LABORATORY DEVELOPMENT

Accelerator Improvements

During 1982 we have continued the work of redesigning and upgrading accelerator systems. As before, the highest priority was given to those improvements which have the largest impact of accelerator reliability and ease of use. In the case of Ion Source Terminal A, where fire damage necessitated a major rebuilding of the interior, it was possible to make some systems better than they were before the fire. Details of the work on Terminal A are documented elsewhere in this report.

In revising the job priority list for 1982 we identified 338 possible jobs of which 270 were selected for attention this year. This total includes work on the Polarized Neutron Facility but excluded work being done on the Dual Spectrometer and Cooler projects. Of the jobs selected, 106 have been completed and significant progress has been made on 20 more. This represents about one half the work we would normally accomplish because of the intense effort expended during the 5 1/2 months required for rebuilding Terminal A.

In the ion source area several systems have been improved or repaired. During the time that Terminal A was down for repair, an optical realignment was completed for beam line 1A, acceleration column A and the lenses, steerers, and P.I.G. source magnet in the terminal. This has resulted in improved steering and transmission for all beams. Major work in Terminal A not directly related to fire damage includes replacement of the 60 kvA alternator which supplies 3-phase power to the ion sources, completion of the helium-3 purification system and installation of a manual operating option for the hydraulic system to help in diagnosis of servo control problems. For Terminal B the hydraulic system was completely overhauled and the main heat exchanger replaced.

In beam line 1 several electrostatic quads have been redesigned and rebuilt and the RF drive system for the f/2 bunchers has been installed. A wide range electronic phase shifter for the beam chopper is now under development.

In the injector cyclotron the RF systems have been extensively improved. In April the RF tuning range was extended to 35.5 MHz. This change, together with an identical improvement in the main stage RF tuning range, allows the use of 4th harmonic acceleration rather than 3rd harmonic acceleration for 200 MeV protons. This improves beam intensity and stability. High-energy operation has also been improved by retuning the injector RF power amplifier output stages to give increased gain (and hence increased dee voltage) at high frequencies. Finally, the reliability and ease of operation of the injector RF system have been improved by replacing autotuning and ALC low level circuits with improved circuits built in NIM modules.

Several RF improvements that affect both cyclotrons have been completed this year. Switching has been provided at the control console to adjust relative dee phase (either 0° or 180°) for both cyclotrons simultaneously. A new electronic phase shifter has been designed for use in all RF systems. The first unit has been installed on the main stage.

The new 10 kW RF drive system for the main stage cyclotron, previously bench tested, was connected to the west resonator during the third quarter. This system is designed to provide increased dynamic range for the final amplifier and higher plate efficiency. Maximum dee voltage will exceed 200 kV. The system has passed all tests successfully and routine operation awaits redesign of the RF feedthrough bushing where sparking at high voltages can occur. Two more units, combining final amplifier and driver stage on a single platform, are under construction.

Earlier in the year a puzzling sparking problem limited the east dee voltage to less than 100 kV. After several possible resonator problems were eliminated, the difficulty was traced to a defective spark gate circuit which controls the RF drive.

In addition to RF improvements, several other main stage jobs were completed this year. An intermittent ground fault in the lower main coil of Sector C has been a source of worry for some time because a second fault could lead to loss of a coil, which in turn would require extensive disassembly of the sector magnet. The offending object which causes the fault is inaccessible and cannot be safely removed, but the fault has been eliminated by driving insulating spacers between the coil and the nearby wall of the valley vacuum chamber which tightly encloses it. The removal of the east valley vacuum chamber required for this fix also afforded the opportunity of adding radiation shielding blocks to the upstream edge of sector D. This protects main coils and trim coil leads from beam spray originating at the kicker magnets in the east dee.

In the north valley a 36" diffusion pump, complete with refrigerated baffle, has been installed. Foreline plumbing and baffle refrigeration are complete. Routine operation awaits electric power and tests.

In order to transmit maximum energy proton beams through the ν_z=1 resonance with high efficiency, new axial harmonic coils are required. These have been designed and constructed and await the availablity of manpower and access for installation.

Several power supply improvements are worth noting. The 300 kVA supply (Alpha 14) which provides current for the main stage sector coils now has a circuit added to protect against operation with unbalanced phases. The 250 kVA supply for the QDDM spectrometer (TR3) has received a similar protection circuit for phase inbalance plus added protection against over temperature faults. New protective circuits are under development for both main stage anode power supplies (350 kVA each). Redundant protection has also been provided for all magnets in the Beam Swinger System, Pion Spectrometer, and Polarized Neutron Facility. This was done by adding one-shot temperature switches to all magnet coils to turn off the appropriate power supply in case of overheating.

Main stage auxiliary loads include magnetic compensators, kicker magnets, axial harmonic coils and figure eight coils. In the past current supplies for these loads were assigned in a random and uncoordinated way. These supplies have been replaced with a new system involving a new power supply control center installed above the beam corridor and a set of modular commercial power supplies rated at 50 and 100 amperes. This system will be expanded later to include some beam transport loads.

Polarized Ion Source

On January 18, 1982 the polarized ion source suffered serious damage due to a fire in Terminal A, apparently caused by a high current power supply which overheated and caught on fire. Damaged in the fire was the power distribution system, vacuum controls, approximately one-half of the polarized source power supplies, the RF transition oscillators, computer controls and readouts and most of the wiring from the source to the relay racks. The polarized source itself, the ionizer, the terminal structure and the acceleration column suffered no damage.

A concerted effort to rebuild the source as quickly as possible was begun very soon after the fire. This effort culminated in successful operation of the source five months later on July 2, 1982.

During the reconstruction a number of improvements were made:

1. An automatic halon fire extinguishing system was installed in the Faraday cage.
2. Smoke sensors were installed in the terminal to kill the power and fans.
3. The alternator was moved out of the terminal greatly reducing both the heat and noise inside the terminal.
4. New very reliable high power RF transition oscillators were purchased and installed.
5. A new larger 20 KV isolated rack for the ionizer power supplies was fabricated.
6. An independent E2 power supply was installed.

Operation of the polarized source since July has shown increased reliability and ease of start-up. The set-up of the RF transitions is extremely reliable and reproducible. One need only dial in the proper magnetic fields and RF frequencies to get a highly polarized beam. Continued searches and optimization have not been necessary. The conditions have now been reproducible from run to run for six months. From July through December the source delivered approximately 250 shifts of beam, or two thousand hours. Of this one third of the running has been with polarized deuterons and two thirds with polarized protons. The average output of the source has been 7.1 ± 1.3 microamperes. Heavy running has made development and futher improvement difficult. Some work has been done on dissociator bottle geometry. The gas inlet system was redesigned to use commercial ultra-torr fittings for ease of bottle removal and change. A method was developed for drilling the exit hole through which the atomic beam leaves the bottle with accurate centering and of accurate diameter.

Further improvements to increase intensity are being considered. These take the form of a further attempt at cooling the exit nozzle of the dissociator bottle and/or the possible addition of a "super ionizer".

Development of a Universal Spin Precession System

Tests have recently been completed that demonstrate the feasibility of accelerating horizontally polarized protons with good transmission of the polarization. These are the first in a series of developmental runs that will extend through the next few months.

The primary element in the Universal Spin Precesion System is a spin precession solenoid with its field along the beam direction. This solenoid is presently located in beam line 1 between the two sets of electrostatic quadrupoles at the exit of the polarized ion source terminal Faraday cage. With the appropriate choice of field, this solenoid rotates the spin direction from vertical to horizontal. The proton spin is then perpendicular to the main field of the two cyclotrons, and it precesses many times during acceleration. So long as there is a unique orbit through the cyclotron (this depends mainly on the quality of the single turn extraction), the spin direction of the beam is still well determined after acceleration.

In practice, the number of turns may not be known, so a high-energy polarimeter is needed to measure the spin direction and degree of polarization after acceleration. If the final spin orientation happens not to be useful, in many cases it should be possible to change the turn number (by altering the main stage dee voltage) and choose another spin direction; a number of discrete choices should be available without major retuning of the main stage. Fine tuning of the spin direction is not presently possible, but would require only a Wien velocity filter after the precession solenoid in beam line 1.

This scheme has several advantages over a single solenoid placed on a high energy beam line. First, a high energy solenoid would require a substantially larger field which could only be obtained in the available space through the use of expensive superconducting technology. Second, the present design offers complete flexibility in the choice of spin direction, making possible both longitudinal and transverse polarization at the target. Third, this flexibility also means that horizontally polarized beam will be available for any experimental area.

A prototype high-energy polarimeter has been constructed, and will be tested shortly. It uses a thin carbon target, and is designed to work upstream from the main experiment. The target should be thin enough that it will not interfere with any experiment, and thus it can provide a continuous monitor of the beam polarization. Various detector geometries have been tested, and it seems adequate to use only a single NaI crystal on each arm with only a front, conical collimator. This scheme provides a resolution of about 1 MeV, adequate to resolve carbon elastic scattering, as shown in Fig. 5. To reduce the false asymmetries, the secondary electron current from the target (about 6-10% of the beam current) will be read at four electrodes along each side of the target and sent to an automatic beam steering circuit. There will be four detectors, two each in the horizontal and vertical planes. When operational, this will give experimenters a continuous monitor of the beam polarization. A furthur possible refinement for experiments in the QDDM is to have two polarimeters, one in the QDDM beam line and another in the switchyard, that together will yield both components of the horizontal polarization.

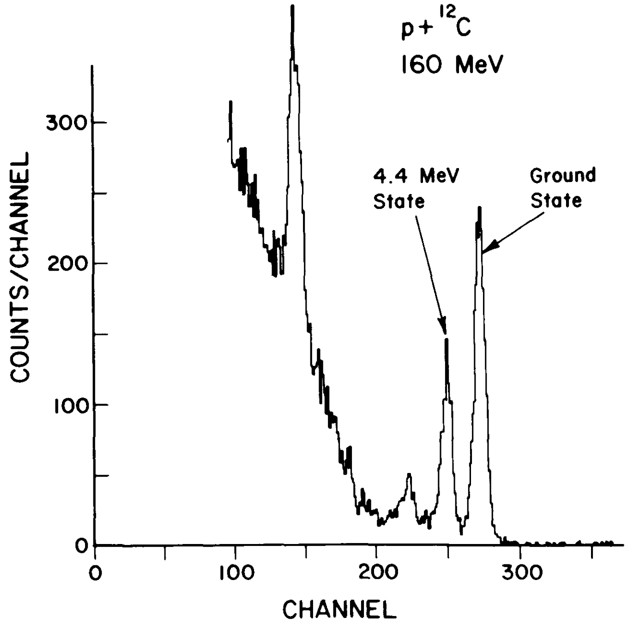

Figure 5. The charged particle spectrum recorded in a NaI crystal exposed to a test carbon target. The elastic scattered protons from carbon are located in an easily separated group.

The spin precession solenoid installed in December is suitable for protons only. During a recent experiment involving the calibration of a carbon-target polarimeter for use with 200 MeV protons at Brookhaven, we ran tests with this solenoid. The results are shown in Fig. 6 as the left-right or up-down asymmetry ε, which is the product of the beam polarization and the analyzing power of the polarimeter (about 0.6 in this case). As the field of the precession solenoid increases, the vertical component of the spin should disappear as the cosine of the field strength, as shown in Fig. 6a. The field for the complete removal of the vertical component was about 205 Amps. During acceleration, the spin precession angle is related to the angle through which the proton bends according to

$$\theta_{prec} = [(m+T)(\mu-1)/m + 1]\ \theta_{bend}$$

where m and μ are the proton's mass and magnetic moment, and T is the proton beam energy. In the test at 200 MeV, $\theta_{prec} = 3.1744\ \theta_{bend}$ at extraction. Thus a change of one turn should move the spin direction by about 63°. In Fig. 6b, the up-down asymmetry is shown as a function of turn number. It has a large magnitude and oscillations of about the right period. The extremes of this curve show the maximum horizontal polarization for this tune, and the depolarization

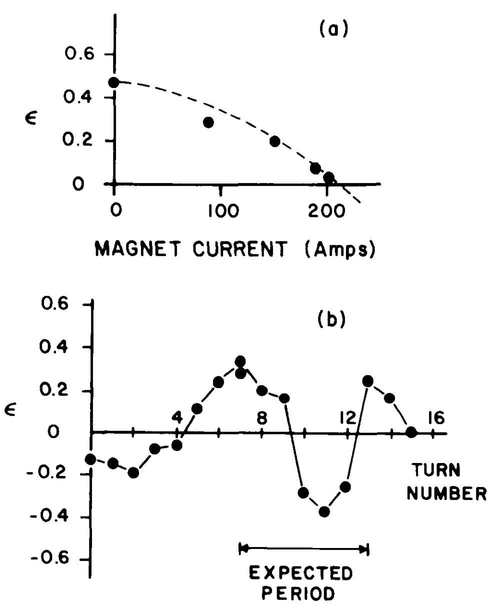

Figure 6. (a) The extinction of the vertical component of the beam polarization as the current in the spin precession solenoid is increased. The vertical axis shows the left-right asymmetry for a polarimeter whose analyzing power is about 0.6. (b) The change in the up-down asymmetry (using the same polarimeter) as the turn number (on an arbitrary scale) is changed in the main stage cyclotron. The period of the oscillation is discussed in the text. The maximum size of the oscillation represents the maximum horizontal polarization.

appeared to be about 25%. Diagnostics were missing at that time on the injector cyclotron, and there is no way of knowing how well separated the turns were then. Nevertheless, the observed polarization is certainly large enough for experiments.

During the next year we will study the long term stability of the machine tune, and seek ways to insure that a single turn is always available for use. This should make possible a variety of new experiments, including the measurement of the spin rotation parameter in elastic scattering and polarization transfer coefficients in (p,p') reactions. With a stronger precession solenoid, we should also be able to rotate the polarized deuteron spin, thus making it possible to study a different tensor analyzing power, A_{xz}, as well as measuring polarization transfer coefficients in deuteron-induced reactions.

Beam Transport System Development

During the repair of the polarized ion source after the electrical fire, the acceleration column was realigned as were a number of magnets and electrostatic elements in the terminal. Three electrostatic quadrupole doublets of an improved and shortened design were assembled, tested, and installed on beam line 1. A spin precession solenoid was installed in beam line 1A to provide in-plane polarized protons for acceleration through the injector and main stage cyclotrons and for feasibility tests performed.

An additional magnetic quadrupole singlet was added at the entrance of beam line 3 (close to the exit of the main stage cyclotron) to improve transmission of heavy ion beams. Local shielding has been added around slits 7, the downstream momentum analysis slits, to reduce neutron levels in the high bay assembly area.

Computer Controls

As the Sigma-2 control computer slips into its dotage, almost the entire software effort on it has been devoted to maintenance rather than development. Fortunately the computer seems to have been little affected by the January fire and only minor changes had to be made to conform to the revamped ion source controls.

Three new developments are worth noting. The program selection array at each operator station was changed from an 8 x 2 pushbutton to a 10 x 2 membrane switch configuration, expanding by about 50% the number of programs potentially available to the operator. The remote load switching facilities were expanded in anticipation of expanded sensor outputs for switched circuits. Finally, beam steering programs were added for the gamma cave and the polarized neutron facility.

On the new PDP-11/44 control computer a 9-track 800/1600 bpi tape unit was installed and system software modified to utilize its dual density capabilities. A DZ-11 with 8 serial ports was also installed. A CAMAC driver was completed and used to include the PDP in the IUCF intercomputer LINK. The LINK was then used to debug a data acquisition routine library using the cyclotron database on the PDP and ADC and status register values read using the Sigma-2. A system was developed to use serial lines to download memory in both mapped and unmapped DEC LSI-11 systems. Initial work was done on generating the standard cyclotron operator display, but further development awaits completion of a prototype LSI-driven operator station.