# Offline measurement of $^{248}$Cm fission products at ZD-MRTOF

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A 10-kBq $^{248}$Cm (SF: 8.39%) fission source was installed in the gas catcher[1] downstream from the ZeroDegree spectrometer to study the ion transport from the gas cell to the ZeroDegree Multi-reflection Time-of-flight Mass Spectrograph (ZD-MRTOF)[2] in offline tests, providing pseudo conditions similar to online beam experiments. The fission source is placed between the inner gas cell and outer vessel chambers such that it can be removed for beam-time experiments. A 2-$\mu$m Ti degrader is attached to the source to reduce the kinetic energy of fission products and match the stopping power of the gas cell. The degrader can also be rotated to increase effective thickness. The transport test of the fission products, $^{104–106}$Nb, Mo, Tc, and Ru, was performed shortly after installation. The stopped fission products were extracted mostly as doubly charged ions, and high-precision mass measurements were made after transportation to ZD-MRTOF. This measurement also serves as an ion counter for transport efficiency measurements from the gas cell to ZD-MRTOF.

A degrader thickness scan was performed by measuring the doubly charged ion count rate at various degrader angles to search for the condition of maximum stopping efficiency. Figure 1 depicts the ion count rate of nine fission products. A similar peak count rate was determined at the approximate angles of 45° and −60°. This difference in the positive and negative peak angular positions is likely caused by the asymmetric structure of the gas cell, such as the DC gradient field applied to collect ions at the RF carpet located on one side of the gas cell.

The maximum count rate of fission products was found at a degrader rotation of approximately 45°, with an effective thickness of 2.83 µm. The stopping efficiency of the gas cell in this condition was 4.9%, roughly estimated by simulation, considering the solid angle, energy, energy spread,[3] energy losses, and range in the material of the fission products. Table 1 lists the observed count rates and transport efficiencies of doubly charged ions. The transport efficiency is obtained after correcting for the stopping efficiency from the total efficiency based on the fission yields of $^{248}$Cm provided by JAEA[4] and the observed count rate. In the mass region of $A = 104 - 106$, the Mo and Tc isotopes have a transport efficiency of approximately 12%, whereas the Nb isotopes have a relatively low efficiency of approximately 5%. The low transport efficiency of the Nb isotopes could be attributed to the different charge distribution from the slightly lower second ionization potential.[5] Another possible factor is molecular formation of Nb isotopes with contaminant molecules. Further investigations on Nb isotopes will be carried out. The offline transport efficiency measurement forms a baseline for future improvements. Two such upgrade plans, the addition of an RF-wire curtain and modification of the RF carpet scheme from the RF + 4-phase AF to 4-phase RF, will be tested with the fission source.

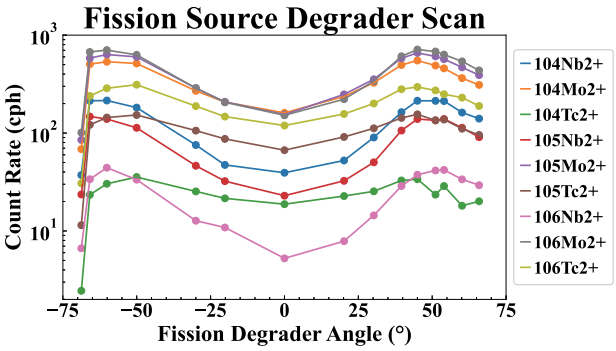


Fig. 1. Count rate (cph) of $^{104–106}$Nb, Mo, and Tc within the degrader angles of −70° to 70°. The positive angles denote counter-clockwise rotation, towards the RF carpet.

Table 1. Observed count rate (cph) and transport efficiency of doubly charged $^{104–106}$Nb, Mo, and Tc ions at a degrader angle of 45°. The uncertainty is specified in parentheses.

| Isotope | Count rate (cph) | Transport eff. (%) |
|---|---|---|
| $^{104}$Nb | 214 (3) | 4.7 (24) |
| $^{105}$Nb | 139 (3) | 5.3 (17) |
| $^{106}$Nb | 38 (1) | 4.0 (25) |
| $^{104}$Mo | 550 (5) | 14.0 (45) |
| $^{105}$Mo | 658 (6) | 11.7 (37) |
| $^{106}$Mo | 712 (6) | 13.5 (43) |
| $^{104}$Tc | 34 (1) | 11.1 (71) |
| $^{105}$Tc | 155 (3) | 13.5 (87) |
| $^{106}$Tc | 296 (4) | 10.6 (34) |

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