Heimdal Instrument @ ESS
IKON September 2020

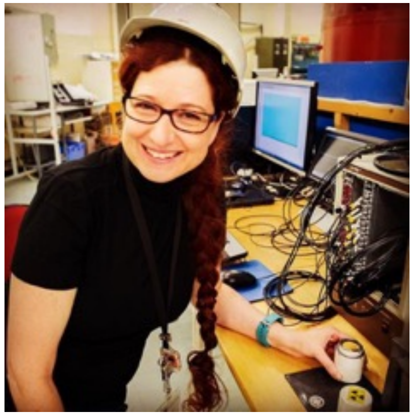
Dan Mannix

Lead Scientist Heimdal Instrument ESS, Lund Sweden

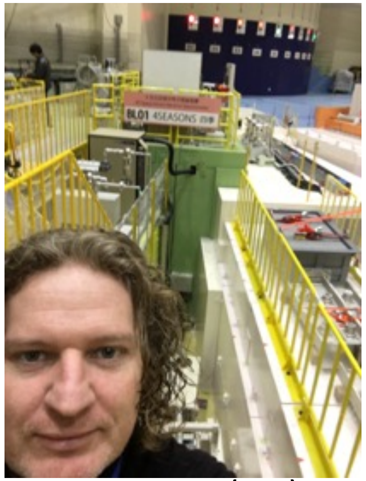
ESS 2020 - September 2020

The Heimdal Team

EUROPEAN SPALLATION SOURCE



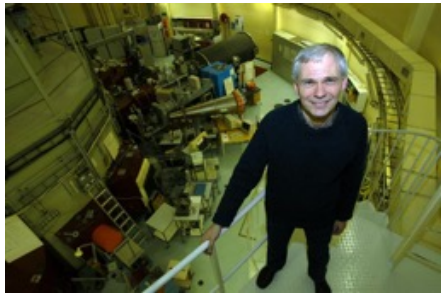
Isabel Llamas (IFE)
choppers



Dan Mannix (AU)
Lead Scientist

Kåre Iversen (AU)
Lead Engineer

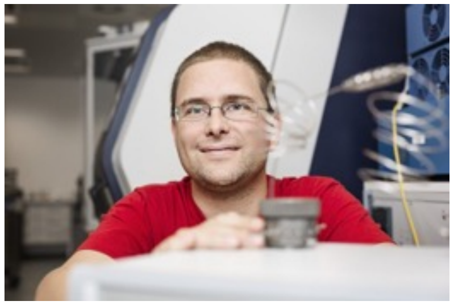
Rodion Kolevatov (IFE)
Neutronics



Bjørn Hauback
Lead in-kind partner IFE

35%

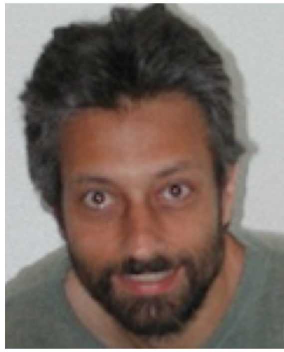
IFE Institute for Energy Technology



Mogens Christensen (PI)
Lead in-kind partner AU

30%

AARHUS UNIVERSITY

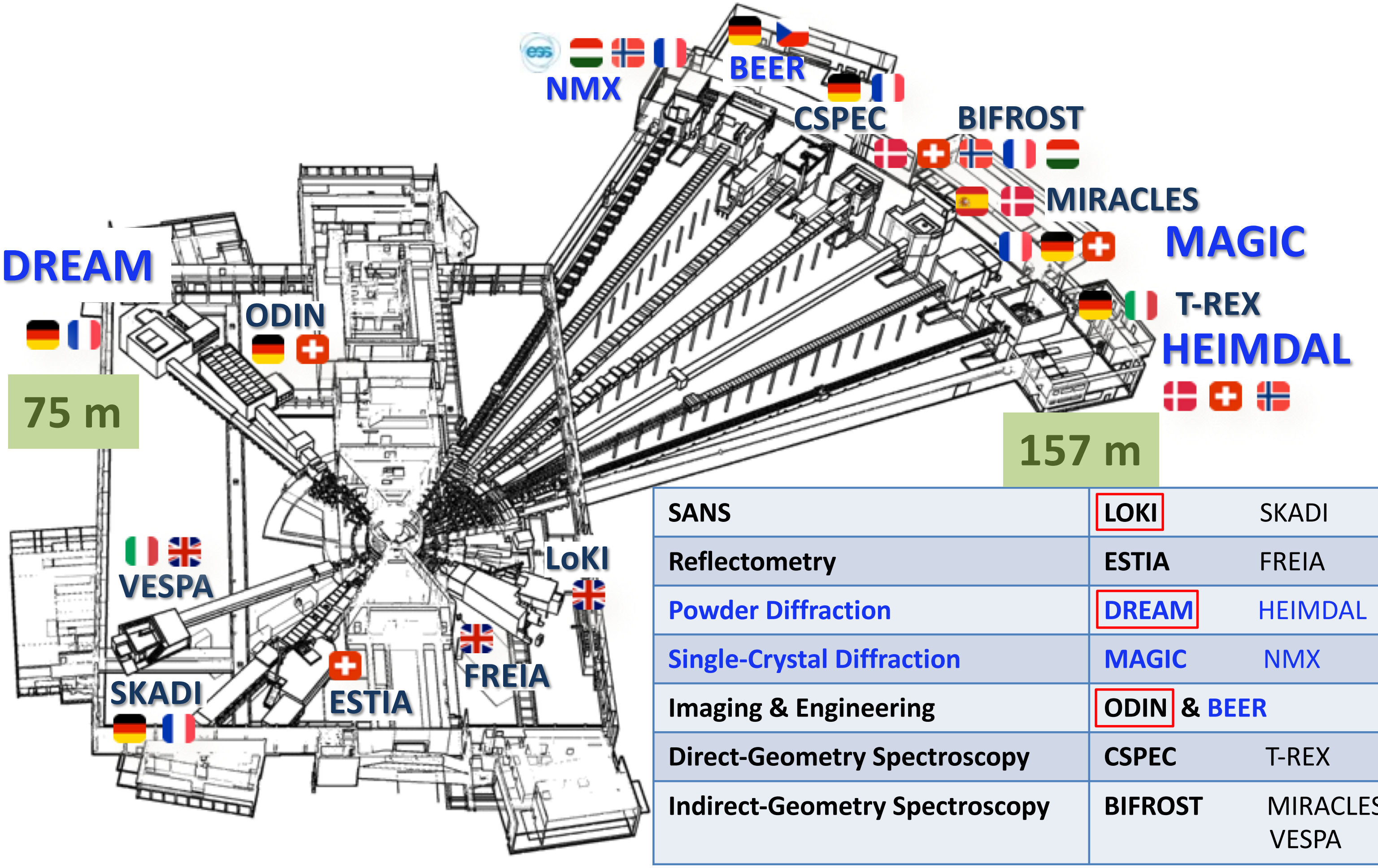


Uwe Stuhr
Lead in-kind partner PSI

35%

PAUL SCHERRER INSTITUT PSI

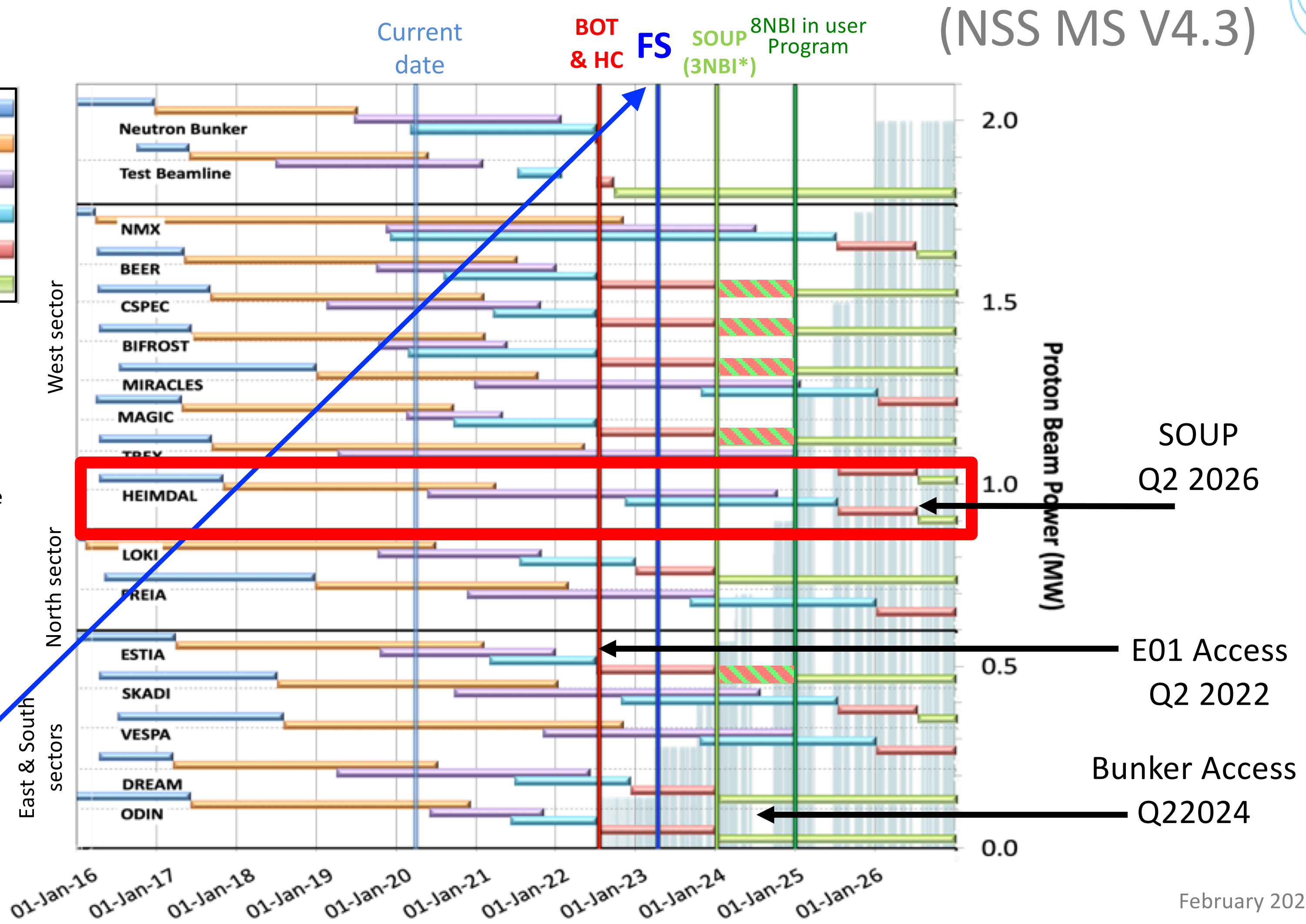
Heimdal



SANS	LOKI	SKADI
Reflectometry	ESTIA	FREIA
Powder Diffraction	DREAM	HEIMDAL
Single-Crystal Diffraction	MAGIC	NMX
Imaging & Engineering	ODIN & BEER	
Direct-Geometry Spectroscopy	CSPEC	T-REX
Indirect-Geometry Spectroscopy	BIFROST	MIRACLES, VESPA

Baseline schedule for Neutron Beam Instruments

(NSS MS V4.3)



- **First 3 NBI selected for SOUP: DREAM, LOKI & ODIN** (best chance for early impact, as agreed by NSS, SAC and ESS Council)
- **Back-up instruments:** (for risk of late access to D01 & D03) BEER, CSPEC, MAGIC or BIFROST, ESTIA

March 2023:

- ***First Science (FS)** with expert teams on some of instruments above*
- *Review progress of first 3 NBI* for SOUP, implement backup plan if needed.*

* NBI = Neutron Beam Instrument

Project Progress

EUROPEAN SPALLATION SOURCE

Component	Procurement	Design Specification	CTV	KO	TG3	SAT	proposed Installation
NBOA	PSI	X	X	X	Q12021	Q1 2021	Q1 2021
Light Shutter	ESS /AU	X			Mar 2021		Q2 2024
Heavy Shutter	AU	X			Mar 2021		Q2 2024
BWI	AU	X	05/20				Q2 2024
Choppers	ESS / IFE	X	05/19	Oct 2020	tbd		Q2 2024
T0 Chopper	ESS / IFE	X	05/19		tbd		Q2 2024
Thermal Guide	PSI	X	03/19	Delayed Q1 2021			Q2 2023
Slits / Collimator	AU	X	05/20		05/20		Q2 2021
Sample X,Y,Z ω	AU	X	05/20		05/20		Q2 2021
2D Detector	PSI / CDT	X	05/20	Delayed Q1 2021		Q2 2023	Q2 2024
Detector Collimator	AU	X	05/20		Mar 2021		Q3 2021
Detector Support	AU	X	05/20		05/20		Q2 2021
Monitors	PSI				Final TG3		Q3 2022
Cave / Beamstop	IFE	X	05/20	12/20	Mar 2021		Q2 2022

Project Progress

EUROPEAN SPALLATION SOURCE

General TG3 Documents	Owner: Dan Mannix	Heimdal Lead Scientist	
Title	ESS Number	Link	Ready to Review ?
Instrument Hazard Analysis	ESS-0434220	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.48384.49625&inline=false	Yes Living Document
Radiation Hazard Analysis	Included in ESS-0434220		Yes
H1 and H2 Scenarios for the Radiation Shielding	ESS-2492189	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.18176.38859&inline=false	In-Review
System Design Description (Draft)	ESS-0434115	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.1792.51433&inline=false	Yes Final TG3
Project Quality Plan	ESS-0434117	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.53504.27923&inline=false	Yes May 2020 Living Document
System Validation Plan (Draft)	ESS-0434434	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.11776.50362&inline=false	Yes May 2020 Living Document
Project Schedule Plan	ESS-2495827	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.13313.4358&inline=false	Yes May 2020 Living Document
Project Management Progress (Monthly)	ESS-2495831	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.18432.33671&inline=false	Yes May 2020 Monthly Document

Project Progress

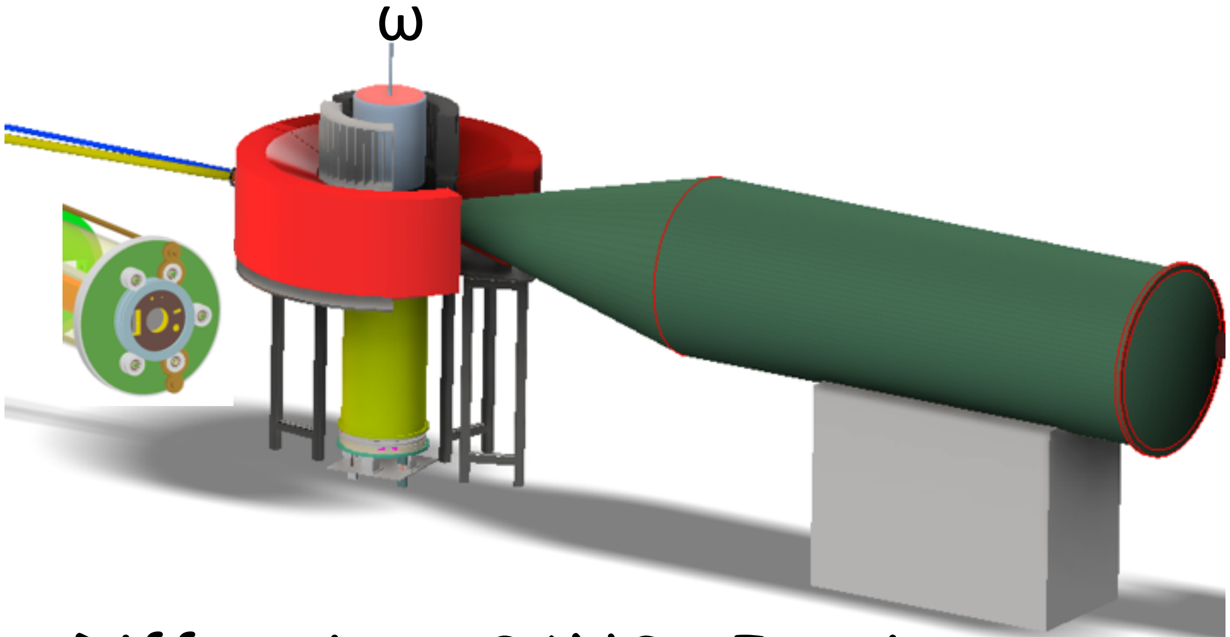
EUROPEAN SPALLATION SOURCE

General TG3 Documents	Owner: Kåre Iversen	Heimdal Lead Engineer	
Title	ESS Number	Link	Ready to Review ?
Interface Descriptions (Draft)	ESS-0434250	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.9984.29410&inline=false	Kåre Check Each System
System Operations and Maintenance Plan (Draft)	ESS-0434436	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.26368.57224&inline=false	Kåre Check Each System
Integration and Verification Plan	ESS-0434381	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.58624.7089&inline=false	Kare Check Each System
Table of Motion	ESS-2492193	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.7168.45377&inline=false	Yes May 2020 Each System
CE Marking	ESS-0434442	https://chess.esss.lu.se/enovia/tvc-action/validVersion?versionObjectId=21308.51166.26368.37086&inline=false	Do This Later Living Document
System 2D 3D drawings	Chess /Drawing Packages	Create files in chess /detailed design (TG3)/Supporting documents/Drawing Packages https://chess.esss.lu.se/enovia/common/emxTree.jsp?objectId=21308.51166.56320.64598	Upload to Chess Each System
System Hazard Check List	Chess /Hazard Check-Lists	Create files in chess /detailed design (TG3)/Supporting documents/Hazard Check Lists https://chess.esss.lu.se/enovia/common/emxTree.jsp?objectId=21308.51166.56320.64598	Upload to Chess Each System

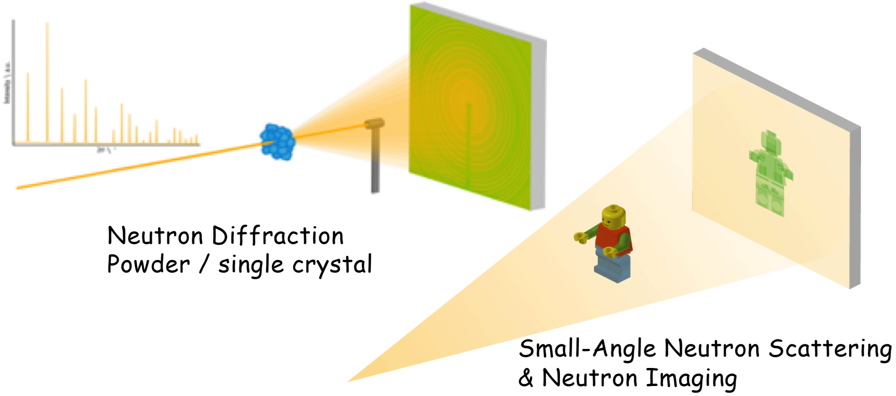
HEIMDAL – Hybrid Diffraction

Multi Length Scale Neutron Scattering Instrument: 10^{-2} – 10^{8} nm

EUROPEAN SPALLATION SOURCE



Diffraction + SANS + Imaging



Thermal Neutron Diffraction + Cold Neutron SANS + Cold Neutron Imaging

Powder / Texture / Single Crystal

2D Rietveld Refinement

2D / 3D Cold Neutron Imaging

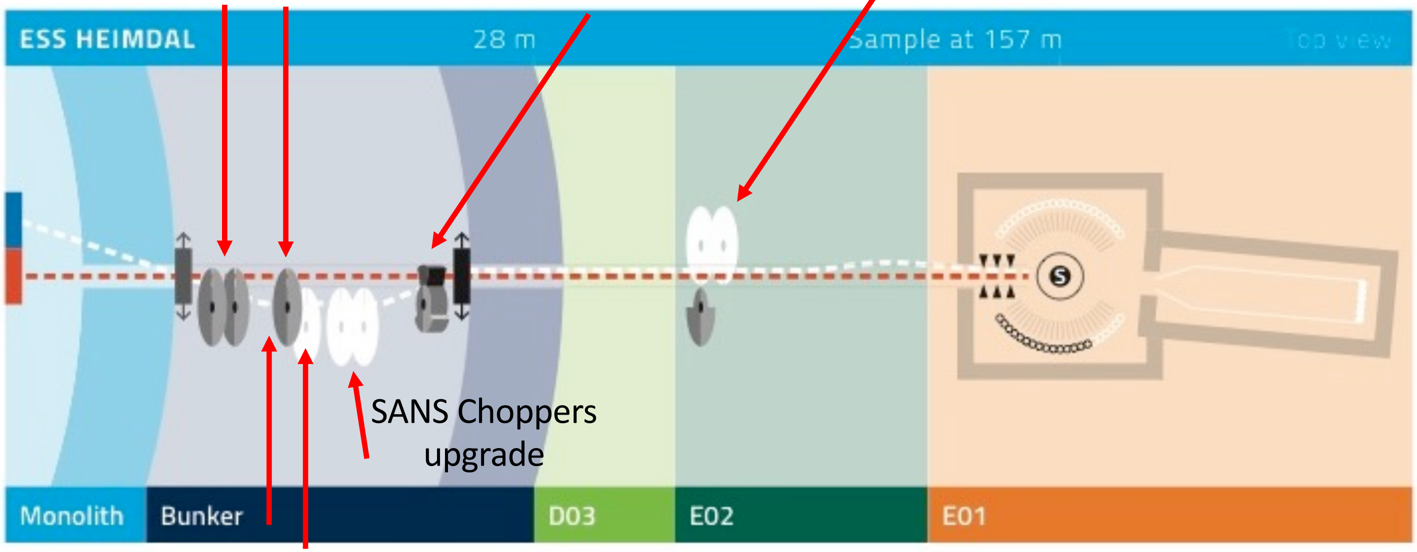
Heimdal – Chopper Overview

1.1 Thermal Pulse Shaping Chopper Double Disc 168Hz @6.5m

1.2 Thermal Wavelength Sorting Chopper 14Hz @8m

1.3 Thermal T0 Chopper 28Hz@21.6m

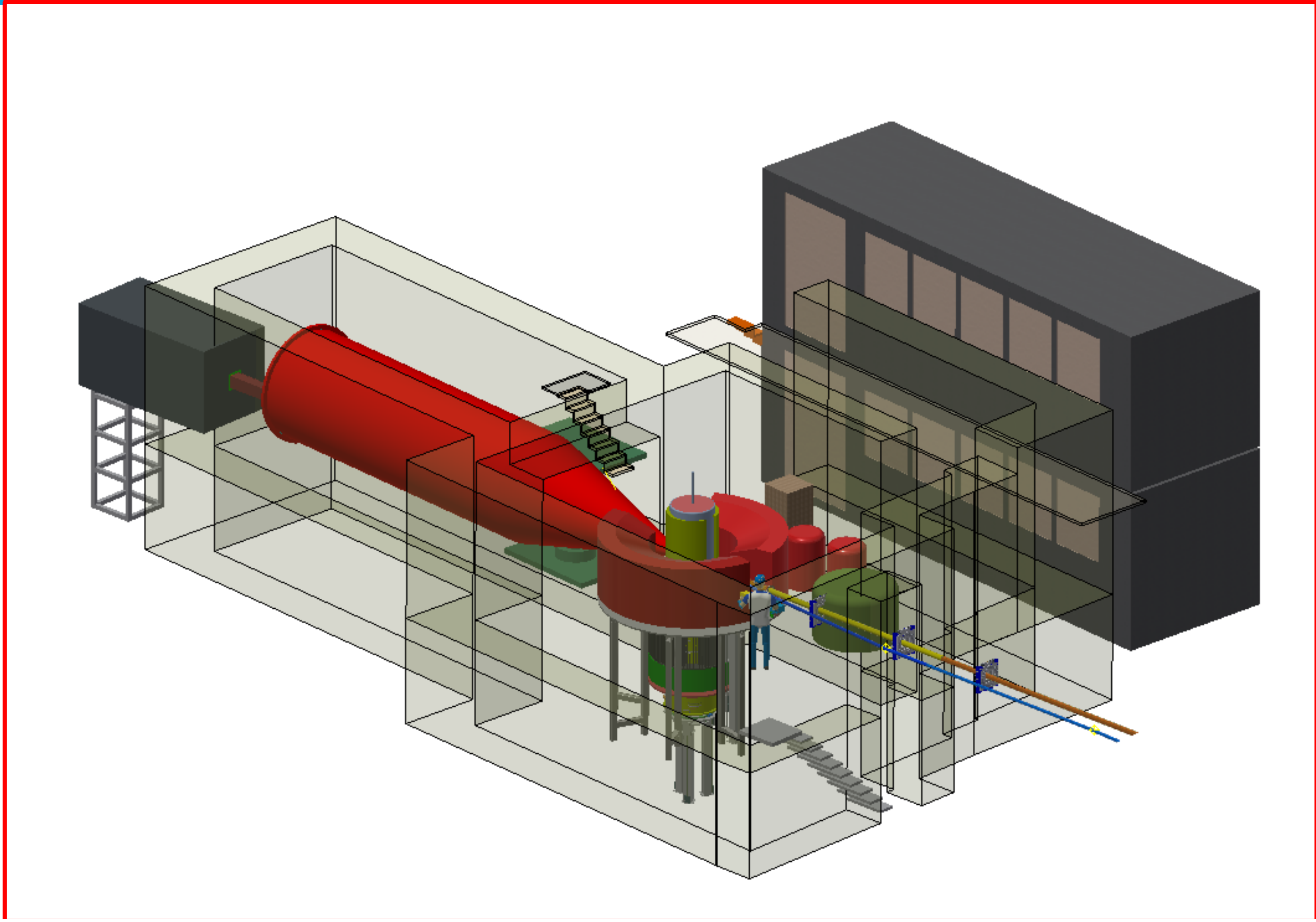
Cold Frame Selection / Frame Overlap Choppers upgrade



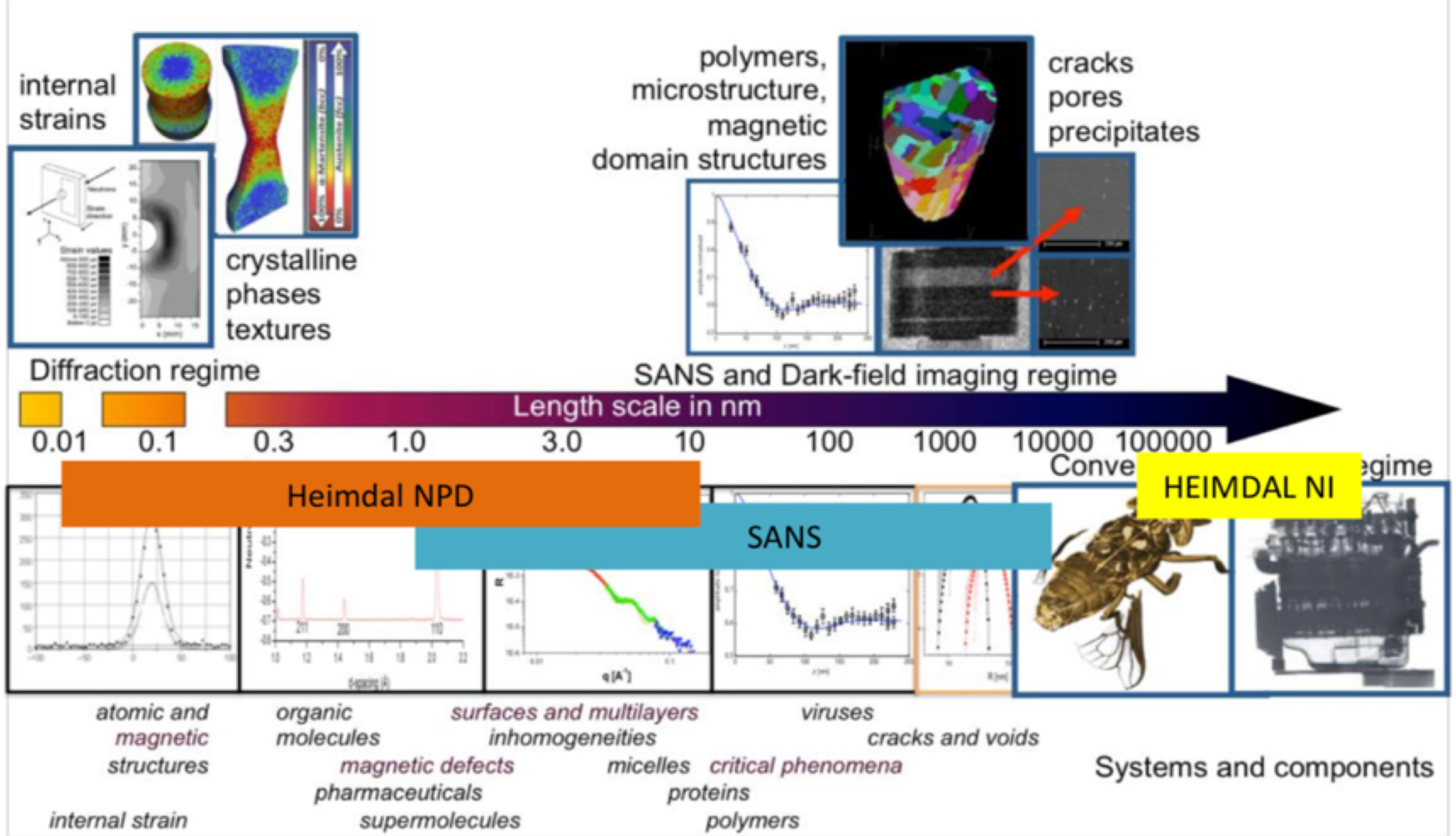
1.5 Thermal Frame Selection Chopper 14Hz @8m Upgrade

1.4 Thermal (& Cold) Frame Overlap Chopper 14Hz @78m

The Heimdal End Station

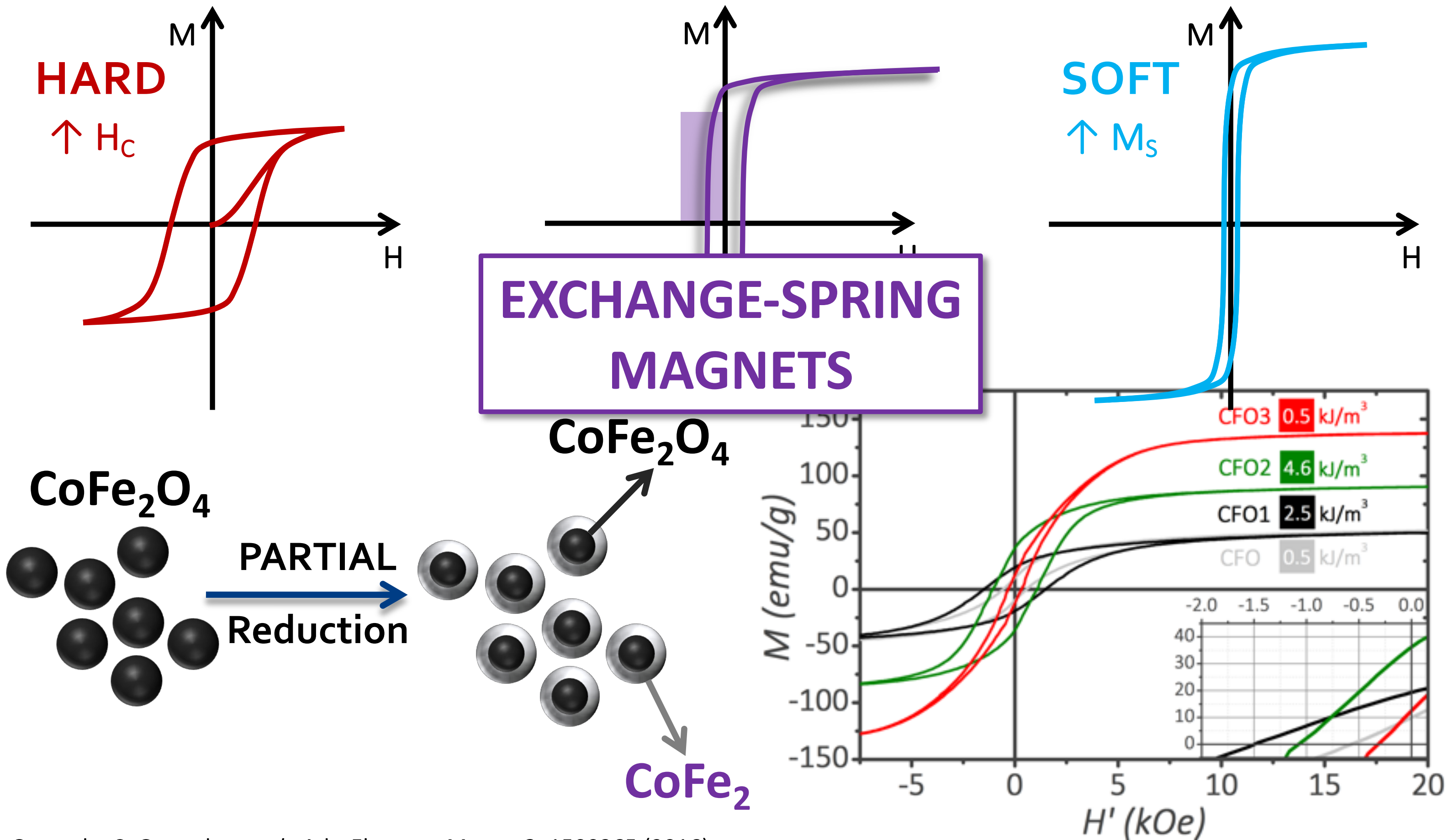


HEIMDAL: Science Case



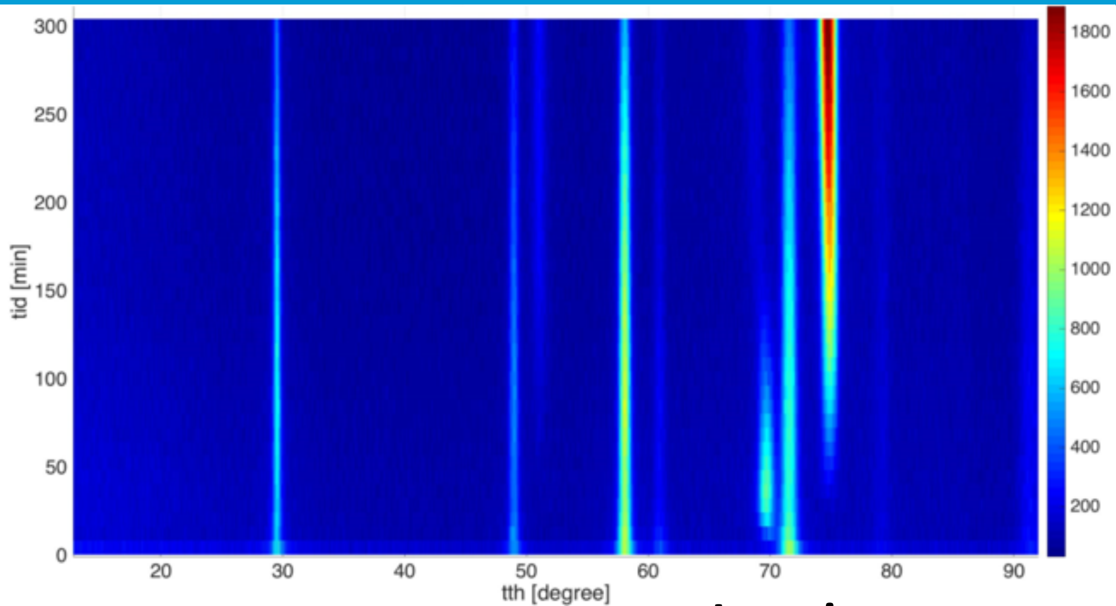
Powder Diffraction + SANS + Neutron Imaging

Improved magnetic materials

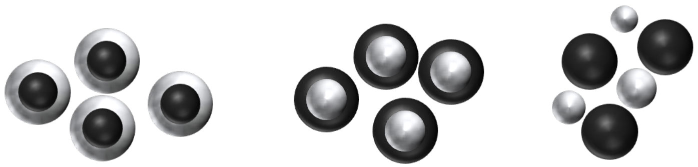


A. Quesada, C. Granados *et al*,. Adv. Electron. Mater., **2**, 1500365 (2016)

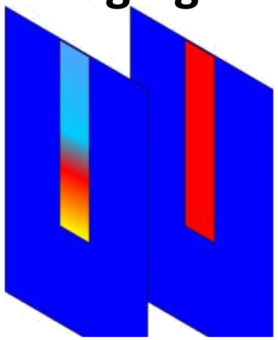
Reduction experiments



SANS



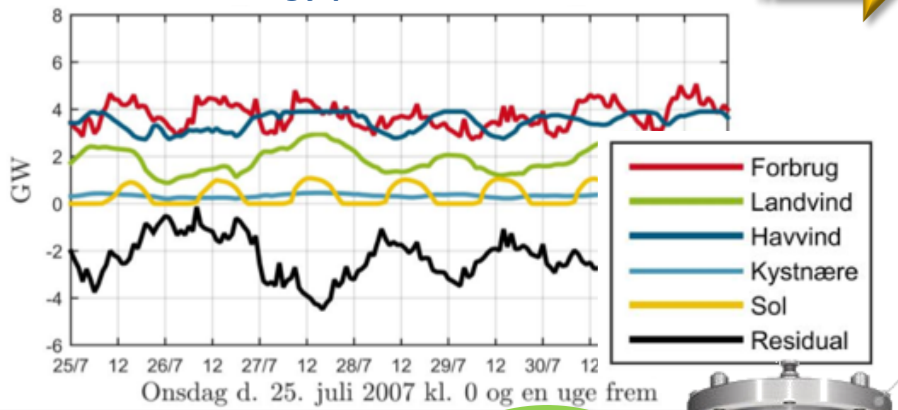
Imaging



Jakob Ahlburg, Cecilia Granados, Henrik Lyder Andersen, Pelle Garbus, Emmanuel, Lukas Keller

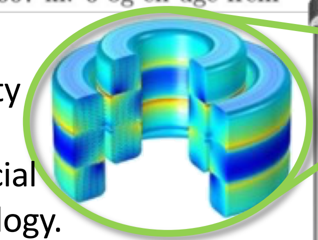
Energy storage

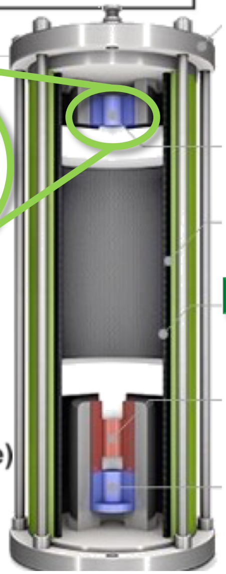
Renewable energy production:

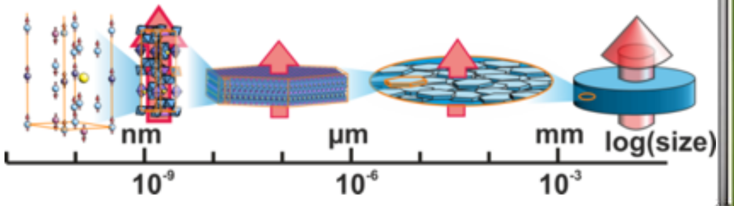


Magnets can interconvert motion and electricity

Magnets can become crucial for energy storage technology.







Rapport – Energikoncept 2030 (energinet.dk)

Need for storage capacity

Hydrogen/hydrolyses:

Efficiency 35%
Slow responds to demand
Long term storage
Cycle life: Irrelevant

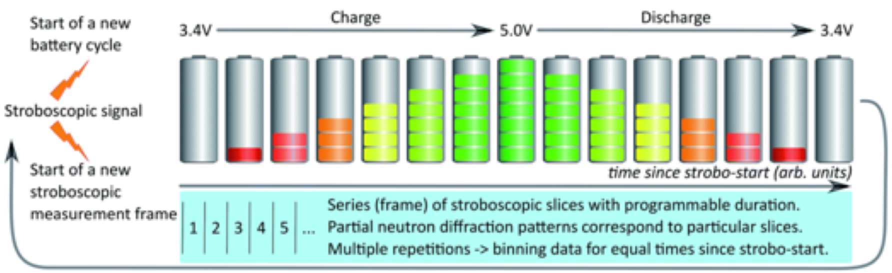
Batteries:

Efficiency 75%
Fast responds to demand
Medium term storage
Cycle life: 2000-4000

Flywheels:

Efficiency >90%
Fast responds to demand
Short term storage
Cycle life: >50.000

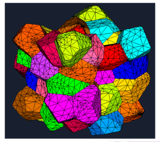
Optimised Batteries

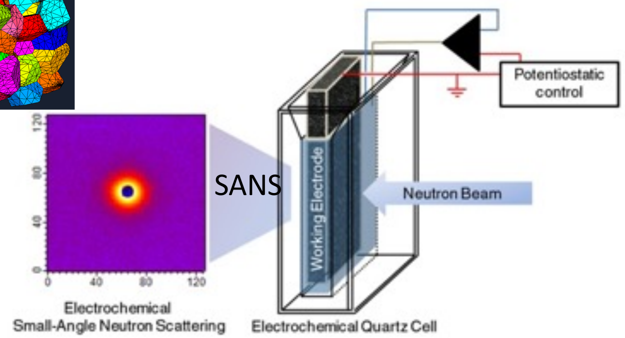


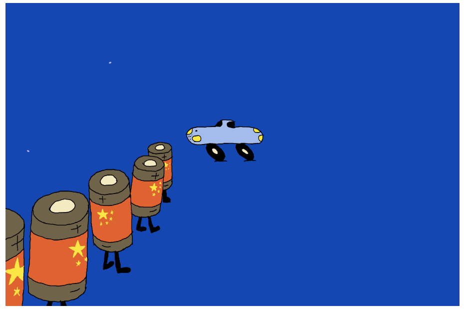
D. Sheptyakov et al. J. *Mater. Chem. A* **8**, 1288 (2020).

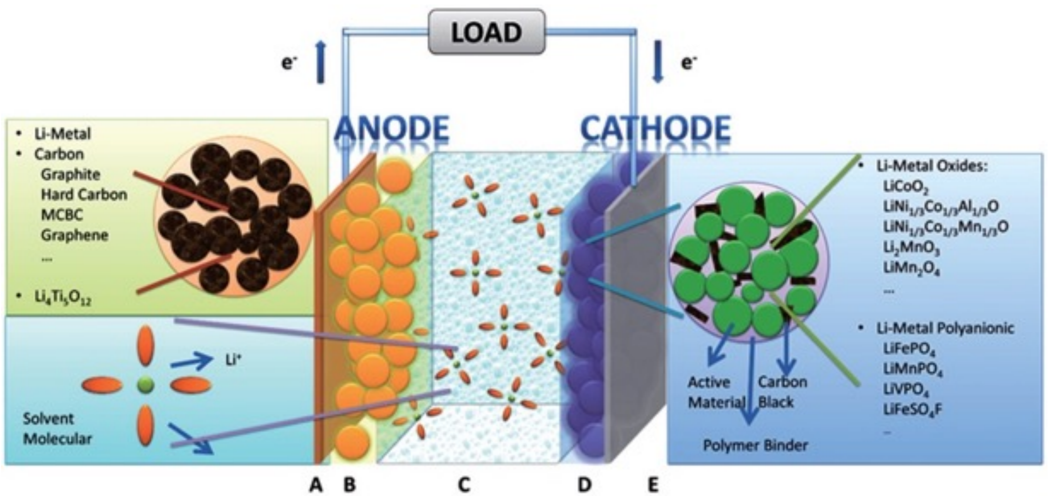
Nano-Crystals
1-10nm

Multi-Grains
10-100nm

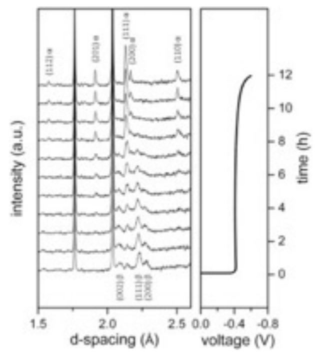




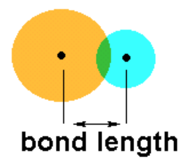




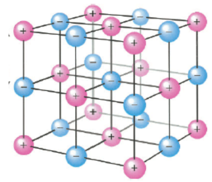
Neutron Diffraction



Bond Lengths
0.01-0.1nm



Atomic Structure
0.1-1nm



Neutron Imaging
Crystal Grain Mapping /3D Tomography

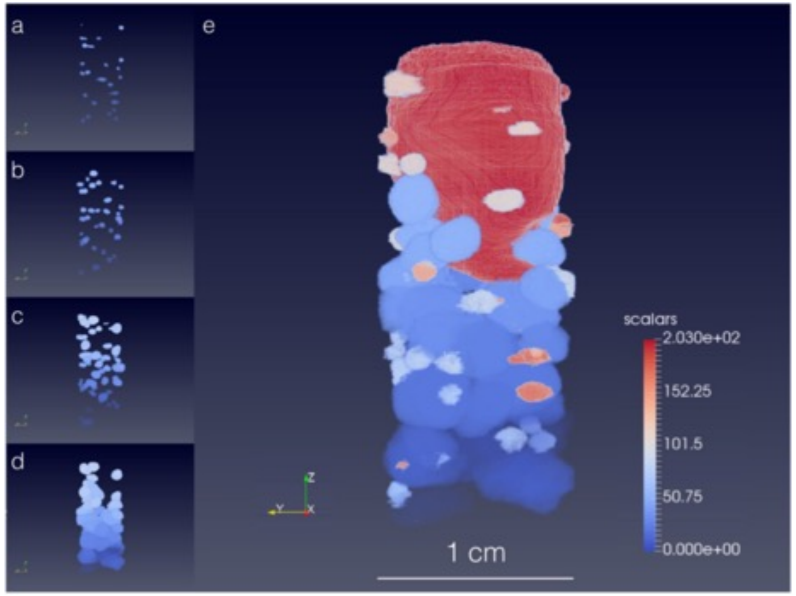
EUROPEAN SPALLATION SOURCE

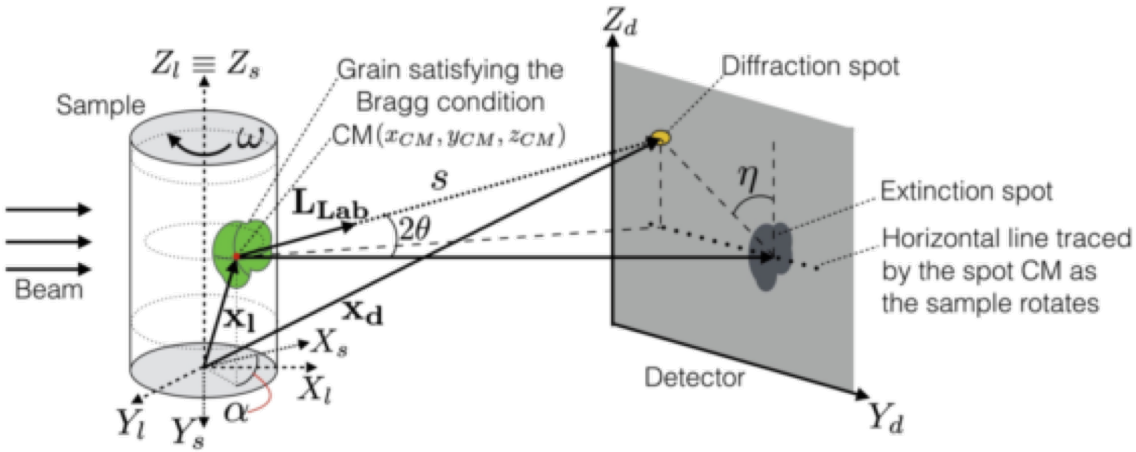
SCIENTIFIC REPORTS

OPEN

Time-of-Flight Three Dimensional Neutron Diffraction in Transmission Mode for Mapping Crystal Grain Structures

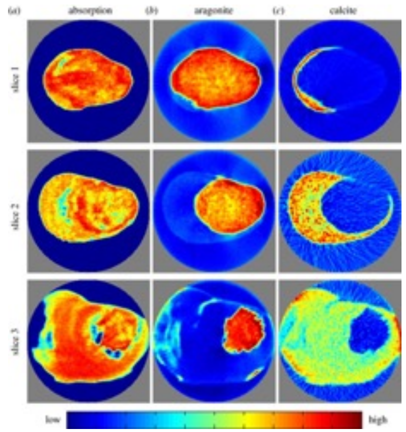
Received: 25 April 2017
Accepted: 28 July 2017





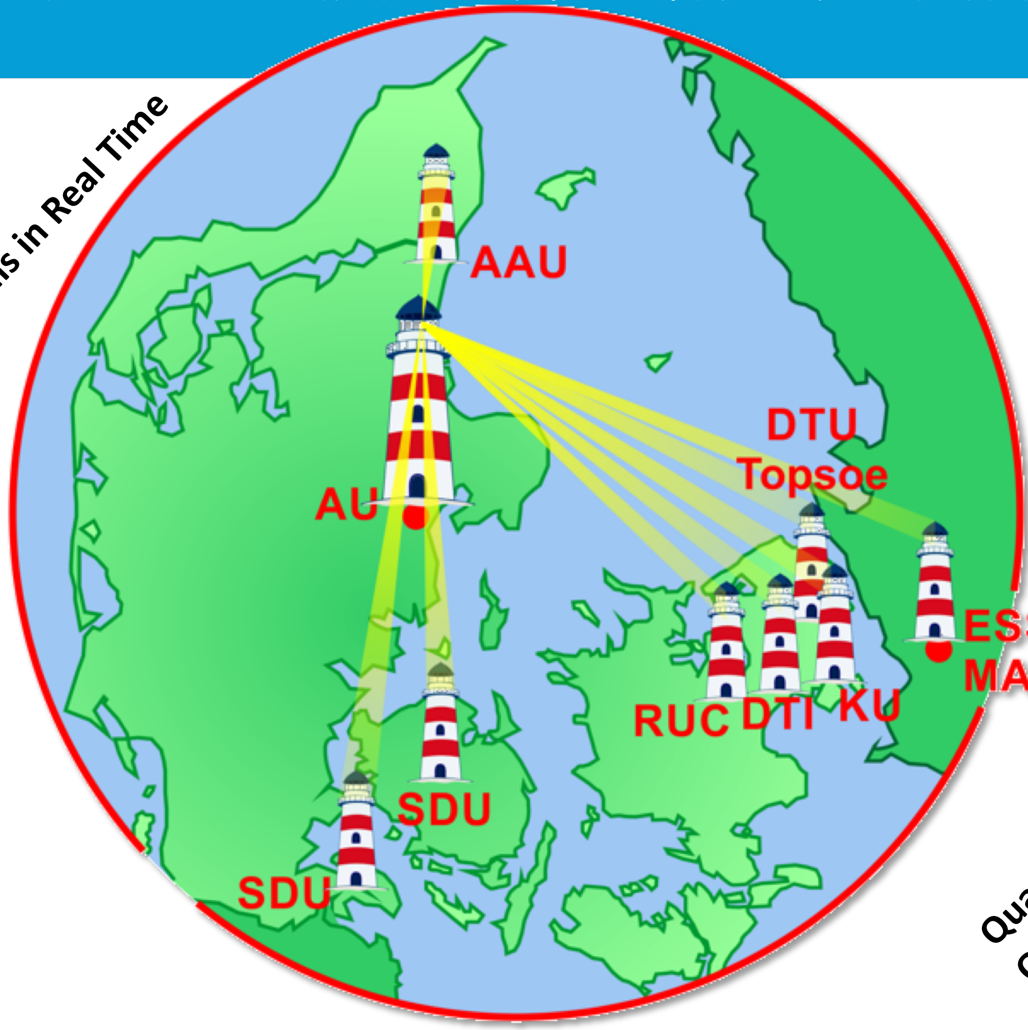
Three-dimensional distribution of polymorphs and magnesium in a calcified underwater attachment system by diffraction tomography

Hanna Leemreize[1], Jonathan D. Almer[2], Stuart R. Stock[3] and Henrik Birkedal[1]



Danish lighthouse 35M DKK + 35M DKK
Funding Materials Research in Neutron Scattering

Structure of Materials in Real Time
SMART

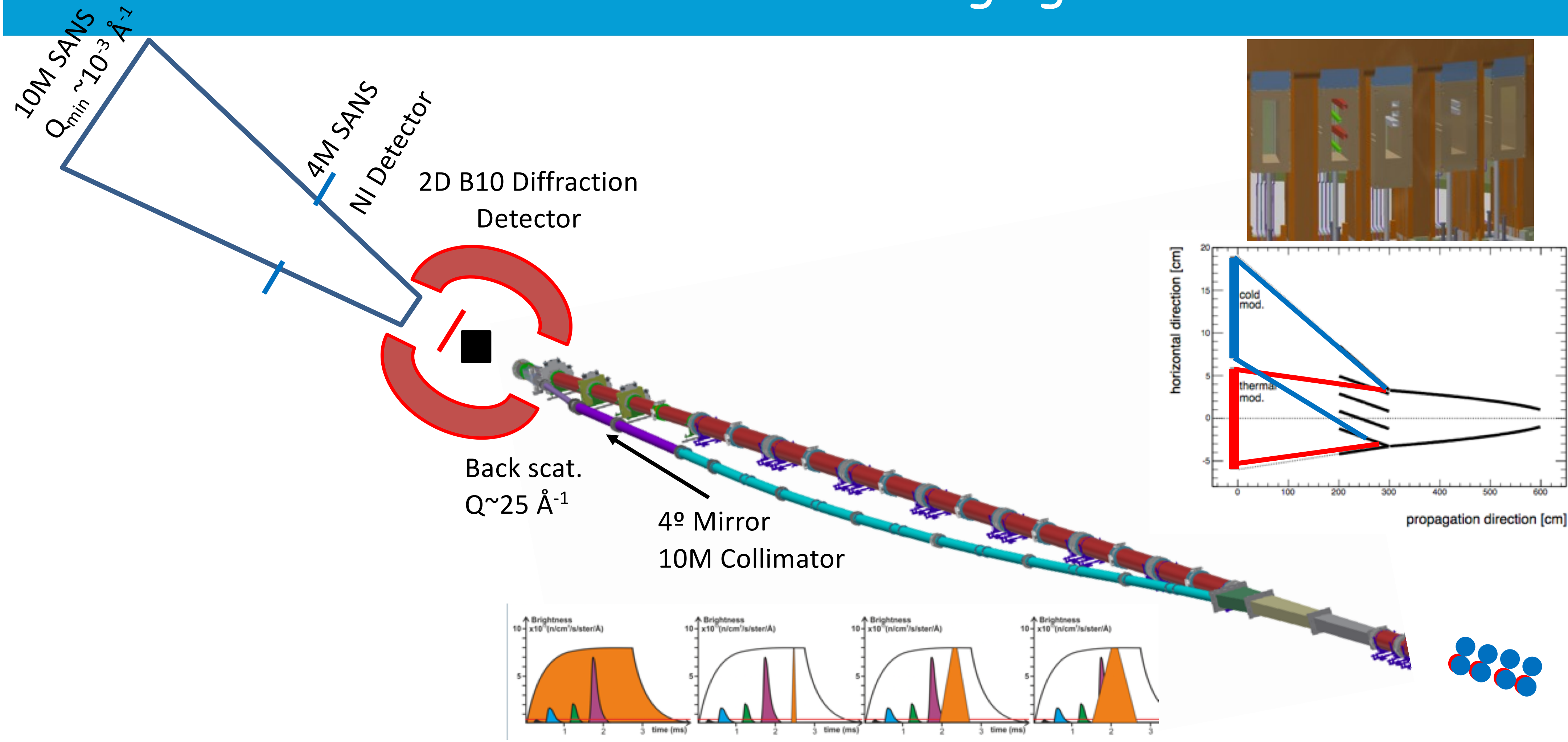


QMaT Light House:
1 Ph.D Student AU/ESS

SMART Lighthouse:
Jakob Overgarrd
Associate Professor (AU)
Shuai Wei
Assistant Professor (AU)
Total 13 Students in Denmark

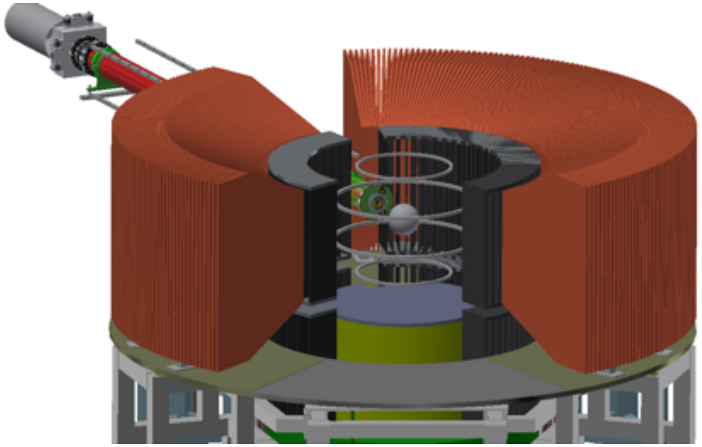
Quantum Materials
Qmat

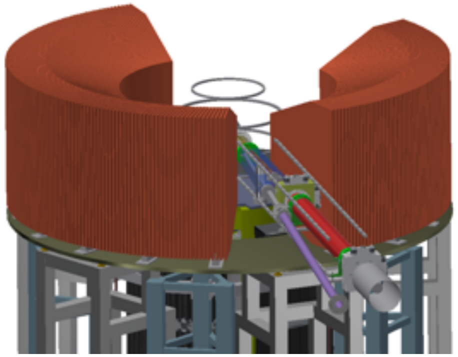
Heimdal – Bi-spectral Hybrid Diffractometer
Diffraction - SANS - Imaging

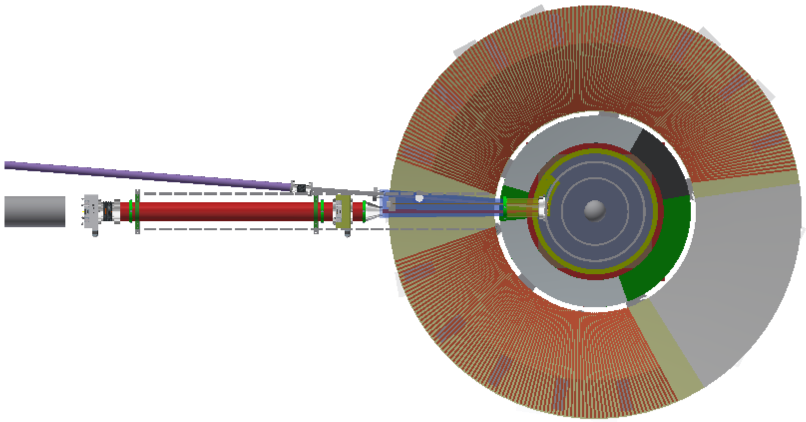


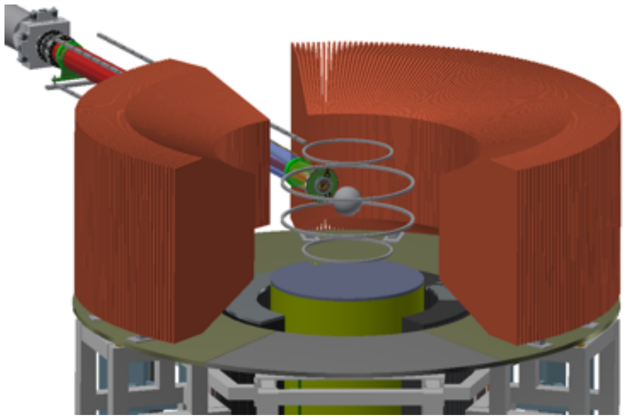
Polarised Neutrons @ Heimdal

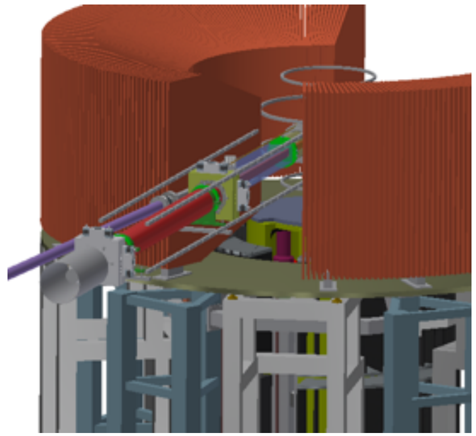
EUROPEAN SPALLATION SOURCE



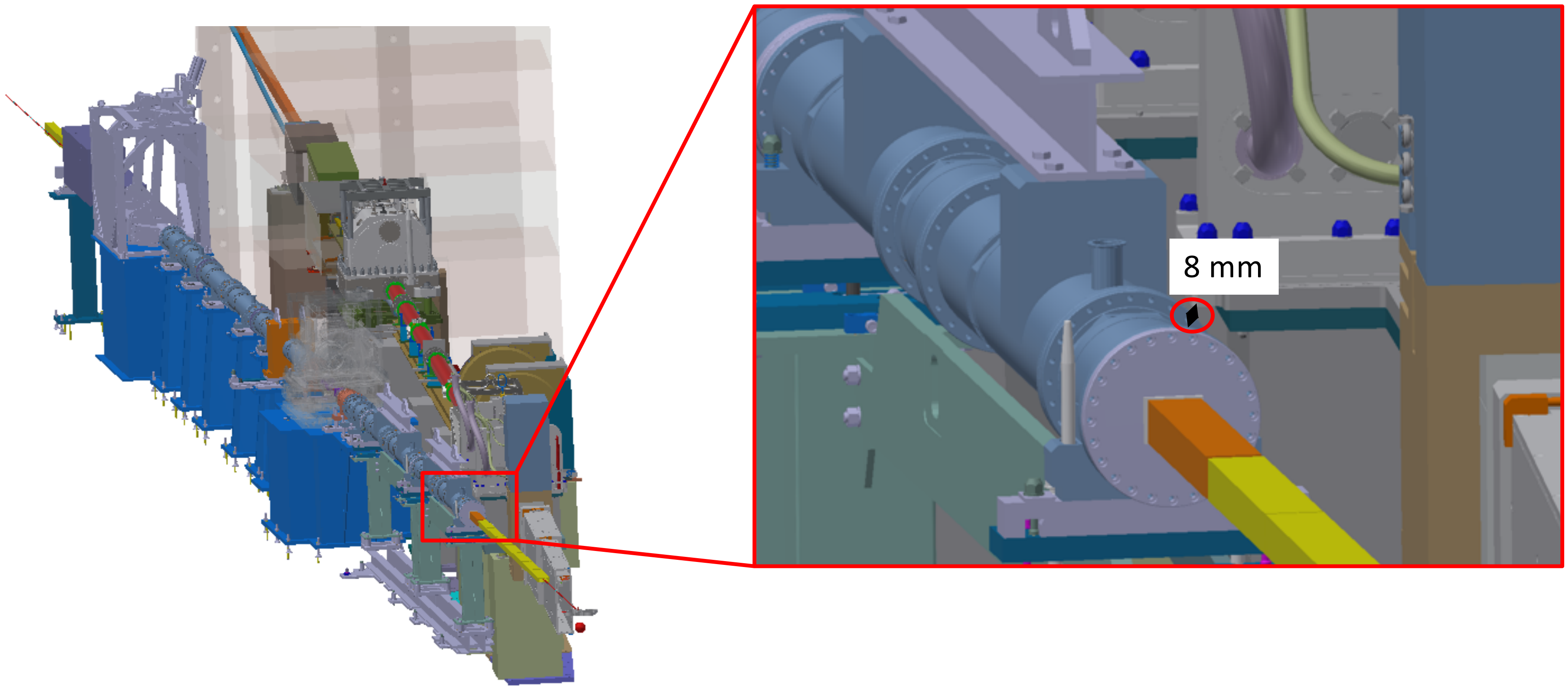






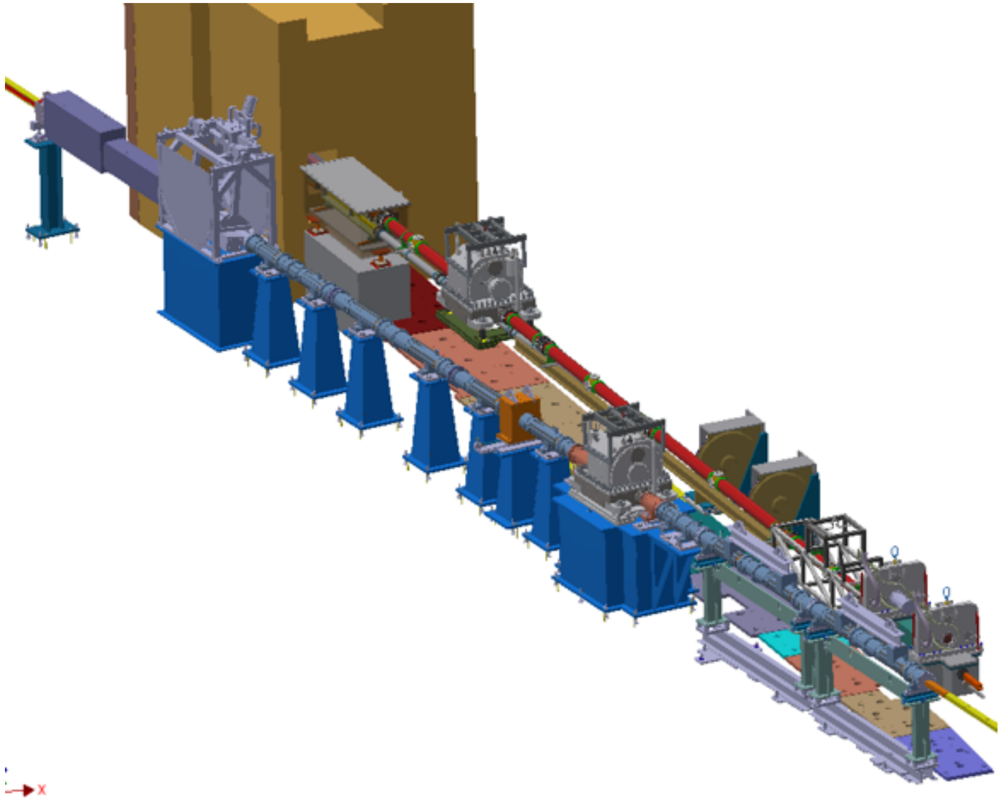


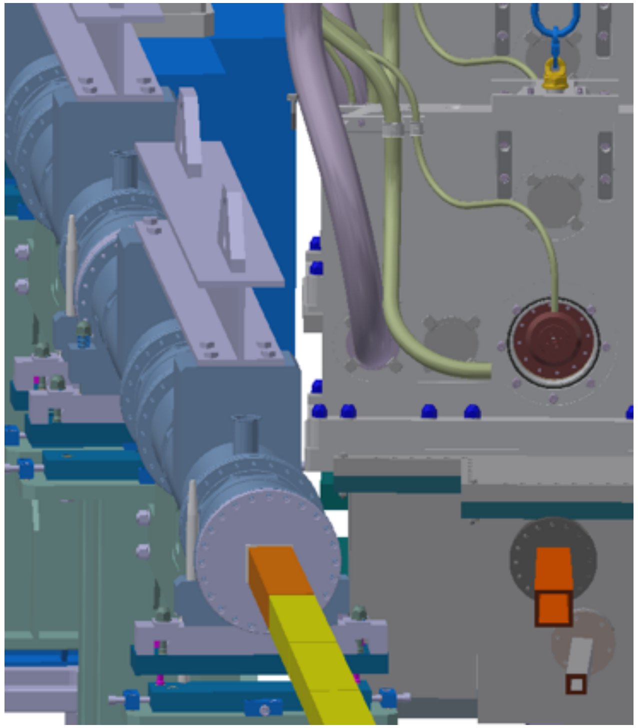
Heimdal – T-rex Clash



Heimdal – T-rex Clash

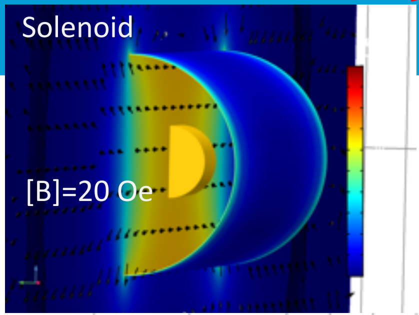
EUROPEAN SPALLATION SOURCE

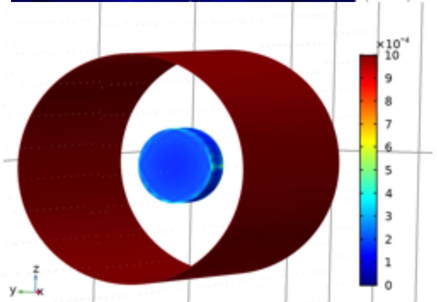




HEIMDAL Polarisation setup

Polariser cell in solenoid
Technique: Polarised ^3He

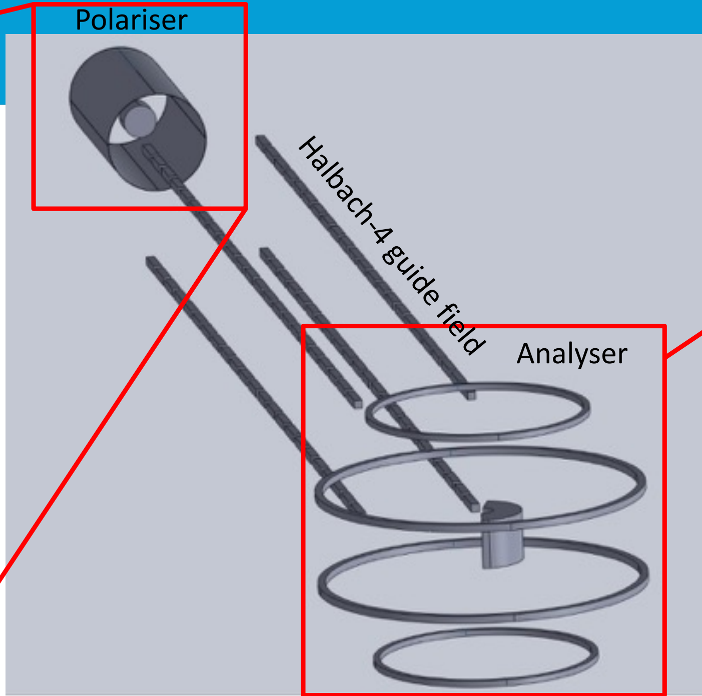




Uniform: gradient < 2E-4/cm

MEOP + local gas exchange
Good: Fast turn-over
Bad: Polarisation decay

SEOP + *in-situ* pumping
Good: Polarisation stable
Bad: 1 day to be ready



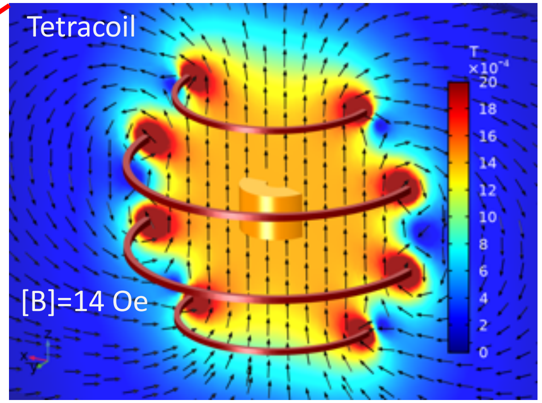
First-cut modelling: a setup will work.

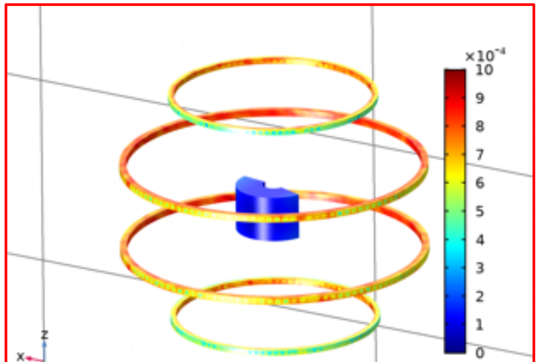
Further development:

- transition region between device.
- Field-turn device
- 3D field

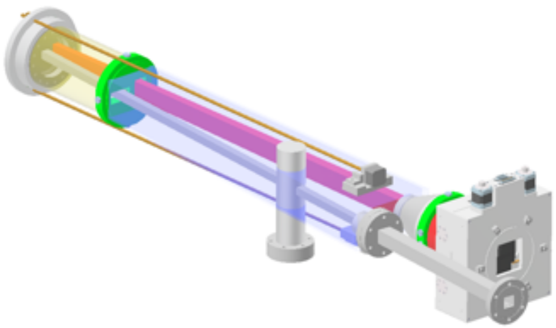
Analyser cell in tetracoil
Technique: Polarised ^3He
MEOP + "Local-filling" to fill cell at HEIMDAL.

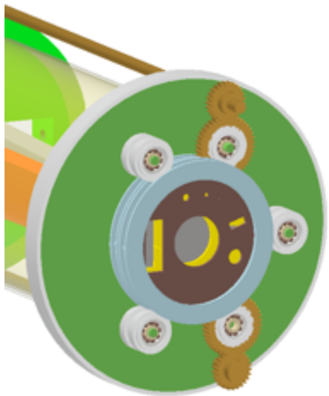
Analyser cell can cover both diffraction and SANS

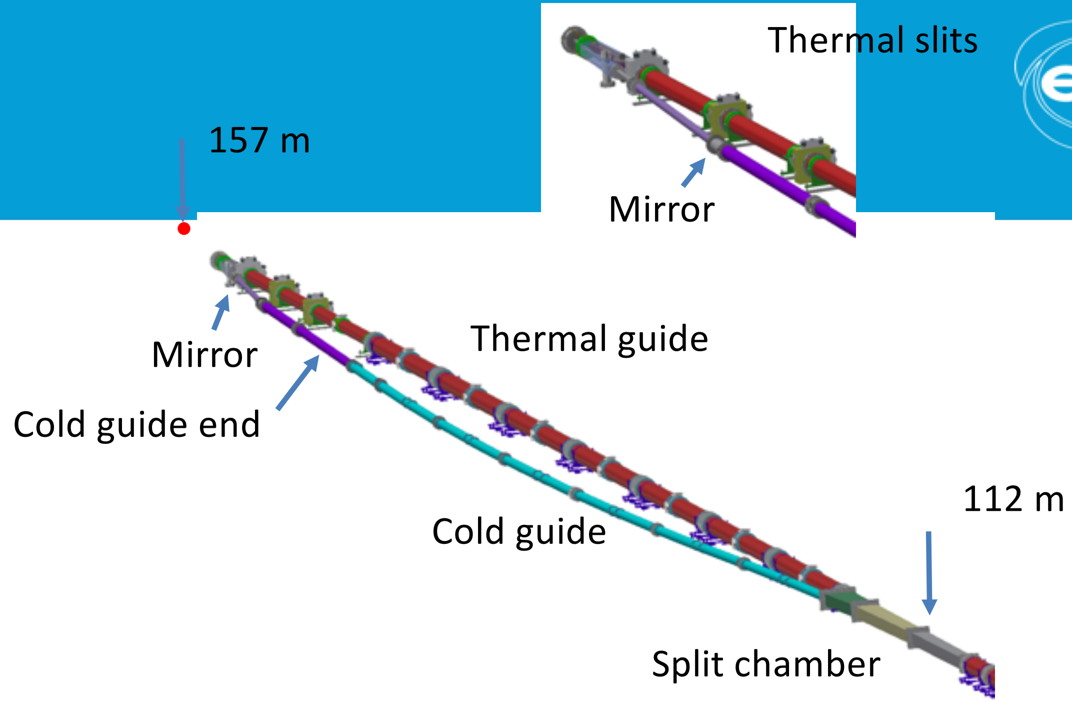


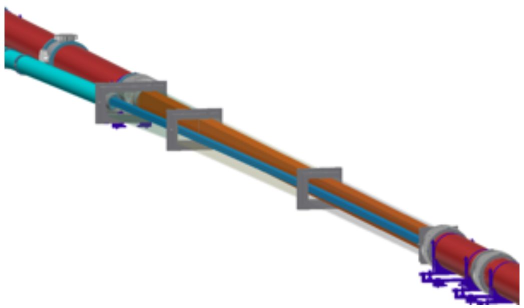


Uniform: gradient < 2E-4/cm






Thermal slits
Mirror
157 m
Mirror
Cold guide end
Thermal guide
Cold guide
112 m
Split chamber



NBOA Status

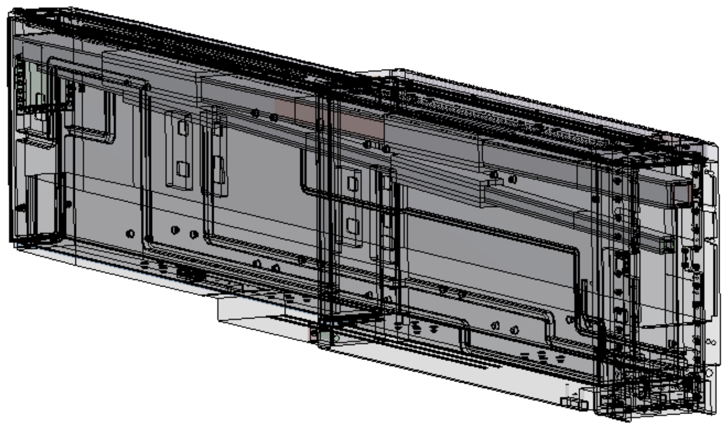
EUROPEAN SPALLATION SOURCE

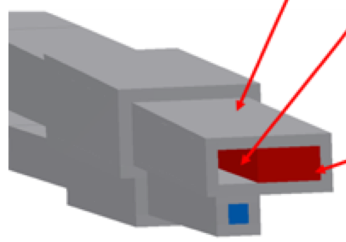
Neutron Optical Components & Instruments SwissNeutronics

SwissNeutronics project data			
Project title	PSI@ESS, HEIMDAL - NBOA neutron guide	Project No.	SN18098
Project manager	Christian Schanzer		
Email	christian.schanzer@swissneutronics.ch		
Customer project data			
Customer	PSI	Customer ref./PO	5200147209
Project manager	Dr. Dan Mannix	Date of contract/PO	--
Email	dan.mannix@esss.se	Amendments	
Report / document data			
Prepard by	Christian Schanzer	Report / Doc. No.	SN18098-002
Date	4-Sep-20	Revision	06
Type	Project management	Status	final

SN18098 Project Report - No. 6

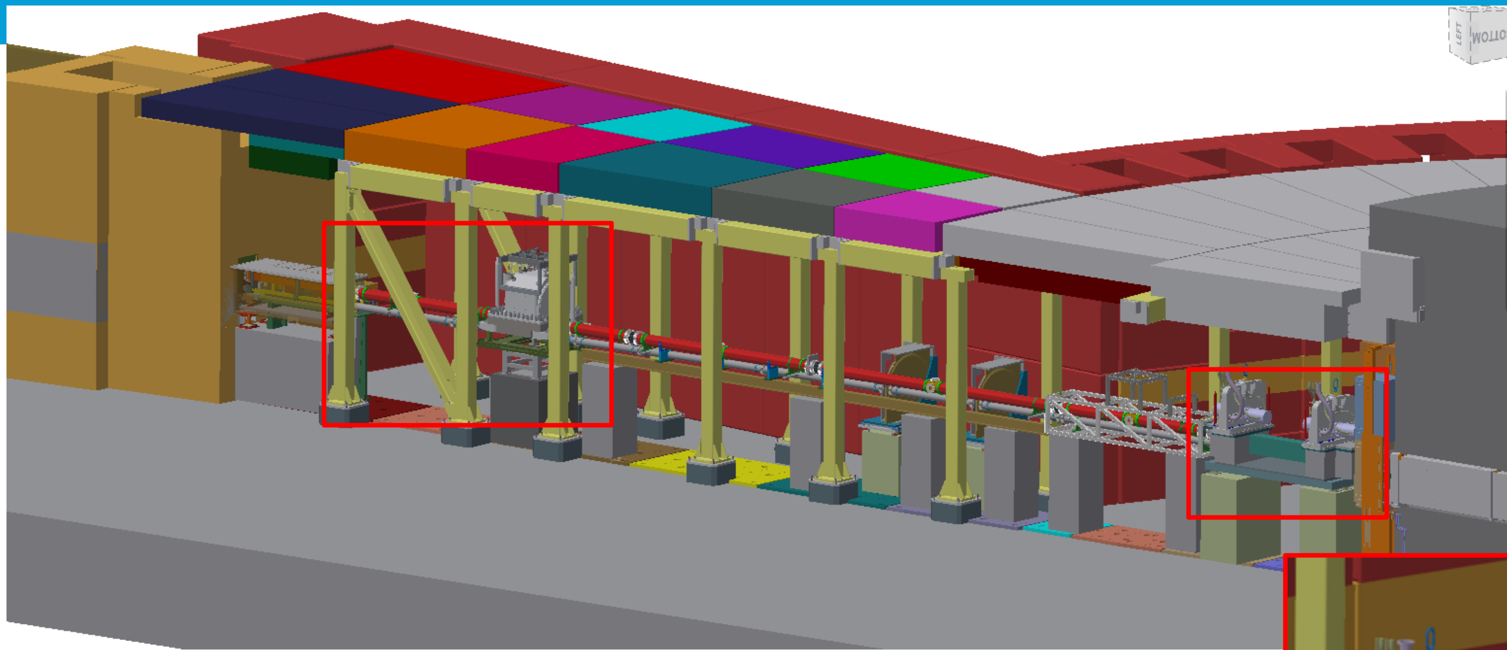
Milestones					
Milestone	Payment	Target date original	Target date updated	Status	Remarks
Final design review	no	31-May-19	tbd.		see status of manufacturability check and open issue No. 1
Ready for manufacturing	yes		tbd.		see status of manufacturability check and open issue No. 1
Ready for delivery	yes	23-Dec-19	expected Apr-2021		assuming a conclusion of the final design by Oct-2020; see also open issue No. 1
Installation	no				
Final acceptance	yes	15-Jan-21			

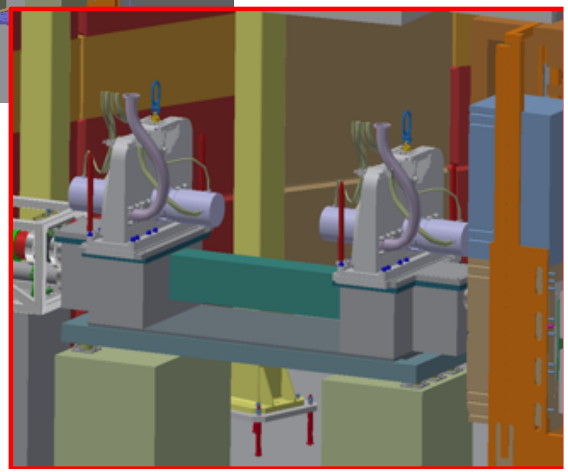




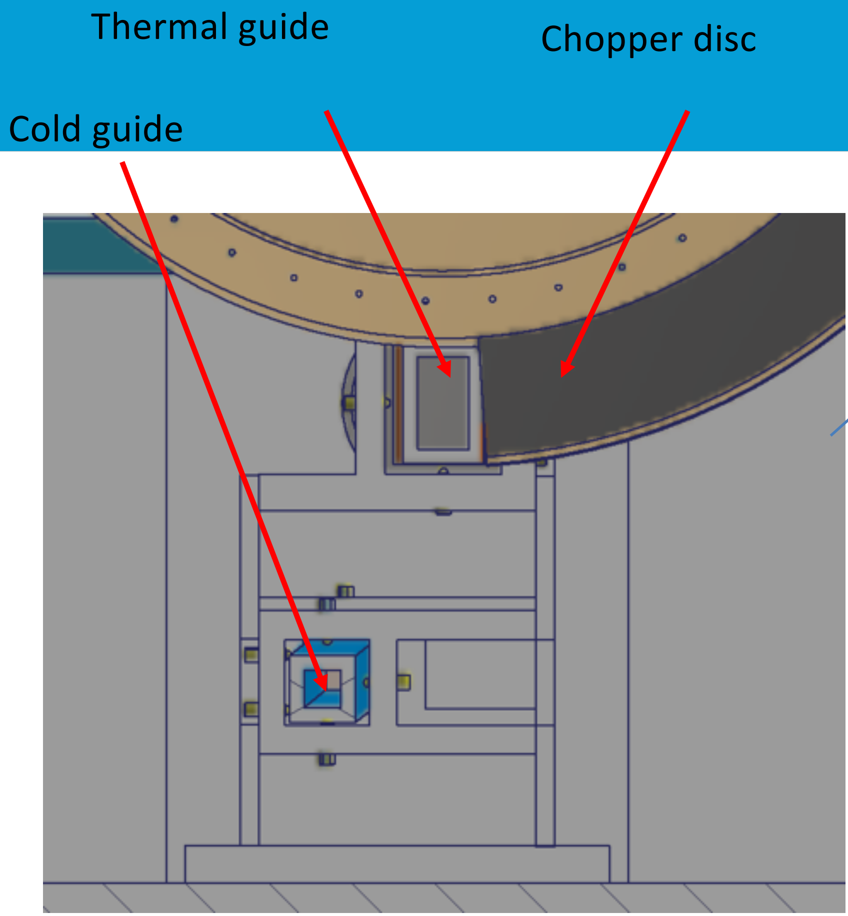
Choppers System Status

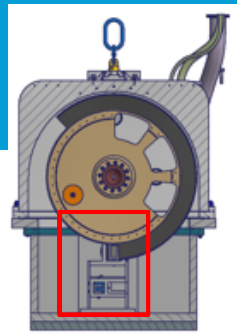
Isabel Llamas (IFE)

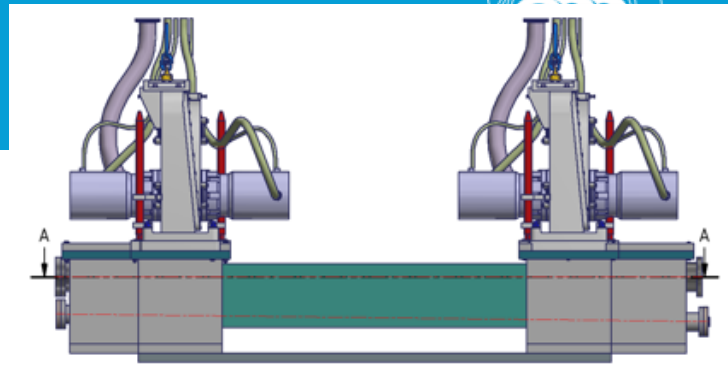


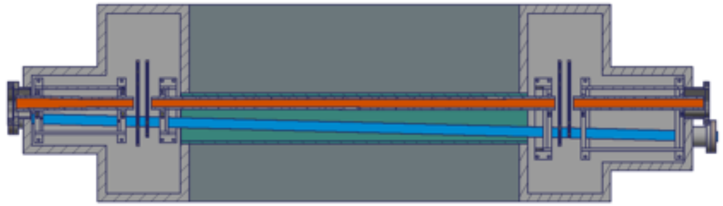


TG3 Chopper Technical Specification approved 21/02/2020
ESS Common Chopper Project
Kick-off scheduled 1st October 2020


Thermal guide
Chopper disc
Cold guide

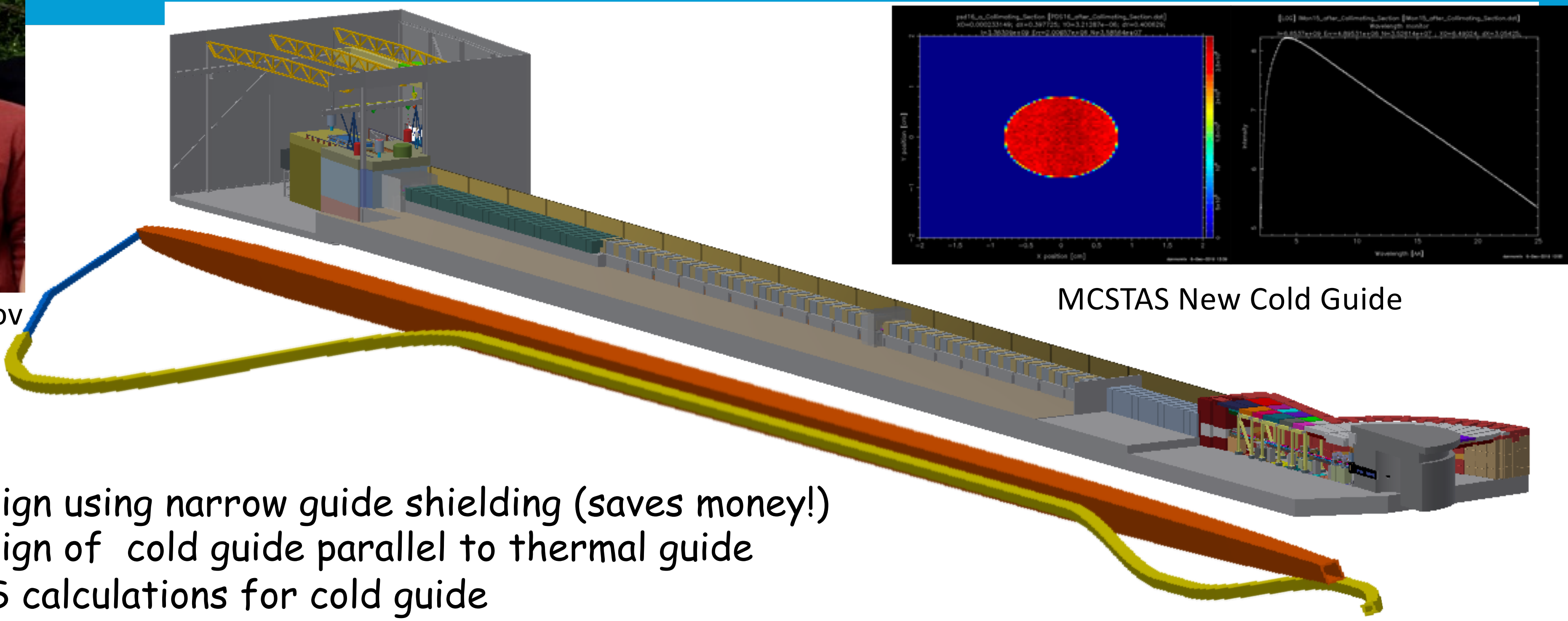






New Design for Thermal & Cold Guides (2019)

Rodion Kolevatov
(IFE)

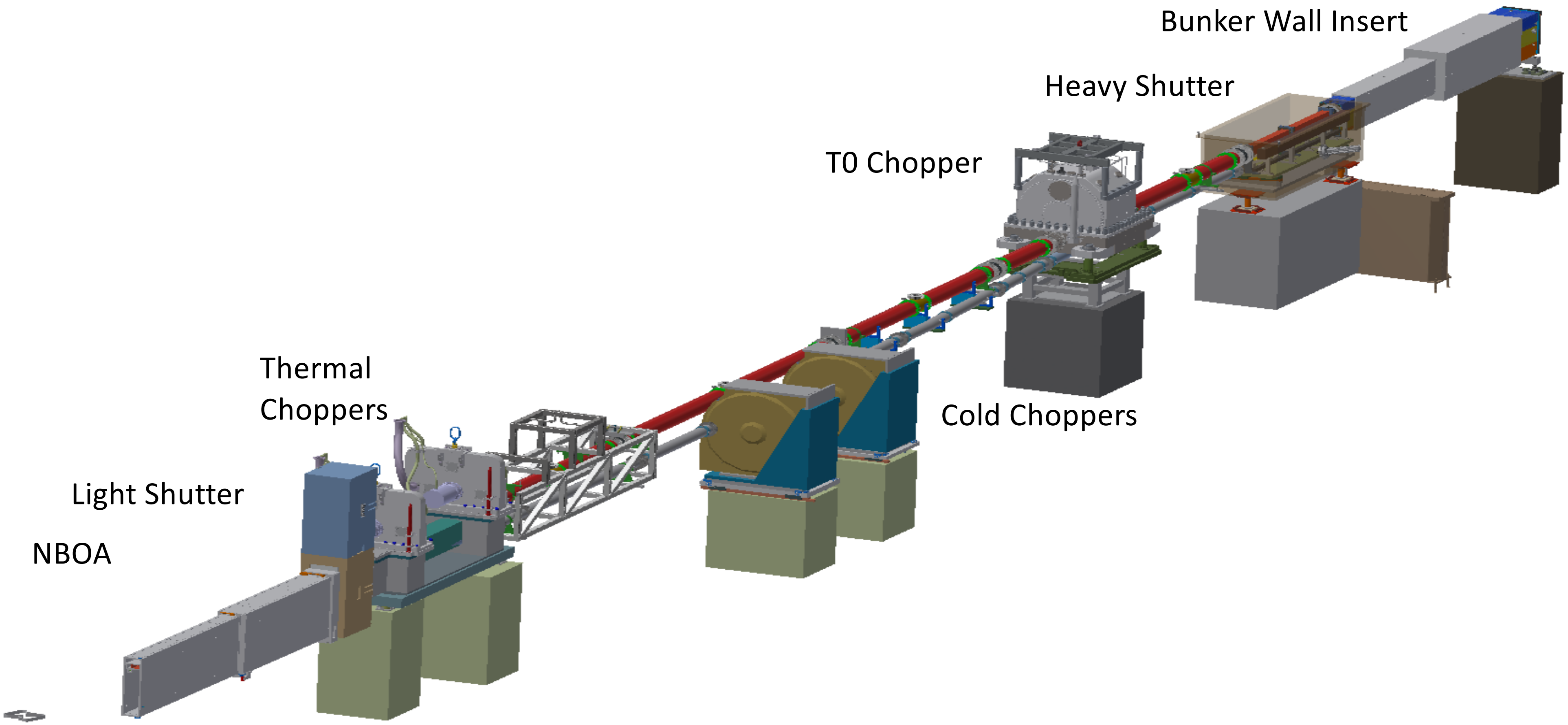


MCSTAS New Cold Guide

New design using narrow guide shielding (saves money!)
New design of cold guide parallel to thermal guide
McSTAS calculations for cold guide

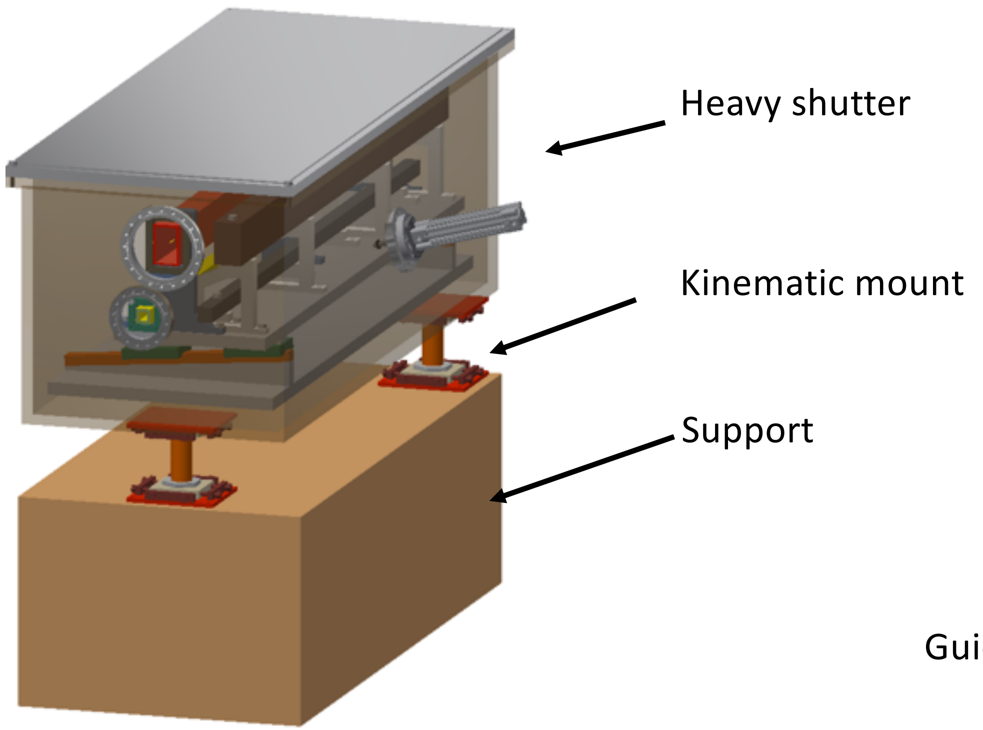
Thermal Guide procurement on hold for PSI until 2021 –
Government in-kind agreement not signed

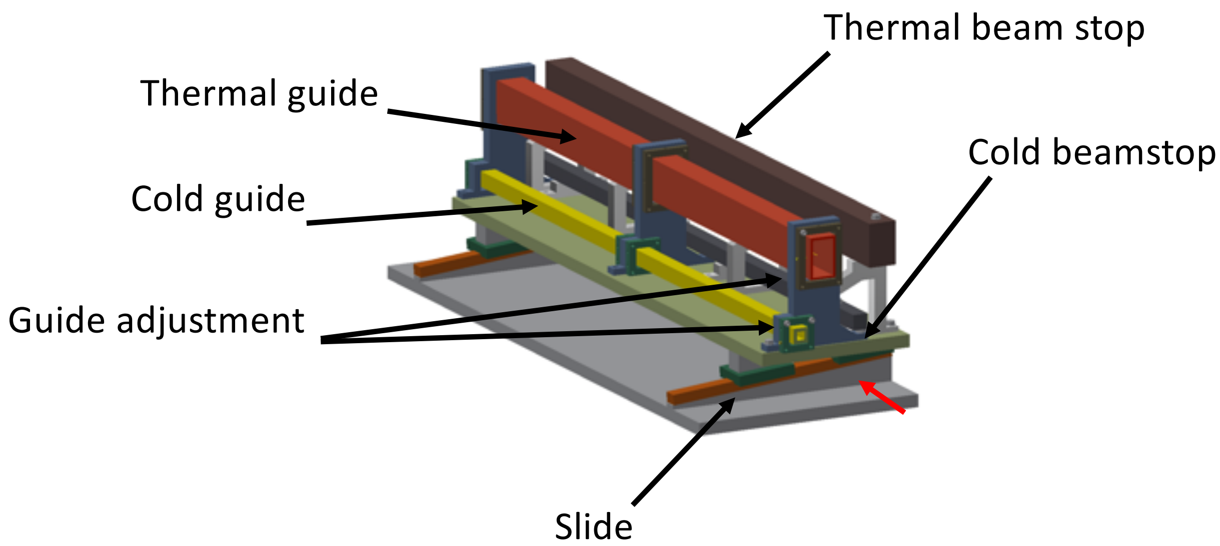
Heimdal In-Bunker Components



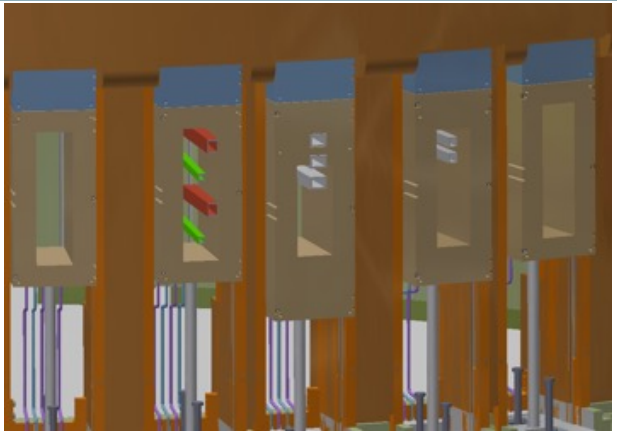
Heimdal Heavy Shutter Design

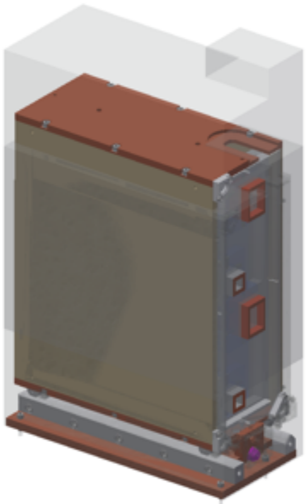
- Design from ESS
- Guide and beam stop in vacuum
- Thermal and cold guide
- Simple iron beam stop 1600 mm
- Only window at bunker wall insert
- Bellow connection to vacuum guide



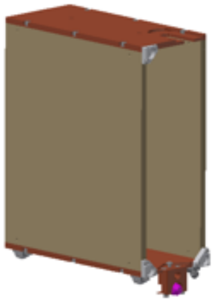


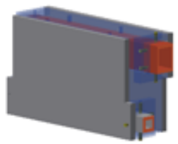
Light Shutter



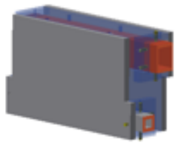


BBG frame

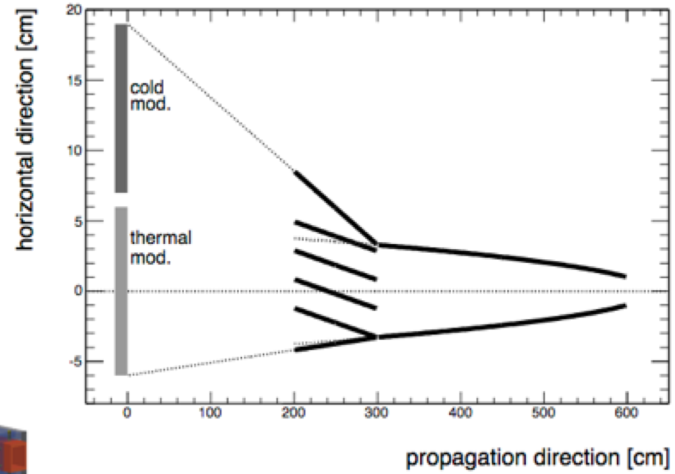




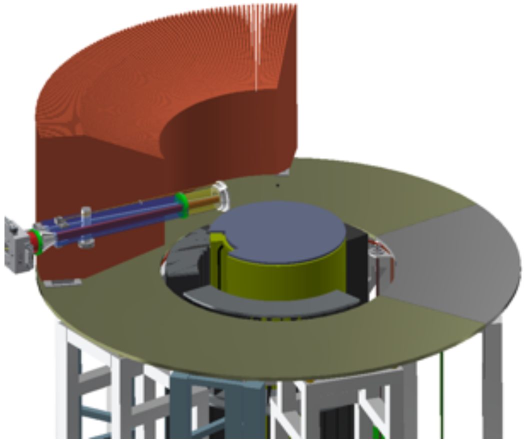
Guide unit to stack with thermal and cold guide and respective adjustment

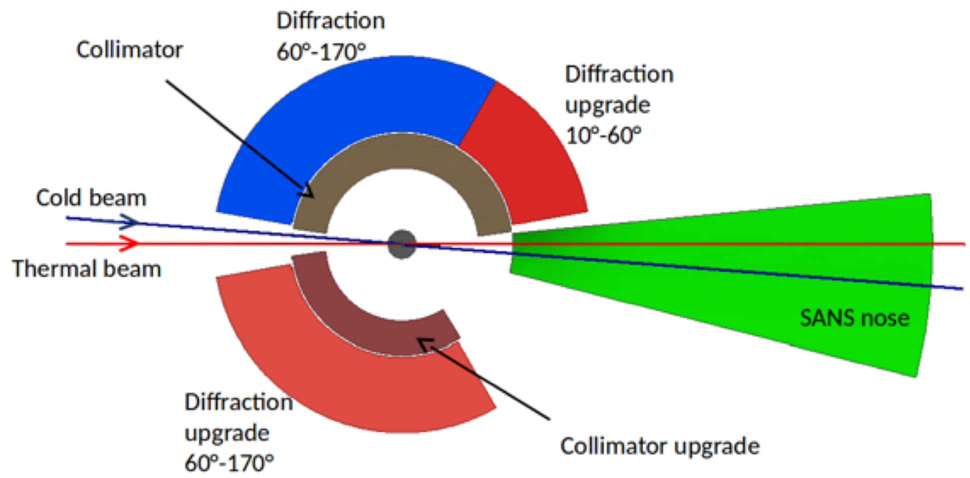


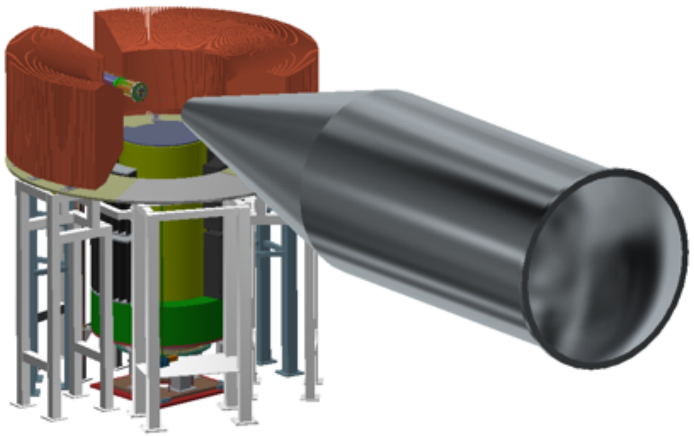
Guide unit with bi-spec mirror



Heimdal Detector System







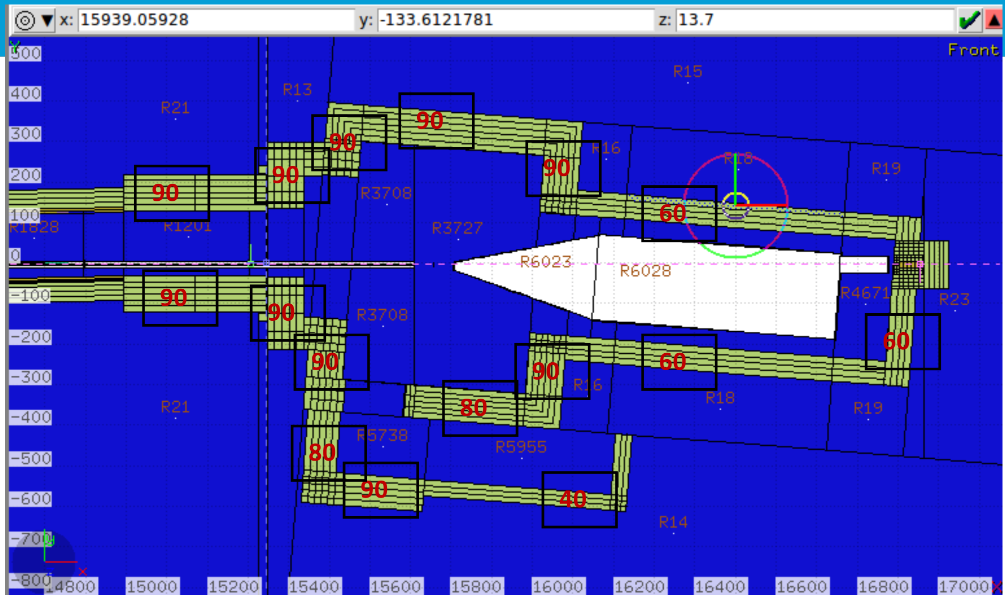
Technical Specification design finished May 2020

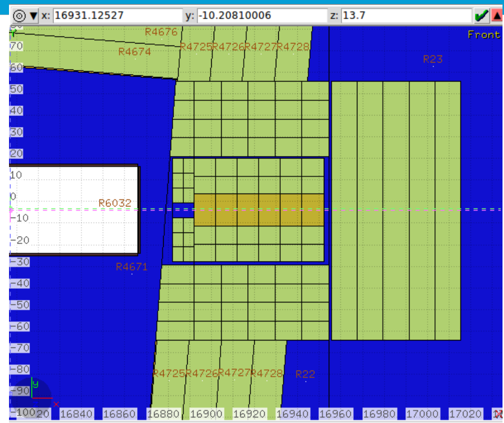
ESS B^{10} 2D Diffraction Detectors – Dream -> Magic -> Heimdal

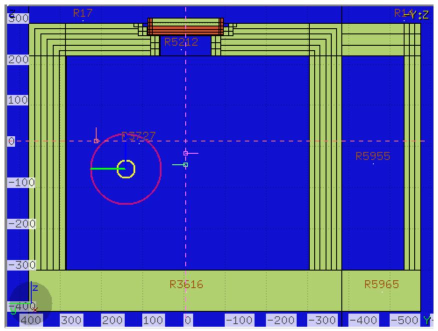
Procurement Scheduled for July 2020

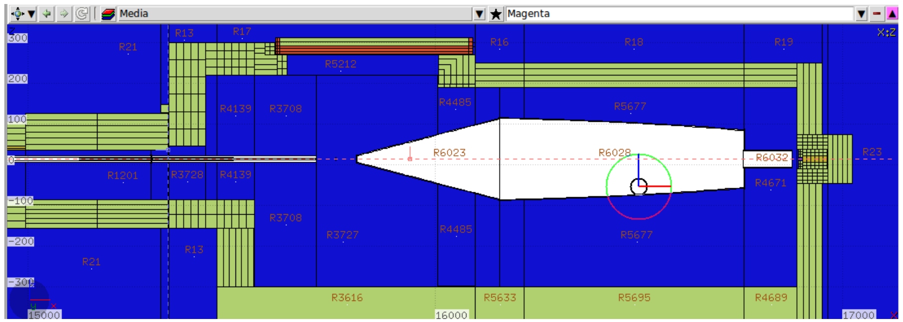
Delayed to 2021 due to no PSI in-kind approval

Cave geometry, starting point (Oct 2019)



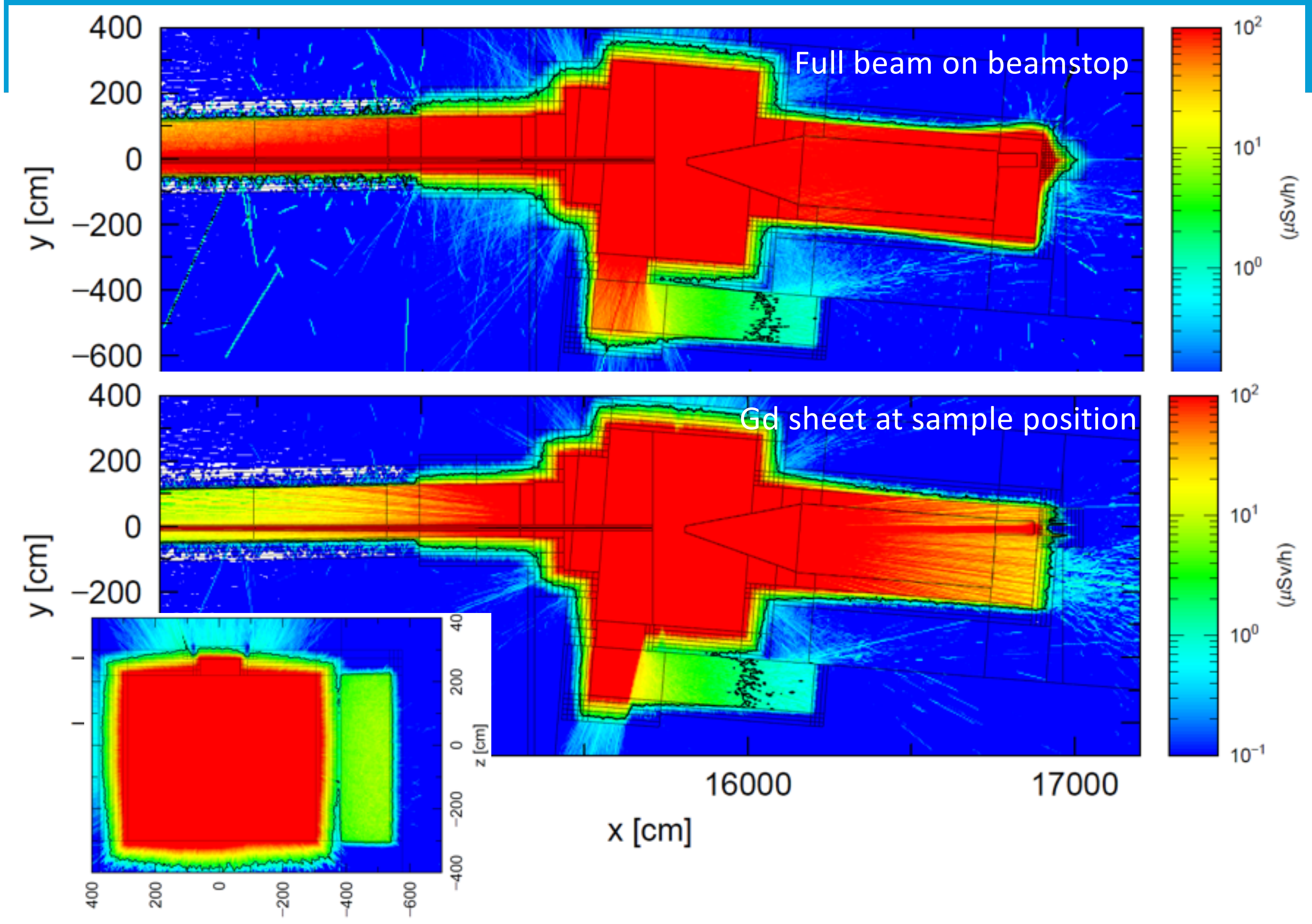






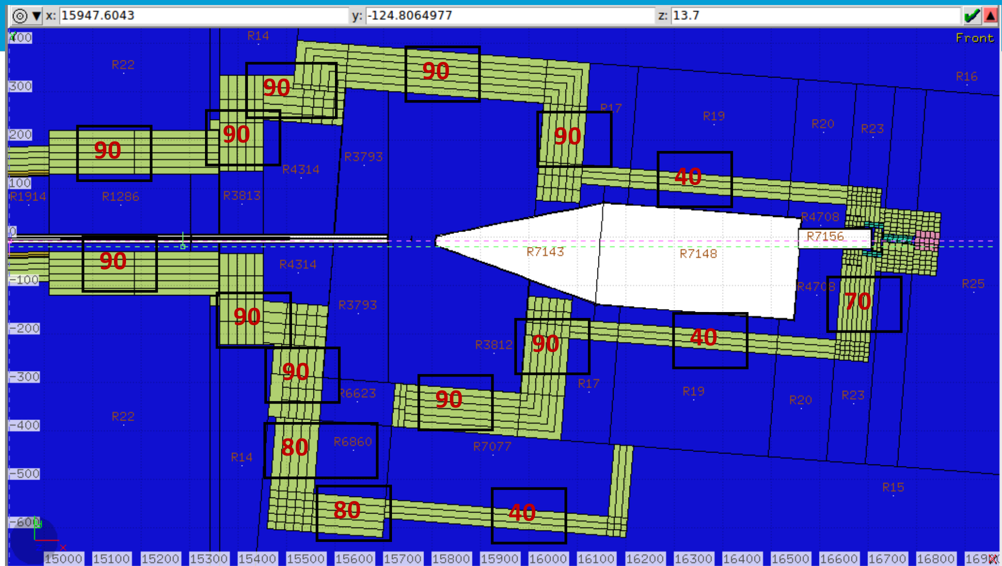
- Guide:90 cm concrete
- Cave: 90 cm diffraction, 60 cm SANS
- Beamstop: 60 cm steel core surrounded by concrete, embedded back wall of SANS cave
- Requires a wide get lost tube due to large thermal neutron flight path
- Hatch: 20 cm steel + 20 cm concrete

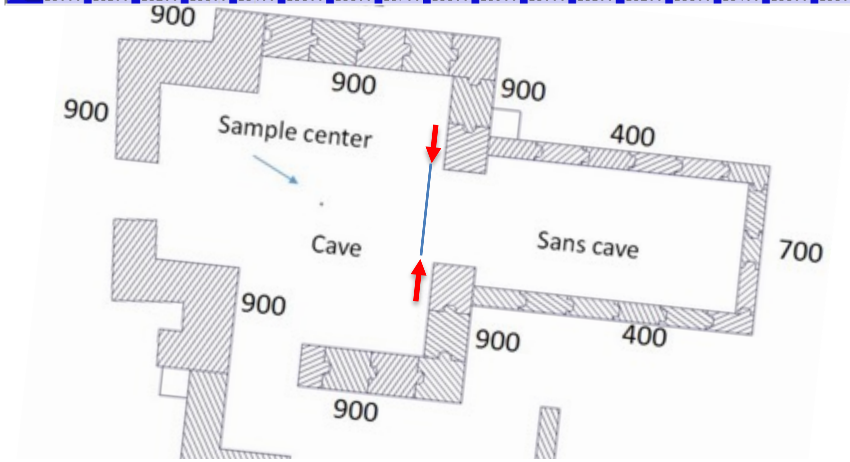
Simulation Results



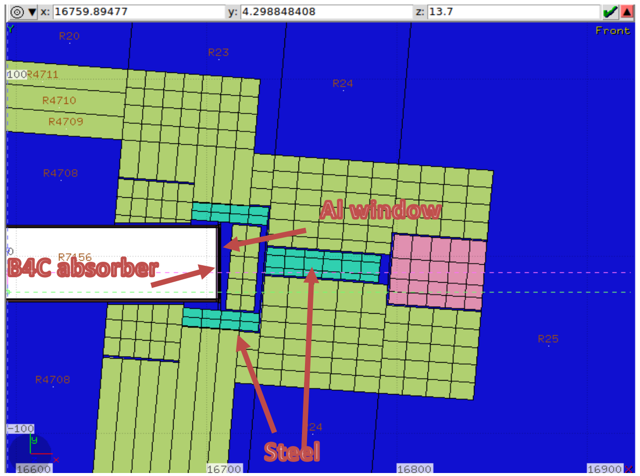
- Walls of SANS cave are unnecessarily thick. 60cm thickness required for ~1m next to diffraction cave and ~2m next to thermal beamstop
- Labyrinth roof thickness can be reduced

Cave geometry, optimized (Sept 2020)



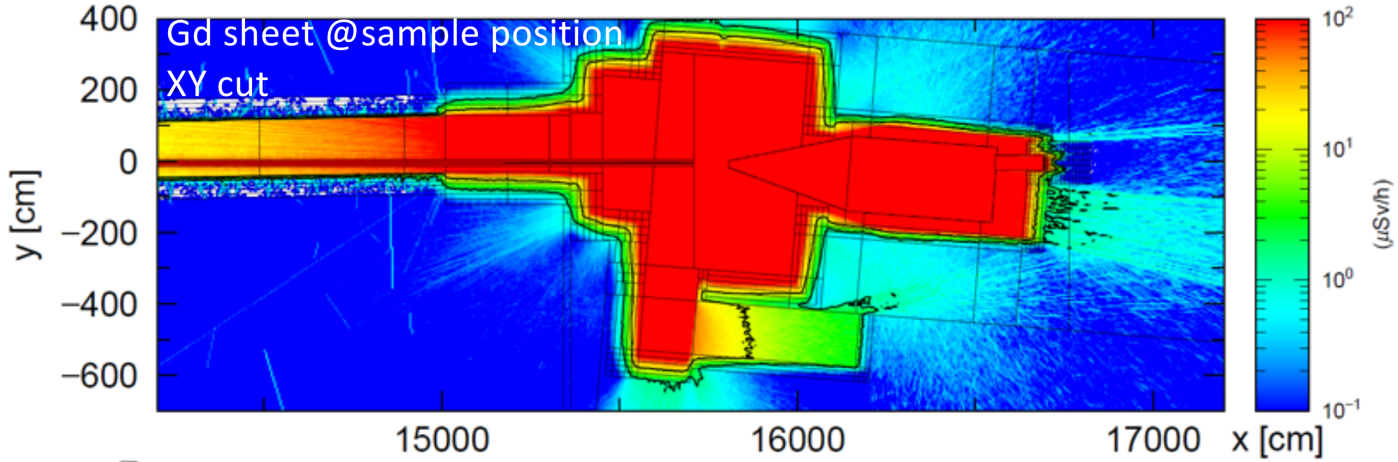


- Reduced length of SANS cave by 2m
  - Had to increase thickness of rear wall to 70cm
- Thermal beamstop moved out of the SANS cave
- Narrowed down connection of diffraction and SANS caves, reduces impact on SANS cave walls
- SANS cave walls thinned down by 20 cm and have a uniform thickness of 40cm.
- Reduced thickness of labyrinth roof

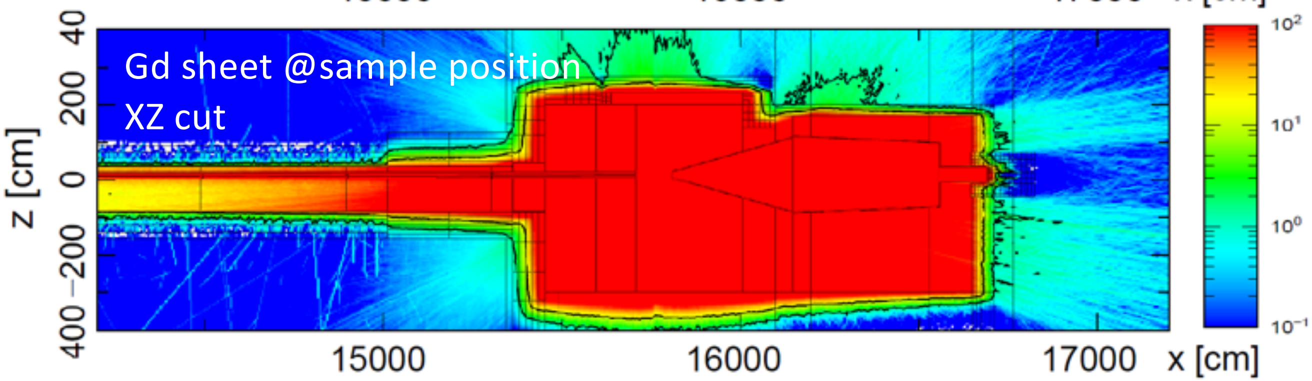


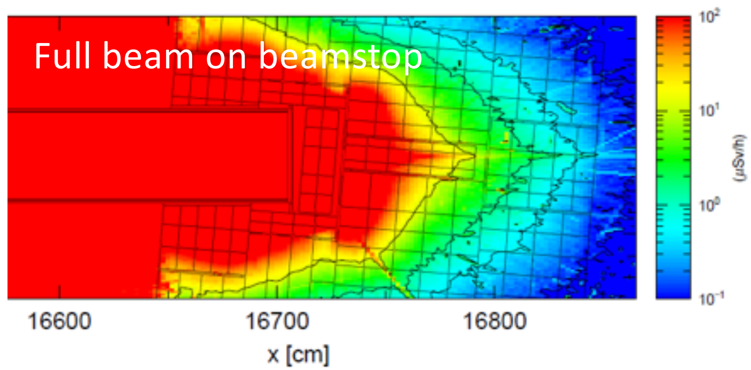
Optimized geometry, performance

Rodion Kolevatov (IFE)



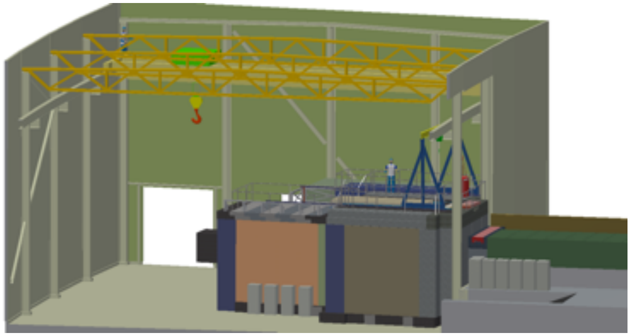
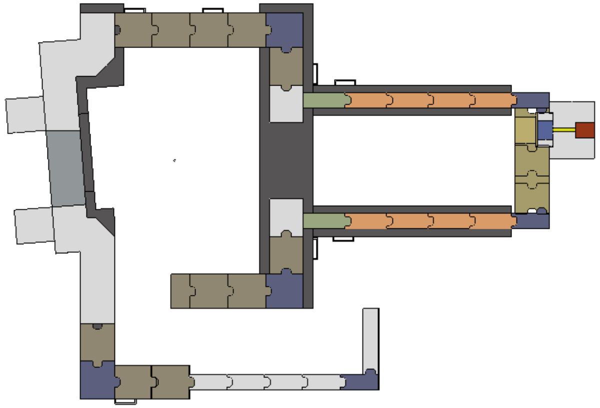
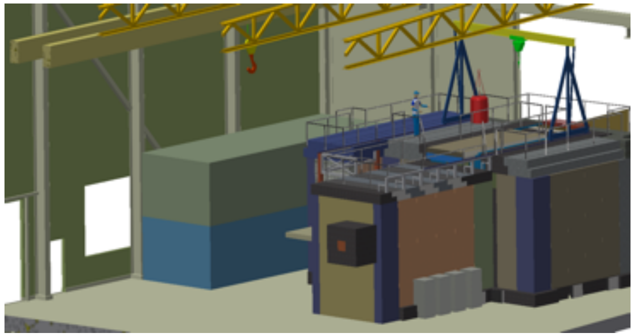
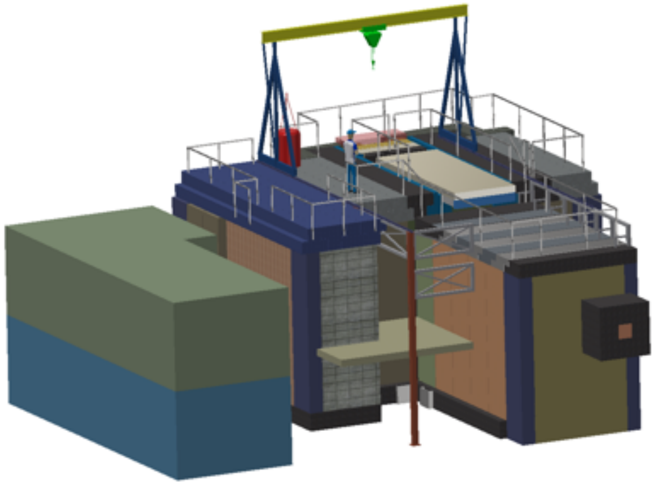
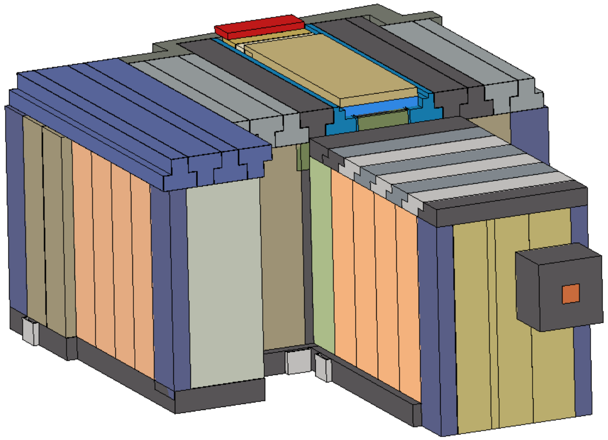
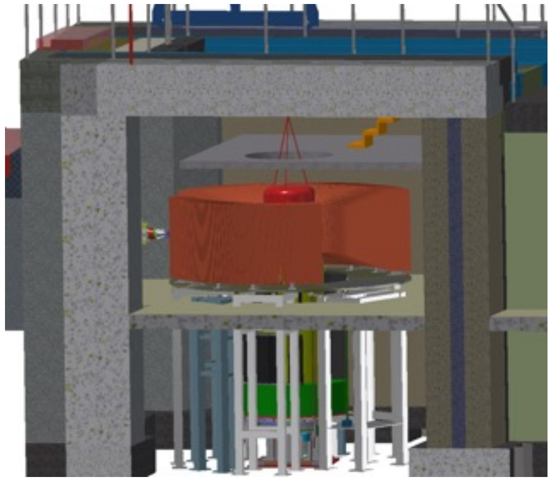
- Reached savings in the amount of concrete compared to initial option
- A tender is to be announced soon



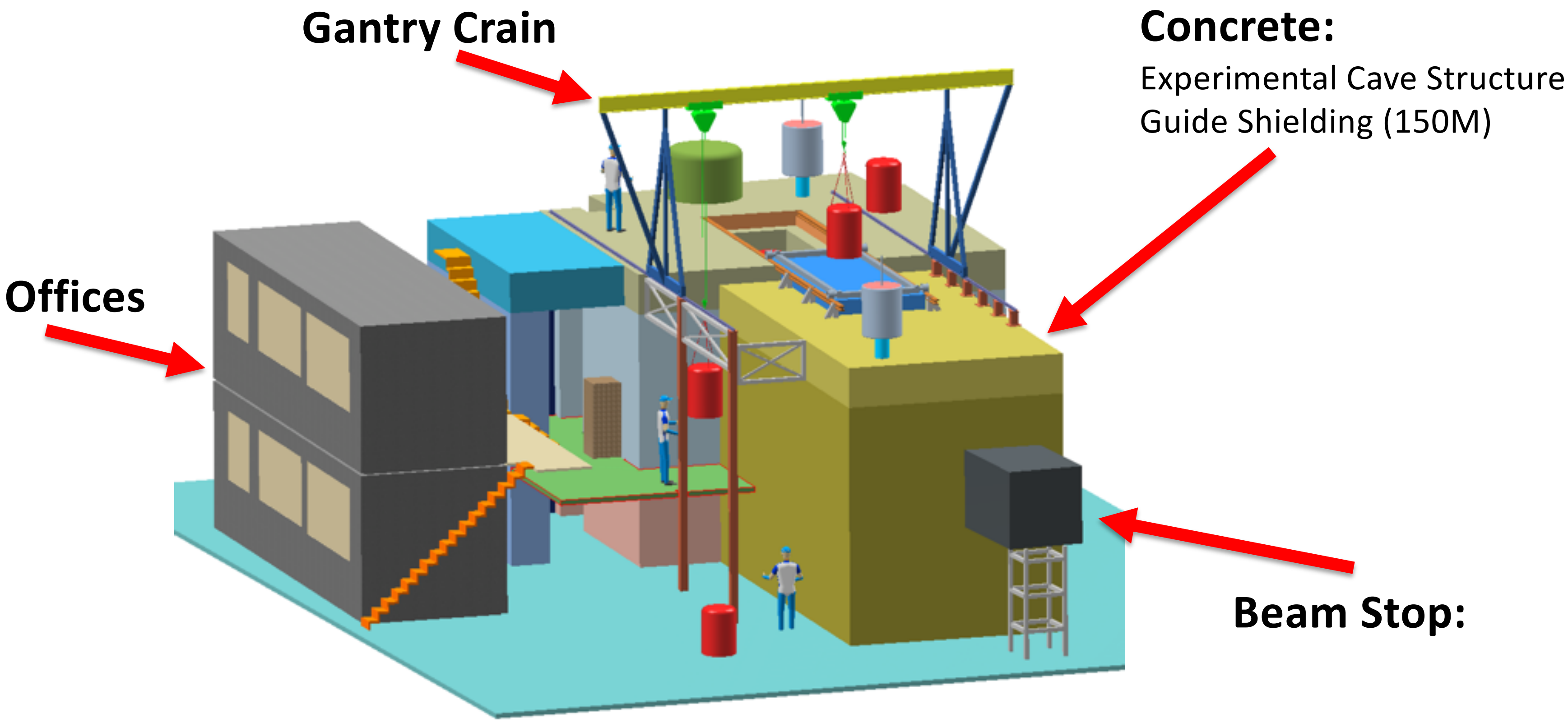


Cave Design CTV Review
September 2020

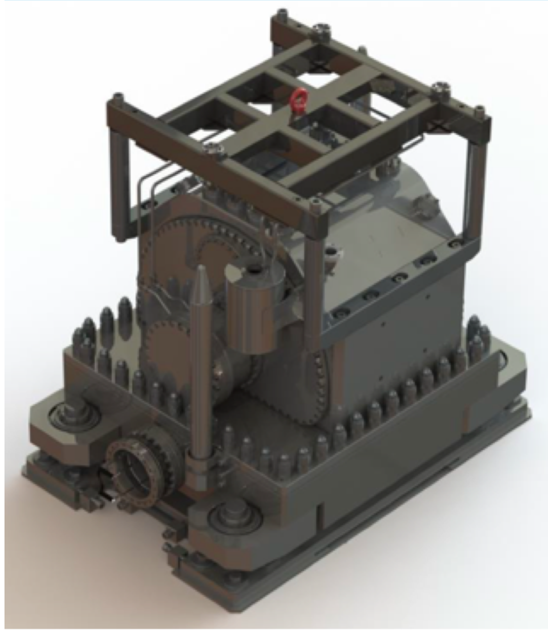
EUROPEAN SPALLATION SOURCE

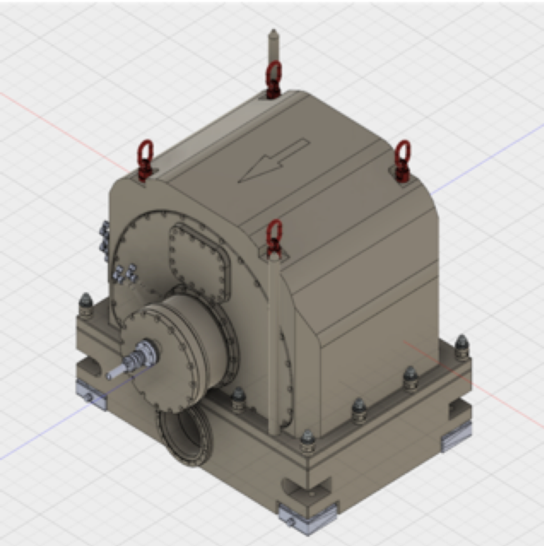







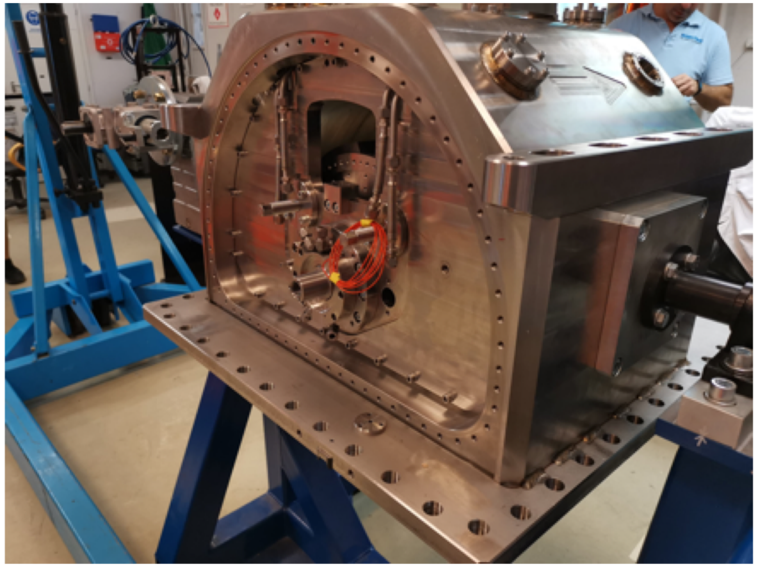
Heimdal End Station



T0 Chopper



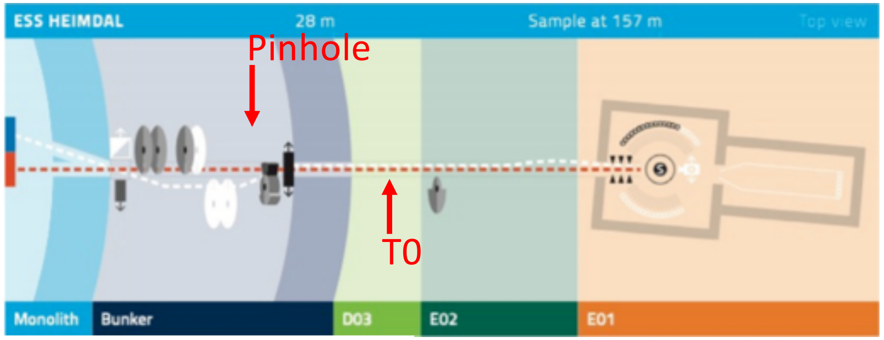


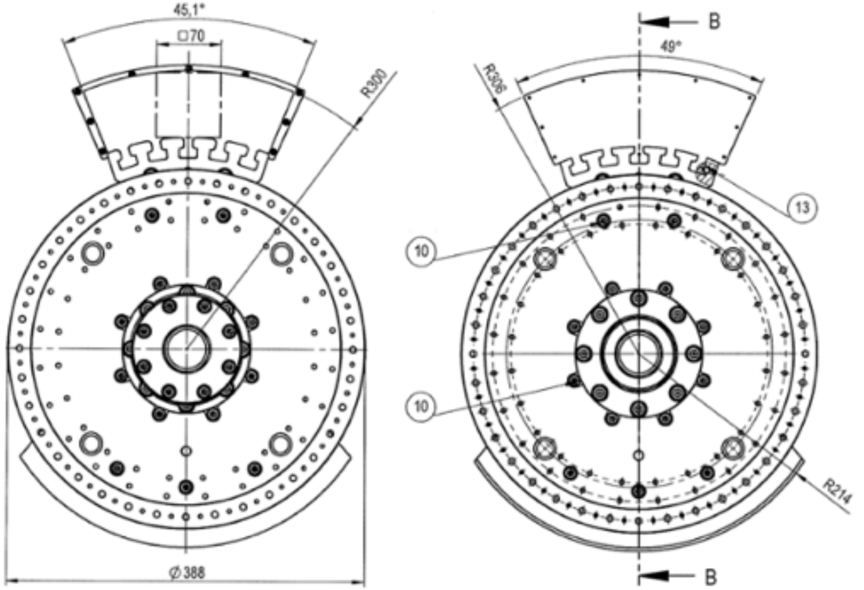


Prototype To Chopper Designed for 60x60 Guide

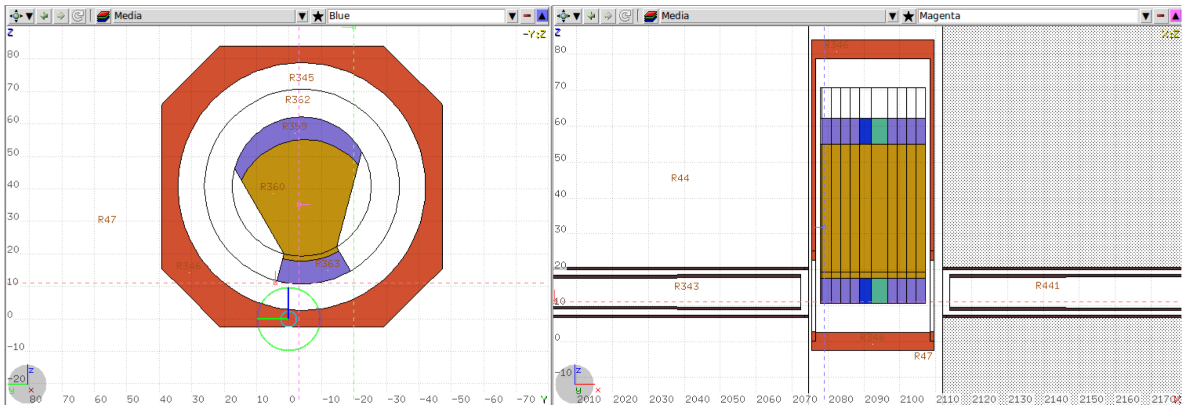
Larger Chopper designed but significantly more expensive
 + include new design costs

T0 chopper



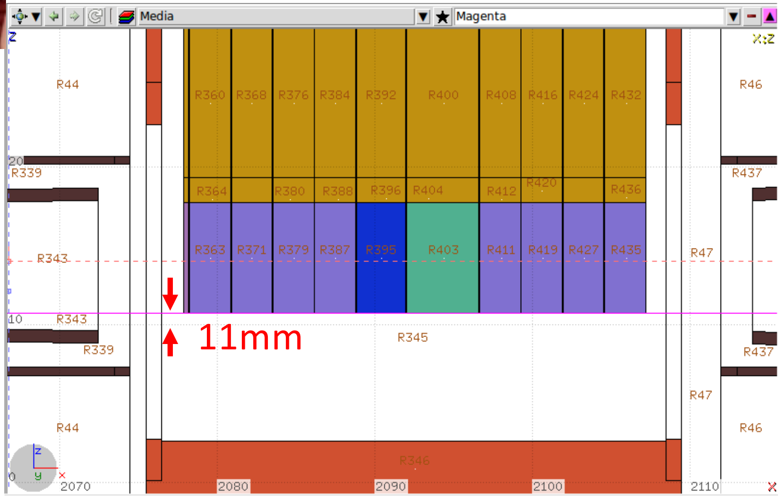


- Standard ESS T0 chopper rotor is designed for 60x60mm guide opening and has 70mm coverage in height
- HEIMDAL guide at a nominal position of T0chopper placement has a height of 81mm
- A pinhole at 6.4 m is 50 mm tall and is fully blocked by the tungsten hammer when viewed from the far end of the guide.
- A possibility for savings from using a rotor with standard hammer dimensions

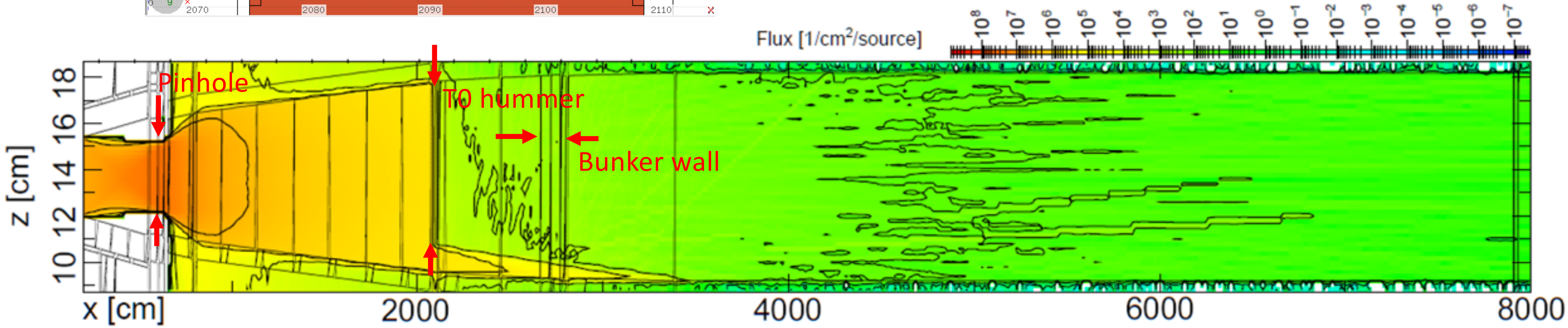


T0 simulation results

Rodion Kolevatov (IFE)



- A T0 chopper is placed leaving 11 mm of the guide space below the hammer open.
- Streaming of neutrons below the hummer is absent beyond 35 meters from target (figure for $E_n > 20\text{MeV}$)
- Same background as for full-sized T0
- Radiation safety fulfilled: guide shielding is designed to provide 1.5 uSv/h outside with T0 parked open.
- 300 uSv/h contact dose rate at T0 hammer 1 week after shutdown, well within 10mSv/h limit.



Heimdal Jalousie 2D Detector

EUROPEAN SPALLATION SOURCE

Irina Stefanescu

2019 JINST14 P10020

Performance study of the Jalousie detector baseline design for the ESS thermal powder diffractometer HEIMDAL through GEANT4 simulations

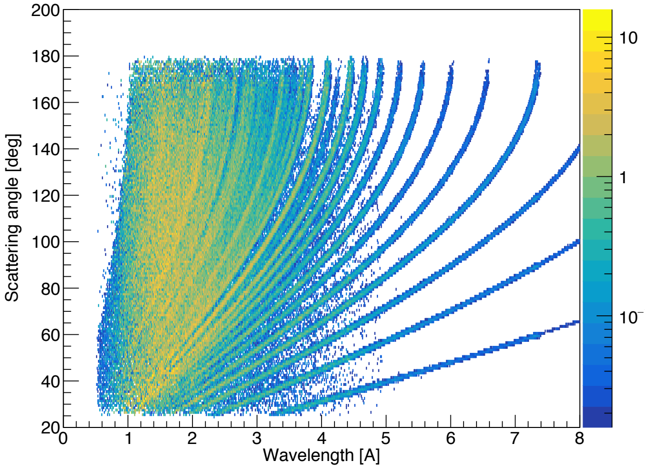
I. Stefanescu,[a,1] M. Christensen,[b] R. Hall-Wilton,[a] S. Holm-Dahlin,[c] K. Iversen,[b] M. K
D. Mannix,[a] J. Schefer,[e] C.J. Schmidt,[d,f] W. Schweika[a,g] and U. Stuhr[e]
[a] *European Spallation Source ESS ERIC,*

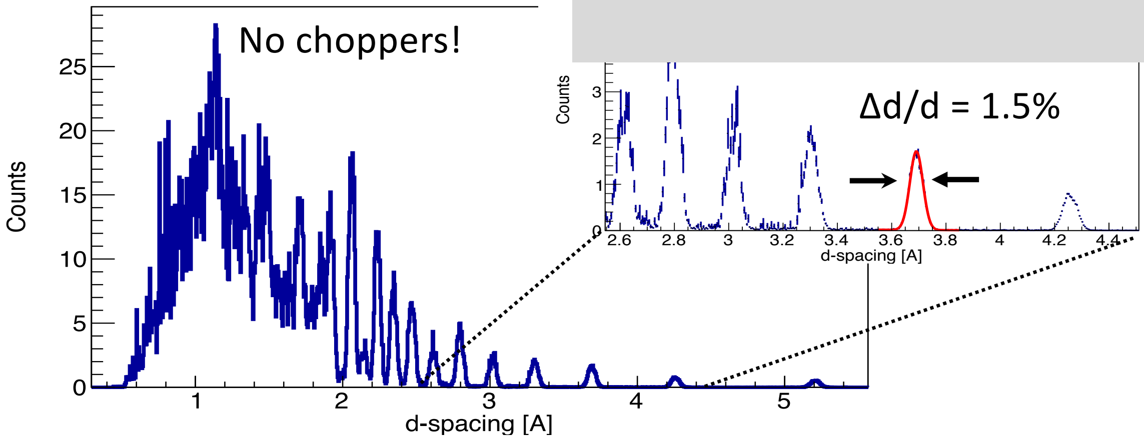
ESS simulation effort to look at the Jalousie detector technology.

The simulations results for HEIMDAL indicate a good performance of the detector.

The Jalousie detector technology comes with a great deal of challenges for the data analysis and reduction, but these simulation can help.

G4 - DMSC collaboration on DREAM detector.



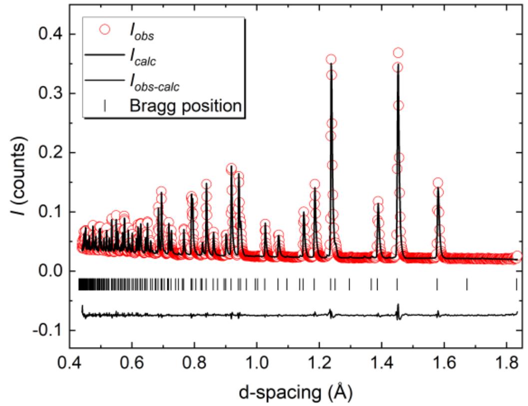


NaCaAlF powder sample + GEANT4 model for the HEIMDAL detector

2D Rietveld Refinement

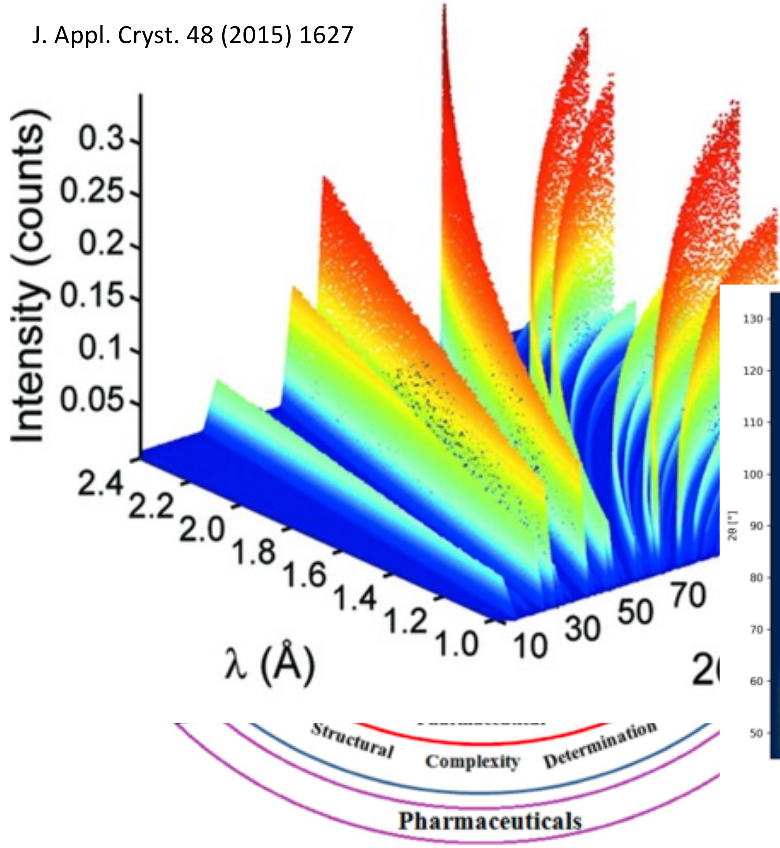
Mathias Mørch Ph.D Starting @ AU 2020

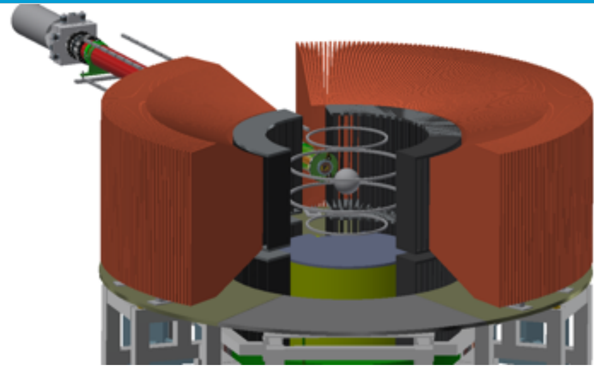
Hugo Rietveld

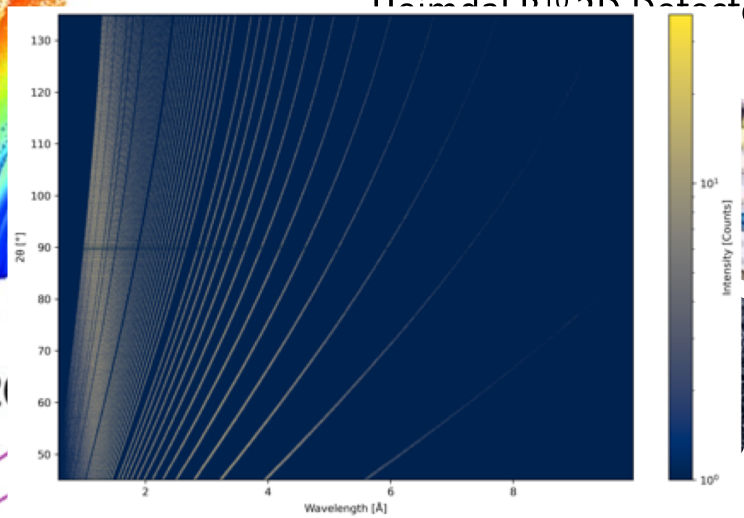


Powder Diffraction

J. Appl. Cryst. 48 (2015) 1627







Heimdal General Sample Environment

EUROPEAN SPALLATION SOURCE

Cooling

Orange Cryo
1.5K-300K

Dilution
~10s mK

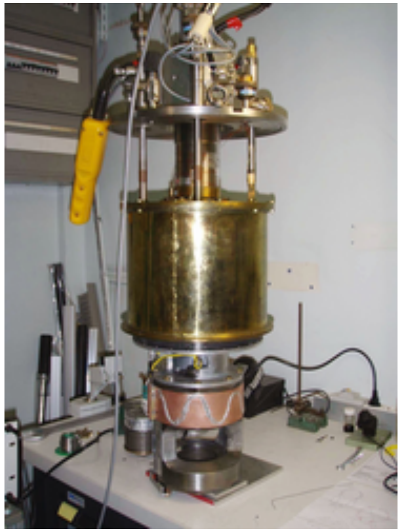
Heating

cryofurnace
1.5K-600K (800K)

Magnetic Field

Cryo-magnetic
8-Telsa

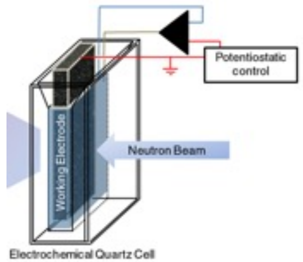
Pressure ? What ?



Paris – Edinburgh ?

Electro-chemistry

Diffraction



SANS

Heimdal Fast Sample Environments
High Throughput Neutron Scattering

EUROPEAN SPALLATION SOURCE

Open Flow Cooling

Oxford Cryosystems:
N_2 cryo system
80-500 K

Cryo Industries America:
Cryocool-LHe : 10-600 K
Consumption: 2L/hour 10 K
Cold zone: 10 mm
Cool down time: 10 min

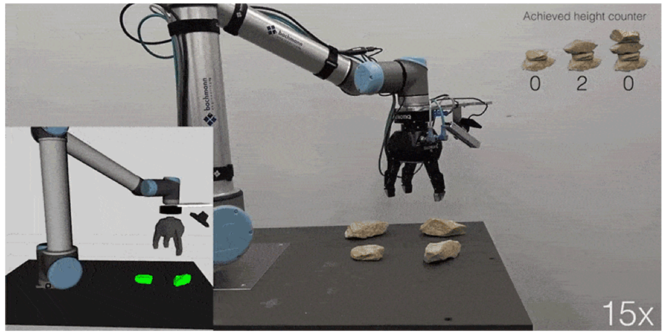
Induction Heating

- Electromagnetic radiation
- Fast heating
- High temperature >1370 °C

Hot Air Blower

1000 W system
40 L/m dry air
- RT - 1000 K in 100s
- combined with
- flow system
- active cooling by dry air
- => fast sample change

+ Robot sample changer



Nordforsk proposal 2020
Heimdal/Dream compatible sample environment
- Fast Heating
+ postdoc