Neutron Instrument Commissioning

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// ACTING HEAD NEUTRON INSTRUMENTS DIVISION

2022-10-10

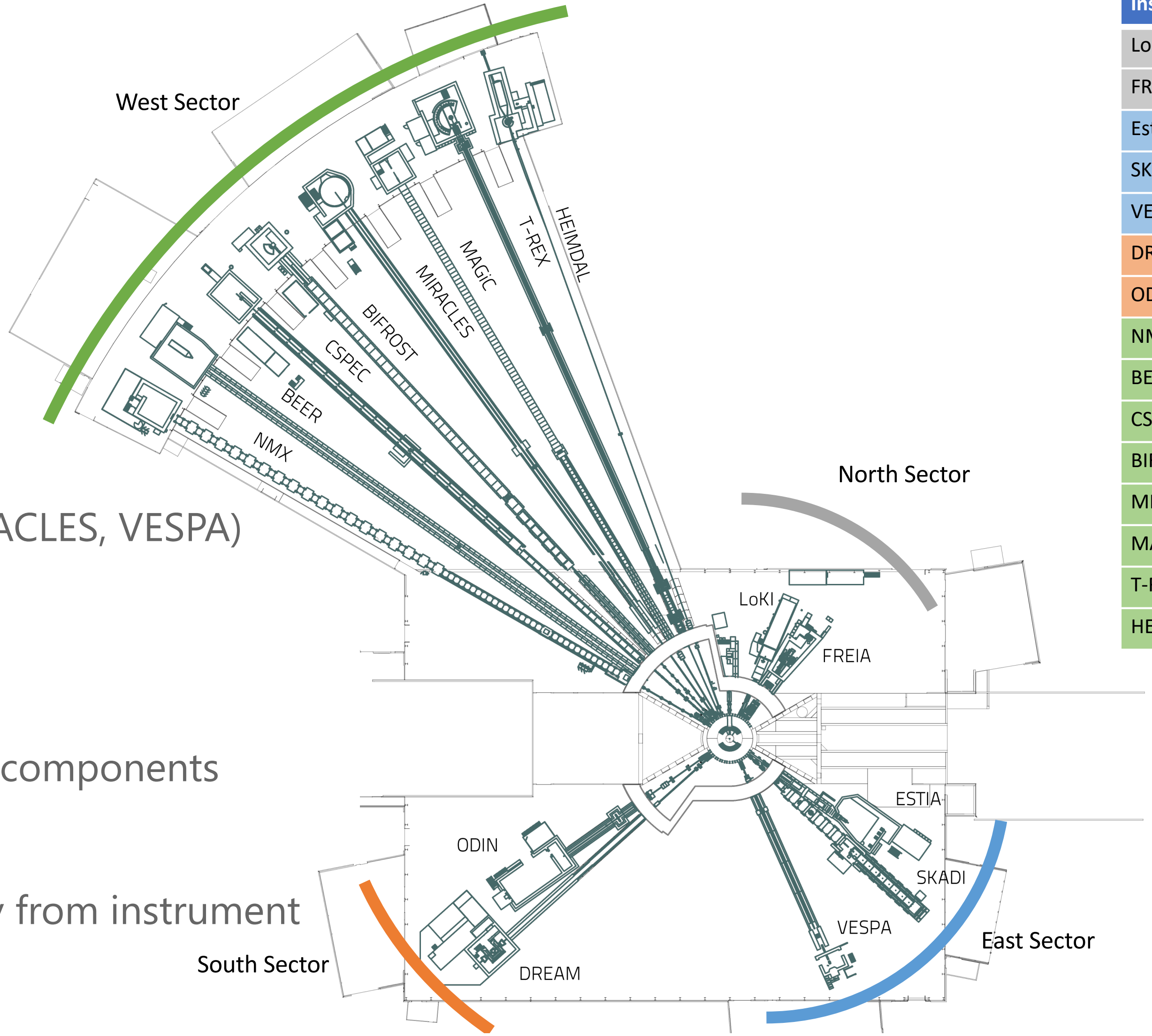
Neutron Instruments

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



Instrument	Beamport
LoKI	N7
FREIA	N5
Estia	E2
SKADI	E3
VESPA	E7
DREAM	S3
ODIN	S2
NMX	W1
BEER	W2
CSPEC	W3
BIFROST	W4
MIRACLES	W5
MAGiC	W6
T-REX	W7
HEIMDAL	W8

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Instrument Project Lifecycle

Instrument Project Lifecycle

Proposal and Planning

Instrument Proposal

Deliverables

- Science case covering scientific relevance, impact and usage
- Conceptual design with credible estimates of performance
- Preliminary costing.

Phase 0
Preparation for Design

Deliverables

- Conceptual design updates
- Prototyping
- Definition of facility requirements and interfaces
- Clarification of institutional responsibilities
- Resource planning

Phase 1
Preliminary Design

Deliverables

- Scientific and technical requirements
- Technical design concept
- Delivery plan for all phases (including hot commissioning)
- Delivery Schedule covering all phases
- Resource plan
- Staging plan for later enhancements
- Budget with contingency at 10% of cost to complete

Design and Construction

Phase 2
Detailed Design

Deliverables

- Complete definition of all major technical components
- Completion of detailed plan for Phase 3
- Refined plan for phase 4
- Refined Resource plan
- Refined delivery schedule, with critical path items and dependencies
- Refined budget with contingency at 10% of cost to complete

Phase 3
Manufacturing and Procurement

Deliverables

- Procurement and manufacture of all major technical components
- Completion of detailed plan for phase 4
- Site preparation
- Refined plans for phase 5 and for staging
- Refined Resource plan
- Refine instrument delivery schedule
- Maintain budget with contingency at 10% of cost to complete

Installation and Commissioning

Phase 4
Installation and Integration

Deliverables

- Construction of physical infrastructure on site.
- Assembly and installation of technical components
- Integration and testing of technical components
- Installation, integration and testing of Personnel Safety System
- Submission of application for approval to hot commission
- Formal project completion

Phase 5
Hot Commissioning

Deliverables

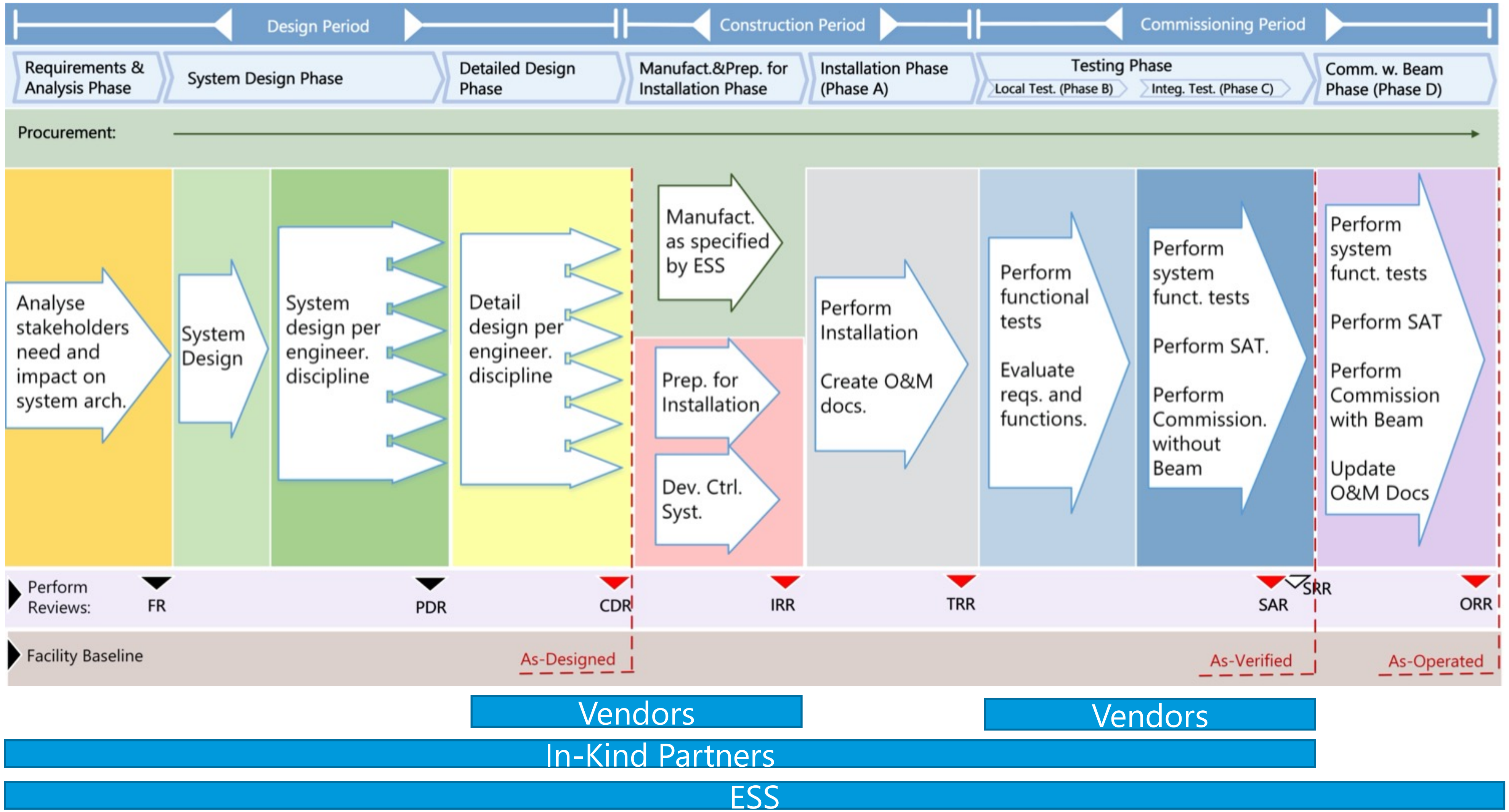
- Verification of performance of Personnel Safety System
- Proof of compliance with radiation dose limits
- Critical performance demonstration of basic functionality
- Scientific performance demonstration
- Friendly user experiments
- Completion of technical and user manuals

Tollgates

- **Tollgate 1** – Proposal Approval
- **Tollgate 2 (PDR)** – Preliminary Design Review
- **Tollgate 3 (CDR)** – Critical Design Reviews
- **Tollgate 4** – Installation Readiness Reviews
- **Tollgate 5** – Instrument handover to NSS
- **TRR SRR SAR**
- **TRR**
- **Operations Readiness Review**

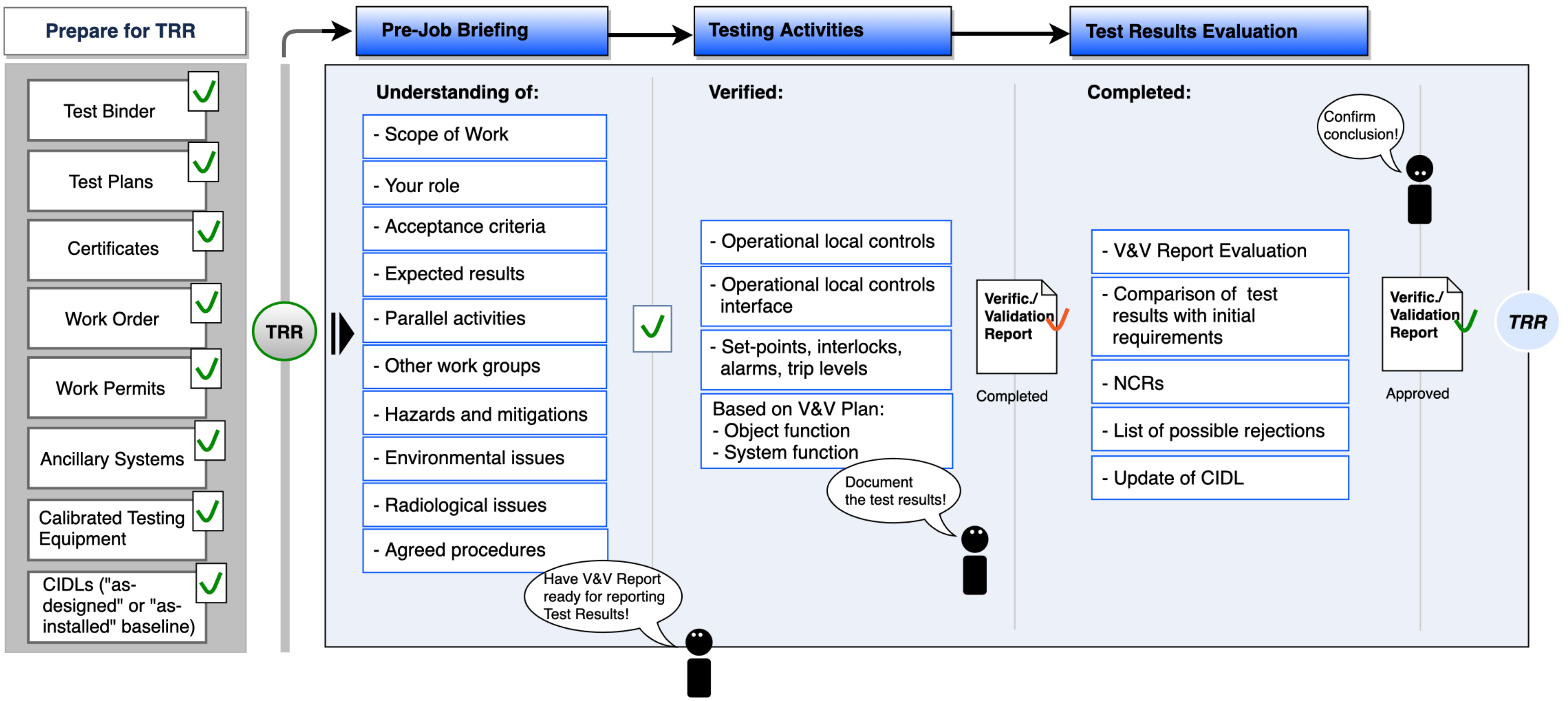
Instrument Project Lifecycle

ESS Engineering Workflow



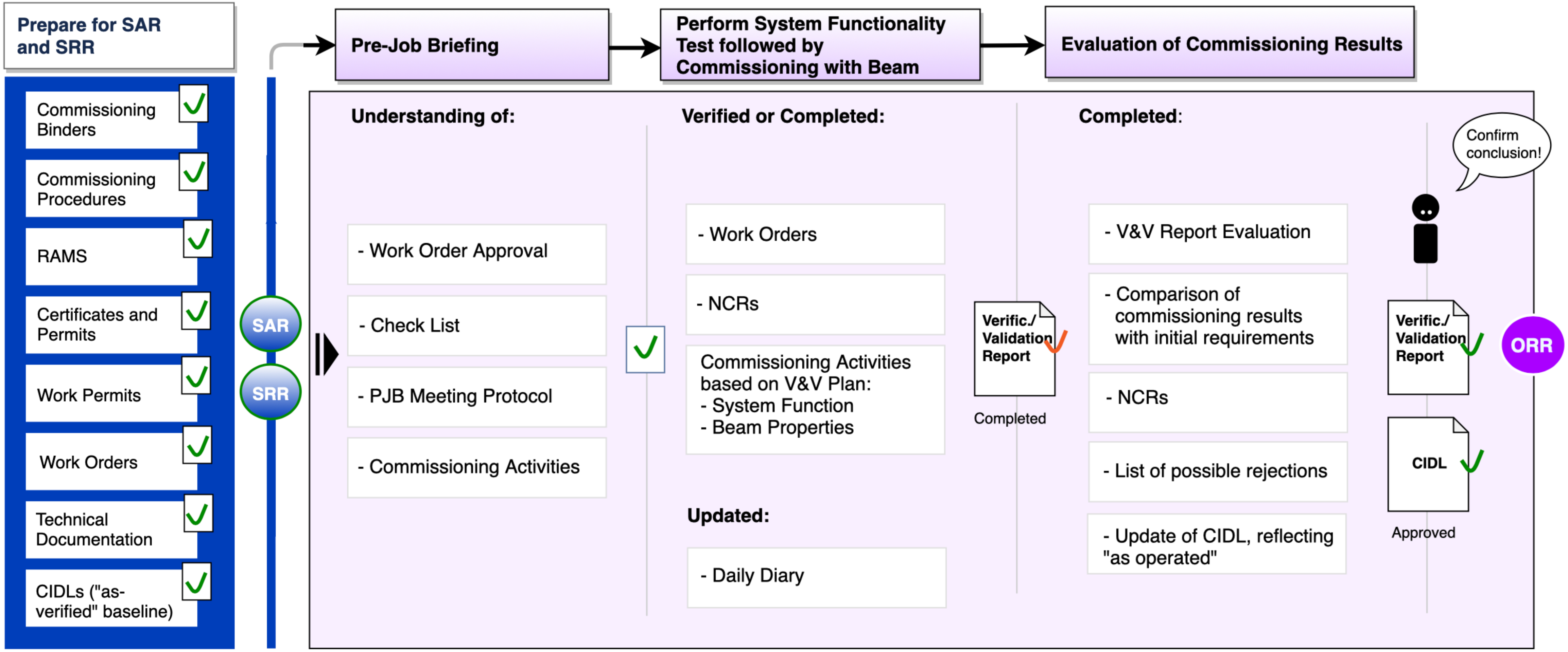
Instrument Project Lifecycle

ESS Engineering Workflow – Testing (Cold Commissioning)



Instrument Project Lifecycle

ESS Engineering Workflow – Commissioning (Hot Commissioning)



Testing and Commissioning

Why?

Verification

"did we build the right thing?"

and

Validation

"did we build the thing right?"

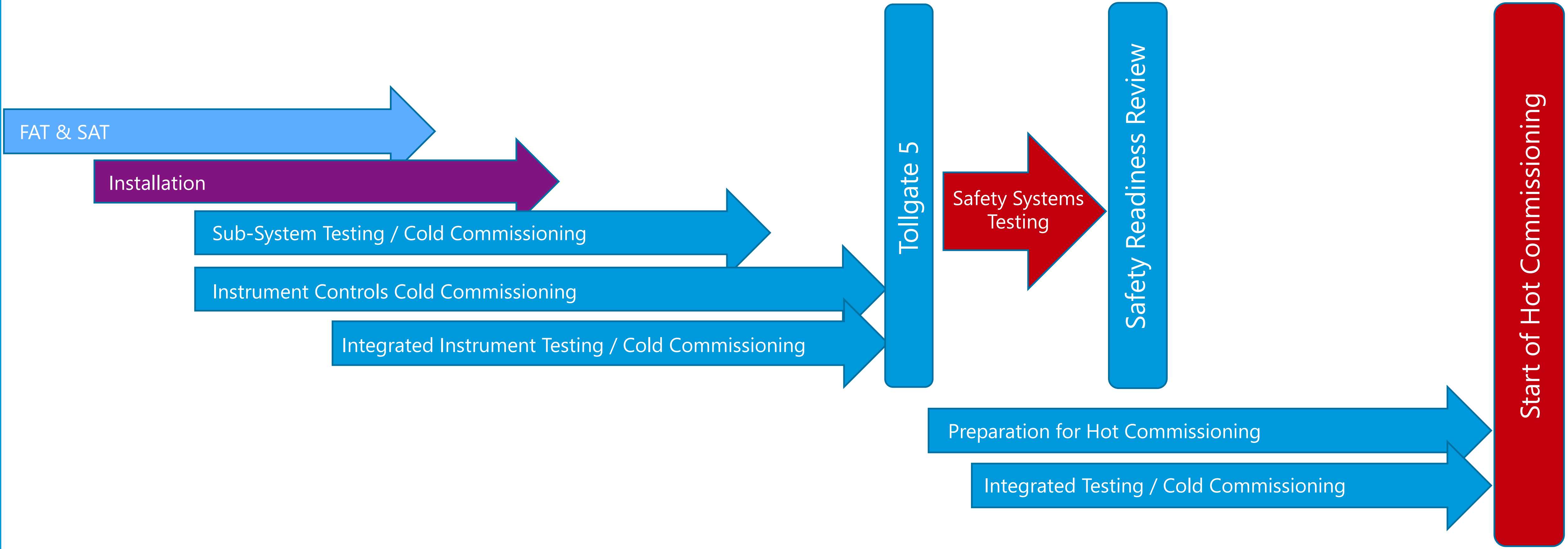
"does it do the right thing?"

2

Cold Commissioning

Testing / Cold Commissioning

Staged approach



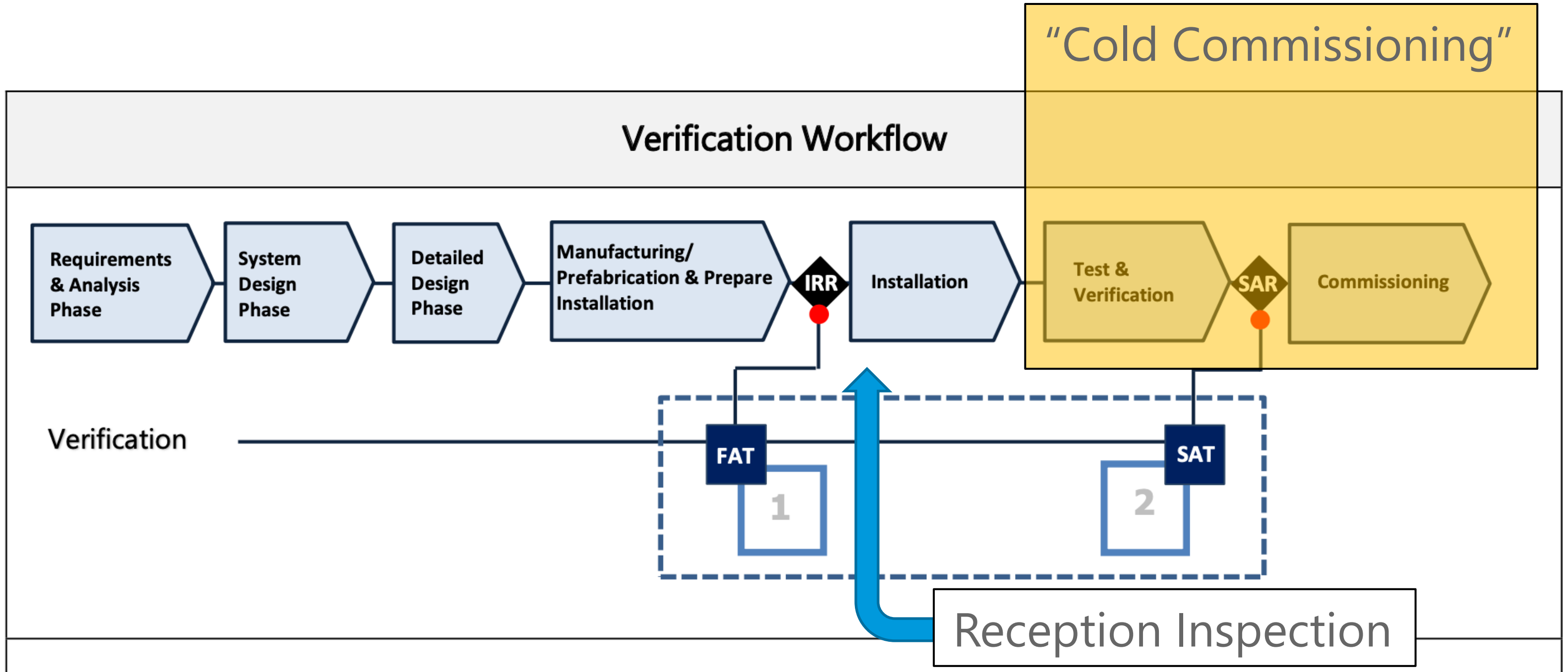
Verification via Inspection and Testing

Key Documents

- ESS-0259709 Quality Control Handbook
- ESS-2972919 ESS Rule for Equipment Compliance
- ESS-0102301 ESS Procedure for Receiving Inspection
- ESS-0094204 ESS Procedure for Factory Acceptance Test (FAT) and Site Acceptance Test (SAT)
- ESS-0113711 Site Acceptance Test (SAT) Template
- ESS-0037830 ESS Template for Project Quality Plan

-> Instrument Verification and Validation Plan <-

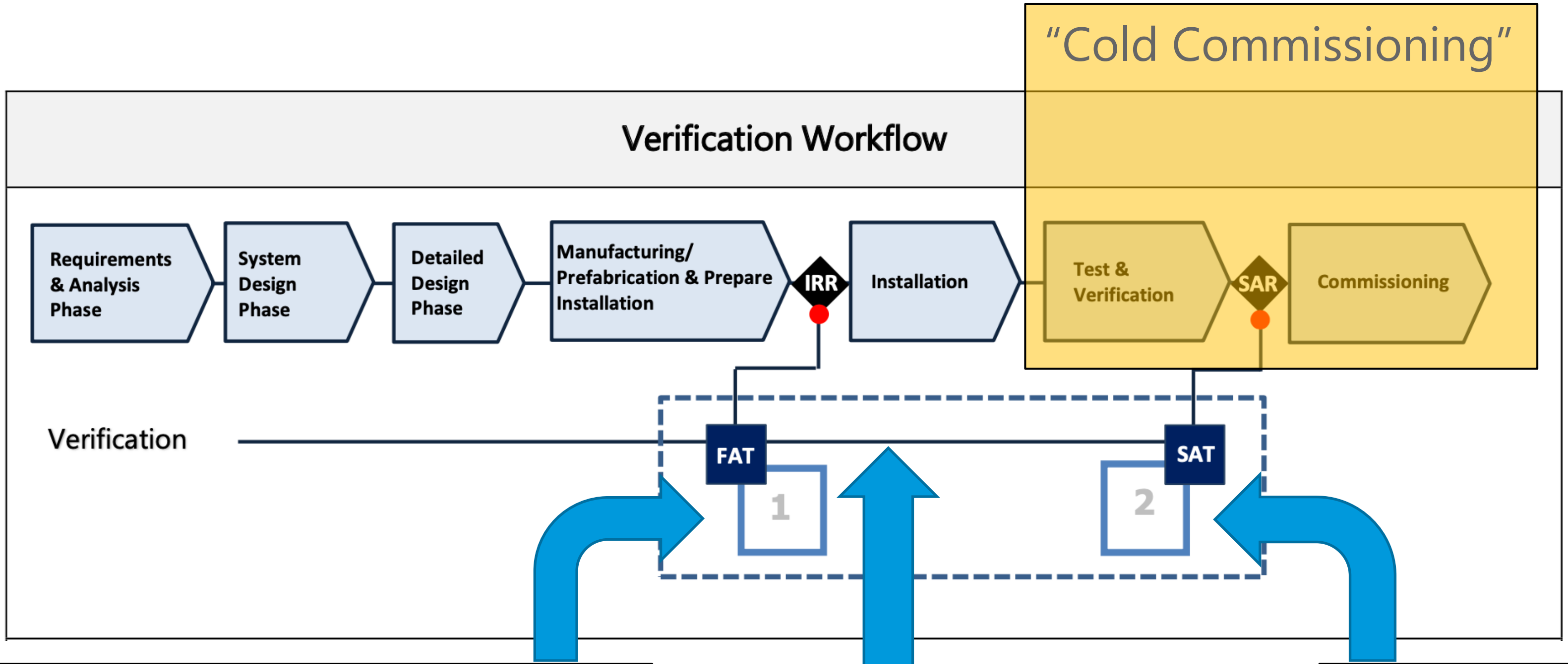
Verification Workflow



STEPS

1 FAT (FACTORY ACCEPTANCE TEST)	2 SAT (SITE ACCEPTANCE TEST)
A FAT can be used to verify that manufactured equipment has been produced according to manufacturing requirements and documentation. The FAT aids in ensuring functionality.	The SAT can be used to check that installed equipment has been manufactured / installed according to manufacturing requirements and documentation. The SAT aids in ensuring functionality.

Verification Workflow



FAT terms agreed in commercial contracts

or

Should be agreed as part of tollgate process for partner manufactred equipment

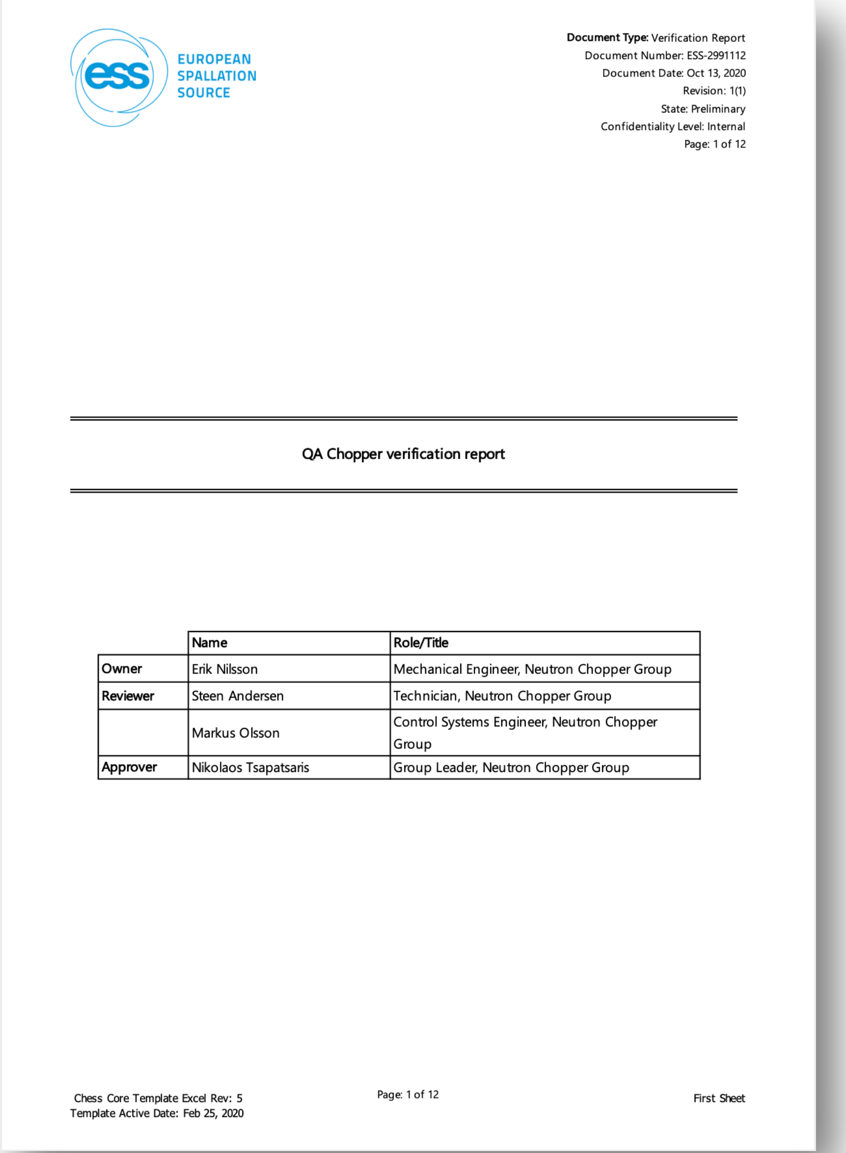
Receiving Inspection – usually just visual inspection for damage – as per ESS-0102301

SAT developed using template ESS-0113711 – taking what is needed. Some can be very simple, others more complex.

Testing and Cold Commissioning Plans

Specific vs Standard

- Standardised testing regimes where possible
- Every component has factory and site acceptance criteria defined at time of procurement
- Test results recorded and stored as verification reports in testing binder
- Individual subsystems have standardised commissioning plans where appropriate (e.g. choppers, motion)
- Each instrument has verification and validation plans to detail specific testing and to outline integrated testing requirements



EUROPEAN SPALLATION SOURCE

Document Type: Verification Report
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Document Date: Oct 13, 2020
Revision: 1(1)
State: Preliminary
Confidentiality Level: Internal
Page: 1 of 12

QA Chopper verification report

	Name	Role/Title
Owner	Erik Nilsson	Mechanical Engineer, Neutron Chopper Group
Reviewer	Steen Andersen	Technician, Neutron Chopper Group
	Markus Olsson	Control Systems Engineer, Neutron Chopper Group
Approver	Nikolaos Tsapatsaris	Group Leader, Neutron Chopper Group

Chess Core Template Excel Rev: 5
Template Active Date: Feb 25, 2020

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First Sheet

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ESS Integrated Commissioning

Test Beamline

ESS Integrated Commissioning Planning

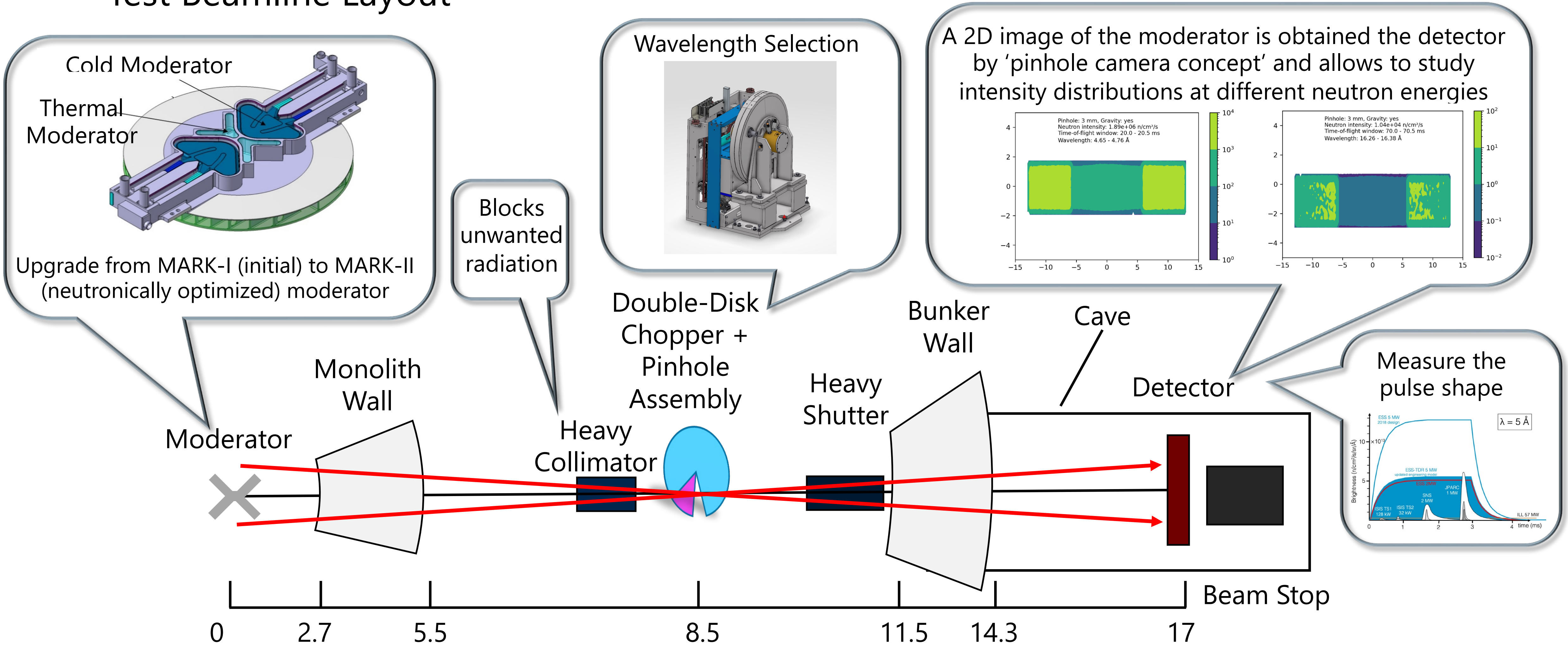
Accelerator, Target, ICS, NSS

- A working group has been formed for Integrated Commissioning between Accelerator, Target and NSS
- NSS Goals for Ramp Up:
  - Goal 1: verify spallation (and neutron detection) – **Test Beamline**!
  - Goal 2: verify timing between Accelerator +Target + NSS (neutron detection) makes sense – **Test Beamline**!
  - Goal 3: Consistency! (pulse to pulse, hour to hour, day to day) – **Test Beamline**!
  - Hot Commission instruments **once the above are established**
- NSS priorities concerning ramping up accelerator (current, pulse length, repetition rate)
  - Pulse length (*under discussion for early stage*) > Repetition (getting to a pulse 14 times a second) > Power

ESS Integrated Commissioning Planning

Accelerator, Target, ICS, NSS

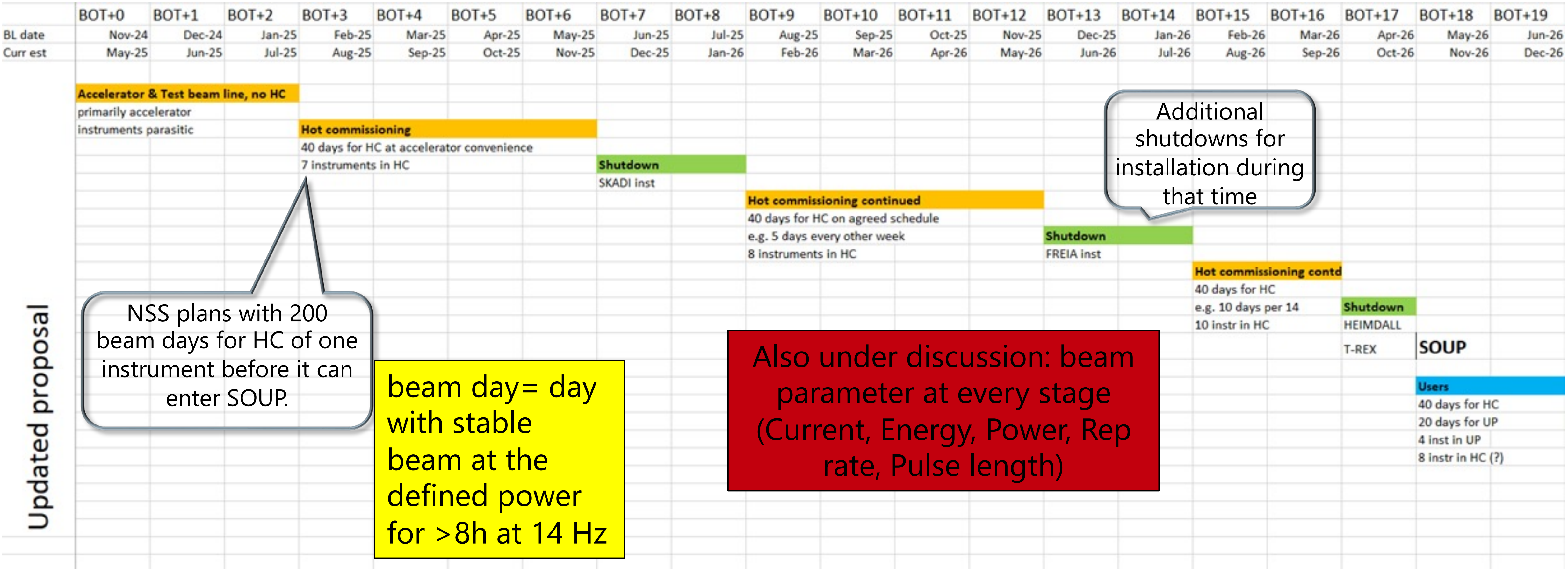
Test Beamline Layout



ESS Integrated Commissioning Planning

Accelerator, Target, ICS, NSS

- 18 months from BOT to SOUP: Commissioning of Accelerator + Target + Instruments will go in parallel
- Plan between all divisions for an operational schedule



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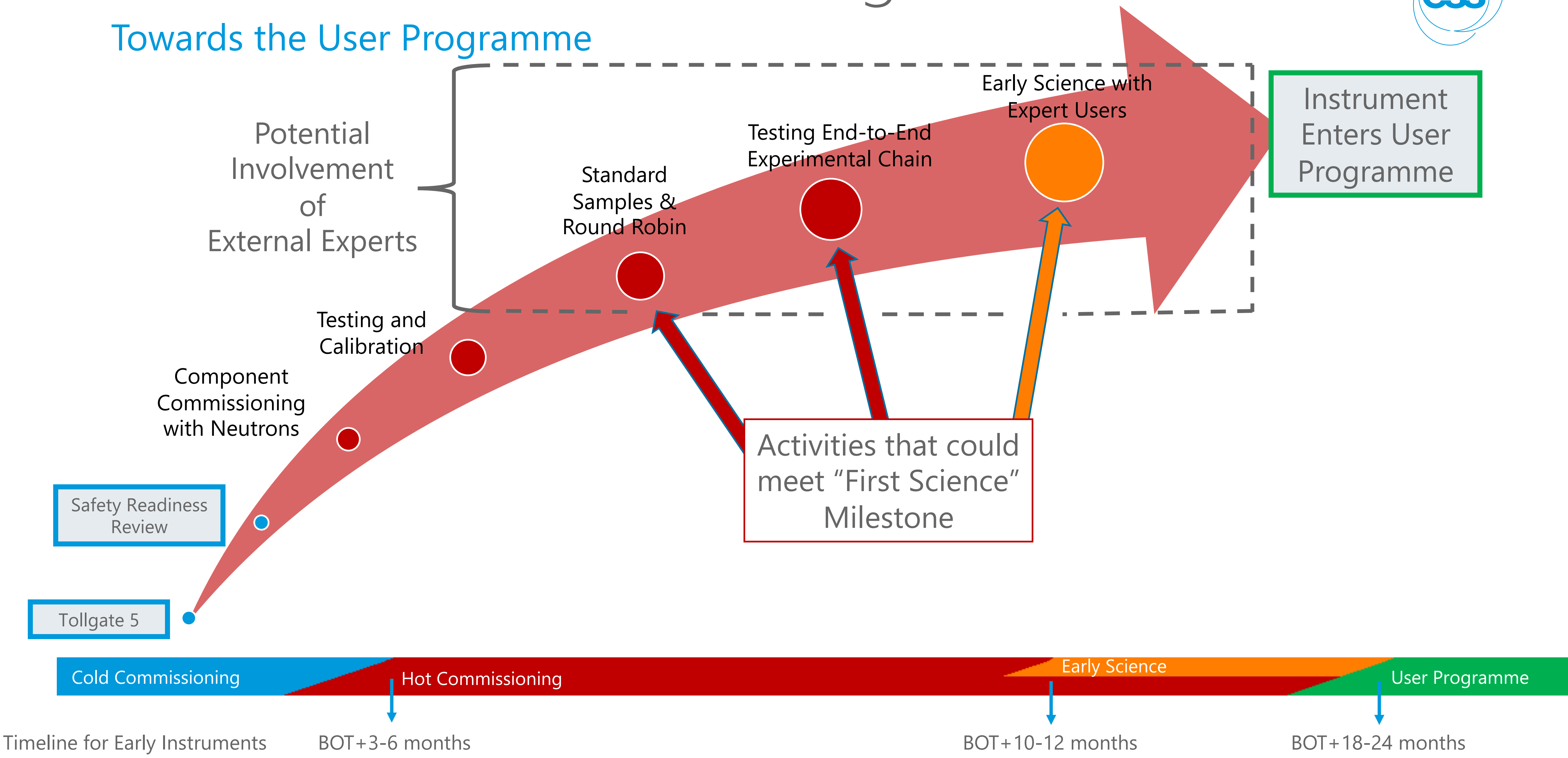
Instrument Commissioning

Instrument Commissioning

Towards the User Programme



Overall Instrument Timeline

Estimates as of August 2022 – with BOT in Q2 2025

	2022				2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
LoKI						TG5																		
SKADI															TG5									
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VESPA																		TG5						
ODIN						TG5																		
BEER									TG5															
TBL																								

BOT

SOUP

The timeline shows :

(blue)	Design, construction, and cold commissioning
(yellow)	Safety readiness checks and approvals
(red)	Hot commissioning (testing and validation with neutrons) and Early Science
(green)	User programme

Instrument Commissioning

Instrument specific HC plans

- Based on the system validation plan (TG3 document)

EUROPEAN SPALLATION SOURCE

Document Type	Document Template
Document Number	ESS-1108651
Date	Jul 18, 2016
Revision	0.3
State	Draft
Confidentiality Level	Internal
Page	1 (13)

LoKI System Validation Plan

	Name	Role/Title
Owner	Judith Houston	LoKI Lead Scientist (ESS)
Author	Richard Heenan Jim Nightingale William Halcrow Clara Lopéz Wojciech Potrzebowski	LoKI Instrument Scientist (STFC) UK-ESS Instruments Project Manager (STFC) LoKI Lead Engineer (STFC) Instrument Integration Engineer (ESS) SANS data scientist (ESS)
Reviewer	Andrew Jackson Peter Sångberg	Head of Neutron Instruments Division (ESS) Systems Engineer (ESS)
Approver	Gabor Laszlo	NSS Lead Instrument Engineer (ESS)

Instrument Commissioning

Instrument specific HC plans

- Based on the system validation plan (TG3 document)
  - Identification of high level activities/sub-systems to be tested
  - Description of the testing procedure for each of them.

3.1 Shielding (steered by RP)

3.1.1 Goal:

Demonstrate the performances of the shielding to the licensing authority

3.1.2 Assumptions:

- Successful Cold Commissioning
- Accelerator stable enough for the foreseen duration of the experiment

3.1.3 Resources needed:

- RP group available

3.1.4 Procedure:

a. Bridge beam guide and heavy shutter closed, check radiation level in various points of the instrument
b. Bridge beam guide open and heavy shutter closed, check radiation level in various points of the instrument (to be repeated every time the accelerator changes some setting).
c. Radiation around the beam stop area and around the door
d. Verify the cave shielding according to the procedure defined in H1H2 document
e. See also generic plan in Anton's document

3.1.5 Check point:

The measured dose outside any points of the bunker, guide shielding and cave is below the threshold of 3 uSv/h and <25 uSv/h on the roof.

What needs to be demonstrated

What is required at this stage (incl. HW)

Which additional resources are needed

High level description of what needs to be dor

What marks the achievement of the activity

Instrument Commissioning

Breakdown of time and resources

- Should be an exercise to carefully think about:
  - what one wants to do
  - how long does it take
  - what would be the best accelerator conditions to achieve it

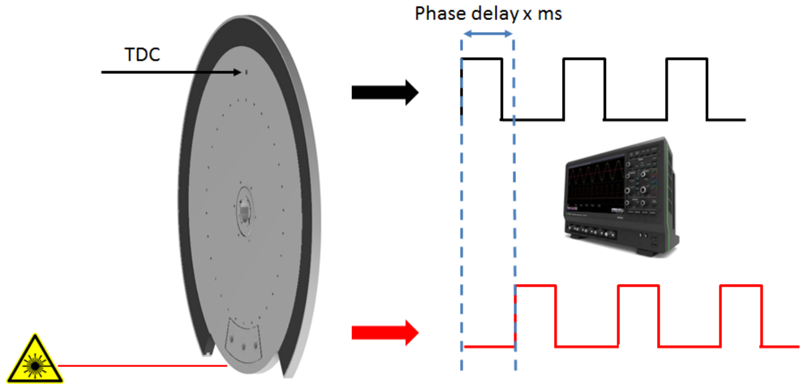
	A	B	C	D	E	F	G	H	I	J	K
1		Accelerator power	projected beam days	#	Activity	required continuous beam days	data analysis days	No. of people required during beamtime	No. of people required during data analysis	Groups potentially required	estimated person days
2	BOT -> BOT+3	<100 kW	~13	1	Fulfil radiation protection requirements **HOLD POINT**	2	0	2	0	RP	4
3	BOT+3 -> BOT+9	100 kW	~70 (the plan is 48h continuous neutron production a week for the first 3 months and then 3-4 days of continuous beam a week)	1	Fulfil radiation protection requirements **HOLD POINT**	2	0	2	0	RP	4
4				2	Gold foil measurement	1	0	2	0	RP?	2
5				3	HC of beam monitors (0-4)	3	2	2	2	DG,ECDC	6
6				4	Choppers phases verification	5	5	2	2	CG	10
7				5	Beam profile with imaging detector	3	2	2	2	DG, ECDC	6
8				6	Flight path calbration	10	2	2	1	MCAG, ECDC	20
9				7	Characterization of background	4	2	2	1		8
10				8	Collection of detector calibration mask data	15	5	2	2	DG, ECDC	30
11				9	Commissioning of sample environment	2	0	2	0	ECDC, MCAG, SEG	4
12				10	Standard samples for detector efficiency iterations.	15	5	2	2	DG, ECDC	30
13											
14					**Total beam days required in phase: :**	**60**					
15					**Total data analysis days:**		**23**				

Instrument Commissioning

Commonalities …

Hardware (tests and calibration) Sub-system neutron tests	Beam Delivery Instrument Neutron Characterization	Instrument Functionality Neutron Operation	Data Analysis Scientific Performance
Shutters	n Flux / Current	Standard samples	Data Reduction Workflow
Choppers	Beam Profile, Divergence	Energy/Resolution /WFM Mode Setting	Detector Pixel Alignment Characterization
Collimation	ToF Spectrum	Rate performance	Instrument-specific samples
Monitors	Energy/Resolution/ WFM Modes	Background	Scientific performance characterization
Detectors	E/Q resolution / peak shape / quality	Signal-to-Noise	
Timing		Integrated Instrument Control	
Motion		Background Dose Rates	
PPS, MPS			

Standardising Methods



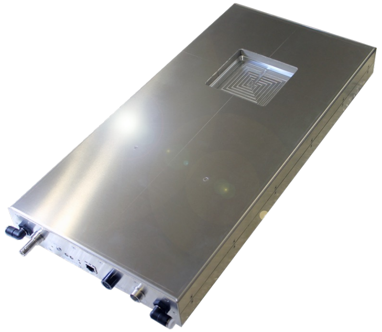
Laser calibration of chopper phases

Evaluation of a method for time-of-flight, wavelength and distance calibration for neutron scattering instruments by means of a mini-chopper and standard neutron monitors

L. Vergara[1], M. Arai[1], M. Olsson[1], A. Quintanilla[1], D. Zielinski[1], S. Alcock[1], J. Nilsson[1], K. Kanaki[1], R. Woracek[1], P.M. Kadletz[1], O. Kirstein[1,2], R. Hall-Wilton[1,3] and N. Tsapatsaris[1] [(a)]

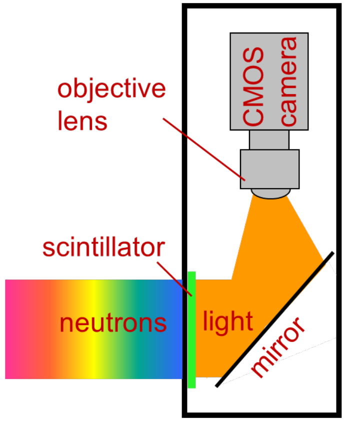
[1] *European Spallation Source ERIC (ESS) - P.O. Box 176, SE-22100 Lund, Sweden.*
[2] *University of Newcastle, School of Mechanical Engineering, NSW, Australia.*
[3] *Università degli Studi di Milano-Bicocca, Piazza della Scienza 3, 20126 Milano, Italy.*

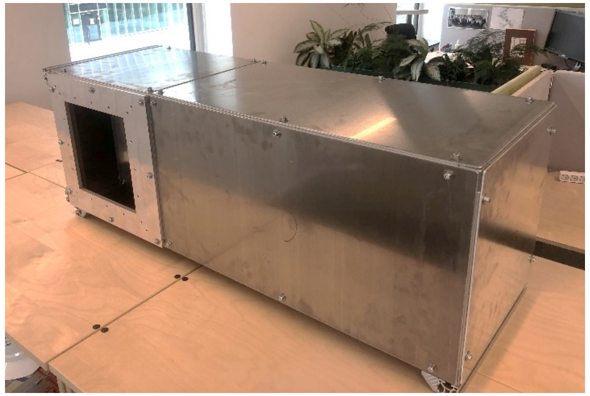
TOF calibration independent of instrument components



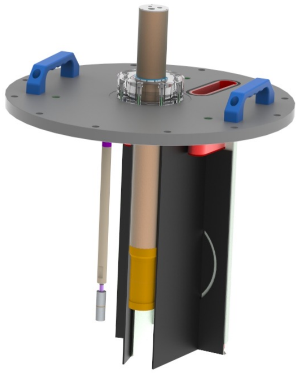
https://github.com/ISISComputingGroup/EPICS-nGEM-BBTX

Off the shelf portable detector
(As used at JPARC and ISIS)





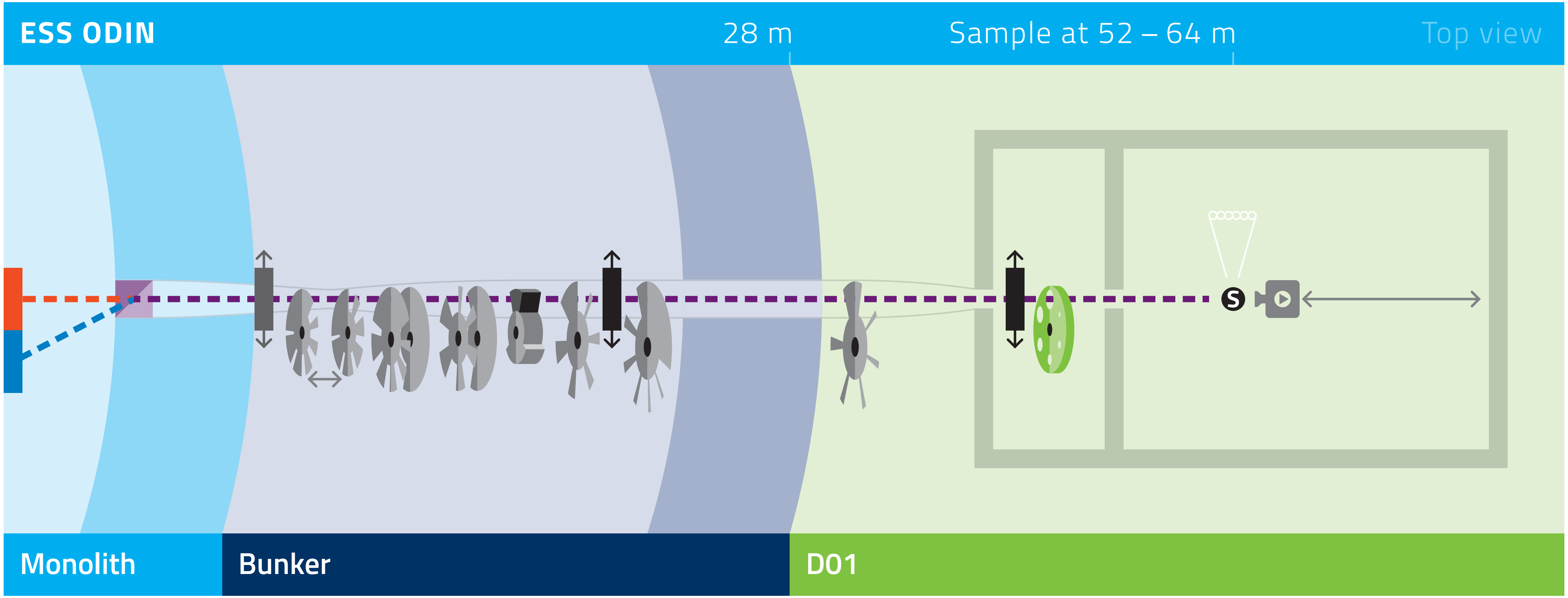
Portable neutron cameras
(under development)



Portable diffraction rig
(similar to ISIS)

Instrument Commissioning

Examples from ODIN



Instrument Commissioning

Examples from ODIN: chopper cascade commissioning

3.7 Chopper phases verification

3.7.1 Goal

Ensure that the chopper cascade is working nominally

3.7.2 Assumptions:

- Sufficiently powerful and stable beam
- Pulse length as by design

3.7.3 Resources needed:

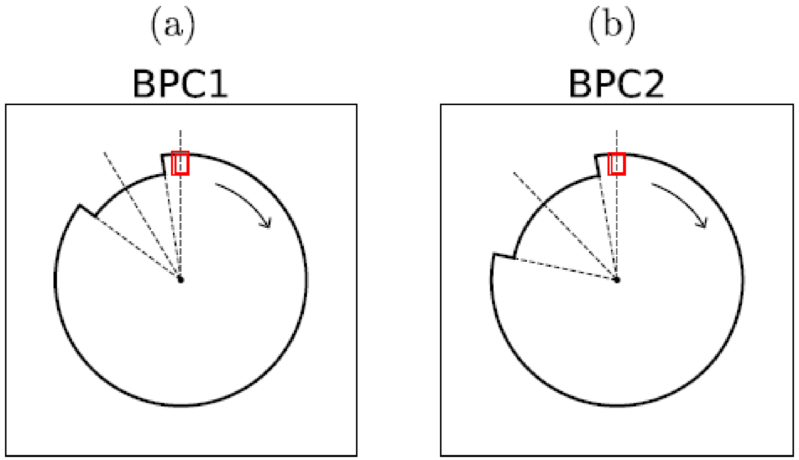
- Chopper group available on demand
- Detector group available on demand

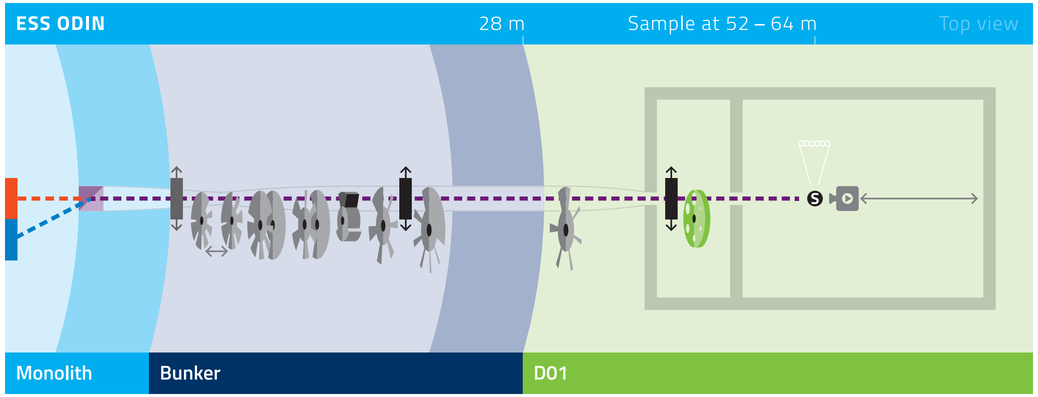
3.7.4 Procedure:

a. From downstream and go upstream. Use monitors
b. Park all choppers open. Step BPC1 in 1deg (or finer) steps
c. Park all choppers open. Step BPC2 in 1deg (or finer) steps
d. Same for FOCs, WFMs.
e. BPC: use Bragg edges to test wavelength ranges.
f. Repeat steps a-e with chopper spinning at the source frequency

3.7.5 Check point

The chopper cascade is sufficiently understood that a user interface can be developed so that the user can directly choose the wavelength range, bandwidth and resolution instead of playing with chopper phases and positions





Instrument Commissioning

Examples from ODIN: WFM data reduction

3.9 Wavelength Frame Multiplication

3.9.1 Goal

Commission the WFM technique for user operation

3.9.2 Assumptions:

- Sufficiently powerful and stable beam
- Data reduction fully functional (at least in “expert mode”)
- All detectors fully integrated
- Data acquisition chain fully established

3.9.3 Resources needed:

- Resources from DMSC

3.9.4 Procedure:

a. Verify the correct phasing of the chopper cascade (link with McStas)

b. Test the data reduction algorithm (frame stitching) with 3 and 6 frames

c. Verify the obtain resolution with <u>known samples</u>

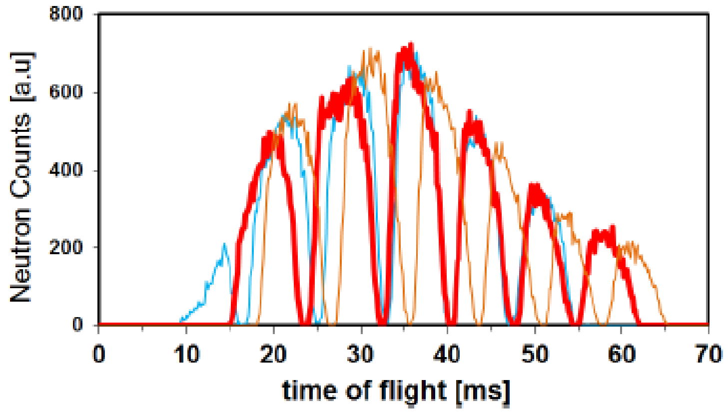
d. Test for <u>local variation</u> of the stitching performance

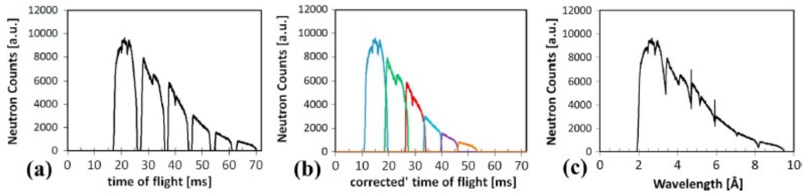
e. Repeat for higher and higher resolution

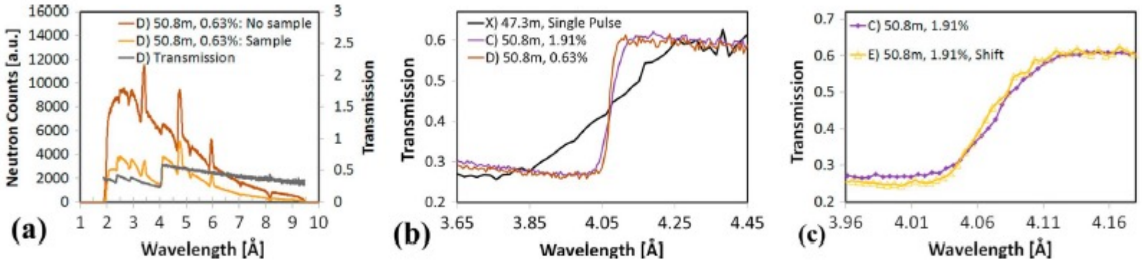
f. Check effect of global phase delay

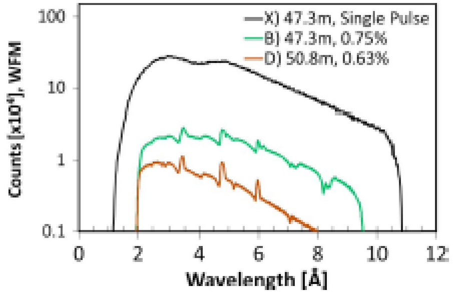
3.9.5 Check point

The reduced data matches the expectation and the mcstas model



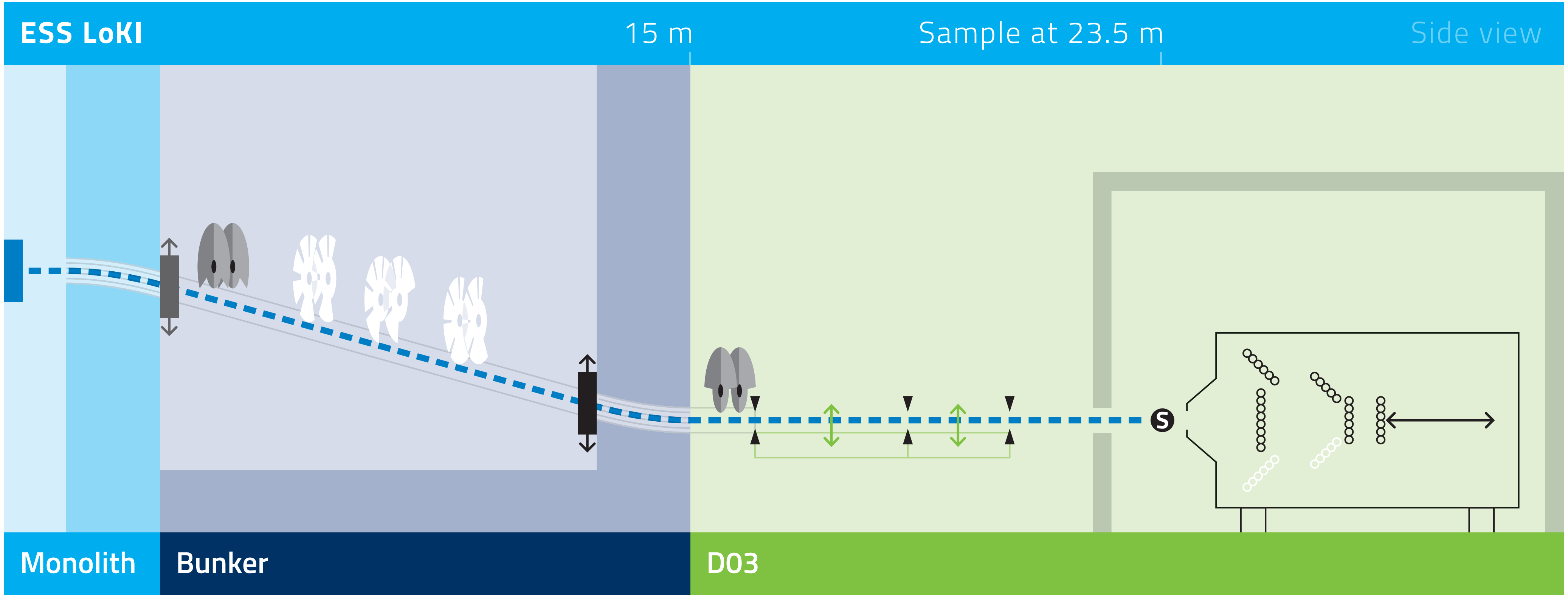






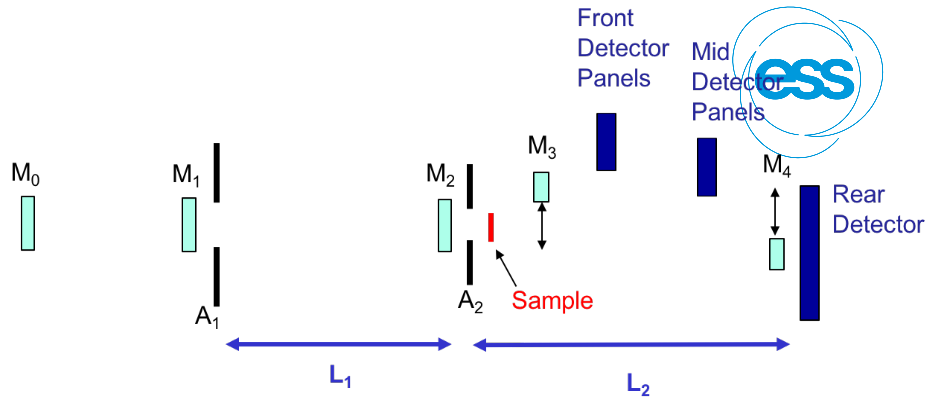
Instrument Commissioning

Examples from LOKI



Instrument Commissioning

Examples from LOKI: Flux and beam profiles



Key personnel: instrument team, detector group, DMSC, and RP for the Au-foil measurements

Requirements/assumptions: Access to a portable neutron camera. Data chain pipeline from monitors and detectors to data reduction software will be tested. Sufficiently powerful and stable beam.

3.2.1 Monitors

Before proceeding with most of the instrument HC

Measure pulse height spectra, count rates, discriminator levels and testing the data chain.

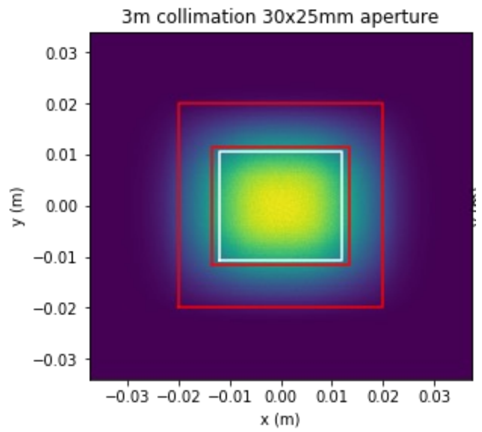
NOTE: The main transmission monitor directly after the sample position may be used for commissioning of the earlier beamline components, e.g. heavy shutter, choppers, collimation slits.

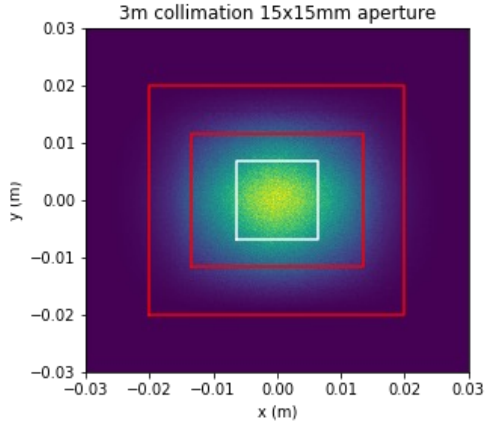
3.2.2 Flux measurements

Calibrate the flux measured by the beam monitors in their predefined positions using gold foils. Compare to McStas data.

3.2.3 Beam profile

Using an imaging detector, we will characterise the beam profile, across a range of instrument configurations, and then compared with McStas simulations.





Instrument Commissioning

Examples from LOKI: Detector verification

Key personnel: instrument scientist and data scientist, DMSC*, detector group*

Requirements/assumptions: The monitors are commissioned. The data acquisition stream will have been tested with simulated and test data.

3.5.1 Detector and TOF distances and for Q

The positions of the detectors will be most accurately determined by the surveying. The reduction process for the different detector banks will also be checked against a rotating silver behenate standard.

3.5.2 Detector position calibration

Position calibration along the length of the detector straws can be made using a Cd, or boron-painted, mask with precisely machined slits, which is mounted directly on the front window of the detector panels

3.5.3 Detector efficiency calibration

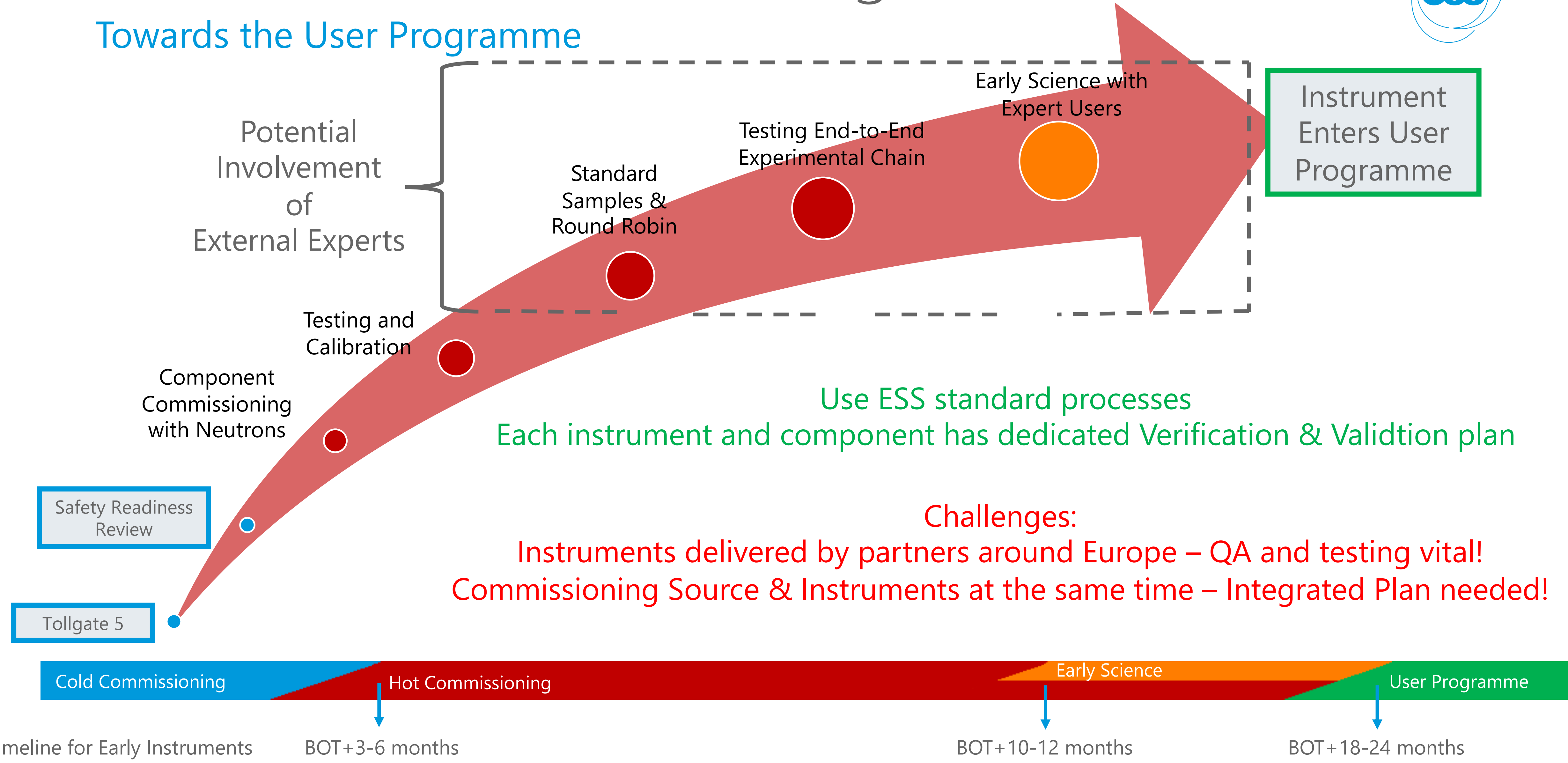
Long SANS and M3 & M4 transmission measurements of standard reference polymer, glassy carbon, empty beam, etc, at all commonly used collimation and aperture sizes.

4

Summary

Instrument Commissioning

Towards the User Programme



Use ESS standard processes
Each instrument and component has dedicated Verification & Validtion plan

Challenges:
Instruments delivered by partners around Europe – QA and testing vital!
Commissioning Source & Instruments at the same time – Integrated Plan needed!