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Radiation Safety Design for the North Pole Neutron Time-of-Flight System at the NIF

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Disclaimer

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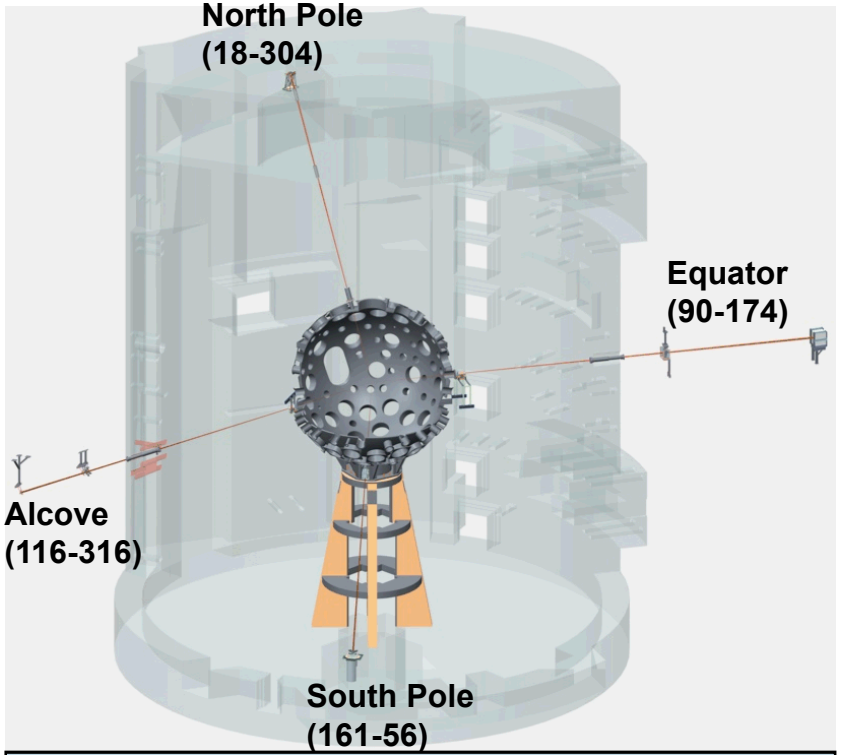
Introduction

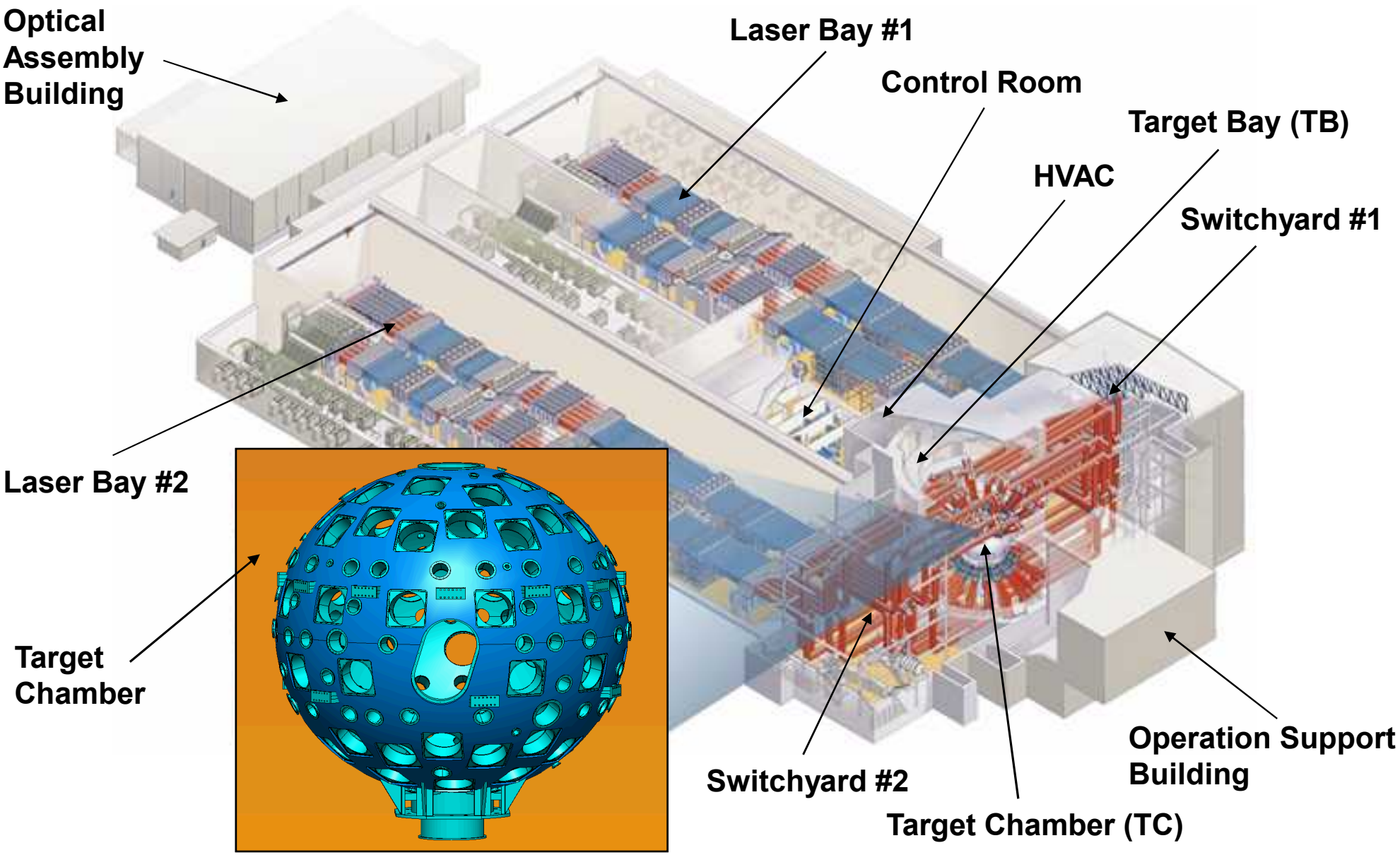
- Neutron time of flight (nToF) detectors are fielded at the NIF to measure neutron yield, ion temperature, and downscattering in the cold fuel for D-T implosions
- The North Pole(NP) nToF detector is located in a hut above the Target Bay roof and at a distance of ~ 21.6 m from the Target Chamber Center
- The detector utilizes a solid bibenzyl scintillator and 4 photomultiplier tubes
- The LOS penetrates the Target Chamber, two Target Bay floors, the Target Bay ceiling
- The neutron beam is collimated using three collimators: a primary collimator located on the Target Chamber, and two secondary collimators located in the 69’ 9” Target Bay floor and the ceiling



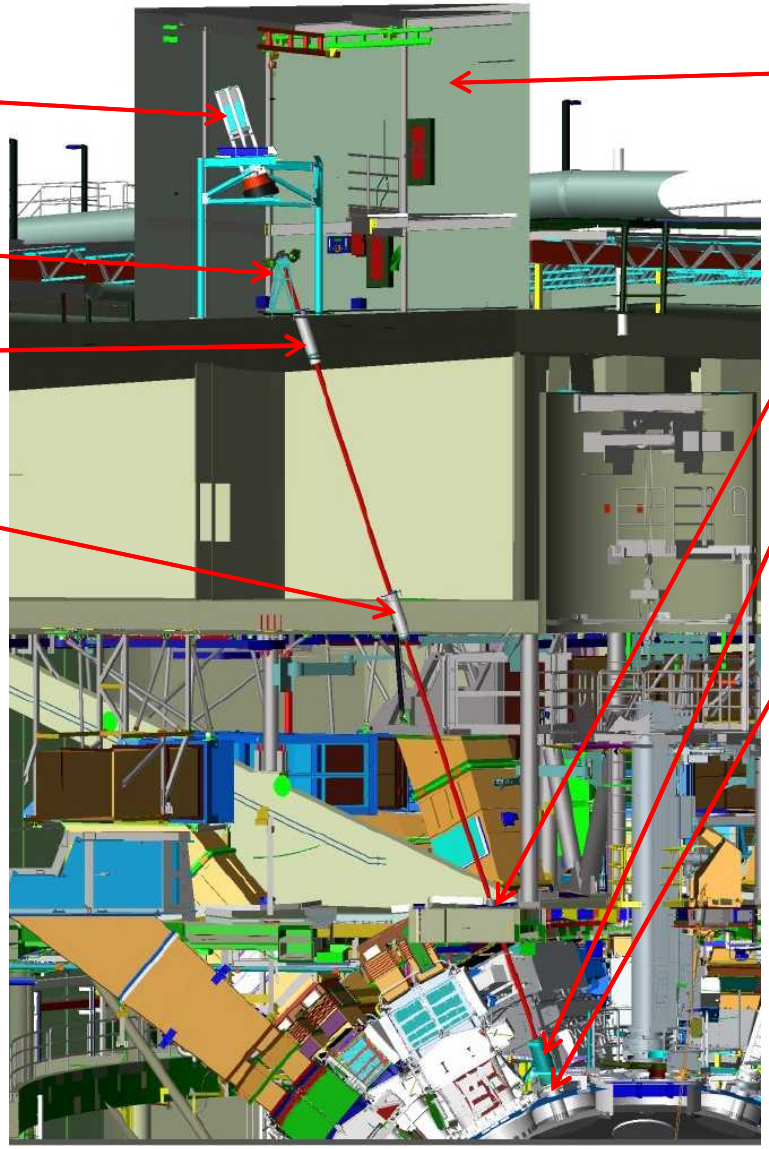
Locations of nToF Detectors

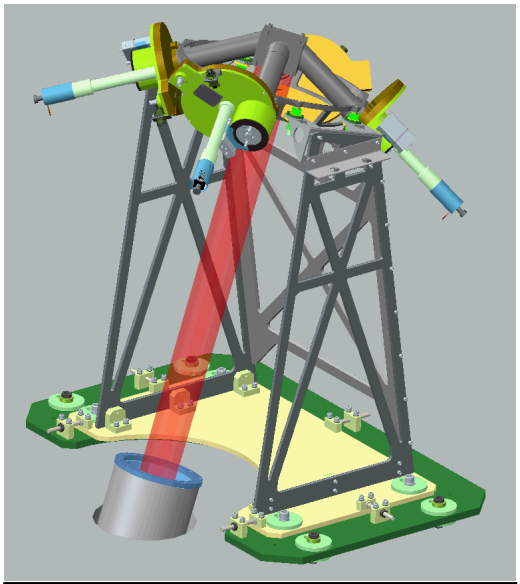

192 Pulsed Laser Beams
Energy 1.8 MJ 3ω
Power 500 TW

NIF layout

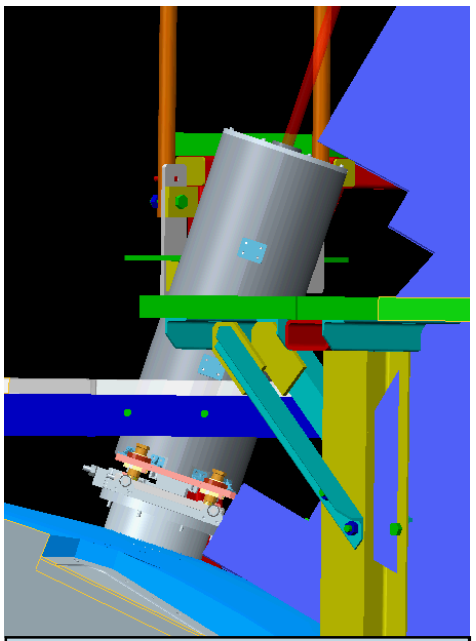

Optical Assembly Building
Laser Bay #1
Control Room
Target Bay (TB)
HVAC
Switchyard #1
Laser Bay #2
Target Chamber
Switchyard #2
Target Chamber (TC)
Operation Support Building

NP nToF LOS overview



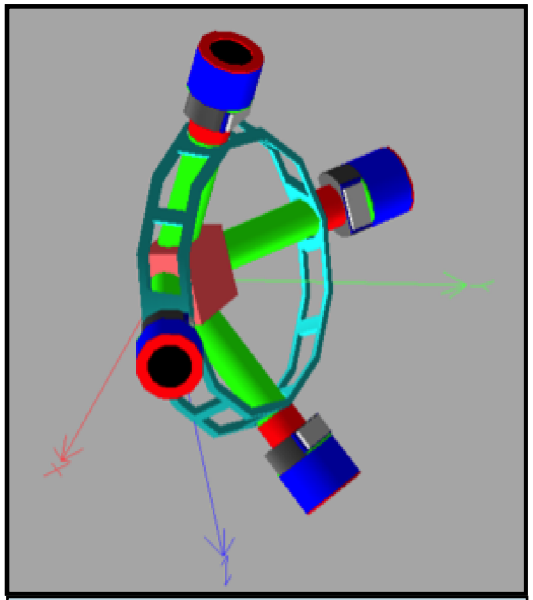


Detector Assembly



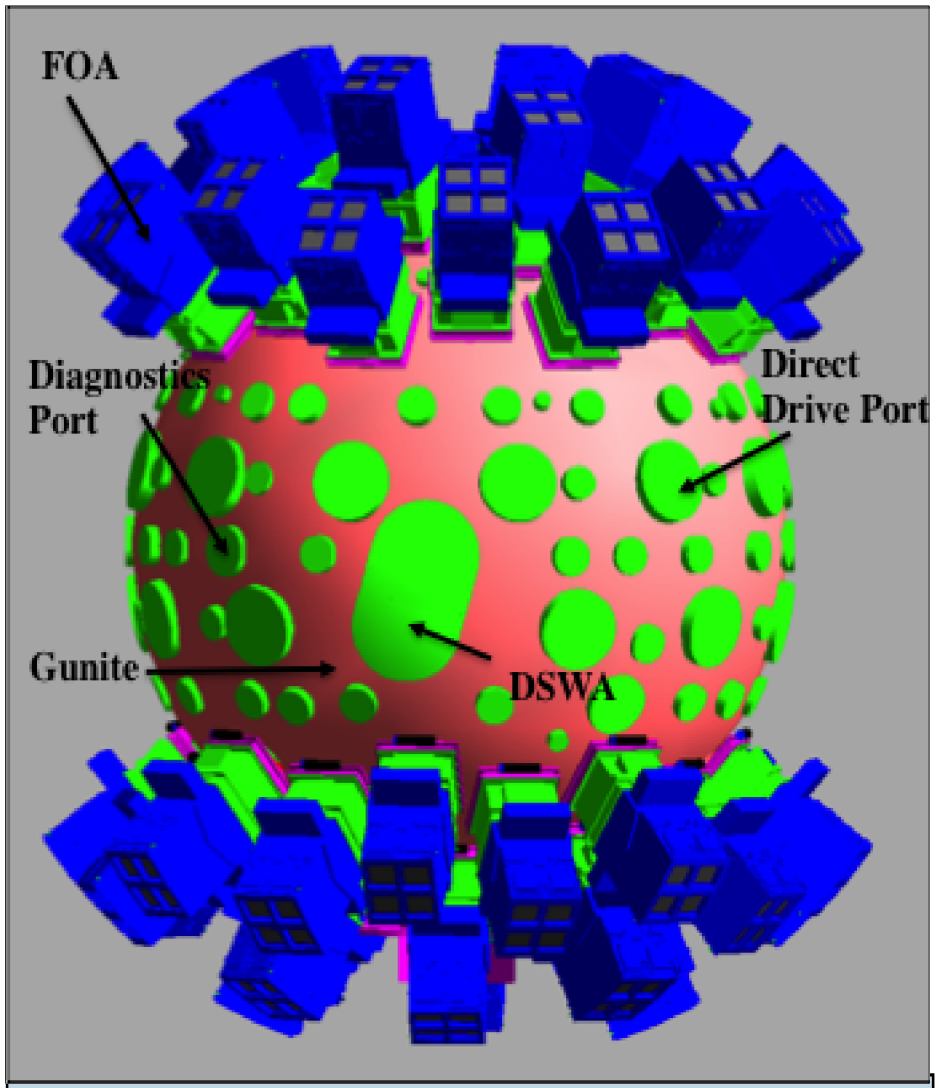
TC Port Collimator

Features of the NIF facility model



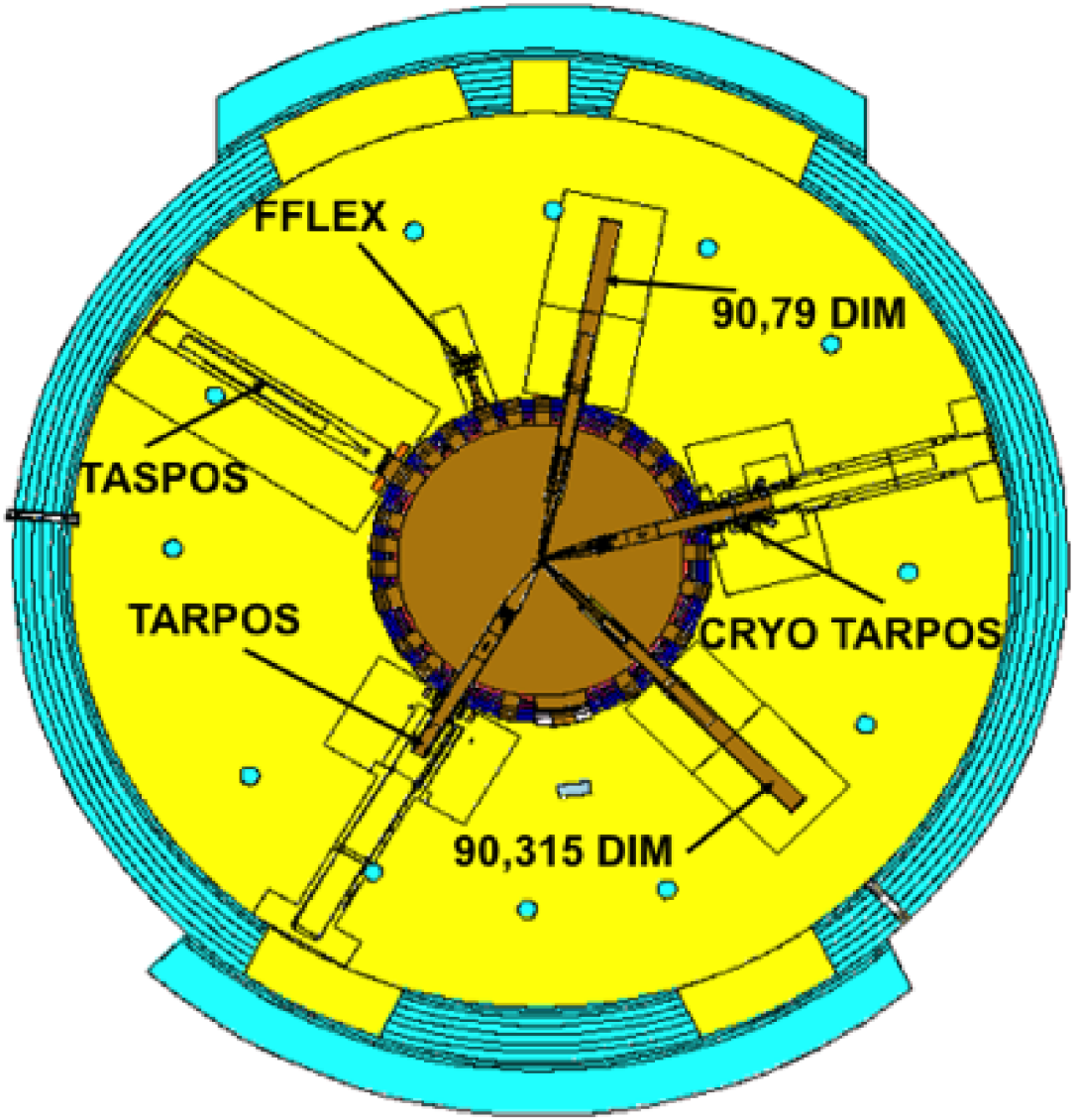
nToF detector model

- 10-cm-thick Al Target Chamber (TC) wall surrounded by 40-cm of borated concrete
- 1.83-m -thick concrete Target Bay (TB) wall
- Final Optics Assemblies (FOAs) are fully modeled
- A 3-D model of the NP nToF detector and hut are added to the NIF model

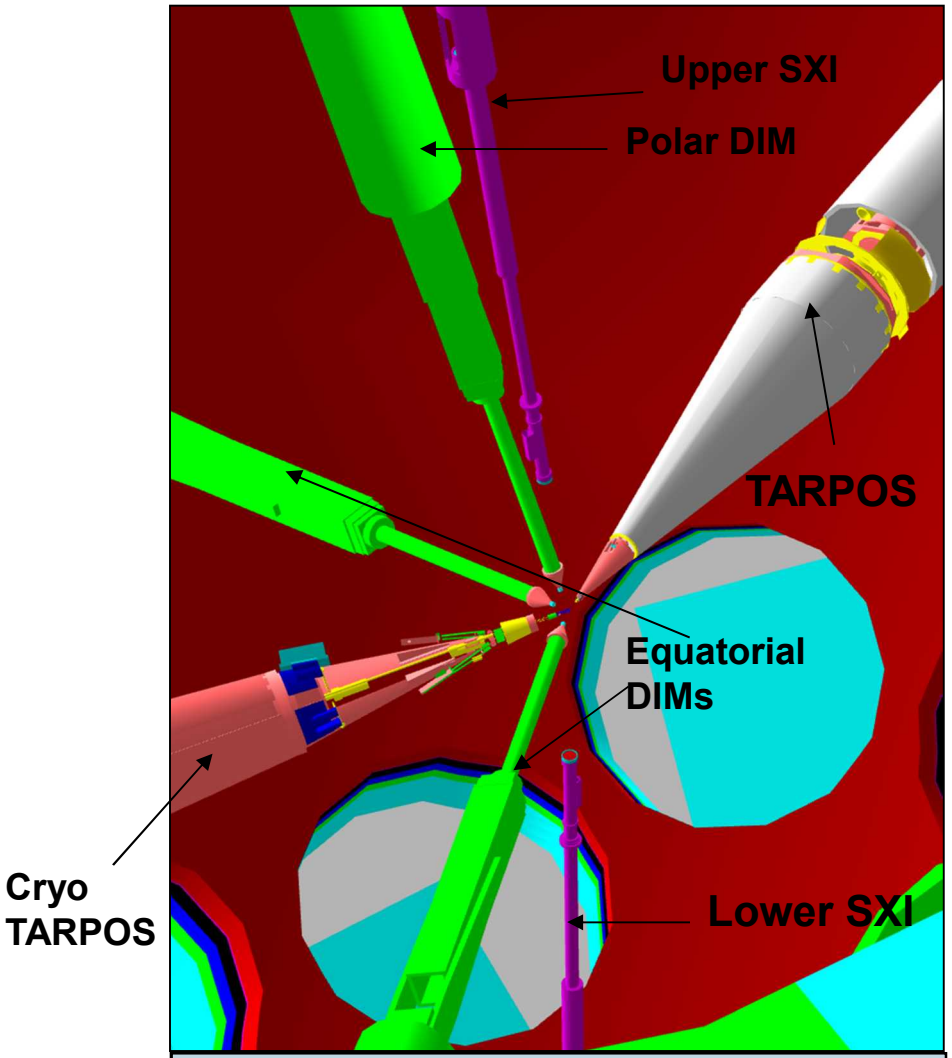


MCNP model of the Target Chamber

Model of the Target Bay during shots

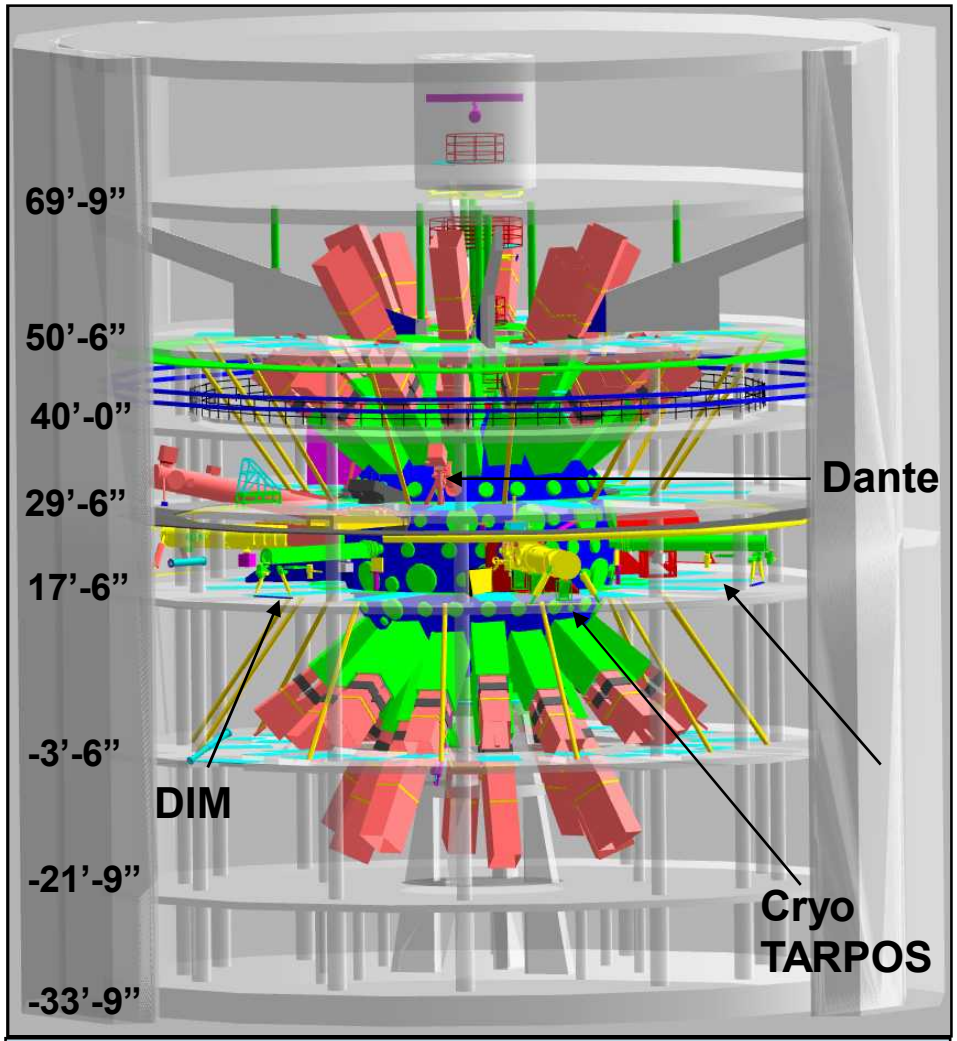


Equatorial view of the Target Bay

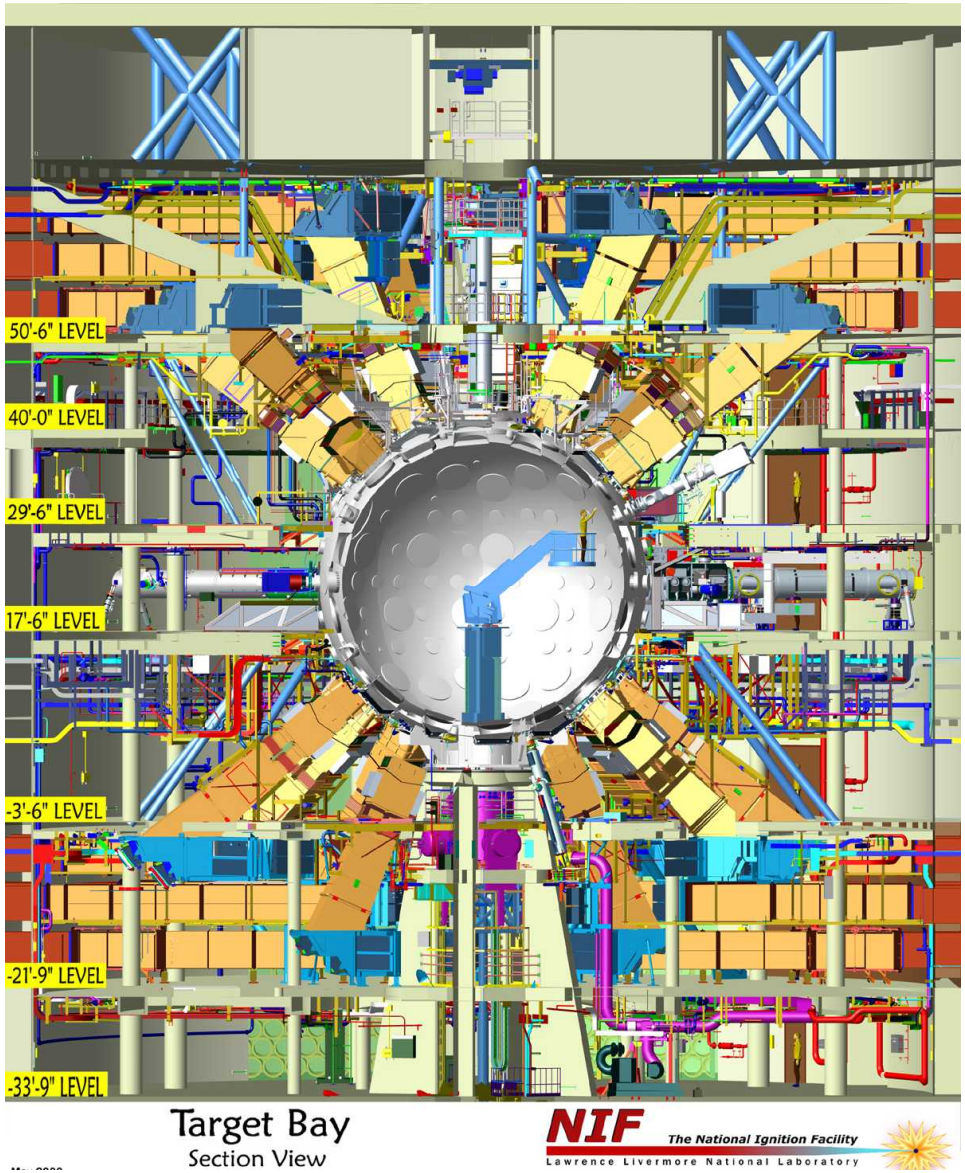


MCNP model of inside of the TC

Sectional view of the Target Bay



MCNP model of the Target Bay



Simulation approach and 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 neutron and gamma fluence and dose maps
- ICRP-74 fluence to effective dose conversion factors

Radiation hazard locations

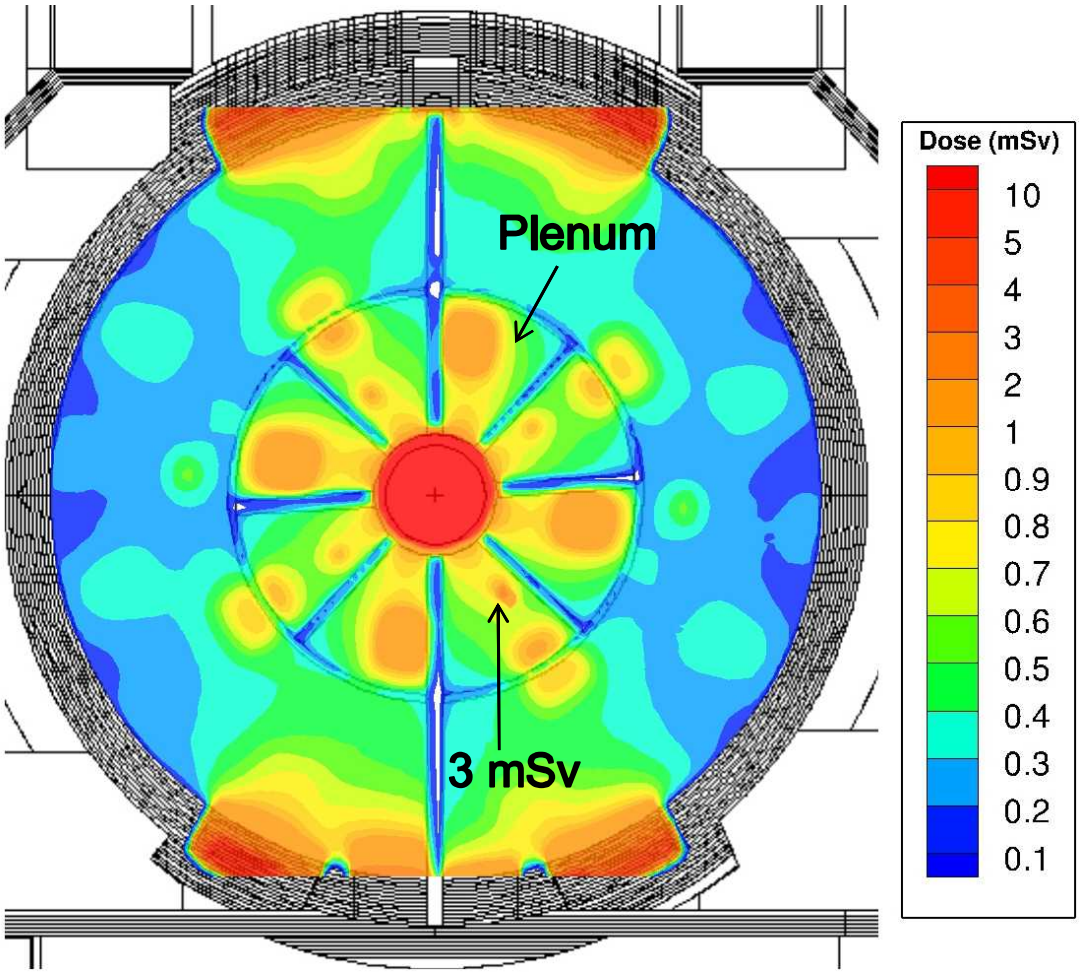
- The 69’ 9” level near the floor penetration
- Target Bay roof outside the NP nTOF hut
- Ground level up to the site boundary
- Commercial flights at an altitude of 300 m
- In the vicinity of the activated beam dump

Prompt dose assumptions

- A 20 MJ shot (7.1×10^{18} neutrons)
- Target Bay roof hut without concrete walls
- Target Bay roof is interlocked
- Maintain dose outside the NP nToF hut to < 5 mSv
- Beam dump (30-cm x 30-cm) is made of 45-cm iron followed by 30-cm concrete

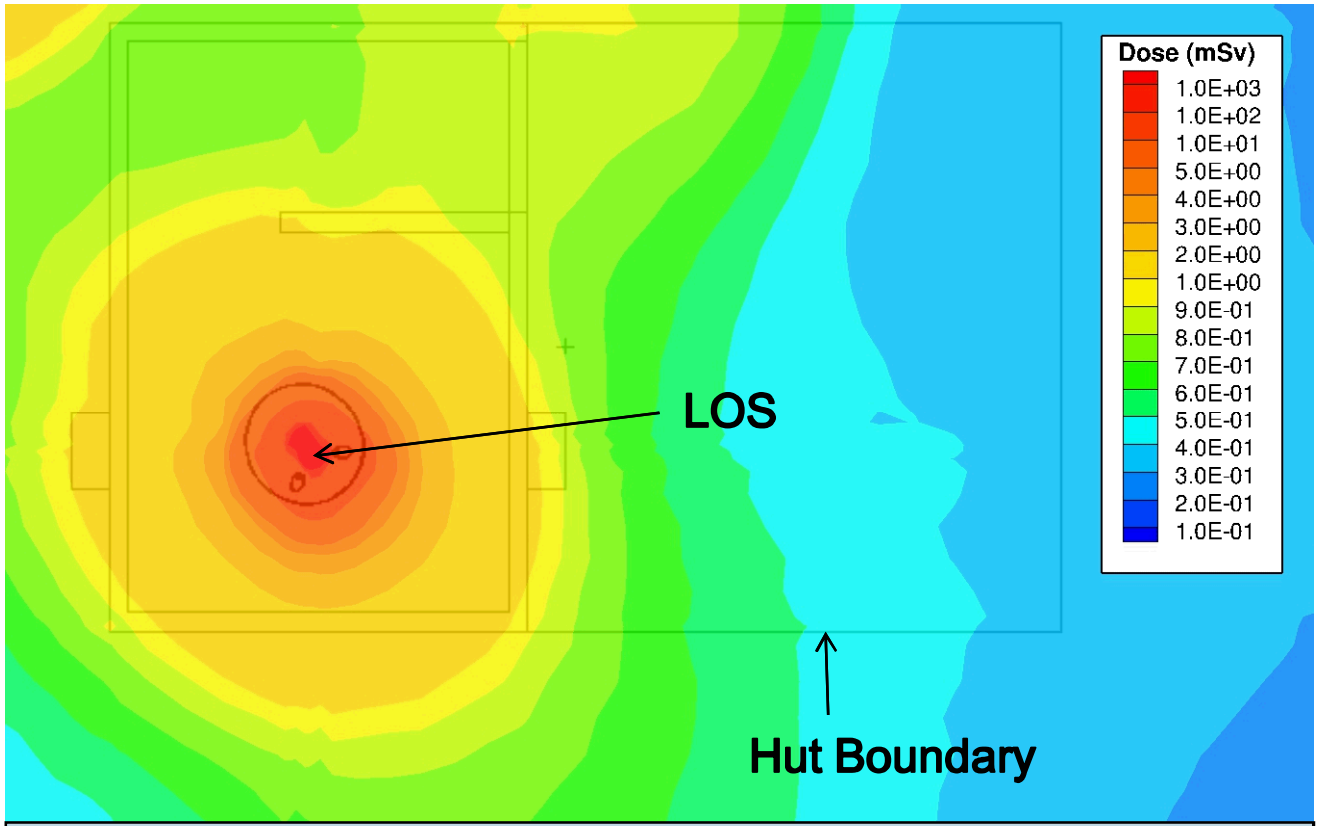
Effective dose at the 69’ 9” floor level

- High dose is expected in the 69’ 9” floor
- Effective dose of ~ 3 mSv is expected during shots with yield close to 10^{16} neutrons
- Access control to the plenum is required for shots with yield higher than 10^{14} neutrons



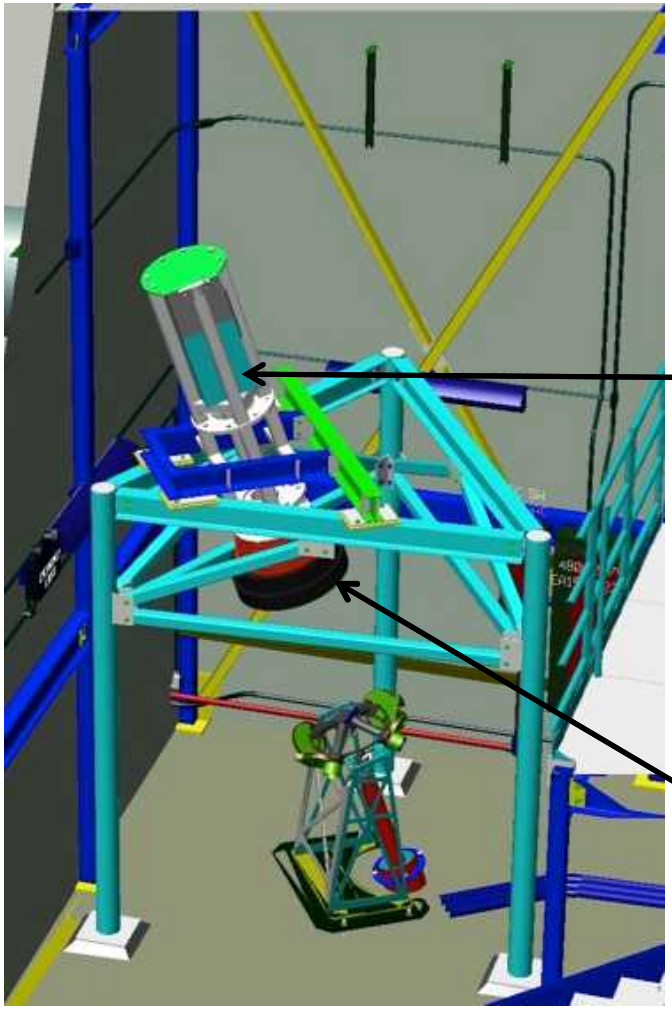
Effective dose outside the NP nToF hut

- Scattered radiation generates an effective dose of ~ 3 mSv outside the hut during a 20 MJ shot (7.1×10^{18} neutrons)
- Access control to the TB roof is required for shots with yield > 10^{16} neutrons
- No access is allowed inside the hut during shots



Effective dose during a 20 MJ shot

Beam dump is used to eliminate skyshine dose

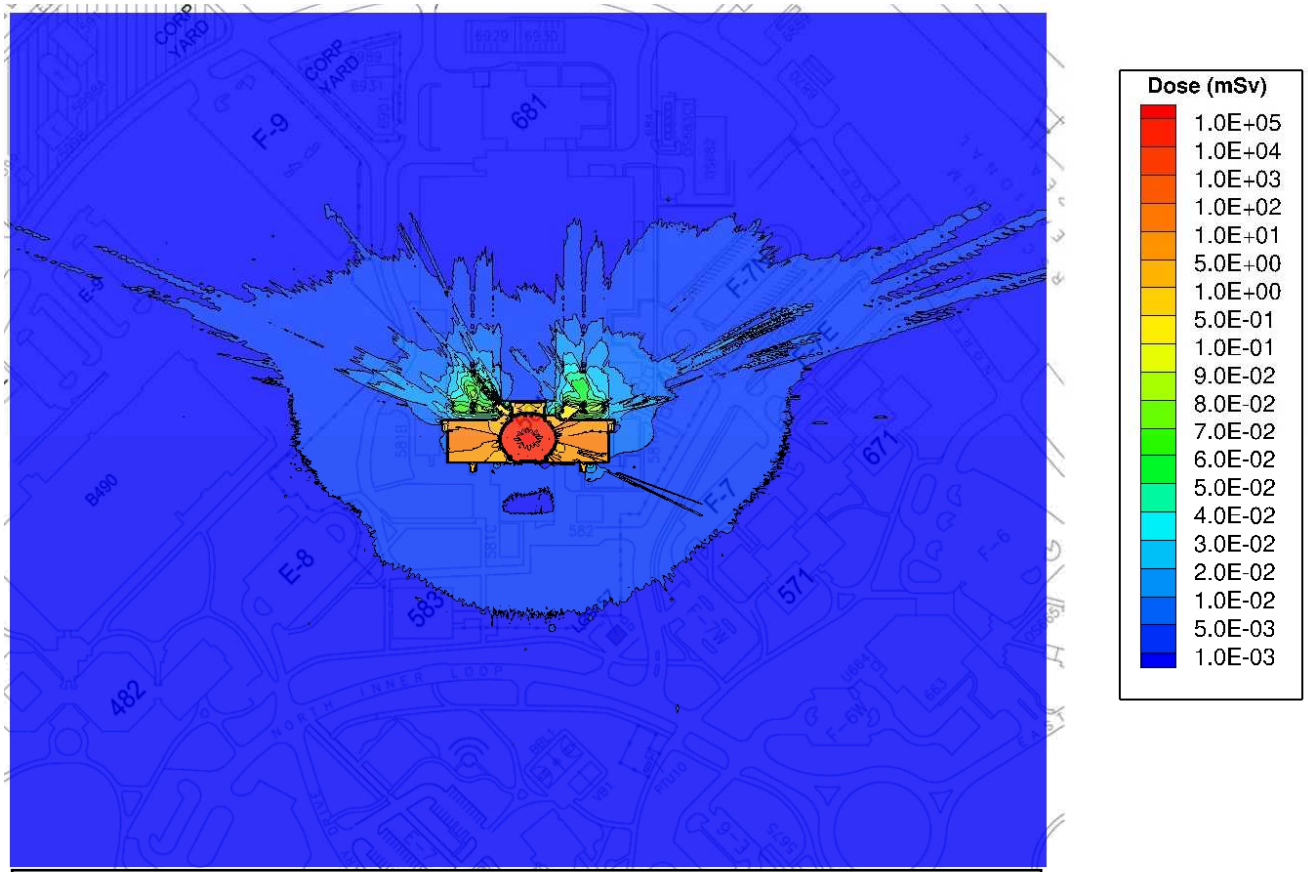


Beam dump: 45-cmsteel, 30-cm concrete

Backscatter shield: 20-cm lead, 20-cm concrete

Effective dose at the ground level

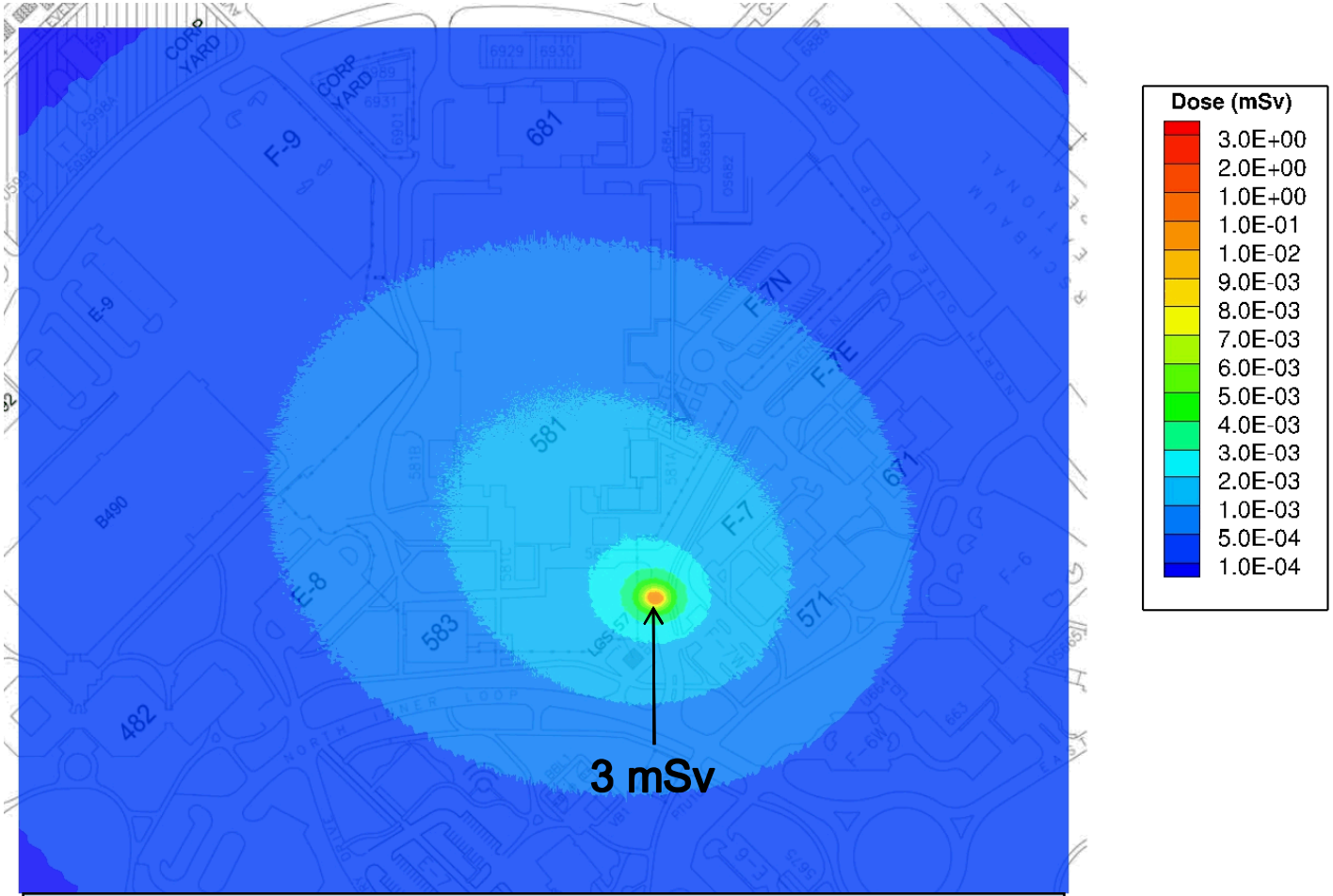
- No new skyshine issue on the ground
- Dose of < 10 μSv at areas outside the NIF building
- Dose of < 1 μSv at areas near the site boundary



Effective dose during a 20 MJ shot

Effective dose at 300 m (airplane altitude) without beam dump

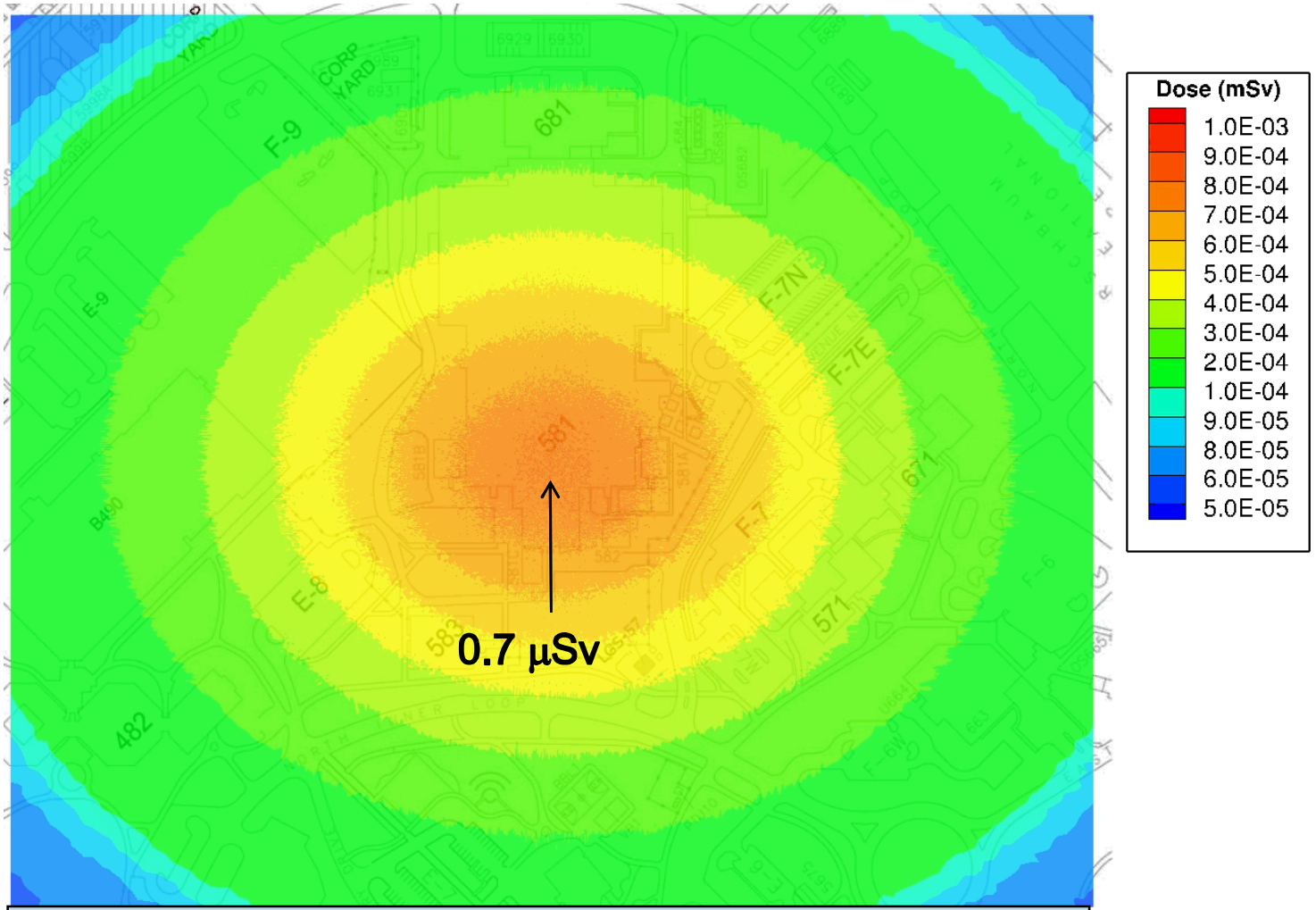
- Beam dump is needed to significantly reduce the line-of-sight (LOS) dose



Effective dose during a 20 MJ shot

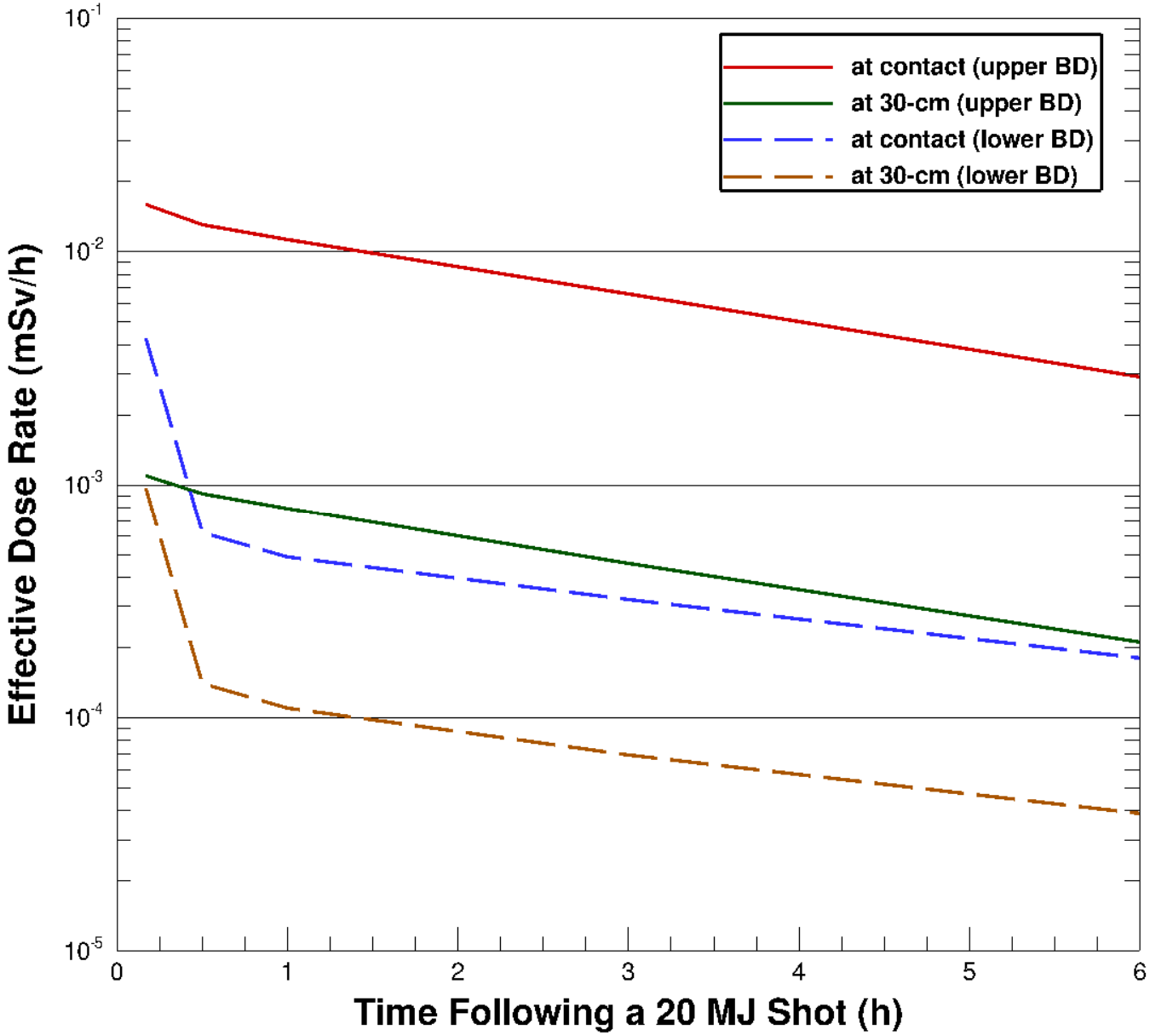
Effective dose at 300 m (airplane altitude) with beam dump

- The beam dump is effective in reducing the LOS dose risk
- Natural background dose rates during commercial flights ~ 3 – 6 μSv/h



Effective dose during a 20 MJ shot

Dose Rates in the vicinity of the beam dump



Summary

- NP nToF can safely operate inside unshielded hut located on the top of the TB roof
- Shots with yield > 10^{16} neutrons require interlocking the TB roof
- A LOS neutron beam dump is required
- No skyshine issues on the ground and the beam dump eliminates the risk to commercial flights
- Successful collimation of the neutron beam resulted in negligible dose values outside the NIF building and at the site boundary
- Dose rates associated with the activated beam dump are low < 10 μSv/h, allowing for immediate maintenance activities inside the hut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