Enabling Science using Neutrons at the European Spallation Source ERIC

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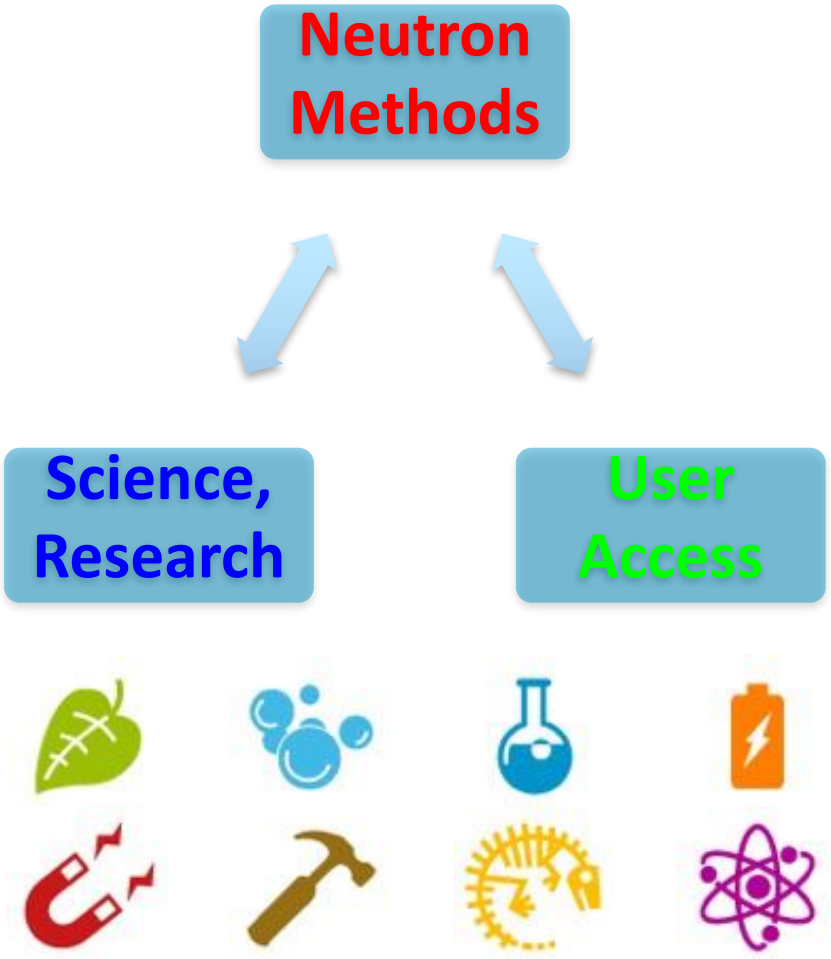
www.europeanspallationsource.se

European Spallation Source - Vision



"Build and operate the world's most powerful **neutron source**, **enabling scientific breakthroughs in research** related to materials, energy, health and the environment, and **addressing** some of the most important **societal challenges** of our time."

idea by user → proposal, sample, labs → experiment, sample env. → data, modeling → publication by user

Journey to deliver the world's leading facility for research using neutrons

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Financing includes cash and deliverables

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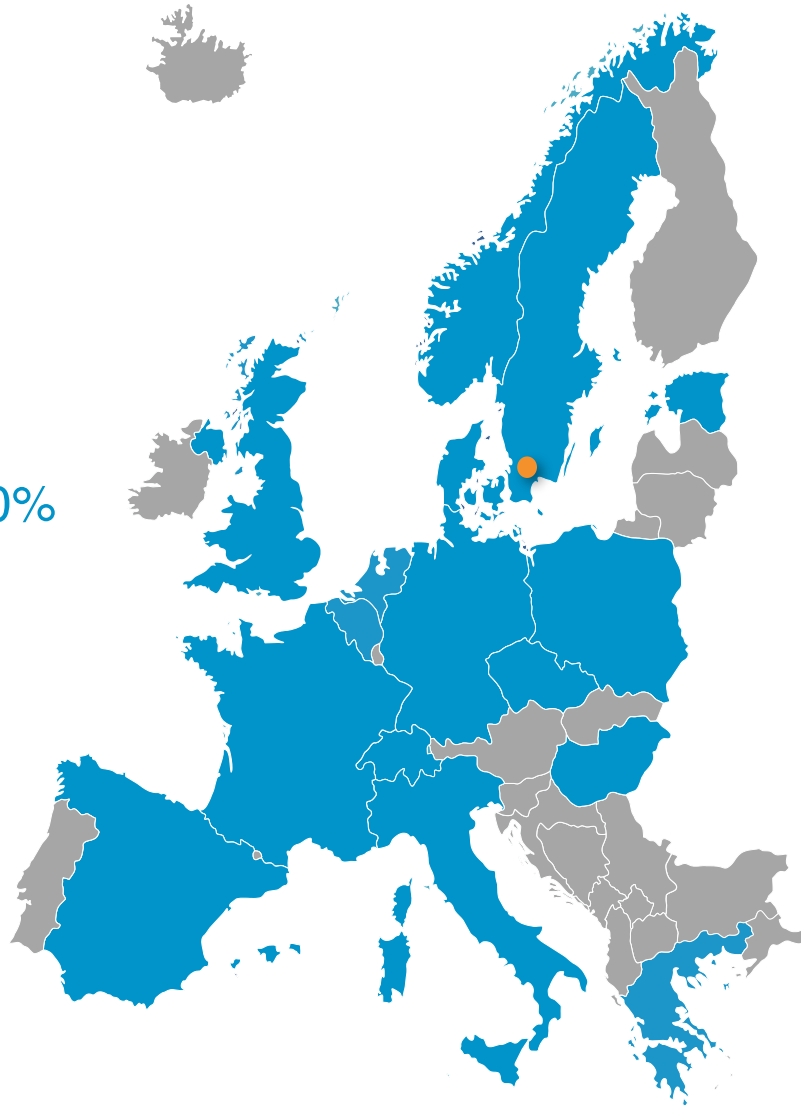
Host Countries Sweden and Denmark

Construction	47.5%	Cash Investment ~ 97%
Operations	*15%*	*TBC*

Non Host Member Countries

Construction	52.5%	In-kind Deliverables ~ 70%
Operations	*85%*	*TBC*



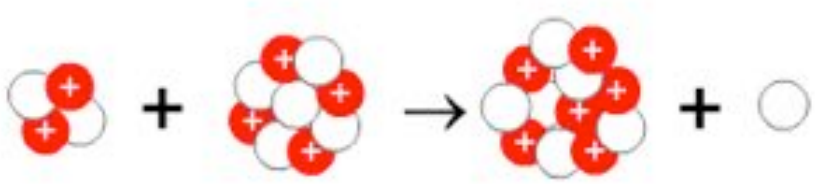
Construction is ongoing …

Aug 2017

July 2014

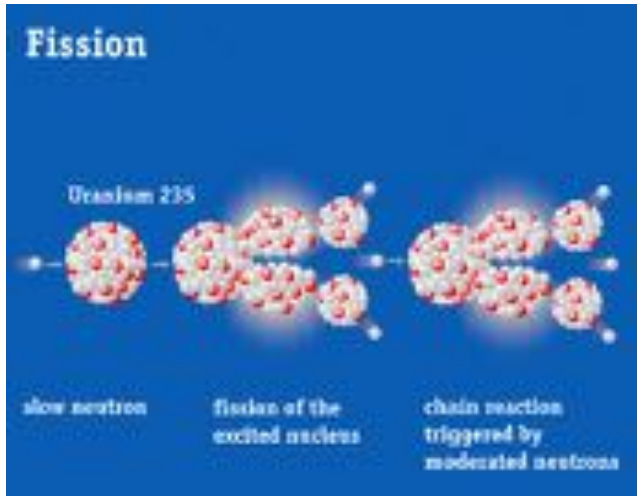
Neutron sources James Chadwick - 1932

Use Polonium as alpha emitter on Beryllium



$^{4}He + {}^{9}Be \rightarrow {}^{12}C + neutron$

Production of neutrons

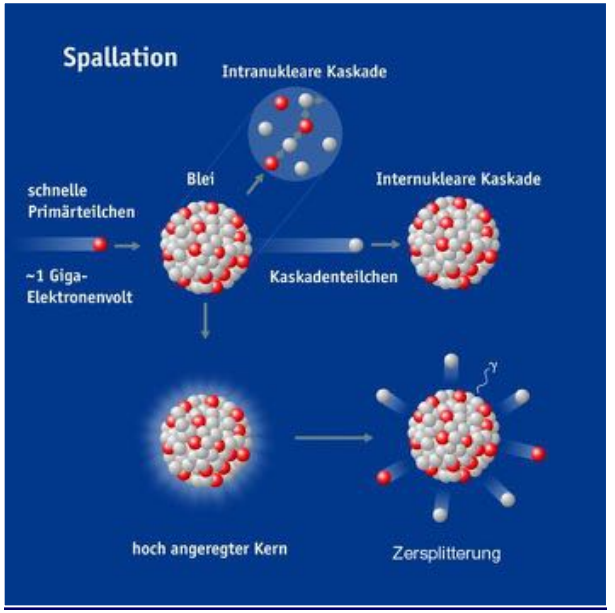


Fission of uranium
in nuclear reactor

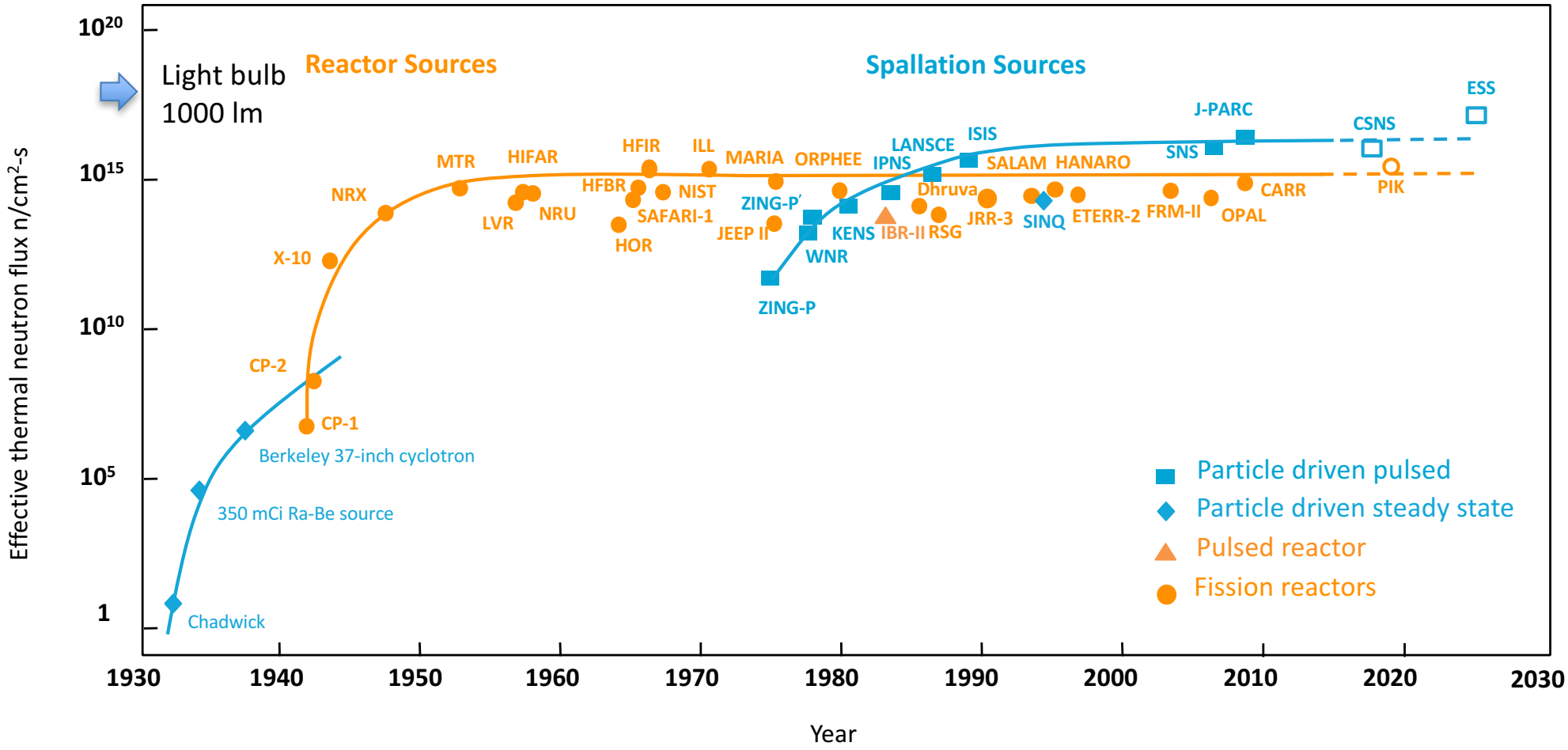
2-3 neutrons per process

Spallation on target
using proton accelerator

30+ neutrons per process



Evolution of Neutron Sources



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

The European Spallation Source

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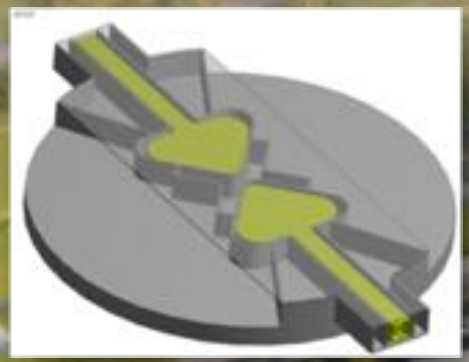
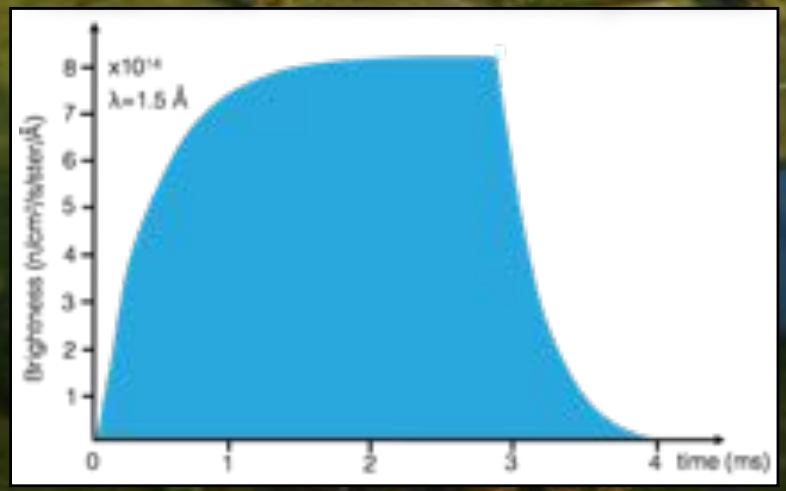
High Power Accelerator means more neutrons

Flat moderator delivering smaller and brighter neutron beams

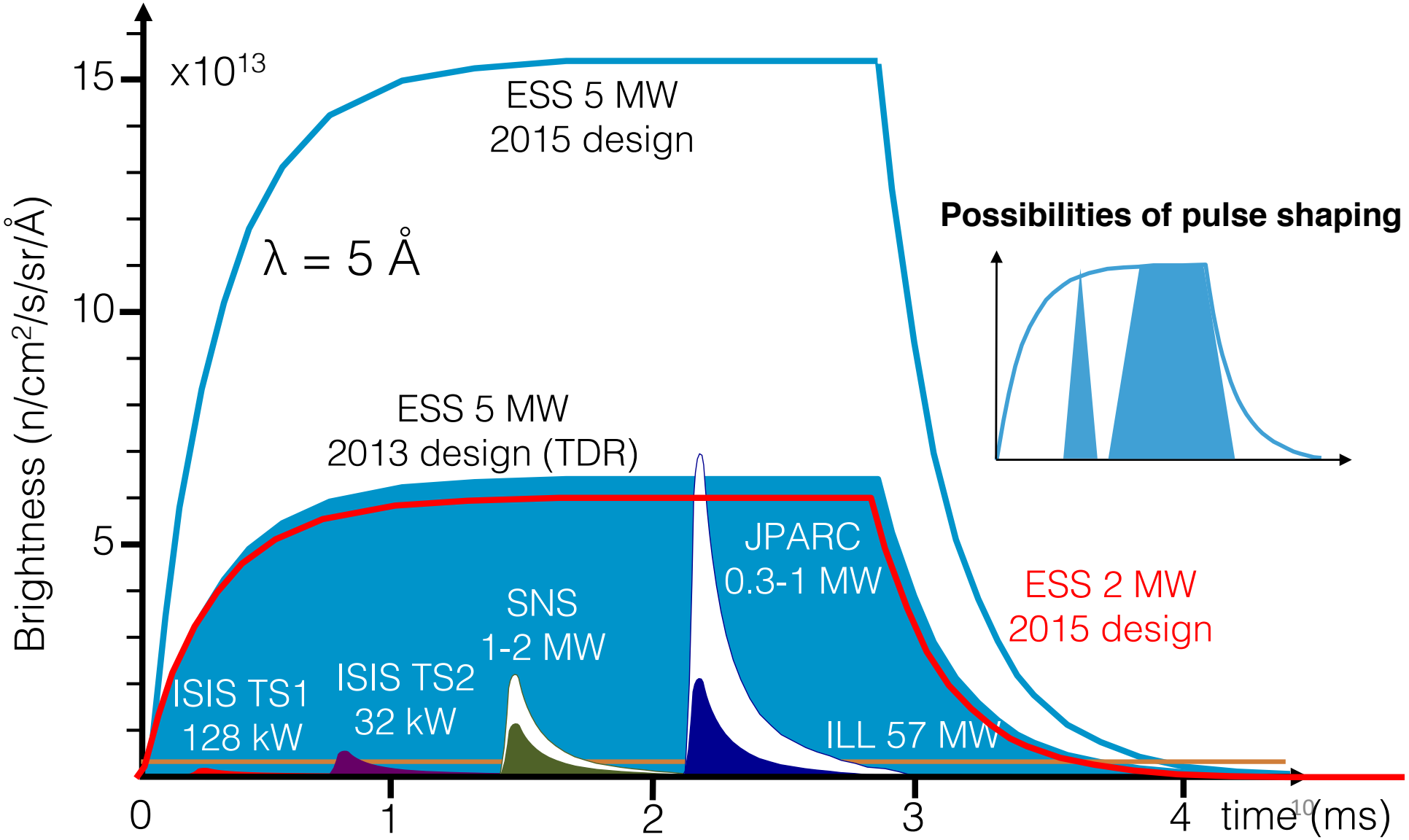


An Innovative Target Station that can host >30 instruments

High brightness and tuneable resolution makes new measurements possible

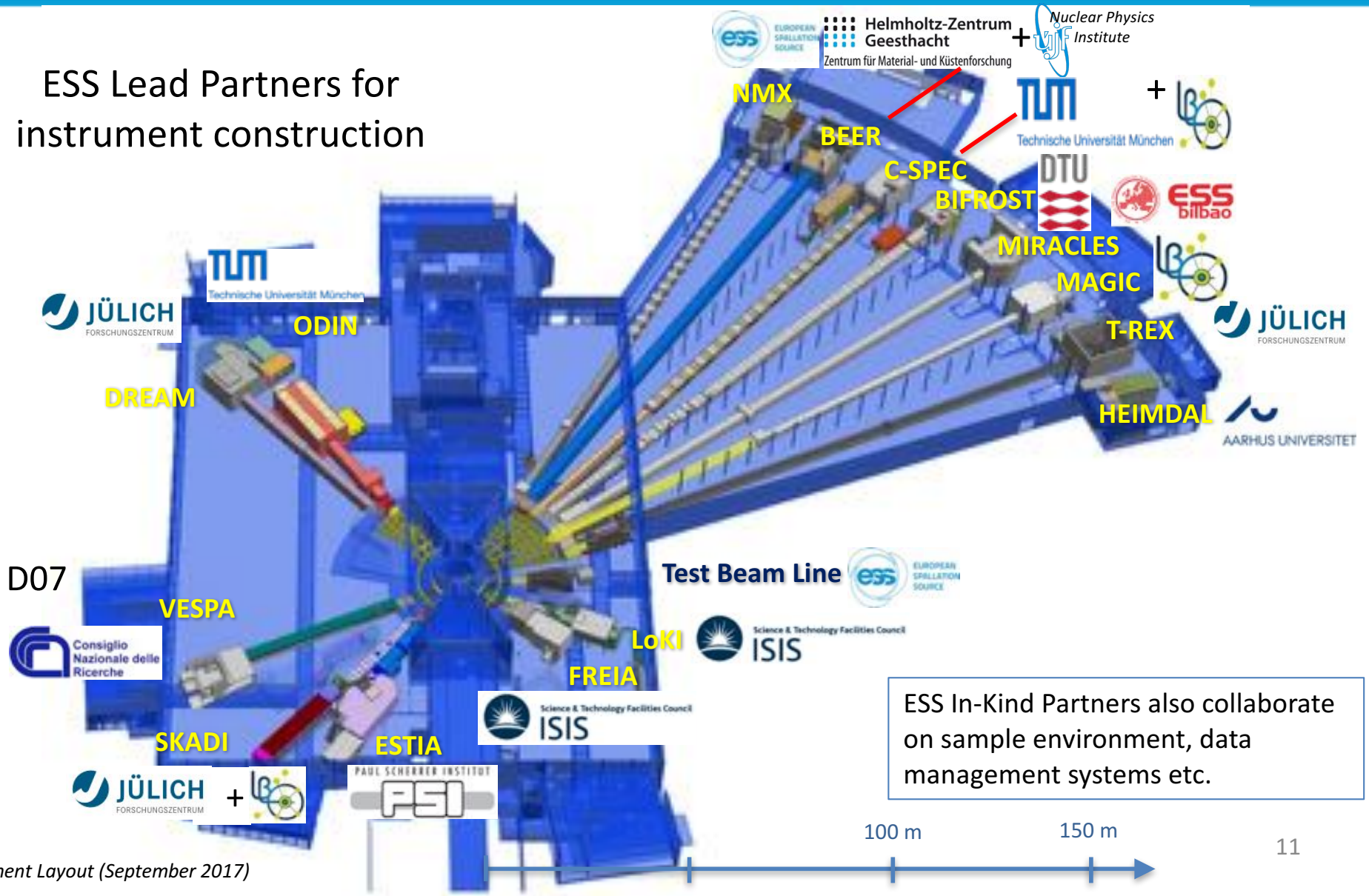


Long-pulse performance



ESS Neutron Instruments 1-15 + test beamline

ESS Lead Partners for instrument construction



ESS In-Kind Partners also collaborate on sample environment, data management systems etc.

ESS Instrument Layout (September 2017)

ESS Neutron Instruments 1-15 and Support Infrastructure

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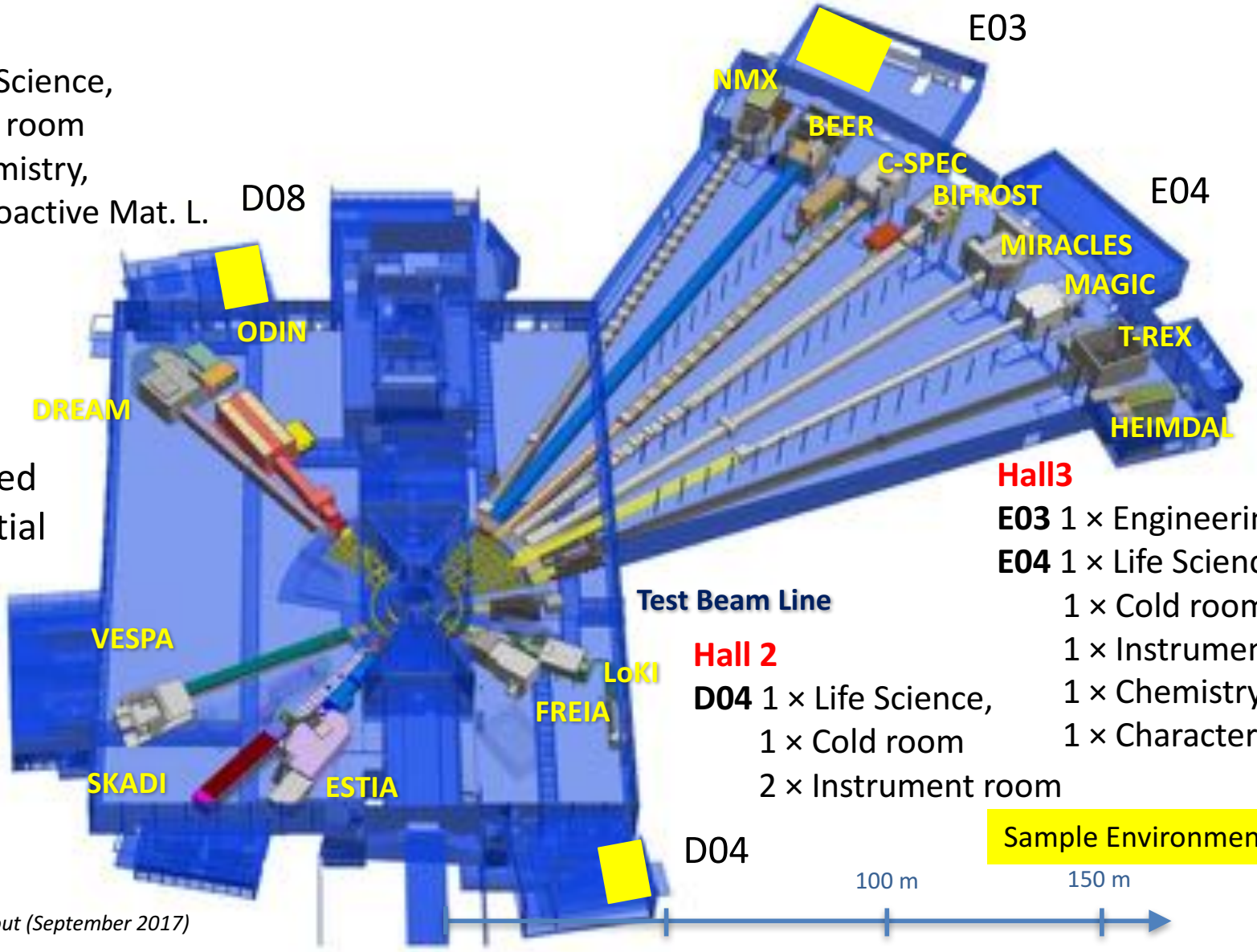
Hall 1

D07 1 × Life Science,
1 × Cold room

D08 1 × Chemistry,
1 x Radioactive Mat. L.

D07 deferred to early Initial Operations



Hall3

E03 1 × Engineering

E04 1 × Life Science,
1 × Cold room
1 × Instrument room
1 × Chemistry,
1 × Characterization

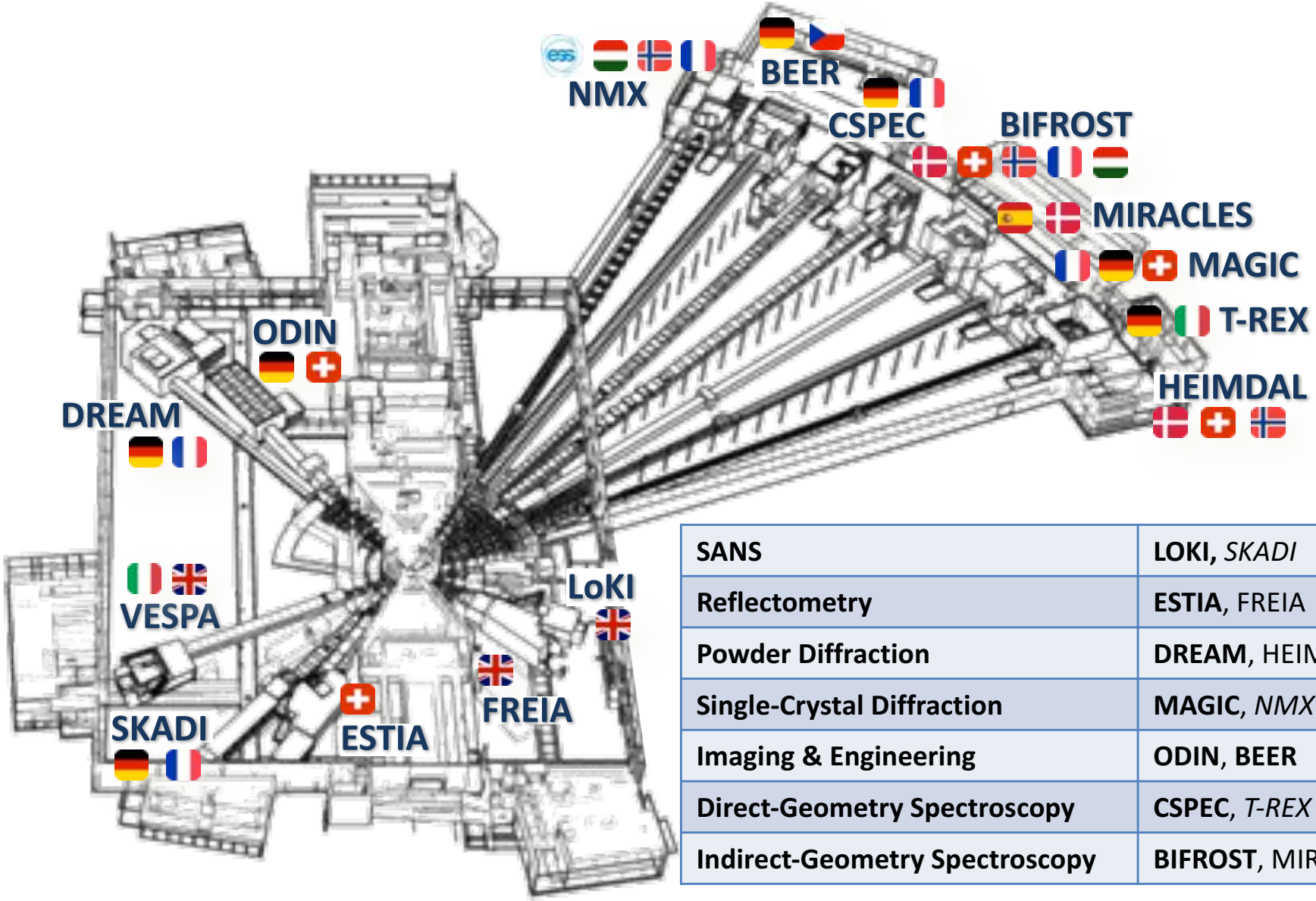
Hall 2

D04 1 × Life Science,
1 × Cold room
2 × Instrument room

Sample Environment Workshops

ESS Instrument Layout (September 2017)

Instrument Suite and Collaboration



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

15 Instruments selected so far
8 to be in user operation by 2023

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Large-Scale Structures

- **ODIN** imaging
- **SKADI** GP-SANS
- **LOKI** Broadband SANS
- Surface Scattering
- **FREIA** Hor. Refl.
- **ESTIA** Ver. Refl.

Diffraction

- **HEIMDAL** Pow. Diffr.
- **DREAM** Pow. Diffr.
- Monochromatic Powder Diffractometer
- **BEER** Eng. Diffr.
- Extreme Conditions Diffractometer
- **MAGIC** Magn. Diffr.
- **NMX** Macromol. Diffr.

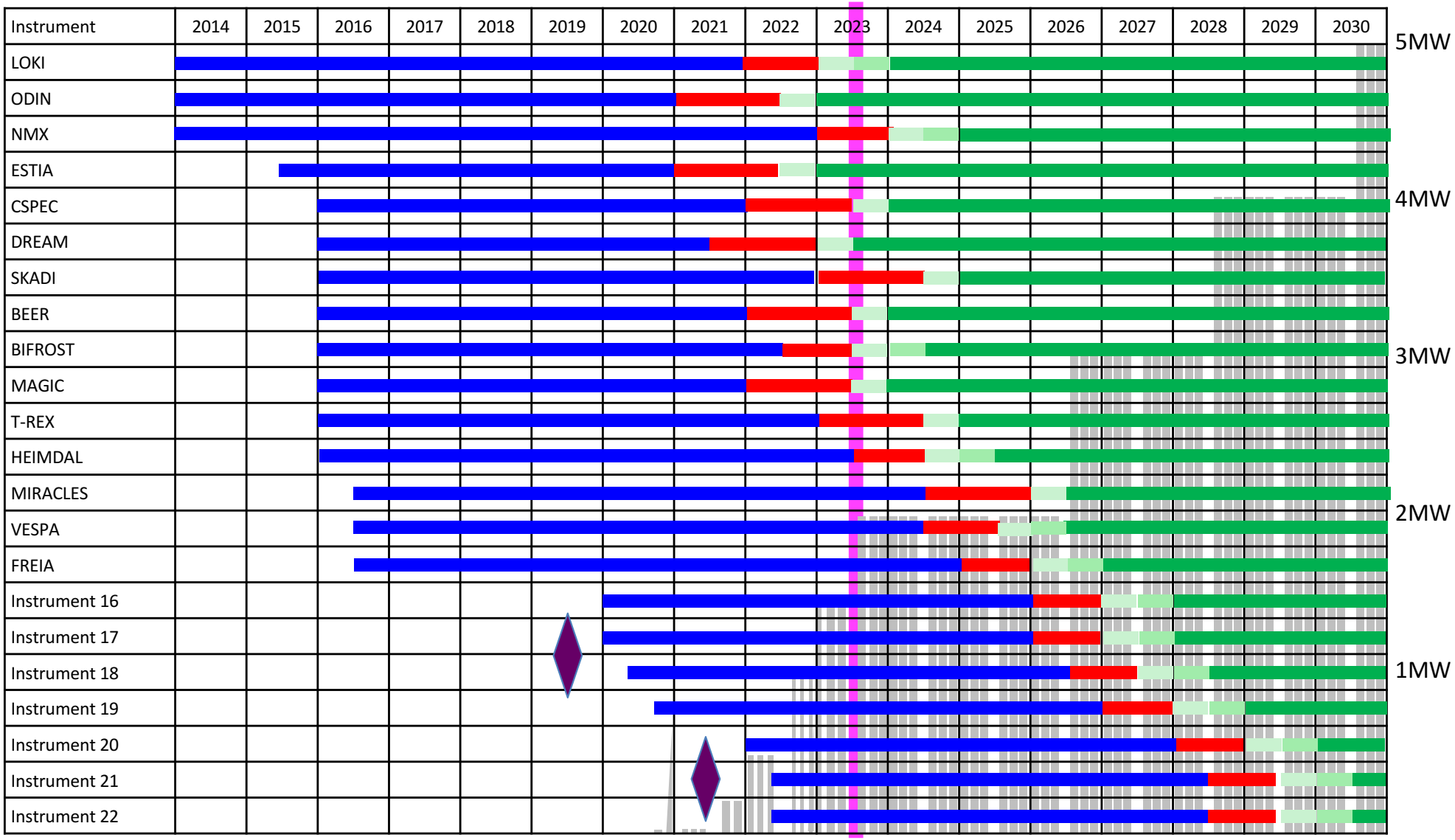
Spectroscopy

- **CSPEC** ColdChopSp
- VOR BroadbandSp
- **T-REX** ThChopSpec
- **BIFROST** Xana Spec
- **VESPA** Vibr.Spec.
- **MIRACLES** BckScatt
- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo
- Particle Physics

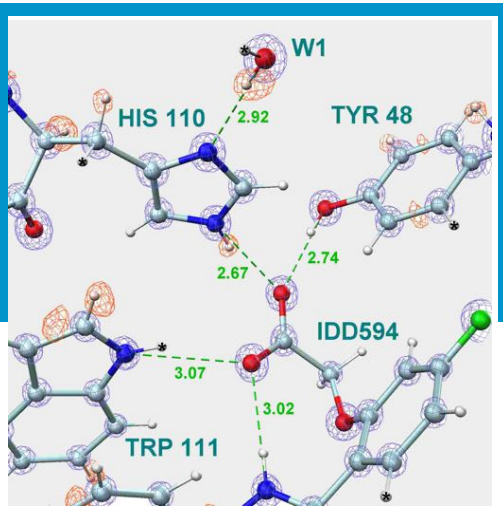
- life sciences
- soft condensed matter
- chemistry of materials
- energy research
- magnetism & superconductivity
- engineering & geo-sciences
- archeology & heritage conservation
- particle physics

Tentative Instrument Ramp-up

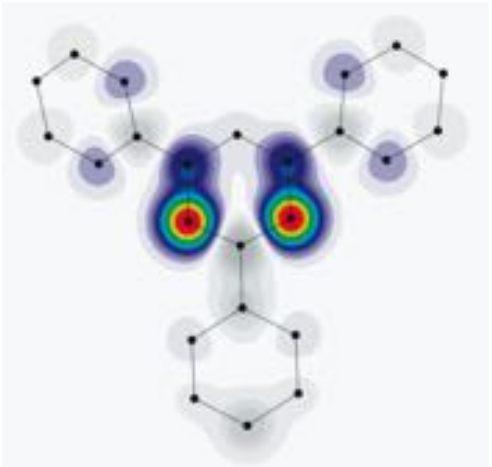
based on Instrument Construction Working Schedule V3.4, 15/9/2017

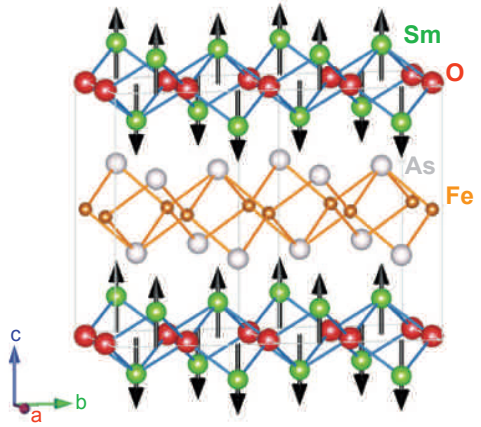


Neutrons are special

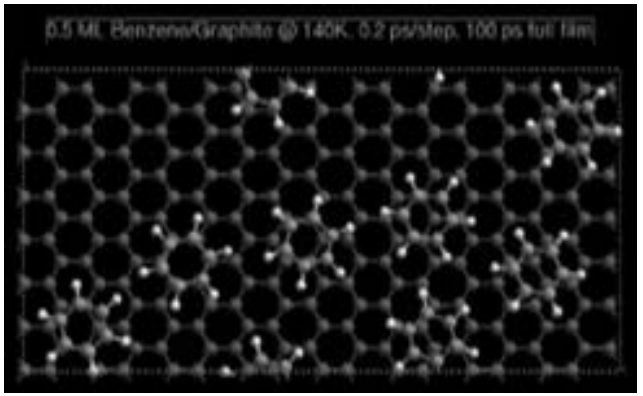


- **charge neutral:** deeply penetrating … except for some isotopes
- **nuclear interaction:** cross section depending on isotope (not Z), sensitive to light elements.
- **spin S = 1/2**: probing magnetism
- **unstable** $n \rightarrow p + e + \underline{\nu}_e$ with life time $\tau \sim 900s$, $I = I_0 \ e^{-t/\tau}$
- **mass**: n ~p; thermal energies result in non-relativistic velocities.
  E = 293 K = 25 meV,
  v = 2196 m/s , λ = I.8 Å

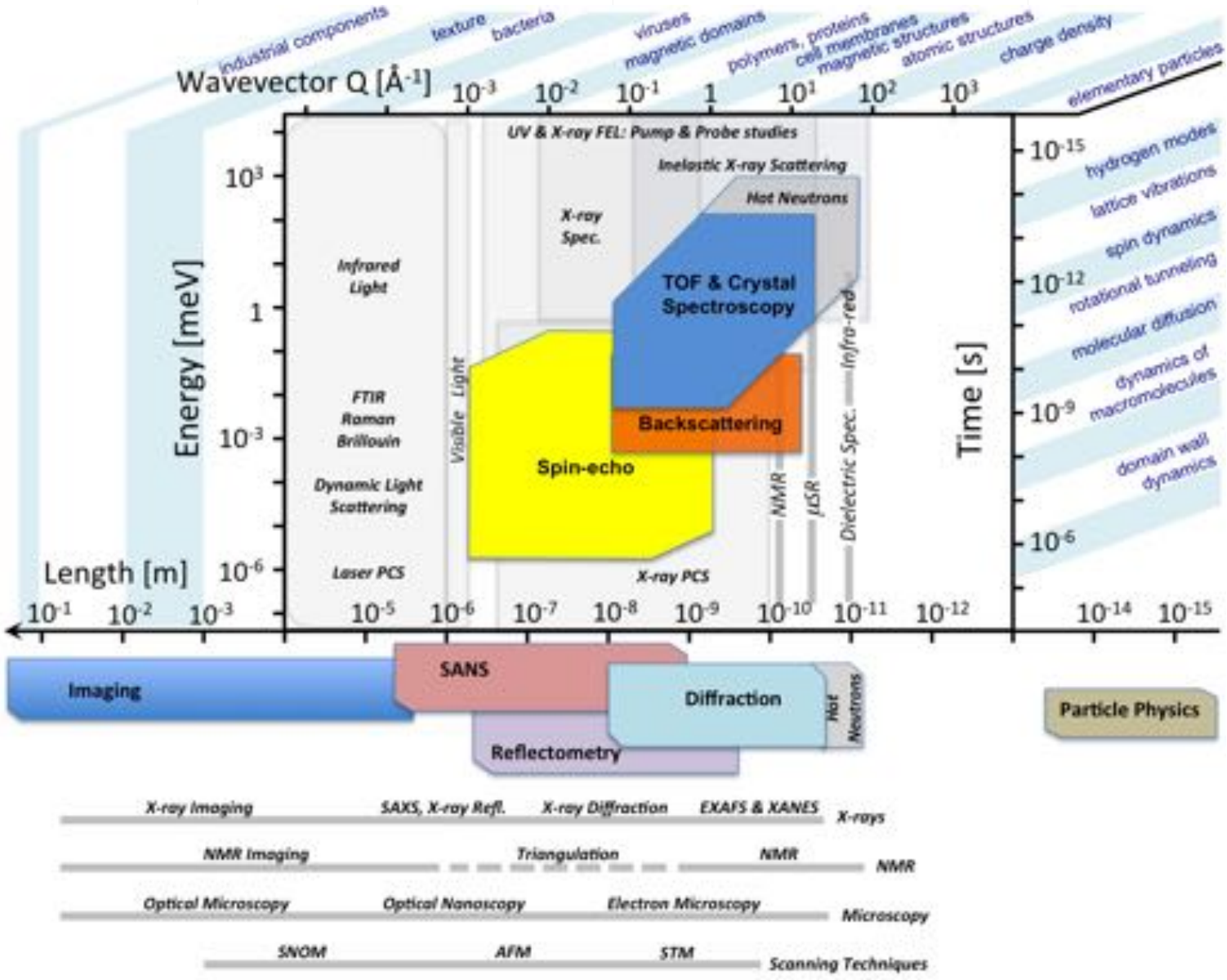




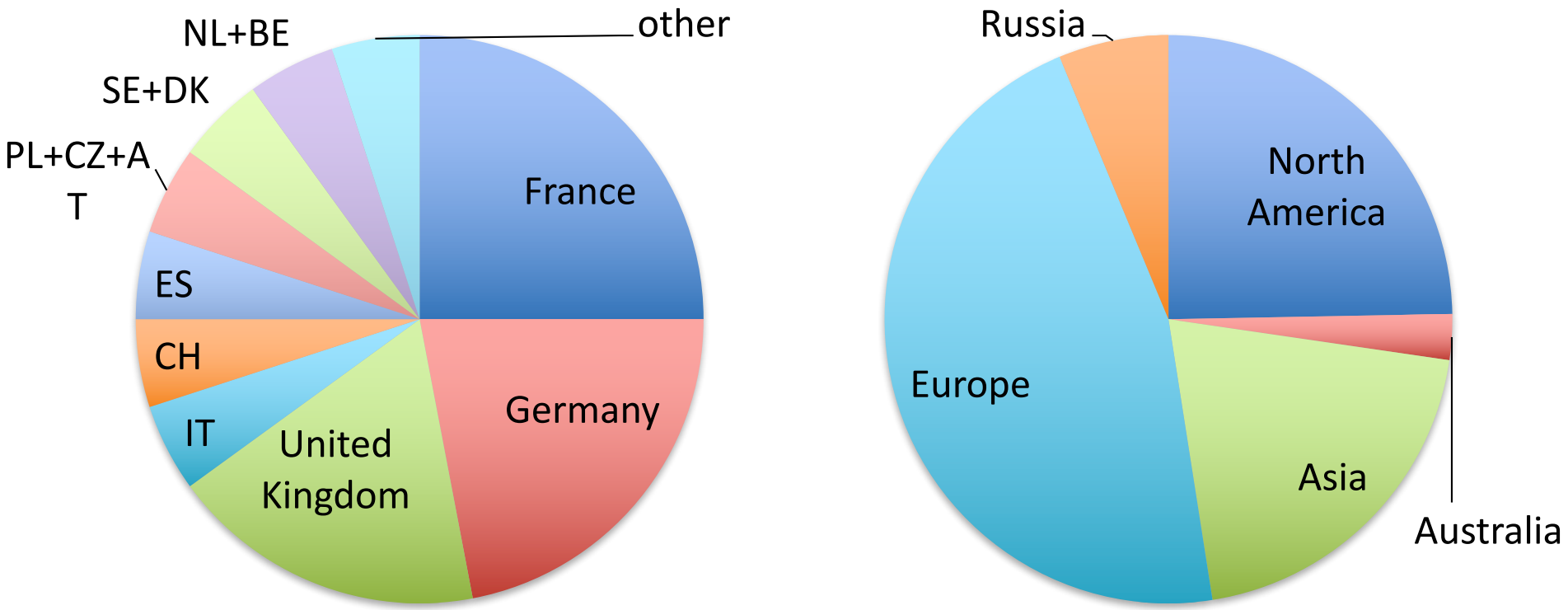
WHERE ARE THE ATOMS AND WHAT DO THEY DO?



Length and Energy Scales



User Community based on publications



European Community

5000 - 6000 researchers

2000 publications per year

data: ESFRI, KFN

Facility-based Survey on Neutron Users

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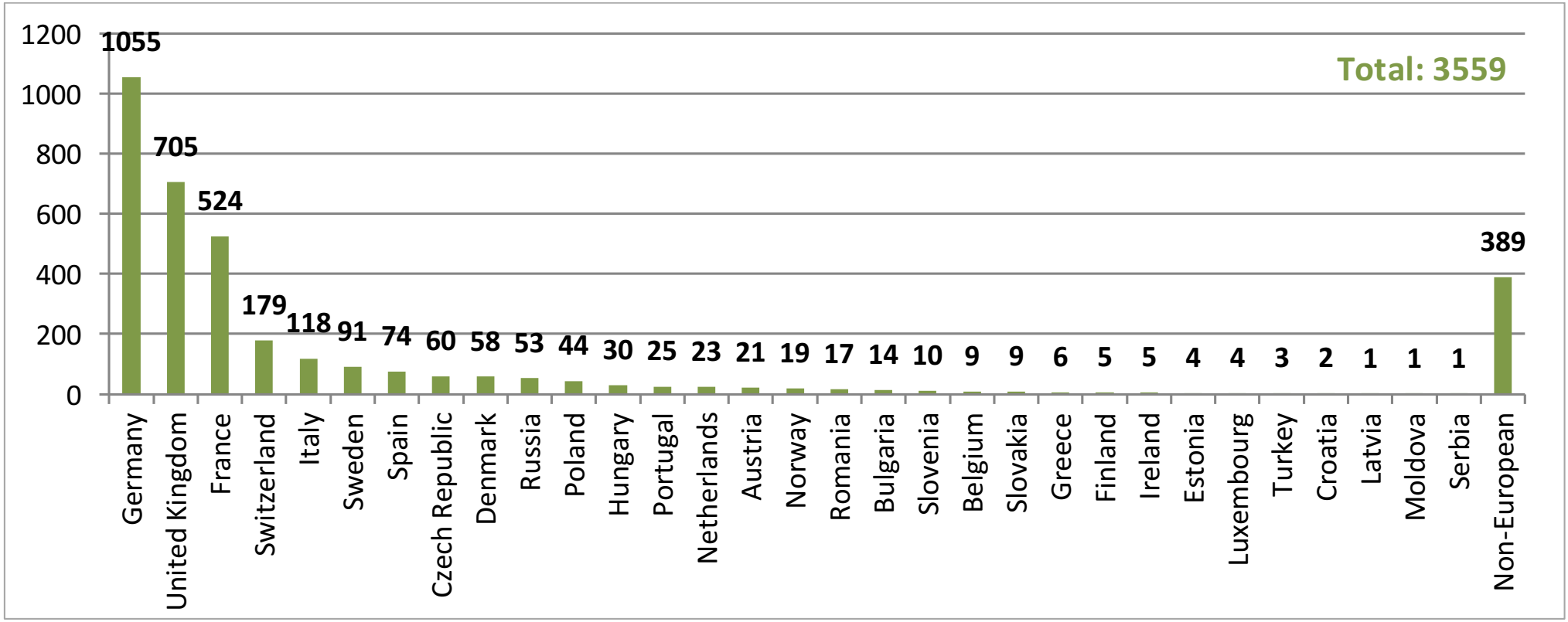
	Facility	Number of unique users	Number of instruments*	Number of experiments/year	Power	Thermal neutron flux at 1,5 Å (neutron/cm^{2}s)	Operational days/year
Big-Sized Facilities	ISIS	1580	31/31	850	200 kW	4.5 x 10^{15} (peak)	150
	ILL	1433	32/37	848	58.3 MW	1.5 x 10^{15}	200
	MLZ FRM II	965	26/26	832	20 MW	8 x 10^{14}	240
	LLB	637	20/23	403	14 MW	3 x 10^{14}	120
	SINQ	477	13/20	485	1 MW	4.1 x 10^{14}	195
Medium-Sized Facilities	BER II	302	13/17***	201	10 MW	2 x 10^{14}	200
	BNC	145	15/15	127	10 MW	2.1 x 10^{14}	120
	NPL	54	8/8	30	10 MW	1 x 10^{14}	189
Small-Sized Facilities	TRIGA JGU	44	4/4	9	100 kW	1 x 10^{12}	200
	JEEP II	43	5/6	65	2 MW	3 x 10^{13}	200
	TRIGA JSI	41	8/8	**	250 kW	5 x 10^{12}	150
	RPI	28	0/1	10	1 MW	1 x 10^{13}	150
	ATI	15	5/5	6	250 kW	5 x 10^{12}	200
	MARIA	13	4/6	46	30 MW	1 x 10^{14}	180
	RID****	0	9/9	**	2 MW	3 x 10^{12}	200

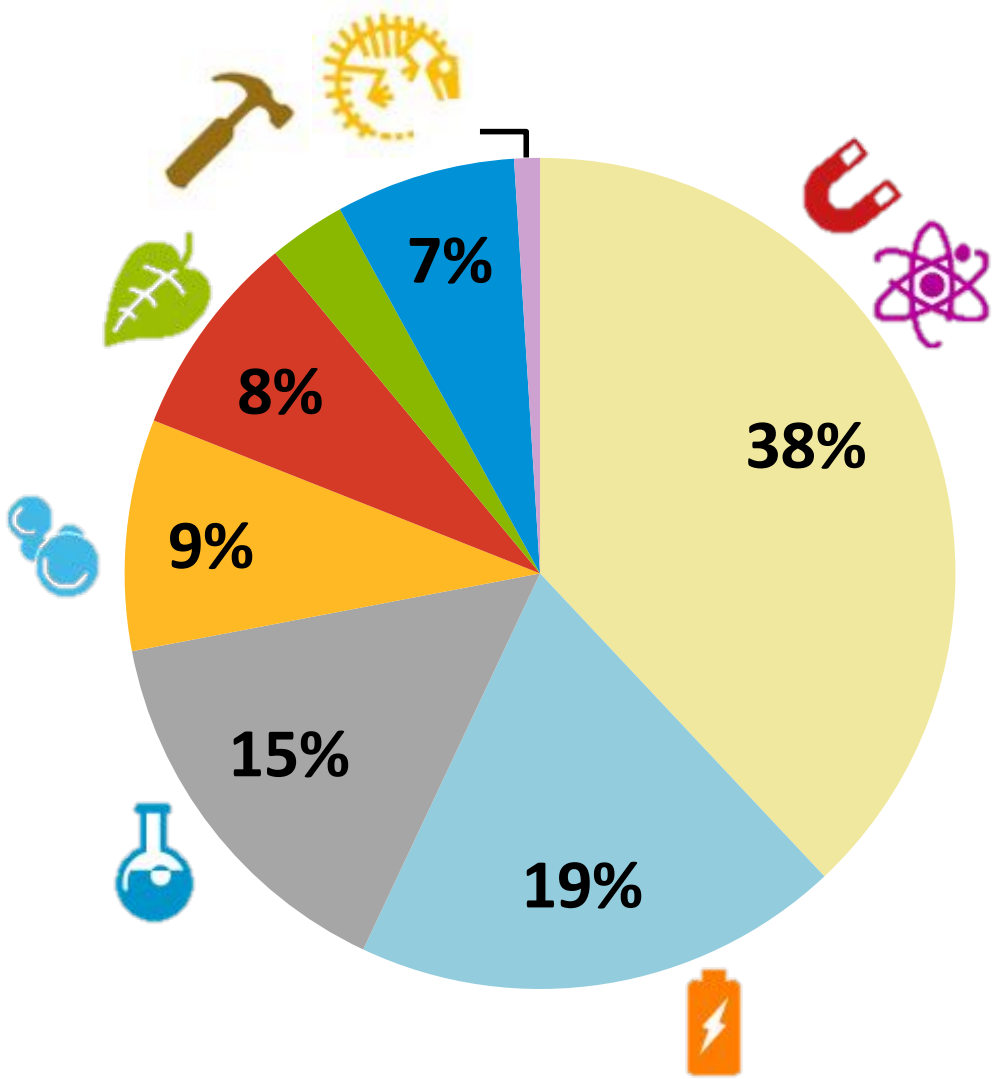
brightness

Facility-based Survey on Neutron Users

Fig 2.12 Europe: Total number of principal investigators per country

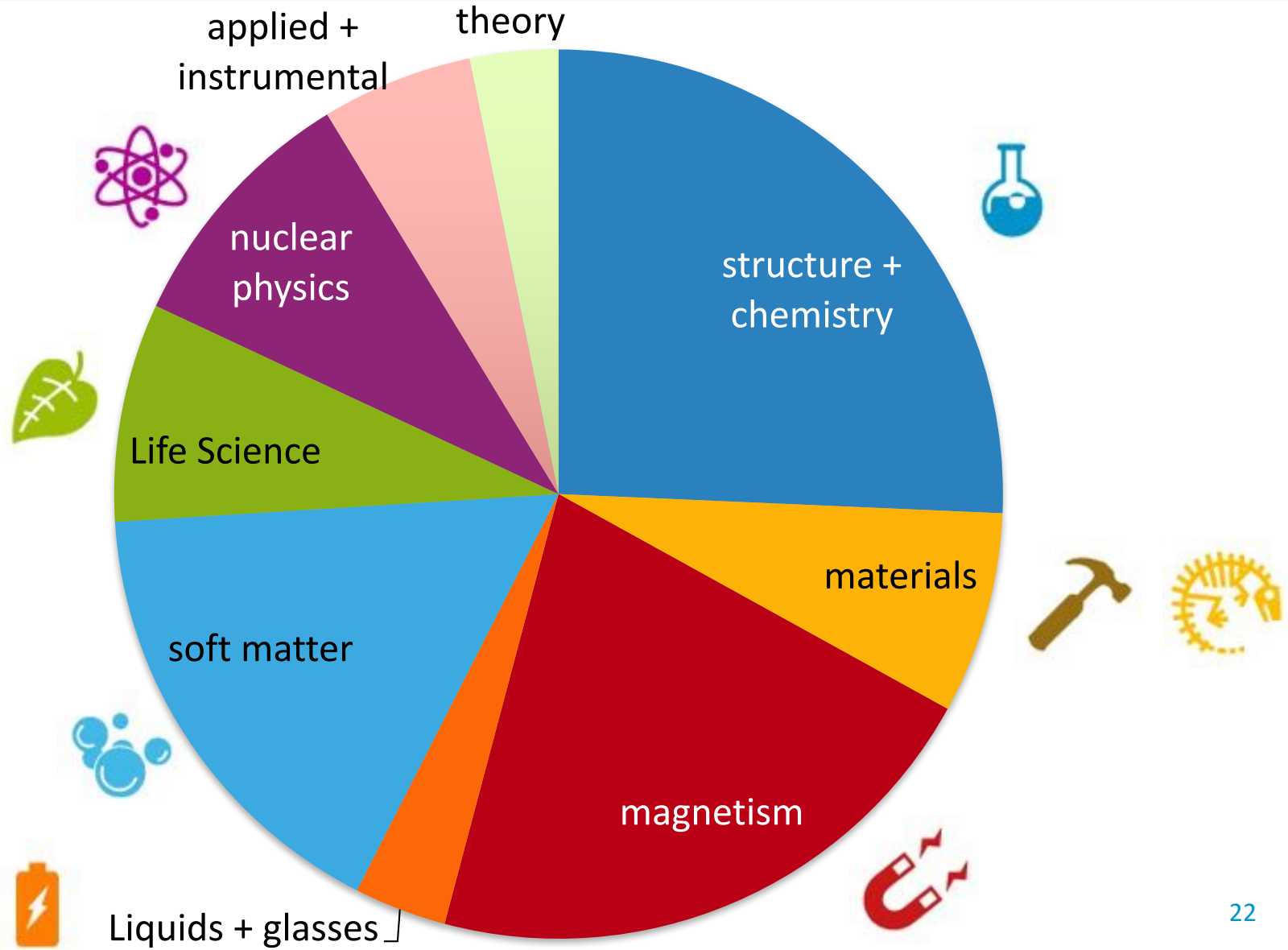


Facility-based Survey on Neutron Users



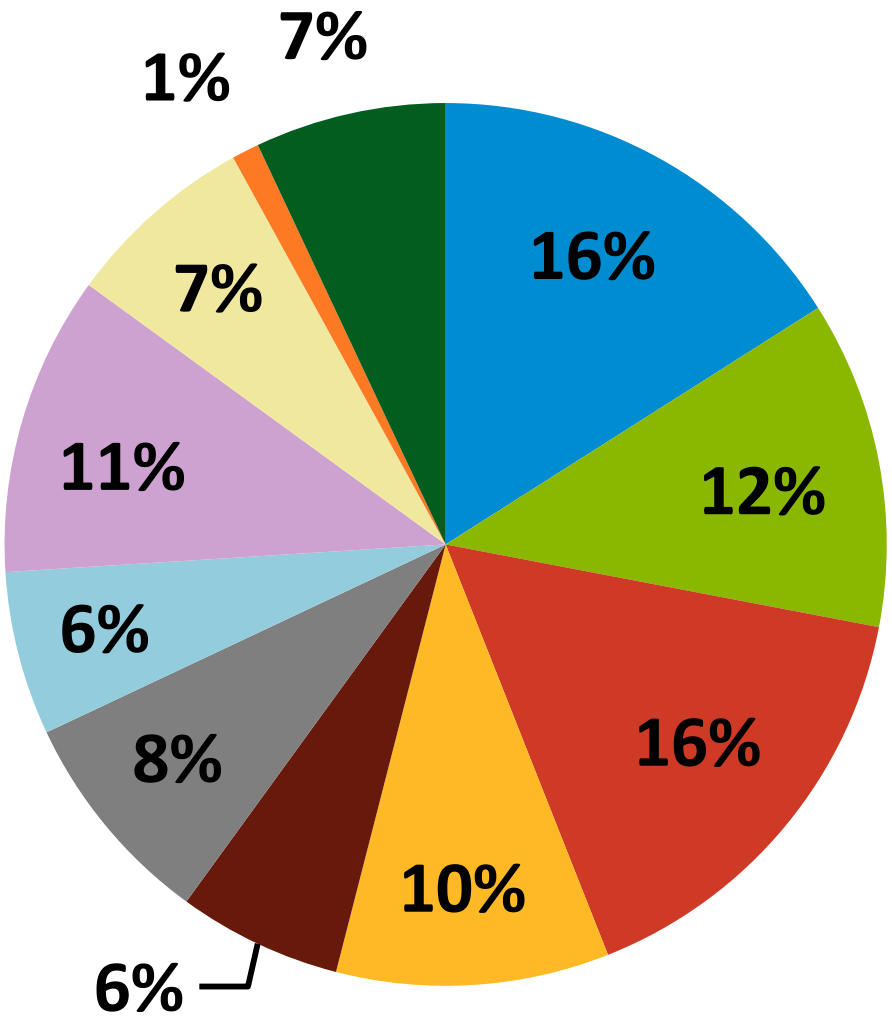
- Physics
- Materials
- Chemistry
- Soft condensed matter
- Life science
- Engineering
- Earth and geo sciences,
- Other

Neutron use per science topic



data: ILL

Facility-based Survey on Neutron Users



- Small Angle Neutron Scattering
- Reflectometry
- Powder/Liquid Diffraction
- Single Crystal Diffraction
- Engineering Diffraction
- Imaging
- High-Resolution Spectroscopy
- Cold/Thermal Triple Axis Spectroscopy
- Cold/Thermal Time-of-Flight Spectroscopy
- Vibrational Spectroscopy
- Nuclear and Particle Physics

Neutron science: Fundamental science with applications

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ERIC statutes and access policy

Article 17

Scientific evaluation and access policy

1. The Organisation shall provide effective access for European and international researchers as well as other relevant users. Access to the ESS shall be based on peer-review evaluation with scientific excellence and feasibility as criteria and granted on the basis of an access policy adopted by the Council. The access policy shall reflect the undertakings in Article 2(2)(a).

2. The ESS shall be open for access to others than members. Such access shall be open to European as well as international users and be available on the basis of the access policy adopted by Council.

Data policy in place – now working on access policy

Early science and starting the user program

2020 First neutrons

2021 Instrument hot commissioning:

Instrument teams to demonstrate the prowess of instruments by performing early experiments.

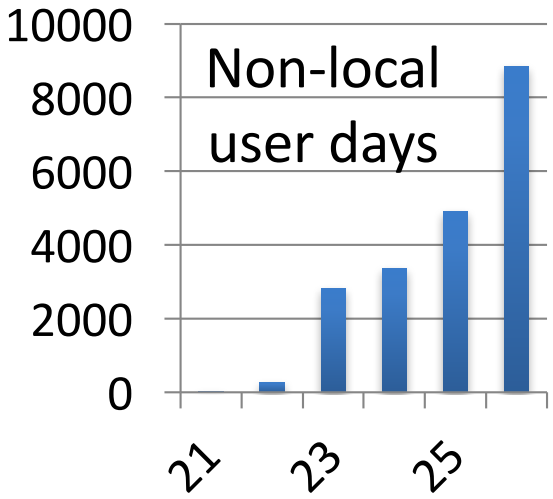
1. Critical performance verification.
2. Demonstrate scientific performance.

2023 User Program opens:

- reliability is key to deliver science.
- The entire organization need to focus on this.

User Programme and Sample Management

- **Average Experiment Duration:** 3 days
- **Users:** ~60 non-local, ~30 local, ~30 long term
- User Office interfaces with ESH on user training, dosimetry, access to supervised areas.
- Travel / accommodation reimbursement up to 2 non-local users per experiment; duration + 1day.



	Reference facility ILL	ESS
guesthouse	30 €	70 €
lunch / dinner	15 €	20 €
travel (split over duration + 1d)	25 € (150 € over 6 days)	60 € (240 € over 4 days)
non-local users on experiment	1.5 x	1.8 x
TOTAL per day	100 €/day	**270 €/day**

Scientific Coordination & User Office – Scope, Requirements and Function

Requirements and Functions:

- Enable user access based on scientific merit and others incl. industrial access
- Ensure community interaction and 'industry as user' support
- Provide training activities and collaborative industry actions.
- Internal and collaborative scientific activities; support young researchers

Scope, Features and Quality Objectives:

- User program incl. proposals, feasibility, scheduling, user visits, reporting
- Scheduling minimizing losses; high availability
- User meetings, science symposia, training activities
- Organizing access for and outreach to industry; industry specific access with other hubs
- Science Focus Teams: scientific seminars and events; PhD program

Scope Exclusions, Interfaces and Responsibilities:

- SCUO software maintenance [DMSC]
- External relations incl. ILO network, legal support, site access [ADMIN]
- User safety training [ESH]
- Individual and collaborative scientific projects [NID]

Scientific Coordination and User Office – Labor, Resources, Costs, Comparison

Cost and Resources: 2737 €

1 FTE scientist, 2 FTE assistants user office
2 FTE scientists, 1 FTE assistant industry access, community interaction, SFTs, PhD program incl. training activities, collaborative industry actions.
Financial compensation for scientists doing SFT coordination; synergies w. MAX IV included.
User reimbursement (270€ per day for average duration + 1 day) for travel and accommodation.

WBS	Personnel	Operations k€/y	Labor k€/y	Minor Cptl k€/y	Total Cost k€/y
20.4.2.2	3 FTE scientists 3 FTE assistants	0380 scuo ops 1267 usr remb 0550 PhD prg	540	0	2737

Benchmarking, Strategy, Experience:

ESS	ILL	ESRF	ISIS	SNS / HFIR
6 FTE **Sc. Coord.** and User Office	4.5 FTE User Office	4 FTE User Office		7 FTE User Service

ILL: college secretary (SFT coordination) by instrument scientists using bonus system.
MAX IV: well integrated approach between 'industry as user' team, user office and comm.

Scientific Coordination - Fostering a scientific culture at ESS as a platform for excellence

Science Focus Teams - 'Feel at home' with

- Strengthen scientific exchange via seminars and science day.
- Ensure scientific student supervision and their (*financial*) support.
- Advise on outreach activities and scientific priorities.
- Prioritize conference coverage and sponsoring.
- Support (emerging) communities and attract (additional) scientific capabilities.

○ *Life Science and Soft Condensed Matter Research*	*Zoë*
○ *Chemistry of Materials, Magnetic and Electronic Phenomena*	*Alex*
○ *Engineering Materials, Geosciences, Archeology, Heritage Conservation and Fast Neutron Applications*	*Robin*
○ *Nuclear and Particle Physics*	*Valentina*

Scientific Outreach

- SFT seminars at ESS and Science Day
- Science Symposia and Conference Support
- General partner outreach and industry-related outreach

ESS, MAX IV and Science Village Scandinavia

Ongoing collaboration

User office software
Data management
Deuteration / Xtalisation
Helium management
Technology
Science …

Conclusions

- ESS will provide world leading opportunities for research using neutrons
- User operation with 8 instruments is planned for 2023
- Vicinity to MAX IV and creation of SVS provides unique opportunities for collaboration
- Strong European Scientific Community is mobilized and ....
  - … we are building ESS together now to meet our needs.