T-REX instrument Project: Report of activities in preparation of the STAP meeting in April 2021.

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 officially passed TG2 in August 2017. The Technical Annex was signed and endorsed in January 2020.
The project of T-REX is expected to achieve completion in June 2025. The access dates to ESS buildings for installation are foreseen for the end of 2022 in building E01 (first access) and in 2024 for the bunker area.

The agreed scope includes the delivery of a world class DGCS, capable of performing INS experiments for a broad user community spanning from magnetism to functional materials and functional soft matter, including the option of using polarized neutrons for x-y-z neutron spin analysis. On 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.

Here we provide a brief overview of the progress made in Q4-2020 and Q1-2021, in preparation of the next STAP meeting in April 2021.
In the reporting period, the instrument team has been working at the **preparation of procurements** of various components.
The following items are currently **ready to start the procurement process with design approval by the ESS**:

1. detector vessel,
2. detectors integration box.

The following items are currently ready to start the procurement process and **their tender includes the final design of relative components**:

3. fast choppers,
4. neutron guide.

In preparation of the reviews and relative procurements, the **design of various components has been further developed and integrated in the instrument model**:

5. updates to the in-bunker section according to review feedback,
6. preliminary out of bunker guide design,
7. analysis of beam monitors integration (dummy design for space reservation),
8. conceptual design of mini cave for polarizer and FAN chopper,
9. cave layout updates:

- ground level entrance for maintenance,
- continuous platform with sample staging area outside,
- external crane to lift sample environment equipment,
- internal bridge crane,
- civil engineering design,

10. gate valve,
11. secondary collimator: finalization of drive and integration components,
12. primary collimator.

We also provide a summary of progress as measured by completion of the Milestones schedule agreed with the ESS.

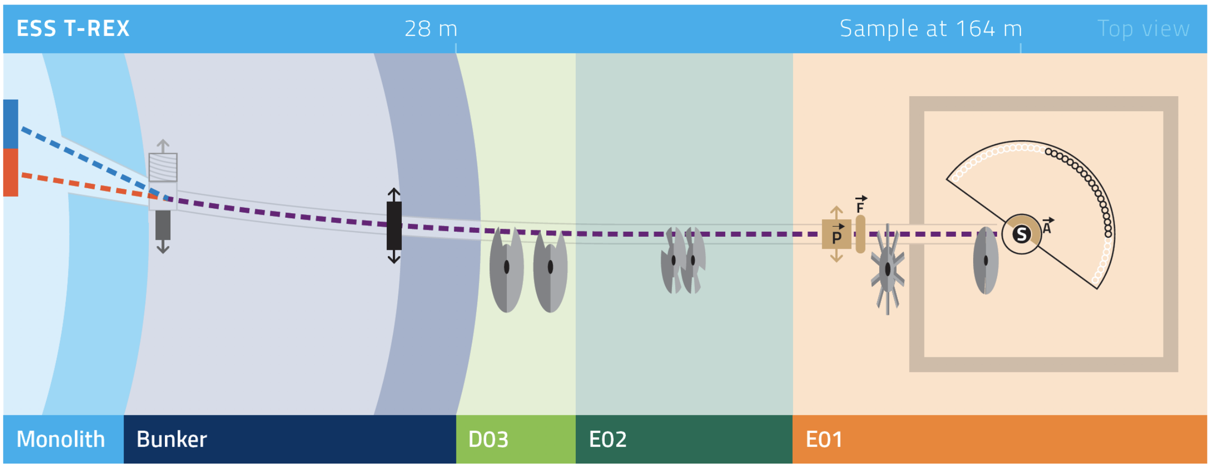


Figure 1. T-REX layout overview.

1. THE DETECTOR VACUUM VESSEL

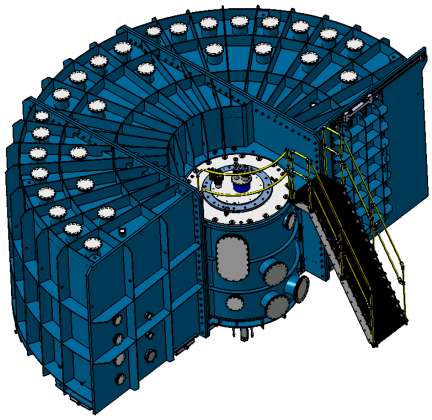


Figure 2. Detector Vessel 3D view.

The tender procedure for the T-REX vacuum vessel failed for formal reasons and it has been closed on September the 28th of 2020. The major obstacle to finding a suitable manufacturer was the high requirement to control the magnetic permeability around the sample area: none of the participants was willing to guarantee the required permeability. We will have to repeat the tender as soon as possible, whilst collaborating with the ESS on the definition of a quality control process that will ensure the required level of permeability is reached. Our proposal to the ESS is to adopt an iterative approach based on controlling and validating the as-built components and use simulations that will include the as-built features, so to have a validation through a combination of simulations and real measurements as part of the FAT. We're discussing this approach with the ESS, while having contacts with potential suppliers to expand as much as possible the tendering participation.

2. DETECTORS INTEGRATION BOX

The Design of prototype of detectors integration box is ready to start manufacturing:

- Design approved by ESS DG,
- Manufacturing drawings complete,
- Budgetary offers received.

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.

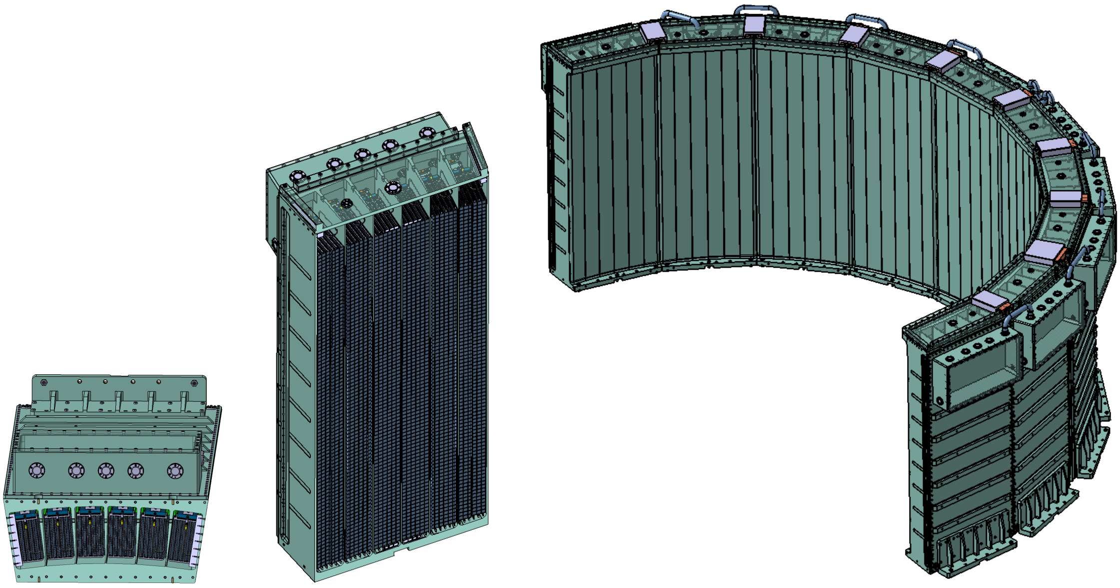


Figure 3. Multi-GRID Detector integration system. Left: top view of the integration box. Center: the integration box. Right: The whole integration system is represented as to cover the entire detector area.

3. FAST CHOPPERS

The Procurement process for the fast choppers of T-REX has been initiated.
There is no substantial change of the choppers' functions and the design choices (from the scientific view point) have been confirmed so far.

4. NEUTRON GUIDE

In the past months the team addressed the comments emerged during the review of the conceptual design of the in-bunker components. Here is the link to the confluence page that captures the current status of this discussion. The procurement specifications for the In-Bunker guide, the bunker wall feedthrough and the neutron guide out-of-bunker have been approved.
In the meantime, we initiated first discussions with the neutron guide suppliers in order to have them informed about the basic principles of our project in advance and received preliminary offers.

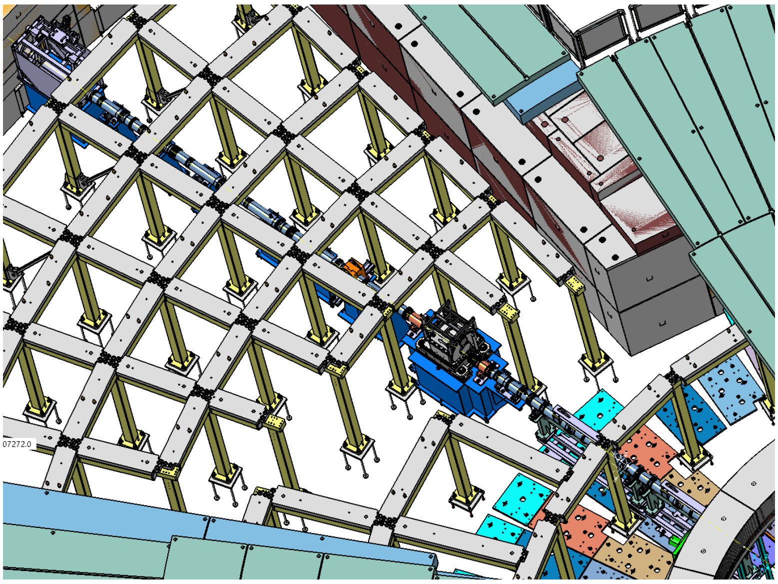


Figure 4. Overview of the in-bunker components.

The T-REX **NBOA** manufacturing has been completed and the supermirrors are currently being tested with neutrons. The FAT for NBOA is planned for the end of April 2021.

5. UPDATES TO THE IN-BUNKER SECTION

- The in-bunker guide model has been updated according to the input from the suppliers: some neutron guide segments were adjusted according to the suppliers' suggestions to improve manufacturability and alignment.

- The remote handling section has been updated according to the IDR review feedback. The lifting lugs can now be assembled directly to the vacuum vessel and not to an additional beam above the tube. Moreover, the guiding pins on the frame were extended, to further improve the alignment process during the assembly of the vessel from above the frame.

- The latest ESS models (e.g.: buildings, feedthroughs, reserved volumes, pillars, heavy shutter, light shutter system) have been implemented and the integration of T-REX into the facility validated.

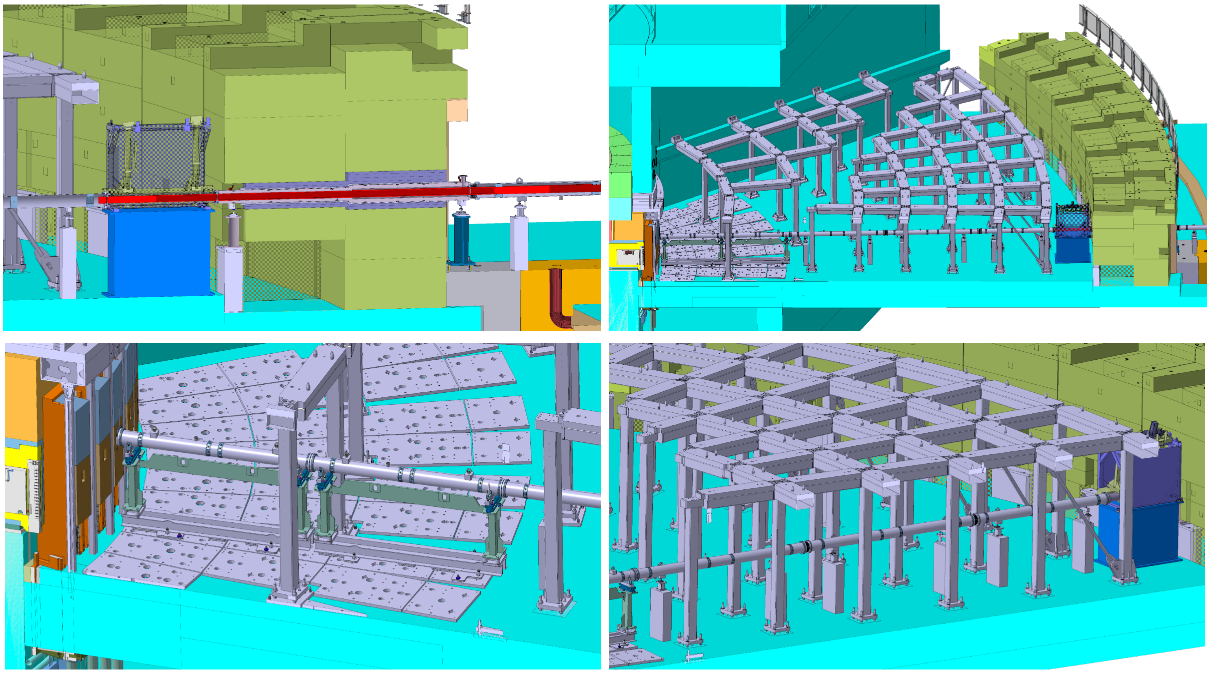


Figure 5 - Some details of the in-bunker neutron guide model.

6. PRELIMINARY OUT OF BUNKER GUIDE DESIGN

- Some engineering effort has been put into making the 3D instrument model consistent with the table of optics (the tool used to document neutron guide features such as dimensions, profile types, required m-index and reflectivity) and compatible with the expected real system, taking into account technical discussions occurred with the potential manufacturers.
- A preliminary model for the out-of-bunker neutron guide has been created, that includes vacuum vessels, supports and shielding.

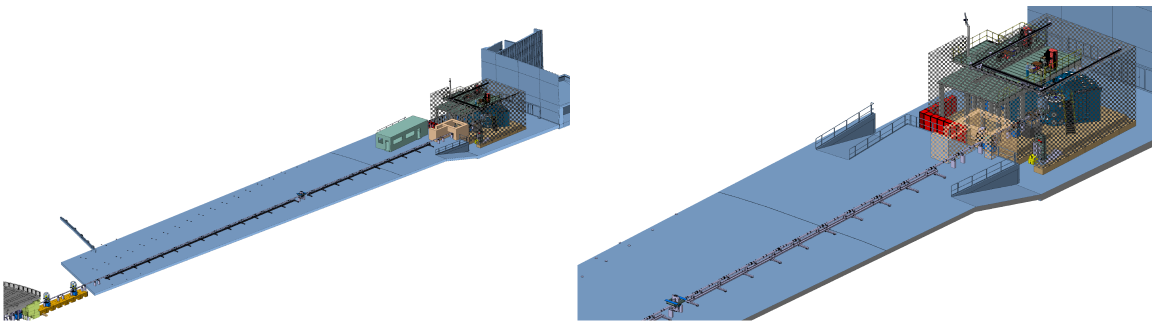


Figure 6 - (Left) Overview of the neutron guide model. (right) A view of the neutron guide in the guide hall.

7. ANALYSIS OF BEAM MONITORS INTEGRATION

At the moment of writing we don't have a specific solution/technology for the monitors, therefore we have included dummy models in the instrument model to ensure there is a proper space reservation for monitors integration along the beamline. As an example we show a screenshot of the model at the M-chopper position.

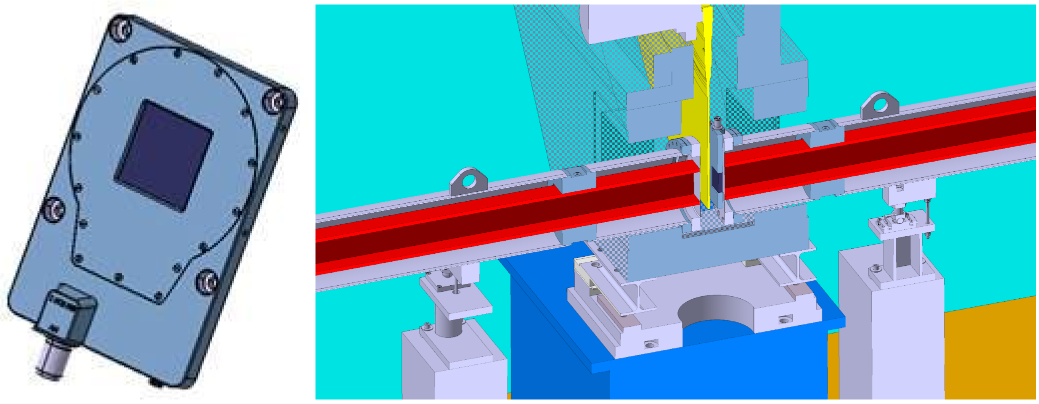


Figure 7 - Dummy models for the beam monitors have been integrated to the model.

8. CONCEPTUAL DESIGN OF MINI-CAVE FOR POLARIZER AND FAN CHOPPER

We're developing the concept of a mini-cave to enable access to the polarizer and the FAN chopper. It will be installed in the area across the experimental cave and the guide hall.
The main considerations/reasons that brought us to consider this solution are the following:

- Placing the polarizer and the FAN chopper inside the experimental cave would most likely require increasing the attenuation power of the shielding to guarantee its radiological safety, therefore increasing complexity and costs.
- Placing the polarizer inside the experimental cave would increase the radiation level inside the experimental area, with a potential increase of the measured background that would also be difficult to reduce afterwards, due to the limited space available.
- Placing the polarizer and the FAN chopper in a separate cave will bring us to reduce the size of the experimental cave, therefore saving costs that could be invested in the mini-cave. We expect some savings overall, but in the worst case, it will be cost neutral.
- The polarizer will need frequent access for maintenance that will be easier with the min-cave (shorter way in and out, simpler search procedure).
- The polarizer will be equipped with a laser that should operate when working on the alignment, therefore the area where it will be installed will be considered a laser-lab. A smaller area will be easier to control and operate as a laser-lab.
- Changing the FAN chopper position doesn't cause any impact on its performance, because the blades design can be adapted to the slightly different requirements and its final engineering design has not started yet.

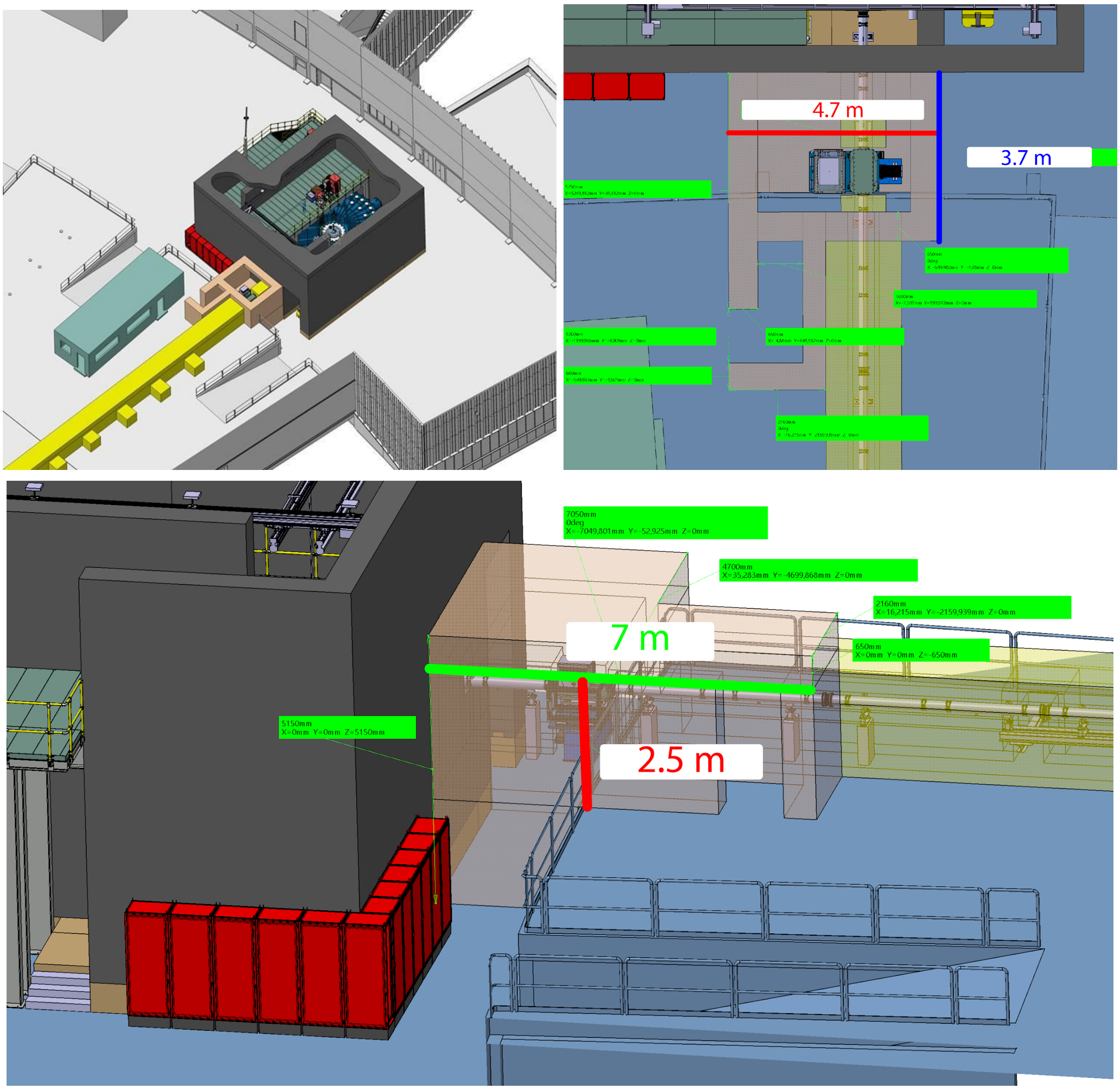


Figure 8 - (Upper left) Overview of the area where the mini-cave is placed. (Upper right) Top view of the mini-cave. (Bottom) Side view of the mini-cave.

9. CAVE LAYOUT UPDATES

Here we summarize the major updates to the experimental cave layout.

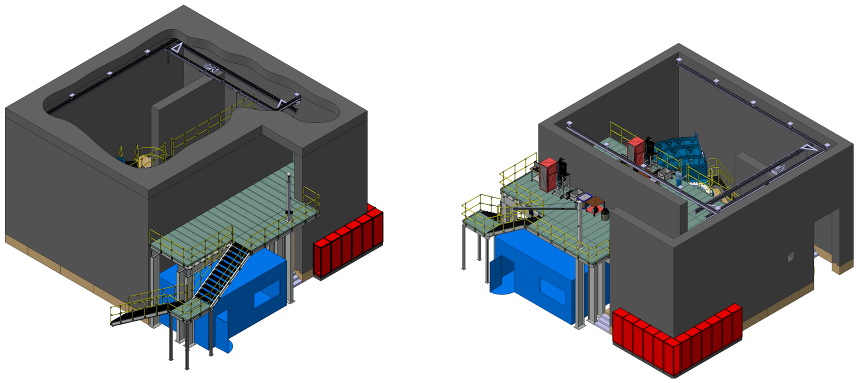


Figure 9. Two different views of the experimental cave.

- **Ground level entrance for maintenance**

An access to the inside of the cave **at the ground level** has been added to the one already foreseen. It will enable access to the M-choppers, the last segments of neutron guide with its polarisation equipment and the electronics of neutron detectors on one side of the vacuum vessel.

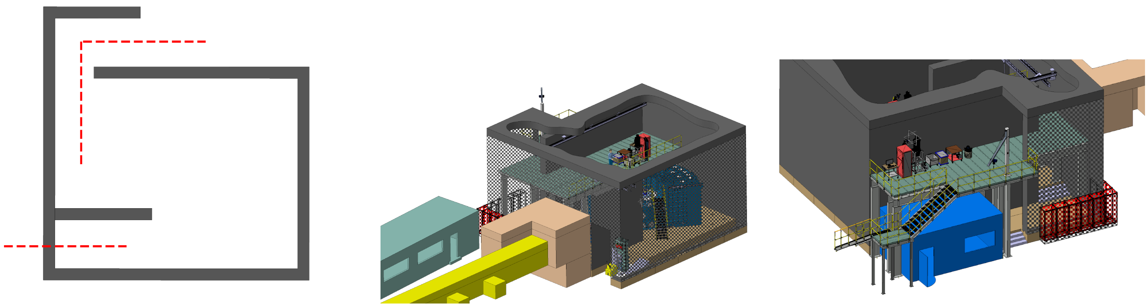


Figure 10 - Access to the experimental cave at the ground level. (Left) Cut of the shielding. (Center) The already foreseen entrance door on the right side. (Right) The additional entrance on the left side.

- **Continuous platform with sample staging area outside**

An elevated access to the inside of the cave has been included in the current design. It will enable:

- A continuous path from the sample environment preparation area to the sample position for sample environment exchange.

- Access for the users to exchange the sample stick.

The platform will be equipped with a crane to elevate the sample environment from ground level, but it's also served by the bridge crane inside the experimental cave.
For major installation work and maintenance, the cave will feature a wider entrance at the ground level. It could be used also for installation of more complex sample environments.

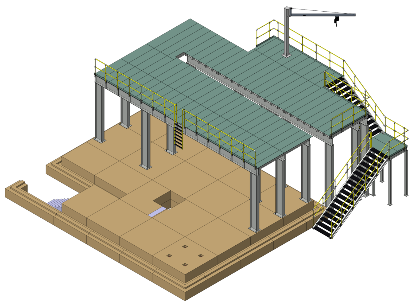


Figure 11 - The elevated platform

- **External crane to lift sample environment equipment**

As already mentioned, the elevated platform is served by a crane to lift the sample environment from the ground floor outside the cave.
This feature will enable the preparation of the next experiment outside the cave, while one other is still running, without interrupting it.

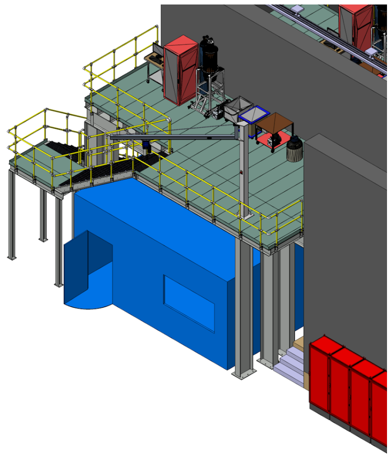


Figure 12 - A view of the crane and the elevated platform.

- **Internal bridge crane**

Two major considerations brought us to include a bridge crane inside the cave:
- It offers more coverage (almost full coverage) than the jib-crane.
- Not having the crane installed on the floor, will free up some space for the escape route, which in turn enables to reduce the experimental cave footprint.

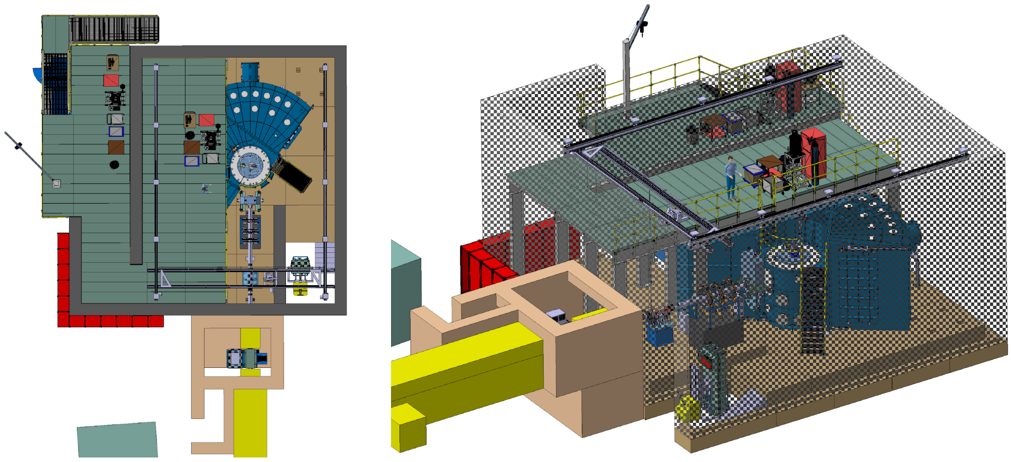


Figure 13 - Top and side view of the cave with emphasis on the bridge crane.

- ## **Civil engineering design**

The current design has been analyzed and further developed with the support of a civil engineer, who has proposed a design for the shielding bricks. As a consequence of this feasibility study the experimental cave has been significantly re-shaped, by simplifying the footprint to reduce design and manufacturing costs.

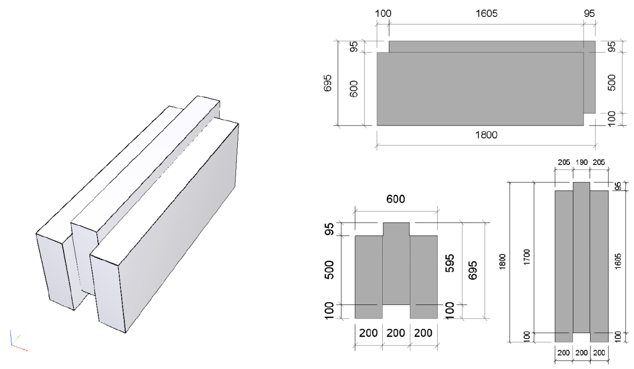


Figure 14 - Technical drawing of a concrete brick of the T-REX experimental cave wall.

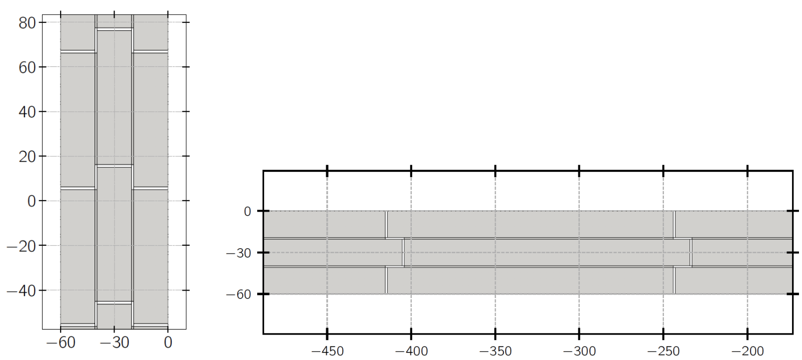


Figure 15 – (Left) Vertical and (Right) horizontal cuts on a single wall showing the arrangement of bricks with a nominal gap of 15 mm.

Now the T-REX experimental cave consists of a main region having an inner dimension of 970 cm x 1040 cm x 820 cm. The region is accessible at the ground level via two doors, one on the right side on and another on the left side. Another access is foreseen on the second floor through the elevated platform. The doors feature a dimension of 200 cm x 280 cm. The right door is located in the upstream beam extended region of an inner dimension of 230 cm x 380 cm, and shielded against the direct radiation from the sample by an inner wall with a dimension of 60 cm x 210 cm x 314 cm.

This design has been validated with neutronics calculations, showing that doors can be left to a void material, therefore reducing complexity and costs.
The inner region of the cave is shielded with concrete walls all around with a thickness of 60 cm.
The beam-stop has been included in the calculations. However, its design has not been fully optimized yet to cope with beam divergence due to beam focusing at the last elements of the neutron guide. In the simulation shown in figure the beam cross section was not fully covered by the Cd sample and hit the steel layer of the beam stop at the front surface which induced higher photon radiation flying backward towards the inside of the cave. This can be solved by properly sizing the get-lost tube of the beam-stop.

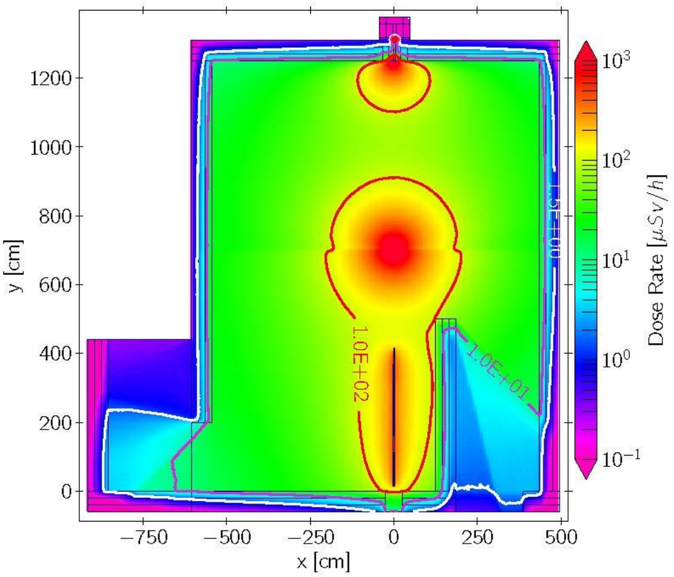


Figure 16 - Distribution of the dose rate on the xy-plane at the beam axis height for H2-2 events.

11. GATE VALVE

The development and mechanical design have reached high maturity:

- All drawings of mechanical parts are finished.
- Integration of components in the current vacuum vessel design and with the floor slab has been considered.
- We received budgetary offers for most parts that need to be procured.

Currently the Motion Control team of JCNS is supporting us with the selection of a drive. When this task will be completed we will be able to present the whole sub system in a review to the ESS.

The gate valve has to be available at the latest, when the vacuum vessel arrives in Jülich to perform integration tests and validate the interaction of the various components.

In April we plan to test the modified interface of the inflatable sealing between gate valve and vacuum vessel at ZEA-1 in. Jülich. The size of the gap has been increased in comparison to the older version to compensate for the expected deformation of the vessel in vacuum.

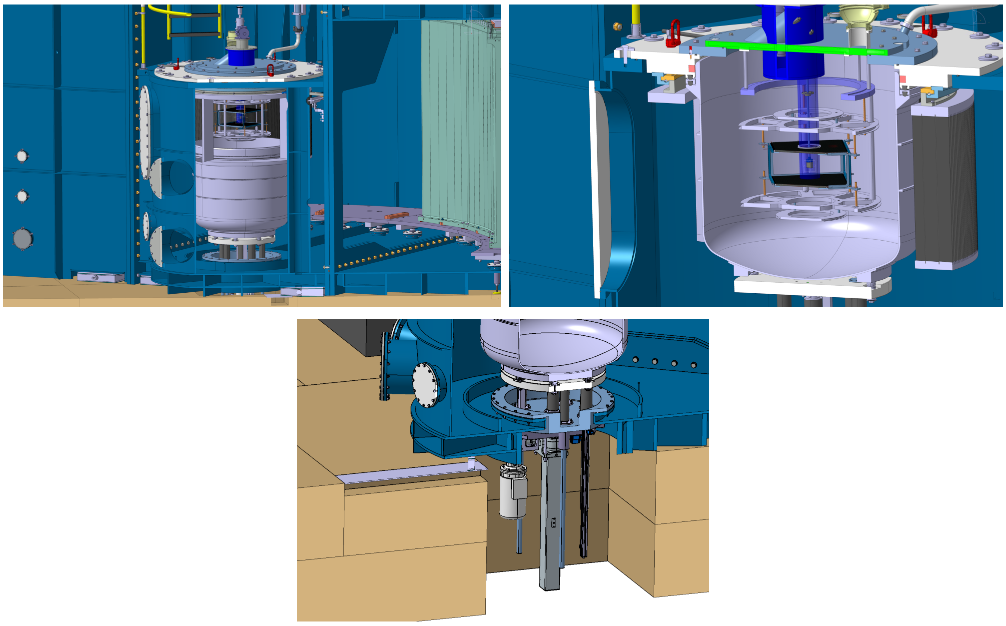
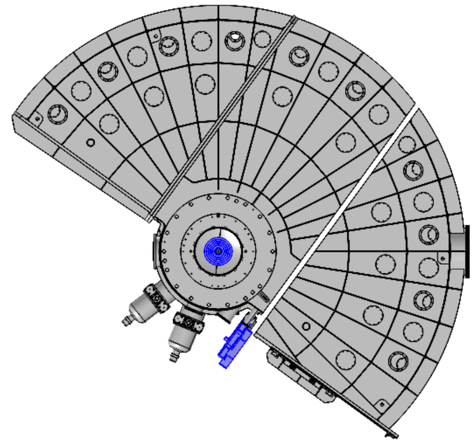
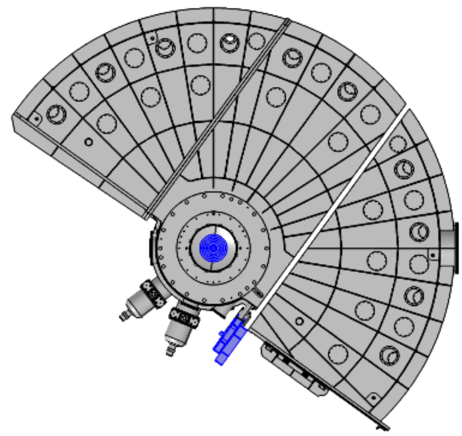


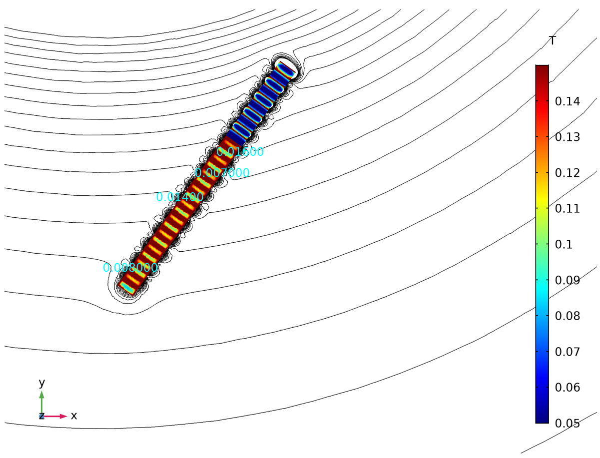
Figure 17 - View of the sample exchange vessel.

12. SECONDARY COLLIMATOR

A substantial effort has been put into the design of the drives for the radial oscillating collimator: 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. This solution has been further developed with the support of the polarization team of the ESS. They 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 the position of the drive and specifications. At the same time there is the feeling that a test phase is necessary to validate the installation. We plan to set up a test bench (see figure below) in order to verify the bearing design and to test the drive. The drawings of the test bench have been finished as well and will be

discussed with the production planning group in the next weeks. The drive is already available at JCNS and can be used for this test.
During the pre-installation phase in FZJ, the team aims to complete the integration tests.

	
Linear drive positions: as in the drawing and displaced radially 150mm	Linear drive positions: as in the drawing and displaced radially 200mm



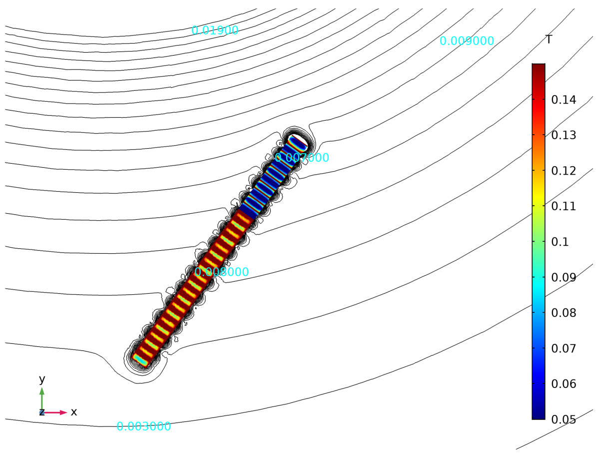


Figure 18. Results of the simulations performed by the Polarisation team of the ESS. The two top pictures show the Detector Vessel and the linear drive (in blue). The two bottom pictures shoe the linear drive in the field generated by a 15T magnet at the sample position.

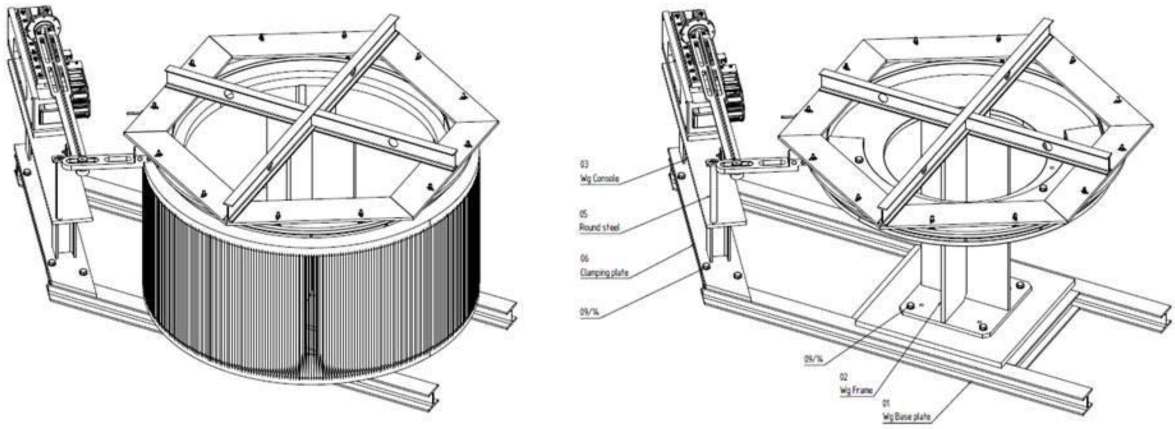


Figure 19 - Drawings of the test bench for the secondary collimator.

13. PRIMARY COLLIMATOR

The design of the primary collimator has been completed. It features three positions in line with the neutron beam (two equipped with different collimations and one with neutron guide). The motion components have been identified and the choice validated by the ESS. This step was necessary to ensure that there will not be interferences with the magnetic fields at the sample position (due to the sample environment), neither with the polarization equipment. At the moment of writing we're further optimizing the interface with the M-chopper that requires validation through neutron ray-tracing simulations.

The driving requirements for this development have been:

- A vacuum window is foreseen on both sides of the M-chopper.
- The vacuum housing should be as thin as possible.
- The neutron guide upstream the M-chopper is in an independent vacuum tube with its window.
- The gap should be as small as possible: we expect it to be nearly 140 mm.

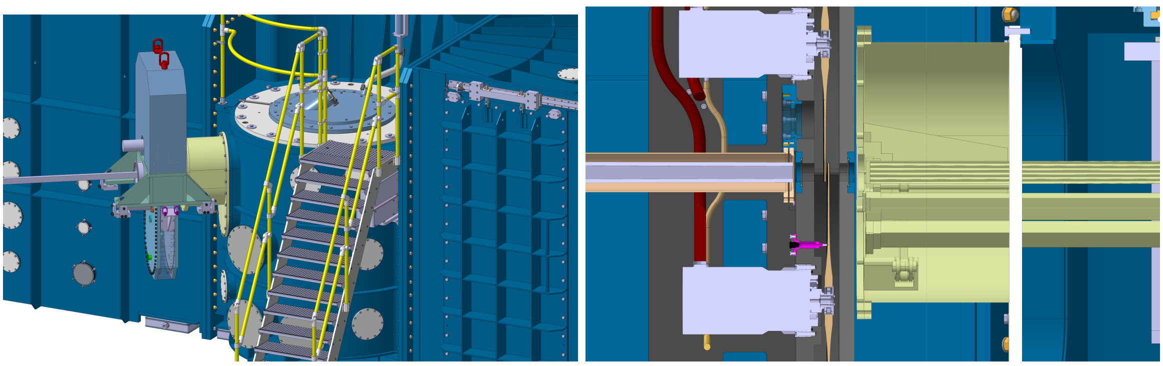


Figure 20 - (Left) Overview of the area where the primary collimator is located. (Right) the interface with the M-choppers assembly.

14. 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 due to 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 will be happening later than originally planned, this will produce extra costs (due to inflation and delays of sub.TG3s).
2. All procurements related to the T-REX project are currently on-hold. The reason is that the projected costs at completion are exceeding significantly 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 neutron guide, fast choppers, detector vessel) are significantly above the allocated and the contingency is not enough to compensate. Here, the JCNS management is working on a solution to cope with the overrunning costs.
3. As already mentioned in this report and discussed in the previous STAP, 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.
4. The current uncertainties on the overall financial situation of the ESS are having consequences on the availability of funding for the CNR work-packages. Cash flow from the funding bodies to the project team is being delayed, with consequently important impacts on the progress of the work-packages.

In the following table we summarize the Milestones (till 2021) agreed with the ESS and their current progress state.

FZJ

Milestone	Description 1	Description 2	Date	Doc. Submitted	Expected Date	Approved	Status
WP08.1	Detector Vessel	Design Reviewed (IDR/CTV)	Jul 18	06.06.18	06.07.18	05.08.18	Complet e
WP01.1	NBOA	Design Reviewed (CTV)	Jul 18	26.07.18	26.07.18	26.08.18	Complet e
WP01.2	NBOA	Procured	Mar 19	15.03.19	01.03.19	22.03.19	Complet e
WP08.2	Detector Vessel	Design Accepted/Sub-TG3. 1	Apr 19	01.04.19	01.04.19	15.01.20	Complet e
WP09.1	Neutron Detector	Protoype Detector Box Design Reviewed (IDR)	Apr 19	04.04.19	01.04.20	05.04.19	Complet e
WP01.3	NBOA	Design Accepted/Sub-TG3. 0	Aug 19	01.08.19		08.05.20	Complet e
WP02.1	In Bunker Components	Design Reviewed (IDR/CTV)	Oct 19	01.10.19	15.07.20	27.10.20	Complet e
WP06.1	Fast Choppers	Design Reviewed (CTV)	Oct 19	01.10.19	15.07.20	27.05.20	Complet e
WP04.1	Beamline Shielding	Design start	Feb 20	01.02.20	15.04.20		In progress
WP01.4	NBOA	Manufactured	Feb 20	15.02.20	15.03.21		Complet e
WP01.5	NBOA	FAT	Mar 20		28.04.21		Delayed
WP03.1	Neutron Guide Outside Bunker	Design Reviewed (CTV)	Apr 20	26.05.20	30.09.20	27.10.20	Complet e
WP06.2	Fast Choppers	Procured	Apr 20		30.04.21		In progress
WP09.2	Neutron Detector	Protoype Detector Design Accepted	Apr 20		30.04.20	22.05.20	Complet e
WP01.6	NBOA	Delivered (ESS)	May 20		No information available		Delayed
WP01.7	NBOA	Installed	Jul 20		No information available		Delayed
WP04.2	Beamline Shielding	Design Reviewed (IDR)	Sep 20		30.11.21		Delayed
WP02.2	In Bunker Components	Procured	Oct 20		31.05.21		Delayed
WP06.3	Fast Choppers	Design Accepted/Sub-TG3. 2	Oct 20		01.12.21		Delayed
WP08.3	Detector Vessel	Procured	Oct 20	25.06.20	01.09.21		In progress
WP03.2	Neutron Guide Outside Bunker	Procured	Dec 20		31.05.21		In progress
WP09.3	Neutron Detector	Prototype Detector Manufactured	Feb 21		01.11.21		In progress
WP12.1	Sample Environment	Design Reviewed (CTV)	Apr 21		30.11.21		Delayed
WP08.4	Detector Vessel	Manufactured	May 21		31.10.22		Delayed

WP08.5	Detector Vessel	FAT	Jun 21		30.11.22		Delayed
WP09.4	Neutron Detector	Prototype Detector Tested	Jun 21		30.03.23		Delayed

CNR

Milestone	Description 1	Description 2	Date	Doc. Submitted	Expected Date	Approved	Status
WP03.1	Monitors	Design Reviewed (CTV)	Oct 20		30.11.2021		In progress
WP04.1	Beamline Shielding	Design Reviewed (CTV)	Oct 20		30.11.2021		In progress
WP05.1	Beam Shutter	Design Reviewed (CTV)	Oct 20		30.11.2021		Delayed
WP07.1	Experimental Cave Shielding	Design Reviewed (CTV)	Oct 20		30.11.2021		In progress
WP01.1	Background Chopper	Design Reviewed (IDR)	Apr 21		30.04.2022		Delayed
WP02.1	Primary Collimator & Slits	Design Reviewed (IDR)	Apr 21		30.11.2021		In progress
WP06.1	Secondary Collimator	Design Reviewed (IDR)	Apr 21		30.04.2022		In progress
WP08.1	Beam Stop	Design Reviewed (IDR)	Apr 21		30.11.2021		Delayed
WP03.2	Monitors	Procured	Jun 21				Delayed
WP04.2	Beamline Shielding	Procured	Jun 21				Delayed
WP05.2	Beam Shutter	Procured	Jun 21				Delayed
WP07.2	Experimental Cave Shielding	Procured	Jun 21				Delayed

RISK REGISTER

Risk title	CAUSE - Risk Description: ("As a result of...")	EVENT ("There is a risk that...")	CONSEQUENCE ("Resulting in...")	Risk type	Partner	Current Untreated Impact	Current Untreated Probability	Current Untreated Rating	Risk treatment	Risk treatment action
NBOA manufacturing process quality assessment	As a result of the covid-19 pandemic	There is a risk that access to neutron facility for testing the NBOA will not be granted	Resulting in accepting FAT without quality testing	Quality	FZJ	**Moderate**	**Likely**	**12**	**Observe**	Communication with the supplier to identify alternatives to the foreseen coating testing
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 ris that the detectors performance will not meet the expected requirements	Resulting in a reduced instrument performance	Quality	ESS	**Very high**	**Significant**	**15**	**Avoid**	The team works in collaboration with the Detector Group of the ESS to manufacture a prototype for testing purposes
Missing Engineering contact person 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	**High**	**Likely**	**16**	**Avoid**	Resources can be made available to the team to hire a Project Engineer
Detector Vessel manufacturing process slows down	As a result of the tender requirements being stringent on magnetic permeability	There is a risk that no contractors can be found	Resulting in a delay in the overall project schedule	Schedule	FZJ	**Very high**	**Likely**	**20**	**Reduce**	Update the specifications, open a new call for tender, communication with potential manufacturers
Overrunning costs	As a result of the currently ECAC (Estimated COST at completion)	There is a risk that the procurements will be postponed	Resulting in a delay in the overall project schedule	Schedule	FZJ	**Very high**	**Very likely**	**25**	**Transfer**	Discussions with funding agency (BMBF) to look for alternative solutions to cover the overrunning costs
Missing ICEB representative for the CNR	As a result of the ICEB representative for CNR not being identified	There is a risk that the project governance will be not effective	Resulting in a delay in the decision-making process	Schedule	CNR	**Very high**	**Very likely**	**25**	**Avoid**	Discussions between FZJ, ESS and the CNR