

# Second Target Station (STS) Project

## QIKR Cave Acceptable Dose Rates Design Criteria Document



January 2025

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**QIKR CAVE ACCEPTABLE DOSE RATES  
DESIGN CRITERIA DOCUMENT**

Author(s)

Wilson, Danielle

Date Published:  
January 2025

Prepared by  
OAK RIDGE NATIONAL LABORATORY  
Oak Ridge, TN 37831-6283  
managed by  
UT-BATTELLE, LLC  
for the  
US DEPARTMENT OF ENERGY  
under contract DE-AC05-00OR22725

Approvals

QIKR Cave Acceptable Dose Rates Design Criteria Document

ISSUE DATE:  
January, 29 2025

PREPARED BY  
Wilson, Danielle

PROJECT  
Second Target Station

DOCUMENT NUMBER:  
**S04080400-DCD10000-R00**

	Signature / Date					
	Rev. 00	Date	Rev. 01	Date	Rev. 02	Date
STS Technical Director	Ken Herwig					
STS Instrument Systems Lead	Leighton Coates					
STS Instruments Systems Engineering Manager	Van Graves					
Radiation Safety Officer	Christi Elam					
ESH&Q Representative	Steve Trotter					
STS Neutronics Group Lead	Igor Remeč					
Radiation Safety Committee Representative	Franz Gallmeier					
Instrument Lead Engineer	Danielle Wilson					

Revision	Description
00	Initial Release

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## ACRONYMS AND DEFINITIONS

ALARA	As Low As Reasonably Achievable
ESH&Q	Environmental Safety, Health, and Quality
QIKR	Quite Intense Kinetic Reflectometer beamline at STS
QIKR-A	The upward-directed QIKR beam path
QIKR-B	The downward-directed QIKR beam path
QIKR-L	The downward-directed QIKR beam path (alternate name)
QIKR-U	The upward-directed QIKR beam path (alternate name)
SE	Sample Environment
STS	Second Target Station
ST01	STS beamport designation, location of EXPANSE
ST02	STS beamport designation, location of QIKR
ST02-A	STS beamport designation for QIKR-A
ST02-B	STS beamport designation for QIKR-B
ST03	STS beamport designation, location of CUPID

## SCOPE

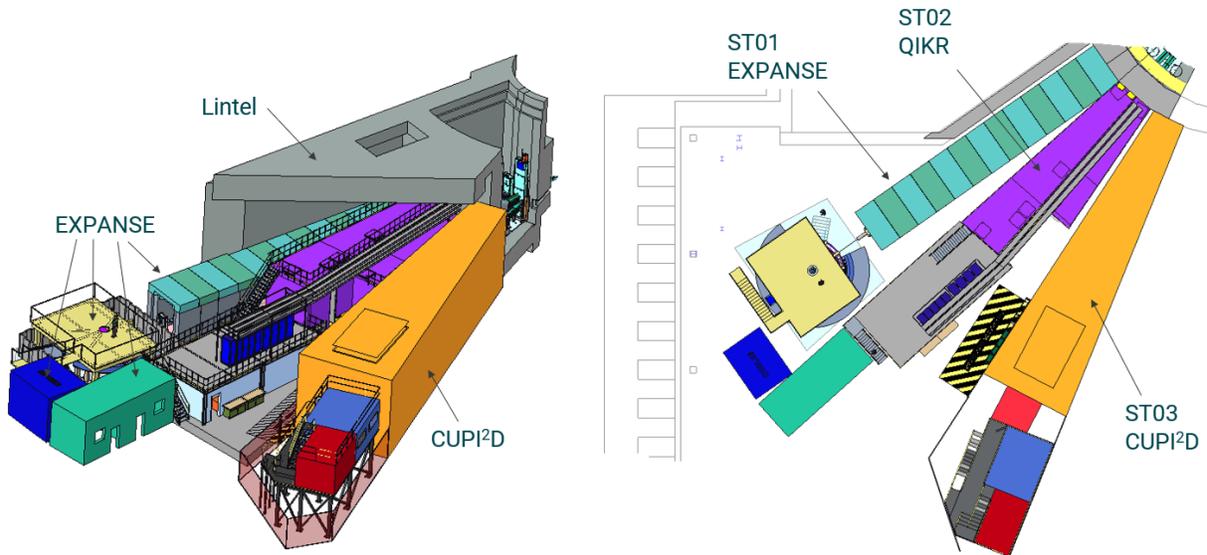
QIKR is a reflectometry beamline at the Second Target Station (STS). This document has two purposes relating to QIKR: (1) define the normal operation and accident scenarios to be used for determining dose rates inside and outside the QIKR cave, and (2) define the acceptable radiation dose rate limits to be used for those scenarios. The focus is only on the interior and exterior cave areas of QIKR, not any other upstream areas.

### 1. INTRODUCTION

Extensive neutronic analysis was performed on QIKR for a variety of possible normal operation and accident scenarios. Following the analysis, a meeting was held with the SNS Radiation Safety Officer and representatives from ESH&Q, STS project management, and STS neutronics scientists to select which scenarios to keep as reasonable, and to determine the acceptable maximum radiation dose rate limits for the QIKR cave, both internally and externally. The reasonable scenarios and acceptable maximum dose rates are presented in Sections 3 and 4.

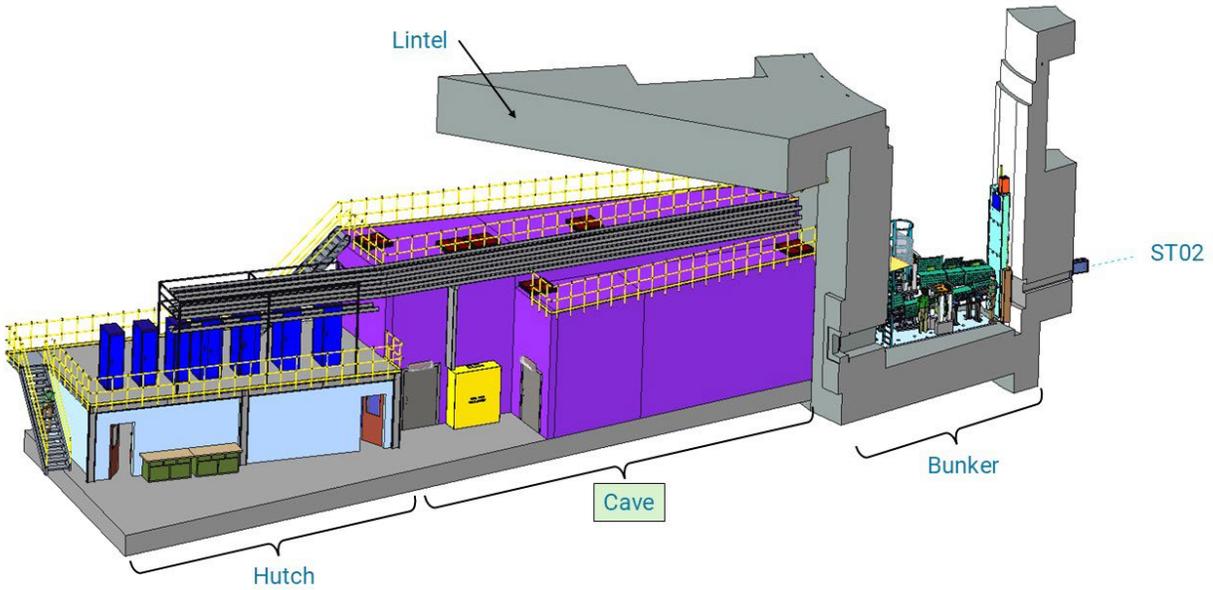
### 2. QIKR OVERVIEW

QIKR is located on the ST02 beam port in the South Hall of STS. It currently has neighboring beamlines on each side. EXPANSE is located on the ST01 beamport, and CUPID is located on ST03 (Figure 1).



**Figure 1:** QIKR (ST02) and its neighbors EXPANSE (ST01) and CUPID (ST03) in the STS South Hall

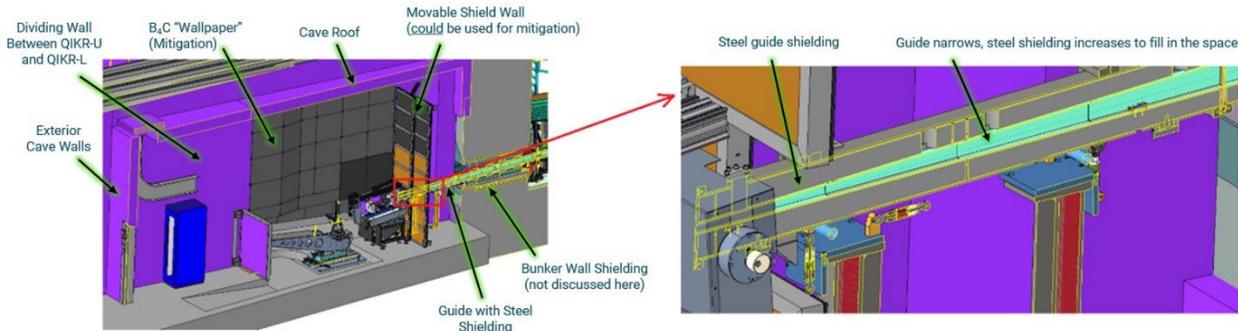
QIKR's space is divided into two halves to accommodate two independently operated beam paths. The beam path on the ST01 side is angled upward at  $2.5^\circ$  and is referred to as QIKR-U, QIKR-A, or ST02-A. The beam path on the ST03 side is angled downward at  $2.5^\circ$  and is referred to as QIKR-L, QIKR-B, or ST02-B. Both beam paths are curved to remove the majority of the fast neutrons prior to the beam entering the cave. QIKR is a cave-only beamline which has no transport tunnel; the cave begins at the exterior bunker wall (Figure 2).



**Figure 2:** QIKR's cave location relative to the bunker

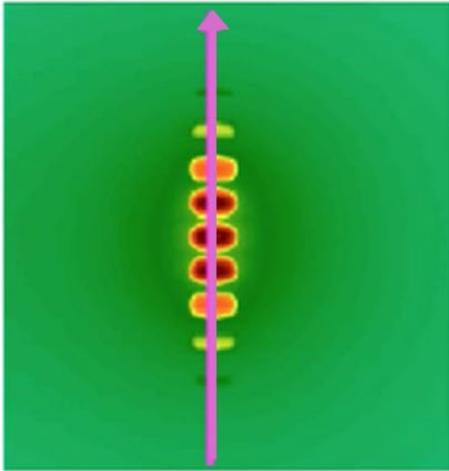
EXPANSE has a transport tunnel that extends past the end of the QIKR cave and allows limited staff-only access to the QIKR-U cave's exterior side surfaces. CUPID is a cave-only beamline that also extends past QIKR's cave but prevents any personnel access (staff and users) to the QIKR-L cave's exterior side surfaces.

Each guide's vertical dimension tapers down quickly at the end (Figure 3) to produce a vertical spread of multiple beams exiting the guide at fixed angle increments from each other. The majority of the neutrons exist in only three of the multiple beam components: one main beam aligned with the  $2.5^\circ$  incline of the guide path, and the adjacent beam components above and below that main beam (separated from the main beam by approximately  $\pm 1.5^\circ$ ). Refer to Figure 4 for data and plots taken from Kursat Beker's neutronic analysis of QIKR.

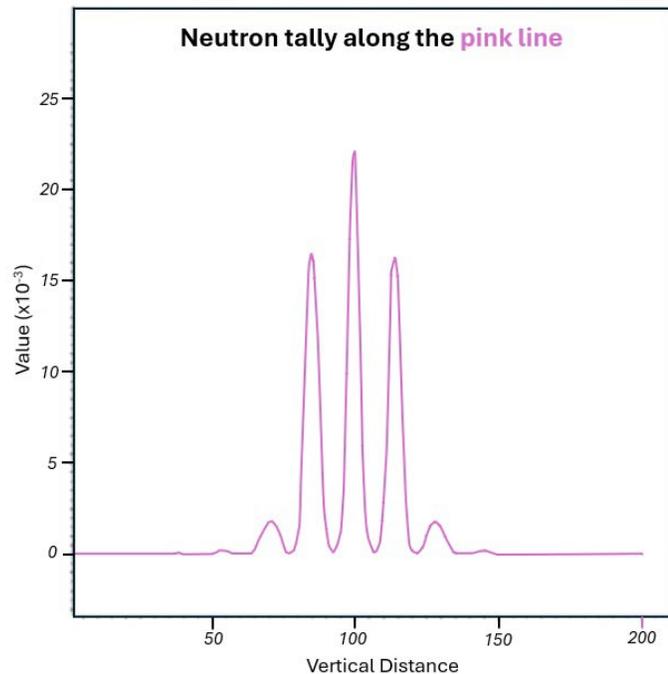


**Figure 3:** QIKR-L cave and guide cross-sections

Analysis and plot: K. Bekar



Analysis and plot: K. Bekar

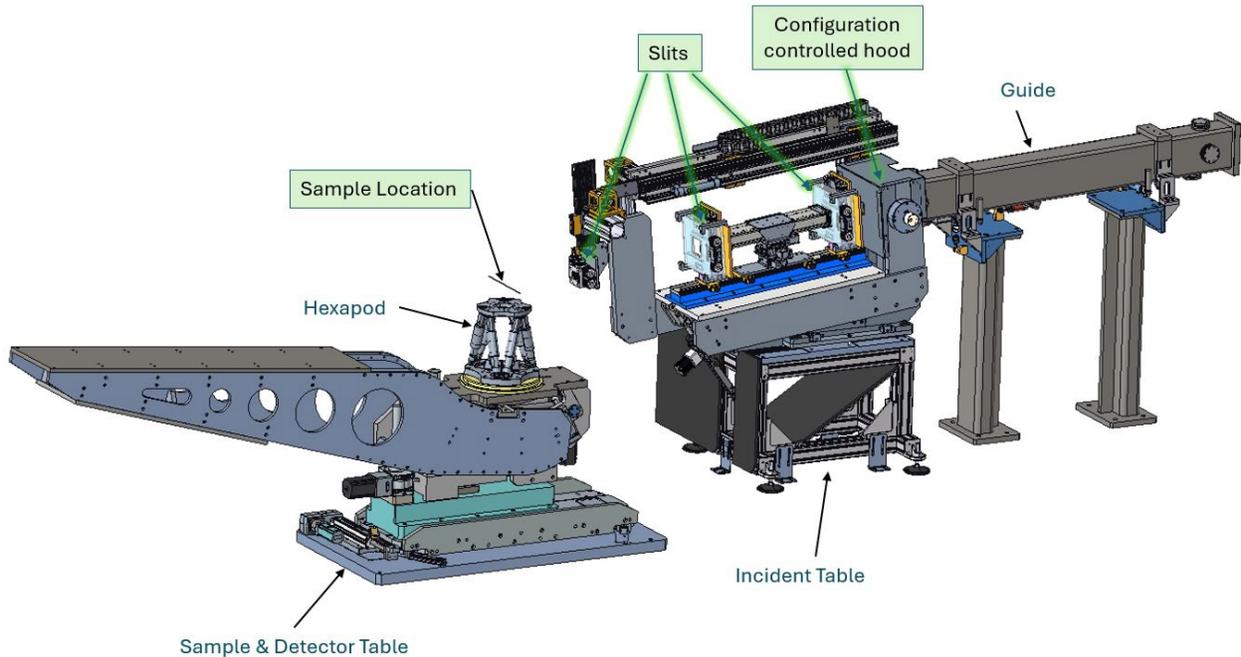


**Figure 4:** Neutron distribution in the beam components (shown at the beam stop location 4m from the guide end)

Once the beam components exit the guide, a single component is selected then shaped to the correct size for a given sample by a series of three motorized slits with variable vertical and horizontal aperture sizes. Useful data cannot be collected from the sample without these slits being present and narrowed to dimensions appropriate for the sample under test. In other words, there would never be a situation where a sample is present and the slits are completely removed from the beamline.

A locked and configuration-controlled hood covers the area between the end of the guide and the location of the first slit to prevent foreign objects from being placed at the guide end and intercepting all beam components exiting from the guide.

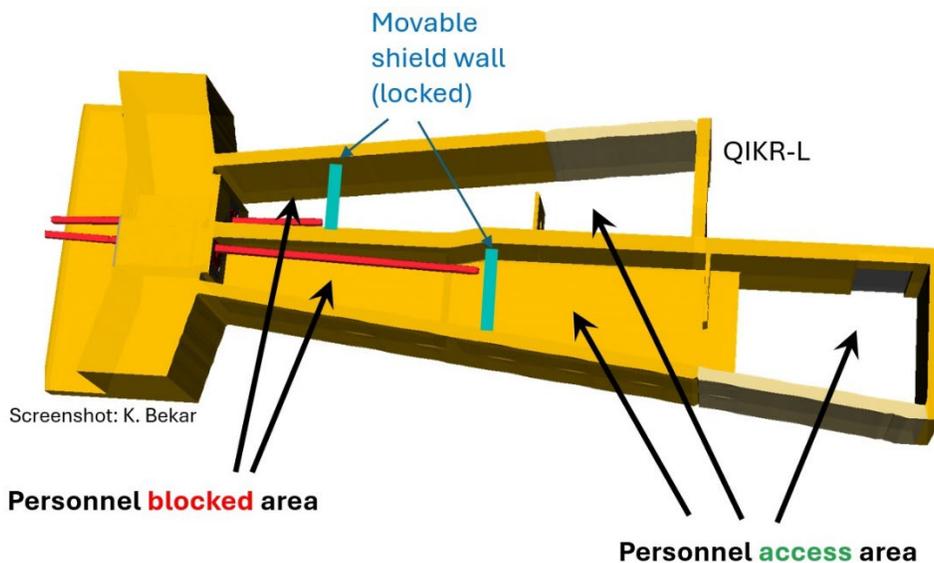
Once the appropriate beam component has been selected and shaped, it travels on to the sample location which is located 2m from the guide end. The sample will typically be a liquid, though solid samples may also be used. The sample environments range from small open containers to larger stainless steel vessels. A hexapod serves as the support and fine positioning mechanism for the sample environments. Figure 5 shows the locations of the configuration-controlled hood, slits, and sample location.



**Figure 5:** QIKR-L slits, sample location, and configuration-controlled hood relative to the guide

The user will have access to the sample & detector table and to the incident table for purposes of setting up an experiment. Personnel (users and staff) will not have access to the guide upstream of the incident table unless both QIKR-U and QIKR-L are inactive; there is a locked and configuration-controlled shield wall (see Figure 6) that prevents access unless both shutters are closed.

QIKR-U and QIKR-L are intended to operate independently of each other, so users may be present in one cave while the other is operating. There is a dividing wall between QIKR-L and QIKR-U that must provide adequate shielding to keep the dose rates within safe limits for both normal operation and accident scenarios. Figure 6 shows the areas where users may be present and the areas where all personnel access (users and staff) is blocked.



**Figure 6:** Top cross-section view of QIKR cave showing center wall, locked shield walls, and personnel access areas

### 3. DEFINITION OF QIKR'S NORMAL AND ACCIDENT SCENARIOS

#### 3.1 NORMAL OPERATION SCENARIOS

QIKR is a liquids reflectometer and as such will primarily use liquid samples. Although solid samples may be used as well, and they may create lower dose rates within the cave, placing a water sample at the sample location in neutronic analysis is deemed to be a good representation of a worst-case normal operation scenario. As mentioned in Section 2, useful data cannot be collected from the sample if the slits are entirely absent or open to their full height and width, so it is deemed unreasonable to remove the slits or to increase the aperture opening beyond the maximum that can be useful in an experiment.

Some sample environments may contain stainless steel materials, but those materials would never be in the beam as part of any normal operation.

Therefore, the reasonable worst-case normal operation scenario for QIKR is:

- 1) All slits present and open to the maximum height & width possible for an experiment
- 2) A water sample is present, sized to intercept the full amount of beam exiting the slits

Maximum slit heights & widths for normal operation:

- Slit 1: H x W = 0.8cm x 2.5cm (slit closest to the guide)  
Slit 2: H x W = 0.5cm x 2.5cm (middle slit)  
Slit 3: H x W = 0.2cm x 2.5cm (slit closest to the sample)

#### 3.2 ACCIDENT SCENARIOS

Removing the slits entirely was not considered to be a reasonable accident scenario. As mentioned previously, there is no circumstance under which it would be reasonable to remove the slits from the beamline prior to running an experiment... the user would know prior to opening the shutter that no useful data could be generated with the slits absent. However, it is reasonable to assume that the slits may be accidentally set to their max aperture openings and that the user would not notice the mistake until there was already beam on the sample.

Stainless steel sample environments are expected to be used to contain the sample in a normal use situation. Although the beam is never intended to be incident on the stainless steel portions of the sample environment (SE), it is reasonable that the SE is accidentally misaligned such that the beam is incident on the stainless steel portions and the mistake may not be noticed until the beam is turned on.

Alternate locations for stainless steel materials were considered in order to represent (for example) accidentally leaving tools in the beam path. The worst-case location would be at the guide end prior to the slits where the stainless steel material would intersect all beam components exiting the guide. However, this location is blocked by a locked and configuration-controlled hood, so it was not considered reasonable that a stainless steel object could accidentally be left in the beam in this location.

Therefore, the reasonable worst-case accident scenario for QIKR is:

- 1) All slits present\* and open to the maximum height & width possible for the slits
- 2) A water sample is present, sized to intercept the full amount of beam exiting the slits, or
- 3) A stainless steel sample is present, sized to intercept the full amount of beam exiting the slits

\*NOTE: in order for the slits to remain present for the accident scenario, they should be locked in place and be configuration controlled.

Maximum slit heights & widths possible for accident scenarios will depend on the particular slit chosen for each location. At BL4B at SNS, the slit closest to the sample has a max opening of 3cm x 3cm, the remaining slits have max openings of 5cm x 5cm. QIKR currently plans to use these slits as well, but may alternately use slits with maximum openings of 5cm x 5cm and 8cm x 8cm, respectively.

#### 4. ACCEPTABLE RADIATION DOSE RATE LIMITS

The user-accessible areas within the cave may have a maximum dose rate of 2mrem/h generally and at a distance  $\geq 30$ cm from the sample location. The dose rate within 30cm of the sample location may have a maximum dose rate of 5mrem/h when the shutter is closed. If any user-accessible areas within the cave could see dose rate spikes above 2mrem/h due to an accident scenario and additional shielding is not practical, the Instrument Personnel Protection System will provide protection in accordance with the *Second Target Station (STS) Project Radiation Safety Policy and Plan* (S01030100-PN0001, October 2020).

There are no dose rate limits for areas that are inaccessible to users and staff while either beamline is active.

User-accessible areas outside the cave walls (in the instrument hall) are not a concern as long as they are limited to 2mrem/h. Dose rates up to 5mrem/h are acceptable for staff-accessible areas provided barriers and signage exist to limit access in those areas to rad workers only. Areas accessible to the general public should be limited to 0.25mrem/h at a distance of 30cm away from the shielding surface (e.g. cave wall).

Although these are the maximum dose rates allowable, lower dose rates are desirable (if possible) per the ALARA principle.