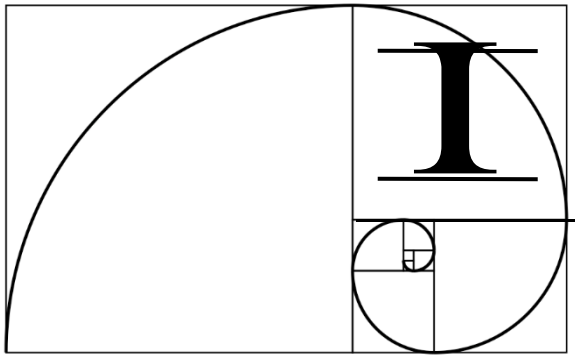


# ISODAR @ KamLAND

# The IsoDAR Target at KamLAND for NBI2014

## and now for something completely different…

L. Bartoszek

**BARTOSZEK ENGINEERING**

**With contributions from the DAEdALUS/IsoDAR collaboration**

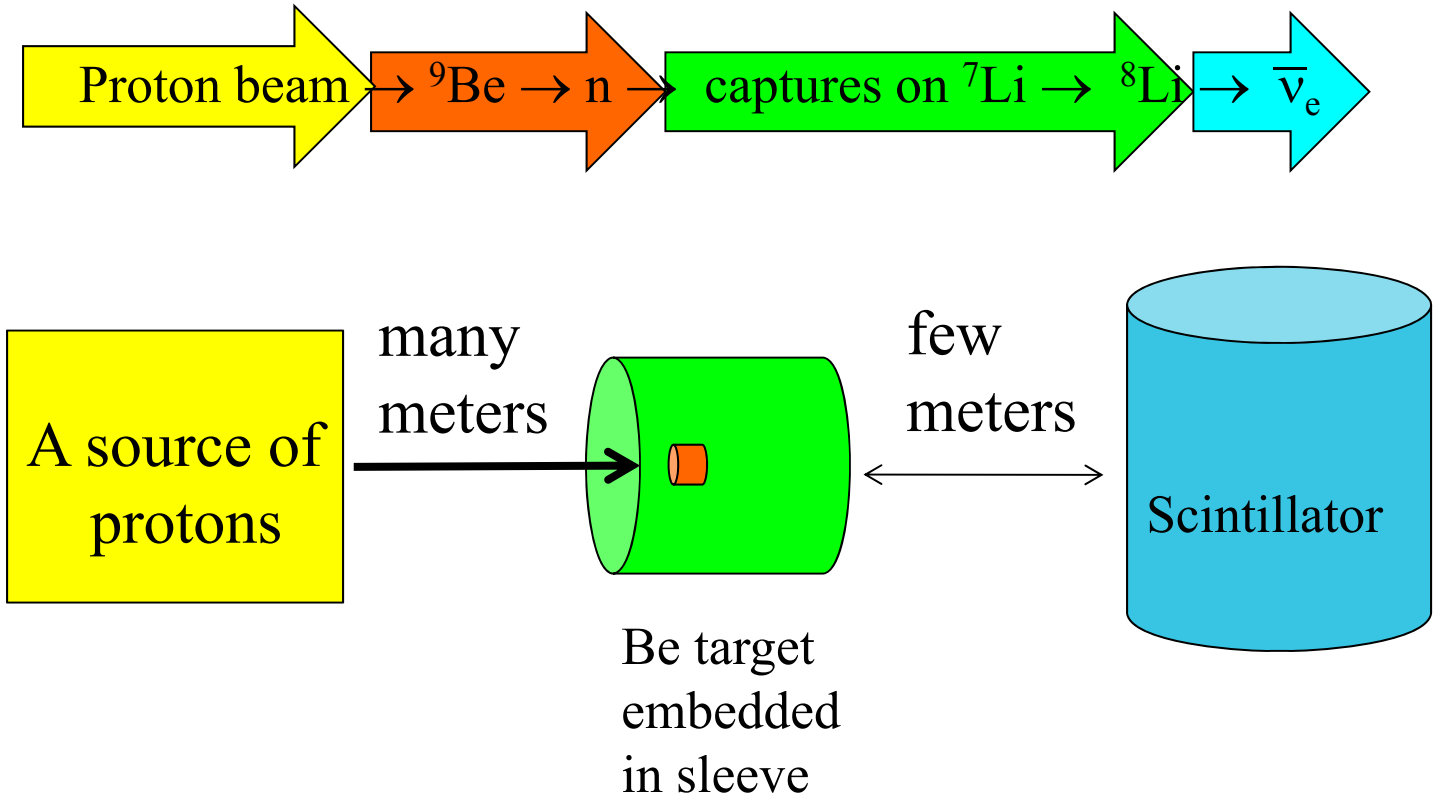
9/25/14

# What is IsoDAR?

IsoDAR is:

1. A search for sterile neutrinos
2. A Decay At Rest neutrino source next to the KamLAND detector (or one like it)
3. A step in the development of the DAEdALUS experiment
   - The IsoDAR cyclotron is the injector for the DAEdALUS cyclotron
   - 10 milliamps of 60 MeV protons, 600 kW on the target, CW

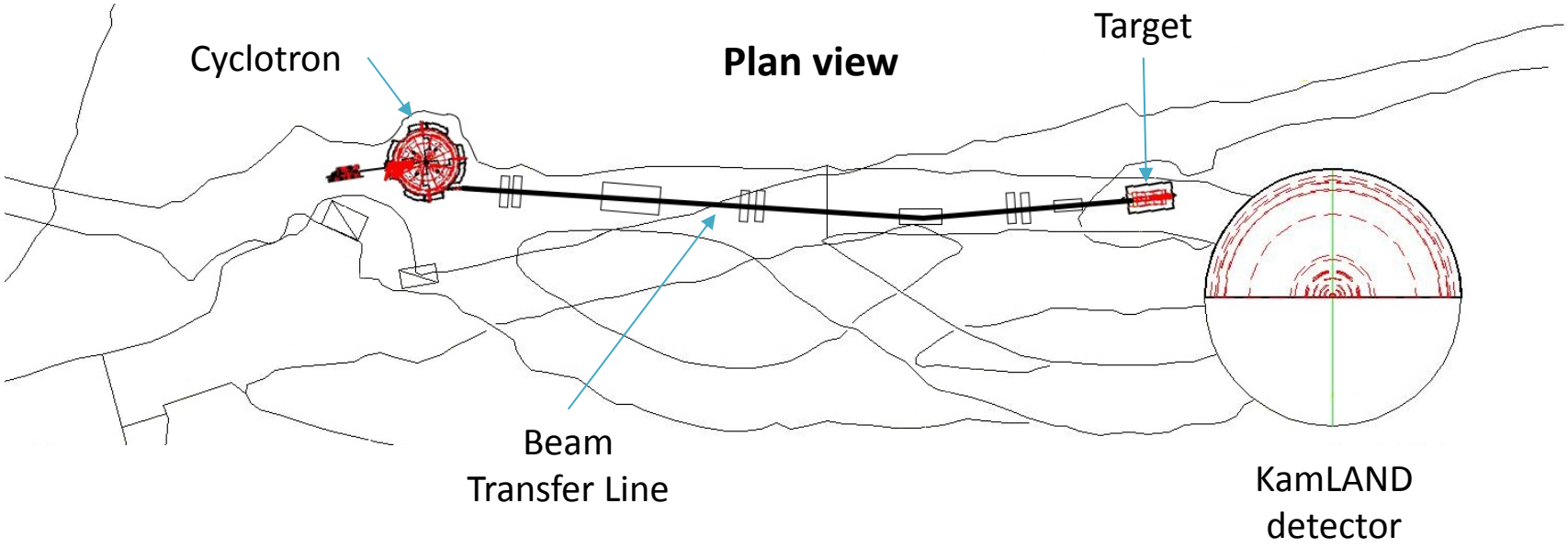
# Schematic of IsoDAR



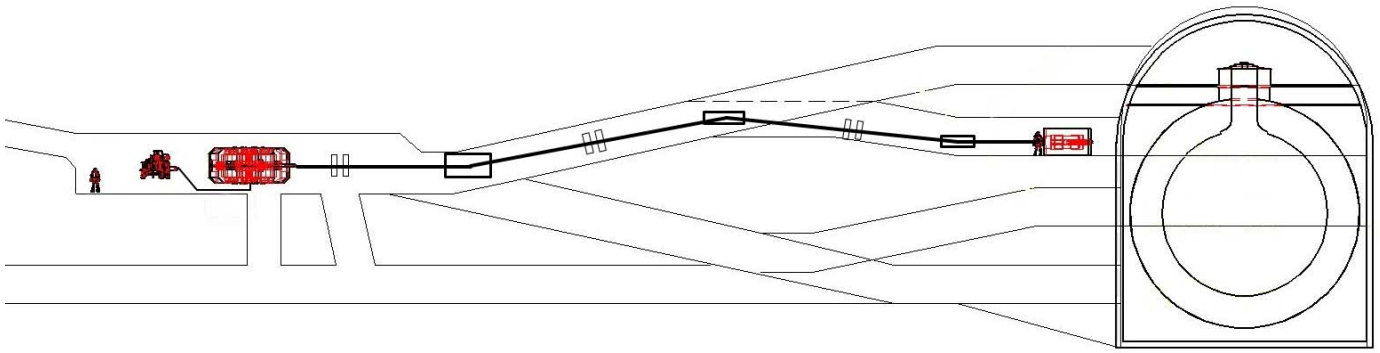

The proton-producing machine (cyclotron) is separate from the neutron-producing target to avoid:

1) Activation of the machine so it can be serviced
2) Unwanted backgrounds to the antineutrino flux

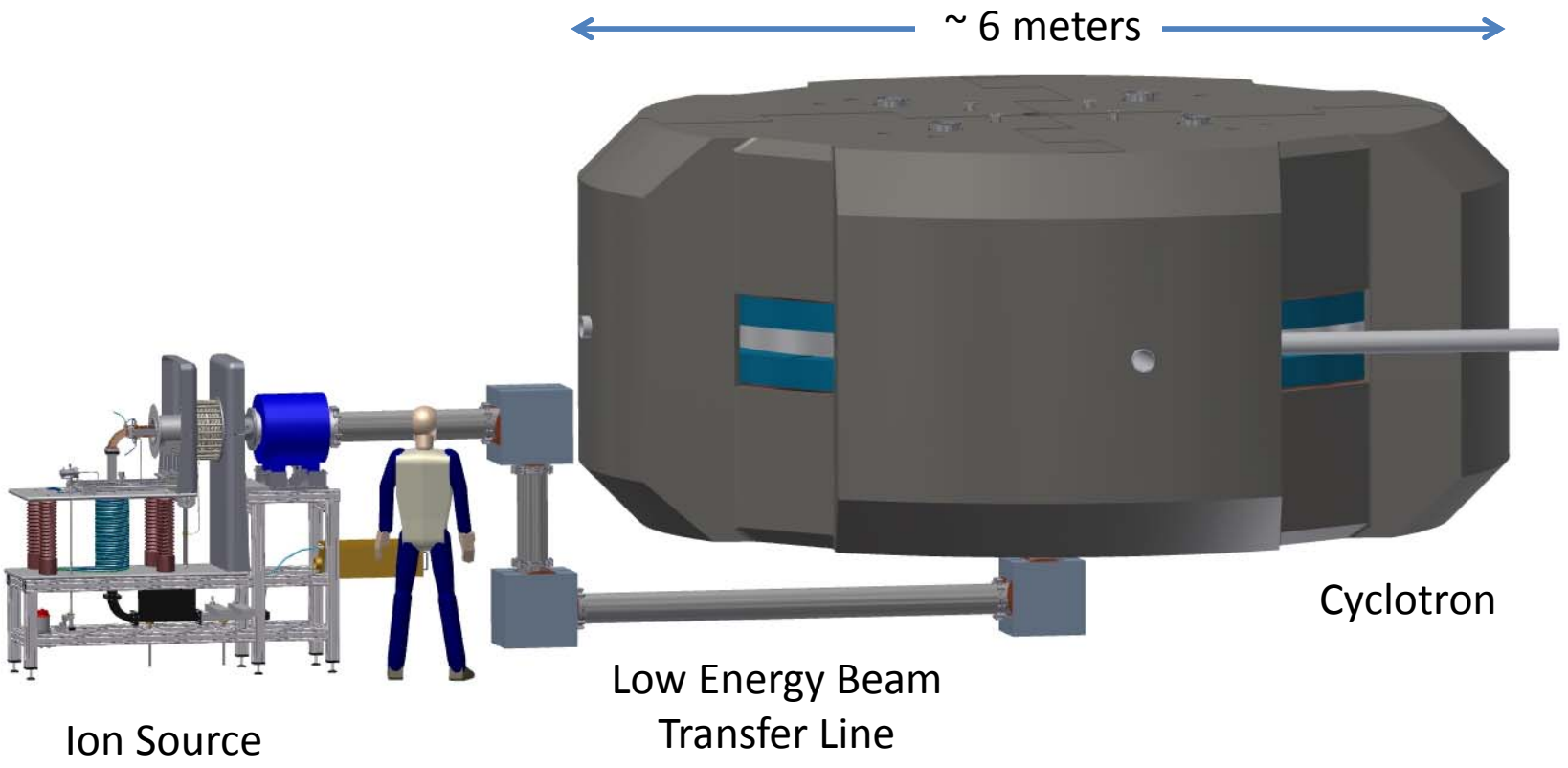
# IsoDAR Configuration at KamLAND



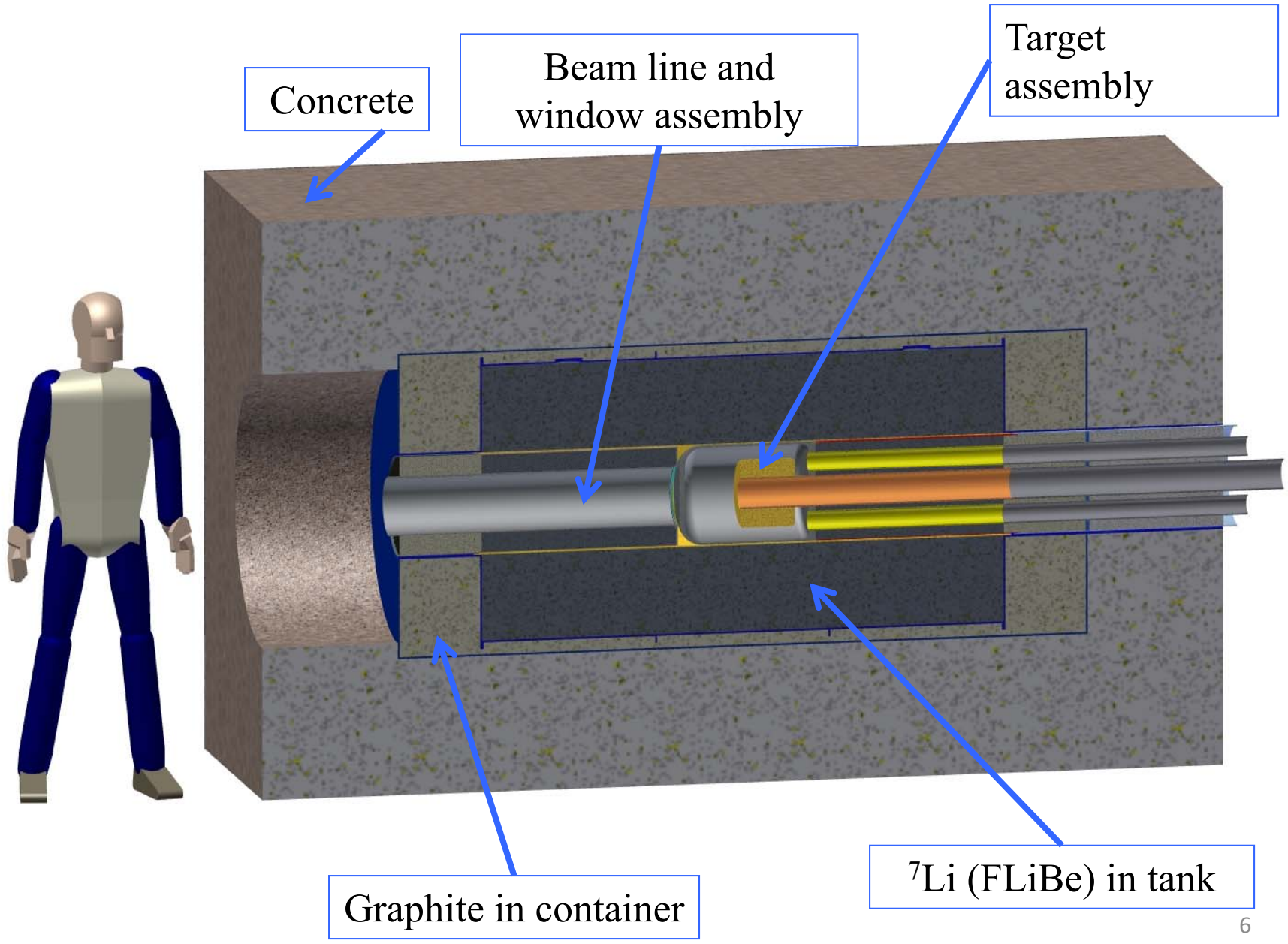

**Elevation view**



# The IsoDAR Cyclotron and Ion Source



# Cross-section of the KamLAND target



# What is FLiBe?

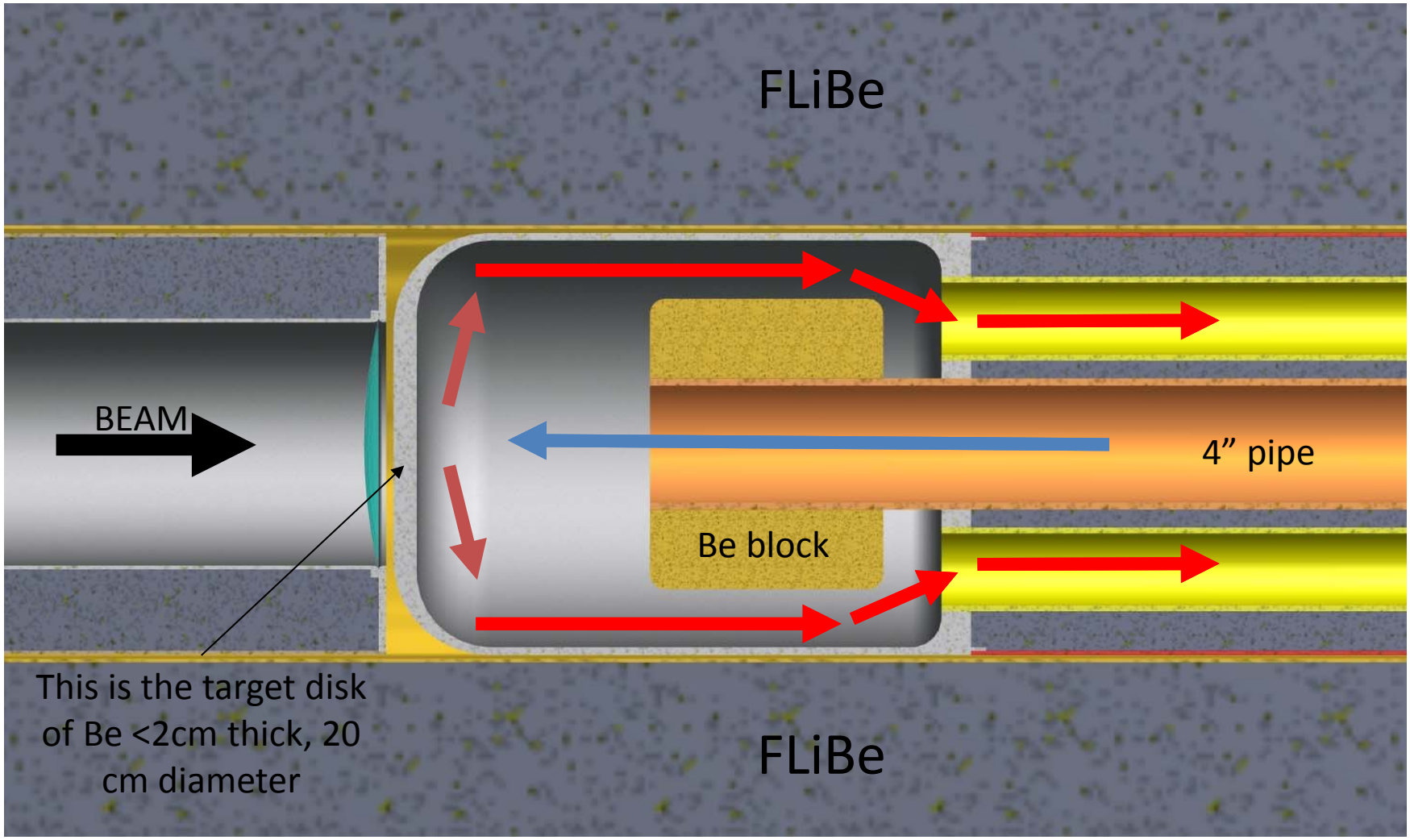
"Purified Flibe" by Bckelleher - Own work.
http://commons.wikimedia.org/wiki/File:Purified_Flibe.JPG#mediaviewer/File:Purified_Flibe.JPG

"**FLiBe** is a salt made from a mixture of lithium fluoride (LiF) and beryllium fluoride ($BeF_2$). It has been used in the Molten Salt Reactor Experiment.

The low atomic weight of lithium, beryllium and to a lesser extent fluorine make FLiBe an effective neutron moderator. As natural lithium contains ~7.5% lithium-6, which tends to absorb neutrons producing alpha particles and tritium, nearly pure lithium-7 is used to give the FLiBe a small cross section."
--from the Wikipedia

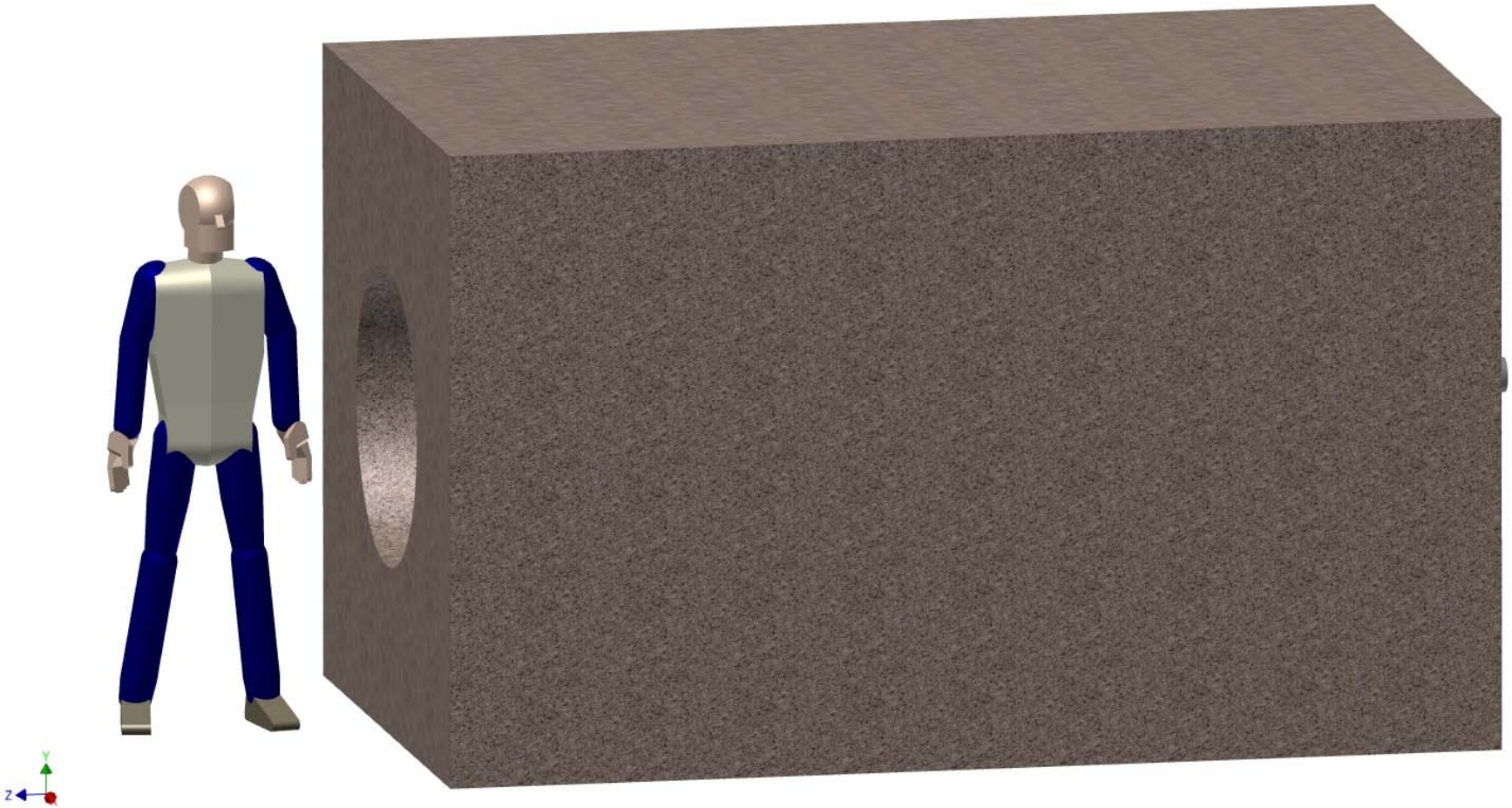
*We need the isotopically pure Li-7 to absorb neutrons, become Li-8, and decay producing anti-electron neutrinos.*

Close-up section view of beryllium water vessel



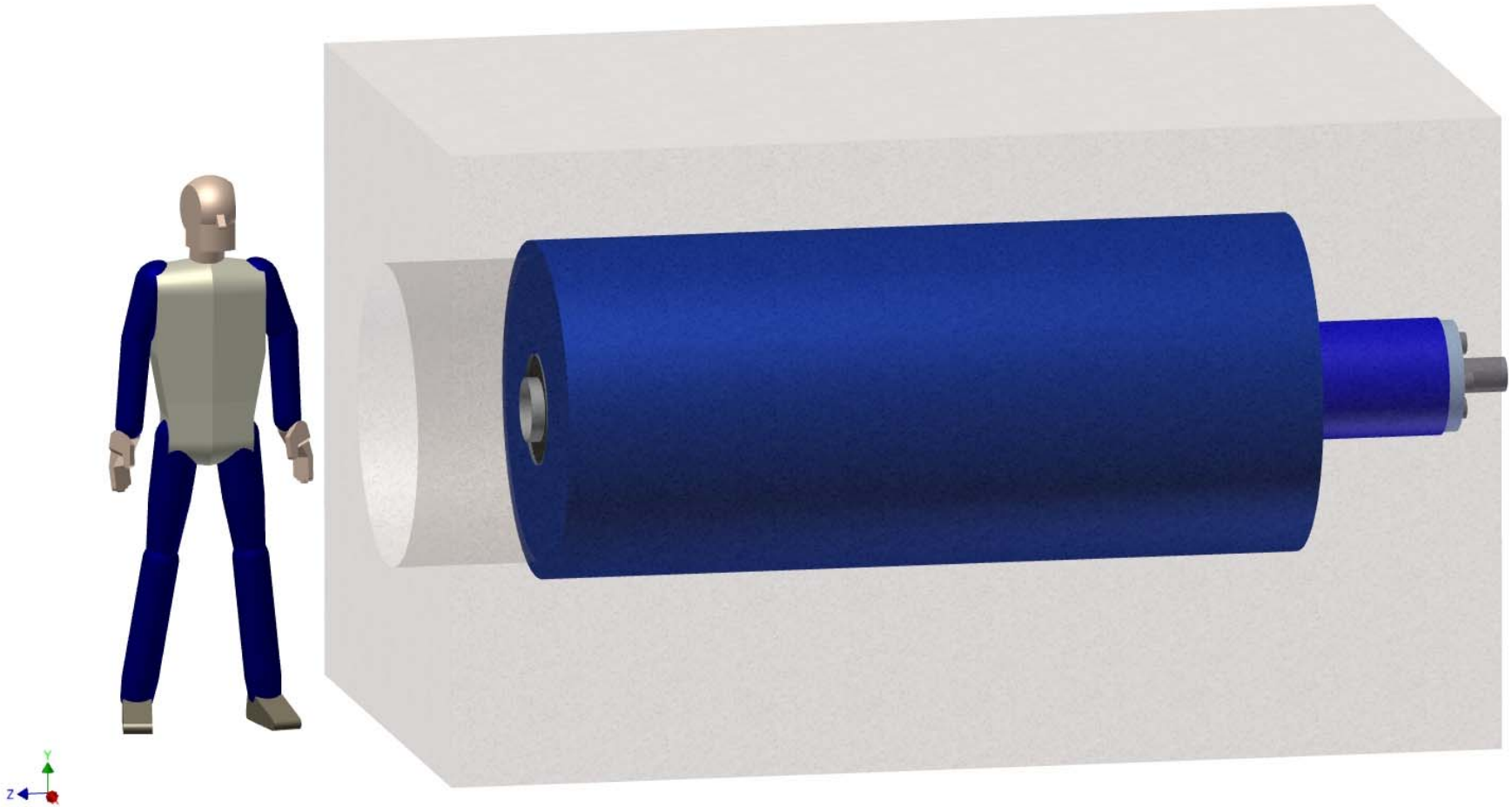

All the metal inside the Li/FLiBe is beryllium to allow neutrons to get into the FLiBe. Arrows indicate water flow.

Outside view of target, everything opaque



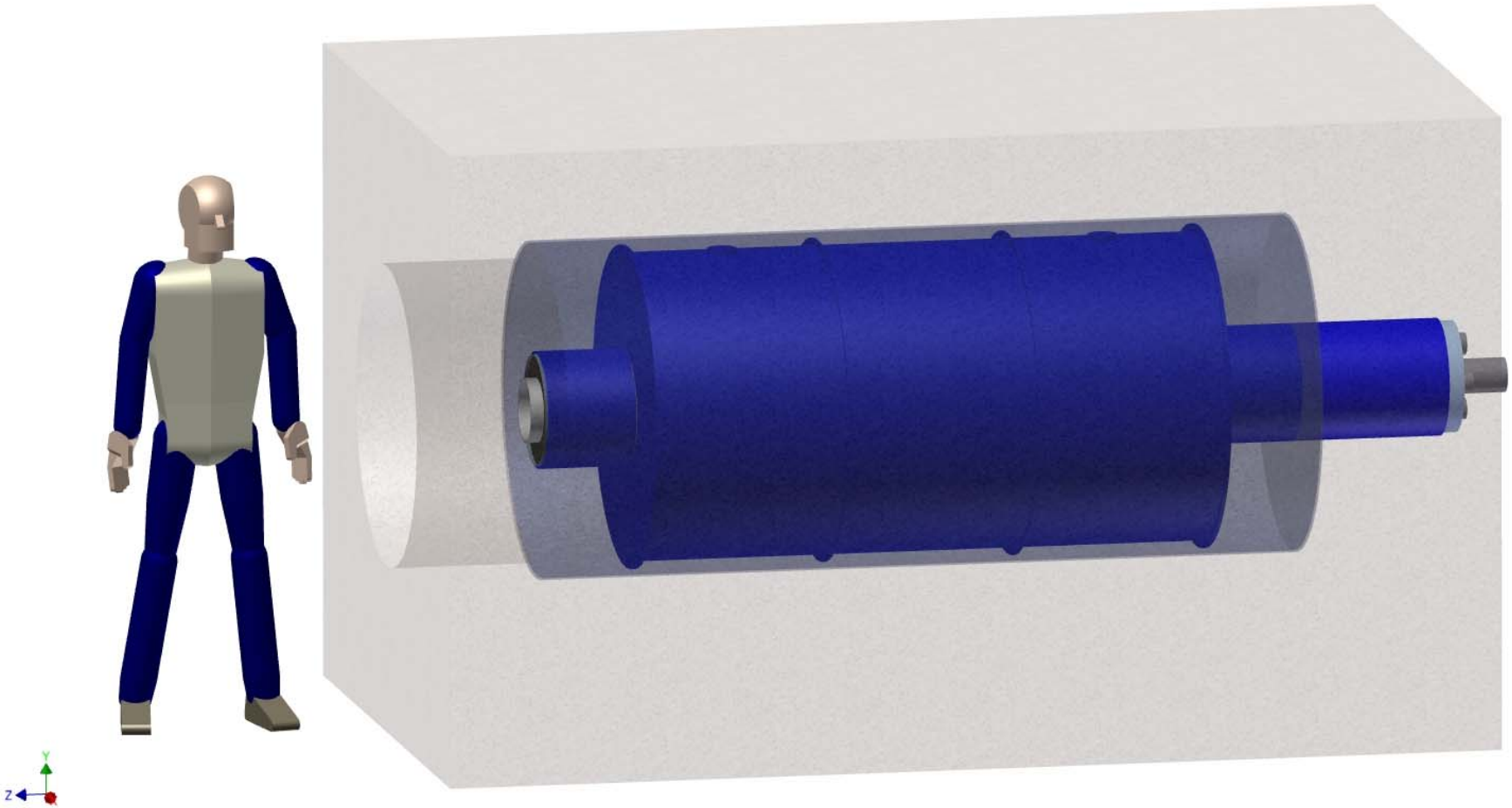
31.8 tons of concrete in the outer block (not counting the concrete in the target module.)

Concrete shield made transparent showing the graphite container



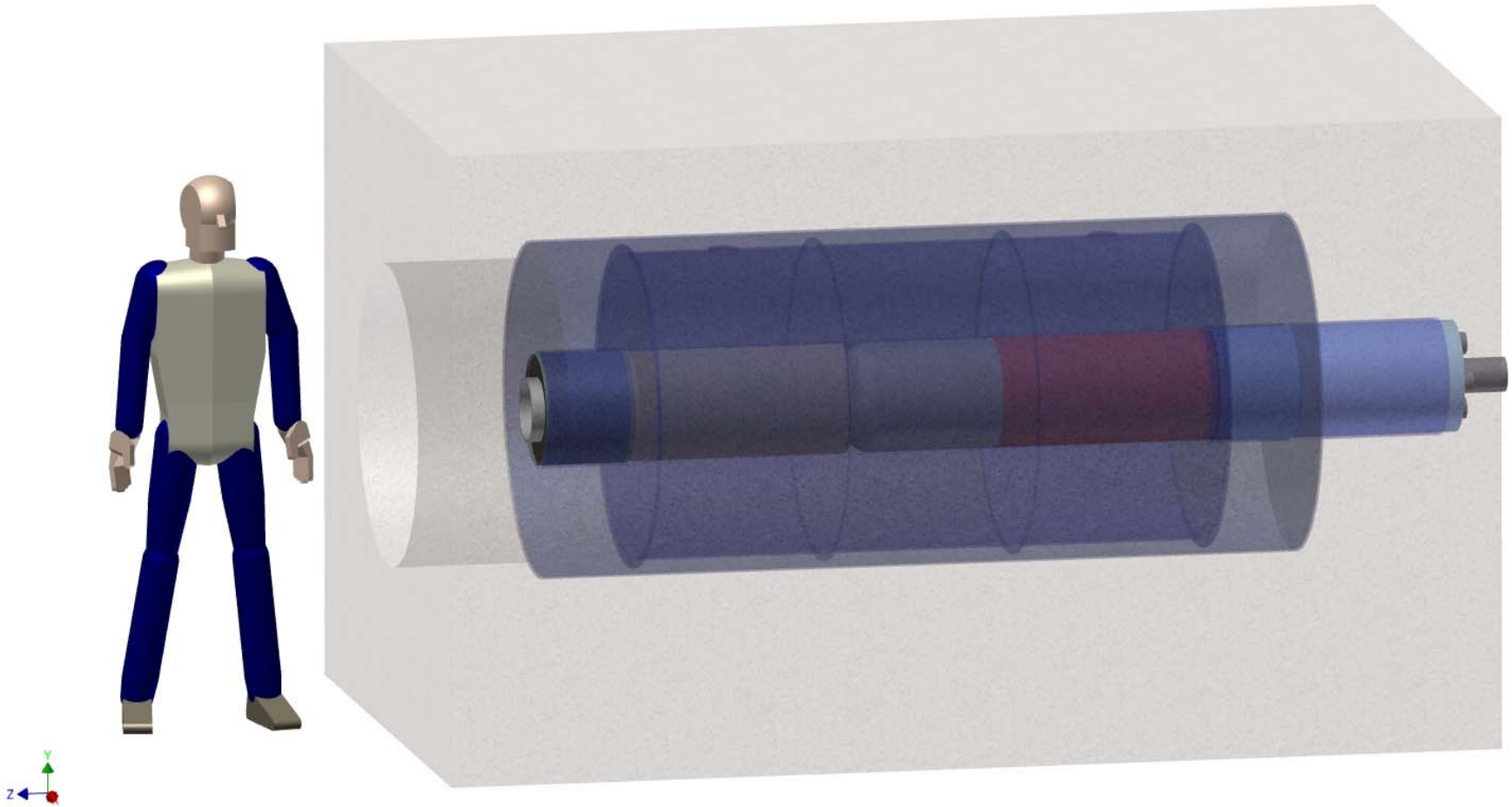
We need to decide if we need dense bricks of nuclear graphite, or can we get away with packing graphite powder around the FLiBe tank? The bricks will be more expensive but denser.

Graphite and its container made transparent showing the Li/FLiBe tank

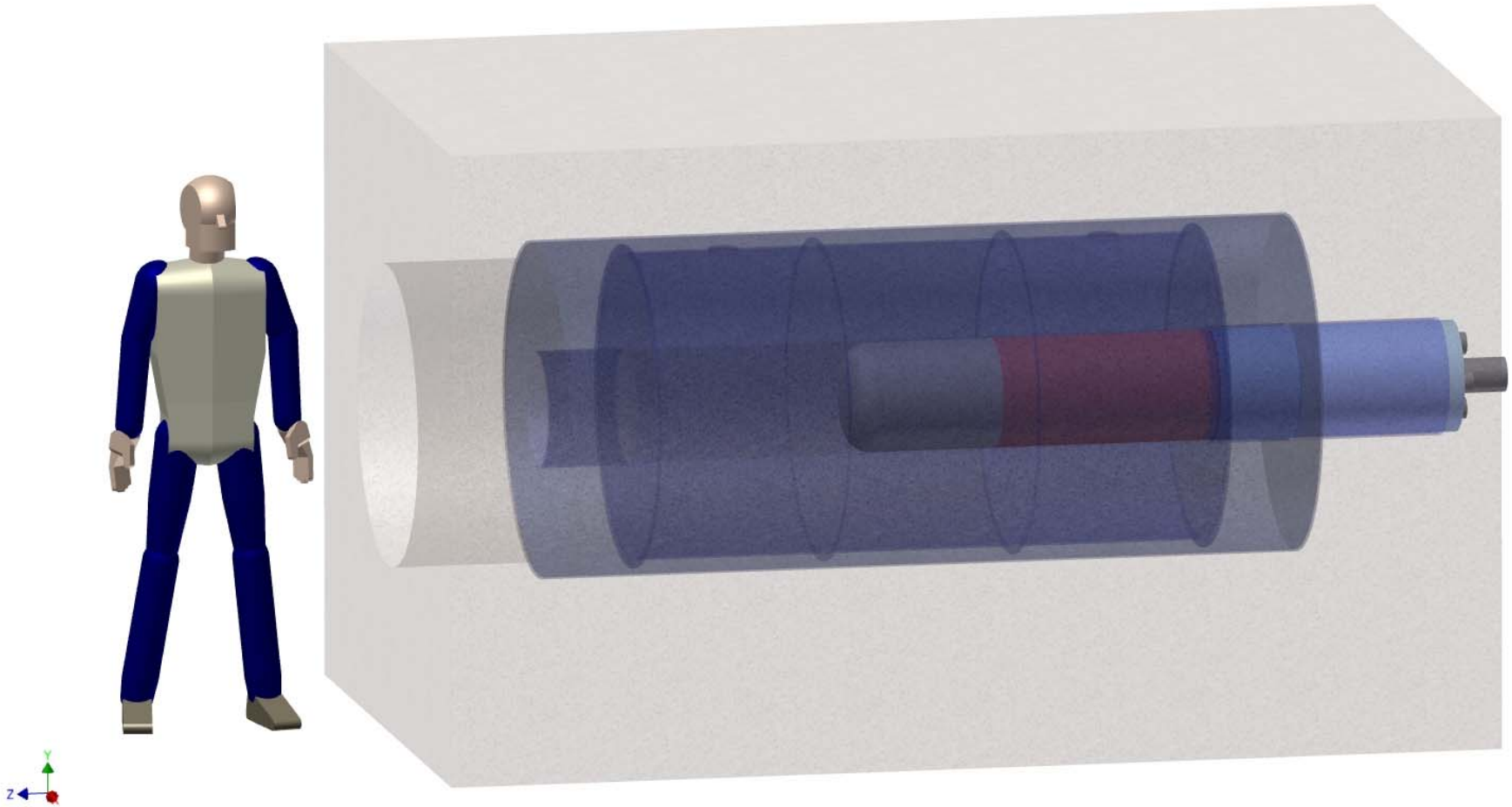


At this point, FLiBe looks more benign than elemental Lithium. Either one can be cast inside this tank, but to cast the lithium the whole thing has to be done in an inert atmosphere making it much more complicated.

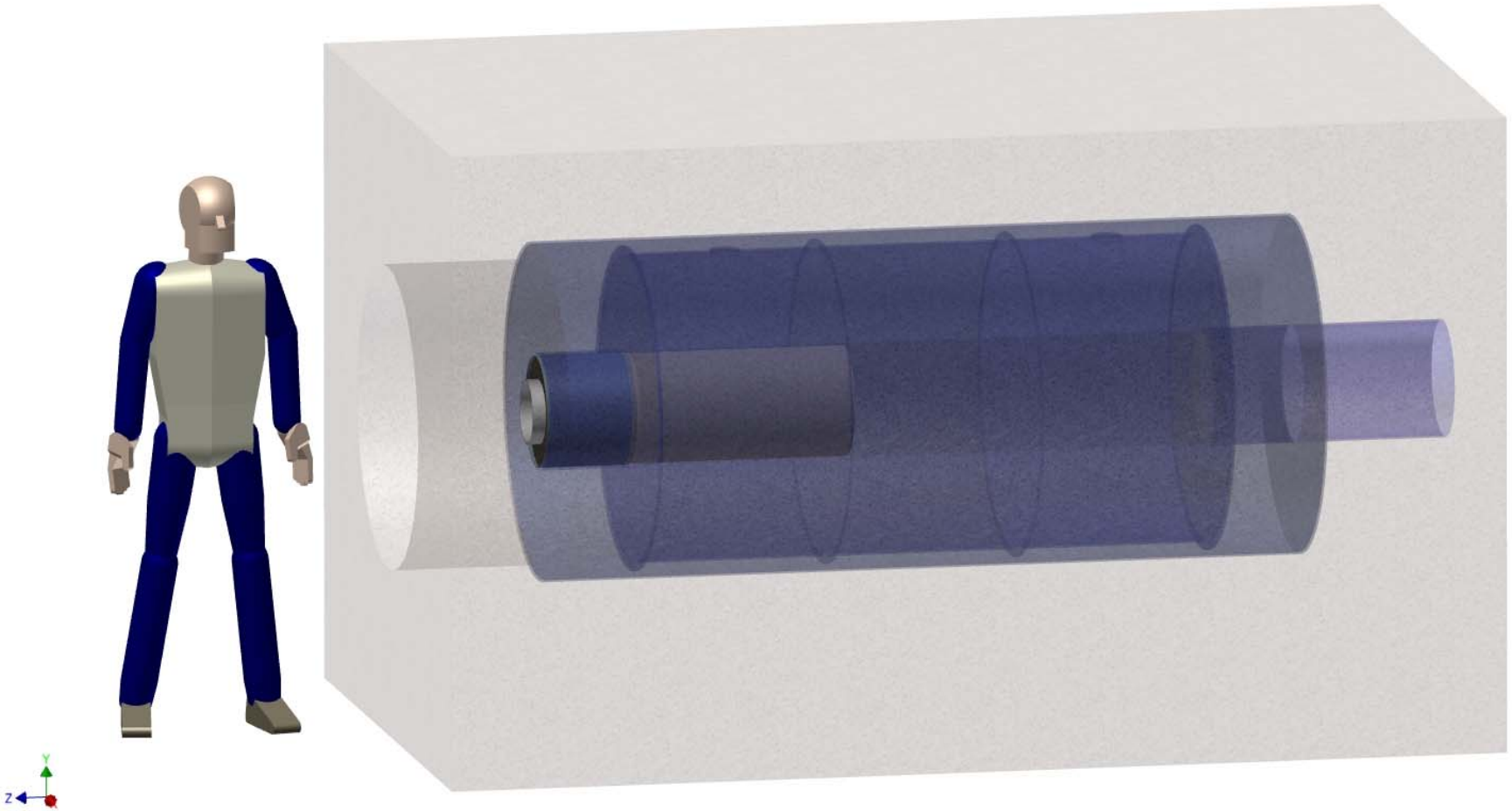
FliBe tank made transparent showing the beam line module and the target module



Beam line module turned off showing only target in place



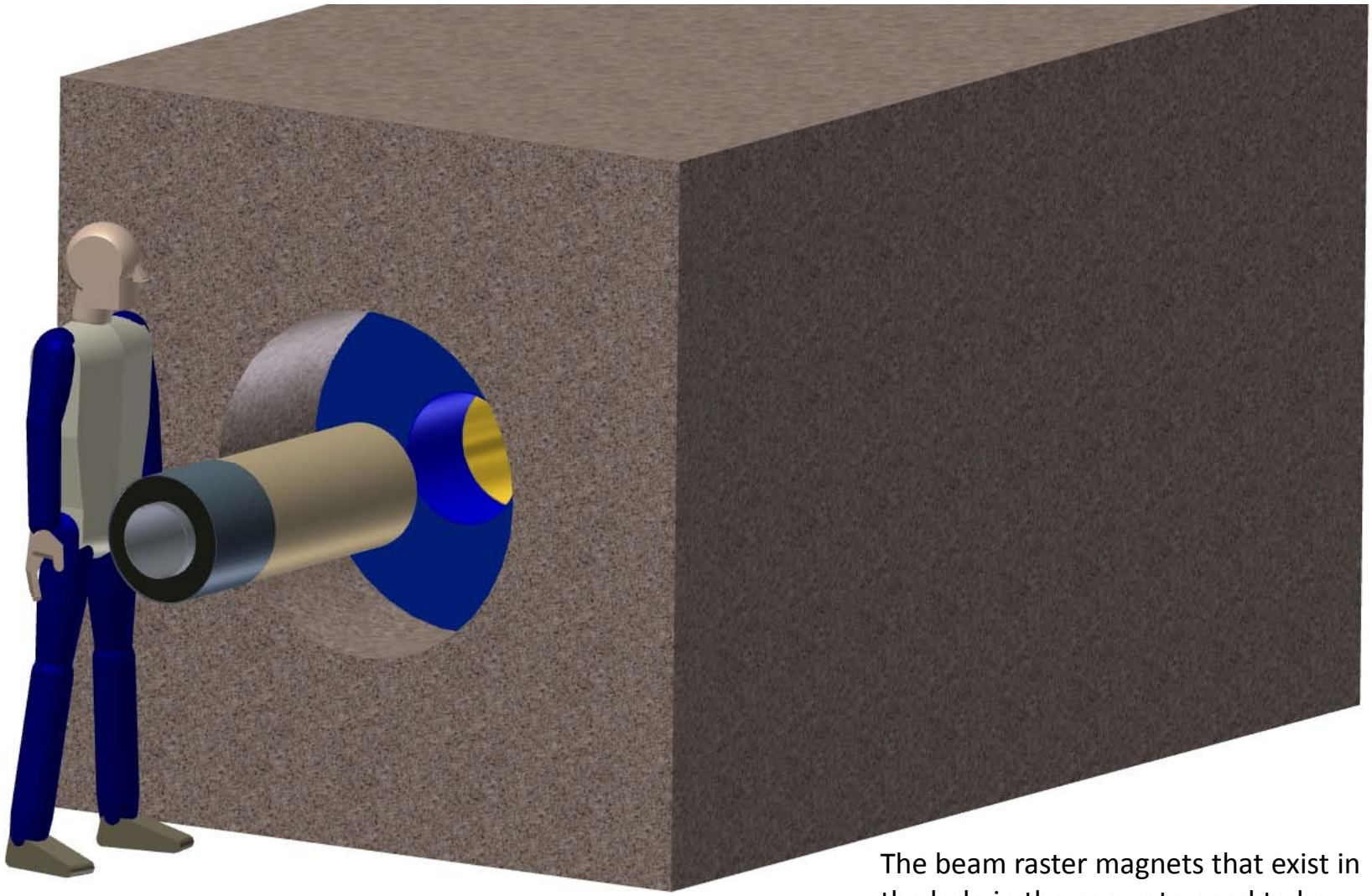
# Target turned off showing beam line module in place



In this design either module can be in or out completely independently of the other. The design philosophy was to put layers of FLiBe and graphite in each module to avoid gaps.

There may be a problem with the beam window in this design getting too hot, or the air gap contributing to air activation. We are looking at evacuating the space around the target.

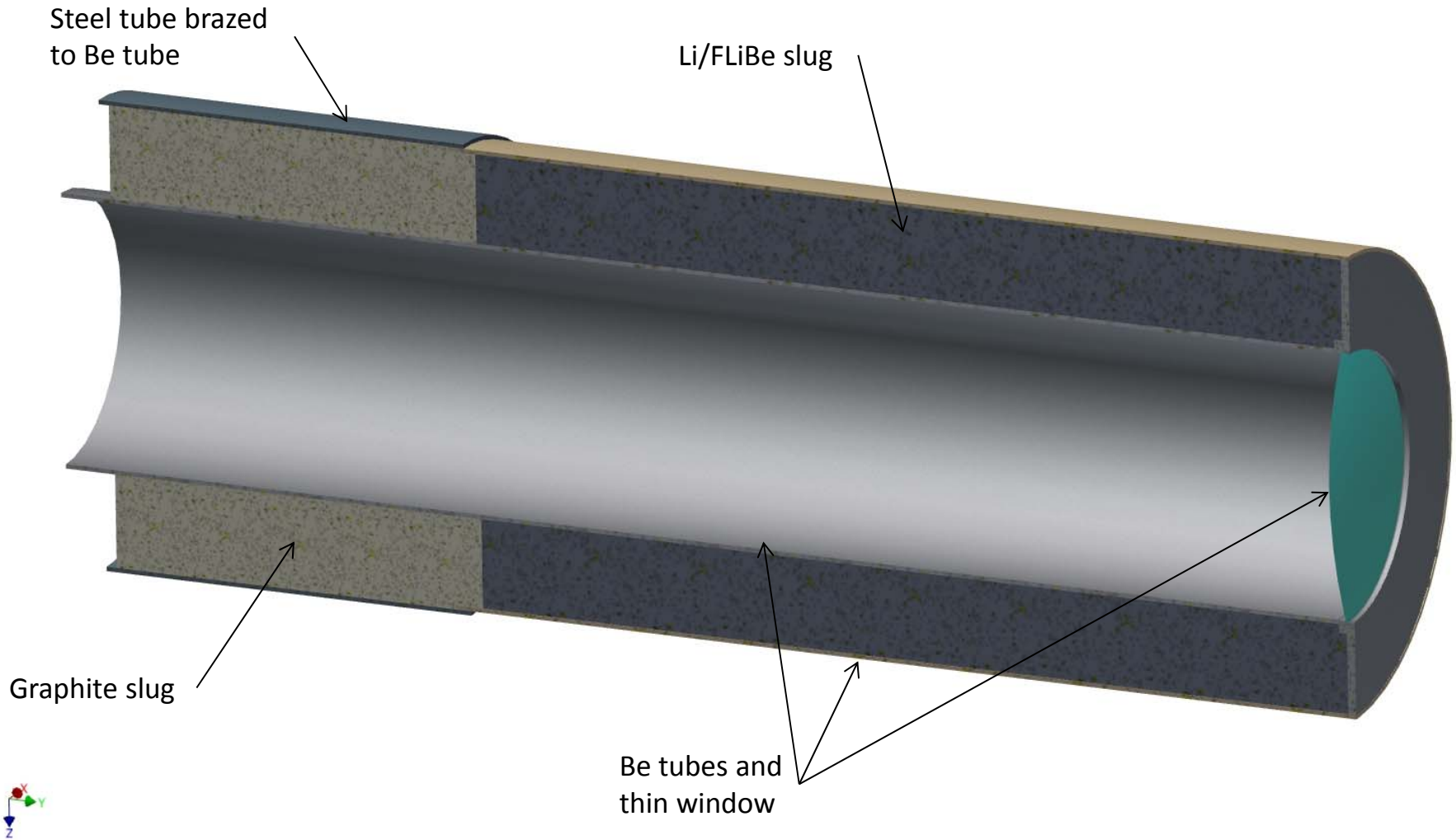
Showing the Beam line module ready for insertion into the target



The module as shown weighs 178 lbs. It will need a rail system to guide it into the opening.

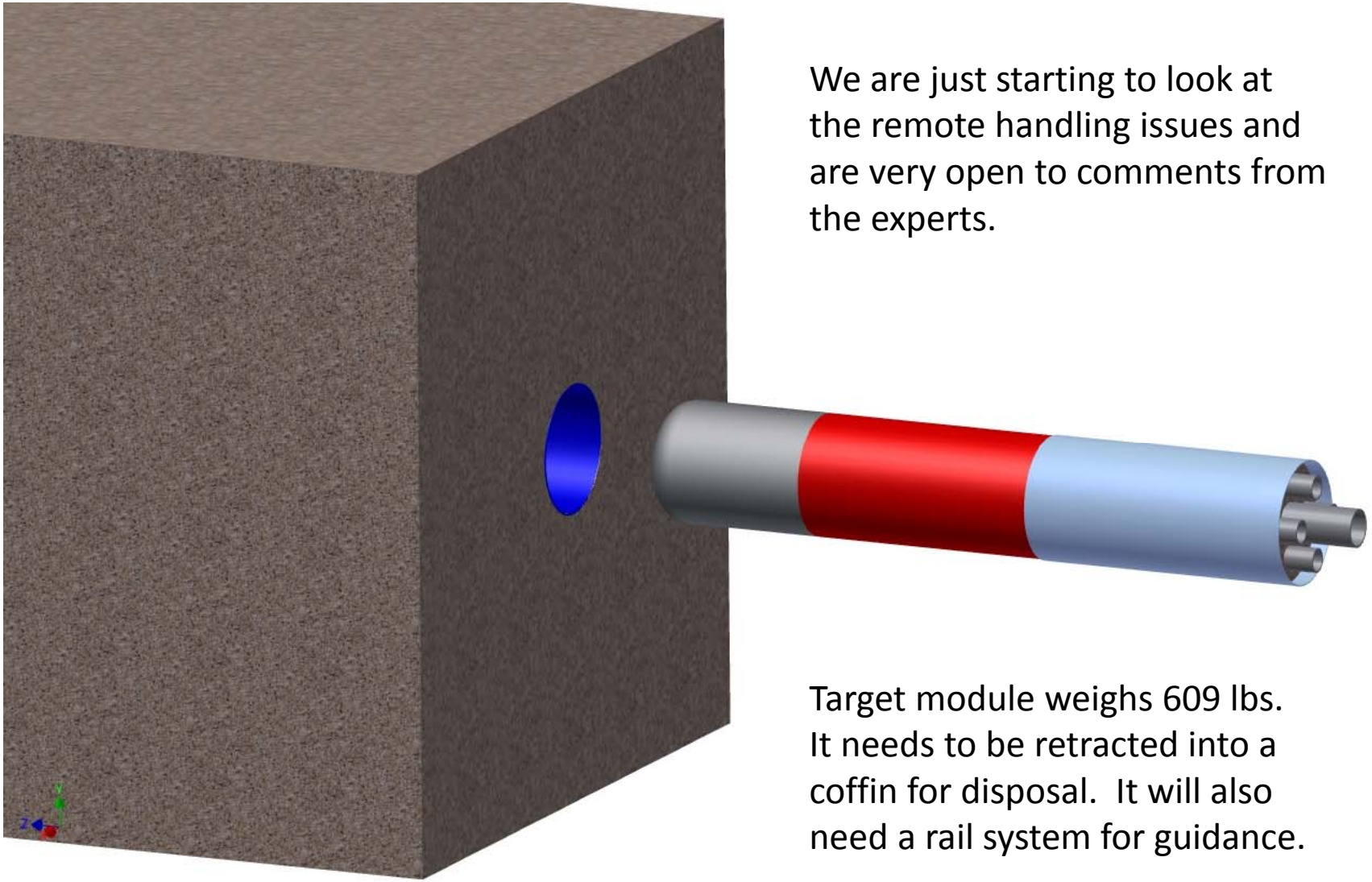
The beam raster magnets that exist in the hole in the concrete need to be removed to replace this module. How hot will it be to expose the Be target core? Need remote handling?

Section view of the beam line module showing the FliBe and graphite




We need to look at the energy deposition in the thin window and check whether air activation will be an issue. This work is in progress.

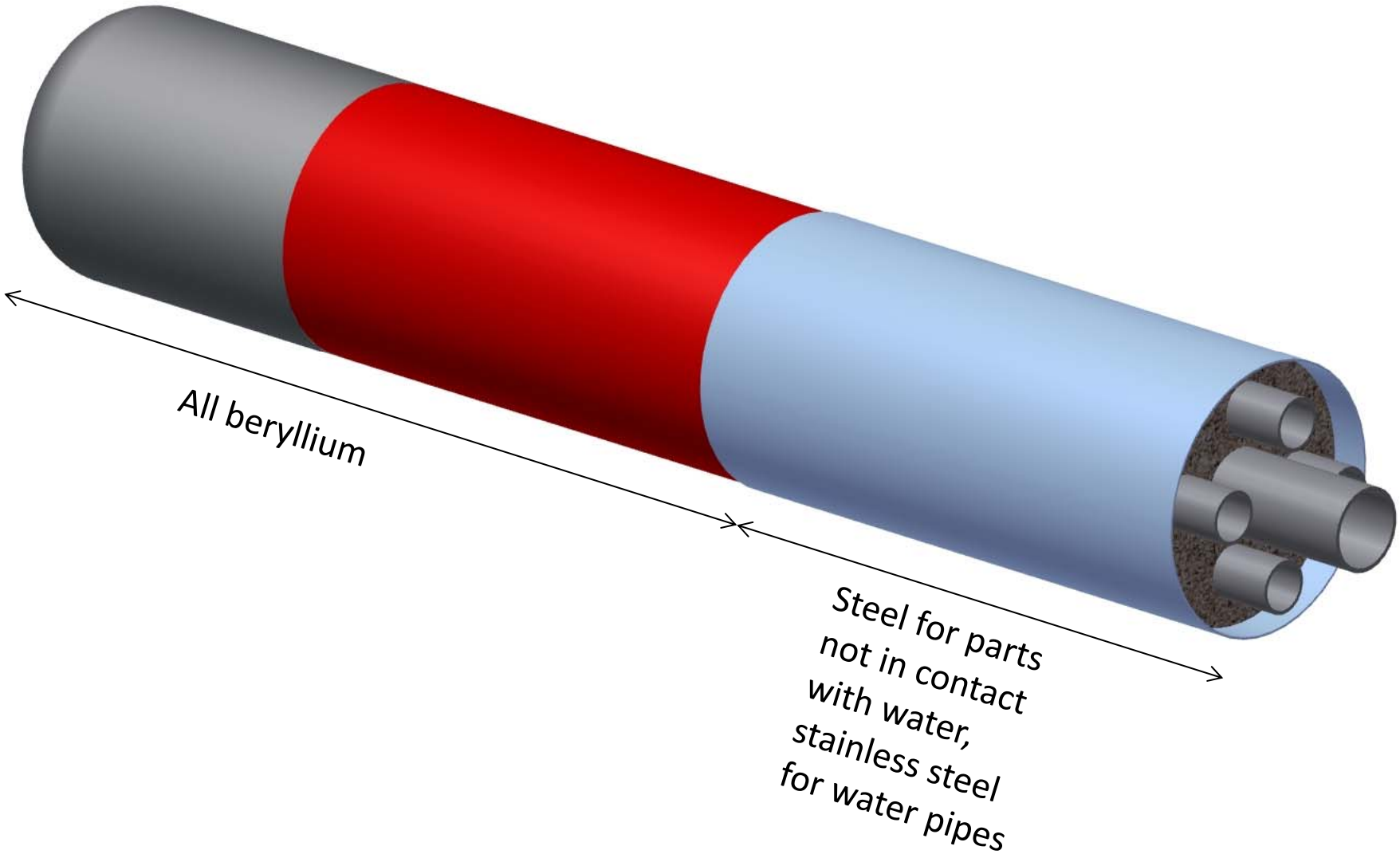
View showing the target module (“torpedo”) ready for insertion



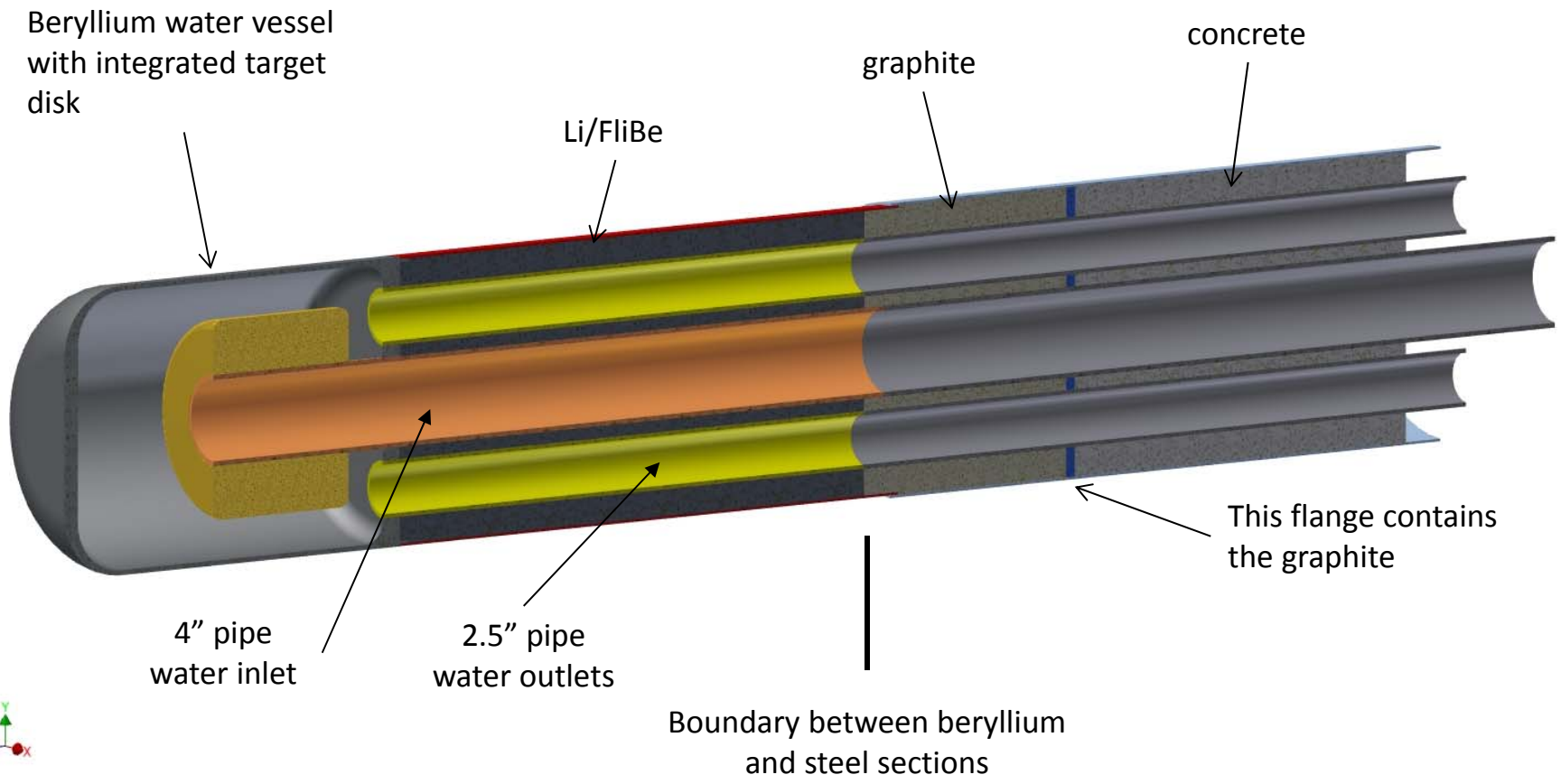
We are just starting to look at the remote handling issues and are very open to comments from the experts.

Target module weighs 609 lbs. It needs to be retracted into a coffin for disposal. It will also need a rail system for guidance.

View of the different sections of the target torpedo

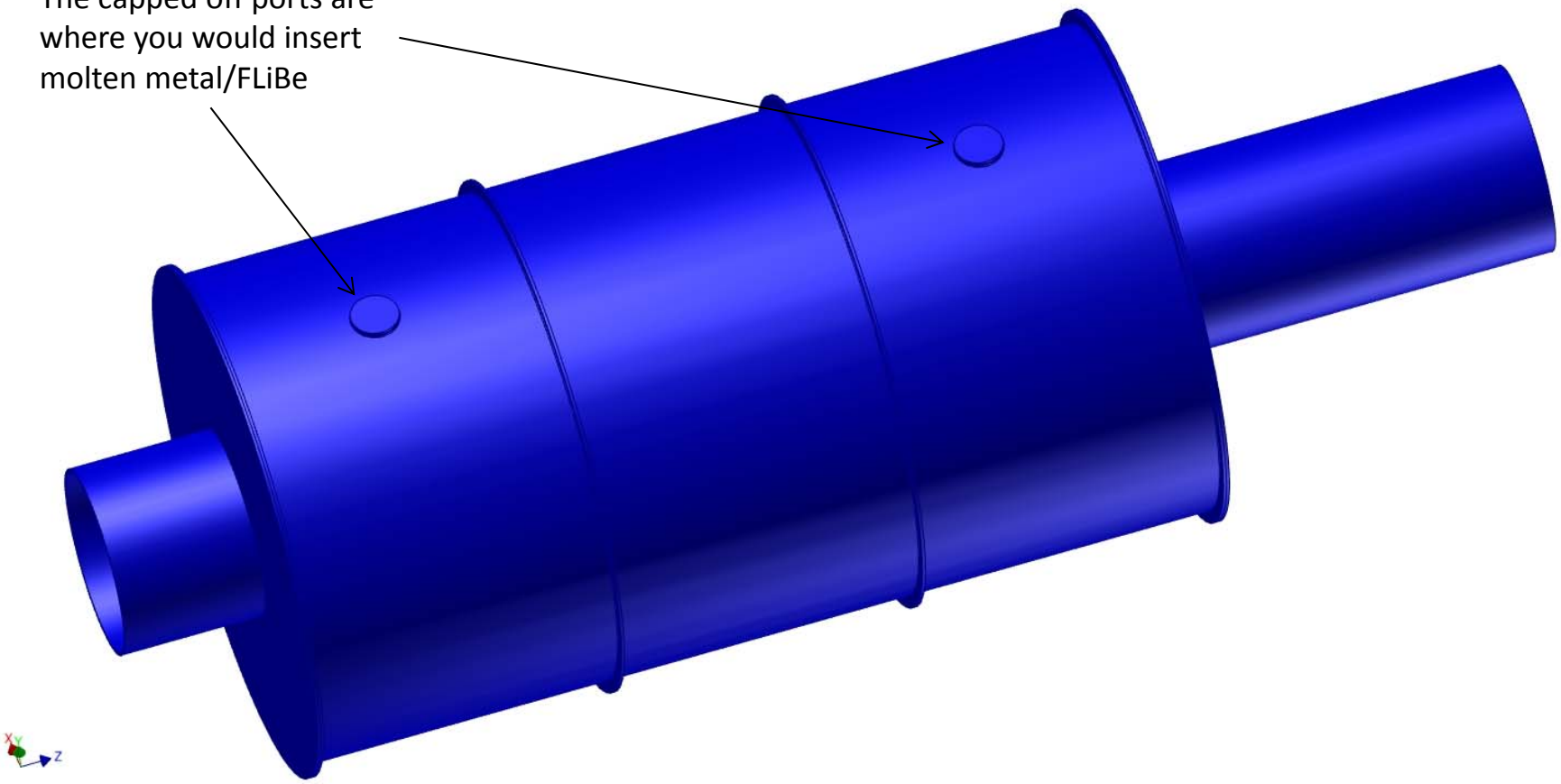


# Section view of the Target torpedo



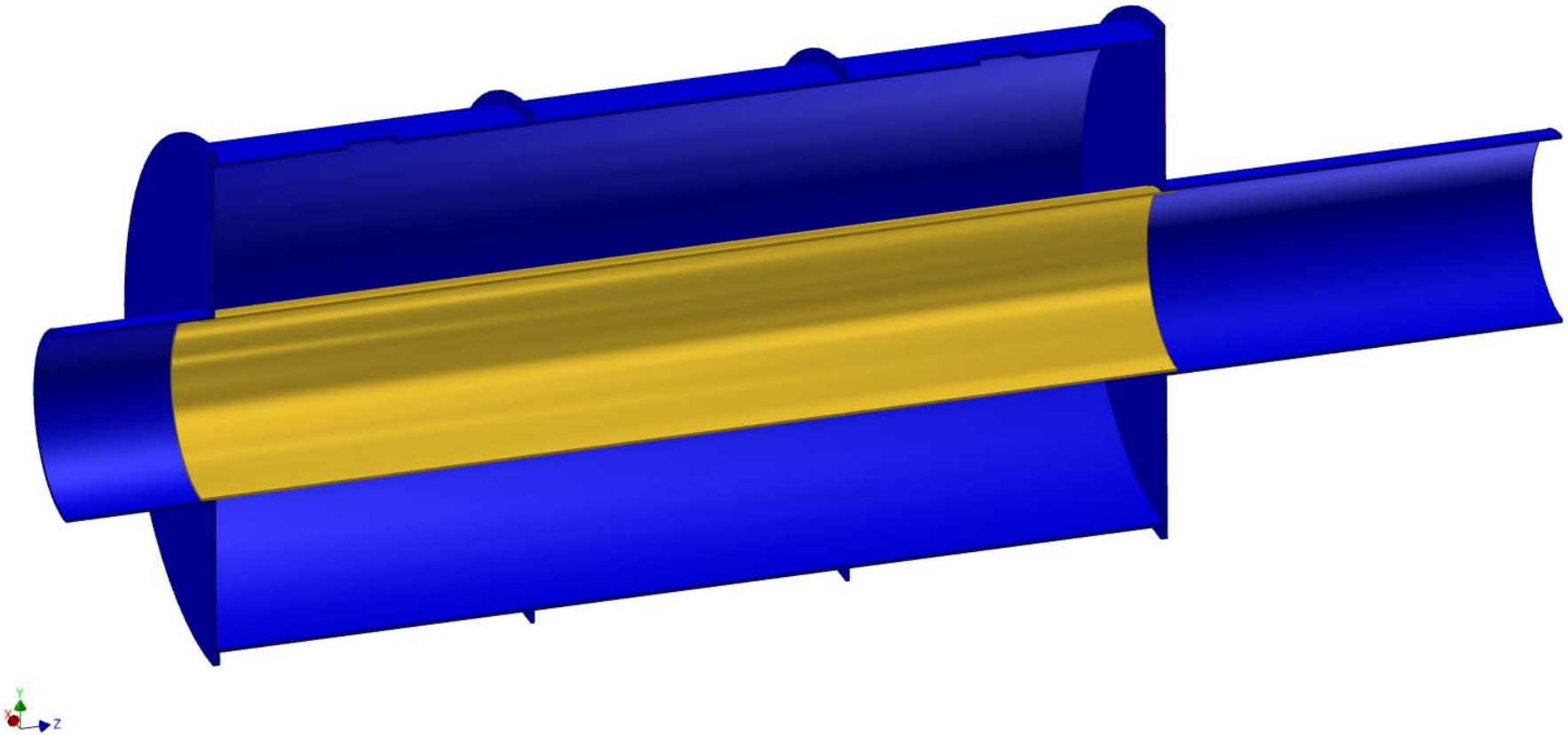
# Outside view of Li/FLiBe casting tank

The capped off ports are where you would insert molten metal/FLiBe



This is a steel fabrication (with a central beryllium tube) that weighs 1,042 lbs.

Section view of the FLiBe tank showing the beryllium tube brazed in the center to create the center section that the beam line and target modules insert into



# Summary of Be manufacturing techniques

- Beryllium fabrication and joining techniques:
  - The joints shown are either brazed or electron beam welded
  - The vessel is a powder metallurgy product
  - The tubes could be extrusions

# The thermal problem

- The IsoDAR target does not resemble existing NuMI, T2K or MiniBooNE targets
- It resembles a scaled up version of the target described in:

**Characterization of a High-Current Tandem Accelerator and the Associated Development of a Water-Cooled Beryllium Target for the Production of Intense Neutron Beams**

by

Brandon William Blackburn

Brandon's paper was about an accelerator and target designed for Boron Neutron Capture Therapy at MIT.

# Submerged Jet Impingement cooling

- We need to remove 300 kW of heat from Be and 300 kW in water deposited by 10 mA of protons at 60 MeV
- Technique is to flow sub-cooled water fast over a hot surface to sweep away bubbles coming from boiling
- Normal forced convection in water achieves $h \approx 5$ kW/m$^2$-K
- Submerged jet impingement achieves $h \approx 250$ kW/m$^2$-K (50X better cooling)

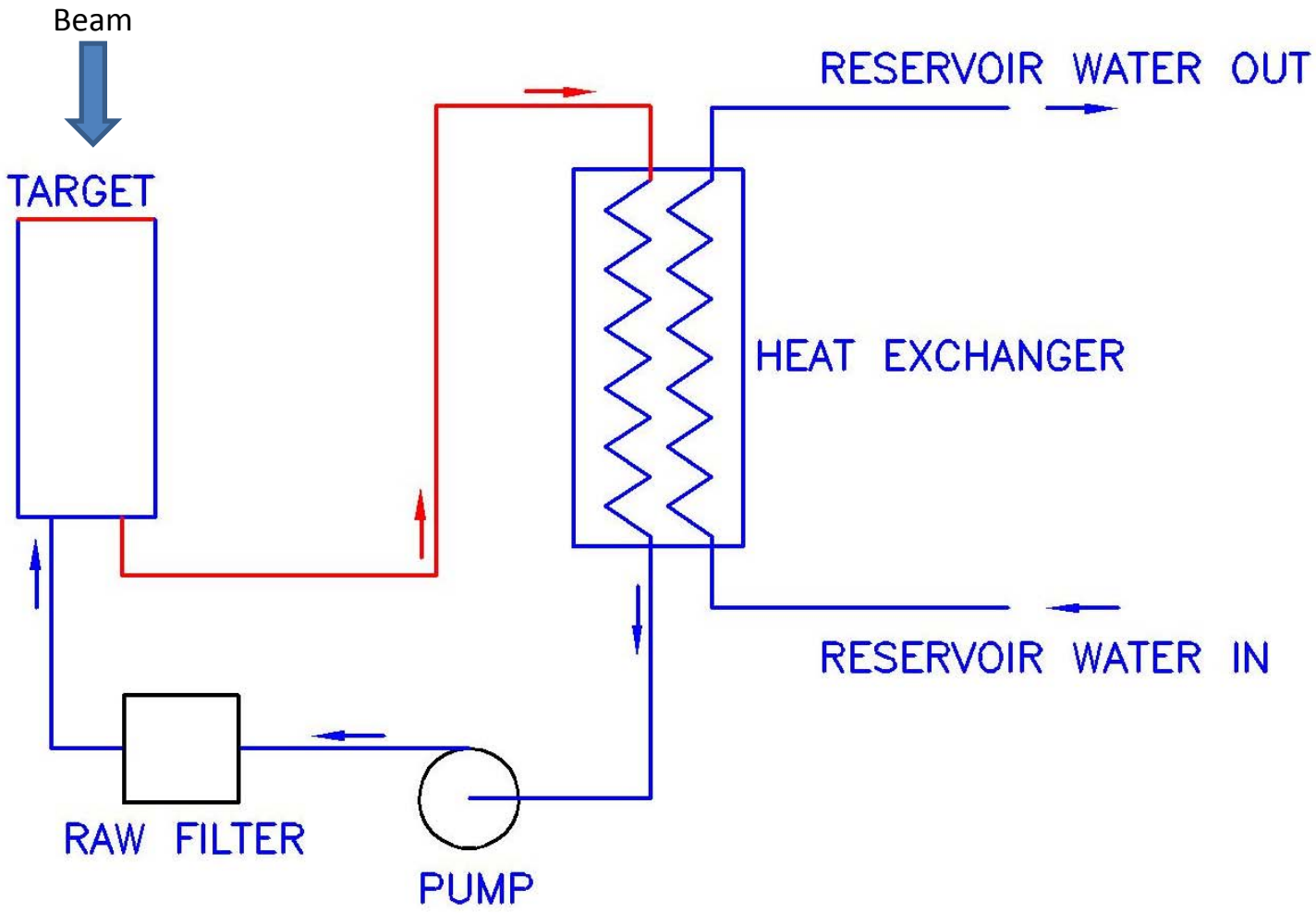
# What has been achieved previously:

- "Submerged jet-impingement cooling has been tested in order to remove heat at fluences approaching 6 kW/cm$^2$."
- "A 17 mm diameter (.67") jet of water impinging normally on a target has effectively removed 5.07 kW/cm$^2$…"
- We will scale up the concept in prototype to measure larger scale cooling parameters
  - Other geometries have been used to extract similar levels of heat so there are existence proofs

# Parameters based on paper

- Optimum diameter for the cooling nozzle is ½ that of the area being cooled.
  - This means our nozzle diameter is 10 cm (4 inch sched 40 pipe)
- Optimum Z/D spacing is 1
  - The nozzle is a Z distance equal to D back from the back side of the target disk
- If the water velocity is 35 m/s, then we need 4,500 GPM flow through the 4 inch pipe.
  - We are studying erosion

# Schematic of a simple plumbing system




Components to produce a static water pressure increase not shown

# Summary

- We have a lot of work to do to mesh a small accelerator complex into the mine tunnel at KamLAND
- Any advice you can give us on remote handling and activation issues is most appreciated