ESS Shielded casks' preliminary design and related monolith maintenance operations

Hotlab 2017, Mito, Japan

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17-09-19

ESS site - Lund, Sweden

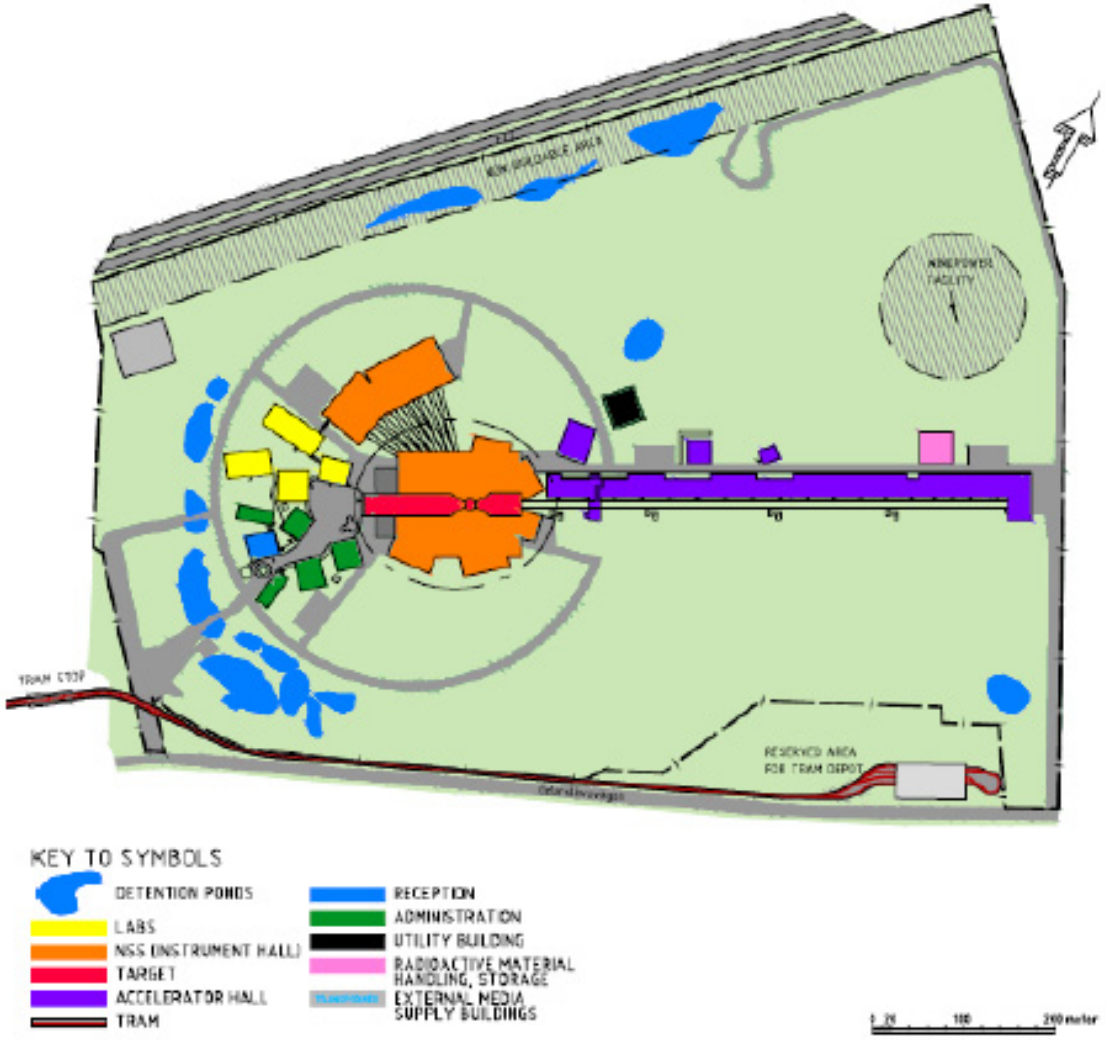
EUROPEAN SPALLATION SOURCE

ESS site - Target station

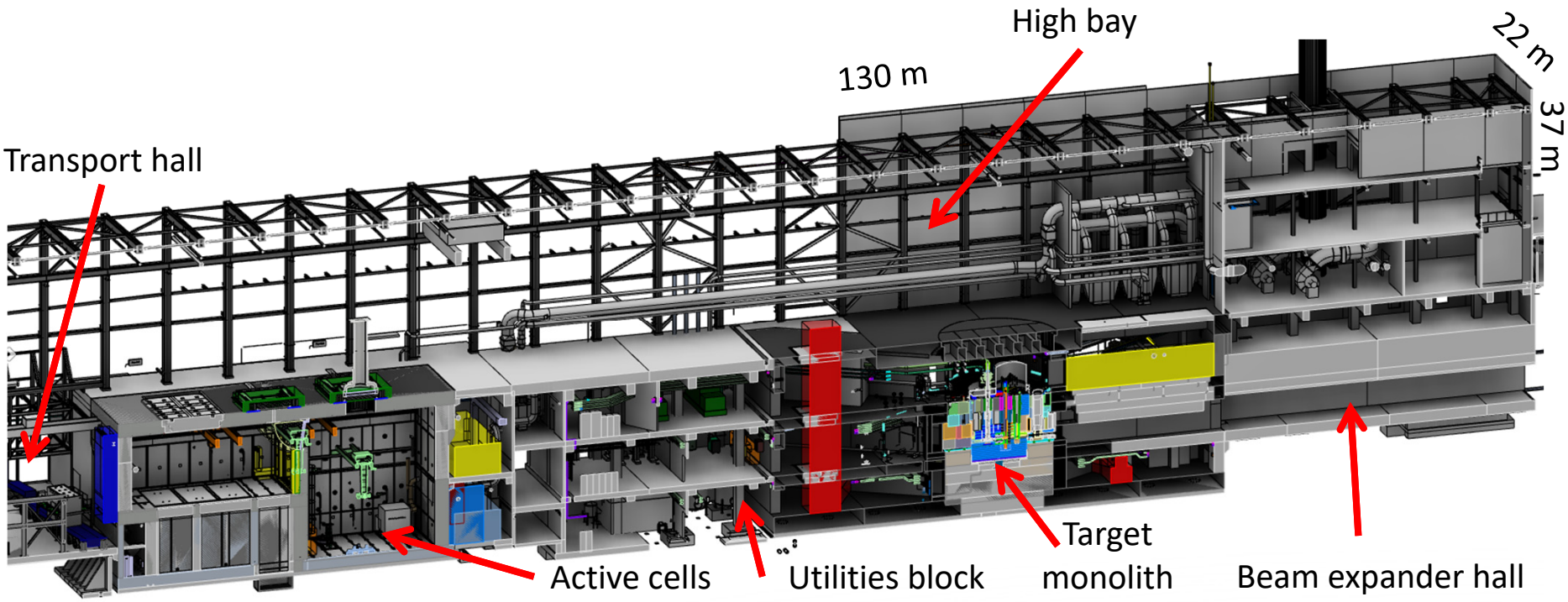
ESS site - Target station

ESS site – Construction 2017-08-17

Layout of the main components on the ESS site

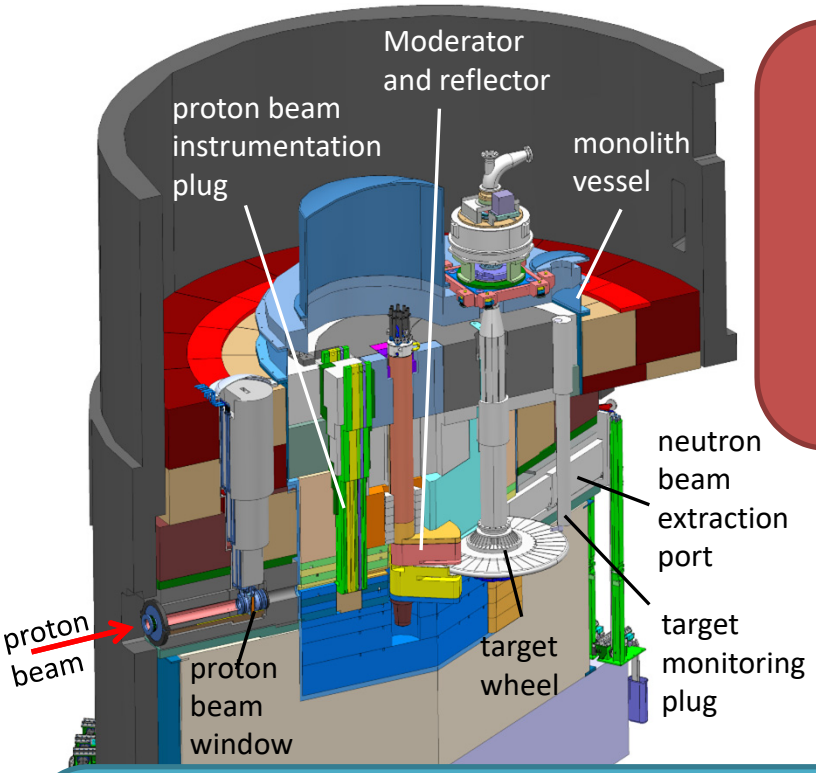


Key features of the ESS Target Station



Key features of the ESS Target Station

EUROPEAN SPALLATION SOURCE



Target Safety System

- Monitors target coolant flow, pressure and temperature, monolith pressure, & target wheel rotation
- Prohibit beam on target if parameters are outside specified limits

Helium cooling of target material

- Mass flow 3 kg/s
- Pressure 11 bar
- Temperature inlet/outlet 40 °C/240 °C

Rotating solid tungsten target

- 36 sectors
- Mass, total 11 tonnes, whereof 3 tonnes of W
- Rotates 23.3 rpm, synchronized with pulsed proton beam 14 Hz

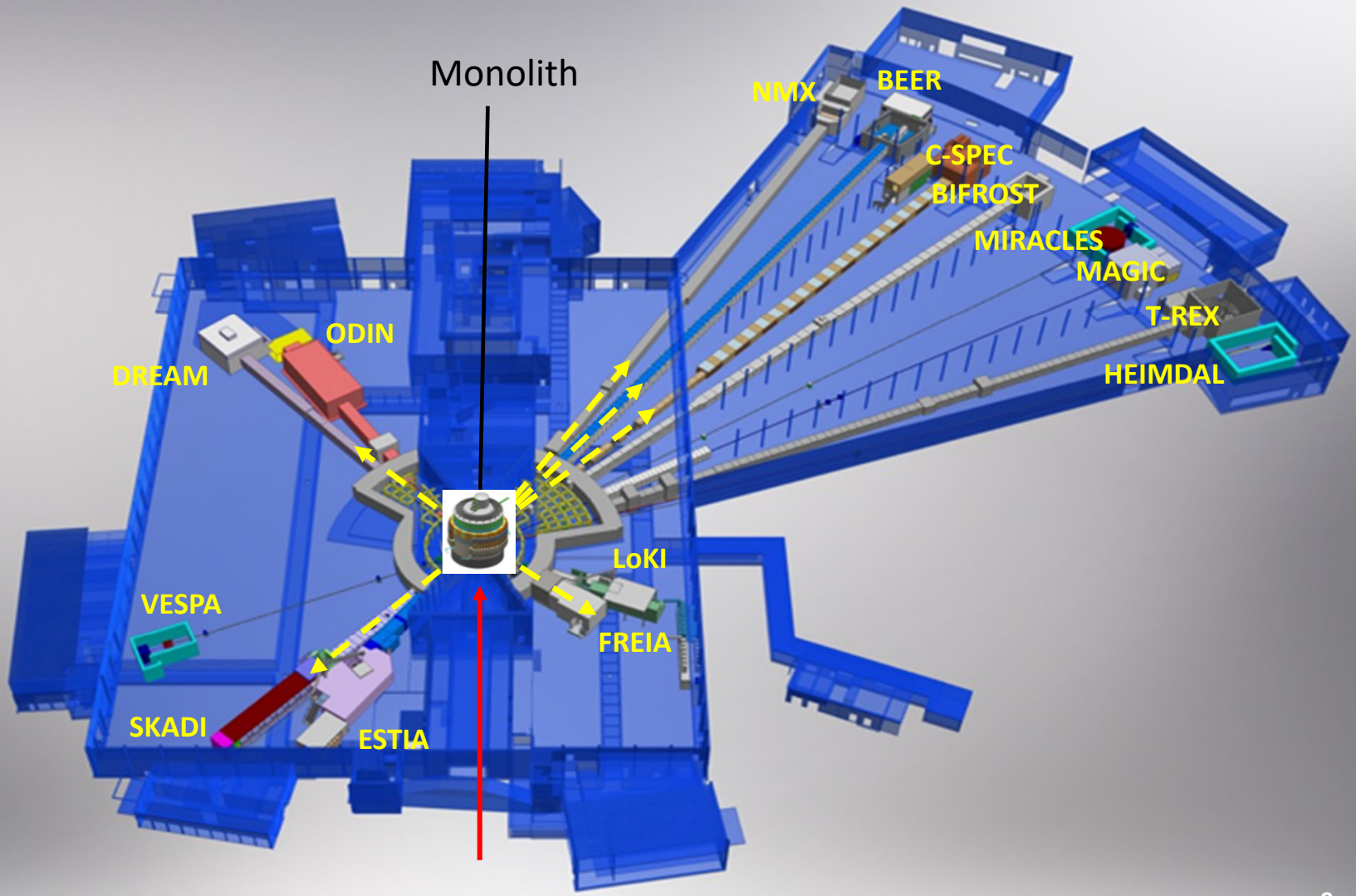
Moderators

- Provisional locations of moderators above and beneath the target wheel, i.e. monolith centre
- 1st MR plug exploits the upper space, offering:
  - ✓ Cold, 30 mm high, liquid H_2 moderators, 17 K
  - ✓ Thermal, 30 mm high, H_2O moderator, 300 K

Diagnostics and instrumentation

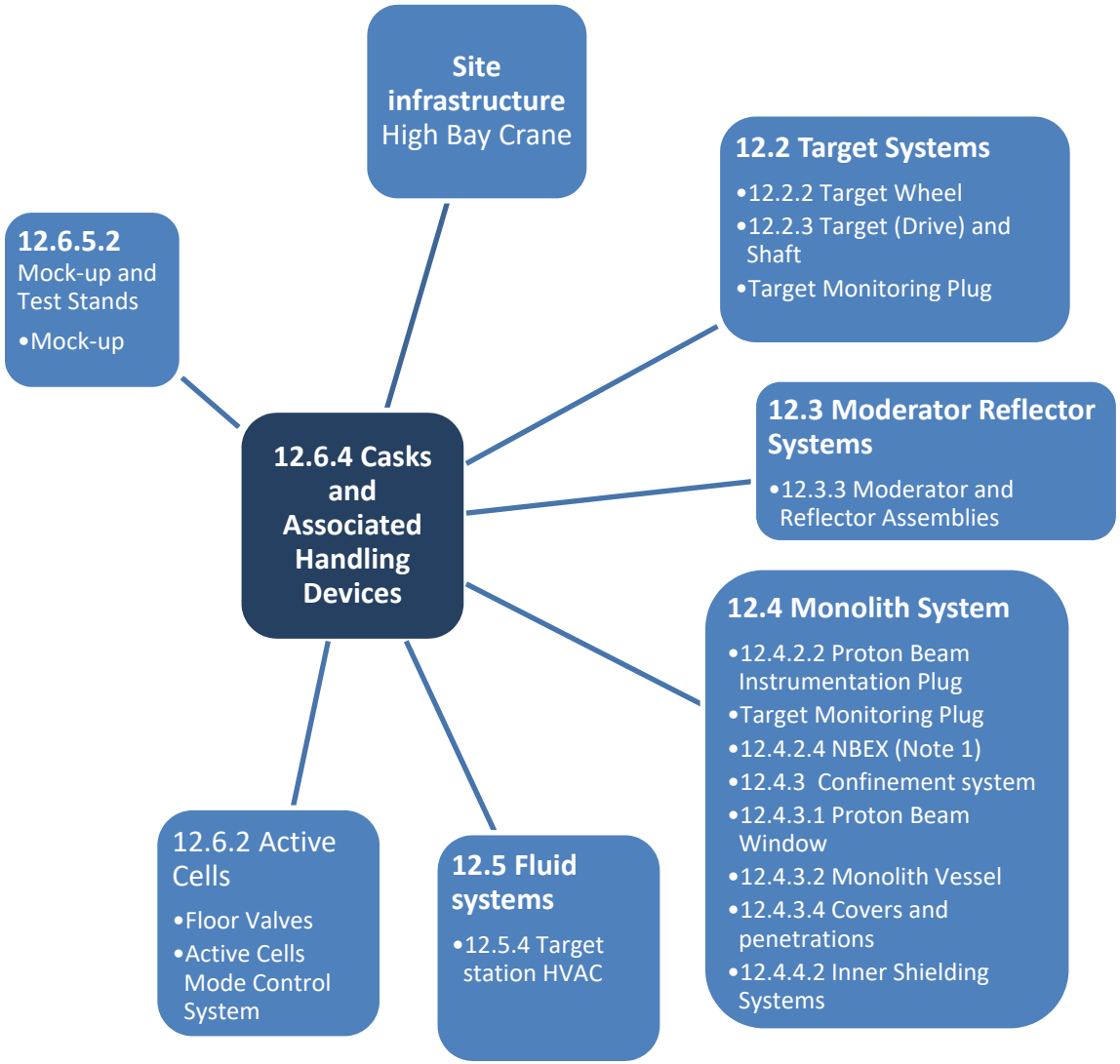
- Controlled and integrated commissioning and operation of the accelerator and target
- Fluorescent coating of PBW and target front face
- Optical paths, grid profile monitor, aperture monitor
- Wheel monitoring including position, temperature, vibration, as well as internal structure

Key features of the ESS Target Station

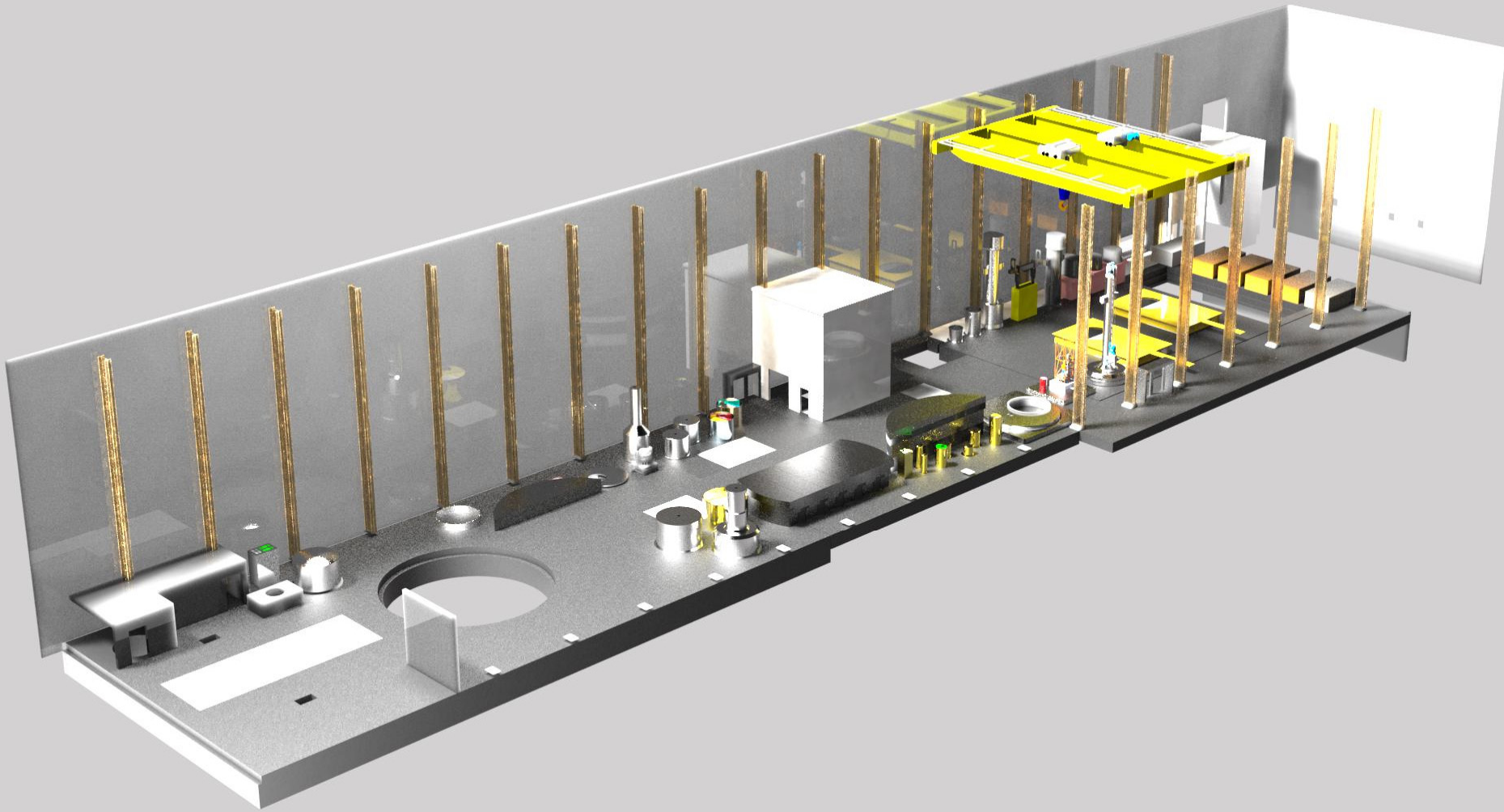


ESS Instrument Layout (December 2016)

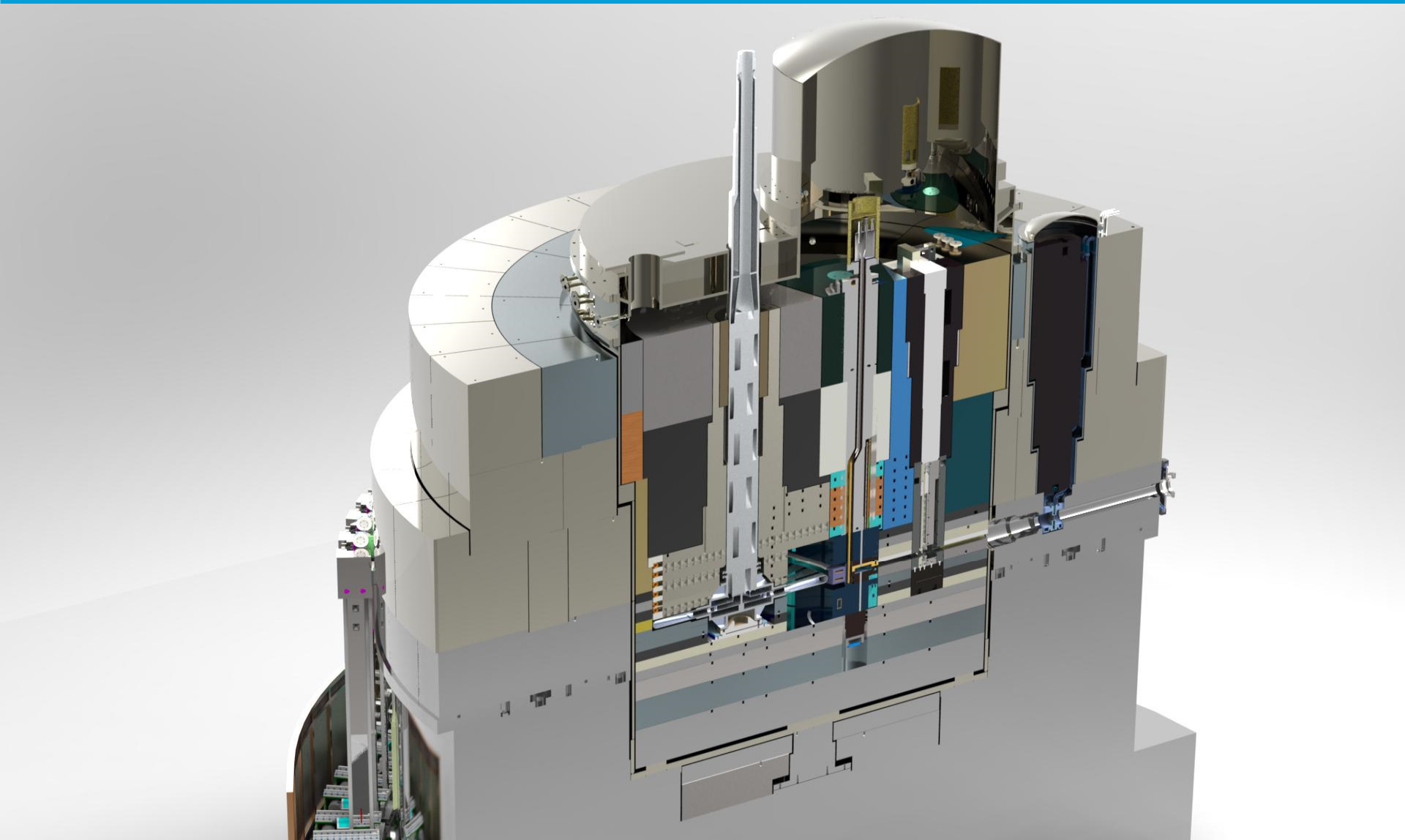
Casks - Interfaces



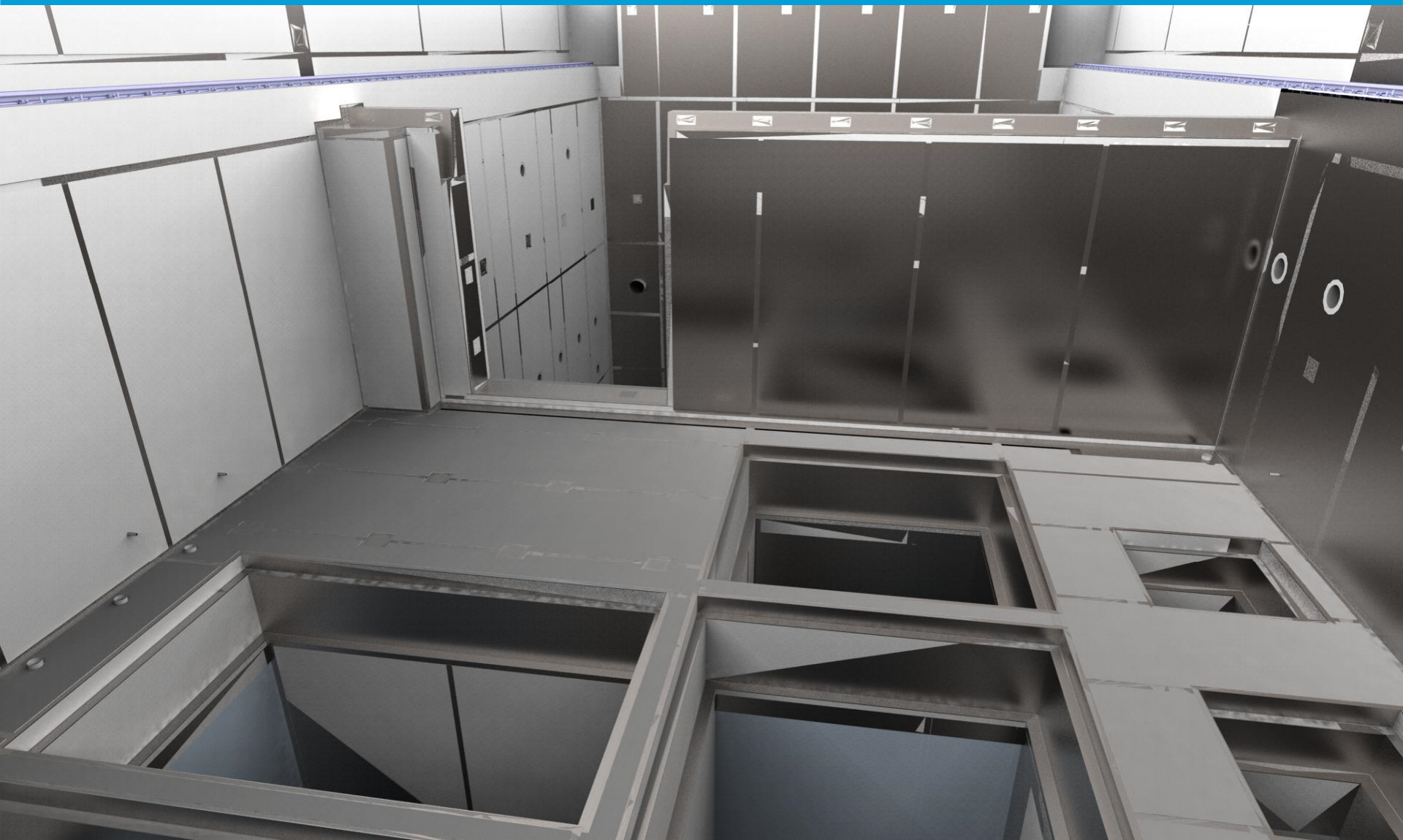
High bay



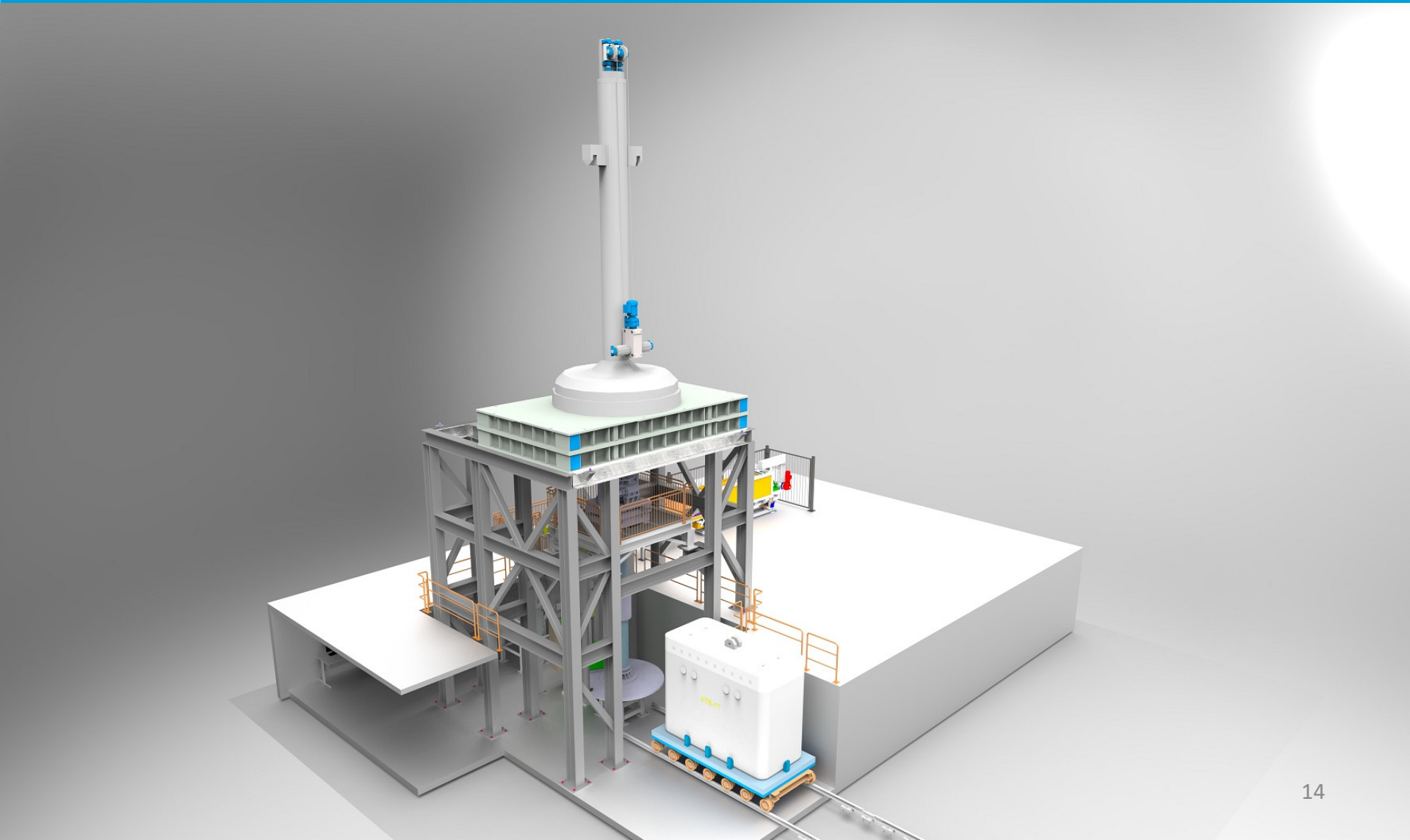
Monolith



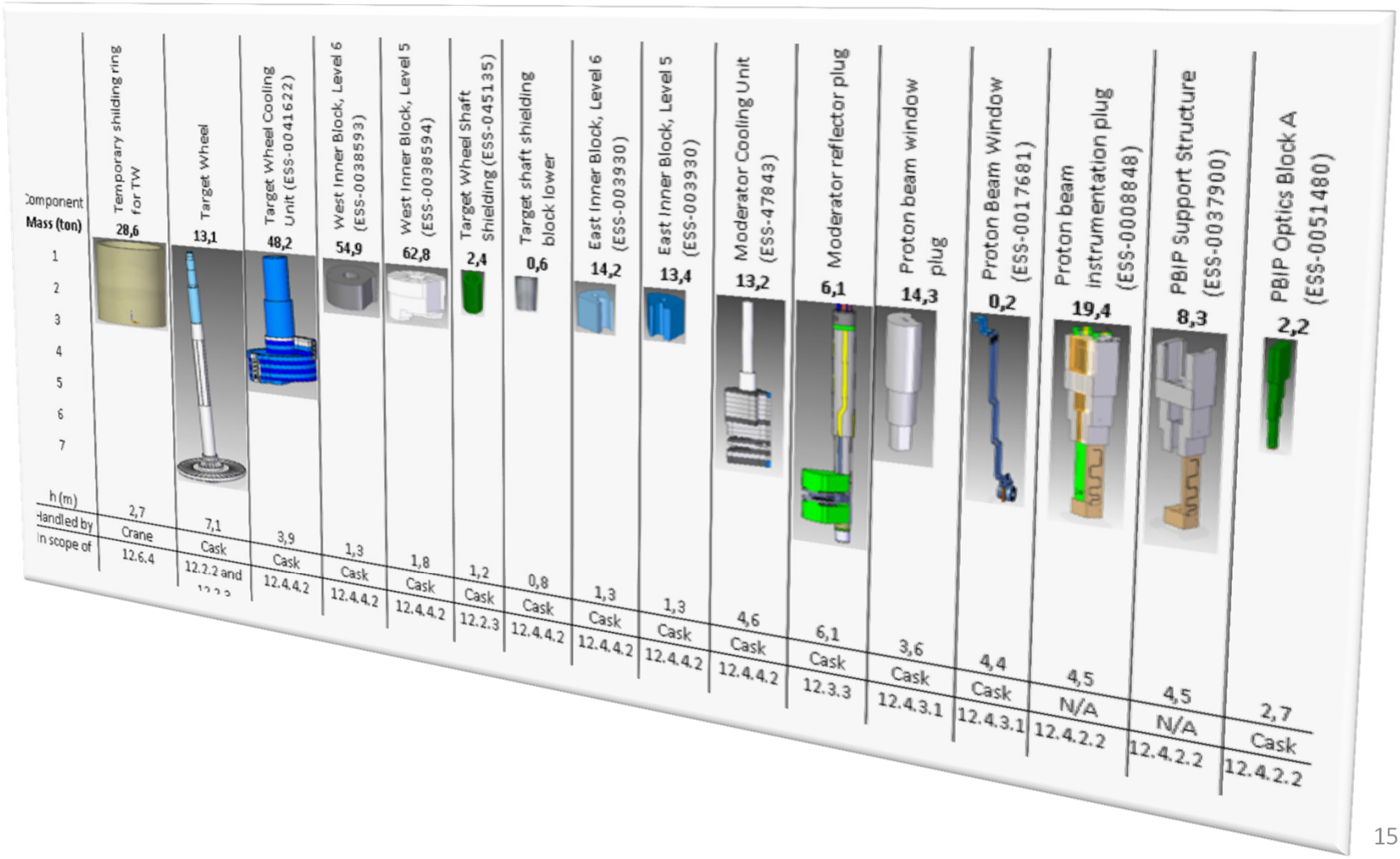
Active cells facility



Mock-Up and Test stand



Target components to be handled by the Remote Handling System



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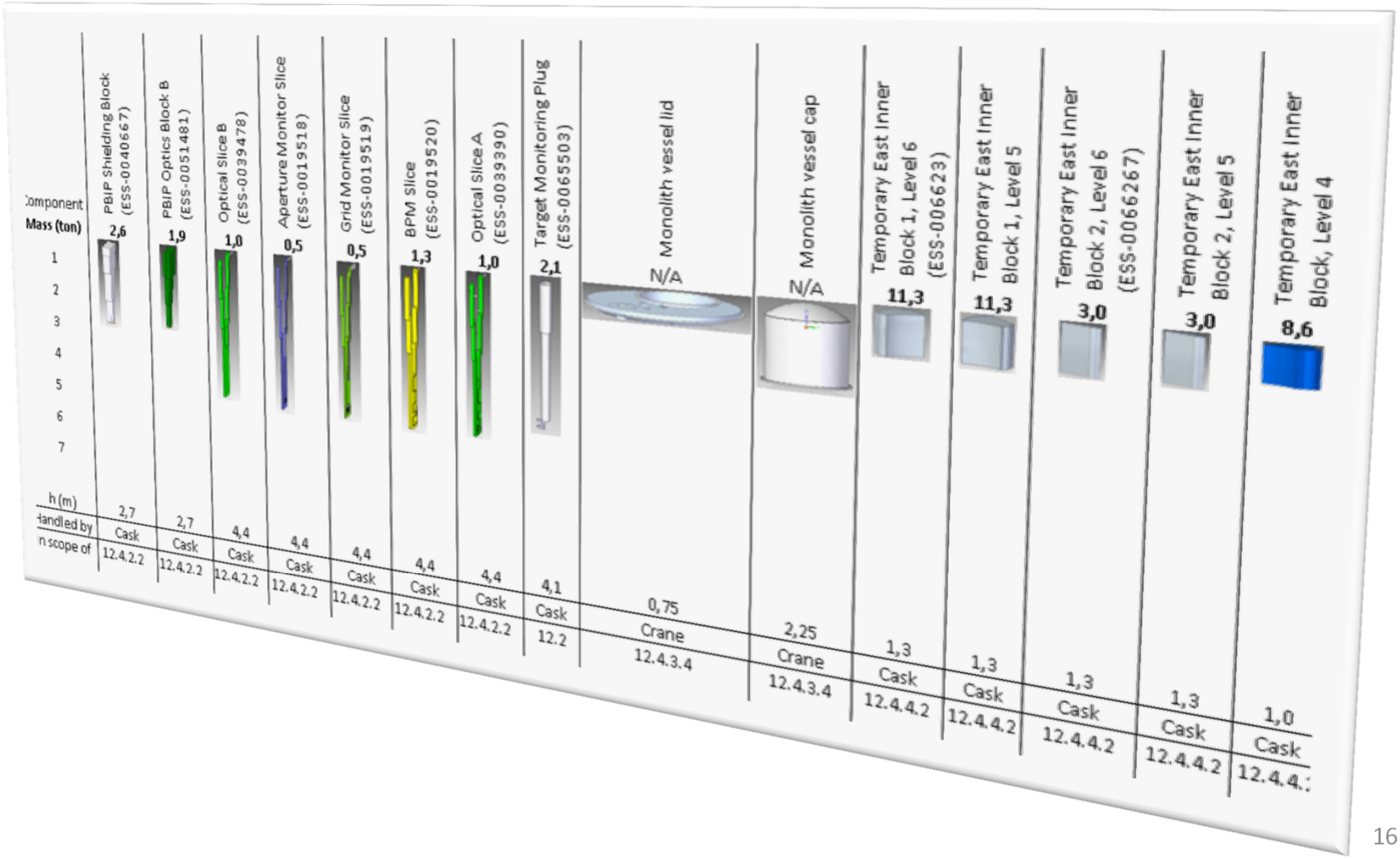


Operational functions

- The casks are required to constitute a **physical enclosure** as well as an interface to high bay crane, active cells, mock-up and test stands and the monolith.
- The main system objective is to constitute a radiation shielding and a foundation for a **safe** functional process for **remote handling** and transports.
- The mechanical design of the casks shall be focused on **functionality and flexibility** and the main objective is to limit the number of specific casks to a minimum.
- The system shall be designed considering **recovery** and reverse processing order and shall cover all steps of the different handling procedures for all monolith components.

Safety functions

- Radiation shielding
- Confinement of radioactive substances
- Provide a level of safety that includes induced secondary effects from cask handling not would endanger any facility barrier.

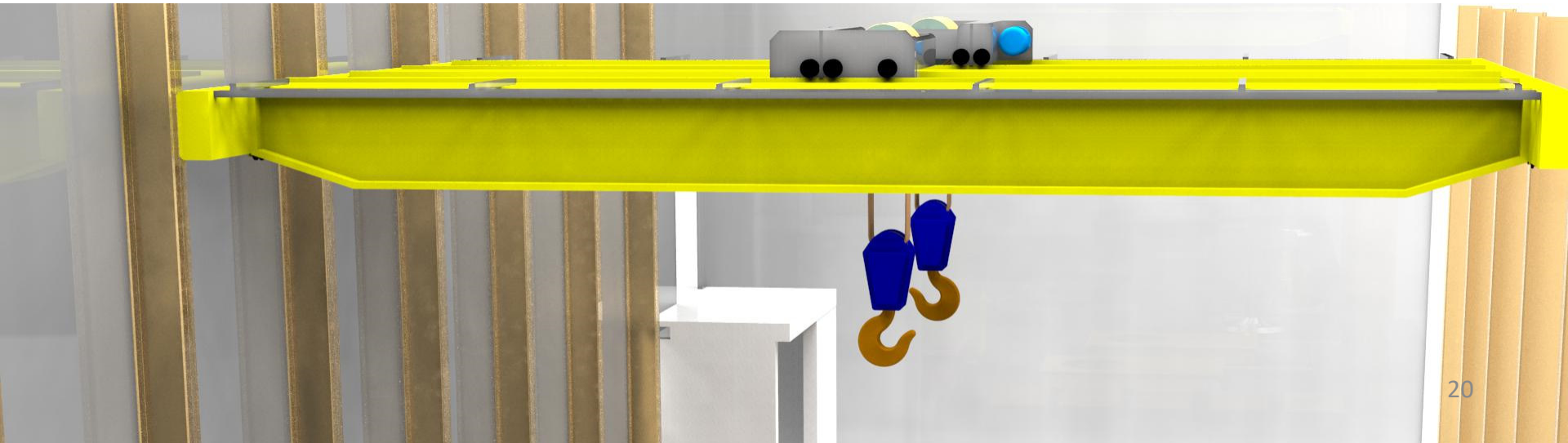
Preconditions for lifting I

- The remote handling system shall safely maintain the load in different transport and handling situations is, according to the hazard analysis and shall be dependent on following three regulations that together govern the chain of lifting:

- Swedish Radiation Safety Authority's:
  - Referral on lifting equipment and lifting operation
  - Special conditions for the ESS facility in Lund
  - Design Guide for Nuclear Civil Structures

Preconditions for lifting II

Lifting and transportation of shielded casks in high bay will be performed with two electrically driven top running double girder bridge cranes with the capacity of 50 ton each. The two cranes can function in tandem for lifting operations over 50 ton which will be the case for the target wheel cask as for an example.



Integrated lifting devices - § 10 SSM lifting guideline:

~~**L1:** Used nuclear fuel~~

~~**L2:** Risk of criticality event or release of radioactive substances outside~~ the facility

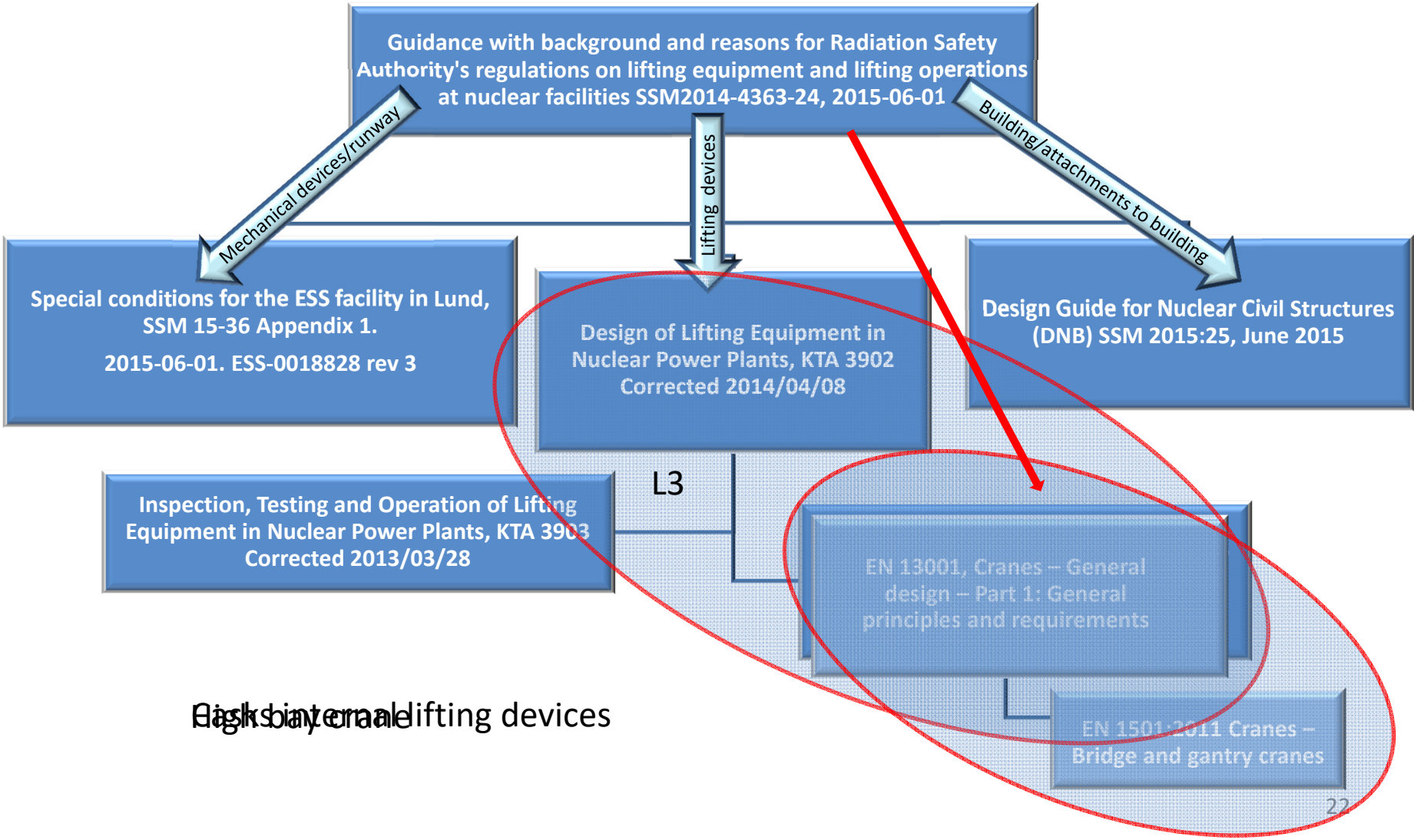
High Bay crane

L3: Lifting where loss of load of radioactive material or other loads, would or might result in the release of radioactive substances within the facility presents a risk that the radiation dose to people exceed the dose limits for workers. ➡ KTA 3902 and 3903

Casks lifting devices

Other lifting devices ➡ AFS 2008:3, EN 13001-series, AFS 2003:6, AFS 2006:4, AFS 2006:6, 2004/108/EG, 2006/95/EG

Integrated lifting devices - Regulation



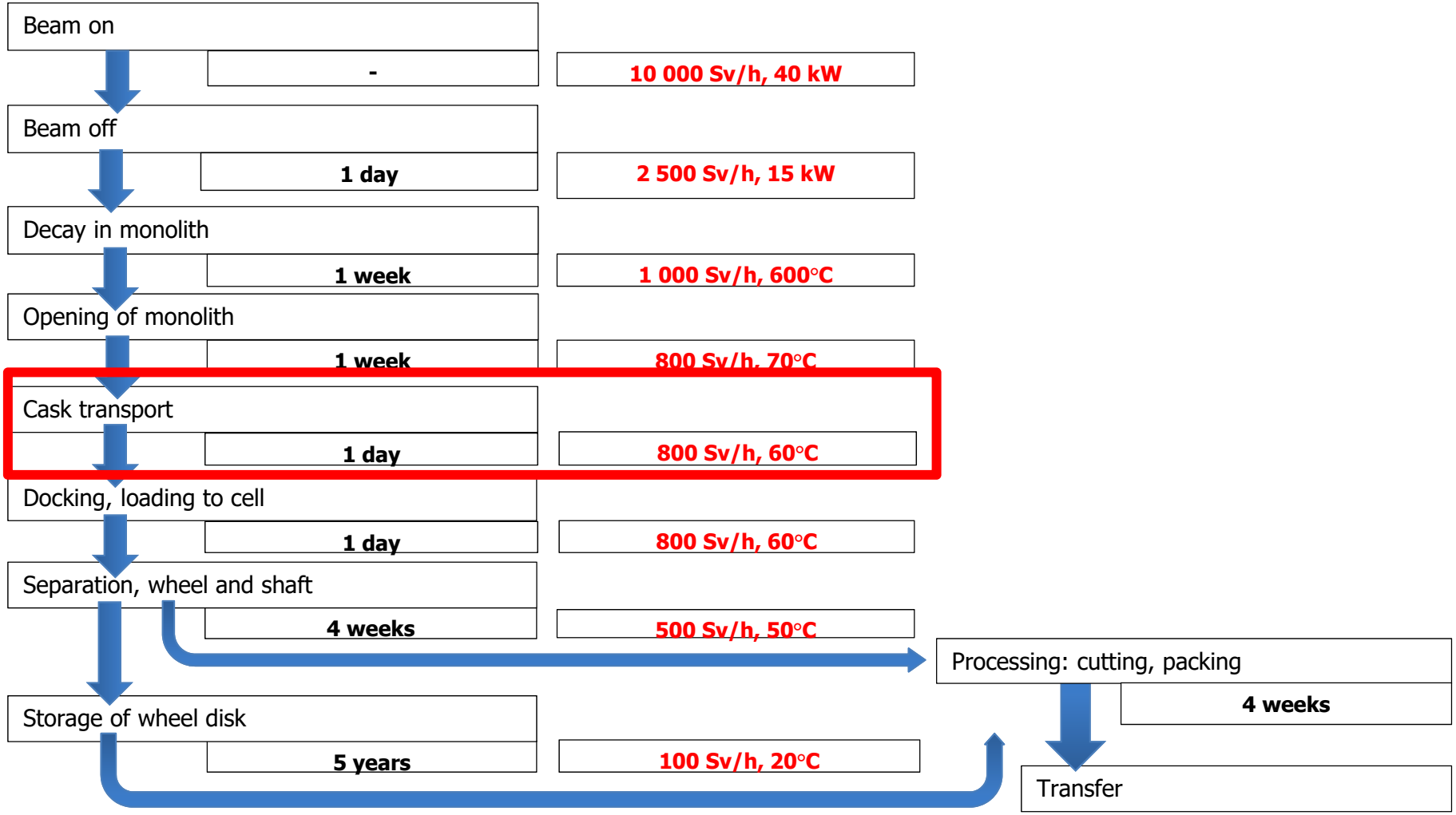
Integrated lifting devices - Conclusion

- Operators are allowed to be present in high bay during cask transport during normal operation if only the requirements of zoning are considered

- High bay crane: SSM **L3** and Section **4.2** of KTA 3902. (Impairment of safety relevant components can not be excluded)

- Casks: Industrial standard - Mechanical fixation of internal load during transport and docking of cask. (Cask hoist completely unloaded during cask transport. Lifting with cask hoist only when docked to confinement)

Estimation of processing time radiation and temperature (TW)

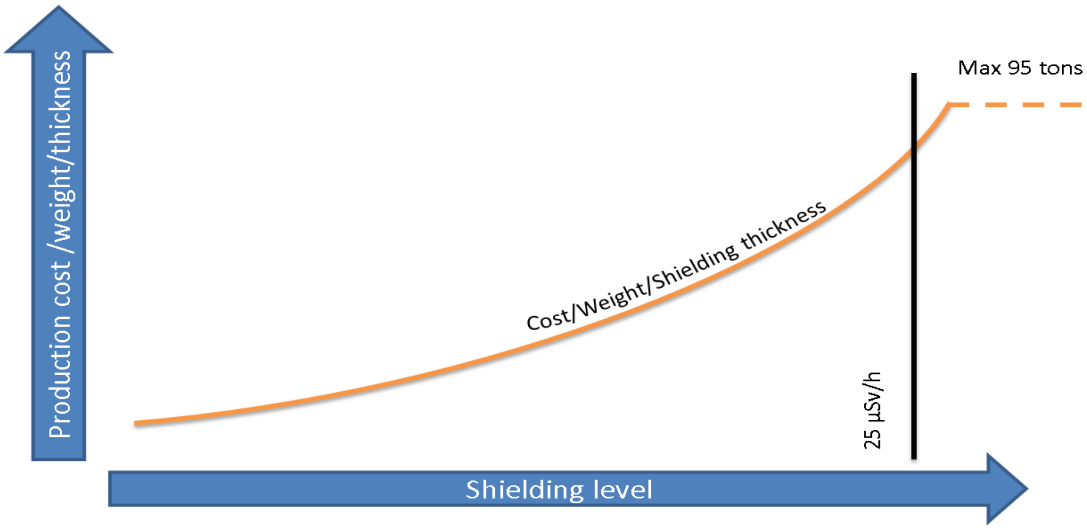


Requirements of radioprotection and shielding

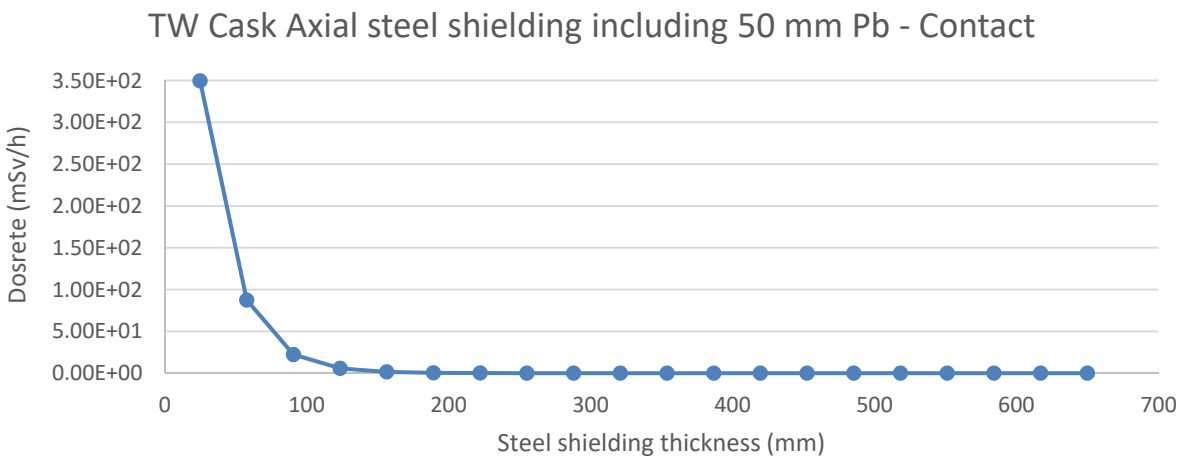
Casks system shall contribute to the protection of operators and the public from exposure due to direct radiation or any contamination contained within the casks.

- The design of the shielding functions shall restrict the dose, 1 m from a cask, not to exceed 25 µSv/h and the contact dose is limited to not exceed 2 mSv/h. Both requirements need to be fulfilled

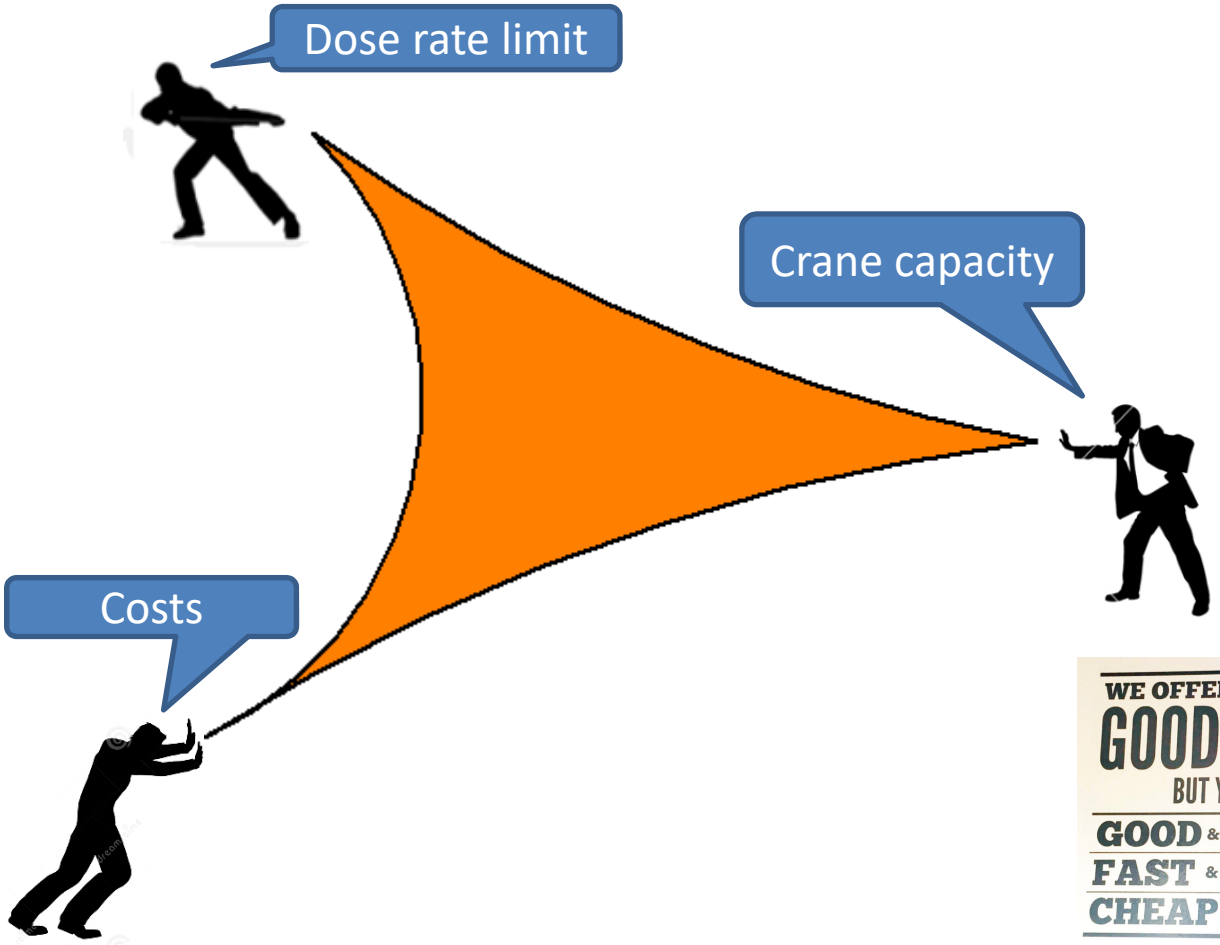
Shielding calculations for total weight - first estimation



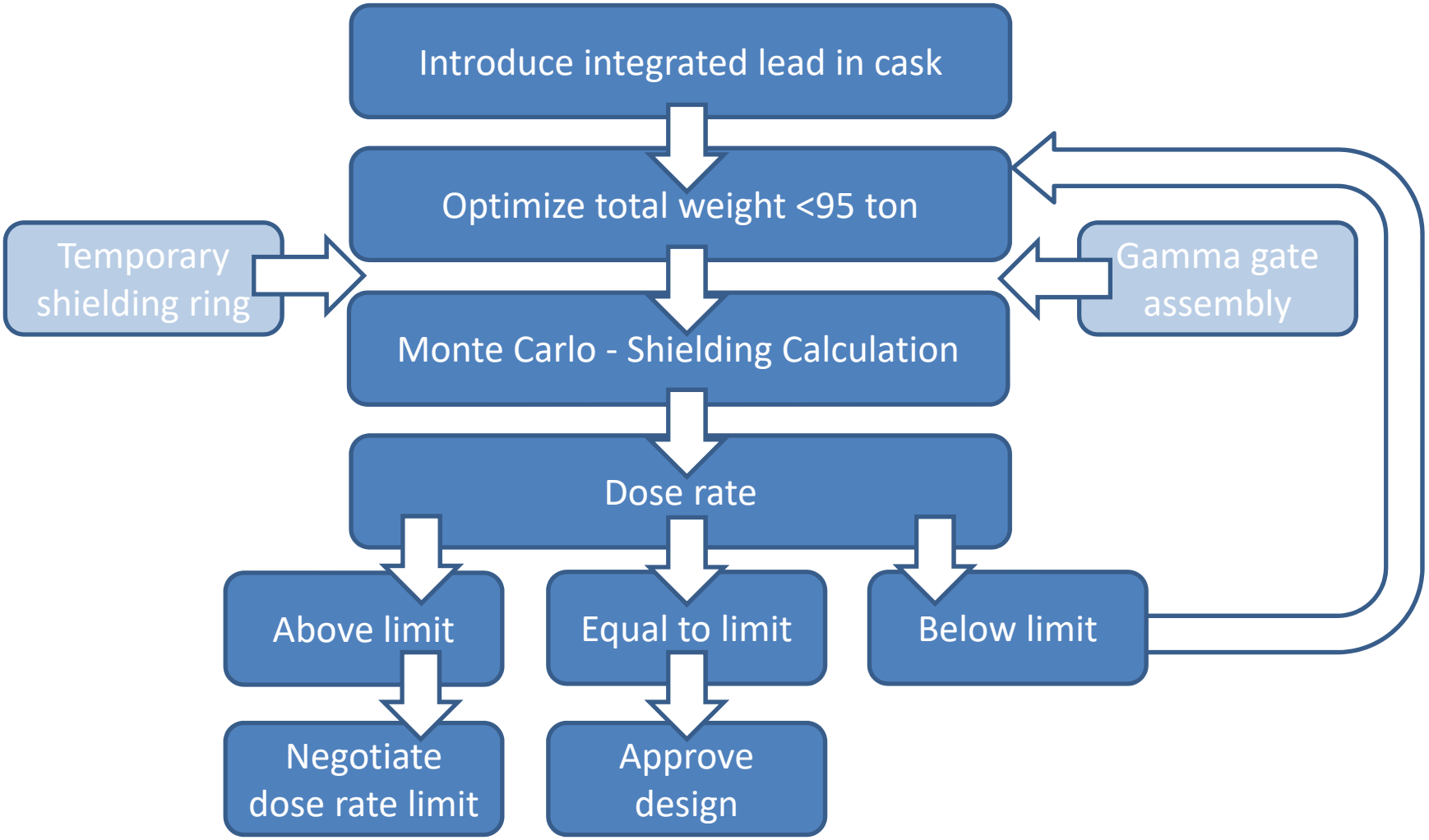
25 µSv/h 1 meter from cask requires a wall thickness of approximately 237 mm



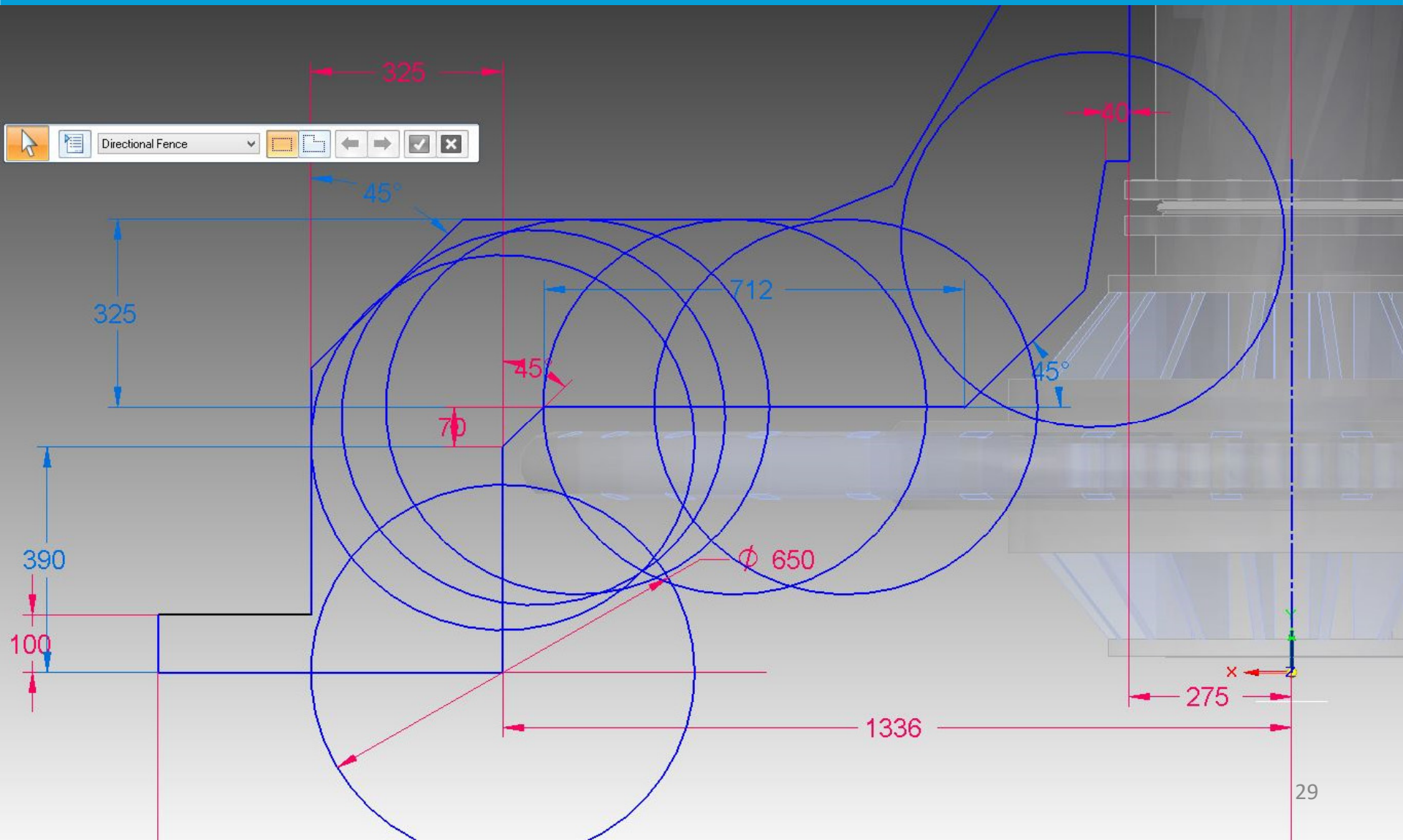
Parameters for shielding design



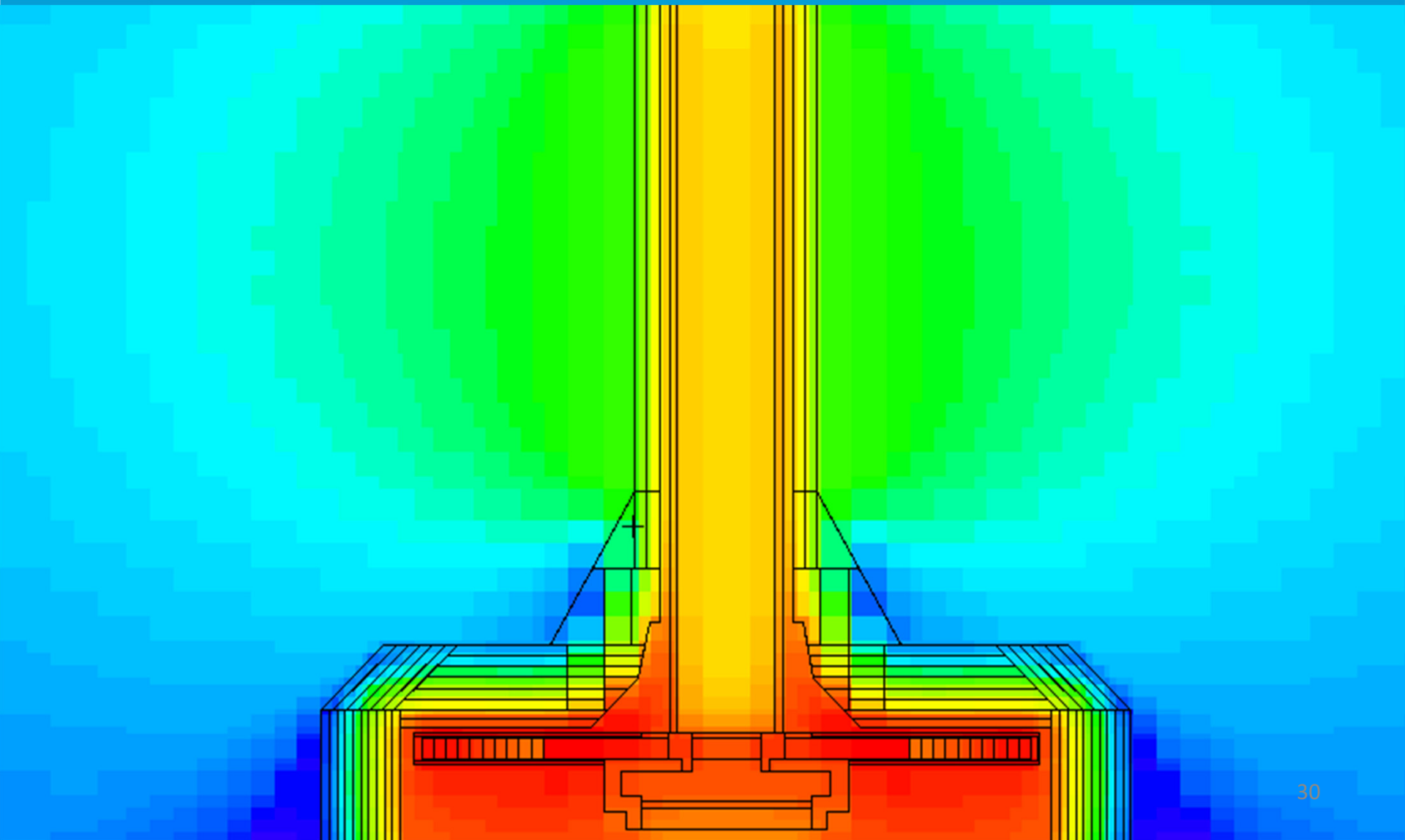
Weight reduction – Shielding calculations



Ongoing dimensioning shielding thickness (TW cask)



Ongoing MCNP calculation



Estimation- Weight of TW cask)

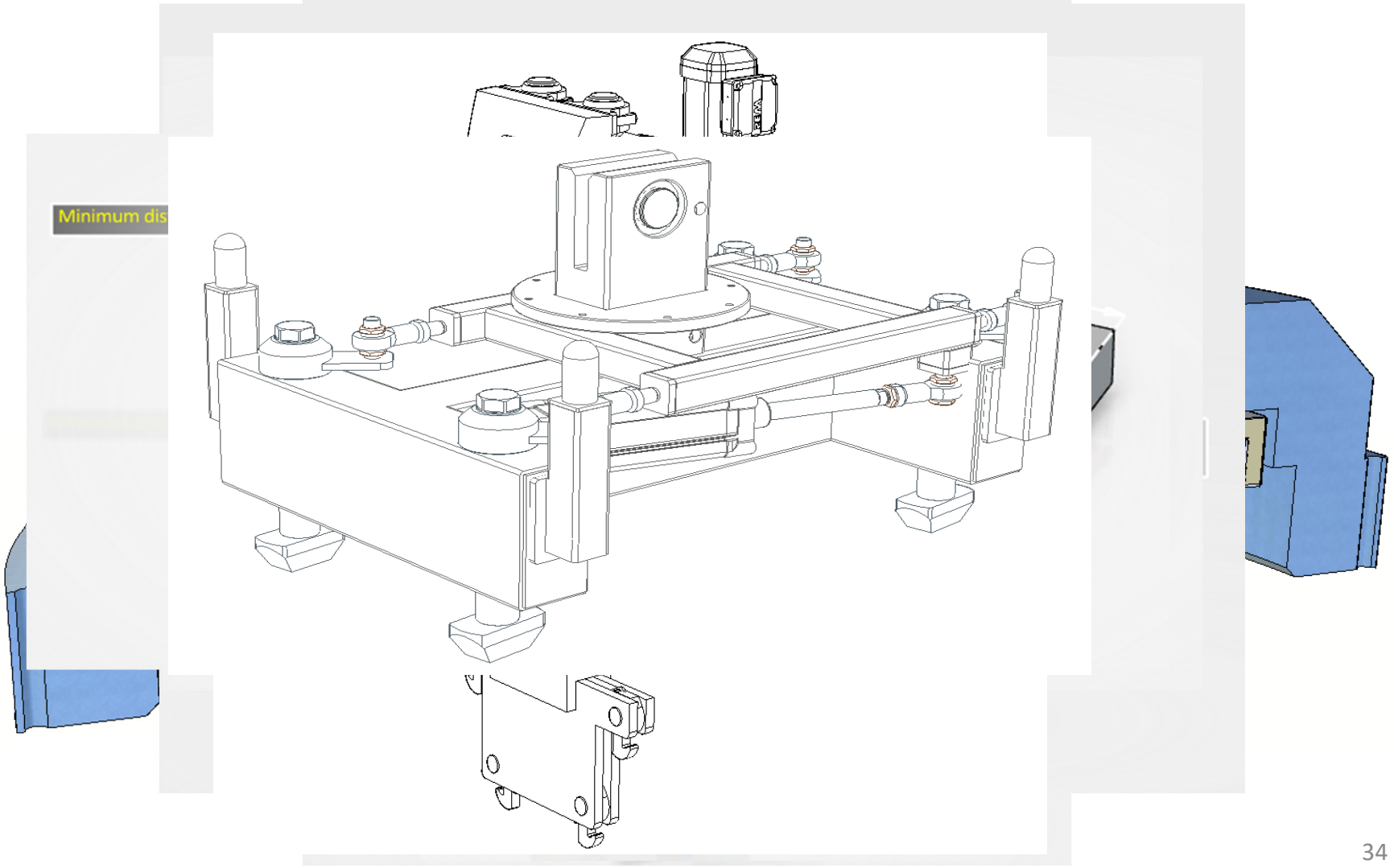
Part	m (kg) Equipment	m (kg) Assembly	
Main shielding hull		36 840	
Hoist, elecrical cabinet, covers etc.		1 500	
Target wheel and shaft		11 296	
Spallation material	3 102		
Cassettes	404		
Target whell vessel	2 011		
Shaft	5 780		
Lead cover		5 299	
Lead	4 608		
Hull	691		
Gamma gate		38 933	
Hull	21 300		
Gate	17 633		
Lifting rig		1 000	
		94 868	Ok

Target wheel cask shielding - conclusion

- Classification of lifting devices in harmony with design and functionality
- Interlocks between high bay crane, internal hoist and opening of active cells floor valves
- Additional safety features included based on hazard analysis
- Weight optimization absolutely necessary to achieve required dose rate limit within maximum weight restriction.
- Lead cover integrated in cask instead of a cover following the TW
- Gamma gate hatch manufactured lead instead of steel
- Temporary shilding inserts between casks gamma gates and monolith structure

Concept design study I

Concept design study II

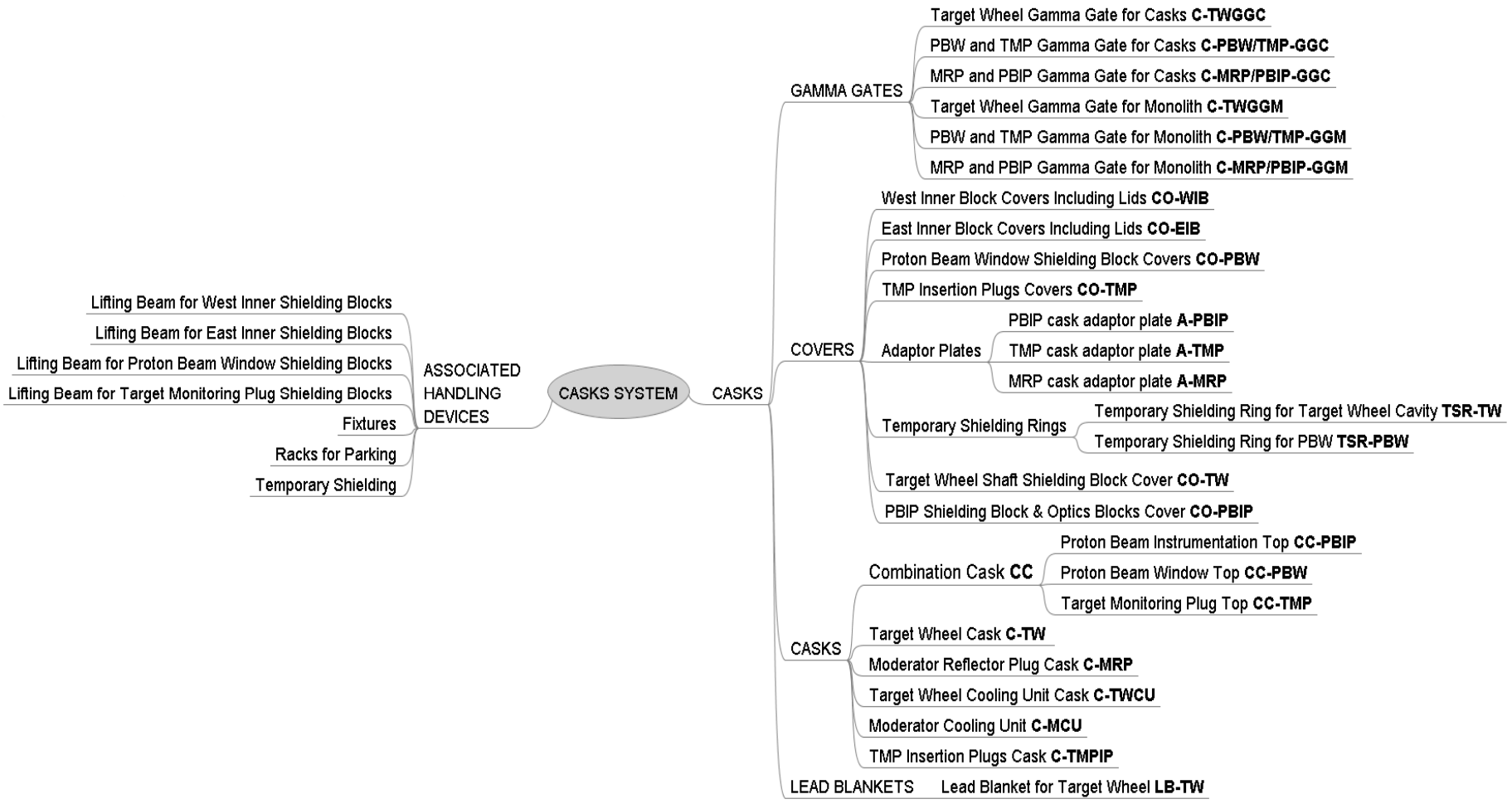


Concept design study III

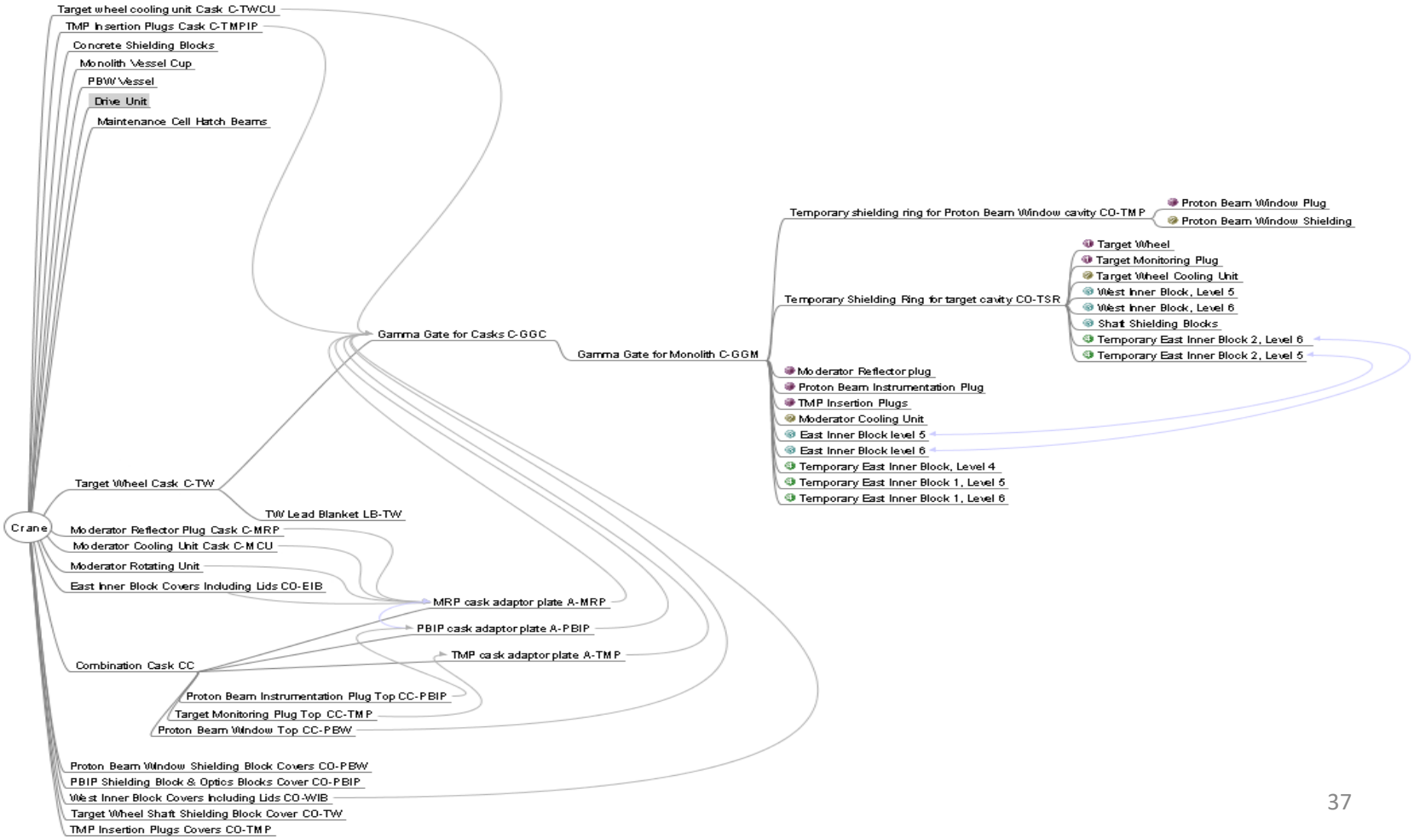
A generic design philosophy is used. The lists in below section shows the features that are shared between the casks.
Uniform:

- geometry of lifting lugs for connection to the lifting rig
- size and shape of studs/screws
- guiding pin systems for casks, covers and interfacing valves
- electrical, I&C connection system
- flange patterns and hole distribution as far as geometrically possible
- internal camera support fixtures

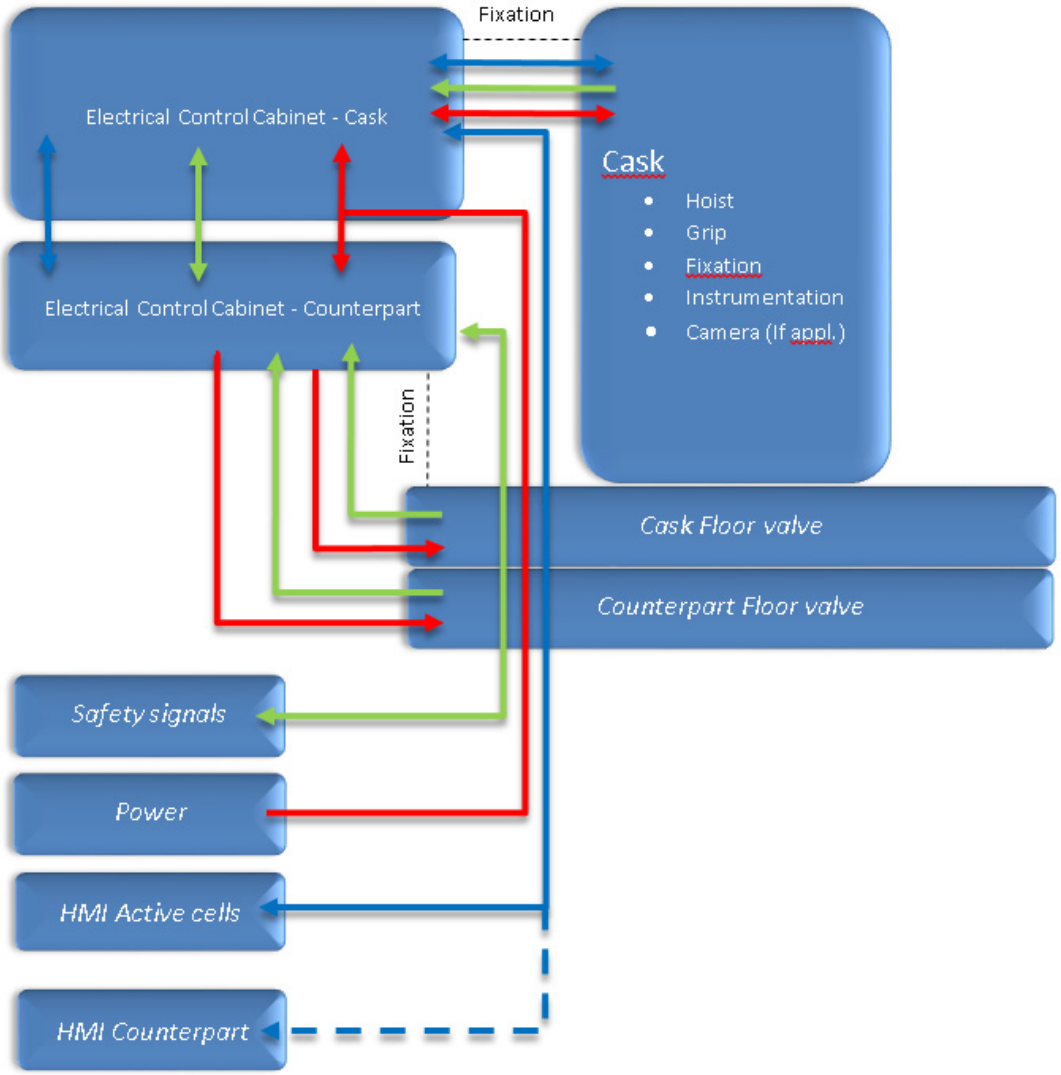
Structure of Casks



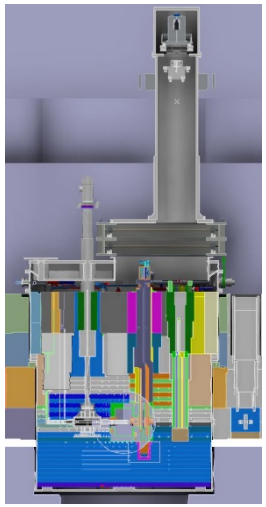
Interdependencies of remote handling tools

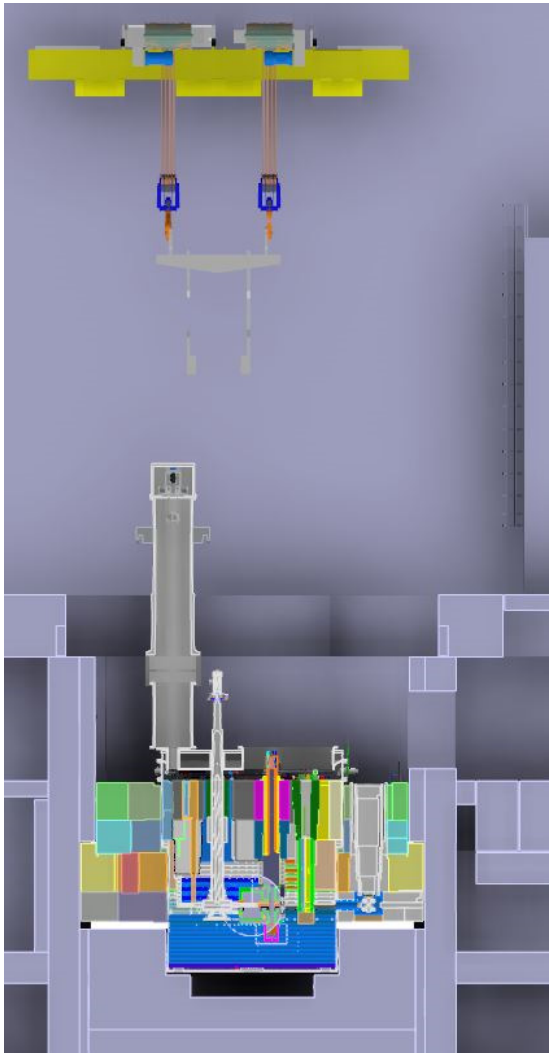


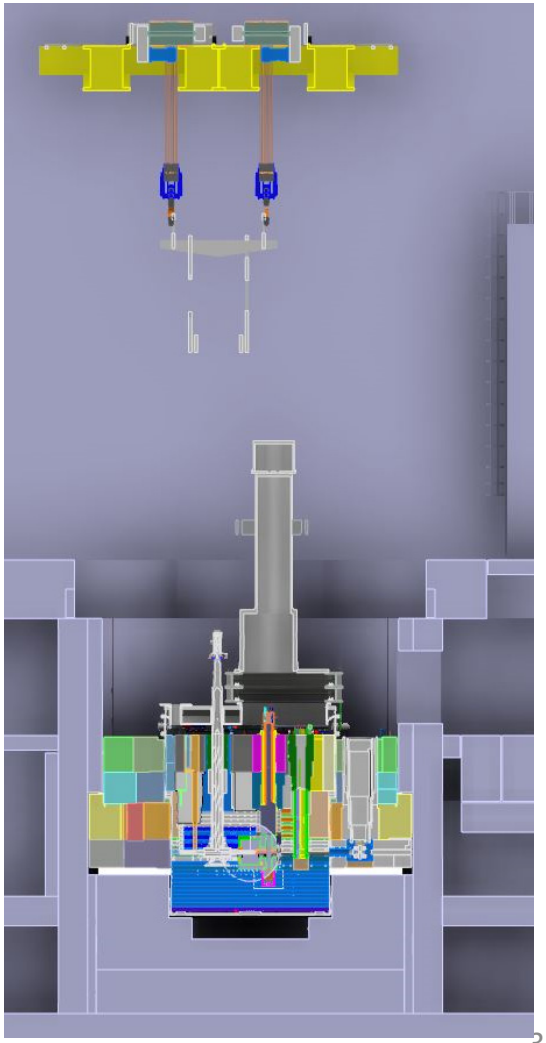
Concept of control interface



Monolith maintenance



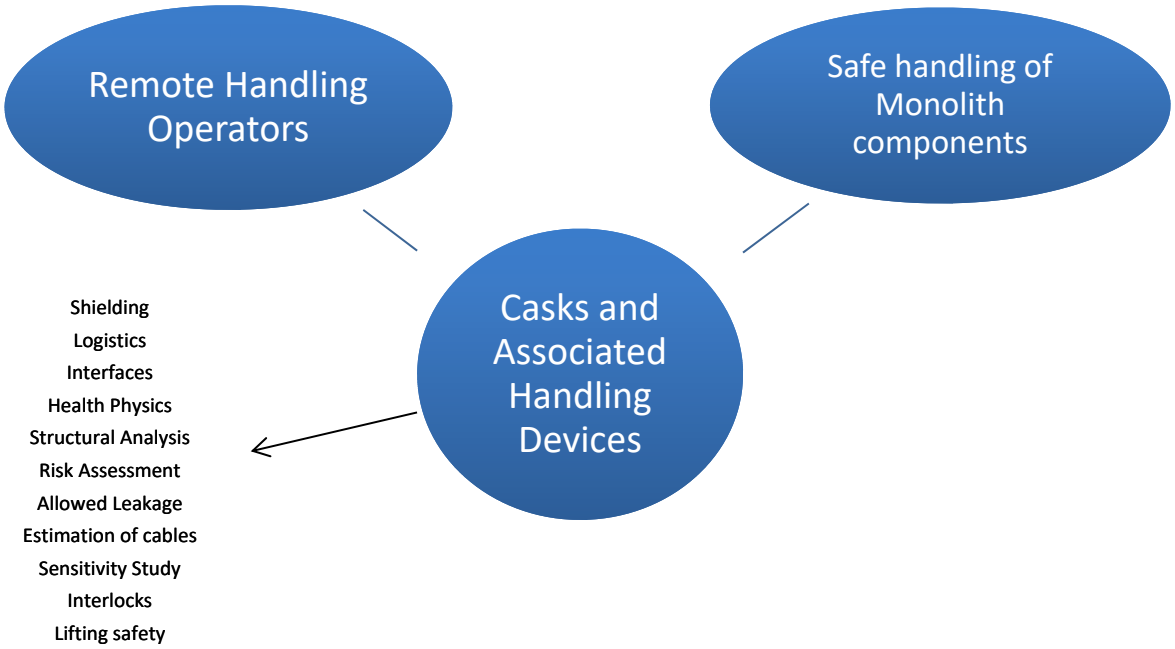




Monolith maintenance
MRP sequence I

Casks and monolith maintenance - conclusion

- Complete shielding analyses needed for all cask configurations and for all steps of monolith maintenance
- Shielding strategy also for temporary storage in high bay
- Complex and comprehensive package with many interfaces



Five-year averaged production of components

	Year 1		Year 2		Year 3		Year 4		Year 5		
	W	S	W	S	W	S	W	S	W	S	Reference
Target wheel and shaft										1	ESS-0030244
Moderator Reflector Plug		1		1		1		1		1	ESS-0031795
Proton Beam Window	1	1	1	1	1	1	1	1	1	1	ESS-0059298
PBIP Slices				5				5			ESS-0059296
Target monitoring plug										1	ESS-0059300
Neutron Beam Guide plugs or inserts	1	2	1	2	1	2	1	2	1	2	
Neutron Beam Shutters	1	2	1	2	1	2	1	2	1	2	ESS-0029936
Bridge Beam Guide Holder	1	2	1	2	1	2	1	2	1	2	
Flange Assembly	1	2	1	2	1	2	1	2	1	2	