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PARAMETERS OF THE RF SYSTEM
FOR THE "WEAK-FOCUSING" LATTICES

H. HAHN

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rf REQUIREMENTS
(Parabolic Distribution)

Bunch half length $= \sqrt{5} \sigma_L$

Bunch phase half width $\phi = \sqrt{5} \sigma_L h/R$

Bunch half height $\Delta_E = \sqrt{5} \delta_E$

Bunch area/amu $S = 5\pi \sigma_L \delta_E \gamma E_o / c = \frac{\gamma E_o}{2 h f_o} \Delta_E \phi$

In the small-amplitude approximation and stationary

$$\phi = \left(\frac{8\pi |\eta| h^3 f_o^2 A^{1/4}}{\gamma E_o eV Q} \right)^{1/4} \sqrt{S}$$

$$\Delta_E = \frac{2h f_o S}{\gamma E_o \phi}$$

Bucket half height required, stationary

$$\Delta_B = \frac{\Delta_E}{\sin \phi/2}$$

Bucket Area/amu required

$$A_B = \frac{4}{\pi} \frac{\gamma E_o}{h f_o} \Delta_B$$

Voltage required

$$V = \frac{\pi}{2} \frac{h |\eta| \gamma E_o A}{e Q} \Delta_B^2$$

$$V \approx 8\pi \frac{|\eta| h^3 f_o^2 A S^2}{e \gamma E_o Q \phi^4} \quad (\phi \ll \pi)$$

Parameter Variations with h_{rf}
(Equipartition)
 $\gamma = 100, Au$

| Lattice | N_B | h_{rf} | δ_E | S eV·sec | L $cm^{-2}sec^{-1}$ | Diamond cm rms | V MV |
|---------|---------------|-------------|---------------------------|-------------|------------------------|-------------------|---------|
| | $\times 10^9$ | $\times 57$ | $\times 10^{-4}$ | | $\times 10^{26}$ | | |
| | | | $\alpha = 0 \text{ mrad}$ | | | | |
| 15/120° | 1 | 12 | 11.3 | 3.8 | 10.5* | 29 | 2.2 |
| | 1 | 6 | 9.8 | 6.6 | 14.* | 57 | 0.85 |
| 12/90° | 1 | 12 | 6.9 | 2.3 | 5.6 | 29 | 2.1 |
| | 1 | 6 | 6.0 | 4.0 | 7.4 | 57 | 0.81 |
| | 1 | 1 | 4.2 | 16.9 | 15.1* | 343 | 0.066 |
| 9/120° | 1 | 6 | 5.9 | 4.0 | 8.4 | 57 | 0.95 |
| | | | $\alpha = 2 \text{ mrad}$ | | | | |
| 15/120° | 2 | 12 | 12.9 | 4.4 | 11. | 12 | 3.0 |
| | 2 | 6 | 11.3 | 7.6 | 6.7 | 14 | 1.1 |
| | 1 | 6 | 9.8 | 6.6 | 1.9 | 13 | 0.85 |
| 12/90° | 2 | 12 | 7.9 | 2.7 | 7.6 | 14 | 2.8 |
| | 2 | 6 | 6.9 | 4.6 | 4.8 | 18 | 1.1 |
| | 2 | 1 | 4.8 | 19.4 | 1.2 | 17 | 0.087 |
| | 1 | 6 | 6.0 | 4.0 | 1.4 | 16 | 0.81 |
| 9/120° | 2 | 6 | 6.7 | 4.6 | 5.1 | 17 | 1.2 |

* $\Delta v > 0.003$
BB

MOMENTUM SPREAD AT TRANSITION

The momentum spread at transition scales like

$$\delta_E \propto \left(\frac{h^2}{\gamma_{tr}^2} \frac{V^2}{\dot{B}} \cos^2 \phi_s \right)^{1/6}$$

with $V \sin \phi_s = 2\pi R \rho \dot{B}$

Assuming the same rf system, the lattices with $\gamma_{tr} \approx 25$ require at transition about 15% more momentum aperture than one with $\gamma_{tr} \approx 38$.

An acceptable rf system for the $\gamma_{tr} \approx 25$ lattices is obtained by using (primed quantities):

$$h' = \frac{1}{2} h; \quad V' = \frac{1}{5} V; \quad \dot{B}' = \frac{1}{4} \dot{B}; \quad \phi_s' \approx \frac{5}{4} \phi_s$$

leading to

$$\delta_E' = 0.7 \delta_E$$

The resulting physical aperture requirement due to momentum spread is

$$(X'_{p \max} = 1.57 \text{ m}, X_{p \max} = 0.7 \text{ m})$$

$$\sigma_H' = 1.57 \sigma_H$$

SUGGESTED rf PARAMETERS

$$f_{\text{rf}} = 6 \times 57 \times f_0 = 26.7 \text{ MHz}$$

$$V_{\text{max}} = 1 \text{ MV}$$

$$V_{\text{acceleration}} = 200 \text{ kV}$$

$$\text{Acceleration time} = 2 \text{ min.}$$

Questions:

- What is dynamics of intrabeam scattering at operating point.
- Parzen will calculate $L = L(t)$
 $\sigma = \sigma_L(t)$
- Slowest beam growth is expected, if full voltage is reached at the end of the acceleration cycle, since

$$\tau_E^{-1} \propto \frac{N_B}{\epsilon S \delta_E^2}; \quad \tau_H^{-1} \propto \frac{N_B}{\epsilon^2 S}$$

CHOICE OF TRANSITION ENERGY

Due to intrabeam scattering the momentum spread of the bunch increases until $\Delta_E = \Delta_B$. If this limit is exceeded, the particles are lost.

At constant voltage

$$\Delta_B^2 \propto \frac{1}{h \gamma |\eta|} = \frac{\gamma_{tr}}{h |\gamma/\gamma_{tr} - \gamma_{tr}/\gamma|}$$

The bucket height requirements vary with energy according to

$$\Delta_E \propto \frac{1}{\sqrt{\gamma}} \quad (\text{equipartition})$$

$$\Delta_E(\gamma=12) > 1.4 \Delta_E(\gamma=100) \quad (\text{Parzen})$$

Equivalent performance over energy range, (i.e. $L \propto \gamma$) requires

$$\gamma_{tr}^2 = \gamma_1 \gamma_2 \frac{(\Delta_1/\Delta_2)^2 \gamma_1 + \gamma_2}{\gamma_1 + (\Delta_1/\Delta_2)^2 \gamma_2}$$

For $\gamma_1=12$ and $\gamma_2=108$ follows the optimized transition energy ($\Delta_1/\Delta_2 \approx 1.4$):

$$\gamma_{tr} = 36 \times 0.6 \approx 22$$