My life as a Researcher

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My job

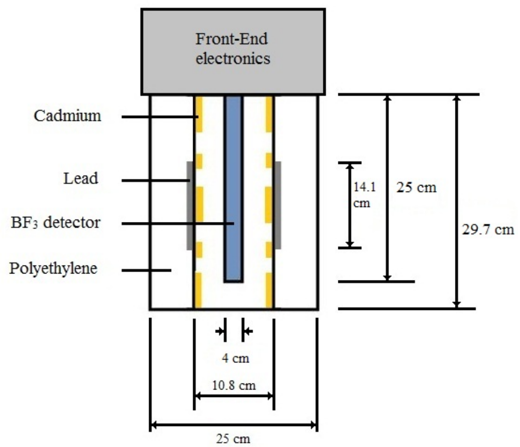
Research Physicist – Field of Nuclear physics and Detector physics

Developing detector for radiation fields around particle accelerators using:

- Experimental data
- Geant4 Monte Carlo Simulations

The Physics (lite version)

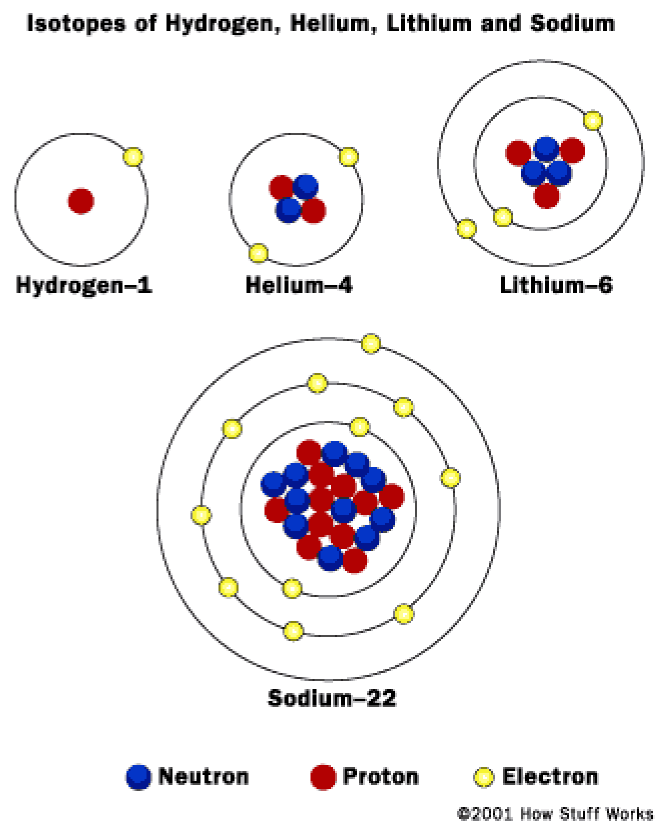
- I work in the development of the LUPIN:
  - This is a neutron REM counter
  - It detects neutrons of all energies
  - Neutrons are hard to detect: the LUPIN works my reducing their energy in the moderator, and then detecting them in a gas chamber



- But what does this mean?!?

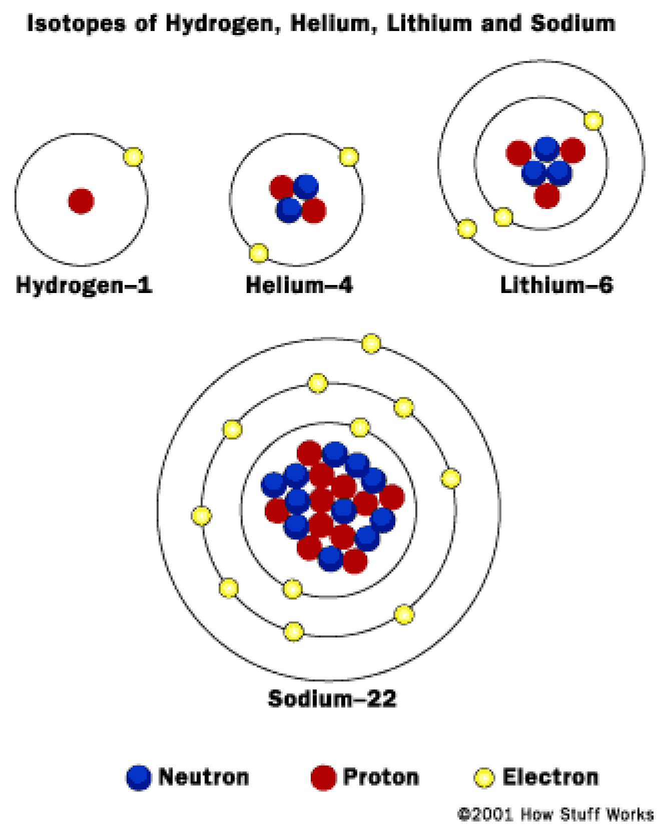
The atom (Bohr model)

- All matter is made up of positive Protons, negative Electrons and neutral Neutrons
- Protons and Neutrons (also called ‘Hadrons’) form the nucleus, and electrons orbit in discrete energy levels
    - Most natural atoms contain an equal amount of protons and electons, giving them a neutral charge



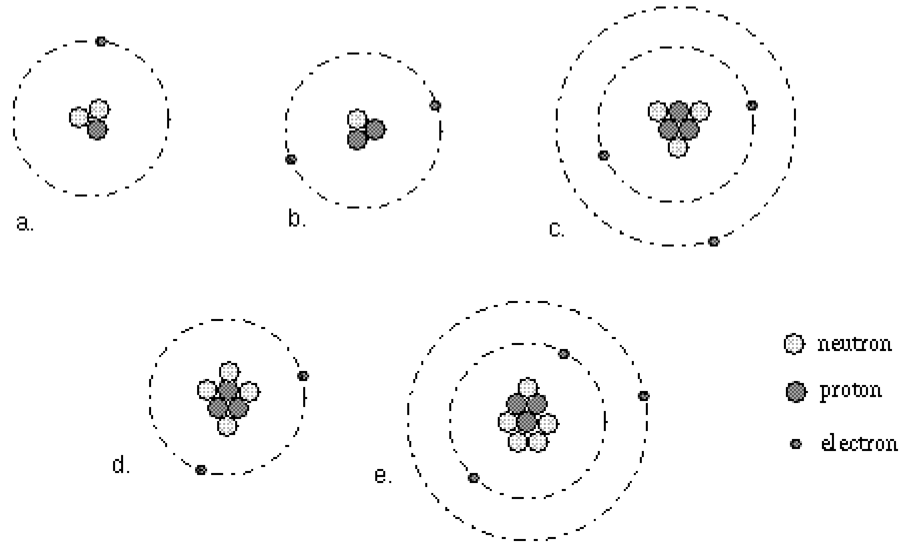
The atom (Bohr model)

- Atoms with different numbers of neutrons are called 'isotopes'
  - For Example: ^{3}He and ^{4}He are isotopes of Helium, with 1 and 2 neutrons respectivly



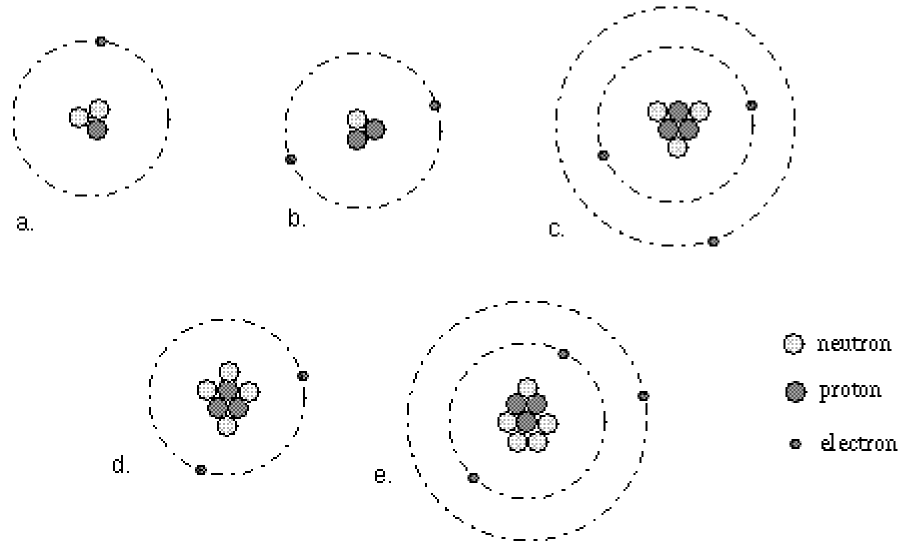
The atom (Bohr model)

- An 'Ion' is an atom that does not have a neutral charge: one with either more or less electrons than protons
- In this image, d. is an Ion, as it has one less electron than proton, giving it a charge of +1∗ e (the charge of an electron)



The atom (Bohr model)

- Radiation can ionize an atom by giving enough energy to an electron: there is a threshold to this process however
- The energy needed for this process is dependent on the number of protons in the nucleus squared:
  - $E = -\frac{Z^2 13.6}{n^2} eV$; where *Z is the atomic number, and n is the orbital number*
  - *eV is the unit 'electron volts', which corresponds to 1.602 * 10^{-19} J*



What is Radiation?

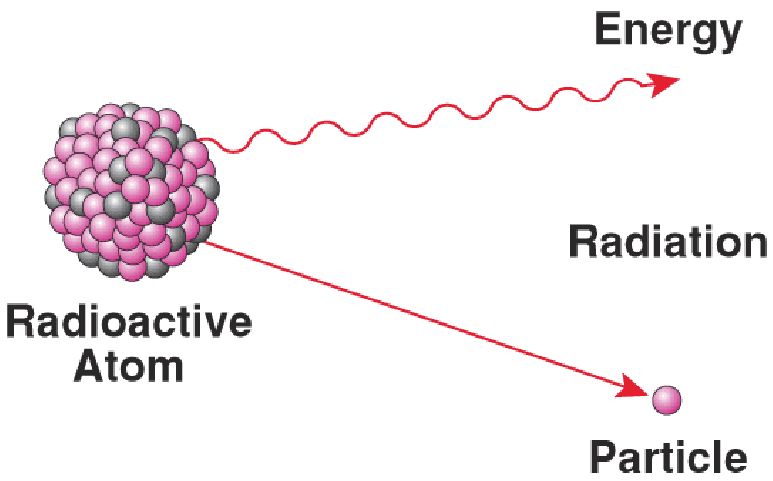
- Particles that carry energy
- Most common can be split into 2 categories:
  - Charged: Protons, electrons, alpha particles and heavy ions
    - These particles have an electrical charge; this is how they transfer the energy to matter
    - These particle carry energy through momentum (Kenetic energy)
  - Uncharged: Photons (also known as X rays, Gamma rays or even visible light) and neutrons
    - These have no electrical charge, and transfer energy by collisions or absorption by matter
    - Photon’s energy is a function of their wavelength; they have no rest mass and therefore no Kenetic energy (this is not strictly correct, but a convenient explanation)

Sources of Radiation

- Naturally occurring unstable isotopes (decay)
- Artificial sources
  - Particle Accelerators
- Cosmic rays

Decay

- 'Radioactive decay' is what happens when nucleus is in an excited state, and must release energy
- Decay cannot happen at any time for 'stable' atoms: there is a 'binding energy', which is what holds the nucleus together -> this must be overcome in order for the nucleus to release radiation

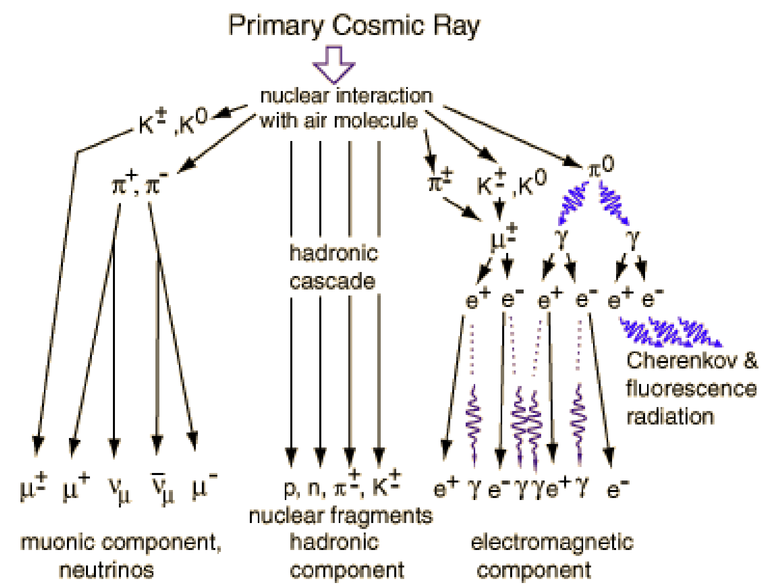


Decay

- Certain isotopes are naturally unstable, meaning they will decay without any input
- The ‘activity’ of a radioactive source is measured in Becquerel (Bq), or number of decays per second

Cosmic Rays

- Radiation from outer space, usually taking the form of high energy protons and heavy ions
- Creates a 'shower' of radiation when hitting the earth's atmosphere
- Significant source of dose for airline crew

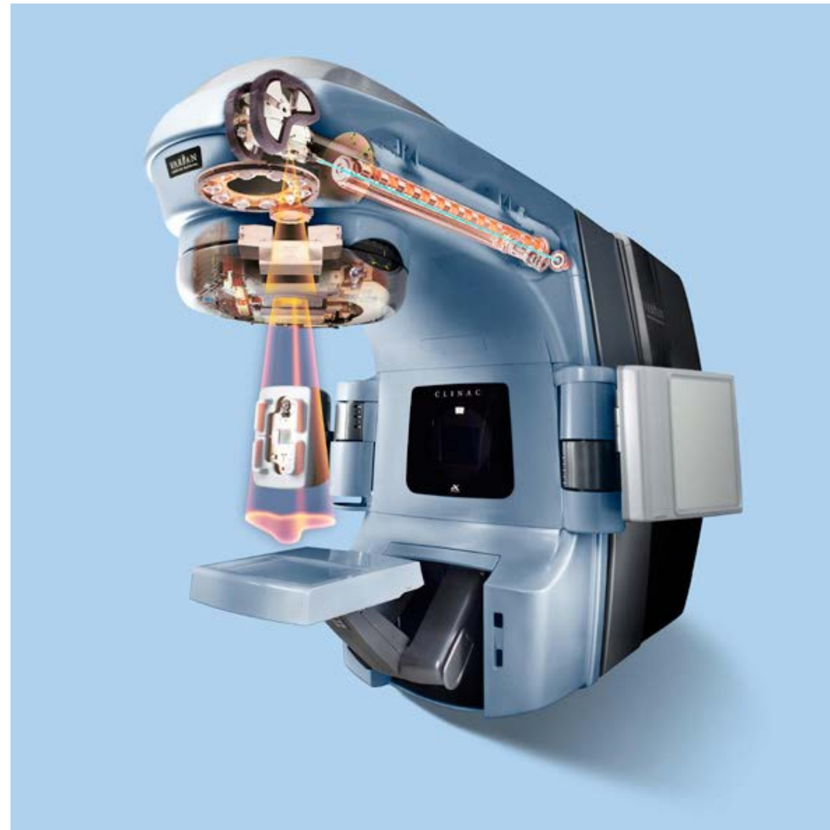


Particle Accelerators

- Take many forms, for different radiation types and energies, for example:
  - Medical Linear Accelerators (LINACs) to produce gamma rays for medical purposes
  - Hadron accelerators for medical (proton cancer therapy) and fundamental research (CERN- LHC, SPS etc): Cyclotron and Synchrotron
- Used for fundamental research, isotope production, medical imaging and treatment

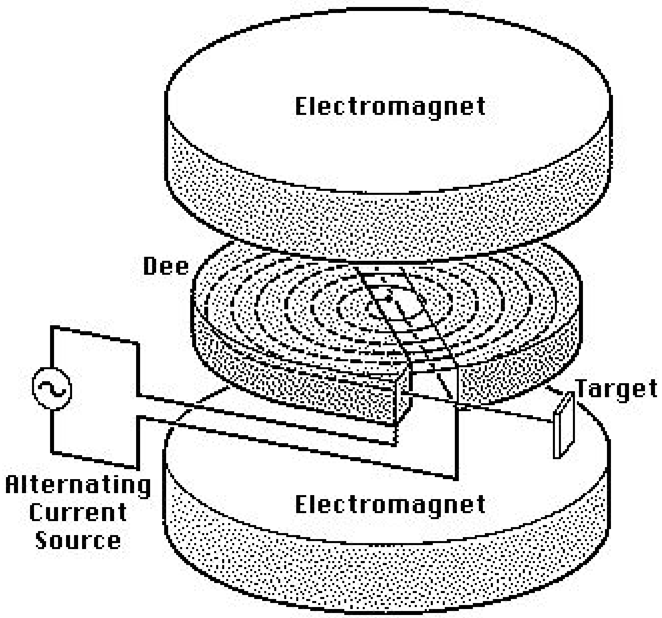
Particle Accelerators

- Medical LINAC
  - Used for cancer treatment
  - Accelerates electrons which then hit a target, producing gamma rays

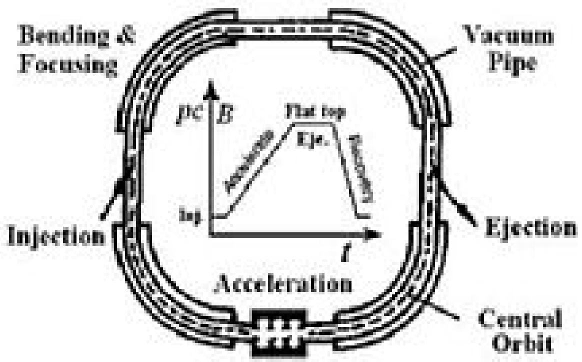


Particle Accelerators

- Cyclotron
  - Accelerates charged particles in a spiral path
  - Uses a fixed magnetic field to curve the path of the particles
  - Gives a continuous beam of accelerated particles
  - Limited by size (have to be very large for protons and hadrons)



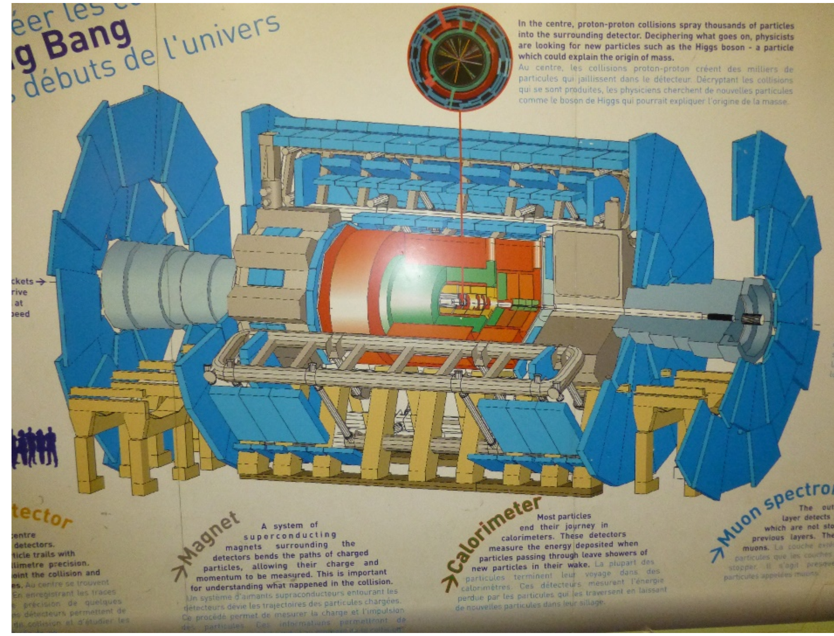
Particle Accelerators

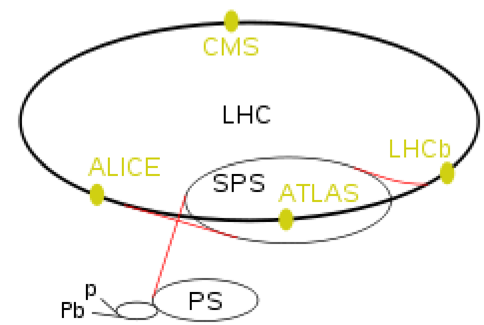


- Synchrotron
  - Accelerates charged particles in a circular path
  - Changes the magnetic field to keep the particles in thin ‘ring’
  - Groups particles into ‘bunches’, creating a pulsed field (long pauses between short pulses of particles)
  - Can go up to very high energy (LHC)
  - Requires a lot of energy (electricity) and is more complicated than other accelerators

Particle Accelerators

- The Large Hadron Collider
  - Accelerates Lead nuclei up to 574 TeV (for comparison, medical LINACs reach 15-18 MeV, or 1/100000 times this energy)
  - Is actually a system of 4 accelerators



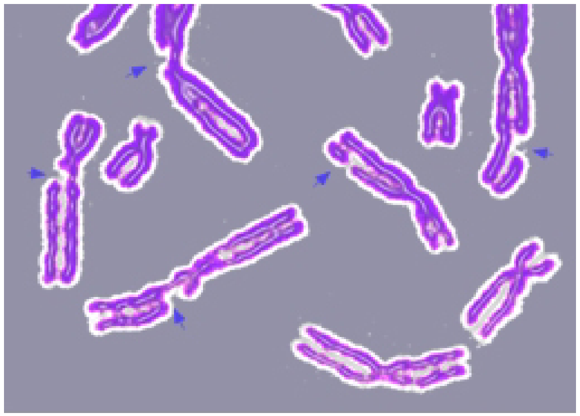


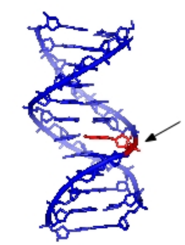
Particle Accelerators

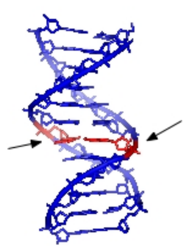
Potential Risks:

- For high energy accelerators, secondary radiation fields can be very dangerous: often, access to the machine is not allowed during operation
- For low energy (medical) accelerators, long exposure can have health effects
- Large accelerators often use dangerous liquids for coolant

Radiation Health Risks







Radiation damages cells by causing breaks in DNA strands

- A single strand break can be repaired
- A double strand break is difficult to repair and often means the cell cant reproduce
- Damage to DNA can lead to mutations (like cancer)

Radiation Health Risks

The only real way to avoid these effects is to limit radiation exposure by:

- Avoiding irradiated areas
- Monitoring exposure
- Taking precautions (breathing apparatus to avoid airborne radioactive particles, regular washing of hands etc)

However, this is easy to do!

The LUPIN

- My detector is used for Radiation protection
- This means it is used to tell if a radiation field is safe, only safe for short time periods or unsafe
- Dose limit for a member of the public is **1 mSv** per year
- For radiation workers, the limit is **20 mSv**
- Standard unit of measure of radiation for radiation protection is 'Ambient Dose Equivalent', expressed in Sieverts (Sv)

Man's Exposure To Ionising Radiation	
Source Of Exposure	**Exposure**
Natural Radiation (terrestrial and airborne)	1.2 mSv per year
Natural Radiation (cosmic radiation at sea level)	0.3 mSv per year
Total Natural Radiation	**1.5 mSv per year**
Seven hour aeroplane flight	0.05 mSv
Chest X-ray	0.04 mSv
Nuclear Fallout (from atmospheric tests in 50's & 60's)	0.02 mSv per Year
Chernobyl (people living in Control Zones near Chernobyl)	10 mSv per year
Cosmic Radiation Exposure of Domestic Airline Pilot	2 mSv per year

http://www.arpansa.gov.au/radiationprotection/factsheets/is_rad.cfm#8

And now for something completely different…

What do scientists actually DO…?

- Basic scientific formula: have an idea, test the idea, fix any problems, repeat
- This means we split our time between working in an office and travelling to experimental facilities
- To present results, we travel to conferences and give talks or show posters
- This is all usually paid for by the institution!

And now for something completely different…

Basically, all this means a lot of paid travelling:

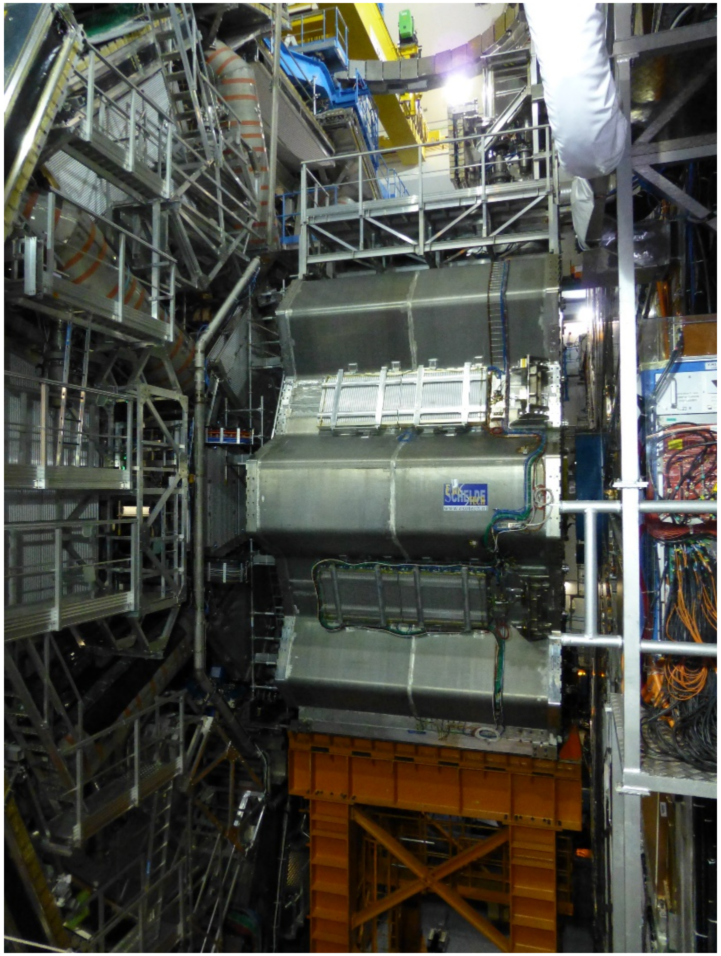
- I have attended conferences in Korea, Germany, Italy, Australia, Austria, Greece, France
- I have done experiments at 5 different experimental facilities in 3 countries (including CERN)

CERN

WHERE THE WEB WAS BORN
In the offices of this corridor, all the fundamental technologies of the World Wide Web were developed.
Started in 1990 from a proposal made by Tim Berners-Lee in 1989, the effort was first divided between an office in building 31 of the Computing and Networking Division (CN) and one in building 2 of the Electronics and Computing for Physics Division (ECP).
In 1991 the team came together in these offices, then belonging to ECP. It was composed of two CERN staff members, Tim Berners-Lee (GB) and Robert Cailliau (BE), aided by a number of Fellows, Technical Students, a Coopérant and Summer Students.
At the end of 1994 Tim Berners-Lee left CERN to direct the WWW Consortium (W3C), a world-wide organization devoted to leading the Web to its full potential. The W3C was founded with the help of CERN, the European Commission, the Massachusetts Institute of Technology (MIT), the Institut National pour la Recherche en Informatique et en Automatique (INRIA), and the Advanced Research Projects Agency (ARPA).
In 1995 Tim Berners-Lee and Robert Cailliau received the ACM Software System Award for the World Wide Web. In 2004, Tim Berners-Lee was awarded the first Millenium Technology Prize by the Finnish Technology Award Foundation.
The CERN Library
June 2004

CERN (ATLAS)

CERN (ATLAS)



Milan

Vienna

Vienna

Korea (Seoul)

POLITECNICO MILANO

Centre for Medical Radiation Physics

Korea (DMZ)

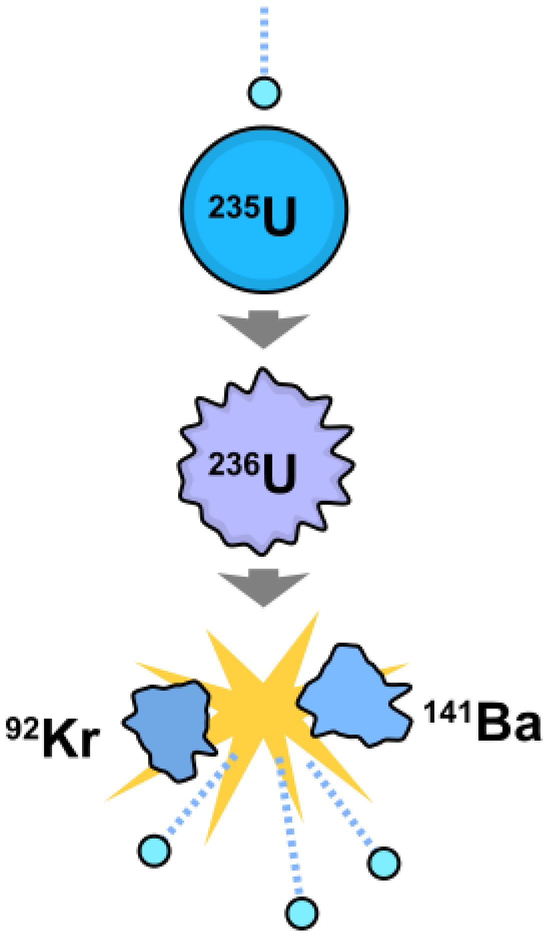

NORTH
KOREA
Military
Demarcation
Line
Demilitarized Zone (DMZ)
2nd Tunnel
4th Tunnel
38th Parallel
1st Tunnel
3rd Tunnel
SOUTH
KOREA

Q & A

Q: Is it possible for Uranium deposits to form a self sustaining nuclear reaction?

Well, how does a reactor work?

- Natural Uranium contains a mixture of the isotopes ^{235}U & ^{238}U
- ^{235}U can absorb a stray neutron (becoming ^{236}U), and then decays producing an average 2.4 neutrons and releasing heat
- With a high enough concentration of ^{235}U, a chain reaction of these decays will occur, as the neutrons released from a reaction are captured by another ^{235}U atom

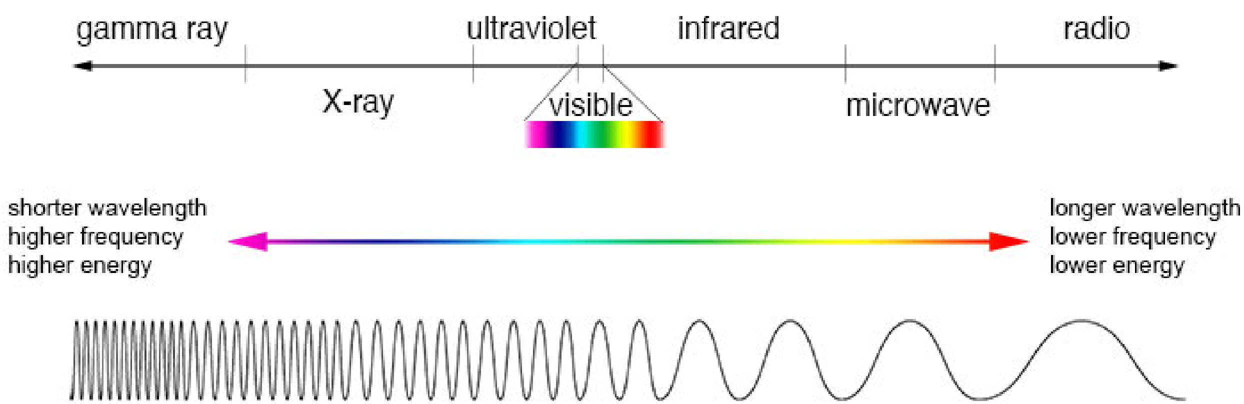


Q & A

A: Oklo, Africa

Due to the properties of the Uranium deposit, it is believed that 1.7 billion years ago, this deposit formed a natural reactor. It is thought that it ran for 100000 years and produced a continuous 100 kW of power (smallest NPP in the US produces 507 MW)

Q & A



Q: In Lego DC Marvel Superheroes, Lex Luthor and the Joker make a substance that tricks Batman into following what he thinks is Kryptonite. Is it possible to have some compounds made that can replicate the properties of elements?

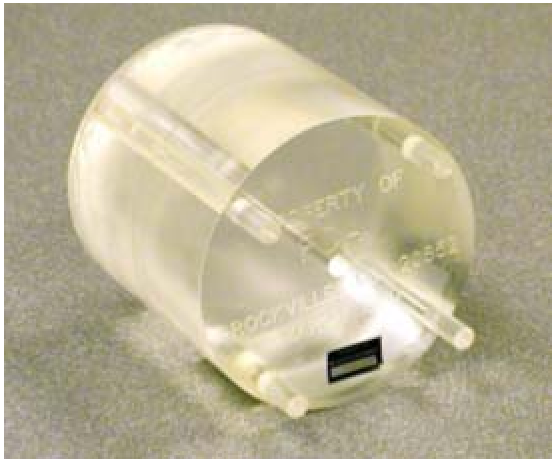
Well, it depends on which properties…

With radiation, the usual method of identification is the type and energy of the radiation (this is called 'spectroscopy' which refers to the spectrum of energies of the radiation)

Q & A

For other properties, such as the density and structure of the material, it can be a bit more complicated.

In the medical field, we use a ‘Phantom’ to simulate the human body for testing of accelerators and detectors. This can be water or a solid material like Perspex. As the body is mostly water, the radiation ‘sees’ a material that has the same properties as the human body. This means we don’t have to irradiate people just to test equipment.



Q & A

Any further questions?

Thanks for your attention!

Backup 1: Banana Equivalent Dose

BED is a 'joke' unit made up to illustrate the presence of low levels of radioactivity in food

- All bananas contain a small amount of the naturally occurring ^{40}K radioactive isotope
- 1 BED = 0.1 µSv in Ambient Dose Equivalent
- Therefore, to reach the exposure limit for a member of the public 10000 bananas would have to be eaten!
- On top of this, the Potassium from the Banana is filtered and expelled from the body after only a few hours…

SO: In order to receive a limiting dose, you would have to eat 10000 bananas / 3 hours = **0.92 bananas per second or 56 bananas per minute!**