A STORAGE RING MODE FOR CEBAF AS A COMMISSIONING TOOL *

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Introduction

The CEBAF project (under construction in Newport News, Virginia) is a recirculated linear accelerator. Two superconducting accelerating sections (240 m each) are connected by semicircular arcs containing beam lines for different energies (4 at one end and 3 at the other). Injected electrons will pass the cavity sections up to 4 times before extraction.

The CEBAF accelerator will be equipped with a variety of diagnostic tools. With the aid of computer modelling these diagnostics will help to reach the proposed beam quality: a transverse emittance of 10^{-9} rad·m and a relative energy spread of 10^{-4}. Nevertheless, some very precise diagnostic tools used in circular accelerators can not be applyed at CEBAF. In particular, the measurement of phase advance by resonant excitation of the beam and absolute beam energy measurement using electron spin polarization are not possible in this linear machine.

In this paper we will propose an extension to the current design that will allow CEBAF to run in a storage ring mode. The optics and configuration of the transport elements required to achieve the new operating mode is presented. Finally, the use of this capability as a commissioning tool is illustrated.

Method

The seperation of beams going from the linacs into the different arcs and finally into the extraction channel is by way of the energy. There are no pulsed kicker magnets involved in this process. It is therefore, without changes in the machine design, not possible to run the machine like a storage ring, although the top view of the machine appears circular.

For the proposed storage mode, electrons in CEBAF should have an energy above 1 GeV, so that the beam is not too sensitive to instabilities. As there is no preaccelerator available and the dynamic range does not allow ramping of the energy starting at 50 MeV, a combination of linear acceleration mode and the storage mode is necessary.

We will start the acceleration of the beam in the normal acceleration mode. The beam is injected into the first linac at 45 MeV. It will be accelerated with the normal precedure and will have, after 3 revolutions, an energy of 3 Gev. This will be our final beam energy and the final arc, designed for 3.5 GeV, is scaled down to accomodate 3 GeV particles.

After reaching the energy of 3 GeV only a small energy gain is required to compensate the synchrotron radiation losses. If we were able to switch off all cavities in an instant after reaching 3 Gev, we could now start our diagnostics. Unfortunately this is not possible. The minimum time to extract the Rf wave is determined by the external Q of the cavity and is 4.4 msec.

Equivalent to switching off is to shift the bunch in time by 90° against the cavity phase. The bunch will then pass the cavities when the accelerating field is zero and will not experience any acceleration. The phase shift is illustrated in Fig. 1.

Since the cavity phase can not be changed instantly we have to shift the bunch. This will be done by a additional dogleg beam line in the 3 GeV arc, which can be selected by a kicker magnet. The additional path length is equivalent to a 90° phase shift.

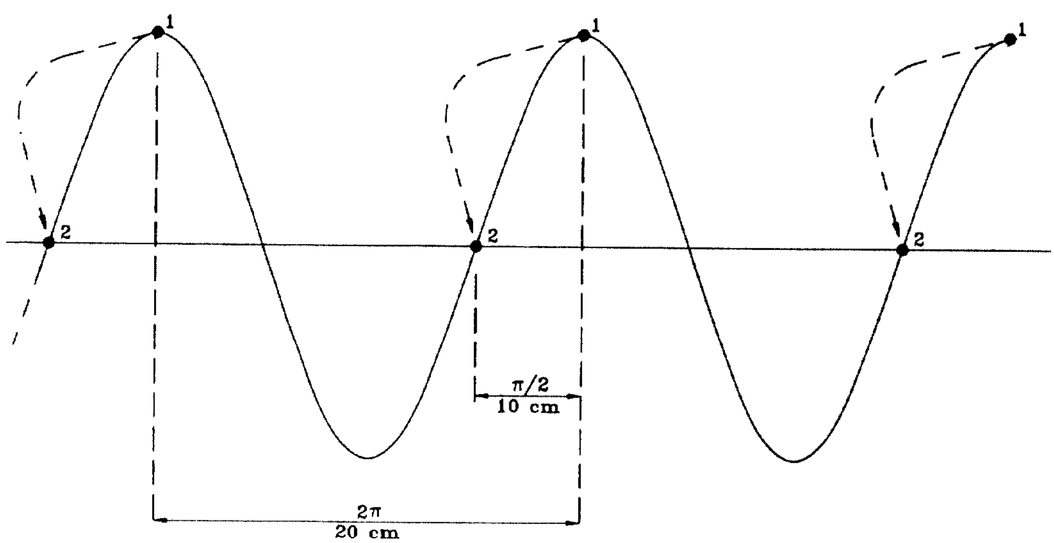

Fig. 1 Phase shift of the electrons from the peak acceleration to the node.

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Fig. 2 shows the layout of the dogleg, which can be installed in the extraction area. The pulsed kicker defelects the beam vertically into the second channel of a Lambertson magnet. The Lambertson magnet has a strength of 1 Tesla and a length of 1 m. The beam is deflected horizontally by 5.5 degrees. A pair of horizontal dipole magnets bends the beam back into a second Lambertson magnet, which recombines the dogleg with the original beam line. A second vertical kicker placed at 180 degrees vertical phase advance compensates the effect of the first kicker.

The cost of such an extension is conservatively estimated to be 250 k$.

The energy scaling has implications on the 3.5 Gev arc spreader and recombiner. The first dipole in the spreader is common to all lines, so its field can not be scaled. Scaling the quadrupoles is therefore equivalent with running on a dispersed trajectory. Tilting the septum magnet by 2.7 degrees provides sufficient aperture to acommodate this beam.

Optical layout

We have chosen a solution that which needs only modification of the 3.5 Gev line. The arc constist of four identical cells with five quadrupole families. Each of these cells is in the normal mode matched to be nondispersive as well as isochronious. It shows that it is easy to rematch the arc cells to obtain an arbitrary momentum compaction factor without changing the Twiss parameters at the ends. The matching sections in the spreader and recombiner allow an easy adjustment of the betatron tunes.

The spreader and recombiner is then matched to the Twiss parameters of the linacs, which are predefined by the optics of the low energy passes.

Measurements in the storage mode

The measurements made possible by the storage mode are grouped into:

- measurements to compare the performance of the machine with the theoretical values.
- general machine studies.

In the first group the most important measurement is the determinaition of the betatron and synchrotron tunes. This is done by exiting the beam with a kicker magnet. The response of the beam is measured with a frequency analyzer.

The CEBAF quadrupoles are all powered with seperate power supplies. Each quadrupole has a attached beam position monitor and a horizontal and vertical correction dipole.

By change the strength of a single quadrupole the beta functions in the quadrupoles can be measured with an acuracy of 10^{-4} by using [1]

$$\Delta\nu = -\frac{1}{4\pi}\int \Delta k\beta ds$$

In a second step the local phase advance between the correctors and monitors can be measured, assuming that the beta function in these devices is not significantly different from that of the attached quadrupole.

In the storage mode it is possible that the electron spins become polarized due to the synchrotron radiation [2]. The necessary condition is that the so-called spin-matching [3] is applied. By using resonant depolarization the spin tune and therefore the beam energy can be measured [4]. The so-calibrated beam can be extracted into the end stations for absolute calibration of energy measurement devices.

An example of the group of general studies is the possibility to vary the momentum compaction factor to any desired value. CEBAF could be used to study the behavior of machines with a momentum compaction factor near zero and the effect of microwave instabilities.

Conclusion

The Storage ring option for CEBAF is a extension that provides variety of diagnostics at relativly low cost. It could be a valuable tool for the improvement of accelerator performance.

For a final proposal, further investigations are necessary. The stability of the beam at high acceleration voltage must investigated by tracking calculations. Also, a modified system using two 180° doglegs can be used to generate an alternative, non-monoenergetic storage mode, in which the beam is repeatedly accelerated to 3.5 GeV and subsequently decelerated to 3.0 GeV.

Acknowledgement

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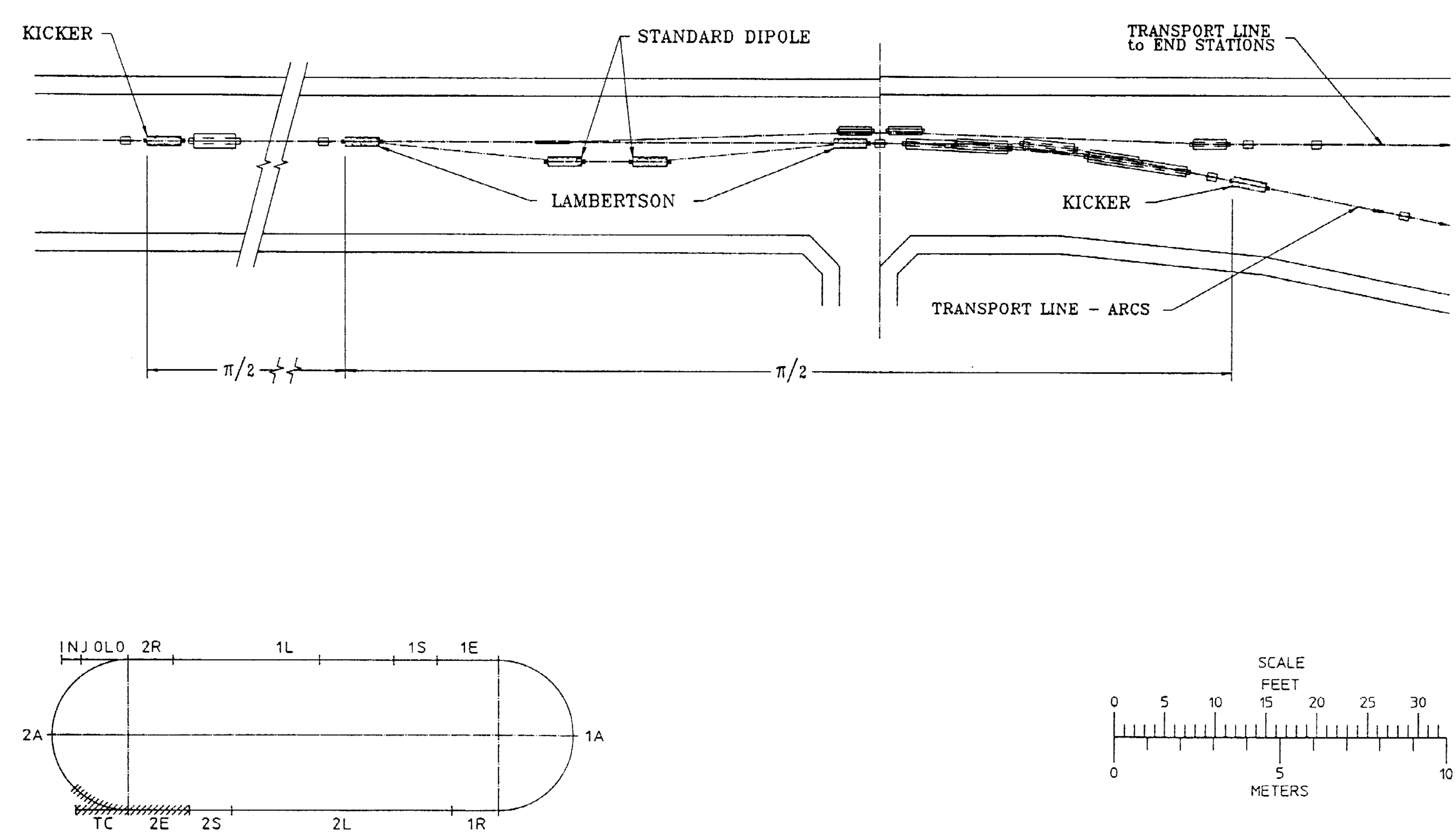

Fig. 2 Layout of the dogleg beam line and its position in the CEBAF accelerator (hatched area).