

Building Instrumentation for Science using Neutrons

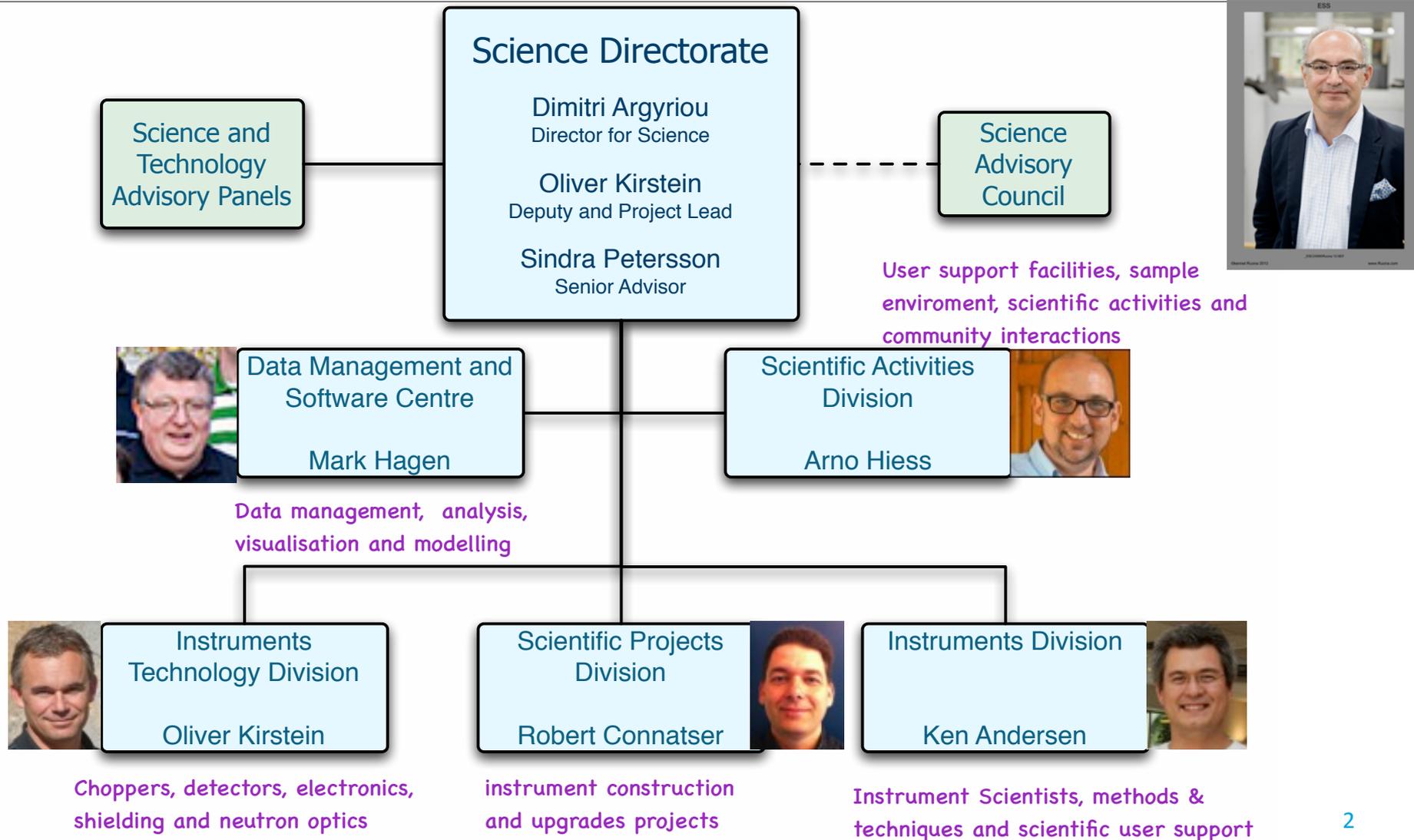
Oliver Kirstein
Head of Instrument Technologies Division &
Deputy Director for Science

www.europeanspallationsource.se



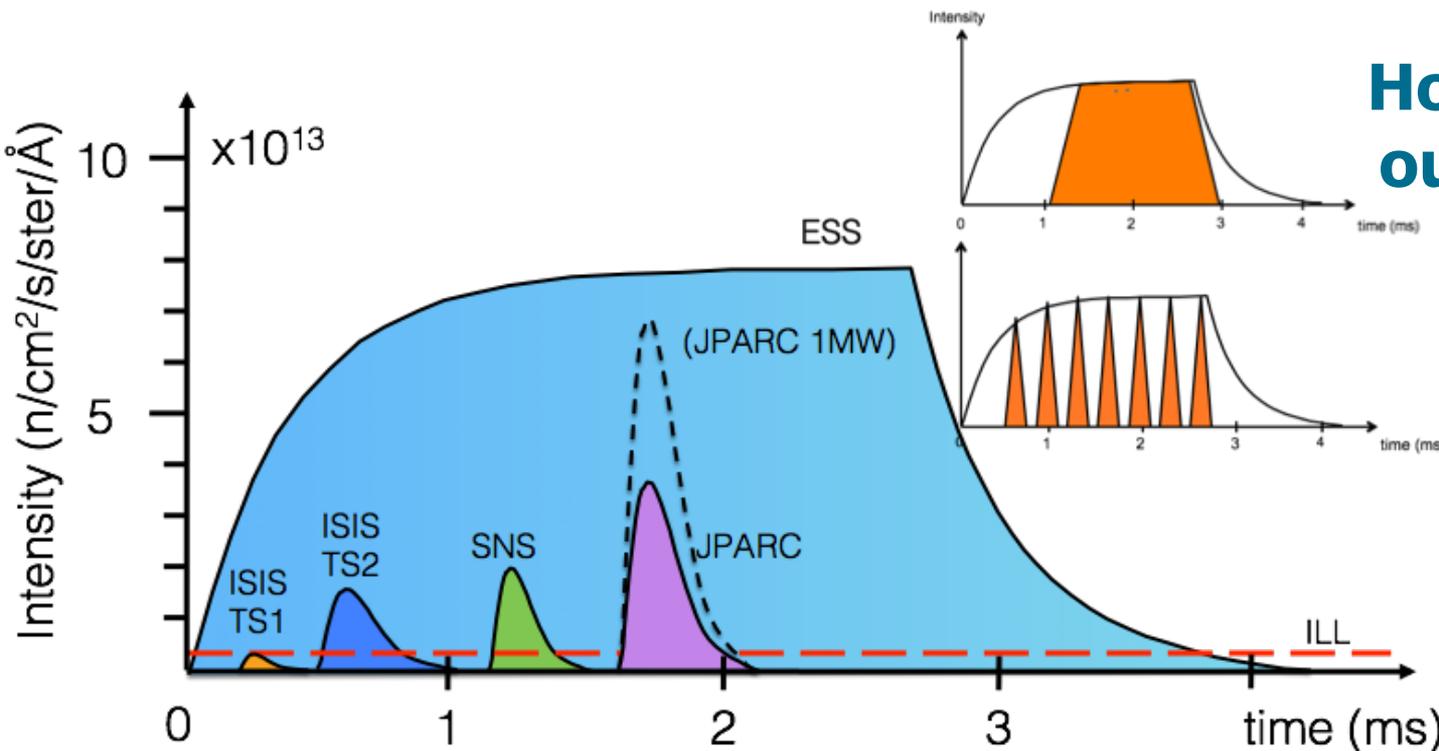
Science Directorate

Krakow, March 2014

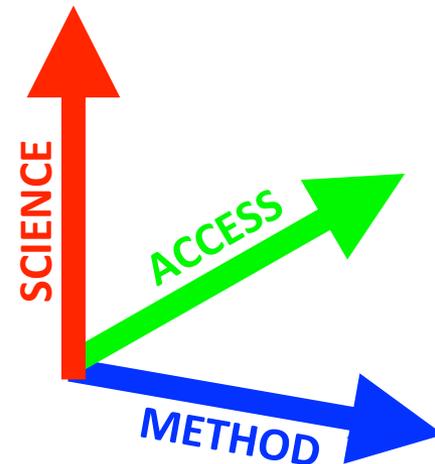


ESS Scope

“A partnership of 17 European nations committed to the goal of collectively building and operating the world’s leading **user facility** for **research** using **neutrons** by the second quarter of the 21st century.”

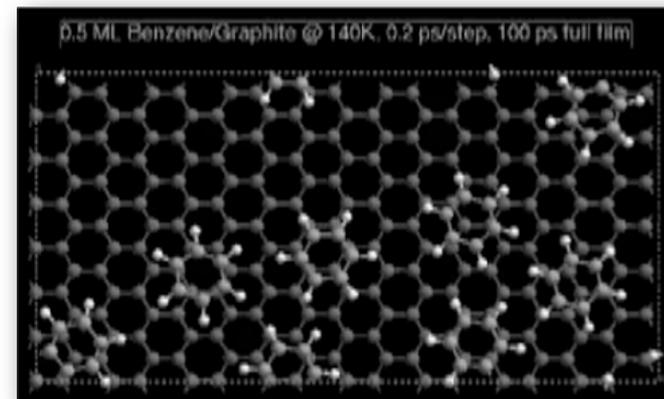
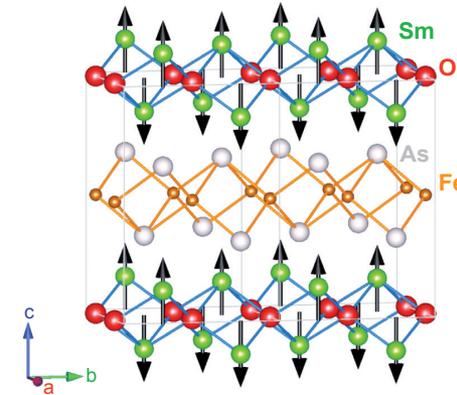
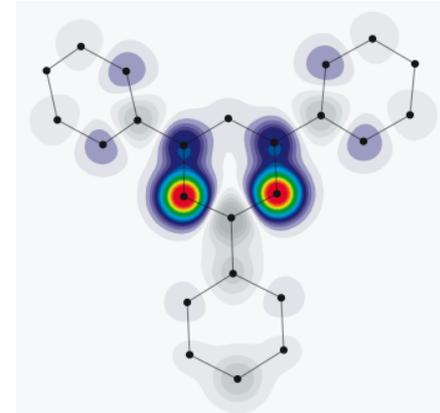
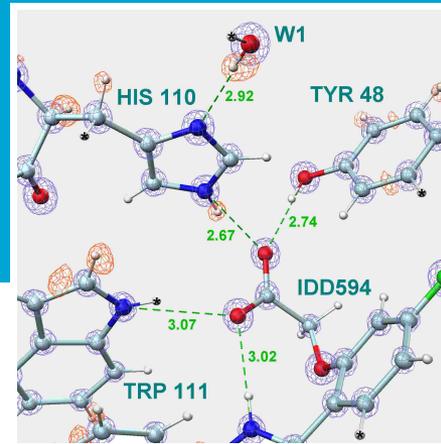


How to best use
our neutrons ...



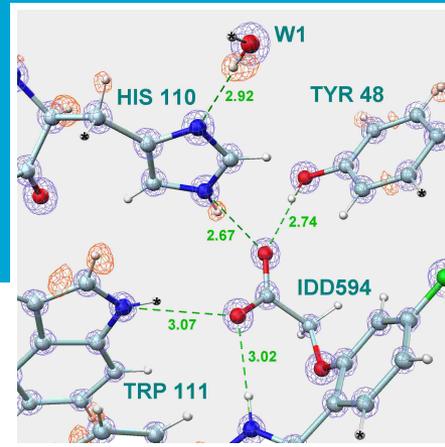
Neutrons are special

- **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** $n \rightarrow p + e + \bar{\nu}_e$ with life time $\tau \sim 900\text{s}$, $I = I_0 e^{-t/\tau}$
- **mass:** $n \sim p$; thermal energies result in non-relativistic velocities.
 $E = 293 \text{ K} = 25 \text{ meV}$,
 $v = 2196 \text{ m/s}$, $\lambda = 1.8 \text{ \AA}$

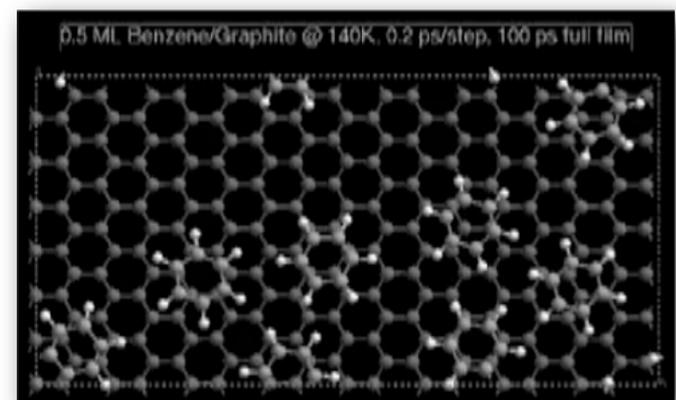
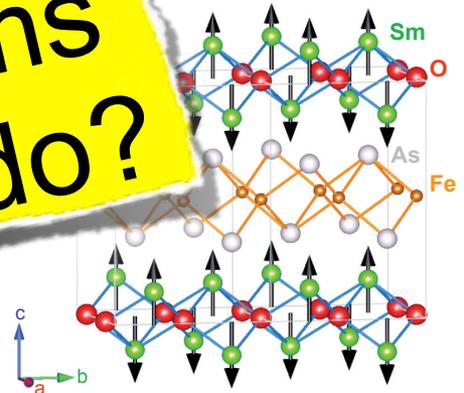


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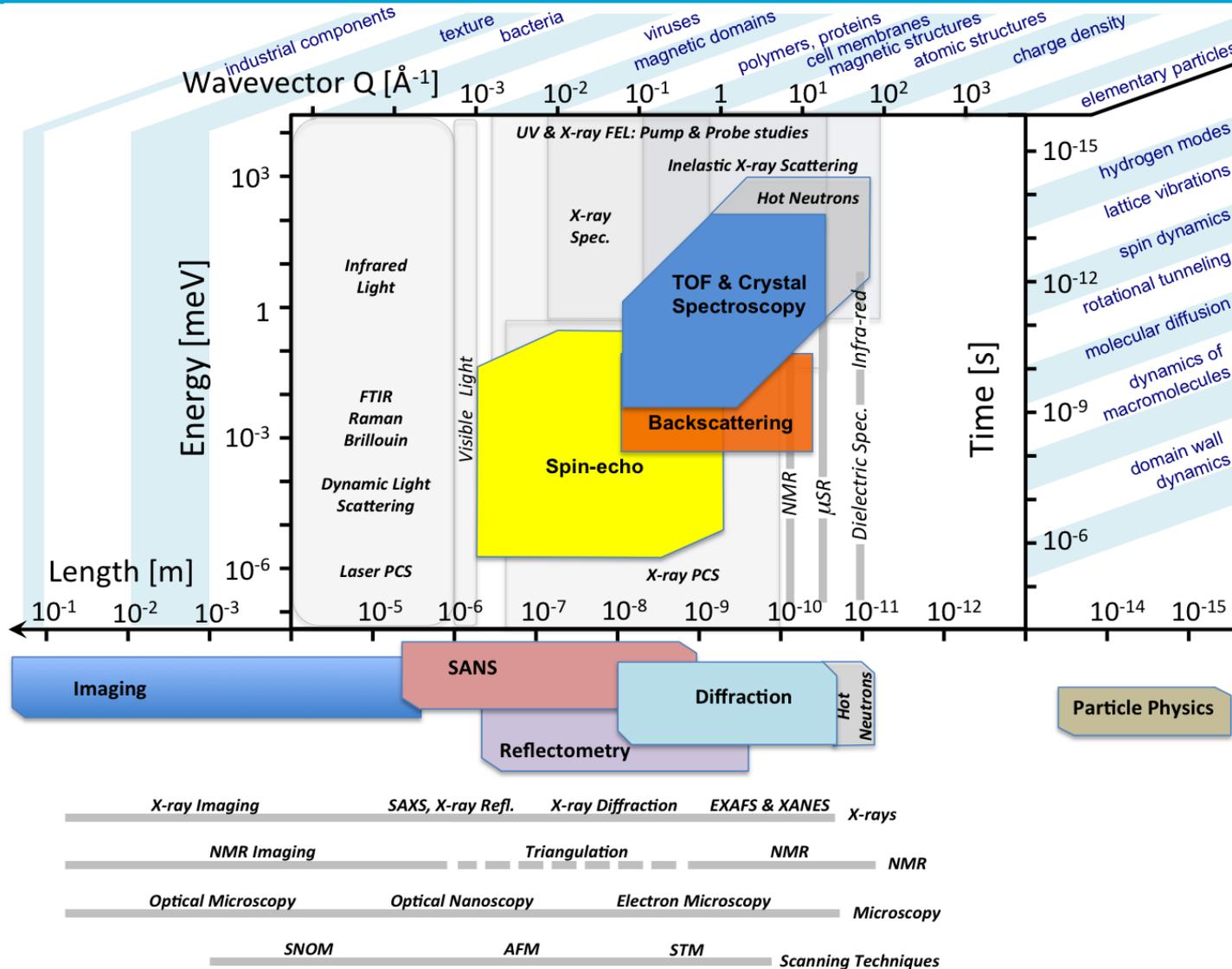


Where are the atoms and what do they do?

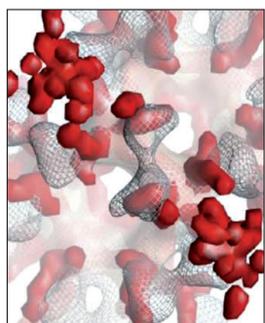
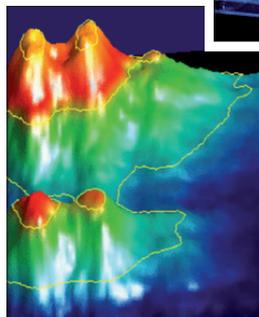
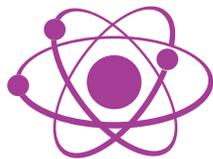
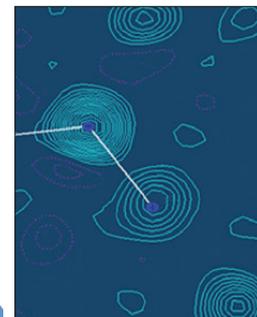
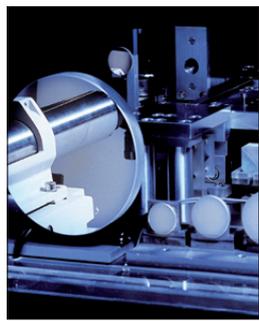


Length and Energy Scales

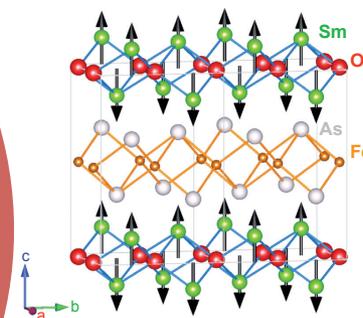
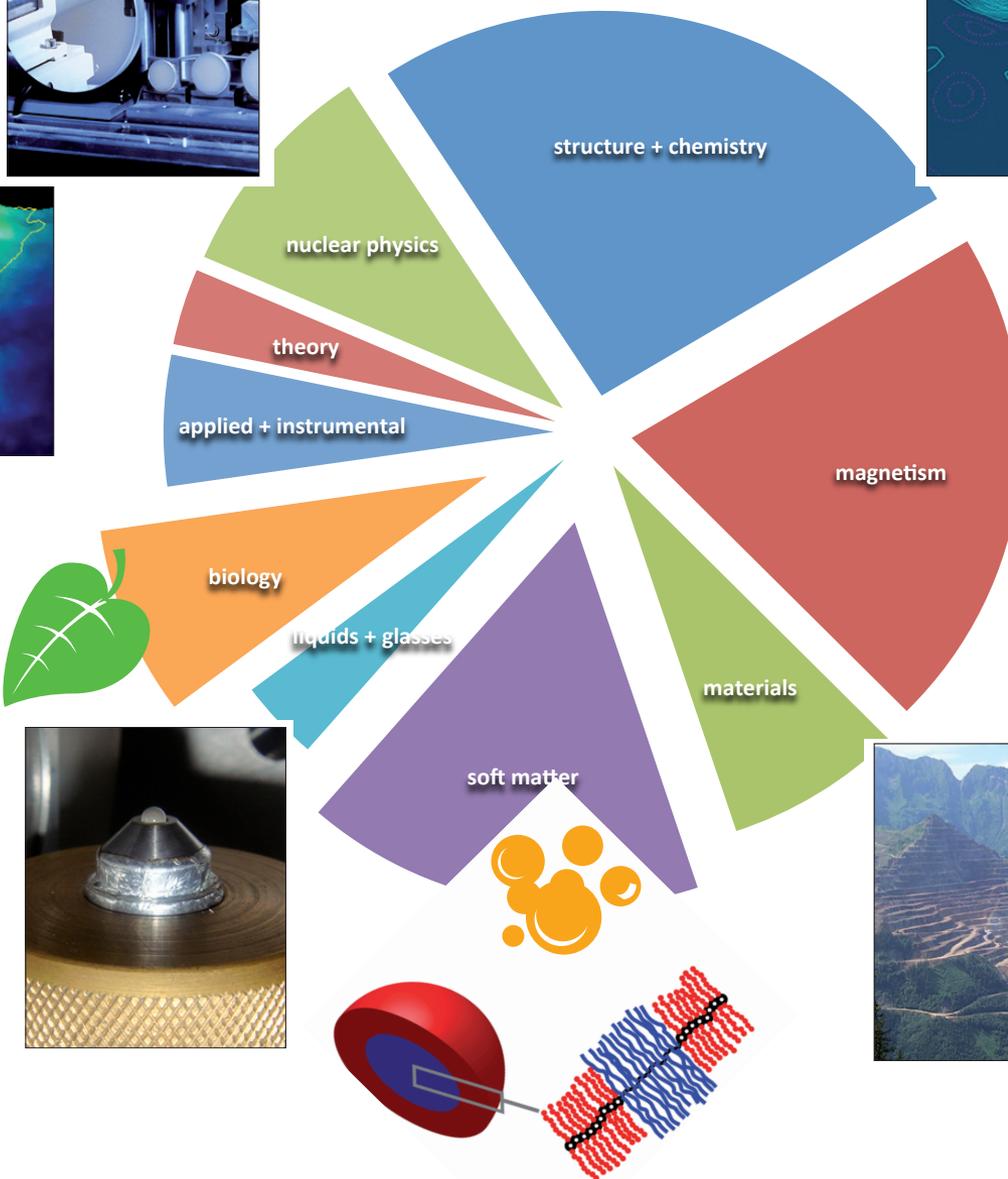
Krakow, March 2014



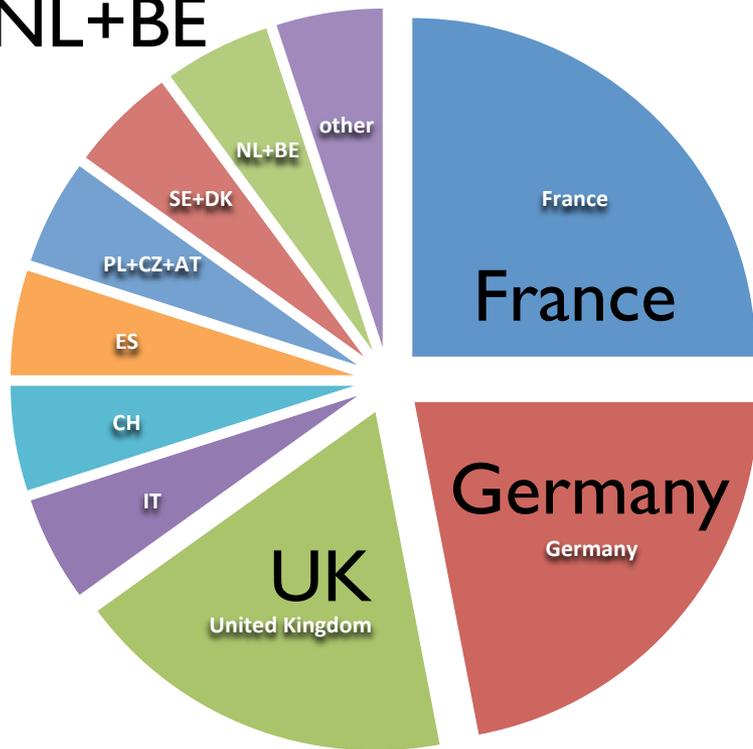
Science Topics Today



data: ILL

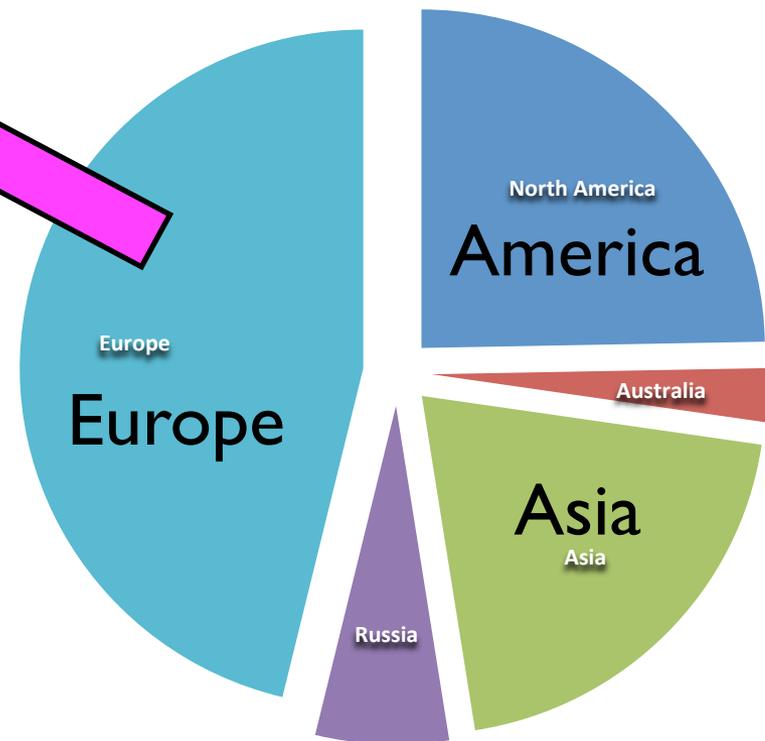
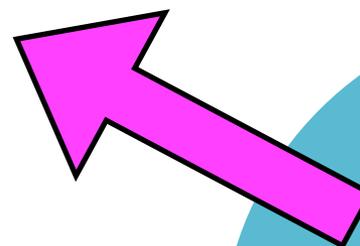


NL+BE



European Publications

5000 - 6000 researchers
2000 publications per year



ILL (80M€, 500p) per year:
7500 days requested
3500 days allocated
1000 visitors
1000 experiments
650 publications

data: ESFRI, KFN

science symposia

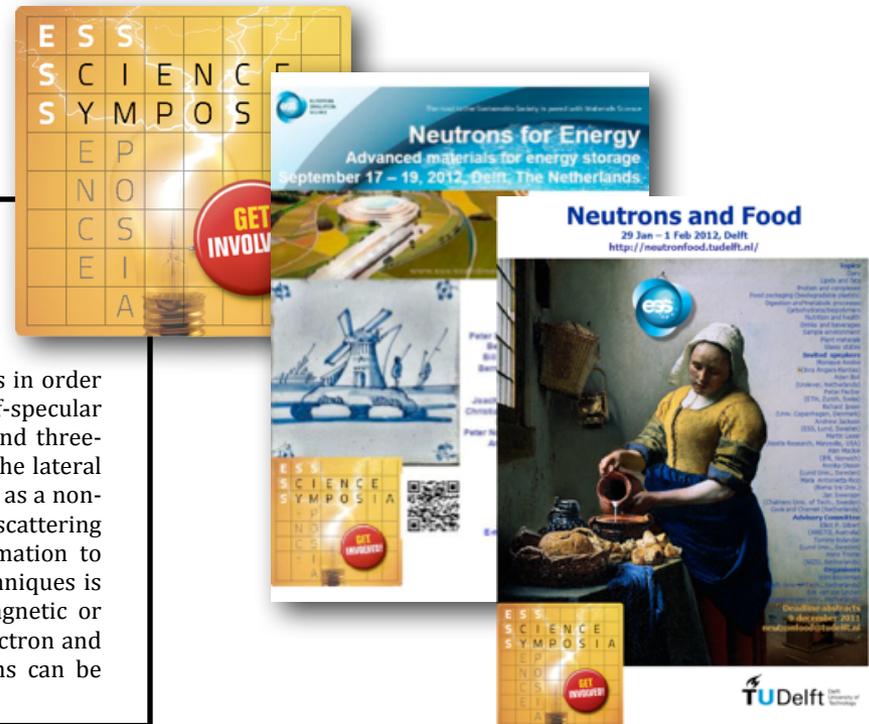
- Science Symposia: 16 symposia exploring the ESS scientific possibilities
- Involves the broader community to build the 'best' for ESS
- Symposium on Engineering
 - will be discussed today at ESS HQ

ESS workshop on Off-Specular Neutron Scattering

Brussels 9-10 January 2012

Organizers: Michele Sferrazza, Mark Geoghegan, and Markus Strobl

Off-specular neutron scattering is concerned with the analysis of films and surfaces in order to obtain lateral structural information. Off-specular neutron scattering includes off-specular reflectometry as well as grazing incidence scattering, which can probe the two- and three-dimensional structure within a film. Off-specular neutron reflectometry measures the lateral structure of buried interfaces on the μm -scale, which makes it particularly powerful as a non-invasive tool to investigate film morphology. Grazing incidence neutron scattering additionally probes structures on the nm-scale, providing complementary information to optical techniques. A particular advantage of using grazing incidence neutron techniques is the ability to highlight specific parts or components of the structures using magnetic or isotopic contrast variation. The information gained is complementary to optical, electron and scanning microscopy techniques, as the average lateral structure and correlations can be measured in-situ without the need for invasive labelling, staining or drying.



Neutron Scattering Systems Project Scope

The scope:

Construct the 22 “public” instrument suite of ESS together with a technical and scientific support infrastructure that enables scientific excellence and high quality scientific user service with reliable and sustainable operations.



22 Instruments + Supporting Technologies



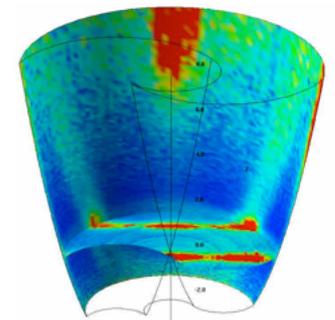
Sample Environment



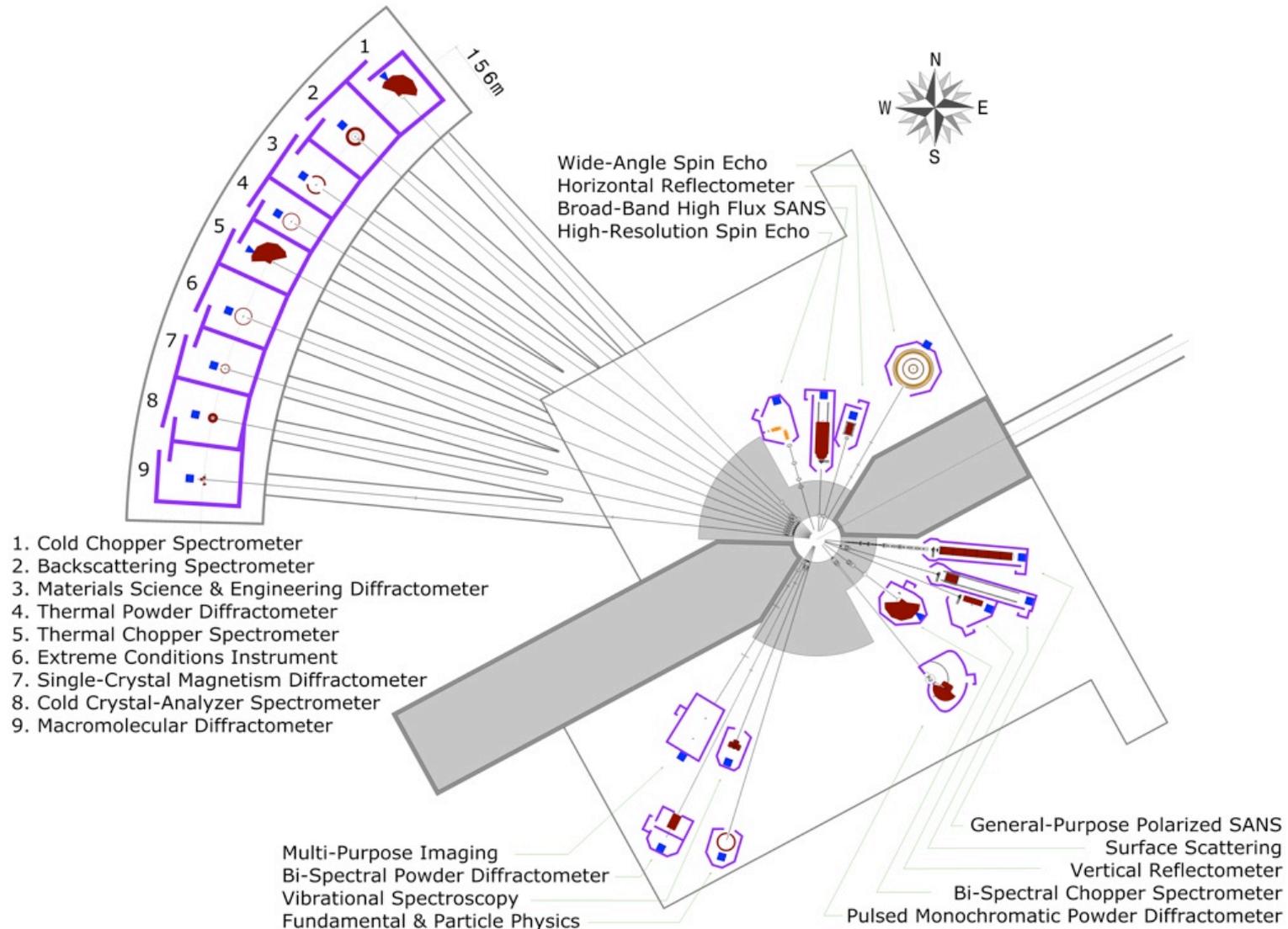
Science Support Laboratories



Analysis and Visualisation Software



Technical Design Report - Reference Instrument Suite



Reference Instrument Suite: Science Drivers

Multi-Purpose Imaging		Cold Chopper Spectrometer	
General-Purpose SANS		Bispectral Chopper Spectrometer	
Broadband SANS		Thermal Chopper Spectrometer	
Surface Scattering		Cold Crystal-Analyser Spectrometer	
Horizontal Reflectometer		Vibrational Spectroscopy	
Vertical Reflectometer		Backscattering Spectrometer	
Thermal Powder Diffractometer		High-Resolution Spin-Echo	
Bispectral Power Diffractometer		Wide-Angle Spin-Echo	
Pulsed Monochromatic Powder Diffractometer		Fundamental & Particle Physics	
Materials Science Diffractometer			
Extreme Conditions Instrument			
Single-Crystal Magnetism Diffractometer			
Macromolecular Diffractometer			

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

Many Instrument Concepts explored

WP	SANS IC2	Reflectometers IC3	Macromol. Diffraction IC4	Single Crystal Diffraction IC5	Powder Diffraction IC6	Materials Engin. Diffraction IC7	Imaging IC8	Direct Geom. Spectroscopy IC9	Indirect Geom. Spectroscopy IC10	Spin-Echo IC11	Fundam. Physics IC12
WU	Conventional SANS Full DU for fast conv. ext. q-range SANS, SD004DE/ab	Reflectometer for liquid surfaces and soft matter Full DU for wide q and add-ons, SD003DE/a	Macromol. Diffractom. Full DU, potent. farm SD036ESS	Single Crystal Mag. Diffractom. Full DU SD068ESS	Bispectral Powder Diffractometer Full DU, wfm, gen. purp., SD005DE/a	Engineering Diffraction SPEED full DU plus prototyping tests, SD005DE/b	Multi-Purpose High-Res Imaging Full DU in close collab. with CH, dark-field, Bragg edge, polarized SD006DE	Cold Chopper Spectrometer Full DU, high res., RRM and pol. cap., SD001DE/a	Phase Space Transformers Full DU, incl. feasibility studies, focussing, SD007DE/a	High Resolution NSE Full DU, small sample, SD002DE/a	Fund. Physics Full DU Not covered
WU	Small-sample SANS Full DU SANS, SD004DE/c	Reflectometer for magnetic layers Full DU, focus. pol., SD003DE/b		Single Crystal Mag. Diffractom. Full DU French collaboration	Multi Purp. Extreme Environ. Diff. Full DU, tests, SD008DE	CEED Full DU, tests, FM, SD013CZ	Larmor Label. Full DU, TOP DF imaging SD056AL	Bispectral Chopper Spectrometer Full DU, RRM pol., SD001DE/b	CAMEA Full DU plus tests and prototyping, SD016DC	Wide Angle NSE Full DU, SD002DE/b	UCN Full DU Not covered
WU	Pol. SANS Full DU, incl. SE devices SD054NL	Vertical focusing reflectometer Full DU, SELENE plus prototype tests, design full instrument, SD017DC/a			Hybrid Diffractometer potent. including SANS and imaging Full DU, SD019DC	Hi Flex. Mat. & Engin. Diff. Full DU, WFM, flex. res., SPEED, Fourier, POLDI SD059ESS	Multi-Purpose High-Res Imaging Full DU in close collab. GER, phase, fast, high res., SD029CH	Thermal Chopper Spectrometer Full DU, RRM and pol. cap. SD038ESS/a	Backscatt. Spectrometer Full DU, variable 1 to 20 micro eV resolution SD029ESS Danish In-kind	NRSE Resonant NSE, SD007DE/b	
WU	Compact SANS Full DU, incl. Monochr. mode, SD018DC	Horizontal focusing reflectometer Full DU, SELENE plus prototype tests, design full instrument, SD017DC/b			Thermal Powder Diff. Full DU, variable to high res. SD035ESS		Multi-Purpose High-Res Imaging TOF conceptual design SD046ESS	Cold Chopper Spectrometer Full DU, RRM and pol. cap. SD064ESS	Vibrational Spectrometer Full DU, SD061ESS, Italian collaboration	Focussing optics Full DU, SD007DE/c	
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Simulation software development, general simulations, supporting GER simulations, VITESS SD061DE											
General simulations, in-house supporting simulations, interface moderator-beam extraction, McStas SD012DK											



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2012 submitted proposals



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General simulations, in-house supporting simulations, interface moderator-beam extraction, McStas SD042DC											

2012 submitted proposals
2013 submitted proposals



IKON1 (Sept. 2011) - IKON6 (Feb. 2014)

Partner Day Poland



Krakow, March 2014



~130 Participants from
ESS and Partner Labs



Discussions
on technologies

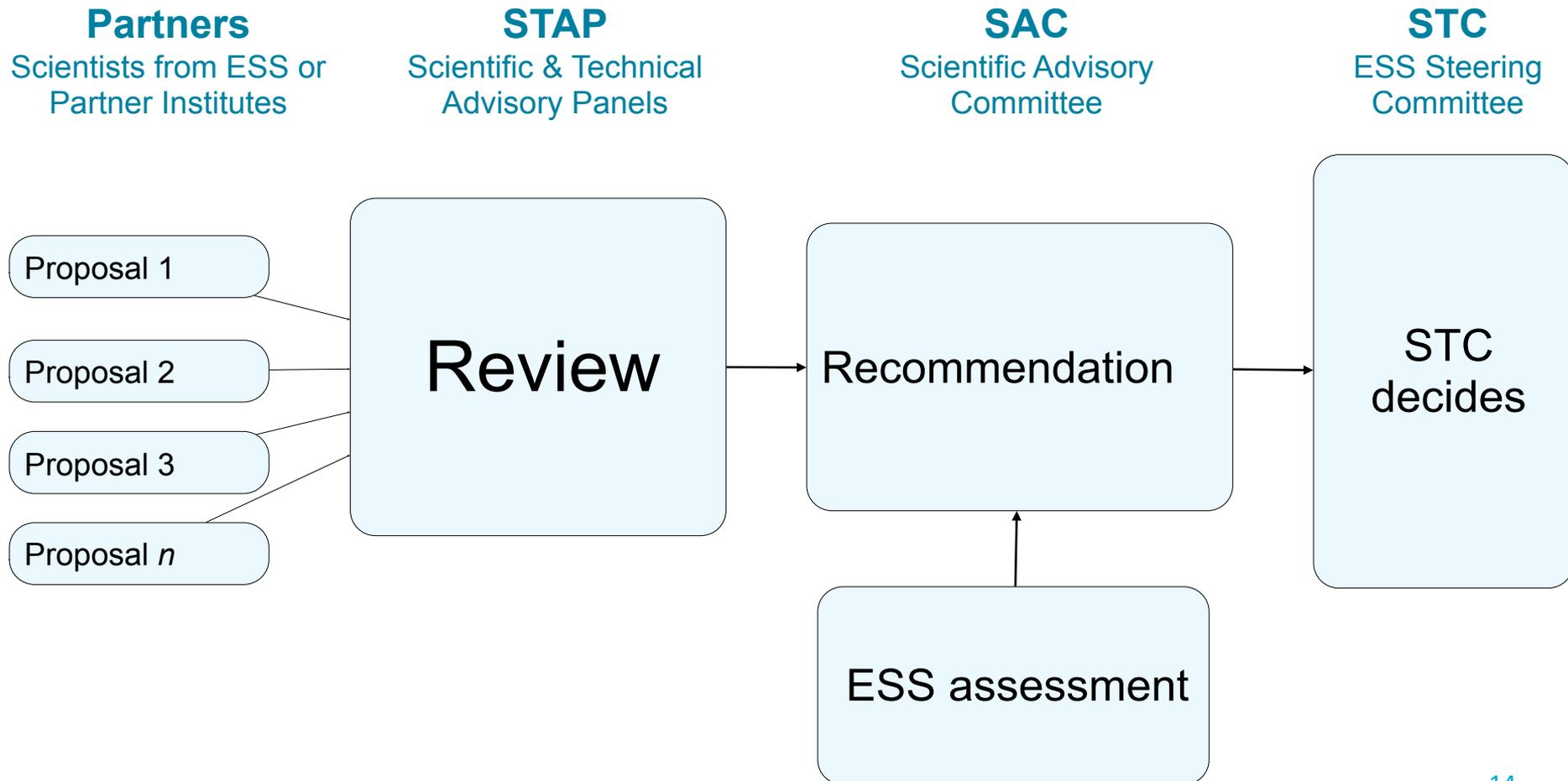


Presentations
on instrument
concepts



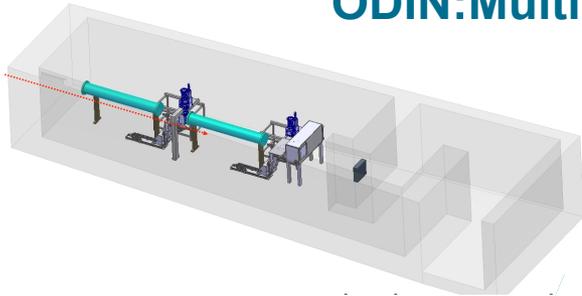
From Idea to Construction via an open process

Krakow, March 2014

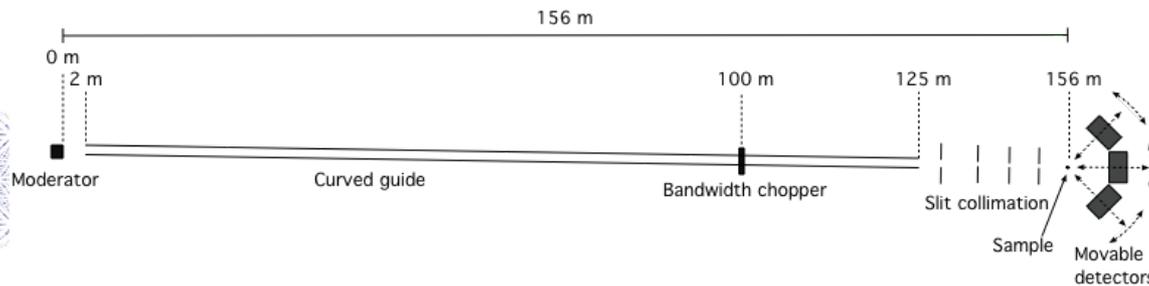
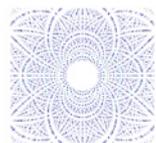
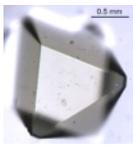


Three instruments from proposals 2012/2013 endorsed for construction

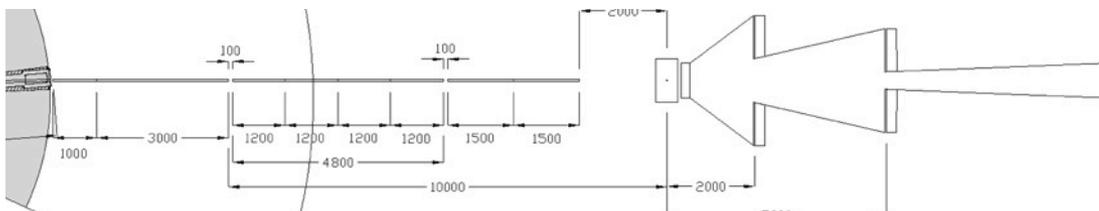
ODIN: Multi Purpose High Resolution Imaging



Single Crystal Macro-molecular Diffractometer

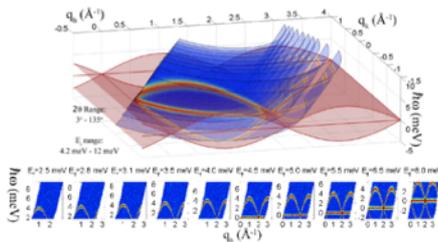


Broad Band High Flux SANS



Proposals submitted in 2013 / 2014

Spectroscopy

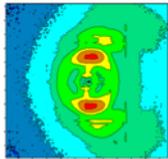


VOR
T-REX
C-SPEC
Tempus Fugit
CAMEA
ESSENSE



Wide Bandwidth Spectrometer
Bi-Spectral Spectrometer
Cold Chopper Spectrometer
Time-Focusing Spectrometer
Indirect Geometry Spectrometer
Spin Echo Spectrometer

SANS

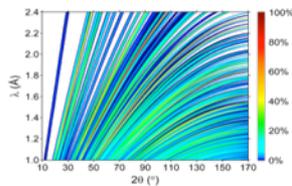


SKADI
Compact-SANS



High Intensity SANS
SANS Biology & Materials Science

Diffraction

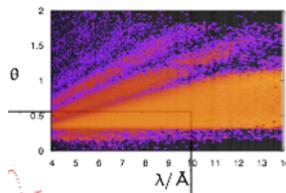


BEER
MODI
HEIMDAL
POWHOW



Engineering Diffractometer
Monochromatic Diffractometer
Thermal Powder Diffractometer
Bi-Spectral Powder Diffractometer

Reflectometry



FREIA
THOR
VERITAS
ESTIA

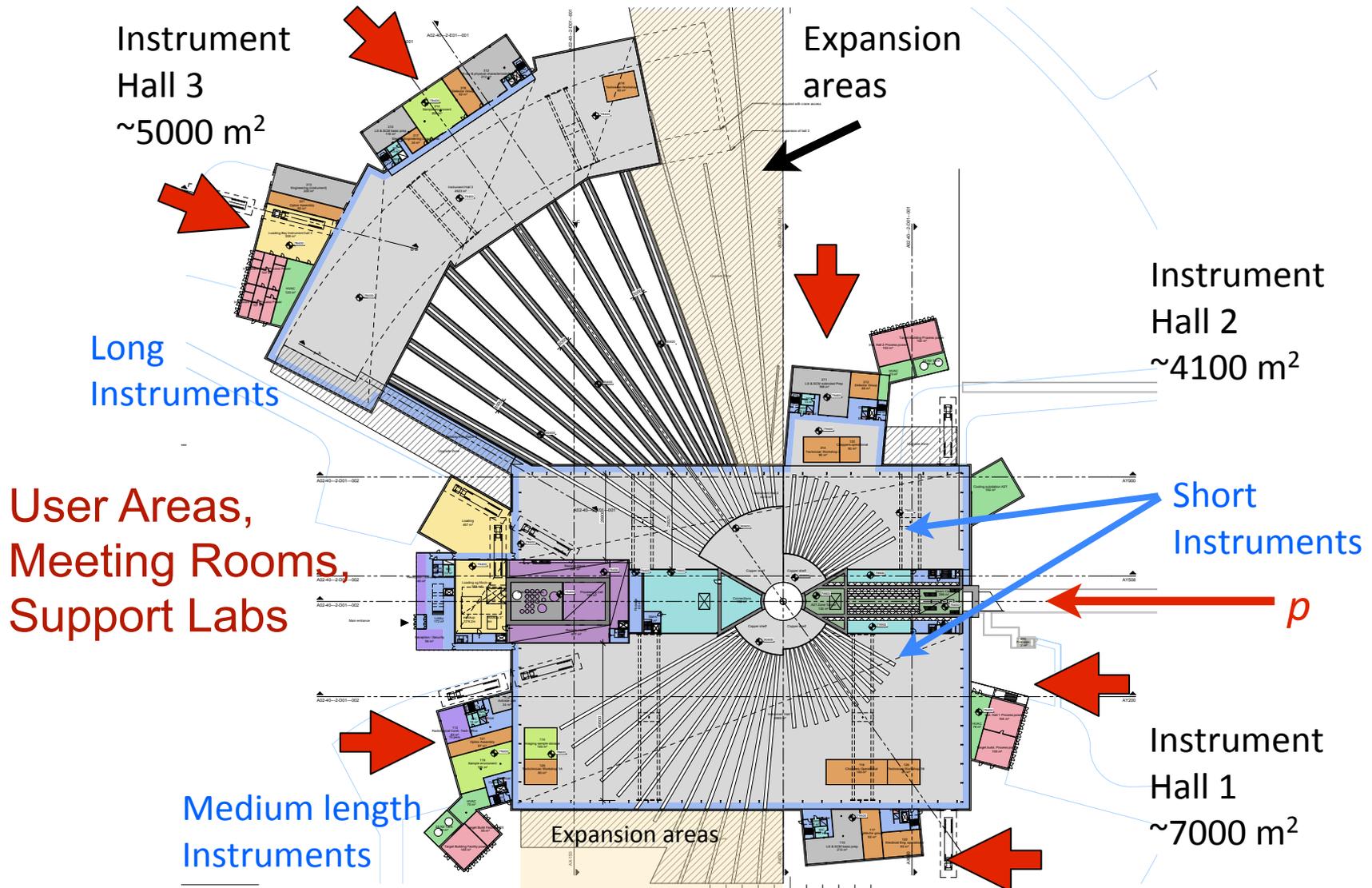


Reflectometer for liquid interfaces
Horizontal Reflectometer
Polarised Reflectometer
Focusing Reflectometer

Early Success Strategy

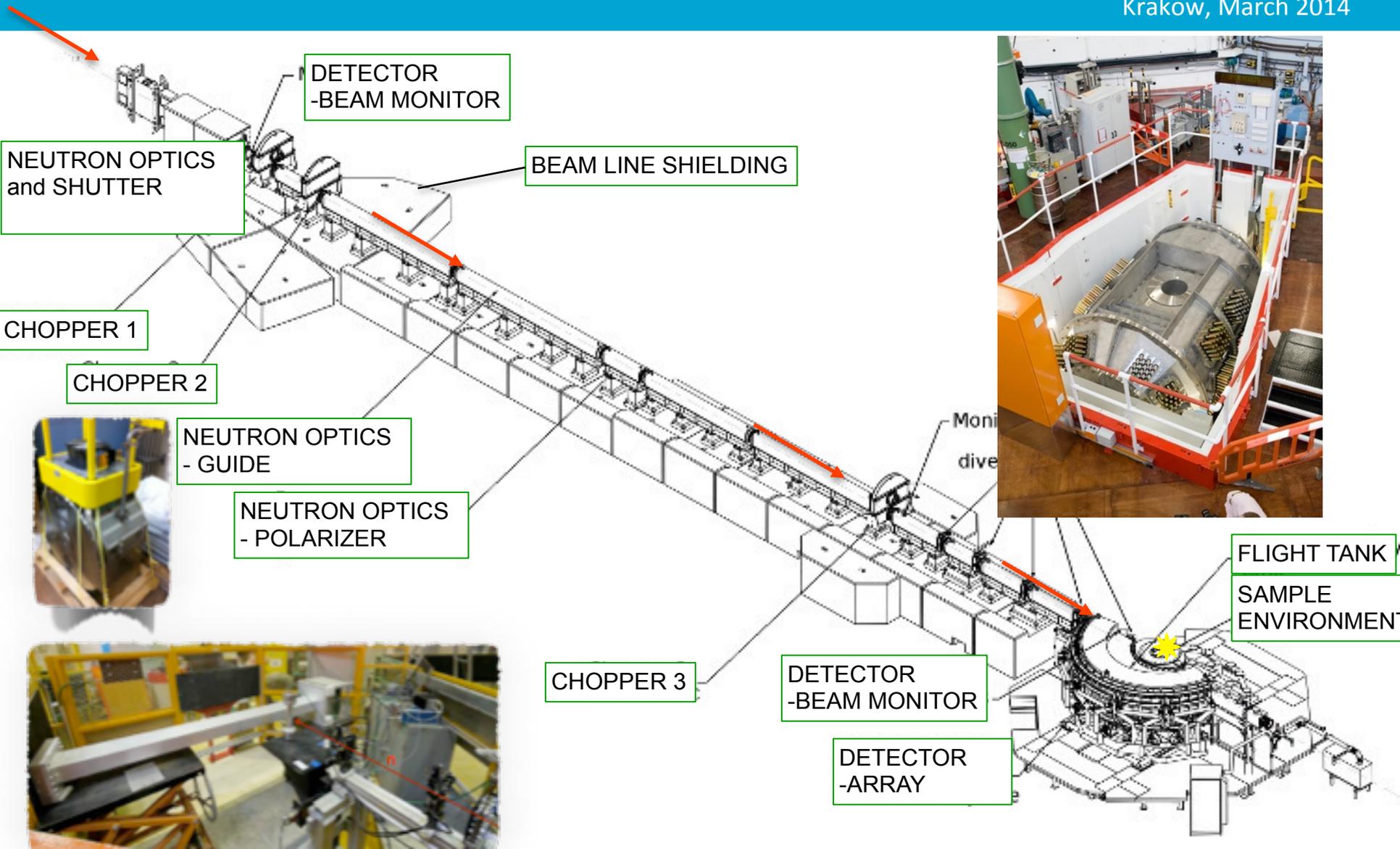
- Coherent and balanced suite in science and method considering inherent strength of ESS source, needs of user community and resources available.
- Early public and scientific attention ensures scientific programme supported through on-going construction.
- World-class instruments with broad science for bulk of users from magnetism, chemistry, soft condensed matter research.
- Instruments that couple to specialist community with potentially high impact science in fundamental physics, extreme environment research, structural biology.

User Areas and Support Labs in the Experimental Halls

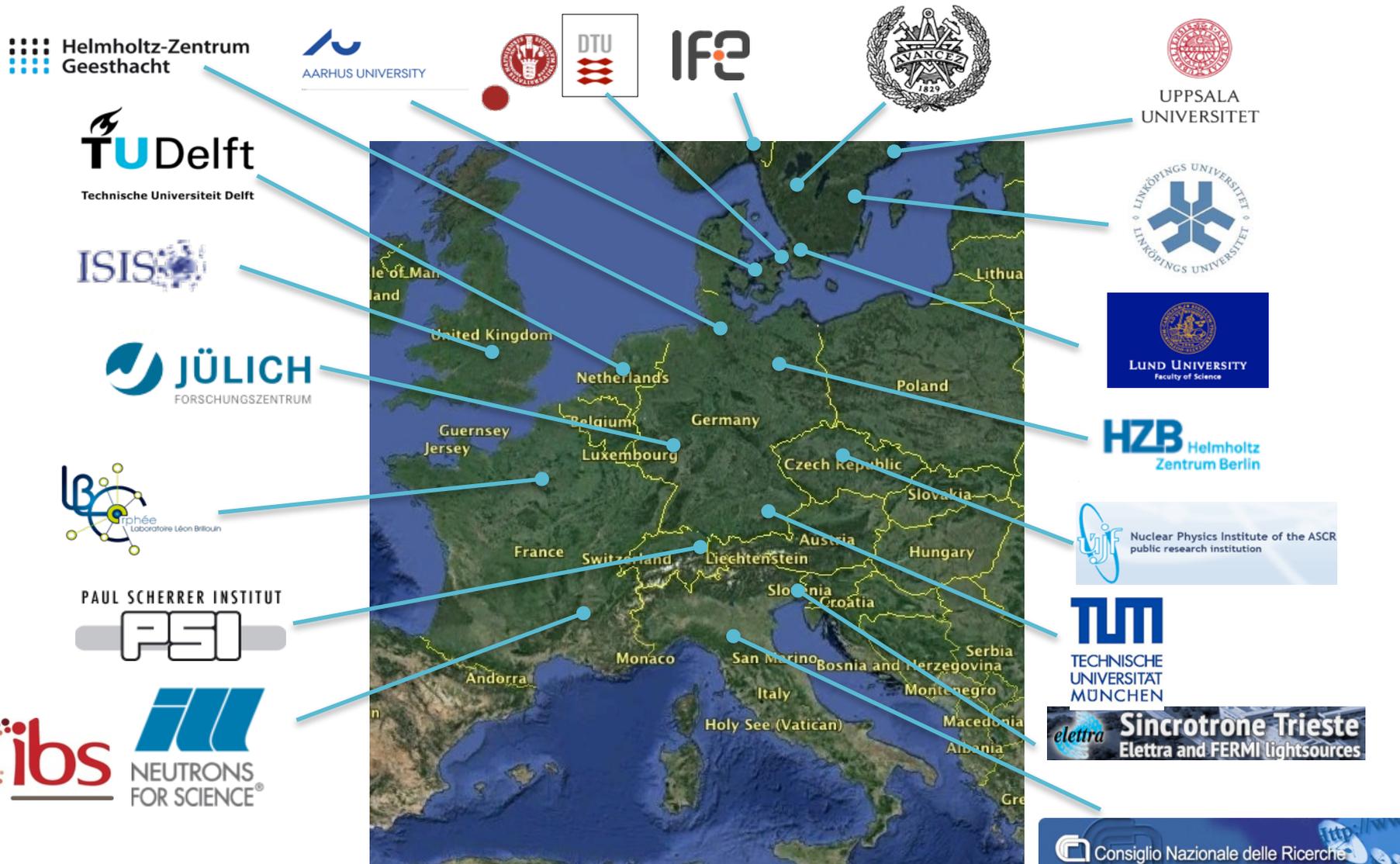


Meeting the Technical Challenges for Instrument Technologies together

Krakow, March 2014



Developing a European Wide Collaboration



timeline for instrument commissioning and user operations

Friendly Proposals

Start of Peer Review User Program



Instrument	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Instrument 1	◆	—	—	◆									
Instrument 2	◆	—	—	◆									
Instrument 3	◆	—	—	◆									
Instrument 4		◆	—	—	◆								
Instrument 5		◆	—	—	◆								
Instrument 6		◆	—	—	◆								
Instrument 7			◆	—	—	◆							
Instrument 8			◆	—	—	◆							
Instrument 9			◆	—	—	◆							
Instrument 10				◆	—	—	◆						
Instrument 11				◆	—	—	◆						
Instrument 12					◆	—	—	◆					
Instrument 13					◆	—	—	◆					
Instrument 14						◆	—	—	◆				
Instrument 15						◆	—	—	◆				
Instrument 16							◆	—	—	◆			
Instrument 17							◆	—	—	◆			
Instrument 18								◆	—	—	◆		
Instrument 19								◆	—	—	◆		
Instrument 20									◆	—	—	◆	
Instrument 21									◆	—	—	◆	
Instrument 22									◆	—	—	◆	

Conclusions

- **European Scientific Community is mobilised and awaits ESS.**
- **Funding is moving in a direction so that ESS will be realised.**
- **Instruments are being defined at a rapid rate.**
- **ESS can only be realised by harnessing European know-how and capabilities - at research institutes and industry.**
- **ESS defines project framework and management, partners take leadership and responsibility in delivering projects.**