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Simulation of the Prompt Dose Environment in the National Ignition Facility during High Yield Shots

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Simulation of the Prompt Dose Environment in the NIF during High Yield Shots
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ANS Annual Meeting

San Francisco, CA

June 11-15, 2017

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Hesham Khater and Sandra Brereton

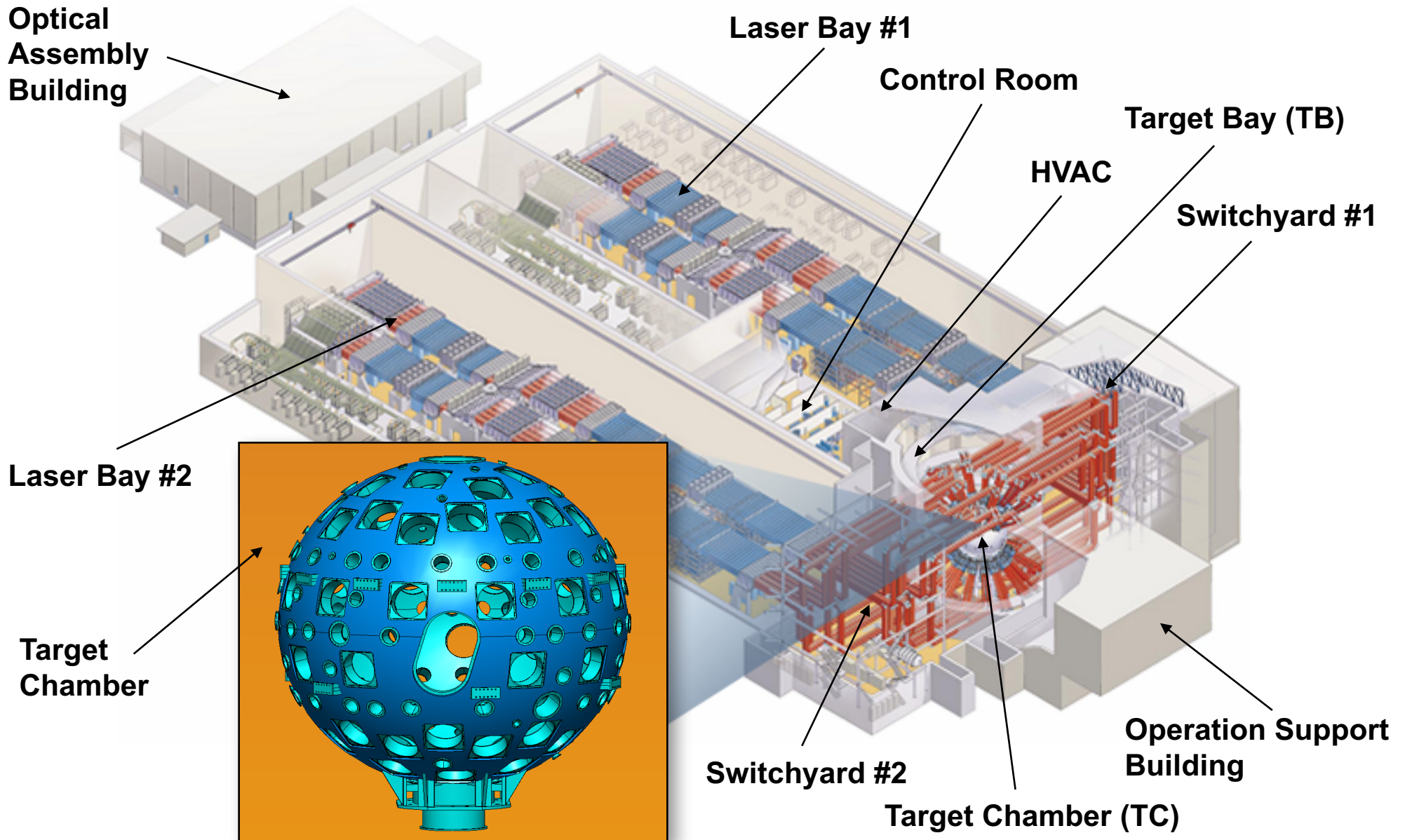
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Introduction

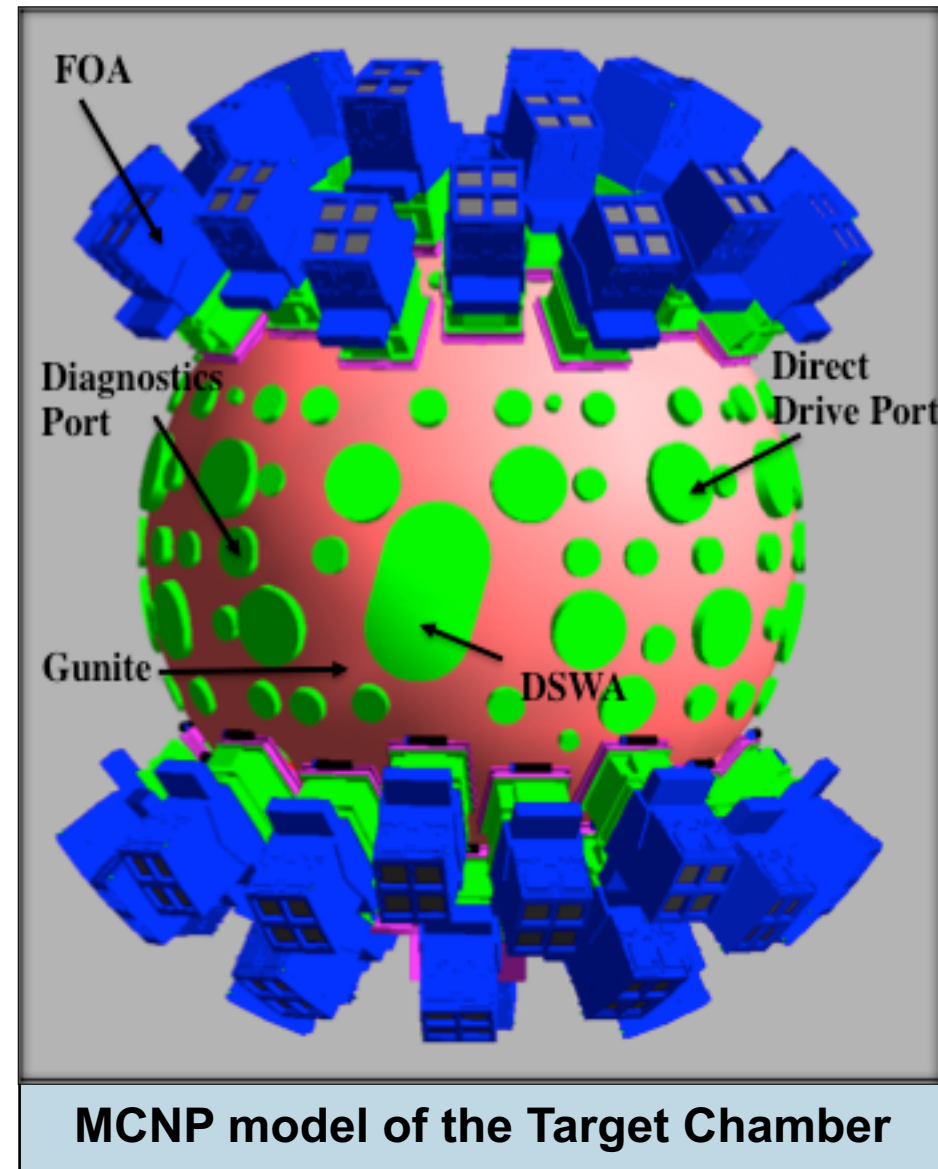
- Detailed 3-D modeling of the NIF facility is developed to accurately simulate the radiation environment within the NIF
- Prompt dose values are calculated for high yield shots (20 MJ of neutron yield per shot)
- Results of the analysis are used to determine the final thicknesses of the shielding doors as well as the required shield thicknesses for all unused penetrations
- Integrated dose values are used to formulate the personnel access requirements within the facility

NIF Layout

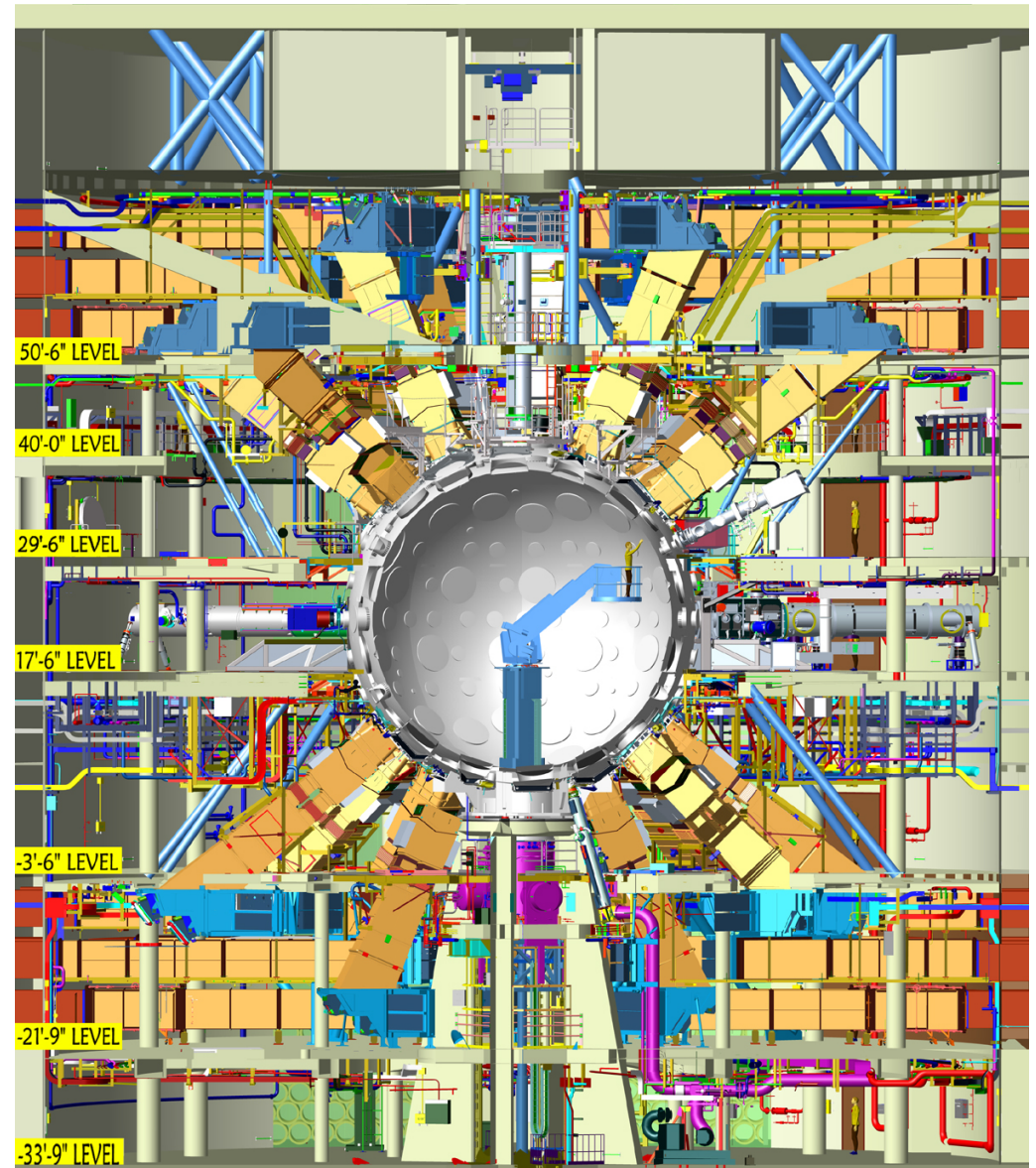
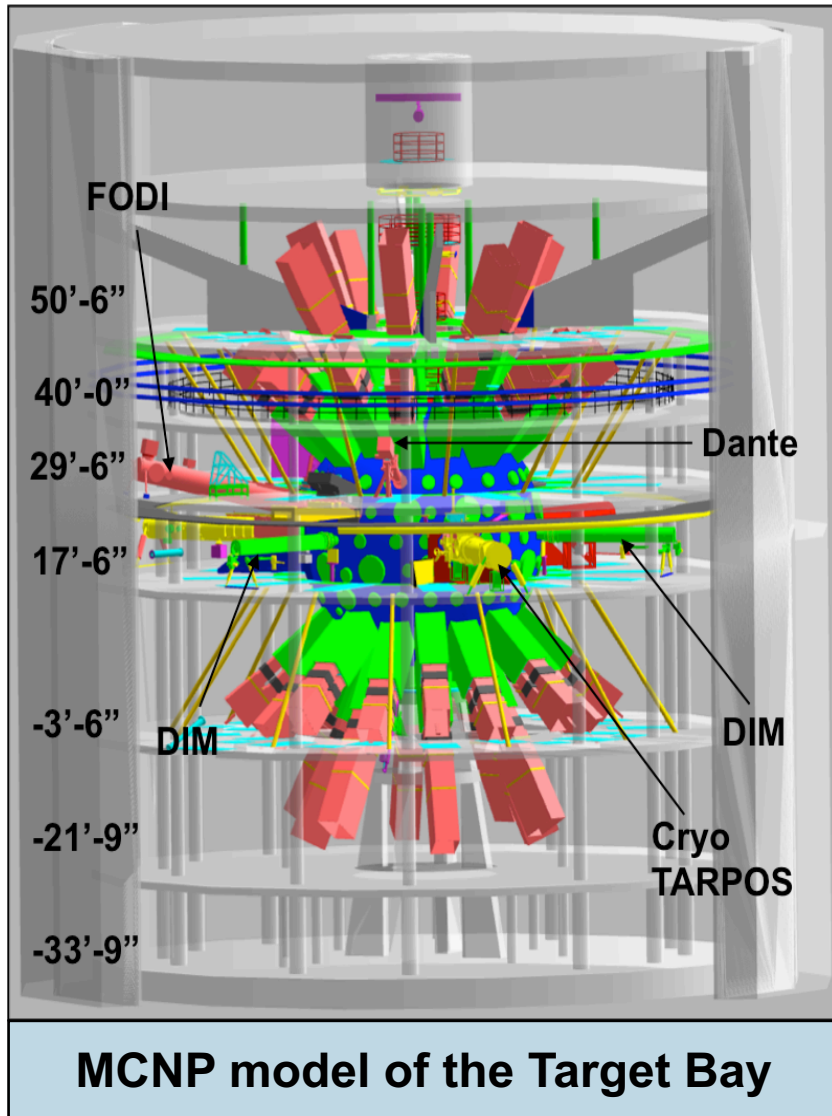


Features of the current NIF facility model

- Based on the facility as-built drawings
- 10-cm-thick Al Target Chamber (TC) wall surrounded by 40-cm of borated concrete
- 1.83-m -thick concrete Target Bay (TB) wall
- 99.1-cm-thick concrete Switchyard walls
- All Target Chamber, Target Bay and Switchyard wall penetrations are modeled
- Diagnostics and Direct Drive ports are only covered with ~ 5-cm-thick aluminum
- Final Optics Assemblies (FOAs) are modeled



Sectional view of the Target Bay

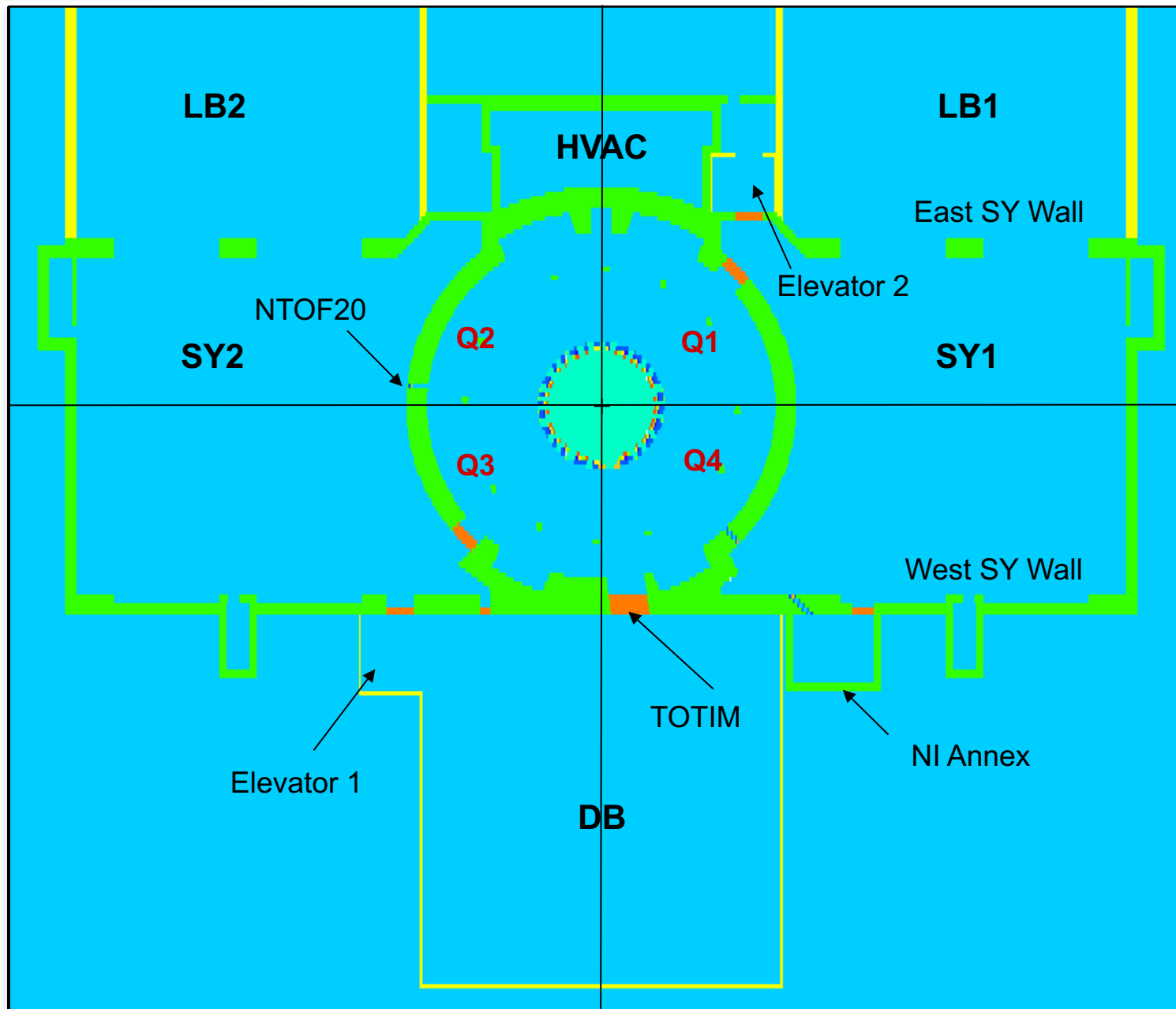


Target Bay
Section View

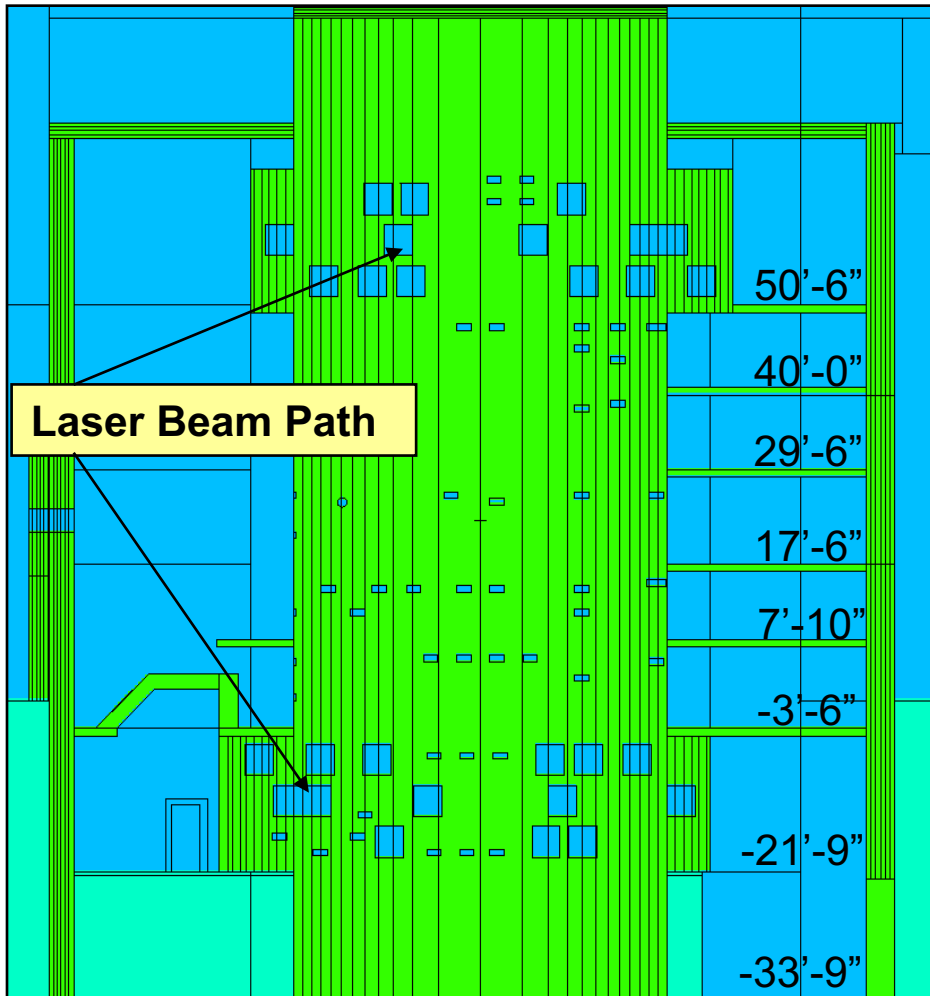
Radiation pathways

- **Target Chamber penetrations**
 - 48 indirect-drive beam ports (FOAs)
 - 24 direct-drive beam ports
 - 120 diagnostic ports
- **Target Bay wall penetrations**
 - Laser beam path in TB walls
 - 176 utility penetrations (40% shielded)
 - 10 diagnostic penetrations
- **West Switchyard wall penetrations**
 - 18 utility penetrations
 - 2 diagnostic penetrations
- **East Switchyard wall penetrations**
 - 26 utility penetrations
 - Laser beam tubes at the 17' 6" level
- **Doors**
 - Target Bay: 20 primary (19 shielded)
 - Switchyards: 32 secondary (27 shielded)

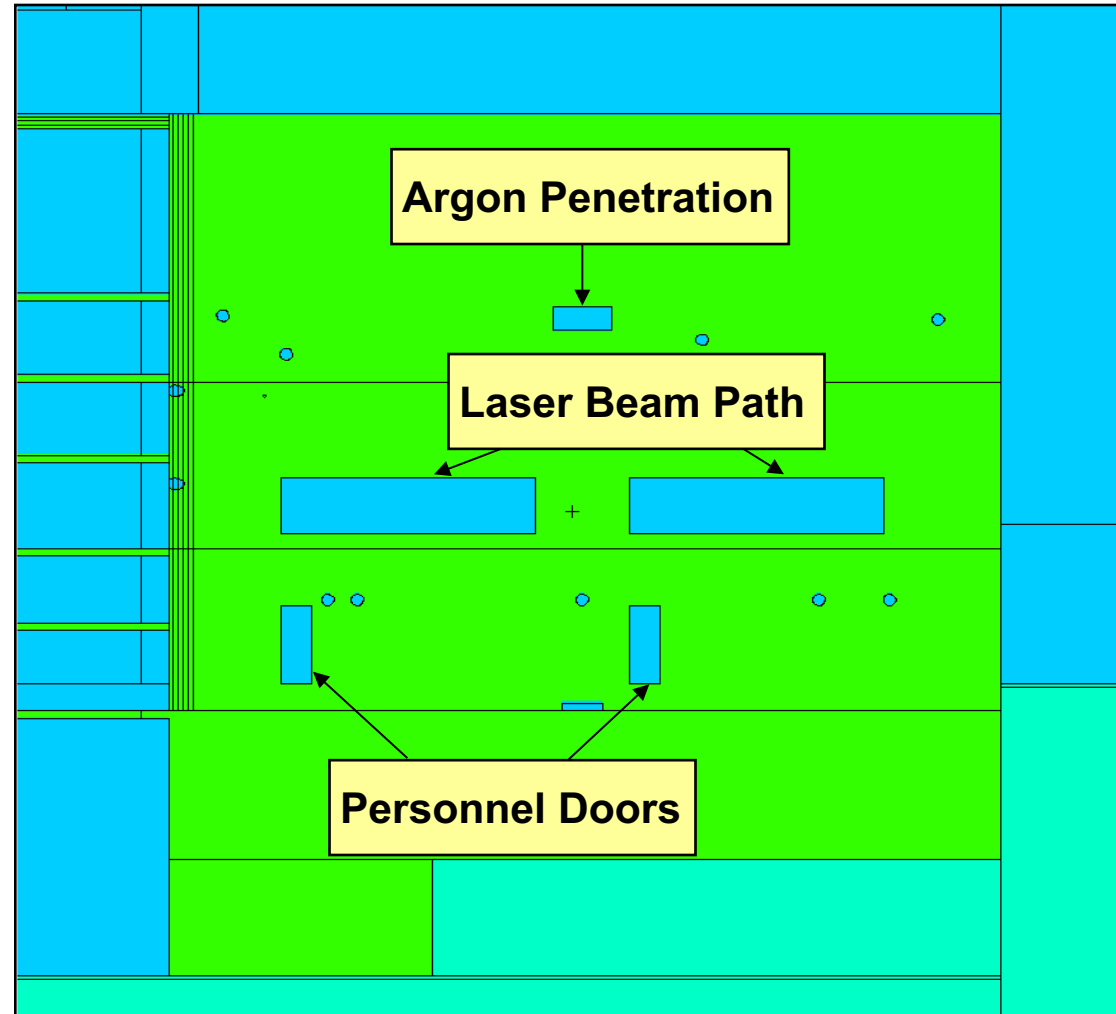
Horizontal view of TB at TCC



Vertical view of Q1 and Q4 of TB wall

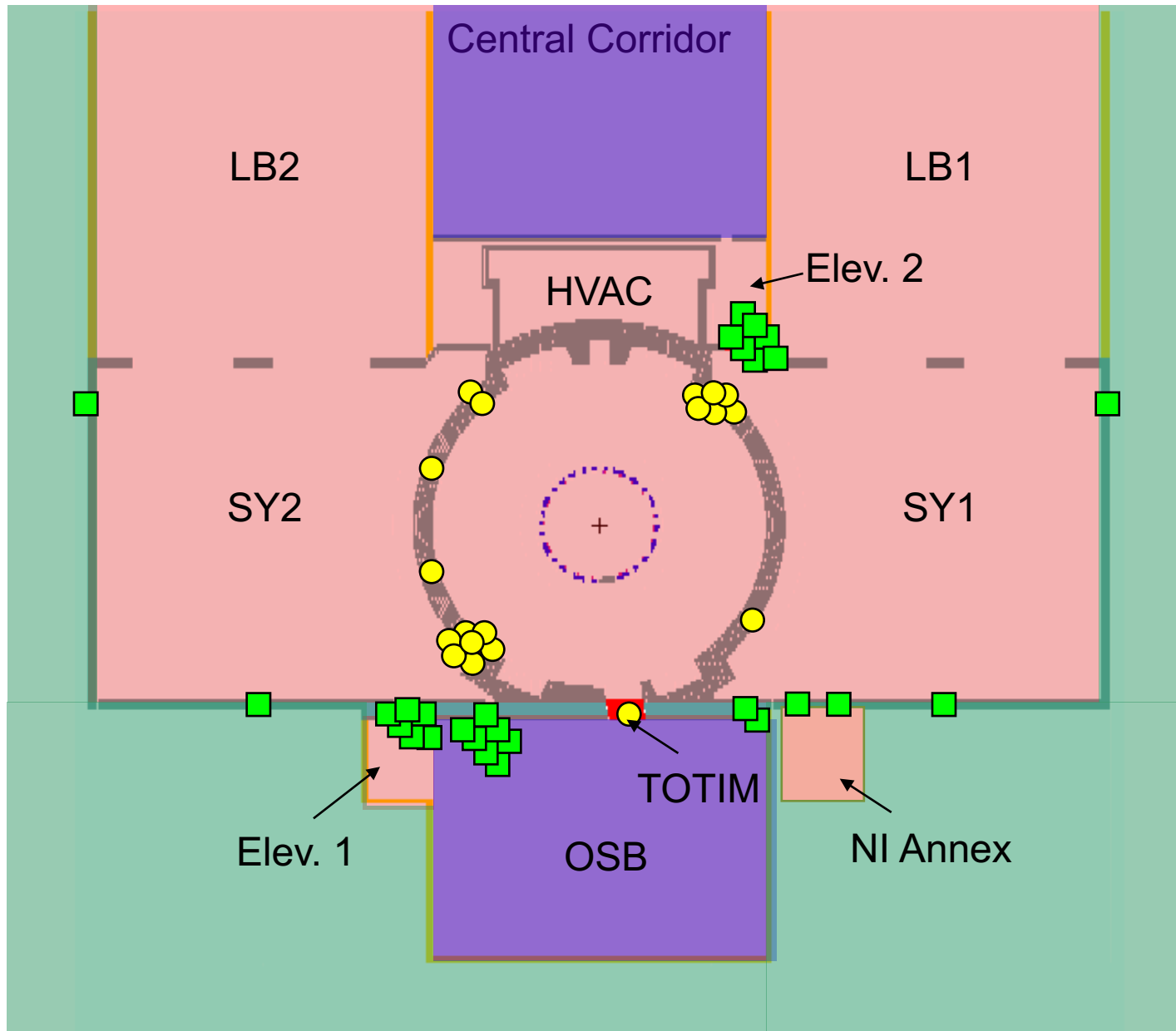


Vertical View of Q1 and Q4 of TB Wall



Vertical View of East Wall of SY1

Summary of shield door locations

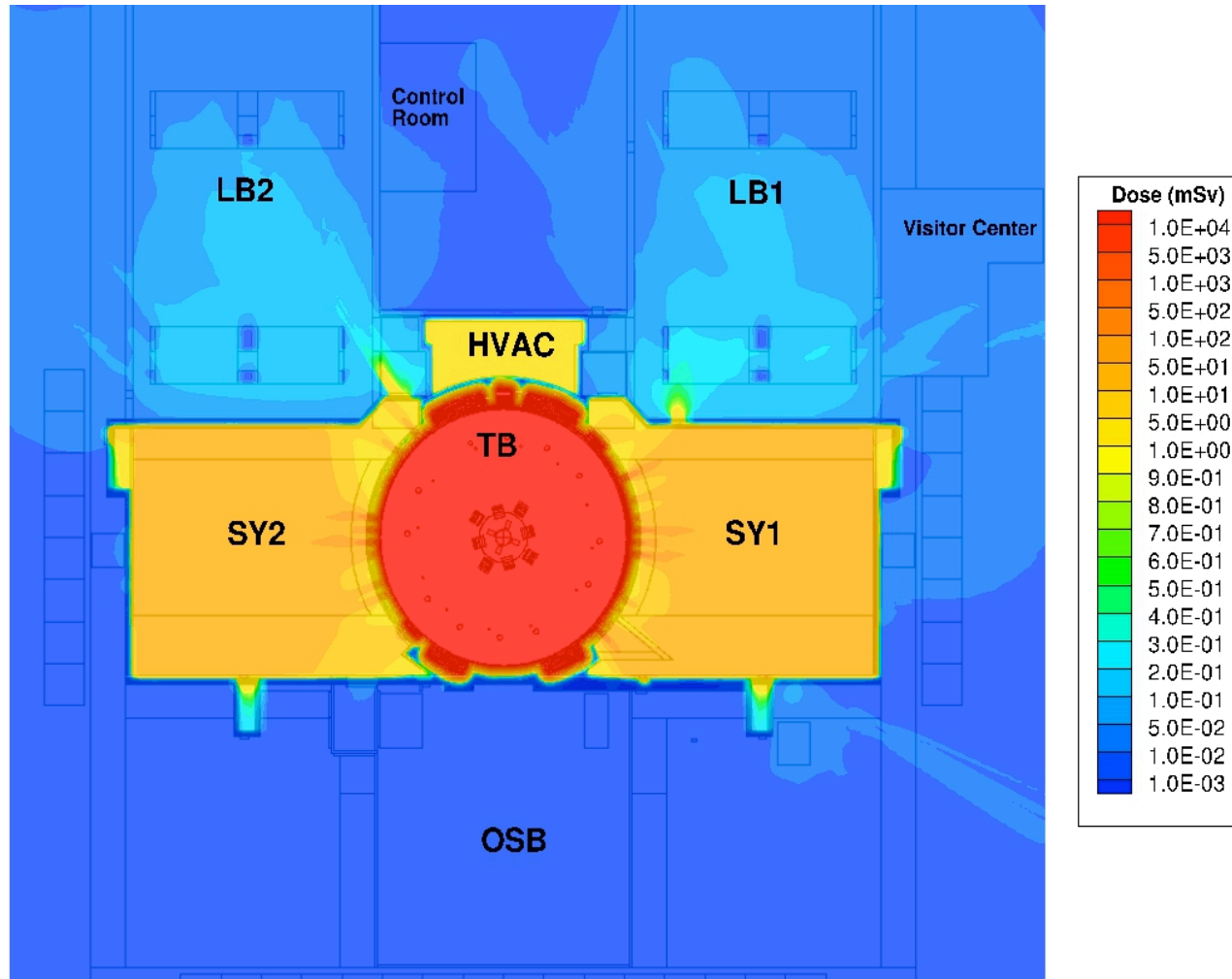


- Exclusion areas
- Normally occupied areas within the facility
- Occasionally occupied areas outside the facility
- Primary shield doors
- Secondary shield doors

Simulation approach/assumptions

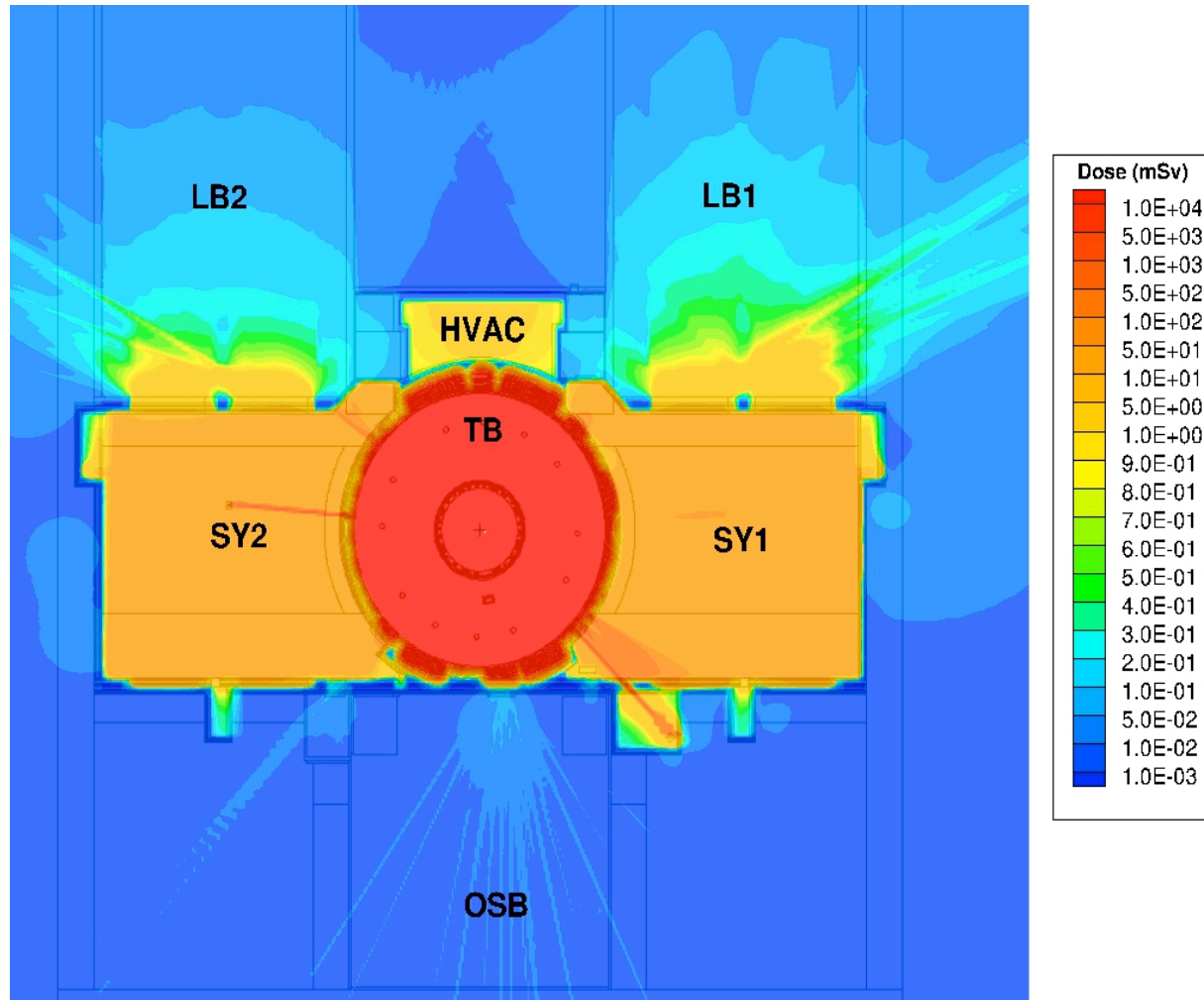
- Radiation transport simulations performed using the MCNP code
- Particle splitting and Russian roulette are used throughout the geometry
- Particle tracks are followed using tally cell-flagging cards
- Mesh tallies are used to produce prompt dose maps of the entire facility
- ICRP-74 fluence to effective dose conversion factors
- High yield shots of 20 MJ or 7.1×10^{18} neutrons per shot
- Maximum annual yield of 1200 MJ
- The NIF radiological design goal is to limit the maximum prompt dose in any occupied area to $< 50 \mu\text{Sv}$ per shot and $< 1 \text{ mSv}$ per year

Prompt dose map for the ground level during a shot



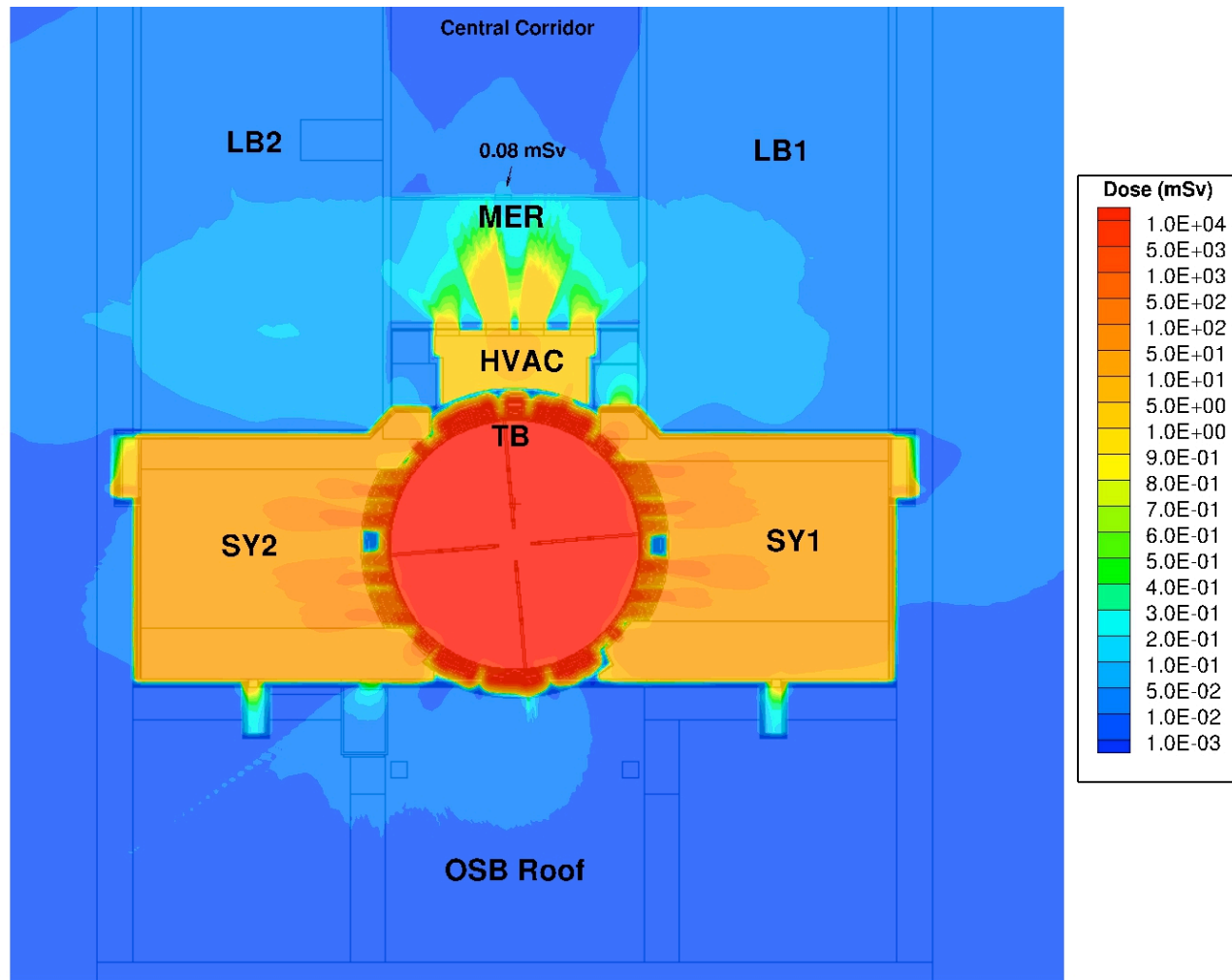
Estimated dose in the Control Room is $\sim 10 \mu\text{Sv}$ and in the Visitor Center is $\sim 30 \mu\text{Sv}$

Prompt dose map for the 17' 6" floor during a shot



Estimated dose outside the TOTIM door in the normally occupied OSB is $\sim 40 \mu\text{Sv}$

Prompt dose map for the 50' 6" floor during a shot



Estimated dose on the top of the OSB roof is ~ 20 μ Sv

Maximum estimated prompt dose values (μSv)

Location	Floor level	Dose (μSv)
OSB	-33' 9"	20
OSB	-21' 9"	10
OSB	-3' 6"	10
Control Room	Central Corridor	10
Visitor Center	Ground	30
Outside SY1	Ground	33
Near Building	Ground (100 m from TCC)	2
Site Boundary	Ground (350 m from TCC)	0.6
OSB	7' 10"	20
OSB	17' 6"	40
OSB	29' 6"	20
OSB	40' 0"	30
OSB Roof	50' 6"	20

Estimated dose values in occupied areas are well below the 50 μSv NIF design goal limit

Summary

- Detailed analyses of expected prompt dose values during high yield shots at the NIF have been completed
- Thicknesses of shield doors in the facility were optimized such that the estimated dose in the NIF occupied areas remain below 50 μSv for a 20 MJ shot and < 1 mSv for 1200 MJ of annual fusion yield
- Most of the normally occupied areas inside the OSB (Operations Support Building) experience limited prompt dose values of 10 to 40 μSv per shot
- Estimated dose values in the control room and the visitor center are 10 and 30 μSv , respectively
- Maximum annual dose at the nearest site boundary location (350 m from Target Chamber Center) is very small and estimated at only ~ 36 μSv for 1200 MJ of fusion yield
- The current NIF shielding is effective in providing the required radiation protection for all phases of the NIF operation



NIF

National Ignition Facility

