The European Spallation Source

Neutron Macromolecular Crystallography (NMX)

MXCuBE Meeting May 2024

2024-05-29

Aaron Finke, Instrument Data Scientist

Macromolecular Crystallography

ESS High Level Design

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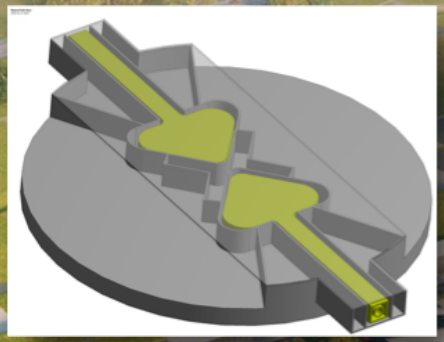
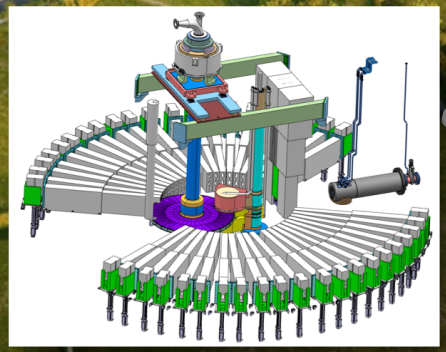
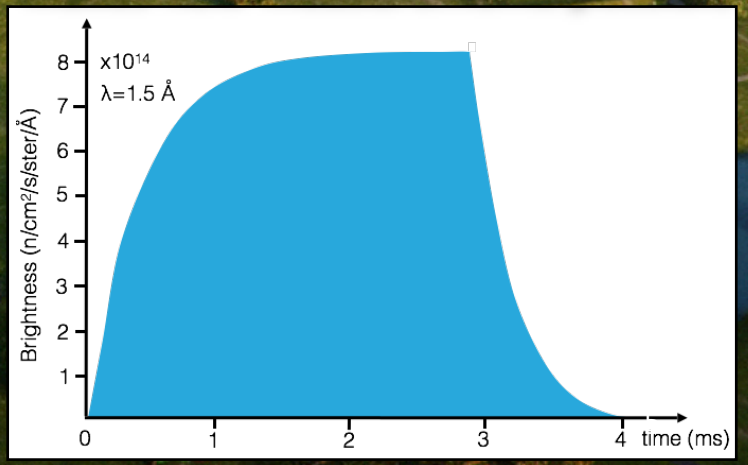
High Power Accelerator means more neutrons

Flat moderator delivering smaller and brighter neutron beams





High brightness and tuneable resolution makes new measurements possible



An Innovative Target Station that can host >30 instruments

The world's brightest neutron source

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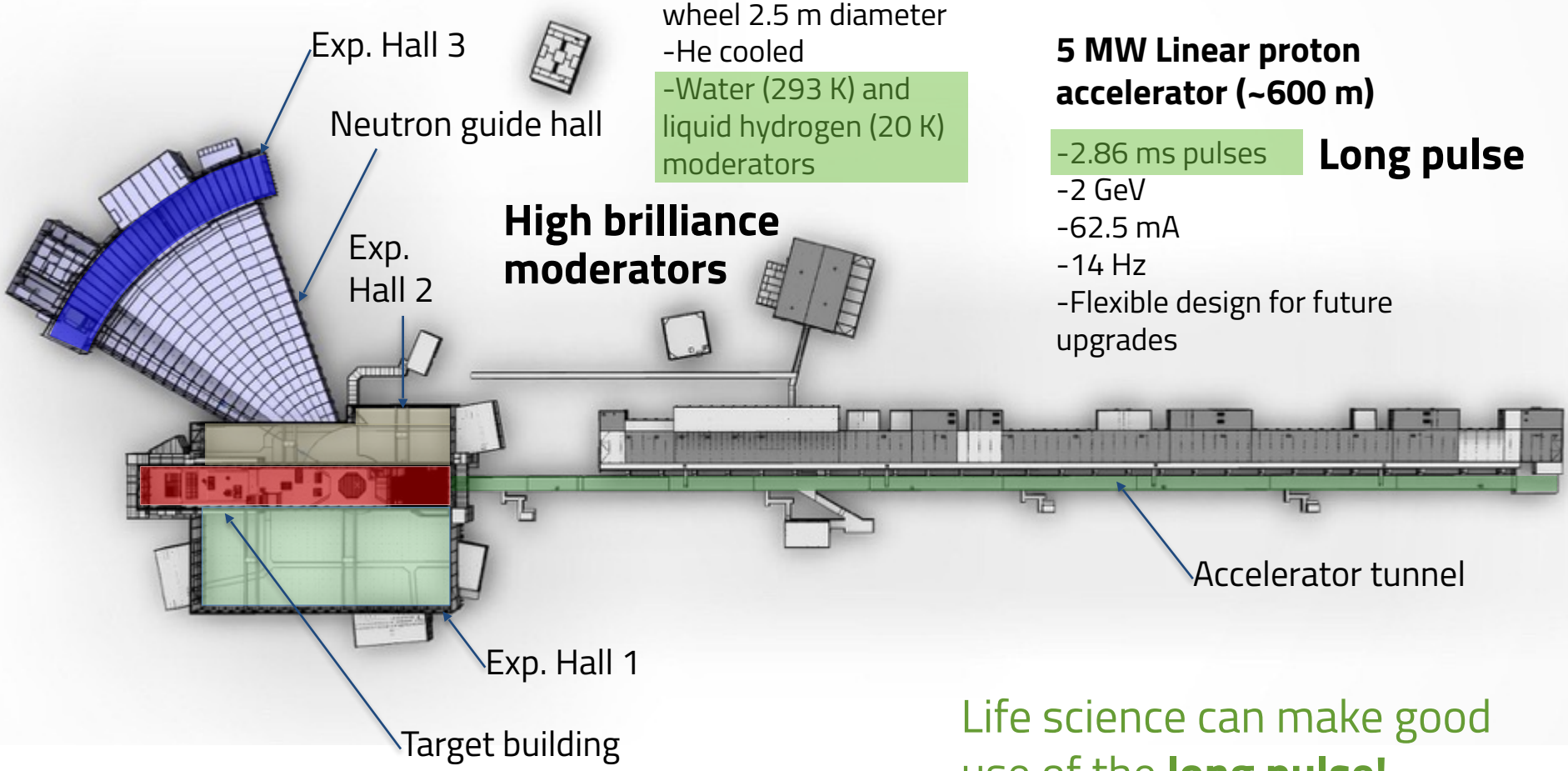
Target station
-Rotating tungsten wheel 2.5 m diameter
-He cooled
-Water (293 K) and liquid hydrogen (20 K) moderators

5 MW Linear proton accelerator (~600 m)
-2.86 ms pulses **Long pulse**
-2 GeV
-62.5 mA
-14 Hz
-Flexible design for future upgrades



Life science can make good use of the **long pulse!**

A European Project

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Host countries

Sweden, Denmark

Construction
47.5%

Operations
15%

Budget for construction €1.84 billion
Estimated annual budget €140 million

Non host member countries

Czech Republic, Estonia, France, Germany, Hungary, Italy, Norway, Poland, Spain, Switzerland, United Kingdom.

Construction
52.5%
(of which 70% is in-kind deliverables)

Operations
85%

A European Project

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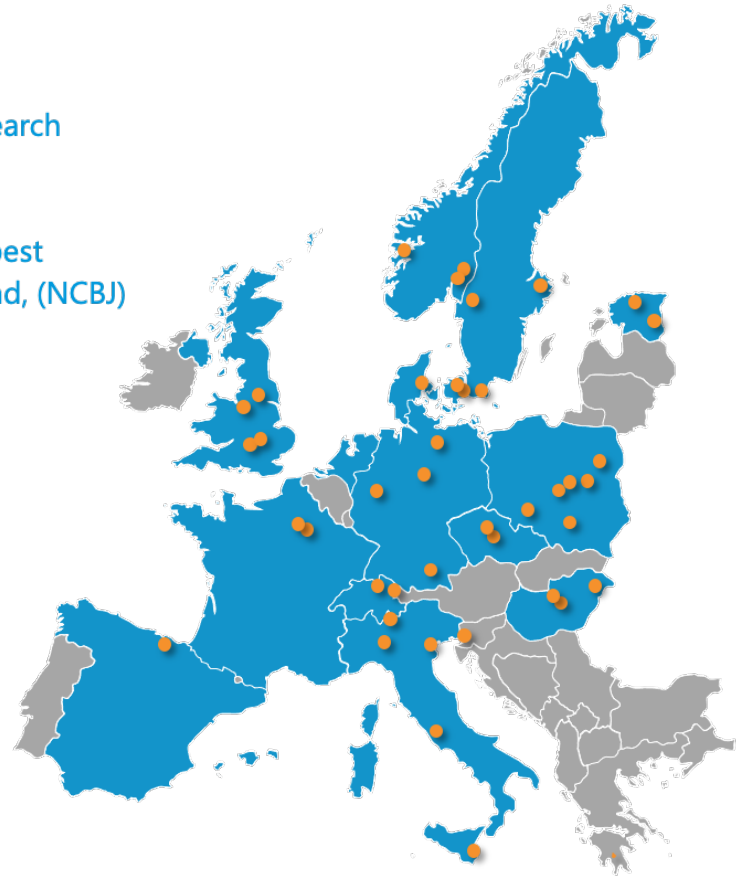
How will it be built?

Aarhus University
Atomki - Institute for Nuclear Research
Bergen University
CEA Saclay, Paris
Centre for Energy Research, Budapest
Centre for Nuclear Research, Poland, (NCBJ)
CNR, Rome
CNRS Orsay, Paris
Cockcroft Institute, Daresbury
Elettra – Sincrotrone Trieste
ESS Bilbao
Forschungszentrum Jülich
Helmholtz-Zentrum Geesthacht
Huddersfield University
IFJ PAN, Krakow
INFN, Catania
INFN, Legnaro
INFN, Milan
Institute for Energy Research (IFE)
Rutherford-Appleton Laboratory, Oxford (ISIS)
Copenhagen University
Laboratoire Léon Brillouin (CEA/CNRS/LLB)
Lund University
Nuclear Physics Institute of the ASCR
Oslo University
Paul Scherrer Institute (PSI)
Polish Electronic Group (PEG)
Roskilde University
Tallinn Technical University
Technical University of Denmark
Technical University Munich
Science and Technology Facilities Council
UKAEA Culham
University of Tartu
Uppsala University
WIGNER Research Centre for Physics
Wroclaw University of Technology
Warsaw University of Technology
Zurich University of Applied Sciences (ZHAW



ESS Instrument Suite

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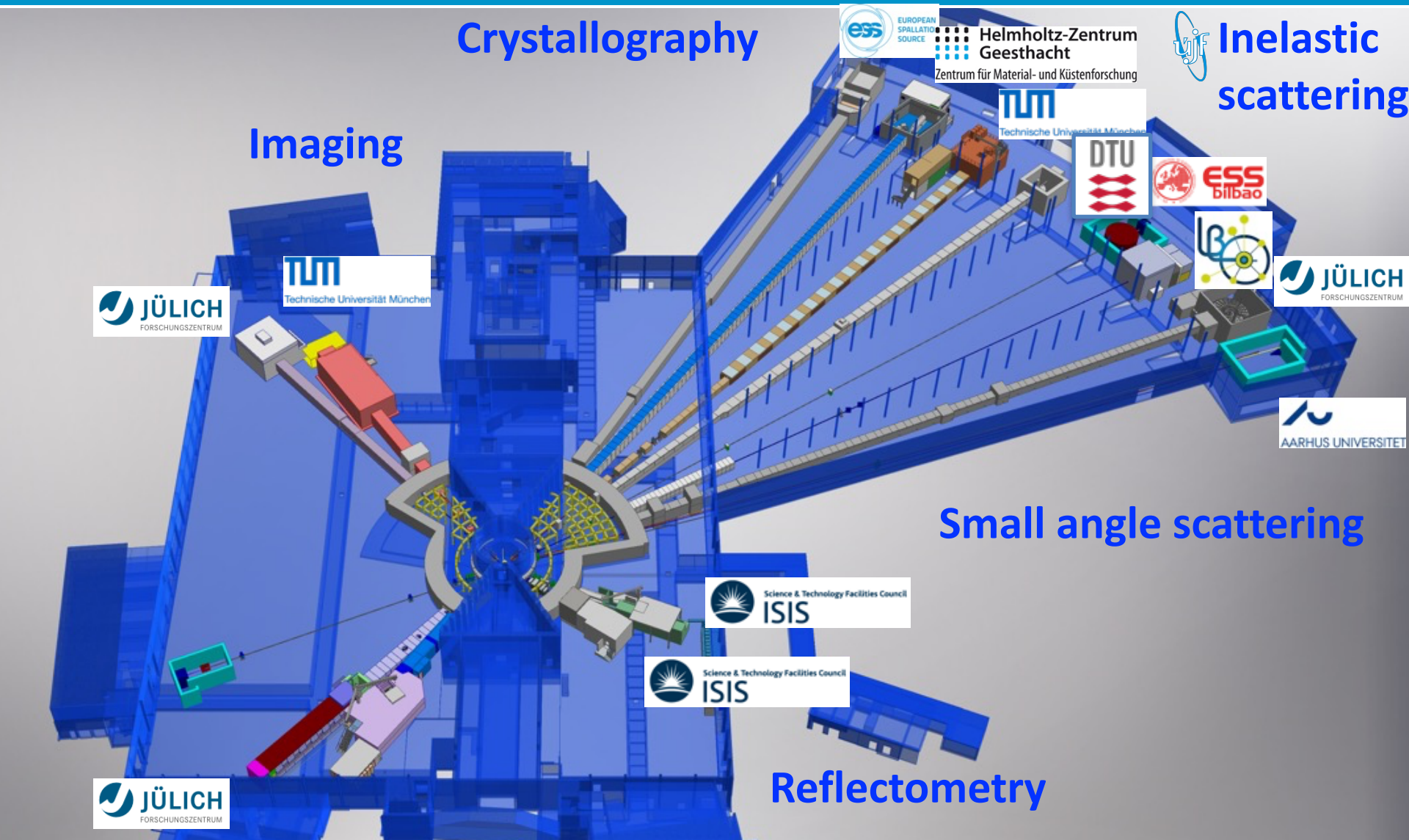

ESS Timeline (reality)

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2003
Concept design of ESS presented

2009
Decision to site ESS in Lund

2012
ESS design update phase complete

2014
Start of construction

2019
Start of initial operations phase

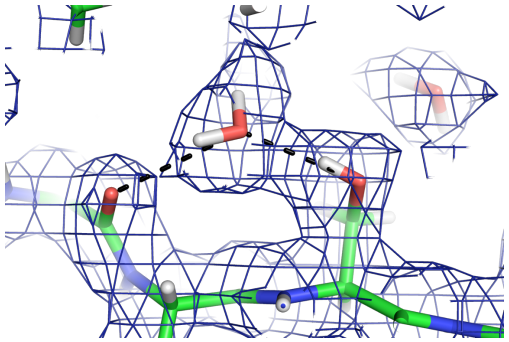
2024
Today

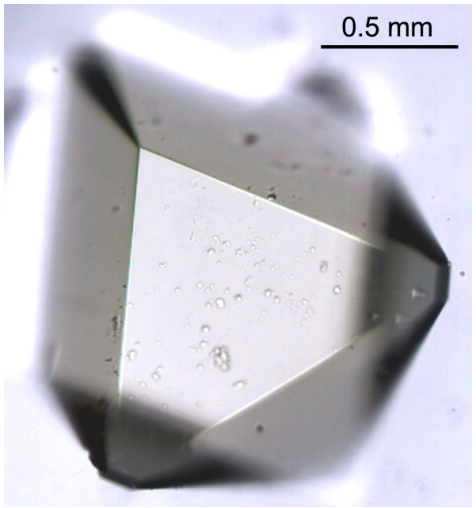
2025
First neutrons

2026
First science

2027
Construction phase completed

Neutron Macromolecular Crystallography





Oksanen, E *et al. J. R. Soc. Interface* 2009, ***6*** *Suppl 5*, S599-610.

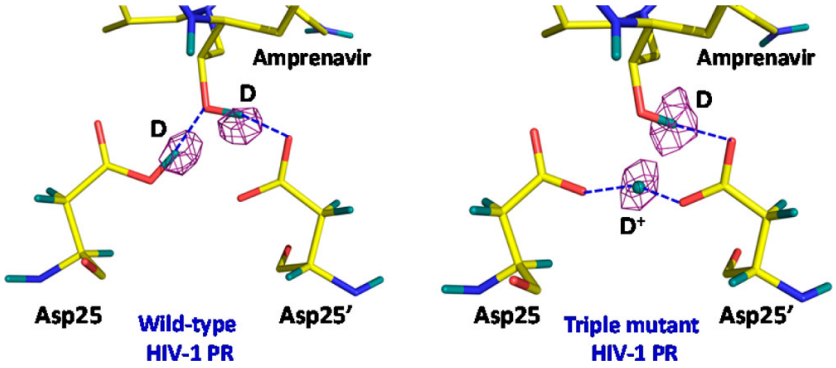
- ☺ Hydrogens are visible
- ☺ No radiation damage
- ☹ Large crystals needed
- ☹ Data collection takes weeks
- ☹ Few instruments available

Where are hydrogens important?

Enzyme mechanisms

Protein-ligand interactions

Proton transport across



Gerlits et al., (2017) J. Med. Chem. **60**, p.2018

Challenges for Neutron Crystallography

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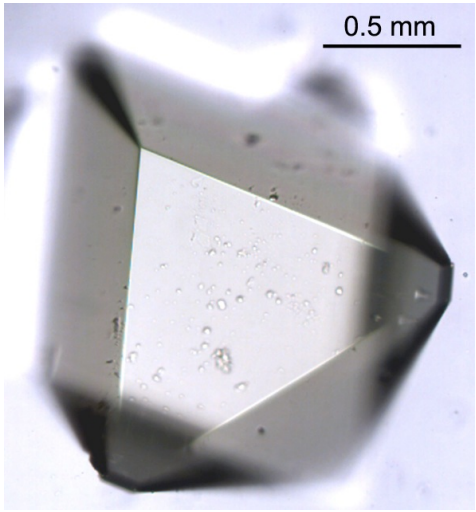
- **Weak neutron sources**
  - Bigger crystals → more diffracting volume
  - Use Laue geometry → make all neutrons count

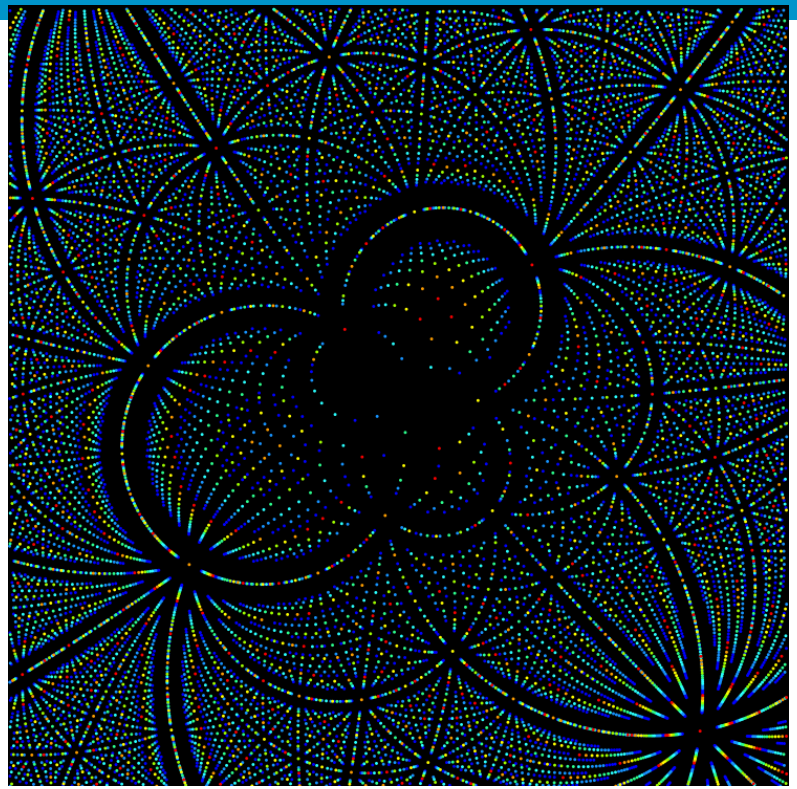


- **Incoherent scattering**
  - Exchange ^{1}H to ^{2}H (deuterium)
  - Produce perdeuterated protein

Oksanen, E *et al. J. R. Soc. Interface* **2009**, *6 Suppl 5*, S599-610.

Laue Crystallography: using more wavelengths

- Uses more of the available flux than monochromatic methods
- Signal at one λ- background at all
- Data processing is more complicated → harmonic & spatial overlap
- Very sensitive to crystal mosaicity



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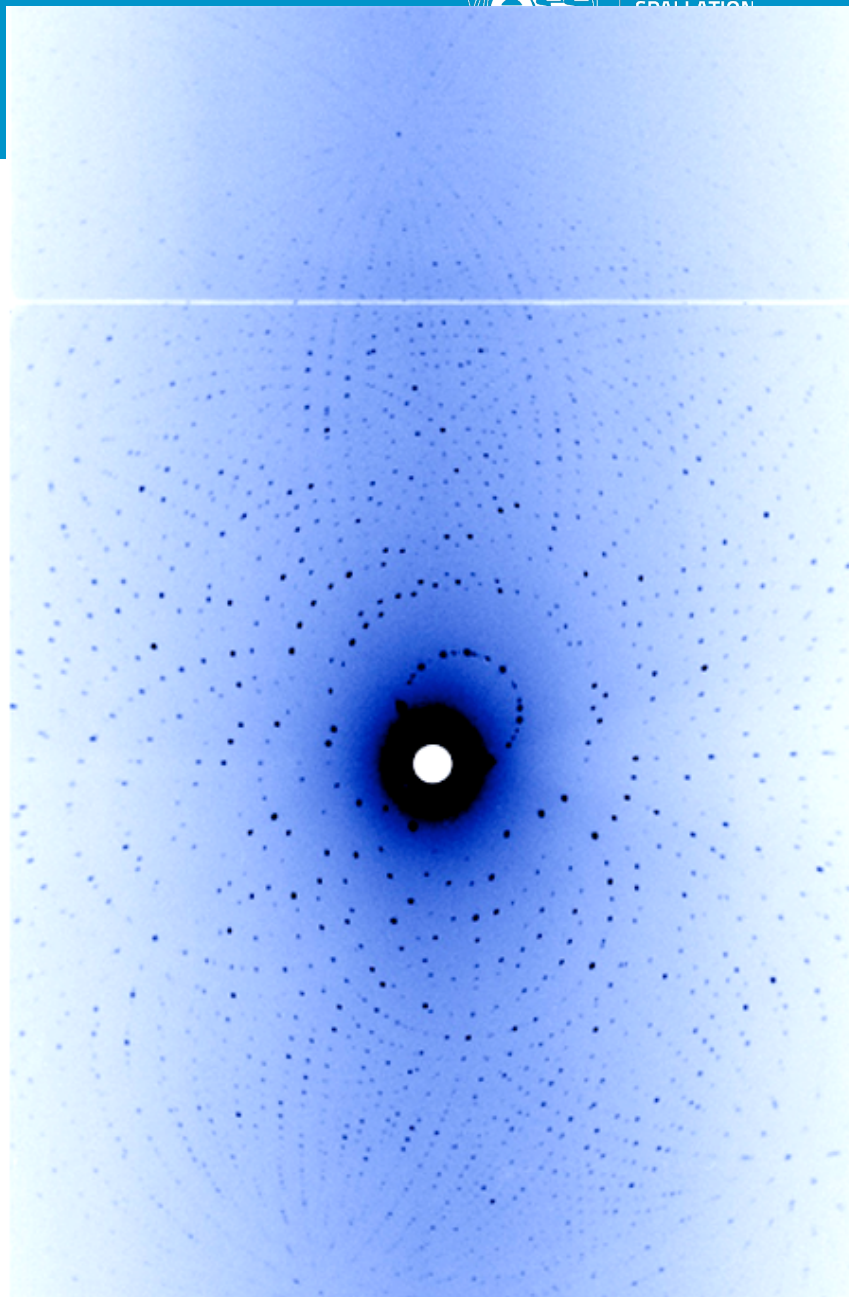
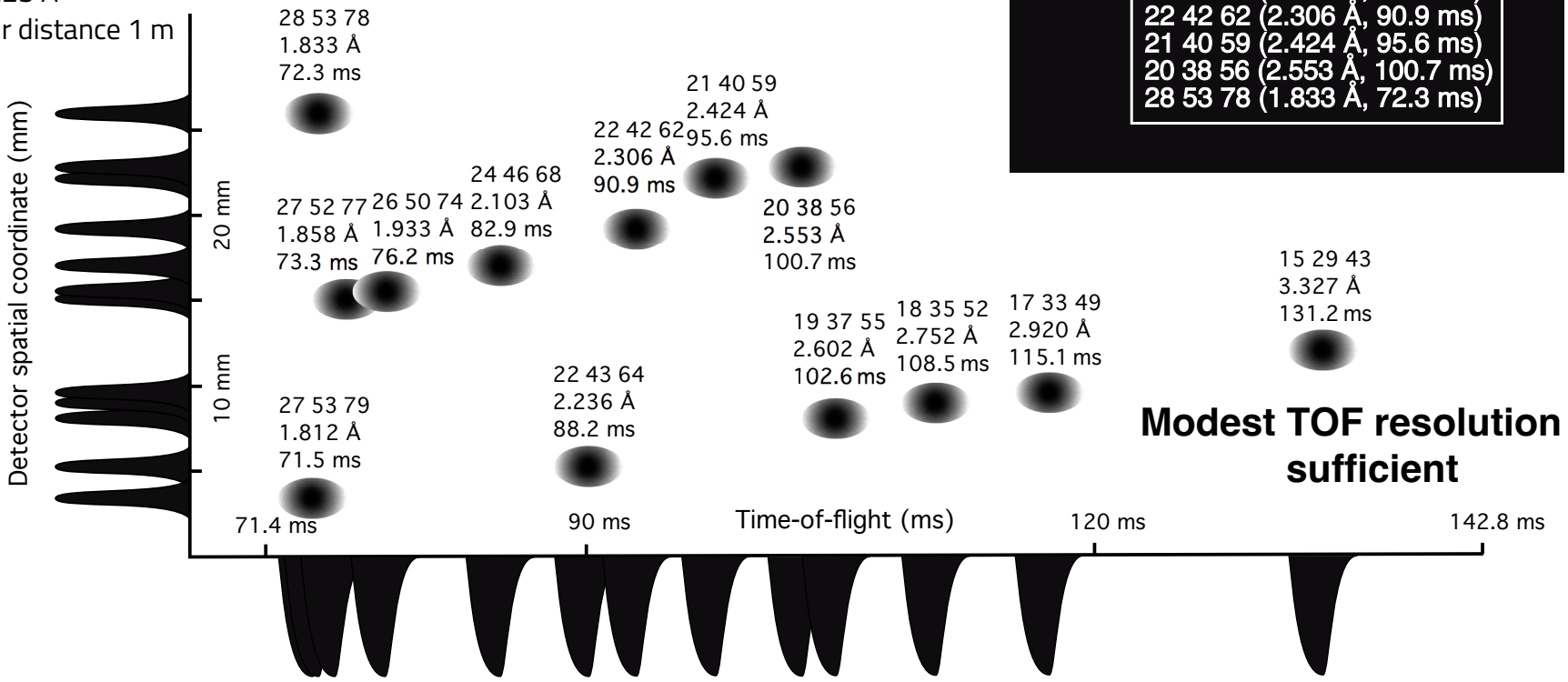
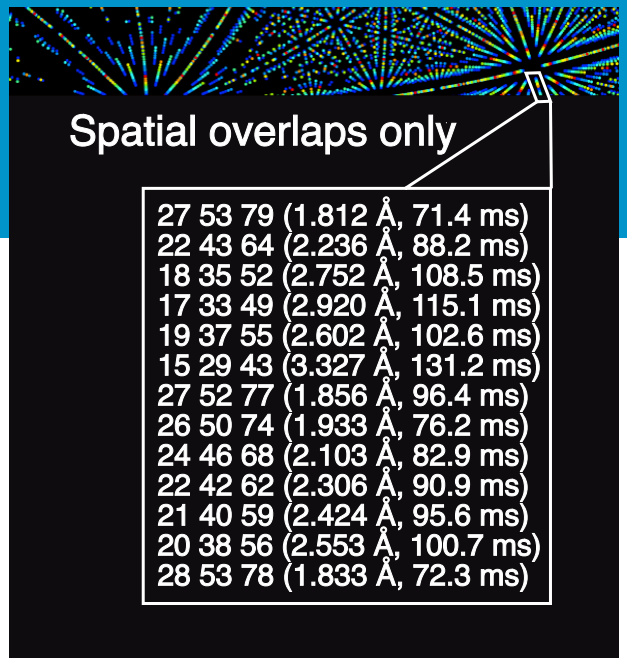


Overlap separation with TOF

Bovine heart
cytochrome c oxidase
$P2_12_12_1$
a = 182.59 Å
b = 205.40 Å
c = 178.25 A
Detector distance 1 m





Modest TOF resolution is sufficient

Sub-mm spatial resolution needed to integrate intensities

NMX – Macromolecular diffractometer at ESS

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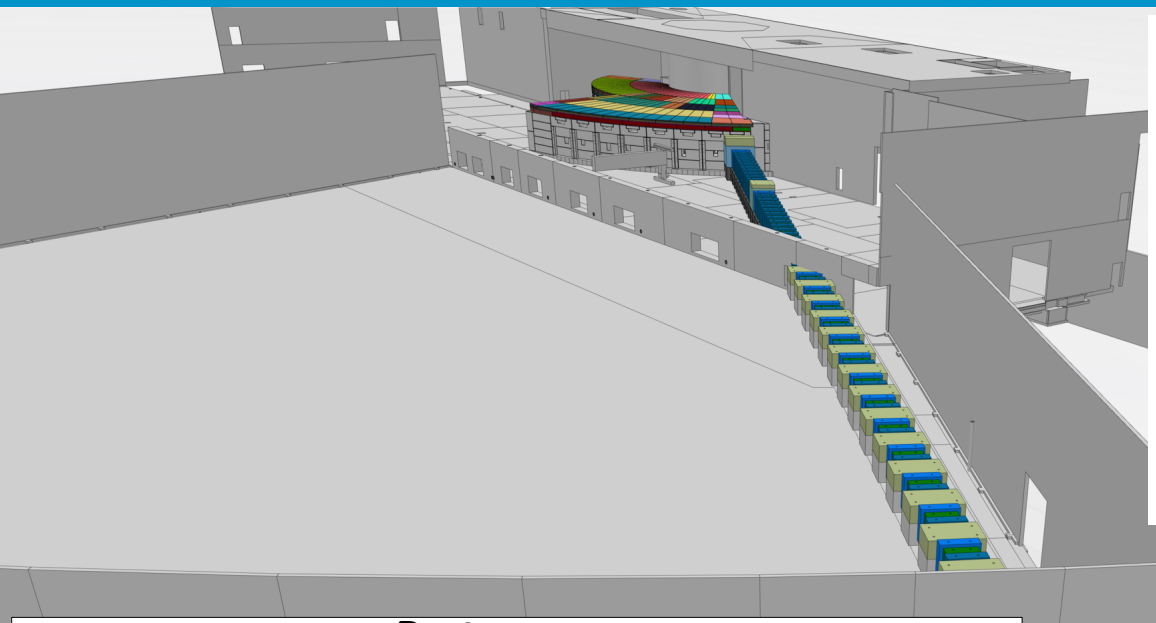


Key advantages of ESS Macromolecular Diffractometer

Smaller crystals needed (200 µm vs. 1 mm)

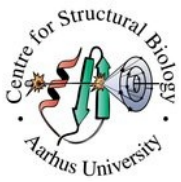
Data collection faster (days vs. weeks)

Larger unit cells possible (300 Å vs. 150 Å)

Partners





NMX – Macromolecular diffractometer at ESS

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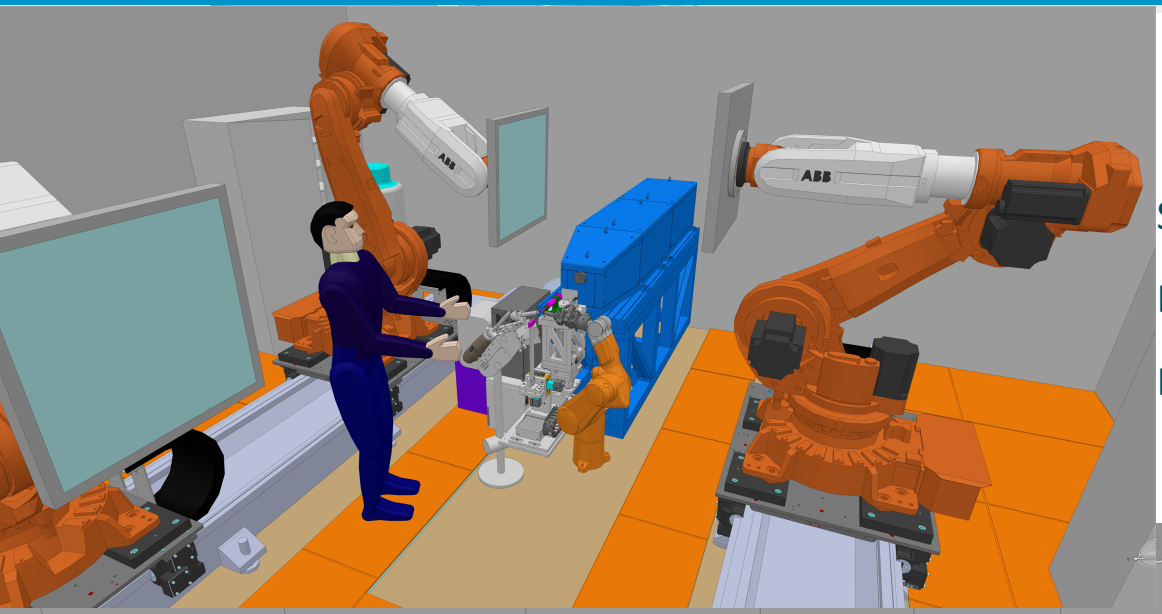

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Partners

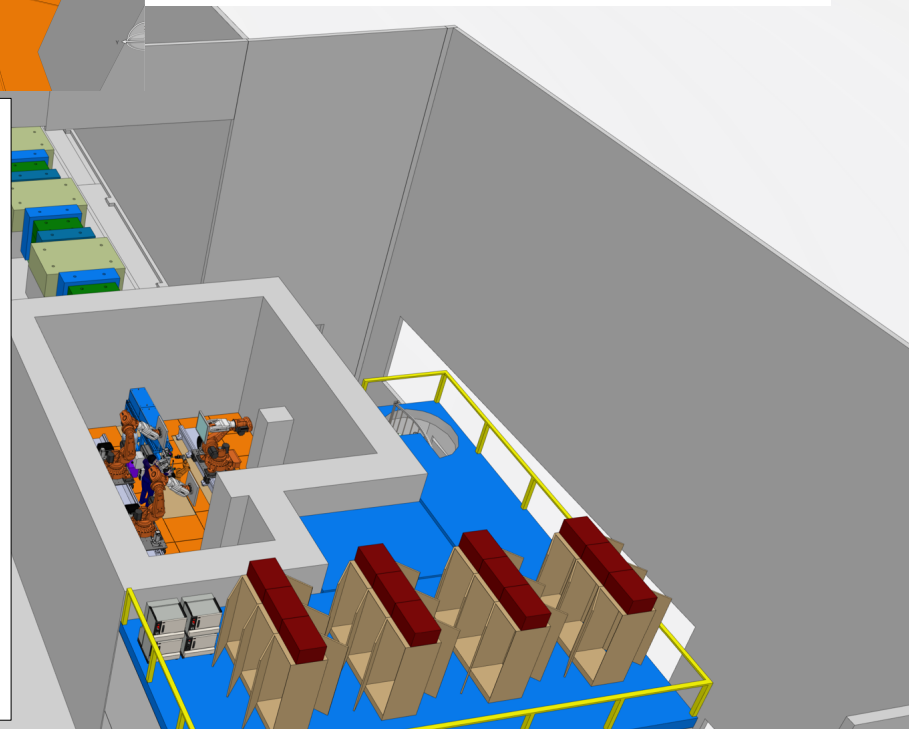
Wigner BRC EK

ibs Institut de Biologie Structurale

Lund University

Universitas Bergensis

Centre for Structural Biology Aarhus University



Software at NMX

- Hardware Controls: Primarily EPICS
- NICOS (ESS)- for instrument scientists
  - Command line, scripting, similar to IDL/SPEC/Sardana
- **nMXCuBE- for user operation**
- Data Collection Strategy for Laue-TOF: TBD
- SCIPP- Data reduction and processing
  - DIALS for Neutrons (with David McDonagh, DIALS)
- SciCat for data archiving and curation

nMXCuBE: MXCuBE at NMX

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- NMX will be the first neutron instrument to utilise MXCuBE
- Streamline the NMX user interface for primarily X-ray users: majority of users (ESRF, DESY, MAX IV) will be familiar with MXCuBE
- Day 1 NMX Users will use NICOS- nMXCuBE deployment scheduled for late 2026

- Laïs Pessine will be adapting MXCuBE for NMX

The Next ~~Six Months~~ Year

- ESS to become official partner in MXCuBE Collaboration
- NMX Cold Commissioning (instrument commissioning without neutrons) to start November 2025
- Data Collection with NICOS prioritised for commissioning
- Hot commissioning (with neutrons) to start whenever we get neutrons into NMX hutch- planned July 2026

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The NMX Team

- Esko Oksanen
- Daniel Lundström
- Aaron Finke
- Justin Bergmann
- Laïs Pessine
- Giuseppe Apriligiano
- Rosa Camilleri Lledó
- Zoë Fischer
- And many, many others…

Questions?

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