C. FACILITIES OPERATION

C.1. Low Energy Ion Collision Facility--*M.P. Stöckli, C.W. Fehrenbach, P.E. Gibson and I. Reiser*

The period since the last 3-year progress report (June 1997) has been very fruitful, as the CRYEBIS delivered numerous beams, i.e. H, He, C, N, O, F, Ne, Al, Cl, Ar, Fe, Co, Kr, Xe, Ta ions and for the first time beams of Si, S, and U ions. The production of U^{64+} has set a new charge state record at our facility (Fig. 1). During the two-year period between November 1997 and November 1999, the CRYEBIS facility idled only 79 days. The 561 days used for physics experiments were divided into 61 beam times ranging from 1 to 24 days, averaging 9 days. Of those 561 days, 274 days (49%) were used by KSU graduate students, post doctoral fellows and faculty working on KSU projects. Another 214 days (38%) were assigned to outside users who came specifically for their beam time. The remaining 73 days (13%) were used by guest scientists and guest students who visited KSU for a longer time period. Training users and teaching KSU-undergraduate students (PHYS506) accounted for another 11 days. Beam development occupied 28 days, and 36 days were used to work on upgrading the facility, while maintenance required only 12 days. During the remaining 3 days the KSU-CRYEBIS was remotely controlled from Atlanta, GA, where the attendees of the Centennial meeting of the American Physical Society had the opportunity to conduct their own studies on the evolution of charge states, ionization thresholds, and dielectronic recombination.

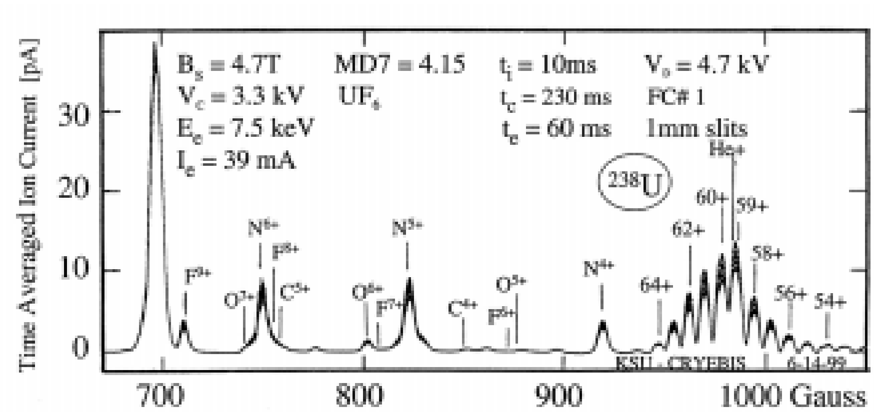

Figure 1. Charge state distribution for U^{238}.

The main recognition of our facility originates from our users who make extraordinary efforts to find answers to the questions in which they are interested. Accordingly we focus most of our efforts on making the facility more efficient and more user-friendly by simplifying controls and improving diagnostics. Unfortunately most commercially available control- and diagnostic equipment does not meet our stringent vacuum requirements, is too bulky to fit our very limited space, and/or is excessively expensive. Therefore most of the desired equipment needs to be designed for UHV, to fit the available space limitations, and to fit our budget. This is often labor intensive and therefore limits the number of improvements which can be implemented. The simplified controls and the improved diagnostics which were implemented, however, had a tremendous impact on the users' productivity as beams are now often tuned in a matter of minutes-to-hours compared to the span of hours-to-days required in 1992 after installing the first beamline. Below follows a brief description of a few of the more important improvements and upgrades that were implemented over the last three years.

The seed gas system has been upgraded with the installation of a spinning rotor pressure gauge that can accurately measure the extremely small flow rates required for the production of the highest charge state, and therefore will shorten the time-consuming optimization of the flow rate. A newly implemented synchronizer allows either for the synchronization of the expulsion with a pulsed target, or for the synchronization of the start of the confinement period with the 60 Hz line frequency, a feature that often substantially improves the stability of the ion beam (Fig. 2).

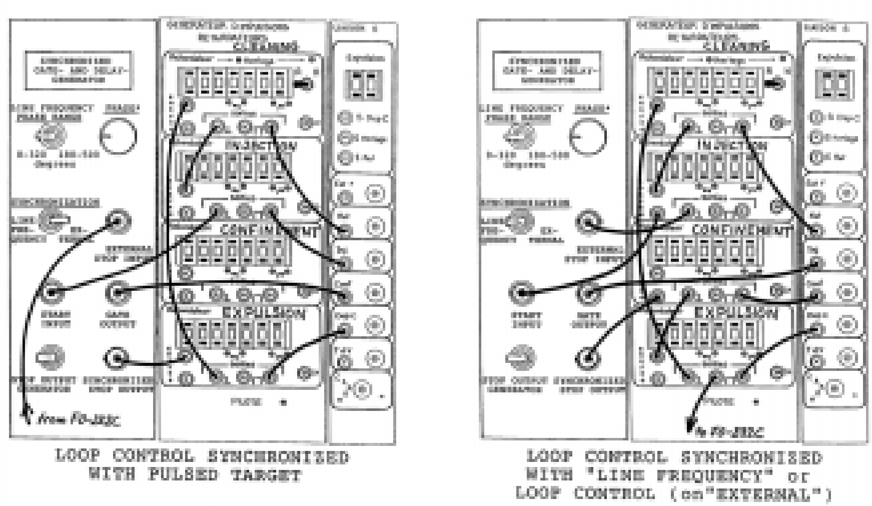

Figure 2. Beam timing and synchronization units.

A newly designed remote controlled retractable Faraday cup and a newly designed remote controlled retractable channeltron have been installed in the exit focal plane of the analyzing magnet. The new Faraday cup produces substantially smaller and faster dampened AC currents induced by the springs used for retractable connections and therefore allows for reliable measurements of substantially smaller ion beam currents. The new channeltron design includes a safety bracket to protect the channeltron in collisions with other extendable equipment. The new remote control automatically activates or disables the channeltron high voltage or the suppressor voltage when activating the corresponding probe. The fast activation and switch-over is a significant time saver and therefore should substantially improve the quality of the tuned ion expulsions.

After being magnetically analyzed, the ions can either be accelerated up to 160 kV per charge or decelerated when desired. The low energy ion transport to the desired target station has been substantially simplified with the installation of an electrostatic einzel lens in front of the quadrupole triplet, which previously was the only focusing device in the ion transport system at ground level. In the past, the deceleration was limited to roughly 20% of the initial ion energy, but the new einzel lens allows for deceleration to less than 2% of the initial ion energy if the ion transport is tuned to form a focus in the exit region of the accelerator column. Our data indicate that an ion beam was decelerated to 40 eV starting from 3 keV without a substantial loss of beam current.

The low energy ion transport on the high voltage platform plays a critical role in the formation of desired ion beams and therefore superior control and adequate information regarding the dialed electric- and magnetic fields are crucial. Therefore, all of our inadequate original electric field controls were replaced with new units featuring digital panel meters that display the output voltage(s) with a selectable sensitivity level. A newly implemented control unit for modular high voltage supplies features easily interchangeable calibration constants and therefore allows for a rapid re-calibration when exchanging high voltage units to match different requirements.

Attenuators are invaluable for a number of diagnostic measurements, especially if the attenuation rates are accurately known. We installed and calibrated our first set of attenuators in 1996 but were to learn that the attenuators sometimes did not yield the expected attenuation rate because a part of the beam passed on the side of the 1.25" wide attenuators designed to fit in the available 2.75"CF ports. This problem has been addressed with a newly designed set of four 2"x2" attenuators that was recently installed in front of 3"x3" slits, which can be easily adjusted to prevent such problems. Very soon we will calibrate and test the new set of attenuators to make sure we can provide calibrated attenuation factors of 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2%, 0.1%, 0.05%, 0.02% and 0.01%. A calibrated attenuation rate of roughly 10^{-4} allows for a rapid on-line measurement of electron multiplier efficiencies by comparing the electric current measured reliably in the pA range with the attenuated rate of a few thousand particles, which electron multipliers can measure reliably.

The high density of beamlines and equipment severely limits the places where slits can be installed. This problem has been essentially solved with a new design of 4-jaw slits where one slit is inverted so that the horizontally moving slits can be controlled from the same side (Fig. 3). This turns out to be also a significant time saver, as one no longer has to walk around the beamline to read the slit setting. Four BNC receptacles, each connected to the electrically isolated slits, allow monitoring the relative beam position. Optional ceramic BNC receptacles allow for trouble-free baking. An optional peripheral shield can also serve as an optimal pumping restriction and has allowed us to reduce the residual gas pressure in several beamlines by several orders of magnitude. The new slits have been crucial for achieving the UHV conditions required for several experiments.

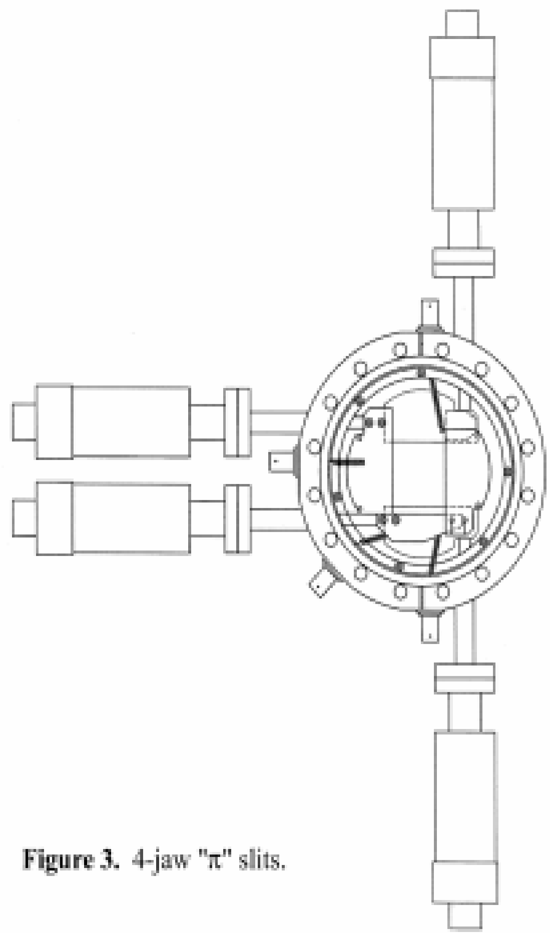

Figure 3. 4-jaw "π" slits.

Many users have benefited from the new beamline alignment system, which allows for checking the alignment even under vacuum. Its key component are expander nipples, which have two mini-CF view ports pointing towards the center of the 2.75"CF end (Fig. 4). Being installed on most of the 2.75"CF gate valves, which isolate the beamline from the switching magnet, the windows allow for illuminating a cross in the center of the gate valve with a modified flashlight without breaking the vacuum. Some users prefer to illuminate the center with a laser for which the exact location can be observed with a mirror on the second view port.

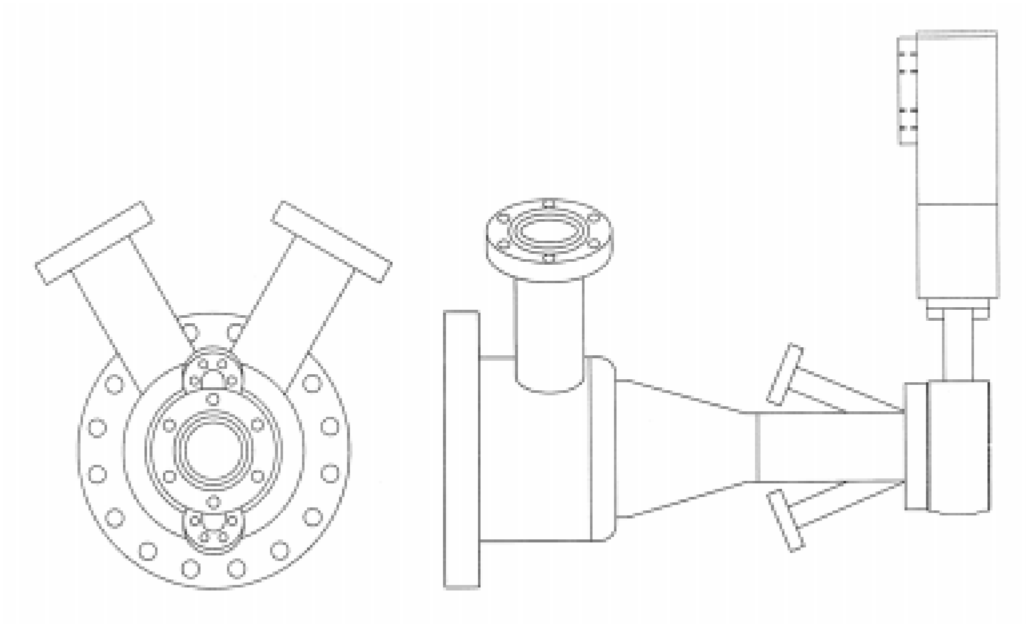

Figure 4. Beamline alignment expander nipples.

The micro-bunching system desired for experiments using time-of-flight techniques has also been substantially upgraded. The new system allows for dialing in the length of the microbunch as well as the length between microbunches (inhibit) with a set of clocks identical to the ones used to control the master cycle (Fig. 5). The two clocks are connected in a loop, which starts at the beginning of the expulsion period and ends at the end of the expulsion period by gating the loop with a VCR (thyristor) controlled by the gate signal from the expulsion clock. The synchronized micro-expulsion mode gives much better beam bunch stability and allows for the elimination of noise by averaging with an oscilloscope (Fig. 6). In addition, the new control emits electronic signals only during the expulsion time when ions can be expected, a signal which can be easily delayed and observed from the grounded end of a fiber optics link to be used as a timing signal or to be counted. A digital rate meter installed on ground informs the user about the microbunch rate or bunch rate averaged over up to 7 s with a 0.1 Hz resolution.

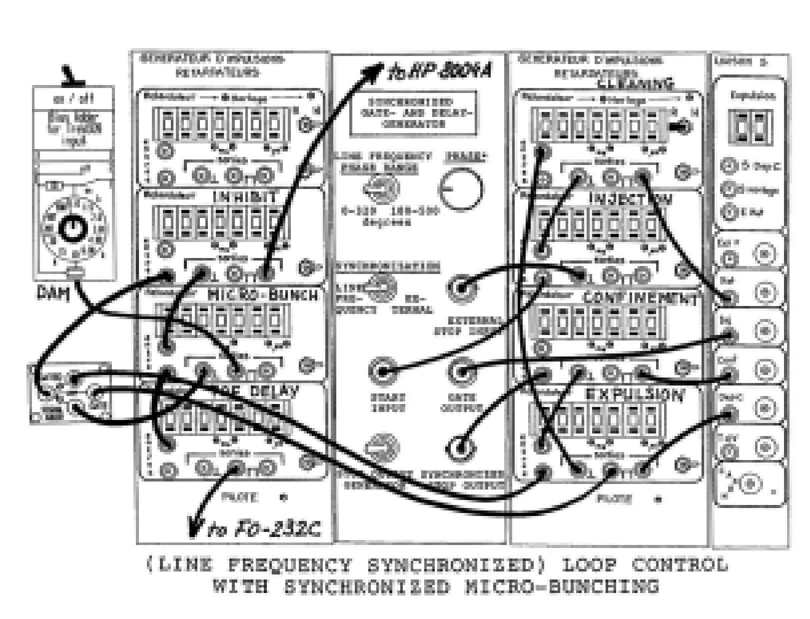

Figure 5. Beam synchronization and microbunching configuration.

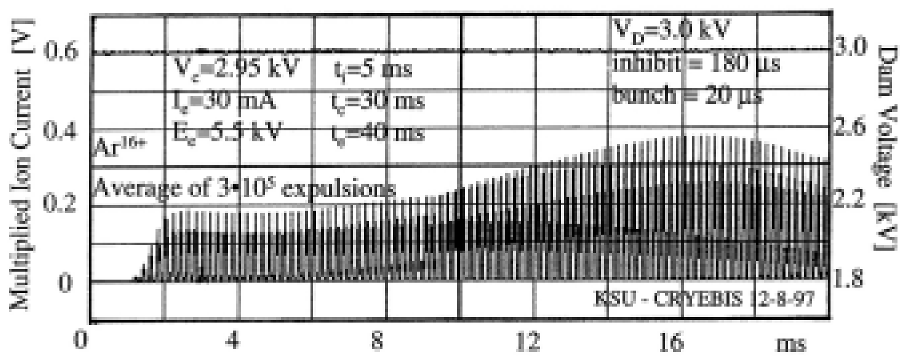

Figure 6. Microbunched Ar^{16+}.

The length of the microbunches, however, is limited by the slew rate of the high voltage amplifier and its control system, and therefore, the ion bunches need to be chopped to achieve an acceptable length. The control of the chopped bunch width has been substantially upgraded with the installation of compacter chopper plates, which are operated with a 10 ns +/- 3 kV push-pull transistor switch. The length of the chopped bunch can now be varied between infinity and 70 ns by varying the length of the control voltage signal to optimize time resolution versus bunch intensity (Fig. 7). This single switch adjustment is very useful as one can initially use the entire ion beam to tune the transport using the conventional probes before reducing the bunch length to levels where the ion beam current becomes unmeasurable.

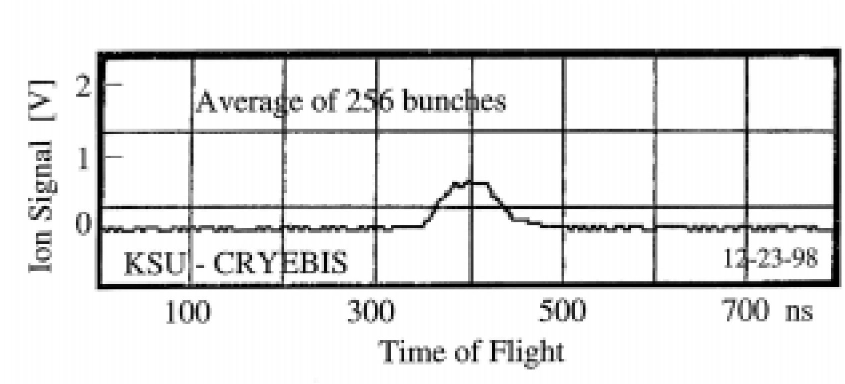

Figure 7. Time resolution of microbunched beam.

A new beamline has been installed on the switching magnet of the 5 GHz ECR ion source, increasing the usage of the ECR ion source as well as the demand for reliable operation. A long series of ECRIS troubles could be traced to an improperly modified high voltage connector which at times made intermittent contact. New power supplies have been installed on the ECR mirror coils replacing the original unit, which often tripped during bad weather. However, the new power supplies appear to frequently shut off the ECR discharge, a more serious problem. Presently we plan to re-install the old supply until we can identify and overcome the problems with the new supply and deliver a stable ion beam for very long durations.

A second set of 4-jaw beam probes has been installed in front of the "EBIS" electromagnetic analysis section to allow the centering of the ion beam before it enters the dipole magnet. These probes allow one to minimize as well as detect ion beam losses in the restrictions of the magnet and the electrostatic deflector. All 4-jaw slits have been replaced with slits of the new design to simplify and improve control as well as to optimize differential pumping. In addition, several differential pumping apertures have been installed to reduce the neutral flux from the ion sources reaching the central interaction region. A quartz heater lamp has been installed inside the vacuum chamber of the 20 degree inflection magnet to speed up the degassing of the magnet chamber after being vented.