Extraction of fission products for TRIGA-SPEC using a helium gas jet with carbon aerosols

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Introduction: High-precision measurements of nuclear ground-state properties like masses, magnetic moments, spin and charge radii reflect the interactions inside the nucleus and are therefore of fundamental importance, with applications in nuclear structure and nucleo-synthesis studies [1]. The TRIGA-SPEC experiment at the TRIGA Mainz reactor aims to investigate neutron-rich fission products and determine these properties in a model independent way by means of Penning trap mass spectrometry and laser spectroscopy [2]. A helium gas-jet arrangement in combination with a carbon aerosol generator has been implemented in order to transfer neutron-rich fission products from the reactor to the TRIGA-SPEC experiment. The gas-jet arrangement will be connected to a 30 cm^3 target chamber close to the reactor core containing a fissionable target, e.g. ^{235}U or ^{249}Cf. The thermal neutron induced fission products having energies of approximately 100 MeV thermalize in the helium gas at a pressure of about 2.5 bars. After thermalization they attach to the carbon aerosols that are added to the gas and can be flushed out of the target chamber in a laminar flow through a PE-capillary to a skimmer system where the helium gas is separated from the aerosols. In order to release the fission products from the aerosols and to ionize them, an ECR ion source is being installed on a high-voltage platform. After ionization the fission products will be mass separated in a 90° dipole magnet and finally transferred either towards the laser spectroscopy experiment or the Penning trap mass spectrometer [3].

Experimental setup and results: Carbon aerosols are produced by constantly charging a capacitor between two sharpened pure graphite electrodes placed in a helium gas flow. When the breakdown voltage of about 1.5 kV is reached, a spark discharge takes place and carbon evaporates. The repetition rate of the discharge can be easily adjusted through the charging current.
Using an electrostatic classifier we observed that the carbon vapour condenses to particles with a diameter of 10 nm to 1 µm lognormally distributed around a maximum at about 100 nm at a gas flow of 1.4 l/min. Despite the erosion of the electrodes, the continuous production of aerosols has been demonstrated over about 8 hours without maintenance, satisfying the requirements of the TRIGA-SPEC experiments.
The accessibility of radionuclides away from the valley of β−stability depends on their half-lives and production rates, thus a rapid and efficient transfer to the experiment is crucial. Thermalization in the target chamber and the transport to the ion source defines mainly the total transfer time since the ionization and the transport of ions are very fast. Hence, the transport time of the fission products has been determined by guiding the aerosols through a 7 m long capillary of 0.86 mm diameter to a filter placed in front of a γ-detector during a reactor pulse. As shown in Fig. 1 γ-radiation is emitted during the reactor pulse, which is observed by the detector. The peak shape as well as the neutron flux in the reactor can be approximated with a Gaussian distribution. After a few hundred milliseconds the fission products arrive and the activity increases first to a maximum and decreases afterwards again down to background level. The transport time is defined as the time difference between the maximum of the reactor pulse and the half of the maximum γ−activity and is determined to be about 400 ms.

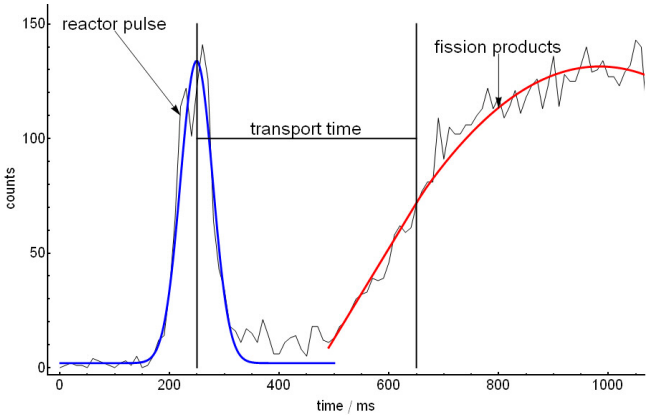

Figure 1: γ-activity recorded during and after a reactor pulse. The transport time is defined as the time difference between the maximum of the pulse and the half of the maximum activity that is caused by the arriving fission products.

Conclusions and outlook:
The extraction of fission products using carbon aerosols was demonstrated. The transport efficiency will be investigated in detail. Values up to 70% have been reached in first tests.
Next steps are to finalize the ECR ion source and connect it to the gas jet via a skimmer to study the ion production.

References:
[1] K. Blaum, Phys. Rep. 425 (2006) 1-78.
[2] J. Ketelaer et al., Nucl. Instr. Meth. A 594 (2008) 162-177.
[3] see reports to TRIGA-LASER and TRIGA-TRAP in this issue

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