Hot Commissioning

=ESS.NSS.H01.LOKI

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2025-09-15

Between now and HC

- Fixing of issues from Cold Commissioning
- Repeating of Integrated Tests
- Robustness/repeatability testing:
  - Leaving chopper systems running
  - Leaving detectors powered and counting
  - Performing repeat movements of motion axes (long running scripts)

Overview of HC Tasks

ESS-1108651

- Fulfil radiation protection requirements
- Hot Commissioning of beam monitors
- ToF Calibration
- Gold foil measurement
- Choppers phases verification
- Characterize beam profile
- Flight path calibration
- Characterization of position and tilt of detectors
- Calibration of detector efficiency and resolution
- Commissioning of sample environment

The test descriptions in ESS-1108651 will be converted to test plans similar to the integrated tests.

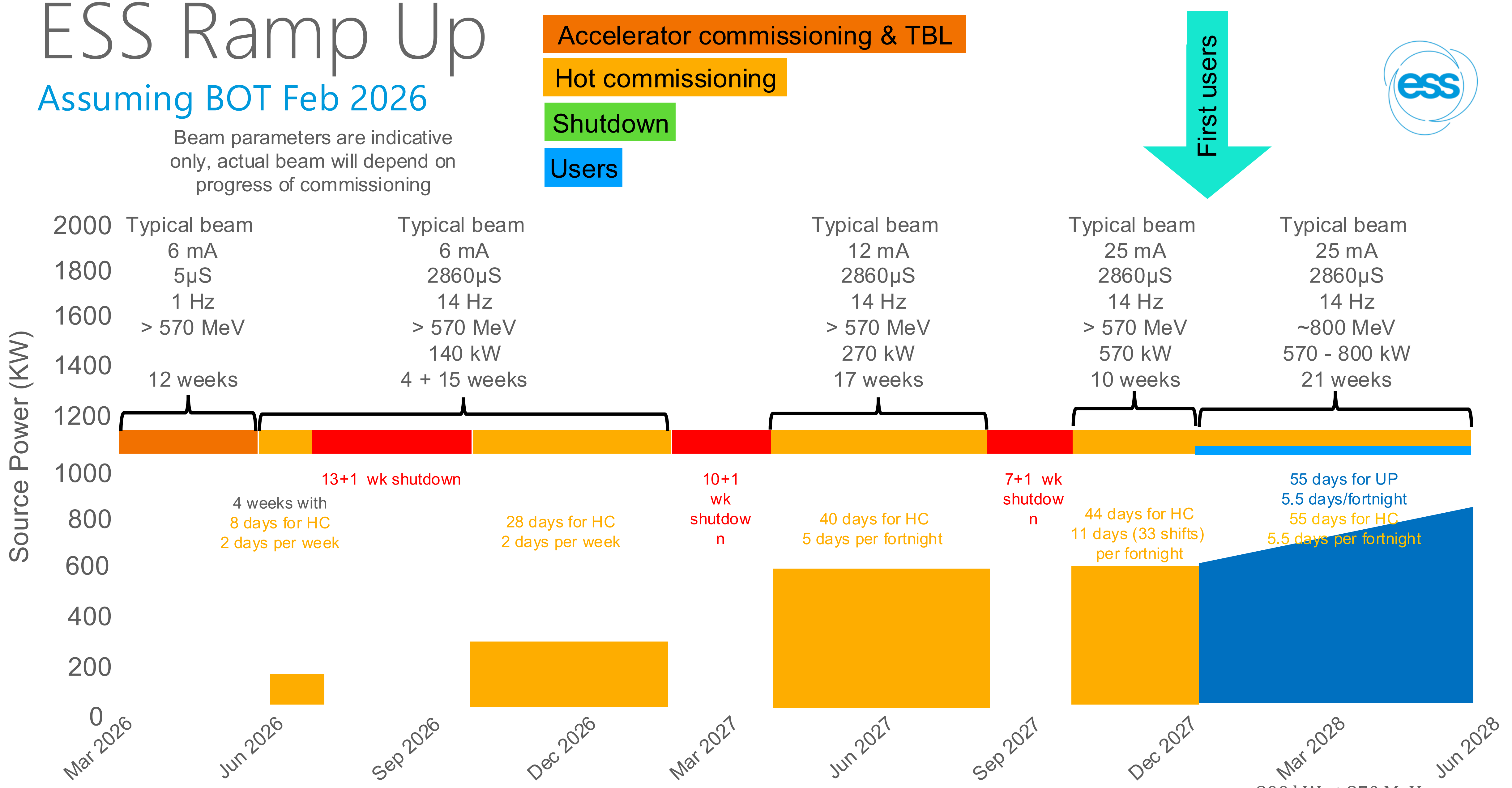
HC plan in ESS-1108651 needs to be updated with experience/new information when Judith returns from parental leave

Note : many of these steps will be repeated multiple times during beam ramp-up

ESS Ramp Up

Assuming BOT Feb 2026

Beam parameters are indicative only, actual beam will depend on progress of commissioning



$$\frac{570\text{ kW at }570\text{ MeV}}{2000\text{ kW at }870\text{ MeV}} \rightarrow 10\ \%\text{ flux}$$

$$\frac{800\text{ kW at }870\text{ MeV}}{2000\text{ kW at }870\text{ MeV}} \rightarrow 40\ \%\text{ flux}$$

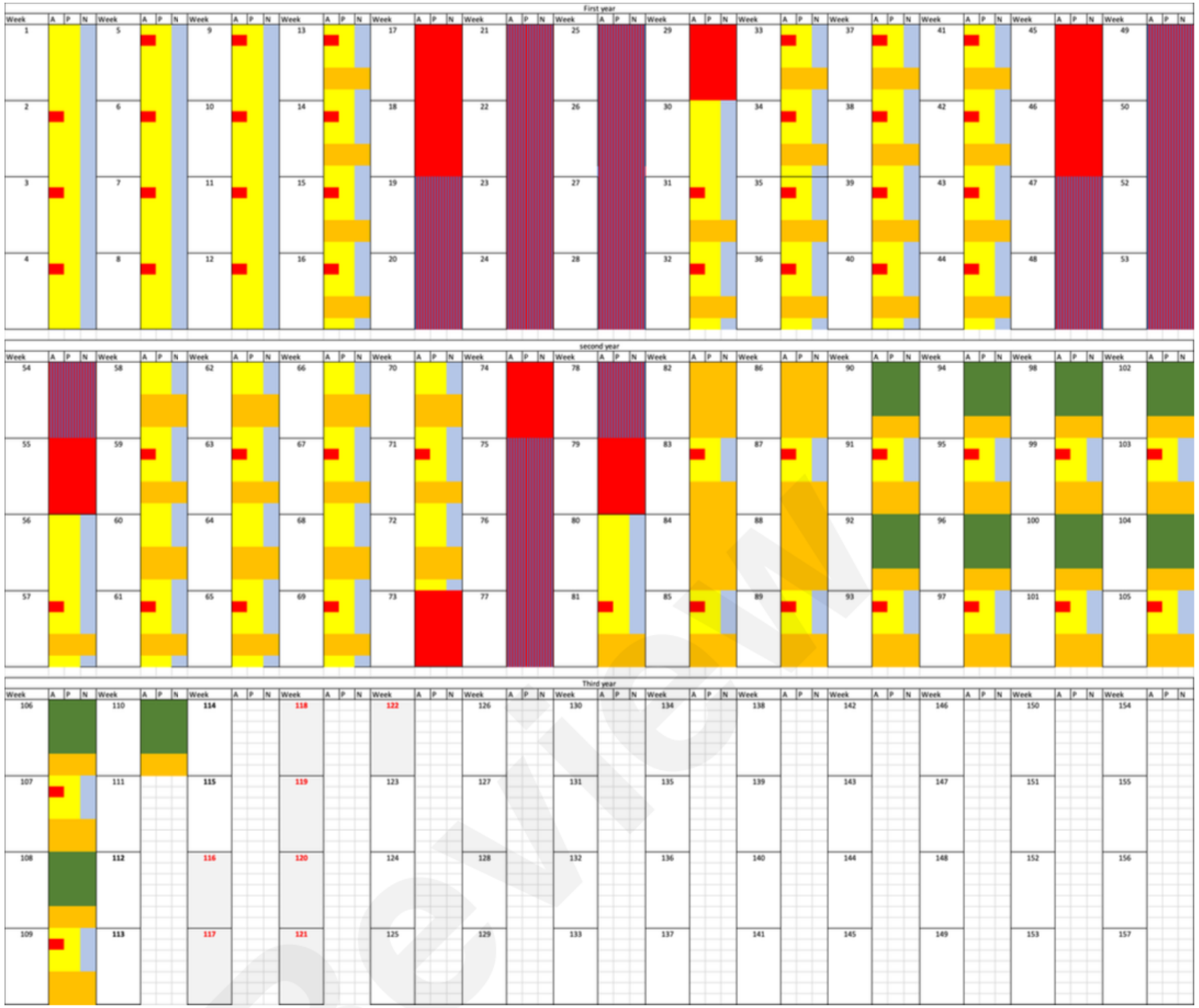
See ESS-0420218 “Early operations of ESS and prerequisites for first scientific results” for more details

Commissioning phases

Phase	Main focus
Accelerator, Target & TBL (12 weeks)	First beam on target. Establish nominal (3ms) pulse length at low current (6mA or lower). Validation of moderator performance using TBL. (stable beam likely available overnight for instruments)
Hot commissioning #1	Power ramp up and availability improvements Target transient tests First dedicated neutron beam for instruments 2 days per week dedicated for instrument hot commissioninig
Hot Commissioning #2	Power ramp up and availability improvements Target transient tests 5 days per fortnight dedicated for instrument hot commissioninig
Hot Commissioning #3	Power ramp up and availability improvements 11 days per fortnight dedicated for instrument hot commissioninig
First User Period	Power ramp up and availability improvements 11 days per fortnight above 500kW for instruments HC Half of the instrument time with users, rest for continued HC

Power level for instruments will be agreed based on commissioning status to provide good availability and beam stability

ESS plan: Yellow is accelerator running, orange is 'useful' beam



ESS plan: Yellow is accelerator running, orange is ‘useful’ beam

Period 0:

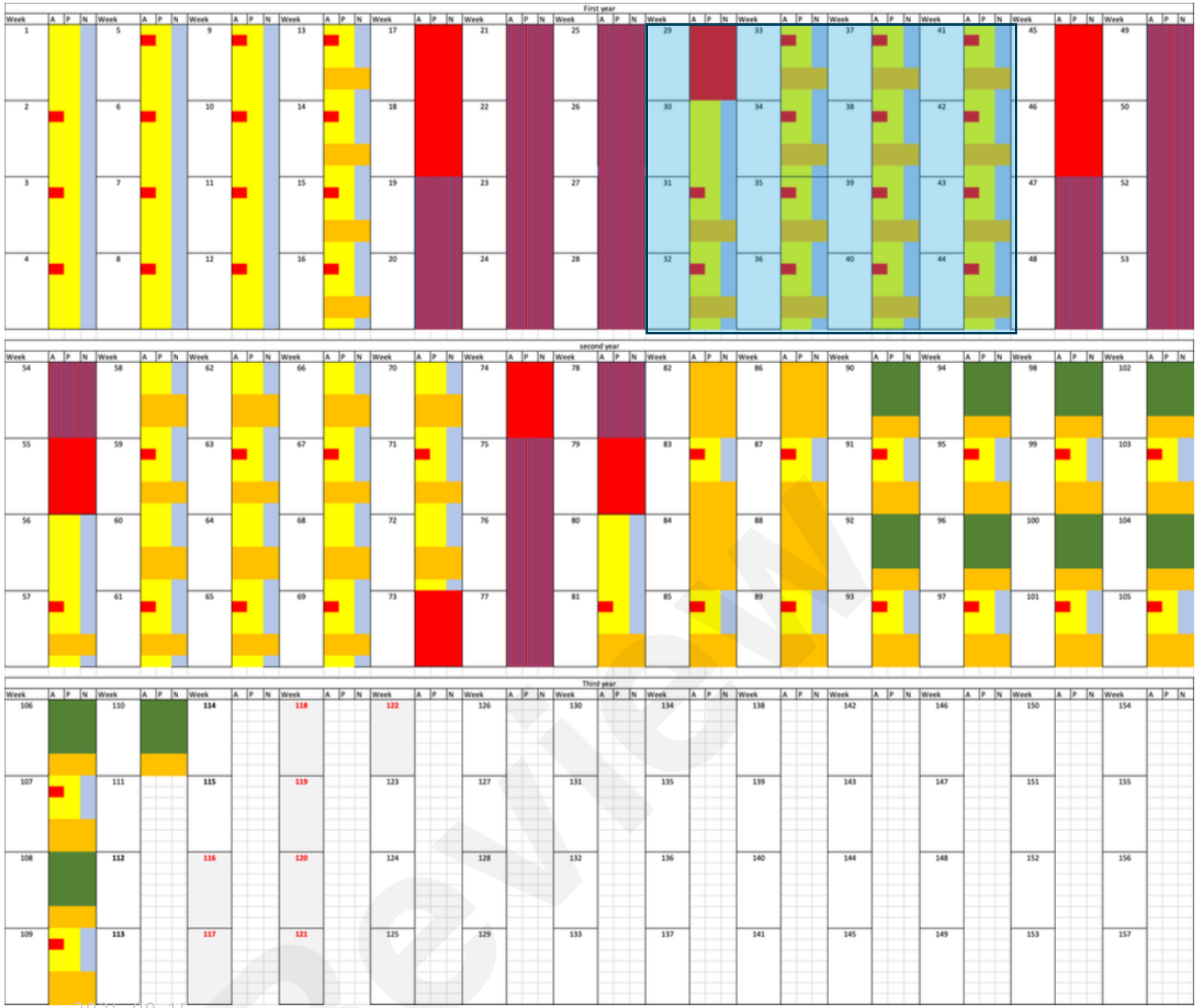
- **12 weeks:** of beam with very low power
  20+ W

- **4 weeks:** with 8 (4 x 2) days of 14 Hz operation

LoKI flux at 100 W: ~$1.6*10^4$ n/s/cm^2
Not useless! Can start testing!

LoKI flux at 140 kW: ~$2*10^7$ n/s/cm^2
Enough to produce top class science
SANS2D : ~$5x10^6$ n/s/cm^2
EQSANS : ~$1x10^7$ n/s/cm^2
D22 : ~$1x10^8$ n/s/cm^2

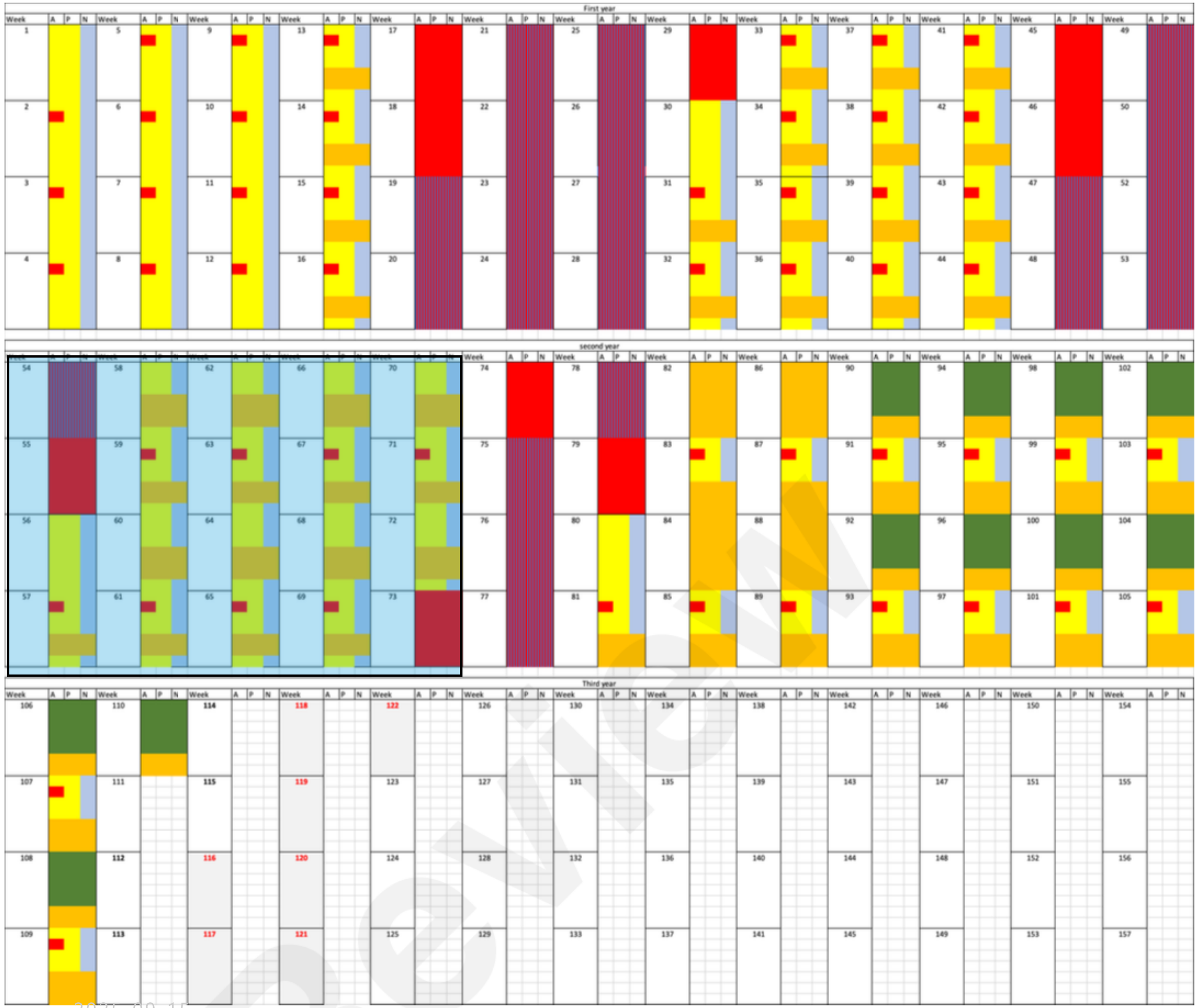
ESS plan: Yellow is accelerator running, orange is ‘useful’ beam



Period 1:

- **15 weeks, yellow:** The beam power and frequency is varying – testing purposes
- **14 weeks, orange:** with 2 days of 14 Hz operation 140 kW
- **28 days** of experimental (HC) beamtime
- **Around 50 days** of beamtime to be used for non-experimental commissioning

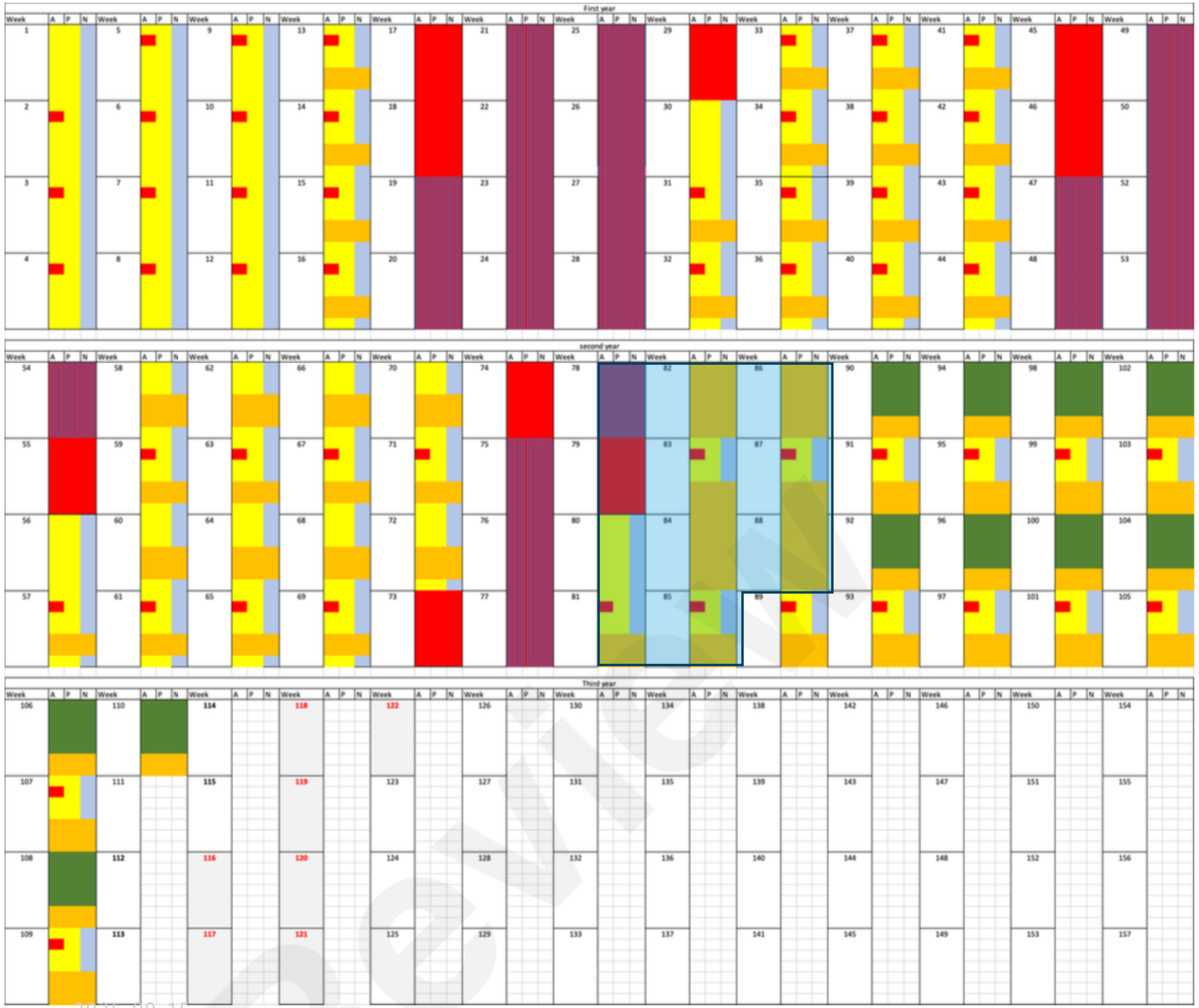
ESS plan: Yellow is accelerator running, orange is 'useful' beam



Period 2:

- **17 weeks, yellow:** The beam power and frequency is varying – testing purposes
- **16 weeks, orange:** with 2.5 days of 14 Hz operation 140 kW
- **40 days** of experimental (HC) beamtime
- **Around 50 days** of beamtime to be used for non-experimental commissioning

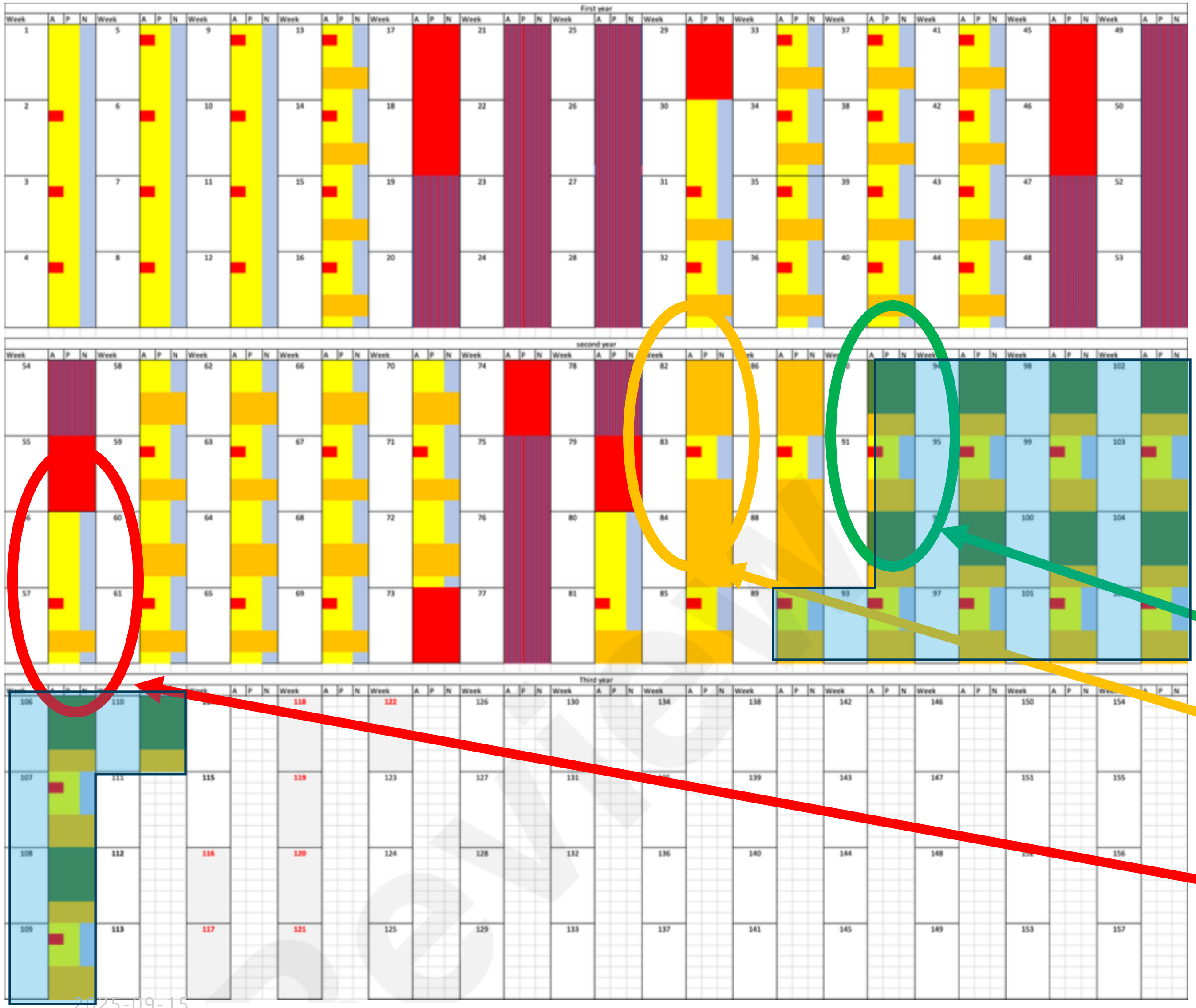
ESS plan: Yellow is accelerator running, orange is 'useful' beam



Period 3:

- **9 weeks, yellow:** The beam power and frequency is varying – testing purposes
- **8 weeks, orange:** with 11 days of 14 Hz operation per fortnight
- **40 days** of experimental (HC) beamtime

ESS plan: Yellow is accelerator running, orange is ‘useful’ beam



Period 4 - early science:

21 weeks – 11 beam days per fortnight
half for user, half for HC
500 kW

No debugging monitors, no detector calibration
no characterization measurements.

Everything should run smoothly, or else we arent ready for SOUP.

If we want to ask a user to come here,

we must be able to perform a real experiment here, and …

… due to proposal submission and review, we need to know here

ESS plan: using the accelerator commissioning time

Non-experimental commissioning tasks could be:

- Detector uniformity (put e.g. PTFE or acrylic slab in beam and count)
- Detector firmware tweaking
- If we get short pulses – initial ToF and flight path calibration from moderator to sample

Experimental commissioning tasks are described in the following but are defined by

- The need for the full pulse to populate the wavelength band
- The need for high flux to generate statistics in low efficiency monitors
- The need for 14 Hz operation to test the work flow for data reduction, initial analysis and calibration

Key Issues/NITs to be solved for HC

Before HC can start:
- Availability of Acc/Target PVs/data to instruments (NIT-327)
- Beamstop system logic (NIT-202,NIT-201, NIT-200, NIT-198, NIT-197,NIT-196)
- Detector failure issues need to be understood

Before collimation commissioning measurements can be made
- Slit precision settings (NIT-344)

Before detector calibration measurements can be made:
- Detector distance recording (NIT-209)
- T0 offset definition (NIT-314)

Before experimental measurements can be made
- Sample environment integration (NIT-182, NIT-181)

Fulfil radiation protection requirements

Key personnel: RP, PSS, and the instrument team

Requirements/assumptions: Successful cold commissioning, accelerator stable enough for the duration of each test measurement

- **Instrument heavy shutter**

Hot commissioning of the heavy shutter is the responsibility is the responsibility of the instrument team, in collaboration with the RP and PSS teams. Hot commissioning of the heavy shutter is expected to simply confirm the cold commissioning process using neutrons, therefore we will check open/close.

- **Cave structure**

The functionality of the doors, roof and PSS systems are assumed cold commissioned when hot commissioning commences. The possibility to test the shielding properties of the cave strongly depends on the proton beam power. Radiation will be measured at several points around the instrument, including, but not limited to, external door, roof door, and sample environment chicanes. Also, if allowed, with the roof door open. Here RP will confirm compliance with the 3uSv/h requirement in green zones and with appropriate levels in other zones.

It should be noted that the instrument shielding is designed for 5 MW worst case scenarios, and it is unlikely that a useful measurement of radiation emerging from the cave can be performed at 500 kW (*initial operations*). Therefore, radiation surveys will need to be repeated at key stages as the source is ramped up, as well as when flux is increased as a result of improved alignment. Samples in the beam during the radiation surveys will progress increase in severity of radiation danger, e.g. empty beam, water, steel, Cd. Firstly, using the longest collimation distance, L1 = 8 m, and then the shortest, L1 = 3 m, all with maximum beam sizes and choppers parked open. Then add full beam scattering samples. Then close down apertures, close fast shutter, or close safety shutter to see what scatters off them into shielding.

Beam Monitor Commissioning

In order to check stability, time-of-flight spectra and ratios between monitors will be compared at ~15 min intervals and compared to the proton beam current.

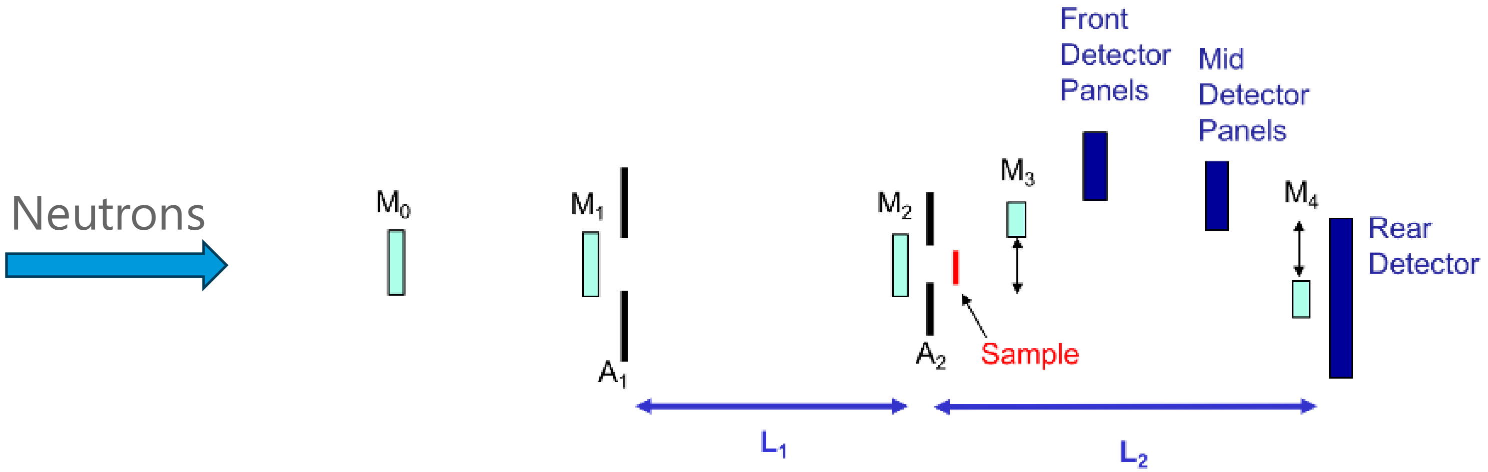
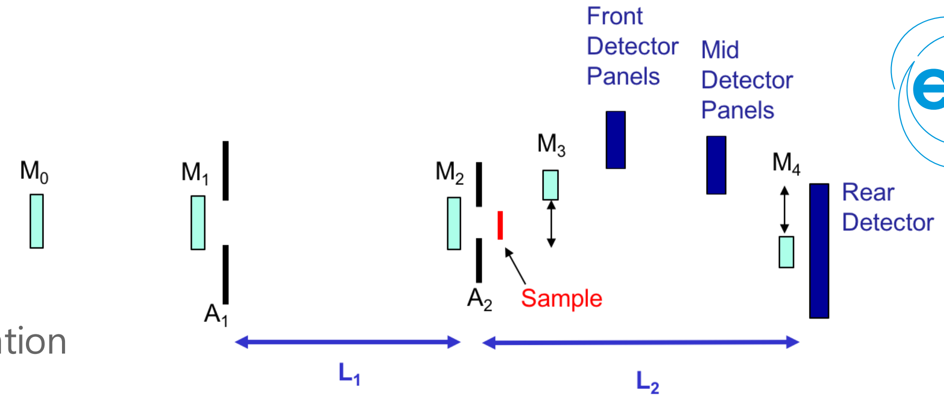


Figure 2.1 Instrument configuration of the monitors and detectors: M_n refers to monitors 0-4, L_1 = collimation length, L_2 = sample-to-detector distance, A_1 = the first collimation aperture 8, 5 or 3 m before the final aperture, A_2.

Flux and beam profiles

Beam Monitors



Key personnel: instrument team, detector group, ECDC, DMSC, Spallation Physics (Gold Foil)

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.

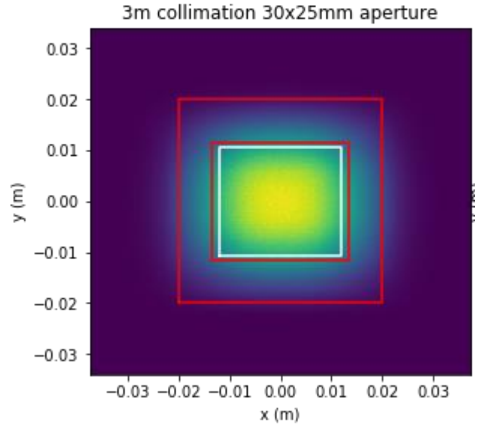
NOTE: The main transmission monitor directly after the sample position may be used for commissioning of the earlier beamline components, e.g. heavy shutter, choppers, collimation slits.

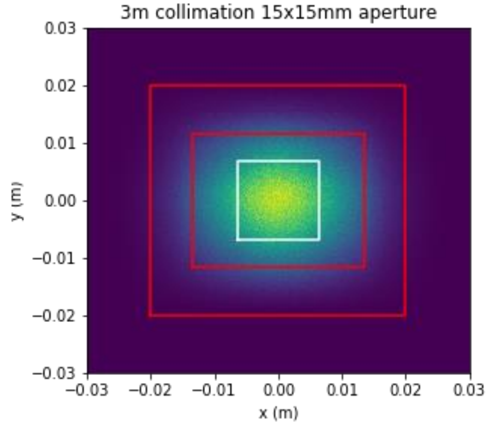
3.2.2 Flux measurements

Calibrate the flux measured by M2, M3, and at the sample position in using gold foils. Compare to McStas data.

3.2.3 Beam profile

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

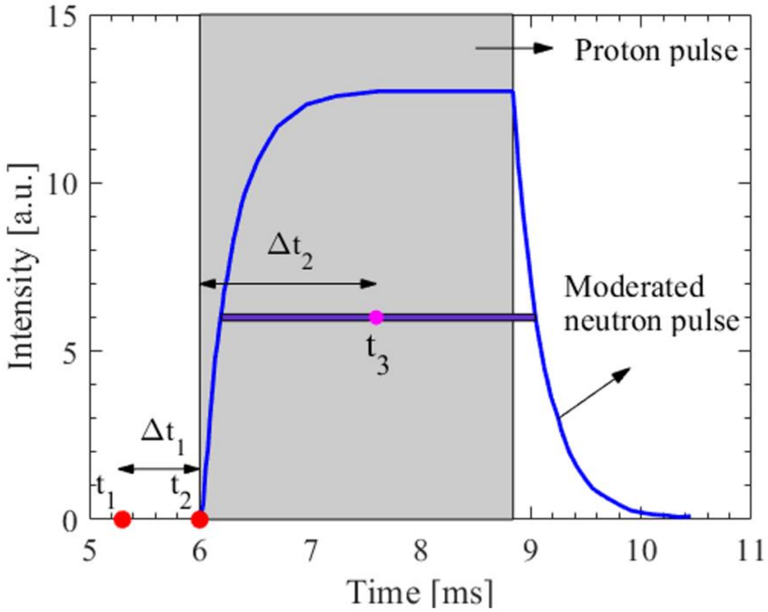


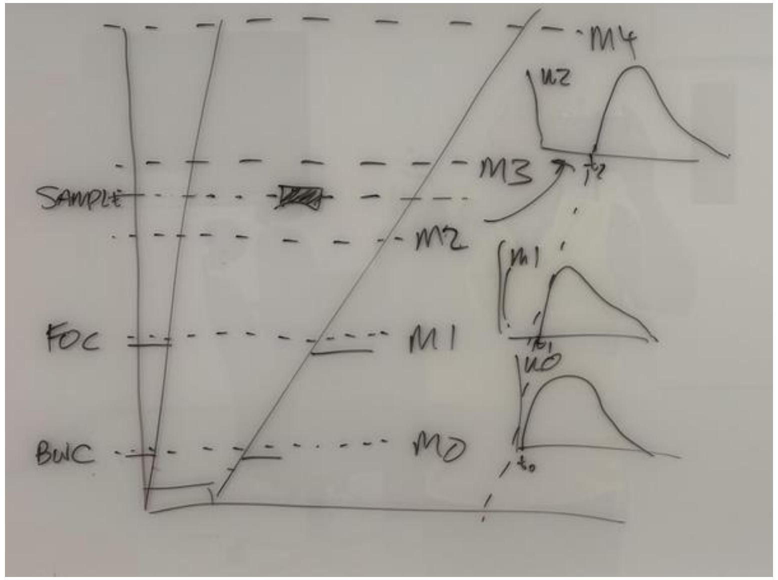


ToF & Distance Calibration

Making use of short pulses

- Choppers running as for 2.86ms 14Hz
- Measure ToA spectrum on 3 beam monitors
- Project back in time to find T0 offset needed for ToA to ToF conversion.
- Assumes we know the distance to each monitor with sufficient accuracy
- Need a diffraction rig/setup to do ToF/wavelength cross-check, or could use bragg edges with short pulses





Choppers

The hot commissioning of the choppers will be supported by the chopper group, with the instrument team participating.

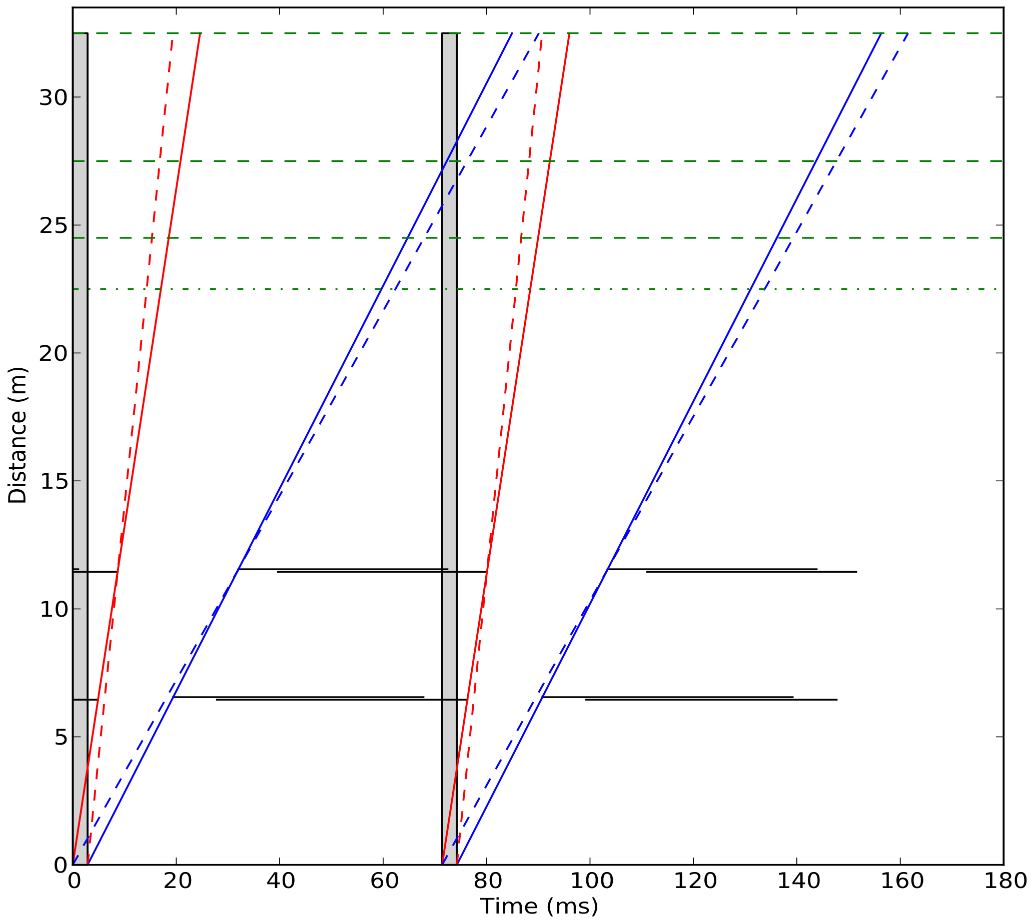
During hot commissioning we will check park open, phasing of the co-rotating discs, and opening angles of all 4 discs at 7 and 14 Hz, with "monochromatic" and "full beam" openings.

This will be a repeat of the integrated tests, but using the timing system as the reference for phasing to the proton pulse.

Firstly, we will feed in the phases for the expected wavelength ranges and compare with the collected monitor detector data.

This would then be cross-checked with the results using the calculation.

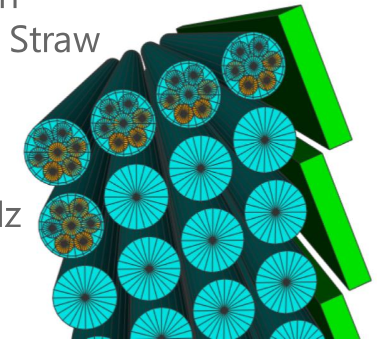
Compare with McStas simulations.



Detectors

Maximising the neutrons we count – make the most of the source

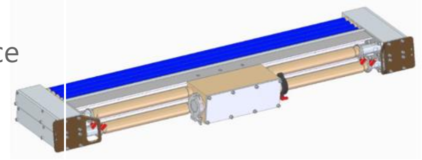
Various different options were considered : 3He tubes, Boron blades (BandGEM) and Boron Straw Tubes. On balance of performance, cost and complexity Boron Straw Tubes were chosen



Efficiency: ~50%-60% at LoKI wavelength
Position resolution: FWHM is ~6 mm up to 350 kHz
Rate capability: 15% rate lost at 2.3 MHz

4 layers of 1" Al tubes, each containing 7 x 8mm boron-coated straws

Signal is read out via 4 wires per tube with multiplexing resistance chain.

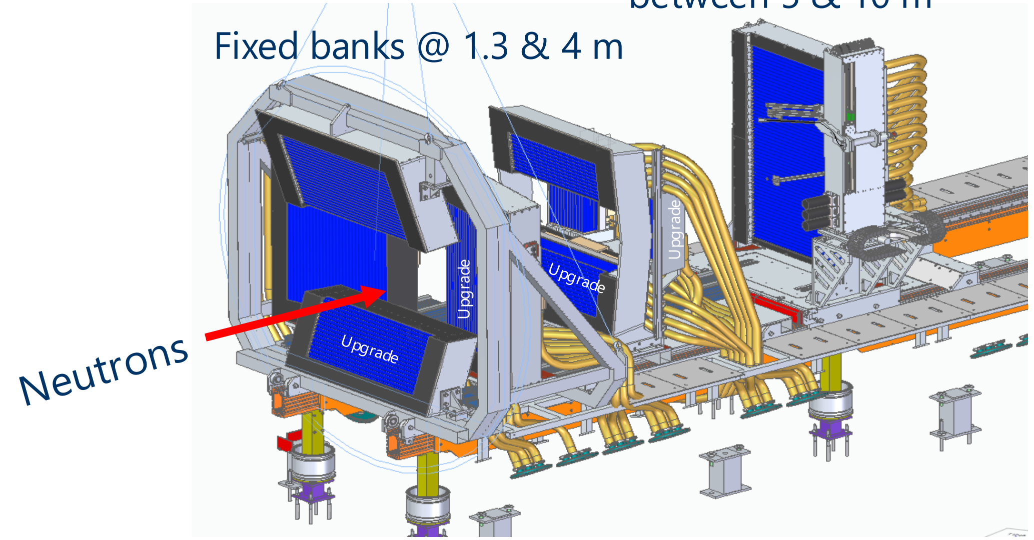


Detectors assembled as modules of 16 tubes.

Preamp and power board in airbox on ends of tube assemblies

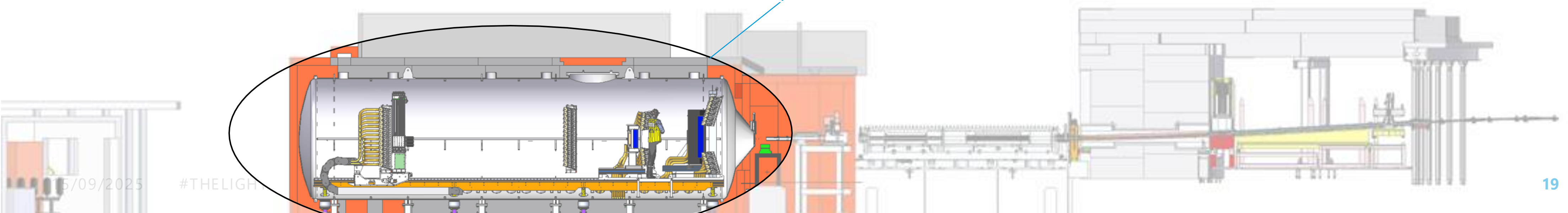
Covering 0º to 45º in scattering angle and 360º in azimuthal angle (180º Day 1).

Rear detector moveable between 5 & 10 m



Day 1 scope : 576 tubes x 7 straws x 256 pixels
= **1,032,192 pixels**

Full scope : 880 tubes x 7 straws x 256 pixels
= **1,576,960 pixels**

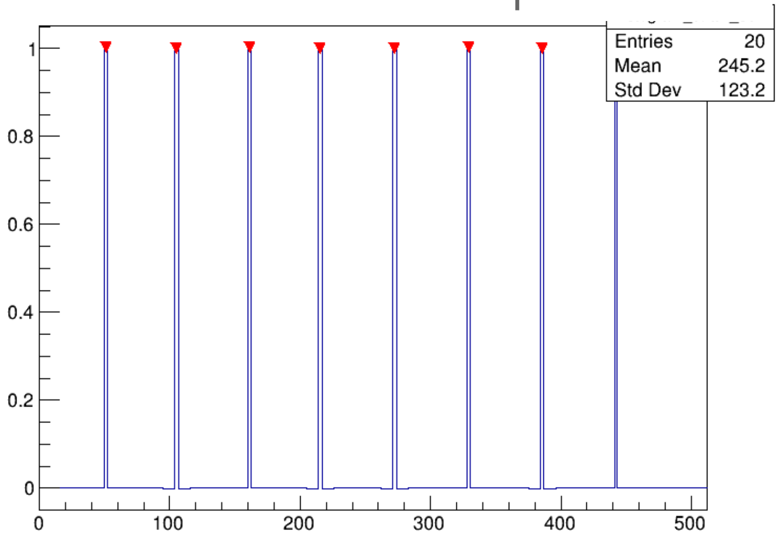


Detector calibration

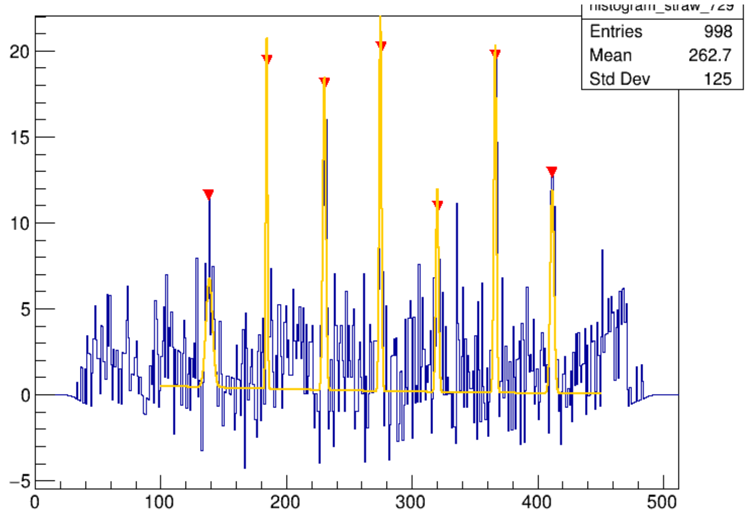
Position

- Position calibration data is generated by place a mask with narrow slits
- For challenging noisy peaks algorithmically approximated
- The difference between simulated and measured peaks is calculated, and a polynomial relationship is fitted.
- The result is used by Event Formation Unit in order to generate position-corrected NeXus files.
- For the LoKI detector tests, the demultiplexing and position correction was originally performed at ISIS by Davide Raspino, but is now replicated by code written by ECDC in preparation for hot commissioning.

Geant4 simulated peaks



Measured peaks (naturally worse towards the back of the detector)

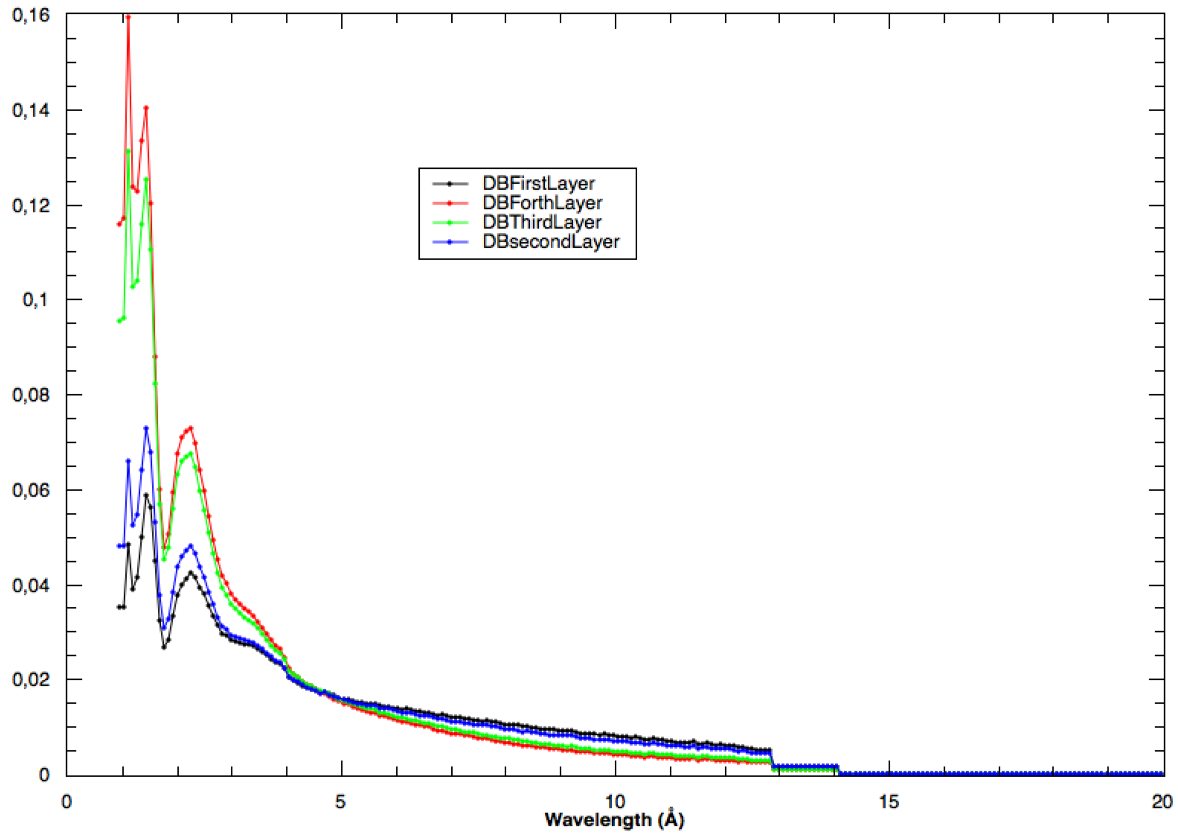


Data from March 2023 STAP report

Detector Calibration

Data reduction of the LoKI test data

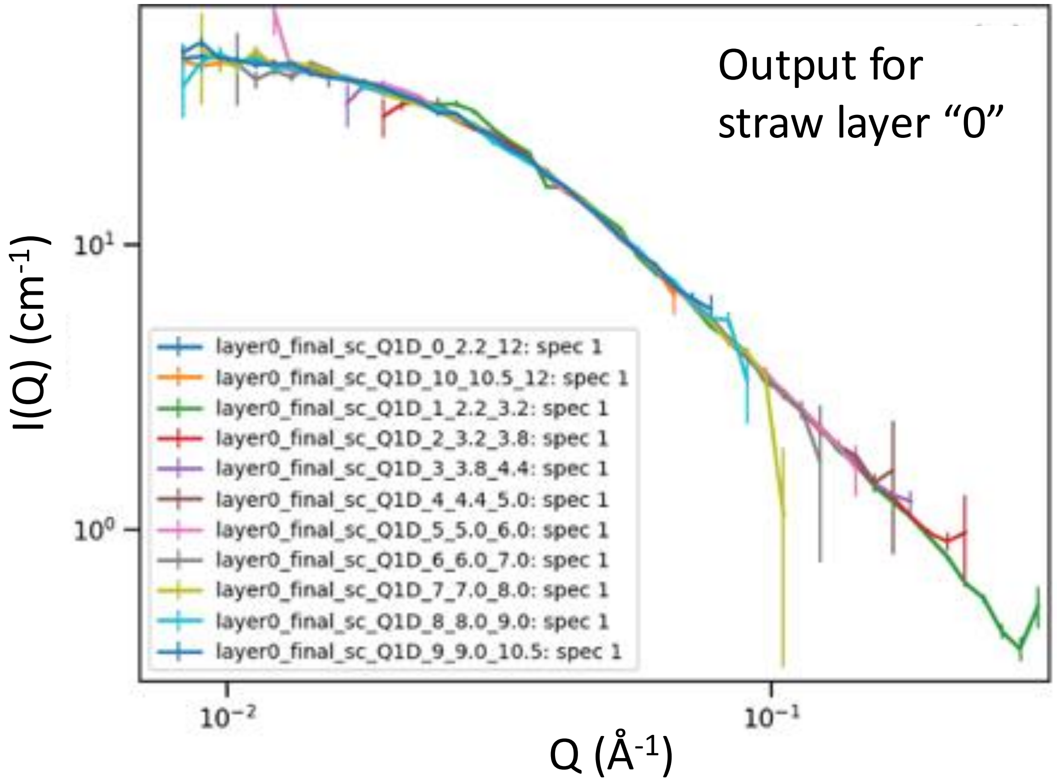
- As expected we observed: a hardening of the direct neutron beam as we go through the panel of detector straws, due to self-screening from one layer of straws to another.
- To account for this effect, we need to create a "direct-beam function" (D(λ)) that changes through the depth of the detector
- D(λ) is the **relative efficiency of the main detector** (or detector straws) **compared to the incident beam monitor as a function of wavelength**. D(λ) allows us to cross-normalise the incident spectrum to that of the empty beam (without sample) is seen on the main detector.



Detector Calibrations

Direct Beam Function

- I(Q) is generated by the reduction of 6 to 12 wavelength bands which are then compared to I(Q) from the full wavelength range. The process is iterated until the correction converges to a nearly flat polynomial.
- We then iterate and correct the wavelength adjustment profile, until the wavelength sufficiently overlaps. The final step simply scales the D(λ) to correct for the overall absolute intensity.
- Start with a simulation of a flat scattering from Geant4. This simulation helpfully picks up any straw-to-straw variability and provides a "master" file in which we can save the new D(λ) functions.
- The generated D(λ) for each layer is then applied to all the straws in the relevant layer of the master file (i.e. original flat simulation).



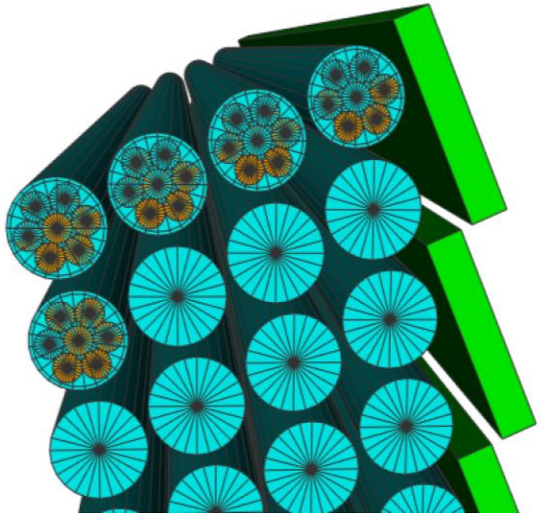
After many iterations we are considering 28 layers (so all straw number 0 in Tube layer 1 are one "layer")

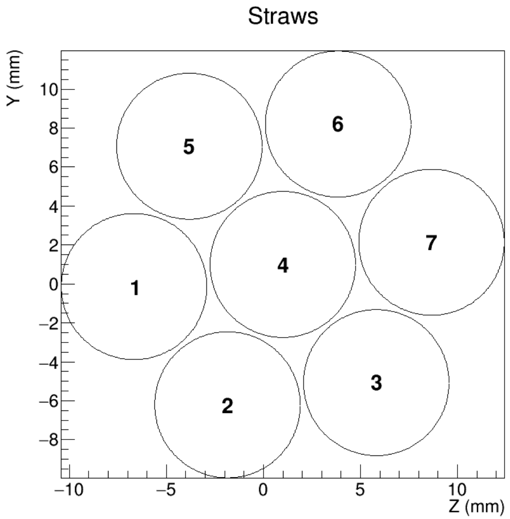
Detector Calibration

Possible D(λ) simplifications … to be determined in HC

One challenge for us has been to decide to what resolution we should be generating the D(λ), e.g. per each straw (difficult with poor statistics), per each "straw layer" (consider 7 straws in each of 4 tube layers = 28 layers), grouping the straw layers in logical geometrical layers (= 11/12 layers), or per each tube layer (= 4 layers).

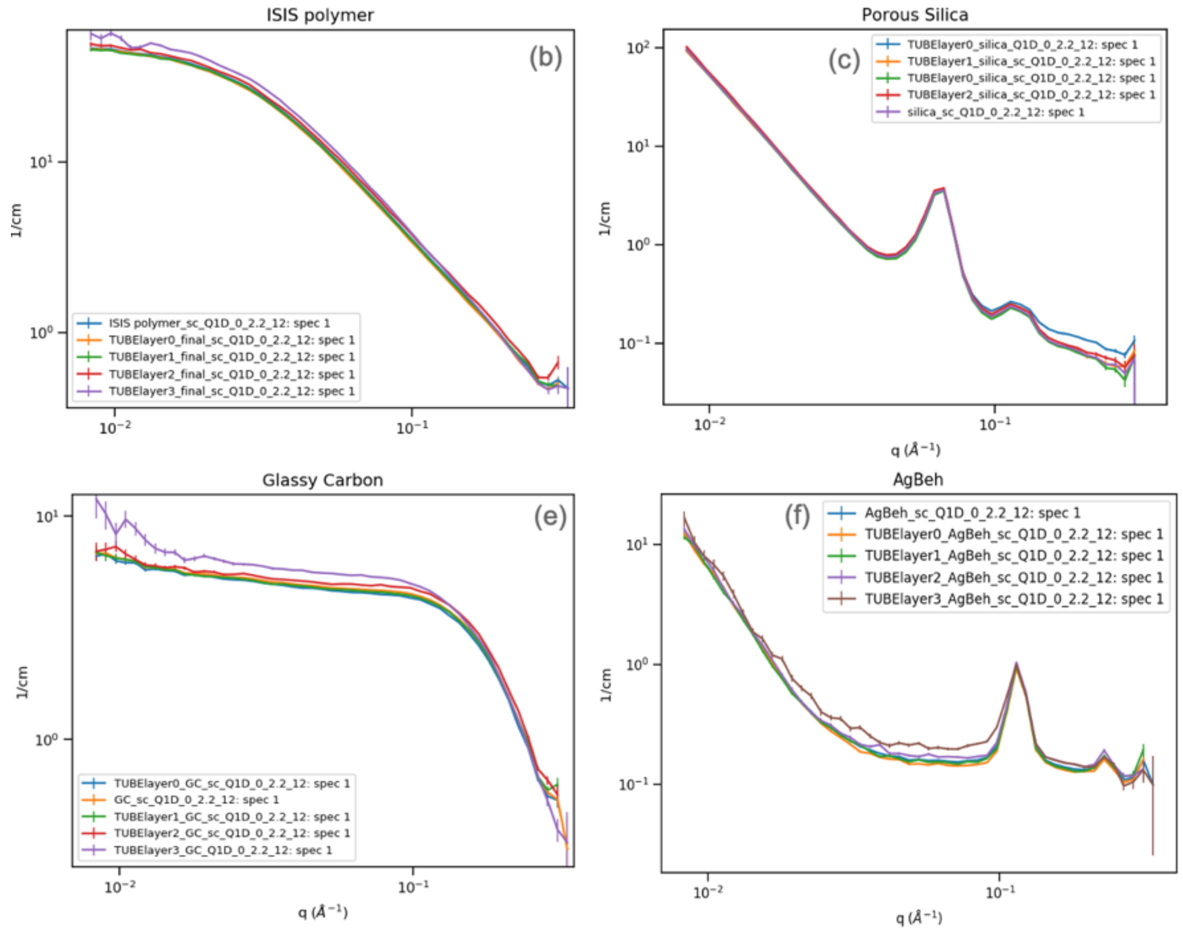
Currently, we are still working with the **28 layers approach** (so all straw number 0 in Tube layer 1 are one "layer").

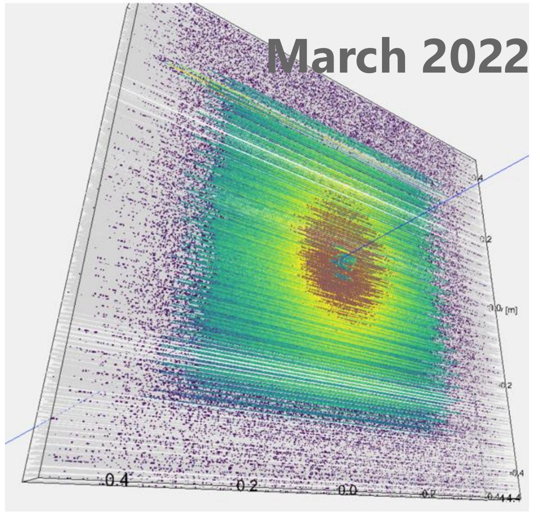




Detector Calibration

Repeat of Detector Tests from 2022 at Larmor (ISIS, UK)





NeXus file displayed in scipp

Sample measured:

1. Cd stripped masks (GdO to be used on LoKI)
2. Silver behenate
3. SDS powder
4. empty beam
5. blocked beam
6. ISIS standard polymer
7. Silica particles
8. Vanadium

Data from previous report

Beam time requirements

Task	Beam days required	Comments
Fulfil radiation protection requirements	5 days in (~0.5 day increments?)	Hold point before any further step can begin. Need to repeat if neutronic alignment and commissioning increases flux.
Gold foil measurements	1	
Check monitor detectors M0 to M4 electronics with neutrons	5 days	Detector group support
Check neutron beam profile	5 days	
Chopper phasing verification	5 days	Chopper group support
Optimise collimation tube, guide and jaw set positions	10 days	Reliant on availability of portable neutron cameras
Check neutron beam through all components in sample area	5 days	Reliant on availability of portable neutron cameras
Collection of detector calibration mask data and silver behenate powder	15 days	Perhaps collect data at night time during some other tasks.
Processing of calibration mask data, integration with survey results, check against reduced behenate powder data.	(~10 days)	Can be during "beam off".
Collection of data from standard samples for detector efficiency iterations.	15 days	
Processing of detector efficiency data.	(~10 days)	Can be during "beam off".
Commissioning of SE	10 days	
Demonstration experiments, interspersed with frequent standards.	25 days	Maybe with friendly users in person.
TOTAL	**100 beam days**	**This total is probably rather optimistic**

Commissioning phases

Phase	Main focus	Nominal Beam Power	LoKI Neutron Flux (n/s/cm²)	LoKI Activities
Accelerator, Target & TBL (12 weeks)	First beam on target. Establish nominal (3ms) pulse length at low current (6mA or lower). Validation of moderator performance using TBL. (stable beam likely available overnight for instruments)	N/A	$1x10^4$ to $1x10^6$	"Parasitic" usage (no dedicated HC days) ToF testing and calibration Detector "flood" tests
Hot commissioning #1	Power ramp up and availability improvements Target transient tests First dedicated neutron beam for instruments 2 days per week dedicated for instrument hot commissioninig	> 100 kW (570 MeV)	> $1.5x10^7$	Beam monitor commissioning Flux and Beam Profiles Chopper commissioning
Hot Commissioning #2	Power ramp up and availability improvements Target transient tests 5 days per fortnight dedicated for instrument hot commissioninig	> 200 kW (570 MeV)	> $3x10^7$	Detector calibration Flux and Beam Profiles Standards measurements
Hot Commissioning #3	Power ramp up and availability improvements 11 days per fortnight dedicated for instrument hot commissioninig	> 300 kW (570 MeV)	> $4.5x10^7$	Detector calibration Flux and beam profiles Standards measurements Test experiments with sample changer
First User Period	Power ramp up and availability improvements 11 days per fortnight above 500kW for instruments HC Half of the instrument time with users, rest for continued HC	> 500 kW (800 MeV)	> $8x10^7$	User experiments Sample Environment Commissioning (beyond sample changer)

Power level for instruments will be agreed based on commissioning status to provide good availability and beam stability

Resources

All testing : IOE + 2 IS + IDS will be involved

- This will be full time work during beam production

All testing : support from ECDC and ICS will be needed

- Not full time, but will be needed 1-2 days at start of any testing period.

Tech group support for specific sub-system tests, but many tests will be cross-functional and need to have support available as needed e.g. we find a problem with choppers during a detector calibration test.

- Hard to predict level of effort needed, but more detailed HC plan will enable some predictability/planning

- We expect only the core team to be available 24/7 during beam days – clear plan for non-standard work hours required

- During work hours, it seems crucial to have manpower to resolve issues quickly and move on to the next test and the next problem.

- Prefer to have people ready, at the same time, during the day to fix things, rather than have people ready to restate a problem at 2:00 AM.