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A pulsed lepton source at LAMPF

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Abstract. A Pulsed Lepton Source is being considered at the LAMPF facility at Los Alamos National Laboratory. The source plan is described together with a description of the components and performance as they exist at present.

1 Introduction

In Fig. 1 is shown a schematic of the LAMPF accelerator complex. For the purposes of description it is convenient to divide the complex into three sections, injection, linear accelerator and the proton storage ring (PSR). At the injection area beams of protons, H^- ions and polarized H^- ions are produced. Beams of protons and H^- can be injected simultaneously although acceleration takes place at different phases of the RF. The accelerator produces pulses up to 1 ms in duration at 120 Hz. H^- beam is used at the PSR, but in discussing beam economics in the complex it is necessary to include the effect of other than H^- beam. The linear accelerator is capable of accelerating a total instantaneous beam current of about 30 mA, which may be divided between any of the components specified above. The linear accelerator is divided into two parts; an Alvarez section that

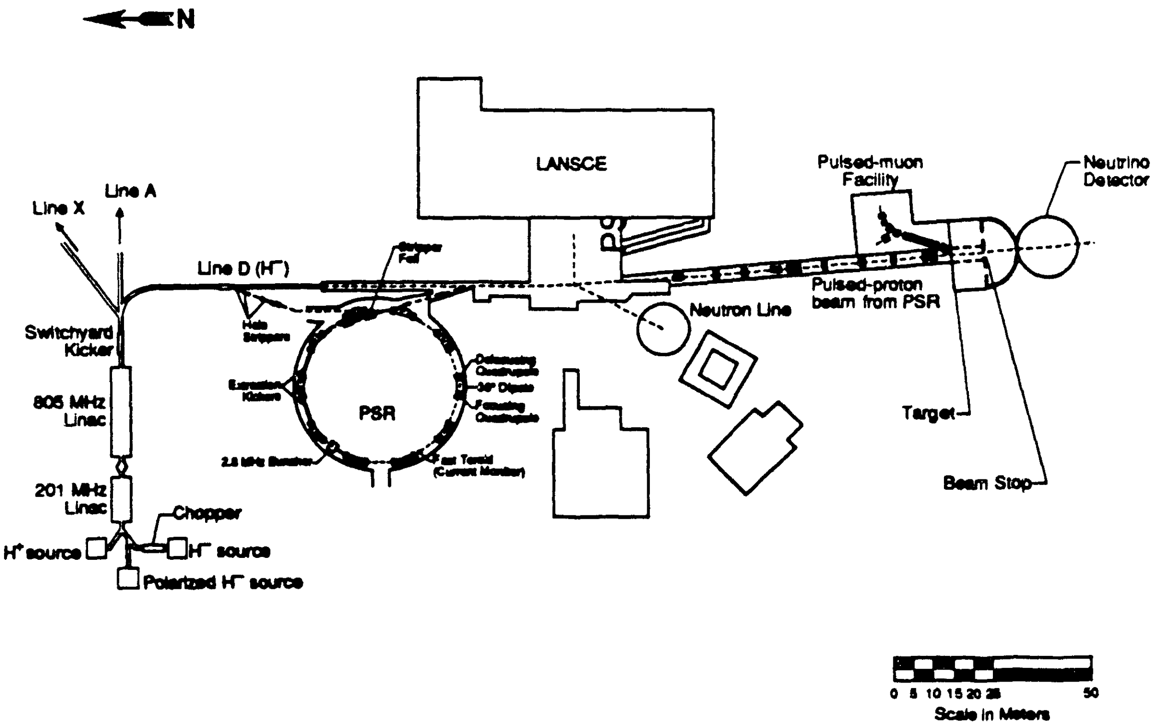

Figure 1. The LAMPF Accelerator Complex.

accelerates at 201 MHz and a side coupled cavity section that completes acceleration to 800 MeV at 805 MHz. The H^- beam is split at 20 Hz at present in a switchyard to the beam transport labelled line D in Fig. 1. The PSR accepts beam throughout the linac macropulse and this accumulation is ejected in a single turn in a pulse of 0.25-μs duration. It is this time compressed output that is relevant for PLS.

2 Injection

The injection area consists of three ion sources. The first produces protons at a peak current of 30 mA. After some scraping is done to produce an appropriate emittance for the linear accelerator, and the pulse length is matched to the accelerating RF acceptance, 14 mA is typically accelerated. Under normal conditions the linac has a macropulse of about 750 μs duration at 120 Hz, which gives an average current of 1 mA. The second source produces a relatively low current of H^- beam (30 μA) with protons polarized at ~ 50%. This beam is stripped after acceleration simultaneously with proton acceleration. An alternate H^- mode is of interest to us here, presently a H^- source produces an unpolarized current of 16 mA, of which 10 mA can also be accelerated at the same time as protons provided the peak beam loading of 30 mA is not exceeded. In fact this beam is chopped near the ion source at the revolution frequency of the PSR so that the ring circumference is not fully filled and only 7 mA is available for PSR injection. Normal operation has unpolarized H^- accelerated at 20 Hz, the PLS proposal envisages this repetition rate being increased to 60 Hz. At the same time it is expected that H^- source brightness can be increased so that a full charge of the proton storage ring can be accomplished in a shorter injection period.

3 The linear accelerator

Acceleration is accomplished in two sections, the first for low ion velocity is an Alvarez drift tube section with 201-MHz accelerating frequency. A transition region connects to a side coupled cavity accelerator operating at 805 MHz, which completes acceleration to 800 MeV. One in four of the high frequency RF buckets is filled giving an output 200 ps wide at intervals of 5 ns. This time structure is diluted by the energy spread in the beam when particles are allowed to drift for significant distances. Beam from the linac is switched to a beam line marked D in Fig. 1, and transported to the PSR area.

4 Proton storage ring

In Fig. 1 the proton storage ring is also shown. After scraping of the halo the beam is transported through a high magnetic field gradient where the H^- beam is stripped to H^0 with 90% efficiency. This beam is then injected into the ring where it is fully stripped by passing through a Carbon foil. The proton storage ring is operated at fixed B field; because of the chopping at the injector a portion of the circumference is particle free for extraction. This particle free region is maintained by a 2.8-MHz RF field. The stored beam passes through the stripping foil on a fraction of the turns determined by betatron oscillations. In Fig. 2 is shown loss rate as a function of time through the injection period. In the first turn, beam injected in the storage ring losses are relatively substantial on the limiting aperture of the ring, after which losses are proportional to the total charge accumulated from multiple scattering in the stripping foil. At the end of injection first turn losses cease and a drop in loss rate occurs. At extraction a further loss component exists mostly due to the finite aperture of the extraction magnet. The limiting aperture during fill is also believed to be the extraction system. With a peak injected current of 7 mA and a total fill of 3.8×10^{13} protons, the injection period must be 975 μs, rather longer than is shown in Fig. 2. The limitation on the amount of beam that can be stored are the losses described above that produce radioactive contamination of the ring making maintenance difficult. At present with a stored beam of 2.5×10^{13} at 20 Hz, the losses during accumulation are 0.4%, followed by 0.15% at extraction. In order to improve this situation a number of steps may be taken which are described below. The limitation on the charge that can be accumulated comes from an instability that is present in the ring at high currents. In Fig. 3 is shown accumulated charge as a function of time on the upper trace and the losses from the ring below. The linear rise of accumulated charge may be seen followed by a flat portion where current is circulating in the ring. During this period the losses gradually increase followed by a substantial increase of these losses during which the accumulated charge falls to one third. It is

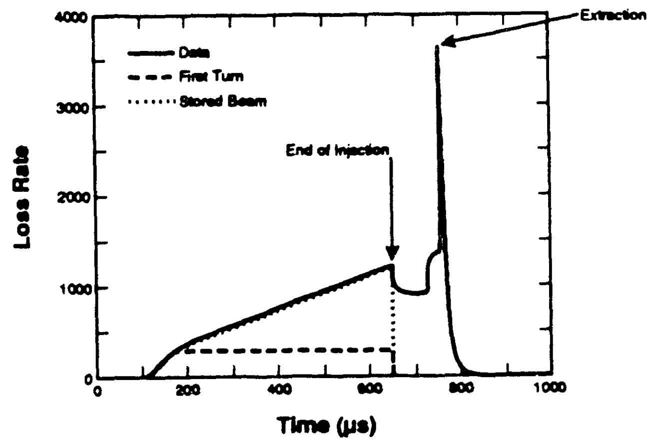

Figure 2. Loss rate as a function of time in the accumulation period. The precursor to the pulse at extraction is due to the finite rise time of the extraction kicker.

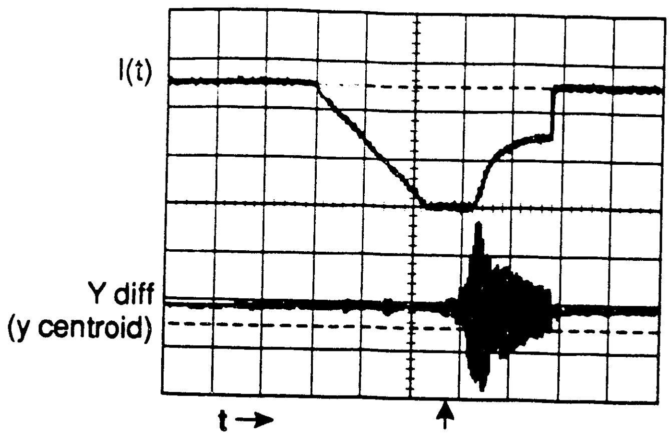

Figure 3. The upper trace is the charge accumulated in the ring. The lower trace shows loss rate, the instability after a period of coasting beam is clear accompanied by loss of beam in the ring.

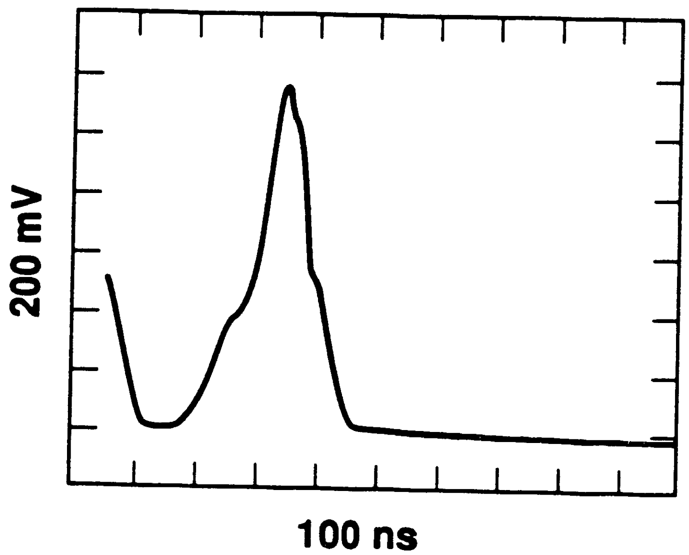

Figure 4. The last pulse in the ring at extraction is shown. This nearly triangular shape is close to that delivered to the experimental area.

believed that this instability is due to an interaction of the proton beam with residual electrons in the ring although this hypothesis is far from certain. What is certain is that this threshold is reasonably stable and the PLS proposal does not involve running the ring above this current.

Low loss at extraction is accomplished in part by the gap in the charge distribution around the circumference of the ring. This gap is maintained by the RF that is maintained during storage. For minimum loss the resulting charge distribution around the ring is not square as it is at injection but becomes almost triangular and this is reflected in the extracted pulse shape as shown in Fig. 4. This pulse shape is advantageous for most applications giving man apparently shorter duty factor than nominal.

5 External beam transport

The extraction as described is that used to feed the neutron spallation source that is presently in operation. The only modification that is envisaged is a kicker to transfer the beam into a PLS channel as is shown schematically in Fig. 3. It is assumed that 20 Hz will continue to be sent to the spallation source, the limitation on repetition rate is given by wraparound problems with neutron time of flight. Then if 40 Hz is sent to PLS this will still leave 60 Hz for polarized protons and other uses of H- from the linac. A beam channel similar to that shown in Fig. 1 has been designed in some detail for a previous proposal, and an appropriately low loss system seems to be straightforward.

6 Target and beam channels

At the target end of the transport it is envisaged that two targets would be mounted close together, one designed for muon channels, and a second designed to make the largest number of pions for neutrino generation. With a proton beam spill less than one microsecond it is straightforward to extend "old" technology and design a horn which would enhance neutrino flux as well as producing an enhancement of the flux from the pion sign that is selected. It is believed that the enhancement that can be achieved will approximately compensate for the difference between 1 mA available at the end of the linac and 200 μA available at PLS.

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