Detection Techniques for On-Line Mass Determination with Penning Traps*

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A Penning trap mass spectrometer is a well established instrument for the precise mass determination of both, stable and short-lived nuclides. For this purpose two different concepts are employed. Masses of stable species are mostly determined by the non-destructive detection of image currents induced in the trap electrodes and a subsequent Fourier transformation (FT). For short-lived nuclides the destructive time-of-flight ion-cyclotron-resonance technique (TOF-ICR) appeared to be the method of choice, since the ions have to be released from the trap prior to their detection. Approaching rarely produced nuclides with prolonged half-lives $T_{1/2}$ or pushing forward to ions with multiple charge states q, the non-destructive Fourier-transform ion-cyclotron-resonance (FT-ICR) technique [1] is very promising. In the first case, the limited ion statistics can be overcome by an extended observation time and secondly, with $q > 1$, single ion detection sensitivity is easily feasible. Both, the destructive detection with microchannel plate (MCP) detectors or Channeltrons and the detection with the FT-ICR technique will be implemented for advanced mass spectrometric studies with the Penning trap system MATS within NUSTAR at the future GSI facility FAIR.

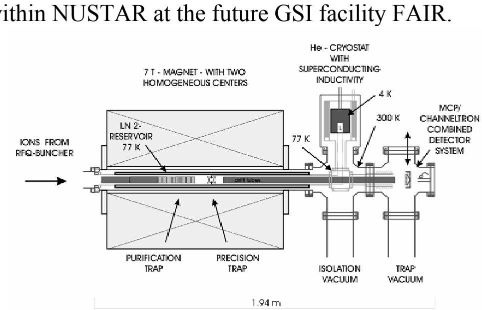

Figure 1: Schematic for a non-destructive detection of image currents in a cryogenic trap enabling the subsequent extraction to an additional detector system.

A corresponding trap system is depicted in Fig. 1. In the precision Penning trap narrow-band FT-ICR detection will be used. The cryogenic environment and the optimized, low-noise electronics enable the detection of single ions and thus a non-destructive detection and mass analysis of the stored ions. The current development at the University of Mainz mostly concentrates on the preparation of this sensitive detection technique for heavy ions at SHIPTRAP [2]. Alternatively, the geometry of the setup allows the ejection of ions for destructive techniques.

For TOF-ICR mass spectrometry [3,4] the ions are ejected from the trap towards a MCP detector or a Channeltron. Figure 2 shows such a combined detector setup. With a linear feedthrough the MCP array can be retracted and the beam line is open to a conversion electrode detector with a Channeltron. The setup with a conversion electrode, where ions are accelerated to, allows an improved detection efficiency of almost 100% compared to the typical efficiency of about 30% for the MCP.

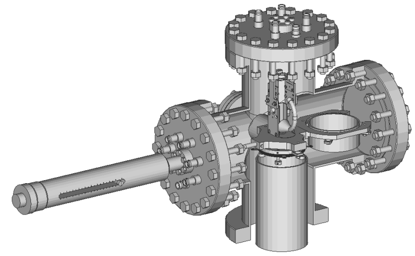

Figure 2: Combined detector system of a retractable MCP and a Channeltron as used for the time-of-flight registration at ISOLTRAP and MATS/Mainz.

The experimental comparison of both detector types using residual gas ions is shown in Fig. 3. An improved detection efficiency of the Channeltron by a factor of three could be verified in this test. The shift in the position of the maximum is due to the respective position of the detector on the beam axis resulting in a different focussing condition corrected by the voltage of an einzel lens. With the current development studies both techniques are well established and ready to use at MATS [5] at FAIR.

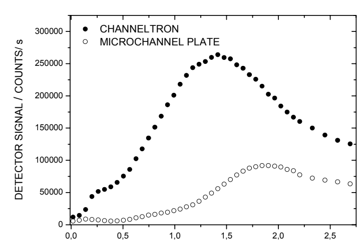

Figure 3: Relative detection efficiencies of a channeltron and a microchannel plate using ionized residual gas.

References

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