LSTAR: an isobar separator for the He-LIG system

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We have submitted a proposal to build "LSTAR", a Light-ion guide Separator for Texas A&M's Rare isotope beams. LSTAR is critically needed to purify the variety of exotic ions produced from the new K150 target station, He-LIG [1], being built to produced proton-rich isotopes for TAMUTRAP. Although the TAMUTRAP research program [2] is insensitive to contaminants – the coincident proton-β condition is extremely clean – a significantly impure beam from the He-LIG system will overload the gas-filled RFQ cooler/buncher. Without purification, we would not be able to efficiently transport RIB from He-LIG and load them in the Penning trap. In addition, experiments from other research programs could utilize the RIB produced by He-LIG with end stations on the 2nd floor high bay with LSTAR purifying the beams.

The basic requirements for LSTAR were determined quite early in the design process. Of the cases under consideration for TAMUTRAP (^{20,21}Mg, ^{24,25}Si, ^{28,29}S, ^{32,33}Ar, and ^{36,37}Ca), the greatest mass resolution necessary to remove isobaric contaminations are the heaviest cases. For example, ^{37}Ca and ^{37}K differ in mass by 0.033%; to separate these nuclides, LSTAR would need a mass resolution of M/ΔM > 3 060. Thus, our design specifications for LSTAR were quickly determined to be:

1. a mass resolution M/ΔM ≥ 5 000 for A=6−50,
2. high acceptance and transmission (> 95%),
3. no energy compensation (meaning no electric dispersive elements),
4. purely electrostatic focusing and corrective elements (so that settings are independent of mass), and
5. the separator must fit in the existing space available in Cave 5 of the Cyclotron Institute.

The ion beam characteristics upon exiting the SPIG are well known based on the similar system at the University of Jyväskylä [3]. The predominantly q=+1 beam is expected to have a transverse emittance of < 3π mm-mrad and < ±1 eV energy spread. The LSTAR design must match these beam characteristics for optimal acceptance and transmission efficiency through the separator.

Many of the same design specifications may be found with the isobar separator built for the CARIBU facility at ANL [4]. We have therefore taken their separator design to guide our preliminary design for LSTAR, and are in the process of finalizing the configuration outlined in Fig. 1. The most significant difference from the CARIBU design is replacement of CARIBU's two 60◦ bending magnets with LSTAR's two 45◦ magnets operating with a dipole field of 0.45 T. This will reduce the mass resolution relative to CARIBU's first-order mass resolution of M/ΔM=22 400, but it allows us to transport the RIB 90◦ up through the roof planks to the TAMUTRAP facility. Our preliminary first-order calculation of LSTAR with 45◦ bending magnets indicates a mass resolving power of >6 000 which is already well within the design specifications. Nevertheless, we expect further optimizations to bring the resolving power up to M/ΔM≈10 000 once higher-order corrections have been applied.

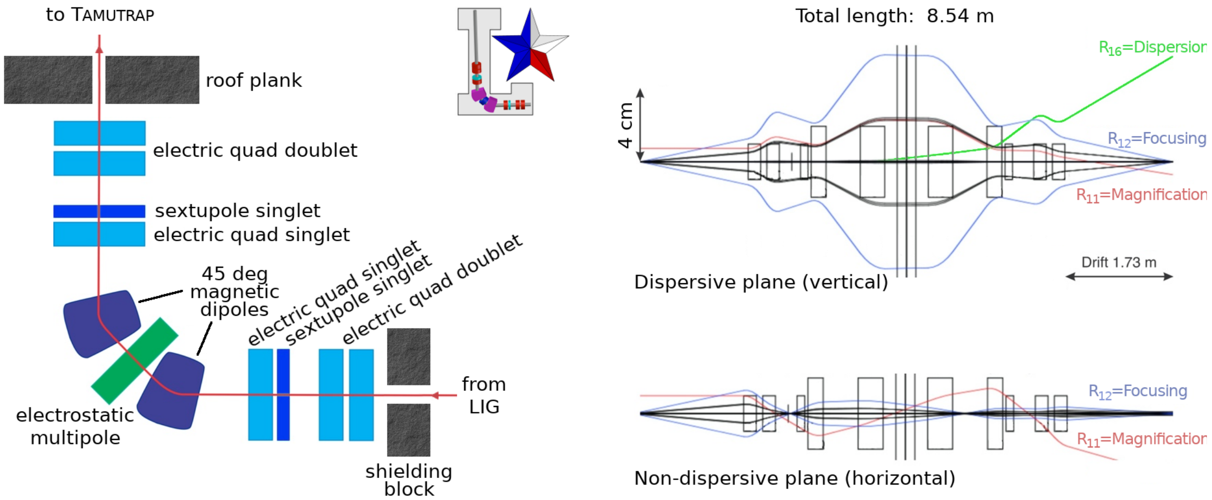

Fig. 1. Current design elements of LSTAR. The schematic layout of LSTAR is shown on the left. The system is symmetric about the electrostatic multipole and has 1.73-m long drifts at the front and the end to pass through the existing shielding blocks. On the right the preliminary ion-optics in both planes are shown. The system will be optimized as explained in the text.

To minimize higher-order aberrations, the LSTAR layout is symmetric about the central electrostatic multipole. Given the tight constraints of Cave 5, this was not a simple task. In order to achieve this, we are required to drill a new hole in the roof plank at a distance of 6.59 m from the gas cell. As of the writing of this report, we are awaiting the final location which will avoid the rebar in the plank; once that is determined, we will be able to optimize the mass resolving power. This can be accomplished by increasing, in the dispersive plane, the dispersion R16 and decreasing the magnification R_{11} while maintaining focusing $R_{12}=0$ at the end of the system. The first-order matrix elements R_{16}, R_{11} and R_{12} are shown in Fig. 1 along the central ray. The coloured lines of the functions of the matrix elements are scaled to distinguish them from the rays in black. The black rays are for a target size of ±0.5 mm and angles of ±6 mrad at the nominal energy of 50 keV. This optimization is time-expensive and sensitively dependent on the geometry, so can only be finalized after we learn exactly where the hole in the roof plank may be drilled.

Conservatively, the design of LSTAR fulfills all of the design specifications listed above. Based on our experience, we estimate that when the optimization is complete, the mass-resolving power of LSTAR will surpass the specification with $M/\Delta M \approx 10\,000$.

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[4] C.N. Davids and D. Peterson, Nucl. Instrum. Methods Phys. Res. **B266**, 4449 (2008).