Accelerator Physics
Particle Acceleration

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Lecture 1

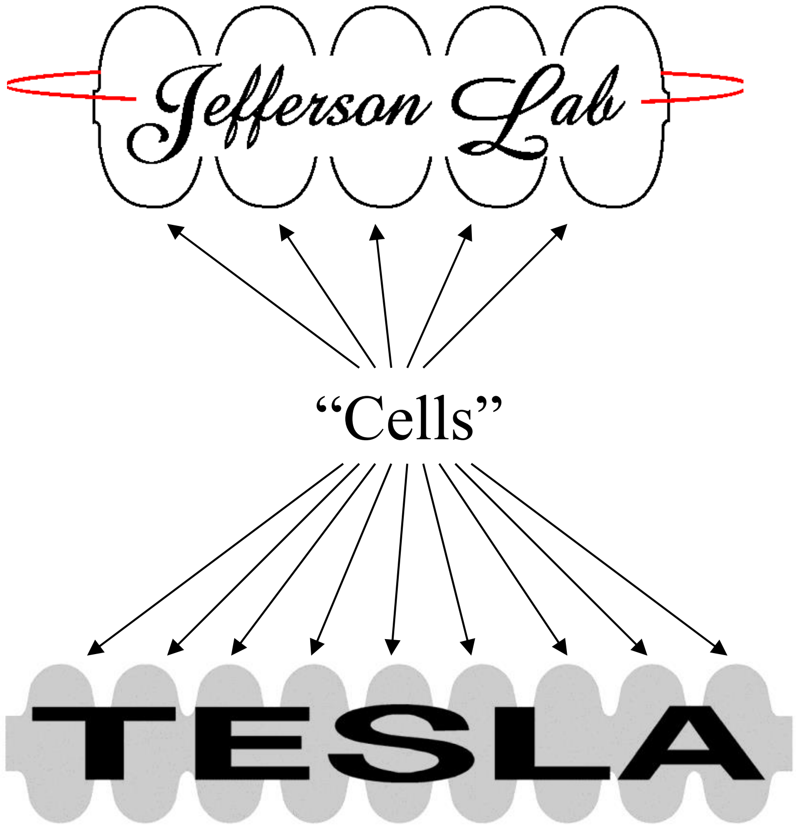
RF Acceleration

- Characterizing Superconducting RF (SRF) Accelerating Structures
  - Terminology
  - Energy Gain, R/Q, Q_0, Q_L and Q_{ext}
- RF Equations and Control
  - Coupling Ports
  - Beam Loading
- RF Focusing
- Betatron Damping and Anti-damping

Terminology

1 CEBAF Cavity

5 Cell Cavity



1 DESY Cavity

9 Cell Cavity

Modern Jefferson Lab Cavities (1.497 GHz) are optimized around a 7 cell design

Typical cell longitudinal dimension: $\lambda_{RF}/2$

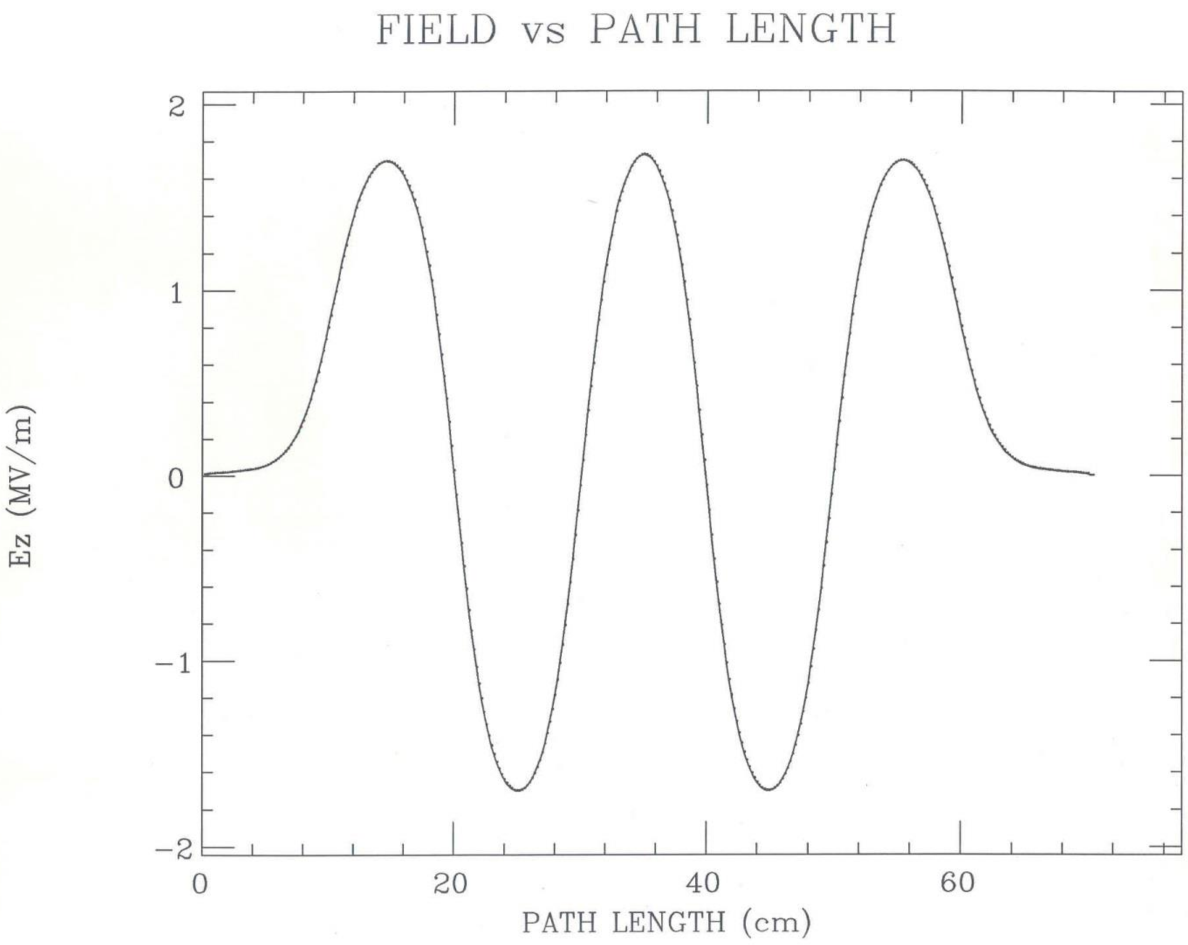
Phase shift between cells: π

Cavities usually have, in addition to the resonant structure in picture:

(1) At least 1 input coupler to feed RF into the structure

(2) Non-fundamental high order mode (HOM) damping

(3) Small output coupler for RF feedback control


FIELD vs PATH LENGTH
Ez (MV/m)
2
1
0
−1
−2
0
20
40
60
PATH LENGTH (cm)

Some Fundamental Cavity Parameters

- Energy Gain

$$\frac{d\left(\gamma mc^2\right)}{dt} = -e\vec{E}\left(\vec{x}\left(t\right),t\right)\cdot\vec{\mathrm{v}}$$

- For standing wave RF fields and velocity of light particles

$$\vec{E}\left(\vec{x},t\right) = \vec{E}\left(\vec{x}\right)\cos\left(\omega_{RF}t+\delta\right) \rightarrow \Delta\left(\gamma mc^2\right) \approx -e\int_{-\infty}^{\infty} E_z\left(0,0,z\right)\cos\left(2\pi z/\lambda_{RF}+\delta\right)dz$$

$$= \frac{e\tilde{E}_z\left(2\pi/\lambda_{RF}\right)e^{-i\delta}+\mathrm{c.c.}}{2} \qquad V_c \equiv \left|e\tilde{E}_z\left(2\pi/\lambda_{RF}\right)\right|$$

- Normalize by the cavity length L for gradient

$$\mathrm{E}_{\mathrm{acc}}\left(\mathrm{MV/m}\right) = \frac{V_c}{L}$$