ODIN: Optical and Diffraction Imaging with Neutrons at the ESS

Status and perspectives of the ODIN Project

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Outline

- ESS overview
- ODIN overview/goals
- ODIN Project
- Design
- Science case

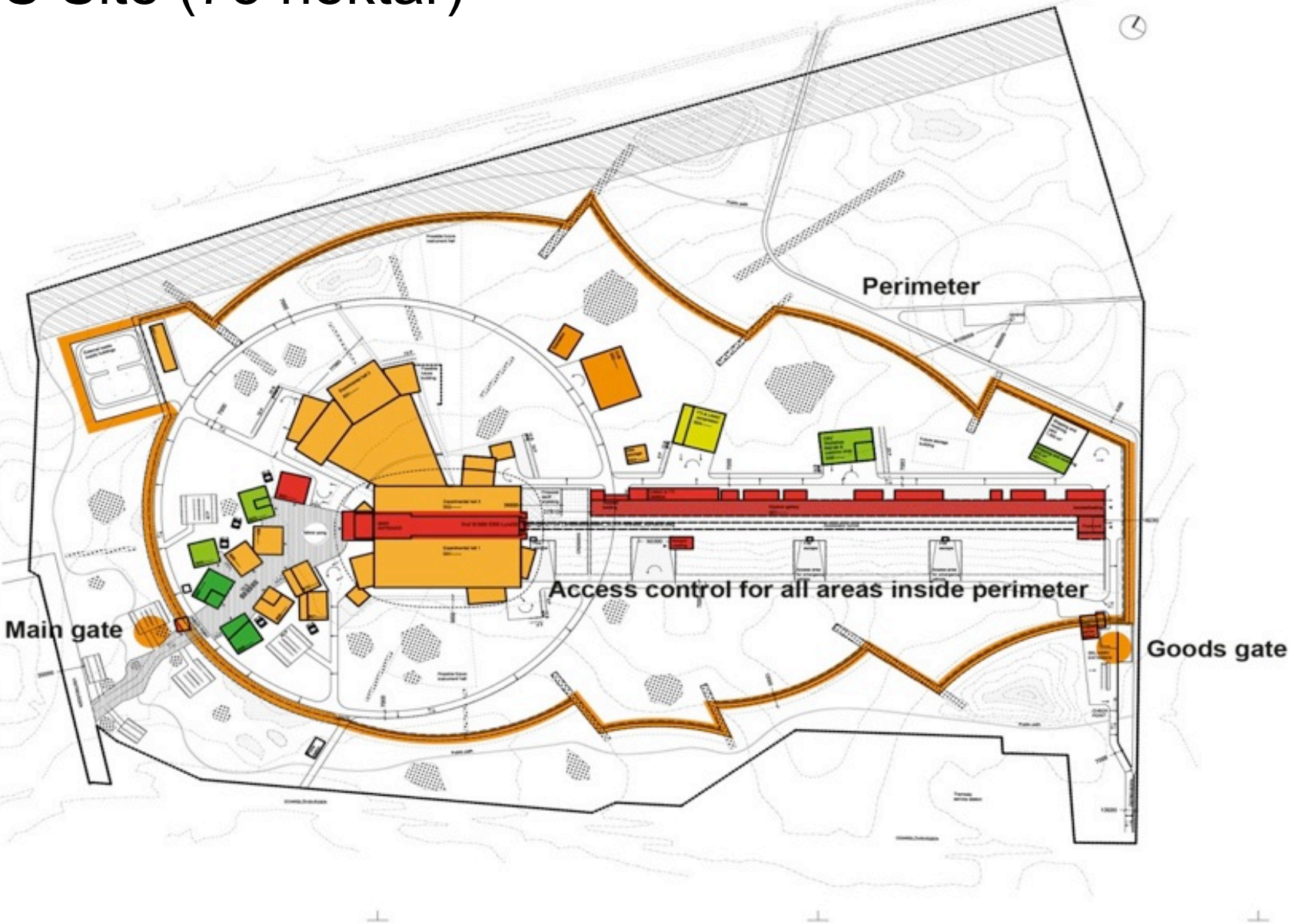
A European Big Science Project

In-kind Collaborations

Aarhus University
CEA Saclay, Paris
CNRS Orsay, Paris
ESS Bilbao
INFN, Catania
Lund University
Uppsala University
Accelerator Science and Technology Centre, Daresbury and Oxford
CERN, Geneva
Cockcroft Institute, Daresbury
DESY, Hamburg
ESS Bilbao
Fermi National Laboratory, Chicago
John Adams Institute for Accelerator Science, London and Oxford
Laval University, Canada
Maribor University, Slovenia
National Centre for Nuclear Research, Poland

Oslo University
Rostock University
Spallation Neutron Source, Oak Ridge
Stockholm University
Techical University of Darmstadt
Nuclear Physics Institute Of The Ascr
Czech Technical University, Prague
Aarhus University
University Of Copenhagen
University Of Southern Danmark
Technical University Of Danmark - Dtu
Institut Laue-Langevin - Ill
Llb (Laboratoire Léon Brillouin)
Helmholtz-Zentrum, Berlin
Helmholtz-Zentrum, Geesthacht
Technical University, Munich
Forschungszentrum, Jülich
Elettra-Sincrotrone Trieste
Università Di Perugia
Consiglio Nazionale Delle Ricerche
Delft University Of Technology
Institute For Energy Technology, Ife
Linköping University
Mid Sweden University
Epfl | École Polytechnique Fédérale De Lausanne
Paul Scherrer Institute, Psi

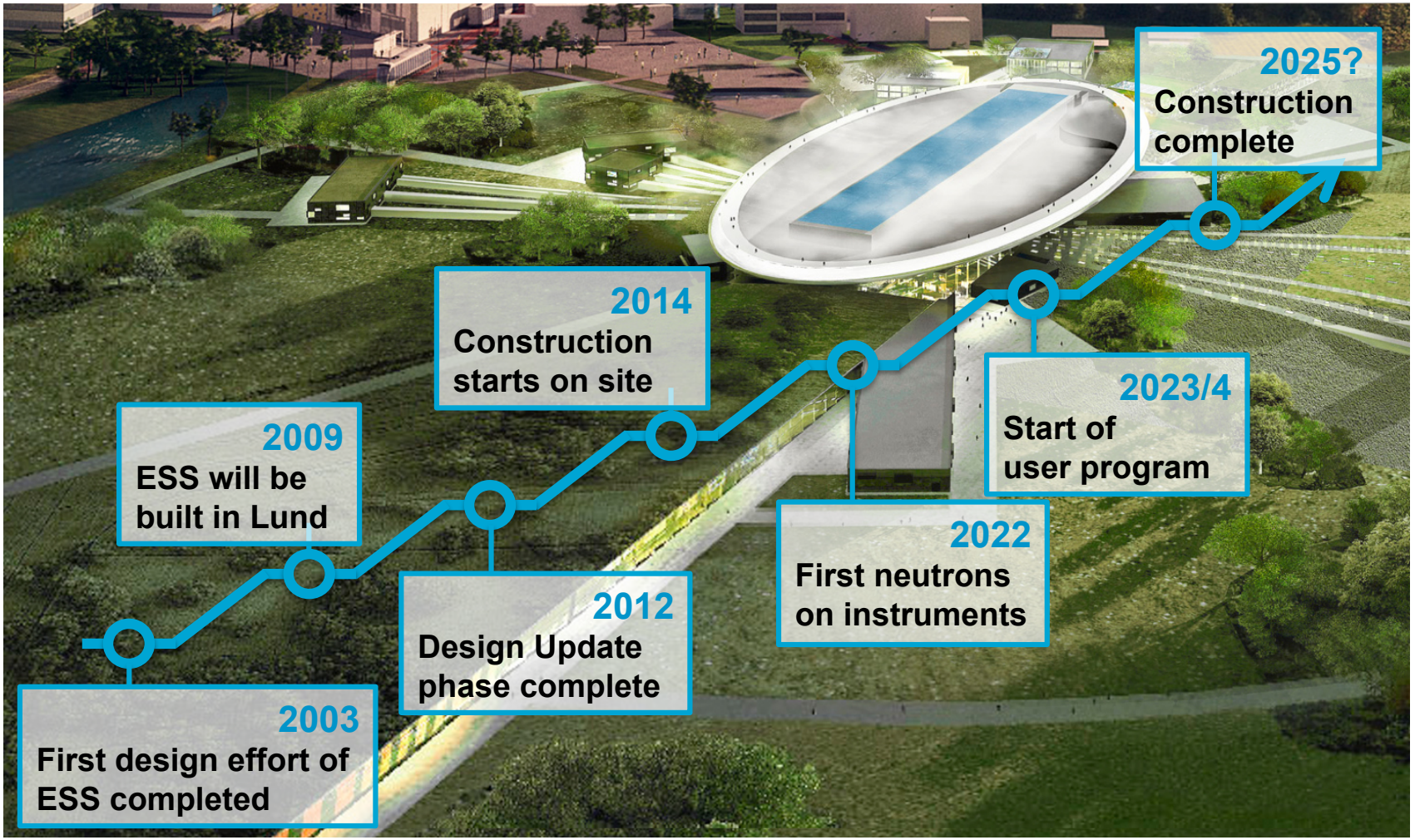
ESS Site (75 hektar)



Civil Construction

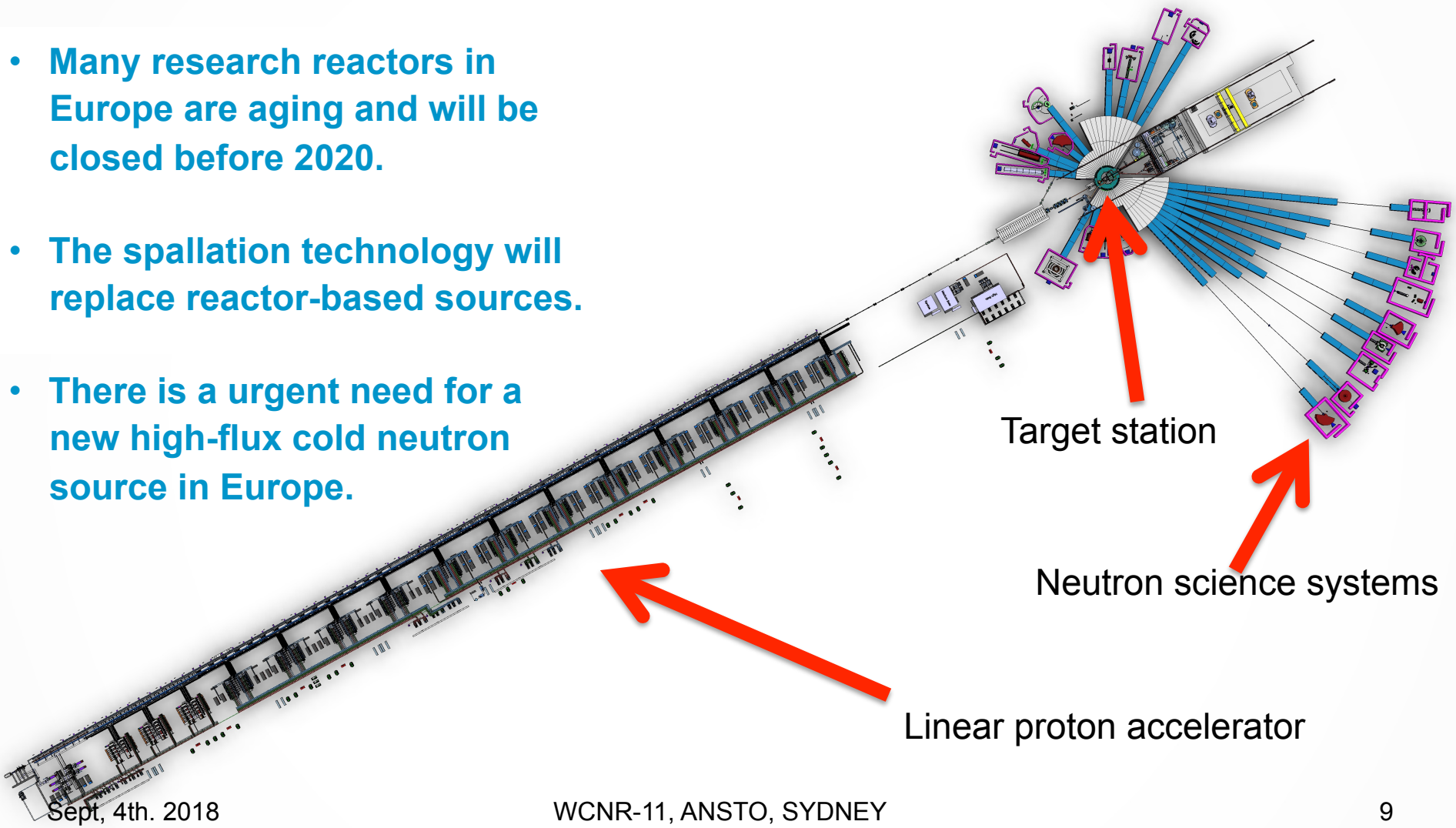
Civil Construction

ESS Roadmap


2025?
Construction complete
2014
Construction starts on site
2009
ESS will be built in Lund
2023/4
Start of user program
2022
First neutrons on instruments
2012
Design Update phase complete
2003
First design effort of ESS completed

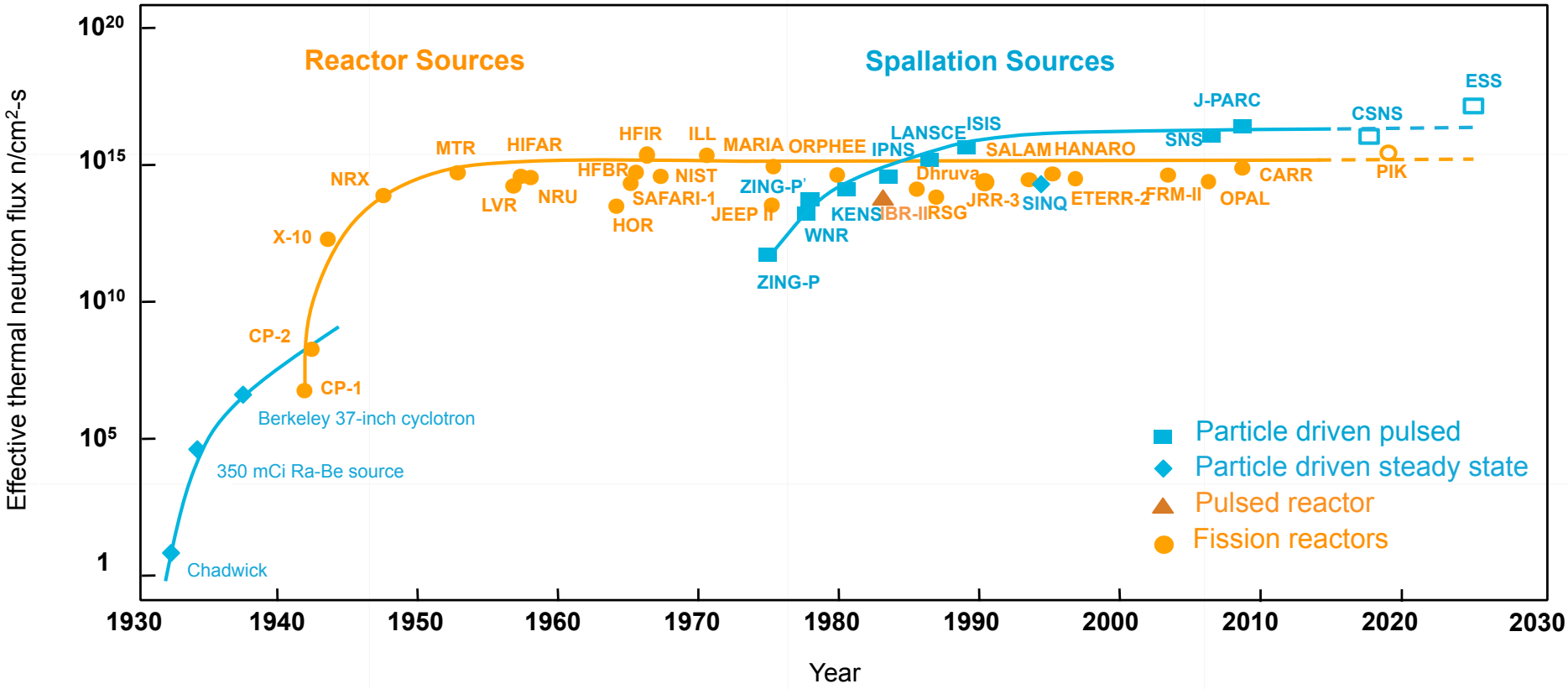
Spallation: Generating Neutrons for Science

- **Many research reactors in Europe are aging and will be closed before 2020.**
- **The spallation technology will replace reactor-based sources.**
- **There is a urgent need for a new high-flux cold neutron source in Europe.**



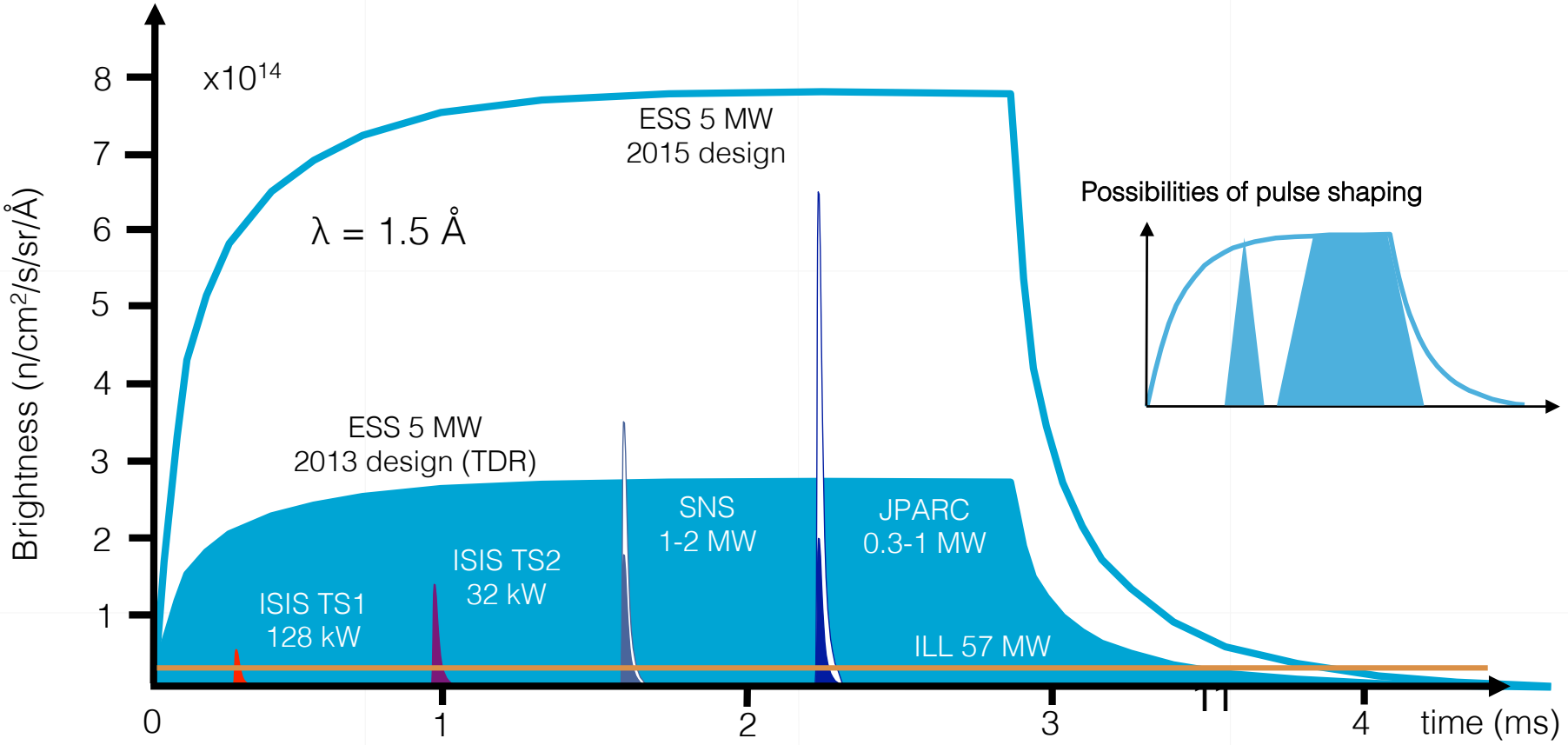
Spallation: Bridging the Gap

- ESS will be brighter than existing sources, complementing them



(Updated from *Neutron Scattering*, K. Skold and D. L. Price, eds., Academic Press, 1986)

Long-Pulse Performance and Flexibility



The ESS Source: a dual moderator

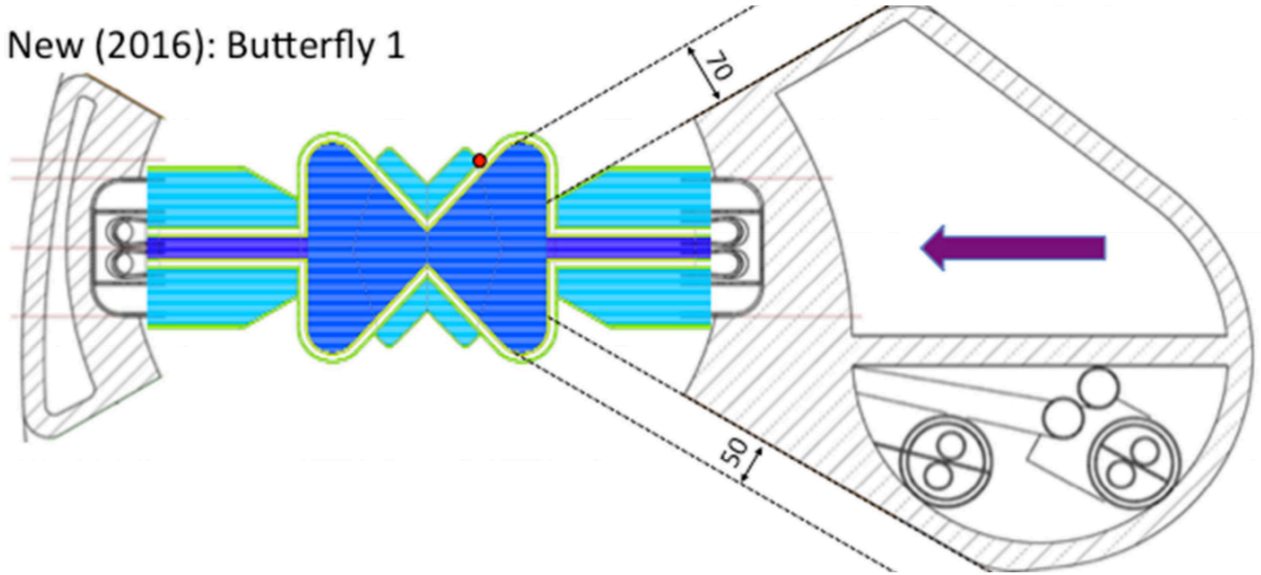


Fig. 1 Butterfly 2 (upper frame) and Butterfly 1 (lower frame) geometries. The direction of the proton beam is indicated by the purple arrow. The water volumes are shown in light blue and the para-H_2 volumes in dark blue. The green lines are the Al walls of the moderator structure. The grey and hatched areas indicate components in the outer reflector which define the viewable moderator width. The viewable projected width of the cold moderator is indicated for beamports N1 and E1. The focal point for the North sector is indicated by the red dot.

ODIN at ESS

- **O**ptical and **D**iffraction **I**maging with **N**eutrons: Neutron radiography and ToF imaging with variable wavelength resolution
- ODIN will be the only imaging instrument installed during the first round
- It will be a “day-1” instrument: first neutrons planned for July 2022
- Joint project of PSI and TUM (lead institution)
- Budget 11.6M€.

High Level Wishlist

- Conventional Imaging
  - High resolution
  - Large homogenous Field of View
  - Variable Wavelength (ultra-cold, thermal, epithermal, fast …)
  - High time resolution (dynamic measurements)

- New (wavelength dependent) techniques
  - Variable Wavelength resolutions
  - Variable Bandwidths
  - High time resolution in quasi-stroboscopic mode.

- Synergy
  - X-ray contrast
  - Diffraction capabilities

High Level Goals

- Conventional Imaging
  - High resolution: **Real space resolution of 10µm**
  - Large homogenous Field of View: **20×20cm^2 with a homogeneity of >75%**
  - Variable Wavelength: **λ-range from 1 to 20 Å**
  - High time resolution: **<70 ms in kinetic measurements**

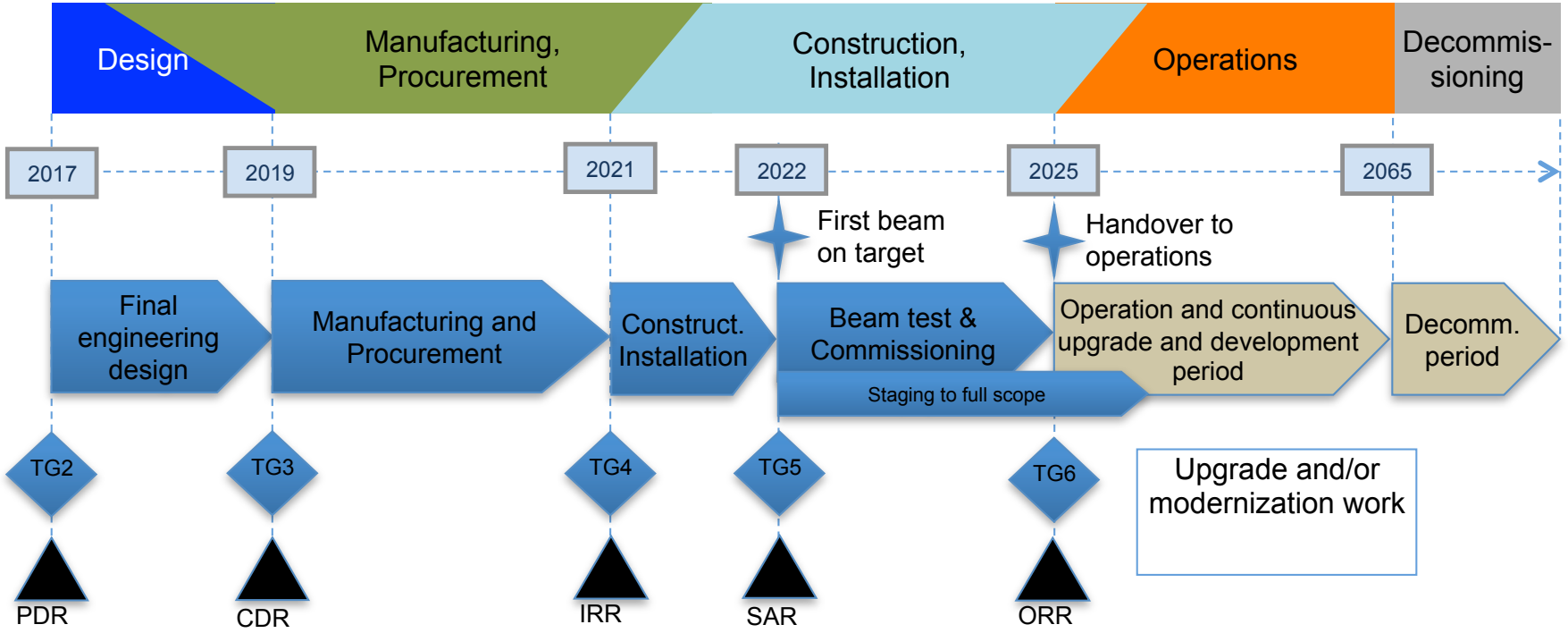
- Wavelength dependent techniques
  - Variable Wavelength resolutions: **10%, 1% and down to below 0.5%**
  - Variable Bandwidths: **Bandwidths of ~4.5 Å or ~9 Å selectable between 1-20 Å**
  - Time resolutions in quasi-stroboscopic mode: **~1 µs**

- Synergy
  - X-ray contrast: **with comparable spatial resolution**
  - Diffraction capabilities: **with equivalent wavelength resolution**

ODIN Overview

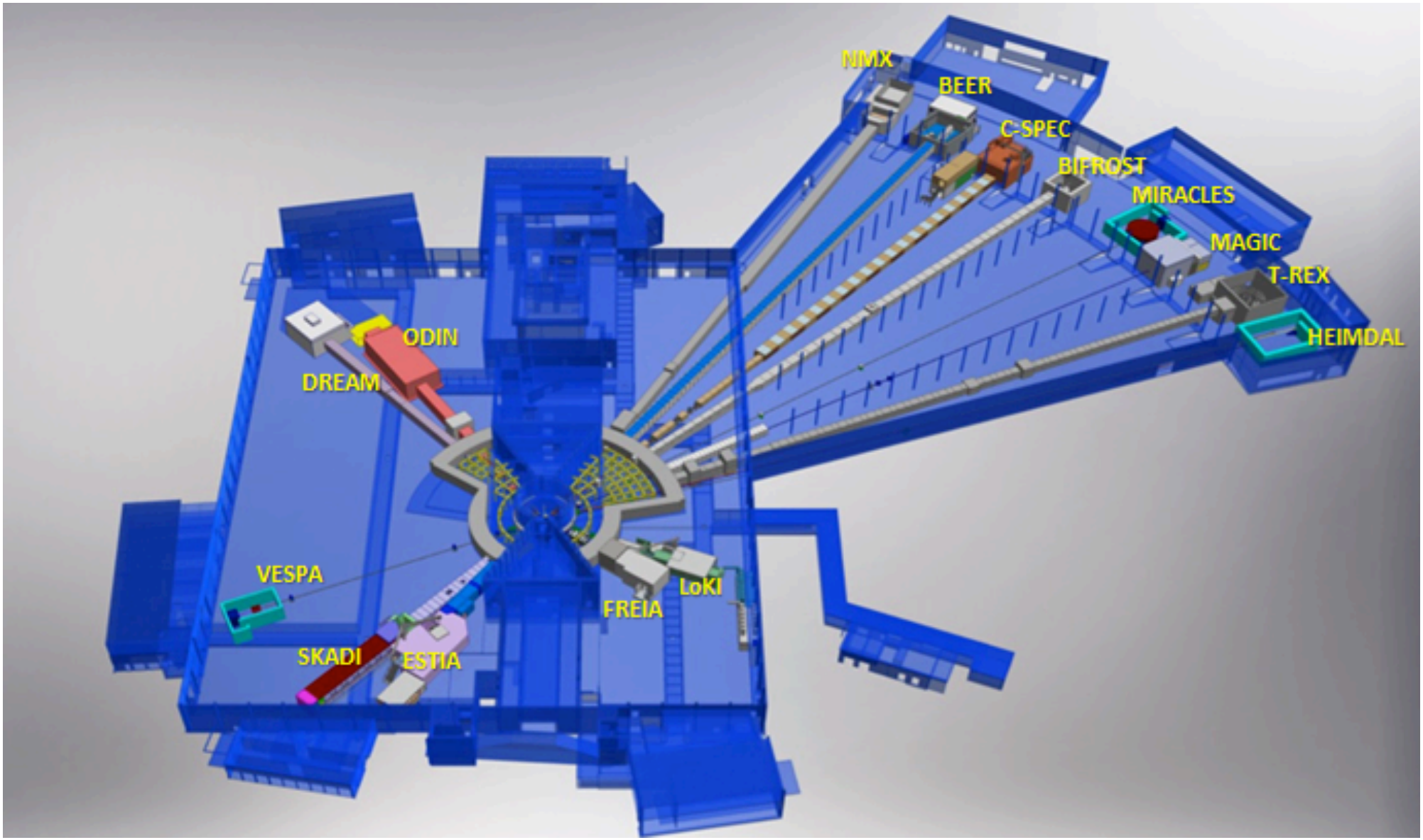
- Multi purpose imaging instrument
- 50m Source to pinhole
- Sample located up to 14m from the pinhole
- Straight beamline (direct view of the source)
- Chopper cascade consisting of 9 axis (plus 1 PPSc)
- Range of operational modes:
  - “White beam” imaging with spectral choice
  - Low Time of Flight resolution
    - Grating interferomete
    - SEMSANS imaging
  - Medium Time of Flight Resolution
    - Polarized and polarimetric neutron imaging set-up, Bragg-edge and diffraction
  - High Time of Flight Resolution: Bragg-edge and diffraction geometry set-up
  - Perpendicular X-ray imaging set-up

Life Cycle

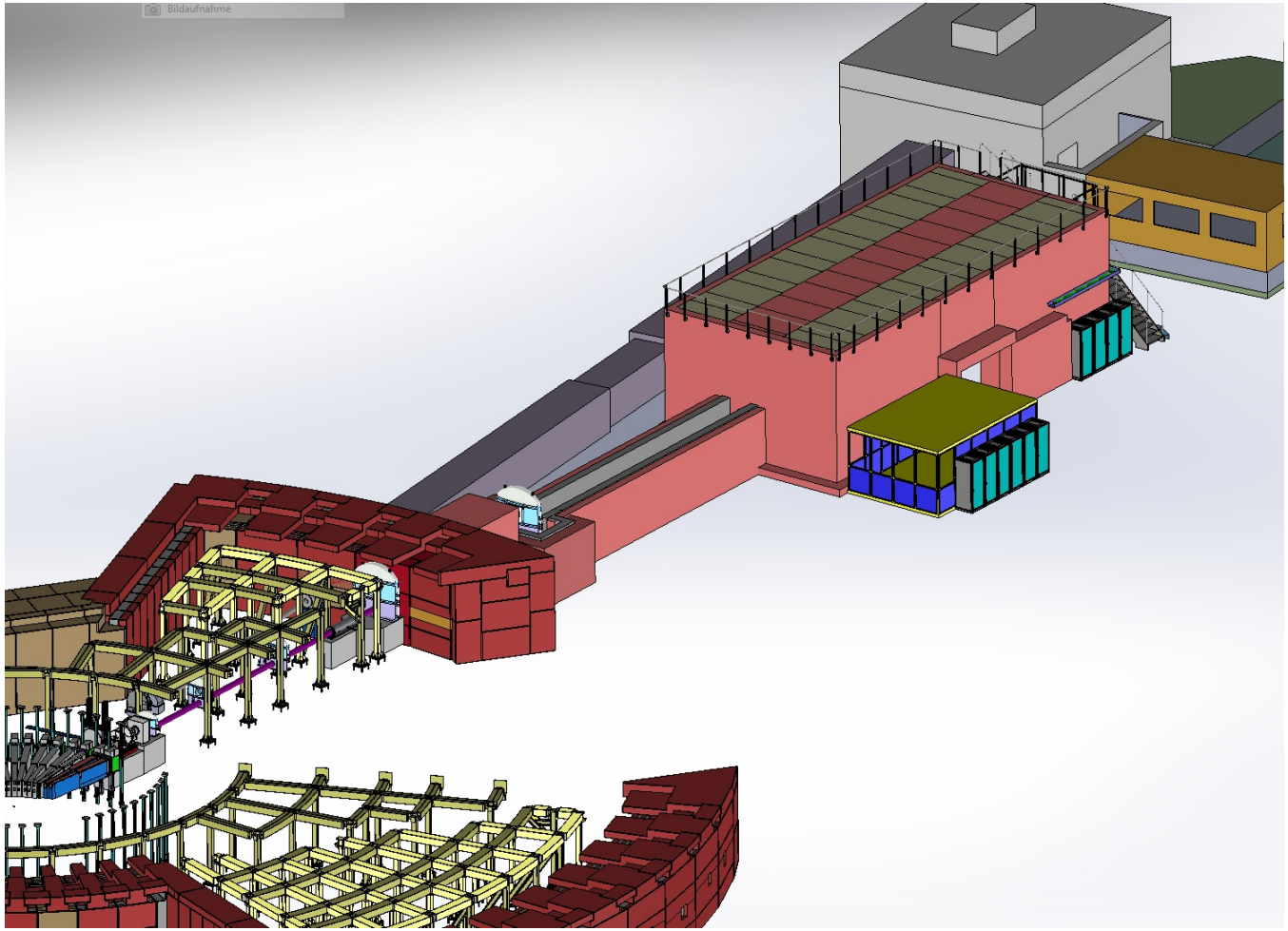


bunker wall penetration design	design monolith insert envelop	arrival in-monolith optics to ESS site	start installation in-monolith inserts	Start In-bunker installation	Partial Access D01	End In-bunker installation	Hot Commissioning (TG5)	User Programme
03-Mar-17	31-Jun-18	24-Jan-19	01-Jun-20	21-Aug-21	03-Jun-21	25-Jan-22	05-Jul-22	31-Dec-23

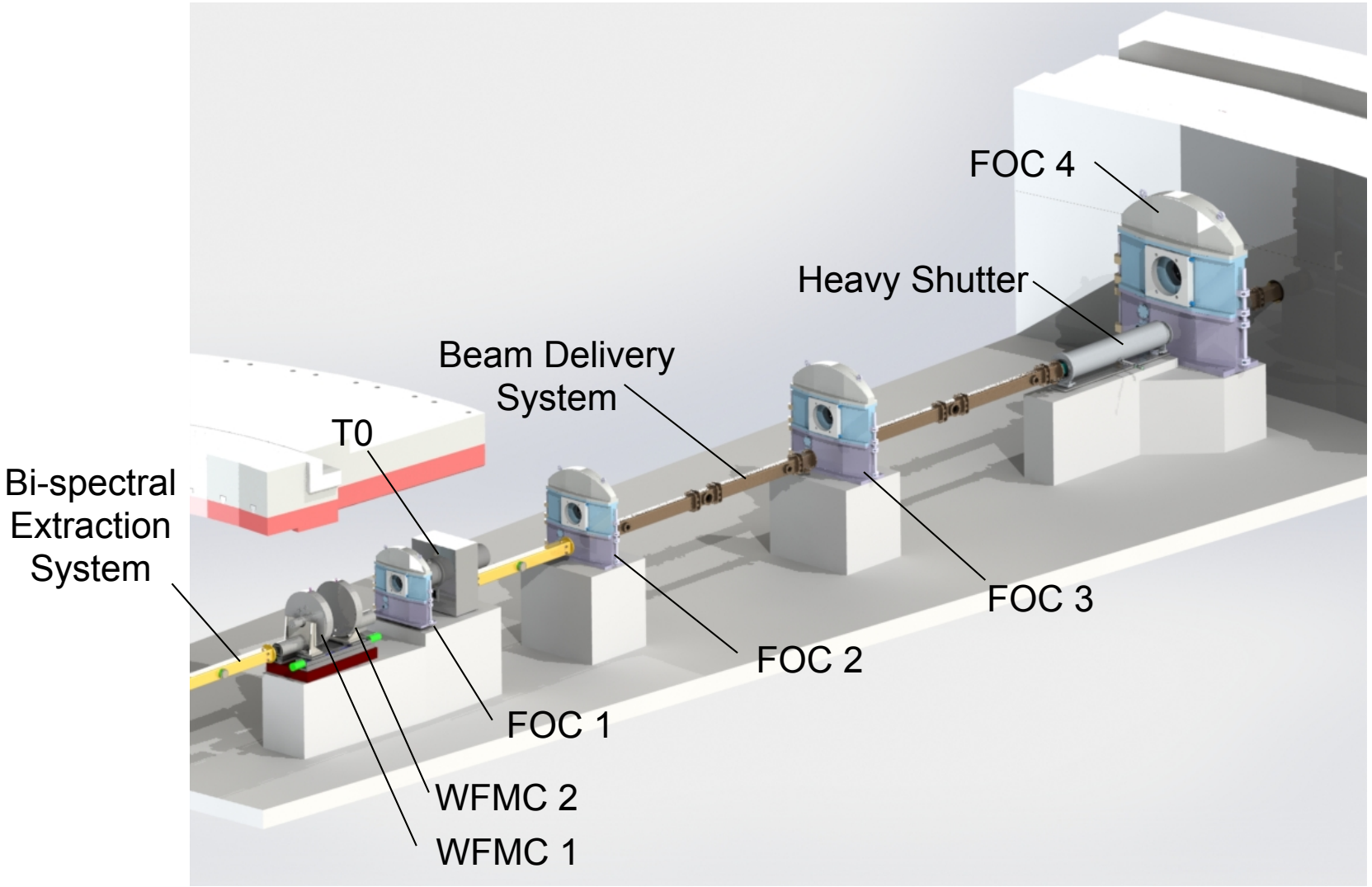
ODIN Overview



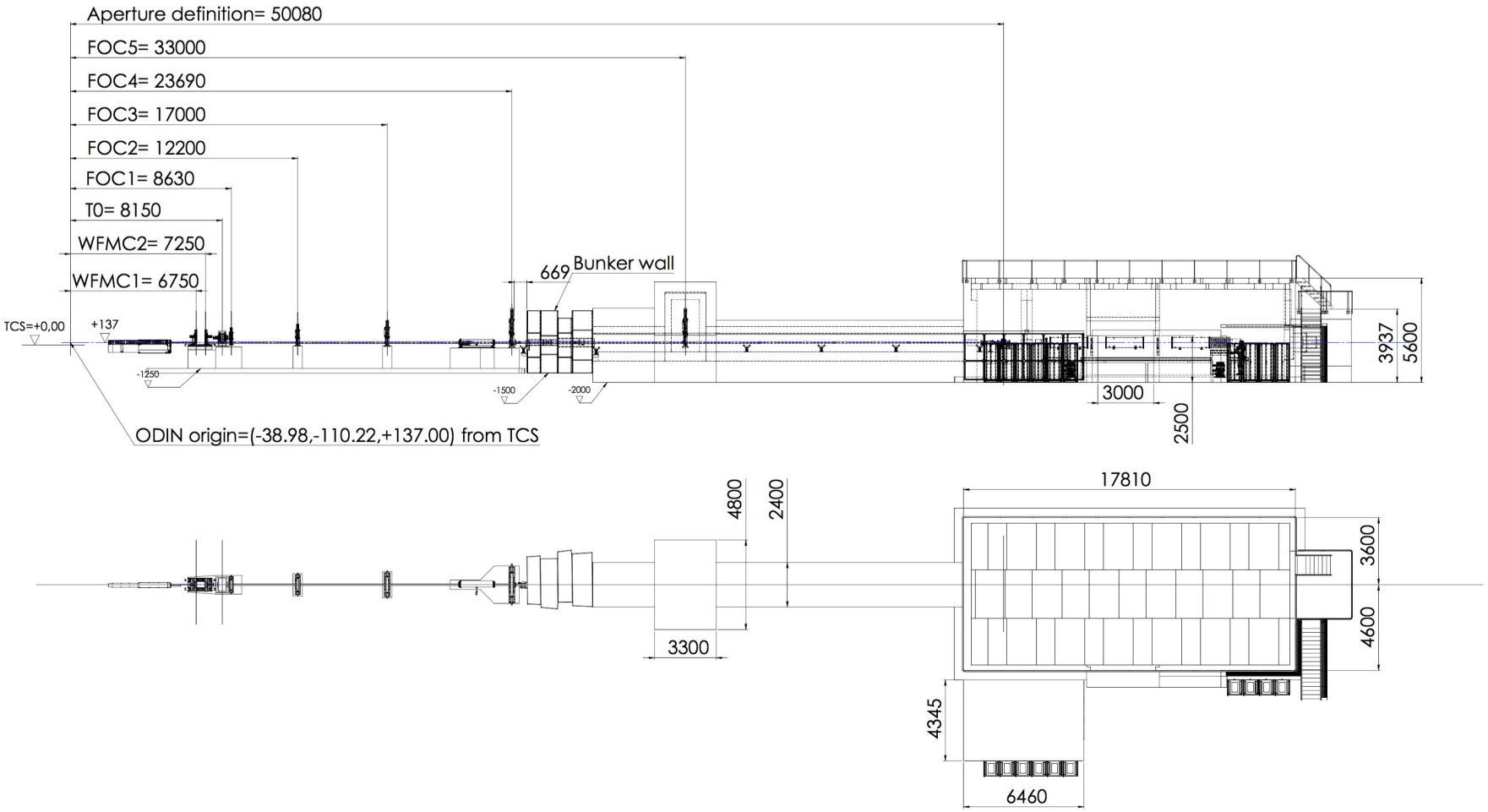
Floorplan



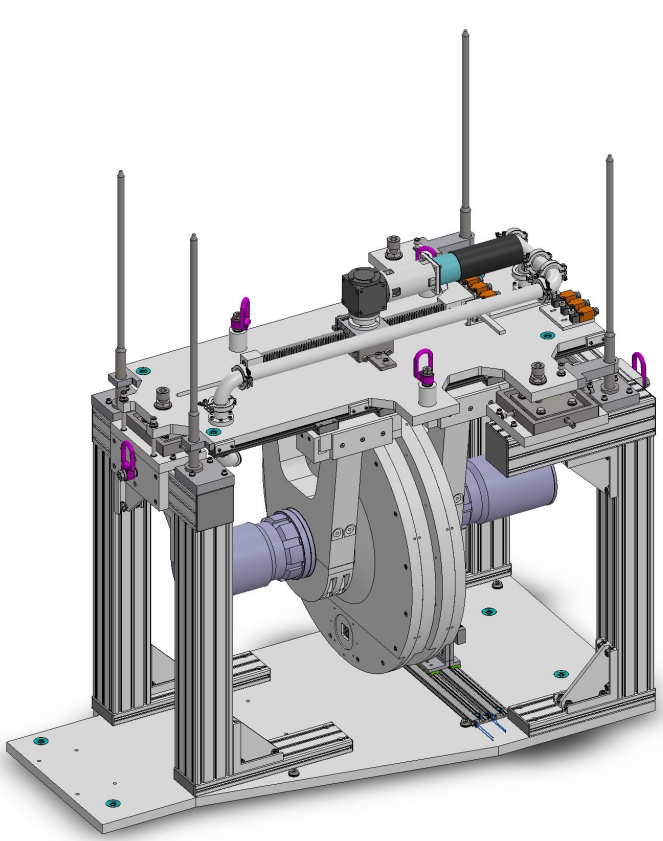
Bunker Area

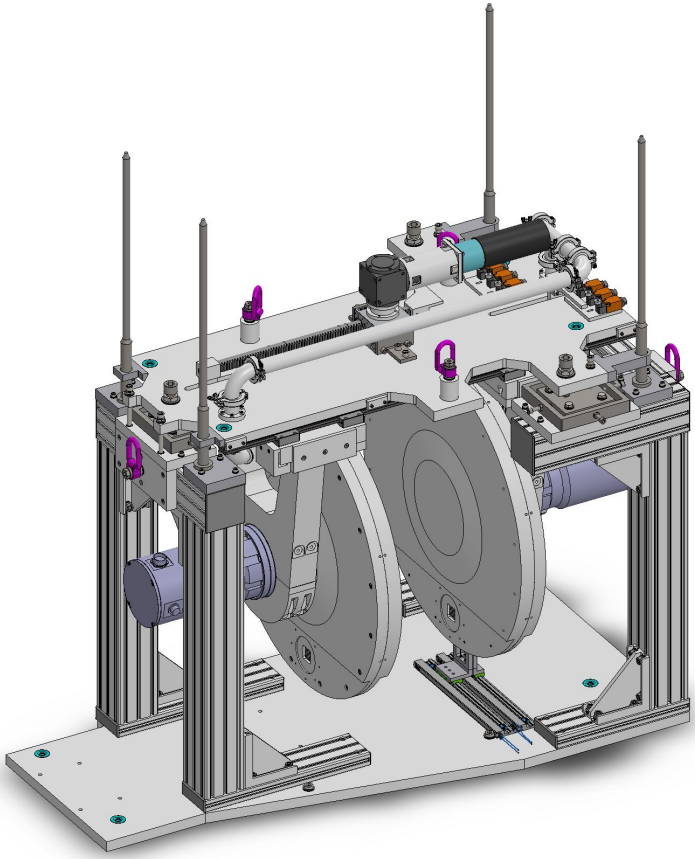

FOC 4
Heavy Shutter
Beam Delivery System
T0
Bi-spectral Extraction System
FOC 3
FOC 2
FOC 1
WFMC 2
WFMC 1

Chopper Cascade

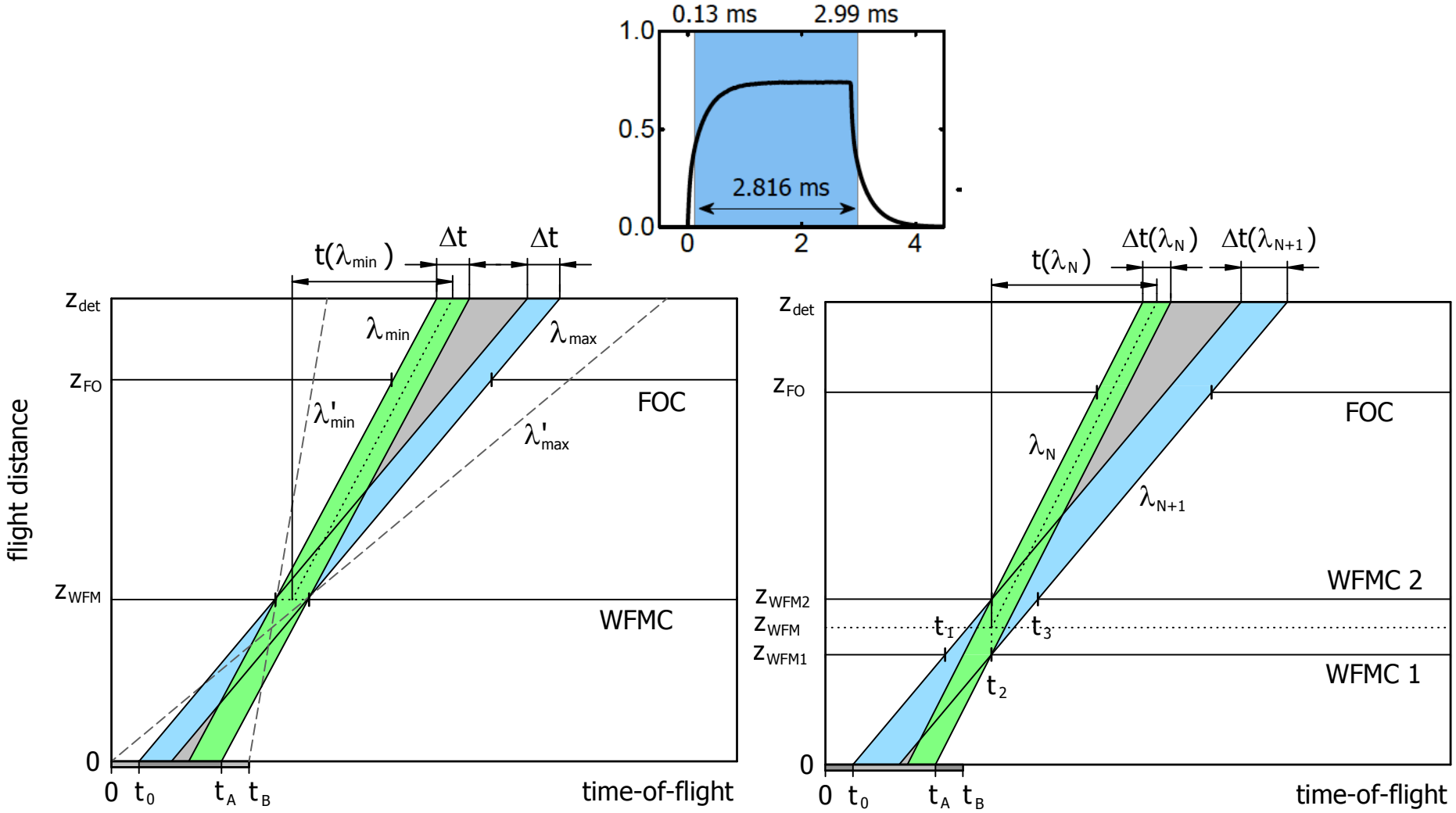


Wavelength Frame Multiplication Choppers

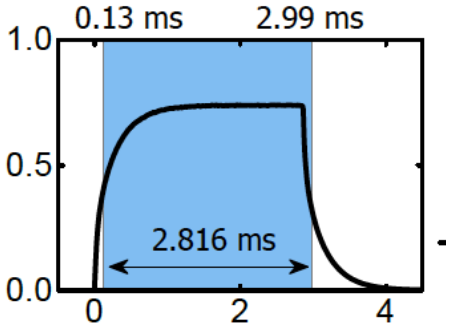


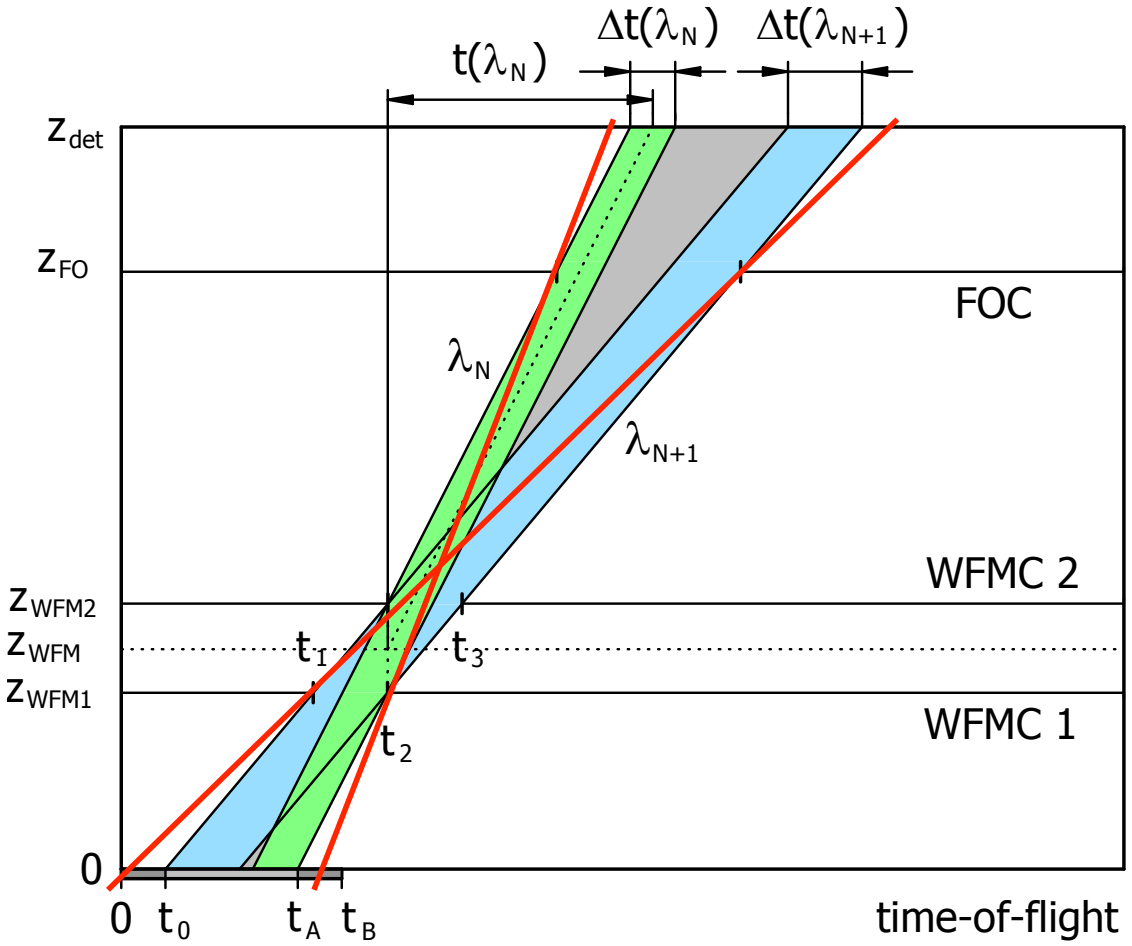


Wavelength Frame Multiplication Chopper

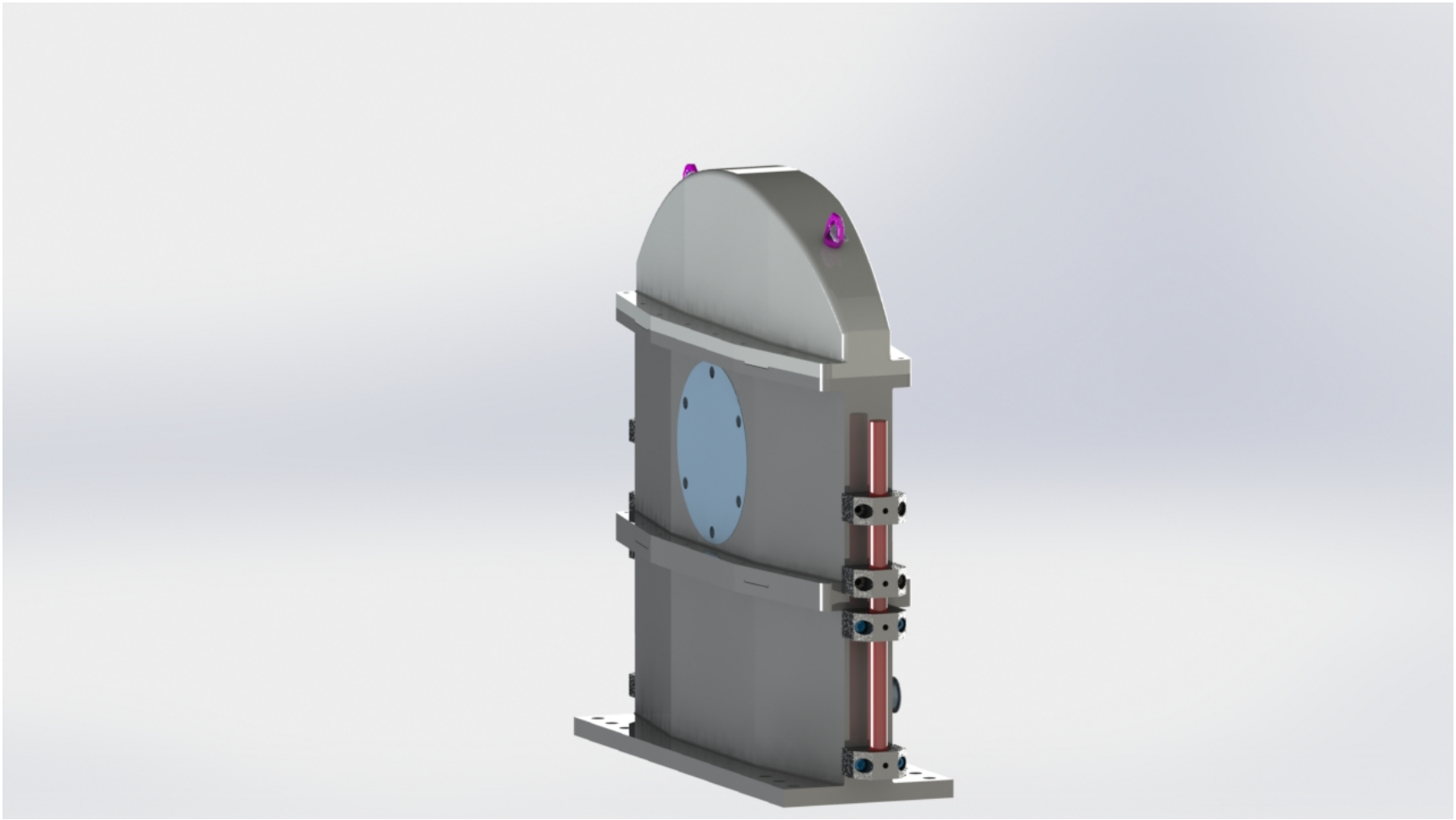


Wavelength Frame Multiplication Chopper

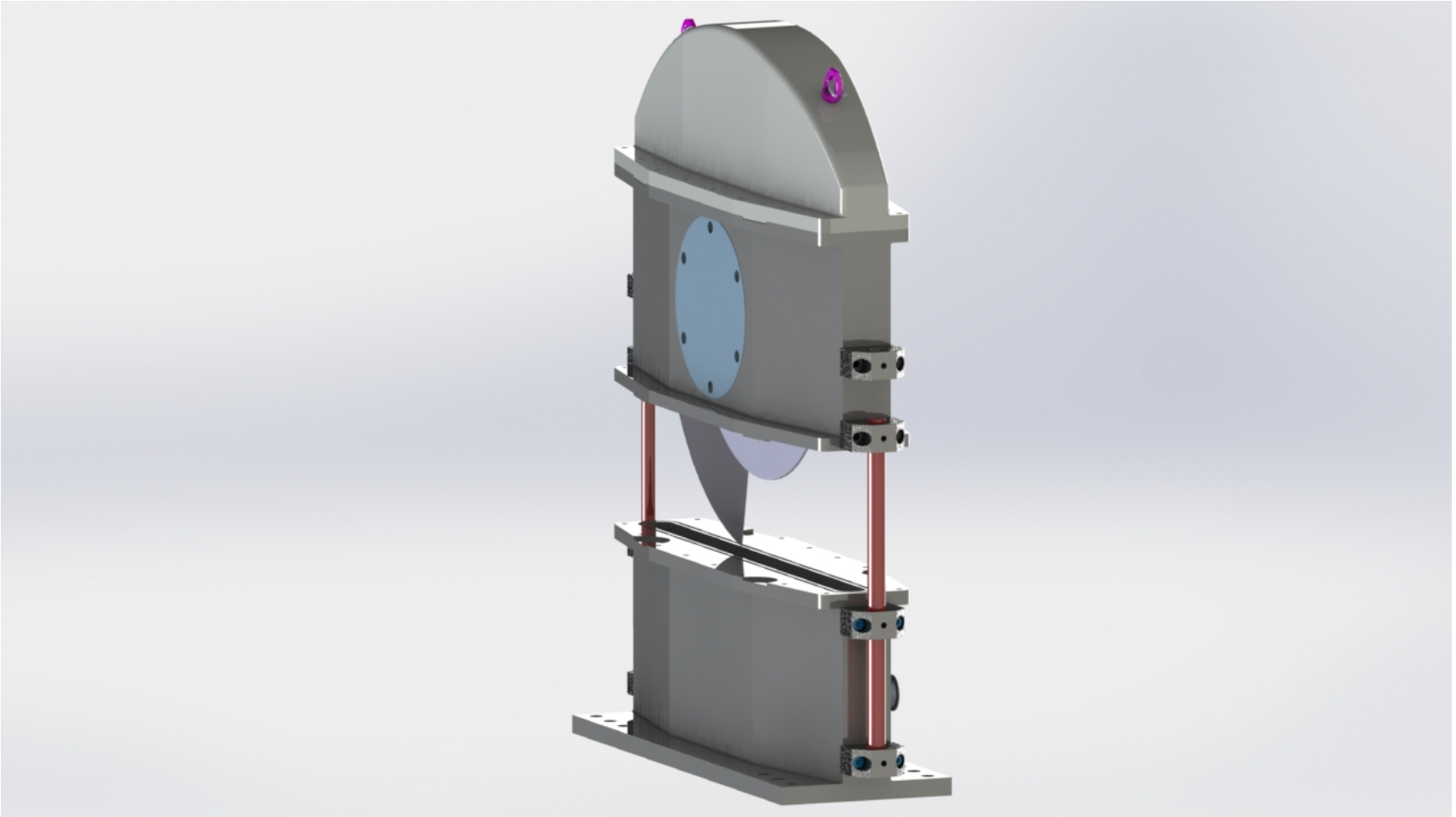




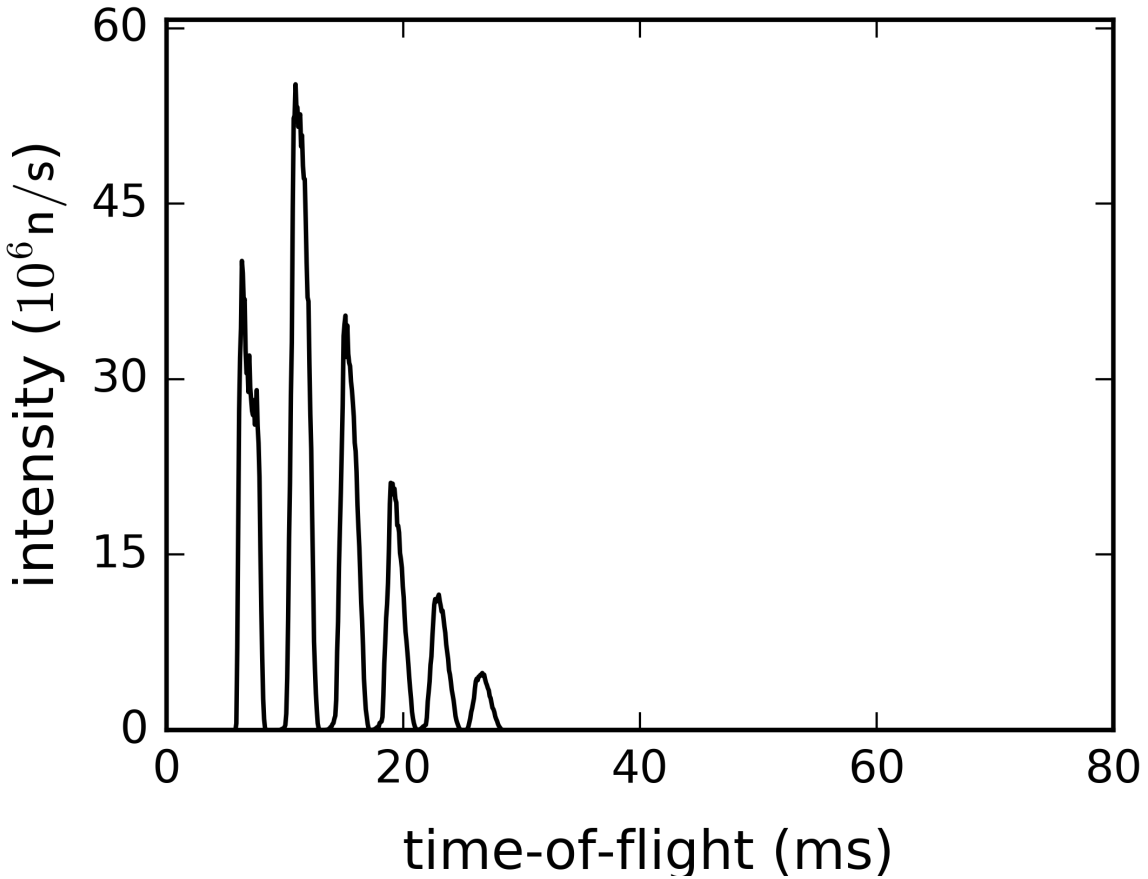
Frame Overlap Chopper



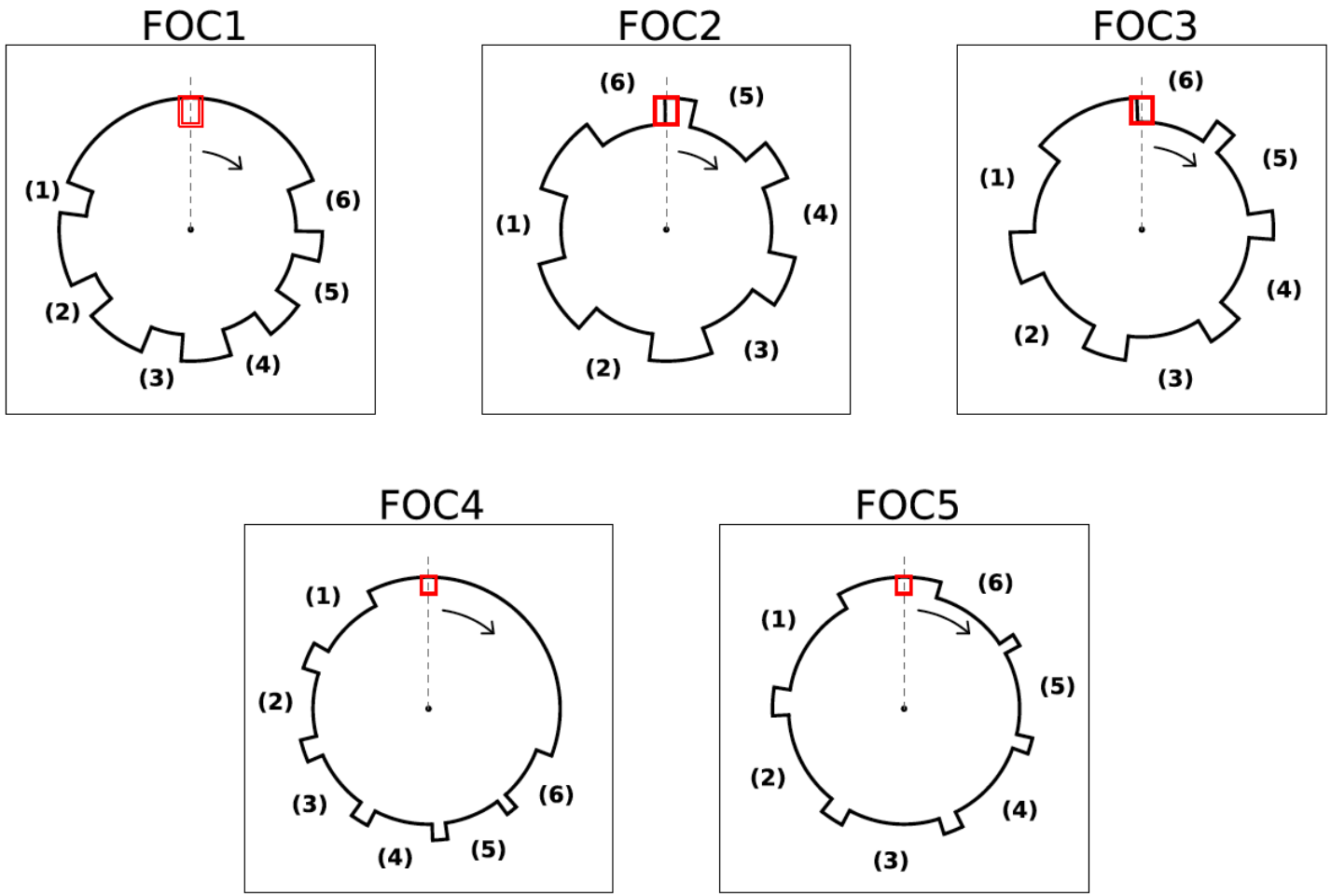
Frame Overlap Chopper



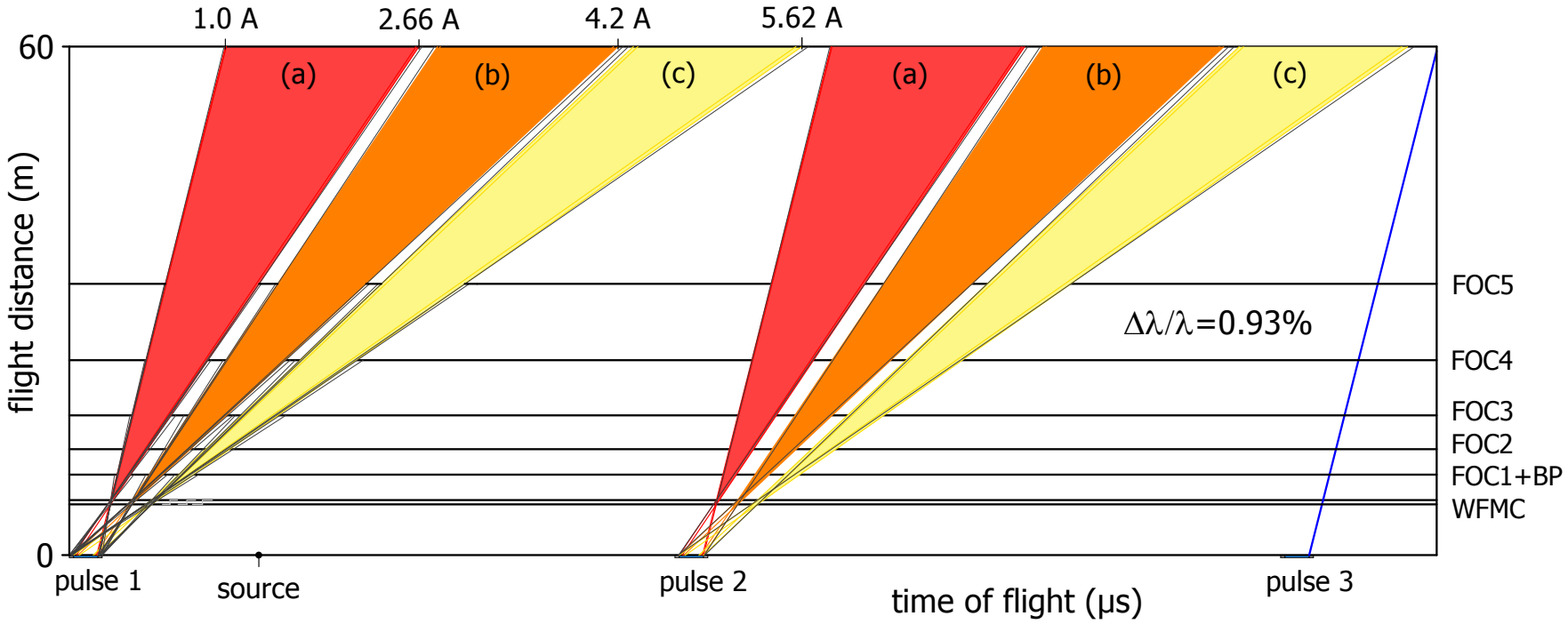
Chopper discs



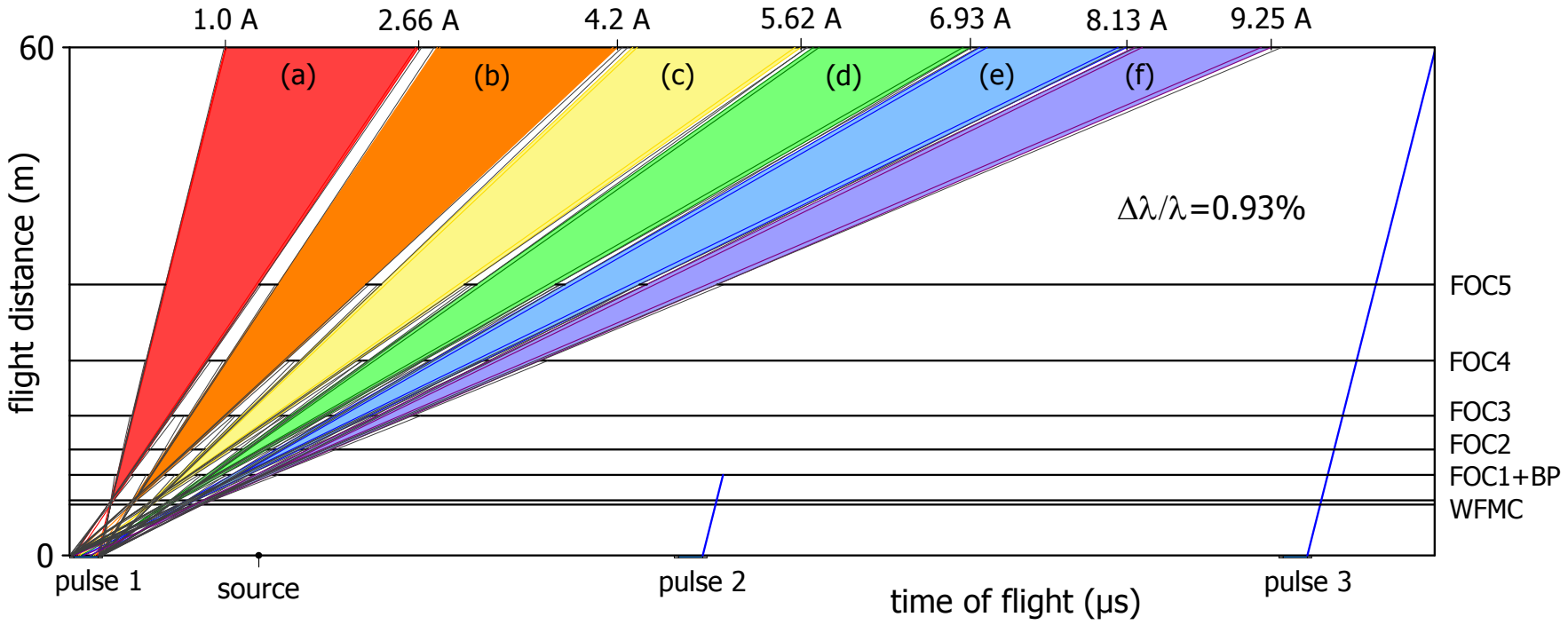
Chopper discs



Chopper System: Every Pulse

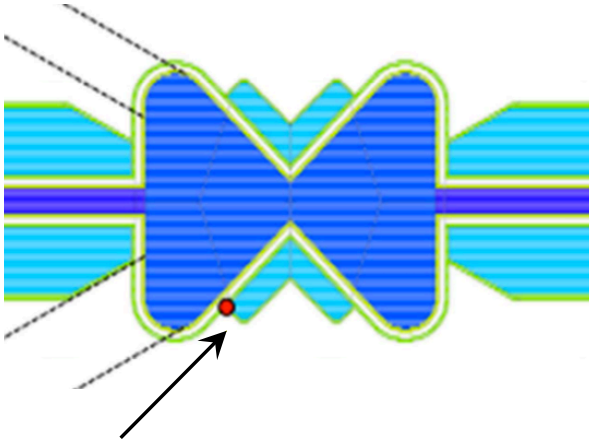


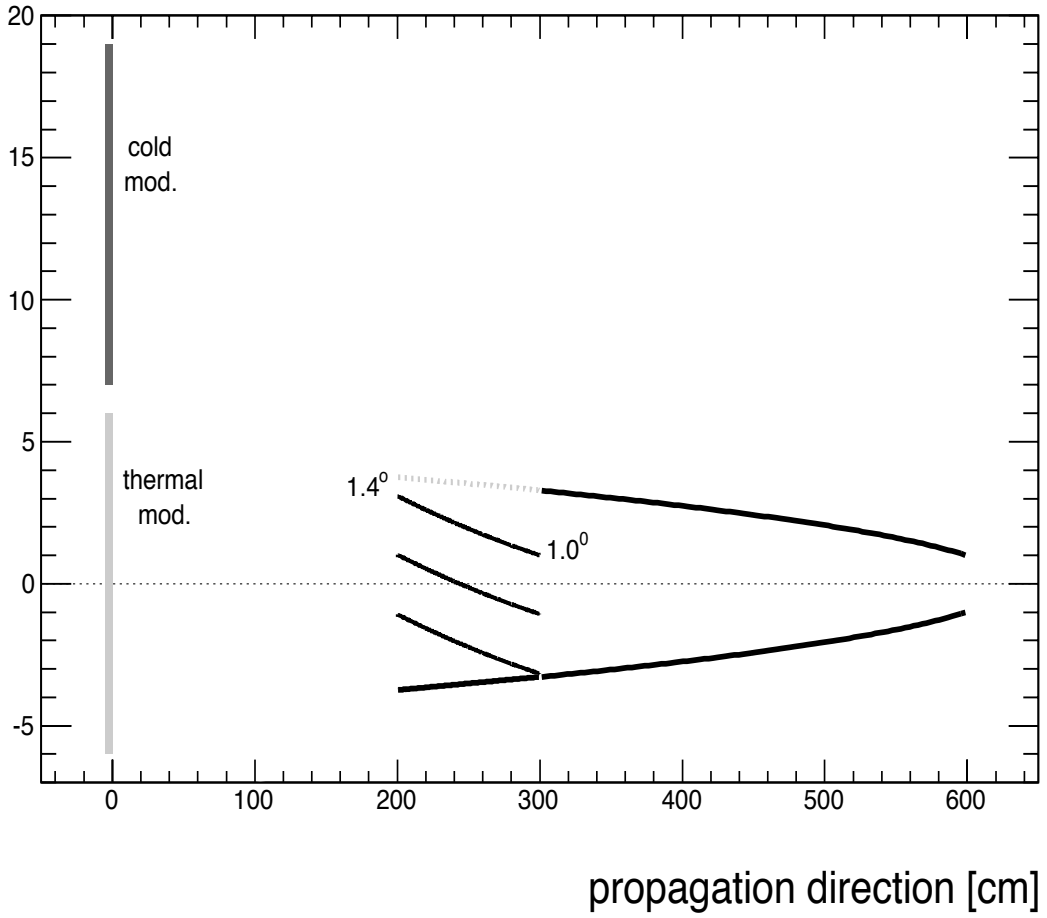
Chopper System: Every 2nd Pulse



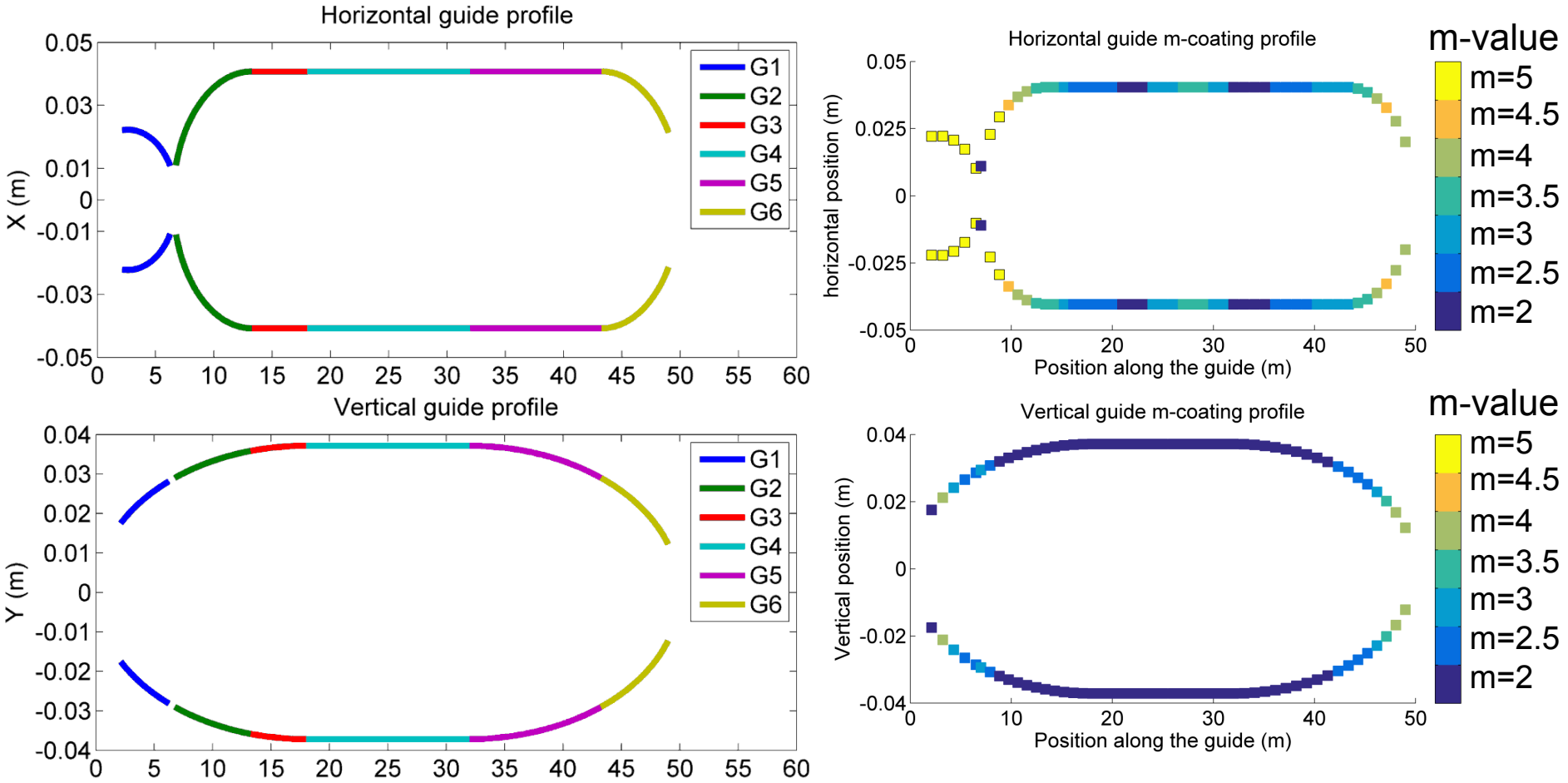
Bi-spectral Extraction System

- Schematic

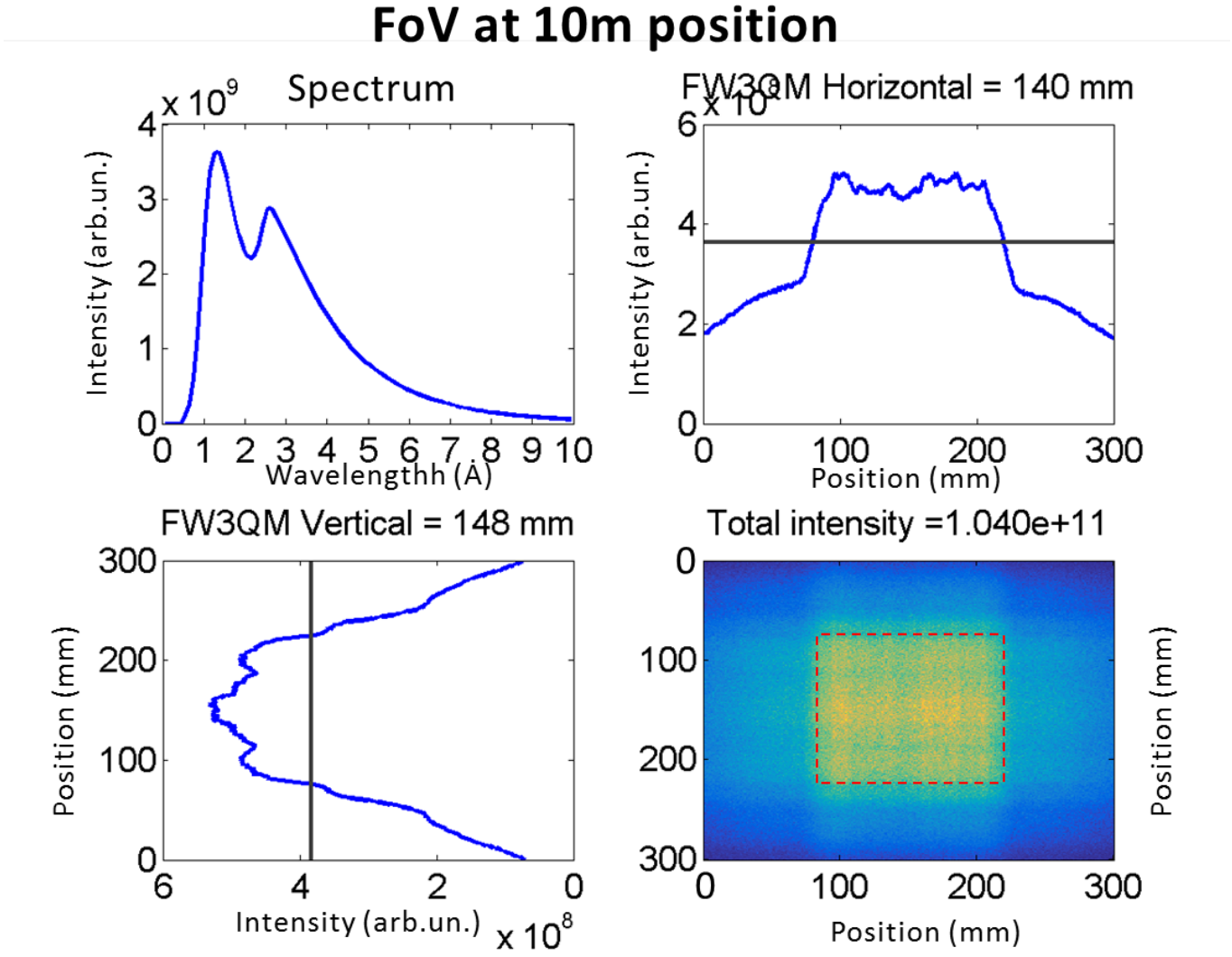




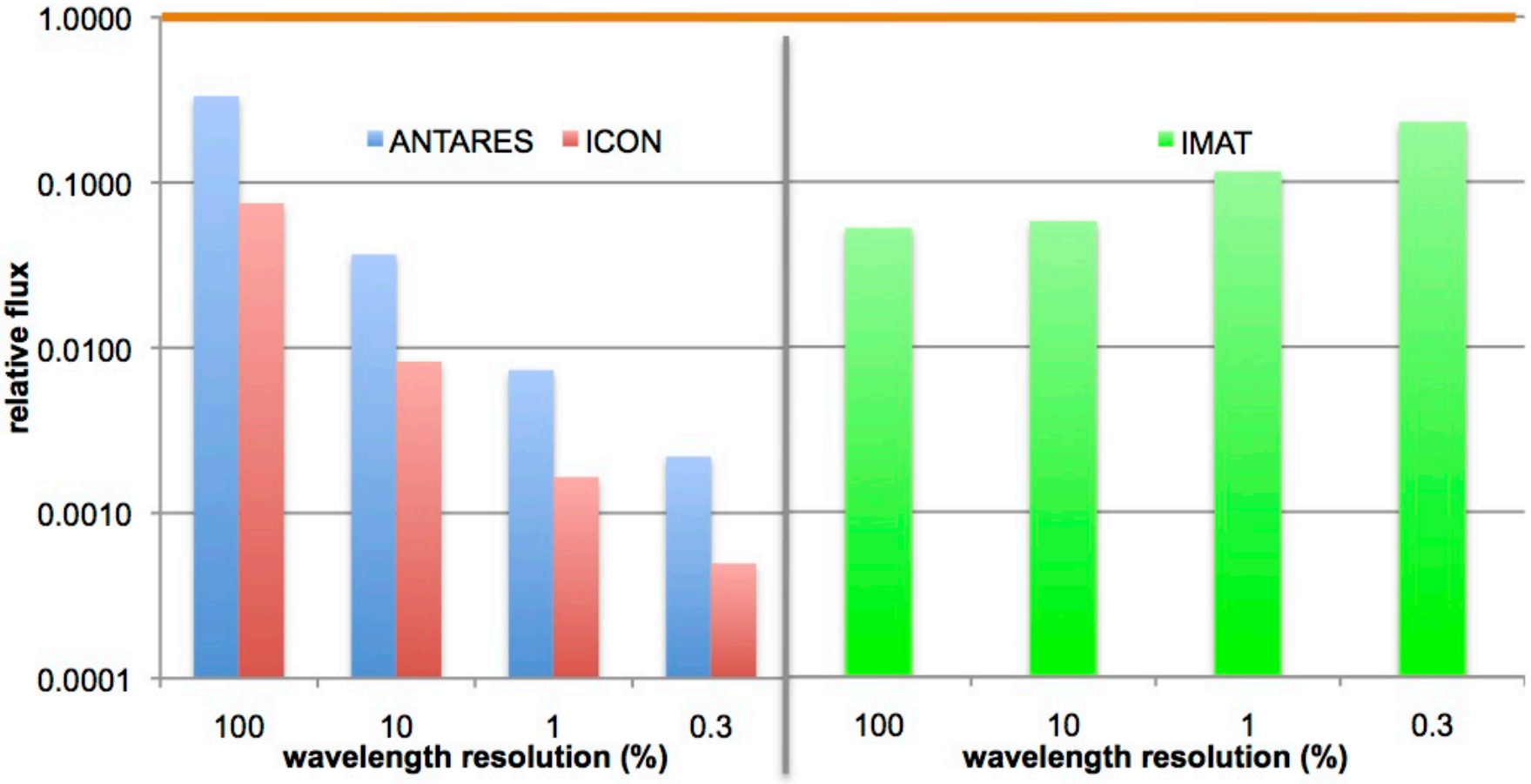
Neutron Guide Shape and Coating



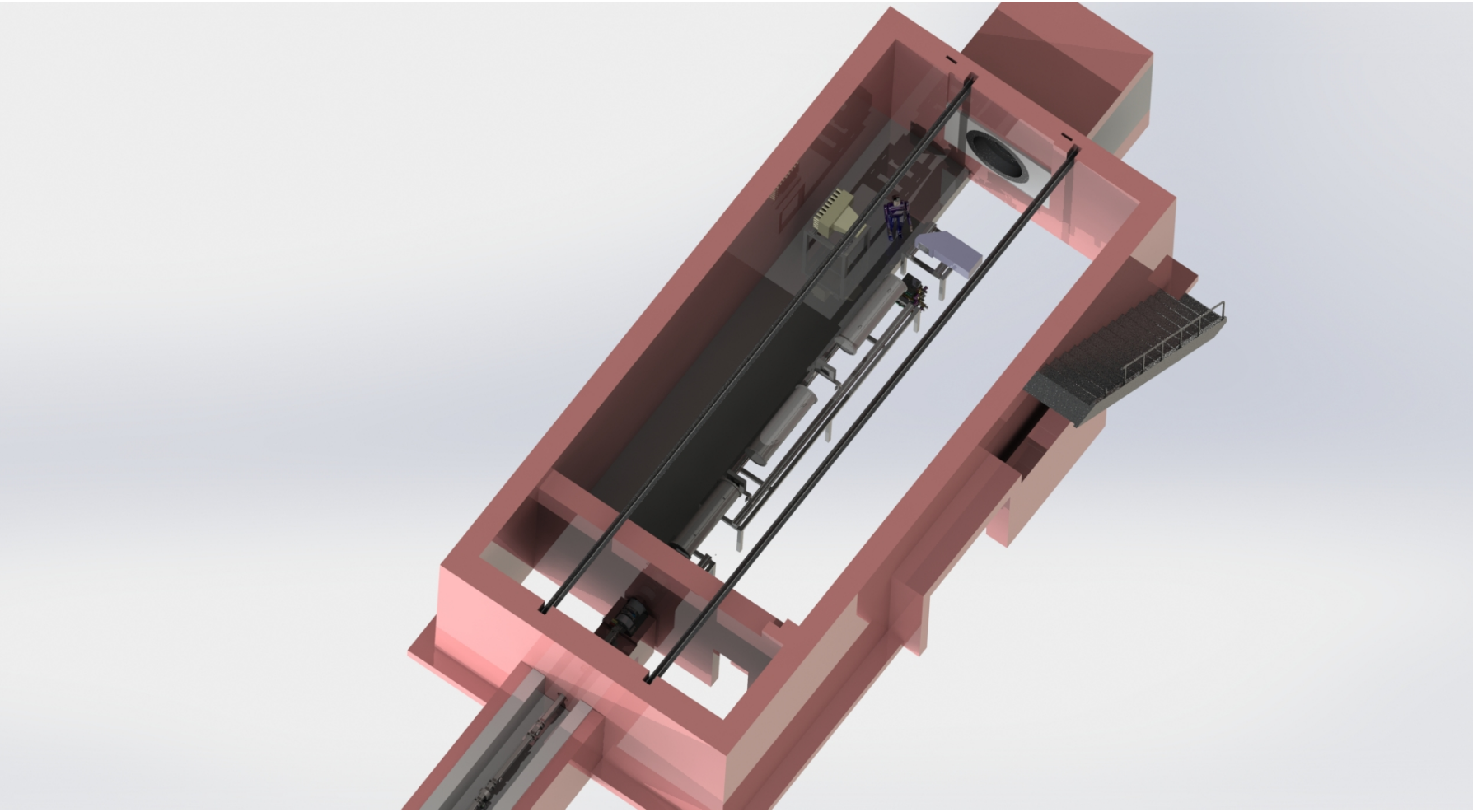
Intensity Distribution



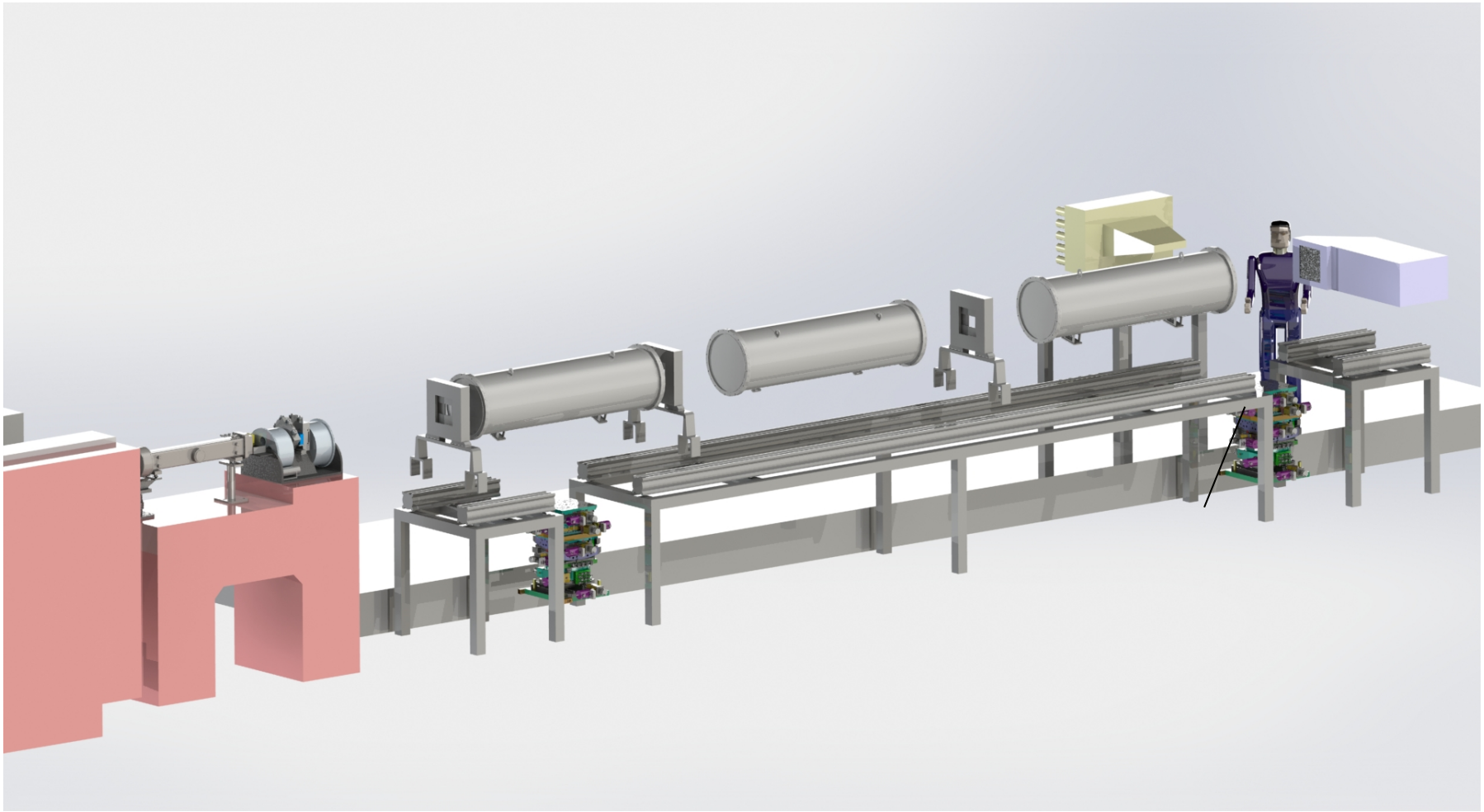
Flux Comparision



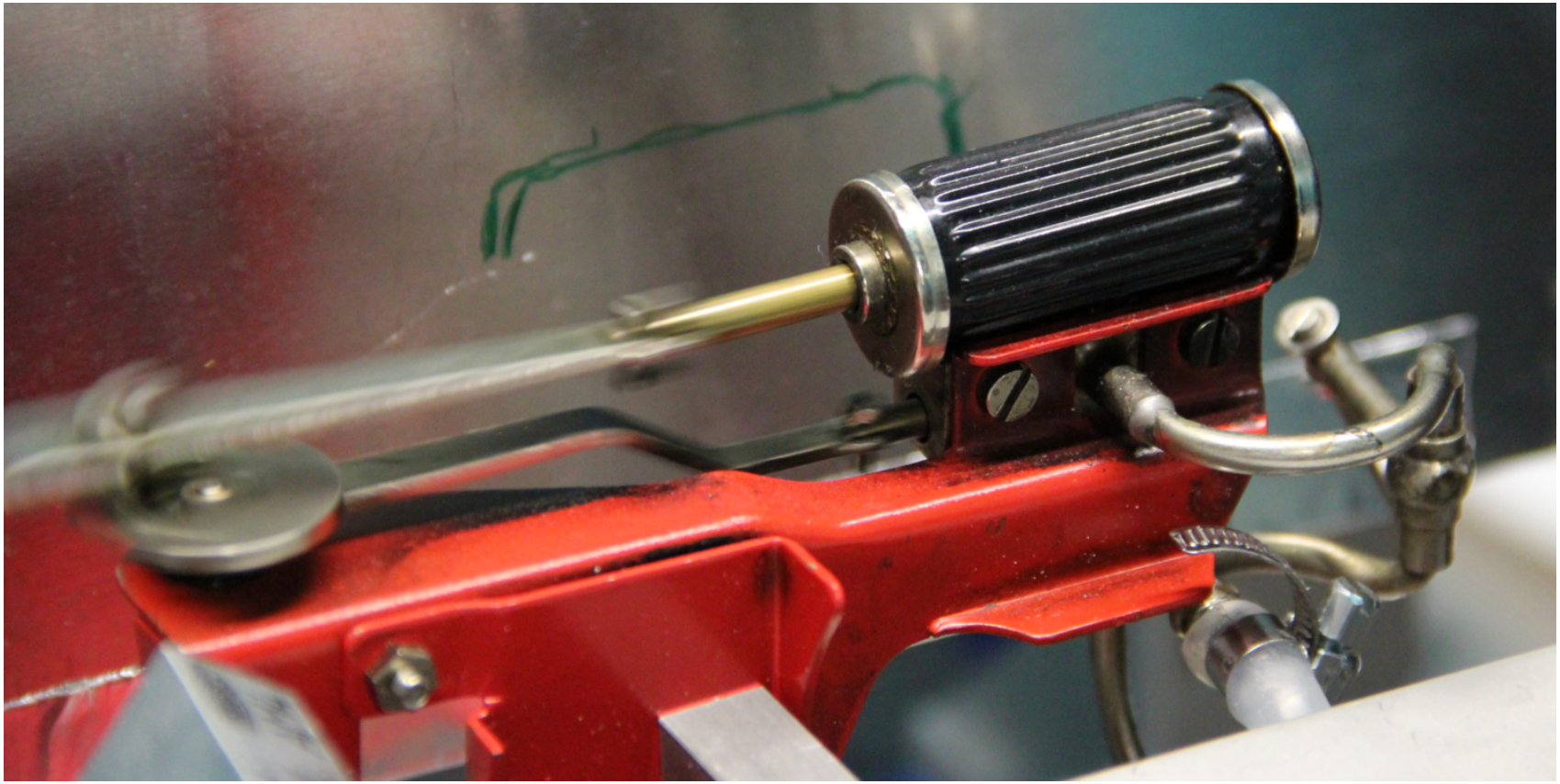
Cave Interior



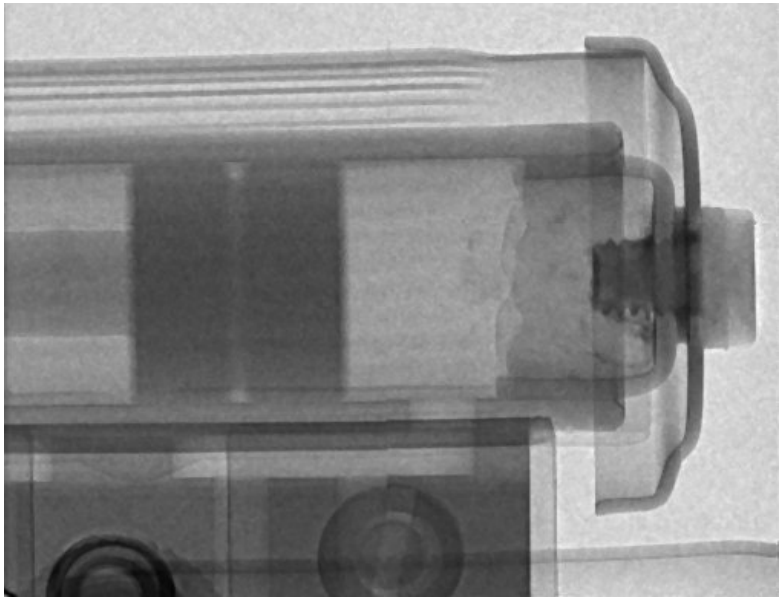
Cave Interior

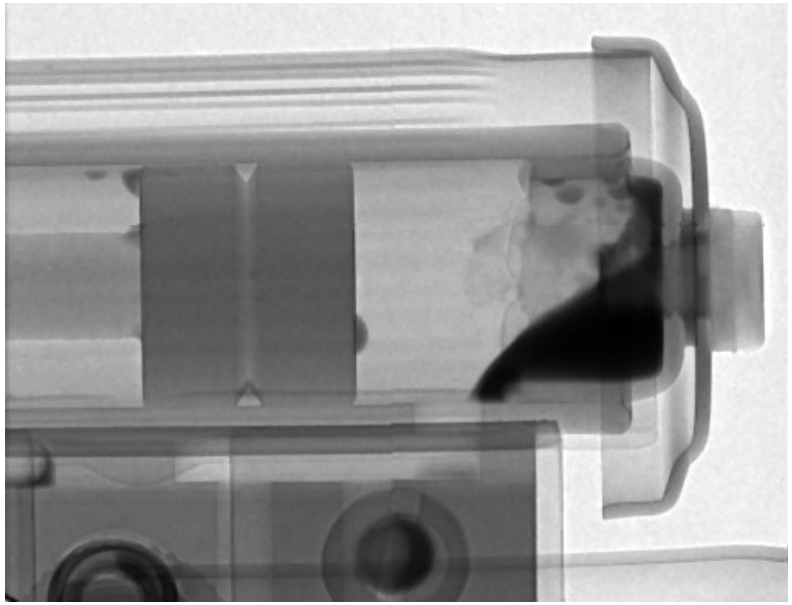


Neutron Imaging of cyclic motion



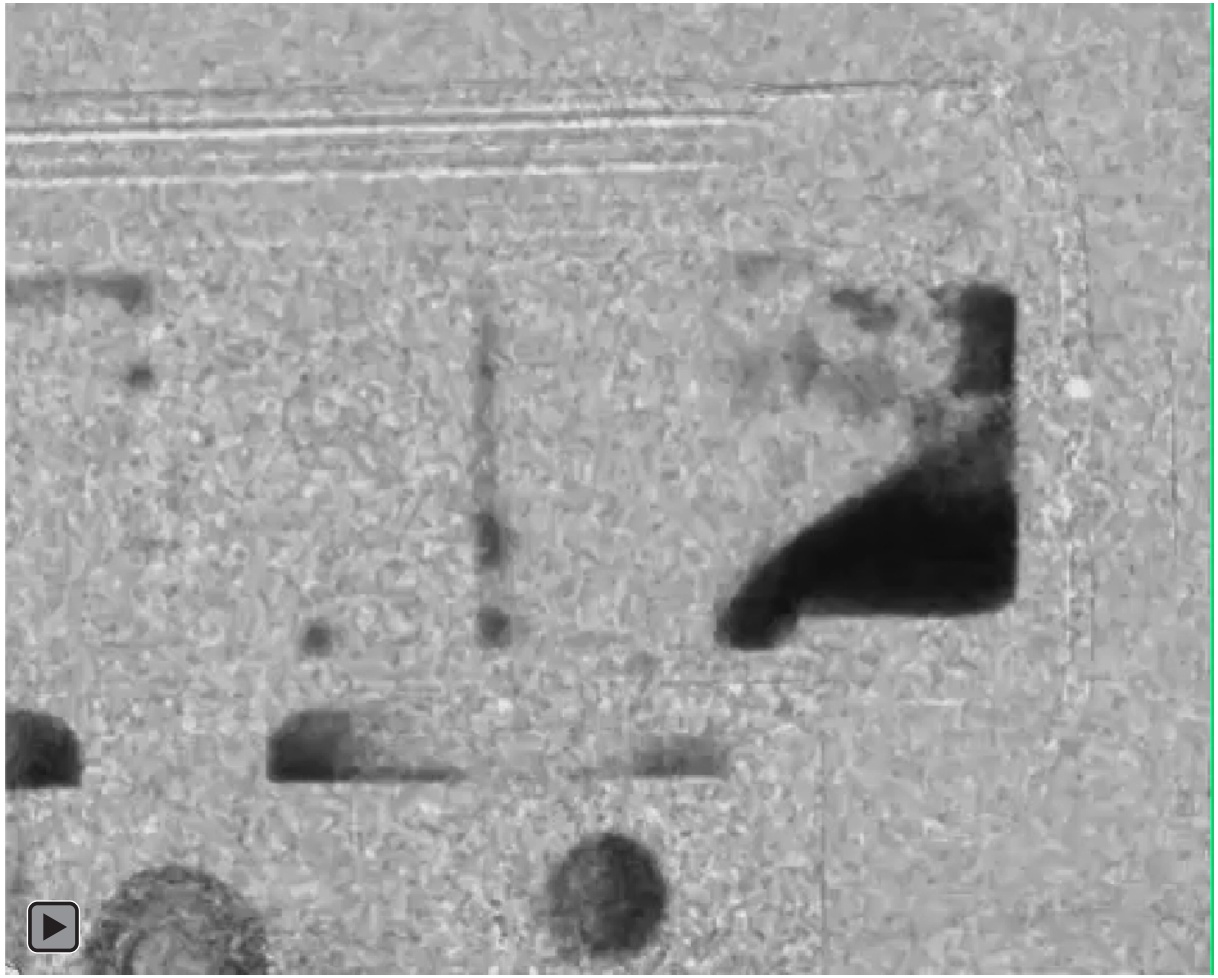
Neutron Imaging of cyclic motion





- Neutron transmission radiography of the steam engine cylinder. LEFT – dry engine driven by the exterior motor with no steam; RIGHT – steam is supplied to the cylinder, engine driven by an external motor at 10 Hz

Neutron Imaging of cyclic motion



ODIN Potential

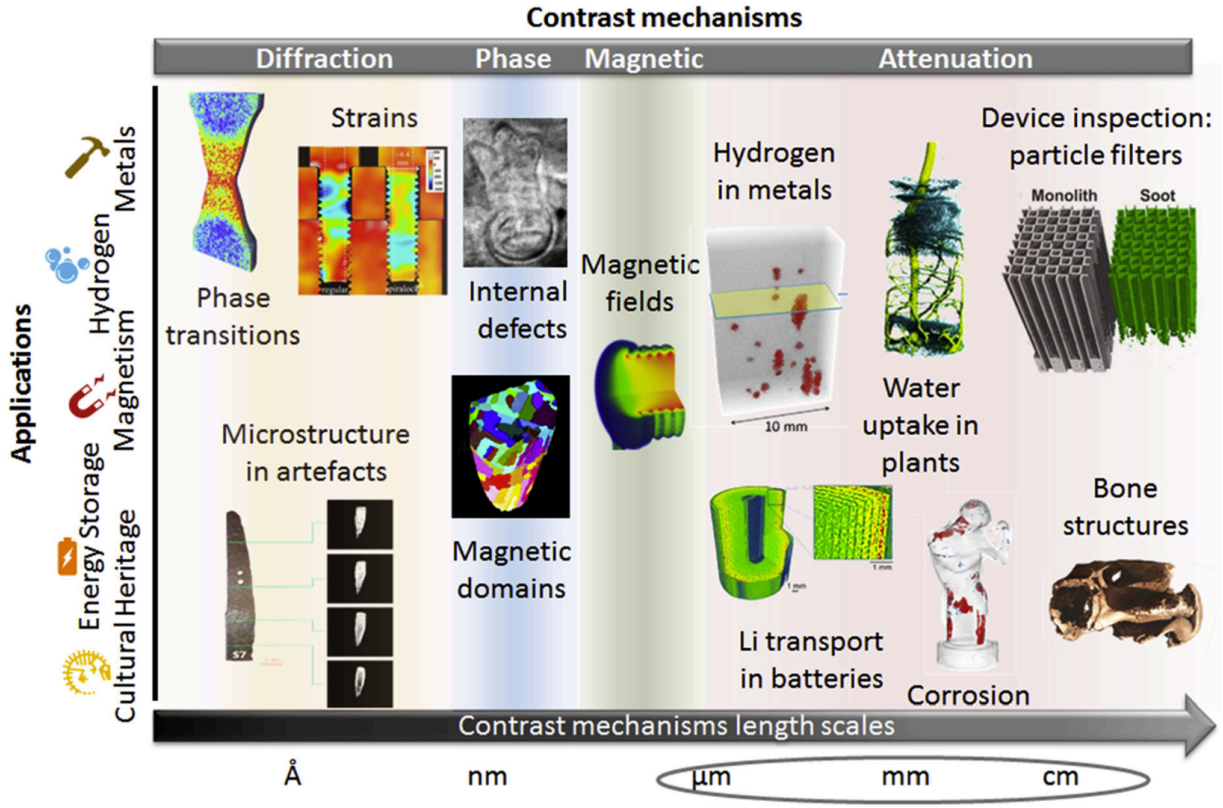


FIGURE 1

Different contrast mechanisms can be used to explore various length scales in materials and to study their properties and related processes. The relation between contrast mechanisms and different application fields is presented. The length scale presented on the lower axis relates to the corresponding contrast mechanism specified on the upper axis. For the attenuation-based image techniques the large length scale was emphasized by grouping the scales from µm to cm.

Nikolay Kardjilov *etal.:* "Advances in neutron imaging" Materials Today **21**, (6), July/August 2018



Thank You!