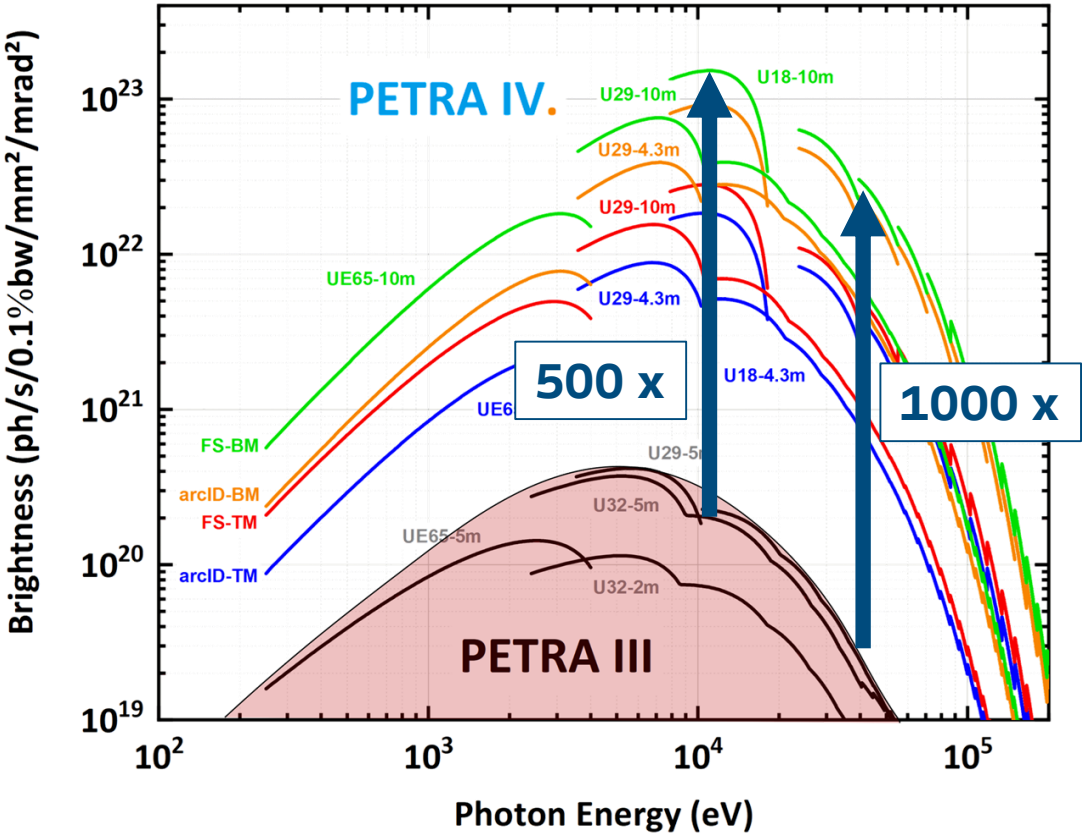
PETRA IV.

The Ultimate 3D X-ray Microscope

PETRA III and PETRA IV. in Numbers

A New X-ray Beam for PETRA Users

	H6BA Technology		DBA Technology	
	PETRA IV		PETRA III	
Mode of Operation	brightness mode	timing mode	continuous	timing mode
Number of Bunches	1600 - 1920	80 (40)	480 - 960	40
Total current [mA] Bunch current [mA]	200 0.125	80 (80) 1.0 (2.0)	120 0.25 - 0.125	100 2.5
Arc ID β_x/β_y [m] long ID β_x/β_y [m]	2.2 / 2.2 4.0 / 4.0		high β: 20.0 / 4.0 low β: 1.4 / 4.0	
Hor. Emittance ε_x [pmrad] Vert. Emittance ε_y [pmrad]	20 5	35 (38) 7 (8)	1300 10	
Bunch length σ_z [ps] Bunch separation [ns]	30 4	65 (75) 96 (192)	40 16 - 8	43 192
Energy spread σ_p [10^{-3}] Touschek lifetime τ [h]	0.9 > 10	1.2 (1.5) > 5	1.3 9 - 13	1.3 1.5
Number of beamlines	30 + 5 + 1 VUV		26 + 1 VUV	



PETRA IV Brightness at 100 keV
higher than for 10 keV at PETRA III today!!

➔ 500 x (hard X-rays)

➔ 1000 x (high-energy X-rays)

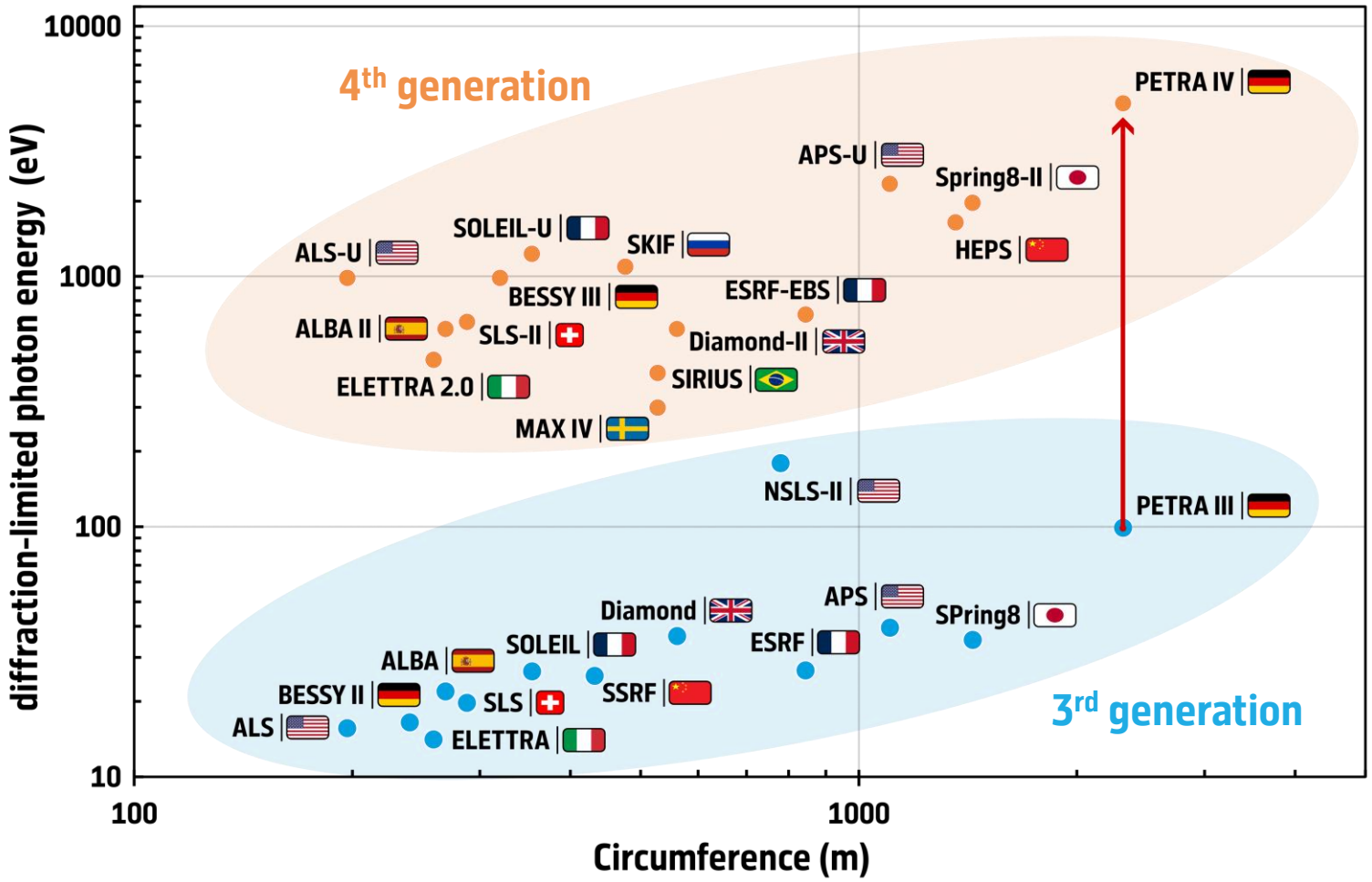
PETRA IV. Project

Global Competitors

Multi-Bend Achromat (MBA) technology underpins the development of diffraction-limited light sources

In an international comparison, the project will be the last to finish, but will have by far the best performance

Comparison – Sources around the World



ESRF-EBS 120 pm·rad (2020); APS-U 42 pm·rad (2024); HEPS <60 pm·rad (2025); SPring8-II ~50 pm·rad (2028); PETRA IV 20 pm·rad (2029)

PETRA IV. Project

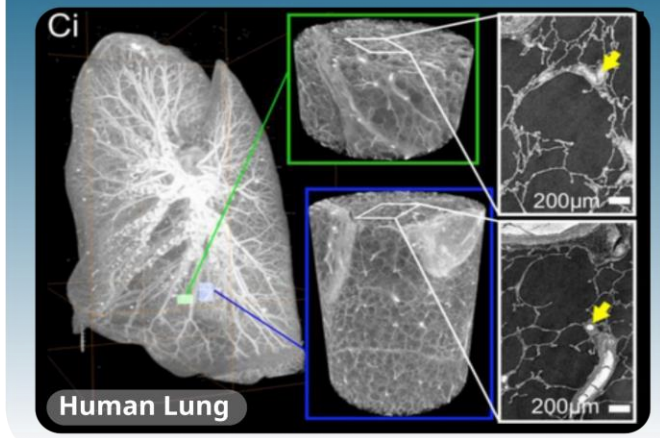
The Ultimate 3D X-ray Microscope for Physical, Chemical, and Biological Processes

Brightness

Macroscopic field of view with nanometer resolution

> Multi-scale imaging - connecting nanometer features across macroscopic dimensions

> Fast sampling with chemical, structural, electronic sensitivity



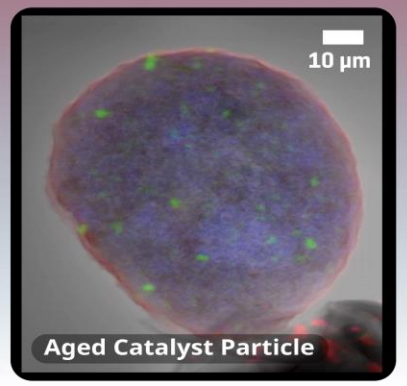
Coherence

Non-periodic materials with highest spatial resolution

> Imaging with spatial resolution down to < 1 nm, localising atoms and molecules

> Improved phase contrast for fast full-field imaging

> Correlation methods improved by 10.000 - 250.000x

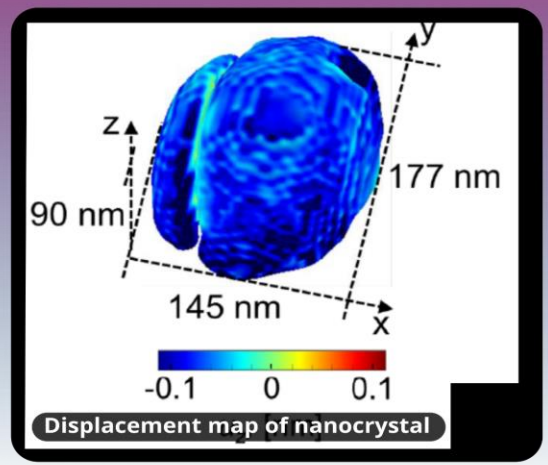


High Energy

Penetrating bulk materials and operating systems

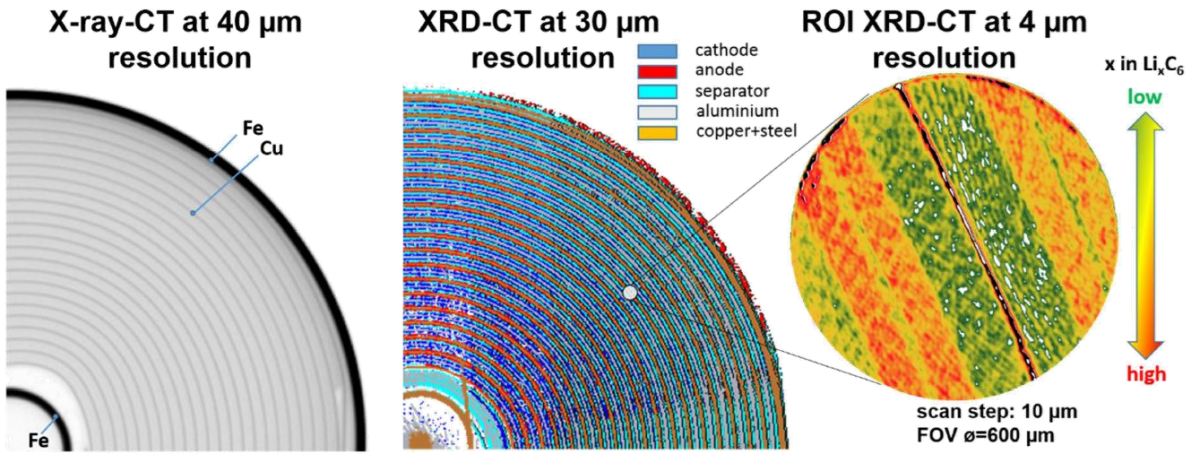
> Enabling coherent techniques well beyond 50 keV

> 3D mapping deep inside bulk materials



PETRA IV. Project

Selected Science/Technology Examples – Material and Process Development



D. Petz, et al., Energy Storage Materials 41 (2021) 546–553d

XRD-CT:

Operando investigation of lithium distribution in Li-ion battery during charge/discharge.

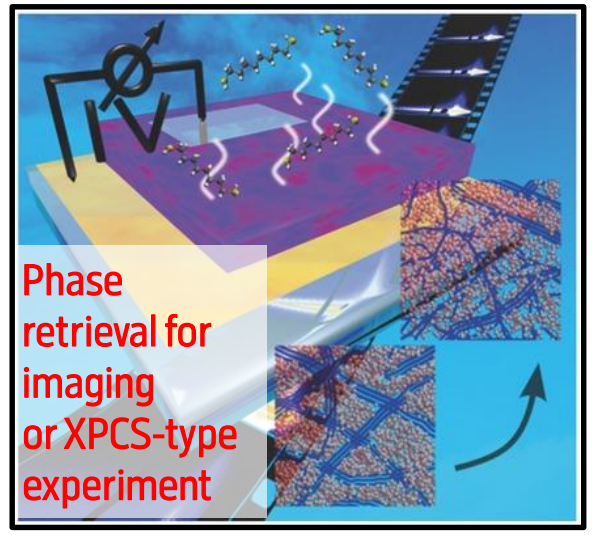
PETRA III (1 x 1 mm^2 in 4 h) – 1 µm resolution

PETRA IV (1 x 1 cm^2 in 8 h) – 1 µm resolution or 1 x 1 mm^2 with much higher spatial resolution

Operando Co-µGISAXS:

Morphological degradation of a running polymer solar cells with time (min).

PETRA IV enables to combine GISAXS with coherent techniques (Coherent-GISAXS)



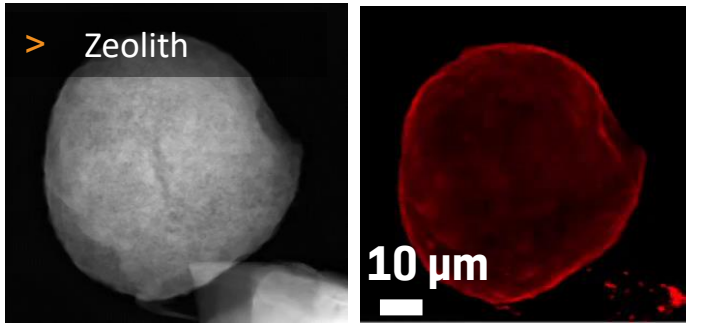
C. J. Schaffer, et al., Adv. Energy Mater. 2016, 6, 1600712

3D X-ray Fluorescence and XAFS:

Imaging of Aged Catalyst Particle (FCC method) including chemical information

PETRA III (70 µm^2 in 1 day).

PETRA IV (70 µm^2 in 1.5 min). or longer times with much higher spatial resolution



Electron Density (ED) **Fluorescence (Fe K_α)**

J. Garrevoet, et al., unpublished

PETRA IV. Project

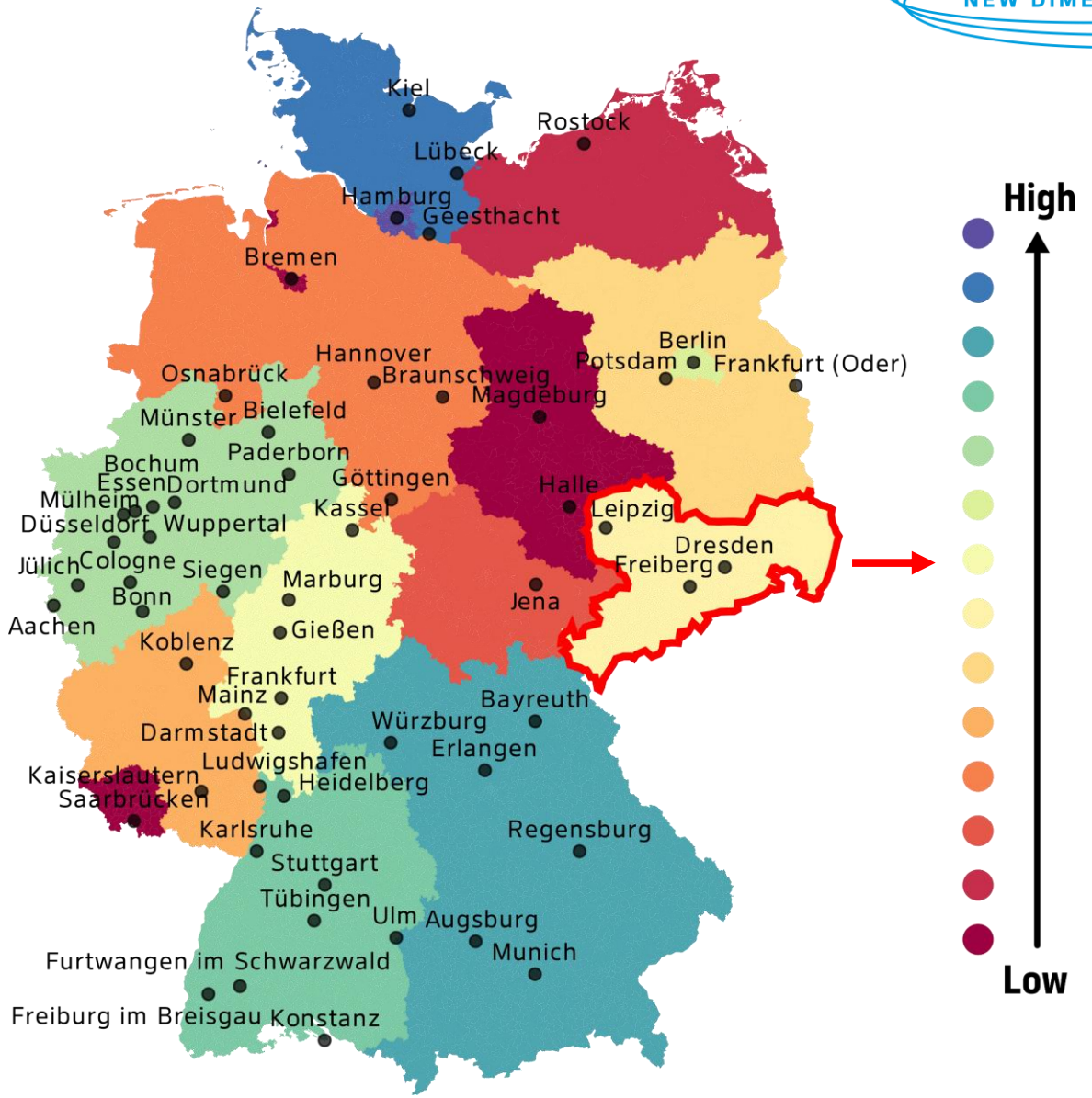
Saxon Involvement in Science and Instrumentation

Scientific Instrumentation Proposals (SIPs):

- Contributing to **16%** of all SIPs !
- Contribution from:
  - TU Bergakademie Freiberg
  - TU Dresden
  - University of Leipzig
  - Max Planck Institute for Chemical Physics of Solids
  - Fraunhofer IFW
  - Helmholtz-Zentrum Dresden-Rossendorf e. V.

Saxony is already a major contributor to PETRA IV Science and Developments

Number of SIP Contributors



PETRA IV. Photon Science Project

A User-Tailored Beamline Portfolio

31 PETRA IV Beamlines:

- Large set of experimental capabilities and analytical methodologies (**multi-scale**)
- Wide range of contrasts, sensitivities, and resolutions (**multi-modal**)
- Balanced high-brightness and high-throughput experiments
- Extended imaging capabilities
- **Unique opportunities** for users
- Beamlines for **targeted use** (science & industry)!

Further continuous exchange with the users and partners will take place to adapt/shape the portfolio to the evolving requirements!

Saxon Collaboration as a strong partner to shape Science and Opportunities at PETRA IV !!

PETRA IV Beamline Portfolio:

Beamline	Techniques	Energy range
Max von Laue (MvL) Experimental Hall:		
BL01 Nuclear Resonance and X-ray Raman Scattering	NFS, NIS, SMS, XRS, (R)XES	6.5 - 73 keV
BL02 AdMiNaXS Beamline	GI/T/SAXS/WAXS, CoGISAXS	7 - 30 keV
BL03 Hard X-ray Photoelectron Spectromicroscopy	HAXPES(ARPES, PEEM, XPD), CDI	2.1 - 15 keV
BL04 High-Energy Scatt. and Diff. Tomography	GI-/XRD/-CT, SAXS, TS, CDI	40 - 120 keV
BL05 High-Energy Mater. Sci. Beamline (HEREON)	XRD/-CT, SAXS	50 - 150 keV
BL06 Surface and Interface Dynamics Beamline	GI-XRD, GI-SAXS, XRR, GI-XPCS	5 - 40 keV
BL07 In-situ Bragg Microscopy Beamline	(GI-)XRD, BCDI	7 - 40 keV
BL08 High-Thru. MX	MX, SSX	6 - 30 keV
BL09 BioSAXS Beamline (EMBL)	BioSAXS, TR-SAXS, HT-SAXS	6 - 20 keV
BL10 High Performance and Microfocus MX (EMBL)	SSX,TR-MX,HT-MX	11 - 35 keV
BL11 Bio Diffraction and Imaging (EMBL)	HT-MX, HiTT	6 - 35 keV
Ada Yonath (PXE) Experimental Hall:		
BL21 High-Energy Beamline for Phys. and Chem.	XRD, TS	50, 85, 100 keV
BL22 Swedish High-Energy Mater. Sci. Beamline (SE)	WAXS/3DXRD, SAXS, Imaging	38 - 100 keV
BL23 HIKA Beamline (KIT)	Tomography, Laminography	8 - 60 keV
BL24 Chemical Crystallography Beamline	PXRD, Crystallography	8 - 66 keV
New PXW Experimental Hall:		
BL31 HRHS Soft X-ray Beamline	ARPES, CDI, STXM-XRF, REMI	0.25 - 4 keV
BL34 Multiscale Mater. Microscope (DESY/HEREON)	Holotomo., Radiography	50 - 200 keV
BL35 Materials Scanning Nanoscope	XRF, XRD, XBIC, XEOL, Ptycho.	2.4 - 40 keV
BL36 In-Situ/High-Resolution 3D Nanoprobe	XRF, XRD, XBIC, XANES, Ptycho.	5 - 34 keV
BL37 Full-Field Imaging for Mater. Sci. (HEREON)	Tomography, Radiography	5 - 50 keV
BL38 CryoBio Nanoprobe Beamline	Compton Micro., Holotomo., XRF	17 - 60 keV
BL39 Coherent Applications Beamline	XPCS, XCCA, Holotomo.	7 - 25 keV
BL41 ExTReM	XRD, PDF, PCI, CDI	8 - 71 keV
BL42 Resonant X-ray Scattering Beamline	RIXS, REXS	2.4 - 14 keV
BL45 Powder Diffraction and Total Scattering	PXRD, TS	20 - 80 keV
BL46 SAXSMAT II Beamline	(Anom./U)SAXS/WAXS, Tens. Tomo.	3.5 - 35 keV
BL48 Applied Analytical XAFS and Q-EXAFS Beamline	XAS, EXAFS, XANES, Q-XAFS	4 - 45 keV
Paul P. Ewald (PXN) Experimental Hall:		
BL61 In-situ Large Volume Press Beamline	AD-/ED-XRD, PXRD, A/PCI	30 - 130 keV
BL62 Materials Science Lab Beamline (MPG)	XAFS, XRD/PDF, Tomography	4 - 60 keV
BL63 X-ray Absorption & Emission Spec. Beamline	HR-XES/XAS, TR-XES/XAS	4 - 35 keV
BL64 Time-Resolved VUV Spectroscopy Beamline	IR-Vis, VUV spectroscopy	0.004 - 0.04 keV

PETRA IV. Beamline Portfolio

Distribution of Beamlines on Experimental Halls

PETRA IV. NEW DIMENSIONS

Phase-II (PXW) Beamlines *Start Operation in late 2030* — **12 BLs + 5 free slots**

Energy Village

- BL48 Appl. and Analy. XAFS and Q-EXAFS BL
- BL47 Free Slot
- BL46 SAXSMAT II Beamline
- BL45 Powder Diffraction and Total Scattering
- BL44 Free Slot
- BL43 Free Slot
- BL42 Resonant X-ray Scattering Beamline
- BL41 ExTReM

Imaging Village

- BL39 Coherent Applications Beamline (187-m length)
- BL38 CryoBio Nanoprobe Beamline (150-m length)
- BL37 Full-Field Imaging for Materials Science (Hereon) (120-m length)
- BL36 In-Situ/High-Resolution 3D Nanoprobe
- BL35 Materials Scanning Nanoscope
- BL34 Multiscale Materials Microscope (Hereon/DESY)
- BL33 Free Slot
- BL32 Free Slot
- BL31 HRHS Soft X-ray Beamline

Paul P. Ewald (PXN) Hall

3 BLs

Beamlines in a village can address complex scientific and technological questions that require cross-disciplinary expertise and capabilities

Ada Yonath (PXE) Hall

4 BLs

18 BLs + 1 VUV — **Phase-I Beamlines** *Start Operation in 2029*

PEXAFS Village

- In-Situ Large Volume Press Beamline
- Materials Science Lab Beamline (MPG) — BL62
- X-ray Absorption & Emission Spectroscopy Beamline — BL63
- Time-Resolved VUV Spectroscopy Beamline — BL64

- Nuclear Resonance and X-ray Raman Scattering — BL01
- AdMiNaXS — BL02
- Hard X-ray Photoelectron Spectromicroscopy — BL03
- High-Energy Scattering and Diffraction Tomography — BL04
- High-Energy Materials Science Beamline (Hereon) — BL05
- Surface and Interface Dynamics Beamline — BL06
- In-Situ Bragg Microscopy Beamline — BL07
- High-Throughput MX — BL08
- BioSAXS (EMBL) — BL09
- High Performance and Microfocus MX (EMBL) — BL10
- Bio Diffraction and Imaging (EMBL) — BL11

Structural Biology Village

- High-Energy Beamline for Physics and Chemistry — BL21
- Swedish High-Energy Materials Science Beamline (SE) — BL22
- Hierachical Imaging at Karlsruhe (KIT) — BL23
- Chemical Crystallography Beamline — BL24

Extension of Services at PETRA IV.

Attract a broader User Community from Academia and Industry

1 Beamlines and Instrumentation:

- New generation of photon beamlines (31 x BLs)
- Cutting-edge instrumentation
- High level of automation and high-throughput

2 Data Management:

- Deal with the expected large amount of data
- User friendly analysis pipelines
- Rapid feedback for agile decision making

6 Access Model:

- Prompt access on demand
- Reliable long-term projects

3 Laboratories and Technical Infrastructure:

- User-tailored lab layout
- Extended laboratory services
- Dedicated lab areas (special equipment)

5 Sample Environment:

- Provision and support of in-situ/operando sample environments (nanoreactors, pressure cells)
- Development of customised equipment

4 Organisation and User Support Group:

- Projects instead of beamtime
- Single-entry point to an easy-to-use and customised interface
- User support group (USG)

PETRA IV. – User Support Group

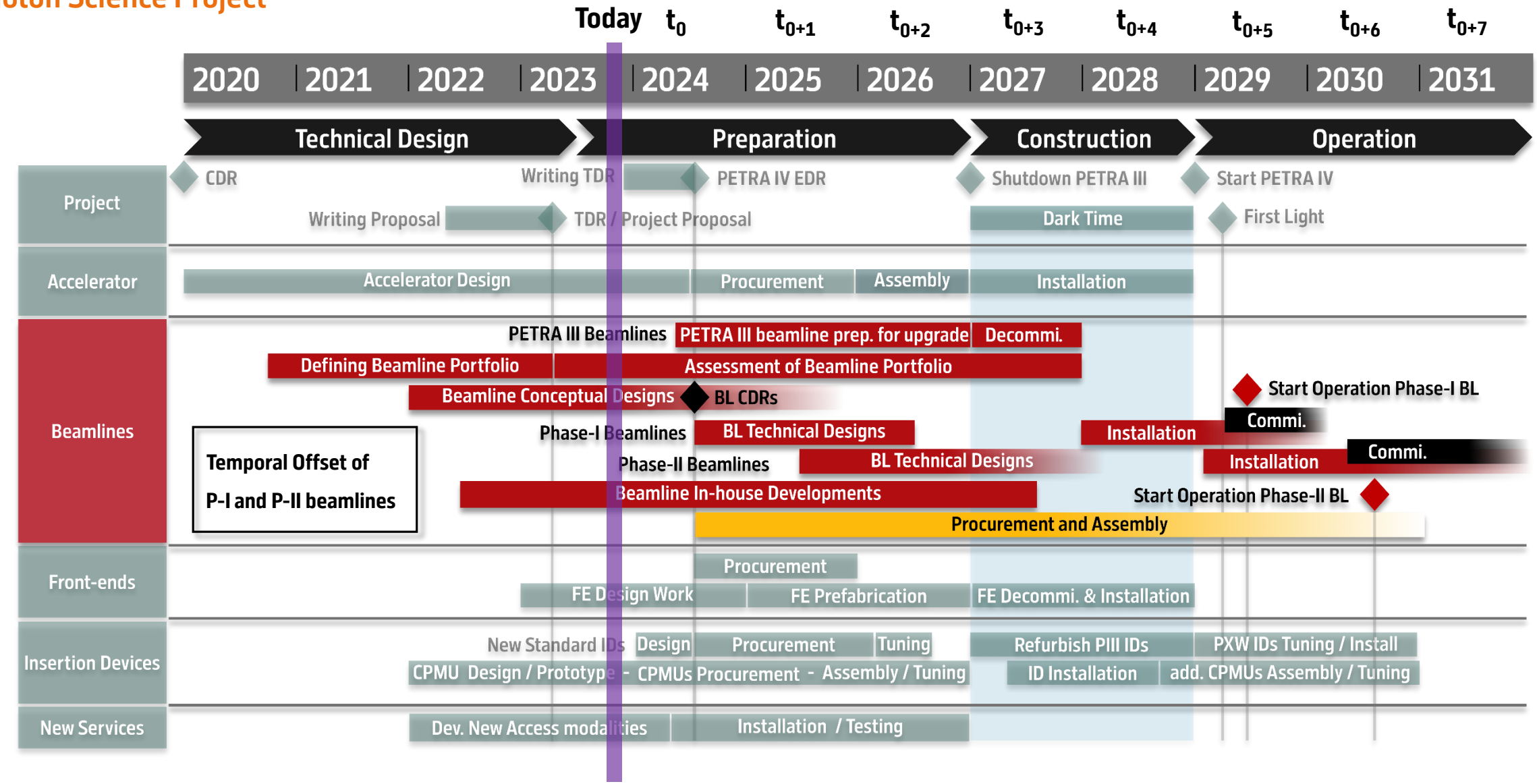
Scientific and administrative support

Extended support services especially for non-SR experts (problem formulation, project planning, data analysis)

- Acts as a **gateway/bridging element** between users and the facility
- Central instance to **coordinate** the entire access and service process (for all users)
- Combines the existing user office with an additional operational service unit.
- Operative team carries out projects independently
- Supplemented by **external service providers** (start-ups, academic partners, …)

PETRA IV. Timeline

Photon Science Project



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The synchrotron radiation source PETRA III and its future ultra-low-emittance upgrade PETRA IV

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