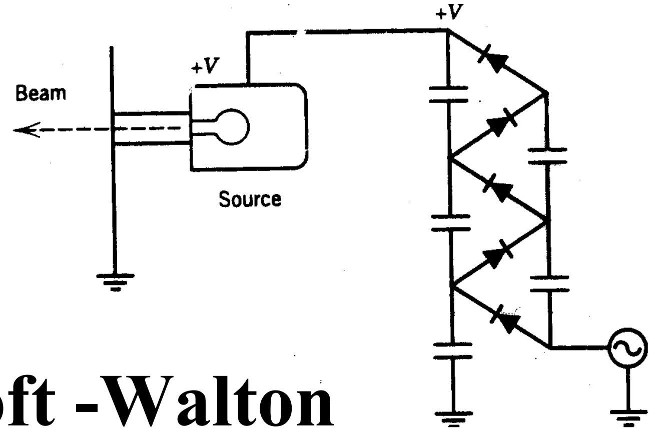
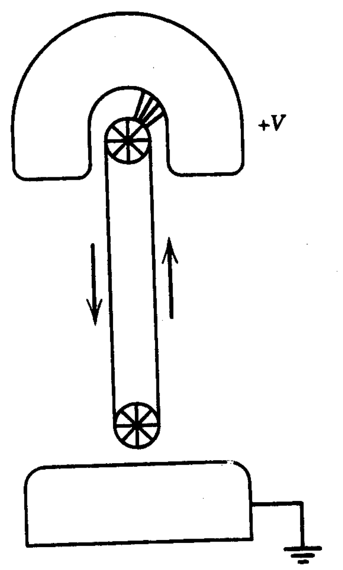
Introduction to Accelerators
Lecture I – History – E. Wilson

- Electrostatic ideas
- The Betatron
- Linear accelerator
- Cyclotron and vertical focusing
- Newton & Einstein
- Pulsed operation - synchrocyclotron
- Components of a synchroton
- Phase stability
- The Woolich betatron
- GEC electron synchrotron
- Birmingham synchrotron
- Cosmotron
- Weak focussing in a synchrotron
- Strong focussing
- CERN 25 GeV PS
- SPS then antiprotons
- Center of mass *v.* Fixed target
- LEP
- Superconducting magnets

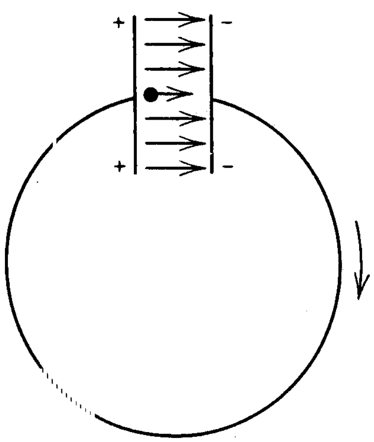
Electrostatic ideas



Cockcroft -Walton



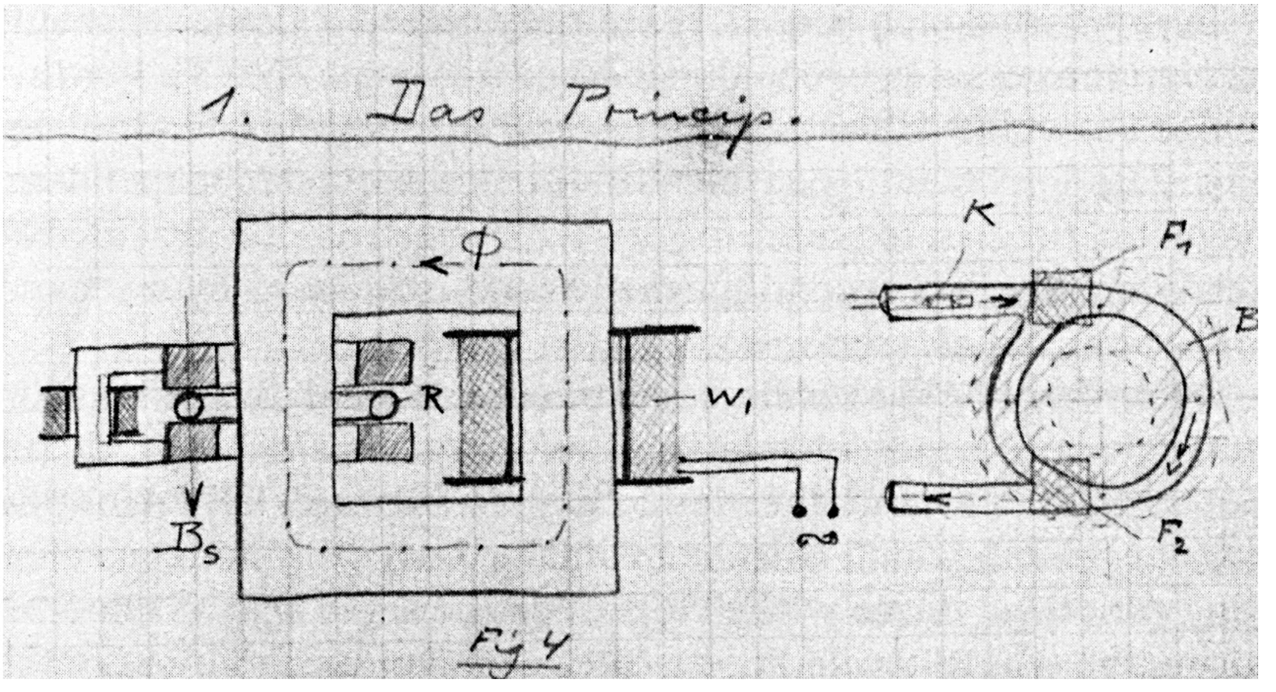
Van der Graaf

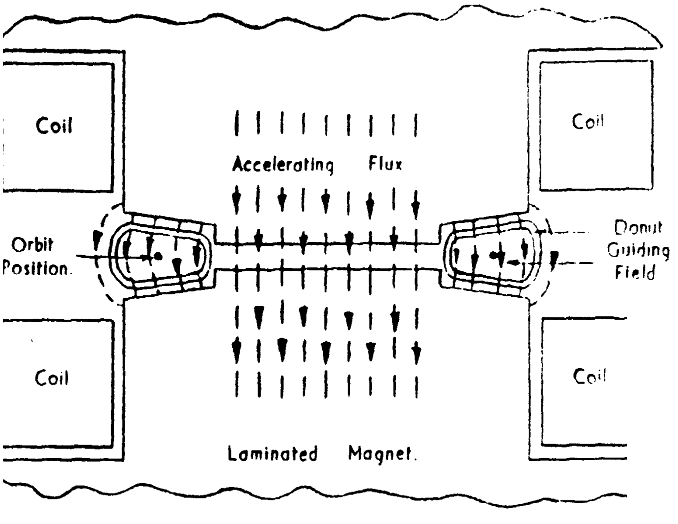


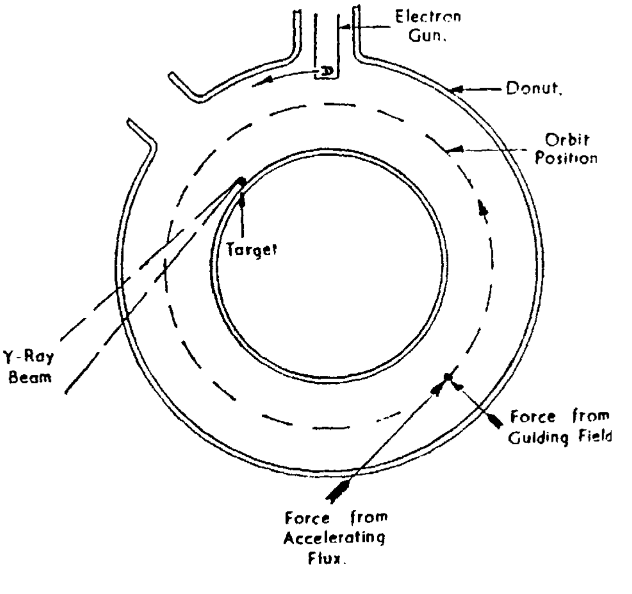
Fallacy

ES/Fallacy.pct

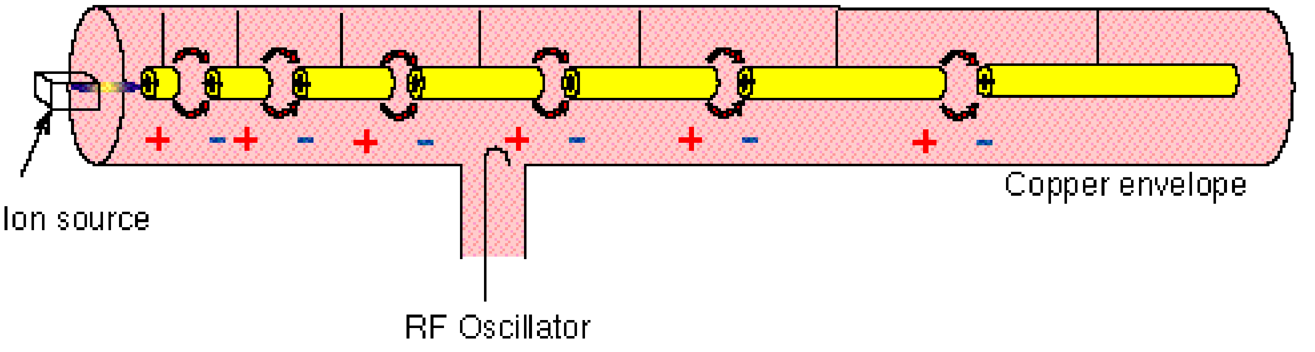
The Betatron



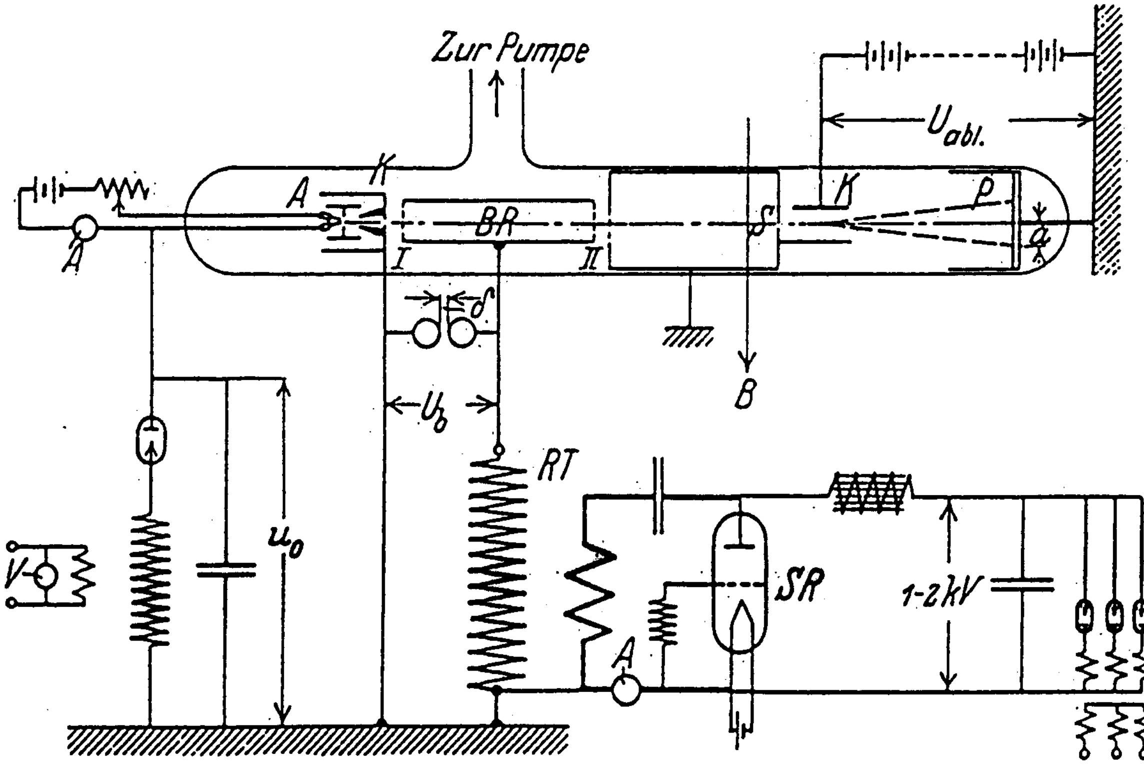




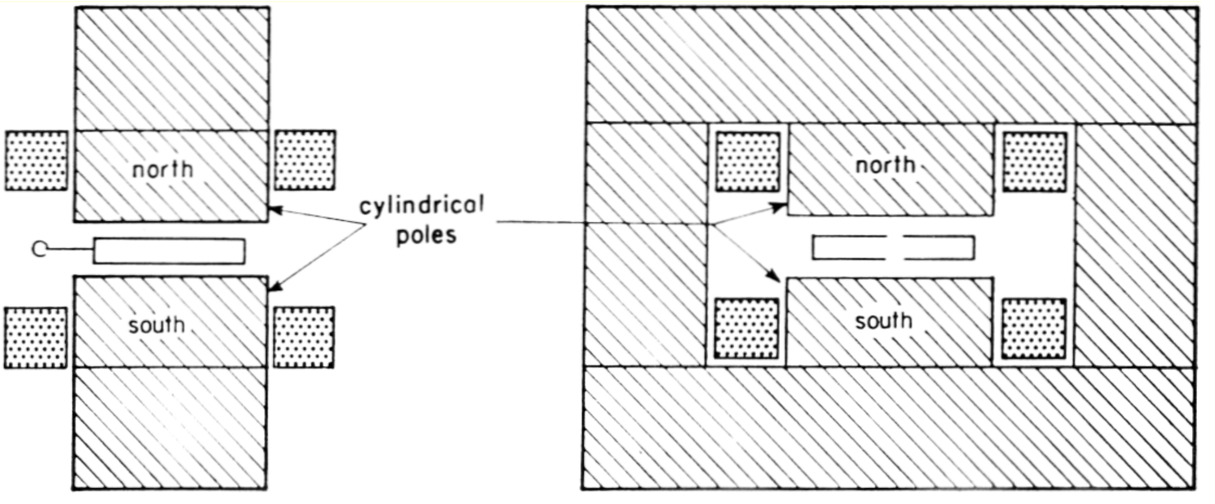
Linear accelerator

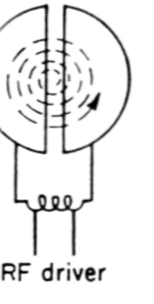


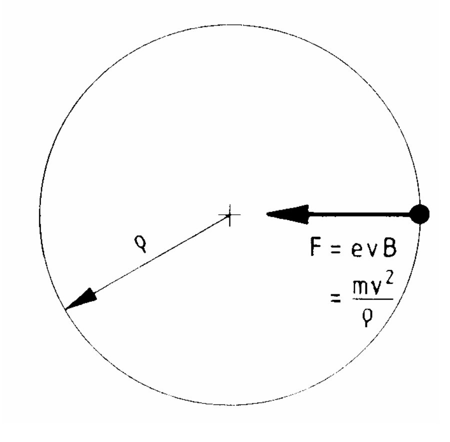
- Particle gains energy at each gap
- Lengths of drift tubes follow increasing velocity
- Spacing becomes regular as v approaches c
- Wideroe's first linac:



Cyclotron (revolution frequency)







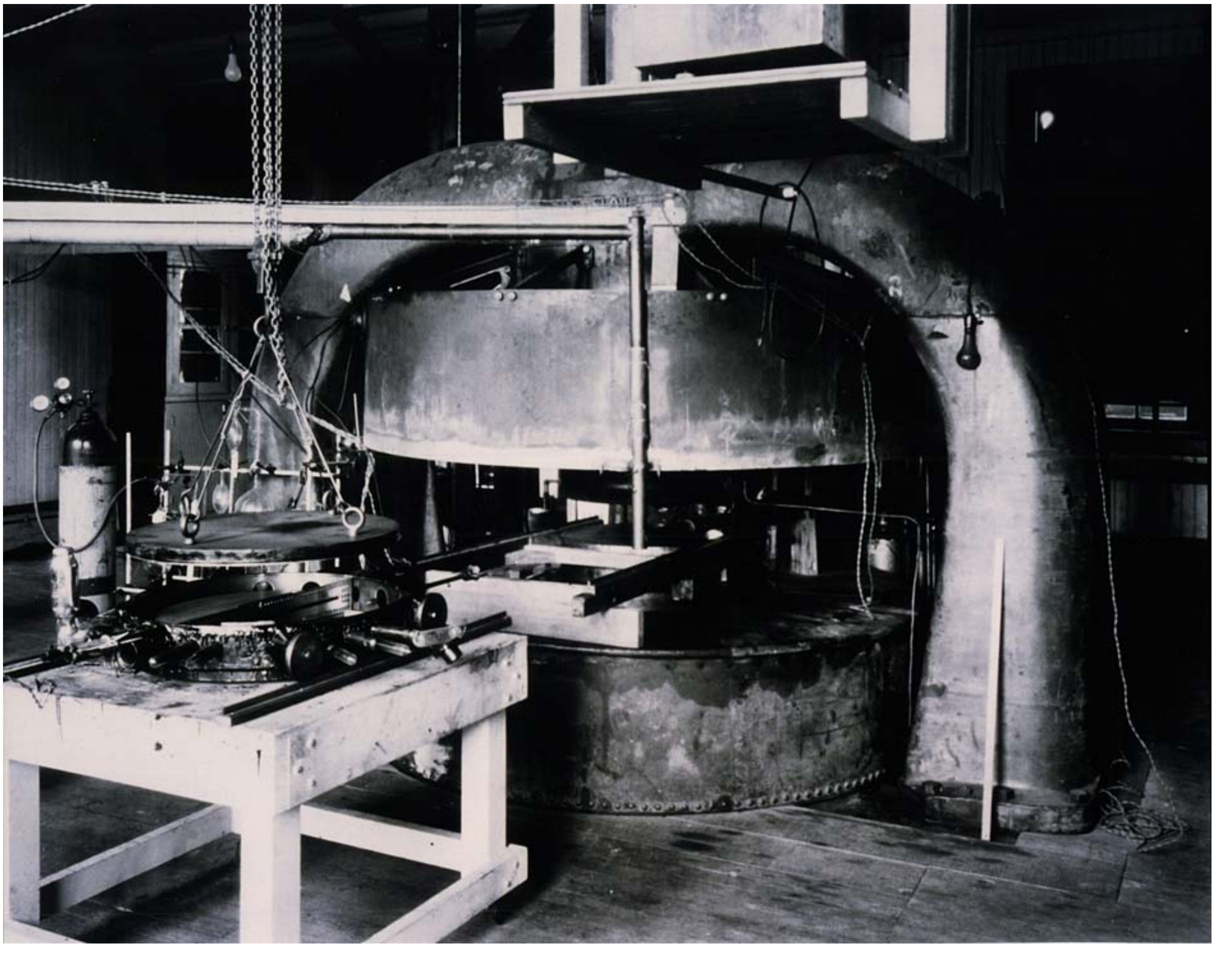
Magnetic rigidity

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

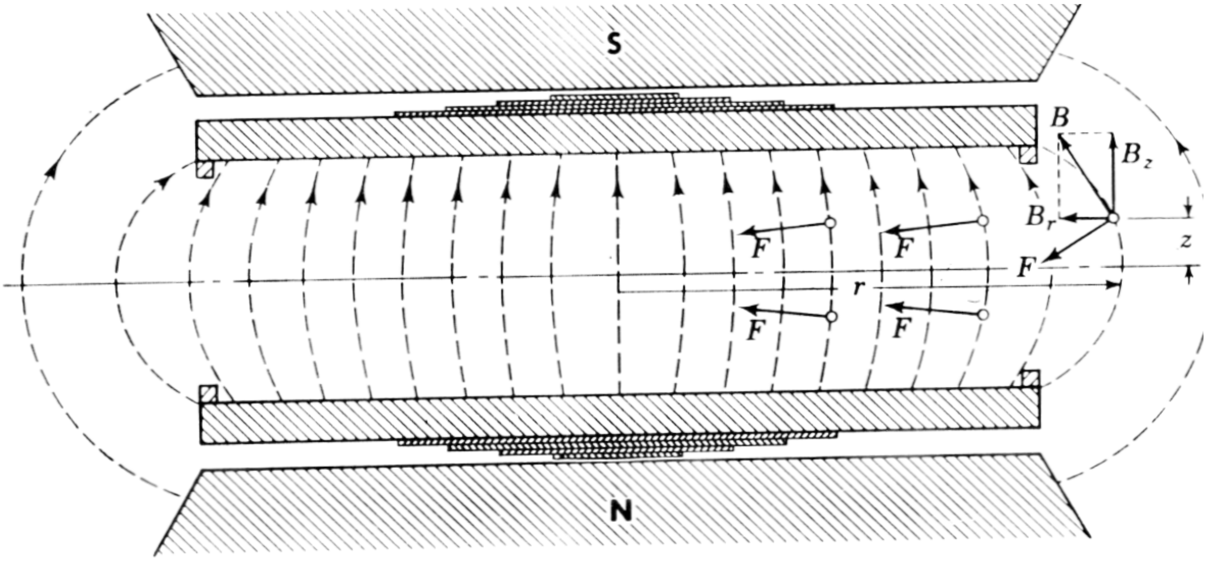
Constant revolution frequency

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

Lawrence's Cyclotron

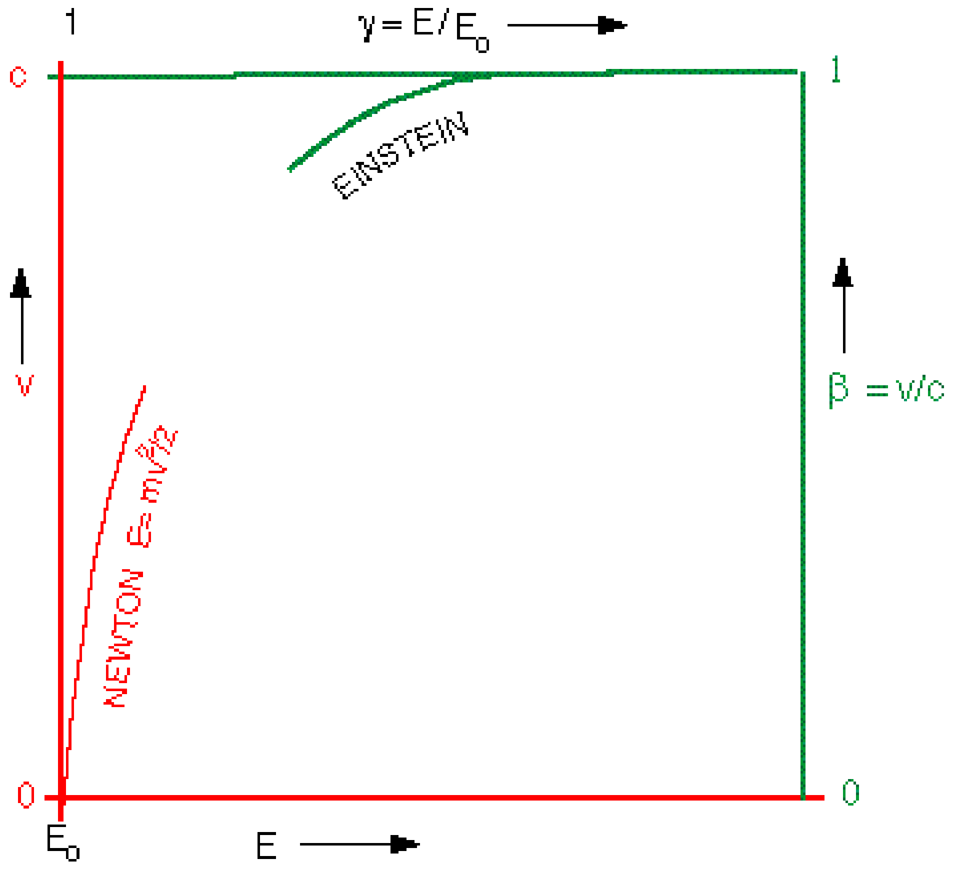


Vertical Focusing



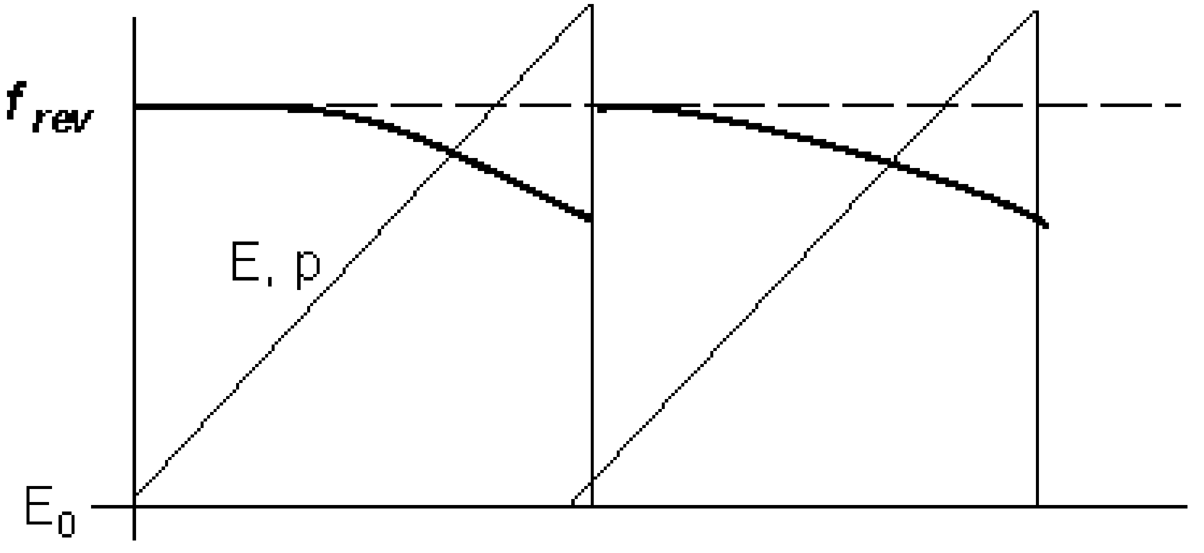
- People just got on with the job of building them.
- Then one day someone was experimenting
- Figure shows the principle of vertical focusing in a cyclotron
- In fact the shims did not do what they had been expected to do
- Nevertheless the cyclotron began to accelerate much higher currents

Newton & Einstein

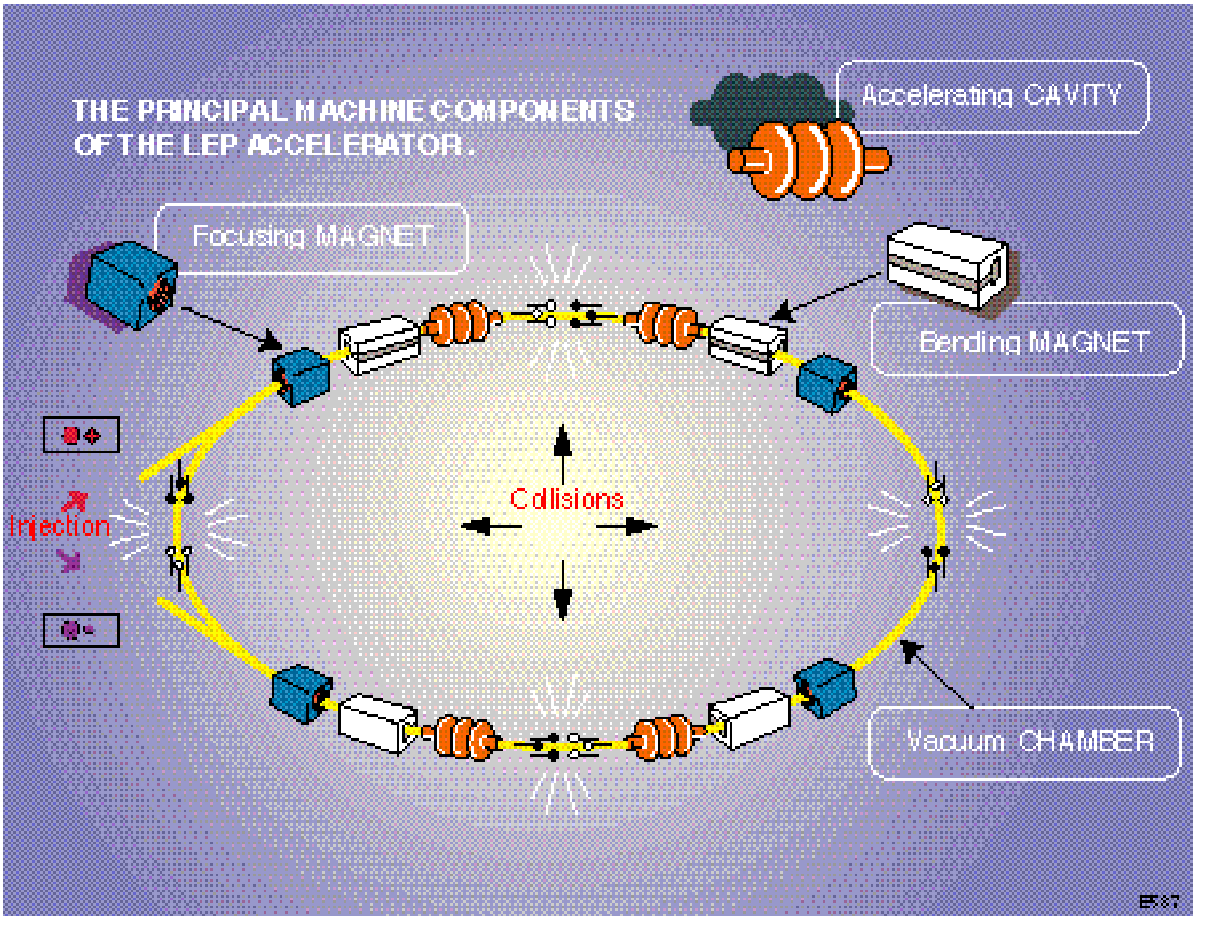


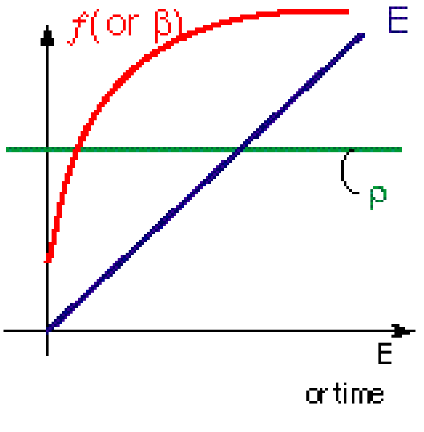
- **Almost all modern accelerators accelerate particles to speeds very close to that of light.**
- **In the classical Newton regime the velocity of the particle increases with the square root of the kinetic energy.**
- **As v approaches c it is as if the velocity of the particle "saturates"**
- **One can pour more and more energy into the particle, giving it a shorter De Broglie wavelength so that it probes deeper into the sub-atomic world**
- **Velocity increases very slowly and asymptotically to that of light**

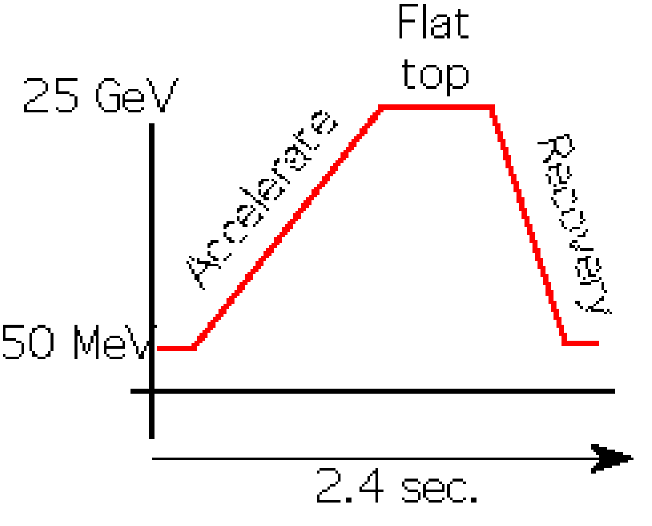
Pulsed operation - synchrocyclotron



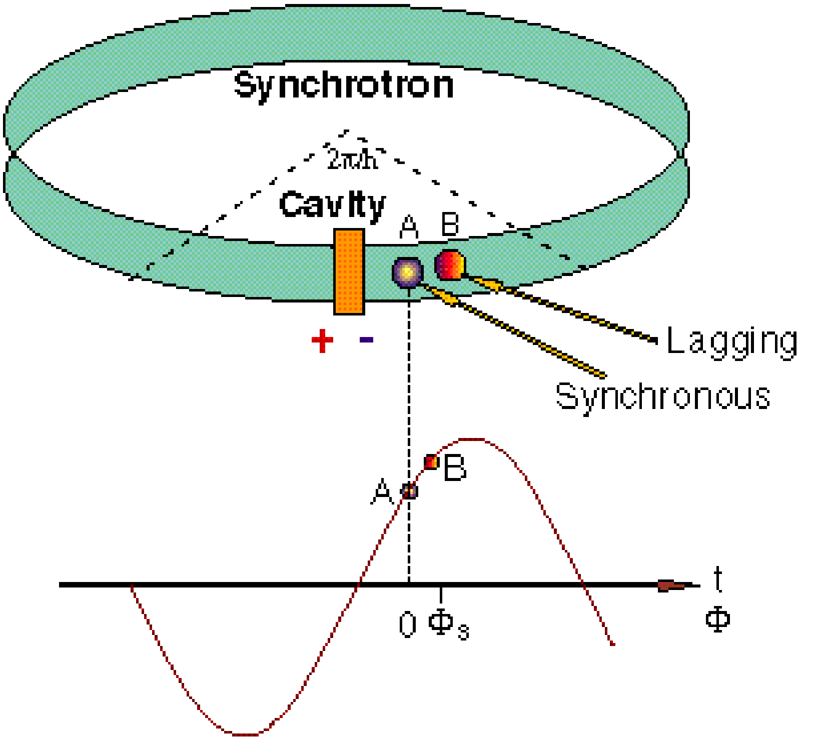
Components of a synchroton

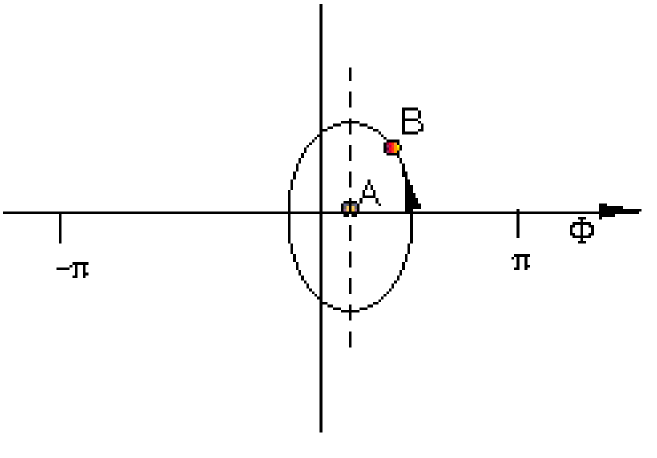




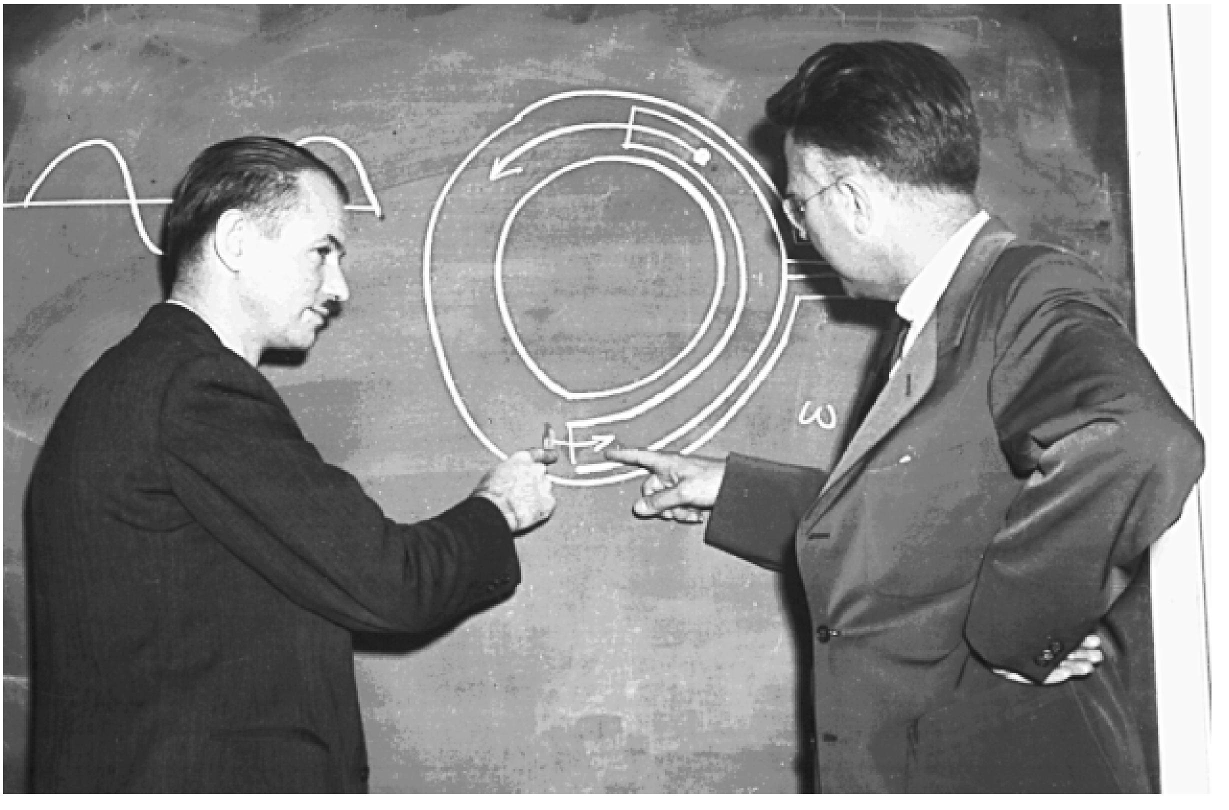


Phase stability





Macmillan explains to Lawrence



MAC-LAW.pct

The Woolich Betatron

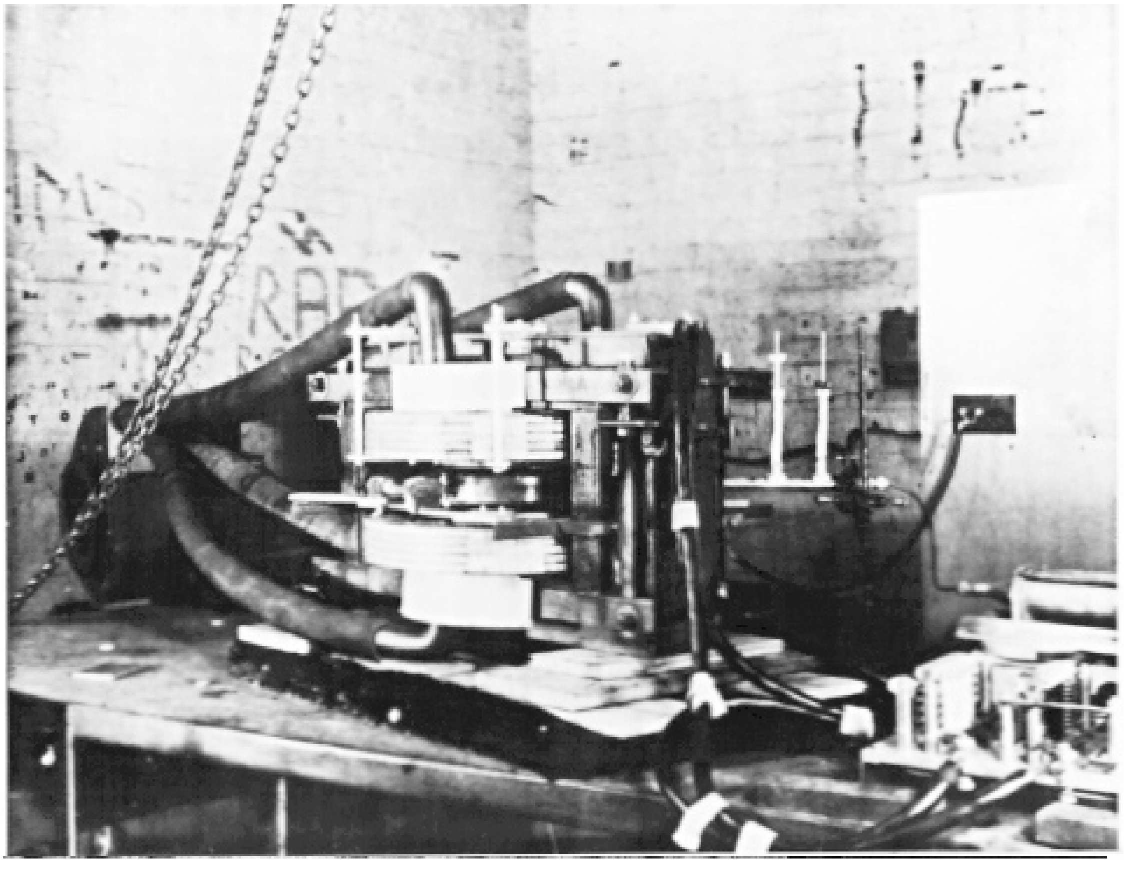
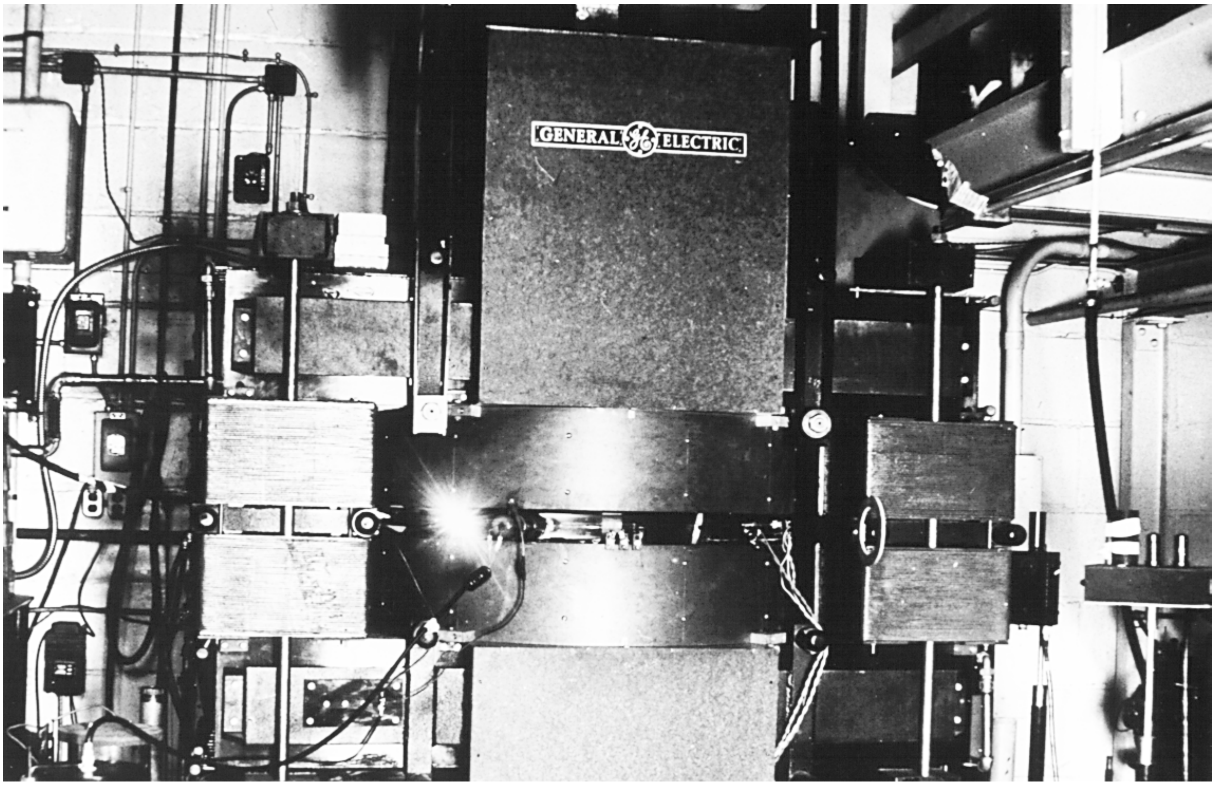
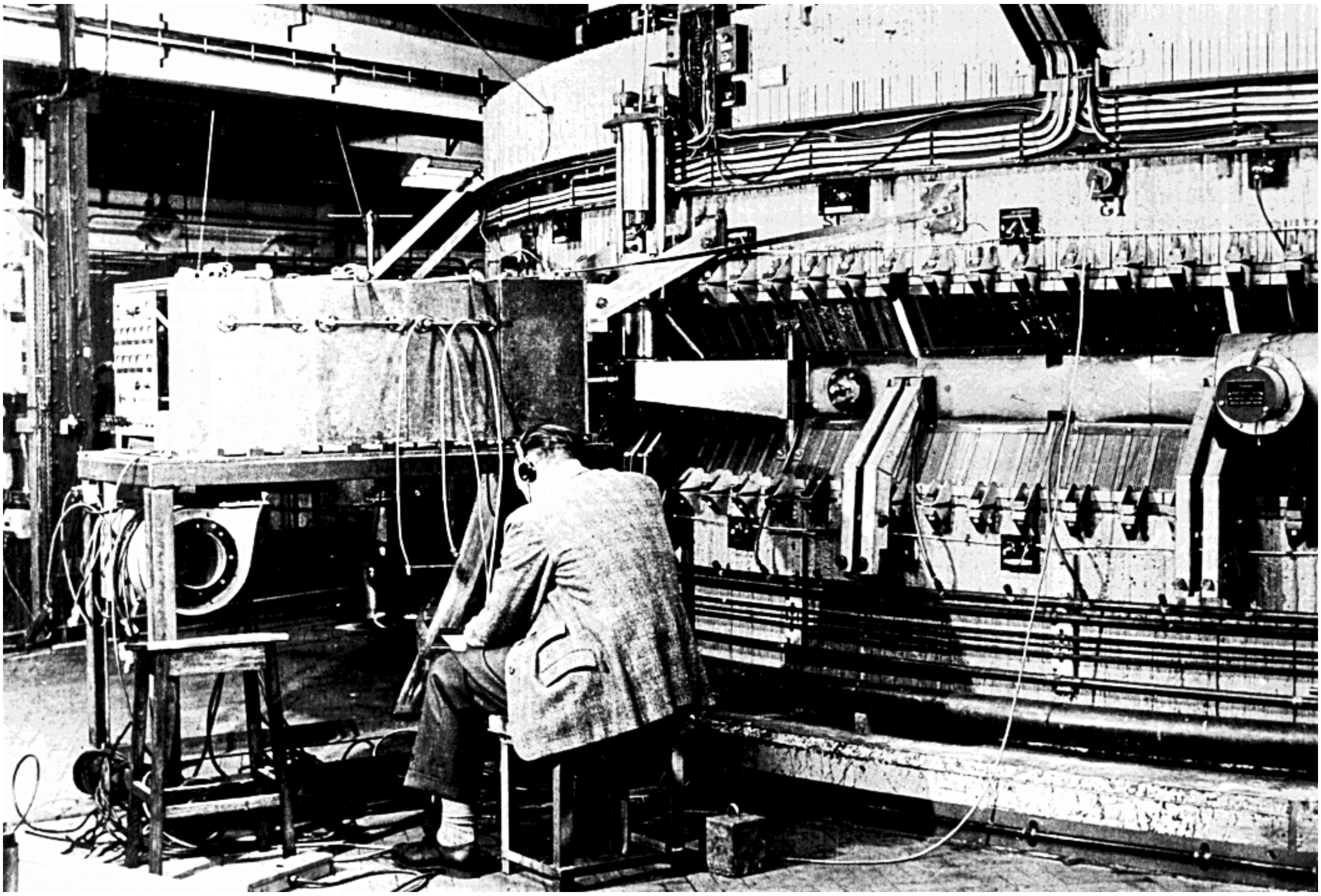


Fig.2(Woolich).pct

GEC Electron Synchrotron

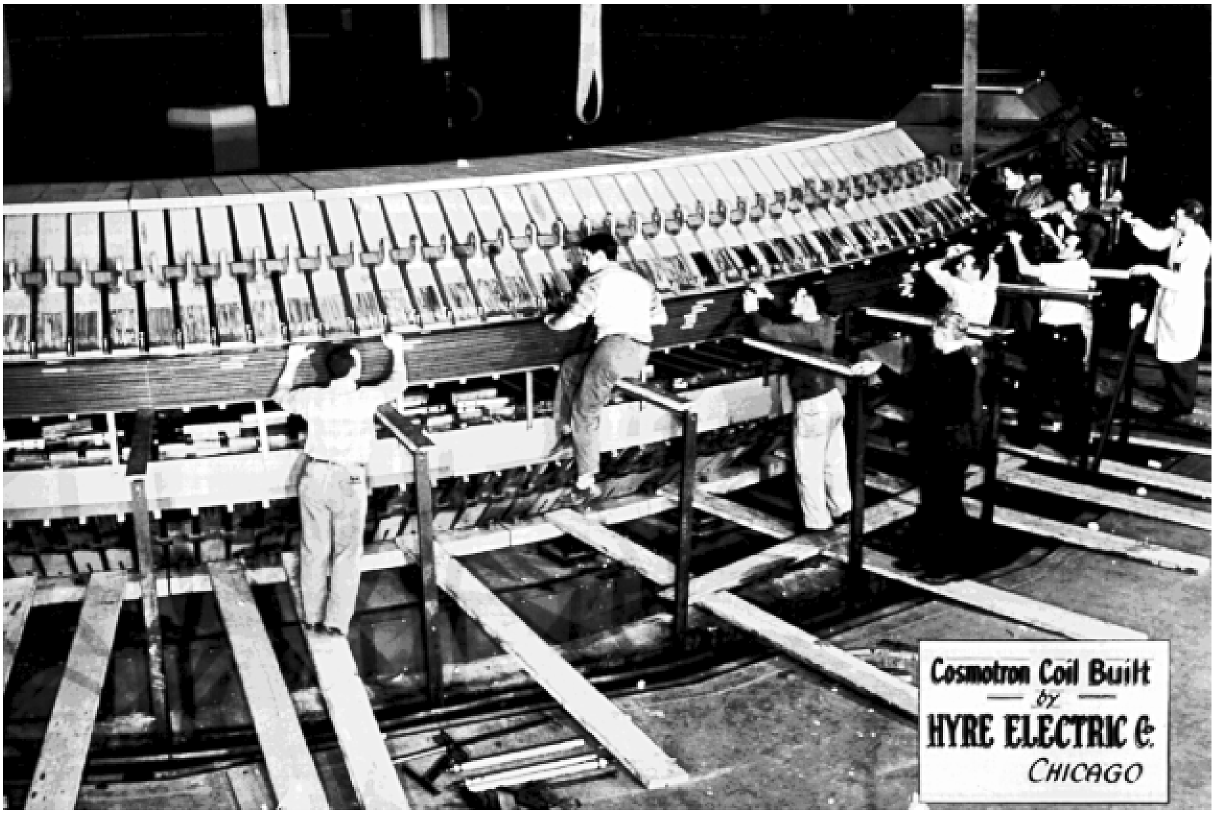


Birmingham synchrotron



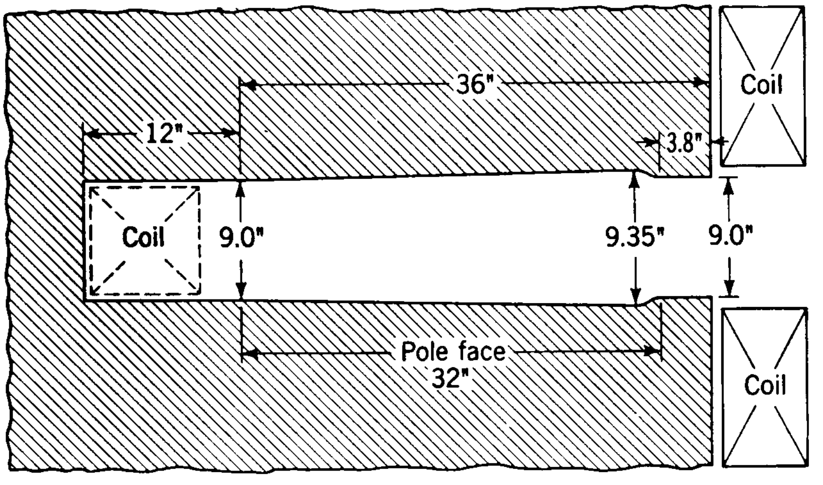
BHAM-PHONES.pct

Cosmotron

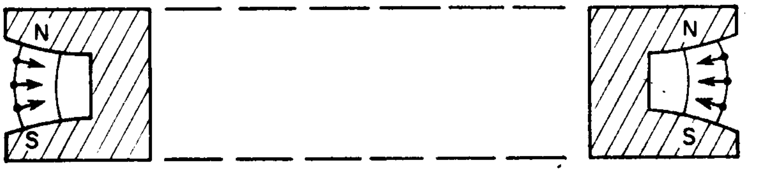


COSMOTRON.PCT

Weak focussing in a synchrotron



The Cosmotron magnet



- Vertical focussing comes from the curvature of the field lines when the field falls off with radius (positive n-value)
- Horizontal focussing 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

Cosmotron people

E.Courant -Lattice Designer

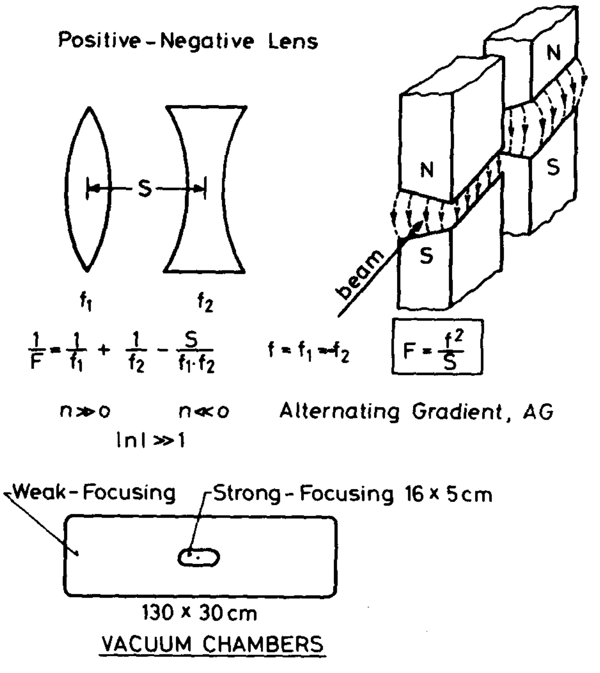
Stan Livingston - Boss

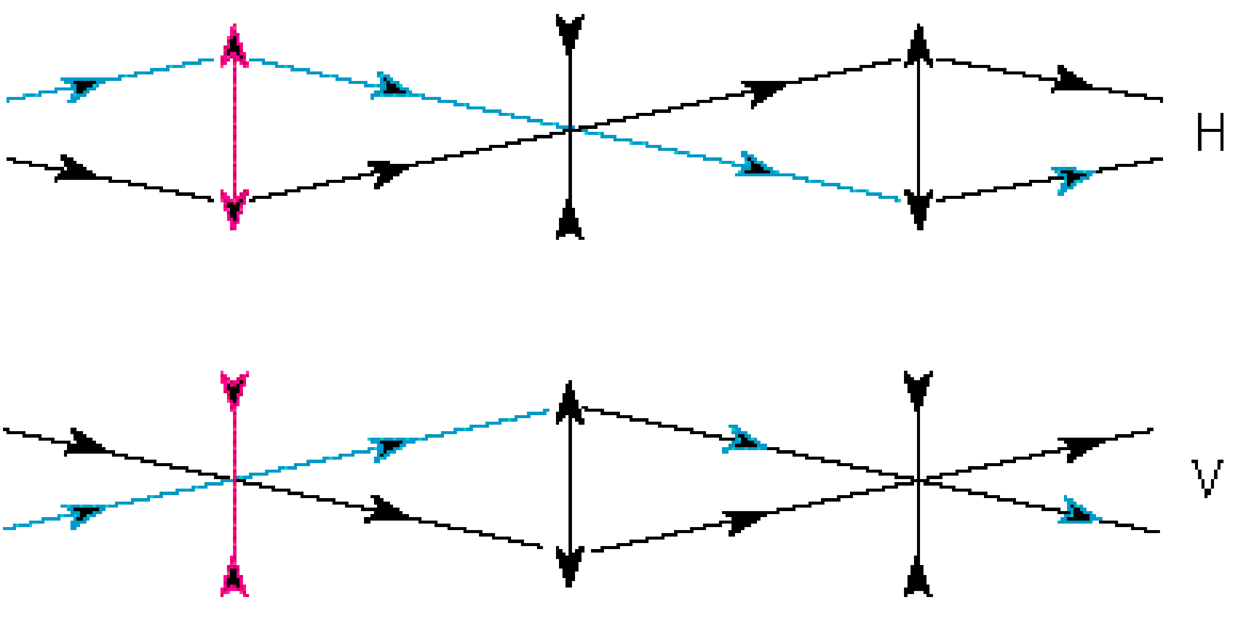
Snyder -theorist

Christofilos - inventor

FOURGUYS.pct

Strong focussing



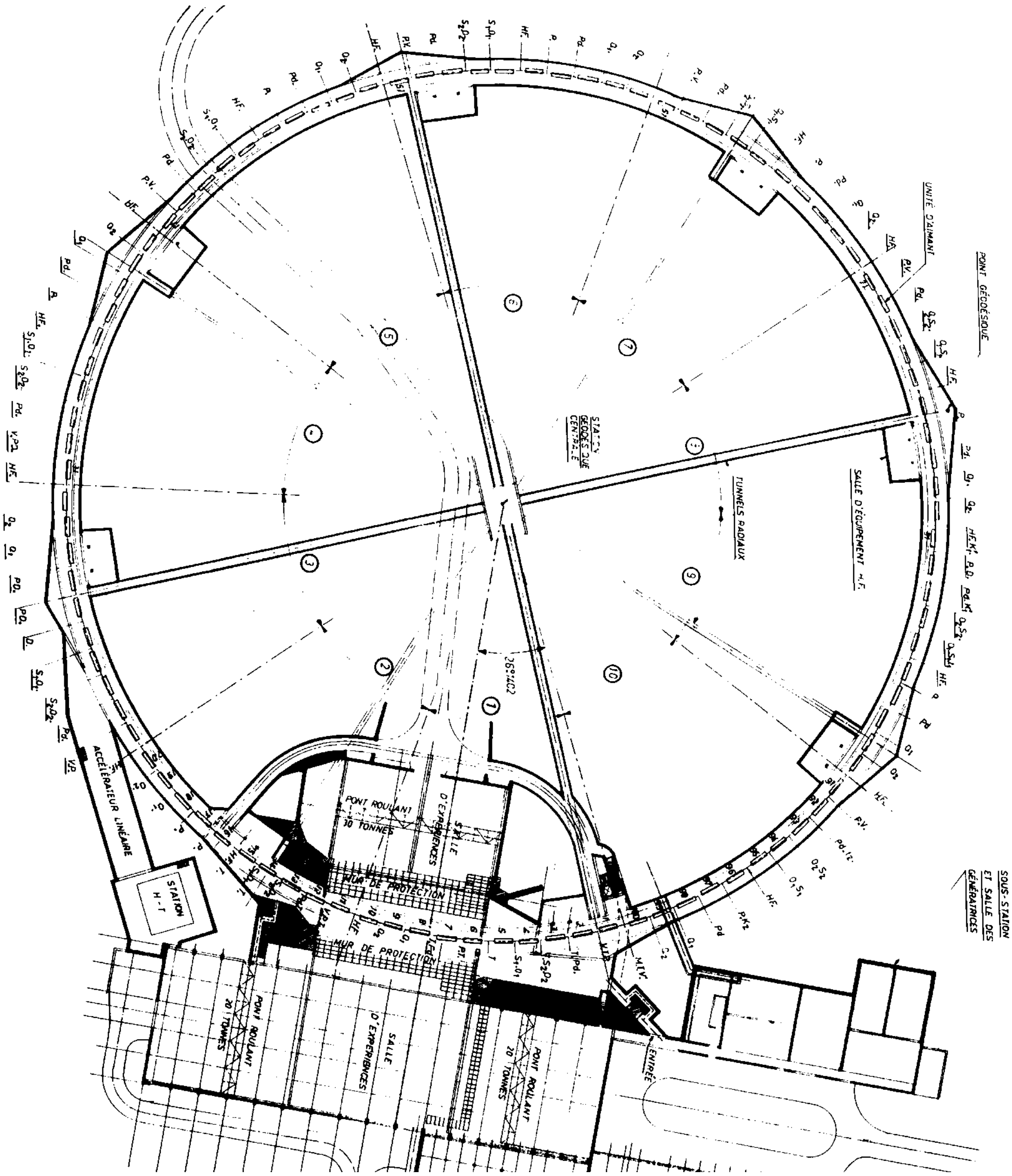


CERN at BNL

- **Odd Dahl, Frank Goward, and Rolf Widerø**
- **(right hand trio)**

Fig.3(CERNVISITORS).pct

CERN 25 GeV PS



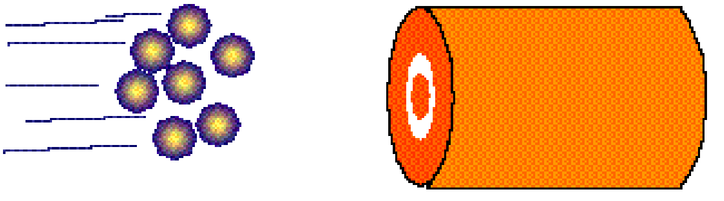
SPS

Center of mass *v.* Fixed target

W = Energy available in center-of-mass for making new particles

For fixed target :

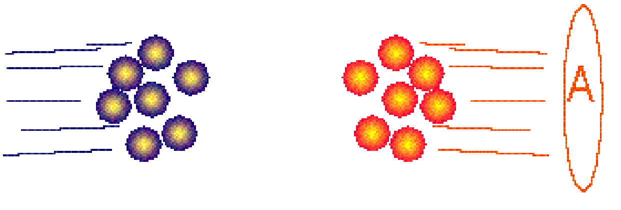
$$E_{c.m.} \cong \sqrt{2 m_T E_B}$$



... and we rapidly run out of money trying to gain a factor 10 in c.m. energy

But a storage ring , colliding two beams, gives:

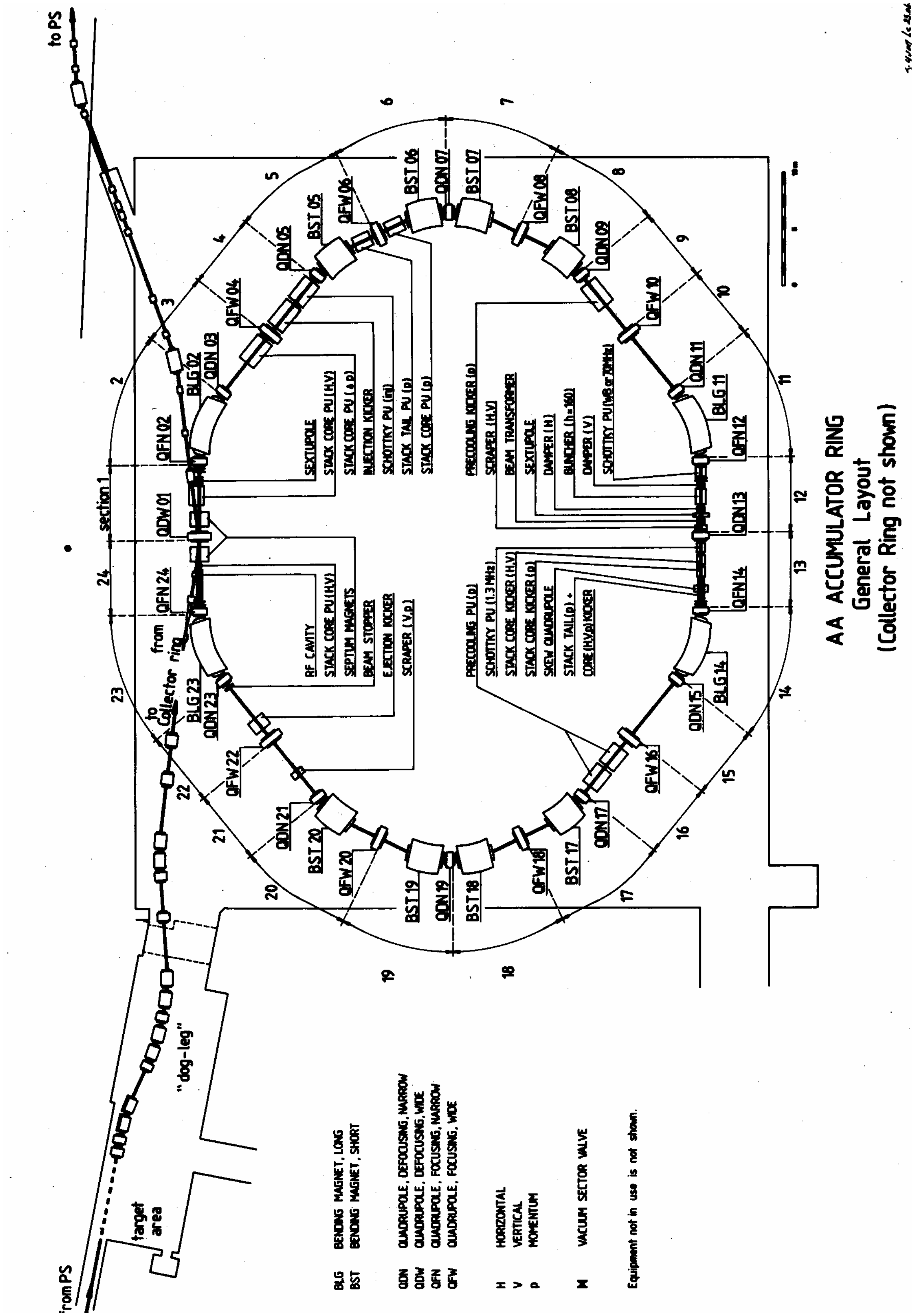
$$E_{c.m.} \cong 2\ E_B$$



Problem: Smaller probability that accelerated particles collide .... "Luminosity" of a collider

$$L = N_1 N_2 \frac{1}{A} \frac{\beta c}{2\pi R} \approx 10^{29} \ldots 10^{34}\, cm^{-2} s^{-1}$$

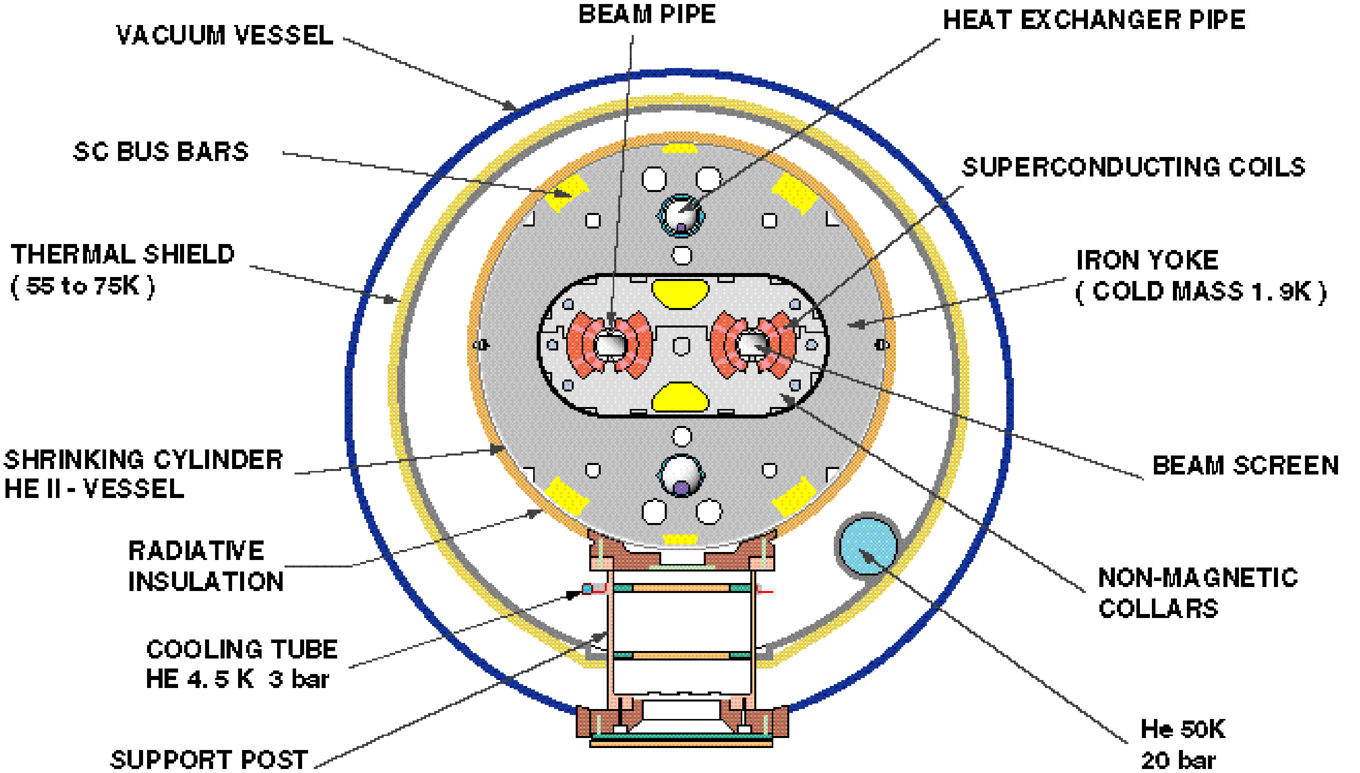
CERN Antiproton Accumulator



AA.PCT

LEP

Superconducting magnets



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