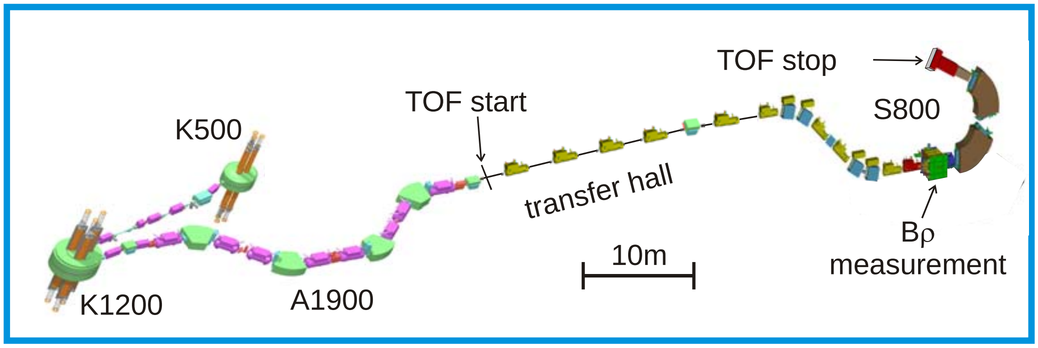
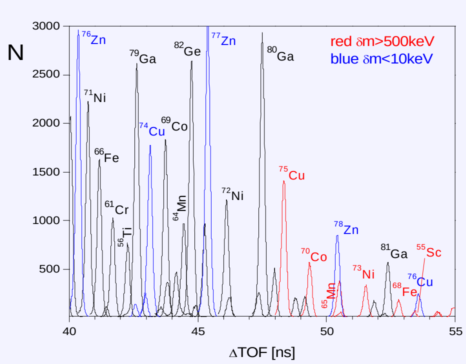
Time-of-Flight Mass Measurements



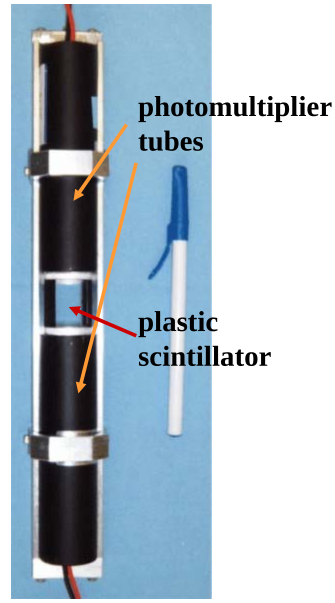
Knowledge of the atomic masses plays a key role in nuclear astrophysics. While the masses of the nuclei close to the valley of stability are well-known, information about masses of very exotic short-lived nuclei that occur in supernovae or neutron stars is limited. Several methods are applied at laboratories around the world to obtain new mass values. The most exotic nuclei can be accessed by the time-of-flight - rigidity (TOF-Bρ) technique at radioactive beam facilities.

This technique has been recently implemented at the National Superconducting Cyclotron Laboratory at Michigan State University by a team of JINA physicists. Beams of stable ^{86}Kr ions are accelerated in the coupled cyclotrons K500-K1200 to an energy of 100 MeV/u (40% of the speed of light). Radioactive ions are produced by fragmentation on a Be target and separated in-flight in the A1900 fragment separator. The time-of-flight of the separated ions is measured up to the focal plane of the S800 spectrometer, a distance of 58 meters (190 feet). The magnetic rigidity Bρ is measured by tracking ions before they enter the S800 spectrograph. Combining both measurements yields the mass of the nucleus.



Example of time-of-flight spectra after the magnetic rigidity correction. Centroid values of the peaks are used for atomic mass determination. Nuclides with well-know masses (in blue) are used to calibrate a relation between the time and mass-to-charge ratio that is then used to determine new, previously not experimentally obtained mass values (in red).

The first mass measurement at the NSCL using this technique was successfully performed with a radioactive beam of ions in the region of ^{68}Fe, an exotic Fe isotope with a half-life of only 130 ms. The mass values in this region are crucial for astrophysical calculations such as the investigation of the thermal balance in the crust of accreting neutron stars or the calculation of r-process seeding nuclei. Accuracies of 150keV or about 1:400,000 have been achieved.



The time-of-flight detector used for the measurement.

Ions of interest pass through a thin (0.254mm) plastic scintillator attached to photomultipliers with a very fast response. The timing resolution achieved in the experiment is 30ps, the time it takes light to travel 1cm (in vacuum).

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