ENGINES OF DISCOVERY

A Century of Particle Accelerators

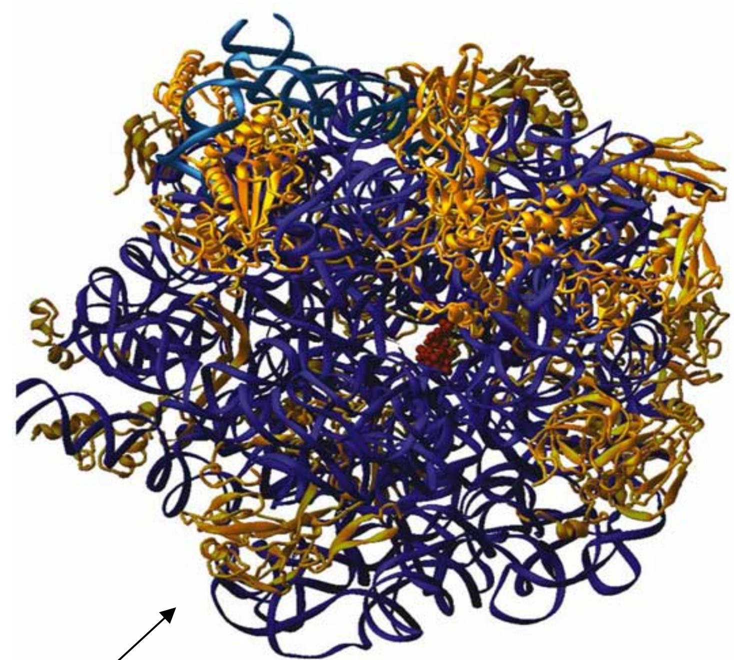
Andrew Sessler
Lawrence Berkeley National Laboratory,

Edmund Wilson
CERN, Geneva, Switzerland

http://www.enginesofdiscovery.com/

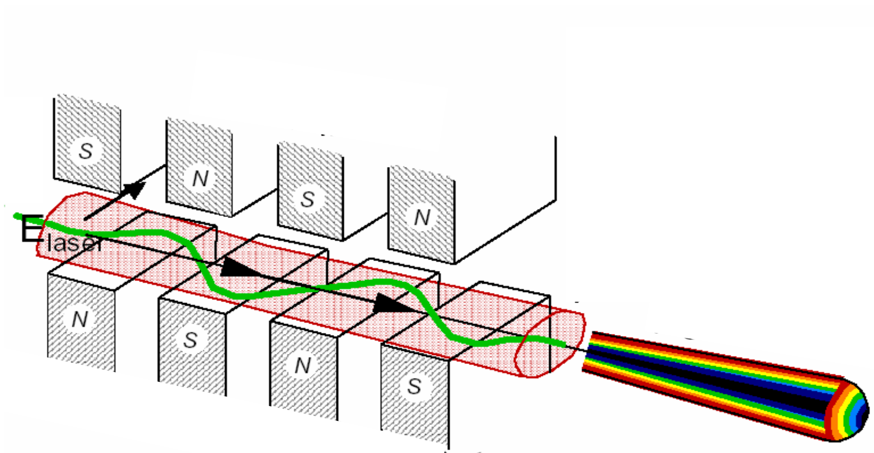
Synchrotron Light Sources

Spring 8, a synchrotron light source located in Japan.



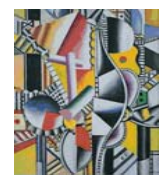
This intricate structure of a complex protein molecule structure has been determined by reconstructing scattered synchrotron radiation

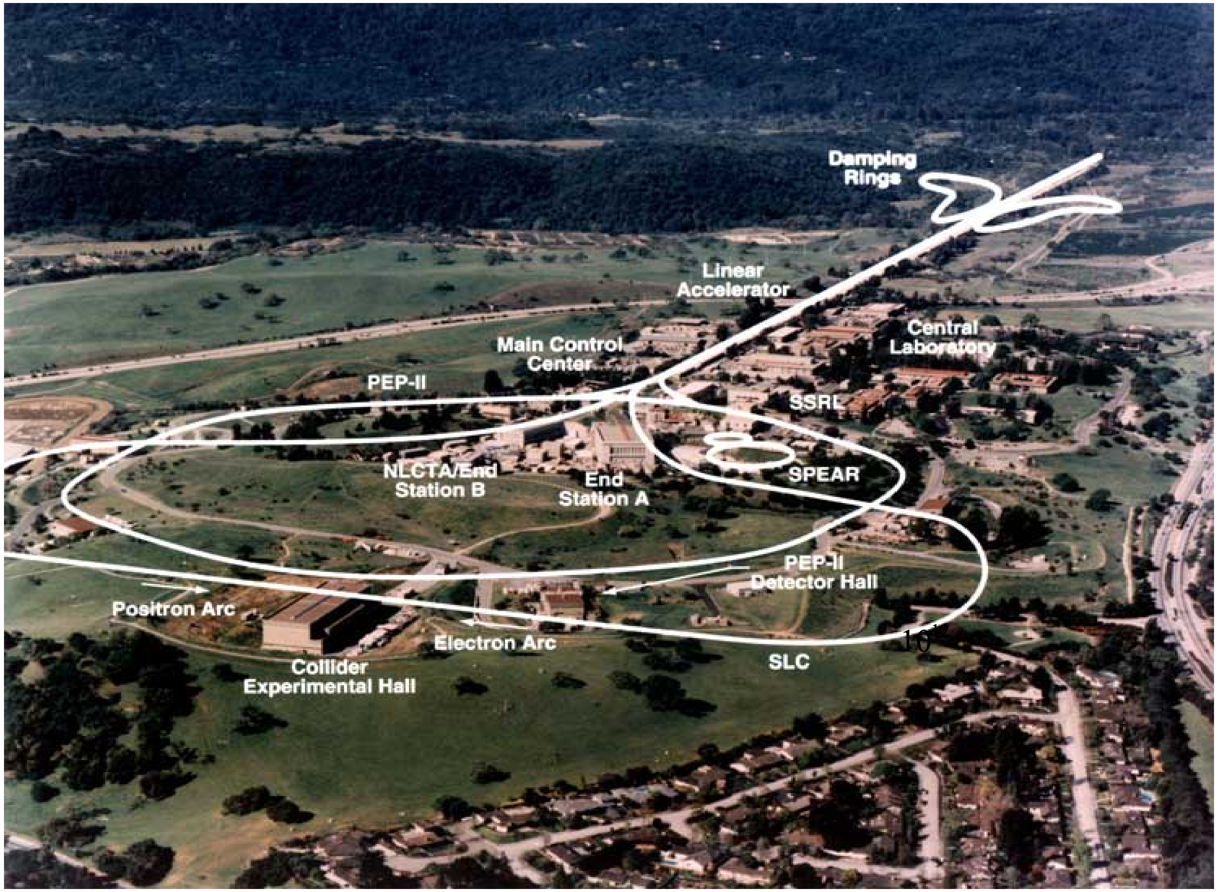
Linac Coherent Light Source and the European Union X-Ray Free Electron Laser (Fourth Generation)



FELs, invented in the late 1970's at Stanford are now becoming the basis of major facilities in the USA (SLAC) and Europe (DESY) .They promise intense coherent radiation. The present projects expect to reach radiation of 1 Angstrom (0.1 nano-meters, 10kilo-volt radiation)

↓

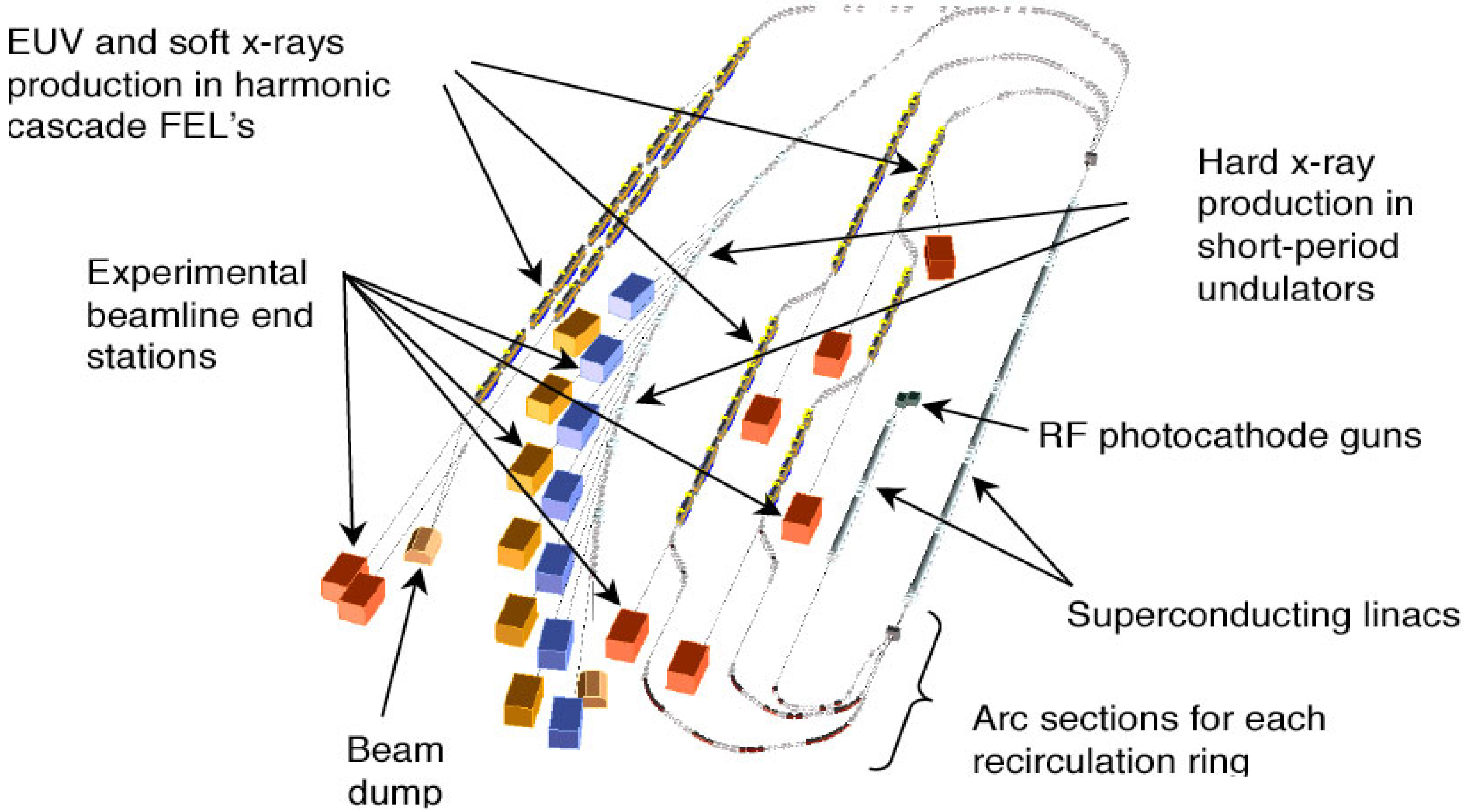




Electrons 14 GeV
Peak current > 1000A
Transversely < 0.1 mm
10^{12} photons
$0.15 < \lambda < 1.5$ nm
Pulse: 100 femtoseconds
down to 100 attoseconds
Rate 120 Hz
1000 to 10000 times brighter
than third generation
Cost M$ 300

The SLAC site showing its two-mile long linear accelerator, the two arms of the SLC linear collider, and the large ring of PEPII. This is where the LCLS will be located.

↓



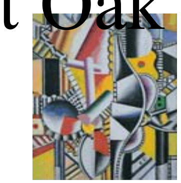
A possible fourth generation light source. This is the proposed facility LUX, as envisioned by a team at LBL. Features a recirculating linac and energy recovery . X-ray pulses of femtosecond length.

Spallation Neutron Sources (SNS)

1GeV protons
mean current 1 mA
= 1.4 MW of power
In a
0.7 microsecuond burst

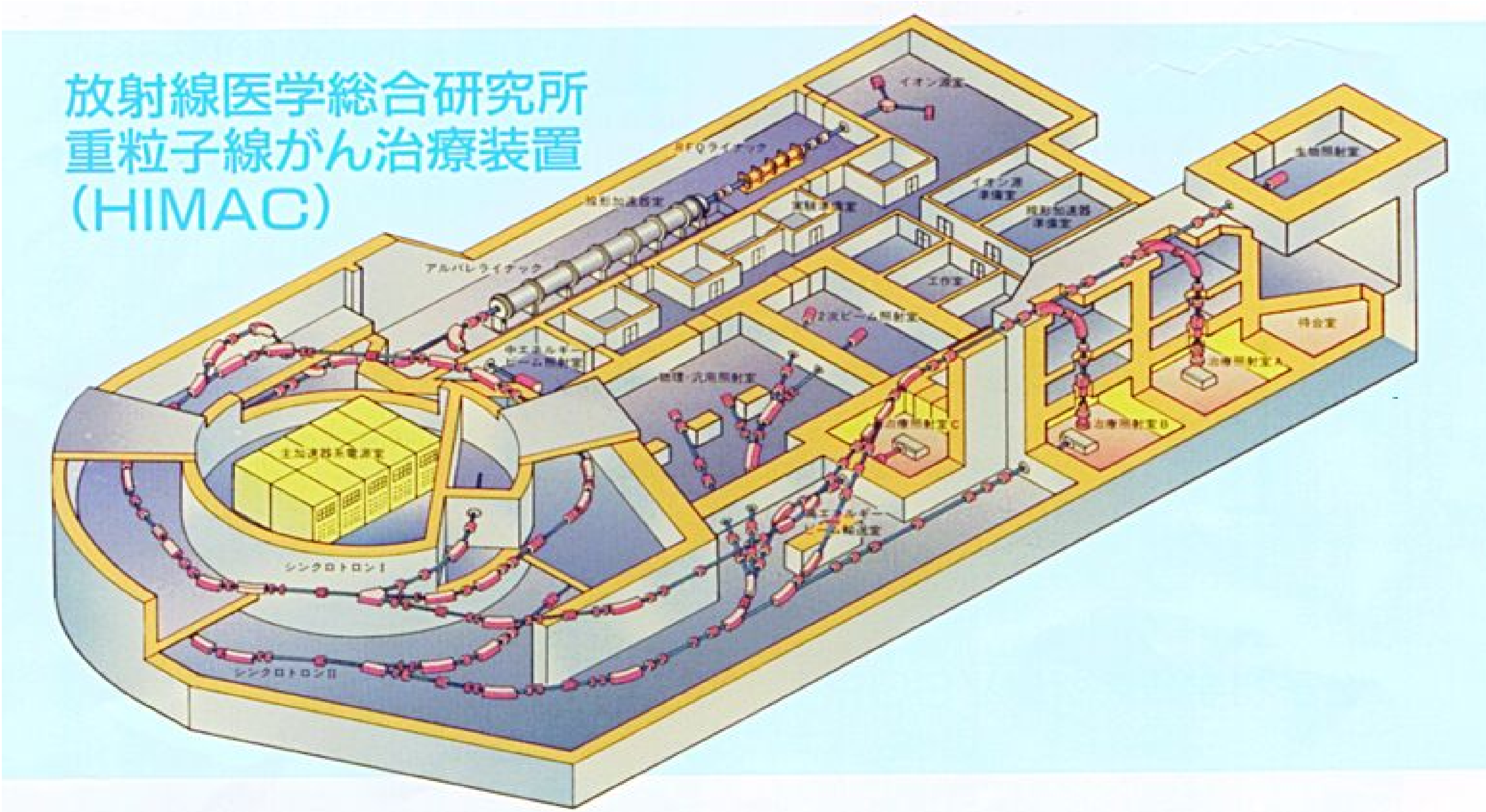
Cost is about 1.5 B$

An overview of the Spallation Neutron Source (SNS) site at Oak Ridge National Laboratory.

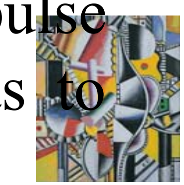


Cancer Therapy Machines

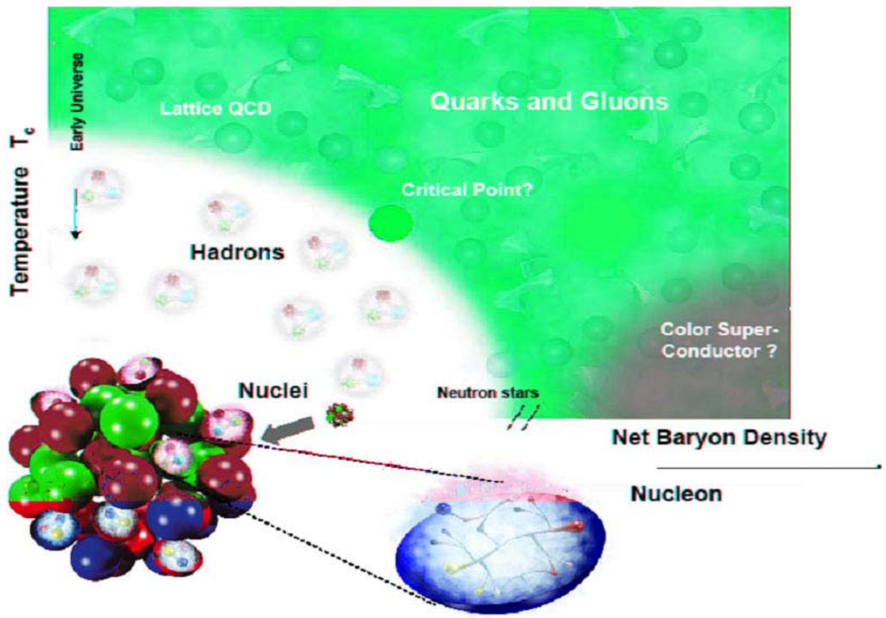
A modern system for treating a patient with x-rays produced by a high energy electron beam. The system, built by Varian, shows the very precise controls for positioning of a patient. The whole device is mounted on a gantry. As the gantry is rotated, so is the accelerator and the resulting x-rays, so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

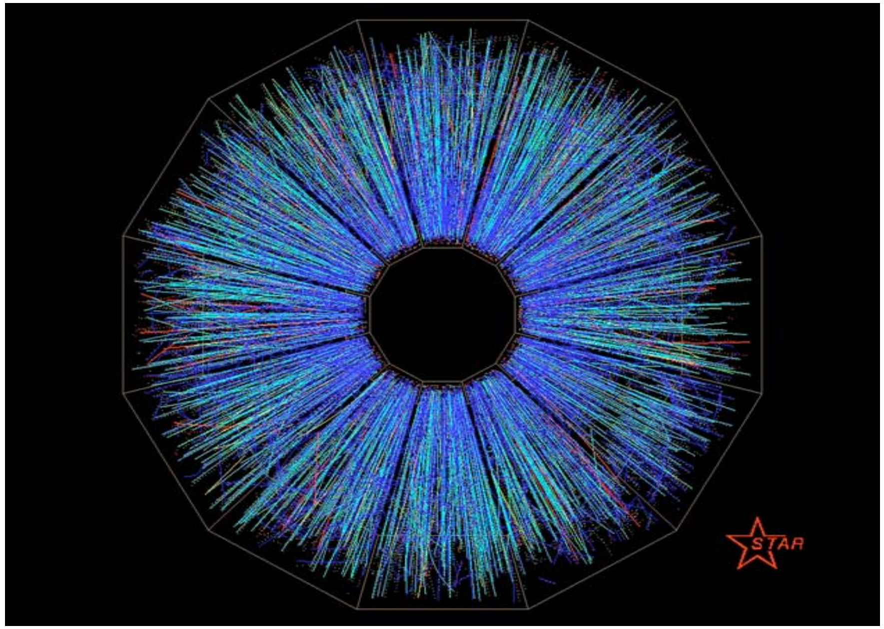


A drawing showing the Japanese proton ion synchrotron, HIMAC. The facility consists of two synchrotrons, so as to maintain a continuous supply of ions (or protons) to the treatment area. The pulse of ions is synchronized with the respiration of the patient so as to minimize the effect of organ movement.



Ions

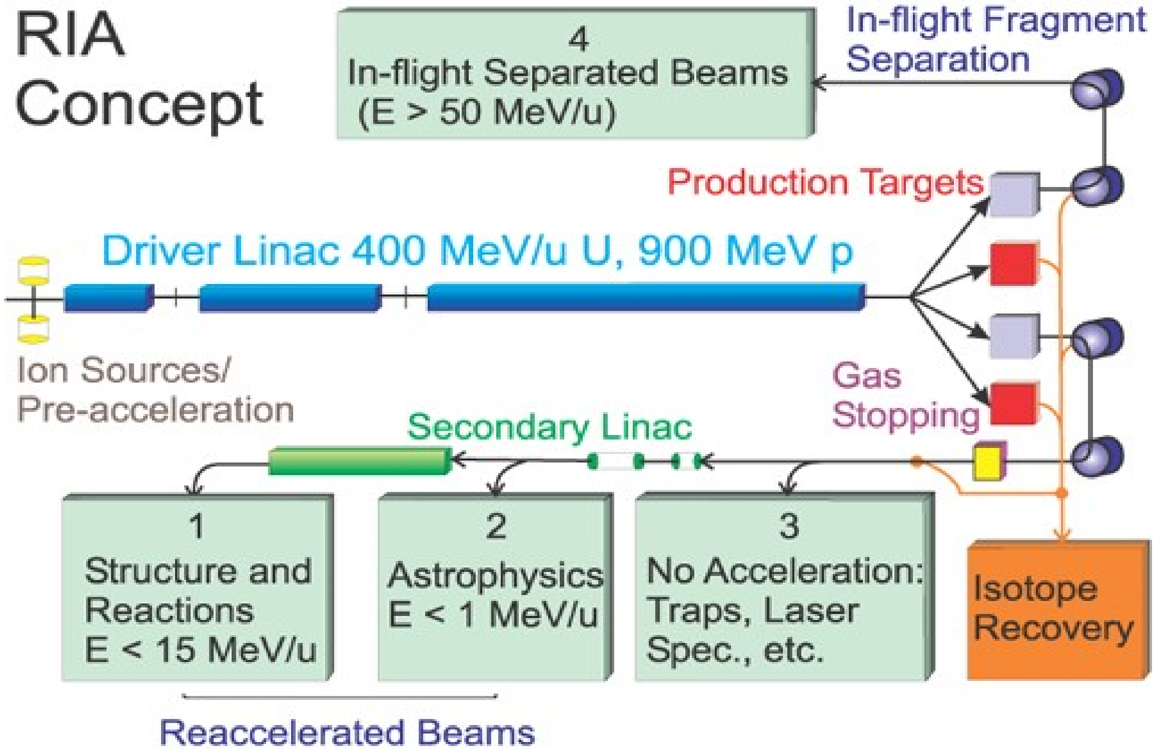


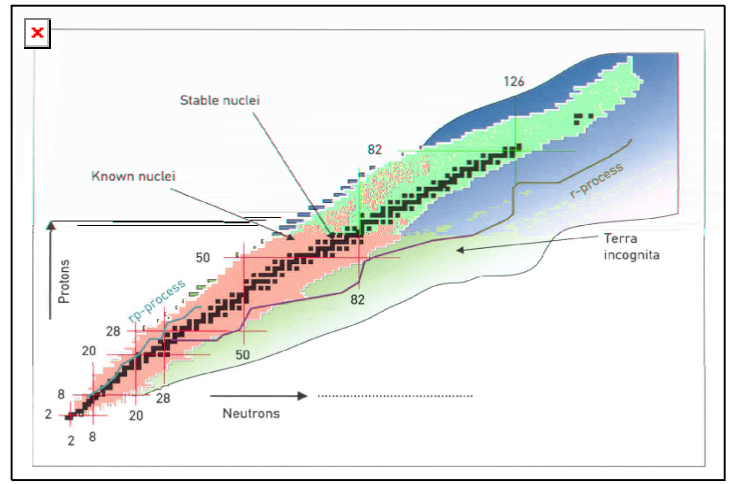


Left is the phase diagram for the quark-gluon plasma

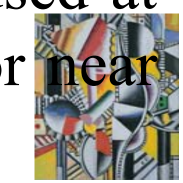
Right is gold-gold collision in RHIC

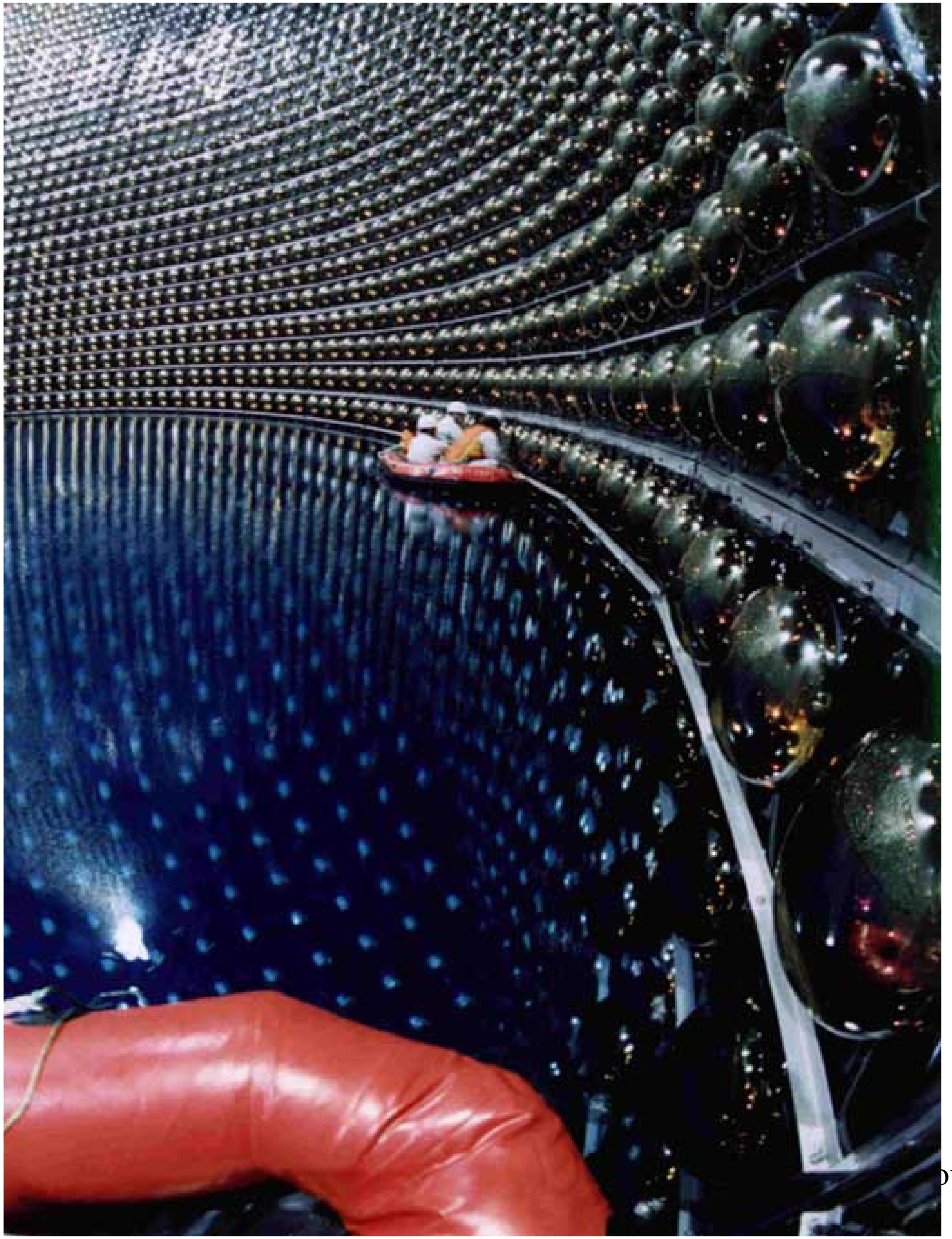
Unstable Isotopes and their Ions





The Rare Isotope Accelerator (RIA) scheme. The heart of the facility is composed of a driver accelerator capable of accelerating every element of the periodic table up to at least 400 MeV/nucleon. Rare isotopes will be produced in a number of dedicated production targets and will be used at rest for experiments, or they can be accelerated to energies below or near the Coulomb barrier.



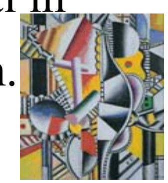


Neutrino experiments

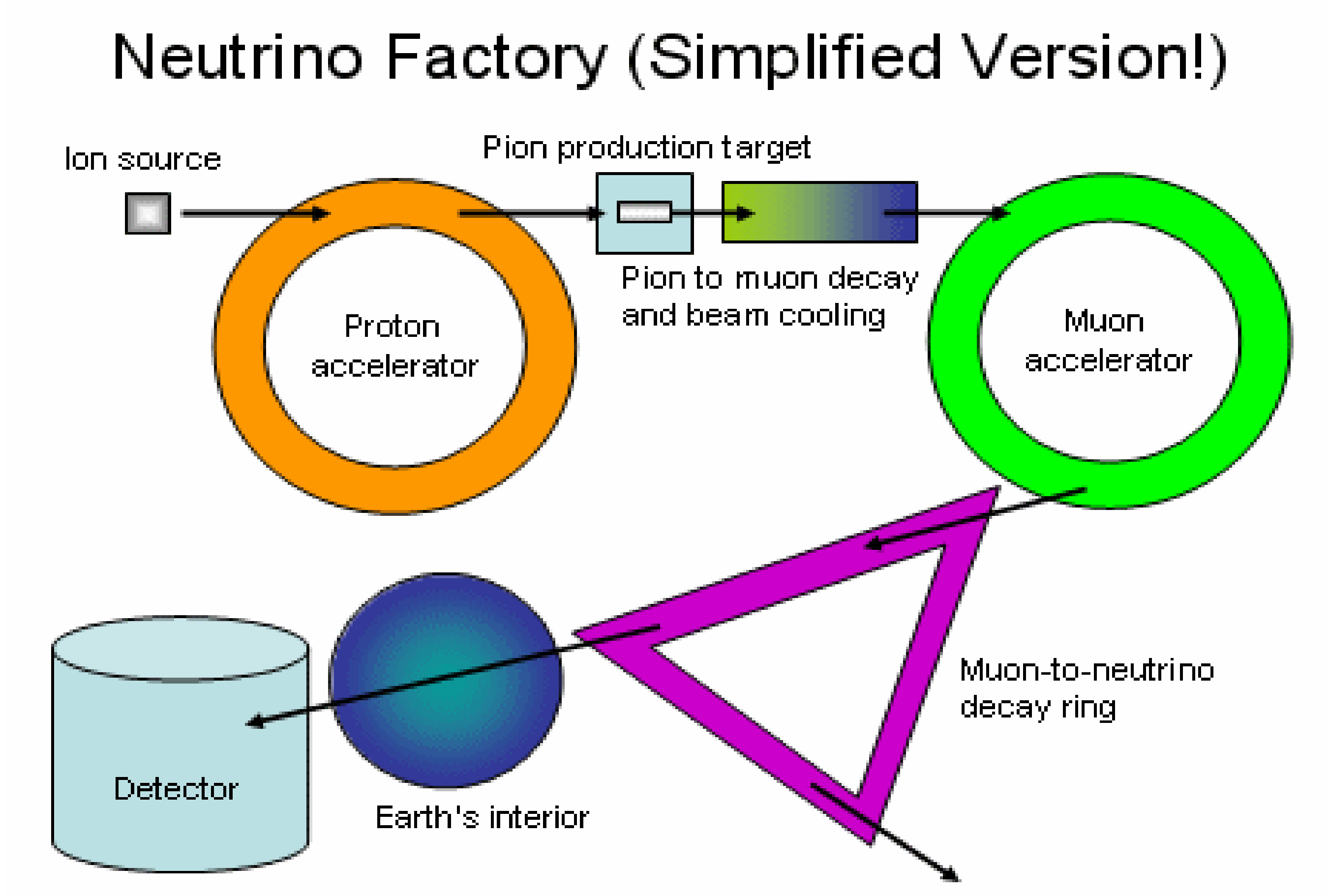
Solar Neutrino Problem
Super K
K to K
Gran Sasso
Minos and NUMI
Super Beams
Neutrino Factories
Muon Colliders

Kamiokande

This very large underground detector, located in the mountains of Japan. Many very important results have come from this facility that first took data in 1996. The facility was instrumental in solving “the solar neutrino problem.

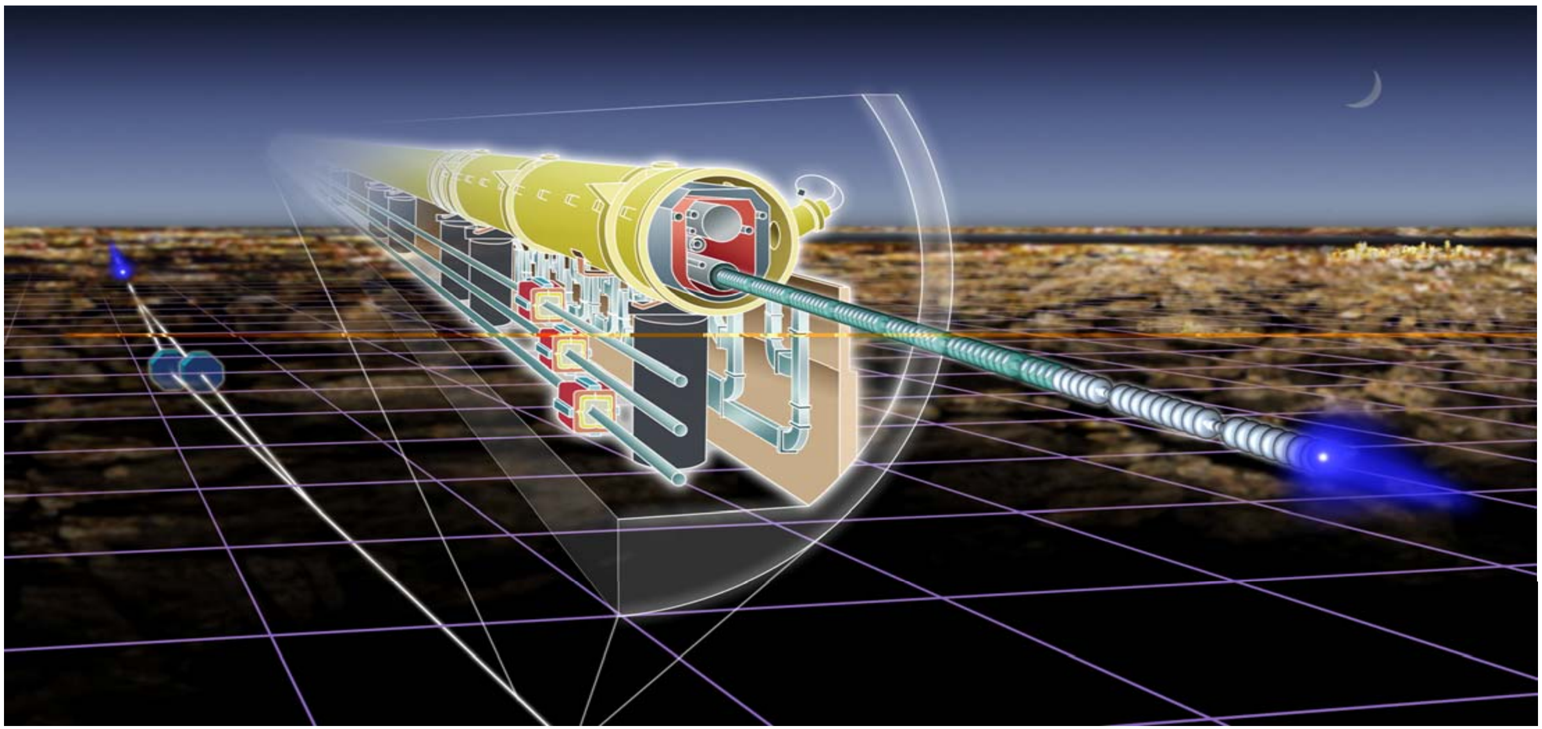


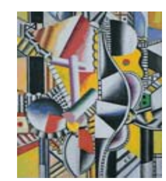
overy



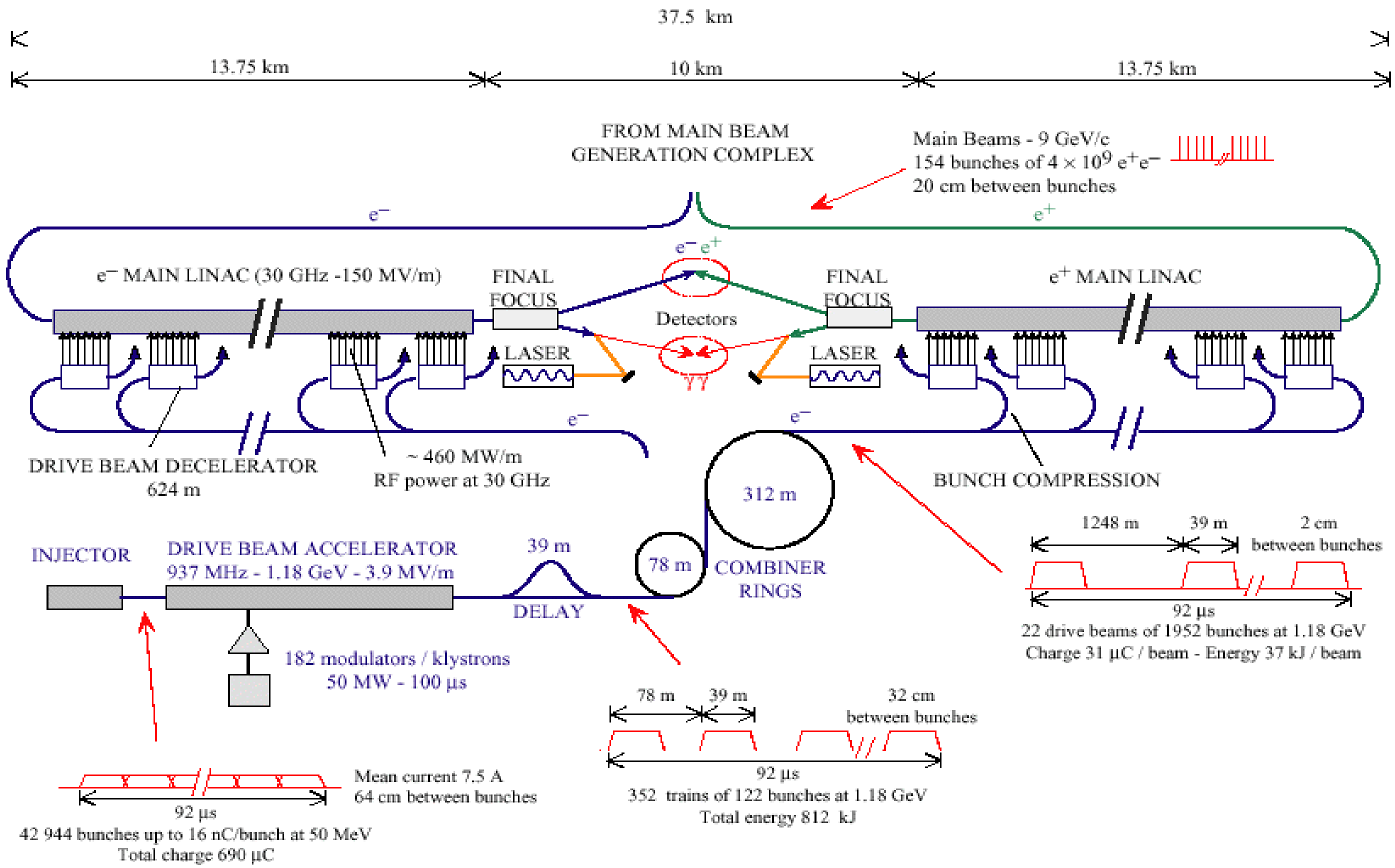
Basis of muon collider

The International Linear Collider (ILC)

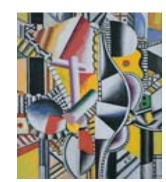




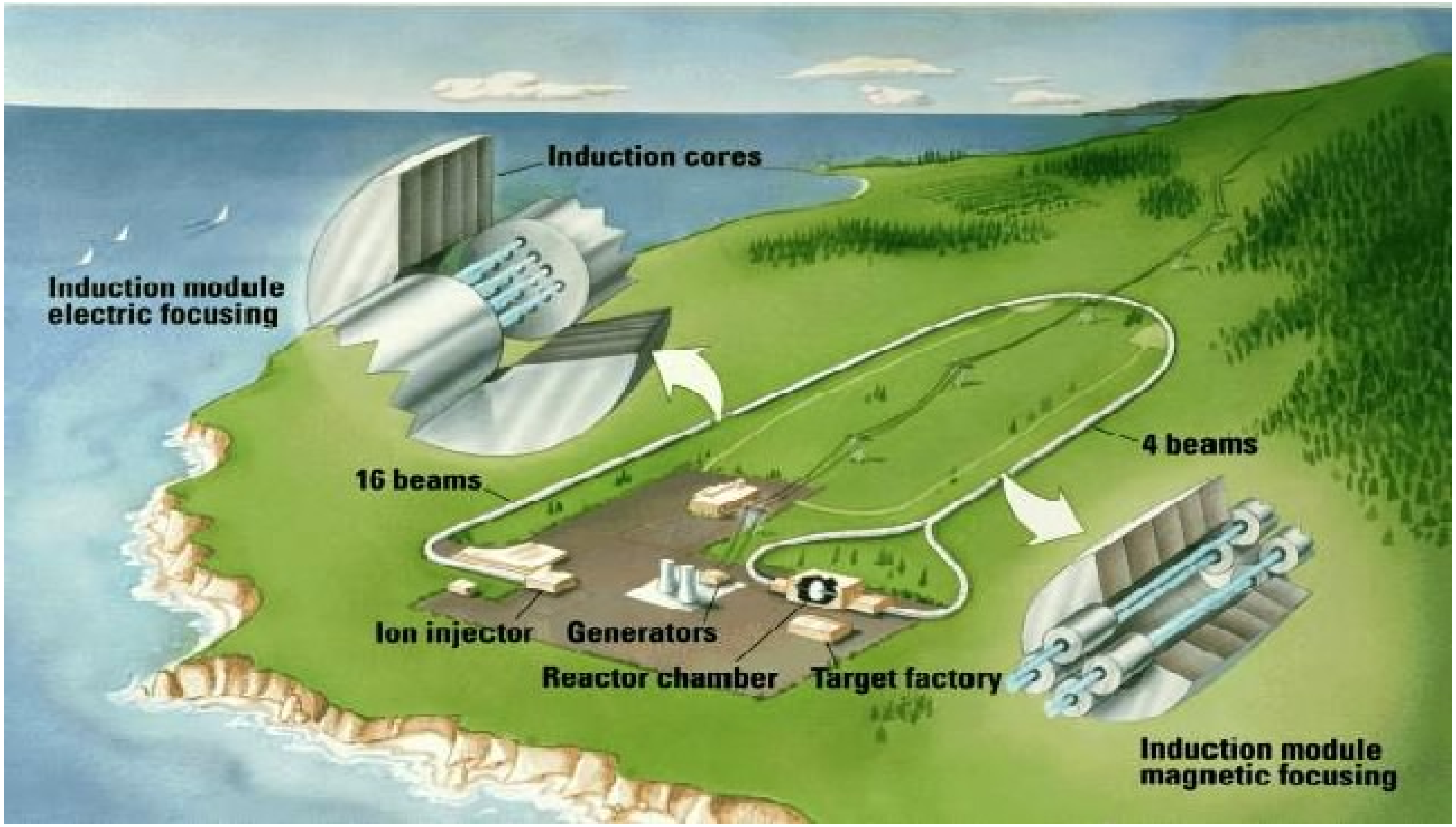
CLIC



A diagram showing the CERN approach to a linear collider. The two main linacs are driven by 12 GHz radio frequency power derived from a drive beam of low energy but high intensity that will be prepared in a series of rings combined with a conventional linac.

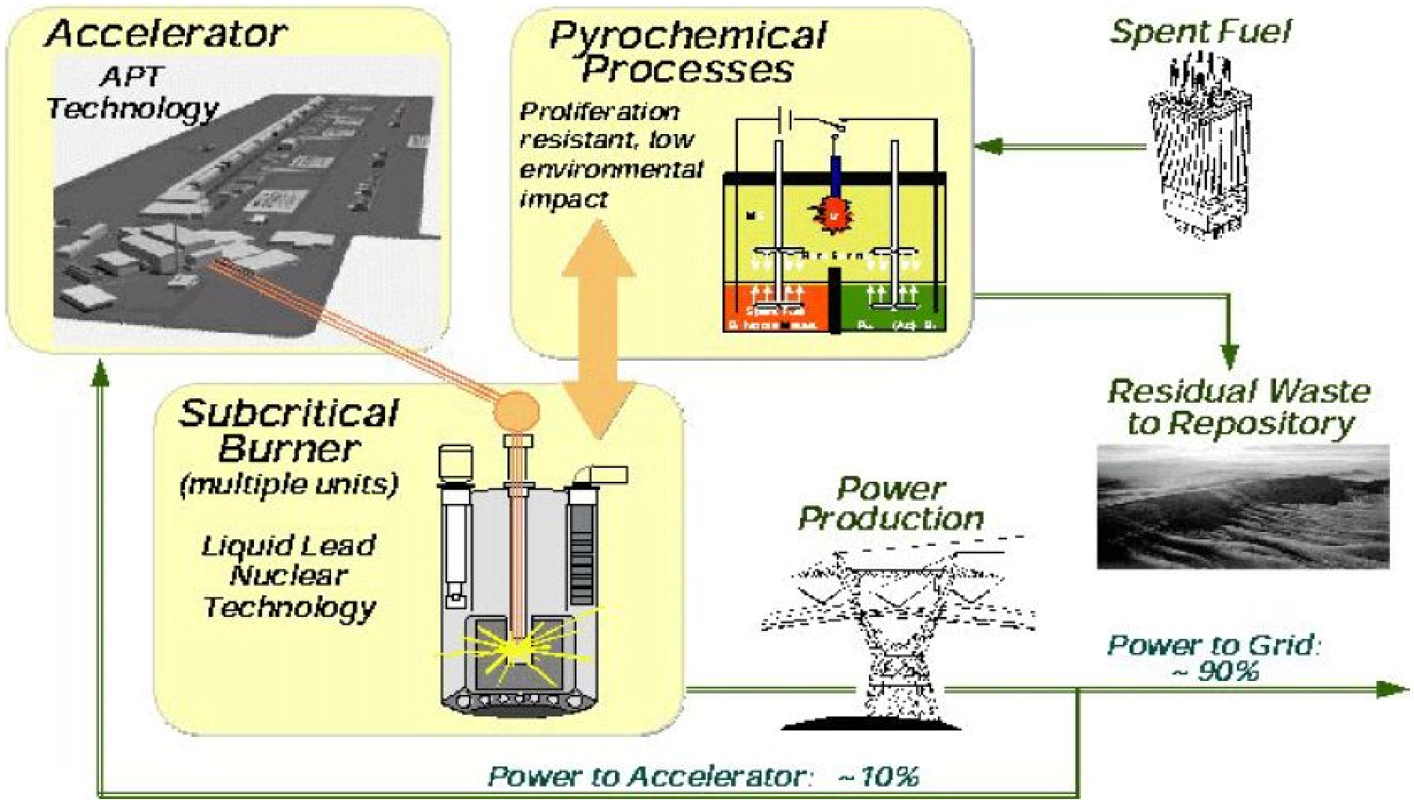


Inertial fusion



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

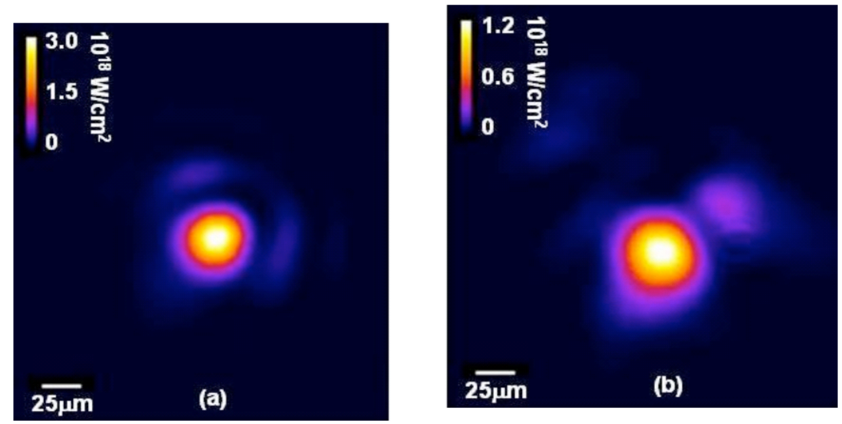
Proton Drivers for Power Reactors



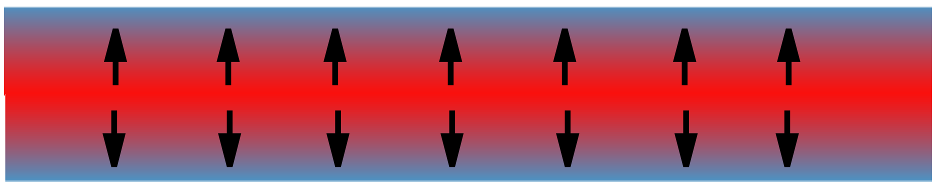
A linac scheme for driving a reactor. These devices can turn thorium into a reactor fuel, power a reactor safely, and burn up long-lived fission products.

Oxford/LBNL Plasma-Laser Experiments:

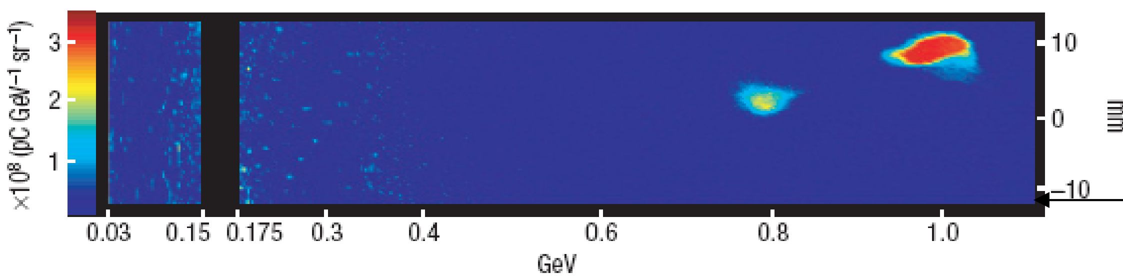
- Guiding achieved over 33 mm:
  - Capillary 190 um
  - Input laser power 40 TW
  - Peak input intensity > 10^{18} W cm^{-2}
  - Plasma: 3×10^{18} cm^{-3}
  - Spot size at entrance 26 μm
  - Spot size at exit 33 μm



Entrance Exit



Plasma channel formed by heat conduction to capillary wall.



$E = (1.0 \pm 0.06)$ GeV

$\Delta E = 2.5\%$ r.m.s

$\Delta\theta = 1.6$ mrad r.m.s.

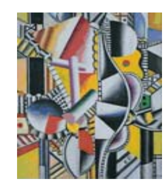
W. P. Leemans et al. *Nature Physics* **2** 696 (2006)

Butler et al. *Phys. Rev. Lett.* **89** 185003 (2002).

D. J. Spence et al. *Phys. Rev. E* **63** 015401(R) (2001)

Accelerators bringing nations together

The King of Jordan discussing with scientists the Sesame Project, which will be located in Jordan and available to all scientists.



Conclusions

- Accelerators embody all that is good in modern technology
- They continue to be “Engines of Discovery” in many research fields for developing countries.
- Their practical application in Industry and Medicine is Expanding
- Their future (for the young engineer or physicist) is a bright one.

Links

Author's e-mail: ted.wilson@cern.ch

Engines of Discovery:

http://www.enginesofdiscovery.com/
This talk:
http://www.enginesofdiscovery.com/eod.pdf

Particle Accelerators

http://www.oup.com/uk/catalogue/?ci=9780198508298