PETRA III

Christian G. Schroer

Cooperation partners
UHH · MPG · EMBL · HZG
CSSB partner institutes
Sweden · India · Russia

CSSB
Centre for Structural Systems Biology

European XFEL

X-Ray Free-Electron Laser
atomic structure & fs dynamics
of complex matter

NanoLab

MPI-SD

CFEL SCIENCE

PETRA III

FLASH

Synchrotron radiation source (highest brilliance)

VUV & soft-x-ray free-electron laser

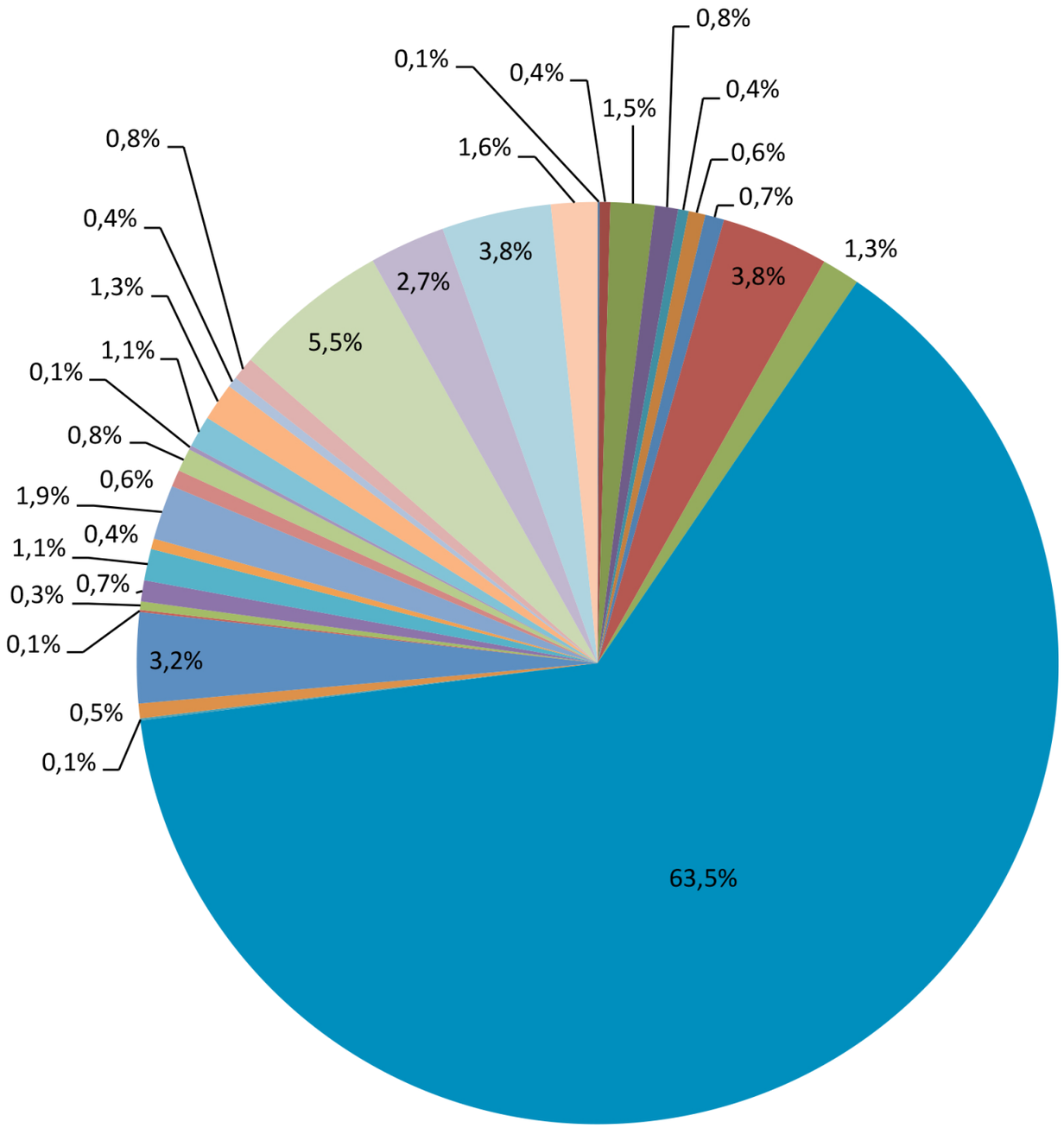
CUI THE HAMBURG CENTRE FOR ULTRAFAST IMAGING

PETRA III: DESY's Brilliant Hard X-Ray Source

- **particle energy:** 6 GeV
- **stored current:** 100 mA (top-up)
- **emittance:** **1.1 nmrad**
- **circumference:** **2304 m**
- **# of undulators:** 25 (incl. canted)
- **# of experiments:** 50
- **X-ray wavelength:** 10 – 0.05 Å
- **annual operation:** 5000 h (for users)

- **built in 1978**
- **rebuilt as a synchrotron radiation source starting in 2007**
- **user operation since 2010**
- **upgrade: March 2014 - April 2015**
- **user operation since: April 2015**

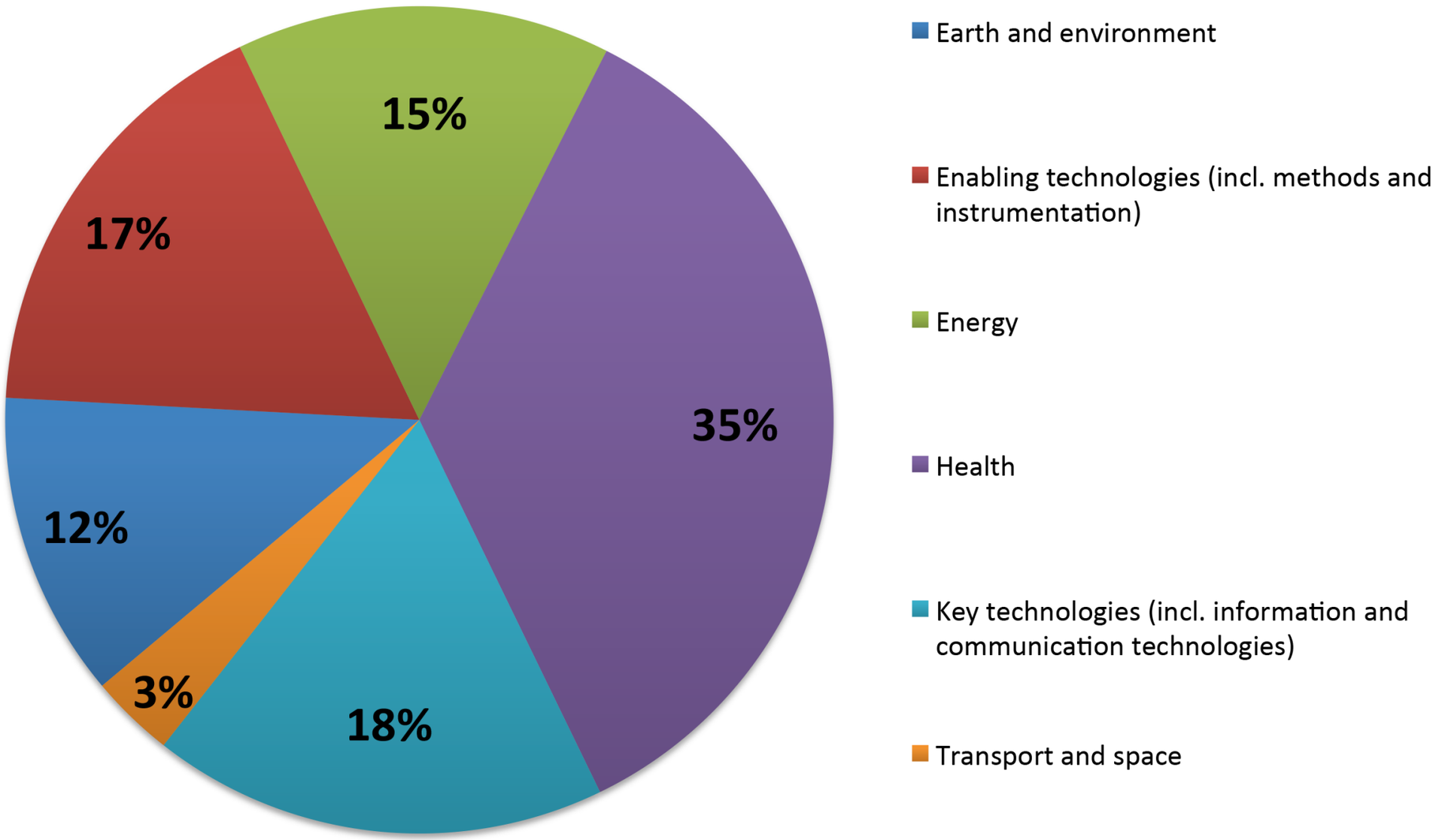
PETRA III: International User Facility



- Argentina
- Australia
- Austria
- Belgium
- Canada
- China
- Czech Republic
- Denmark
- France
- Germany
- Greece
- Hungary
- India
- Indonesia
- Ireland
- Israel
- Italy
- Japan
- Netherlands
- Norway
- Poland
- Portugal
- Russia
- Slovakia
- South Korea
- Spain
- Sweden
- Switzerland
- United Kingdom
- United States

2015: ~2000 users, oversubscription up to 4.5, average 3

PETRA III Science and Societal Challenges



PETRA III Access

http://photon-science.desy.de/users_area/users_guide/

USER OFFICE
CALLS & DEADLINES
NEW USERS
INDUSTRIAL USERS
USERS' GUIDE
- India@DESY User Information
- Find a beamline
- Proposal Categories
- Write a Proposal
- Review & Approval
- Perform an Experiment
- Safety Requirements
- Publications & Acknowledgements
- Reports & Feedback
- Travel Cost Reimbursement

SAFETY REQUIREMENTS
USER COMMITTEE
USERS' MEETING

Home / Users' Area / Users' Guide ·

Users' Guide

Here we provide you with detailed information on how to prepare and submit a proposal and what to do before, during and after your experiment at DESY Photon Science.

The DESY Photon Science facilities PETRA III and the free-electron laser FLASH provide 20 beamlines for manifold applications in fundamental and applied research.

Detailed technical information of the beamlines and experimental facilities are provided on the facility pages of PETRA III and FLASH. For questions concerning the applicability of your experiment you may directly contact the individual beamline scientists listed on the respective PETRA III beamline pages.

PETRA III beamlines P12-P14

Users who are interested in working at the PETRA III beamlines P12-P14 have to prepare their proposal according to EMBL guidelines and have to submit it via the EMBL User Portal.

CATEGORIES

- India@DESY User Information
- Find a beamline
- Proposal Categories
- Write a Proposal
- Review and Approval
- Perform an Experiment
- Safety Requirements
- Publications & Acknowledgements
- Experimental Reports & Beamtime Feedback
- Travel Cost Reimbursement

User facility:
academic and industrial users

Academic users:

> beamtime application process open worldwide

> beamtime granted through external peer-review

> Detailed information on DESY website

> Calls for proposals twice a year: March 1st and Sept. 1st

> Proposals are assigned by topic to Proposal-Review Panels (PRPs)

PETRA III Access

PHOTON SCIENCE
DESY generates pulses of brilliant light.

http://photon-science.desy.de/about_us/committees/prp/

Project Review Panels (PRP)

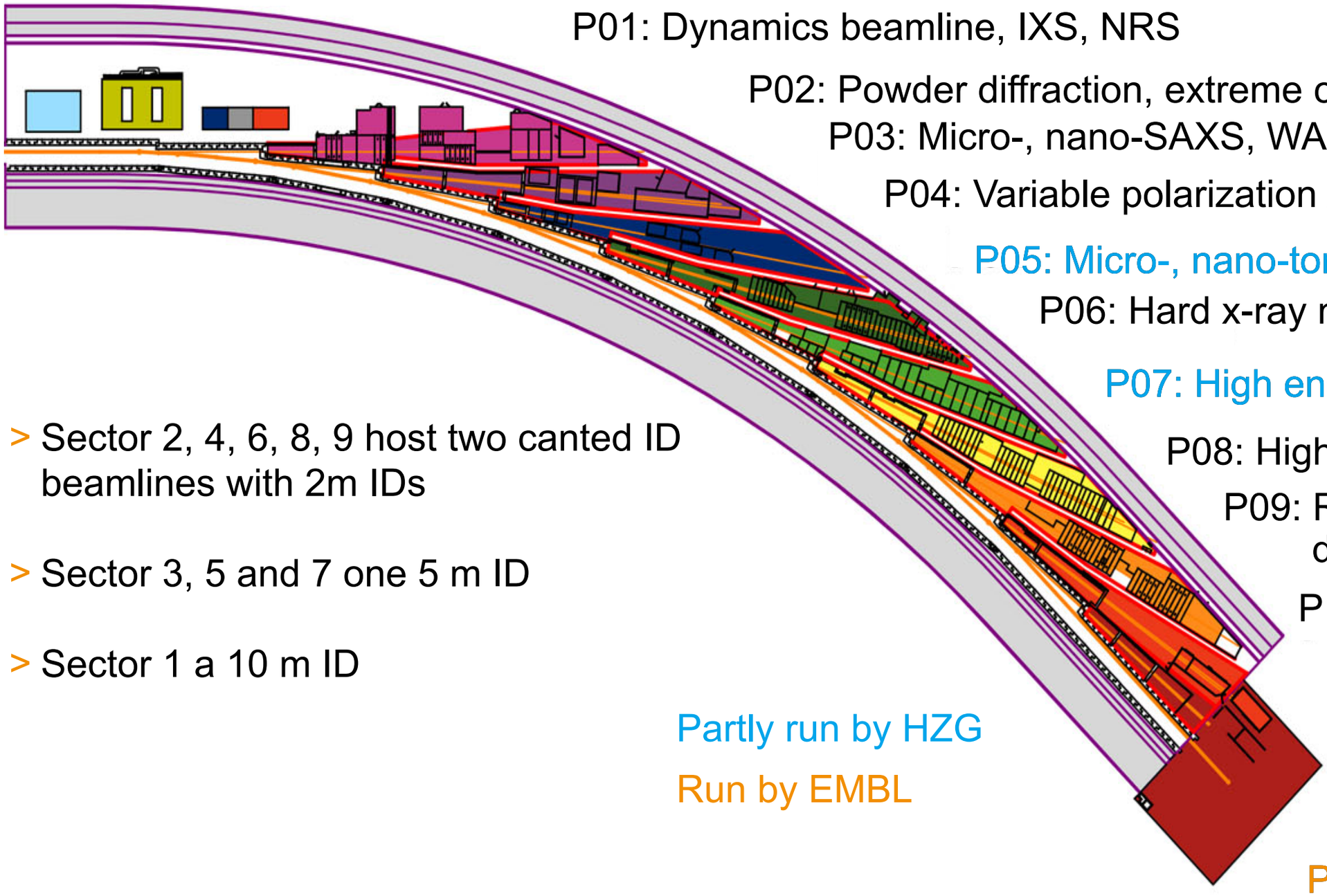
The 'Research **Project Review Panels** ' rate user proposals for new research projects regarding their quality, their feasibility at the proposed PETRA III or FLASH experimental station, and their position in the general research program.

The **PRPs** are review committees each consisting of several external national and international experts (period 3 years) and a DESY Photon Science representative acting as secretary. New members are nominated by the present members and the DESY Photon Science Management. The Project Review Panel meetings are scheduled 2 times a year (~ in May and October). An additional Project Evaluation Committee (PEC) evaluates proposals submitted for the EMBL Life Science beamlines P12-P14

The PRPs cover the following reseach fields:

VUV- and Soft X-ray
X-ray Spectroscopy
High Pressure and Extreme Conditions
Engineering Materials Science
Soft Condensed Matter: Bulk
Soft Condensed Matter: Surfaces and Interfaces
Imaging (full-field, scanning, coherent)
Methods and Instrumentation
Hard Condensed Matter: Surface and Coherent Scattering
Hard Condensed Matter: Bulk (diffraction and scattering)
Soft X-ray - FEL Experiments (FLASH)
PEC: EMBL Life Science beamlines P12-P14 and Bio-crystallography at P11

Max von Laue Hall: 9 Sectors – 14 Beamlines



P01: Dynamics beamline, IXS, NRS

P02: Powder diffraction, extreme conditions

P03: Micro-, nano-SAXS, WAXS

P04: Variable polarization XUV

P05: Micro-, nano-tomography

P06: Hard x-ray micro-, nanoprobe

P07: High energy materials science

P08: High-resolution diffraction

P09: Resonant scattering/ diffraction

P10: Coherence applications

P11: Bioimaging/ diffraction

P12: BioSAXS

P13/14: MX

> Sector 2, 4, 6, 8, 9 host two canted ID beamlines with 2m IDs

> Sector 3, 5 and 7 one 5 m ID

> Sector 1 a 10 m ID

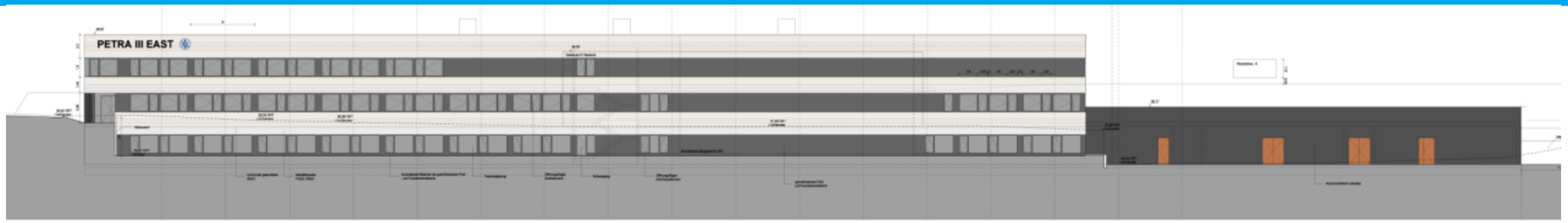
Partly run by HZG

Run by EMBL

PETRA III Extension

PETRA III Extension

PETRA III Extension East



P21: High-energy materials science (1Q 2017)

P22: Nano x-ray spectroscopy (4Q 2016)
(India-motivated beamline)

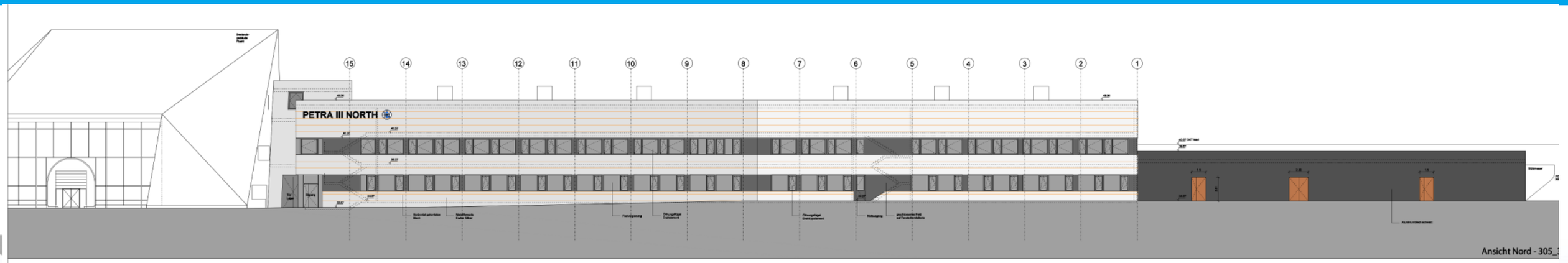
P23: Nano x-ray diffraction (4Q 2016)

P24: Chemical crystallography (3Q 2016)

P25: Education & test BL
(not yet funded)

PETRA III East

PETRA III Extension North



P61: High-energy x-ray engineering materials science (1Q 2017)
(built and operated by HZG and DESY)

P62: SAXS (~ 2018)

P63: t.b.c

now accepting user proposals

P64: XAS (3Q 2015)

P65: XAS (3Q 2015)

P66: time-resolved luminescence spectroscopy (1Q 2017)

P61A

P62

P61B

P65

P63

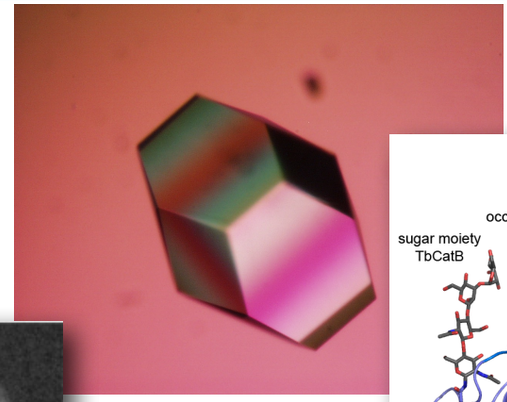
P64

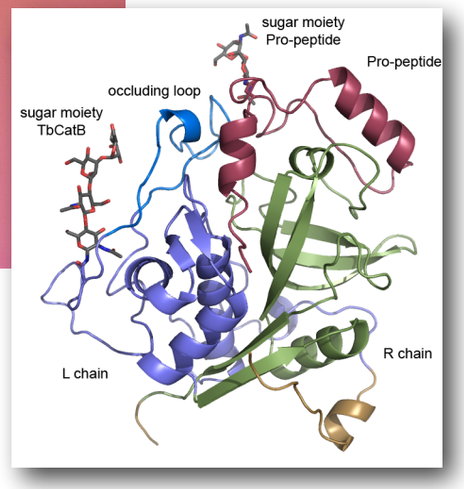
PETRA III North

PETRA III Extension North

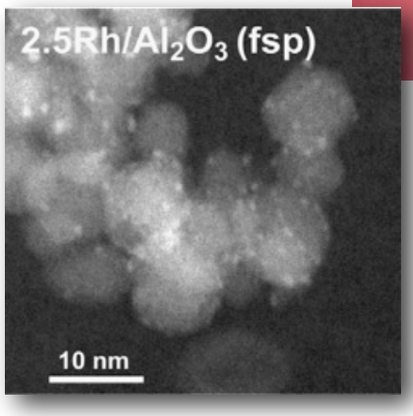
September 2015

PETRA III: Research Topics

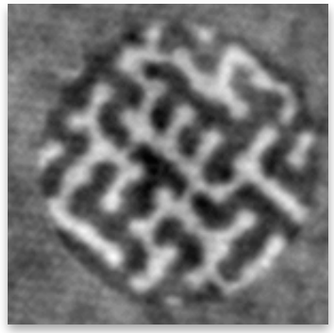


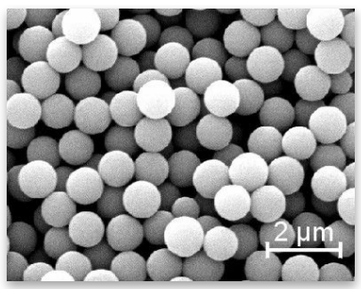


- Life sciences
  - structure of proteins (small crystals, membrane proteins)
  - cell physiology (e. g. photosynthesis)
  - drug design
- Chemistry (e. g. catalysis)
  - heterogenous catalysis on nanoscale
  - surface reactions
  - battery research (electro chemistry)

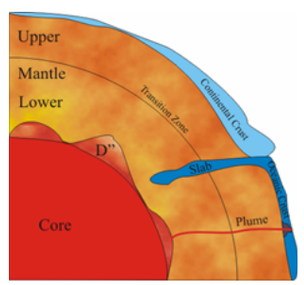


- Solid-state physics and chemistry
  - ordering of electronic degrees of freedom
  - single defects and structure and dynamics (e. g., domain boundaries)
  - magnetic thin films (electronic structure at surface and interfaces)
  - dynamics of strongly correlated electron systems
  - multiferroics
  - (photo-induced) phase transitions





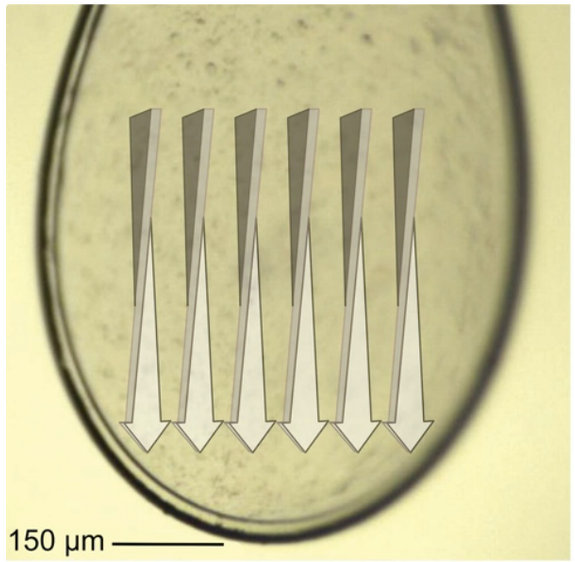
- Soft matter
  - properties of colloids, complex fluids
  - glass transition
- Environmental science
  - environmental behavior of various elements (distribution and chemistry)
  - uptake of toxins by biological systems
- …

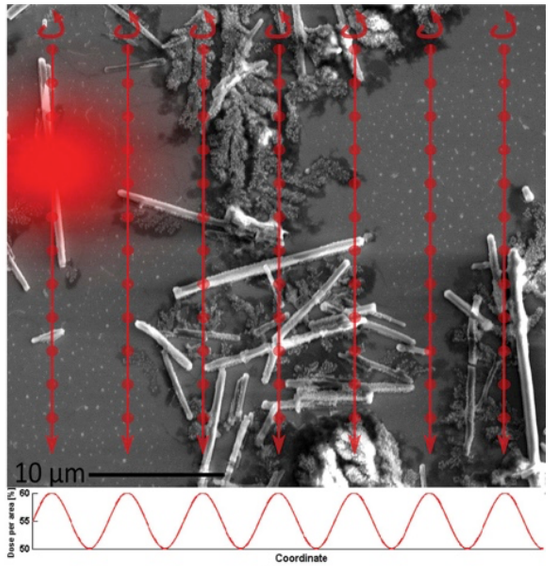


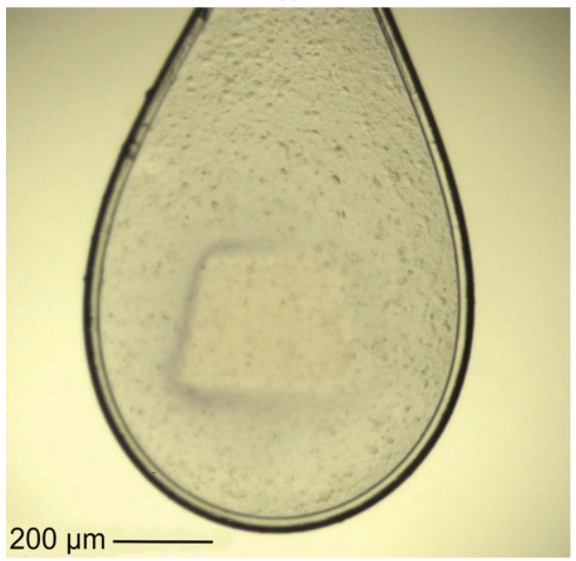
Serial Crystallography Using Synchrotron Radiation

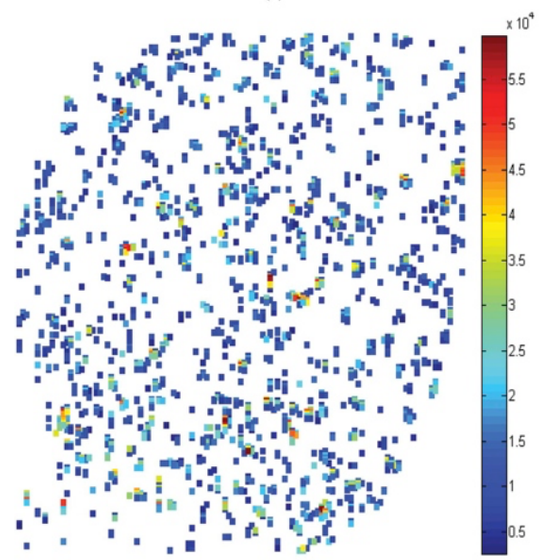
Serial crystallography on in vivo grown microcrystals

Gati et al. , IUCrJ (2014). 1, 87–94 (March 2014)







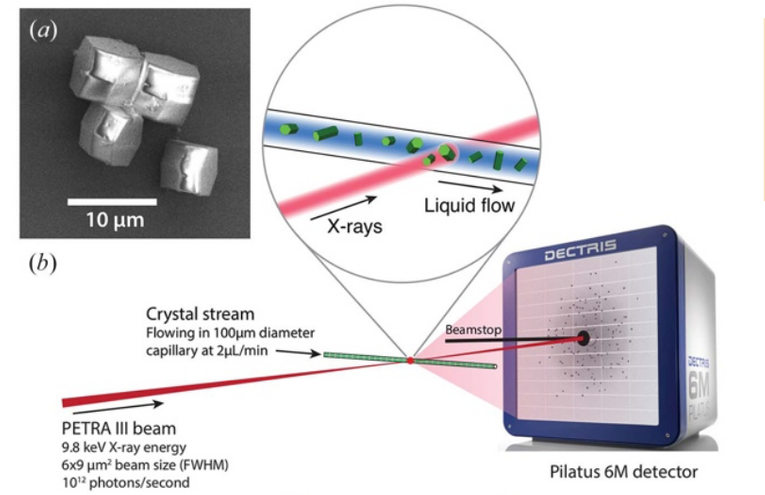


standard cryogenic loop: isolated in vivo grown procathepsin B microcrystals
Beamline P14 (EMBL)

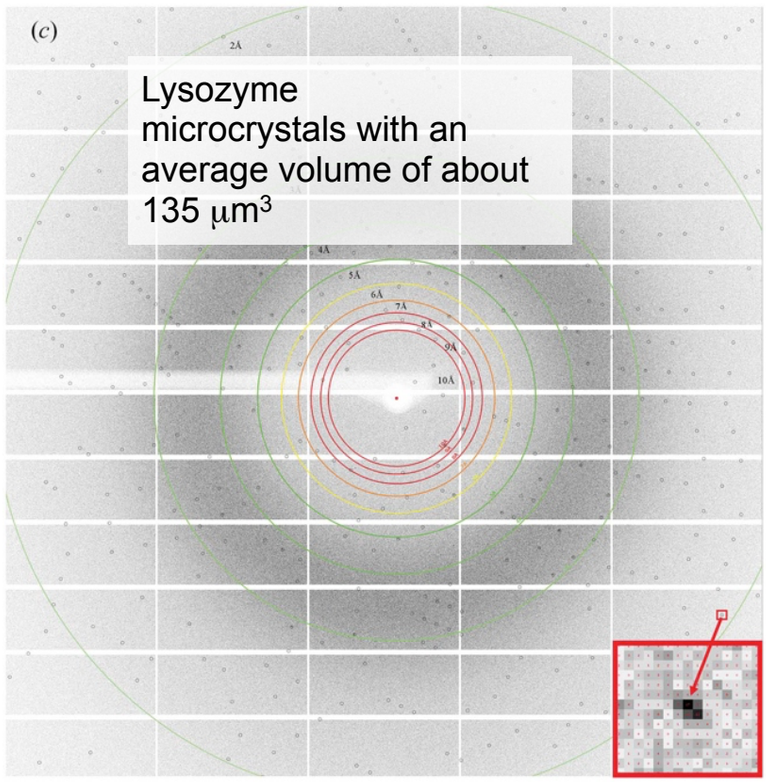
measurement time of about 8 h

Serial crystallography on room-temperature macromolecular crystals

Stellato et al. IUCrJ (2014). 1, 204–212 (Juli 2014)



crystal stream in a capillary
Beamline P11

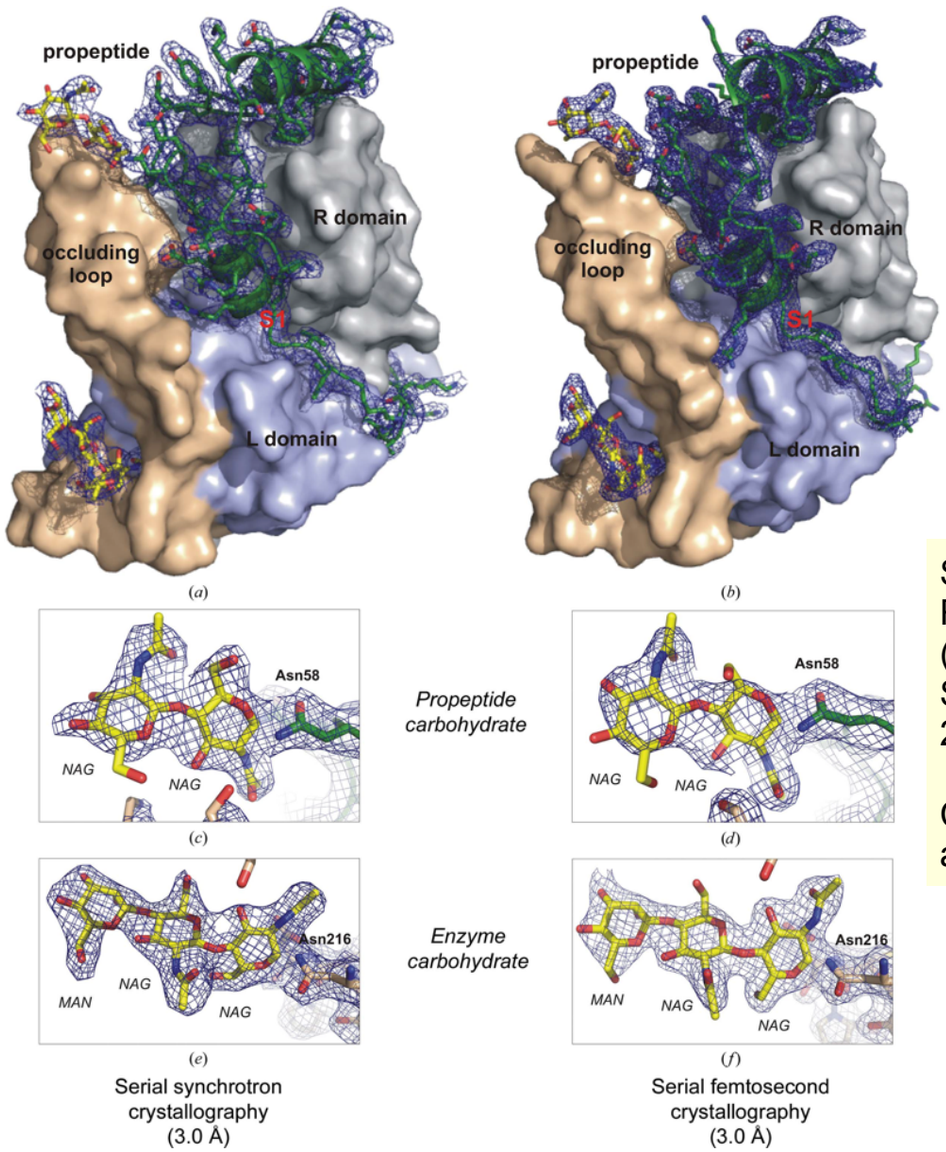


measurement time: about 17 h

Serial Crystallography Using Synchrotron Radiation

Serial crystallography on in vivo grown microcrystals

Gati et al. , IUCrJ (2014). 1, 87–94 (March 2014)



Serial synchrotron crystallography (3.0 Å)

Serial femtosecond crystallography (3.0 Å)

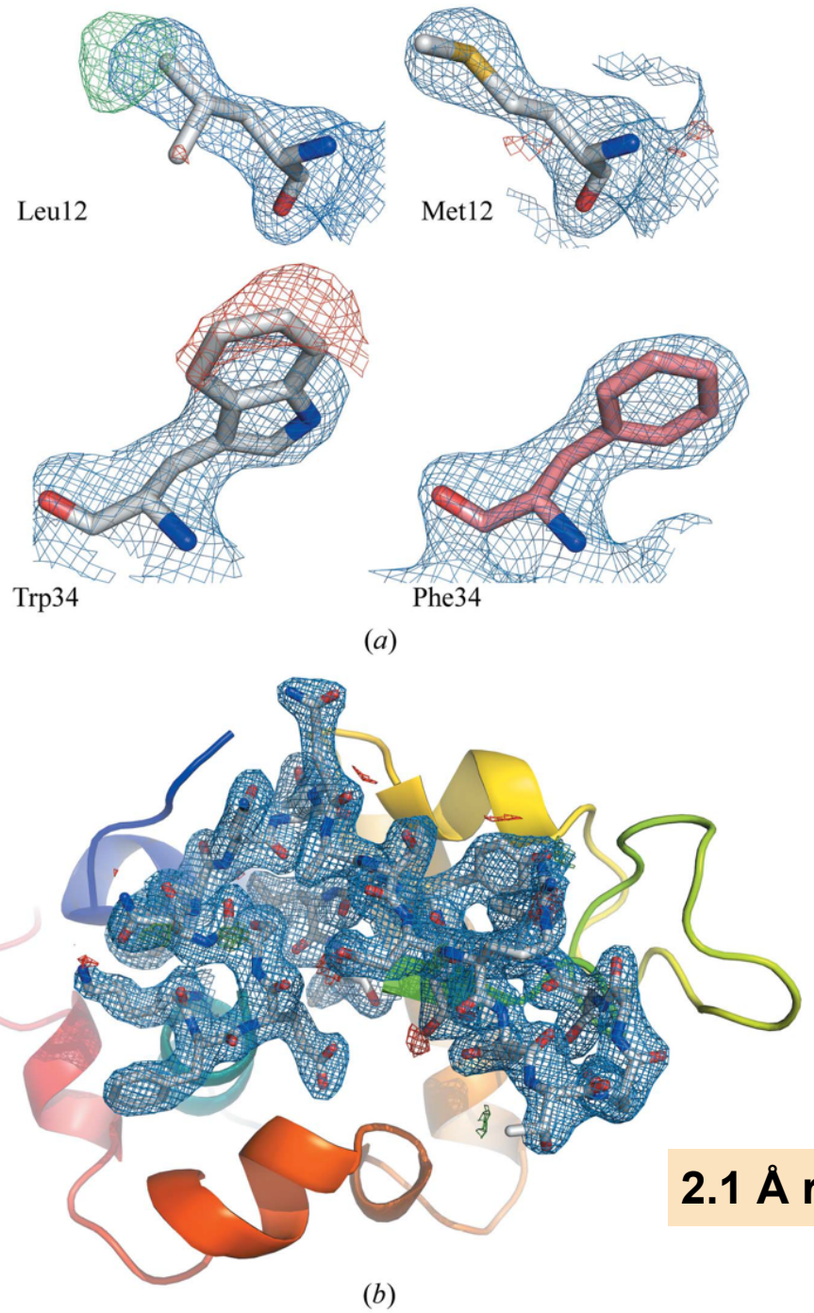
SFX Data: Redecke et al. (2013). Science, 339, 227–230

CXI beamline at LCLS

3.0 Å resolution

Serial crystallography on room-temperature macromolecular crystals

Stellato et al. IUCrJ (2014). 1, 204–212 (Juli 2014)



2.1 Å resolution

Multilayer Growth of the Fullerene C_{60} in Real Time

Nanoscopic understanding of growth of organic thin films.

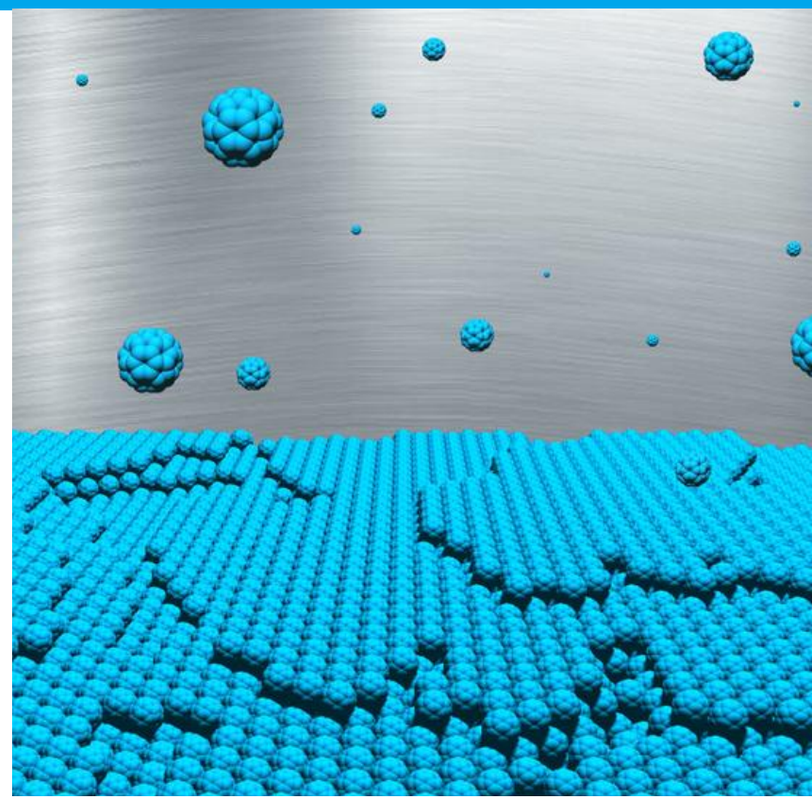
Monitoring the growth of C_{60} @ P03/PETRA III

S. Bommel, el al., *Nature Communications* **5**, 5388 (2014).

Simultaneous measurement of

> vertical film formation (film roughness)

> lateral film formation (island density)



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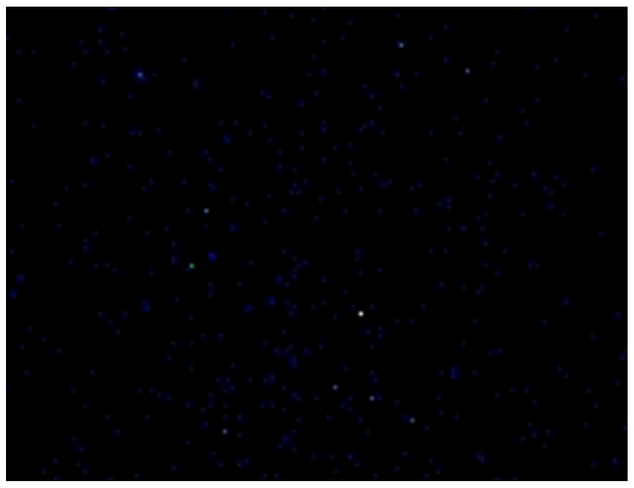
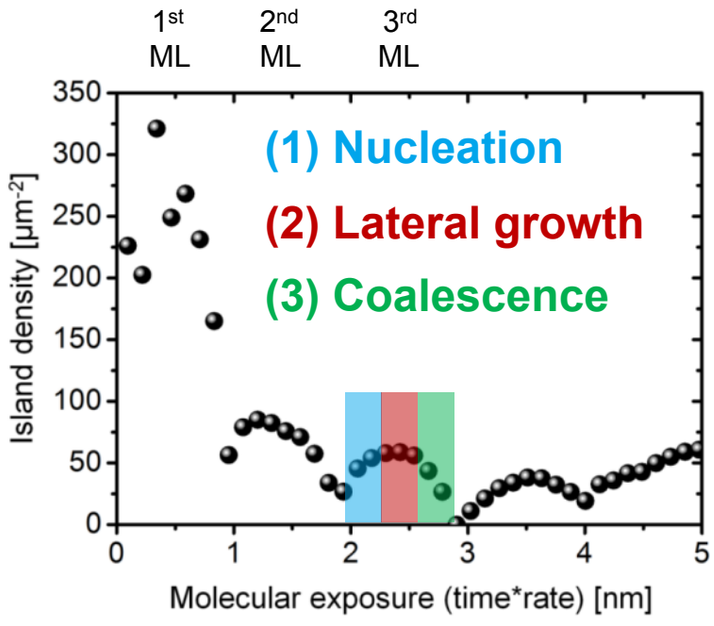
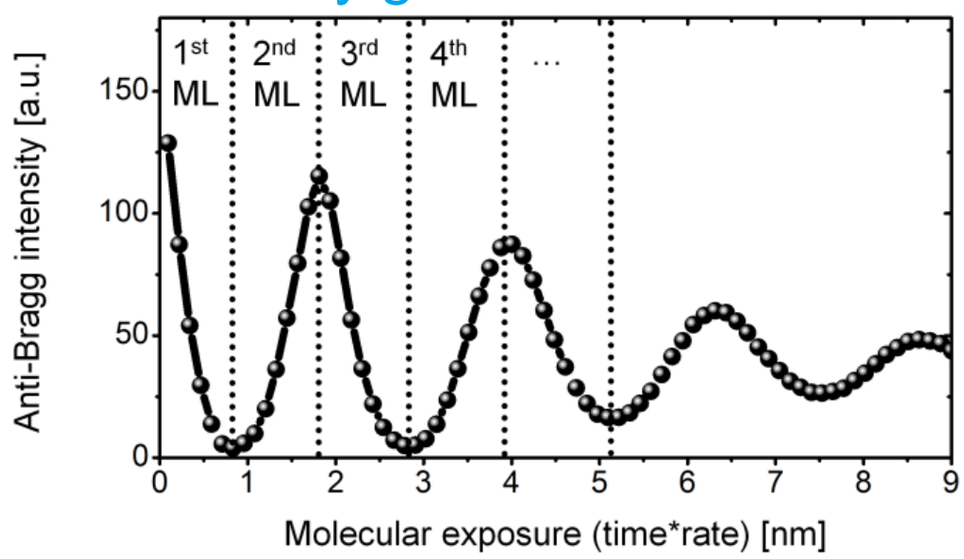
diffuse X-ray scattering (GISAXS)





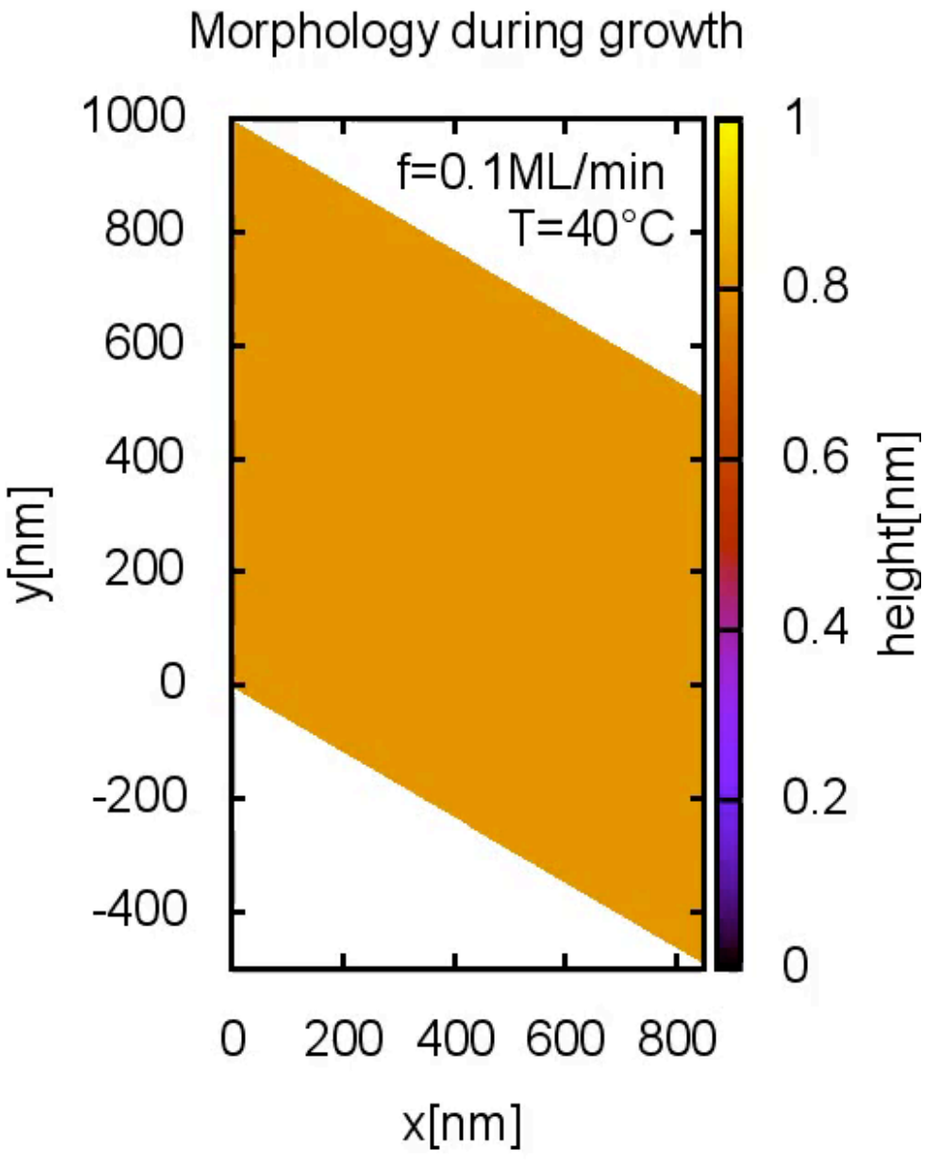
X-ray growth oscillations

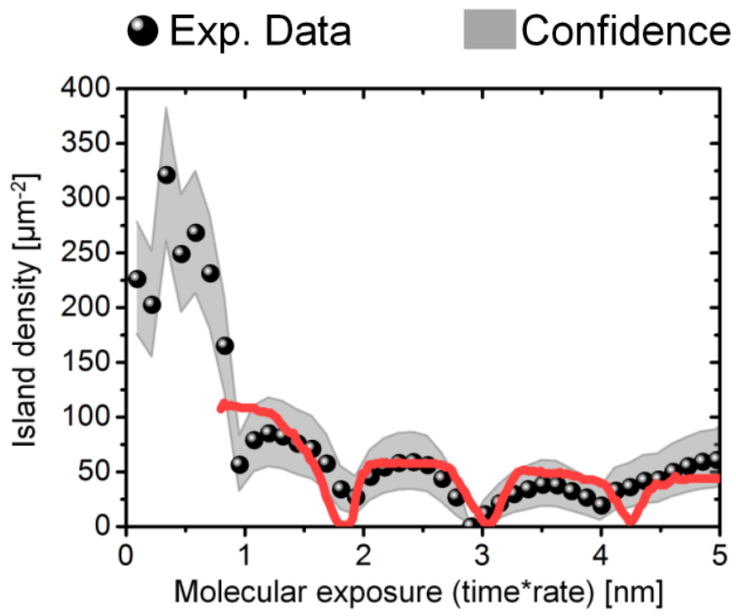


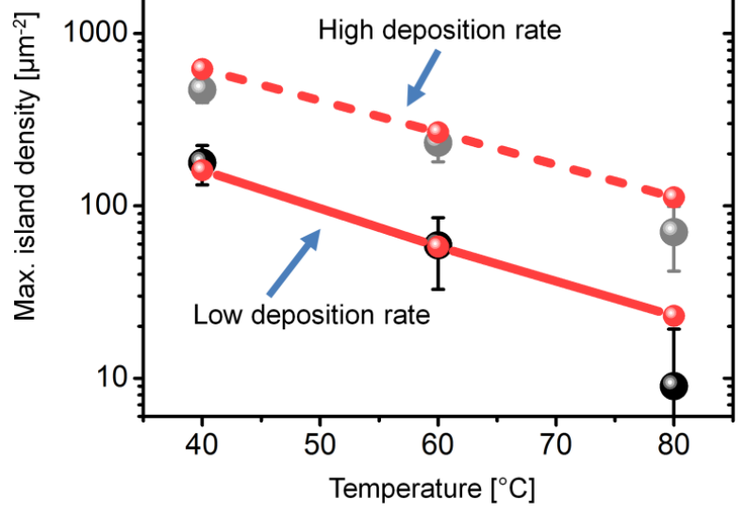
Research project is collaboration of DESY (S. Roth) and HU Berlin (S. Kowarik)

Multilayer Growth of the Fullerene C_{60} in Real Time

> Comparison with **K**inetic **MC** simulations performed by S. Klapp (TU Berlin)

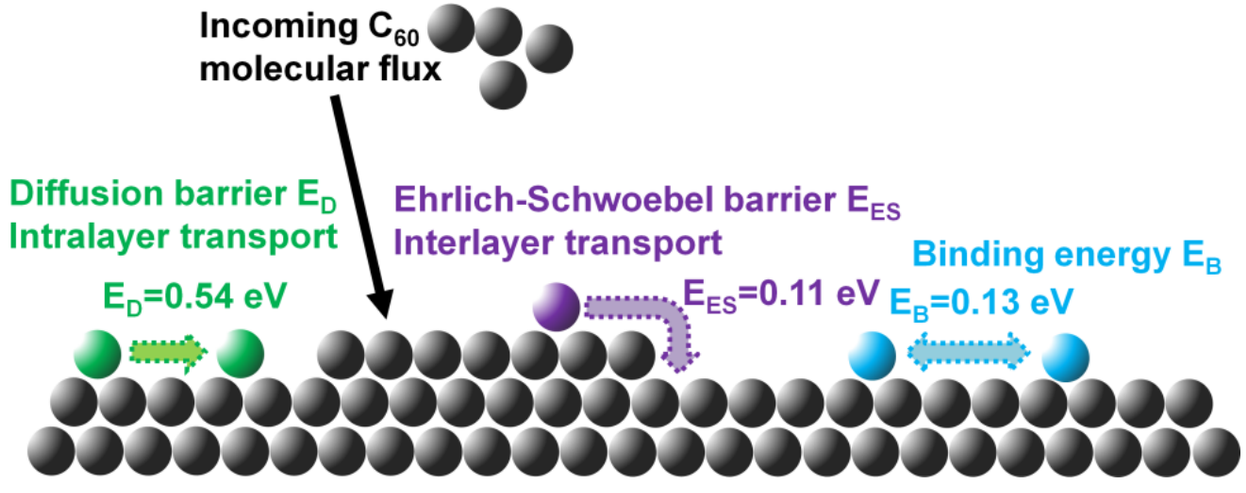






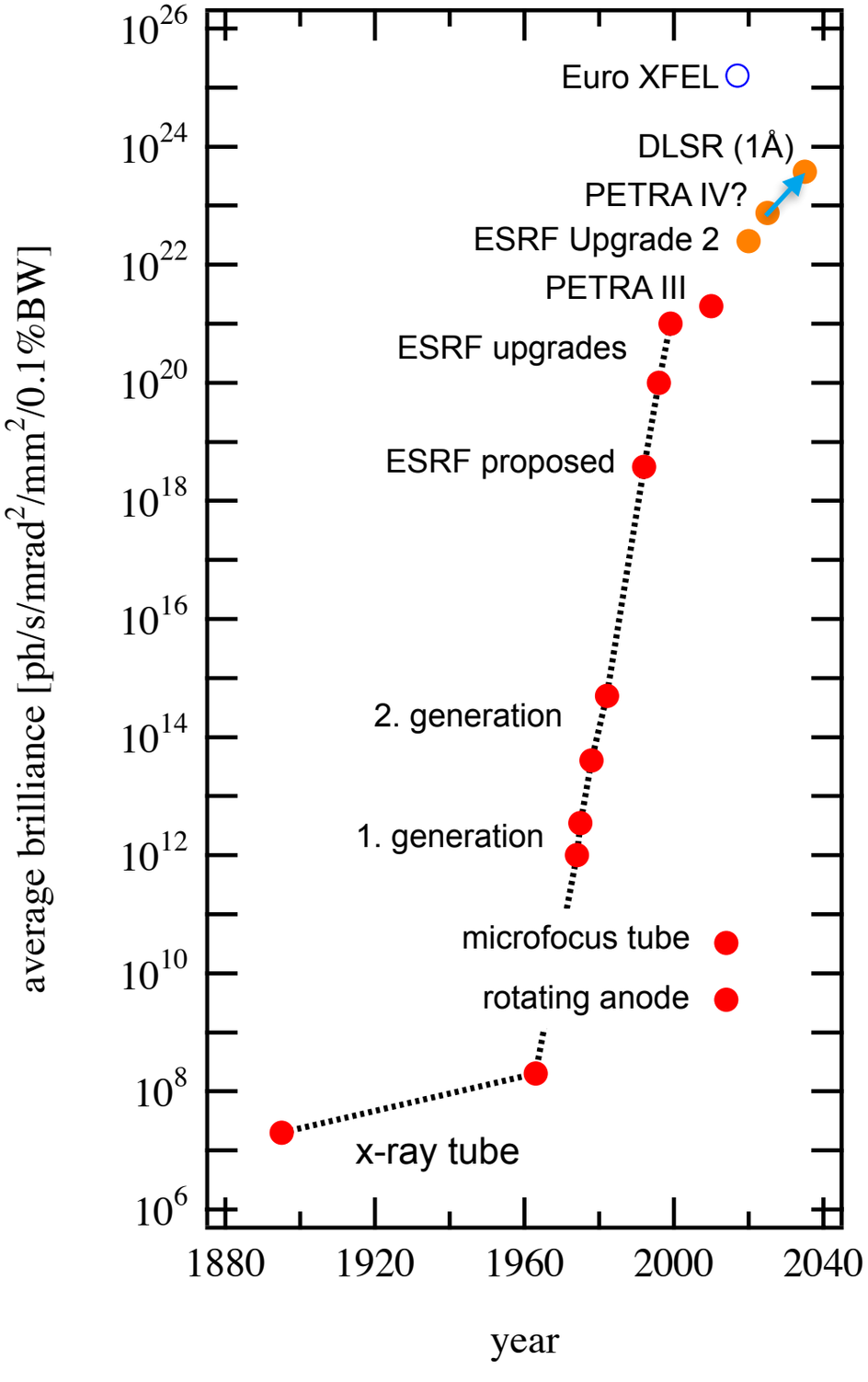
S. Bommel, el al., *Nature Communications* **5**, 5388 (2014).

> Quantification of surface processes



> Predictive simulations of C_{60} nanostructures

Future Perspectives for PETRA III



Improvements in brightness:

- faster measurements (time resolution)
- nano-imaging (spatial resolution)
- spectroscopy (energy resolution)

PETRA III medium term perspective (until 2019):

- completion of the PETRA III extension project
- completion of the PETRA III beamline portfolio
- mild (20 - 30%) horiz. emittance reduction

→ parallel operation of 27 undulator stations

PETRA IV: ultra-low emittance source

- reduced emittance: → 10 - 20 pmrad or smaller
- major upgrade of storage ring and beamlines
- time frame: 2026 onward

Design of a New Source

source size:
140 µm x 6 µm

New Multi-Bend-Achromat technology

source size:
6 µm x 6 µm

asymmetrical x-ray beam

round x-ray beam

Gain factor
50

PETRA III

3rd generation SR source
1000 pm rad

Max. brilliance: ~10^{20}
coherence: ~0.1-1%

nanometer focusing

PETRA IV

4th generation SR source
~20 pmrad

Max. Brilliance: >10^{22}
Coherence: > 25%

PETRA IV

> new multi-bend-achromat (MBA) technology +

> 2.3 km circumference (largest SR source)
emittance scales as 1/(circumference)^3

→ diffraction limited down to a wavelength of 1 Å (ultimate storage ring)

Quantensprung in Synchrotronstrahlungsanalytik

In-situ 3D-Microscopy on nanometer scale

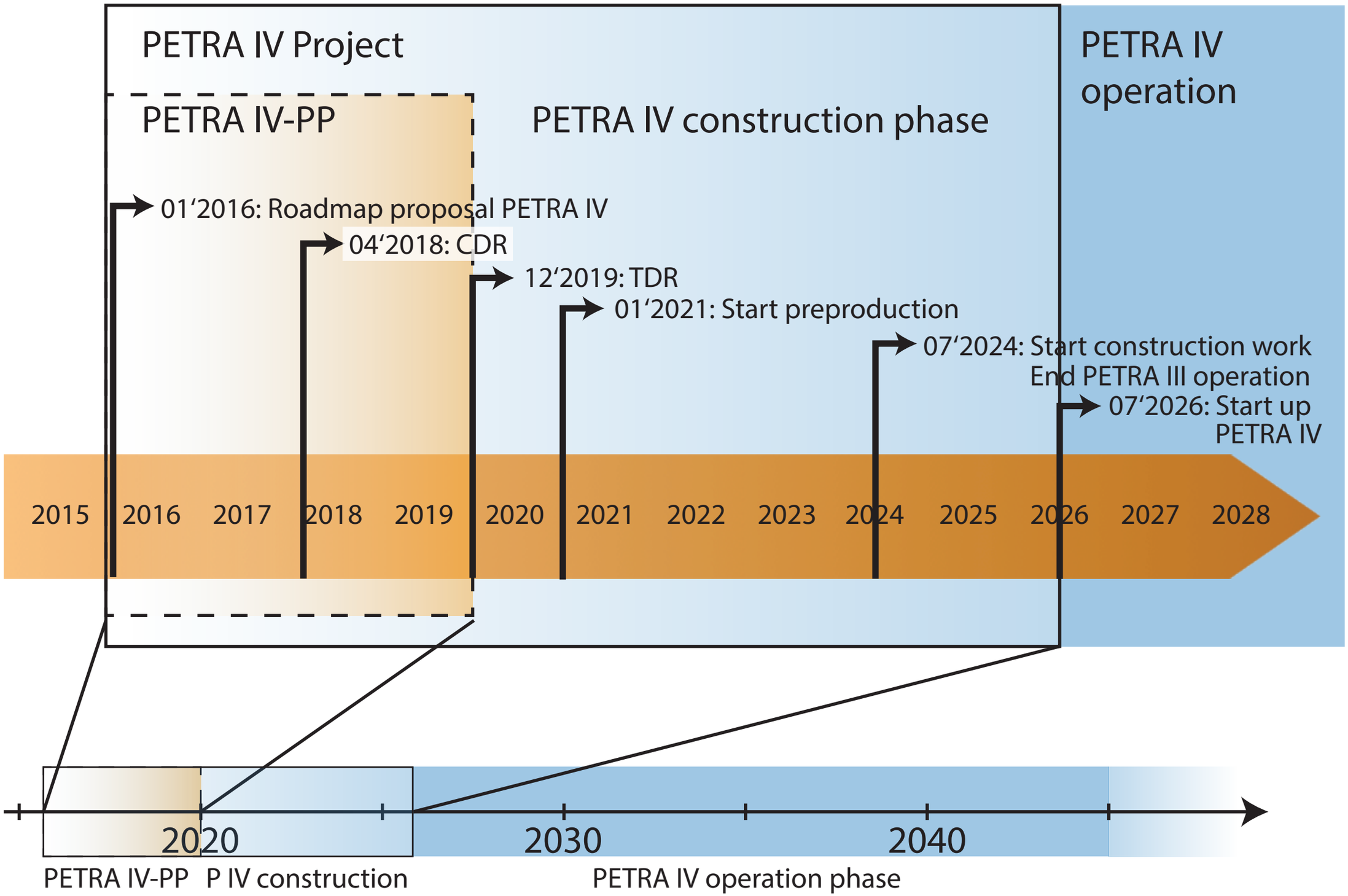
Operando nanoimaging of

> structure, chemistry

> electronic and magnetic properties

> dynamics on the sub-nanosecond scale

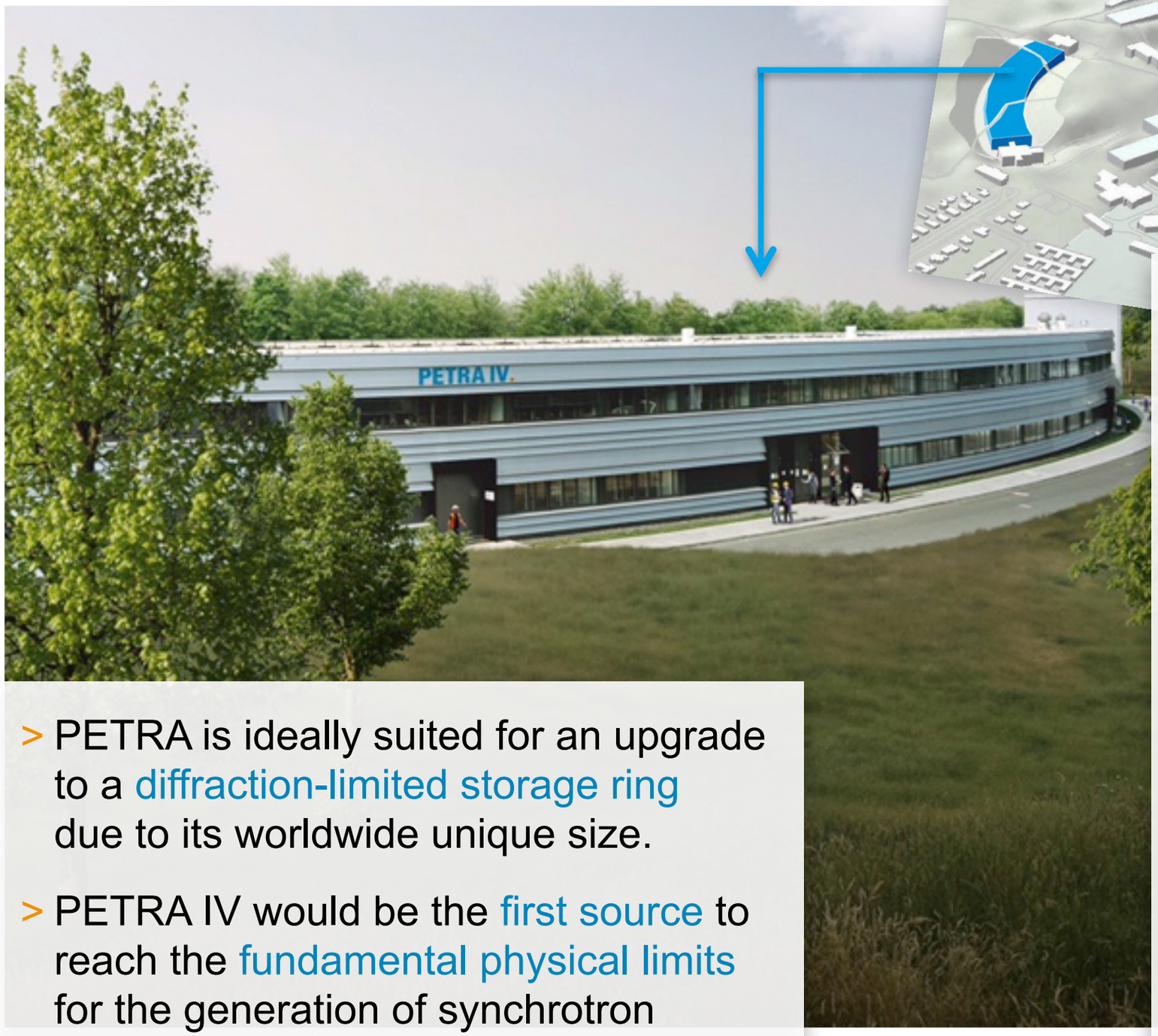
PETRA IV Project Timeline

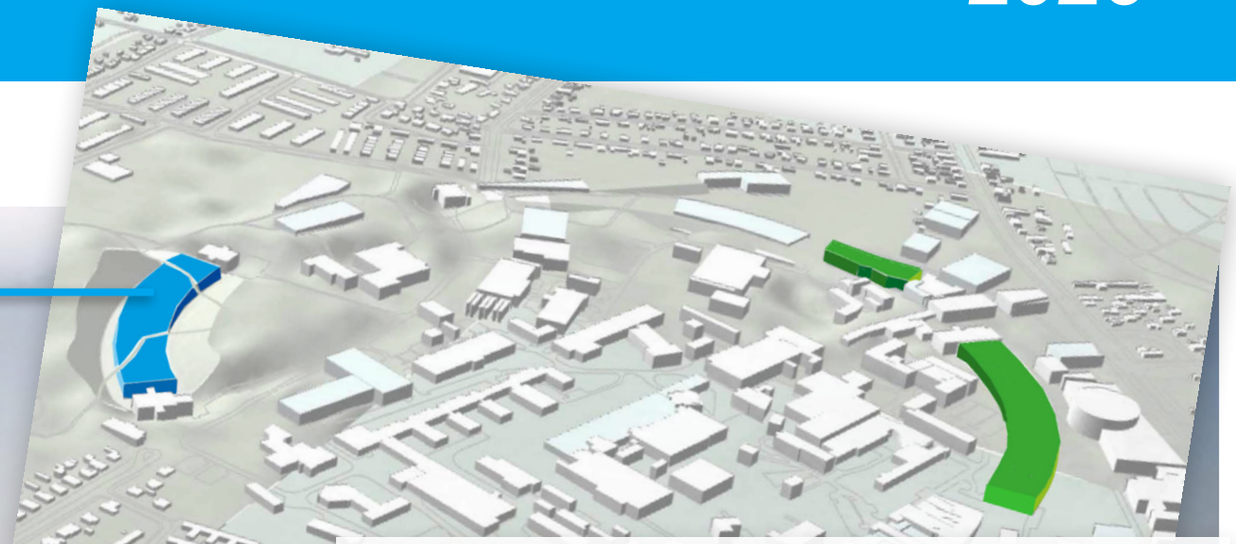


PETRA IV Project

2026+

PETRA IV Experimental Hall





- PETRA is ideally suited for an upgrade to a diffraction-limited storage ring due to its worldwide unique size.
- PETRA IV would be the first source to reach the fundamental physical limits for the generation of synchrotron radiation at 1 Å wave length.

- In-situ/operando 3D microscope nano imaging of processes with
  - chemical
  - structural
  - electronic
  - magnetic
  - …

  contrast on all relevant length and (slower) time scales (~ ns)
- Novel contributions:
  - health
  - energy
  - mobility/transport
  - IT/communication
  - earth and environment
  - …