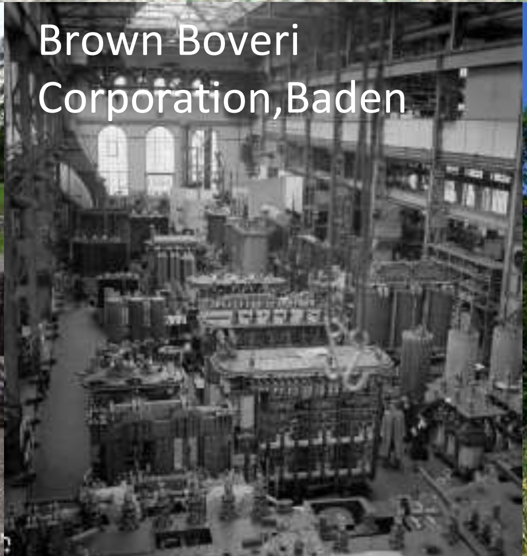
Artur Glavic, Laboratory for Neutron and Muon Instrumentation, PSI
for Michel Kenzelmann, Laboratory for Neutron Scattering & Imaging, PSI

Neutron Scattering at the Swiss Neutron Spallation Source SINQ

ICANS, Dongguan, 29 October – 3 November 2023


Paul Scherrer Institut
SwissFEL
SLS
SINQ
SμS

Paul Scherrer Institut in Aargau, Switzerland



Paul Scherrer Institute in numbers

Where Science meets Society

Overall staff 2200 (1/3 externally financed)

310 Phd students, 100 technical students

Typically:

4800 users/year

1300 publications/year

5800 patients/year

The proton accelerator and SINQ

Pre-
cyclotron
72MeV

Cockroft-
Walton, 12 MeV

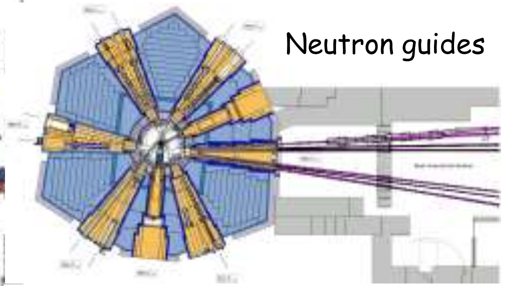
Main cyclotron 590MeV

590MeV
~2 mA
50MHz

SINQ, 590 MeV
~1.3 mA on target

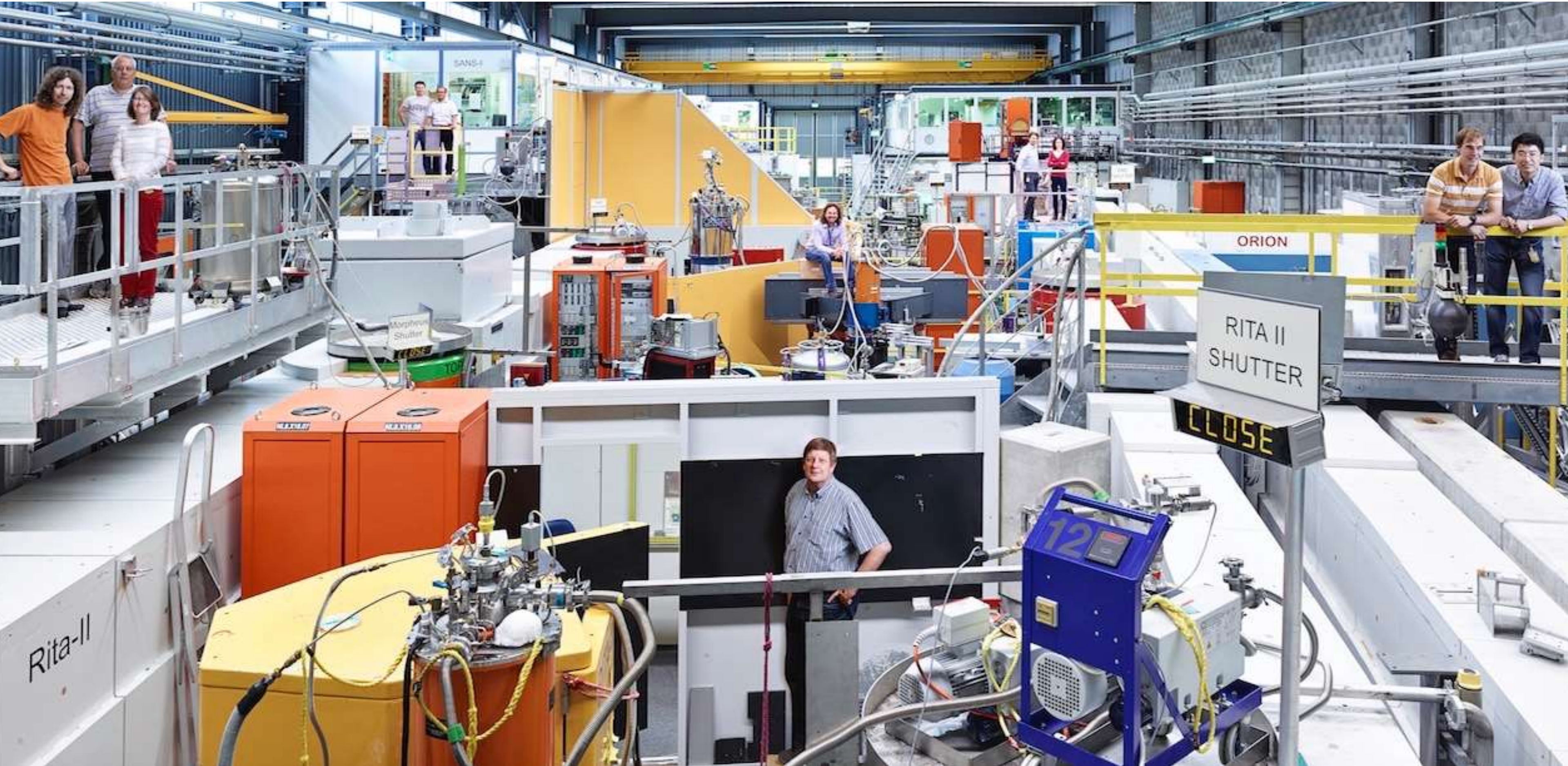
Muon instruments

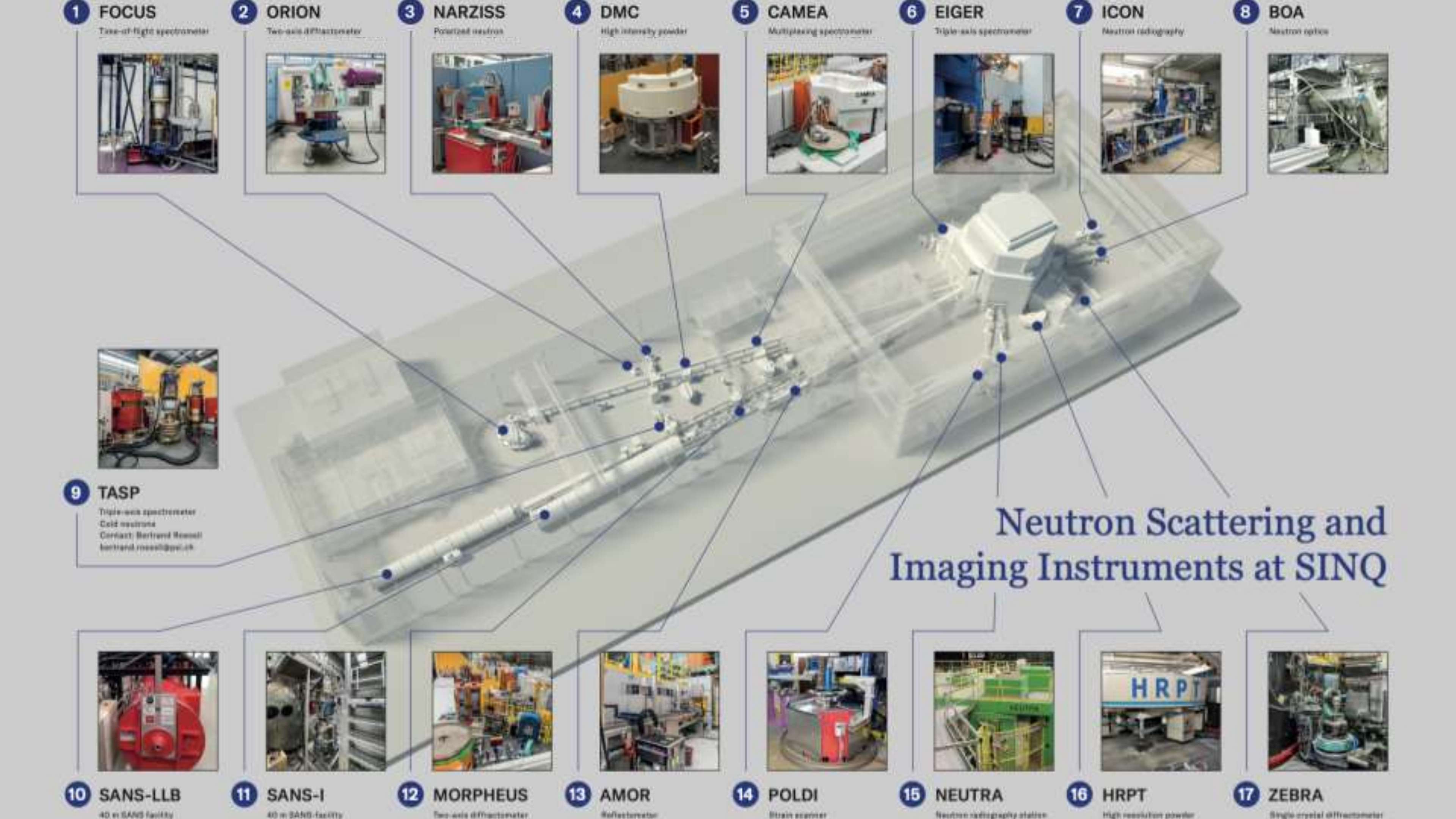
Neutron guides



PAUL SCHERRER INSTITUT PSI

Swiss Spallation Neutron Source SINQ

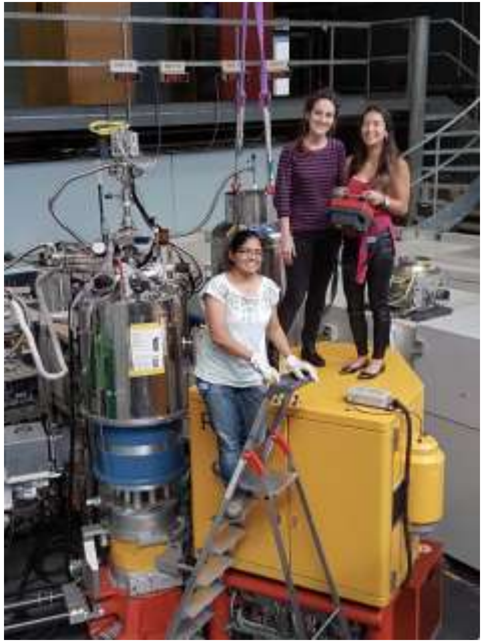




Neutron Scattering and Imaging Instruments at SINQ
1 FOCUS
Time-of-flight spectrometer
2 ORION
Two-axis diffractometer
3 NARZISS
Polarized neutron
4 DMC
High intensity powder
5 CAMEA
Multiplexing spectrometer
6 EIGER
Triple-axis spectrometer
7 ICON
Neutron radiography
8 BOA
Neutron optics
9 TASP
Triple-axis spectrometer
Cold neutrons
Contact: Bertrand Roessli
bertrand.roessli@psi.ch
10 SANS-LLB
40 m SANS facility
11 SANS-I
40 m SANS-facility
12 MORPHEUS
Two-axis diffractometer
13 AMOR
Reflectometer
14 POLDI
Strain scanner
15 NEUTRA
Neutron radiography station
16 HRPT
High resolution powder
17 ZEBRA
Single crystal diffractometer

Science program at SINQ

- Team of about 30 permanent scientists runs user program at >11 instruments (~450 user visits/year)
- 6 additional instruments for in-house use or being upgraded
- Fundamental and applied in-house research with PhD students and postdocs
- Development of neutron instrumentation
- Contribution to design of 5 instruments at ESS
- Organization of workshops/conferences



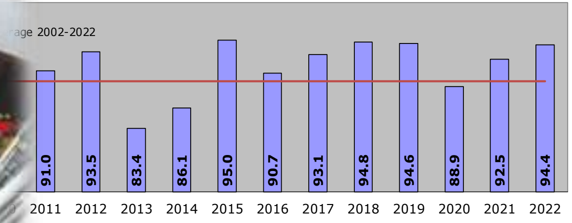
PAUL SCHERRER INSTITUT PSI

SINQ operations in 2022 and 2023

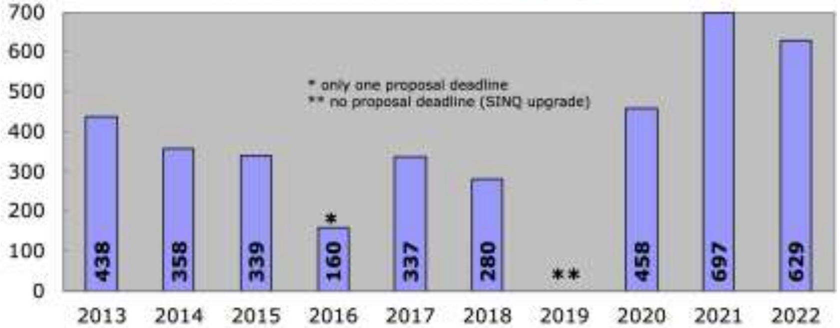
- In 2022: SINQ ran from early May through 19 December with 10.5 user instruments (early shutdown because of high prices on energy spot market)
- In 2023: Start up of SINQ on 11 May (8 days early to support the ESA Ariane 5/6 programs) and scheduled to run through Christmas with >11 user instruments
- Cold neutron diffractometer DMC now in regular user service
- SANS-LLB and reflectometer AMOR in friendly user access mode
- Upgrade POLDI and NEUTRA ongoing

SINQ user program in 2022

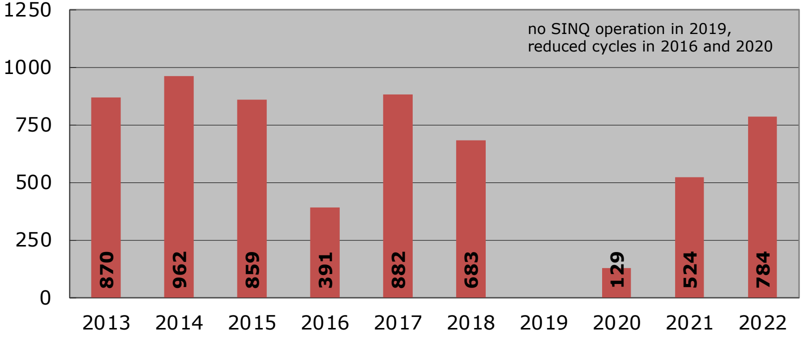
availability proton accelerator HIPA in %



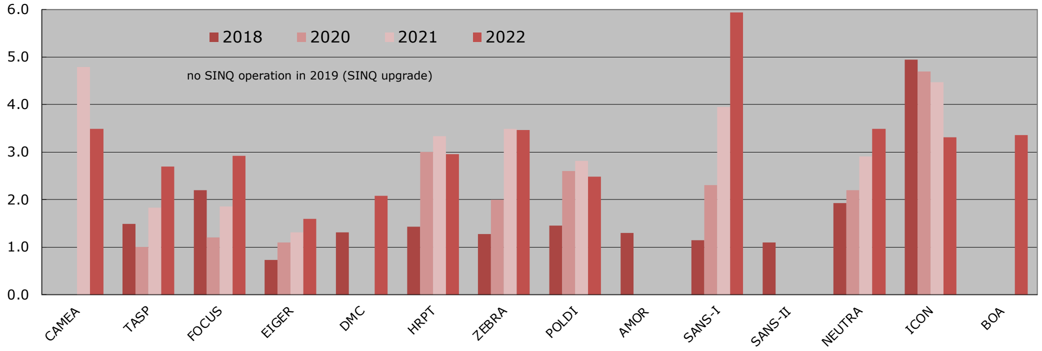
submission of new proposals SINQ



user visits SINQ - 10y history

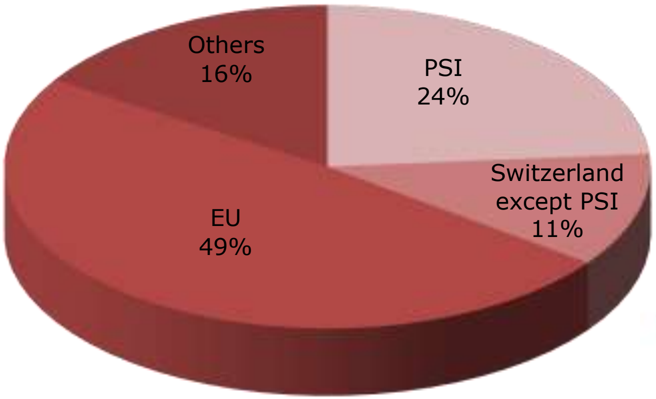


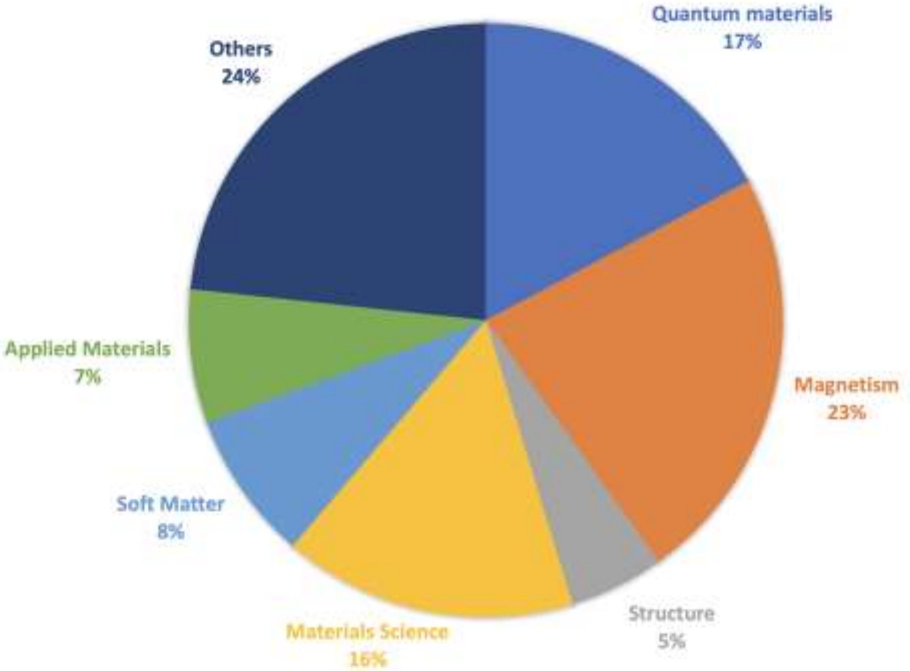
Overbookings SINQ instruments 5y history



Use of the Swiss Spallation Source SINQ

Geographic distribution of SINQ beamtime 2022





About 2/3 of research at SINQ deals with hard condensed matter, we are in the process to increase our activities in soft matter and applied materials

PAUL SCHERRER INSTITUT PSI

Education, practical courses, conferences

Education: University lectures, PSI Master School

Workshops with partners: IFE-PSI, LLB-PSI workshops

Workshops: LNS sponsered workshop

Condensed Matter Camp Zuoz since 2020

Nordic Perspectives on Advanced Neutron Imaging End of Nov 2022

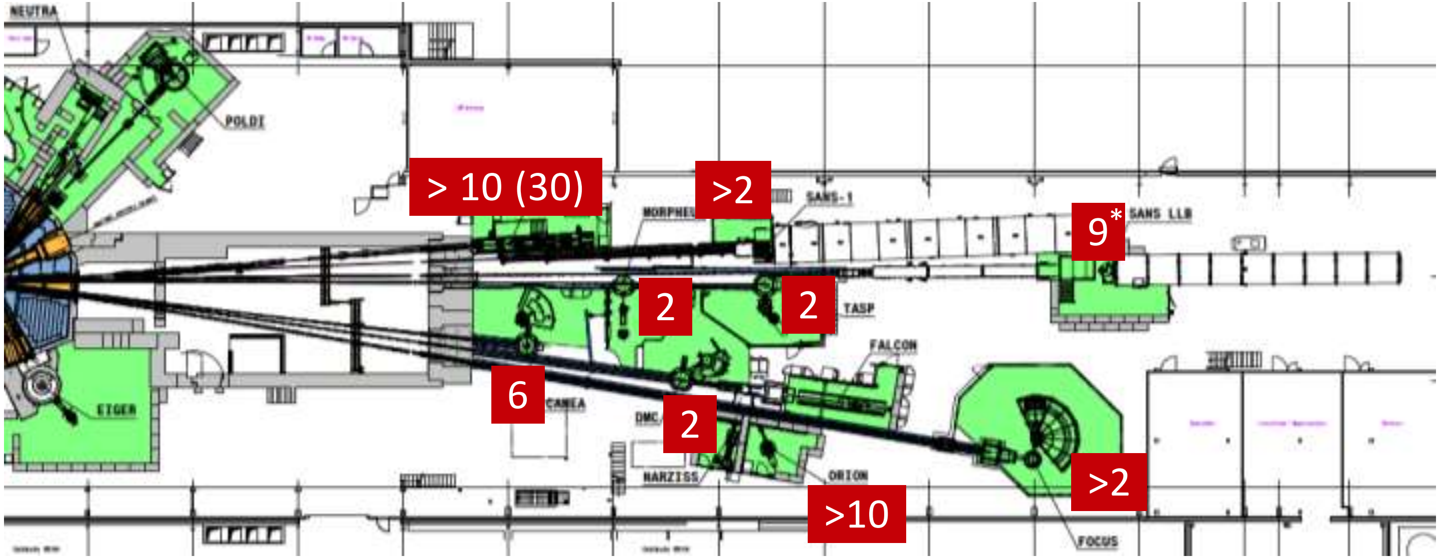
SINQ guide upgrade

- Complete neutron guide upgrade from January 2019 through March 2020
- Flux increase of the order of 2-30

PAUL SCHERRER INSTITUT PSI

Performance of new neutron guide system

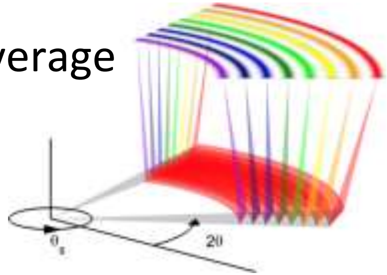
- All instruments/guides have at least an intensity gain of a factor 2 (in comparison to 2018).
- Instruments with elliptic neutron guide gain more – up to factor 30.

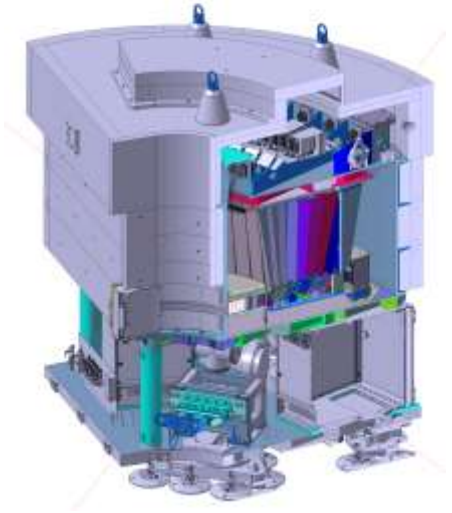


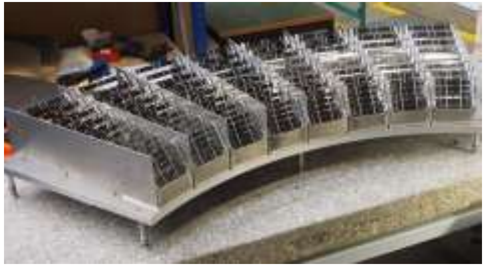
* Gain factor is in comparison to SANS-2 (2018)

CAMEA cold neutron spectrometer

- Multiplex Neutron Spectrometer 60° coverage
- 8 final energies: 3.2-5 meV with Be filter
- Collaboration: PSI, EPFL







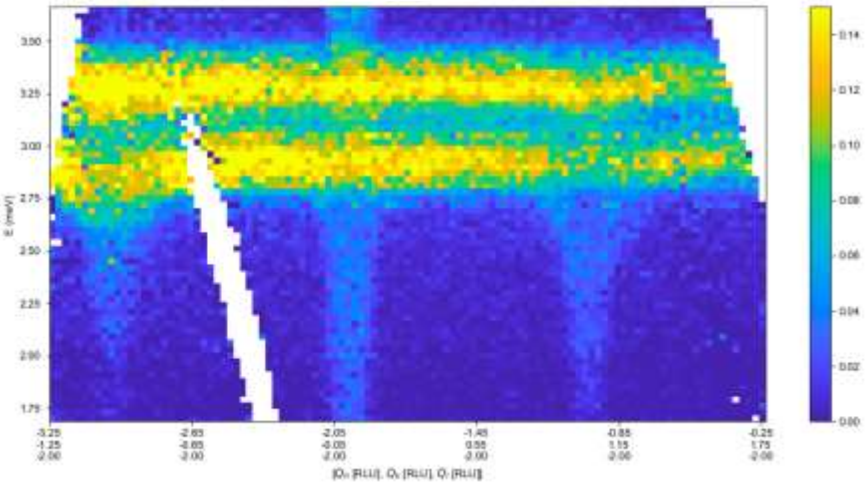
Scientific Case

- **Small samples** of new emergent materials
- **Multi-extreme conditions** (temperature, pressure, magnetic and electric fields)

Comparison CAMEA/LET on $Yb_3Fe_5O_{12}$

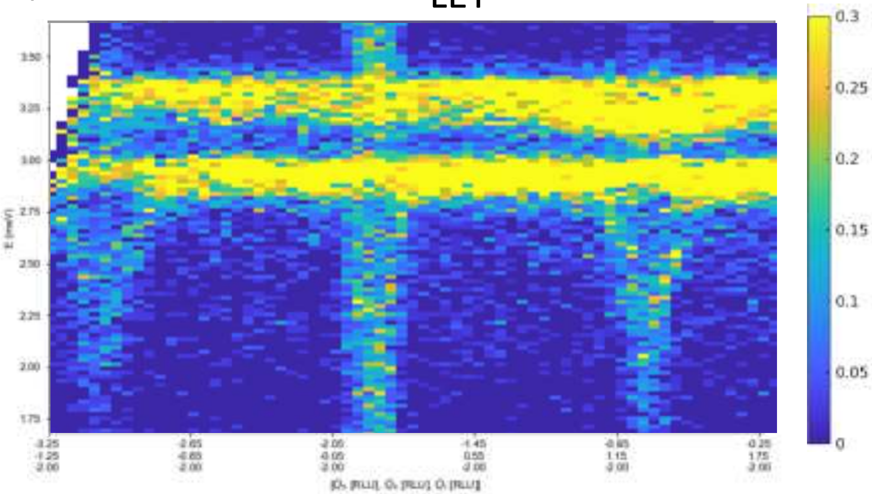
m ~ 1.5 g, *T* = 2 K, $\mu_0 H$ = 3 T

CAMEA



4 min/point

LET



7 min/point

CAMEA multiplexing spectrometer
E_i = 6.9, 6.77meV
Total time: 9.3 hours

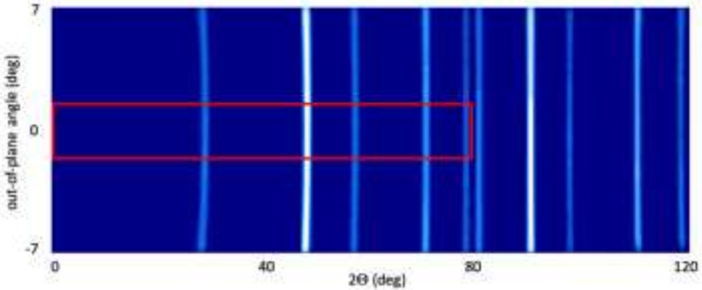
LET TOF spectrometer E_i = 5.5 meV
E_i = 5.5meV
Total time: 16.3 hours

DMC cold-neutron diffractometer with new 2D high-efficiency detector

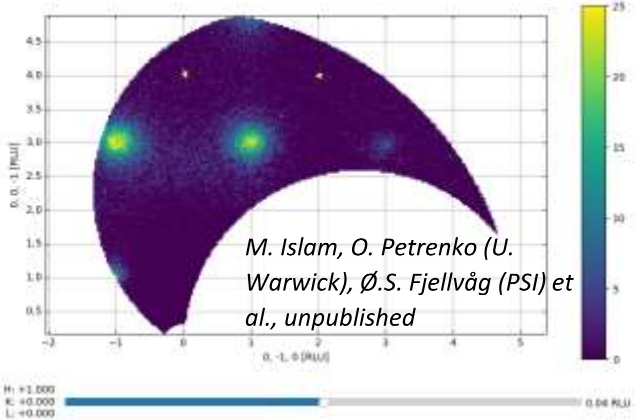
- Detector collaboration between TUM & PSI
- Design and construction of two identical neutron detectors for powder and single-crystal diffraction
- Based on BNL detector design for $WAND^2$ at ORNL and WOMBAT at ANSTO
- ^{3}He gas detector with 2D readout
- Scattering angle range 132°, Height 200 mm
- DMC allows single-crystal measurements

TUM

PAUL SCHERRER INSTITUT PSI



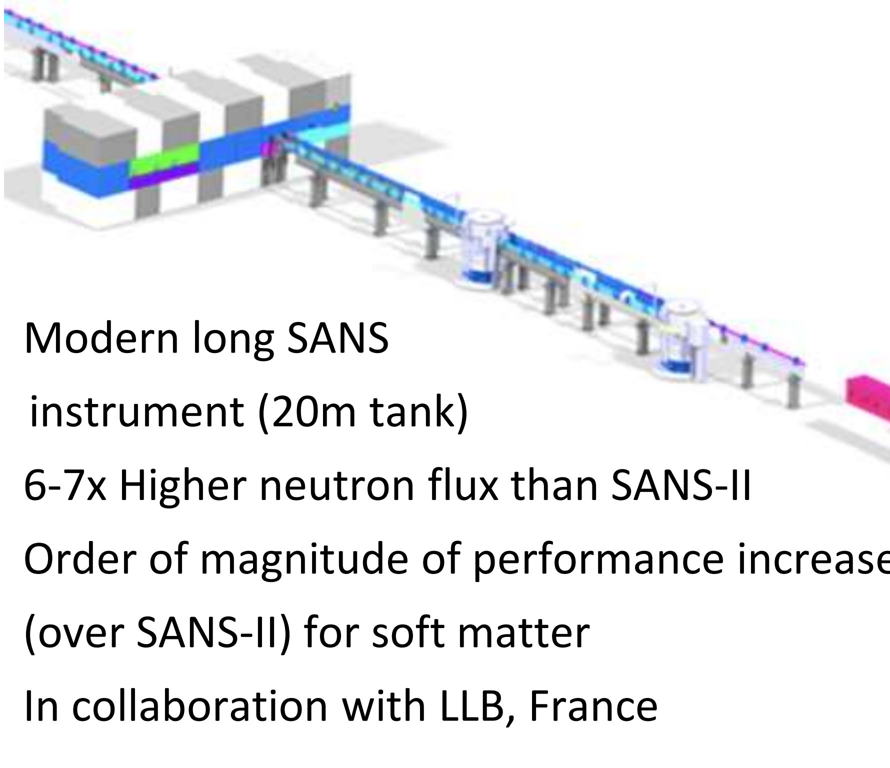
$Mn_3Al_2Ge_3O_{12}$ (1cm^3, diff map 7.5 K – 90 K)

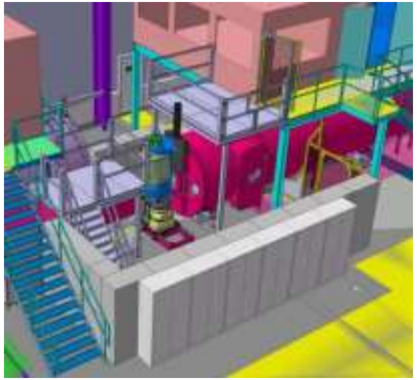


M. Islam, O. Petrenko (U. Warwick), Ø.S. Fjellvåg (PSI) et al., unpublished

Observation of diffuse magnetic scattering

Replacement of SANS II: SANS-LLB

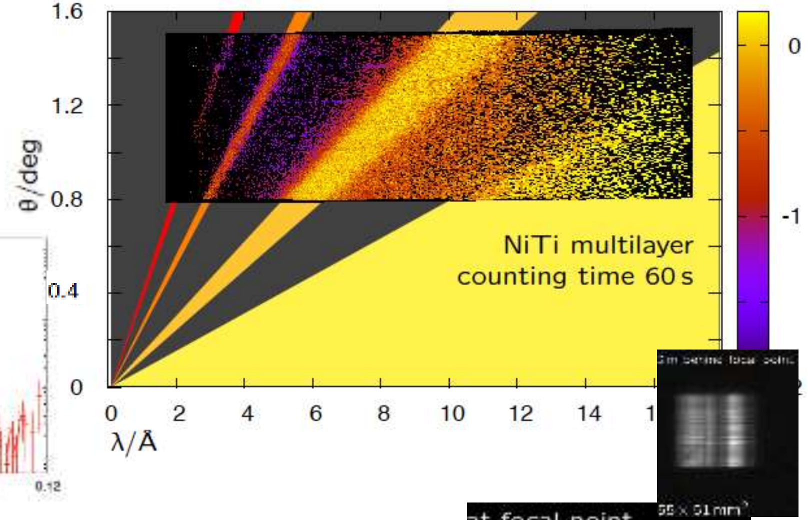


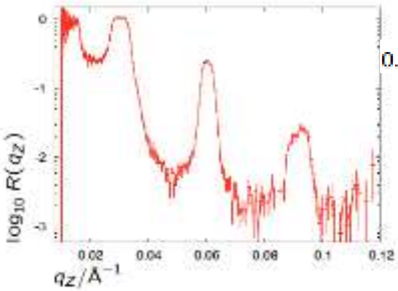


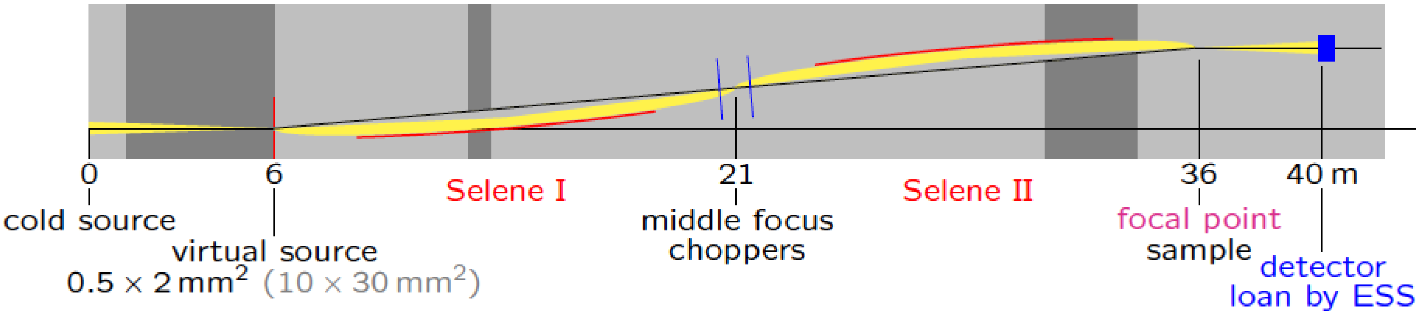
- Modern long SANS instrument (20m tank)
- 6-7x Higher neutron flux than SANS-II
- Order of magnitude of performance increase
- (over SANS-II) for soft matter
- In collaboration with LLB, France

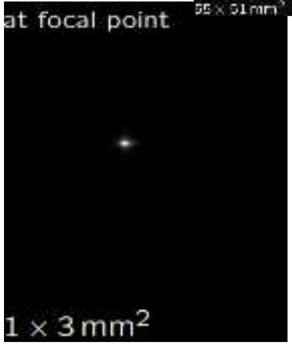
Amor reflectometer & Selene optics

- Focusing optics allows energy- and angle-dispersive modes simultaneously
- Large SELENE optics successfully commissioned: focused beam at focal point demonstrated
- Instrument performance:
  - wave-vector resolution 2%
  - gain factor: 10
  - counting time reduced by 90%



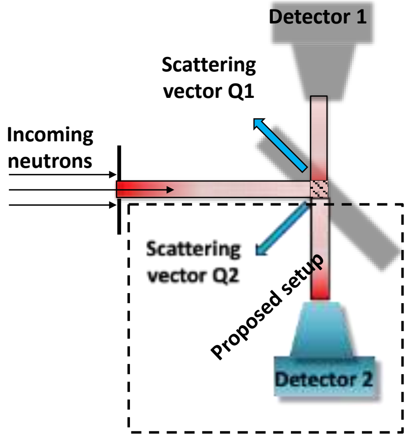


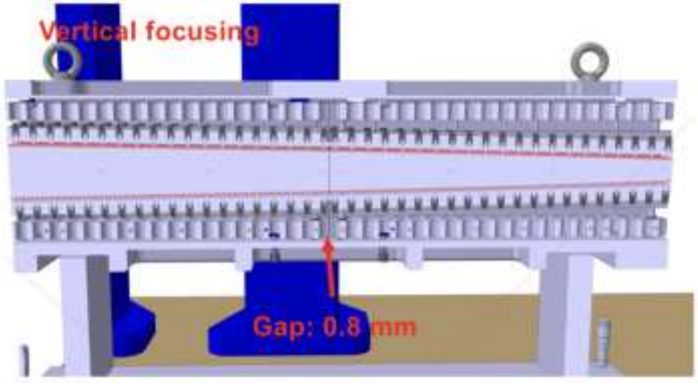




Upgrades: engineering diffraction instrument POLDI

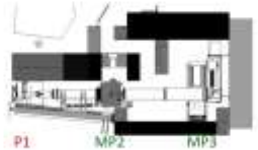
- CASCADE detectors from CDT will be installed
- Two detectors banks allow simultaneous measurement of 2 strain directions
- Vertical focusing in front of sample leads to two-fold flux increase in flux at sample positions
- Overall we expect a 5x performance increase for engineering diffraction
- In collaboration with IFE, Norway



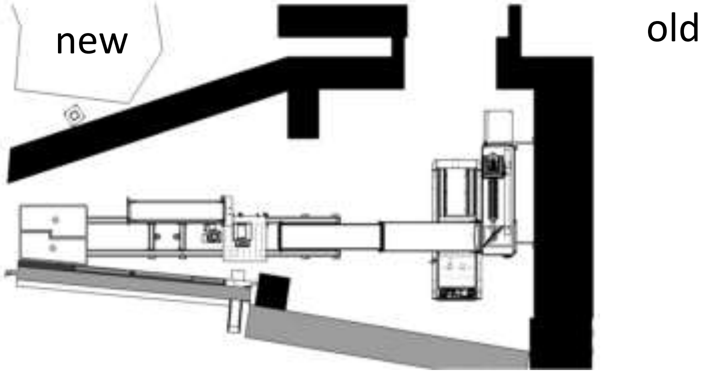


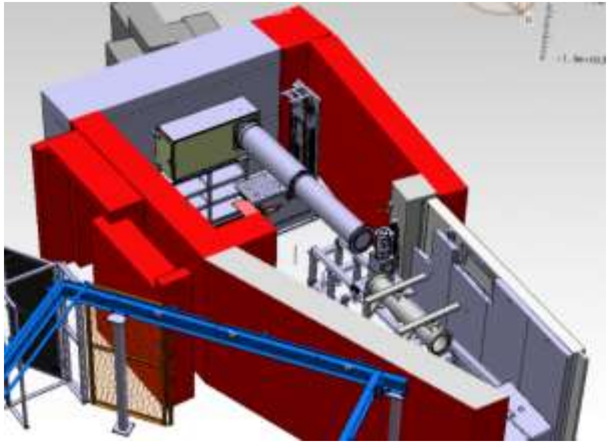
PAUL SCHERRER INSTITUT

Upgrades: imaging instrument NEUTRA



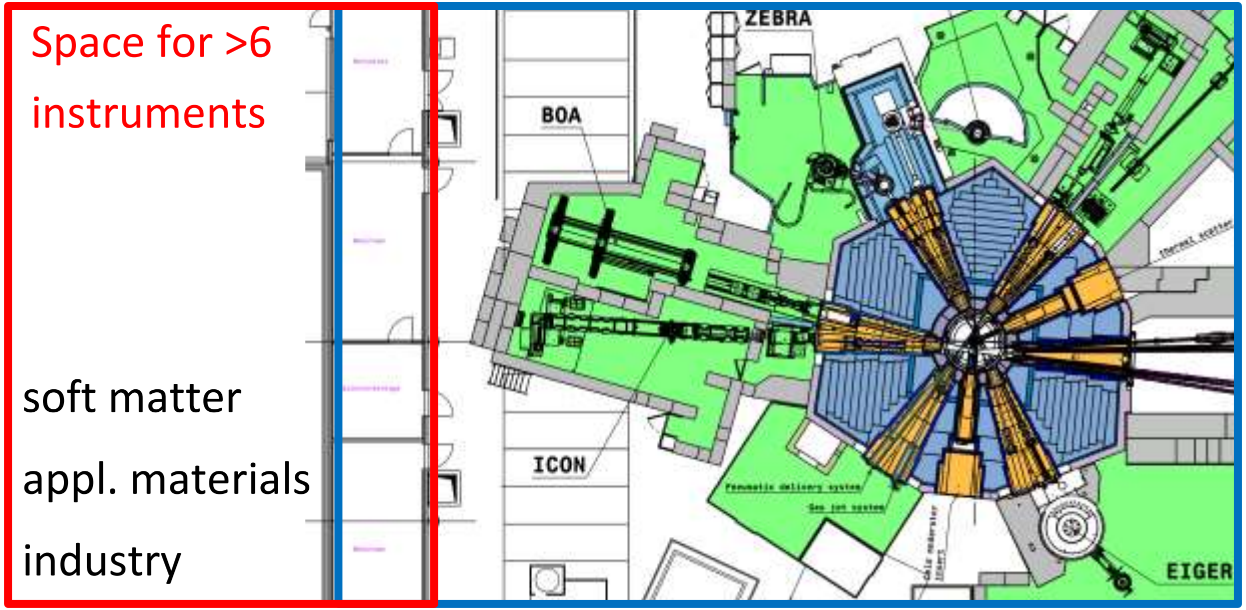
- Significant bunker enlargement
- Higher flexibility of our thermal neutron imaging instrument
- Three different measurements positions, with access to higher flux position
- Use of higher resolution detectors and dedicated neutron optics possible
- In-situ bimodal N/X-ray imaging option possible
- In collaboration with IFE, Norway



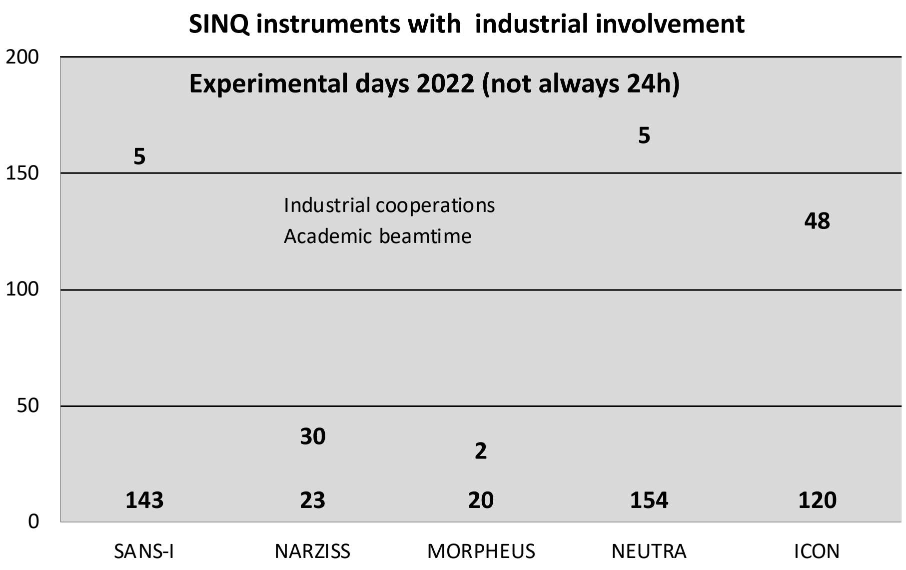


Our plans for a neutron guide Hall North

- Inexpensive way to increase European neutron capacity
- External audit recommends to develop further plans for a new guide hall
- Preliminary study 2022-2025
- Realization towards the end of the decade
- Can be done with international partners



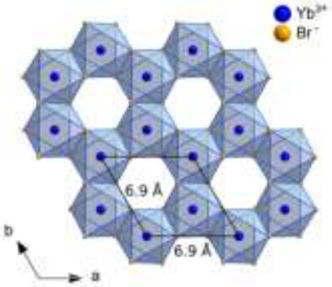
Industry use and ANAXAM



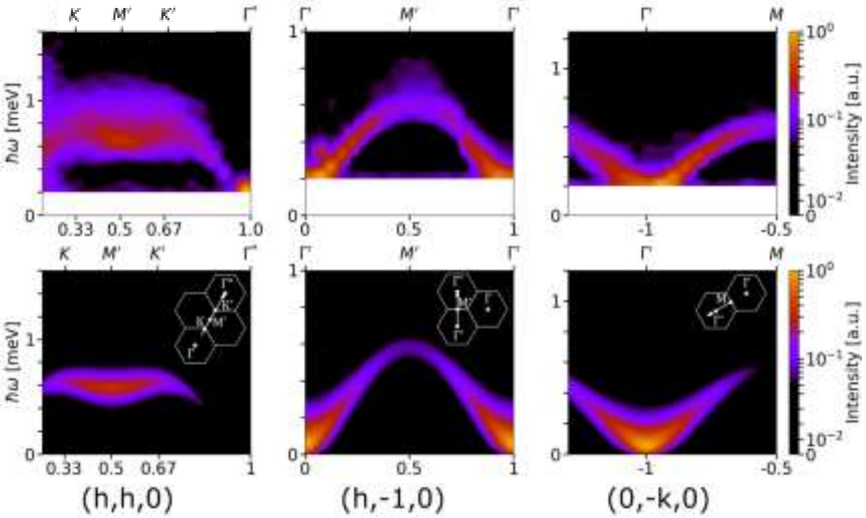
Analytics with Neutrons And X-Rays for Advanced Manufacturing: www.anaxam.ch/en

- Swiss association with many customers as members
- In operation since 1.12.2019

Spin-liquid with plaquette fluctuations in $YbBr_3$

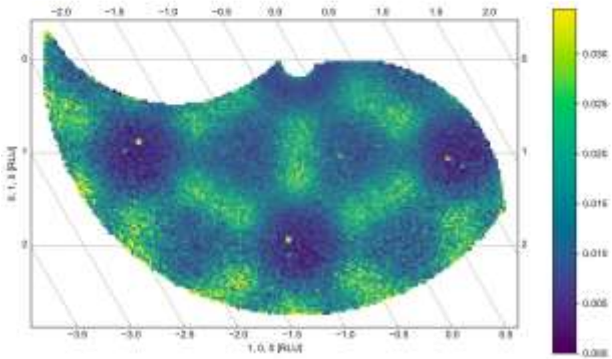


- small-moment 2D Heisenberg honeycomb magnet
- only short-range correlations observed
- Continuum excitations extend up to 1.2 meV



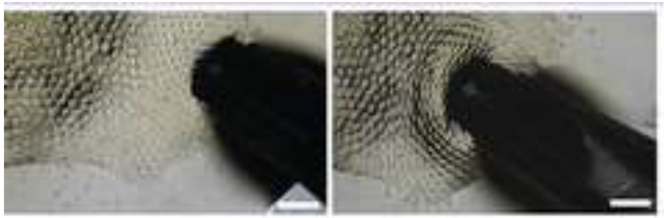
C. Wessler *et al.*, NPJ Quantum Materials **5,** 85 (2020).

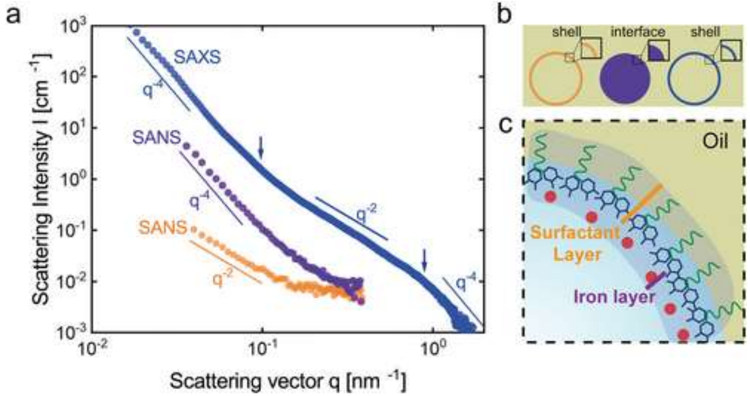
- Characteristic wave-vector dependence matches that of plaquette correlations



From surfactants to viscoelastic capsules

- Study of viscoelastic capsules with very thin shells of ~10nm, flexible, self-healing and impermeable, suitable for drug delivery
- Shells from ionically crosslinked surfactants with Fe^{3+} and with catechol-derivatives
- SAXS is mostly sensitive to Fe^{3+} layer
- SANS provides evidence of a sharp interface between the core and the solvent
- Combined analysis of SAXS and SANS provides a total shell thickness of about 11 nm, and a Fe^{3+} layer thickness of about 2 nm.

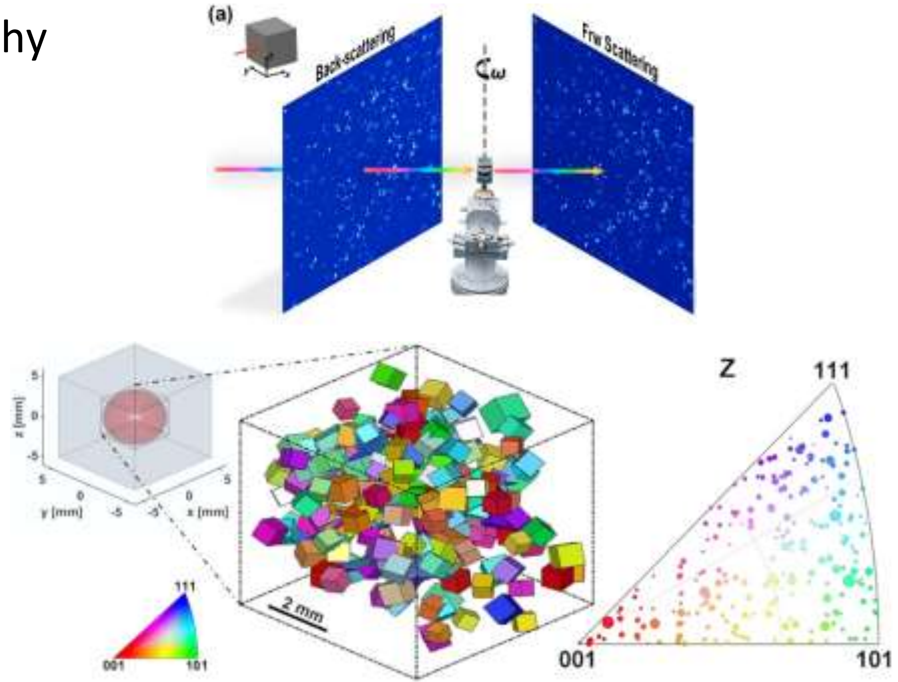




G. de Angelis, N. Gray, V. Lutz-Bueno, E. Amstad, Adv. Mat. Interfaces, 2202450 (2023).

Grain Mapping at FALCON

- Laue 3D Diffraction Neutron Tomography (3DNT) enables grain mapping
- Demonstration that 500 grains can be mapped
- A project funded by the SDSC allows for an efficient reconstruction
- Providing access to bulk local texture characterisation
- Laue 3DNT has been implemented meanwhile at POLDI

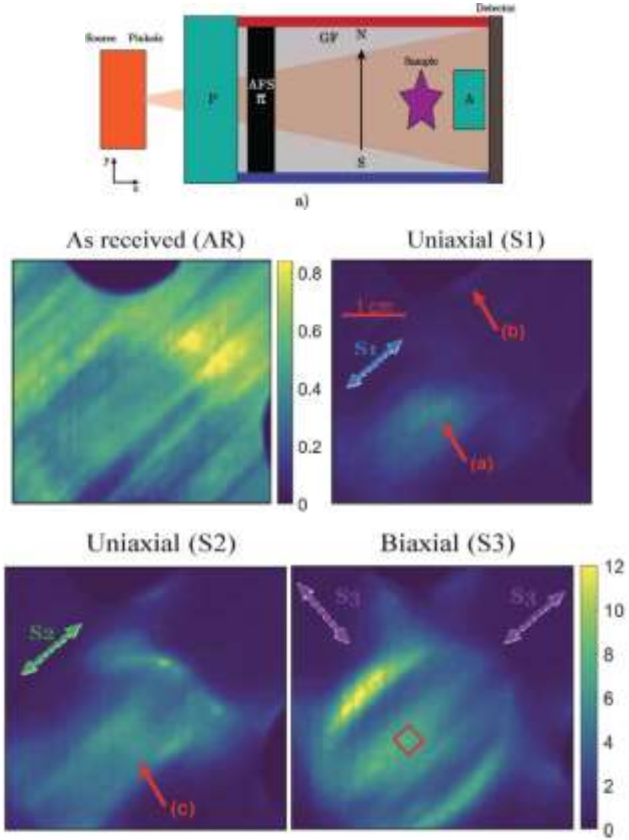


S. Samothrakitis, C. Buhl Larsen, J. Capek, Efthymios Polatidis, M. Raventos, M. Tovar, S. Schmidt, M. Strobl *Microstructural Characterization Through Grain Orientation Mapping with Laue Three-Dimensional Neutron Diffraction Tomography,* Materials Today Advances **15**, 100258 (2022).

In-situ phase transformation mapping

Depolarisation Imaging @ BOA

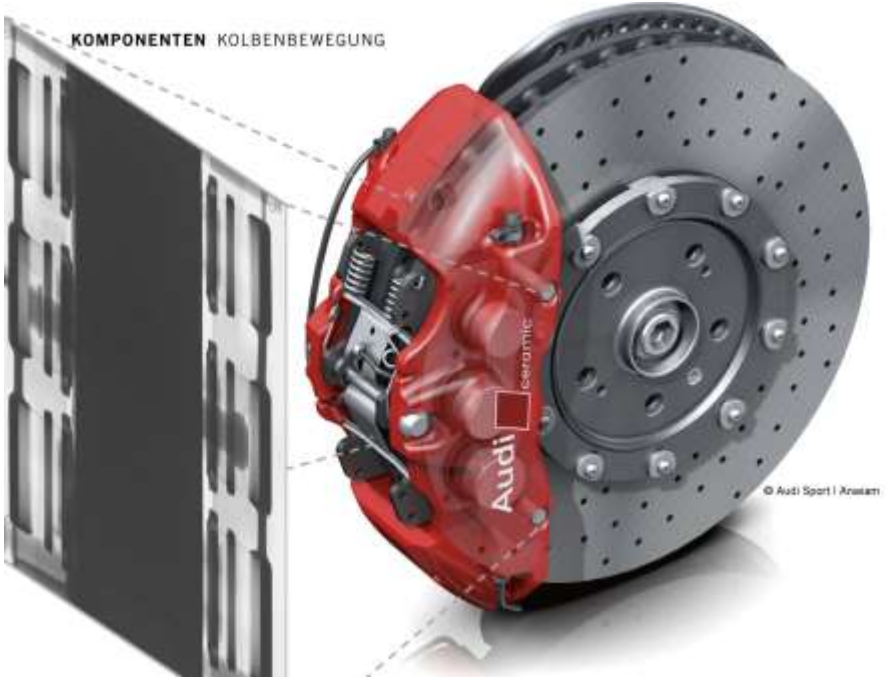
- Neutron Depolarisation Imaging implemented at BOA
- In-situ mapping of the austenitic to (magnetic) martensitic phase transformation, high sensitivity (%)
- Development of martensitic phase was observed in cruciform sample under load
- Measurements are much faster (seconds to minutes) than using Bragg edge imaging
- Especially useful to study effects of initial load



M. Busi, E. Polatidis, C. Sofras, P. Boillat, A. Ruffo, C. Leinenbach, M. Strobl, *Polarization contrast neutron imaging of magnetic crystallographic phases Materials,* Today Advances **16,** 100302 (2022).

Industrial highlight

- Visualization of micromovements of piston movement of disk brakes using neutron imaging
- Work confirmed a strategy of a redesign of the brakes to reduce rest braking moment
- Work done by public-private partnership ANAXAM on behalf of the Audi Sport corporation



Wir schaffen Wissen – heute für morgen

- Questions?