Research in nuclear chemistry that is centered on the production and use of the most exotic, short-lived nuclei provides the ability to produce beams of very exotic radioactive ions. These short-lived nuclei are interesting in their own right, some of which have not been observed before. My graduate students work on unraveling the mechanisms of nuclear reactions, on studying the decay properties of the most exotic nuclei, or on developing new techniques to separate, capture and deliver exotic nuclei. The National Superconducting Cyclotron Laboratory (NSCL) is a unique facility that brings together a strong group of nuclear scientists and provides an exceptional setting for studying the properties of nuclei right on the MSU campus. The very high energy beams react with a target nuclei to produce new nuclear fragments with a distribution of sizes, some of which are very unstable and quite unusual. The probability distributions of the products and the momenta, or velocities, of the fragments are distributed around that of the beam and we have shown that they can be predicted by models of the nuclear reaction. The fast-moving fragments are passed through an isotope separator to produce beams of individual radioactive ions. We help to design and develop these fragment separators, which have become the central instruments for research at the NSCL and the Facility for Rare Ion Beams (FRIB) under construction at MSU. The NSCL currently relies on its second-generation fragment separator completed in 2001 while a revolutionary new fragment separator is being constructed for the FRIB facility that will replace the NSCL.

Along with using the new fragment separator for production and decay studies, our group has developed a series of auxiliary devices to slow down the exotic reaction products to thermal energies. The initial devices used a helium filled chamber tailored to stop and collect the exotic isotopes produced by the A1900 fragment separator. The gas is removed using a differential pumping system in a process related to atmospheric-sampling mass spectrometry. The so-called gas-catcher system was used in many successful and extremely precise mass measurements at the NSCL carried out by the group headed by Prof. Bollen (MSU Physics). More recently the thermalized ions were used in collinear laser spectroscopy experiments, precision decay studies, and nuclear reaction studies. We are currently completing construction of a next-generation device based on the concept of a reverse cyclotron. The reaction products spiral inward towards the center of a helium-filled chamber in a strong magnetic field. The so-called cyclotron-stopper uses a four-meter diameter superconducting magnet that weighs approximately 200 tons (see below).

Photograph of the gas-filled reverse-cyclotron during testing in 2014. The device relies on an inner 2 meter diameter beam chamber contained inside a 200 ton superconducting magnet. The particles will enter parallel to the floor from the right and be bent onto spiral paths by the magnetic field. They will slow down by collisions with helium gas and the thermalized ions will be extracted along the central axis.