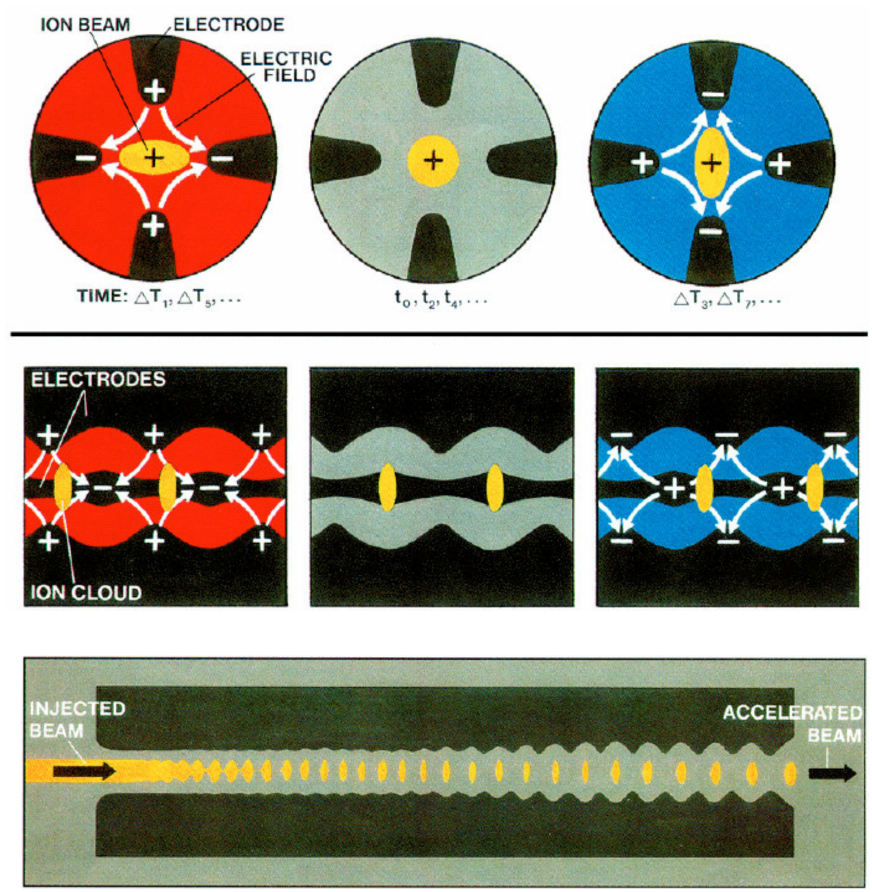
The RF quadrupole (RFQ)

- 1970: Kapchinskii and Teplyakov invent the RFQ



Three historic lines of accelerators

CHESS & LEPP

Transformer Accelerator

Direct Voltage Accelerators Resonant Accelerators

- 1924: Wideroe invents the betatron
- 1940: Kerst and Serber build a betatron for 2.3MeV electrons and understand betatron (transverse) focusing (in 1942: 20MeV)

Betatron:

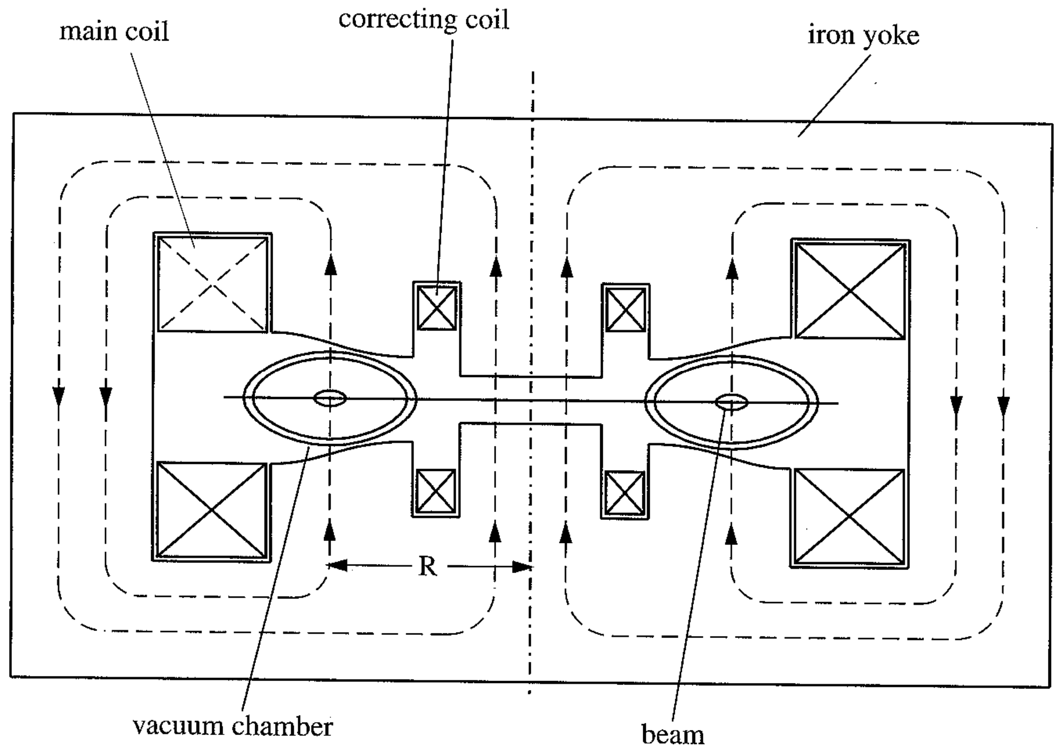
R=const, B=B(t)

Whereas for a cyclotron:

R(t), B=const

No acceleration section is needed since

$$\oint_{\partial A} \vec{E} \cdot d\vec{s} = -\iint_A \frac{d}{dt} \vec{B} \cdot d\vec{a}$$



The Betatron Condition

Condition: $R = \frac{-p_\varphi(t)}{qB_z(R,t)} = \text{const.}$ given $\oint_{\partial A} \vec{E}\cdot d\vec{s} = -\iint_A \frac{d}{dt}\vec{B}\cdot d\vec{a}$

$$E_\varphi(R,t) = -\tfrac{1}{2\pi R}\int \tfrac{d}{dt}B_z(r,t)\,r\,dr\,d\varphi = -\tfrac{R}{2}\left\langle \tfrac{d}{dt}B_z\right\rangle$$

$$\tfrac{d}{dt}p_\varphi(t) = qE_\varphi(R,t) = -q\tfrac{R}{2}\left\langle \tfrac{d}{dt}B_z\right\rangle$$

$$p_\varphi(t) = p_\varphi(0) - q\tfrac{R}{2}[\langle B_z\rangle(t) - \langle B_z\rangle(0)] = -RqB_z(R,t)$$

$$B_z(R,t) - B_z(R,0) = \frac{1}{2}[\langle B_z\rangle(t) - \langle B_z\rangle(0)]$$

Small deviations from this condition lead to transverse beam oscillations called betatron oscillations in all accelerators.

- Today: Betatrons with typically about 20MeV for medical applications

The Synchrotron

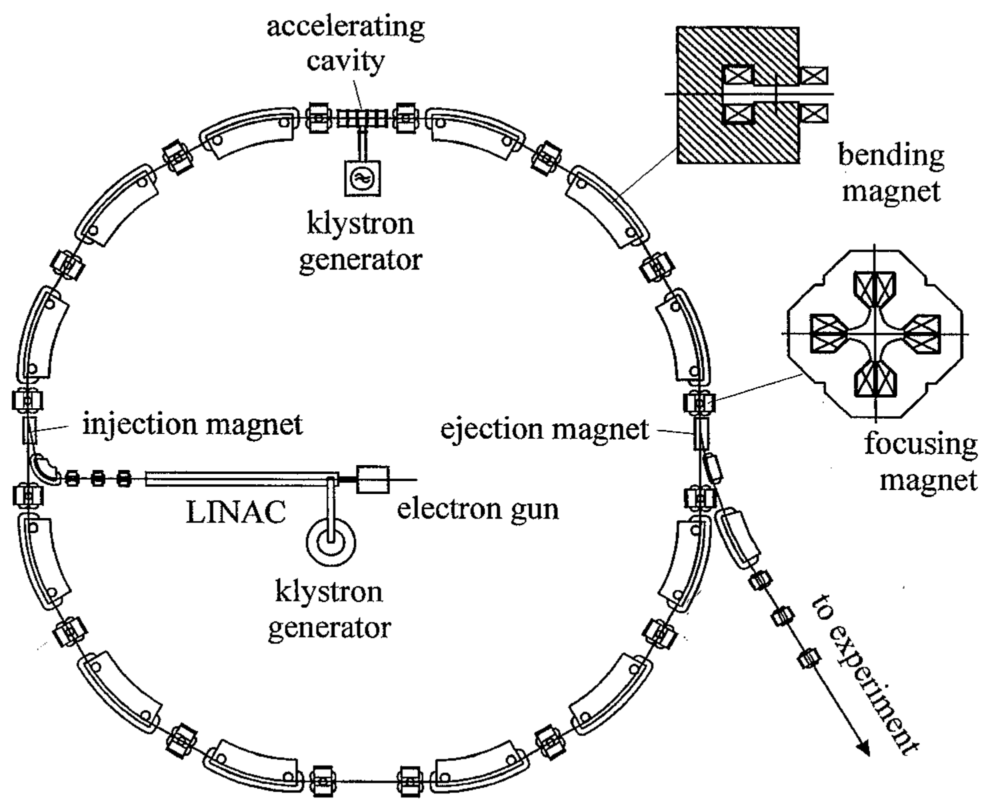
- 1945: Veksler (UDSSR) and McMillan (USA) invent the synchrotron
- 1946: Goward and Barnes build the first synchrotron (using a betatron magnet)
- 1949: Wilson et al. at Cornell are first to store beam in a synchrotron (later 300MeV, magnet of 80 Tons)
- 1949: McMillan builds a 320MeV electron synchrotron

- Many smaller magnets instead of one large magnet
- Only one acceleration section is needed, with

$$R = \frac{p(t)}{qB(R,t)} = \text{const.}$$

$$\omega = 2\pi \frac{v_{\text{particle}}}{L} n$$

for an integer n called the harmonic number

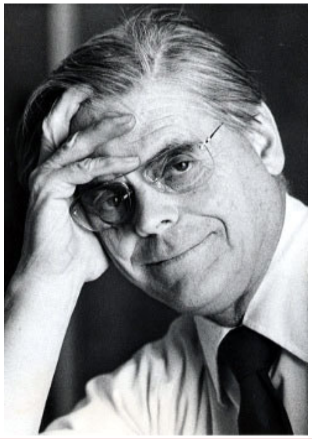


Rober R Wilson, Architecture

CHESS & LEPP

Science Ed Center, FNAL (1990)

Wilson Hall, FNAL



Robert R Wilson
USA 1914-2000