Mass measurements beyond ^{132}Sn using the ZD MRTOF-MS

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About half of the elements in our solar system are believed to originate from the rapid-neutron capture process (r-process), which occurs in neutron-rich environments such as neutron star mergers. However, simulations struggle to reproduce r-process abundances above the second peak, potentially owing to neutron captures bypassing β-decay near proton shell closure $Z = 50$ or uncertainties in nuclear mass models.[1,2] Fission recycling has been proposed to compensate for underproduction, but this depends heavily on fission models. This work aims to address uncertainties in neutron capture by measuring masses of neutron-rich isotopes beyond ^{132}Sn, to provide insights into the nuclear physics governing this mass region.

The ZeroDegree-Multi-Reflection Time-of-Flight Mass Spectrograph (ZD MRTOF-MS) setup[3] was utilized to measure the masses of the isotopes of interest. The experiment was conducted as a parasitic beam time PE24-03, employing BigRIPS setting that is close to the accepted proposal NP2212-RIBF218. The neutron-rich nuclei of interest were produced with the in-flight fission of a 345 MeV/nucleon primary beam of ^{238}U on a Be target. The resulting cocktail beam was subsequently separated and transported using the BigRIPS-Zerodegree spectrometer.

At the final two focal planes of the ZeroDegree spectrometer, monochromatic wedge and thickness-adjustable Al degraders were placed to efficiently stop the ions of interest within a He-filled gas cell (RFGC). Here, the radio-frequency ion-surfing and trapping technique[4] was applied to thermalize and transport the ions to the MRTOF-MS, where their TOF was measured to extract their nuclear masses.

The MRTOF-MS setup was improved by the installation of a new Micro-Channel Plate coupled with a MIRON PIPS silicon detector (MCP-Si),[5] replacing the previous β-TOF detector. This has enabled a resolving power of ≈500000, although further tuning efforts are required to optimize performance. The setup supports low-noise, high-resolution measurements of subsequent β-decay events following ion impact on the silicon detector. Additionally, the implementation of a mass-filter via an in-MRTOF deflector device has enabled the clean selection of specific A/q (mass-to-charge ratio) regions, as showed in Fig. 1(a). These advancements have also enhanced the identification of β-decaying species, which are now more clearly discernible in the decay spectrum gated in coincidence with the TOF events, as exemplified by the case of ^{138}Sb in Fig. 1(b).

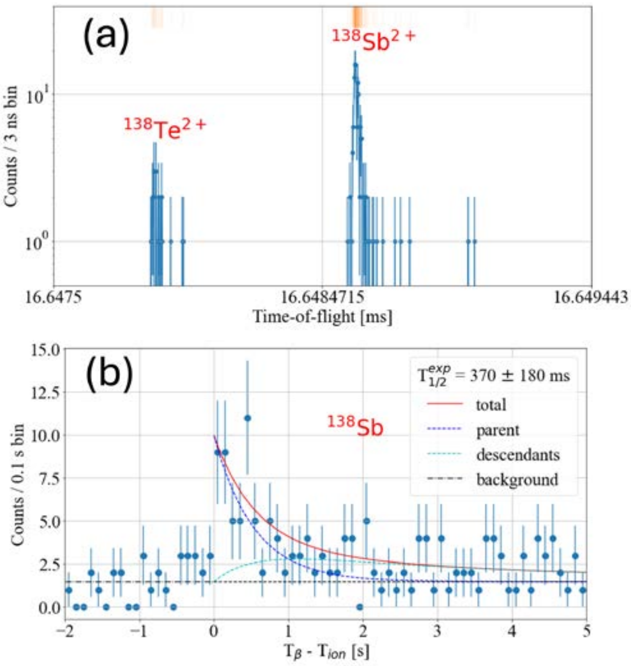

Fig. 1. (a) TOF spectrum of ions with $A/q = 138/2$; (b) Maximum-likelihood fitted decay curve of β-correlated TOF events for ^{138}Sb. The extracted half-life is in agreement with the literature value in Ref. 6) within 1σ.

Detailed analyses on new masses and β-correlated spectra, incorporating various degrader, mass-filter and other MRTOF settings are currently ongoing. These efforts aim to further refine the precision and accuracy of the measurements, contributing to a deeper understanding of the nuclear properties of the isotopes under investigation.

References

1) A. Arcones, G. Martınez-Pinedo, Phys. Rev. C **83**, 045809 (2011).
2) S. Shibagaki *et al.*, Astrophys. J. **816**, 79 (2016).
3) M. Rosenbusch *et al.*, Nucl. Instrum. Methods Phys. Res. A **1047**, 167824 (2023).
4) M. Wada *et al.*, Nucl. Instrum. Methods Phys. Res. A **204**, 570 (2003).
5) T. T. Yeung *et al.*, RIKEN Accel. Prog. Rep. **54**, 99 (2021).
6) J. Wu *et al.*, Phys. Rev. C **101**, 042801(R) (2020).

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