# RIA Target Station Design and Infrastructure

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**2nd High-Power Targetry Workshop**
**October 10–14, 2005**
**Oak Ridge, TN**

# RIA Overview

- R&D Activities
- Overall Layout and Parameters
- Remote Maintenance Requirements
- ISOL Target Design and Analysis
- Fragmentation Beam Dump Design
- Project Status

# Rare Isotope Accelerator (RIA)
# DOE Sponsored R&D Areas

- Beam Simulation
- Front End
- Driver Linac
  (2$^{nd}$ Stripper Region RH Considerations)
- Isotope-Separator-on-Line (ISOL)
- Fragment Separation- for Fragment Separators
- Fragment Separation- for Gas Cell
- Post Acceleration
- Multi User Considerations

# ISOL Target

- **Analysis and evaluation of target concepts (Mercury, Tungsten/Water Cooled)**
- **Identification of required utilities and corresponding remote maintenance capabilities**
- **Activation and Heating Calculations**
- **Target Gallery layout and optimization for maximum availability**

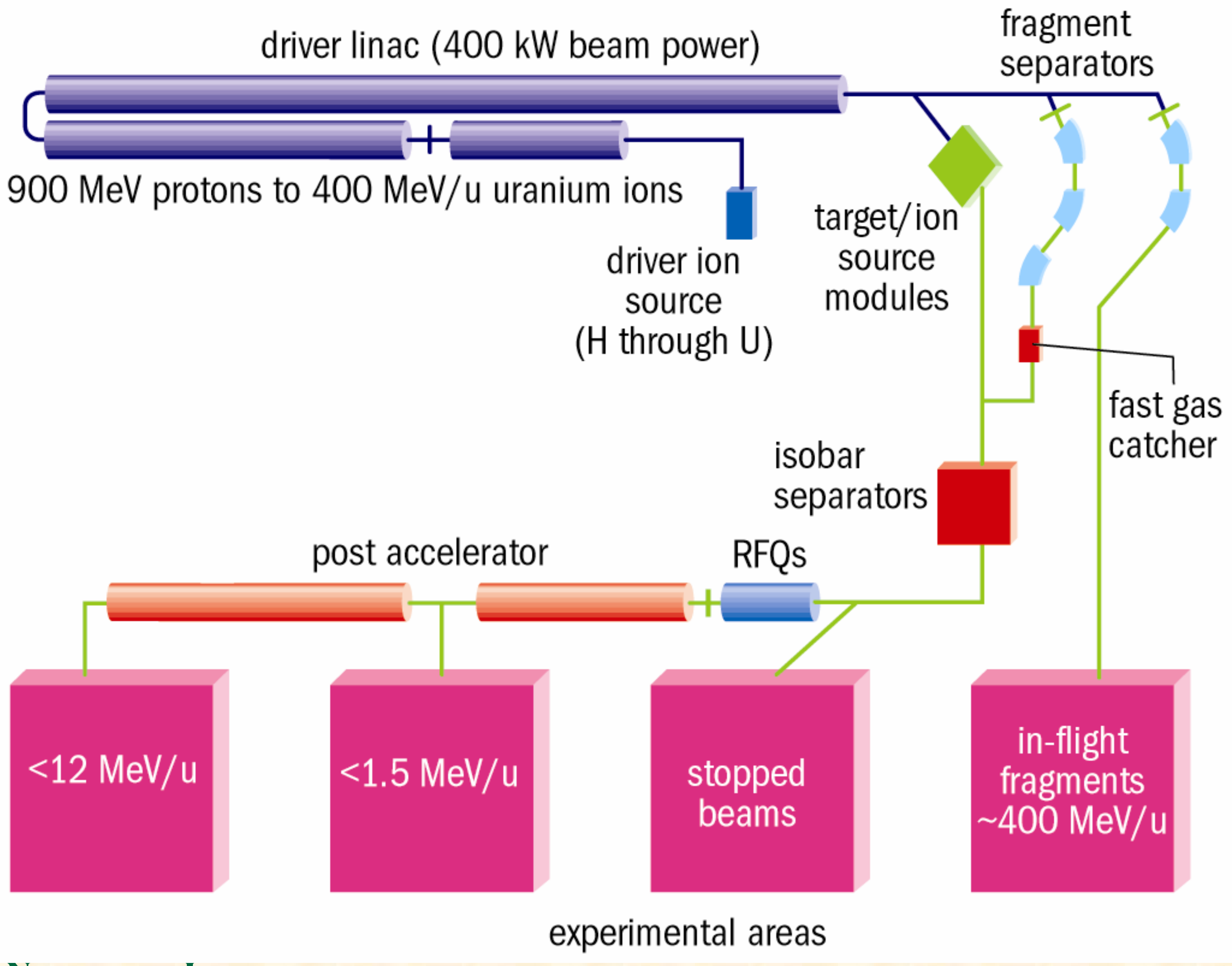
# Fragmentation Target

- Development of simulation codes for heavy ion transport
- Evaluation of Beam Dump for full range of production scenarios
  [Cu (water or gas cooled), Lithium Stream]
- Development of high-power target concepts
- Simulation of radiation doses to magnets and other components
- Development of concepts for remote maintenance for damaged components
- Materials Research

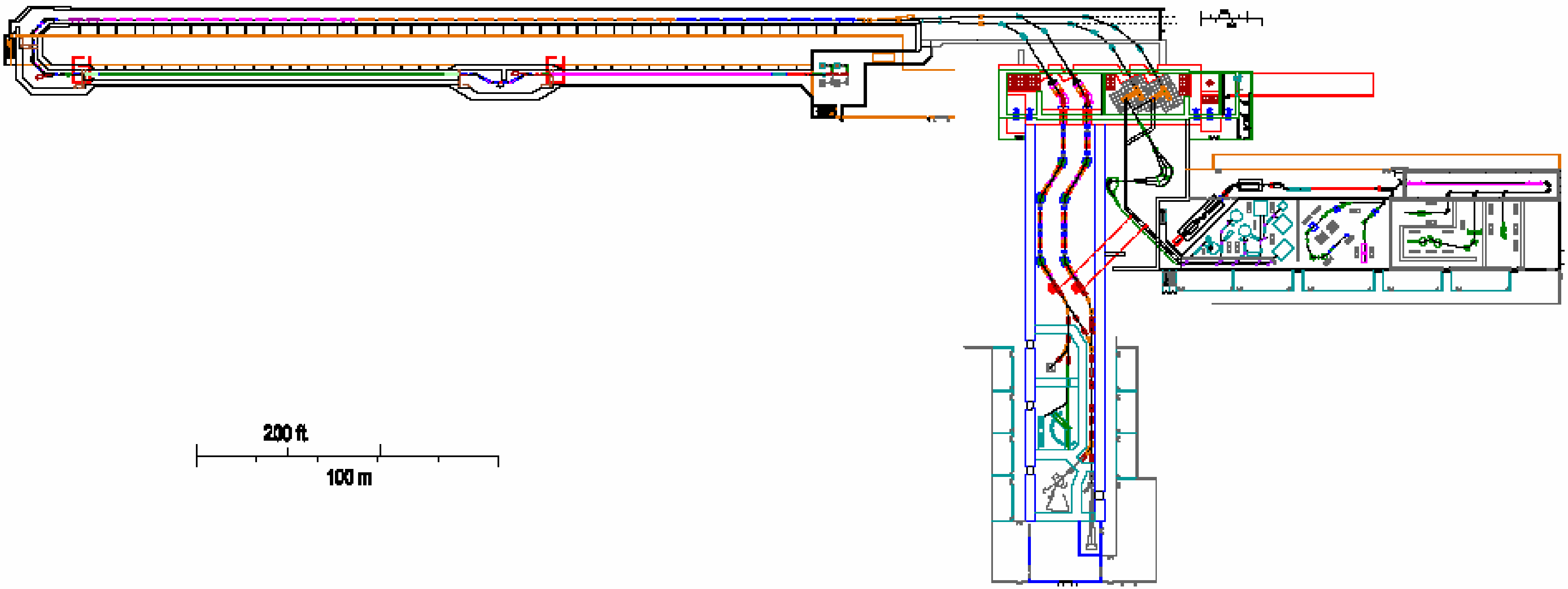
# Multi-User Considerations

- Incorporate capability for simultaneous independent experiments
- Multiple target vs. Cost Optimization
- Maximize availability

# The RIA facility schematic layout and areas of R&D



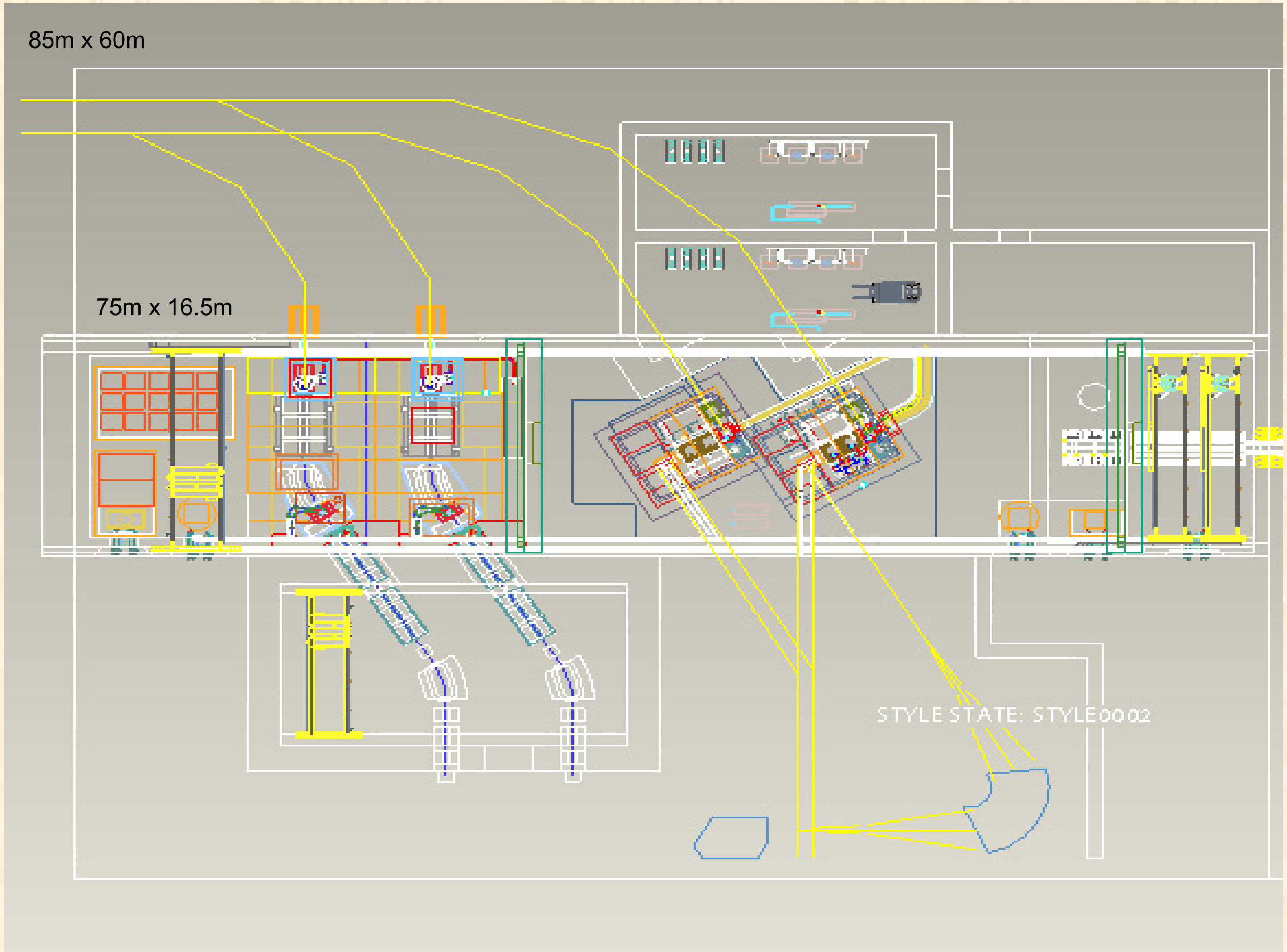
# A Possible RIA Site Layout



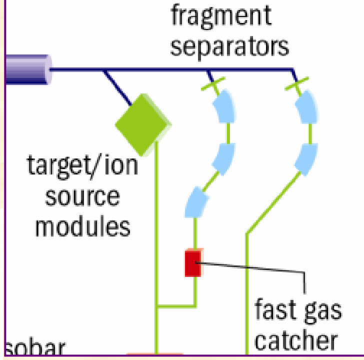
## RIA Parameters List

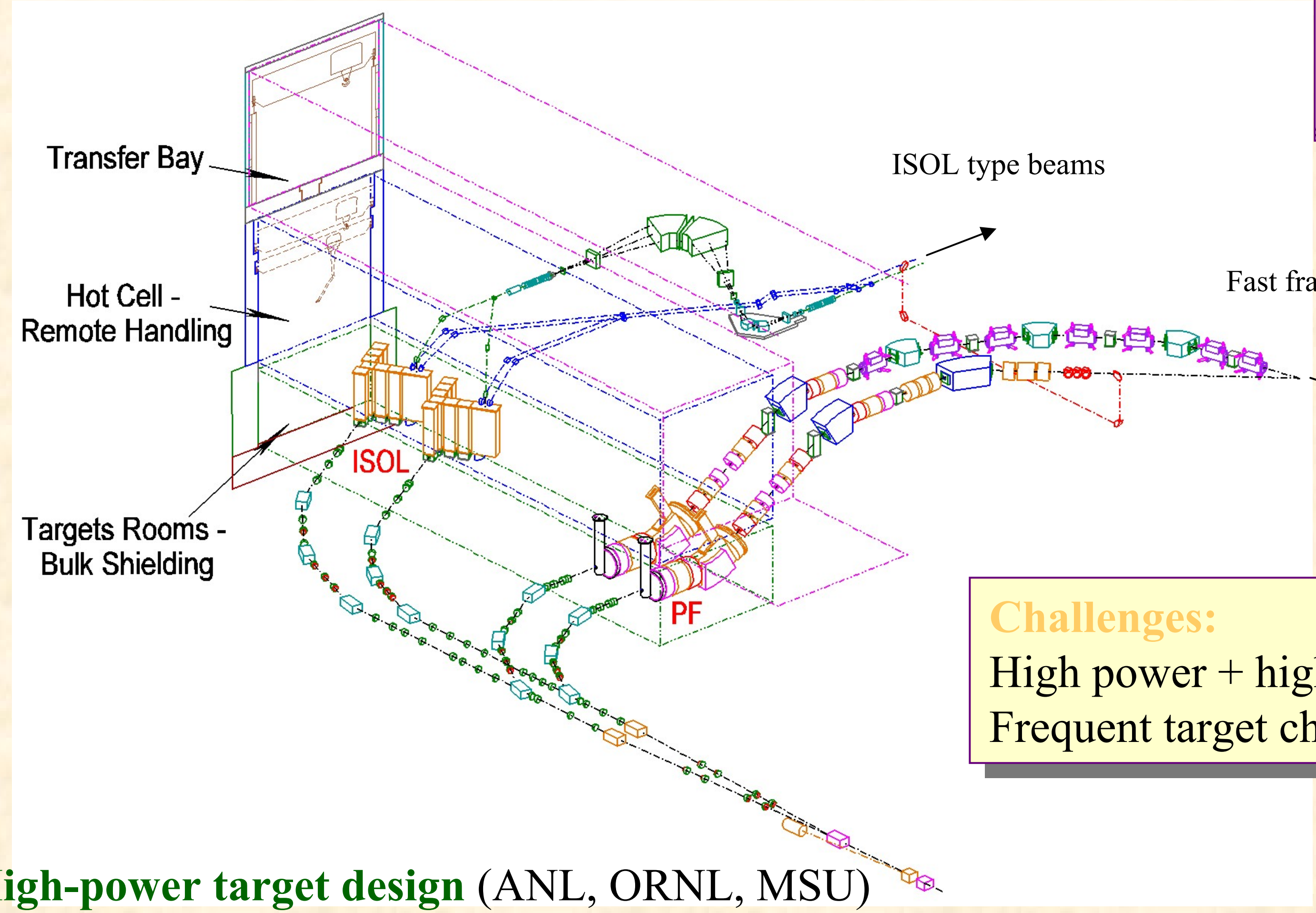
| WBS | Parameter | BaseValue | Unit | Comments |
|---|---|---|---|---|
| 1.0 GLOBAL PARAMETERS | | | | |
| 1. 0. | Maximum beam power on target | 400 | kw | |
| 1. 0. | Primary beam kinetic energy on target | 1.0 | GeV protons | |
| | | 400 MeV/u | uranium | |
| 1. 0. | Beam Frequency | Steady State | | |
| 1. 0. | Protons/sec | 2.5x1015 | | |
| 1. 0. | Ion Types | H thru Uranium | | |
| 1. 0. | Front end length | TBD | | |
| 1. 0. | Linac Length | TBD | | |
| 1. 0. | HEBT Length | TBD | | |
| 1. 0. | RTBT Length | TBD | | |
| 1. 0. | Maximum uncontrolled beam loss | 1 W/m | | |
| 1. 0. | ISOL Target material | Hg,W,Ta,Ucx ..... | | |
| 1. 0. | Fragmentation target material | Li, Graphite, ?? | | |
| 1. 0. | Number of ISOL targets | 2 | | (3rd optional) |
| 1. 0. | Number of Fragmentation targets | 2 | | |
| 1. 0. | Number of stripper stations | 2 | | |
| 1. 0. | Initial number of instruments | ?? | | |

# RIA Target Gallery Layout



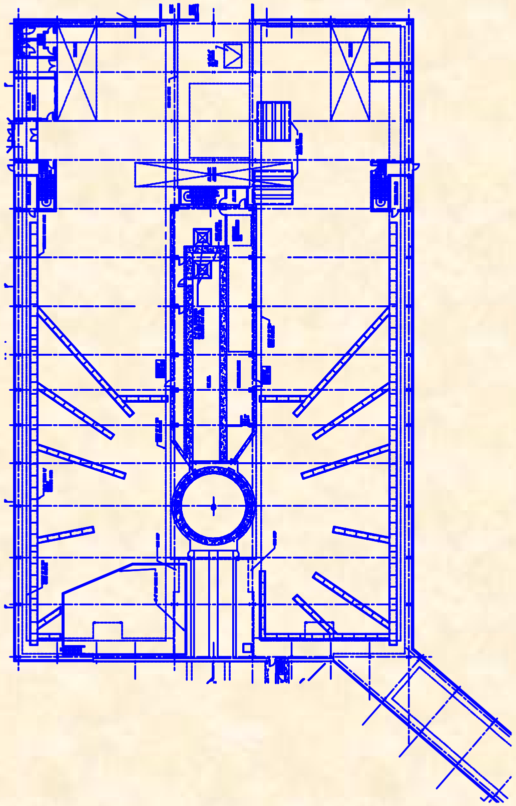
# RIA Beam production area

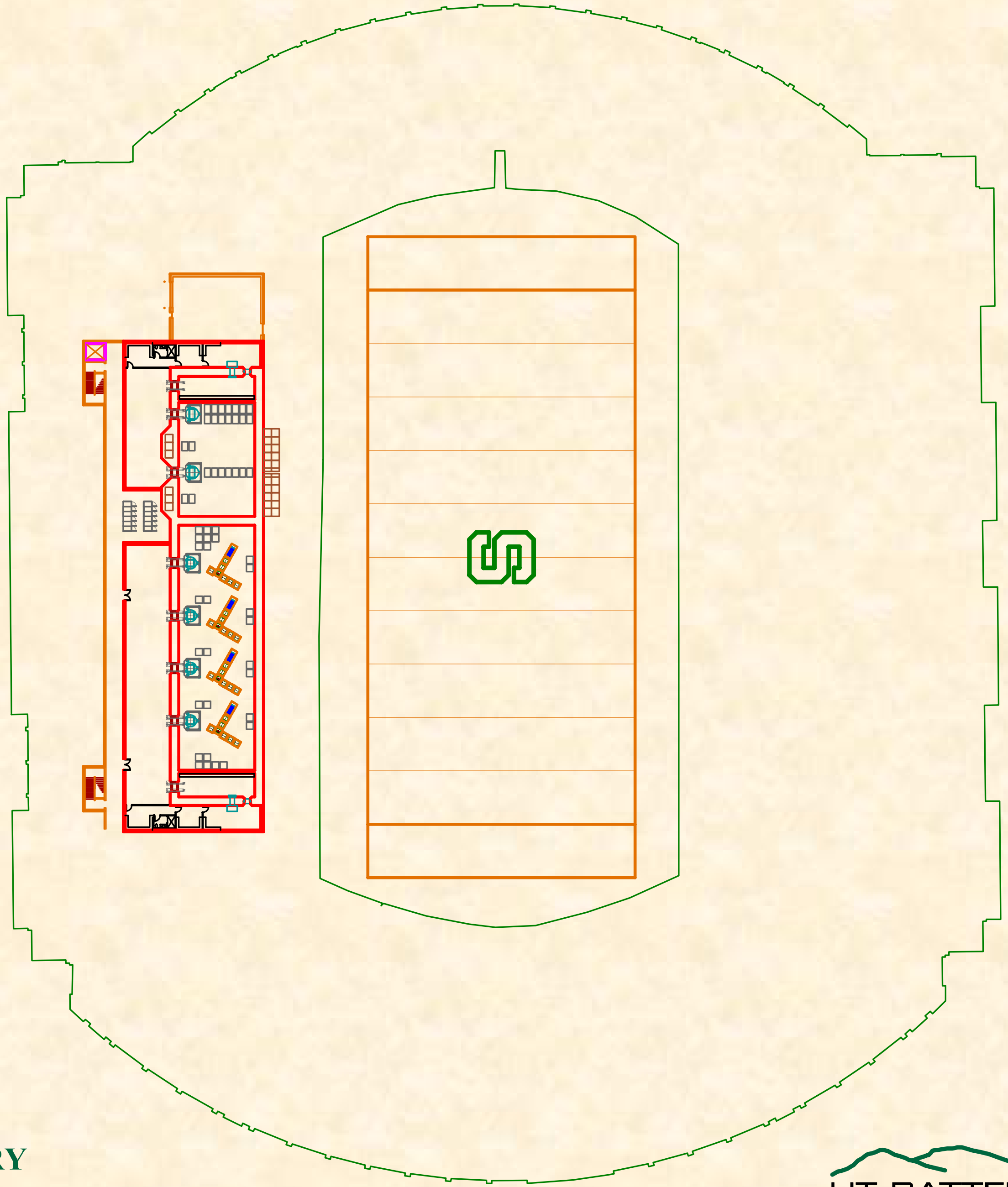


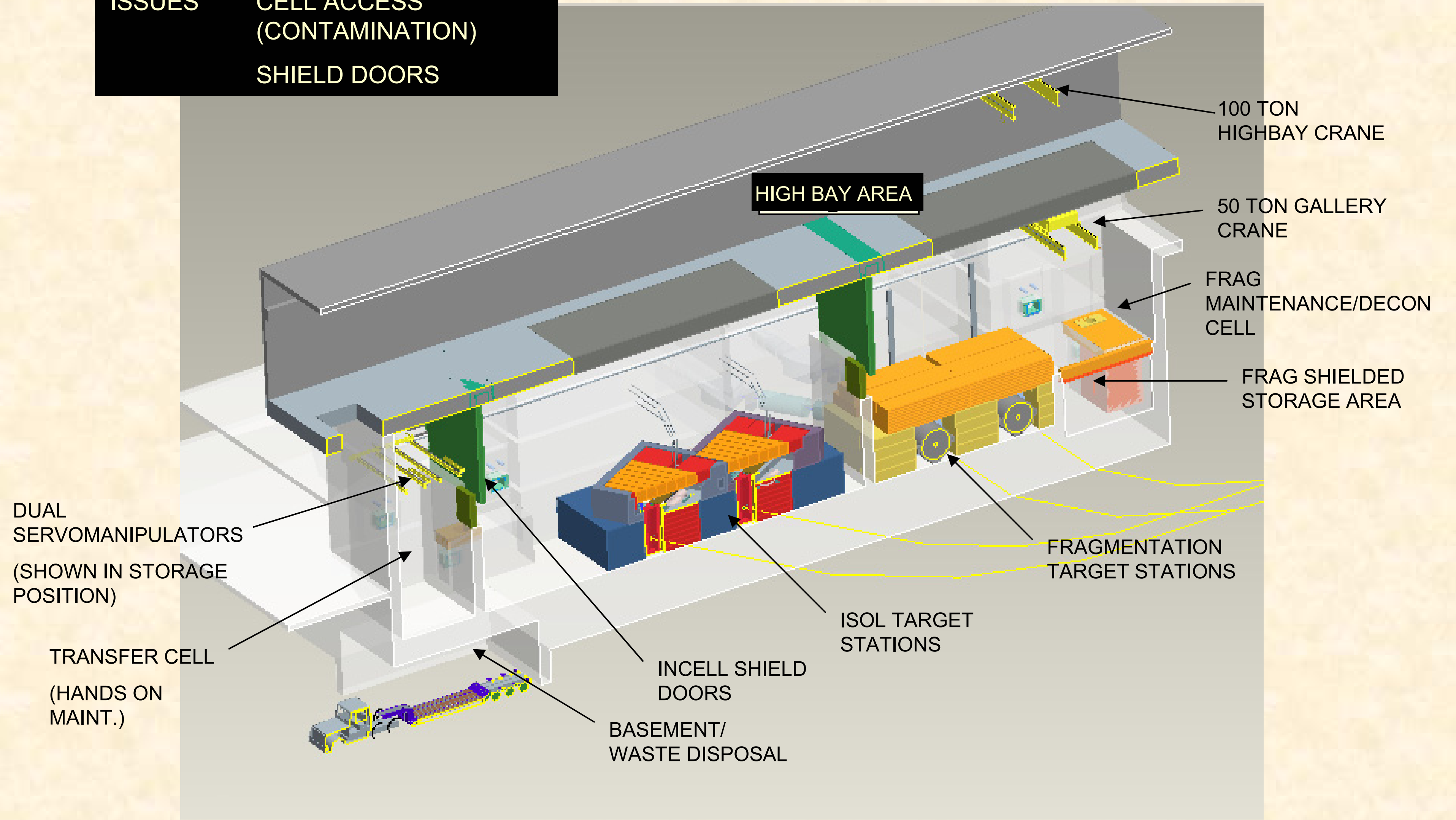

**Challenges:**
High power + high power density
Frequent target changes

- **High-power target design** (ANL, ORNL, MSU)
- **Development of overall concepts for the beam production areas** (MSU, ORNL, LLNL, LBNL, LANL, ANL)

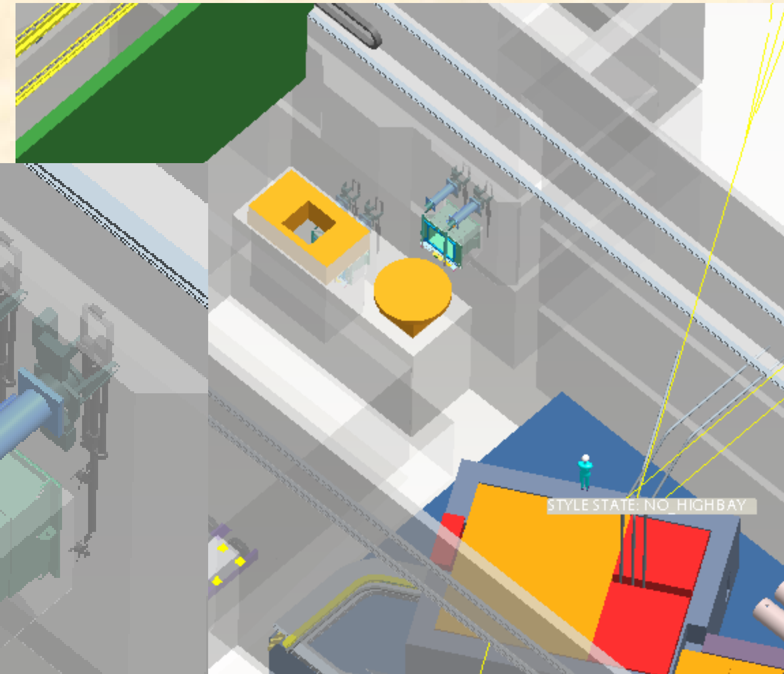




| | |
|---|---|
| ISSUES | CELL ACCESS (CONTAMINATION) |
| | SHIELD DOORS |

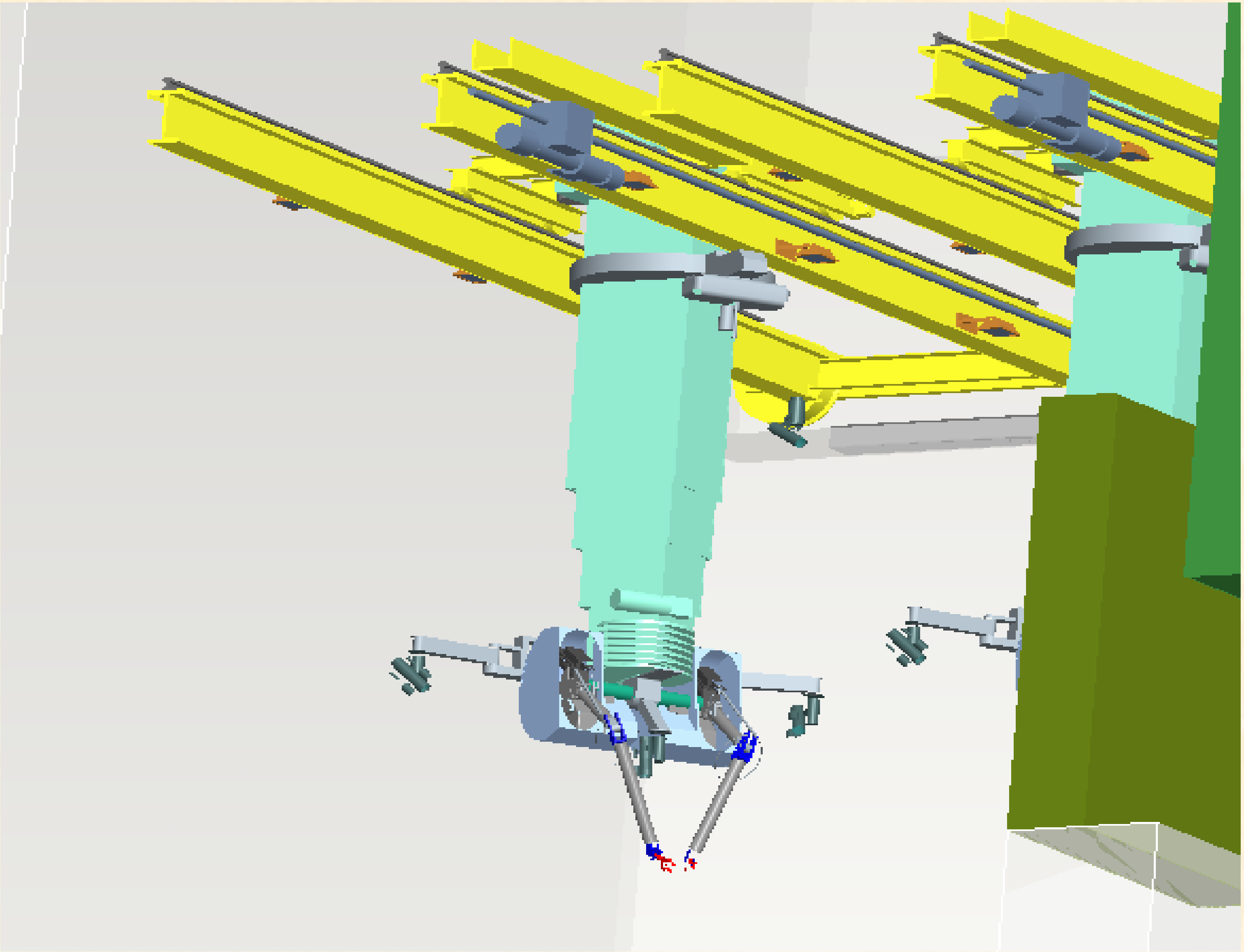


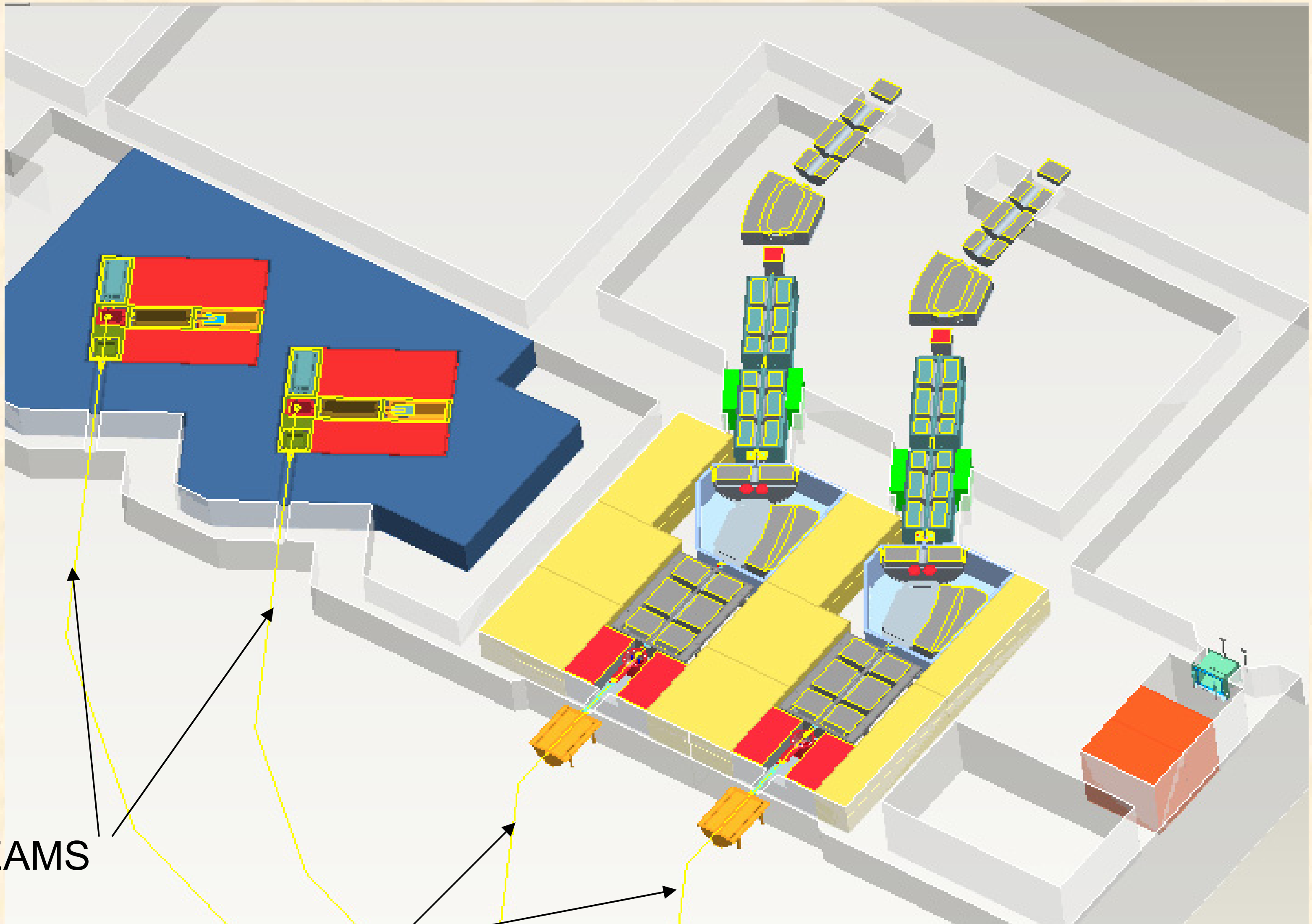
SHIELDED HOTCELL


| | |
|---|---|
| ISSUES | MODULE SIZE |
| | DOSE LIMITS? |

# BRIDGE MOUNTED SERVO MANIPULATOR

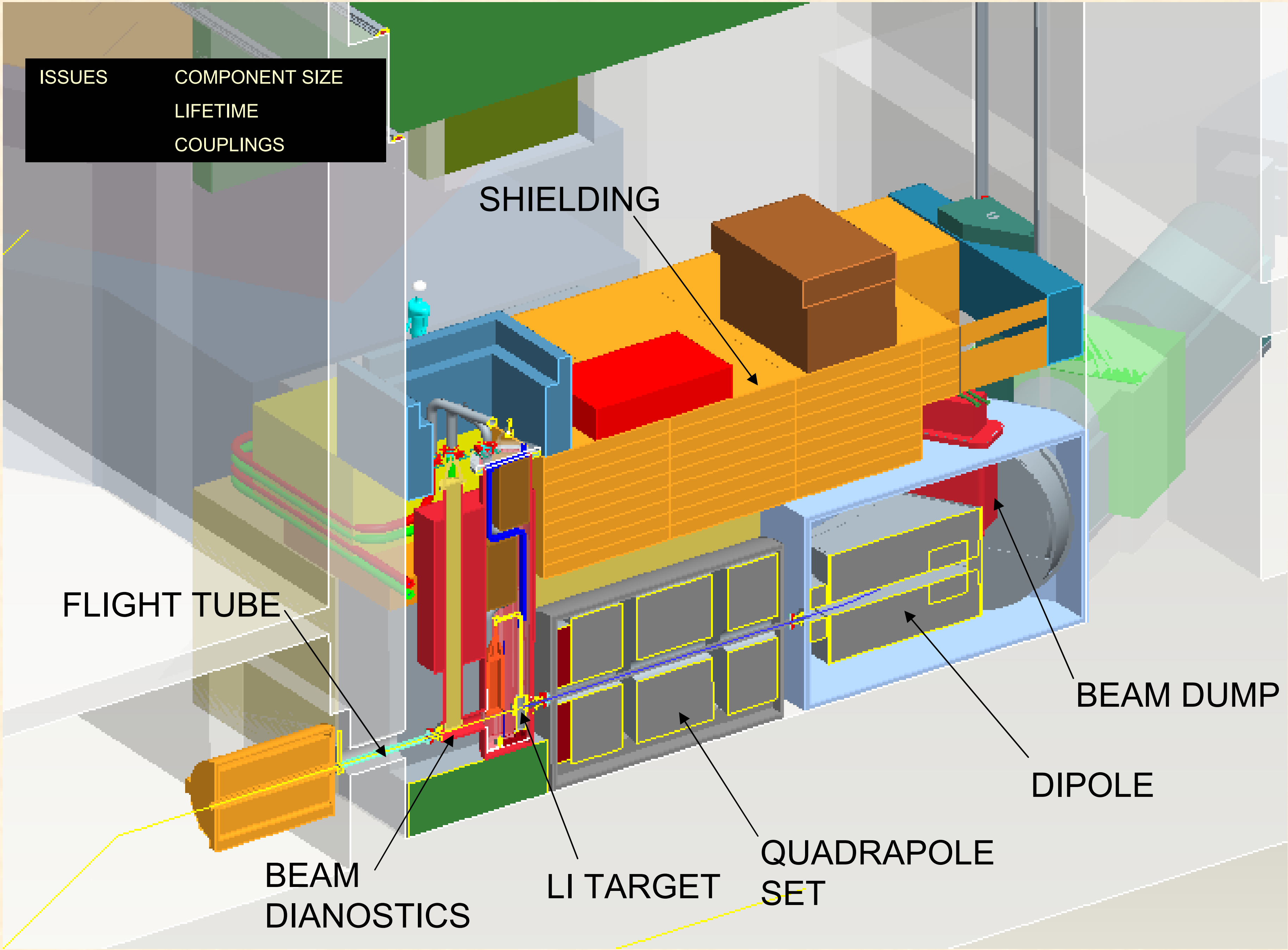


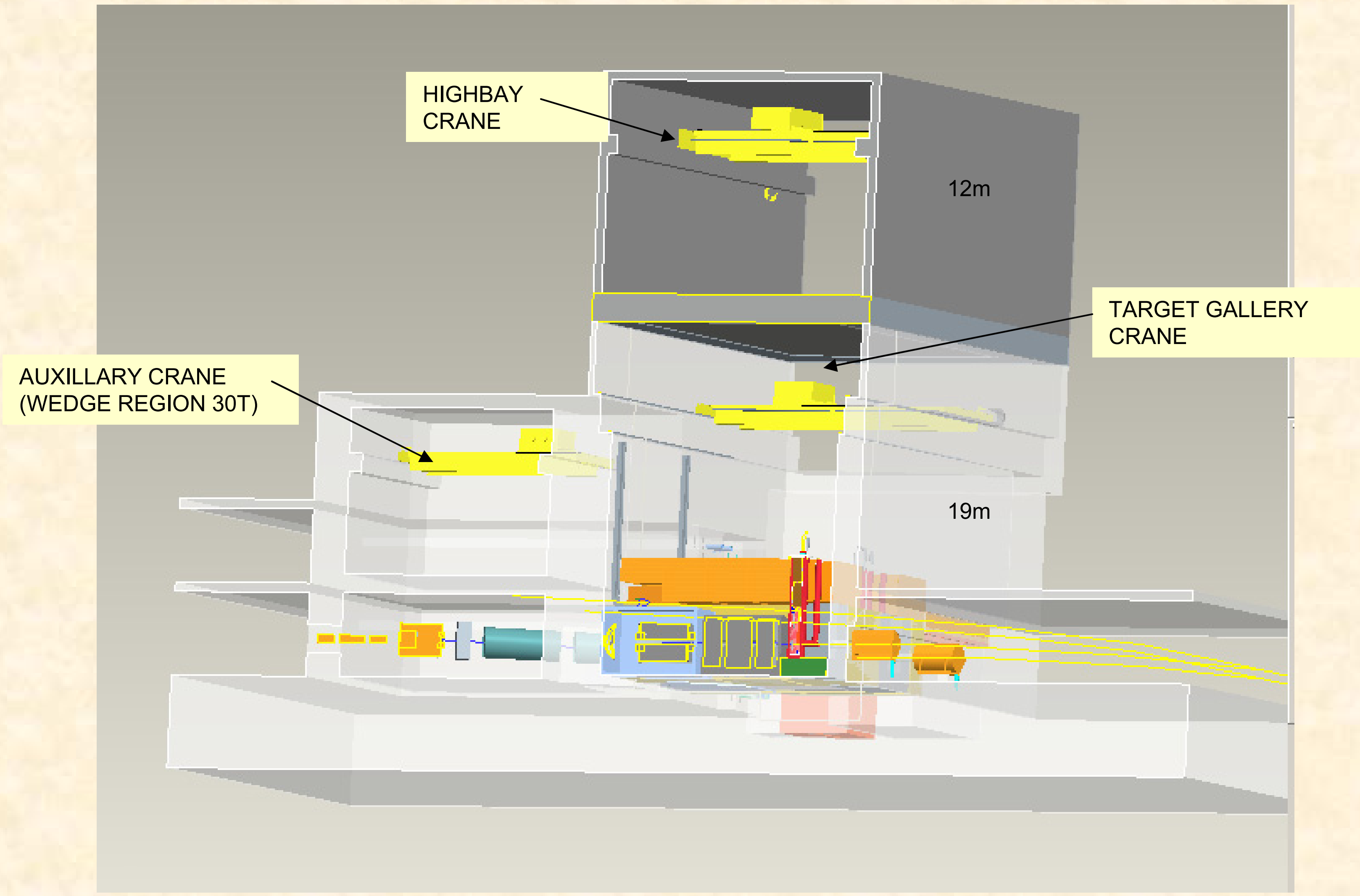


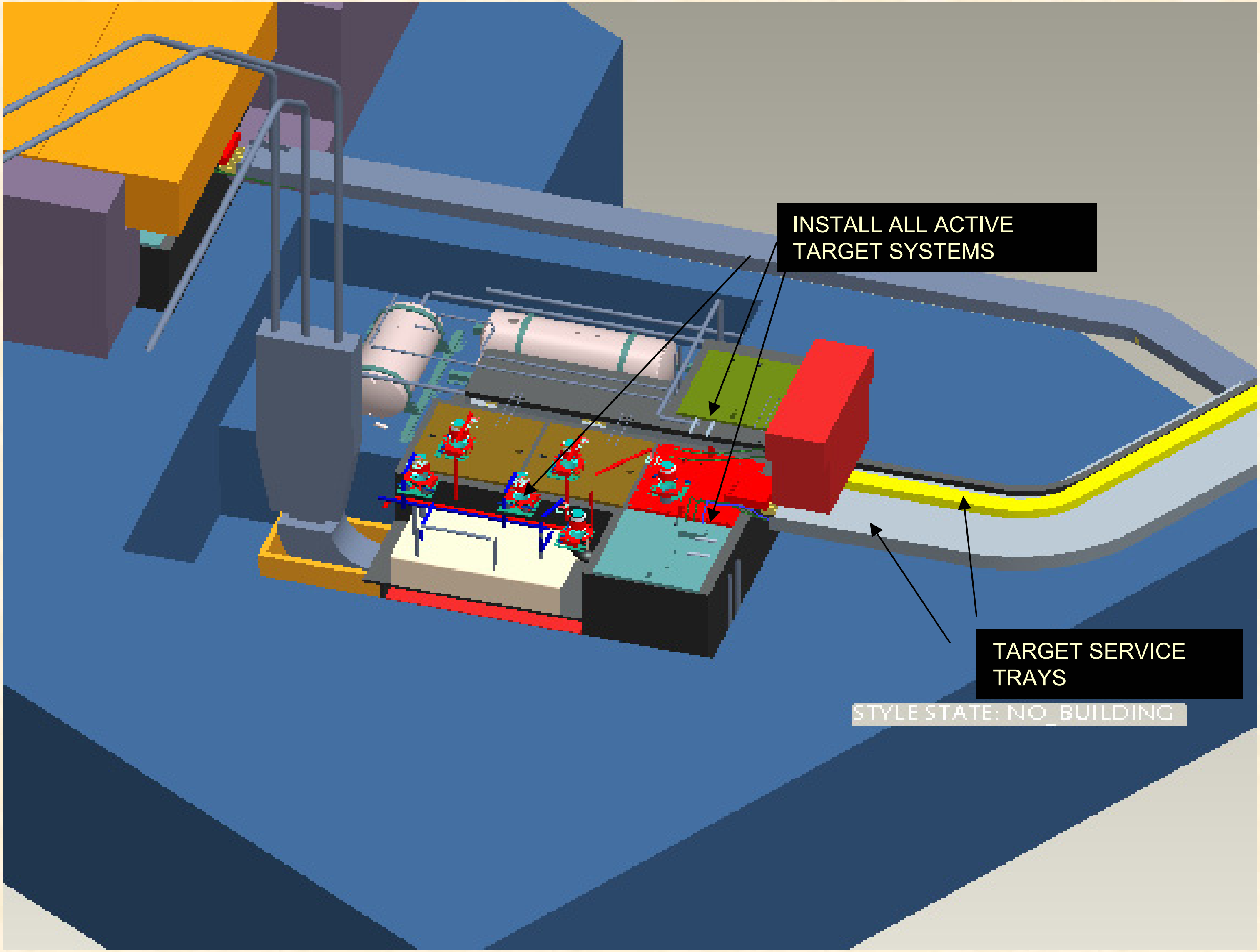
ISOL BEAMS

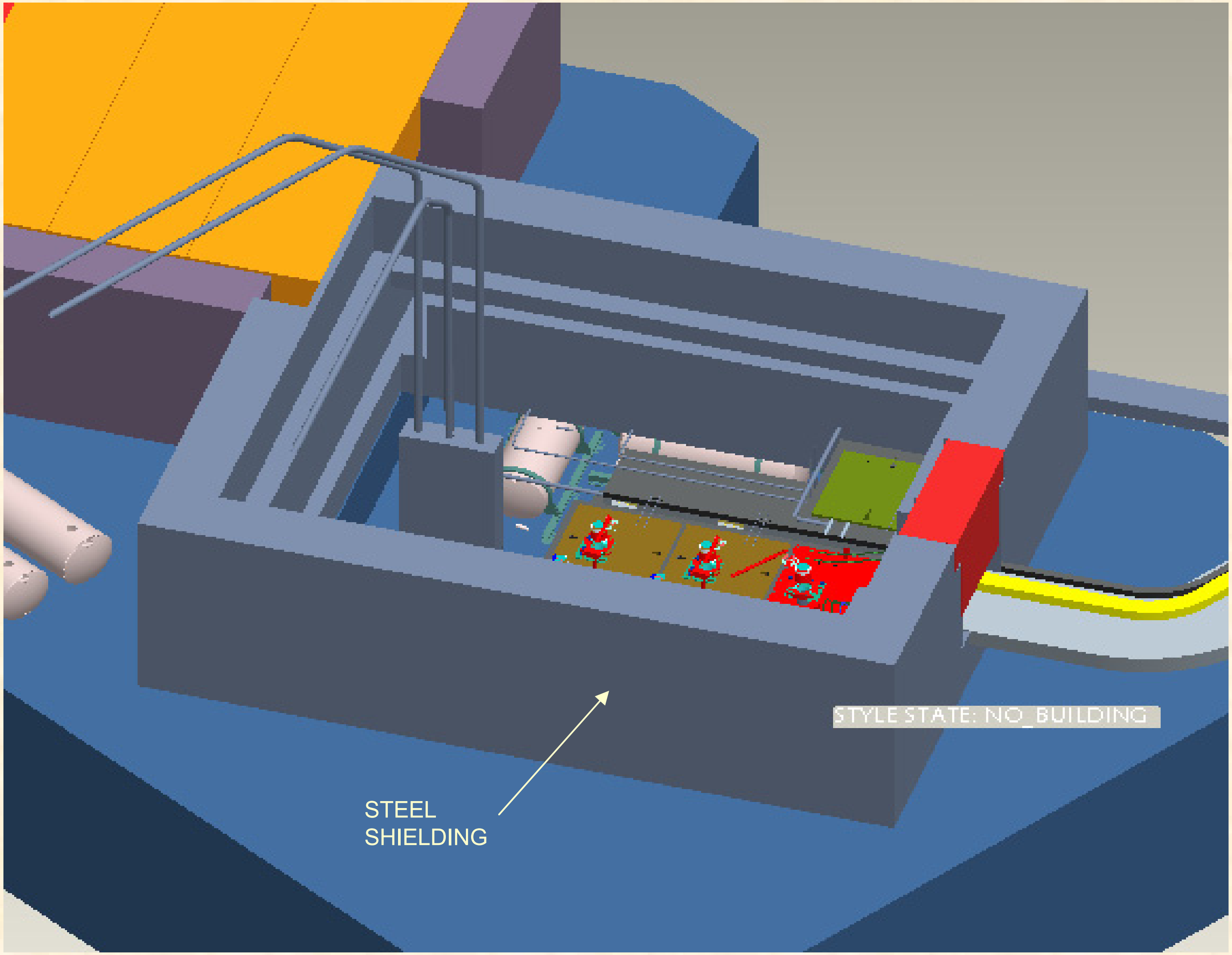
FRAGMENTATION BEAMS

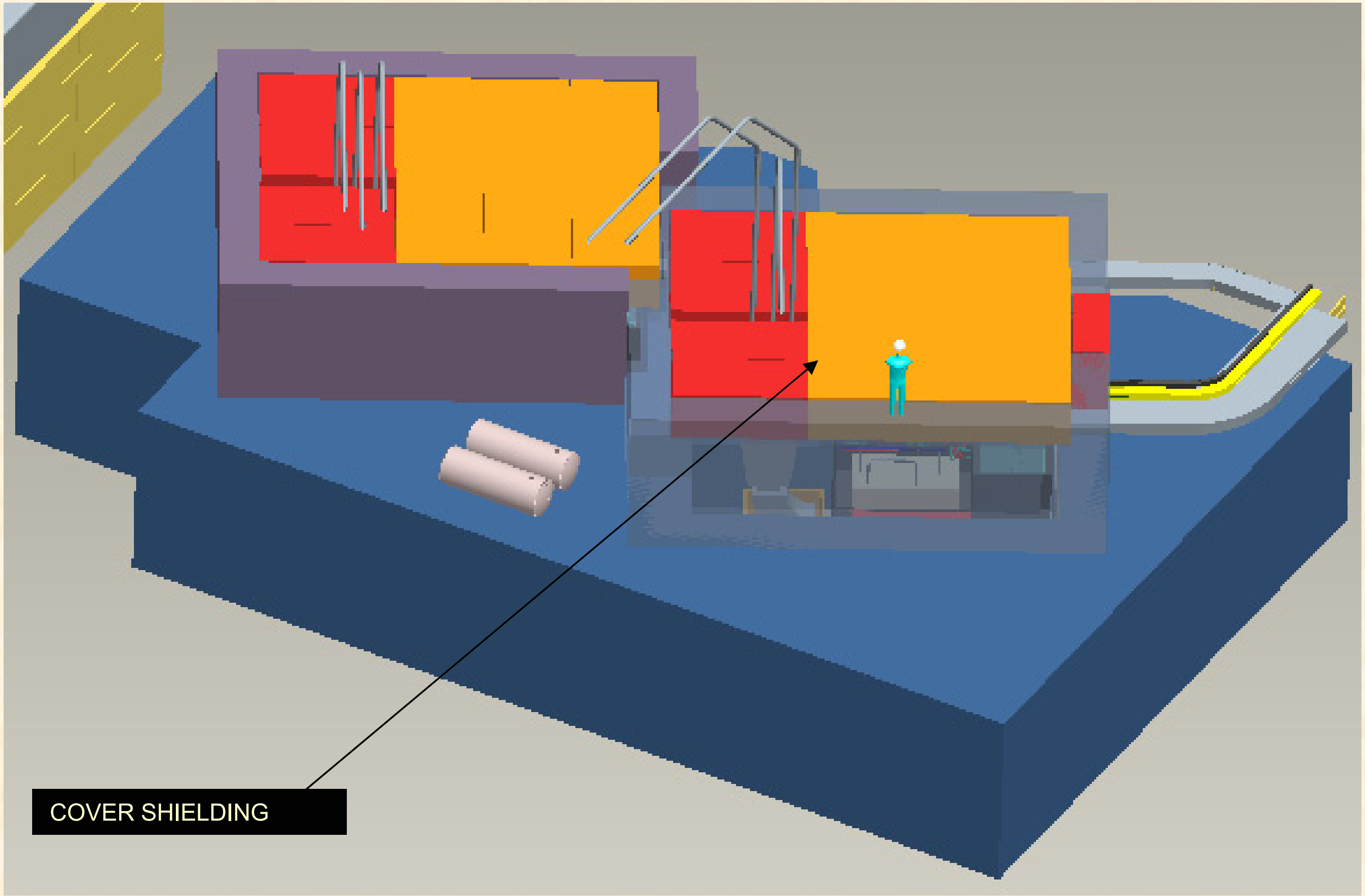
| | |
|---|---|
| ISSUES | COMPONENT SIZE |
| | LIFETIME |
| | COUPLINGS |




HIGHBAY
CRANE
12m
TARGET GALLERY
CRANE
AUXILLARY CRANE
(WEDGE REGION 30T)
19m


INSTALL ALL ACTIVE
TARGET SYSTEMS
TARGET SERVICE
TRAYS
STYLE STATE: NO_BUILDING

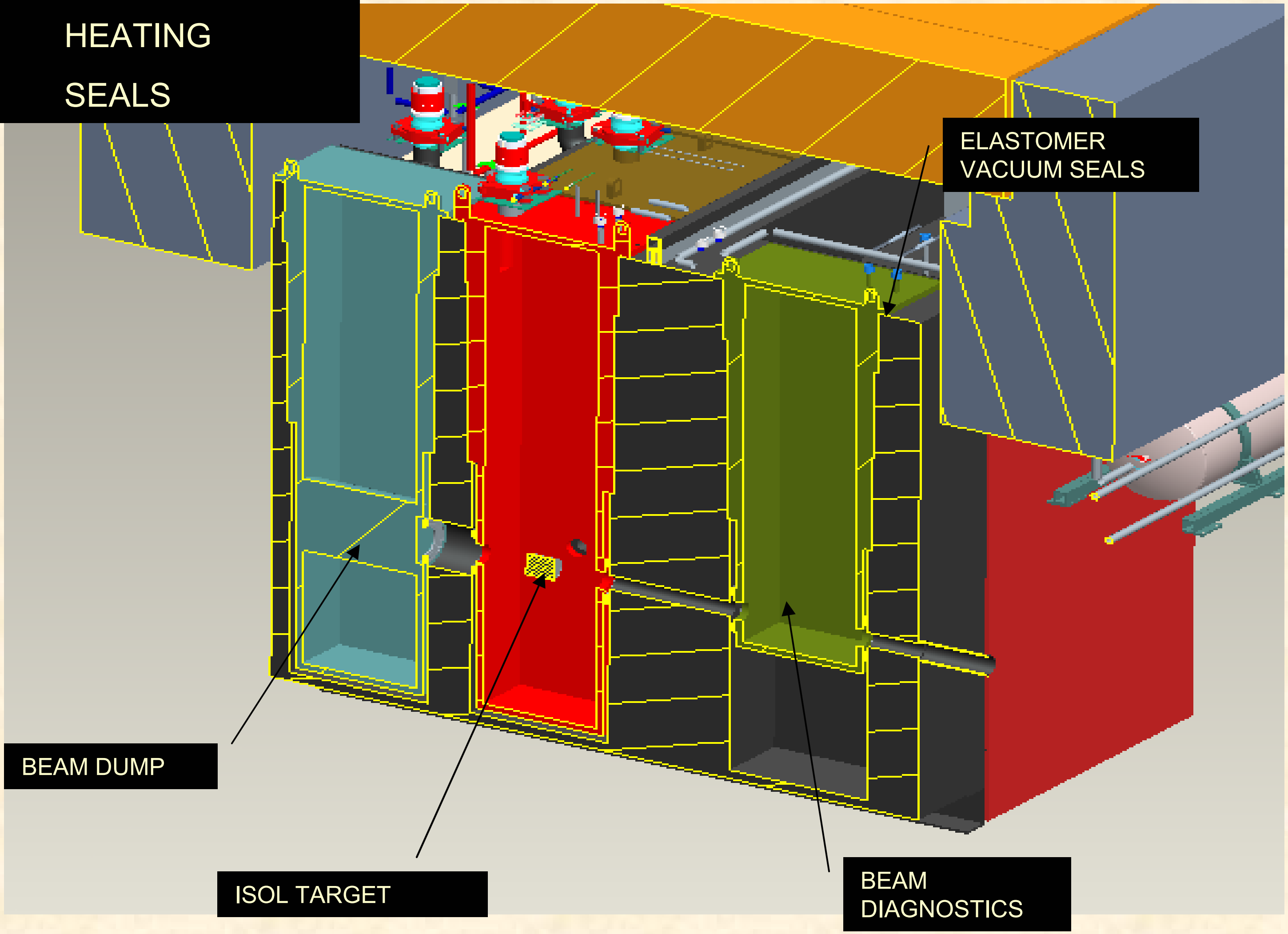

STYLE STATE: NO_BUILDING
STEEL
SHIELDING

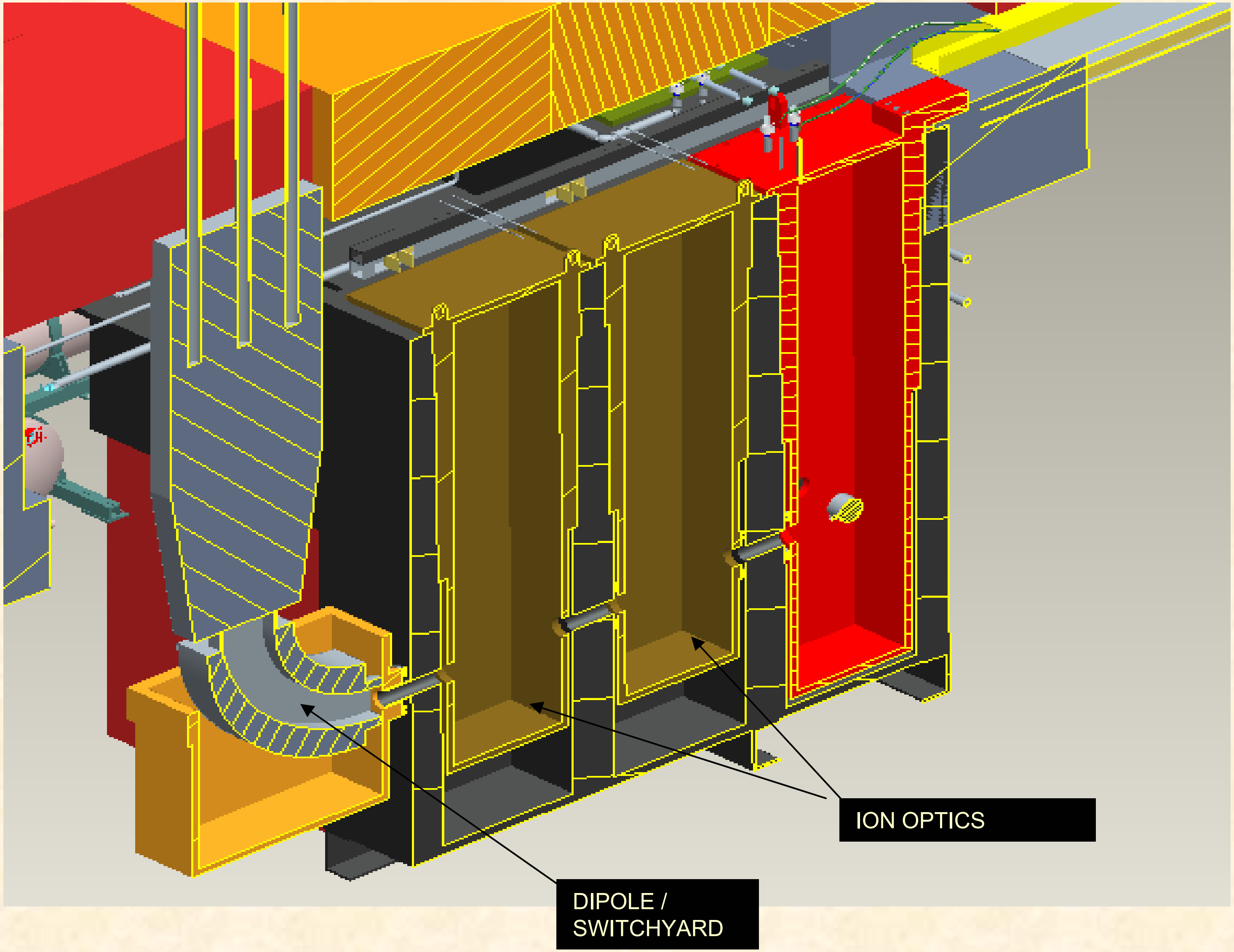

COVER SHIELDING

ISSUES MODULE SIZE

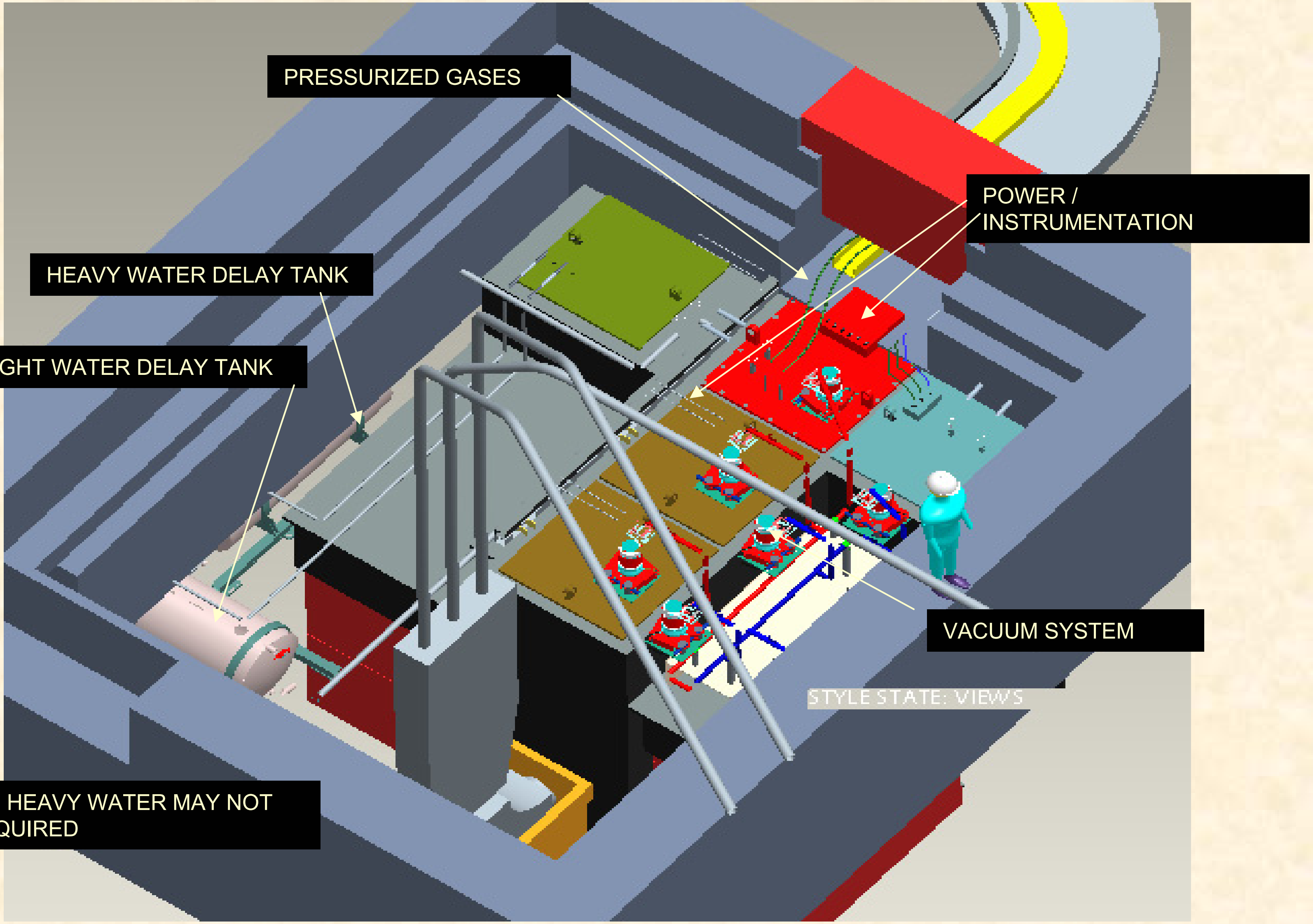
HEATING

SEALS

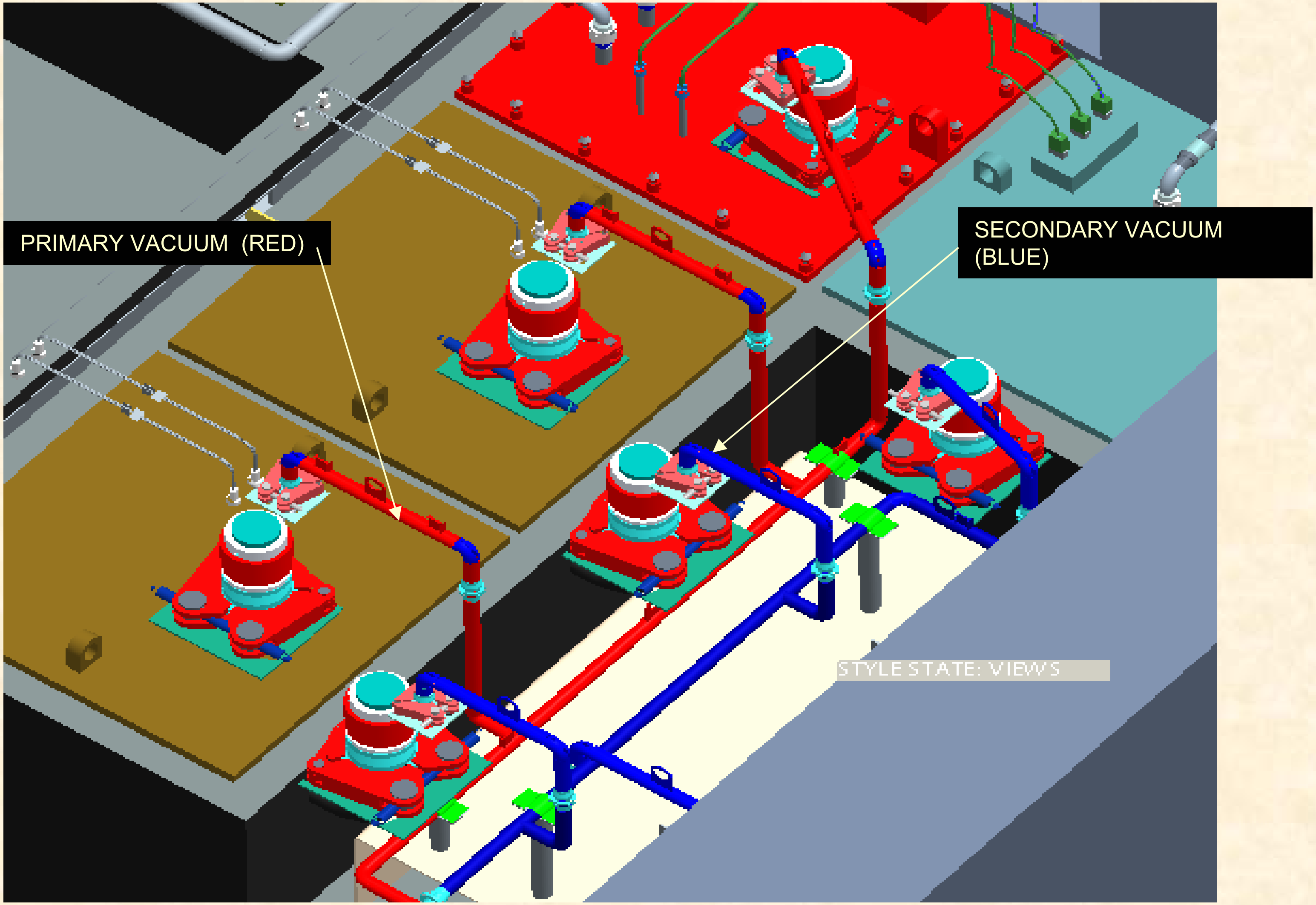


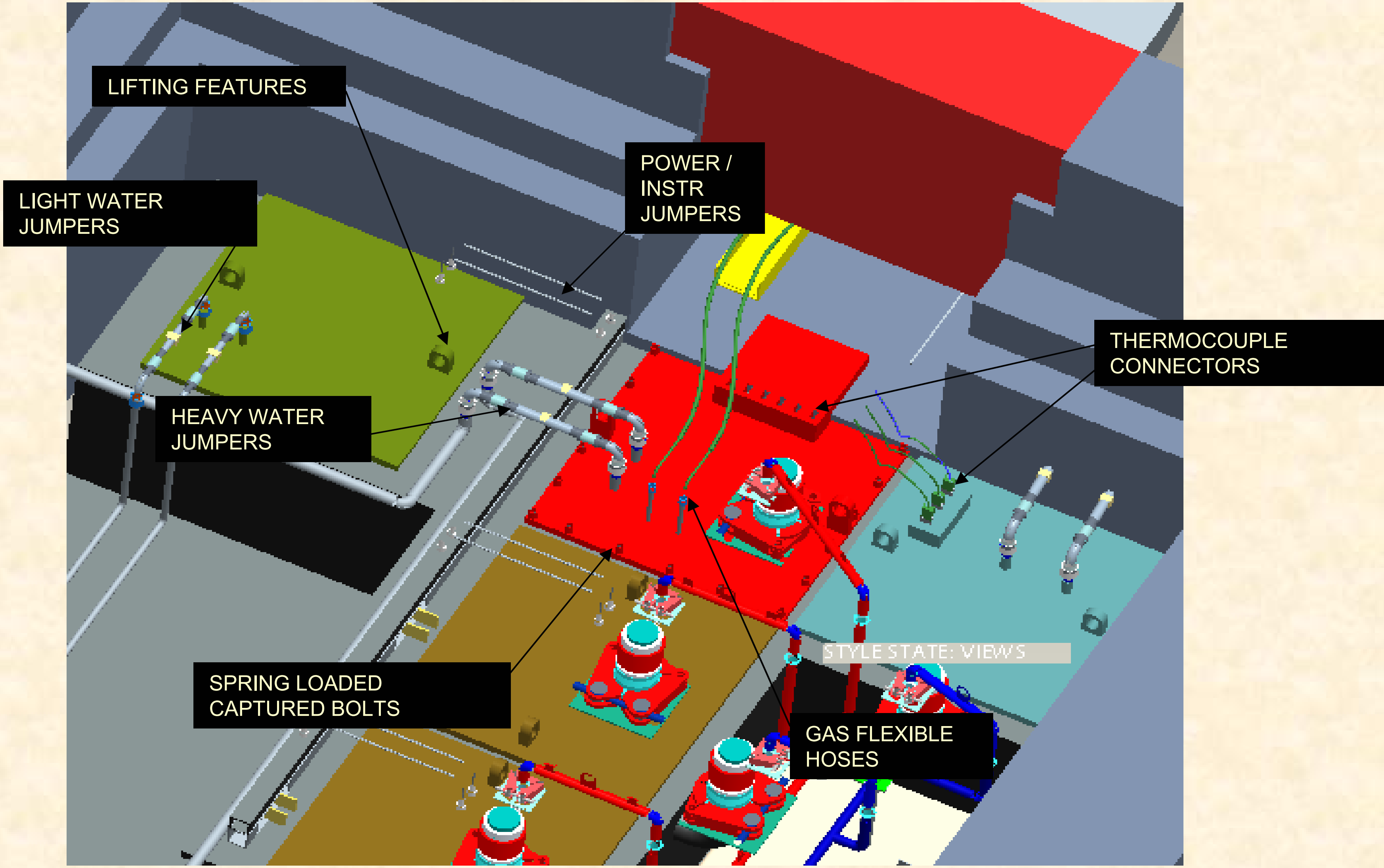

ION OPTICS
DIPOLE / SWITCHYARD

# ISOL TARGET UTILITIES




NOTE: HEAVY WATER MAY NOT BE REQUIRED


PRIMARY VACUUM (RED)
SECONDARY VACUUM (BLUE)
STYLE STATE: VIEWS


LIFTING FEATURES
LIGHT WATER JUMPERS
POWER / INSTR JUMPERS
THERMOCOUPLE CONNECTORS
HEAVY WATER JUMPERS
SPRING LOADED CAPTURED BOLTS
GAS FLEXIBLE HOSES
STYLE STATE: VIEWS


RIA Overview

# Requirements for RIA Target Building Remote Maintenance

- Large Hot Cell Remote Handling Equipment
- Large Hot Cell Configuration and Function
- Component Design for Remote Handling
- Remote Tooling

# Remote Handling Manipulators

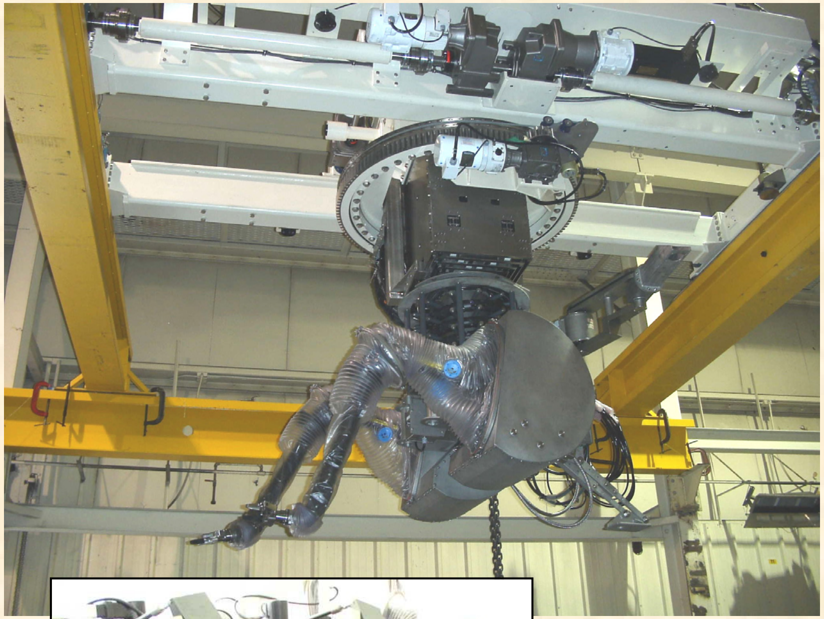
- There are three basic types of manipulators:
  - Wall Mounted Master-Slave Manipulator
  - Power-arm mounted on bridge
  - Servomanipulator mounted on bridge

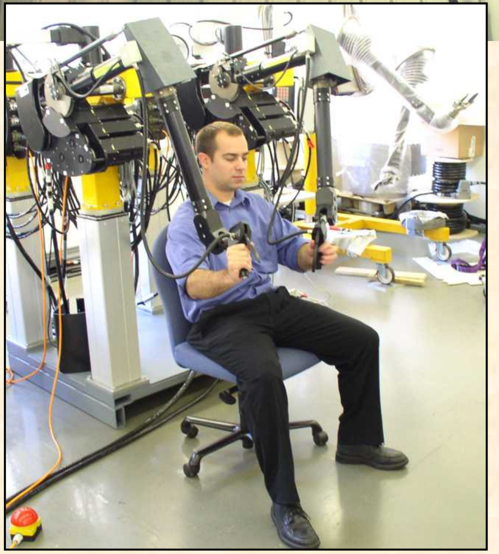
# Master-Slave Manipulator (MSM)

- Advantages
  - Highly dexterous
  - Force reflecting
  - Inexpensive
  - Reliable (HD models)
  - Work well with a shielding window
- Disadvantages:
  - Limited reach
  - Small effective working volume
  - Require a shielding window workstation
  - Can be overloaded by operator

# Bridge Mounted Servomanipulator

- **Advantages:**
  - Highly dexterous handling
  - Force reflecting
  - 5 to 8 X hands-on task times
  - Reduces need and cost of special remote handling features on components
  - Moderately powerful
  - Can be equipped with an auxiliary hoist to assist with material handling





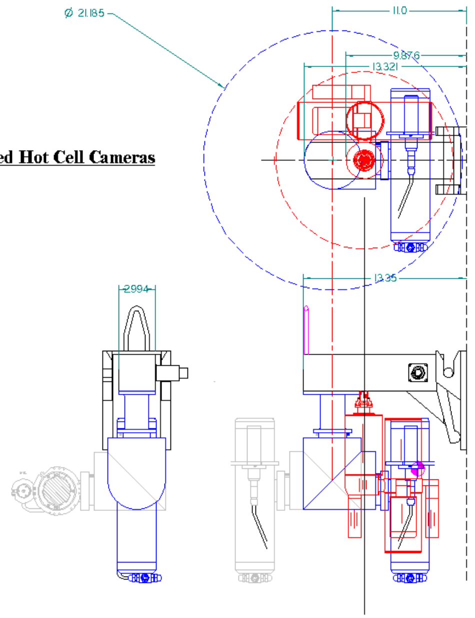
- **Disadvantages:**
  - Expensive
  - Complex and potentially unreliable
  - Mechanically compliant arm limits positioning accuracy in robotic mode

# Hot Cell Video Cameras - Rad Tolerant

Radiation hard IST/REES R981 Cameras (industry standard )

- Advantages
  - Wall and bridge mountable
  - Can include lights and cameras
  - Rad resistance to >$10^5$ rads
  - Reliable
- Disadvantages
  - High cost
  - Hands-on maintenance required
  - Black and White only
  - Relatively poor visual quality
  - Limits hot cell background

SNS Proposal for Wall Mounted Hot Cell Cameras



# Hot Cell Functions

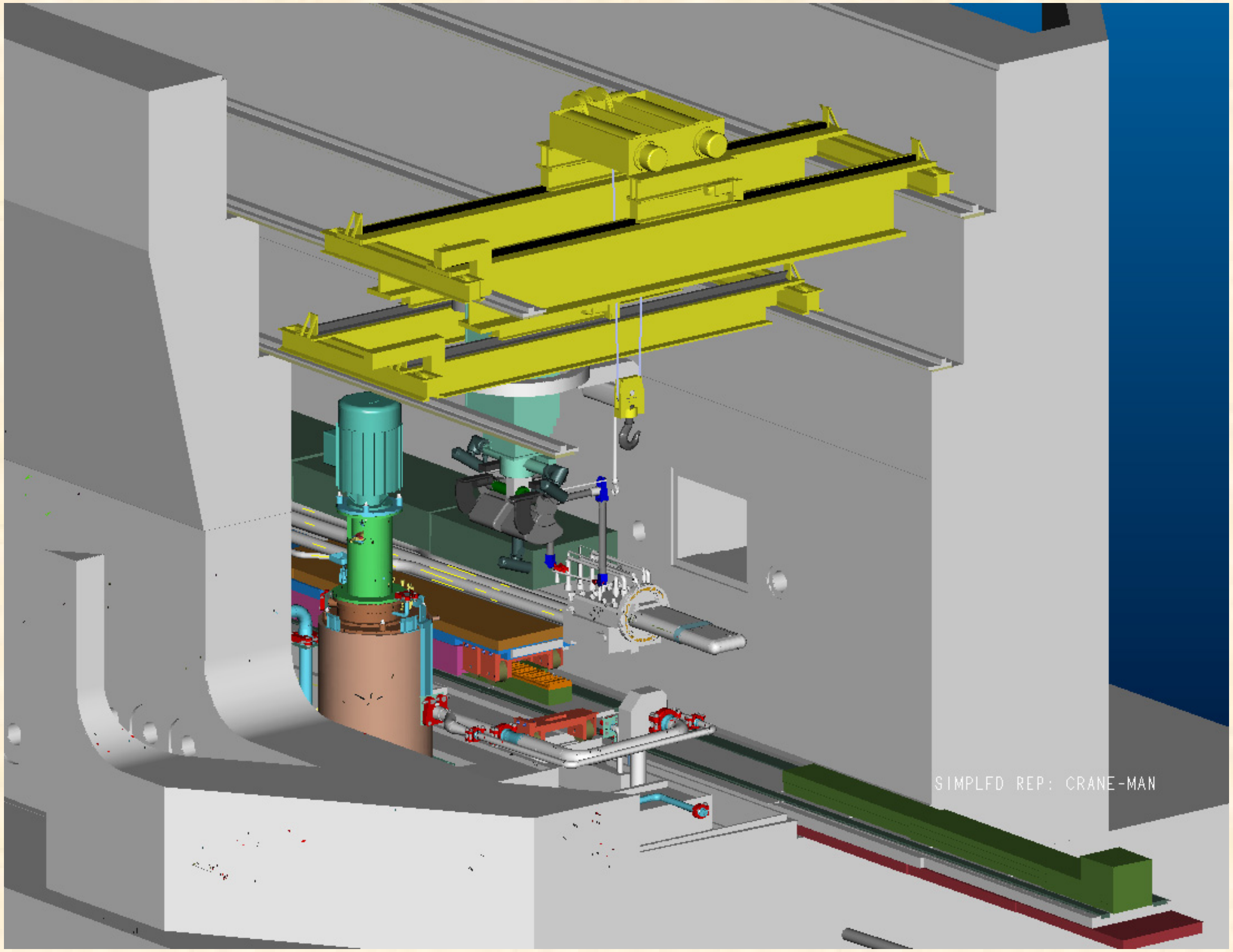
- Hot cells have two primary functions
  1. Radiation Control; passive elements such as concrete, shielding windows and vault doors.
  2. Contamination Control; active systems
     - high efficiency ventilation
     - low level liquid waste water treatment
     - Solid waste treatment, handling and shipping
  - Each of the three active systems is expensive and large

# Hot Cell Material Handling

- Gravity is our only friend; therefore…..
- Virtually all material handling is accomplished by bridge cranes; as a result:
  - Cells tend to be high to provide head room, hook height and clearance over servomanipulator bridges.
  - Cells tend to be long and narrow to reduce the bridge width and allow for easier monitoring of bridge motions.
  - Working areas of cell determined by bridge coverage; thus crowning of the cell is advantageous.
  - Cell modules should be designed for the minimum possible load since larger cranes have less coverage.

# Crane and Servomanipulator Combinations

- Overhead bridge crane is mounted above the servo bridge
- Servomanipulator and transporter with Aux hoist must be able to pass bridge crane to operate on both sides of the hook
- Retrieving tools and lift fixtures is difficult and time consuming
- RIA will probably require multiple cranes and servo systems to provide backup and reduce turn-around times.

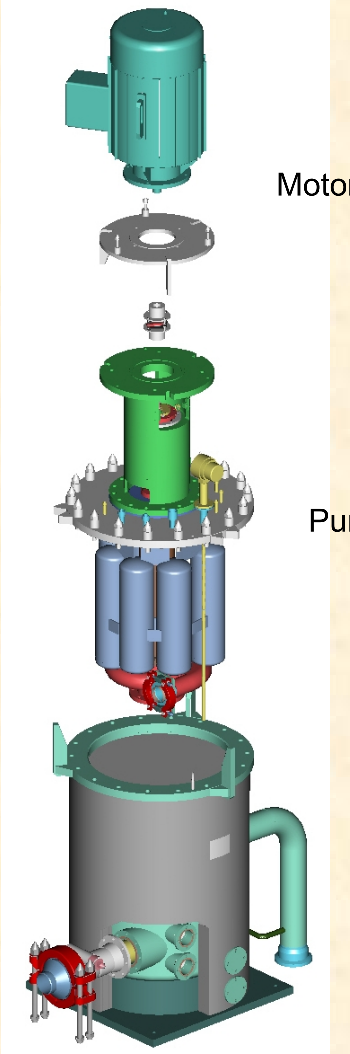


# Personnel Access vs. Fully Remote

- A Fully Remote Hot Cell Is Completely Different from a Personnel Accessible Cell in Cell Design, Component Design, Layout, Tooling, and Operation.
- A Cell Designed To Operate Partially Hands-on Cannot Be Easily Converted To Full RH.
- Cooling water vaults can be entered after 1-3 days of radiation cool-down if filters and IX columns have local shielding.

# Remote Maintenance Design

- **Process components modularized based on expected maintenance frequency**
- **Remote handling interfaces incorporated to facilitate remote disassembly and assembly of modules with standardized remote tooling and lift fixtures**
- **Maintenance accomplished by replacement of failed component**




SNS Hg Pump

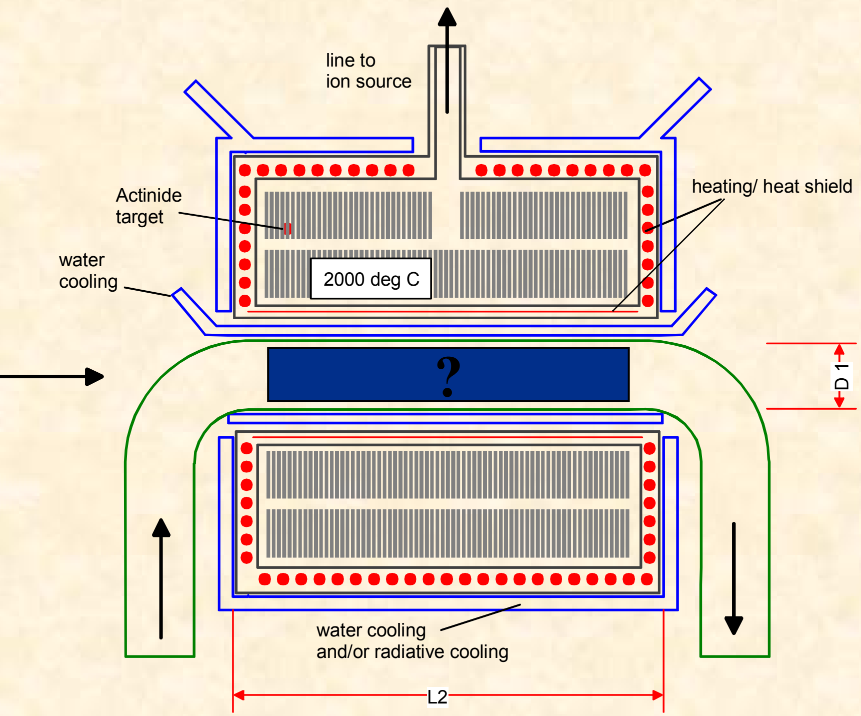
# Identification of Tasks

Remote handling tasks must be identified early; the list is the basis of design for the RH system and the components

| Summary Top Level Maintenance Design Parameters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Expected | Oper. Life | Restoration | Time Goals | Spare | Repair |
| 1. | 0. | Target Process Components | | | | | | |
| | 1. | Target Module | >4 | Mo | < 5 | D | Yes | No |
| | 2. | Primary Mercury Pump | ~20 | Yr | <30 | D | No | No |
| | 3. | Primary Mercury Pump Motor | ~5 | Yr | < 5 | D | Yes | No |
| | 3. | Process Control Sensors | 1 | Yr | <2 | D | Yes | No |
| | 4. | Vacuum Pump Module | ~5 | Yr | <5 | D | No | No |
| | 6. | Mercury Process Gas Valves | ~5 | Yr | <5 | D | Yes | No |
| | 7. | Mercury Transfer Valve | ~20 | Yr | <5 | D | No | No |
| | | Mercury Transfer Valve Operator | ~5 | Yr | <2 | D | Yes | No |
| | 8. | Hg/Water Heat Exch. | >15 | Yr | <60 | D | No | No |
| | 9. | Pipe Spools (Frequent Coupling) | >10 | Yr | <60 | D | No | No |
| | 10. | Collection Basin | LOF | | | | No | No |

# Remote lift fixture examples

# Two-step fission targets for ≥ 100 kW beam power




**Principle of 2-step fission targets:**
- Neutron converter for neutron production and dissipation of beam power
- Surrounding blanket of fissionable material for rare isotope production

**Original proposal (J. Nolen, ANL):**

**Li-cooled W converter**

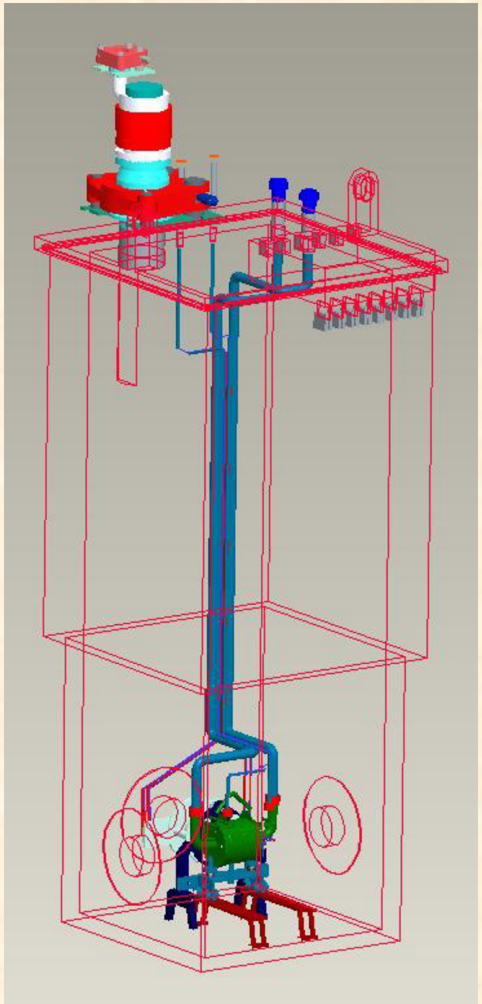
**Are there alternatives to Li +W ?**

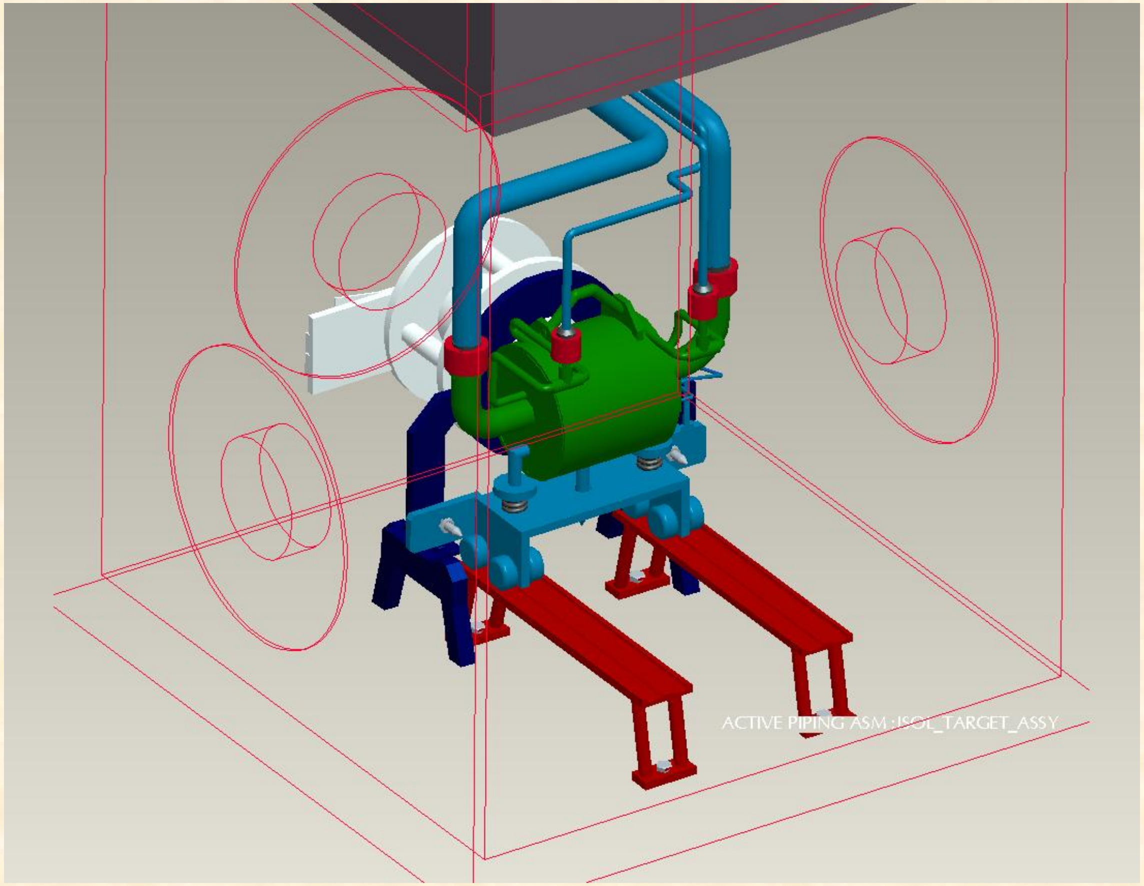
**(MSU, ORNL, LLNL)**

1) **Mercury as target and coolant**
2) **Water-cooled W**

**Choice of converter type has impact on design of target area →**

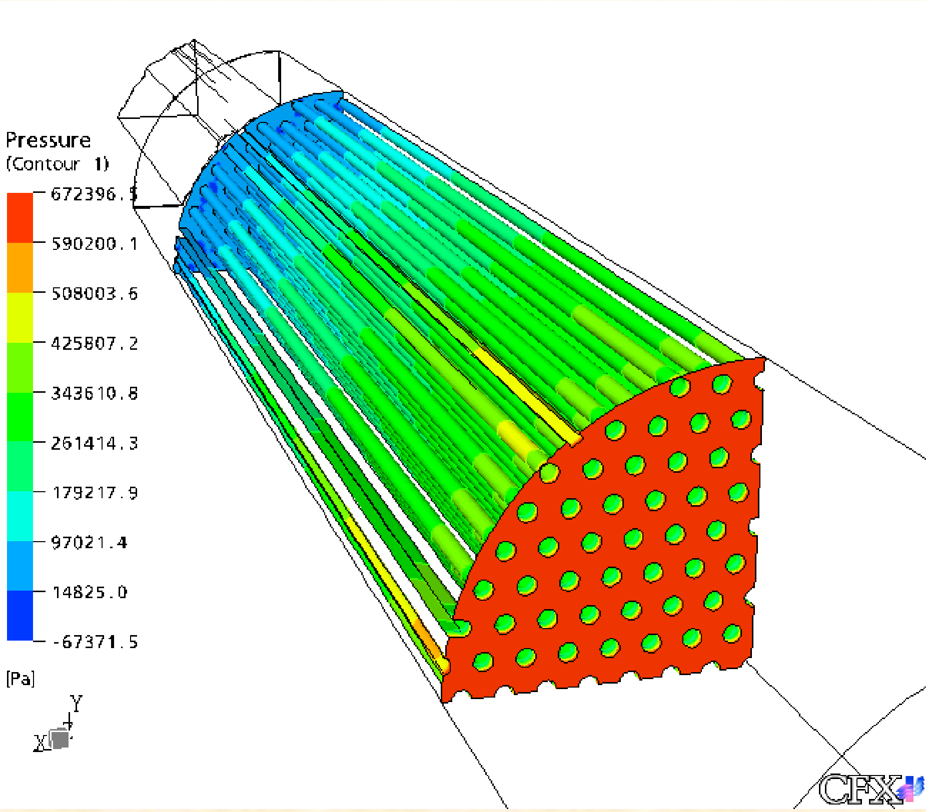
- Investigation of neutron/fission yields, beam and decay heating, radiation damage for 400 kW 2-step target
- Conceptual design studies of cooling schemes



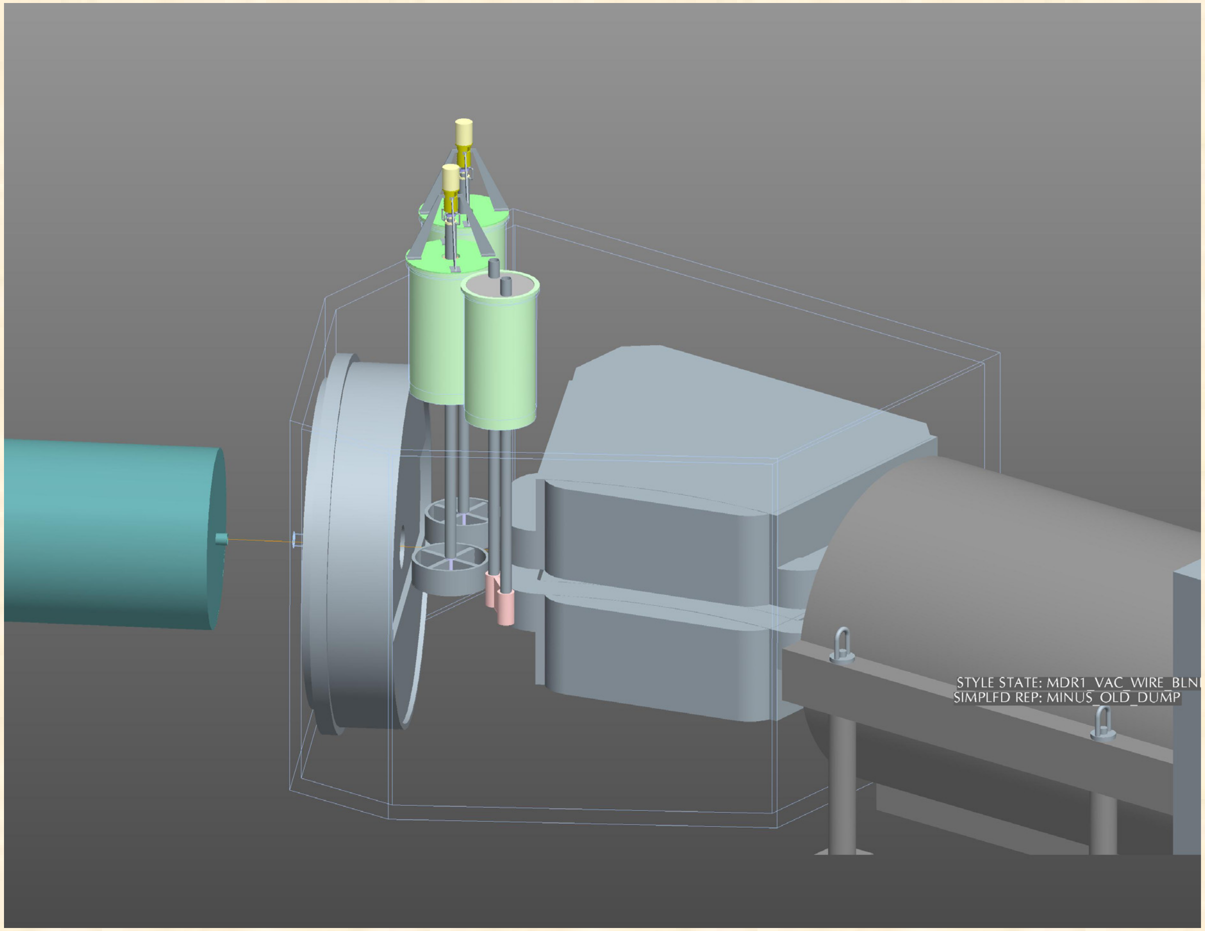

ACTIVE PIPING ASM :ISOL_TARGET_ASSY

# Axial flow Design
# Water velocity of 18.2 m/s

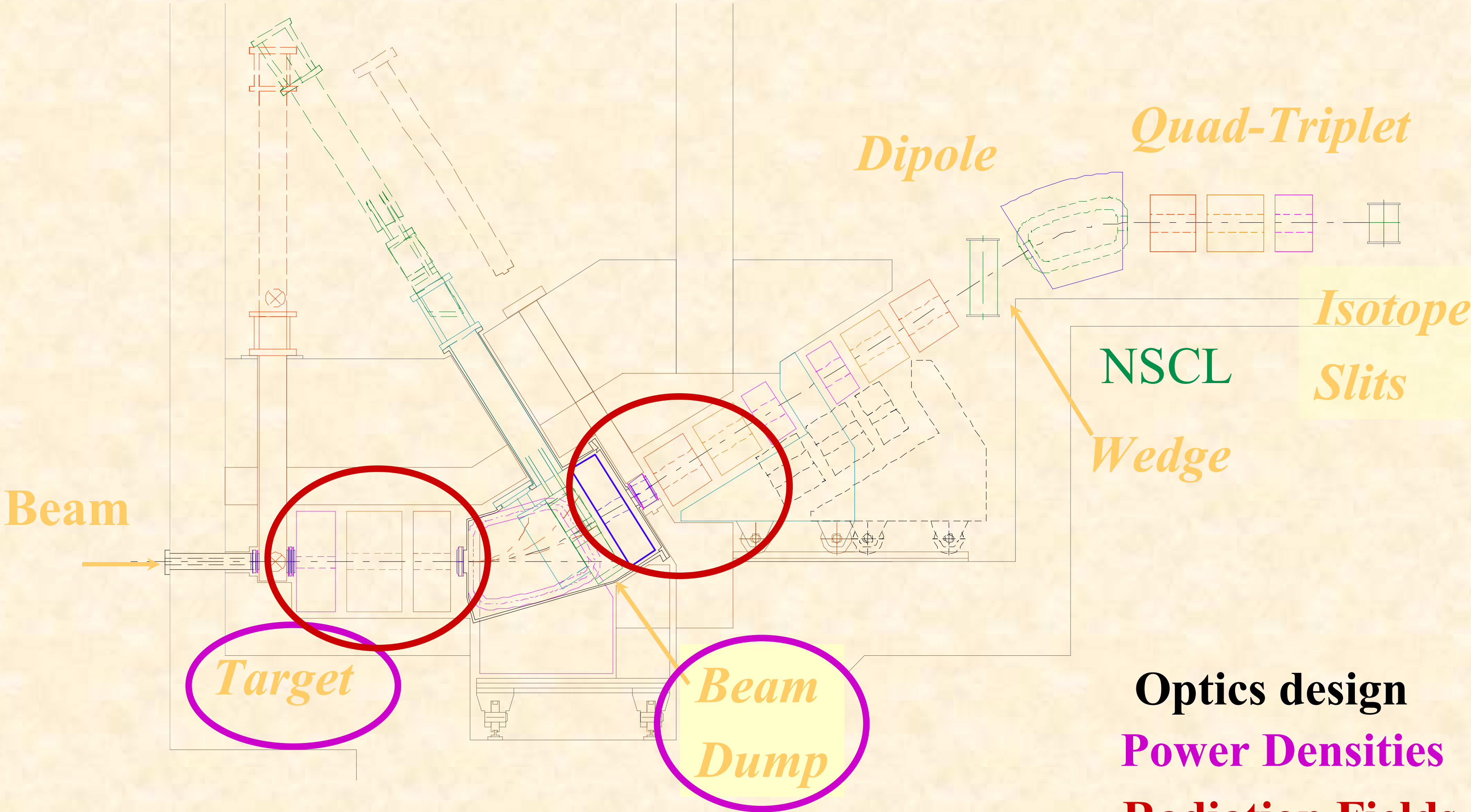
| | Grid 1 | Grid 2 |
|---|---|---|
| **W Volume** | **80%** | **80%** |
| **Velocity** | **18.2 m/s** | **18.2 m/s** |
| **Inlet Temperature** | **40ºC** | **40ºC** |
| **Outlet Temperature** | **62ºC** | **62ºC** |
| **Pressure Drop** | **97 psi** | **100 psi** |
| **Max W Temperature** | **224ºC** | **214ºC** |
| **Max D2O Temperature** | **143ºC** 75/210ºC | **134ºC** 76/191ºC |



# two wheels and one stationary beam dump



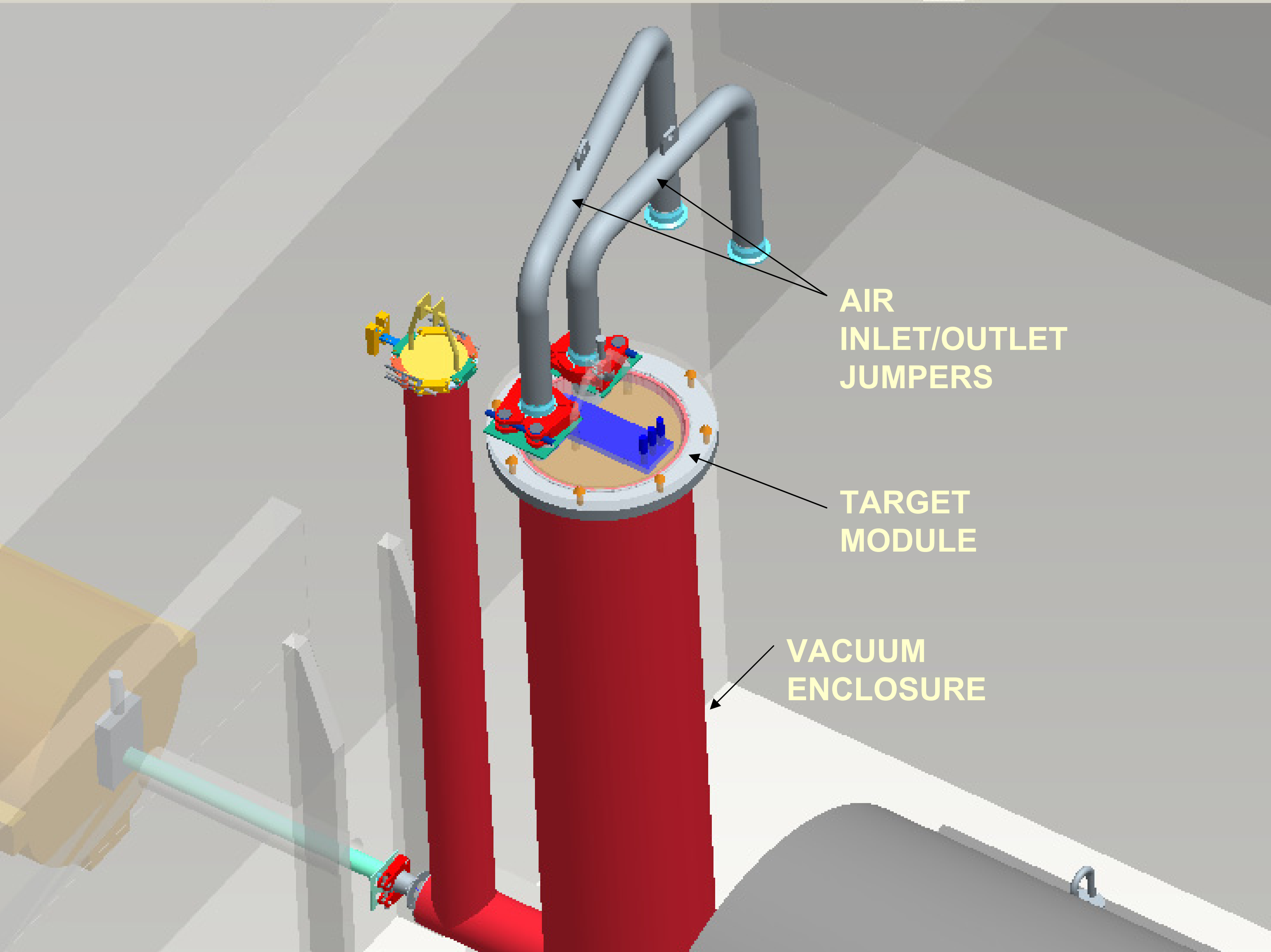
# Example of a RIA Pre-Separator

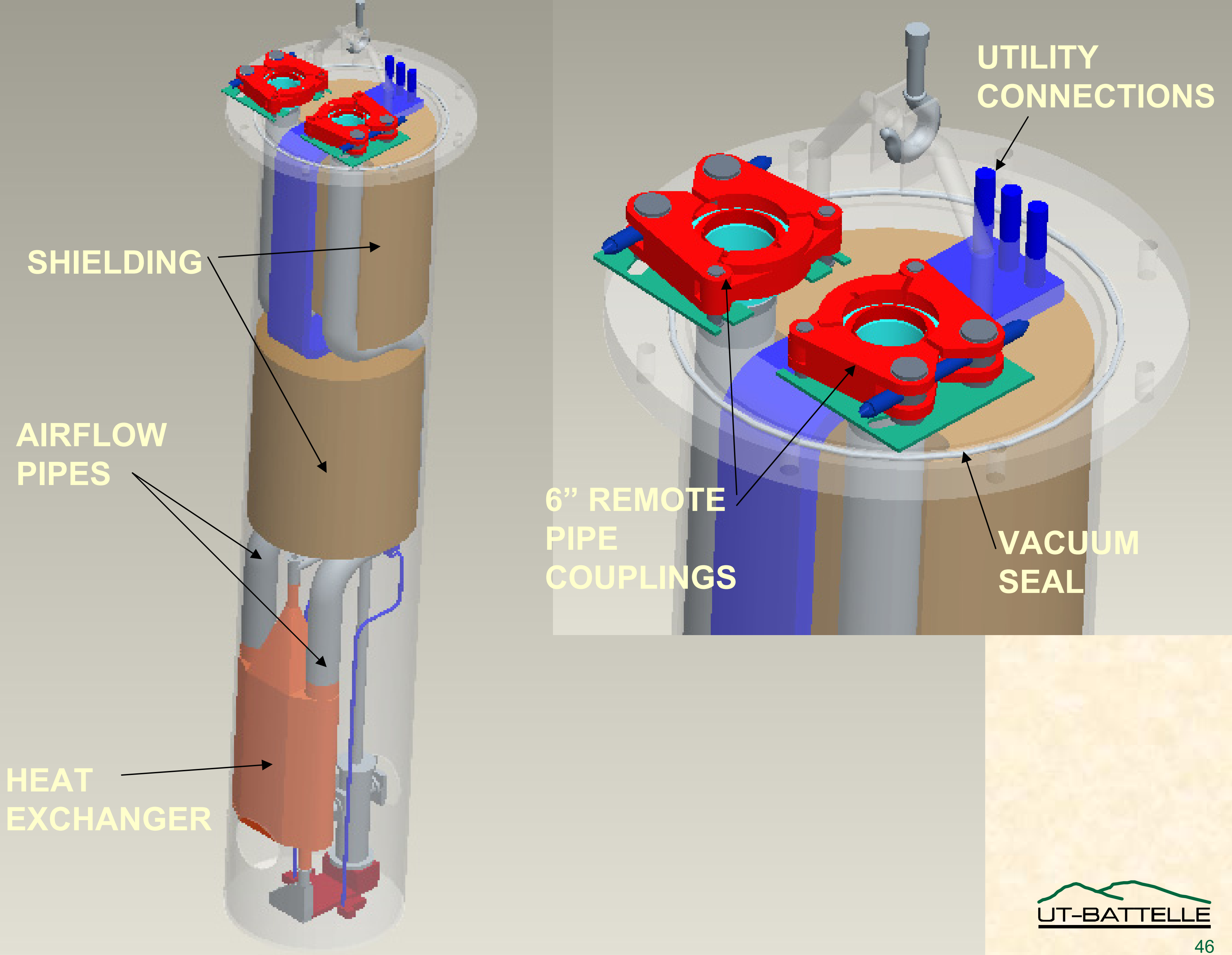



**Optics design**

**Power Densities**

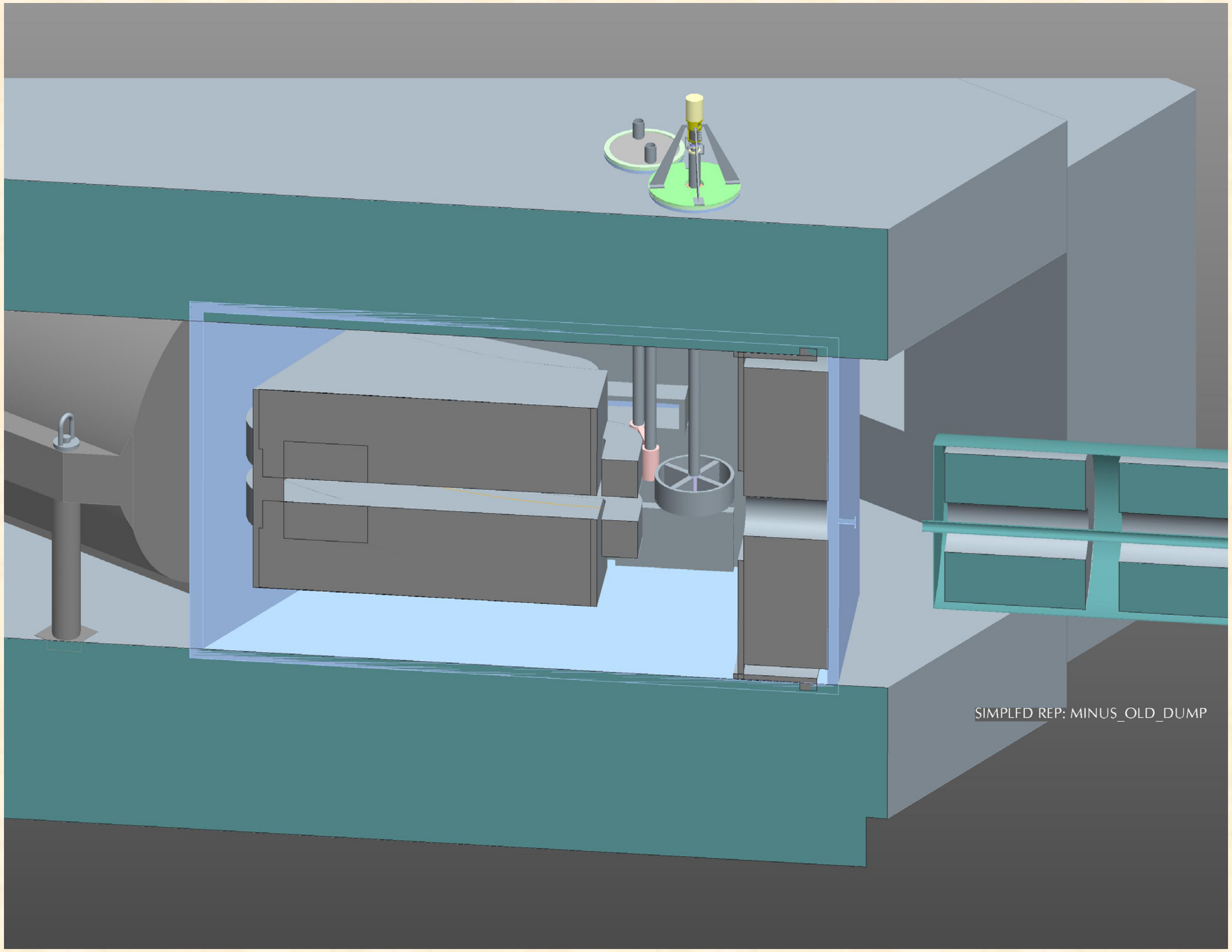
**Radiation Fields**


AIR
INLET/OUTLET
JUMPERS
TARGET
MODULE
VACUUM
ENCLOSURE

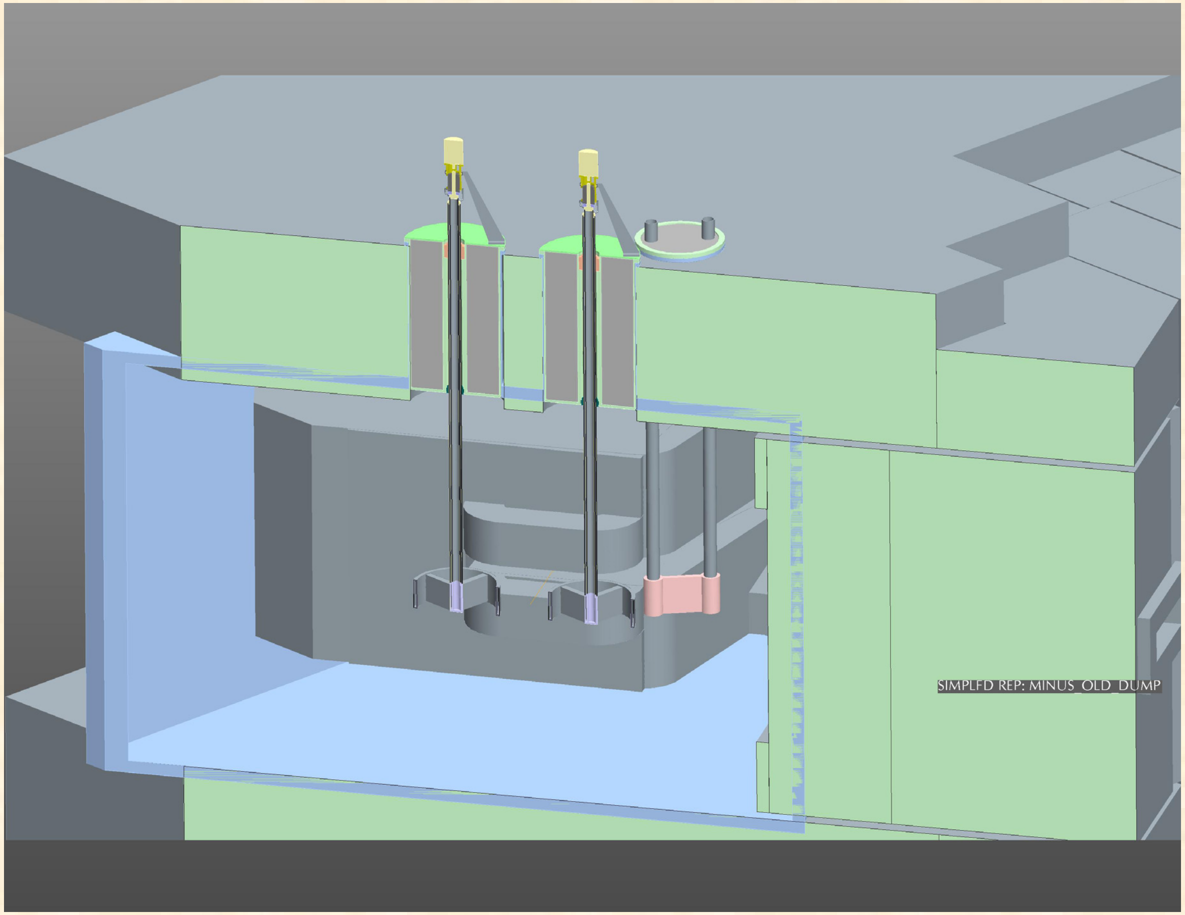

UTILITY CONNECTIONS
SHIELDING
AIRFLOW PIPES
6” REMOTE PIPE COUPLINGS
VACUUM SEAL
HEAT EXCHANGER

UT-BATTELLE

# floor between dump motor and vacuum space



# Beam dump section; magnet vacuum space extended to top of above floor.



# RIA Project Status

- CD0 granted
- Unfunded Mandate—Construction start Sept 2008