Update on the He-LIG and LSTAR projects to produce RIB for TAMUTRAP

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As described in last year's report [1], we are developing a 3He-based light-ion guide (He-LIG) system, complementing the existing (proton-driven) p-LIG system, to increase RIB production at the CI using the high intensity of the K150 cyclotron. The light-ion guide separator for Texas A&M's K150 rare isotope beams (LSTAR) is concurrently being designed to transport and purify the RIBs produced by the He-LIG. As mentioned in another of last year's report [2], the 2×45° vertical bend we designed (see Fig. 1) would provide adequate mass resolution to resolve isobars of the species of interest; however, if our estimations of the emittance of the beam as it exits the He-LIG are underestimated by a factor of 2, we quickly start to lose efficiency which needs to be high to produce the highly-neutron-deficient RIB of interest to TAMUTRAP. Furthermore, as we developed a realistic layout of LSTAR for the specification document, we found an incorrect dimension in a drawing and realized this design would have a quadrupole element, Q6, in the roof plank; this would require a larger hole which is problematic for the structural integrity of the planks, access and alignment.

A significant amount of time and effort would be required to address the issue of fitting Q6 in the roof planks, so we took a step back and re-evaluated our design options. Following detailed discussions with the CI Operations group, we decided the shielding blocks in Cave 5 could be removed (the red rectangles in Fig. 1). This greatly increases the real estate available in Cave 5, enough that we considered a horizontal layout for LSTAR rather than vertical. This would not only will be easier to support and align compared to a vertical layout, but it also allows for larger bending angles for greater mass resolution.

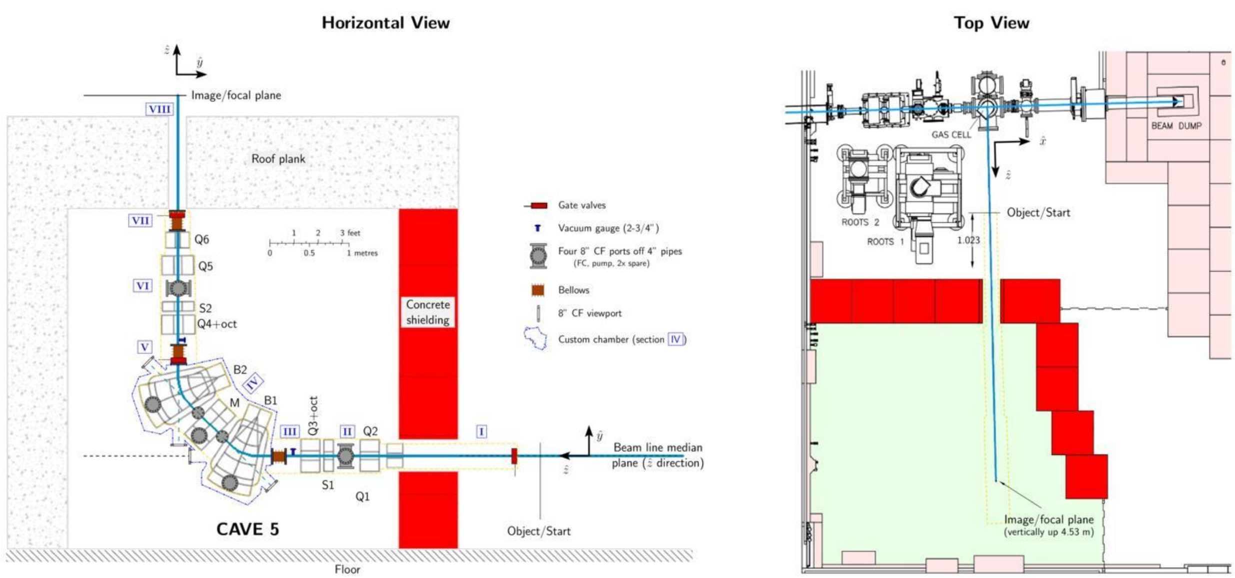

Fig. 1. Original $\mathbf{2 \times 45^{\circ}}$ vertical design for LSTAR shown from the side (left) and from above (right). When reconsidering options, it was decided the concrete shielding blocks in Cave 5 could be removed, which allows us to consider the larger footprint of a horizontal design.

Fig. 2 shows our new concept for LSTAR as a horizontal separator with two $62\frac{1}{2}^{\circ}$ bends, an increase of 35° over the vertical design. Furthermore, there is enough room that we can place our RFQ cooler/buncher in Cave 5 rather than above the roof planks in the TAMUTRAP area. This will greatly reduce beam-transport losses to the RFQ as well as keep the HV elements (He-LIG chamber and RFQ) of the beamline all contained in Cave 5. As Fig. 2 shows, we can also fit a pulsing cavity to reduce the energy of the very small emittance ($< 0.7\,\pi$mm mrad) bunched beam; cooling and bunching the beam immediately following the focus of LSTAR will increase overall efficiency *and* allow us to keep the hole in the roof planks as small as 4" in diameter. This is smaller than other existing holes so will be

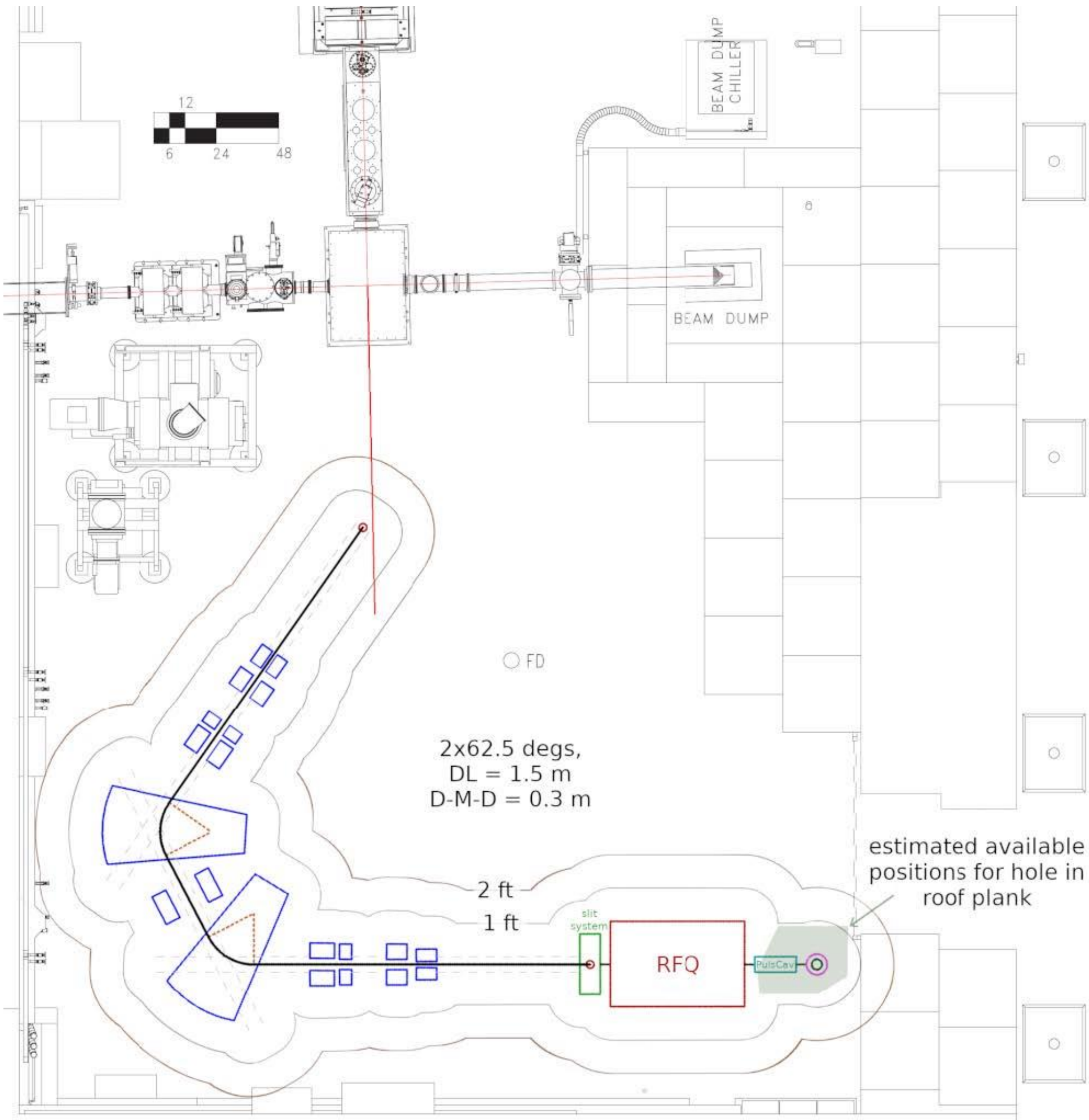

Fig. 2. Proposed layout of the isotope separator in Cave 5, with the RFQ (red rectangle) and pulsing cavity (cyan rectangle) both placed horizontally before electrostatically bending the beam upward through a 4"-diameter hole in the roof planks. With slight translations and/or rotations of LSTAR, the final hole may be placed anywhere within a roughly 2'x3' area (shaded region). Shown also are contours depicting 1-ft and 2-ft clearance from the elements. Note that the RFQ is the (only) element which needs to be floated up to 75 kV.

acceptable as long as we can avoid the rebar within the planks; as indicated by the green shaded region in Fig. 2, there is an approximately 6 ft^2 allowed with this design, ensuring we can avoid the rebar.

We considered other designs ($50°, 55°, \ldots, 70°$) and decided upon $2 \times 62\frac{1}{2}°$ based on how well it fit within the constraints of Cave 5. A first order calculation indicates a 30% increase in the mass resolution, with higher-orders currently being optimized. The re-design delays the project and the larger dipoles will cost more, but the rewards are too great to pass up: much better mass resolution; an easier and more robust support structure; easier alignment; cooling/bunching at focus and transporting low-emittance, low-energy beam; small hole in roof planks won't jeopardize structural integrity. We expect to finalize our technical designs in the fall of 2022 and solicit bids before the end of the year.

[1] P.D. Shilding *et al*., Progress in Research, Cyclotron Institute, Texas A&M University (2020-2021), P. V-68.
[2] G. Chubarian *et al*., Progress in Research, Cyclotron Institute, Texas A&M University (2020-2021), p. V-71.