OAK RIDGE National Laboratory

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Lunch Talk: What-Ifs …

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U.S. DEPARTMENT OF ENERGY

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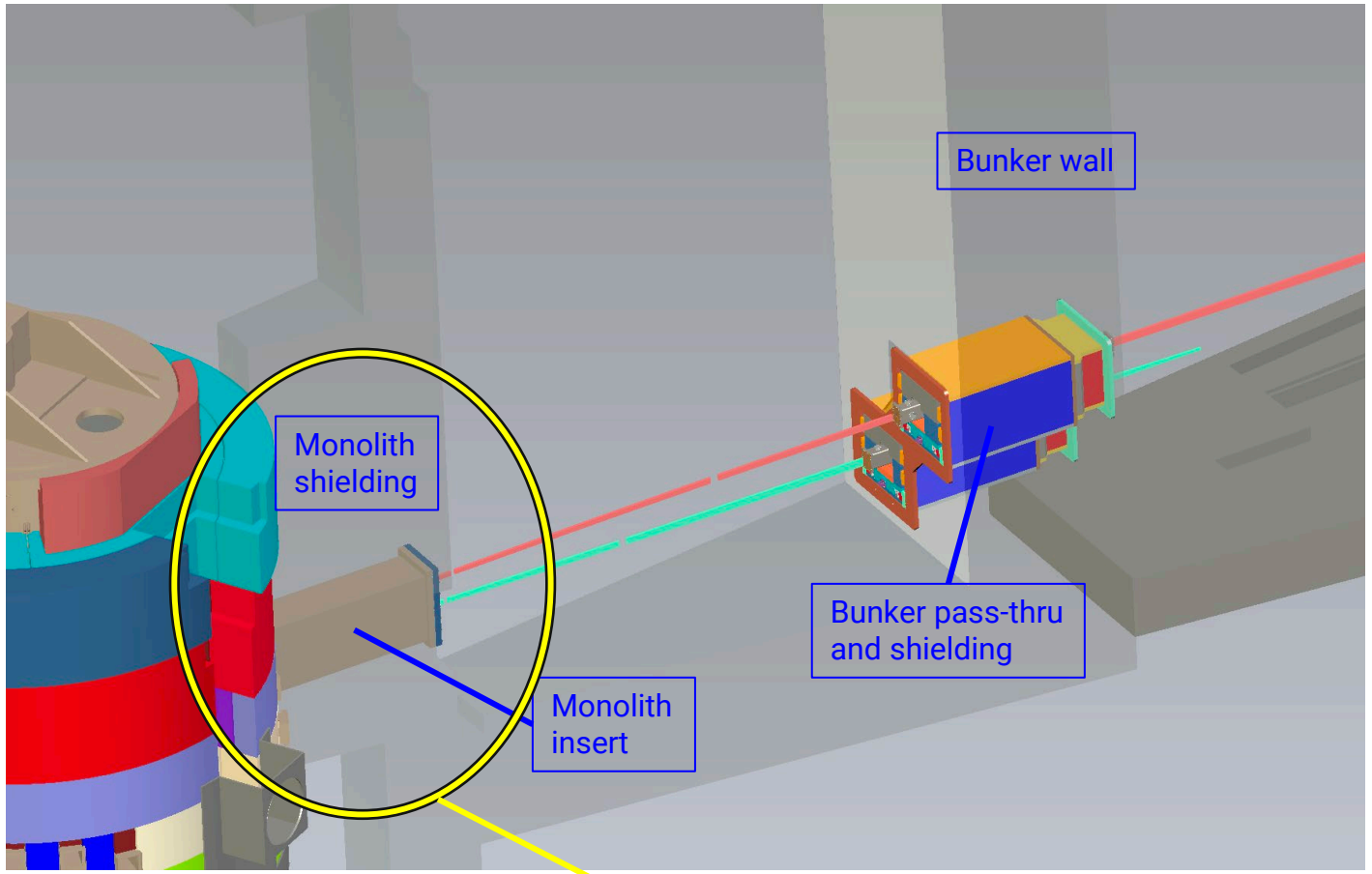
Neutronic analysis to support QIKR needs

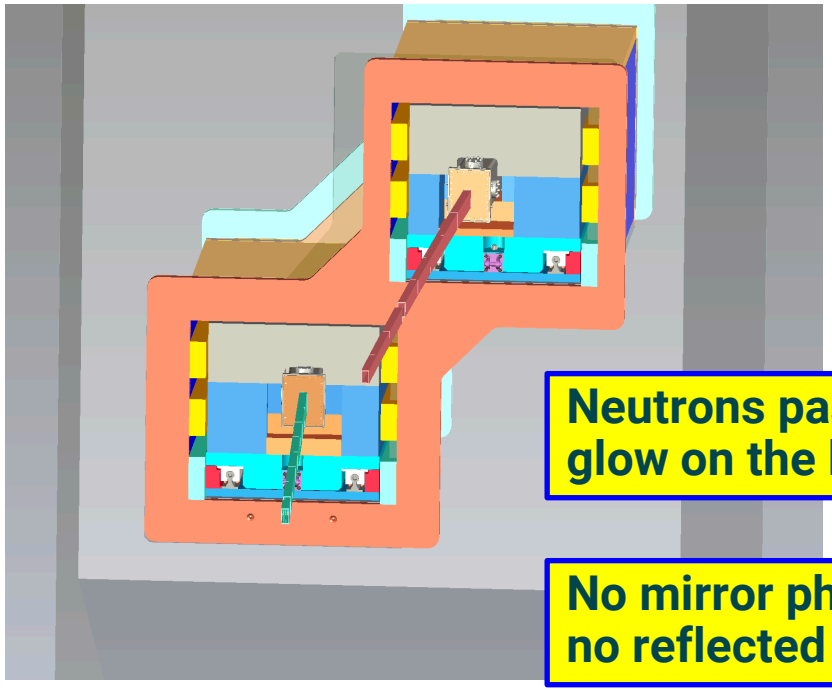
- A snapshot of dose profiles on bunker wall
- Where are the high-energetic neutrons (line-of-sight neutrons)?
- Identify the potential streaming paths in monolith area
- What-if anti-streaming block is removed
- What-if the height taper in the optics inserts is removed
- What-if upstream steel insert placed into upstream cavity and chicane removed



The gaps in/around the monolith and optical inserts are potential neutron streaming paths (especially high energetic neutrons)

A snapshot of dose profiles on bunker wall

A simple deterministic calculation provides an insight about the potential streaming paths for HE neutrons

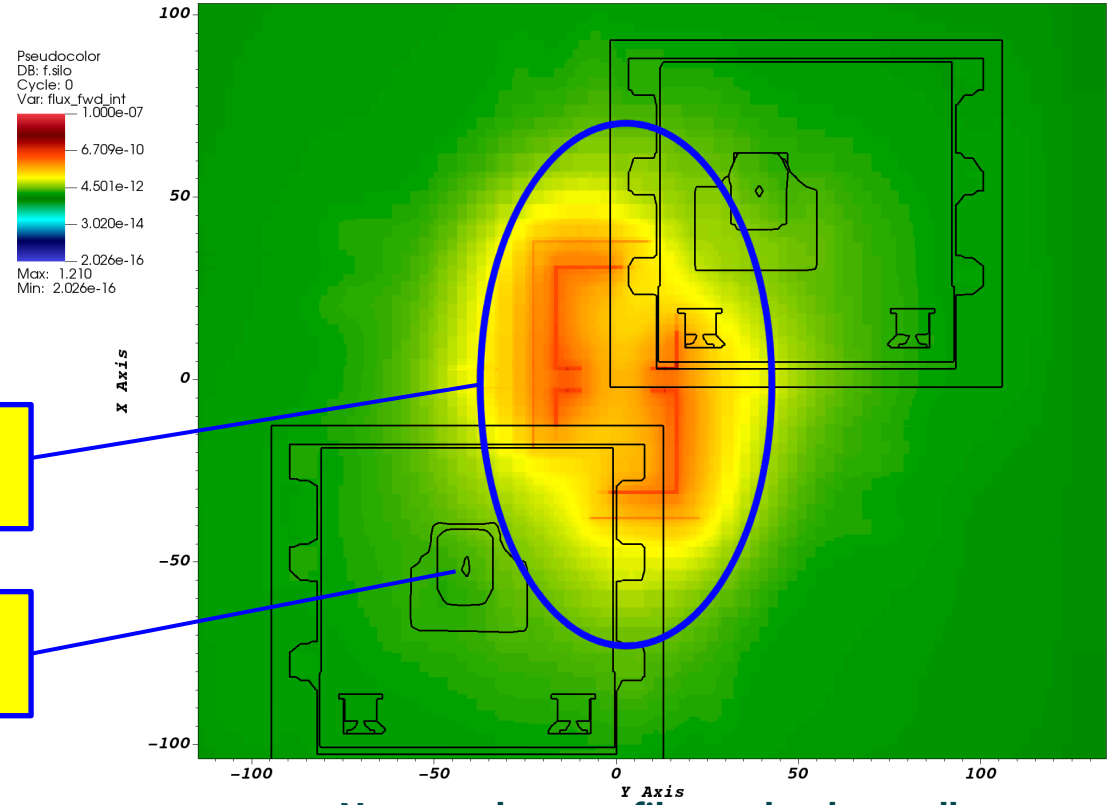


Bunker pass-thru and its shielding
(view from bunker area)

Neutrons passing through gaps glow on the bunker wall surface

No mirror physics in Denovo → no reflected neutrons in guide

Denovo calculation (deterministic solution)

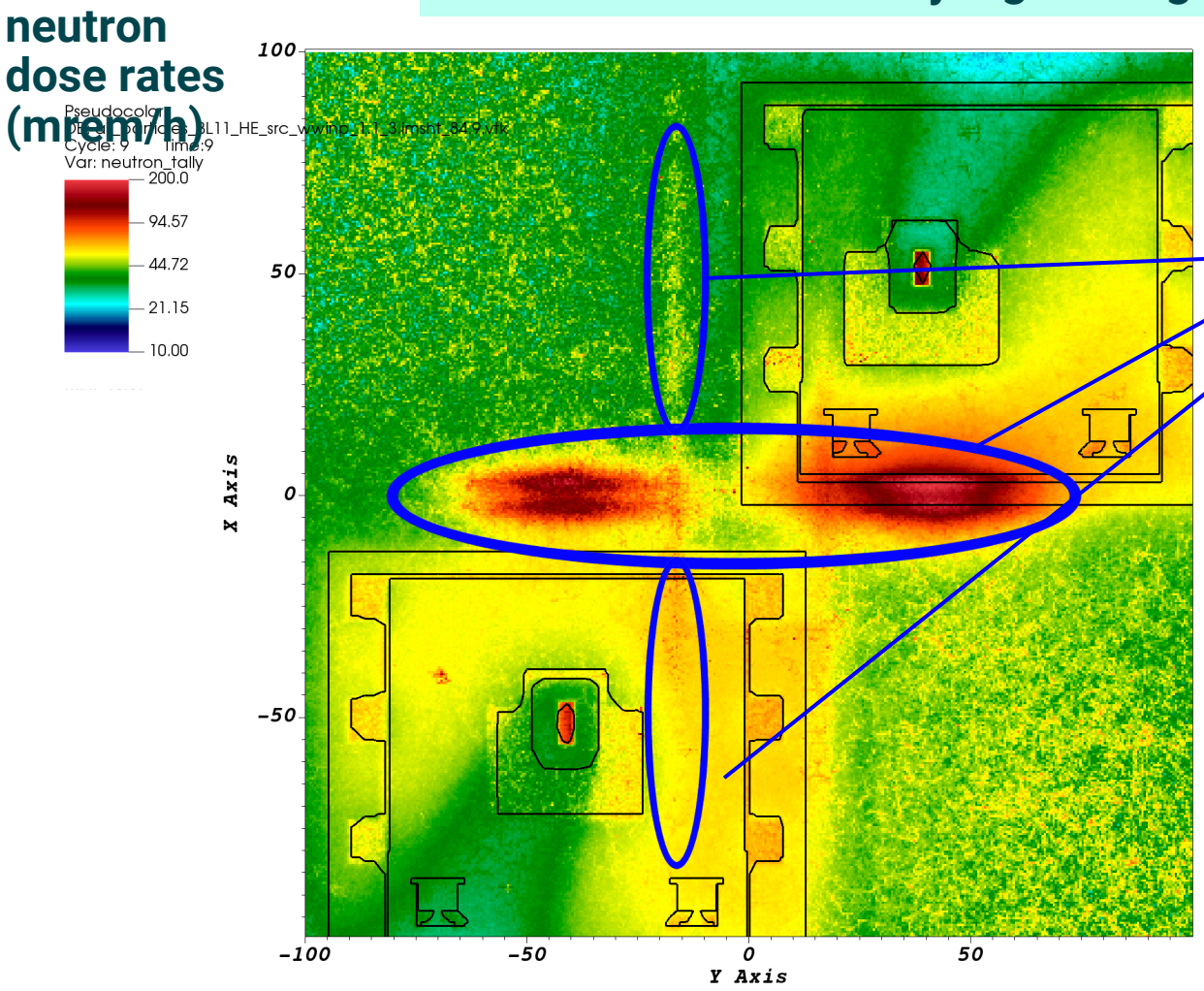


Neutron dose profiles on bunker wall
(view from bunker area)

No line-of-sight neutrons are shown on bunker wall??

A snapshot of dose profiles on bunker wall

MCNP simulation -- only high-energetic (HE) neutrons (E > 10.67 eV)



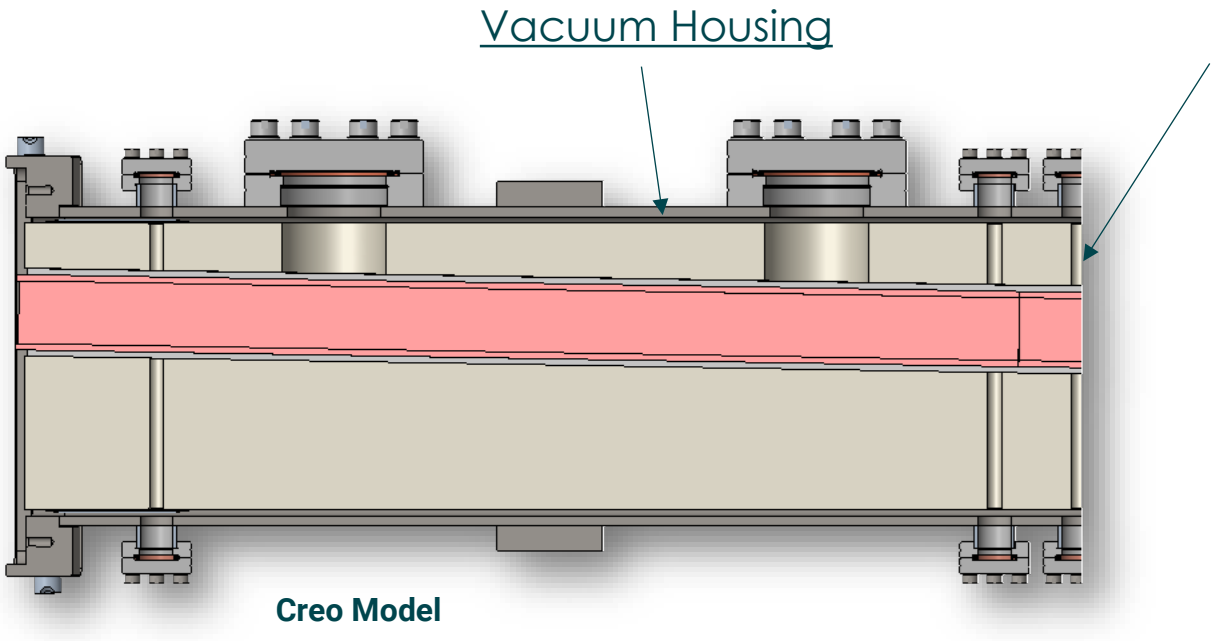
These are the HE neutrons which stream through gaps around/in monolith/optic inserts

No line-of-sight neutrons are shown on bunker wall??

Guide steel shield eliminates the line-of-sight neutrons ➔

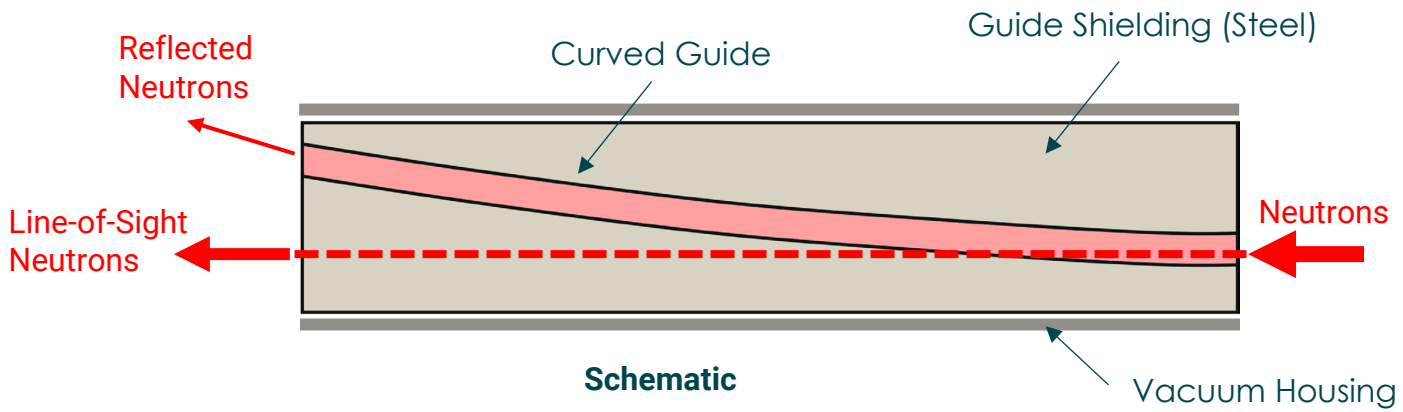
Neutron dose profiles on bunker wall (view from bunker area)

Steel Shielding Around In-Bunker Guides… Needed to Eliminate High Energy Line-of-Sight Neutrons?



Creo Model

- Guide Shielding certainly helps block line-of-sight neutrons, but it would save cost to eliminate that quantity of steel…
- Would the bunker wall alone be sufficient to stop the line-of-sight neutrons?



Schematic

Line-of-sight neutrons appear when we remove the guide steel shield

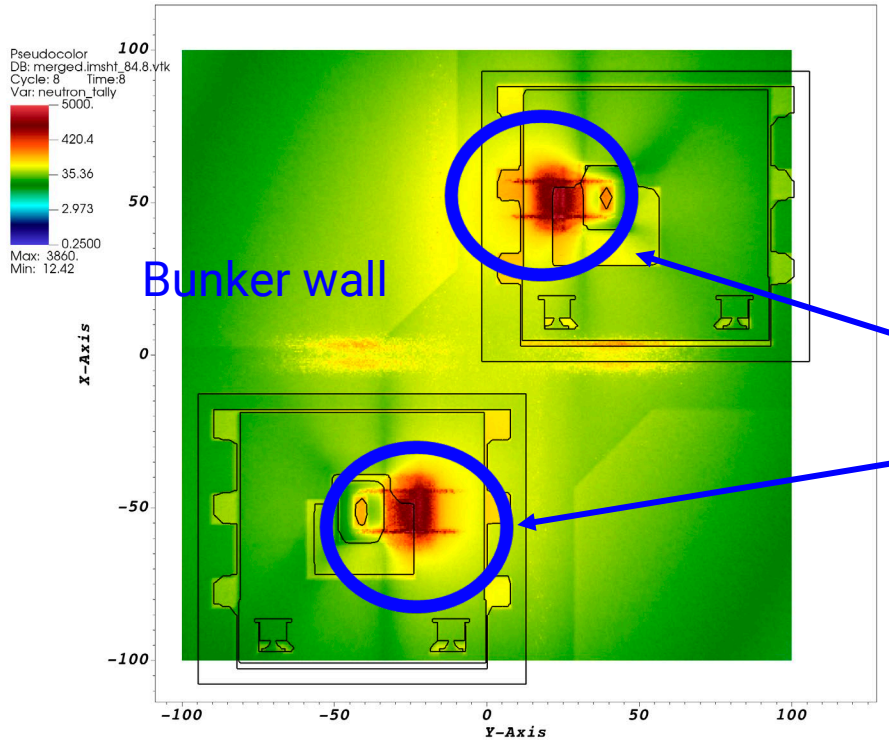
Repeat calculation by removing steel shield from each guide section (filled with air)

neutron dose rates (mrem/h)

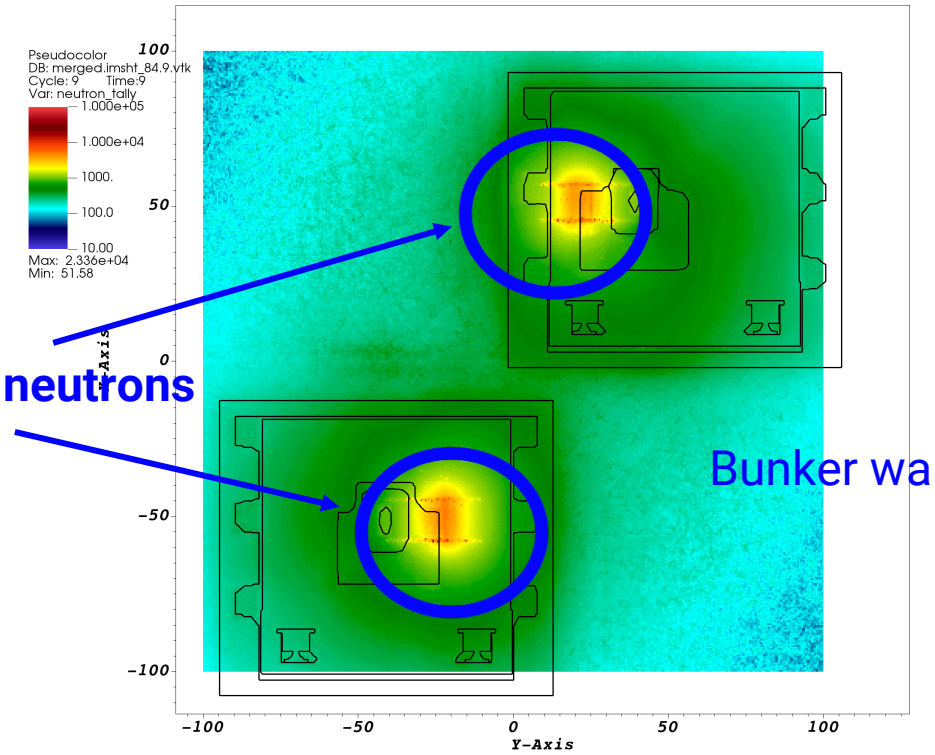
Very high energetic neutrons (> 100 MeV)

Guide steel removed

All neutrons (> 10.67 eV)



Line-of-sight neutrons



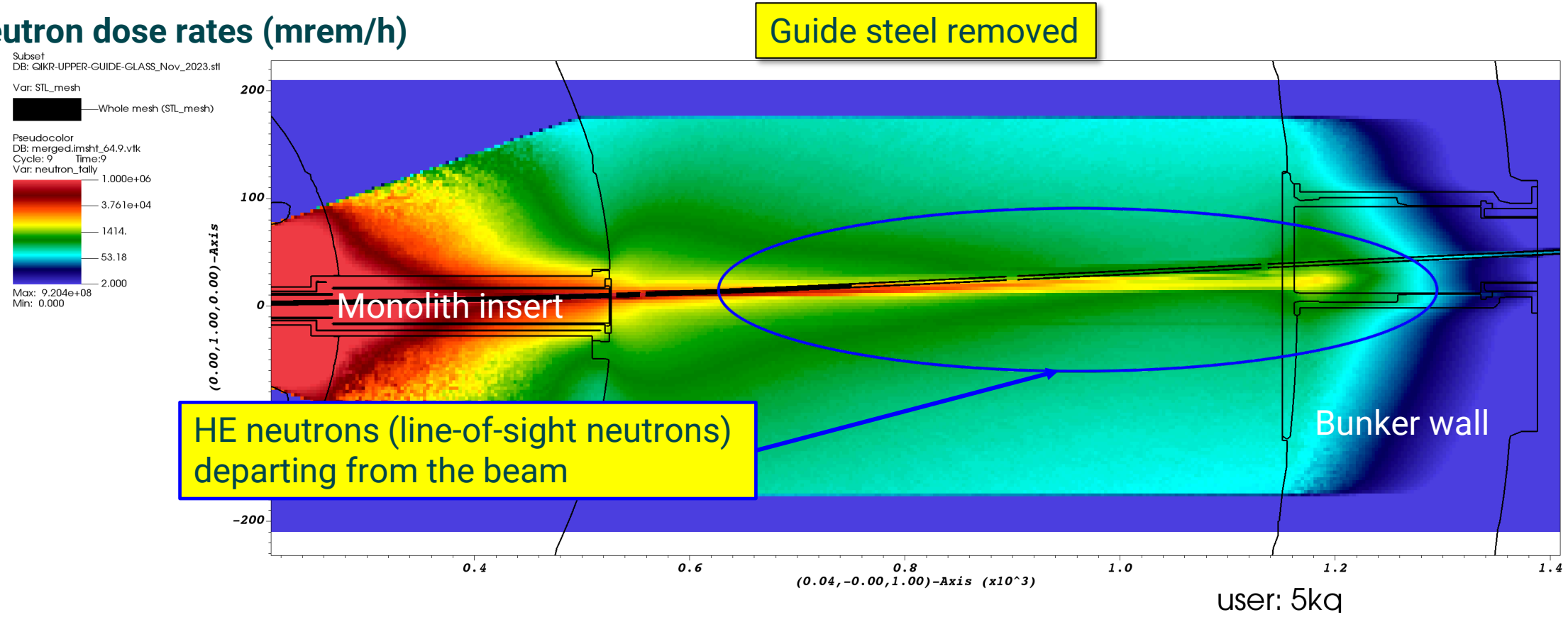
user: 5kq
Sat Jan 6 22:06:11 2024

user: 5kq
Sat Jan 6 22:08:53 2024

Line-of-sight neutrons appear when we remove the guide steel shield

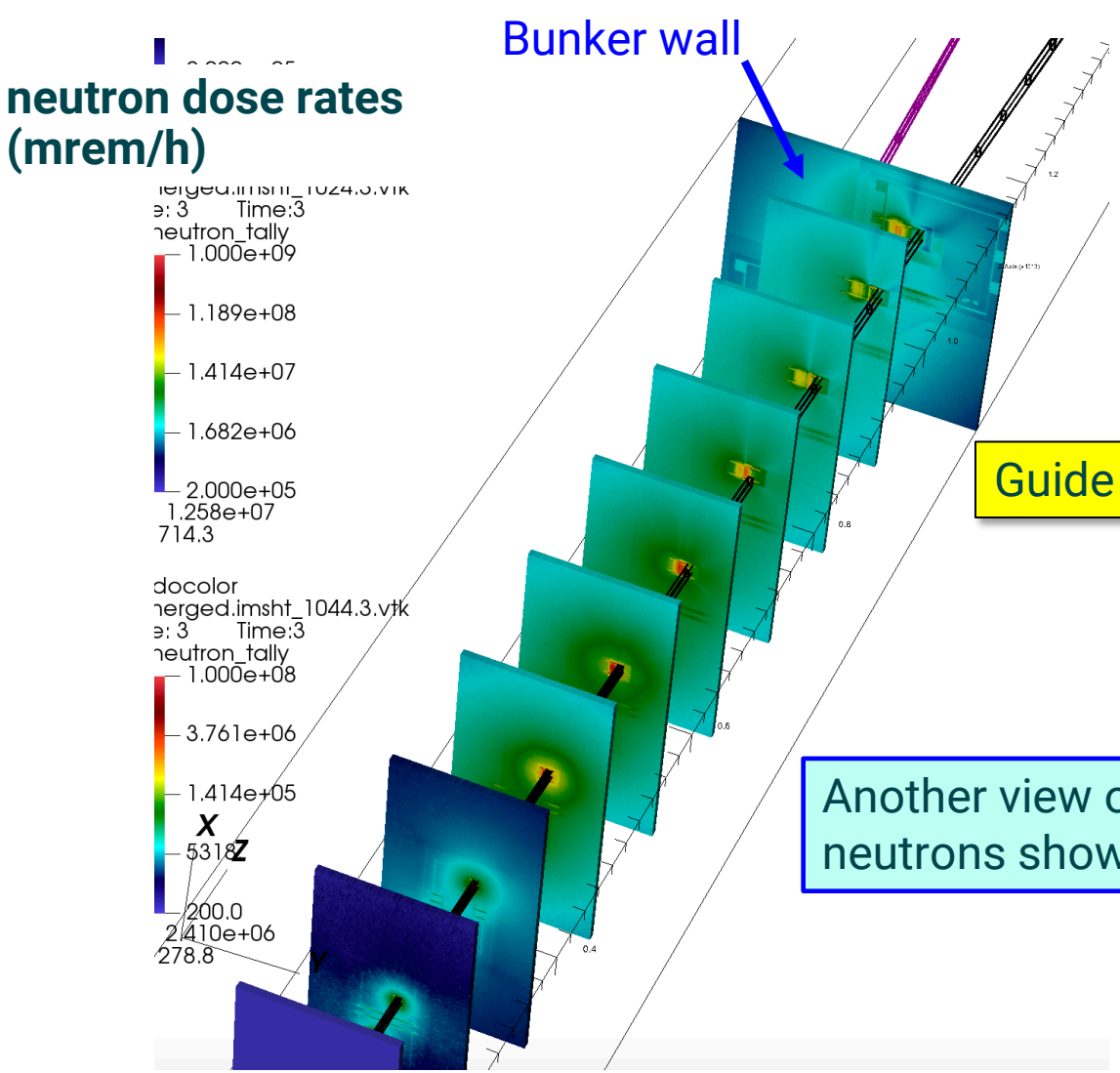
Line-of-sight neutrons, QIKR-L guide without steel shield

neutron dose rates (mrem/h)



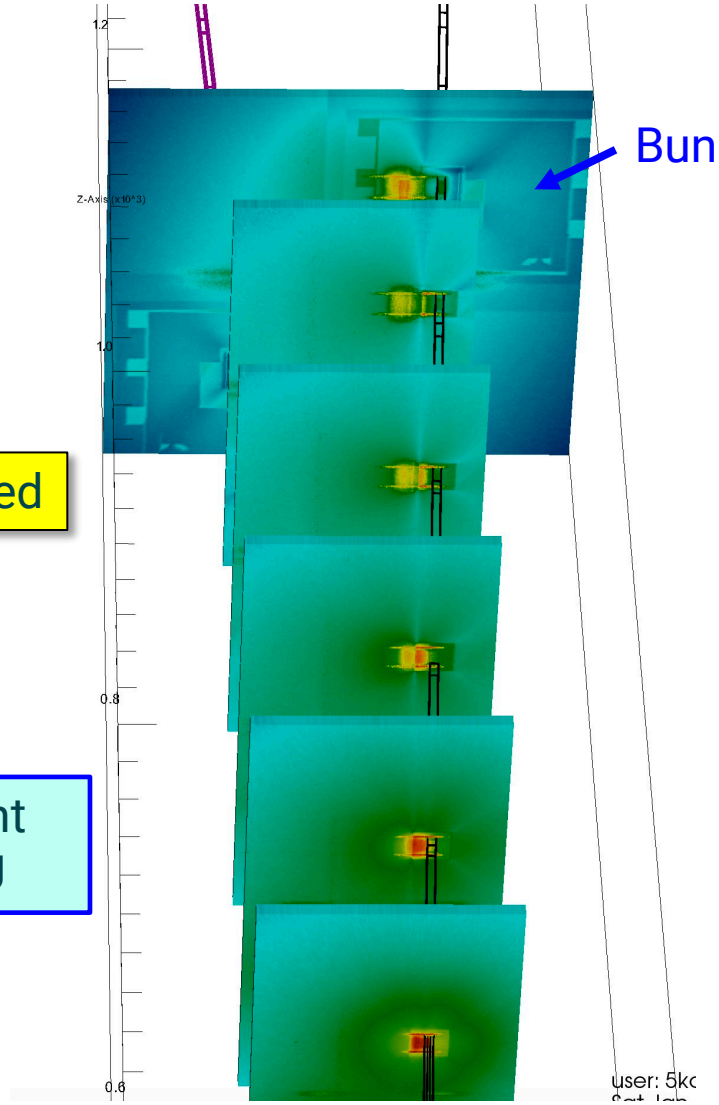
Horizontal cut-view along the QIKR-L guide elevation (plan-view)

Line-of-sight neutrons appear when we remove the guide steel shield



Guide steel removed

Another view of line-of-sight neutrons shown for QIKR-U

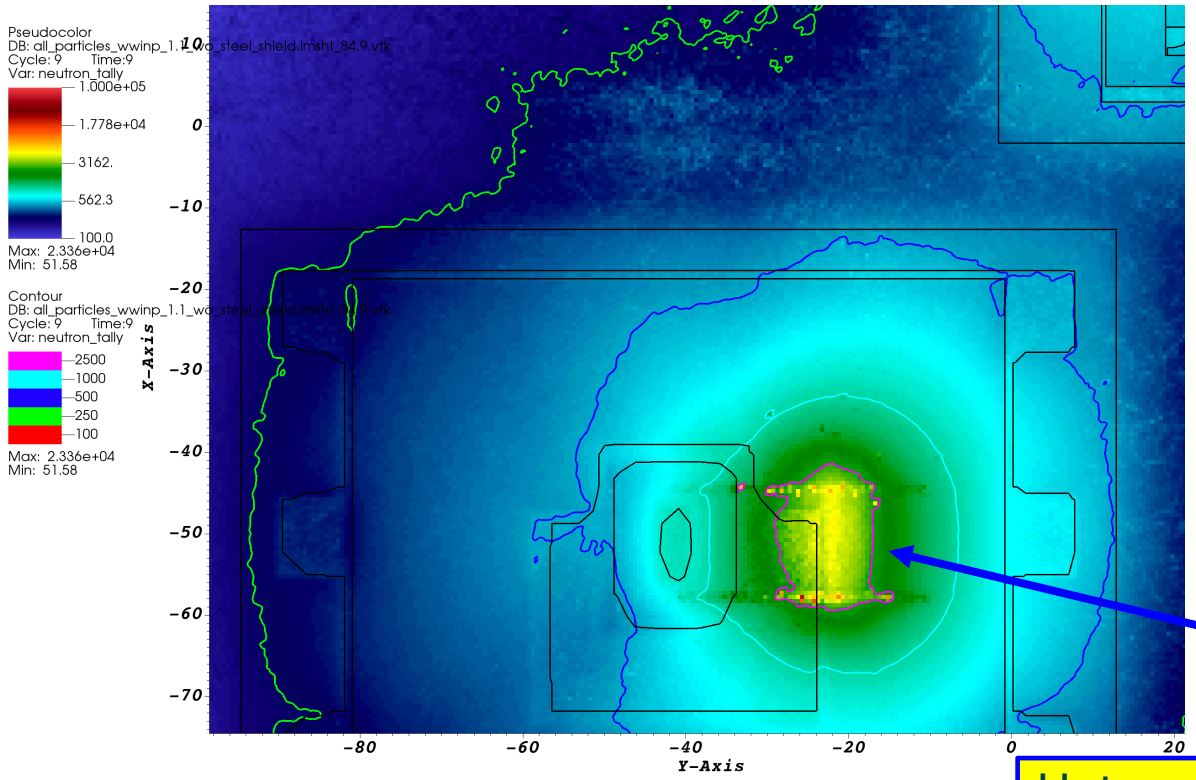


Neutron dose profiles at the end of each guide section (vertical cut-views perpendicular to the beam)

Line-of-sight neutrons appear when we remove the guide steel shield

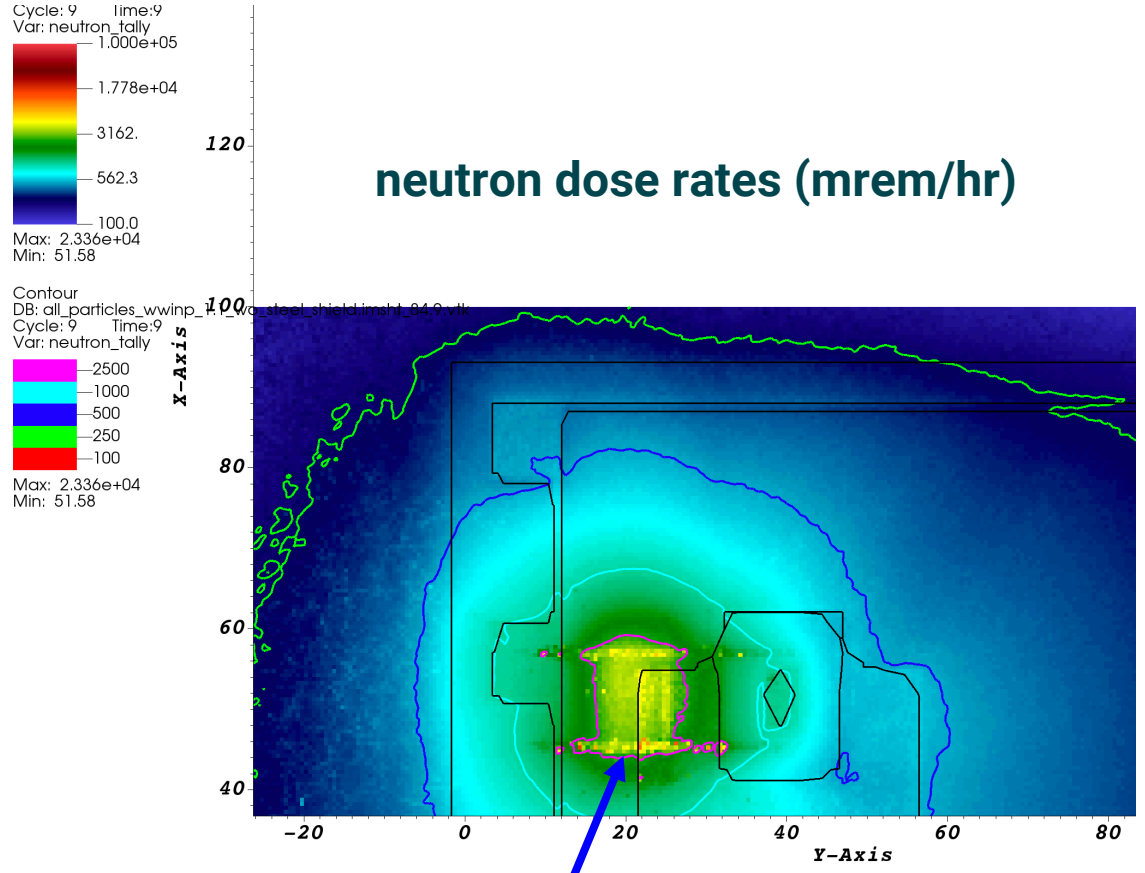
Guide steel removed

neutron dose rates (mrem/h)



vertical cut-view at bunker wall (QIKR-L)
(view from bunker area)

neutron dose rates (mrem/hr)



vertical cut-view at bunker wall (QIKR-U)
(view from bunker area)

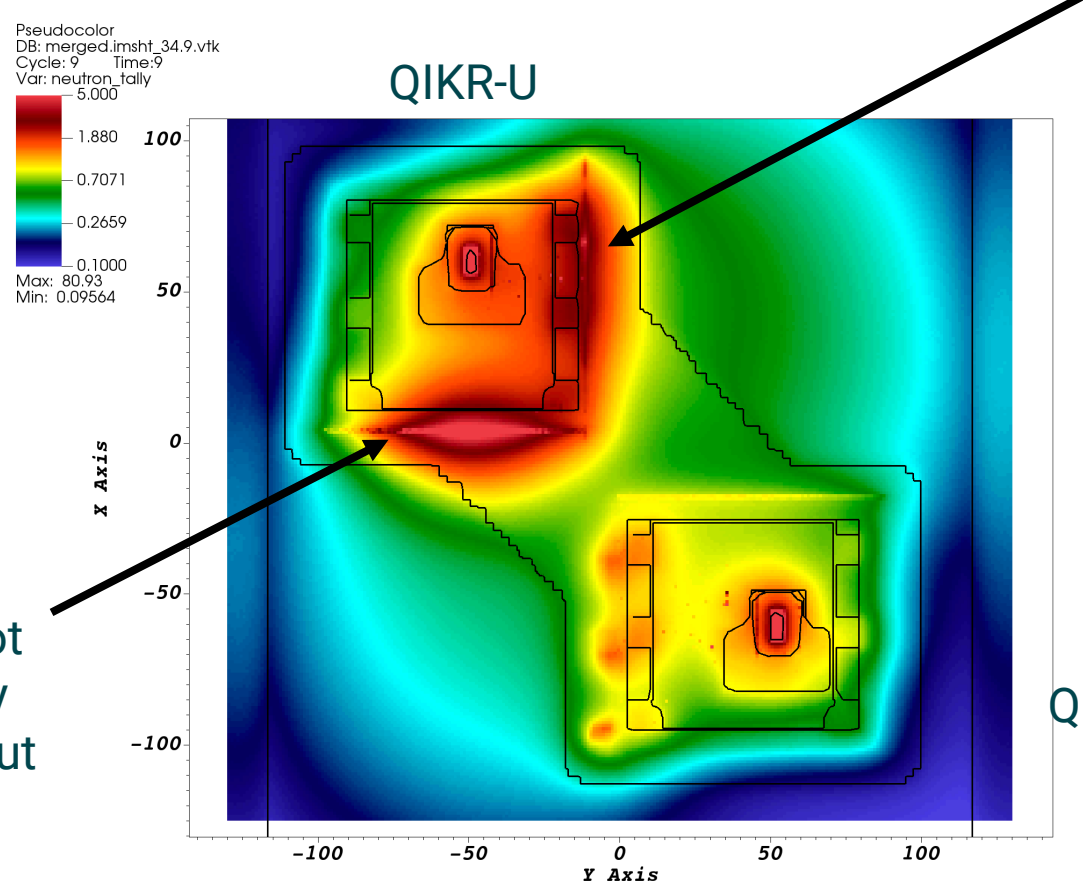
Hot spots are ~ 15-20 cm away from the beam openings

Very high dose rates on bunker wall → how about inside the cave?

Elevated dose rates inside the cave if there is no guide steel

neutron dose rates (mrem/h)

Very high dose rates inside the cave → no way to remove guide steel shield



Maximum neutron dose rate at the upstream cave location ~ 80 mrem/h

Guide steel removed

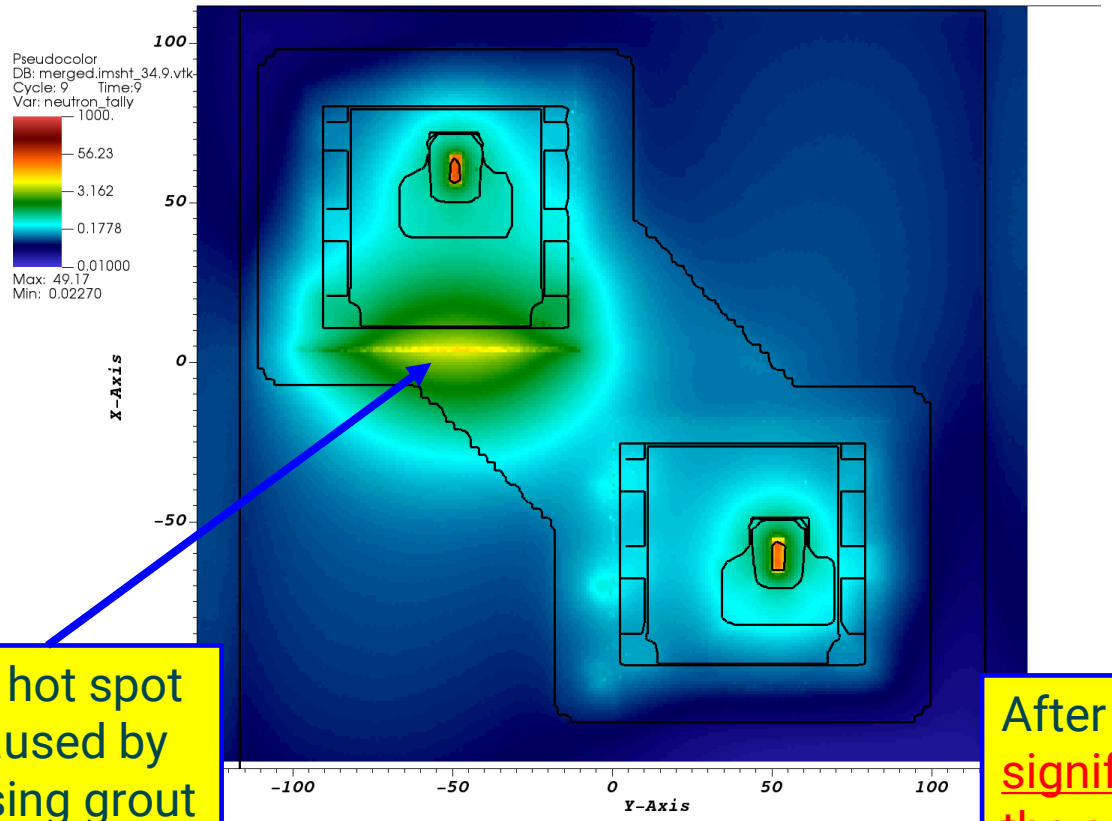
This hot spot is caused by missing grout under steel base plate

vertical cut-view at the exit face of bunker pass-thru (view from inside the cave)

Dose rates reduced significantly when we added back the guide shield

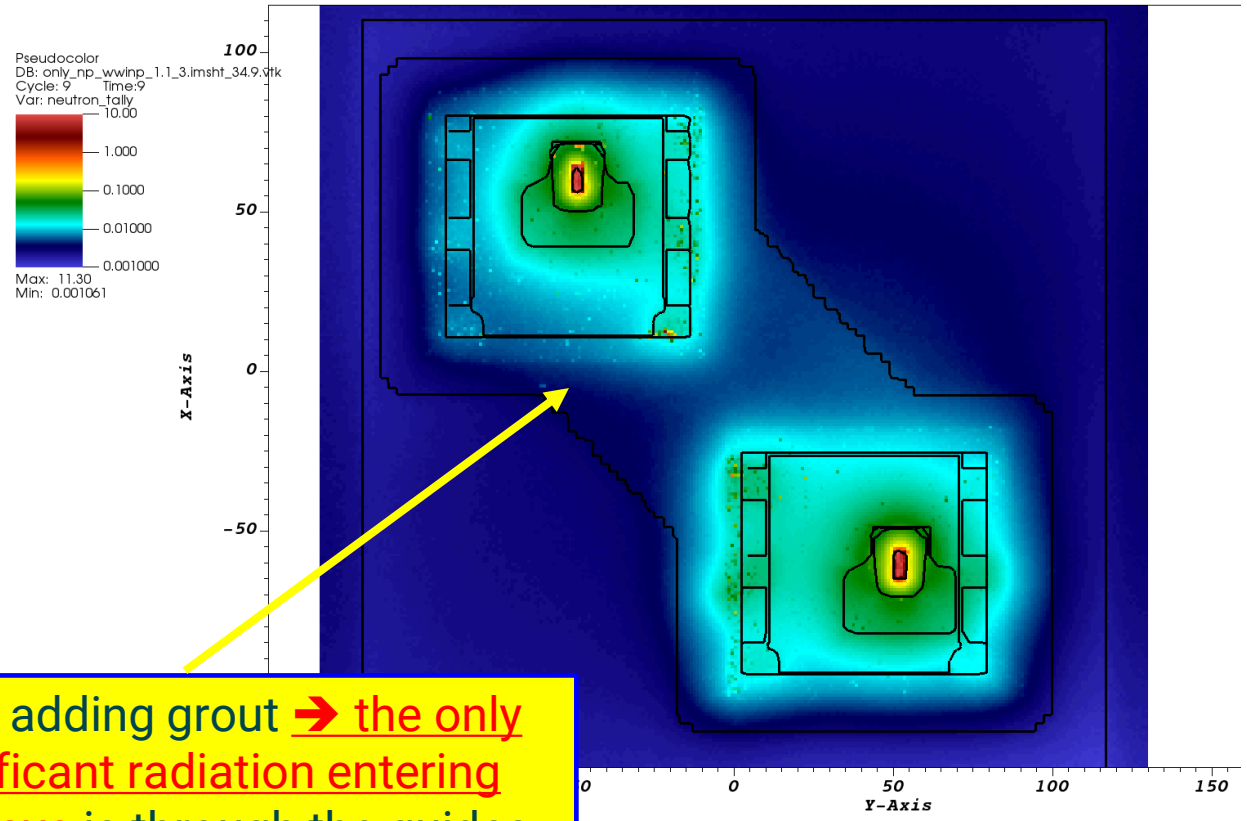
neutron dose rates (mrem/h)

Guides with steel shield



This hot spot is caused by missing grout under steel base plate

Without grout



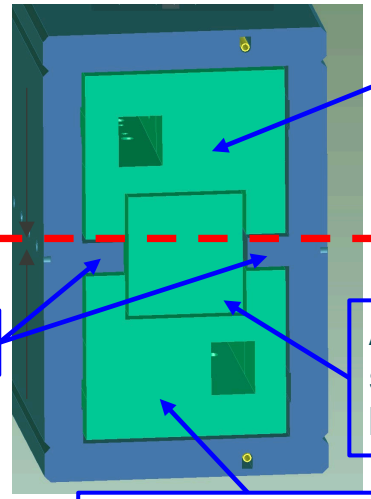
After adding grout ➔ the only significant radiation entering the cave is through the guides themselves, not through the bunker wall or pass-thru

With grout

vertical cut-view at the exit face of bunker pass-thru (view from inside the cave)

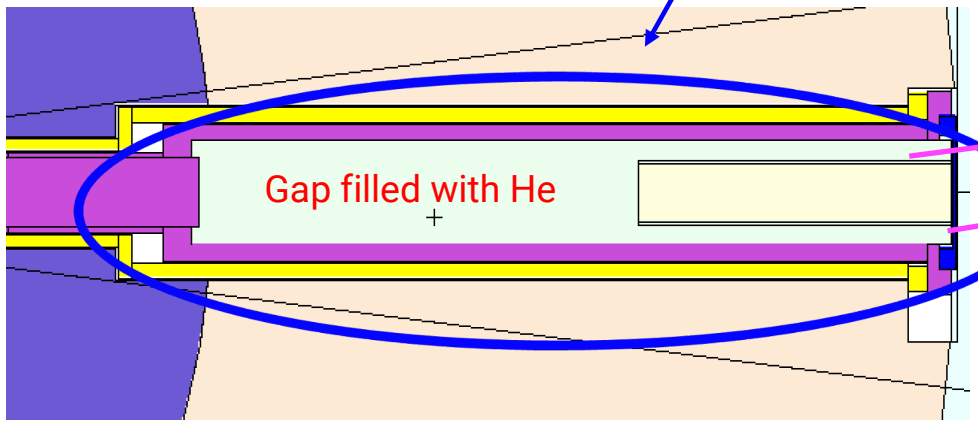
Identify streaming paths in/around the monolith and optic inserts

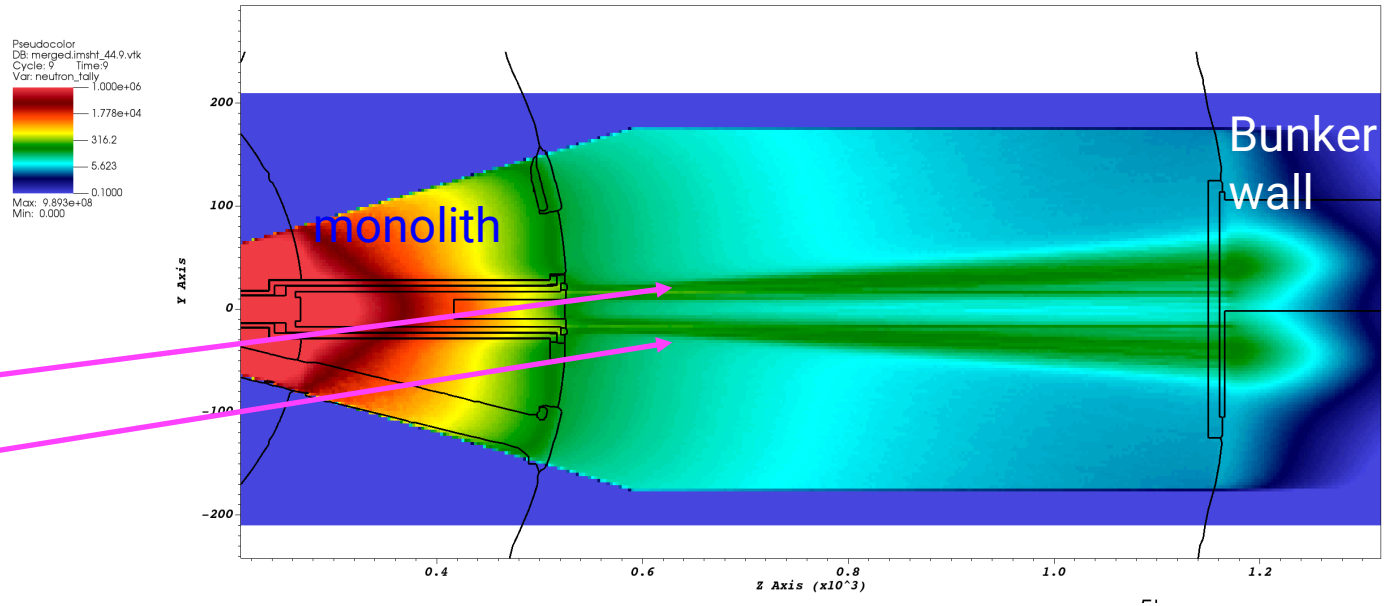
Guides were removed from the MCNP model when identifying streaming paths and their impact



This is the largest gap, neutrons streaming through this gap glow on the bunker wall

high-energetic (HE) neutrons (E > 10 MeV)





horizontal cut-view 2.5 cm above from the moderator elevation

Plan-view, monolith and optic inserts
horizontal cut-view 2.5 cm above from the moderator elevation

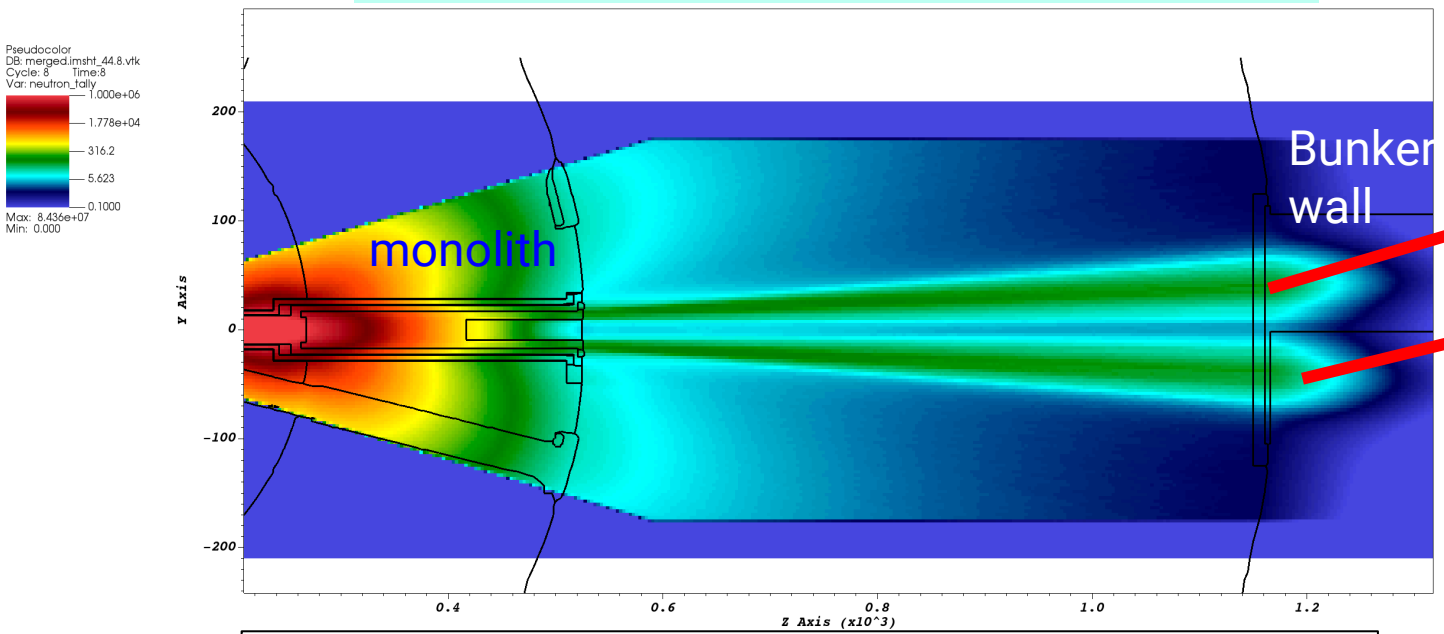
Identify streaming paths in/around the monolith and optic inserts

Guides were removed from the MCNP model when identifying streaming paths and their impact

neutron dose rates (mrem/h)

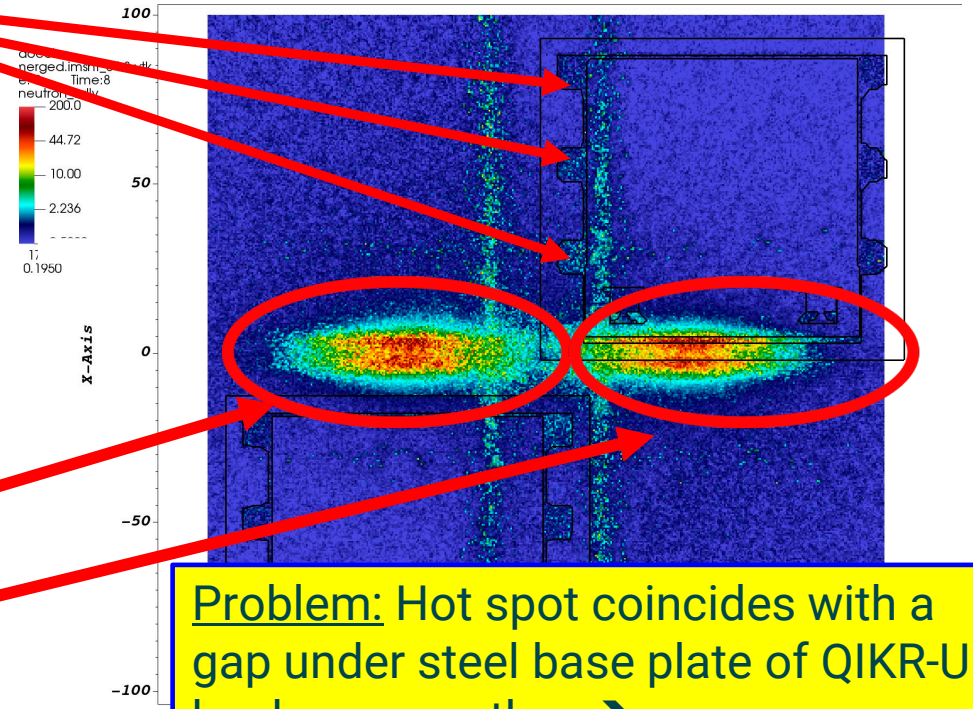
Problem:
Inner cable cavities line up with one of the gap in/around optic insert ➔ remove the cavities/reduce their size

high-energetic (HE) neutrons (E > 10 MeV)



horizontal cut-view 2.5 cm above from the moderator elevation

high-energetic (HE) neutrons (E > 10 MeV)

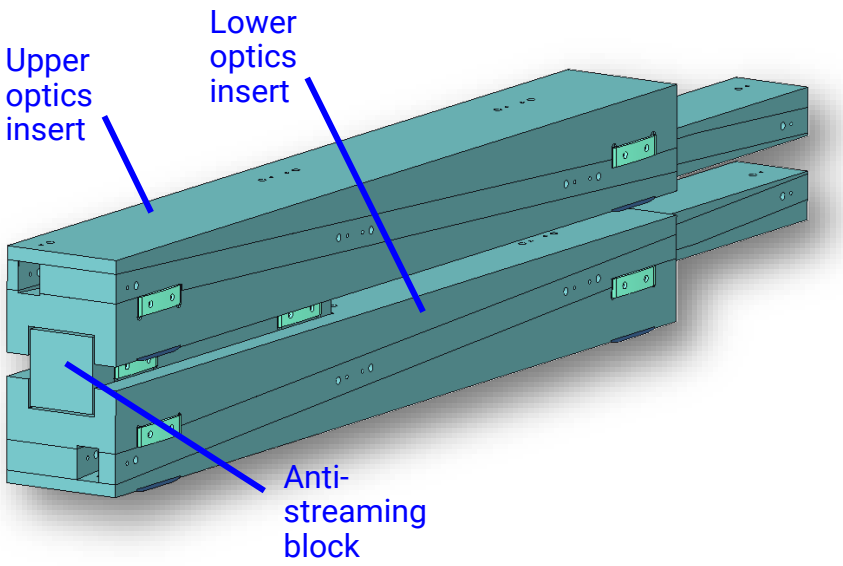


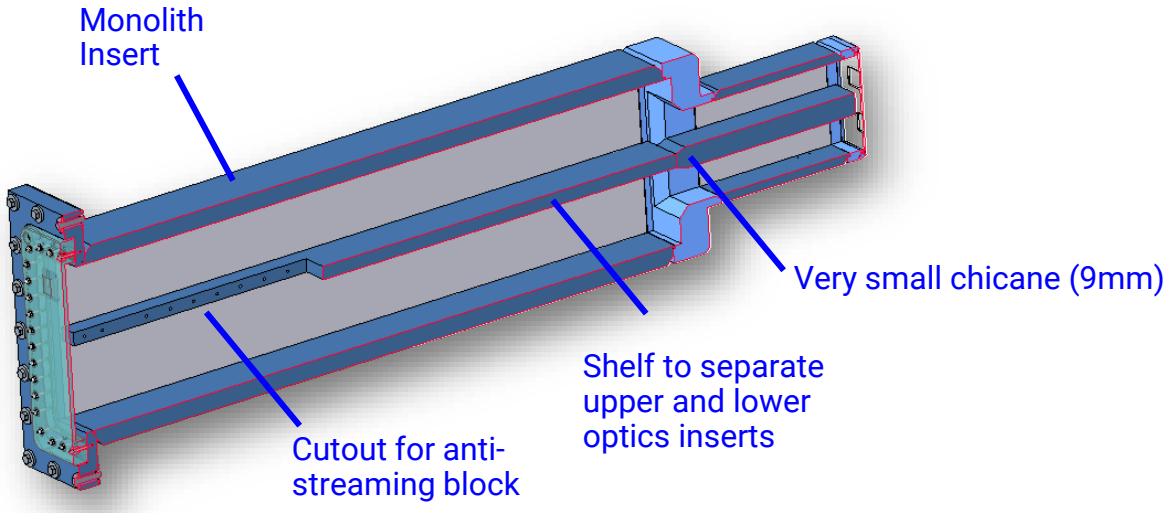
Problem: Hot spot coincides with a gap under steel base plate of QIKR-U bunker pass—thru ➔

Filling this gap with grout mitigate the potential issue in the cave area (see slide 11)

Neutro
(view f

Optics Insert Anti-Streaming Block… Needed?

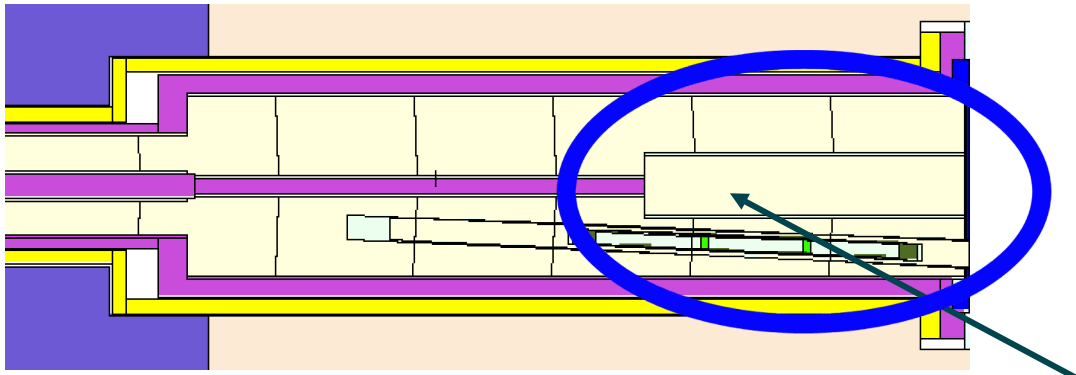




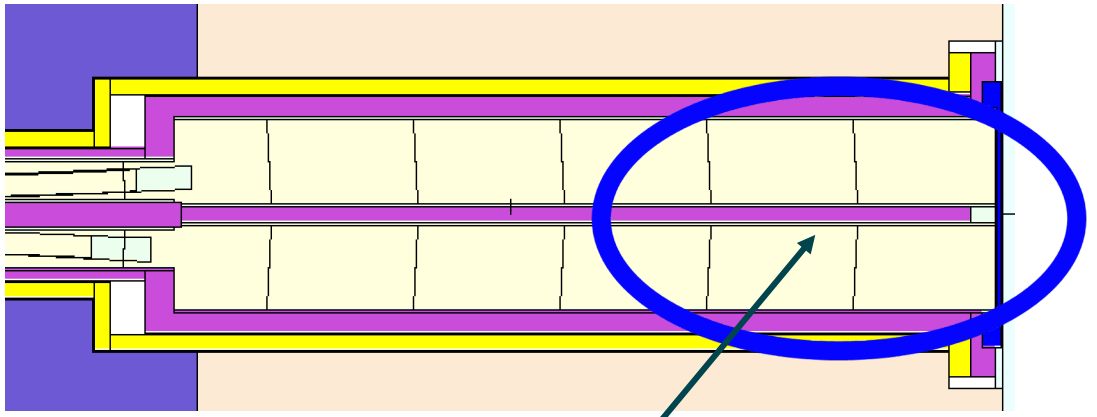
- The monolith insert has a center shelf to allow the lower and upper optics inserts to be separate from each other (the shelf provides a surface for the upper optics insert to roll along when being installed)
  - Combined optics inserts was originally thought to be too heavy for the bunker's optics insert handler to manage (it has since been determined that the handler can lift a combined optics insert)
- There is only room for a very small chicane between the monolith shelf and optics insert… may not be enough to prevent streaming between the shelf and optics inserts?
- The center shelf has a downstream cutout to allow for an anti-streaming block, but must leave some shelf material on the sides for the upper optics insert to roll on when being installed

What-if the anti-streaming block is removed?

Removing anti-streaming block enlarge the gap width at the monolith insert exit face…

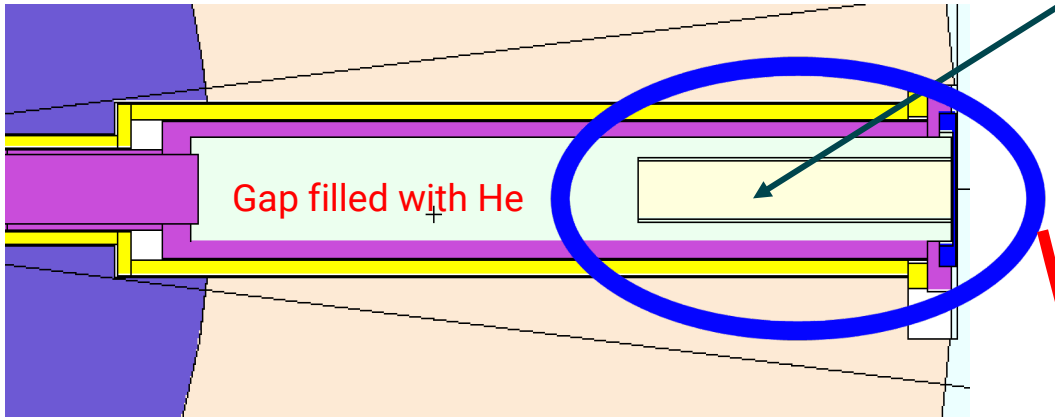


vertical cut-view along QIKR Z-axis

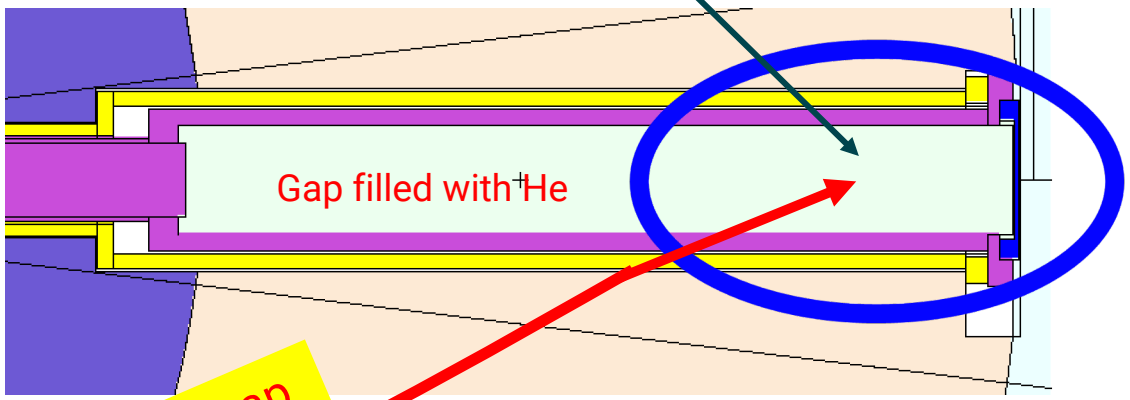


Anti-streaming block

NO anti-streaming block



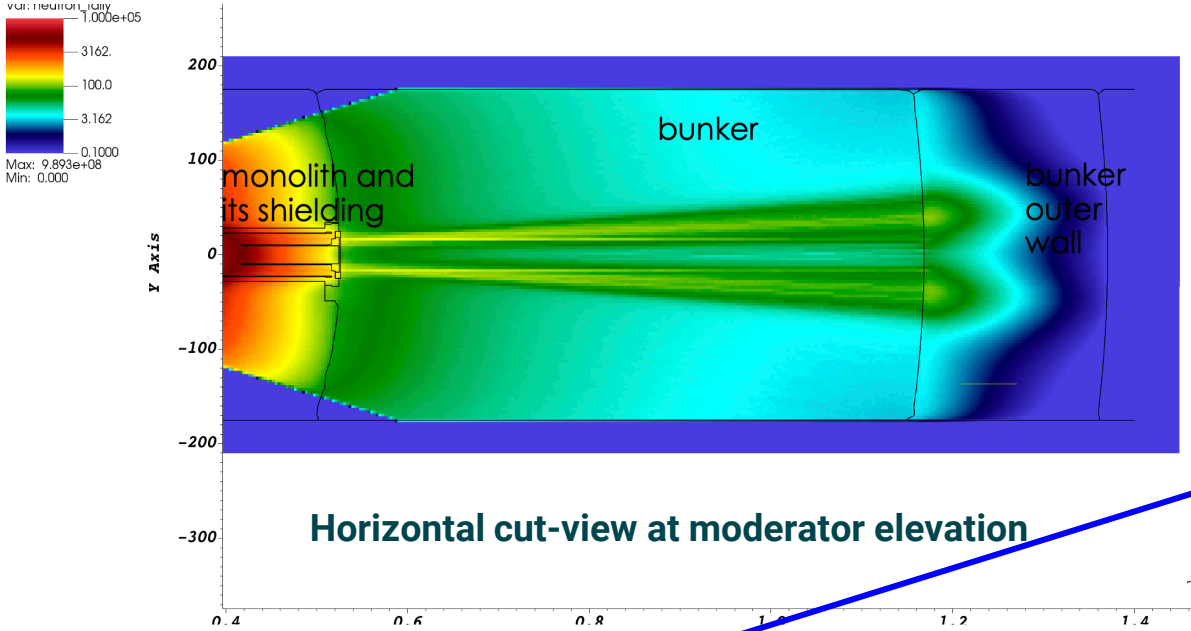
horizontal cut-view 2.5 cm above from the moderator elevation



Enlarged gap

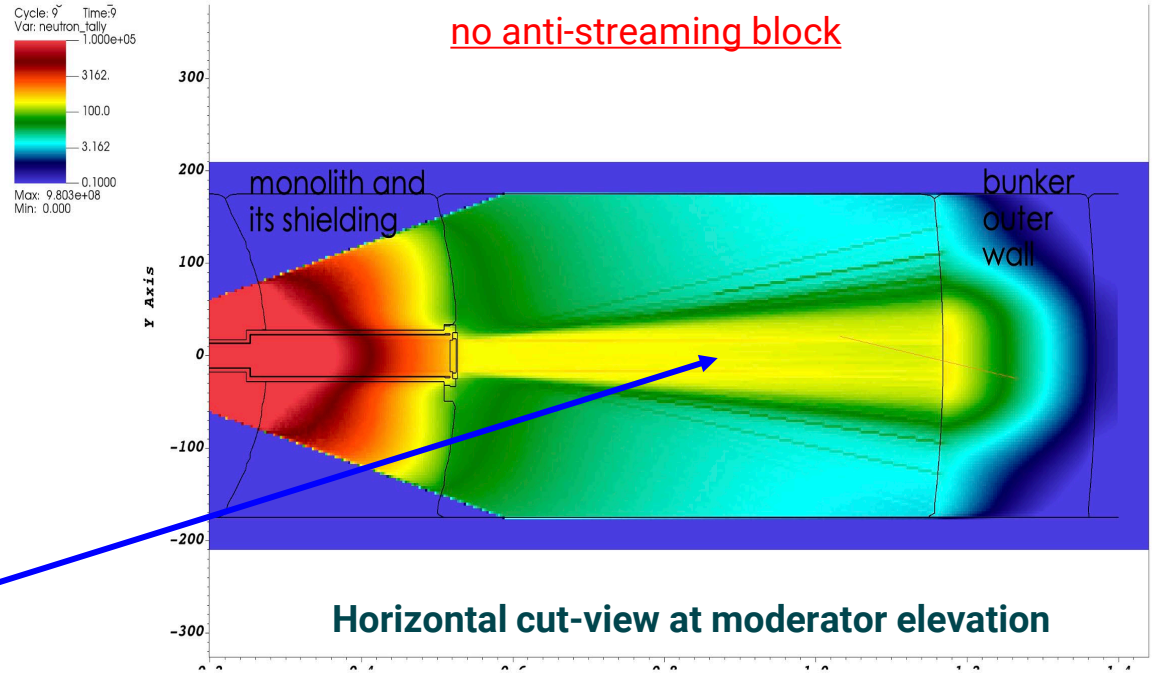
What-if anti-streaming block is removed

with anti-streaming block



Horizontal cut-view at moderator elevation

no anti-streaming block

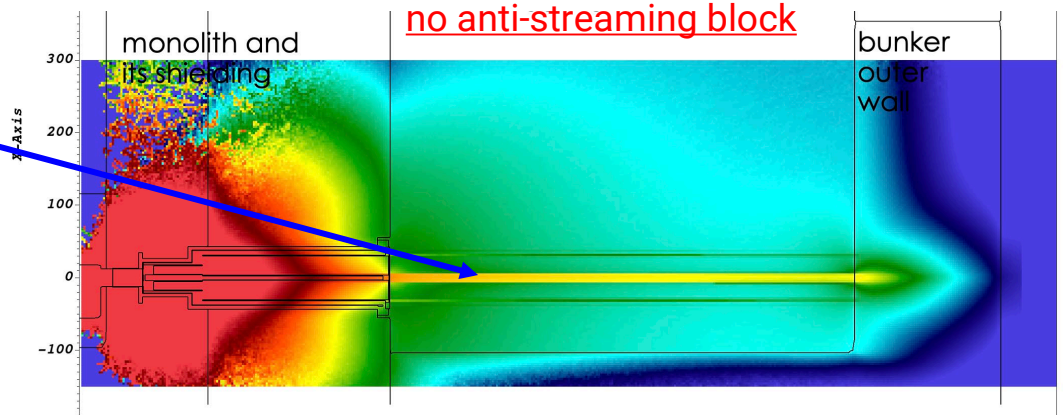


Horizontal cut-view at moderator elevation

No anti-streaming block → strong streaming through the gaps between shelf and optic inserts

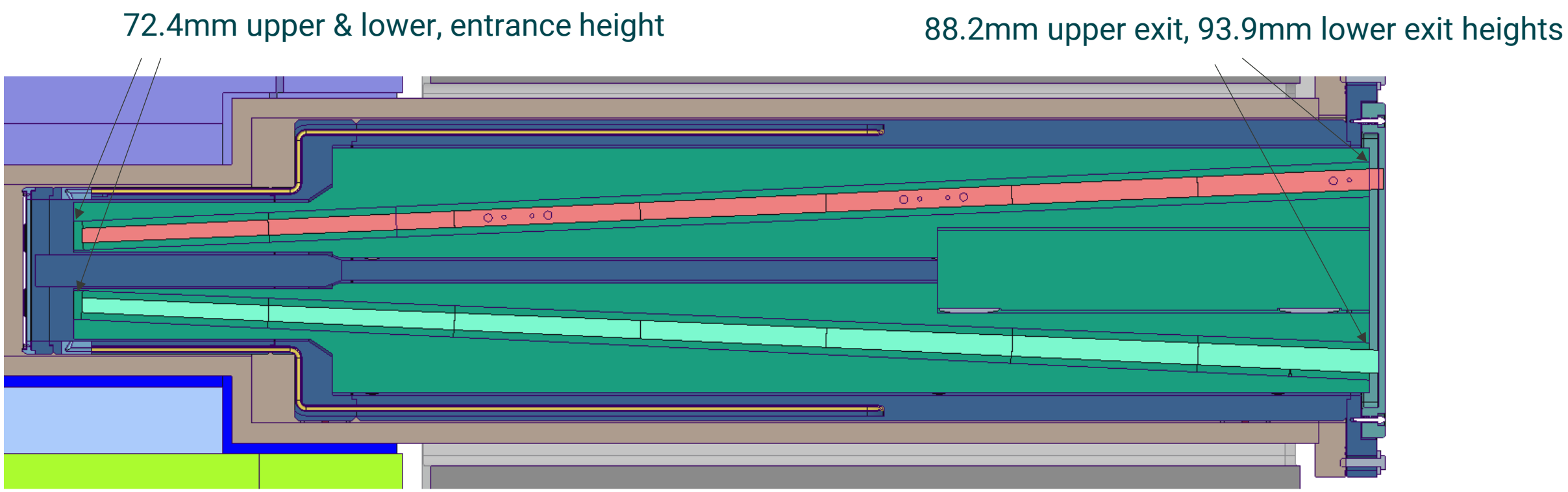
anti-streaming block is needed, keep it in the design

no anti-streaming block



Vertical cut-view along QIKR-Z axis

Guide Taper Within the Optics Insert… Insert Should Follow?

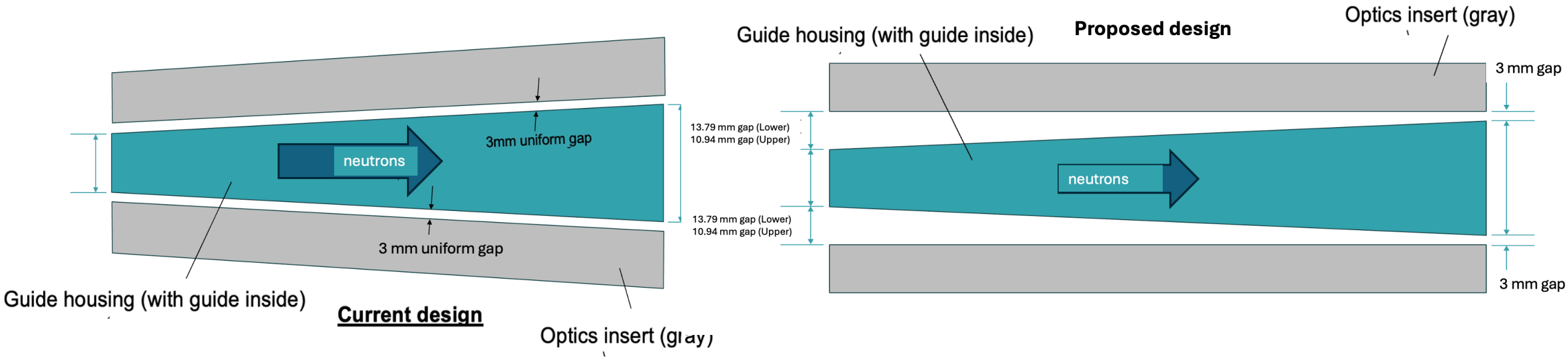


- The height of each QIKR guide continually increases as it progresses through the optics inserts
- Is the height change large enough to need the optics insert channels to taper along with the guides, or can the channels be machined with uniform height (still would maintain the 2.5 incline)
  - Removing the height taper in the optics inserts could simplify machining

What-if the height taper in the optics inserts is removed

Question: Can we use variable gap between optic inserts and guide?

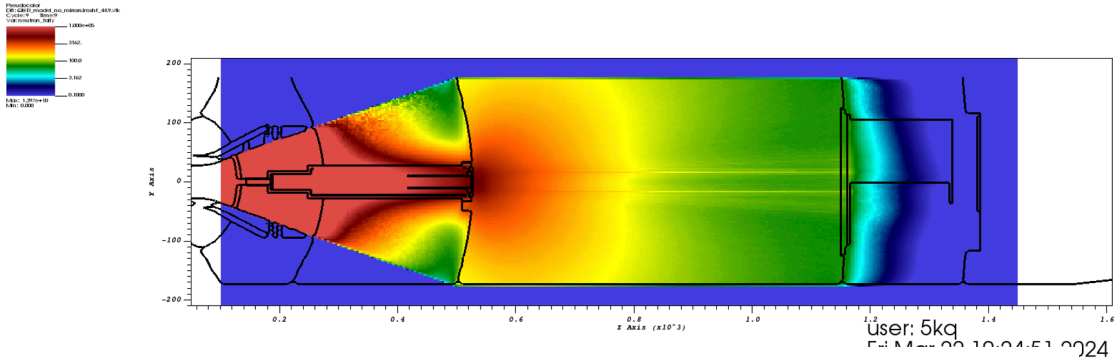
Evaluate the impact of variable gap between guide housing and optic inserts



What-if the height taper in the optics inserts is removed

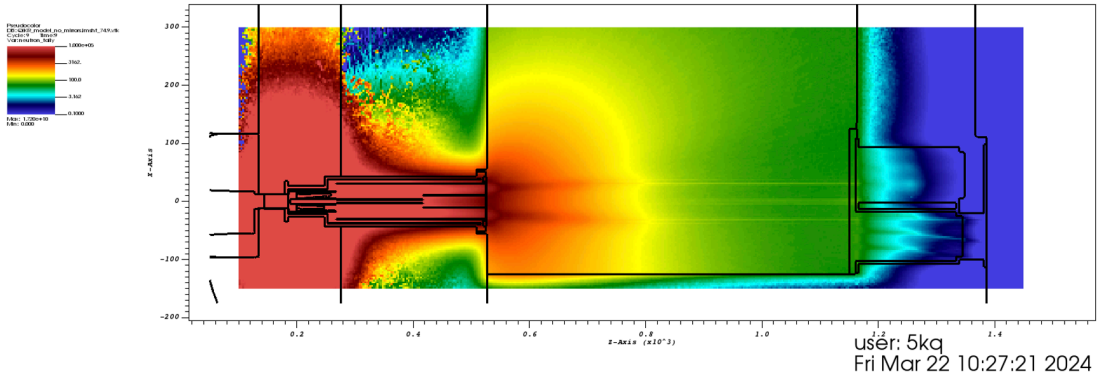
Uniform 3mm-thick gap

Neutron dose rate (mrem/hr)



Horizontal cut-view at the moderator elevation

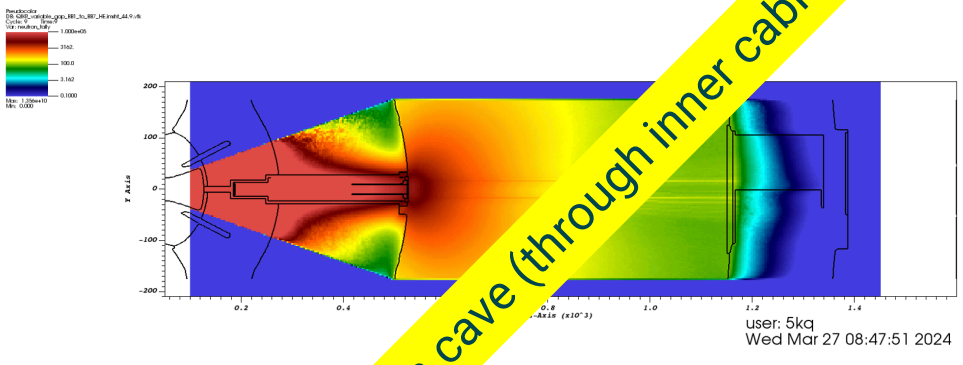
Neutron dose rate (mrem/hr)



Vertical cut-view at the QIKR-Z axis

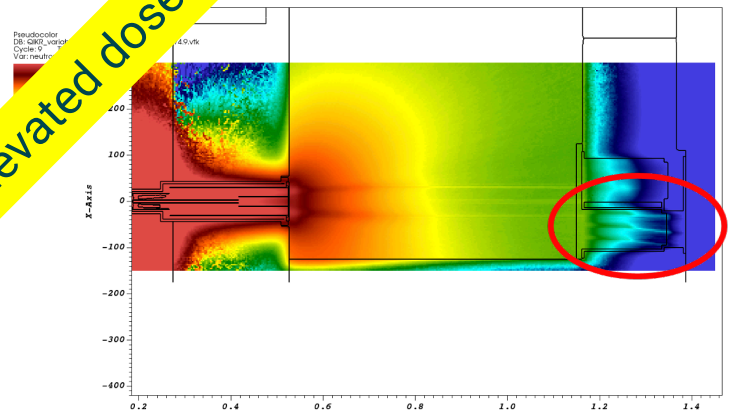
Variable gap

Neutron dose rate (mrem/hr)



Horizontal cut-view at the moderator elevation

Neutron dose rate (mrem/hr)



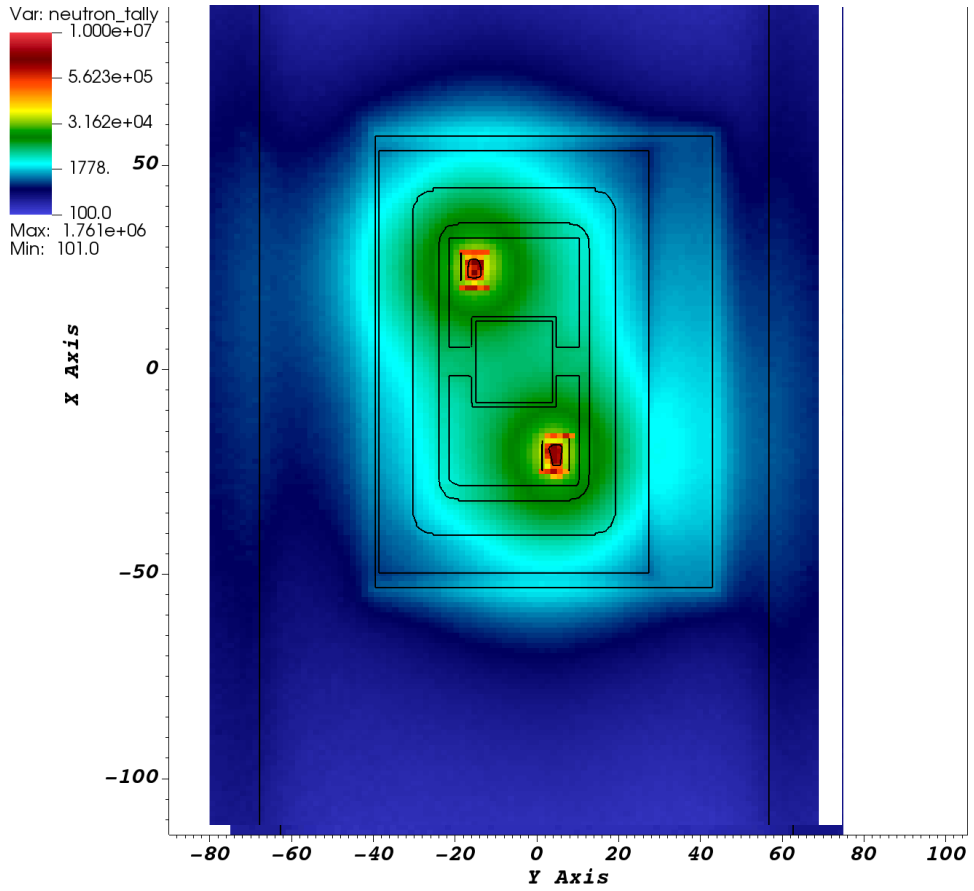
Vertical cut-view at the QIKR-Z axis

Slightly elevated dose rates in cave (through inner cable cavities)

What-if the height taper in the optics inserts is removed

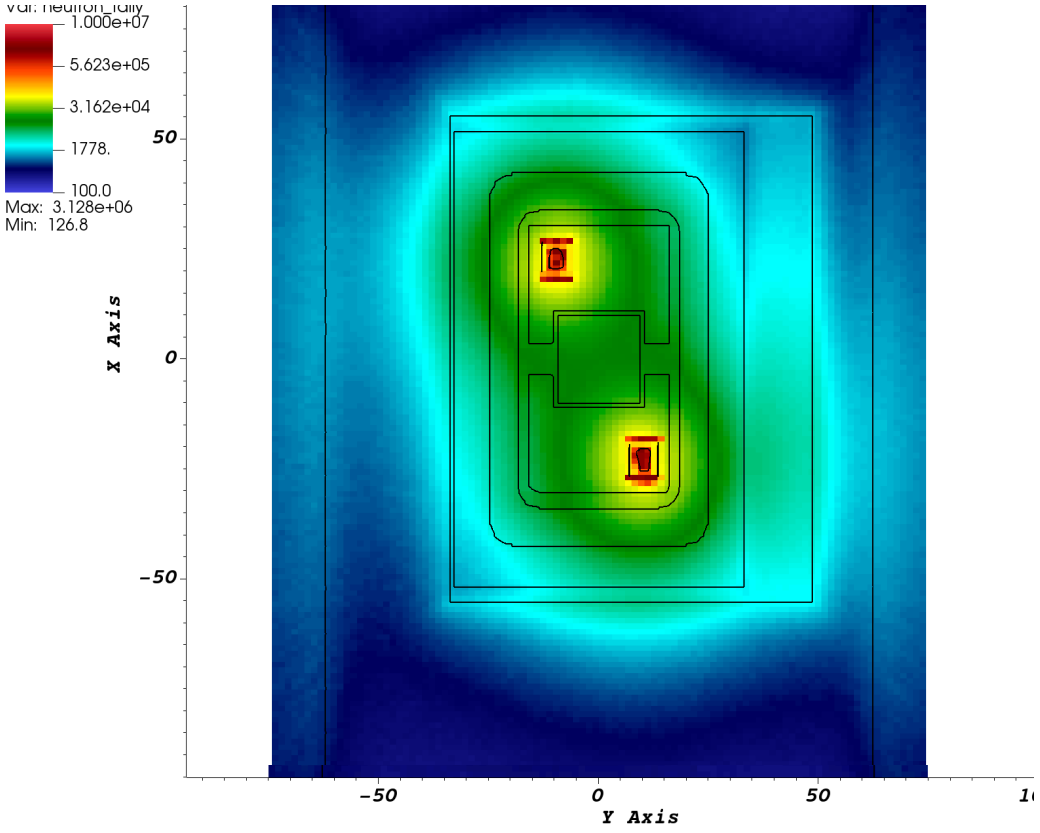
Neutron dose rate (mrem/hr)

HE neutrons (> 1 MeV)



3mm uniform gap

HE neutrons (> 1 MeV)



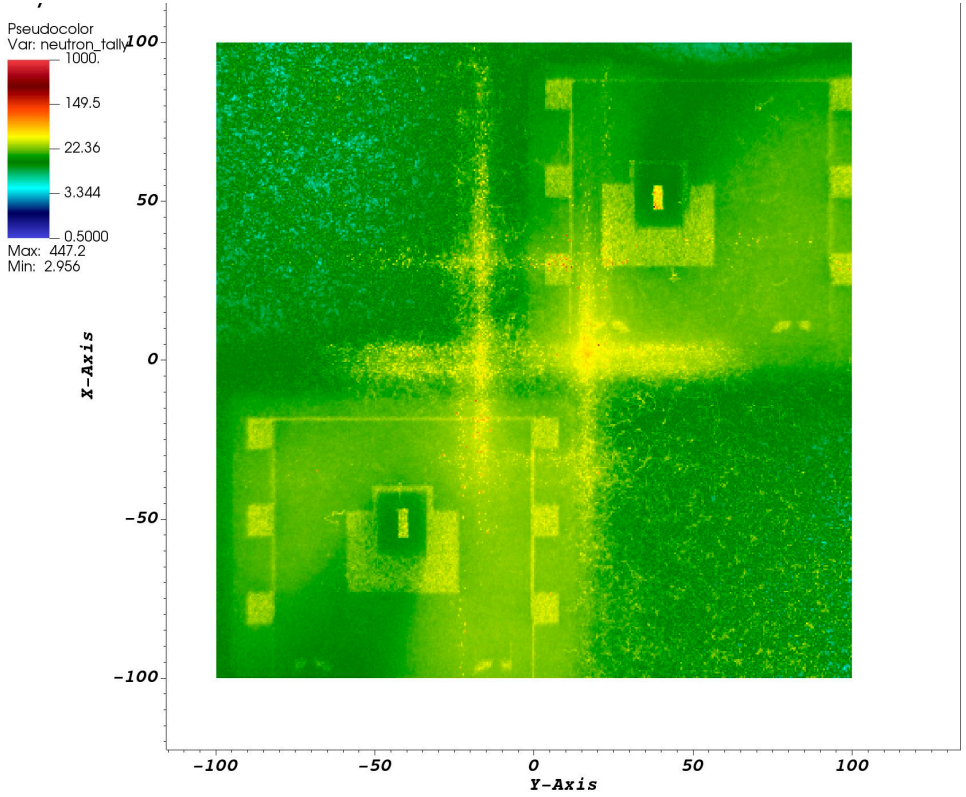
variable gap

Vertical cut-view at monolith exit face (view from bunker area)

What-if the height taper in the optics inserts is removed

Neutron dose rate (mrem/hr)

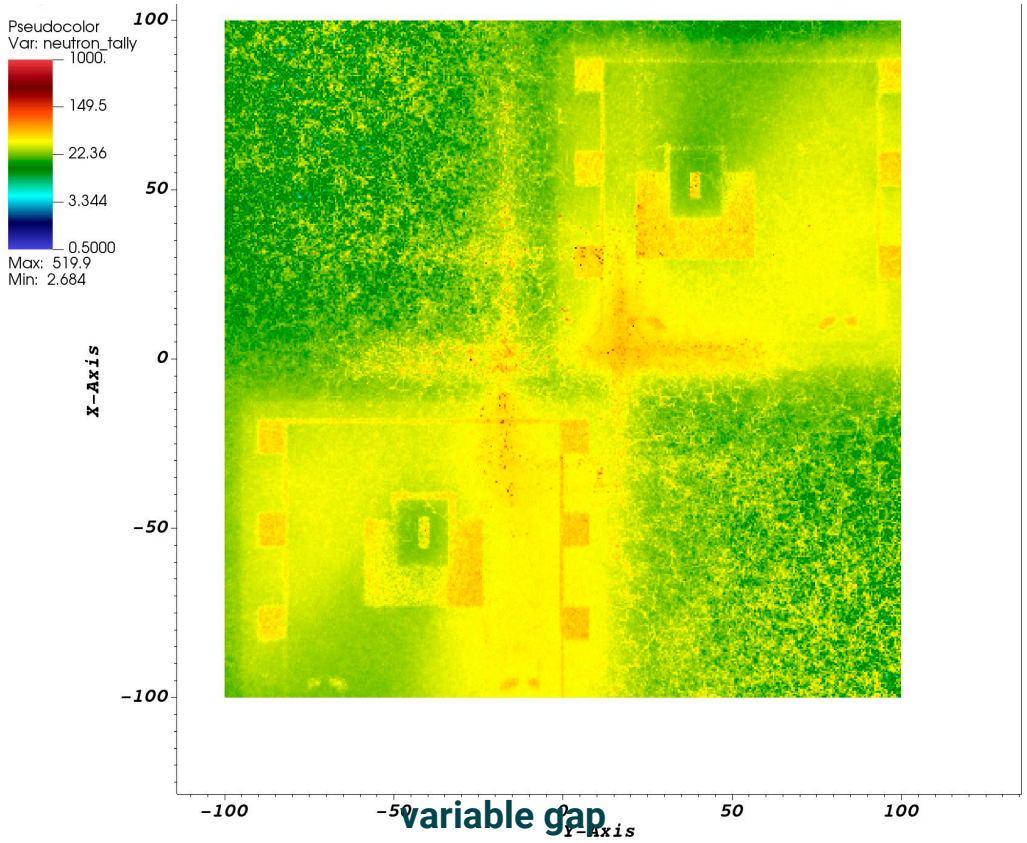
HE neutrons (> 1 MeV)



3mm uniform gap

Variable gap inside monolith increases the dose rates on bunker wall surface (bunker pass-thru upstream face)

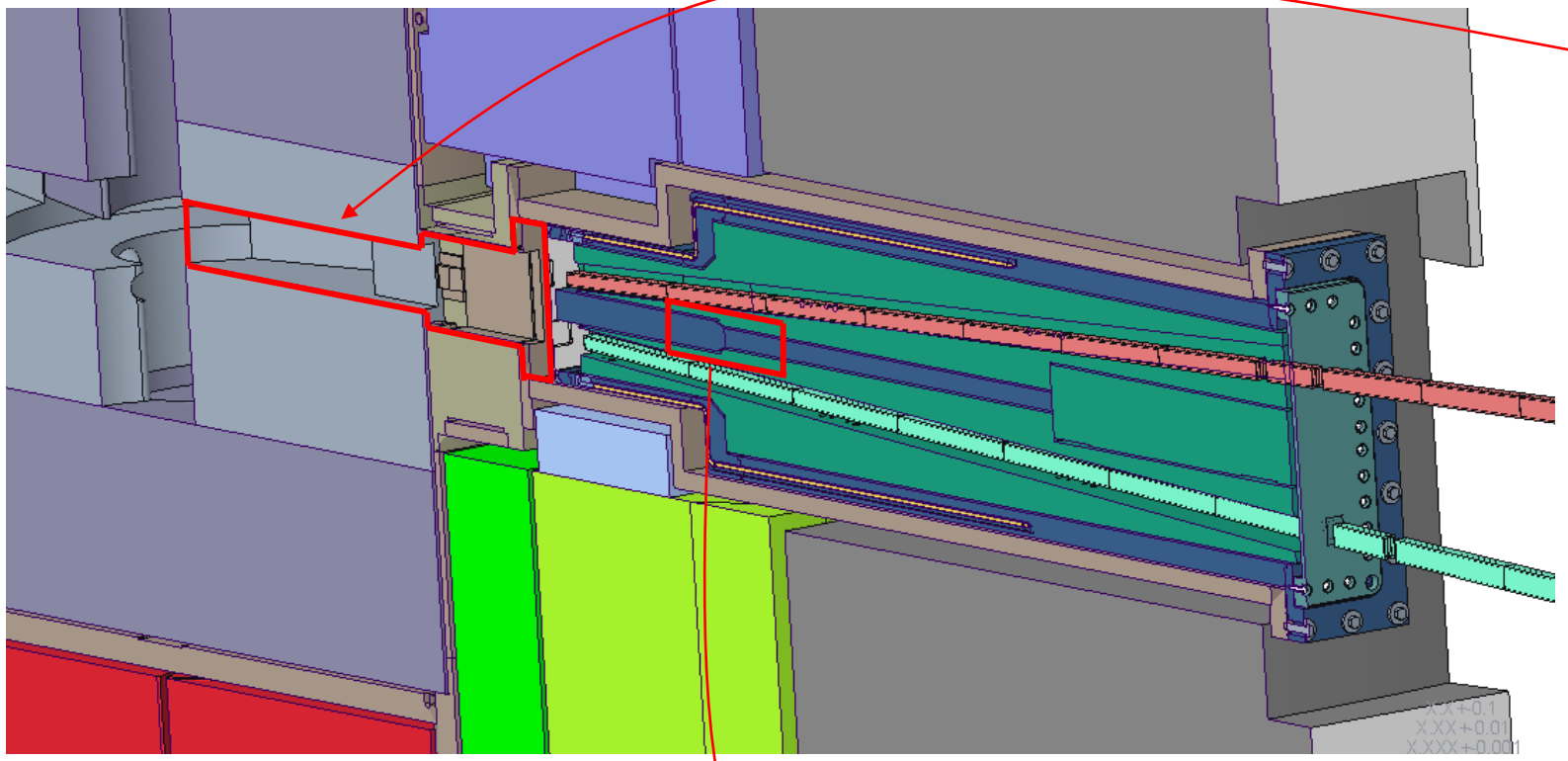
HE neutrons (> 1 MeV)



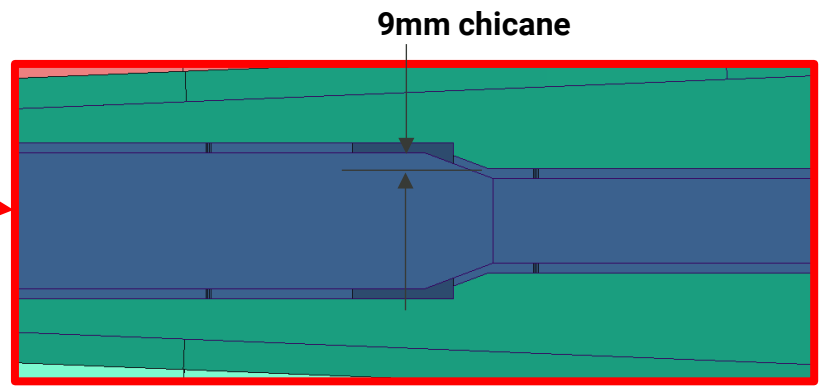
Variable gap

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

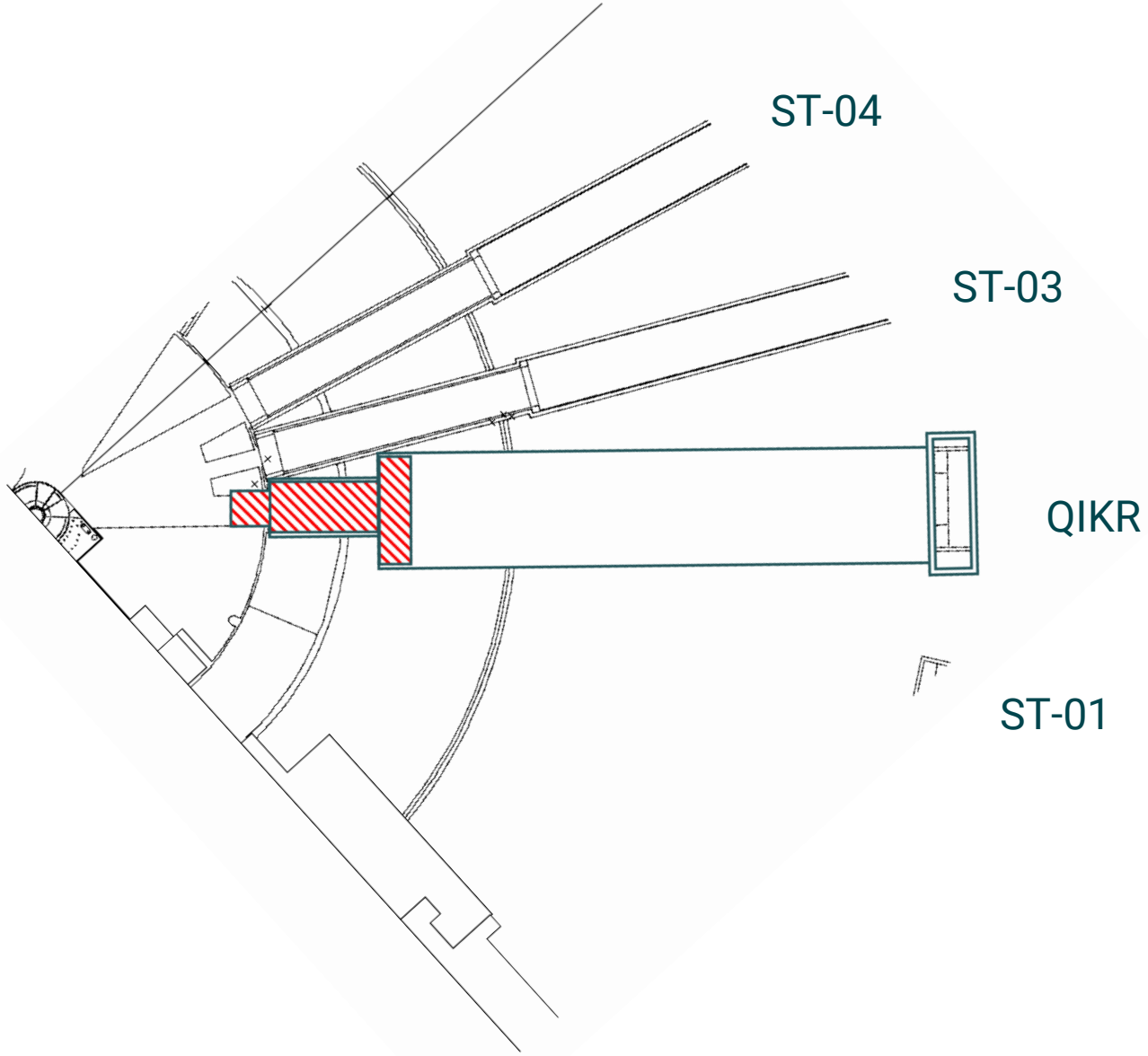
Removing Monolith Insert Chicane, Adding Steel Upstream



There is empty space between the monolith insert upstream window and the moderator… would filling this space with steel be more effective than the small monolith insert chicane at preventing neutron streaming?



What-if upstream steel insert placed into upstream cavity



In QIKR monolith design, shaded area depicted in the figure was empty space

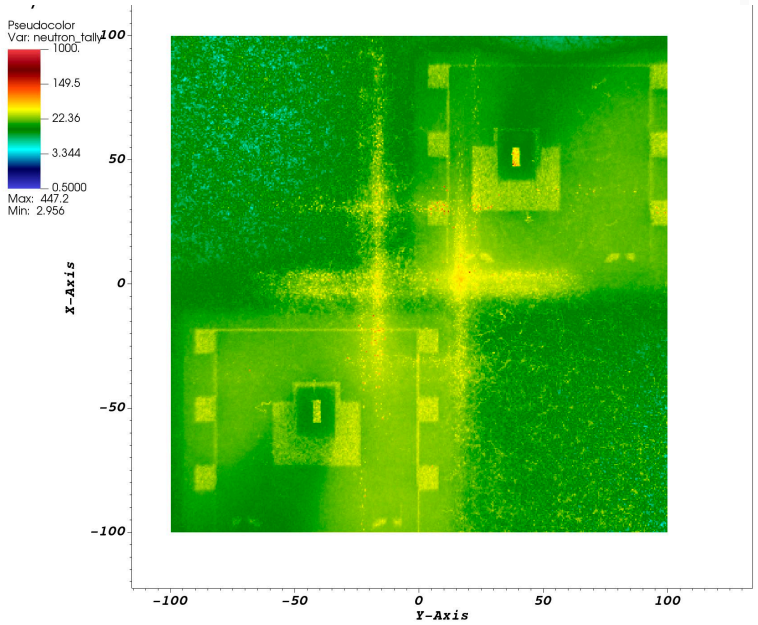
Filling this gap with steel (named upstream steel insert, USI) will reduce the high-energetic neutrons streaming through gaps around/in monolith/optic inserts

Assess the impact on USI on dose rates

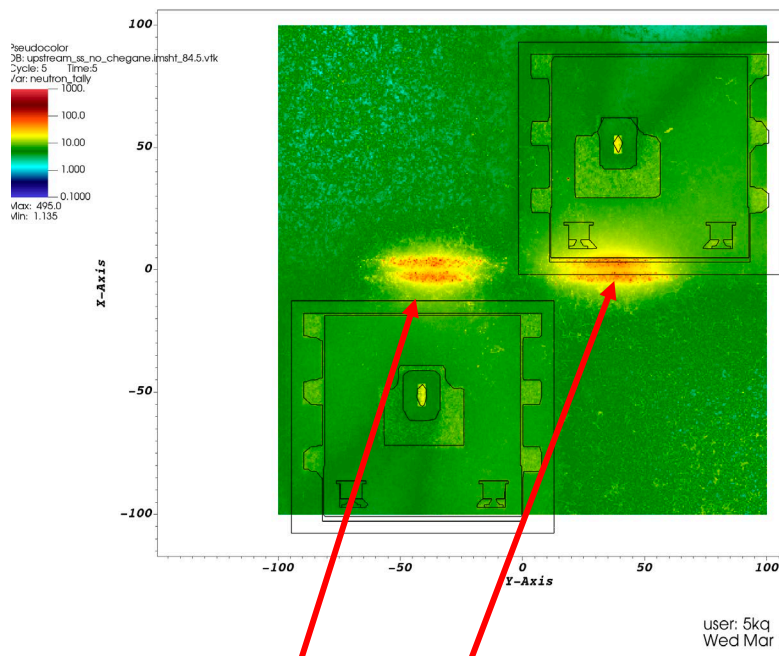
Neutron dose rate (mrem/hr)

HE neutrons (> 1 MeV)

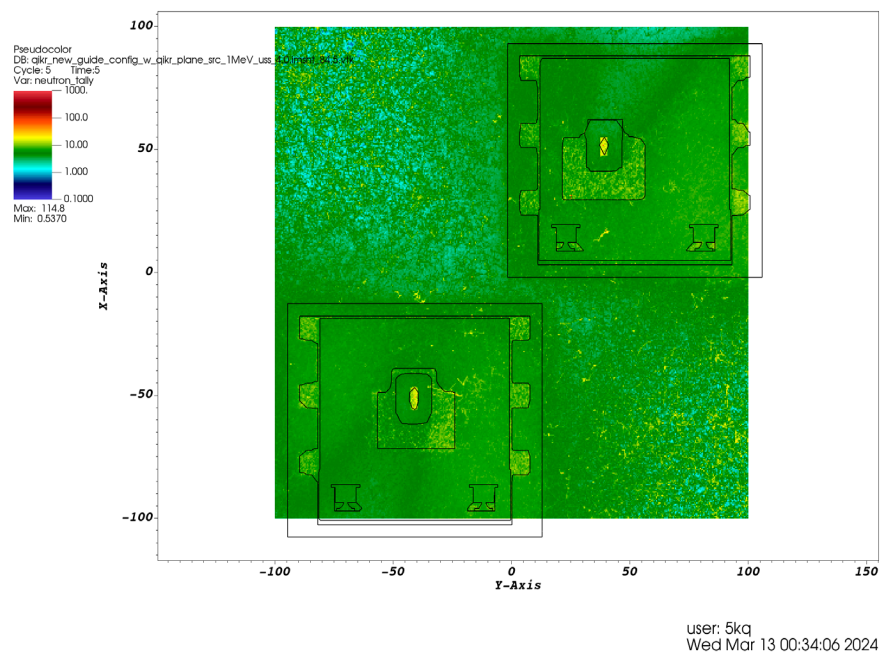
No upstream steel insert



Upstream steel insert, no chicane



Upstream steel insert, with chicane



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

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 is neutronically best (better shielding performance)

Questions??