Larmor Labelling at ESS: Opportunities and Perspectives

School on Neutron Precession Techniques, 5/7/2017

Erice, Italy

Ken Andersen, Neutron Instruments Division

Contents

- Quick Introduction and Status of ESS
- Instrument Selection
  - TDR reference suite
  - Concept development
  - Proposal rounds
  - 15 instruments chosen out of the 22-instrument suite
- The ESS Spin-Echo Saga
  - WANSE vs HRNSE
  - ESSENSE vs RESPECT
- NSE Add-ons
  - TU-Delft work: TOFLAR, SESANS, SEMSANS, SERGIS
- Future Plans
  - choosing and building instruments 16-22

ESS High-level Description

- Long-pulse spallation source
  - 5 MW, 14 Hz repetition rate, 2.86 ms pulse length
  - peak brightness ~ JPARC at 1 MW
  - time-average brightness ~ ILL at 57 MW
- Next-generation machine
  - Superconducting linac, no compressor ring
  - Rotating W target wheel
  - 3cm-tall butterfly moderators

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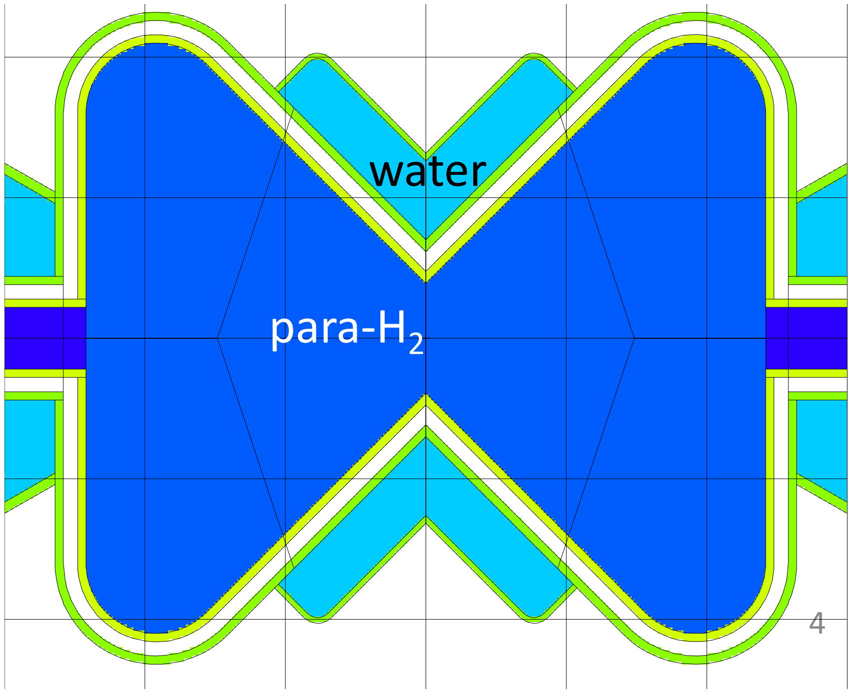

ESS High-level Description

EUROPEAN SPALLATION SOURCE

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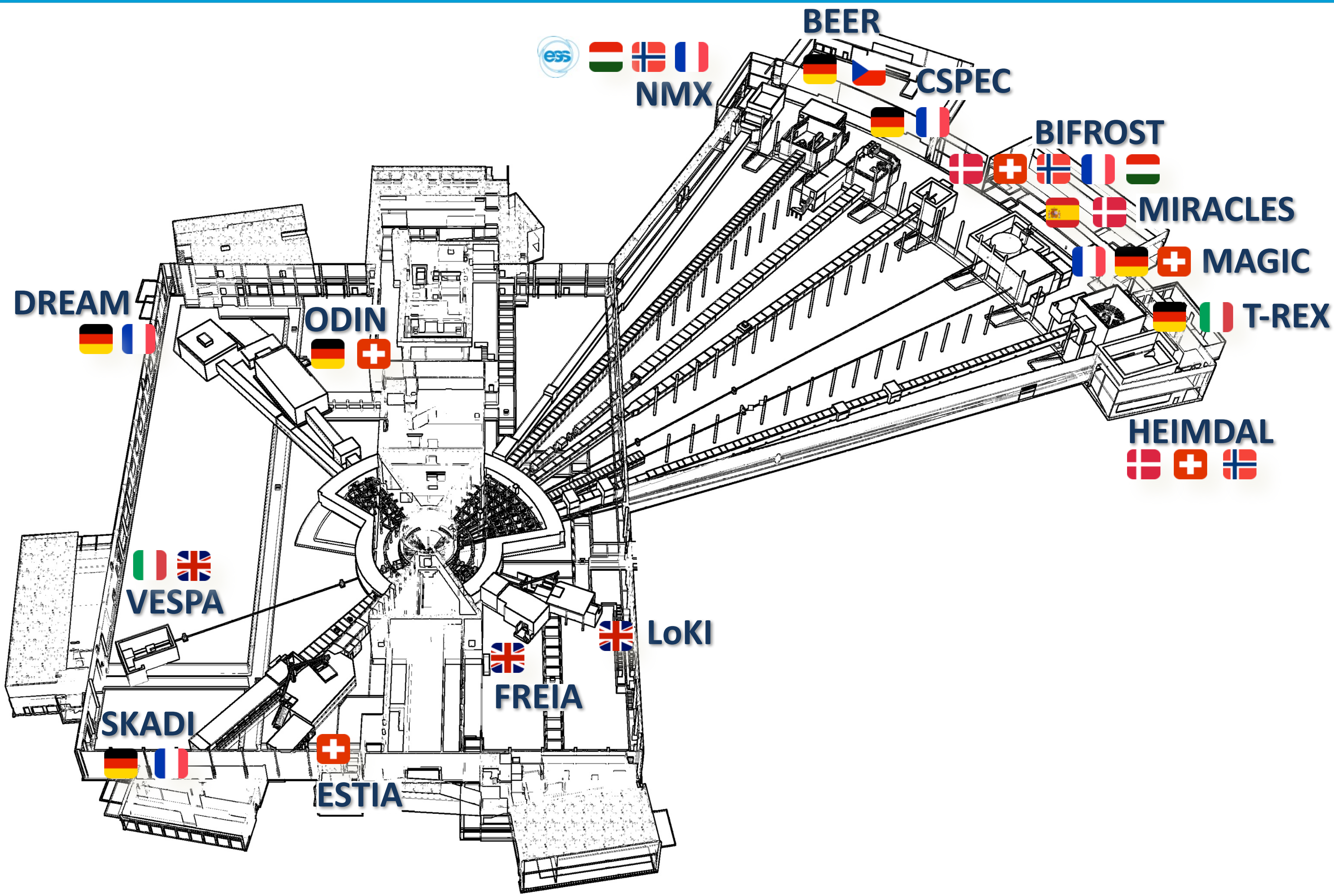
- Next-generation machine
  - Superconducting linac, no compressor ring
  - Rotating W target wheel
  - 3cm-tall butterfly moderators
  - 22 instruments (15 paid out of construction)
  - 42 beamports: good upgrade possibilities)
- High-level numbers
  - 200 days/year of operation
  - Construction budget: 1843 M€
  - Operating budget: 140 M€/year

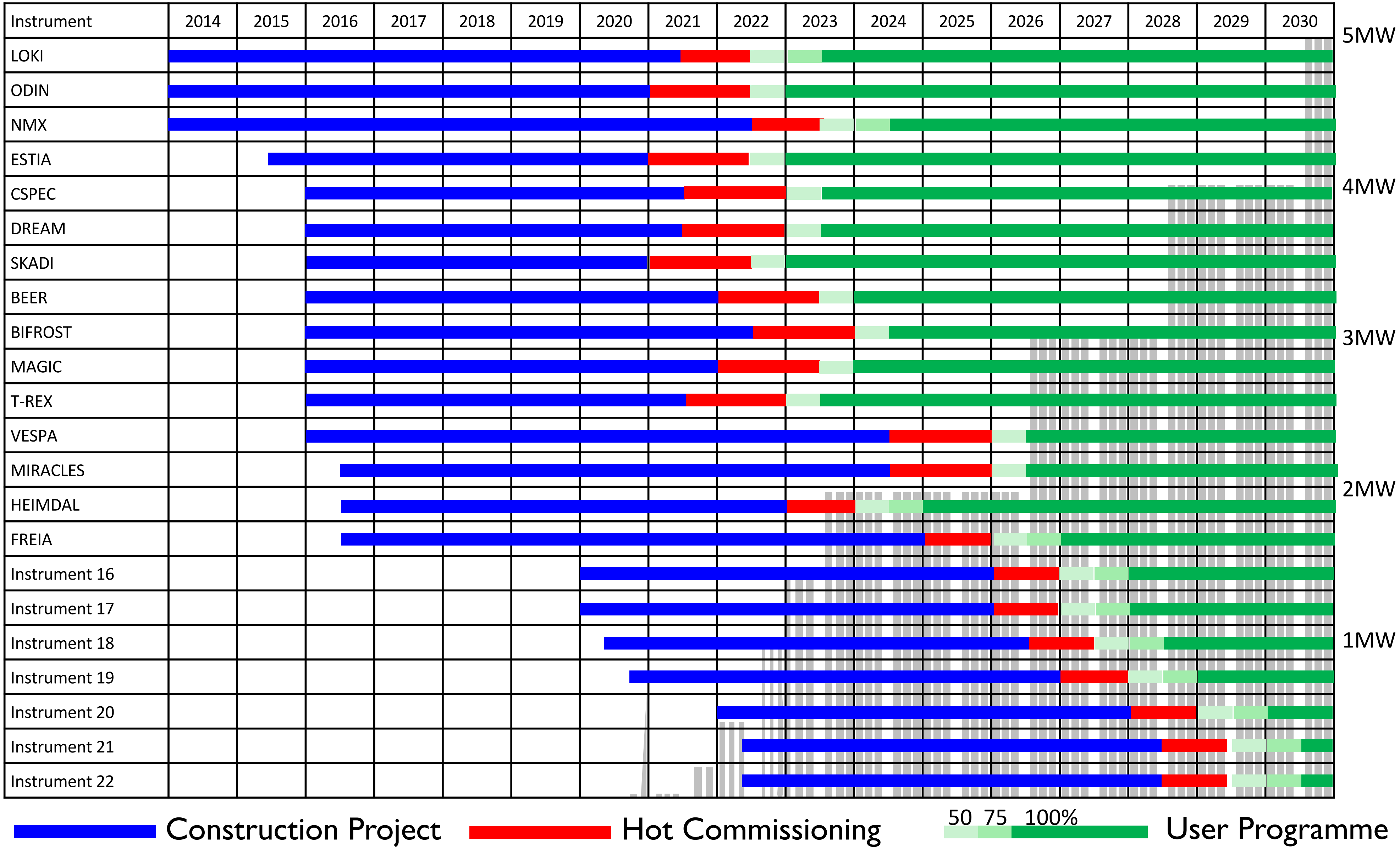
Instrument Suite



Tentative Instrument Ramp-up

EUROPEAN SPALLATION SOURCE

based on Instrument Construction Working Schedule V3.1, 25/4/2017

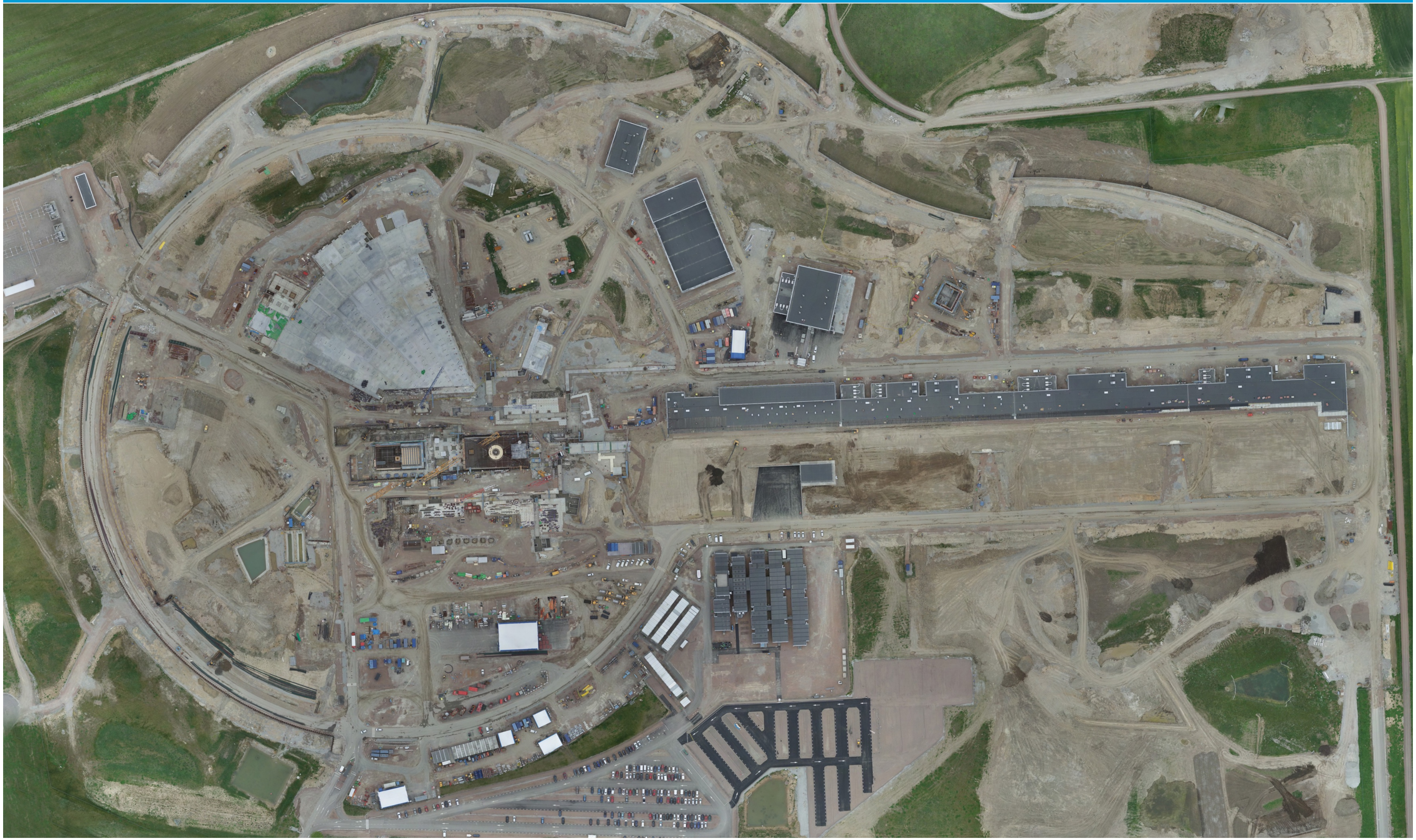


Site Layout

EUROPEAN SPALLATION SOURCE

Site Photos

EUROPEAN SPALLATION SOURCE



Site Photos

EUROPEAN
SPALLATION
SOURCE

Site Photos

EUROPEAN SPALLATION SOURCE

Vaals "Experts Meeting" 2010

EUROPEAN SPALLATION SOURCE

Large-Scale Structures

- Radiography & Tomography
- General-Purpose SANS
- Small-Sample SANS
- Combi-SANS
- Horizontal Reflectometer
- Vertical Reflectometer

Diffraction

- Narrow-Bandwidth Tuneable Diffractometer
- Hybrid Diffractometer
- Structured Pulse Engineering Diffractometer
- Extreme Conditions Diffractometer
- Single-Crystal Magnetism Diffractometer
- Macromolecular Diffractometer

Spectroscopy

- Cold Chopper Spectrometer
- Extreme Environments Spectrometer
- Backscattering Spectrometer
- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo

Fundamental & Particle Physics

Group 1: **Paolo Radaelli**, Dimitri Argyriou, Robert von Dreele, Takashi Kamiyama, Matt Tucker, Axel Steuwer

Group 2: **Bob Cubitt**, Albrecht Wiedenmann, Mikhail Zhernenkov, Frédéric Ott, Jochen Stahn, Joachim Kohlbrecher

Group 3: **Toby Perring**, Ken Herwig, Arno Hiess, Thomas Keller, Peter Böni, Kenji Nakajima

Group 4: **Katia Pappas**, Sasha Ioffe, Oliver Zimmer, Roger Pynn

Group 5: **Dieter Richter**, Ken Andersen, Thomas Brückel, Kurt Clausen, Feri Mezei

TDR Reference Suite 2013

EUROPEAN SPALLATION SOURCE

Large-Scale Structures

- Multi-Purpose Imaging
- General-Purpose SANS
- Broadband SANS
- Surface Scattering
- Horizontal Reflectometer
- Vertical Reflectometer

Diffraction

- Thermal Powder Diffractometer
- Monochromatic Powder Diffractometer
- Materials Science Diffractometer
- Extreme Conditions Diffractometer
- Single-Crystal Magnetism Diffractometer
- Macromolecular Diffractometer

Spectroscopy

- Cold Chopper Spectrometer
- Cold Crystal-Analyser Spectrometer
- Backscattering Spectrometer
- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo

Fundamental & Particle Physics

TDR Reference Suite 2013

EUROPEAN SPALLATION SOURCE

Large-Scale Structures

- Multi-Purpose Imaging
- General-Purpose SANS
- Broadband SANS
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- Horizontal Reflectometer
- Vertical Reflectometer

Diffraction

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- Bispectral Powder Diffractometer
- Monochromatic Powder Diffractometer
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- Extreme Conditions Diffractometer
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- Cold Chopper Spectrometer
- Bispectral Chopper Spectrometer
- Thermal Chopper Spectrometer
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- Vibrational Spectroscopy
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- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo

- Fundamental & Particle Physics

TDR Reference Suite 2013

EUROPEAN SPALLATION SOURCE

Large-Scale Structures

- Multi-Purpose Imaging
- General-Purpose SANS
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- Horizontal Reflectometer
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Diffraction

- Thermal Powder Diffractometer
- Bispectral Power Diffractometer
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- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo

Fundamental & Particle Physics

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

Selected Instruments Now

EUROPEAN SPALLATION SOURCE

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
- Bispectral Chopper Spectrometer
- T-REX ThChopSpec
- BIFROST Xana Spec
- VESPA Vibr.Spec.
- MIRACLES BckScatt
- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo

Fundamental & Particle Physics

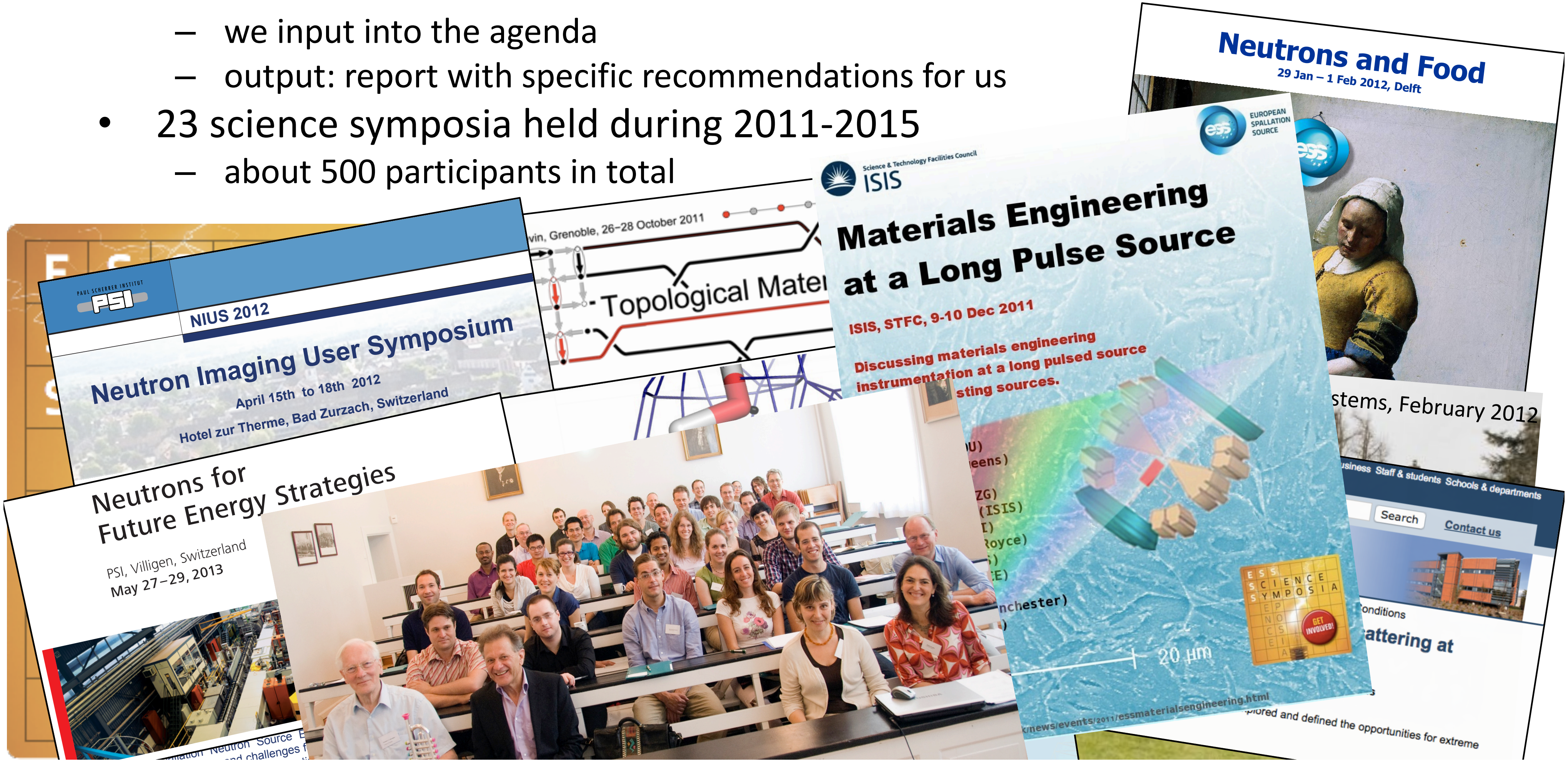
- life sciences
- soft condensed matter
- chemistry of materials
- energy research
- magnetism & superconductivity
- engineering & geo-sciences
- archeology & heritage conservation
- fundamental & particle physics

Instrument Selection Process

- ESS and Partners developed concepts
  - guided by Science Symposia
  - coordinated centrally by ESS
  - concept development as in-kind contributions
- Annual instrument proposal rounds (2012,13,14)
  - peer-review panels (STAPs and SAC)
  - guided by early success strategy
  - accepted instruments built as in-kind contributions

Science Symposia

- Organised by the community
- ESS co-funding with some strings attached
  - make recommendations on how ESS can contribute to their field
  - we input into the agenda
  - output: report with specific recommendations for us
- 23 science symposia held during 2011-2015
  - about 500 participants in total



Instrument Concepts 2010-14

EUROPEAN SPALLATION SOURCE

Large-Scale Structures

- Conventional SANS
- Small-Sample SANS
- Compact SANS
- Broadband SANS
- Liquids Reflectometer
- Magnetism Reflectometer
- Vertical Focusing Reflectometer
- Horizontal Focusing Reflectometer
- Fast Kinetics Liquids Reflectometer

Diffraction

- Macromolecular Diffractometer
- Cold Magnetism Single-Crystal Diffractometer
- Thermal Magnetism Single-Crystal Diffractometer
- Bispectral Powder Diffractometer
- Extreme Environments Beamline
- High-Pressure Diffractometer
- Hybrid Multiscale Diffractometer
- Thermal Powder Diffractometer
- Pulsed Monochromatic Diffractometer
- Multiplexing Engineering Diffractometer
- In-Situ Engineering Diffractometer
- High Flexibility Engineering Diffractometer

Spectroscopy

- Cold Chopper Spectrometer
- Bispectral Chopper Spectrometer
- Thermal Chopper Spectrometer
- Broadband Chopper Spectrometer
- Crystal Monochromator Spectrometer
- Crystal-Analyser Spectrometer
- Backscattering Spectrometer
- Vibrational Spectrometer
- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo
- Longitudinal Resonance Spin-Echo

Imaging

- Fast Kinetics Imaging
- High-Resolution Imaging
- Multi-Purpose Imaging

FP

- Fundamental Physics Beamline
- Ultra-Cold Neutron Facility
- Chip Irradiation Facility
- Neutron-AntiNeutron Oscillations

39 instrument concepts studied + 8 add-ons

Managing Instrument Concept Development

EUROPEAN SPALLATION SOURCE

- Arrange into 11 Instrument Classes
  - SANS, Reflectometry, Macromolecular Diffraction, Single-Crystal Diffraction, Powder Diffraction, Engineering Diffraction, Imaging, Direct-Geometry Spectroscopy, Indirect-Geometry Spectroscopy, Spin-Echo, Fundamental Physics
- Recruit Instrument Scientists to manage Concept Development
  - Instrument Class Coordinators
- Set up an advisory panel for each Instrument Class:
  - Scientific and Technical Advisory Panel (STAP)
- Persuade/Cajole/Push/Manipulate teams into collaborating and adapting
  - Instrument Class Coordinators and STAPs
  - Twice-Yearly In-Kind Collaboration (IKON) Meetings
- Deliverable for each Instrument Concept Development: Instrument Proposal
  - science case, instrument description & performance, technical risks
- Annual Reviews of Instrument Proposals
  - 2012: 4 proposals
  - 2013: 16 proposals
  - 2014: 11 proposals
- Peer Reviews by STAPs and Scientific Advisory Committee (SAC)

Instrument Concepts 2010-14

EUROPEAN SPALLATION SOURCE

Large-Scale Structures

- Conventional SANS
- Small-Sample SANS
- Compact SANS
- Broadband SANS
- Liquids Reflectometer
- Magnetism Reflectometer
- Vertical Focusing Reflectometer
- Horizontal Focusing Reflectometer
- Fast Kinetics Liquids Reflectometer

Diffraction

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- Cold Magnetism Single-Crystal Diffractometer
- Thermal Magnetism Single-Crystal Diffractometer
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- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo
- Longitudinal Resonance Spin-Echo

Imaging

- Fast Kinetics Imaging
- High-Resolution Imaging
- Multi-Purpose Imaging

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- Fundamental Physics Beamline
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- Chip Irradiation Facility
- Neutron-AntiNeutron Oscillations

39 instrument concepts studied + 8 add-ons

Instrument Concepts 2010-14

EUROPEAN SPALLATION SOURCE

Large-Scale Structures

Conventional SANS	proposal 2013 ✓
~~Small Sample SANS~~	
Compact SANS	proposal 2012&13 ✗
Broadband SANS	proposal 2012 ✓
Liquids Reflectometer	proposal 2013 ✗
Magnetism Reflectometer	proposal 2013&14 ✗
Vertical Focusing Reflectomet	proposal 2013 ✓
~~Horizontal Focusing Reflectometer~~	
Fast Kinetics Liquids Reflecton	proposal 2013 ✓

Diffraction

Macromolecular Diffractomet	proposal 2012 ✓
Cold Magnetism Single-Crystal Diffractometer	proposal 2014 ✓
Thermal Magnetism Single-Crystal Diffractometer	
Bispectral Powder Diffractome	proposal 2013 ✓
~~Extreme Environments Beamline~~	
High-Pressure Diffractometer	proposal 2014 ✗
Hybrid Multiscale Diffractome	proposal 2013 ✓
~~Thermal Powder Diffractometer~~	
Pulsed Monochromatic Diffra	proposal 2014 ✗
Multiplexing Engineering Diffractometer	
In-Situ Engineering Diffractom	proposal 2013 ✓
High Flexibility Engineering Diffractometer	

Spectroscopy

Cold Chopper Spectromet	proposal 2013 ✓
~~Bispectral Chopper Spectrometer~~	
Thermal Chopper Spe	proposal 2013&14 ✓
Broadband Chopper Spec	proposal 2013 ✓
Crystal Monochromator S	proposal 2013 ✗
Crystal-Analyser Spectron	proposal 2013 ✓
Backscattering Spectrome	proposal 2014 ✓
Vibrational Spectrometer	proposal 2014 ✓
High-Resolution Spin-	proposal 2013&14 ✗
~~Wide-Angle Spin Echo~~	
Longitudinal Resonance S	proposal 2014 ✗

Imaging

Fast Kinetics Imaging	
High-Resolution Imaging	proposal 2012 ✓
Multi-Purpose Imaging	

FP

Fundamental Physics Bea	proposal 2014 ✗
Ultra-Cold Neutron Facilit	proposal 2014 ✗
~~Chip Irradiation Facility~~	
Neutron-AntiNeutron Oscillations	

39 instrument concepts studied + 8 add-ons

Instrument Proposal Rounds

	SANS	Reflectometry	Macromolecular & Single Crystal Diffraction	Powder Diffraction	Materials & Engineering Diffraction	Imaging	Direct Geometry Spectroscopy	Indirect Geometry Spectroscopy	Spin Echo Spectroscopy	Fundamental & Particle Physics
2012	LOKI ✔		NMX ✔			ODIN ✔				
	Sleipnir									

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	Sleipnir									
2013	Sleipnir	THOR		DREAM ✔	BEER ✔		C-SPEC ✔	BIFROST ✔	ESSENSE	
	SKADI ✔	VERITAS		HEIMDAL ✔			VOR ✔			
		ESTIA ✔		HOD			T-REX			
		FREIA ✔					Tempus Fugit			

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2012	LOKI ✓		NMX ✓			ODIN ✓				
	Sleipnir									
2013	Sleipnir	THOR		DREAM ✓	BEER ✓		C-SPEC ✓	BIFROST ✓	ESSENSE	
	SKADI ✓	VERITAS		HEIMDAL ✓			VOR ✓			
		ESTIA ✓		HOD			T-REX			
		FREIA ✓					Tempus Fugit			
2014		HERITAGE	MAGIC ✓	HOD			T-REX ✓	MIRACLES ✓	ESSENSE	ANNI
				ESPRESSO				VESPA ✓	RESPECT	UCN

Instrument Proposal Rounds

EUROPEAN SPALLATION SOURCE

	SANS	Reflectometry	Macromolecular & Single Crystal Diffraction	Powder Diffraction	Materials & Engineering Diffraction	Imaging	Direct Geometry Spectroscopy	Indirect Geometry Spectroscopy	Spin Echo Spectroscopy	Fundamental & Particle Physics
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	Sleipnir									
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	SKADI ✓	VERITAS		HEIMDAL ✓			VOR ✓			
		ESTIA ✓		HOD			T-REX			
		FREIA ✓					Tempus Fugit			
2014		HERITAGE	MAGIC ✓	HOD			T-REX ✓	MIRACLES ✓	ESSENSE	ANNI
				ESPRESSO				VESPA ✓	RESPECT	UCN

2012-14 STAPs

Instrument Proposal Rounds

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		ESTIA ✓		HOD			T-REX			
		FREIA ✓					Tempus Fugit			
2014		HERITAGE	MAGIC ✓	HOD			T-REX ✓	MIRACLES ✓	ESSENSE	ANNI
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2012-14 STAPs

2014-15 STAPs

Instrument Proposal Rounds

SAC

EUROPEAN SPALLATION SOURCE

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	Sleipnir									
2013	Sleipnir	THOR		DREAM ✔	BEER ✔		C-SPEC ✔	BIFROST ✔	ESSENSE	
	SKADI ✔	VERITAS		HEIMDAL ✔			VOR ✔			
		ESTIA ✔		HOD			T-REX			
		FREIA ✔					Tempus Fugit			
2014		HERITAGE	MAGIC ✔	HOD			T-REX ✔	MIRACLES ✔	ESSENSE	ANNI
				ESPRESSO				VESPA ✔	RESPECT	UCN

2012-14 STAPs

2014-15 STAPs

Selected Instruments Now

EUROPEAN SPALLATION SOURCE

Large-Scale Structures

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- SKADI GP-SANS
- LOKI Broadband SANS
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- FREIA Hor. Refl.
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Fundamental & Particle Physics

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

The ESS Neutron Spin-Echo Saga

The ESS Neutron Spin-Echo Saga

EUROPEAN SPALLATION SOURCE

- TDR: 2 NSE instruments: high-resolution (IN15) and wide-angle (SPAN)
- 2014 proposal round
  - ESSENSE (FZJ) not supported by SAC: unclear if high-resolution or wide-angle should be first
  - NSE science workshop: high-resolution NSE is priority

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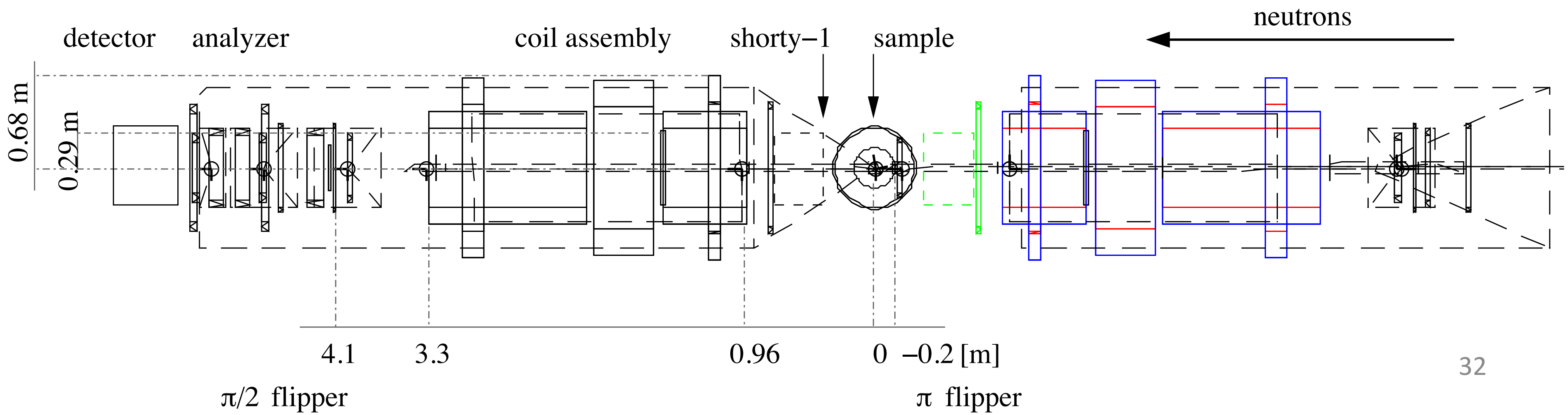
- 2015 competing proposals
  - ESSENSE (FZJ) conventional high-resolution

Wavelength range	3 – 25 Å
Bandwidth	8 Å

Max. field integral	> 1.5 T.m
τ-range	1ps-1μs

Fully-compensated superconducting coils with magnetic shielding
Very low field-integral inhomogeneity



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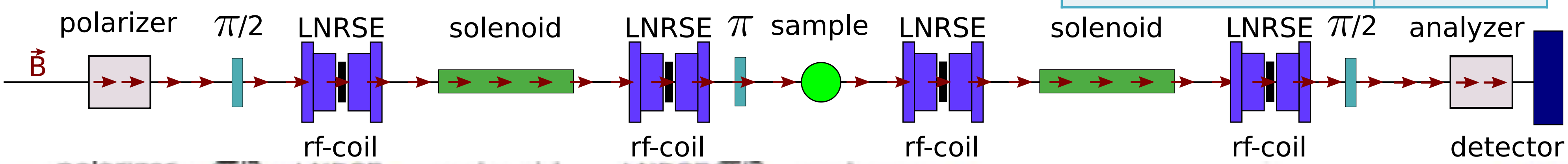
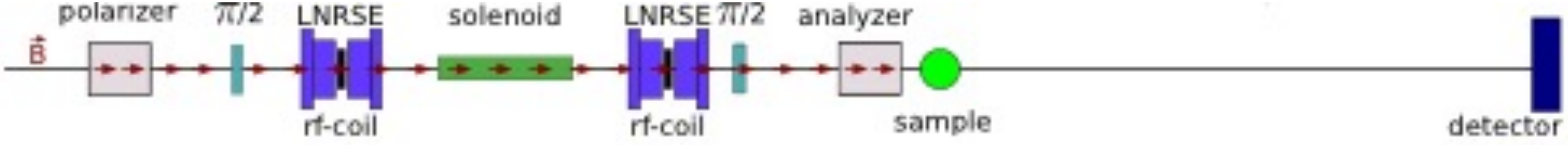
- 2015 competing proposals
  - ESSENSE (FZJ) conventional high-resolution
  - RESPECT (TUM) longitudinal neutron resonant spin-echo (LNRSE)

Wavelength range	3 – 25 Å
Bandwidth	8 Å

Effect. field integral	1 T.m
Max. radio freq.	5 MHz
τ-range	<<ps - 1μs

Options	
LNRSE	MIEZE-1
Inelastic NSE Larmor diffraction	MIEZE-2





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- 2015 competing proposals
  - ESSENSE (FZJ) conventional high-resolution – endorsed by STAP
  - RESPECT (TUM) longitudinal neutron resonant spin-echo (LNRSE) – not endorsed by STAP
  - SAC advice: postpone decision until LNRSE is more mature

The ESS Neutron Spin-Echo Saga

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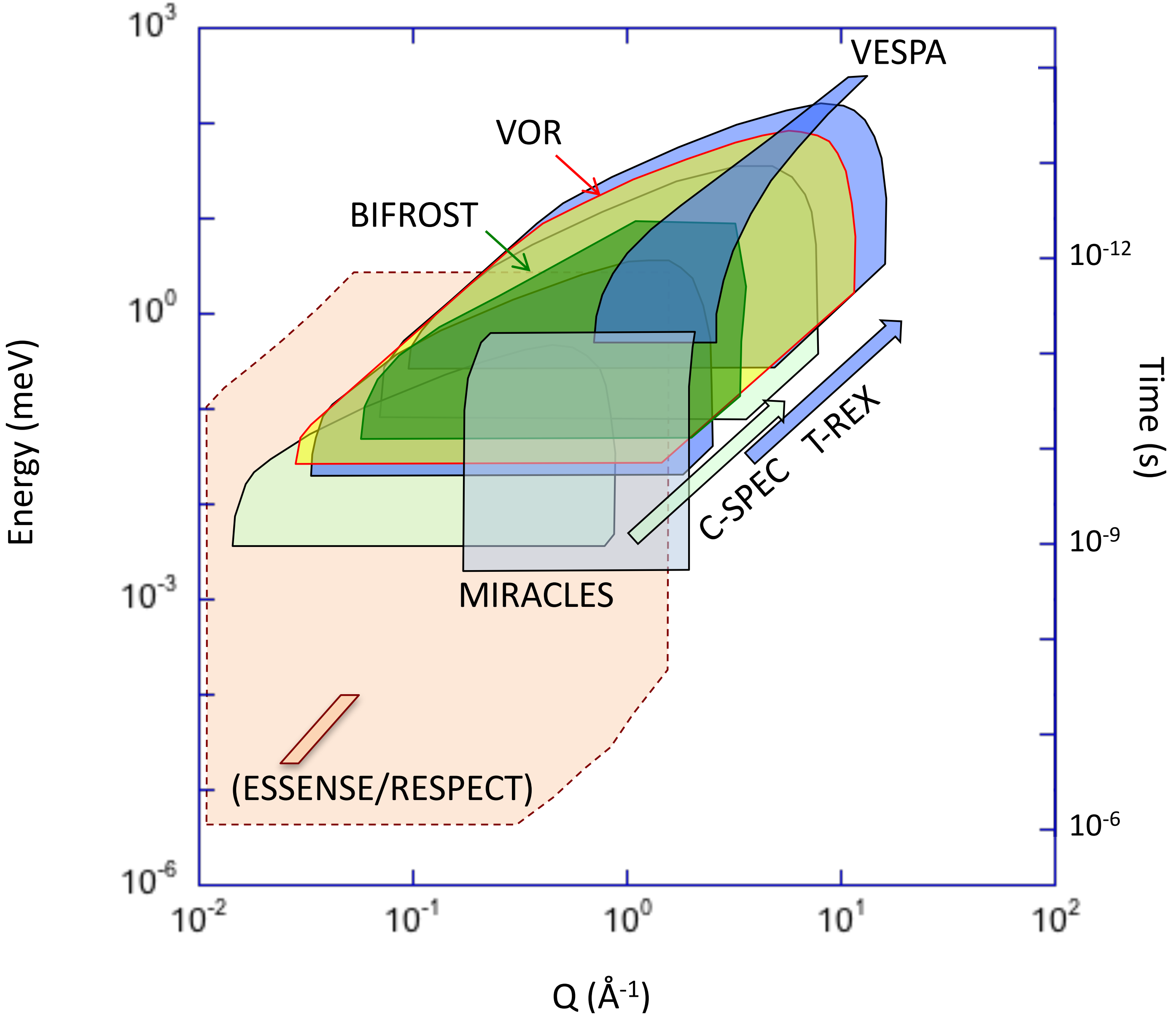
  - ESSENSE (FZJ) conventional high-resolution – endorsed by STAP
  - RESPECT (TUM) longitudinal neutron resonant spin-echo (LNRSE) – not endorsed by STAP
  - SAC advice: postpone decision until LNRSE is more mature
- Technical issues to address
  - ESSENSE: resistive or superconducting (IN15 and J-NSE upgrades)
  - RESPECT: longer Fourier times (RESEDA), focusing guide with LNRSE, study field correction
- Project decision
  - Go ahead with the other 15 instruments
  - NSE not included in instrument suite yet

Neutron Spin-Echo



Neutron Spin-Echo at ESS in 2015

EUROPEAN SPALLATION SOURCE

- Opportunity for increasing time range by 3 orders of magnitude
- Strongly flux-limited technique
  - rather specialised community
- ESS instrument may be transformative for wider user community
- Technical uncertainties
  - ESSENSE: resistive or superconducting coils?
  - RESPECT: very immature technique
- Two-year programme
  - demonstrate promise of longitudinal resonant spin-echo
  - can neutron guides be used within “precession” region?
  - can conventional and LNRSE techniques be combined?
- August 2015: FZJ and TUM decide to collaborate on CONSENS
  - ESS welcomes collaboration and emphasises resolving technical issues
- November 2015: CONSENS kick-off meeting
  - work plan agreed on for answering technical issues
  - hybrid instrument being developed
  - plan to end work in 2017
  - agreement to invite STAP advice in 2016
  - ESS needs to be able to make a well-informed decision on the best HR-NSE instrument

Spin-Echo STAP Meeting (Garching)

Friday 16/9/2016	
9:00	Welcome & ESS Update Ken Andersen
9:30	NSE History and Meeting Scope Melissa Sharp
10:00	Presentation of CONSENS design
13:00	Presentation of CONSENS results
15:00	Closed Session
16:00	Feedback

STAP members
Georg Ehlers
Stéphane Longeville
Thomas Keller
(Hitoshi Endo)
Peter Falus
Jason Gardner

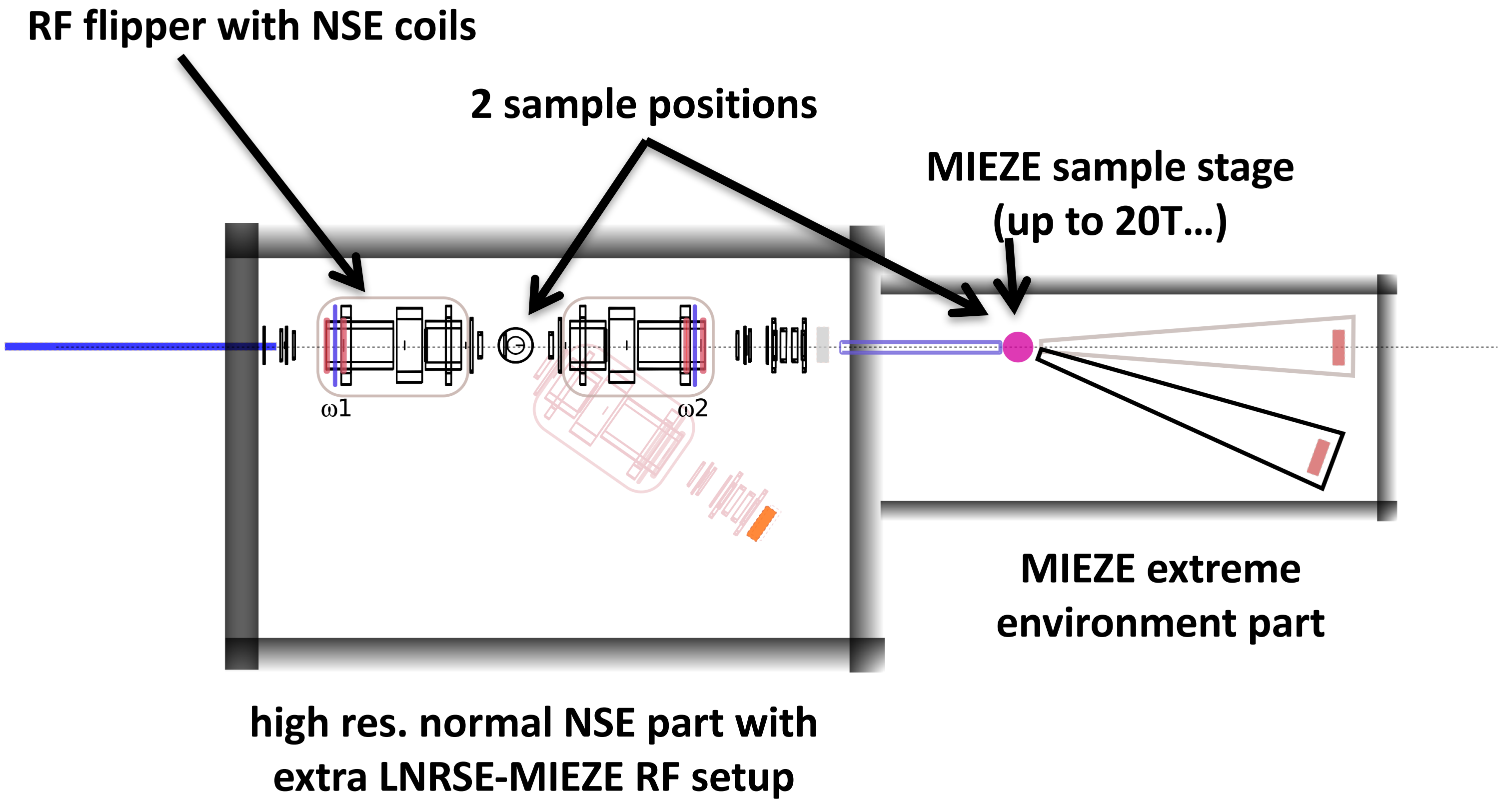
ESS team
Ken Andersen
Melissa Sharp

ESSENSE team
Michael Monkenbusch
Stefano Pasini
Teddy Kozielewski

RESPECT team
Christian Pfleiderer
Peter Böni

Instrument Status

- CONSENS
  - highest possible resolution for both soft and hard condensed matter
  - combines standard NSE and LRNSE
  - MIEZE option allows high magnetic fields at sample



Instrument Status

- Coil upgrades: IN15 & J-NSE
  - field profiles
  - correction elements
- RESEDA upgrades
  - L-MIEZE demonstrated: 5 orders of magnitude in t_{NSE}
  - demonstration of straight guide
- Optimisation of CONSENS primary spectrometer
  - adaptation to new moderator geometry
  - improved polarisation
  - chopper system

NSE STAP Findings & Recommendations

- Hybrid CONSENS instrument is not viable
  - well-optimised ESSENSE
  - highly compromised RESPECT add-on
- Great progress made in LNRSE development
- Stop development of hybrid instrument
- Update and improve ESSENSE
  - study SNS-NSE limitations and apply lessons
  - profit from IN15 and J-NSE upgrades: evaluate NC vs SC coils
- Continue work on RESEDA to improve RESPECT
  - demonstrate longer Fourier times
  - compatibility with focusing optics
  - need for and performance of field correction elements
- Produce updated proposals in 2017/18
  - timing to be determined by proposal rounds for instruments 16-22

NSE Add-Ons

- Only full instrument concepts considered so far
  - 8 add-on options were also considered
- TU-Delft considered several NSE add-ons in 2011-15
  - SANS: accessing lower Q via SESANS and SEMSANS
  - Reflectometer: measuring in-plane structures via SERGIS
  - Imaging: dark-field imaging using SEMSANS
  - Diffractometer: accessing inelastic information using TOFLAR

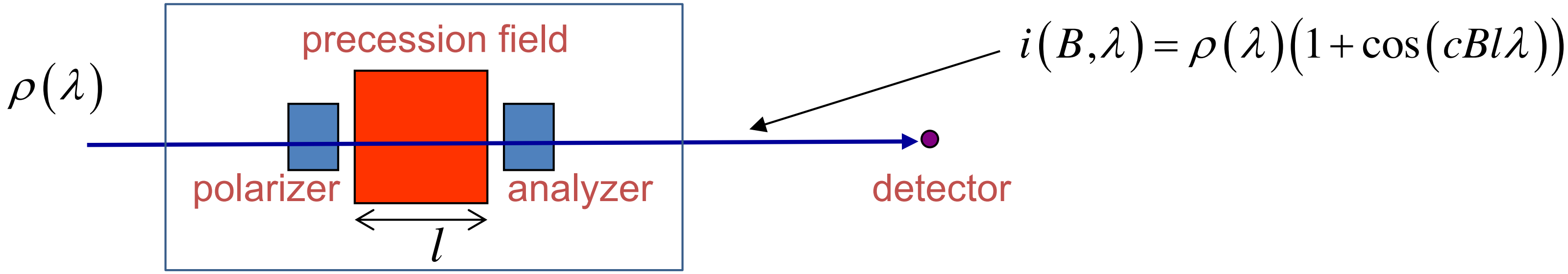
Larmor labelling techniques

- TOFLAR labelling of wavelength

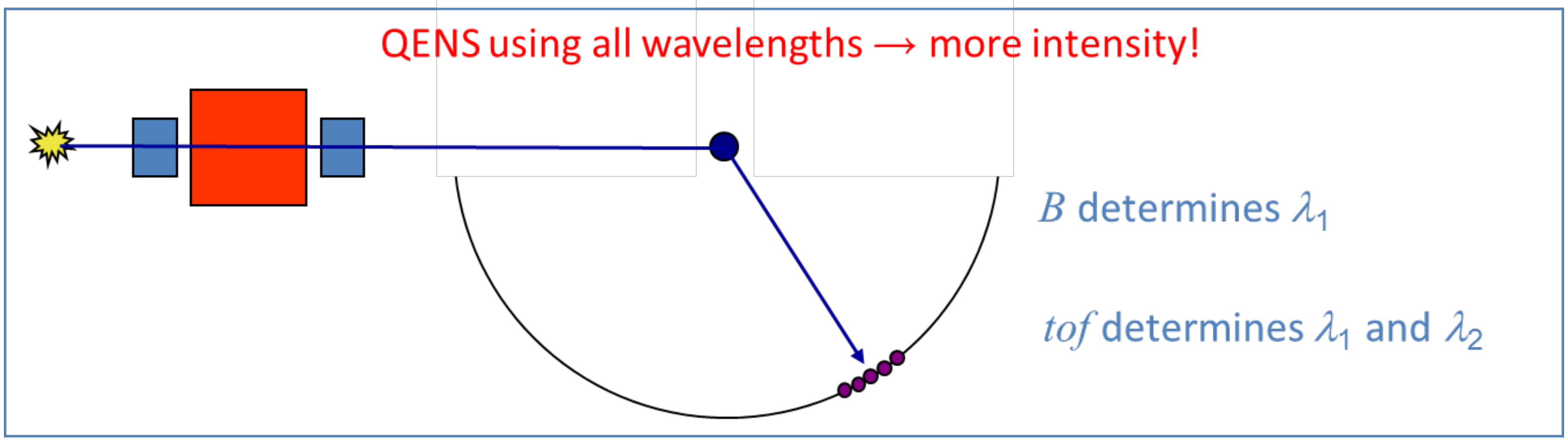
- SESANS
  SERGIS labelling of scattering angle
  SEMSANS

Larmor labelling techniques

- TOFLAR   labelling of wavelength

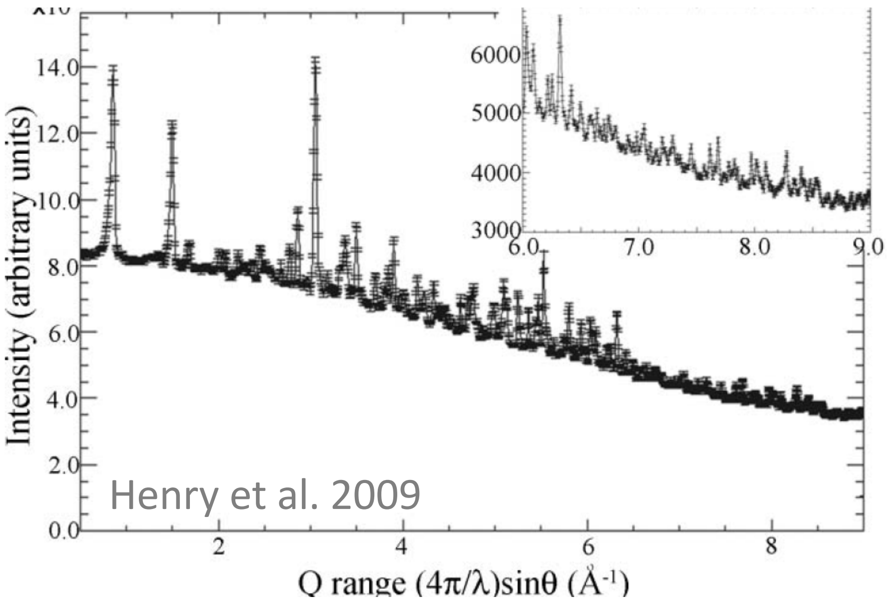


Intensity at detector: $I(B) = \int i(B,\lambda)\, d\lambda$ is the Fourier transform of the spectrum



TUDelft

TOFLAR applied in neutron diffraction



Bragg peaks: elastic-coherent

Background:

- Elastic-coherent (static disorder)
- Elastic-incoherent
- Inelastic-coherent
- Inelastic-incoherent

can be determined
by means of TOFLAR add-on
(modulator, < 2m, in primary beam)

Test measurements at SNS and ISIS are not yet decisive[1,2], will be continued

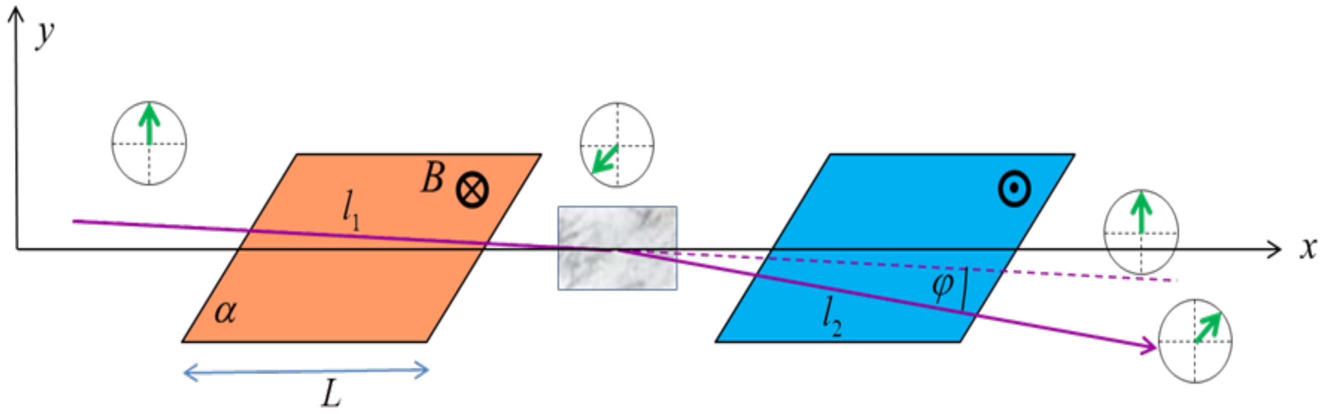
[1]Kusmin *et al*., EPJ Web of Conferences **83** (2015) 03009

[2]Kusmin *et al*., ISIS experimental report RB1620260

TU Delft

Larmor labelling techniques

- SESANS
  SERGIS labelling of scattering angle

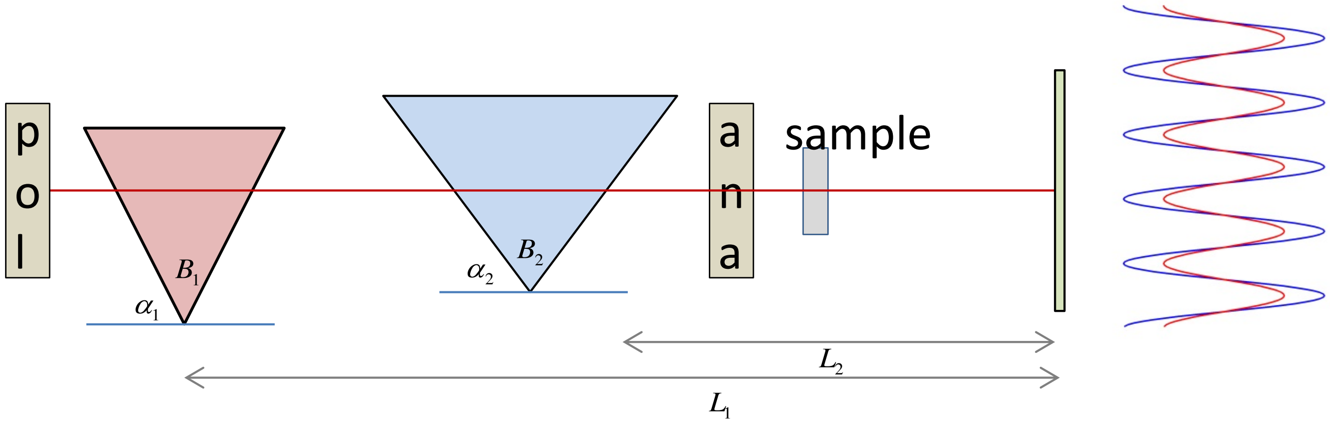


- precession field before and after sample
- spin-echo polarisation as a function of wavelength and magnetic field yields structural correlation function in real space
- coding direction / structural information : y-direction
- length scale: 30 nm – 10 μm

TUDelft

Larmor labelling techniques

- SEMSANS labelling of scattering angle

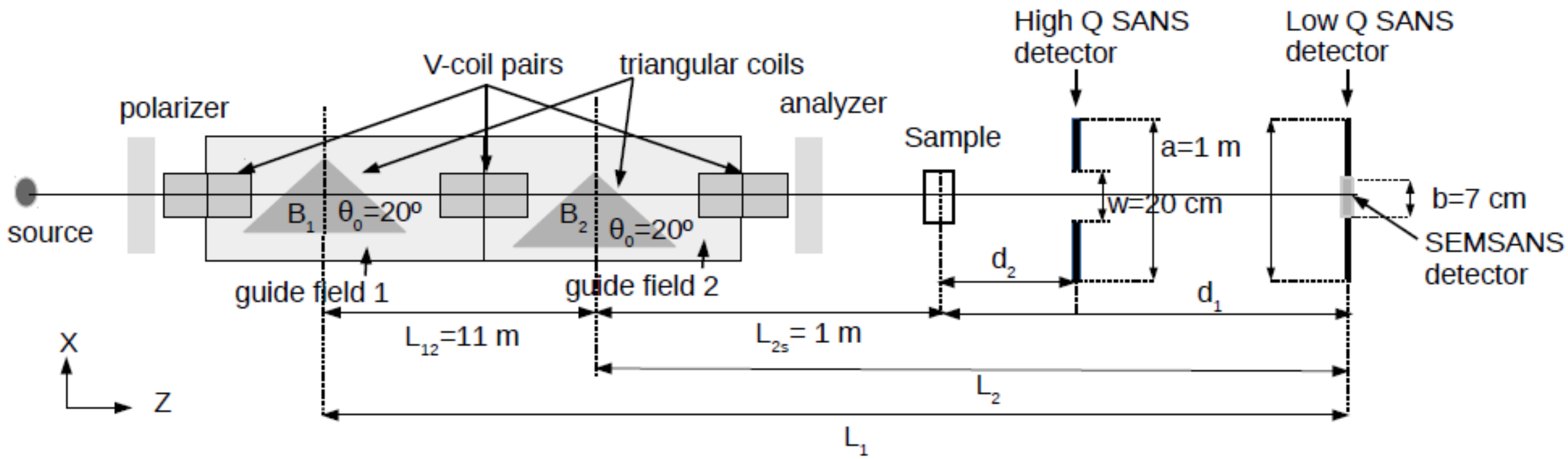


- alternative for SESANS[3]
- all spin-manipulation components before sample (magnetic samples possible)
- for right combination α_1, α_2, B_1, B_2, L_1, L_2: intensity modulation on detector
- with sample: decrease of modulation amplitude → structural information
- length scale: 30 nm – 10 μm

[3]Bouwman *et al.*, Physica B 404 (2009) 2585

TUDelft

SANS with SEMSANS add-on at LOKI [4]

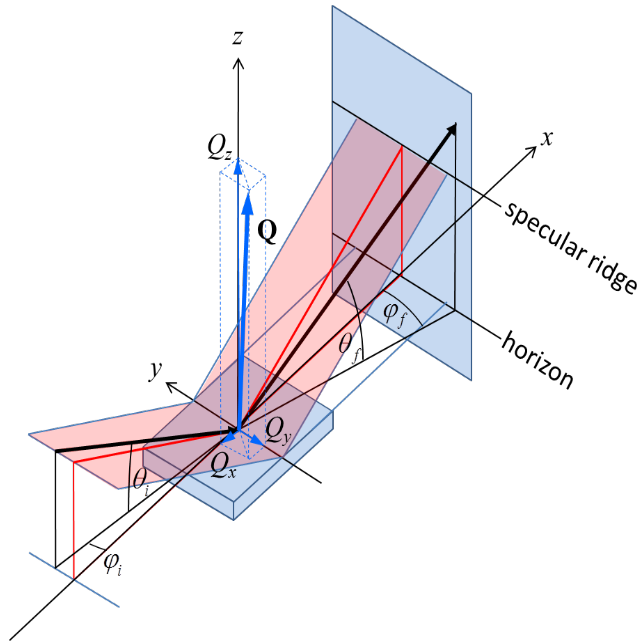


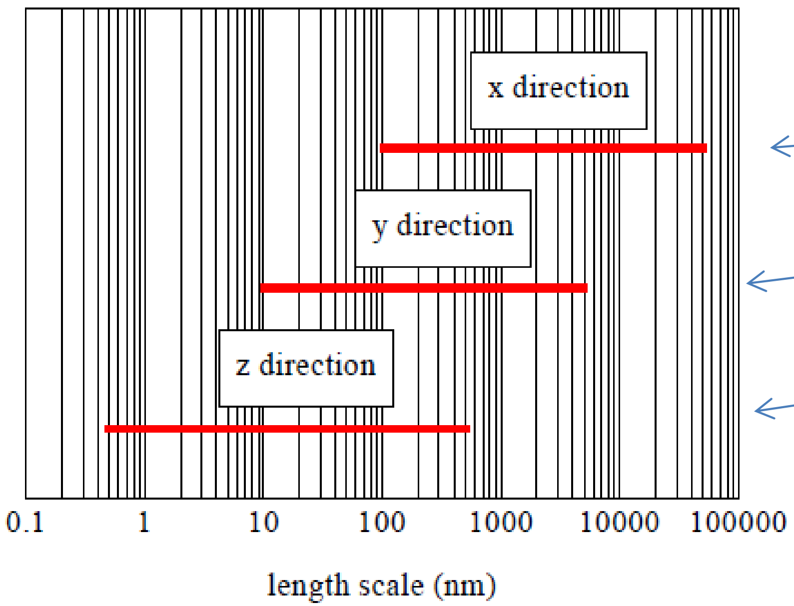
- replace beam stop by SEMSANS detector
- simultaneous SANS/SEMSANS: scale probed: 1 nm – 10 μm

[4]Kusmin *et al.*, NIM A. **856** (2017) 119

Larmor labelling in reflectometry (SERGIS)

- Principle





off-specular reflection (in-plane structure)

spin-echo coding (in-plane structure)

specular reflection (perpendicular profile)

Larmor labelling in reflectometry (SERGIS)

Conclusions from one decade of research

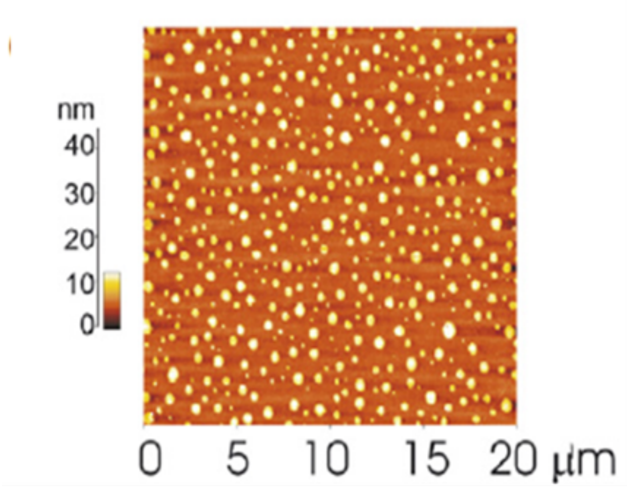
- Spin-echo signal (SERGIS) in specular intensity only measurable in very special cases (highly-scattering sample, e.g. from gratings[5])
- SERGIS has to be determined in off-specular intensity
- This means that in-plane structures > 10 μm should be present
- SERGIS is sensitive for structures ~ 10 – 500 nm
- Science case: samples with large range of length scales of in-plane structures

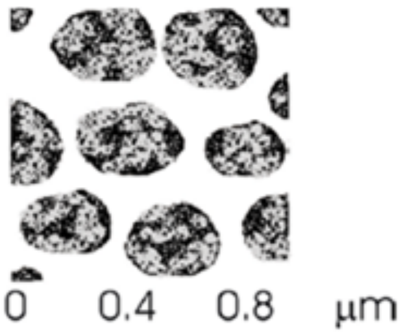
[5] R. Ashkar et al., J. Appl. Phys. **110** (2011) 102201

Larmor labelling in reflectometry (SERGIS)

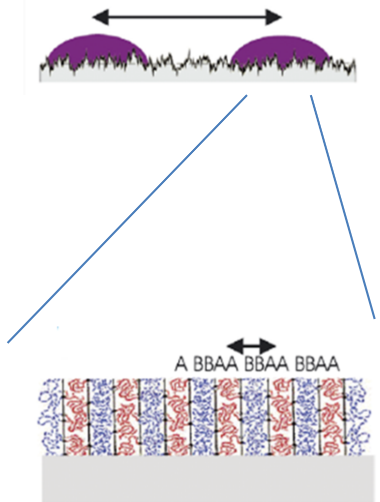
Example: dewetted block-copolymer P(dS-b-pMS) [6]

AFM measurements





interpretation, incl. GISAXS, GISANS



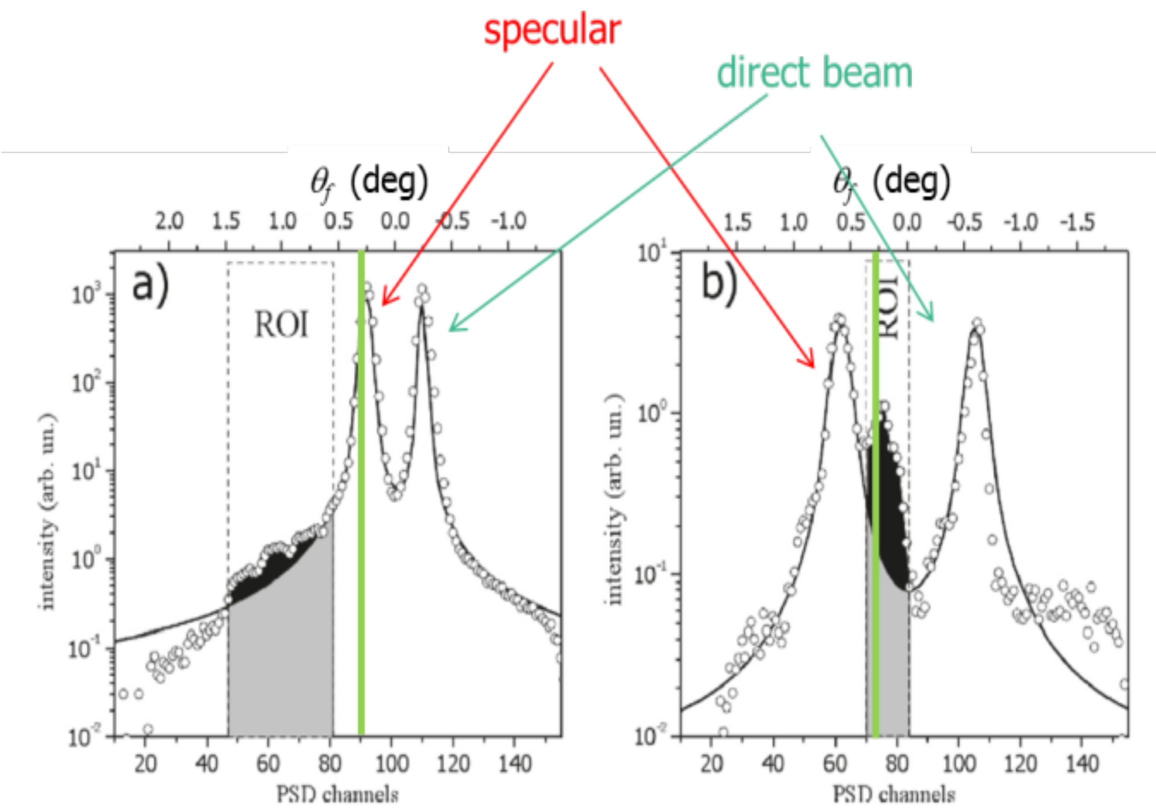
- Droplet separation ~ 1µm
- Internal structure of droplets with period ~ 100 nm

[6] P. Muller-Buschbaum, J. Phys.-Cond. Matter **17** (2005) S363-S386

Larmor labelling in reflectometry (SERGIS)

Example: dewetted block-copolymer P(dS-b-pMS)

SERGIS with monochromatic reflectometer (ADAM, ILL)[7]



$\theta_i = 0.25^\circ = 0.96\theta_c$ $\theta_i = 0.60^\circ = 2.36\theta_c$

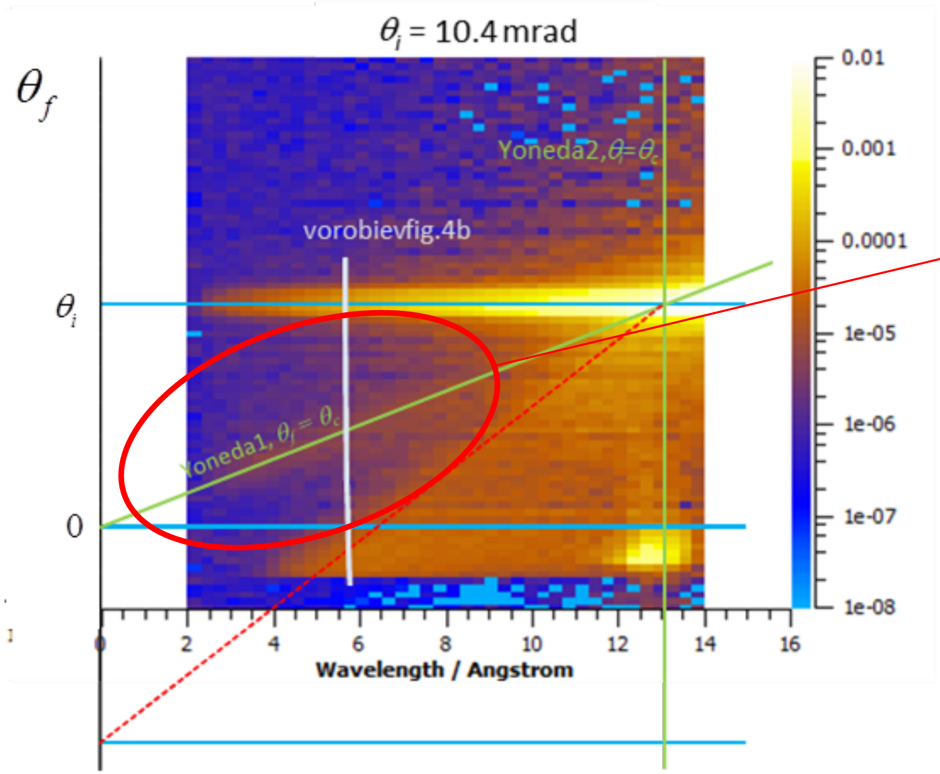
SERGIS signal was determined in off-specular intensity (ROI), i.e. very weak signal

[7]A. Vorobiev *et al.*, J. Phys. Chem. B **115** (2011) 5754

Larmor labelling in reflectometry (SERGIS)

Example: dewetted block-copolymer P(dS-b-pMS)

SERGIS with TOF reflectometer (Offspec, ISIS)[8]



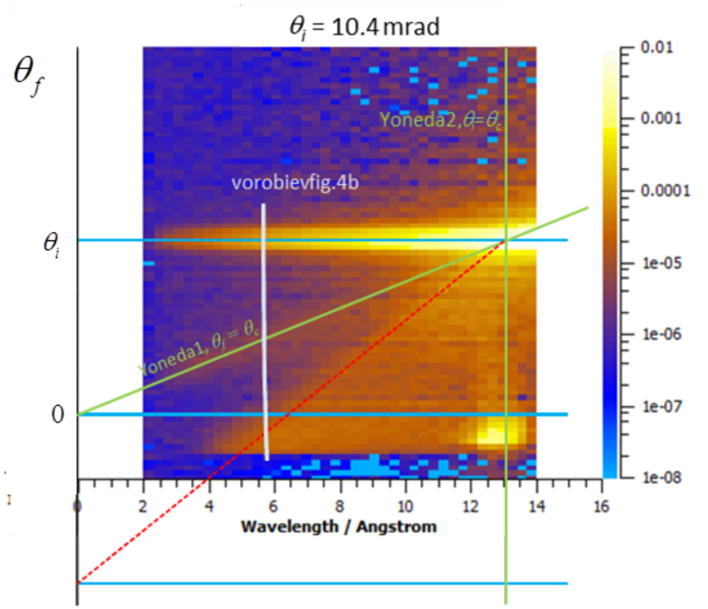
off-specular intensity too weak to analyse SERGIS signal

[8]A. A. van Well *et al.*, ESS-report (2014)

Larmor labelling in reflectometry (SERGIS)

Conclusion:

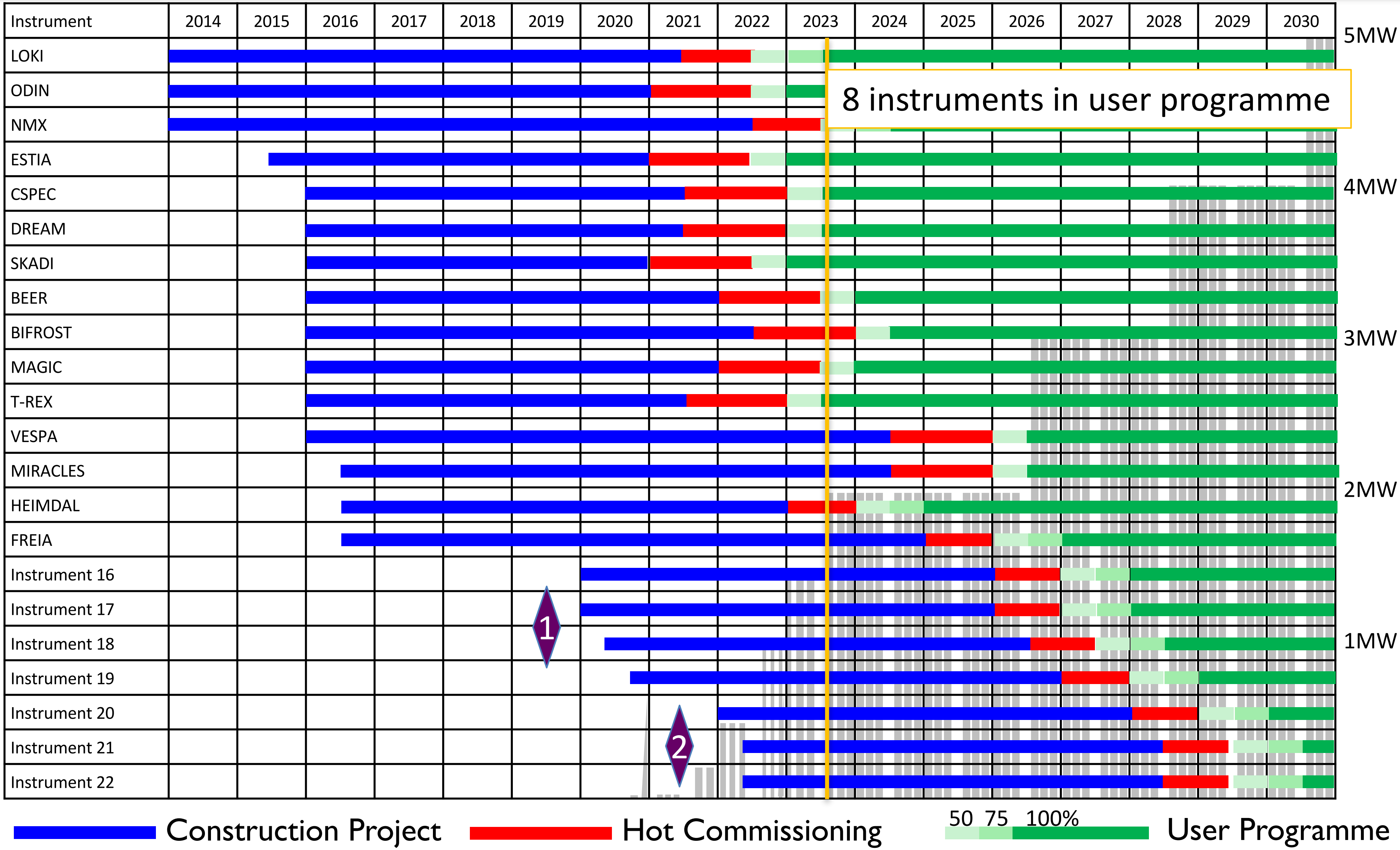
- With monochromatic setup all neutron intensity cab be focussed on narrow area in Q-space, while in TOF setup intensity is spread over large Q-area (compare 3-axis - TOF)[9]
- That is why the ILL SERGIS on weak-scattering samples is more successful as compared to the ISIS experiments
- Since the average neutron flux of ESS is comparable to ILL flux, the SERGIS signal at ESS will sufficient
- Moreover, a large Q-range will be probed simultaneously, with at least the same quality as the ILL results (see figure: total plot, TOF, versus white line, mono)
- Science case: large range of length scales should be present
- Possible inplementation in FREIA



[9]S.R. Parnell *et al.*, ICANS (2017)

Tentative Instrument Ramp-up

based on Instrument Construction Working Schedule V3.1, 25/4/2017



Instrument Concepts for Evaluation

- Update Existing Instrument Proposals
  - VOR Broadband Chopper Spectrometer (already endorsed by SAC)
  - ESSENSE & RESPECT High-Resolution NSE
  - ANNI Fundamental Physics
  - ESPRESSO High-Pressure Diffraction
  - SLEIPNIR Bio-SANS
  - HOD Crystal-Monochromator Diffractometer with Polarisation Analysis for Hydrogenous Systems
- Develop New Instrument Proposals
  - Surface Scattering
  - Alternative High-Resolution NSE
  - Wide-Angle NSE
  - Very Fast Crystal-Analyser Spectrometer (as proposed by Rob Bewley at ECNS 2015)
  - Ultra-Cold Neutrons (based on Expression of Interest from 2015 proposal round)

Selected Instruments Now

EUROPEAN SPALLATION SOURCE

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
- Bispectral Chopper Spectrometer
- T-REX ThChopSpec
- BIFROST Xana Spec
- VESPA Vibr.Spec.
- MIRACLES BckScatt
- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo

Fundamental & Particle Physics

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

Possible Instruments for Round 1 (2019)?

EUROPEAN SPALLATION SOURCE

Large-Scale Structures

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

Diffraction

HEIMDAL Pow. Diffr.	
DREAM Pow. Diffr.	
Monochromatic Powder Diffractometer	
BEER Eng. Diffr.	
Extreme Conditions Diffractometer	Update ESPRESSO proposal
MAGIC Magn. Diffr.	
NMX Macromol. Diffr.	

Spectroscopy

CSPEC ColdChopSp	
Bispectral Chopper Spectrometer	Already accepted
T-REX ThChopSpec	
BIFROST Xana Spec	
VESPA Vibr.Spec.	
MIRACLES BckScatt	
High-Resolution Spin-Echo	Update NSE proposals
Wide-Angle Spin-Echo	
Fundamental & Particle Physics	Update ANNI proposal

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

Possible Instruments for Round 1 (2019)?

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Large-Scale Structures

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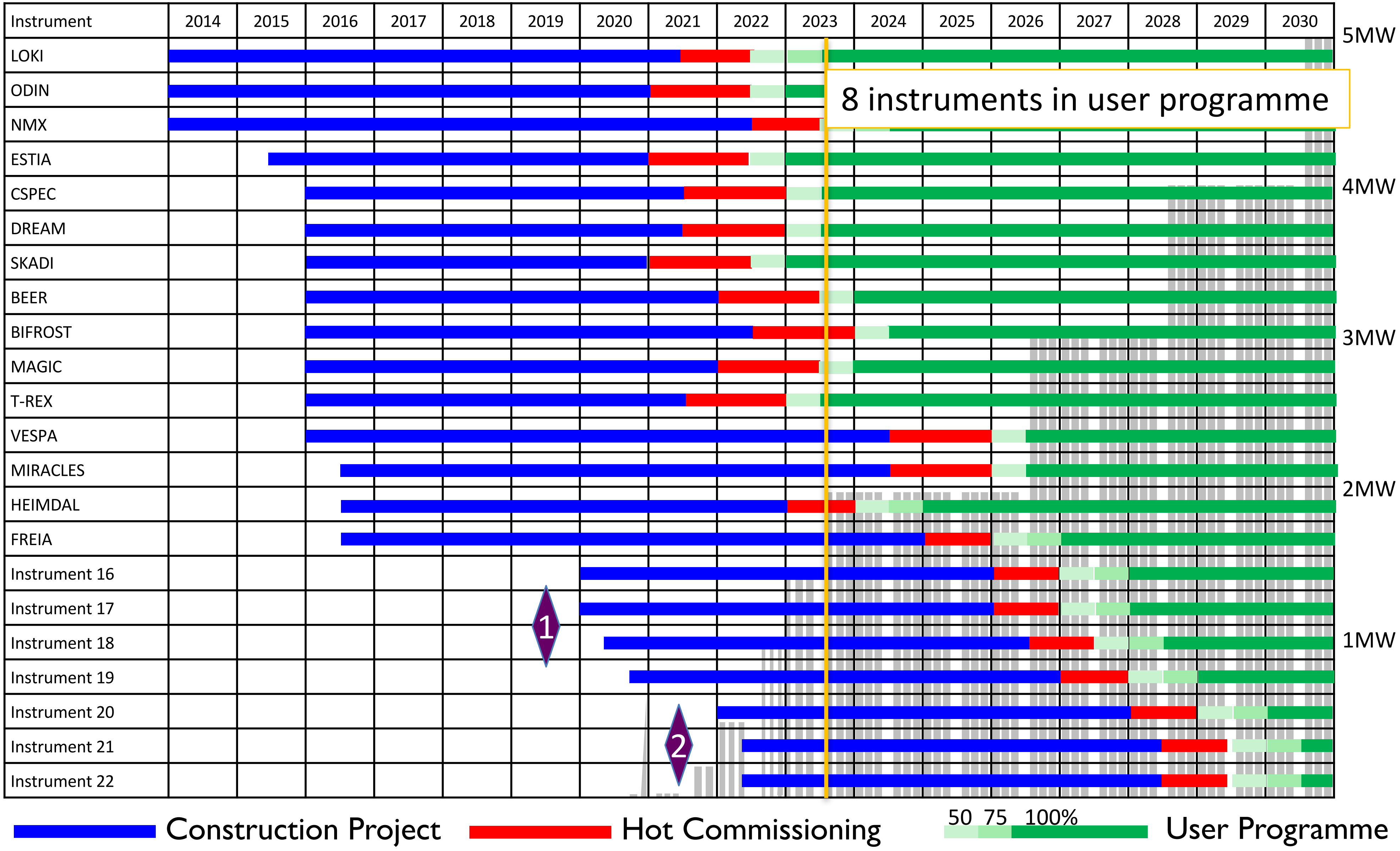
VESPA Vibr.Spec.	
MIRACLES BckScatt	
High-Resolution Spin-Echo	Update NSE proposals
Wide-Angle Spin-Echo	
Fundamental & Particle Physics	Update ANNI proposal

Round 2 (2021):
Space for exciting new ideas
Open call with competitive process

Tentative Instrument Ramp-up

EUROPEAN SPALLATION SOURCE

based on Instrument Construction Working Schedule V3.1, 25/4/2017



Thank You!