Radiological Calculations on the LBNE Neutrino Beamline

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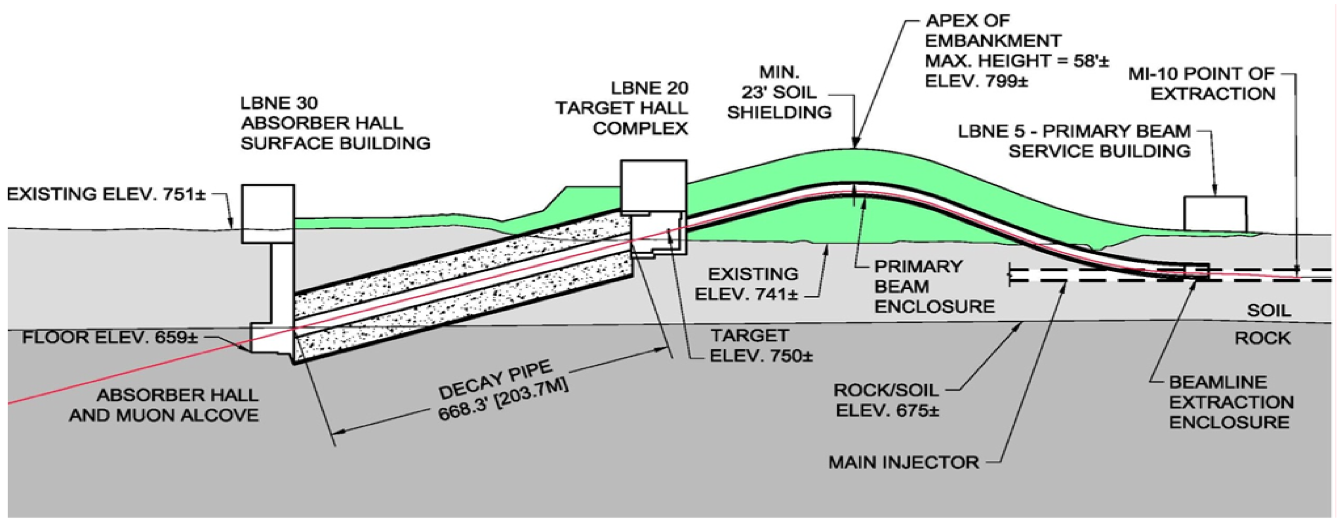
Introduction

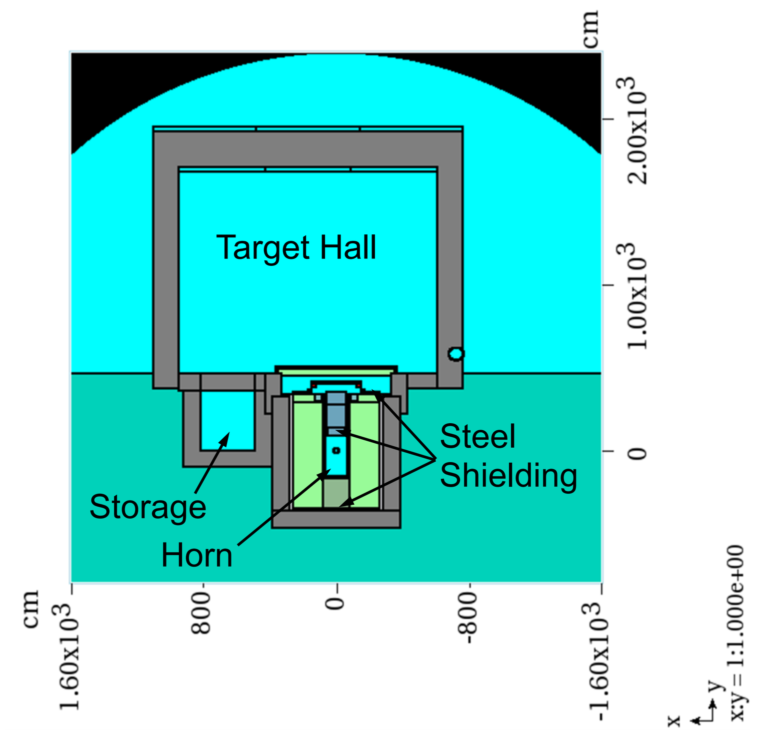
- The proposed Long Baseline Neutrino Experiment (LBNE) beamline is planned to deliver high intensity neutrino beam to a detector approximately 1300 km away in South Dakota.
- Intense proton beams incident on a graphite target will produce mesons which will decay in flight to produce the neutrino beam.
- With an initial beam power of 1.2 MW for 5 year followed by an upgraded to 2.3 MW for 15 years, shielding must be sufficient to protect both the environment and people.
- MARS15 is used in various radiological calculations for the experiment.

LBNE Beamline Layout

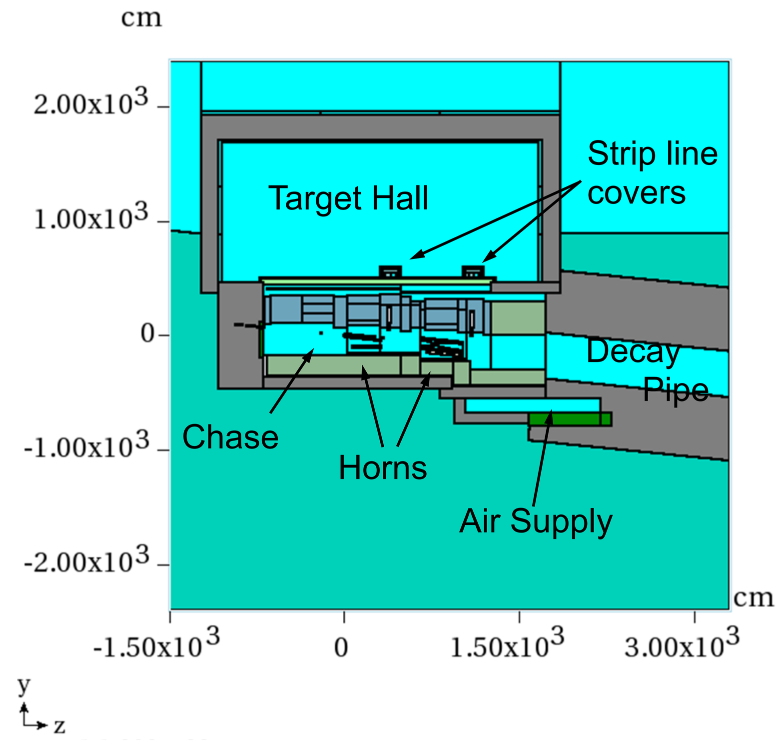


MARS LBNE Neutrino Beamline Model

Cross Section View



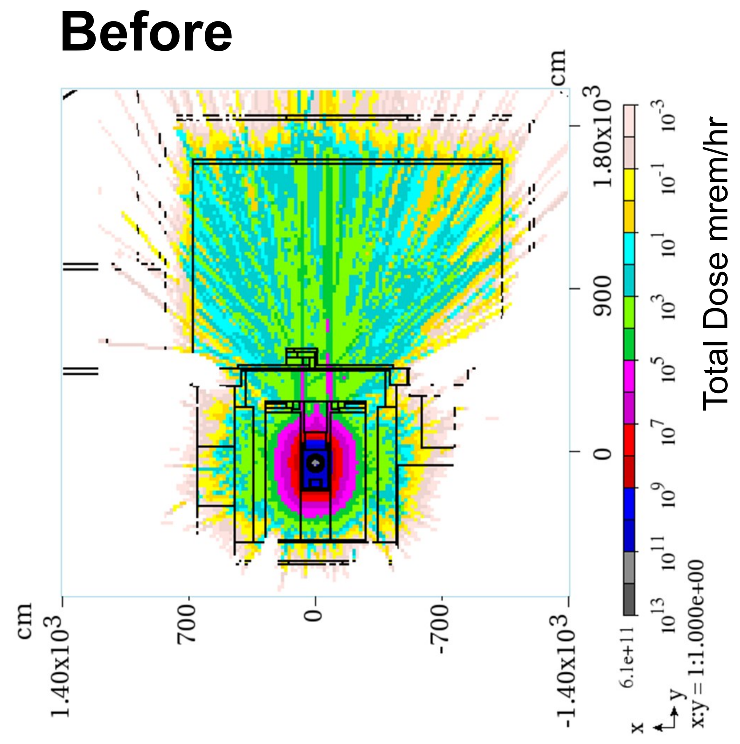
Target Hall Detail



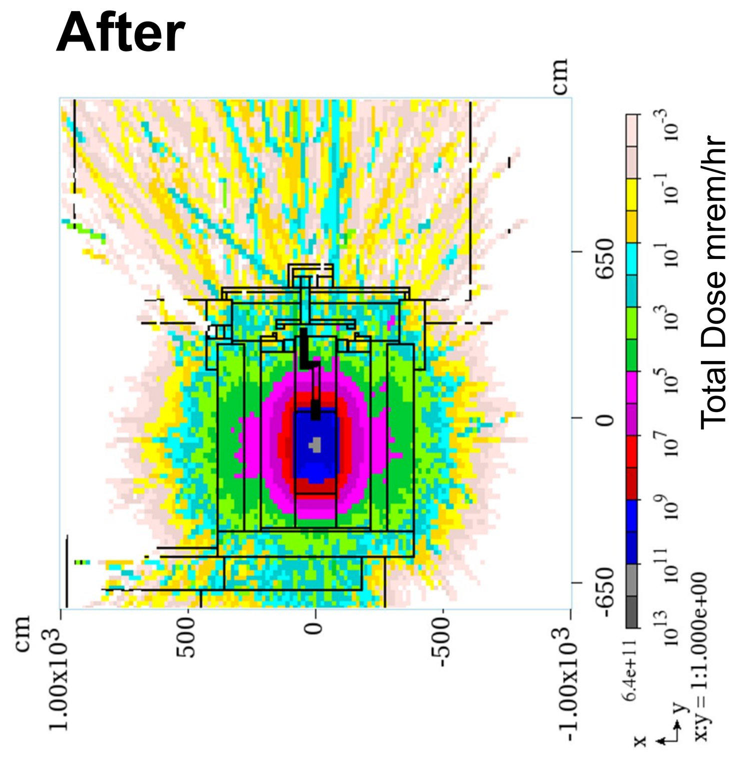
Total Dose in Target Hall

- Design goal of 100 mrem in target hall during operation.
- Gaps in the steel chase shielding allowed significant particle flux into the target hall.
- The addition of 46 cm of steel shielding above the chase reduced the amount of shine from the gaps.
- Dose in target hall is under 100 mrem/hr with extra shielding.

Before



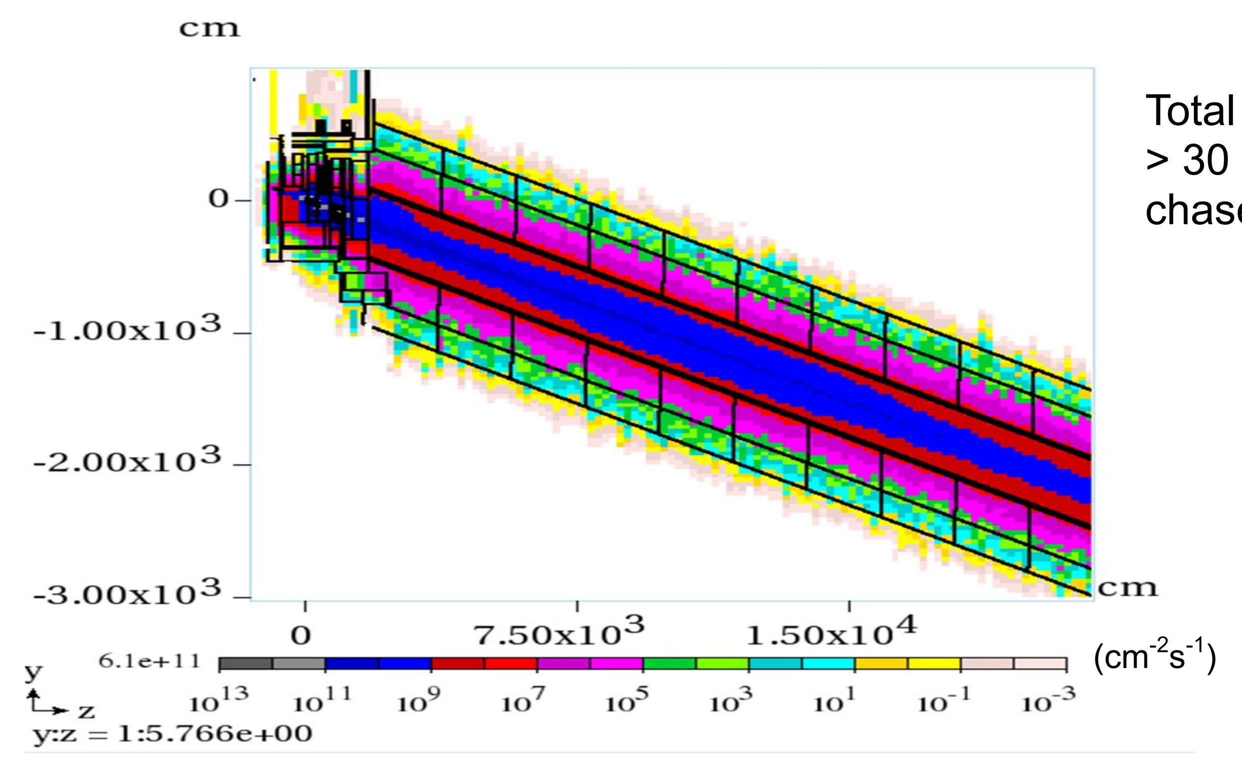
After



Total dose in chase and target hall before and after 46 cm of steel shielding is placed above the chase. Before the extra steel was in place, 10 rem/hr was being emitted from the gaps. After the steel is placed, the dose in the target hall goes below 100 mrem/hr.

Air Activation

- Total release from all Fermilab not to exceed 0.1 mrem/year for a maximally exposed offsite individual (MEOI)
- LBNE goal of <30 μrem for release.
- Use MARS to estimate total fluxes for the air in chase and decay pipe.
- Factor in flow and leak rates from air handling system, cooling times.



Total flux for energies > 30 MeV in the target chase and decay pipe.

	^{3}H	^{11}C	^{13}N	^{15}O	^{41}Ar
Annual Release (Ci)	1.22×10^{-5}	221	0.426	6.84×10^{-7}	82.6

Estimated annual release activity for no cooling time.

T_{cool} (hr)	Total Annual	MEOI total
0	304 Ci	101%
0.5	148 Ci	49%
1.0	84 Ci	28%

Total annual activity and fraction of maximally exposed offsite individual dose limit as a function of cooling time (T_{cool}). At least 1 hour of cooling is needed to meet the air emission target.

Ground Water Protection

- Estimated concentrations of ^{22}Na and ^{3}H should meet Federal and State regulatory standards.

Federal Limits: $$\sum_i \frac{C_i}{C_{i,\max}} \le 1$$

- C_i = Concentration of i^{th} nuclide
- $C_{i,max}$ = Derived Concentration Standard

Nuclide	Ground Water Limit (pCi/mL)	Surface Water Limit (pCi/mL)
^{3}H	20	1900
^{22}Na	0.4	10

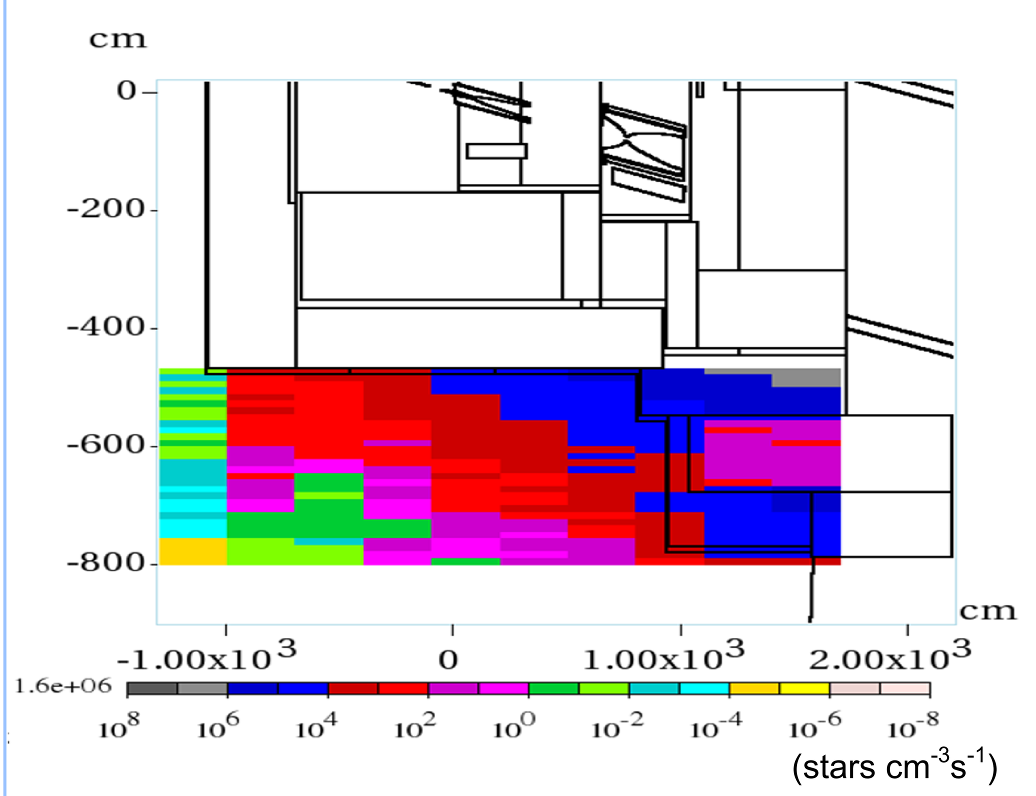
Derived Concentration Standards for ground and surface water.

Nuclide Concentration

- Use MARS to calculate inelastic interaction (star) densities and the number of nuclides produce per star in soil.
- Calculate using MARS the number of ^{3}H and ^{22}Na nuclides produced per star in soil (K_i).
- K_{3H} = (2.9±0.3)×10^{-2}
- K_{22Na} = (2.6±0.2)×10^{-2}

Target Hall

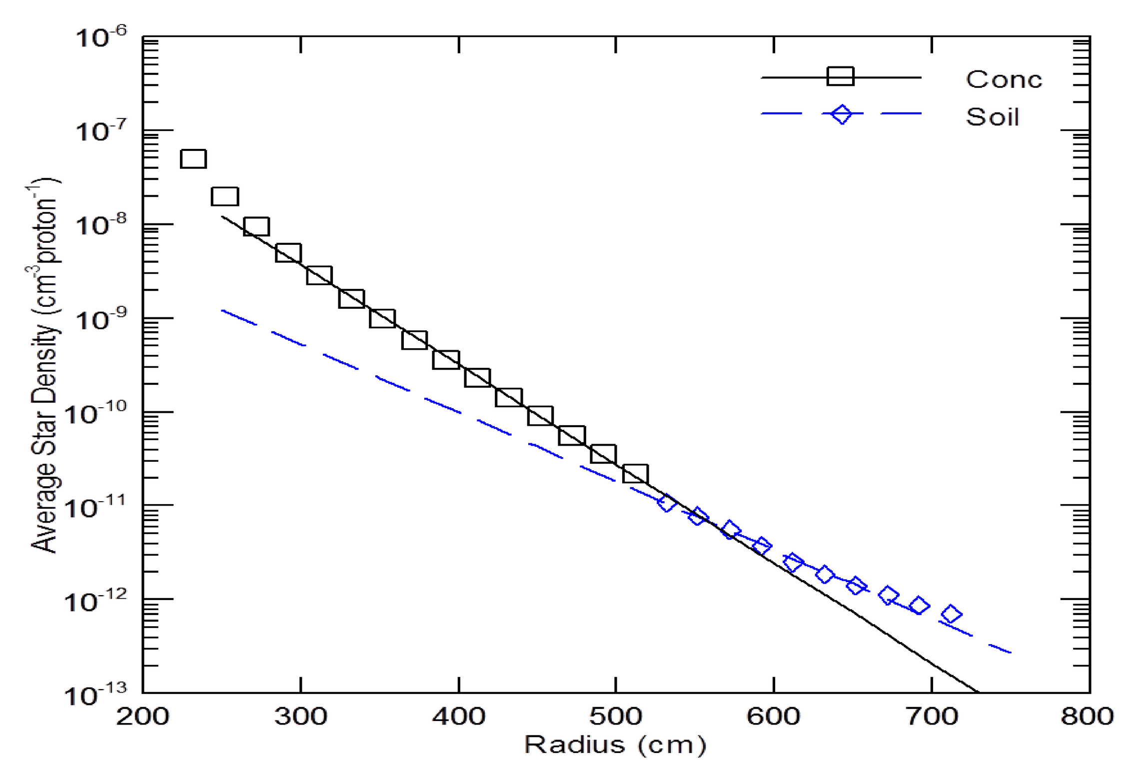
- Use surface water limits as the target hall is at ground level.
- For the current target hall shielding design, the radionuclide concentrations will reach the surface water limit in 9 years of operation.
- To go past the 9 year limit, a robust under-drain system will be employed to collect any contaminated water.



Star densities in the ground beneath the target hall

Decay Pipe

- Use ground water limits as decay pipe penetrates the bedrock.
- Determine minimum shield thickness that maintains radionuclide concentrations below 10% of the federal limit.
- Extrapolate concentration results for a 3 m thick shield to determine a shield thickness which satisfies the regulatory standards.
- Minimum shield thickness is found to be 559 cm for operating at 2.3MW for 20 years.



Star density distribution in the concrete shield and the soil. The attenuation lengths in soil and concrete are used to extrapolate results to different shield thicknesses.