IEEE Transactions on Nuclear Science, Vol. NS-28, No. 3, June 1981

LAMPF DUAL-ENERGY OPERATION*

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Summary

The Los Alamos Meson Physics Facility (LAMPF) operated with simultaneous H^+ and H^- beams until June 1980, when a method of providing a variable energy H^- beam as well as a full-energy H^+ beam was brought into use. The scheme is based on time sharing between H^+ and H^- beam pulses. It is now possible to provide H^- beams with energy as low as 300 MeV along with the usual 800-MeV H^+ beams. The method requires a reduction in duty factor of the H^+ and H^- beams; however, the total duty factor has been increased to 9% which compensates in large measure for the reduction due to dual-energy operation. The necessary modifications to the beam switchyard and accelerator timing systems are described.

Introduction

The Los Alamos Meson Physics Facility (LAMPF) provides beam for a variety of purposes including several different programs in applied research as well as a broad spectrum of fundamental research. The primary beams from the accelerator[1] are H^+ and H^- which have until recently been produced simultaneously. The H^+ beam is used primarily for producing secondary meson beams and various isotopes; the beam energy is normally 800 MeV and its intensity is usually in excess of 0.5-mA-average current. The H^- beam is used primarily for nucleon-nucleon studies and directly as a nuclear probe; two separate H^- injectors are available so that the H^- beams can be provided either as a polarized or as an unpolarized beam. The average intensity of the polarized H^- beam is ~15nA (9% duty factor) and the unpolarized beam intensity may be as much as 6 μA.

Although meson production is most copious with the full available energy of the H^+ beam, the nucleon physics program benefits greatly from energy variation of the H^- beam. This need for energy variation could not be met by simply running the facility at lower energy for extended periods of time; the cost of operation is so high that all production time must be arranged to optimize efficiency with the maximum number of simultaneous users.

A previous investigation explored the possibility of inducing a large enough phase oscillation to spill the H^- beam at a low energy;[2] unfortunately this approach would not produce a beam of satisfactory quality. The only feasible solution has been to deliver time-separated H^+ and H^- beam pulses at different energies. Time-sharing permits the H^+ average beam current to be kept above 0.5 mA while delivering a low-energy H^- beam, each with somewhat reduced duty factor.

Accelerator Modifications

The linear accelerator used at LAMPF has the property that, aside from minor steering problems, beam transport through the accelerator is nearly unchanged for beam energies between 300 and 800 MeV. Further, the machine in this region is organized in separately powered accelerating modules each of which has an energy gain of approximately 16 MeV. Thus, to provide the desired energy to a step size of 16 MeV, no other machine adjustment is required other than to provide rf power to the appropriate number of modules. The accelerator steering adjustments, at least with low-beam current, are small enough when changing energies so that the necessary changes can be made almost entirely by varying steering in the regions where the H^+ beam is spatially separated from the H^- beam. Thus, aside from the change in duty factor, operation at H^- energies between 300 and 800 MeV does not affect production of an H^+ 800-MeV beam.

The basic time structure for the LAMPF beam is 120 beam pulses per second with pulse lengths as long as 750 μs (9% df). Straightforward but extensive modifications of the LAMPF timing system were required to permit pulse-by-pulse control of the separate beams.

The timing system is controlled by the Master Timer, whose most basic function is to supply properly timed gates to the rf power modules and injectors. A new Master Timer was developed to allow sharing of the 120 pulses per second between H^+ and H^- beam gates in any programmed pattern (typically one out of three pulses is H^-). A high-energy or low-energy precursor pulse precedes each beam gate.

The H^- energy is determined by a command which turns off acceleration beyond the rf module where the beam reaches the desired energy. Modules enabled by this command do not turn on during the rf gate if preceded by the low-energy precursor pulse. (These modules follow instead the delayed rf gate, which permits some rf power to be supplied after the beam pulse is over to maintain resonance control.)

Beam Switchyard Modification

In the switchyard, dual-energy operation required changes only to the H^- beam transport downstream of the first two bending magnets, LABM1-2, where the H^+ and H^- beams are separated. With these magnets set to deflect the H^+ beam 4° at 800 MeV, extra deflection of the low-energy H^- beam occurs, up to 5° extra at 200 MeV. The H^- trajectory is restored upstream of the first transport element of the original Line X beamline by a pair of new bending magnets, as shown in Fig. 1. The first of the new magnets has 250-mm width of good field region in the bending plane to cover all low-energy trajectories. This arrangement preserves the achromaticity of the Line-X 45° bend.

Two concerns were foreseen in the transverse match of the low-energy H^- beam to the design optics of Line X: first, the expected growth of beam phase space due to absence of adiabatic damping, and second, change in phase space orientation. Measurements made at an early stage of dual-energy planning showed that these effects were smaller down to 300 MeV than the normal tuning variations experienced with 800-MeV H^-, and that the matching capabilities of Line X were adequate to meet operating requirements of the downstream beam lines. Therefore, no extra quadrupole elements were added.

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*Work performed under the auspices of the U. S. Department of Energy.

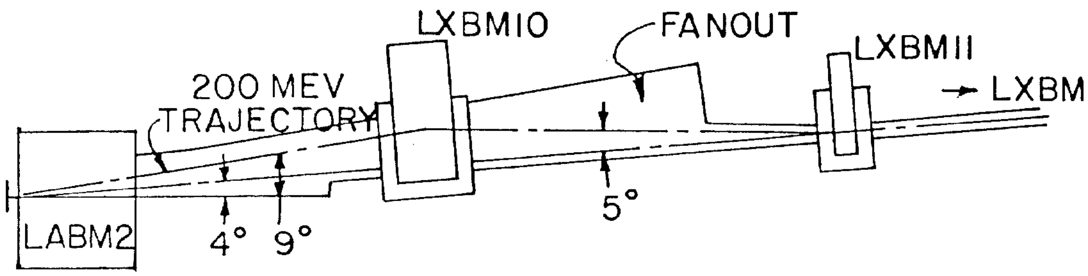

Fig. 1. H^- beam trajectories in the switchyard.

The design of the new bending magnets was constrained in several ways. Both magnets must operate in series from the same power supply without any current shunting or other field correction devices. The field integral of the first magnet (LXBM10) must be exactly twice that of the second magnet (LXBM11). The magnets must provide correction for any energy between 200 and 800 MeV; this requires a maximum bend angle of 10° in LXBM10. The necessary aperture was 10 cm and space constraints in the rather crowded switchyard required "C" magnets with special handling fixtures for installation.

Following the above constraints the magnet modeling code POISSON was used to design both magnets. The program was used to select current densities and coil cross sections which would attain the desired maximum fields, to adjust the transverse dimensions to give acceptable transverse field uniformity, and to make the iron dimensions large enough to avoid saturation effects.

The pole length was chosen to give the required field integral for LXBM10 (10°). One-half the length was chosen for LXBM11 (5°), then the pole-tip lengths and chamfers were fine-tuned to improve the 2:1 tracking over the full range of excitation.

The coil design was conventional using water-cooled rectangular conductor wound in pancakes. The conductor size was chosen to provide the desired dc impedance.

Results and Conclusions

The dual-energy operation of LAMPF has performed as expected. The magnets performed well in accord with the predictions of the design calculations. No major surprises were found in performance of either the accelerator or the switchyard. Only a minor surprise in the extent of the fringe field from one of the new magnets was found; this was readily corrected by addition of a "field clamp."

This change in the operation of LAMPF has greatly increased the versatility of the facility and revitalized a major research area at LAMPF. There has been a dramatic increase in interest by the user community in the use of the H^- beams since the inception of variable-energy operation.

References

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