

# **Beam Loading and Smaller Range in FFAG Rings**

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My WWW home directory:

`http://keil.home.cern.ch/keil/  
MuMu/Doc/FFAG05/FFAG\_Apr05/05Apr05.pdf`

## Beam Loading

- 1.3 GHz pillbox shaped RF cavities of copper with conductivity  $\sigma = 5.8 \cdot 10^7 / \Omega / \text{m}$  have intrinsic impedance  $R/Q = 121 \Omega$  and quality factor  $Q = 11673$ , neglecting the beam ports

- The RF power  $P$  in an RF cavity is  $P = V^2 / 2Q(R/Q)$ .

- Imposing the condition that the energy extracted by the beam  $W_e$  from the RF cavities in  $n$  turns is much smaller than the energy stored there

$$W_e = ICVn/c\beta_r \ll W_s = V^2 / 4\pi f_{\text{RF}}(R/Q)$$

yields an upper bound for the beam current

$$I_b \ll V / [4\pi n h (R/Q)]$$

- This upper bound is pessimistic, since RF cavities in all cells are assumed. With fewer RF cavities,  $I_b$  would be higher.
- A calculation of transient beam loading, taking into account the variation of phase and acceleration is beyond the scope of this note.
- The beam observation system must work accurately enough at beam currents  $\ll I_b$ .

## Electron Models with 1.3 GHz RF System

- Use  $E_r, p_t, T, \mu_x, \lambda_{\text{RF}}, L_p$  in design equations, and calculate  $V$  and  $N_p$
- Columns 2 and 3 were calculated at meeting on 14 Jan 2005, and show that reducing  $p_t$  has large effect on  $N_p \propto p_t^2$
- $L_p = 2\lambda_{\text{RF}}$  is nice, column 4 shows effect
- Increasing  $\mu_x$  is possible at smaller  $p_t$ , column 5 shows that it reduces  $N_p$

Reference energy $E_r/\text{MeV}$	15	15	15	15
Range $p_t$	$\pm 1/3$	$\pm 1/4$	$\pm 1/4$	$\pm 1/4$
No. of turns $T$	10	10	10	10
Phase advance $\mu_x/2\pi$	0.233	0.233	0.233	0.263
Cell length $L_p/\text{m}$	0.5	0.5	0.46	0.46
No. of cells $N_p = N_c$	63.95	35.97	33.09	25.97
RF cavity voltage $V/\text{kV}$	20.64	25.32	27.52	35.06

## Reasoning

- Reducing range from 2 to  $5/3$  reduces number of periods and circumference, and presumably cost
- Longitudinal phase space dynamics essentially unchanged
- Number of resonances reduced in ratio  $5/6$
- Reduced range can be made plausible to funding agencies
- Idea not liked by participants at phone conference
- Parameters for reduced range machines calculated by Scott Berg