *PETRA IV West/Nord*

Underground media supply: *Campus West*



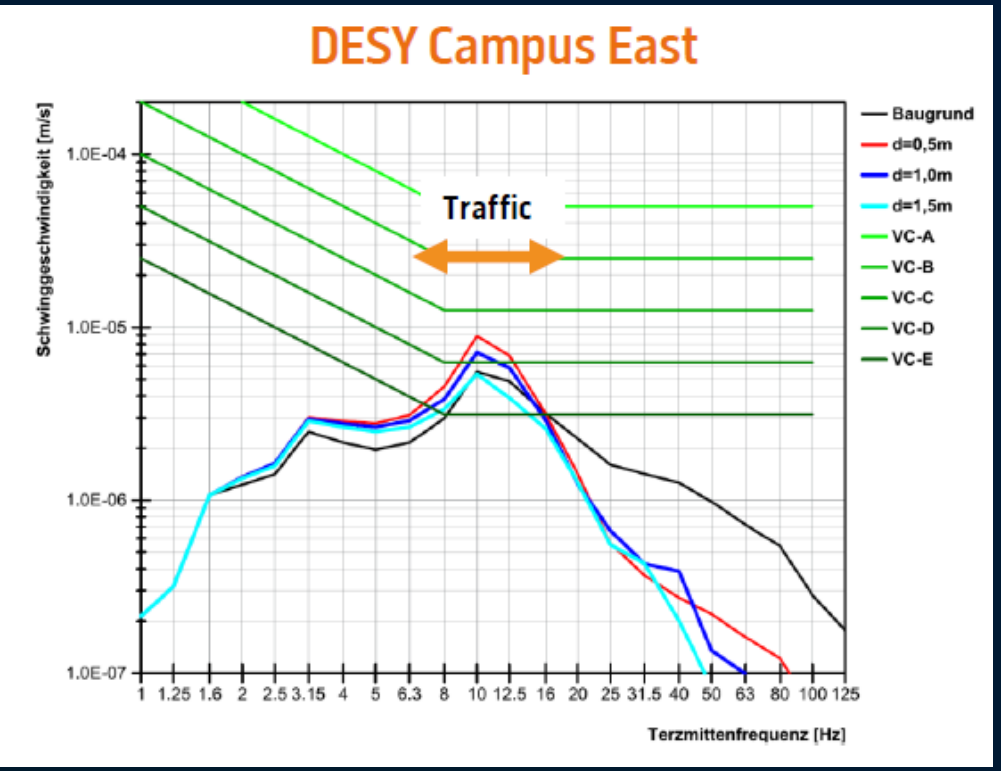
PETRA IV – PXW Building Design

3D CAD Design progressing well

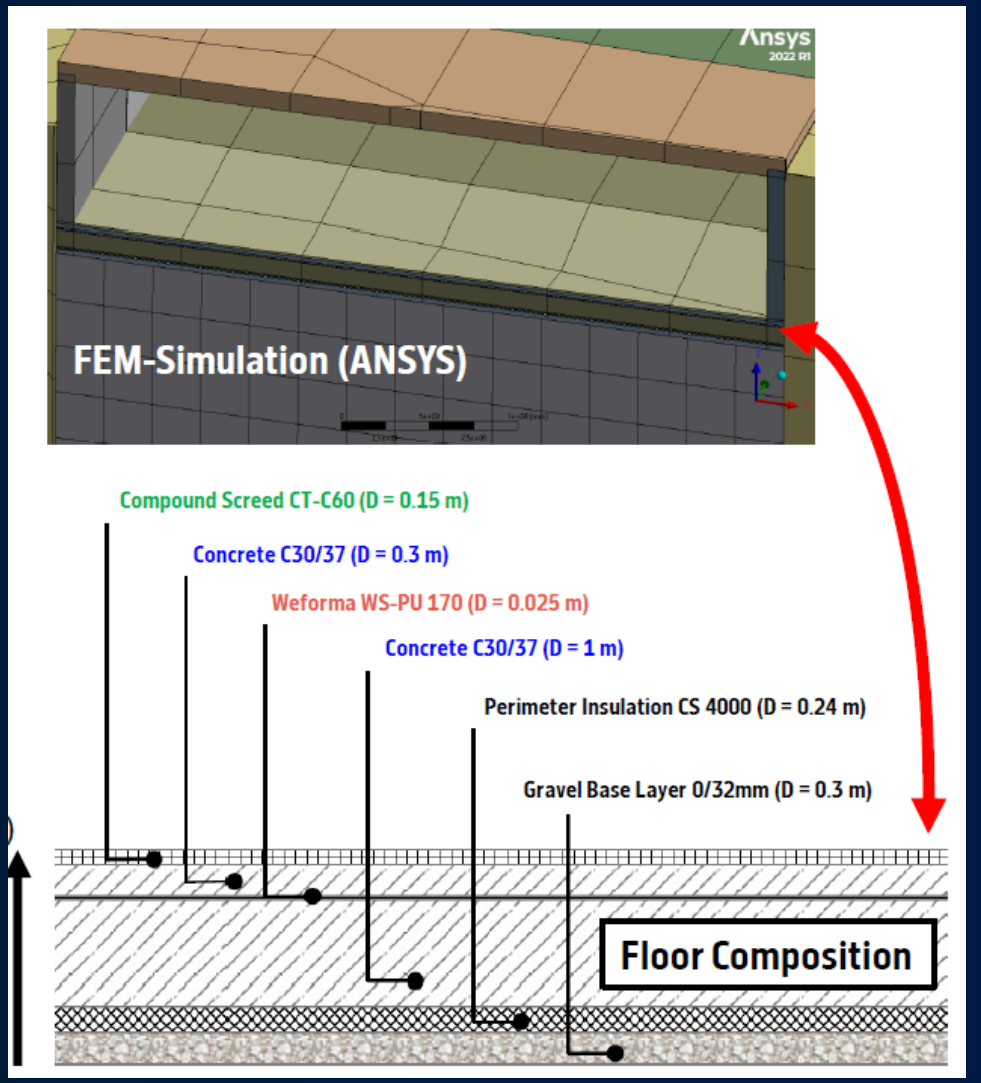


PXW – Stability

Quest to increase stability for operation – floor vibration & temperature stability



Curve Criterion	Amplitude[1] µm/s (µin/s)	Detail Size[2] µm
Workshop (ISO)	800(32,000)	N/A
Office (ISO)	400 (16,000)	N/A
Residential Day (ISO)	200 (8000)	75
Op. Theatre (ISO)	100 (4000)	25
VC-A	50 (2000)	8
VC-B	25 (1000)	3
VC-C	12.5 (500)	1 - 3
VC-D	6.25 (250)	0.1 - 0.3
VC-E	3.12 (125)	< 0.1
VC-F	1.56 (62.5)	N/A
VC-G	.78 (31.3)	N/A
NIST-A		



→ Talk by Roland Platzer

PETRA IV – RF Hall / Supply Space North

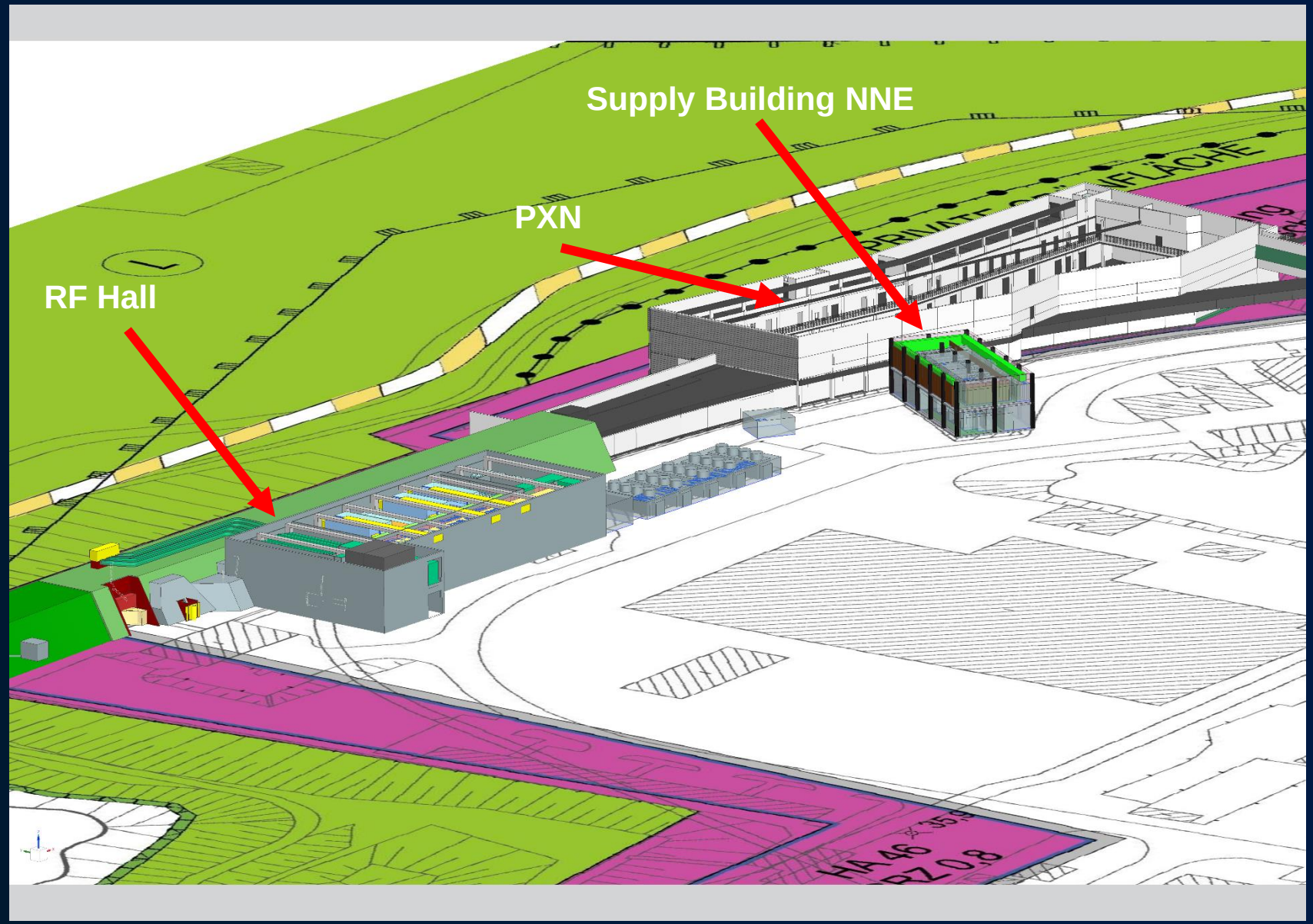
3D CAD Design progressing well

Needs of user have been reviewed

- RF system
- Diagnostics
- Magnet power supply
- Environmental control (T)
- ……..

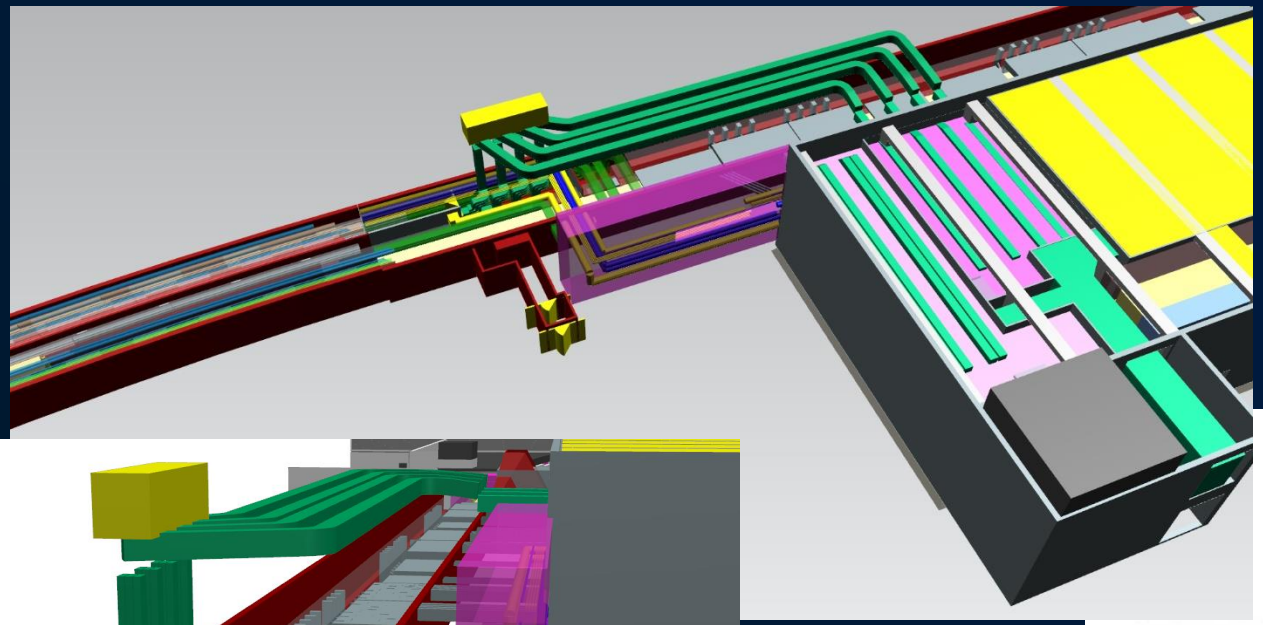
Primary supply needs fixed

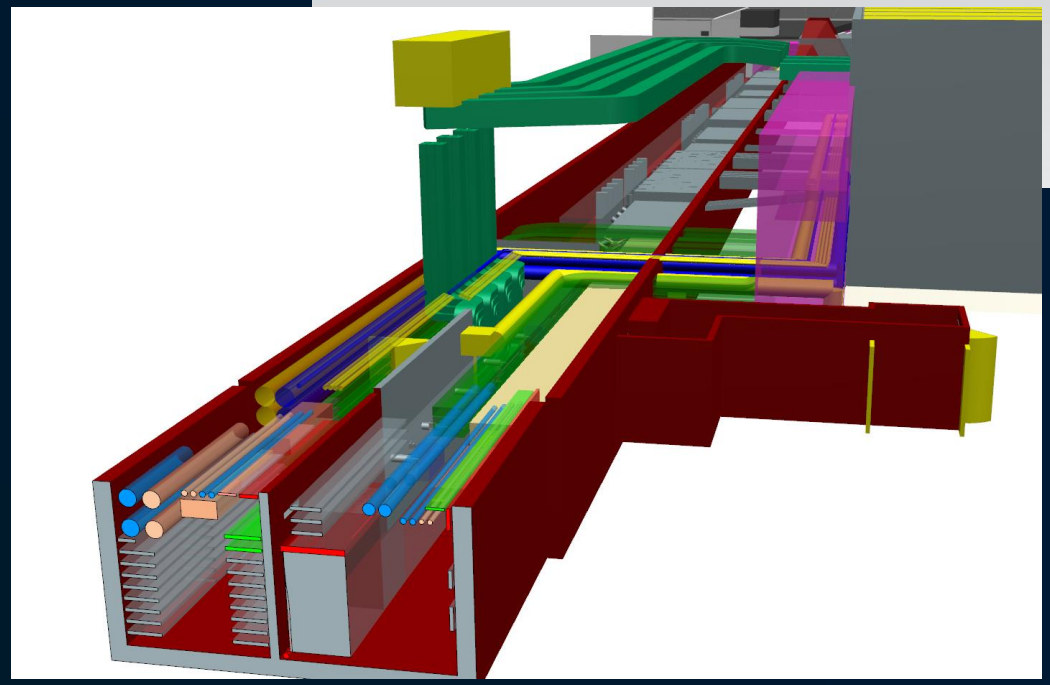
- Power supply
- Cooling water
- AC capacity
- ……

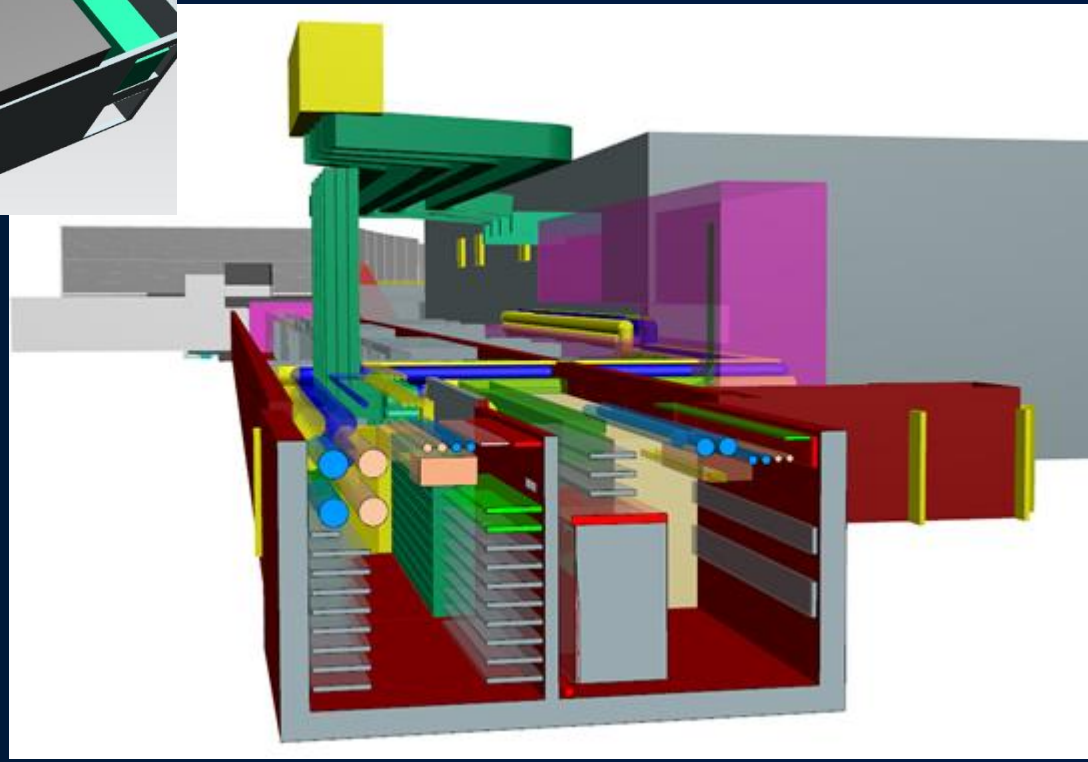


RF Hall (PRN) – Connection to Tunnel NW

Detailed planning for media supply

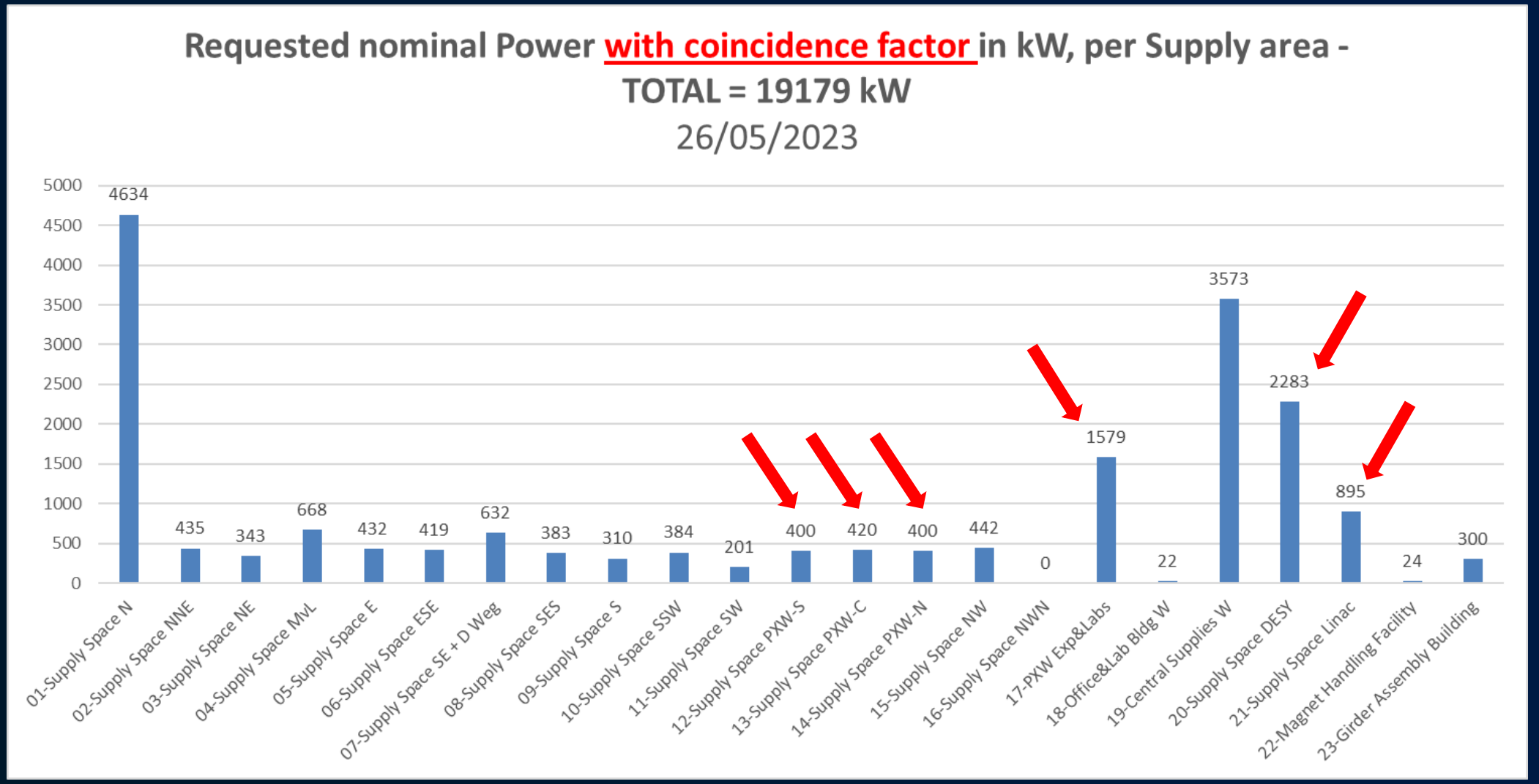






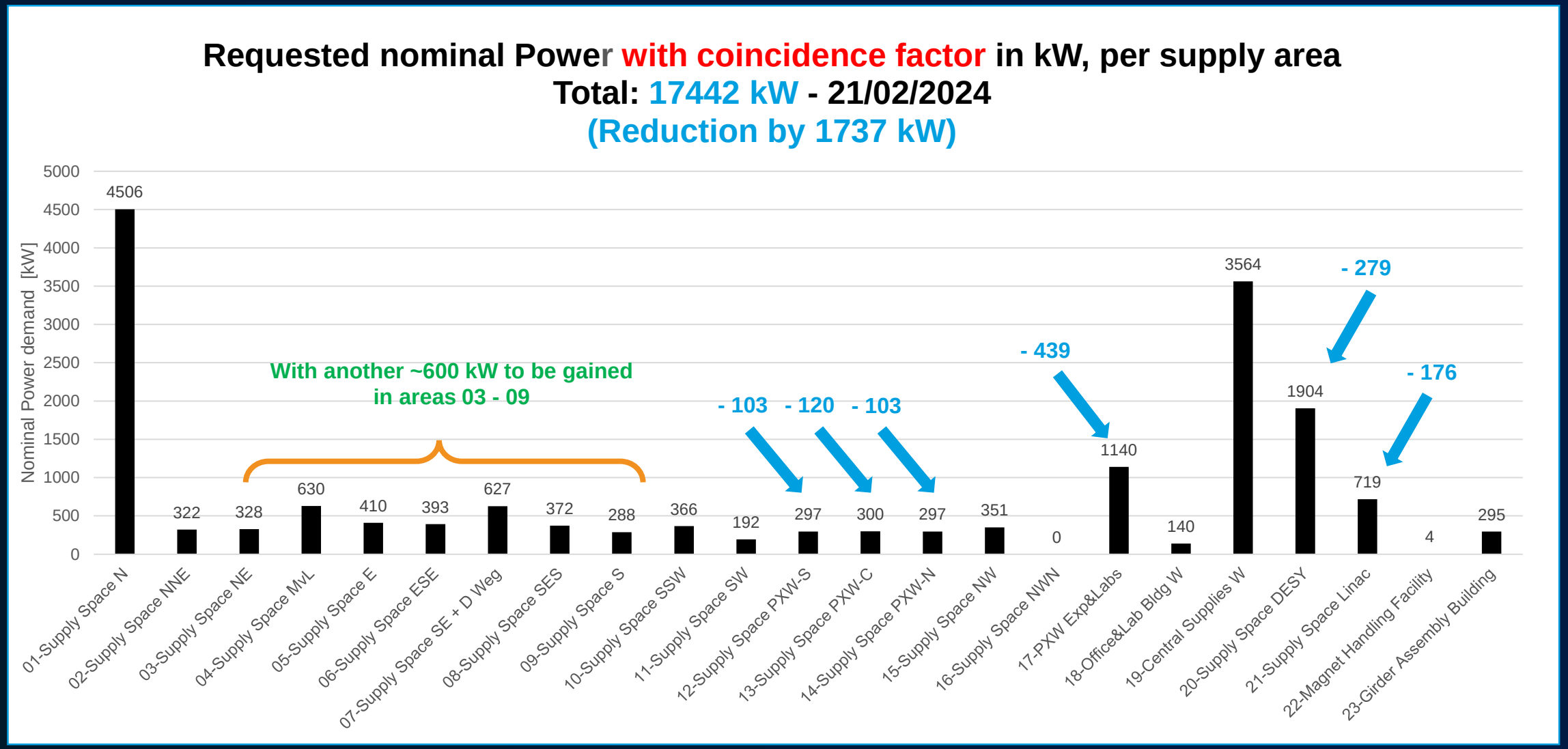
PETRA IV – Sustainability / Refinement of the Room Books

Quest to increase sustainability for construction and operation



PETRA IV – Sustainability / Refinement of the Room Books

Quest to increase sustainability for construction and operation



The PETRA IV Machine Upgrade

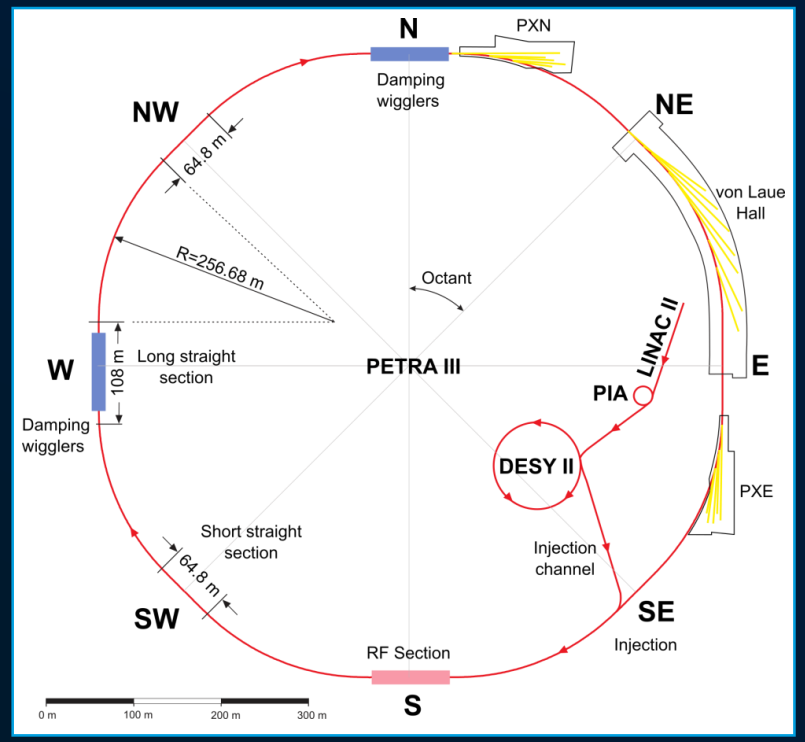
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

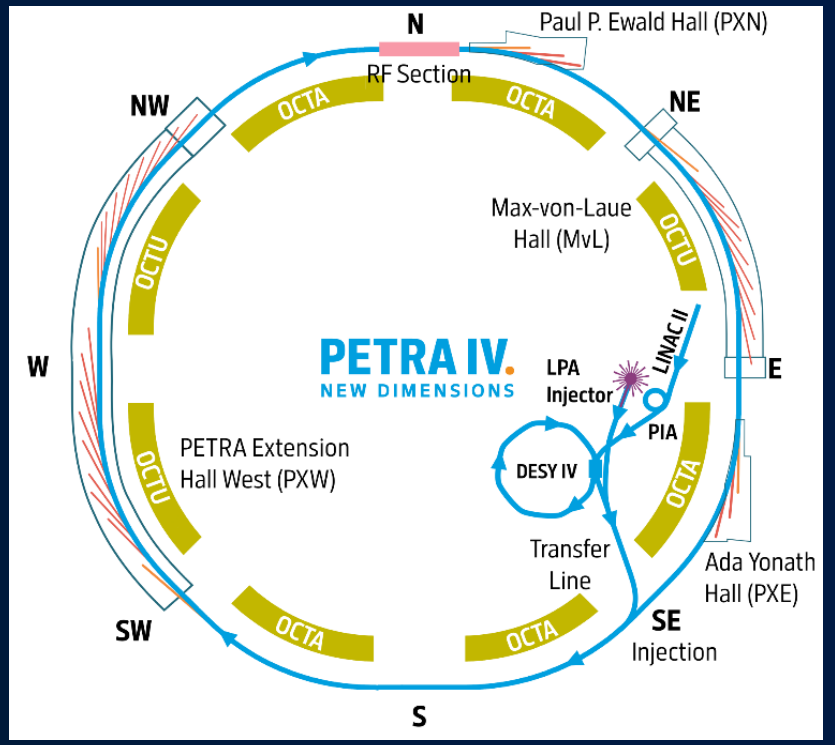
DESY.

From PETRA III to PETRA IV

New storage ring

1300 pm·rad → 20 pm·rad





Eight Arcs (45°), 201.6 m long

One arc build from 9 ***DBA cells*** L_{cell} = 23 m, 5 m ID straight sections

5 pure FODO-arcs + 2 modified FODO arcs with 2 ***DBA cells***

Beamlines

Max von-Laue Hall:14; PXN:5; PXE: 7

Eight Arcs (45°), 201.6 m long

72 cells ***H6BA cells***

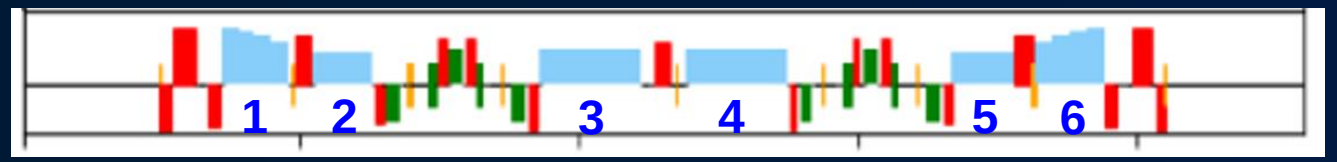
9 cells per arc L_{cell} = 22.75 m, 4.3 (tbc) m ID straight sections

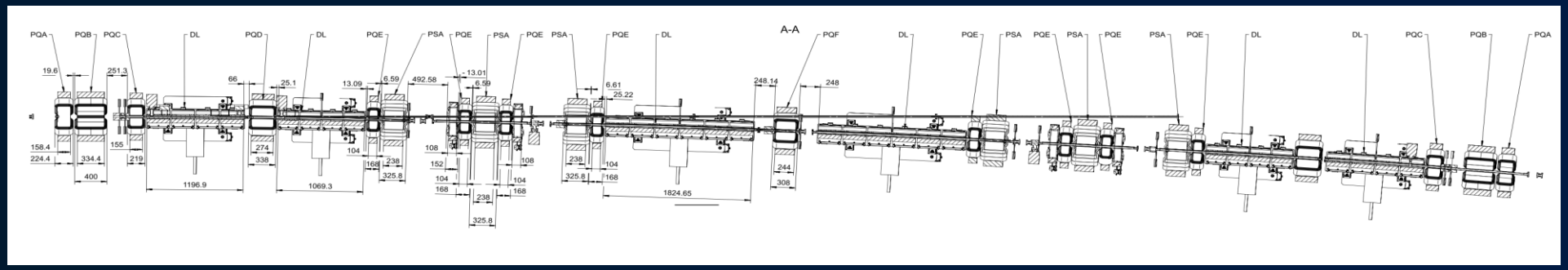
Straights for Beamlines

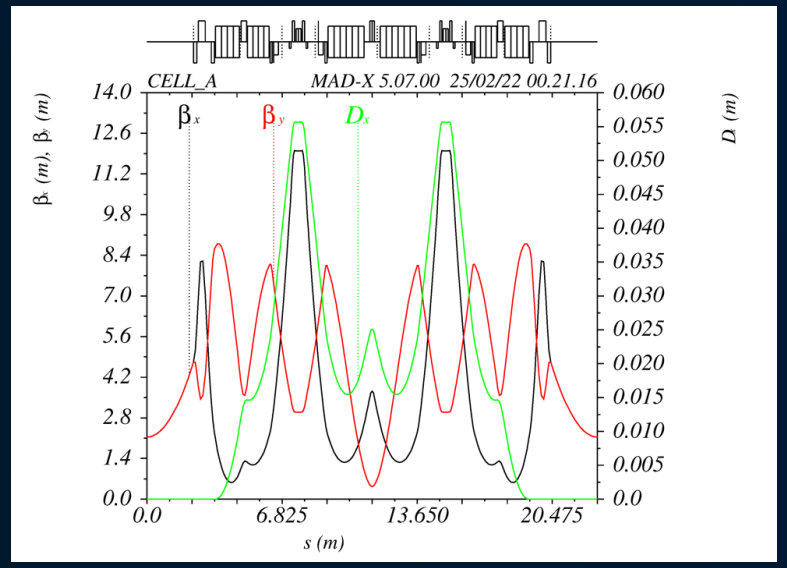
Max von-Laue Hall: 9; PXN: 3; PXE: 3 + PXW Hall: 9 + 9(8)

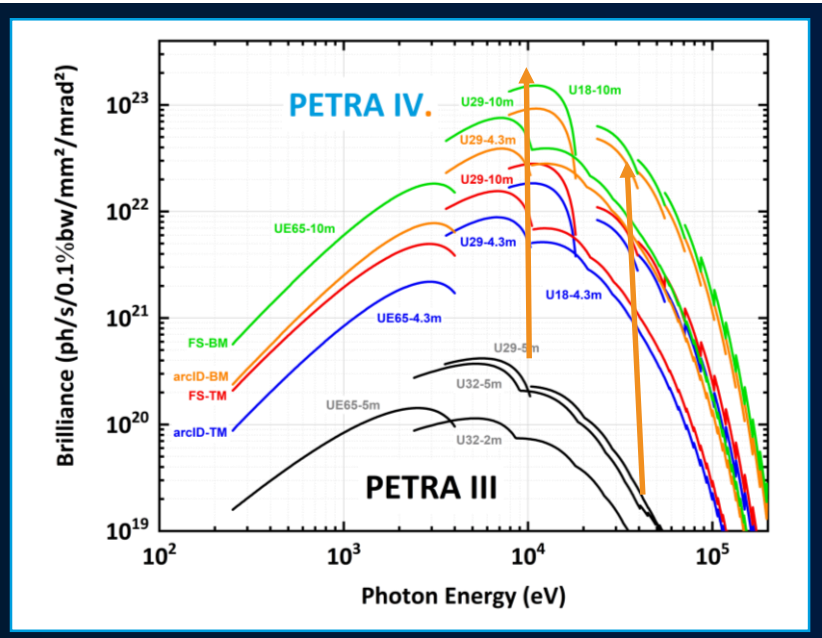
PETRA IV Storage Ring – A World-Leading Machine

Novel cell structure (H6BA) for the lattice that is replicated identical across all octants (72 cells)









43 pm·rad bare lattice
20 pm·rad with damping wigglers

extensive use of PM for the combined function dipoles

> emittance: ~ 20 x 4 pm·rad²
> undulators: 4.3 m and 10 m

Average brightness increase: 500

PETRA IV Prototype Programme

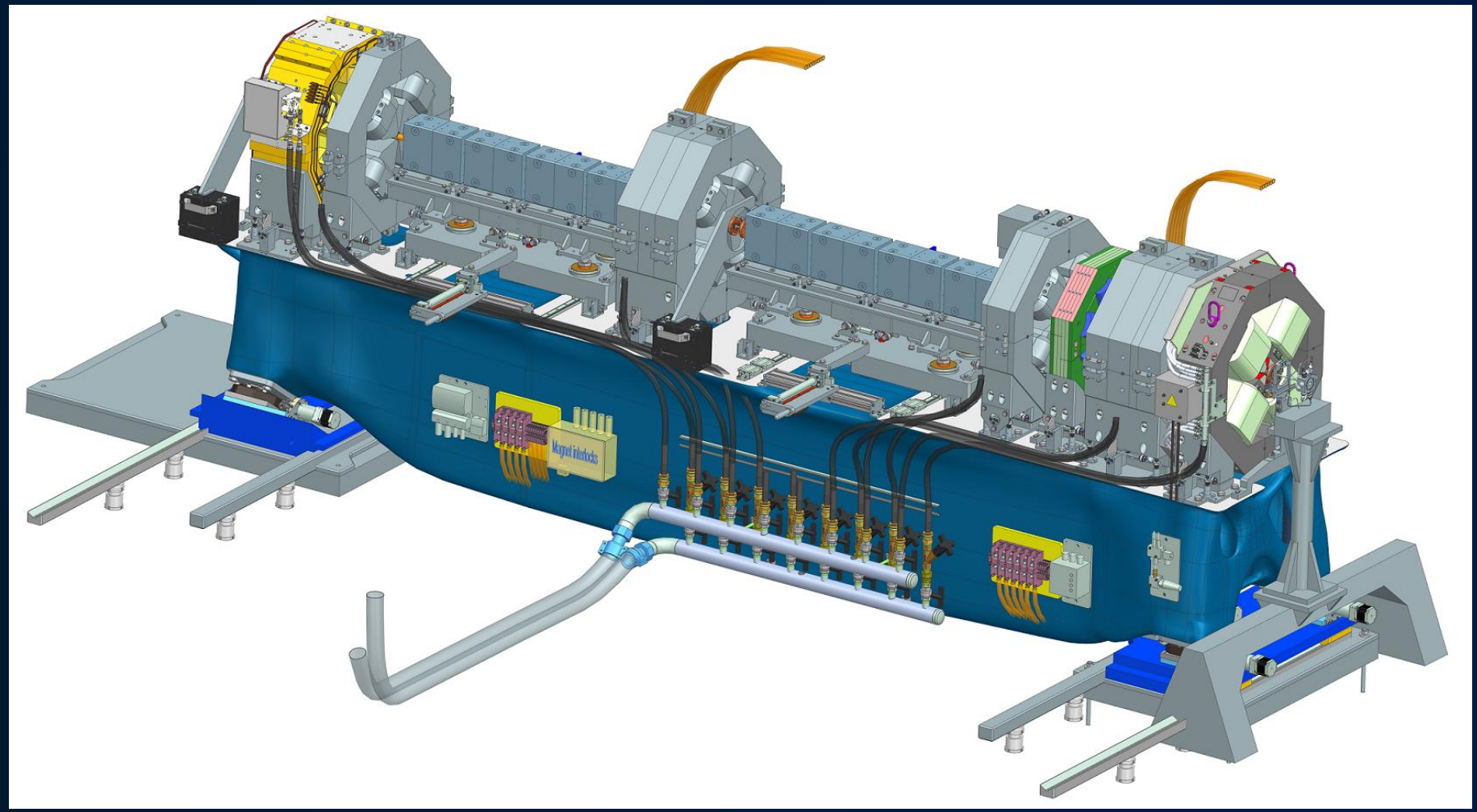
The most challenging subsystems have been prototyped

- alpha girder: casted at Coswig – visit 20/12/23
  https://syncandshare.desy.de/index.php/s/tescg9wJGbZKewC
- high gradient quadrupole PQA at SIGMAPHI
- Sextupole PSA on track at DANFYSIK
- All dummies for the TDR girder mock-up under production
  e.g. DLQ
- Cabin for magnetic measurements installed in Hall 2

PETRA IV Prototype Programme

Engineering integration progressing well

- More prototypes continue to arrive on site
- TDR girder mock-up assembly to start when girder pedestals and movers are on site: → August 2024



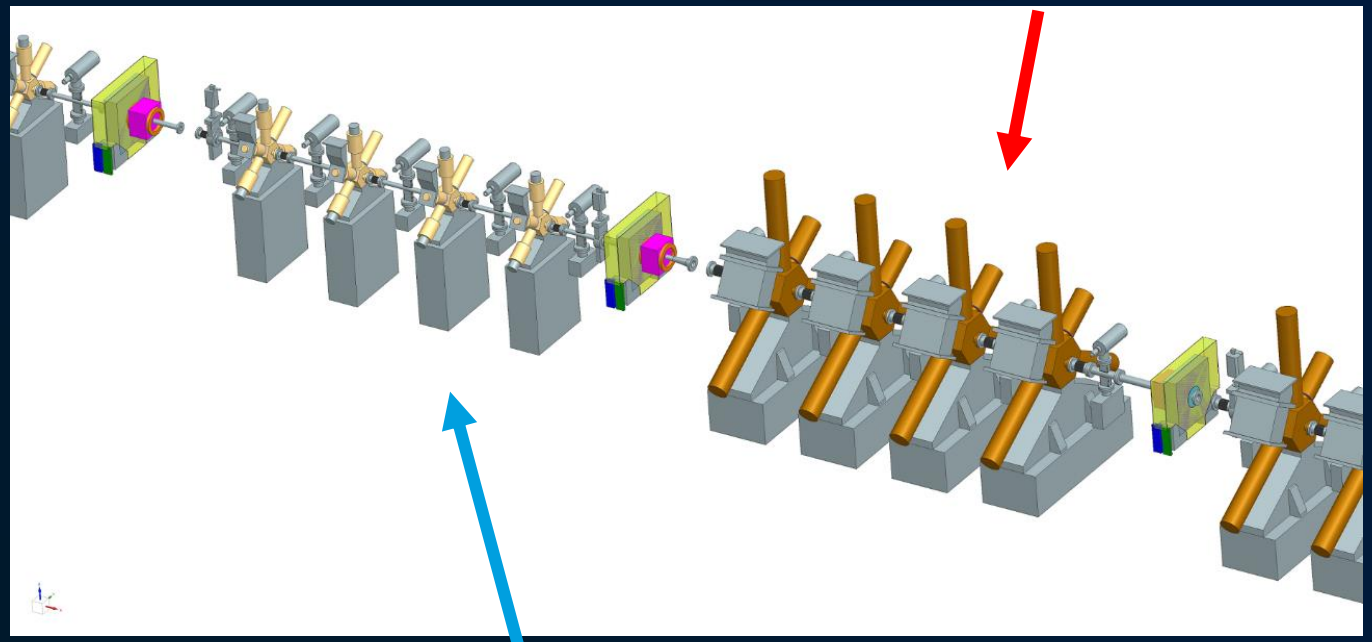
Talk by Normann Koldrack

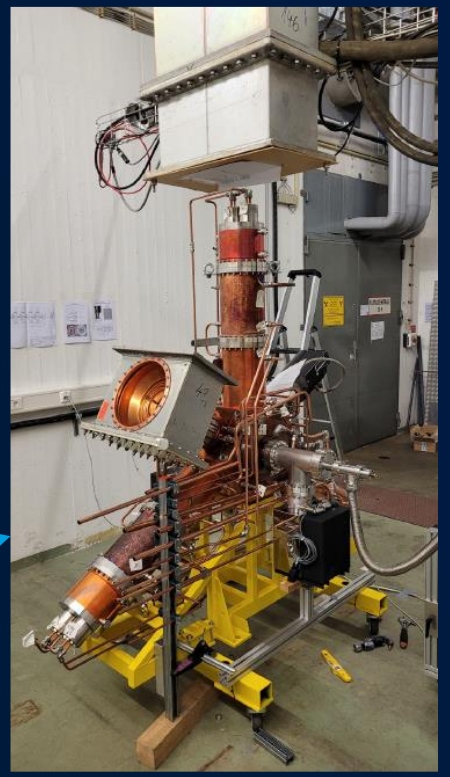
PETRA IV Prototype Programme

The RF system is designed – Prototypes are on-site and tested

- The RF system provides the RF power necessary to keep the beam at the right energy in the machine.
- It will be installed in the straight section (North) and contains

24 RF cavities: 500 MHz cavities





24 harmonic RF cavities: 1.5 GHz third harmonic cavities

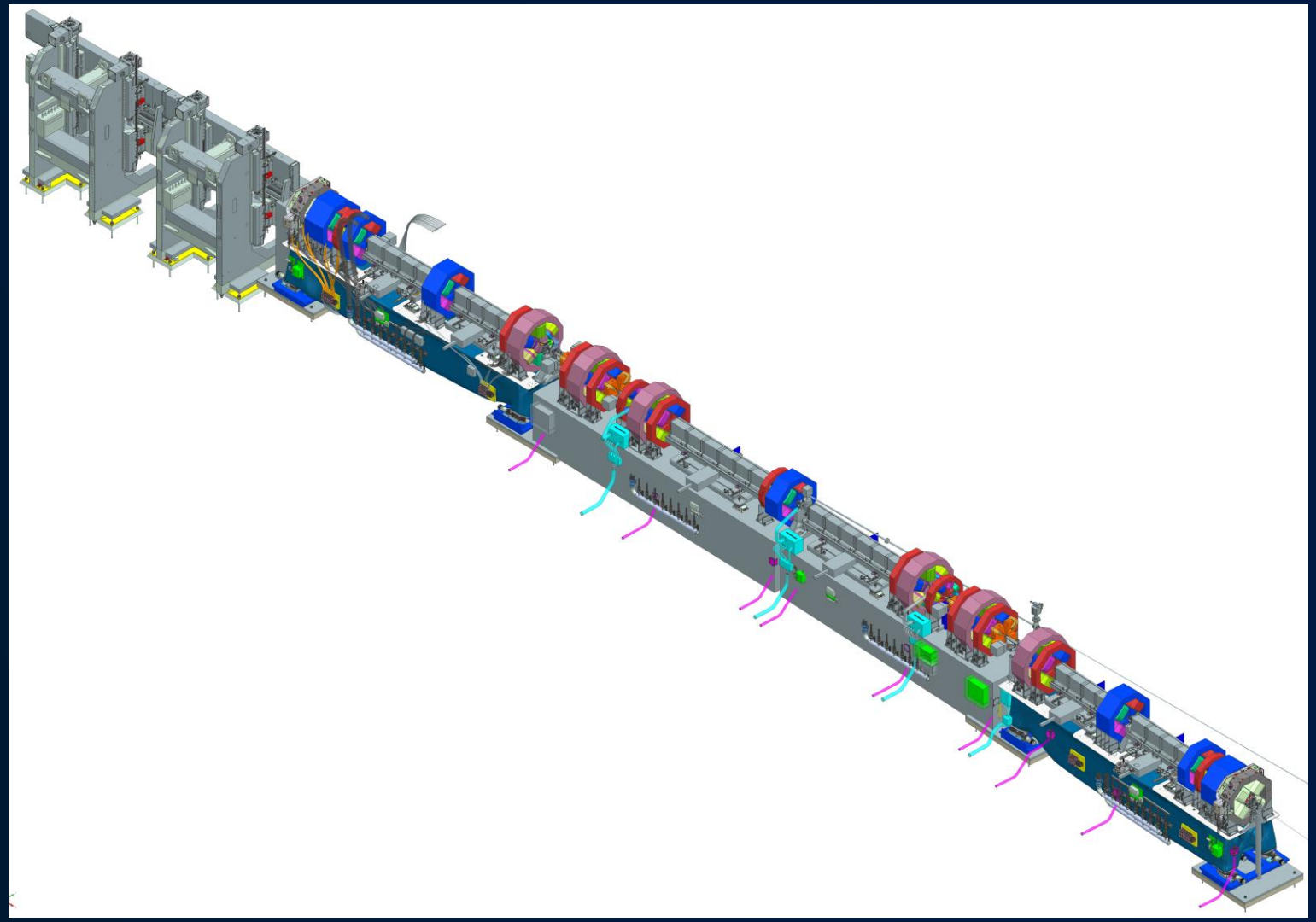
WP 1: PETRA IV Preparation – Accelerator Engineering Design

Prototyping for PETRA IV / WPG 2 (Accelerators) and PETRA IV / WPG 3 (Experiments)

3.5 M€ Investment

1.5 M€ Personnel

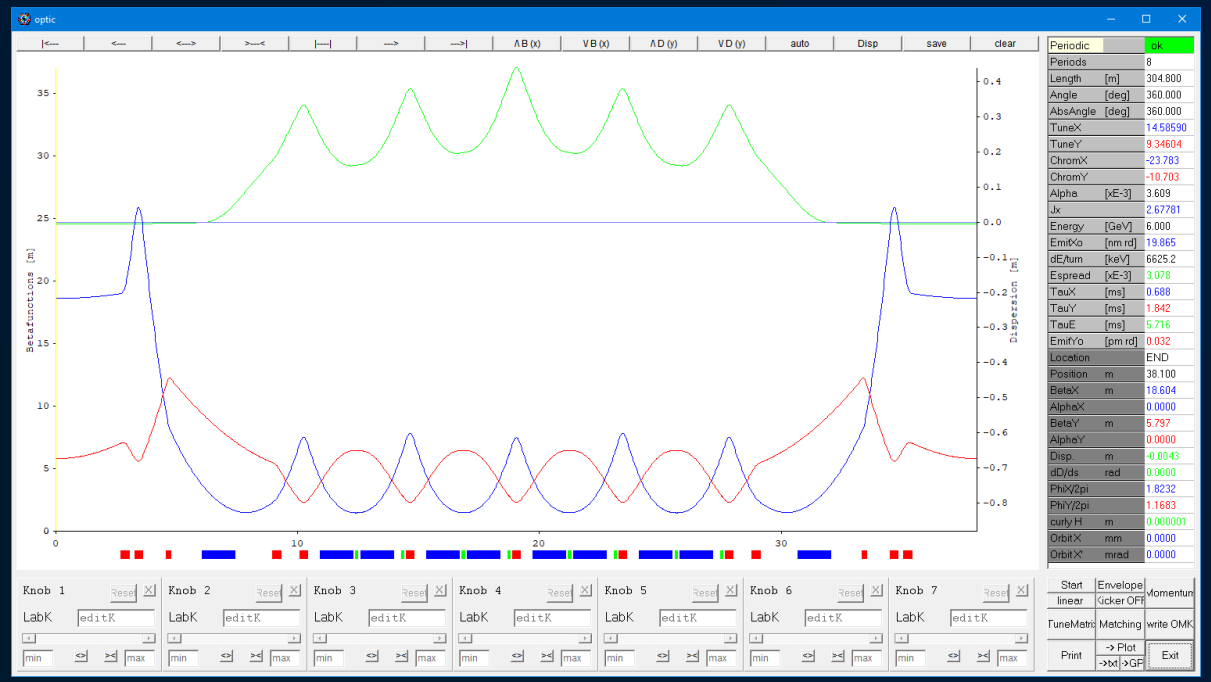
	Work Package	Item
WPG2	2.02 Magnets - Resistive	Slow / Fast Corrector
	2.02 Magnets - Resistive	Quadrupole PQD/PQE
	2.02 Magnets - Resistive	Benches: small equipment
	2.02 Magnets - PM	Variable gap damping wiggler (prototype)
	2.02 Magnets - PM	Bench for DLQ (to be reused for undulators?)
	2.02 Magnets - PM	Bench DW - stretched wire bench
	2.02 Magnets - PM	Cooperation ESRF (JC)
	2.02 Magnets - PM	8th module for DLQ
	2.02 Magnets - PM	DLQ prototype
	2.04 Vacuum Systems	NEG Coating and Chamber Prototypes
	2.05 Diagnostics	Stripline BPM Detector
	2.05 Diagnostics	BPM electronics and feedthroughs prototypes
	2.05 Diagnostics	BPM mechanics prototypes
	2.06 Girders	Mock-up TDR steel plates
	2.07 Alignment	Acceleratometer
	2.08 Feedbacks	Electronic development - Fast-corrector test stand - Essential
	2.08 Feedbacks	Electronic development - Additional
	2.11 Magnet Power Supplies	FOFB cables prototyping
	2.11 Magnet Power Supplies	Test system for hot-swap
	2.11 Magnet Power Supplies	Electronic racks testa, water cooled
	2.11 Magnet Power Supplies	Prototype power supply for FOFB
	2.12 RF Systems	Shintake cavity prototype including SSA
	2.12 RF Systems	Low-level RF test system
	2.12 RF Systems	Circulator for main RF
	2.12 RF Systems	cleaning booster cavities
	2.14 Injection and Extraction	Prototype dump kicker
WPG3	3.03 Ultra-Precision Mechanics	Parts for SPIDER
	3.03 Ultra-Precision Mechanics	Parts for CRL-Transfocator
	3.04 Nano-Optics	Budget for lens polishing studies (external partners)
	3.04 Nano-Optics	Budget for lens polishing studies (internal studies, parts)
	3.04 Nano-Optics	Laser objective/instrumentation for pinhole manufacturing
	3.04 Nano-Optics	Instrumentation in-vacuum coherence sensor prototype
	3.04 Nano-Optics	Instrumentation in-vacuum wavefront sensor prototype



DESY IV Lattice

The DESY IV lattice has been revisited

The Beam Physics group provided lattices for all options with equivalent performance to the baseline DESY IV:
From hexagonal to octogonal symmetry to follow the floor layout with better compatibility for the test beamlines



Parameter	3h3l-v8 ceiling	Option 3 Intermediate
Circumference C	316.8 m	304.8 m
Nat. emittance $\varepsilon_{x,0}$	19.0 nm	19.0 nm
Tune Q_x/Q_y	17.37 / 12.15	15.18 / 8.27
Nat. chromaticity ξ_x/ξ_y	-41.7 / -13.8	-24.4 / -10.9
MCF α_c	$3.2 \cdot 10^{-3}$	$3.2 \cdot 10^{-3}$
Hor. damp. par. nr. J_x	2.56	2.29
Rel. energy spread σ_E	$2.6 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$
Energy loss/turn ΔE	6.5 MeV	6.6 MeV

DESY IV parasitic operation for testbeamlines

discussion ongoing on the required modification to the baseline operation:
ramped 5Hz for top-up, followed by CW operation for test beamlines

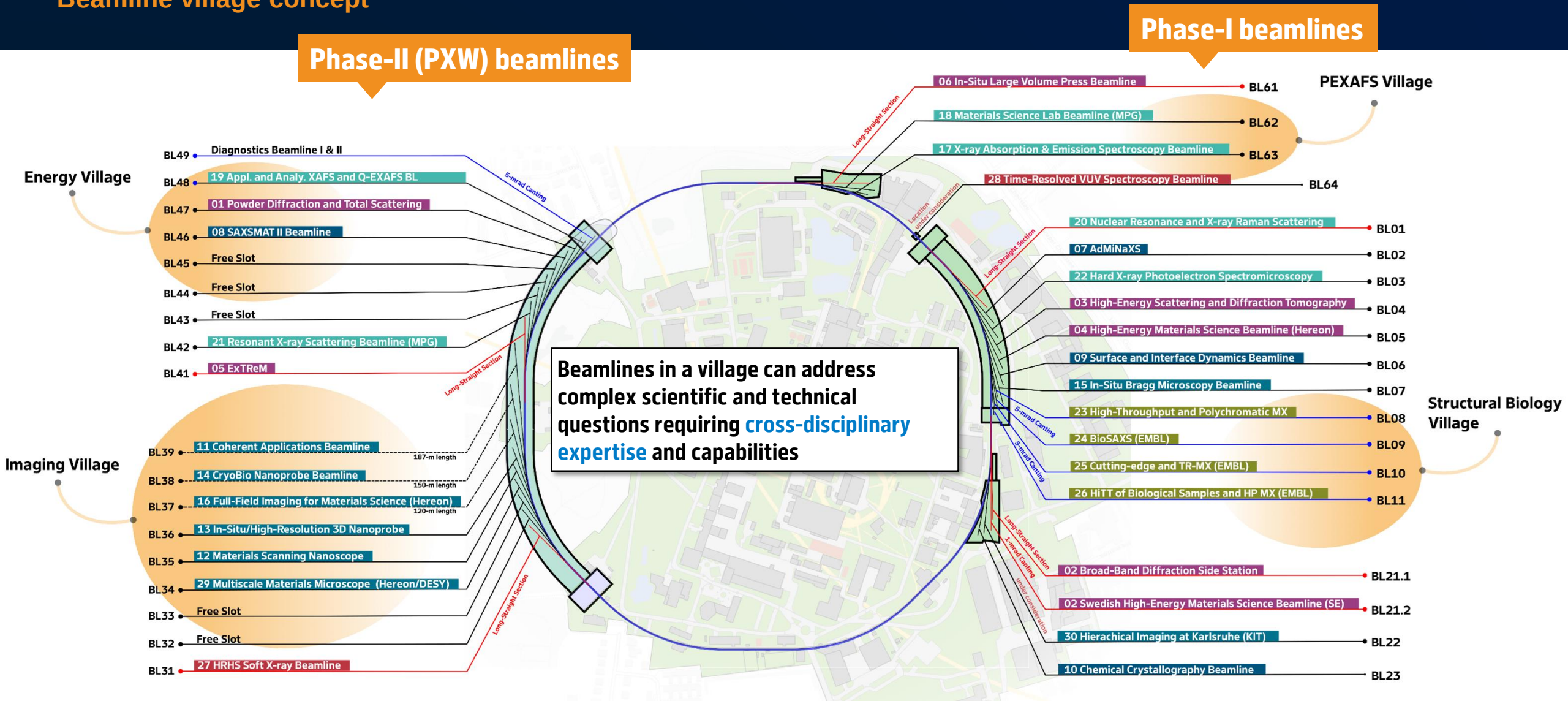
PETRA IV Beamline Programme

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

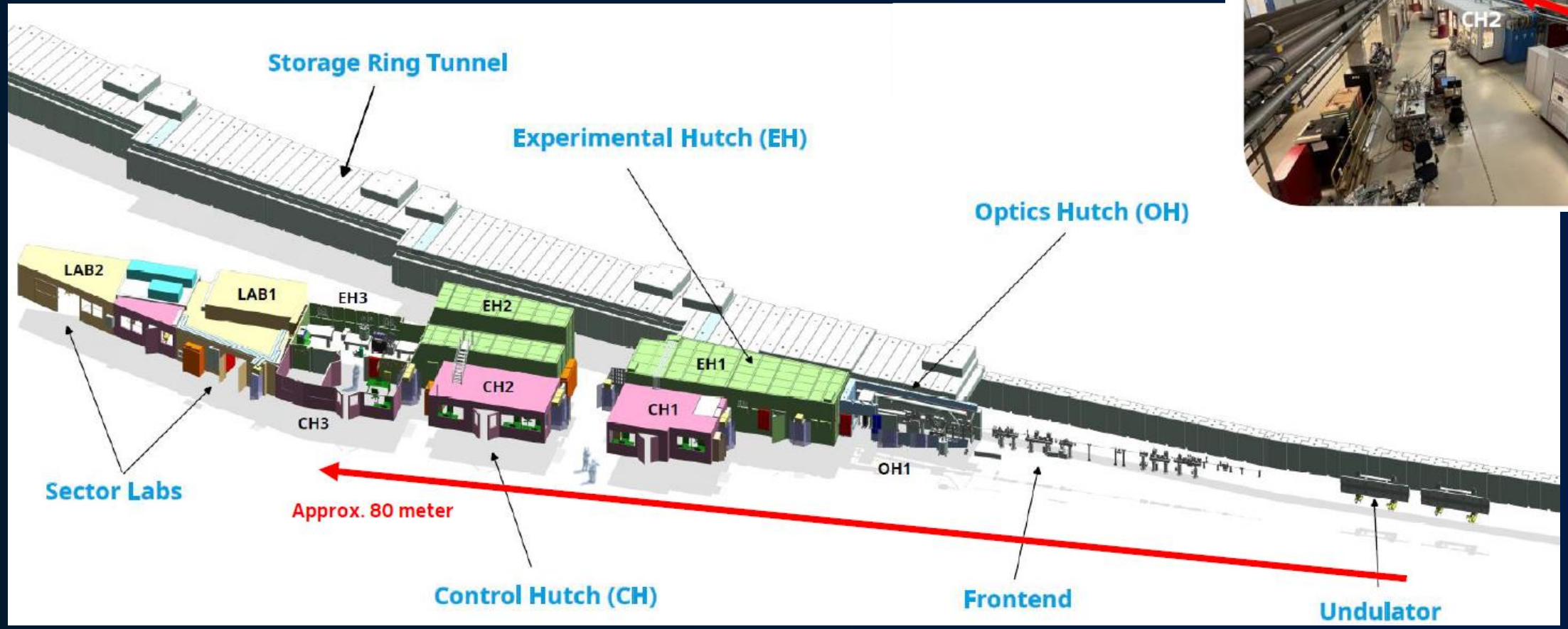
PETRA IV – Beamline Portfolio

Beamline village concept



PETRA IV – Beamline Portfolio Development

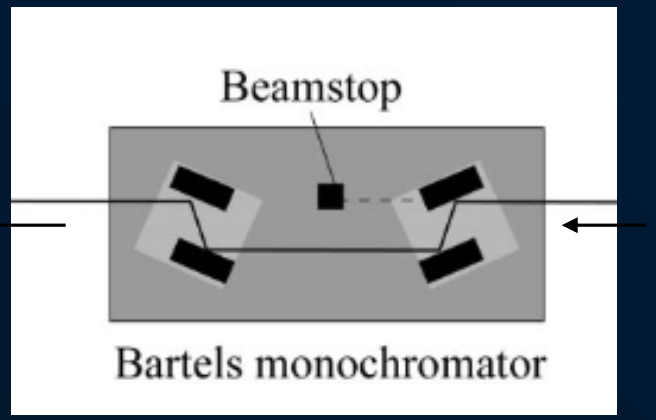
Beamline Conceptual Design – translate the excellent source properties into experiments



PETRA IV – Beamline Technology

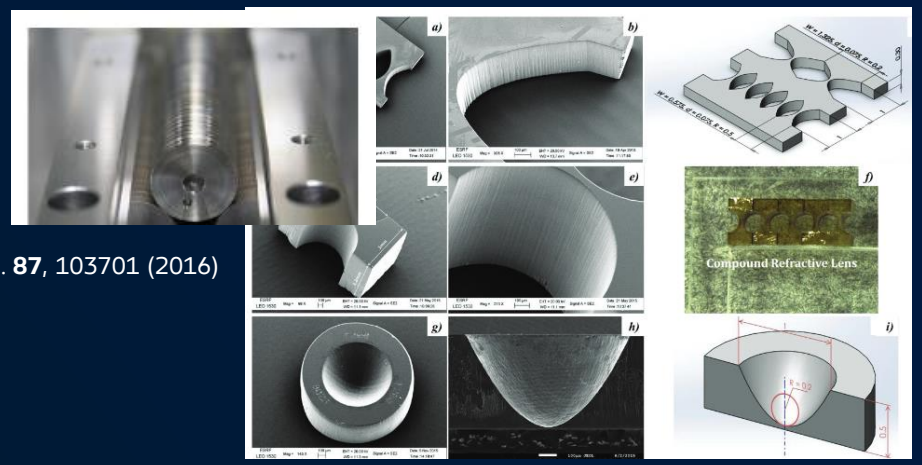
Enhanced Beamline Capabilities

4-bounce monochromator



D. Lübbert et al., Acta Cryst. (2004). D**60**, 987-998

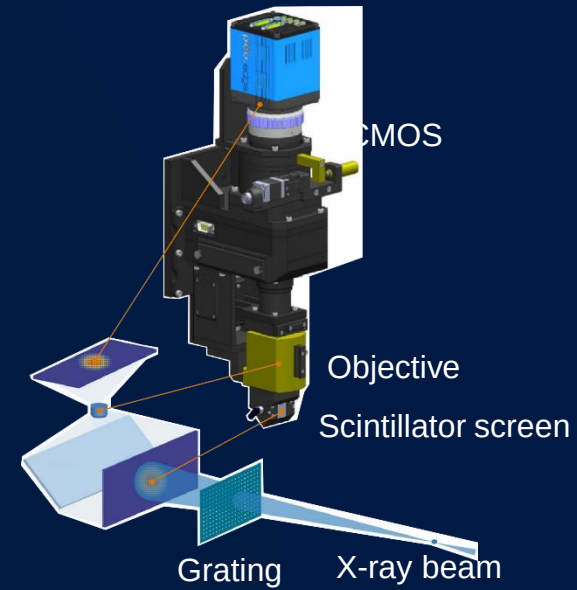
Diamond CRLs and Lens changer



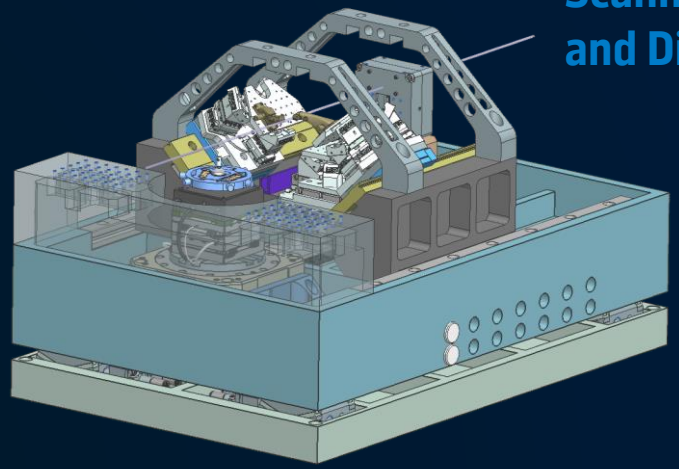
B. Nagler et al.
Rev. Sci. Instrum. **87**, 103701 (2016)

M. Polikarpov et al.,Physics Procedia **84** (2016) 213 – 220

Wavefront Sensor



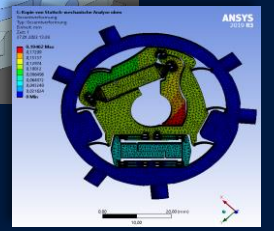
Scanning Platform for Imaging and Diffraction with Extreme Resolution



SPIDER-Project

QSP-Project

PI-Rest Actuators



PETRA IV – List of Major Items

Buildings/Infrastructure
Experimental Hall West (PXW)
Supply Buildings
RF Hall
Refurbishment of a large number of Buildings

- 39 New buildings & building extensions
- 11 Existing buildings to be refurbished
- 28 Buildings to be demolished
- 4 refrigeration plants
  (13 MW water cooling)
- Air handling systems (8 MW)
- Expansion of power supply network
- Renewal and/or expansion of IT networks
- 2400 Electronic racks

New Accelerator structures
LPA injector
DESY IV Booster synchrotron
H6BA PETRA IV storage ring
Transfer lines

- 2300 Resistive magnets (SR)
- 300 Resistive magnets (Booster)
- 432 Permanent magnet dipoles
- 288+6 Girders
- 48 RF cavities
- 48 (SR) + 9 (Booster) SSAs
- 1250 Vacuum chambers
- 1000 Vacuum pumps
- 5000 power supplies
- 10 Kickers & HV pulsers 10
- 4 septa
- BPMs, Diagnostics, etc.

Experiments
16 new beamlines
10 completely refurbished beamlines
5 partially refurbished beamlines

- 34 Insertion Devices
- 102 Hutches
- 20 Monochromators
- 41 Transfocators
- 26 Mirror systems
- 22 KB systems
- 39 Pixel detectors
- 35 Other detectors
- 62 Endstations
- 445 BL control electronics elements (ZMX, MicroTCA, Timer, NIM, ADC)
- Large amount of IT hardware