

To: Sayed Rokni**From:** H. Y. Khater and Heinz Vincke**Subject:** Shielding Calculations for the Proposed E163 Penetrations

INTRODUCTION

Plans for the E163 experiment include drilling a one 6"-diameter penetration (#1) in the 6'-thick concrete sidewall of the NLCTA shielding enclosure. The beam passes through the NLCTA shielding wall into the future E163 enclosure. Under normal experimental circumstances (for future E163 operation), a current of 10 pC @ 60 MeV, 10 Hz beam will exit the NLCTA enclosure via a 25.5° bend dipole originating from the position of the NLCTA Faraday Cup FARC1140. In the meantime, the current long-pulse operation of the NLCTA allows for a maximum credible beam of 126 W (1.5 A, 140 ns, 60 MeV, and 10 Hz). Since this penetration will need to be blocked during the construction of the E163 enclosure, an analysis of radiation streaming through the penetration was performed to calculate the required shielding. In addition, the plan calls for drilling two 4"-diameter laser and diagnostic penetrations (#2 and #3) in the sidewall of NLCTA (the 8-pack side). The center of each penetration is 72" above beam line. A third 4"-diameter penetration (#4) is drilled vertically through the roof to allow for rf waveguide to enter the NLCTA shielding enclosure. This penetration is located in the roof of the west entrance labyrinth (no direct exposure to the beam line).

SHIELDING CALCULATIONS

The SHIELD11 code was utilized to calculate the neutron and gamma dose rates at the penetration (#1) exit (outside the NLCTA wall). The SHIELD11 calculations were performed for a maximum credible beam loss of 126 W. Since a beam loss may be produced by beam interactions with thin target (e.g., beam pipe), the SHIELD11 results (thick-target) need to be adjusted. To take into account the thin target effect, gamma and neutron dose rate results from SHIELD11 (with thick target) were compared to dose rates calculated by using the photon and neutron source terms from thin targets generated using a separate FLUKA simulation [1]. In this simulation, a 3-GeV electron beam was assumed to hit a 1°-tilted, 0.7-cm-thick Cu plate (10 cm high and 200 cm long), as a simulation of a beam hitting a thin beam pipe. At an angle of 25.5° with respect to the beam pipe, the FLUKA photon and neutron thin target results were a factor of 22 and 1.4 higher than the SHIELD11 results, respectively.

Based on discussions with the NLCTA physicists, the normal loss at the Faraday Cup location (with a disabled Faraday Cup) is about of 1% of the total beam. In case of radiation streaming through the E163 penetration (#1) during a normal beam loss (1.26 W) from a 126 W beam, results of the analysis showed the need for using a (15" iron + 6" poly) plug to reduce the dose rate outside the NLCTA wall to less than 1 mrem/h. This dose rate is based on the assumption that the integrated dose rate is limited to less than 1 rem during 1000 hours of operation. The

plug reduced the dose rate due to the loss of 1.26 W (1 % of the beam) to a 0.3 mrem/h. The same plug size reduced the dose rates outside the NLCTA wall due to a mis-steering beam loss to a 30 mrem/h. This value is lower than the mis-steering limit of a 400 mrem/h. Finally, to take into account that the plug might not fully fill up (radially) the penetration and hence allowing for radiations streaming through the cracks, an additional shielding of 4” of iron and 2” of poly should fully cover the exit of the penetration on the E163 enclosure side. The shield reduces the dose rate behind the shield to a 5 mrem/h. These shielding requirements are calculated under the assumption that the maximum dose rate to an organ is about a factor of four higher than the dose limit to the whole body.

In order to evaluate the two laser penetrations (#2 and #3) in the NLCTA sidewall, the SHIELD11 code was utilized to calculate the neutron and gamma doses at the entrance of the penetration. The SHIELD11 calculations assumed either a 1.26 W (normal loss), or a 126 W (mis-steering loss) beams hitting a thick target at a 90° angle with respect to the penetrations. Dose rate values at the exit of each penetration were calculated by using the conservative reflection coefficients for monoenergetic x-rays ($\alpha_\gamma = 0.03$) and neutrons ($\alpha_n = 0.06$) given in Appendices E.15 and F.12 of the NCRP Report No. 51 [2]. Equal angles of incidence and reflection were assumed while choosing the reflection coefficients from the NCRP report. In addition all calculations assumed that the streaming radiation undergo a single reflection (bounce) within each penetration.

Table I. Summary of dose rate results (at the exit) for radiation streaming through the two laser penetrations (#2 and #3).

Loss Type	SHIELD11	SHIELD11 with Thin Target Correction
Normal (1.26 W)	80 mrem/1000h	300 mrem/1000h
Mis-steering (126 W)	8 mrem/h	30 mrem/h

Results in Table I show the dose rates outside the two laser and diagnostic penetrations. The results in the table assume that the penetrations are not filled. As shown in the table, at the exit of each penetration, the dose rates during 1000 hours of exposure due to normal loss of a 1% of a 126 W beam is 300 mrem. In the meantime, a mis-steering beam of 126 W would result in a dose rate at the penetration exit of a 30 mrem/h. The accumulative SHIELD11 dose rate (photon + neutron) is about a factor of four lower than the thin target dose rate. The table also shows that mis-steering dose rates caused by radiation streaming through the penetrations are below the limit of a 400 mrem/h. Since the penetrations are located at more than 8’ from the floor of End Station B, personnel working inside the building would be exposed to lower level of radiation (larger distance form the penetration exit). The actual dose rates are proportional to the inverse of distance square (in meters) between each penetration and the nearest personnel on the floor. Finally, since the rf penetration (#4) in the roof of the west entrance labyrinth is not directly exposed to the beam line and located down beam from the low energy part of beam line, the dose rate caused by radiation streaming through this penetration is smaller than the values shown in Table I.

CONCLUSION

We recommend the approval of the penetration drilling request under the following conditions:

1. The 6"-diameter penetration (#1) is plugged with a (15" iron + 6" poly) plug.
2. 4" of iron and 2" of poly should fully cover the exit of the penetration (#1). To reduce the shield weight, the shield could be cut (on the inside) to only cover the cracks along the edge of the penetration. This shield must be also locked in place by an ADSO lock.
3. The entrance to the penetration (on the NLCTA beam line side) is covered (e.g, with a metal plate) and locked with an ADSO lock.
4. The NLCTA Faraday Cup is disabled and locked out with an ADSO lock.
5. The unused laser penetrations (#2, #3) must be filled up as much as possible.
6. The BAS of the NLCTA must be modified to reflect all of the previous requirements.
7. Radiation physics will perform a survey to check the adequacy of the shielding prior to NLCTA operation.

REFERENCES

- [1] J. Liu et al., "FLUKA Calculations of Source Terms and Attenuation Profiles for Generic Shielding Design of SPEAR3 Ring," RP Note 02-20, SLAC, Dec. 2002.
- [2] National Council on Radiation Protection and Measurements, "Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerator Facilities," NCRP Report No. 51, 1977.

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