FREIA update for STAP April 2020

Since the last meeting the project has moved into detailed design and begun some early procurements. The full FREIA Technical Annex was finally signed in January, later than possible after ESS prioritised the TA's of earlier other instruments.

Impact of Covid-19

STFC have implemented a policy of working from home for all non-essential staff, which includes the engineering team. At the moment this has not had a huge impact on design progress as most of the work is computer based and is possible remotely. We are, however, expecting delays to our procurements (see below) and the wider project to trickle down and impact FREIA

Early procurements

NBOA

The first procurement was the the monolith insert optics (NBOA) which was ordered from S-DH at the beginning of March last year. The final design is now complete, and manufacture is underway at S-DH, with the copper substrates currently being machined. The development of the m=4 coatings for the top and bottom surfaces is progressing, but currently on-hold due to the closure of neutron sources due to Covid-19.

Figure 1 - NBOA final design from S-DH

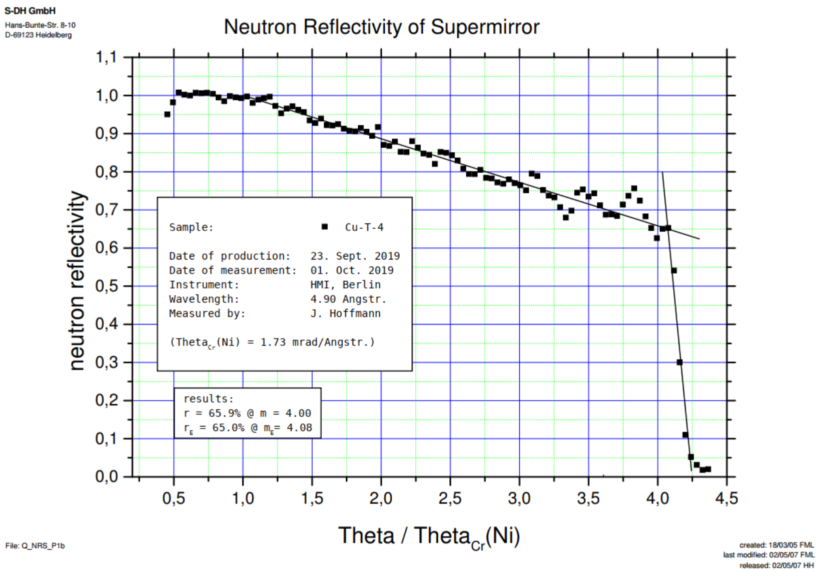


Figure 2- Results from m=4 sample from S-DH in October 19 show 66% reflectivity, whereas the contracted value is 75%

Guide

The next major procurement to launch is the instrument guide. The specification is complete, and is currently being approved by STFC's procurement organisation. ESS have placed a hold on all guide procurements for instruments 8-15 until July – previously it was planned to publish the tender in January. This will impact the design of related components.

WFM chopper discs

The WFM chopper discs are one of the highest technical risks in the instrument. A tender exercise was run for these but had no bidders and so we were able to place the order directly with Airbus. The kick-off meeting for the five Ø1.3m carbon-fibre chopper discs was held with Airbus in January, with the design progressing well. The first design review was held in March, where the design of the first WFM disc was presented. An initial FEA study showed that Airbus' flexible hub design is not suitable for Freia, as the natural frequencies fall close to the operating speed of the disc. An alternative rigid hub design is being developed. The first disc is expected to be ready for testing in Summer 2020.

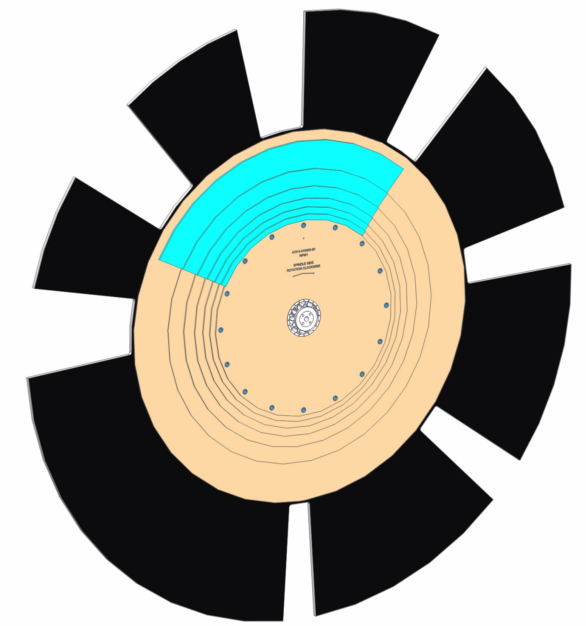


Figure 3 - WFM1 disc design from Airbus

Detailed design progress

In general design is progressing well. We have employed a new design engineer through an arrangement with Uppsala University. This has gone some way to solving some of the engineering resource issues that the project had, although we are still under-resourced because the expected design effort that was due to be transferred from the LoKi project is delayed.

The bunker feedthrough design is progressing in line with the feedthrough casing project. Some minor modifications were made to the design in order to eliminate some streaming paths identified by simulation.

It was identified that the requirements on the repeatability of the FREIA light shutter are the most demanding of all instruments. This is because of the channelled guide in this section of the instrument which means that relatively small misalignments of the guide have a relatively large impact on the transmitted flux. As a result, FREIA will be treated as an exception and some special consideration will be given to its design.

Monitors

The ESS common monitors project seems to be progressing well and it looks like the chopper diagnostic monitors will have a suitable solution, probably a combination of ionisation chambers and "GEM" monitors depending on location. We have incorporated all the windows and monitor positions into the McStas model, which can be combined with MCPL simulations of the monitors to produce an accurate simulation of the monitor performance. However, this work is on hold while offer documents are being prepared for the prioritised early instruments ODIN, BIFROST, NMX and ESTIA.

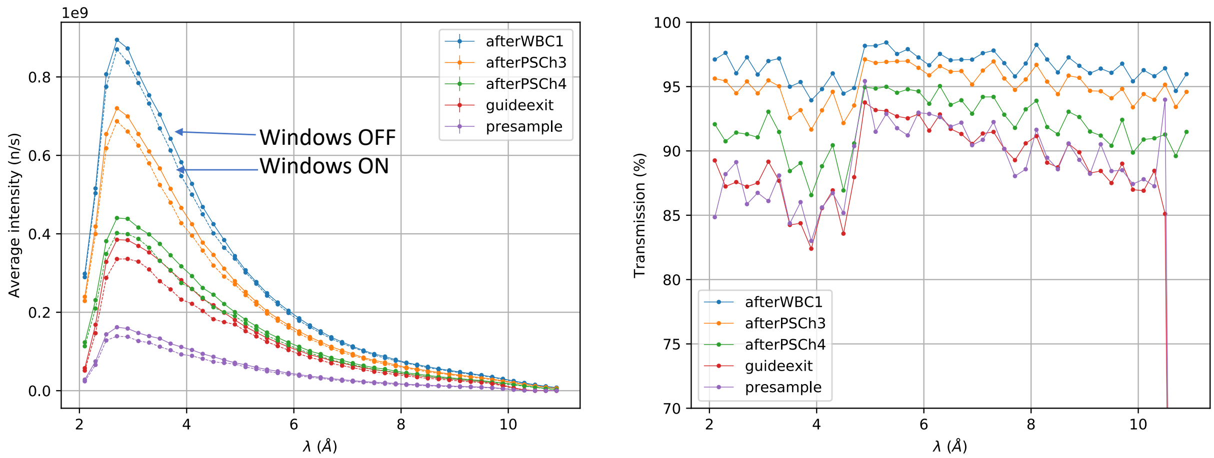


Figure 4 Provisional simulation results for 5 different monitor positions assuming 1mm guide windows and 150µm windows on monitor

Wavelength band choppers

Work on the three wavelength band choppers (WBCs) has begun. The positions of these choppers have been moved slightly to minimise the transmission of long wavelength (>90Å) neutrons. The apertures are now fixed and this nominally limits the wavelength band for pulse-skipping to about 15Å (because the aperture sizes are not variable).

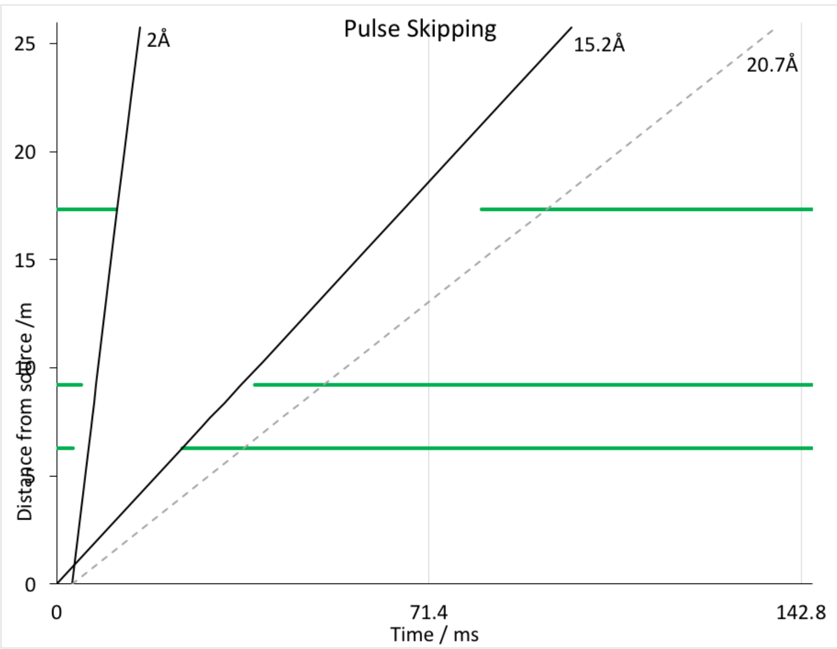


Figure 5 Distance -Time of flight diagram for the pulse-skipping mode using the WBCs at 7Hz

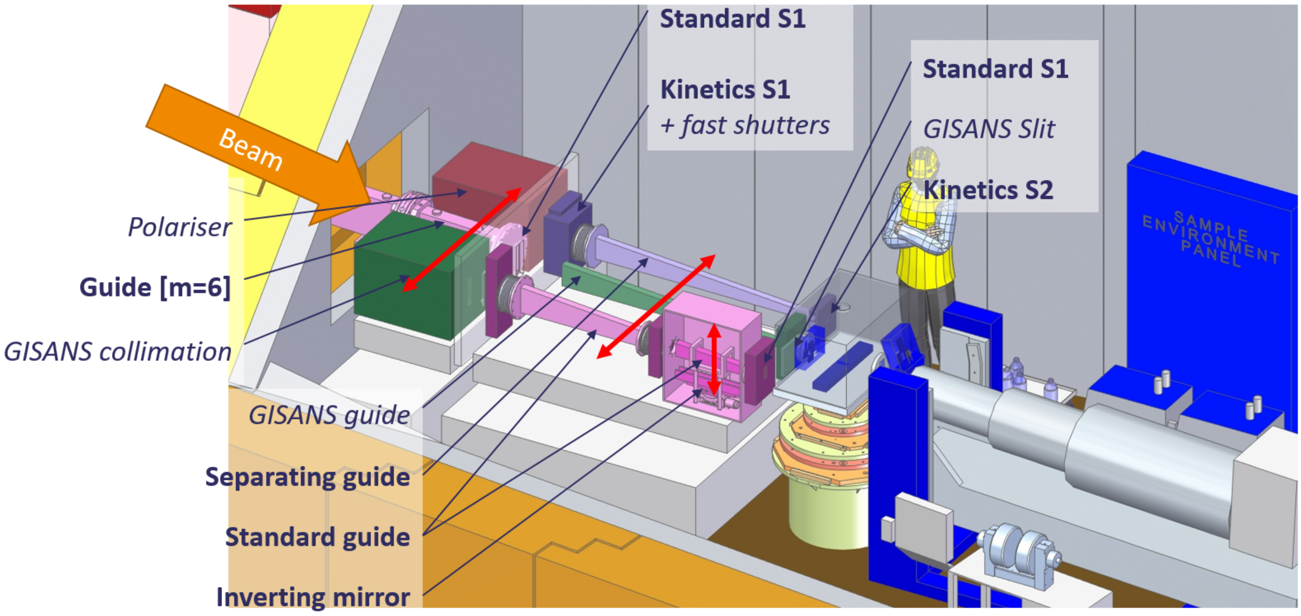
Since these choppers do not need to be as big as the WFM choppers it is possible to make them from Aluminium. However at least one of the choppers has an aperture close to 180° and this creates balancing issues which are now being investigated in detail by the ISIS chopper group.

Collimation design

The detailed design of the collimation section is still relatively conceptual and we would appreciate the STAP's comments on these design choices.

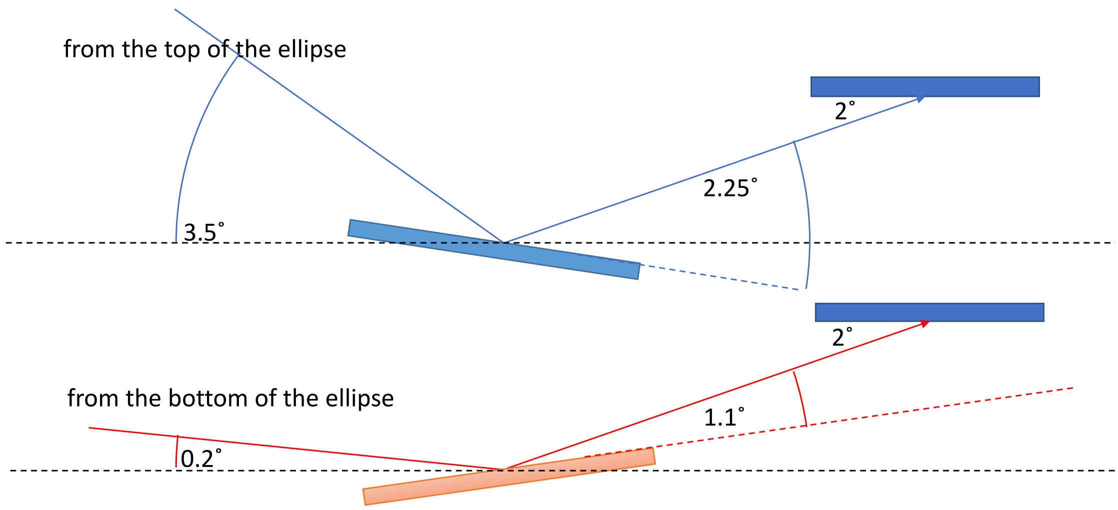
Collimation changer

The conceptual design of the pre-sample collimation is progressing, with a design review held in January. The preferred concept is to use separate evacuated flight paths for the standard and inverted mode, and for fast kinetics mode. A translation stage will allow the flight paths to be interchanged. This approach maximises the flexibility and upgradability of this section since it does not require a large vacuum vessel. However, as a result there are more windows than would otherwise be needed. The exact number of windows depends on the extent of evacuated flight path.



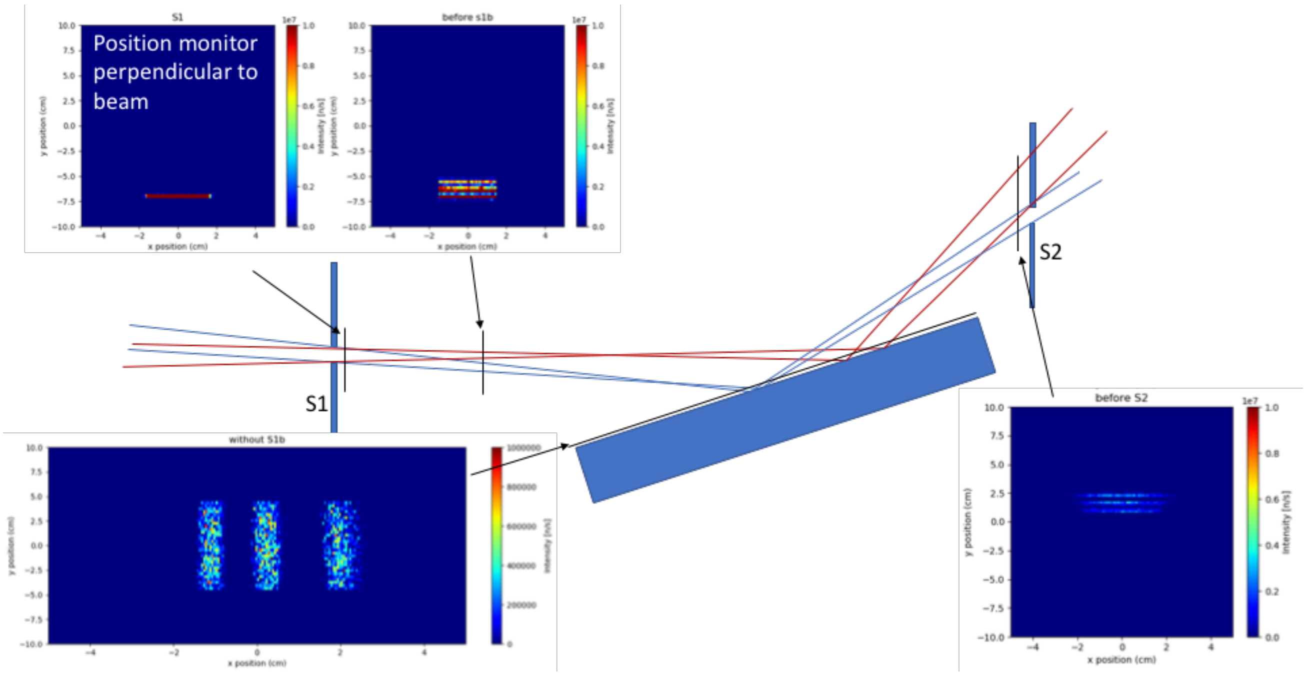
Inversion Mirror

There are a few possibilities for implementing an inversion mirror into the instrument so we can take some care in making design choices that will improve the usability of this system. The maximum Q required for the inversion mode is limited in the “concept of operations” to $0.2Å^{-1}$, but it would be nice to be able to exceed this. For 2Å neutrons this corresponds to an incident angle on the sample of 2°.



Nominally, we then have a choice of using a collimated beam from any part of the elliptical guide. However, for any given incidence angle on the sample, the deflection required by the supermirror is lower for a beam taken from the bottom of the ellipse. Therefore, by using the beam from the bottom of the ellipse we can ensure transmission of the short wavelength neutrons for a more cost-effective m-coating. It should be noted that this arrangement also results in smaller movements of the sample and detector are required, which has some advantages in terms of the engineering.

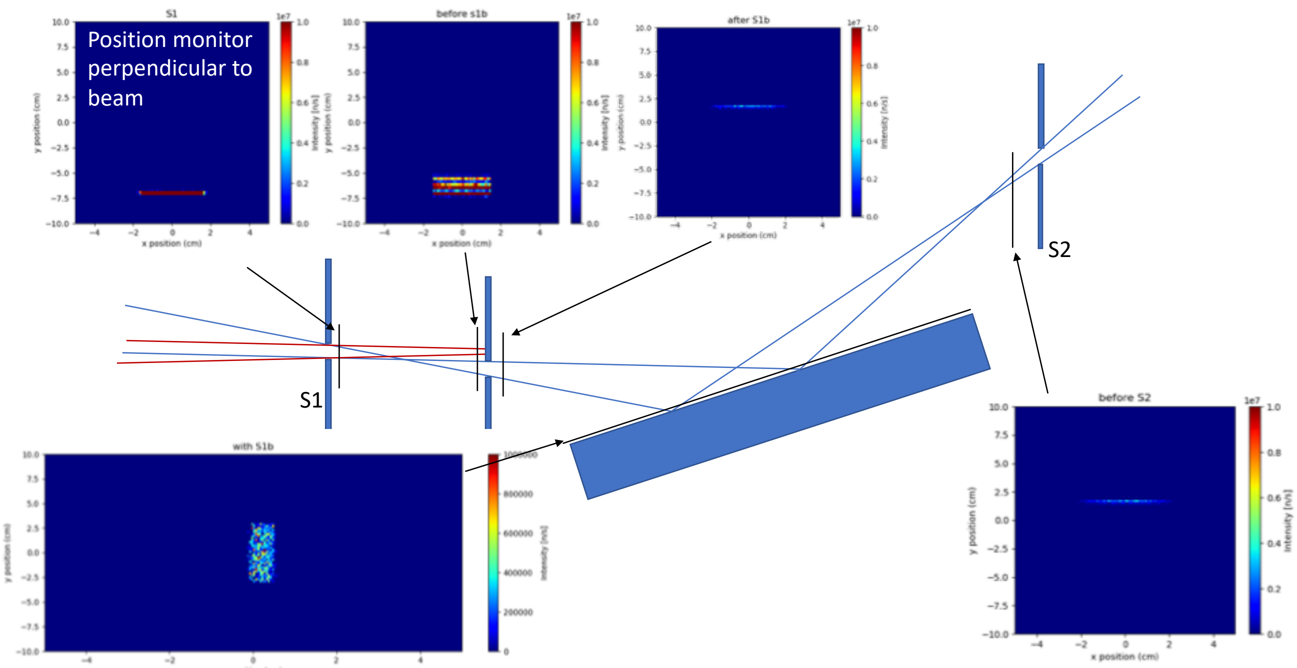
FREIA has a unique situation in terms of how a mirror can be aligned. This is because the large elliptical guide means that a single collimation slit prior to the mirror will allow a very divergent beam to be transmitted on to the mirror. This is shown schematically below together with some McStas simulation results that show the extent of the divergence.



This is not a problem in terms of a well-aligned mirror because the second set of slits can appropriately collimate the beam, although in reality there may be some issues around cross-talk between the slits (neutrons that travel directly between the slits without reflecting off the mirror). Such cross-talk is a fairly common scenario and it can lead to background issues so is often improved by using a “knife-edge” above the centre of the mirror surface to block the direct path.

However, the alignment (particularly initially) of this system may be difficult since the positioning of the mirror and the corresponding distances and angles will be highly dependent on the neutron beam.

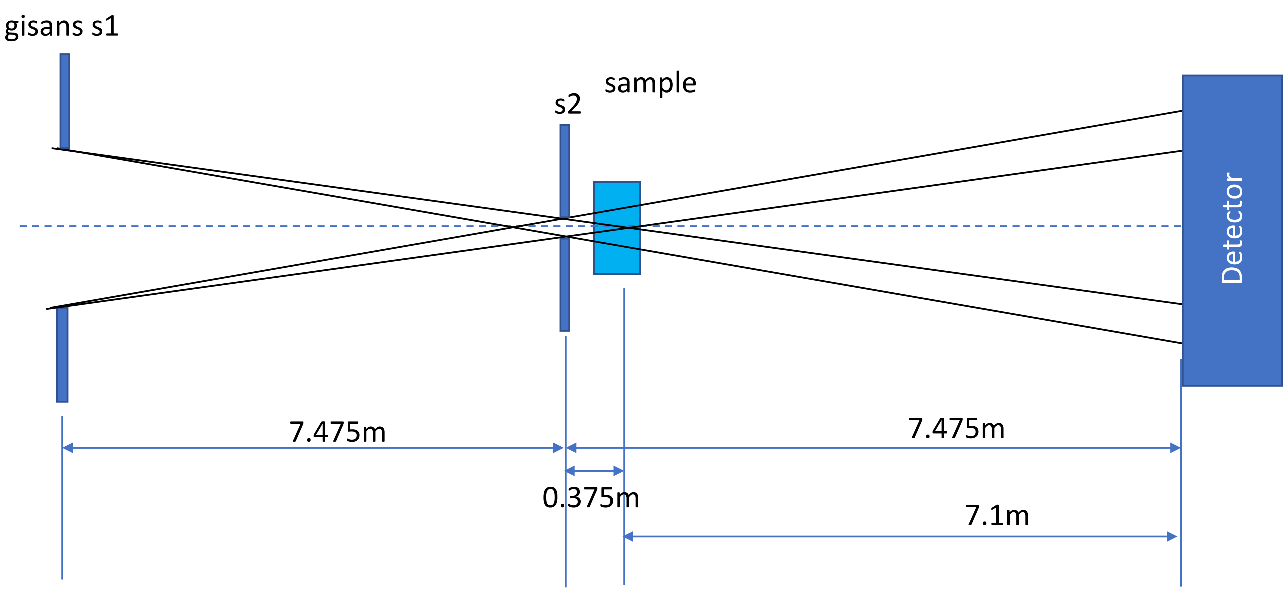
The alignment process should be significantly improved by pre-collimation. Since the footprint of the beam on the supermirror is likely to be less than 0.5m, it should be possible to include a third set of slits to provide some better definition of the beam during alignment:



In this geometry a knife-edge may also help to reduce cross-talk between the final two slits although it is not clear whether this is necessary and if so whether it should be a movable or fixed relative to the mirror. These factors obviously have an impact on the detailed engineering of this section of guide.

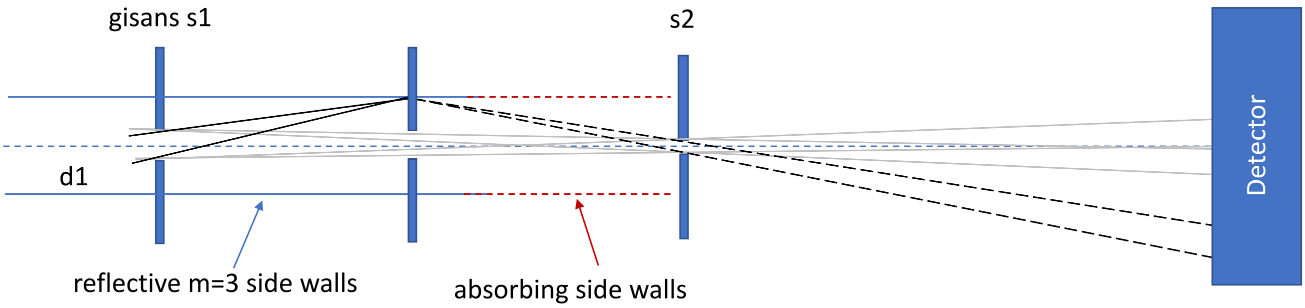
GISANS upgrade

The GISANS upgrade requires that FREIA allow for some additional slits to collimate the beam in the horizontal direction in order to optimise the Qx resolution. In an ideal world the minimum Q that would be accessible is driven by both the collimation and detector distance. The ideal layout would place the detector as far as possible from the sample and requires that the first slit is around the same distance upstream from the sample. However, the fact that this aspect of the instrument was removed from the construction scope means that some compromises have already been made. In particular, it is not

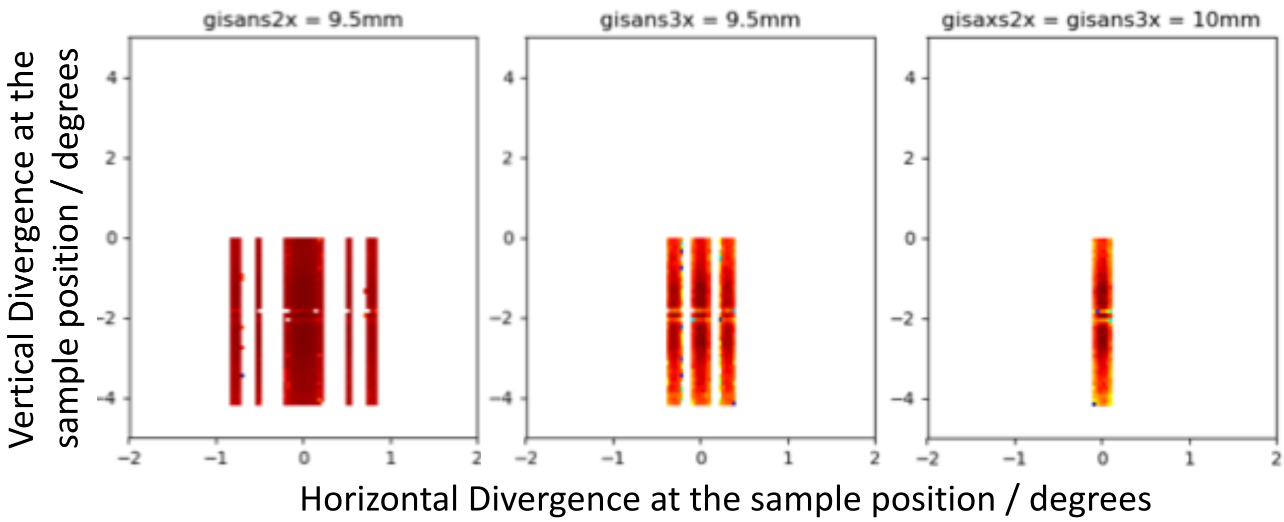


practical to place slits inside the bunker (e.g. the guide is still curved there), which means the first slit can be, at most, 7.85m from the sample (just outside the bunker wall). If we use the existing s2 slit (0.375m from the sample) as the second slit then the optimal sample-detector distance is around 7.1m. If we assume a 10mm aperture for the first slit and 5mm for the second then this would give a range of $0.0008Å^{-1} \leq Qx \leq 0.26Å^{-1}$ for the upgraded multiblade detector.

At this time, it is not necessary to consider the scientific merits of such an upgrade, but we do need to show that the upgrade is possible. To do that we need to consider the effectiveness of the slits. The difficulty comes from the fact that the collimation requirements for GISANS and NR are quite different. In particular, the side walls of the guide are highly reflective and will actually inhibit effective collimation:



In order to stop these reflections, we require some additional slits in between the two main collimation slits to block the unintended flight paths. Ideally these would be placed around half-way between the slits. Unfortunately, the positioning of such slits is restricted by the existing chopper locations and the principle that we should avoid adding additional gaps in the guide wherever possible. The result is that we require at least two slit sets between the primary slits, but this does provide adequate collimation:



Polarisation upgrade

Since the last STAP meeting ESS have employed Wai (Hal) Tung Lee to lead the ESS polarisation group. In consultation we believe that there is a solution to putting the polariser before the first set of NR slits. This means that the first element inside the cave is an approx. 0.7m removable section of guide that can be replaced or incorporated into a future polariser. Additionally, a removable section of the detector flight tube could accommodate an analyser. We are also considering the magnetic requirements in the design of the collimation section and detector bench.

Detector Bench & flight tube

The design concept for the detector bench and flight tube has progressed, with a Preliminary Design Review held in April. The current design achieves the wide range of angular motion required, as well as the need to vary the height of the sample position when the instrument is running in inverted mode.