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BEER - Sub-System Design Description – Beam Transport and Conditioning

Revision (1)

Components included in Revision (1): Safety Shutter, Beam Stop, Shielding (Beam transport and Conditioning)

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The list of contributors to the feedback of each components, can be found at the end of this document.

Revision (2)

Components included in Revision (2): transport guide, focussing guide, guide housing (vacuum) – out of the bunker part, guide support system – out of the bunker part, beam shaping slit system, beam geometry conditioning support and alignment, exchangeable focussing guide system

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The list of contributors to the feedback of each components, can be found at the end of this document.

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1. SCOPE

The scope of this document is to describe the technical design of the sub-systems of the BEER instrument related to the beam transport functionality. The fulfilment of high- [1] and low-level [2] BEER instrument requirements are verified.

A description of parts made in this document are in a level sufficient to understand the main functionality of the sub-system. Detailed descriptions are provided in the referenced annexes.

This document will be updated throughout the process of the detail design of the whole instrument and will be freeze by the time of the final TG3.

In the Rev1 it contains the design description of the following PBS sub-systems:

- 13.6.6.1.8.3 – Safety Shutter
- 13.6.6.1.8.6 – Beam Stop
- 13.6.6.1.10 – Shielding (Beam Transport and Conditioning)

This document will be updated throughout the process of the detail design of the whole instrument and will be freeze by the time of the final TG3.

In the Rev2 it contains the design description of the following PBS sub-systems:

- 13.6.6.1.2.1.4 – Transport guide
- 13.6.6.1.2.1.5 – Focussing guide
- 13.6.6.1.2.2 – Guide housing (vacuum) – out of the bunker part
- 13.6.6.1.2.3 – Guide support system – out of the bunker part
- 13.6.6.1.4.5 – Beam shaping slit system
- 13.6.6.1.4.8 – Beam geometry conditioning support and alignment
- 13.6.6.1.4.9 – Exchangeable focussing guide system

In Rev2, there was removal of the text part dealing with the 13.6.6.1.10 – Shielding (Beam Transport and Conditioning) because the scope of that sub-TG3 changed and the instrument joined the common shielding project. The PBS 13.6.6.1.10 will be dealt with in the next revision.

Due to the contract reasons with the manufacturer, the whole guide system was split into two parts called Part I and Part II. Part I relates with the guide system from the bunker wall till the focusing section start (from 28 to 144.5 m along the beam in ISCS), including safety shutter insert. Part II comprises of focussing part of the guide, all three slits systems and guide exchanger. Detail description of the individual parts and performance of the optical system can be found in the *BEER Optics Specification* [3] and *Optics Report for the BEER Instrument* [4]. Below is the list of the optic sections as they are split between the individual parts. The design of each part contains both neutron guide and vacuum housing. Table 1 represents the *Section ID*, short *Description*, internal *Name* used in for internal purposes, in McSats model and in [4], and also manufacturer *Part Number* which can be found in the drawing documents.

- Part I: W02-13, W02-14, W02-15, W02-16, W02-17
- Part II: W02-18, SL1, W02-19, SL2, W02-20-01, W02-20-2, SL3, guide exchanger
- Guide support and alignment

Table 1 - Short description of the optical parts and their identifiers.

Item	Section ID	Description	Name	Part Number	Quantity
1	W02-13	Neutron guide insert in the safety shutter system	GSH2	MR439-1000-00	1
2	W02-14	Straight, parallel neutron guide	GE2AS	MR439-2100-00	1
		Horizontally expanding neutron guide	GE2A		
3	W02-15	Horizontally expanding neutron guide	GE2B	MR439-3000-00	1
4	W02-16	Horizontally curved parallel neutron guide	GT1	MR439-4100-00	1
5	W02-17	Horizontally curved parallel neutron guide	GT2	MR439-4200-00	1
6	W02-18	Vertically focusing neutron guide	GF1	MR439-7500-00	1
7	SL1	Adjustable neutron slit	SL1	SL1 Slit SS80x80 V_00_00	1
8	W02-19	Vertically focusing neutron guide	GF2	MR439-7600-00	1
9	SL2	Adjustable neutron slit	SL2	SL2 Slit SS80x80 V_00_00	1
10	-	Neutron optics exchanger system	-	MR439-8000-00	1
11	W02-20-01	Vertically focusing neutron guide at the 1st exchanger position	GEX1		1
12	W02-20-02	Neutron flight tube with absorbing walls at the 2nd exchanger position	GEX2		1
13	SL3	Neutron slit system for beam shaping with variable dimensions and adjustable distance from the sample axis	SL3		1
14	-	Guide support system	-	-	1

2. ISSUING ORGANISATION

Nuclear Physics Institute (NPI) in collaboration with suppliers of the sub-systems as NUVIA and Mirrotron.

3. CONTEXT

The BEER instrument is the engineering instrument dedicated to the in-situ and in-operando studies in the field of material science under real conditions. The novel pulse modulation technique will allow the fast strain scanning of even real shape engineering samples.

The beam transport sub-system provides the basis for the delivery of the high quality and intense neutron beam to the sample position. It consists of several important parts which can be described as beam extraction (monolith insert, bi-spectral switch), beam shaping (chopper and slit systems), beam transporting (neutron guides), beam stopping (safety shutter, beam stop), beam monitoring (monitors) as well as beam shielding (shielding tunnels). All these parts have a lot of interfaces which need to be properly defined to allow the expected functionality.

4. DESIGN CONFORMITY DECLARATION

During the design the contractor followed the Machinery Directive and the laws and standards listed. Standards used at the design:

■	98/37/EC	Machinery directive (21/1998 IKIM decree)
■	21/1998 IKIM decree	on safety requirements and conformity assessment of machinery
■	93/68/EEC	COUNCIL DIRECTIVE 93/68/EEC of 22 July 1993 amending Directives 87/404/EEC (simple pressure vessels), 88/378/EEC (safety of toys), 89/106/EEC (construction products), 89/336/EEC (electromagnetic compatibility), 89/392/EEC (machinery), 89/686/EEC (personal protective equipment), 90/384/EEC (non-automatic weighing instruments), 90/385/EEC (active implantable medicinal devices), 90/396/EEC (appliances burning gaseous fuels), 91/263/EEC (telecommunications terminal equipment), 92/42/EEC (new hot-water boilers fired with liquid or gaseous fuels) and 73/23/EEC (electrical equipment designed for use within certain voltage limits)
■	2/2016 NGM decree	on technical-safety authority surveillance of pressure vessels, charging equipment, small power compressed gas equipment and on periodic inspection of gas tanks
■	23/2016 NGM decree	on distribution, safety requirements and conformity assessment of electrical equipment designed for between determined voltage limits
■	MSZ EN ISO 12100:2011	Safety of machinery. General principles for design. Risk assessment and risk reduction (ISO 12100:2010)
■	MSZ EN ISO 13857:2008	Safety of machinery. Safety distances to prevent hazard zones being reached by upper and lower limbs
■	MSZ EN ISO 13850:2016	Safety of machinery. Emergency stop function. Principles for design
■	MSZ EN 60204-1:2010	Safety of machinery. Electrical equipment of machines. Part 1: General requirements (IEC 60204-1:2005, modified)

5. SUB-SYSTEM DESCRIPTIONS

The whole beam transport sub-subsystem is divided into different work packages which will be parts of individual sub-TG3 evaluations. In the following table, there is a list of particular sub-systems and their sub-TG revisions of this document.

Table 2: Table of sub-system descriptions

ID	Name	Position	Revision
1	Monolith insert	Monolith	
2	Bi-spectral switch	After BBG	
3	Chopper system	In-bunker + 80 m	
4	In-bunker neutron guide	In-bunker	
5	Safety shutter	Outer bunker wall	1
6	Transport guide	D03 + E02	2
7	Guide exchanger	Experimental cave in E01	2
8	Guide support for D03 and E02	D03 + E02	2
9	Guide shielding and shutter and chopper pits	D03 + E02	
10	Beam stop	Experimental cave in E01	1

The design of the neutron optical sub-system follows, beside the high-level documents as *ConOps* [1] and *SysReq* [2], the requirements and specifications of the following documents:

- Contract on delivery of neutron optical system for BEER Part I [5]
- Contract on delivery of neutron optical system for BEER Part II [6]
- BEER Optics Specification [3]
- MCA Components Standard [7]

Schematic layout of the out-of-the-bunker parts of the neutron guide are illustrated and depicted in Figure 1. Detailed engineering drawing of the layout of the neutron optics sub-system is presented in the file MR439-0000-00.pdf in [8].

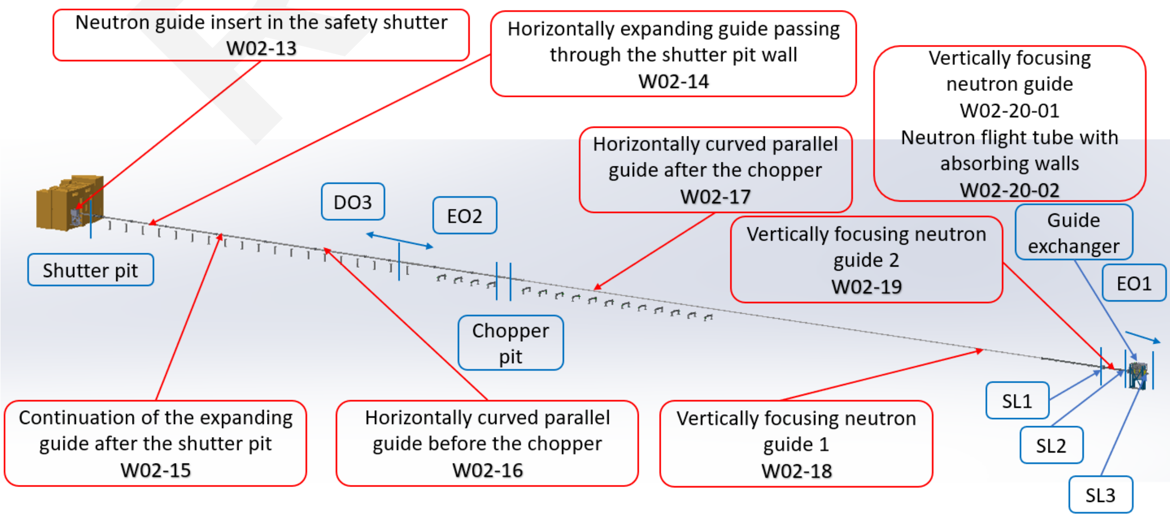


Figure 1: Description of the neutron optics system parts.

5.1. Safety shutter (PBS 13.6.6.1.8.3)

The aim of the shutter is to shield the beamline, to provide a safe personal access to an experimental cave or to down-stream parts as a neutron guide located in a shielded tunnel or a chopper pit. The shutter is located just after the bunker wall at 28 m from the source in D03 hall and is surrounded by a shutter bit which is a part of the shielding sub-system description (design of the shutter pit is a part of the common shielding project and will be provided in future revisions). The position of the shutter is situated after a curved neutron guide which loses a line of sight (LOS) for the 1st time in the bunker wall assembly.

The closed shutter is primarily designed to dump the thermal neutrons transported from the source to the sample and additionally shield residual fast neutrons propagating in to the shutter pit the bunker wall or along the neutron beam guide. The closed shutter together with the shutter pit need to provide sufficient shielding to satisfy the dose limits [9] for the supervised area outside the pit and guide tunnel shielding (maximum 3 µSv/h) and also behind the shutter pit wall inside the guide tunnel (maximum 25 µSv/h). The safety factor of 2 or 3 needs to be applied, if dealing with MCNP or handbook calculations, respectively. Based on the detailed MCNP simulations [10], the shutter shielding block will consist of several different layers. It will be layers of boron carbide (Mirrobor), copper and polyethylene with 5% of boron, listed along the beam direction. A total length of the shielding block will be 61.5 cm, perpendicular dimensions will be 51×51 cm^2 including 5 mm Mirrobor layer on the all outer surfaces. The first layer is Mirrobor-like material which will be 1 cm thick. The second layer is a copper with thickness of 50 cm and finally polyethylene with 5% of boron with thickness of 10 cm. The MCNP calculation model along with the dose rate distribution around the shutter is shown in Figure 2. The total weight of the shutter shielding block will be approximately 1148 kg. The whole shielding block will be coated by Mirrobor layer (approximately 5 mm thickness) to absorb thermal neutrons and thus reduce activation of the materials inside the shutter pit. The shielding block centre will be at the centre of the neutron beam coming out from the bunker via a bunker-throughput. The centre of the bunker-throughput and the neutron beam is located asymmetrically within the shutter pit. The shutter pit wall is 55.5 cm to the left and 74.5 cm to the right (looking downstream) from the beam centre.

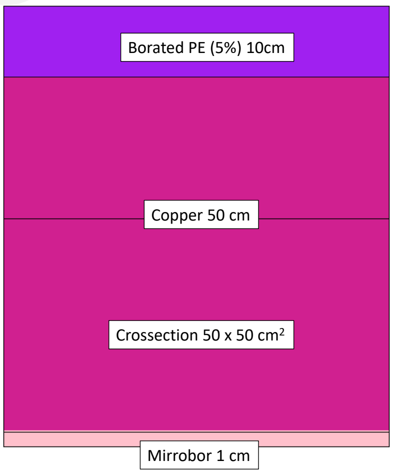


Figure 2: Simplified shutter model for radiological calculations

The shutter is designed as a safety shutter which closes the incoming beam in the case of any utility disconnection or a system failure and is triggered by gravity. The closing of the shutter or move of the shutter to its parking or zero position is designed as trapping or lowering mechanism or in other words, a constant force needs to be applied to keep the shutter open.

The shutter motion is conceived as a swing. In Figure 3, you can see a 3D model of safety shutter with its individual parts description.

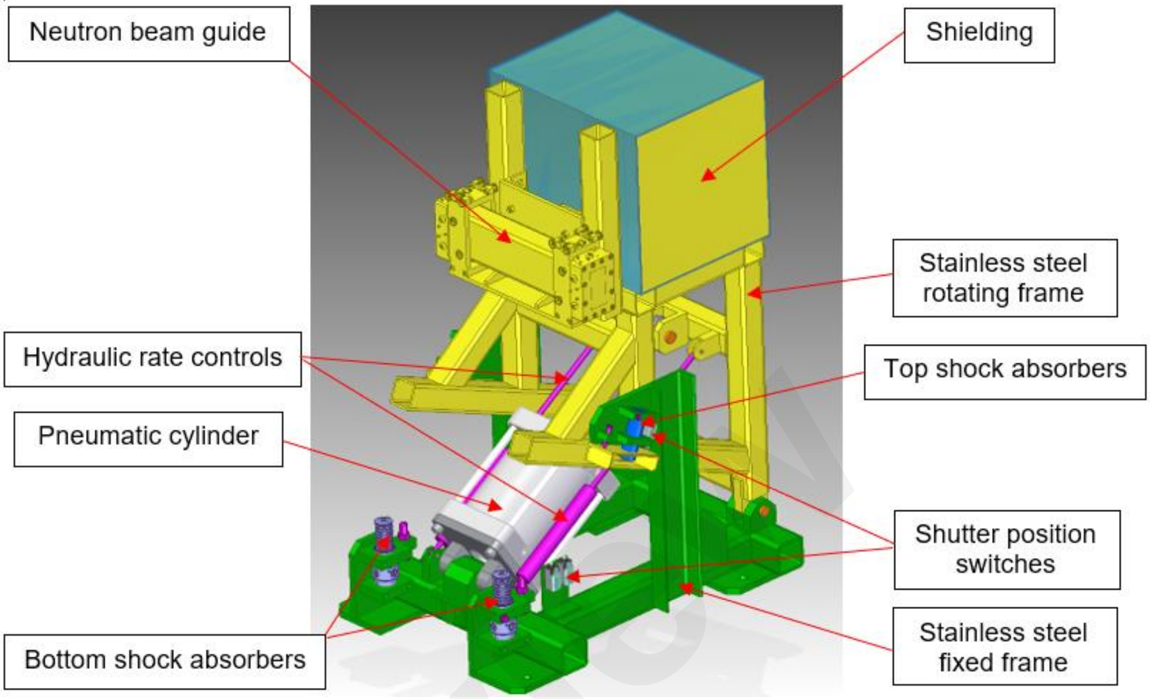


Figure 3: Safety shutter model

The second main function of the shutter mechanism is to allow repeatable and precise positioning of the neutron beam guide attached to it (see Figure 3) in the shutter opened position.

The motion of the safety shutter body is done by a pneumatic cylinder. The safety shutter includes mechanical hard stops (adjustable), hydraulic shocks absorbers and hydraulic control rates.

The neutron beam guide is fixed to the shutter rotating frame by a specific frame that allows a fine setting of the neutron beam guide position in two directions up/down and from/to the shielding block. This specific frame also allows a fine setting of the neutron beam guide angle. The precision and repeatability of the movement is ensured by, a precise pivot connection between the shutter rotating frame and the shutter fixed frame, and adjustable mechanical hard stops to limit the rotating frame movements in opened/closed position.

Hydraulic shock absorbers are used to absorb mechanical shocks during operation and to protect the system in case of accidental scenario (fall of the shutter rotating frame due to air supply loss).

Hydraulic control rates allow a smooth operation of the shutter. Without hydraulic control rates the shutter shall jerk due to a big variation of the gravity centre distance compared to the rotation axis.

The safety shutter fixed and rotating frames are made of steel plates and hollow sections that are welded are bolted together. A paint is applied to the steel frames to protect the steel and make easier the decontamination of the system during operation or decommissioning.

For more detail information see *Shutter – Technical report* [11].

Drawings, material list and further document can be found in the directory DPS01.01 – Safety Shutter.

5.2. Beam stop (PBS 13.6.6.1.8.6)

The purpose of the beam-stop is to attenuate the direct neutron beam passing through the sample or even without the sample. It will be installed in the experimental cave on its the back wall and it will its integral part. The structure of the beam-stop consists of a 20 mm thick plate of B_4C imbedded in a lead block (see Figure 4). The lead block surrounds the B_4C plate in the perpendicular direction to the neutron beam to shield a prompt γ radiation produced by interaction of the neutrons with boron. The size of the beam stop is designed to be able to accommodate the size of the full uncollimated divergent beam (for more details see *BEER – Radiation Safety Analysis* [10]).

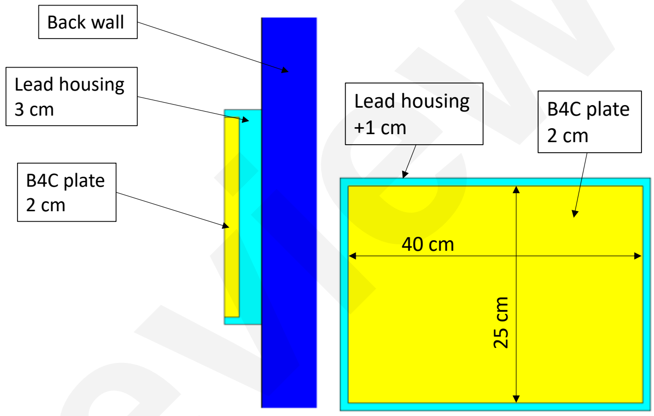


Figure 4: BEER beam stop detailed description

5.3. PART I – vacuum housing and the neutron guides (PBS 13.6.6.1.2.1.4 and 13.6.6.1.2.2)

Part I consists of the safety shutter insert (W02-13) and curved transport guide in sections W02-14 to W02-17 as described in [3]. Those parts are located between x = 28 m to x = 144.5 m along the neutron axis (ISCS coordinates). At x = 80 m, there is an allocated space for the frame overlap chopper pair, which is not designed yet.

Along the transport section (W02-15 – W02-17), there are designed six vacuum ports for connection to the vacuum manifold (manifold not part of the design) which are situated in the following position of the vacuum housing along the beam (ISCS coordinates):

- 32 610 mm – housing for W02-15 (drawing MR439-3000-00.pdf in [8])
- 52 610 mm – housing for W02-16 (drawing MR439-4000-00.pdf in [8])
- 72 610 mm – housing for W02-16 (drawing MR439-4000-00.pdf in [8])
- 92 610 mm – housing for W02-17 (drawing MR439-4000-00.pdf in [8])
- 112 610 mm – housing for W02-17 (drawing MR439-4000-00.pdf in [8])
- 132 610 mm – housing for W02-17 (drawing MR439-4000-00.pdf in [8])

An additional vacuum port found on housing for W02-13 (drawing MR439-1100-00.pdf in [8]) at ISCS 28 610 mm.

5.3.1. W02-13 – safety shutter insert (GSH2)

5.3.1.1. Details of the vacuum housing for W02-13

Detailed engineering drawing MR439-1000-00.pdf and MR439-1100-00.pdf in [8].

Vacuum housing total length:	610 mm
Housing weight with guide:	~79 kg
Vacuum port dimension:	ISO-CF 40
Thickness of AlMgSi1 vacuum windows:	0.5 mm
Vacuum house material:	S235JR steel, zinc coated

The guide itself sits in a hollow structural section (HSS) steel. The housing is closed on both ends with 0.5 mm thick AlMgSi1 windows fixed to the steel flanges (see Figure 5). The flanges are welded to the steel section. A CF 40 vacuum port is placed on the top of the vacuum housing. The neutron guide is fixed inside the vacuum housing with the adjusting bolts than its relative position to the fiducials recorded (Figure 6). Adjusting of the neutron guide in 3D is done by moving the whole vacuum housing by inbuilt bolts in the adjusting frame (see Figure 7). The vacuum housing is fixed through a mounting unit on the pendulum mechanism (see Figure 10, Figure 12). Vertical alignment of the housing to the mounting unit is done with a spring bolt mechanism which is accessible from above from long distances (see Figure 8, Figure 9). The mounting unit consists of two, perpendicularly welded steel plates (see Figure 11), fitting bolts, aligning plate and locating pins for positioning the vacuum housing.

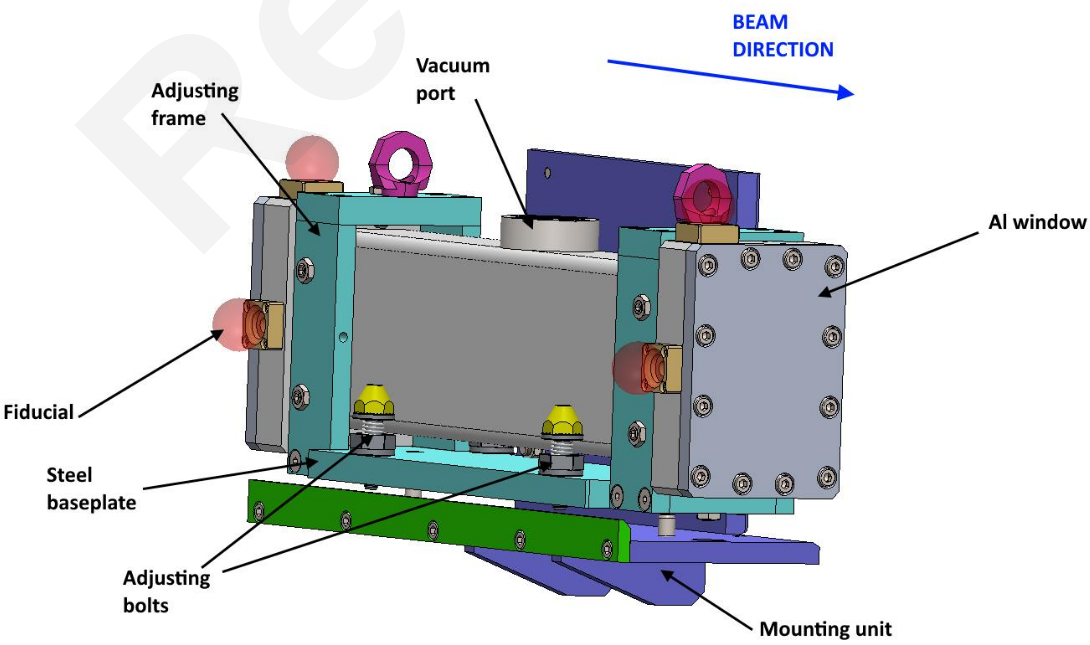


Figure 5: Overview of W02-13 vacuum housing assembly and description of individual parts.

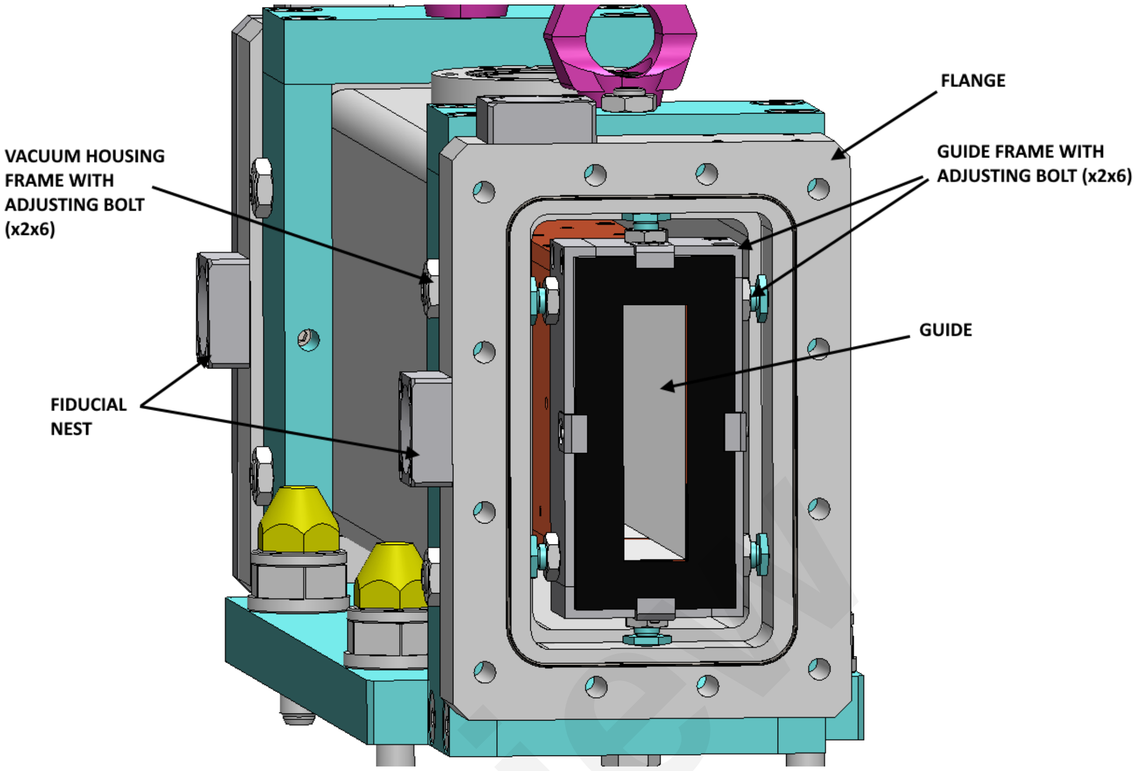


Figure 6: Detail of the neutron guide inside of the vacuum housing with the Al-window removed. The vacuum housing's adjusting bolts, which align the vacuum housing laterally and vertically through the adjusting frame.

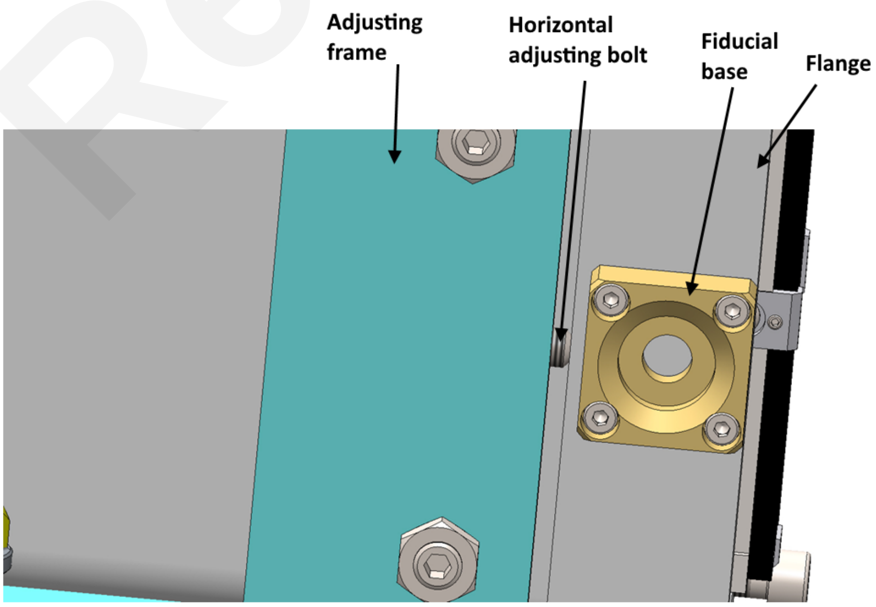


Figure 7: Horizontal adjusting of the housing through its flange with bolts inside the adjusting frame.

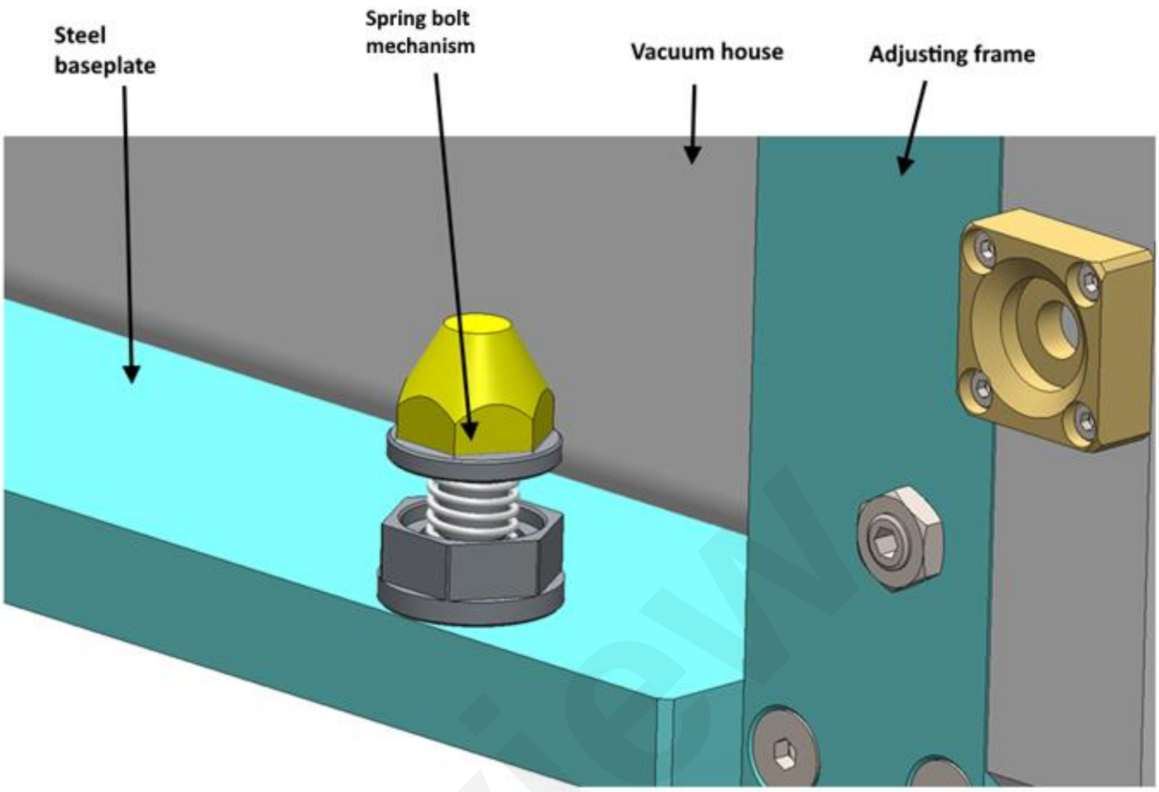


Figure 8: Vertical alignment of the vacuum housing with the spring bolt mechanism.

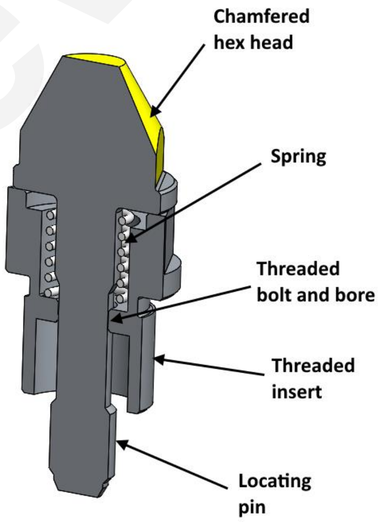


Figure 9: Section view of the spring bolt mechanism. The chamfered hex head allows adjusting of the locating pin from a long distance. The threaded insert fixes the mechanism to a steel baseplate.

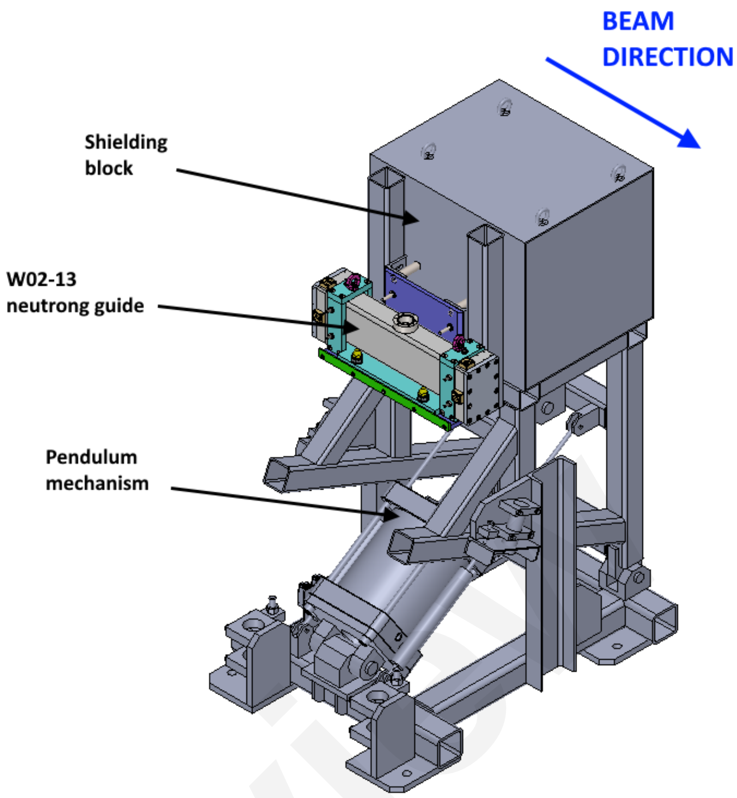


Figure 10: Vacuum housing of W02-13 neutron guide section and shielding block fixed on the pendulum mechanism.

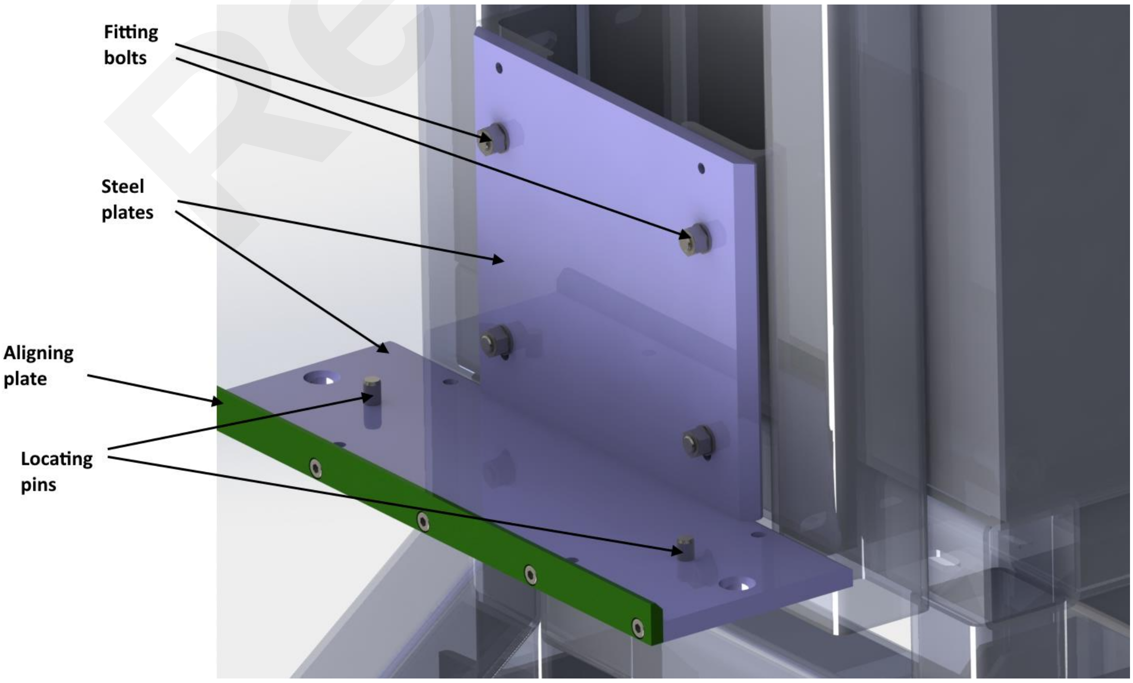


Figure 11: Construction of the mounting unit fixed on the pendulum mechanism.

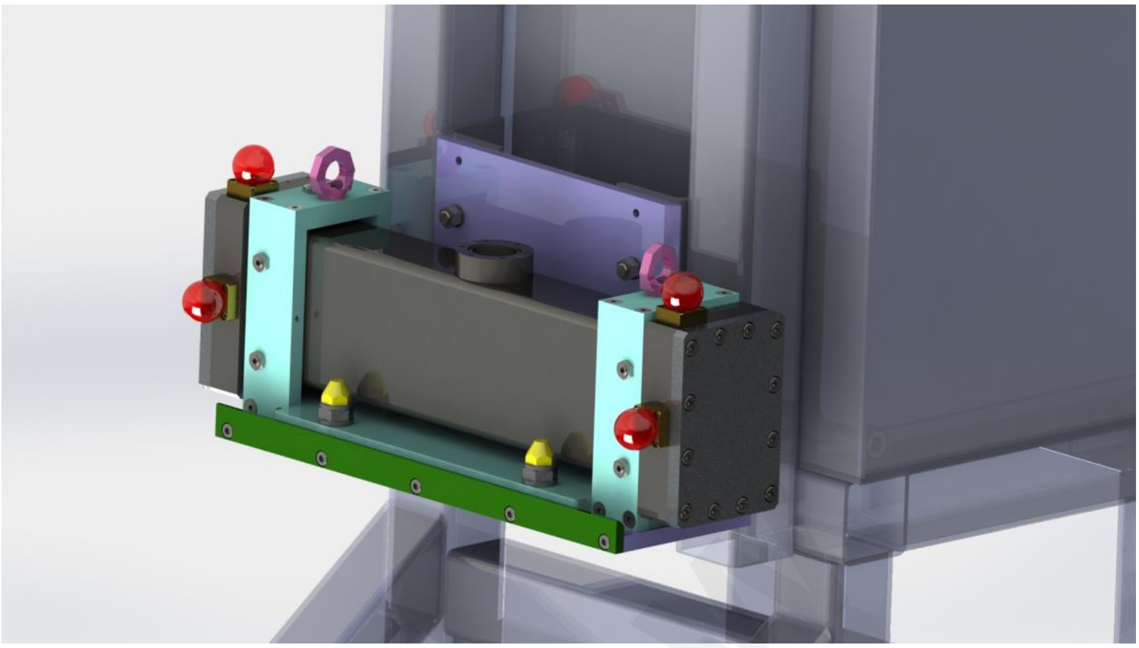


Figure 12: Closer view of the W02-13 vacuum housing mounted on the pendulum mechanism with the mounting unit.

5.3.1.2. Details of the neutron guide section W02-13

Detailed engineering drawing MR439-1110-00.pdf in [8].

Neutron guide total length (with Mirrobor^{TM} shielding):		604 mm
Neutron guide inner size (W x H):		20.00 x 80.00 mm^2
Support frame:		
	Material:	AlMgSi1, anodized
	Thickness:	10 mm
Substrate:		
	Material:	Copper CW008A
	Thickness:	8 mm
Coating m-value:		
	Left/Right:	2.5
	Top/Bottom:	2
Upstream front face shielding:		
	Material:	Mirrobor^{TM}
	Thickness:	5 mm
Guide weight:		~11 kg

The neutron guide section W02-13 on the safety shutter system is a one-piece (Figure 13) 599 mm long guide, which consists of 8 mm thick copper supermirror substrates which fixed on anodized aluminium alloy support frames on both ends (**Error! Reference source not found.**). The c opper plate will be assembled in a stress-relieved condition. The upstream part covered with 5 mm thick Mirrobor^{TM} shielding, which is vertically and horizontally adjustable and fixed with bolts on the steel plates (Figure 14). Adjusting bolts with straining nuts are attached around the guide for vertical and horizontal positioning inside the vacuum housing (Figure 15).

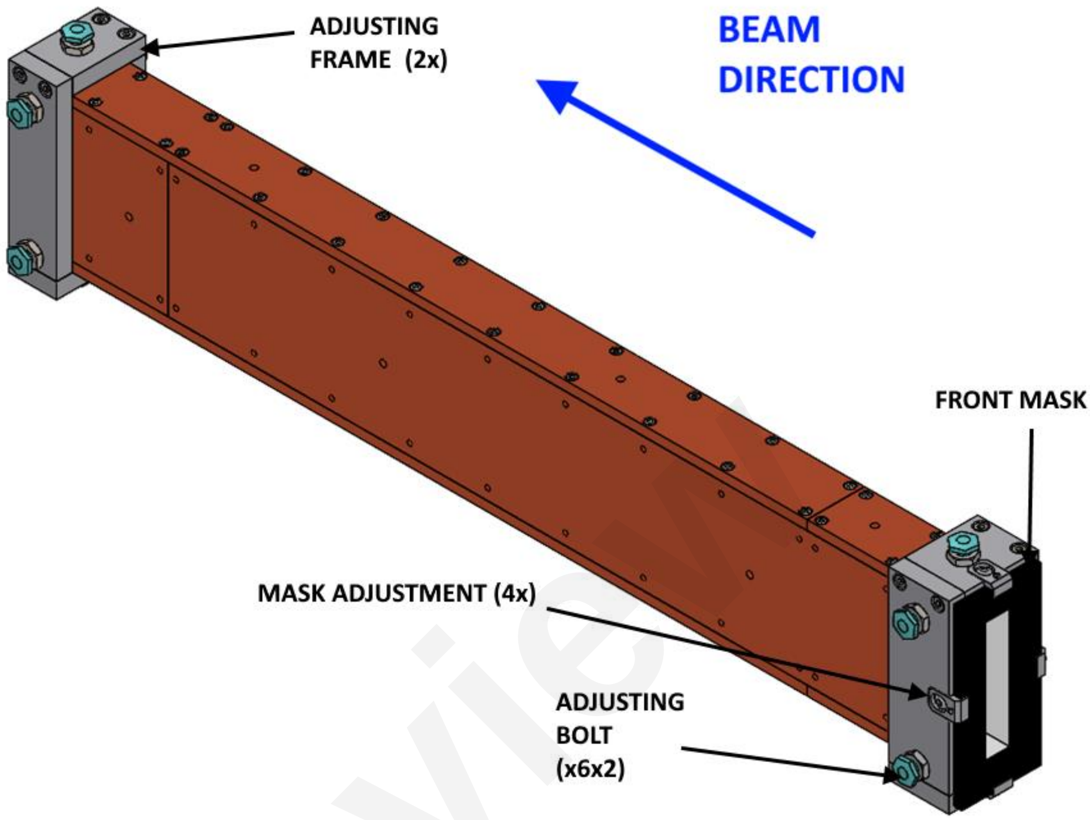


Figure 13: Overview of the part W02-13 of the neutron guide including the Mirrobor™ shielding mask.

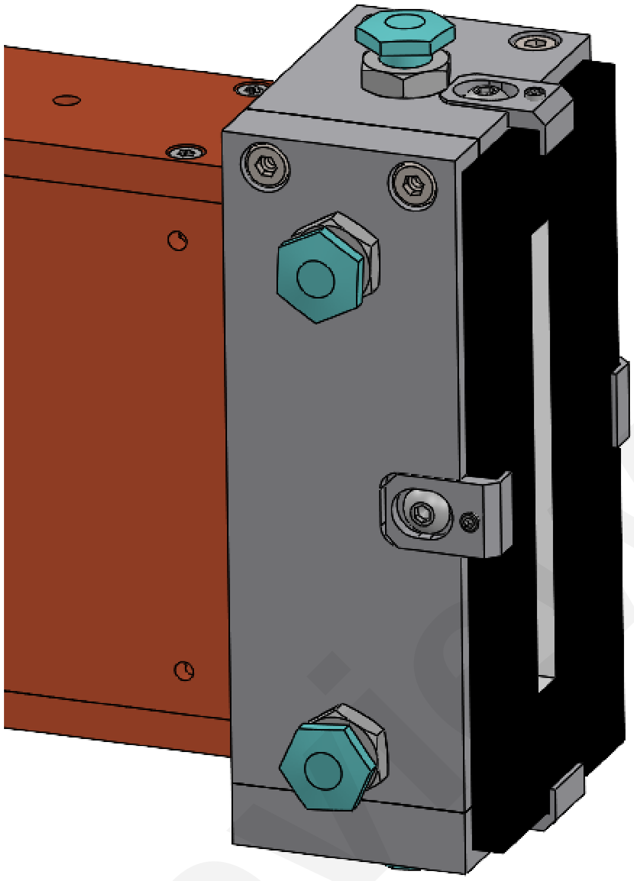


Figure 14: Closeup view of the upstream part showing the adjustable neutron shielding assembly and the connection of the Mirrobor™ shielding mask on the front face.

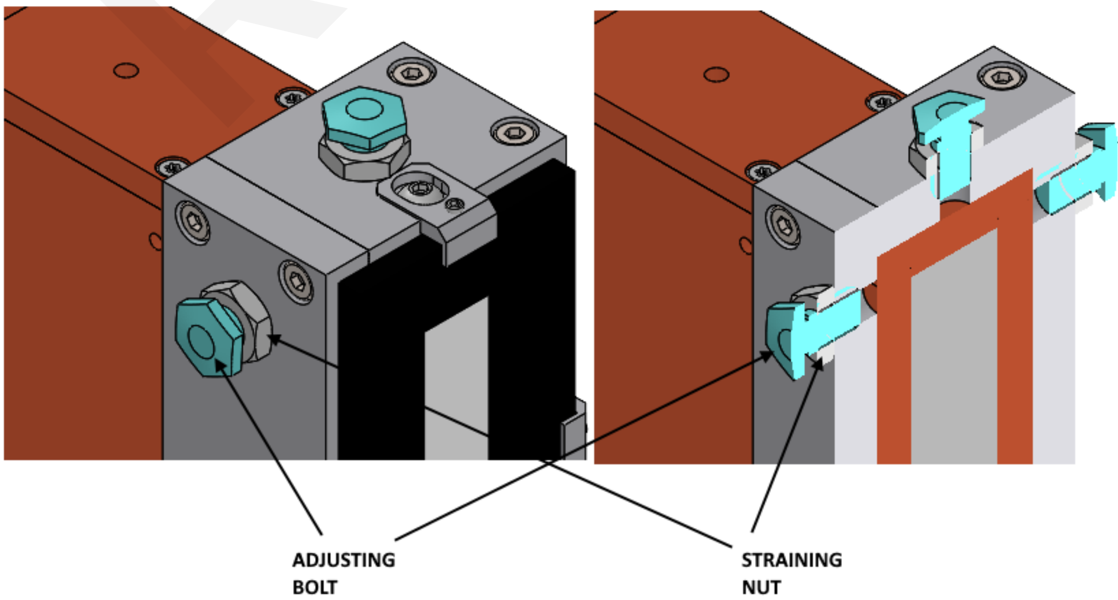


Figure 15: Left – the adjusting bolt with the straining screw. Right – showing the same in section view.

5.3.2. W02-14 (GE2AS & GE2A) – shutter pit inserts

5.3.2.1. Details of the vacuum housing for W02-14 (GE2AS and GEA2)

Detailed engineering drawing MR439-2000-00.pdf in [8].

Vacuum house total length:		2870 mm
Thickness of Al-window:		0.5 mm
Housing weight with guide:		~340 kg
Bellow coupling:		ISO-K DN160
Vacuum house material:		S235JR steel, zinc coated
Vacuum sealing:		99.99% Pb wire
Casing dimensions (second segment):		
	Length:	1282 mm
	Width:	106 mm
	Height:	160 mm
	Thickness:	18 mm
Case material:		S235JR steel, zinc coated
Dimensions of shutter pit throughput:		
	Length:	980 mm
	Width:	150 mm
	Height:	202 mm
Shutter pit throughput material:		S235JR steel, zinc coated
Filling on shutter pit throughput:		
	Material:	advisably Mirrobor-S^{TM}
	Thickness:	5 mm
Shielding unit dimensions:		
	Width:	206 mm
	Height:	260 mm
	Total thickness:	20 mm
Shielding unit layer stacking:		
	S235JR steel:	5 mm
	B_4C:	5 mm
	B_4C:	5 mm
	S235JR steel:	5 mm

The vacuum housing for W02-14 section of the neutron guide is made up of 2 main segments (see Figure 16, Figure 17). Upstream, the vacuum housing assembly starts with a 0.5 mm thick AlMgSi1 vacuum window connected to a steel flange. Downstream, the vacuum housing assembly connects to the succeeding segment with an ISO-K DN160 bellow coupling (bellow details in Figure 23). The first segment is 1380 mm long and is made from hollow structural section steel and in fact it consists from two sub-segments. All sub-segments are connected with flanges. The flanges are welded to the steel sections and have built-in adjusting bolts which are covered with sealing caps (see Figure 19 and Figure 22). The second segment is 1486 mm long and runs in a steel casing made of steel plates fixed by threads. The ending 1000 mm part of the casing passes through the shielding of the shutter pit. This part has an additional 14 mm thick casing and a 5 mm filling material around it (advisably made of Mirrobor-S^{TM}) and begins with a 20 mm thick multi-layered shielding unit made of steel and B_4C (see Figure 18). The casing steel plates are assembled in an overlapped construction for additional neutron shielding. The Al-window, the flanges and their sealing caps have two sealing grooves: the inner used temporary for vacuum tests and the outer for permanent sealing filled with high purity, antimony-free lead wire (see Figure 19, Figure 20, Figure 21, Figure 22).

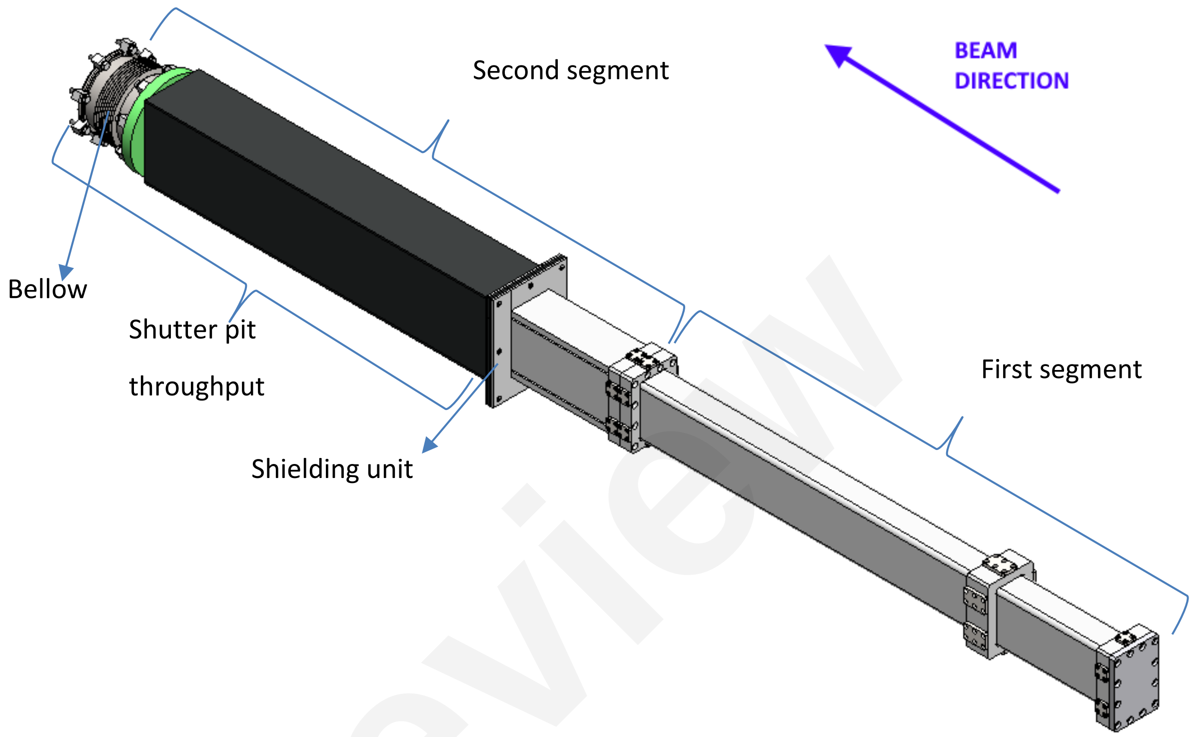


Figure 16: Assembly of vacuum housing for W02-14 sections of the neutron guide.

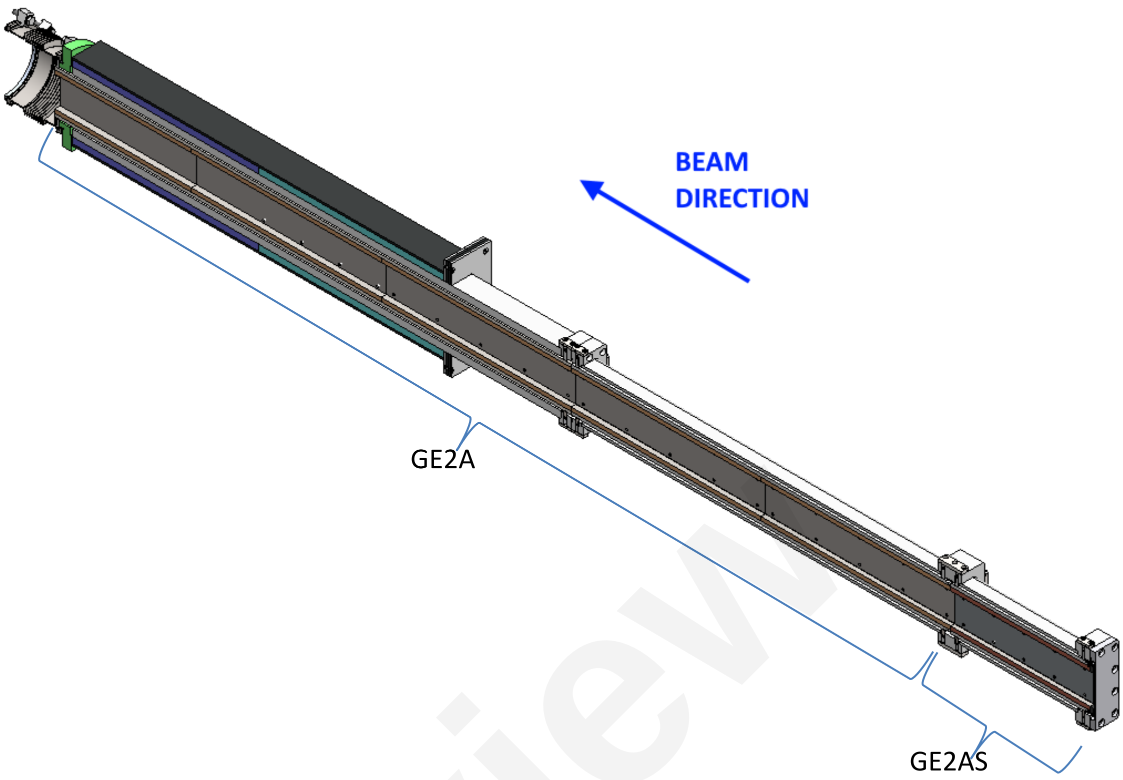


Figure 17: Section view of the vacuum housing for W02-14 showing the two sub-guides GE2A and GE2AS in it.

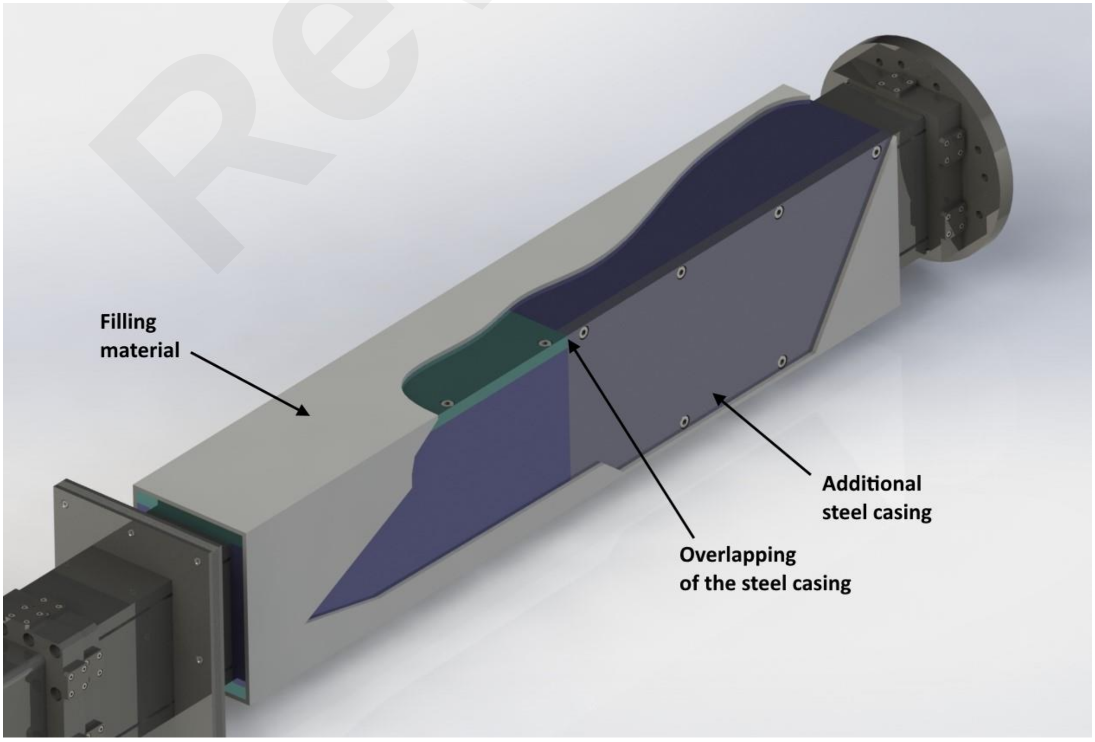


Figure 18: Break out view of the shutter pit throughput.

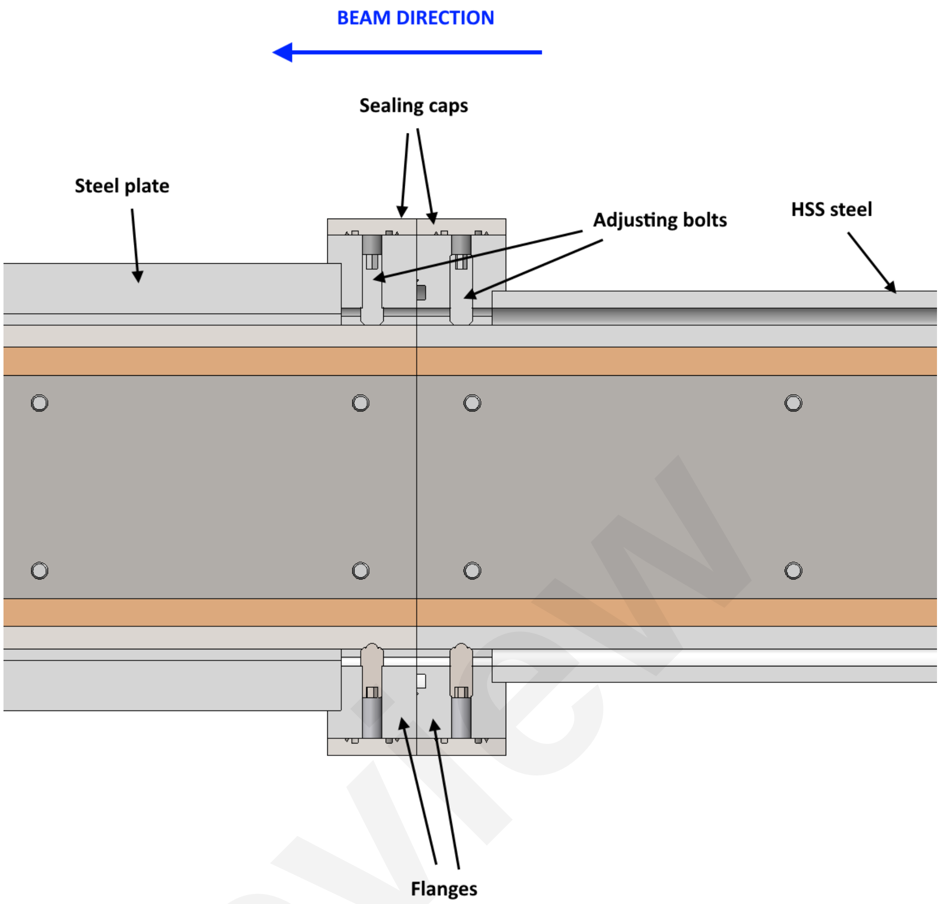


Figure 19: Section view at the connecting flanges.

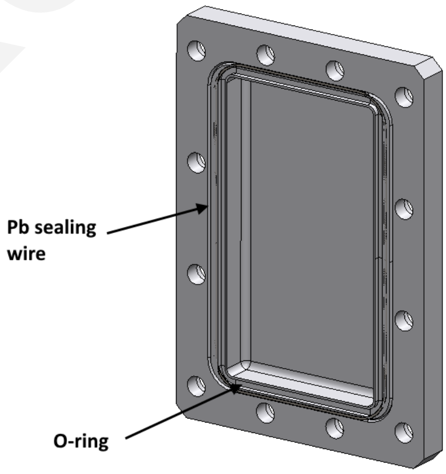


Figure 20: The O-ring and Pb wire sealings in the Al window

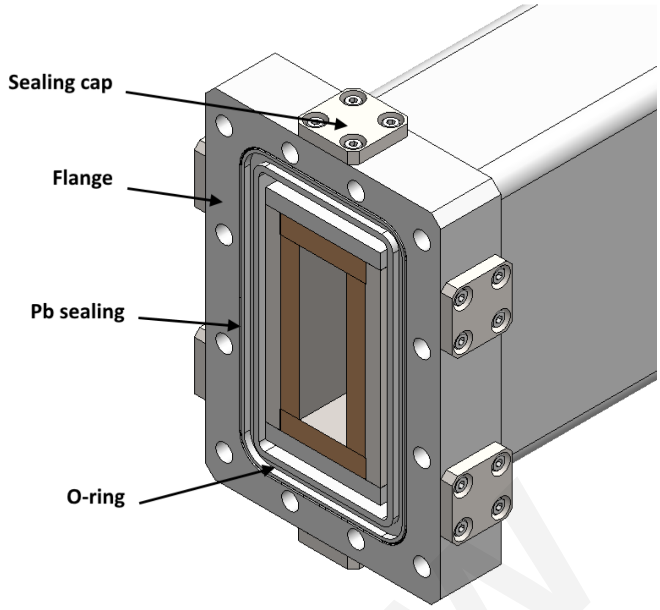


Figure 21: Section view showing the Pb sealing wire and NBR O-ring in the flange.

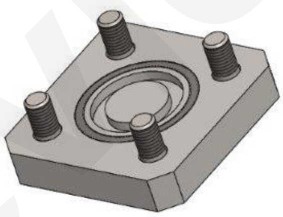


Figure 22: Sealing cap with inlayed Pb wire.

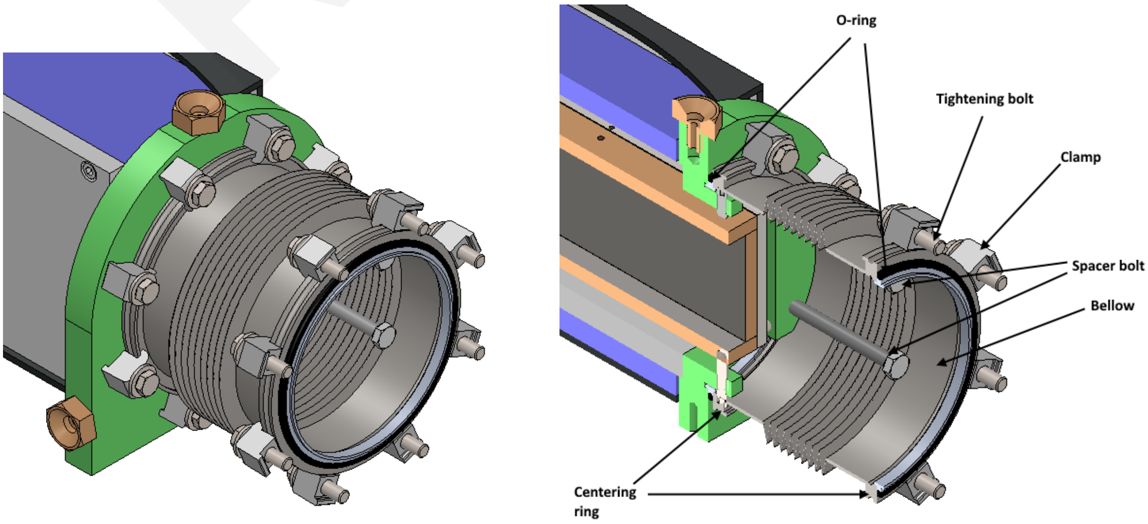


Figure 23: ISO-K DN160 bellow coupling on the right. The same part in section view showing the description of individual components.

5.3.2.2. Details of the neutron guide sections W02-14

Detailed engineering drawing MR439-2400-00.pdf in [8].

GE2AS sub-guide

Neutron guide length (with Mirrobor™):		377 mm
Neutron guide upstream inner size (W x H):		20.00 x 80.00 mm^2
Neutron guide downstream inner size (W x H):		20.00 x 80.00 mm^2
Support frame:		
	Material:	AlMgSi1, anodized
	Thickness:	10 mm
Substrate:		
	Material:	Copper CW008A
	Thickness:	8 mm
Coating m-value:		
	Left/Right:	2.5
	Top/Bottom:	2
Guide weight:		
		~3 kg

GE2A-1 sub-guide

Neutron guide length:		1000 mm
Neutron guide upstream inner size (W x H):		20.01 x 80.00 mm^2
Neutron guide downstream inner size (W x H):		25.06 x 80.00 mm^2
Support frame:		
	Material:	AlMgSi1, anodized
	Thickness:	10 mm
Substrate:		
	Material:	Copper CW008A
	Thickness:	8 mm
Coating m-value:		
	Left/Right:	2.5
	Top/Bottom:	2
Guide weight:		~18 kg

GE2A-2 sub-guide

Neutron guide length:		1358 mm
Neutron guide upstream inner size (W x H):		25.06 x 80.00 mm^2
Neutron guide downstream inner size (W x H):		29.99 x 80.00 mm^2
Support frame:		
	Material:	AlMgSi1, anodized
	Thickness:	10 mm
Substrate:		
	Material:	Copper CW008A
	Thickness:	8 mm
Coating m-value:		
	Left/Right:	2.5

Top/Bottom:	2
Guide weight:	~43 kg

The W02-14 neutron guide section contains three sub-guides: the GE2AS, GE2A-1 and GE2A-2. Both guides have 8 mm thick copper supermirror substrates which have aluminium frames fixed on both ends and will be assembled in a stress-relieved condition. The upstream part of GE2AS is covered with 5 mm thick Mirrobor^{TM} shielding which is adjustably fixed on the steel plates on both sides, top and bottom as well.

The GE2AS is a straight, 377 mm long (including 5 mm thick Mirrobor^{TM} mask at the front end), parallel neutron guide (see Figure 24). The succeeding GE2A is an elliptically expanding (ellipse parameters are semi-major axis: 11547 mm, semi-minor axis: 20 mm, centre: 39000 mm), 2360 mm long guide and contains 4 pieces of 500 mm and a 360 mm long sub-segment (see Figure 25). The ellipse shape is approximated by 0.5 m long flat segments.

For the design of the steel plates and the fixation of the Mirrobor^{TM} shielding mask see section 5.3.1.2.

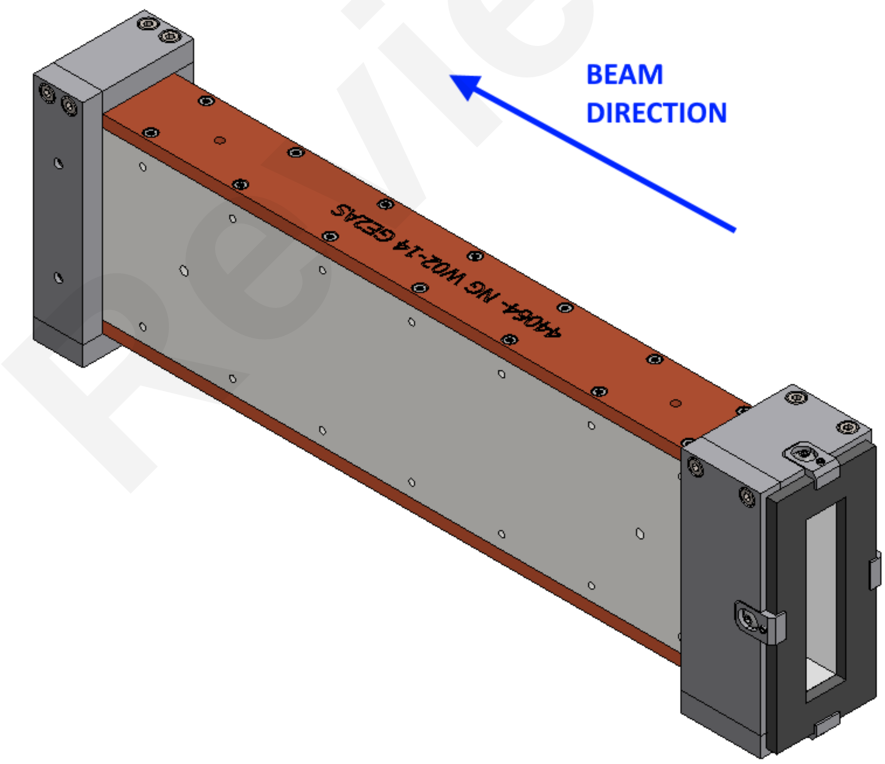


Figure 24: GE2AS sub-section assembly of the neutron guide W02-14 with the from end 5 mm thick Mirrobor^{TM} mask.

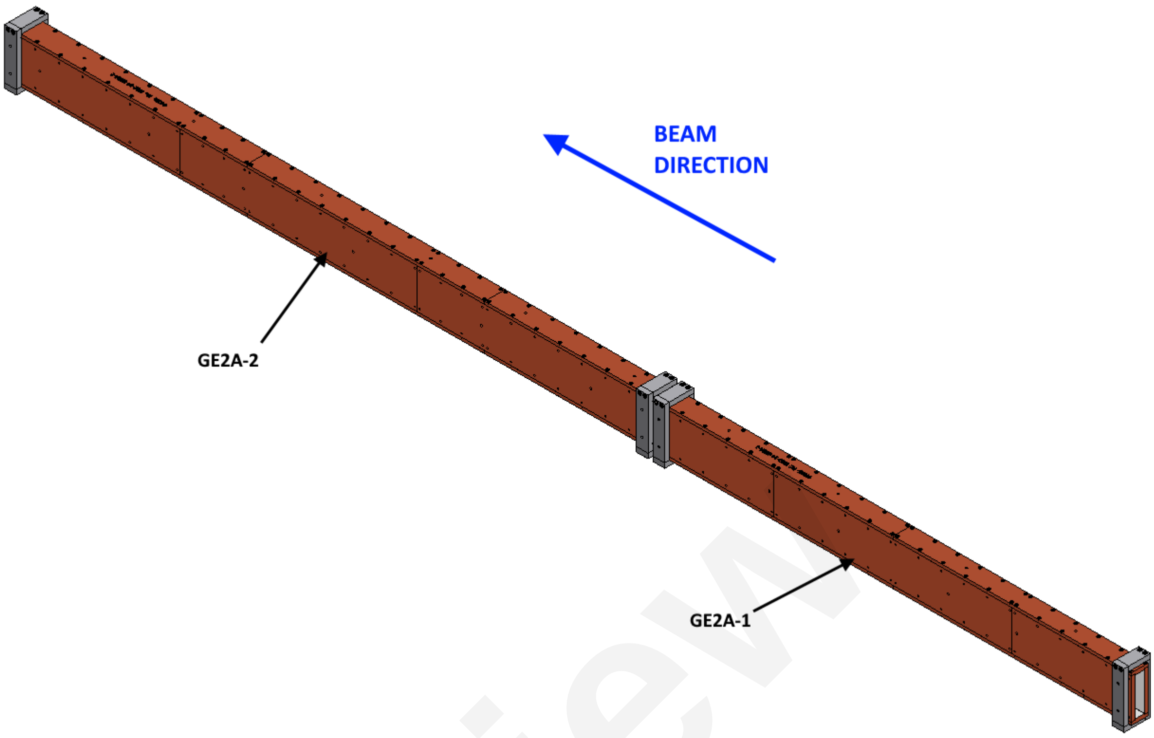


Figure 25: GE2A-1 and GE2A-2 sub-section assembly of the neutron guide W02-14.

5.3.3. W02-15 – expanding transport neutron guide (GE2B)

5.3.3.1. Details of the vacuum housing for W02-15

Detailed engineering drawing MR439-3000-00.pdf in [8].

Vacuum house total length:	7531 mm
Housing weight with guide:	~1062 kg
Vacuum port dimension:	KF 40
Bellow coupling:	ISO-K DN160
Vacuum house material:	S235JR steel, zinc coated
Vacuum sealing:	NBR

The vacuum housing for W02-15 section of neutron guide is made of two main sections which are connected by bellow located just above the support structure (see Figure 26). Those main sections are created from several beam units which each is formed from two longitudinally welded U-beam units made of structural steel. The beam units are connected via flanges (for details see Figure 28, Figure 29, Figure 30). The housing contains three (start, end and section connection points) edge welded ISO-K DN160 type bellow beam couplers for a compensation of misalignment and offset. The adjusting bolts on the flanges are covered with sealing bolts fitted with NBR O-rings for vacuum tightening. Vertical and horizontal fiducial bases are placed at the bellow flanges (see Figure 27). At 1155 mm (32515 mm ISCS) from the upstream a vertical KF 40 vacuum port is welded on the vacuum housing (see Figure 27). The vacuum house shares a common vacuum space with the preceding and succeeding guide optics.

For the design of the bellow see section 5.3.2.1.

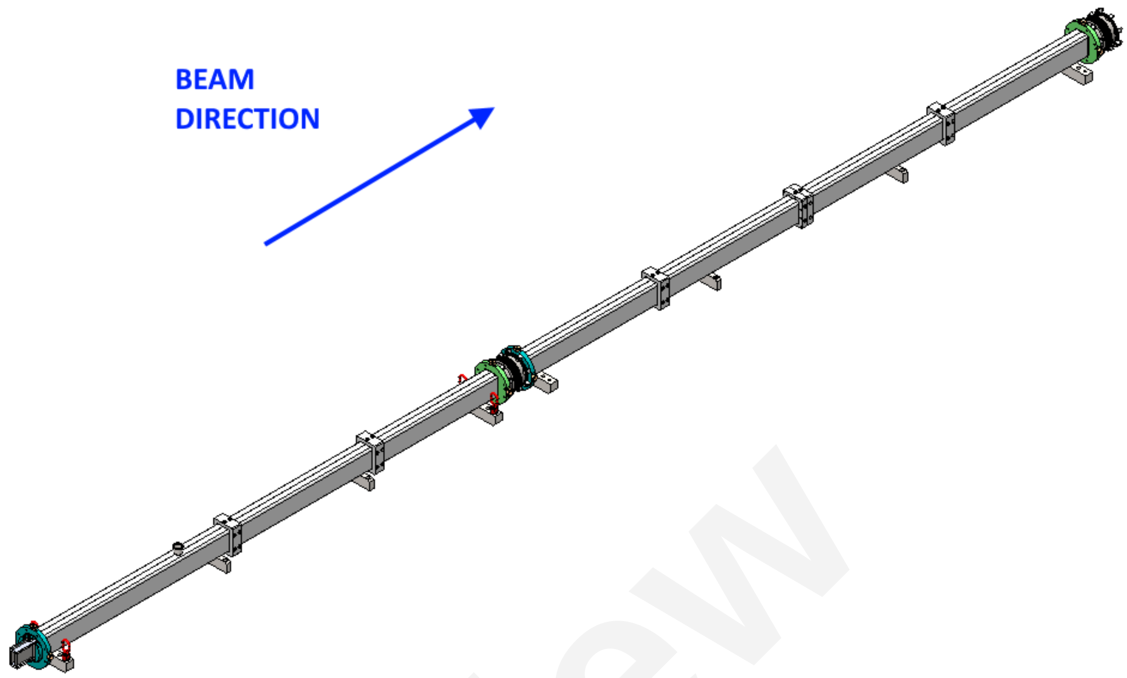


Figure 26: Assembly of the vacuum housing for W02-15 section of the neutron guide.

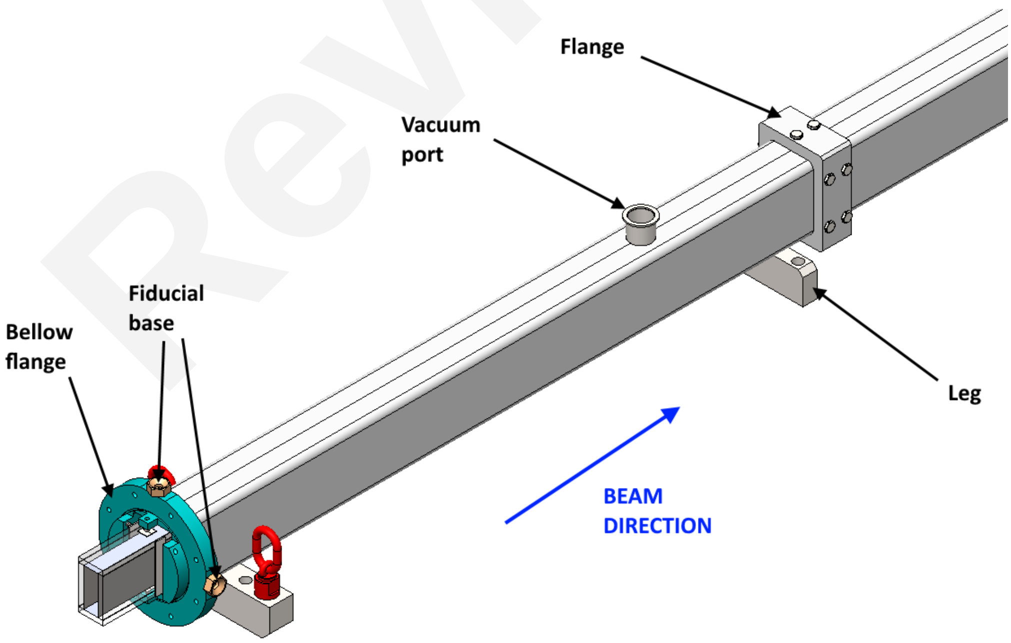


Figure 27: Upstream part of the vacuum housing showing fiducial point on bellow flanges, vacuum port and flange connecting beam units.

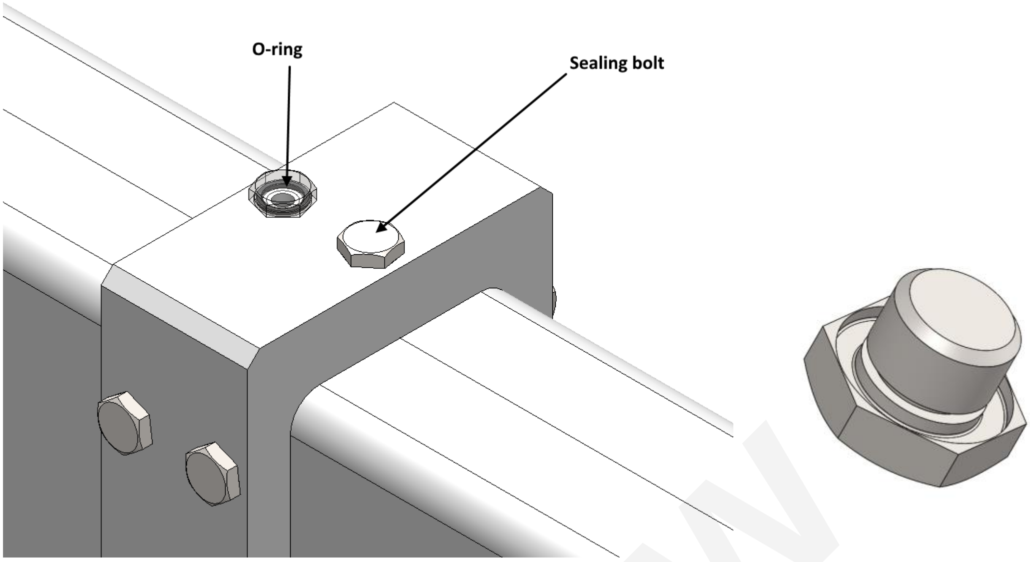


Figure 28: Left – sealing bolt and sealing O-ring on a flange. Right – groove in a sealing bolt for the O-ring.

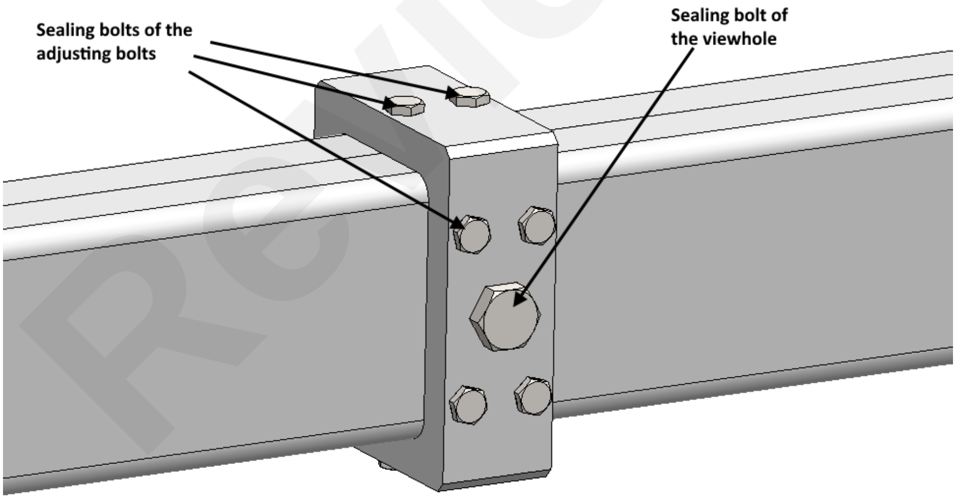


Figure 29: Beam connecting flange. On one side it has a view hole covered with an NBR O-ring sealed bolt.

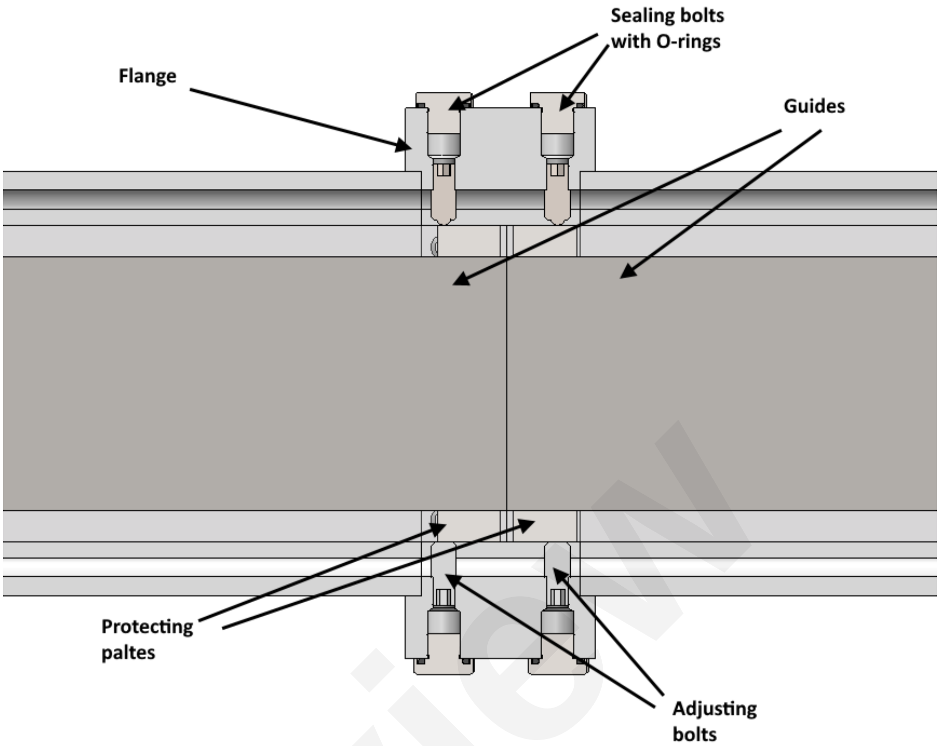


Figure 30: Section view of a beam connecting flange. The sealing bolts covering the adjusting bolts.

5.3.3.2. Details of the neutron guide section W02-15

Detailed engineering drawing MR439-G-3100-00.pdf in [8].

Neutron guide total length:		7638 mm
Neutron guide upstream inner size (W x H):		30.00 x 80.00 mm^2
Neutron guide downstream inner size (W x H):		40.00 x 80.00 mm^2
Substrate material:		NBK-7
Coating m-value:		
	Left/Right:	2.5
	Top/Bottom:	2
Guide weight:		~57 kg

The section W02-15 of the neutron guide is a vertically parallel and horizontally elliptically expanding section (ellipse parameters are semi-major axis: 11547 mm, semi-minor axis: 20 mm, centre: 39000 mm). The ellipse is approximated by 0.5 m long flat segments. The whole guide assembly contains following number segments: 1 x 1500 mm, 5 x 1000 mm (see Figure 31) and 1 x 1139 mm. The last irregular piece is made from two sub-segments with length of 500 and 638 mm. The segments have protecting plates on both ends and 2-2 connecting bridges on the top and bottom (see Figure 31). The protecting plates separate the adjusting bolts and the guide glasses, so they do not have a direct contact. The connecting bridges couple the sub-segments.

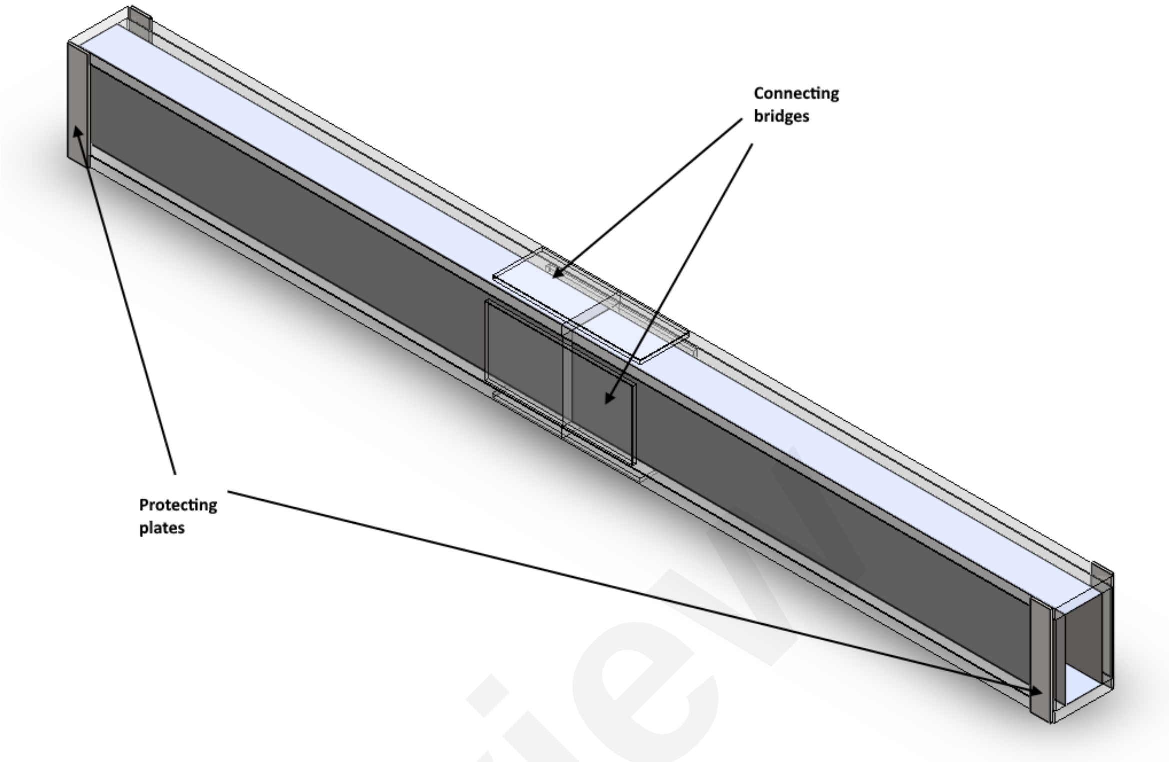


Figure 31: A 1 m long segment of the W02-15 section of the neutron guide showing the connection bridges between the 0.5 m long guide sub-segments and the protecting plates on the side edges.

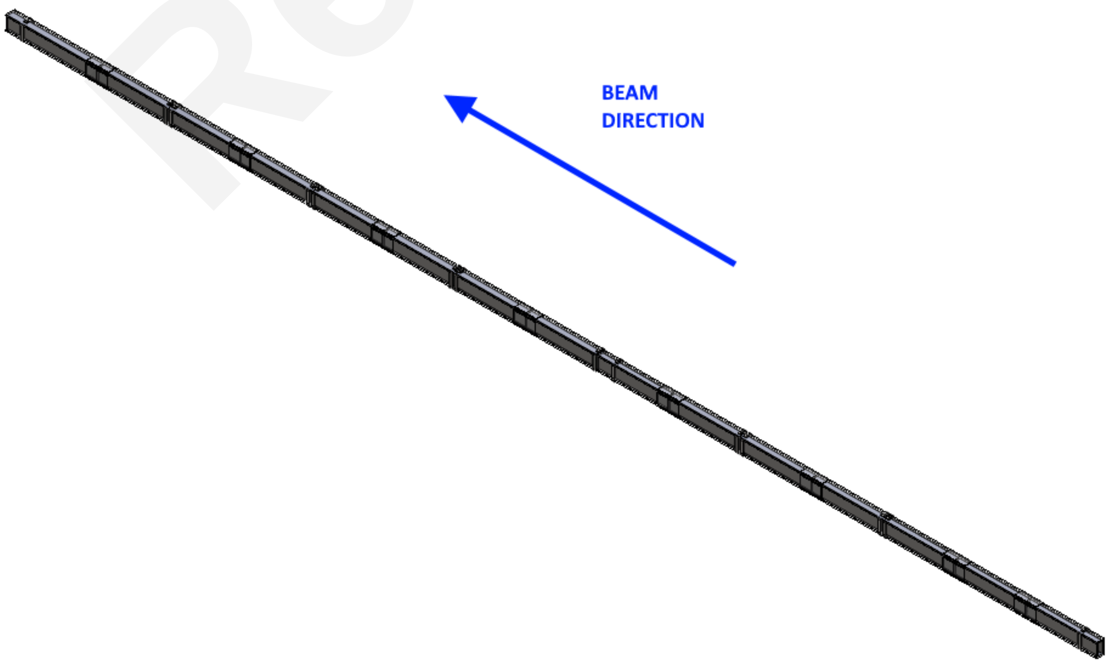


Figure 32: Whole assembly of W02-15 section of the neutron guide.

5.3.4. W02-16 – curved transport neutron guide (GT1)

5.3.4.1. Details of the vacuum housing for W02-16

Overview detailed engineering drawing MR439-4000-00.pdf in [8].

Vacuum house total length:	106284 mm
Housing weight with guide:	~1750 kg
Vacuum port dimension:	KF 40
Bellow coupling:	ISO-K DN160
Vacuum house material:	S235JR steel, zinc coated
Vacuum sealing:	NBR

The vacuum housing for W02-16 section of the neutron guide resembles to the one for W02-15 (section 5.3.3.1). It shares a common vacuum space with the preceding guide optics and further chopper vacuum housing (not part of this design). The whole assembly is made out of the 8 sections connected with bellows. The first and last sections are around 2 m long, and the others are about 6 m long. Detail engineering drawings of each section can be found in [8] (1 x MR439-4310-00.pdf, 3 x MR439-4320-00.pdf, 1 x MR439-4330-00.pdf, 1 x MR439-4340-00.pdf, 1 x MR439-4350-00.pdf, 1 x MR439-4360-00.pdf). At the bellow position, there are fiducial bases installed (see Figure 33). The segment where the vacuum housing passes through the wall between D03 and E02 halls, the guides are running in the steel plates instead in the beam units (made from welded U-beams) for fixation (see Figure 34). That bellow which is found right after the wall is electrically insulated by PE fittings at its bolts and PE plate at its flange (see Figure 35 and Figure 36). Five pieces of KF 40 vacuum ports are found along the W02-16 vacuum housing assembly (see Figure 33).

For the design of the bellow and steel casing see section 5.3.2.1.
For the design of the vacuum housing, the beam alignment, the flanges and adjusting bolts sealings, see section 5.3.3.1.

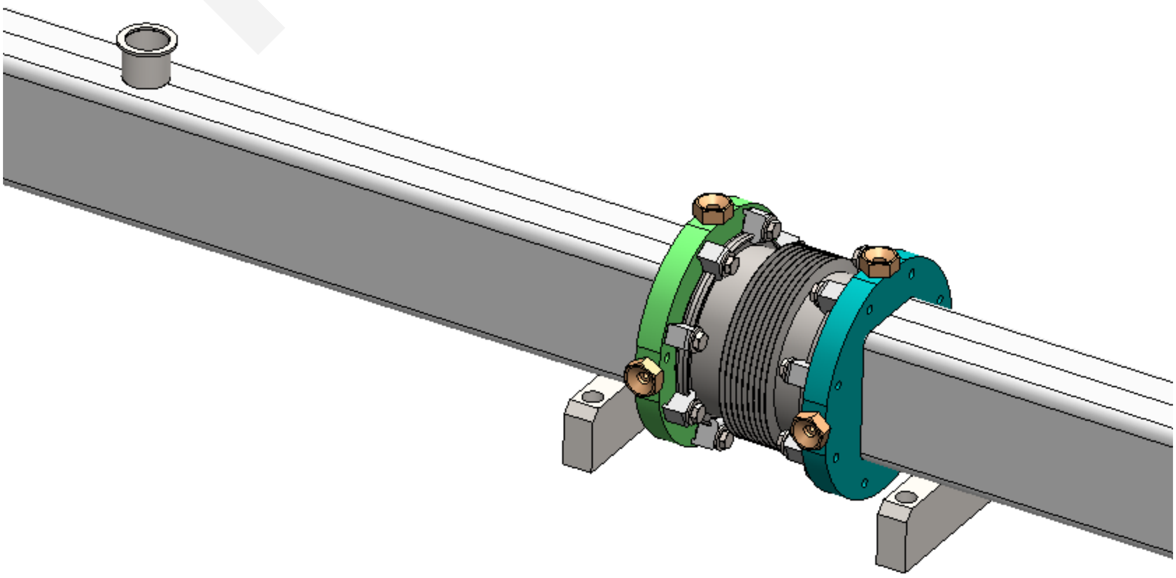


Figure 33: A vacuum port and fiducial bases at a bellow coupling as designed for the vacuum housing for W02-16 section of the neutron guide.

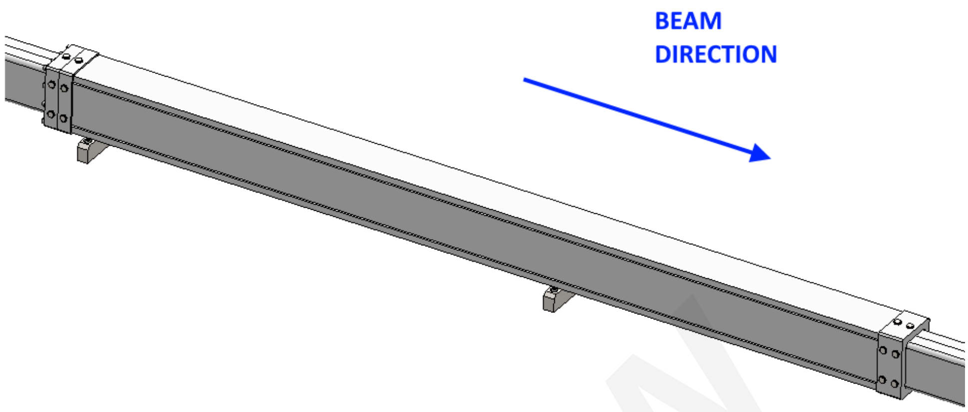


Figure 34: Steel casing of the guide where it passes through the wall between D03 and E02 halls.

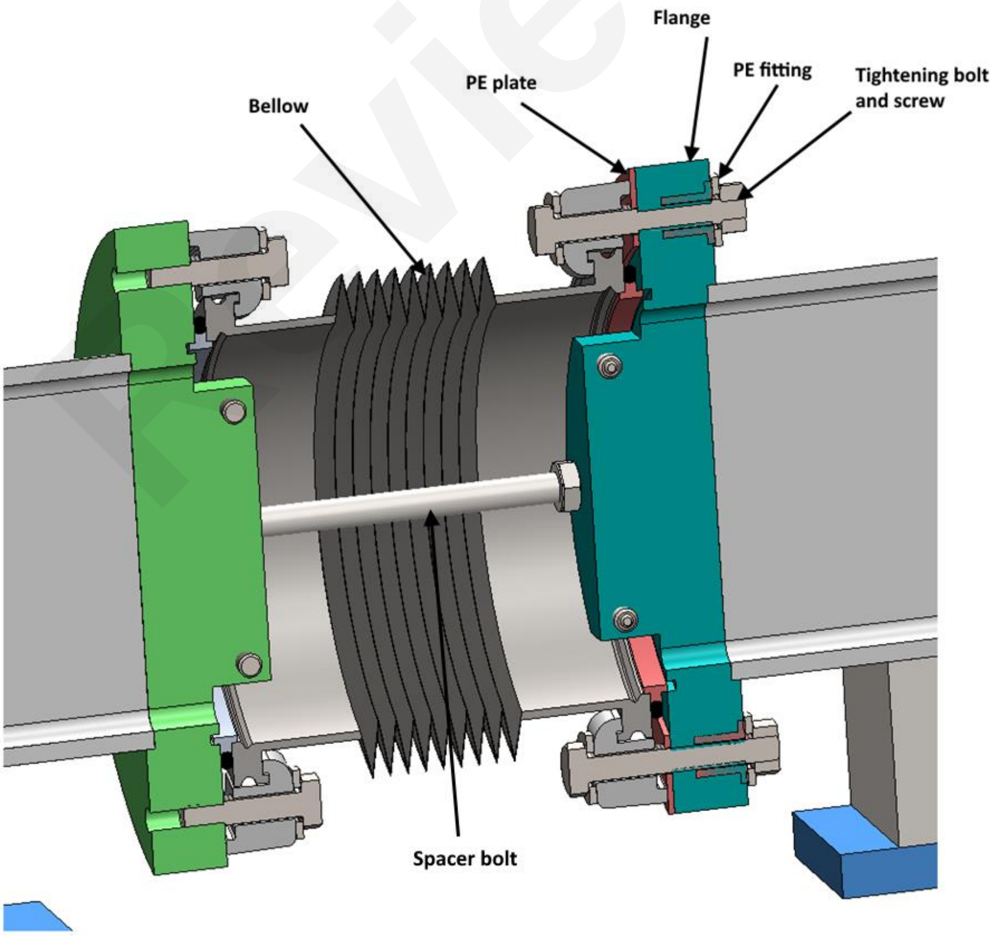


Figure 35: PE plate and fittings in the bellow which electrically separate the vacuum housing between D03 and E02 halls.

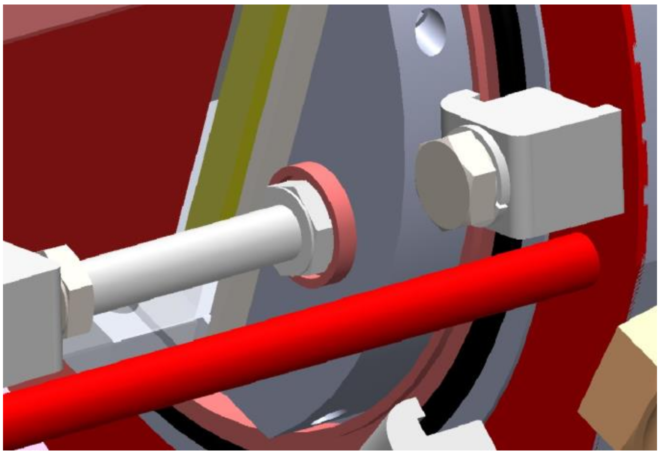


Figure 36: The insulating cap on the spacer bolt at the bellow between D03 and E02 halls.

5.3.4.2. Details of the neutron guide section W02-16

Detailed engineering drawing MR439-4100-00.pdf in [8].

Neutron guide total length:		40950 mm
Neutron guide upstream inner size (W x H):		40.00 x 80.00 mm^2
Neutron guide downstream inner size (W x H):		40.00 x 80.00 mm^2
Bending radius:		20000 m
Substrate material:		NBK-7
Coating m-value:		
	Left:	2
	Right:	2.5
	Top/Bottom:	2
Guide weight:		~321 kg

The W02-16 section of the transport neutron guide is a horizontally curved parallel neutron guide with 20 km bending radius. The guide is built up by 13 pieces of 1500 mm (3 x 500 mm long sub-segments) segments, 11 pieces of 1499 mm (499 mm + 2 x 500 mm) segments, one-piece of 2400 mm (4 x 600 mm), one-piece of 1197 mm (197 mm + 2 x 500 mm) segment, and two separated pieces of 600 and 751 mm long. The 2 mm gap between guide segments is added just at the bellow position to facilitate the realignment and to prevent the segments touching. The exact sequence of the segments along the whole assembly can be found in the drawing MR439-4100-00.pdf in [8].

For the structure of the neutron guide see section 5.3.3.2.

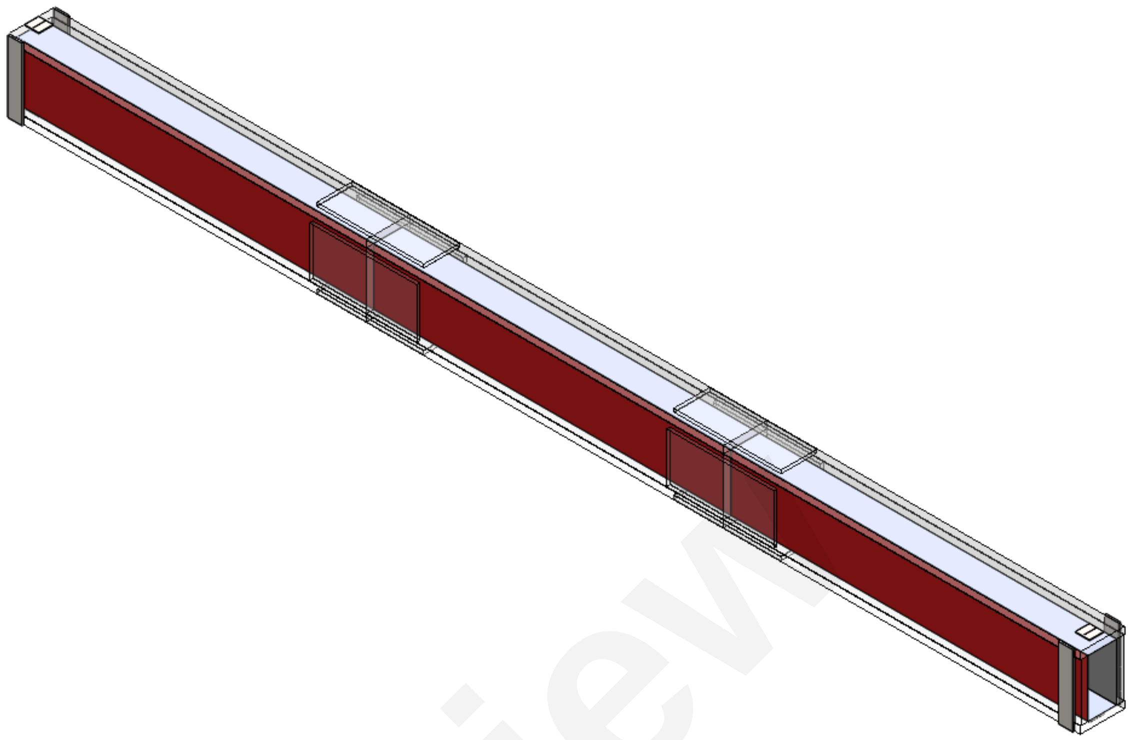


Figure 37: A 1.5 m long segment of W02-16 section of the neutron guide.

5.3.5. W02-17 – curved transport neutron guide (GT2)

5.3.5.1. Details of the vacuum housing for W02-17

Overview detailed engineering drawing MR439-4000-00.pdf in [8].

Vacuum house total length:	64450 mm
Housing weight with guide:	8076 kg
Vacuum port dimension:	KF 40
Bellow coupling:	ISO-K DN160
Vacuum house material:	S235JR steel, zinc coated
Vacuum sealing:	NBR

The vacuum housing for the W02-17 section of the neutron guide resembles the one for W02-16 section (section 5.3.4.1). The vacuum housing shares a common vacuum space with the previous and following sections. The whole assembly is made out of the 16 sections connected with bellows. The first section is around 5 m long, and the others are about 4 m long. Detail engineering drawings of each section can be found in [8] (1 x MR439-4370-00.pdf, 11 x MR439-4380-00.pdf, 3 x MR439-4390-00.pdf, 1 x MR439-4310-00.pdf). At the bellow position, there are fiducial bases installed (see Figure 33). The first 746 mm of the following neutron guide section W02-18 extends to this vacuum house (Figure 40).

For the design of the bellow see section 5.3.2.1.

For the design of the vacuum housing, beam alignment, the flanges and adjusting bolts sealings, see section 5.3.3.1.

5.3.5.2. Details of the neutron guide section W02-17

Detailed engineering drawing MR439-4200-00.pdf in [8].

Neutron guide length (with Mirrobor^{TM}):		64449 mm
Neutron guide upstream inner size (W x H):		40.00 x 80.00 mm^2
Neutron guide downstream inner size (W x H):		40.00 x 80.00 mm^2
Bending radius:		20000 m
Front face shielding:		
	Material:	Mirrobor-H^{TM}
	Thickness:	5 mm
Substrate material:		N-BK7
Coating m-value:		
	Left:	2
	Right:	2.5
	Top/Bottom:	2
Guide weight:		~504 kg

The W02-17 section of the neutron guide has similar features like the W02-16 one. It is a horizontally curved parallel neutron guide with 20 km bending radius. It built up from 15 pieces of 1500 mm (3 x 500 mm long sub-segments) segments, 15 pieces of 998 mm segments (2 x 499 mm), one-piece of 1000 mm long segment (2 x 500 mm) and 756 mm long segment (256 + 500 mm). The guide starts with a 5 mm thick Mirrobor-H^{TM} shielding. The 2 mm gap between guide segments is added just at the bellow position to facilitate the realignment and to prevent the segments touching. The exact sequence of the segments along the whole assembly can be found in the drawing MR439-4200-00.pdf in [8].

For the structure of the neutron guide see section: 5.3.3.2.

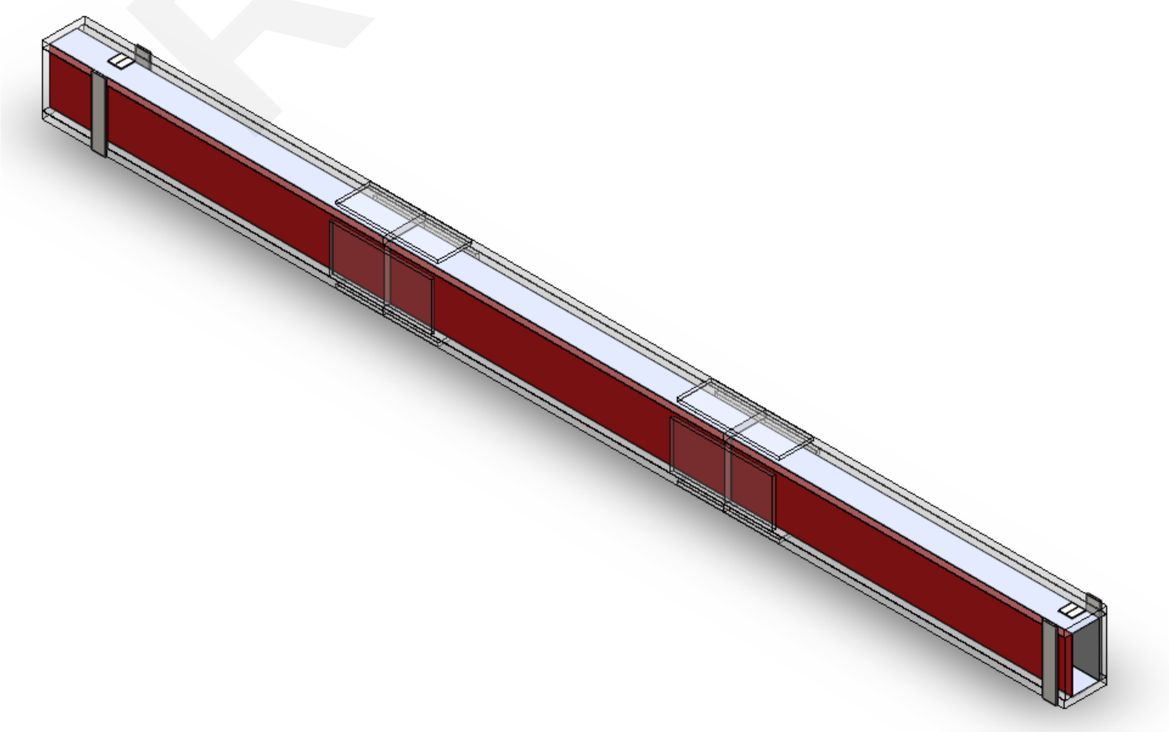


Figure 38: A 1.5 m long segment of W02-17 neutron guide section.

5.4. PART II – vacuum housing and neutron guides (PBS 13.6.6.1.2.1.5 and 13.6.6.1.2.2)

Part II consists of the neutron guide sections from W02-18 to W02-20, three slit systems SL1, SL2 and SL3 as described in [3]. Those parts are located between x = 144.5 m to x = 157 m along the neutron axis (ISCS coordinates).

Along the transport section (W02-18 – W02-19), there is designed one vacuum port (KF 40) for connection to the vacuum manifold (not part of the design) and are two vacuum ports (KF 40 and KF 25) are on the guide exchanger neutron guide sections W02-20-01/02 which are situated in the following position of the vacuum housing along the beam (ISCS coordinates):

- 152 610 mm – housing for W02-19 (drawing MR439-7000-00.pdf in [8])
- 155 514 mm – housing for W02-20-01 (drawing MR439-8300-00-DE.pdf in [8])
- 155 920 mm – housing for W02-20-02 (drawing MR439-8010-00-DE.pdf in [8])

5.4.1. W02-18 – focussing guide (GF1)

5.4.1.1. Details of the vacuum housing for W02-18

Overview detailed engineering drawing MR439-7000-00.pdf in [8].

Vacuum house total length:	7402 mm
Housing weight with guide:	~666 kg
Bellow coupling:	ISO-K DN160
Slit coupling:	ISO-CF DN160
Vacuum house material:	S235JR steel, zinc coated
Vacuum sealing:	NBR

The vacuum housing for the section W02-18 resembles the one for W02-16 (section 5.3.4.1). It consists of 2 segments which are connected with bellow (see Figure 39). The first segment is made out of 4 sub-segments connected with flanges. The second one is made of two sub-segments. Beside the fiducials on bellows, additional vertical and horizontal fiducial bases are placed at every flanges of each section (see Figure 40). The vacuum housing starts with a bellow and ends with the SL1 flange, and it shares a common vacuum space with the preceding and succeeding guide optics.

For the design of the bellow see section 5.3.2.1.

For the design of the vacuum housing, the beam alignment, the flanges and adjusting bolts, sealings see section 5.3.3.1.

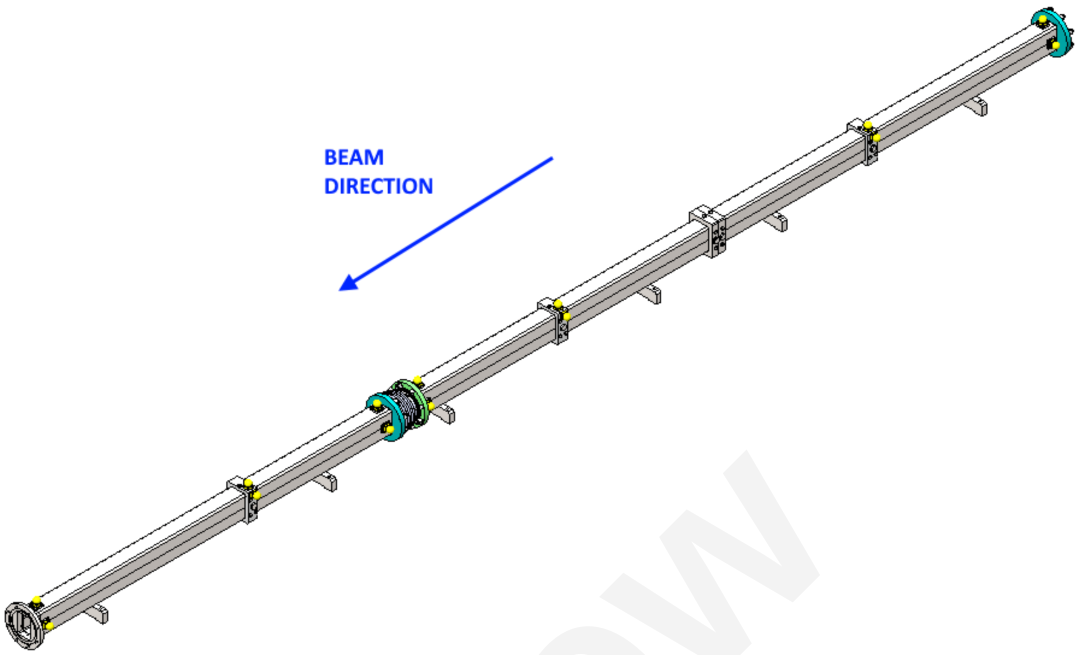


Figure 39: The vacuum housing assembly for W02-18 section of the neutron guide.

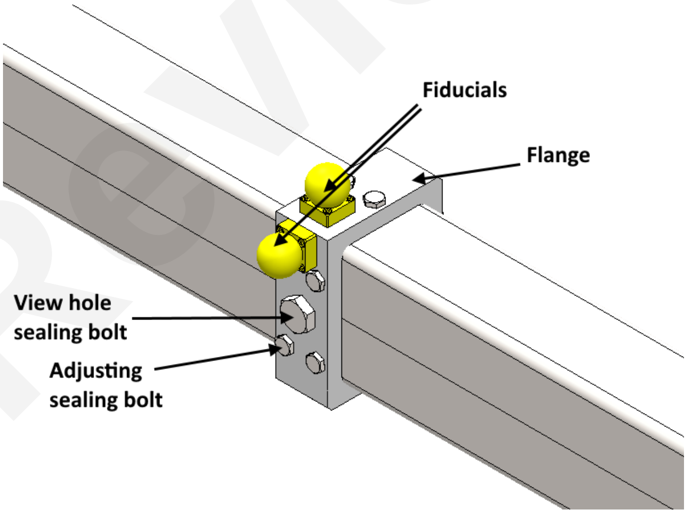


Figure 40: Additional vertical and horizontal fiducial bases on a flange.

5.4.1.2. Details of the neutron guide section W02-18

Detailed engineering drawing MR439-G-7500-00.pdf in [8].

Neutron guide length:		7485 mm
Neutron guide upstream inner size (W x H):		40.00 x 80.00 mm^2
Neutron guide downstream inner size (W x H):		40.00 x 66.54 mm^2
Substrate material:		NBK-7
Coating m-value:		
	Left/Right:	2.5
	Top/Bottom:	3
Guide weight:		~55 kg

The section W02-18 of the neutron guide is a vertically focusing neutron guide following an ellipse shape (parameters of the ellipse are semi-major axis: 13484 mm, semi-minor axis: 40 mm, centre: 144500 mm). The ellipse is approximated by 0.5 m long flat segments. It contains of following segments: 4 x 1000 mm (2 x 500 mm long sub-segments), 1 x 746 mm (500 mm + 248 mm), 1257 mm (257 mm + 2 x 500 mm) and 1 x 1480 mm (480 mm + 2 x 500 mm) segment. The guide segments structure resembles the one of W02-15 (section: 5.3.3.2, Figure 31). At the connections of the first/second and fifth/sixth sub-section, there is a bellow coupling of the vacuum housings with 2 mm gap between substrates. The first 746 mm of the guide runs in to the vacuum housing of W02-17 due to bellow coupling (Figure 43).

For the structure of the neutron guide see section: 5.3.3.2.

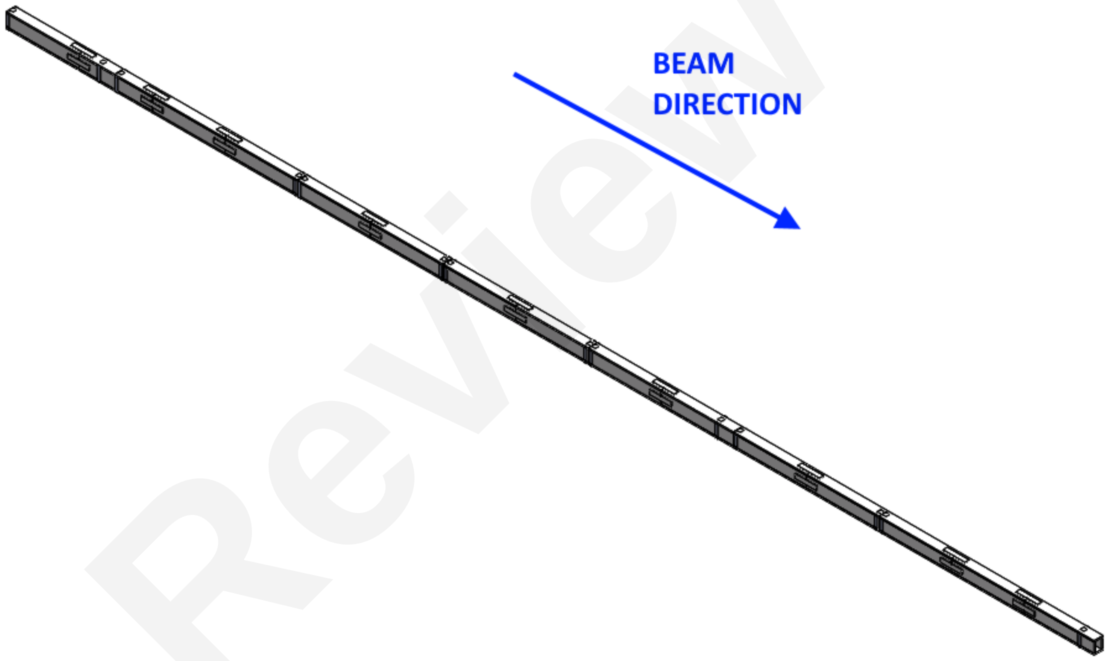


Figure 41: W02-18 section assembly of the neutron guide.

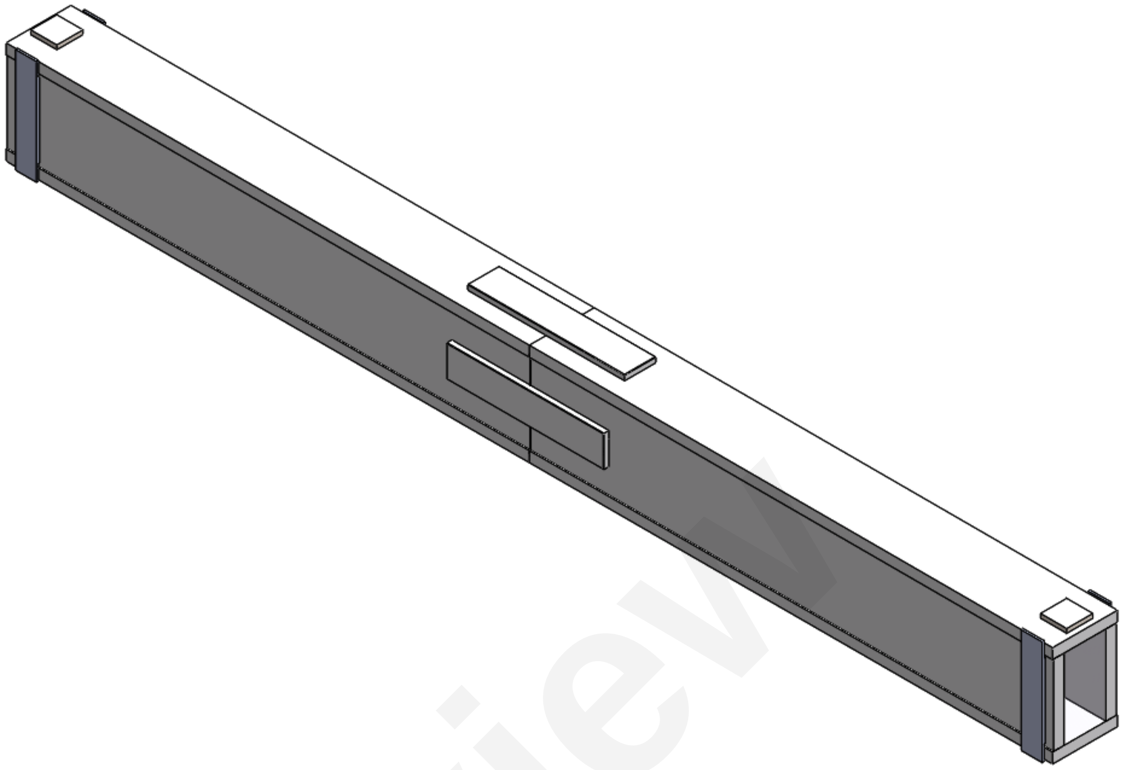


Figure 42: A 1 m long segment of W02-18 section of the neutron guide.

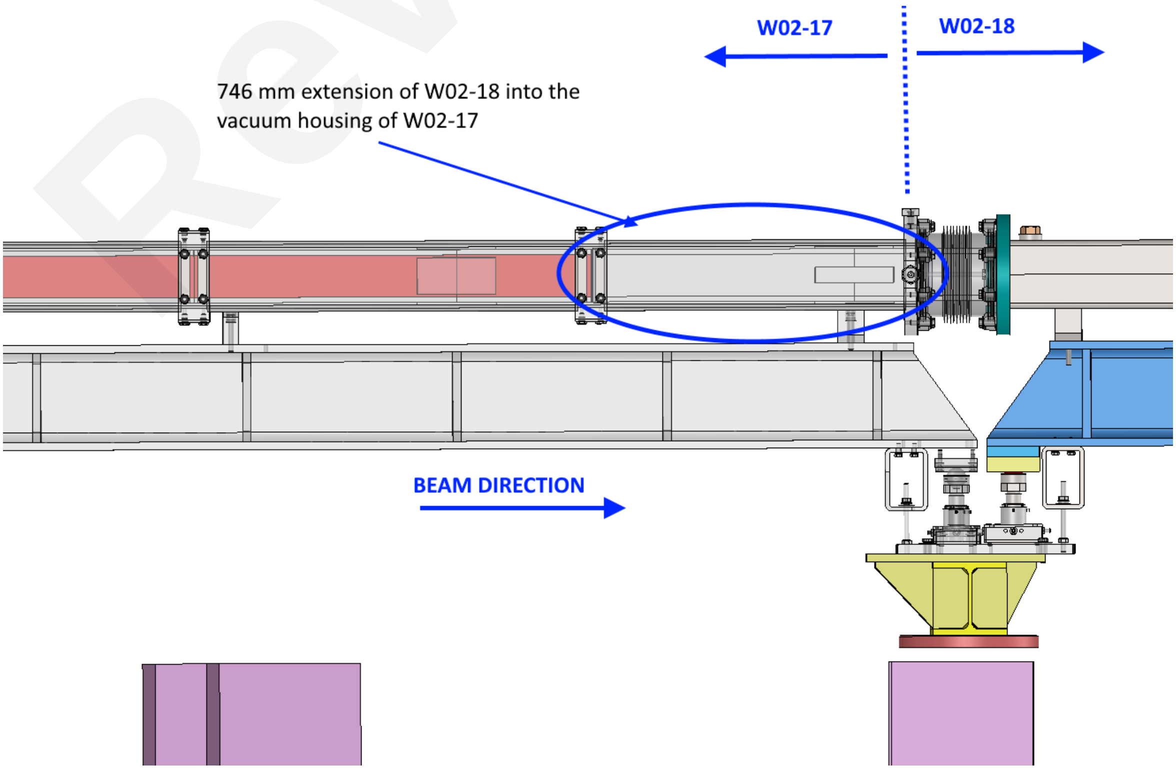


Figure 43: The extension into W02-17 vacuum housing.

5.4.2. W02-19 – focussing guide (GF2)

5.4.2.1. Details of the vacuum housing for W02-19

Overview detailed engineering drawing MR439-7000-00.pdf in [8].

Vacuum house total length:		2820 mm
Housing weight with guide:		~1768 kg
Slit coupling:		ISO-CF DN160
Vacuum port dimension:		KF 40
Vacuum house material:		S235JR steel, zinc coated
Vacuum sealing:		NBR
Casing dimensions (second segment):		
	Length:	718 mm
	Width:	124 mm
	Height:	144 mm
	Thickness:	18 mm
Case material:		S235JR steel, zinc coated
Dimensions of wall throughput:		
	Length:	980 mm
	Width:	158 mm
	Height:	176 mm
Wall throughput material:		S235JR steel, zinc coated
Filling on shutter pit throughput:		
	Material:	advisably Mirrobor-S™
	Thickness:	5 mm
Shielding unit dimensions:		
	Width:	224 mm
	Height:	244 mm
	Total thickness:	20 mm
Shielding unit layer stacking:		
	S235JR steel:	5 mm
	B_4C:	5 mm
	B_4C:	5 mm
	S235JR steel:	5 mm

The vacuum housing for W02-19 section of the neutron guide is made up of two segments (see Figure 44). The first segment resembles the one for W02-16 (section 5.3.4.1). It has a bellow and a vertical ISO-KF 40 vacuum port on it. The second section similar to the one for W02-13 shutter pit throughput (section 5.3.1.1). It passes through the instrument cave wall and has a steel casing, additional steel and shielding layer and it also has a multi-layered shielding unit. The housing shares a common vacuum space with the preceding guide optics and the succeeding slit.

For the design of the additional steel casing, shielding unit and bellow 5.3.2.1.

For the design of the vacuum housing, the flanges, beam alignment and adjusting bolts sealings, see section 5.3.3.1.

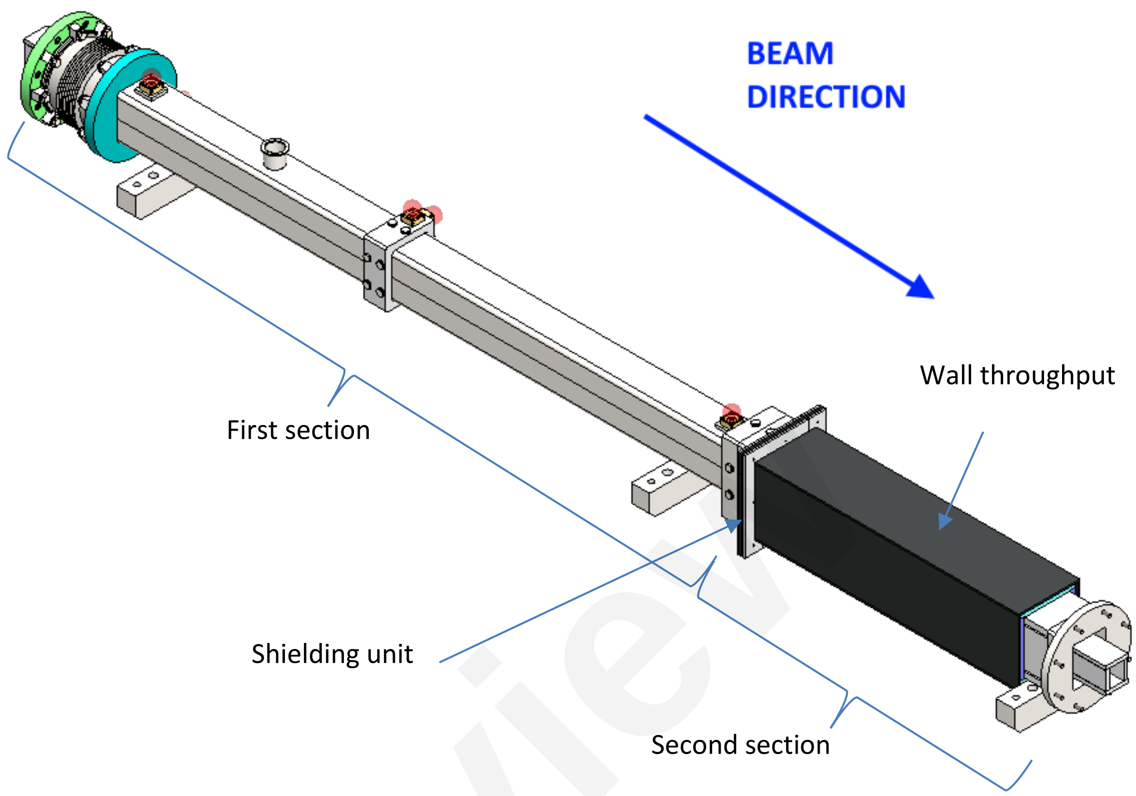


Figure 44: The vacuum housing for W02-19 section of the neutron guide.

5.4.2.2. Details of the neutron guide section W02-19

Detailed engineering drawing MR439-G-7600-00.pdf in [8].

Neutron guide length (with Mirrobor^{TM}):		2960 mm
Neutron guide upstream inner size (W x H):		40.00 x 66.38 mm^2
Neutron guide downstream inner size (W x H):		40.00 x 50.33 mm^2
Substrate material:		NBK-7
Coating m-value:		
	Left/Right:	2.5 (for first 2.5 m, then absorbing)
	Top/Bottom:	4
Guide weight:		~18 kg

The W02-19 section of the neutron guide is the continuation of W02-18. It is a vertically focusing guide following an ellipse shape (ellipse parameters are semi-major axis: 13484 mm, semi-minor axis: 40 mm, centre: 144500 mm). The ellipse is approximated by 0.5 m long flat segments. The whole assembly contains following segment: 1 x 1000 mm (2 x 500 mm sub-segments), 1 x 965 mm segment (500 mm + 465 mm) and 1 x 990 mm (500 mm + 490 mm). The guide segments structure resembles the one of W02-15 (section: 5.3.3.2, Figure 31). The lateral m-value of the supermirror is 2.5 for the first 2.5 m, then it turns into absorbing coating for the rest.

For the structure of the neutron guide see section 5.3.3.2.

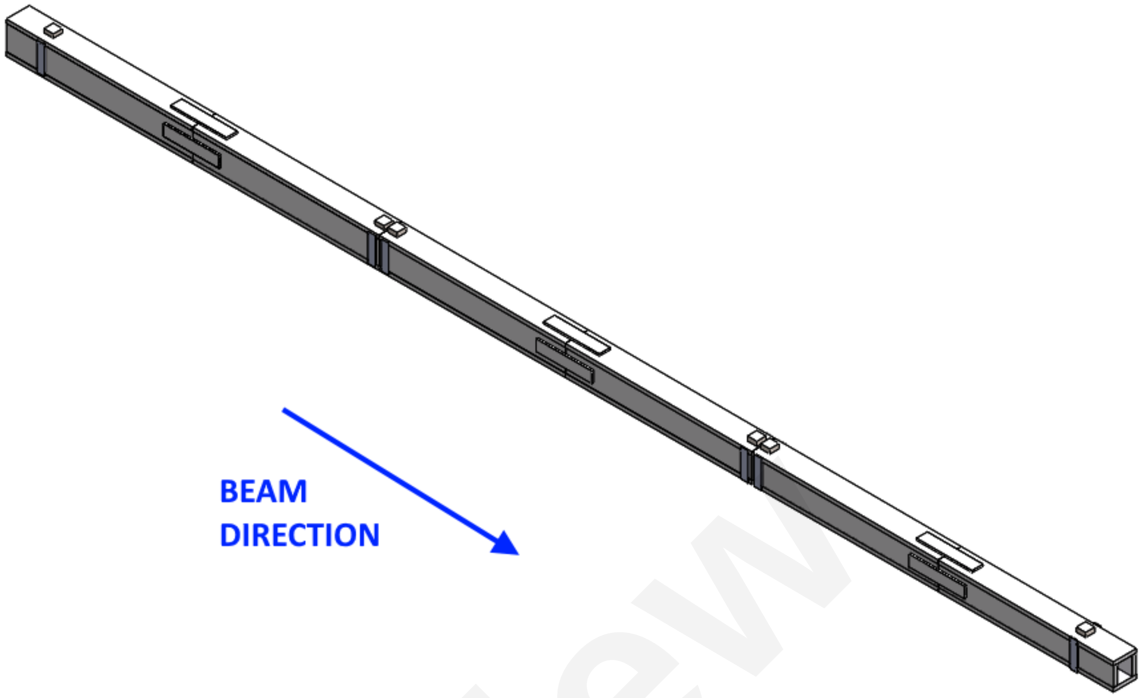


Figure 45: Assembly of W02-19 section of the neutron guide.

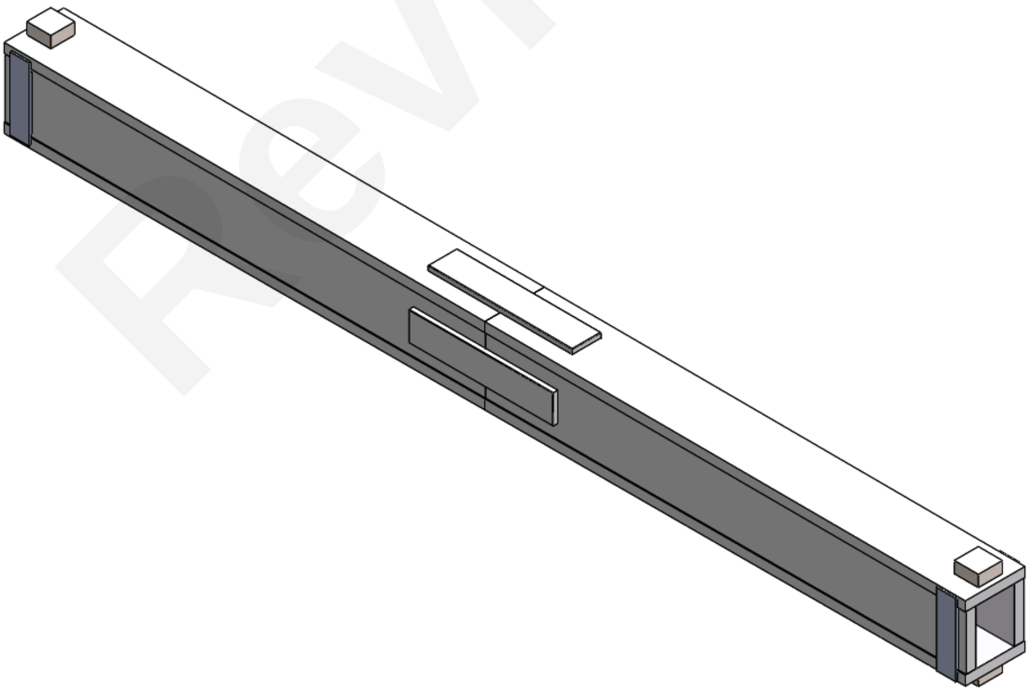


Figure 46: 1 m long segment of W02-19 section of the neutron guide.

5.4.3. SL2 – second slit system

5.4.3.1. Details of the neutron guide in SL2

Overview detailed engineering drawing MR439-7000-00.pdf and guide drawing MR439-G- 7700-00.pdf in [8].

Neutron guide length (with Mirrobor™):	98 mm
Neutron guide upstream inner size (W x H):	40.00 x 50.01 mm^2
Neutron guide downstream inner size (W x H):	40.00 x 49.31 mm^2
Substrate material:	NBK-7
Coating m-value:	
Left/Right:	2.5
Top/Bottom:	4
Guide weight:	~1 kg

The slit has a built-in vertically elliptic mini-guide propagating neutron beam to the exchanger system. It is made of one single, 93 mm long segment and has protecting plates on both sides and a 5 mm thick front face shielding. The shortened guide length of W02-20-01 (see section 5.4.4.2) indicates the mounting of this unit.

For the structure of the neutron guide see section 5.3.3.1.

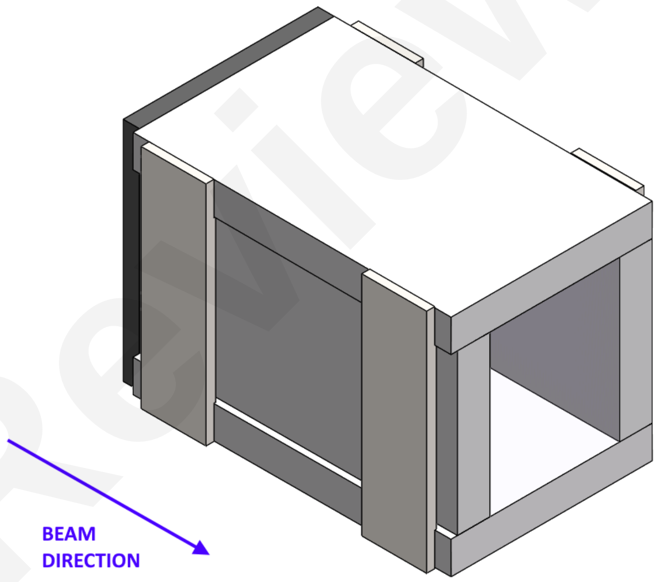


Figure 47: The mini-guide in SL2 slit system.

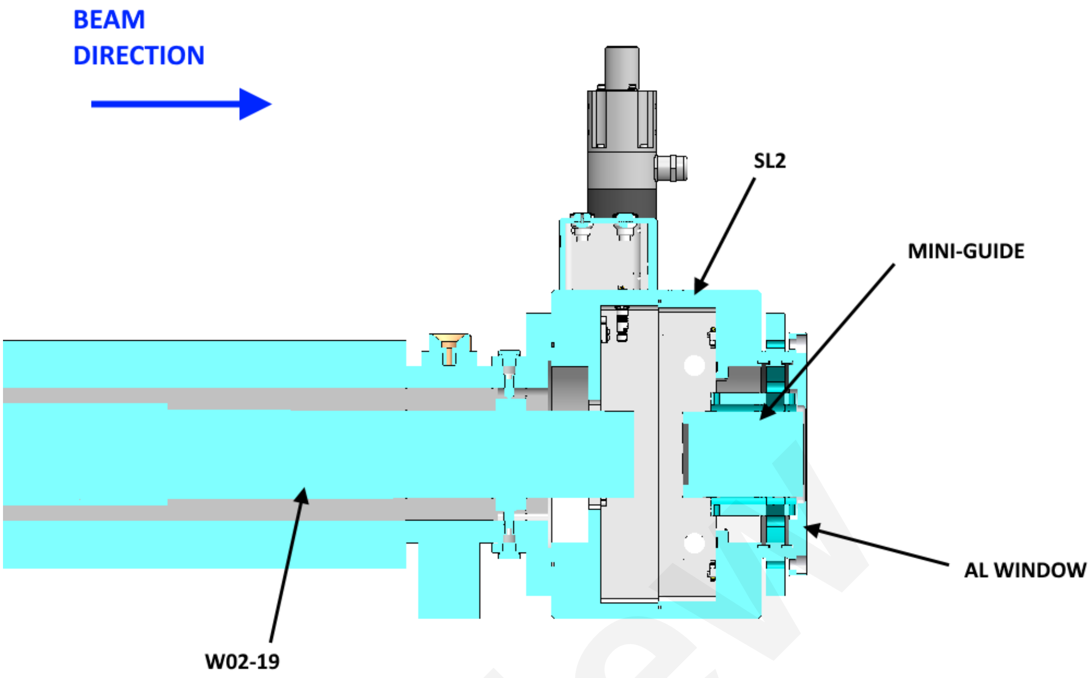


Figure 48: Section view of SL2 showing the mini guide placement.

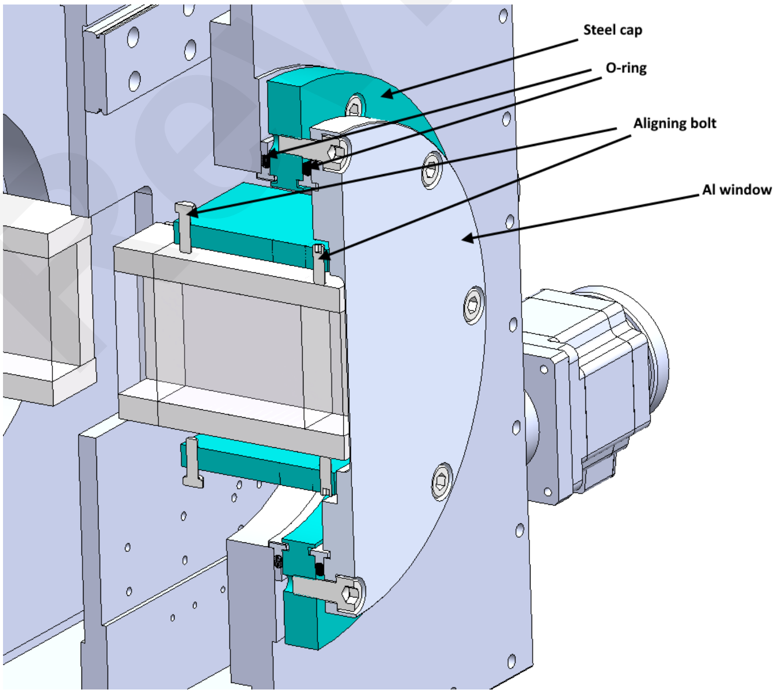


Figure 49: Section view showing the construction of the mini-guide alignment in SL2.

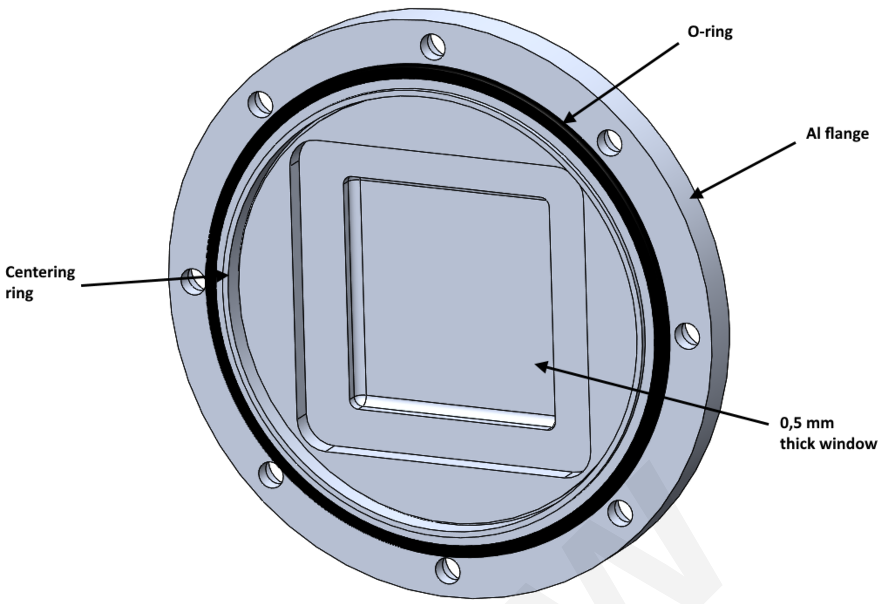


Figure 50: Design of SL2's Al-window.

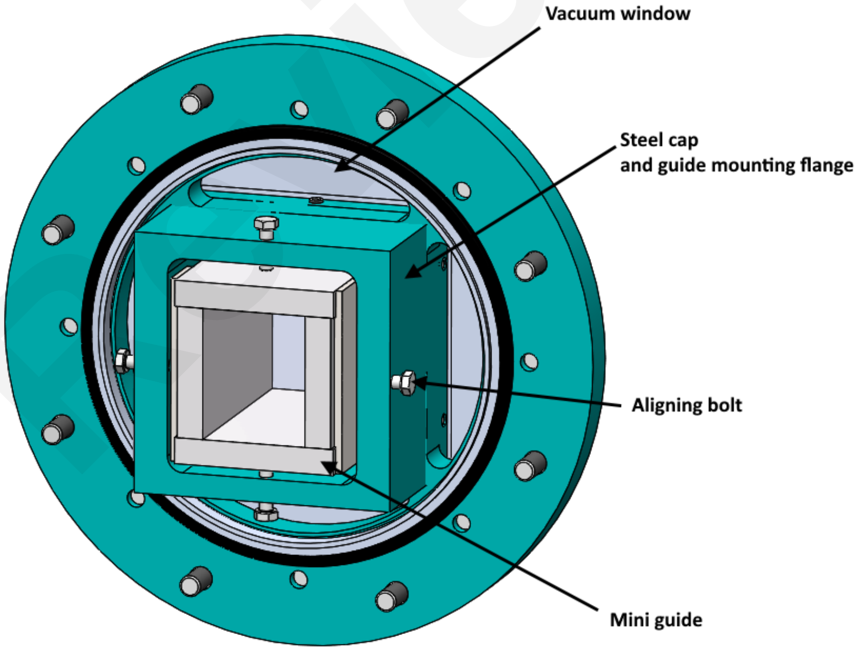


Figure 51: Design of the guide mounting flange on the SL2 assembly.

5.4.4. W02-20-01 – focussing guide on exchanger (GEX1) (PBS 13.6.6.1.4.9.2)

5.4.4.1. Details of the vacuum housing for W02-20-01

Vacuum house total length:	1876.5 mm
Housing weight with guide:	~116 kg
Vacuum port dimension:	KF 40
Thickness of AlMgSi1 vacuum windows:	0.5 mm
Vacuum house material:	S235JR steel, zinc coated

Vacuum sealing: NBR

The W02-20-01 section of the neutron guide sits in an HSS steel section as vacuum housing. The housing is closed on both ends with NBR sealed, 0.5 mm thick AlMgSi1 caps connected to steel flanges. The downstream window has 4 pieces of M5x4 mm threaded holes allocated on a 90x90 mm^2 square for possible slit mounting. The flanges are welded to the steel section. The flanges have inbuilt adjusting screws which are covered with sealing caps. The housing has a KF 40 vacuum port on the lateral side. Steel plates are welded on the bottom of the vacuum housing for fixation to the horizontal alignment units of the exchanger frame.

For the design of the vacuum housing, the flange, beam alignment and the adjusting bolts sealings, see section 5.3.3.1.

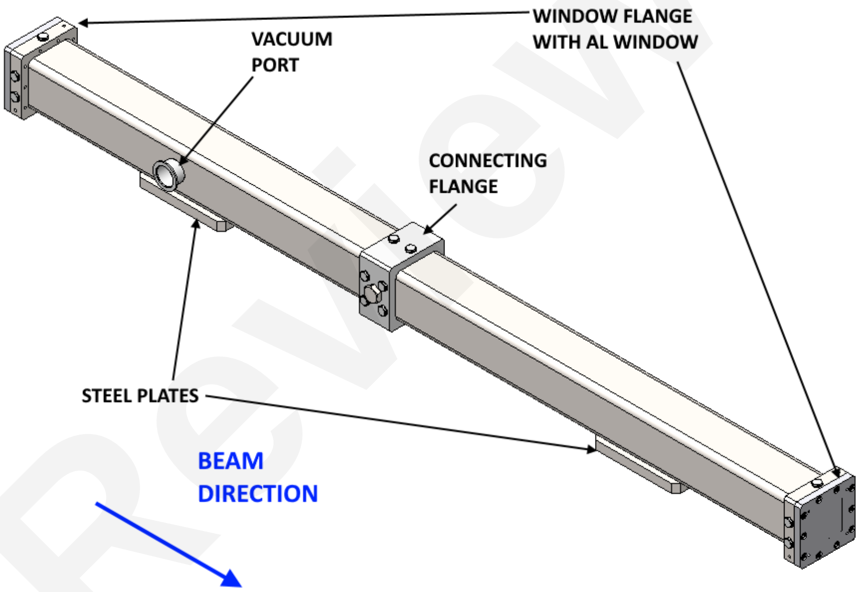


Figure 52: Vacuum housing for the W20-20-01 section of the neutron guide.

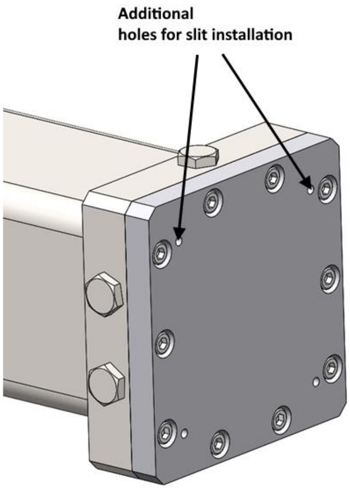


Figure 53: Closeup view of the downstream window showing the threaded holes for slit mounting.

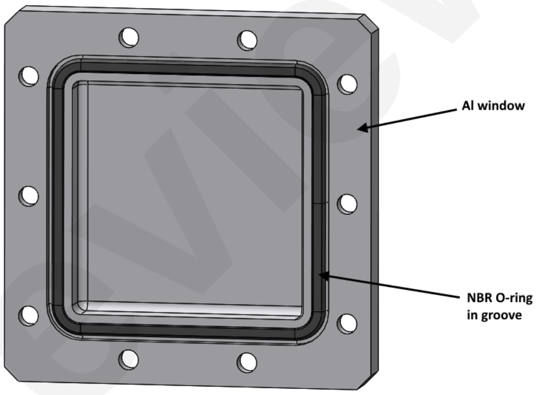


Figure 54: Al-window is vacuum tight sealed with O-ring.

5.4.4.2. Details of the neutron guide section W02-20-01

Detailed engineering drawing MR439-G-8110-00.pdf in [8].

Neutron guide length (with Mirrobor™):		1871.4 mm
Neutron guide upstream inner size (W x H):		40.00 x 49.16 mm^2
Neutron guide downstream inner size (W x H):		40.00 x 30.00 mm^2
Substrate material:		NBK-7
Coating m-value:		
	Left/Right:	0 (absorbing)
	Top/Bottom:	5
Front and end face shielding:		
	Material:	Mirrobor-H™
	Thickness:	5 mm
Guide weight:		~60 kg

The W02-20-01 section of the neutron guide is a vertically focusing, horizontally straight neutron guide. It contains 2 pieces of 500 mm long segments, one piece of 417 mm and one piece of 444.5

mm long segment. The upstream and downstream face of the guide covered with 5 mm thick Mirrobor-H^{TM}. The guide was shortened by 101 mm relative to the prescribed length. The reason for this solution is the dimensions of the SL2 housing. 98 mm of the shortened length was replaced in the SL2 as the mini-guide (see: section 5.4.3.1). The overall shortage of the guide length is 3.1 mm, this does not cause adverse effects considering the mini-guide vertically elliptic shape and the 4.7 mm gap between W02-19 and W02-20-01/02.

The top and bottom glasses have reflective, the lateral ones have absorbing coating. The coated substrate made of NBK-7 glass.

For the structure of the neutron guide see section 5.3.3.2.

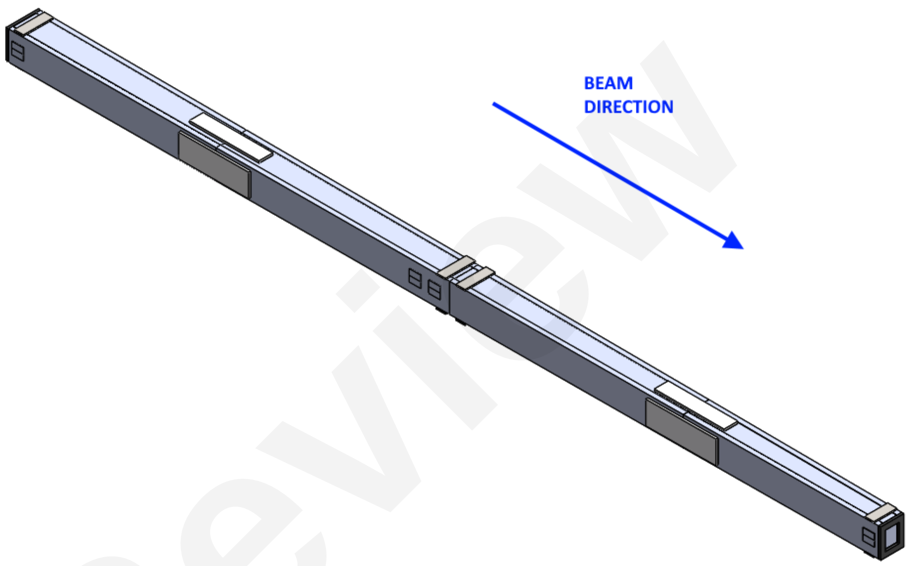


Figure 55: W02-20-01 section of the neutron guide.

5.4.5. W02-20-02 – collimator on exchanger (GEX2) (PBS 13.6.6.1.4.9.3)

5.4.5.1. Details of flight tube

Total length:		1876.5 mm
Upstream inner size (W x H):		52.00 x 52.00 mm^2
Downstream inner size (W x H):		52.00 x 52.00 mm^2
Shielding on sides:		
	Material:	Mirrobor-H^{TM}
	Thickness:	5 mm
Thickness of AlMgSi1 vacuum windows:		0.5 mm
Vacuum port dimension:		KF 25
Material:		S235JR steel, zinc coated
Vacuum sealing:		NBR
Weight:		~23 kg

The W02-20-02 section of the neutron guide is a collimating flight tube from hollow structural steel. The flight tube is closed on both ends with 0.5 mm thick AlMgSi1 windows connected to steel flanges. The flanges are welded to the steel section. The housing has a KF 25 vacuum port on the lateral side. Steel plates are welded on the bottom of the vacuum housing for fixation to the alignment unit. The flight tube is covered with 5 mm thick Mirrobor-S^{TM}.

The flight tube was shortened by 96 mm from the prescribed length. For the details see section 3.2.3. and 3.2.4.2.

For the design of the Al-window see section 5.4.4.1.

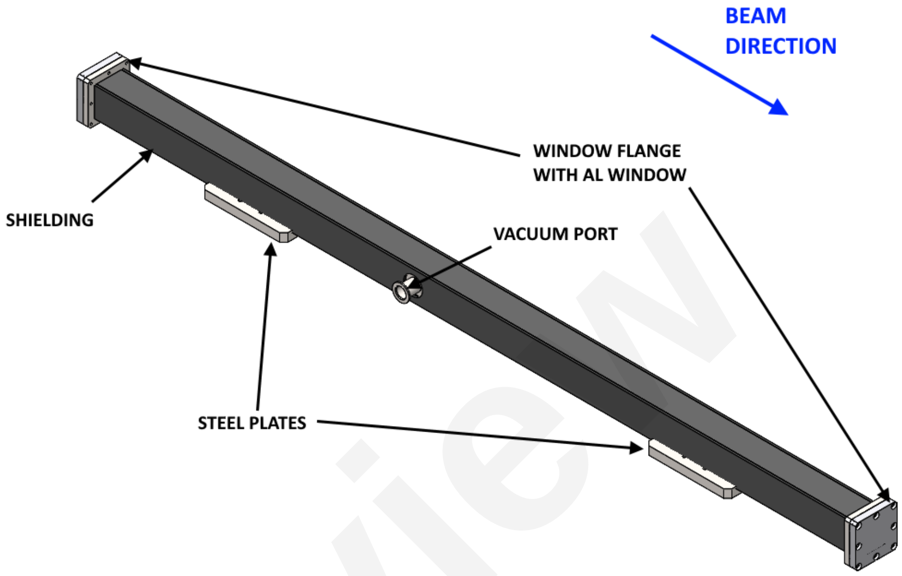


Figure 56: W20-20-02 section of the neutron guide – the collimating flight tube.

5.5. Support system for vacuum housing (PBS 13.6.6.1.2.3)

Detailed engineering drawing [8]:

- I-BEAMS
  - MR439-3010-02
  - MR439-3020-03
  - MR439-4311-02
  - MR439-4321-03
  - MR439-4361-02
  - MR439-4371-03
  - MR439-4381-02
  - MR439-4411-02
  - MR439-7200-01
  - MR439-7300-01
  - MR439-4351-03
- LEGS
  - MR439-2040-00
  - MR439-3030-00
  - MR439-3040-00
  - MR439-4312-00
  - MR439-4322-00
  - MR439-7310-00

  - MR439-7320-00
- CROSS-BEAMS (for double pillar plates)
  - MR439-5010-00
  - MR439-5020-00
- KINEMATIC STANDS
  - MR439-2010-00
  - MR439-2020-00
  - MR439-2030-00

The support system aligns and fixes the optical system in the required position. It was designed for easy assembling, accurate and lasting positioning and simple re-alignment. Due to the different types of vacuum housing and geometric conditions it contains the combinations of legs, baseplates, kinematic stands, and I-beams.

Along whole the neutron guide, the vacuum housings lay on rib enforced DIN 1025 IPB200 I-beams and they are fixed with bolts. The I-beams are positioned with 3-point kinematic stands. The stands allow the accurate vertical and horizontal positioning of the vacuum housings (Figure 31 and Figure 31). Both of the kinematic stands allow +10/-20 mm vertical (Z-axis) adjustment. In addition, the fix stand allows 10 mm X and Y positioning and the linear allows 10 mm positioning in Y direction. The fix stand is blocked in horizontal. Two points of the kinematic stand system – linear and point – are paired on one side of the I-beam, the fix one stands alone. During the installation, the adjuster base plates will be fixed to the leg with four bolts, in the case of the fix and linear they could be set in the final position with six bolts (forward and lateral).

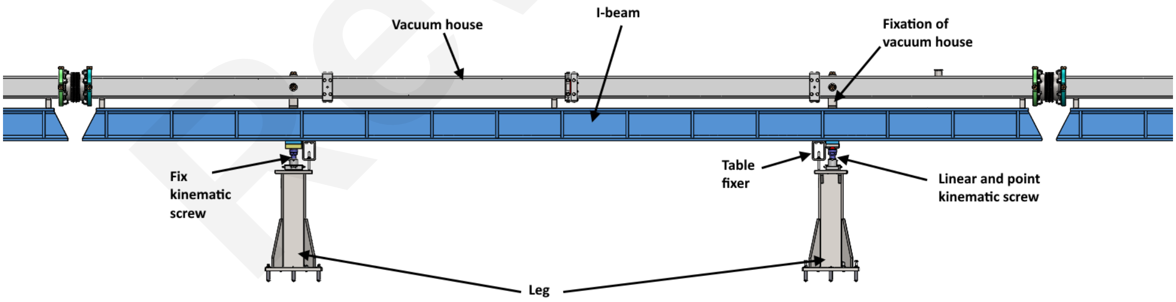


Figure 57: A 4 m long I-beam section. From guide section W02-16 the vacuum houses are interrupted by a bellow coupling every 4 meters.

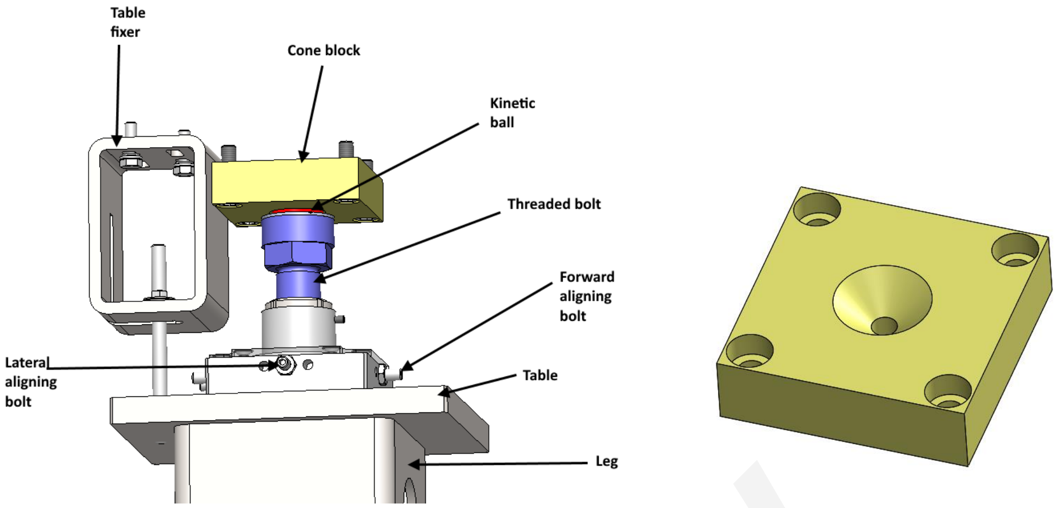


Figure 58: The fix kinematic stand (left) and its cone block (right). The adjusting in the X and Y directions 10 mm and +10/-20 mm in the Z direction.

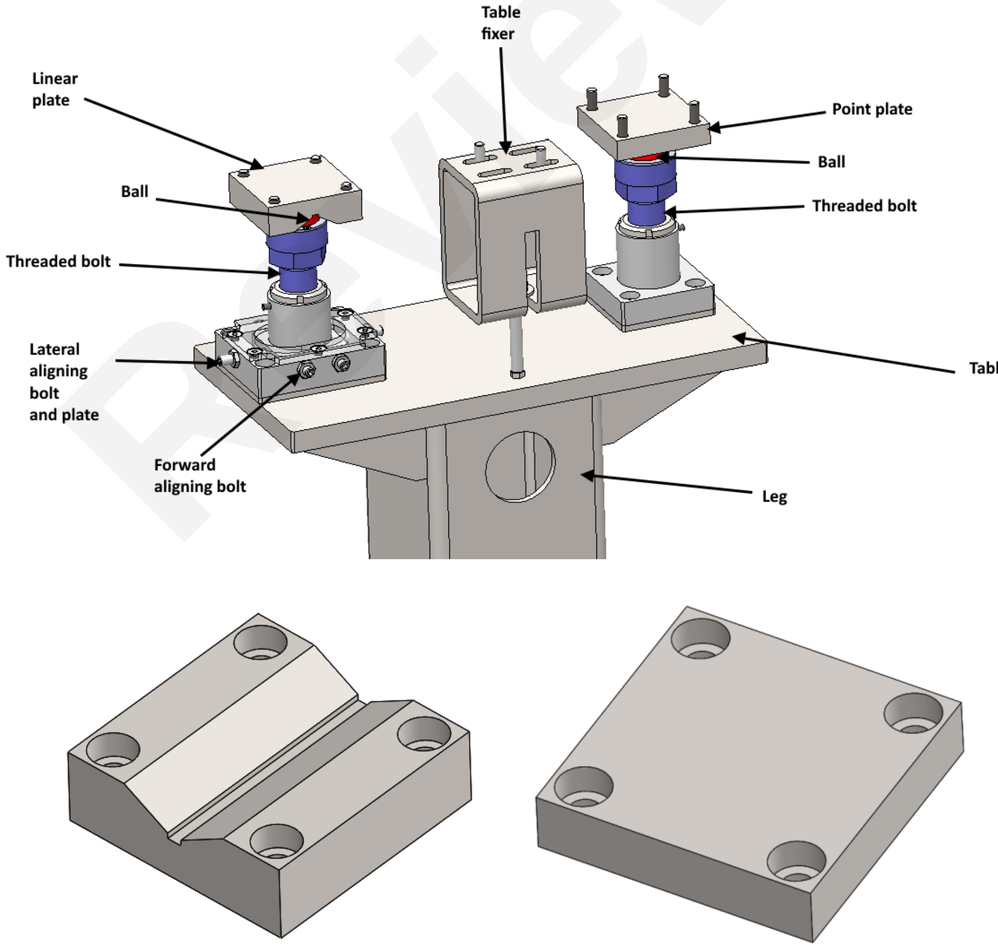


Figure 59: Top: linear and point kinematic stands. Left: linear kinematic plate allowing. Right: point kinematic plate. The adjusting of the linear kinematic stand 10 mm in the Y direction a +10/-20 mm in the Z direction. The point's adjusting is +10/-20 mm in the Z direction.

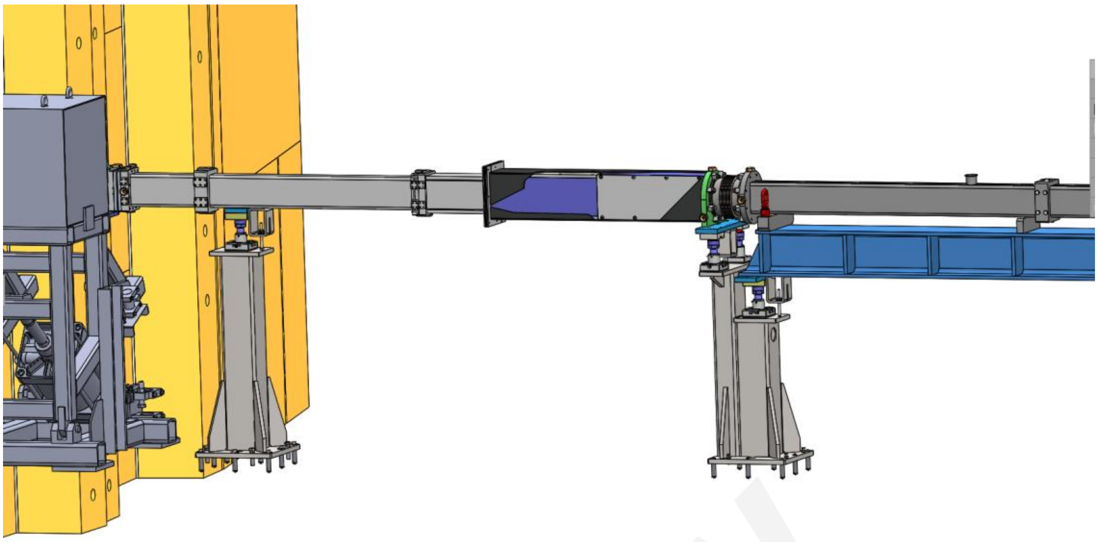


Figure 60: Support at the shutter pit throughput.

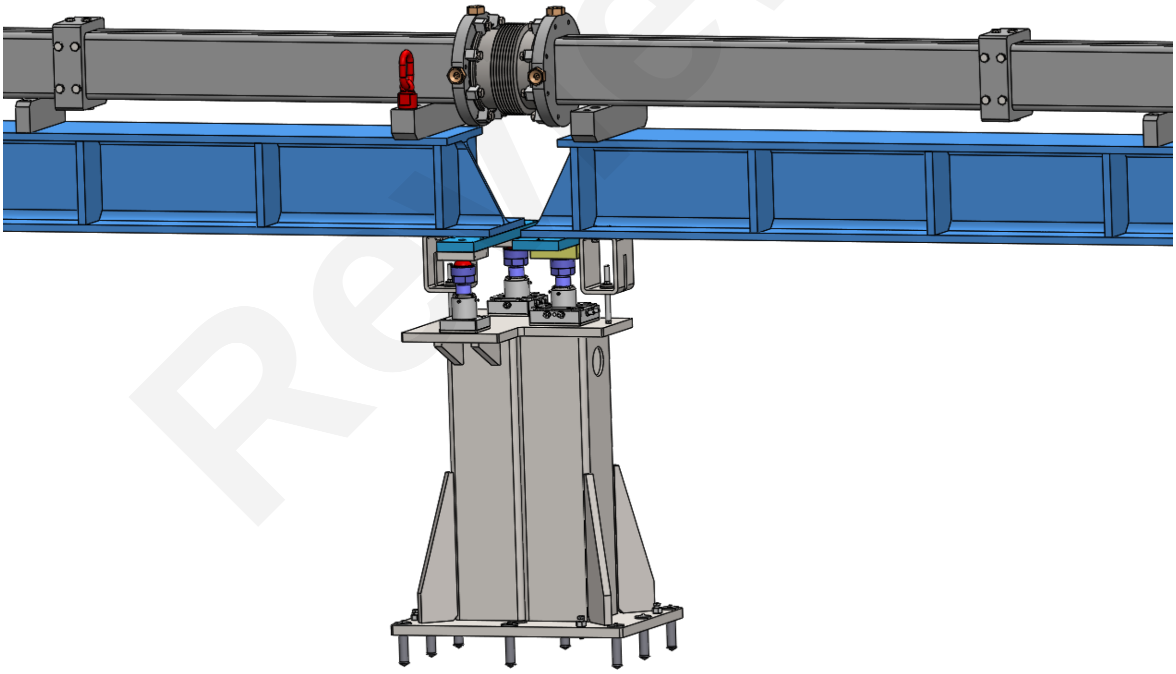


Figure 61: The kinematic stands are fixed on one single stand but aligning two separate I-beams.

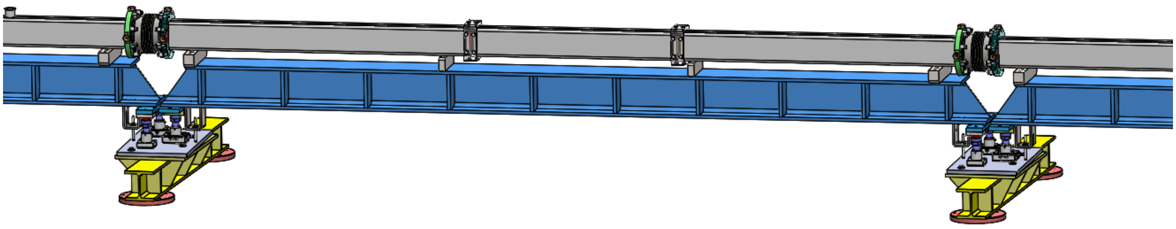


Figure 62: Kinematic stand on a double pillar plate. Note that the actual positioning deviation of the piles are ±100 mm.

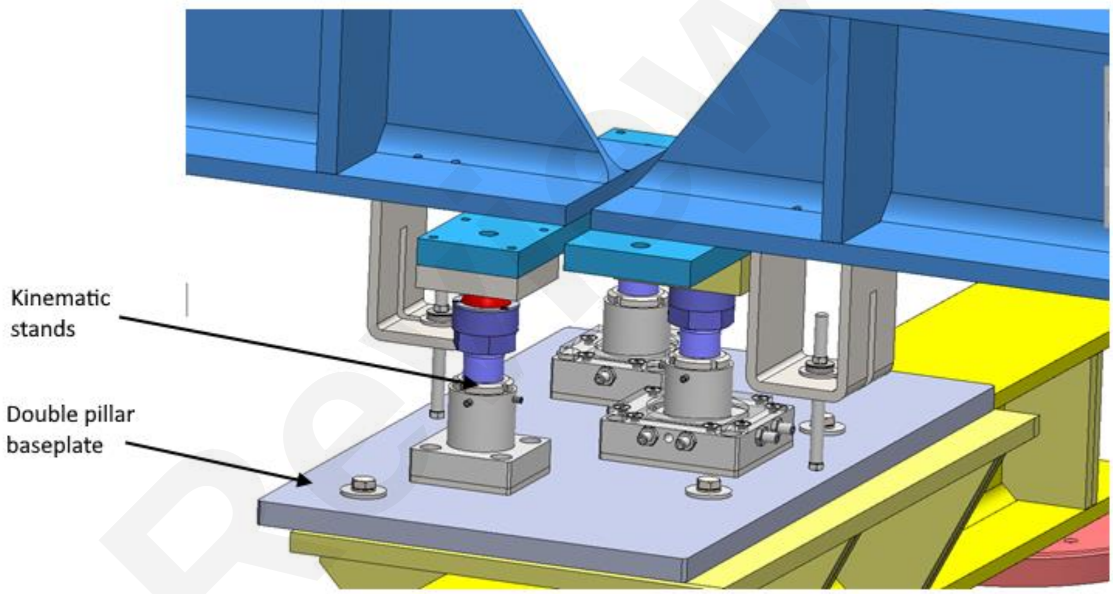


Figure 63: Closeup view of the double pillar showing its baseplate.

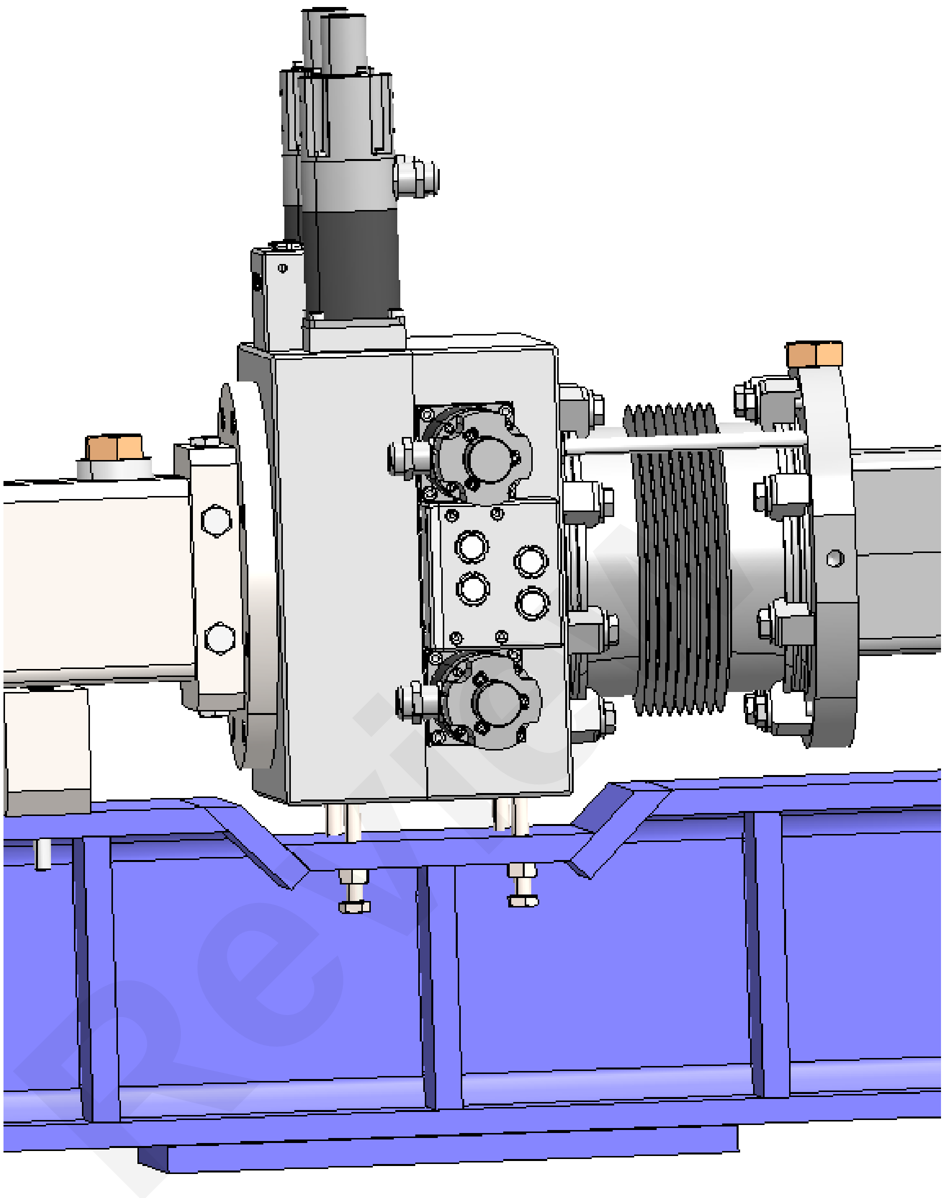


Figure 64: Cut-out form the I-beam at SL1, it is reinforced with welded ribs.

5.6. Exchanger system (PBS 13.6.6.1.4.9)

The exchanger has three vertical positions with pre-aligned neutron optics elements of an elliptical focusing element (W02-20-01), a Neutron flight tube with absorbing walls (W02-20-02) and a blank exchanger position for future upgrade. On the downstream end the SL3 Huber-slit is installed. Relative to the preceding guide end, the reproducible installation and alignment precisions of these elements are σ_a=0.0002 rad angular and σ_x=0.05 mm horizontal to the neutron beam. The neutron exchanger system contains mechanical support, exchanger frame, optical elements and alignment mechanics. The three positions of the exchanger system have the following vertical space:

- low: 140 mm
- middle: 140 mm
- top: 193 mm

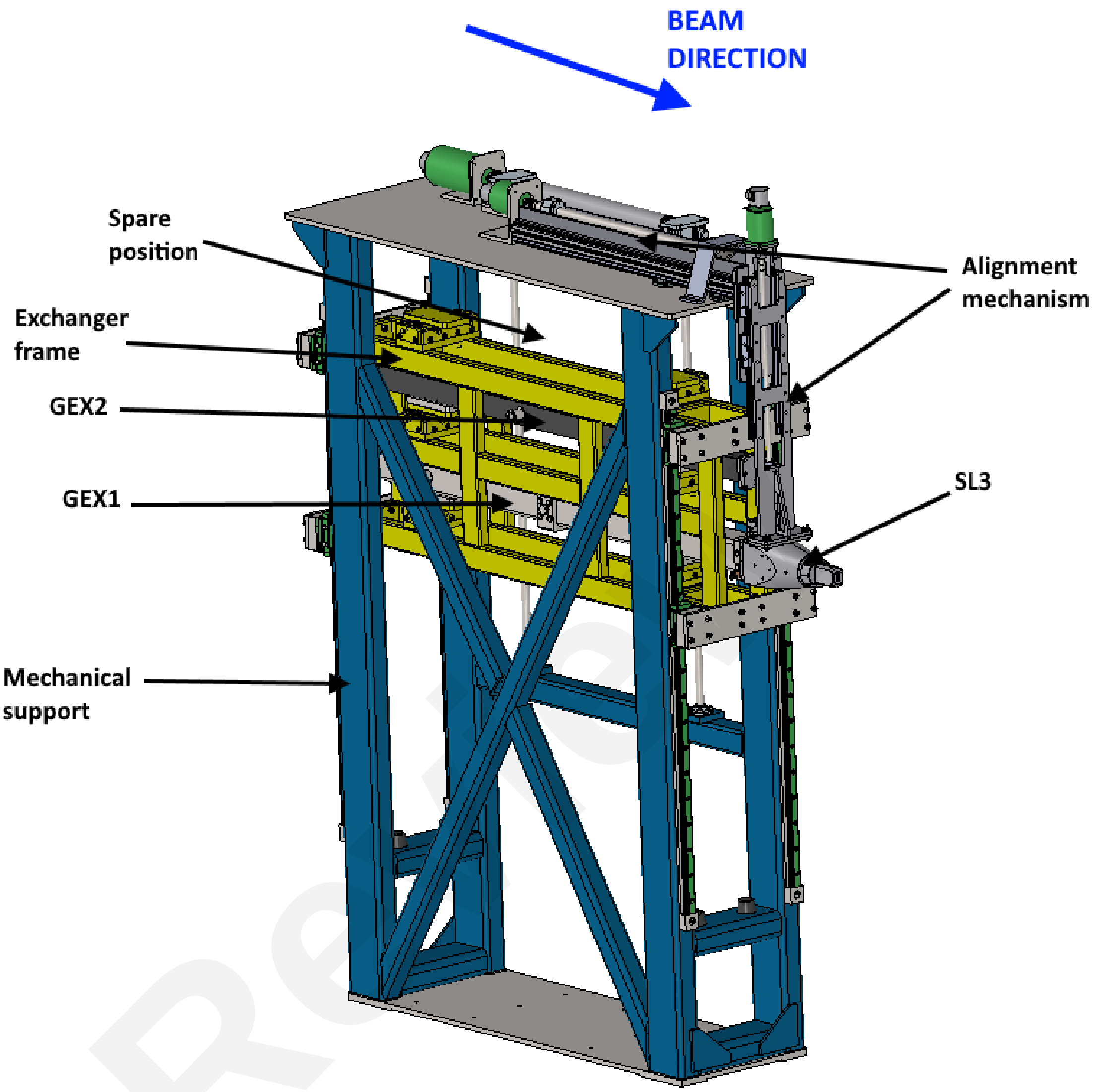


Figure 65: The exchanger with neutron optics, mechanical support, exchanger frame and alignment mechanics

5.6.1. Mechanical support

Weight:	~740 kg
Material:	S355 steel, painted
Vibration damping elements:	Elesa+Ganter DVB.6-60-40-M10-12-70
Limit switches:	Euchner NZ1HS-538-M

The painted mechanical support is a welded construction made of hollow structural steel sections and braced with steel plates. Rubber pins damping the vertically moving parts on the construction, mechanical stoppers keep the moving rails at their tracks. The frame is equipped with limit switches.

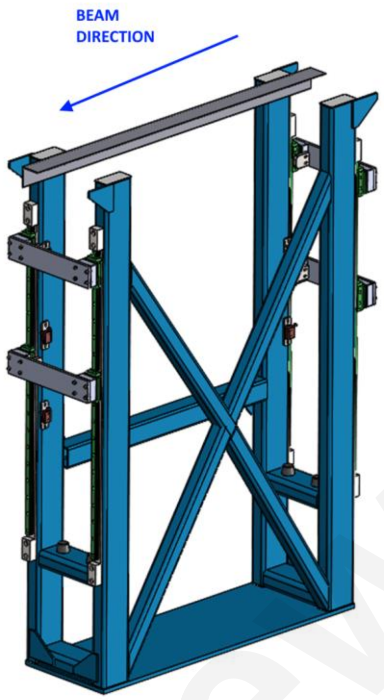


Figure 66: Mechanical support of the neutron optics exchanger.

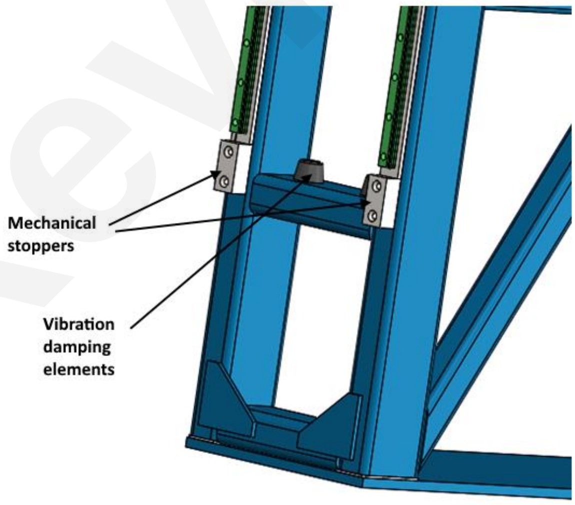


Figure 67: Closeup view of the frame showing the stoppers and damping.

5.6.2. Exchanger frame

Weight:	~170 kg
Material:	S235JR, painted

The frame made of welded HSS steel and positions the optical elements inside mechanical support by the alignment mechanics. Horizontal alignment units position the neutron optics in all exchanger positions.

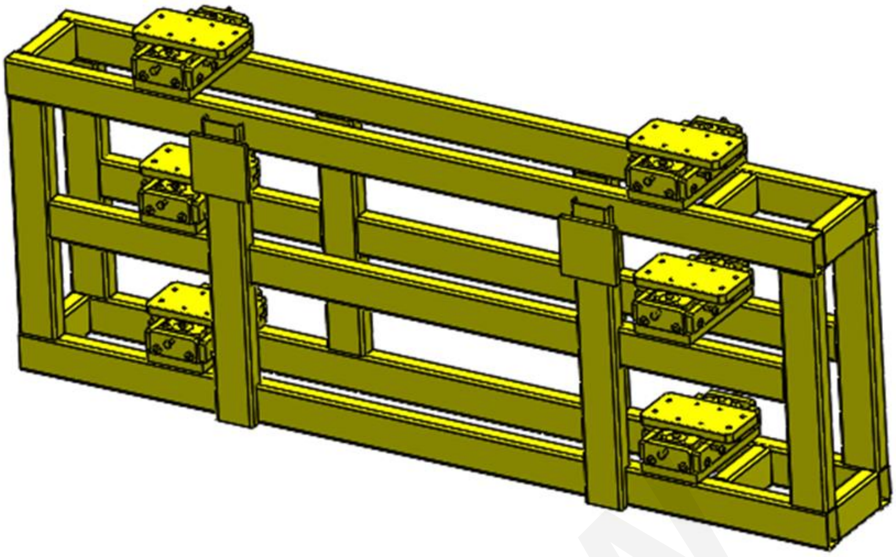


Figure 68: Exchanger frame.

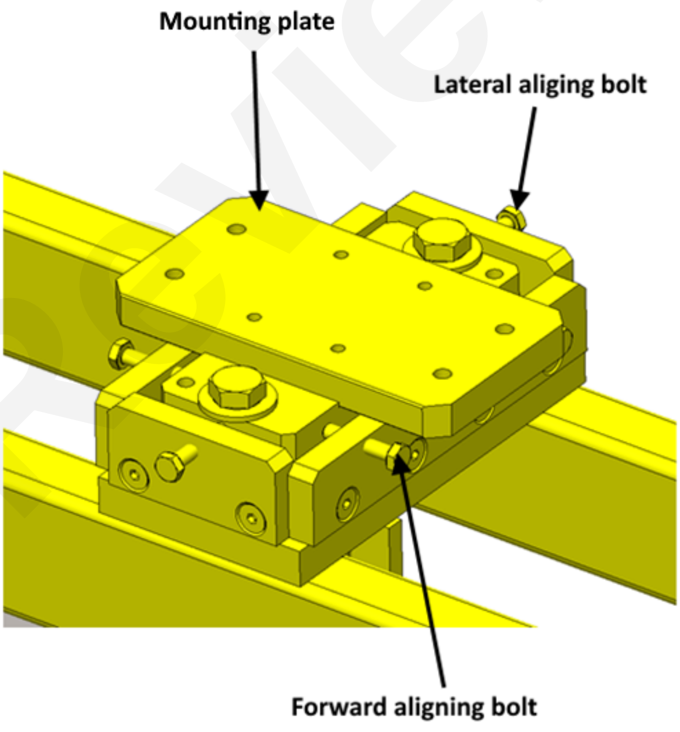


Figure 69: Horizontal positioning element. Positioning is done by adjusting bolts.

5.6.3. Exchanger alignment mechanics

Stepper motor:	Stögra SM107.4.18M12W-Zyyy	
	2-phase hybrid stepper motor	
	Number of steps:	400/revolution
	Torque:	~10 Nm
		at 300 rpm
		at 60 V

Connector:	Lemo EEJ.3B.305.CYC
Resolver:	AMCI R11X-J10/7N
	Permitted input frequency: 5 kHz
	Accuracy: 7‘
Connector:	Lemo PFJ.2B.310.CYB.DXX
Screw-jack system:	Zimm screw-jacks Z series
	Z-10-RL-KGT 20x4-S trapezoidal screw

The alignment mechanism of the exchanger frame is driven by a Stögra stepper motor. The torque transmitted to two, vertical spindles through jaw couplers and ZIMM screw jacks. The vertical spindles position the exchanger frame through ball screws. The stroke of the driven exchanger frame is ±270 mm from the middle position. Both of the stepper motors are equipped with resolvers allowing for remote position control.

5.6.3.1. Calculations for the Stögra SM 107.4-KV motor:

All the data are from ZIMM Austria Screw-Jack Systems XII 1.1

Abbreviation used in the calculations:

M_s	necessary drive torque [Nm] for a screw jack
F	lifting load (dynamic) [kN]
$\eta_{gearbox}$	efficiency of the screw jack (without screw)
η_{screw}	efficiency of the crew
P	screw pitch [mm]
i	drive ration of the screw jack
M_L	idling torque [Nm]
P_M	motor drive power

I. Determine a drive torque of a single jack (see Figure 70 for point numbering)

1. Drive torque M_g [Nm]

$$M_g = \frac{F[kN] \cdot P[mm]}{2\pi \cdot \eta_{gearbox} \cdot \eta_{screw} \cdot i} + M_L \text{ [Nm]}$$

$$M_g = \frac{3[kN] \cdot 4\,[mm]}{2\pi \cdot 0.84 \cdot 0.391 \cdot 4} + 0.26 = \frac{12}{8.254597} + 0.26 = 1.453735 + 0.26 = \mathbf{1.713735\ Nm}$$

2. Motor Power P_M [kW]

$$P_M = \frac{M_G[Nm] \cdot n[rpm]}{9550} = \frac{1.713735[Nm] \cdot 1500[rpm]}{9550} = \frac{2570.603}{9550} = \mathbf{0.269173\ kW}$$

3. Motor Power P_M [kW] with safety factor 1.5

$$0.269173087 \text{ kW} \cdot 1.5 = \mathbf{0.40376\ kW}$$

II. Drive for screw-jacks – precise calculation (see Figure 70 for point numbering)

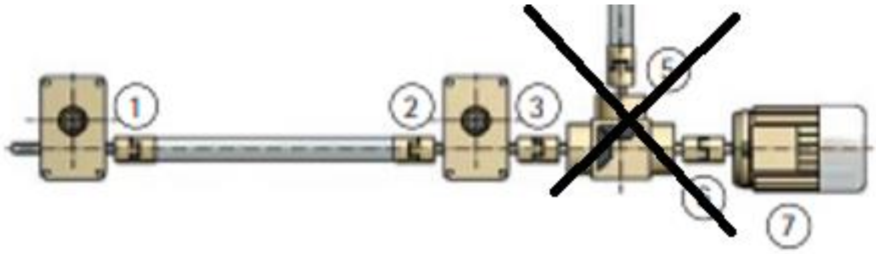


Figure 70: Layout of the junction points similar to the design with enumerated points used for calculation.

1. Drive torque M_g [Nm]

$$M_g = \frac{F[kN] \cdot P[mm]}{2 \cdot \pi \cdot \vartheta_{gearbox} \cdot \vartheta_{screw} \cdot i} + M_L \text{ [Nm]}$$

$$M_g = \frac{3[kN] \cdot 4\ [mm]}{2 \cdot \pi \cdot 0.84 \cdot 0.391 \cdot 4} + 0.26 = \frac{12}{8.254597} + 0.26 = 1.453735 + 0.26 = \mathbf{1.713735\ Nm}$$

2. Calculating with the efficiency of the connecting shaft

$$\frac{1.713735 \text{ Nm}}{0.95} = \mathbf{1.803932\ Nm}$$

3. Needed torque after the two gearboxes

$$1.713735 \text{ Nm} + 1.803932 \text{ Nm} = \mathbf{3.517667\ Nm}$$

7. Recommended multiplying with a safety factor

$$3.517667\ Nm \cdot\ 1.4 = \mathbf{4.924734\ Nm}$$

The safety factor is between 1.3 … 1.5, but it is up to 2 for small system and for low speeds.

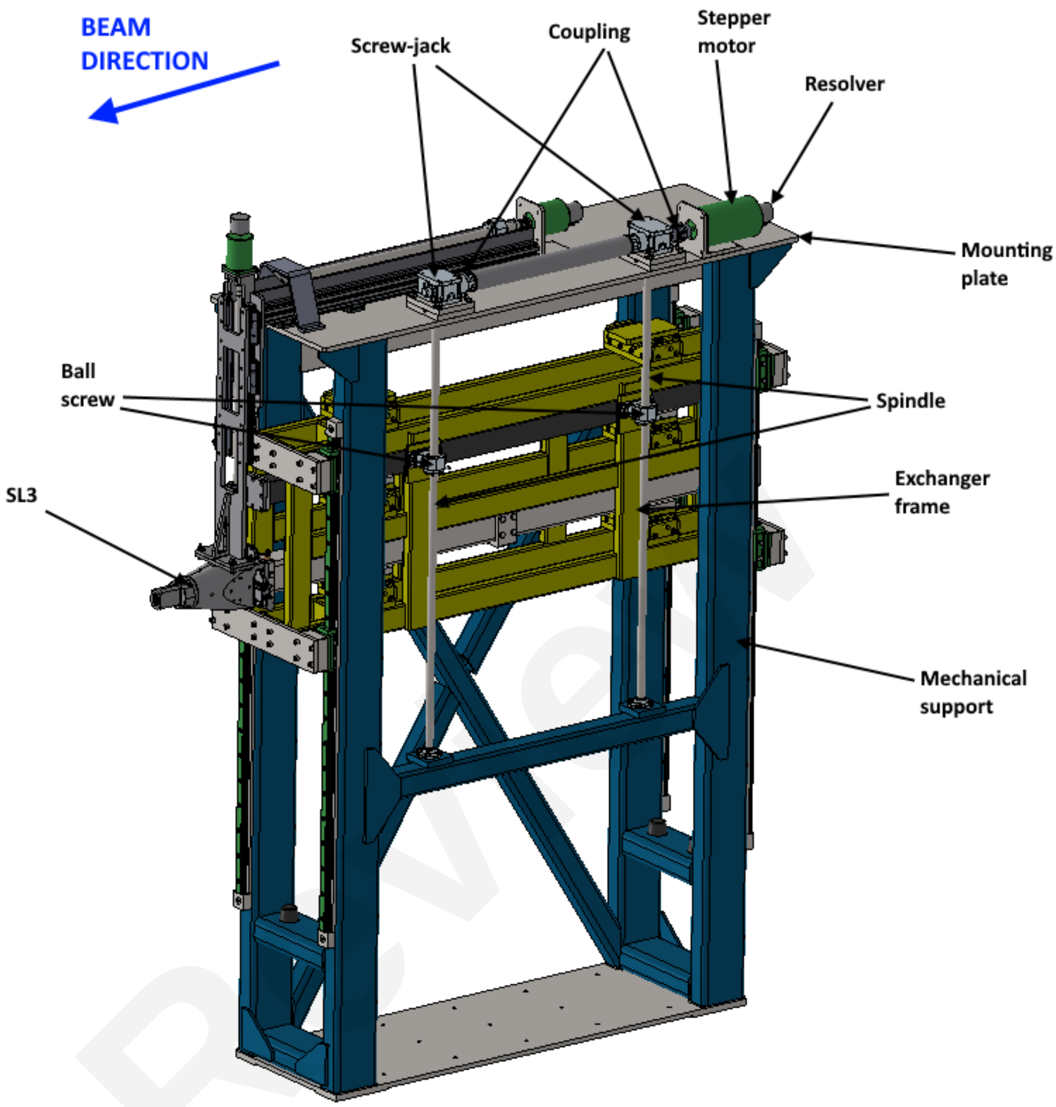


Figure 71: Exchanger alignment mechanics mounted on the mechanical support

Horizontal stepper motor:	Stögra SM88.3.18M12NWZxxx	
	Number of steps:	400/revolution
	Torque:	7 Nm at 300 rpm at 72 V
Vertical stepper motor:	Stögra SM 88.3.18M12NWZxxx	
	Number of steps:	400/revolution
	Torque:	7 Nm at 300 rpm at 72 V
Socket:	Lemo EEJ.3B.305.CYC	
Resolver:	AMCI R11X-J10/7N	
	Permitted input frequency:	5 kHz
	Accuracy:	7‘
Connector:	Lemo PFJ.2B.310.CYB.DXX	

Horizontal rail: TRH 15Fe
Vertical rail: Franke FD25

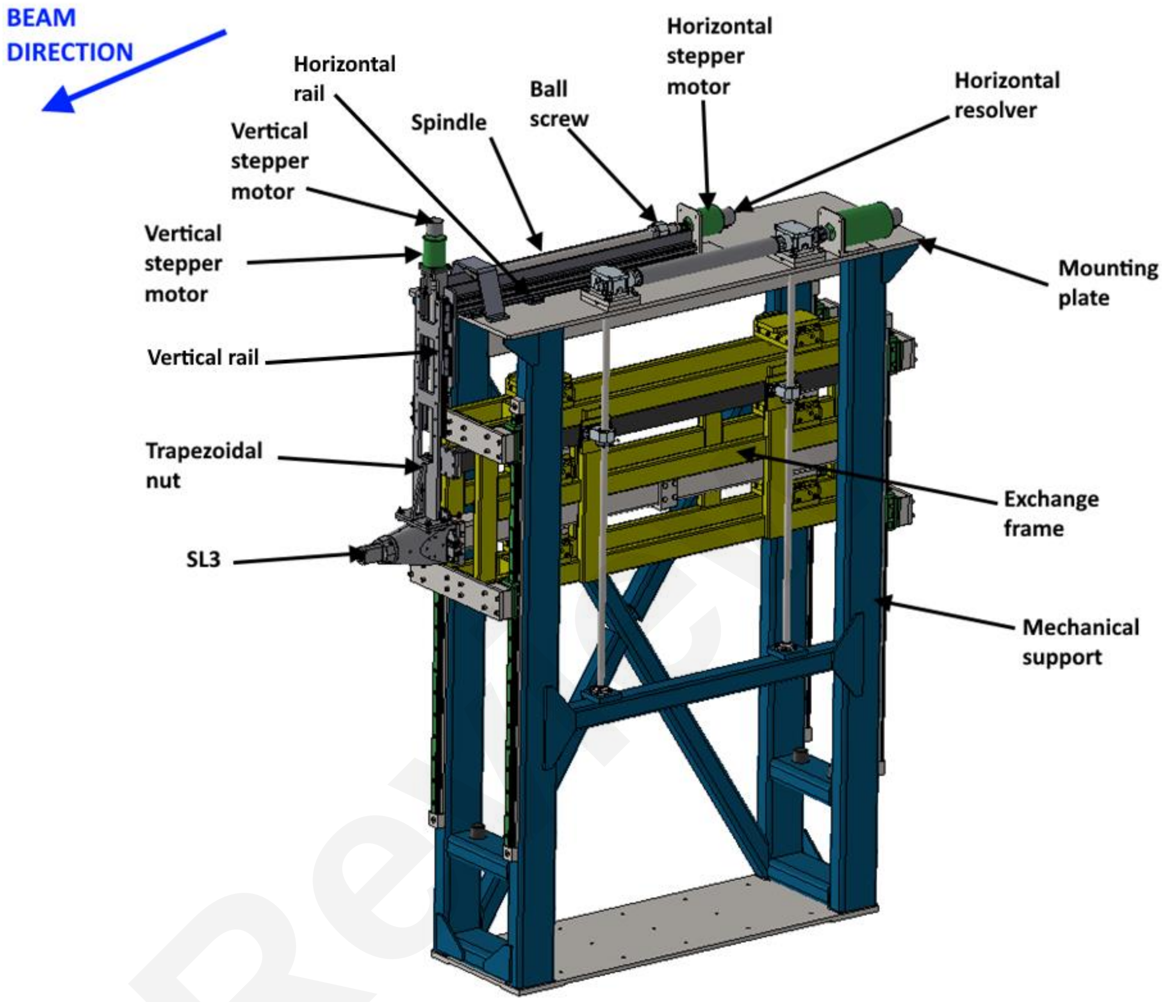


Figure 72: SL3 alignment mechanics mounted on the mechanical support

5.7. SLITS (PBS 13.6.6.1.4.5)

The neutron slits are found along the neutron optics, these are SL1 at ISCS position 151 990…152 010 mm, SL2 at 154 990…155 010 mm and SL3 at 157 940…157 960 mm.

5.7.1. SL1 (PBS 13.6.6.1.4.5.1)

SL1 is an 80x80 mm^2, horizontally and vertically adjustable neutron slit. Its positioning repeatability is 0.05 mm and allows complete closure. The instrument is equipped with stepper motors and resolvers for remote control and allows independent end positioning signals. The slit shares a common vacuum space with the preceding and succeeding optics and connects with an ISO-CF DN160 flange.

Specification of the motor:

- type: Stögra SM56.3.18J3W ZXXX stepper motor
- connector: Lemo EEJ.2B.304.CYC

Specification of the resolver:

- type: AMCI R11X-J10/7N
- connector: Lemo EEJ.2B.310.CYB

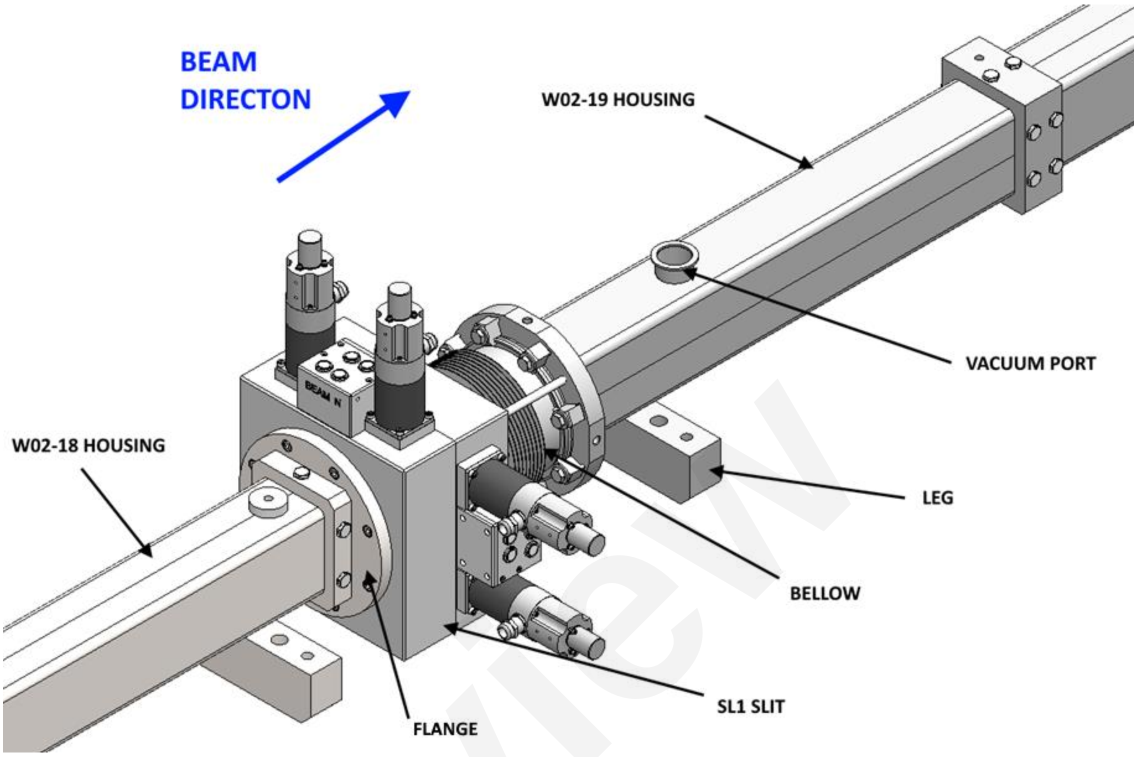


Figure 73: The SL1 slit between the W02-18 and W02-19.

5.7.2. SL2 (PBS 13.6.6.1.4.5.2)

The SL2 slit is the same as SL1: it is a 80x80 mm^2, horizontally and vertically adjustable neutron slit. Its positioning repeatability 0.05 mm and allows complete closure. The instrument is equipped with stepper motors and resolvers for remote control and allows independent end positioning signals. The slit shares a common vacuum space with the preceding optics and connects with an ISO-CF DN160 flange. The downstream closed with a 0.5 mm thick AlMgSi1 window cap. The slit has an inbuilt vertically elliptic miniguide propagating neutron beam to the exchanger system. Inside the slit the gap between the mini guide and W02-19 is 30 mm.

For the inbuilt mini-guide see section 5.4.3.1.

Specification of the motor:

- type: Stögra SM56.3.18J3W ZXXX stepper motor
- connector: Lemo EEJ.2B.304.CYC

Specification of the resolver:

- type: AMCI R11X-J10/7N
- connector: Lemo EEJ.2B.310.CYB

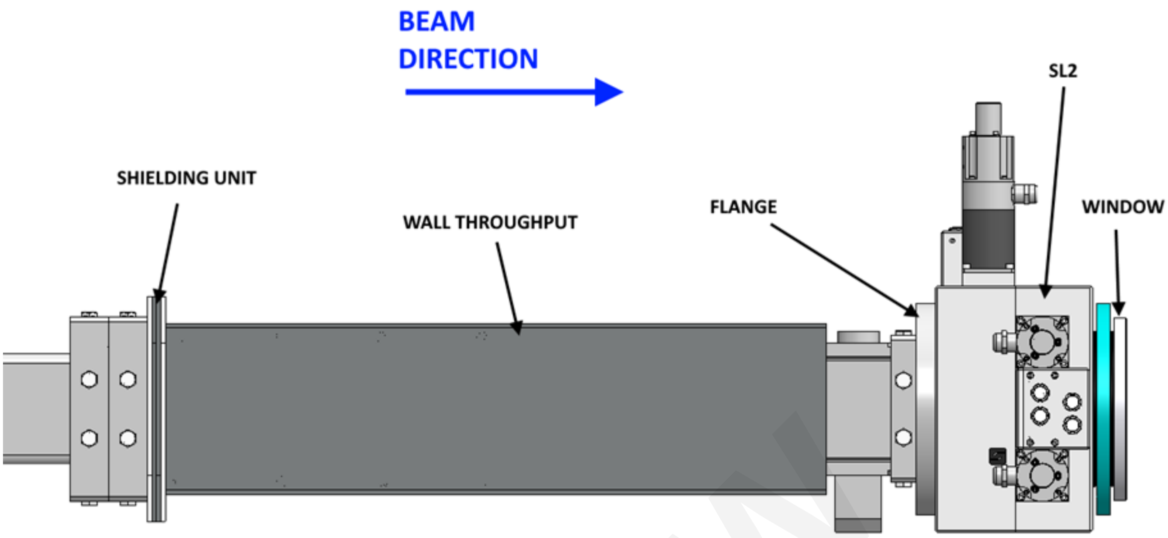


Figure 74: The SL2 slit after W02-19.

5.7.3. SL3 (PBS 13.6.6.1.4.5.3)

Slit type: 3002.90M Huber-slit
Resolver: supplied by ESS
Connector type: to be specified by ESS to Huber
Stroke:
X-direction: 600 mm
Z-direction: 150 mm

The SL3 is a commercial Huber-slit fixed on the aperture aligner of W02-20-01/02 and can be moved 600 mm in X-direction (beam direction) and 150 mm in Z-direction (vertically). Its driving mechanics and positioning frame mounted on the exchanger system's mechanical support. The gap between the slit and the preceding optics is 10 mm. Further information from this unit will be provided later.

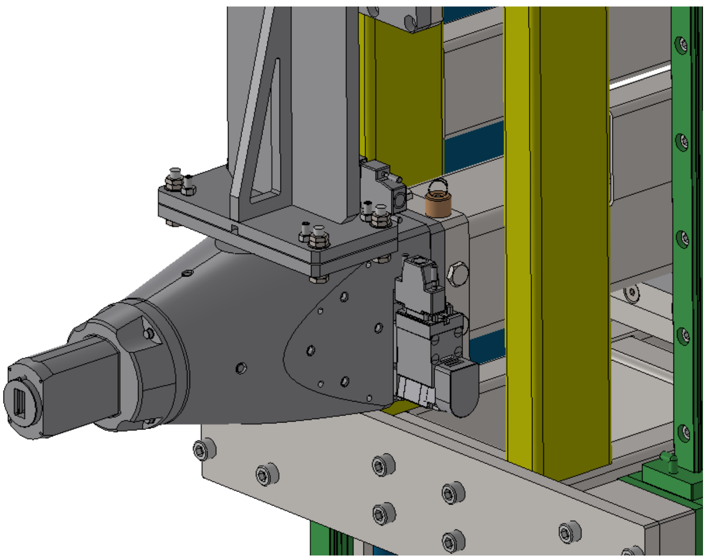


Figure 75: SL3 fitted on its positioning frame.

6. DESIGN VERIFICATION

The design verification contains FEM analyses of aluminium windows, vacuum houses, I-beams and neutron guides. The analyses done with SolidWorks 2019 and contains the evaluation of displacements and von Mises stresses. Deformations are scaled up on the images and do not represent the real conditions, they are only for illustration.

6.1. VACUUM HOUSES

The vacuum houses are assembled of S235JR low carbon steel. The longest, 6 m long house was evaluated during FEM analysis with 0.1 MPa (1 bar) pressured placed on its outer surface simulating inside vacuum.

The evaluation revealed that the deformation of the house is ~0.03 mm, the von Mises stress is ~16 MPa.

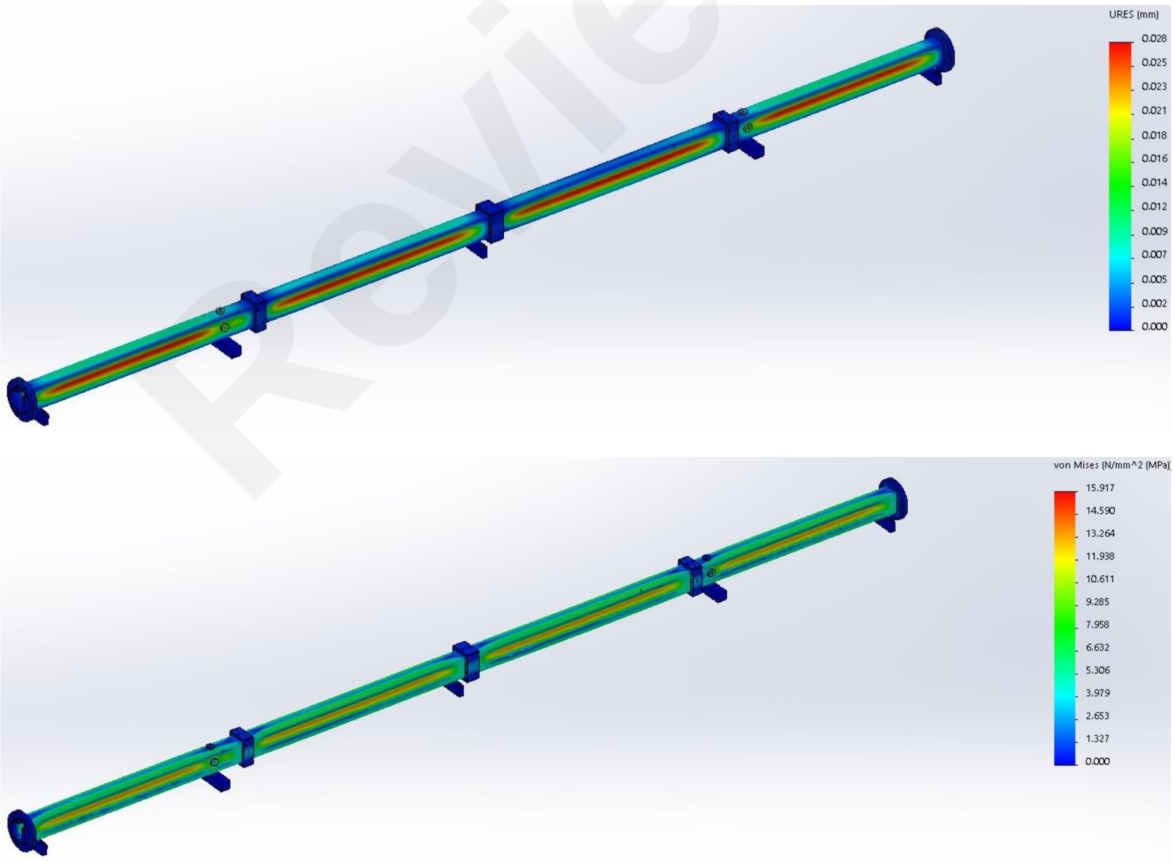


Figure 76: FEM evaluation of the 6 m long vacuum house. Top: displacement, bottom: von Mises stress.

6.2. Al-windows

The analyses of the windows were done with 0.1 MPa (1 bar) pressure placed on the outer surface of parts for simulating internal vacuum. All the windows made of AlMgSi1 (6082-T6) aluminium alloy which yield strength is 275 MPa.

6.2.1. W02-14-01 (GE2AS)

The displacement of the upstream window is ~1.4 mm, the highest value of the von Mises stress is ~2100 MPa, which does not reach the materials yield strength.

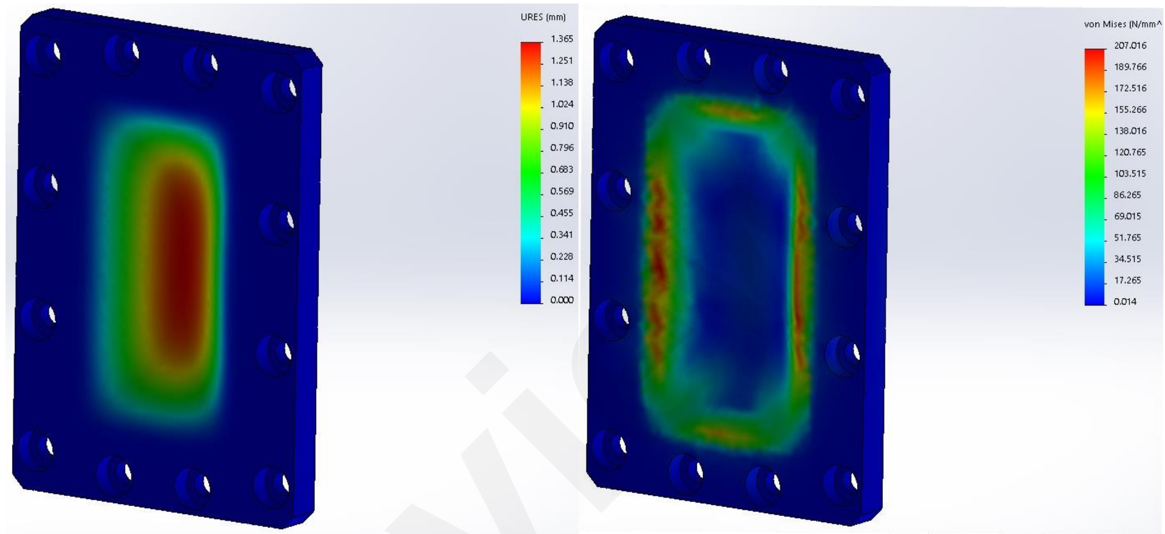


Figure 77: FEM evaluation of the window on W02-14 (GE2AS) Left: displacement, right: von Mises stress

6.2.2. SL2

The deformation of the window cap at SL2 slit is ~1.2 mm, the von Mises stress is ~115 MPa which does not exceed yield strength.

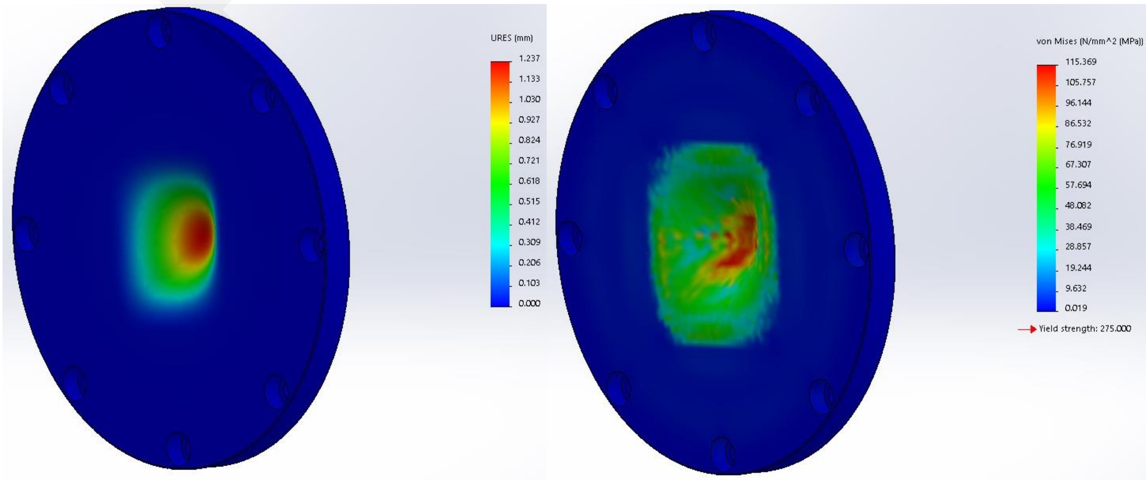


Figure 78: FEM evaluation of the cap on slit SL2. Left: displacement, right: von Mises stress.

6.2.3. W02-20-01 (GEX1)

The displacement of the window is ~0.6 mm, the highest value of the von Mises stress is ~100 MPa, which is under the yield strength.

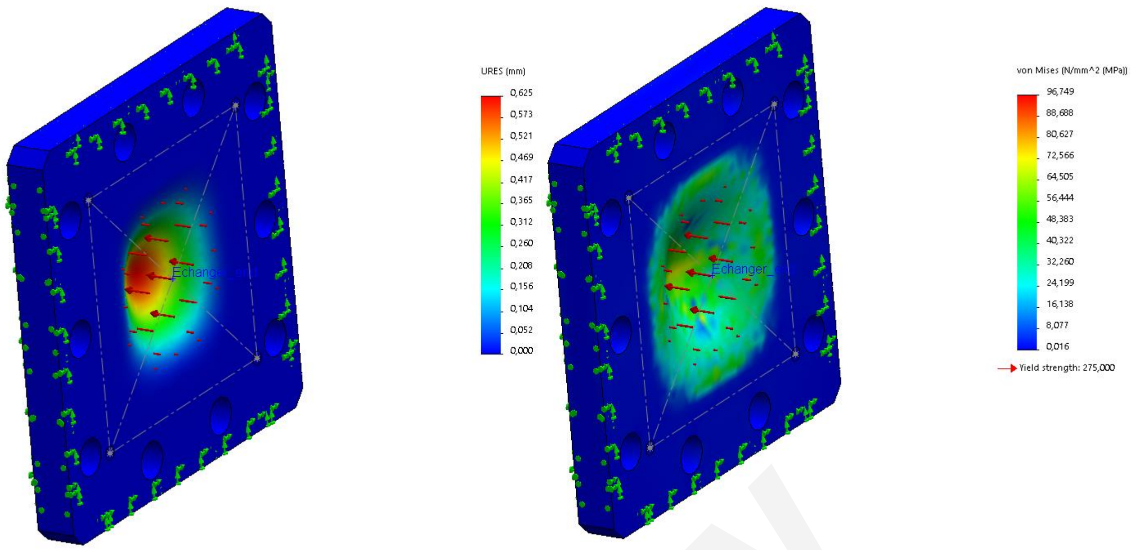


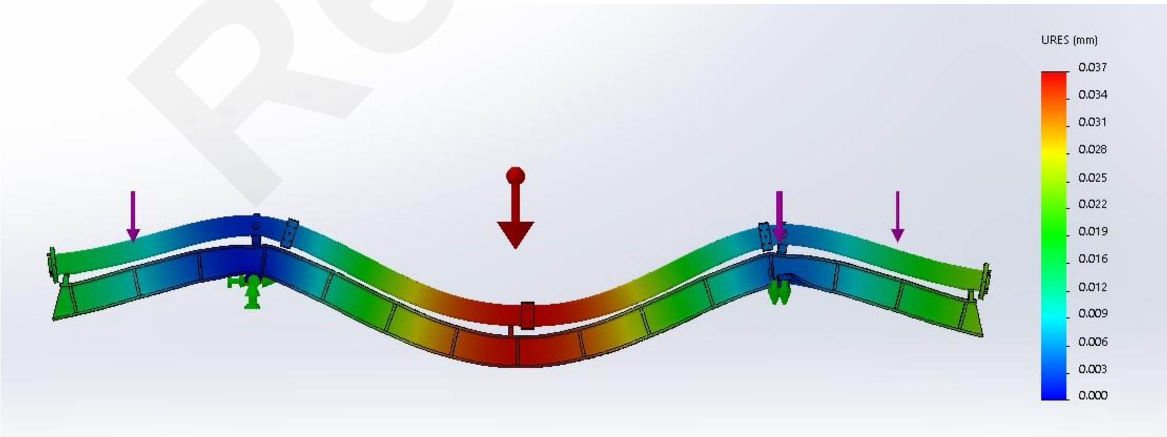
Figure 79: FEM evaluation of the window on W02-20-01 (GEX1) Left: displacement, right: von Mises stress.

6.3. I-Beams

The analyses of the I-beams were done with 550 N spread load along its surface. The I-beams are made of S235JR low carbon steel which yield strength is 235 MPa.

6.3.1. 6 m long I-beam

The displacement of the 6 m long I-beam is ~0.04 mm, the highest value of the von Mises stress is ~20 MPa, which does not exceed the yield strength.



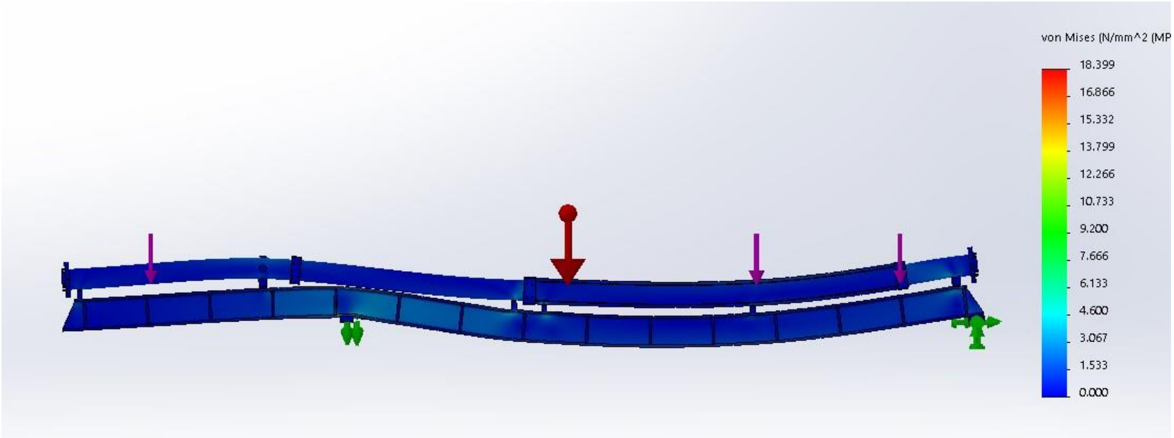


Figure 80: FEM evaluation of the 6 m long I-beam. Top: displacement, bottom: von Mises stress.

6.3.2. I-beam before the shutter pit

The beam at the shutter pit throughput is also evaluated. The displacement of the I-beam is ~0.1 mm, the highest value of the von Mises stress is ~20 MPa, which does not exceed the yield strength.

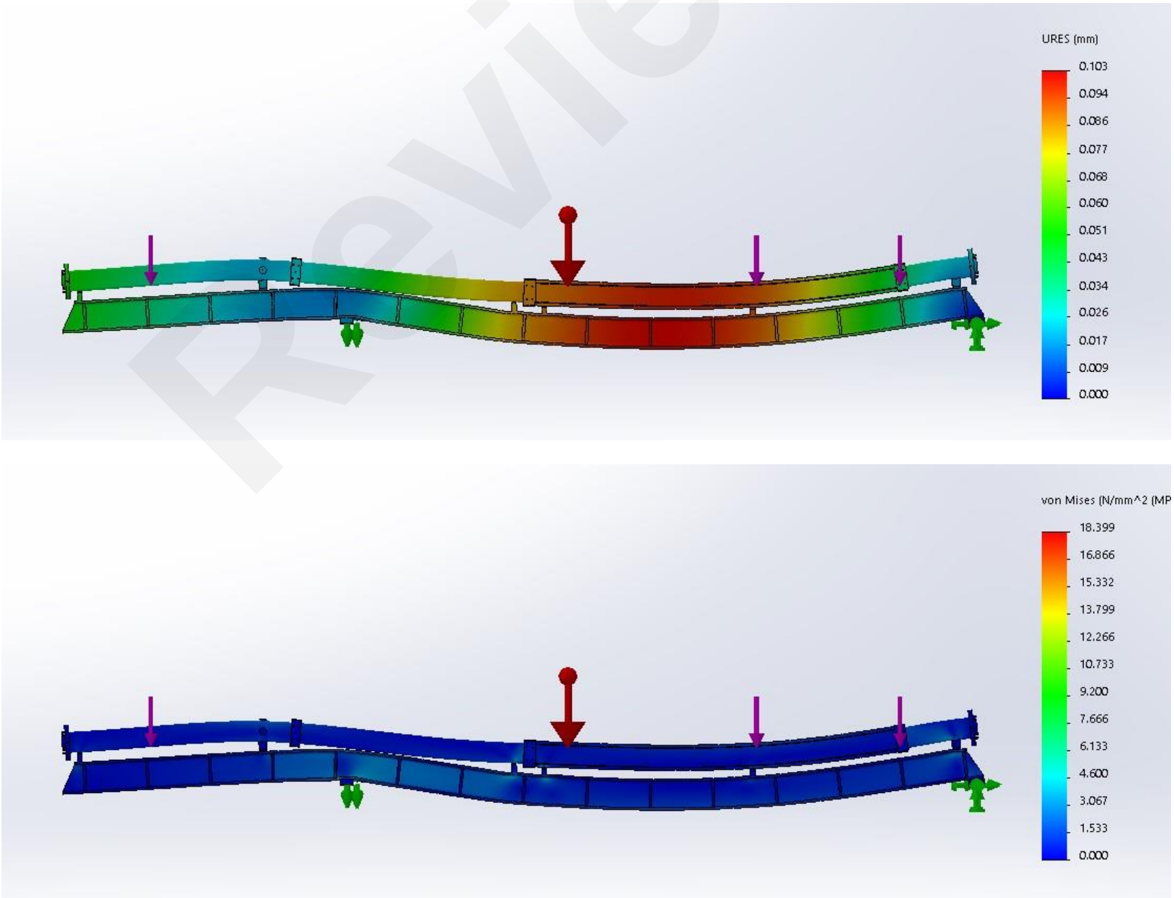


Figure 81: FEM evaluation of I-beam at the shutter pit. Top: displacement, bottom: von Mises stress.

6.4. Neutron guides

The stresses of the guides were evaluated with their own weight, they do not have external load.

6.4.1. 1500 mm long beam

The deformation of the beam is ~0.02 mm and the stress does not exceed 2 MPa.

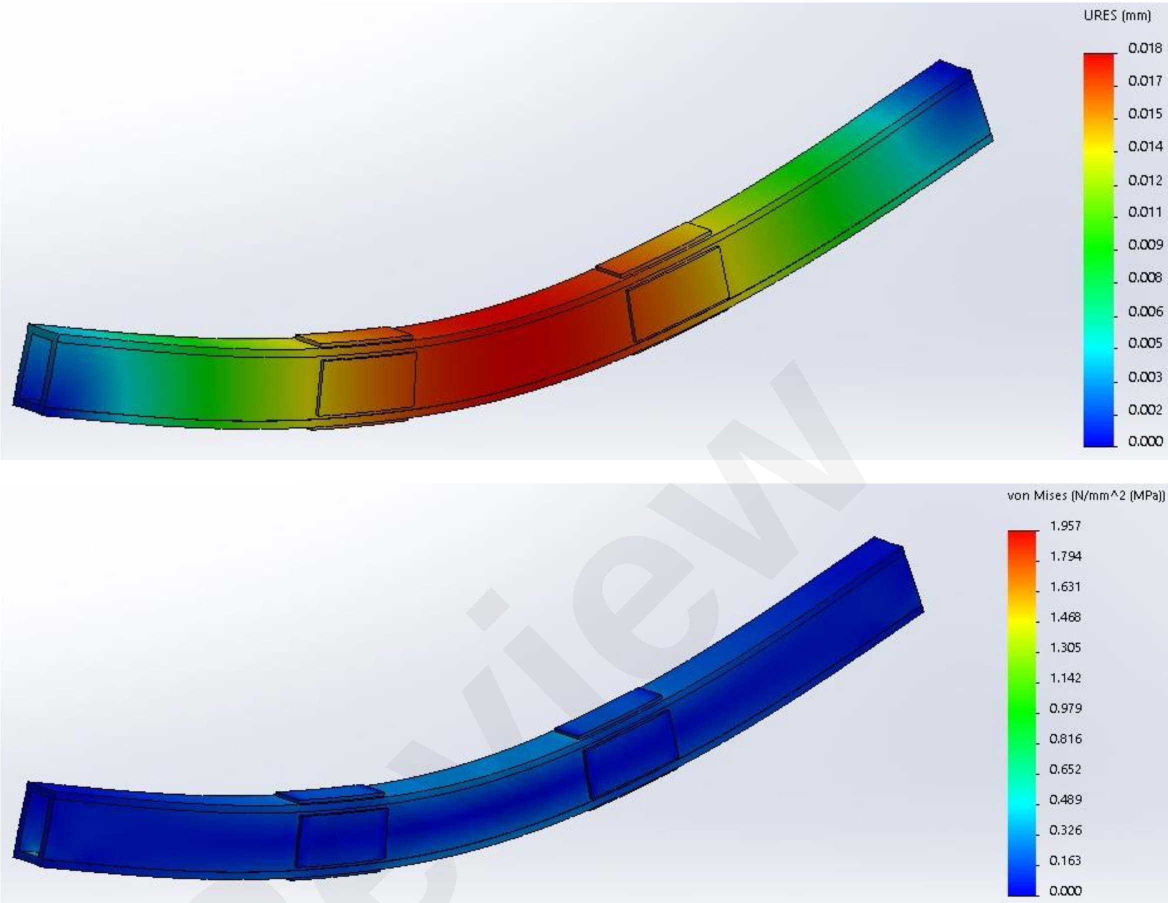
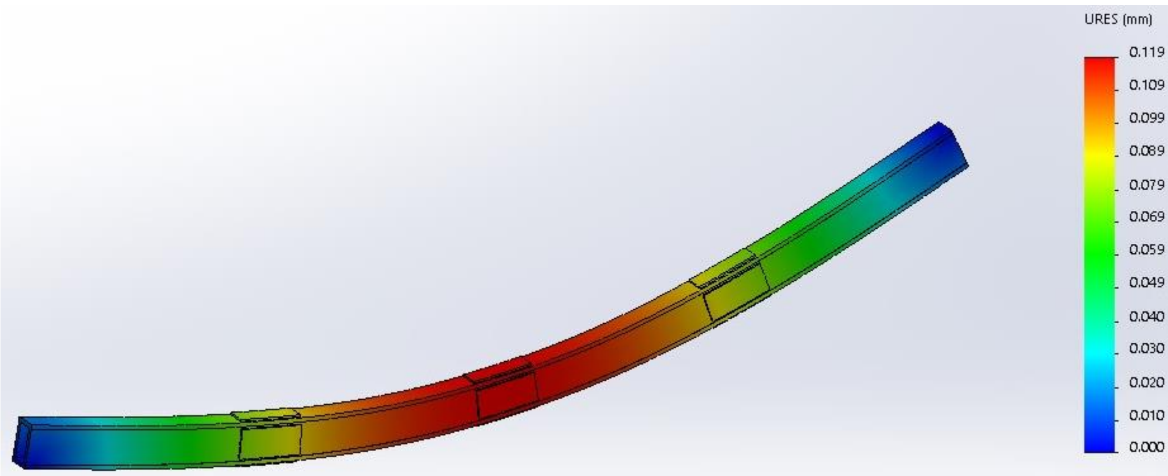


Figure 82: FEM evaluation of the 1500 mm long neutron guide. Top: displacement, bottom: von Mises stress.

6.4.2. 2400 mm long beam

The deformation of the 2400 mm long beam is ~0.12 mm and the stress ~7 MPa. During installation the technical team will avoid this misalignment.



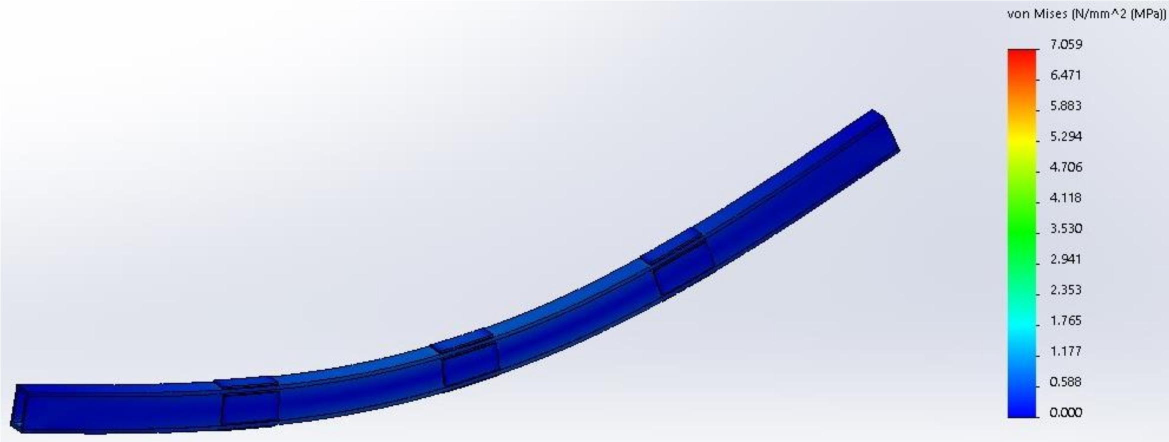


Figure 83: FEM evaluation of the 2400 mm long neutron guide. Top: displacement, bottom: von Mises stress.

7. TECHNICAL RISK EVALUATION

In Table 3 there are listed a technical risk during the manufacturing of the sub-system components and its prevention strategy.

Table 3: Technical risks list

Source of Hazard	Cause	Event	Consequence	Prevention
SL1 slit not moving	Motor torque not enough	Failure of beam shaping at slit SL1	System malfunction	Using motor with bigger torque
SL2 slit not moving	Motor torque not enough	Failure of beam shaping at slit SL2	System malfunction	Using motor with bigger torque
Exchanger frame not moving	Motor torque not enough	Failure of changing guide at exchanger system	System malfunction	Using motor with bigger torque
Mirror substrate dimension out of tolerance	Improper design of substrate	Distortion in beam shape	System malfunction	Multi-level revision and acceptance of design
Failure of weldment	Improper design of weldments	Vacuum level decreases	System damage	Multiple examination of the vacuum tightness of housings
Failure of weldment	Improper design of weldments	Vacuum housing breaks	System damage	Oversizing of weld seam dimensions
Vacuum housing at shutter pit	Instrument cave wall at D03-E02	Distortion in beam shape	System malfunction	Oversizing of vacuum housing support

Source of Hazard	Cause	Event	Consequence	Prevention
throughput is not supported	prevents the use of support			

8. BEER TG3 REQUIREMENTS & SOLUTIONS

The following description tries to summarize the influence of the high- and low-level requirements on the design of the beam transport sub-system. Any design restrictions that result in the modification or adaptation of the requirement are marked and explained, and the system requirements specification document is adequately updated.

8.1. High level requirements

In Table 4, there are listed high-level system requirements and comments about their fulfilment from the perspective of the transport and conditioning sub-systems. Whole list of the high-level BEER requirement is summarised in the *ConOps* document [1].

Table 4: Table of High-level requirement and its fulfilment by the design of the transport and conditioning sub-system

Req. # 13.6.6.1	Description	Design and description
R1	BEER shall allow the measurement of structural data of engineering materials (e.g. duplex-steel) in the form of determination of cell parameters with accuracy of $\Delta a/a \sim 10^{-5}$.	The requirement is fulfilled is such extent that the neutron guide system is designed to transport appropriate wavelength range to allow measurement of cell parameters of engineering materials.
R6	The detector coverage together with the available wavelength bandwidth shall be optimized for a sufficient d-range for common engineering materials which is identified as 1 - 3 Å.	The second part of this requirement is fulfilled by the design of the neutron guide allowing to transport required wavelength bandwidth.
R7	BEER shall allow the gauge volume to be adjusted for the experiment down to about 1 mm^3.	The design of the sample slit system allows to scale down the incoming beam which together with other component will allow measurement of a gauge volume of required size.
R9	BEER shall allow data to be collected to d_{min} of about 0.7 Å for detectors at 90°.	Design of the neutron guide system allows to transport the neutron of wavelength as required, what makes the requirement fulfilled from the transport perspective.

8.2. Low level requirements

In Table 5, there are listed low-level system requirements dedicated for the transport and conditioning sub-systems described in this document. Whole list of BEER system requirement is summarised in the *SyReq* document [2]. The fulfilment of each requirement is commented.

Table 5: Table of low-level requirements dealing with transport and conditioning of the neutron beam

Req. # 13.6.6.1	Description	Design and description
R1	Wavelength resolution	-
R2	Beam size	Beam stop is designed to accommodate such big beam at the distance of 10 m from the sample position. Neutron guide and the slit systems are able to produce the requested maximal beam size. The sample slits is retractable and removable what can produce very huge variety of beam sizes for experimental needs.
R3	Beam spot	Sample slit system (SL3) is designed on retractable platform and allow the variable slits opening to fully fulfil the requirement.
R4	Beam homogeneity	Design of the sample slits alignment and closing mechanism fulfil this requirement.
R5	Beam divergence	Transport properties of the neutron guide is able to transport required maximum vertical and horizontal divergences and slits systems apertures allow proper adjustment.
R6	Bandwidth selection	-
R7	Useful wavelength range	Transport properties of the neutron guide fully fulfil the requirement of transport neutron within the required wavelength range.
R8	Background	This requirement is fulfilled by the safety shutter and the beam stop design.
R9	Divergence profile	Transport properties of the neutron guide fulfil the requirement of transport neutron with smooth divergent from the source to the sample.
R10	Wavelength contamination	-
R11	Accessibility	This requirement is fulfilled by safety shutter design.
R12	Chopper Systems in the bunker	-
R13	Pulse Shaping Chopper System	-

Req. # 13.6.6.1	Description	Design and description
R14	Pulse Shaping Chopper movement	-
R15	Modulation Chopper System	-
R16	Frame Definition Chopper System	-
R17	Chopper phase monitoring	-
R18	Beam monitoring	The design of the guide exchanger and the sample slits allows installation of the sample monitor and then fulfil this requirement.
R47	Access	The requirement fulfilled by design of the safety shutter just after the bunker wall.
R50	Beam stop	Beam stop is designed to fulfil this requirement. No lost tube is expected.

9. ESS REQUIREMENTS

9.1. Radiological calculation

For the radiological calculation see document *BEER – Radiation Safety Analysis* [10].

9.2. Materials

For the material inventory used within the sub-systems *BEER - Material inventory for activation analysis* [14].

9.3. Motion control

The pneumatic cylinder of the safety shutter will be driven by electro-pneumatic valve.

Hydraulic shock absorbers are used to slow the shutter rotating part before reaching the end positions (closed/opened). The hydraulic shock absorbers are described in [11].

Motors and encoders for slit system are described in **chapter 5.7** within this document.

The motors requirements and solutions for guide exchanger system are described in **chapter 5.6** within this document.

10. GLOSSARY

Term	Definition
NPI	Nuclear Physics Institute

BEER	Beamline for European Materials Engineering Research
CO	Civil object
C-SPEC	Instrument Cold Chopper Spectrometer
EC	Experimental Cave
ESS	European Spallation Source
MCNP	Monte Carlo N-Particle Transport Code
NMX	Instrument Macromolecular Diffractometer
PE	Polyethylene
TCS	Target coordinate system
D2B	Distance to beam

11. REFERENCES

[1] BEER – Concept of operation (ESS-0124310)
[2] BEER – System Requirements Document (ESS-0124328)
[3] BEER Optics Specification (ESS-0478295)
[4] Optics Report for the BEER Instrument (ESS-0238217)
[5] Contract on delivery of neutron optical system for BEER Part I, Annex 1 Part A, Rev 4.2, Date: 13/11/2018
[6] Contract on delivery of neutron optical system for BEER Part II, Annex 1 Part A, Rev 4.2, Date: 13/11/2018
[7] MCA Components Standard (ESS-0439471)
[8] BEER – neutron guide and vacuum housing drawings (ESS-1812156)
[9] ESS rules for supervised and controlled radiation areas (ESS-0001786)
[10] BEER – Radiation Safety Analysis (ESS-0432365)
[11] Shutter – Technical report (ESS-1407431)
[12] BEER – Interface Description (ESS-0432366)
[13] ESS – Instrument Technical Interfaces (ESS-0403282)
[14] BEER – Material inventory for activation analysis (ESS-1416976)

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue	Jiri Petru	2018-11-08
1	Second issue	Jiri Petru	2019-07-31
2	Merge and update from Mirrotron	Balazs Orosz	2021-02-25

BEER - Sub-System Design Description – Beam Transport and Conditioning

Revision (1)

Components included in Revision (1): Safety Shutter, Beam Stop, Shielding (Beam transport and Conditioning)

List of PBS included in Revision (1):

13.6.6.1.8.3 – Safety Shutter

13.6.6.1.8.6 – Beam Stop

13.6.6.1.10 – Shielding (Beam transport and Conditioning)

List of revisions: ESS-0506957

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	Marie-Louise Ainalem	Project Planning Officer
	Paul Barron	Electronics Engineer
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BEER - Sub-System Design Description – Beam Transport and Conditioning

Revision (2)

Components included in Revision (2): transport guide, focussing guide, guide housing (vacuum) – out of the bunker part, guide support system – out of the bunker part, beam shaping slit system, beam geometry conditioning support and alignment, exchangeable focussing guide system

List of PBS included in Revision (2):

13.6.6.1.2.1.4 – Transport guide

13.6.6.1.2.1.5 – Focussing guide

13.6.6.1.2.2 – Guide housing (vacuum) – out of the bunker part

13.6.6.1.2.3 – Guide support system – out of the bunker part

13.6.6.1.4.5 – Beam shaping slit system

13.6.6.1.4.8 – Beam geometry conditioning support and alignment

13.6.6.1.4.9 – Exchangeable focussing guide system

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