Design of the Electrode System for the Cryogenic Buffer Gas Stopping Cell at SHIPTRAP ◇

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The SHIPTRAP facility at GSI allows for high-accuracy mass measurements of heavy radioactive ions behind the SHIP velocity filter using a double Penning trap system. In 2008 the first ever direct mass measurement of transuranium isotopes could be successfully performed in ^{252,253,254}No with as low as 0.5 ions entering the trap per second [1]. In order to extend the capabilities of this unique system to heavier ion species with even lower production cross sections, the efficiency of SHIPTRAP has to be increased significantly. Therefore the buffer gas cell of SHIPTRAP will be upgraded, which is currently limited to an overall (i.e. stopping + extraction) efficiency of about 4%. The buffer gas cell, which was built by the LMU group [2], thermalizes the incoming heavy fusion products in ultra-pure helium (50-100 mbar). Subsequently the ions are guided by electric DC and RF fields to a nozzle at the exit of the gas cell, where they are extracted by the gas flow in a supersonic jet and injected into the acceptance of a subsequent radiofrequency quadrupole (RFQ) designed as ion transport channel and phase space cooler. In this part of the gas catcher the carrier gas is pumped away and the ions gradually enter the high vacuum regime.
So far the efficiency of the buffer gas cell at SHIPTRAP was limited by several constraints: due to space restrictions the injection into the cell had to be performed almost perpendicular to the extraction axis, requiring an accurate stopping of the incoming ions on the central axis, which is specifically difficult in view of the large beam dimensions behind SHIP with a beam diameter of at least 60 mm. Moreover, severe purity requirements for the buffer gas inside the stopping chamber had to be fulfilled in order to minimize ion losses due to charge exchange reactions. Here in the past several intrinsic gas contamionations (especially from Xenon isotopes) had to be removed via the use of a liquid-nitrogen filled cryotrap in the gas feeding line at the entrance to the gas cell.
A significant increase of the stopping and extraction efficiency can be expected when using a cryogenic gas cell, where the low temperature (about 40 K) will inherently ensure the purity of the helium gas by freezing out of impurities, while allowing at the same time to operate the gas cell at a higher helium density, equivalent to a higher gas pressure as presently available at the room temperature system. Cryogenic operation also allows for a wider choice of materials inside the gas cell compared to an ultra-high vacuum compatible system, e.g. in future not all electrical contacts will have to be fed individually into the vacuum chamber, which in the past reperatedly caused problems by leakages occurring at the sensitive ceramic multi-pin feedthrough connectors. Instead in the cryogenic case electronic circuits (like voltage dividers) will be allowed also inside the vacuum chamber. While the design of the cryogenic vacuum chamber is performed by the GSI group, the interior part of the stopping cell with its electrode system has been designed under the responsibility of the LMU group. Fig. 1 shows the complete view of the cryogenic gas cell design.

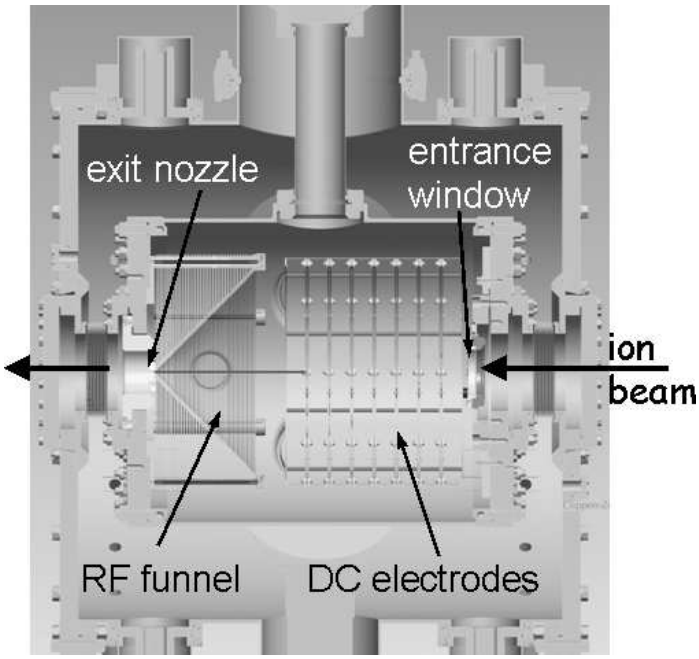

Fig. 1: Design of the cryogenic gas cell for SHIPTRAP with the cold inner part of the gas cell, isolated by an outer evacuated vessel. The inner part carries the extraction electrode system: the metallic entrance window, the segmented DC electrodes, the RF funnel and the extraction nozzle.

Based on the experience from the MLL-IonCatcher system [3], a longitudinal injection is foreseen for the cryogenic gas cell, where the ions will enter through a metallic entrance window (e.g. Titanium, thickness 2.5-3.5μm, diameter 60 mm). In contrast to the existing gas cell devices at SHIPTRAP and Garching, the entrance window and its support grid will act as first DC electrode. Thus the full length of the gas volume will be available for ion stopping and extraction. Therefore the window support flange will be isolated against the cage end flange as well as against the DC electrode system. Here the same metal-ceramic bonding technique will be used as already successfully operated for the insulation of the nozzle electrode. The metallic window foil will be supported by an etched planar support grid and sealed with a 1 mm gold wire, while the support flange will be sealed against the cage end flange by a CF100 standard copper sealing.
Subsequently the stopped ions will be guided by an electrical field gradient of $\geq$10 V/cm towards the extraction nozzle. The electrical field will be provided by 8 DC electrode segments, each consisting of a thin (0.2 mm) steel foil with a width of 28.4 mm and an inner diameter of 260 mm. Fig. 2 shows a view of the DC electrode system.

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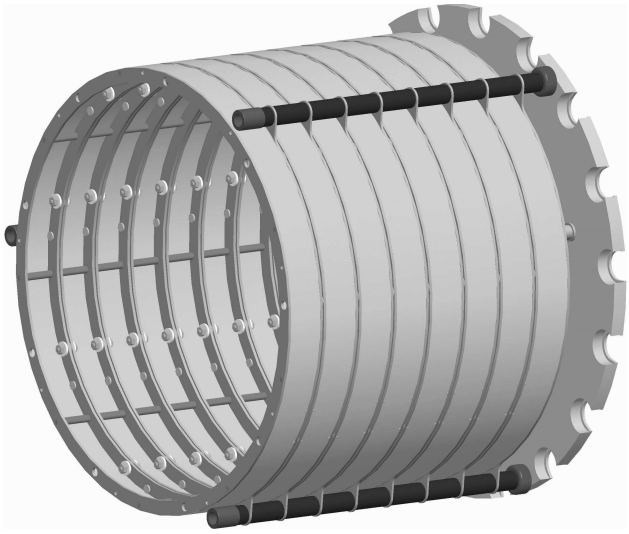

Fig. 2: Design of the eightfold-segmented DC electrode system for the cryogenic gas cell at SHIPTRAP.

The DC electrode system will be mounted to support rods, isolated by ceramic tubes and fixed in distance by ceramic spacer tubes. The external boundary of the DC electrode system will be given by thin (0.3 mm) stainless steel foils covering the radial circumference of each DC electrode segment. These foils replace the mesh structure so far used at SHIPTRAP or for the MLL-IonCatcher, since it will prevent distortions of the electrical field especially in the region near the entrance electrode, while the increased surface area will not deteriorate the vacuum properties due to the cryogenic environment. The DC gradient will be provided by a voltage divider directly mounted to the electrode system, thus drastically reducing the number of required electrical feedthroughs. Fig. 3 displays in a detailed view the mounting and support of the DC electrode system described above.

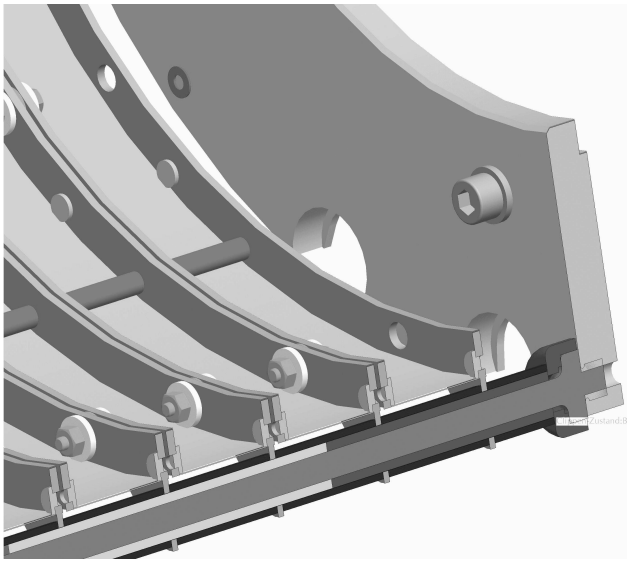

Fig. 3: Mounting of the segmented DC electrode system. The eight segments are supported by 3 steel rods (diameter 6 mm), which themselves are electrically isolated via ceramic tubes from the eye ring holders. The distance between the segments is preserved via ceramic spacers.

The ions will be further guided towards the extraction nozzle by an RF funnel system, consisting of 75 individual ring electrodes with inner diameters ranging from 266 mm down to 5 mm near the extraction nozzle. In the backward region of the funnel 55 electrodes will be mounted each with a thickness of 1 mm and distances between neighbouring electrodes of 1 mm, while for the 20 electrodes near the nozzle exit higher electrical fields can be reached by a reduced thickness and spacing of the electrodes of 0.5 mm. The ring electrodes will be mounted each to three support rods. Each electrode will be isolated with respect to their neighbours, thus reducing the capacitance of the funnel systems. Thus 6 support rods will be mounted to a base plate, covered at their ends by ceramic caps in order to prevent sparking to the adjacent DC electrode. Fig. 4 shows the RF funnel leading to the extraction nozzle.

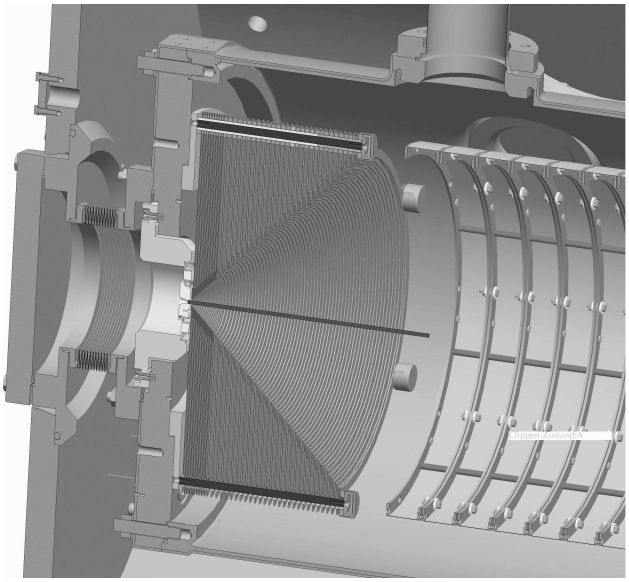

Fig. 4: Design of the RF (+DC) funnel system with 75 ring electrodes.

The last electrode of the buffer gas stopping cell will be the extraction nozzle, which will be electrically isolated using a metal-ceramic soldering technique. A nozzle throat diameter of 0.6 mm is foreseen, as used for the MLL IonCatcher and the existing SHIPTRAP gas cell.
With the upgraded cryogenic buffer gas stopping cell and increase of the overall stopping and extraction efficiency from presently about 4% up to 20% is envisaged, thus allowing to extend the measurement capabilities of SHIPTRAP significantly to rarer transuranium species.

References

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[3] J. Neumayr *et al.* Rev. Sci. Instr. **77** (2006) 065109