# From MLL-IonCatcher to MLLTRAP ◇

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With MLLTRAP [1] (schematically shown in Fig. 1) a new ion-trap facility is presently under construction at the MLL. The set-up is designed to combine several novel technologies to decelerate, charge breed, cool, bunch and purify the reaction products and perform high-precision nuclear mass measurements. The aim is to reach a mass accuracy of about $10^{-10}$ needed for precision mass measurements contributing to an improvement of the accuracy of fundamental constants, like the molar Planck constant $N_A h$ and for unitarity tests of the CKM-matrix via a determination of the $V_{ud}$ quark mixing matrix element.

Following the production target and the 90° separator dipole magnet the first part of MLLTRAP is represented by the MLL-IonCatcher [1], a combination of a buffer-gas cell and an RFQ-based extraction system. The MLL-IonCatcher is used for the thermalisation of the reaction products from energies of around 50 - 500 keV/u down to several electronvolts.

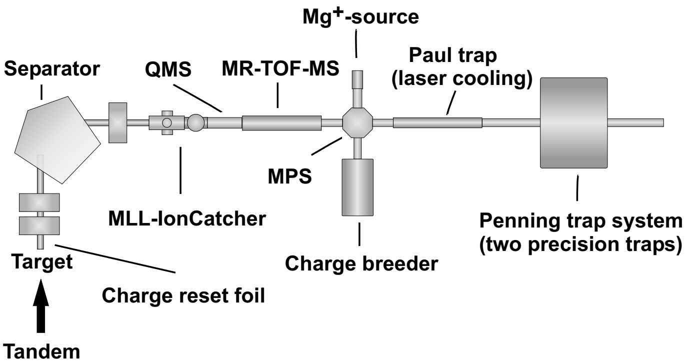


Fig. 1: Schematic view of MLLTRAP. Following the set-up for the ion production and separation MLLTRAP will consist of a buffer-gas cell/extraction-RFQ combination (MLL-IonCatcher), devices for the beam purification (QMS, MR-TOF-MS), a charge breeder for the generation of highly charged ions, devices for the application of sympathetic laser ion cooling and two Penning traps located in a superconducting magnet with 7 T.

Behind the MLL-IonCatcher a system for the purification of the extracted ion beam will be installed. While a QMS (Quadrupole Mass Spectrometer) will be used for a (A-selective) pre-separation, the isobaric purification will be done by a MR-TOF-MS (Multi-Reflection Time-Of-Flight Mass-Separator) based on the design of the Gießen group [2]. The purification at this place is needed since the later described traps will both be used for high precision measurements, while at other facilities using two traps (as e.g. SHIPTRAP [3]) the first trap is used for the isobaric purification. In addition the buffer-gas cooling method, usually applied for isobaric purification, cannot be used for highly charged ions. Subsequent to the MR-TOF-MS an MPS (Multi-Passage-Switch) will be installed for the connection of two additional subsystems to the beam line. A charge breeder (EBIS or by laser ionisation) will generate high charge states of the ions of interest allowing for an improvement of the precision of the mass measurements [4]. Since buffer-gas cooling is not applicable the sympathetic laser cooling technique will come into operation, taking place in a linear Paul trap which will also act as buncher device for the ion injection into to the trap system. The sympathetic cooling will be applied using $Mg^+$ ions provided by an ion source coupled to the MPS. Laser cooling of highly-charged ions in a strongly coupled plasma will allow for an improvded localization of the ion cloud in the trap center and hence reduce systematic uncertainties. Details on this novel technique can be found in Ref. [5]. The main part of MLLTRAP is the trap system with two Penning traps located in one superconducting magnet with a flux density of 7 T.

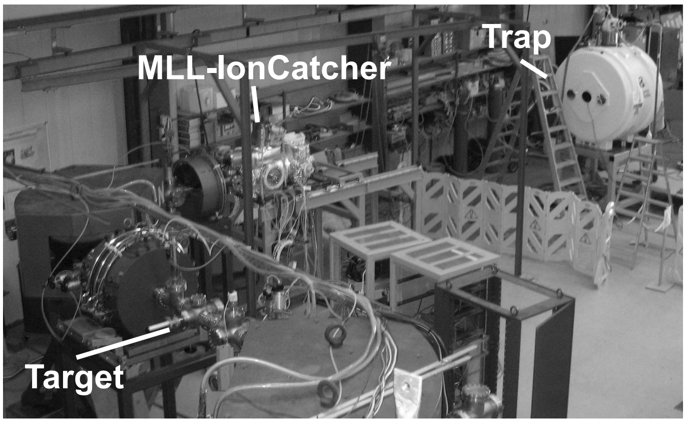


Fig. 2: Photo of MLLTRAP in hall 2 of the Tandem lab with the MLL-IonCatcher and the superconducting magnet.

The complete MLLTRAP facility has been moved in 2006 to the present location (experimental hall 2) at the Tandem accelerator lab of the MLL. Figure 2 shows a photo with the present arrangement of the MLLTRAP components with the existing MLL-IonCatcher device (on the left hand side connected to the set-up for the ion production and separation) and the superconducting 7 T magnet (right hand side) containing the two Penning traps. Besides a larger area available for the arrangement of present and upcoming MLLTRAP components the new location offers also the opportunity for a more efficient ion production and separation prior to the injection into the MLL-IonCatcher. In addition to a larger acceptance (aperture 100 mm instead of 45 mm) and higher field gradients of the now used quadrupole lenses the efficiency improvement is reached by the usage of an additional lens (horizontal focussing) in front of the buffer-gas cell which will help to avoid ion losses due to the broad horizontal beam distribution after passing through the dipole magnet. Another improvement is given by the charge reset foil (diameter 90 mm, see [6]), placed behind the production target, which is now movable, thus enabling a higher variability in the beam diagnostics. A main advantage of the present location compared to the former situation is the inclusion of the

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D0 analysing dipole magnet following the Tandem accelerator into the beamline for an effective separation of the primary beam (in the previous location (hall 3) only the Wien filter was applicable under 0°). In the first commissioning tests using the $\alpha$ emitter $^{152}$Er the expected improvement in efficiency of the new set-up could be verified. Besides these tests new fusion reactions are being investigated in view of thefuture physics program with MLLTRAP.

The first operational part of MLLTRAP is the MLL-IonCatcher. The device is described in more detail in [1] and shows presently a maximum overall stopping and extraction efficiency of around 16%. Major efforts are presently concentrated on the optimisation of both the stopping efficiency as well as the electrical guiding fields inside the buffer-gas cell. Concerning the stopping of the ions the most crucial part of the MLL-IonCatcher is its entrance window. Therefore, tests with thin (3 $\mu$m) Kapton foils (provided by the target laboratory of the IRMM JRC-EC/Geel) are being conducted in order to investigate the possibility of reducing the energy acceptance of the presently metallic entrance window from about 180 keV/u (for 3.5 $\mu$m titanium) to values around 50 keV/u.

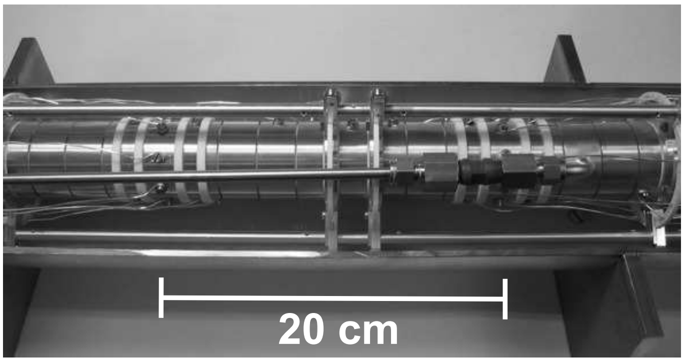


Fig. 3: Photo of the two cylindrical Penning traps for MLLTRAP.

Triggered by a quench of the superconducting trap magnet, the subsequent move of the whole MLLTRAP facility to its new location allowed to lift the trap magnet onto a newly built support stand at the nominal height of the MLL beamline system (while in the previous position the limited height of the experimental hall forced to operate the magnet at a significantly lower height, thus enforcing a complicated coupling scheme to the preceding MLL-IonCatcher).

After the re-energising the homogeneity of the magnetic field was fine-tuned ('shimming') by the manufacturing company (Magnex Ltd., UK). The magnet has two homogeneous magnetic field regions (1 cm$^3$ each), located at a distance of 10 cm to both sides of the magnet centre. In these regions, where the two cylindrical Penning traps will we placed (see Fig. 3), the homogeneity could be adjusted to below 0.3 ppm. This way MLLTRAP differs from the other existing double Penning-trap facilities (e.g. JYFLTRAP, SHIPTRAP, ISOLTRAP), where one of the two trap centres has been adjusted to ultimate homogeneity (ca. 0.1 ppm), while the other centre typically is less accurate by about a factor of 6-8. This is due to the fact that those facilities operate the first trap as isobaric purification trap, while at MLLTRAP two equivalent precision traps will be operated. The reached value of the homogeneity is the best symmetric value achievable in view of the fact that only one field centre can be adjusted via shimming coils while the fine tuning has to be performed by physically adding ferromagnetic strips to the beamtube.

Subsequently the vacuum beam tube inside the (warm) magnet bore was mounted onto an adjustable support in order to allow for the alignment of the geometrical beam axis with respect to the magnetic field axis. For this procedure a dedicated alignment tool was built and inserted into the vacuum tube. A filament located at the magnet centre creates electrons (current ca. nA) that are accelerated and transported along the magnetic field lines and have to pass pairs of narrow diaphragms (0.2 mm pin hole near the filament, 0.5 mm in a variable distance up to 40 cm away from the filament, see Fig. 4). The outer diaphragms are surrounded by a segmented plate for a position-sensitive measurement of the electron current. The opening of the diaphragms reflects the width of the electon beam at the magnet centre and at both ends of the trap magnet, taking into account the increasing field inhomogeneities towards both ends of the magnet. By comparing the electron current in different segments one can recalculate the position of the beam tube inside the magnet. Centering the tube required to adjust the tube ends in a way to maximize the electron current through the 0.5mm pin holes. Once the final position of the beam tube has been fixed, the field homogeneity will be remeasured to validate the shimming result that was obtained without the beamtube. This time-consuming alignment is a mandatory prerequisite for the subsequent setup of the trap electrodes and the vacuum system, that had been tested already successfully before.

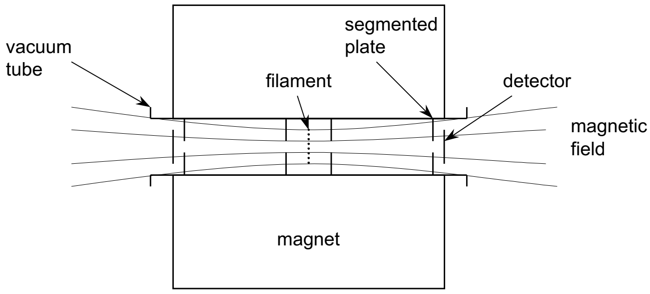


Fig. 4: Schematic view of the set-up for the alignment of the beam tube inside the superconducting magnet.

In parallel to the work ongoing at the superconducting trap magnet, the control system of MLLTRAP has been set up. To control the various hardware devices an event driven, object oriented control system, developed at GSI, was adapted to fulfill the needs of the MLLTRAP experiment.

## References


[1] J.B. Neumayr *et al.*, Rev. Sci. Instrum. **77** (2006) 065109
[2] T. Dieckel, Diploma thesis, JLU Gießen (2006).
[3] M. Block *et al.*, Eur. Phys. J. **A25** (2005) 49
[4] V.S. Kolhinen *et al.*, Annual report 2005, p. 83
[5] M. Bussmann *et al.*, this report, p.55
[6] J.B. Neumayr, Ph.D. thesis, LMU München, 2004