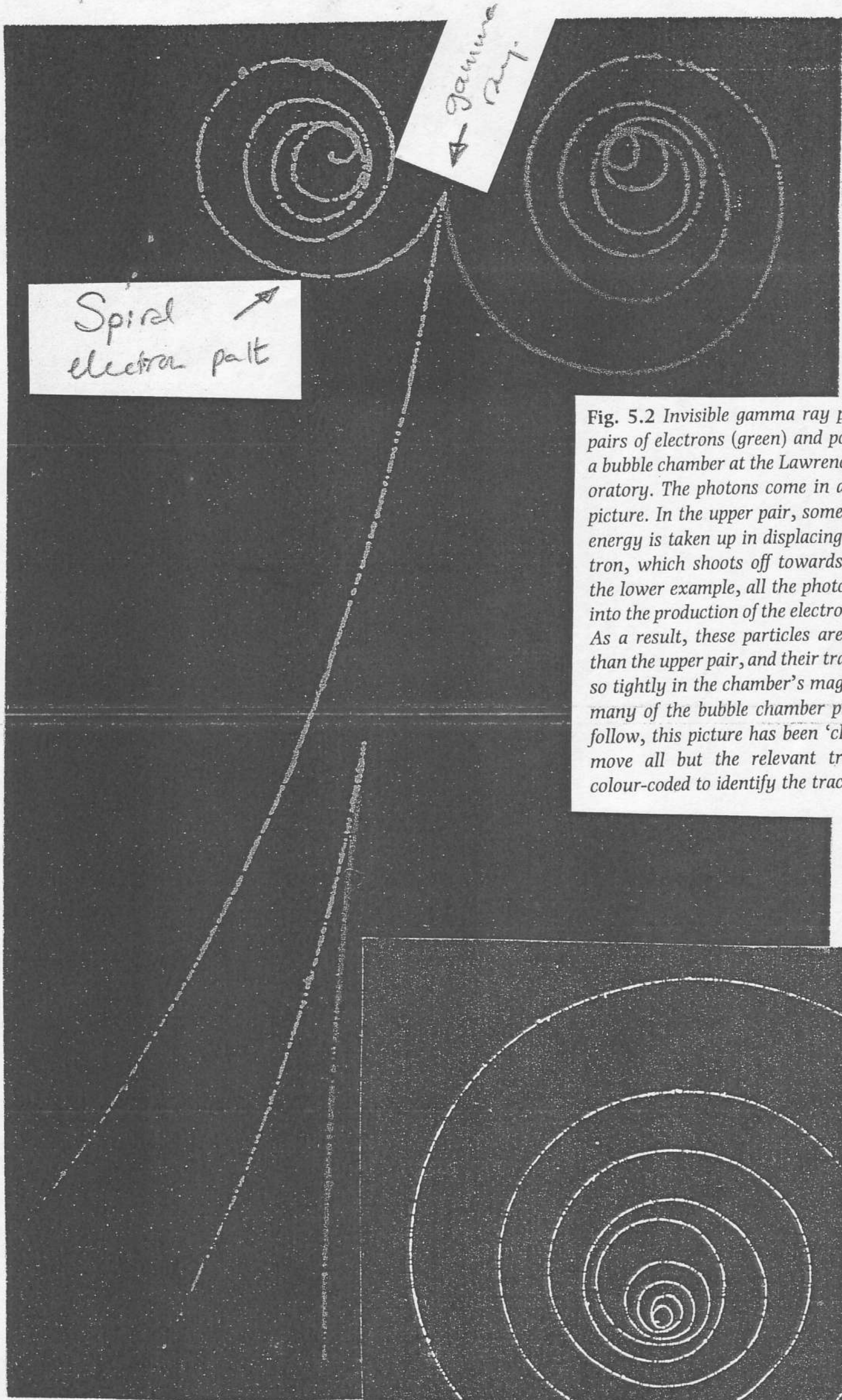
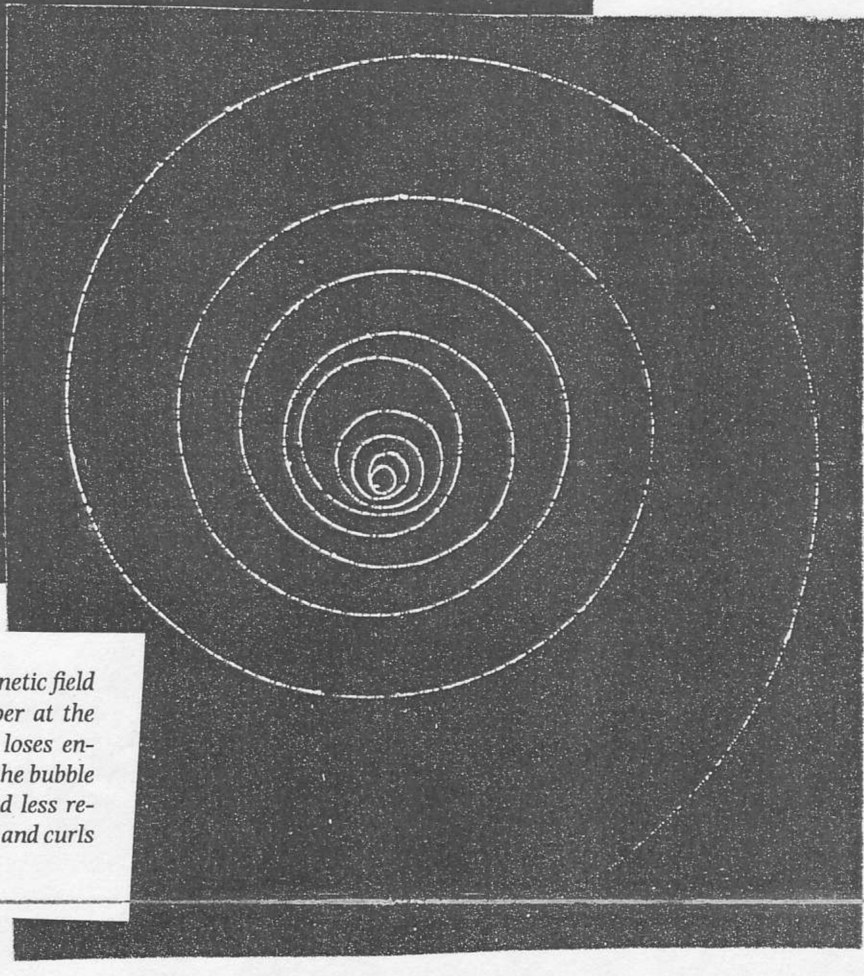
Subatomic particles + their paths



from "The Particle Odyssey" Frank Close 2004

Fig. 5.2 *Invisible gamma ray photons produce pairs of electrons (green) and positrons (red) in a bubble chamber at the Lawrence Berkeley Laboratory. The photons come in at the top of the picture. In the upper pair, some of the photon's energy is taken up in displacing an atomic electron, which shoots off towards bottom left. In the lower example, all the photon's energy goes into the production of the electron–positron pair. As a result, these particles are more energetic than the upper pair, and their tracks do not curve so tightly in the chamber's magnetic field. (Like many of the bubble chamber photographs that follow, this picture has been 'cleaned up' to remove all but the relevant tracks, and then colour-coded to identify the tracks.)*

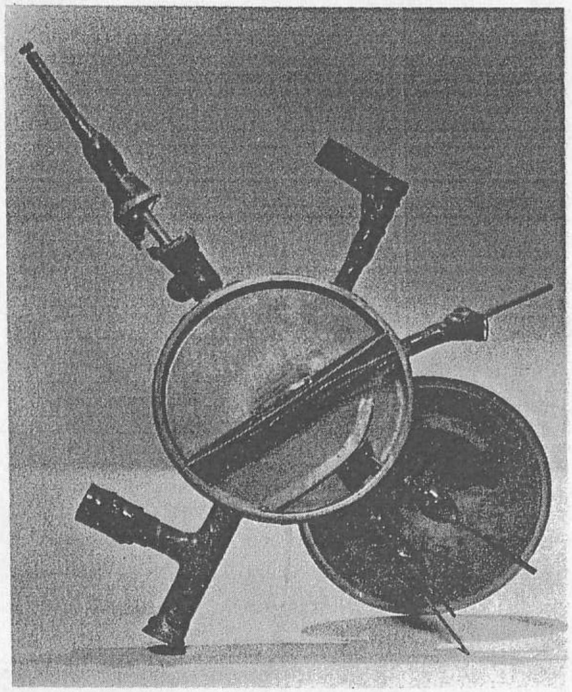


from "The Particle Explosion" Frank Close, 1987

Fig. 3.9 *An electron spirals in the magnetic field of the 10 inch (25 cm) bubble chamber at the Lawrence Berkeley Laboratory. As it loses energy in ionizing the liquid hydrogen in the bubble chamber, the electron becomes less and less resistant to the force of the magnetic field and curls inwards on successively tighter curls.*

May '02 + Oct '13

Accelerated Particles



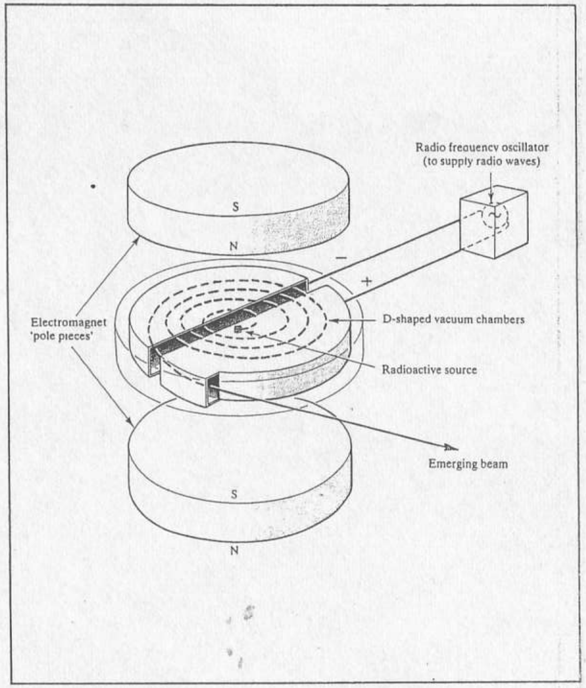


Fig. 6.6 (*left*) *Lawrence's first successful cyclotron, built in 1930, was only 13 cm in diameter and accelerated protons to 80 keV.*

This is a proton accelerated by a p.d. of 80kV.

(1) What is the proton's k.E?

(2) ... velocity?

$e = 1.6 \times 10^{-19}$ C

$m_p = 1.7 \times 10^{-27}$ kg

$m_e = 9.1 \times 10^{-31}$ kg

$h = 6.6 \times 10^{-34}$ Js.

Fig. 6.7 (*right*) *The basic components of a cyclotron are an electric field to accelerate the particles and a magnetic field to curve them round on a cycling path. In practice, the magnetic field is supplied by two electromagnetic 'pole pieces'. These generate a vertical north–south field through the path of the particles, which are contained in a horizontal plane. The electric field is provided across a gap between two hollow D-shaped metal vacuum chambers. Particles emanating from a radioactive source at the centre of the device are accelerated when they cross the gap between the 'dees'. By applying an electric field oscillating at radio frequencies, the direction of the field can be changed so that it is in the correct direction to accelerate the particles each time they cross the gap. The particles curl round in the cyclotron's magnetic field, but as they increase in energy, they curl less and less, so that they spiral outwards until they eventually emerge from the machine.*

Questions – on the spiral electron track

(1) what is the magnetic flux direction?

(2) If the magnetic flux density was 5×10^{-2} Tesla, what was the initial speed of the electron?

(3) What was the electron's initial kE?

(3) Estimate the frequency of the photon

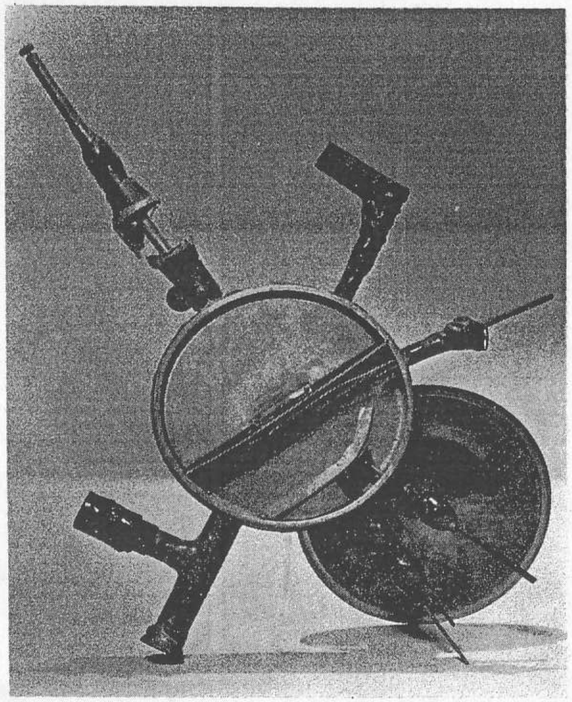
(4) The electron is slowing down – why? and how can you tell?

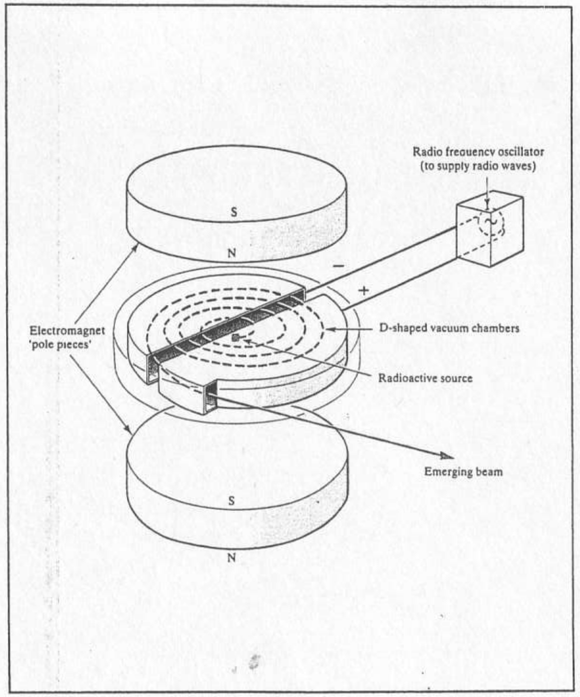
DRW
Mar '05

Accelerated Particles

Answers

TJW





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Questions – on the spiral electron track

(1) What is the magnetic flux direction?

Left Hand rule

– field into paper

(2) If the magnetic flux density was 5×10^{-2} Tesla, what was the initial speed of the electron?

initial $r = 20 \times 10^{-3}$m

40mm

$F_c = F_m$

$\frac{mv^2}{r} = BQv \Rightarrow v = \frac{BQr}{m_e} = \frac{5 \times 10^{-2} \times 1.6 \times 10^{-19} \times 20 \times 10^{-3}}{9.1 \times 10^{-31}}$

$= 1.8 \times 10^{8}$ m/s

(3) What was the electron's initial kE?

$kE = \frac{1}{2} m_e v^2 = \frac{1}{2} \times 9.1 \times 10^{-31} \times (1.8 \times 10^{8})^2$

$= 1.47 \times 10^{-14}$ J

TJW May '02

(4) Estimate the frequency of the photon

Use $E = hf \Rightarrow f = E/h = 1.47 \times 10^{-14} / 6.6 \times 10^{-34}$

$= 2.2 \times 10^{19}$ Hz

(5) The electron is slowing down – why? and how can you tell?

– colliding with much heavier nuclei

– see the radius of the track decreasing

check $\frac{mv^2}{r} = BQv \Rightarrow$ radius $= \frac{mv}{BQ}$ constant

(1) Elec PE = kE

$QV = \frac{1}{2}mv^2 = 1.6 \times 10^{-19} \times 80{,}000$

$= 1.3 \times 10^{-14}$ J

(2) $v_p = \sqrt{2 \times kE/m}$

$= (2 \times 1.3 \times 10^{-14} / 1.7 \times 10^{-27})^{\frac{1}{2}}$

$v_p = 3.9 \times 10^{6}$ m/s