PETRA IV.
NEW DIMENSIONS

PETRA IV Planning & Opportunities

Industry opportunities at light source infrastructures , LEAPS Big Science Supplier Forum, 1 December 2023

Harald Reichert

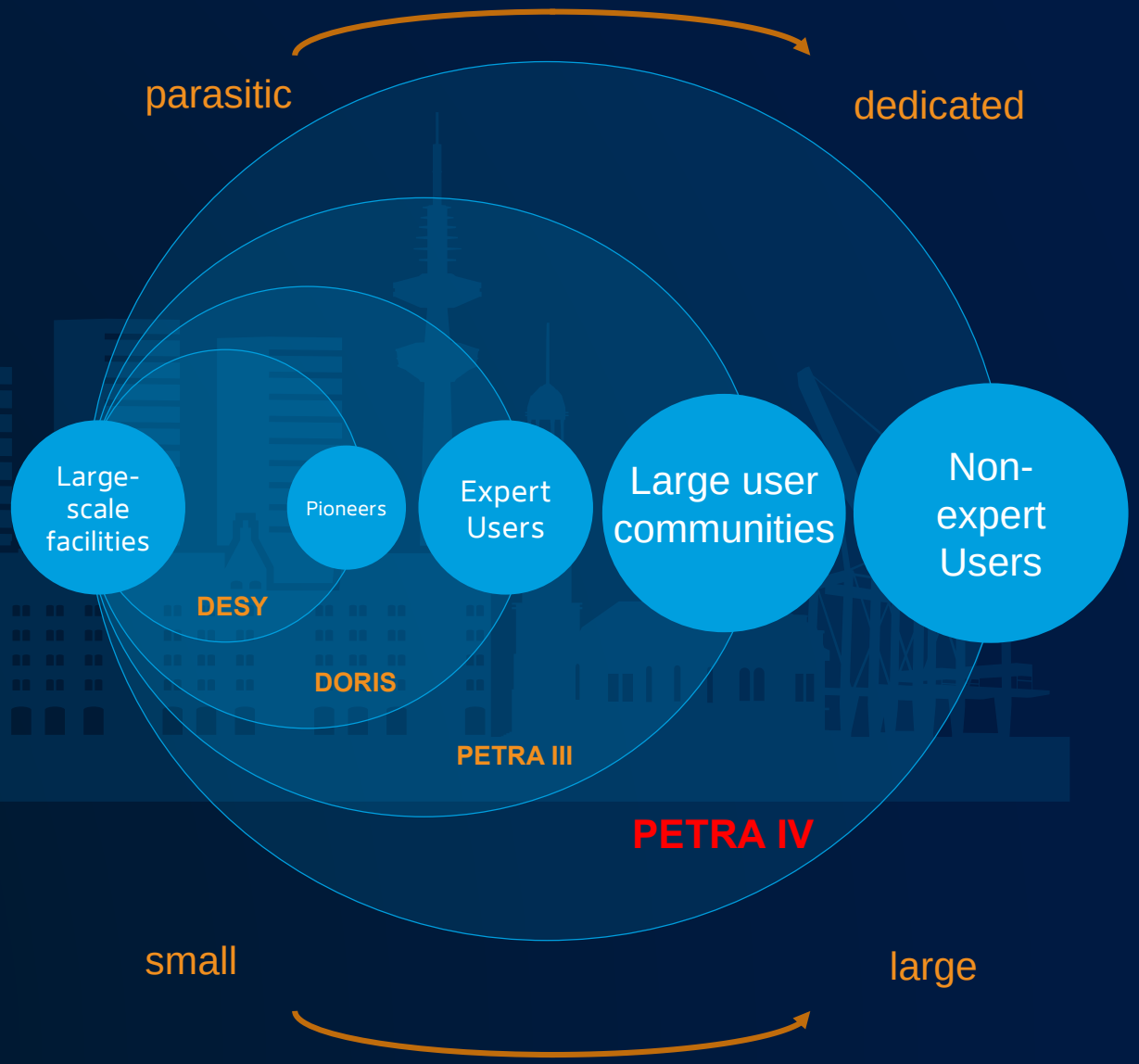
Project Leader PETRA IV

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

The Evolution of Synchrotron Radiation Sources at DESY

From basic science to broad application – crucial backbone infrastructure

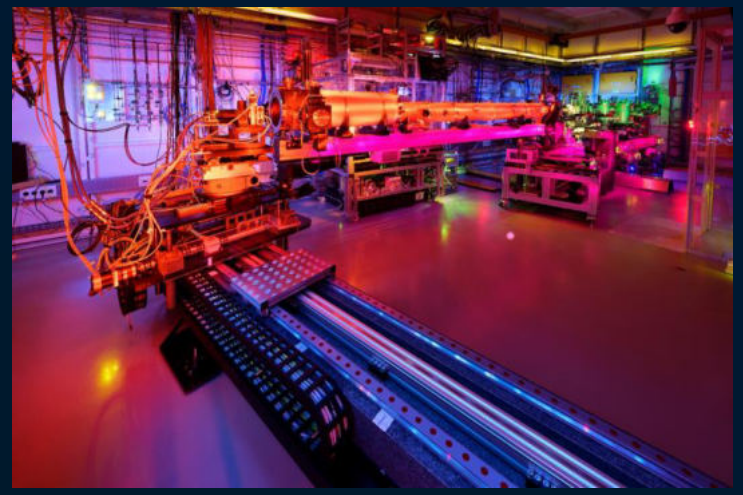


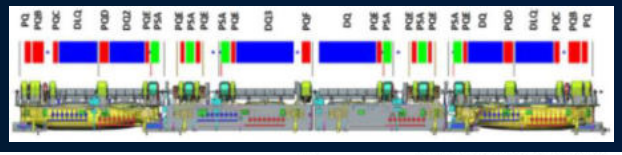
PETRA IV Project

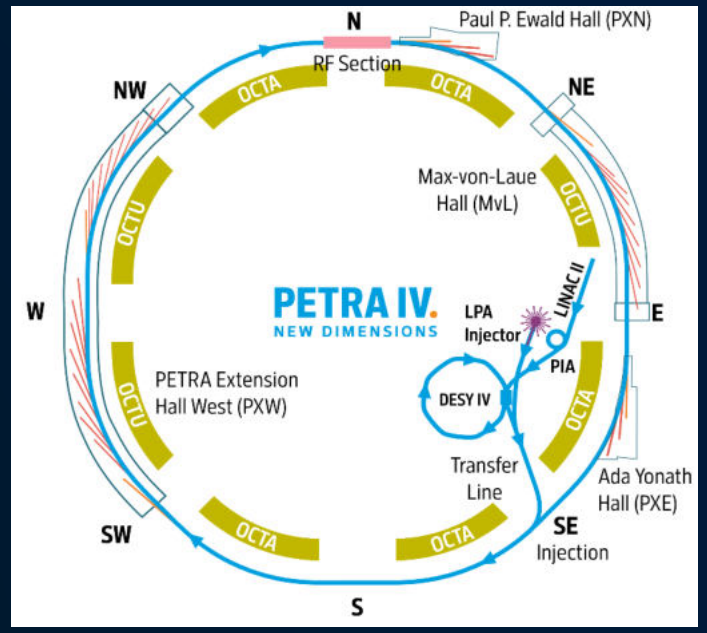
Extension/Refurbishment of the existing infrastructure, accelerator complex, and experimental facilities

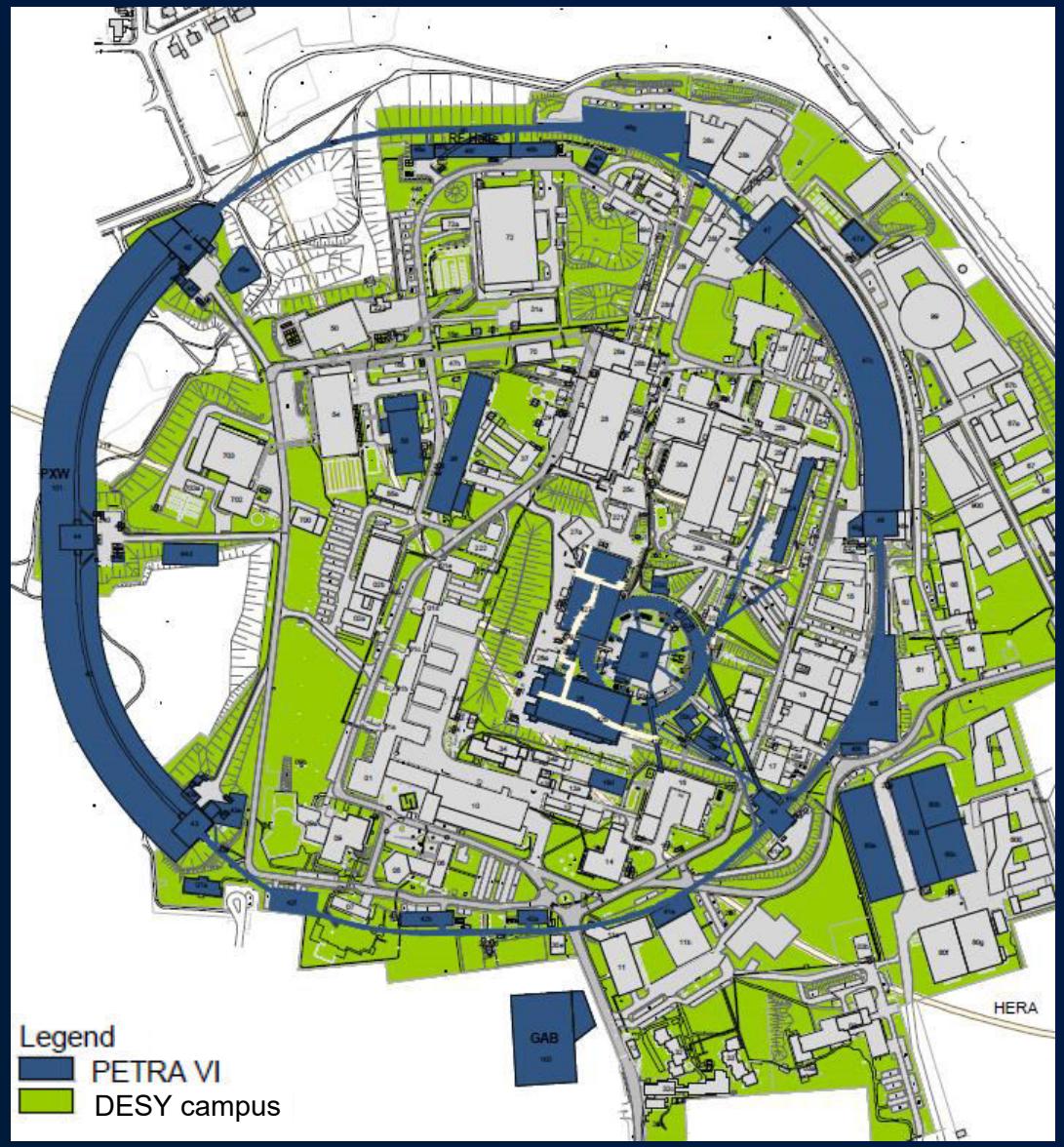
Baseline design is fixed and costs have been assessed and reviewed on that basis

Increase in performance by a factor of 500

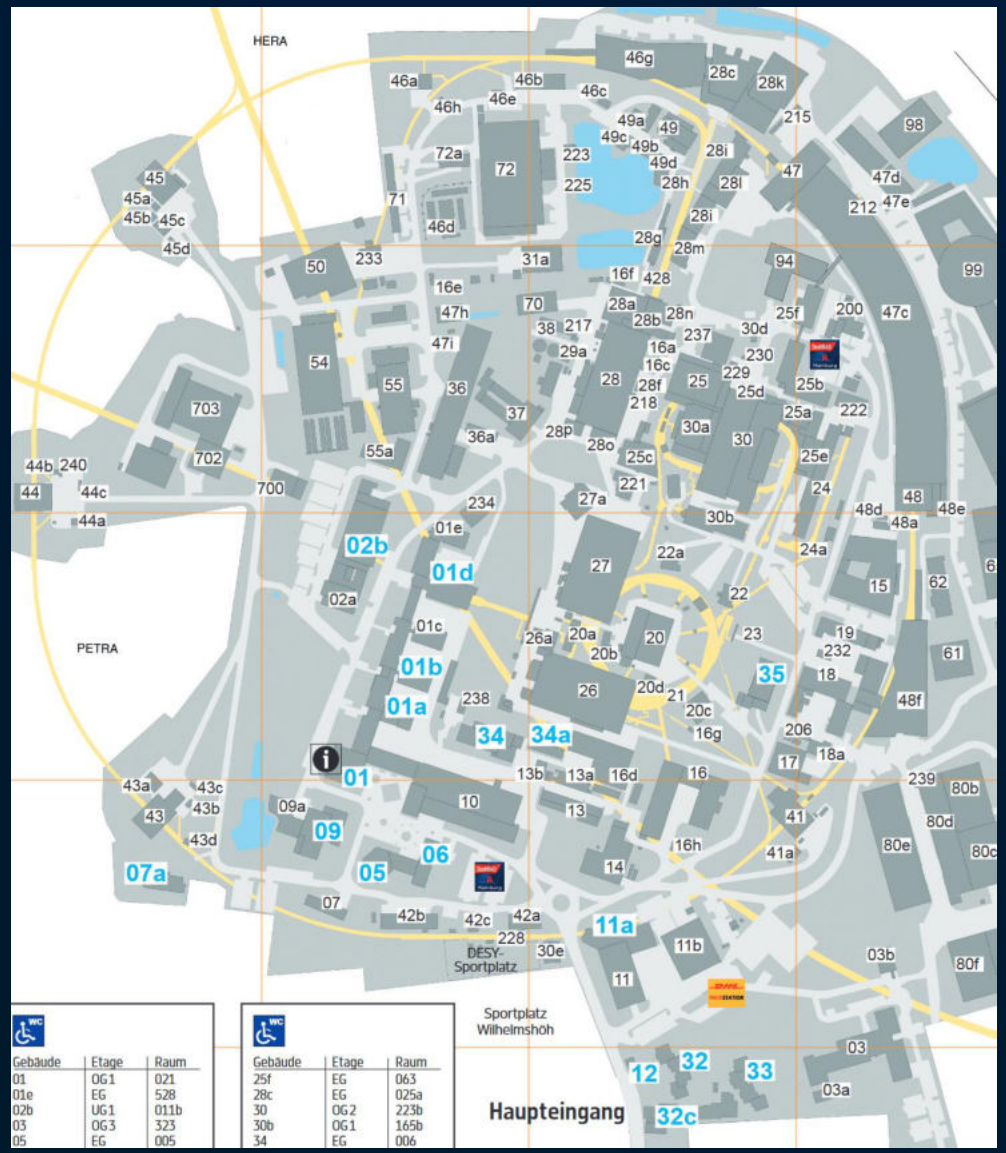








PETRA IV – Civil Construction



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 – Civil Construction

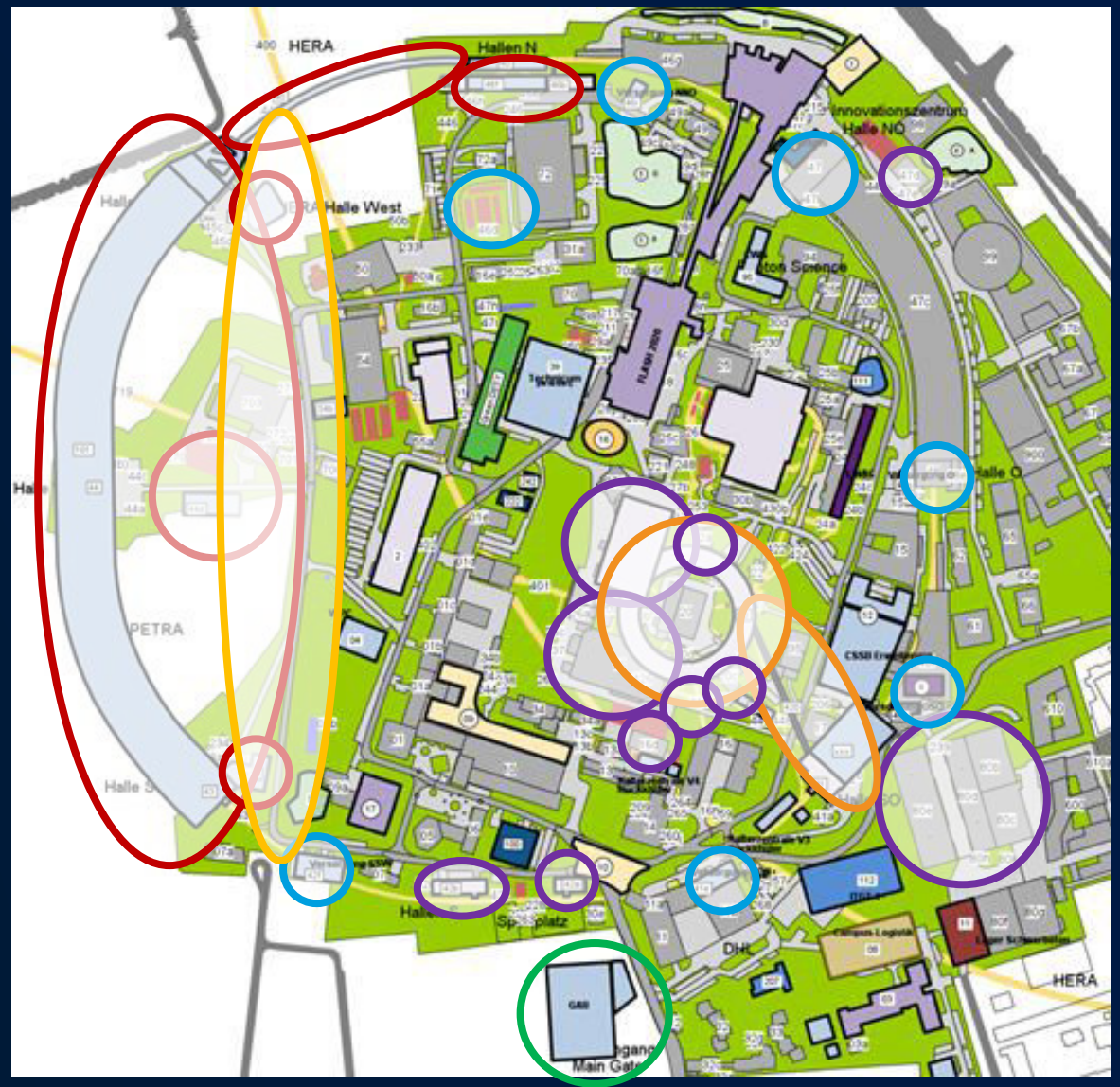
Civil construction programme (status end of March 2023)

organised in 11 packages

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

+ Works under the responsibility of the City

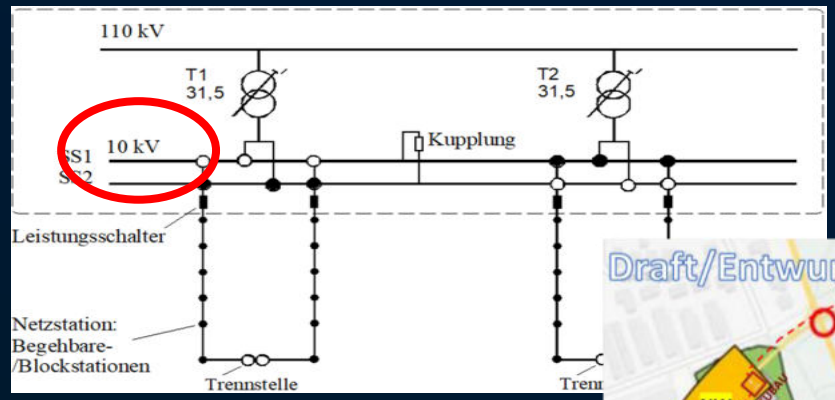
- Relocation of the biotopes
- Replacement of sports facilities
- Reconstruction Lise-Meitner-Park



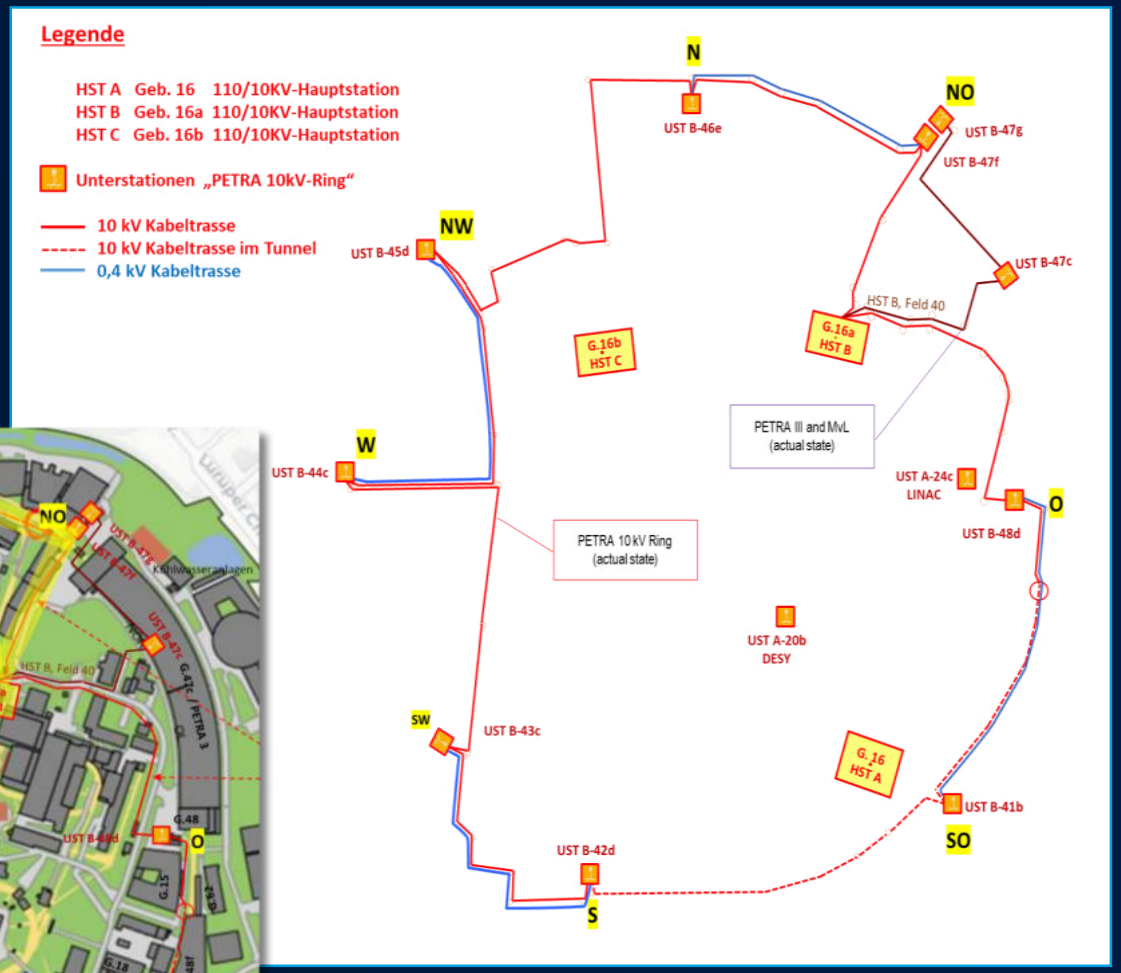
PETRA IV – Power Supply

Main power lines

3 110 kV power lines supply the DESY Campus



Power supply via 10 kV Ringleitung



PETRA IV / PXW Erschließung/ development

HST A Geb. 16 110/10kV-Hauptstation
HST B Geb. 16a 110/10kV-Hauptstation
HST C Geb. 16b 110/10kV-Hauptstation

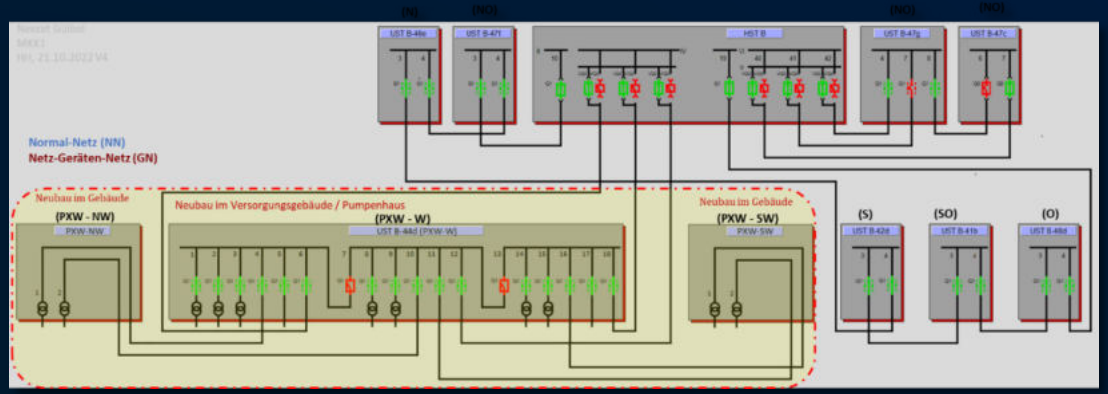
Unterstationen „PETRA IV 10kV-Ring“

10 kV Kabeltrasse
10 kV Kabeltrasse (PXW-Ringversorgung)
10 kV Kabeltrasse im Tunnel
0,4 kV Kabeltrasse

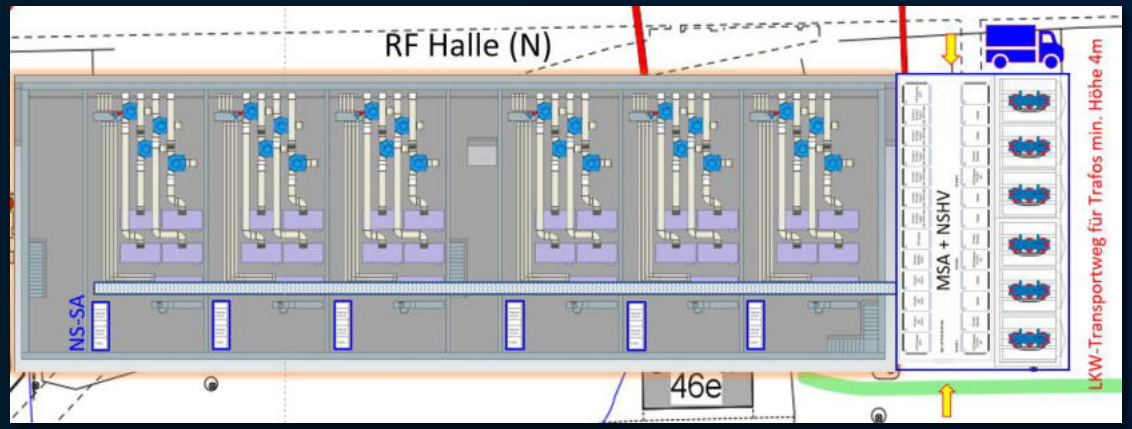
PETRA IV – Power Supply

Main supply areas

PETRA IV PXW sub-station



Power supply for the RF-System



Power supply organised aggregated supply areas

PETRA IV – Power Supply

New Installations & Refurbishments

Power consumption (peak power)

Area	PETRA III	PETRA IV
Offices	100 kW	150 kW
Laboratories	150 kW	300 kW
Experimental Floor	400 kW	800 kW
Air Cooling	500 kW	1.700 kW
Water Cooling	6.000 kW	11.600 kW
Magnets	3.000 kW	3.200 kW
RF	3.000 kW	3.300 kW
DESY, PIA, LINAC	2.000 kW	2.000 kW
Diagnostic	250 kW	700 kW
Vacuum Systems	200 kW	600 kW
Total	15.650 kW	24.350 kW

Electricity supply units and their condition

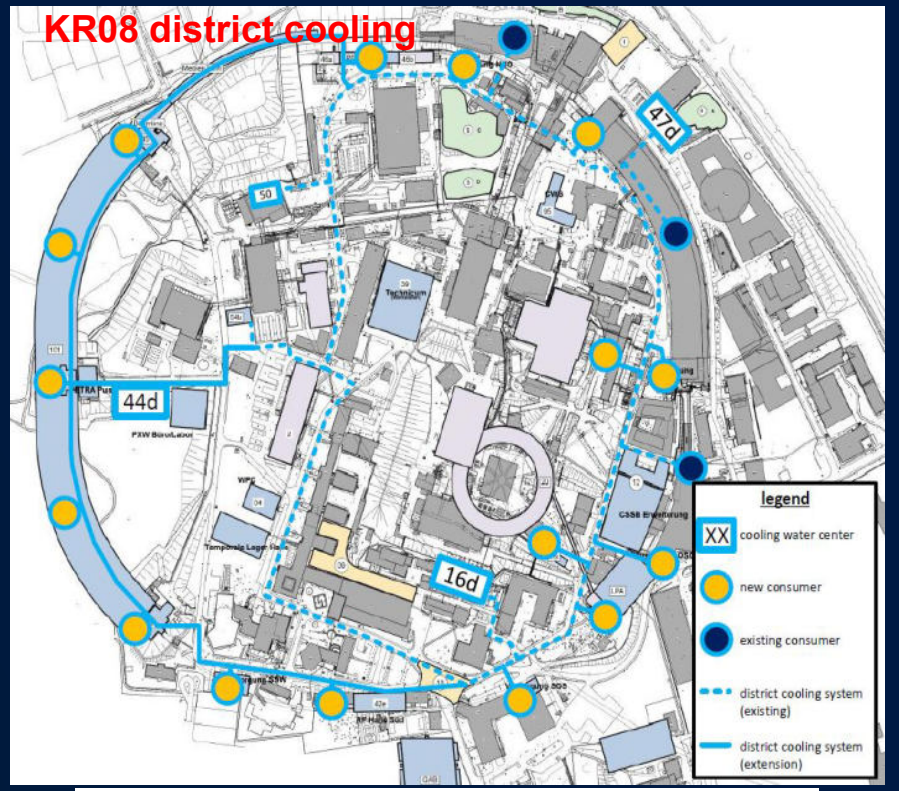
Equipment	Year	Quantity	Condition	Action
Substations (MVSB)	1995 – 2008	2	aceptable	replace later, modifications
Diesel Generator	1998	1	aceptable	replace later, modifications
Transformers	1962 – 1969	10	not ok	replace now
	1977 – 1996	4	aceptable	replace later, modifications
	2020 – 2021	4	ok	replace later, modifications
Main Distribution (LVSB)	2008	9	ok	Small modifications
Sub Distribution (LVSB)	1966	73	not ok	replace now
	2008 – 2022	24	ok	Small modifications

PETRA IV – Water Cooling

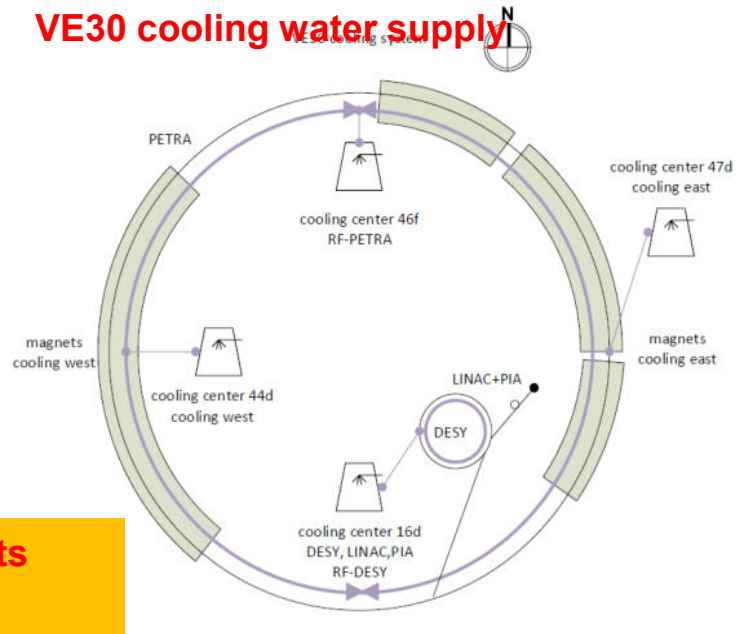
Povision of 6 different cooling water qualities

water type acronym	consumer stakeholder	temperature (inlet)	water quality	piping materials
cooling water VE30	magnets, RF, magnet power supplies, vacuum system	30 °C	deionized water electr. conductance: < 1 µS/cm BTGA 3.003	stainless steel copper red brass
chilled water ALU25	Undulators	25 °C	deionized water electr. conductance: < 1 µS/cm BTGA 3.003	stainless steel aluminum
chilled water KW20	server racks	20 °C	BTGA 3.003	stainless steel copper red brass
chilled water VE20	laboratories experiments	20 °C	deionized water electr. conductance: < 1 µS/cm BTGA 3.003	stainless steel copper red brass
chilled water RLT KW09	AC units	9 °C	BTGA 3.003	stainless steel copper red brass
district cooling KR08	district cooling/ campus distribution	8 °C	BTGA 3.003	carbon steel copper red brass

KR08 district cooling



VE30 cooling water supply



4 separate refrigeration plants (16d, 44d, 46f, 47d)

PETRA IV – HVAC

District heating

Connection to the external district heating netwerk

DESY local district heating supply

- Primary district heating circuit (55 to 105 °C)
- Secndary district heating circuits (50 °C)

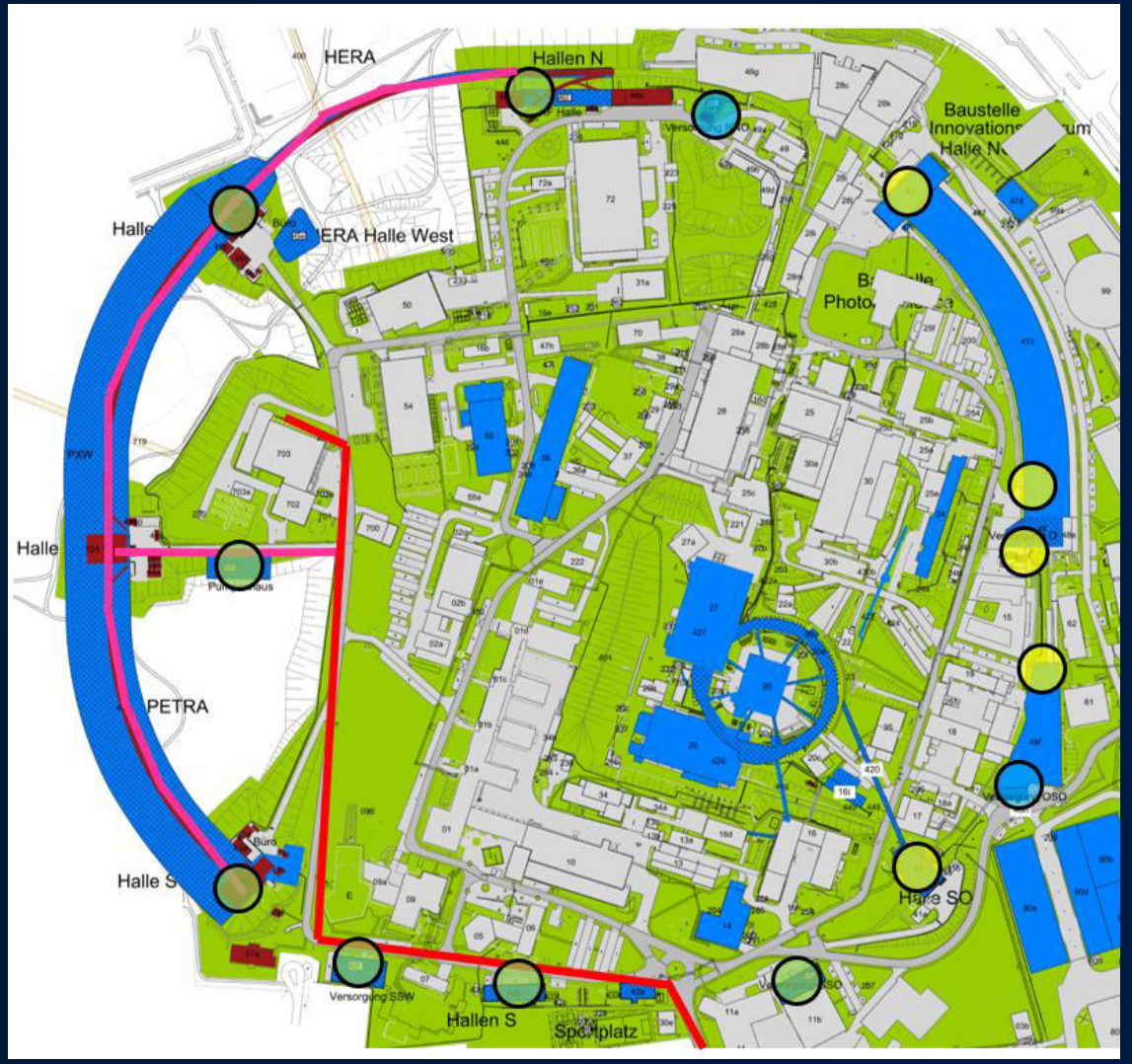
Existing district heating distribution – available for PETRA IV

New district heating connections for PETRA IV (low-T)

Newistrict heating circuits für PETRA IV (high-T)

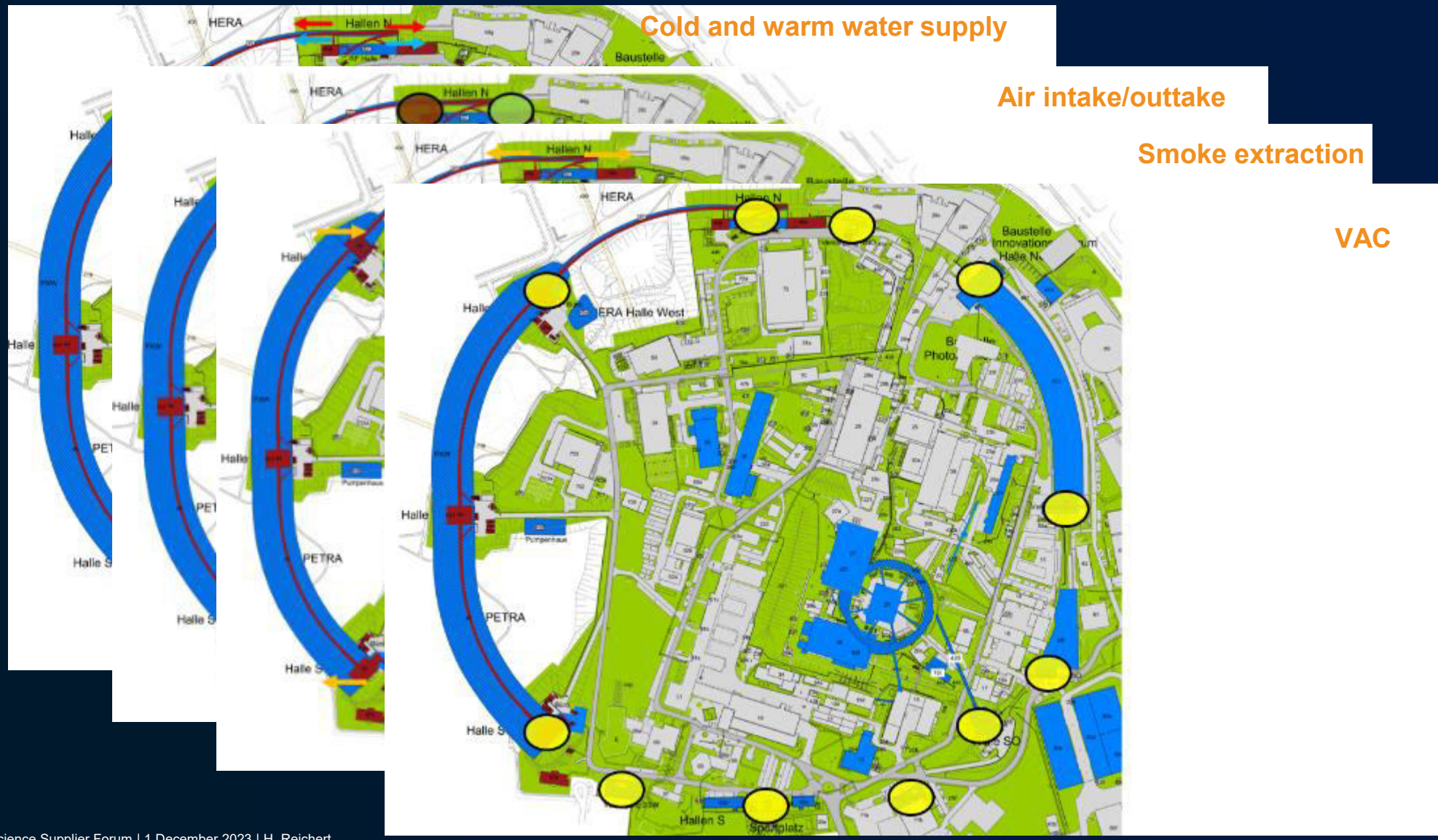
Extension of the low-T network

District heating connection from XFEL to Campus South



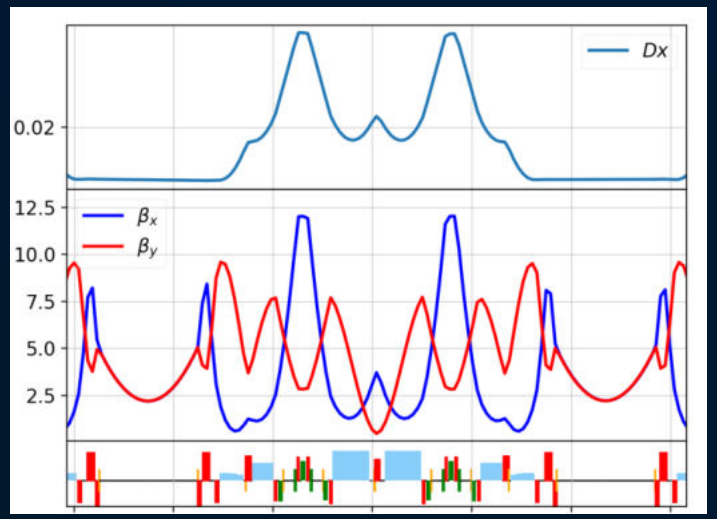
PETRA IV – HVAC

Water and fresh air supply

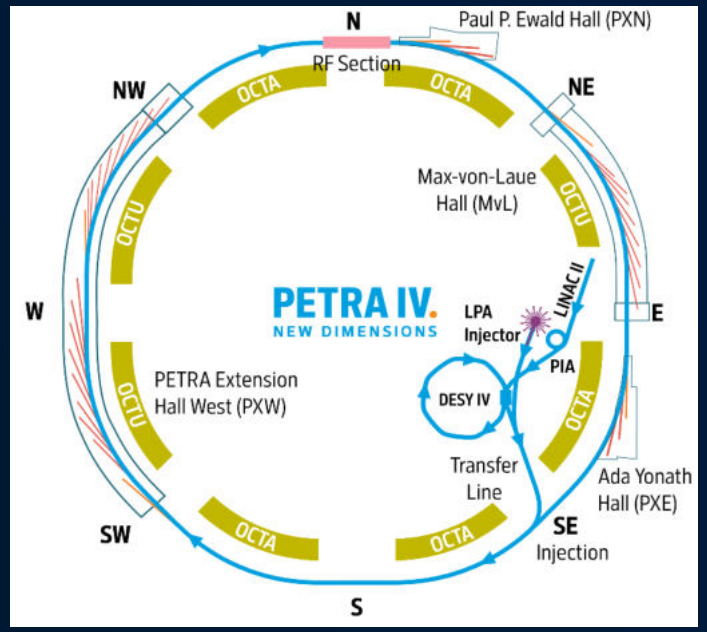


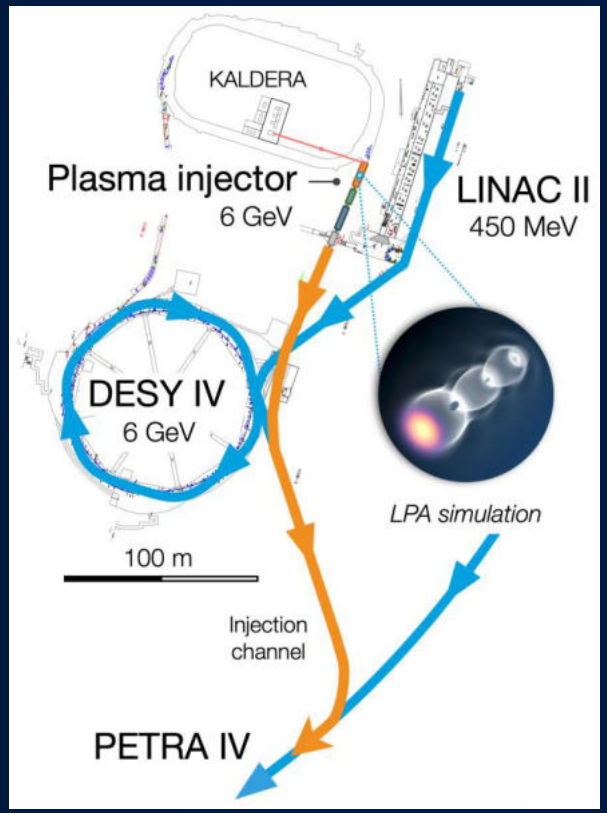
Accelerator Complex – PETRA IV Lattice Design in Place

Lattice with novel H6BA unit cell (design frozen) that is replicated identical across all octants (72 cells)



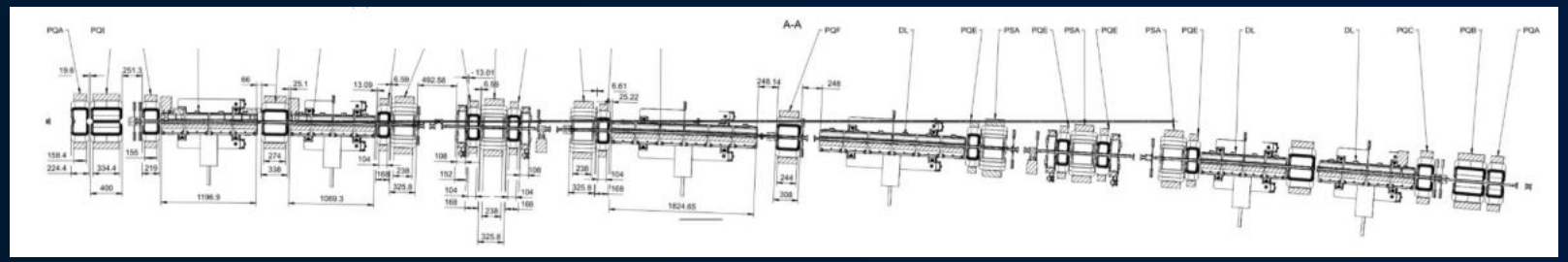
20 x 4 (pm·rad)²

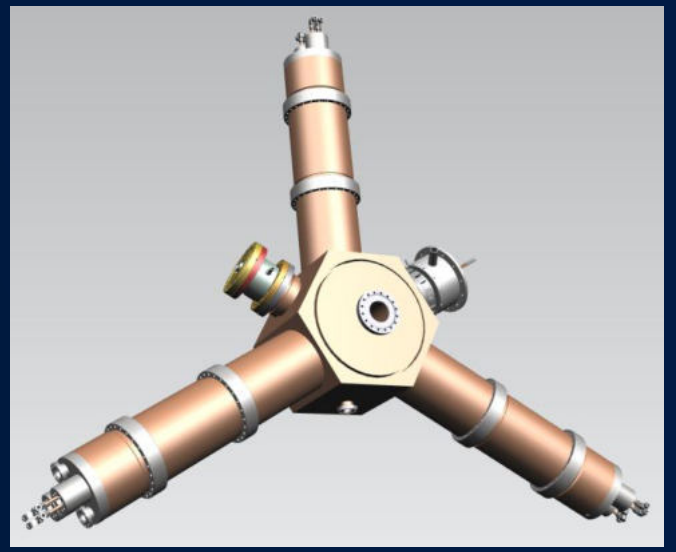


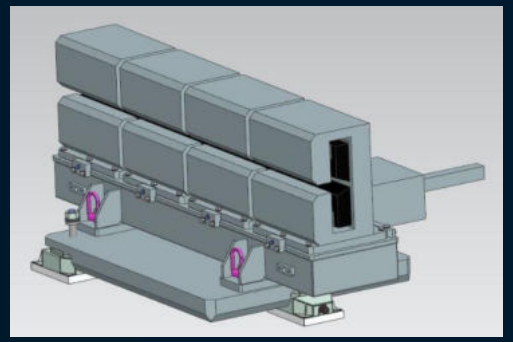


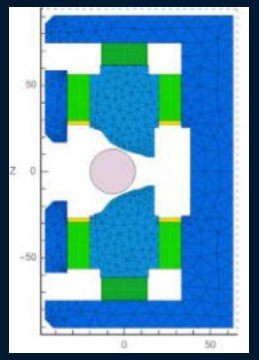
Accelerator Engineering Design

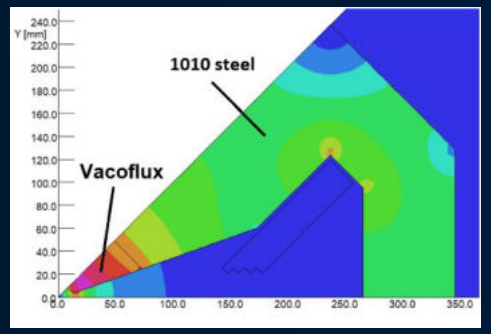
Engineering design is progressing well and the prototyping/testing programme is ongoing

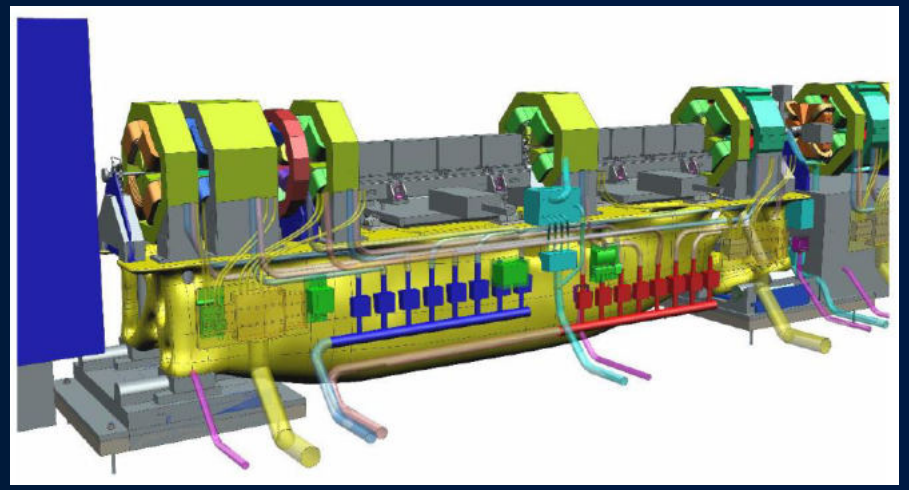










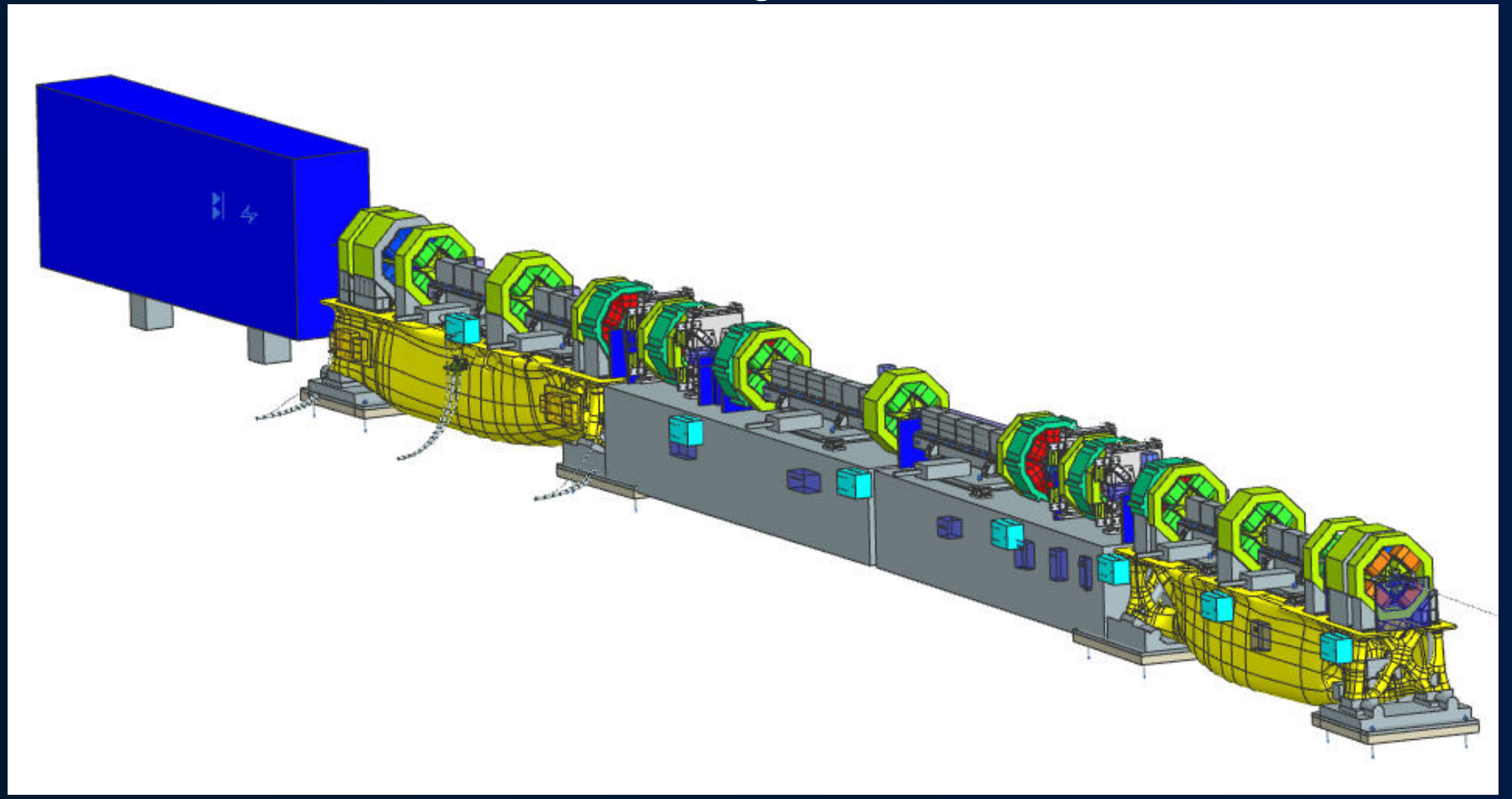


Accelerator Engineering Design

The accelerator components are mounted on girders

„Girder“ refers to the full assembly with magnets, vacuum string, cables, pipes and auxiliaries

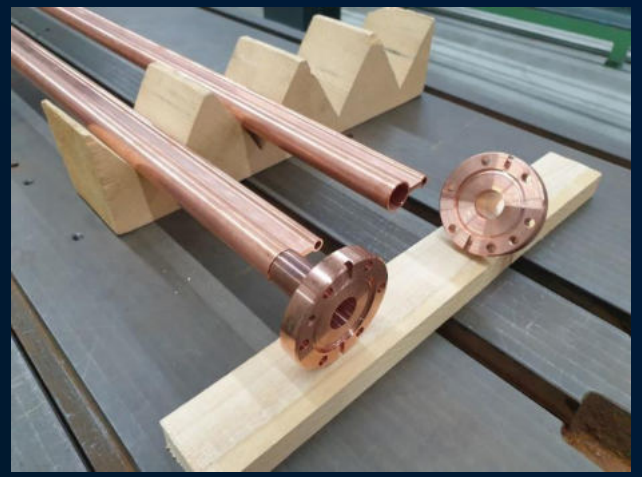
The total number of girders is 8*9*4=288

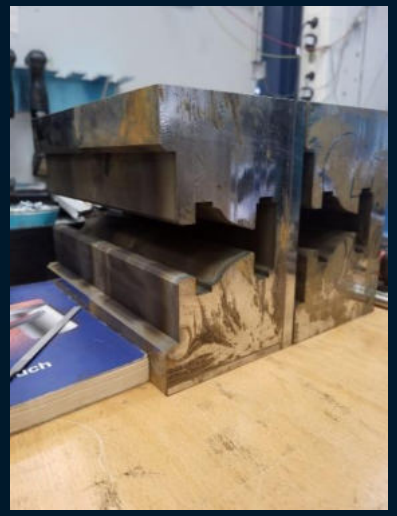


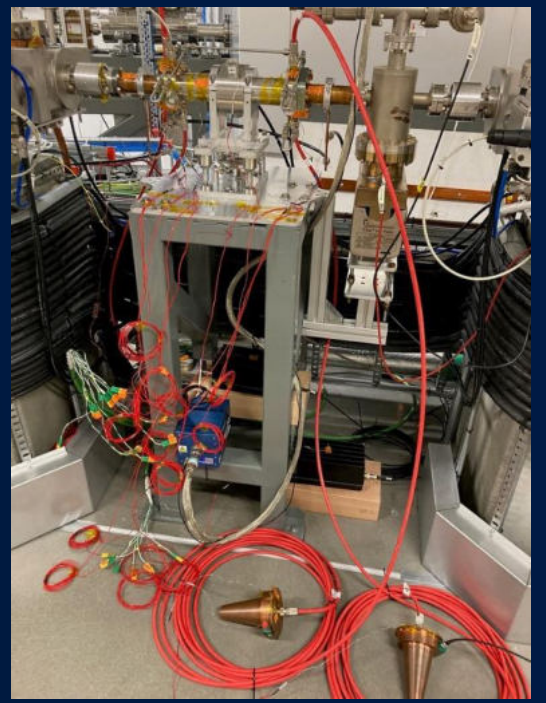
Prototyping is underway

Very large number components:

- ~ 4000 magnets & power supplies
- ~ 1000 vacuum chambers
- ~ 1000 pumps
- ~ 2400 racks
- 48 RF cavities



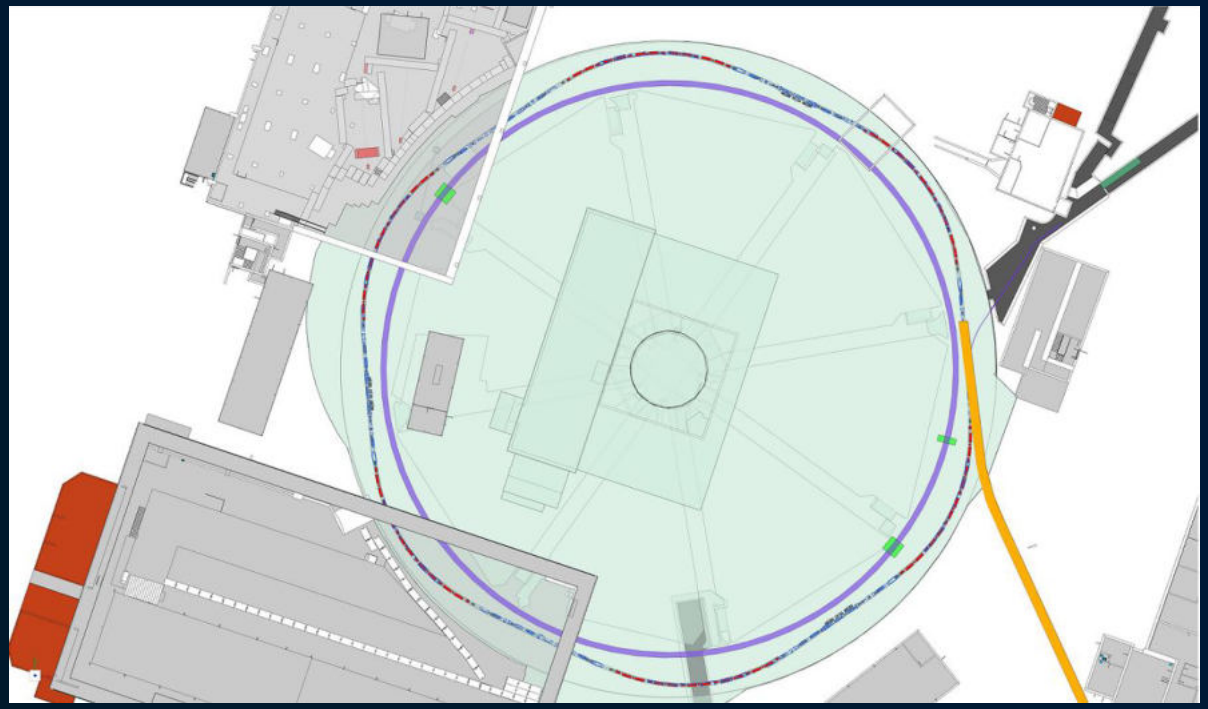




DESY IV Booster Synchrotron

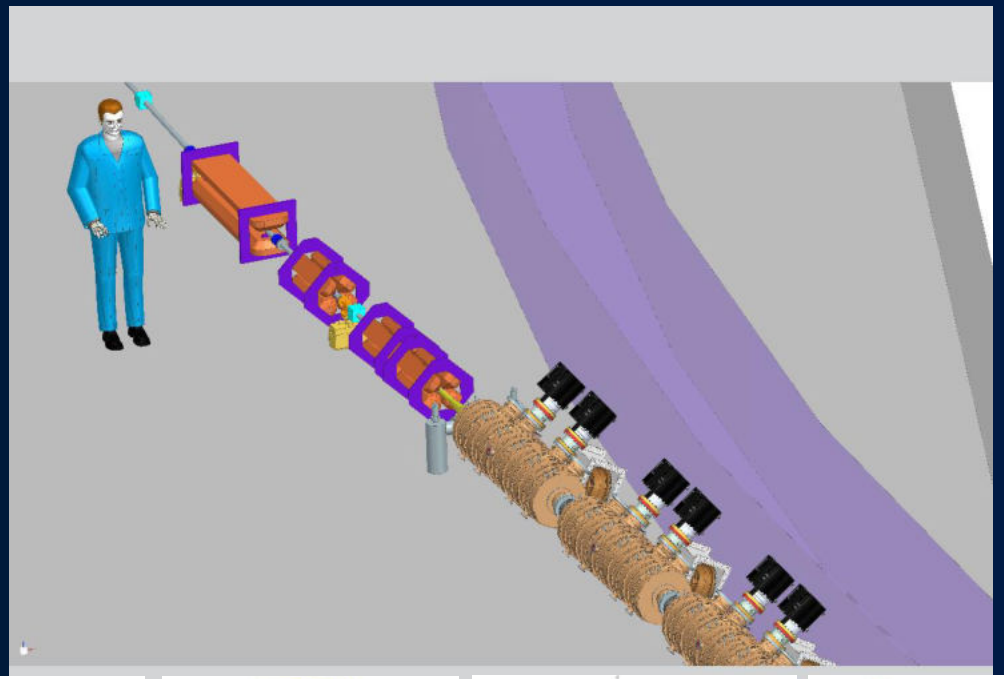
Construction of the new booster DESY IV for injection into PETRA IV

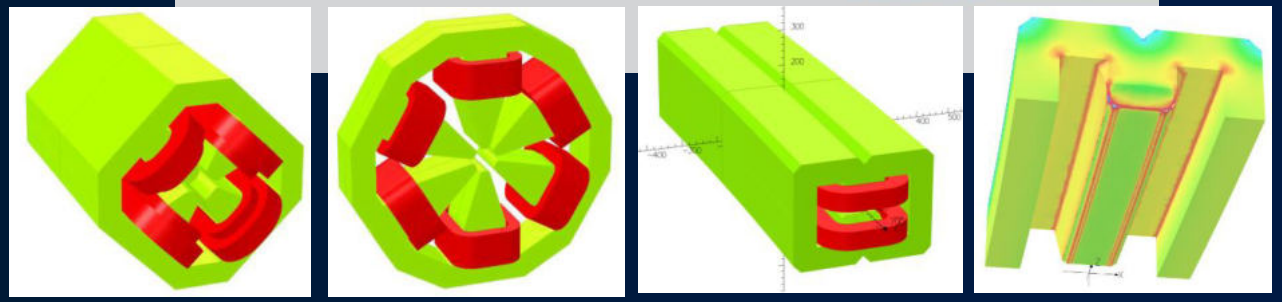
The lattice was frozen last year with a design delivering 20 nm – 1 nC single bunch operation reusing the LINAC-II and PIA ring



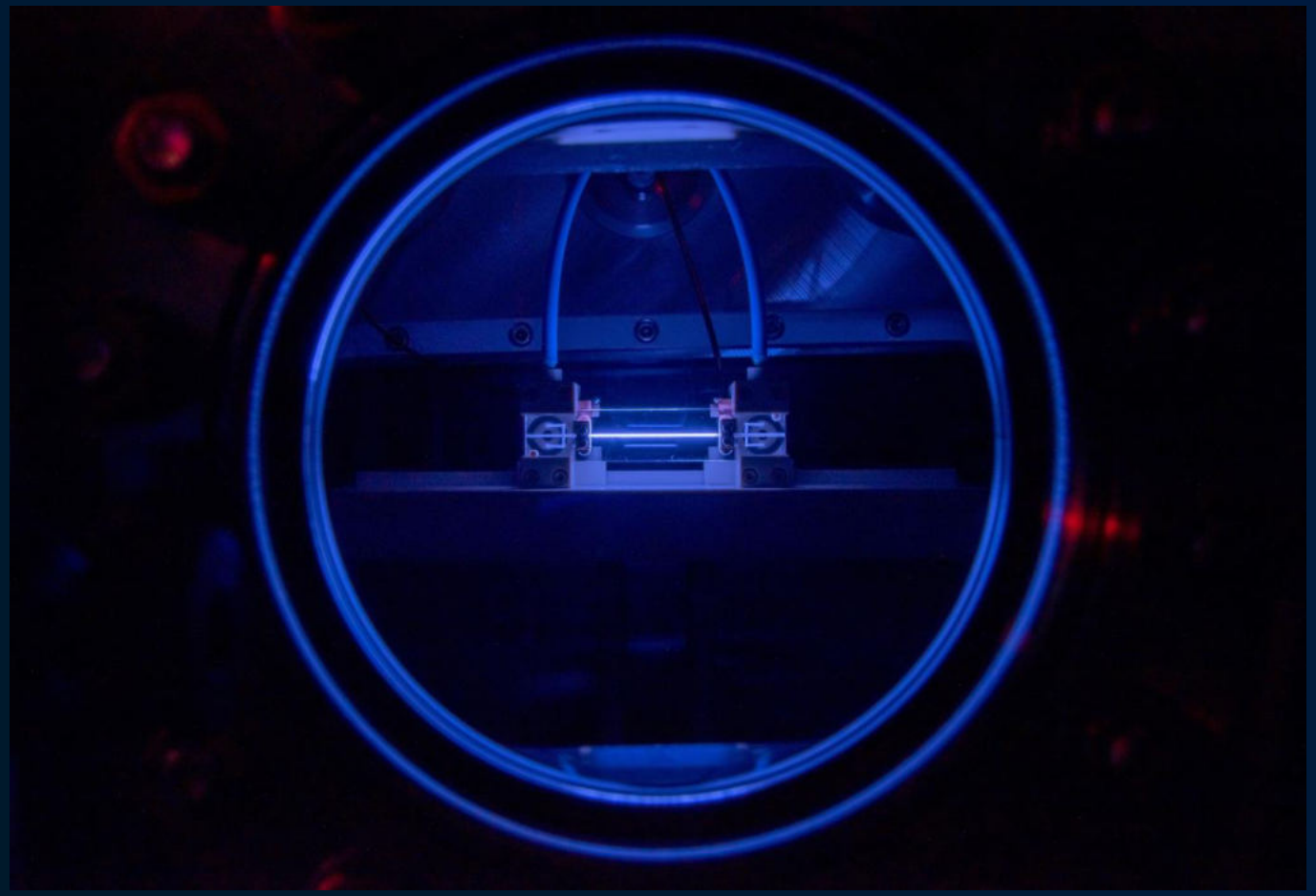
The DESY IV booster (316.8m) has
252 magnets and ***9 RF cavities***

System design and CAD integration



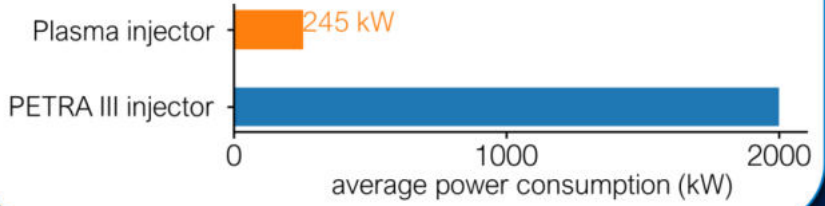


PIP4 – Laser Plasma Injector for PETRA IV



Why?

- Compact
  - plasma injector + beamline: < 50 m
- Cost-effective

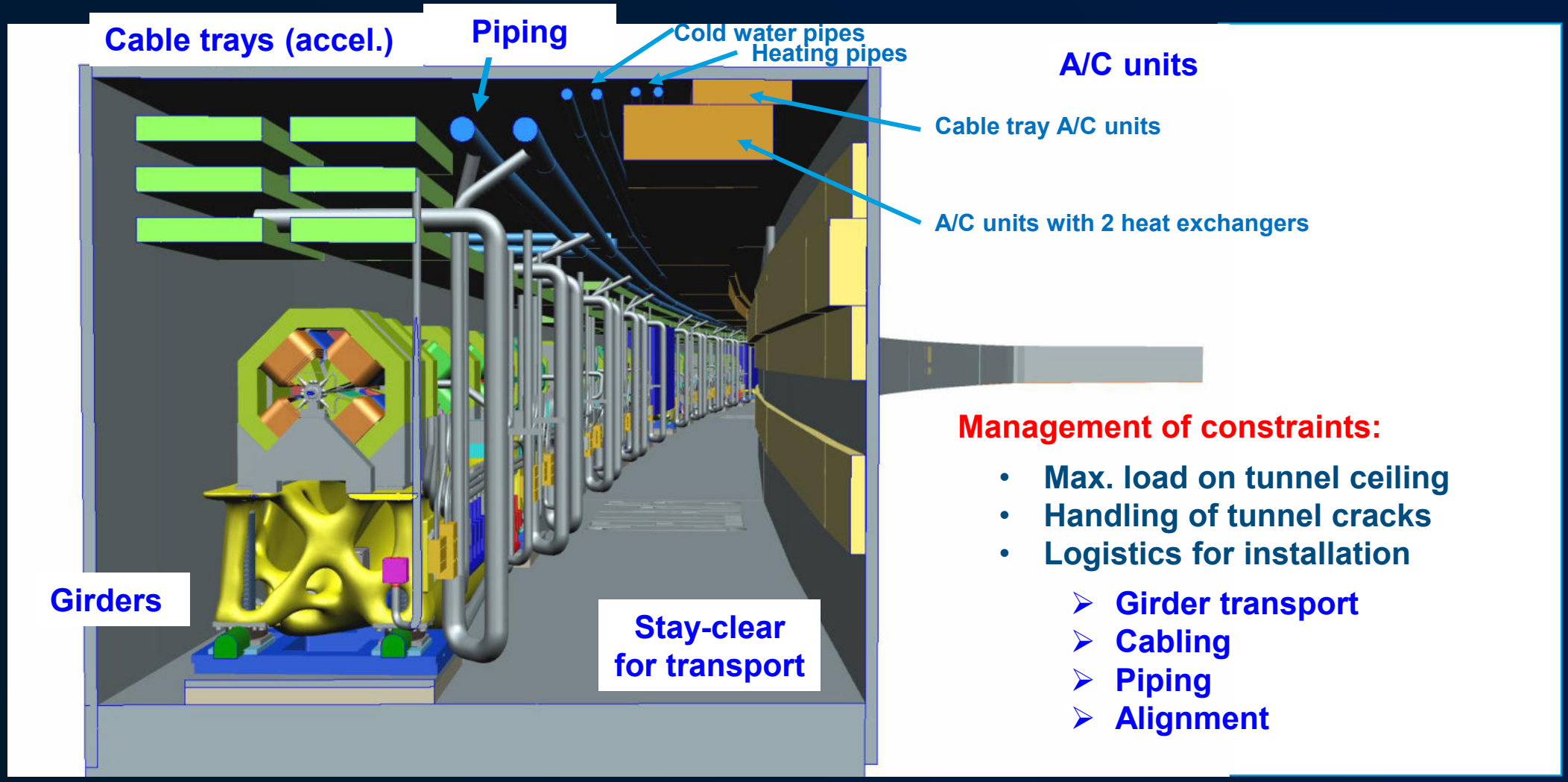


Key challenges

- 6 GeV injection energy
- Energy spread acceptance ±1%
  including all jitters
- Average current 2.7 nC/s
  for filling the ring in 10 minutes
- 99%+ uptime for user happiness

View into the PETRA tunnel

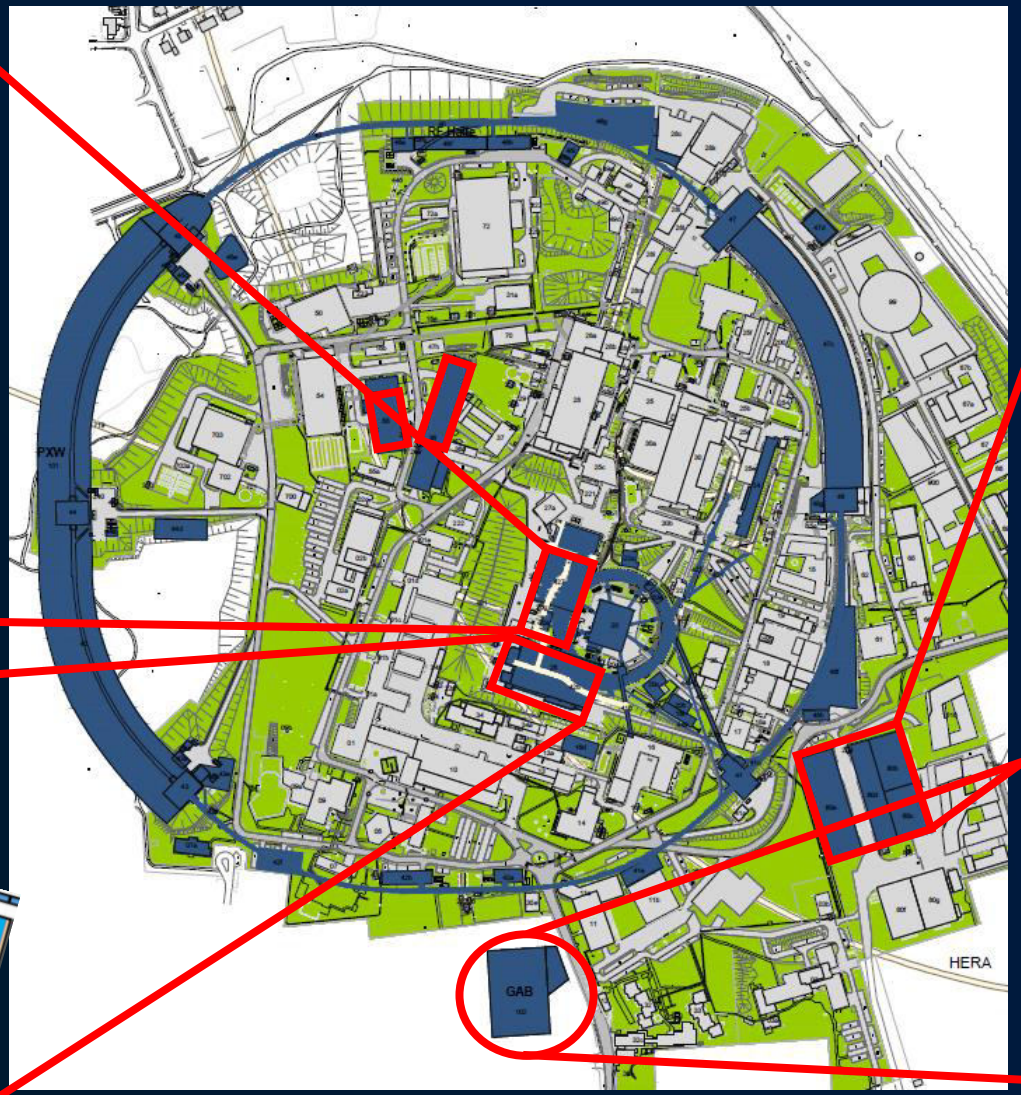
very crowded environment

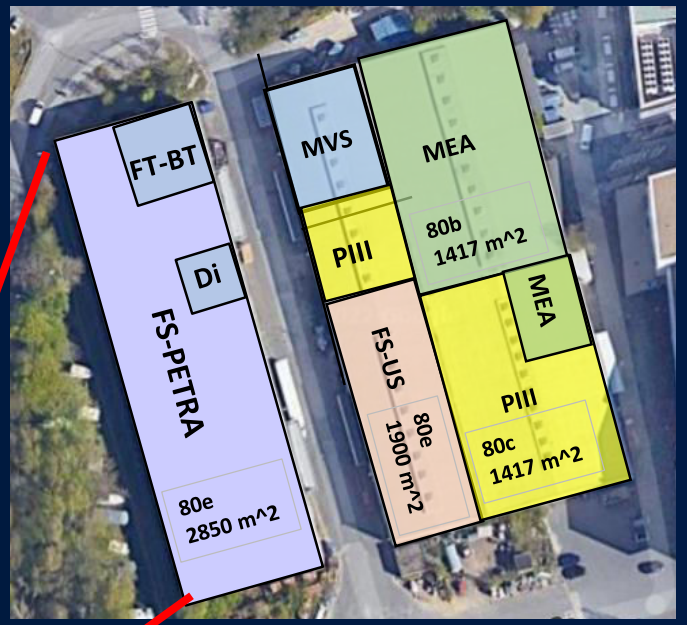


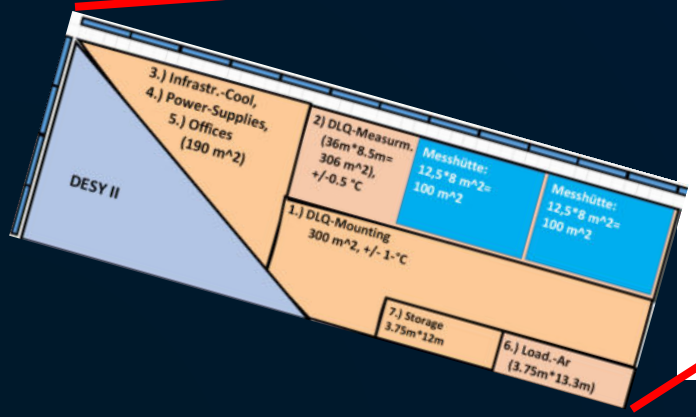
Management of constraints:

- Max. load on tunnel ceiling
- Handling of tunnel cracks
- Logistics for installation
  - Girder transport
  - Cabling
  - Piping
  - Alignment

PETRA IV – Logistics





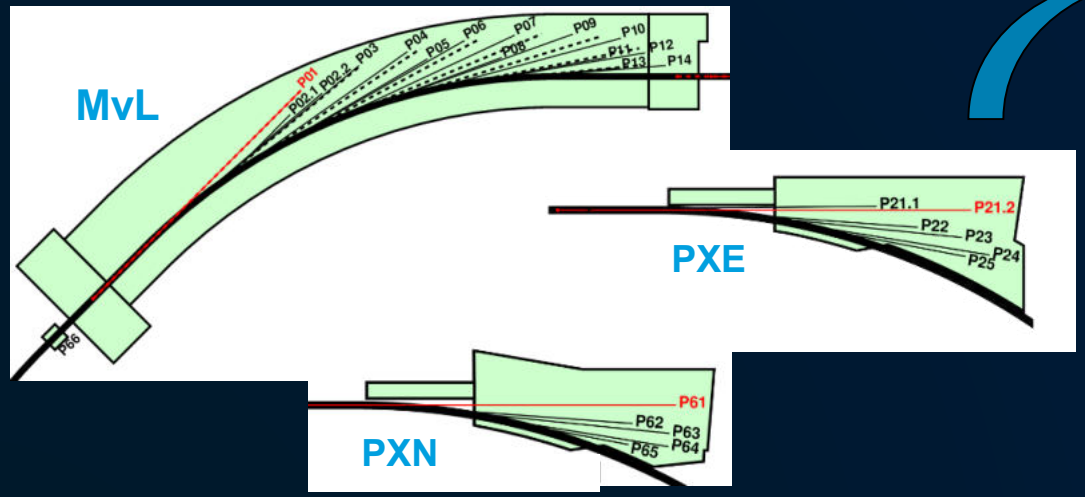


PETRA IV – Experiments

Number and Distribution of Beamlines

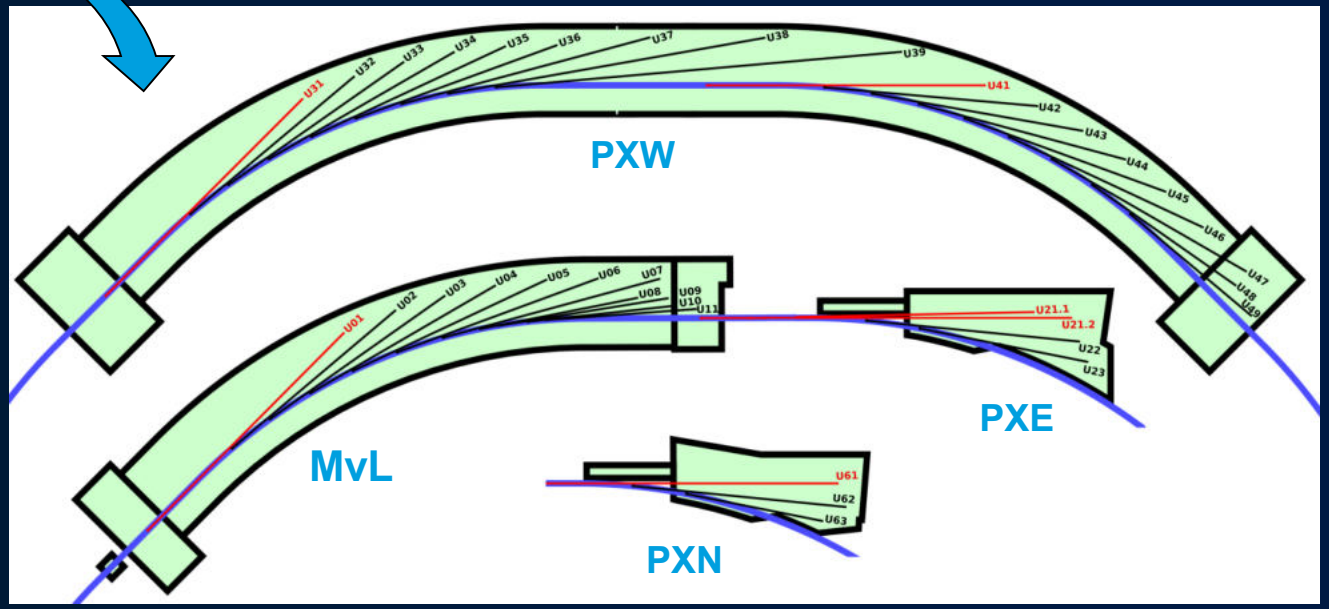
PETRA III Beamlines (max): 26 + 1 VUV

- 25 beamlines in operation (3 experimental halls)
- Many canted sectors (2 m and 5 m IDs)
- Partners: 3 EMBL, 2.5 Hereon, 1.3 India (virtual), Sweden, MPG



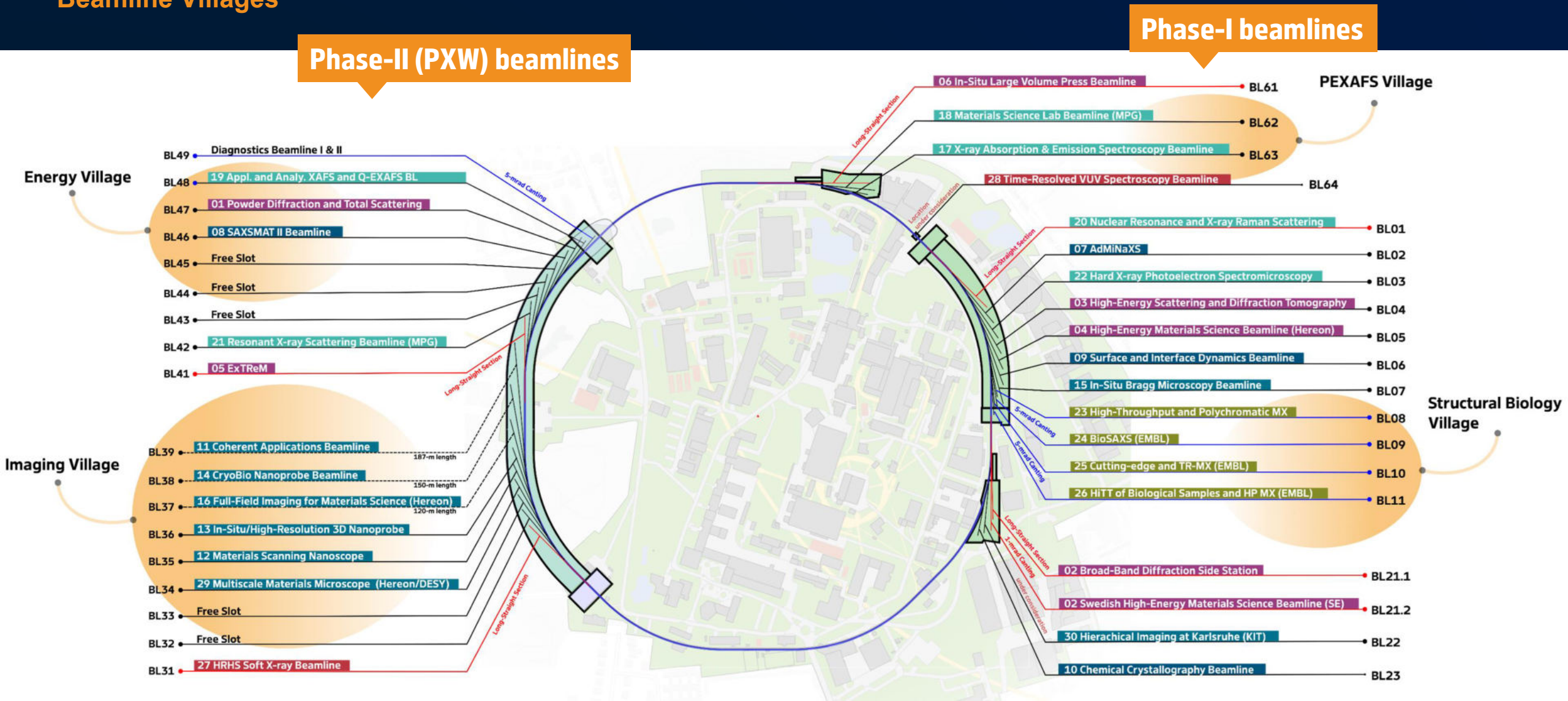
PETRA IV Beamlines (max): 35 + 1 VUV

- 31 ID project beamlines (4 experimental halls)
- Preservation of BL infrastructure in existing halls possible
- Canting very limited (1 – 5 mrad only, 4.3 m IDs)
- 5 high-brightness beamlines (10 m IDs)
- Partners: EMBL, Hereon, India, Sweden, MPG, …



PETRA IV – Beamline Portfolio

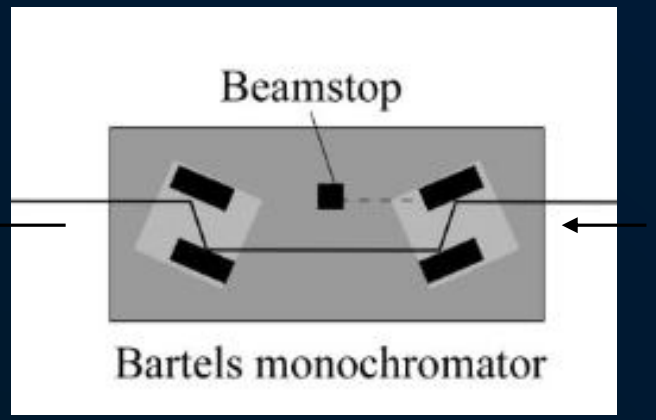
Beamline Villages



PETRA IV – Beamline Technology

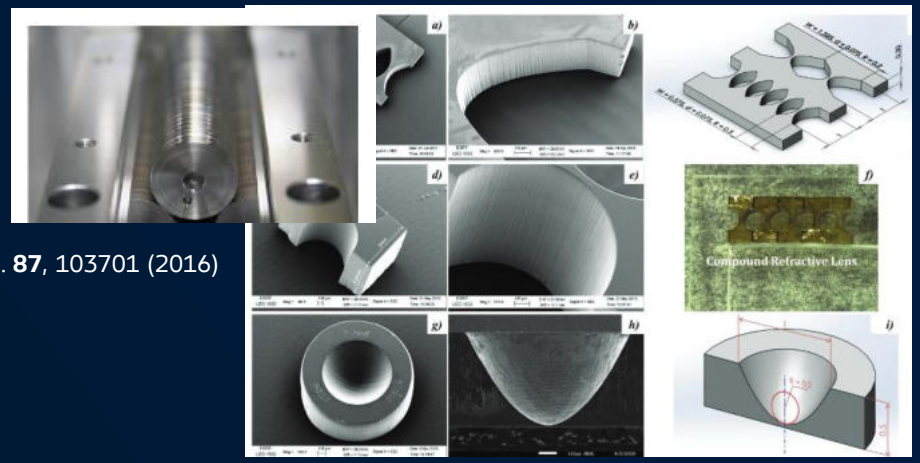
Enhanced Beamline Capabilities

4-bounce monochromator



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

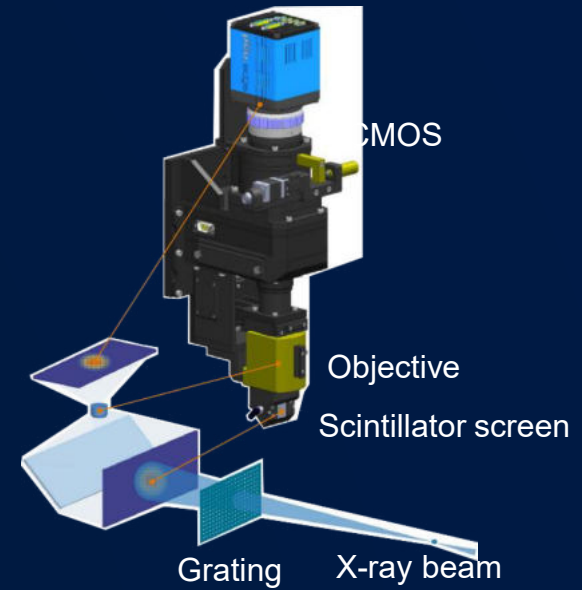
Diamond CRLs and Lens changer



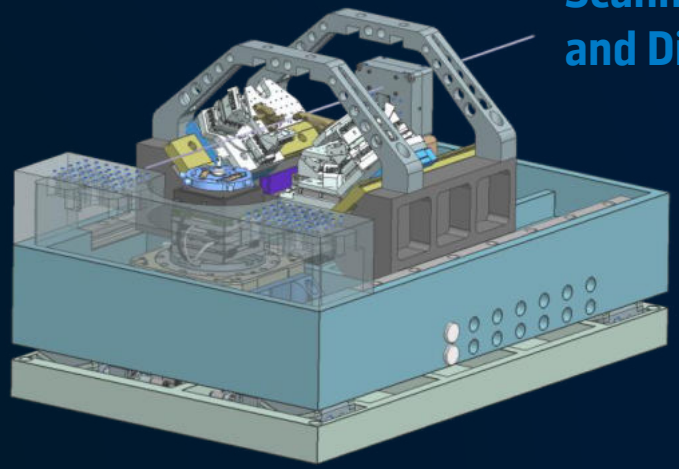
B. Nagler et al.
Rev. Sci. Instrum. **87**, 103701 (2016)

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

Wavefront Sensor

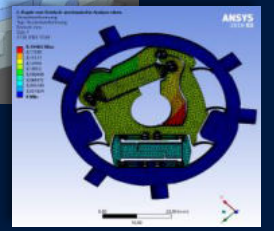


Scanning Platform for Imaging and Diffraction with Extreme Resolution



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

- 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

PETRA IV – Schedule

Project fixed by (external) boundary conditions

- Start of operation 1/2030 with 19 beamlines
- Shutdown of max. 2 years (2028/2029)
- Overall project duration to full project delivery: 8 years (2025-2032)