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Calculation of Neutron Dose in Vicinity of Crane Opening in PHENIX Hall

This note describes the calculation of the neutron dose expected in the PHENIX hall in the vicinity of the opening for the overhead crane. The PHENIX hall shielding wall is described in the drawing 908-01-03-C02. Previously calculations have been done [1] These calculations use the basic description of the PHENIX shielding wall described in that note. An opening of dimensions 24" × 40" is cut in the shielding wall for the rail that supports the overhead. The crane rail opening is positioned approximately 6 meters above beam height and next to the building walls. The crane rail opening will be filled with concrete after installation. In these calculations I have assumed that the crane rail openings are *not* filled with concrete. This allows a very conservative margin for normal operations and it would give a realistic estimate in the event that the crane rail opening is not filled in the early low luminosity running.

The estimates in this calculation are made with MCNPX version 2.1.4. MCNPX is a merger of the previous Lahet Code System (LCS) for high energy transport with the MCNP which handles the low energy hadron transport. Previously LCS was run producing files of low energy neutrons that were transported in MCNP. Also previously LCS and MCNP were run on an IBM RS6000 platform. Since these new calculations involve a new computer code and are performed on the PCs using the LINUX operating system with the GNU compilers, comparisons using the previous analysis have been made on the new machines using the new codes. The results showed consistency down to the expected machine accuracy.

We have looked at dose at the crane opening with and without the rail in place. The rail will either shield neutrons in certain directions and enhance the dose by scattering in other directions. Table 1 show the locations of locations of the point detectors around the opening. The coordinates given in the table are in a coordinate system centered on the beam with the beam direction in the z direction and the beam intersection point at Z=1300. One of the detectors is positioned in the center of the crane rail opening at a distance of 1.5 meters outside the shielding wall. Another detector is place at 1 meter beneath the first detector. It is below the crane opening and is expected to be shielded by the rail. A third detector is place at the same elevation as the first detector $\frac{1}{2}$ meter upstream of that detector. This detector is at the edge the opening but might be expected to see neutrons scattered from the rail. Table 2 shows rates for detectors 1 and 2 when there is no crane rail in place. The neutron doses are quoted in units of 10^{-10} rem per interacting proton for a beam of 100 GeV/c protons. The different rows correspond to different source positions for the initial interaction. The + sign implies that the initial proton was directed from the IP towards the hall side where the detectors are present.

The statistical errors on the numbers in Table 2 are approximately 8%. Table 3 shows similar doses for the case where the steel rail supporting the crane is in place. The rail is modeled as an I-beam in the calculation. It can diminish or enhance the signal by either shielding or scattering neutrons. The position of detectors 2 (3) were chosen to see a diminished (enhanced) signal. The statistical errors on the calculation with the rail in place are approximately 45%.

If an incident occurred where half the beam of ~~10~~ 1.2 $\times 10^9$ Au ions per bunch and ~~57~~ 114 bunches is deposited in the upstream DX magnet located at Z=350 cm (for an example of a design based accident), one would expect to see an instantaneous dose of 25 mrem. This calculation includes the additional factor of 2 for the low energy neutron quality factor required for new facility calculations. However, this number only includes the low energy component. High energy hadrons are not included in the calculation.

Table 1: Location of detectors. Dimensions are *centimeters*. The coordinate system is described in the text.

Detector	X	Y	Z	Description
1	1100	600	2250	Centered at the Crane Opening
2	1100	500	2250	Below Crane Opening
3	1100	600	2200	Offcenter at Crane Opening

Table 2: Neutron dose calculated in the vicinity of the opening for the crane. In this set of calculations there is no crane rail present. The dose is given in units of 10^{-10} rem per interacting proton.

Interaction Location	Detector 1	Detector 2
+2050	2.41×10^{-5}	0.99×10^{-5}
+1650	3.11×10^{-5}	1.93×10^{-5}
+1250	4.64×10^{-5}	3.02×10^{-5}
-2050	5.64×10^{-5}	4.06×10^{-5}
-1650	4.44×10^{-5}	2.70×10^{-5}
-1250	2.56×10^{-5}	1.56×10^{-5}

$5 \times 10^{13} \times 5.64 \times 10^{-15} \times \frac{1}{2} \times 2$ ← Qe

$= 330$ mrem NO $\left(\frac{300}{250}\right)^{.8}$

$2.24 \times 10^{13} \times 8 \times 10^{-16} \times 2$

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Table 3: Neutron dose calculated in the vicinity of the opening for the crane. The dose is given in units of 10^{-10} rem per interacting proton.

Interaction	Detector	Detector	Detector
Location	1	2	3
+1250	1.48×10^{-5}	5.36×10^{-6}	
+850	1.27×10^{-5}	5.00×10^{-6}	1.61×10^{-5}
+350	1.55×10^{-5}	4.91×10^{-6}	1.35×10^{-5}
-850	1.13×10^{-6}	1.56×10^{-7}	1.56×10^{-6}

References

1. Estimates of Dose Equivalent Associated with Penetrations in the PHENIX Shield Wall, S. Kahn and A.J. Stevens. #

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