Commissioning the Penning trap for the TAMUTRAP facility

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The TAMUTRAP facility has a planned program in measuring the β decay of superallowed $T=2$ β-delayed proton transitions, starting with ^{32}Ar. En route to that goal, we have built and installed a prototype cylindrical Penning trap which has an inner diameter of 90 mm. While this prototype is already the worlds largest ion trap, we need one that is double the size to contain the β-delayed protons which have a Larmour radius of $R_L \leq 90$ mm.

The AutoCAD design of the trap as well as the final product are shown in Fig. 1. The electrode structure is based on our novel design [1] with a much larger radius-to-length ratio compared to typical cylindrical Penning traps. The trap was installed in the summer of 2016, and by the fall we demonstrated the ability to trap stable Potassium ions for long times, up to 30 s. The time-of-flight spectrum for different trapping times is shown in the left panel of Fig. 2 where one can see the effect of cooling the the ions with increased trapping times.

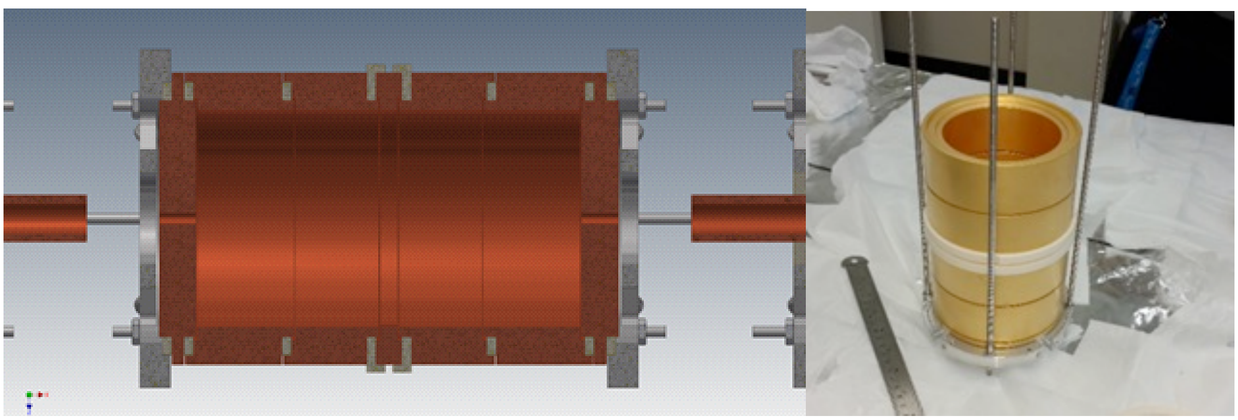

FIG. 1. Design (left) and the assembled prototype Penning trap for the TAMUTRAP facility (right). With an inner radius of 90mm, this is the world's largest cylindrical Penning trap. The time-of-flight (TOF) of the ions relative to ejection from the trap is made using a micro-channel plate situated outside of the superconducting solenoid (to the right of the trap).

We have since optimized injection of ions from the RFQ cooler and buncher, and characterized the trap's performance for different injection energies, trap depths, trapping times, etc. A major milestone was reached when we demonstrated the ability to manipulate the ion motion by exciting the magnetron motion of the trapped ions (typically used to remove contaminants at other Penning trap facilities). By applying rf at the appropriate frequency (420 Hz for ^{39}K) to the centre electrode, the trapped ions gain energy and are promoted to a larger radius. When ejecting these ions from the trap, ions that are excited do not make it through the 6 mm opening on the ejection (right) side of the trap.

We next applied dipole excitation to the ions at 2.7 MHz to excite the cyclotron motion of the ions As described in more detail in last year's report [2], the ions gain energy when in resonance with the cyclotron frequency with the net effect being a reduced TOF upon ejection relative to non-resonant frequencies. The first TOF vs frequency scan is shown in Fig. 2, where the ion rf was applied for just 10 ms. If the magnetic field of the magnet was precisely known, the frequency of the minimum TOF would represent a mass measurement. This frequency curve instead is actually a precise measurement of the magnetic field: B=7.019246 (4)T, better than a ppm precision. We have installed a 2nd offline ion source, this time Sodium, and are in the process of making a similar frequency scan. With the field calibrated to the ^{39}K ions, we will truly make a mass measurement of ^{23}Na. This is of course a well known quantity, but will serve to demonstrate our ability to make mass measurements at the ppm level and commission this aspect of the TAMUTRAP facilty.

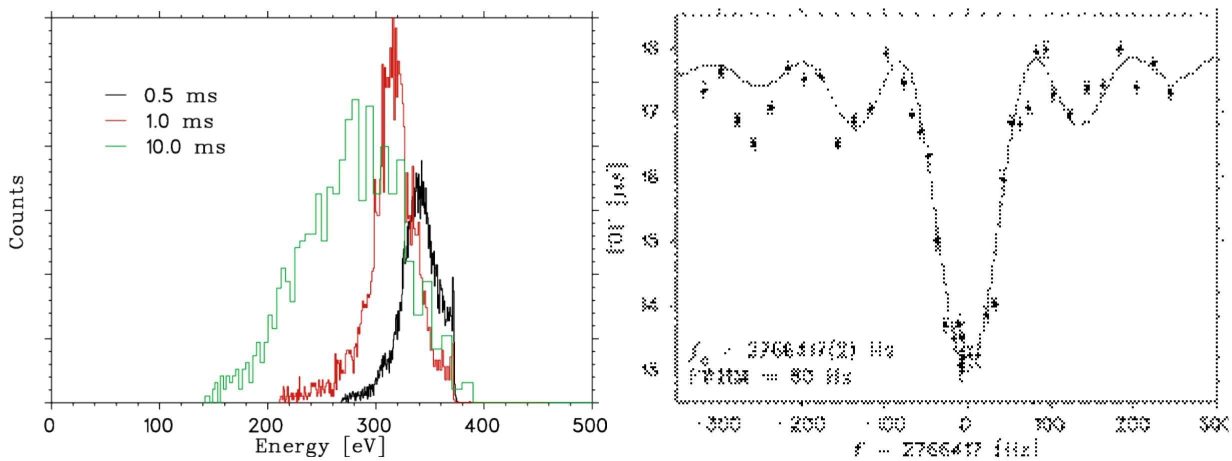

FIG. 2. TOF spectrum for the first trapped ions at TAMUTRAP (left), and the first cyclotron resonance curve of stable ^{39}K (right). The reduced average energy for longer trapping times demonstrates ion cooling from residual He atoms coming from the RFQ cooler/buncher. The resonance curve on the right is not perfect, but the width of the main drop in TOF is only ~20% larger than expected from the short (10 ms) rf excitation time. The mass-resolving power of this resonance curve corresponds to 30 ppm.

With the prototype trap commissioned and abiltiy to perform mass measurements demonstrated, we have started to design the full-sized Penning trap and expect to install it next year.

[1] M.Mehlman *et al.*, Nucl. Instrum. Methods Phys. Res. **A712**, 11 (2010).

[2] E. Bennett *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2015-2016), p. I-62.