Penning trap facility – Program for the study of fundamental weak interaction

R. S. Behling, B. Fenker, M. Mehlman, D. Melconian, and P. D. Shidling

The initial program of the Penning trap facility at the Institute involves measuring the *ft* values and correlation parameters of T=2 superallowed β-delayed proton emitters. Such measurements will: improve our understanding of isospin-mixing corrections [1]; provide new nuclei with which we may extract additional measurements of V_{ud} (used to test unitarity of the CKM matrix); and search for possible scalar currents in the weak interaction via the b-n correlation parameter. The facility will also allow us to carry out mass measurements of stable and radioactive nuclei with life-times as short as ≈400 ms.

The radioactive beams for the present program will be produced by the upgrade project. The high intensity primary beam from the re-commissioned K150 Cyclotron will be bombarded on a ^{3}He gas target. Reaction products of interest will be separated from other reaction products using BigSol, a large bore 7-Tesla superconducting solenoid. Following BigSol, the beam will be stopped in a gas catcher. The low-energy secondary beam will be extracted from the gas catcher and transported through a multi-RFQ to the Penning trap facility.

The beam line optics from the multi-RFQ to the setup has been designed using SIMION [2]. Secondary beams will be accelerated to 15 keV for efficient transport. Two einzel lens and two pairs of steering plates will be used to focus and direct the beam upward through the roof planks. Ions will be deflected twice by 90^o using deflecting mirrors and will be directed further using an einzel lens into the injection optics. Before injection into the RFQ, the beam must first be electrostatically decelerated down to energy in the range of 10 to 20 eV. This is accomplished by placing the RFQ and the injection optics on a potential slightly below the corresponding ion beam energy.

Ions will be cooled and bunched using a segmented gas-filled RFQ. The ions will enter the RFQ with an energy around 15 eV. The RFQ is 700 mm long with r_0 =6 mm. In order to apply the longitudinal potential, the structure is divided axially into 24 segments. The radius of each segment is r = 7 mm and the segments are all separated by a 1.0 mm gap. The gas-filled RFQ will be operated at room temperature at a pressure of 1×10^{-2} mbar. A longitudinal electric field equal to 0.75 V/cm will be applied over the segments of the system. The ions will be accumulated by forming a shallow potential well on the final three electrodes. Simulations show that the ions will reach equilibrium in less than 700 µs. In the present simulation, the ions are further cooled and accumulated into the trap potential minimum for an additional period of 2 ms. Bunched ions will be extracted from the RFQ and pass through the extraction optics, which consists of an extraction plate and einzel lens, and then will be accelerated to 2.7 keV in the first pulsing cavity. Once the ions are inside the pulsing cavity, its potential will be switched down to ground potential and the ions will leave the cavity without any further change in their kinetic energy. The ions will be refocused with the help another einzel lens and will be deflected 90^o with a third electrostatic mirror. A pair of einzel lens will be used to further focus and direct the beam into the second pulsing cavity, located inside the superconducting magnet. Ions will be decelerated to a few tens of electron volts by pulsing the second pulsing cavity with a potential slightly below the incoming ion energy. Ions will enter the first purification trap at ground potential with an energy of □80 eV, time spread of 1.7 μs, and an energy spread of 6 eV.

We have designed the Penning trap to have the flexibility of carrying out β-delayed proton decay studies and precision mass measurement of isotopes. The Penning trap system, consisting of a two cylindrical traps in a superconducting magnet with field strength of 7 Tesla has a very open geometry and will be especially useful for decay studies.

The first trap is used as a purification trap. The trap is a seven electrode cylindrical trap with inner diameter of 32 mm and total length about 212 mm. The trap has been designed to efficiently capture and cool the bunched ions using a pressure of 1×10^{-5} mbar.

The second Penning trap, the measurement trap, is also cylindrical with an inner diameter around 90 mm. It utilizes a tunable, orthogonalized 5 electrode geometry. The measurement trap will have a larger diameter than any other existing Penning trap facility, uniquely allowing for full radial containment of up to 4 MeV protons produced in the T=2 superallowed β-decays.

The large-bore magnet from Magnex Scientific will arrive on September 20th, 2011. The design of beamlines leading up to the Penning trap magnet is shown in Fig.1. The mechanical design of different components of the facility is in progress and we expect to begin building components later this year.

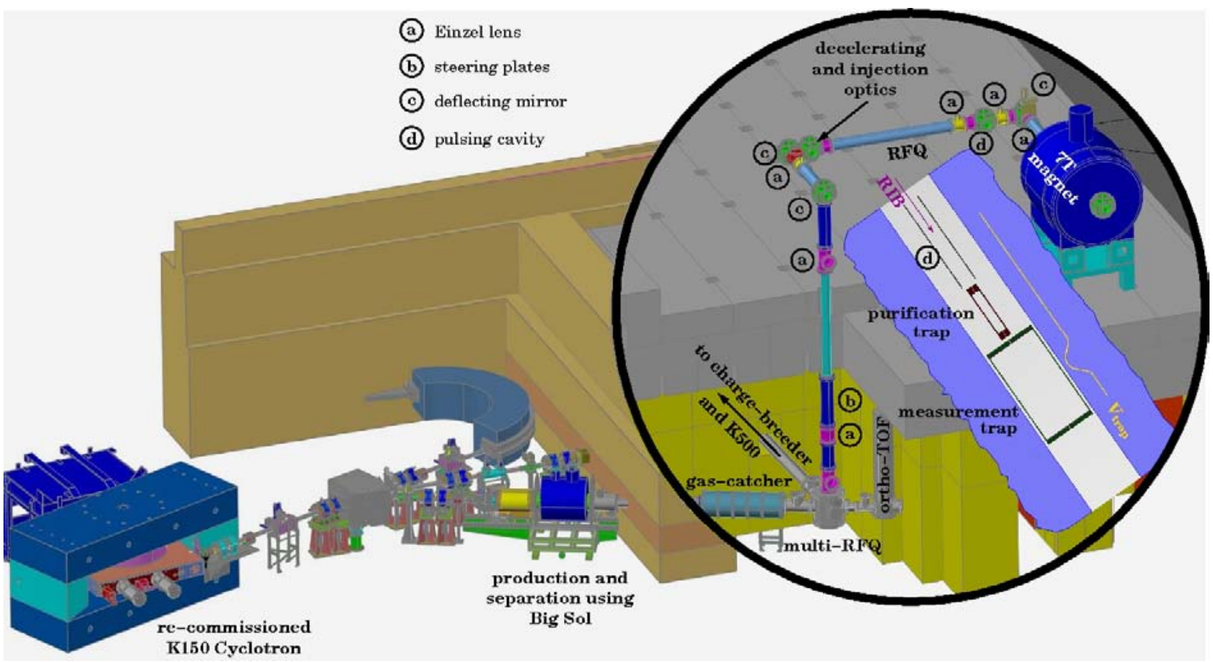

FIG. 1. Layout of the Penning trap facility. Primary beams from the recommisioned K150 cyclotron will produce radioactive ions in front of BigSol which will separate contaminants before the beam is stopped in the gas-catcher. Ions will be transported to the Penning trap magnet as shown.

[1] M. Bhatacharya *et al.*, Phys. rev. C **77**, 065503 (2008).
[2] SIMION Version 9.0.