Accelerators: Engines for Traversing a Large and Often Difficult Landscape

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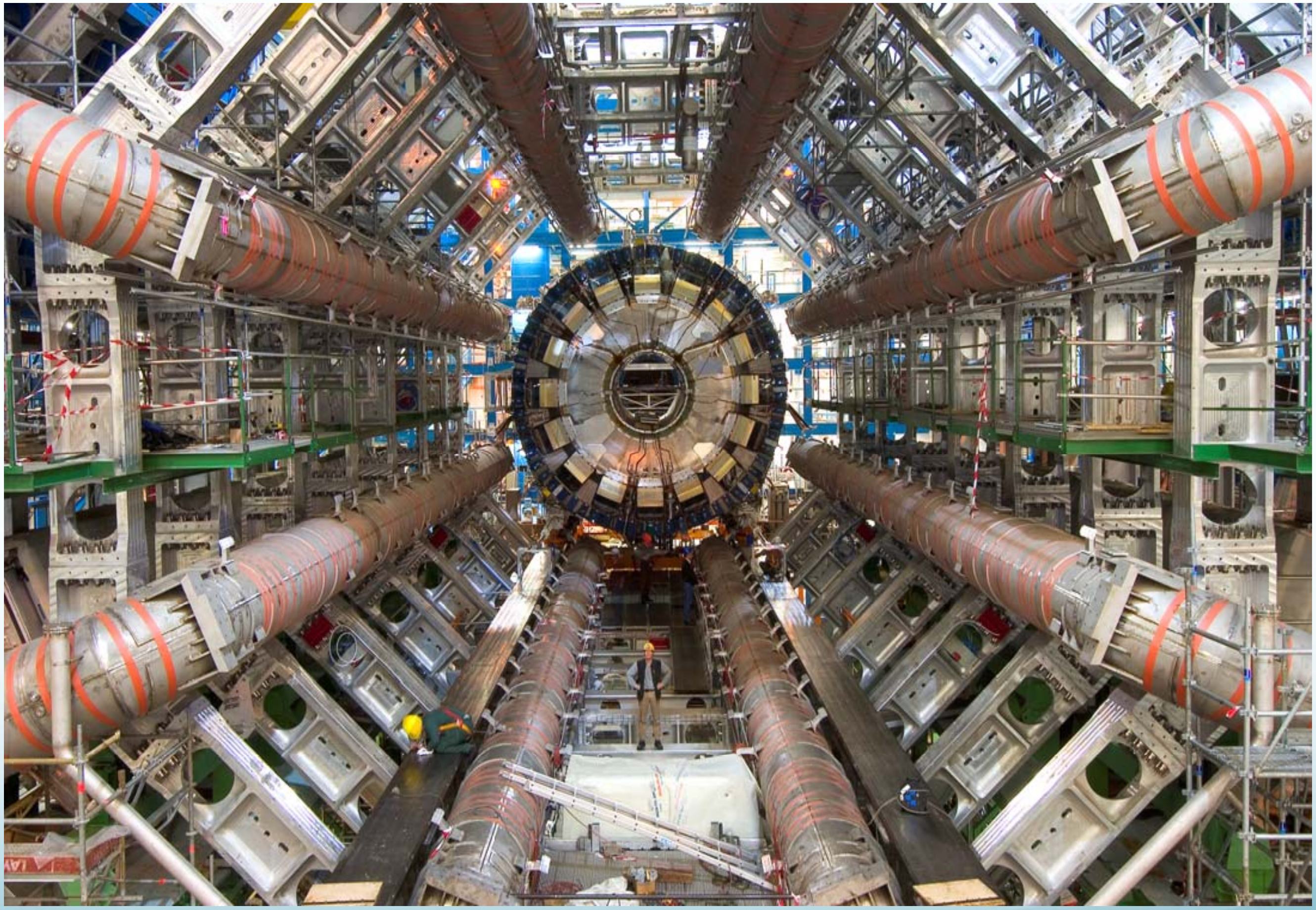
Dedicated to the memory of Dieter Moehl
and Andrey Lebedev

Basic Physics

The Atlas Detector at the LHC

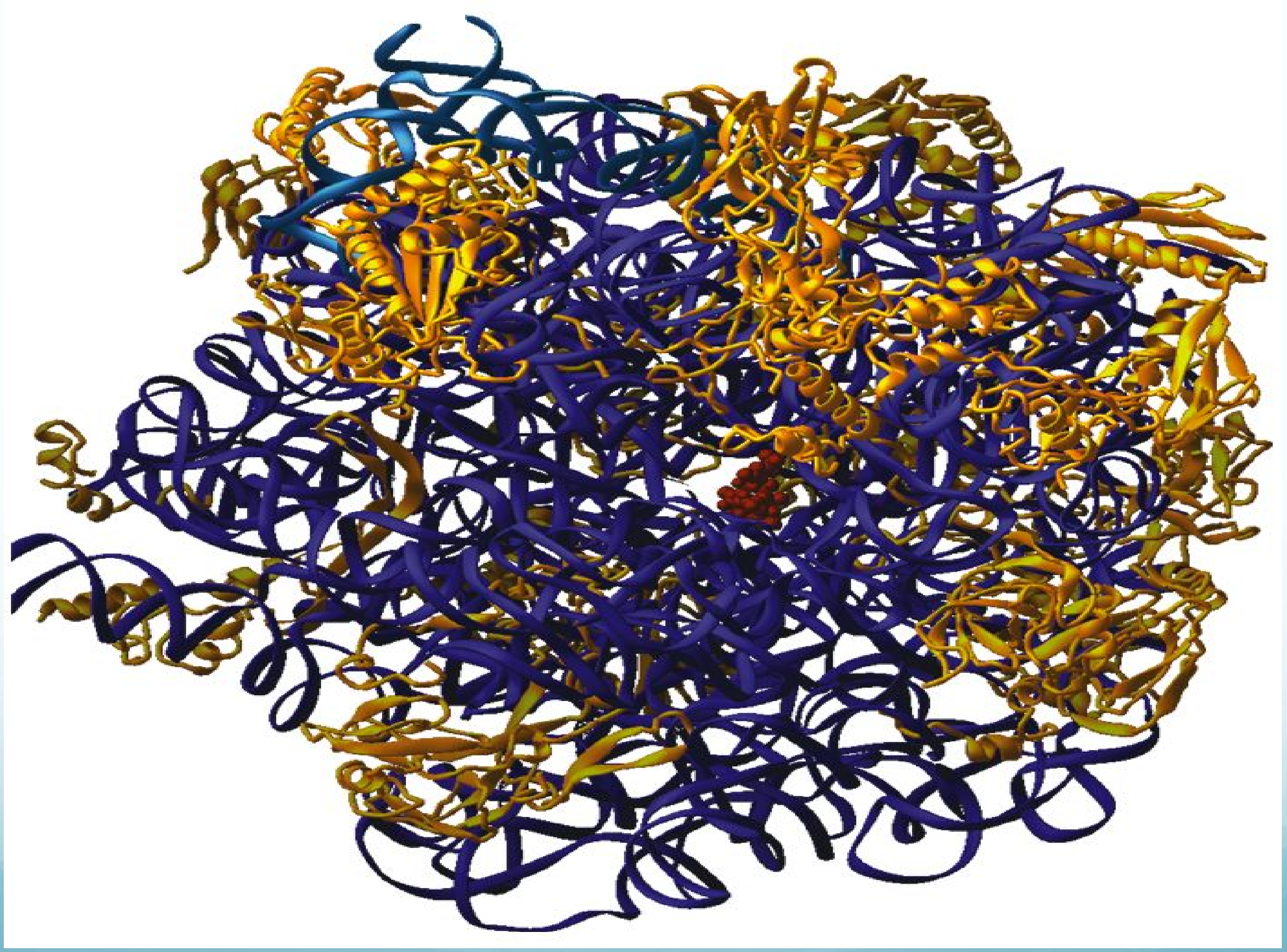


Abstract

- The many applications of accelerators are presented, with pictures and comments, upon the machines and the results obtained with them. Attention is then given to possible future applications, along with comments as to what is requited for these applications. Finally, some remarks are made as to what might be the future development of accelerators. In short, the presentation should serve as an introduction to the Conference itself where there shall be many – wonderfully detailed -- contributions to all of this.

One Application: Synchrotron Radiation

A protein molecule structure determined by
X-Ray scattering



Contents

1. Types of Accelerators

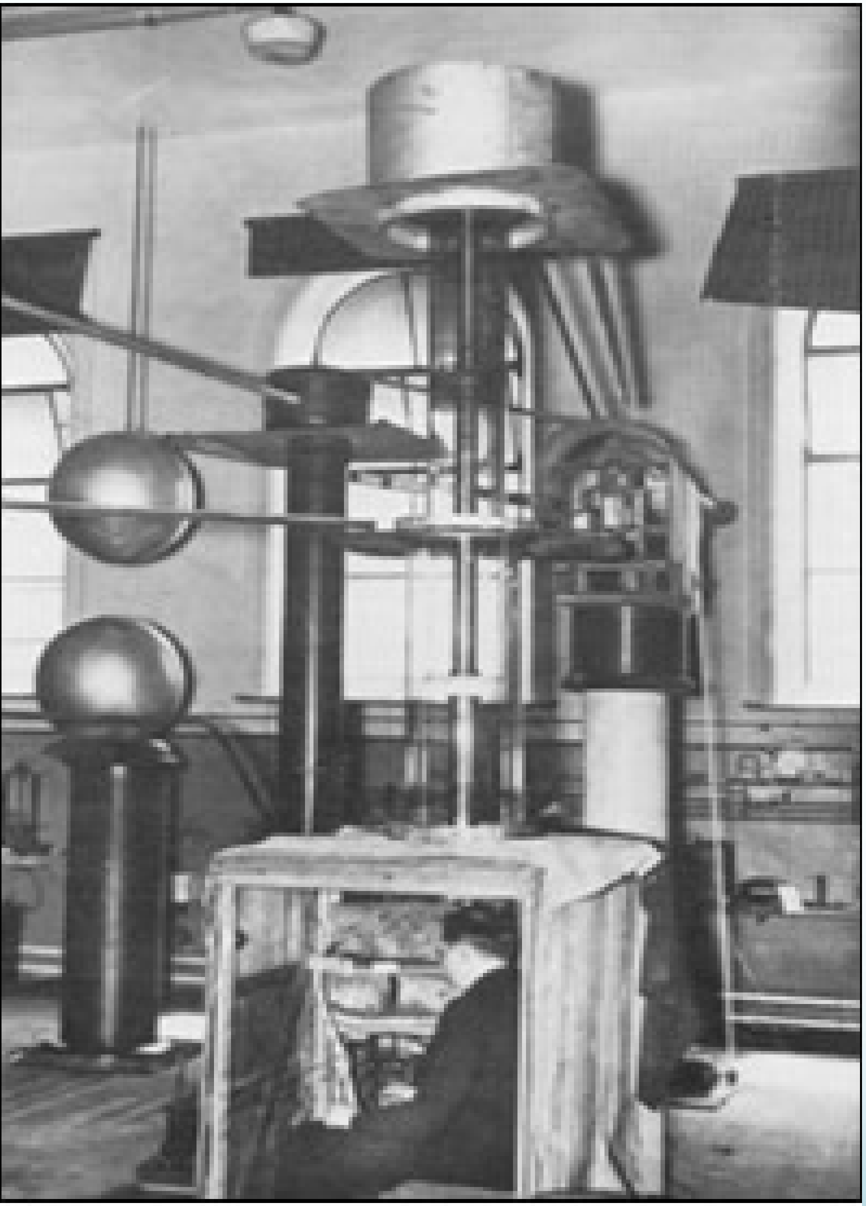
Electrostatic, Cyclotrons, Linacs, Betatrons, Synchrotrons, Colliders, Muon and Laser/Plasma

2. Applications of Accelerators

High-Energy and Nuclear, Synchrotron Radiation, Isotope Production and Cancer Therapy, Spallation, National Security, Energy and Environment, Industry

- More than 24,000 accelerators built over the last 60 years for industrial purposes
- More than 11,000 accelerators for medical purposes

3. Conclusions



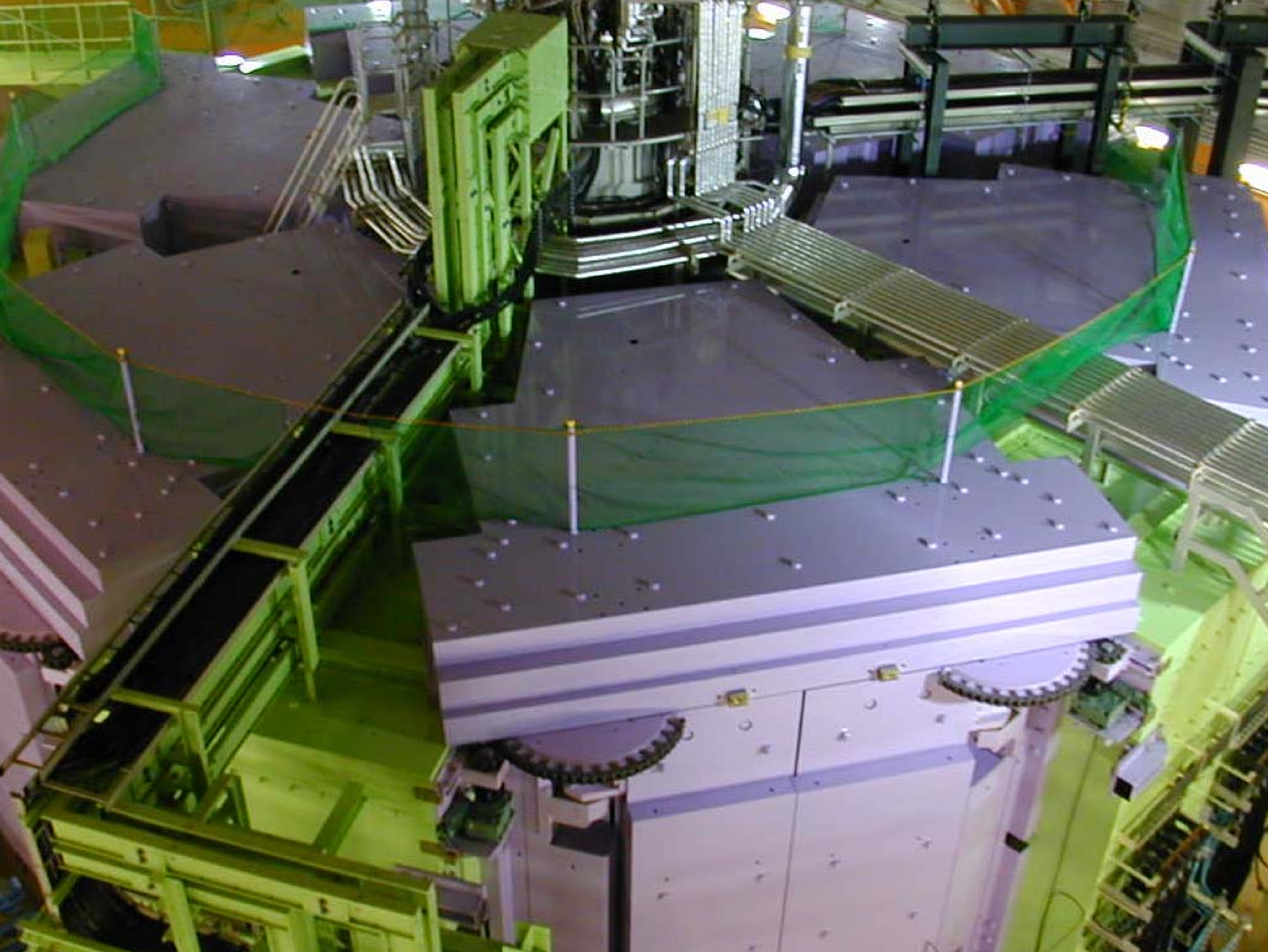
Walton and the machine used to "split the atom"

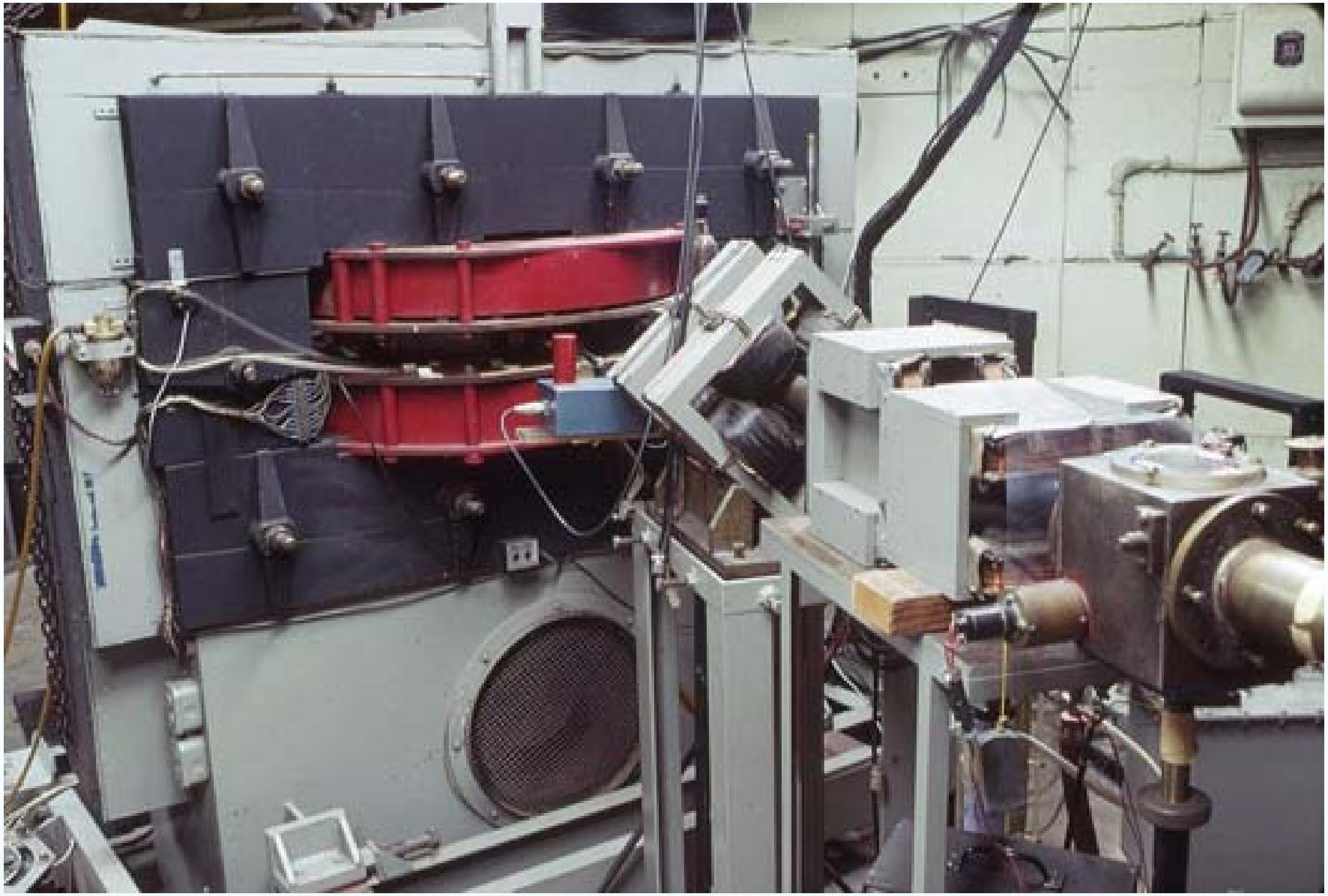
The original Cockcroft-Walton installation at the Cavendish Laboratory in Cambridge. Walton is sitting in the observation cubicle (experimental area) immediately below the acceleration tube.

A tandem accelerator at ORNL, built by the National Electrostatics Corporation. The high-voltage generator, is located inside a 100-ft-high, 33-ft-diameter pressure vessel.

The First Cyclotron

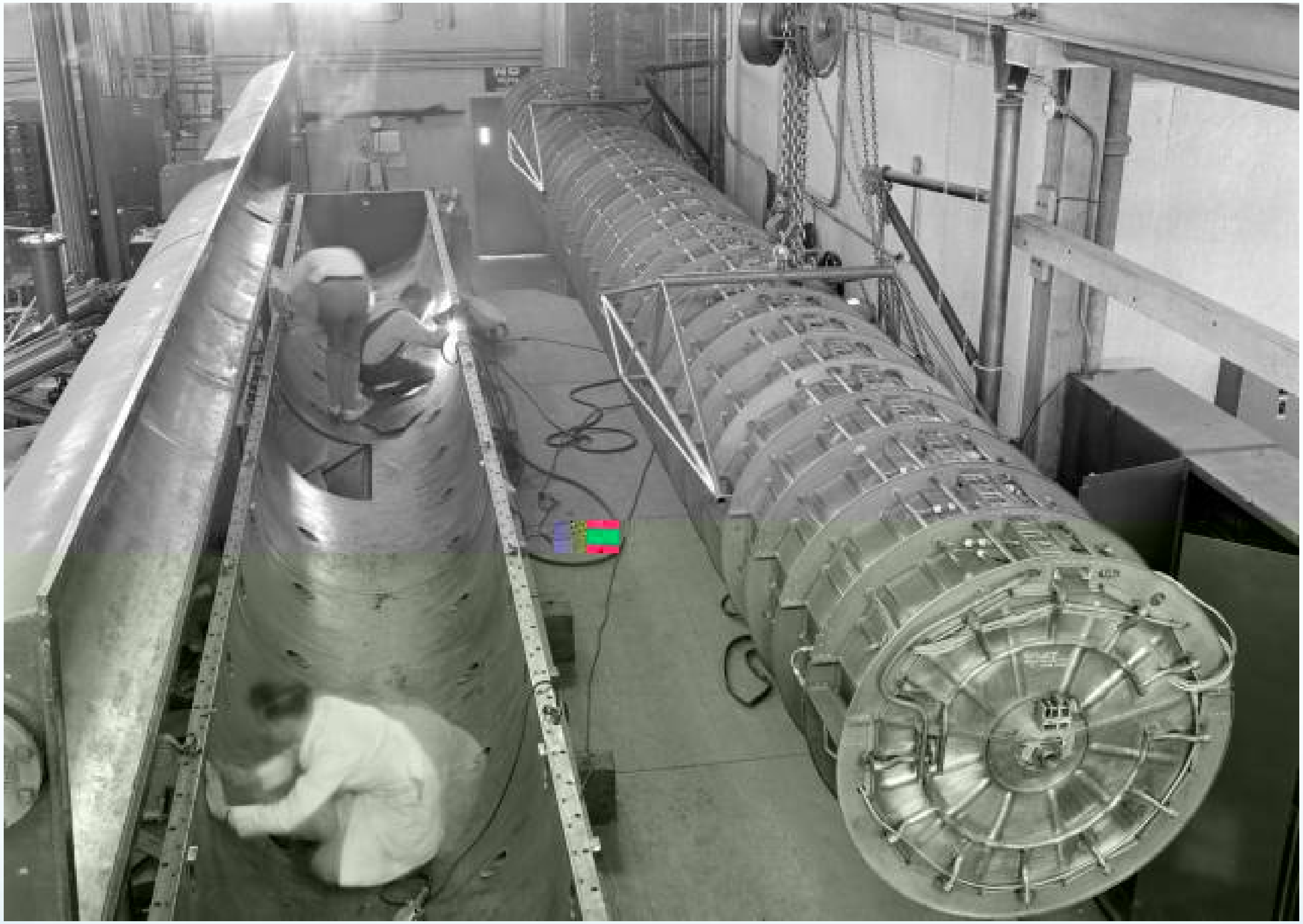
Five inches in diameter.



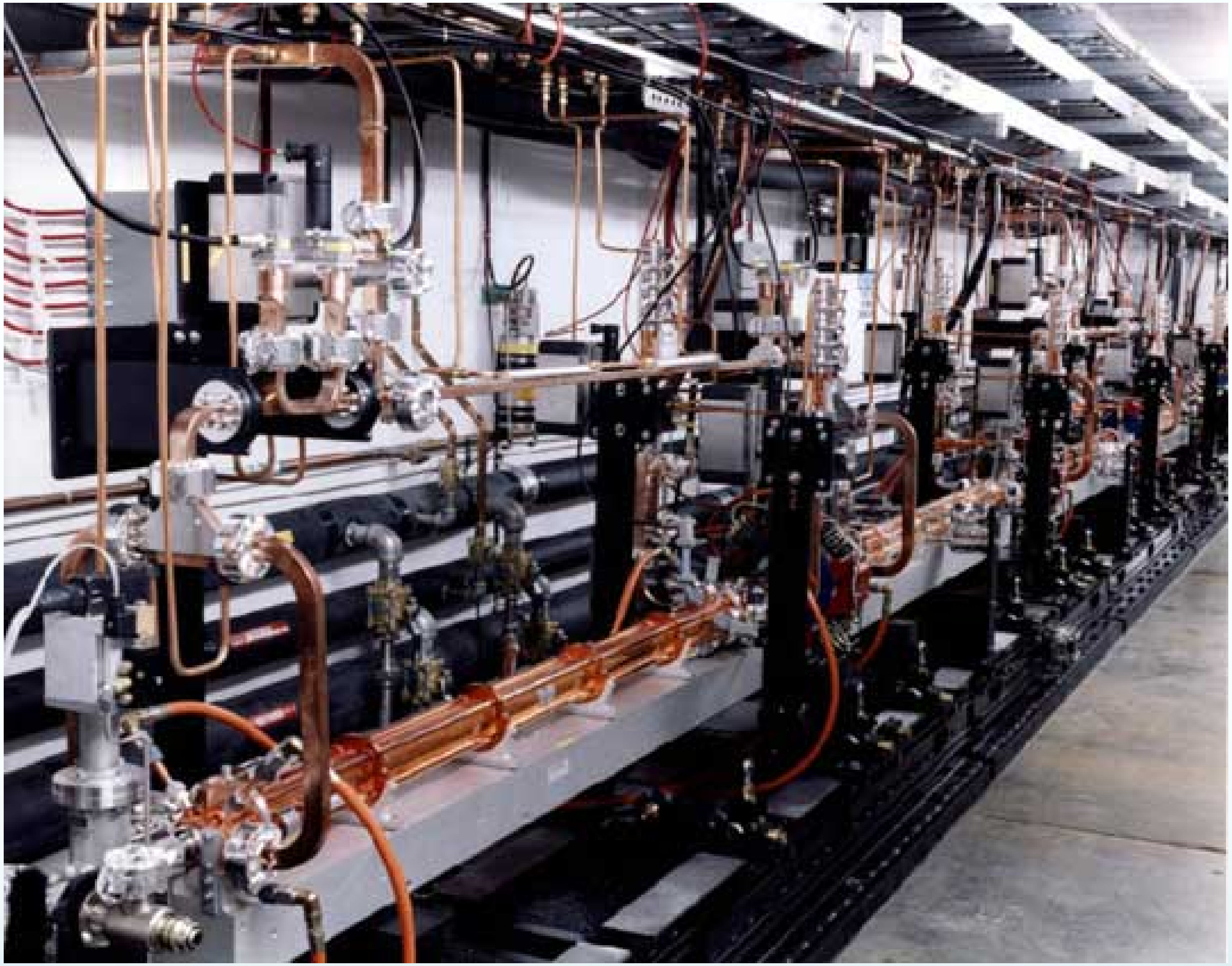


One of the first betatrons, built in the early 1940s. The so-called 20 inch machine at the University of Illinois.

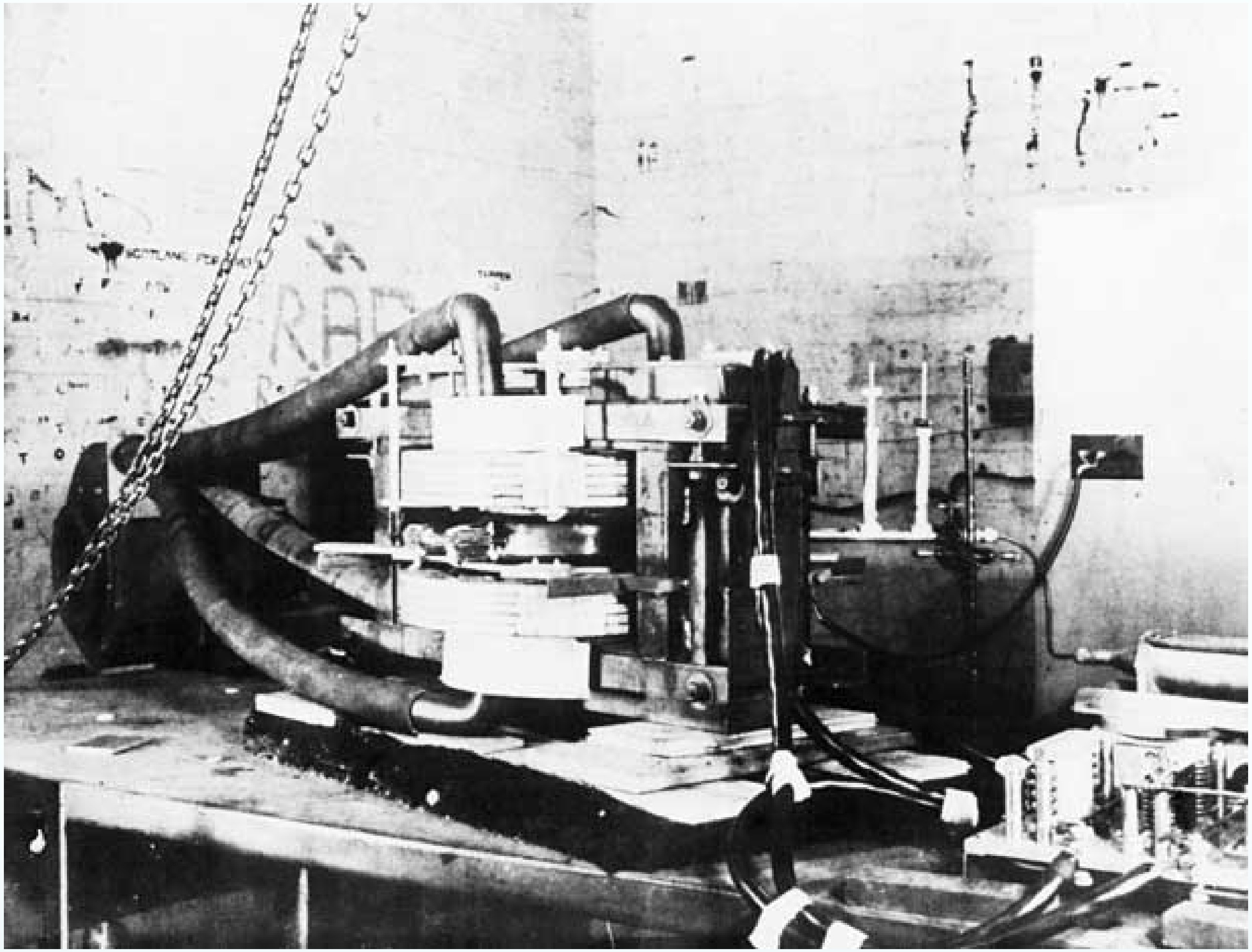
A modern, very compact betatron, commercially produced. It is used to produce x-rays to look for defects in large forgings, steel beams, ship’s hulls, pressure vessels, engine blocks, bridges, etc.



An accelerating tank of the first, Alvarez, linac built just after WWII.

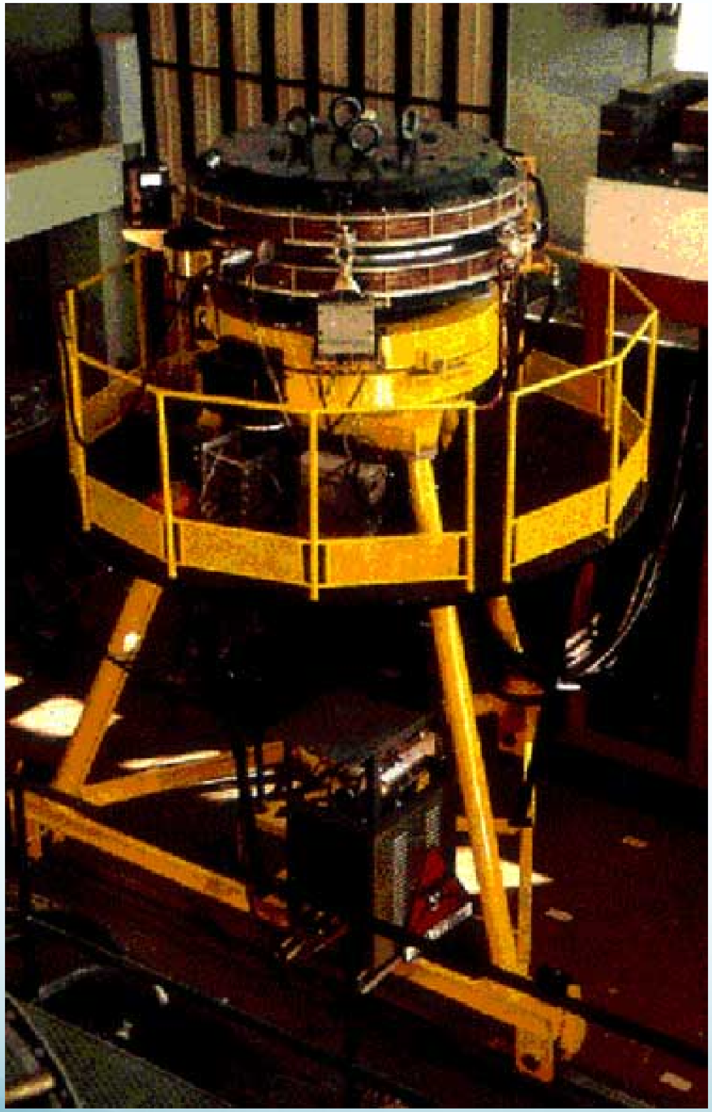


The X-Band Test Accelerator at SLAC. Here one of the approaches to an International Linear Collider was tested by actually building a section of a collider. It is not the approach of choice.



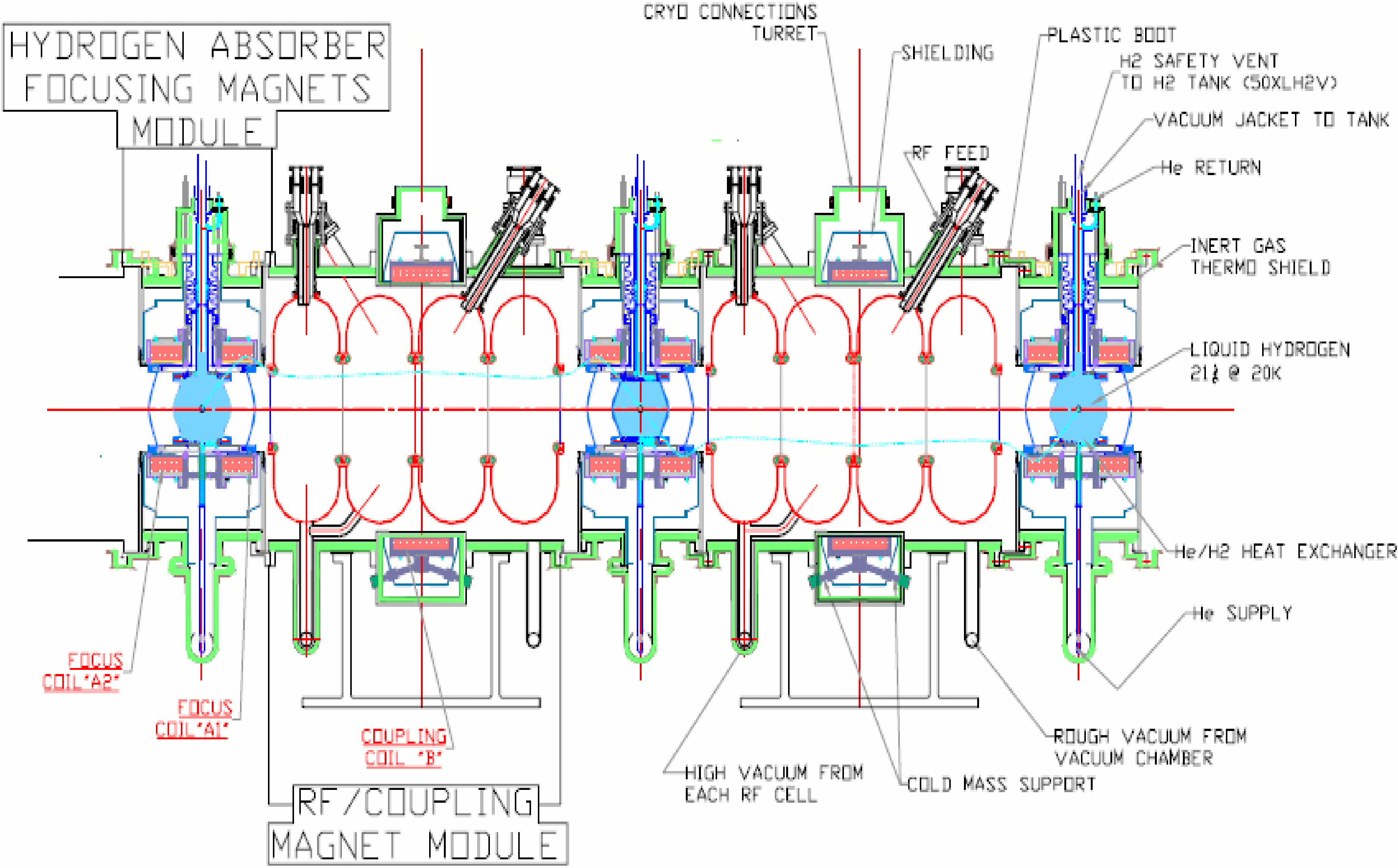
Late in World War II the Woolwich Arsenal Research Laboratory in the UK had bought a betatron to "X-ray" unexploded bombs in the streets of London. Frank Goward converted the betatron into the first “proof of principal” synchrotron.

Fermilab's superconducting Tevatron can just be seen below the red and blue room temperature magnets of the 400 GeV main ring.



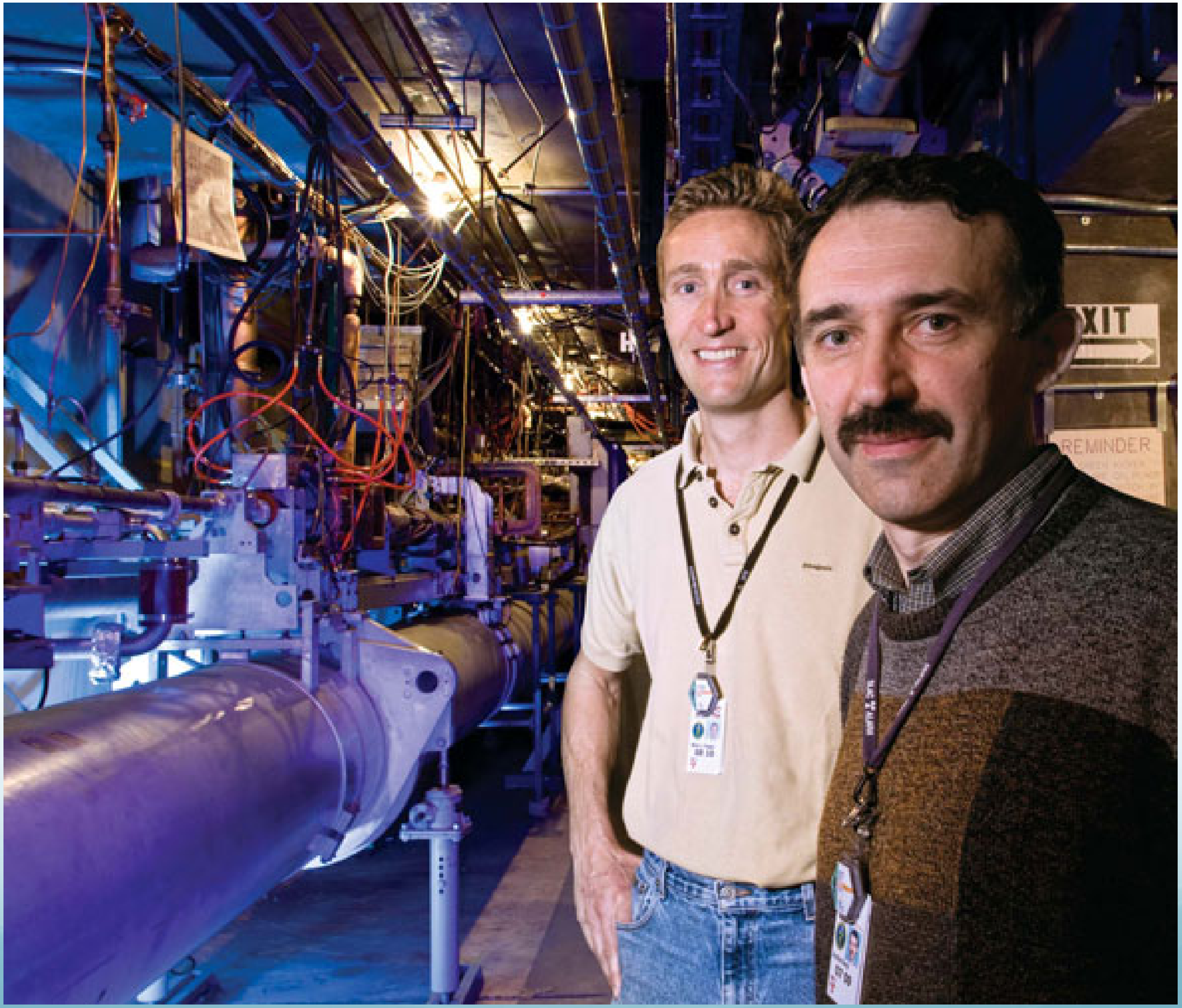
The first electron-positron storage ring, AdA. (About 1960) Built and operated at Frascati, Italy and later moved to take advantage of a more powerful source of positrons in France.

The Large Hadron Collider (LHC)

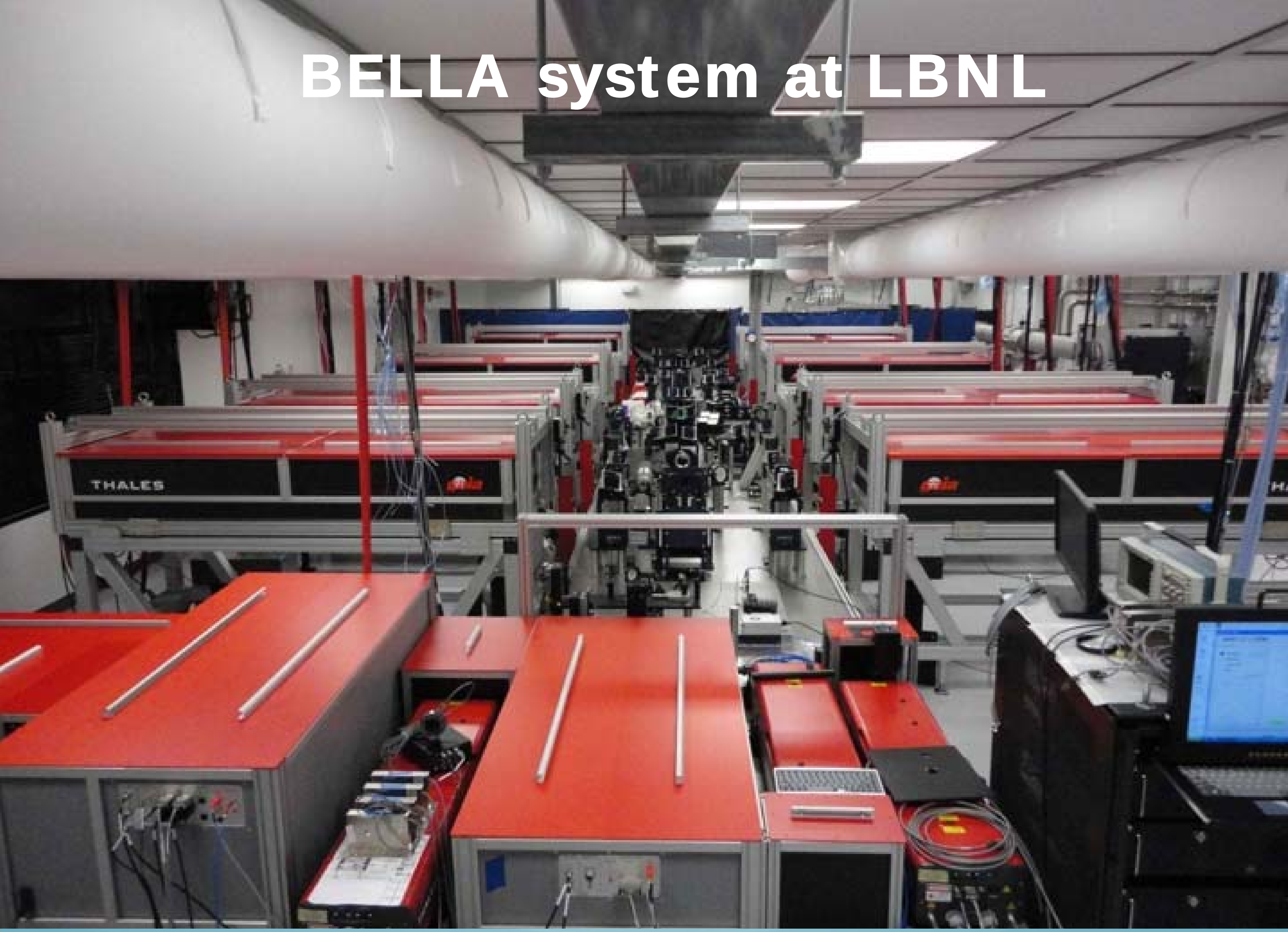


A diagram of the muon cooling experiment MICE being carried out at the Rutherford-Appleton Laboratories in England.

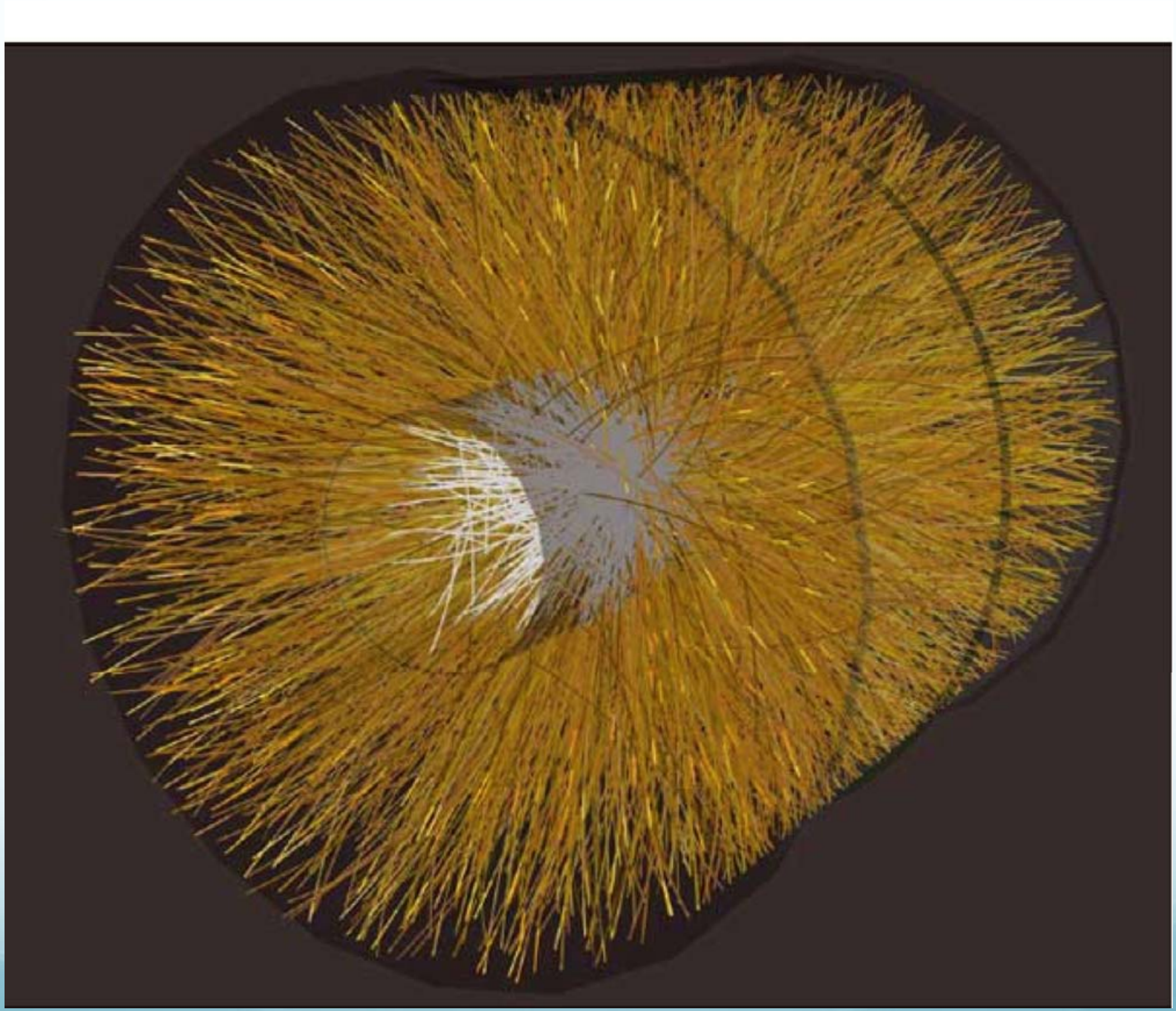
SLAC researchers Mark Hogan (left) and Andrei Seryi are working to transform this section of the SLAC linac into the FACET experimental area.



BELLA system at LBNL



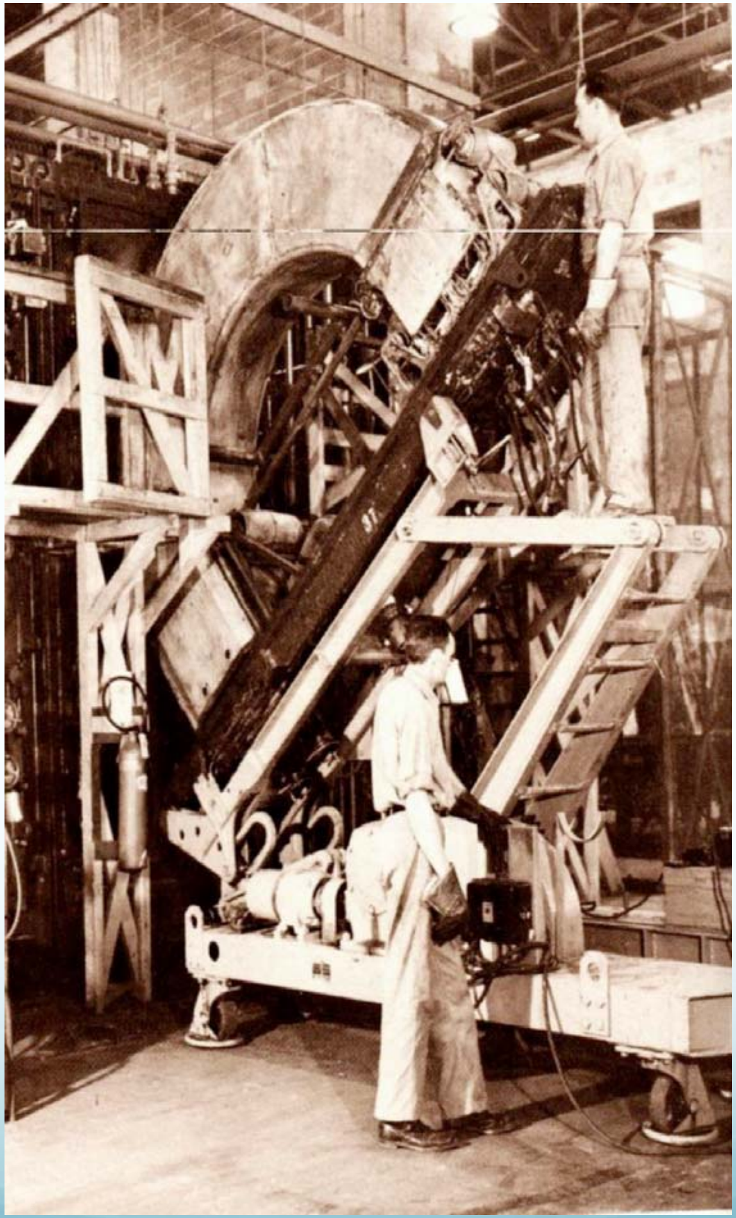
Lead-lead collision at ALICE (LHC)



An aerial picture of the European Synchrotron Radiation Facility (ESRF) located in Grenoble, France. Construction was initiated in 1988 and the doors were open for users in 1994.

The SLAC Facility showi

The Spallation Neutron Source at Oak Ridge

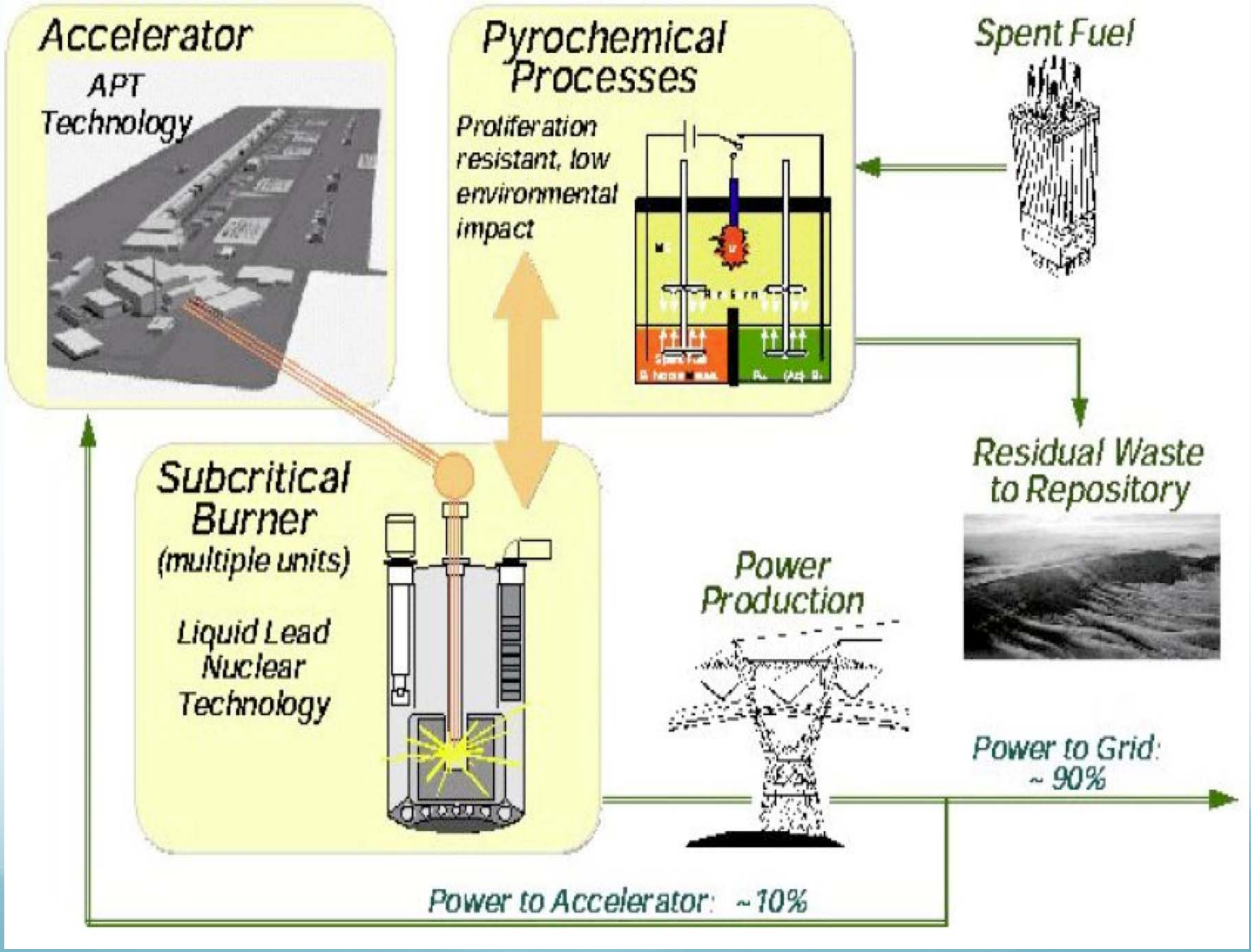


A Calutron Tank

The Dual Axis Radiological Hydrodynamics Test Facility (DARHT)

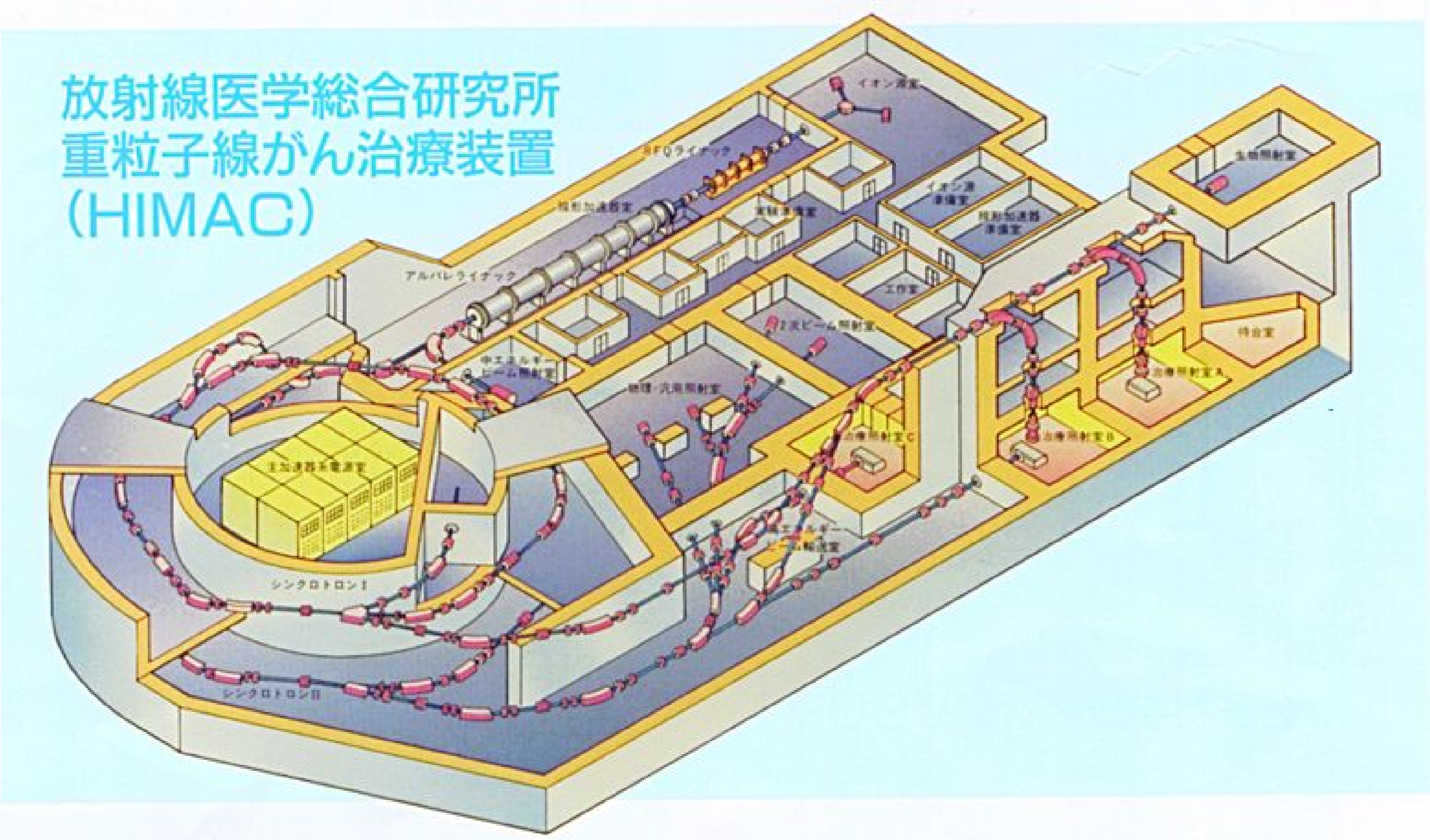
A Rail Cargo Scanner produced by L3 Communications, Security and Detection Systems

A linac scheme for driving a reactor. These devices can turn thorium into a reactor fuel, power a reactor safely (when the accelerator turns off, so does the reactor) and burn up long-lived fission products so as to reduce the long-term waste storage problem.



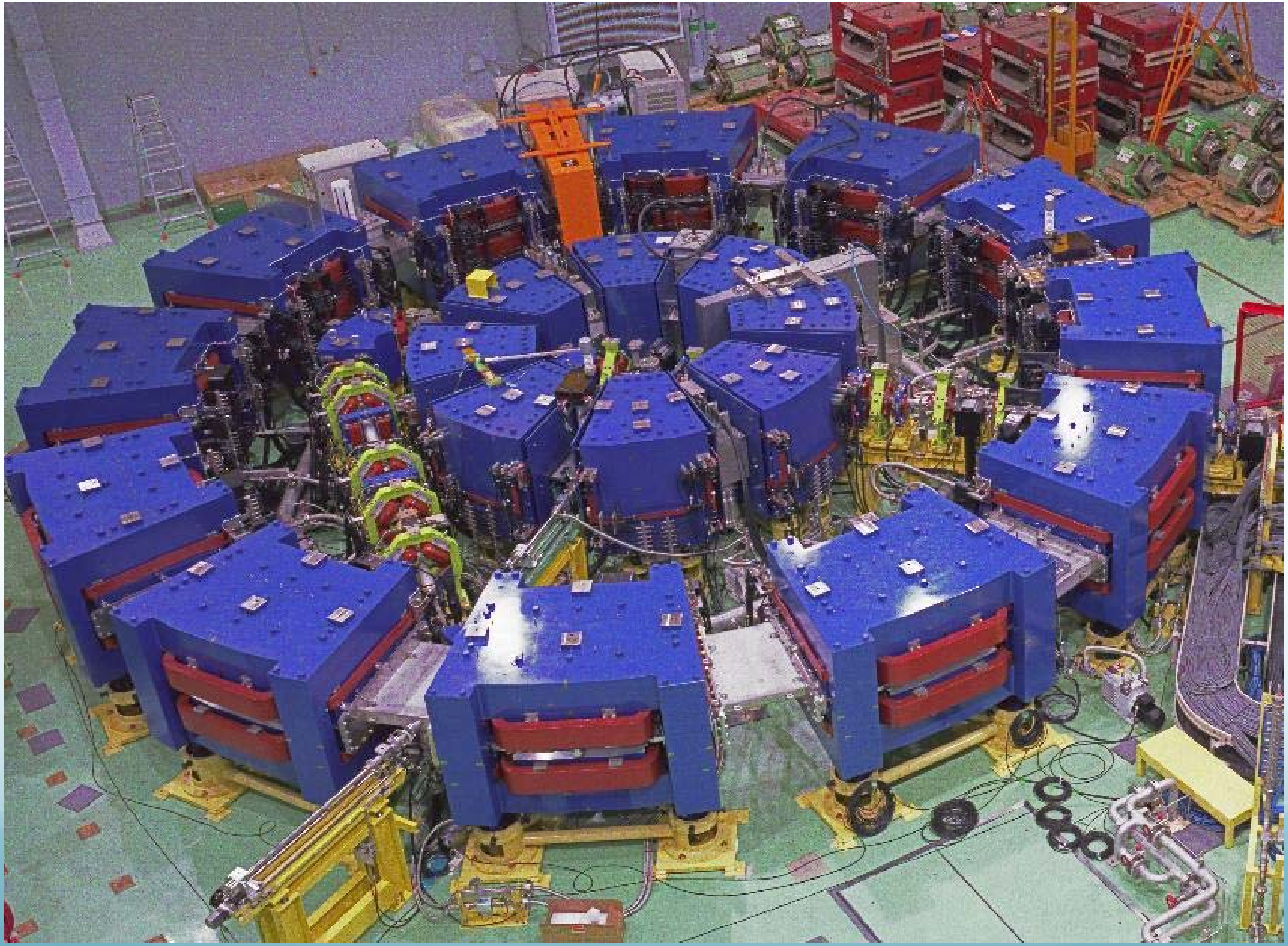
A modern system for treating a patient with x-rays produced by a high energy electron beam. The system, built by Varian, shows the very precise controls for positioning of a patient. The whole device is mounted on a gantry. As the gantry is rotated, so is the accelerator and the resulting x-rays, so that the radiation can be delivered to the tumor from all directions.

Proton therapy precisely targets tumors to ensure fewer side effects,
less damage to healthy tissue and a higher cure rate for localized cancers. (Indiana)

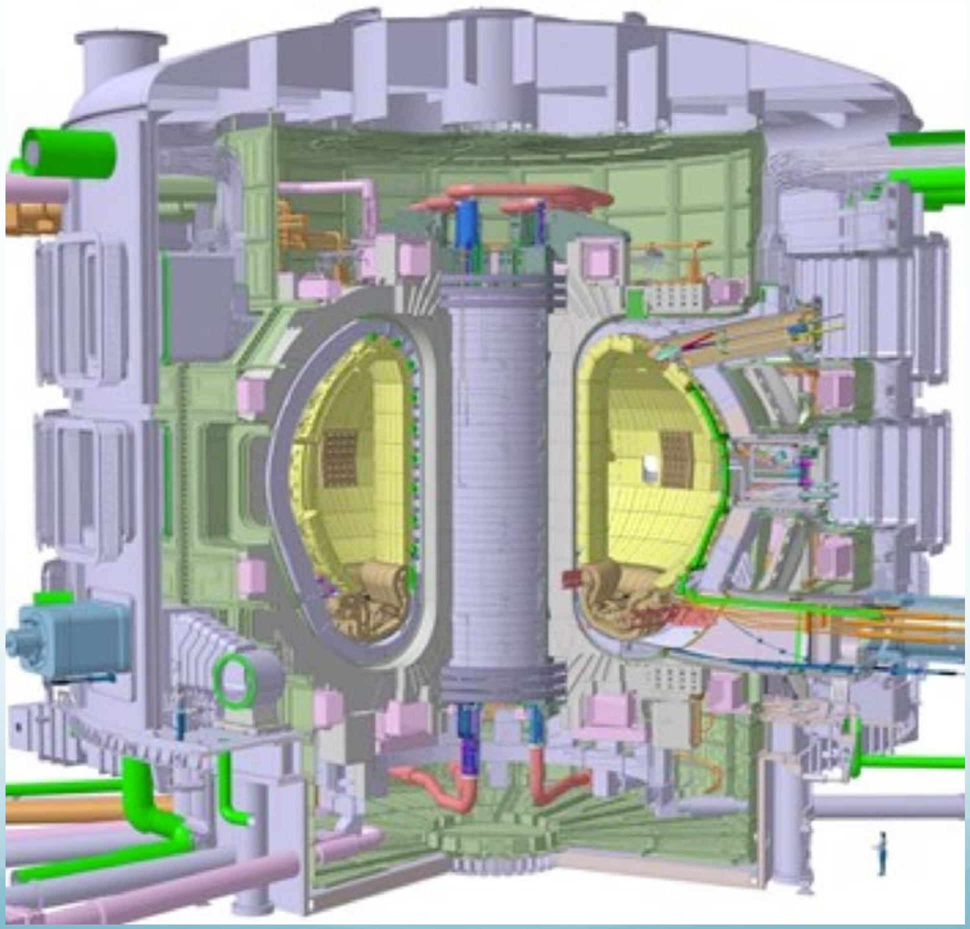


A drawing showing the Japanese (two) proton ion synchrotron, HIMAC. The pulse of ions is synchronized with the respiration of the patient so as to minimize the effect of organ movement.

The KURI FFAG Complex for sending a beam into reactor



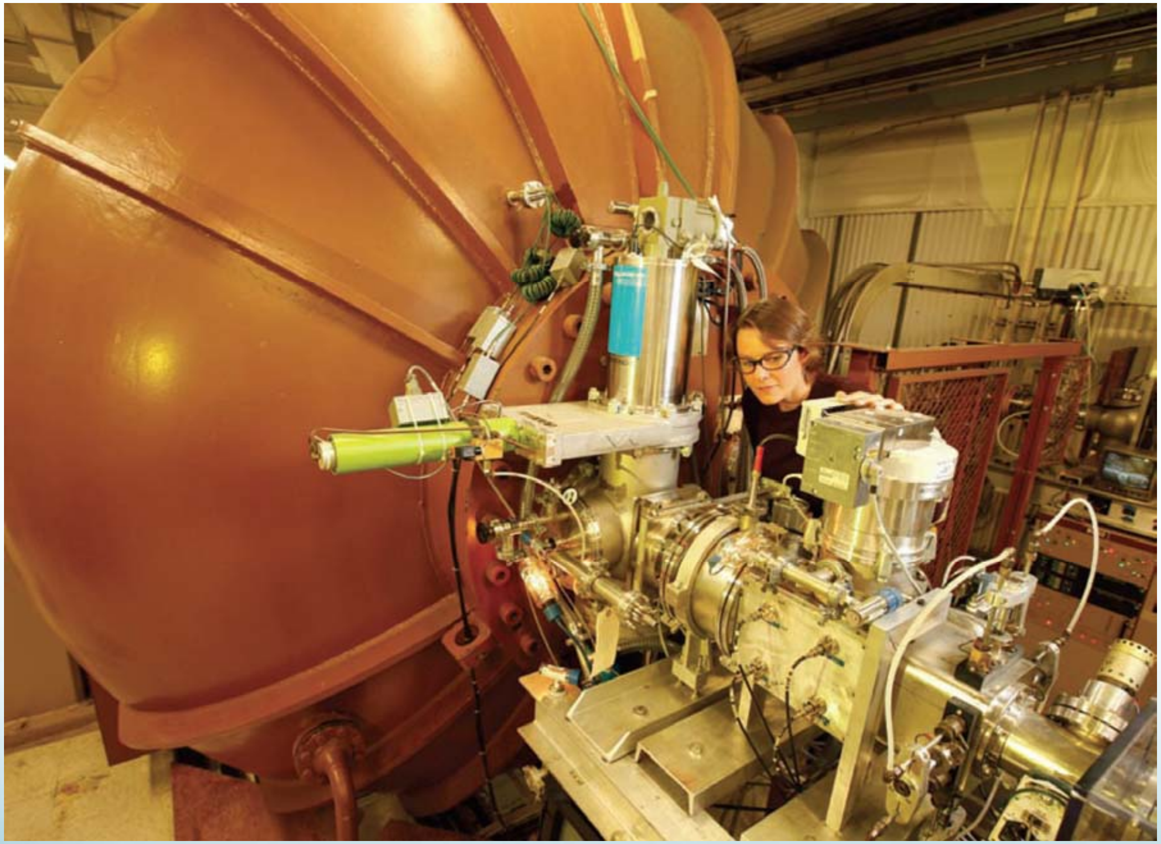
The incredibly complex ITER Tokamak will be nearly 30 metres tall, and weigh 23, 000 tons. The plasma volume will be 840 m^3(compared to previous reactors of about 100 m^3).The very small man dressed in blue at bottom right gives us some idea of the machine's scale. The machine will have neutral beam heating and current drive.



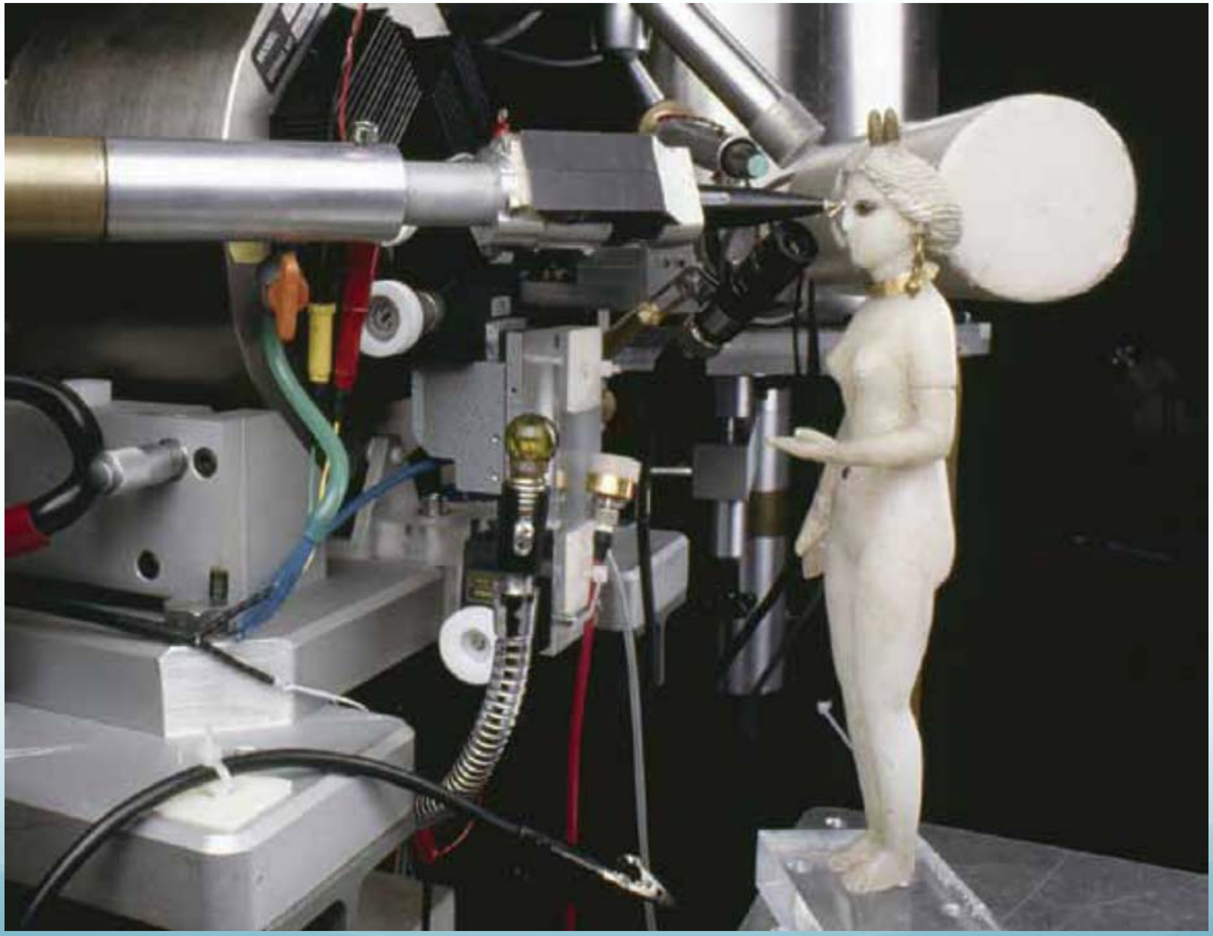
An artist's view of a heavy ion inertial fusion facility. Although the facility is large, it is made of components that all appear to be feasible to construct and operate.


E-Beam Medical Product Sterilization
by WebEchoes

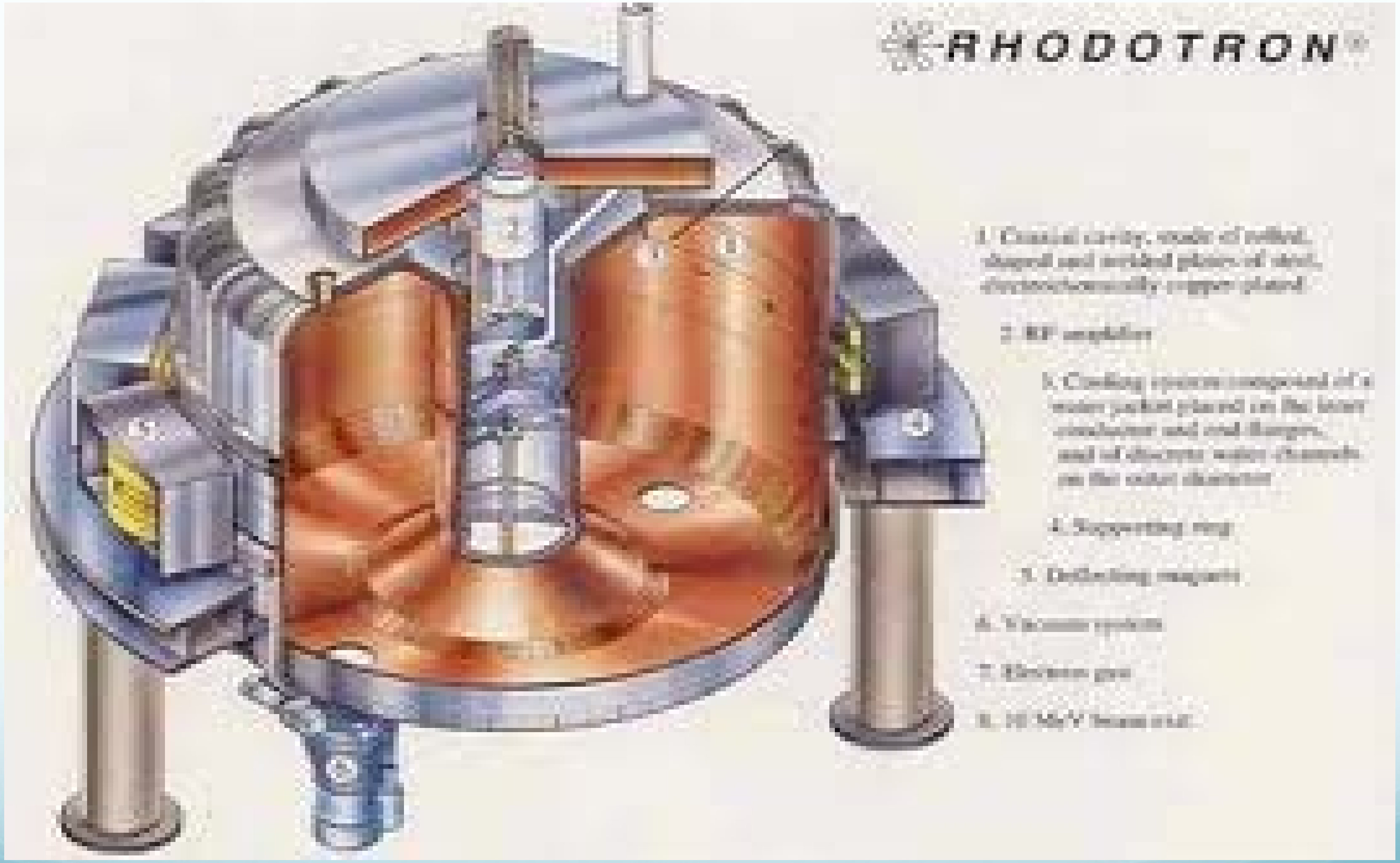
Accelerator Mass Spectroscopy Facility at the
Lawrence Livermore National Laboratory.



AGLAE, Accélérateur Grand Louvre d’Analyse Élémentaire in Paris, is the world’s only accelerator facility fully dedicated to the study and investigation of works of art and archeological artifacts. The 4-million electron-volt proton beam probes: jewels, ceramics, glass, alloys, coins statues, paintings and drawings.



IBA sells them. Used for food and US mail radiation



Cross linking of polymers by an electron beam improves heat resistance of coatings for wires and cables.

Crosslinking of polymers by an electron beam, as in this Illinois plant, improves heat resistance of coatings for wire and cable.
Photo: Reidar Hahn, Fermilab

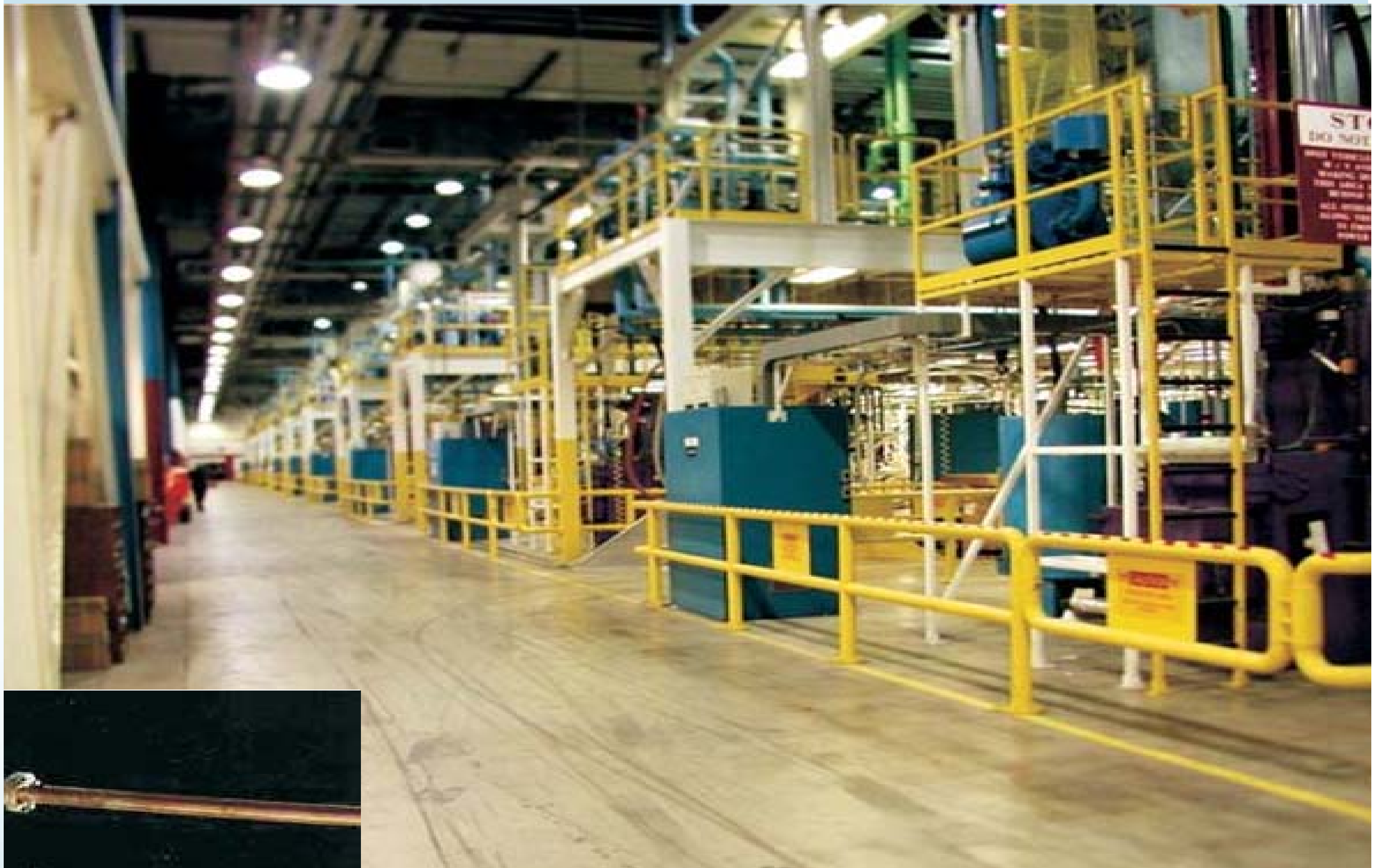


Figure 2. A typical electron-beam processing facility, employing 10 large electron accelerators arrayed in a row of production stations. This facility produces shrink-wrap material. (Photo courtesy of Air Seal Corp, Duncan, SC.)

Applications of electron-beam technology include cross-linking of polymers in radial tires, making tire manufacture less expensive and more environmentally friendly. *Image courtesy of Analytical Research LLC*

Conclusions

- The variety and capability of accelerators has made them instrumental in a surprisingly large number of endeavors. Their use can be expected to ever increase.

- It is necessary, and possible, to ever-improve accelerators. Since the use of accelerators is broad, in contrast with what it once was (namely almost exclusively for nuclear and high-energy physics), the necessary R&D on accelerators must be supported either from a variety of sources (appropriate to their particular interest) or by one sponsor, (but with an understanding of the broad applications of accelerators). In most countries this will require a change in administrative practices.

- In the very-long-term accelerators will probably look very different than now they do. (They may, for example, be laser/plasma accelerators or collective accelerators.) It is important that support be given to these activities with the understanding that some will not work ("If we knew what we are doing, it wouldn't be research."), but some will revolutionize the field and open up possibilities we can't even dream about.

Acknowledgments

- To the tens of thousands of scientists, engineers, and technicians, who working, over the last century, in a hundred different places and in about twenty-five different countries, who have made accelerators powerful, diverse, and so capable.
- Pictures from : "Engines of Discovery: Particle Accelerators at Work" by Ted Wilson and Andy Sessler, World Scientific, 2013.
- **Thank You**