

T-REX instrument Project: Report of activities in preparation of the STAP meeting in May 2022

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1.1 Instrument project overview

The T-REX instrument project is a collaboration between the German JCNS (75%) and the Italian CNR (25%), with a total agreed value of 16.85 M€. The project passed officially TG2 in August 2017. The Technical Annex has been signed and endorsed in January 2020.

The project of T-REX is expected to achieve completion in June 2026. The access dates to ESS buildings for installation are foreseen for the end of 2022 in building E01 (first access) and in May 2023 for the bunker area.

The agreed scope includes the delivery of a world class DGCS, capable to perform INS experiments for a broad user community spanning from magnetism to functional materials and functional soft matter, including the option of using polarized neutron for x-y-z neutron spin analysis. In the first-day, T-REX will be equipped with about 40% of detector area, equivalent to 0.8 sr. The instrument specific SE will be a dedicated cryostat.

We here provide a brief overview of the progress in Q4-2020 and Q1-2021, in preparation of the next STAP meeting in May 2022.

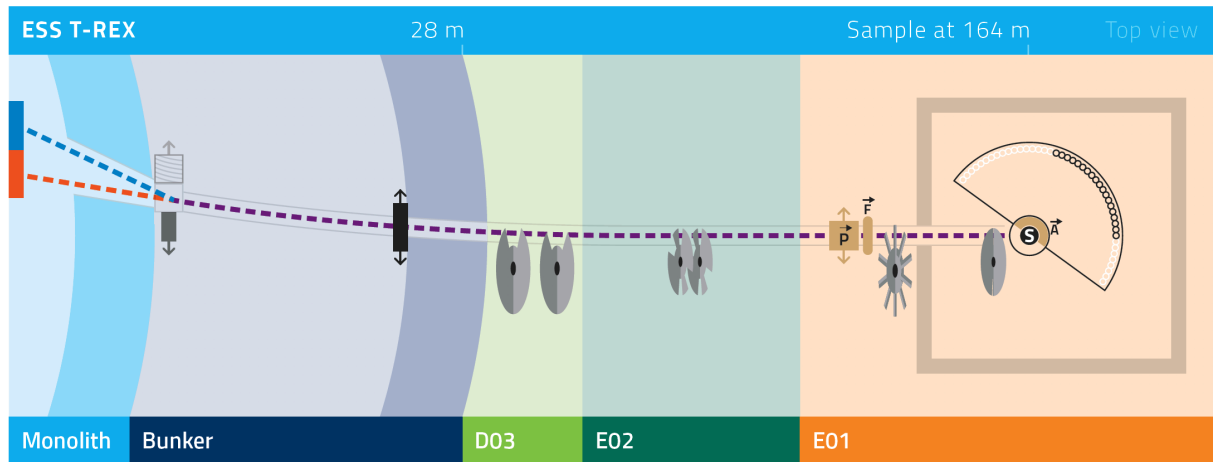


Figure 1. T-REX layout overview.

1.2 Beam transport system

1.2.1 Neutron guide

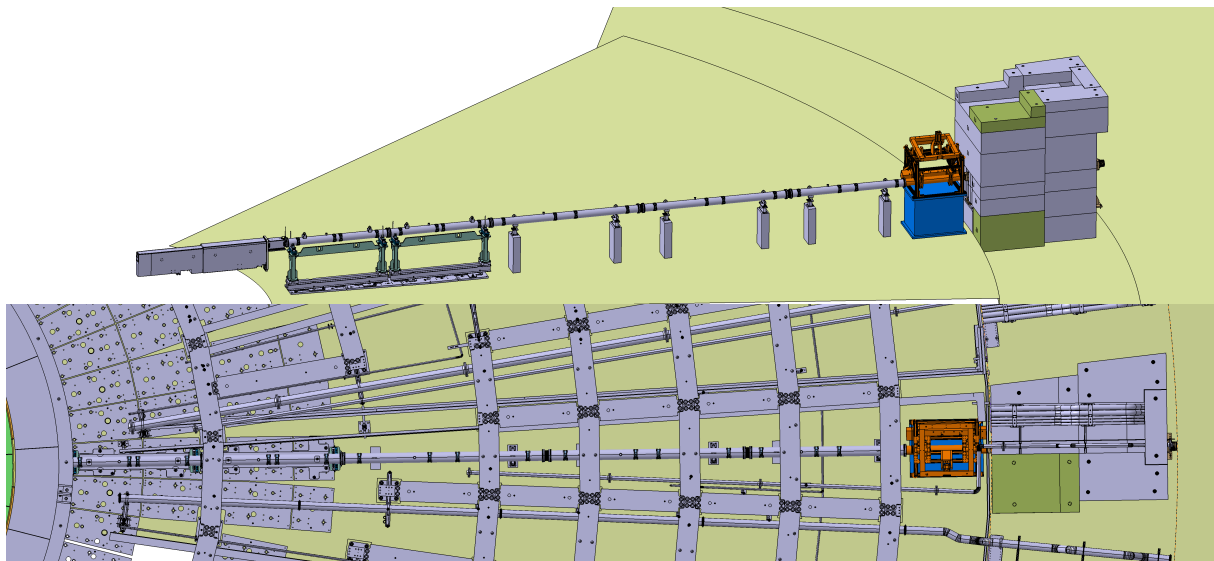


Figure 2. Overview of the in-bunker components.

Status of the sub-projects:

- NBOA is undergoing FAT. During the reflectivity measurements in Budapest, detectors failed. Measurements will be done again. New expected delivery date to ESS might be May 2022 at the earliest.
- Neutron guide in-bunker: documentation for sTG3 is in preparation: <https://confluence.ess.lu.se/x/r6amFw>.
- Neutron guide out-of-bunker: contracted awarded to S-DH. Kick-off meeting on the 1st of April.

- BBGOA: CTV approved, procurement in progress.

Question from the previous STAP report:

Is the project ready for in-bunker component installations?

The BBGOA seems to be late in this respect?

The sub-TG3 for all in-bunker components is planned in May 2022, after approval manufacturing can start. Delivery to the ESS of the in-bunker components is expected in May 2023 (see the Milestones table for more details). The current schedule will enable installation during the expected time window allocated to T-REX, which is Q3-2023.

The BBGOA procurement was excluded from the in-bunker neutron guide purchase because:

- it will not be installed inside the bunker together with the other components, but from the basement underneath target and bunker,
- we could expect a different manufacturer for this specific component, due to the specific expertise required.

1.2.2 Heavy shutter

Status of the sub-project:

The heavy shutter design is ready for the sub-TG3 in May 2022. The relative documentation is in preparation.

The heavy shutter is located upstream beam to the bunker wall insert, with a gap of about 9 mm between them. Figure 2 shows the Monte Carlo geometry used to assess the radiological function of the shutter.

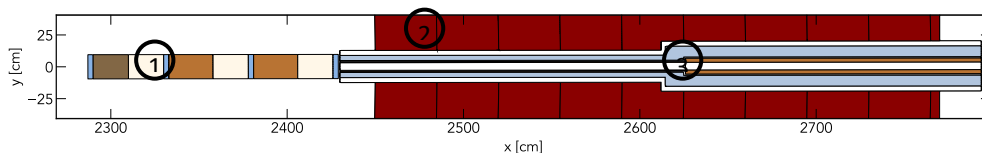


Figure 3 - Geometry model for the T-REX heavy shutter simulation which includes (1) the heavy shutter, (2) the bunker wall and (3) the bunker insert structure.

Figure 3 shows the structure and thicknesses of the layers of the T-REX heavy shutter. It consists of a sequence of lead/copper-polyethylene bilayers, having a 3 cm light boron carbide layer (density of 1 g/cm^3) between bilayers. Its total length is 1420 mm and its cross section is 190 mm x 210 mm.

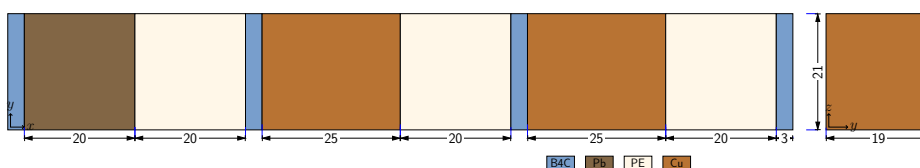


Figure 4 - Schematic layout of the T-REX heavy shutter. The beam direction is parallel to the x-axis. Units are in cm.

The attenuation power of the heavy shutter is shown by the radiation (neutron and photon) dose rate map shown in Figure 5. At the exit of the bunker wall, the total dose rate is mainly

due to the neutrons. The required $1.5 \mu\text{Sv/h}$ dose rate level is reached inside the bunker wall. This will enable access to all components outside the bunker.

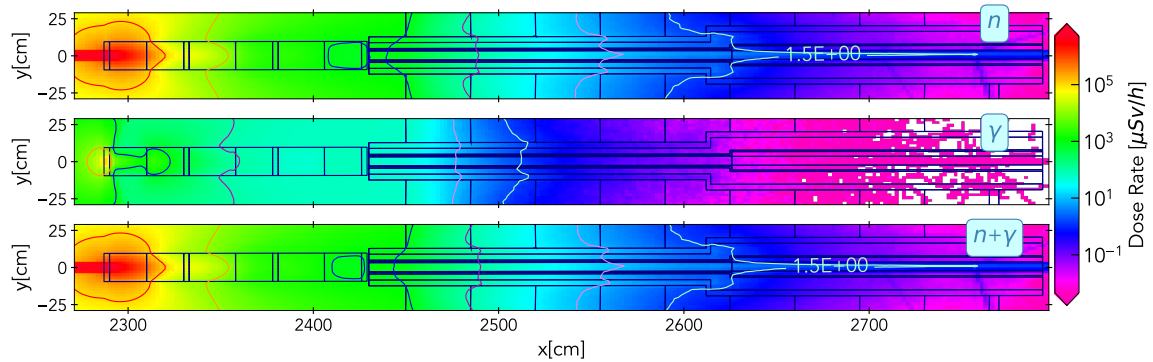


Figure 5 - Radiation dose rate map showing the attenuation power of the T-REX heavy shutter.

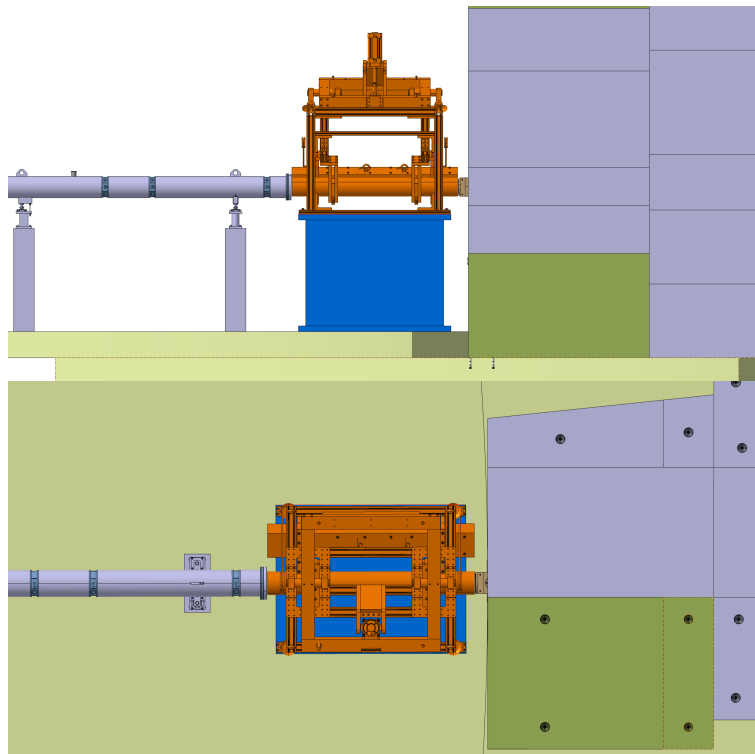


Figure 6 - Top and side view of the heavy shutter within its installation context inside the bunker.

1.2.3 Shielding

Status of sub-project:

- Pending decision on procuring it through the common shielding project or not, currently waiting for the updated ESS offer.
- Preliminary engineering design is ongoing along with the first iteration of neutronics calculations.

1.2.4 Choppers

Status of sub-projects:

- **Bandwidth choppers:** pending decision on procuring it through the common chopper project or not, currently waiting for the ESS offer. This is keeping the work package on hold.
- **P- and M- choppers:** the sub-project was assigned to the ZEA-1 (Jülich) chopper team, kick-off is foreseen in May 2022.
- **FAN chopper:** at FZJ we're currently working on hiring a mechanical engineer to start the design work already identified and specified.

1.2.5 Primary collimator

Status of sub-project:

- *Conceptual design of mechanical components and motion ready for review*
- *Definition of interfaces in progress*

The collimator assembly enables the exchange of a guide element with two collimators with different collimation, therefore providing 3 options for the experiment: large, intermediate and low neutron beam collimation at the sample position.

The interfaces around this component are highly complex and include the M-chopper, the magnetic field for spin transport and rotation and the detectors vacuum vessel. For this reason a substantial team effort is put in place in order to develop the various components in parallel, therefore trying to reduce the need for iterations.

We summarize here some elements of the current design:

- The M-chopper will have an separate vacuum atmosphere,
- The design goal for the gap in the neutron guide across the M-chopper is 70 mm,
- The guide field around the collimator is made of 2 big Halbach rings mounted outside the vacuum and supported directly on the collimator housing,
- The adiabatic spin rotation will be performed with a x-y-z coil placed downstream the collimator inside the detectors vacuum vessel.
- A monitor and a system of beam shaping slits will be incorporated into the collimator assembly in vacuum atmosphere.

1.2.6 Polarization

Status of sub-projects:

- **Cold neutrons polarizer:** conceptual design complete, CTV in preparation, vendor identified.
- **Thermal neutrons polarizer:** design ready for review.
- **Guide field (spin transport):** magnetic field calculations in progress, necessary components identified.
- **Adiabatic field (spin rotation):** magnetic field calculations in progress, necessary components identified.
- **Guide/polarizer exchange unit:** design ready for review.
- **PASTIS set-up:** unstarted.

Some more details on the cold neutrons polarizer.

The cold neutrons polarizer is installed at approximately 158m from the instrument origin, and located at 4m from the guide end. It will be installed on a motorized surface that translate horizontally, to enable the exchange of a guide section with the two polarizers (see **Error! Reference source not found.**). It will be 1m long and feature entrance and exit dimensions of: 38.9 mm x 49.1 mm (WxH) and 35.7 mm x 46.1 mm (WxH), respectively.

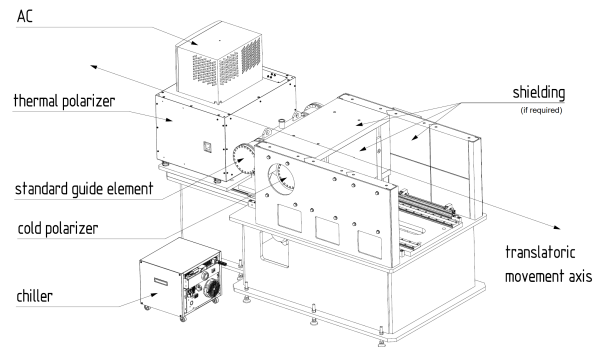


Figure 7- The guide exchanger unit where the polarizer will be installed.

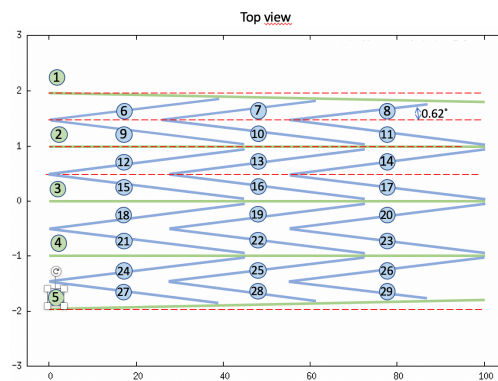


Figure 8 - Supermirrors assembly description: the polarizing mirrors, the sides and the blades.

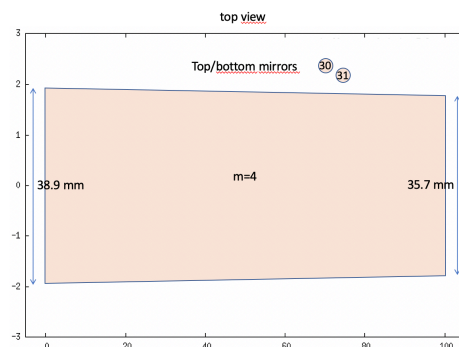


Figure 9 - Supermirrors assembly description: top and bottom mirrors.

The polarizer is an assembly composed by 31 mirrors:

- 24 vertical polarizing supermirrors forming three layers of a 4-V cavity with inclination angle of 0.62° with respect to the direction parallel to the neutron beam,

- 2 vertical reflecting mirrors on the left and right side,
- 3 vertical (blades) forming 4 channels,
- 1 reflecting mirror on the top,
- 1 reflecting mirror on the bottom.

Table 1 - Supermirrors description. Numbers refer to Figure 8.

n.	polarizing	m-index	coating		length [mm]	substrate
			2 sides	1 side		
1 and 5	NO	3		x	1000	borkron
2,3,4	NO	3	x		1000	borkron
9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26	YES	5.5	x		450	Si
6,27	YES	5.5	x		320	Si
7,28	YES	5.5	x		340	Si
8,29	YES	5.5	x		390	Si
30,31	NO	4		x	1000	borkron

The Polarizer purpose is to ensure proper polarization of the thermal neutron beam in the $2.5 < \lambda < 7.0$ wavelength range.

Its expected performance has been evaluated by means of neutron raytracing simulations in Vitess 3.10, showing neutron polarization efficiency above 97% and transmission of about 35%.

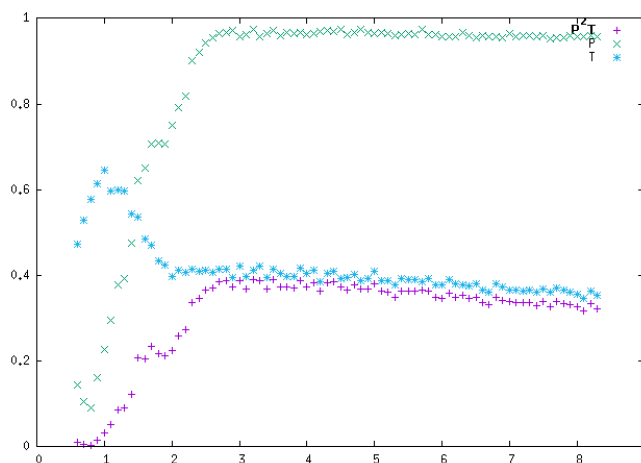


Figure 10 - Neutron polarization and transmission.

To ensure proper magnetization of the FeSi coating, the elements will be placed in a vacuum housing and surrounded by a saturating magnetic field.

1.3 Scattering characterization System

1.3.1 Detector vacuum Vessel

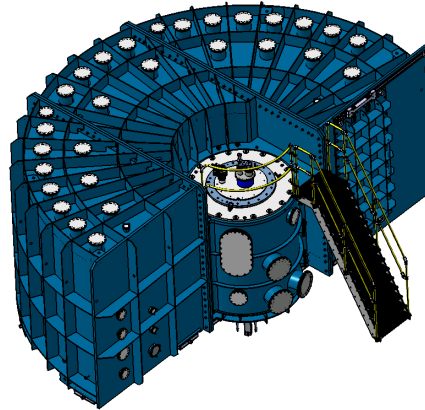


Figure 11. Detector Vessel 3D view.

Status of sub-project:

- The new tender was published on 01.04.2022, deadline for submission of offers on 23.05.2022.

Question from the previous STAP Report:

The formal procurement process for the detector tank will be repeated. Fundamentally, the issue with vendors not guaranteeing the magnetic permeability is unresolved, but FZ Jülich and ESS performed tests to increase their confidence in the choice of materials. We are wondering why it did take so much more time for preparing a re-run of a European call for tender?

- The requirements were discussed with a certain number of potential suppliers and this took time and effort (find them, invite them, discuss with them iteratively)
- The cost for materials increased significantly and the estimated cost was clearly above the budget and this caused a discussion with the funding agency to secure extra budget.
- The engineer responsible for this sub-project is assigned part-time to the T-REX project.

1.3.2 DETECTORS INTEGRATION BOX

Status of sub-project:

The prototype of detectors integration box is ready to start manufacturing at KRESS, the company that won the bid for manufacturing. They received the raw material on 21.04.2022.

Some more details on the design.

The instrument team completed the design of a prototype of the vacuum integration box for the multi-GRID of T-REX and the Detector Group of ESS has approved it after validating the interface with the detectors. The requirements of (a) small gap between neighbour GRID columns, and (b) a small Al window in the neutron beam brought us to a challenging design

from the point of view of mechanical stress and deformation, so we consider the construction of a prototype a necessary step to limit the technical risk associated with this engineering development. Moreover, the interfaces with electronics and supply have been analysed along with the requirements of maintenance and access to electronics with a minimum work.

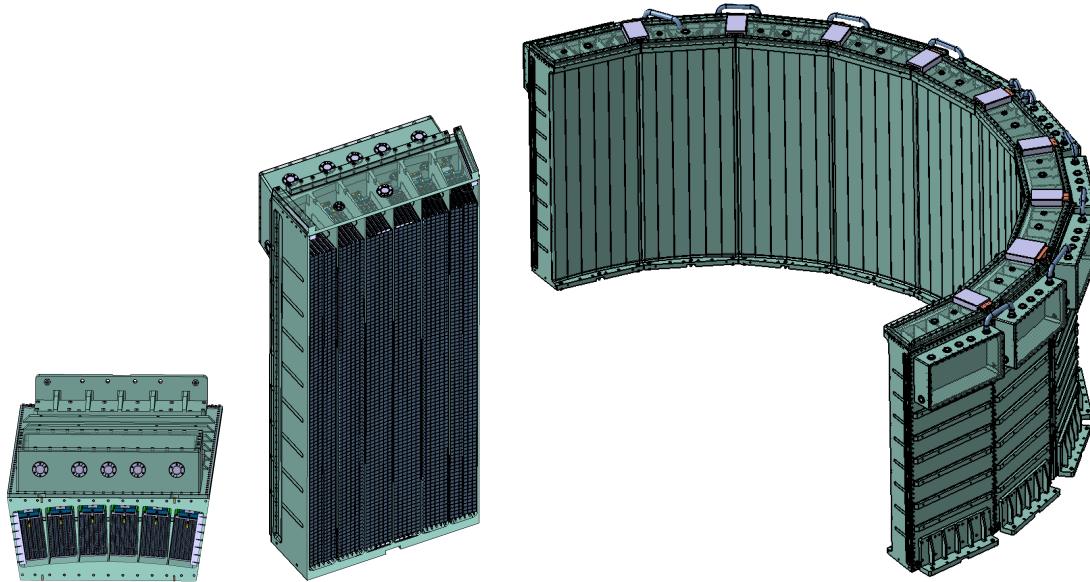


Figure 12. Multi-GRID Detector integration system. Left: top view of the integration box. Center: the integration box. Right: The whole integration system represented as to cover the entire detector area.

Question from the previous STAP:

The design of a neutron detector prototype is complete. The team expect delivery within one year. What does the schedule look like for the completion of the detector system overall?

- The overall schedule is subject of an agreement that is waiting for ESS signature. Due to the present situation within the ESS Detector Group, this is currently on hold.
- The proposed schedule can be seen in more details in Section 1.6.1.

1.3.3 Oscillating collimator

A substantial effort has been put into the design of the drives for the collimator in the past: the engineering requirements are quite challenging in this case, due to the interface with the vacuum vessel and the magnetic requirements imposed by the need to use T-REX with polarization, while still being able to run also measurements with magnetic fields at the sample area. The team has proposed a solution with a linear drive that seems to meet all requirements. The polarization team of the ESS performed simulations to estimate what the field gradient at the position of the drive would be in the case a 15T magnet should be placed at the sample position. This helped the team define position of the drive and specifications.

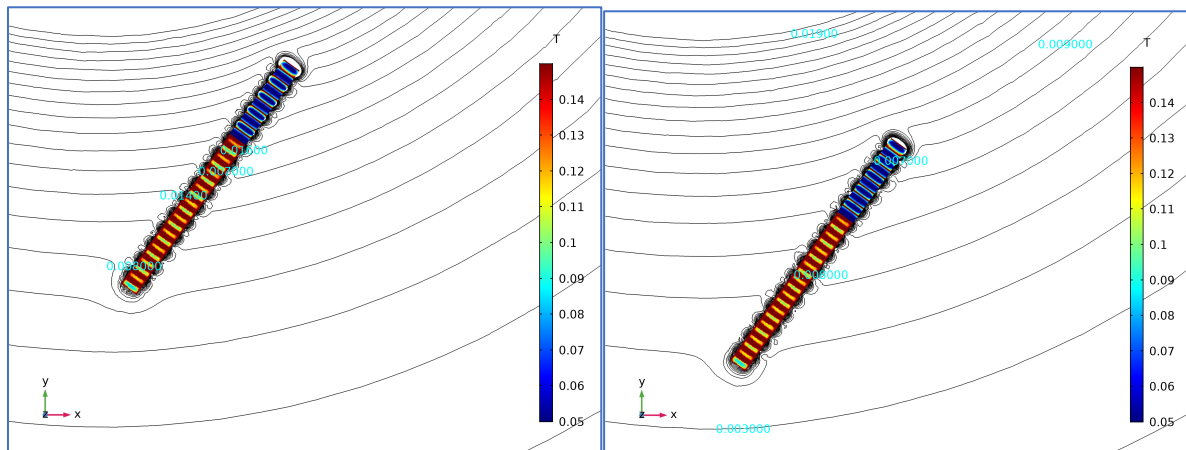
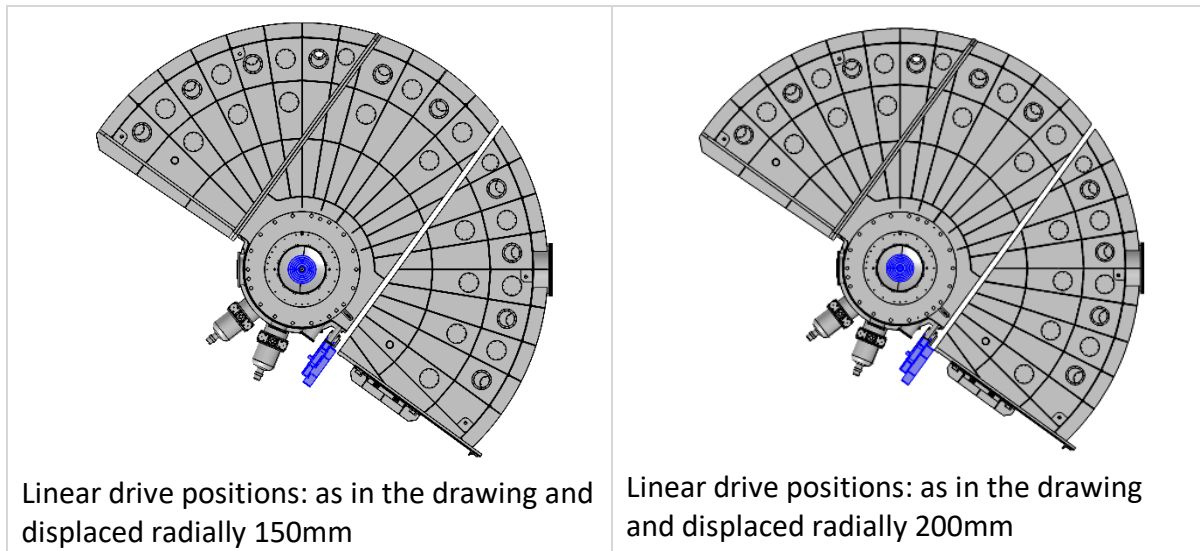


Figure 13. Results of the simulations performed by the Polarisation team of the ESS. The two top pictures show the Detector Vessel and the linear drive (in blue). The two bottom pictures show the linear drive in the field generated by a 15T magnet at the sample position.

Now, the design of the radial collimator is quite mature. We plan to set up a test bench in order to verify the bearing design and to test the drive. The drive is already available at JCNS and can be used for the test. The bearing for the radial collimator is developed by Franke GmbH, they are still conducting manufacturing trials in order to find a non-magnetic material with low radiological activation for the bearing race way. Unfortunately, this takes longer than expected. They might have to stop these activities if they don't come to a conclusion soon and in this case we would have to go ahead with the spring steel material with a proportion of 40% cobalt and shield it.

The picture below shows a cross-section of the bearing. The raceways are the 4 wires at each corner of the rolling elements. The wire has to be shaped and grinded according to the roller geometry.

The design has a very high maturity level and technical drawings of the complete bearing, collimator interfaces and drive support are available.

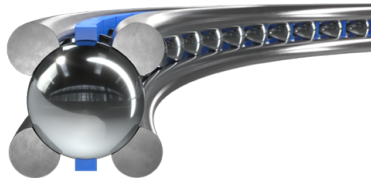


Figure 14 - A picture showing the bearing.

1.4 Experimental cave

Status of sub-project:

- IDR level civil engineering design
- Radiation levels validated
- Developing the interfaces (e.g. polarization equipment requires a laser lab)

1.4.1 Current design of the cave

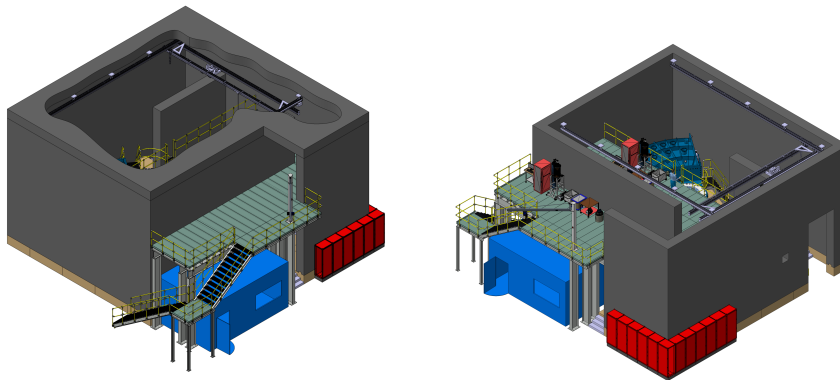


Figure 15. Two different views of the experimental cave.

An elevated access to the inside of the cave has been included in the current design that will enable faster handover of the sample environment through a platform inside the cave, which will enable access for the users to exchange the sample stick. For major installation work and maintenance the cave will feature a wider entrance. It could be used also for installation of more complex sample environments.

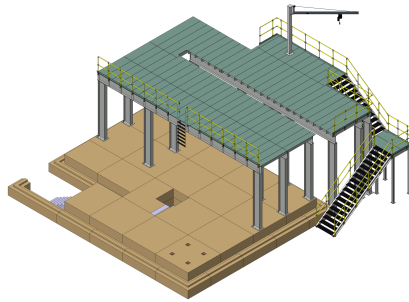


Figure 16 - The elevated platform

A crane will be placed outside the cave and used to lift sample environment equipment

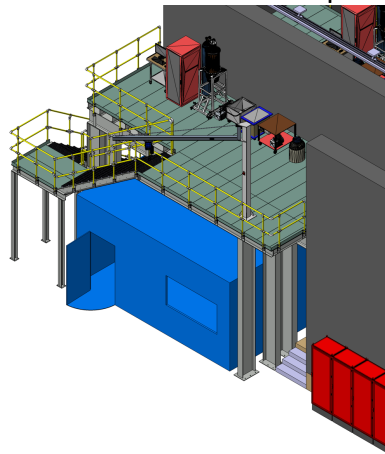


Figure 17 - The crane outside the cave.

Inside the cave a bridge crane will be used for installation, maintenance and sample environment exchange.

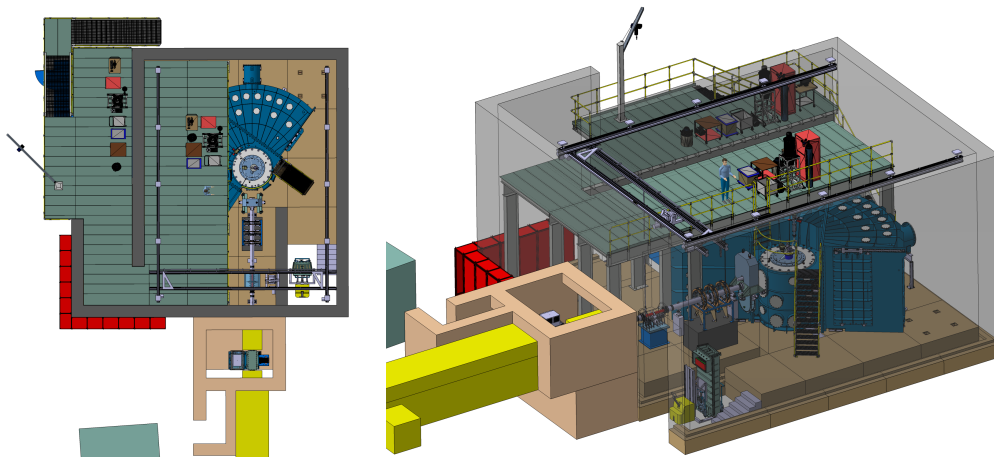


Figure 18 - The bridge crane inside the experimental cave.

The T-REX experimental cave consists of a main region having an inner dimension of $W \times L \times H = 970 \text{ cm} \times 1040 \text{ cm} \times 820 \text{ cm}$. The region is accessible via two doors, one on the right side on the ground floor and another on the left side on the second floor, both with a dimension of $W \times H = 200 \text{ cm} \times 280 \text{ cm}$.

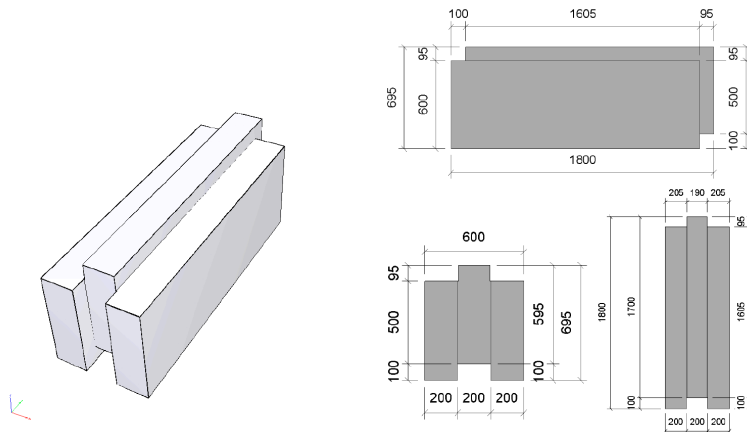


Figure 19 - Technical drawing of a concrete brick of the T-REX experimental cave wall.

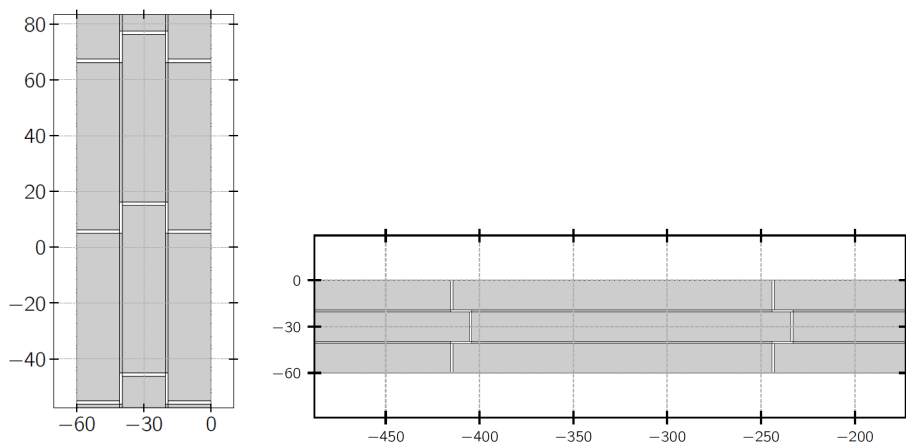


Figure 20 - (upper) Vertical and (lower) horizontal cuts on a single wall showing the arrangement of

1.4.2 Laser lab

A laser safety lab is required to operate the thermal neutrons polarizer at the ESS. Because its position is inside the experimental cave, we need the ESS to approve the laser lab in order to freeze the interface with the cave and floor and be able to proceed with their purchase. For this reason, we dedicated some effort into developing the concept and present it to the ESS stakeholders.

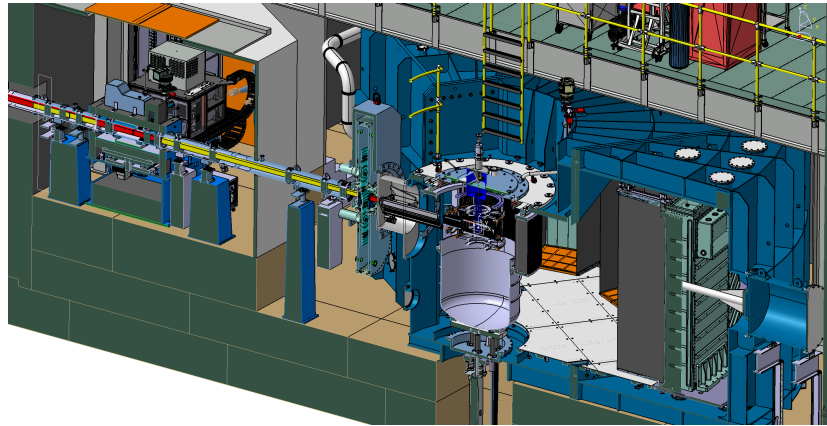


Figure 21 - A view of the laser lab inside the cave showing also the physical interfaces around the sample area.

We envisage the use of a modular system from the company IPM (<https://www.laserkabinen.com/lasersschutz-komponenten.html>). Besides the cell panels they provide top loading-, sliding- and roller doors which are tested according to DIN EN 60825-4 Appendix „D“. Laser detectors through optical sensors and warning lights can be included. These requirements meet those of class 4 lasers, such as the one we will implement in the thermal neutrons polarizer. We requested a budgetary offer from them in order to take a “make or buy” decision. Current design foresees a sliding top loader door for equipment and a roller door for staff.

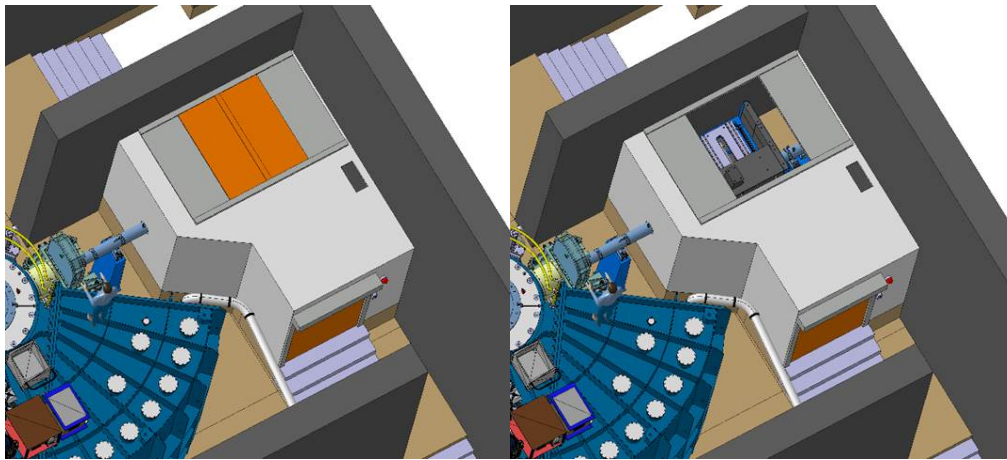


Figure 22 - The laser lab inside the experimental cave showing the sliding roof.

1.5 Safety systems

Nothing to report on this.

1.6 Project progress tracking

Some external factors have an impact on the progress of the instrument project:

1. In 2020 the ESS has adopted a staged-approach to procurements of neutron guide and fast choppers, that has given priority to instruments expected to deliver earlier than T-REX. This approach had a direct impact on the T-REX schedule (postponement of procurements obtained by the ESS postponing the CTV approvals) and an indirect impact, that is the fact that the vendors cannot allocate resources to deliver the components according to the original schedule (resulting in delays of sub.TG3s and final TG3). Because the procurements happened later than originally planned, this is producing extra costs (due to inflation and delays of sub.TG3s).
2. All procurements related to the T-REX project were put on-hold in 2021. The reason is that the projected costs at completion are significantly exceeding the allocated budget. The costs for personnel are higher than originally planned to cope with the demanding TG3 process and the budgetary offers for the most expensive components (such as fast choppers and detector vessel) are significantly above the allocated budget and the contingency is not enough to compensate. In this scenario, the management of JCNS was not entitled to allocate budget for procurements and needed to find a solution with the funding agency (BMBF) and the ESS. This discussion was concluded by a formal agreement with the BMBF in December 2021.
3. As already mentioned in this report and discussed in the previous STAP meetings, the tender for the Detector Vessel failed for formal reason, therefore causing the need to rework the tendering and finding a solution to guarantee the permeability as requested by the ESS.

In the attached tables we summarize the Milestones agreed with the ESS and their current progress status.

1.6.1 Project Milestones

See attachments:

FZJ: 2022-04_T-REX_Project Milestones_FZJ.pdf

CNR: 2022-04_T-REX_Project Milestones_CNR.pdf

1.6.2 Installation plan

A preliminary installation plan is attached:

T-REX_STAP_installation_plan.pdf

1.6.3 Project Risks

	Risk title	CAUSE	EVENT	CONSEQUENCE	Risk type	Partner	Status	Impact	Probability	Rating
1	Missing Engineering resources at CNR	As a result of the CNR not having a project engineer assigned to T-REX project	There is a risk that the components assigned to the CNR will be delivered late	Resulting in a delay in the overall project schedule	Schedule	CNR	Open	High	Likely	16
2	Key personnel leaving the project / programme	As a result of the significant delay on the overall ESS timeschedule	There is a risk that key personnel will temporarily leave the project	Resulting in delays due to loss of competences on the project	Schedule	FZJ	Open	High	Significant	12
3	General delays on procurements (Detector Vessel)	As a result of the stringent magnetic requirements and long procurement processes	There is risk of procurement failing or taking longer than expected	Resulting in delays on the procurement of components (Detector Vessel)	Schedule	FZJ	Open	Very high	Likely	20
4	Lack of neutrons for testing (NBOA)	As a result of the Pandemic	There is a risk that there is no access to neutrons for testing components (NBOA)	Resulting in delays or unfulfilment of the quality requirements	Schedule	FZJ	Open	High	Likely	16
5	Procurement of works and services from ESS (Multi-GRID Detectors)	As a result of all the legal implications of amending TAs to procure the works and services from ESS	There is a risk that the detectors that FZJ needs to procure from ESS are not available	Resulting in a delay on the whole project	Schedule	ESS	Open	High	Very likely	20
6	Detector performance requirements may not be met	As a result of the Detector not being a proven technology, but a development still in progress	There is a risk that the detectors performance will not meet the expected requirements	Resulting in a reduced instrument performance	Quality	ESS	Open	Very high	Very likely	25
7	Increasing costs of materials (Detector Vessel)	As a result of the inflation and interrupted supply chain due to the Pandemic	There is a risk that the costs of materials will increase significantly (Detector Vessel)	Resulting in increased costs of the components (Detector Vessel)	Cost	FZJ	Open	High	Likely	16
8	Increasing costs of materials (Beamline shielding)	As a result of the inflation and interrupted supply chain due to the Pandemic	There is a risk that the costs of materials will increase significantly (Beamline Shielding)	Resulting in increased costs of the components (Beamline shielding)	Cost	CNR	Open	High	Likely	16
9	Increasing costs of materials (Experimental cave)	As a result of the inflation and interrupted supply chain due to the Pandemic	There is a risk that the costs of materials will increase significantly (Experimental cave)	Resulting in increased costs of the components (Experimental cave)	Cost	CNR	Open	High	Likely	16
10	Instruments EAC (2020) significantly higher than CBV	As a result of inflation, CBV in 2013, personnel costs higher than ESS CBV, delays from ESS side, etc	There is a risk that the projects will cost significantly higher than expected	Resulting in missing budget for the project and/or project termination	Cost	FZJ	Escalated	Very high	Very likely	25
11	Heimdal's chopper protruding into the in-bunker guide	As a result of the Heimdal's chopper being protruding into the T-REX neutron guide	There is a risk that the revision of documentation at ESS will be postponed or delayed depending on the priority of the instrument	Resulting in significant delays on the project	Schedule	ESS	Open	High	Likely	16