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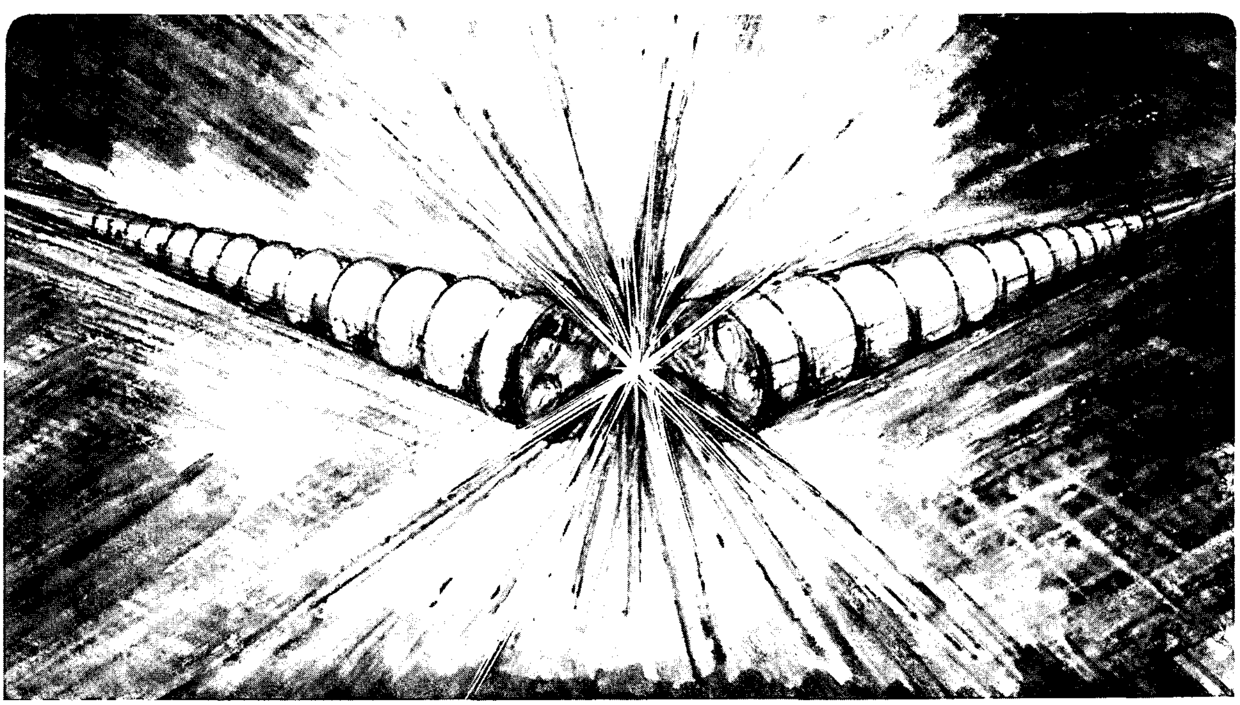

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BEVALAC VERSATILITY: OPERATIONS ACHIEVEMENTS IN THE MULTI-TASKING MODE*

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Abstract

Demand for relativistic heavy ion beams at the Bevalac has increased dramatically in the past two years. To keep pace, the Bevalac makes use of five injectors, precise guide field control, preset beam transport line tunes, nine nuclear science target areas, and three biology/radiotherapy areas, along with elegant control computer algorithms, to achieve high operating efficiency. Routine operation includes as many as ten ion/energy/beamline changes per day, 15 major nuclear science experiments each year, radiotherapy on nearly a daily basis, with biology experiments operating biweekly. High operating efficiency and low failure rates combine to produce high annual research hours.

Introduction

Operations achievements of the Bevalac have been described before.[1,2] In this paper, the most recent developments will be discussed. Between 1987 and 1989 our emphasis has been on maximizing research time while still maintaining versatility of operation, including fast-switching of ion, beam line and energy, to accommodate each of our research teams. We have made improvements to the accelerator facility to increase the variety and intensity of ions available to the experimenter. We have made improvements in understanding and capitalizing on the optical properties of our beam transport lines. We have continued to evolve the beam-line equipment and experimenter facilities. Accelerator control systems are being redesigned; implementation is in progress to facilitate the fast-switching techniques reported earlier. As the nuclear science programs advance, their demands on the accelerator for intensity and stability have increased, and we are meeting those demands. Charged-particle radiotherapy has, of necessity, focused on the Bevalac as the source of ions following the shutdown of LBL's 184" cyclotron, which was used for helium ion delivery. We have added a therapy treatment area. As the programs served by the Bevalac have evolved, so have the methods of addressing them.

Specific Achievements

Research Hours

For both FY 1987 and FY 1988 the Bevalac was able to deliver just over 4000 research hours to our nuclear science and life sciences programs. This represents a 26% increase over the average of the two previous years and has come about in part through very careful attention to the limited operations budget with emphasis on research hour production and a lowering of priorities for other operations-related projects that could be deferred. Our failure rate remains at about 13-14% of total scheduled hours and consists mostly of short outages scattered throughout the year. Record research hours in FY1988 is a particularly significant achievement because an entirely new facility, what we call "Biomed Cave III", was commissioned.

Scheduling the Bevalac

Very substantial effort has been expended in the development of fast-switch techniques[1,2,3] so that nuclear science experiments could make use of about 20 minutes every half hour during the day four days per week when the beam was not needed for the radiotherapy program. That effort paid off in 1987 and early 1988 when the daytime interstices could be filled by nuclear science experiments. With the arrival of helium radiotherapy at the Bevalac, and an increased patient load, a new operating philosophy was required. Over a period of several months, in cooperation with both the nuclear sciences and life sciences divisions, a scheduling algorithm was developed which addresses the needs of both disciplines and is proving to be a satisfactory implementation of the new philosophy.

Our current philosophy is to devote the accelerator to charged particle radiotherapy for 10 hours each day for four days per week. During these 10 hours both helium and neon radiotherapy in two treatment areas is accomplished; fast-switching techniques developed earlier have been instrumental in enabling us to deliver the beams at the energies and intensities required to each treatment area with but a few minutes notice. Radiobiology, which complements the radiotherapy program, and has independent areas of research, enjoys two overnight periods every other week. Nuclear science programs operate every weekend and on most other overnight periods. In addition, the nuclear science program every ninth week has a ten day period available, a total of some 230 uninterrupted experimental hours. Maintenance periods have been consolidated and reduced to the minimum reasonable for sustained operation of the accelerator. Accelerator studies are pursued for a few hours each week.

Building on past accomplishments, we are able to tune up a nuclear science experiment early in a week, and then quickly return to that tune some days later by recall of appropriate parameters from the control computer data base, another result of the fast-switch development. Research hours in the past two years have been maintained, even with the substantial increase in complexity of the experimental programs we serve.

Beam Delivery

One of the limiting factors in providing high intensity beams to our experimenters and radiotherapists is the substantial time-dependent structure of the extracted beam. Work has proceeded along two fronts. The first has been to develop beam extraction hardware[4] that minimizes time-dependent structure. At the same time, this hardware was developed to provide a constant intensity beam from Bevalac pulse to Bevalac pulse. The second front is advancing at this time with the development of a solid-state power supply for the Bevatron's main guide field magnet[5] capable of supplying low-ripple d.c. for particle energies of 250 MeV/n and lower. In addition, development is proceeding on extension of the flattop portion of the magnet cycle from about a 1 second beam delivery time to 5-10 seconds, thus improving the duty cycle substantially.

External Particle Beam Transport System

We have refined the application of optics calculations to the external beam transport lines, and have been able to achieve solutions that are easily reproducible from week to week. For delivery of radioactive beams generated at F1 of the external particle beam system, these solutions have allowed us rapid tuning to downstream targets with minimum transmission losses.

Just downstream of F1, at the beam line branch point, a new laminated dipole magnet has been installed[6], replacing two older dipoles that had been doing the same job. The replacement removes

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the scaling requirement for currents in the old dipoles and reduces the dipole d.c. power needed at that point. Switching time for this new magnet is just a few seconds, so that rapid moves from one target station to another are truly possible now.

Magnet power supplies have been reworked to provide much higher regulation and better overall performance. Details are available in a companion paper at this conference[7].

Experimental facilities presently available include the Low Energy Beam Line (Beam 39); Beam 44, which is a combined line for both low energy and secondary-beam experiments, and is one of two lines used for radioactive beam exploration of rare isotope production; Beam 30, which contains the Di-lepton Spectrometer and an additional pion-production spectrometer downstream; the Streamer Chamber (Beam 26); a general purpose spectrometer used primarily for atomic physics and cosmic-ray physics (Beam 40); the Heavy Ion Superconducting Spectrometer (Beam 42); and an irradiation station for high-fluence bombardments.

Three biomedical areas are presently in service; two are patient treatment areas and one is a research area. One patient treatment area that contains ISAH is commented on below.

Accelerator Control System

For the past two years we have been remodeling the accelerator control system, replacing systems installed in 1975-77 with a modern one[8], capable of responding to our needs for accelerator multi-tasking. This control system is based on Sun Workstations and graphics presentations rather than character presentations being used by the operators for control. Basic to the control architecture is a networking scheme of processors for various tasks reporting to whichever control console is being used at the moment. This flexibility of designing the processor system to match the unit being controlled is new to us. Our previous system relied on four centrally driven processors to control the many hardware tasks required for accelerator operation. Response time with the new system will be on a pulse-to-pulse basis, virtually real time for the operations staff.

Particle Availability

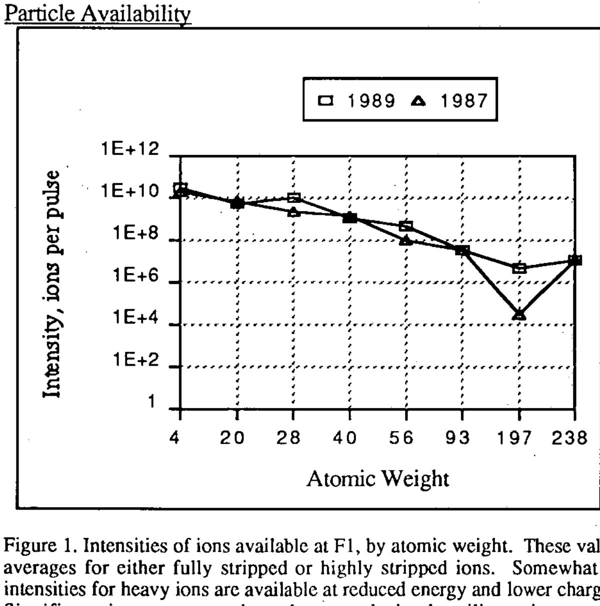

Figure 1. Intensities of ions available at F1, by atomic weight. These values are averages for either fully stripped or highly stripped ions. Somewhat higher intensities for heavy ions are available at reduced energy and lower charge state. Significant improvements have been made in the silicon, iron, and gold intensities.

Ionizable elements throughout the periodic chart are available. We have standardized on several (atomic weight): helium (4), carbon (12), neon (20), silicon (28), argon (40), calcium (40), iron (56), niobium (93), lanthanum (139), gold (197), and uranium (238), but have accelerated more that 20 different species of ion, including ^{46}Ti and ^{98}Mo. Beam intensities at F1, the first focus of the External Particle Beam transport system, are shown in Figure 1. These intensities are in terms of particles per Bevalac pulse, and should be reduced by a factor of about five to convert to average particles per second over a 1-minute or longer time period.

Large improvements in intensities have been made for several ion species throughout the range. Not so large, and not readily visible in Figure 1, are improvements of factors of two to five for most ions. These improvements have come about as a result of several improvement projects at the SuperHILAC and the commissioning of a duoplasmatron source at the Bevalac's local injector for high intensity very light ions (protons, deuterons, helium).

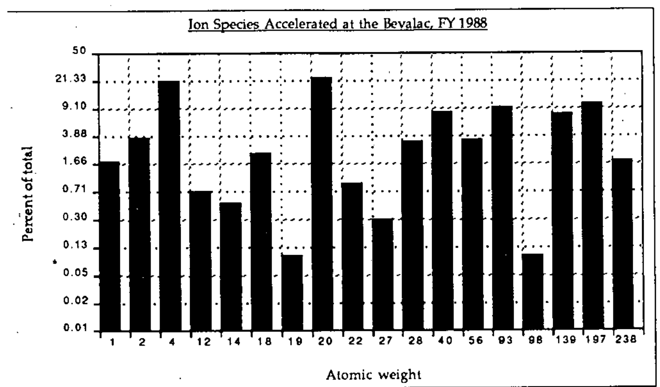

Figure 2. Graph of relative use of ions as a function of atomic weight during FY1988. Note that ordinate is logarithmic; the breadth of ion availability is emphasized here.

The breadth of ions available is shown in Figure 2. Although the plot is for FY1988, a very similar figure obtains for FY1987. The most used ions are helium and neon, and are accounted for by the radiotherapy program. Many ions, from light to heavy, register at the 3-9% level, showing the range of experiments being done.

Ion availability has been improved by SuperHILAC projects centered around modification of pre-stripper drift tube quadrupoles[9] to provide higher focussing strengths and better optics through the accelerator. In addition, bunchers were installed for the ADAM (mass 22-136) and the ABEL(mass 40-238) ion sources. Careful study of the emittance of the SuperHILAC[10] should lead to much better matching of the SuperHILAC to the Bevalac, and to still higher intensity heavy ion beams.

Helium ions at high intensity, demanded in the radiotherapy program, are now being delivered by the local injector duoplasmatron source[11]. In addition, of course, the local injector PIG source regularly provides ions up to neon, and can produce some silicon and argon beams.

New Facility

Closure and demolition of LBL's 184" cyclotron beginning in January, 1988 compelled two charged-particle radiotherapy programs using helium beams from that facility to relocate to the Bevalac[12]. Already in existence was a beam line to CaveIII, the final target area in the beam lines used by the Life Sciences programs. Necessary for implementation of the helium radiotherapy program at the Bevalac was relocation of "ISAH" (Irradiation Stereotactic Apparatus Human) from the 184" area to Cave III. ISAH is a large framework supported on a granite base that can position an object as large as a person with a placement resolution of less that 1 mm. It was built at LBL and is unique. Its relocation was accomplished in the estimated 5 months, and the first Bevalac patient was treated in early July, 1988, launching yet another new program at this accelerator, one which needed to be and was integrated into the daily operation of the Bevalac.

Outlook

A bright future is in store for the Bevalac. Programs for improvement currently in place will provide unprecedented opportunities for high intensity heavy ions delivered at a uniform rate for as many as 36 seconds per minute, instead of the current 12. Radiotherapy, biology, nuclear science and atomic physics will have a modern accelerator facility, with state of the art beam delivery and transport systems. Multi-tasking of this accelerator is a way of life for us. It is very comfortable, and we intend to maximize its utility to our users.

References

1. F. Lothrop, R. Stevenson, R. Miller, and J. Alonso, "Achievement of Bevalac Rapid Mode Switching". IEEE Transactions on Nuclear Science Vol. NS-32, Number 5, p. 3119 (1985), also LBL-18939.

2. F. Lothrop, J. Alonso, G. Krebs, R. Miller, R. Stevenson "Mixing and Matching Bevalac Programs: A Progress Report on Rapid Switching of Ions and Other Operations Highlights", Proceedings of the IEEE Particle Accelerator Conference, p. 1594, also LBL-22166.

3. B. Frias, J. Alonso, R. Dwinell, and F. Lothrop, "Control of the Bevatron/Bevalac Main Guide Field Power Supply for Fast Ion Switching Operation", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL 25887.

4. M. Nyman , S.A. Lewis, L.L. Shalz, and M.M. Tekawa, "Beam Intensity Control Algorithm at the Bevalac", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL-25949.

5. R. Frias,J. Alonso, R. Dwinell, and F. Lothrop, "A Proposal to Pulse the Bevatron/Bevalac Main Guide Field Magnet with SCR Power Supplies", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL-25929.

6. S. Abbott , J. Alonso, J. Brown, J. Kalnins, G. Krebs, and R. Reimers, "Design of a Pulsed Switching Magnet for the Bevalac", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL-25884.

7. G.D. Stover, J. Halliwell, "Novel Improvements and Upgrades of Existing Magnet Power Supplies at the Bevalac", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL-25946.

8. S.A. Lewis, J.R. Guggemos, L.L. Shalz, A.K. Biocca, W.L. Brown, and G.S. Boyle, "Progress on a New Control System for the Bevalac", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL-25928.

9. B. Feinberg, G.U. Behrsing, K Halbach, J.S. Marks, M.E. Morrison, and D.H. Nelson, "Laced Permanent Magnet Quadrupole Drift Tube Magnets", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL-25916.

10. G. Krebs, J.G. Kalnins, M.S. Abinante, J.R. Alonso, B. Feinberg, K. Fowler, J. Guggemos, J. Staples, R. Thatcher, and E. Zajec, "Emittance at the SuperHILAC and Bevalac Transfer Line", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL-25988.

11. E. Zajec and G. Stover, "Bevatron Local Injector Duoplasmatron Ion Source Performance", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL-25882.

12. J. Alonso, J. Bercovitz, W. Chu, B. Ludewigt, M. Nyman, C. Pascale, M. Phillips, T. Renner, R.P. Singh, R. Stradner, R. Tafelski, and R. Walton, "Relocation of the Helium Ion Radiotherapy Program from the 184" Synchrocyclotron to the Bevalac", presented at the 1989 Particle Accelerator Conference, Chicago, Il, March 20-23, 1989, also LBL-25972.

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