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Deflecting Cavities for Proton Beam Spreader in CiADS Project*

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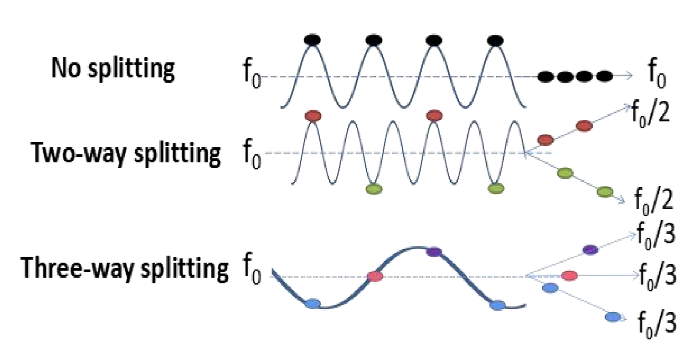
Abstract

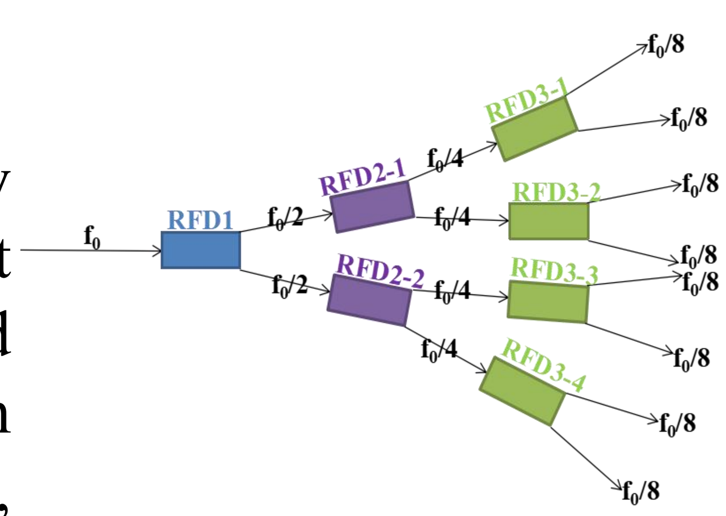
Chinese initiative Accelerator Driven Subcritical System (CiADS) is supposed to accelerate continuous 162.5MHz, 10 mA (or higher) proton beam to 500 MeV (or higher energy) with a superconducting driver linac. More application scenarios based on this high power intensity proton linac are now under considerations. Beam spreader system based on deflecting cavities for multiple users simultaneous operation are discussed in this paper, as well as the RF structure options for the equal eight- and nigh- beam-line split schemes.

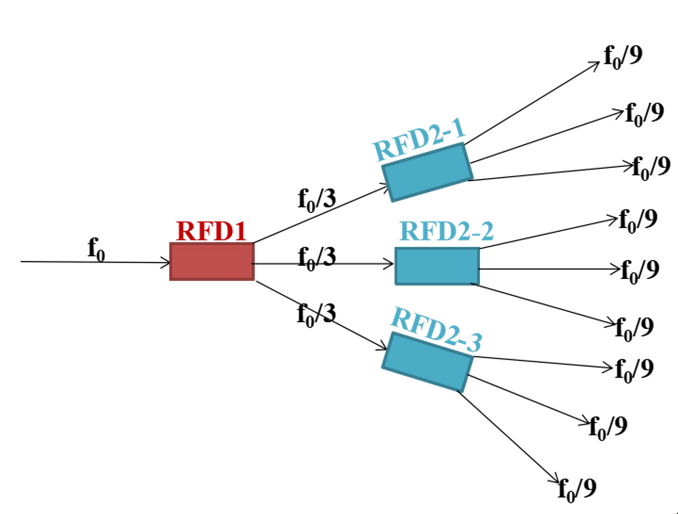
Introduction

Deflecting cavities for beam separation were originally proposed at CEBAF and SLAC. With proper bunch phase to RF cavity resonant frequency, the incoming bunch train could be separated to two ways or there ways equally.



More beam lines could be achieved by repeating this process on each split beam line, with the second and the third class of deflecting cavities. With seven cavities classified into three categories, the incoming bunch train with repetition frequency f_0 could be separated to eight bunch trains with equal repetition frequency $f_0/8$. With four cavities classified into two categories, the original bunch train f_0 could be split ted to nine $f_0/9$ bunch trains.





Deflecting voltage and RF Power Estimation

Consider a charged particle with rest mass m and charge q incident on the deflecting cavity on the beam axis with the kinetic energy E_k, the deflecting voltage V_{def} for given kick angle θ could be derived as:

$$V_{def} = \frac{E_k}{q}\tan\theta \frac{\alpha+2}{\alpha+1} \qquad \alpha = \frac{E_k}{mc^2}$$

Here c is the speed of light. For 500 MeV Proton bunches, the required deflecting voltage is 825 kV for 1 mrad kick angle. The required bunch separation at the Lambertson-type septum magnets is about 40-50 mm, to limit the drift distance to 10 meter, the required kick angle is about 5 mrad in the deflecting cavity, thus resulting about 4 MV deflecting voltage. RF power losses for given beam energy and kick angle could be estimated with:

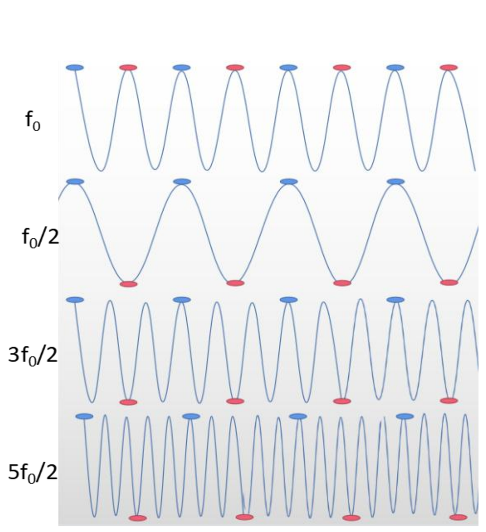
$$P = \frac{\left(\frac{V_{def}}{\sin\varphi}\right)^2}{R_{sh}}$$

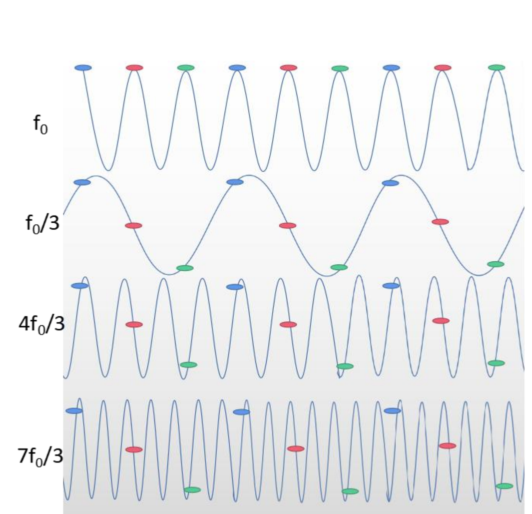
R_{sh} is in the magnitude of ~100s MΩ for normal conducting cavities. The estimated RF power is larger than 100 kW, thus multiple normal conducting cavities are required. To make the system more compact, superconducting cavities are considered.

RF frequency of the Deflecting Cavity

For the two-way splitting scheme, the RF frequency of the deflecting cavity (RFD1) could be $f_0/2$, $3f_0/2$, $5f_0/2$, and higher. For the three-way splitting scheme, the RF frequency of the deflecting cavity (RFD1) could be $f_0/3$, $4f_0/3$, $7f_0/3$, and higher.

Higher RF frequency are help to make the cavity more compact. However, large deflecting field curvature and derivation during the traveling period of bunches, which will finally result to transverse emittance dilution. The stronger the kick, the larger the emittance growth. Lower frequency is help to reduce the emittance, however, the cavity size is cumbersome. Final cavity frequency should be determined with considerations of both the cavity size and beam dynamic requirement.

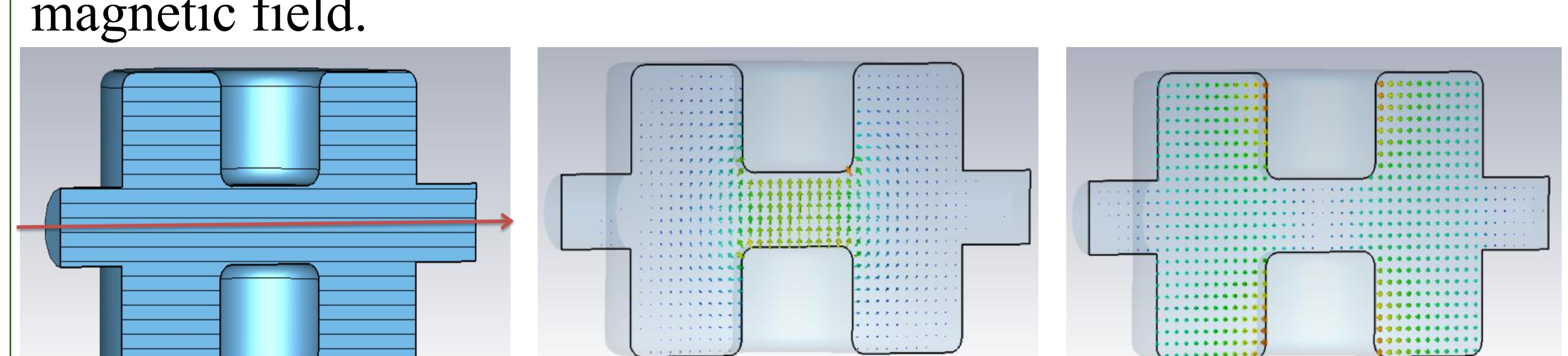




	Eight-beam-line	Nine-beam-line
RFD1	81.25, 243.75, 406.25, or higher	54.17, 216.67, 379.17, or higher
RFD2	40.625, 121.875, 203.125, 284.375, 365.625, 446.875 or higher	18.06, 72.22, 126.39, 180.56, 234.72, 288.89, 343.06, 397.22 or higher
RFD3	20.3125, 60.9375, 101.5625, 142.1875, 182.8125, 223.4375, 264.0625, 304.6875, 345.3125, 385.9375, 426.5625, Or higher	

Superconducting RF Deflecting Cavities

For 162.5 MHz proton bunches, double quarter-wavelength cavity with compact geometry and great mechanical stability are considered. Charged particles passing through the cavity will be deflected by both the transverse electric field and the transverse magnetic field.



For RFD1 in the eight-beam-line scheme,to provide 4 MV deflecting voltage, two 243.75 MHz cavities are preferred with appropriate cavity size and safety surface electric and magnetic field.

Frequency (MHz)	81.25	243.75	406.25
Aperture (mm)	100	100	100
R_t/Q (ohm)	2540	571	244
G (ohm)	63	111	114
E_{pk}/V_{def} (1/m)	3.71	11.2	20
B_{pk}/V_{def}(mT/MV)	3.79	13.8	29
Longitudinal Size (mm)	900	700	520
Horizontal Size (mm)	800	538	323
Vertical Size (mm)	1300	390	316

Further optimization on the cavity geometry including reduce the cavity size, increasing the mechanical stability with consideration of the beam dynamics requirement.

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