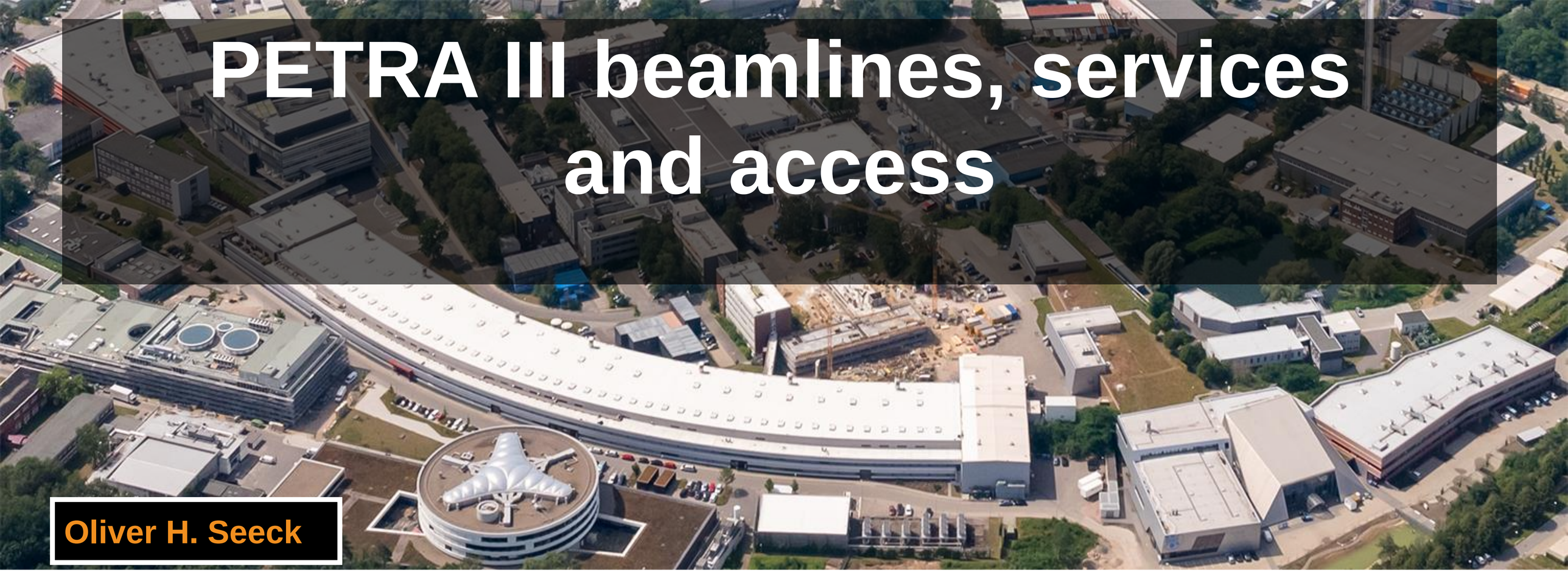
PETRA III beamlines, services and access



Oliver H. Seeck

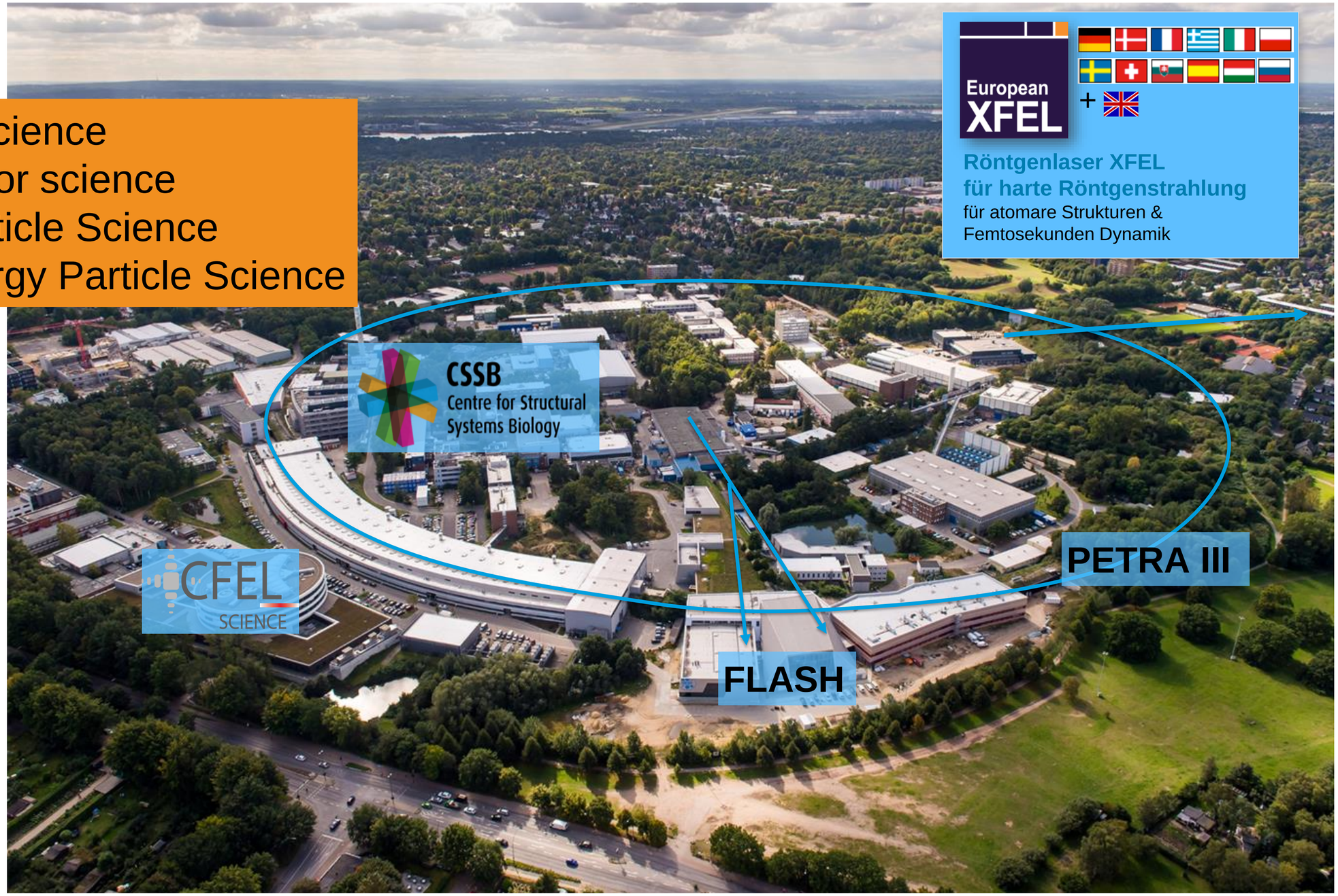
Saxony – DESY workshop
November 23rd & 24th, 2023

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

DESY

Photon Science
Accelerator science
Astro Particle Science
High Energy Particle Science



PETRA III fact sheet

DESY's Brilliant Synchrotron Radiation Source

History of PETRA:

1978: PETRA I built for high-energy physics, first direct observation of the gluon

1988: PETRA II as pre-accelerator for HERA

2007: rebuild of PETRA as a 3. generation synchrotron radiation source (PETRA III)

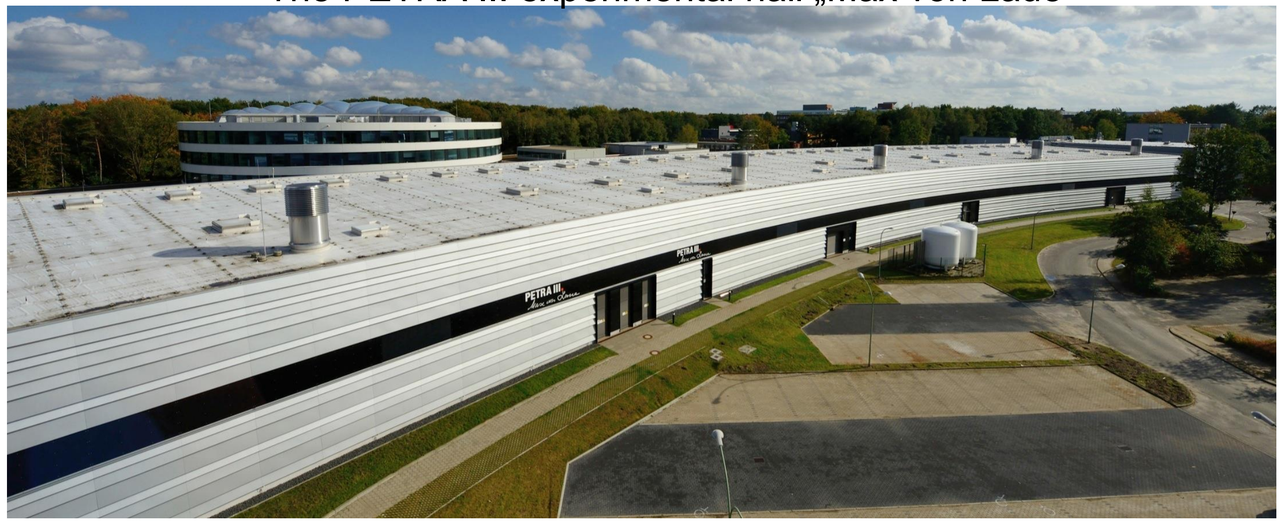
2010: start of user operation with the first three beamlines

2013: all 15 beamlines fully operational in the experimental hall "Max v. Laue"

2016: PETRA III extension project starts users operation with the first two beamlines

planned for 2027: shutdown of PETRA III as part of PETRA IV upgrade

The PETRA III experimental hall „Max von Laue"



electron energy	**6 GeV**
stored current	**100 / 120 mA**
emittance (h × v)	**1.3 nmrad × 15 pmrad**
circumference	**2304 m**
photon energy range	**250 eV - 150 keV**
beamlines in operation	25
beamlines under construction	1 (P25)
beamlines still open	1 (P63)
user operation (hours/year)	5000
bunch separation	**192 ns or 16 ns**

PETRA III

more than 50 experiments covering most relevant methods

Diffraction & Scattering

P02.1, P02.2, P07, P21.1, P21.2, P61	High energy X-ray, white beam diffraction & imaging
P03, P12, P62	Small angle scattering, GISAXS, µASAXS
P08, P23, P24, **P25 (2024)**	Crystallography & Surfaces scattering,
P11, P13, P14	Macromolecular crystallography
P04, P06, P10	Coherent diffraction & scattering
P09	Resonant magnetic scattering

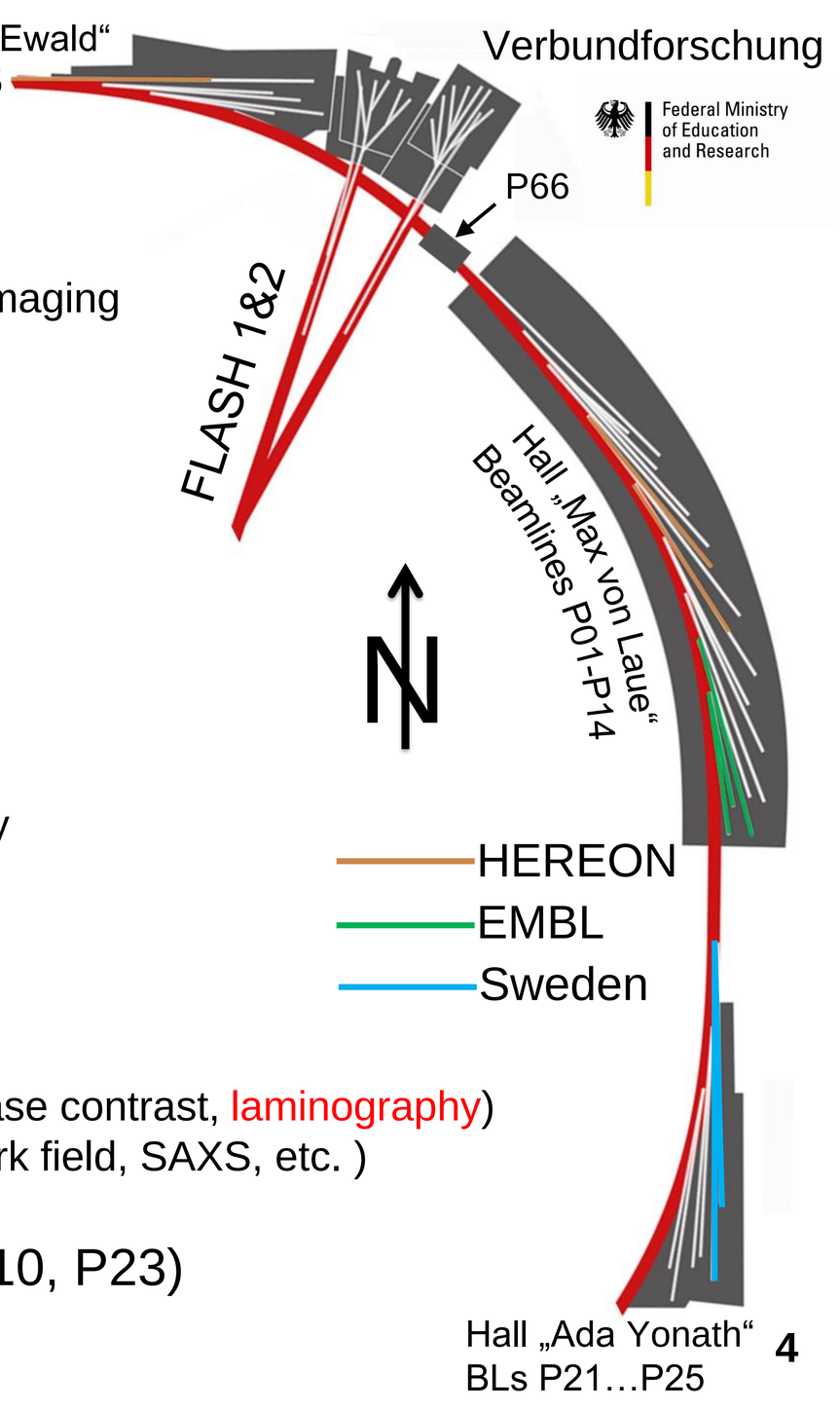
Spectroscopy

P01	Inelastic and nuclear resonant scattering
P22	Hard X-ray photoelectron spectroscopy
P04	Soft X-ray photoelectron spectroscopy
P64, P65	X-ray absorption & fluorescence spectroscopy
P09	XMCD
P66	VUV spectroscopy, t-resolved

Imaging

P04, P06, P10	Micro & Nano imaging (coherence)
P05, P06, P07, P14, P61, **P23-KIT (2024)**	Micro & Nano imaging (absorption & phase contrast, laminography)
P03, P06, P21.1, P21.2, **P62, P25 (2024)**	Micro & Nano imaging (fluorescence, dark field, SAXS, etc.)

➔ Several beamlines host multiple methods (P01, P04, P07, P09, P10, P23)



X-ray beam parameters

Insertion devices

Low-β sector (hor. x ver. RMS):

β function	approx. 1.3x3 m^2
Source size	35x6 μm^2
Source divergence	28x6 μrad^2

High-β sector:

β function	approx. 18x3 m^2
Source size	140x6 μm^2
Source divergence	8x6 μrad^2

Photon flux at $\Delta E/E = 10^{-4}$

Coherent flux	10^{11} ph/sec
Full beam	$3 \cdot 10^{13}$ ph/sec

Focusing of X-rays :

2µm (easy)

100nm (needs some attention)

5nm (lowest ever achieved)

Photon energy of X-rays :

5 beamlines with > 60keV available

➔ good opportunities for materials science

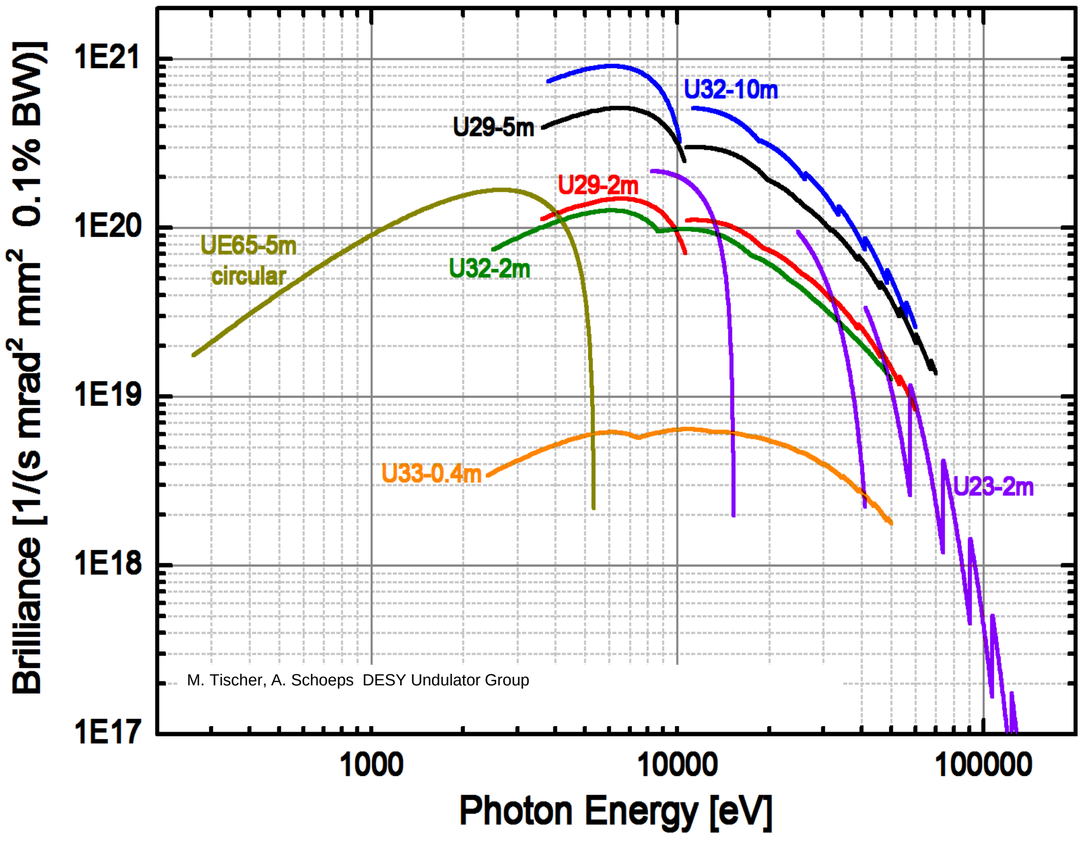
Bunch length 100 ps

Bunch mode for timing:

timing mode: 40 bunches 192 ns

Bunch mode for continuous beams:

continuous: 480 bunches 16 ns



PETRA III

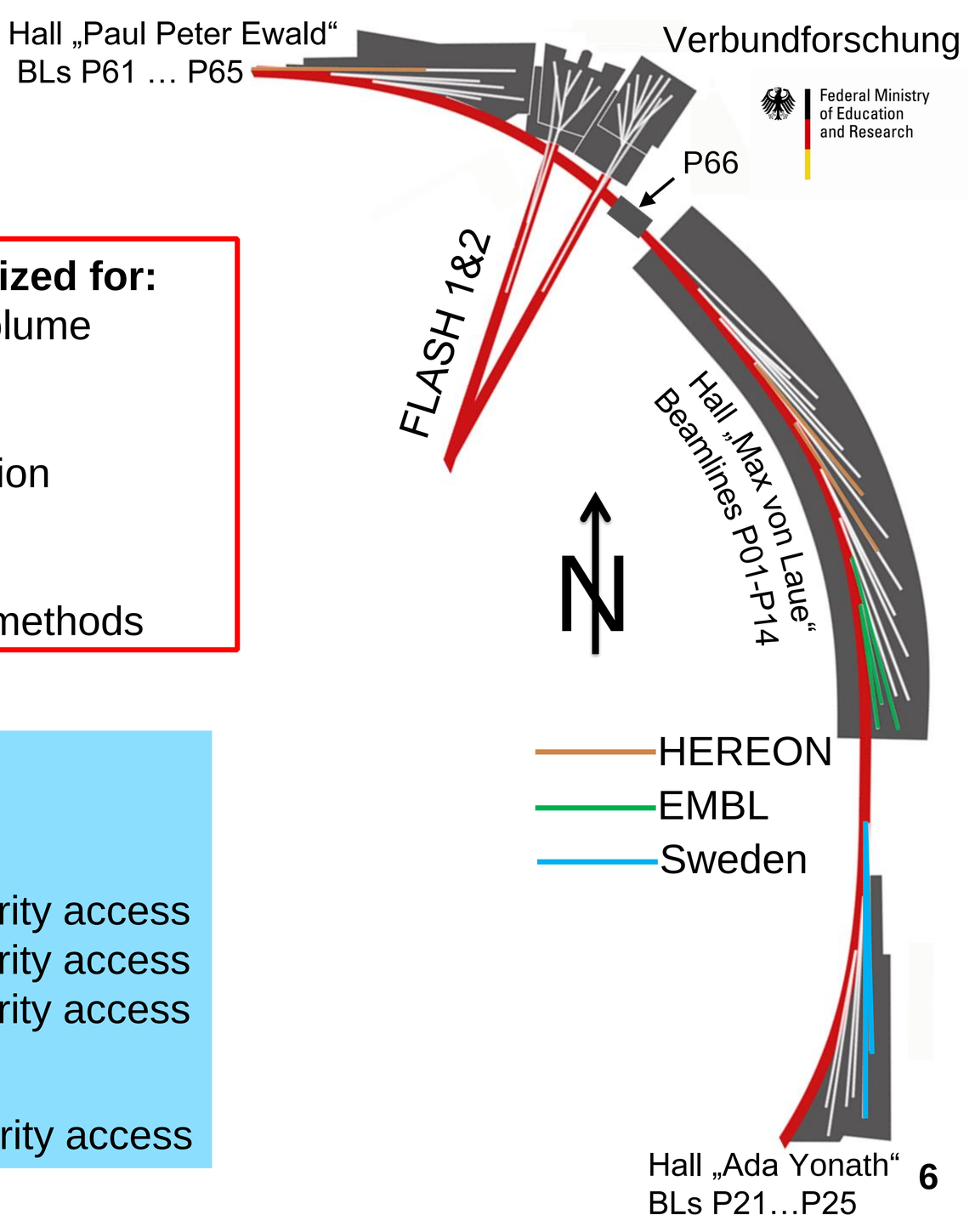
23 Beamlines operational

Methods at beamlines
- Scattering
- Diffraction
- Spectroscopy
- Imaging
- Coherence applications

With experiments optimized for:
- Large coherence volume
- High flux
- Small focus
- High energy resolution
- High stability
- Speed
- In-situ & operando methods

External contributions or responsibilities

3	Beamlines operated by EMBL	
2.5	Beamlines operated by HEREON	
1.3	„Indian virtual beamline“	➔ priority access
0.325	**„Saxonian virtual beamline”**	➔ priority access
1.89	Swedish beamline equivalents	➔ priority access
	with the two Swedish beamlines P21.1 and P21.2	
	1 beamline several MPG/Helmholtz involvements	➔ priority access



PETRA III

User Operations & Schedule 2020

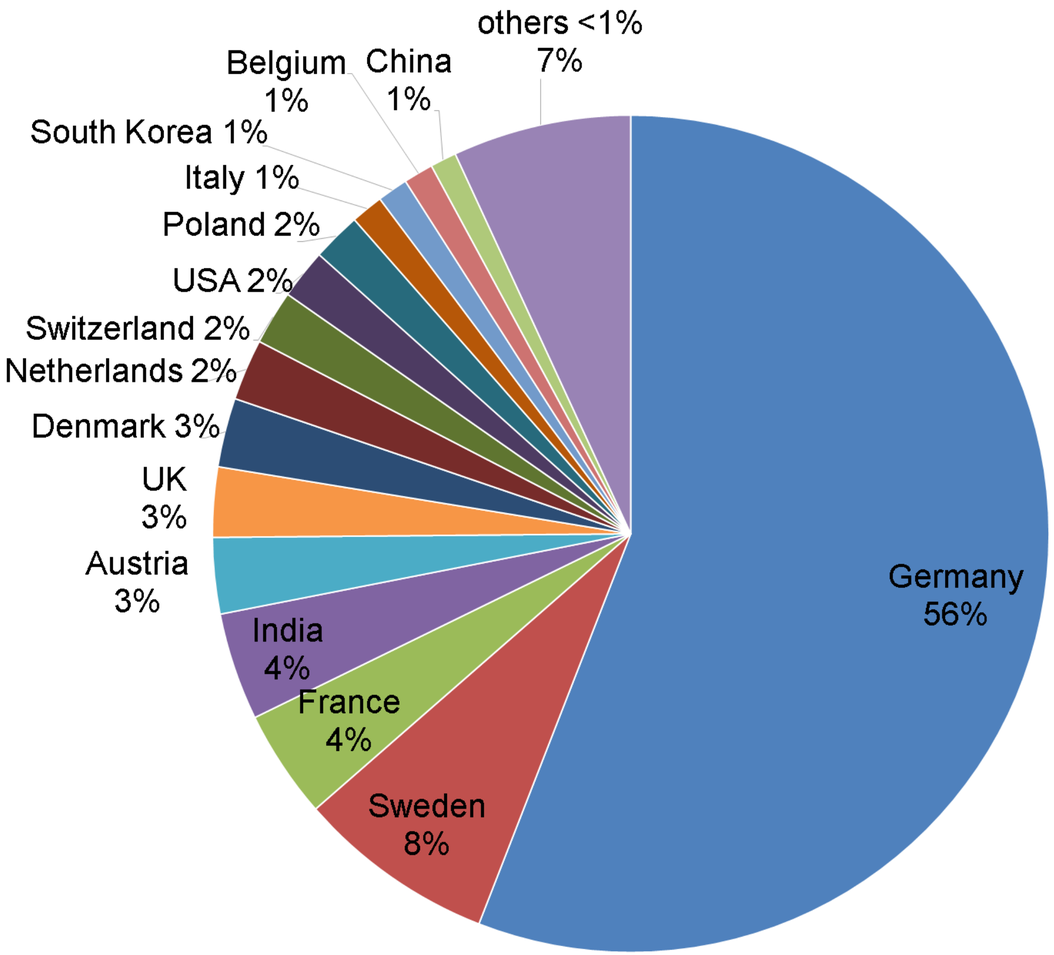
Available (with >98% availability)
- user time : 4000 h/a
- internal time : 1000 h/a

Unique users: 3350 per year
User visits: 7500 per year

Visits from Saxony
since 07/2022: **289**
(07/2018-12/2019: 148)

Unique User from Saxony
since 07/2022: **157**
(07/2018-12/2019: 89)

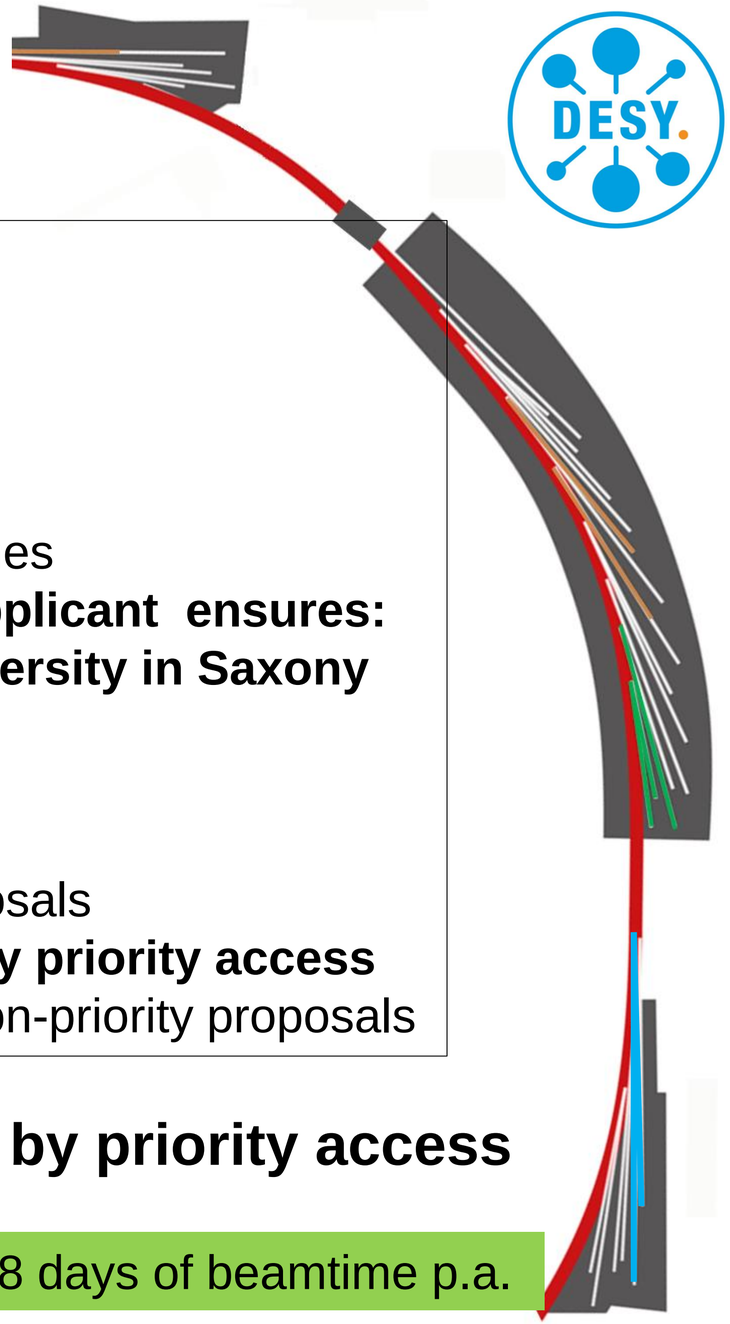
Experiments from Saxony
since 07/2022: **86**
(07/2018-12/2019: 61)



Since start of the Saxonian-DESY Cooperation x 2 more users and 30% more experiments

PETRA III access for proposals from Saxony

Priority access



The access is compatible with the so-called „Swedish Model“.

In short this means:

- Saxonian users write **beamtime proposals** parallel to other users via the web-interface **DOOR**
- Saxonian users are **FREE** to apply for beamtime at **ALL** PETRA III beamlines
- In DOOR, during the process of completing the beamtime proposal. The **applicant ensures:**
  - + that the DOOR-“Project Leader” is **staff member** at an **institute/university in Saxony**
  - + chooses the value **“Saxony-DESY collaboration”** at the drop-down menu “User Group/Collaboration”
- Beamtime proposals marked as “Saxony-DESY collaboration” are **reviewed by the DESY Project Review Panel** in parallel to all other proposals
- Saxony-DESY proposals are selected by **scientific excellence AND/OR by priority access**
- Saxony proposal to HEREON or EMBL beamlines are treated as regular non-priority proposals

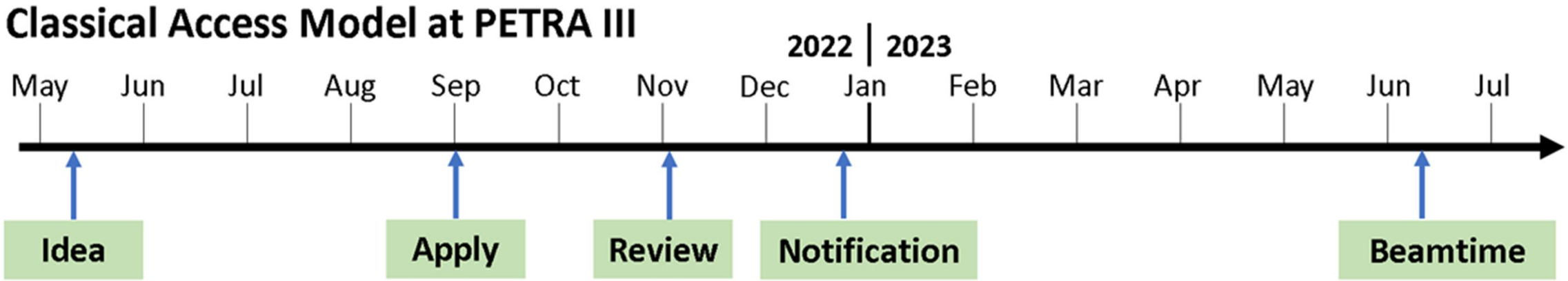
Two ways to receive beamtime: regular scientific excellence or by priority access

Reserved for Saxonian-DESY cooperation: 0.325 beamline equivalents = 910h = 38 days of beamtime p.a.

PETRA III new rolling access model

Current access model is NOT flexible

Beamtime access is bound to calls: March 1st and September 1st.
Beamtime is scheduled: March call: August-December
September call: February-July

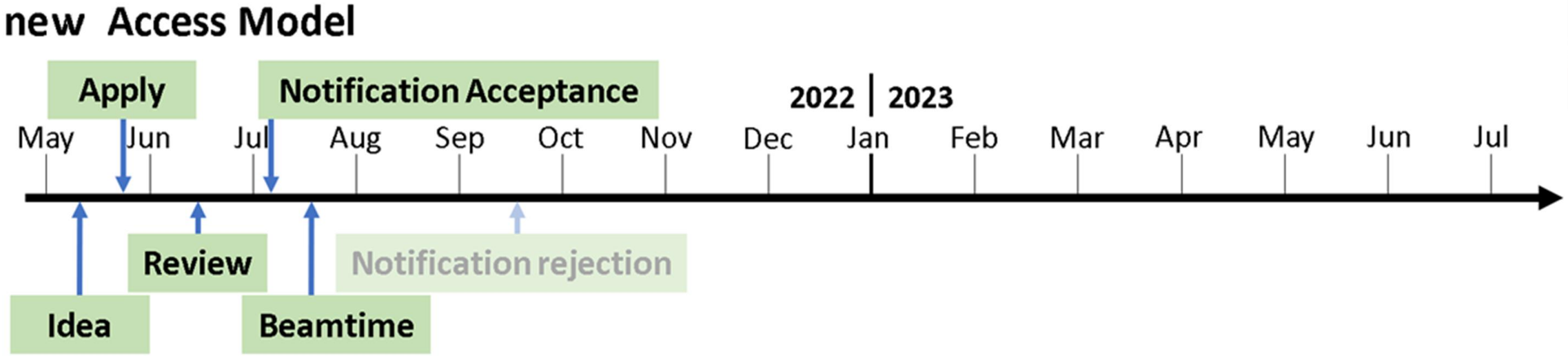


Long waiting time (up to 15 Months) even for small and simple experiments

PETRA III new rolling access model

New rolling access model at P08, P11, P22, P23, P24 and chemistry lab + nano lab

No call, no deadline



You will be able to submit a proposal at any time.
You will be able to specify “long lead time” or “prompt access”.
You will be able to split a beamtime (e.g. 18h ➔ 3 x 6 shifts beamtime).

Starting 2024 for P08, P11, P22, P23, P24, chemistry labs and nano lab instruments

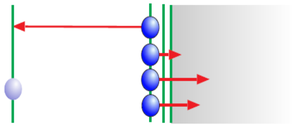
PETRA III

Beamlines can serve many different science areas

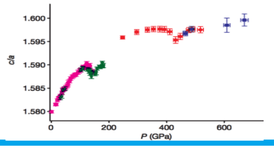
PETRA III users conduct science in many areas, Swedish community is strongest

Extreme States of Matter: From Cold Ions to Hot Plasmas

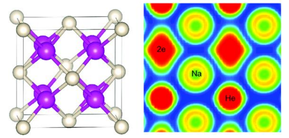
4 e^- Auger transition



750GPa Osmium

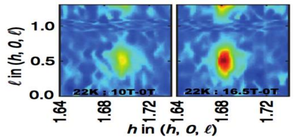


$NaHe_2$ compound

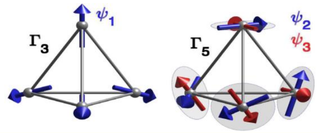


Quantum Condensed Matter: Magnetism, Superconductivity, and Beyond

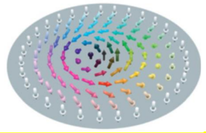
CDWs in YBCO



Spin Waves in Iridates

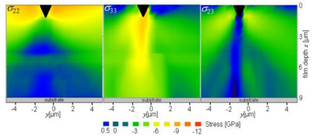


Skyrmions

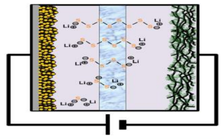


Materials and Processes for Energy and Transport Technologies

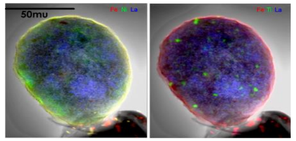
Nano-Indenter



Li/S fuel cell

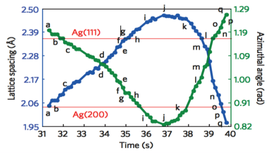


XRF & Ptychography

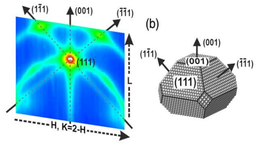


Nanoscience and Materials for Information Technologies

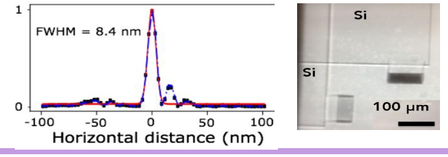
Grain Rotation



Nano-dot Surfaces

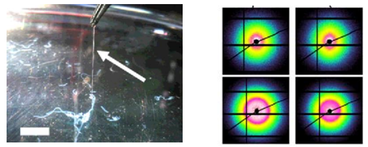


Nanofocus Multilayer-Laue Lens

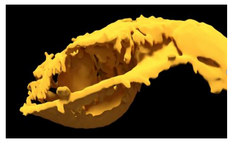


Soft Matter, Health and Life Sciences

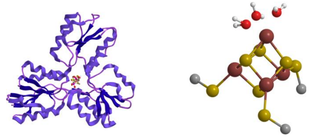
Strongest Protein Fiber



Ancient Midge



Lytb/IspH Structure



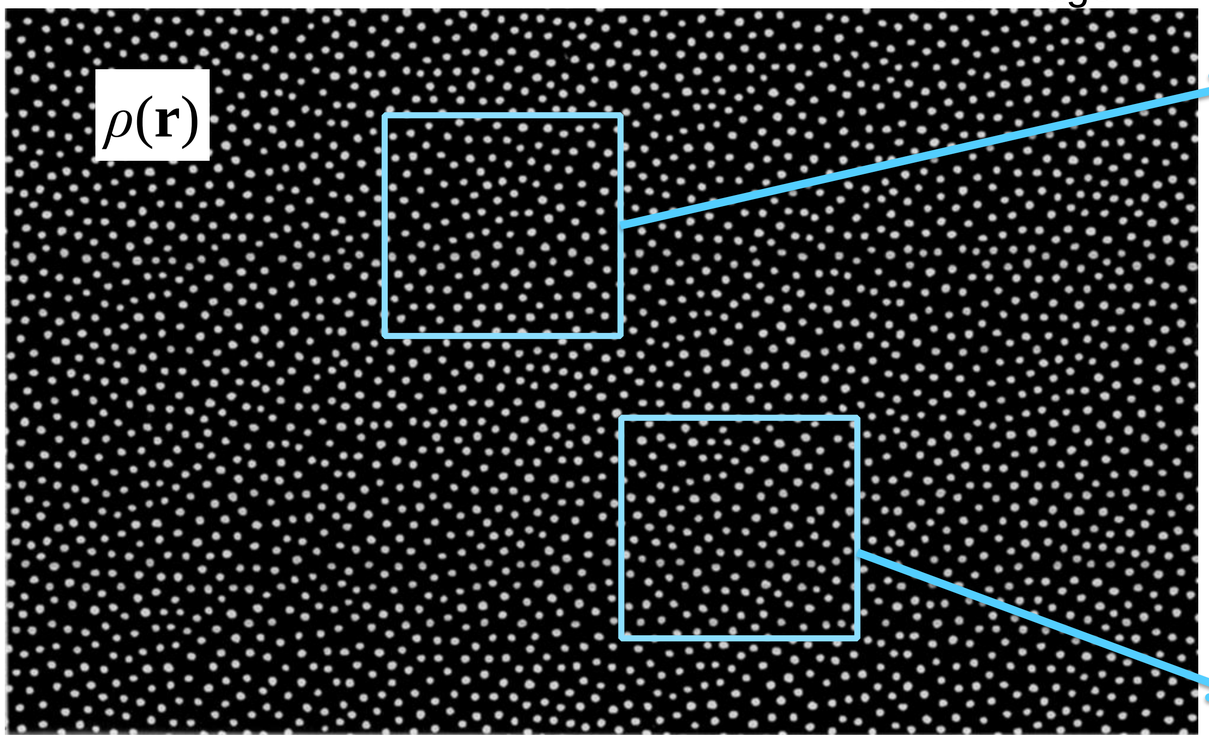
PETRA III delivers coherent photons

Coherence for experiments (demonstrator)

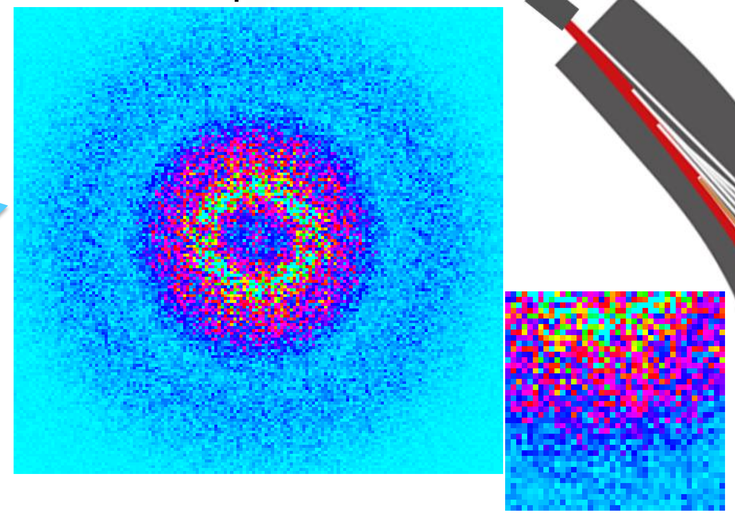
$$A(\mathbf{q}) \propto \int_{V_{\mathrm{coher}}} \rho(\mathbf{r}) \exp(i\mathbf{q}\cdot\mathbf{r})\, d^3r = \mathfrak{F}\{\rho(\mathbf{r})\}$$

coherence volume

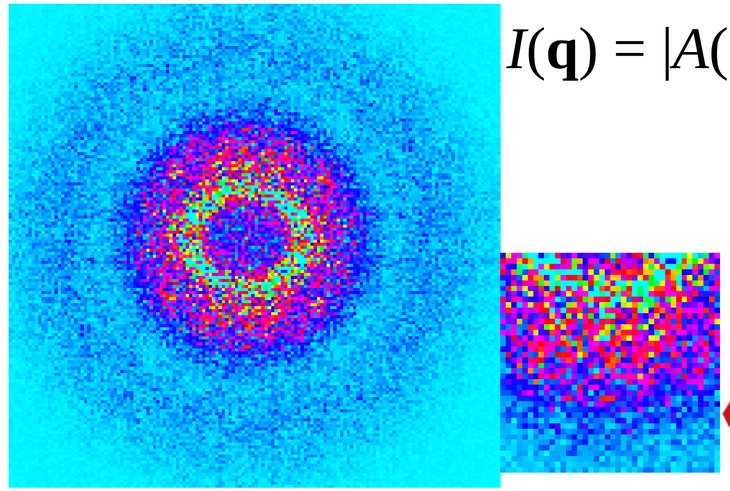
Real image



Coherent scattering with speckles



two diffraction patters:
„similar but different in details“



$$I(\mathbf{q}) = |A(\mathbf{q})|^2$$

➔speckles contain the details of illuminated are
➔overall shape contains the general sample characteristics

Measurement with partially incoherent beam
would be the incoherent sum of all patterns ➔ liquids scattering

PETRA III (Example)

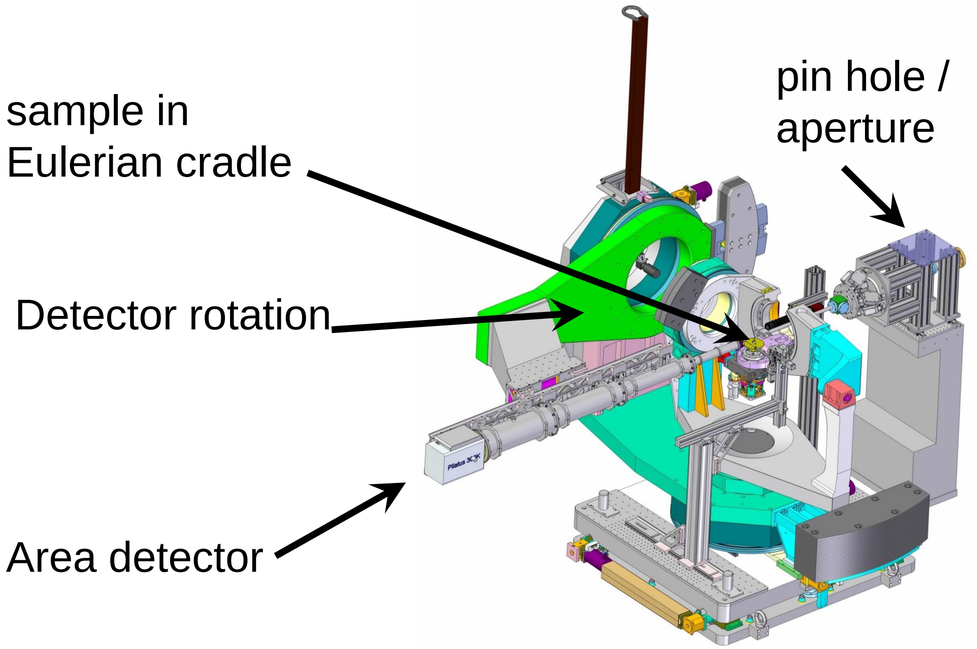
Selected Beamlines: Nano-wires

P10 : Coherence applications

Science Cases

- Structure of nano-particles
- multimodal bio imaging
- Bragg Coherent Diffraction Imaging (CDI)

Energy range : 5 keV – 18 keV
Beamsize @ sample : some 10nm … 500µm
Coherent Flux @ sample: 10^{10} ph/s – 10^{11} ph/s



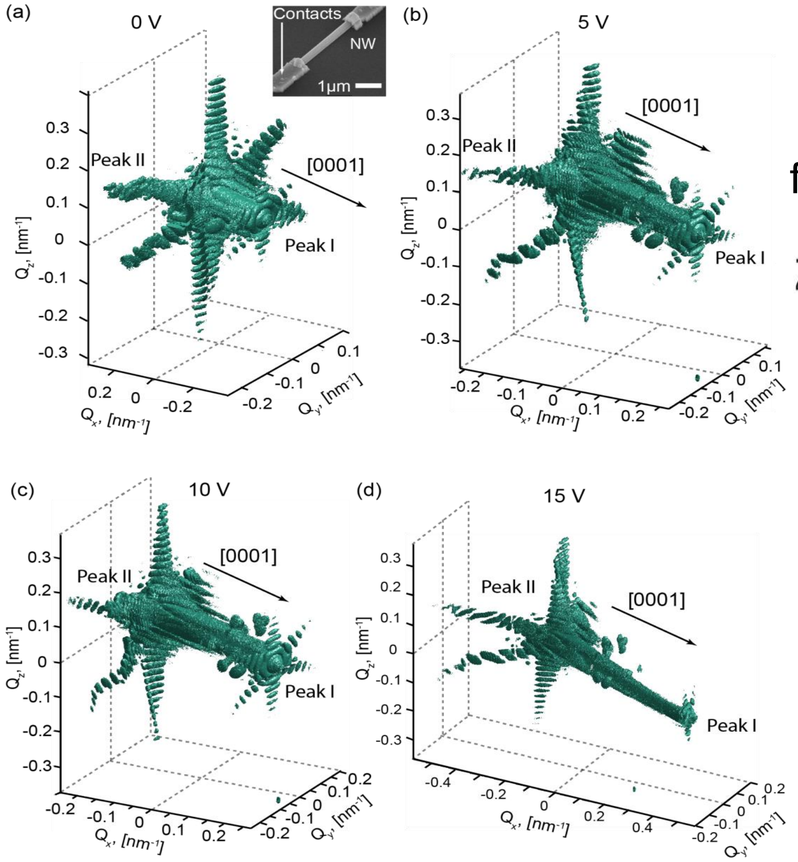
Structural changes in a single GaN nanowire under applied voltage bias

S. Lazarev et. al., Nano Lett. 18, 5446 (2018) P10 @ DESY

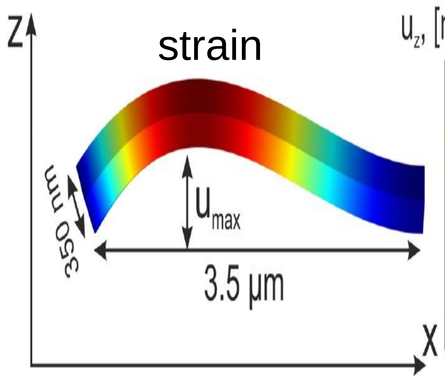
GaN nanowire under heat impact by electrical current

➔ thermal denaturation of crystal lattice?

➔ nano-strain and shape?



Mapping of the 0001 GaN Bragg Reflection as function of position



- exponential growth of aggregates and relaxation time

PETRA III (Example)

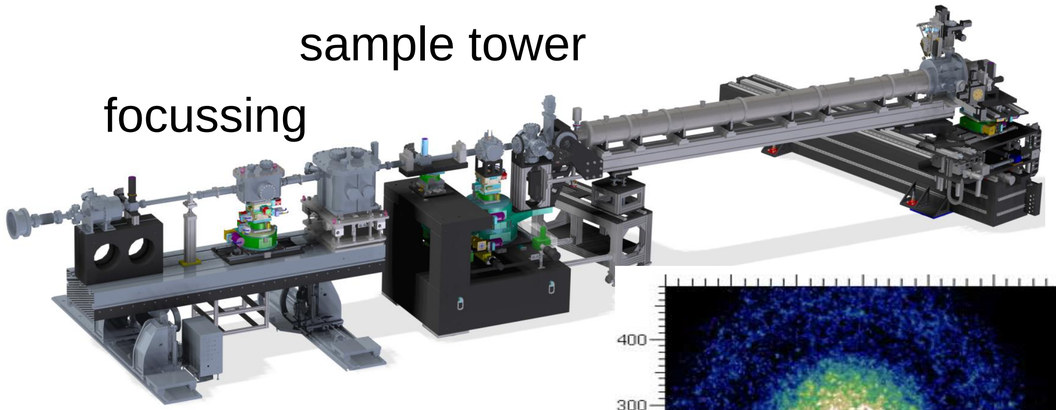
Selected Beamlines: Kinetics/Dynamics

P10 : Coherence applications

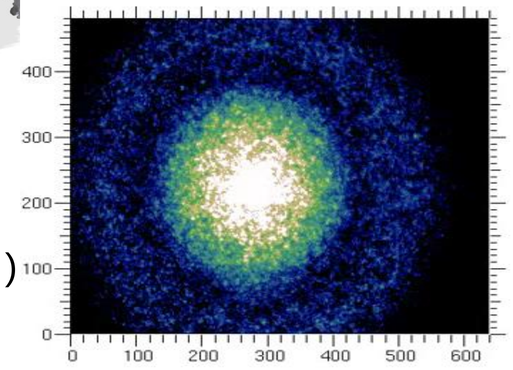
Science Cases
- Dynamics/Kinematics of soft matter
- multimodal bio imaging
- ultra high resolution SAXS

Kinetics of Network Formation and Heterogeneous Dynamics of an Egg White Gel Revealed by Coherent X-Ray Scattering
N. Begam et. al., Phys. Rev. Lett. 126, 098001 (2021) P10 @ DESY

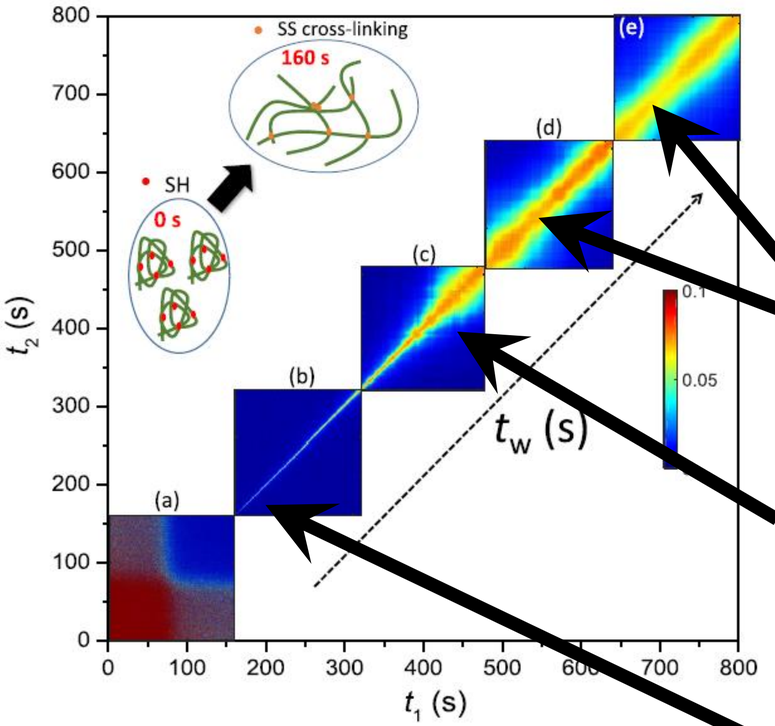
cooking of egg white:
➔ thermal denaturation into a gel network (at 80°C)
➔ kinematics?



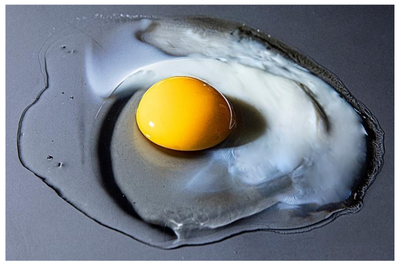
- In-plane diffraction up to 30°
- Focus (10x10nm^2 .. 10x10µm^2)
- XPCS
- Holography
- combines USAXS + coherent imaging



Kinematics of colloids



2-time correlation functions for different waiting times



- periodic “melting” and change of dynamics
➔ heterogeneous dynamics

- slowing down of dynamic
- gelation almost finalized

- expontenial growth of aggregates and relaxation time

PETRA III

Photon Science Team

HC Wille

C.G. Schroer

O.H. Seeck

Thank you !!