Lecture 1 - Overview of Accelerators

ACCELERATOR PHYSICS

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Links

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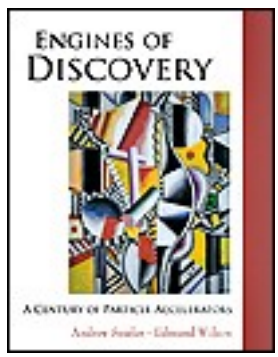
"Engines of Discovery":

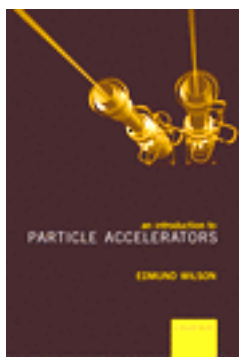
http://www.worldscibooks.com/physics/6272.html

http://www.enginesofdiscovery.com



"Particle Accelerators"

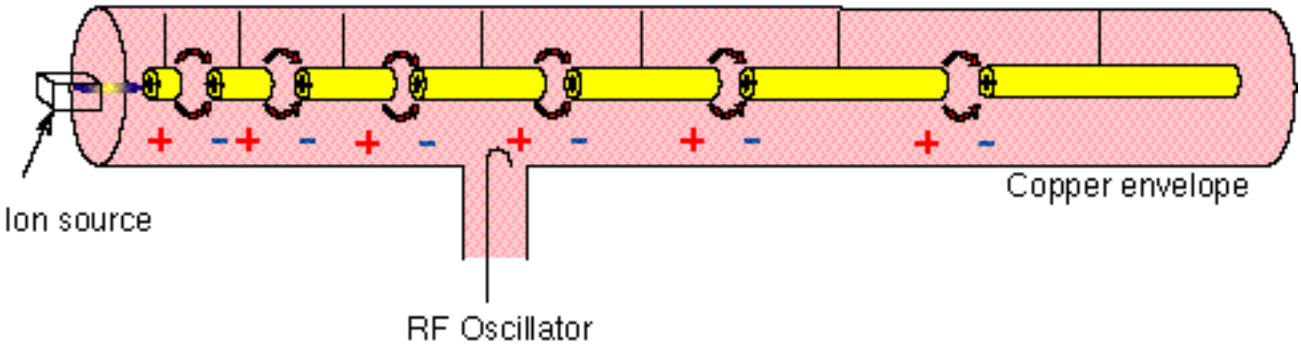
http://www.oup.com/uk/catalogue/?ci=9780198508298



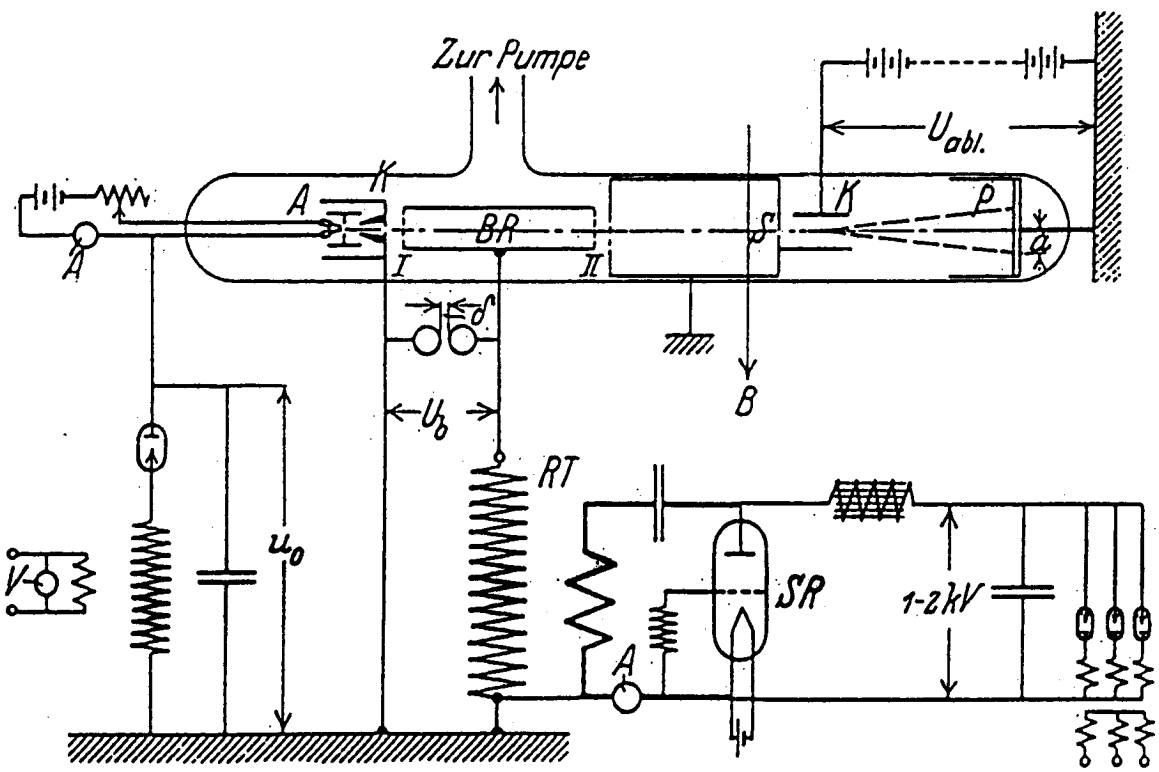
Lecture 1 – Overview - Contents

- Linear accelerator
- Acceleration on a wave
- Magnetic rigidity
- Cyclotron
- Magnetic rigidity
- Vertical focussing
- Components of a synchrotron
- Phase stability
- Weak focusing synchrotrons
- Strong focusing
- CERN 25 GeV PS
- Center of mass *v.* Fixed target
- Luminosity
- Superconducting magnets

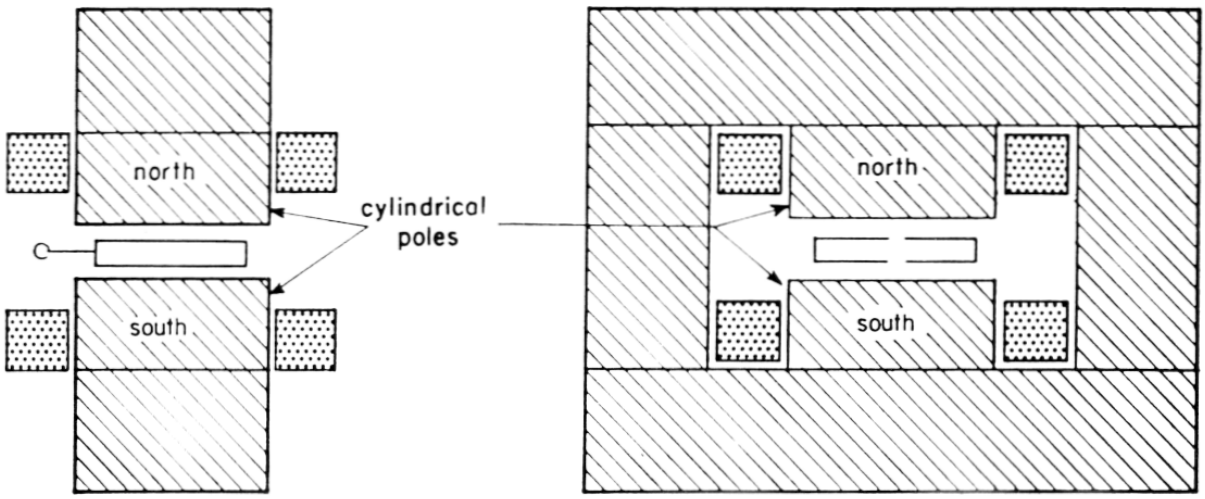
Linear accelerator

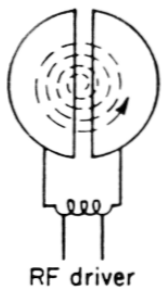


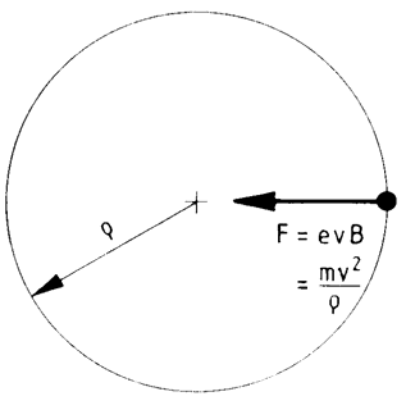
- **Particle gains energy at each gap**
- **Lengths of drift tubes follow increasing velocity**
- **Spacing becomes regular as v approaches c**
- **Wideroe's first linac:**



Cyclotron







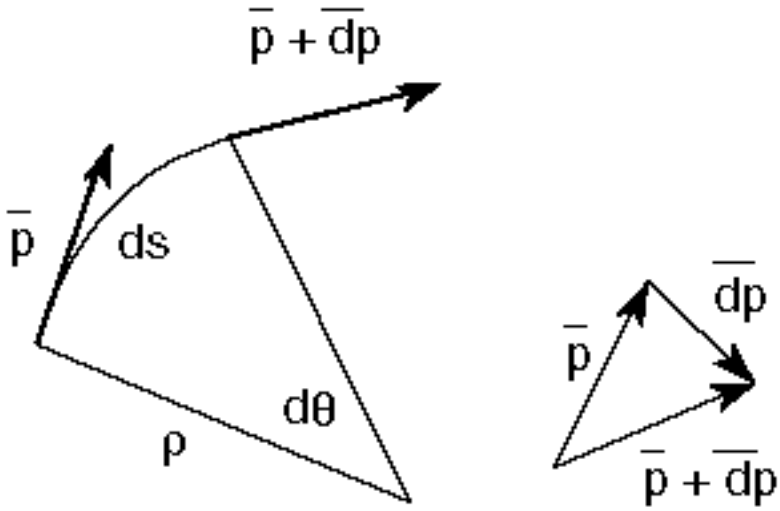
Magnetic rigidity

$$B\rho = \frac{mv}{e} = \frac{p}{e}$$

Constant revolution frequency

$$f_{rev} = \frac{v}{2\pi\rho} = \frac{v}{2\pi}\frac{eB}{mv} = \frac{eB}{2\pi m}$$

Magnetic Rigidity



$$e\ \ \mathbf{v}\times\mathbf{B}=\frac{d\mathbf{p}}{dt}$$

- **from resolution of momenta that:**

$$\frac{d\mathbf{p}}{dt}=|\mathrm{p}|\frac{d\theta}{dt}=\frac{|\mathrm{p}|}{\rho}\frac{ds}{dt}$$

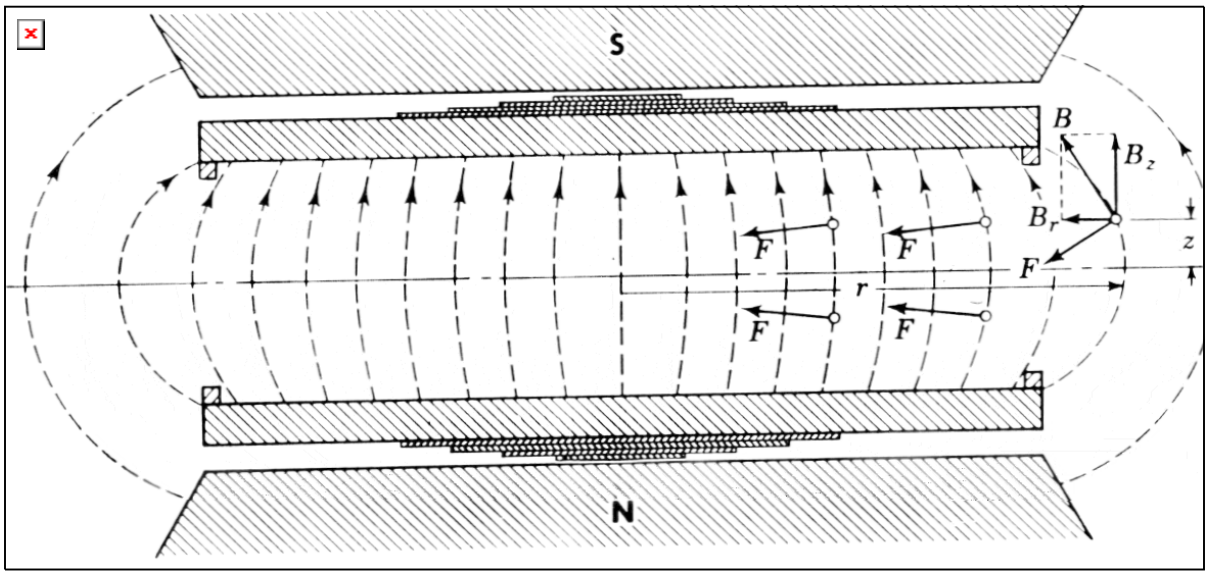
- **the magnitude of the force may be written:**

$$e|\mathbf{v}\times\mathbf{B}|=e|\mathrm{B}|\frac{ds}{dt}$$

- **Equating the right hand sides of the two expressions above, we find we can define a quantity known as magnetic rigidity:**
- **A common convention in charged particle dynamics is to quote pc in units of electron–volts. Whereupon:**

$$(B\rho)[T.m]=\frac{pc[eV]}{c\left[m.s^{-1}\right]}=3.3356(pc)$$

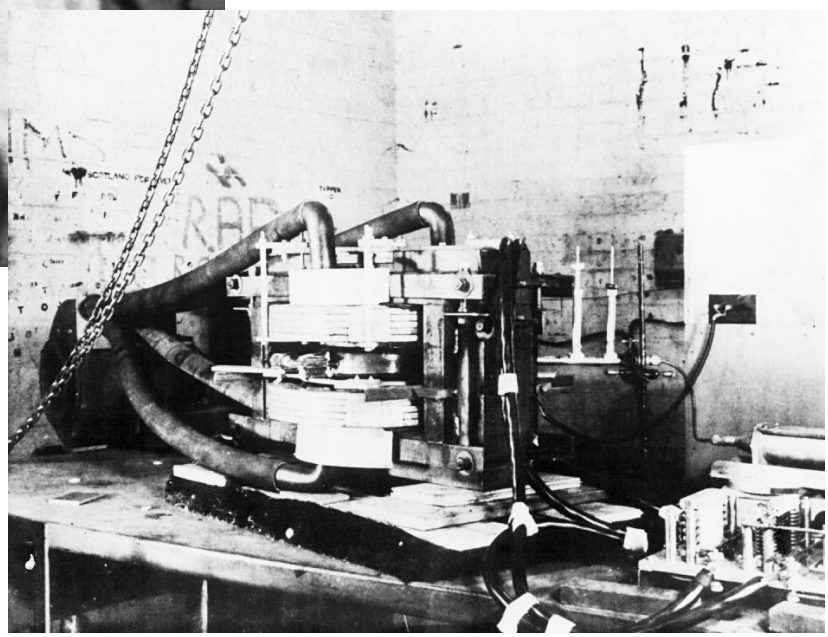
Vertical Focusing



- People just got on with the job of building them.
- Then one day someone was experimenting
- Figure shows the principle of vertical focusing in a cyclotron
- In fact the shims did not do what they had been expected to do
- Nevertheless the cyclotron began to accelerate much higher currents

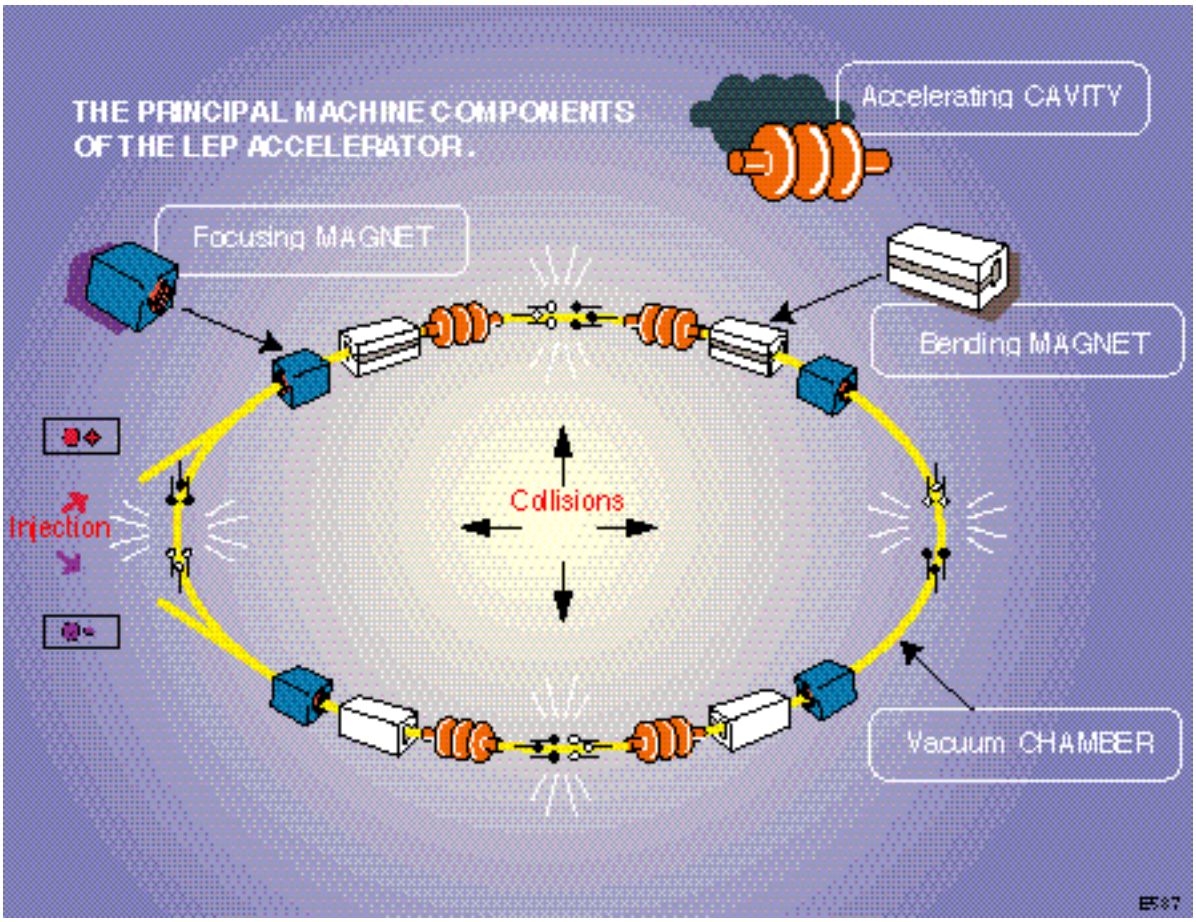
Discovery of the Synchrotron

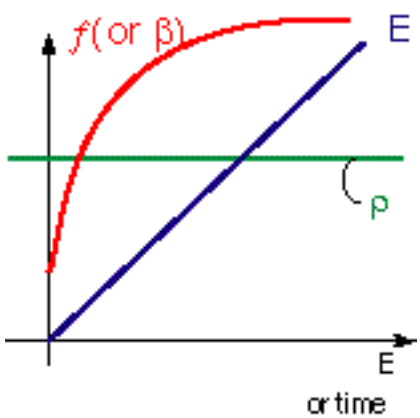
- **Marcus Oliphant– later to become Governor of South Australia**

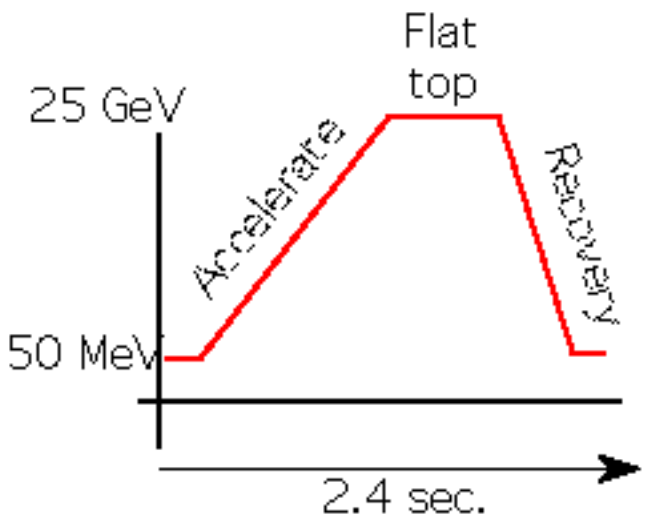


- **The Arsenal Synchrotron- Late in World War II the Woolwich Arsenal Research Laboratory in the UK had bought a betatron to "X-ray" unexploded bombs in the streets of London. Frank Goward converted the betatron into the first "proof of principal"**

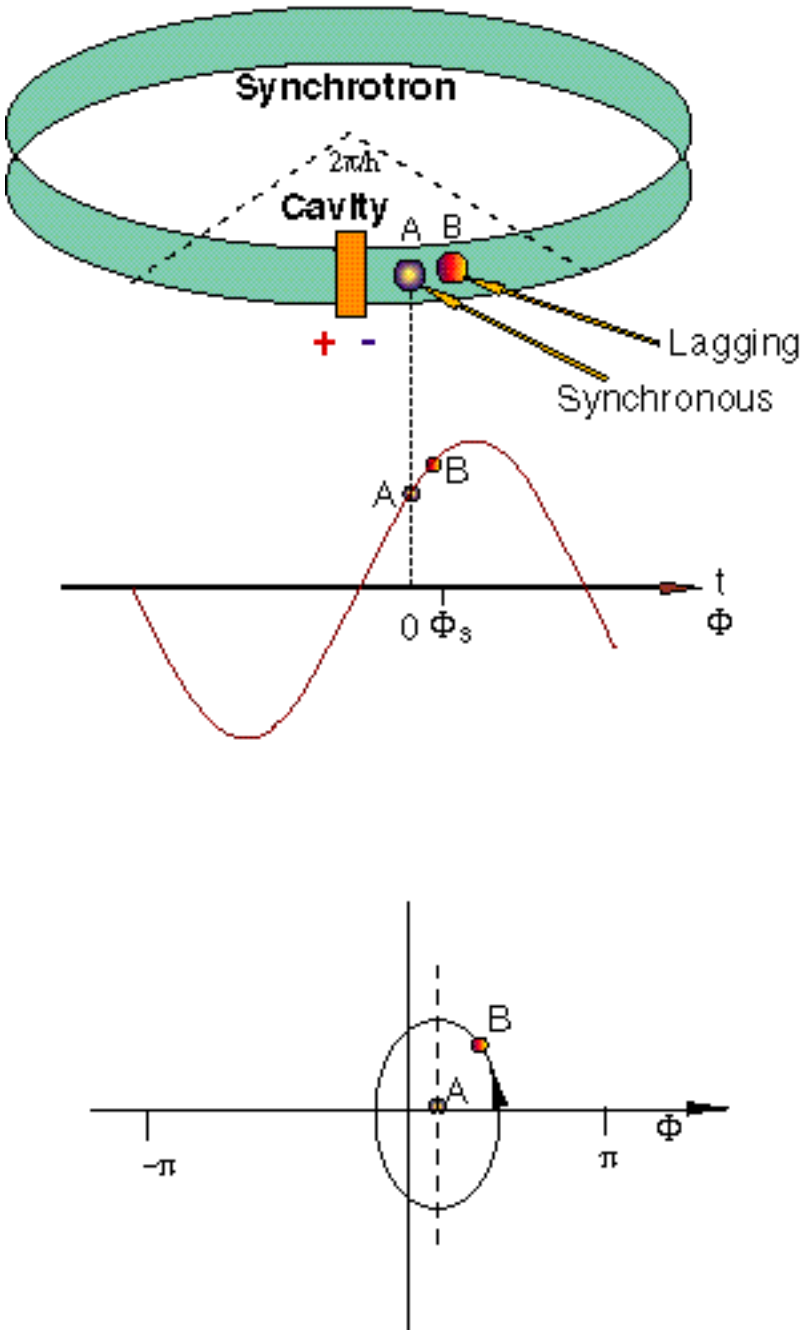
Components of a synchrotron



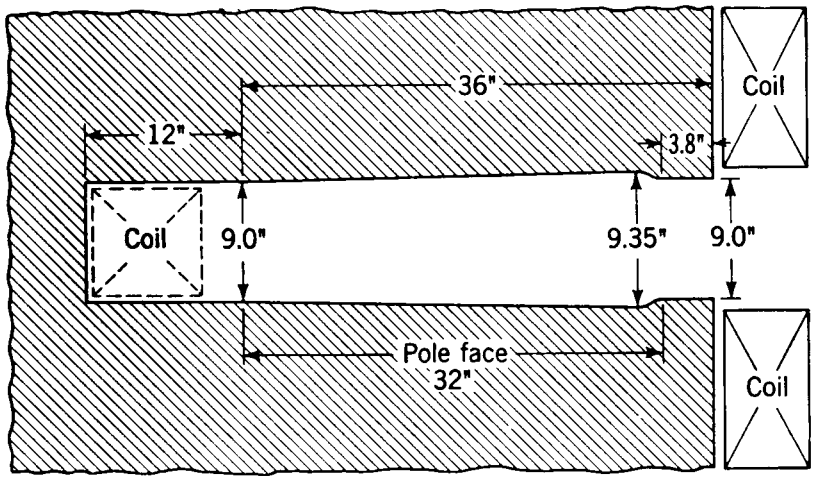




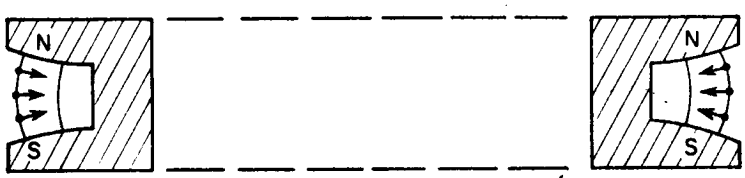
Phase stability



Weak focusing in a synchrotron

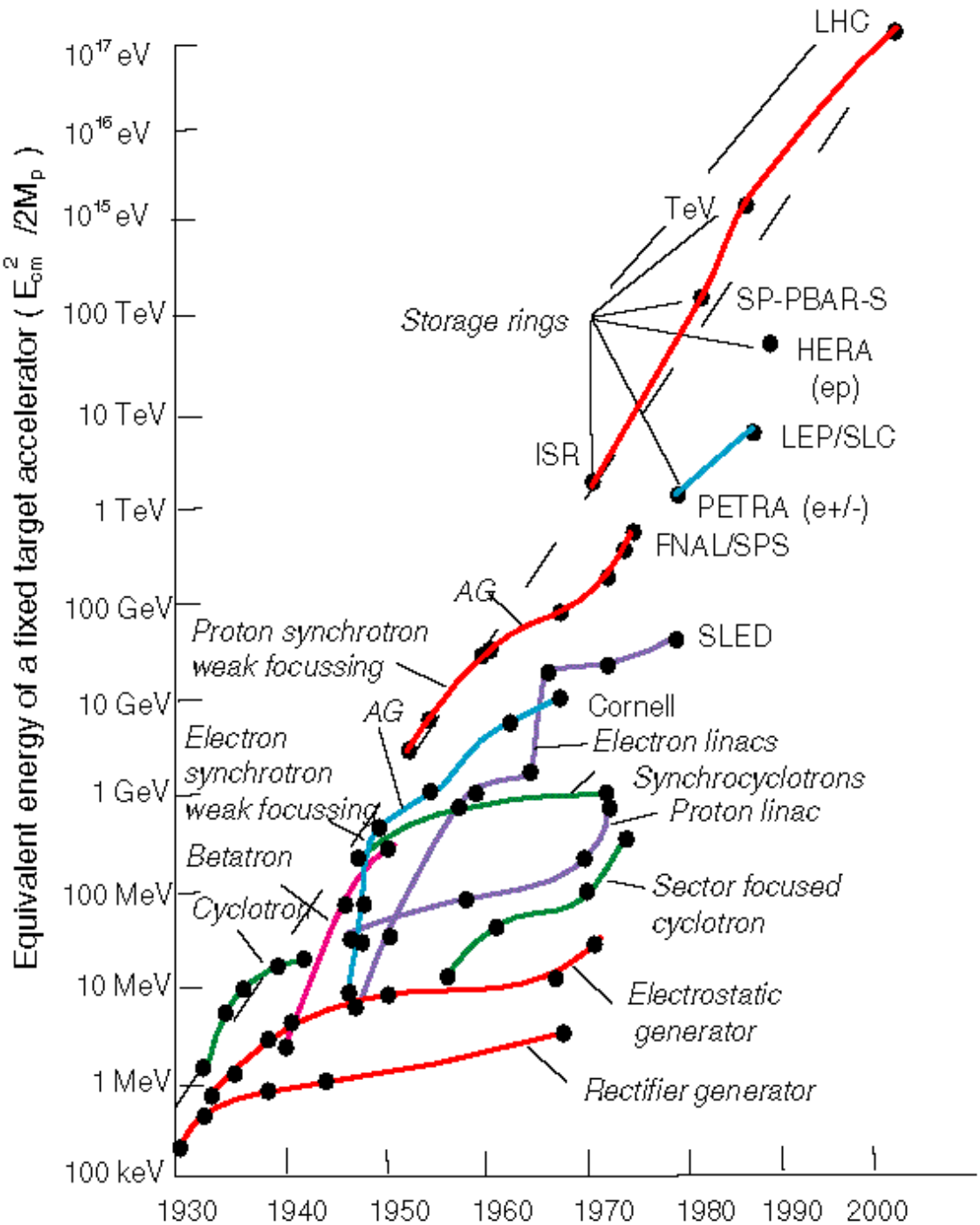


The Cosmotron magnet

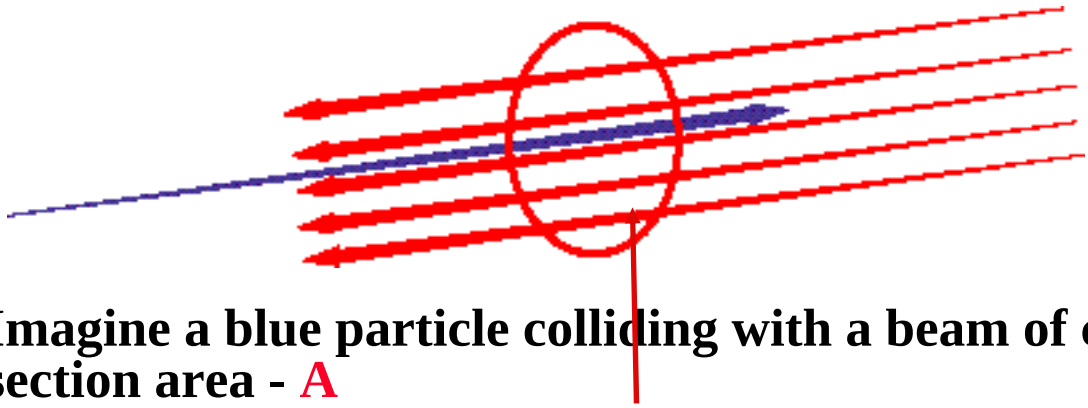


- Vertical focusing comes from the curvature of the field lines when the field falls off with radius (positive n-value)
- Horizontal focusing from the curvature of the path
- The negative field gradient defocuses horizontally and must not be so strong as to cancel the path curvature effect

The history of accelerators



Luminosity



- **Imagine a blue particle colliding with a beam of cross section area - A**
- **Probability of collision is** $\frac{\sigma}{A} \cdot N$
- **For N particles in both beams**
- **Suppose they meet *f* times per second at the revolution frequency** $\frac{\sigma}{A} \cdot N^2$
- **Event rate** $f_{rev} = \frac{\beta c}{2\pi R}$

$$\frac{f_{rev} N^2}{A} \cdot \sigma$$

Make big

e.g. 10^{-25}

Make small

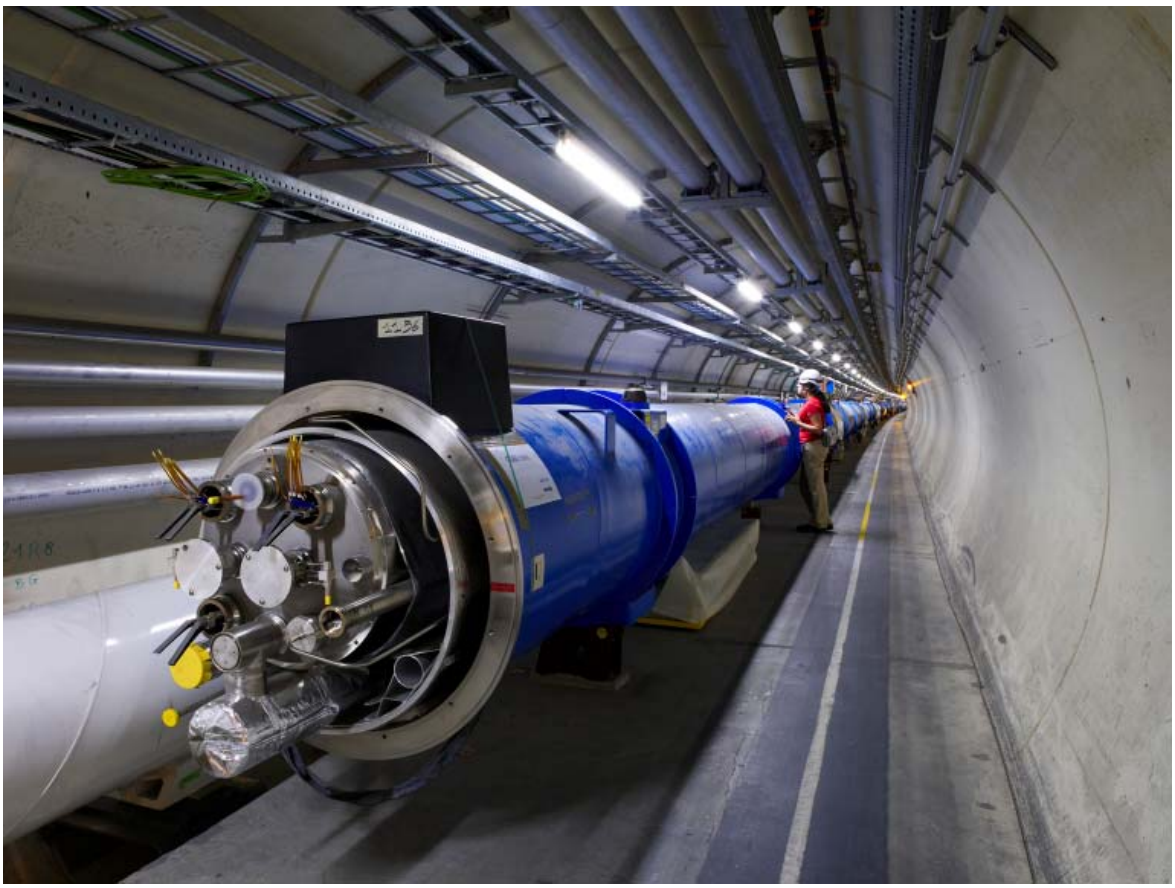
LUMINOSITY $\approx 10^{30}$ to 10^{34} $\left[\text{cm}^{-2}\ \text{s}^{-1}\right]$

SPS

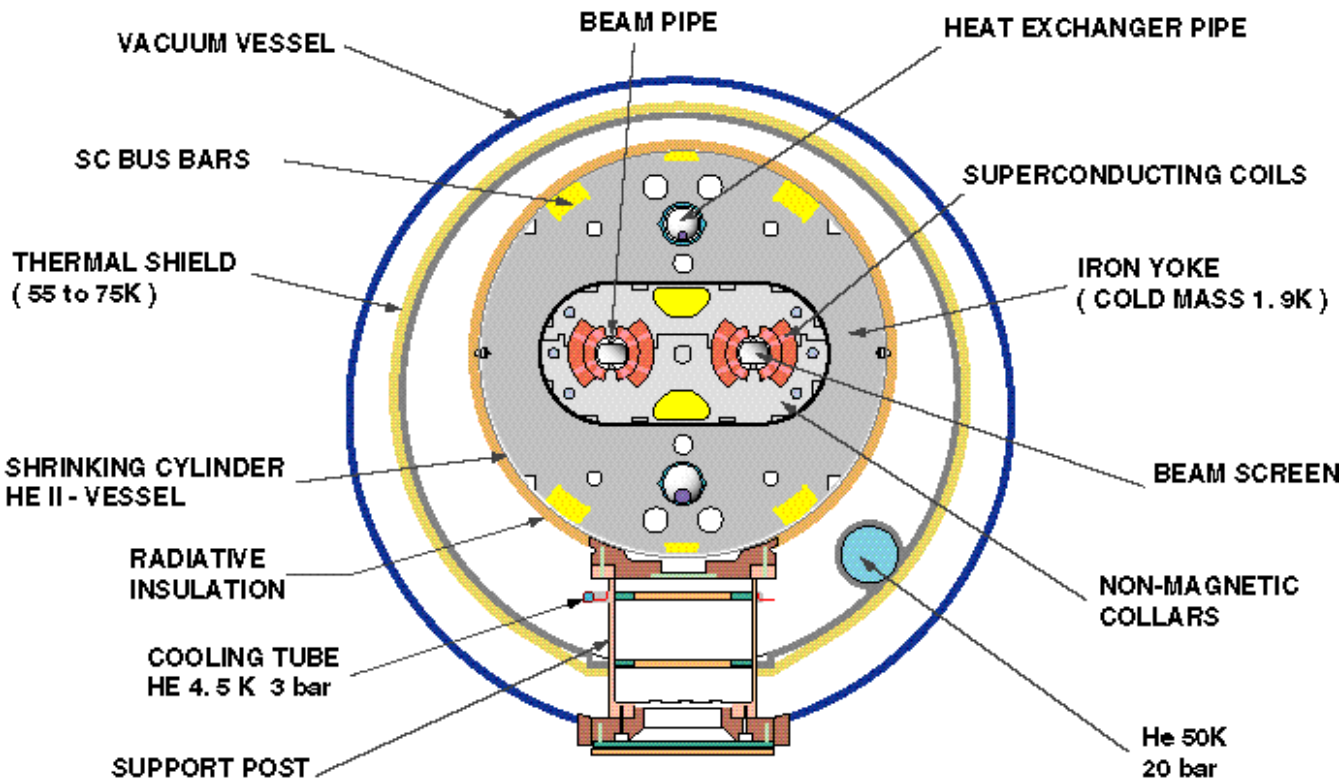
LEP

LEP(small).pct

The Large Hadron Collider (LHC)



Superconducting magnets



Summary

- History of accelerators
- Need for accelerators
- Linear accelerator
- Acceleration on a wave
- Magnetic rigidity
- Cyclotron
- Magnetic rigidity
- Vertical focusing
- Components of a synchrotron
- Phase stability
- Weak focusing synchrotrons
- Weak focusing in a synchrotron