The Joint Institute for Nuclear Astrophysics

TOF-Bρ Mass Measurements at NSCL, MSU

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Motivation

Mass measurements play an important role in most of the calculations for nuclear astrophysics. Model calculations in the neutron-rich area for the r-process and neutron star crust are based largely on theoretical mass models.

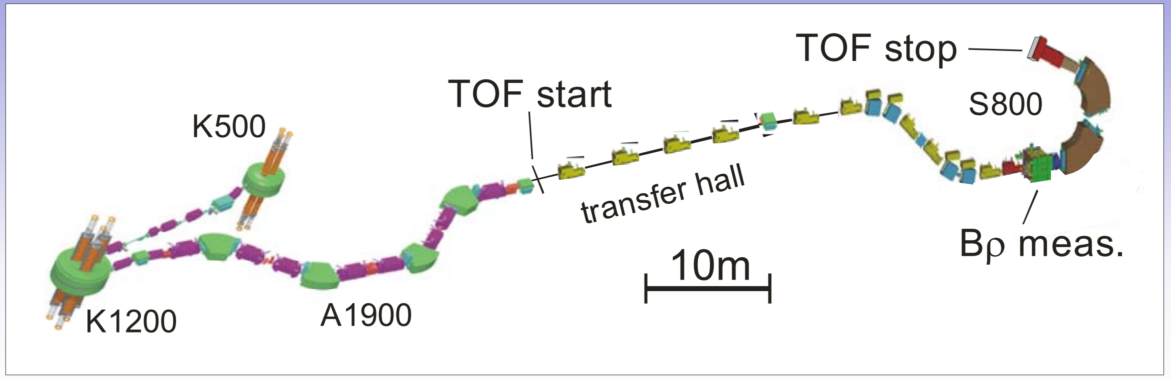
The poor experimental knowledge of masses in the neutron-rich region is due to difficulties in mass measurements caused by very short half lives of nuclides, their complicated production, problems in Q_β determinations, etc. The TOF-Bρ mass measurements with radioactive relativistic beams overcome all the complications and offer an access to new mass values.

Experimental Method

At the NSCL a primary beam is accelerated in the coupled superconducting cyclotrons K500 and K1200. A fast radioactive beam is then produced by fragmentation reactions in the A1900 fragment separator [1]. For this experiment the 58 m long time-of-flight line is used. It starts at the A1900 extended focal plane and ends at the focal plane of the spectrograph S800 [2]. Fast scintillator detectors provide a timing resolution of about 30 ps, the relative magnetic rigidity Bρ is measured at the momentum dispersive plane of the S800 spectrograph by position sensitive micro-channel plates detector [3].

The method is based on the relation between nuclide's mass–to-charge ratio, magnetic rigidity Bρ and time-of-flight *t* over a distance *l*,

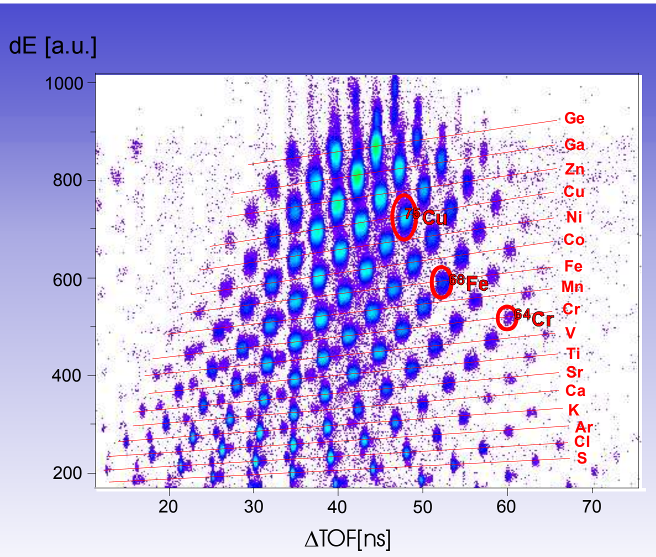
$$\frac{m_0}{q}\gamma = B\rho\frac{t}{l}. \qquad (1)$$



Mass Measurement of ^{86}Kr Fragmentation Products

In February 2006 the TOF-Bρ mass measurement experiment was for the first time performed at NSCL, MSU. The primary beam ^{86}Kr at 100 A.MeV was used to produce neutron-rich exotic nuclides by fragmentation in Be targets. The target thickness was regularly changed between 47mg/cm^2 and 94 mg/cm^2 to cover a large area of nuclides. The magnetic optics setting was the same for both target thicknesses so that data can be combined.

The combination of the energy loss measurement in the standard S800 ion chamber detector with the time-of-flight offers the possibility of particle identification as shown in the figure.



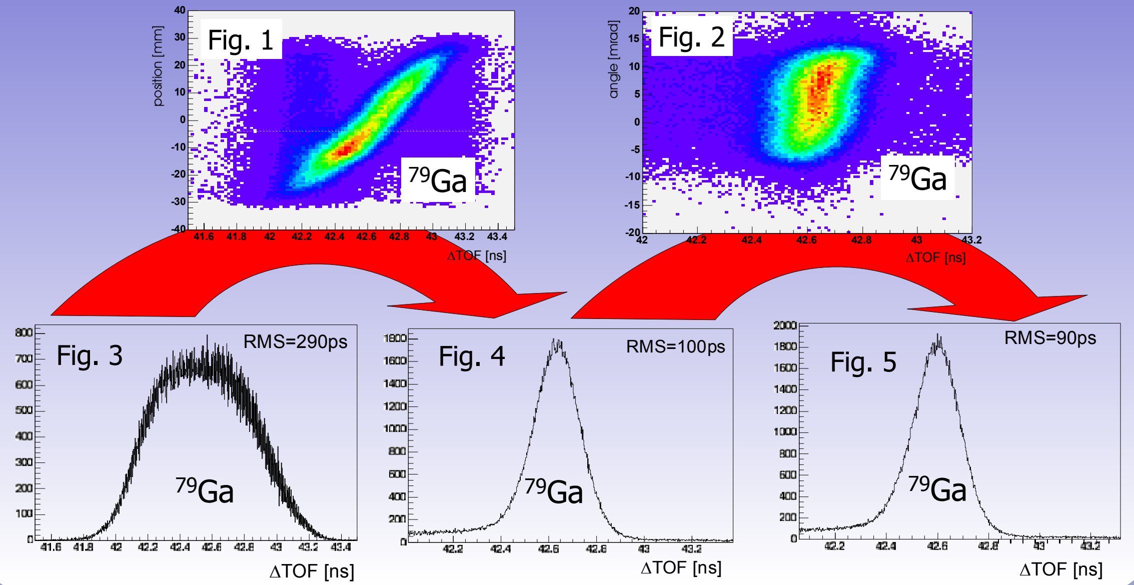
References:
[1] A. Stolz, et al., *Nucl. Instrum. Methods Phys. Res.* **B241** 858–861 (2005).
[2] D. Bazin, et al., *Nucl. Instrum. Methods Phys. Res.* **B204** 629–633 (2000).
[3] D. Shapira, et al., *Nucl. Instrum. Methods Phys. Res.* **A454** 409–420 (2000).
[3] G. Audi, et al., *Nucl. Phys.* **A729** 1–128 (2003).

TOF-Corrections

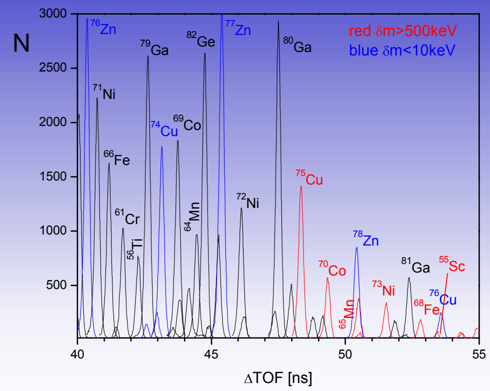
For the mass measurements the spectrograph S800 is set in the dispersion-matched mode so that the position *y* on the micro-channel plate detector corresponds to particle's magnetic rigidity Bρ.

The time-of-flight for one nuclide depends directly on the particle's magnetic rigidity, see Fig. 2. The time-of-flight value can be therefore corrected to the particle's Bρ using the the position at the dispersive plane, so that the Bρ can be considered to be constant. Figure 4 shows the time-of-flight corrected to the Bρ (position at the dispersive plane), compare with the uncorrected one in Fig.3.

Ideally, the flight distance *l* can be considered to be constant for all particles. However, there are small differences in the path due to angles and positions at the focal planes. Therefore we monitor positions and angles by a couple of CRDC's at the S800 Focal plane. Figure 2 shows there is a small dependence on the angle that could improve a resolution by 10%, see Fig. 5.



Time-of-Flight Spectra



The mass value of a nuclide is determined from its time-of-flight with respect to the time-of-flight of a nuclide with well-known mass, the so-called reference mass (or reference nuclide [4]).

The nuclides with mass uncertainties lower than 10keV (shown as blue in the figure [4]) are used for the calibration of the relation between the mass-to-charge ratio and the time-of-flight.

This relation can be used to determine the new mass values for the nuclides with unknown mass or mass with large uncertainty (shown as red in the figure [4]) from its measured time-of-flight.

The nuclides with masses previously measured with higher uncertainties can be used to estimate the systematic errors.

The preliminary time-of-flight resolution achieved in the online analyses is better than 100ps.

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