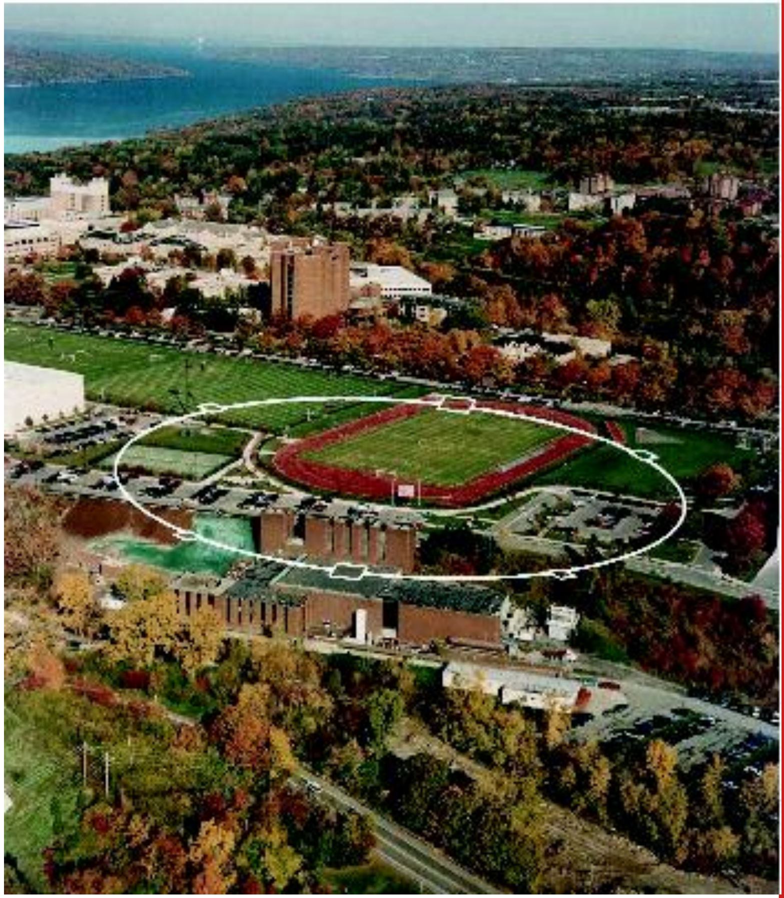
Introduction to Accelerator Physics

CHESS & LEPP

Content



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Images are taken from many sources, including:

The Physics of Particle Accelerators, Klaus Wille, Oxford University Press, 2000, ISBN: 19 850549 3

Particle Accelerator Physics I, Helmut Wiedemann, Springer, 2nd edition, 1999, ISBN 3 540 64671 x

Teilchenbeschleuniger und Ionenoptic, Frank Hinterberger, 1997, Springer, ISBN 3 540 61238 6

Introduction to Ultraviolet and X-ray Free-Electron Lasers, Martin Dohlus, Peter Schmüser, Jörg Rossbach, Springer, 2008

Various web pages, 2003 – 2017

Literature

Required:

The Physics of Particle Accelerators, Klaus Wille, Oxford University Press, 2000, ISBN: 19 850549 3

Optional:

Particle Accelerator Physics I, Helmut Wiedemann, Springer, 2nd edition, 1999, ISBN 3 540 64671 x

Related material:

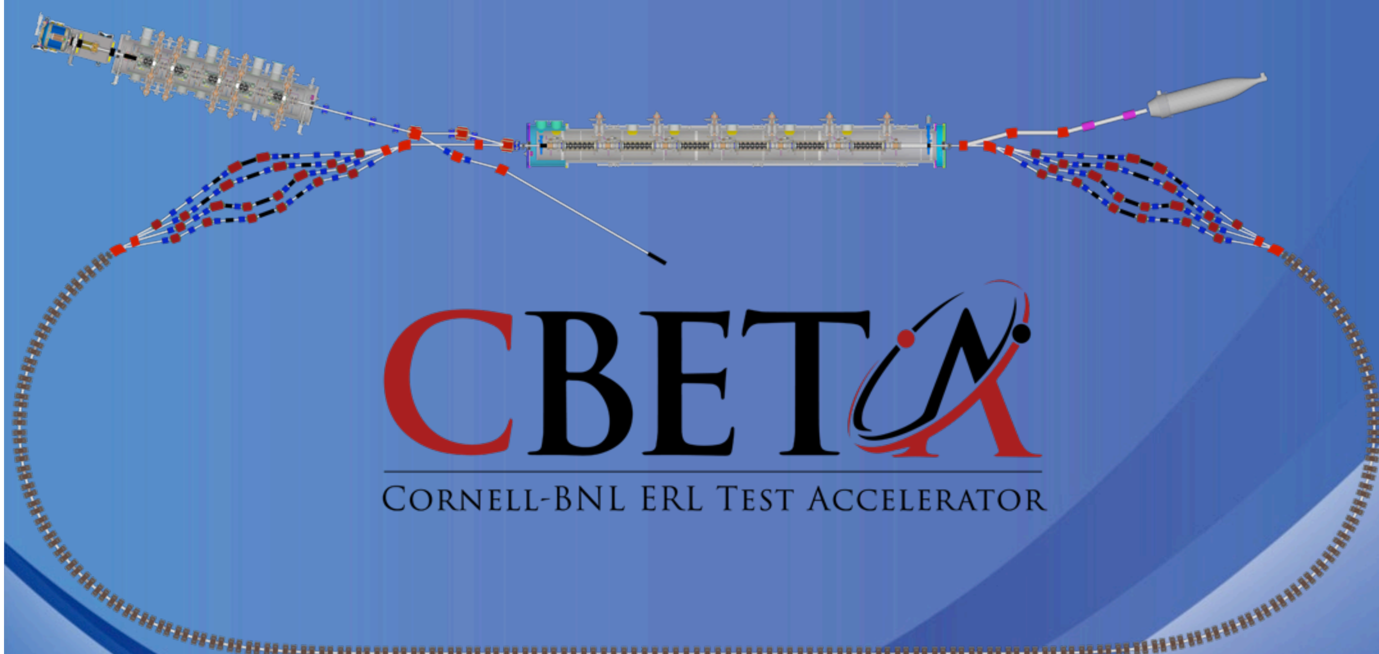
Handbook of Accelerator Physics and Engineering, Alexander Wu Chao and Maury Tigner, 2nd edition, 2002, World Scientific, ISBN: 981 02 3858 4

Particle Accelerator Physics II, Helmut Wiedemann, Springer, 2nd edition, 1999, ISBN 3 540 64504 7

From a recent colloquium at Cornell April 2017

A new kind of particle accelerator:
The Cornell-BNL ERL Test Accelerator
for eRHIC Prototyping and Bright-Beam Applications

Georg Hoffstaetter (Cornell)



CBETA

CORNELL-BNL ERL TEST ACCELERATOR

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

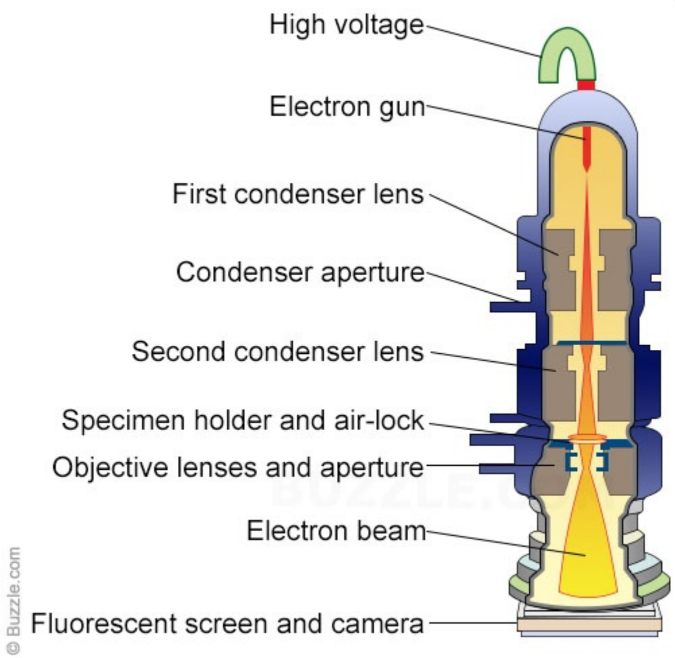
Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

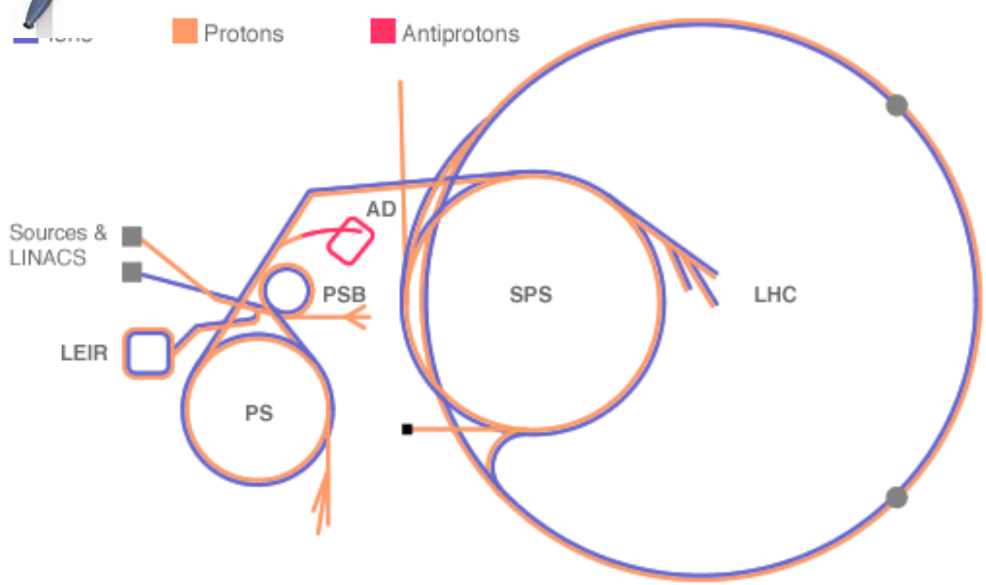
What is accelerator physics

Accelerator Physics has applications in particle accelerators for high energy physics or for x-ray science, in spectrometers, in electron microscopes, and in lithographic devices. These instruments have become so complex that an empirical approach to properties of the particle beams is by no means sufficient and a detailed theoretical understanding is necessary. This course will introduce into theoretical aspects of charged particle beams and into the technology used for their acceleration.

- Physics of beams
- Physics of non-neutral plasmas
- Physics of involved in the technology:
  - Superconductivity in magnets and radiofrequency (RF) devices
  - Surface physics in particle sources, vacuum technology, RF devices
  - Material science in collimators, beam dumps, superconducting materials

Particle accelerators, large and small





Why accelerator physics ?

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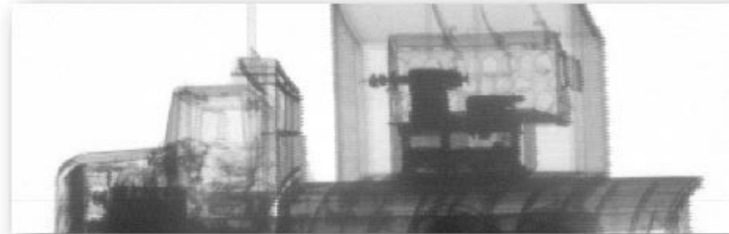
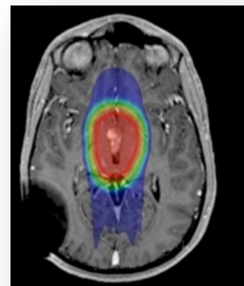
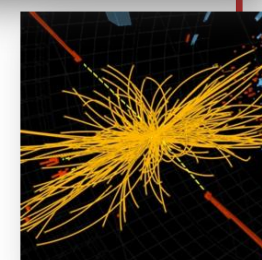


- Industry
  - Food & product safety
  - Contraband detection
  - Semiconductor fabrication
  - Bridge safety



- Medicine
  - Tumor detection and treatment.

~30,000 industrial and medical accelerators are in use, with annual sales of $3.5 B and 10% growth per year.



- Research
  - X ray sources and colliders for nuclear & particle physics
  - Electron microscopes

Since 1943, a Nobel Prize in **Physics** has been awarded to research benefiting from accelerators every 3 years.

Since 1997, the same has been true of **Chemistry**.

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Accelerator physics at Cornell

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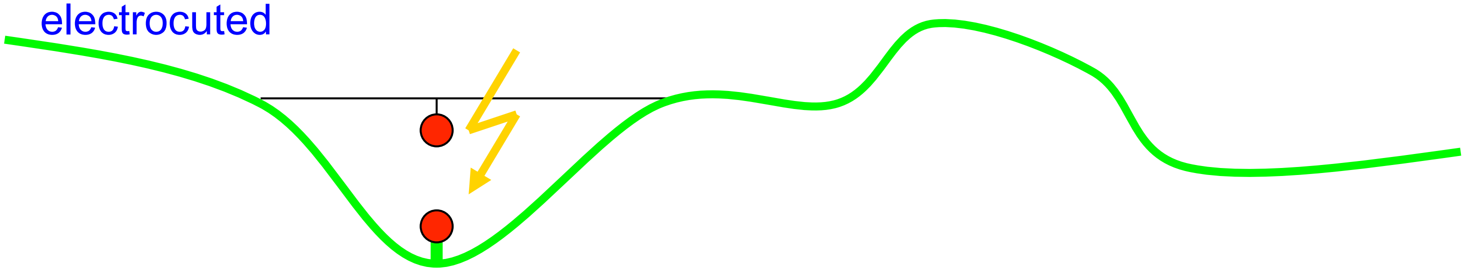
- 1932: Brasch and Lange use potential from lightening, in the Swiss Alps, Lange is fatally electrocuted



- 1934: Livingston builds the first Cyclotron away from Berkely (2MeV protons) at Cornell (in room B54)
- 1949: Wilson et al. at Cornell are first to store beam in a synchtotron (later 300MeV, magnet of 80 Tons)
- 1954: Wilson et al. build first synchrotron with strong focusing for 1.1MeV electrons at Cornell, 4cm beam pipe height, only 16 Tons of magnets.
- 1979: 5GeV electron positron collider CESR (designed for 8GeV)
- Currently:

CESR operation and optimization for the CLEO experiment

CESR operation and optimization for CHESS

ERL prototyping facility (ERL e-source and injector linac)

Construction of the worlds first multi-turn SRF ERL - CBETA

Accelerator simulations, damping ring studies with CESR

Accelerator history at Cornell

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Cornell accelerators:

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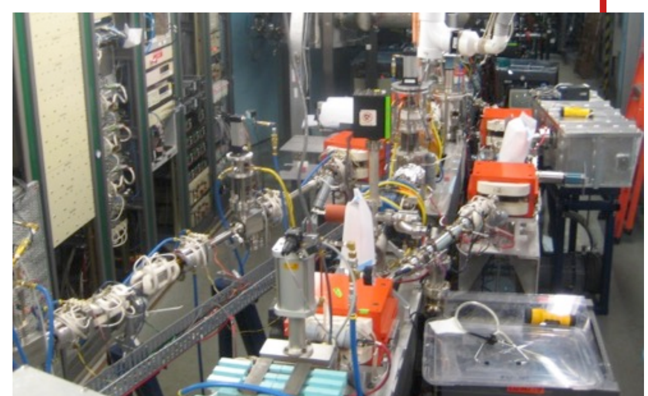
1930 1940 1950 1960 1970 1980 1990 2000 2010 2015

Cornell is a world leader in accelerators

Superconducting acceleration.

Bright electron sources. World record high current, low emittance.

Energy Recovery Linacs. The new accelerator paradigm.



Cornell's academic program in accelerator science is the strongest in the U.S.

Most faculty, most PhD's, most high-impact accomplishments.

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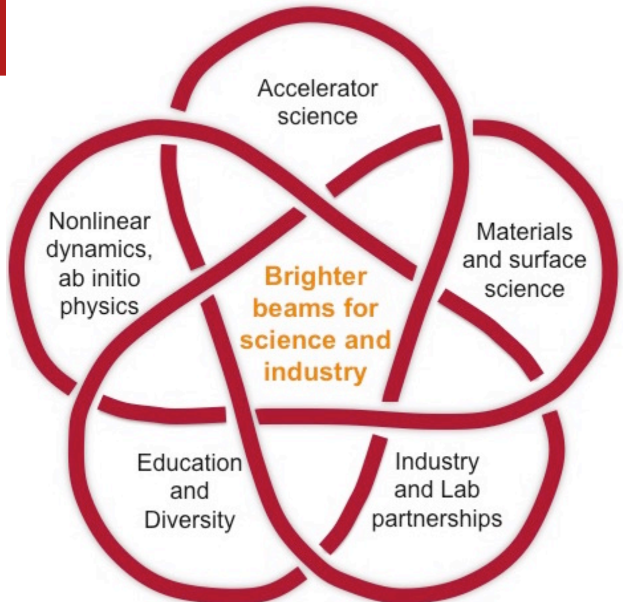
Center of Bright Beams (CBB)



CBB Vision:

Better particle beams for applications ranging from giant colliders to table top electron microscopes enabling new opportunities for science and industry.

CBB Mission:

Transform the reach of electron beams by increasing their brightness x100 and reducing the cost and size of key enabling technologies.

Transfer the best of these technologies to national labs and industry.

Cornell University
UF University of Florida
The University of Chicago
UCLA
University of Toronto
BYU
University of Maryland
Chicago State University
Morehouse College
Clark Atlanta University
Berkeley Lab
Fermilab
TRIUMF

Cornell's synchroton and storage ring

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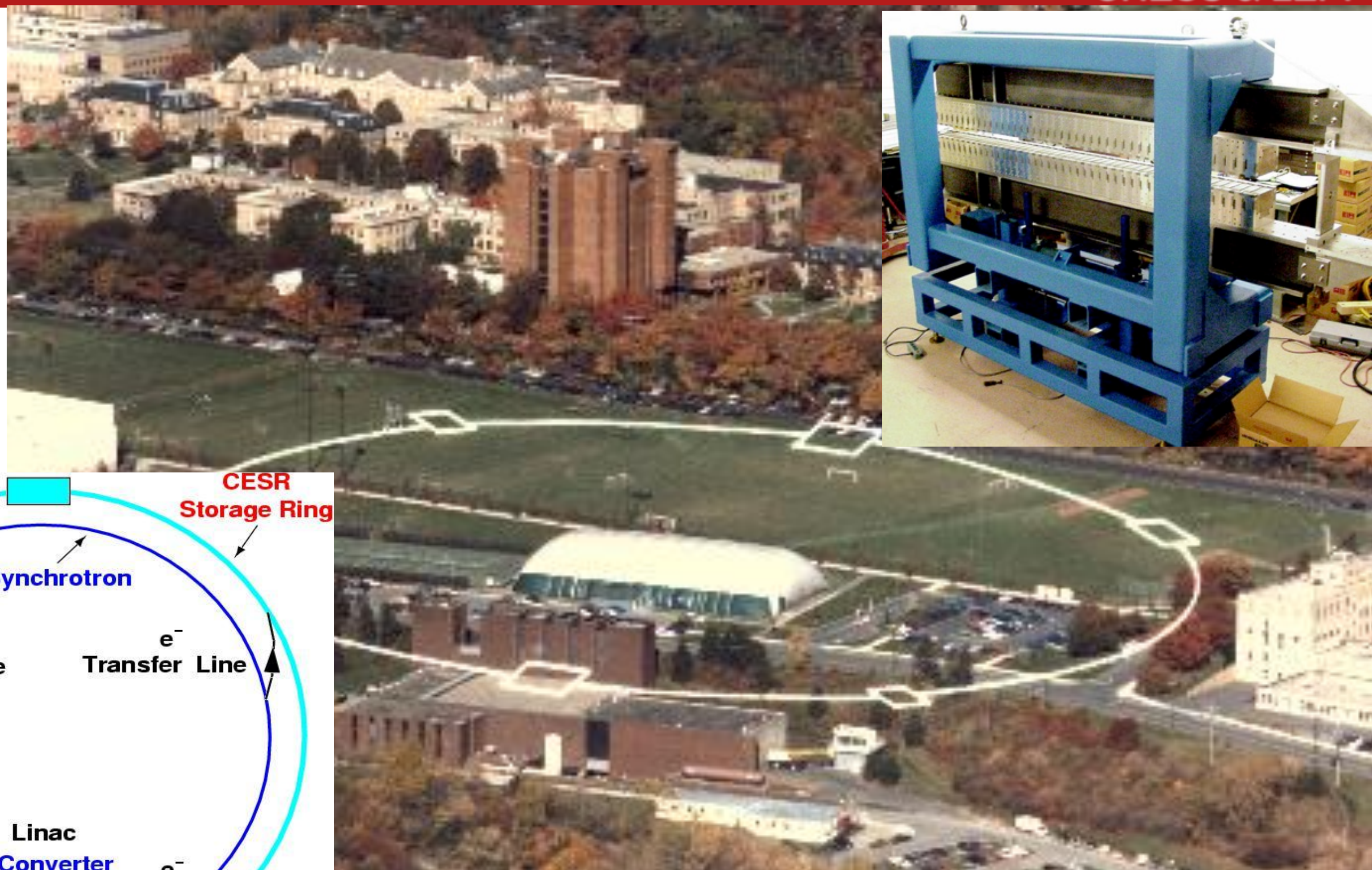
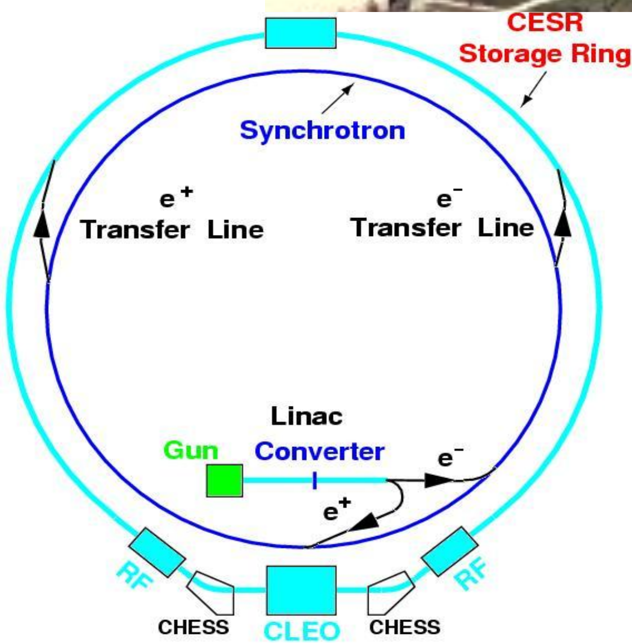




An early construction and NSF project

In ...

Tunnel digging
(as of 1966)

... out

The largest single NSF investment at
up to date at the time.

Cornell's long tradition of tunnels

Tunnel digging
(as of 1830s)

At Ithaca falls, constructed by Ezra Cornell.

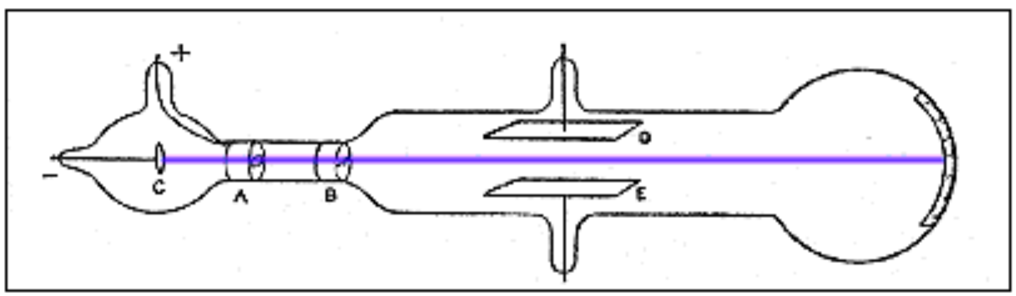
A short history of accelerators

- 1862: Maxwell theory of electromagnetism
- 1887: Hertz discovery of the electromagnetic wave
- 1886: Goldstein discovers positively charged rays (ion beams)
- 1894: Lenard extracts cathode rays (with a 2.65um Al Lenard window)
- 1897: JJ Thomson shows that cathode rays are particles since they followed the classical Lorentz force $m\vec{a} = e(\vec{E} + \vec{v} \times \vec{B})$ in an electromagnetic field
- 1926: GP Thomson shows that the electron is a wave (1929-1930 in Cornell, NP in 1937)

NP 1905

Philipp E.A. von Lenard

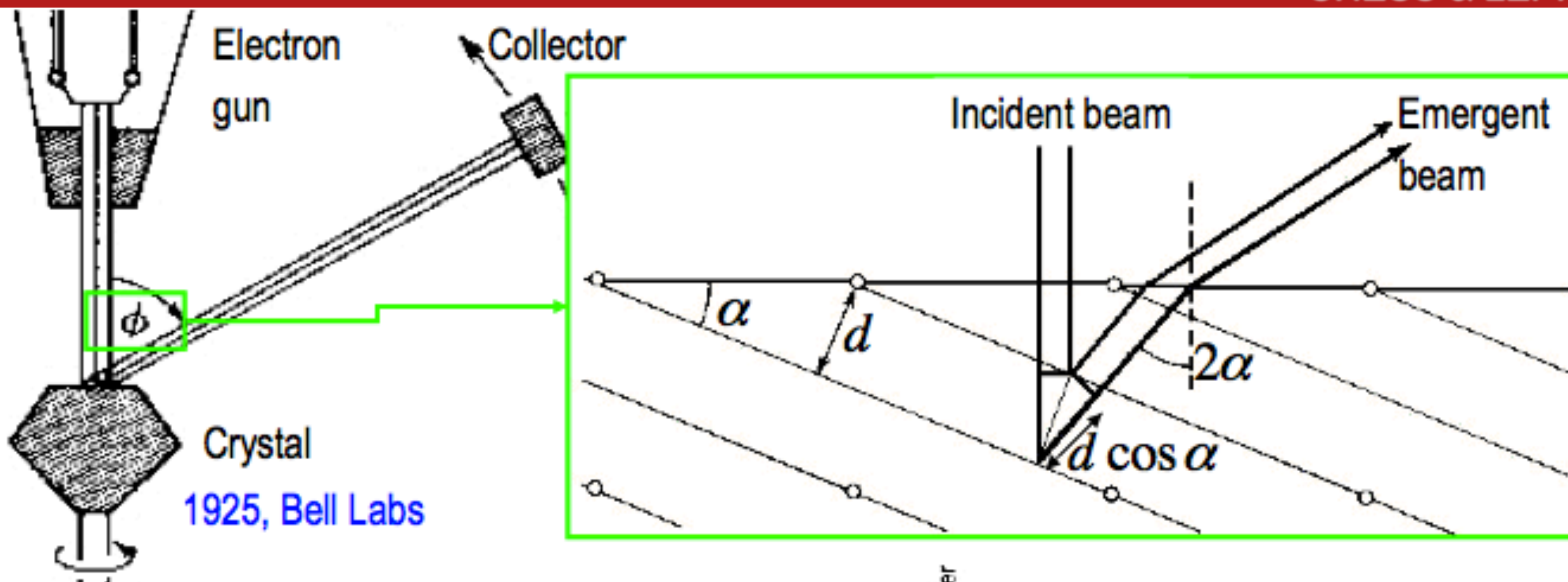
Germany 1862-1947



NP 1906

Joseph J. Thomson

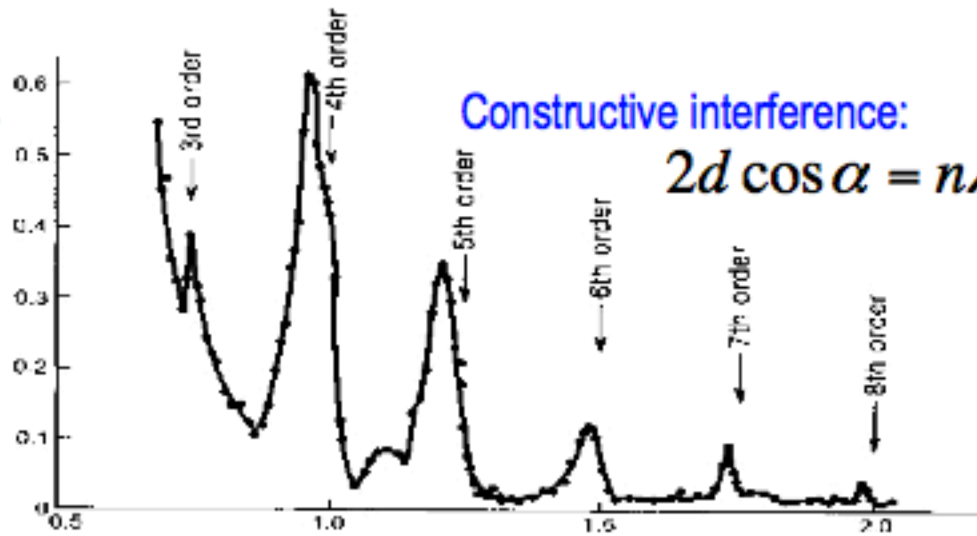
UK 1856-1940



1925, Bell Labs

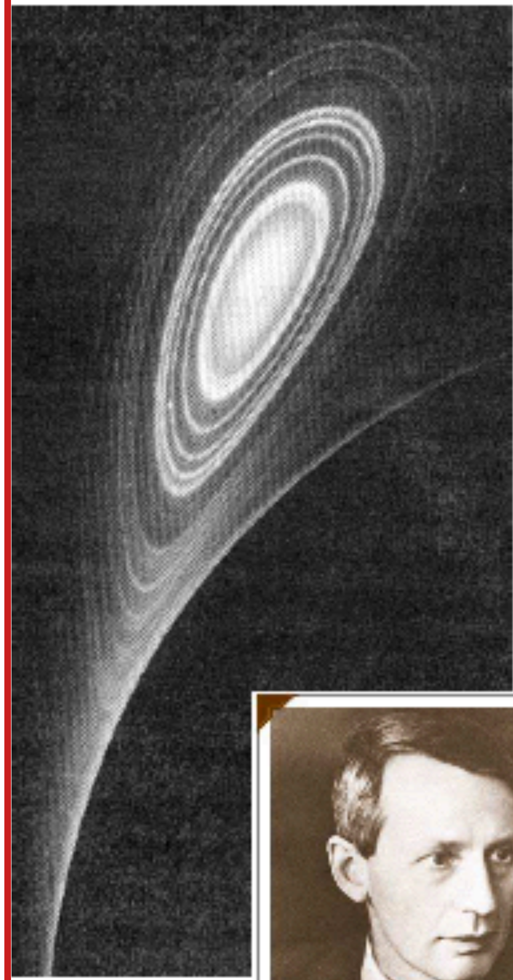
Clinton Davisson
(1881-1958)
Nobel Price 1937

Reflection as a function of energy

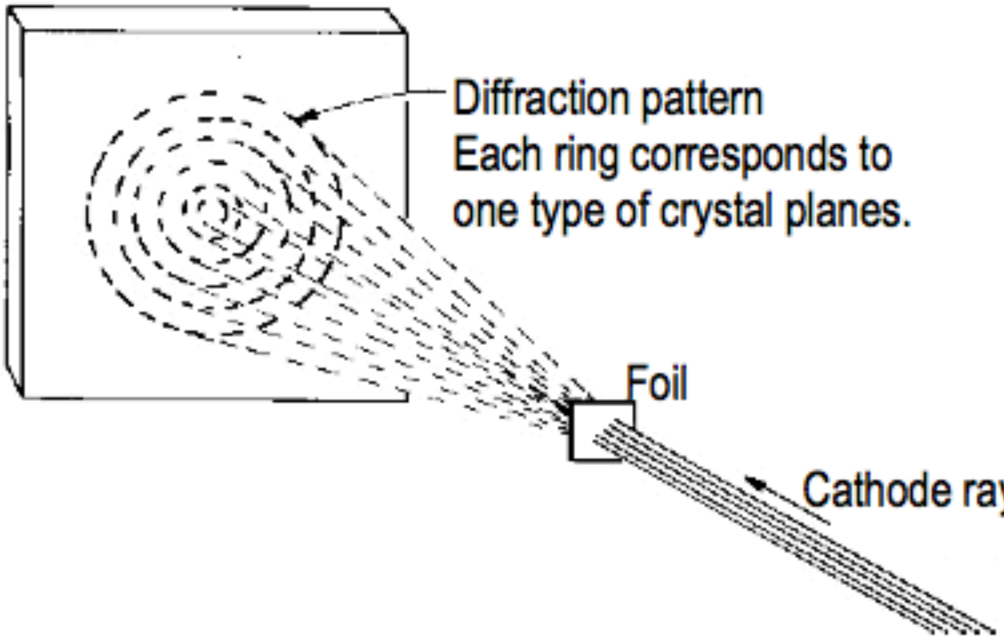


Constructive interference:

$$2d\cos\alpha = n\lambda$$



In a powdered, microcrystalline substance there is always some crystal which has the correct angle for constructive interference $2d\cos\alpha = n\lambda$



George P.Thomson
(1892-1975)
1937 Nobel prize
Son of Joseph J. T.

A magnetic field can change the rings, showing the the waves are associated with the electron charge.