Development of the control system for TAMUTRAP: characterizing dampening effects in mass measurements of alkali ions

M. Nasser, G. Chubarian, V.E. Iacob, V.S. Kolhinen, D. McClain, D. Melconian, A. Ozmetin, B. Schroeder, and P.D. Shidling

As reported last year [1], a number of software systems have been created for TAMUTRAP to improve flexibility and control of the beamlines, RFQ and Penning trap: the Scan Automation System (SAS), Python-Pulsing Software (P2S) and Time-Of-Flight Fitter and Integrator (TOFFI) have all contributed to the operation of TAMUTRAP's system and improved the mass measurements used to commission the Penning trap. Here we describe some improvements that have been developed as these control systems have evolved and new measurement techniques are pursued at TAMUTRAP.

One example of how the control software has required updating is to allow us to pursue a new (more sensitive) approach to mass measurements. The Ramsey method of oscillatory fields [2], described elsewhere in this report [3], has a more complex excitation pattern with a corresponding frequency scan exhibiting a different structure compared to the regular TOF-ICR technique. The Ramsey method has required SAS and P2S to be expanded to include the ability to add the extra excitations, and TOFFI had to be adapted to perform the fit to the more sinusoidal frequency scan.

Another example of how the control system has been upgraded to accommodate the developing TAMUTRAP program is the one-trap purification scheme, also described elsewhere in this report [4]. Although in this case the frequency scan is the regular TOF-ICR resonance curve (so TOFFI did not need alteration), again the excitation pattern is lengthier and more complicated, requiring SAS and P2S to be re-written to allow for this purification scheme.

Perhaps the most significant improvement, however, is the inclusion of dampening in the model used by TOFFI to fit the resonance scans taken at TAMUTRAP. The data plotted in the top panel of Fig. 1 exhibits a clear attenuation of the fringe pattern expected from a resonance scan. This is attributed to the finite vacuum from residual buffer-gas in the Penning trap from the RFQ (which in this case was operated at an atypically high pressure). As can be seen from the fit in Fig. 1, the reduced χ^2 is dramatically reduced when including the dampening term compared to when it is neglected. It is worth noting that since we adopt the PDG approach of scaling measurement uncertainties by $\sqrt{\chi^2/\mathrm{dof}}$, this has led to mass measurements which are as much as 4× more precise. The model of dampening implemented into TOFFI suggests a linear relationship between the pressure in the trap and the dampening parameter, γ. We have confirmed this with resonance scans at pressures of $(1–7)\times10^{-7}$ mbar and, as the bottom plot of Fig. 1 shows, we do indeed see a linear dependence.

As we develop more and more offline techniques to improve control and efficiency of the TAMUTRAP facility (beamlines, RFQ and Penning trap), the control system is being developed to allow for all upgrades. Near-term goals are to better quantify the dampening parameter, and a more complete automated logging of parameters and settings when frequency scans are performed.

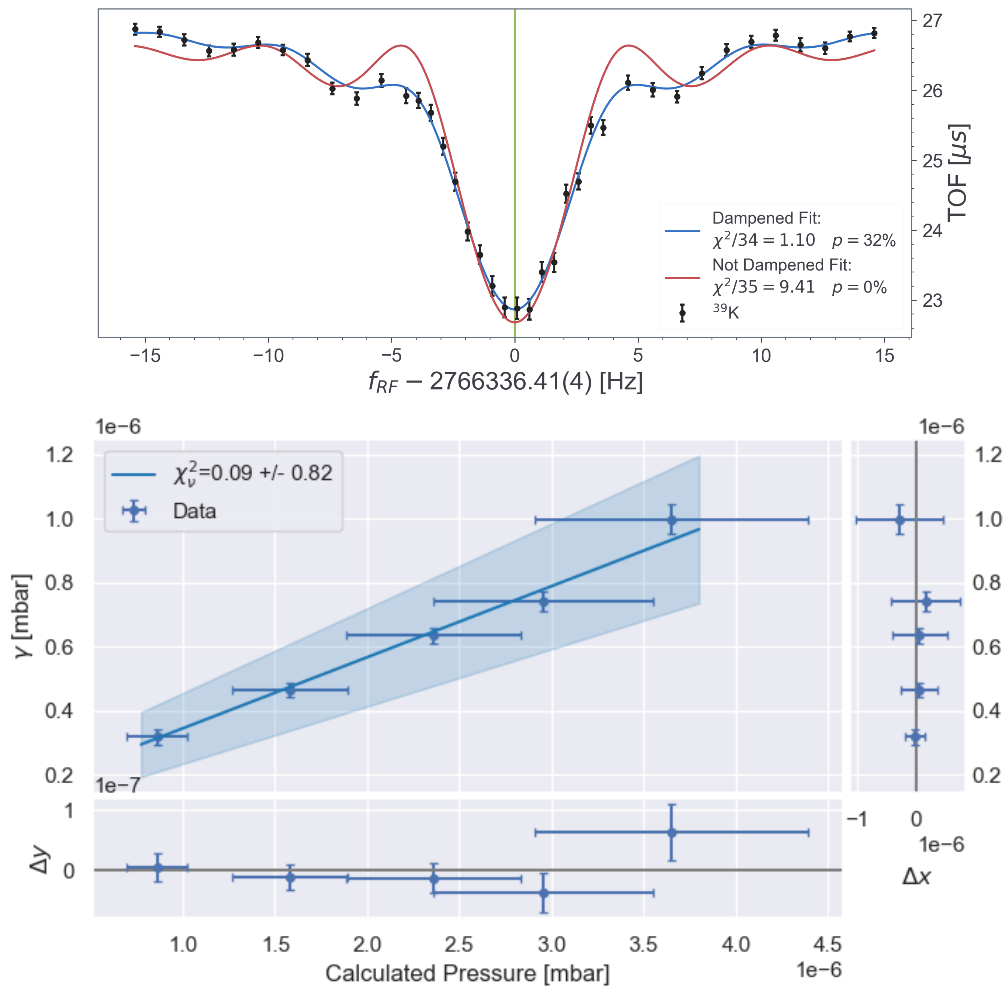

Fig. 1. Top panel: fits to a ^{39}K resonance scan with and without dampening included when the pressure in the trap was 3.7×10^{-7} mbar. Bottom panel: the fit dampening parameter, γ, as a function of pressure in the trap, showing the expected linear relationship.

[1] M. Nasser *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2018-2019) p. IV-44.

[2] S. George *et al.*, Phys. Rev. Lett. **98**, 162501 (2007).

[3] V.S. Kolhinen *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2019-2020) p. IV-90.

[4] V.S. Kolhinen *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2019-2020) p. IV-98.