# Status of the TASCA Commissioning Program*

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The **T**rans**A**ctinide **S**eparator and **C**hemistry **A**pparatus, **TASCA**, project [1] is focusing on the separation and investigation of neutron-rich transactinide nuclides produced in actinide target based reactions. The envisioned research program includes both chemical investigations of transactinide or superheavy elements after preseparation with the gas-filled separator and physics motivated nuclear structure and nuclear reaction studies.

The central device of TASCA is a gas-filled separator in a DQQ configuration. It can be operated in the "High Transmission Mode" (HTM, $DQ_hQ_v$) and in the "Small Image Mode" (SIM, $DQ_vQ_h$); see Refs. [1-4] for more details. The separator was installed at the UNILAC beam line X8 and, after having all crucial parts of the control system [5] running, an extensive commissioning program was carried out in 2007. This report briefly summarizes the nuclear reactions applied and the most important parameters studied. A few examples are discussed in a very exemplary way. In addition, recent target developments and the progress in the coupling of chemistry set-ups will be outlined. The first chemical study behind TASCA is described in a separate contribution [6].

All nuclear reactions applied are listed in Table 1 together with the mode of TASCA operation (HTM=H, SIM=S) and the separator gas. Also indicated are experiments aimed to test or apply a recoil transfer chamber (RTC) in addition to measurements performed with a focal plane detector (FPD). As the standard FPD we used a (8x3.6) $cm^2$ large position-sensitive 16-strip silicon detector. Some experiments were devoted to test prototype double-sided silicon strip detectors (DSSSD) which are planned to be used in future experiments with superheavy elements (SHE).

To understand TASCA as a separator and to build up a solid data base providing good predictive power concerning separator operation for future SHE experiments, we investigated the following most important parameters: (i) the magnetic rigidity of reaction products between $Z$=76, Os, and $Z$=102, No, produced at different recoil velocities, and the corresponding best settings of the dipole magnet, (ii) the quadrupole focusing, which is especially relevant for the SIM, (iii) the target thickness dependence of the separator transmission - strongly depending on the asymmetry of the nuclear reaction -, and (iv) the optimum gas pressure with respect to focusing and to transmission - being quite different in the HTM and in the SIM. The analysis of a huge amount of data from these experiments is in progress, and it is important to realize that most of the above mentioned parameters influence each other.

Table 1: Nuclear reactions applied in TASCA commissioning experiments; see text for details.

| Beam | Target | Product | Mode | Gas | RTC |
|---|---|---|---|---|---|
| $^{22}$Ne | $^{nat}$Ta | $^{198m-199}$Bi | H + S | He | |
| | $^{179}$Au | $^{215}$Ac | H + S | He | |
| | $^{238}$U | $^{255}$No | H + S | He | |
| $^{30}$Si | no | $^{30}$Si | H + S | Vac | |
| | $^{181}$Ta | $^{205-206}$Fr | H | He | |
| $^{40}$Ar | $^{nat}$Ce | $^{173,175}$Os | H | He | yes |
| | $^{144}$Sm | $^{180-182}$Hg | H + S | He | yes |
| | $^{nat}$Gd, $^{152}$Gd | $^{194-196}$Pb, $^{188}$Pb | H + S | He | yes |
| | $^{nat}$Lu | $^{210}$Ac | H + S | He, $N_2$ | |
| | $^{208}$Pb | $^{245}$Fm | H + S | He | yes |
| | $^{232}$Th, $^{238}$U | targettest, background | H | He | |
| $^{48}$Ca | $^{144}$Sm | $^{188}$Pb | H + S | He | |
| | $^{206}$Pb | $^{252}$No | H + S | He | |
| | $^{208}$Pb | $^{254}$No | H | He, $H_2$ | |
| $^{54}$Cr | $^{nat}$Gd | $^{209-210}$Ra | H + S | | |

Always as a first step, the best dipole setting was found in HTM by centring the product distribution with a typical width of ≈ 6 cm on the FPD. A magnetic rigidity range from 1.5 to 2.2 Tm was covered in those experiments. The quadrupole focusing was found to be insensitive to small quadrupole current changes in the HTM while it reacts very sensitively in the SIM. Optimized SIM settings were determined to obtain maximum rates and narrow distributions of ≈ 1.5 cm FWHM.

The target thickness dependence of the transmission was extensively studied in the reactions $^{22}$Ne + $^{197}$Au (55, 130, 255, 580 μg/cm$^2$) and $^{40}$Ar + $^{144}$Sm (75, 190, 380, 930 μg/cm$^2$) in both modes. A comparison of these data with model calculations [7] will allow selecting an optimum target thickness with the highest product rate for all the envisioned nuclear reactions.

Many experiments were devoted to find the optimum He pressure and to determine the response to pressure changes. For this we checked the spatial distribution and the total rate of the products in the FPD. While a pressure of about 1 mbar is generally best in the HTM, a signifi-

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cantly lower pressure in the 0.2 to 0.5 mbar range gives optimum results in the SIM. A more detailed investigation of the pressure dependence is under way.

One of the most interesting but least understood parameter in the operation of gas-filled separators is the gas filling. In addition to He as our standard gas, we did first test experiments with $H_2$, $N_2$, and mixtures of He and $N_2$. In the $^{40}$Ar + $^{nat}$Lu reaction we probed the influence of small amounts of $N_2$ in He on the magnetic rigidity and tested the pressure dependence in pure $N_2$. From the $^{48}$Ca + $^{208}$Pb reaction clean α-spectra of $^{254}$No and its daughter $^{250}$Fm were measured in the HTM with He and $H_2$ fillings. Figure 1 shows an example obtained with 1.5 mbar $H_2$.

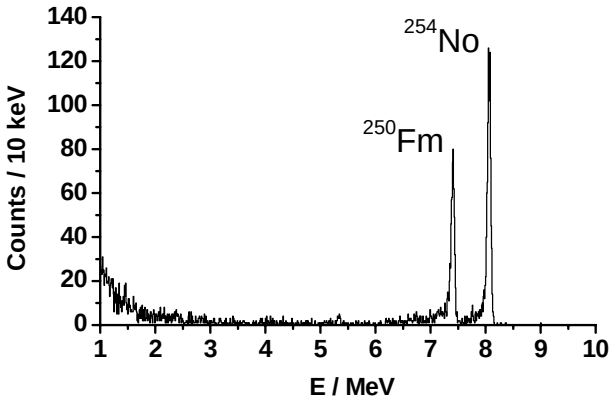


Figure 1: α-spectrum of $^{254}$No separated in a 1.5-mbar $H_2$ gas filling of TASCA. $^{250}$Fm is the daughter nucleus.

The $^{22}$Ne($^{181}$Ta,xn)$^{198m,199}$Bi reaction was used to check the calculated transmission [7] in the HTM and in the SIM. $^{198m,199}$Bi were collected in Al catcher foils directly behind the target (used as the 100% reference value) and in the focal plane. Subsequent γ-ray spectroscopic measurements of these foils allowed determining the transmission and, from a measurement of segments, the spatial product distribution in the focal plane. Very good agreement was found between theoretically calculated transmissions and distributions and the measured ones.

Target development and testing with $^{40}$Ar beams of up to 2 μA(particle) continued and concentrated on metallic Th and U targets on 2 μm Ti backings. In addition, large varieties of $^{144}$Sm, $^{179}$Au and $^{206,208}$Pb targets were prepared and used for intense parameter studies at TASCA. Preparations towards new transuranium targets were concentrating on $^{244}$Pu. In this ongoing program, considerable progress has been achieved recently.

Commissioning experiments for the RTCs [8], which were built for both two ion-optical modes, focused on finding best conditions for transporting preseparated nuclides to sites where chemistry experiments are envisaged to take place, i.e., a position inside X8 as well as in the nearby radiochemistry laboratory. Suitable nuclides were produced with $^{40}$Ar beams, e.g., α-decaying 25-s $^{188}$Pb and 4-s $^{245}$Fm as well as longer-lived Os, Hg, and Pb isotopes that were identified with γ-ray spectroscopy.

Yields of preseparated Pb isotopes, transported with a He/KCl gas-jet to the chemistry laboratory, were measured as a function of parameters like (i) the thickness of degrader foils installed in front of the RTC window, (ii) the RTC depth, (iii) the pressure inside the RTC, and (iv) the gas-flow rate. Maximum yields of about 65% were obtained for transport to the radiochemistry laboratory through a 10-m long PE capillary at He flow rates of 2.5 L/min at a pressure of 1.2 bar in the RTC.

The product range in the He-filled RTC was measured by inserting catcher foils to positions with different distances from the RTC window. The measured ranges in He turned out to be larger than the values predicted by SRIM calculations, even though the energy loss in the Mylar degrader foil and window agrees well with such calculations. This was confirmed in measurements of EVRs in the FPD after passing through degrader foils.

Preseparated $^{188}$Pb was measured after transport into ROMA [9]. Clean α-spectra and high yields allowed determining the half-life of (23.4±0.4) s with better precision than the literature value of (24.2±1.0) [10]. Furthermore experiments were performed where $^{245}$Fm was transported into ROMA; see Figure 2. They prove that the TASCA-RTC system is ready for experiments with SHE.

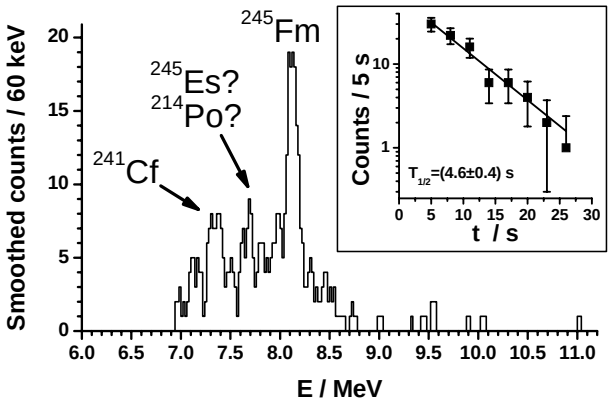


Figure 2: α-spectrum of $^{245}$Fm. The insert shows the decay curve for α-particles with 8.05 MeV < $E_\alpha$ < 8.25 MeV.

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