FREIA update for STAP October 2021

Since the last meeting the project has been progressing well with increased resources as the ISIS engineering team moves effort from Loki to Freia. Detailed design has progressed significantly and the project has issued or is preparing to launch a number of procurements for significant subsystems.

Earlier this year the Freia project has undergone a significant project rebaseline following delays to the awarding of the critical guide contract. Due to the significant float in the overall project this has not affected the planned date for TG5 (end of the construction project) at the end of 2025. We are now assessing the impact of the overall ESS project delays.

The previous STAP report asked, "Do the teams have processes in place to ensure that as the pieces are designed, built and tested they will perform in unison as intended?" This is clearly a non-trivial task, but we have planned to try to do this. The current plan includes a prebuild at ISIS to ensure full integration of all components, including chopper modules, the guide, the collimation system, the sample stack and detector bench. This approach should allow for all components to be tested in an integrated way prior to delivery to ESS. It is the same process that has been undertaken for the Loki instrument at ISIS (and will happen in the same physical location after Loki components are shipped to Sweden). We also expect to learn from earlier instruments as they move into commissioning… particularly ODIN (WFM) and ESTIA (Multiblade).

Detailed Progress:

Choppers and Housings

The chopper system consists of five Ø1.3 m WFM discs and three Ø1 m WBC discs. Six of the discs (all of the WFM discs and WBC2) are carbon-fibre and supplied by Airbus with in-house designs for the remaining two; WBC1 & 3. The design of the chopper housings which will be compatible with both the ISIS and Airbus discs has progressed significantly, particularly for the in-bunker area.

In the bunker, the choppers and guide housings are grouped into three independent "modules" to aid extraction from the bunker. Prototype kinematic features have been tested at ISIS, pending final results. We are now finalising design concepts for the guide housings and lower chopper housings with an internal CDR for Module 2 due in October.

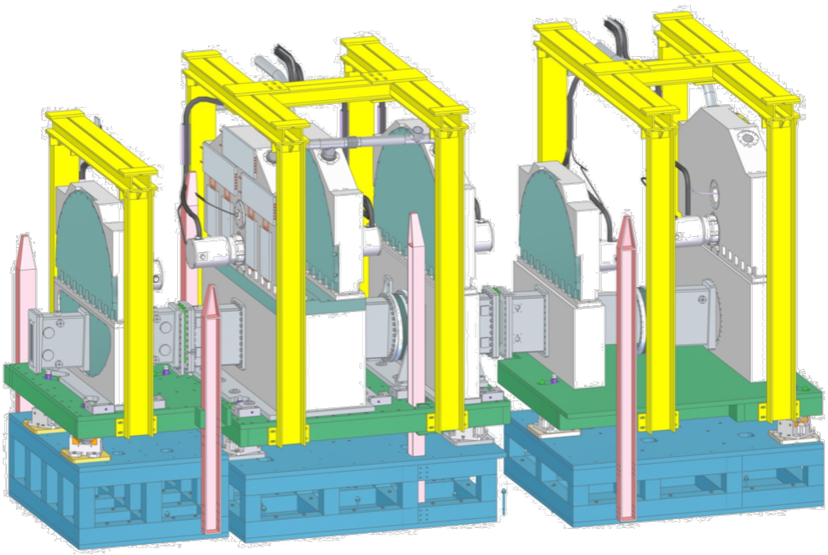

Figure 1: Current design of the in-bunker chopper modules.

The chopper upper housings are standardised 3 sizes; Ø1m single, Ø1.3m single and Ø1m double which is to allow for the upgradability of the final WBC chopper. A CDR of lower housings was held in May and design progressing well, with input from SNAG on guide interfaces.

Airbus chopper discs

As previously reported, a rigid hub design has been developed, to increase the natural frequency of the torsion mode to well above the operating frequency. WFM1 spinning tests were completed successfully in February, demonstrating that carbon-fibre discs are viable.

Analysis of the first prototype chopper disc (WFM1) showed some potential problems with the epoxy coating that contains the $^{10}B_4C$. A test sample was analysed using X-ray tomography subsequently with a destructive TGA analysis. This showed that the coating was not as thick as specified and contained some inhomogeneities. Subsequently Airbus were able to improve their processes and have now manufactured all of the remaining discs (Figure 2). Initial tests of the coatings on these discs show a clear improvement (Figure 3), but further investigation is ongoing. Airbus have agreed to add additional coating material to WFM1, which would ensure that the absorption meets the specification. However, this does potentially increase the risk of delamination so we are seeking assurances over the robustness of this process.

Figure 2 The 6 assembled carbon-fibre chopper discs for FREIA

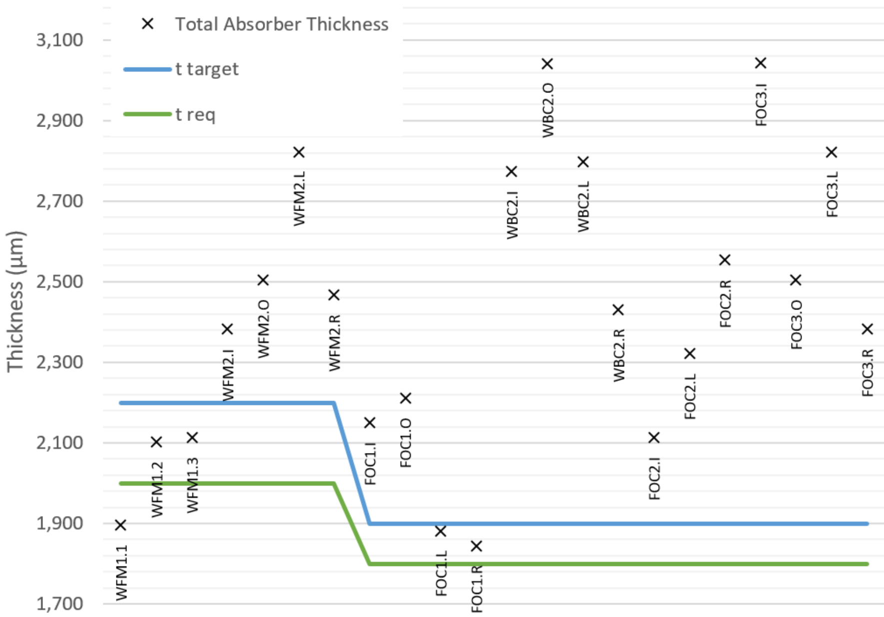

Figure 3: Results of measurements on the coating thicknesses for all 6 Airbus choppers. Only WFM1 has regions that are below the specification requirement.

Overall these tests have led to a delay compared to the planned delivery dates, but this is not expected to impact the overall schedule. We expect that the FAT will be held later in 2021. Following the FAT, the discs will be shipped to ISIS to await integration with the housings.

SKF Chopper Drives

The SKF components for the chopper system are in high demand. As anticipated this has proved to be a bottleneck for later instruments. After negotiation with ESS chopper group we have agreed to delay the delivery of the Freia drives and spindles to ensure that some of the first-8 ESS instruments are able to meet their schedules. This negotiation has ensured that these components will still be available for testing of the FREIA chopper system when required. Manufacture of the components is now due to be completed in late 2021.

Hutches

Given their proximity it was decided to procure and install the Loki & Freia hutches together. This tender was won by MICo Shielding who have now been successful with a number of hutch and cave procurements at ESS. The design has recently passed TG3 with installation due to start in November and complete this year.

The design includes a raised technical flooring on the roof where control racks for both instruments will be located, and a shared access bridge to the cave rooves for both instruments.

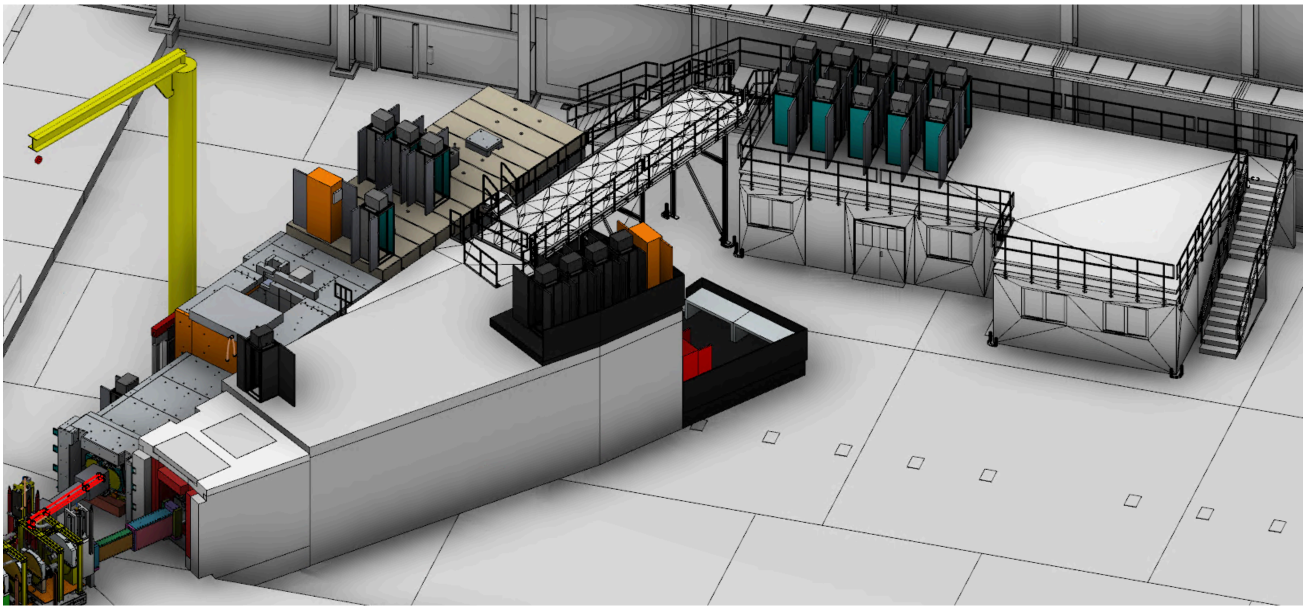

Figure 4: The Loki (left) and Freia (right) hutches are located at the back of the guide hall D03.

Guides

NBOA and NBPI

The monolith insert optics (NBOA) and its housing (NBPI) have progressed well.

A technical solution to the waviness problems previously reported was agreed and the first element of the NBOA was assembled in June (see Figure 5). All remaining substrates have now been machined to size, and are being coated and assembled. As of June, the coatings are 89% complete, 78% verified to meet specification. The average reflectivity for the m=3 coatings is 87.4% (Specification requirement was 85%) and for the m=4 coatings it is 76.3% (Specification requirement was 75%).

Post-assembly waviness measurements have proved difficult due to the narrow channel width (10mm). Nonetheless, we expect to have final results and a Factory Acceptance Test soon.

The NBPI is the scope of Target division. The FREIA NBPI/NBOA is due to be installed in the monolith at about the same time as the LoKi NBPI (to ensure that this installation does not interfere with subsequent LoKi installations). As such this is in the second batch of NBPIs being designed and manufactured in Jülich. In order to mitigate against high energy streaming paths, we recently met with the design team and agreed on the need to backfill with steel some gaps generated by the assembly process. The design will soon undergo a critical design review.

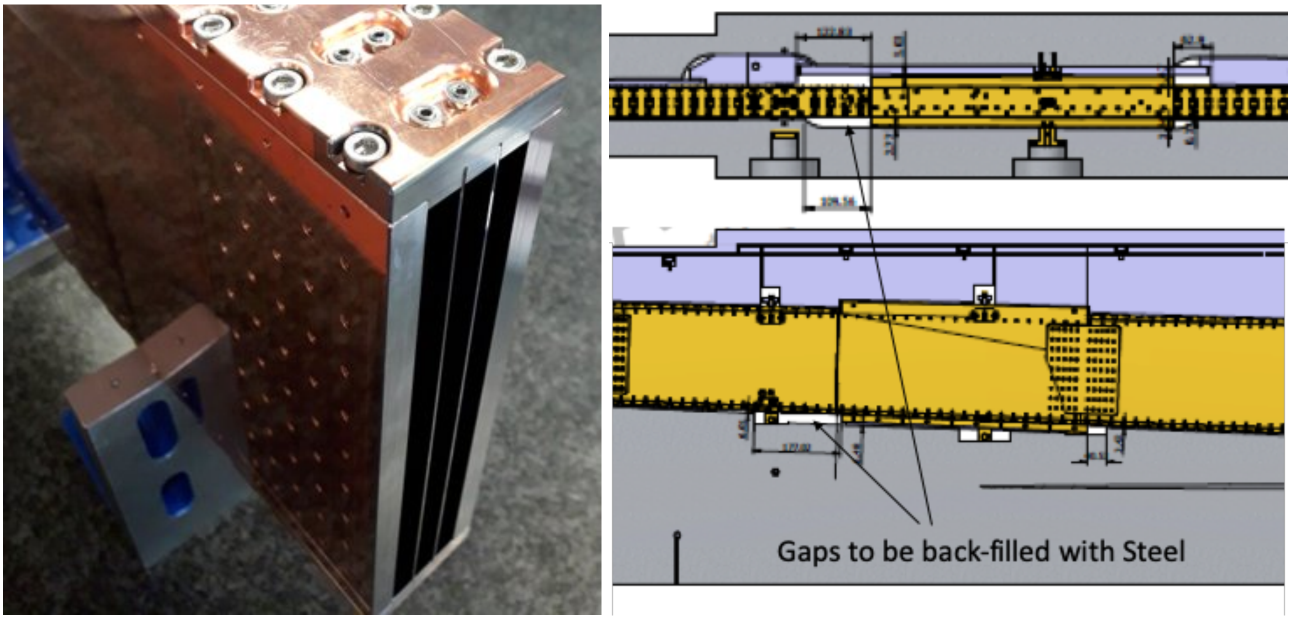

Figure 5: First completed element of Freia's NBOA and a technical drawing of the NBOA (yellow) within the NBPI (grey) that shows the location of some material gaps (white) that are required to insert the NBOA into the NBPI.

Main Guide

The design of the main guide units is underway at Swiss Neutronics, after an approximately 2 month delay. At the request of ESS the delivery of the bridge beam guide (the guide inside the light shutter), the heavy shutter guide, and bunker wall insert has been accelerated from their planned delivery dates in order to be ready for the new (rebaselined) bunker access.

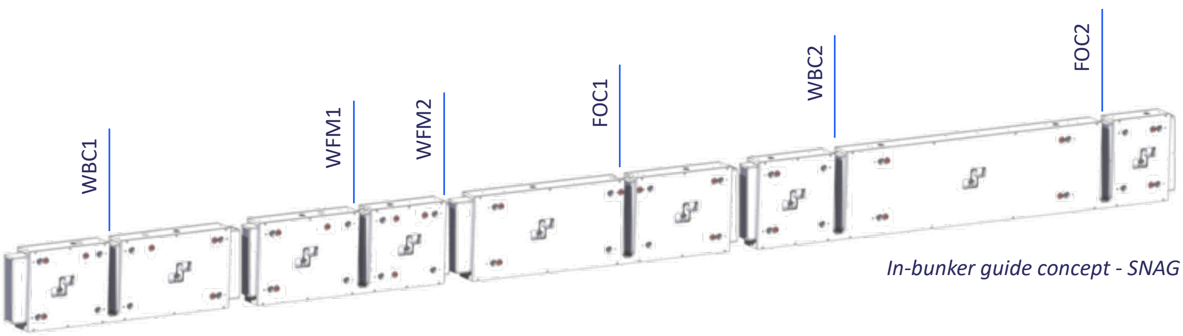

Figure 6: The in-bunker section of the FREIA guide. Detailed design is now in progress.

The conceptual design avoids a potentially challenging installation of many short guide elements, by joining sections together with bridging jackets to simplify installation and alignment. Each element can be pre-aligned within the jacket, accounting for deflection in the bridges. Currently the forecast for design completion is on track for late 2021 in order to ensure the interfaces are frozen, thereby allowing STFC to complete the associated design work of chopper & guide housings.

Heavy shutter

The heavy shutter mechanical design is loosely based on Loki's heavy shutter, however it is significantly bigger in order to accommodate the large guide and substantially more mass is necessary in the beam dump to sufficiently attenuate the beam. The amount of space for the heavy shutter is quite limited because of the large number of chopper modules that need to fit into the bunker. Extensive neutronics simulations have been carried out to evaluate the performance of various materials to ensure that the required attenuation and activation is achieved. This has included generating a Freia specific MCNP source term that accounts for higher energies than the standard source term used for other instruments. These calculations showed a potential problem with activation. Three metals were evaluated, Copper, Tungsten and Molybdenum, with calculations showing that, while all three adequately attenuate the beam, the activation from Molybdenum looks the most promising (see Figure 7). However, the final material choice will be based on an assessment of impurities and manufacturability.

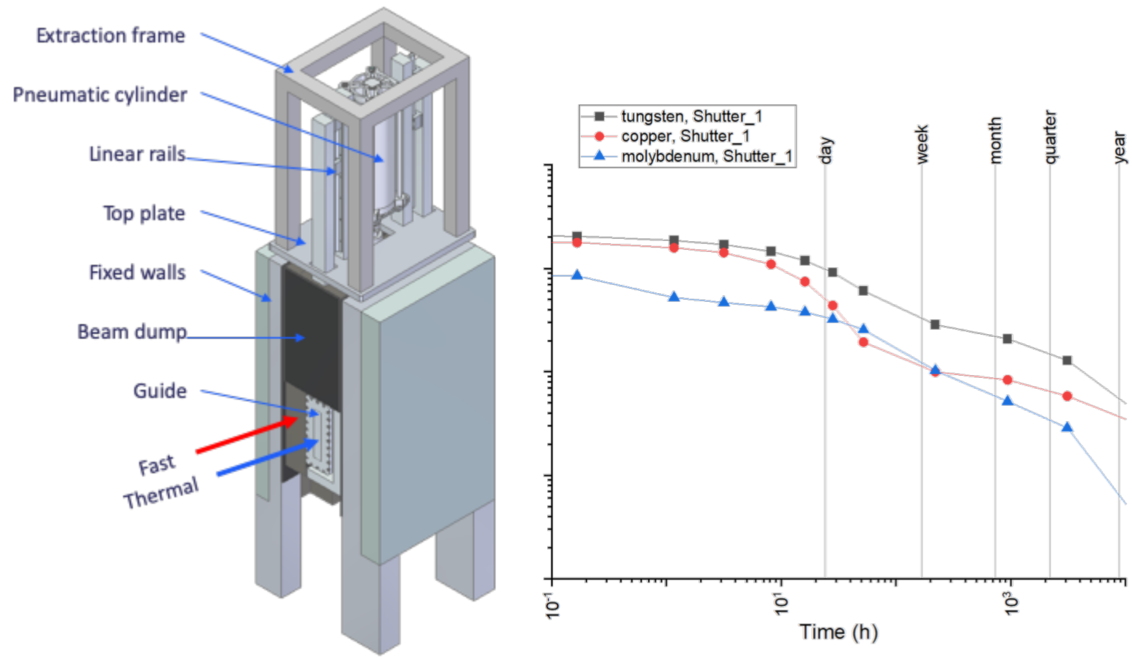

Figure 7: Design of the FREIA heavy shutter (left) and calculation of the cool-down times for these materials after a prolonged exposure to the full beam (right).

Detector Bench

Through an arrangement with Uppsala University, the design of the detector bench is progressing well. The conceptual design of the bench features three screw-driven axes – one controlling the angle of the detector, and two to compensate for the offset between the sample and the pivot. This allows the detector to be positioned from 7.5° below to 21° above horizontal, and also allows for changes in the vertical location of sample position, which is necessary for operating with inverted geometry.

The detailed mechanical design of the motion system is progressing well, with an internal CDR held in June. Servo motors have been selected from the ESS standard parts list and will be coupled to lead screws to drive the motion. The full travel range can be completed in 2-3 minutes, which minimises time lost changing bench angle. All axes will be fitted with absolute encoder feedback. Over the coming months a detailed FEM analysis of the structural elements of the motion system will be undertaken.

Detailed design of the flight tube is currently on-hold, pending input from ESS Detector Group on the detector interface.

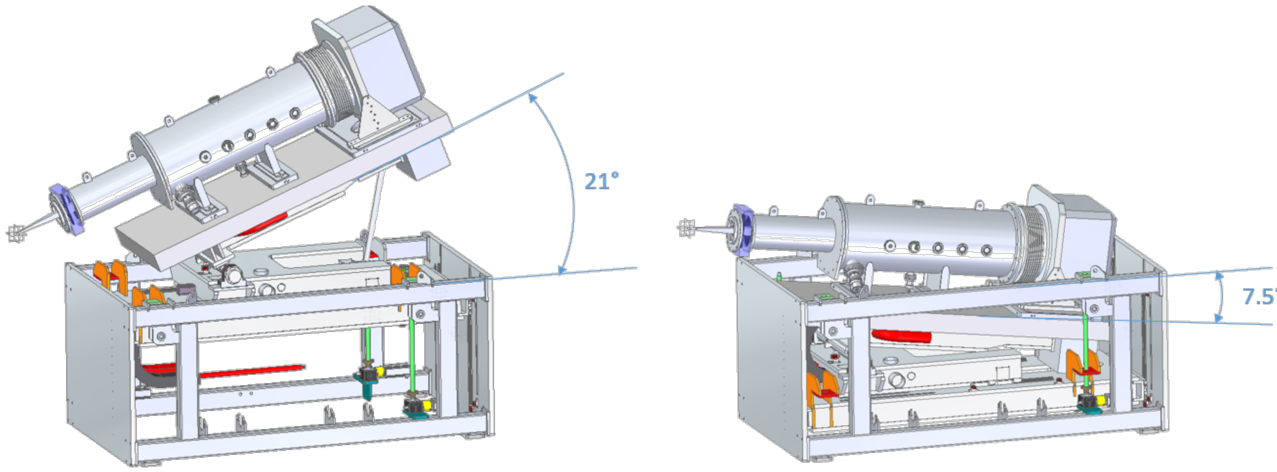

Figure 8 - Detector bench concept

Collimation System & Kinetics mode

The design of the collimation system has been progressing well. The conceptual design for the system as a whole is now as described previously. In order to manage the engineering and procurement this has been split into three sub-components.

We are currently preparing tender documentation for the vacuum vessel and the standard slits for this system. We are expecting material costs to be substantially higher than the pre-covid budget assumed, which will impact the cost of the Aluminium vacuum vessel in particular. Meanwhile the slits tender specification will include options for 3 or 4 slit sets to include a slit set in between the two primary collimation slits and a slit set at the entrance to the detector flight tube. Both of these tenders should be launched in October.

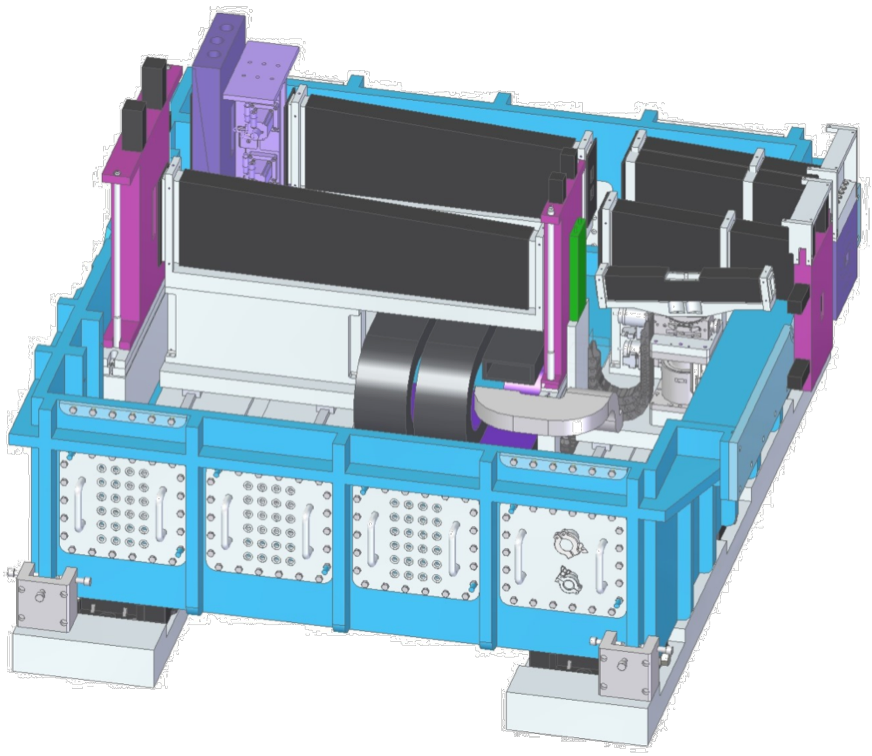

Figure 9 Collimation system concept design showing the standard (pink) and fast (purple) slit systems, the absorbing guides and alignment stages all inside a large vacuum vessel (blue).

For the collimation guides themselves, preparation of a detailed specification is underway including an inverting mirror and the internal motions. One of the key technical issues for this system is how to effectively absorb the unwanted neutrons and minimise unwanted scattering, since this will have a big impact on the background of the instrument. This is particularly challenging for the partitioned guide that is fundamental to the concept of the three-slit system. Discussions are ongoing, including with Swiss neutronics, to understand what low-scatter, high-absorption materials can be used for the absorbing vanes between the three channels in this guide. Under consideration is a combination of simple absorbing baffles and thin vanes of a (null-scattering alloy) TiGd film on absorbing material.

We would welcome any advice the STAPs may be able to give on minimising stray scattering.

Sample positioning system

A tender exercise for the sample positioning system failed earlier this year. After consultation with relevant suppliers the tender specification has been rewritten to clarify a number of technical requirements and to remove some complicated options from the scope. This tender is now live and due to close in October.

Monitors

The Freia monitors will be provided as part of the ESS common monitors project. All six monitors will be based on nitrogen-GEM technology and will be designed by the University of Milan-Bicocca. The design will include monitors that are sized to fit the unusual shape of the Freia guide, the largest will have an active area of 260 x 50 mm with the GEM-foil having 64 strips giving a vertical spatial resolution of about 3.5mm. While this resolution is not strictly necessary for the chopper diagnostic monitors it is does ensure that the monitors can cope with the very high data rates expected.

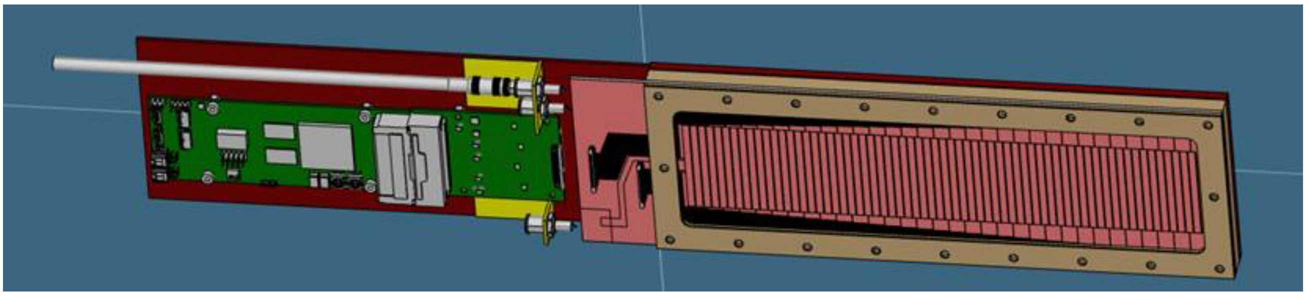

Figure 10: Current design of the N2-GEM monitors for Freia.

The next steps in the design process is to refine the interface with the guide housings so that this can be frozen to ensure this does not interfere with the guide design progress. The detail of positioning of controls cards and routing of services will follow, particularly important for the in-bunker services design work.

Detector

The progress on the Multiblade is going with assembly of the full detector for Estia in progress. We are following this progress closely, including ensuring that the controls interface work is compatible for both instruments. It is worth noting that the budget and schedule for the Freia detector has been agreed. The budget projection suggests that the full-scope detector can be delivered for the cost of the TG2 reduced scope detector. Formally this would be a change of scope and as such needs NSS approval.

Out-of-scope Developments

Progress of the fast-shutter development

The fast-shutters are not within the scope of the instrument, and will be added later as an upgrade. However, we do have a VR funded project with Lund and Uppsala Universities to develop a conceptual design for this system.

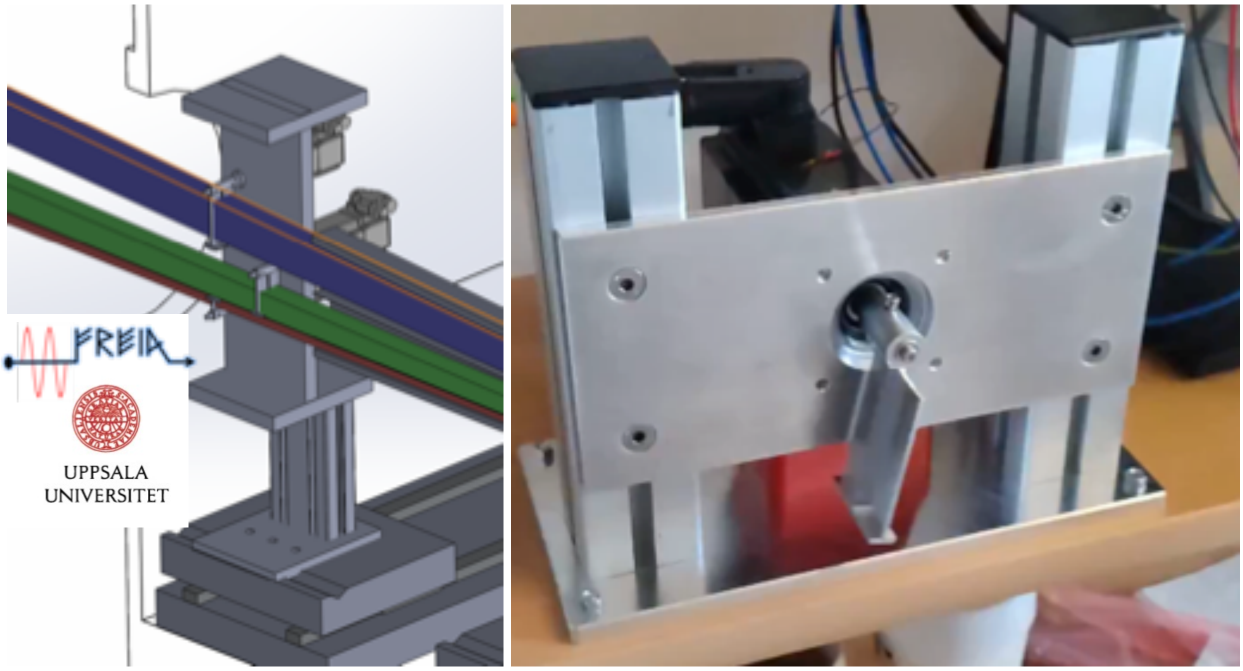

Figure 11 Conceptual design of the fast-shutter system and the prototype used for testing at FREIA lab in Uppsala University.

This project is proceeding well and has now included a fully integrated conceptual design into the FREIA collimation system (visible in Figure 11) A prototype shutter has been tested and shown to achieve the required timing even in vacuum. The project is now considering what kind of temperature dissipation will be required and has begun planning for online testing on the ZOOM beamline at ISIS when the beam returns to TS2 in 2022.

Sample Environment

The sample environment for FREIA is also not within the scope of the instrument but it remains crucial to the success of the instrument. There have recently been some opportunities for external Swedish funding of ESS instrument related developments, principally in the form of staff resources.

A project funded by Tillväxtverket with Adrian Rennie at Uppsala University has now been approved. This project will deliver the physical hardware for solid-liquid cells for ESTIA as well as enabling some important development studies that are required to enable both ESTIA and FREIA to reach their full potential. An engineer will start working on this project very soon (the position has been agreed and is waiting on a work permit).

Additionally, an application for funding of a post-doc from NordForsk was also successful and Nico Paracini has now started his project based in Malmö. This will cover the development of a multi-channel solid-liquid cell to improve throughput and consistency of samples that require significant preparation (such as Langmuir-Schaffer coating.) These two projects on solid-liquid cells will be managed in cooperation to ensure cross-compatibility.

A further Tillväxtverket funded project has also recently been approved with Thomas Ederth at Linkoping University. This will build on his existing project for in-situ ellipsometry and IR measurements with a view to adapt the existing designs to be compatible for both the ESTIA and FREIA beamlines.

Finally, a Röntgen Ångstrom Cluster proposal was submitted in May. This proposal is for a collaboration with Shen Chen (DESY, Beamline P08 / LISA), Bridget Murphy (Kiel) and Adrian Rennie (Uppsala) and will look at developing some more sophisticated sample changing for free liquid interfaces. This project, in particular, considers the challenges posed by increased flux and sample throughput that we expect on the FREIA instrument.