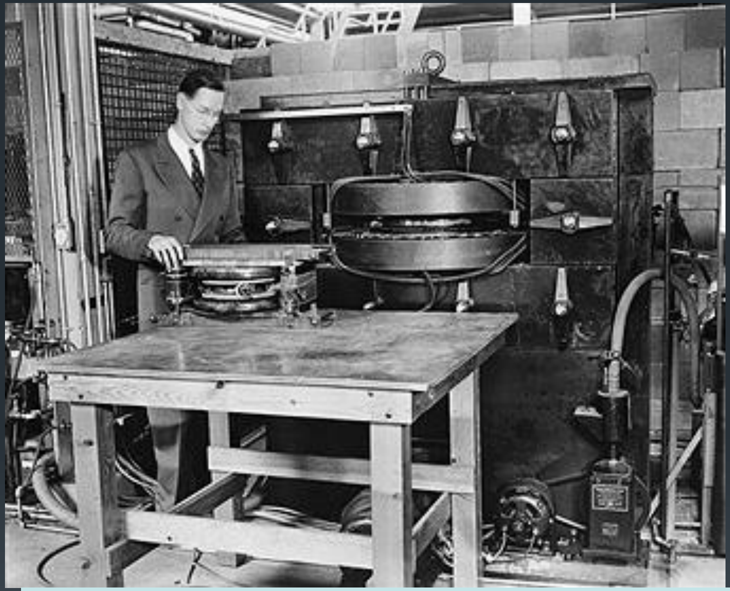
Accelerators

Lecture (2)

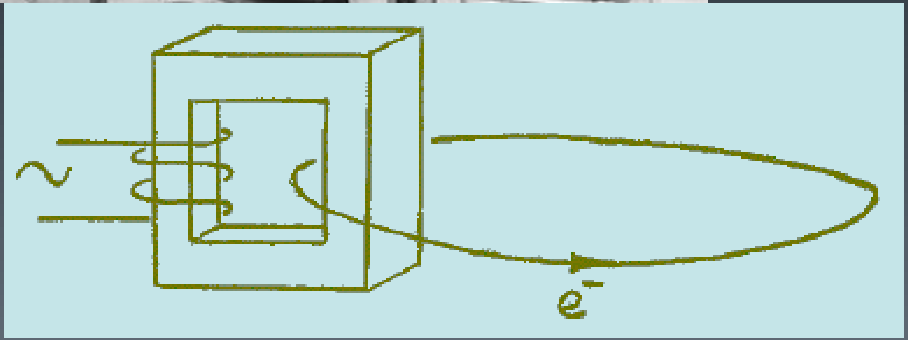
Circular accelerators (cont.)

- The Betatron

D.W. Kerst at University of Illinois



The maximum energy is 300 MeV for electrons due to synchrotron radiation.



$$B(R) = B/2$$

The Betatron condition

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\oint \nabla \times E \, . \, ds = -\oint \frac{\partial B}{\partial t} \, . \, ds$$

$$\oint E \, . \, dl = - \oint \frac{\partial B}{\partial t} \, . \, ds$$

$$E_\theta \, . \, 2\pi R = -\pi R^2 \frac{dB}{dt}$$

$$E_\theta = -\frac{R}{2}\frac{dB}{dt}$$

$$F = \frac{d(mv)}{dt} = eE$$

$$\frac{d(mv)}{dt} = \frac{eR}{2}\frac{dB}{dt}$$

$$mv = \frac{eRB}{2}$$

$$\frac{mv^2}{R} = evB(R)$$

$$mv = eRB(R)$$

$$B(R) = B/2$$

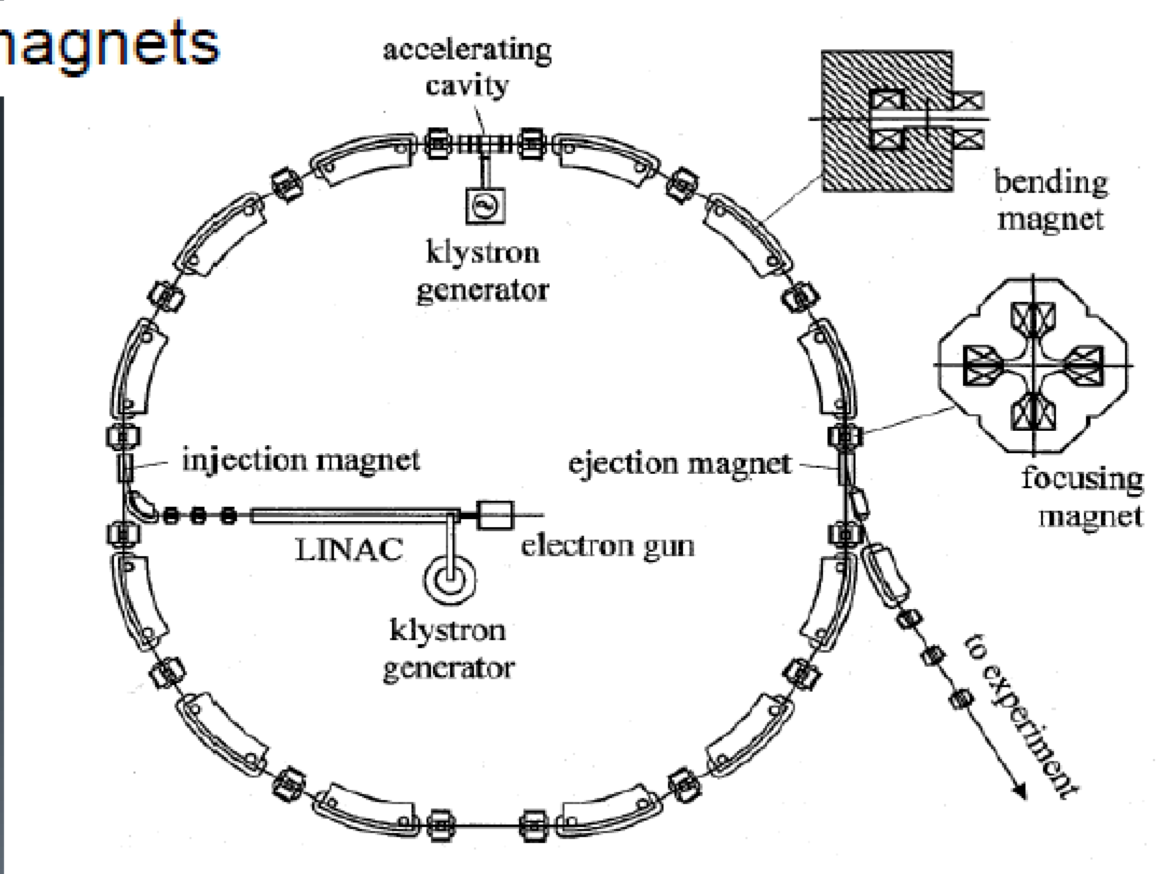
Circular accelerators (cont.)

- The Synchrotron

1.5 T in conventional magnets

$$R = vE/eBC^2$$

As the energy increases, the radius increases and this means that we need a large magnet and it is not feasible to produce one. To overcome this, a fixed orbit is chosen with narrow bending magnets.



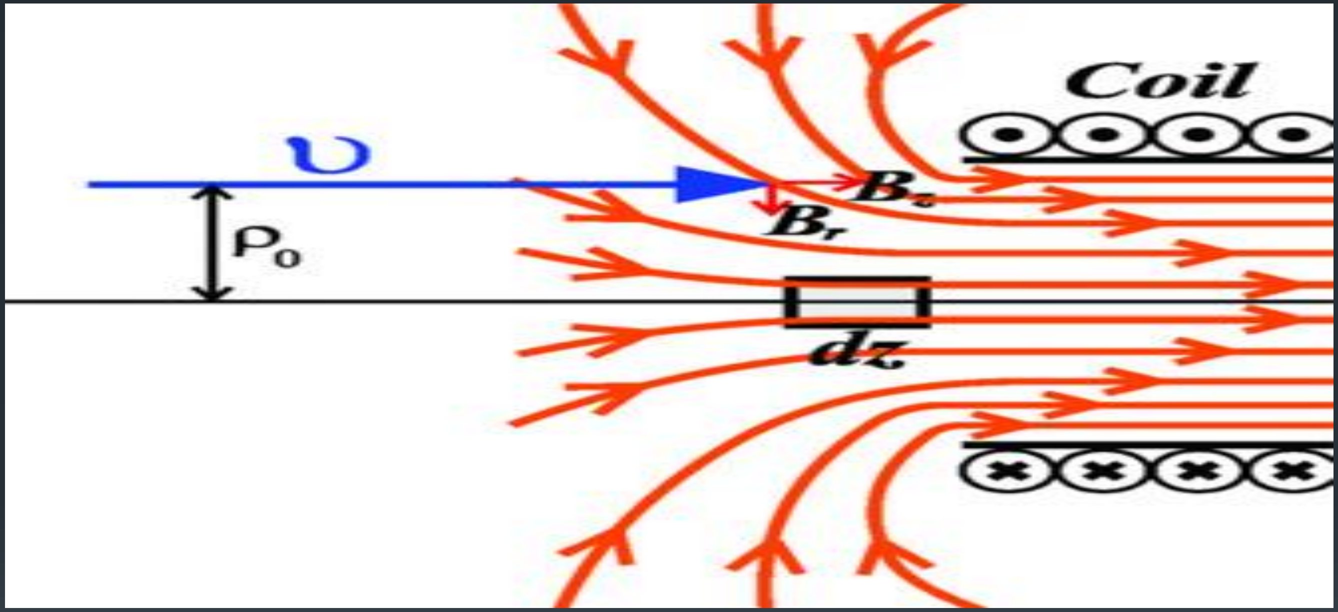
Accelerator components

- Particle source
- Magnets

1. Solenoid
2. Dipoles
3. Quadrupoles

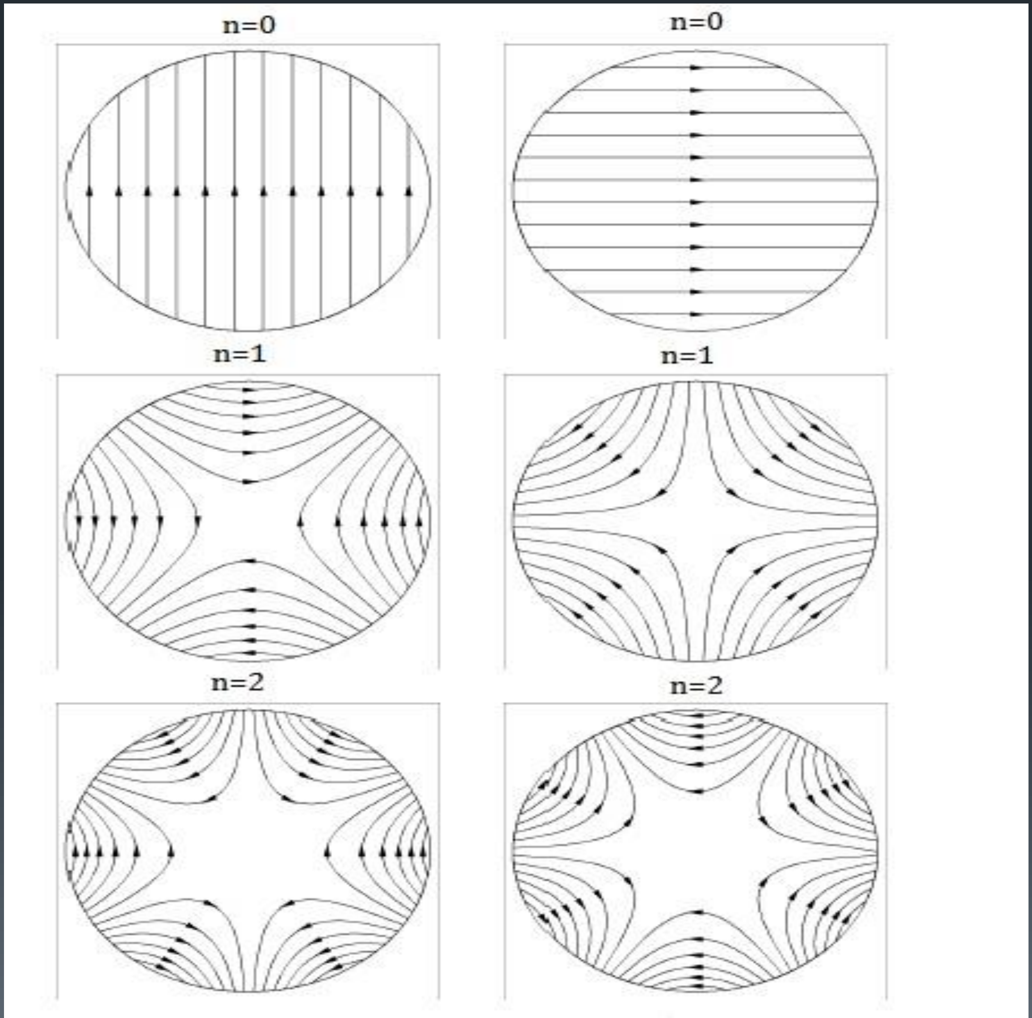
- RF system
- Diagnostic tools

Solenoids



At the center of the solenoid a total magnetic flux is $\pi r^2 B_0$ and the integrated radial field per fringe field is $(-r/2)(\frac{\delta B_z}{\delta z})$ where B_0 is the strength of the magnetic field at the center of the solenoid and r is the offset from the center

Dipoles

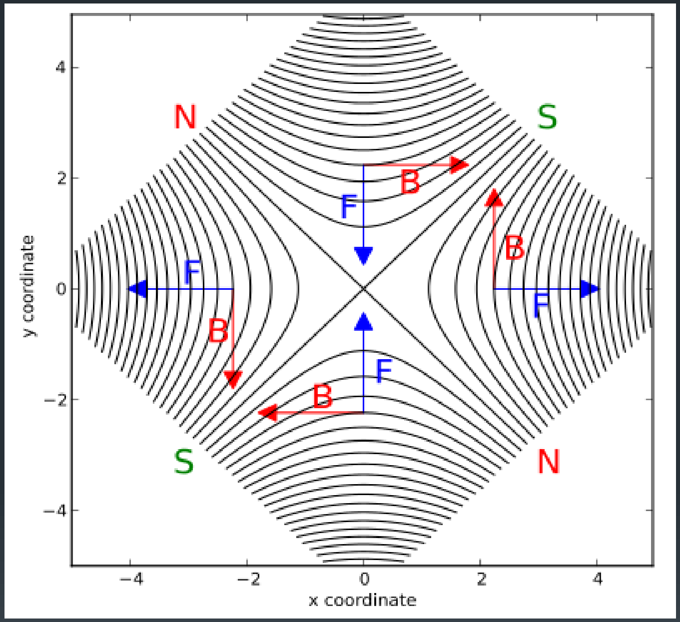


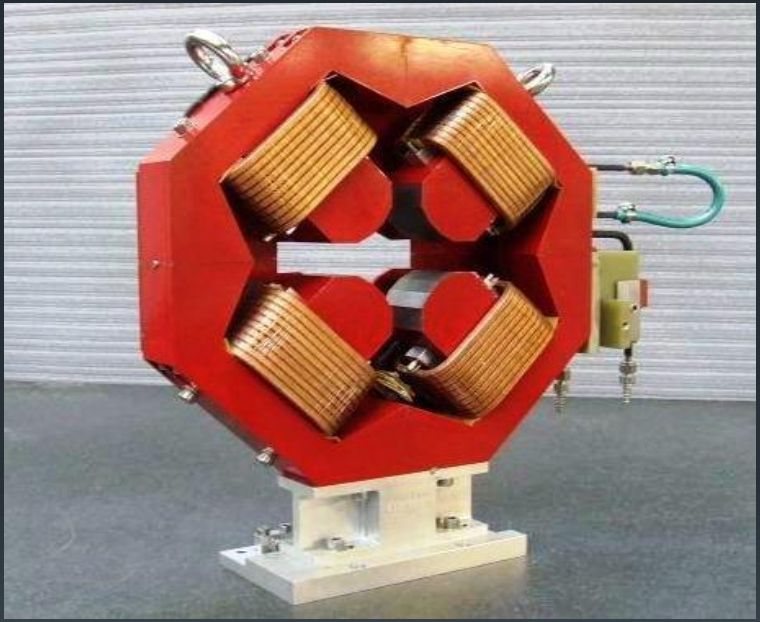
Top: dipole. Middle: quadrupole. Bottom: sextupole. Fields on the left are normal; those on the right are skew

The field of a magnet can be rewritten in complex form using Cartesian notation:

$$B_x - iB_y = B_0 \sum_{n=0}^{\infty} (a_n - ib_n) \left(\frac{x + iy}{a} \right)^n$$

Quadropoles





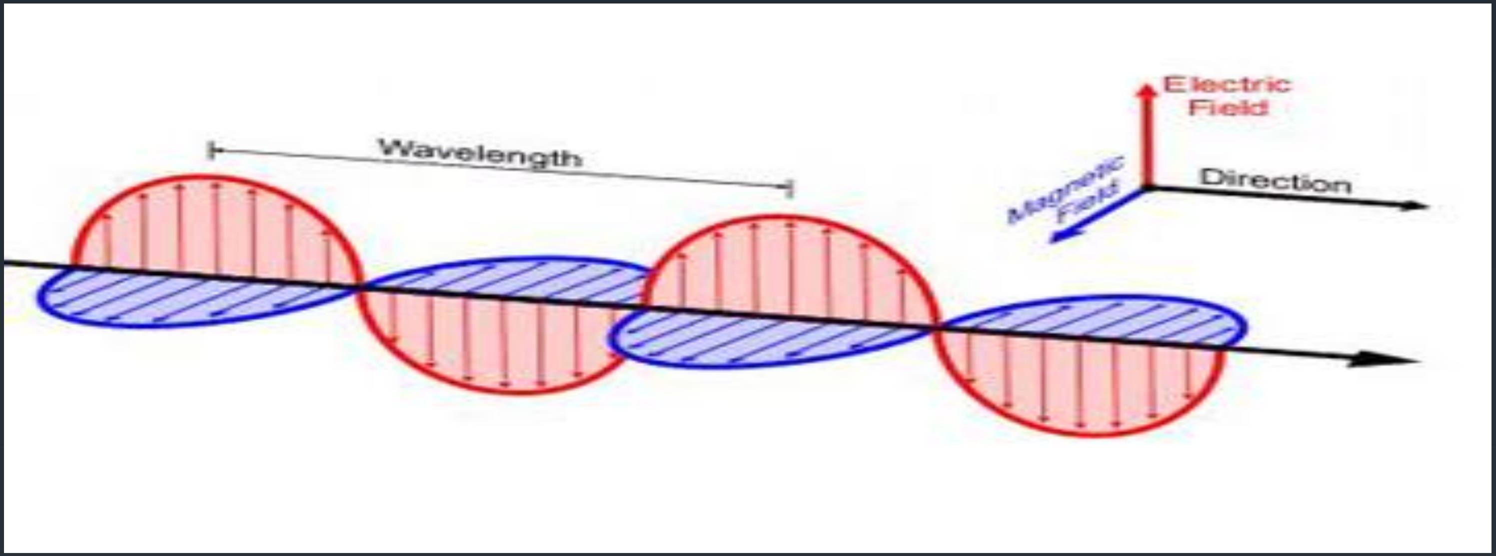
$$F_x = -qvB_y$$

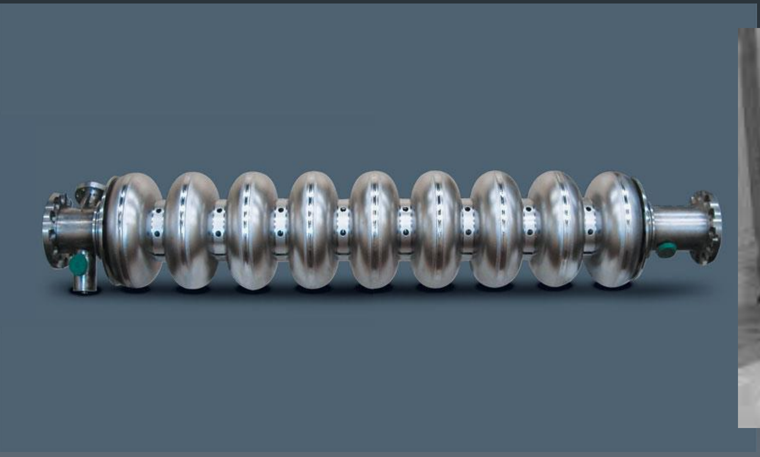
$$F_y = qvB_x$$

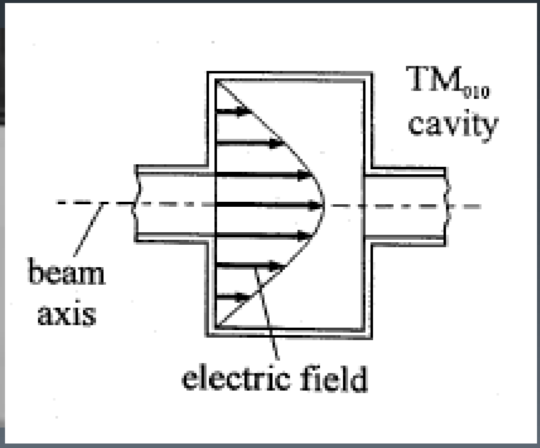
The B-field gradients in the x and y-directions (g_x, g_y) are defined by

$$g_x = \frac{\delta B_y}{\delta x} \quad and \quad g_y = \frac{\delta B_x}{\delta y}$$

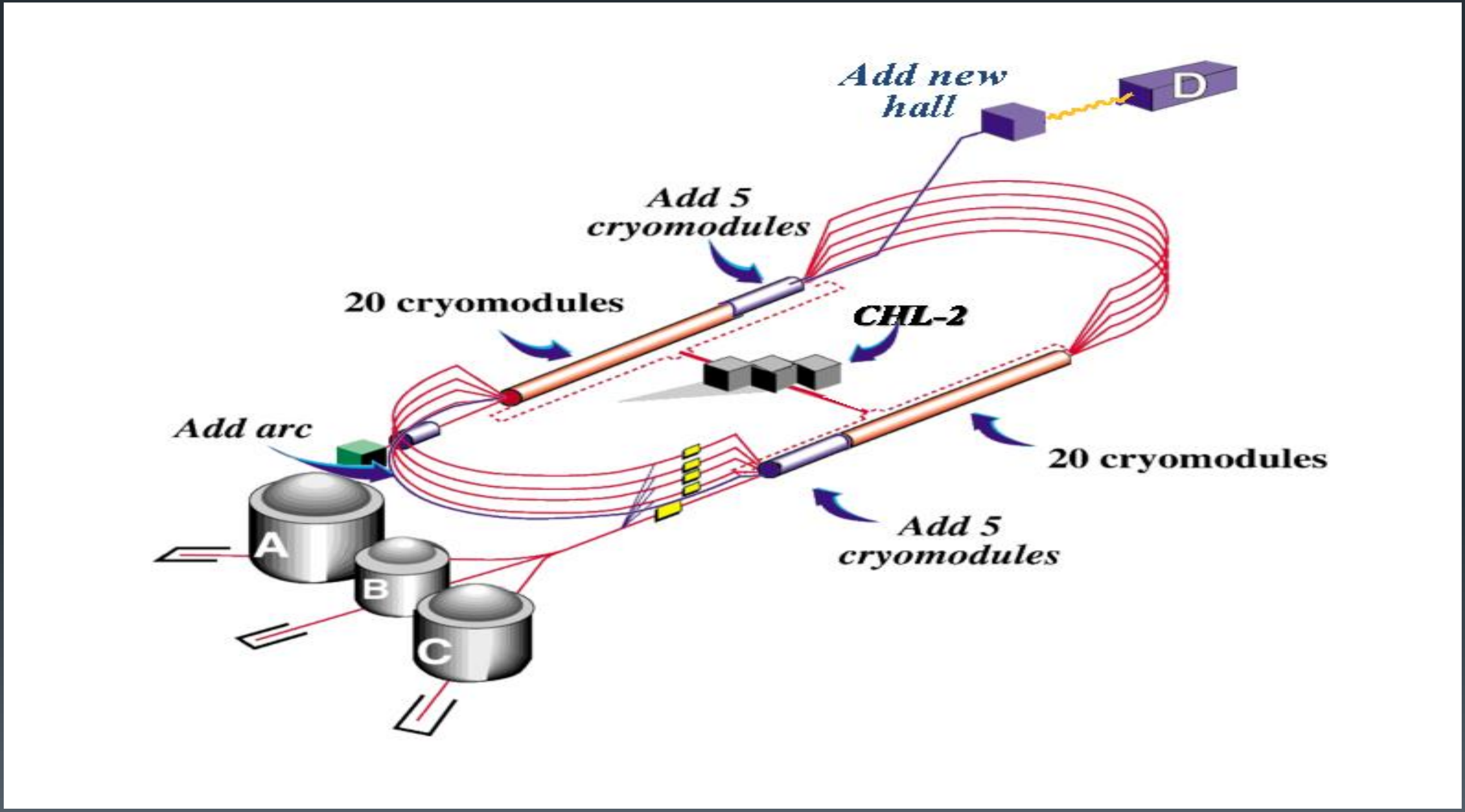
RF system


Wavelength
Electric Field
Magnetic Field
Direction



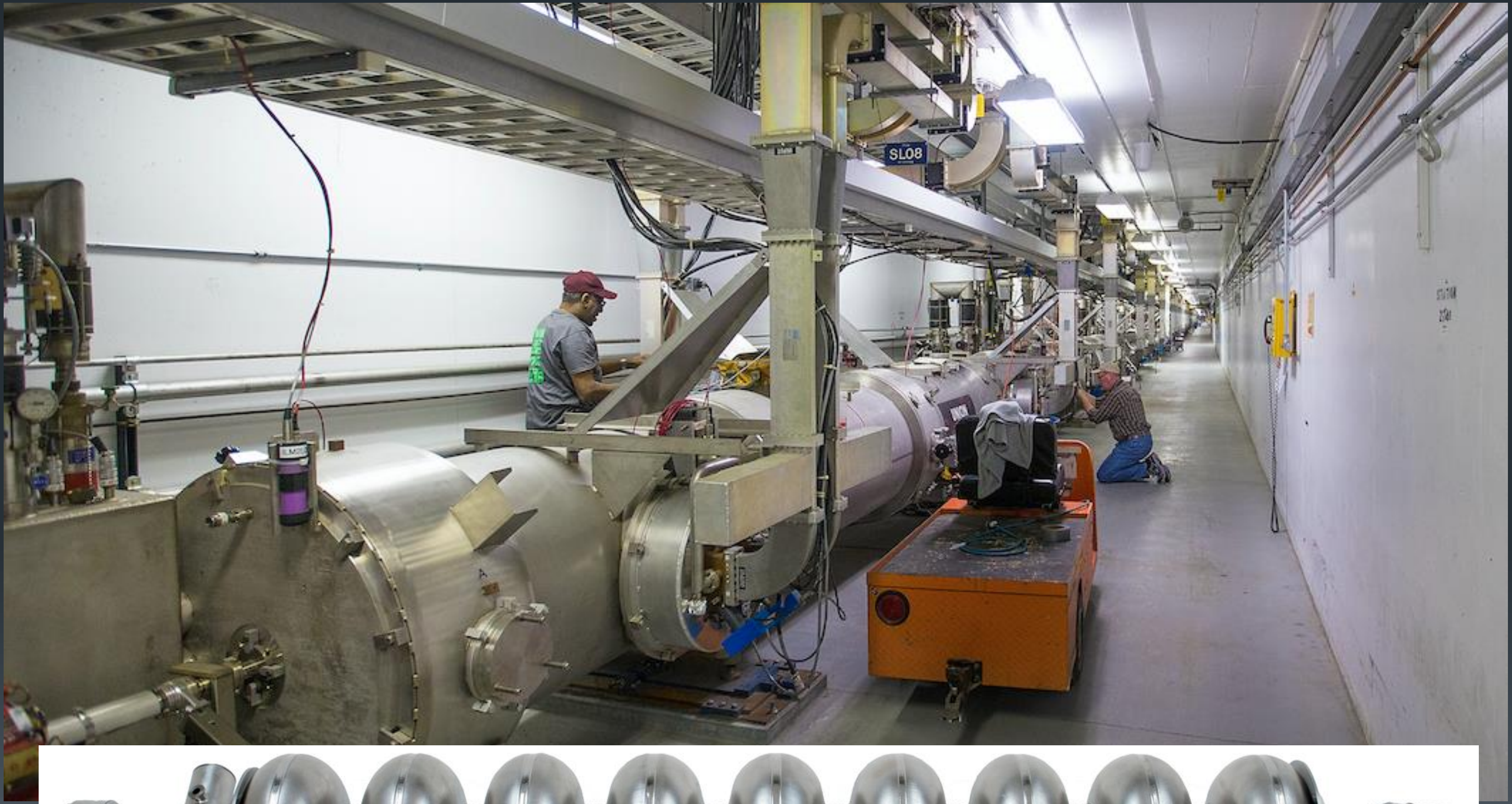

TM_{010} cavity
beam axis
electric field

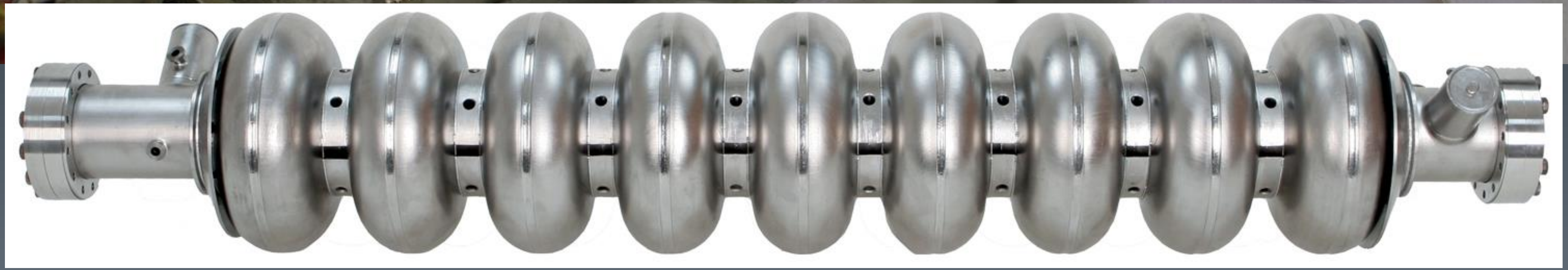
CEBAF



Add new hall
D
Add 5 cryomodules
20 cryomodules
CHL-2
Add arc
20 cryomodules
Add 5 cryomodules
A
B
C

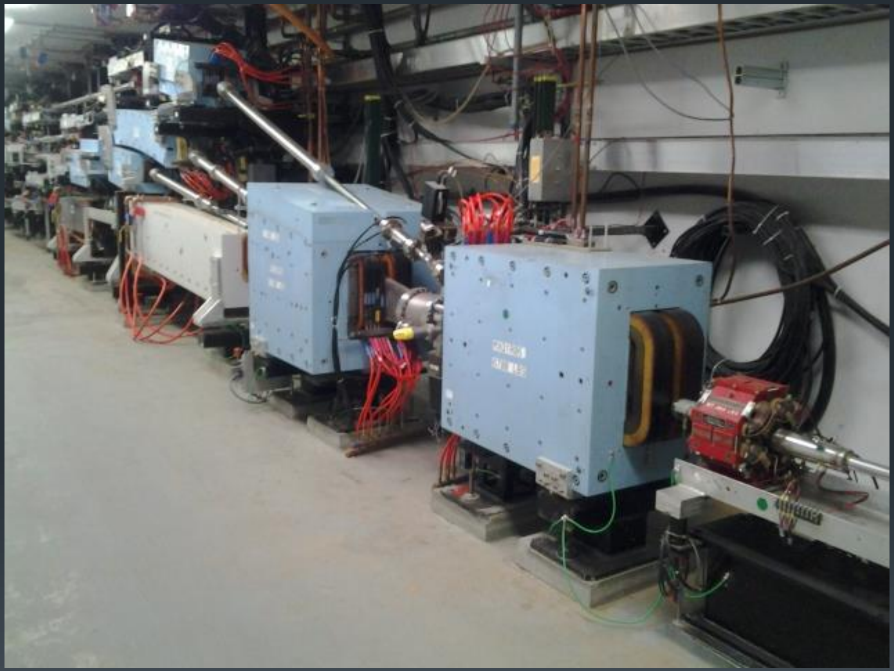
CEBAF Cryomodule





CEBAF Spreader & Recombiner

Spreader



Recombiner

CEBAF Control room