CYCLOTRON

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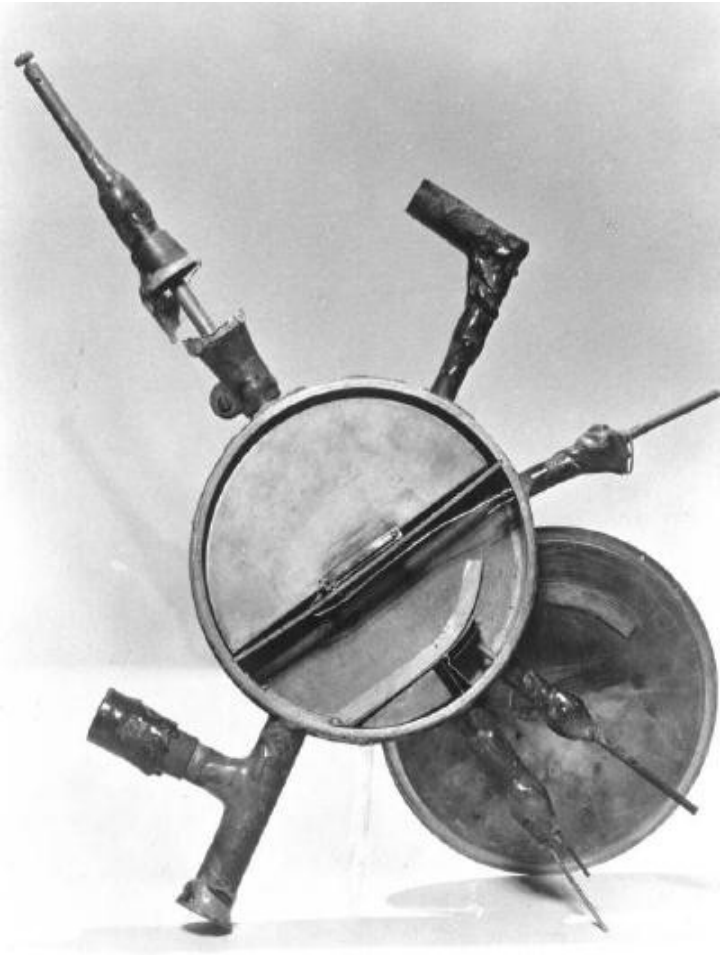
LAWRENCE'S CYCLOTRON

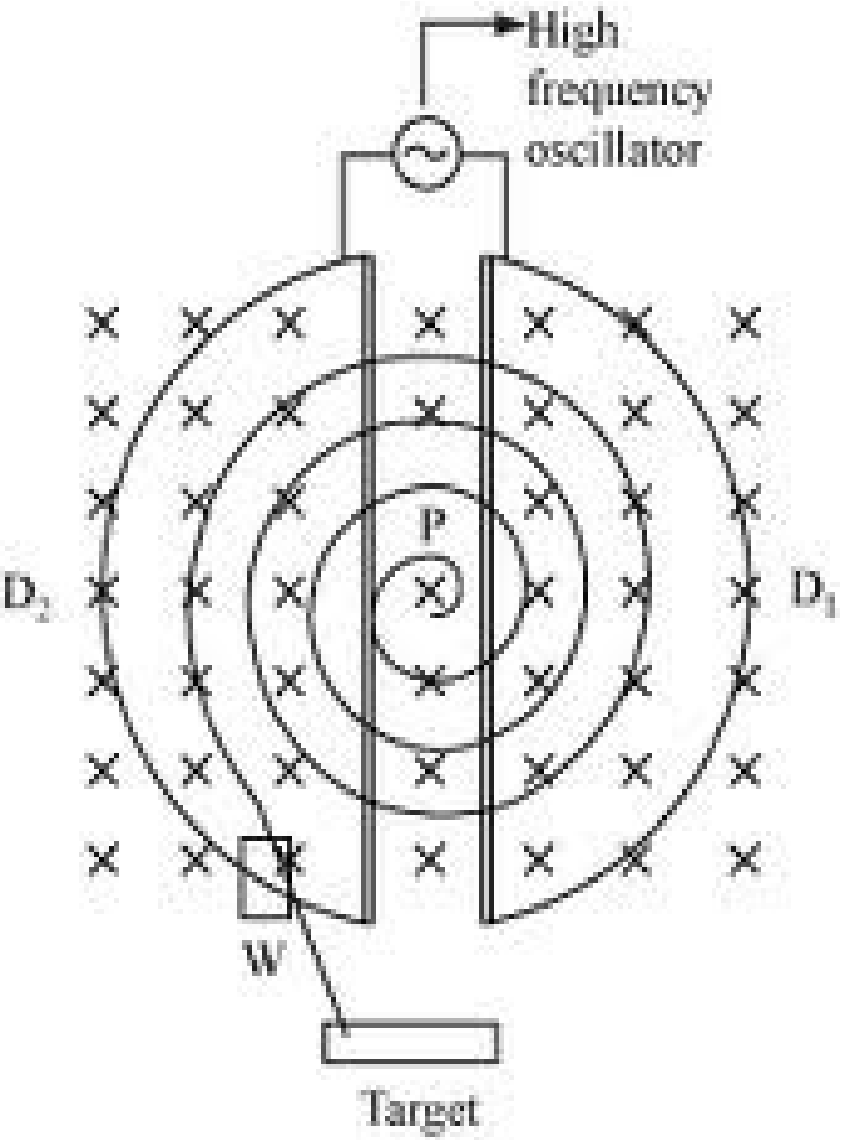


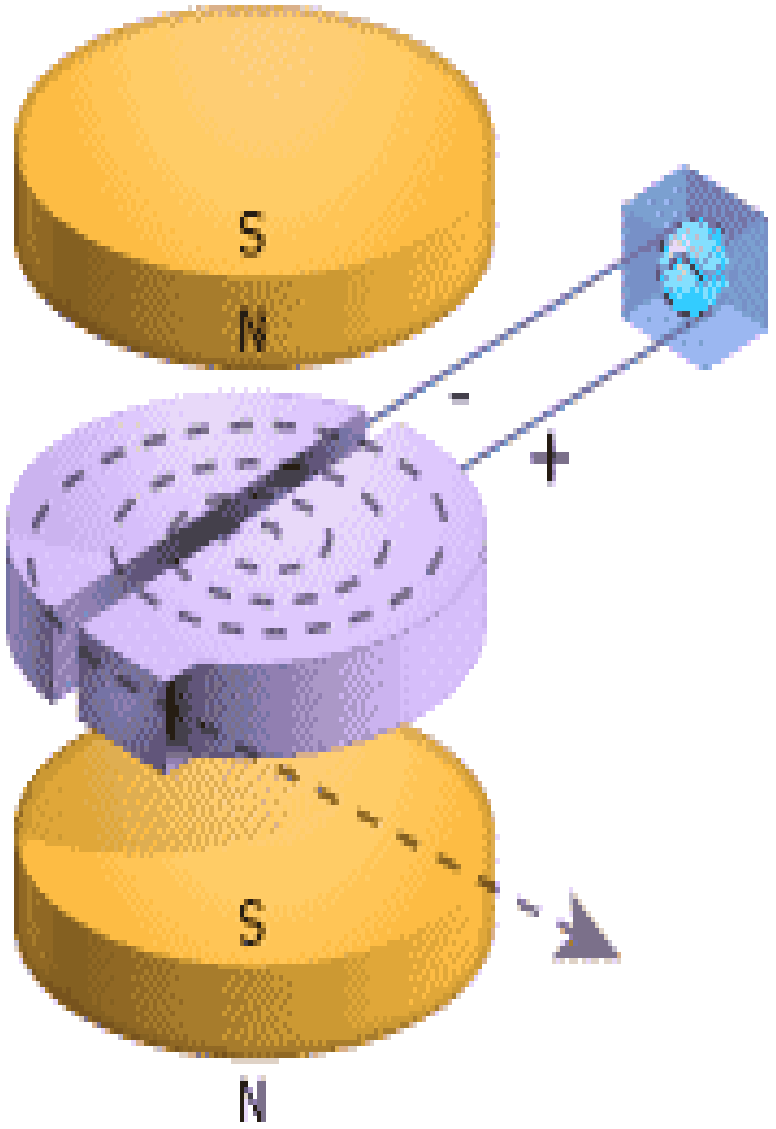
- In 1929, Ernest Lawrence developed the first circular accelerator

- This cyclotron was only 4 inches in diameter, and contained two D-shaped electrodes separated by a small gap

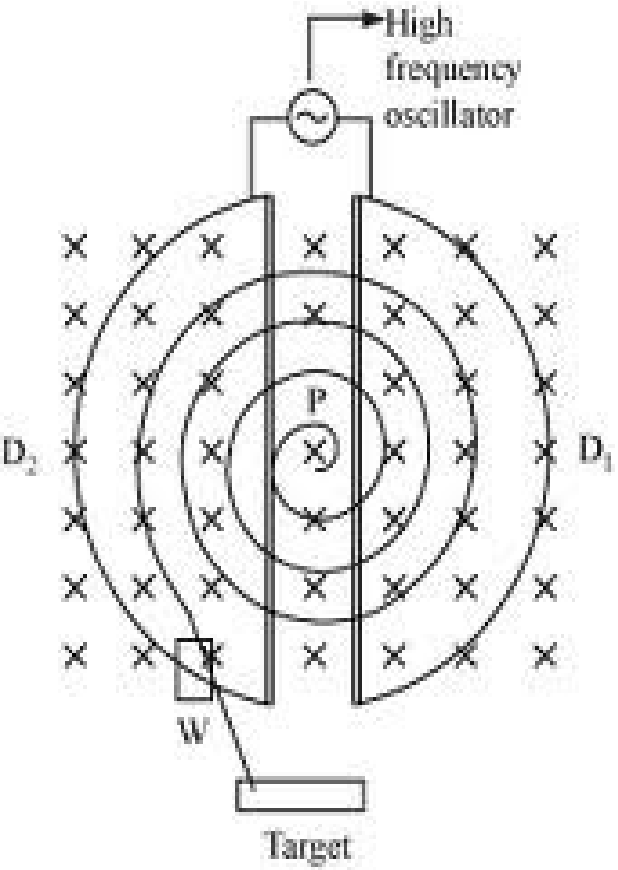
- An oscillating voltage created an electric field across the small gap, which accelerated the particles as they went around the accelerator

WORKING OF THE CYCLOTRON





MATHEMATICS OF A CYCLOTRON



❖The proton moves in a circular path of radius:

$$r = mv/qB$$

❖Frequency

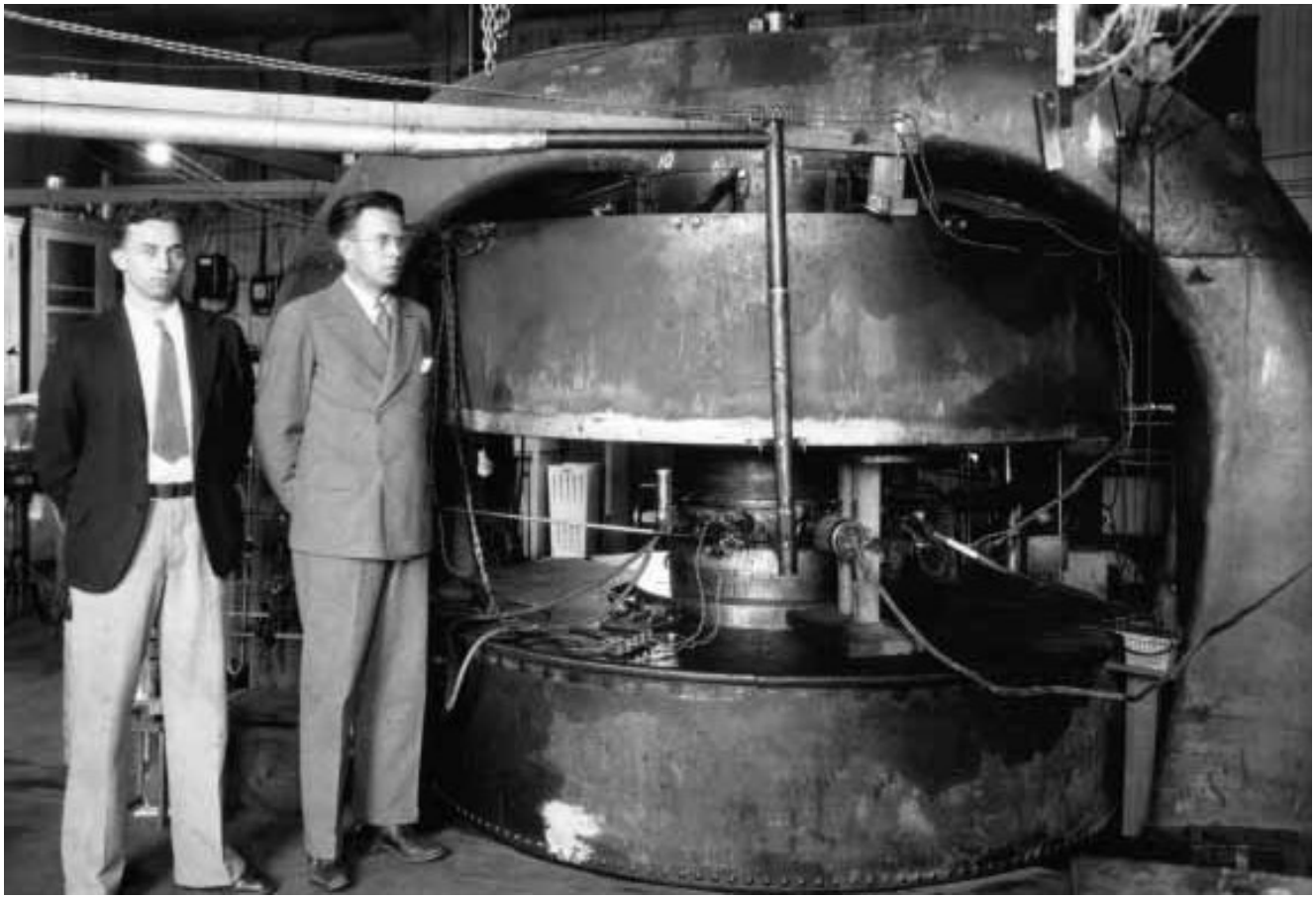
$$f = qB/2\pi m$$

❖Resonance condition

$$f = f_{osc}$$

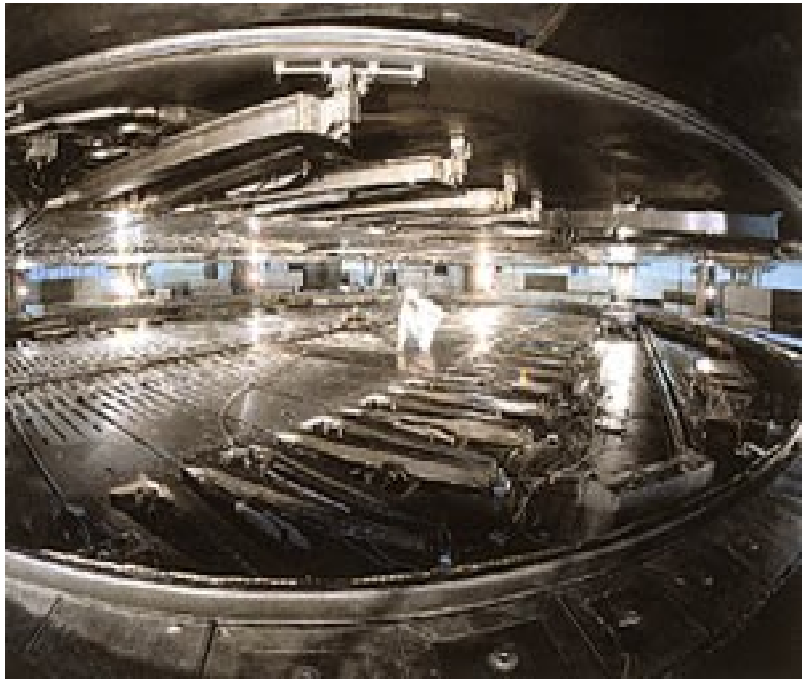
Or

$$qB = 2\pi m f_{osc}$$



M. Stanley Livingston and Ernest O.Lawrence, with their 27-inch cyclotron at Berkeley Radiation Laboratory. (Courtesy Lawrence Berkeley National Laboratory)

APPLICATIONS OF THE CYCLOTRON



- **Important research tools in nuclear physics.**
- **Used for medical purposes e.g. radiation surgery and therapy.**

The separated sector cyclotron in Vancouver, provides 600 MeV negative hydrogen ions and it is the largest of all cyclotrons. The picture shows the gap inside which the ions are accelerated.

LIMITATIONS OF THE CYCLOTRON

- Cannot accelerate neutral particles.
- Not useful in accelerations of electrons.
- With increased velocity, the beam gets out of phase with the oscillating electric field.

The radius of curvature for a particle moving relativistically in a static magnetic field is

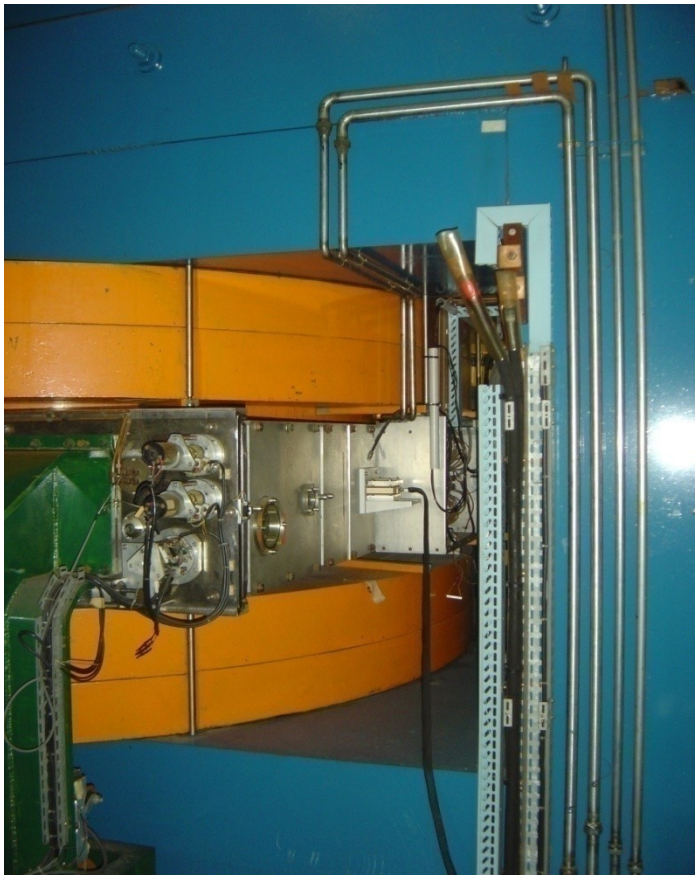
$$r = \frac{\gamma m v}{qB}$$

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

Relativistic cyclotron frequency is

$$f = f_c \sqrt{1 - \left(\frac{v}{c}\right)^2}$$

SYNCHROCYCLOTRON

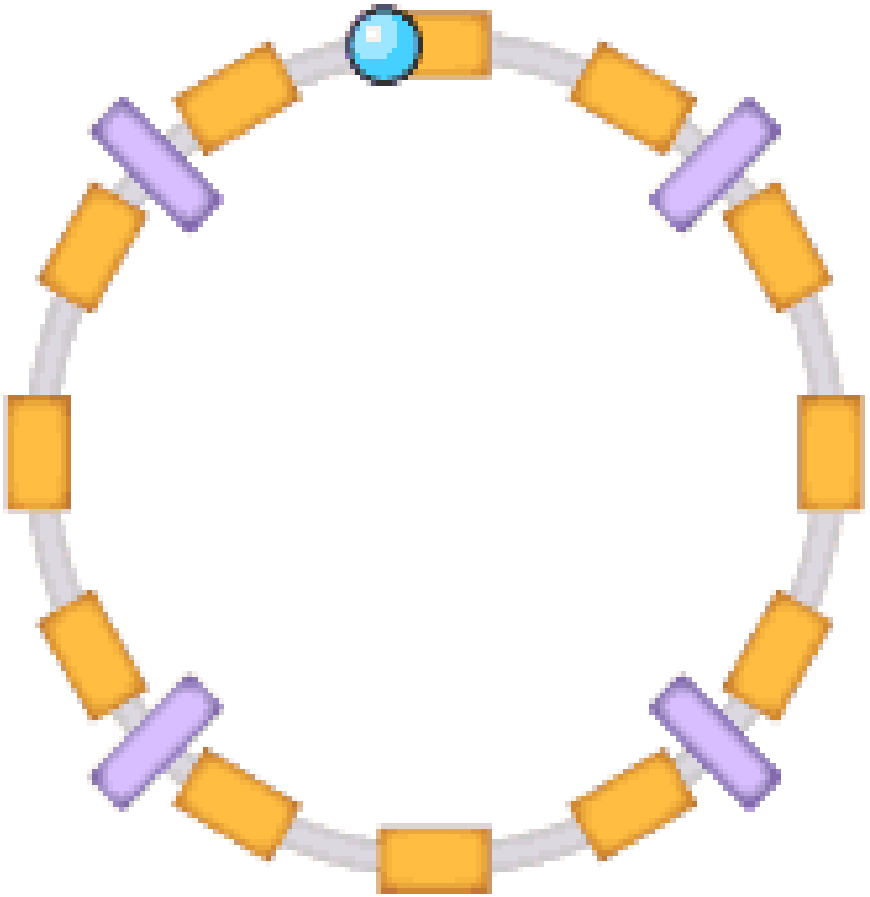


❖Only one dee is used instead of two.

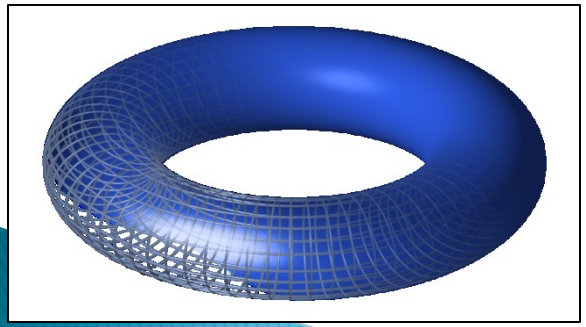
❖the frequency of the driving RF electric field is varied to compensate for relativistic effects as the particles' velocity begins to approach the speed of light.

A part of a magnet from the Orsay (France) synchrocyclotron, now used by the proton therapy center

THE SYNCHROTRON

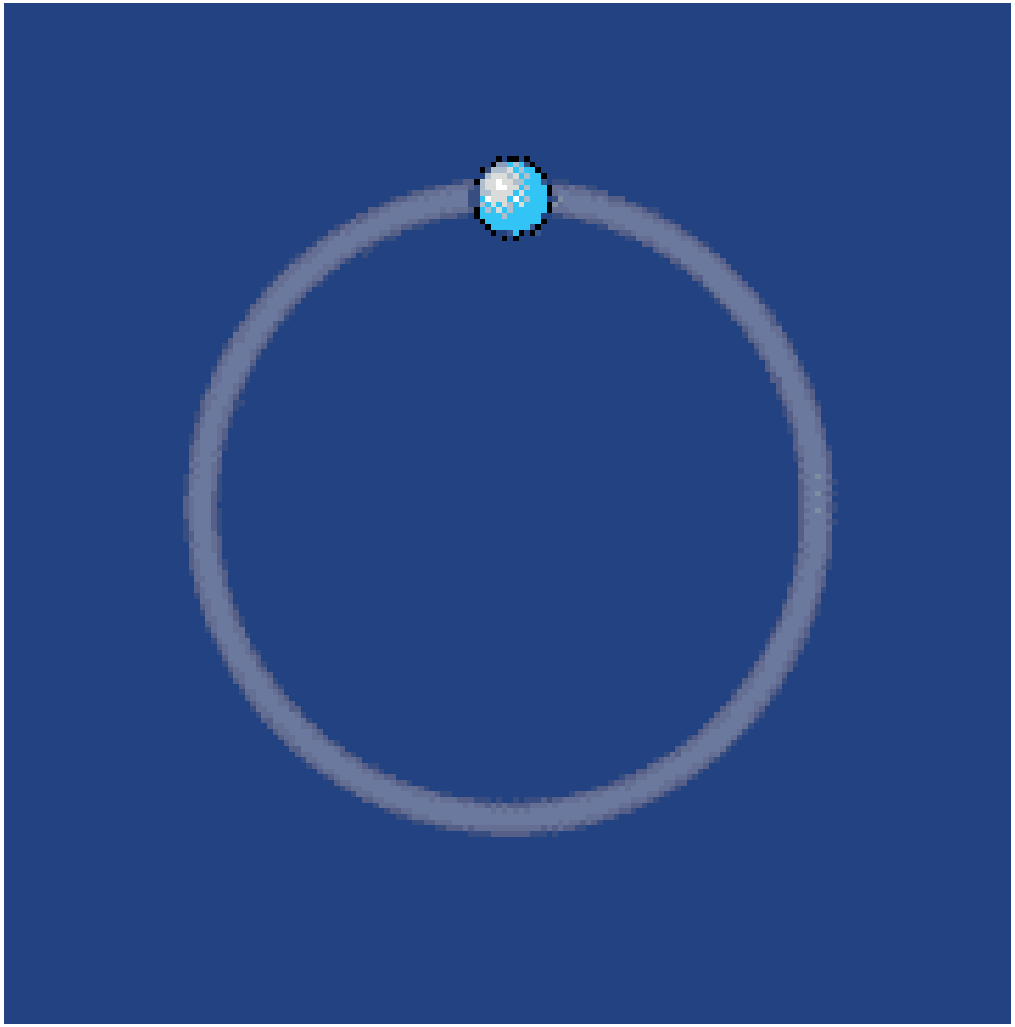


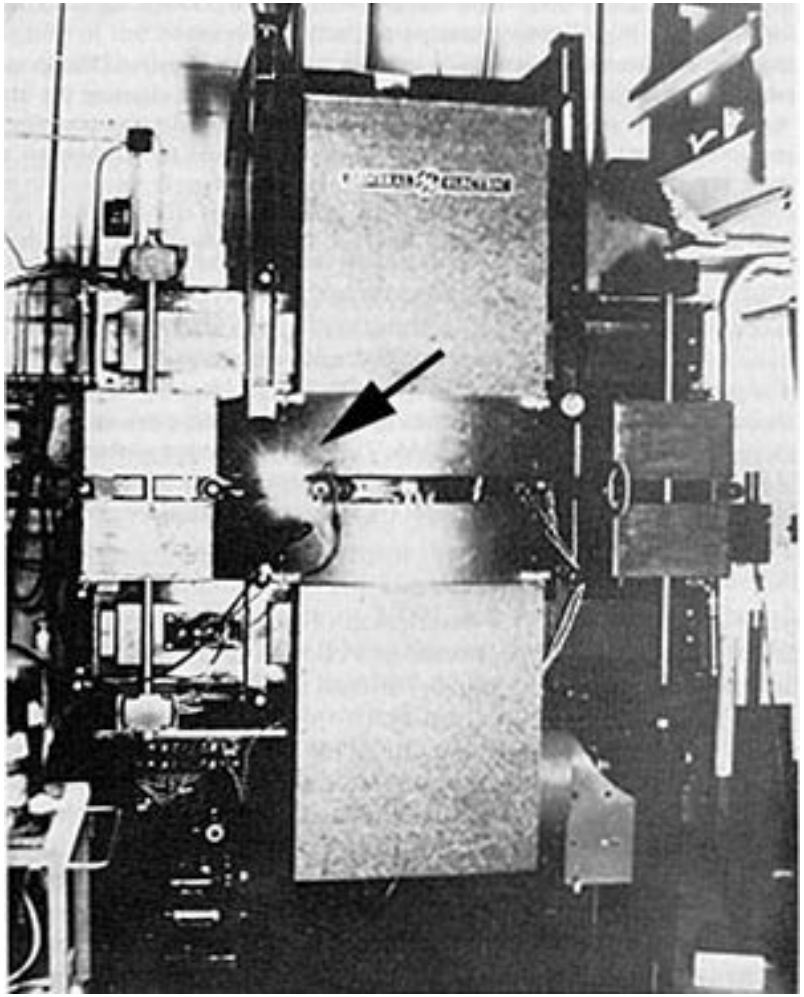
The magnetic field was synchronised with the increasing energy of the accelerated particles; the synchrotron was born.



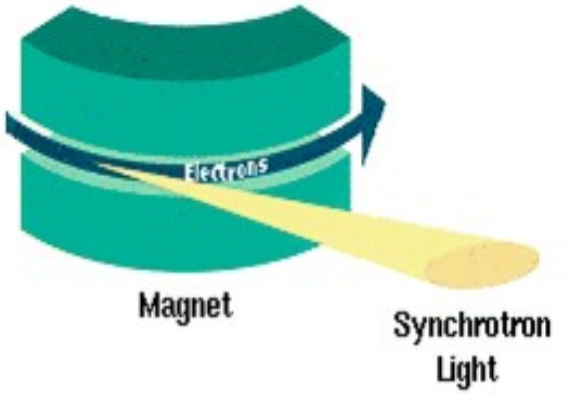
torus

SYNCHROTRON RADIATION





The synchrotron radiation, the "light" of modern accelerators has become an important tool to explore biological structures and the surface structure of metals and other materials.



Properties of synchrotron radiation

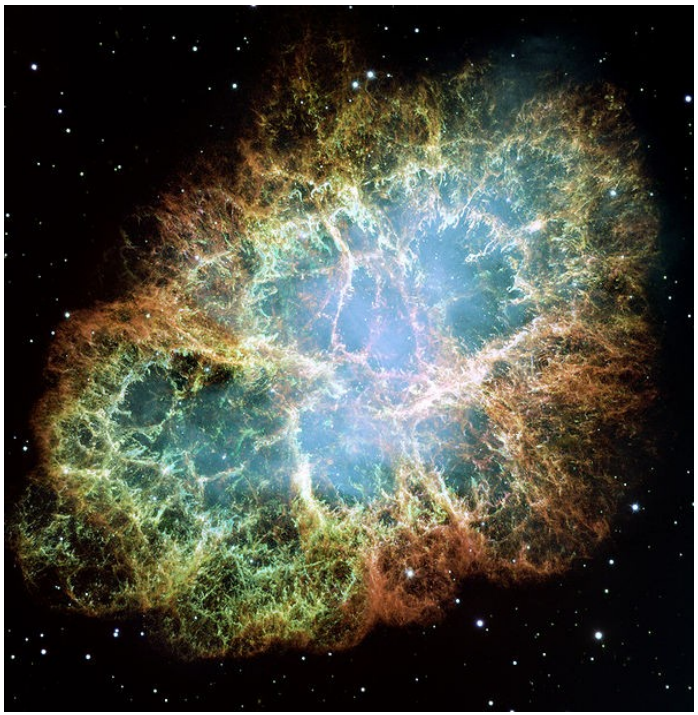
❖Broad Spectrum which covers from hard X-rays to microwaves: the users can select the wavelength required for their experiment.

❖High Flux

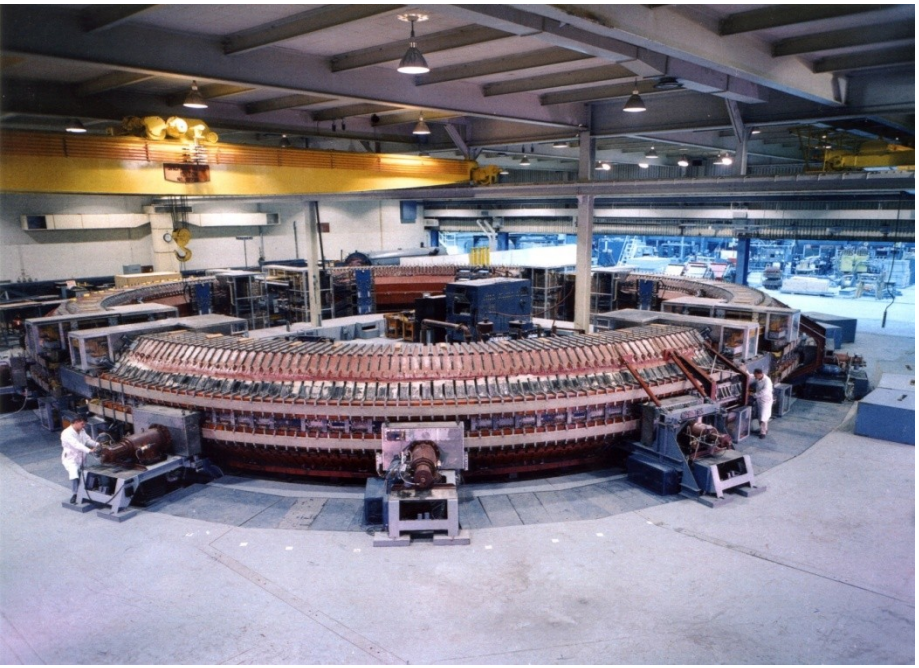
❖High Brilliance

❖High Stability

❖Polarizaton



COSMOTRON



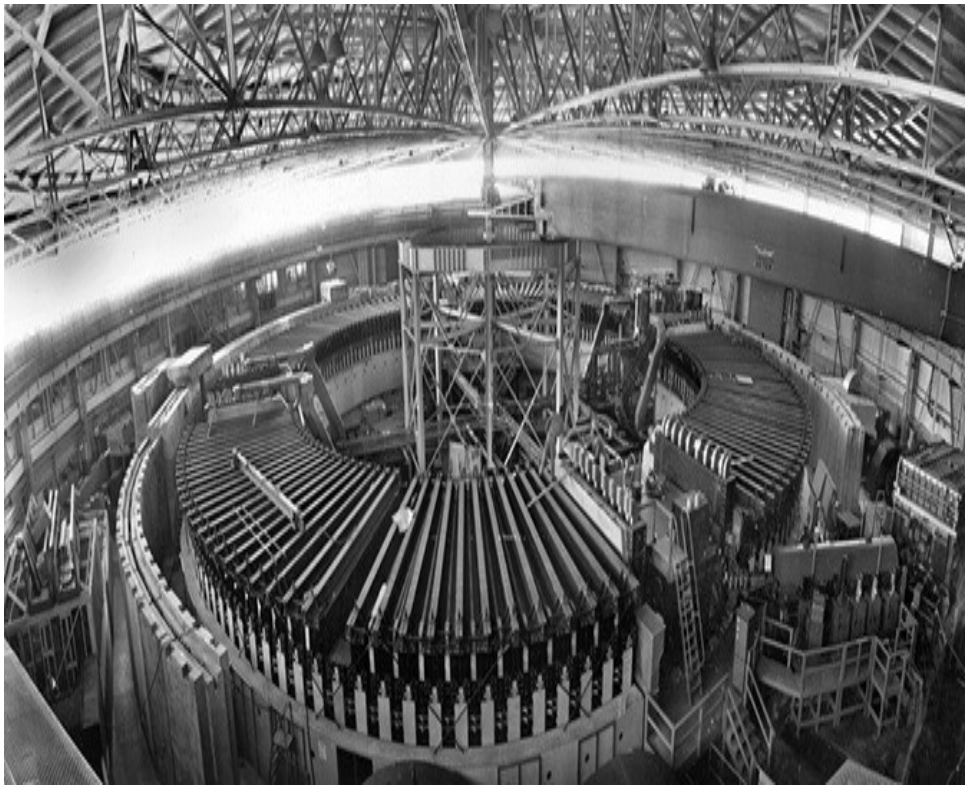
❖Its construction was approved by the U.S. Atomic Energy Commission in 1948, it reached its full energy in 1953, and it continued running until 1968.

❖ It accelerated protons to 3.3 GeV.

❖ It allowed the extraction of the particle beam for experiments located physically outside the accelerator.

❖It was used to observe a number of mesons previously seen only in cosmic rays.

BEVATRON

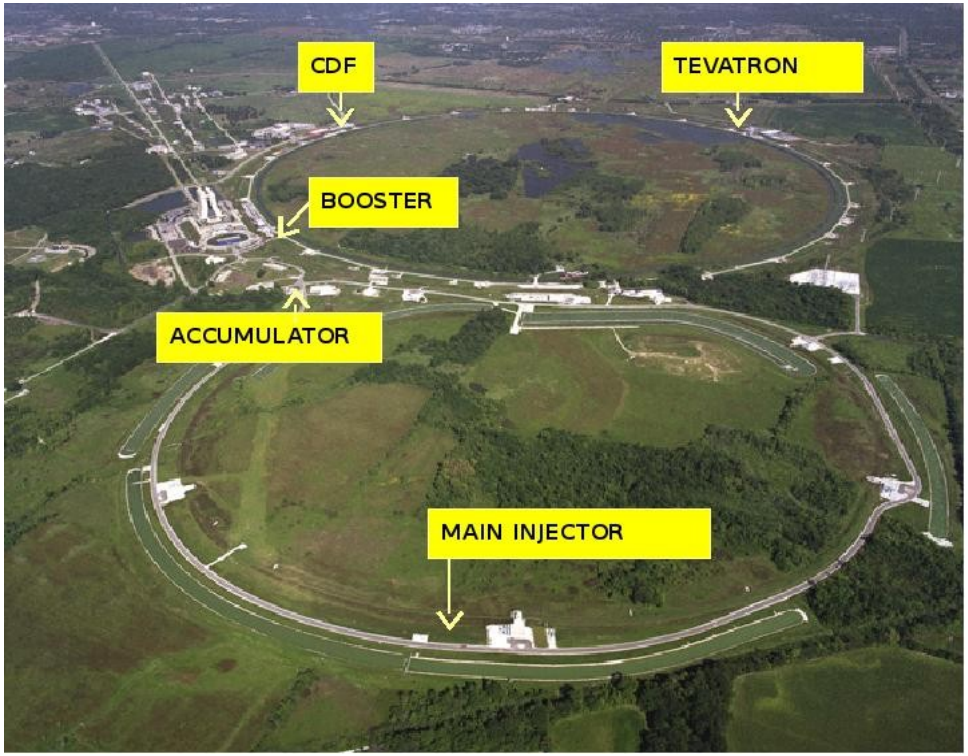


❖The Bevatron was a proton synchrotron— Berkley National Laboratory, which began operating in 1954.

❖ The antiproton was discovered there in 1955, resulting in the 1959 Nobel Prize in physics for Emilio Segre and Owen Chamberlain.

❖It accelerated proton into a fixed target, and was named for its ability to impart energies of billions of eV.

TEVATRON



❖The Tevatron is a circular particle accelerator at the Fermilab.

❖ It is the second highest energy particle collider in the world after the Large Hadron Collider(LHC).

❖The Tevatron accelerates protons and antiprotons in a 6.28 km (3.90 mi) ring to energies of up to 1 TeV.

LARGE HADRON COLLIDER

- **The Large Hadron Collider (LHC) is the world's largest and highest energy particle accelerator.**
- **The LHC lies in a tunnel 27 kilometres (17 mi) in circumference, as deep as 175 metres (574 ft) beneath the Franco-Swiss border near Geneva, Switzerland.**
- **It is designed to collide opposing particle beams of either protons at an energy of 7TeV per nucleon, or lead nuclei at an energy of 2.76 TeV per nucleon.**