WEBINAR

ESS ROADMAP FOR FUTURE INSTRUMENTS: WAY FORWARD

Pascale Deen
Spectroscopy

Mikhail Feygenson
Imaging and Diffraction

Giovanna Fragneto
ESS Science Director

Andrew Jackson
Large Scale Structures

23 SEPTEMBER 2025
15.00 - 16.00

- Target audience: scientists interested in contributing to the roadmap for future instrumentation at ESS.
- There will be dedicated time for questions at the end, and participants should raise their hand to ask them directly. Chat also possible but visible only by organisers.
- The Heads of Instrument Divisions will be available for further clarifications during the Q&A session.
- The webinar will not be recorded - slides will be shared at the call website: https://ess.eu/instrument-roadmap

Summary

- Introduction to neutron science and ESS
- Update current status facility and scientific activities
- Call for roadmap
- High level overview of proposals currently under discussion
- Process of selection
- Q&A

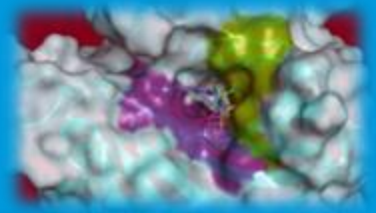
Science with neutrons

Composition, structure (Å → μm) and dynamics (ps → ns ms→ s) of matter

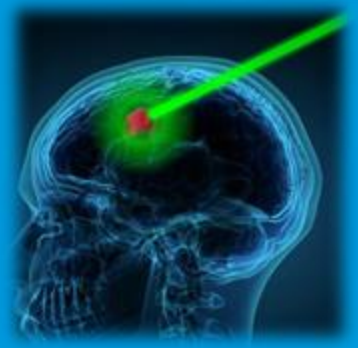
Sensitive to light elements, isotopes and magnetic properties

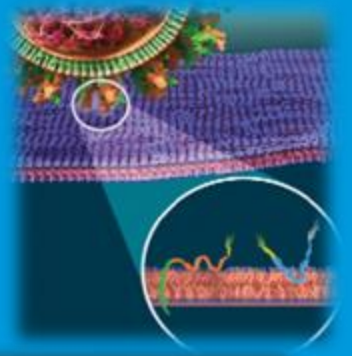
Highly penetrating and non-destructive, complementary to x-rays & light

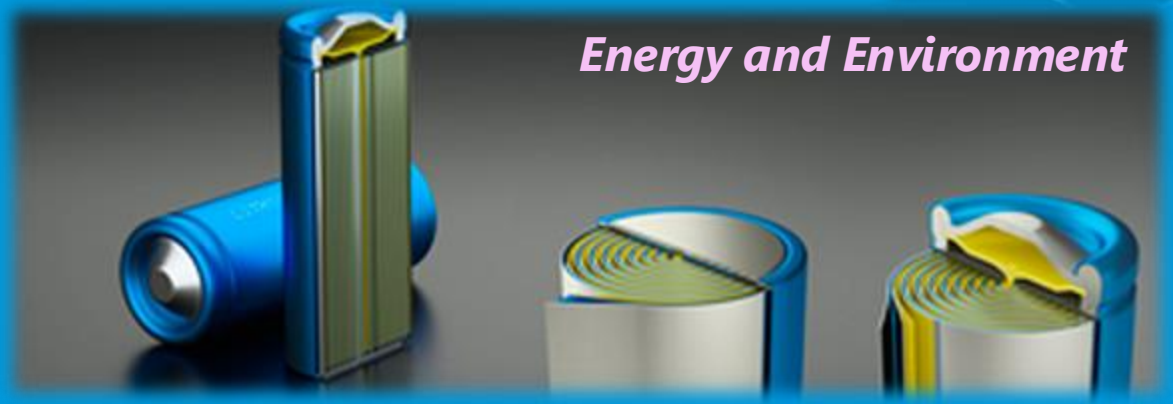
Past and current facilities have demonstrated the power and uniqueness of neutron methods and in a wide variety of fundamental and applied systems



Health

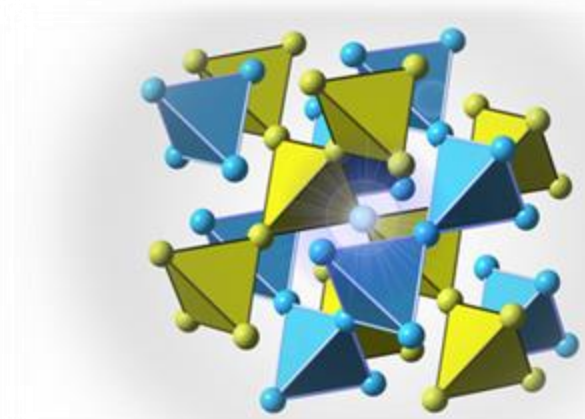






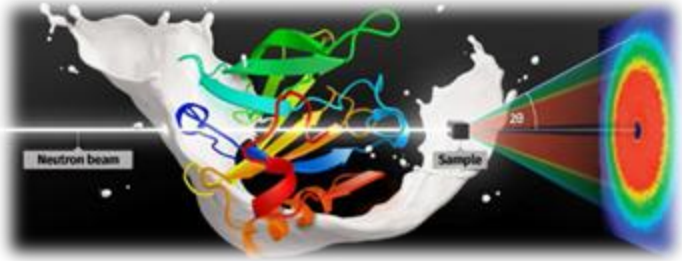
Energy and Environment

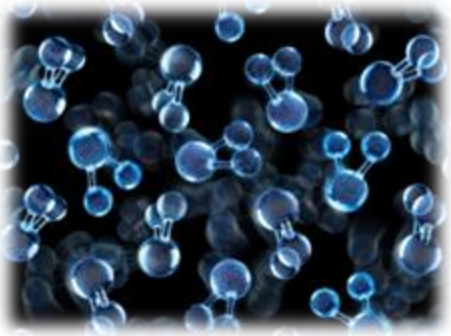
Magnetism and quantum materials



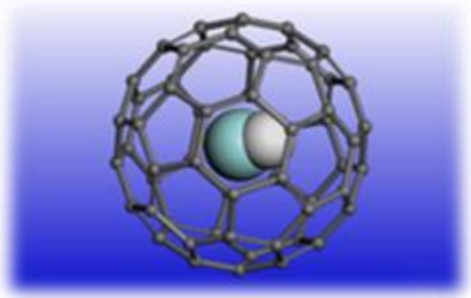
Universe

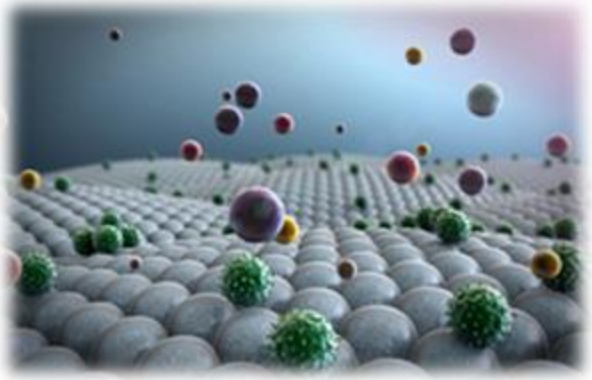
Soft matter and food science





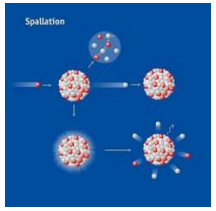
Chemistry and Materials



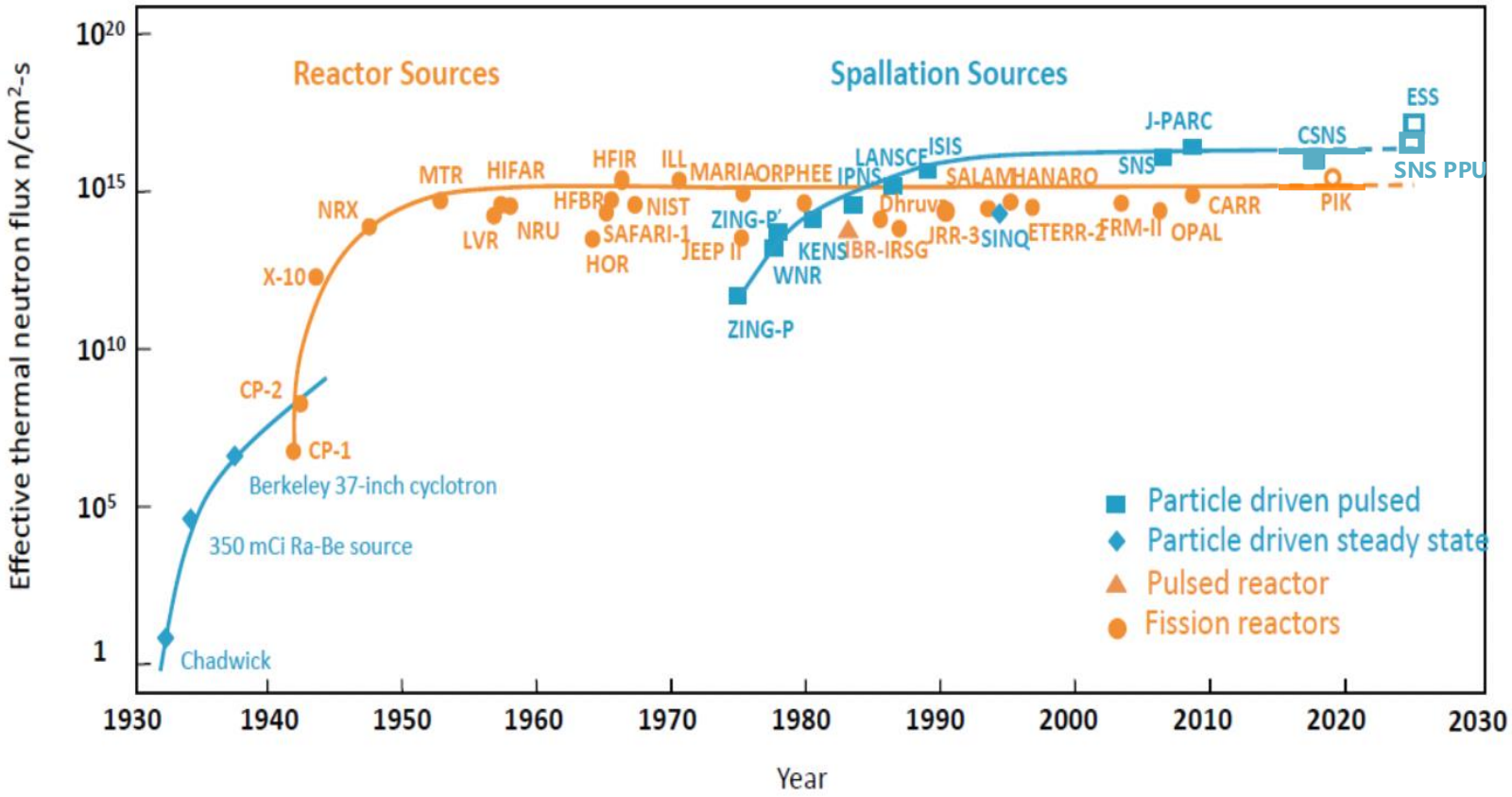


ESS peak flux 20 (2MW)-50 (5MW) brighter than the ILL

ESS mission



Long pulse (2.86ms) spallation neutron source fed by a linear proton accelerator (870MeV 2MW) and rotating Tungsten target

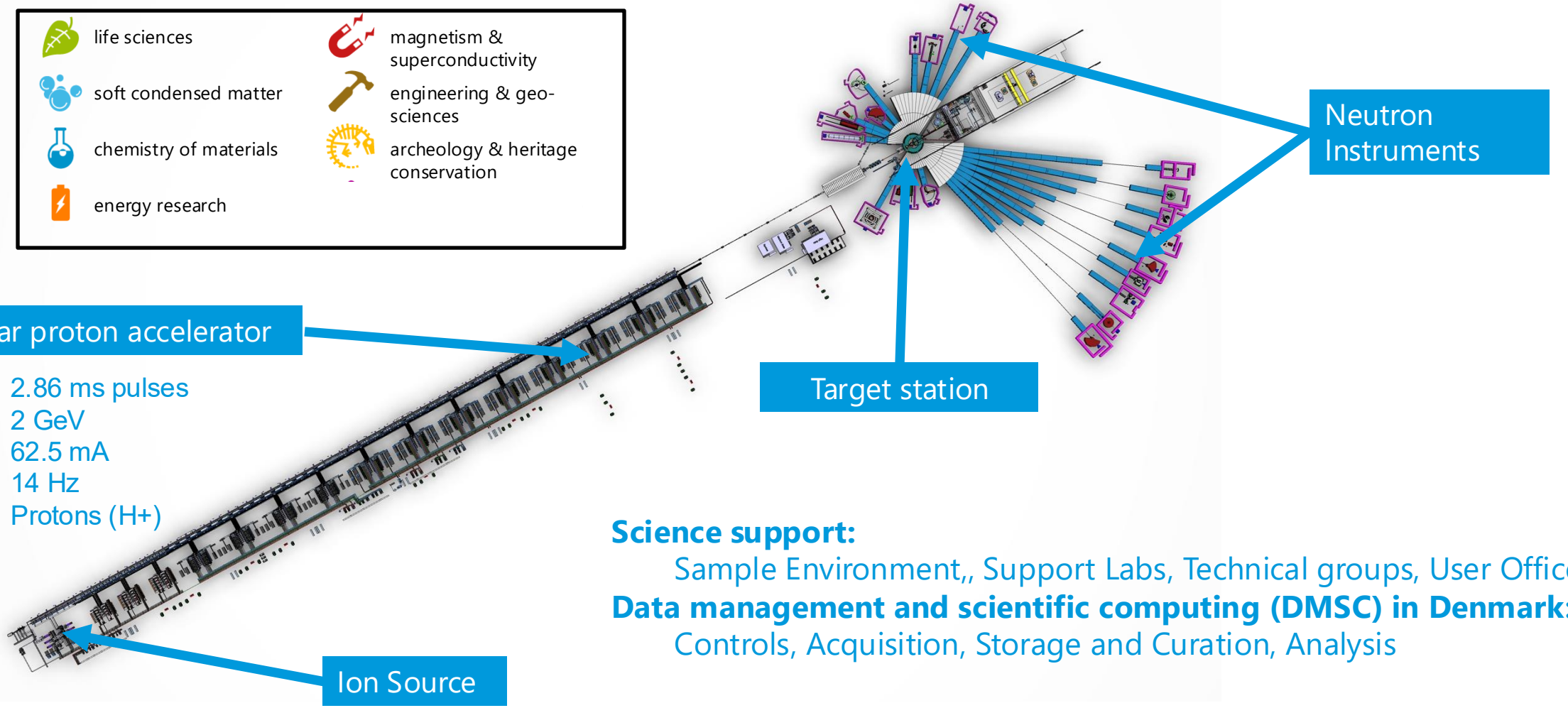


To build and operate the world most intense neutron source that will enable scientific breakthroughs in research relating to materials, energy, health and environment and address some of the most important challenges of our time

The ESS Facility

Accelerator, Target, and Instruments for Science

- life sciences
- soft condensed matter
- chemistry of materials
- energy research
- magnetism & superconductivity
- engineering & geo-sciences
- archeology & heritage conservation



- 2.86 ms pulses
- 2 GeV
- 62.5 mA
- 14 Hz
- Protons (H+)

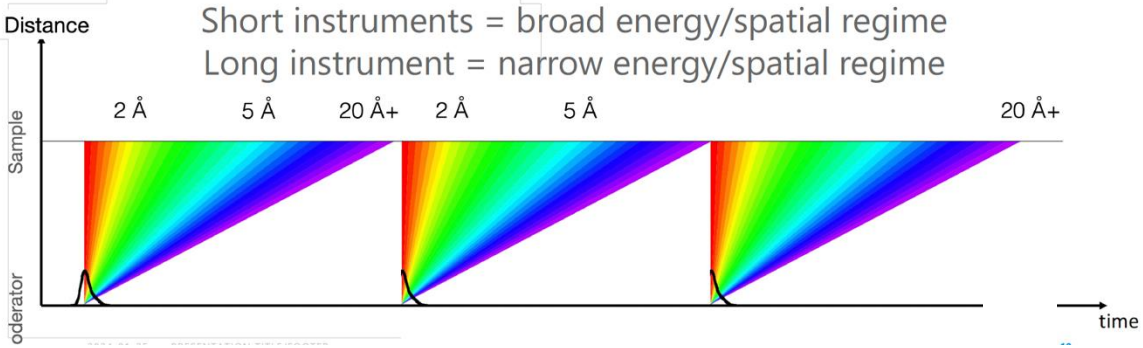
Science support:
Sample Environment,, Support Labs, Technical groups, User Office

Data management and scientific computing (DMSC) in Denmark:
Controls, Acquisition, Storage and Curation, Analysis

Long-pulse Performance and Flexibility

Spallation and time of flight at ESS
Broad energy range from spallation & moderation process
Effective for 0.2-200 meV.

Length of instruments determined by science case.
14 Hz pulses. ΔT ≅ 71 ms
1) Short instruments = broad Δλ, long instrument = narrow Δλ
Short instruments = broad energy/spatial regime
Long instrument = narrow energy/spatial regime



Possibilities of pulse shaping

$$\frac{\Delta\lambda}{\lambda} \propto \frac{\Delta T}{T}$$

Neutron Instruments

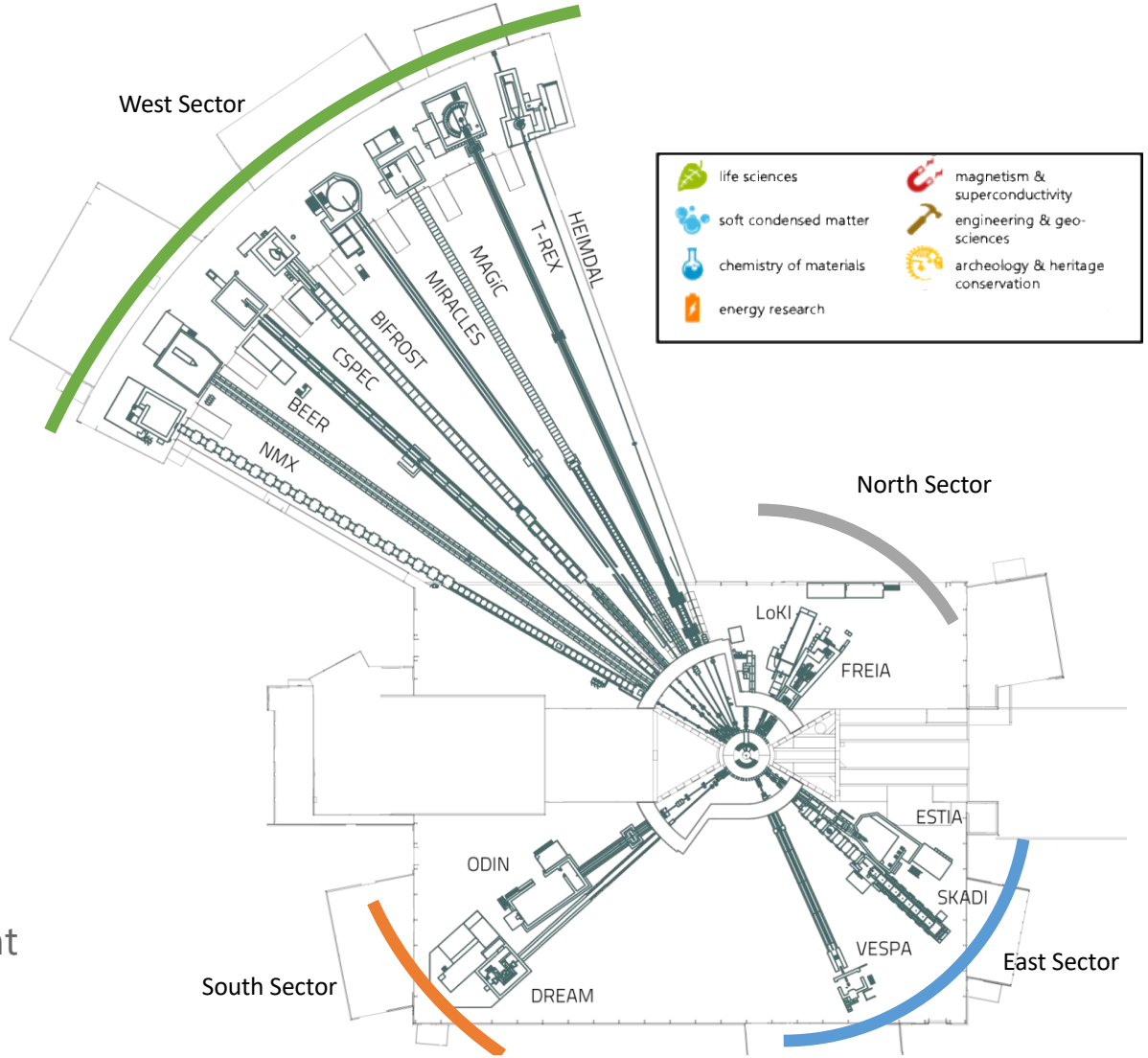
Andersen, K. H.; Argyriou, D. N.; Jackson, A. J. et al. The Instrument Suite of the European Spallation Source. *Nuclear Instruments and Methods in Physics Research Section A:* **2020**, *957*, 163402. https://doi.org/10.1016/j.nima.2020.163402.

15 instruments + Test Beamline

Diffractometers (DREAM, MAGiC, HEIMDAL)
SANS (LoKI, SKADI)
Reflectometers (Estia, FREIA)
Imaging (ODIN)
Engineering Diffraction (BEER)
Macromolecular Crystallography (NMX)
Spectrometers (CSPEC, T-REX, BIFROST, MIRACLES, VESPA)

Novel detector technologies and geometries
Complex pulse-shaping

Shared neutron bunker – common space for components
Common timing system for facility
Single controls infrastructure (EPICS)
Control and data recording running remotely from instrument



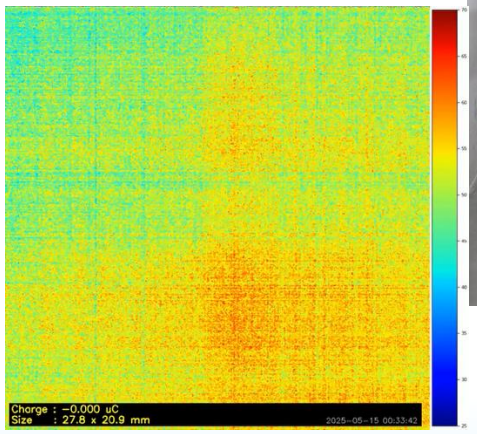
UPDATE ACCELERATOR

Beam on Dump on 16th May 2025

A major milestone on ESS Road to Science

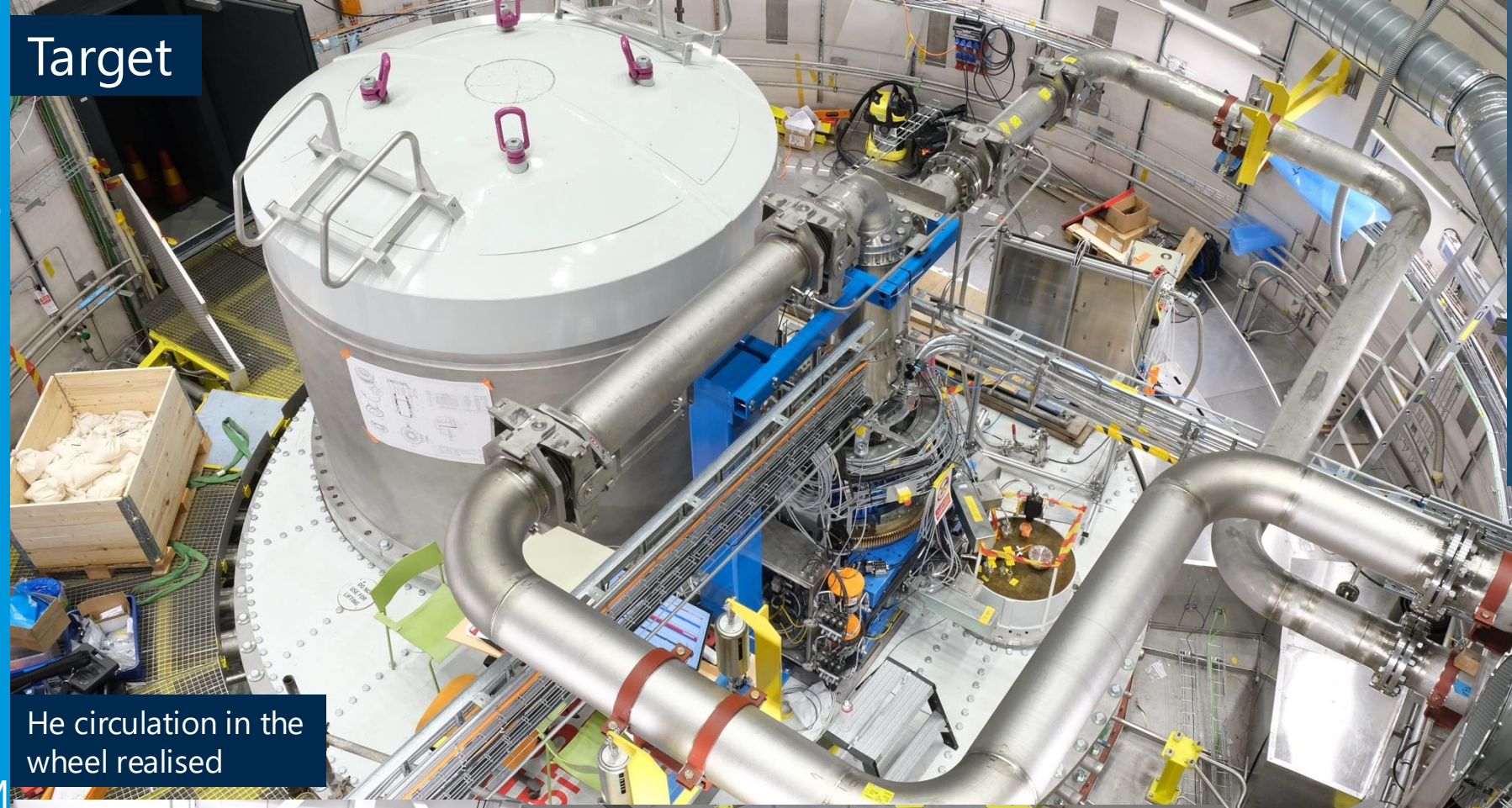
For the first time, protons have travelled the full **542.5 metres** through the ESS accelerator and beam transport system at the correct energy (800 MeV) – from the ion source all the way to the tuning beam dump.

This achievement is clear proof that the accelerator and its many subsystems are operating together as a fully integrated machine.

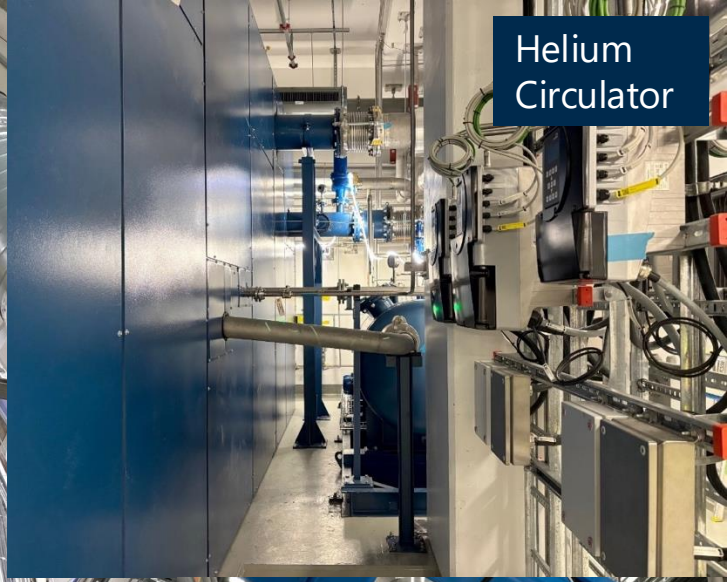


UPDATE TARGET/MODERATOR

Target

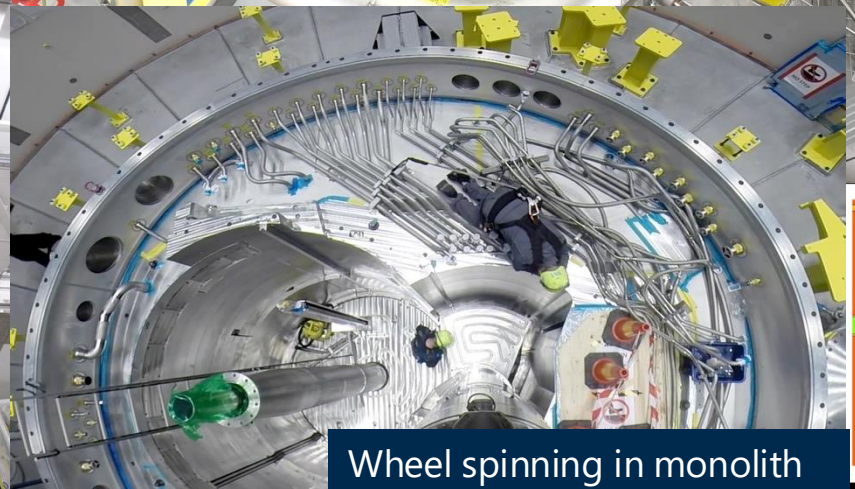


He circulation in the wheel realised

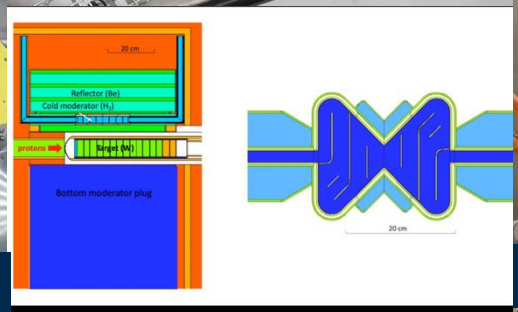


Helium Circulator

MUTS Cask 3 testing



Wheel spinning in monolith



Refurbished HRU

Instruments

UPDATE INSTRUMENTS

DREAM detector installation completed

CSPEC local crane

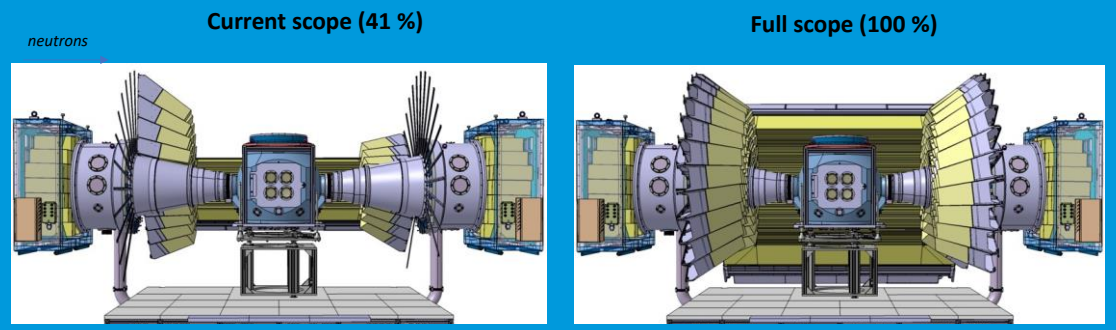
LOKI completion

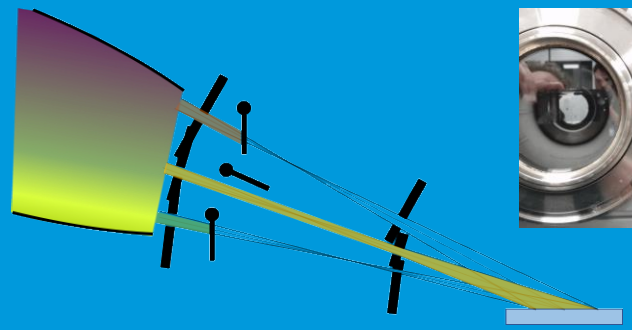
BIFROST completion

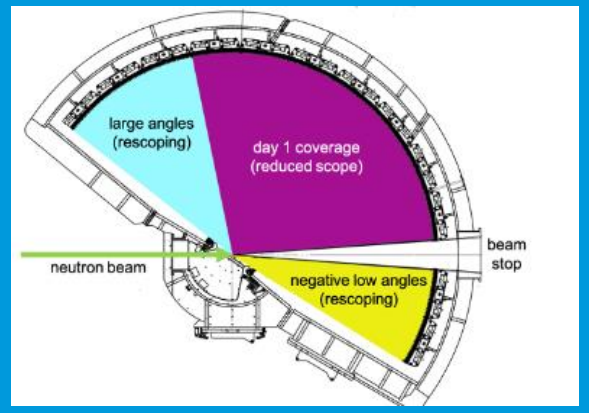
BEER cave progresses

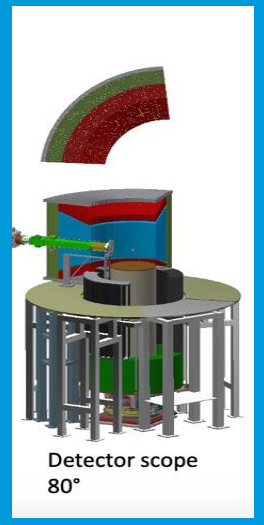
BEER detector base plates

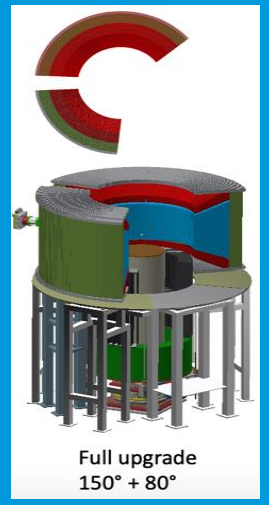
Rescoping











- LoKI full det coverage *in progress*
- FREIA shutters *in progress*
- DREAM full det coverage *in progress*

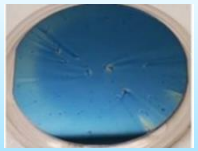
- VESPA T0 chopper *in progress*
- CSPEC ^{3}He ~5 bar (full det coverage) *in progress*

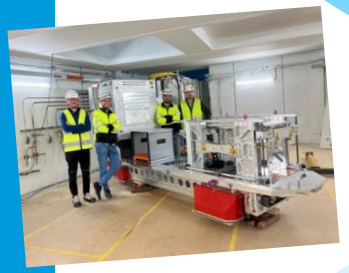
- HEIMDAL detectors
- VESPA analyser modules
- T-REX full coverage detector
- MAGiC full coverage detector
- BEER texture detectors
- BEER multiplication choppers
- ODIN 3D Polarimetric Tomography
- SKADI full coverage detector
- NMX Gd coated detectors

Current post-Beam On Target schedule

Start of user operation in the last quarter of 2027 at 800kW → 2MW in steady state operation (future upgrade to 5MW)

Small samples
Fast kinetics
Extreme conditions
Variable resolution





LoKi

Estia

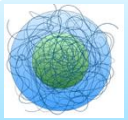
Odin

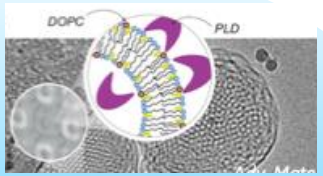
Early Science

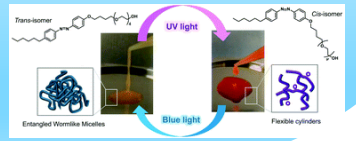
DREAM

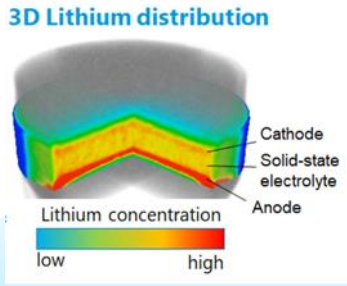
Bifrost

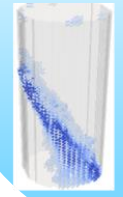
NMX

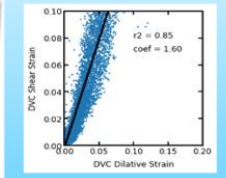


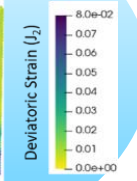


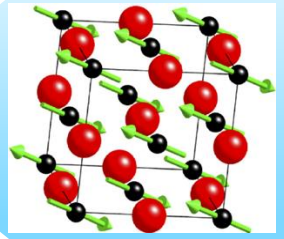


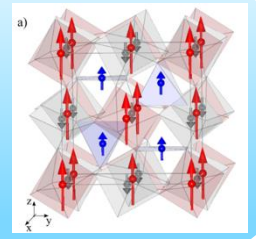


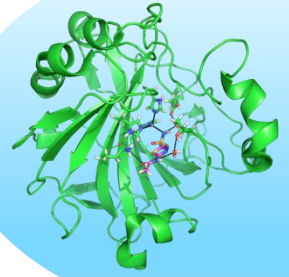


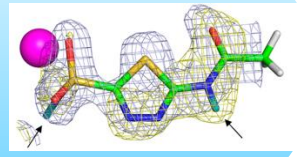


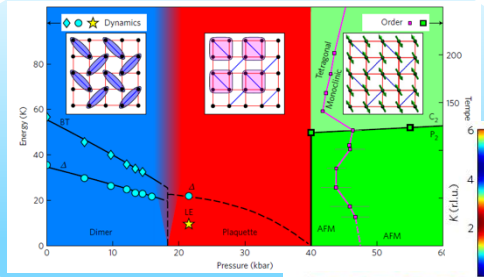


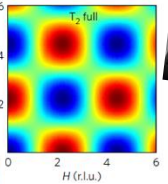


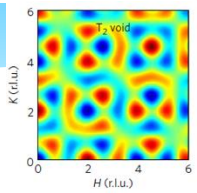












Small samples
Fast kinetics
Extreme conditions
Variable resolution

Preparing for user operation

numerous outreach activities

- Hiring scientific and support staff and reorganising towards a user service facility
- Policies for user access, data and publications
- Successful first science workshops
- Visibility at national user meetings
- Agreements with partners for first science
- Participation in grants' applications
- Internal call for post-docs
- Roadmap for future instruments

ORSC


BIFROST first science workshop


Fundamental Nuclear and Particle Physics workshop

ESS is expected* to, and committed* to, delivering more than 15 instruments for science (up to 32 beamports available)

Timely start planning the expansion of the facility

* *ESFRI report (2003)*
* *ESS Technical Design Report (2013)*
* *ESS Statutes (2016)*

Why now?

- Get as much science as possible out of the ESS source as early as possible.
- Missing capacity and capabilities: need for an update of gap analysis that takes into account latest scientific developments and European neutron strategy *(see ENSA position paper 2025)*
- Build instruments while we have the skilled staff on site.
- From first idea to instrument commissioning a project can take between 5 and 10 years
- Pressure from some countries and communities.

https://ess.eu/instrument-roadmap

Call for Input to the ESS Instrument Roadmap

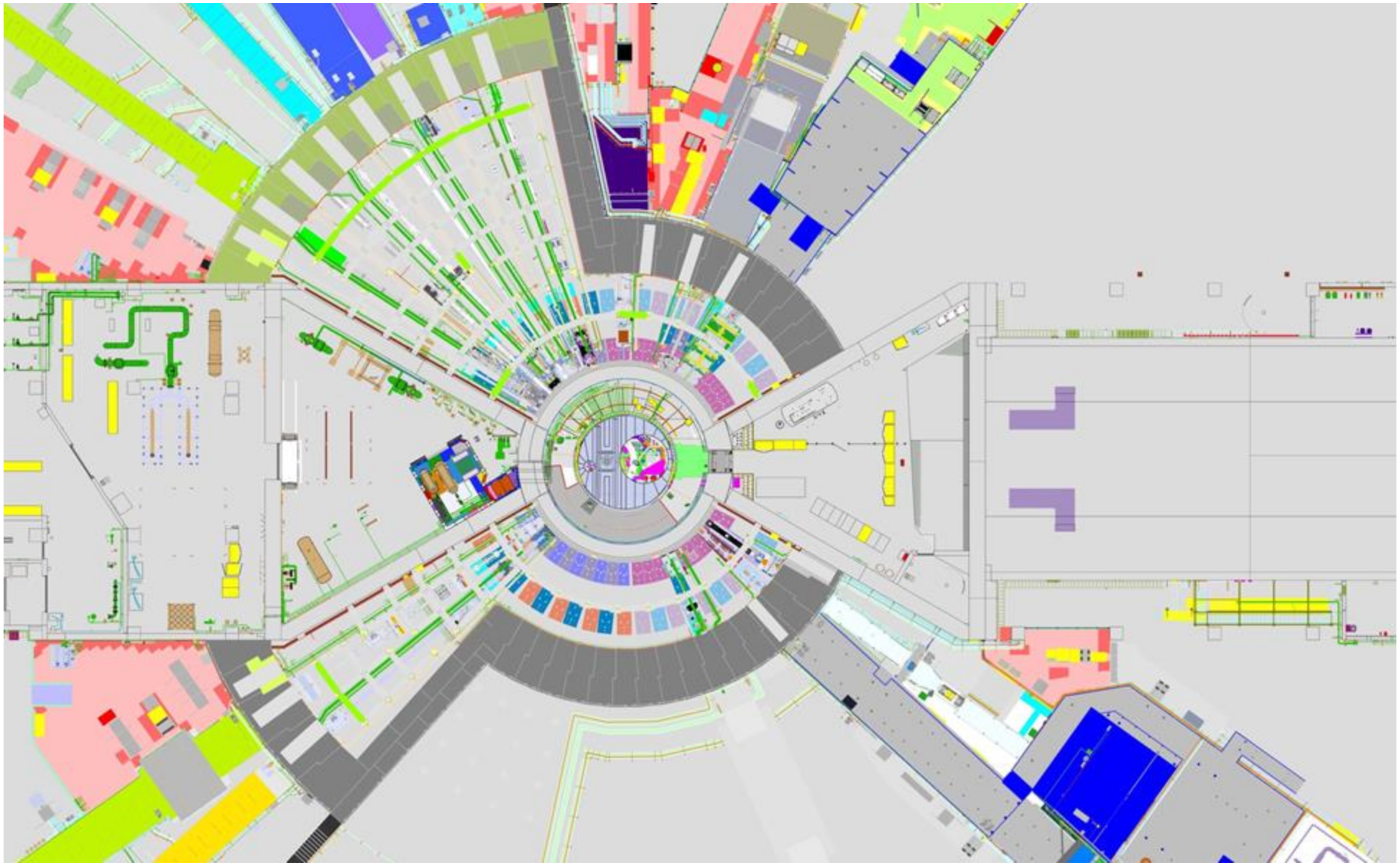
Call open until end of Jan 2026

ESS is pleased to invite the European scientific community to contribute input to a roadmap for instruments beyond the 15 currently under construction. This roadmap will guide future developments of the instrument suite, ensuring that ESS supports a versatile science portfolio in the decades to come. The call will be open for one year.

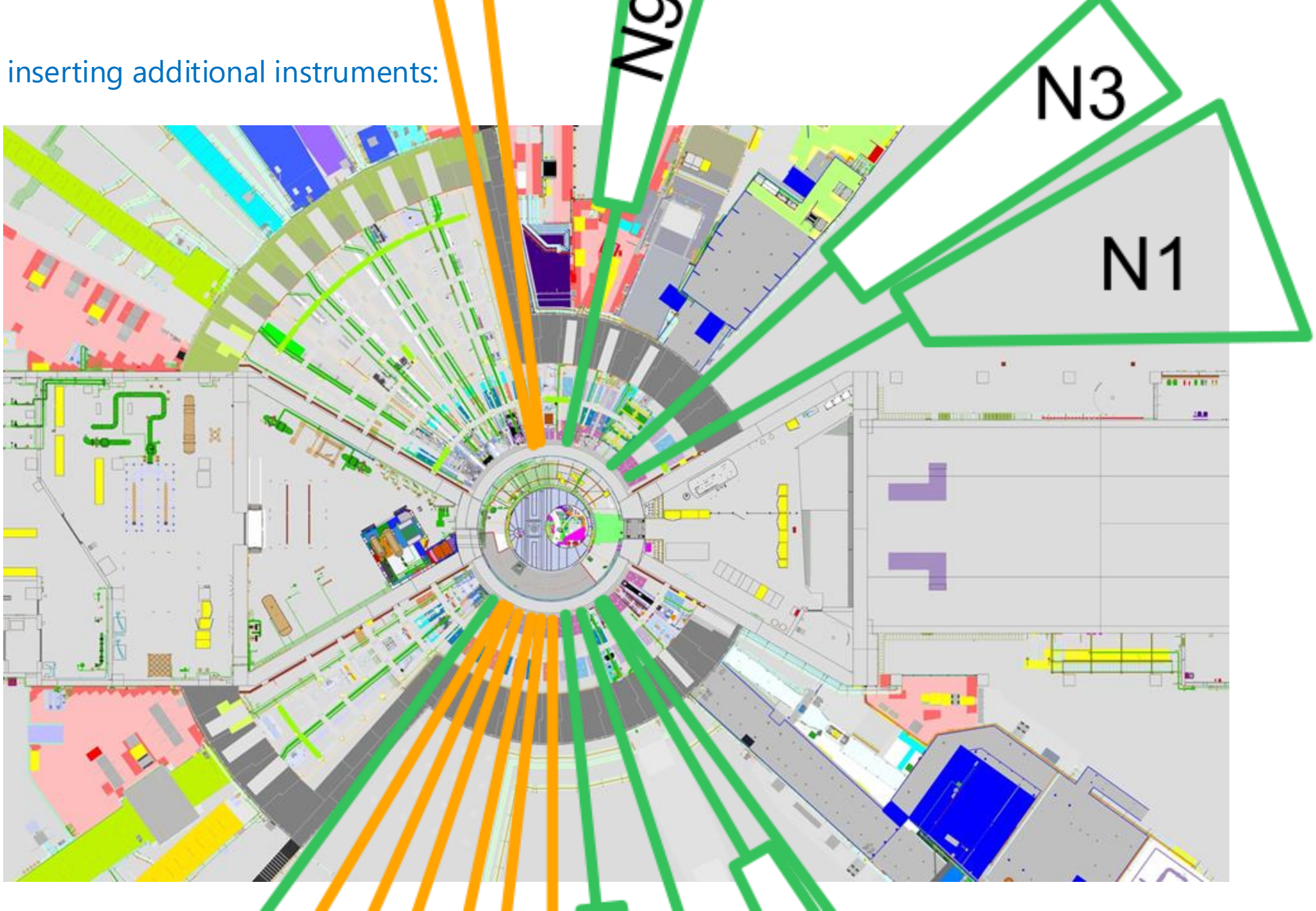
Contact us : instrumentroadmap@ess.eu

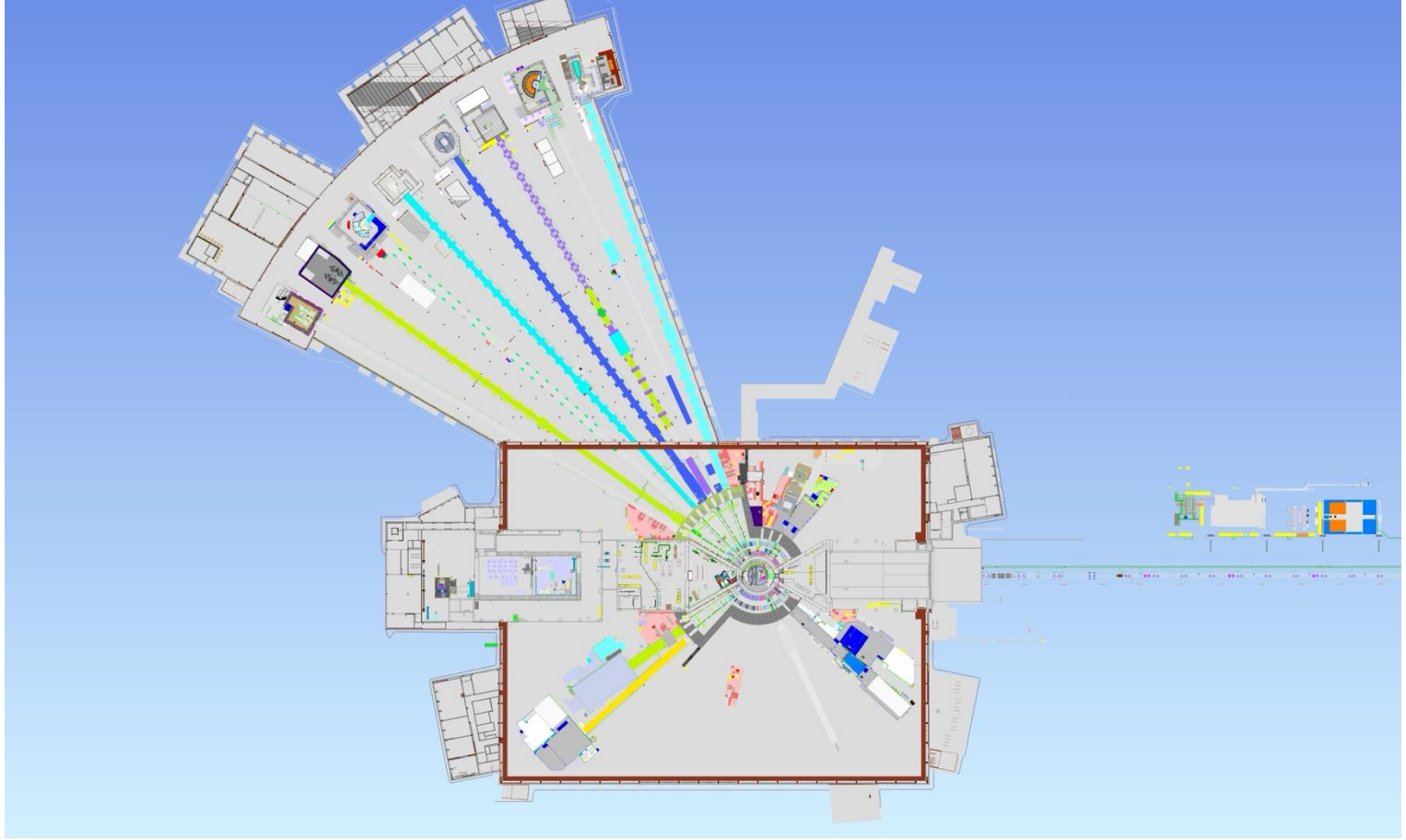
- We are looking for science driven instrument proposals that suit the unique properties of neutrons and the possibilities offered by the high flux, long pulse and flexible resolution of ESS
- The call is not limited to neutron scattering instruments but includes any scientific use of the neutron source
- Need to leverage capacity and capability
- Need to leverage fundamental studies and innovation
- Encourage involvement of the community
- Engage in the process academia as well as ESS advisory committees

Currently occupied ports:

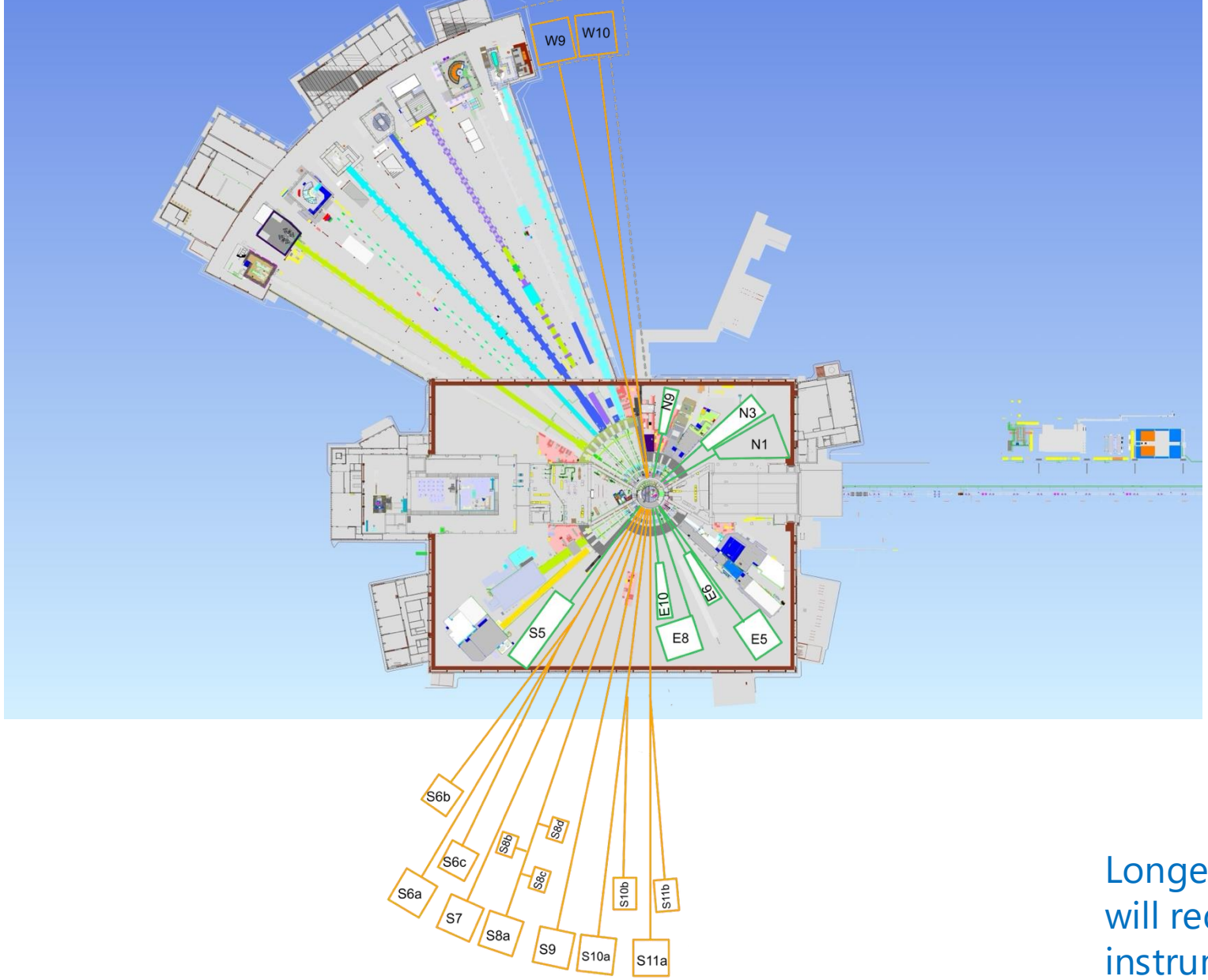


Possibilities for inserting additional instruments:





In current instrument halls only short instruments (up to 40-50m from moderator can be accommodated

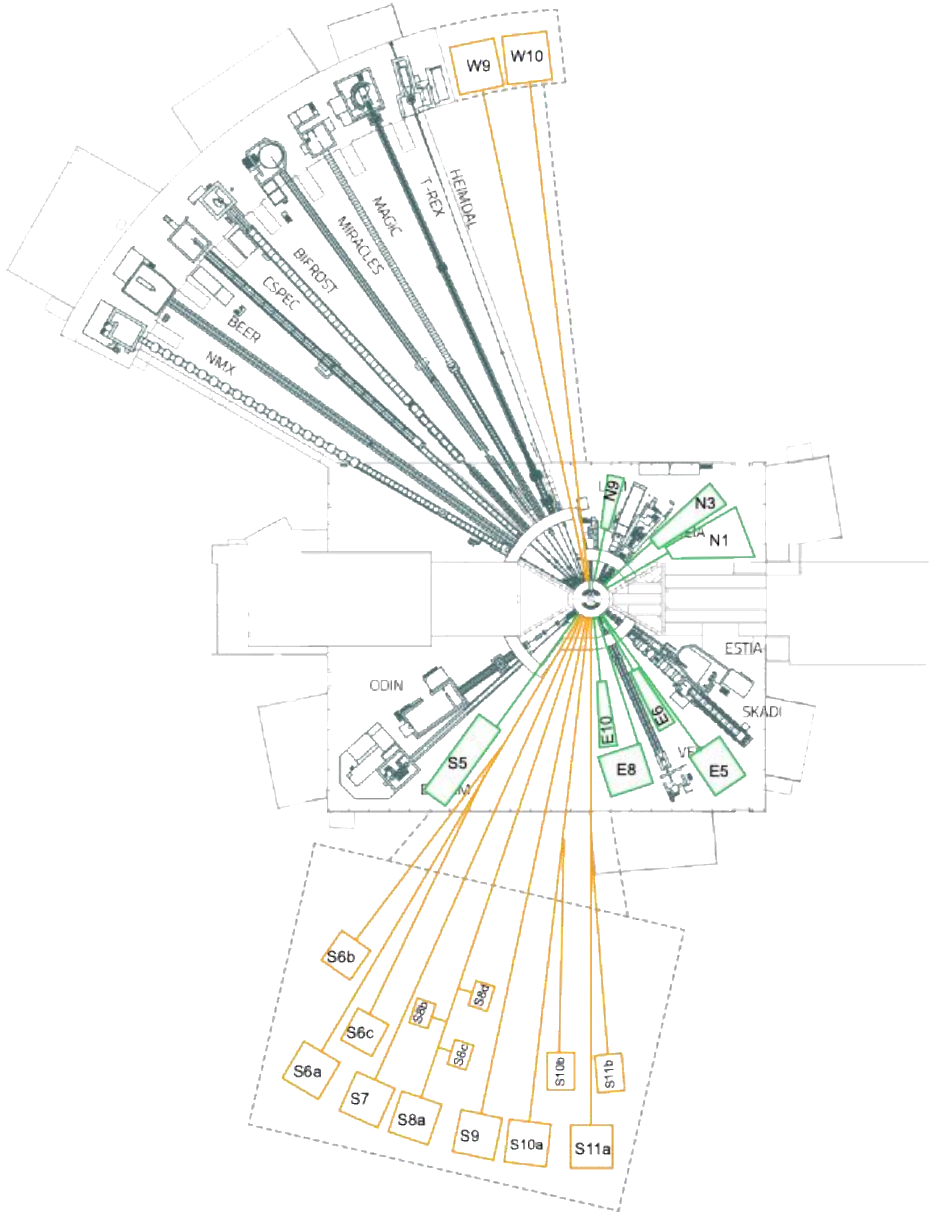


Possible beamline positions fitting in existing experimental halls

Possible beamline positions requiring new or expanded experimental halls

Schematic of Possible Instrument Suite Expansion
Andrew Jackson 2024-10-16

Longer instrument projects will require extensions of instrument halls



Possible beamline positions fitting in existing experimental halls

Possible beamline positions requiring new or expanded experimental halls

Schematic of Possible Instrument Suite Expansion
Andrew Jackson 2024-10-16

Interested parties in ESS member countries are welcome to submit proposals via our instrument divisions.

We aim at proposals supported by consortia of academic and research institutions including large involvement of ESS staff.

We plan to go beyond the in-kind model used so far and lead construction from the ESS.

We will strive to profit from the expertise of our European partners and we are looking now at possible collaboration models within a new FRAMEWORK for PARTNERSHIPS *(to be validated).*

https://ess.eu/instrument-roadmap

How to submit a proposal

Contact us First : Prior to submitting a proposal, please contact the appropriate Head of Division for a discussion on feasibility.

Pascale Deen, Head of the Spectroscopy Division
Mikhail Feygenson, Head of the Diffraction and Imaging Division
Andrew Jackson, Head of the Large-Scale Structures Division
For Nuclear and Particle Physics, contact Pascale Deen.
For general questions regarding the Call for Input, contact instrumentroadmap@ess.eu.

Propose an instrument concept, not a fully designed instrument. Focus on scientific capacity and capability, and explain how your concept would complement the current instrument suite at ESS as well as the global neutron landscape, and how it would enable ground-breaking science. Explain how technical solutions will make your concept feasible and excellent, but do not provide a full instrument design.

https://ess.eu/instrument-roadmap

How to submit a proposal

Contact us First : Prior to submitting a proposal, please contact the appropriate Head of Division for a discussion on feasibility.

Pascale Deen, Head of the Spectroscopy Division
Mikhail Feygenson, Head of the Diffraction and Imaging Division
Andrew Jackson, Head of the Large-Scale Structures Division
For Nuclear and Particle Physics, contact Pascale Deen.
For general questions regarding the Call for Input, contact instrumentroadmap@ess.eu.

A proposal should include the following:

1. Executive summary
2. Scientific case
2.1. Key scientific drivers
2.1.1 Potential societal relevance of the science case
2.2. Potential new science
2.3. Potential user community
3. An initial technical overview of the proposed instrument, discussing technical feasibility.
4. An explanation of how the concept makes use of the ESS long-pulse source, if relevant.
5. Plans or requirements for sample environment and laboratory access.
6. Proposed location of the instrument at the ESS facility including motivation.
7. Gap analysis in terms of both capability and capacity, in relation to ESS and the global facility landscape.
8. Comparison to other similar instruments in the world, if possible.

Ideas for new instruments under discussion in the Diffraction & Imaging division

Mikhail Feygenson
Imaging and Diffraction

1. **Single-crystal diffractometer with high-pressure capabilities** (ESS, PSI, ESS Bilbao, ISIS, Edinburgh University)
2. **PDF dedicated diffractometer with Q_{MAX} ~50 $Å^{-1}$** (PSI, ESS, TUM, ISIS, Duisburg-Essen University, Uppsala University)
3. **MAGNI—Microscopy, Advanced and Grating Neutron Imaging-** neutron imaging instrument optimized for high neutron flux (PSI, DTU, ESS)
4. **IDUN - Guide bundle instrument** for imaging, engineering diffraction and SANS (DTI, ESS)

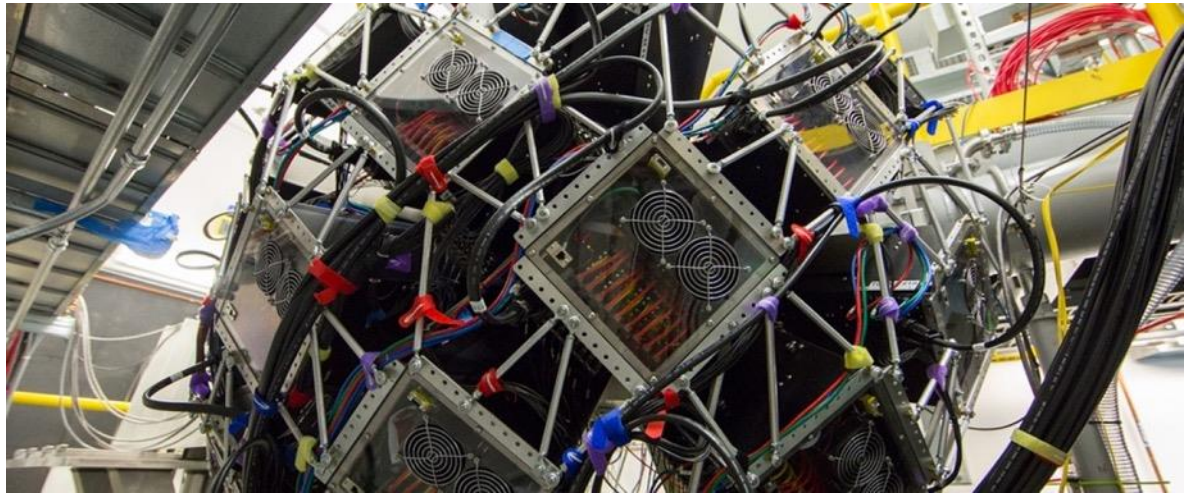
Single-crystal diffractometer with high-pressure capabilities

Closes the capacity gap in a dedicated single-crystal diffractometer with unpolarised neutrons at ESS

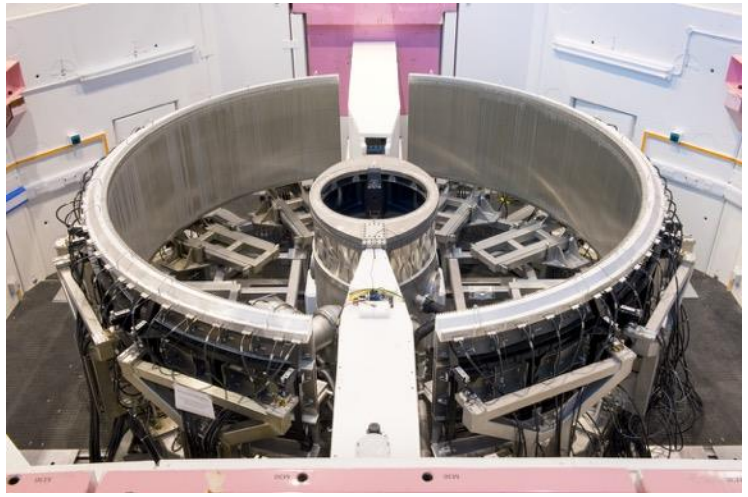
Features: wide Q-range diffraction, high-pressure neutron diffraction, in operando studies, provision of laser heating, and DAC compatibility

Community: crystallographers, engineering, x-ray community, and industries like pharmaceuticals

TOPAZ @ SNS



WISH@ISIS



SENJU @ Jparc

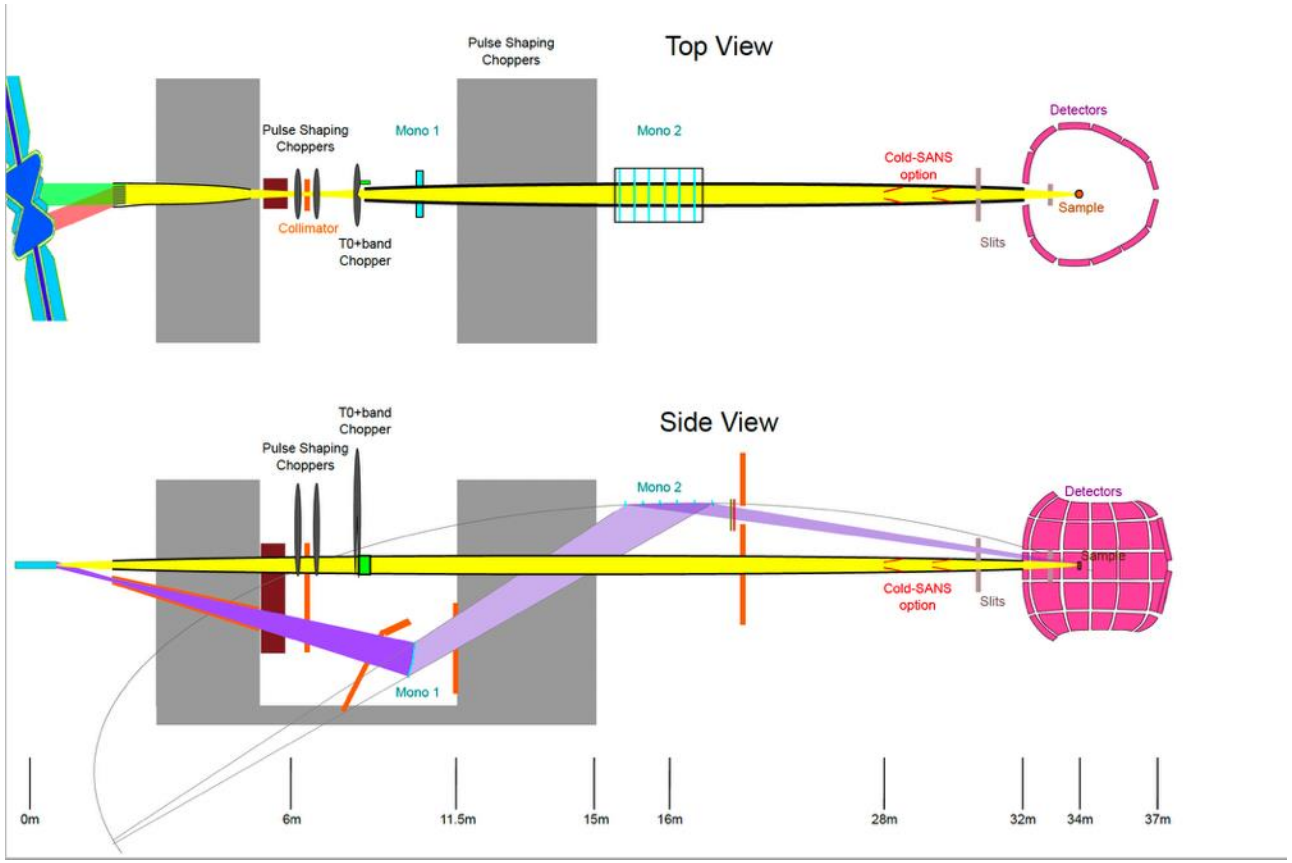
PDF dedicated diffractometer

Original idea by A. Glavic (PSI)

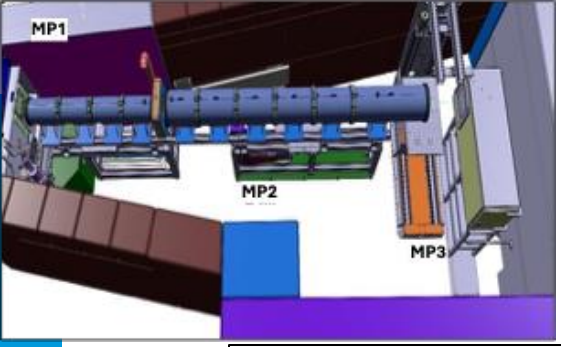
DREAM and **HEIMDAL** can measure pair-distribution function (PDF) with medium resolution defined by Q_{MAX} = 24 Å^{-1}

A **dedicated PDF instrument with** Q_{MAX} = 50 Å^{-1} is needed to support the large PDF community in Europe with a dedicated sample environment

The instrument will complement the existing suite of ESS diffractometers, similar to PDF-instruments like **GEM** , **NIMROD, NOMAD**



Courtesy to A. Glavic



MAGNI

Microscopy, Advanced and Grating Neutron Imaging

Markus Strobl (PSI/DTU) Luise Theil Kuhn (DTU) Robin Woracek (ESS) et al.

Thor's mighty son in Norse mythology

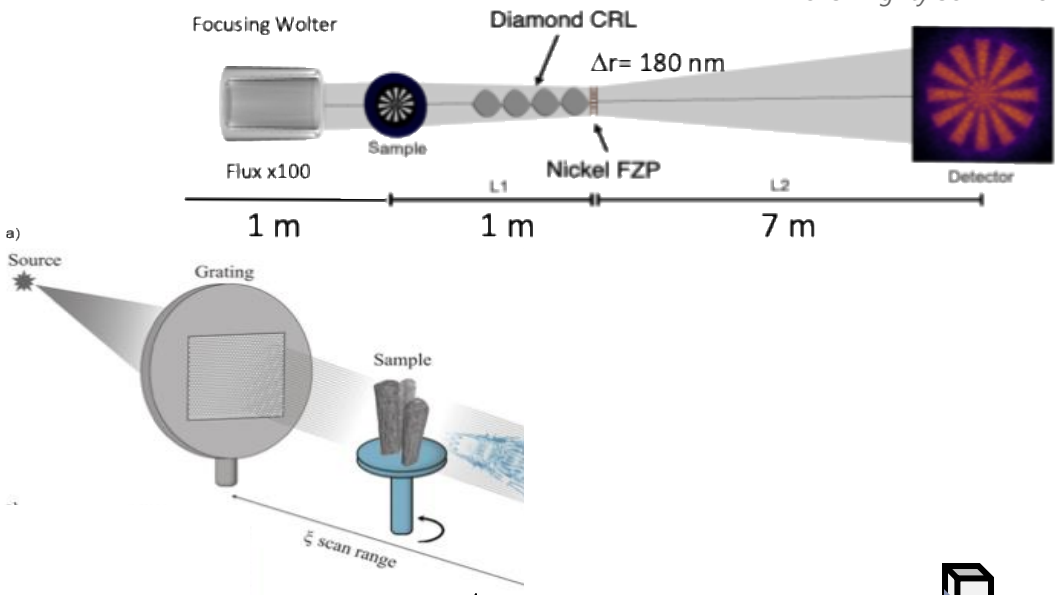
short – high flux – high resolution - relaxed wavelength resolution – large field of view

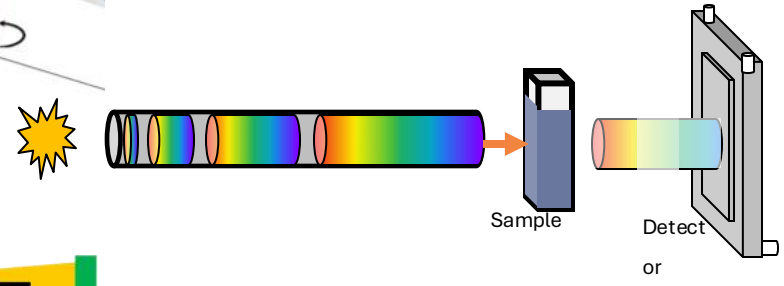
High-resolution neutron microscopy, through a pioneering dedicated neutron microscope;

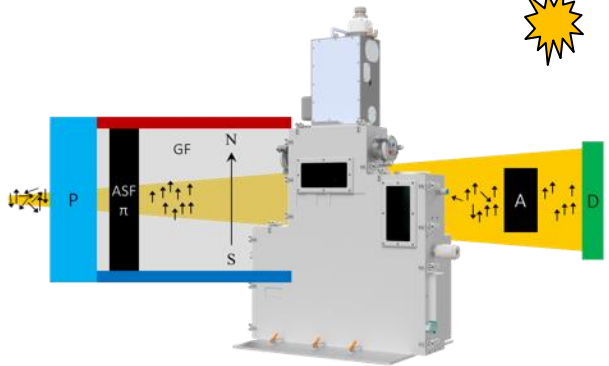
Dark-field contrast imaging for multiscale investigations, from the macroscopic to the nanometer range, using versatile grating-based setups;

Advanced spectroscopic neutron imaging, leveraging low wavelength resolution for inelastic scattering studies;

Large field-of-view imaging, enhancing applicability to industrial-scale components and devices.





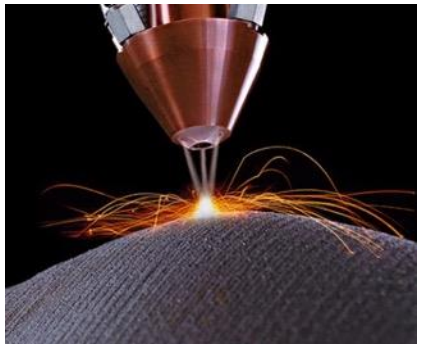


MAGNI – Microscopy, Advanced and Grating Neutron Imaging

Scientific Case.

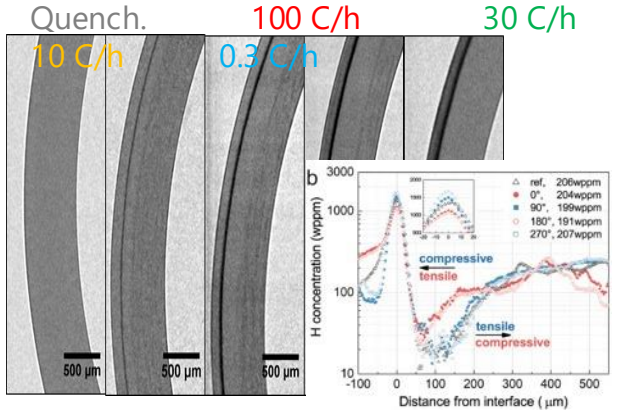
large industrial components

industrial processes

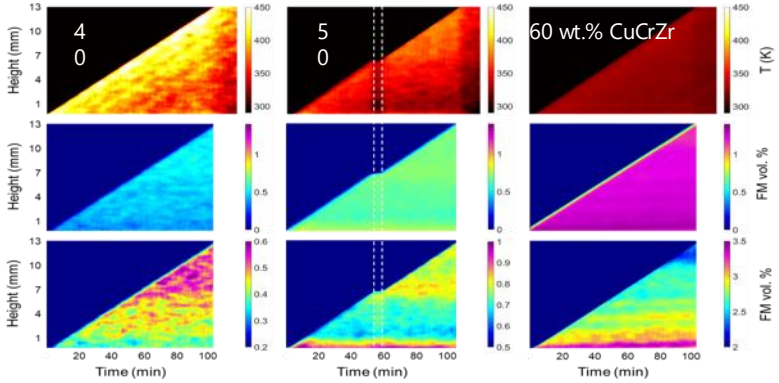


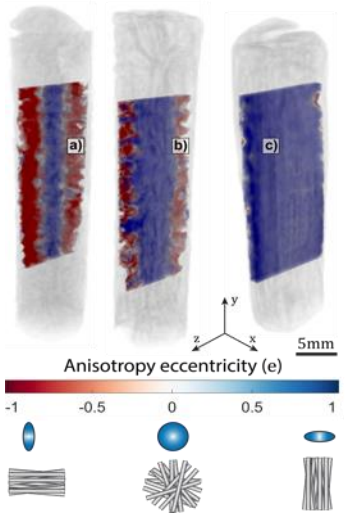
- Emerging & Trans-formative techn.
- Industry 4.0
- Power-to-X
- Circular Economy
- Green Deal
- Space

Hydrogen & hydrides in metal

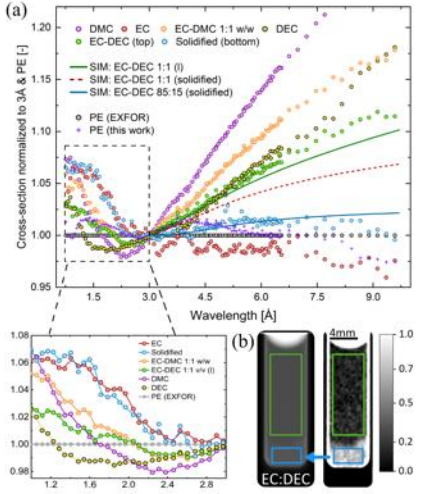


Fast operando evolution of phases





Multi-scale mapping - nano-structures in macro-scopic context



Revealing heterogen-eous dynamics In out of equilibrium systems

IDUN — Industrial& Utilitarian Neutron Instruments

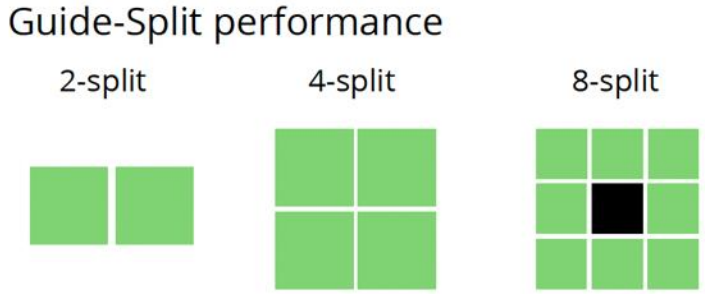
Original idea by Sonja Holm-Dahlin (DTI)

Guide bundle — neutron instrument farm that can host imaging, engineering, diffraction and SANS beamlines at optimized cost

High-throughput instruments, aimed at the fast experiments for industry users

Increases **capacity** for high-throughput diffraction, imaging and SANS instruments

More details in *S. L. Holm, et al. Nucl. Instr. Meth. Phys. Res. A 782, 1 (2015)*



All split options have a high performance above a wavelength of 2 Å when optimized for a phase space with a sample size of 1x1 cm² and a divergence ±0.5°.

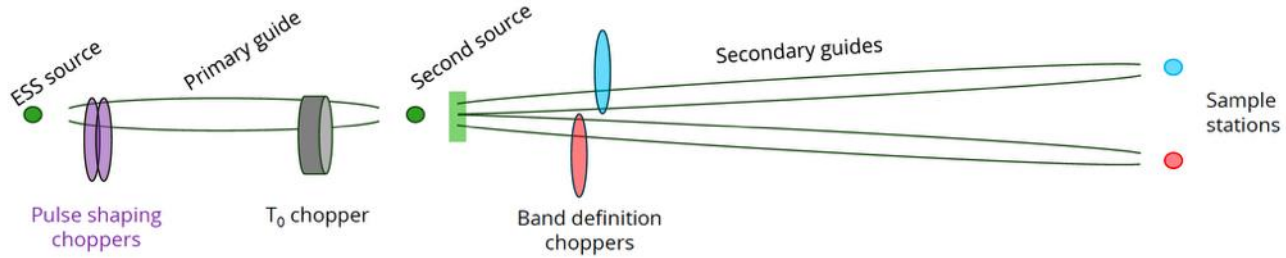
Guide-Split concept

Elliptical guides can transport an almost filled phase space within a large divergence (±2°).

The end of a primary elliptical guide can therefore be used as a "second" source.

It is possible to place several secondary guides side by side and rotated in slightly different directions.

This rotation transforms divergent neutrons from the primary guide into low (and useful) neutrons in the secondary guides.



Ideas for new instruments under discussion in the Large Scale Structures division

Andrew Jackson
Large Scale Structures

- **SAGA – Dedicated surface scattering instrument for 3D studies of interfaces**

  Swedish Collaboration : ESS, KTH, LINXS, LiU, LU, MaU, UU – study funded by VR

- **Structural Biology Cluster – 2nd NMX with DNP and a dedicated Bio-SEC-SANS**

  Collaboration with HUN-REN Centre (HU)

- **SMÅ - High throughput SANS***

  Contacted possible collaborators, will hold zoom workshops

- **ULL - Membrane Diffractometer and WANS***

  Contacted possible collaborators, will hold zoom workshops

- **MIMER - Solid-Liquid Bio-Reflectometer***

  Contacted possible collaborators, will hold zoom workshops

- **Yggdrasil – SANS/WANS**

  Laboratoire Leon Brillouin (Saclay, FR)

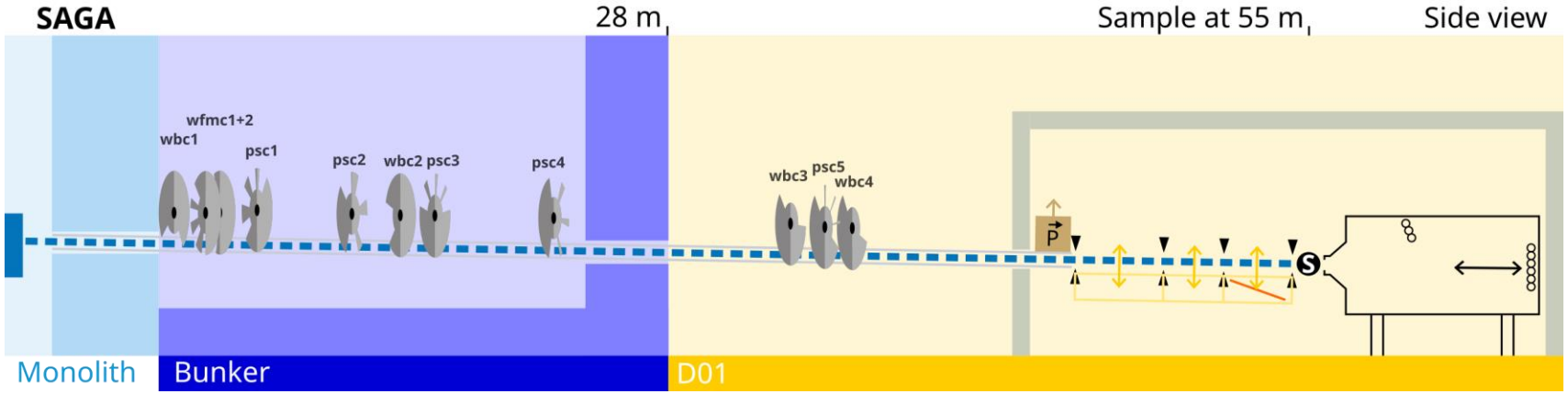
- **SANS at very low Q – Upgrades to SKADI and/or dedicated instrument**

  Contacted possible collaborators, will hold zoom workshop

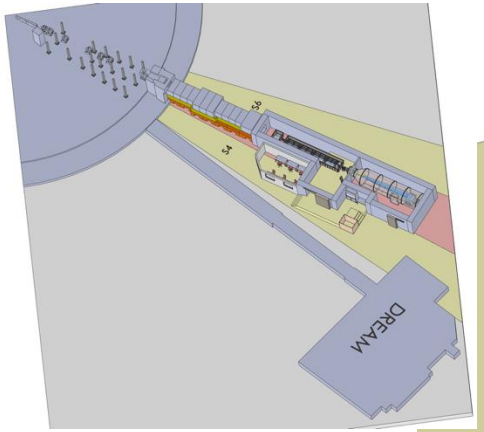
**names are preliminary and for convenience/entertainment only!*

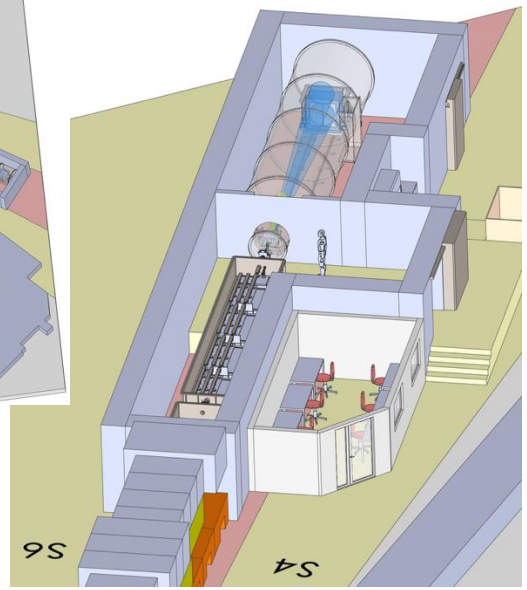
SAGA

A surface scattering beamline



SAGA – Quick facts	
Instrument length (GISANS/NR)	65m/58m
Bandwidth GISANS	3.7Å
λ-resolution for GISANS	2.1-4.4%
Bandwidth NR	4.2Å
λ-resolution for NR	2.3-4.9%
λ-resolution in WFM mode (both)	1%





Proposed location: Beamport S5 (next to DREAM)

Science Case

- Energy & Materials
  - Organic photovoltaics and batteries
  - Advanced coatings
  - High speed measurements of structural changes during processing
- Quantum Materials
  - Magnetic thin films
  - Topological
  - Spintronics
- Life sciences & Soft Matter
  - Self-assembled structures
  - Model membranes / RAFTs

Technical features

- GISANS + NR on same sample
- TOF-GISANS => depth sensitivity
- Horizontal Surface => liquids
- Polarisation Analysis => magnetism
- π-GISANS type mode for higher flux => kinetics without depth sensitivity
- Possible k-focussing mode
- Capable of NR-Tomography
- Capable of transmission SANS

Structural Biology Cluster

Split beam extraction with two guides:

1. Protein diffractometer for dynamic nuclear polarisation

   Expand protein crystallography availability and capability, building on the experience from NMX.

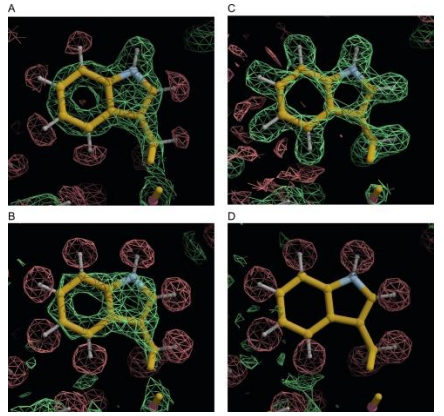
   Non-magnetic end-station enabling DNP for background suppression

2. SANS/WANS end-station designed to study changes in protein structure in solution.

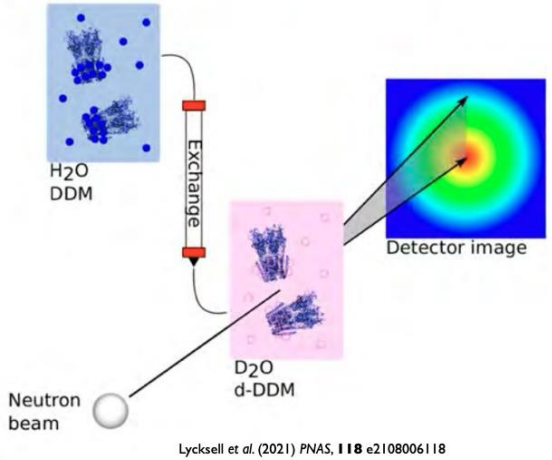
   Q-range and resolution optimised for protein-in-solution and membrane protein-in-nanodisc studies.

   Permanent SEC setup

Beamport S6



Pierce et al. (2020) *MIE*, **634**,153-175



Together with MaxIV, LU, and SciLifeLab we would be able to provide critical tools to the integrative structural biology toolbox.

SMÅ

High Throughput SANS

SMÅ : Studying Materials Automatically

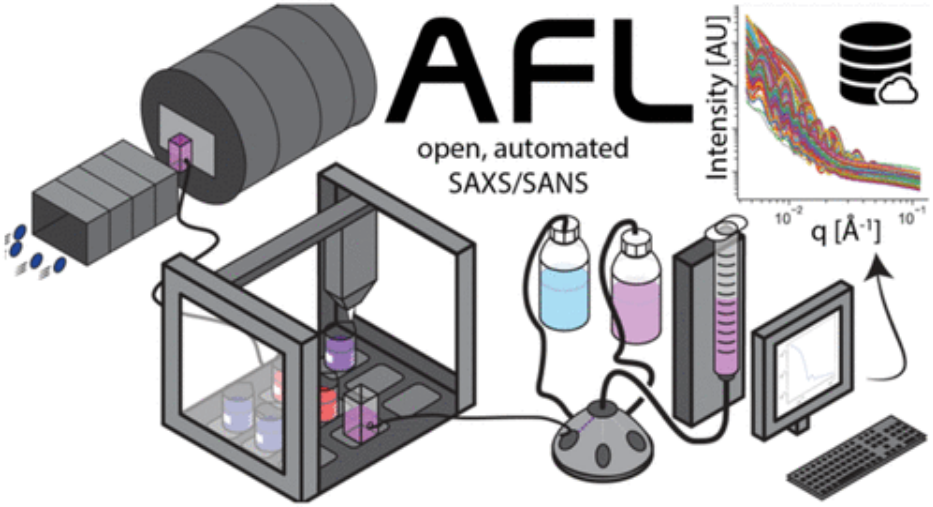
Science focus on large parametric studies of soft matter, complex fluids, and formulations.

Designed with the aim of efficiently supporting industrial measurements, rapid access, and mail-in.

Simple, fixed collimation SANS, with the option of different high throughput sample environments:

- Robotic autosampler
- Flow cell setup
- Automated/autonomous formulation using Machine Learning and physics-informed AI models

Beamport N9, N3, or E10



Chem. Mater. 2023, 35, 3, 846–852

https://www.nist.gov/ncnr/ncnr-facility-upgrades/autonomous-formulation-lab-afl

ULL

Membrane / Partially Ordered Systems Diffractometer

ULL : Understanding Lipids and Liquids

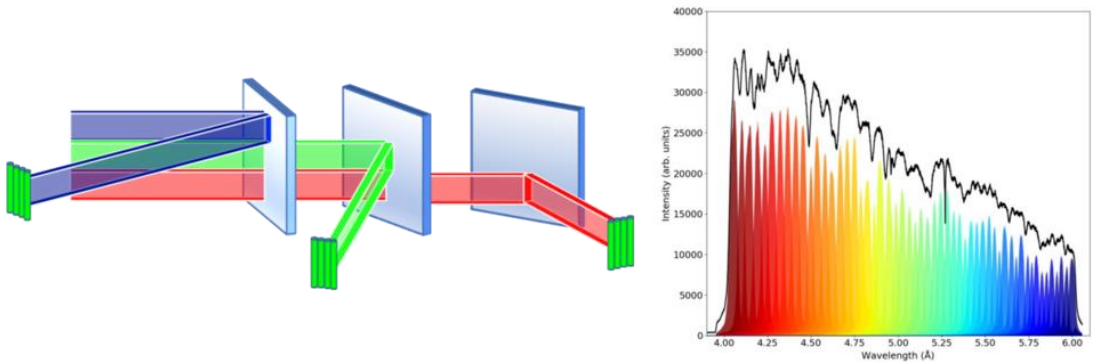
Instrument for membrane diffraction and WANS (for example liquid crystals, polymer crystallinity)

Investigating the possibility of liquids diffraction.

Various technical solutions possible, but we are considering CANDOR type backend (multi-analyser energy selection) to obtain required wavelength resolution

Beamport N3, E10, or S6 (shared with structural biology cluster)

- Candor has 2Å bandwidth with Q resolution, dQ/Q, ~2.5%
- Low-background - 8 orders of magnitude dynamic range – ideal for low scattering applications
- Suitable for wide angle detector geometries



Credit: Brian Kirby and David Hoogerheide (Left) Schematic illustrating the wavelength selection of pyrolytic graphite monochromators (right) measured wavelength sensitivity associated with each individual detector for an example CANDOR array. Solid black line is the summed intensity vs. wavelength.

MIMER

Solid-Liquid Bio-Reflectometer

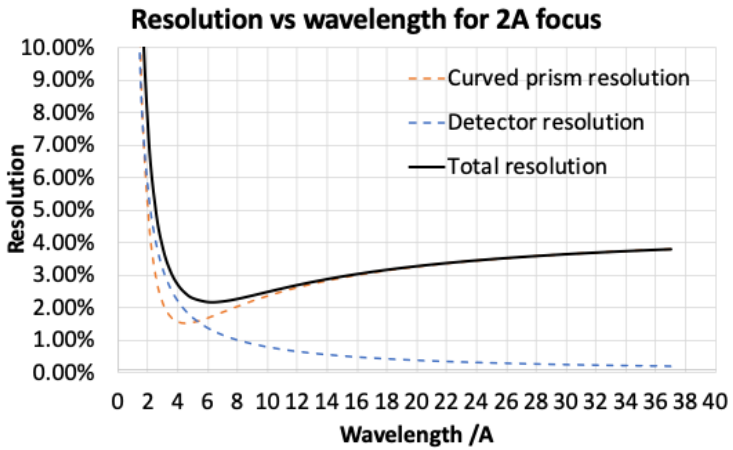
MIMER : Measuring Interfaces and Membranes at ESS with Reflectometry

Expanding ESS capabilities for the support of studies of lipid membranes and protein-membrane interactions.

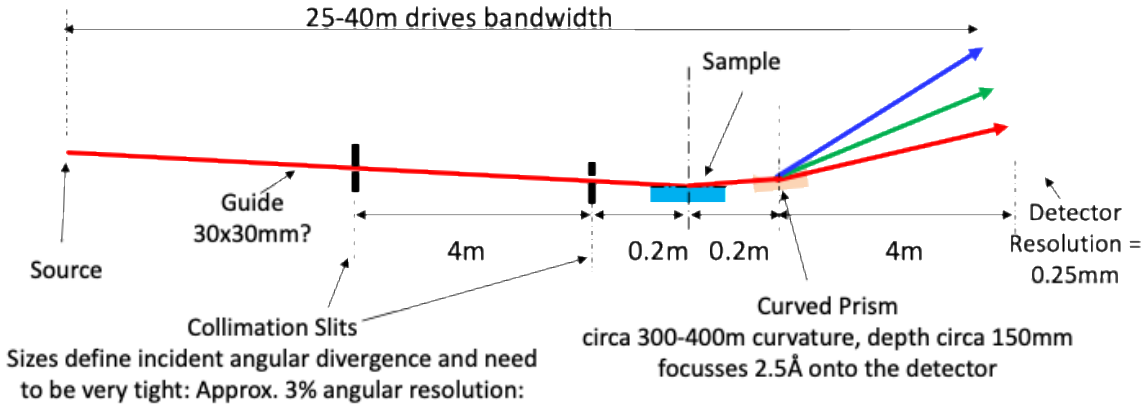
Estia and FREIA will be able to support these studies, but this instrument increases capacity and is optimised for work-horse solid-liquid experiments.

Beamport N3 or

Split guide



- Short instrument to provide wide bandwidth
- No complex chopper system – resolution is delivered by RAINBOWS or CANDOR in the end station
  - Rainbows can deliver resolution <4% using modified multiblade concept.
  - CANDOR can potentially remove inelastic scattering to improve background
- Optimised for high-throughput of solid-liquid samples
  - Includes substantial effort on automation (sample changing, intelligent decision making)
- Include polarisation for magnetic reference layers
- Limited to samples without off-specular scattering
- Sample space may be restricted by optics



Yggdrasil

Polarised SANS/WANS

In Norse mythology the World Tree

Marion Grzelka, Ioanna Chazapi, Gergory Chaboussant, Alexis Chennevière

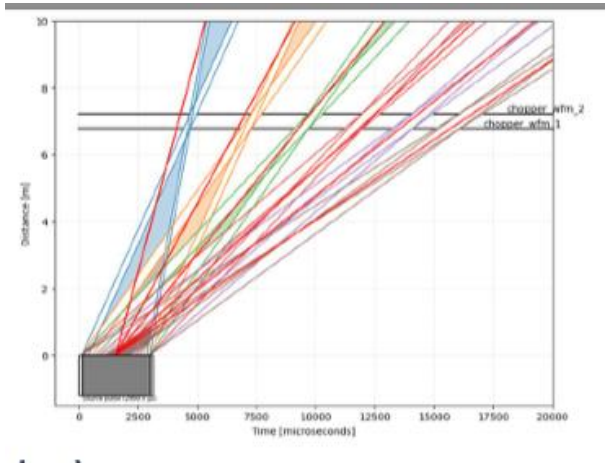
Extending SANS to High Q (>5Å^{-1}) with polarisation analysis.

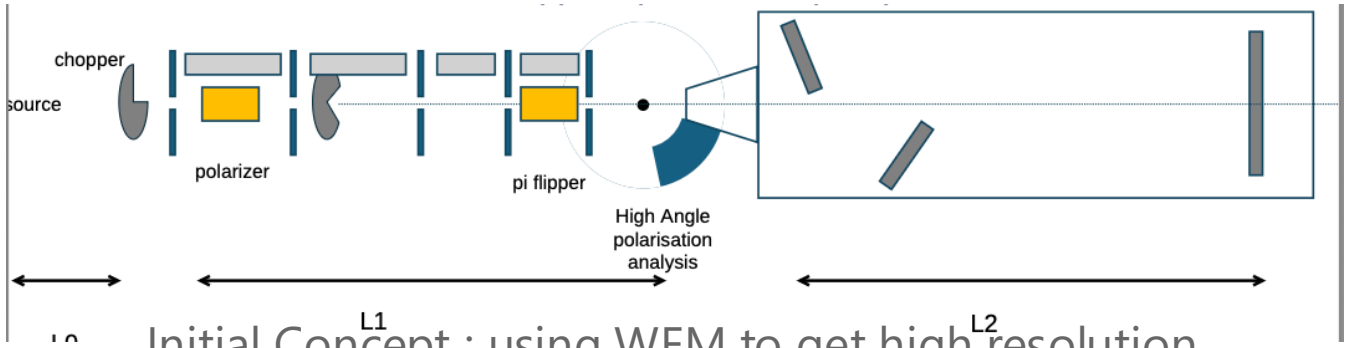
Increased capacity (SANS) with extended capability (WANS).

Connecting with DREAM Q range

Key Science Areas:

- Understanding hybrid inorganic-organic nanoparticles
- Polymer systems and composite materials
- Energy storage
- Porous materials
- Electrolytes





Initial Concept : using WFM to get high resolution

SANS at very low Q

VSANS/SEMSANS/USANS

Science Areas:

- GUV/Lipids
- Protein aggregation
- Polymer composites
- Geology
- Nano to microparticles and interactions

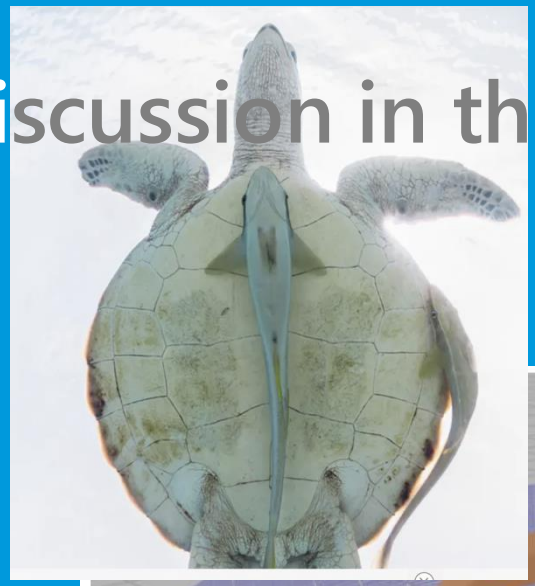
Connect to Imaging size range

Complementary to neutron grating interferometry on ODIN

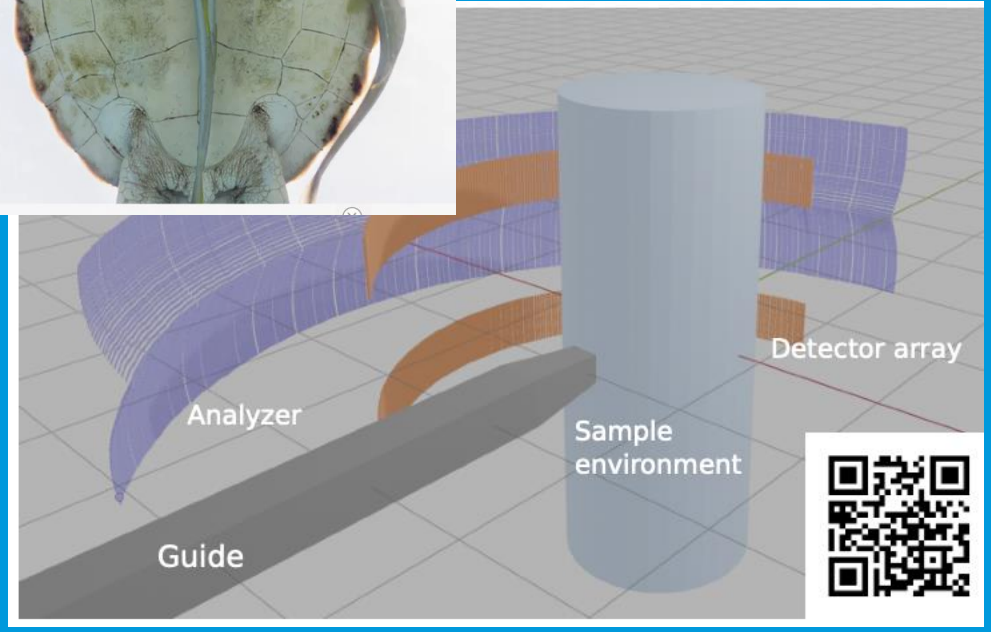
Technical Options:

- Compact pinhole VSANS (reduced complexity, ISIS currently in the process of developing this) – upgrade to SKADI or dedicated instrument on shared guide
- SEMSANS – possible upgrade to SKADI or dedicated SANS/SEMSANS instrument
- DCD USANS (Bonse-Hart) – making use of high integrated flux of ESS to deliver world leading USANS capability

Ideas for new instruments under discussion in the Spectroscopy division



Pascale Deen
Spectroscopy



1. **NSE** Broad community collaboration
2. **NJORD** } ESS/DTU/TUM/FZJ
3. **REMORA** }
4. **KVASIR** ESS/KU/LLB
5. **VOR** ESS/KU
6. **Short low div., thermal spectrometer** ESS/Univ.Trento/Uni. Perugia
7. **Pulsed magnetic field opportunities** EPFL/TUM

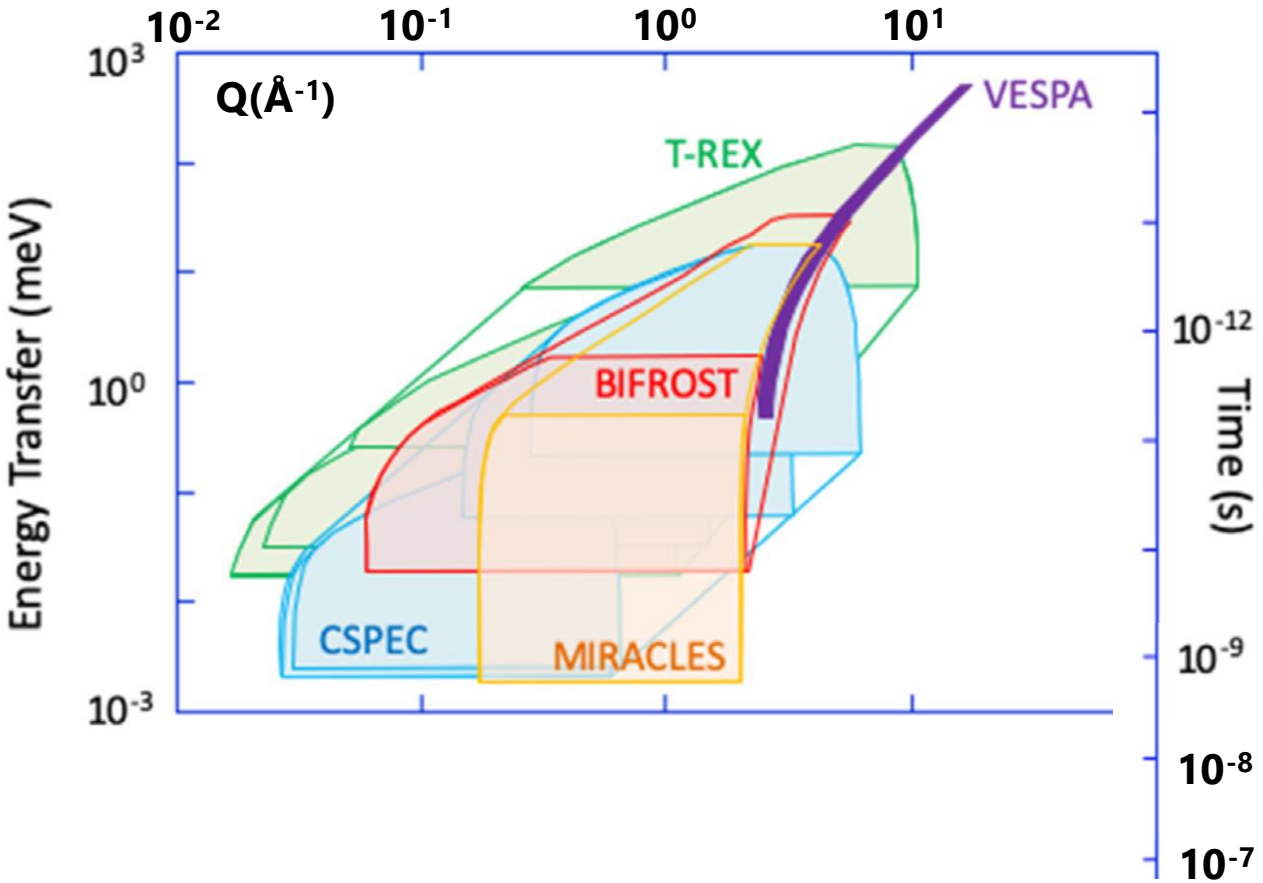
Spectroscopy @ ESS

Nuclear Inst. and Methods in Physics Research, A 957 (2020) 163402

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima



Spectroscopy @ ESS

Nuclear Inst. and Methods in Physics Research, A 957 (2020) 163402

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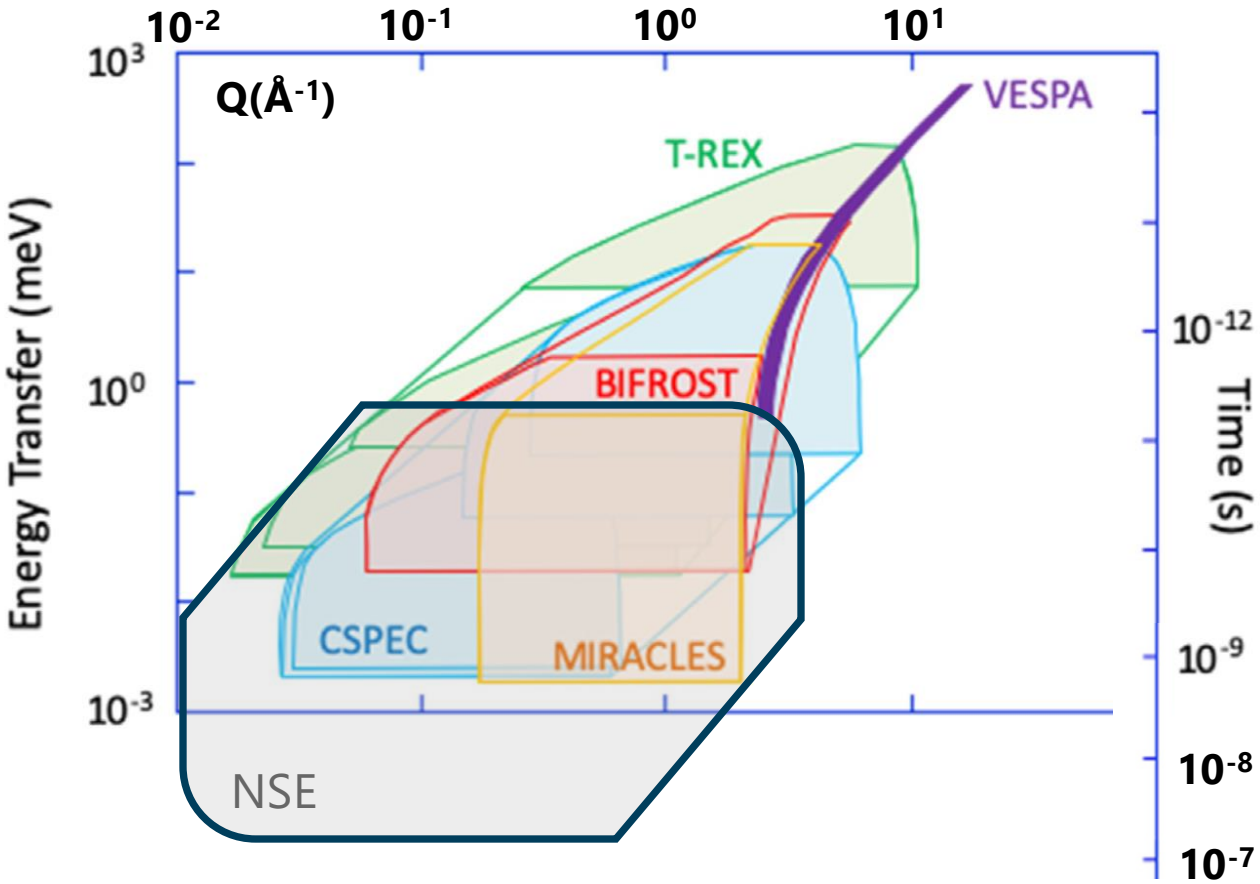


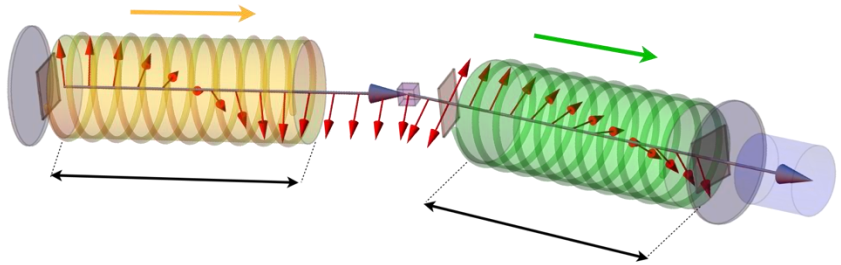
High resolution Neutron Spin Echo: New capability

A **community proposal** with the participation of the international scientific community, including experts from ILL, JCNS, and LLB, coordinated by a core group of spokepersons at the ESS and Lund University.

NSE is the unique technique able to fill the gap in the energy-*Q* window of several nanometers and hundreds of nanoseconds.

By exploiting the ESS source:

- Simultaneous use of broad wavelength band
- Novel broader *Q* range and real-time or parameter scans
- Favourable relaxation-resolution match at different wavelengths
- Better post-selected and high *Q* resolution

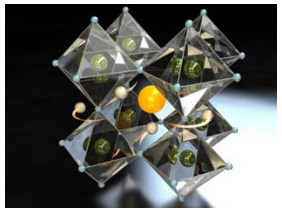


The instrument will be optimised to address the scientific needs in soft matter, life science and liquids and glasses, as well as energy materials, hard condensed matter and magnetism. This will include the use of different sample environments and polarisation analysis.

We need NSE to…

design smart pharmaceuticals

DOI: 10.1039/D2NR00882C

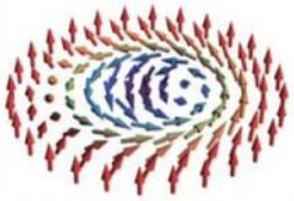


bring fuel cells into everyday life

https://doi.org/10.1021/acs.macromol.5c01060

improve vehicle safety

https://doi.org/10.1021/acs.macromol.5c01060



develop spintronics

http://dx.doi.org/10.1038/s41567-023-02120-5

…and many more!

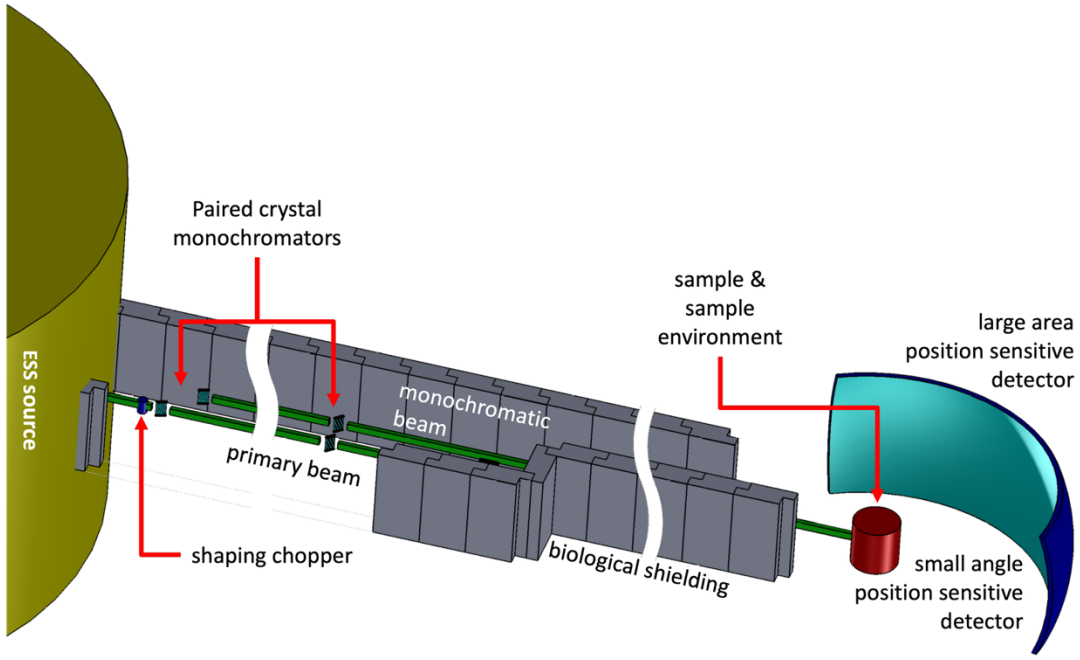
Short, low divergence, thermal spectrometer: New capability

Andrea Orecchini and Francesco Sacchetti, University of Perugia; Marco Zanatta, University of Trento; Daria Noferini and Mohamed Aouane, ESS

- Short instrument (ca 30 m)
- High flux at the sample position
- Low divergence
- Low background (primary and monochromatic beams are physically decupled)
- Multiple wavelengths (1, 2, 4 Å)
- Large sample area → flexible sample environments (pressure, in-situ, high magnetic field, combined characterisations…)
- Polarisation analysis option

Focus on small angle (ca 1-10º) with wide angle option

Multipurpose instrument: liquids and glasses, atomic dynamics in crystals, magnetic and quantum systems, biological systems, soft matter…

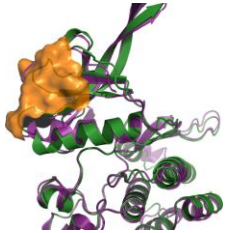


Examples of possible applications:

Materials for next-generation nuclear energy
https://doi.org/10.1080/23746149.2021.1871862

Advanced materials for quantum computation
https://doi.org/10.1103/PhysRevResearch.1.033121

Folding dynamics of proteins
https://doi.org/10.1021/jacsau.4c00109



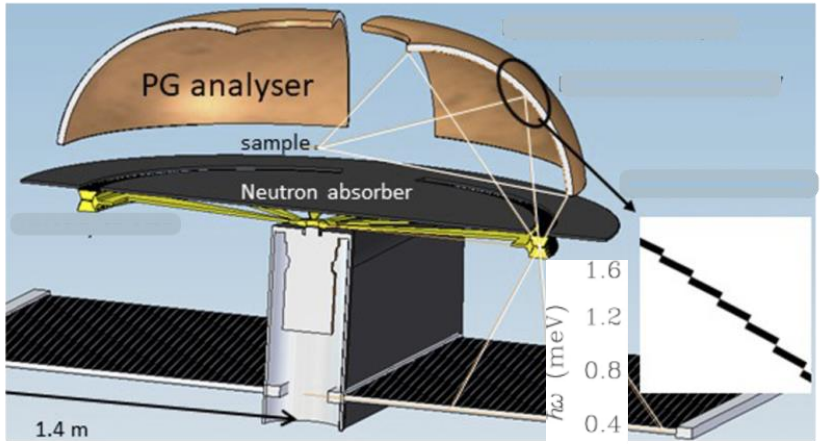
Indirect geometry spectrometers: Capacity & novelty

NJORD (N) (162 m): Medium-resolution indirect spectrometer with polarization analysis and out-of-plane coverage (ΔE < 15 meV, δE < 0.1 meV)

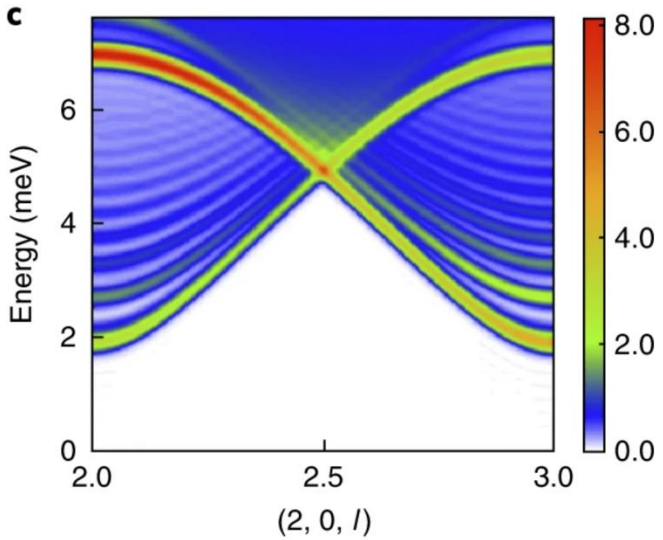
REMORA (R) (78 m): Direct geometry symbiotic spectrometer, utilizing neutron excess in the chopper system. (ΔE < 18 meV, δE < 0.5 meV, ΔE < 4 meV, δE < 0.05 meV)

Science case: *Quantum magnetism, superconductivity, diffusion dynamics in biological systems and ionic conductors, functional magnets for information technology.*

Indirect geometry backend (R. I. Bewley, NIM-A (2021))

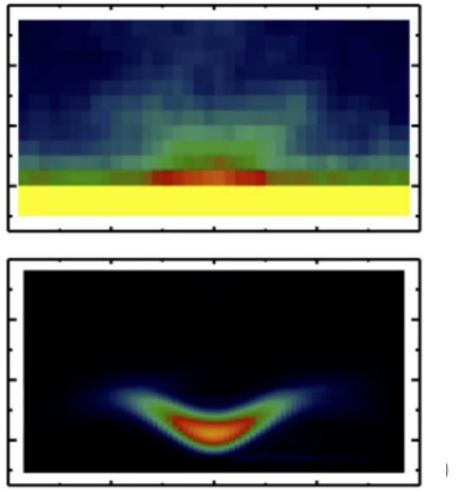


Topological quantum dynamics



Q. Fauvre, *Nature Phys* **14**, 716–722 (2018).

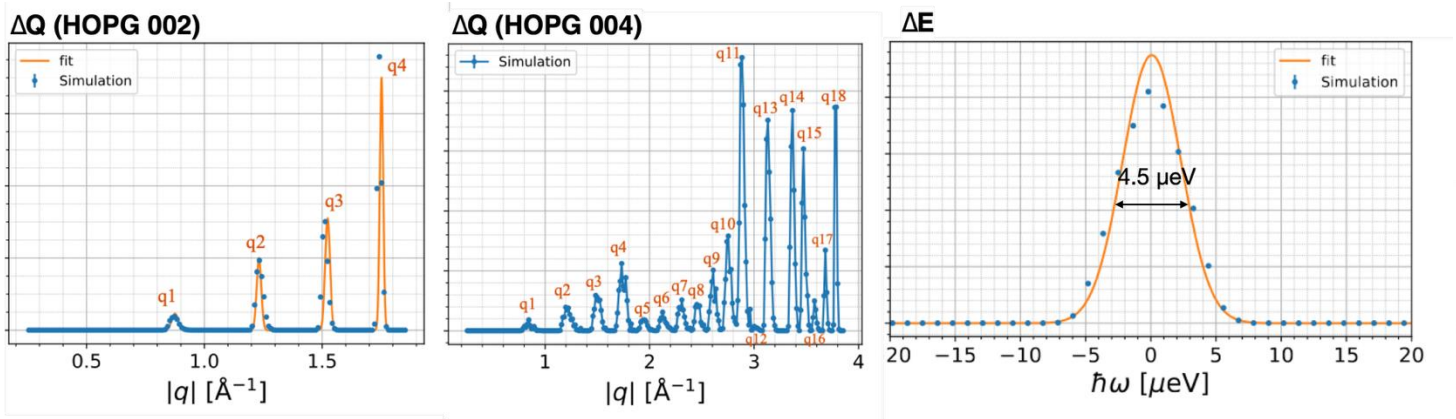
Pressure induced quantum criticality

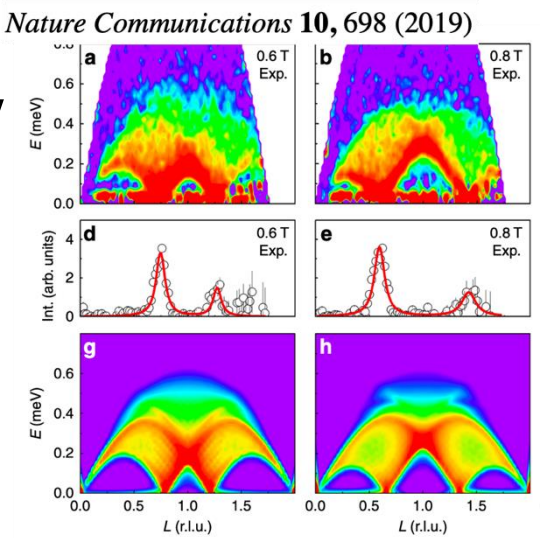


T. Hong, *Nat Commun* **13**, 3073 (2022).

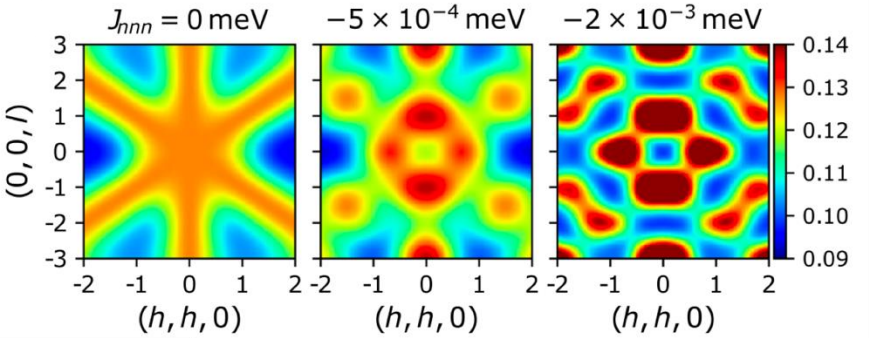
Indirect geometry spectrometer: New capability.

KVASIR (160 m): Indirect TOF optimised for ESS pulse: **E range: +/- 0.5 - 2 meV**
Backscattering HOPG (0 0 2)/(0 0 4): **ΔE : 4 μeV / 65 μeV**
Large sample environment on 1cm^3 (15 T magnet) / PA : Affects **ΔQ = 0.03 Å-1**
Aspherical analyser crystal geometry to simultaneously **optimise ΔE and ΔQ**





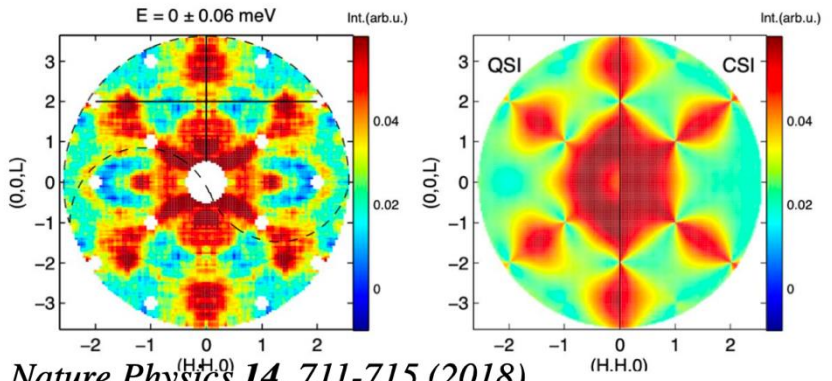
Science case: *Quantum topology*
Emergent states
Quantum magnetism
Superconductivity
Functional materials: Solid-State conductors
Hybrid perovskites



Bhardwaj, A.*et al.npj Quantum Mater.* **7**, 51 (2022)

KVASIR: A backscattering neutron spectrometer for hard condensed matter at ESS

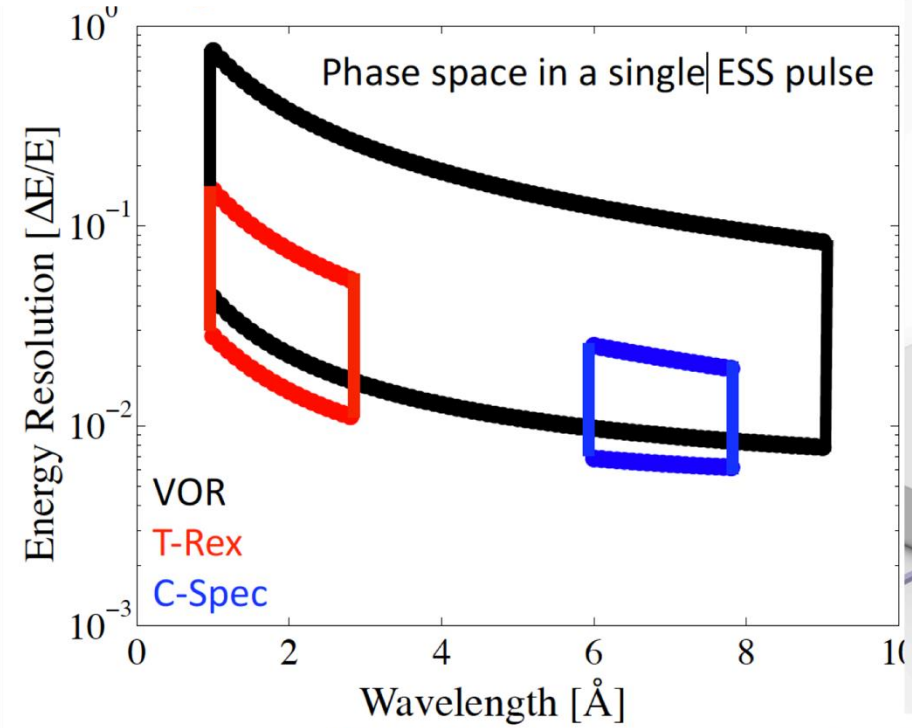
Amalie F. Davidsen,[1,2] Kristine M. L. Krighaar,[1] Pascale P. Deen,[3,1] and Kim Lefmann[1]

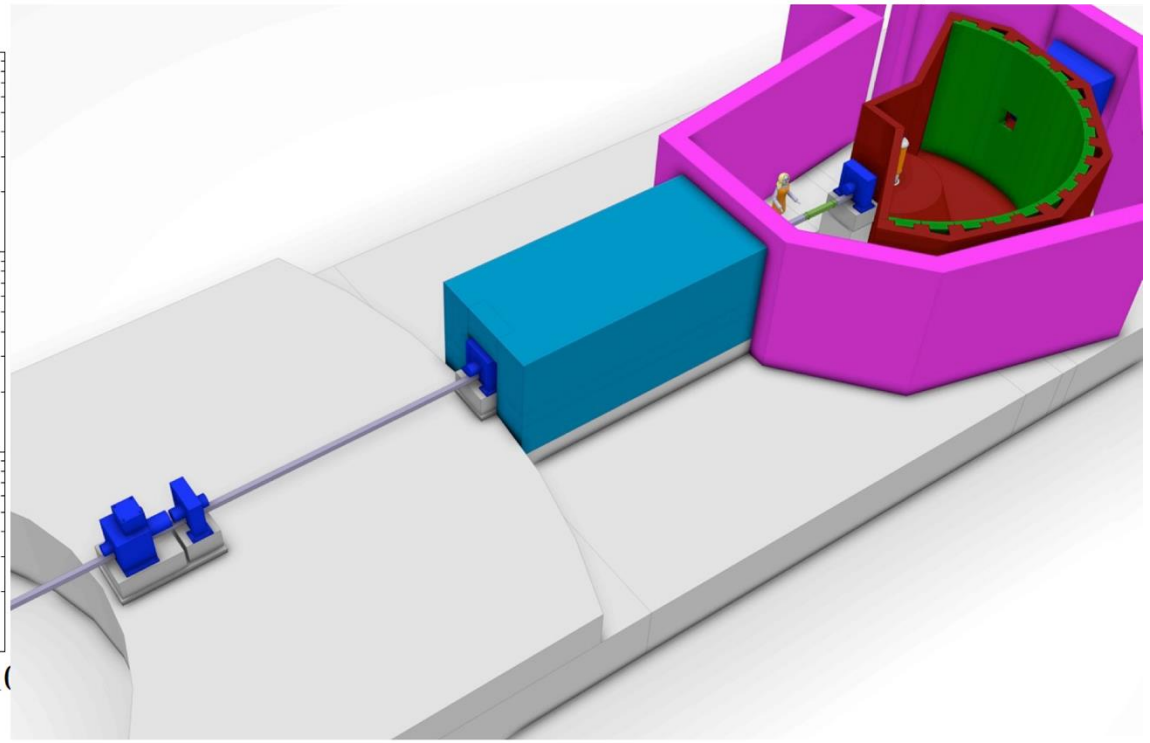


Nature Physics **14**, 711-715 (2018)

Direct geometry spectrometer: New capability and capacity

VOR - Versatile Optimal Resolution chopper spectrometer





- 10 - 100 times current day TOF spectrometer flux on sample
- In conjunction with novel chopper configuration will:

"will bring the entire field of neutron scattering forward."

(STAP Report April 2014.)

Choppers to optimise the repetition rate multiplication technique on a direct geometry neutron chopper spectrometer.

A. Vickery
Technical University of Denmark, Department of Physics, Fysikvej, DK-2800 Kgs. Lyngby, Denmark
Niels Bohr Institute, University of Copenhagen, Universitetsparken 5, DK-2100 Copenhagen, Denmark

P. P. Deen
European Spallation Source ESS AB, Box 176, 22100 Lund, Sweden
Niels Bohr Institute, University of Copenhagen, Universitetsparken 5, DK-2100 Copenhagen, Denmark
(Dated: October 22, 2014)

BEYOND NEUTRON SCATTERING:

Fundamental Nuclear and Particle Physics workshop Lund University 15-17th January

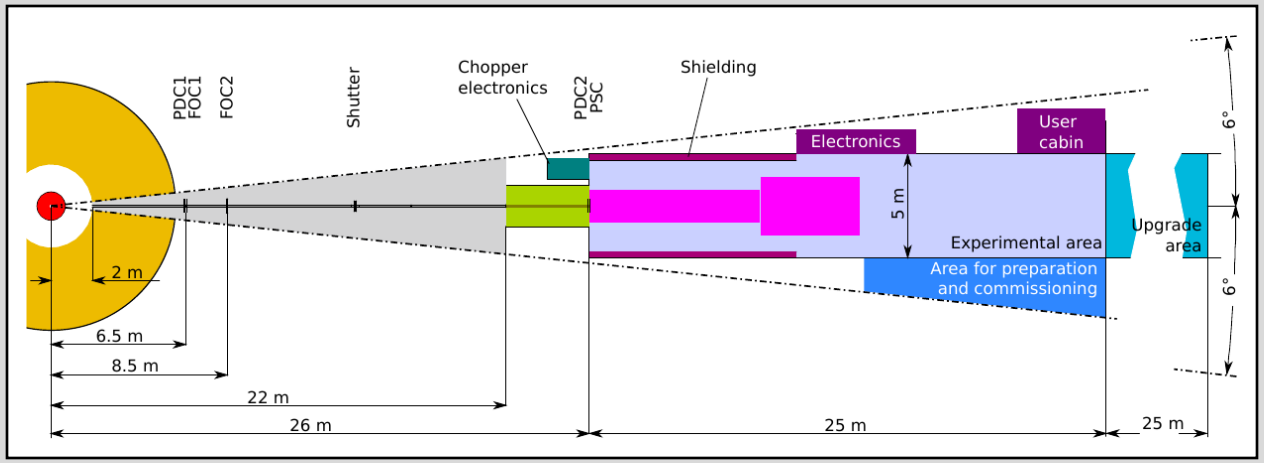
- More than one hundred participants from all around the world gathered and discussed proposals for ESS that could be included in the roadmap for future activities.
- An opportunity to produce an inventory of current ideas in the field, to define what is impactful, what is relevant for ESS, what is feasible.
- **A report has been produced and submitted to the European Strategy for Particle Physics (ESPP) that will contribute a first step to make a strong case for funding next wave of instruments and activities in this very active field of science.**

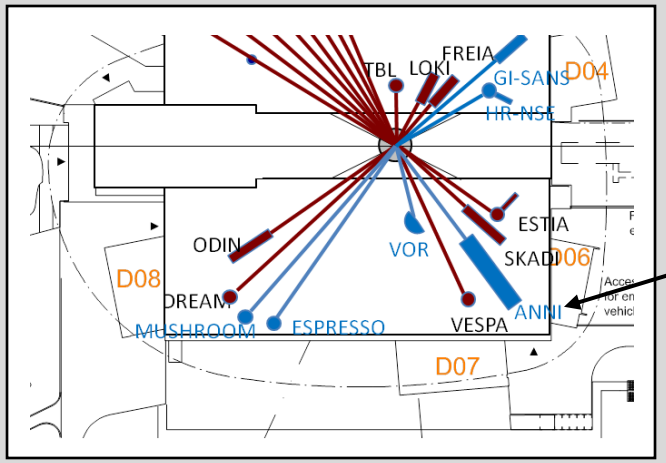
ANNI versatile pulsed cold neutron beam facility for particle physics at ESS

- Short instrument to maximally exploit ESS pulse structure: **lowest systematics at full statistics**
- Guide design suppresses fast neutrons and gammas from target monolith: **clean beam**
- Optimized for *Flux density* ⊗ *Integral flux* ⊗ *Divergence* to **enable many experiments**:

Neutron beta-decay, Electric Dipole Moment, Electric charge, Hardonic weak interaction,
Nuclear Physics, CRES, UCN production, Exotic searches & Axions, HiBeam and nnbar-R&D etc.

Phys. Rep. 1023, 1 (2023)





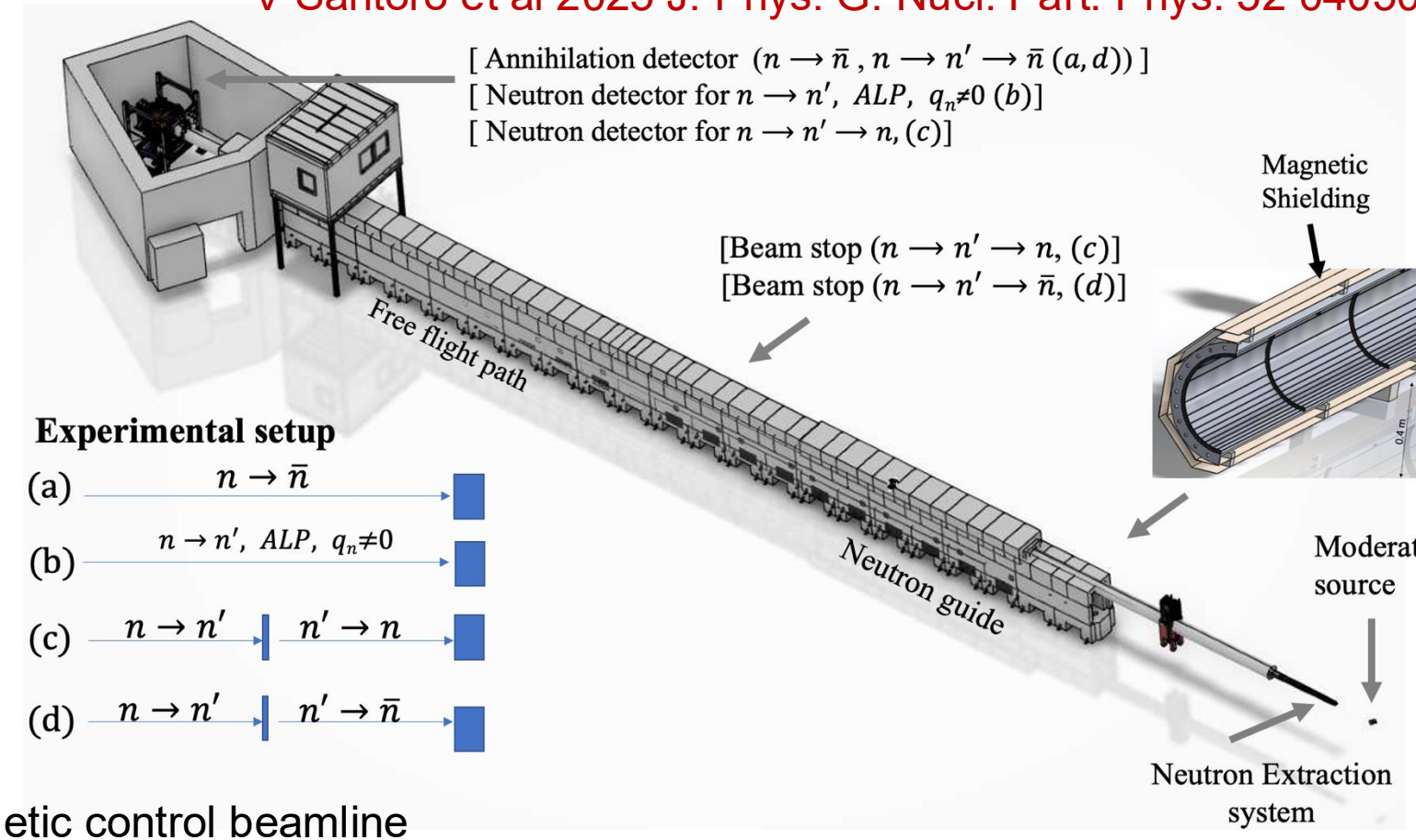
ideal position at beam port E5

Contact: Florian Piegsa (Bern) & Torsten Soldner (ILL)

EPJ Web of Conf. 219, 10003 (2019)

HIBEAM High Intensity beam extraction and measurements

V Santoro et al 2025 J. Phys. G: Nucl. Part. Phys. 52 040501



Generic magnetic control beamline

- Searches for neutron oscillation
- Searches for axion-like particles
- Electromagnetic properties of the neutrons (EDM and electric charge) and other searches

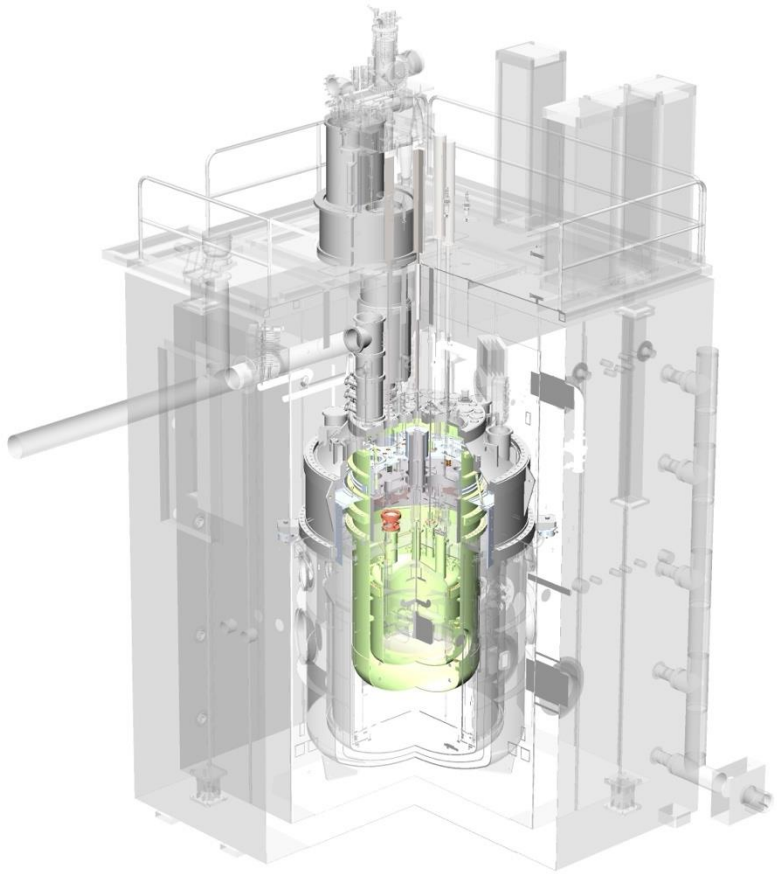
25 Institutions involved from 7 countries

CDR already completed, TDR ready by the end of this year

Search for non Electric Dipole Moment of neutrons

U.S./European Cryogenic Neutron EDM Initiative

- A large scale cryogenic experiment to measure the neutron EDM at a sensitivity below $3 \cdot 10^{-28}$ e·cm.
- Mostly developed by US Department of Energy and National Science Foundation, but funding terminated in 2023 with construction underway.



New Effort

- Planning a sequence of preparatory demonstration measurements at ILL
- Experiment could be installed at ESS for improved precision beyond goals at Oak Ridge's Spallation Neutron Source

- Uses cryogenic techniques to improve all aspects of the experiment
- Production of ultra-cold neutrons in situ in superfluid He provides high density in measurement cell

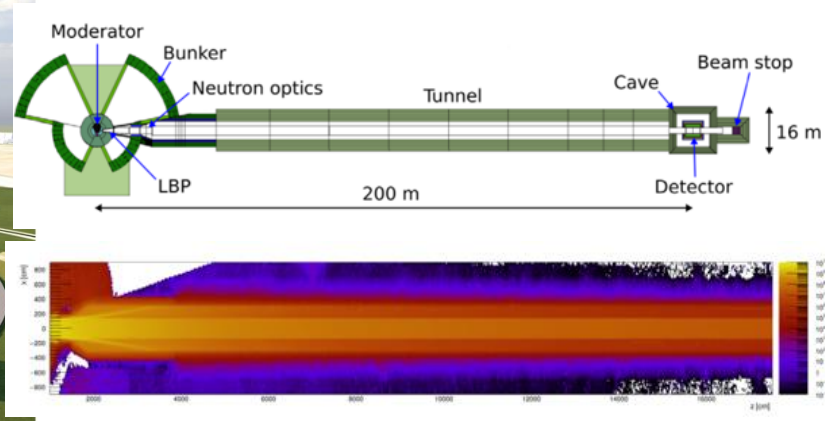
EDMs experiment can be installed at ANNI or HIBEAM

NNBAR Experiment

HighNESS conceptual design report: Volume II. The NNBAR experiment. Cite

Article type: Research Article

Authors: Santoro, V.[a; b; *] | Abou El Kheir, O.[c] | Acharya, D.[c] | Akhyani, M.[d] | Andersen, K.H.[e] | Barrow, J.[f; g] | Bentley, P.[a] | Bernasconi, M.[c] | Bertelsen, M.[a] | Beßler, Y.[h] | Bianchi, A.[a] | Brooijmans, G.[i] | Broussard, L.[e] | Brys, T.[a] | Busi, M.[j] | Campi, D.[c] | Chambon, A.[k] | Chen, J.[h] | Czamler, V.[l] | Deen, P.[a] | DiJulio, D.D.[a] | Dian, E.[m; n] | Draskovits, L.[n] | Dunne, K.[o] | El Barbari, M.[h] | Ferreira, M.J.[a] | Fierlinger, P.[p] | Fröst, V.T.[q] | Folsom, B.T.[a; c] | Friman-Gayer, U.[a] | Gaye, A.[a] | Gorini, G.[c] | Gustafsson, A.[q] | Gutberlet, T.[h] | Happe, C.[h] | Han, X.[r; s; t] | Hartl, M.[a] | Holl, M.[a] | Jackson, A.[a] | Kemp, E.[u] | Kamyshkov, Y.[v] | Kittelmann, T.[a] | Klinkby, E.B.[k] | Kolevatov, R.[w] | Laporte, S.I.[c] | Lauritzen, B.[k] | Lejon, W.[o] | Linander, R.[a] | Lindroos, M.[a] | Marko, M.[n] | Márquez Damián, J.I.[a] | McClanahan, T.C.[e] | Meirose, B.[o; b] | Mezei, F.[m] | Michel, K.[a] | Milstead, D.[o] | Muhrer, G.[a] | Nepomuceno, A.[x] | Neshvizhevsky, V.[l] | Nilsson, T.[y] | Odén, U.[a] | Plivelic, T.[z] | Ramic, K.[a] | Rataj, B.[a; b] | Remec, I.[e] | Rizzi, N.[k] | Rogers, J.[v] | Rosenthal, E.[h] | Rosta, L.[n] | Rücker, U.[h] | Samothrakitis, S.[j] | Schreyer, A.[aa] | Selknaes, J.R.[a] | Shuai, H.[m] | Silverstein, S.[o] | Snow, W.M.[ab] | Strobl, M.[j] | Strothmann, M.[h] | Takibayev, A.[a] | Wagner, R.[l] | Willendrup, P.[a; k] | Xu, S.[a] | Yiu, S.C.[o] | Yngwe, L.[q] | Young, A.R.[ac] | Wolke, M.[ad] | Zakalek, P.[h] | Zavorka, L.[e] | Zanini, L.[a] | Zimmer, O.[l]



Dedicated search for $n \to \bar{n}$

Address matter-antimatter asymmetry and explore new physics to PeV scale and beyond.

Unique potential of the ESS (large beam port, flux, length)

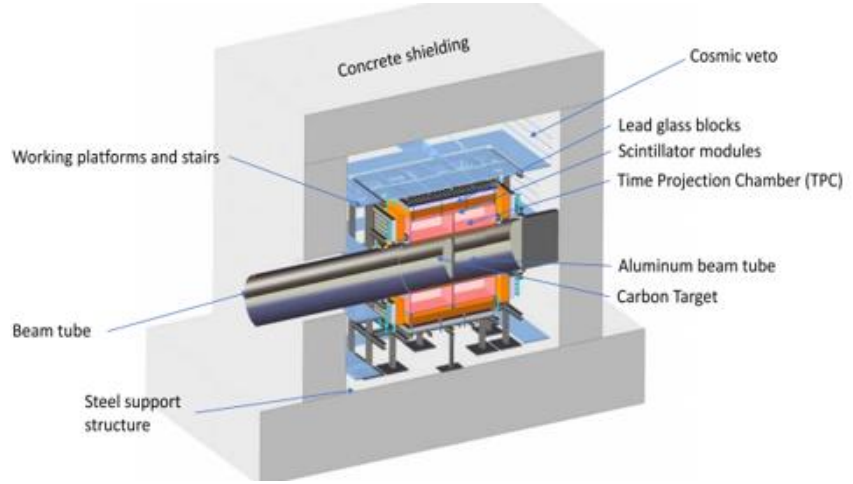
x1000 improvement in discovery sensitivity than last experiment at ILL (1990's)

Horizon 2020: 3MEuro HigNESS : NNBAR CDR

J.Neutron Res. 25 (2024) 3-4, 315-406

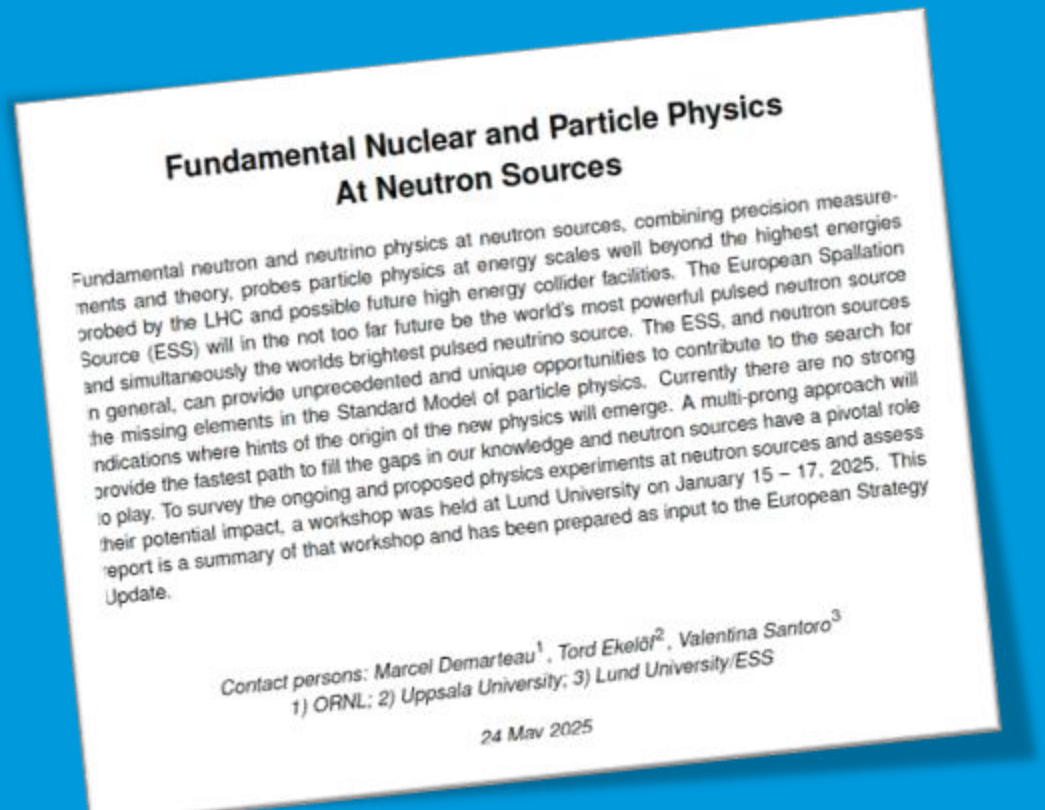
Multi-disciplinary collaboration: moderator design, neutronics, magnetics, detector design, civil engineering

~25 institutes from 7 countries.



Neutrino physics and more ....

See report for European Strategy for Particle Physics (ESPP)



Fundamental Nuclear and Particle Physics At Neutron Sources

Fundamental neutron and neutrino physics at neutron sources, combining precision measure-
ments and theory, probes particle physics at energy scales well beyond the highest energies
probed by the LHC and possible future high energy collider facilities. The European Spallation
Source (ESS) will in the not too far future be the world's most powerful pulsed neutron source
and simultaneously the worlds brightest pulsed neutrino source. The ESS, and neutron sources
in general, can provide unprecedented and unique opportunities to contribute to the search for
the missing elements in the Standard Model of particle physics. Currently there are no strong
indications where hints of the origin of the new physics will emerge. A multi-prong approach will
provide the fastest path to fill the gaps in our knowledge and neutron sources have a pivotal role
to play. To survey the ongoing and proposed physics experiments at neutron sources and assess
their potential impact, a workshop was held at Lund University on January 15 – 17, 2025. This
report is a summary of that workshop and has been prepared as input to the European Strategy
Update.

Contact persons: Marcel Demarteau[1], Tord Ekelöf[2], Valentina Santoro[3]
1) ORNL; 2) Uppsala University; 3) Lund University/ESS

24 May 2025

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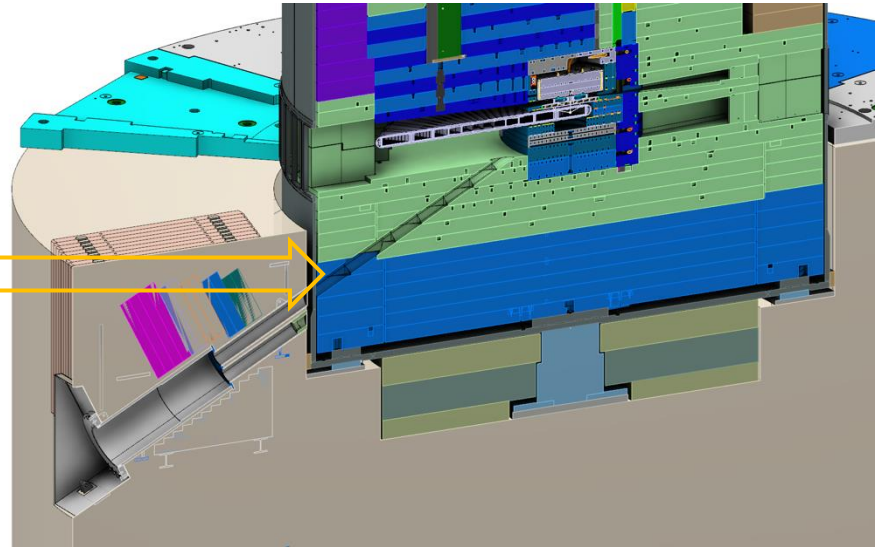
ECHIR (ESS CHip IRradiation) beamline

ESS contact pia.kinhult@ess.eu

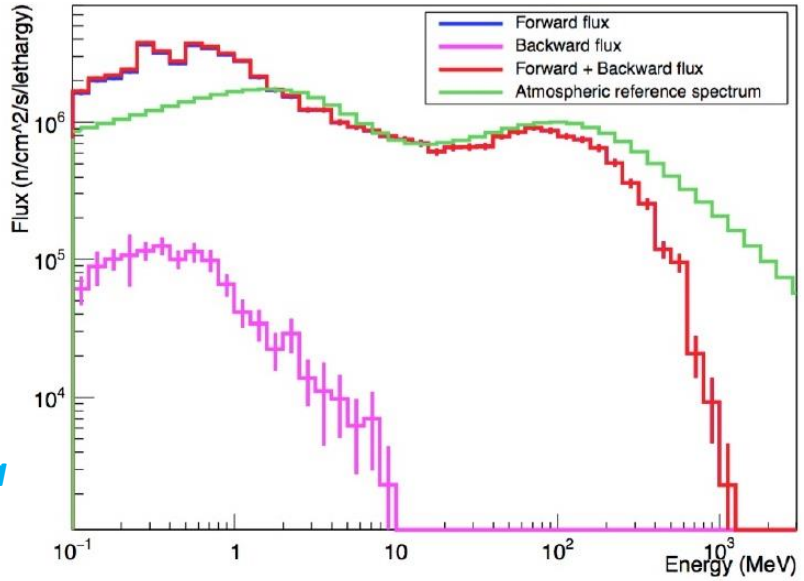
- A chip irradiation facility to study single event failure of electronic components
- In synergy with CHIPIR at ISIS.
- Higher flux than CHIPIR expected.
- Proposed by CNR in early 2010's
- Direct view of high-energy neutrons from the spallation reaction, mimicking the atmospheric spectrum originating from cosmic rays
- Strong interest from **Industry** companies to test microelectronics and power devices, and nuclear industry to test sensors.
- Interest from **academia**: Lund University (nanoelectronics); particle physics community to test detectors.

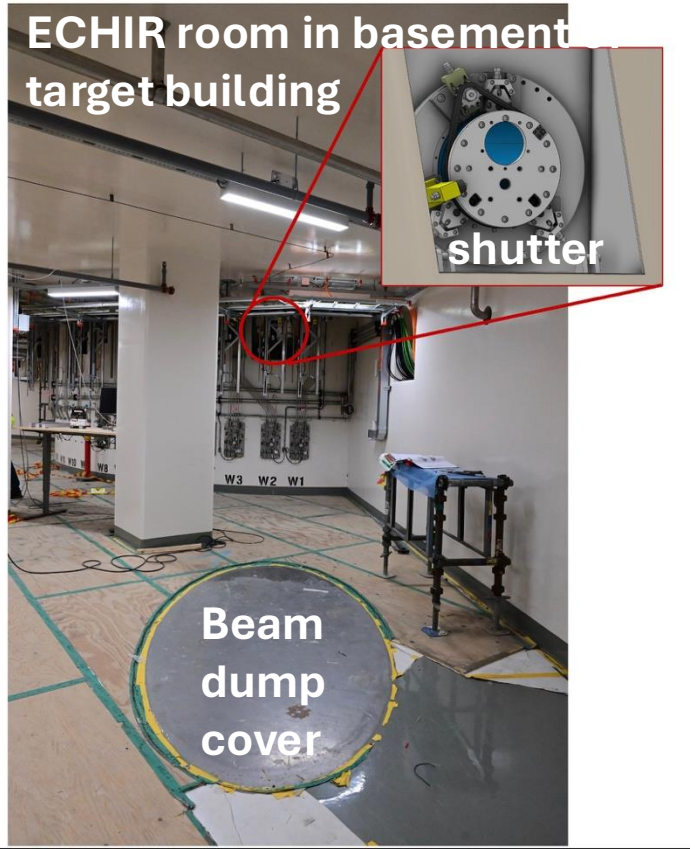
Current consortium includes: CNR, ISIS, PSI, Infineon, STMicroelectronics, Lund & Uppsala Univ.

ECHIR opening in the Target monolith shielding for direct view of the spallation neutrons



ECHIR neutron spectrum (red) compared with atmospheric spectrum (green)

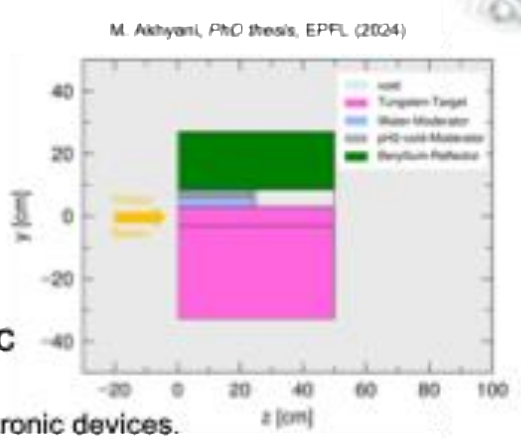


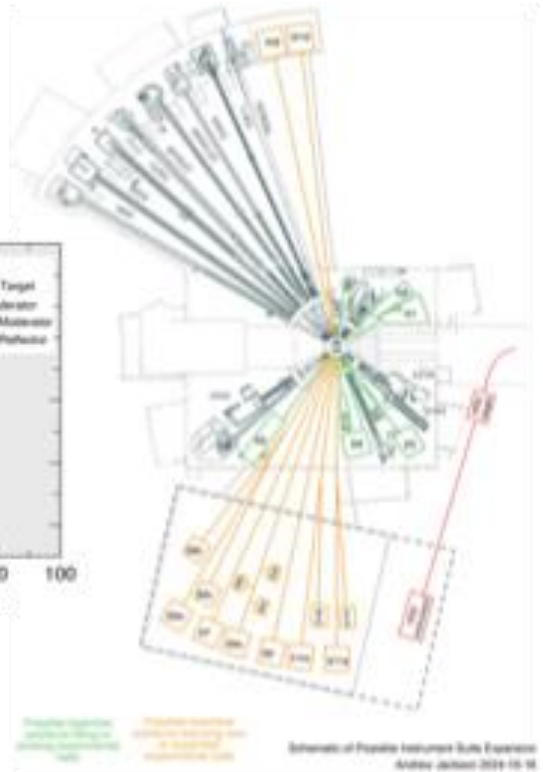


Optimized mHz source-instrument assembly for very high pulsed magnetic field experiments

Science case for very high magnetic fields:

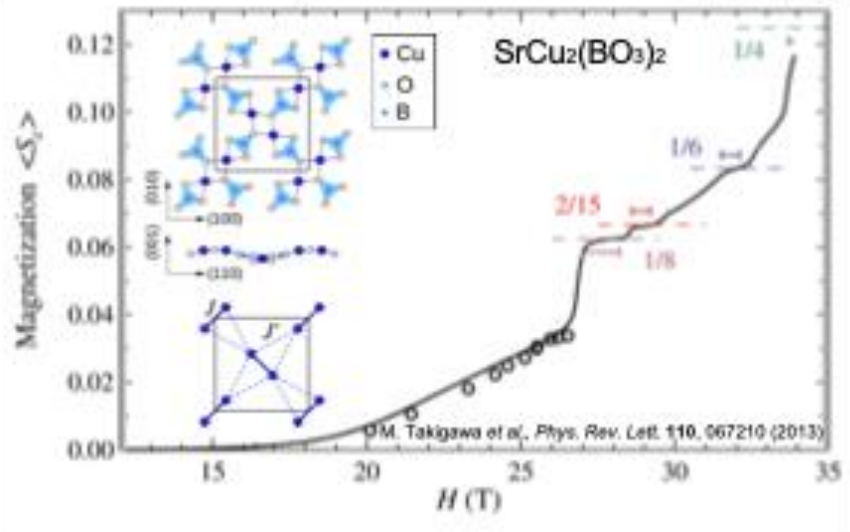
- Novel phases and transitions in quantum matter
  - New proximate orders accessible above ~20–40 T
  - Fractionalized excitations & confinement by field in quantum spin liquids
- Superconductivity exposed to pair breaking fields
  - unmask competing orders CDW/SDW, FFLO states, amplitude "Higgs" modes
- Topological magnonics & spintronics, magneto-elastic, multiferroic
  - restructure electron and magnon bands (gaps, Dirac/Weyl points, Chern phases), enabling nontrivial electron and thermal Hall responses and tunable magnonic/spintronic devices.
  - Strong B reveals spin-phonon coupling, magnetostriction, and field-switchable ferroelectric states
- Technological magnets
  - Establish predictive models for mechanisms, time-scales and control of magnetization dynamics in technologically relevant magnets
- Out-of-equilibrium studies





mHz dedicated source optimized for one instrument

- 50-60 T pulsed magnet with 10-30 minute duty cycle
- 5 proton pulses per duty cycle -> mHz source (1 signal / 4 bck)
- 10^4 less heat and radiation -> perfect target-moderator-neutronics optimization for a single instrument
- Instrument optimized for pulsed magnet
- **=> factor 20-100 better statistics than pulsed magnet on standard instrument**



Contact: Henrik M. Rønnow, EPFL

Way forward: process of selection

Oct 2025	Preliminary discussions at *Scientific and Technical Advisory Panels* and *Scientific Advisory Committee* meetings - setting up of dedicated expert committee. Proposal of a strategy for projects prioritisation (scientific impact/innovation impact/maturity of concept/timescale & resources/….)
Feb 2026	Collection and editing of all proposals Call ends beginning of February 2026 Initial presentation at *Strategy Council* *Discussion on framework for partnerships (approval of funding models…)*
Apr 2026	Discussion with dedicated expert committee and prioritisation
May 2026	Endorsement of prioritisation list by *Scientific Advisory Committee*
Jun 2026	Presentation at *ESS Council* – request of endorsement of prioritised projects
2026 - 2027	Strengthening of conceptual design of two projects
2027	**Start of detailed design of one/two projects**

https://ess.eu/instrument-roadmap

Please contact Pascale Deen, Mikhail Feygenson and Andrew Jackson, if you have ideas or want to contribute to the science case for any of the current proposals or if you have additional ones!

Or write to: instrumentroadmap@ess.eu

THE PROCESS WILL BE DRIVEN FROM ESS
WE WILL SET-UP CONSORTIA FOR EACH PROJECT AND SUBMIT WITH THE COMMUNITY OR ON BEHALF

Acknowledgements:
Raquel Costa (webinar organisation)
Sindra Petersson Årskold (call organisation)

ESS scientists, engineers, partners, advisory panels,
colleagues in the community interested in the future of ESS

Q&A

WEBINAR

ESS ROADMAP FOR FUTURE INSTRUMENTS: WAY FORWARD

Pascale Deen
Spectroscopy

Mikhail Feygenson
Imaging and Diffraction

Giovanna Fragneto
ESS Science Director

Andrew Jackson
Large Scale Structures

23 SEPTEMBER 2025
15.00 - 16.00

Additional slides

Selecting the initial suite of ESS instruments

2013 - 2015

EUROPEAN SPALLATION SOURCE

Early Success Strategy

Date 14-04-04

Guidelines from 2014 on how to build for scientific success are still relevant today!

An Early Success Strategy for ESS

Selecting Instruments and Preparing Support for Early Scientific Success

1. GUIDELINES FOR INSTRUMENT PRIORITIZATION

1.1 World-class instruments that address the needs of the bulk of the user community.

1.2 Instruments that build on the unique strengths of the ESS source.

1.3 Instruments catering to science communities with limited neutron usage today, but with clear potential to bring large scientific impact.

Selecting the initial suite of ESS instruments

2013 - 2015

Three consecutive calls for proposals, each followed by review process and decision were held: 2013, 2014, and 2015.

Ideas were developed in collaboration with the ESS team, and ESS supported the development of conceptual designs of the instrument ideas prior to submission of proposals.

Instrument concepts were then costed based on the conceptual design.

These proposals were much more detailed and much more project-mature than what we are asking for now.

To promote visionary ideas, no cost ceiling was given. Budget realities later led to rounds of descoping.

Box 1: Key steps in the selection of an instrument for construction

1. An instrument idea is conceived and proposed to ESS
2. The instrument idea is incorporated into the ESS programme
3. A conceptual design for the instrument is developed
4. An instrument proposal is submitted to ESS
5. The instrument proposal is reviewed
6. Feed-back and revisions lead to a mature instrument concept
7. ESS makes decision on instrument construction

Selecting the in

2013 - 2015

Proposals were reviewed by ESS internally (technical teams, project office, scientists), STAPs and SAC.

Based on these reviews, ESS management made a final recommendation to the ESS Steering Committee (later replaced by Council), who made the final decision.

Box 2: Contents of the instrument proposal

Based on recommendations from the Scientific Advisory Committee and the Steering Committee (April 2011), the instrument proposal shall address the following topics with respect to the proposed instrumentation:

Scientific impact:	Estimate the impact on the relevant scientific fields, analyse overlap with other instrumentation in terms of possible measurements, and relate this to the ESS science strategy.
User base and demand:	Identify the strength and future potential for the user base.
Instrument performance:	Calculate and compare the expected instrument performance to existing instruments and other potential instruments.
Strategy and uniqueness:	Position the instrument in the global instrument park, taking into account both similar instrumentation and different instrumentation that addresses similar scientific questions.
Technical maturity:	Evaluate feasibility, present risk-management strategy, specify key components, and provide technical specifications.
Costing:	Include complete costing specifications.

A more detailed template for instrument proposals will be made available.

Proposals 2013-2015

2013 instrument proposal round		
Compact SANS	SANS optimised for biological systems in solution	Rejected
LOKI	Broadband SANS	Approved
NMX	Macromolecular crystallography	Approved
ODIN	General-purpose imaging	Approved
2014 instrument proposal round		
BEER	Engineering materials diffractometer	Approved
Compact SANS	SANS optimised for biological systems in solution	Rejected
CSPEC	Cold chopper spectrometer	Approved
BIFROST	Extreme-conditions crystal-analyser spectrometer	Approved
DREAM	General-purpose bispectral powder diffractometer	Approved
ESSENSE	High-resolution superconducting conventional spin-echo	Rejected
ESTIA	Vertical-sample focusing reflectometer	Approved
FREIA	Horizontal-sample reflectometer optimised for fast kinetics	Approved
HEIMDAL	Hybrid powder diffractometer for in-situ studies	Approved
HOD	Crystal-monochromator diffractometer for hydrogenous systems	Rejected
SKADI	High-resolution SANS	Approved
Tempus Fugit	Rotating-crystal monochromator spectrometer	Rejected
T-REX	Bispectral chopper spectrometer	Rejected
THOR	General-purpose horizontal-sample reflectometer	Rejected
VERITAS	General-purpose vertical-sample reflectometer	Rejected
VOR	Wide-bandwidth chopper spectrometer	Approved
2015 instrument proposal round		
ANNI	Cold-neutron particle-physics beamline	Rejected
ESPRESSO	High-pressure diffractometer	Rejected
ESSENSE	High-resolution superconducting conventional spin-echo	Rejected
HERITAGE	General-purpose horizontal-sample reflectometer	Rejected
HOD	Crystal-monochromator diffractometer for hydrogenous systems	Rejected
MAGIC	Single-crystal diffractometer for magnetism	Approved
MIRACLES	High-resolution backscattering spectrometer	Approved
RESPECT	High-resolution longitudinal resonant spin-echo	Rejected
T-REX	Bispectral chopper spectrometer	Approved
VESPA	Vibrational spectroscopy	Approved

THE ESS INSTRUMENT SUITE – A CAPABILITY GAP ANALYSIS

Ken Andersen, Malcolm Guthrie, Hanna Wacklin-Knecht, Andrew Jackson, Werner Schweika, Pascale Deen, Alex Holmes, Rasmus Toft-Petersen, Arno Hiess, Jonathan Taylor, Oliver Kirstein, Sindra Petersson Årsköld, Shane Kennedy, and Andreas Schreyer

The list above covers all instrument proposals submitted in the three ESS instrument proposal rounds. In addition, the following instrument concepts were studied as part of the ESS Design Update, or submitted as Expressions of Interest or Letters of Intent:

- Small-sample SANS
- Horizontal focusing reflectometer
- Extreme environments beamline
- Thermal powder diffractometer
- Bispectral chopper spectrometer
- Wide-angle spin-echo
- Chip-irradiation facility
- n-nbar experiment
- UCN facility

Complement to new proposals:

Neutron Electric Dipole Moment

D. Beck (Illinois), F. Piegsa (Bern)

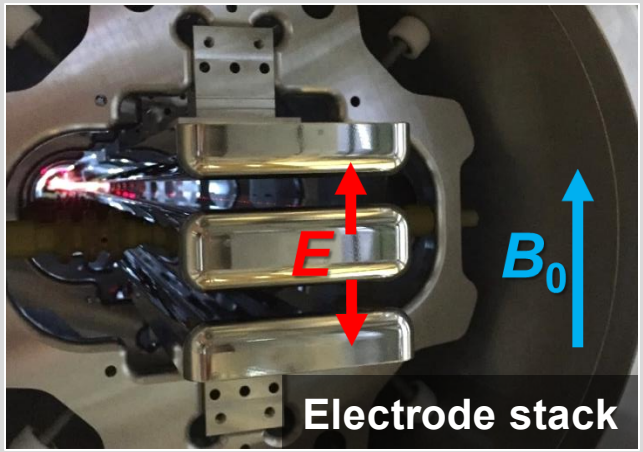
- Current limit: $|d_n| < 1.8 \times 10^{-26}$ e·cm limits beyond SM physics; sources of CP violation
- Complementary methods to measure with cold/ultracold neutrons

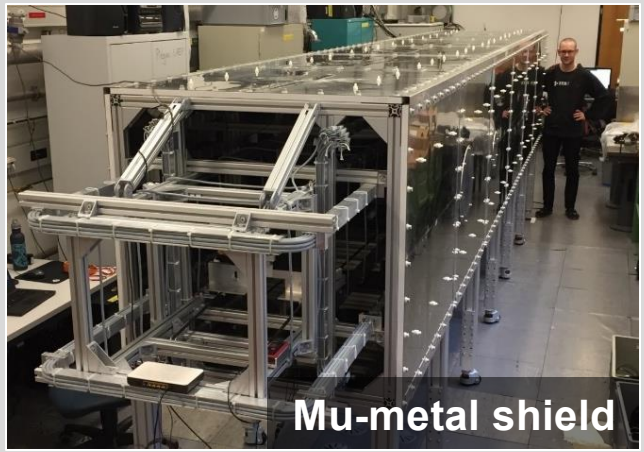
- Cold neutrons: Ramsey measurement with time-of-flight in beam
  - Very high flux compensates for short interaction time, intended for ANNI beam line
  - Complementary to UCN-type experiments: with different systematics accessible via ESS pulse structure
  - Prototype successfully operated at PSI and ILL, concluded with a Dark Matter search

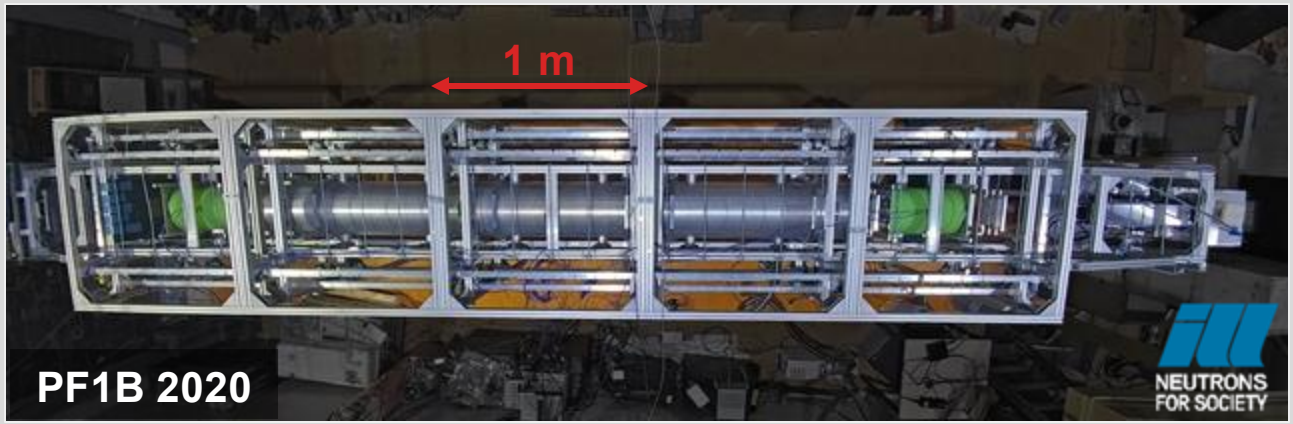
- Ultracold neutrons: next generation measurement in situ
  - Produce and measure UCN in same superfluid He volume
  - High UCN densities (demonstrated in SuperSUN at ILL), long storage times > τ_n, higher electric fields
  - Possible to measure precession in real time with polarized ^{3}He in the superfluid
    - Other detection possibilities lining walls of production/measurement volume
  - Additional systematics tools possible, e.g. free induction decay vs. spin dressing

- High cold neutron flux from ESS essential for these experiments

Beam EDM



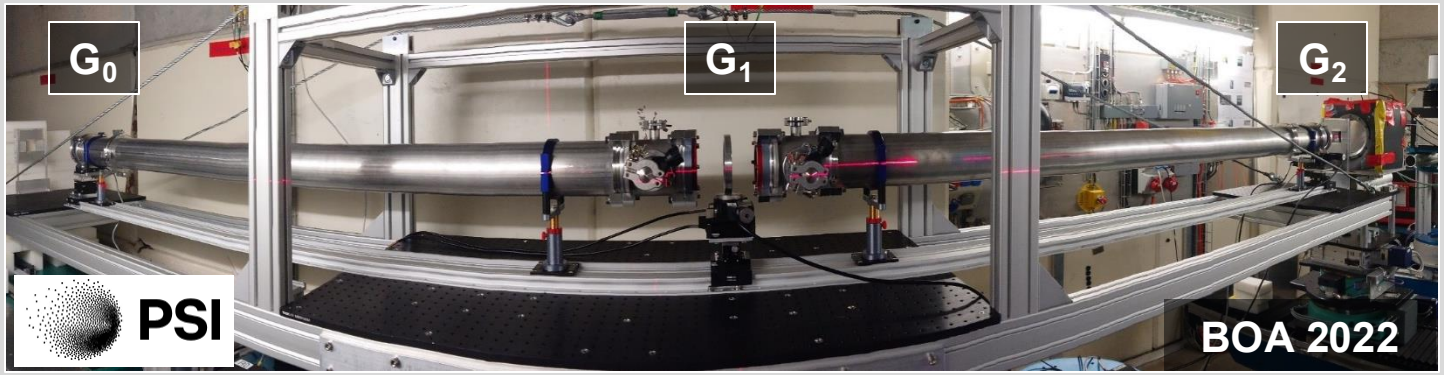


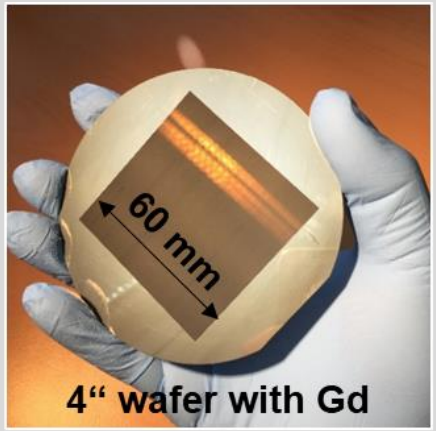


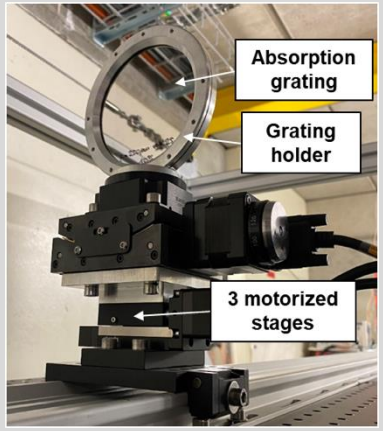
- New complimentary neutron EDM search fully exploiting the pulsed beam
- Project based in Bern with proof-of-principle experiments at PSI and ILL
- Published Dark Matter search analysis *
- Full-scale experiment intended for ANNI at ESS, competitive to UCN experiments

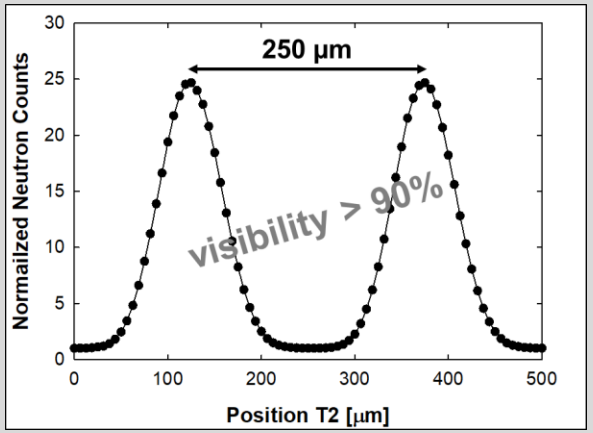
Piegsa, *PRC* 88, 045502 (2013)
Chanel et al., *EPJ Conf.* 219, 02004 (2019)
* Schulthess et al., *PRL* 129, 191801 (2022)

QNeutron









- Neutron Talbot-Lau interferometry using absorption gratings
- Successful proof-of-principle phase with experiments at PSI and ILL with first charge measurement *
- Goal: measure the neutron electric charge with improved sensitivity at ANNI at ESS

Piegsa, *PRC* 98, 045503 (2018)
* Persoz, *PhD Thesis Bern* (2024)

Team composition for

NJORD & REMORA:

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Greg Tucker (ESS/DMSC)
Mohamed Aouane (ESS)
Ellen Fogh (TUM)
Nicolai Lindaa Amin (DTU)
Robert Georgii (TUM)
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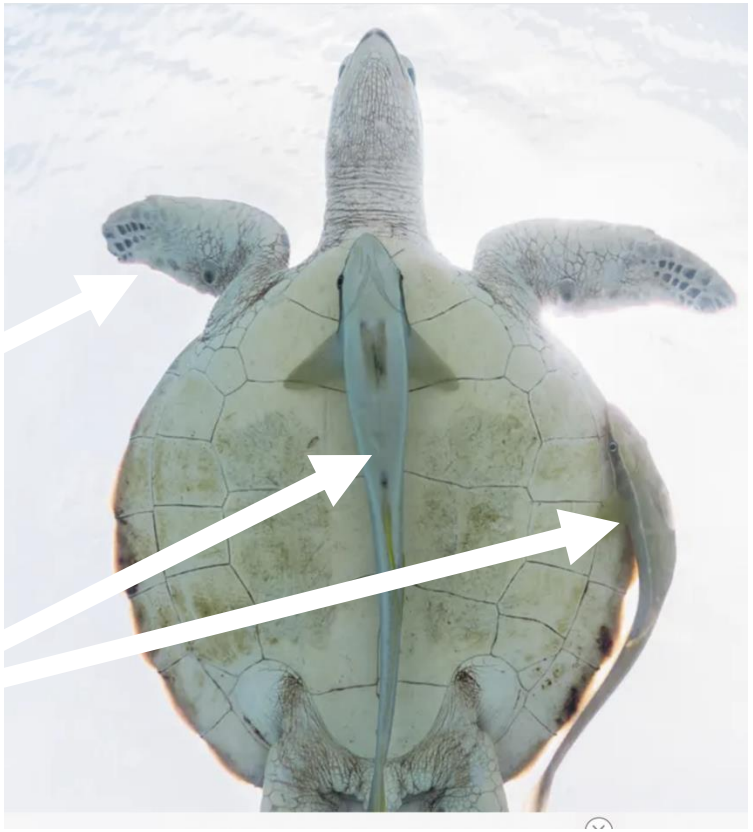
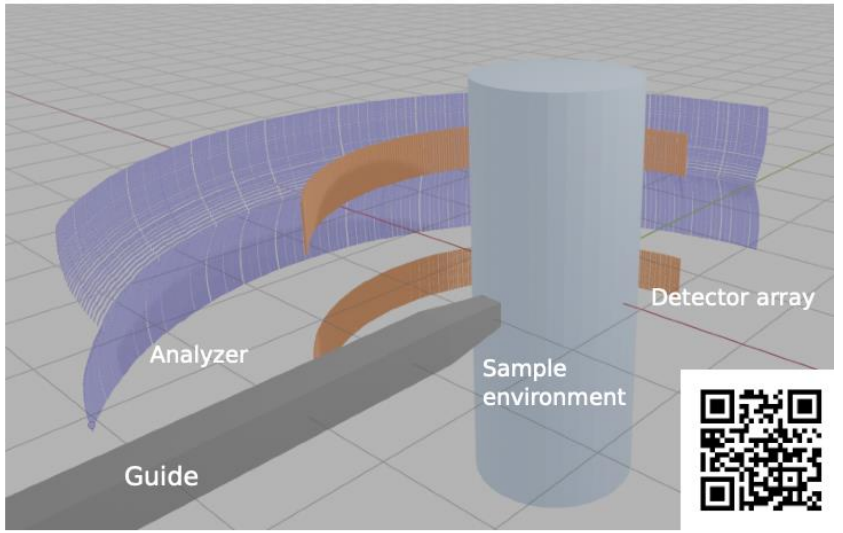


NJORD

REMORA

KVASIR:

Pascale Deen (ESS & KU)
Kim Lefmann (KU)
Amalie Davidsen (KU)
Kristine Krighaar (KU)
Sylvain Petit (LLB)



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SOURCE