IFMIF-DONES related activities at Lithuanian Energy Institute

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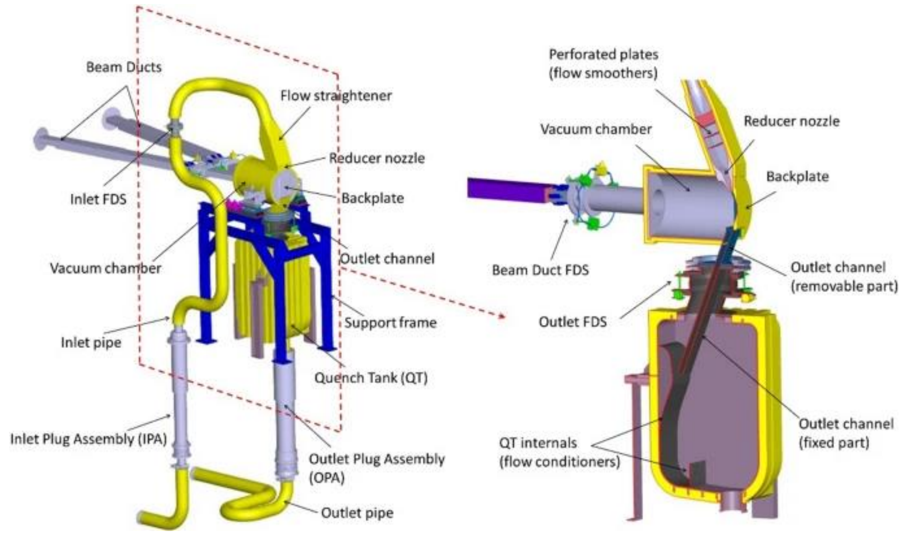
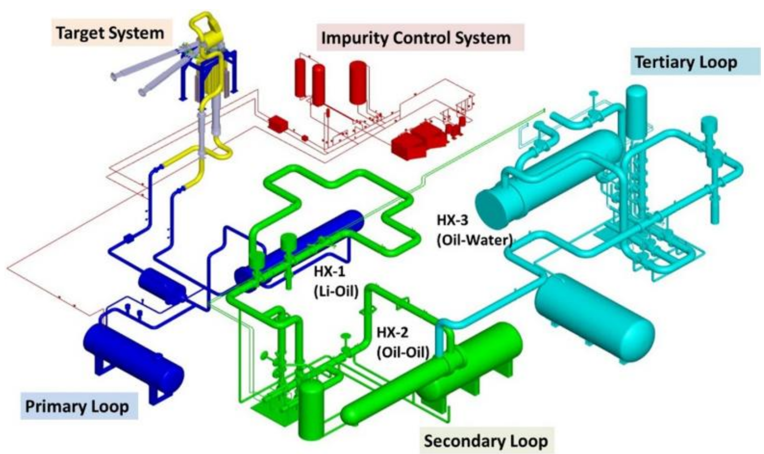
Outline

- Introduction to the Lithium loop cell
- Simplified model
  - Key assumptions of source term modelling
- Detailed model
  - Extended assessment

Lithium Loop Source Term

- High-intensity deuteron beam (125 mA, 40 MeV) interacts with lithium
- **Key reactions:**
  - **7Li(d,2n)7Be & 6Li(d,n)7Be → Beryllium-7** (dominant radioisotope)
  - Neutron activation of **SS316L & EUROFER** → Activated Corrosion Products (ACPs)
- **Key considerations:**
  - Dissolution
  - Deposition
  - Trapping and purification efficiency



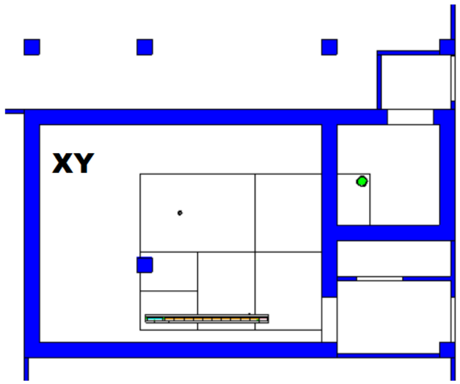


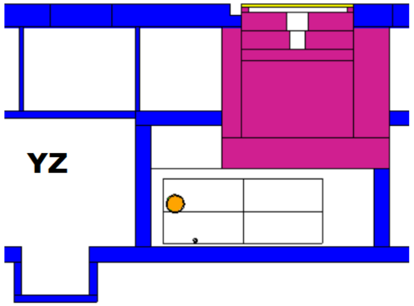
Bernardi, D., et al. J Fusion Energ 41, 24 (2022)

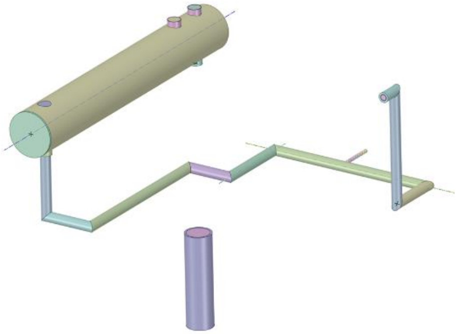
Model and Assumptions

Simplified Lithium loop model

- **Lithium Loop System Components:**
  - **Cold Leg (CL):** Outflow from heat exchanger
  - **Cold Trap (CT):** Mesh filter for Be-7 and impurities
  - **Heat Exchanger (HX):** Maintains lithium temperature and impurity removal
- **Key Assumptions:**
  - **Be-7 uniformly dissolved** in lithium at 3.26E-05 appm
  - **Flow regime** 300°C in the cold leg, and a 2% flow rate
  - **Two corrosion models:**
    - Basic: **2 µm/year** corrosion for all components
    - Reduced: **0.4 µm/year** for CL, HX, hot leg; **0.133 µm/year** for quench tank
  - Gamma spectra calculated at 0s, 1h, 1d, 1 week decay



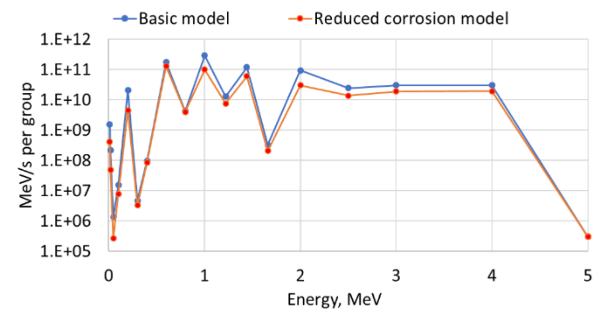


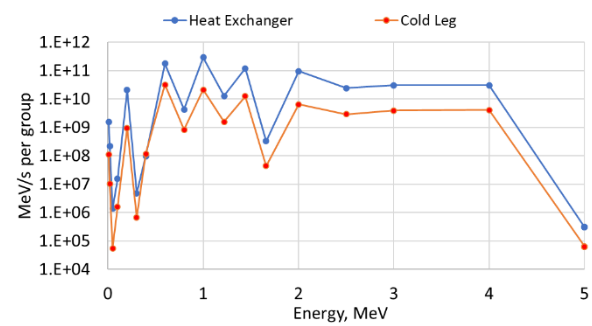


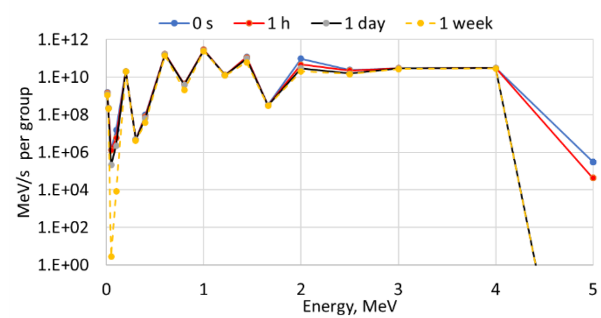
Gamma Spectra Analysis

FISPACT-2 code was utilized for the spectral and decay calculations

- **Gamma Spectra Breakdown:**
  - **Be-7:** Peak at **477.6 keV**, dominates activity in cold trap
  - **ACPs:**
    - **HX & CL:** Co-58, Co-60, Mn-54, Fe-55…
    - **Cold trap:** 3 orders of magnitude higher Be-7 activity
  - Spectra divided into **18 energy groups** (0–5 MeV)
- **Key difference:**
  - Reduced corrosion model shows **~5x lower cobalt levels**

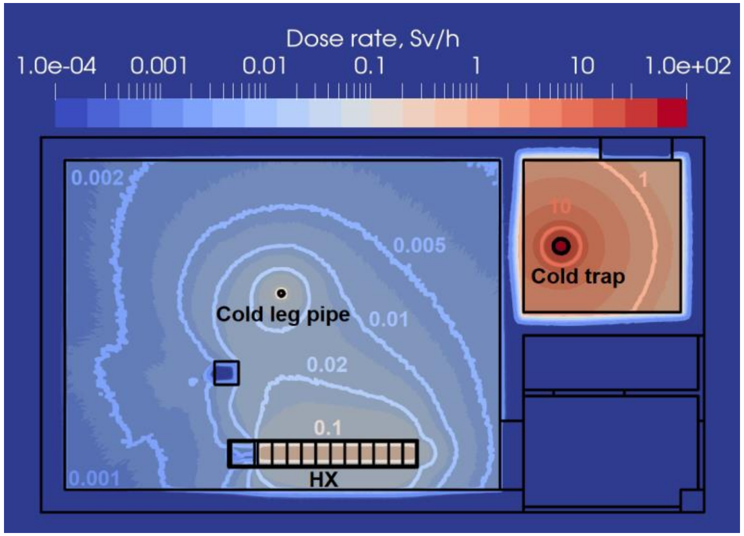






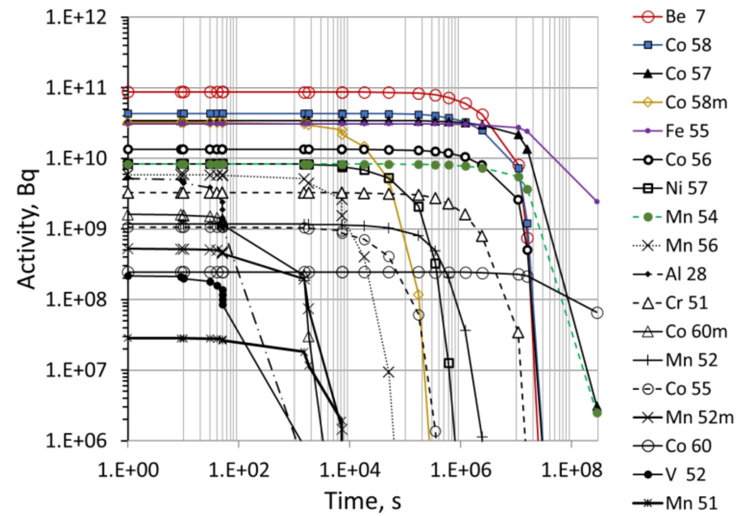
Dose Rate Calculations

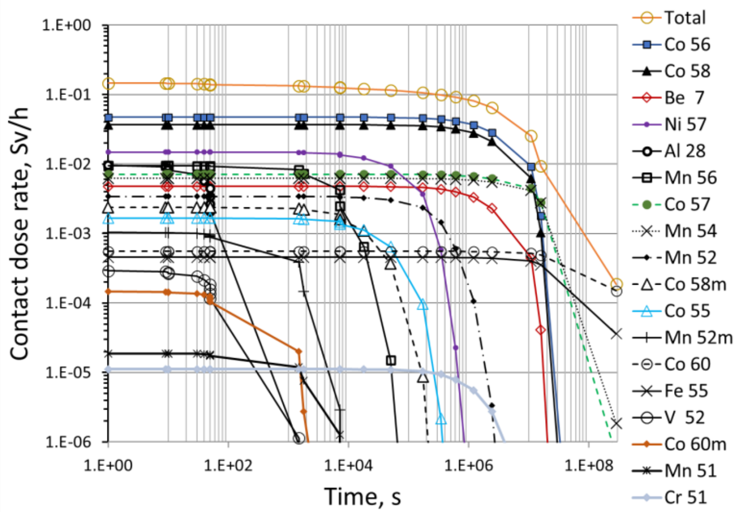
- **MCNP 6 Simulations:**
  - Biological dose rates using ANSI/ANS 6.1.1-1977 conversion
  - 2×10^9 particle histories per run
  - tally planes used for spatial dose mapping
- **Dose Rate Findings:**
  - General range: **1–100 mSv/h** (LLC)
  - Peak values near sources: **Up to 10 Sv/h and more** (Cold Trap)
  - Cold Leg causes **radiation streaming through the ceiling**



Effect of Corrosion Models & Cooling

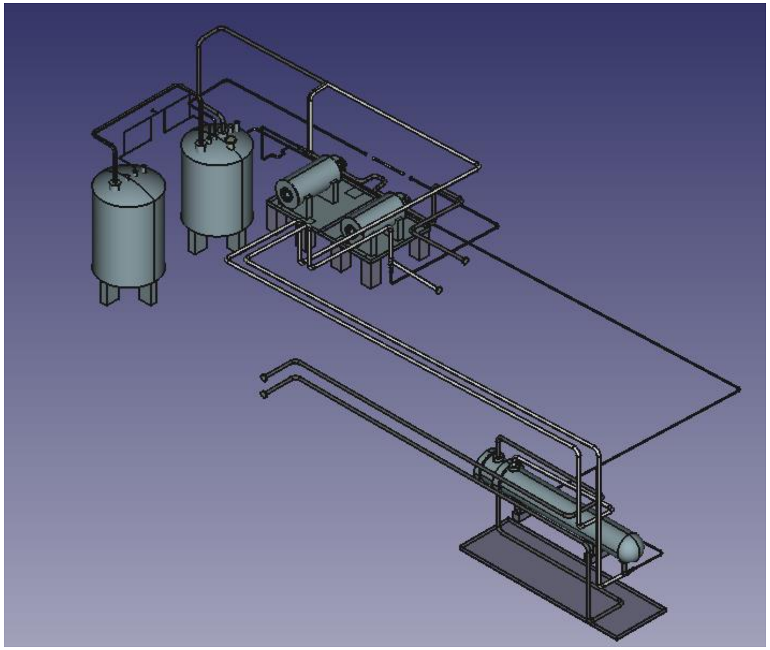
- **Cooling for 1 week:**
  - Be-7 activity reduced by **~10%**
  - ACPs (Co-58, Mn-54, Fe-55) decrease by **~20%**
- **Reduced Corrosion Model Effects:**
  - Minimal impact on dose rates
  - Cobalt isotopes lower in lithium but remain significant
- **10-Year Radionuclide Trends:**
  - Co-60 dominates dose rates
  - Fe-55 dominates activity
  - No new significant radionuclides form during decay
  - Differences in corrosion models:
    - **EUROFER vs. SS316L** affects cobalt & chromium levels
    - **Cobalt moderately soluble** → higher presence in basic model
    - **Chromium less soluble** → minor impact





Lithium Dump Tanks (DT) & Electro-Magnetic Pumps (EMP)

- **Lithium Dump Tanks (DT) Functions:**
  - Store and melt lithium during system startup
  - Collect lithium during shutdowns (normal or emergency)
  - Purify lithium via nitrogen trapping
- **Updated Design:** Two separate tanks
  - **DT1:** Lithium storage and melting
  - **DT2:** Lithium purification with nitrogen trapping
- **Electro-Magnetic Pumps (EMP):**
  - Ensure continuous lithium flow
  - Provide redundancy for safety compliance
- **CAD to MCNP:**
  - McCAD was used in Salome environment.

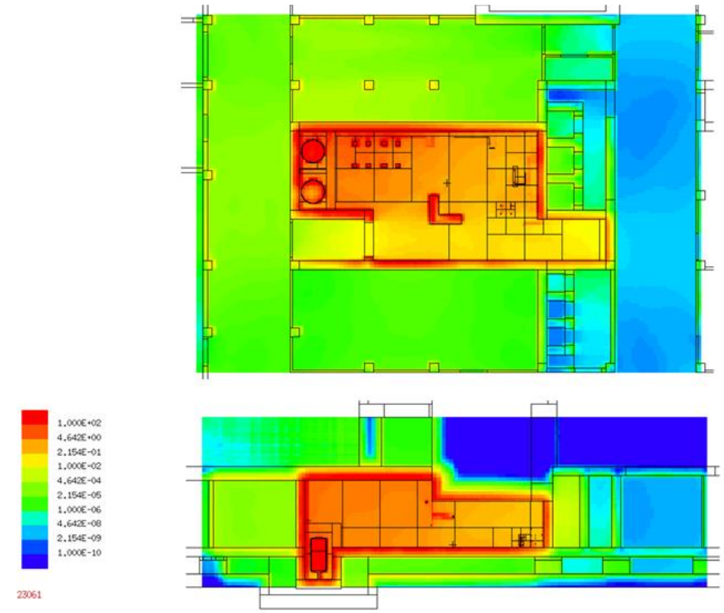


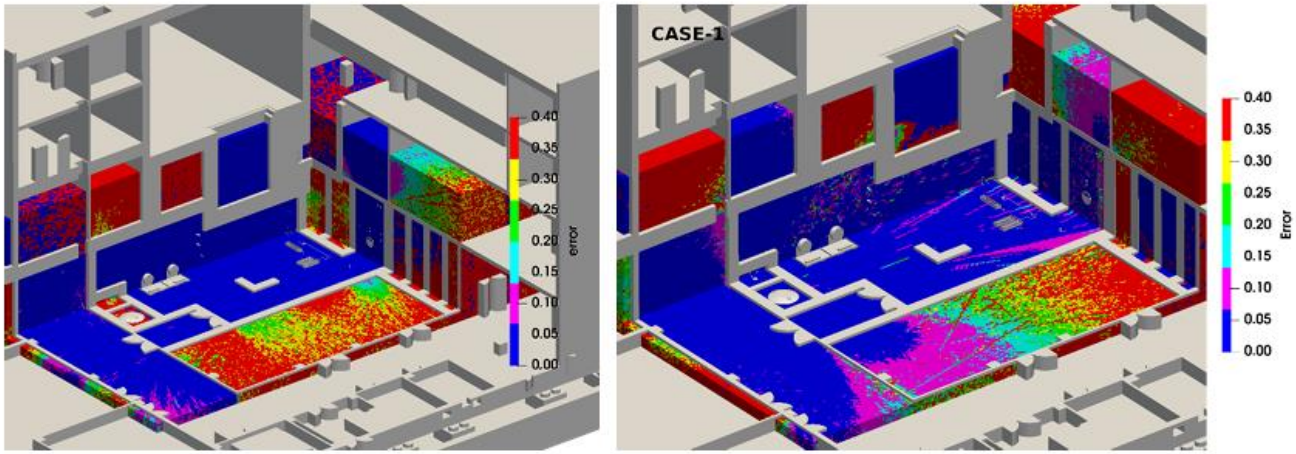
Shielding Considerations

- **Radiation Sources in Lithium System:**
  - **Be-7**
  - **ACPs**
- **Shielding Approaches:**
  - **DT shielding:** 100 cm cover of standard concrete, 50 cm separation wall
- **Expected results:**
  - **Room R016 dose rates:** 1–100 mSv/h (up to 20 days after shutdown)
  - **Shielded DT reduces dose to µSv/h levels**

New modelling assumptions

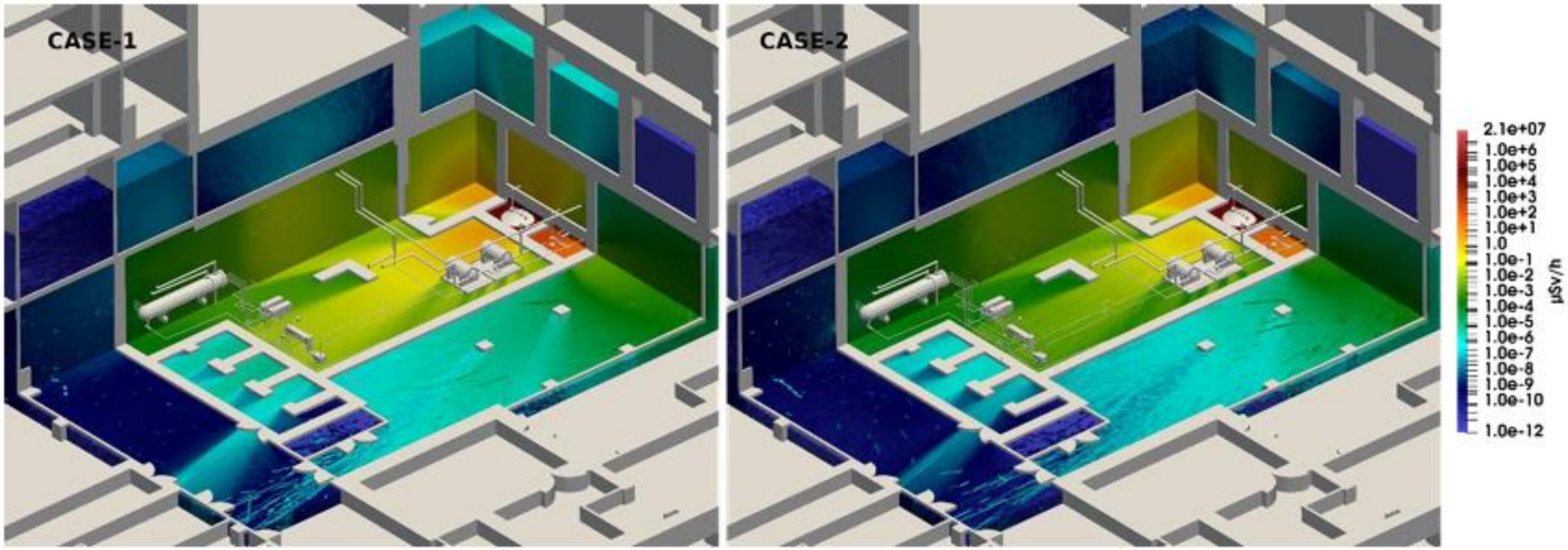
- **Variance Reduction with ADVANTG:**
  - Improves accuracy near leakage points
  - Reduces uncertainties by 10%
- **Assumptions:**
  - Beam off scenario (lithium in DT, traces in the pipes)
  - Beam on scenario (lithium circulated in pipes, traces of lithium in DT)
  - Standard vs. heavy concrete
- **Lithium traces were not considered!**





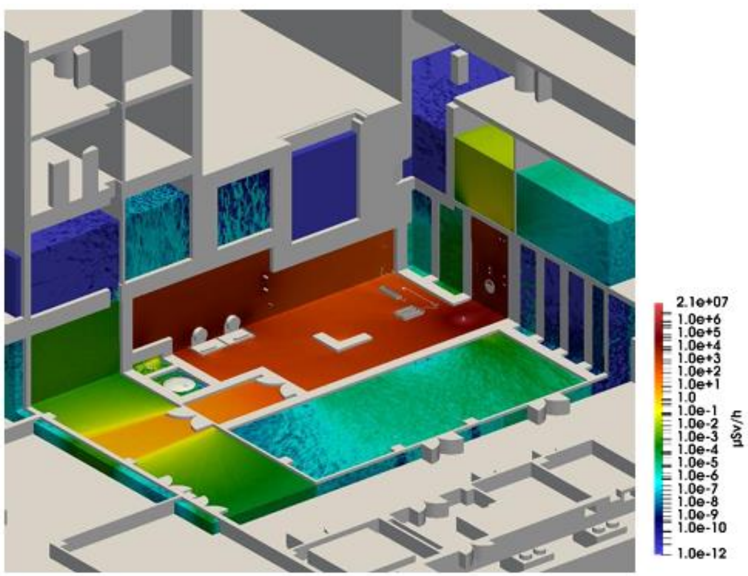
Dose Rate Calculations – Beam-Off Scenarios

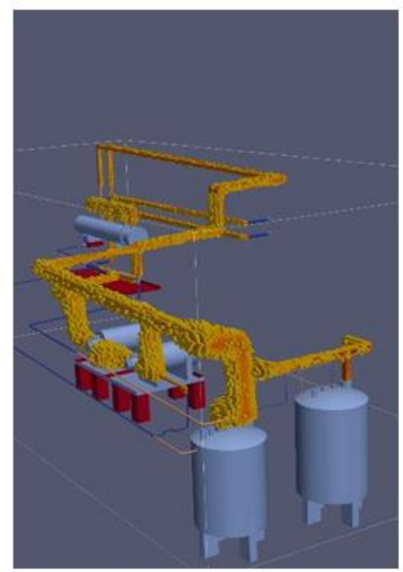
- **Case 1: Ordinary Concrete Shielding (Beam-Off)**
  - DT pit with **1m concrete cover + 50cm separation wall**
  - Dose rate outside shielding: **10 µSv/h**
- **Case 2: Heavy Concrete Shielding (Beam-Off)**
  - Same geometry
  - Dose rate reduced to **1 µSv/h**



Dose Rate Calculations – Beam-On Scenario

- **Case 3: Beam-On with Lithium in Piping**
  - Dose rates: **Up to 10^4 µSv/h inside LLC room**
- **External Exposure:**
  - Corridor C002: 10 µSv/h
  - Cold Trap Cell (R009-1): 1 µSv/h
- **Shielding Effectiveness:**
  - 1m of concrete shields **most of LLC room**
  - Heavy concrete reduces external dose by **10x**





Summary

- **Key Findings:**
  - Reduced corrosion model has **limited impact on dose reduction**
  - Beam-off dose rates are manageable with shielding
  - Beam-on operation causes high radiation fields (10^4 µSv/h)
  - Heavy concrete is around 10 times greater in mitigating dose rates outside DT
  - Radiation Levels in adjecets rooms
- **Things to consider**
  - **ACP and Be-7 trapping optimization**
  - **Improved shielding designs**
  - **Refinement of corrosion models**