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QIKR Shielding PDR: Mechanical Overview

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U.S. Department of Energy

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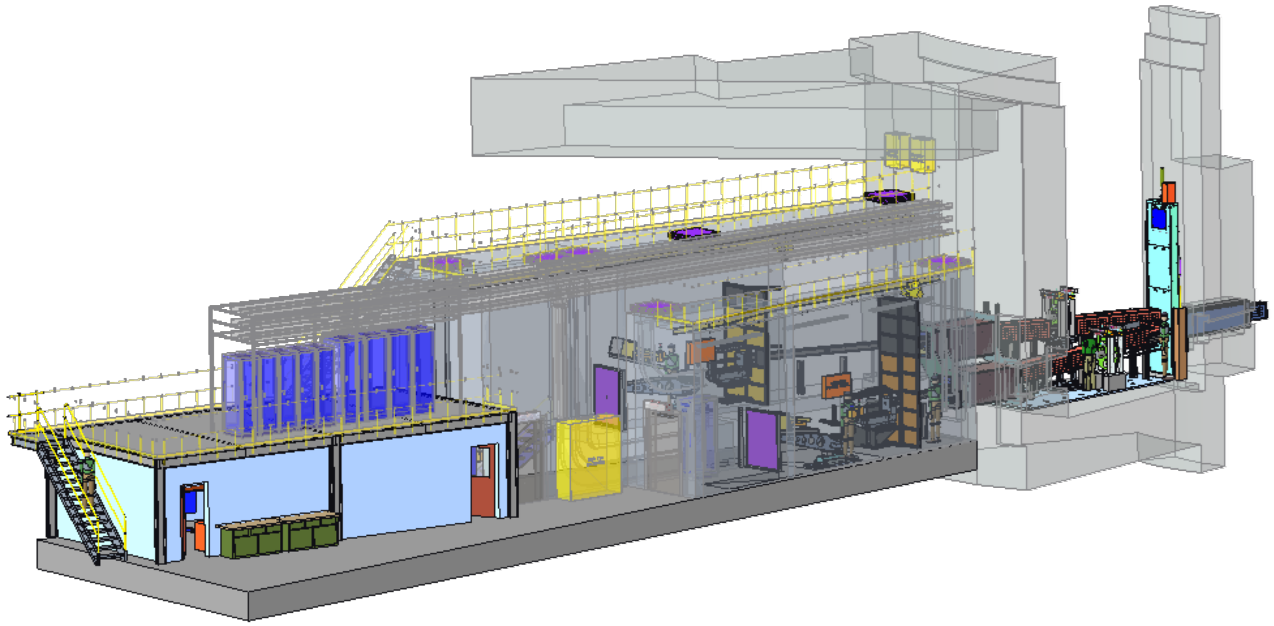
Outline

- QIKR Overview
  - Review Scope
  - Documentation
  - High level QIKR description

- Shielding Components
  - Monolith Shielding
  - Optics Insert
  - Guide Shielding
  - Shutter
  - Bunker Wall and Wall Insert Shielding
  - Cave
  - Beam Stop



QIKR Overview

Review Scope

Included

- Description of model used in Neutronics Analysis (safety shielding components only)
  - Monolith & guide shielding (Overview)
  - Shutter beam blocker thickness
  - Bunker wall shielding (Overview)
  - QIKR cave (shielding functionality only, no discussion of structural design)
  - In-cave beam stop
- Neutronic Analysis Results
- Discussion of current state of design (design evolution beyond what was analyzed)
  - Changes to monolith shielding, shutter, bunker wall, cave
  - Background Reduction Shield Wall

Not Included

- Details of the monolith wall shielding (installation, cost, etc.)… this is part of Target design reviews
- Details of the monolith optics & guide shielding… this will be part of the QIKR Optics FDR
- Details of the bunker wall shielding… this will be part of the Bunker Shielding PDR
- Cave structural analysis will be done at FDR & will not be discussed at PDR

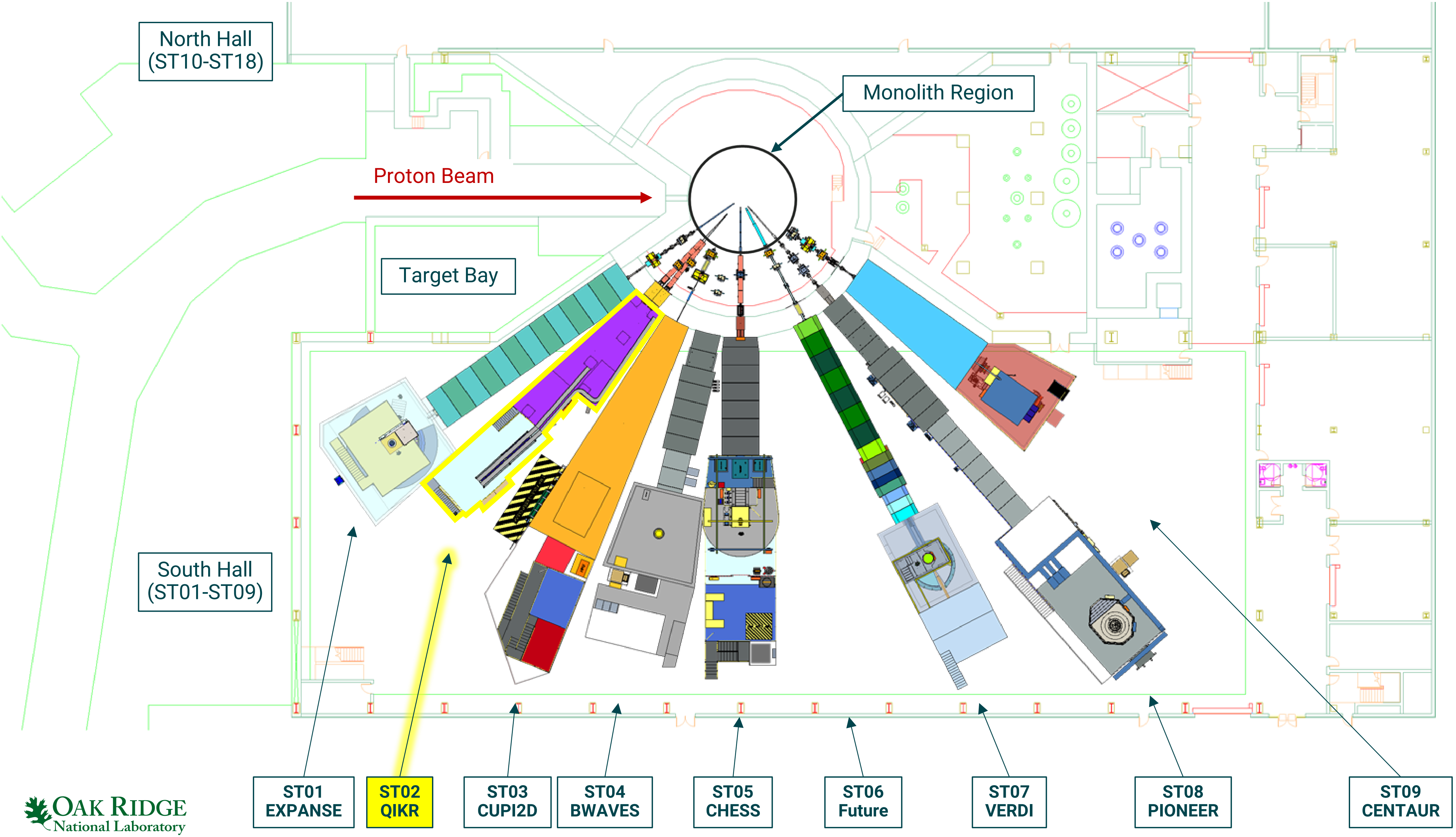
Requirements, CQLD, Interface, FMEA Documents

- **Requirements Documents**:
  - QIKR Instrument Requirements: **S04080100-SRD10000-R02** (not released)
    - The latest revision (R02) has not been released yet, awaiting optics alignment updates
- **CQLD Biological Radiation Shielding**:
  - Quality Level 2, Configuration Level 2: **S04080400-QAI10000-R00** (released)
    - Quality Level 2 is because of radiation safety impact of shielding failure, Configuration Level 2 is because radiation shielding is defined as a Configuration Item which requires a Level 2 rating
- **CQLD Non-Safety Related Shielding**:
  - Quality Level 3, Configuration Level 3: **S04080400-QAI10001-R00** (released)
- **Interface Documents**:
  - Interface CF to Bunker wall feedthrough: **S01020500-IST10023-R00** (not released)
  - Interface to CF (pits in the cave): **S04010100-C8U-8800-A10000 r5** (updates not released)
- **FMEA for Shielding:** **S04080400-FMA10000-R00** (not released)

Requirements, CQLD, Interface, FMEA Documents

- **Neutronics Analysis**:
  - Bunker Wall, in-Bunker Guide Shielding, Shutter Beam Blocker, Monolith Wall Shielding: **TBD** (WIP)
  - Cave, Beam Stop, In-Cave Guide Shielding: **TBD** (WIP)
    - Cave analysis includes operating and accident scenarios using input conditions from analyses done for the upstream areas of QIKR (monolith, bunker, etc.)
    - **The data from this document & the one above is presented in this PDR in the Neutronics slides**
- **QIKR Cave Acceptable Dose Rates:** S04080400-DCD10000-R00 (released)
  - This also defines the approved normal use and accident case scenarios

STS Instrument Suite



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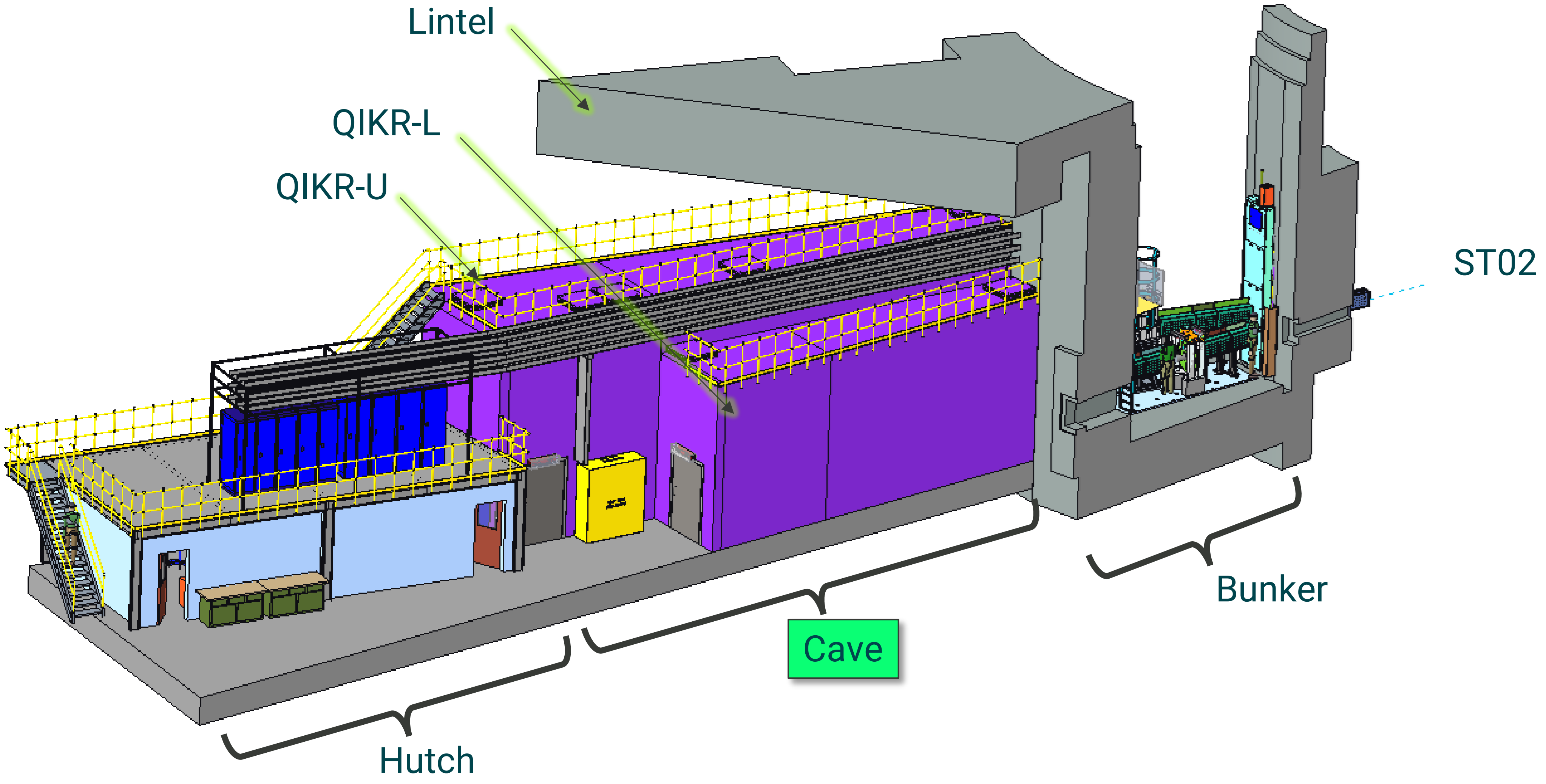
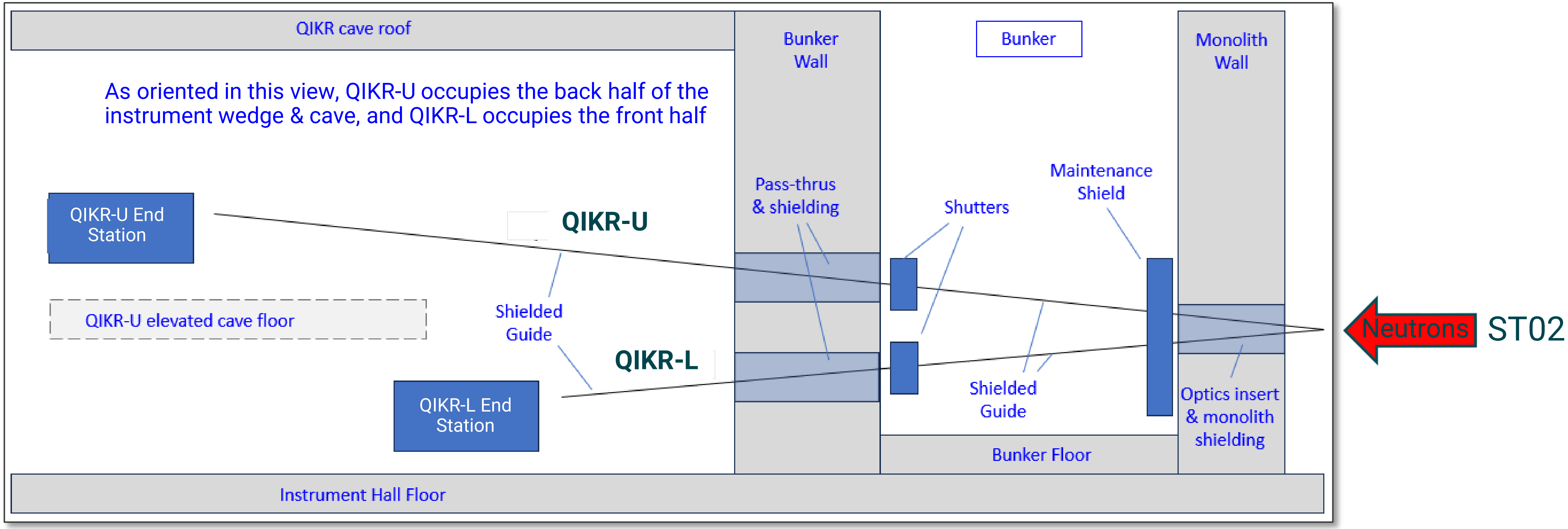
QIKR Instrument Sections

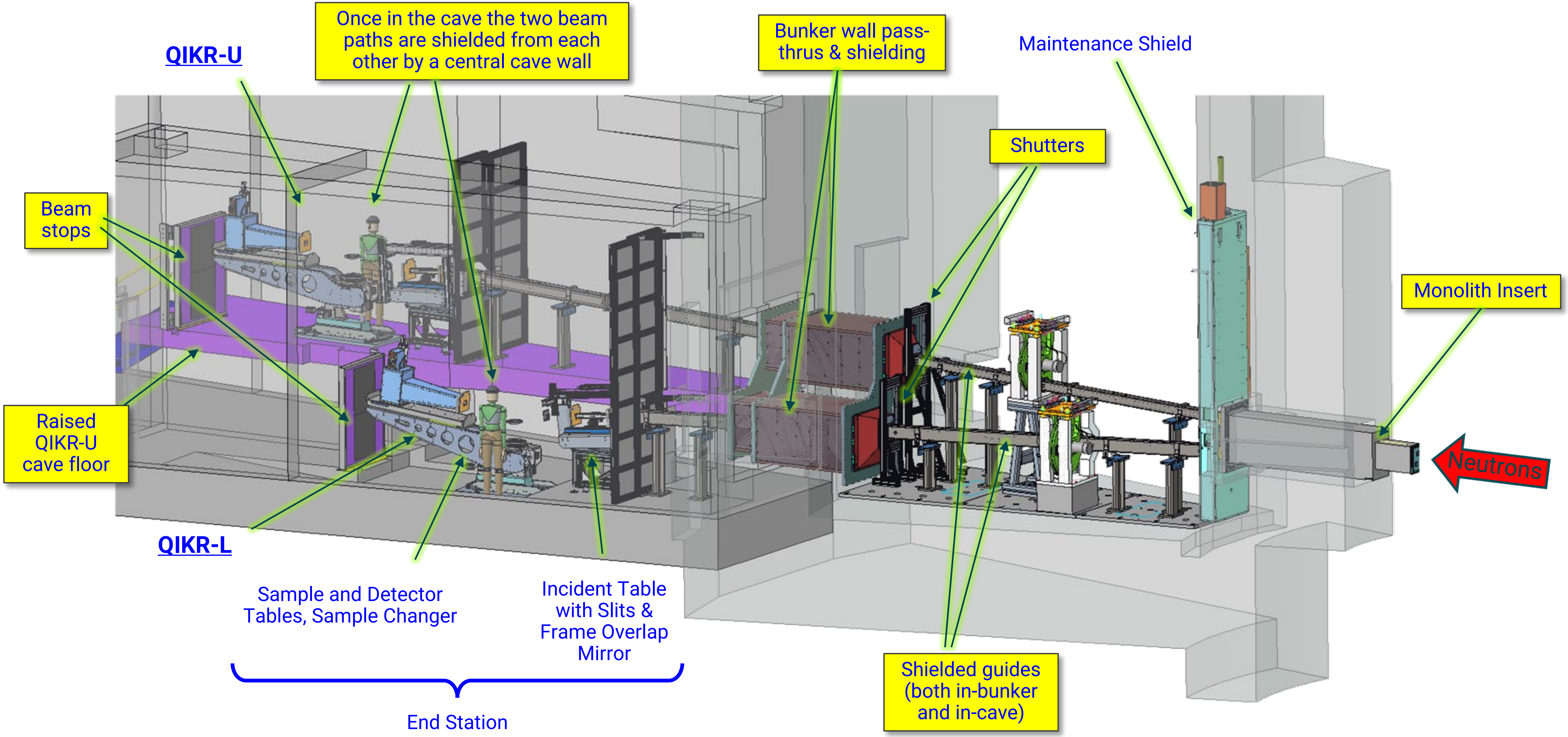


QIKR – Schematic View

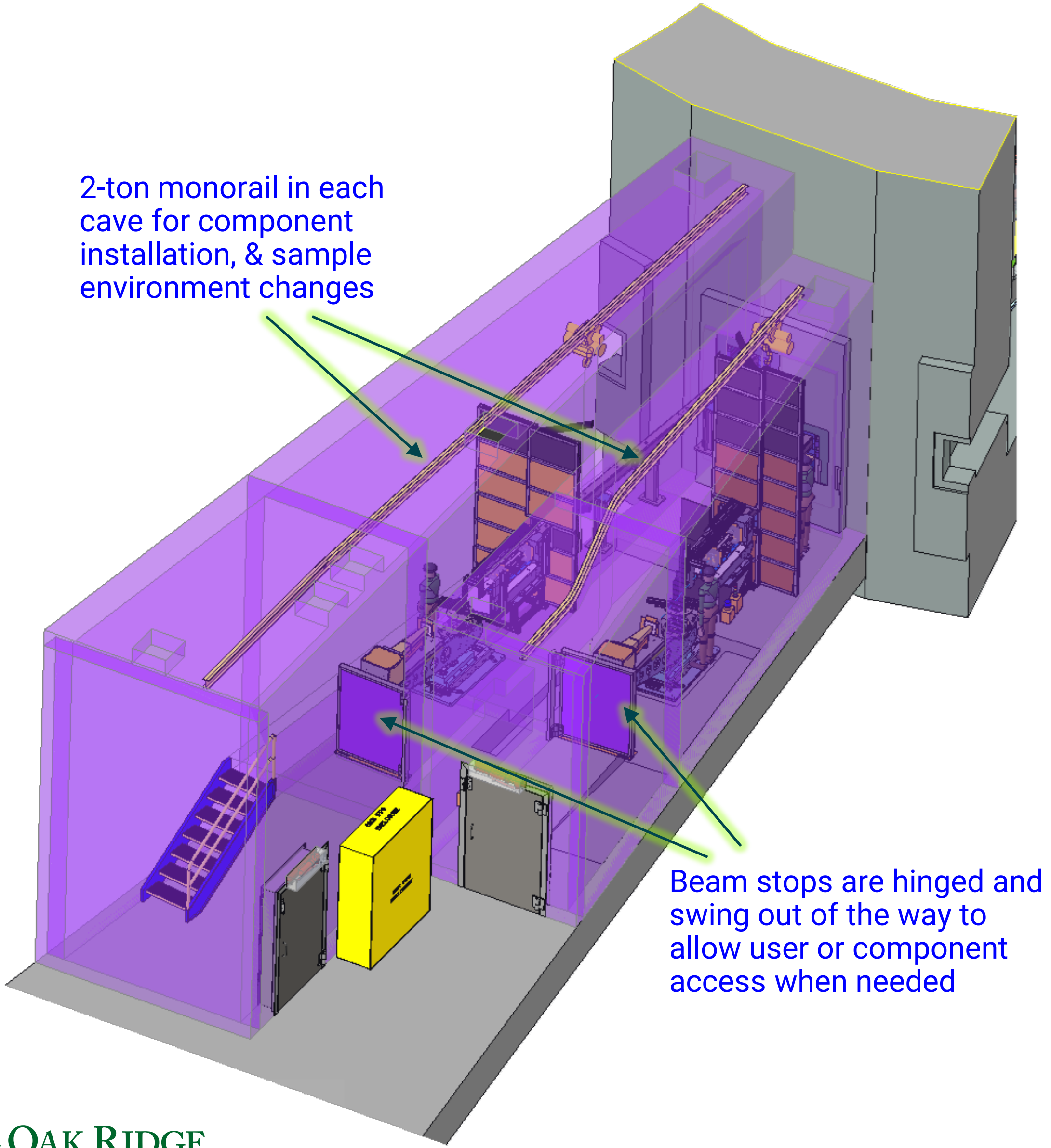


- The maintenance shield does not perform a beam blocking function
- The End Station consists of the Incident Table with Slits and Frame Overlap Mirror, the Sample Table, the Detector Table, and the Sample Changer

QIKR –3D Model View



Installation of Components



- All QIKR in-bunker components will be installed by removing the bunker roof panels and using the 50-ton high bay gantry crane
- Most QIKR in-cave components will be installed by bringing the components into each cave on a cart, then carrying them to their final location with a 2-ton monorail hoist
- The monorail will also be used during operations to swap sample environments and to service end station components

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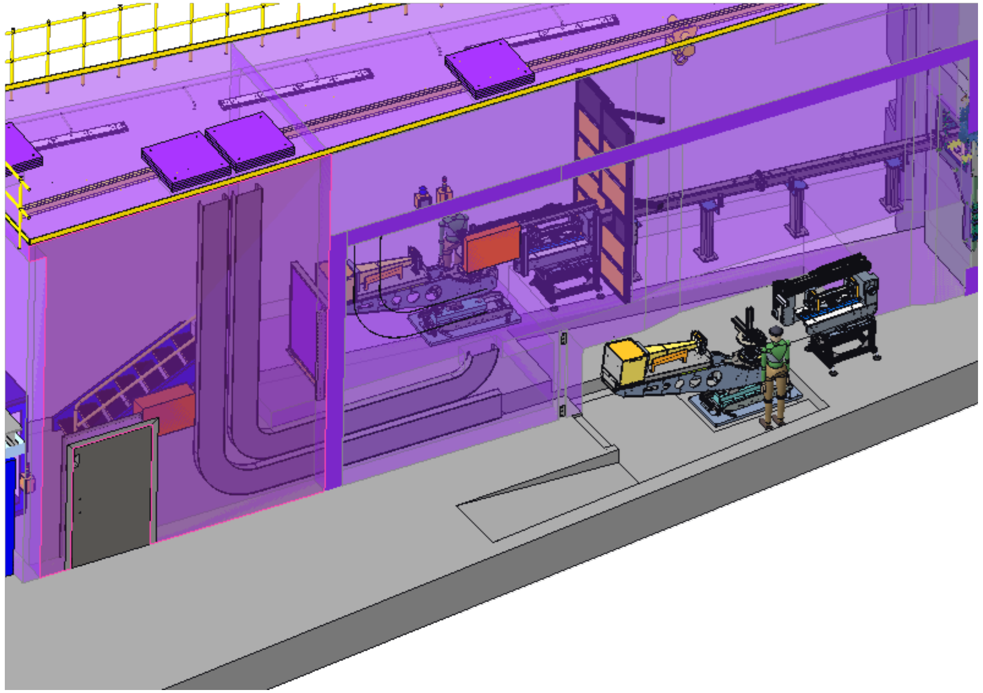
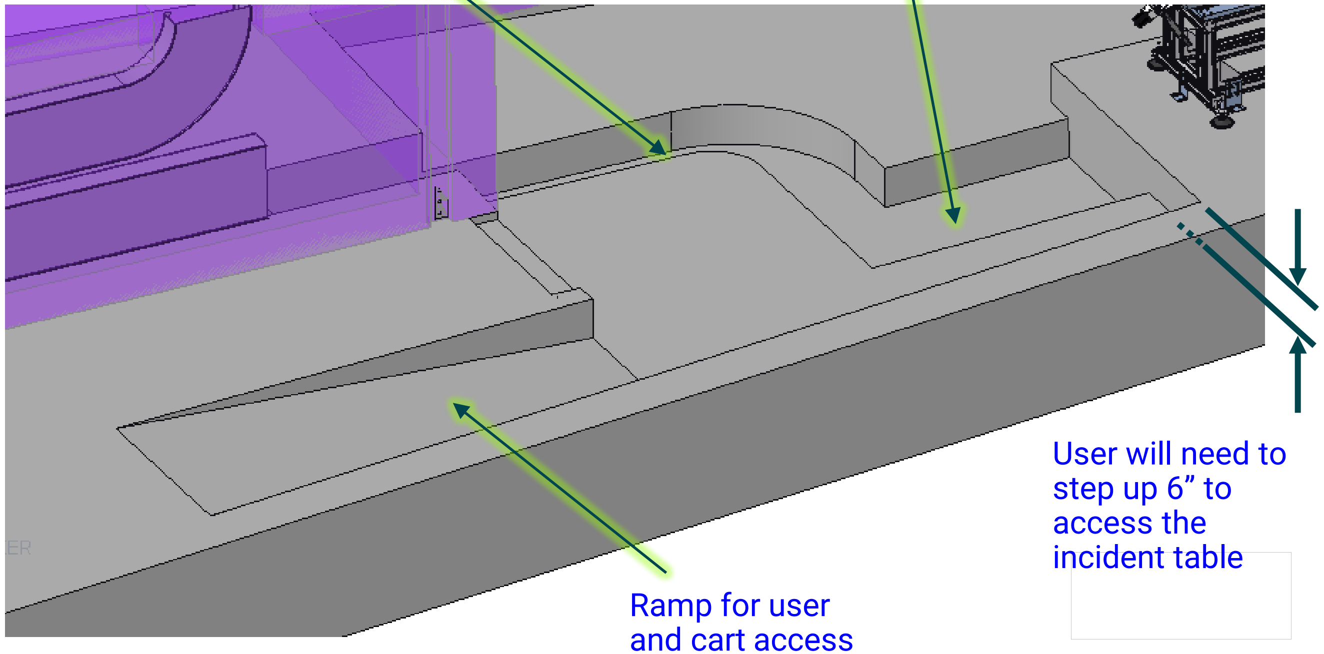
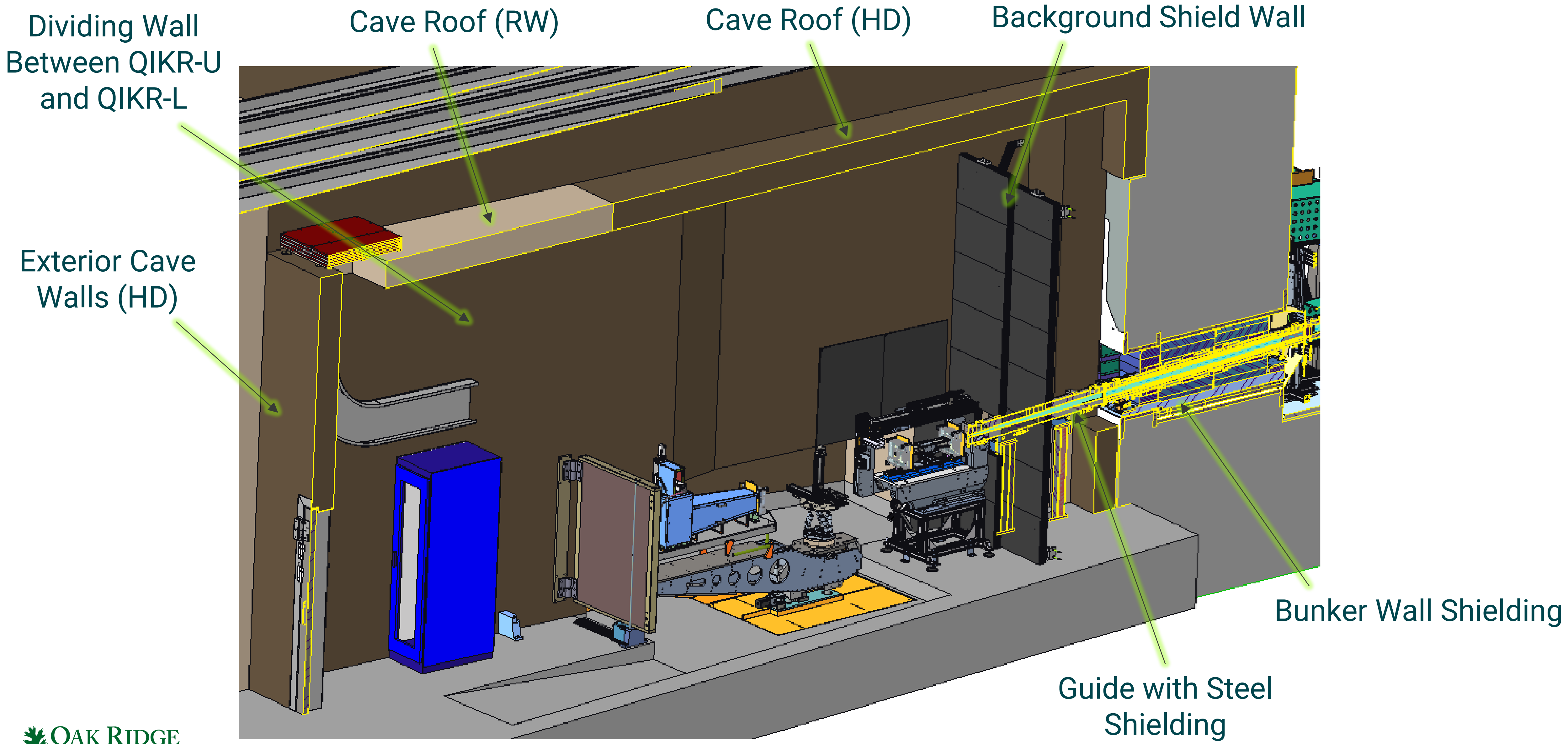
Need for a QIKR-L Pit





- QIKR-L requires a pit for the end station because of the downward sloping beam
- The pit is two-level to allow a reasonable height for the user to stand & to wheel in equipment carts
- The end station pit is combined with a cable channel to route motion cables into the upper cave (QIKR-U), then out to the control racks through the QIKR-U roof

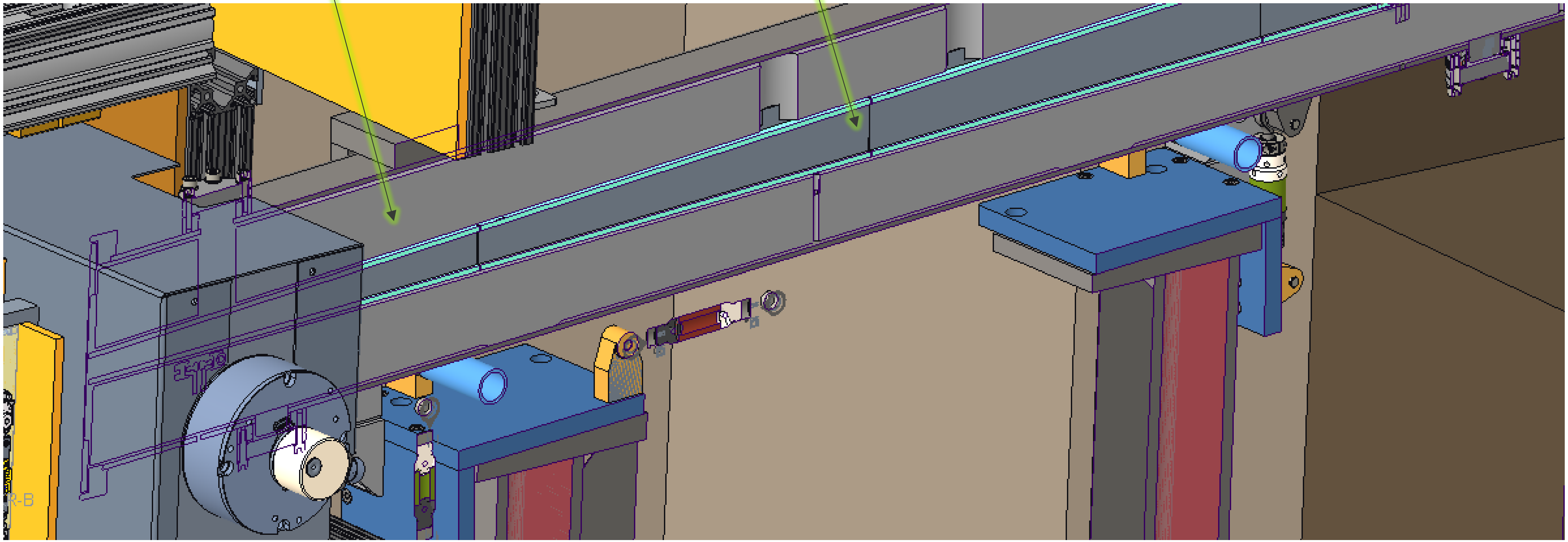
Component Details – QIKR-L Shown (QIKR-U is Similar)



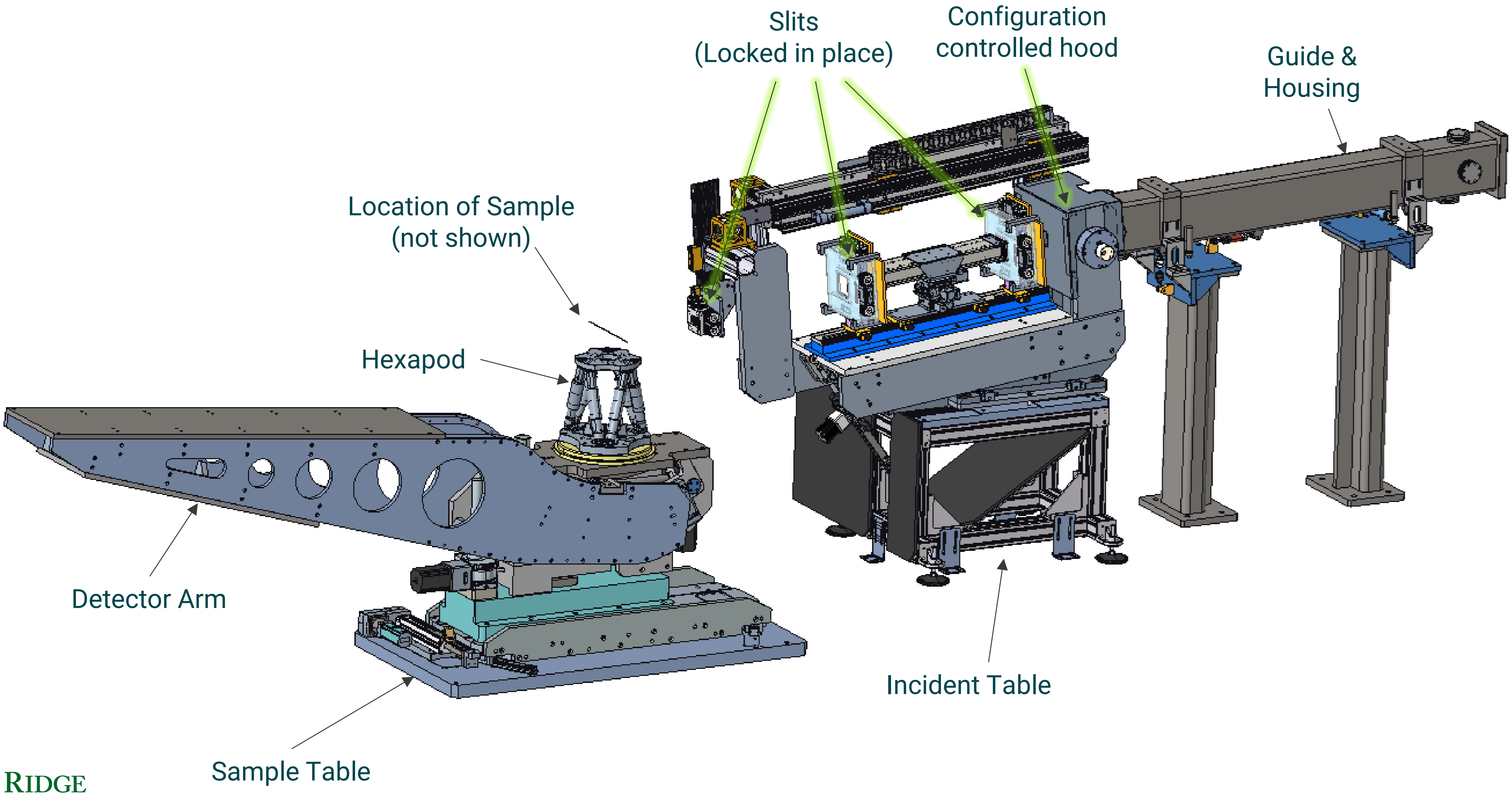
Component Details – QIKR-L Shown (QIKR-U Similar)

Steel guide shielding

Guide narrows, steel shielding increases to fill in the space



Component Details – QIKR-L Shown (QIKR-U is Similar)



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QIKR Shielding Requirements (S04080100-SRD10000-R02)

Req. No.	Description
S.04.08.04-R1	The beamline shielding, cave walls, and beam stop shall limit dose rates to the maximum dose rates given in S04080400-DCD10000.
S.04.08.04-R2	There shall be sufficient shielding in the bunker to absorb line-of-sight neutrons prior to the cave
S.04.08.04-R3	All shielding within the bunker space, within the bunker wall penetration window, and within the cave must be removable
S.04.08.04-R4	The QIKR cave must provide shielding to allow personnel access to one beam path's sample while the other beam path is operating
S.04.08.04-R5	QIKR must have separate beam stops in the cave areas, one each for the upper and lower beam paths

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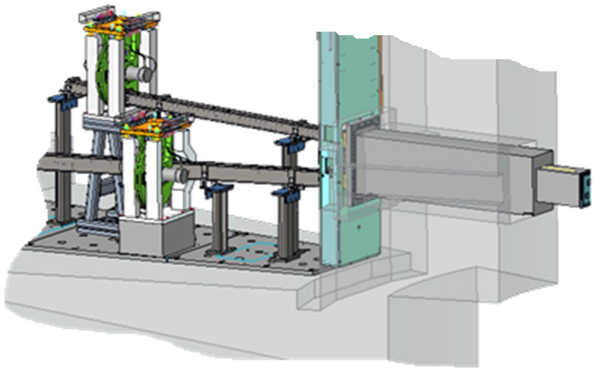
Monolith Shielding

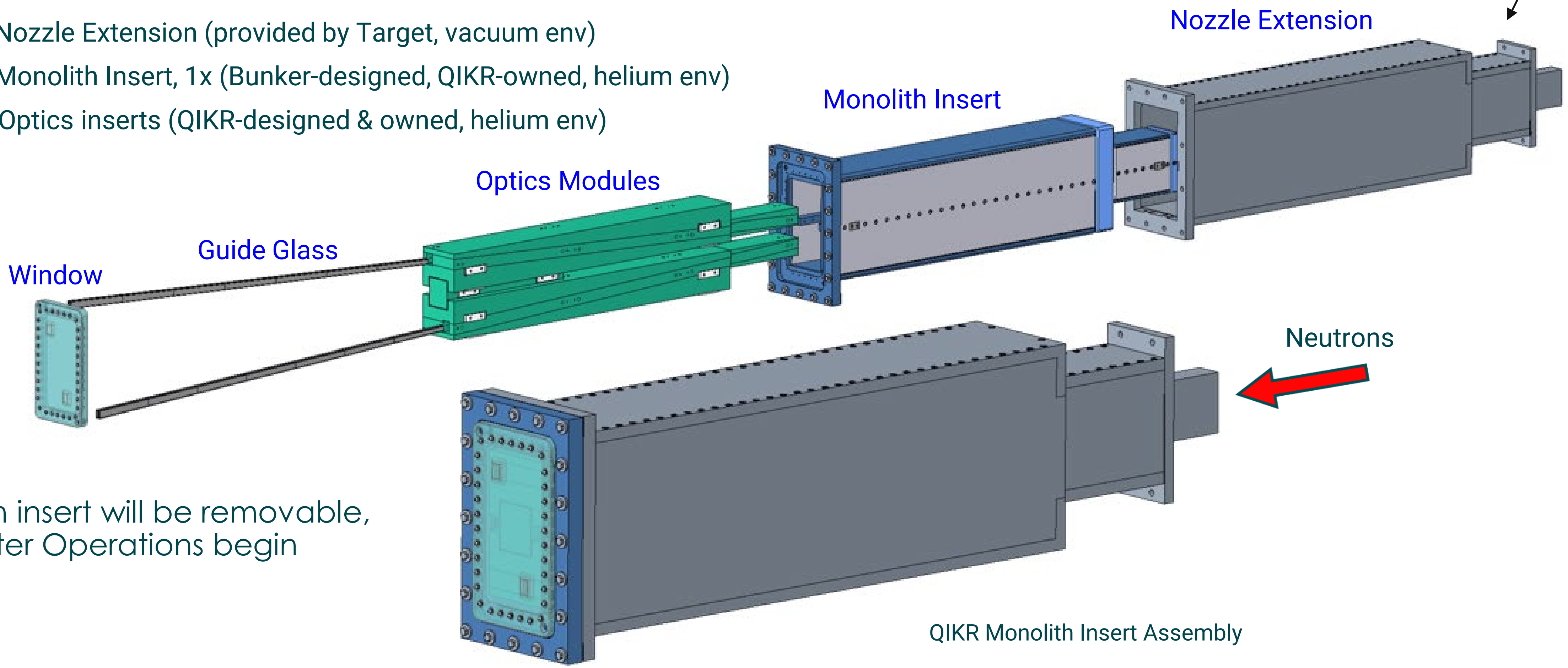
Monolith and Optics Inserts

Credit: Cameron Hart

- Both upper and lower beam paths will be contained together within the monolith section. They will be installed (and can be removed) using a bunker-designed handler.

- The monolith section consists of:
  - One Nozzle Extension (provided by Target, vacuum env)
  - One Monolith Insert, 1x (Bunker-designed, QIKR-owned, helium env)
  - Two Optics inserts (QIKR-designed & owned, helium env)



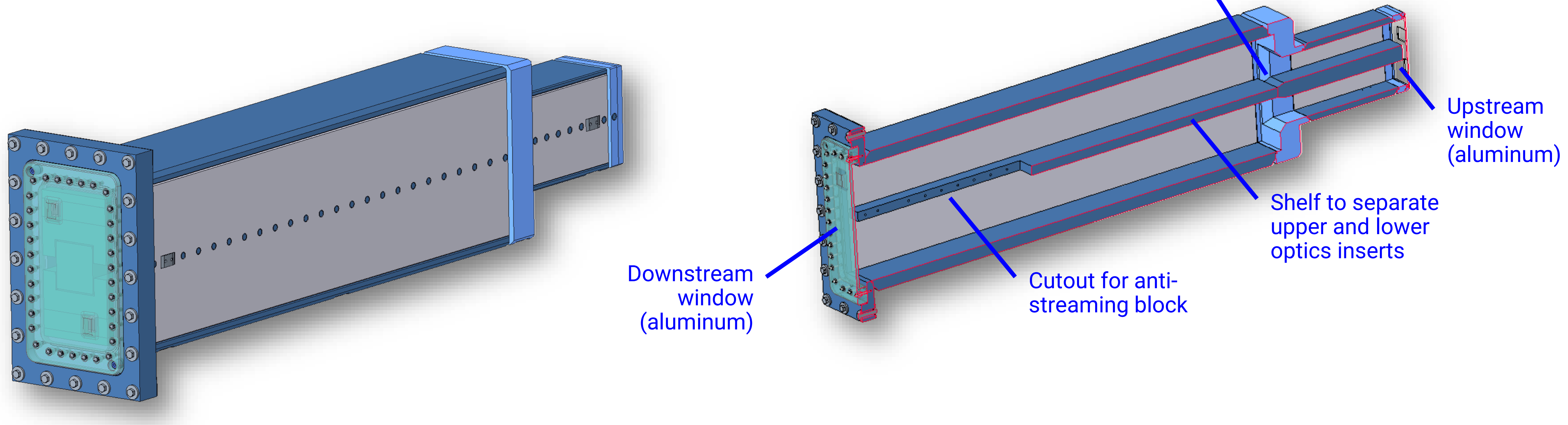


QIKR Monolith Insert Assembly

- Monolith insert will be removable, even after Operations begin

Monolith Insert

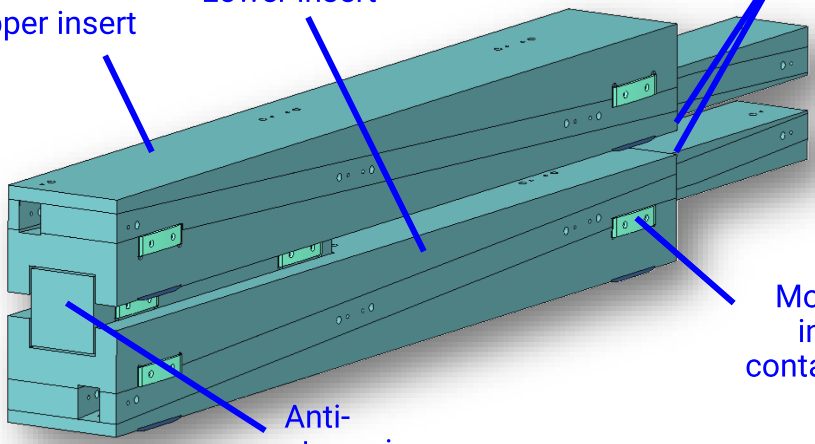
Credit: Cameron Hart

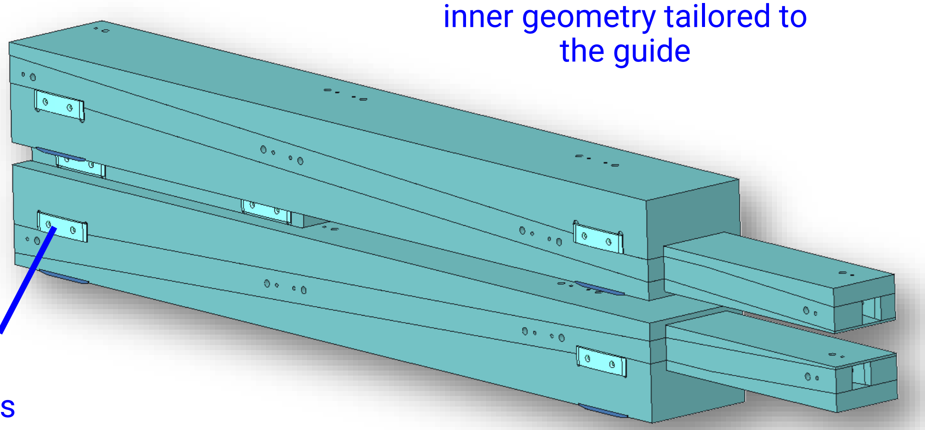


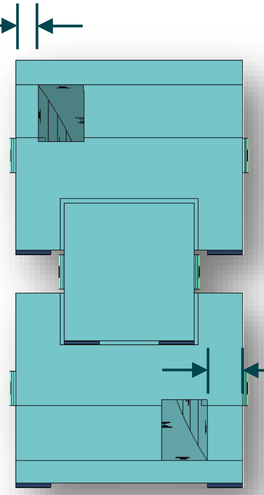
- The monolith insert has two windows to isolate the guide environment (helium) from either the target environment (vacuum) or the bunker environment (air)
- The monolith insert has a center shelf to allow the lower and upper optics inserts to be separate from each other
  - It was originally though that combined optics inserts would be too heavy for the bunker's insert handler to manage
- The center shelf has a downstream cutout to allow for an anti-streaming block

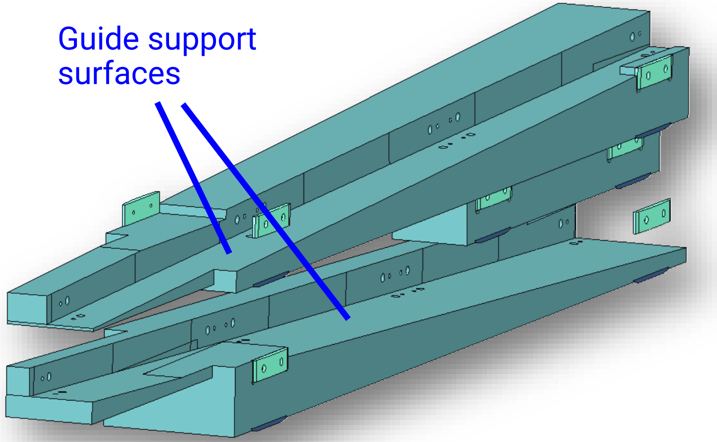
Optics Inserts

Credit: Cameron Hart



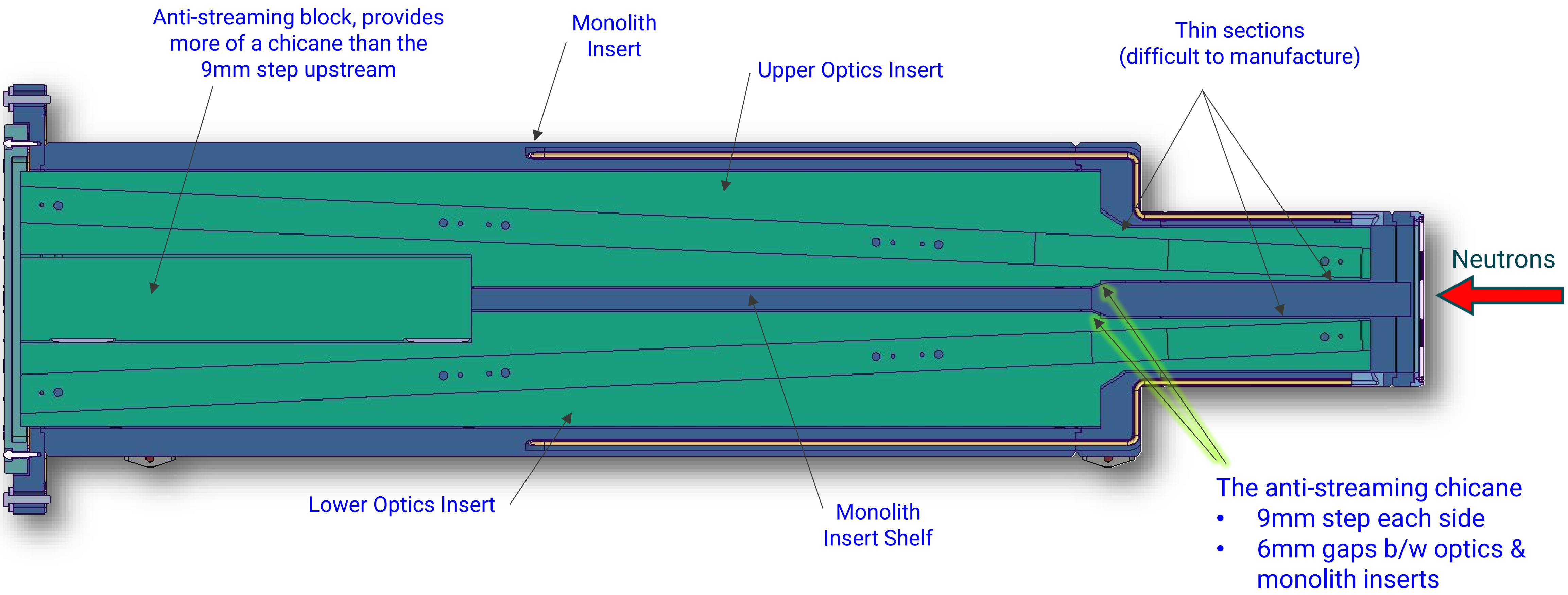






- Each insert consists of four pieces: a floor, a roof, and two side walls Material = anti-corrosion coated steel, custom fabricated
  - Pieces generally mate to each other along a ±2.5° ramped surface except in areas where monolith insert contact pads are located
  - Pieces could be split up along the z-dir to aid in fabrication, but ORNL manufacturing confirms they can handle 3.25m as a single length
- The anti-streaming block compensates for having very limited space for chicane features between the monolith and optics inserts
- Guide routing is constrained by available width for the optics inserts… guides cannot curve or angle in a way that causes them to be outside the optics insert boundaries

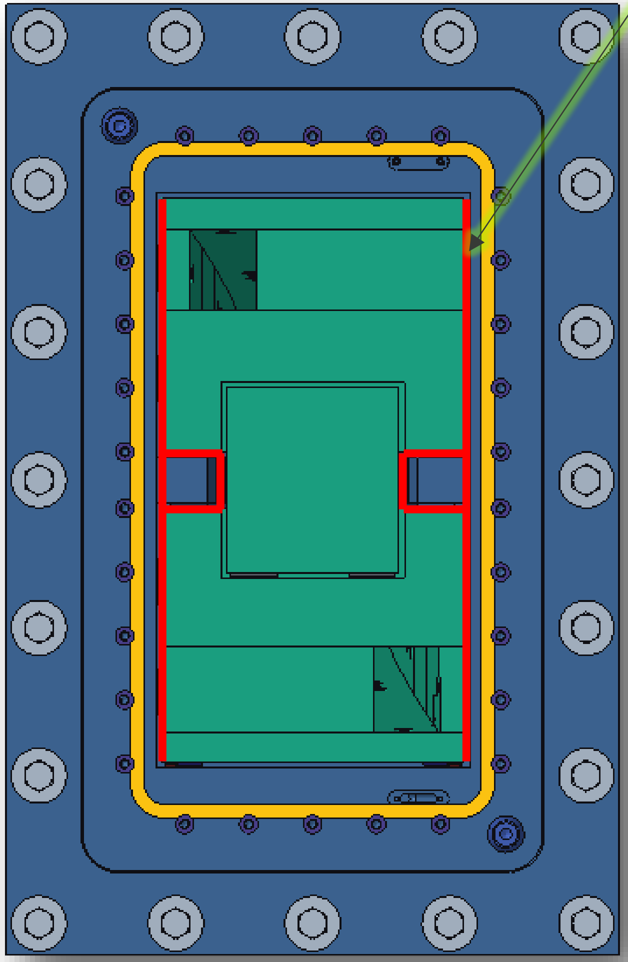
Monolith/ Optics Insert Assembly

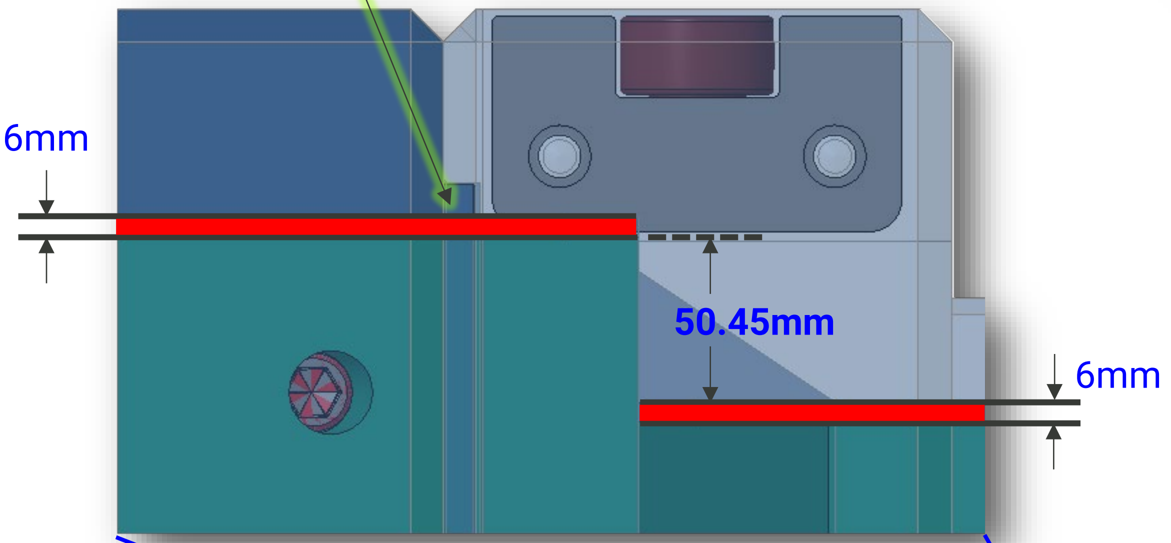


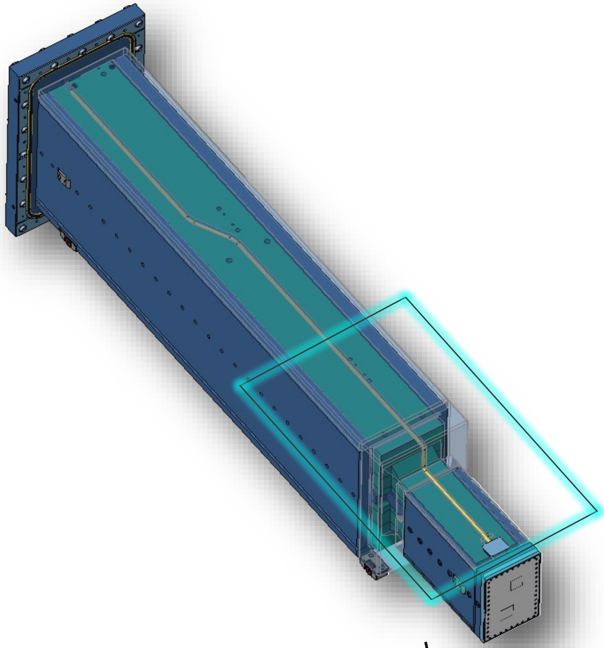
Elevation (Side) View

Monolith/ Optics Insert Streaming Paths

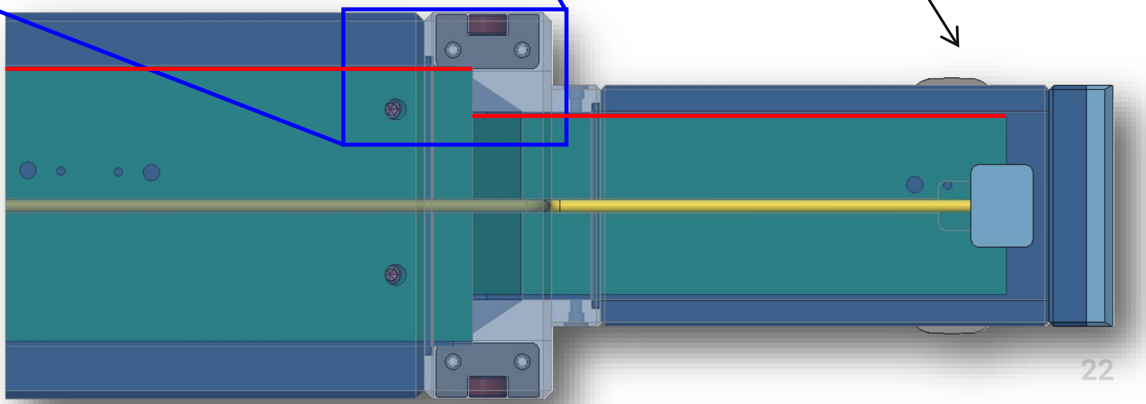
6mm gaps (red) allow neutron streaming



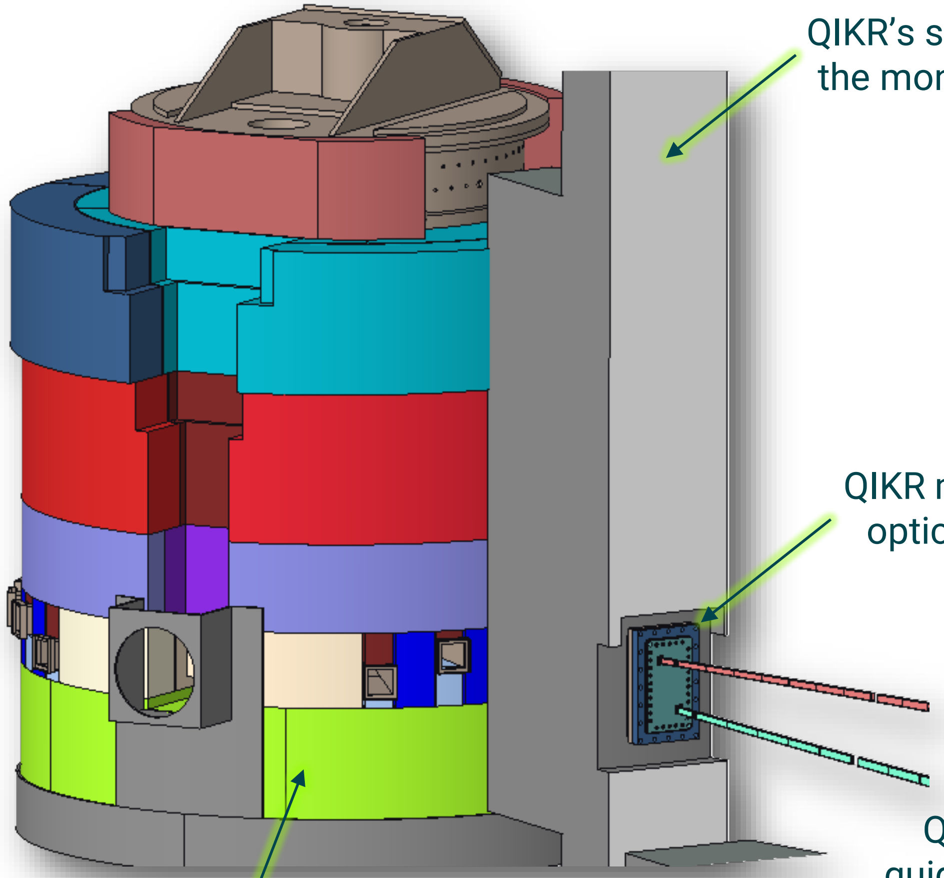


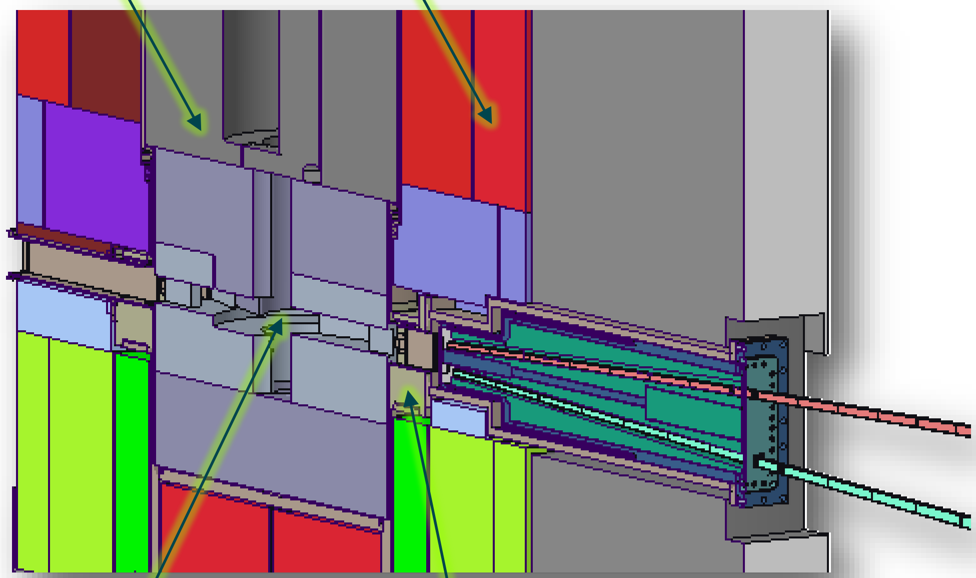


The 6mm gaps along the insert sides are long and have only a single chicane

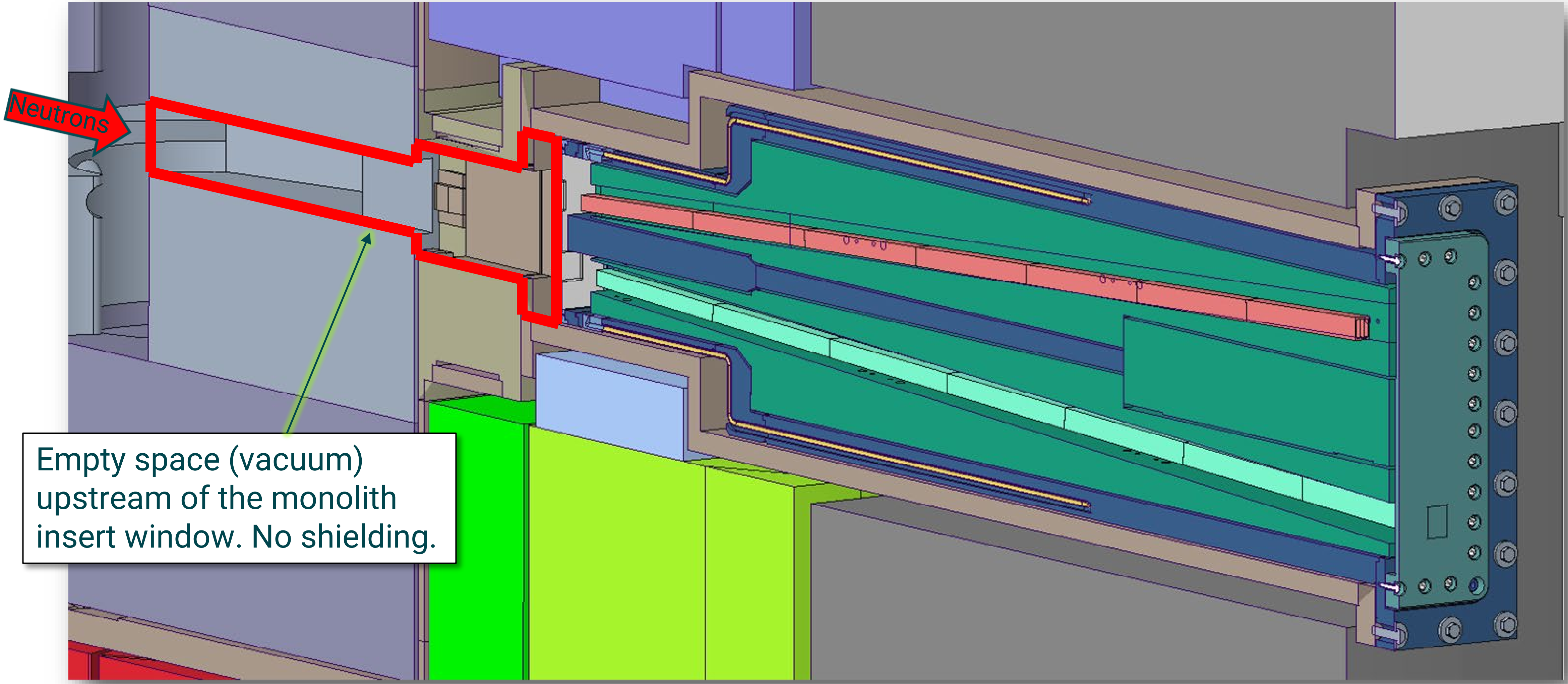


Monolith Shielding



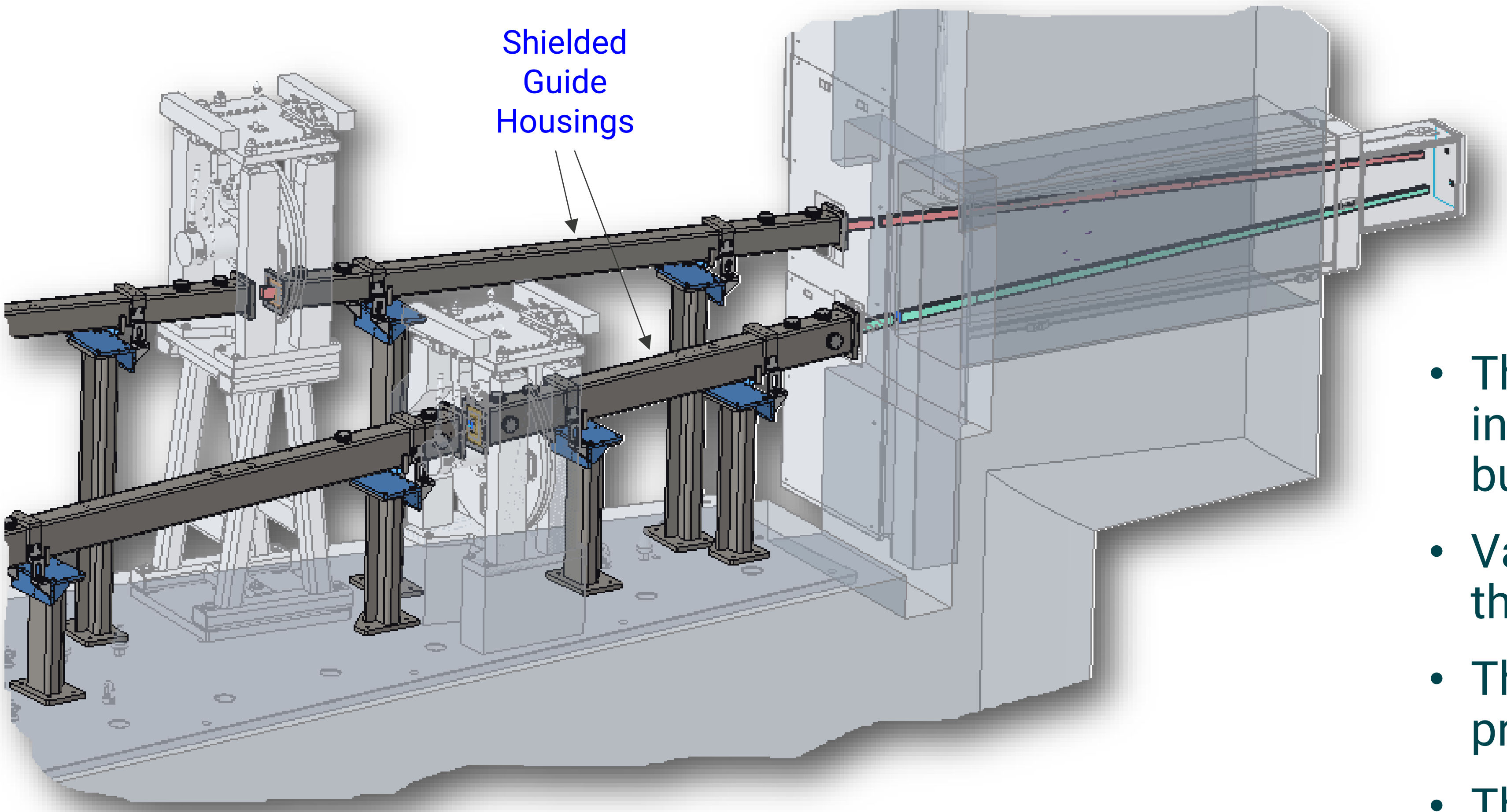


Monolith Shielding – Upstream Empty Space (Vacuum)



Guide Shielding

Guide Shielding

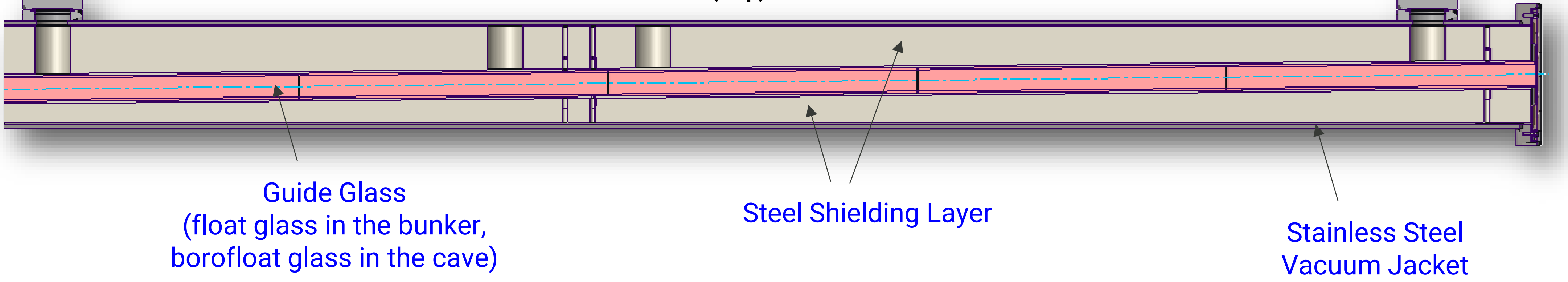


- The QIKR guides are enclosed in two-layer housings from the bunker start to the guide ends
- Vacuum environment inside the housings
- The outer housing layer (steel) provides the vacuum boundary
- The inner housing layer is steel and provides shielding around the guide glass… 3mm gaps surrounding each layer

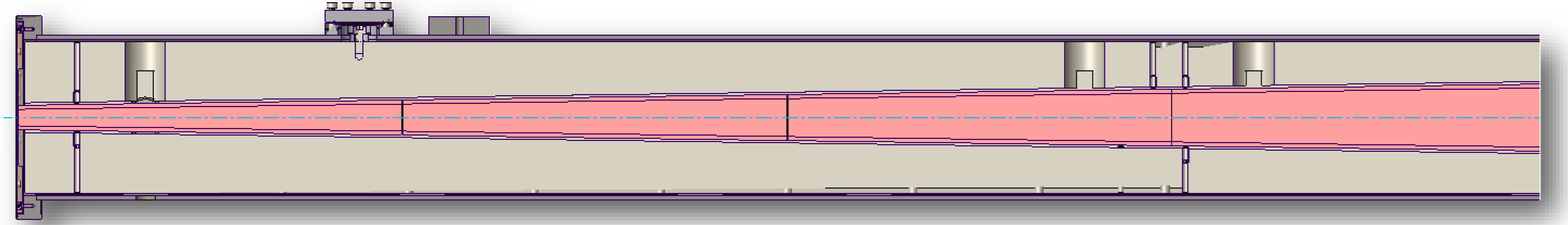
Guide Shielding

Horizontal cross-section of an in-bunker guide housing, shows change in shielding layer thickness due to guide curving/angling

Plan (Top) view



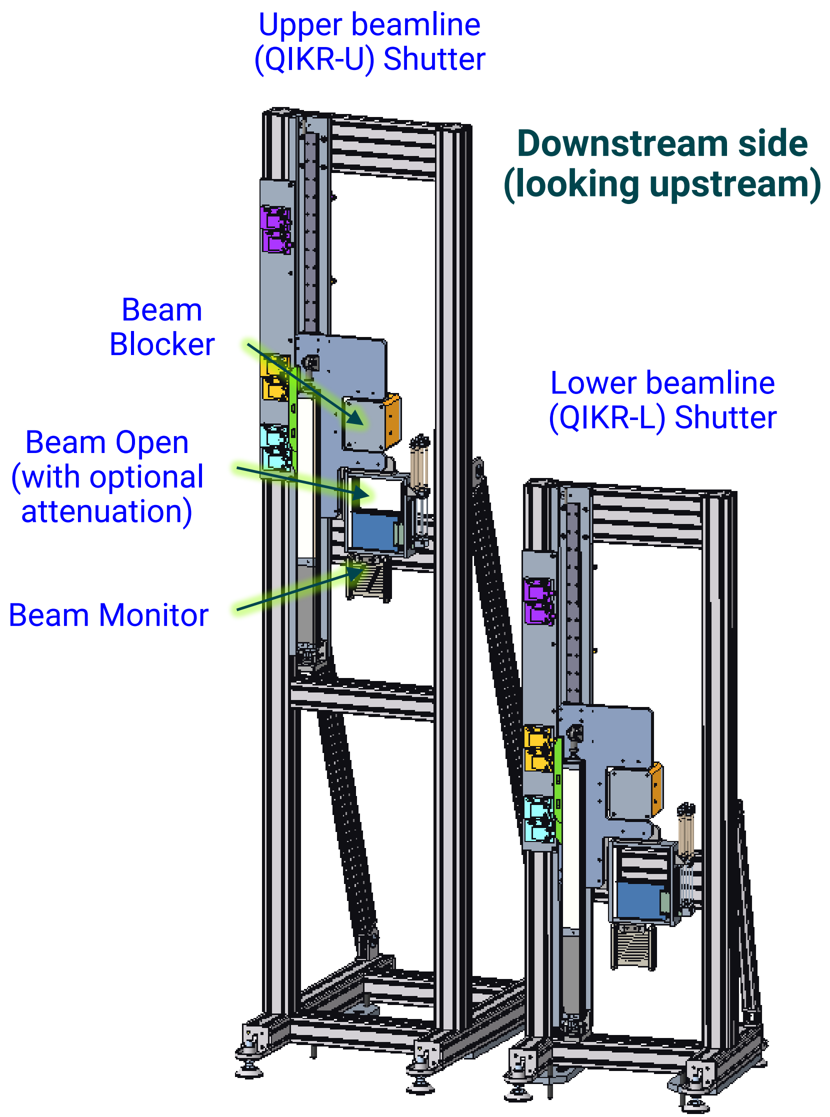
Vertical cross-section of the last in-cave guide housing (QIKR-U), shows change in shielding layer thickness due to guide taper



Elevation (Side) view

Shutter

Shutter – Description

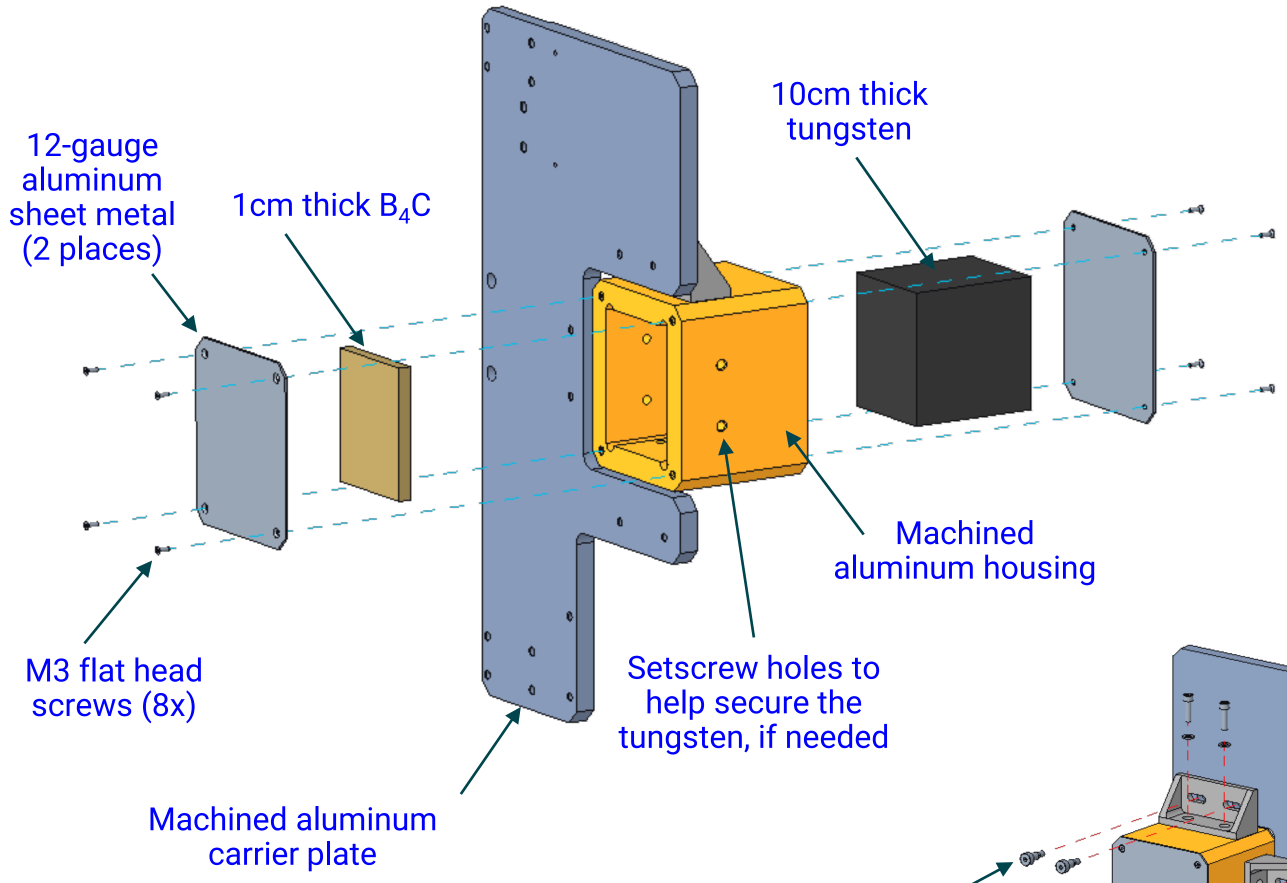


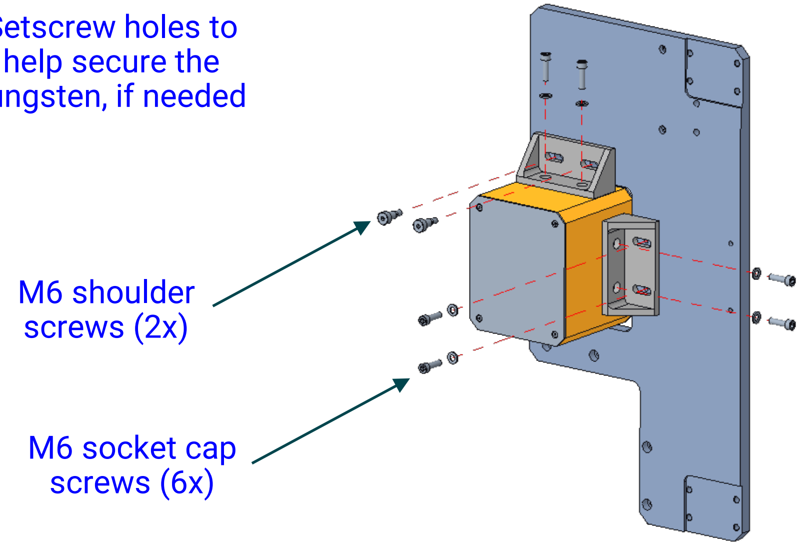
- The Shutter blocks the neutron beam to allow personnel access to the cave… there is one shutter per beamline (two total)
- The QIKR shutter follows the standard design for failsafe operation, support structure, and control & PPS switches
  - The beam blocker will drop into position to block the beam if there is a loss of power or compressed air
- The composition of the beam blocker is 10cm of tungsten (upstream) followed by 1cm of boron carbide

The 10cm tungsten thickness is more conservative than required by neutronic analysis… 8.11cm is sufficient for QIKR-U, 6.52cm is sufficient for QIKR-L

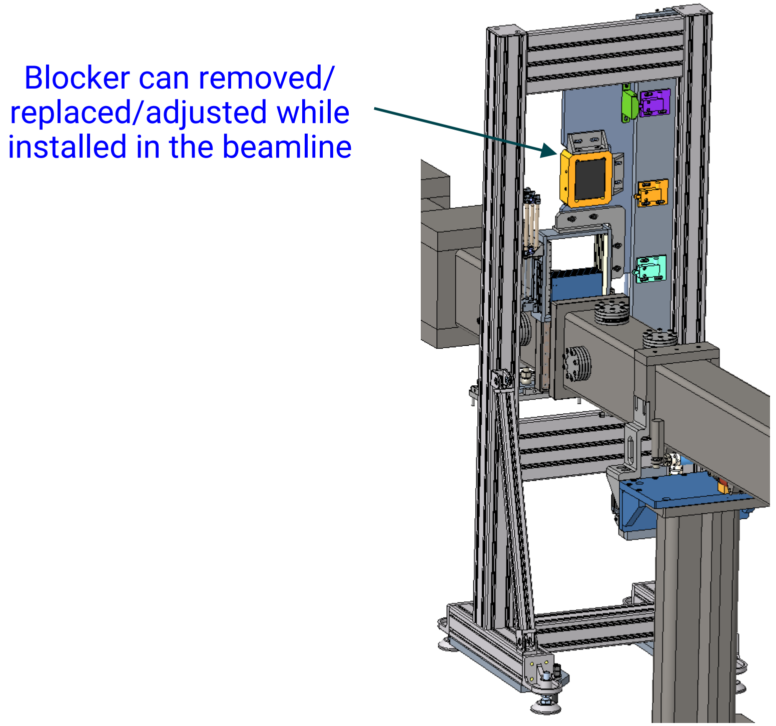
Design credit: Rudy Thermer

Shutter – Beam Blocker





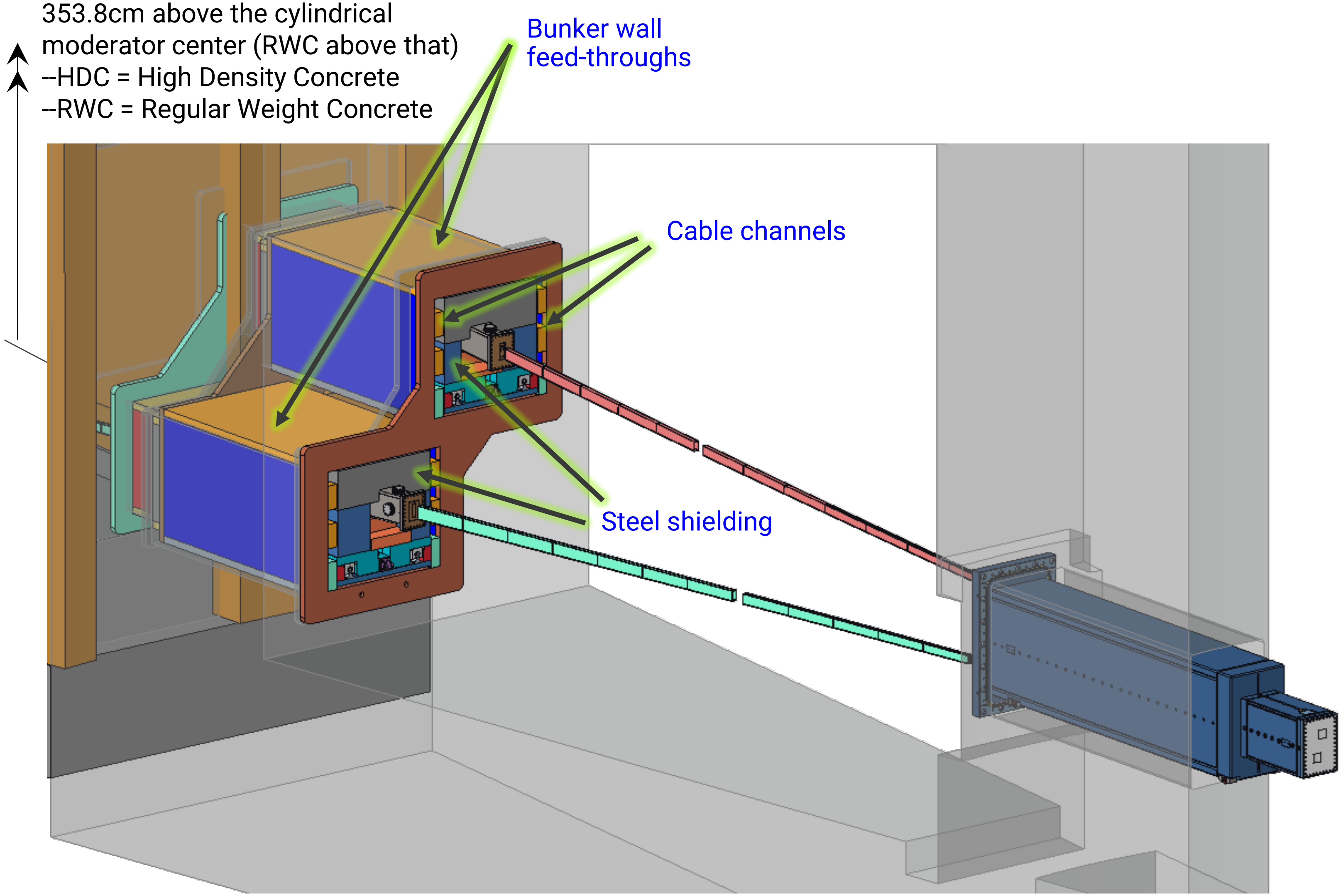
- Beam blocker is 10cm of tungsten followed by 1cm B_4C
  - Produces <.25mrem/h dose rate from the blocked beam at the sample location
- The tungsten and B_4C are placed in a housing and secured with aluminum sheet metal end caps and (if needed) setscrews
- The housing is attached to the shutter carrier plate by two brackets & M6 screws
  - Top bracket is attached to carrier plate by shoulder screws to provide good vertical location
  - Side bracket and housing are attached by socket cap screws



Bunker Wall and Feed-Through Shielding

Bunker Wall & Feed-Throughs

Bunker Wall = 203.2cm thick HDC
353.8cm above the cylindrical moderator center (RWC above that)
--HDC = High Density Concrete
--RWC = Regular Weight Concrete



- The bunker wall contains feed-through openings to allow the guide to pass from the bunker into the cave
- On either side of the feed-through, there are chicaned channels to allow cables to pass between the bunker & cave (needed for shutter and chopper power & signals)
- Steel shielding is placed between the guide housing and walls of the feed-throughs
- Both the steel shielding and cable channels are chicaned to minimize neutron streaming

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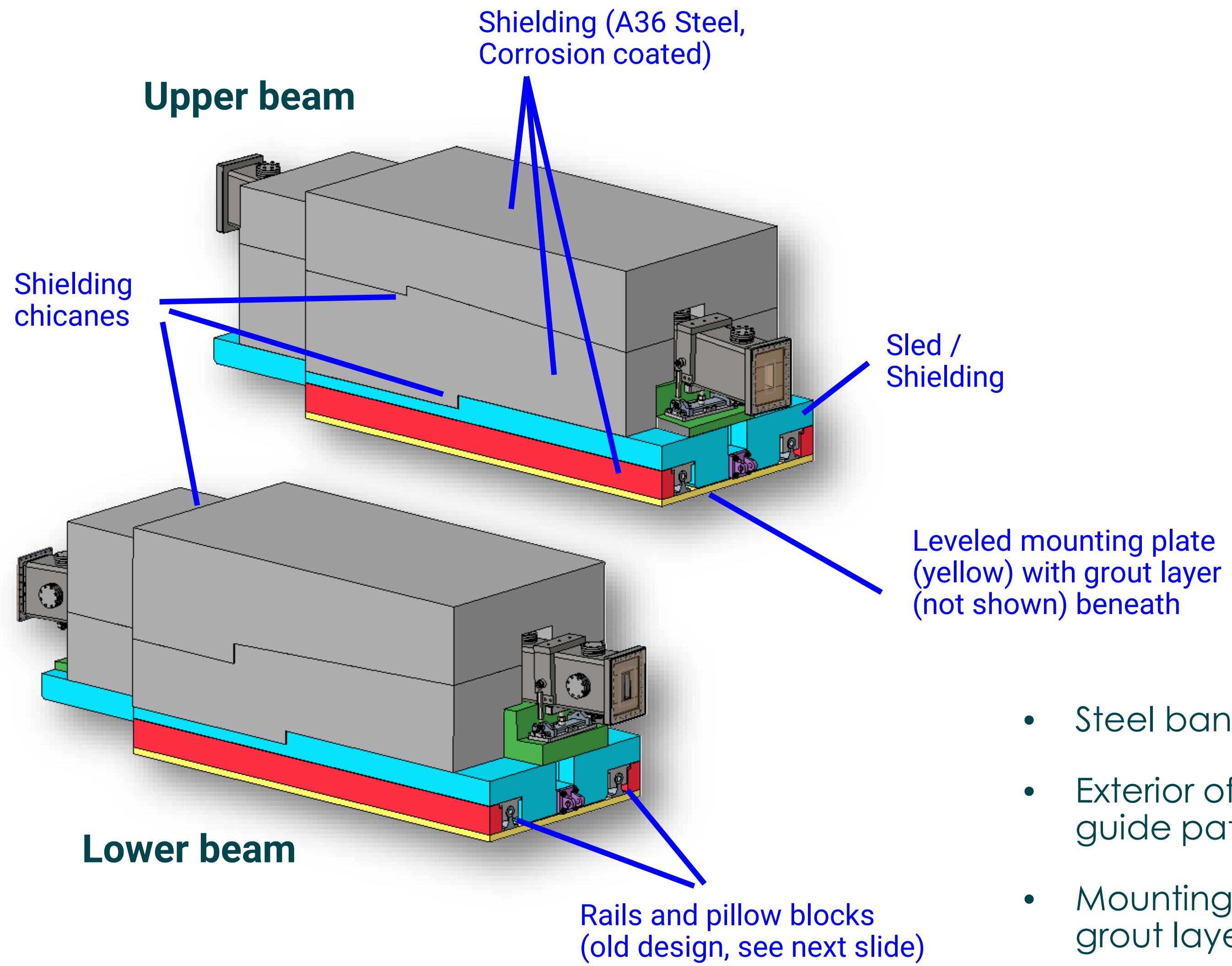
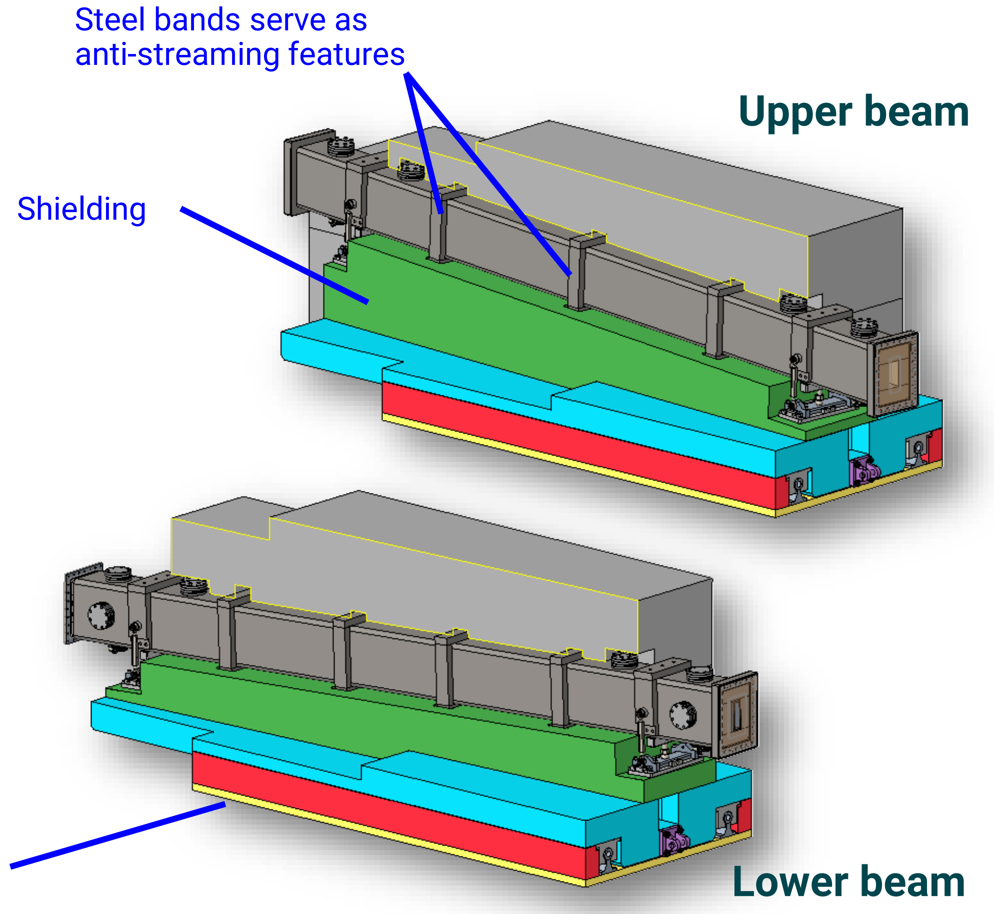
Feed-Through Shielding & Optics

Credit: Art Diaz

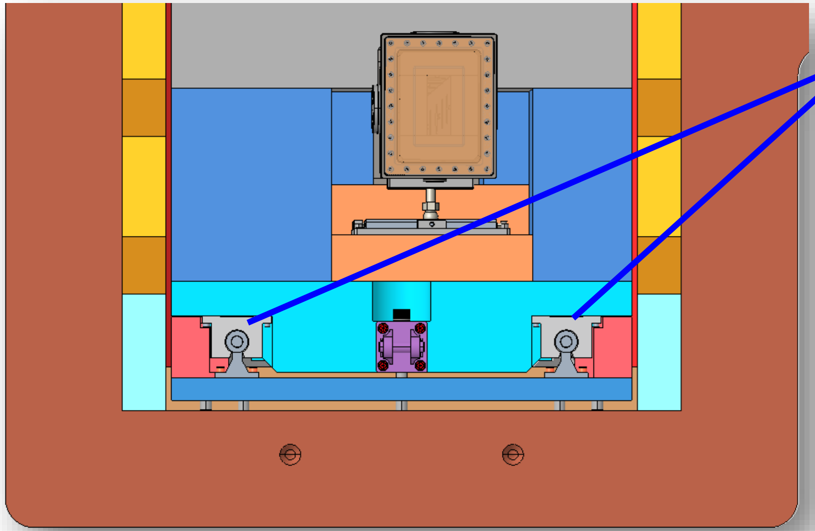




- Steel bands encircling the housings serve as anti-streaming features
- Exterior of the shielding is rectangular, interior is contoured to fit the guide path
- Mounting base plate is leveled with a regular weight concrete (RWC) grout layer (not shown) underneath
- Housing and shielding assembly is slid into the bunker feed-through opening on rails attached to the mounting base plate

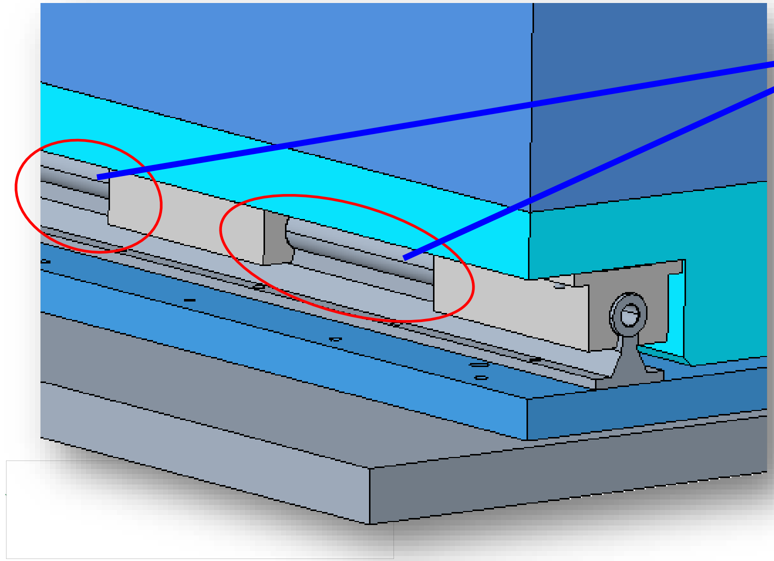
Change in Feed-Through Rollers

Original Design



Rails on both sides need good alignment to each other

Original (pillow block bearings and rails)

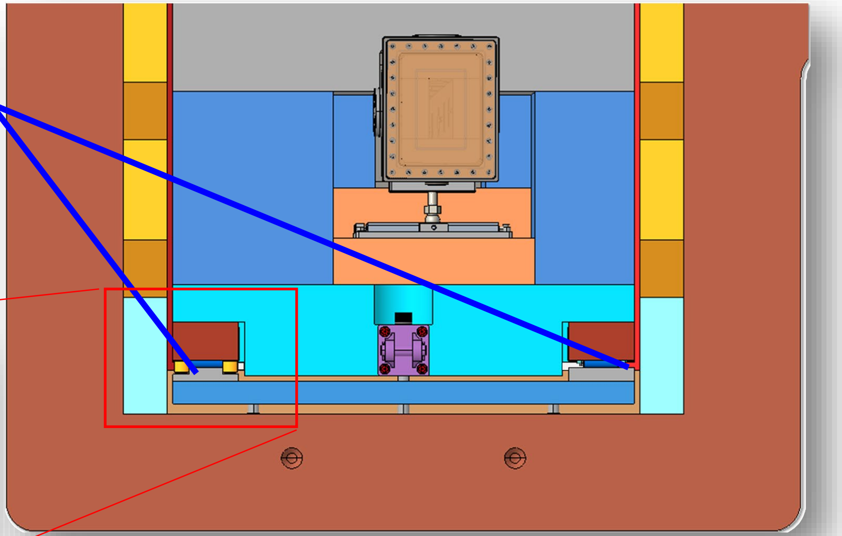


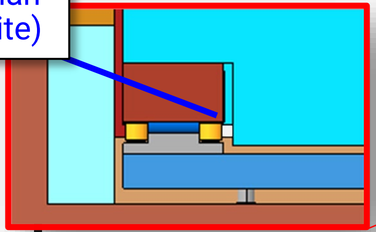
Empty space (non-shielded)

There are gaps, but no unobstructed streaming paths except at the Hilman roller corners (white)

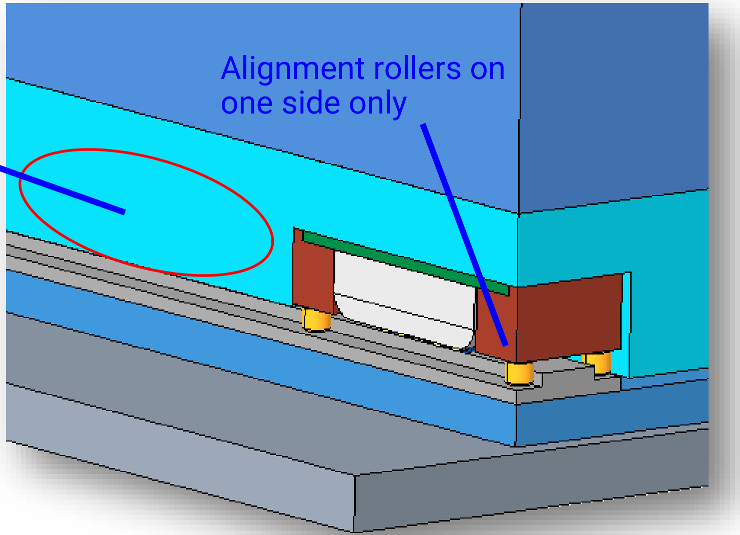
Neutronic Analysis Design

Only one side of the Hilman roller system provides lateral motion constraint… the two rails do not need to be tightly aligned to each other





Hilman



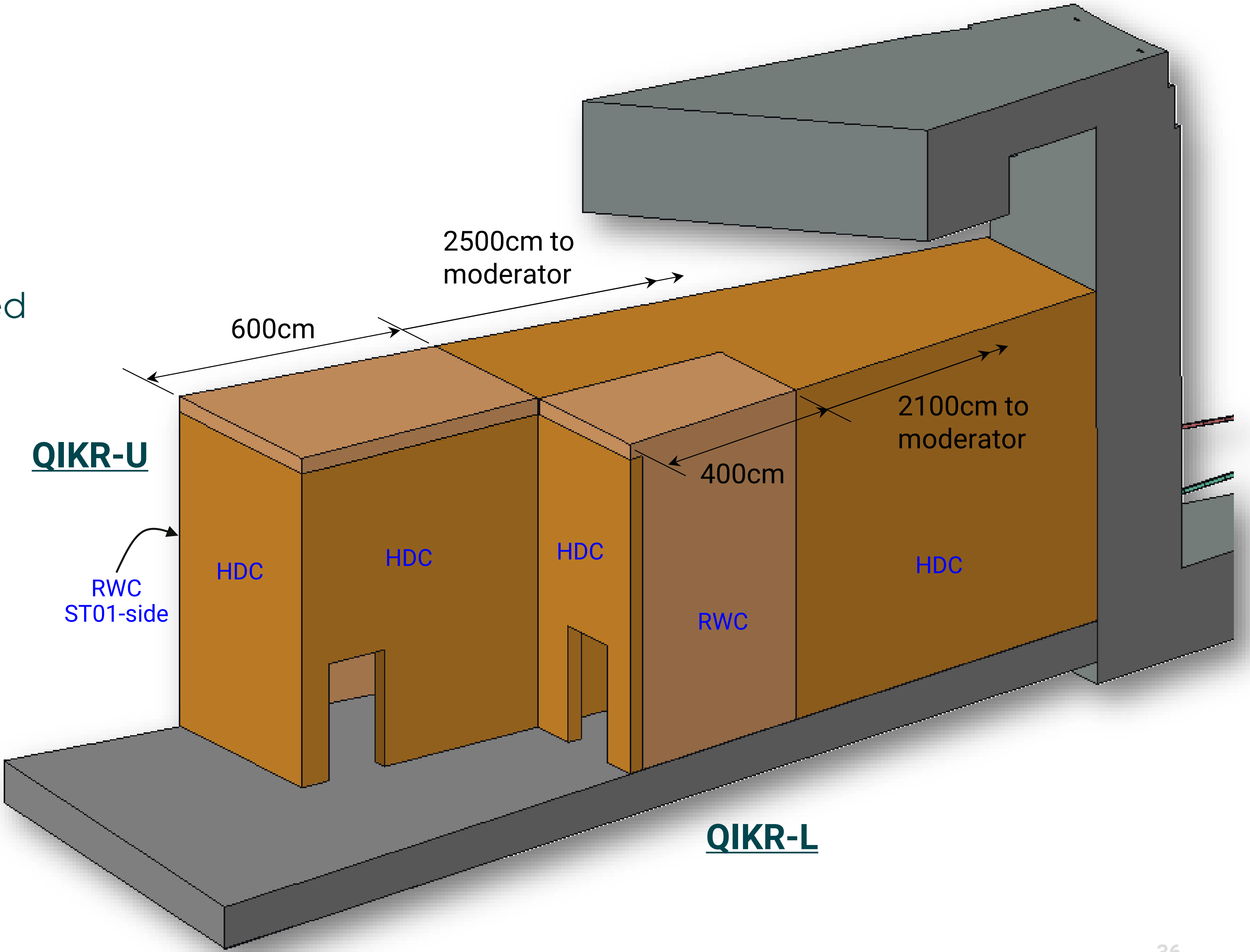
Shielded space

- Benefits of Hilman rollers:
  - allow for easier rail alignment
  - Less empty space, better anti-streaming

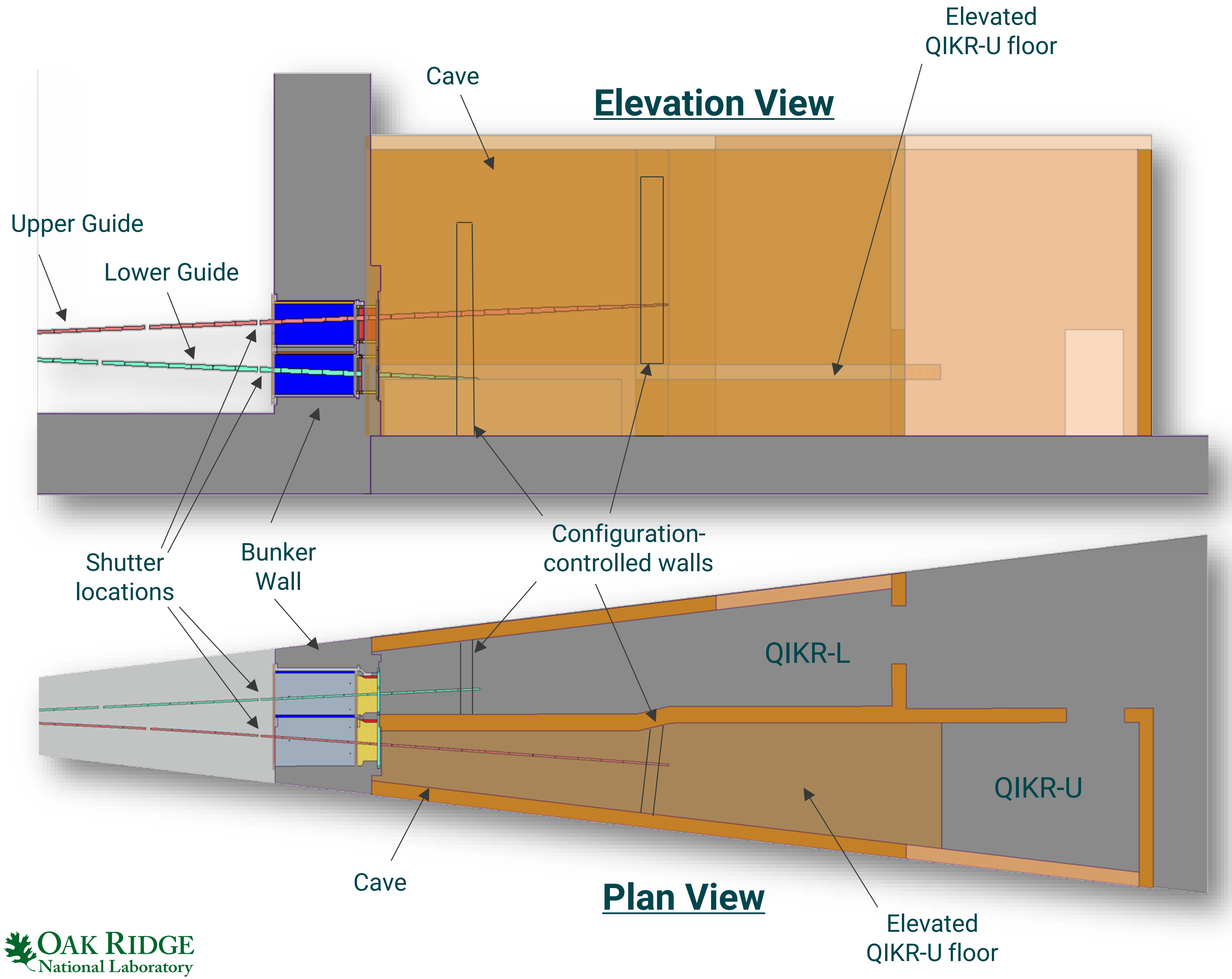
Cave

Cave – Exterior

- Cave dimensions and materials match those used in the neutronics analysis
- Cave doors (not shown) are 70mm thick steel, PPS interlocked



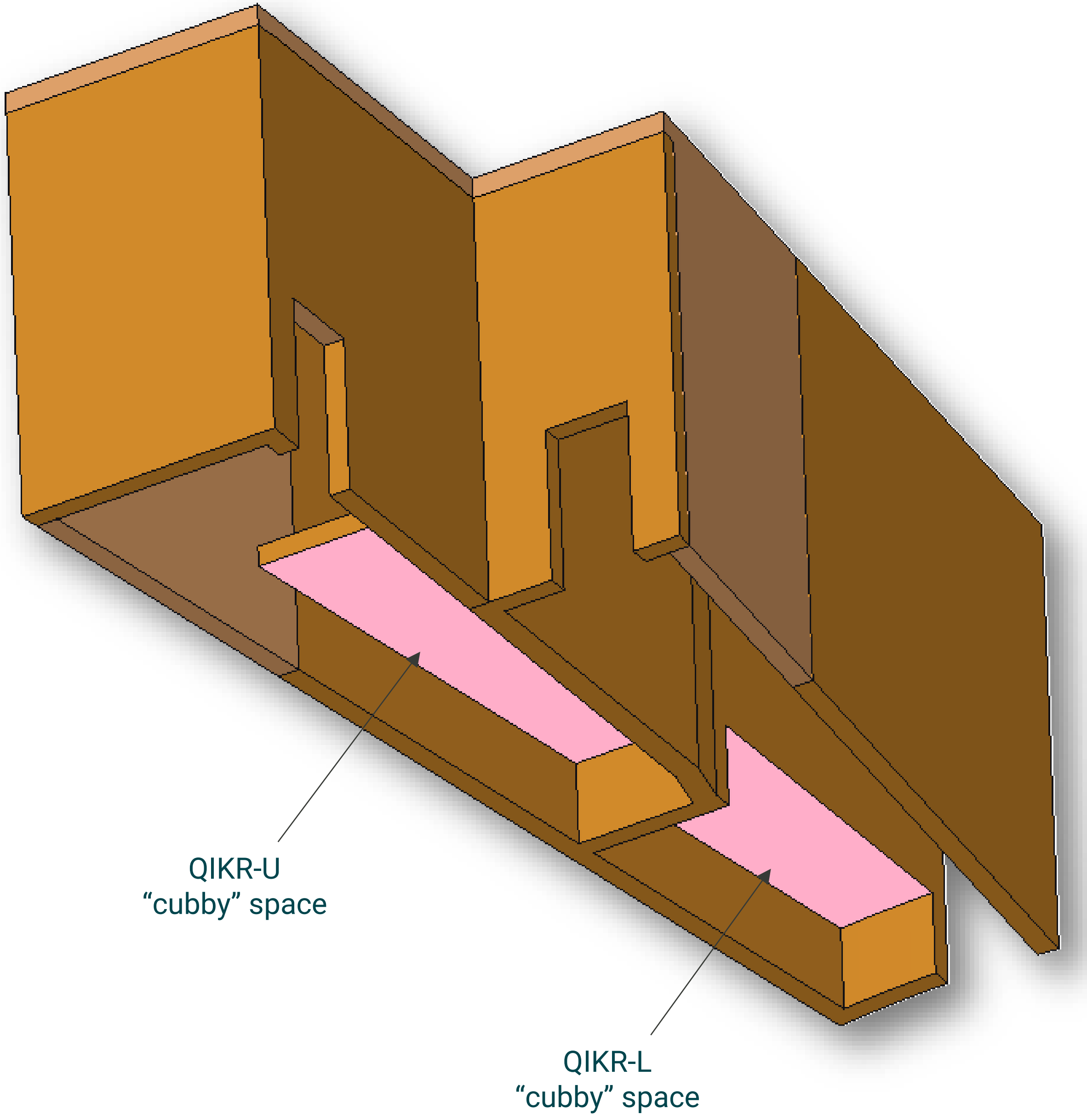
Cave – Interior



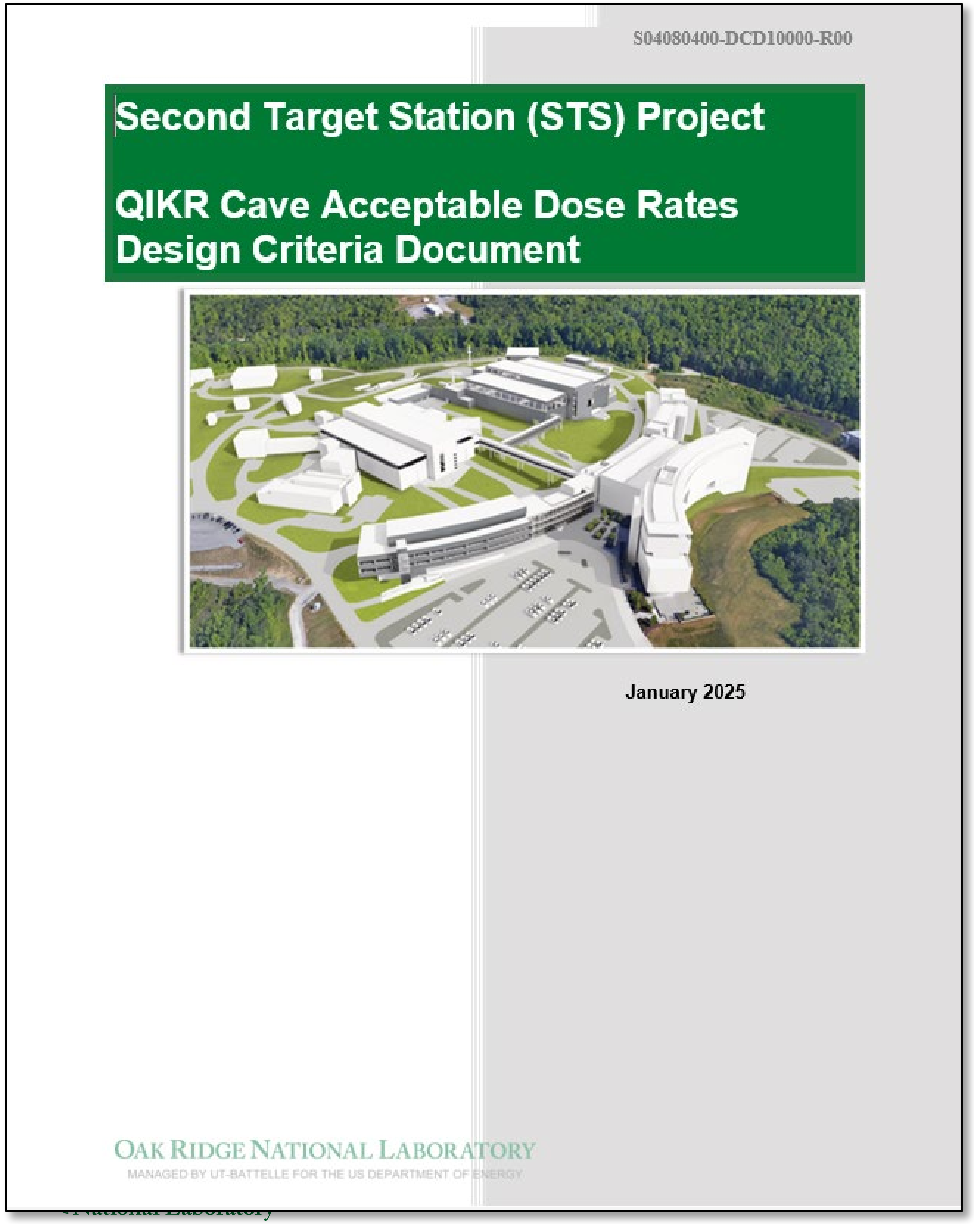
- Center wall is 350mm thick HDC
- Outer walls are 300mm thick HDC or RWC (see previous slide)
- QIKR-U has an elevated floor to hold the guide supports and end station equipment
  - User will stand on the elevated floor to access the QIKR-U sample environments and end station
- Space beneath the QIKR-U floor is accessible to QIKR-L for sample environment equipment (called the QIKR-L "cubby")
- Space beneath the QIKR-U on the downstream end is used for QIKR-U sample environment equipment
  - Also used to route cables from both the QIKR-U and QIKR-L end stations
- Personnel access to the guides upstream of both end stations is blocked by a movable but locked & configuration-controlled wall
  - These walls were not part of the neutronics analysis… they play no role in radiation shielding except to create personnel-inaccessible areas where dose rates are allowed to be unlimited

Cave – Cubby spaces

- Cubby spaces are both ~4ft in height
- Space beneath the QIKR-U floor on the upstream end is accessible to QIKR-L for sample environment equipment (called the QIKR-L "cubby")
- Space beneath the QIKR-U on the downstream end is used for QIKR-U sample environment equipment
  - Also used to route cables from both the QIKR-U and QIKR-L end stations



Discussion of Allowable Dose Rates in the Cave



S04080400-DCD10000-R00

Second Target Station (STS) Project

QIKR Cave Acceptable Dose Rates
Design Criteria Document

January 2025

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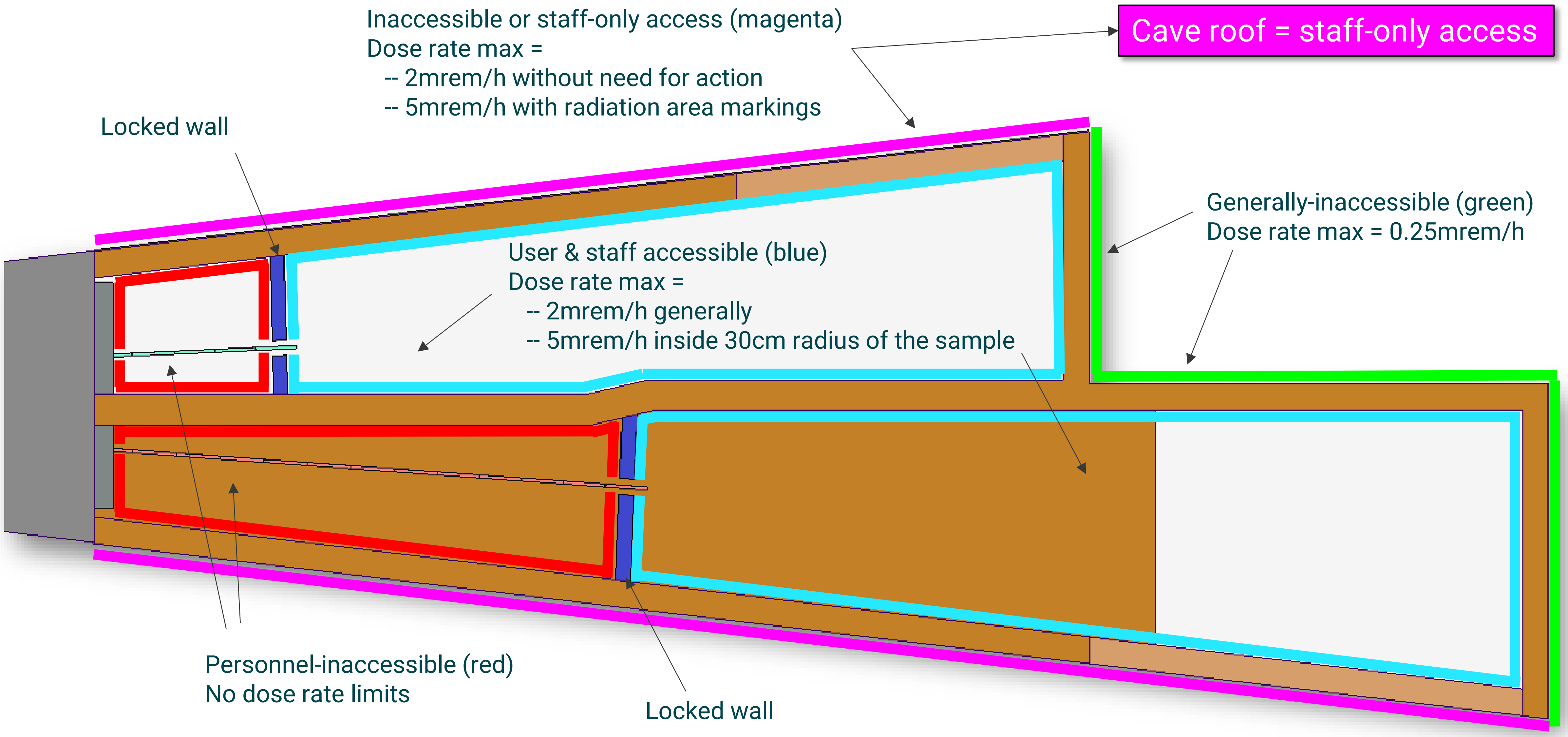
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

- S04080400-DCD10000-R00 describes the reasonable normal operating and accident scenarios to be evaluated for the QIKR cave
- Normal operating scenario:
  - Slits present and open to the max values used in an experiment
  - Water sample present at the sample location
- Accident scenarios:
  - Slits present and open to their max widths & heights
  - Water sample present at the sample location
  - Stainless steel sample present at the sample location
- Acceptable max dose rates in the cave during both operating and accident scenarios:
  - No limit inside the cave in areas where personnel cannot access
  - 2mrem/h in personnel-occupied spaces inside the cave
  - Up to 5rem/h at the sample location within a 30cm radius of the sample
  - Up to 2mrem/h outside the cave with no need for signage where personnel access is limited
  - Up to 5rem/h outside the cave with radiation area signage in place

Discussion of Allowable Dose Rates In & Above the Cave



Summary: Normal Operation

No significant elevated dose rates inside/outside the QIKR instrument cave enclosure

The normal operating scenarios here use slits at max aperture… more conservative than required

normal operation (QIKR-L active and QIKR-U active)			
Cave	Location		maximum total dose rate (mrem/h)
QIKR-L	Outer wall, ST03 side	Upstream (HDC)	0.72
		Downstream (RDC)	0.28
	Back Wall		< 0.25
	Roof	Upstream (HDC)	< 0.25
		Downstream (RDC)	0.43
QIKR-U	Outer wall, ST01 side	Upstream (HDC)	0.64
		Downstream (RDC)	0.34
	Back Wall		< 0.25
	Roof	Upstream (HDC)	0.31
		Downstream (RDC)	0.51
normal operation (only QIKR-U active)			
QIKR-L	in-beam		0.27
	bisector wall (inside cave)	Upstream (HDC)	1.02
		Downstream (RDC)	0.49
normal operation (only QIKR-L active)			
QIKR-U	in-beam		0.28
	bisector wall (inside cave)	Upstream (HDC)	0.71
		Downstream (RDC)	0.29

Data table from Kursat Bekar's analysis

Summary: Accident Conditions

Data table from Kursat Bekar's analysis

Cave	Location		maximum total dose rate (mrem/h)
accident condition (QIKR-L normal operating and QIKR-U accident)			
QIKR-L normal	Outer wall, ST03 side	Upstream (HDC)	0.72
		Downstream (RDC)	0.31
	Back Wall		< 0.25
	Roof	Upstream (HDC)	< 0.25
		Downstream (RDC)	0.43
QIKR-U accident	Outer wall, ST01 side	Upstream (HDC)	1.79
		Downstream (RDC)	0.30
	Back Wall		< 0.25
	Roof	Upstream (HDC)	0.65
		Downstream (RDC)	0.88
accident condition (QIKR-L accident and QIKR-U normal operating)			
QIKR-L	Outer wall, ST03 side	Upstream (HDC)	2.70
		Downstream (RDC)	< 0.25
	Back Wall		0.31
	Roof	Upstream (HDC)	0.38
		Downstream (RDC)	0.71
QIKR-U	Outer wall, ST01 side	Upstream (HDC)	0.94
		Downstream (RDC)	0.34
	Back Wall		< 0.25
	Roof	Upstream (HDC)	0.31
		Downstream (RDC)	0.51
accident condition (QIKR-L inactive and QIKR-U accident)			
QIKR-L	in beam		0.28
	bisector wall	Upstream (HDC)	1.01
		Downstream (HDC)	2.76
accident condition (QIKR-L accident and QIKR-U inactive)			
QIKR-U	in beam		0.27
	bisector wall	Upstream (HDC)	2.35
		Downstream (HDC)	0.35

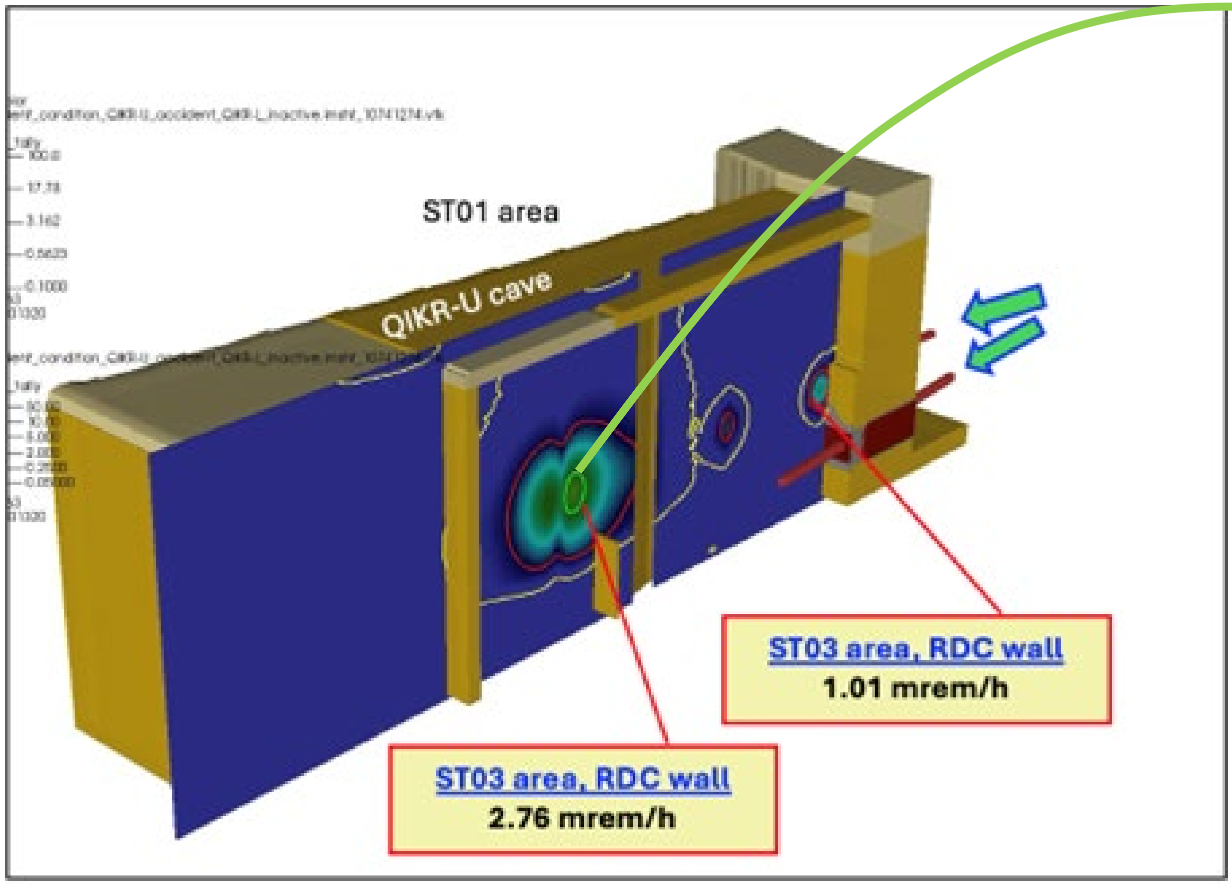
This area outside the cave may need radiation area markings, depending on which beamline is on ST03. Currently, this area is blocked by CUPI^{2}D & is inaccessible to personnel. Is it a concern for beamline cross-talk?

This dose rate is in a personnel-occupied section of the QIKR-L cave & is above the allowed max of 2mrem/h, but is located high on the wall where users would not be (see next slide)

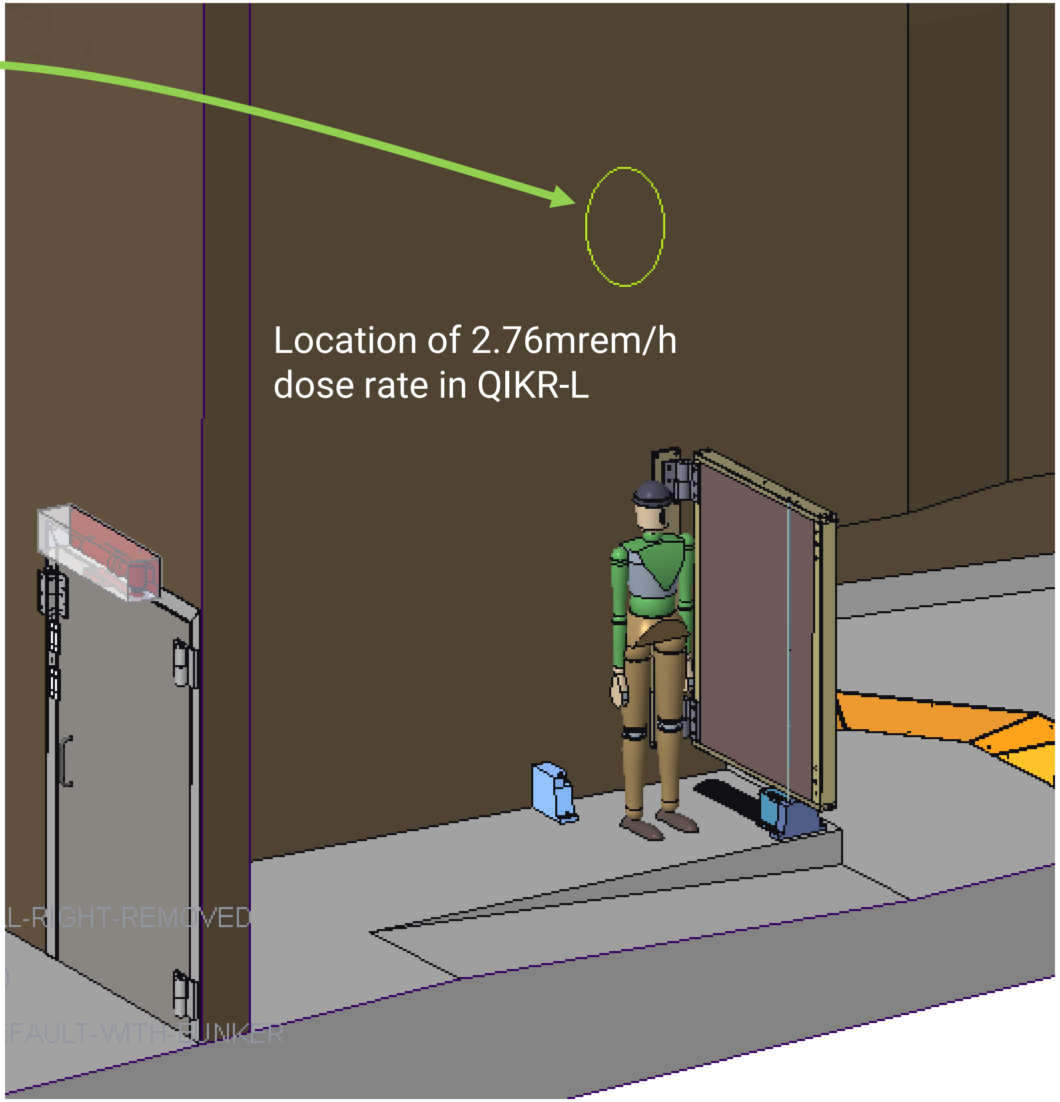
This dose rate is in an area inaccessible to personnel while either beamline is operating.

Discussion of Allowable Dose Rates In & Above the Cave

Figure from Kursat Bekar's analysis

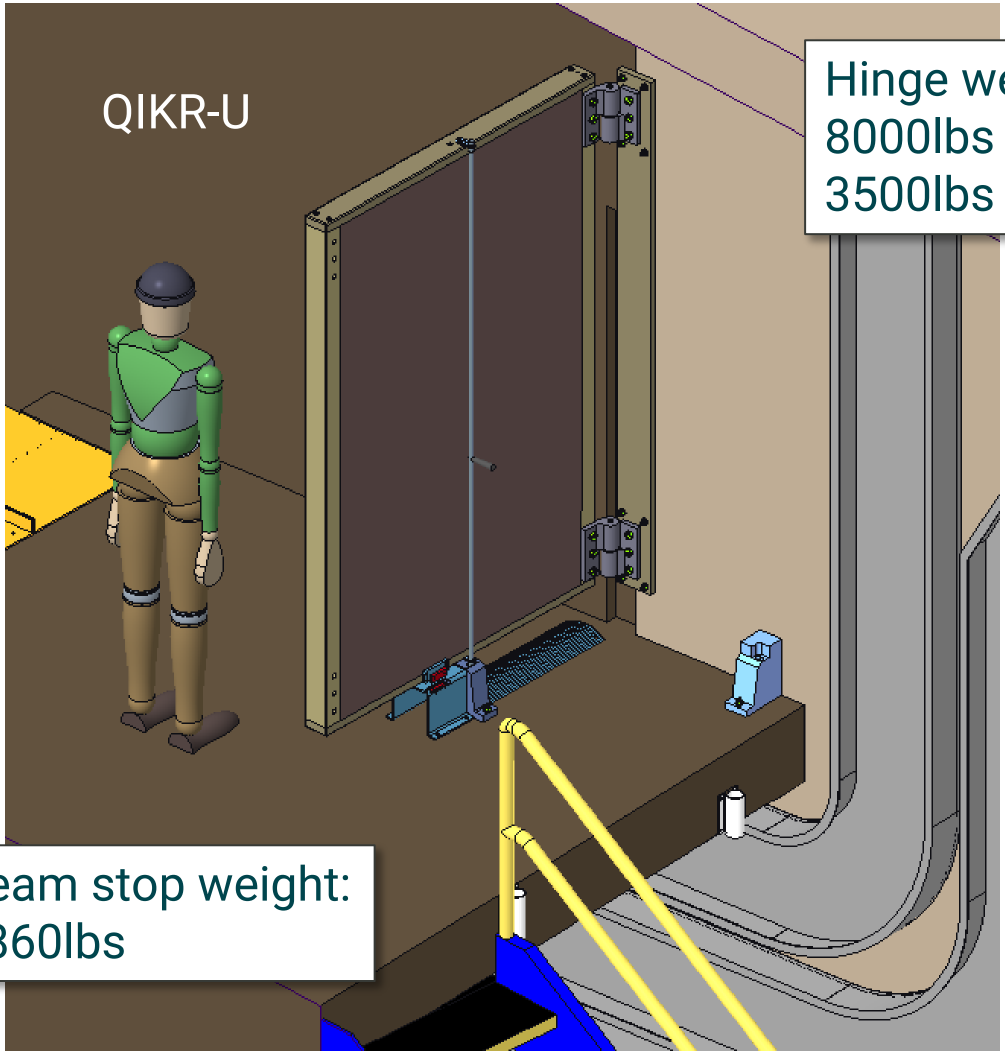


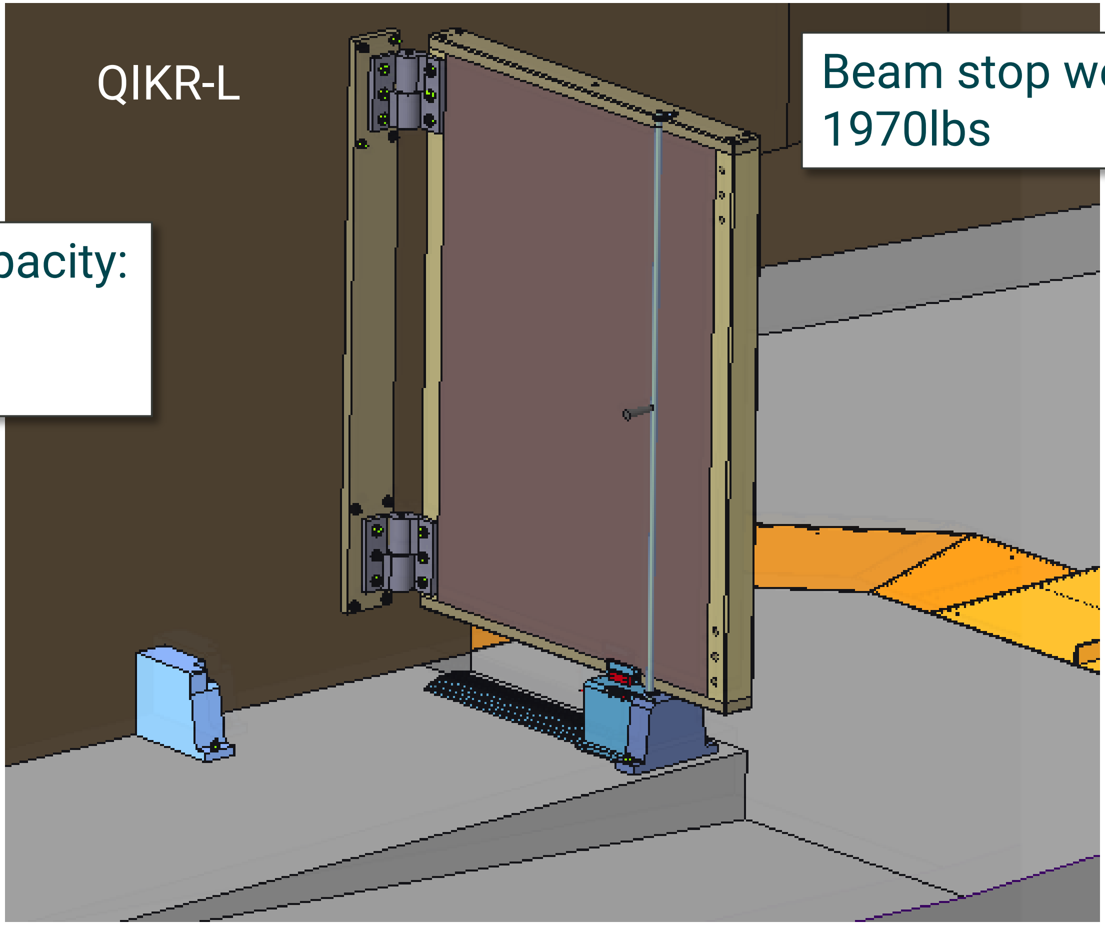
(b) Dose profiles along the inner wall inside QIKR-L cave
(QIKR-U is in accident, QIKR-L is inactive)



Beam Stop

Beam Stops – Overview

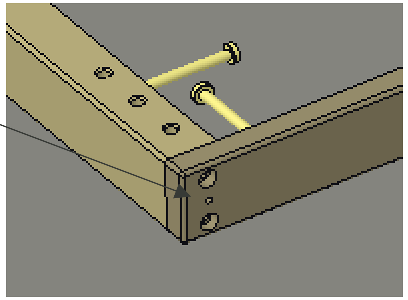


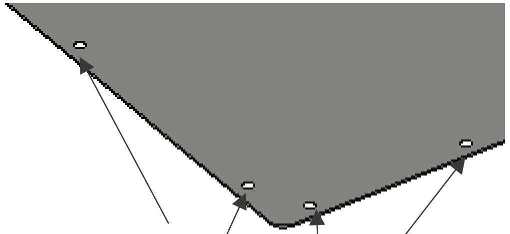


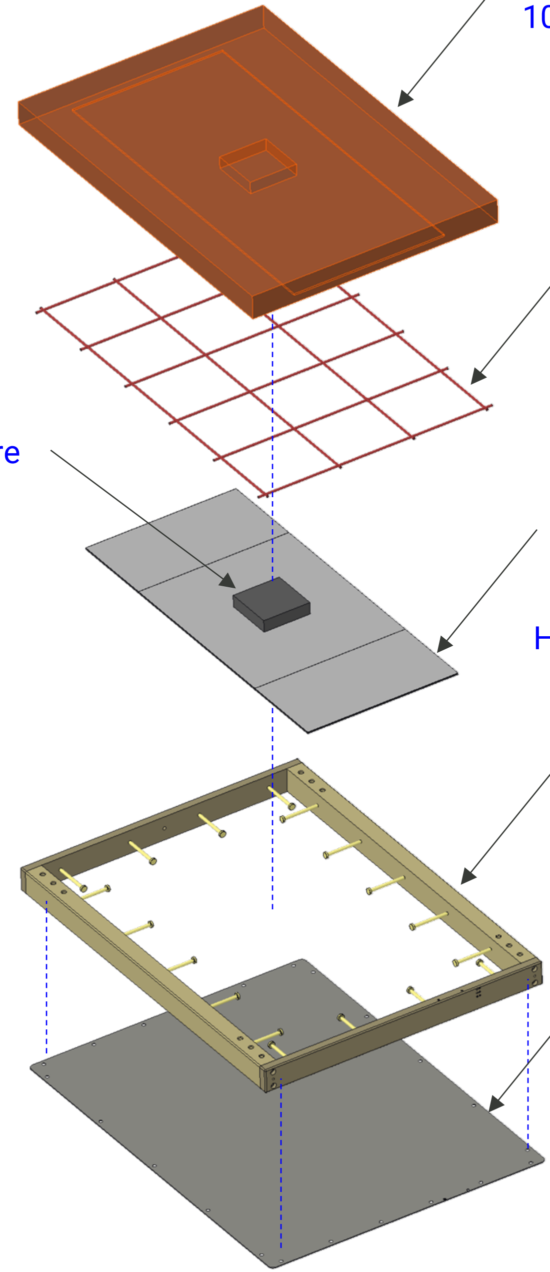
- Both QIKR-L and QIKR-U beam stops are hinged to allow easier access to the back side of the end stations when needed (expected to be infrequent)
- Beam stops are manually moved and manually latched in the "open" and "closed" positions
  - "closed" position is for "beam on" condition & is indicated to IPPS via magnetic sensor (two sensors for redundancy)

Beam Stop – Construction

- Neutronics analysis model for the beam stop has the same B4C, HDC, and steel block thicknesses & HxW dimensions
- Steel frame, Nelson studs, aluminum face plate, and reinforcing steel rods (rebar) are **departures from the MCNP model**
  - Changed made to make the beam stop manufacturable
- Because of concerns the HDC concrete may crack when suspended from one side by the hinges, beam stop construction may change to only B_4C + steel
  - Will need re-evaluation by neutronics at FD

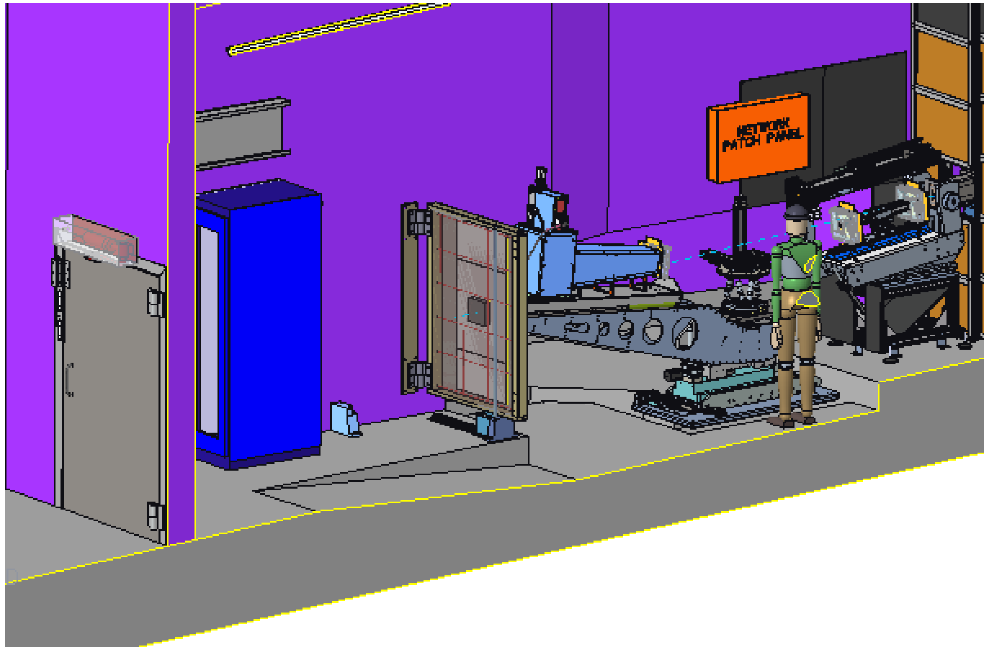




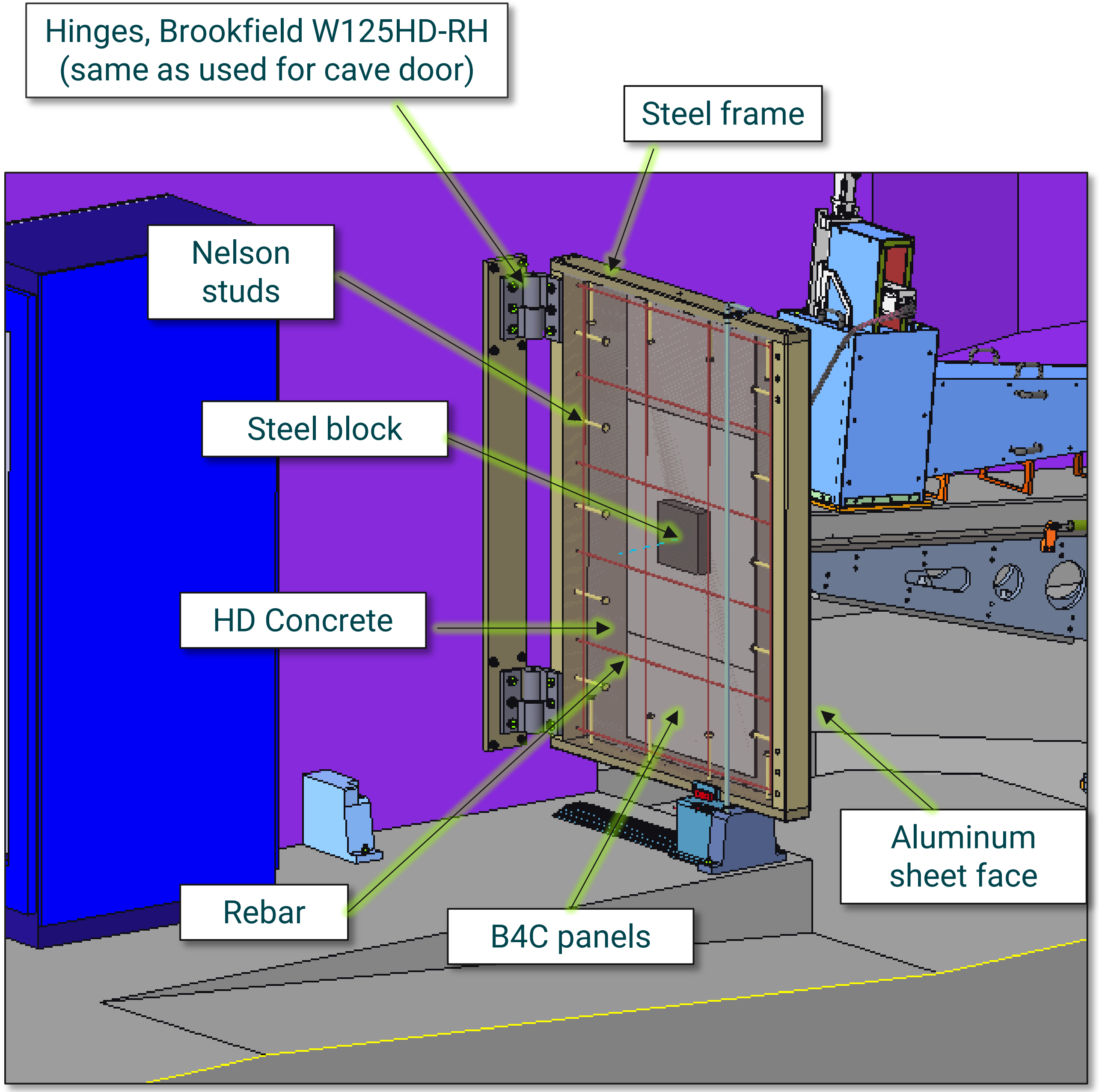


Oak Ridge National Laboratory

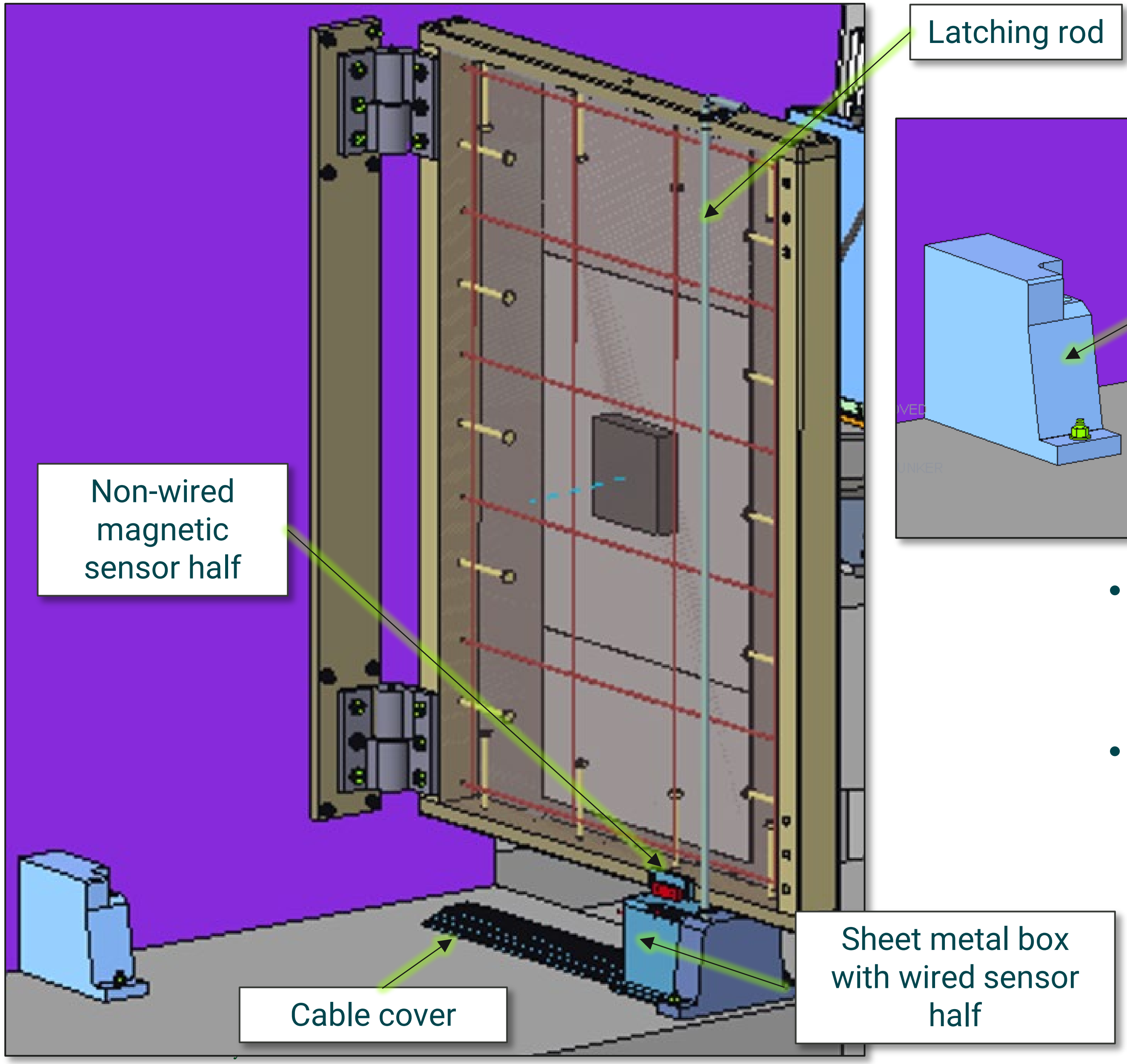
Beam Stop – QIKR-L

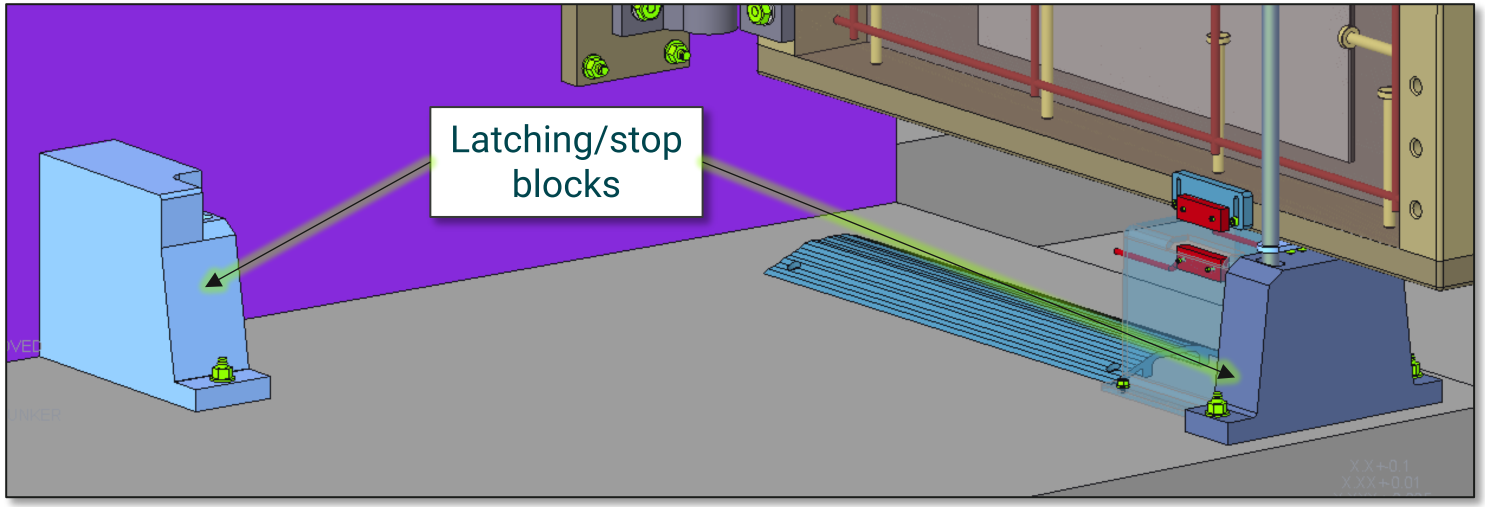


- Beam stop is hinged to swing up against the cave wall when needed.
- Steel frame contains lift attachments on the top, Nelson studs along the inside surfaces, and attachments for a latching rod and a magnetic sensor on the bottom



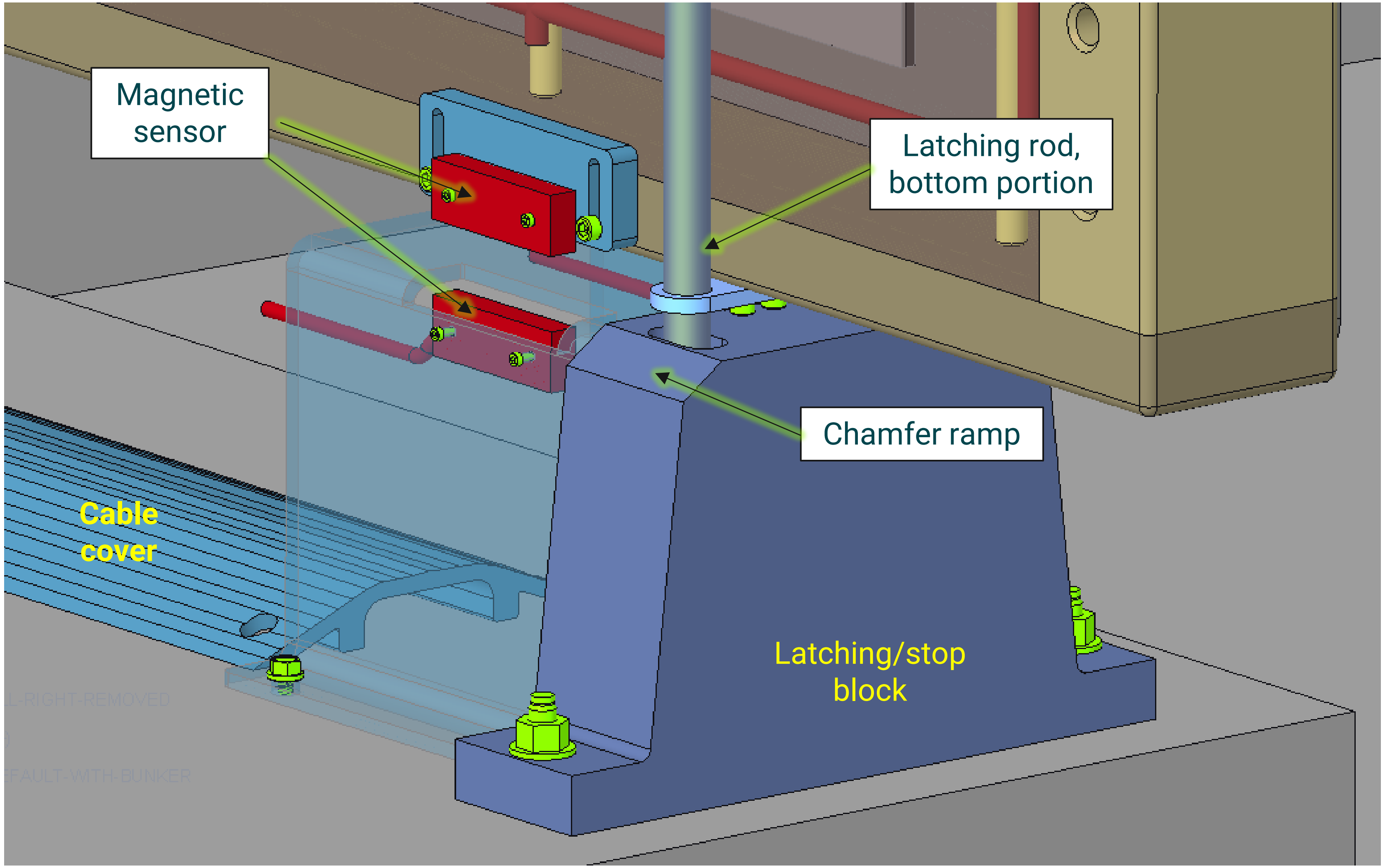
Beam Stop – QIKR-L

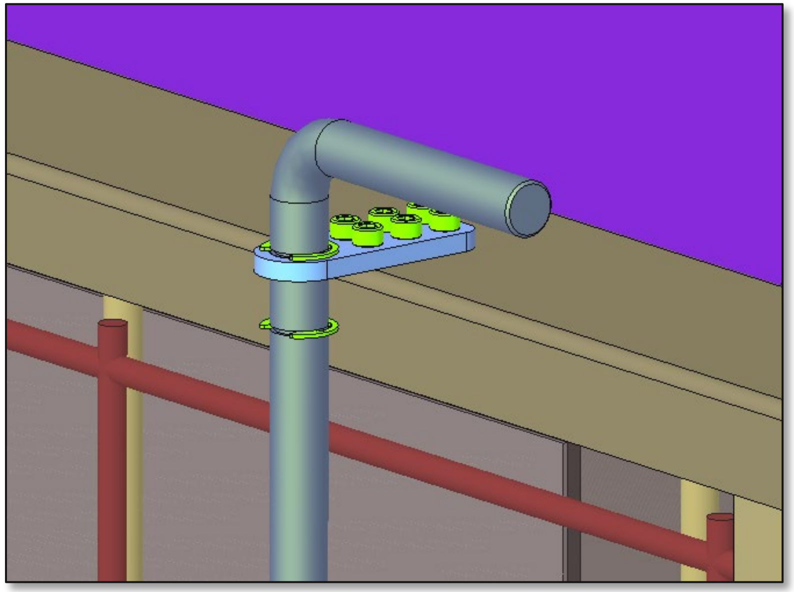




- Two latching/stop blocks that stop the beam stop in the correct position (open or closed) and provide a means of latching the beam stop in place
- In the closed position, there are two magnetic PPS sensors on the bottom edge, one on the back, one in the front.
  - The non-wired halves of the sensors are attached on adjustable brackets on the beam stop steel frame
  - The wired halves are attached to an aluminum sheet metal box, the cables run along the floor to the center cave wall

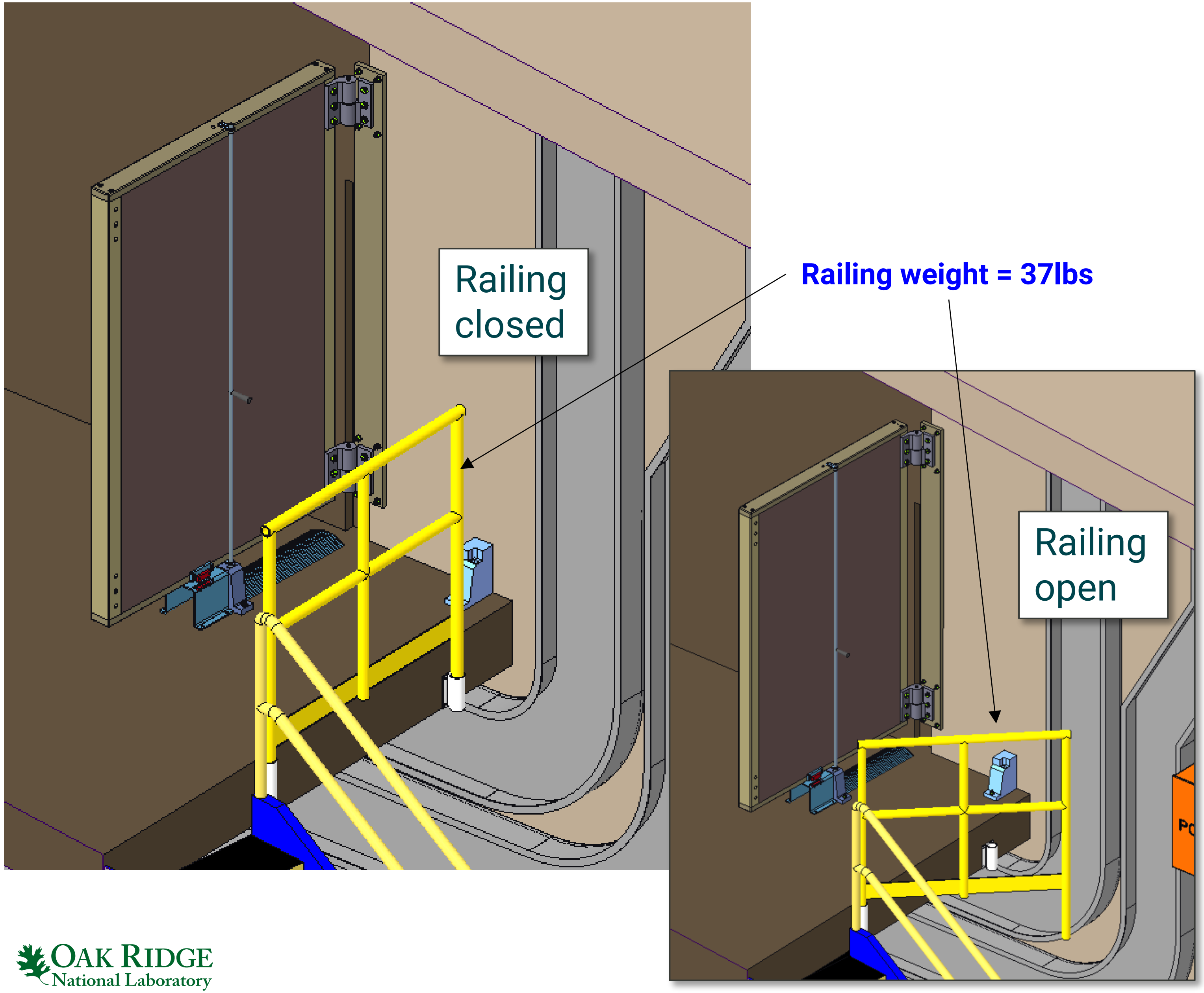
Beam Stops – QIKR-L





Latching rod, top portion

Beam Stop – QIKR-U Safety



- The upper beamline version is the same as the lower except mirrored and taller, with the stops shifted inboard
  - Inward shift of the stops is because of the length of the upper floor relative to the length of the beam stop
  - Additional vertical length is because of the upward angle of the beam that shifts the beam stop upward away from the floor
- The sensor is shifted inboard as well here, but could actually be shifted outward to the free end of the beam stop
- The section of railing behind the beam stop would be lifted and rotated out when the beam stop is swung open… can be rotated back into place once the beam stop is open (railing = 37lbs)

Questions?