Shielding evaluation for the light ion guide and heavy ion guide

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The Upgrade Project at Cyclotron Institute arrived at the stage where the hall accommodating the Light Ion Guide (LIG) and the Heavy Ion Guide (HIG), the new radioactive beam production devices, is being prepared for the final configuration. This new hall will include the primary beam dump [1] bunker; consequenctly, careful design of the shielding is required. During the normal operation, the primary beam will be stopped into a high purity aluminum stopper. The stopper is embedded in a box-like structure with the dimensions of 31.7” x 41.5” x 19.7” with walls made from concrete, 4” thick borated polyethylene and 2” thick steel. This box is installed inside a concrete bunker, it rests on a concrete brick base and it is surrounded by several concrete wall panels with the approximate dimensions of 10’ tall, 45” or 30” wide and 15” thick. On the top of the beam dump box three large concrete blocks fill the void in the ceiling of the cave.

The roof of the hall consists in two layers of concrete roof planks: the first layer (the original one) is 39”wide and 30” thick with serpentine channels for ventilation and cable conduit; the second one is a new addition to the hall and is only 15” thick with the same 39” wide. The second layer is placed staggered on the top of the first one in order to cover the cracks from the first layer of roof planks. At the

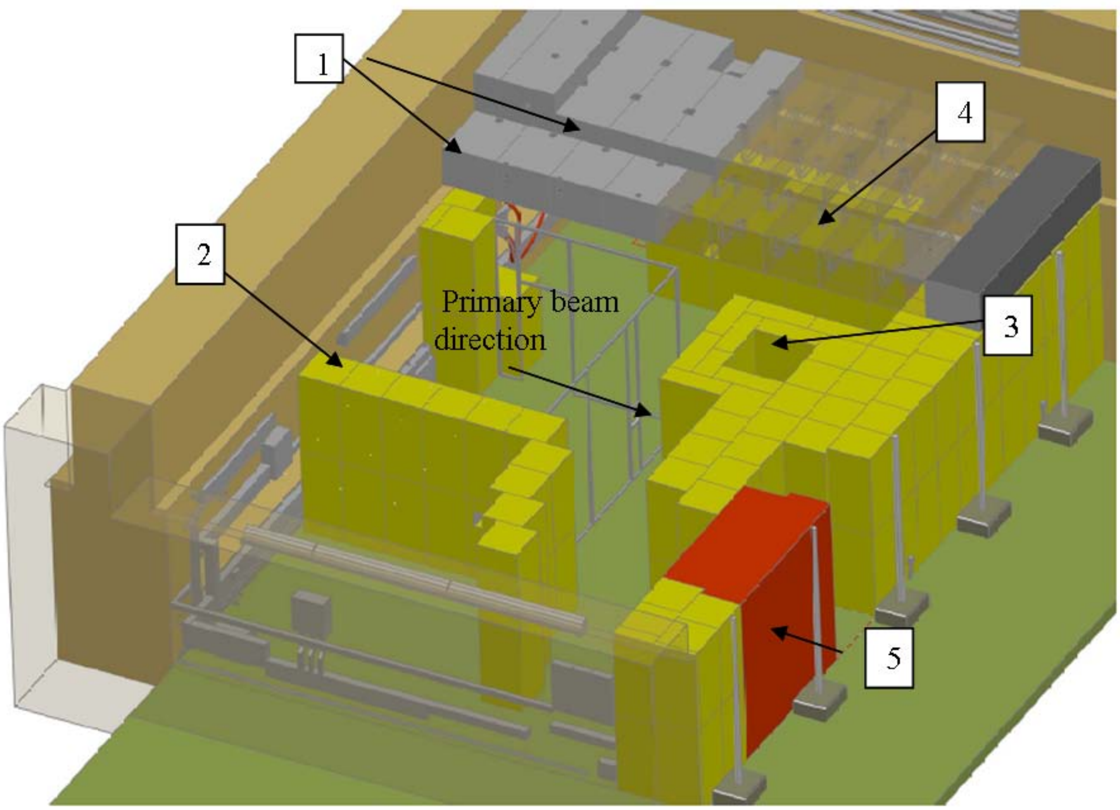

FIG. 1. View of the Light Ion Guide (LIG) and the Heavy Ion Guide (HIG) hall. 1. First and second layer of roof planks. 2. Separation wall between LIG and HIG areas. 3. Concrete bunker. The concrete blocks filling the void are missing. 4. Separation wall in the LIG for area for the vertical injection line. 5. Concrete sliding door.

positions of the ventilation openings from the first layer, square openings are present in the second layer. Figure 1 represents a view of the hall.

Inside the hall two new walls were built: one separates the LIG area from the HIG area, and the second one separates the vertical injection line from the rest of the cave. The two walls have the role in reducing the neutron and gamma flux in the HIG area, where electric equipment sensitive to radiation will be located and above the LIG area at the vertical injection line penetration location where human personnel might be present.

This shielding design was studied throughout the years using Monte-Carlo type radiation transport codes MCNPX [2] and PHITS [3], coupled essentially with Los Alamos Natl. Lab. libraries. The simulations are time consuming and different approaches of the problem were considered in order to minimize the calculation time and to have reasonable results with reasonable errors. Two types of simulations were performed: one covers the situation where the primary beam is stopped inside the concrete bunker (normal operation) and one covers the unfortunate situation when the primary beam is stopped outside the bunker. The last situation could appear, for example, in the case when magnetic elements in the beam line fail to operate and the beam takes other trajectories, being stopped in the beam pipe walls. This last case was studied in detail and also recently some few measurements were performed.

In the following we will report neutron calculated equivalent dose at 8 locations above the experimental hall; they are compared with recent performed measurements. The MCNPX calculations consider a 30 MeV proton beam with an intensity of 10 μA stopped in an aluminum block outside the

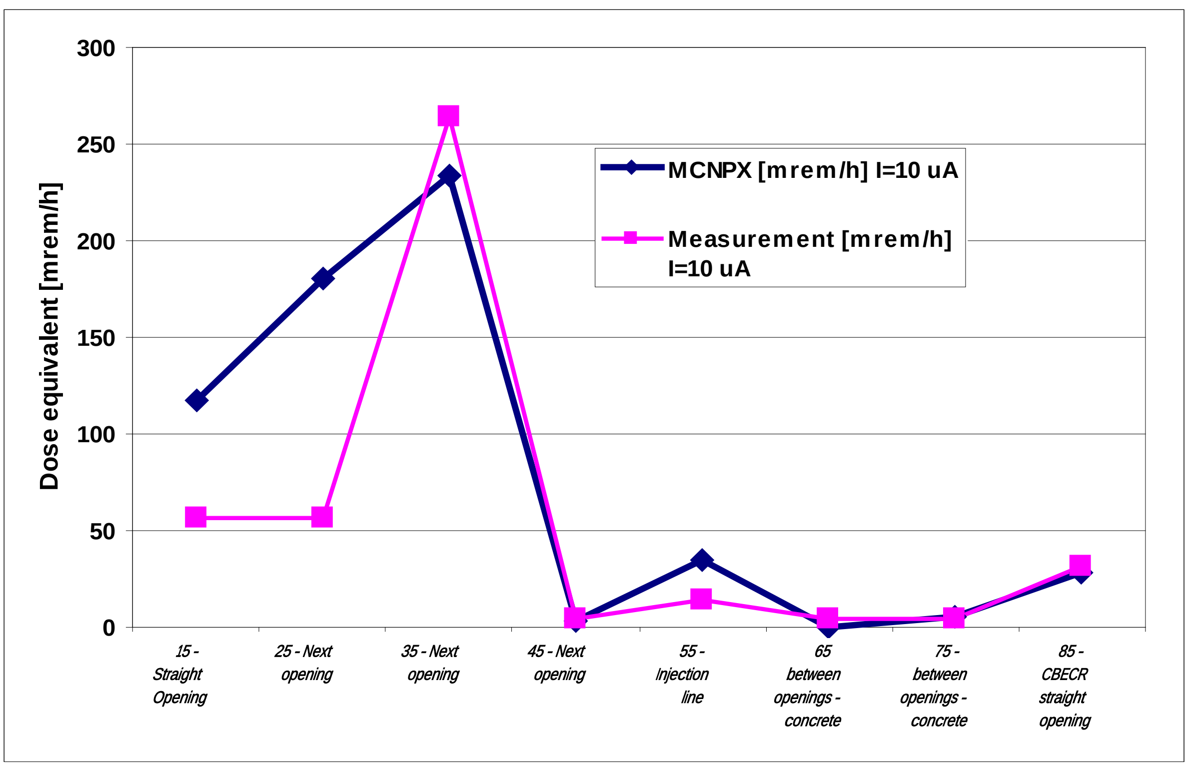

FIG. 2. Comparison between calculated dose equivalent (blue) and measured dose equivalent (magenta) for neutrons at 8 locations above the LIG area. The largest dose is measured and calculated at the beam stopper location.

concrete bunker. The measured current on the block was 10 μA as well. Figure 2 presents the calculated dose equivalent in mrem/h in comparison with the measured dose equivalent using a Neutron Survey Meter (model REM 500 by Health Physics Instruments [4]). The calculations follow very well the measurements, the highest measured dose being at the stopper location. It is also remarkable the fact that some of the measured values are in very good agreement with the calculated one showing the power of prediction of the MCNPX code.

The measurements showed the necessity of declaring an exclusion zone above the LIG area. As the calculations predicted, in the vast majority, the neutrons escaping from the hall follow the serpentine ventilation channels contributing to a dose enhancement immediately above the square opening in the second layer of roof planks. Polyethylene or other hydrogenous materials together with steel will be used to cover the openings aligned with the primary beam line. Outside the walls neutrons were not detected; however higher gamma doses were measured at the joint between the wall and the roof planks.

Overall the shielding will protect human personnel from exposure, but a few precautions need to be considered when accessing the location above the LIG area. Future plans include new measurements with the primary beam stopped inside the concrete bunker (normal operation) and an activation / cooling analysis.

[1] G. Tabacaru and H.L. Clark, Progress in Research, April 1, 2006 – March 31, 2007, Cyclotron Institute,http://cyclotron.tamu.edu/2007%20Progress%20Report/5%20Superconducting%20Cyclotron%20and%20Instrumentation/V_21_shielding.pdf

[2] http://mcnpx.lanl.gov

[3] K. Niita *et al.* PHITS: Particle and Heavy Ion Transport code System, Version 2.23, JAEA-Data/Code 2010-022 (2010)

[4] http://www.fwt.com/hpi/hpi_rem500ds.htm