MARS Simulation of the Beam Delivery Section

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Outline

- **Model**
- **Magnet activation**
- **Radiation damage to magnet coils**
- **Ground water activation**
- **Muon background at IP**

Model

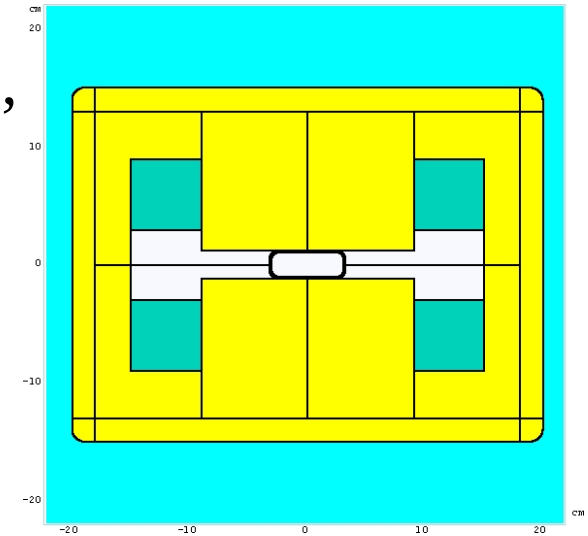
- **Simulations were done with the MARS15 code**
- **Model describes the last ~1500 m of 20-mrad e^+ line**
- **e^- line is similar**
- **The model includes beam elements, collimators and tunnel**
- **Collimation system was designed by A.Seryi (SLAC), A.Drozhdin (FNAL)**
  - Designed to localize beam losses in a specially equipped part of the line
  - Collimation system is multistage
    - 3 spoilers intercept beam halo particles and out-scatter them
    - Out-scattered halo particles are absorbed by secondary collimators
  - Particle tracking and beam losses were simulated with the STRUCT code

Model

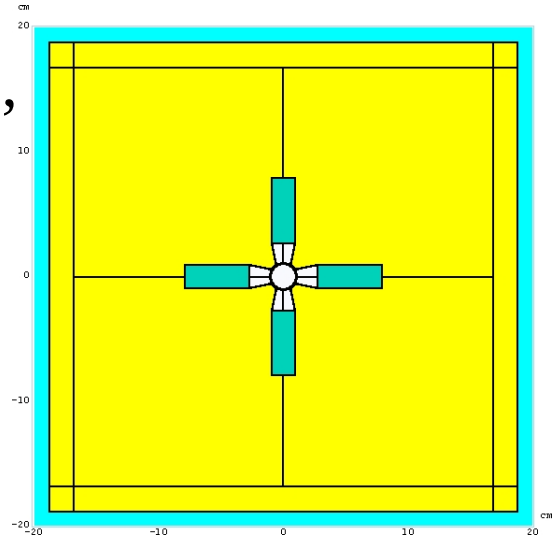
- **STRUCT model redefines apertures of the beam line elements to avoid beam losses in magnets and beam pipe**
- **Beam line elements used in STRUCT and MARS models:**
  - 10 types for drifts (5-round, 5-parallelepiped)
  - 3 types for dipoles (‘H20’, ‘H25’ and ‘H60’)
  - 5 types for quadrupoles
  - 3 types for sextupoles
  - 3 types for octupoles
  - 25 collimators - spoilers, absorbers and masks
- **In reality a smaller number of types could be used**
- **MARS model does not rely on beam loss studies done with STRUCT. Only initial particle distributions at the spoilers were generated with STRUCT. MARS model performs tracking through the line, simulates interactions in matter.**
- **Kinetic energy of the beam – 250 GeV. Beam losses – 0.1 %.**

Model: Elements

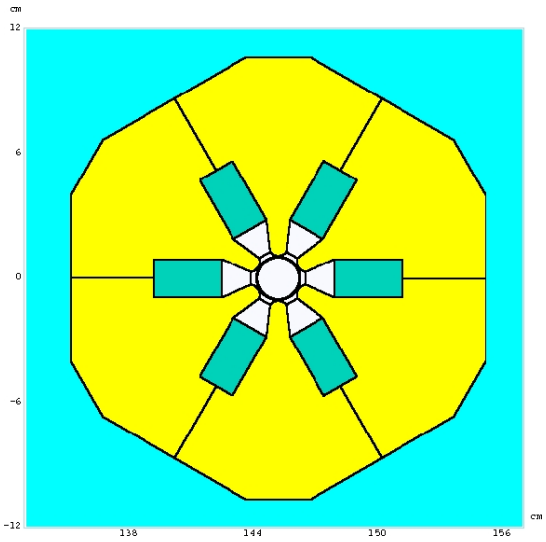
‘H20’



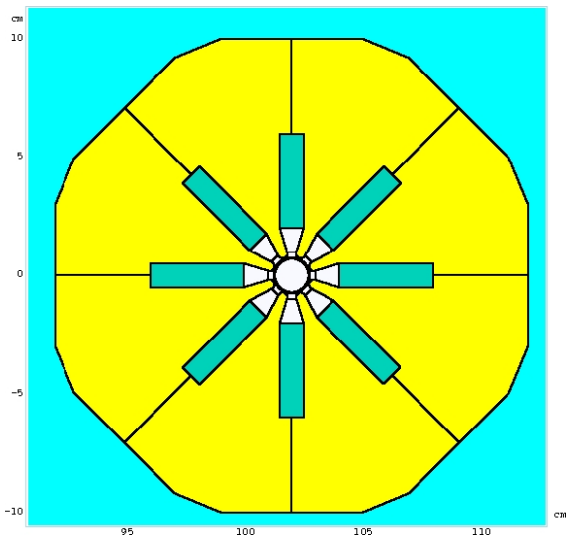
‘Q10’



‘S10’

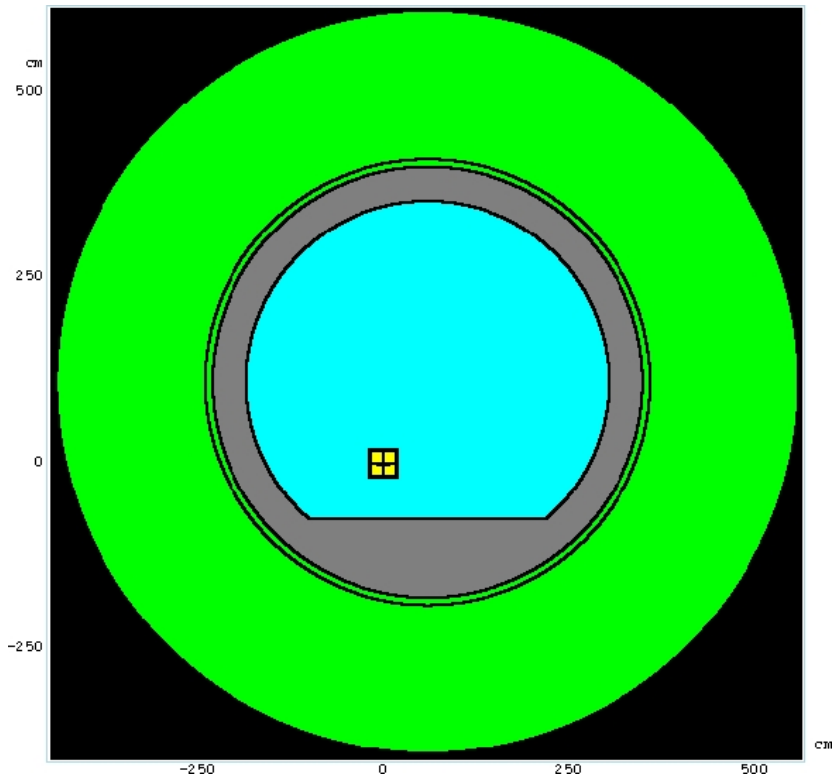


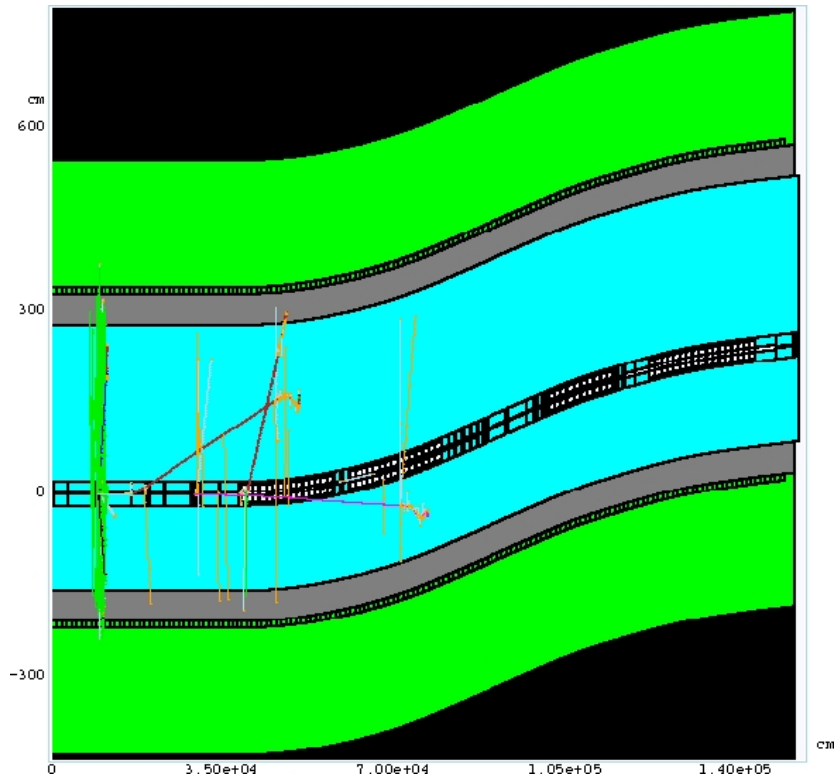
‘O7’



Model: Tunnel

- Tunnel R = 2.44 m
- Concrete wall thickness = 0.46 m
- Soil layers thickness =10 cm

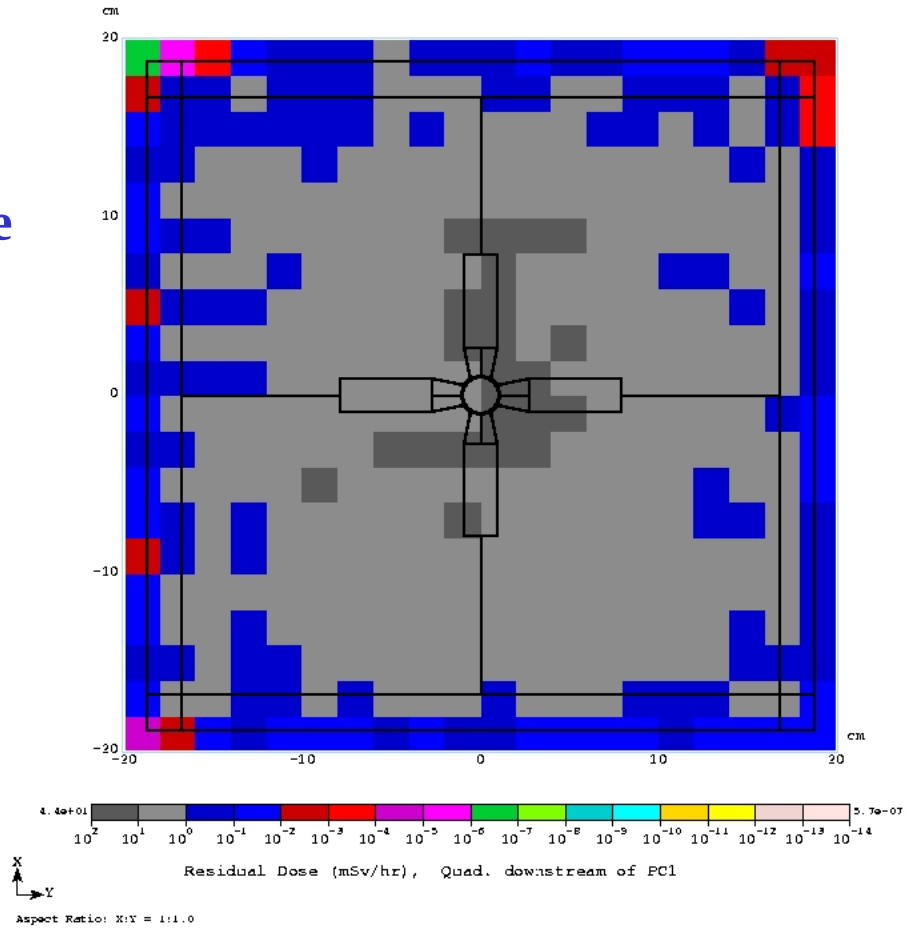




Magnet Activation

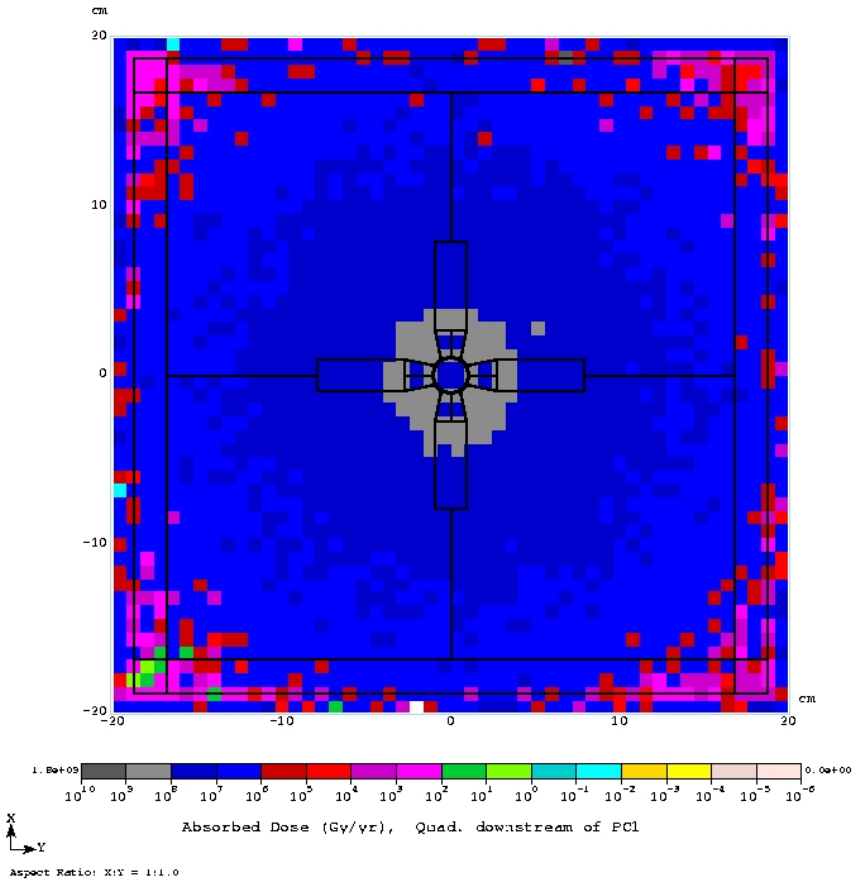
- **Hands-on maintenance residual dose, P_γ, should be below 100 mrem/hr (100 mrem = 1 mSv). P_γ is at 1' after 100 day irradiation, 4 hours after shutdown.**
- **Four locations with activation above 100 mrem/hr were located**
  - Quadrupole downstream of PC1: P_γ=730 ± 118 mrem/hr
  - Quadrupole downstream of PC5: P_γ=444 ± 91 mrem/hr
  - Quadrupole downstream of PC8: P_γ=598 ± 113 mrem/hr
  - Dipole downstream of PC9: P_γ=152 ± 40 mrem/hr
- **Local shielding is required**

Residual dose on upstream surface. Quadrupole downstream of mask 'PC1'



Radiation Damage to Magnets

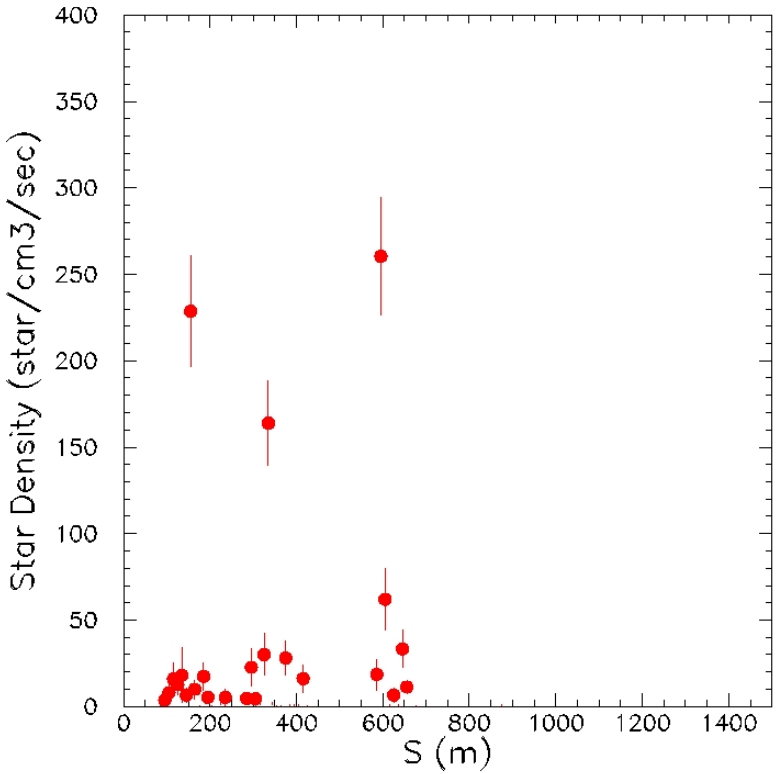
- **Absorbed dose in epoxy and cable insulation should be below 400 Mrad (1 Gy = 100 rad).**
- **Peak absorbed dose in coils > 10^4 Mrad/yr**



Ground Water Activation

- **The standards for ground water (DOE order 5400.5) are designed to limit the doses to the public to 4 mrem/yr**
- **Regulatory limits on radio nuclide concentration in drinking water - 20 pCi/ml for ^{3}H, 0.4 pCi/ml for ^{22}Na**
- **If a machine were built in a water supplying layer (aquifer), then the limits would apply directly**
- **To calculate radio nuclide concentration, many factors must be taken into account**
  - Maximal star density (amount of nuclear interactions)
  - Number of radio nuclides per star
  - Water leaching factor (how well isotopes are washed out by water)
  - Soil/rock density and porosity (water contents in rock)
  - Isotope half-life
  - Time needed for the activated water to reach aquifer (if machine is not in aquifer) (water velocity)

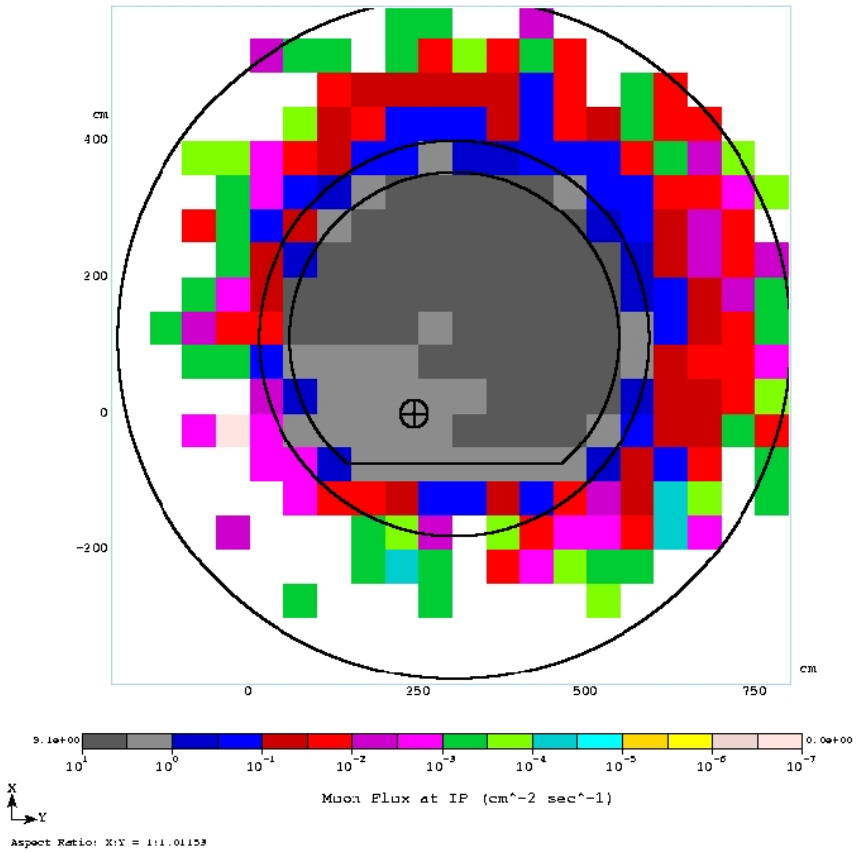
Ground Water Activation

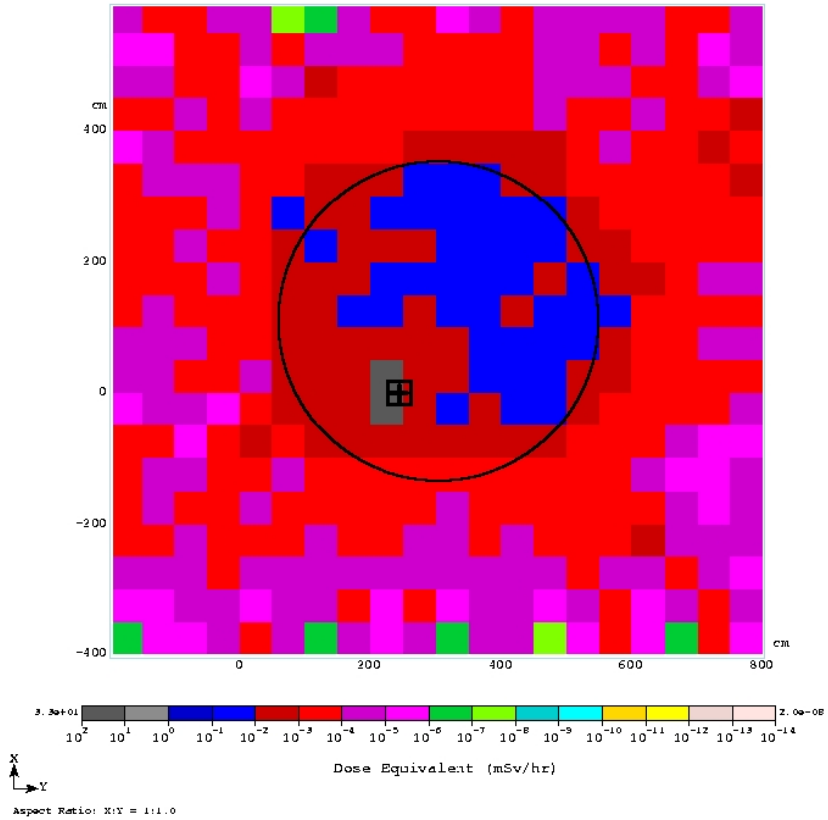


- **The factors are site specific**
- **For the NuMI target station (Fermilab) the limit on peak activation is ~170 star/cm^3/sec. The target station is in aquifer (dolomite).**
- **Safety factor 2-3 is required**
- **For the model, there are three places with ground water activation above the limits**
- **If ILC were in aquifer, then the tunnel wall must be thicker.**

Muon Background at IP

- $<N_\mu>=4.6\ cm^{-2}\ sec^{-1}$, $<N_\gamma>=4.7\ cm^{-2}\ sec^{-1}$
- For 150 bunches, $<N_\mu>=0.0489 cm^{-2}$ or 8855 muons in the tunnel aperture
- 'Muon spoilers' might help (L. Keller, SLAC). Needs confirmation.

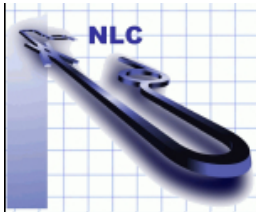




CONCLUSIONS

- **Shielding will be required to protect magnets against activation and radiation damage to coils**
- **Ground water activation is site/depth dependent. It is not necessarily a problem but keep an eye on it.**
- **Muon background is high. 'Muon spoilers' might help. Extra studies are required.**

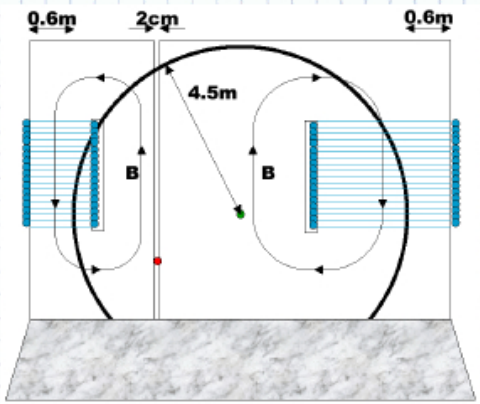
Backup Slide



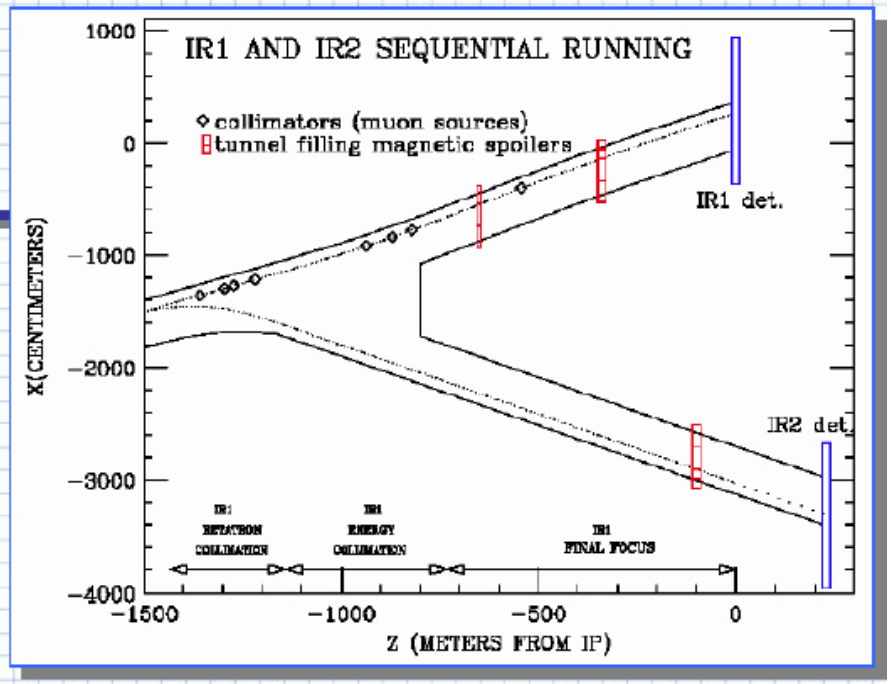
Dealing with muons

Lew Keller

Assuming 0.001 of the beam is collimated, two tunnel-filling spoilers are needed to keep the number of muon/pulse train hitting detector below 10



Tunnel filler



Good performance achieved for both Octupoles OFF and ON

Would like to confirm these MUCARLO simulations with MARS

Studies at FNAL with MARS are ongoing. N.Mokhov

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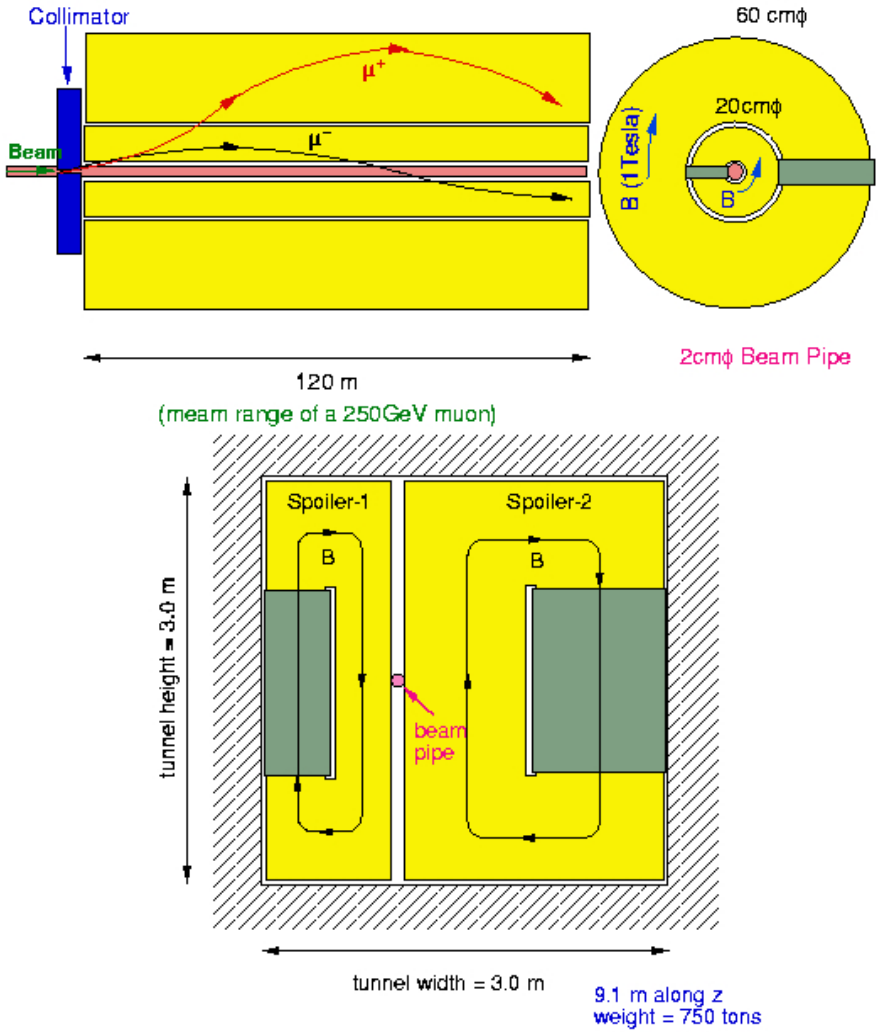
A.Seryi, 07/14/03, ALCW03

Backup Slide



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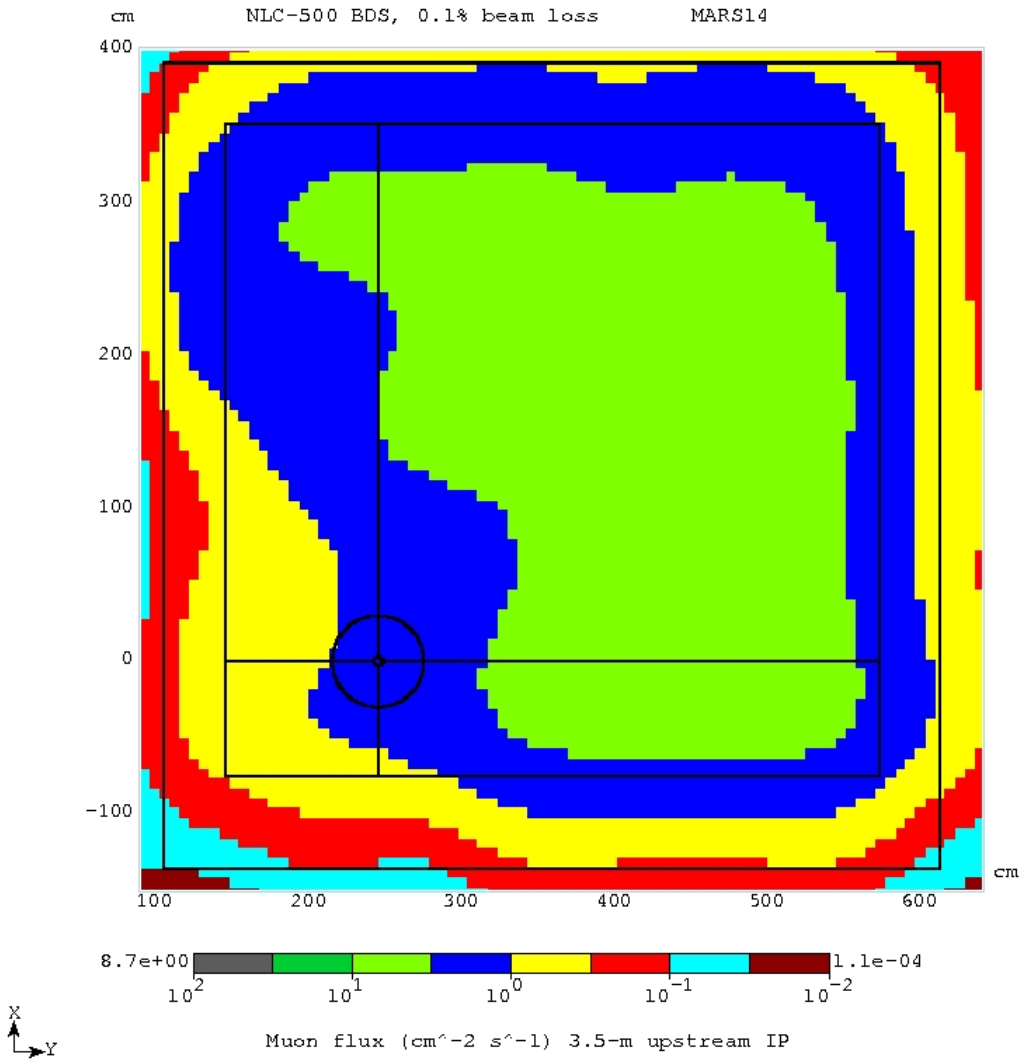

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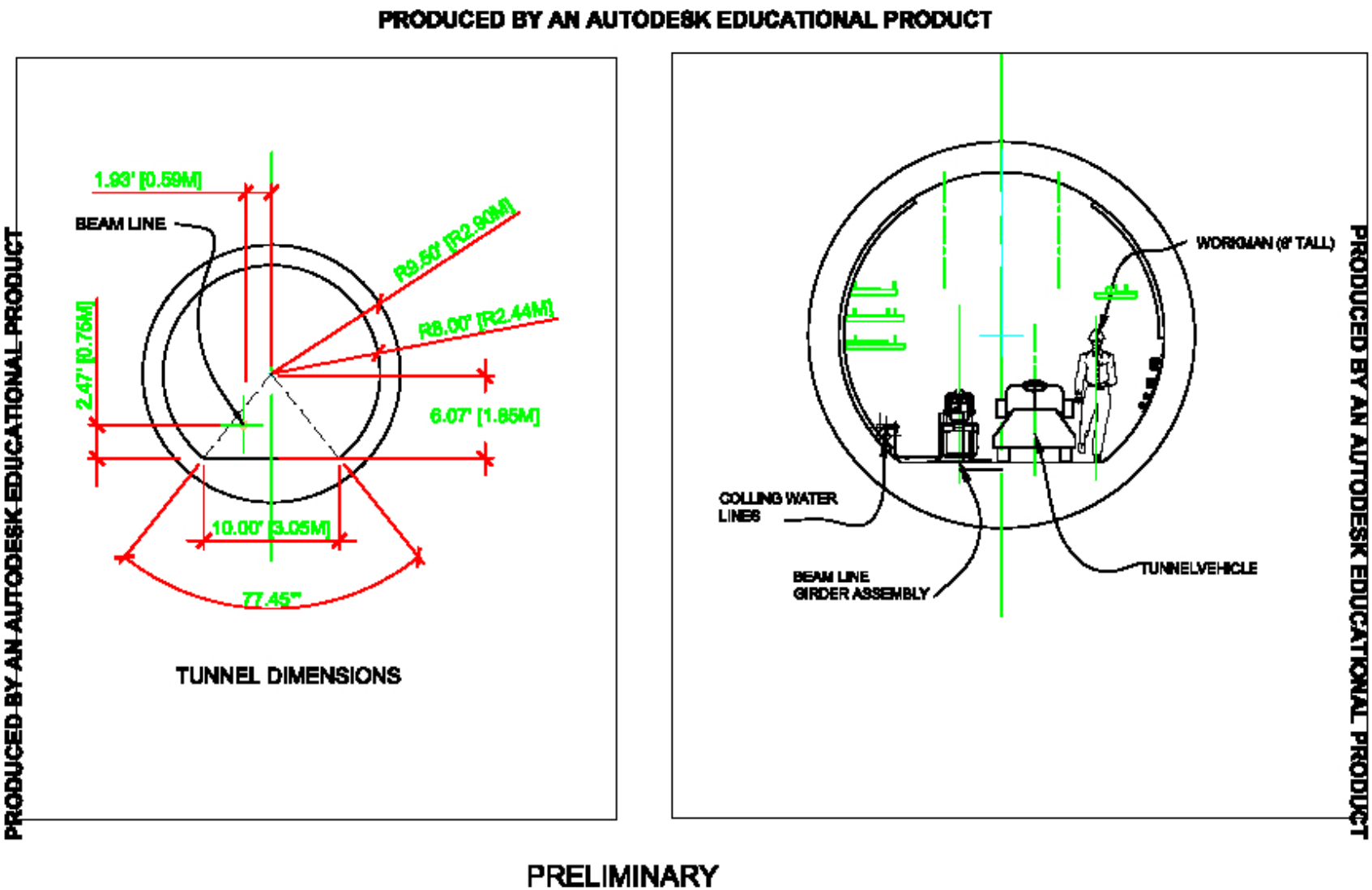

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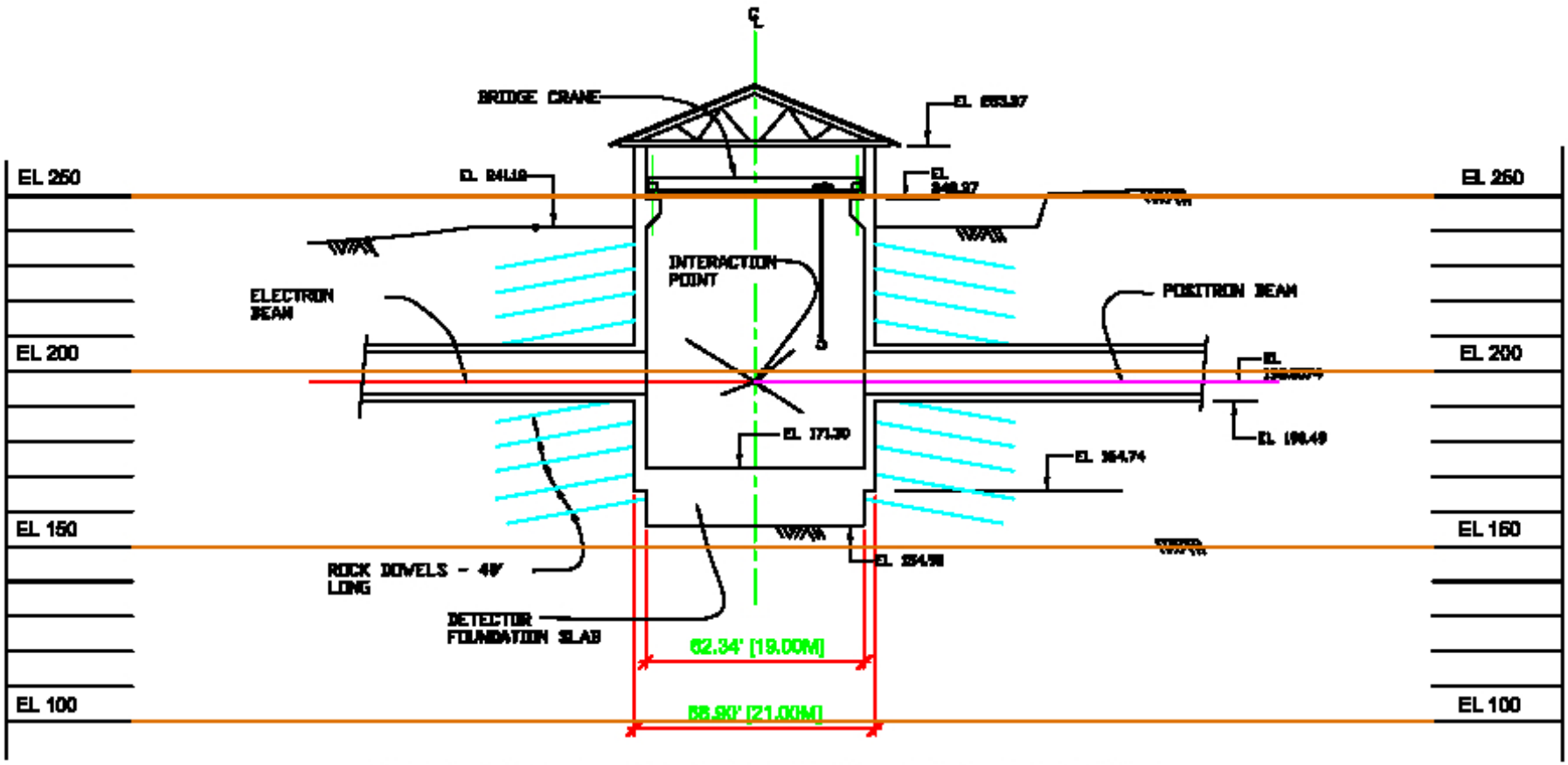

SECTION B-B PROFILE ALONG BEAM LINE
- INTERACTION HALL No. 1 (IH-1)

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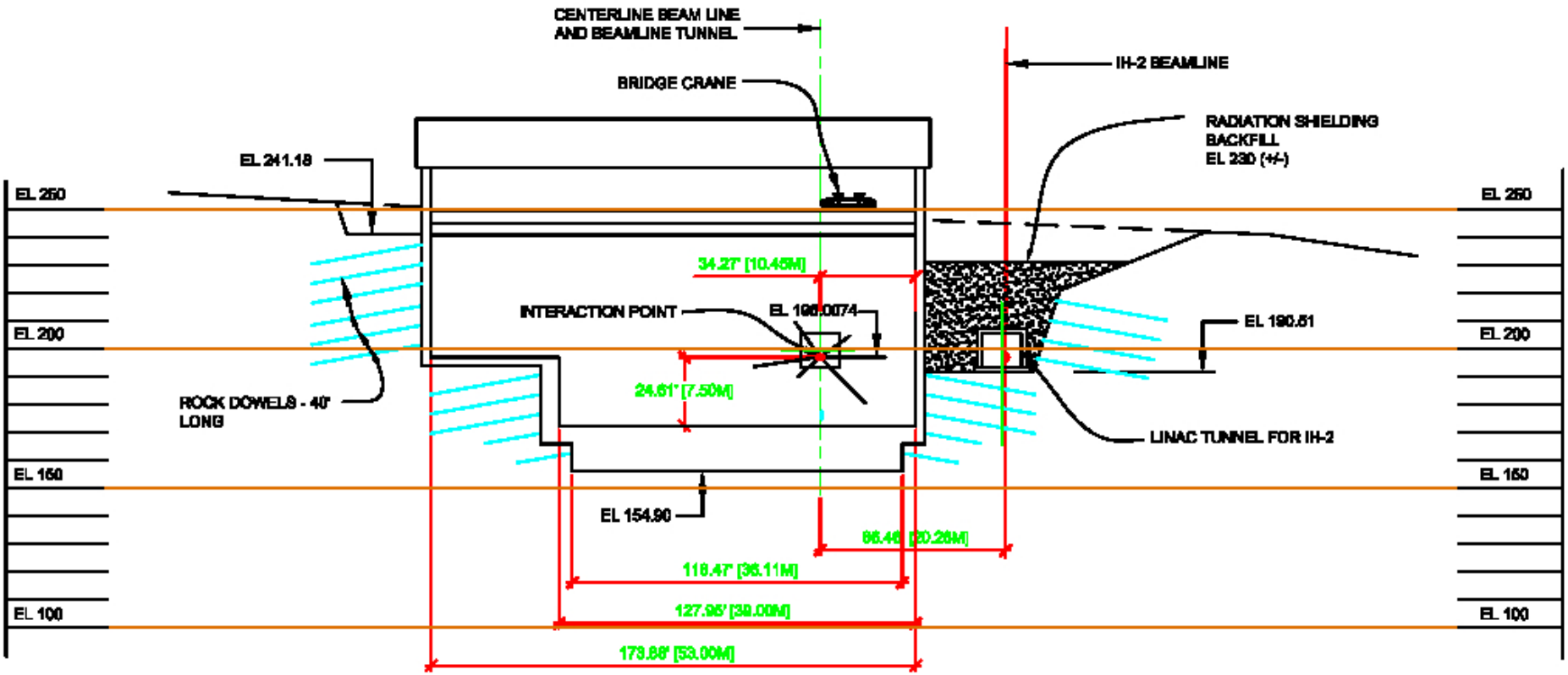

SECTION A-A LONGITUDINAL PROFILE OF IH-1