Science & Technology Facilities Council
Rutherford Appleton Laboratory

ESS Freia Neutron Guide Proposal

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Summary

This document presents a basic specification for the supermirror guide of the Freia neutron reflectometer currently being designed for the European Spallation Source ERIC. The purpose of the document is to obtain cost estimates and to identify technical issues with Guide Suppliers.

Revision History

Revision	Revision Date	Summary of changes
1	20/06/17	First issue

Approvals

This document has the following approvals:

Name	Title
Jim Nightingale	Lead Engineer

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Definitions

STFC – Science and Technology Facilities Council
ISIS - the name of a neutron facility in Oxfordshire, UK
Freia – the name of a reflectometer instrument currently in design
ERIC - European Research Infrastructure Consortium

1 Introduction

The European Spallation Source ERIC is a neutron facility currently under construction in Sweden. STFC ISIS are collaborators providing engineering resource for the concept phase of the Freia instrument.

Freia is a neutron reflectometer with a sample position approximately 23m from the moderator. More details can be found on the European Spallation Source ERIC website:

https://europeanspallationsource.se/article/revealing-change-over-time-freia-brings-fast-kinetic-studies-reflectometry

A project toll-gate review will occur in summer 2017, where the instrument concept, scope and budget will be fixed. This concept specification is in order to approach Guide Suppliers and gather realistic technical solution, budget and project timescales.

2 Requirements Overview

The requirement is for suppliers to provide:

1) Advice on technical feasibility of delivering to this specification – including any concerns
2) Cost to deliver to specification – individual cost estimates to be given for:
    a. Guide,
    b. Support/adjustment structures,
    c. Shielding components,
    d. Installation.
3) Realistic delivery timescales and any known commitments that may affect delivery
4) Recommendations that may improve the design and/or reduce cost and improve delivery timescales
5) List of all excluded items

3 Technical Specification

3.1 Basic Description of Freia

Freia consists of an approximately 18m long elliptical focussing supermirror guide. The elliptical geometry focuses on the moderator and sample position. The guide side walls are constant aperture of 40mm. The guide is inclined downwards at 2 degrees. The neutron flight path geometry can be seen in Figure 1 below – and drawing JBN-004779.

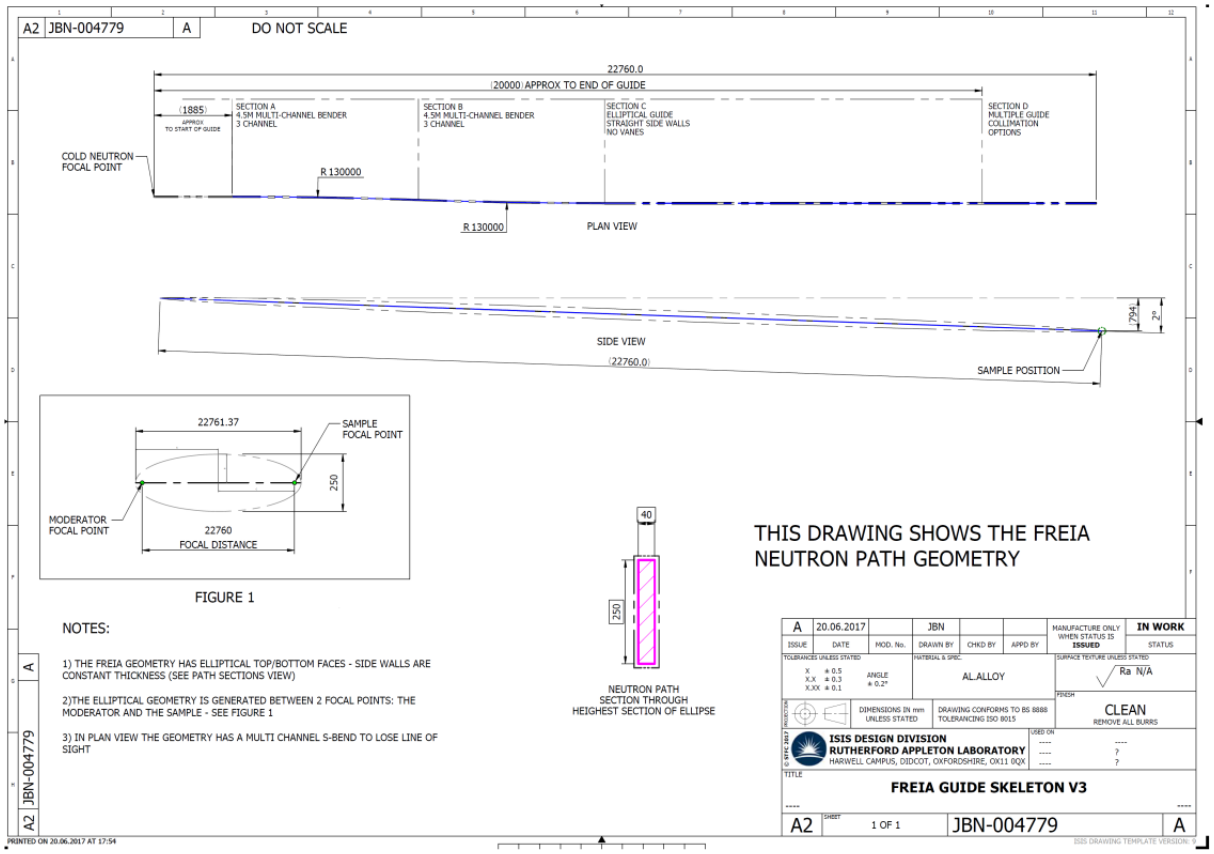


Figure 1- Freia neutron path

In order to lose line of sight, the guide has 2 x 4.5m benders (s-bend), which is then followed by a straight section. The benders are 3 channel multi-vane guides.

Owing to the high radiation levels – the entire guide will need to be constructed on a metallic substrate. This should be mainly aluminium, although copper substrate has been suggested in certain locations by European Spallation Source ERIC for reasons of high energy neutron activation.

3.1.1 Section A

Type	Multi-channel elliptical bender R=130m
Total Length	4500mm arc length
Number of vanes	2
Vane material	Silicon (or aluminium)
Vane Thickness	<=1mm
Vane coating	M=3
Top surface	Varies (see section 3.3)
Bottom Surface	Varies (see section 3.3)
Side Walls	M=3

3.1.2 Section B

Type	Multi-channel elliptical bender R=130m
Total Length	4500mm arc length
Number of vanes	2
Vane material	Silicon (or aluminium)
Vane Thickness	<=1mm
Vane coating	M=3

Top surface	Varies (see section 3.3)
Bottom Surface	Varies (see section 3.3)
Side Walls	M=3

3.1.3 Section C

Type	Elliptic guide (no channels)
Total Length	~9115mm
Number of vanes	0
Vane material	N/A
Vane Thickness	N/A
Vane coating	N/A
Top surface	Varies (see section 3.3)
Bottom Surface	Varies (see section 3.3)
Side Walls	M=3

3.1.4 Section D

3.1.4.1 Collimation Option D1 – Three slit collimation – see drawing JBN-004878

Type	Multi-channel
Total Length	~1800mm
Number of vanes	2
Vane material	Al, Silicon, kapton, mylar (guide supplier to advise)
Vane Thickness	0.5mm – 1mm
Vane coating	Neutron absorbing material
Top surface	Neutron absorbing material
Bottom Surface	Neutron absorbing material
Side Walls	M=3

3.1.4.2 Collimation Option D2 – Inverted Geometry

Type	Single Reflective mirror
Length	1000mm
Width	42mm
Depth	15mm aluminium substrate
Top Surface	M=6

3.2 Generic Guide Specification

3.2.1 Substrate

European Spallation Source ERIC have specified that glass substrate cannot be used in the first 15m of the instrument. As Freia is a short instrument (approx. 22.3m from moderator to sample) the entire guide construction should be manufactured on metallic substrate. Aluminium alloy is preferred - although alloy composition will need to be specified by guide manufacturer and its suitability for radiation approved by ESS. European Spallation Source ERIC has requested that, for neutronics reasons, short sections of the guide should be constructed from copper substrate. This may be technically challenging given the high m values required. The additional cost, lack of data of long term operation of copper substrates in service, and the technical challenges mean that copper substrate requires further investigation. However, honest advice from Suppliers would be appreciated. The author suggests that a potential alternative is to use copper streaming shielding

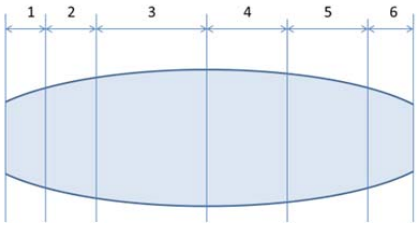
collars around a coated aluminium substrate. This would remove the potential risks of copper guide reliability and allow more flexibility to reposition streaming shielding following detailed neutronic calculations.

3.2.2 Substrate flatness / profile tolerance

Freia guide geometry is relatively complex. We would like to know the cost/time vs performance benefits of a 'truly curved' elliptical guide compared with a more conventional faceted straight sections. Also, Suppliers are requested to present any variation that might be available.

3.3 Super-mirror Coating

The super mirror coating varies along the length of the ellipse as detailed in Figure 2 below.



	Distance from moderator focal point (mm)		Supermirror Coating (m value)			
	From	To	Top surface	Bottom Surface	Side Walls	Vanes
	0	1893	No guide			
1	1893	3000	6	6	3	3
2	3000	4500	5	5	3	3
3	4500	10000	4	4	3	3
4	10000	14500	3	3	3*	3*
5	14500	19000	4	4	3	-
6	19000	20000	5	5	3	-

* bender ends at 10893mm from focal point

Figure 2- Supermirror m values along guide

3.4 Guide Geometry

The actual Freia guide geometry is complicated by the requirement for many gaps in the guide to accommodate chopper discs, inserts, shutters and other equipment. Figure 3 shows a section through the guide and the surrounding equipment. The guide design can be seen in more detail in drawing JBN-004780.

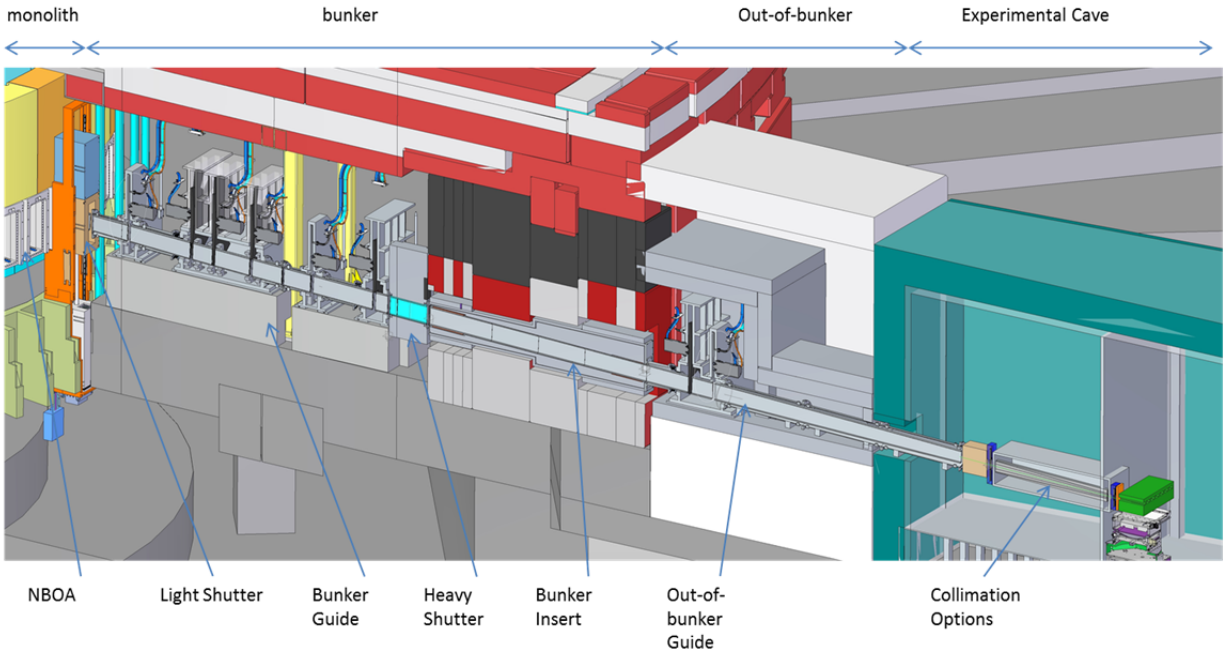


Figure 3- section view of Freia concept showing the guide interface equipment

3.4.1 Monolith Insert

The guide starts at approximately 1885mm from the moderator and the first section will be housed in the monolith insert assembly. The upstream end of the insert will have a protective window to maintain an environment in the target and for safety reasons. Its proximity to the target means that the insert (and the guide) will require cooling. European Spallation Source ERIC are responsible for providing the design of the insert, which is currently not known. Figure 4 shows the concept space envelope for the insert. Copper collars will be required to minimise streaming of high energy neutrons.

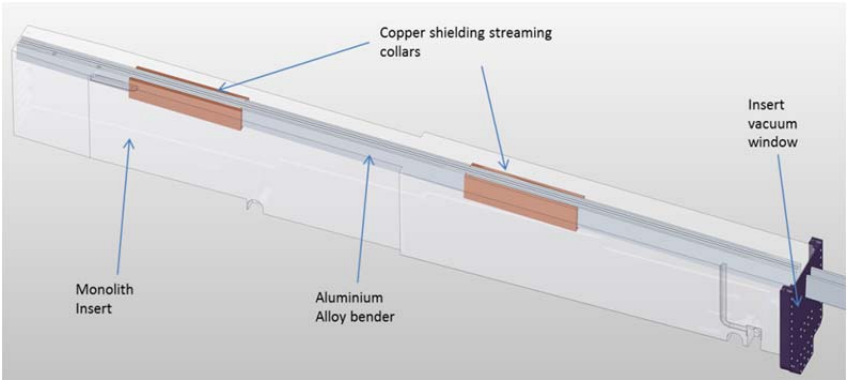


Figure 4- view of monolith insert – section through mid-plane of guide

3.4.2 Light Shutter

The light shutter is a gamma blocking device that translates vertically. European Spallation Source ERIC are responsible for this component and a concept can be seen in Figure 5. European Spallation Source ERIC are currently specifying a guide housing vessel, supporting structure and surrounding environment and further information is not currently available.

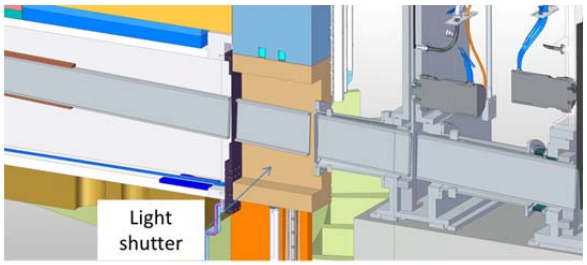


Figure 5- section view of Freia concept showing the light shutter concept

3.4.3 Chopper Sections

Freia will employ horizontally split choppers – with minimises vacuum windows. It is envisaged that the housings will contain shielding and adjustment features for the guide sections. The housings will be connected with vacuum flight tubes. Currently the concept is to use 300mm diameter aluminium alloy tubes with ISO320 vacuum flanges. Figure 6 shows the sections of guide and how they interact with the choppers

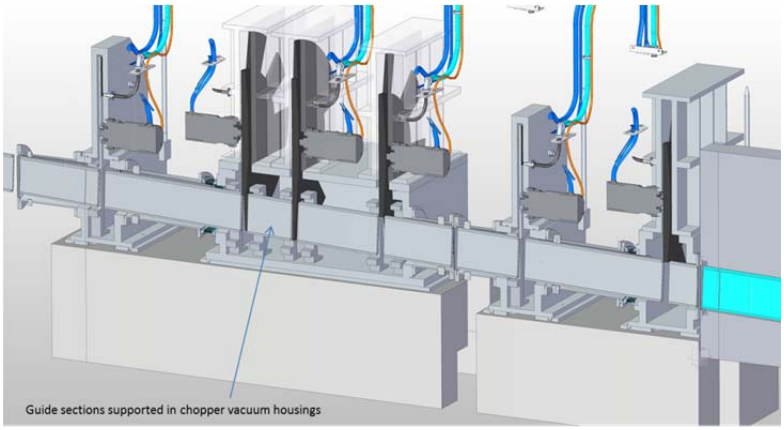


Figure 6- section view of Freia concept showing the guide interface equipment

3.4.4 Heavy Shutter

The heavy shutter will be a large vertically translating beam blocker that will contain a section of guide in a vacuum housing, probably constructed from steel. The heavy shutter will be designed by ISIS, although an exact specification is not yet available. A basic space envelope can be seen in Figure 7.

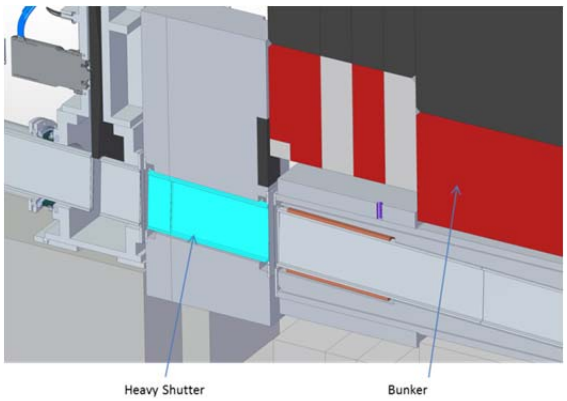


Figure 7- section view of Freia concept showing the guide interface equipment

3.4.5 Bunker Insert

The bunker is being designed by European Spallation Source ERIC. The current proposal is to have a large vacuum flight tube that encompasses a length of guide in a steel housing, as depicted in Figure 8.

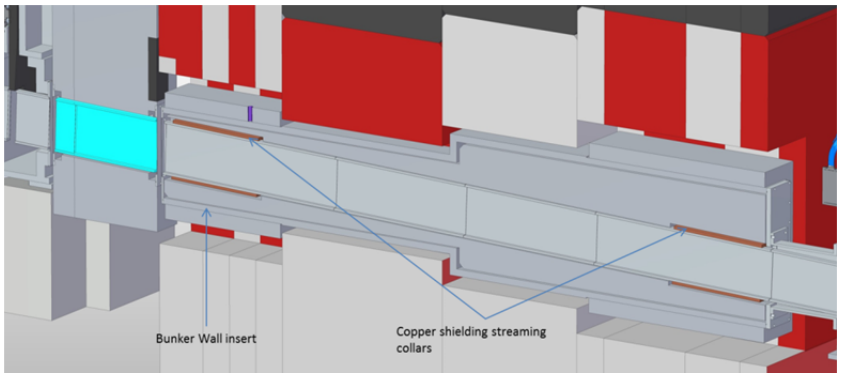


Figure 8- section view of Freia concept showing the guide interface equipment

3.4.6 Guide Collimation Options

After the elliptical guide finishes there will be a translation stage that allows the instrument to switch between different operating modes, see Figure 9.

2 guide sections are required (see section 3.1.4 for specification):

- a fixed multi-vane guide with reflective sidewalls
- a single mirror that will have motion controlled angle positioning to allow the beam to work in inverted geometry

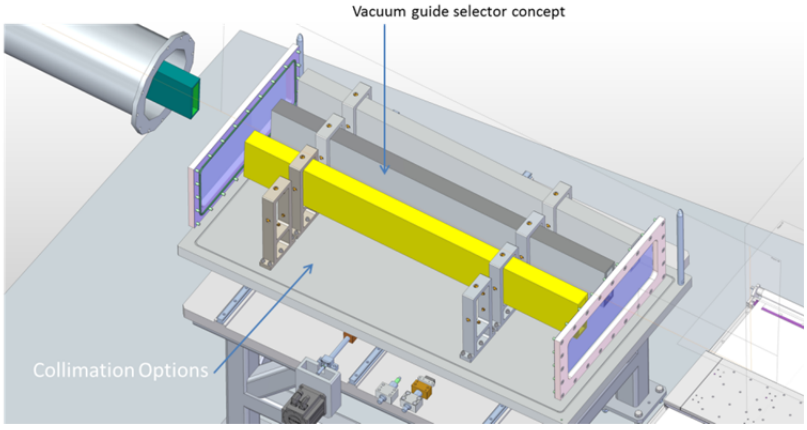


Figure 9- section view of Freia concept showing the guide interface equipment

3.5 Delivery

Freia is still in concept phase and does not have accurate milestone dates. However, the current estimated timescales are:

Tollgate 2 review (progress to detail design)	September 2017
Insert installation	2020
Bunker zone installation	Early 2022
Outside of bunker installation	Late 2022
Instrument Commissioning	2023

3.6 Supplier Pro-forma

STFC appreciate that the concept and specification is not well enough developed to request accurate costs. However, estimations with error margins will help set a budget for the project. STFC request that the guide Supplier provides the following information:

1	Guide sections
1.1	Estimated cost for supermirror coated aluminium alloy substrate neutron guides to the specification listed in this document
1.2	A technical description of the proposed guide assembly
1.3	The benefit vs cost of different substrate geometry options (e.g. truly curved vs faceted)
1.4	Technical opinion on the guide geometry and concept – raising any areas of concern or potential for value engineering
1.5	Margin of error on estimation and brief explanation of margin
2	Guide collars
2.1	Cost for supplying copper collars as externally fitted to guide (as detailed in this specification)
2.2	Cost for supplying collar sections as supermirror coated copper sections
2.3	Technical evidence that copper supermirror guide is feasible and has proven durability in service
2.4	Margin of error on estimation and brief explanation of margin
3	Adjustment features
3.1	Estimated cost of suppliers preferred adjustment mechanisms for the specified guide concept
3.2	Technical details of proposed adjustment features
3.3	Margin of error on estimation and brief explanation of margin
4	Installation
4.1	Cost of installation and alignment of guide sections at European Spallation Source ERIC, Lund, Sweden – assuming 2 separate visits (insert requires early installation)
4.2	Provide advice on your recommended requirements for successful installation
5	Delivery Timescales
5.1	Provide timescales for delivering guide following a detailed quotation
5.2	Provide details of any current commitments or capacity issues that may impact delivery dates
6	Recommendations
6.1	Recommendations that may improve the design and/or reduce cost and improve delivery timescales
7	Exclusions
7.1	List any items that you will not supply or are not interested in supplying

STFC would be grateful to discuss the concept and design in more detail with the Guide Suppliers before producing a formal specification.