Update on LSTAR, the isobar separator for the He-LIG system

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As explained in last year's report [1], the **L**ight-ion guide **S**eparator for **T**exas **A**&M's K150 **R**adioactive beams (LSTAR) is needed to purify and transport radioactive ion beams from the new He-LIG [2] production system up to the TAMUTRAP facility.

TAMUTRAP's initial program will be measuring β-delayed proton transitions ^{20,21}Mg, ^{24,25}Si, ^{28,29}S, ^{32,33}Ar, ^{36,37}Ca (and possibly heavier Ti and Cr, depending on K150 upgrades) for test of fundamental symmetries. The unique β-*p* coincidence of our detectors will ensure a background-free measurement regardless of contaminants. However, the efficiency of transport and loading the RIB of interest will dramatically suffer if the background is orders of magnitude larger, with the bottleneck of $<10^5$ (perhaps as high a 10^6) ions/s for >10% efficiency of the gas-filled radiofrequency quadrupole (RFQ) cooler and buncher; once the RFQ gets saturated, the efficiently quickly goes to zero. The cross section for production of isobaric contaminants is 2-3 orders of magnitude larger in the odd *A*=21, 25, 29, 33 and 37 masses, and 3-5 orders larger in the superallowed *A*=20, 24, 28, 32, and 36 cases, so efficient *and* effective isobaric separation is critical.

The figure of merit for our design was initially the mass resolving power of the separator, however this definition is highly dependent on the initial beam emittance. Instead, to best determine the demands of LSTAR's performance, we used SimION [3] to provide realistic ion positions and trajectories upon exiting the SPIG of the He-LIG system, accelerated them to 65 keV, and then used that as input to a COSY INFINITY [4] calculation of the LSTAR design. The COSY calculation transports ions through the design (including fringe fields) and provides a spectrum of ions – both good and contaminant – at the focal plane of the exit of LSTAR, where we can see how many good ions got through and how many contaminants were vetoed. We included a 3.3 eV FWHM energy spread when tracing rays through COSY. We took the most difficult case and made our benchmarks compared to that. Of the RIBs of interest to TAMUTRAP listed above, ^{37}Ca has the closest contaminant, ^{37}K, produced with 1750x the cross section. With an estimated 2×10^4 ^{37}Ca/s produced via a ^{36}Ar(^{3}He,2*n*) fusion-evaporation reaction, the 3.5×10^7 pps of ^{37}K would overload the RFQ. However, if the separator removes 97% of the ^{37}K, the RFQ may be able to handle 10^6 ions/s. If LSTAR removed 99.75% of the ^{37}K, then only 10^5 ion/s would reach the RFQ which will certainly not overload it. The plots in Fig. 1 show the COSY calculations for two mass separations of good and contaminant ions (corresponding to ^{37}Ca/^{37}K and the easier 21Mg/21Na cases) and two values for the emittance of the ions exiting the SPIG (what SimION predicts, and twice as big). In the initial stages of the TAMUTRAP program, LSTAR will easily be able to completely purify the RIB and transport it from the He-LIG with near-perfect transmission. Even in the most difficult case, mass 37 with SimION underestimating the emittance by a factor of two (bottom right plot), LSTAR will veto >99% of the contaminants while still transporting >88% of the ions of interest through LSTAR.

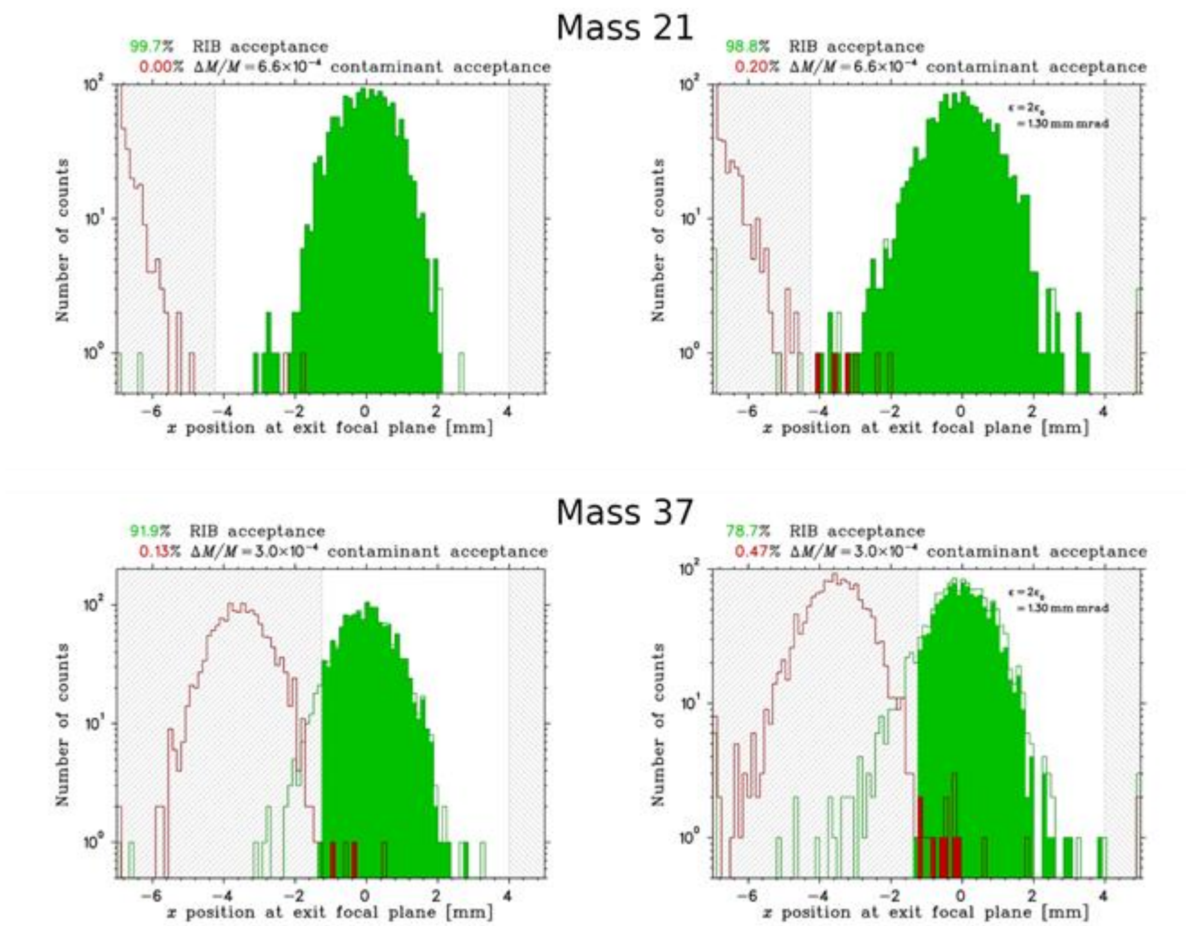

Fig. 1. Final positions of ions at the exit focal plane of LSTAR using the SimION-simulated initial emittance $\epsilon_0 = 0.652\ \mathrm{mm \cdot mrad}$ (left) and twice as large (right). The unfilled histograms are the positions of all good (green) and $\Delta M/M = 3\times10^{-4}$ contaminants (red), while the filled are the subset that successfully exit the final rectangular aperture, indicated by the grey hatched regions.

We submitted a proposal to fund the construction of LSTAR, which was fully funded by the Department of Energy, Office of Science for $0.78M. We are finalizing the technical document and plan to submit the bid request for building LSTAR before the fall of 2021.

[1] G. Chubarian *et al*., *Progress in Research*, Cyclotron Institute, Texas A&M University (2019-2020), p. IV-94.

[2] P.D. Shidling *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2019-2020), p. IV-95.

[3] SIMION 8.1 Ion optics simulation program. https://simion.com/.

[4] M. Berz and K. Makino, Department of Physics and Astronomy, Michigan State University, MSU Report MUSHEP 151103-rev (2017).