Accelerators

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Today

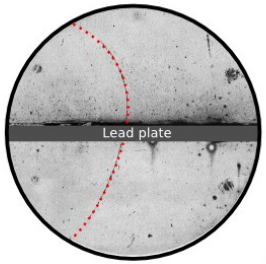
- Review methods of detection
- Demo: superconductor, current loops
- Discussion
- Slides about accelerator technology

Review Methods of Detection

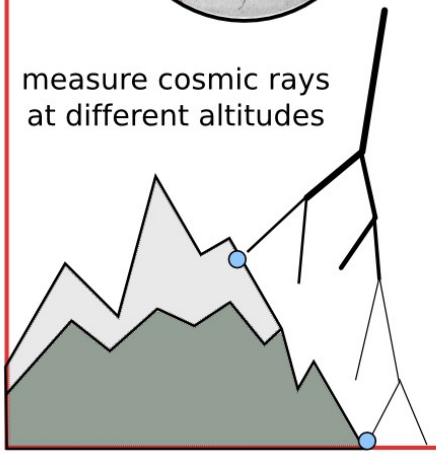
Methods of Particle Detection

Cloud Chamber

Particles leave tracks of ionization, clouds form

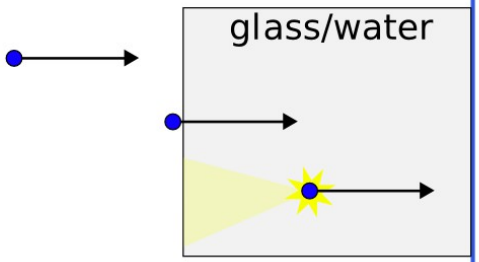


measure cosmic rays at different altitudes



Cherenkov

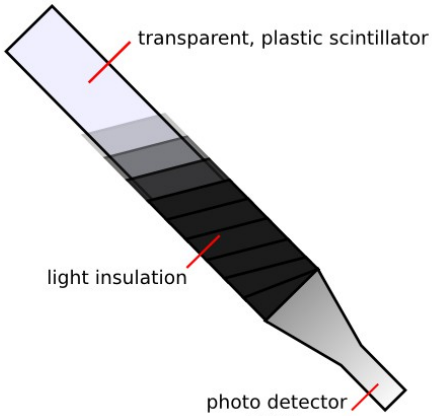
Particles moving faster than speed of light in medium, polarize medium

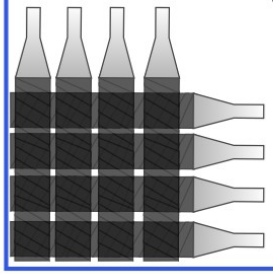


PHENIX RICH

Scintillation

Particles excite electrons in media, media emits light

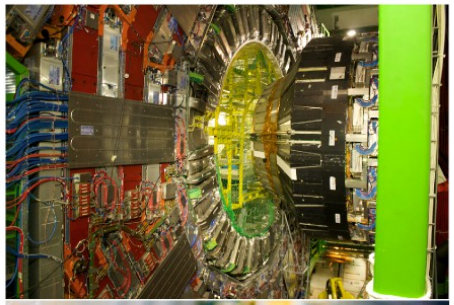


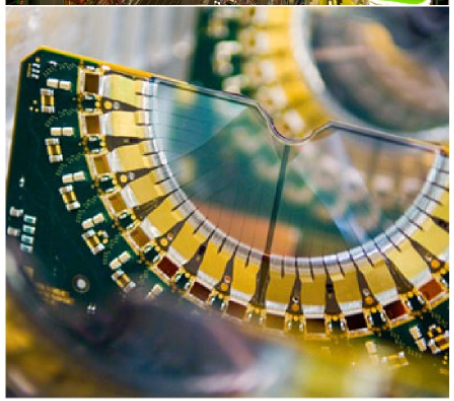


Build into array

Silicon

Silicon detectors used for precision tracking

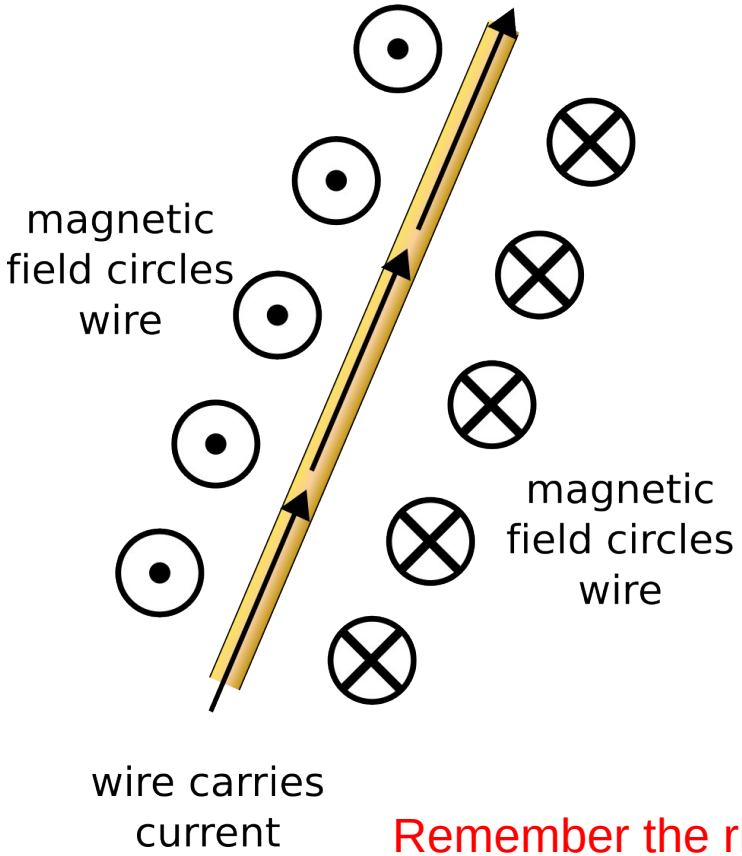




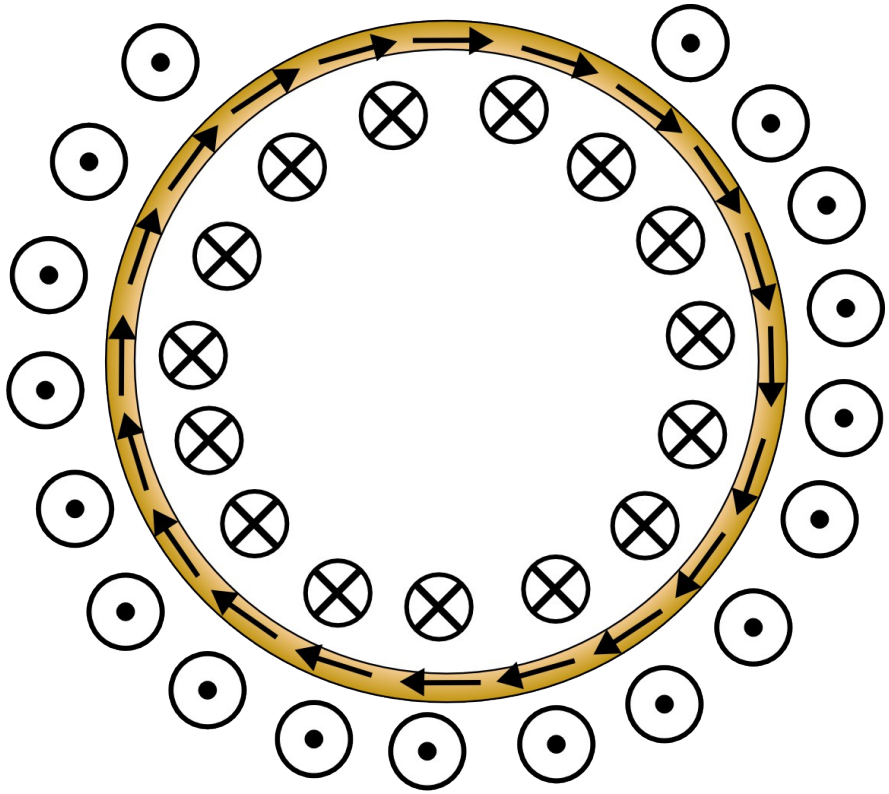
Magnets how do they work?

How an electromagnet works

Moving charge
creates magnetic field



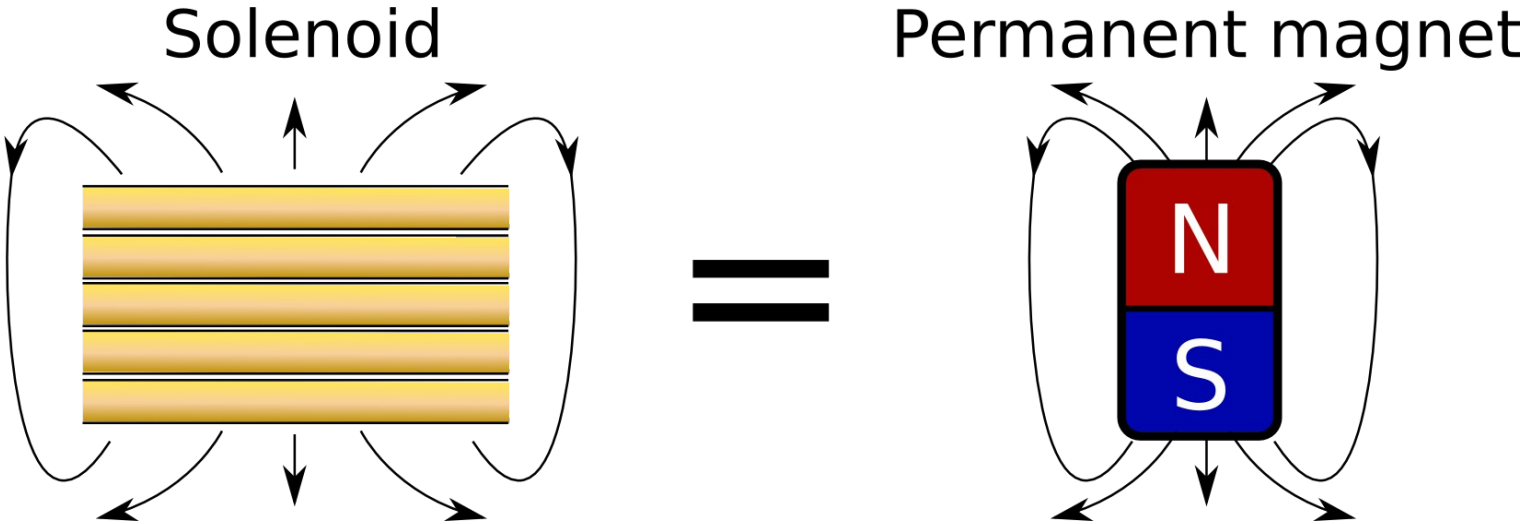
Current loop



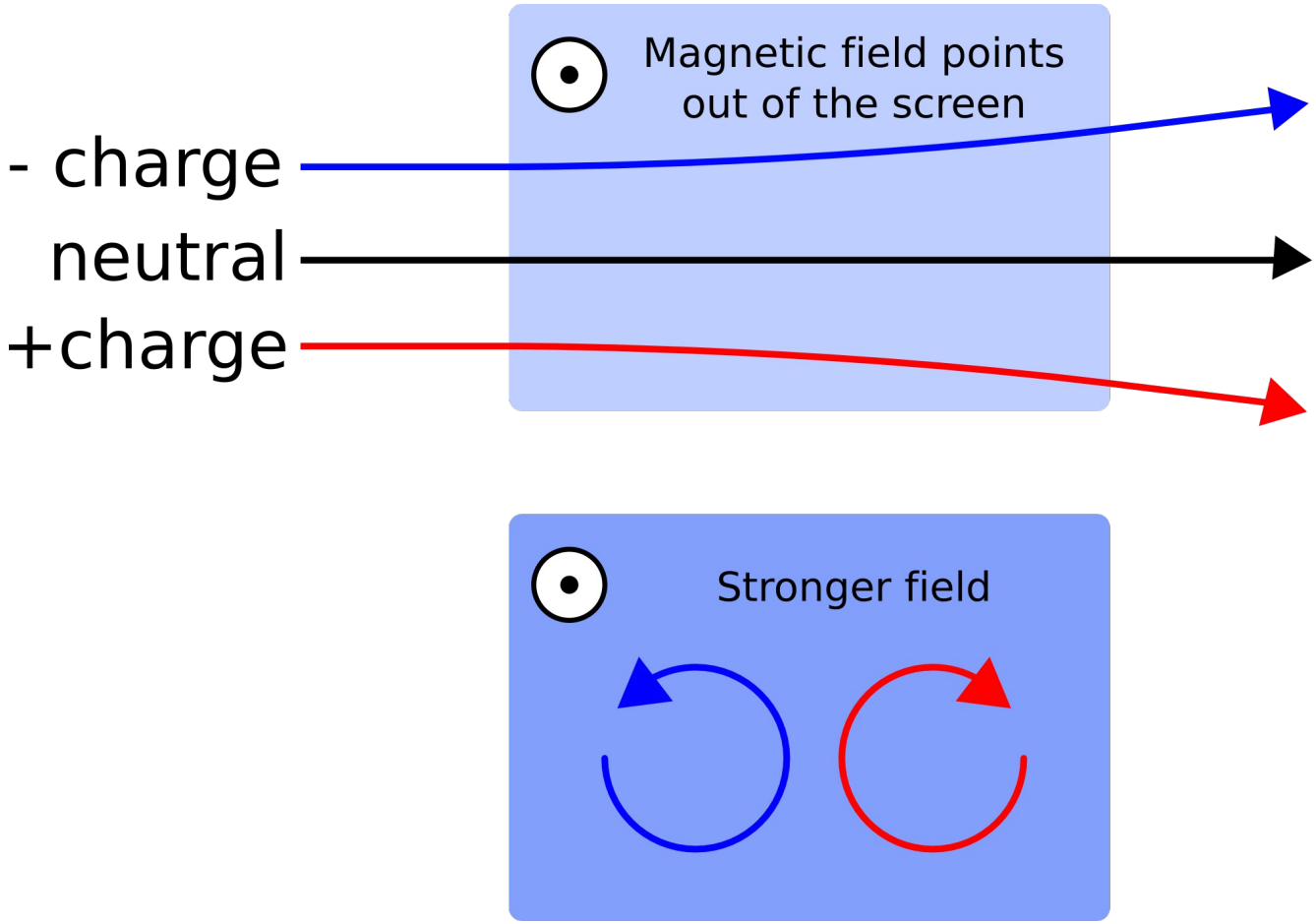
Remember the right hand rule

How an electromagnet works

stack of wire loops



The magnetic field



How does a superconductor work?

- When cold enough, electrons can move ***freely and in any direction***
- Once an electron starts moving, it doesn't stop
  - No resistance
  - Can travel in endless “eddy currents”
- Can carry **huge** current – makes it good for building a powerful magnet
- When we place the permanent magnet over the superconductor, a bunch of *tiny current loops of electrons* are created. These *hold the magnet in place*

What is energy?

What is **energy**?

- Energy is the ability to make something happen
  - A moving particle has **kinetic energy**
  - A massive particle has **mass energy**
- **Momentum** is measured in eV/c^2
  - Physicists ignore c! It's a waste of time
  - Write $E=mc^2+pc$ as **E=m+p**
  - *Momentum and mass have same units!*

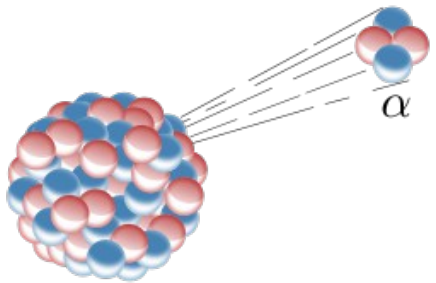
What are the units?

- Physicists use **electron volt**:
  - Energy to push 1 electron up one volt
  - 1 Calorie = $2.6 \cdot 10^{19}$ **eV**
- Measure everything in KeV, MeV, GeV, TeV
  - 9 eV = energy for electron on "–" 9v battery terminal
  - 1 MeV = mass of electron
  - 1 GeV = mass of proton
  - 7 TeV = energy per collision at LHC

Accelerator Physics

Radioactive Accelerator

- Nature's gift to physicists
- Radioactive nuclei spit out streams of 5MeV alpha particles
- Rutherford used this in his gold foil experiment
- Low energy and unfocused



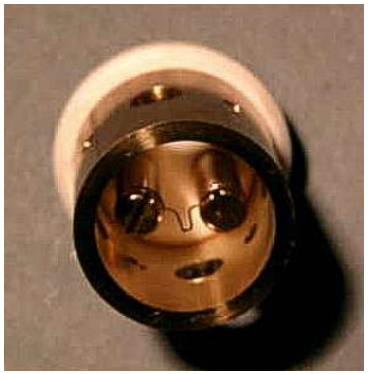
http://en.wikipedia.org/wiki/Alpha_decay#mediaviewer/File:Alpha_Decay.svg

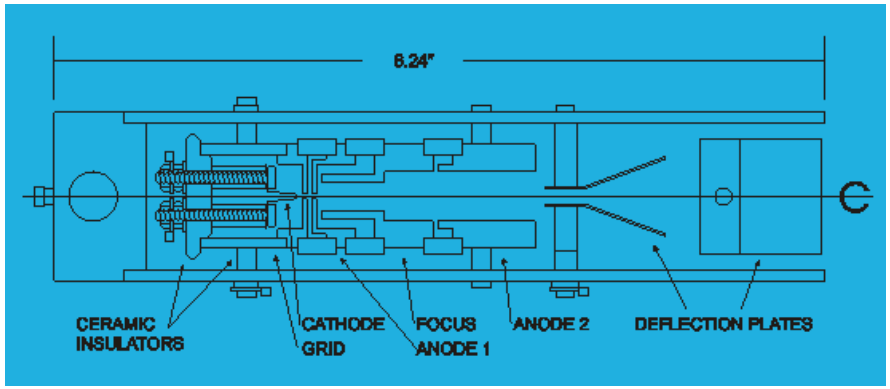
Cosmic Rays

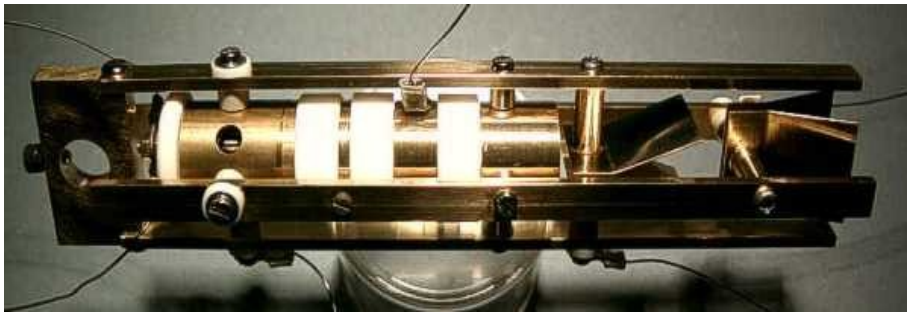
- High energy ($3 \cdot 10^{20}$eV) **protons** or **photons** strike atmosphere
- Create shower of pions, muons, etc
- Provides easy source of exotic particles
- Drawbacks:
  - Unpredictable location
  - Low rate
  - Unknown source
  - Can't build detector in space

Cathode Ray Tube

- First artificial accelerator 1897
- Cathode heated, electrons boil off
- Beam is accelerated via electrostatic force (charged plates pull e- along)
- Simple to construct
- Steady, predictable beam
- Used by Tomson, discovery of electron



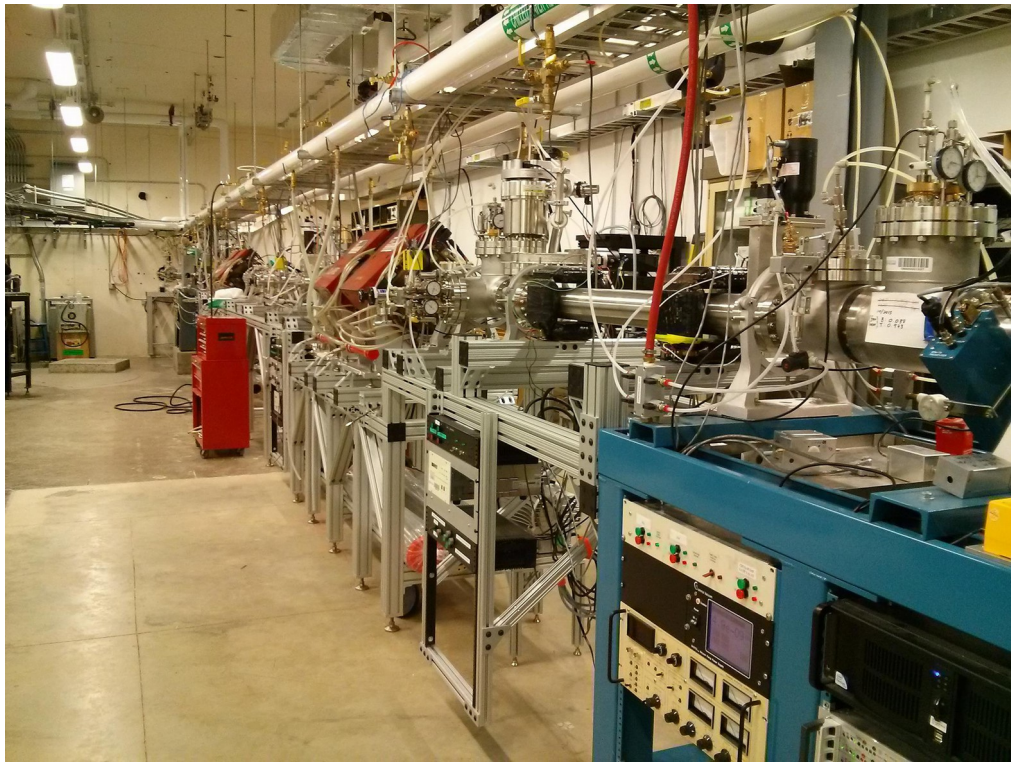




http://www.teralab.co.uk/Experiments/Electron_Optics/Electron_Optics_Page1.htm

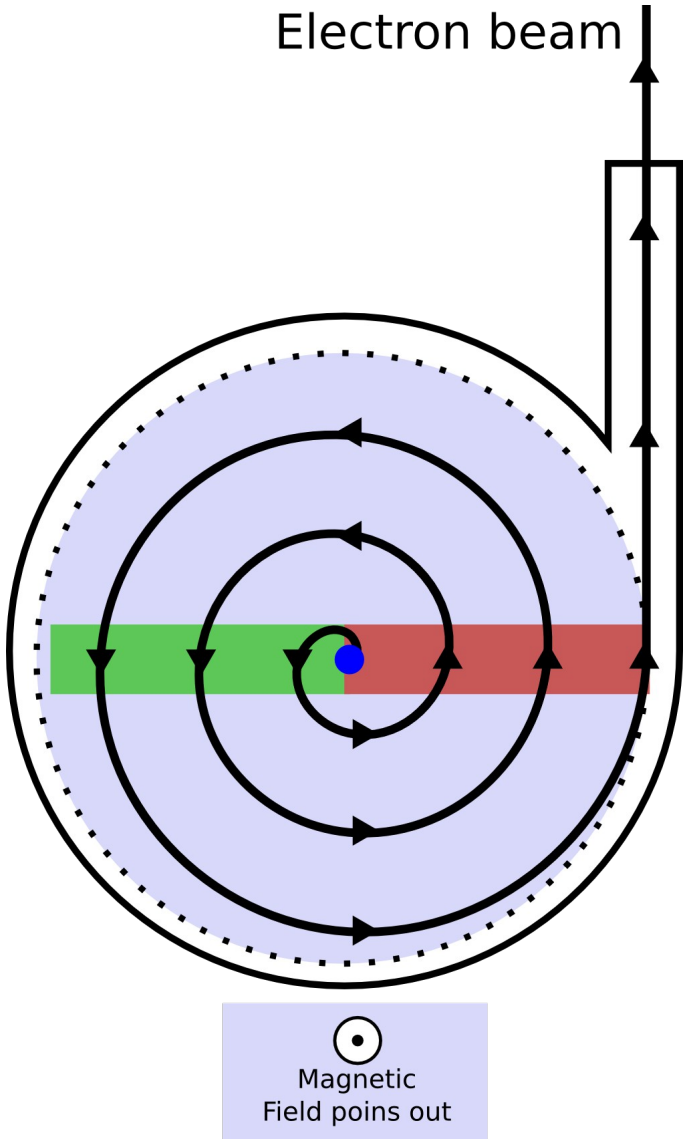
Van de Graaf Accelerator

- Invented 1929
- Uses a belt to physically carry electrons to a cathode
- 1-10MeV energies
- Still in use today for low energy nuclear physics
- Particles pushed through series of voltage potentials
- ISNAP beamline pictured

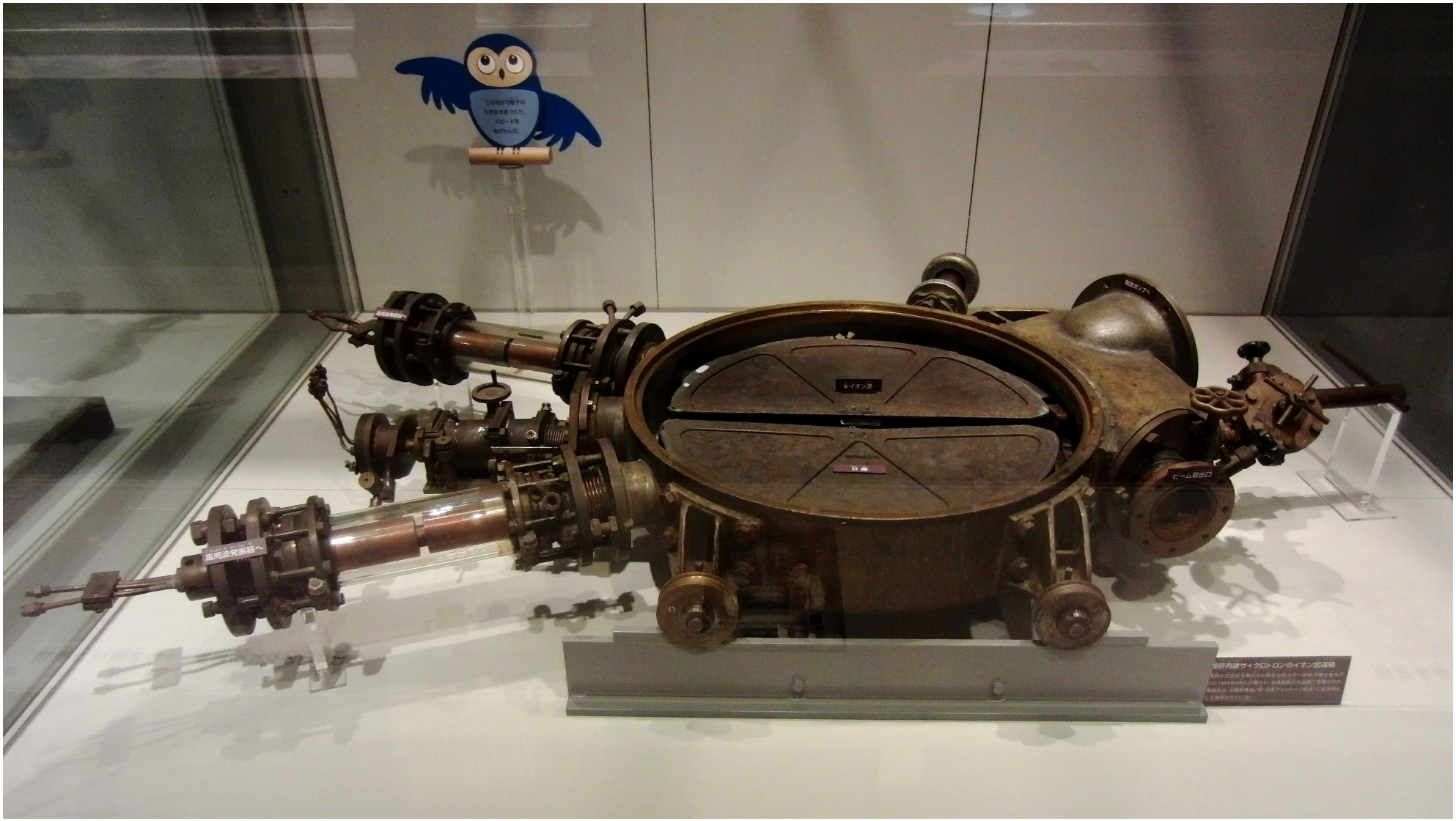


Cyclotron

- Lawrence in 1929, 500MeV
- Electron starts in center
- Magnetic field bends around in circle
- Passes through **voltage gradient** multiple times
- *Frequency~charge*field/mass* does not depend on radius. Useful property of cyclotron



Cyclotrons

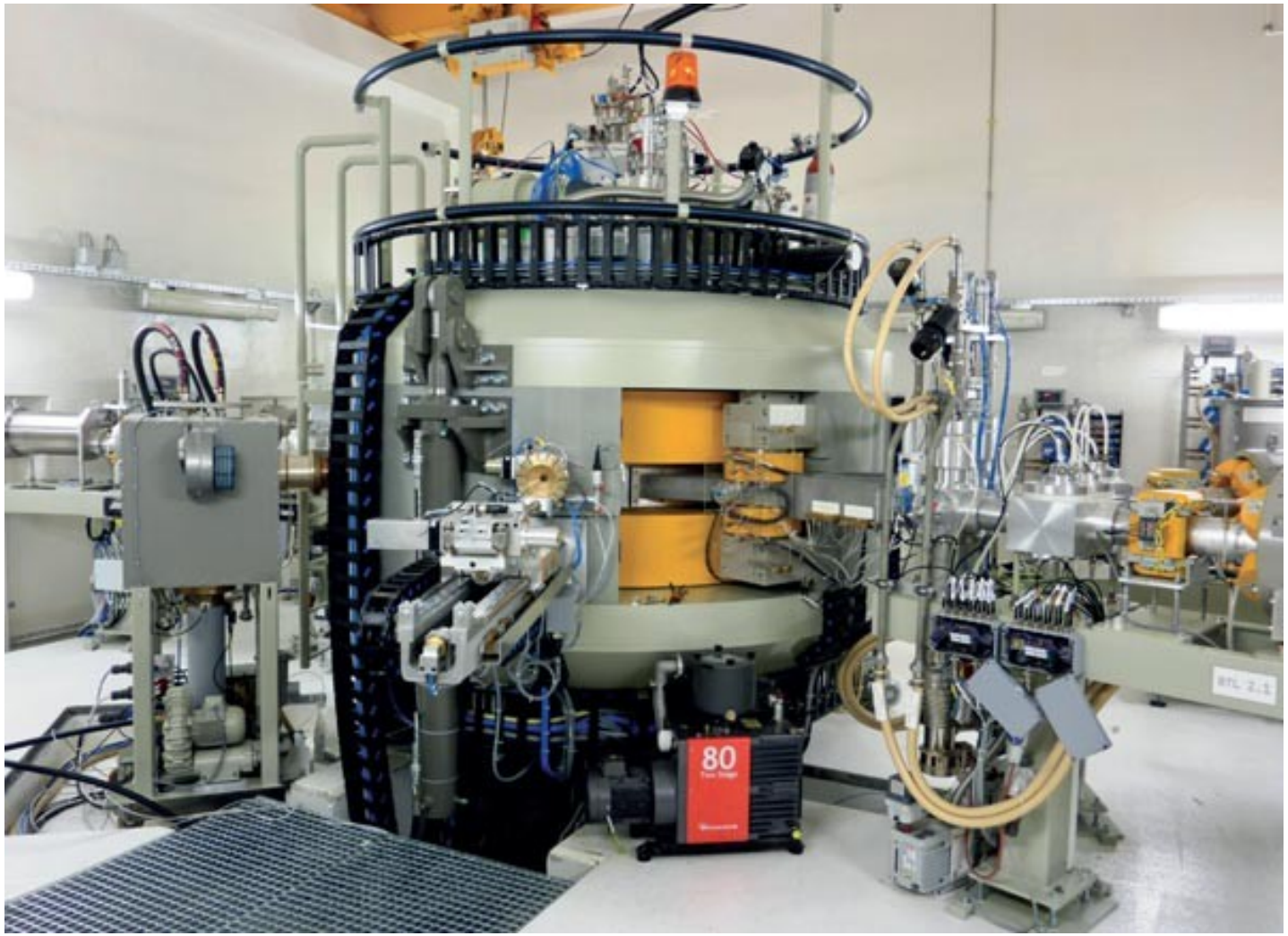


http://upload.wikimedia.org/wikipedia/commons/b/ba/RIKEN_Cyclotron_Accelerator.jpg

Cyclotrons

http://en.wikipedia.org/wiki/File:1937-French-cyclotron.jpg

Cyclotron



30 MeV

http://images.iop.org/objects/ccr/cern/52/3/23/CCmed2_03_12.jpg

Synchrotron

- Cyclotrons have an energy limit:
  - *Frequency~charge*field/mass*
  - In relativity, mass changes with increasing energy!
- Synchrotron fixes this
  - Increase field as mass increases
- McMillan, 1945
- Modern high energy machines are based on this
- Synchrotrons have a lot of external purposes:
  - Imaging
  - Cancer treatment, etc

Modern Synchrotron

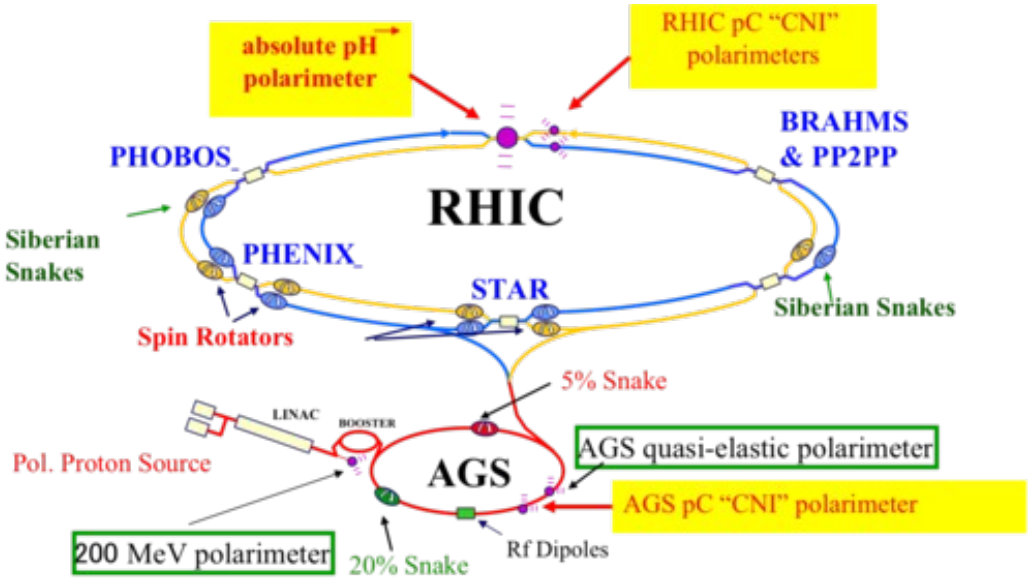
Nat. Sync. Light Source 2

http://www.linde-kryotechnik.ch/public/news/brookhaven/4463188026_775cbe4417_o.jpg

Circular Collider - RHIC

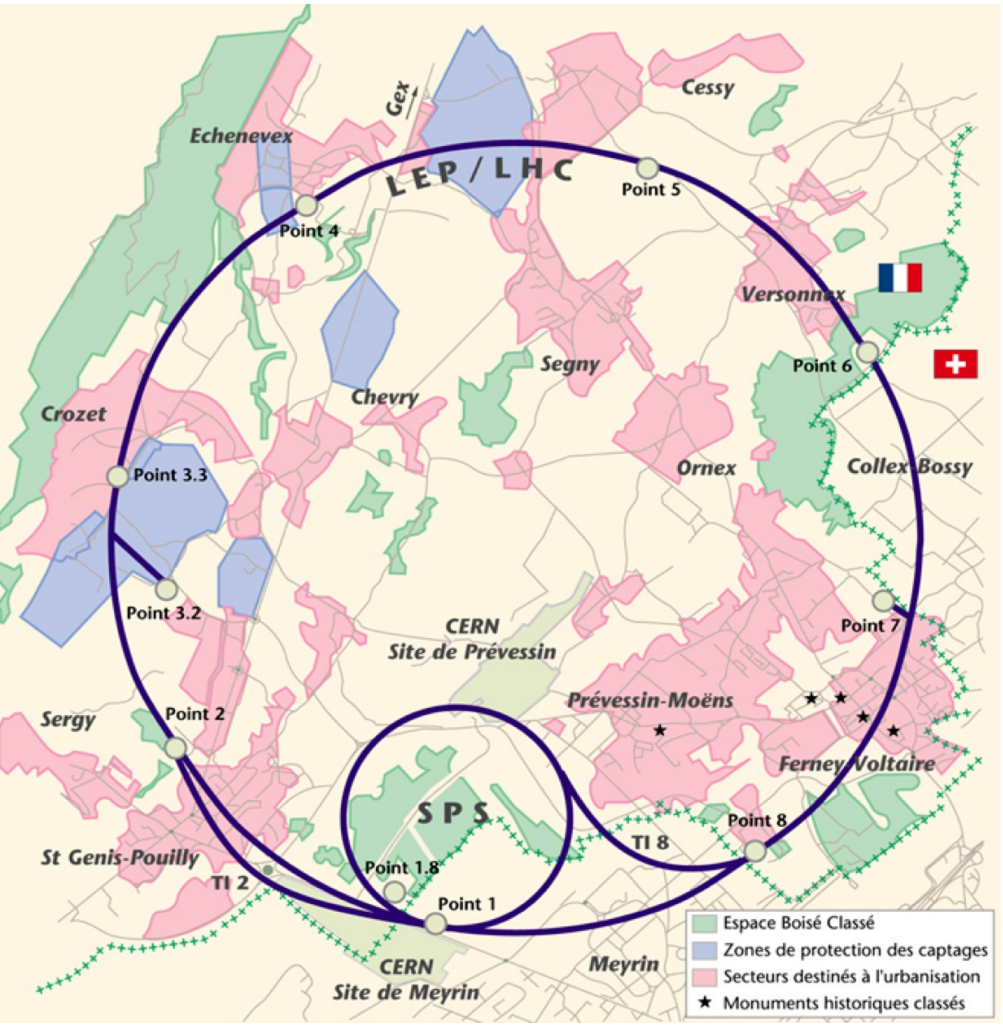
- What happens if you take two opposite direction synchrotrons, and smash their beams together?
  - **Collider!**
- Example, RHIC, Brookhaven 500GeV beams

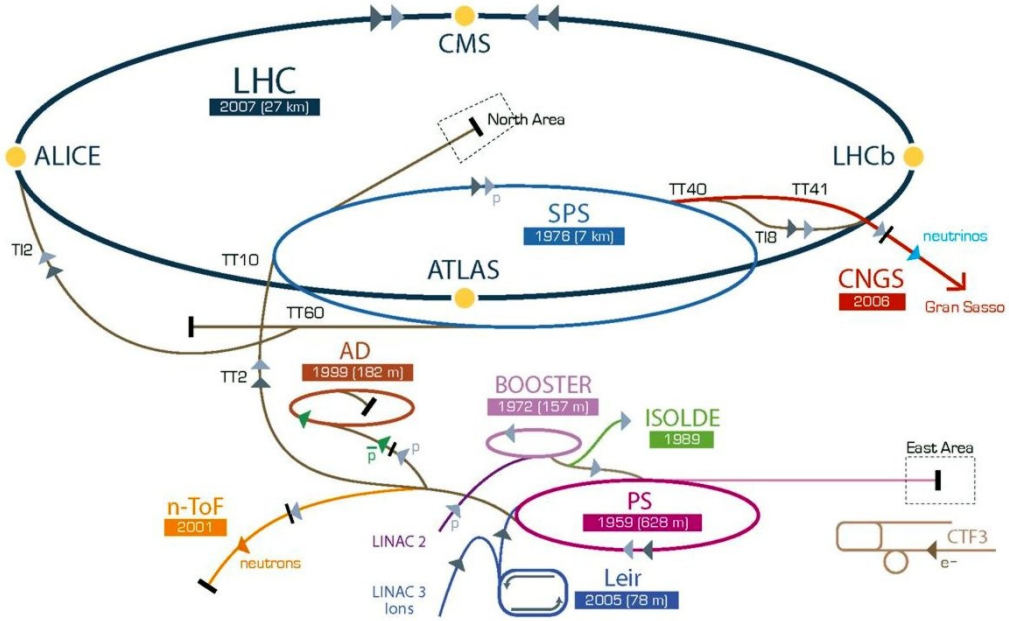
http://i.huffpost.com/gen/972986/thumbs/r-RHIC-SHUTDOWN-large570.jpg?12

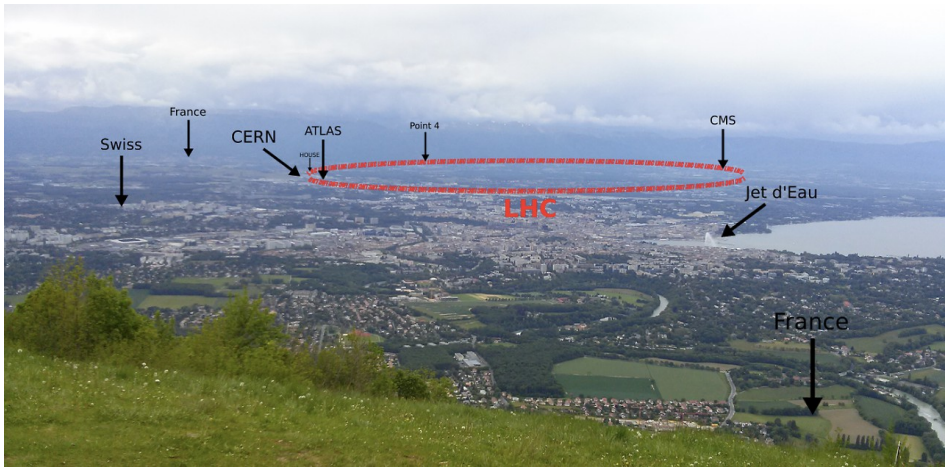


Circular Collider - LHC

- 7TeV Beams pp and lead ion, CERN







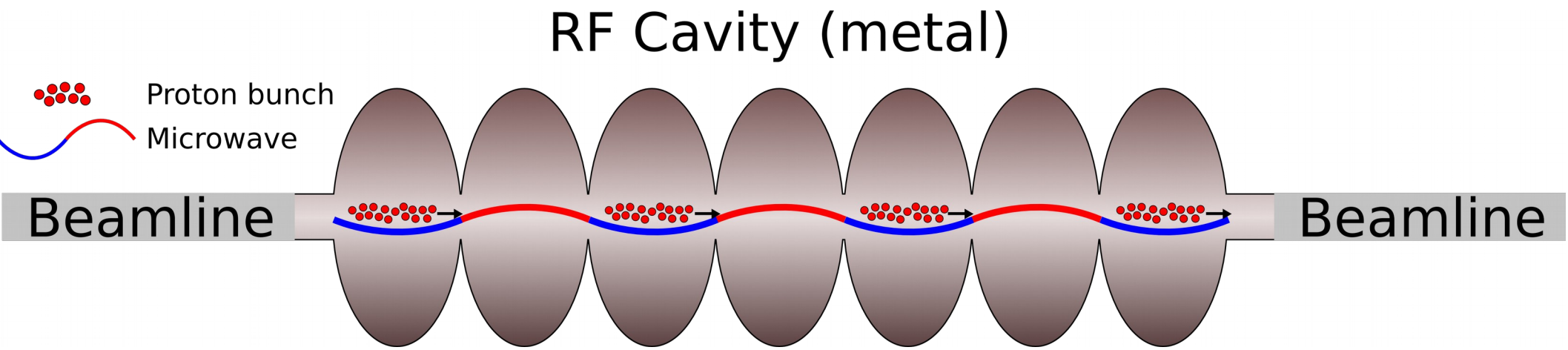
http://void.printf.net/~conor/sa/LHCb/cernschema.jpg , http://cds.cern.ch/record/842418/files/lhc-pho-1997-181.jpg

Linear Accelerator

- Pros:
  - Bending the beam causes it to **radiate** energy
  - Linear collider is straight, no synchrotron radiation
- Cons:
  - Lower energy, beam only passes through accelerator **once**
- Example, SLAC, JLAB

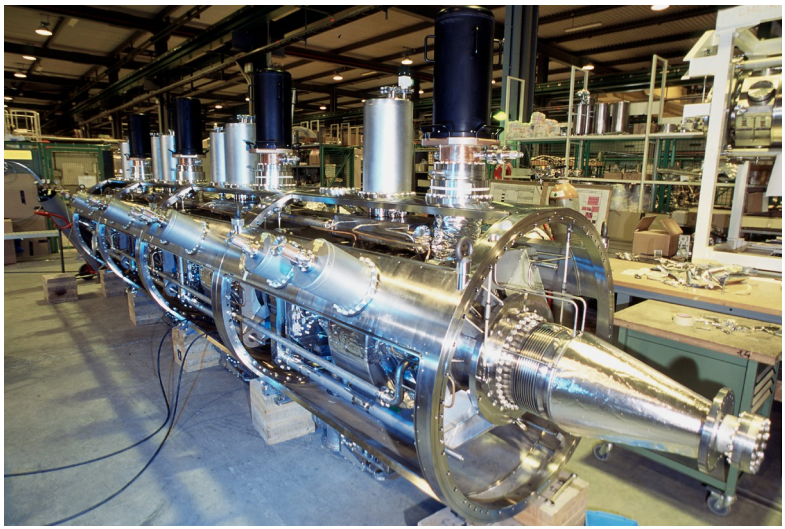
http://today.slac.stanford.edu/images/2009/slac-arial.jpg , http://upload.wikimedia.org/wikipedia/commons/c/c3/Jlab_aerial1.jpg

Radio Frequency Cavity



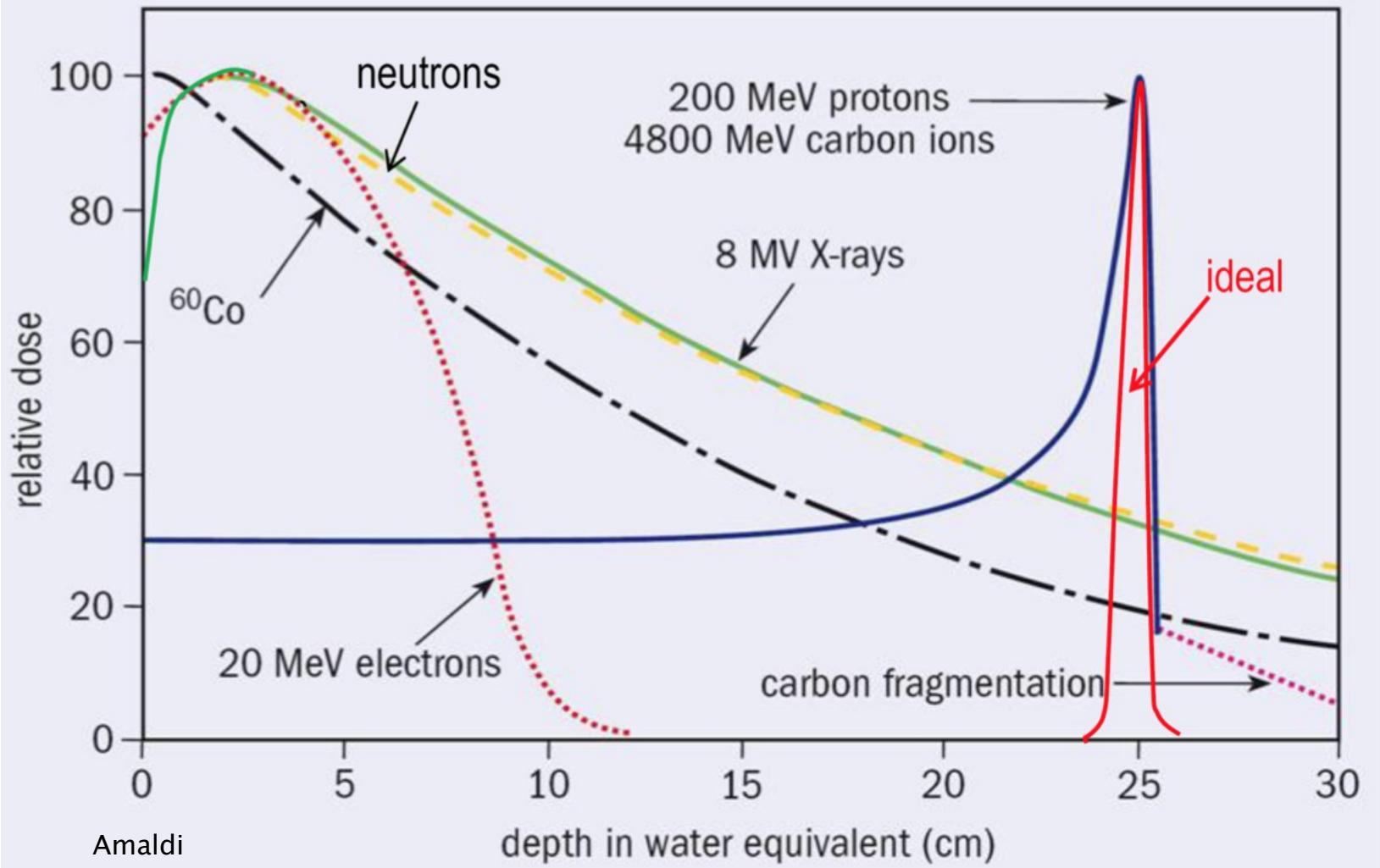
Metal amplifies the microwave
Very high wattage, driven by klystron machine

http://www.phys.vt.edu/~kimballton/gem-star/workshop/images/sc_cavity.jpg



http://at-dep-acr-op.web.cern.ch/at-dep-acr-op/images/module_LHC.jpg

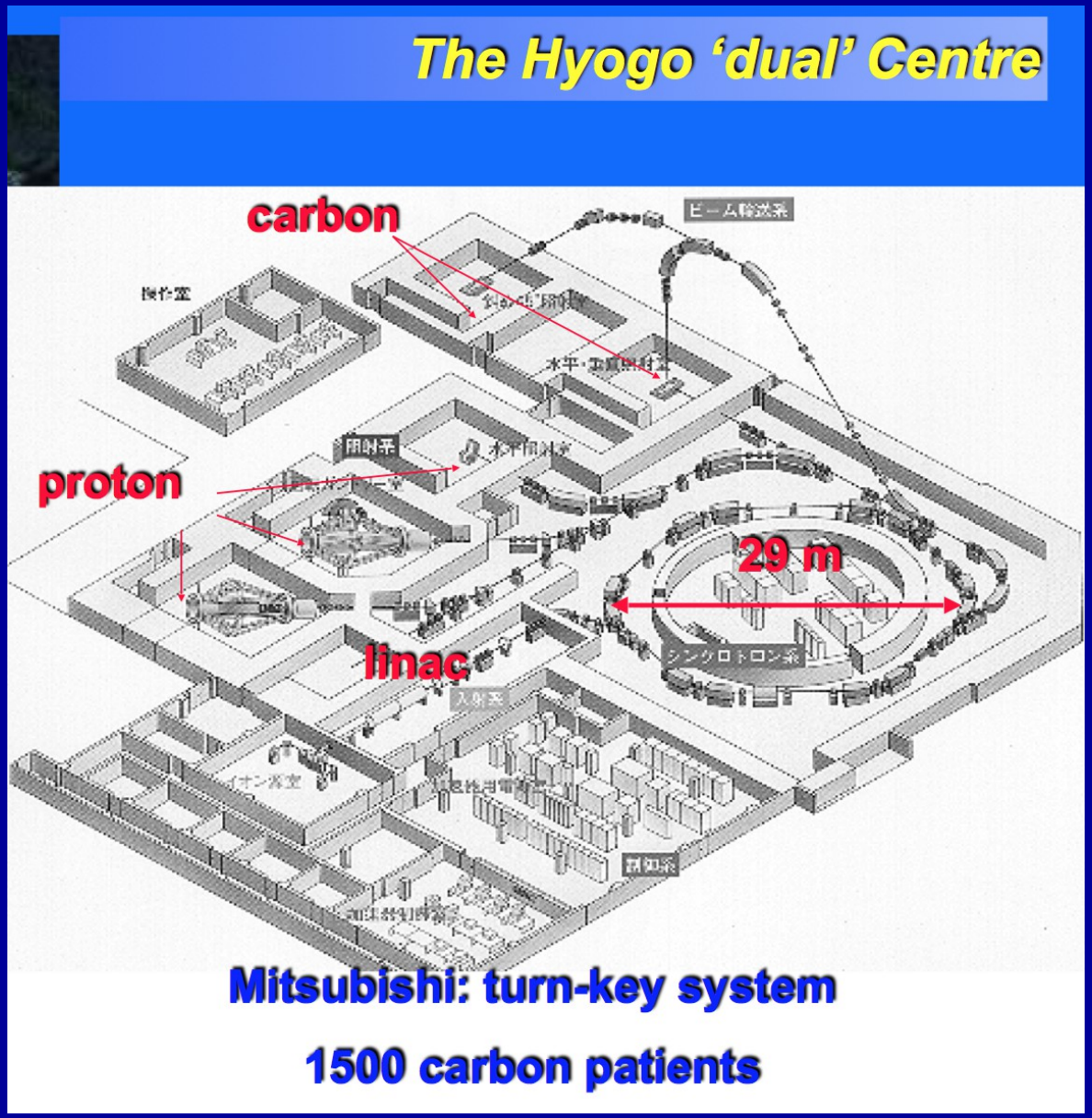
Medical applications



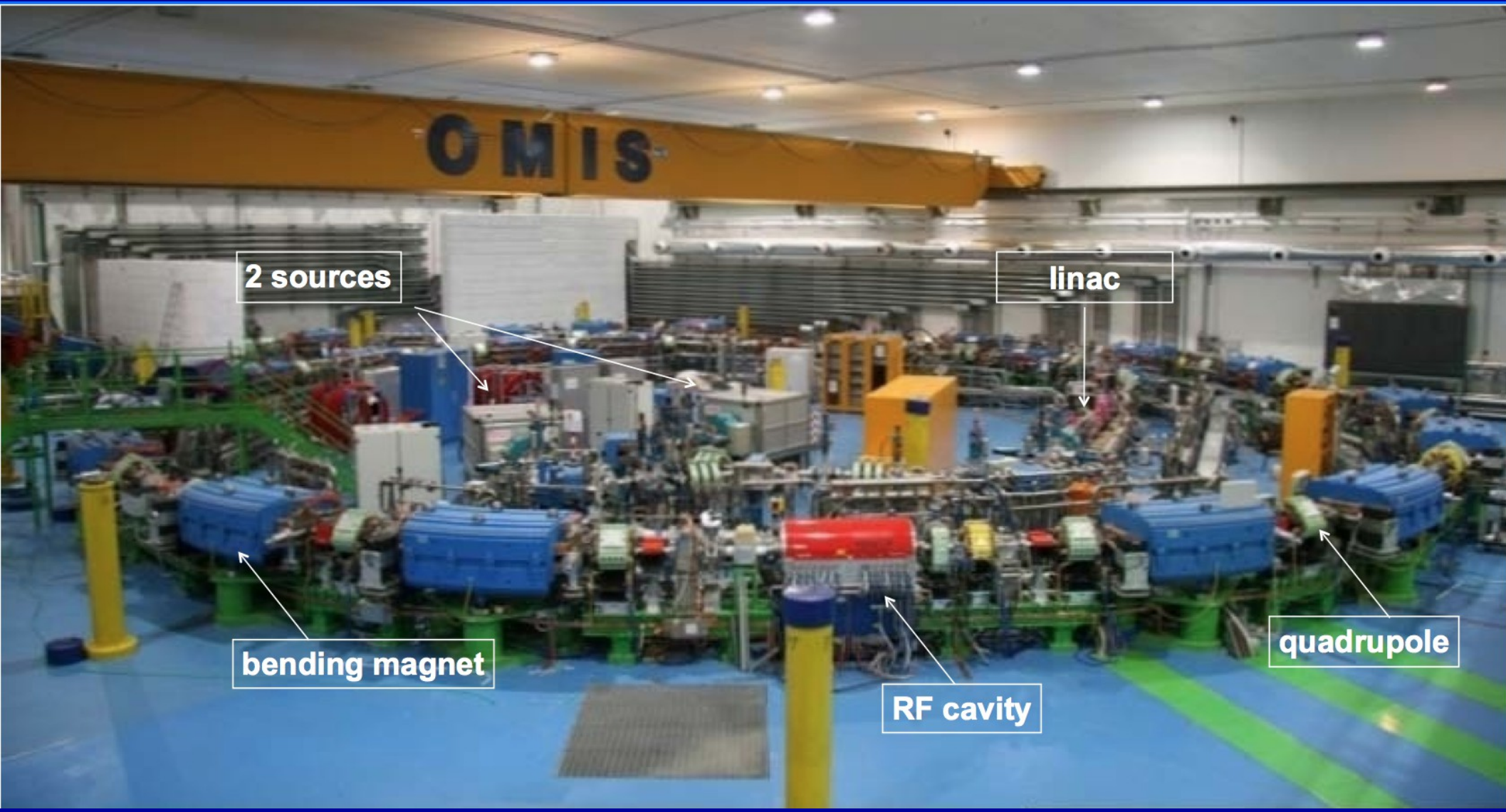
Medical applications

- Stealing these from Ugo Amaldi's slides

Medical applications



Medical Applications



Questions?