Status of exit-beam dump for BigRIPS

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The BigRIPS separator incorporates beam dumps to intercept unreacted beams resulting from the primary beam + production target reaction at the focal plane F0. The exit-beam dump[1)] is located at the exit of the D1 magnet and was employed to capture the ^{238}U, ^{78}Kr, and ^{70}Zn primary beams during the year 2022. In the course of a semiannual routine maintenance for the BigRIPS in May 2023, observations revealed a torn surface and a caterpillar-like structure on the exit-beam dump, as depicted in Fig. 1. Through an analysis of the beam conditions on the dump during the year 2022 and these structures, it was determined that the caterpillar-like structure manifested as a molten mark resulting from the direct impingement of the ^{70}Zn primary beam during the accelerator tuning in December 2022. However, the torn surface can be attributed to the deposition of copper vapor on the upper surface of the dump, and subsequent tearing owing to the cooling process employed by the dump. This report provides an overview of the analysis conducted.

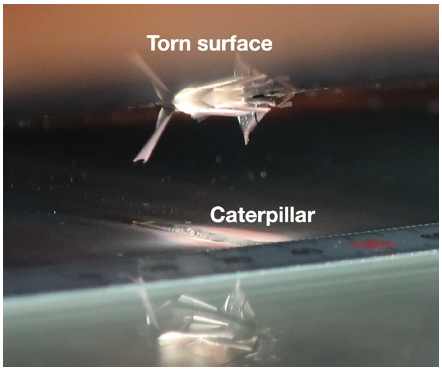

Fig. 1. Surface of the exit-beam dump in May 2023. A scale was placed in front of the caterpillar like structure.

In resolving the specific beam setting responsible for the caterpillar-like structure, we conducted a comparative analysis between the structure's position and the calculated hit positions of primary beams on the dump for each beam setting. The structure's position was measured with a precision of 1-mm. The hit positions of these primary beams were determined by utilizing the beam energies measured by the BigRIPS. The position of the ^{70}Zn primary beam during the accelerator tuning corresponded precisely with the location of the caterpillar-like structure. Consequently, we posit that the emergence of the caterpillar-like structure is attributed to the impact of the ^{70}Zn primary beam during the accelerator tuning in December 2022.

A metal thin film retrieved from the torn surface underwent analysis utilizing an electron probe microanalyzer. The results yielded a composition comprising 88% copper, 12% oxygen, and trace amounts of chromium. This composition aligned with that of the exit-beam dump (copper with 1% chromium and 0.2% zircon). Consequently, it was inferred that the torn surface represented a deposition of CuCrZr vapor on the opposing surface of the caterpillar-like structure. This can be torn owing to a large temperature gradient around the deposited position.

A thermal simulation of the dump was conducted employing the finite element method through the ANSYS code. The beam-spot size at the dump was modeled as a 2D Gaussian function, with the σ values of 1.5 mm and 3.7 mm in the horizontal and vertical directions, respectively. The size were derived from an analysis of beam profiles between the SRC and F0. Aligning with the position of the caterpillar-like structure, the beam position was shifted 6 mm downward in the vertical direction from the center of the exit-beam dump. The assumed beam intensity was 670 particle nA. Further, the temperature, pressure, and flow velocity of the cooling water within the dump were set to values used in December 2022.

The surface temperature of a cooling water pipe T_{pipe} inside the dump was a criterion to form a molten mark on the dump. If T_{pipe} exceeded the critical temperature T_c, the cooling capability of the water pipe was considerably reduced as the surface of the water pipe was covered with water vapor owing to vigorous boiling of the cooling water. Thereafter the dump starts to melt due to the reduced cooling capability. T_c for the present condition is calculated to be 250°C,[2,3)] which corresponded to the heat flux of 37 MW/m^2.

The simulation yielded a T_{pipe} of 217°C, which is lower than T_c. The dump surface temperature at the beam spot was 378°C, which was lower than the melting point of copper. The simulation also indicated that the dump would melt with a 20% increase in the beam heat flux. Thus, that there may be inaccuracies in the beam size estimation and/or degradation of dump's cooling capability.

We will continue using the exit-beam dump with the molten mark. Several interlocks will be added for safe operation of the dump. In addition, a test will be performed to conclude the cause of the molten mark.

References
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