OAK RIDGE National Laboratory

QIKR Shielding PDR: Mechanical Overview

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U.S. DEPARTMENT OF ENERGY

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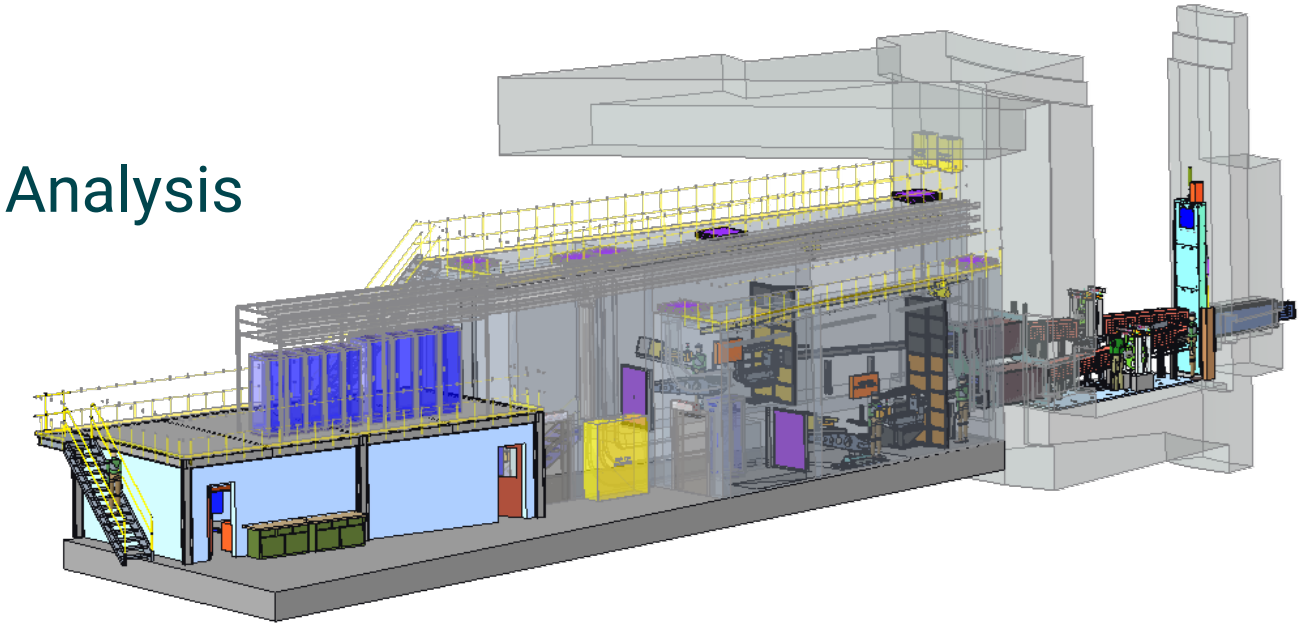
Outline

- Model Changes Following Neutronic Analysis
  - Target Area Shielding
  - Monolith Optics Insert
  - Bunker Feed-Through Shielding
  - Cave

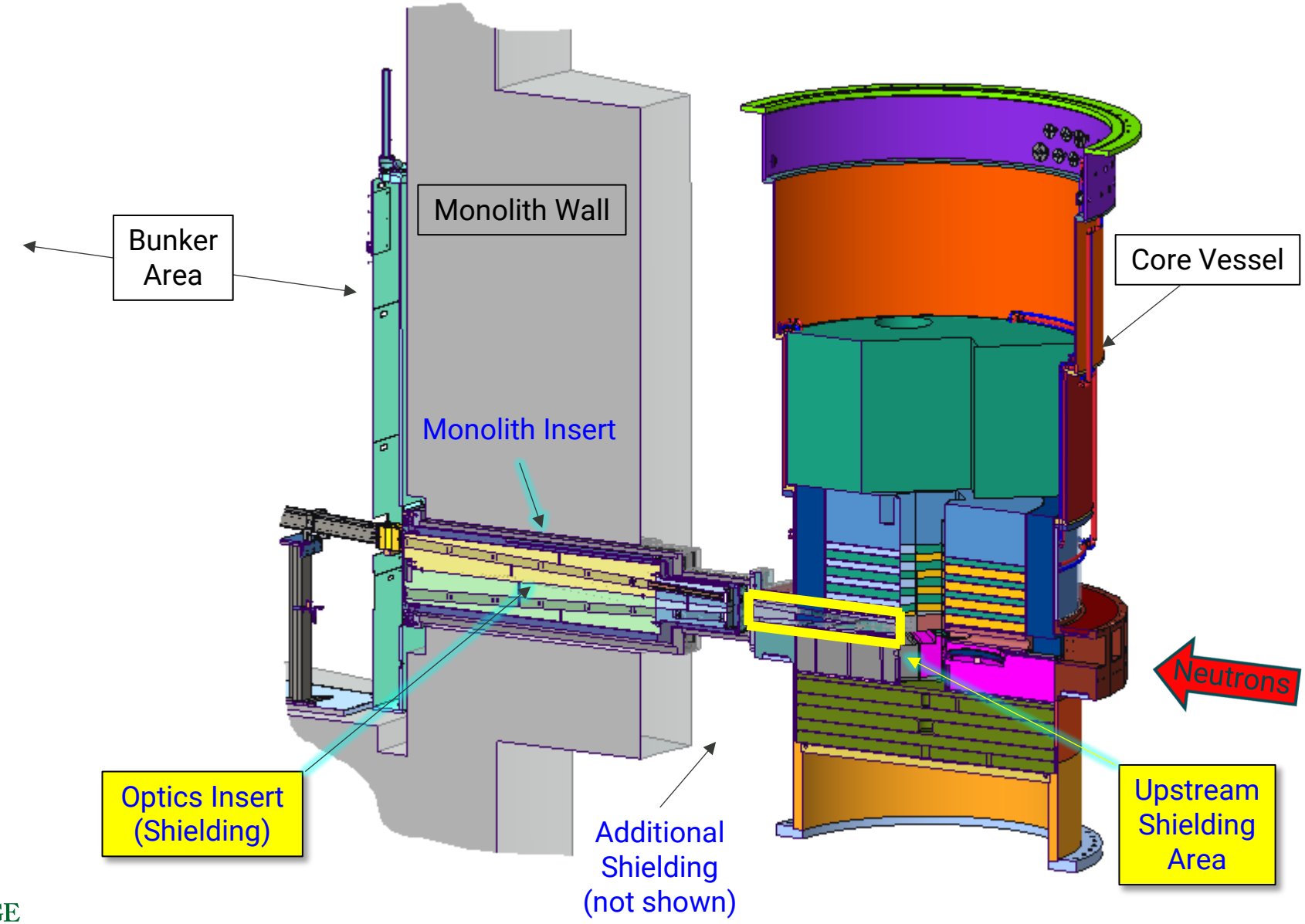


- Components Not Neutronically Analyzed
  - Background Shield Wall

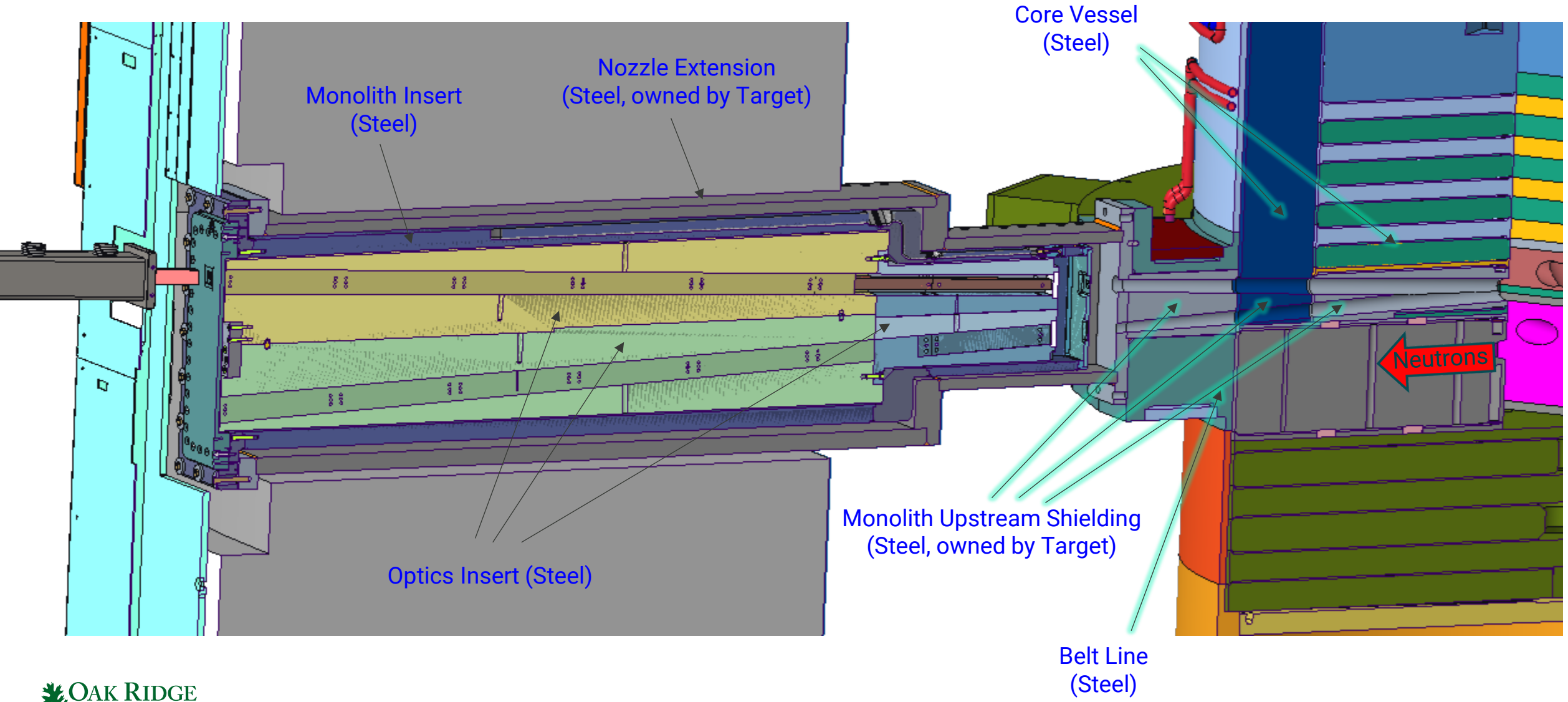
- Component Acquisition, Manufacturing, Installation Strategies & Costs

Target Area Shielding/ Monolith Optics Insert

Monolith Shielding, Upstream & Optics

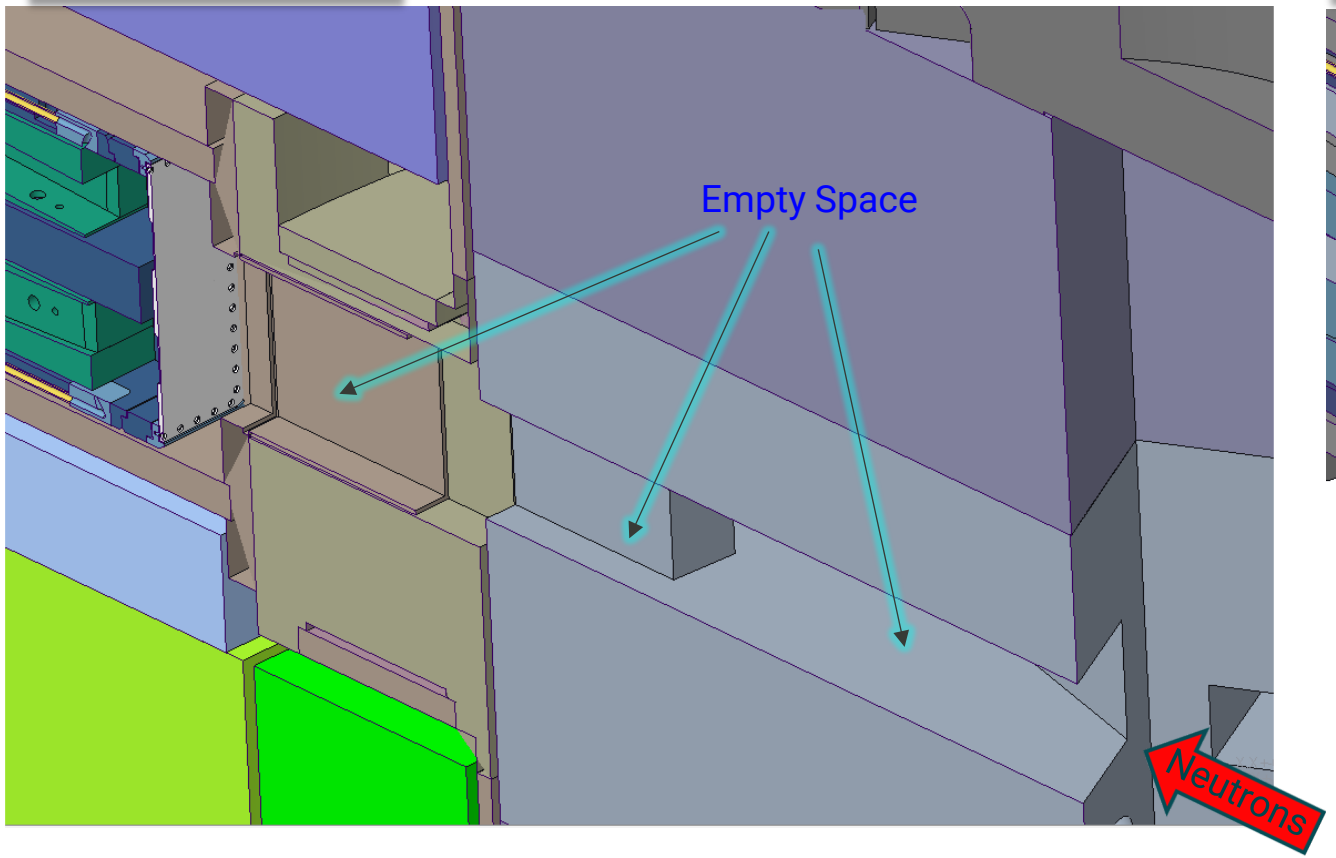


Monolith Shielding, Upstream & Optics



Monolith Upstream Shielding – Current vs. Neutronics Model

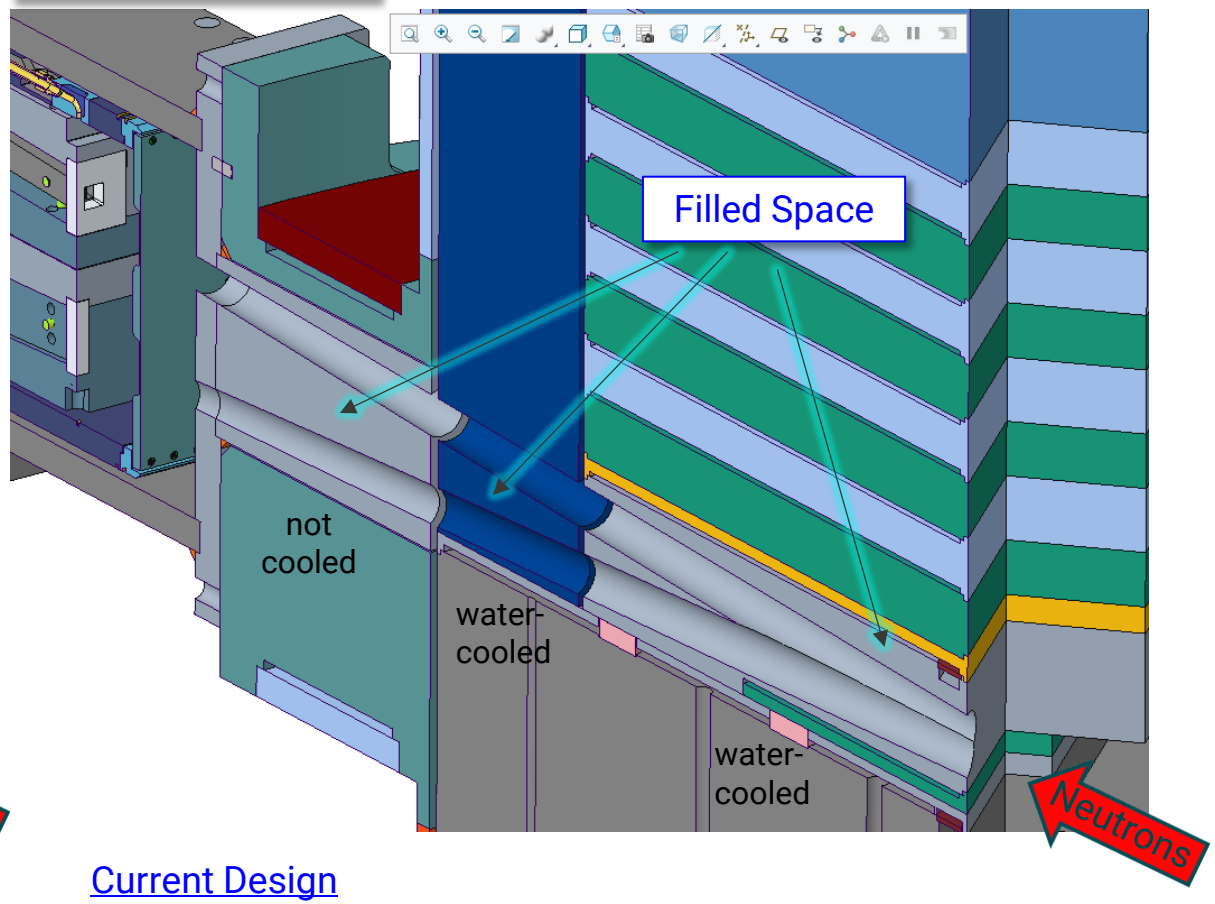
Original Design



Version initially used in Neutronics Analysis

- One variant was to fill the space completely with steel with circular openings circumscribing the guide path dimensions… this led to the design shown at right

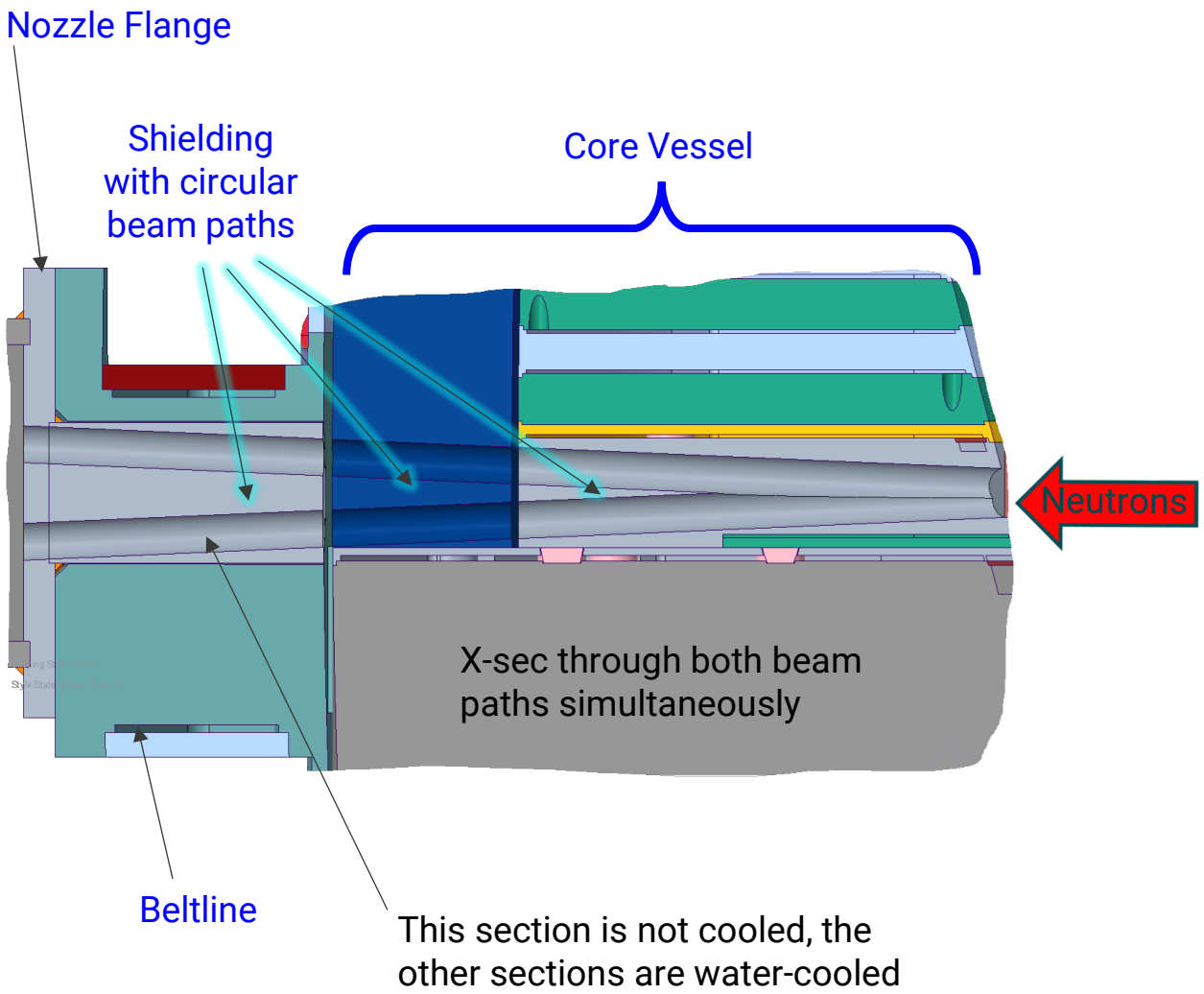
Current Design

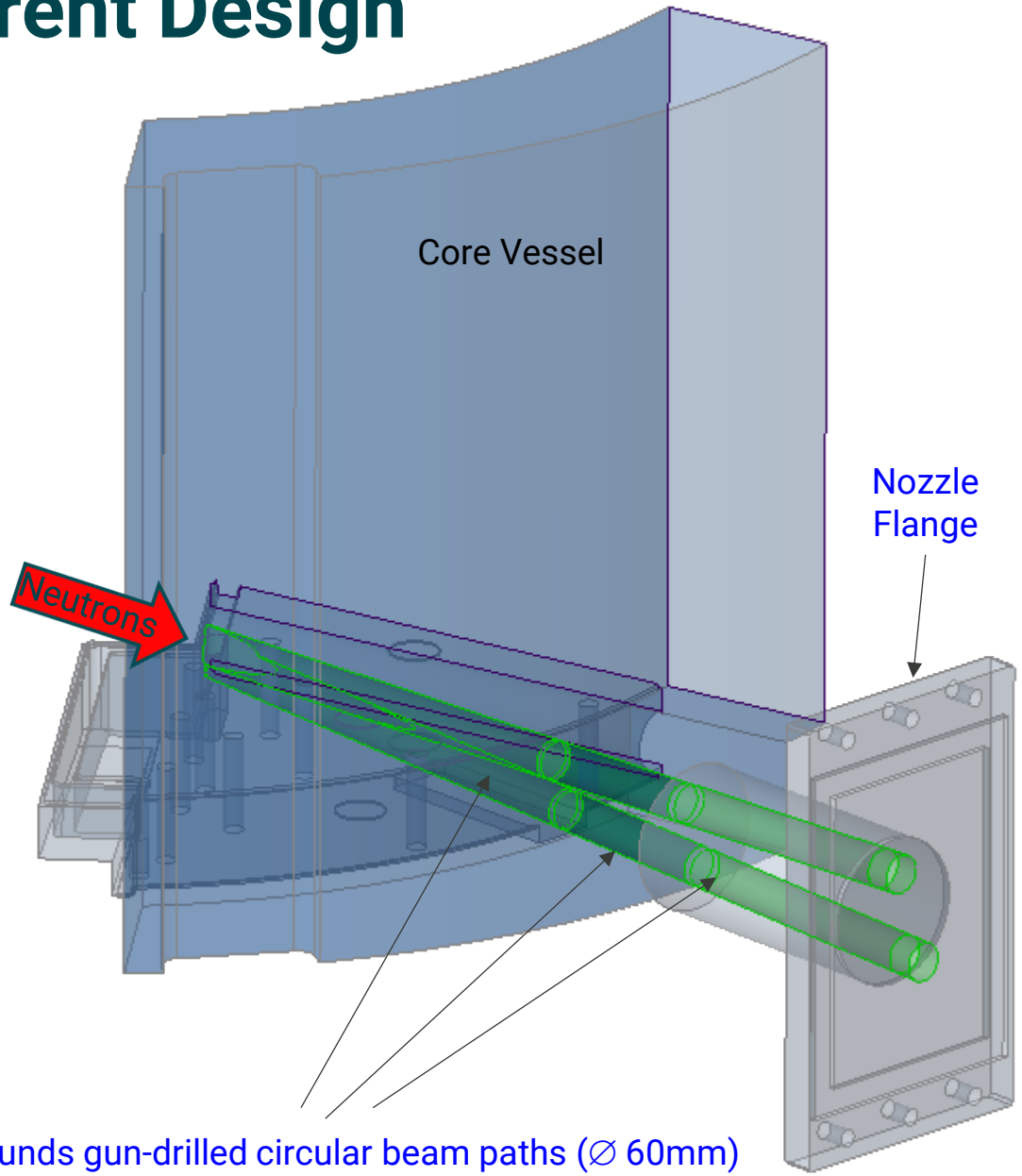


Current Design

- Target shielding includes two water-cooled sections of steel (upstream) and one non-cooled section of steel attached to the nozzle extension
- Guide paths pass through oversized (∅60mm) circular openings in the steel (guide paths = 30mm x 26.5mm)

Monolith Upstream Shielding – Current Design



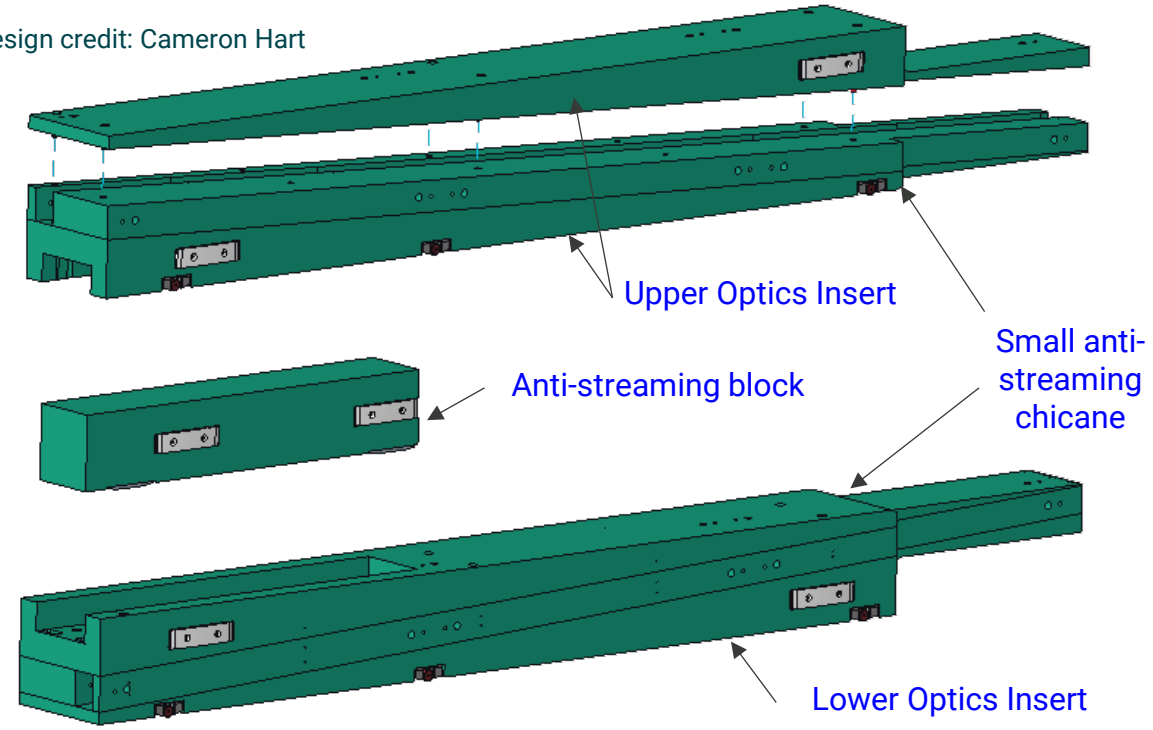


Steel shielding surrounds gun-drilled circular beam paths (∅ 60mm)
(desired guide path dimensions: 30mm W x 26.5mm H)
Surrounding belt line shielding is not shown here

Monolith Optics Shielding

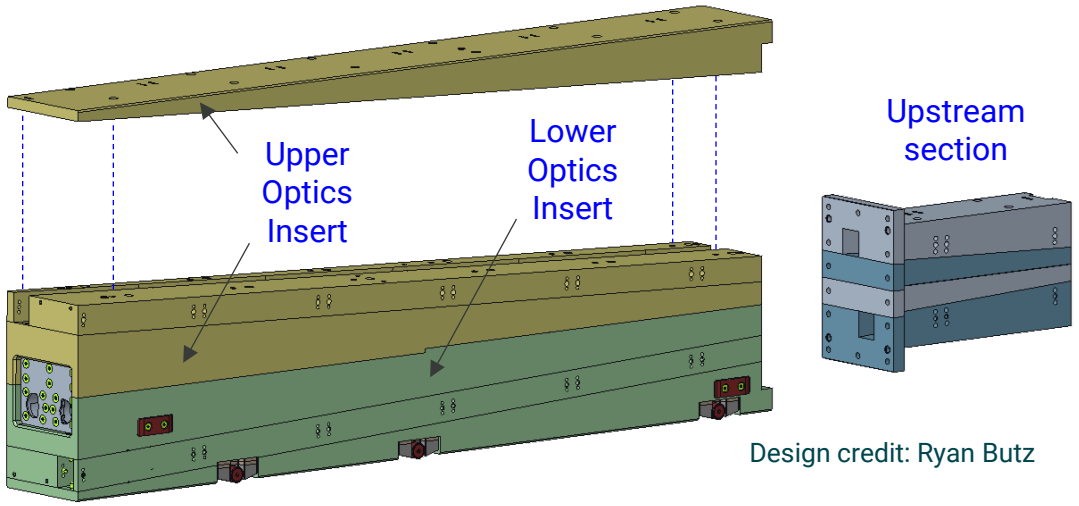
Previous, Neutronics Analysis Design

Design credit: Cameron Hart



- Steel layers, separate upper and lower insert… each built and installed separately
- Anti-streaming block installed separately (after inserts) to compensate for the very small chicane between the optics inserts and the monolith insert shelf that separates them (see next slide)
- Significant streaming paths seen in neutronics analysis

New Design

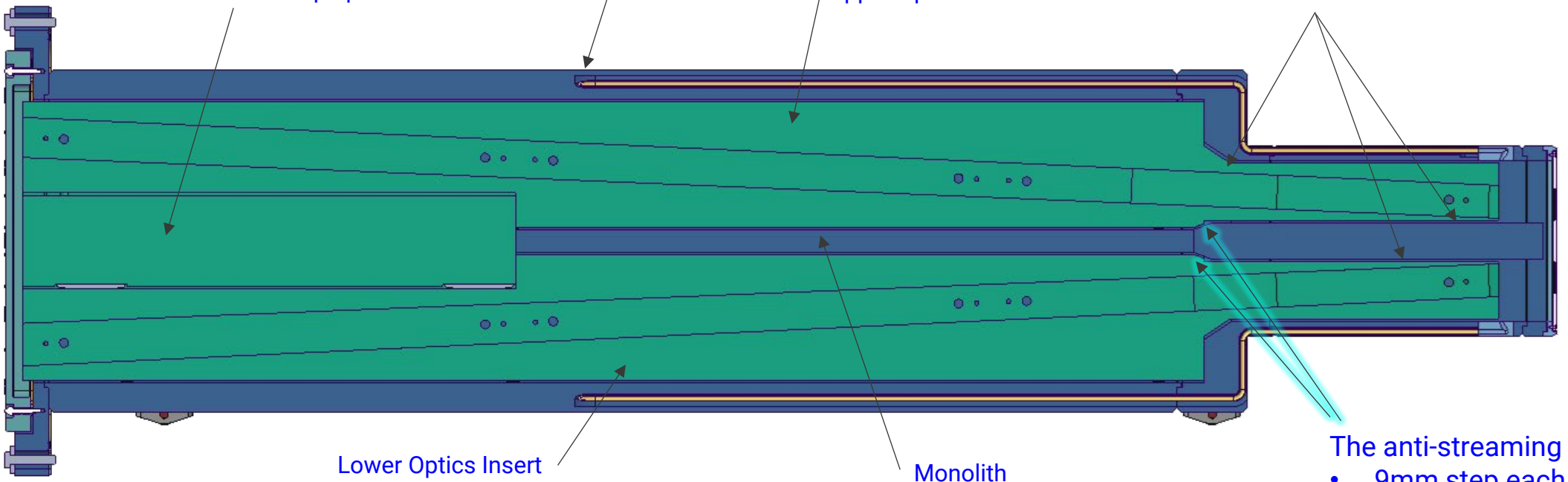


Design credit: Ryan Butz

- Steel layers, combined upper and lower insert… built as a single assembly in layers
- Upstream section is separate but attached in layers along with the downstream section
- Entire assembly inserted into monolith in one operation
- Fewer gaps & streaming paths compared to original version

Monolith Optics Shielding – Old Design

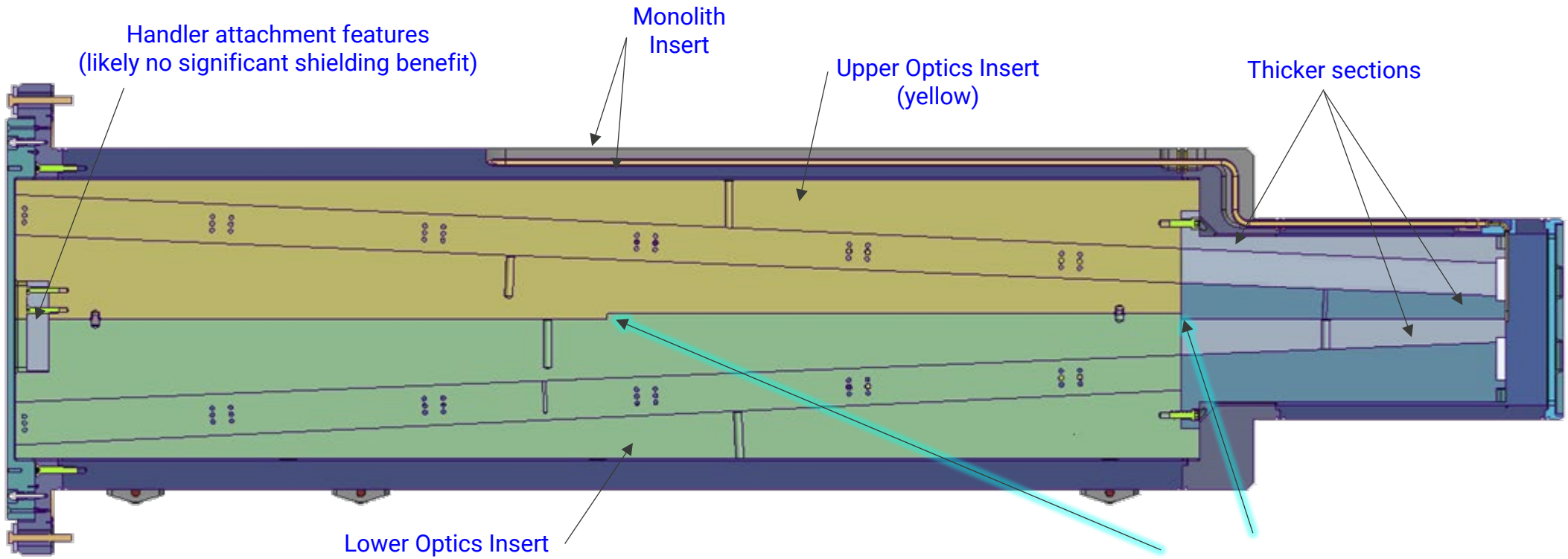
Previous Design, Used in Neutronics Analysis



The anti-streaming chicane
- 9mm step each side
- 6mm gaps b/w optics & monolith inserts

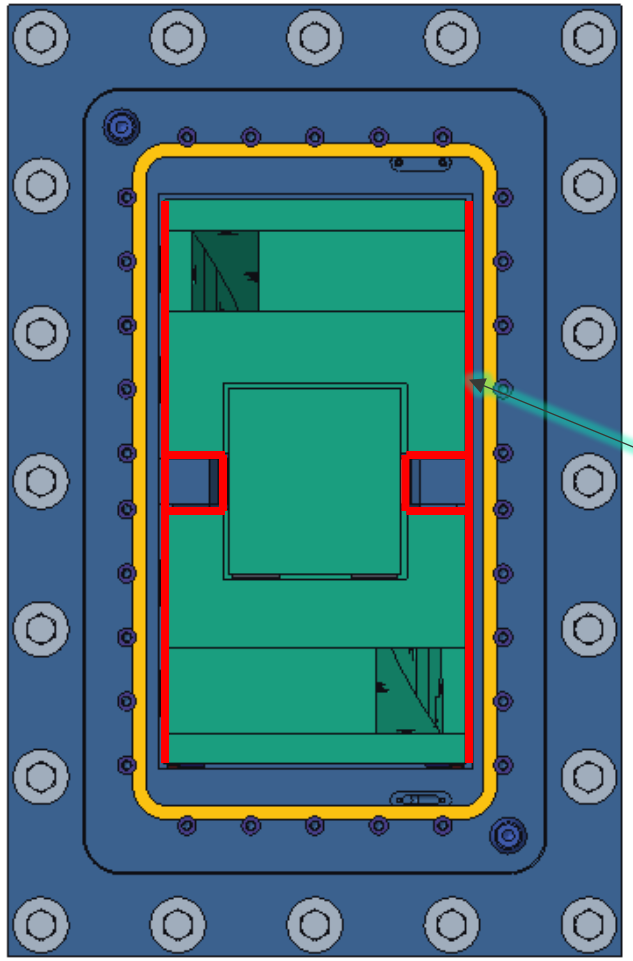
Monolith Optics Shielding – New Design

New Design, not yet analyzed



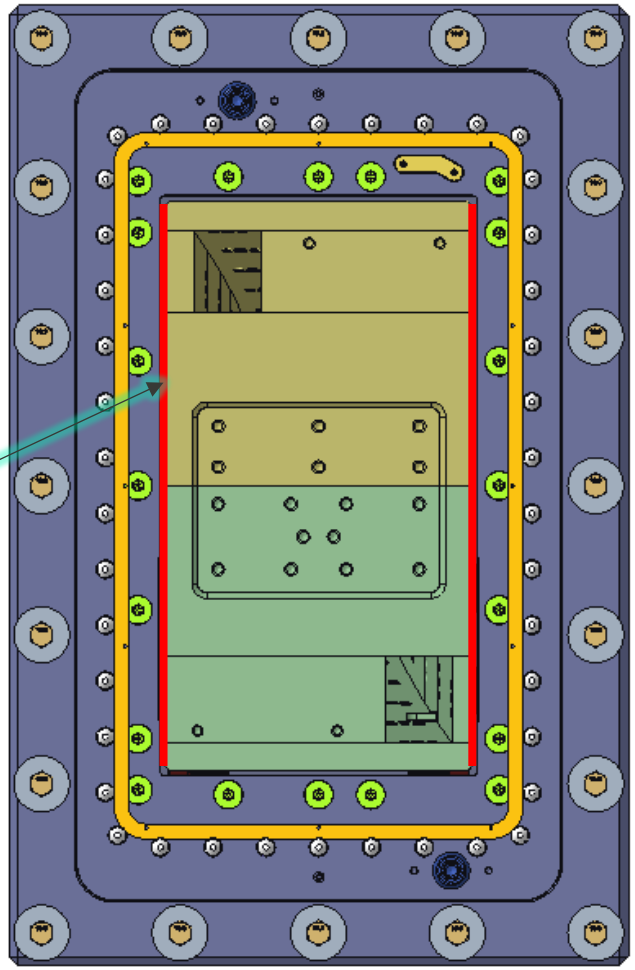
Monolith Optics Shielding

Previous Design, Used in Neutronics Analysis



Significant Gaps (red)…
fewer for the new design

New Design, not yet analyzed



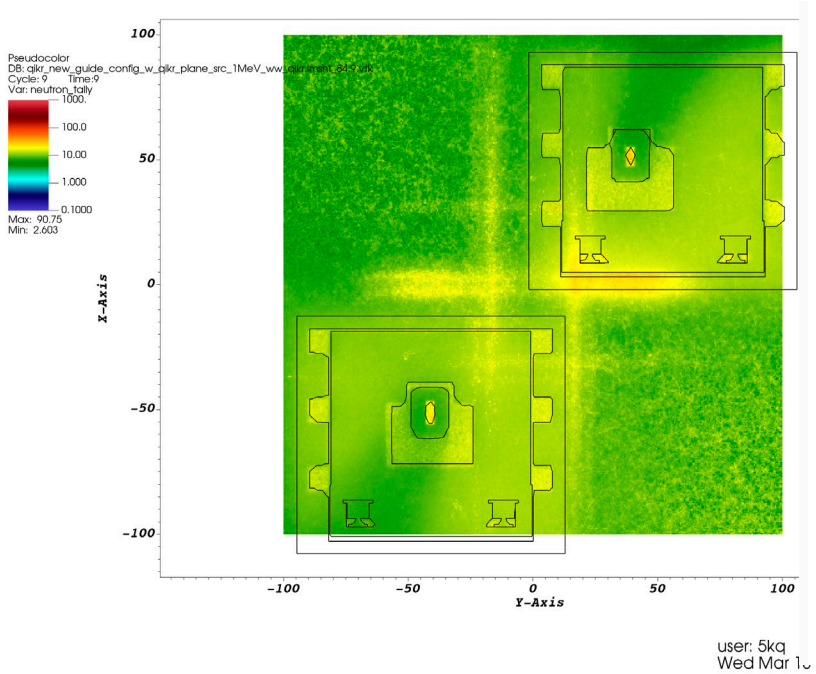
Neutronics Analysis with Upstream Steel

Screenshots taken from Kursat Bekar's analysis of QIKR

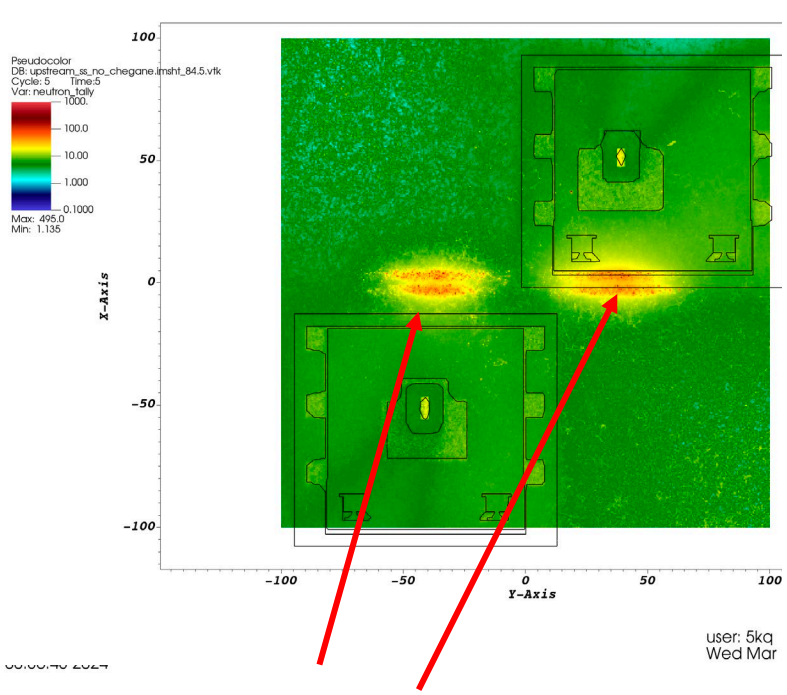
Neutron dose rate (mrem/hr)

Vertical cut-view at the bunker wall (view from the monolith)

No upstream steel insert

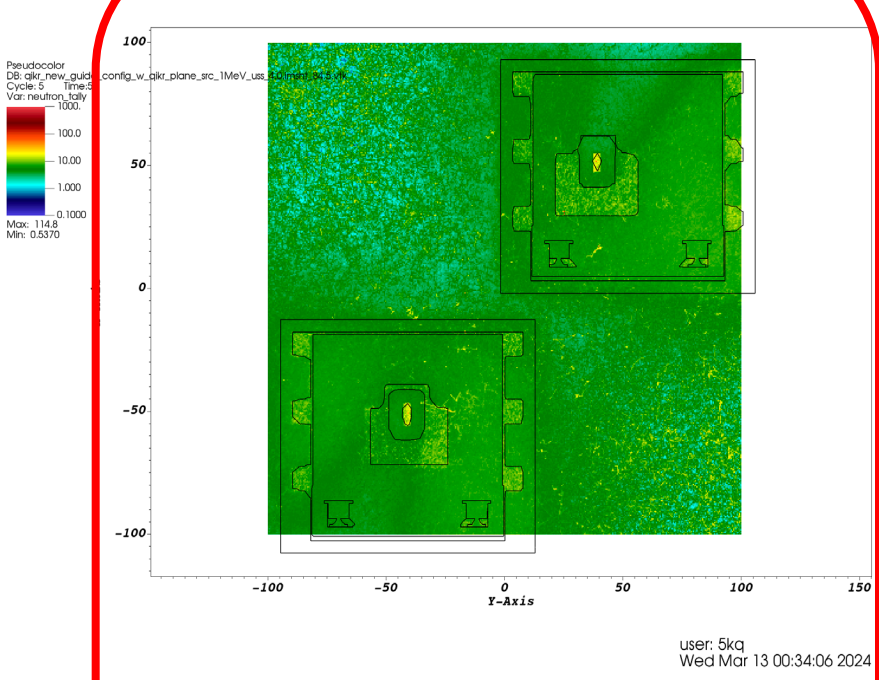


Upstream steel insert, no chicane



Removing chicane will introduce straight streaming pathways along the monolith insert! Therefore, relatively higher dose rates on the bunker wall face

Upstream steel insert, with chicane



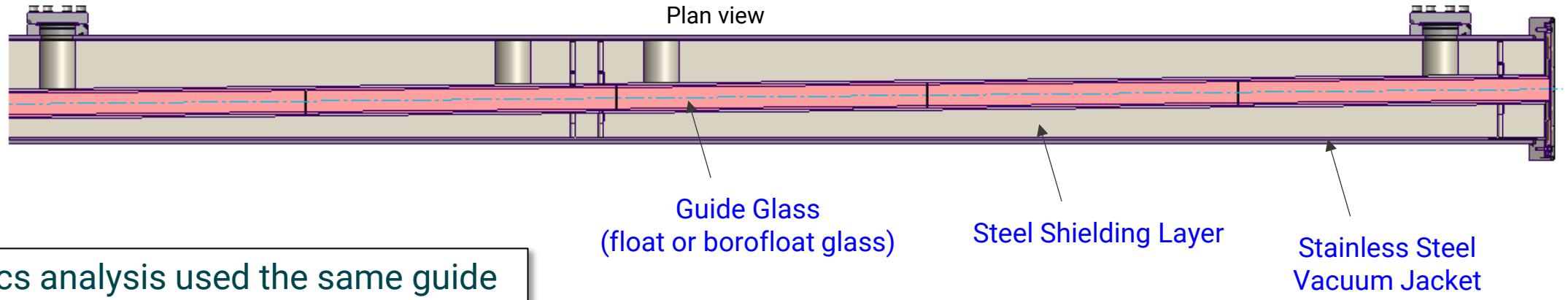
Upstream steel insert with chicane is neutronically best (better shielding performance)

Current design now most closely matches this scenario

Guide Installation

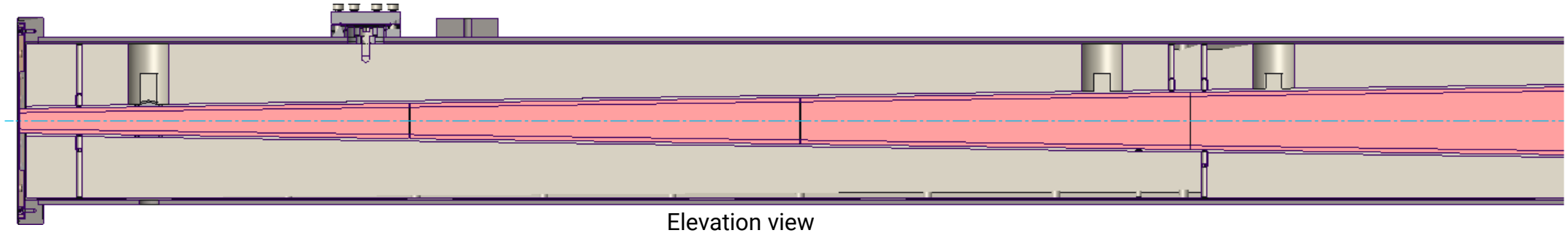
Guide Shielding – Reminder

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



Neutronics analysis used the same guide construction except for a steel vacuum jacket… current design is stainless steel

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



Guide Shielding – Installation

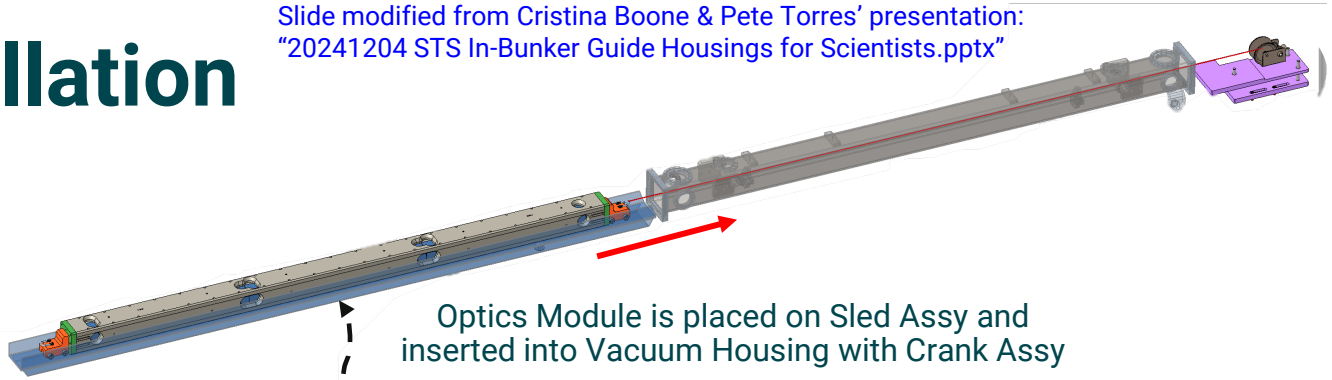
Slide modified from Cristina Boone & Pete Torres' presentation: "20241204 STS In-Bunker Guide Housings for Scientists.pptx"

A. The guide segments and shielding layers are assembled, guide segments aligned. Wheeled "trucks" are attached to the ends.

B. Guide/shielding assembly is lifted and placed on the sled assembly

C. The crank assembly is used to pull the guide/shielding assembly (rolling on the truck wheels) into the vacuum housing sleeve

D. The trucks are removed, and flange covers & windows are installed; the guide housing is ready for transport.



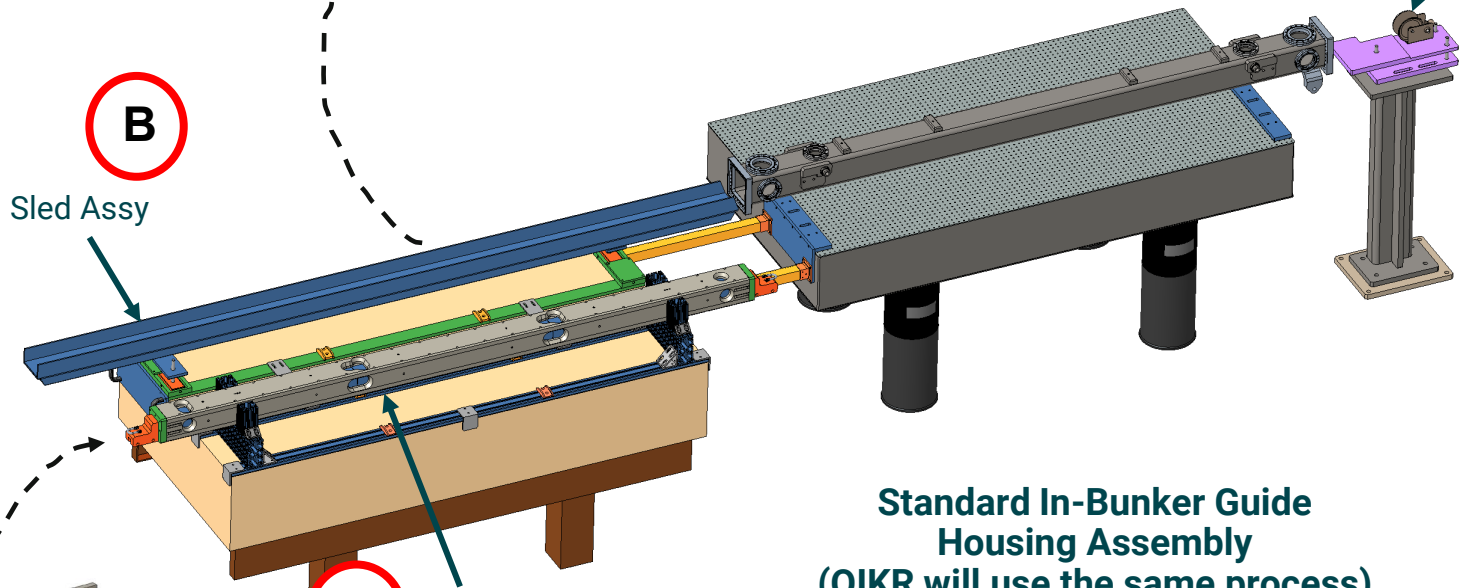
Optics Module is placed on Sled Assy and inserted into Vacuum Housing with Crank Assy

C

Crank Assy

B

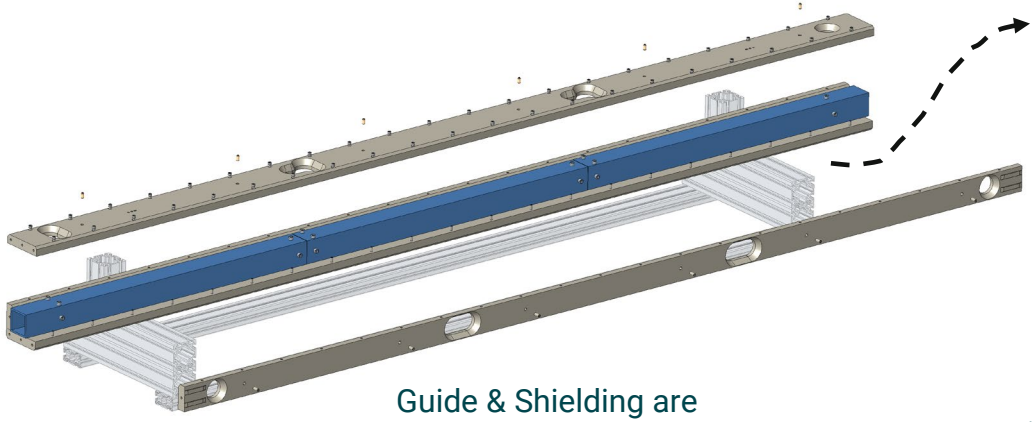
Sled Assy



A

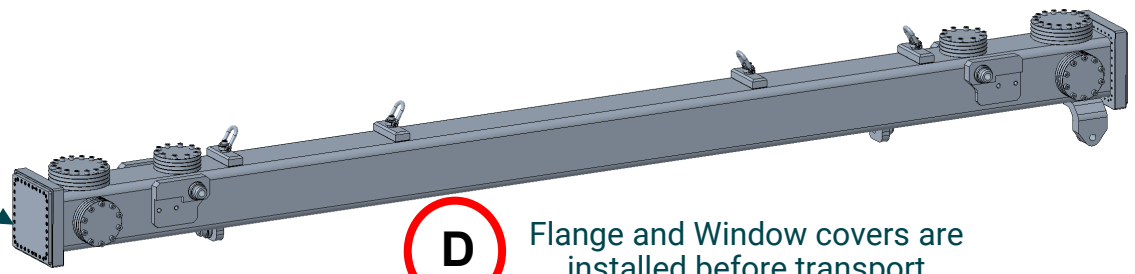
Cradle Assy

Standard In-Bunker Guide Housing Assembly (QIKR will use the same process)



Guide & Shielding are assembled on Cradle Assy

Windows installed

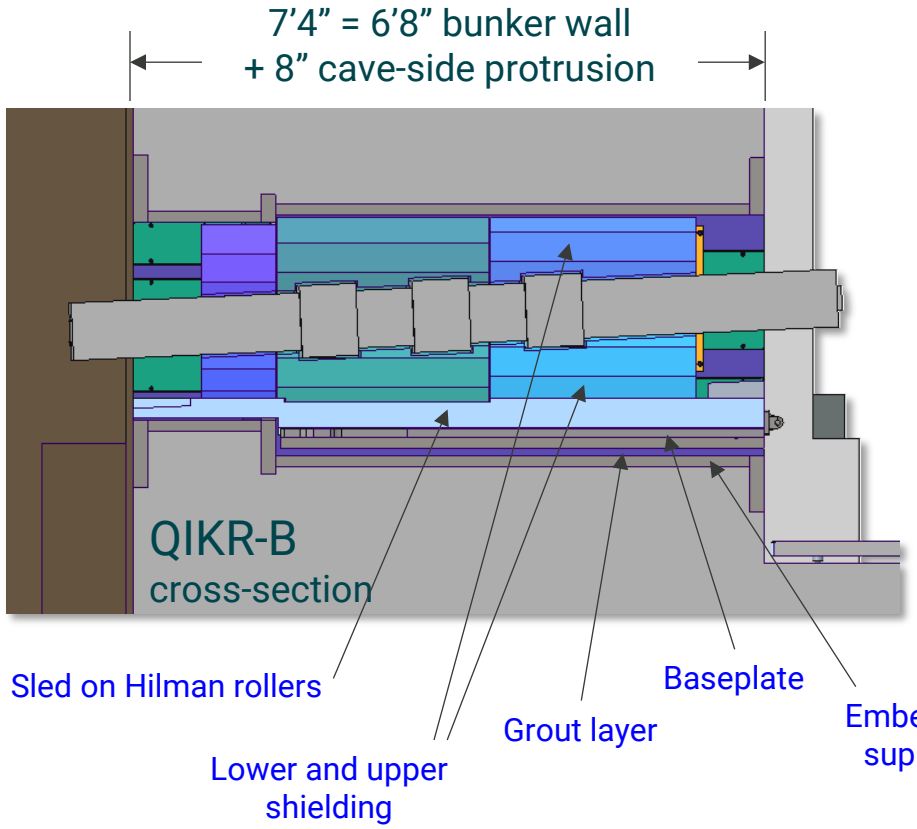


D

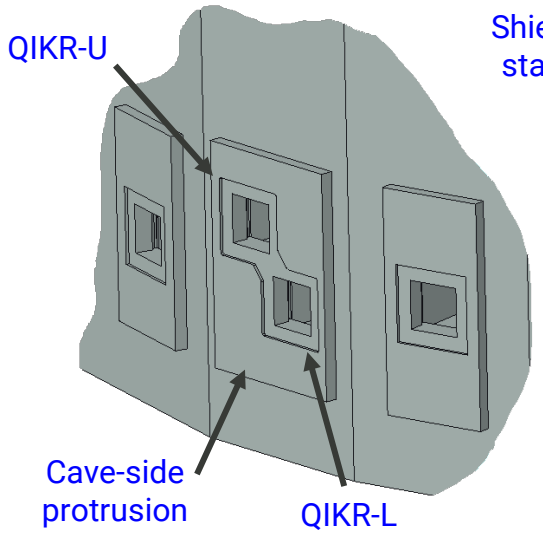
Flange and Window covers are installed before transport

Bunker Wall & Feed-Through Shielding

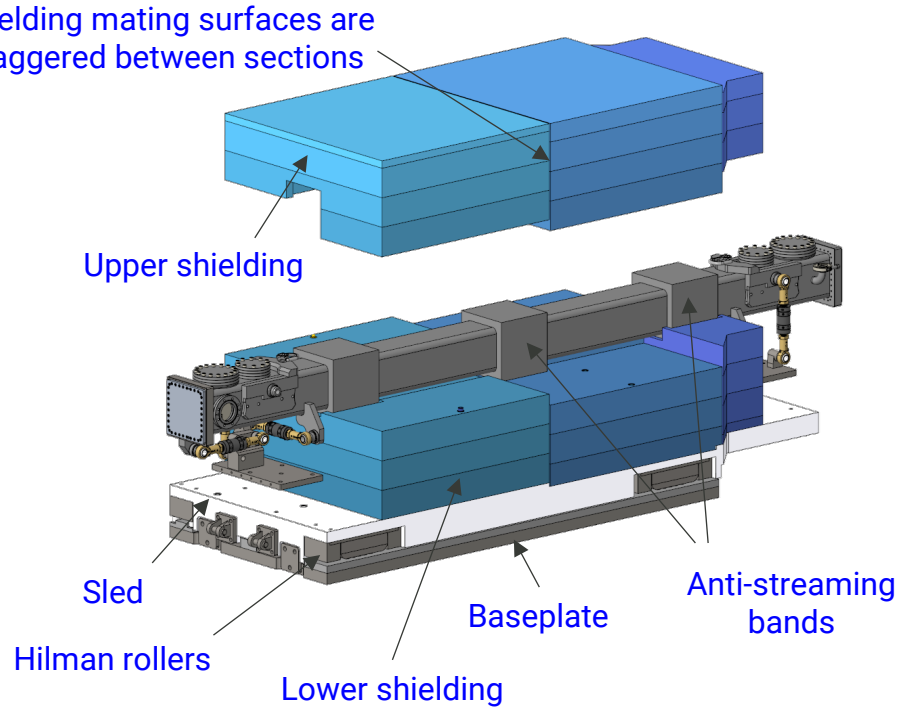
Bunker Wall – New



Exterior bunker wall



Standard guide and shielding

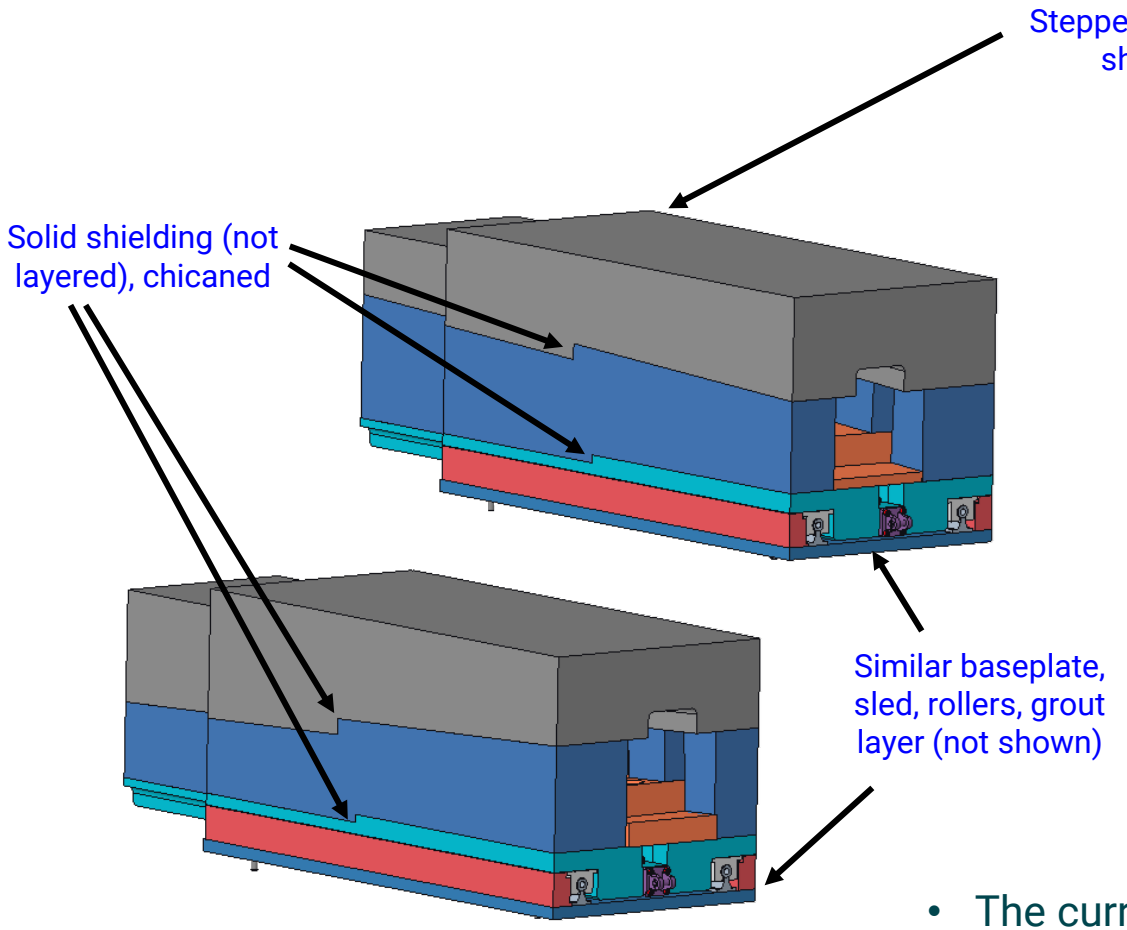


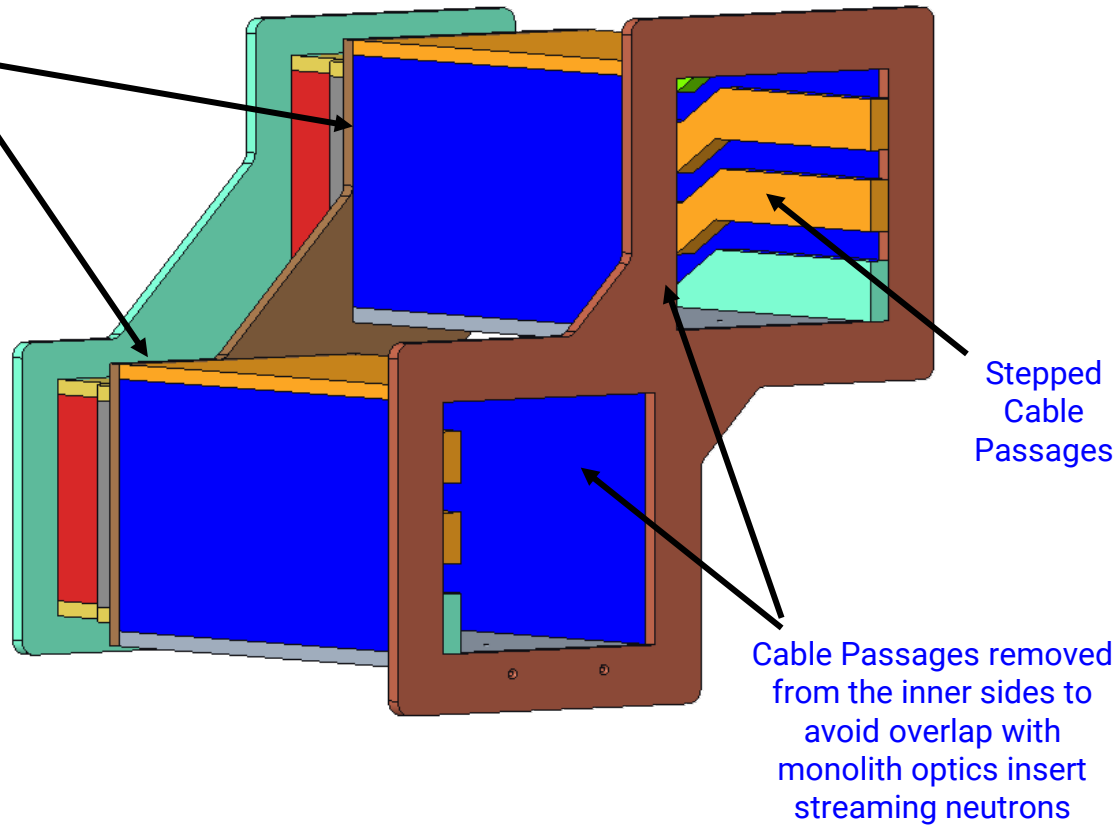
Current Design

Screenshot taken from Cristina Boone & Pete Torres’ presentation: “20241204 STS In-Bunker Guide Housings for Scientists.pptx”

- QIKR follows the standard design for bunker wall shielding and chicanes (steel)
  - Shielding is layered with no nominal gaps between layers, each section of shielding is staggered relative to the next to prevent streaming paths
  - The feedthrough frame is wider on the bunker side than on the cave side to provide an anti-streaming chicane
  - Gaps are cut into the center of the shielding to fit the guide and its anti-streaming bands

Bunker Wall – Shielding & Cable Channels Used in Analysis

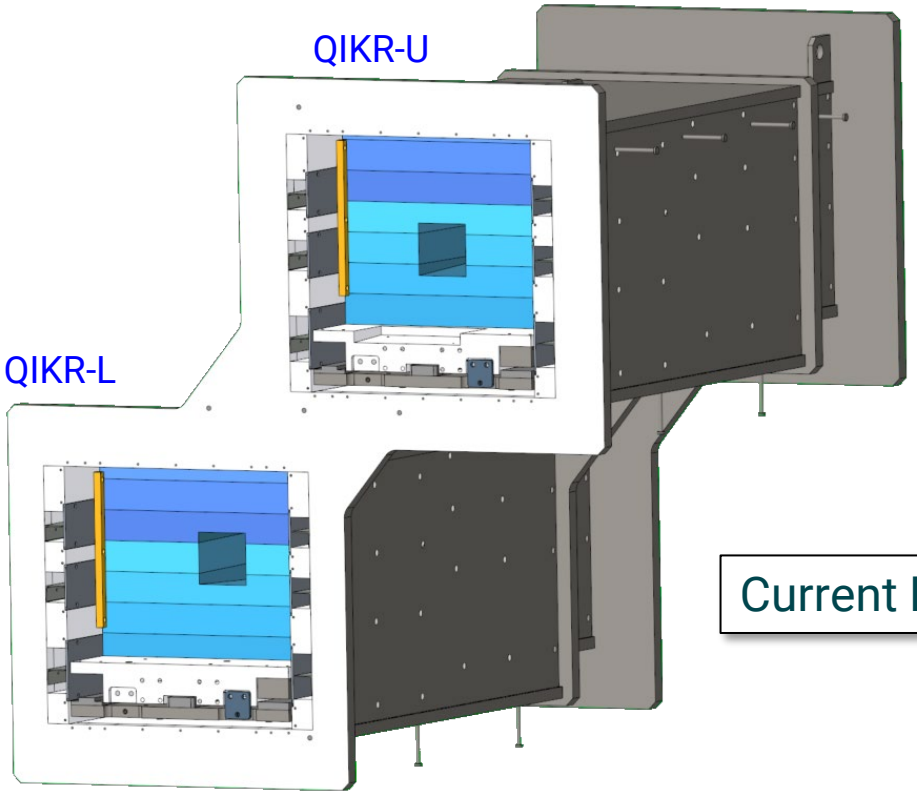




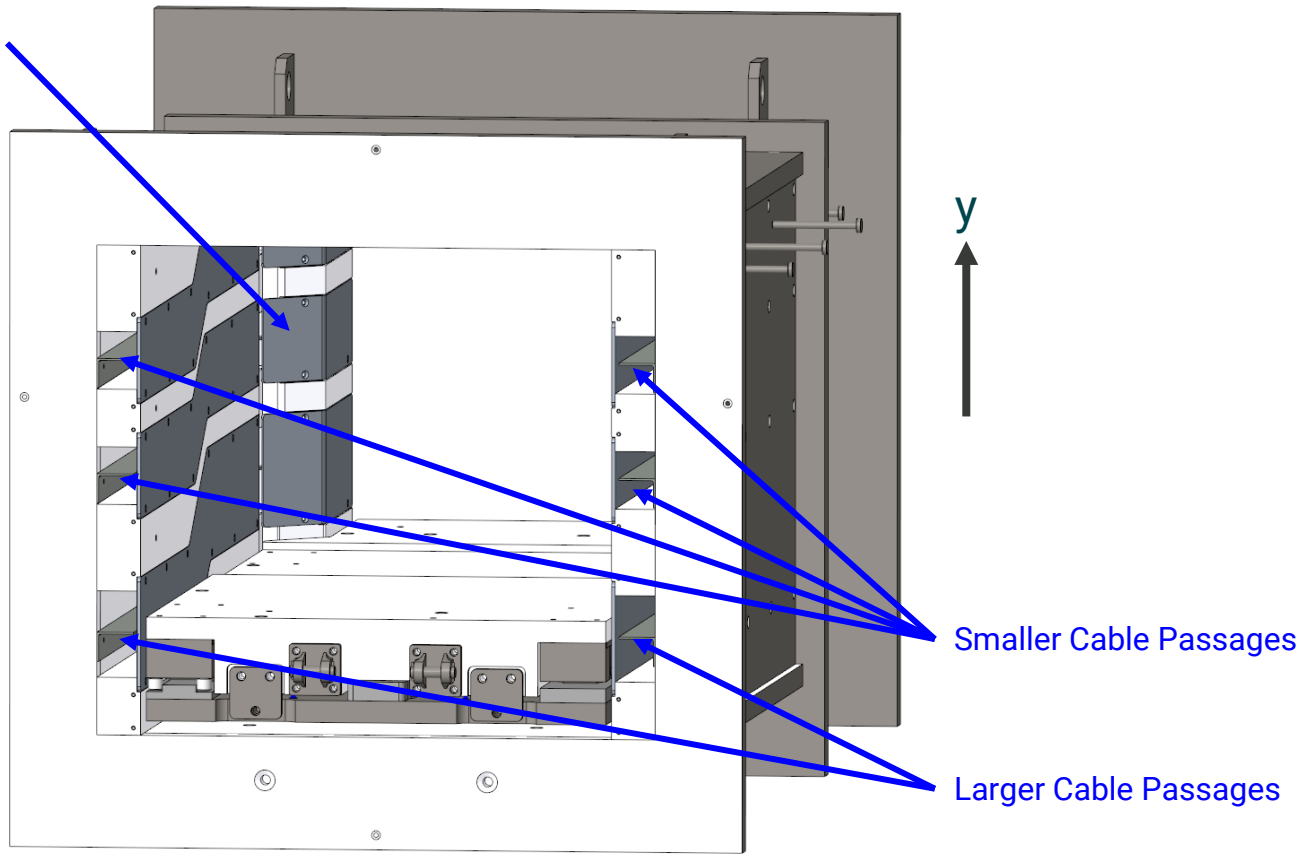
- The current standard design was based on the one shown here, which was used in QIKR's neutronic analysis… the current standard design is expected to have a similar neutronic performance
- The standard design has the inner cable passages in place. QIKR may remove those again, but the new optics insert may help eliminate the need for that

Bunker Wall – Cable Channels (New)

Screenshots taken from Cristina Boone & Pete Torres' presentation:
"20241204 STS In-Bunker Guide Housings for Scientists.pptx"



Current Design



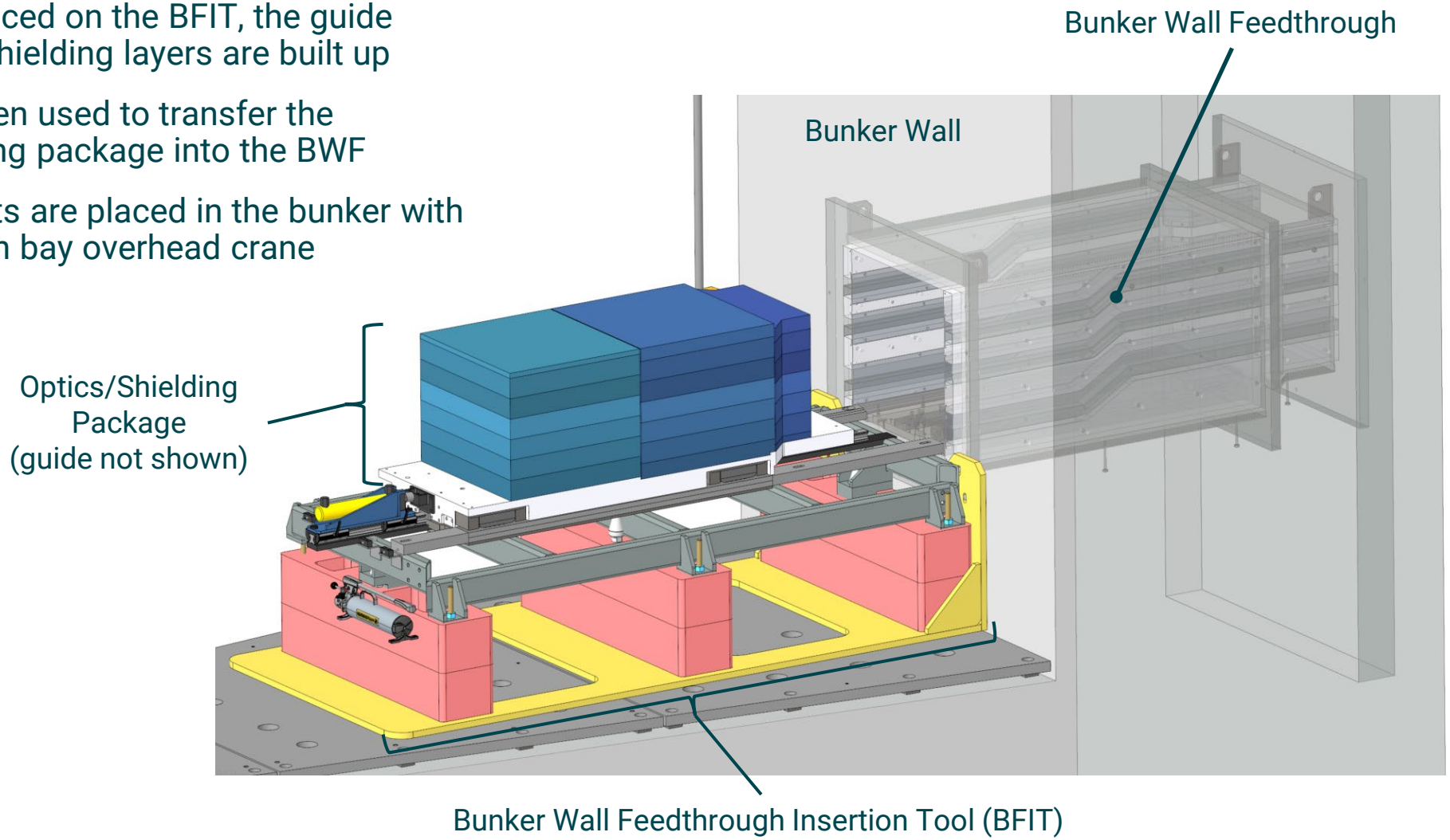
Cable Passages are stepped in "y" to avoid streaming

New design is very similar to the old design. Rather than remove the inner cable channels though, QIKR would fill them with steel

Bunker Wall – Shielding and Guide Installation

Modified slide taken from Cristina Boone & Pete Torres' presentation:
"20241204 STS In-Bunker Guide Housings for Scientists.pptx"

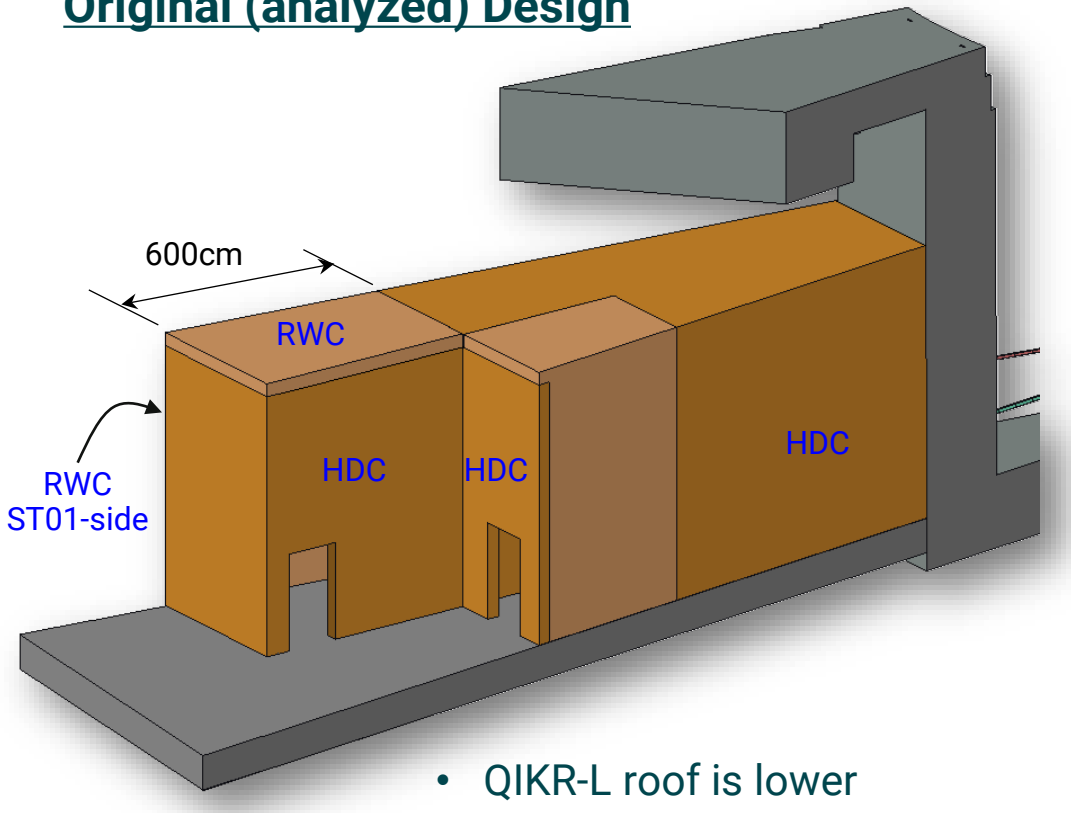
- BFIT is aligned to the BWF
- The sled is placed on the BFIT, the guide housing and shielding layers are built up
- The BFIT is then used to transfer the optics/shielding package into the BWF
- All components are placed in the bunker with the 50-ton high bay overhead crane



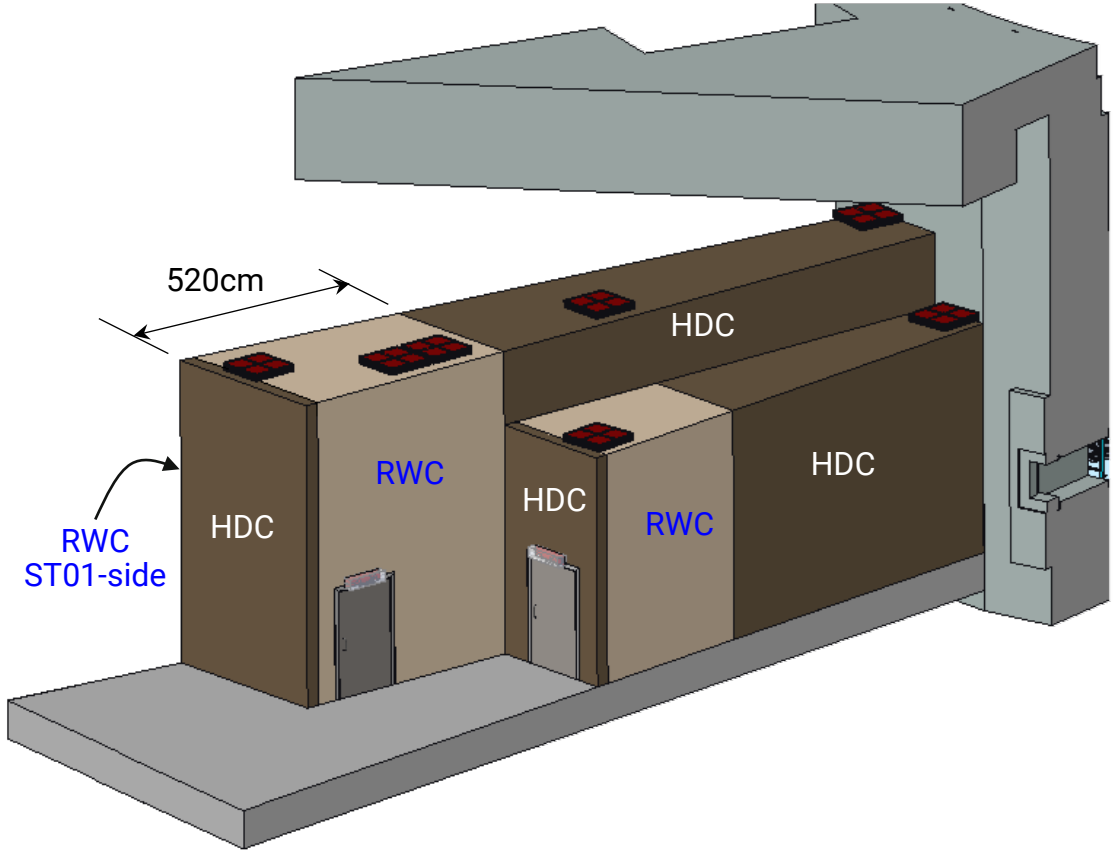
Cave

Cave Exterior – Design Updates

Original (analyzed) Design



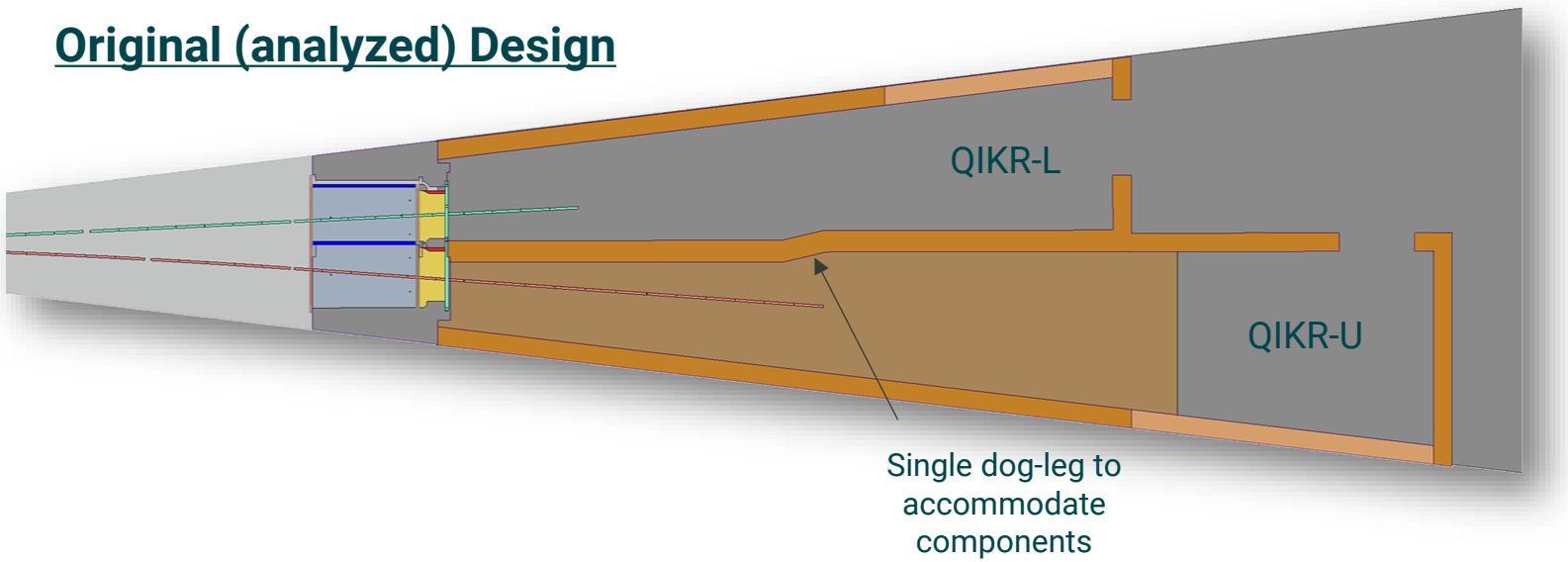
Current (un-analyzed) Design



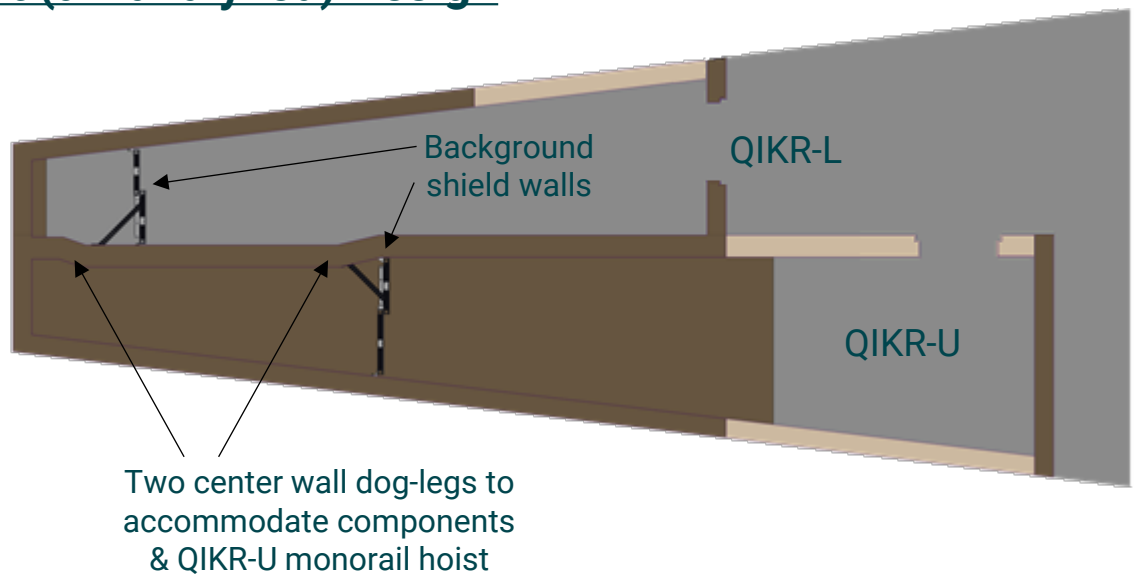
- QIKR-L roof is lower
  - Improves cave structure, reduces cost
- Cable pass-thrus added to the roof
- QIKR-U RWC section shortened, end portion of center wall converted to RWC
  - Reduces cost; dose rates are very low on this section of the center wall

Cave Interior – Design Updates

Original (analyzed) Design



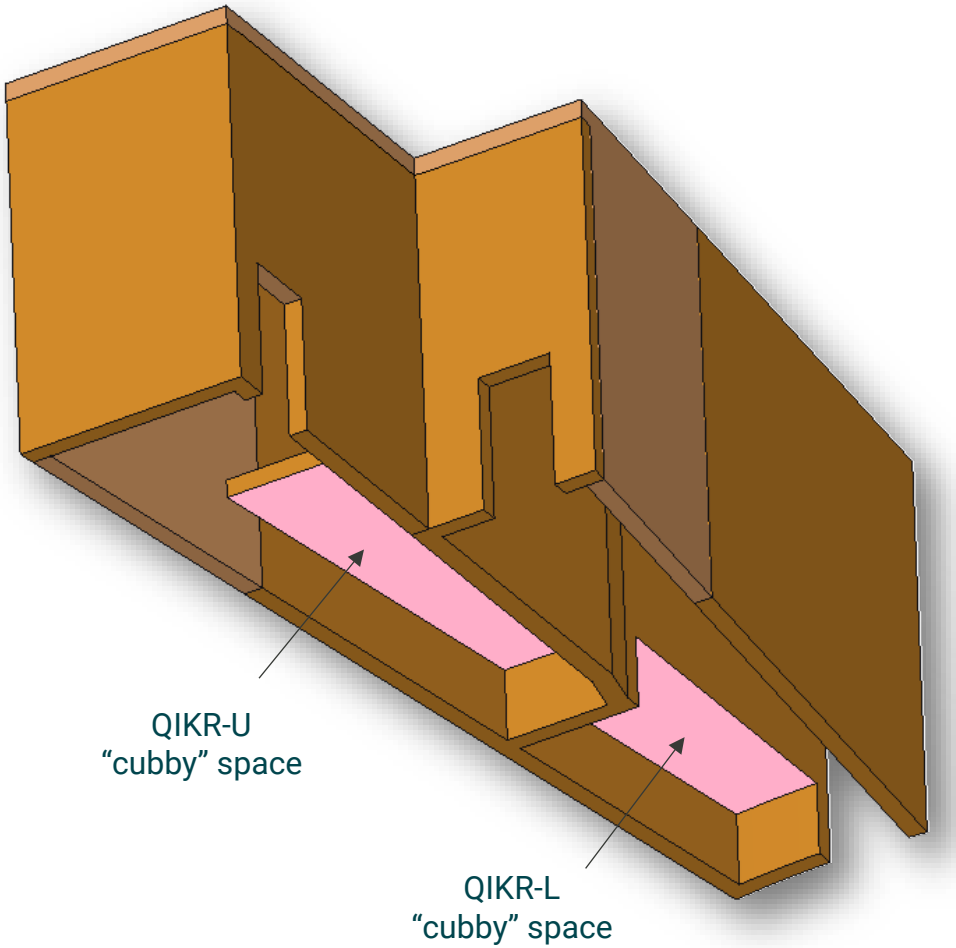
Current (un-analyzed) Design



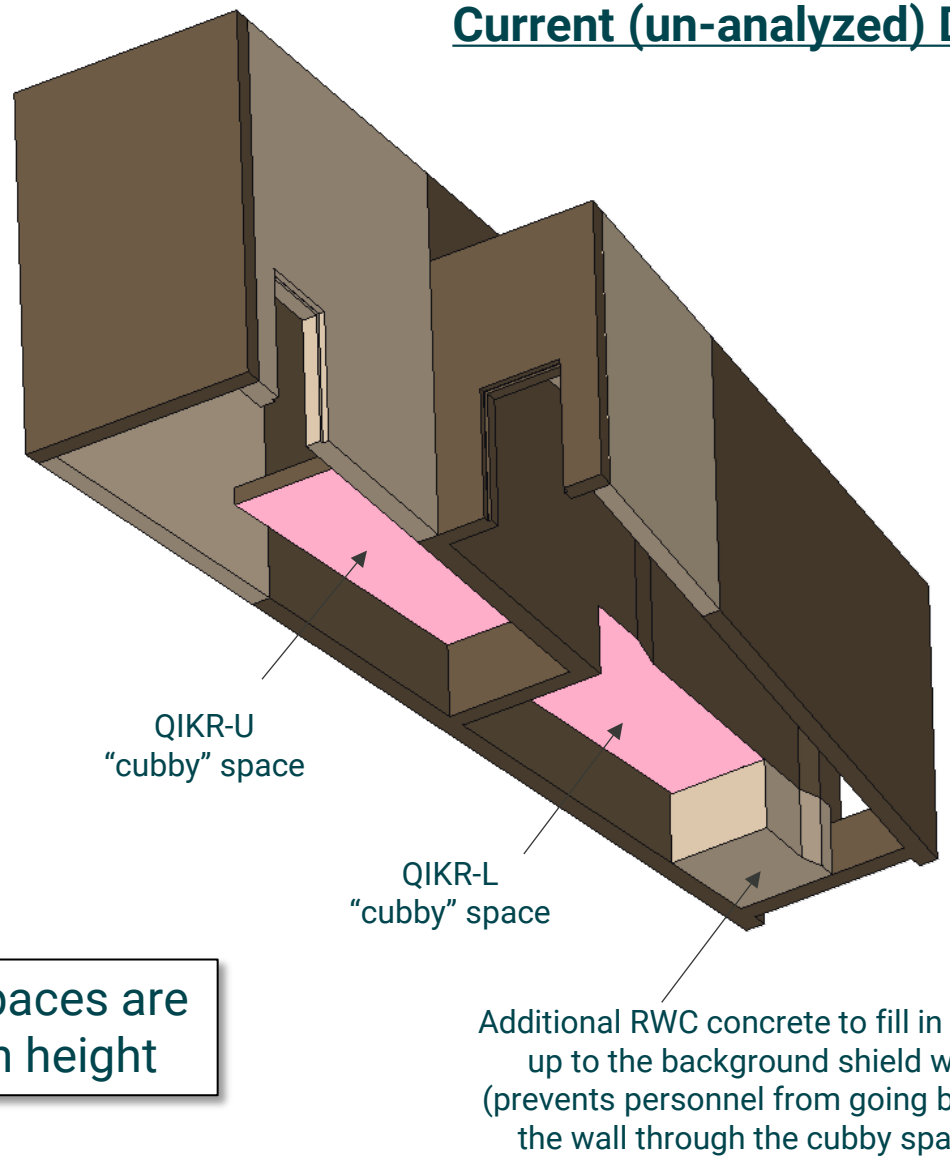
- Center wall has 2 dog-leg features instead of 1
  - Allows additional room for components and QIKR-U monorail hoist motor
- Background shield walls added
  - Their presence was known at the time of neutronic analysis, but they were not included because they are not intended to provide radiation shielding for personnel safety

Cave – Cubby Spaces

Original (analyzed) Design

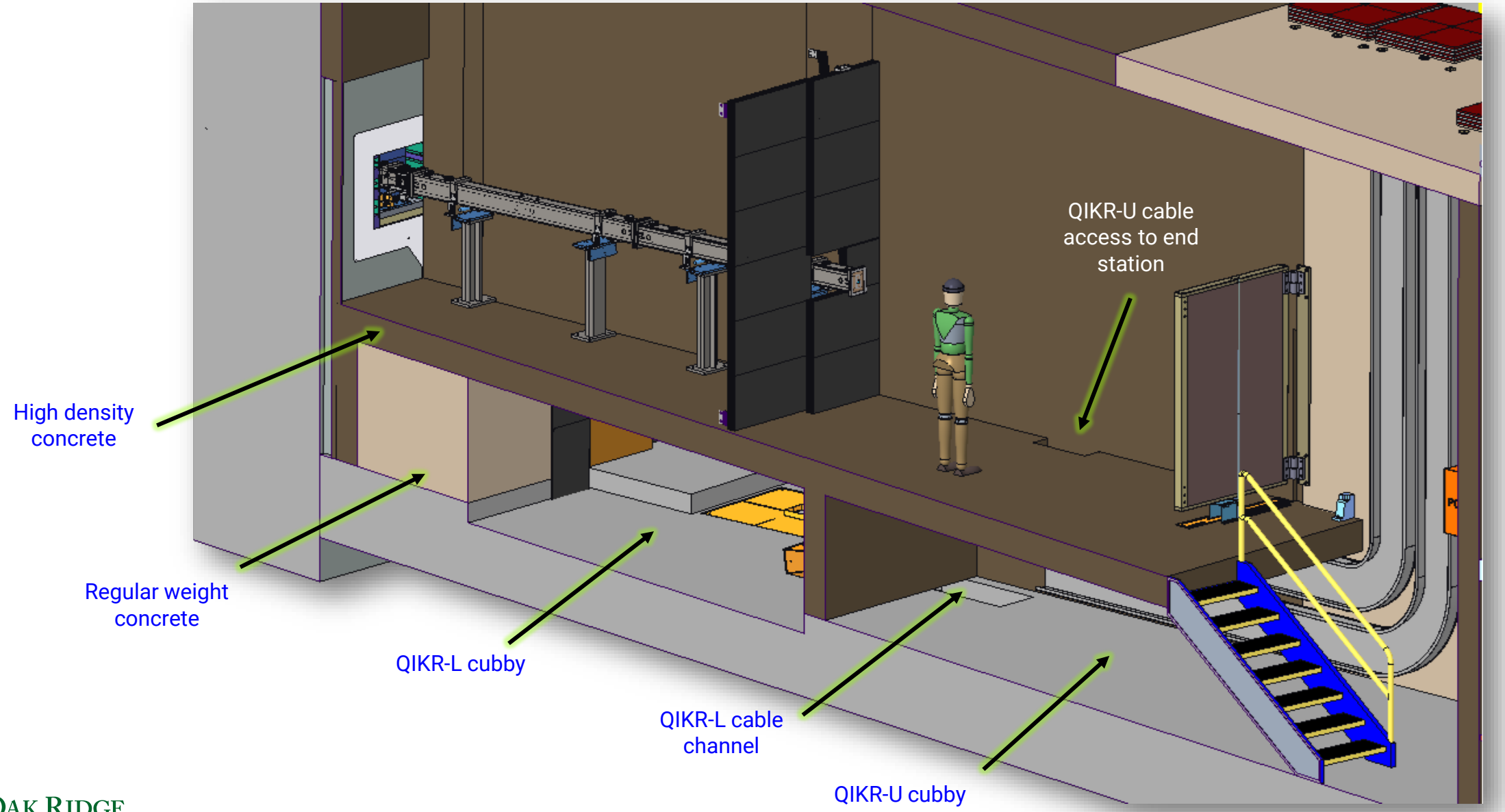


Current (un-analyzed) Design



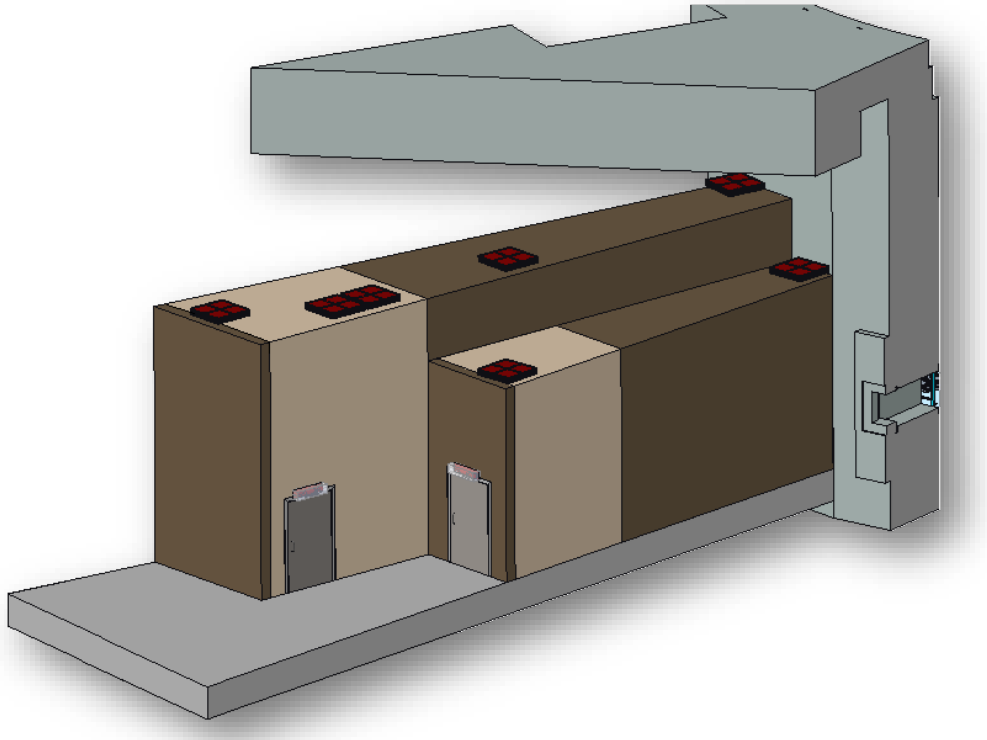
Cubby spaces are all ~4ft in height

Cave – QIKR-U View of Cubby Spaces



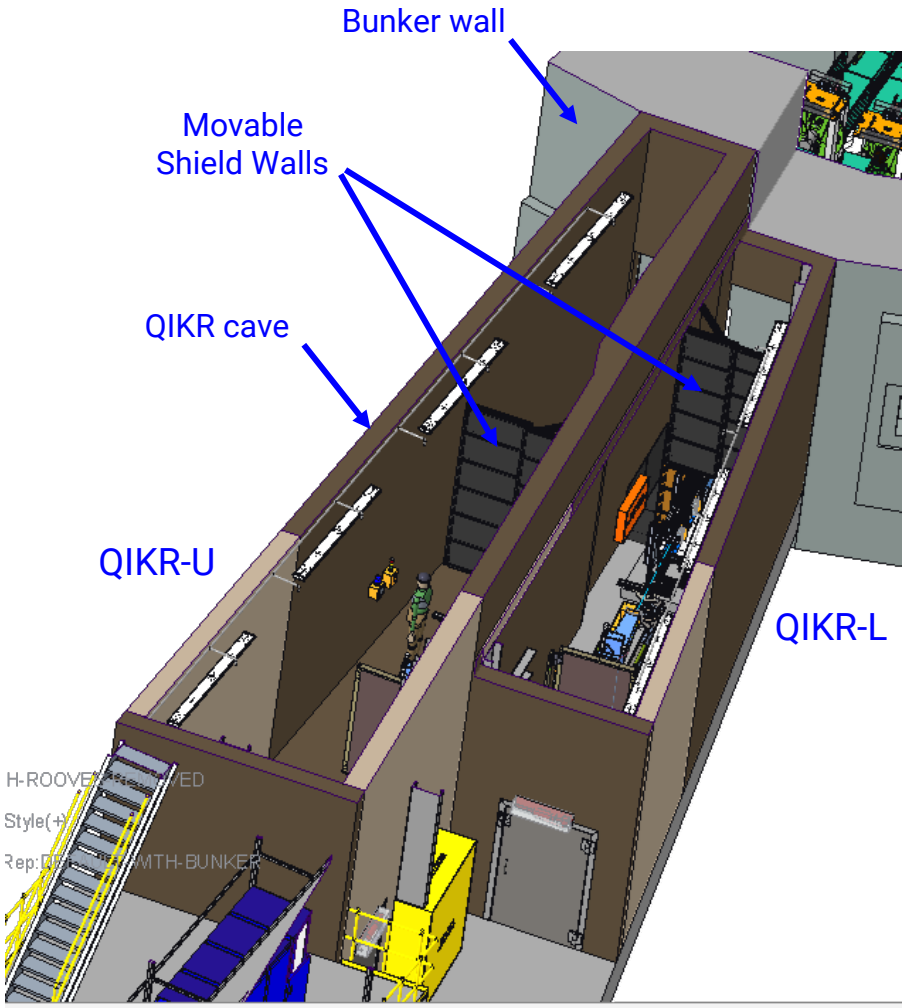
Cave Installation

- Cave will be pour-in-place (PIP) concrete, poured in sections
- The current thickness of the walls may not support the current wall height, particularly for QIKR-U
  - If this is confirmed, the plan will be to install a steel girder skeleton first, then pour the concrete around it… the skeleton will provide additional structural support



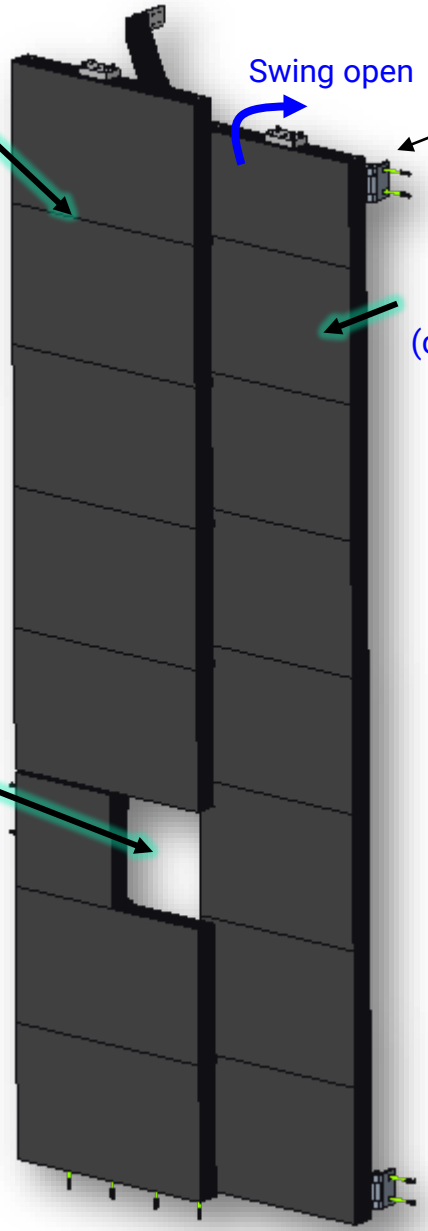
Background Shield Walls

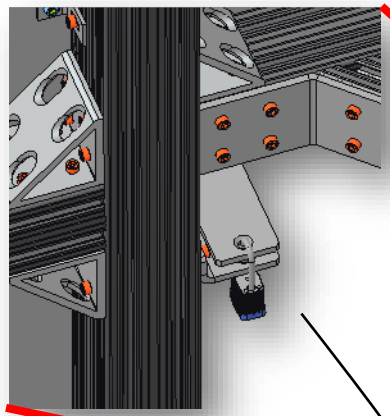
Background Shield Wall (for Detector Background Reduction)

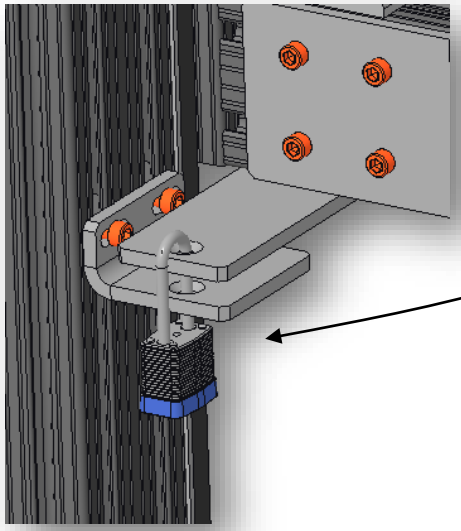


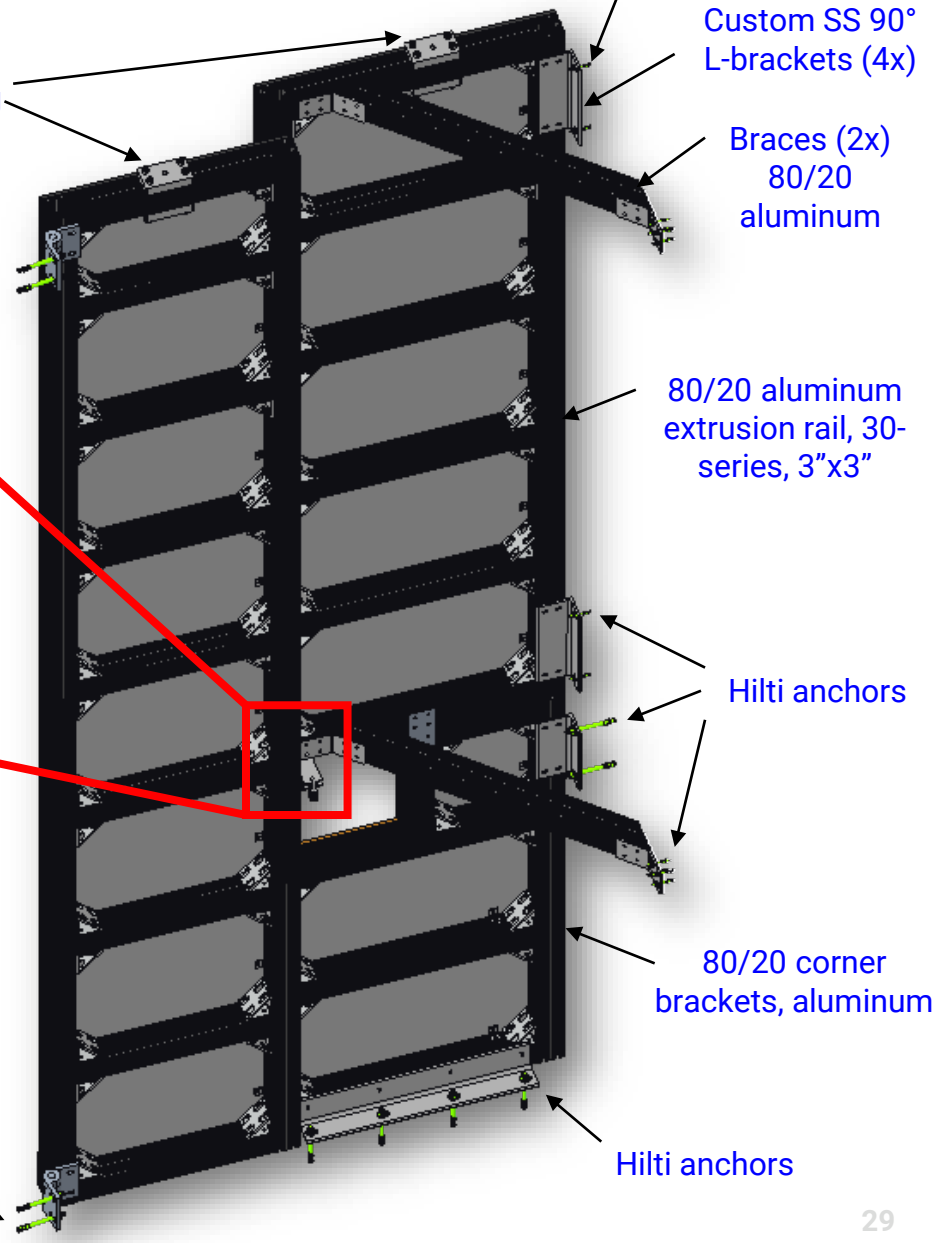
- Background Shield Walls are placed at the end of the guides in each of the QIKR-U and QIKR-L caves
  - One half of the wall is fixed, the other is hinged to allow personnel access to the in-cave portion of the guides
  - The hinged half is configuration-controlled and remains manually locked unless either both beamlines are inactive, or the proton beam is off
  - The QIKR-U wall is slightly wider and shorter than the QIKR-L version because of the different detector locations in the cave and the detectors' different view angles (QIKR-U looks more downward, QIKR-L looks more upward)
- The primary purpose of the background shield walls is to fill the detector's view with B_4C (ZHIP mix panels) to reduce background noise from concrete surfaces (cave walls and floor)
- The walls are <u>not</u> intended as radiation shielding for personnel but <u>do</u> block personnel access to areas of the cave that may have higher dose rates in certain operating conditions.

Background Shield Wall – QIKR-L (mirrored for QIKR-U)

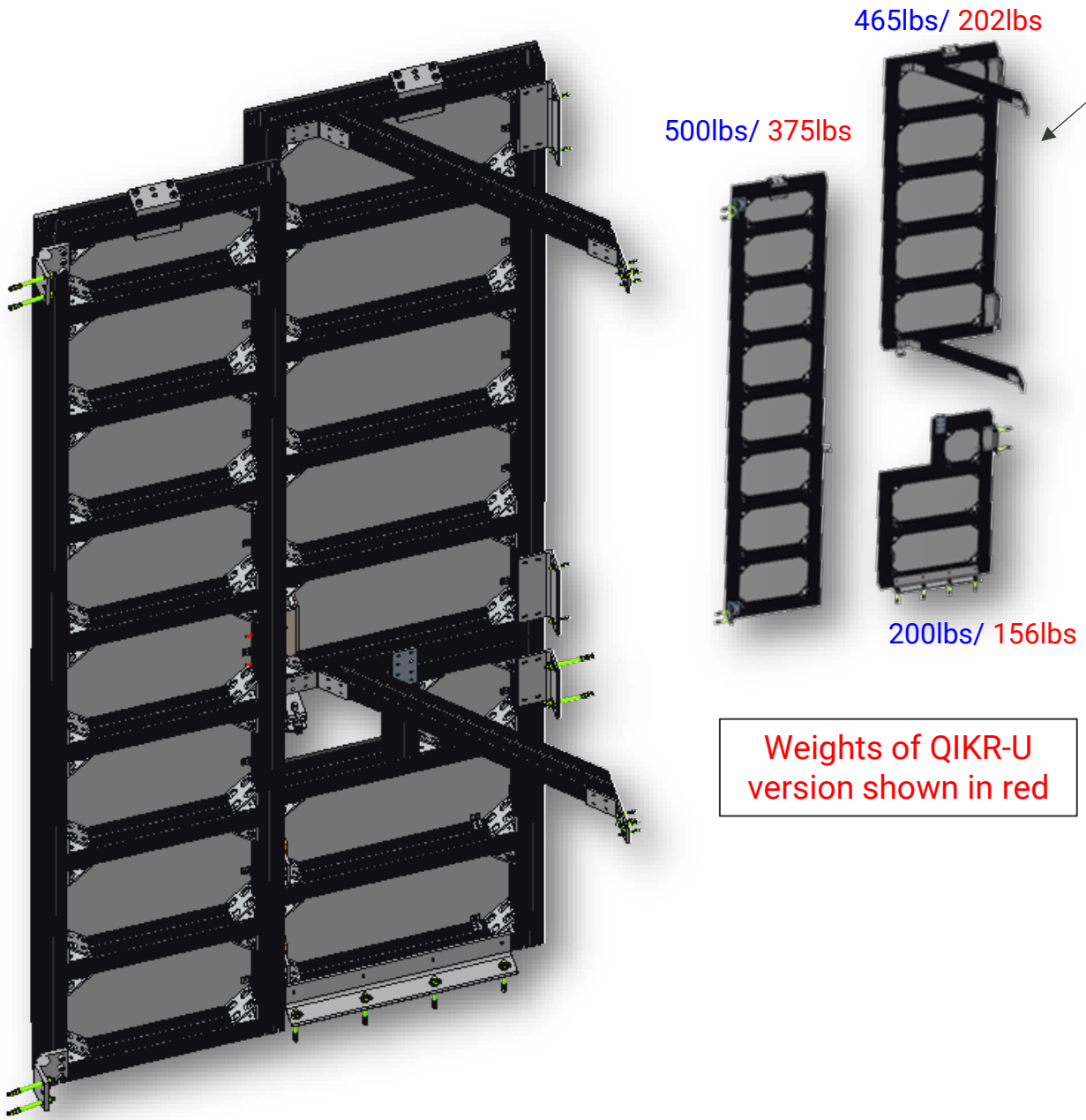








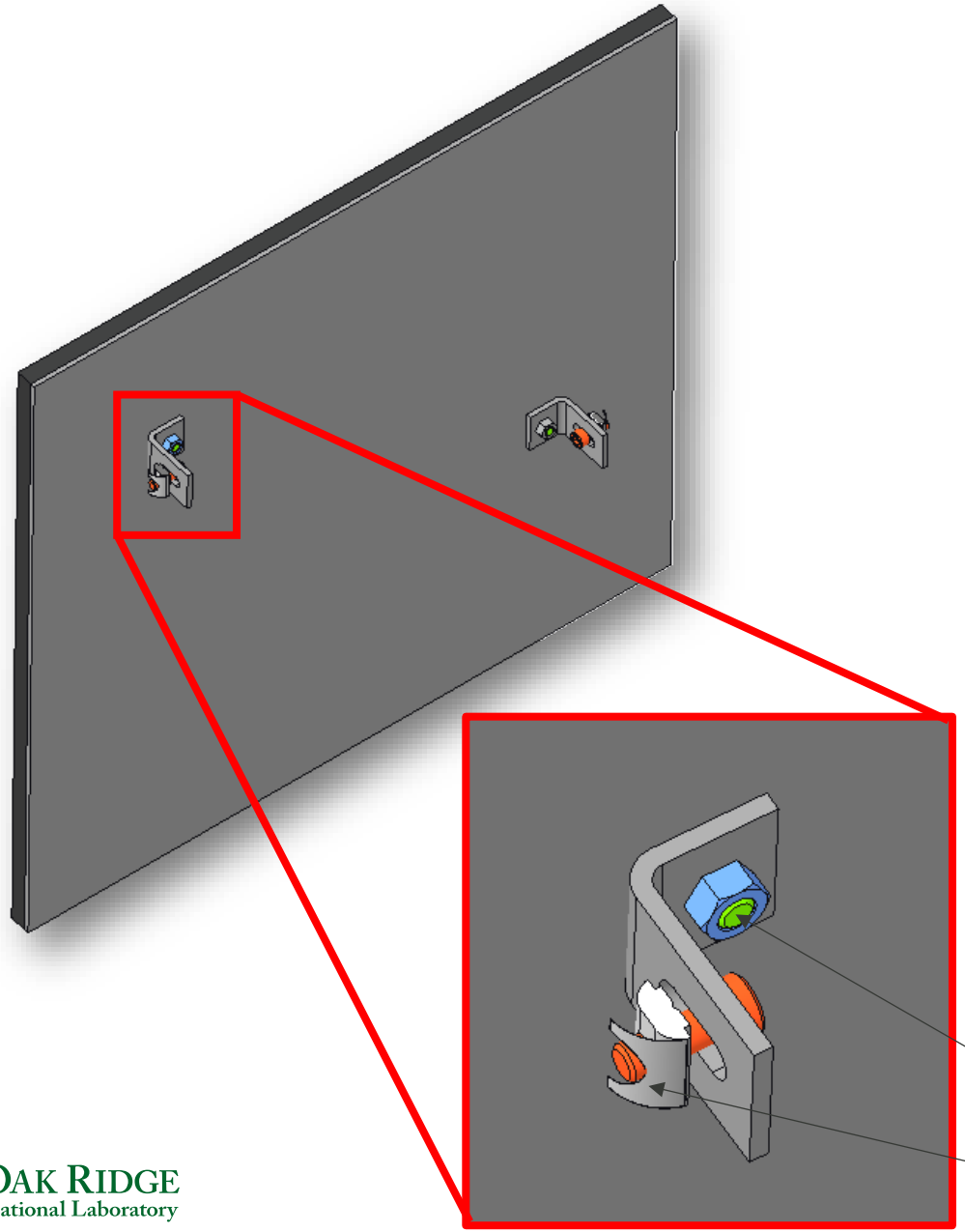
Background Shield Wall – QIKR-L



Weights of QIKR-U version shown in red

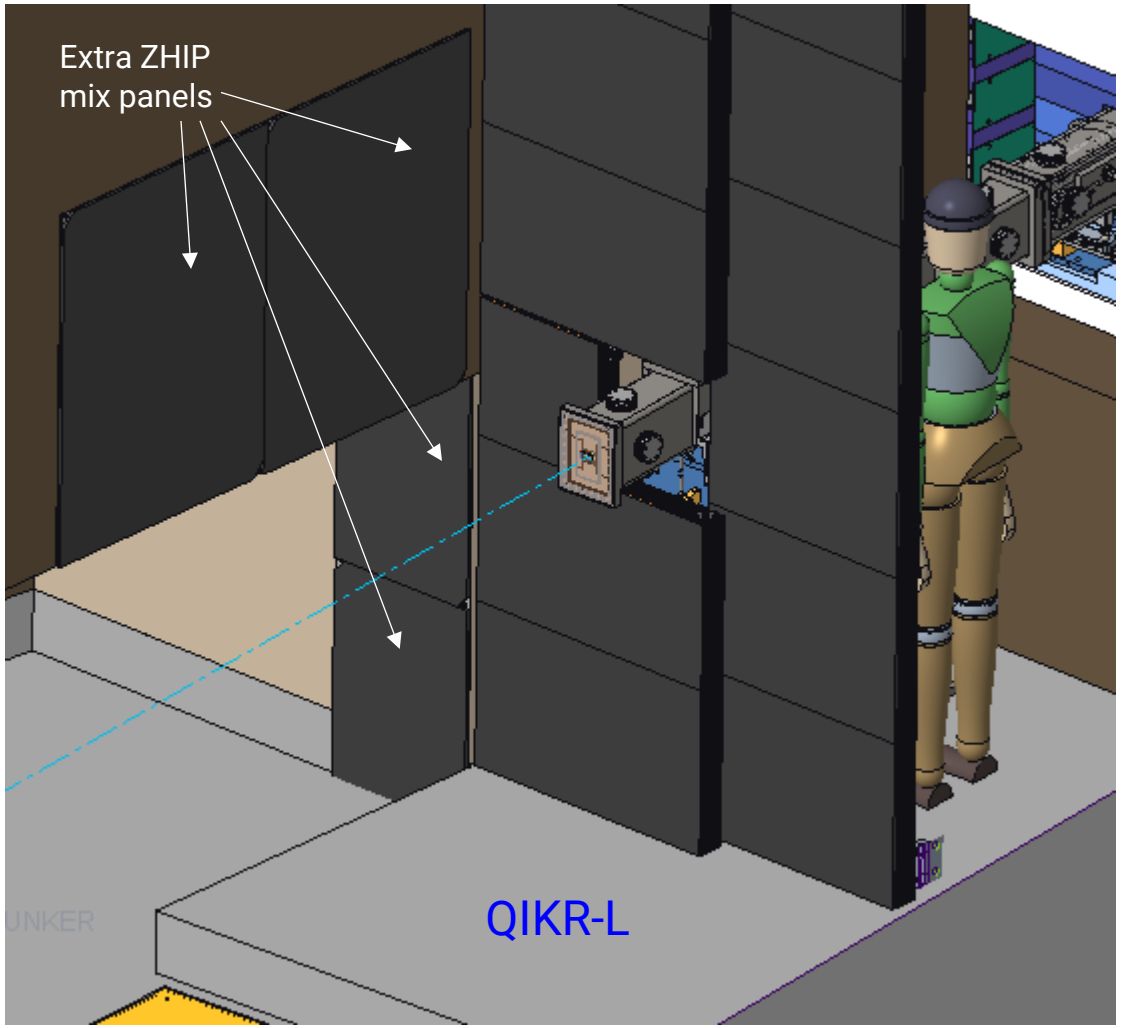
- Each background shield walls is built in three sections for easier installation around the guide
  - The larger sections have plate to attach a swivel hoist ring for crane transport
  - All sections are intended to be assembled in-cave by ORNL staff. If built elsewhere, the two heaviest sections may be transported by crane using swivel hoist ring lift points.
  - Construction is an aluminum 80/20 frame with ZHIP mix panels mounted to the downstream side
- The ZHIP mix panels have an aluminum backing plate with threaded studs pre-installed by Dielectric Sciences
  - Panels are attached to the 80/20 frame using two COTS L-backets… this method keeps the attachment hardware from being visible to the detector
- The hinged side of the door (500lbs) is supported by 2000lb capacity hinges & padlocked to the fixed side & configuration controlled
- All attachment to the concrete walls & floor is done with Hilti anchors

Movable Shield Wall – ZHIP mix panels

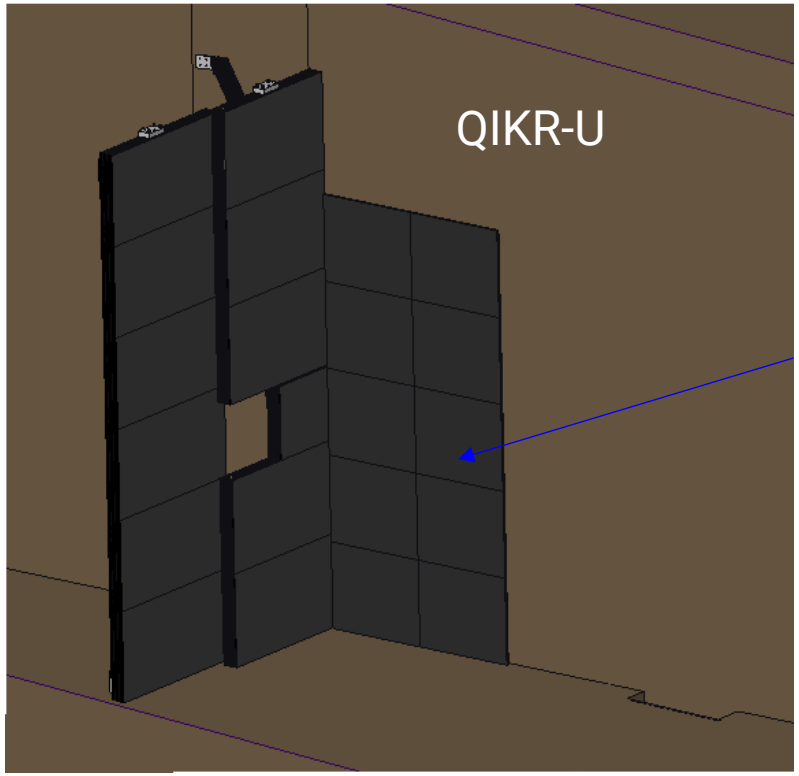


- ZHIP mix panels are procured from Dielectric Sciences (single source)
  - The vendor provides the ZHIP mix on an aluminum backing panel with threaded studs pre-installed
  - ZHIP mix layer is 11mm thick, aluminum layer is 3mm thick (may need to increase the aluminum layer to 6mm, waiting for vendor feedback)
- Panels are attached to the 80/20 frame with COTS aluminum L-bracket & 80/20 spring-loaded T-nuts
  - T-nuts are spring loaded to stay in place if the panel is removed & replaced (may need to be done if panel becomes damaged
- Highest ZHIP mix panel weight = 34lbs (QIKR-U)

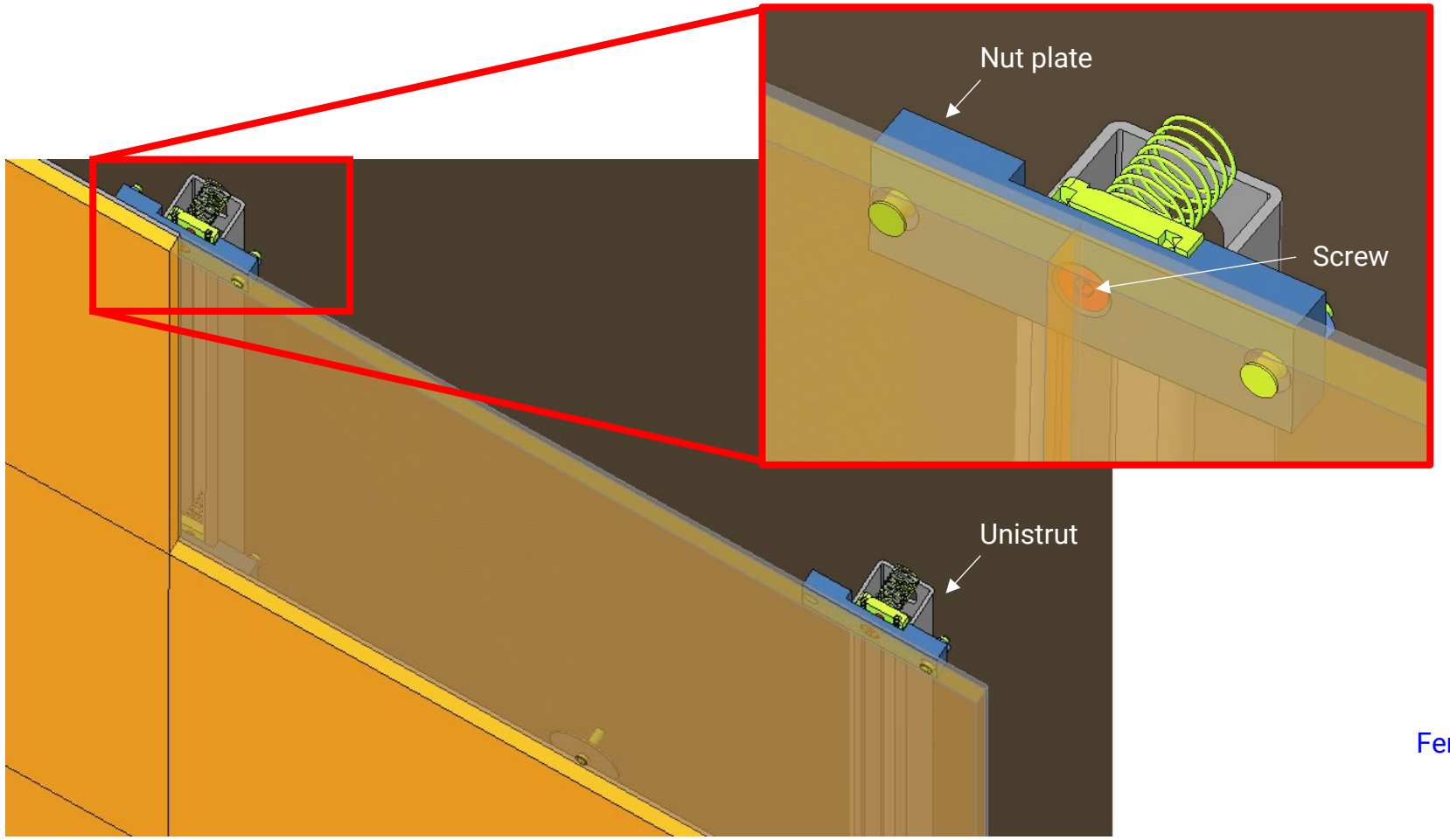
Background Shield Wall – ZHIP mix panels

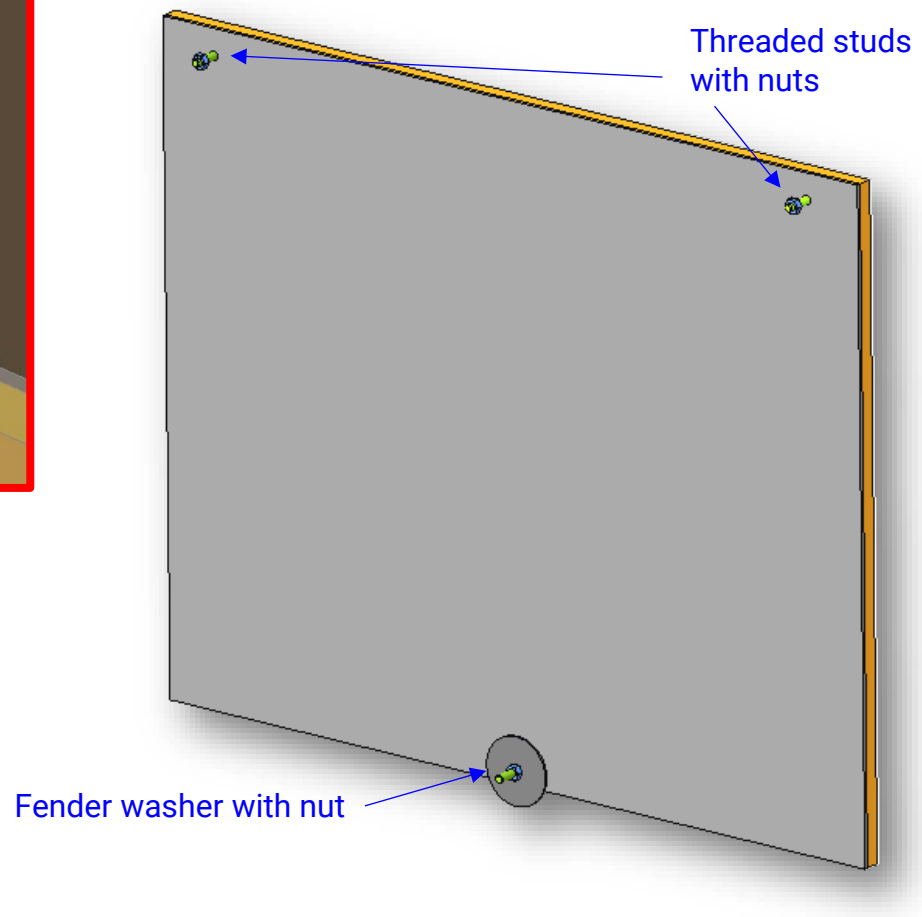


- Additional ZHIP mix panels are installed on the QIKR-L cave walls to block the detector's view of concrete surfaces
- Panels are attached via Hilti anchors at their corners (ZHIP mix is not present on the corners)
- Heaviest panel = 34lbs



Background Shield Wall – ZHIP Mix Panels Attachment to Wall





- Similar to the background wall panels, threaded studs are inserted into the ZHIP mix aluminum backing panels
- Panels attach to Unistrut on the cave wall along their top edges (in-cave manual installation, ORNL labor)
- Panels attach to the previous panel with pre-tightened fender washer on their bottom edges (in-cave manual installation, ORNL labor)

Acquisition, Manufacturing, Installation

Acquisition strategy

Shielding component	Competitive Bid or Sole Source	Vendor Location	Exotic Mat'ls	Supplier Constraints/ Comments
Lower Beam Stop	Competitive	Domestic	No	
Bunker Wall Feed-Through (QIKR-L & QIKR-U)	Competitive/ Sole Source	Domestic	No	Rollers are sole sourced from Hilman, steel shielding is competitively bid
QIKR-L Background Shield Wall	Sole Source	Domestic	No	ZHIP mix panels are sole source, frame is sourced from 80/20
Cave, RWC	Competitive	Domestic	No	
Cave, HDC	Competitive	Domestic	No	

Note: not currently planning to purchase an upper beam stop or background shield wall unless contingency allows

Manufacturing strategy

Optics component	Manufacturing Strategy
Lower Beam Stop	Beam Stop Panel: Build-to-print Hardware & PPS Switches: COTS In-house assembly of some components (e.g. hinges, PPS switches, latches)
Bunker Wall Feed-Through (QIKR-L & QIKR-U)	Build-to-print fabrication, in-house assembly
QIKR-L Background Shield Wall	Build-to-print ZHIP mix panels, wall-attach brackets All other components are COTS or modified-to-print COTS (hinges, 80/20 frame) In-house assembly of all components
Cave, RWC	Design/build subcontract with specifications supplied by ORNL
Cave, HDC	Design/build subcontract with specifications supplied by ORNL

Installation Plan

Optics component	Installation Plan
Lower Beam Stop	The beam stop/ B4C sub-asm supplied by a vendor, final installation done by in-house SNS technicians
Bunker Wall Feed-Through (QIKR-L & QIKR-U)	Installed in-house by SNS technicians and SAM team
QIKR-L Background Shield Wall	Installed in-house by SNS technicians
Cave, RWC	Installed on-site by subcontractors
Cave, HDC	Installed on-site by subcontractors

Costs

Total Costs – Original P6 Estimate vs. Current Design

Year 2030 dollars

Component	Original P6 Estimate	Current Cost
Lower Beam Stop	$109,724	$75,267
Bunker Wall Feed-Through	$318,352	$224,828
QIKR-L Background Shield Wall	$383,424	$50,754
Cave, RWC	$55,441*	$65,056*
Cave, HDC	$1,503,422	$1,405,691

*Cost does not include installation

Includes labor costs

Summary

Summary

- Neutronics analysis shows that the dose rates within the analyzed cave design are below the limits set in S04080400-DCD10000-R00 in most cases
    - Some exceptions in certain accident scenarios… may be dealt with using radiation monitors
- Design changes since neutronic analysis will need follow-up analysis prior to FDR
    - Some changes are expected to be an improvement:
        - Additional steel upstream of the monolith insert
        - Conversion of the optics insert from two separate components to one combined assembly
        - Reduction in volume of the QIKR-L cubby
    - Some changes are expected to have the same shielding performance
        - Guide shielding unchanged from first round of analysis
        - Bunker feed-through shielding very similar to the analyzed design
    - Some changes may be detrimental
        - Lowering of QIKR-L roof
        - Additional of cable openings in both the QIKR-U and QIKR-L roof
        - Conversion of some HDC to RDC, shortening of QIKR-U RDC section

Questions?