II. OPERATION AND DEVELOPMENT OF ATLAS

OVERVIEW

Highlights of the operation of the Argonne Tandem Linear Accelerator System (ATLAS), a DOE national user facility, and related accelerator physics R&D projects are described in this chapter. ATLAS is funded for basic research in nuclear physics but also provides beams for other areas of research and development, including material science, and fusion research. In addition ATLAS has a rich program in developing the tools of accelerator mass spectroscopy (AMS) applied to wide ranging research programs such as oceanography, nuclear physics, astrophysics and geology. Over half of the beam time is allocated to experiments for which the spokesperson is an outside user. Recent ATLAS operating performance and related development projects are described in the next section. ATLAS personnel are also involved in developing technology in support of a future advanced facility, based on ATLAS technologies, for beams of short-lived nuclei. Projects related to the Rare Isotope Accelerator (RIA) Facility are described in the third section below.

Due to budgetary constraints, the ATLAS operating schedule was reduced in June 2001 from a 7 day-per-week schedule to a running schedule averaging 5 ⅓ days per week. With this reduced operating schedule ATLAS provided over 4400 hours of beam for research and provided thirty-seven different isotopic beams. Statistics about beam hours and users are given in Table II-1. Improvements in the funding are anticipated, which will allow resumption of 7-day operation in the second half of FY2003 coinciding with the reinstallation of Gammasphere at ATLAS.

ATLAS provides a range of radioactive species with intensities in the range 3×10^6 particles per second. This year 7.4% of all beam-time went to radioactive beams. Beams of long-lived species ($T_{1/2} > 2$ hours) produced at other facilities and placed in the ATLAS tandem ion source and beams of short-lived species produced in-flight by inverse-kinematics reactions have been developed at ATLAS. See the Heavy-Ion Research section for a summary of recent physics results from experiments using radioactive beams.

Table II-1. Summary of ATLAS experiments and user statistics.

	FY2002 (actual)	FY2003* (extrap.)	FY2004 (pred.)	FY2005 (pred.)
Beam Use for Research (hr)				
Nuclear Physics	3896	4550	5240	5200
Atomic Physics	0	0	00	0
Accelerator R & D	105	150	180	200
Accelerator Mass Spectroscopy	325	400	400	400
Other	90	100	100	100
Total	4416	5200	5920	5900
Number of Experiments Receiving Beam	37	45	53	53
Number of Scientists Participating in Research	123	160	200	200
Institutions Represented				
Universities (U.S.A.)	20	19	19	19
DOE National Laboratories	5	5	5	5
Other	21	27	27	27
Usage of Beam Time (%)				
In-House Staff	57	35	25	25
Universities (U.S.A.)	28	38	45	45
Other DOE National Laboratories	7	12	15	15
Other Institutions	8	15	15	15
Total	100	100	100	100

*Assumes 5-days/week operations, started June 1, 2001, continues through FY2002 and 7-day/week operation resumes in FY2003.

A. OPERATION OF THE ACCELERATOR

(R. C. Pardo, D. Barnett, J. Bogaty, A. Deriy, G. Gribbon, R. Jenkins, A. Krupa, E. Lindert, A. McCormick, S. McDonald, F. H. Munson, Jr., D. R. Phillips, D. Quock, A. Ruthenberg, R. H. Scott, S. Sharamentov, J. R. Specht, P. Strickhorn, R. C. Vondrasek, L. Weber, and G. P. Zinkann)

a.1. Operations Summary

ATLAS provided a total of 36 different isotopes for research in FY2002. The distribution of species is shown in Figure II-1. There continues to be a strong trend toward increased variety in requested beam species over past years and this year represents another new record for ATLAS in the number of isotopes provided, even during a period of reduced operating hours. Even so, ^{58}Ni continued to be the most popular beam, commanding over 25% of all beam time. Beams heavier than nickel were provided 18.9% of the time.

This year the tandem injector provided a little less than 20% of the beams for ATLAS research. This was due in large part to the seriously deteriorated condition of the tandem. At this time the corona voltage grading system is unable to operate at terminal voltages greater than 6.5 MV. The tandem continues to be an important part of the ATLAS facility, both for operational flexibility with lighter beams and especially for its role in the long-lived radioactive beam program that continues to be an important research program. Therefore we have committed to a major upgrade of the tandem injector by replacing the corona system with an all-resistor voltage grading system. Other improvements that are part of the project include a new terminal communication system, foil changer readout and reactivation of the terminal electrostatic quadrupole/steerer system. The schedule is to begin disassembly of the tandem corona system in June 2003 and return the tandem to operation in September 2003.

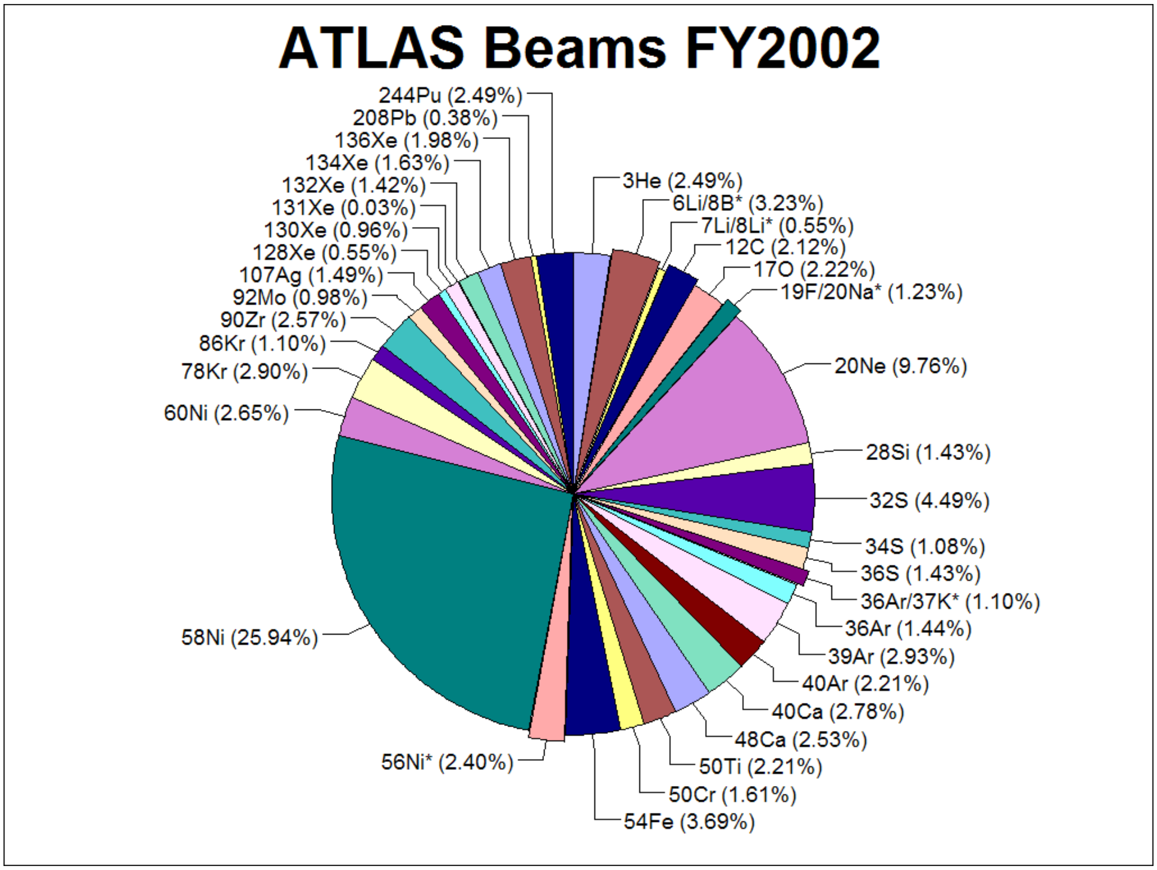

Fig. II-1. Distribution of beam time by isotope provided by ATLAS in FY2002. A total of 36 different isotopes were provided to the research program. Radioactive beams comprised 7.4% of all beam time in FY2002.

On the administrative side of operations, the facility's Safety Analysis Document (SAD) was rewritten and brought up to date. As part of the process, the facility's Safety Envelope and Operations Envelope were revised. These revisions provide us with some additional flexibility in handling higher current beams as needed in a variety of ongoing research programs such as in-flight radioactive beam production and the search for superheavy elements. The revised SAD has been reviewed and recommended for approval by a local ad-hoc committee and has been submitted to the DOE for acceptance of the revised Safety Envelope.

B. DEVELOPMENTS RELATED TO ATLAS

b.1. Status of the ECR Ion Sources (R. C. Vondrasek, R. H. Scott, and R. C. Pardo)

The ECR ion sources provided 27 different isotopes for the experimental program during FY2002, accounting for 82% of the beams produced at ATLAS. The increased reliance upon the ECR sources for beam production has been the impetus behind a program of upgrading the support systems of the ion sources. In addition to this work, refinement of existing techniques for material introduction into the ion source has continued.

Two development projects from last year have paid their dividends this year. The two-frequency heating implemented on ECR2 has produced a ^{238}U beam at intensities and charge states not before achieved at ATLAS. The peak usable charge state increased to 37+ with 3.0 eμA of beam. This allowed the beam to be accelerated to the coulomb barrier without the need of further stripping. In addition, the maximum intensity achieved was increased to 21.0 eμA in the 28+ charge state.

The second project was the utilization of a quartz liner on ECR2 during AMS experiments investigating ^{39}Ar. Even with the damaged hexapole bar reported last year still in place a running mode was found that allowed the first ocean samples to be measured. The quartz liner produced a reduction factor of 120 in the background ^{39}K contaminant.

The improved geometry of ECR1, realized through the rebuild in 2001, has allowed the source to operate at ever increasing magnetic field levels. This necessitated improvements in the source water-cooling system. The first step in this process was the replacement of the rotary water pump with a multi-stage centrifugal pump that delivers higher pressure and flow. In addition, the pump is constructed of materials which are highly resistant to the deionized water required by the system. This change has increased the cooling capacity of the system, but work continues on the primary side of the system to allow even more heat to be extracted.

As part of the ECR1 rebuild, the stainless steel plasma chamber was replaced with one constructed of aluminum. The change in the geometry of the chamber produced a mismatch of the RF into the chamber resulting in higher than normal reflected powers. To remedy this situation the klystron frequency was manually tuned from 10.500 GHz to 10.441 GHz producing a better match into the chamber. As a result, reflected RF power decreased from 25% of the total forward power to < 2.0% resulting in improved source stability.

On ECR2 a dry forepump has been installed to alleviate the problem of oil contamination in the ion source system. This change from an oil to a dry forepump has reduced the carbon contamination in the source from a typical $^{12}C^{4+}$ background intensity of ~30 eμA to ~3.0 eμA. The reduction in carbon background has improved the source charge state performance.

As was reported last year, the ECR2 hexapole magnetic field has been slowly degrading. This degradation was initially brought on by a loss of cooling to the hexapole in 1997 and then worsened by the continued heating due to the increased plasma loss in the degraded areas. Rather than repair individual magnet bars, the decision was made to replace the entire hexapole assembly. The new hexapole will be constructed of higher grade permanent magnet material and will have a slightly different geometry. These changes will result in a 10.6% increase in the radial confining field produced by the hexapole.

A general improvement made on both sources was the installation of gas handling systems. These systems allow for a speedier change from one sample gas to another as well as a reduction in contaminants. Dry pumps are utilized to evacuate the system, and the boil-off nitrogen from the cryogenic system provides the back-fill gas.

Solid material introduction continues to be the main focus of development activities. Several new techniques have been developed for the introduction of minute quantities of sample material (~4.0 mg) as well as an increased efficiency in the sputtering process.

To improve the sputtering efficiency, the location of the sample material was shifted from the front of the target to the side. Due to the magnetic and electric field lines in the region of the sputtering process, material on the side of the sample is preferentially sputtered. This process was exploited during a ^{180}Hf AMS run when “side sputter” samples were utilized in order to reduce any possible contamination from the sputter holder itself. The geometry of the sample holder was also altered to better direct the field lines to the region where the sample material was located. Both of these changes improved the efficiency with which the sample material was consumed by the source and helped to minimize the degradation of the sample holder.

High temperature ovens continue to be a focus for the ECR group. In the previous status report it was commented on that higher purity alumina was going to be utilized for oven construction in order to increase their operating temperature. An improvement was seen due to the new material but was not of the order to allow reliable oven operation at the temperatures required for the production of a high intensity titanium beam – which is the present goal.

b.2. ATLAS ECR Source High-Voltage Monitoring and Control (J. M. Bogaty)

All ion species are injected into ATLAS PII Linac at the same velocity, 0.0085c. Velocity matching of our two ECR ion sources is very important so as to allow beam tunes performed with one source to be used with the other source. To minimize retuning time and deliver the best beam quality, the replacement ion source must quickly be set up for the same total acceleration voltage. This requires precise absolute measurement of extractor and platform voltage for both ion sources.

We presently measure and display ECR source extractor and platform voltages with 12 bit (0.024%) ADC's. Overall accuracy is certainly less than this because our commercial high voltage power supplies use standard analog amplifiers to process voltage divider signals.

Independent, high-quality commercial voltage dividers have been installed to monitor extractor voltage at both ion sources. The dividers are sensed by precision instrumentation amplifiers developed at ATLAS. Particular attention was paid to closely matching the calibration of both ion source extractor voltage monitors. Our precision instrumentation amplifier and new high voltage dividers provide a relative measurement accuracy of 30ppm between ECRI and ECRII. Accuracy is preserved by replacing the 12 bit ADC's with 16 bit ADC's. Similar electronic techniques have been employed to monitor platform acceleration voltages for ECRI and ECR II.

b.3. Vibration Damper for an I-3 Interdigital Resonator (G. Zinkann, S. Sharamentov, and M. Kelly)

The last in a series of three very-low-velocity interdigital resonators was fitted with a vibration damper. The installation was completed on resonator R113, a β=0.016c cavity. Presently in the PII section of ATLAS there are now dampers installed in a β=0.008c cavity and two β=0.016c cavities.

The construction of the last damper was modified in order to reduce the cost as compared to the previous two dampers. The tapered cylinder on the first two dampers was machined out of a solid 3"X 26" cylinder of stainless steel. The new damper cylinder was formed from 0.125" stainless sheet. This modification lowered the construction cost by approximately $4,000.

The amount of power need for the fast tuner control is directly proportional to the fast tuner window. The average tuning window of the fast tuners prior to installing the vibration dampers was 389 Hz. After installing the damper on the first β=.016c cavity, we were able to reduce the fast tuner window by 35%. The operation experience demonstrated that this reduction was conservative. Under normal operating conditions, it is possible to reduce the average tuning window by as much as 50%. This would result in a 50% reduction in the power dissipated into the liquid nitrogen that cools the fast tuner system.

A new frequency vibration monitor chassis was constructed and employed in the analysis of the new damper installation.

The results for the last damper that was installed on the β=.016c resonator is shown in the Figs. II-2 and II-3.

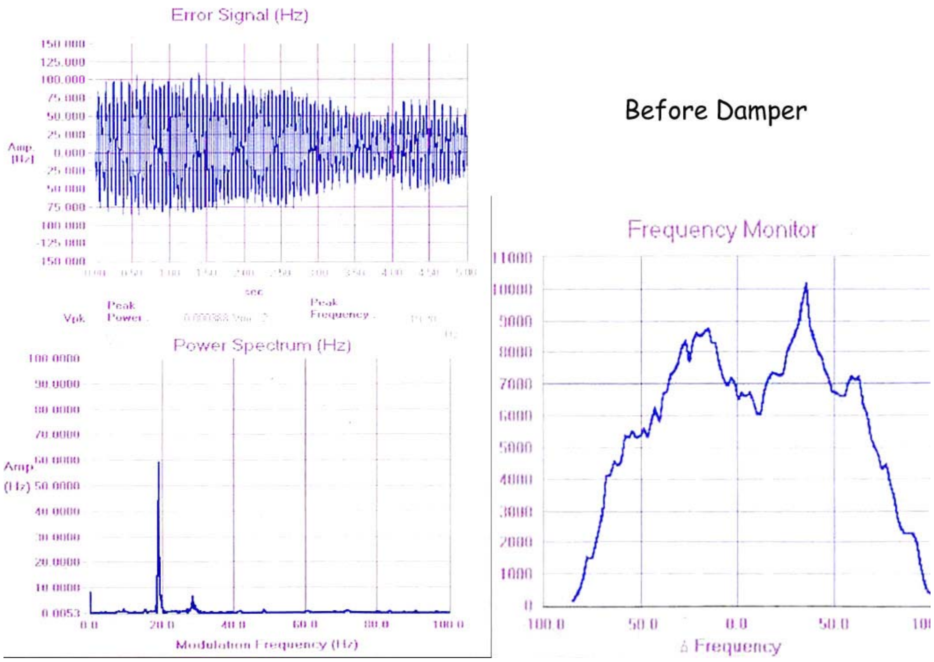

Fig. II-2. The lower right hand graph shows the distribution of the frequency deviations from the master oscillator frequency before the damper installation on R113, β=0.016c.

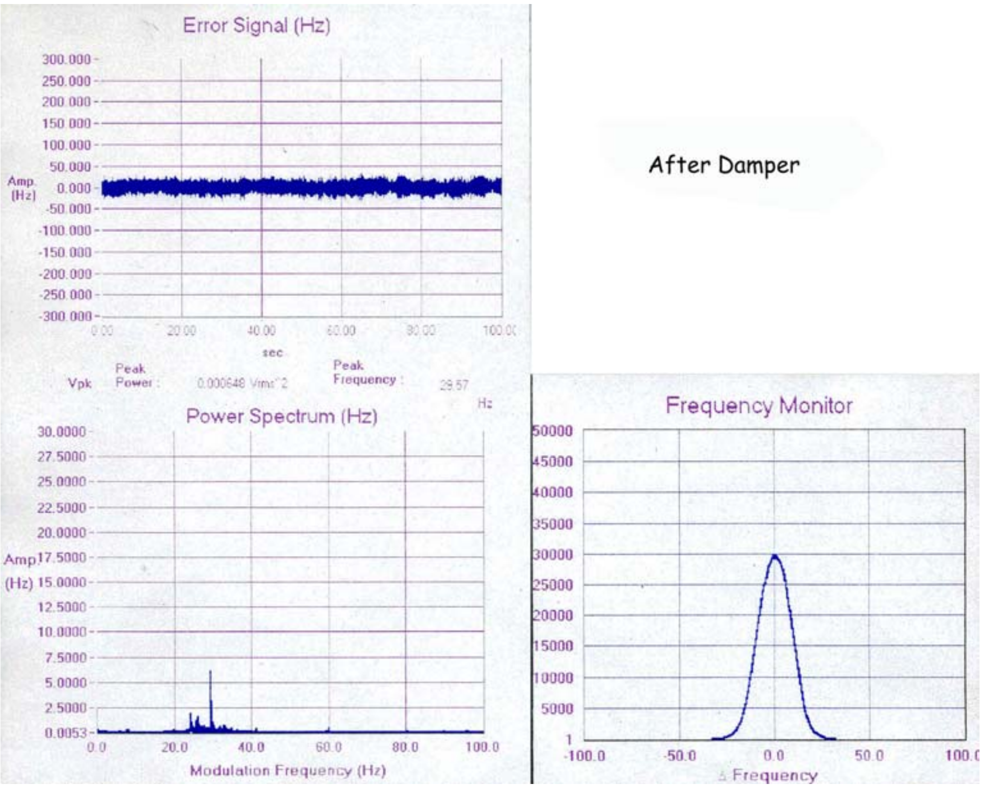

Fig. II-3. The lower right hand graph shows the distribution of the frequency deviations from the master oscillator frequency after the damper installation on R113, β=0.016c.

b.4. Superconducting Resonator as a Beam-Induced Signal Pickup (S. Sharamentov, P. Ostroumov, B. Clifft, R. Pardo, G. Zinkann, and D. Quock)

The first demonstration of using a downstream resonator as a beam-induced RF field detector was presented in the 2001 Physics Division Annual Report. To test this concept, one of the 48 MHz RF control modules was modified and a new version of a 360^0 linear phase shifter was built to implement a *continuous phase rotation* scheme. This module along with the linear phase shifter was used for the extraction of beam-induced phase information from the pickup resonator's composite RF field. Using this hardware, a series of reference tunes were done. All of the superconducting resonators in α-cryostat were tuned for a range of ion beam species with a charge-to-mass ratio from 0.15 to 0.375. Subsequent ATLAS accelerator runs with various beam species using this library of reference tunes showed that the quality of the tunes was extremely good.

The first version of the application software, which can be used for automated beam phase measurements, was also developed. We plan to test this software after all of the α-cryostat RF control modules are modified.

b.5. Bunch Shape Measurements in ATLAS (P. N. Ostroumov, N. E. Vinogradov, R. C. Pardo, S. I. Sharamentov, and G. P. Zinkann)

A device for the measurement of cw heavy-ion bunch time profile (or bunch shape) with resolution ~20 psec was built and installed at ATLAS in the beginning of 2002. The Bunch Shape Monitor (BSM) is based on the detection of secondary electrons produced by a primary beam hitting a tungsten wire. The bunch shape of the primary beam is transformed to a spatial distribution of low energy secondary electrons through transverse RF modulation. The modulation is achieved with a 97 MHz RF sweeper. The distribution of the secondary electrons is detected by a chevron microchannel plate detector (MCP) coupled to a phosphor screen. The signal image on the screen is measured by using a CCD camera connected to the PC.

During the last year, the BSM has been modified to provide user-friendly operation. The hardware modifications were related to the reconstruction of the HV power supply of the MCP and phosphor screen. A 90% transmission grid was installed upstream of the MCP to stop parasitic low energy secondary electrons. The BSM software based on LabView was modified for remote control and improvement of the data presentation. Complete operation of the BSM can be done from the ATLAS control room.

The BSM has been used for the measurements of various ion beam properties. As was found, the background signal observed during the first stage of BSM commissioning was originated by the primary beam halo hitting some parts of the wire holder. A careful vertical tuning completely eliminates any background signal. Figure II-4 shows typical bunch shapes for three different ion beams. Some measurements were done at a beam intensity of ~1 pnA (see Fig. II-4b). The BSM was applied for the longitudinal emittance measurements. For these measurements the very last Booster cavity was set in the bunching mode and its RF field level was varied while the bunch time profile was measured. Rms beam size was evaluated from the bunch time profile and used for a fitting procedure on the basis of beam dynamics simulation code TRACK. As a result of this procedure the graphs shown in Figure II-5 were calculated.

For some ATLAS runs a detection of the beam energy jitter is necessary and the BSM can be effectively used for this purpose and provide a resolution $\frac{\Delta W}{W} \cong 5 \cdot 10^{-4}$. The BSM is a powerful device for the measurement of longitudinal beam parameters and should be extensively used in the future RIA facility.

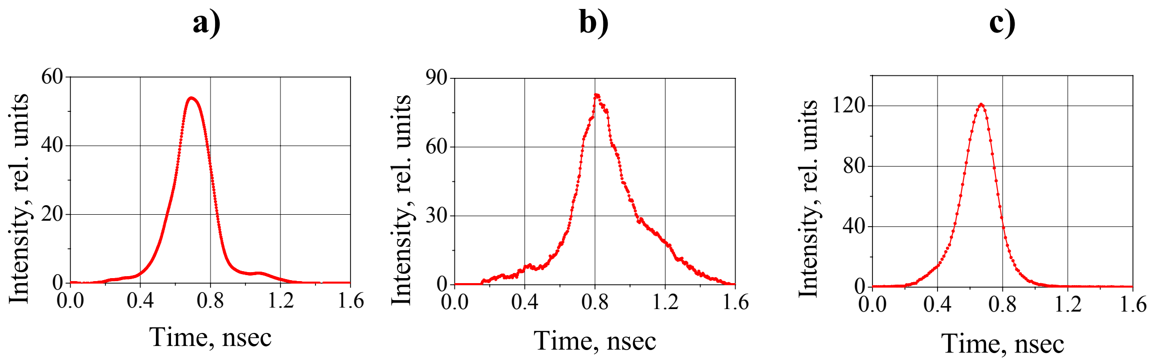

Fig. II-4. Typical bunch shapes. a) 397 MeV $^{58}Ni^{15+}$ beam, FWHM=344 psec; b) 153 MeV $^{16}O^{8+}$ beam, FWHM=315 psec; c) 185 MeV $^{54}Fe^{16+}$ beam, FWHM=215 psec.

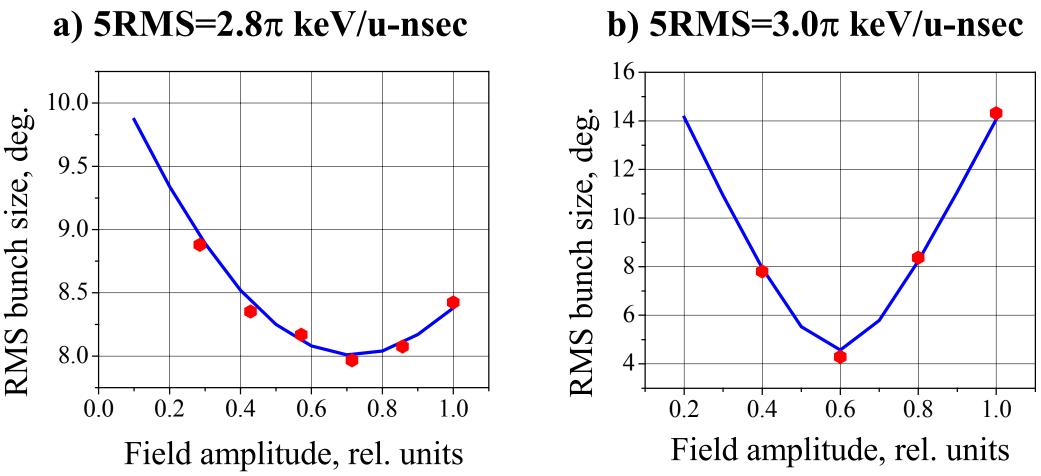

Fig. II-5. Rms bunch size as a function of the RF field amplitude in the buncher. Dots are measurements; solid curves are fitted by the TRACK code. a) 153 MeV $^{16}O^{8+}$ beam; b) 185 MeV $^{54}Fe^{16+}$ beam.

b.6. **Resonator Microphonics Monitor** (S. Sharamentov and G. Zinkann)

A Frequency Vibration Monitor (FVM) chassis was built for conducting two different types of frequency stability measurement. The first type of measurement is a measurement of the mechanical stability of a super conducting resonator (SCR). For this mode, the SCR works in a phase locked loop (PLL), and the instantaneous frequency difference between a cavity feedback signal and a high-stability reference signal generator are monitored. The second type of measurement is a direct frequency deviation measurement between a test signal (for example, ATLAS master generator RF signal) and a reference RF signal. FVM utilizes the Cavity Resonance Monitor principle proposed by J. Delayen.[1] It has a frequency range from 6 MHz to 400 MHz, which covers all ATLAS and RIA RF frequencies. The sensitivity of the FVM is about 10 mV/Hz, typically.

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[1] G. Davis, J. Delayen, M. Drury, T. Hiatt, C. Hovater, T. Powers, J. Preble, Proceedings of the 2001 Particle Accelerator Conference, Chicago, IL, 2001, edited by Peter Lucas (IEEE, Piscataway, NJ, 2001, p. 1152.

b.7. Resonator High Pressure Rinse (G. Zinkann, M. Kelly, and R. Jenkins.)

We have continued with the High Pressure Rinse (HPR) program described in last year's annual report. Six cavities in F cryostat and four cavities in B cryostat have been rinsed. The results for the most recently rinsed cavities are shown in Figures II-6 and II-7.

The first cryostat that was rinsed in August 2001 has degraded slightly in performance. The field levels in Figure II-8 show the operating levels before the HPR, immediately after the HPR and now (March 2003).

Using the current operating field levels for C cryostat, the average operating field levels for all of the resonators that have been rinsed to date went from 2.50 MV/m before the HPR, to 3.28MV/m after the HPR.

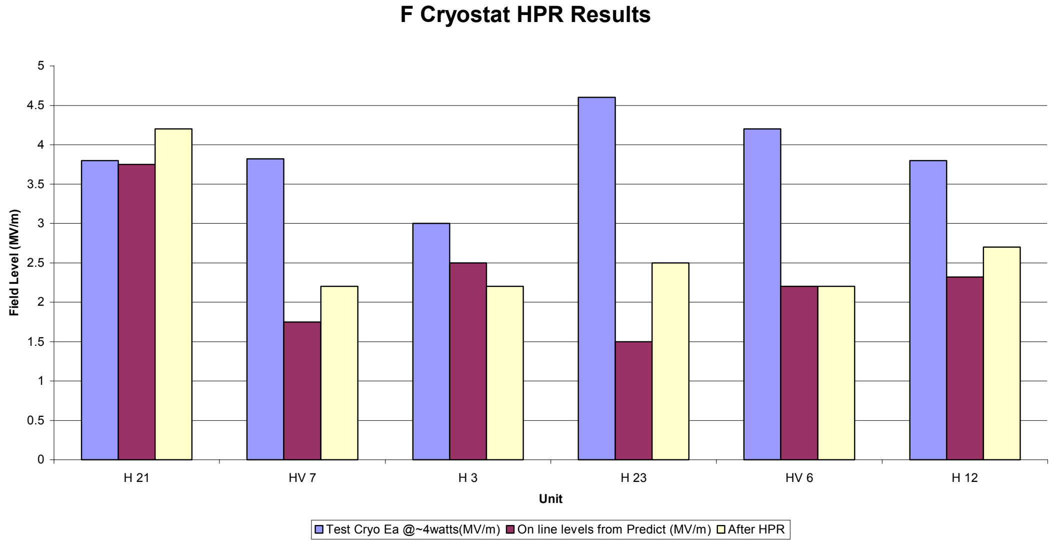

Fig. II-6. The HPR results for the six split-ring cavities in F cryostat.

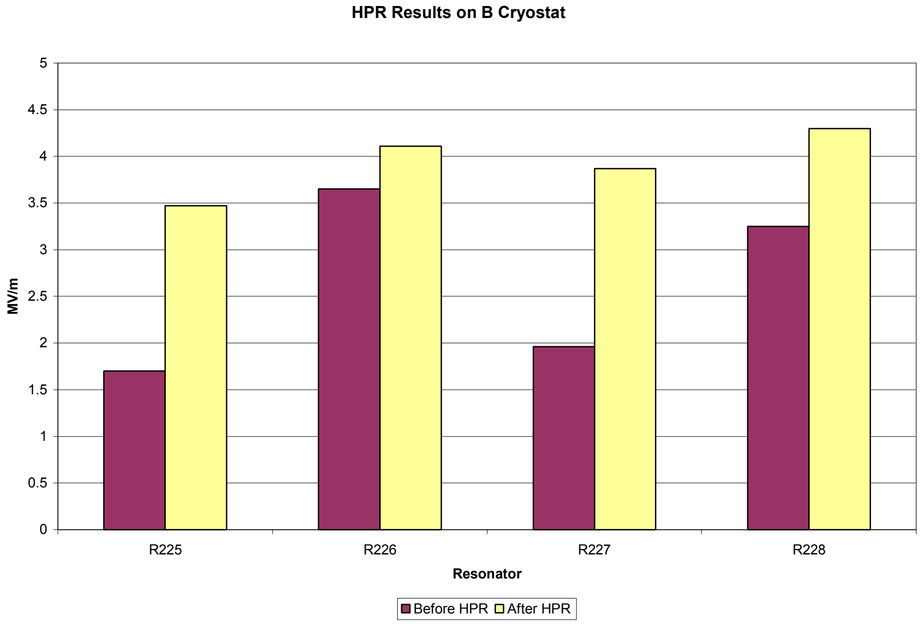

Fig. II-7. The HPR results on four cavities that were rinsed in B cryostat.

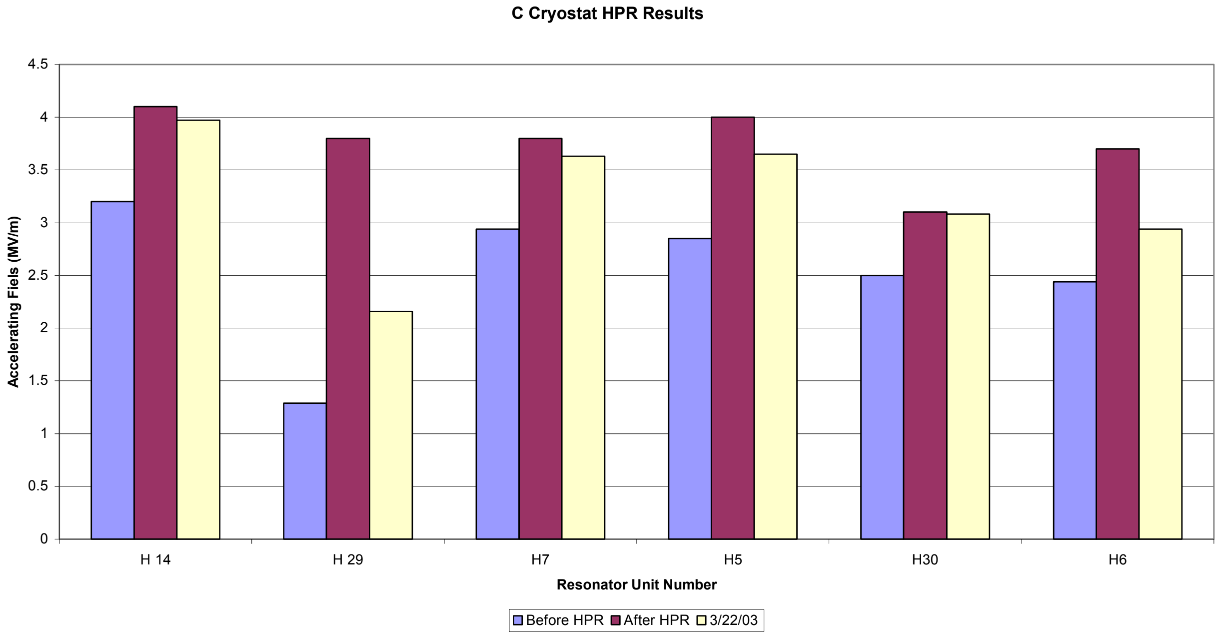

Fig. II-8. The operating field levels in C cryostat before the HPR (blue), immediately after the HPR (red) and about one and a half yeas after the HPR (tan).

b.8. ATLAS Control System (F. H. Munson, D. Quock, and R. Enshiwat)

It is important for computer systems involved with the ATLAS control system to keep pace with commercial software upgrades and versions. The real-time portion of the ATLAS control system is based on the commercial product Vsystem marketed by Vista Control Systems. A Beta release of the newest Vsystem version (version 4.3) has been provided by the manufacturer. This version has been installed on an off-line system, and is being tested as a precursor to a future on-line installation.

Remote access to the ATLAS control system by authorized personnel is crucial for supporting operations. In the past this access has been provided by a telephone modem. With the heightened level of computer security, the laboratory has discouraged the use of telephone modems. To address this issue a new system has been installed that provides VPN (Virtual Private Network) and NAT (Network Address Translation) capabilities. These capabilities allow password protected remote access to the ATLAS control system through a secure channel, and the telephone modem has been disabled.

Several new or upgraded processes have been implemented. A new process that provides a graphical interface for controlling and monitoring a series of vacuum gauges that are associated with the ATLAS cryogenic subsystem has been made available. A new process has been installed that digitizes beam profile waveforms, and graphically reproduces the waveforms at the operator's console with the capability of archiving the data in a relational database. A new process has been made available that automatically reads a pre-determined set of Faraday cup currents with an option for archiving the data in a relational database. A new process has been implemented that enhances the capabilities of resonator module testing and data recording, which provides multiple options for data reporting and storage. The "Mass Scan" process has been updated. This new version allows the user to start multiple instances of the process, running each instance simultaneously and separately for each ion source at ATLAS. Finally, a new version of the process that measures TOF (time-of-flight) beam energies has been created. The new version makes it possible to read TOF energies in both the ATLAS exit area and Target Area 2 by detecting which target area is in use in order to use the correct detector pair combinations.

b.9. ATLAS Cryogenic System (J. R. Specht, S. W. MacDonald, and R. C. Jenkins)

A computerized vacuum readout and control system was installed and commissioned. This system monitors all LHe and LN_2 distribution line vacuums via the ATLAS Vista control system. The Vista system also provides control of the vacuum gauges.

The installation of a new superconducting solenoid magnet was completed. This system required the installation of new LN_2 and LHe filling systems. This magnet is used to focus radioactive beams for the experimental program.

The planning and engineering necessary for installing a surplus model 2800 LHe refrigerator obtained from LLNL was started. This 300 watt refrigerator would replace our existing 150 watt model 1600. Besides providing additional cooling, vacuum breaks would be added to the distribution system allowing increased cryogenic operating and maintenance flexibility.

Two additional He compressors were added to the existing ATLAS compressor system. These units were obtained from LLNL. They will provide standby capability in the event of failure of any of our eight previously installed compressors. In addition they will provide the additional capacity needed when the LLNL 2800 is installed.

b.10. Selectable Power Supply and Magnet (P. Strickhorn, B. Clifft, and S. Sharamentov)

ATLAS emergency maintenance relies heavily on exact replacement spares that may be quickly swapped with a failed unit to restore operation quickly. For major magnet power supplies this philosophy is difficult to implement, but has been possible for some of our most important magnets. The ability to select between two (2) magnet power supplies and two (2) magnets (22º magnet and Michigan magnet) provides for a quick change over to an existing backup supply in case the original supply fails. This permanently wired switchover system reduces switching time between large power supplies to approximately 15 minutes versus up to 2 hours during off-shift hours. It also enhances personnel safety, since the system is hard wired, and eliminates the potential of working hot or incorrect termination when connecting the current leads.

This system consists of two power supplies, two DPDT switches, two magnets (22º magnet and Michigan magnet) and an interlock chassis. The interlock chassis is a latching interlock system and monitors which power supply and magnet are selected, display the status of each device selected along with its corresponding water flow and temperature switches, and provides an interface into the ATLAS control system.