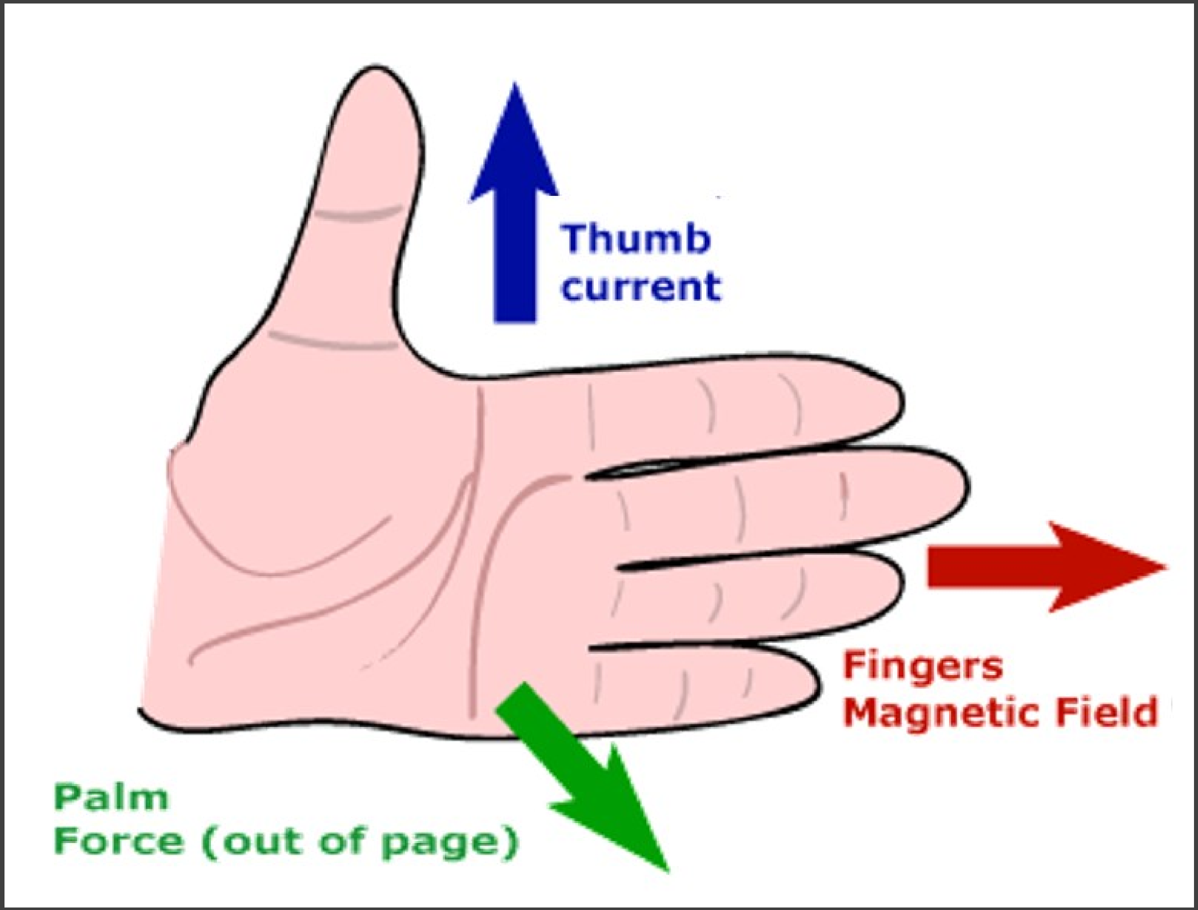
Particles ACCELERATORS

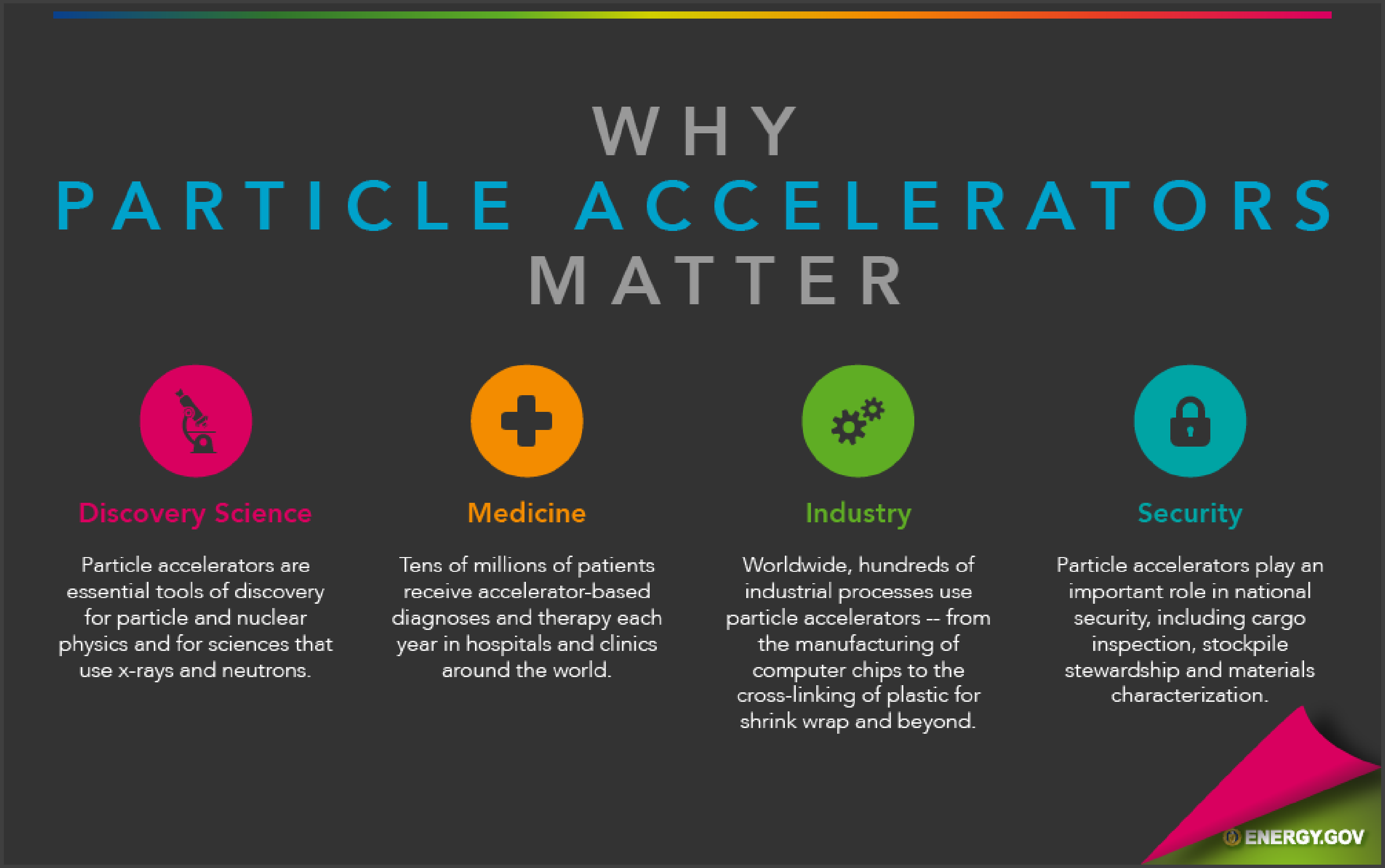
Higher Physics



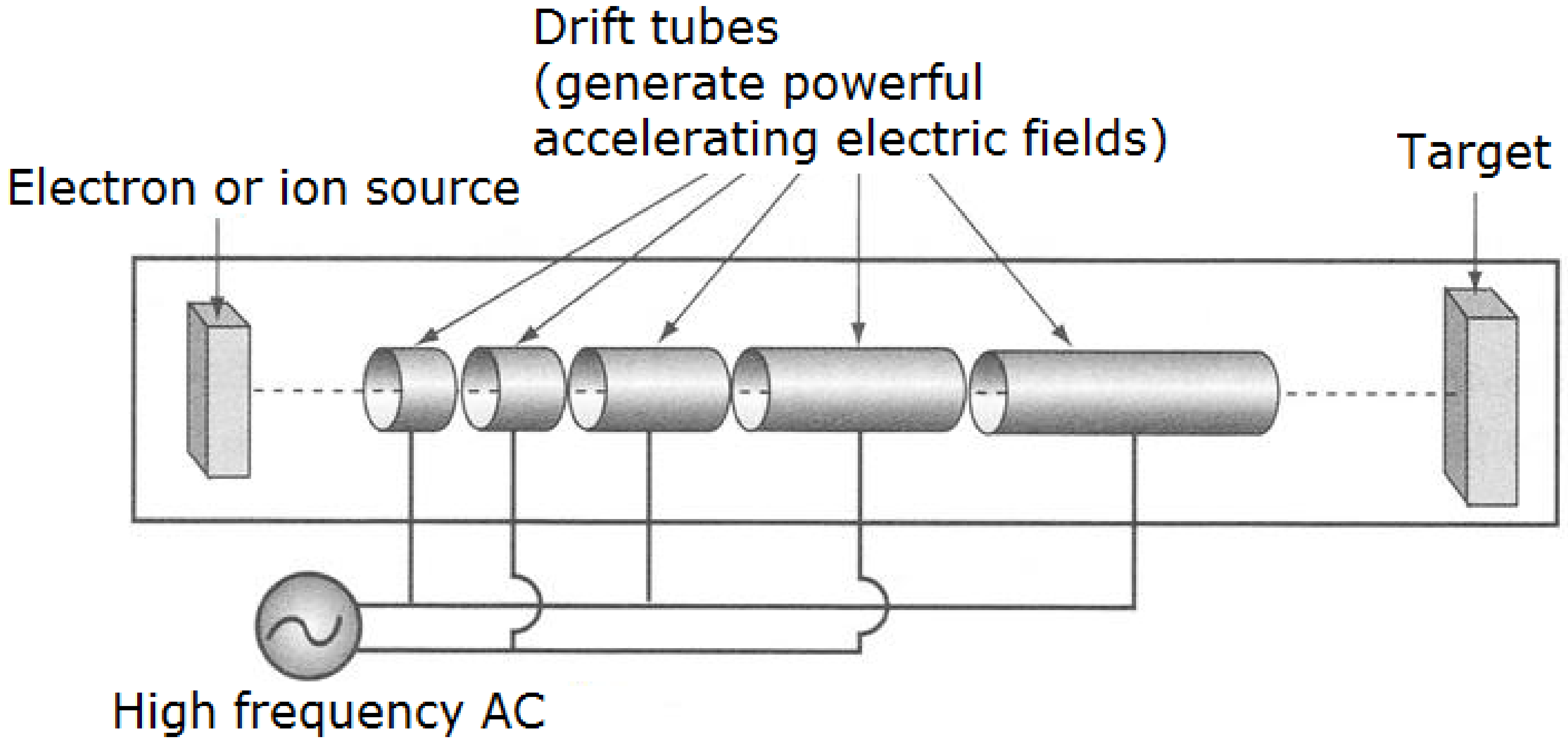
LEFT HAND SLAP METHOD.

- **The Left-hand Slap Rule where the four fingers of the left point in the direction of the magnetic field B and the thumb points in the direction of the electron current I, the direction of slapping would be the direction of force F on the conductor.**


- partic
Not as much pain (negative)
Force
HIT ON TABLE
FIELD
SLAP NEGATIVE



- Scientists use particle accelerators to study the origins of the universe, investigate the subatomic structure of the world around us and advance research in medicine, environmental clean-up and more.



Linear accelerator

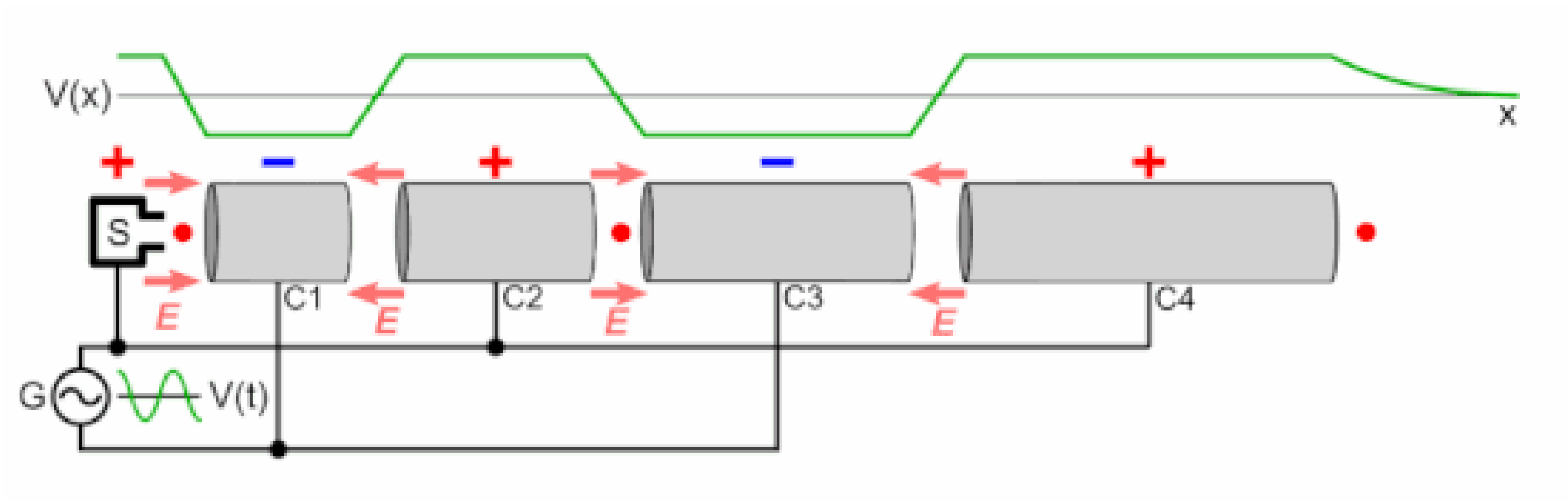
The particles pass through a line of hollow metal tubes enclosed in a long-evacuated cylinder.

The frequency of the alternating voltage is set so that the particle is pushed forward each time it goes through a gap between two of the metal drift tubes.

The largest linac in the world, at Stanford University in the USA, is 3.2km long.

Linear accelerator

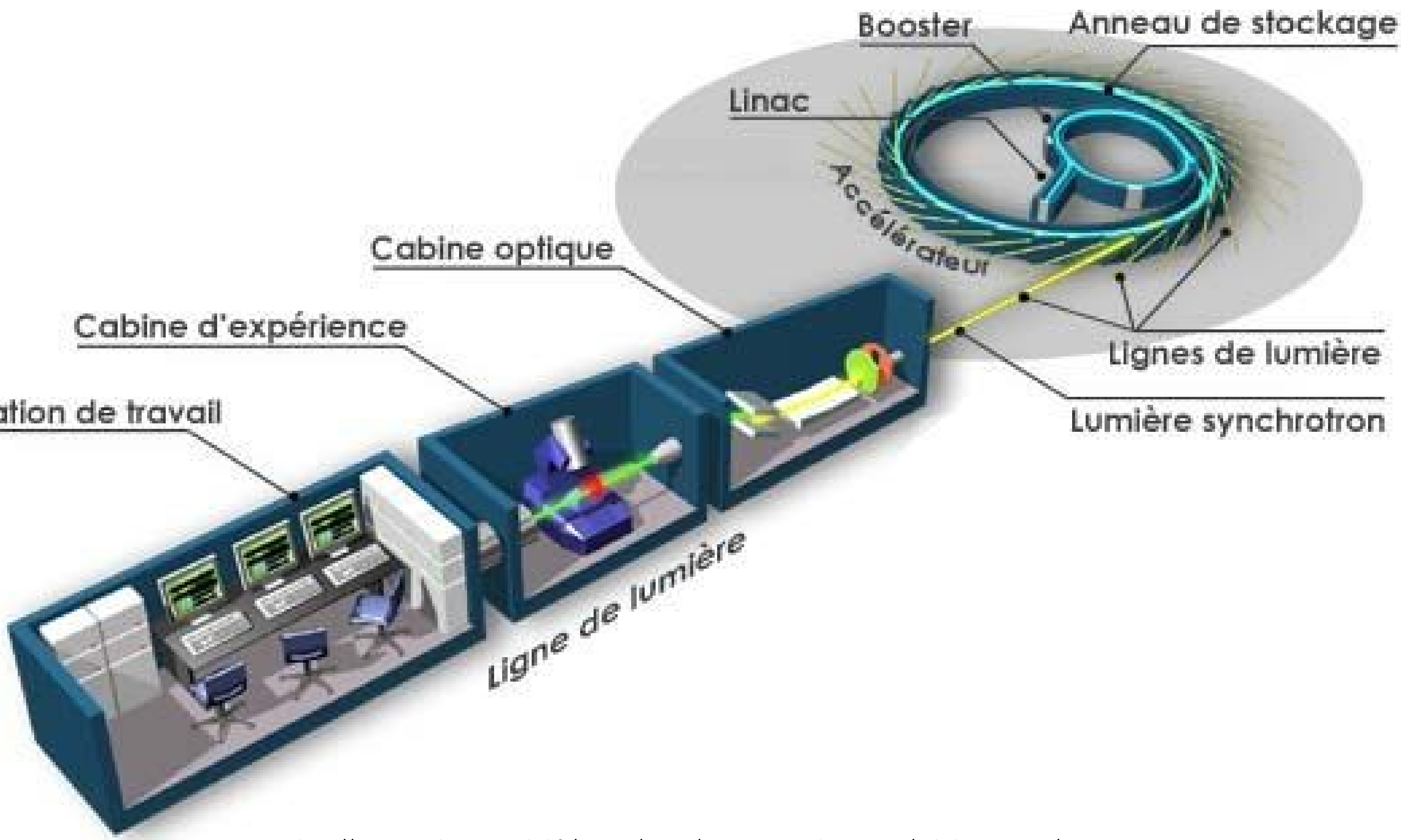
Particle accelerators are used to produce CHARGED nuclear particles with high kinetic energies. Two particle beams may then be made to collide 'head on' and the interaction can produce other nuclear particles and/or nuclear reactions.



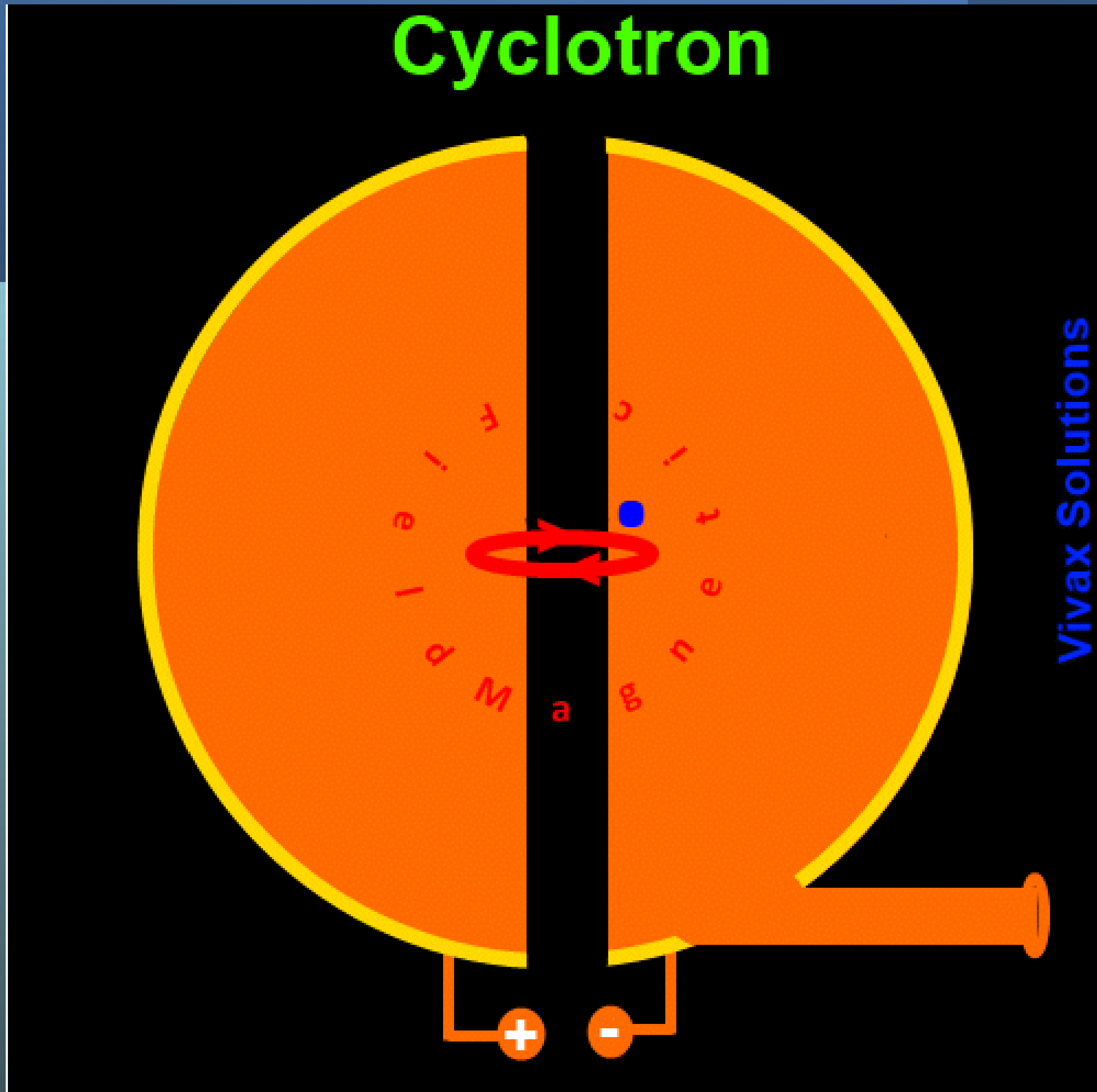
AC is constant frequency

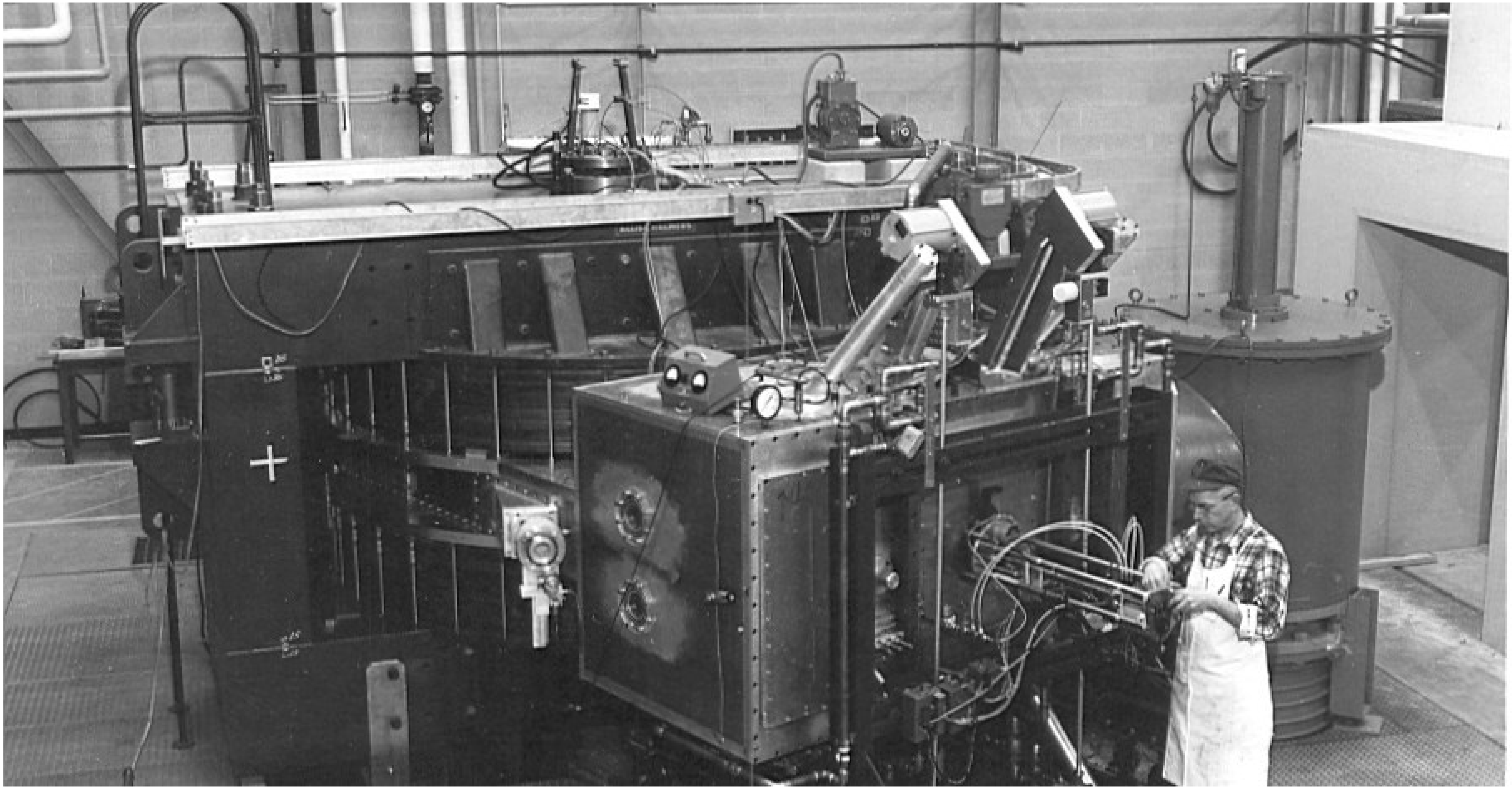
- https://upload.wikimedia.org/wikipedia/commons/thumb/0/08/Linear_accelerator_animation_16frames_1.6sec.gif/550px-Linear_accelerator_animation_16frames_1.6sec.gif

Linear accelerator



http://www.synchrotron-soleil.fr/images/Image/RessourcesPedagogiques/Soleil3Questions/image013.jpg

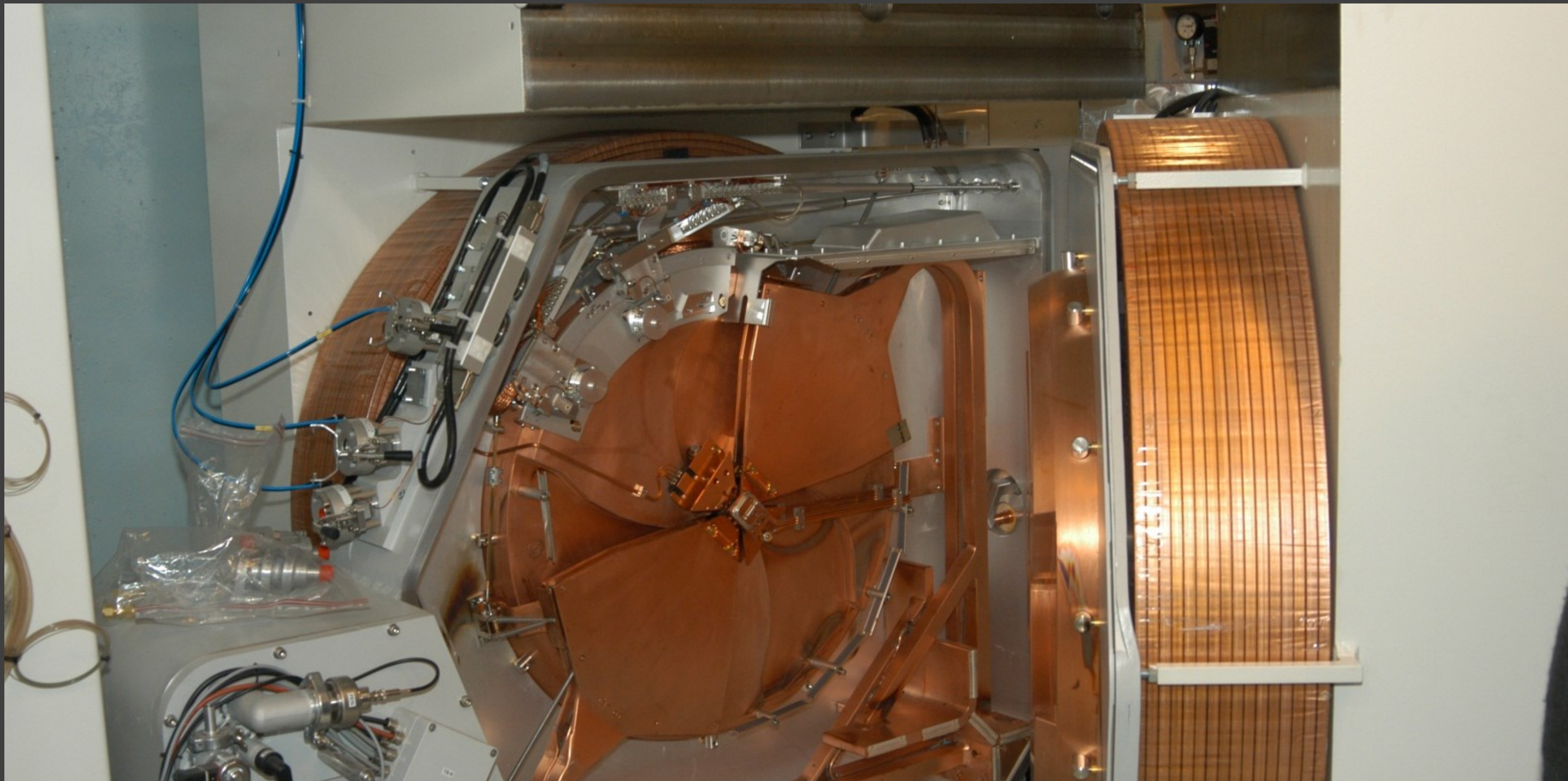

Cyclotron
Magnetic Field
Vivax Solutions
+
-



1969 at Michigan state National Superconducting Cyclotron Laboratory

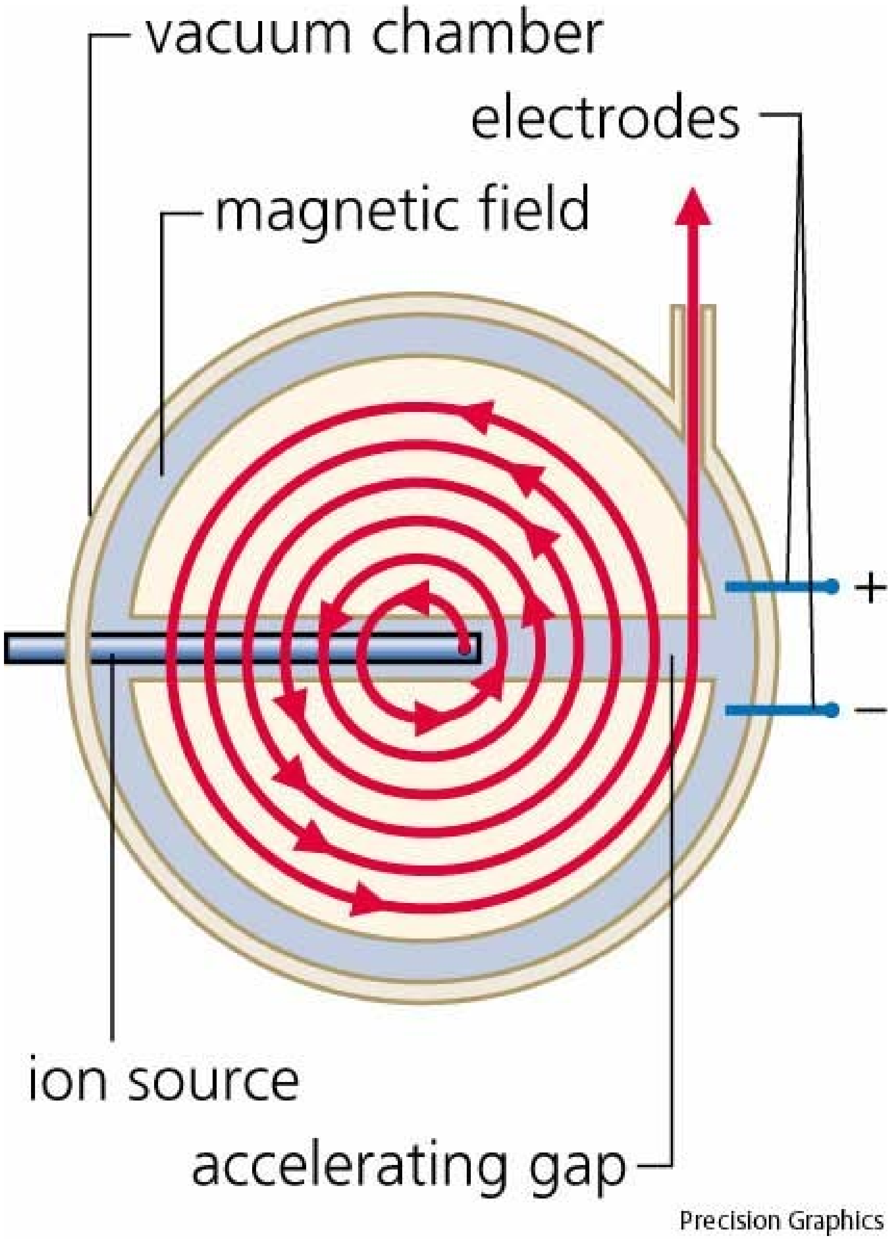
From outside

- http://www.pennmedicine.org/perelman/images/proton/cyclotron.jpg

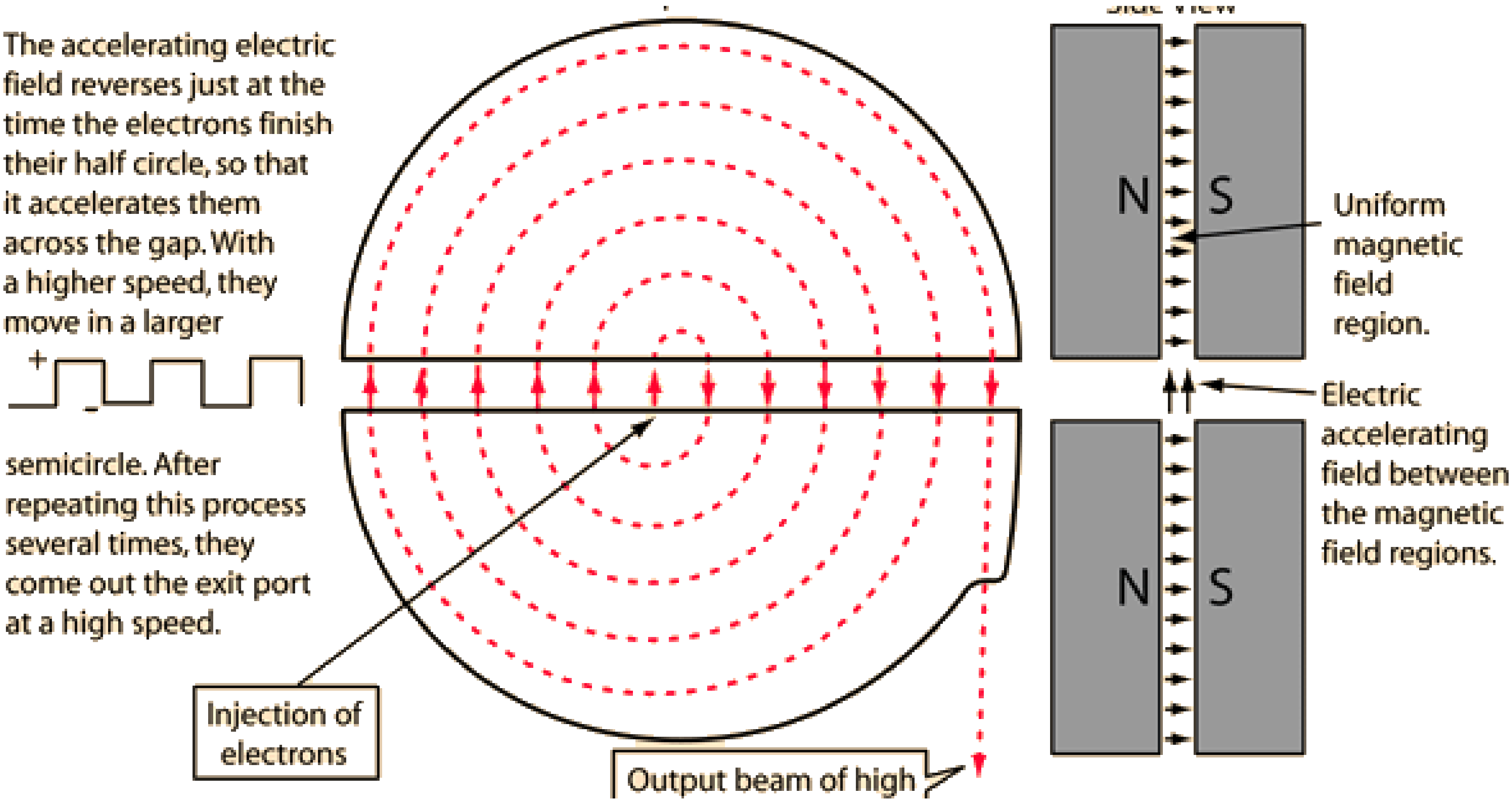


Inside

Inside

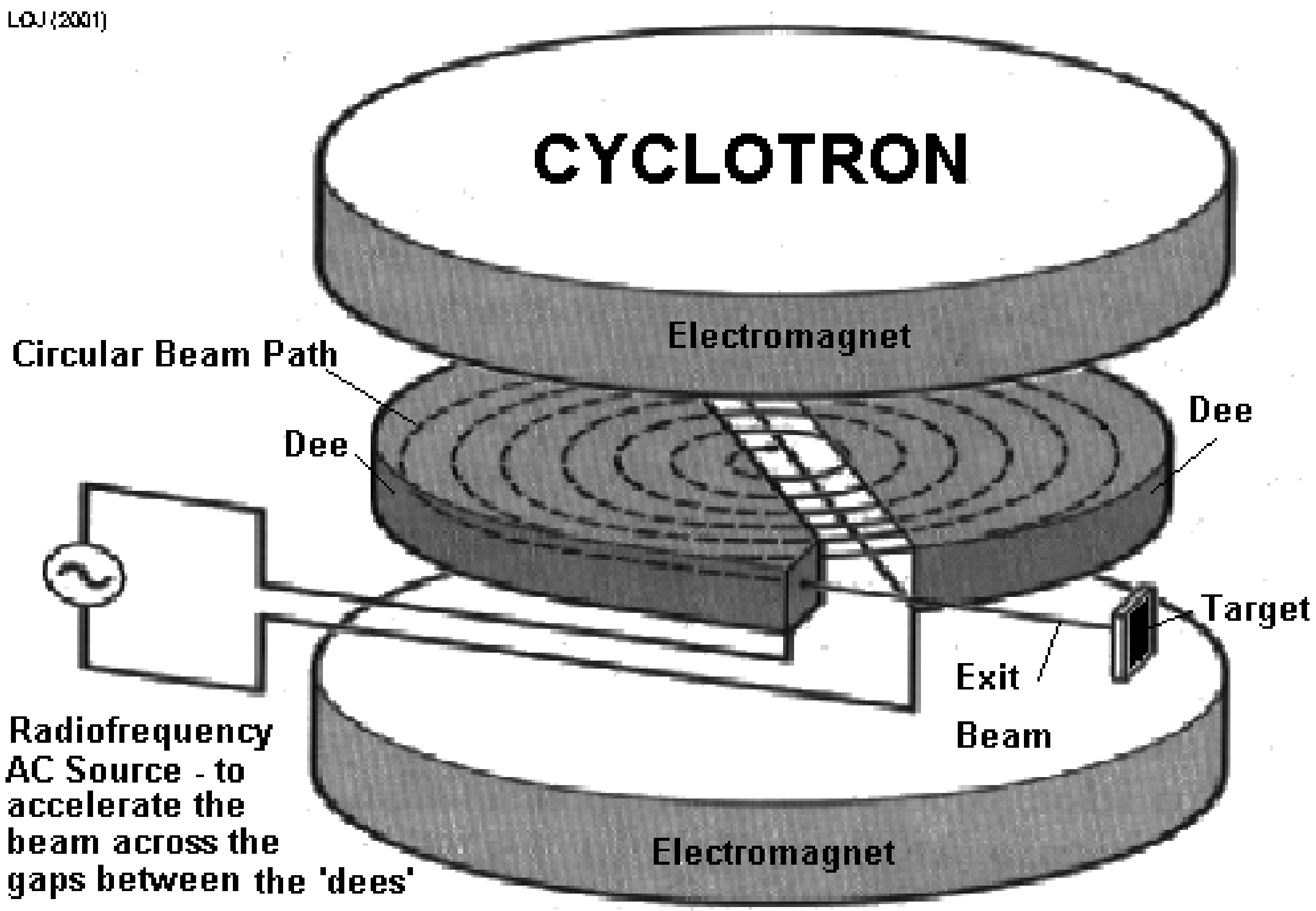


http://content.answcdn.com/main/content/img/ahd4/A4cyctrn.jpg



Cyclotron

Hence the “double D”



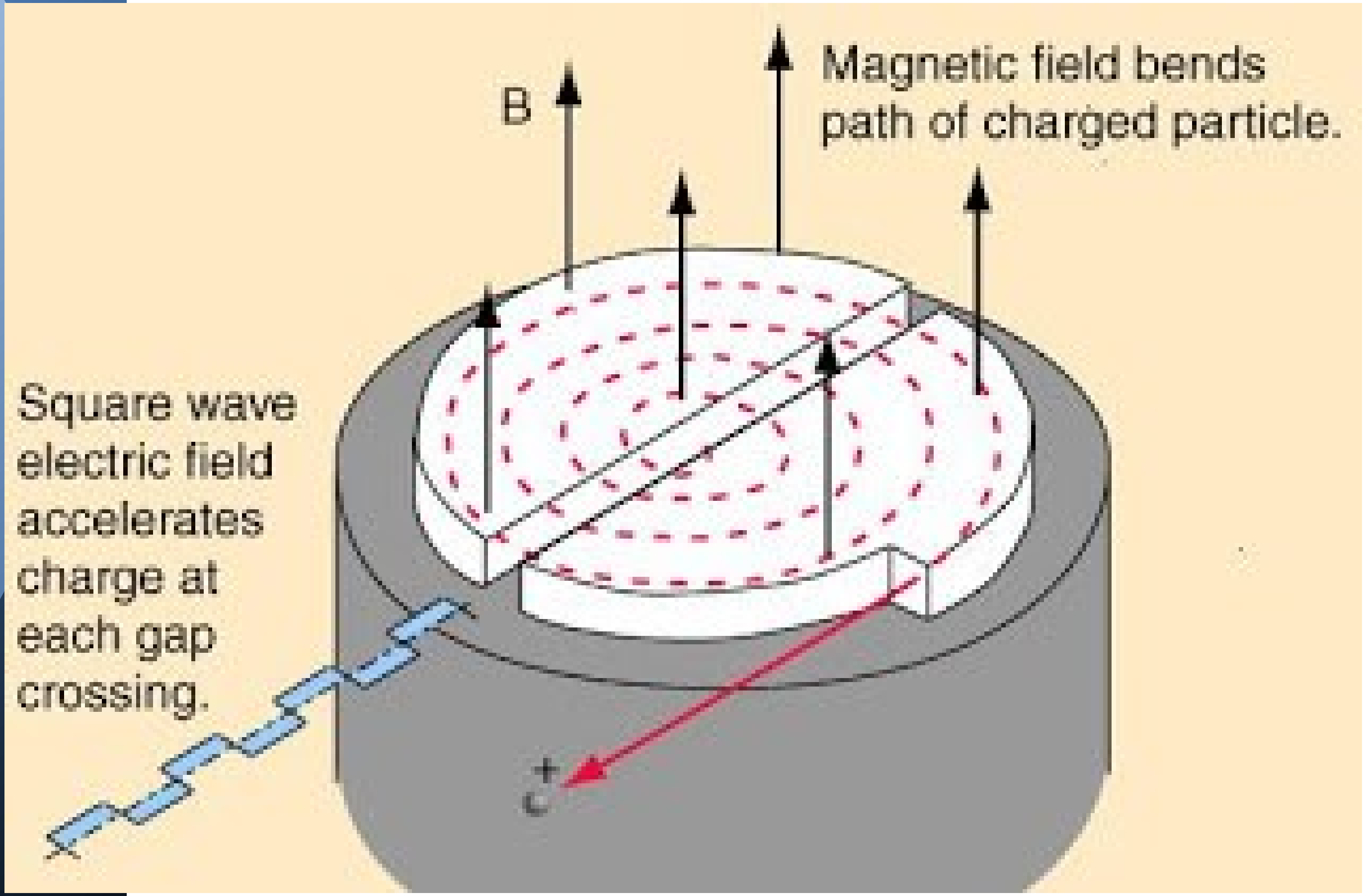
Exploded Schematic

http://www.cyberphysics.co.uk/topics/atomic/Accelerators/Cyclotron/cycfig.gif

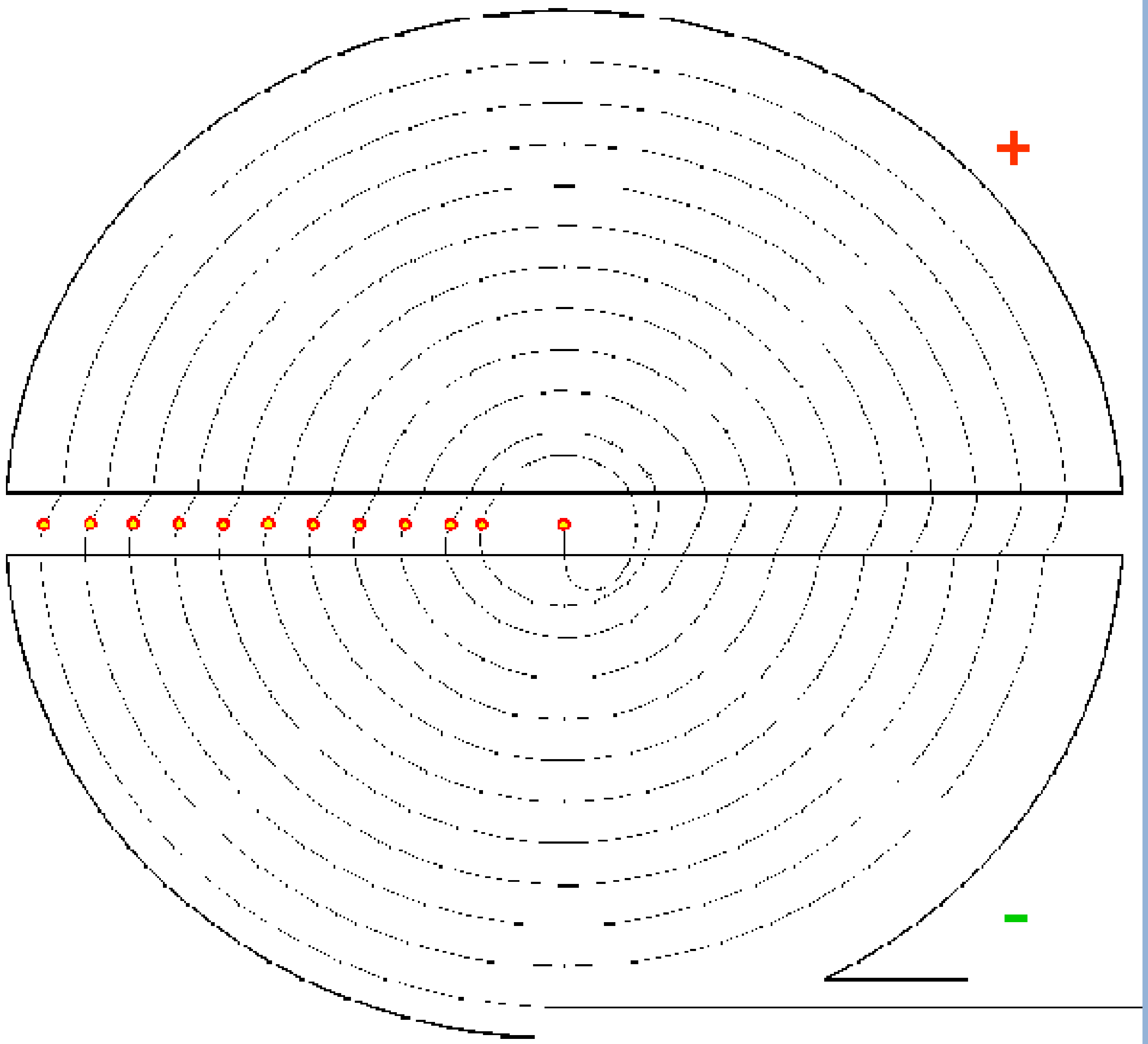
Cylotron and synchrotron

Linear accelerators have limitations when the speed or energy of the particles become very large. Due to relativisitc effects it is common to work with energies of particles rather than their speeds. The unit of energy used is often the electron-volt (eV). (1 eV is the energy gained when 1 electron is moved through a p.d. of 1 V. So 1 eV = $1.6 \times 10^{-19} \times 1 = 1.6 \times 10^{-19}$ J. Typical energies are in MeV or TeV !)

AC applied across gap



http://1.bp.blogspot.com/_eAzT4VdyVNk/SQa1b44JZxI/AAAAAAAAAIA/3Kbxun2e1DQ/s320/cyclotron.JPG



http://jol.liljenzin.se/CYCLOTR/CYCLOANI.HTM

Cyclotron model

Cyclotron - Key points

Electric field accelerates proton across gap

Need AC as protons cross from side to side

Magnetic field keeps protons in circular motion to recycle

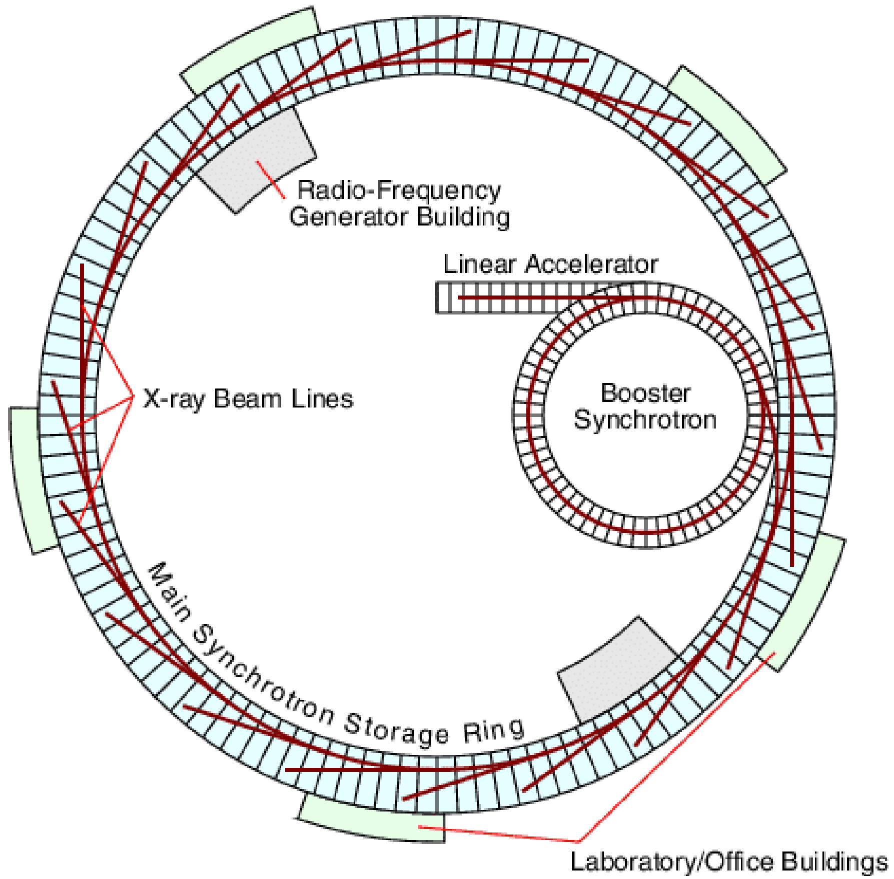
Time for each semicircle is constant.

Once radius is large enough proton escapes to target.

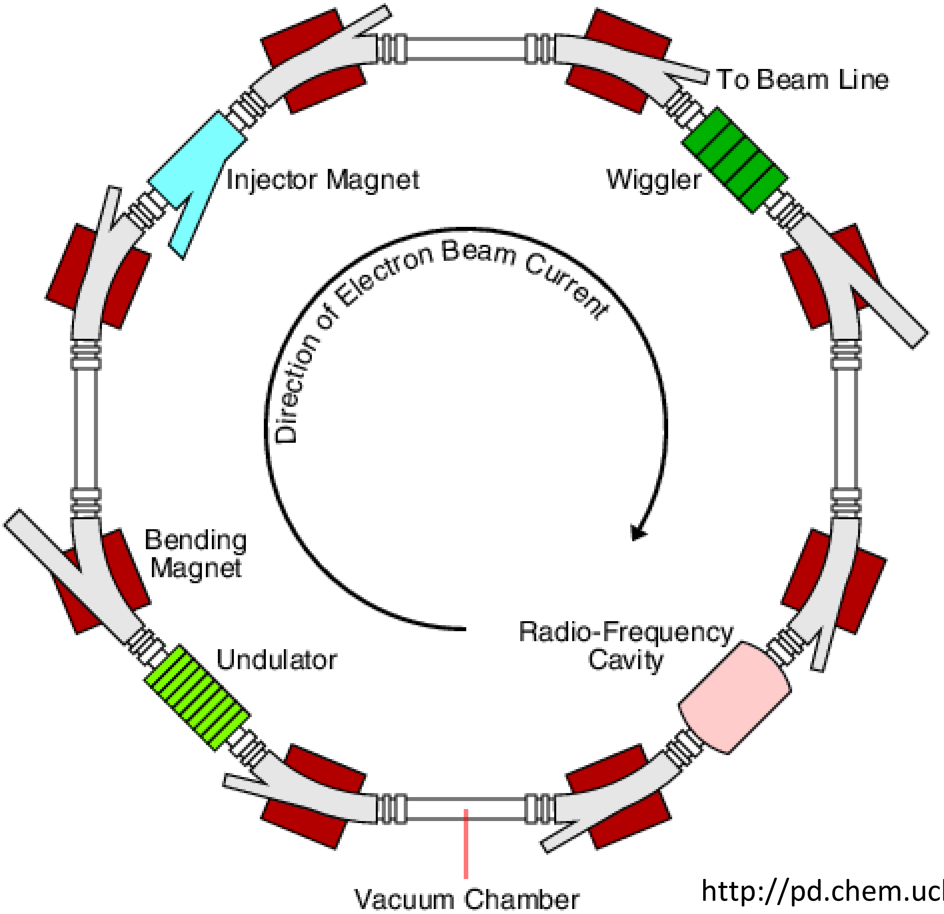
Grenoble

Synchrotron layout

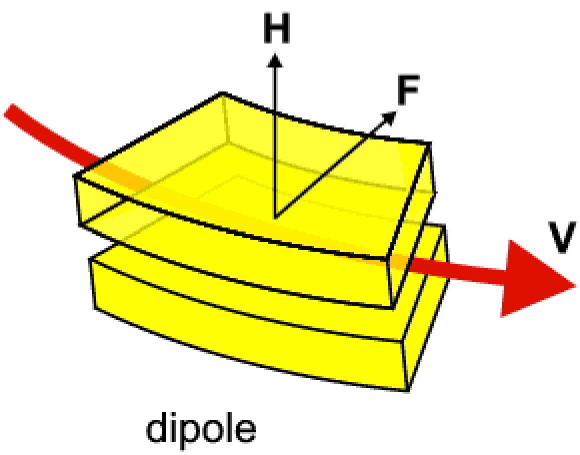
- http://pd.chem.ucl.ac.uk/pdnn/inst2/plan.gif



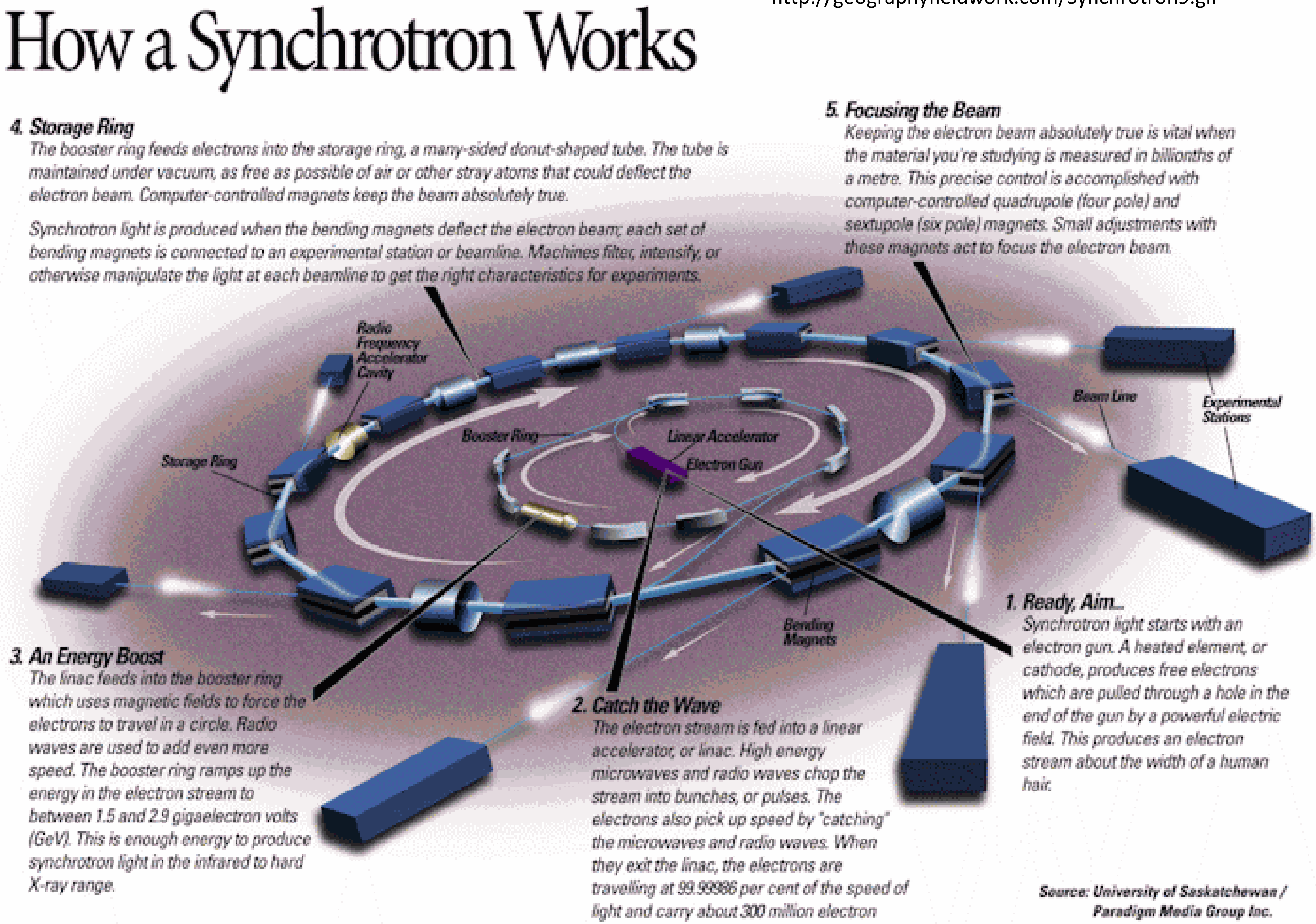
Synchrotron components



- Dipole



http://pd.chem.ucl.ac.uk/pdnn/inst2/work.htm http://geographyfieldwork.com/Synchrotron9.gif



Elettra Synchrotron, Trieste

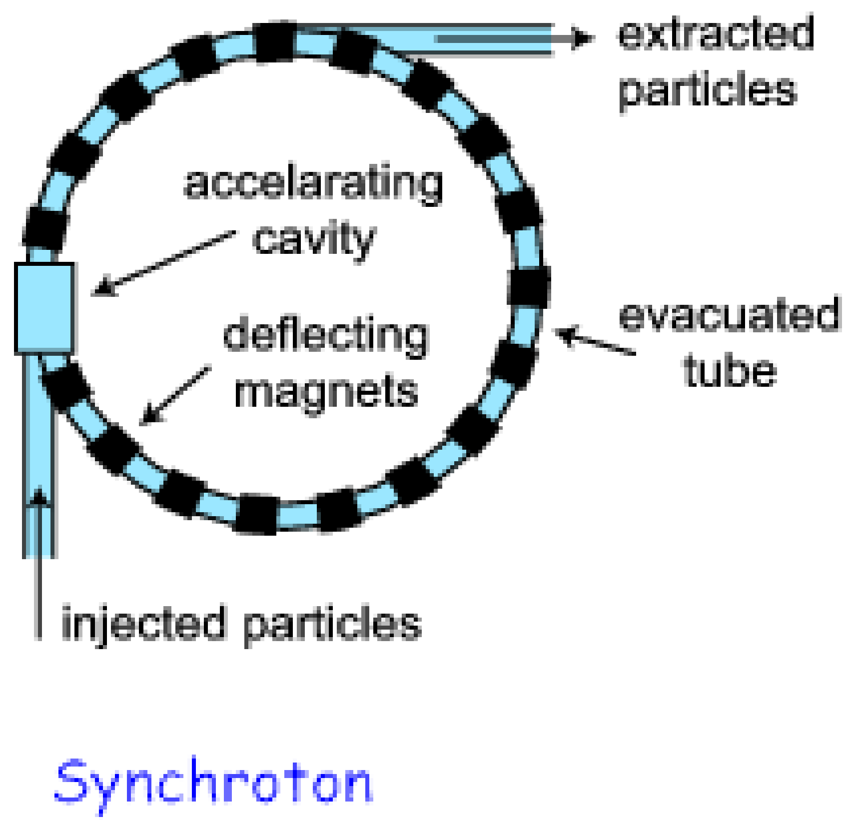
https://www.youtube.com/watch?v=I4NSF-gkKCU (4 mins)

synchrotron
- Key points

- Electric fields accelerate particles at different parts in the loop.
- Need multiple accelerators
- Magnetic field keeps particles in circle
- Both fields need to be changed as speed increases.
- Particles can be diverted at different points.

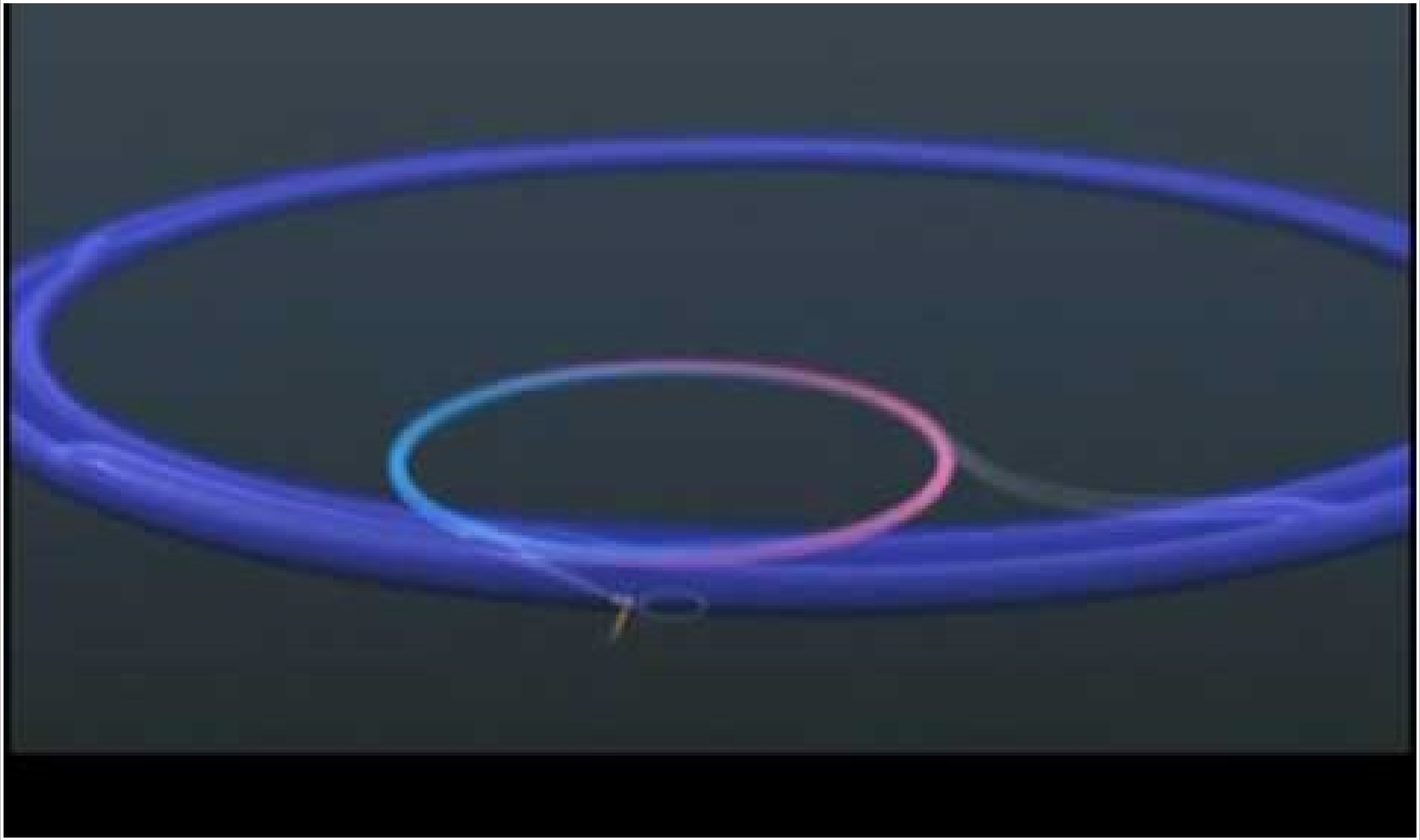
- The synchrotron is more powerful and more advanced.
- The largest and most powerful synchrotron in the world is at CERN near Geneva in Switzerland

A synchrotron consists of a tube in the shape of a large ring through which the particles travel.



▼

- Strong **magnets** keep the particles moving through the centre of the tube.
- The particles enter the tube after already having been accelerated (usually by a linac).
- The particles enter acceleration cavities (**electric fields**) driven by a high frequency oscillator as they travel around the accelerator.
- The strengths of the magnets surrounding the ring is increased as the particles gain energy, taking account of the relativistic increase in the mass of the particles (hence the name synchrotron).
- The particles can be steered out of their orbit using magnets and directed towards a target.
- At CERN, a synchrotron allows for collisions between particles travelling in opposite directions around its ring. The energy associated with colliding beams is much greater than that involving a stationary target.



CERN LHC

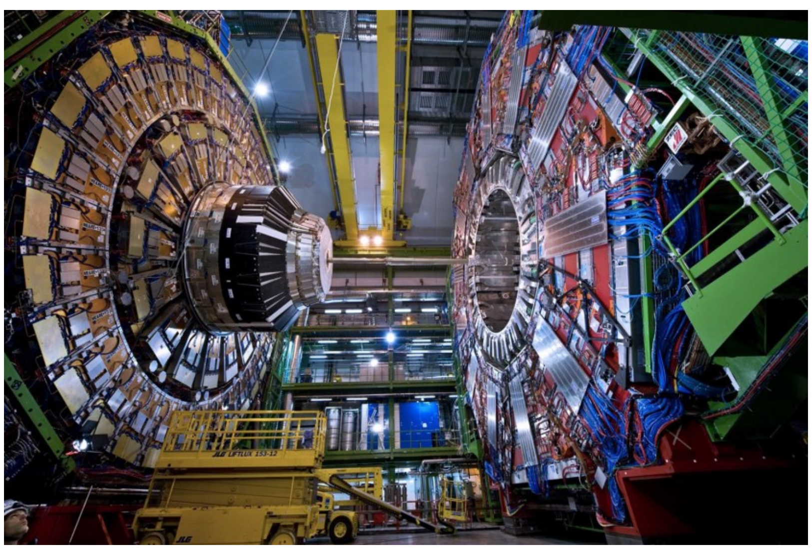
Tracks and the ATLAS detector

What does it detect?

How does it work?

How big is it?

What has it discovered?



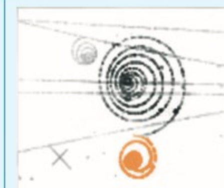
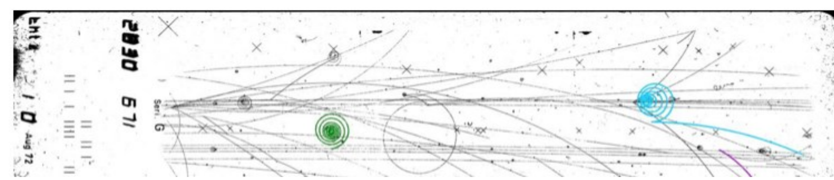
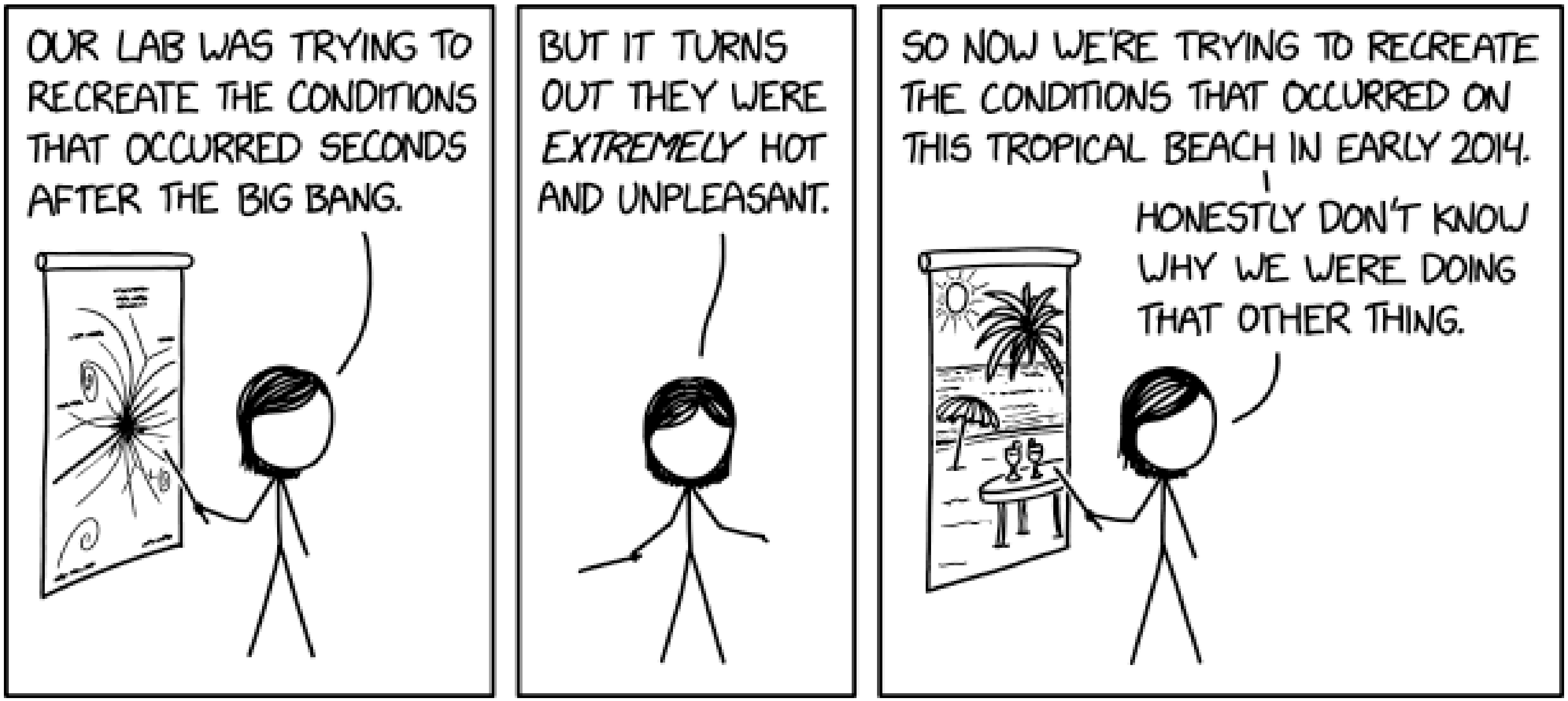
	Electron	Electron-positron pair	Proton
Signature track			
Description	Upward-curving track, starting at another visible particle track	Downward-curving track (positron) starting 'out of nowhere', together with an upward-curving track (electron)	Downward-curving track, starting at the visible track of another particle
Production process	An electrically charged particle enters the chamber and interacts with an electron in the liquid.	A photon transforms into an electron-positron pair. (The photon does not leave a track.)	An electrically charged particle enters the chamber and interacts with a proton in the liquid.

Table 1: Particle signatures and production processes



https://www.scienceinschool.org/content/track-inspection-how-spot-subatomic-particles https://imgs.xkcd.com/comics/recreate_the_conditions.png



Particle Accelerators

Higher SQA content

Knowledge that a moving charge produces a magnetic field.

Determination of the direction of the force on a charged particle moving in a magnetic field for negative and positive charges.

Knowledge of the basic operation of particle accelerators in terms of

acceleration by electric fields,	deflection by magnetic fields and	high-energy collisions of charged particles to produce other particles.

Virtual Higher Physics

Standard model - Summary

Electric field

The electric field shown is around a single ______ charge.

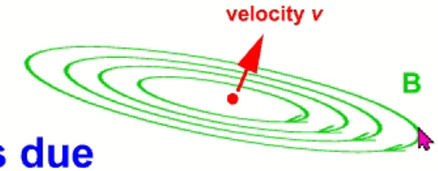
All moving and stationary ______ particles have an electric field.

The force on a charged particle in an electric field is ______ to the lines of electric field.

A charged particle will gain ______ energy when accelerated across a p.d. of *V* volts.

The energy gained by a charged particle ______ by an electric field across a p.d. of *V* volts is *Q* x *V*.

Magnetic field



The magnetic field shown is due to a ______ charge.

The arrow on a line of magnetic field shows the direction the ______ pole of a magnet would point.

The force on a moving charged particle in a magnetic field is ______ to the lines of magnetic field. The force is also perpendicular to the ______ of the particle.

There is no force on a charged particle moving parallel to the lines of ______ field.

The 27 km accelerator in the Large Hadron Collider is a ______.

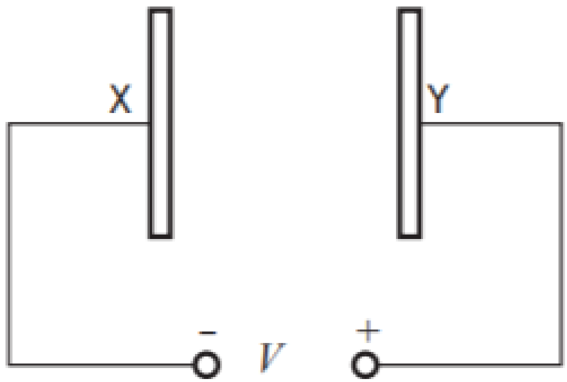
charged	negative	synchroton	potential	magnetic	north	perpendicular
parallel	velocity	moving	kinetic	positive	south	accelerated

Click and drag the words into the correct space.

There are 11 blanks in this summary.

You have correctly completed - 0

10. Two parallel metal plates X and Y in a vacuum have a potential difference V across them.



An electron of charge e and mass m, initially at rest, is released from plate X.

The speed of the electron when it reaches plate Y is given by

A $\frac{2eV}{m}$

B $\sqrt{\frac{2eV}{m}}$

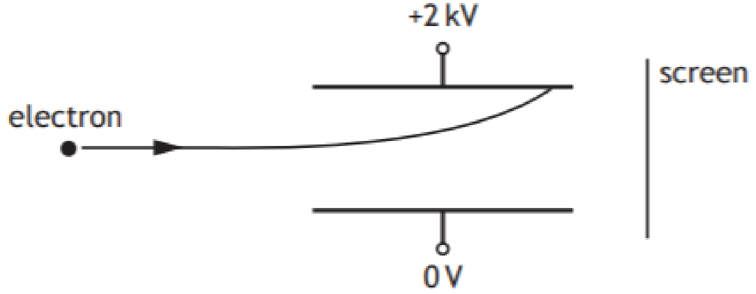
C $\sqrt{\frac{2V}{em}}$

D $\frac{2V}{em}$

B

11. A potential difference of 2 kV is applied across two metal plates.

An electron passes between the metal plates and follows the path shown.



A student makes the following statements about changes that could be made to allow the electron to pass between the plates and reach the screen.

I Increasing the initial speed of the electron could allow the electron to reach the screen.

II Increasing the potential difference across the plates could allow the electron to reach the screen.

III Reversing the polarity of the plates could allow the electron to reach the screen.

Which of these statements is/are correct?

A I only

B II only

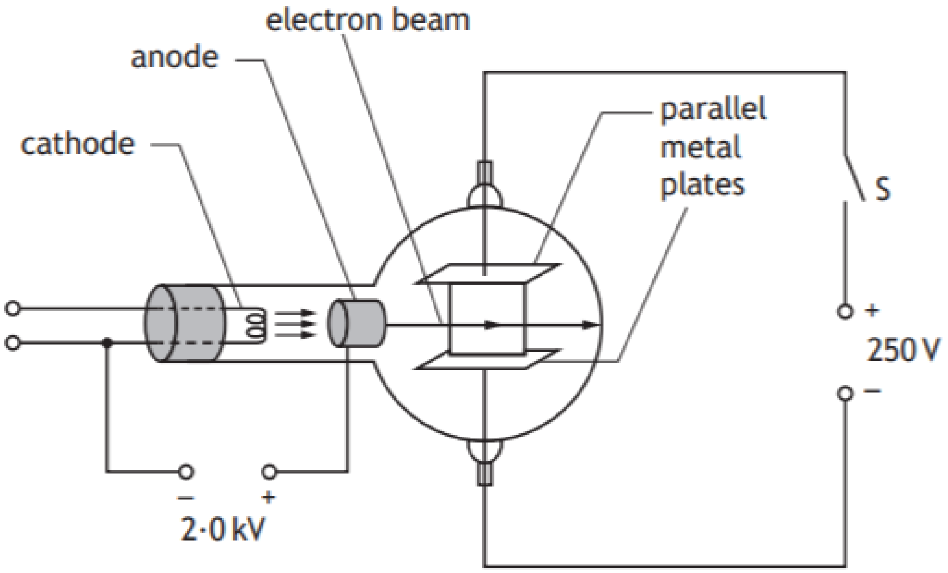
C III only

D I and II only

E I and III only

A

7. An experiment is set up to investigate the behaviour of electrons in electric fields.



(a) Electrons are accelerated from rest between the cathode and the anode by a potential difference of 2·0 kV.

Calculate the kinetic energy gained by each electron as it reaches the anode. **3**

(b) The electrons then pass between the two parallel metal plates.

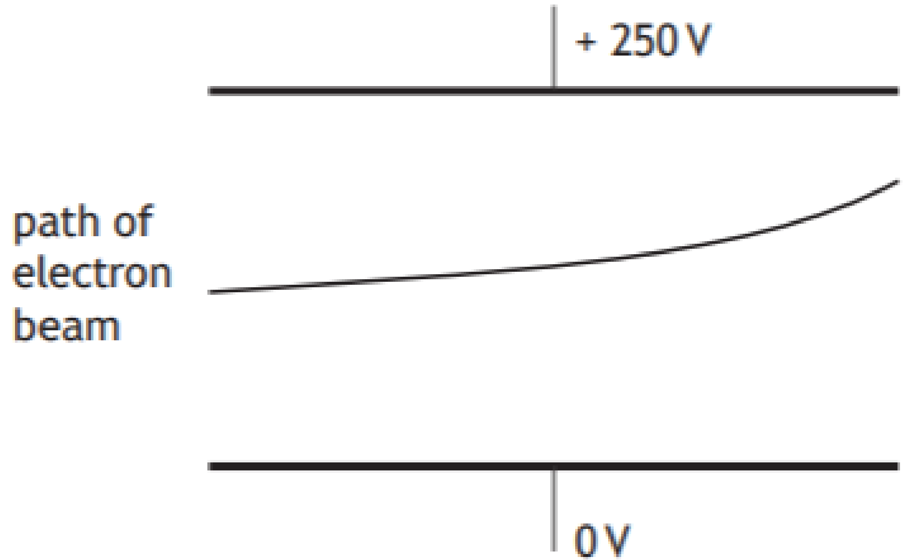
The electron beam current is 8·0 mA.

Determine the number of electrons passing between the metal plates in one minute.

(c) The switch S is now closed.

The potential difference between the metal plates is 250 V.

The path of the electron beam between the metal plates is shown.



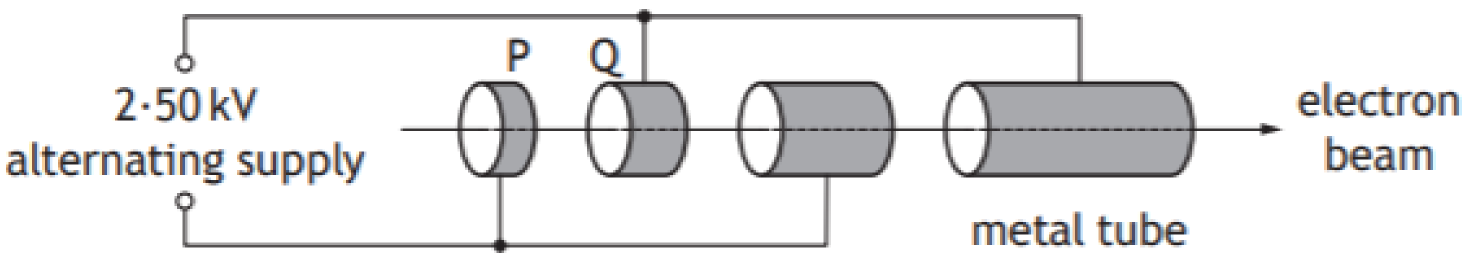
Complete the diagram to show the electric field pattern between the two metal plates. 1

Question			Answer	Max Mark	Additional Guidance
7.	(a)		$W = QV$ (1) $= 1 \cdot 6 \times 10^{-19} \times 2000$ (1) $= 3 \cdot 2 \times 10^{-16}\ J$ (1)	3	Sig figs: Accept 3×10^{-16}, $3 \cdot 20 \times 10^{-16}$, $3 \cdot 200 \times 10^{-16}$, Ignore negative sign for charge.
	(b)		$Q = It$ (1) $= 0 \cdot 008 \times 60$ (1) $= 0 \cdot 48\ (C)$ (1) $number = \frac{0 \cdot 48}{1 \cdot 6 \times 10^{-19}}$ $= 3 \cdot 0 \times 10^{18}$ (1)	4	Sig figs: Accept 3×10^{18} If the response stops at 0·48 then a correct unit is required. Candidates can arrive at this answer by alternative methods eg P=IV and E=Pt **OR** Q=It to calculate the time for 1 electron.
	(c)		Straight lines with arrows pointing downwards.	1	spacing should be approximately equal (ignore end effect) Field lines must start and finish on the plates Lines at right angles to the plates

8. X-ray machines are used in hospitals.

An X-ray machine contains a linear accelerator that is used to accelerate electrons towards a metal target.

The linear accelerator consists of hollow metal tubes placed in a vacuum.



Electrons are accelerated across the gaps between the tubes by an alternating supply.

(a) (i) Calculate the work done on an electron as it accelerates from P to Q.

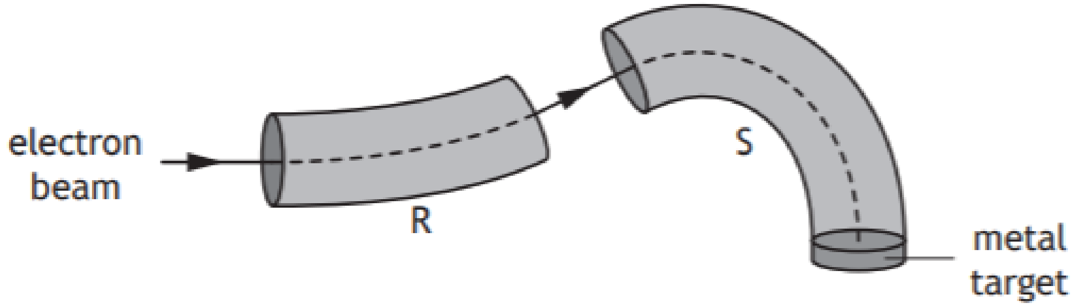
Space for working and answer

(ii) Explain why an alternating supply is used in the linear accelerator.

(b) The electron beam is then passed into a "slalom magnet" beam guide. The function of the beam guide is to direct the electrons towards a metal target.

Inside the beam guides R and S, two different magnetic fields act on the electrons.

Electrons strike the metal target to produce high energy photons of radiation.



(i) Determine the direction of the magnetic field inside beam guide R. **1**

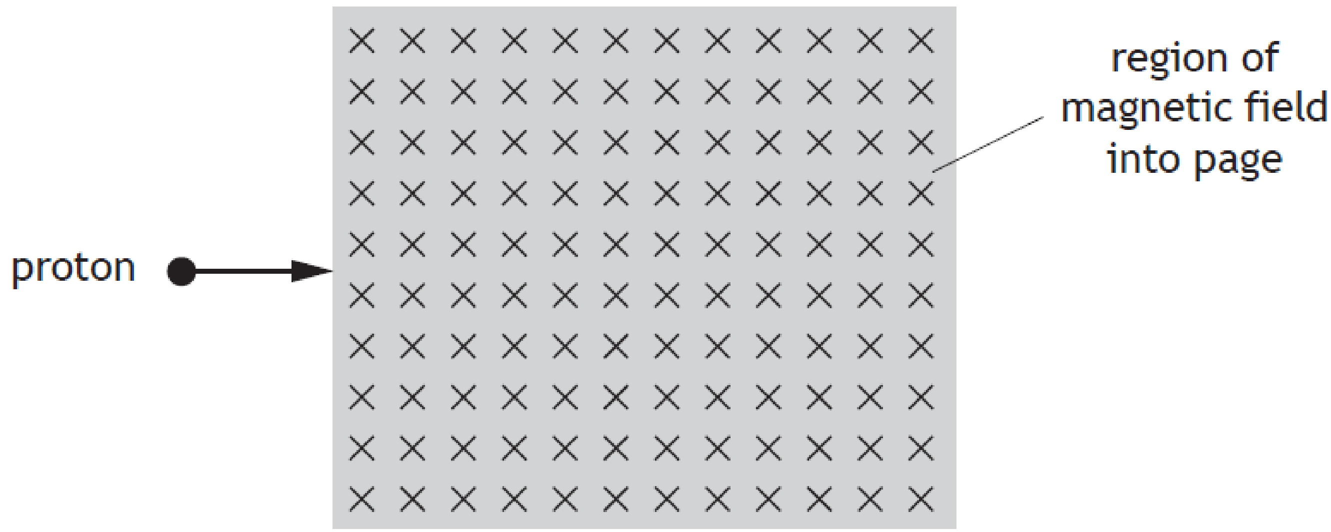
(ii) State **two** differences between the magnetic fields inside beam guides R and S. **2**

(c) Calculate the minimum speed of an electron that will produce a photon of energy $4{\cdot}16 \times 10^{-17}$ J.

3.	(a)	(i)	W or $E_W = QV$ 1 $= 1{\cdot}60 \times 10^{-19} \times 2{\cdot}50 \times 10^{3}$ 1 $= 4{\cdot}00 \times 10^{-16}$ J 1	3	Suspend significant figure rule and accept 4×10^{-16} J. Ignore negative sign for charge.
		(ii)	Particle (always) accelerates in the same direction/forwards **OR** Force on particle/electron is always in same direction **OR** Ensure the direction of the electric field is correct when particle/ electron passes between (alternate) gaps	1	Candidate must make some implication of 'same direction'.
	(b)	(i)	Out of page	1	Do not accept: 'upwards' on its own, **OR** 'out of the page' with other comments such ad 'circular' 'clockwise'.

	(ii)	(Magnetic fields are in) opposite directions 1 (Magnetic field in) S is stronger than (field in) R 1	**2**	Independent marks Or consistent with (b)(i) for first mark as long as a linear field is described. Accept statement referring to direction of (magnetic field in) S alone ONLY if (b)(i) has been answered. Do not accept: 'different directions' 'force in S is opposite to force in R' alone.
(c)		$E_K = \frac{1}{2}mv^2$ 1 $4{\cdot}16 \times 10^{-17} = \frac{1}{2} \times 9{\cdot}11 \times 10^{-31} \times v^2$ 1 $v = 9{\cdot}56 \times 10^6$ ms^{-1} 1	**3**	Accept: 9·6, 9·557, 9·5566

10. A proton enters a region of magnetic field as shown.



On entering the magnetic field the proton

A deflects into the page

B deflects out of the page

C deflects towards the top of the page

D deflects towards the bottom of the page

E is not deflected.

C

12. A student makes the following statements about particles in electric fields.

I A neutron experiences a force in an electric field.

II When an alpha particle is moved in an electric field work is done.

III An electric field applied to a conductor causes the free electrons in the conductor to move.

Which of the statements is/are correct?

A II only

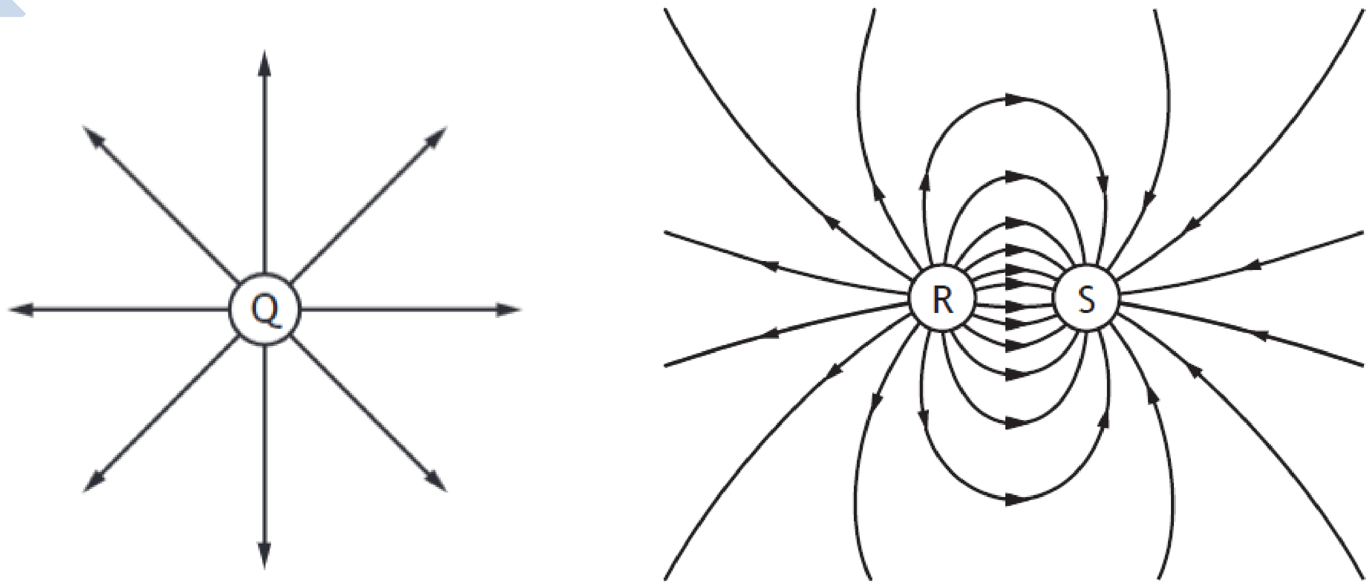
B III only

C I and II only

D II and III only

E I, II and III

D

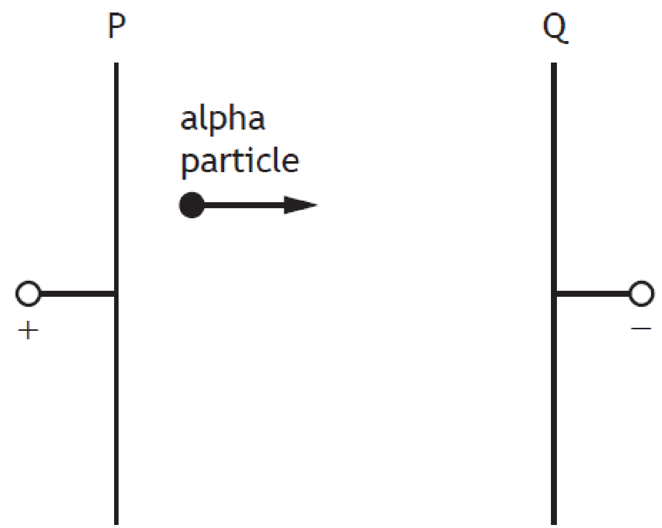


Which row in the table shows the charges on particles Q, R and S?

	Charge on Q	*Charge on R*	*Charge on S*
A	negative	negative	positive
B	positive	positive	negative
C	negative	positive	negative
D	negative	negative	negative
E	positive	positive	positive

B

11. An alpha particle is accelerated in an electric field between metal plates P and Q.



The charge on the alpha particle is $3{\cdot}2 \times 10^{-19}$ C.

The kinetic energy gained by the alpha particle while travelling from plate P to plate Q is $8{\cdot}0 \times 10^{-16}$ J.

The potential difference across plates P and Q is

A $2{\cdot}6 \times 10^{-34}$ V

B $2{\cdot}0 \times 10^{-4}$ V

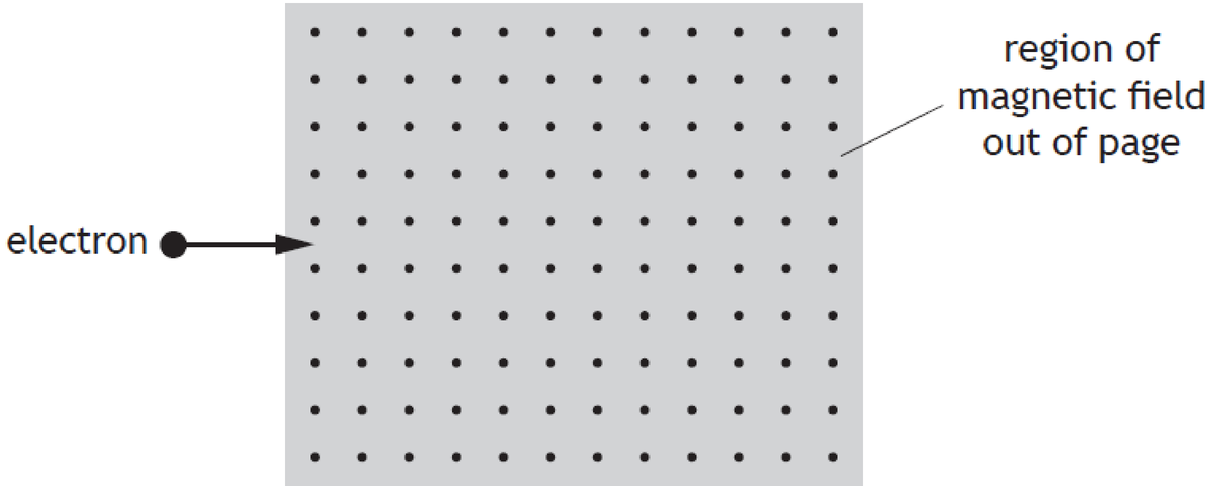
C $4{\cdot}0 \times 10^{-4}$ V

D $2{\cdot}5 \times 10^{3}$ V

E $5{\cdot}0 \times 10^{3}$ V.

D

12. An electron enters a region of uniform magnetic field as shown.



The direction of the magnetic force on the electron immediately after entering the field is

A towards the top of the page

B towards the bottom of the page

C towards the right of the page

D into the page

E out of the page.

A