Norway and accelerators

a historical view

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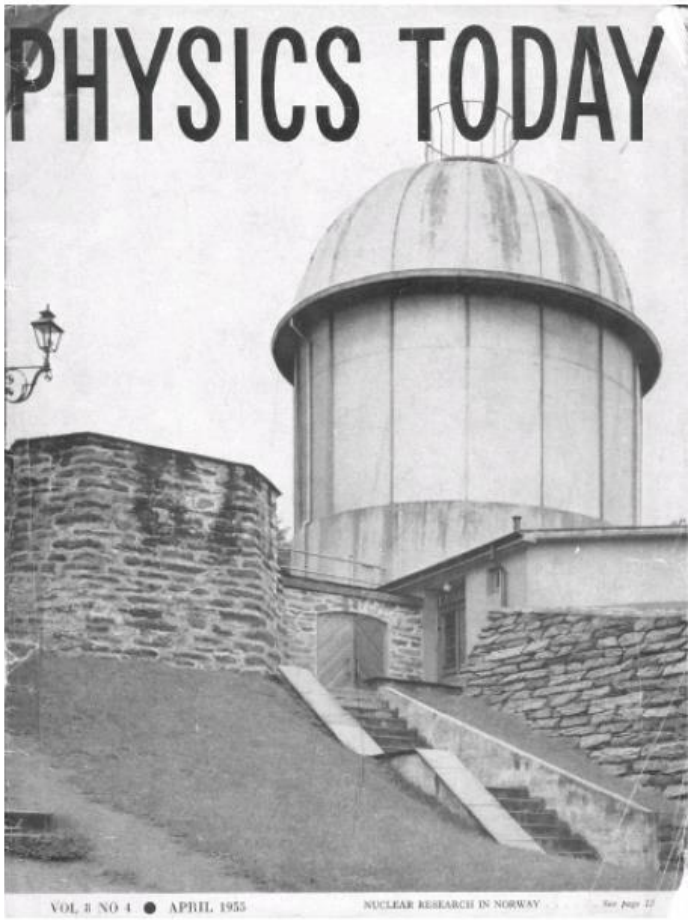
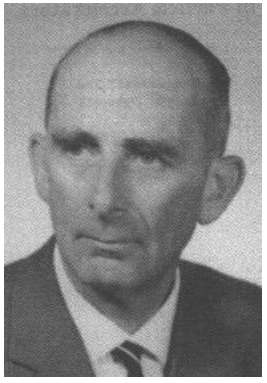
UiB, Norway



Norway and accelerators - a historical view

- **Rolf Widerøe (1928): use of alternating electric fields to accelerate charged particles**
  - **First circular accelerator: Betatron**

    -> inspired Ernest Lawrence (Berkeley) to build a proton cyclotron (1931)
  - **First radio frequency linear accelerator (LINAC)**



Über ein neues Prinzip zur Herstellung hoher Spannungen[1].

Von

Rolf Wideröe, Berlin.

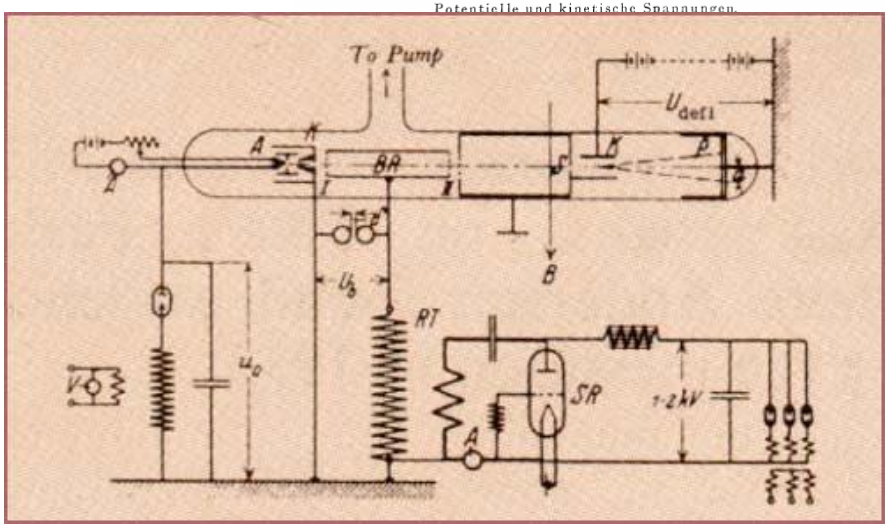
I. Einleitung.

Schwierigkeiten in der Beherrschung hoher Spannungen.

Bekanntlich liegen alle Schwierigkeiten bei der Herstellung hoher Spannungen in der Beherrschung der elektrostatischen Felder. Alle technischen Isoliermaterialien haben eine begrenzte Isolierfähigkeit, bei einer gewissen Feldstärke schlagen sie durch und werden leitend. Die Höhe der erzeugten Spannung wird deswegen hauptsächlich durch die stark zunehmenden Dimensionen der Isolierung begrenzt.

Es besteht nun aber die Möglichkeit, diese Grenze der erzeugten Spannungen wesentlich zu erhöhen, indem man elektrostatische Felder weitgehend vermeidet und die Hochtransformierung mit Hilfe schnellbewegten Elektronen und Ionen vornimmt.

Potentielle und kinetische Spannungen.



Betatron – a circular induction accelerator

- **Widerøe's PhD, Aachen, 1927**

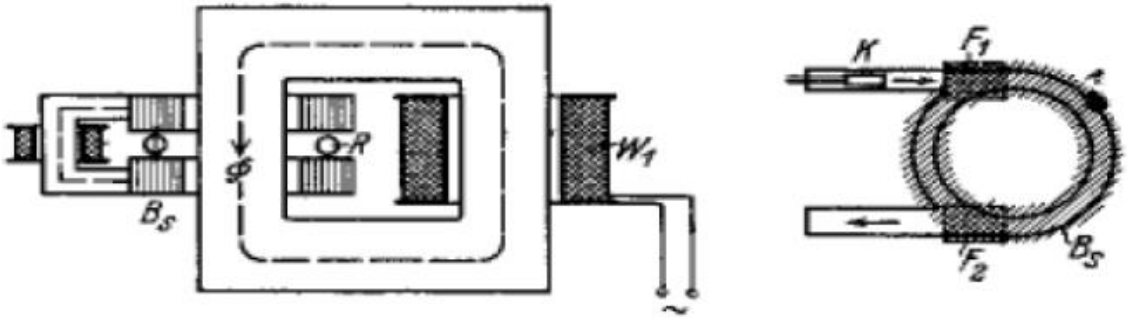
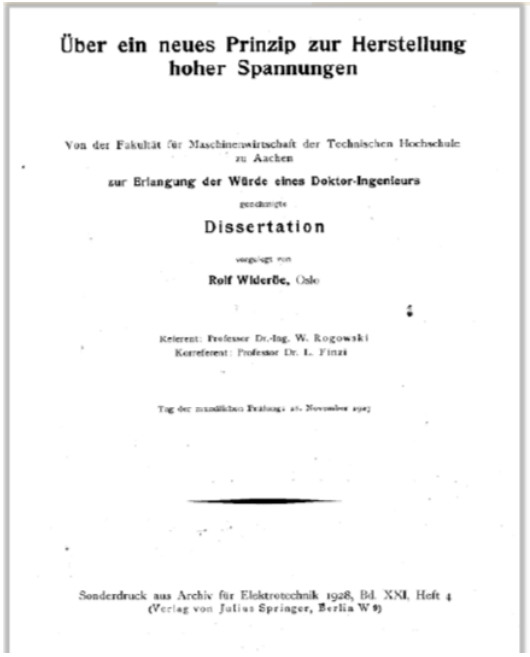


Bild 11. Wirkungsweise des Strahlentransformators.

Die Beschleunigung in Wirbelfeldern würde sehr hohe Spannungen erzeugen können. Das Verfahren scheitert daran, daß die Möglichkeiten fehlen, die Elektronen auf einer Kreisbahn zu binden. Die Lösung dieser Frage scheint zur Zeit große Schwierigkeiten zu bereiten.



Über ein neues Prinzip zur Herstellung hoher Spannungen

Von der Fakultät für Maschinenwirtschaft der Technischen Hochschule zu Aachen

zur Erlangung der Würde eines Doktor-Ingenieurs

genehmigte

Dissertation

vorgelegt von

Rolf Widerße, Oslo

Referent: Professor Dr.-Ing. W. Rogowski
Korreferent: Professor Dr. L. Finzi

Tag der mündlichen Prüfung: 21. November 1927

Sonderdruck aus Archiv für Elektrotechnik 1928, Bd. XXI. Heft 4
(Verlag von Julius Springer, Berlin W 9)

did not manage to get it working

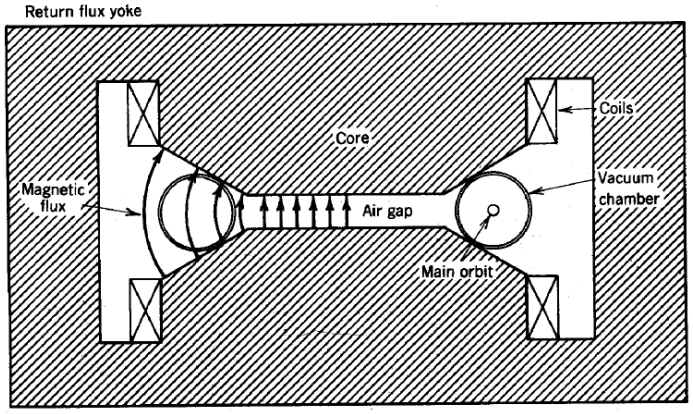
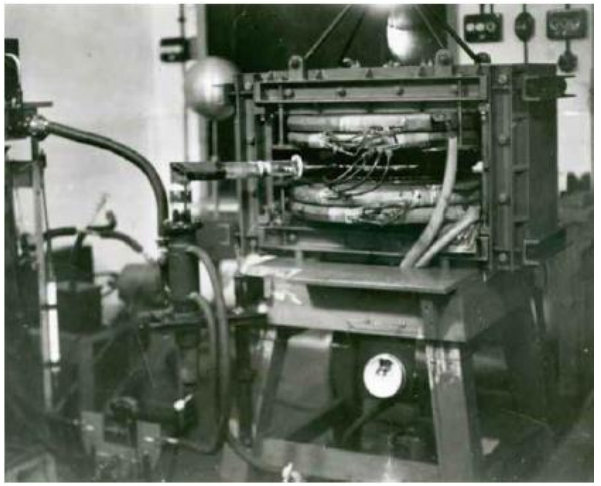


Figure 11.1 Schematic diagram of betatron with air gap.

Widerøe's first (15 MeV) Betatron 1943-45



Betatron – inspiration for cyclotron

- **Ernest Lawrence at Berkeley, 1932**

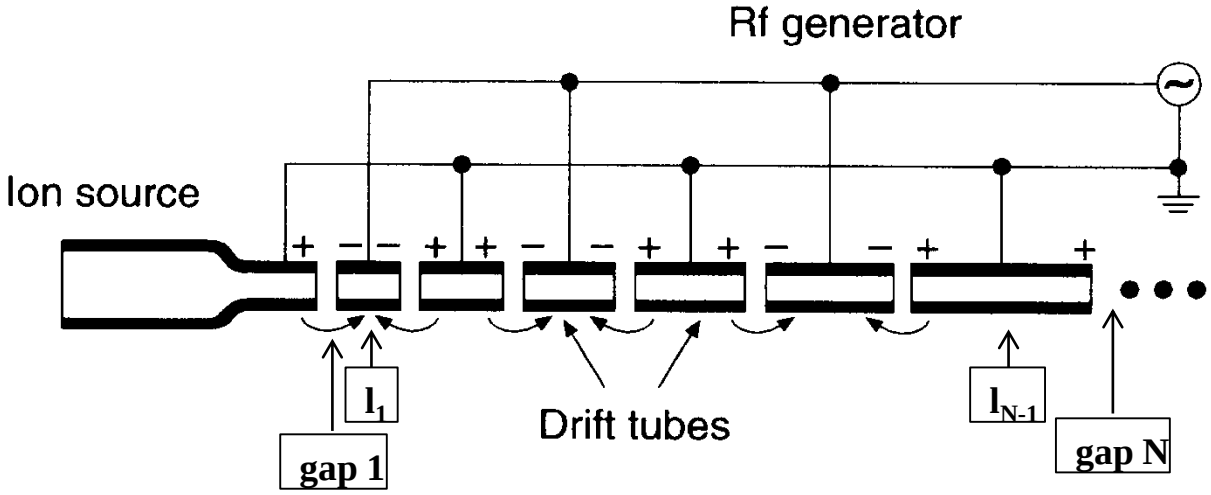
  11-inch proton cyclotron: 1.2 MeV

not being able to read German easily, I merely looked at the diagrams and photographs of Wideroe's apparatus and from the various figures in the article readily ~~obtained~~ understood ~~the~~ his general approach to the problem – i.e. the multiple acceleration of the positive ions by application of radio frequency oscillating voltages to a series of cylindrical electrodes opposite

BNL

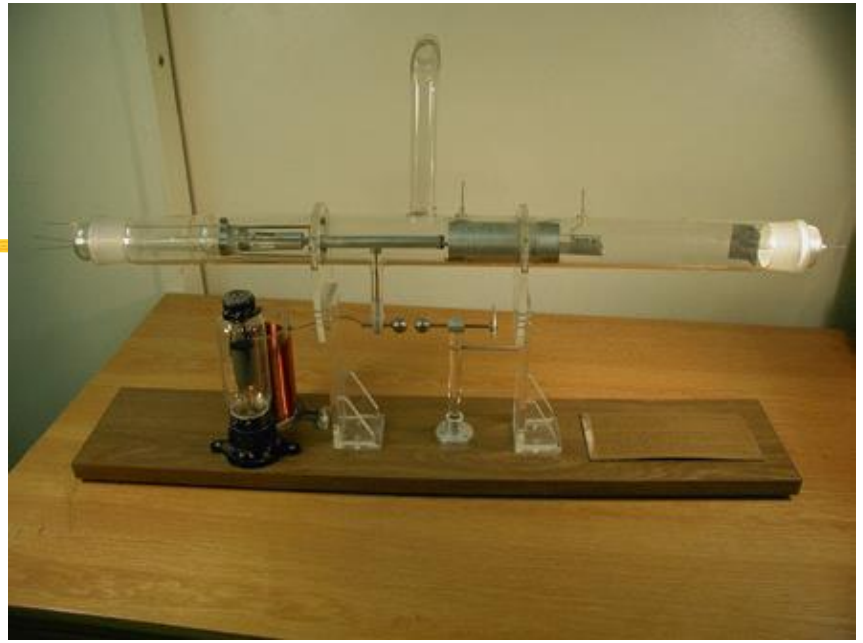
Drift tube linac

- **Energy gain: $\Delta E = e \cdot N_{gap} \cdot V_{RF}$**
- **Period length increases with velocity $l = v/2 \cdot f$**
- **RF phase changes by 180° while the particles travel inside the tubes, i.e. while the electric fields point in the "wrong direction" the particles are shielded by the drift tubes**



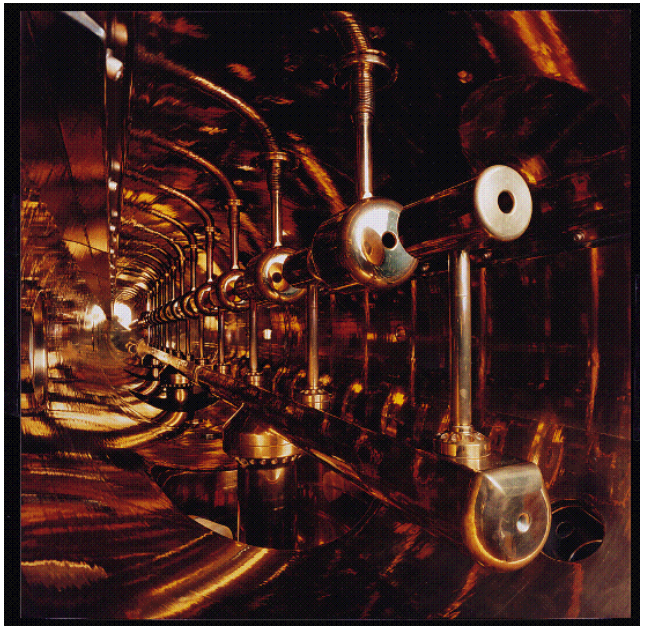
- **higher frequencies (> 10 MHz) were not practical, because the drift tubes would act more like antennas**
- **when using low frequencies, the length of the drift tubes becomes prohibitive for high-energy protons, e.g. 3 m at 20 MeV**

Widerøe's Linac

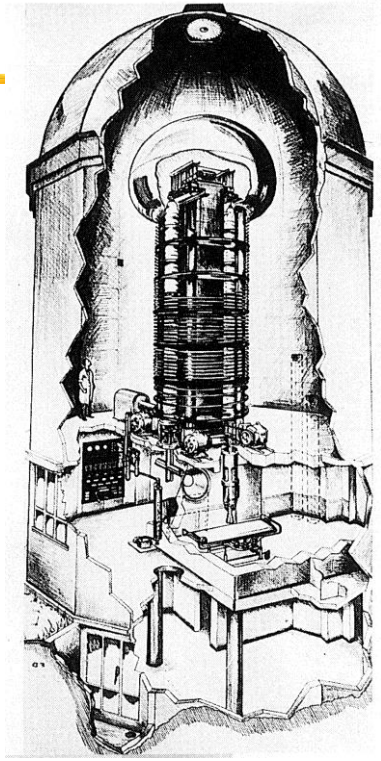


- **Widerøe's prototype**
  (exact replica of the first high-frequency linear accelerator successfully built, 1927)

- **Widerøe structure at UNILAC - GSI**



Norway and accelerators – a historical view



- **1931/32** — **First 1 MeV electrostatic accelerator by Robert J. Van de Graaff, Carnegie Institution of Washington, USA, based on high-voltage generators developed by Odd Dahl et al.**

- **1939-1942** — **First Van de Graaff machine (1.5 MeV) in Europe for cancer treatment at Haukeland University Hospital (HUS), built by Odd Dahl, at that time at the Christian Michelsen Institute in Bergen.**

Design and start of construction of a second accelerator for "Radiumhospitalet" in Oslo – the order was later canceled.

Van de Graaff electrostatic accelerator

- **Bergen Van de Graaff**
  - **first machine built by Odd Dahl for cancer treatment (1939)**
  - **first nuclear physics machine (1950)**

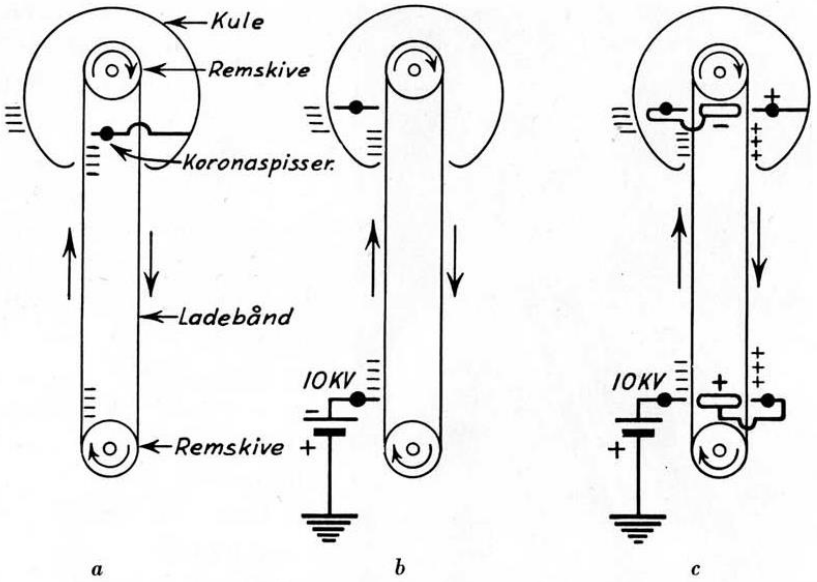


Fig. 1. Prinsippet for elektrostatiske høyspenningsgeneratorer. *a*) Ladningen frembringes ved en gnidningsprosess og tilføres høyspenningselektroden ved hjelp av et løpende bånd. *b*) Ladningen frembringes ved at båndet passerer et jonisert område og belegges med joner. Elektroden E har høyspenning i forhold til jord. *c*) Begge båndparter er aktive. Venstre båndel tilfører kulen negativ ladning og den høyre transporterer positiv elektrisitet fra kulen til jord.

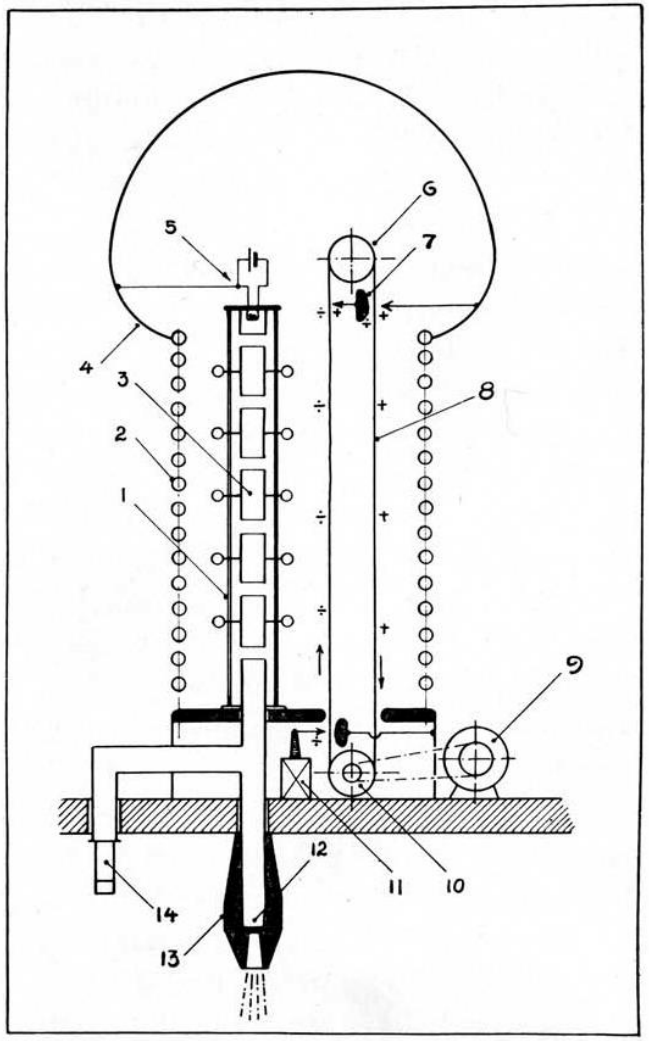
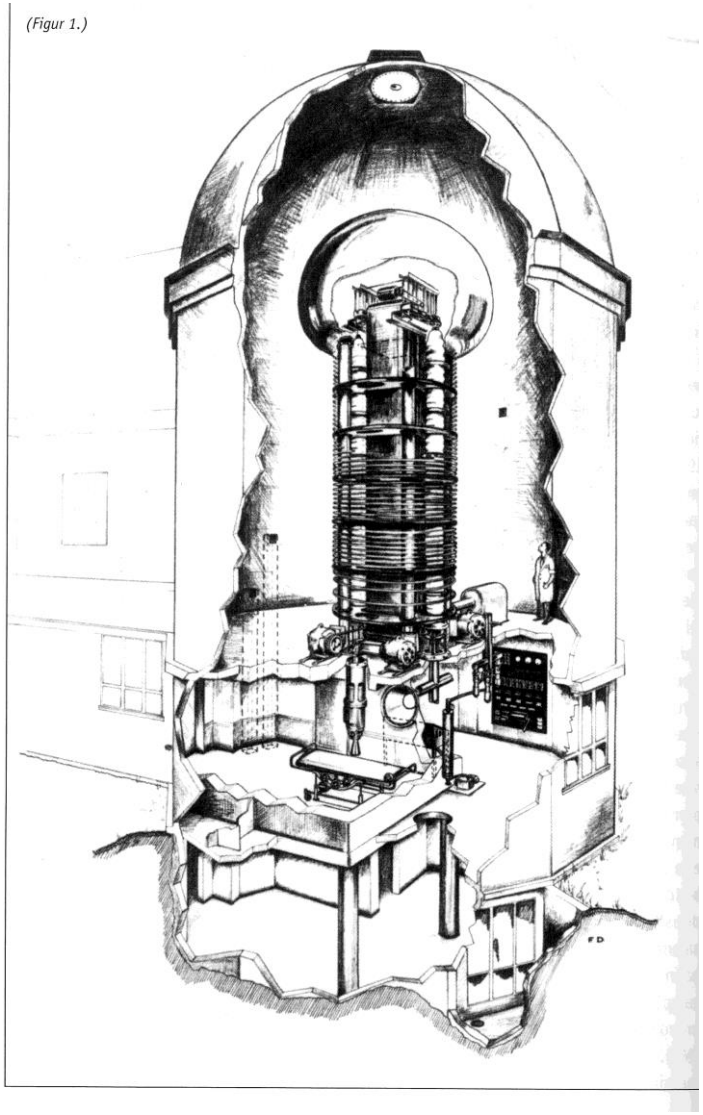
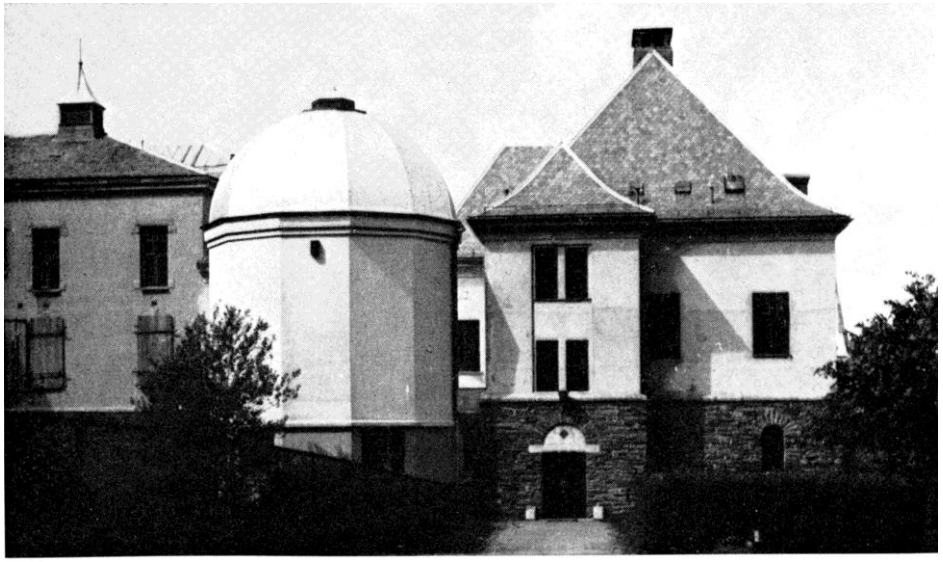
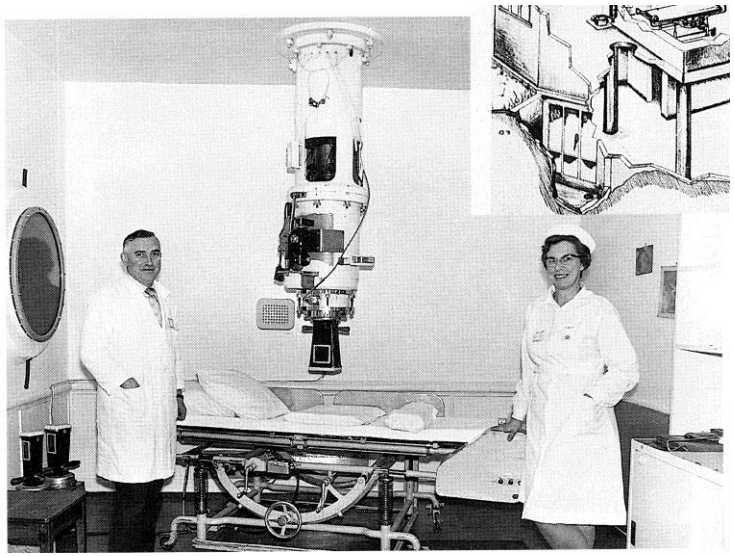


Fig. 7. Skjematisk fremstilling av en karakteristisk elektrostatisk «Super-røntgeninstallasjon».

Van de Graaff accelerator @ HUS

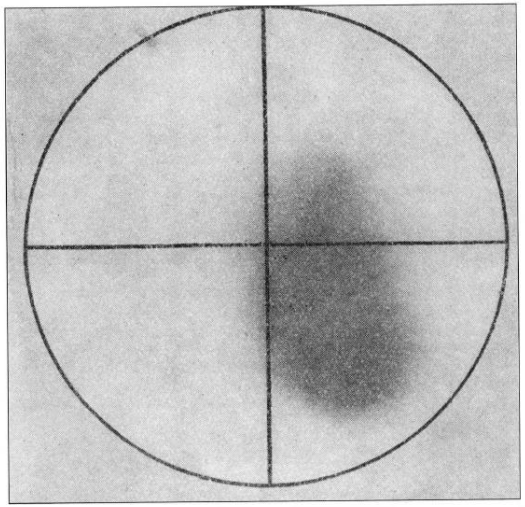


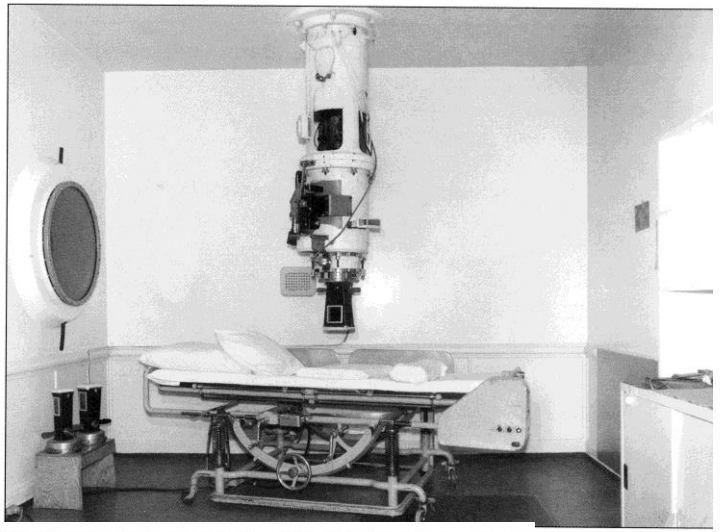




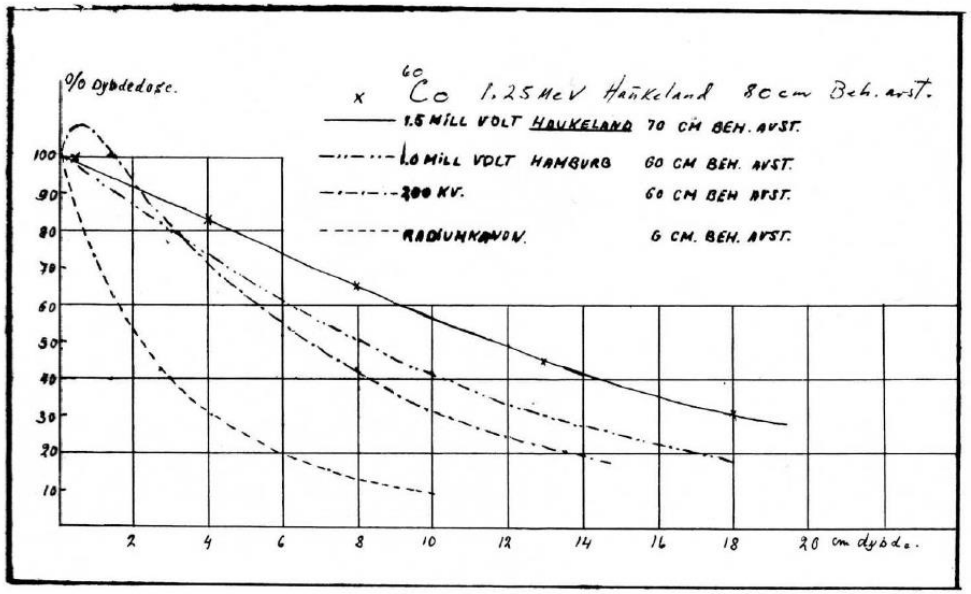
Van de Graaff accelerator @ HUS

- **Beam spot**



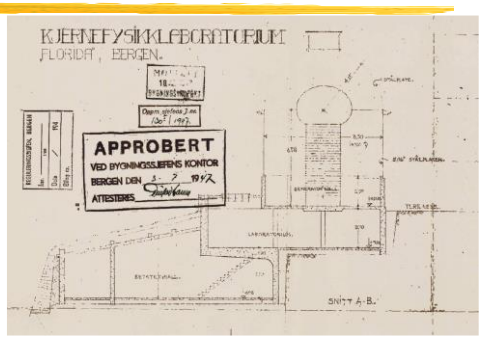


- **Dose-depth distribution**

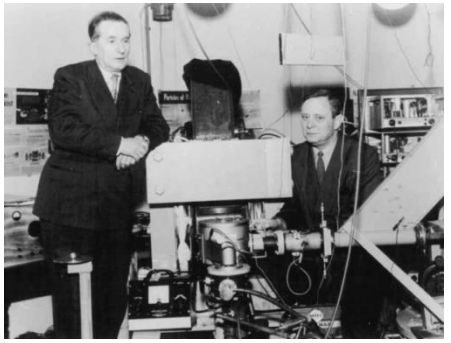


Norway and accelerators - a historical view

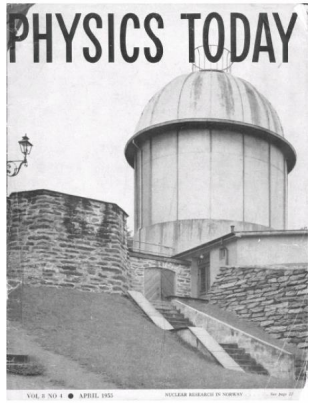
- **1947** — **Start of the construction of the laboratory building and the accelerator at the newly founded university in Bergen by Bjørn Trumpy and Odd Dahl**



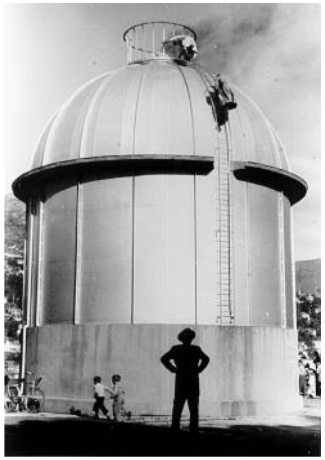
- **1950** — **Van de Graaff accelerator operational – 1.25 MeV; re-using parts of the planned Oslo medical machine**



- **1954** — **The Bergen Nuclear Physics Laboratory - cover page in Physics Today**



- **1956** — **Accelerator destroyed in a fire**

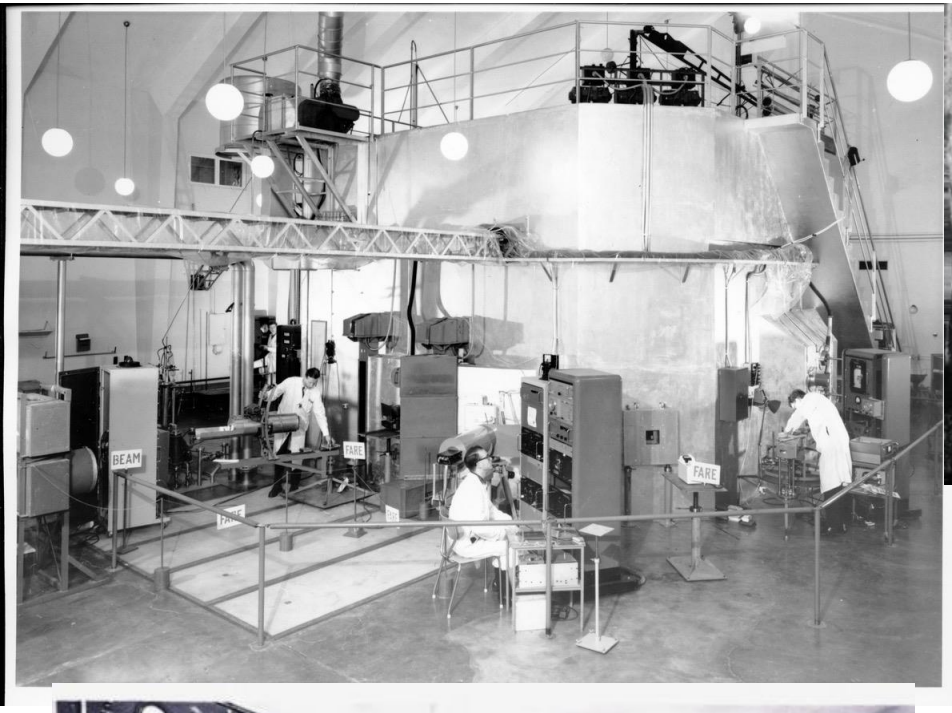


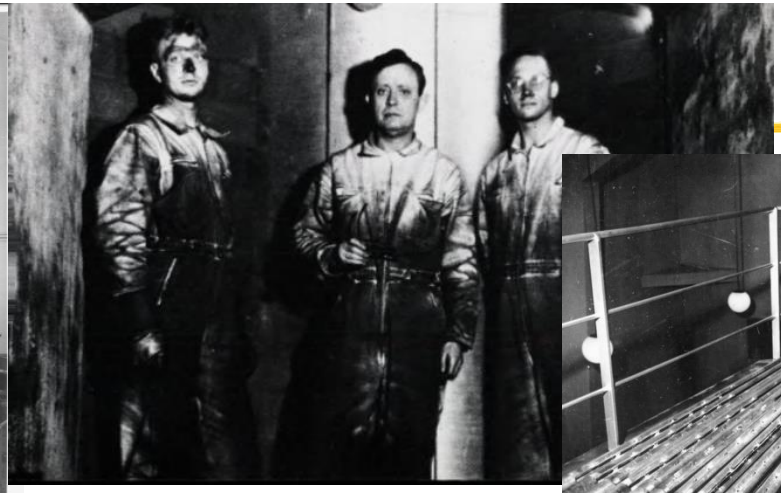
- **1957-1959** — **Re-building of the VdG accelerator**
- **Since 1959** — **Operational for research in nuclear physics**

Nuclear reactor in Norway

- **First reactor outside the nuclear weapon states**
  - **Built by Odd Dahl and Gunnar Randers at Kjeller (near Oslo)**
  - **Joint Establishment Experimental Pile (JEEP I) went critical in 1951**

JEEP I





Inauguration 1951

Accelerator complex – synchrotron → higher energies

- **CERN was established in 1952/1954**
- **Odd Dahl was appointed as the director of one of CERN's accelerator groups to plan the construction of a proton synchrotron, with Widerøe as a part-time consultant.**
- **Odd Dahl, Rolf Widerøe: Members of CERN's Proton Synchrotron design team (1953-1959)**

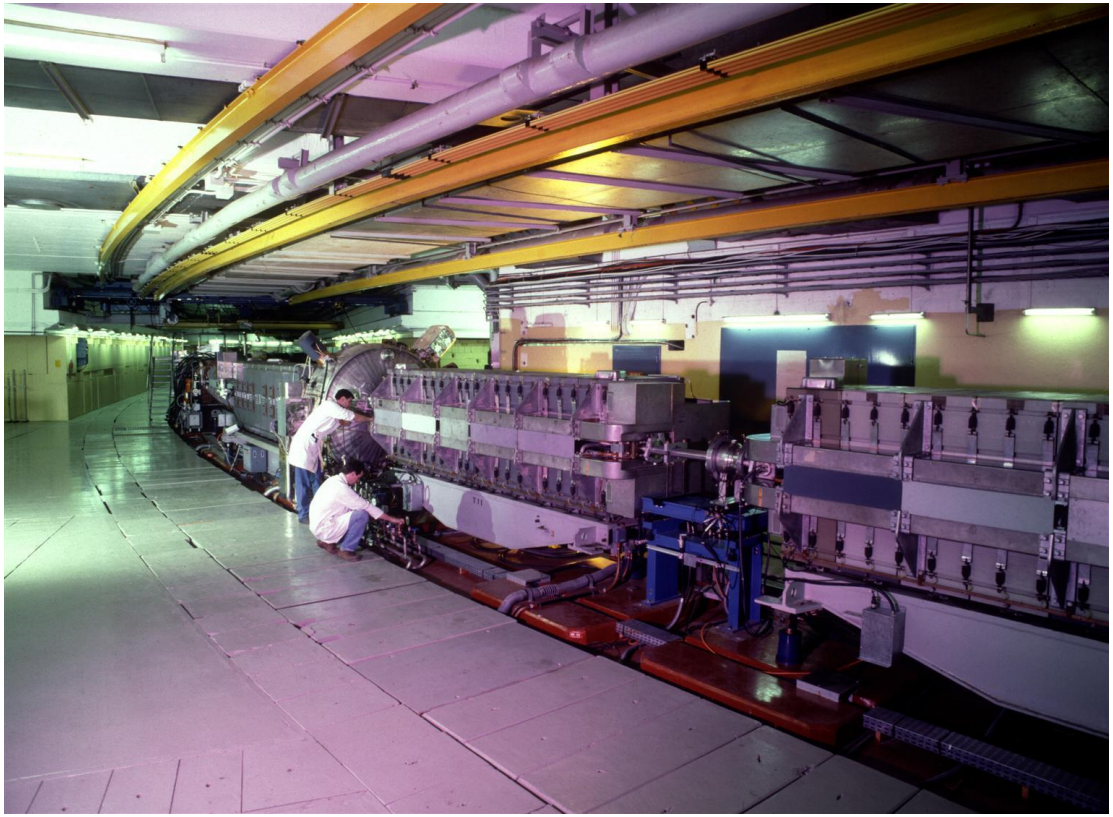
A CERN foundation meeting (1953)

In 1952, a group from Europe visited Brookhaven National Laboratory in preparation for the establishment of CERN. George Collins (Brookhaven), Odd Dahl, Rolf Widerøe and Frank Goward

CERN's proton synchrotron

- **First Alternate Gradient Synchrotron (1959)**

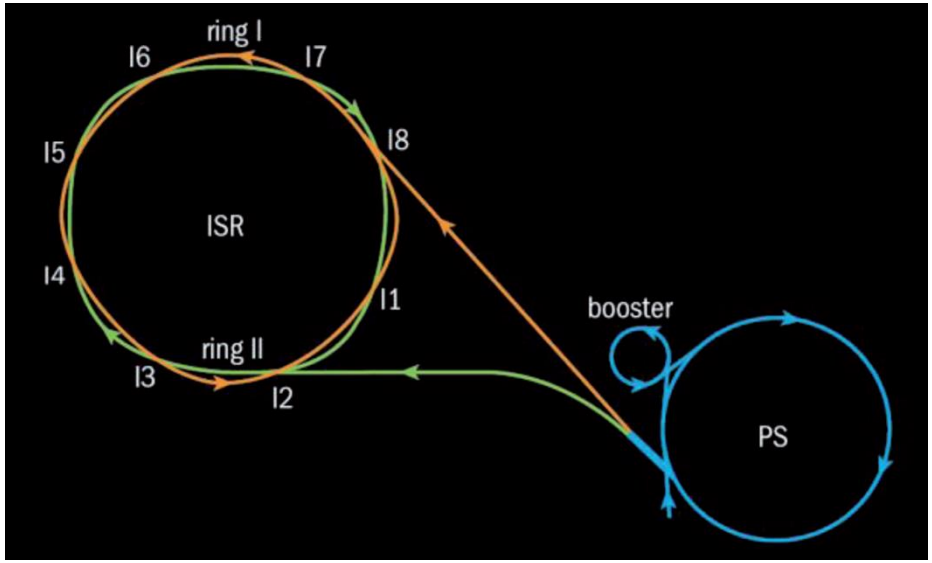
CERN PS ring

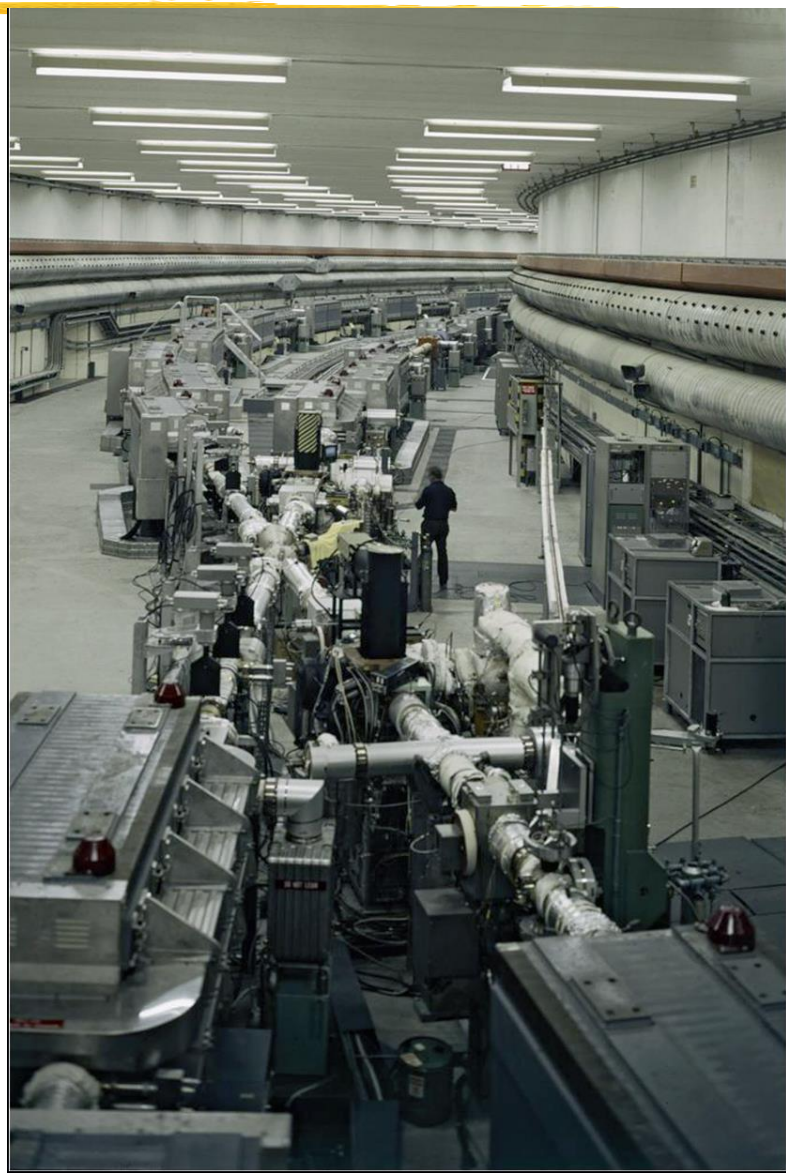


19 MHz cavity resonator

Storage rings and colliders

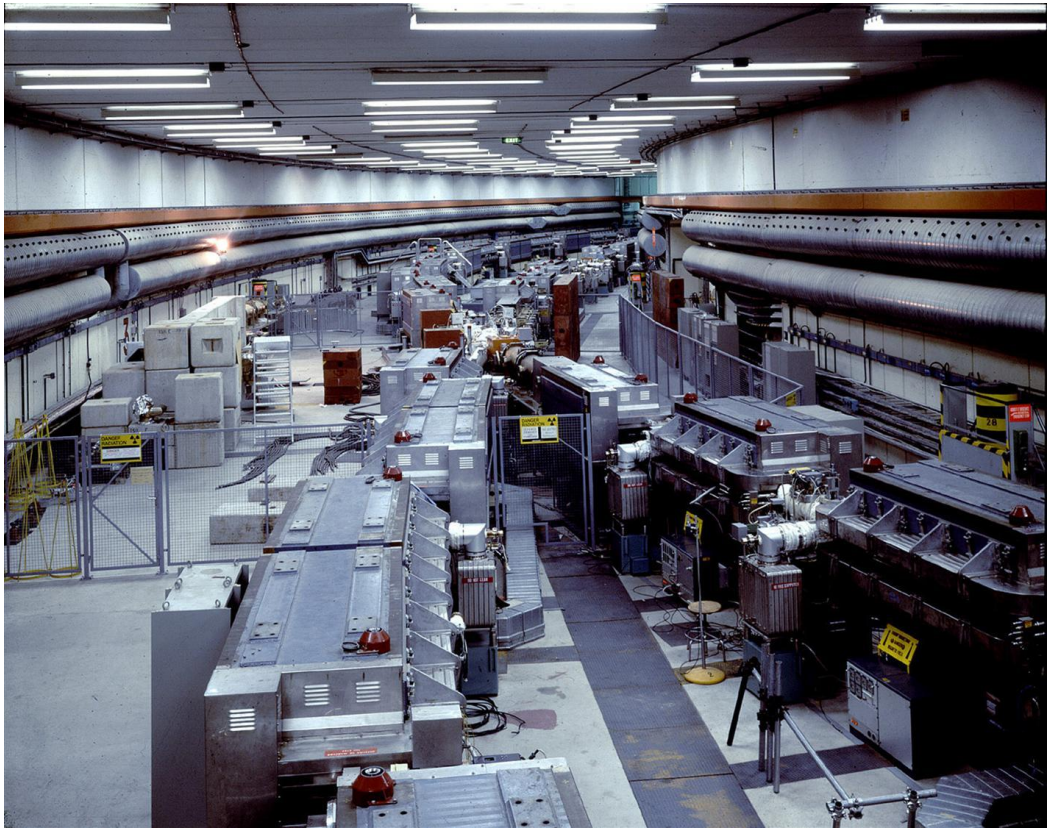
- **Rolf Widerøe, Kjell Johnsen (Prof. II @ UiB)**
  - **Conceptual design of a collider: Widerøe (1943)**
  - **Construction of the Intersecting Storage Ring at CERN: Johnsen (1964-1971)**

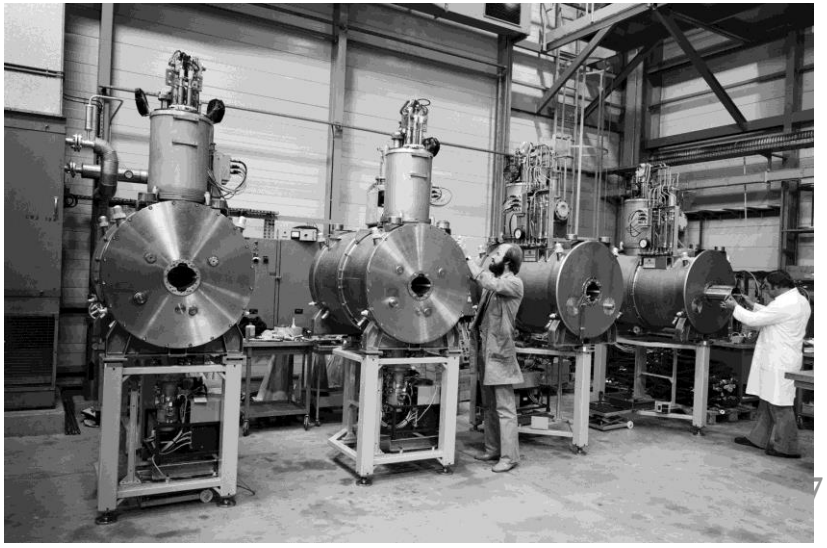




CERN's Proton Collider Program: ISR

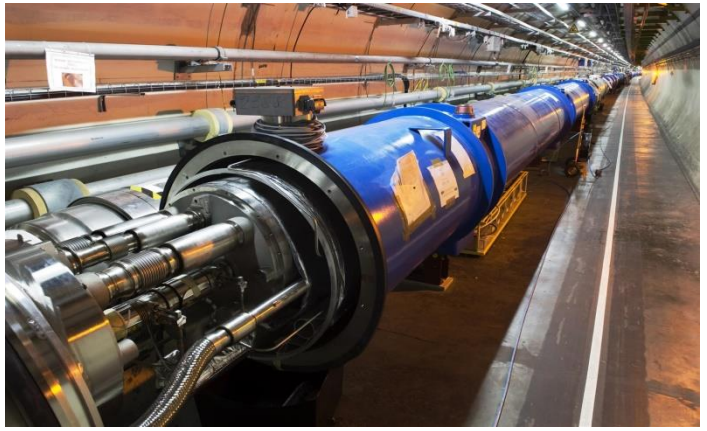
- **1971: First Proton Collider (62 GeV)**





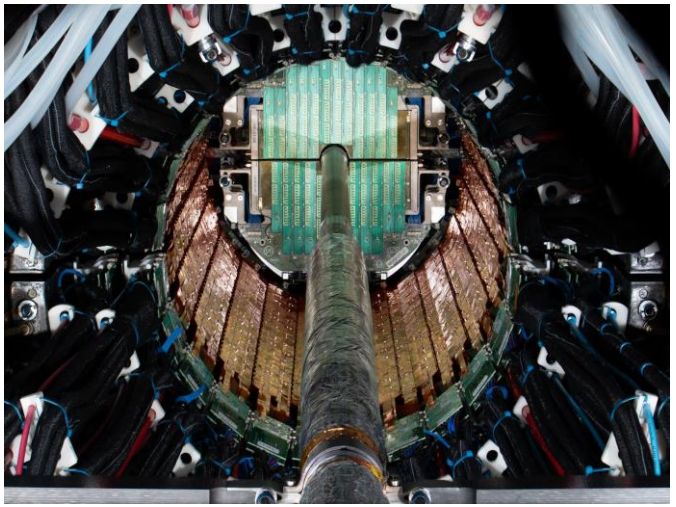
Large Hadron Collider at CERN – the Norwegian present and future

LHC

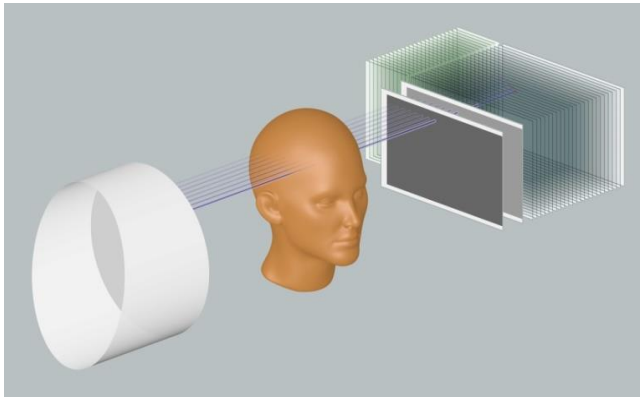


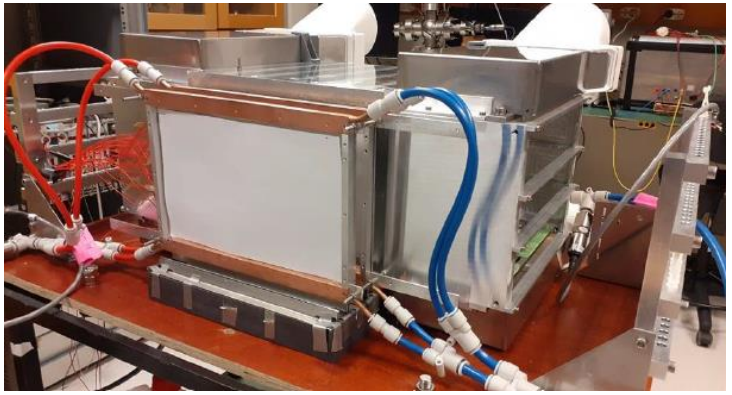
Large Hadron Collider at CERN – the Norwegian present and future

- **Experiments with UiB participation: ATLAS & ALICE**



- **Spin-off: from basic research to proton-CT**





Bergen today

- **Proton therapy facility at HUS (cyclotron) - 2024**

- **VdG at UiB**