OPTIONS FOR AN 11 GEV RF BEAM SEPARATOR FOR THE JEFFERSON LAB CEBAF UPGRADE*

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Abstract

The CEBAF accelerator at Jefferson Lab has had, since first demonstration in 1996, the ability to deliver a 5-pass electron beam to experimental halls (A, B, and C) simultaneously. This capability is provided by a set of three, room temperature 499 MHz rf separators in the 5th pass beamline. The separator cavity is a two-rod, two-cell TEM mode type resonator, which has high shunt impedance. The 12 GeV baseline design does not preserve the capability of separating the 5th pass, 11 GeV beam for the 3 existing halls. Several options for restoring this capability, including extension of the present room temperature system or a new superconducting design in combination with magnetic systems, are under investigation and are presented.

INTRODUCTION

The 12 GeV baseline design for the CEBAF accelerator includes an existing 499 MHz injector chopping system and an expanded RF separation system that allow for beam delivery to any three of four experimental end stations simultaneously. The design also provides the capability to send any of the 5 passes around the machine to any two of Halls A, B or C while simultaneously delivering beam at 5-1/2 passes to Hall D or to all three of Halls A, B, and C when Hall D is not scheduled to take beam.

The existing 6 GeV design also provides the capability to send the 5-pass beam simultaneously to all three halls A, B, and C. The 11 GeV Separator project will restore this capability to send the 5^{th} pass highest energy beam simultaneously to halls A, B, and C when Hall D is not running or to any two of the existing halls when Hall D is running. In the former case the 5^{th} pass horizontal system is turned off to allow beams for Halls A, B, and C to drift beyond the ARC 10 extraction point to an existing 10.8 m drift section that can be populated with a new set of vertical RF extraction cavities. In the latter case the 5^{th} pass horizontal system is used to extract Hall D beam and the new downbeam vertical cavities are used to separate the remaining two beams for Halls A, B, or C.

* Authored by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177. . The U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce this manuscript for U.S. Government purposes.
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Requirements

The Separator cavities must provide a 499 MHZ transverse vertical deflection to the 1497 MHz bunch train. The amplitude of the kick is derived from the requirement to have the beams to halls A, B, and C vertically separated by 1.7 cm at the entrance of a Lambertson style magnet in the Beam Switchyard located 43 m from the start of the 11 GeV Separator drift space. The quadrupole lattice is designed to amplify the initial kick in the vertical plane to minimize the power required from the rf system.

Table 1: System Requirements.

Parameter	Requirement
Energy	11023 MeV
Theta NC	455 micro-radians
Theta SC	433 micro-radians
Phi	$\frac{2}{3}\pi$

NORMAL CONDUCTING DESIGN

For the normal conducting solution the requirement is to keep the power per cavity below a nominal 3 kW. We can use eight of the existing 73.2 cm cavities [1,2], shown in Fig. 1, each separated by 50.8 cm in the 10.8 m drift space. With this configuration the optics model, shown in Fig. 2, predicts we will need a 455 micro-radian kick. The power required for the normal conducting design is given by

$$P = \frac{\left(\dfrac{E \cdot \theta}{\sin \phi}\right)^2}{n \cdot R} \qquad (1.1)$$

where n is the number of cavities, E is the beam energy in electron-volts, θ is the transverse vertical kick in radians, ϕ is the phase angle of the 1497 MHz micro-bunch structure relative to the RF phase in radians and R is the cavity shunt impedance in ohms. Using the parameters in Table 1 we will need just under 20 kW or 2.5 kW/cavity.

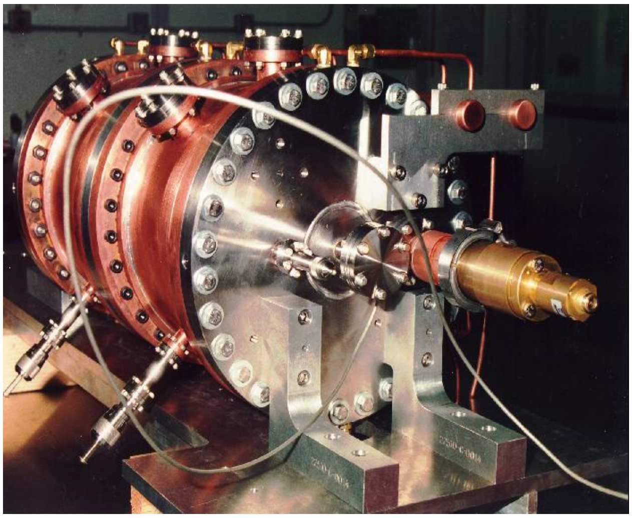

Figure 1: Normal conducting 499 MHz Cu cavity. Eight of these cavities would be needed to provide the required transverse kick at 11 GeV.

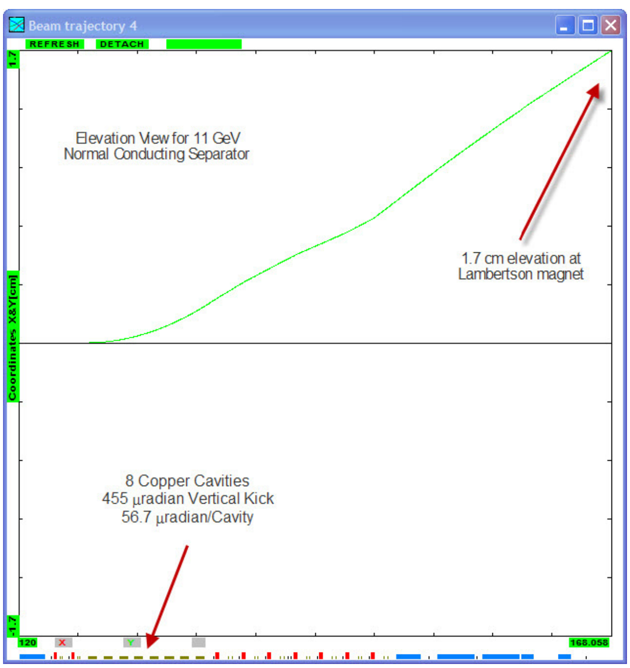

Figure 2: Optics model for the 48 m extraction beamline. Eight NC cavities at the start of the lattice combine to give the required vertical offset at the Lambertson magnet. Quadruples (red boxes) amplify the initial rf kick.

SUPERCONDUCTING DESIGN

For the superconducting design the requirement is to minimize the surface fields in the cavities. With a nominal choice of two cavities we will need 432 micro-radians or 216 micro-radians per cavity.

A conceptual design and a preliminary implementation of a 499 MHz superconducting deflecting cavity are shown in Figs. 3 and 4.

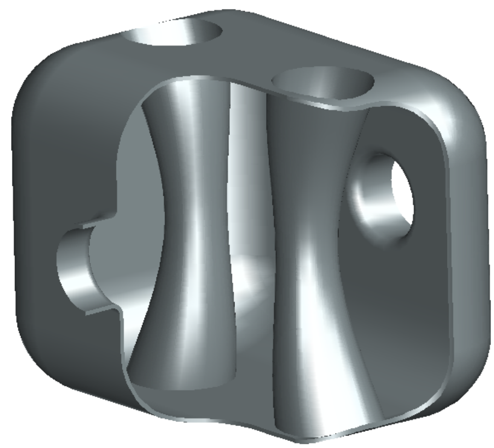

Figure 3: Conceptual design of a parallel-bar deflecting cavity.

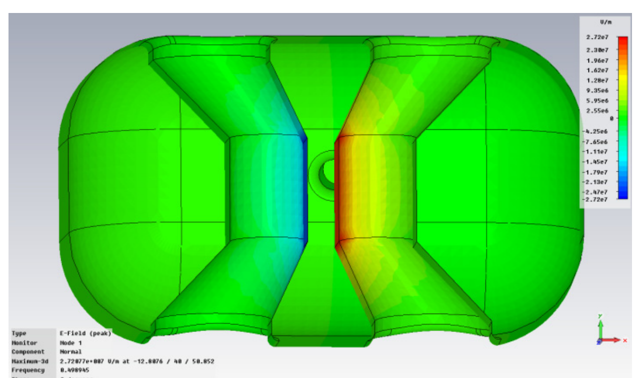

Figure 4: Preliminary design of a 499 MHz parallel-bar deflecting cavity.

The optics model for the 48 m extraction line using 2 superconducting cavities is shown in Fig. 5.

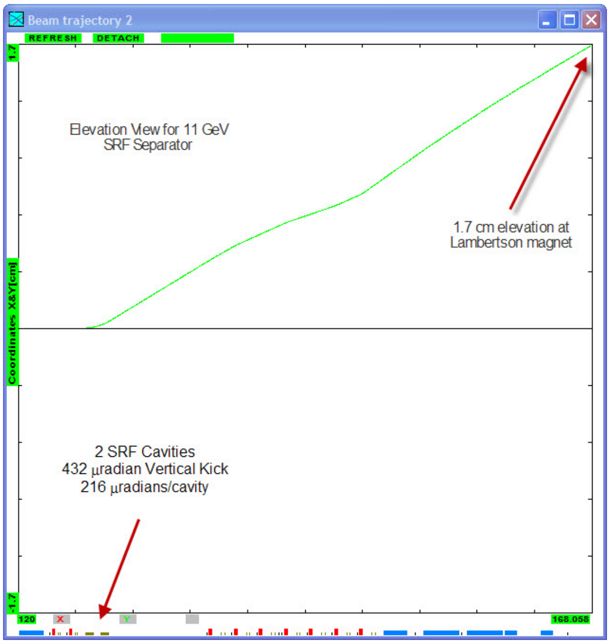

Figure 5: Optics model for the 48 m extraction beamline. Two SC cavities at the start of the lattice combine to give the required vertical offset at the Lambertson magnet. Quadruples (red boxes) amplify the initial rf kick.

OPTIONS COMPARISON

Properties of normal conducting and superconducting deflecting cavities are shown in Table 2. Preliminary analysis indicates that both options are viable as deflecting systems for CEBAF's 11 GeV beam separation.

The normal conducting option is based on an existing design but requires 8 cavities and about 20 kW of rf power. The superconducting option would require only 2 cavities and about 4 kW of rf power, but is based on a new design and requires more prototyping.

Both options will be analyzed further and prototyped before selection of the final design.

Table 2: Properties of parallel-bar structure shown in Figure 4 calculated from Omega3P and comparison with CEBAF's separator cavity.

Parameter	Fig. 6	CEBAF	Unit
Freq. of deflecting mode	499	499	MHz
$\lambda/2$ of deflecting mode	300.4	300.4	mm
Freq. of next higher mode	778.5	~537	MHz
Cavity active length	300.4	~300	mm
Cavity width	400	292	mm
Cavity height	233.1	292	mm
Bars radius (R)	30	10	mm
Bars axes separation ($2A$)	84.1	35	mm
Aperture dia. (2A-2R)	24.1	15	mm
Deflecting voltage V_t *	0.300	0.300	MV
Peak surface E-field E_p*	3.14	3.39	MV/m
Peak surface B-field B_p*	5.56	8.87	mT
Stored energy U *	0.0133	0.012	J
Geometry factor G	75.6	34.9	Ω
Transverse R_t/Q	2159.8	24921	Ω
* at E_t=1MV/m			

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