‘The early years: Bristol, Emulsions, Pion discovery’

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Don Perkins – the Early Years

Bristol, Emulsions, Pion Discovery

Brian Foster

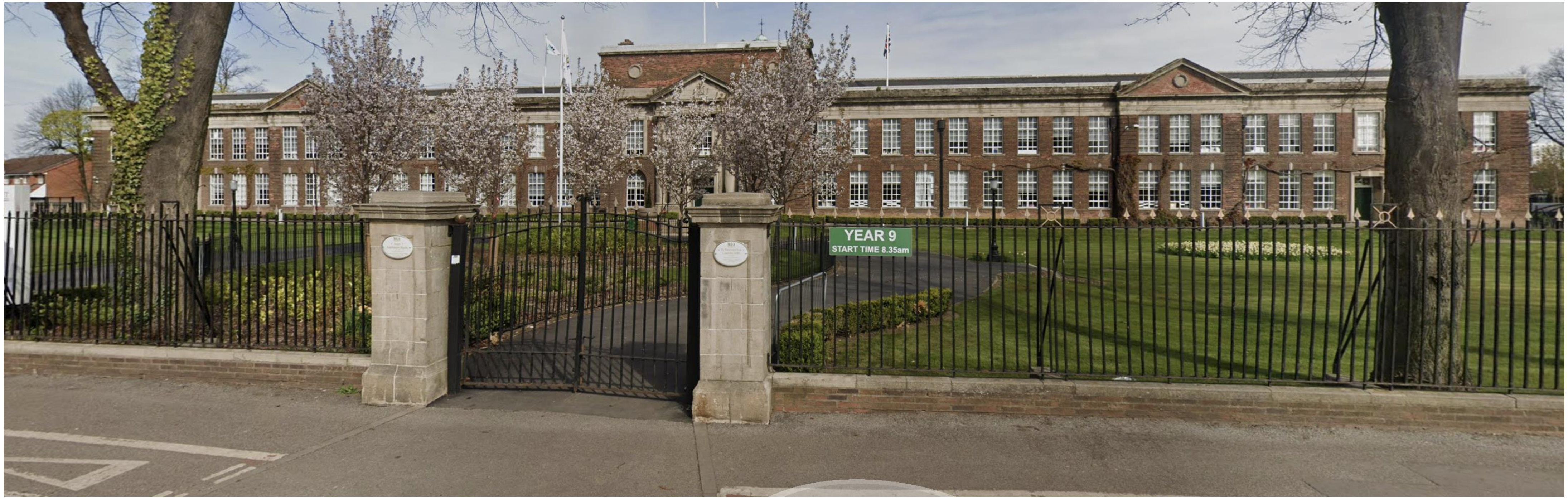
Donald H. Perkins Professor Emeritus of Experimental Physics, Oxford

Perkins in a nutshell

- Born 15/10/1925 in Hull. B.Sc. (1945) & Ph.D. (1948) ICL
- Exhibition of 1851 Senior Scholar, 1948–51; G. A. Wills Research Associate in Physics, Univ. of Bristol, 1951–55; Lawrence Radiation Lab., Univ. of California, 1955–56; Lectr in Physics, 1956–60, Reader in Physics, 1960–65, Univ. of Bristol.
- Professor of Elementary Particle Physics, 1965–93, and Fellow of St Catherine’s College, since 1965, Oxford University
- Mem., SERC; Chair, Nuclear Physics Board 1985–89.
- FRS, 1966; Hon. DSc: Sheffield, 1982; Bristol, 1995; ICL, 2016. Guthrie Medal, Inst. of Physics, 1979; CBE, 1991; Holweck Medal and Prize, Société Française de Physique, 1992; Royal Medal, Royal Soc., 1997; High Energy Physics Prize, Eur. Physical Soc., 2001

Early Life & School

- Both Don's father and mother were teachers.
- His school, Malet Lambert High, was a tough one. It was a new school, founded as a grammar school in 1932 to the north of Hull city centre.



Early Life & School

- Nevertheless, he flourished academically.
- He also had extra-curricular activities, that led to his first publications when he was 12: The Meccano Magazine

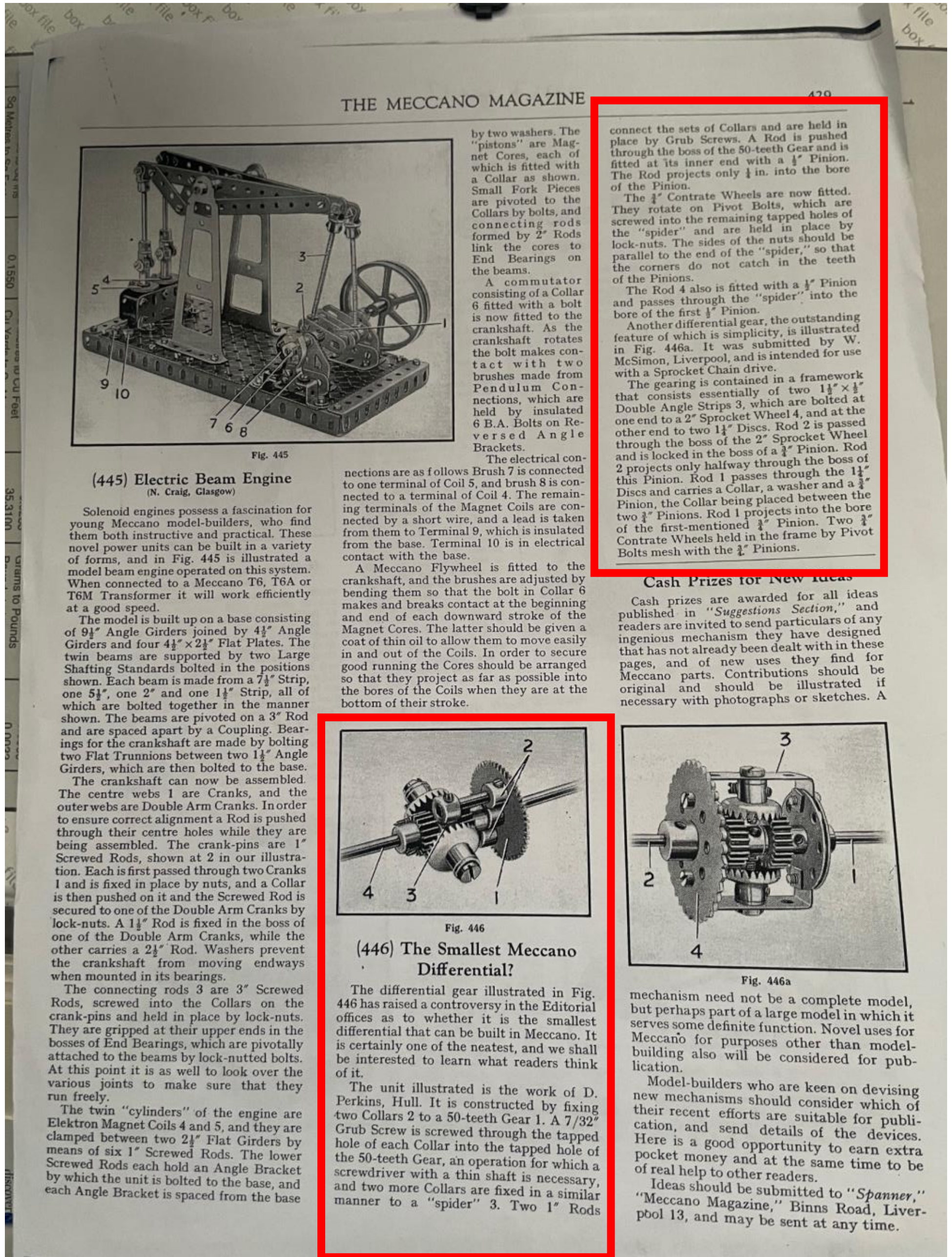


Fig. 445

(445) Electric Beam Engine

(N. Craig, Glasgow)

Solenoid engines possess a fascination for young Meccano model-builders, who find them both instructive and practical. These novel power units can be built in a variety of forms, and in Fig. 445 is illustrated a model beam engine operated on this system. When connected to a Meccano T6, T6A or T6M Transformer it will work efficiently at a good speed.

The model is built up on a base consisting of 9½" Angle Girders joined by 4½" Angle Girders and four 4½" × 2½" Flat Plates. The twin beams are supported by two Large Shafting Standards bolted in the positions shown. Each beam is made from a 7½" Strip, one 5½", one 2" and one 1½" Strip, all of which are bolted together in the manner shown. The beams are pivoted on a 3" Rod and are spaced apart by a Coupling. Bearings for the crankshaft are made by bolting two Flat Trunnions between two 1½" Angle Girders, which are then bolted to the base.

The crankshaft can now be assembled. The centre webs 1 are Cranks, and the outer webs are Double Arm Cranks. In order to ensure correct alignment a Rod is pushed through their centre holes while they are being assembled. The crank-pins are 1" Screwed Rods, shown at 2 in our illustration. Each is first passed through two Cranks 1 and is fixed in place by nuts, and a Collar is then pushed on it and the Screwed Rod is secured to one of the Double Arm Cranks by lock-nuts. A 1½" Rod is fixed in the boss of one of the Double Arm Cranks, while the other carries a 2½" Rod. Washers prevent the crankshaft from moving endways when mounted in its bearings.

The connecting rods 3 are 3" Screwed Rods, screwed into the Collars on the crank-pins and held in place by lock-nuts. They are gripped at their upper ends in the bosses of End Bearings, which are pivotally attached to the beams by lock-nutted bolts. At this point it is as well to look over the various joints to make sure that they run freely.

The twin "cylinders" of the engine are Elektron Magnet Coils 4 and 5, and they are clamped between two 2½" Flat Girders by means of six 1" Screwed Rods. The lower Screwed Rods each hold an Angle Bracket by which the unit is bolted to the base, and each Angle Bracket is spaced from the base by two washers. The "pistons" are Magnet Cores, each of which is fitted with a Collar as shown. Small Fork Pieces are pivoted to the Collars by bolts, and connecting rods formed by 2" Rods link the cores to End Bearings on the beams.

A commutator consisting of a Collar 6 fitted with a bolt is now fitted to the crankshaft. As the crankshaft rotates the bolt makes contact with two brushes made from Pendulum Connections, which are held by insulated 6 B.A. Bolts on Reversed Angle Brackets.

The electrical connections are as follows Brush 7 is connected to one terminal of Coil 5, and brush 8 is connected to a terminal of Coil 4. The remaining terminals of the Magnet Coils are connected by a short wire, and a lead is taken from them to Terminal 9, which is insulated from the base. Terminal 10 is in electrical contact with the base.

A Meccano Flywheel is fitted to the crankshaft, and the brushes are adjusted by bending them so that the bolt in Collar 6 makes and breaks contact at the beginning and end of each downward stroke of the Magnet Cores. The latter should be given a coat of thin oil to allow them to move easily in and out of the Coils. In order to secure good running the Cores should be arranged so that they project as far as possible into the bores of the Coils when they are at the bottom of their stroke.

Fig. 446

(446) The Smallest Meccano Differential?

The differential gear illustrated in Fig. 446 has raised a controversy in the Editorial offices as to whether it is the smallest differential that can be built in Meccano. It is certainly one of the neatest, and we shall be interested to learn what readers think of it.

The unit illustrated is the work of D. Perkins, Hull. It is constructed by fixing two Collars 2 to a 50-teeth Gear 1. A 7/32" Grub Screw is screwed through the tapped hole of each Collar into the tapped hole of the 50-teeth Gear, an operation for which a screwdriver with a thin shaft is necessary, and two more Collars are fixed in a similar manner to a "spider" 3. Two 1" Rods connect the sets of Collars and are held in place by Grub Screws. A Rod is pushed through the boss of the 50-teeth Gear and is fitted at its inner end with a ½" Pinion. The Rod projects only ¼ in. into the bore of the Pinion.

The ¾" Contrate Wheels are now fitted. They rotate on Pivot Bolts, which are screwed into the remaining tapped holes of the "spider" and are held in place by lock-nuts. The sides of the nuts should be parallel to the end of the "spider," so that the corners do not catch in the teeth of the Pinions.

The Rod 4 also is fitted with a ½" Pinion and passes through the "spider" into the bore of the first ½" Pinion.

Another differential gear, the outstanding feature of which is simplicity, is illustrated in Fig. 446a. It was submitted by W. McSimon, Liverpool, and is intended for use with a Sprocket Chain drive.

The gearing is contained in a framework that consists essentially of two 1½" × ½" Double Angle Strips 3, which are bolted at one end to a 2" Sprocket Wheel 4, and at the other end to two 1¼" Discs. Rod 2 is passed through the boss of the 2" Sprocket Wheel and is locked in the boss of a ¾" Pinion. Rod 2 projects only halfway through the boss of this Pinion. Rod 1 passes through the 1¼" Discs and carries a Collar, a washer and a ¾" Pinion, the Collar being placed between the two ¾" Pinions. Rod 1 projects into the bore of the first-mentioned ¾" Pinion. Two ¾" Contrate Wheels held in the frame by Pivot Bolts mesh with the ¾" Pinions.

Fig. 446a

Cash Prizes for New Ideas

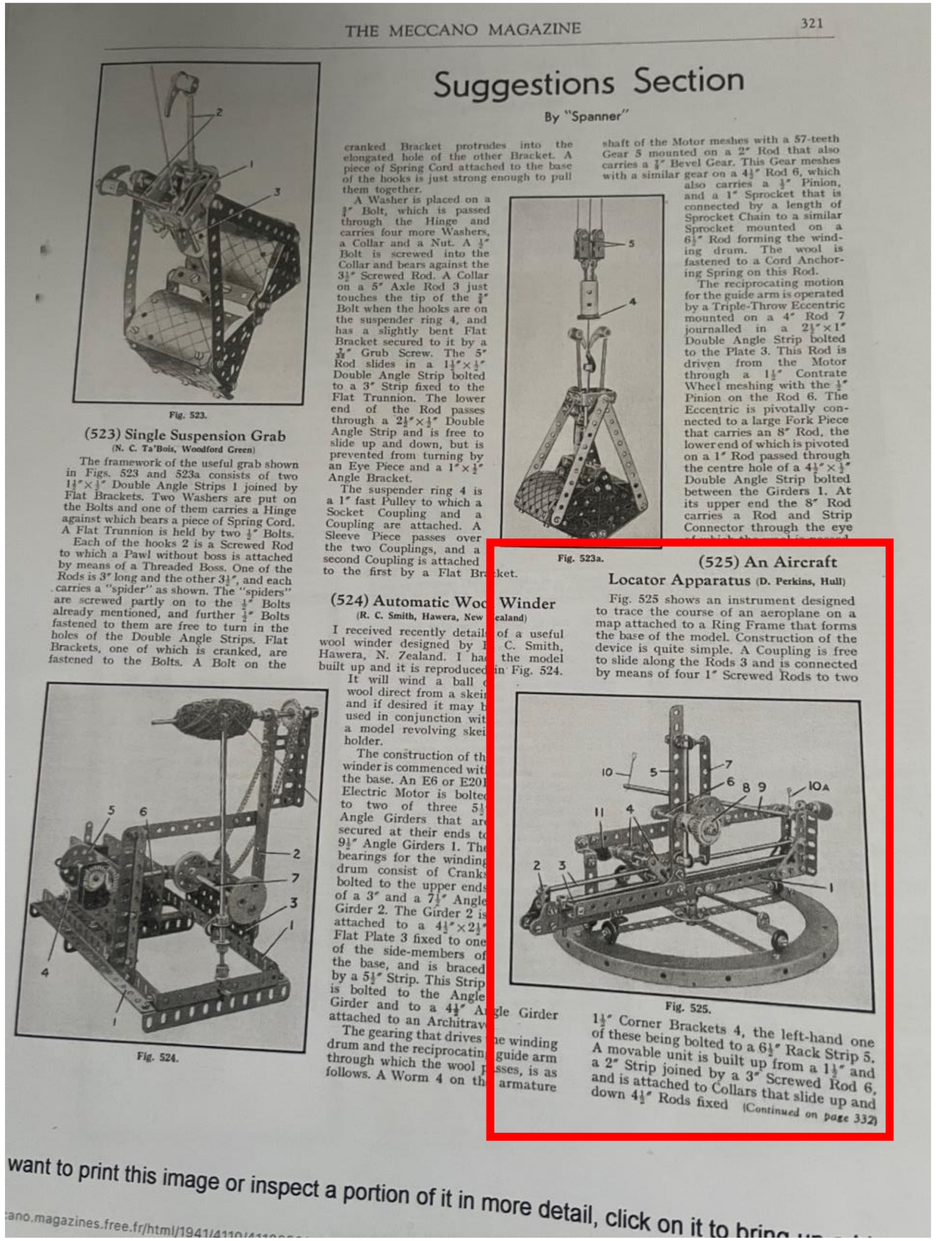
Cash prizes are awarded for all ideas published in "*Suggestions Section*," and readers are invited to send particulars of any ingenious mechanism they have designed that has not already been dealt with in these pages, and of new uses they find for Meccano parts. Contributions should be original and should be illustrated if necessary with photographs or sketches. A mechanism need not be a complete model, but perhaps part of a large model in which it serves some definite function. Novel uses for Meccano for purposes other than model-building also will be considered for publication.

Model-builders who are keen on devising new mechanisms should consider which of their recent efforts are suitable for publication, and send details of the devices. Here is a good opportunity to earn extra pocket money and at the same time to be of real help to other readers.

Ideas should be submitted to "*Spanner*," "Meccano Magazine," Binns Road, Liverpool 13, and may be sent at any time.

Early Life & School

- And his second publication:
  The Meccano Magazine, 1941
- Also at the age of 16, he built a crystal radio receiver and picked up transmissions from Italy.
- He also maintained his uncle's extensive collection of moths and butterflies, eventually donated to the Hull museum.


THE MECCANO MAGAZINE 321

Suggestions Section

By "Spanner"

Fig. 523.

(523) Single Suspension Grab

(N. C. Ta'Bois, Woodford Green)

Fig. 523a.

(524) Automatic Wool Winder

(R. C. Smith, Hawera, New Zealand)

I received recently details of a useful wool winder designed by R. C. Smith, Hawera, N. Zealand. I had the model built up and it is reproduced in Fig. 524.

Fig. 524.

(525) An Aircraft Locator Apparatus (D. Perkins, Hull)

Fig. 525 shows an instrument designed to trace the course of an aeroplane on a map attached to a Ring Frame that forms the base of the model. Construction of the device is quite simple. A Coupling is free to slide along the Rods 3 and is connected by means of four 1" Screwed Rods to two

Fig. 525.

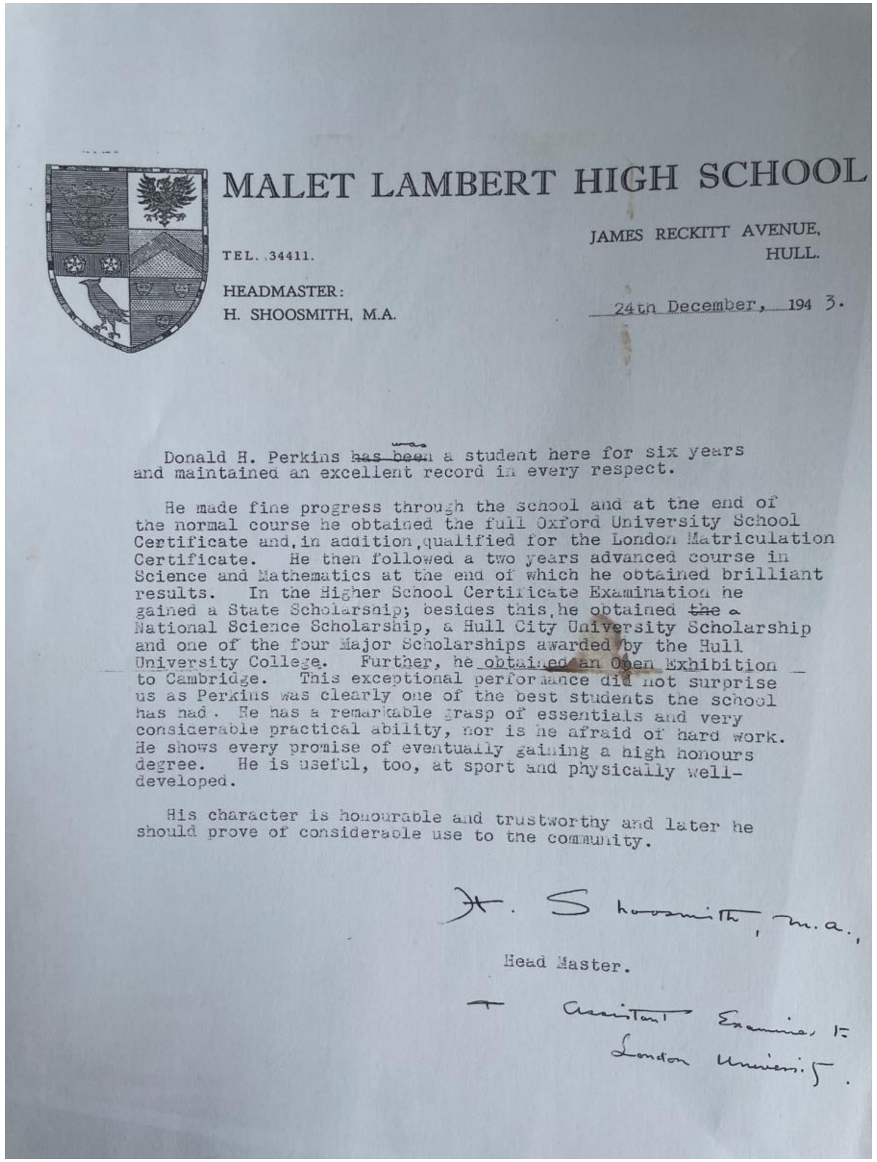
1½" Corner Brackets 4, the left-hand one of these being bolted to a 6½" Rack Strip 5. A movable unit is built up from a 1½" and a 2" Strip joined by a 3" Screwed Rod 6, and is attached to Collars that slide up and down 4½" Rods fixed (Continued on page 332)

want to print this image or inspect a portion of it in more detail, click on it to bring ...

...ano.magazines.free.fr/html/1941/4110/...

Early Life & School

- Don left school in 1943 with an excellent report.
- He had an offer from Trinity Cambridge, where he hoped after taking a science degree to study medicine. However, he didn't have the requisite Latin(!), so instead he went to Imperial College, where a Yorkshire friend had also registered. In 1945, he graduated with a B.Sc. with First Class Honours. He qualified for a postgraduate scholarship and registered for a PhD at IC.



MALET LAMBERT HIGH SCHOOL

TEL. 34411.

HEADMASTER:
H. SHOOSMITH, M.A.

JAMES RECKITT AVENUE,
HULL.

24th December, 1943.

Donald H. Perkins ~~has been~~ was a student here for six years and maintained an excellent record in every respect.

He made fine progress through the school and at the end of the normal course he obtained the full Oxford University School Certificate and, in addition, qualified for the London Matriculation Certificate. He then followed a two years advanced course in Science and Mathematics at the end of which he obtained brilliant results. In the Higher School Certificate Examination he gained a State Scholarship; besides this, he obtained ~~the~~ a National Science Scholarship, a Hull City University Scholarship and one of the four Major Scholarships awarded by the Hull University College. Further, he obtained an Open Exhibition to Cambridge. This exceptional performance did not surprise us as Perkins was clearly one of the best students the school has had. He has a remarkable grasp of essentials and very considerable practical ability, nor is he afraid of hard work. He shows every promise of eventually gaining a high honours degree. He is useful, too, at sport and physically well-developed.

His character is honourable and trustworthy and later he should prove of considerable use to the community.

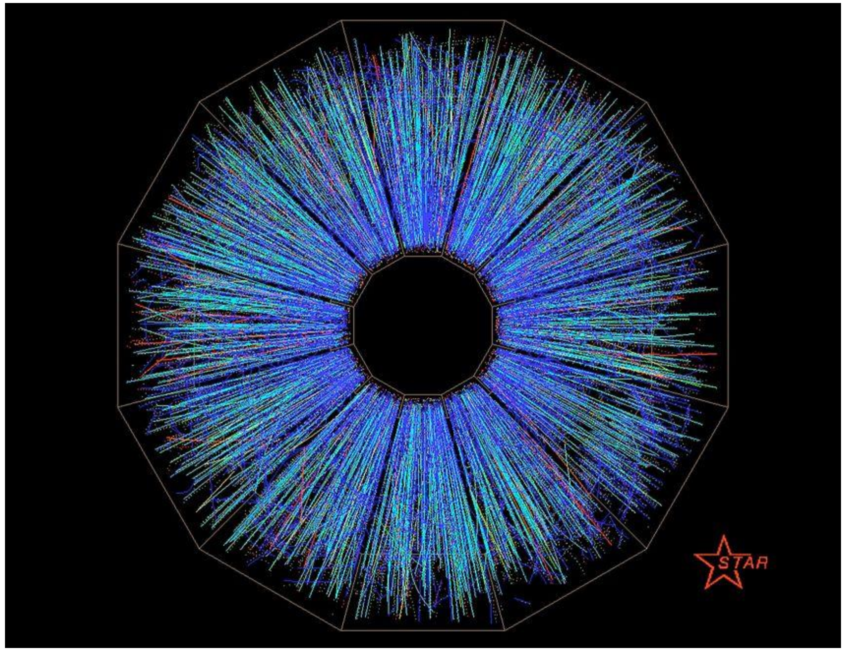
H. Shoosmith, M.A.,

Head Master.

+ Assistant Examiner, London University.

The π–meson

- When Don began his Ph.D., only the proton, neutron, electron (positron) and muon were known – and no-one had any idea what the muon was; everyone thought the neutrino existed but it was not found experimentally until 1956.
- The pion was postulated by Yukawa in 1935 as the carrier of the strong nuclear force. It is the lightest stable strongly interacting particle – copiously produced in modern experiments:



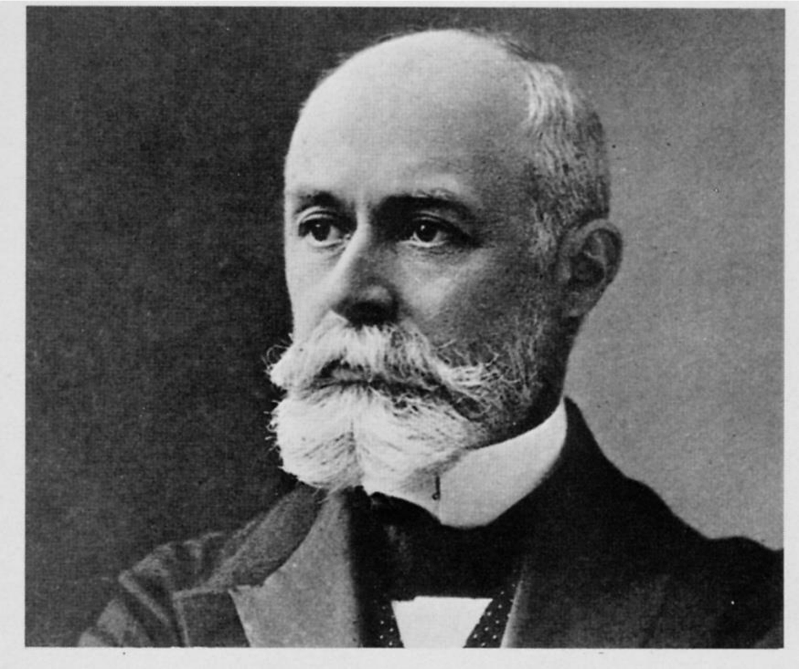
Emulsions in physics

- Emulsions go right back to the dawn of particle physics

- Serendipity at end of 1895 in Wilhelm Röntgen’s laboratory in Würzburg.

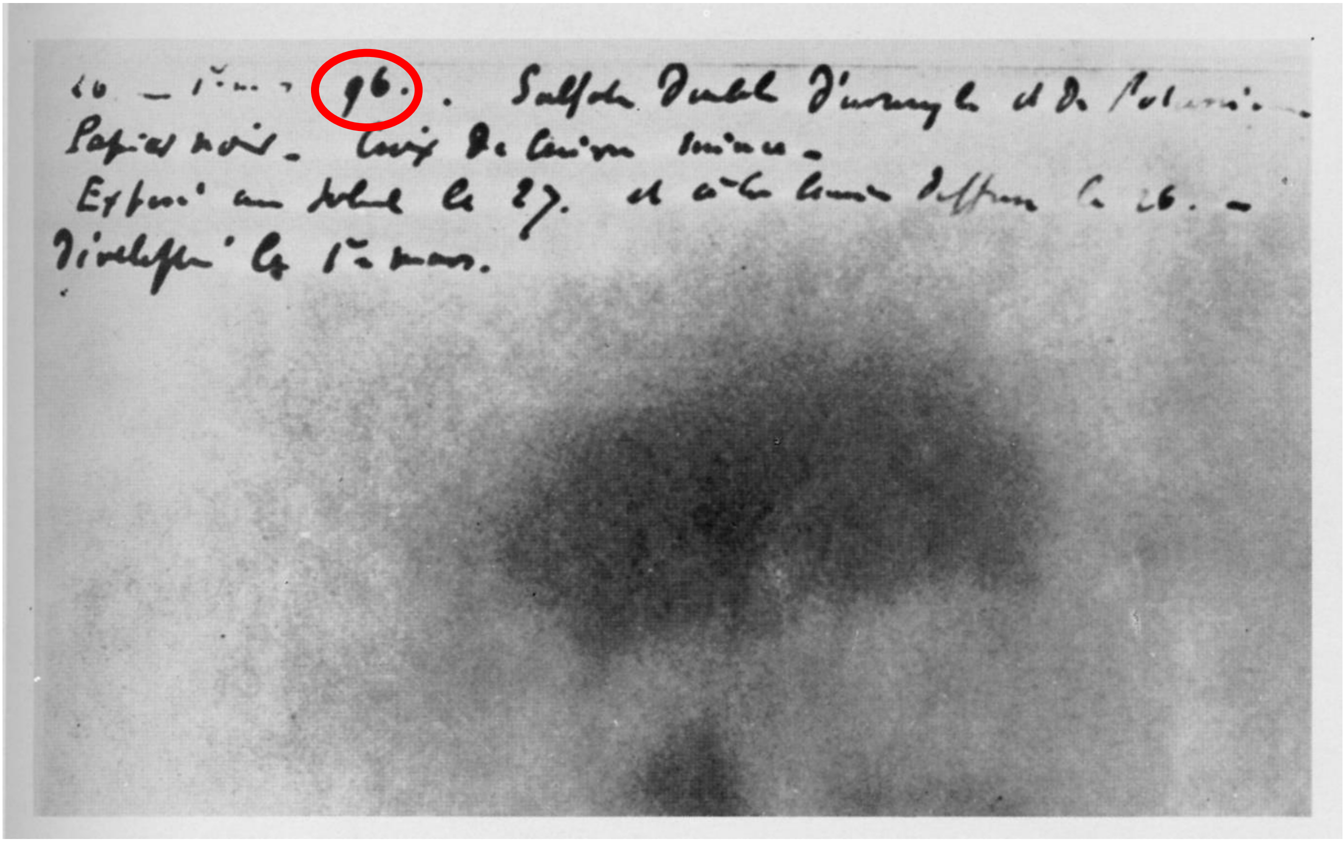
Emulsions in physics

- Emulsions go right back to the dawn of particle physics



Antoine Henri Becquerel

Serendipity strikes again:



Beginning research

- Don’s supervisor was G.P. Thomson, the son of J.J. Thomson. (J.J. got the Nobel Prize for proving the electron was a particle; G.P. got the Nobel Prize for proving the electron was a wave).

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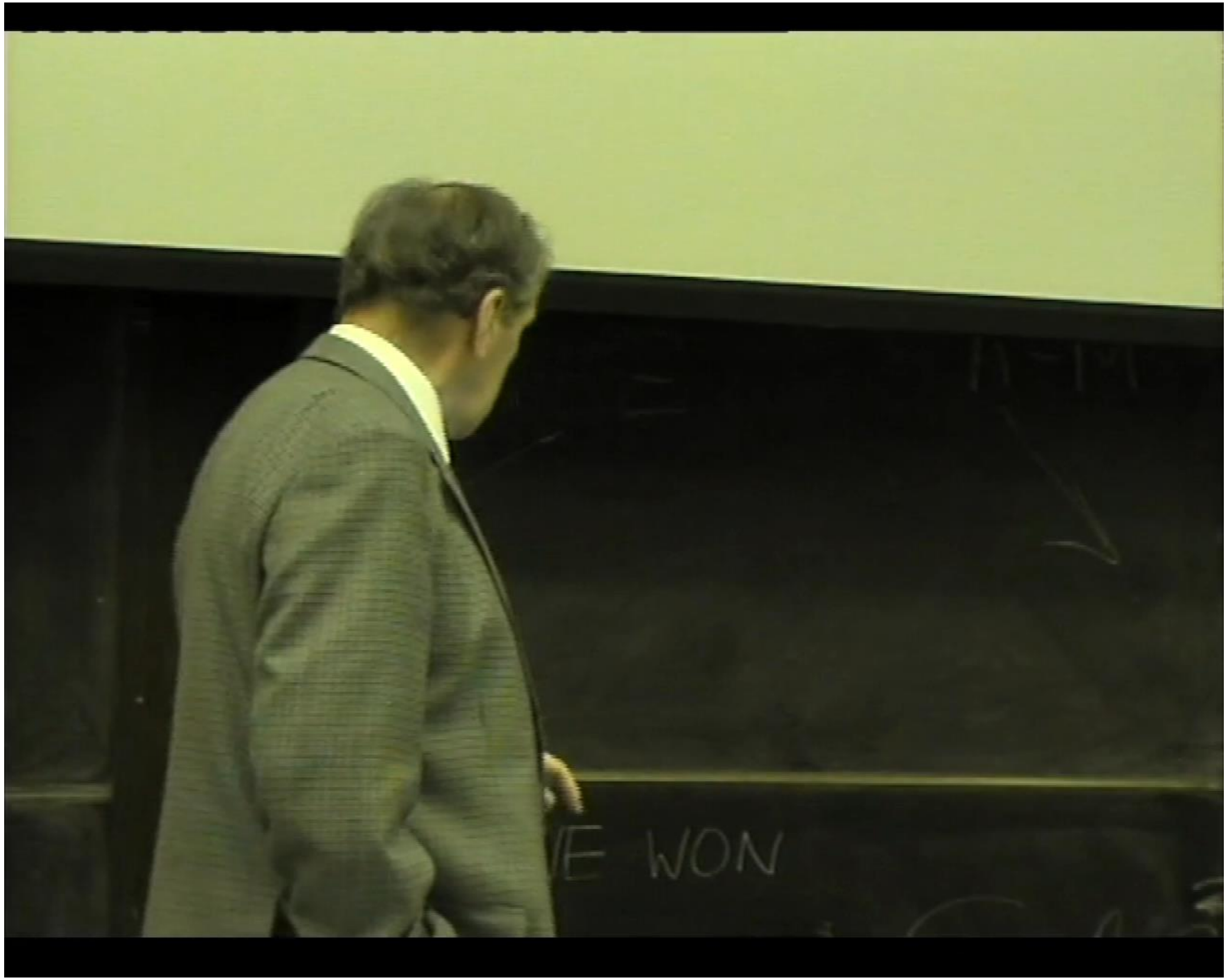


1947 “Annus Mirabilis”

TABLE I. – *Papers on meson physics 1946-1947.*

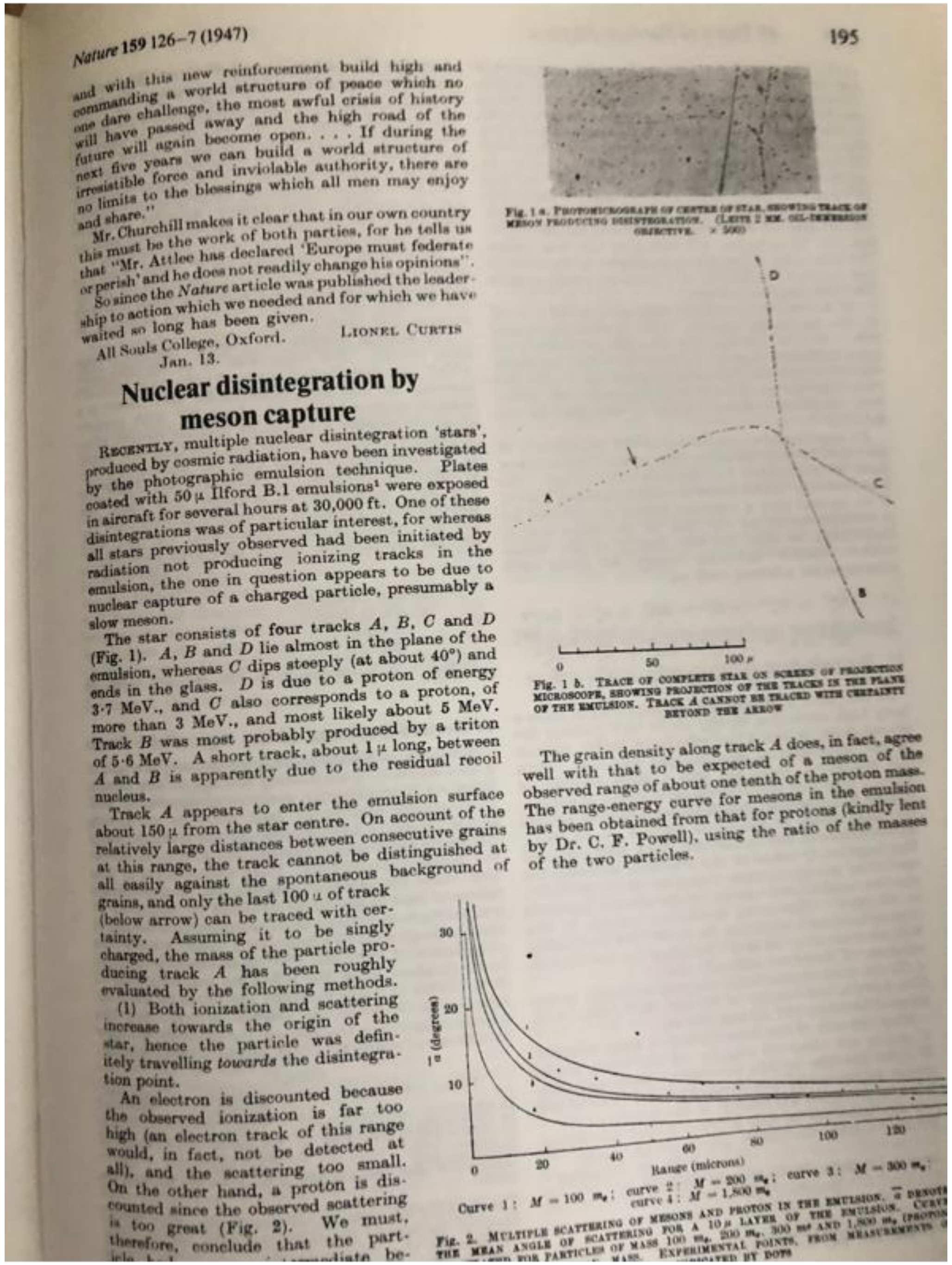
Nov. '46	SAKATA S. INOUE T.	*Prog. Theor. Phys.*, **1**, 143	2-meson hypothesis
Jan. '47	PERKINS D.	*Nature*, **159**, 126	First σ-star' (π^-)
Feb. '47	CONVERSI M. PANCINI E. PICCIONI O.	*Phys. Rev.*, **71**, 209	Negative mesotrons decay in carbon (μ^-)
Feb. '47	OCCHIALINI G. POWELL C.	*Nature*, **159**, 186	6 'σ-stars'
May '47	LATTES C. OCCHIALINI G. MUIRHEAD H. POWELL C.	*Nature*, **159**, 694	2 π-μ decays
Sept. '47	MARSHAK R. BETHE H.	*Phys. Rev.*, **72**, 506	2-meson hypothesis (again)
Oct. '47	LATTES C. OCCHIALINI G. POWELL C.	*Nature*, **160**, 453	644 mesons 105 σ-stars 11 complete π-μ 499 ρ-mesons ($\mu^{\pm}$)
Oct. '47	FRANK C.	*Nature*, **160**, 525	Meson-induced fusion (μ HD)
Dec. '47	ROCHESTER G. BUTLER C.	*Nature*, **160**, 855	V-particles

Getting a Ph.D.

- G.P. had been very active in WWII and had a lot of pull with the RAF. Don asked him to arrange for a flight from RAF Benson (Oxon) to take his pieces of emulsion up to 35000 ft and fly them around for several hours (in Spitfires!)

Getting a Ph.D.

- G.P. had been very active in WWII and had a lot of pull with the RAF. Don asked him to arrange for a flight from RAF Benson (Oxon) to take his pieces of emulsion up to 30000 ft and fly them around for several hours (in Spitfires!)


Nature 159 126–7 (1947)

and with this new reinforcement build high and commanding a world structure of peace which no one dare challenge, the most awful crisis of history will have passed away and the high road of the future will again become open. . . . If during the next five years we can build a world structure of irresistible force and inviolable authority, there are no limits to the blessings which all men may enjoy and share."

Mr. Churchill makes it clear that in our own country this must be the work of both parties, for he tells us that "Mr. Attlee has declared 'Europe must federate or perish' and he does not readily change his opinions".

So since the *Nature* article was published the leadership to action which we needed and for which we have waited so long has been given.

LIONEL CURTIS

All Souls College, Oxford.
Jan. 13.

Nuclear disintegration by meson capture

RECENTLY, multiple nuclear disintegration 'stars', produced by cosmic radiation, have been investigated by the photographic emulsion technique. Plates coated with 50 μ Ilford B.1 emulsions[1] were exposed in aircraft for several hours at 30,000 ft. One of these disintegrations was of particular interest, for whereas all stars previously observed had been initiated by radiation not producing ionizing tracks in the emulsion, the one in question appears to be due to nuclear capture of a charged particle, presumably a slow meson.

The star consists of four tracks *A*, *B*, *C* and *D* (Fig. 1). *A*, *B* and *D* lie almost in the plane of the emulsion, whereas *C* dips steeply (at about 40°) and ends in the glass. *D* is due to a proton of energy 3·7 MeV., and *C* also corresponds to a proton, of more than 3 MeV., and most likely about 5 MeV. Track *B* was most probably produced by a triton of 5·6 MeV. A short track, about 1 μ long, between *A* and *B* is apparently due to the residual recoil nucleus.

Track *A* appears to enter the emulsion surface about 150 μ from the star centre. On account of the relatively large distances between consecutive grains at this range, the track cannot be distinguished at all easily against the spontaneous background of grains, and only the last 100 μ of track (below arrow) can be traced with certainty. Assuming it to be singly charged, the mass of the particle producing track *A* has been roughly evaluated by the following methods.

(1) Both ionization and scattering increase towards the origin of the star, hence the particle was definitely travelling *towards* the disintegration point.

An electron is discounted because the observed ionization is far too high (an electron track of this range would, in fact, not be detected at all), and the scattering too small. On the other hand, a proton is discounted since the observed scattering is too great (Fig. 2). We must, therefore, conclude that the particle had ...

FIG. 1 *a*. PHOTOMICROGRAPH OF CENTRE OF STAR, SHOWING TRACK OF MESON PRODUCING DISINTEGRATION. (LEITZ 2 MM. OIL-IMMERSION OBJECTIVE. × 500)

FIG. 1 *b*. TRACE OF COMPLETE STAR ON SCREEN OF PROJECTION MICROSCOPE, SHOWING PROJECTION OF THE TRACKS IN THE PLANE OF THE EMULSION. TRACK *A* CANNOT BE TRACED WITH CERTAINTY BEYOND THE ARROW

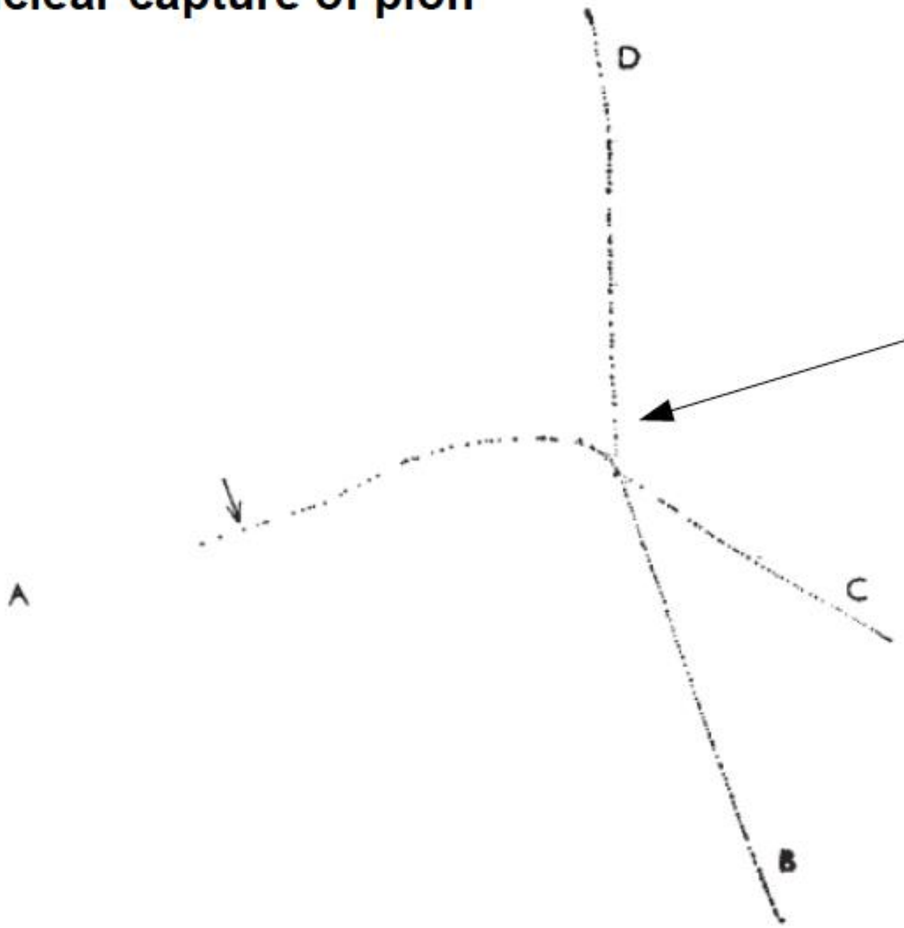
The grain density along track *A* does, in fact, agree well with that to be expected of a meson of the observed range of about one tenth of the proton mass. The range-energy curve for mesons in the emulsion has been obtained from that for protons (kindly lent by Dr. C. F. Powell), using the ratio of the masses of the two particles.

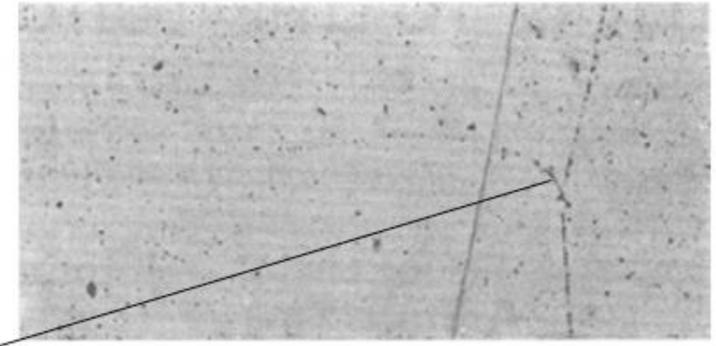
Curve 1: $M = 100\ m_e$; curve 2: $M = 200\ m_e$; curve 3: $M = 300\ m_e$; curve 4: $M = 1{,}800\ m_e$

FIG. 2. MULTIPLE SCATTERING OF MESONS AND PROTONS IN THE EMULSION. ...

The π Discovery - Overture

Nuclear capture of pion





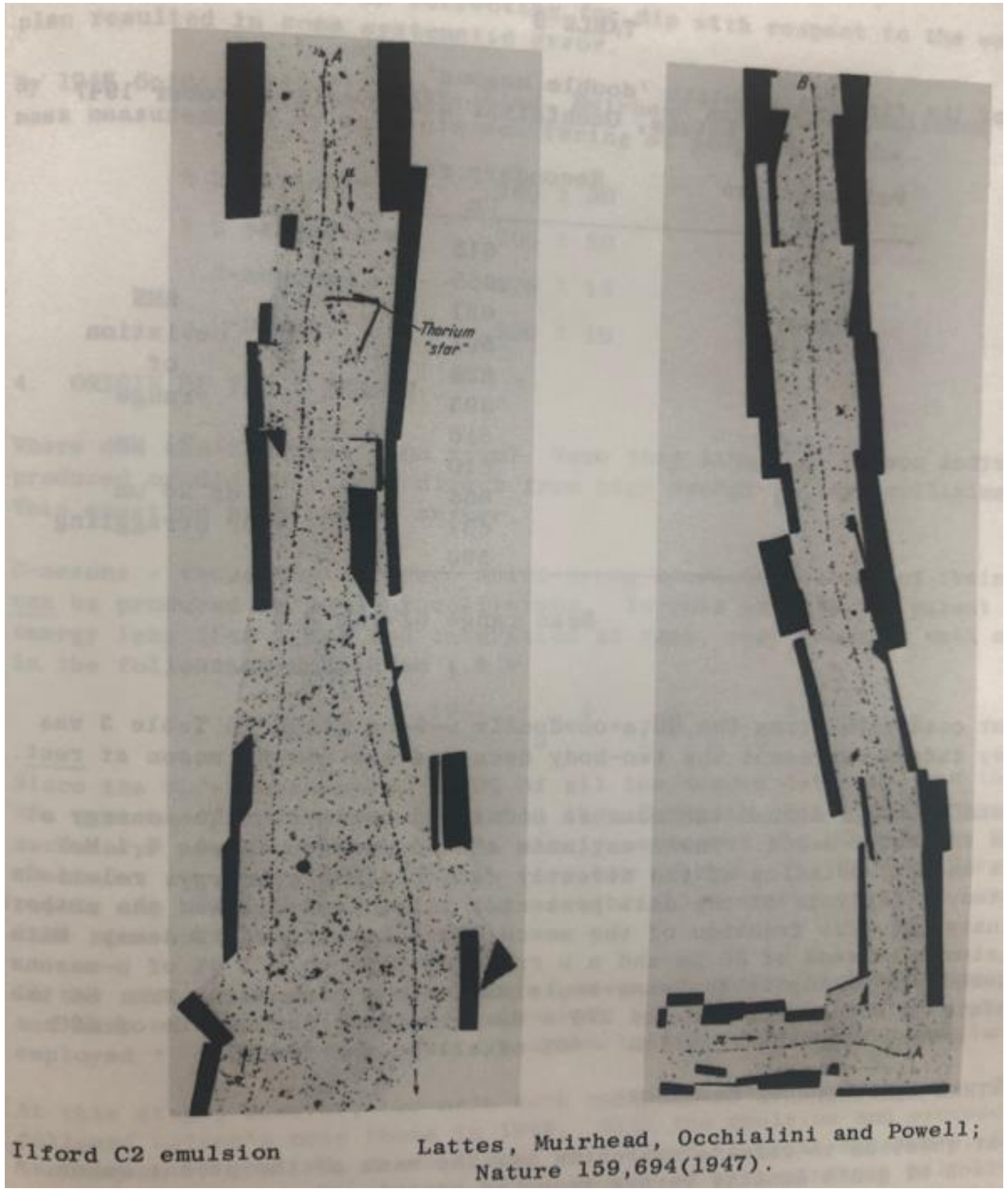
g. 1 a. PHOTOMICROGRAPH OF CENTRE OF STAR, SHOWING TRACK OF ESON PRODUCING DISINTEGRATION. (LEITZ 2 MM. OIL-IMMERSION OBJECTIVE. × 500)

- A is the new meson
- B,D,C are likely protons
- Track C goes into the page

Why A is a new meson:
electron: range too large
proton: scattering too large
muon: frequent nuclear interaction

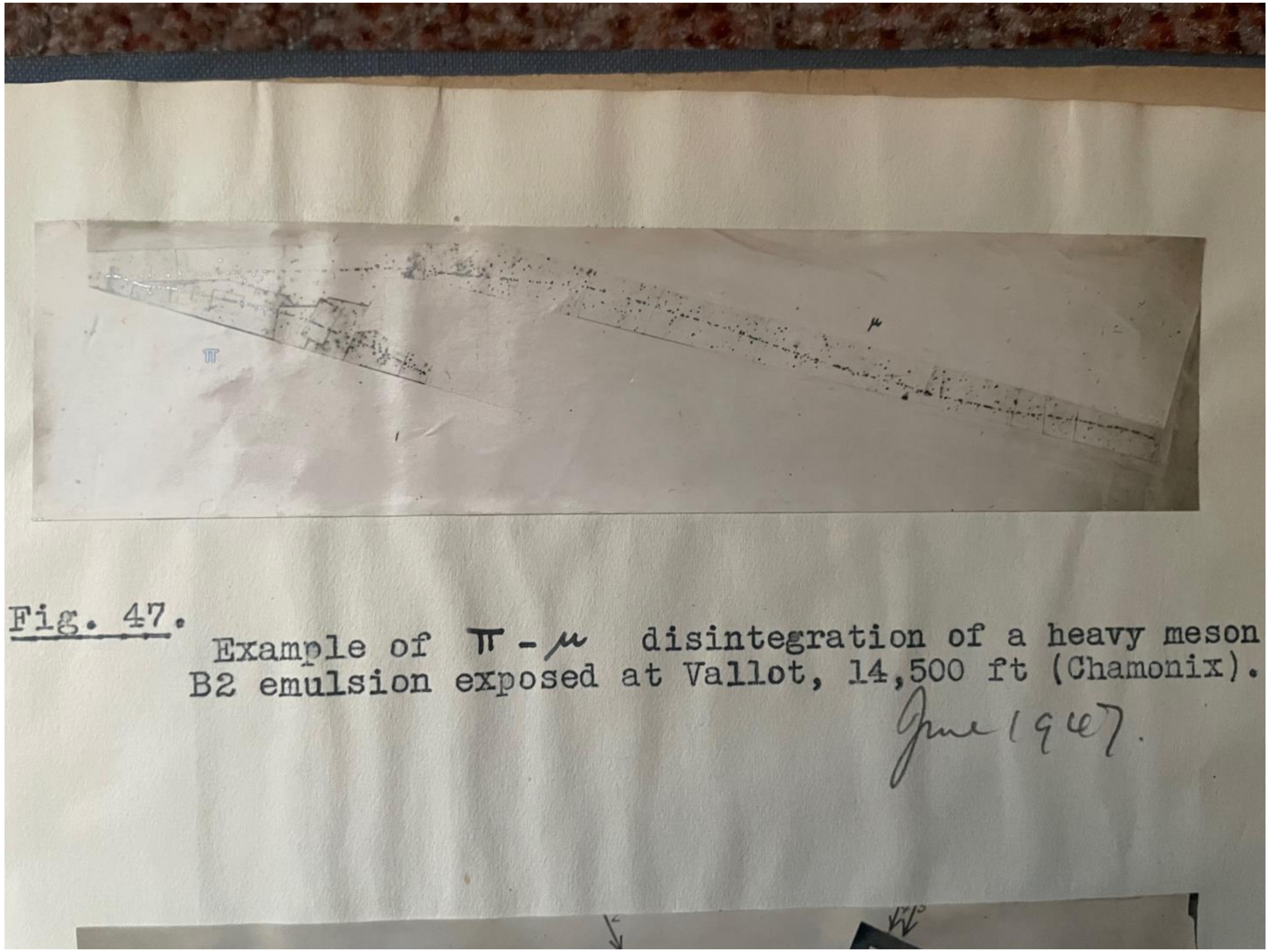
The π Discovery – First Act

- In Bristol in 1946, Ochiallini & Powell, exploiting much better quality photographic emulsions, exposed them at Pic du Midi (2800m).
- 2 events were found – published in Nature, October 1947
- Shortly after Don's publication, Occhialini & Powell published 6 more.



The π Discovery – Entr'act

- The "secret" pion – exposed for Don at Chamonix by LePrince-Ringuet.
- He found this a few months after the first one but didn't bother to publish it because he was so convinced by the Bristol paper!
- He put it in his thesis though.



The π Discovery – Second Act

At the other end of Europe, in England, a by-product of the war and the nuclear programme was the setting up, in 1946, of a panel by the Ministry of Supply to oversee the development of special photographic emulsions to record nuclear particles. The chairman was Joseph Rotblat (winner of the 1995 Nobel Peace Prize) and the eight or nine of us on the panel included Cecil Powell, Otto Frisch, George Rochester and Berriman and Waller, the chemists from Kodak and Ilford. Under constant prodding and goading, by mid 1946 Ilford had produced a series of emulsions with four times the normal silver halide/gelatine ratio, which would record tracks of charged particles of ionisation down to about six times the minimum value. The series were called A, B, C... in order of increasing "grain" (= microcrystal) size, and B1, B2... in order of increasing sensitivity.

I was in the fortunate position at Imperial College, where I was a graduate student, that my supervisor, Sir George Thomson, was a Nobel Prizewinner and had been chairman of the famous Maud Committee in 1940, which had pronounced that a ^{235}U fission weapon would be possible. So he had a lot of clout, got on to the Air Ministry and persuaded them to arrange that flights of the RAF Photographic Reconnaissance Unit at Benson, near Oxford, should carry some of these emulsions for me (a total of six $3'' \times 1''$ 50 micron thick B1 emulsions). In November 1946 I got these back, processed them and found about 20 nuclear disintegrations, one of which was produced by an incoming charged particle (see fig. 2). From scattering and ionization variation I estimated the

- Perkins – a graduate student – already at the centre of affairs!

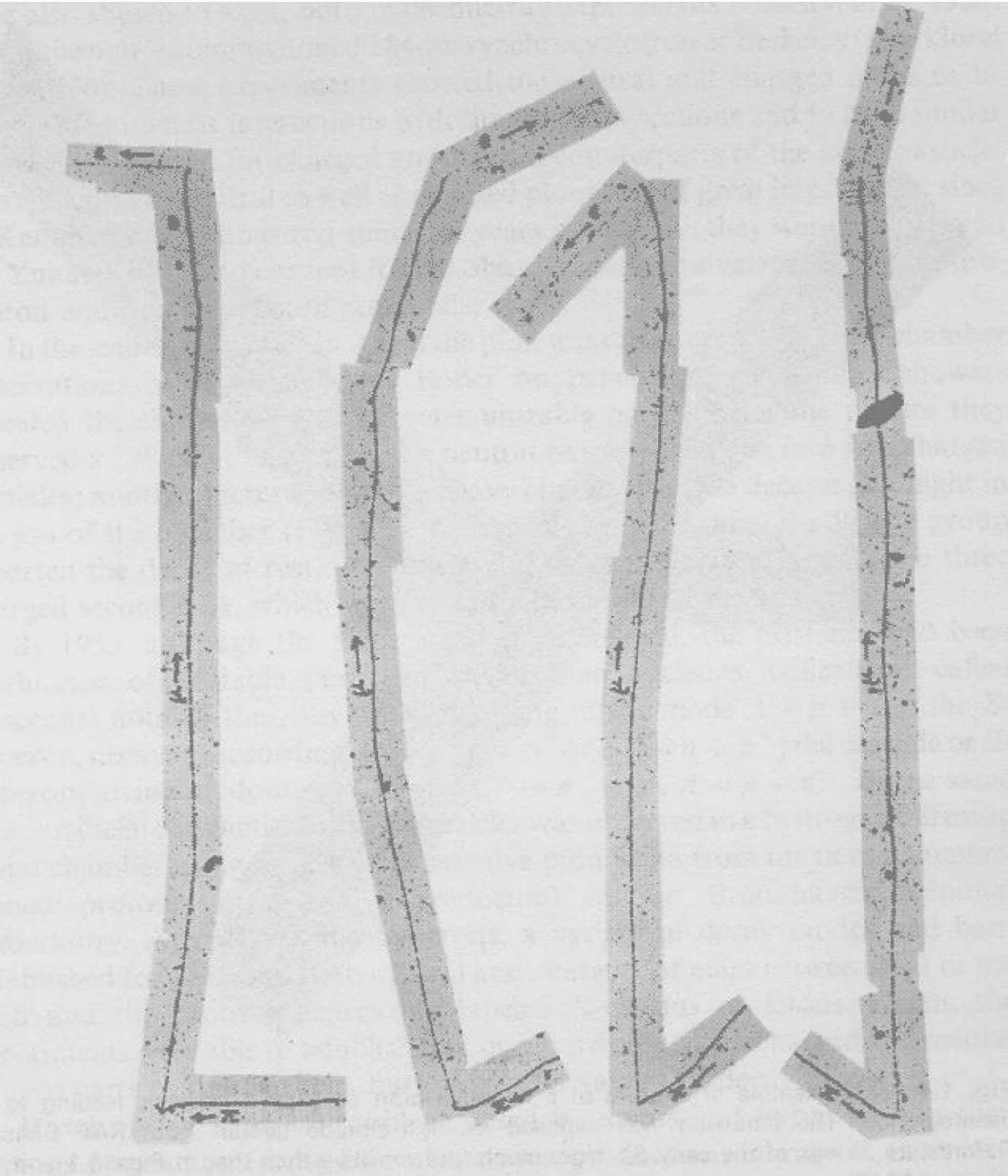
- Don's paper on the pion discovery – Enrico Fermi Summer School - DOI: 10.3254/978-1-61499-222-6-1

1948 – Don finally gets to the mountains

1948 – Don finally gets to the mountains

The π Discovery - Finale

- Advent of e-sensitive emulsions in 1949 made the whole picture clear.
- Don (and just before him Peter Fowler) arrived in Bristol just too late to share in the π discovery, for which Powell received the Nobel Prize in 1950.
- He arrived in Bristol in 1949 with a Scholarship of the Exhibition of 1851 – according to the History of Bristol Physics he (also?) had a Royal Society McKinnon Scholarship.



Bristol

- A wealth of physics poured out from Bristol in the 50s. Don and Peter were at the centre of it.
- The Bristol group around 1950

Bristol

- A wealth of physics poured out from Bristol in the 50s. Don and Peter were at the centre of it.
- A younger Peter Fowler in ~1930.

Bristol

- Fowler & Perkins were the first to propose the use of pions in cancer therapy in a Nature article in 1961 - pioneers in applying the fruits of their research to other problems.

Bristol

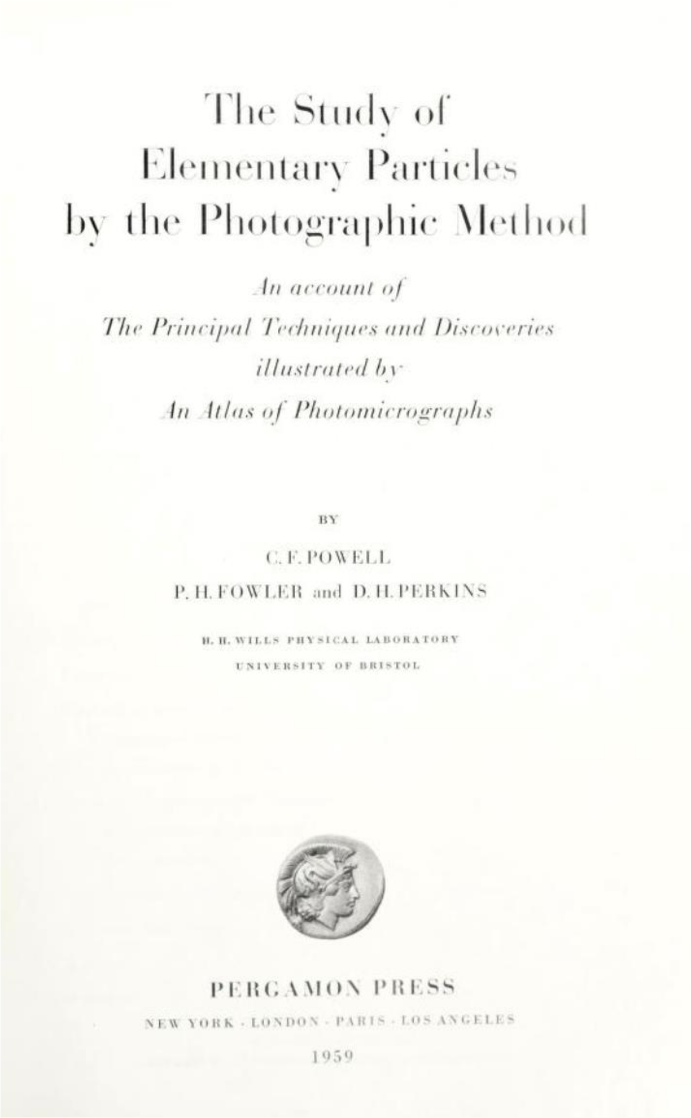
- The decays of the charged K (first seen as neutrals in V-particles in – of course – 1947) were particularly rich and confusing and took many years to unravel with Don & Peter playing important roles.

Bristol

- Balloon flights could be dangerous!

Bristol

- A wealth of physics poured out from Bristol in the 50s. Don and Peter were at the centre of it, publishing the “bible” of emulsions, Powell, Fowler & Perkins.



The Study of
Elementary Particles
by the Photographic Method

An account of
The Principal Techniques and Discoveries
illustrated by
An Atlas of Photomicrographs

BY

C. F. POWELL
P. H. FOWLER and D. H. PERKINS

H. H. WILLS PHYSICAL LABORATORY
UNIVERSITY OF BRISTOL

PERGAMON PRESS
NEW YORK · LONDON · PARIS · LOS ANGELES
1959

Bristol

- Don's publications while at IC & Bristol.

LIST OF PUBLICATIONS : D.H. PERKINS

1946-49, University of London

1.	Nuclear Disintegration by Meson Capture	Nature 159,126, 1947.
2.	'Evaporation' of Heavy Nuclei	Nature 160,299, 1947.
3.	Origin of Cosmic Ray Stars at sea-level	Nature 160,707, 1947.
4.	Disintegration of Highly Excited Nuclei	Nature 161,486, 1948.
5.	Nuclear Capture of Mu-mesons	Nature 163,682, 1949.
6.	Mechanism of Pi-meson Disintegrations	Phil.Mag. 40,601,1949.
7.	Emission of Protons and Alpha-particles in High Energy Cosmic Ray Stars	Phil.Mag.41,138, 1950.
8.	Double Stars (with T.T. Li)	Nature 161,844, 1948.
9.	Measurement of Neutron Fluxes by a new method (with R.D. Lowde)	Unpublished AERE Report 1946.
10.	Production of Heavy Mesons in Cosmic Ray Stars (with J.B. Harding)	Nature 164,285, 1949.
11.	Absorption of star-producing radiation in Ice (with J. Harding, S. Lattimore and T.T. Li)	Nature 163,319, 1949.
12.	Nuclear Disintegrations produced by Cosmic Radiation (with J. Harding and S. Lattimore)	Proc. Roy. Soc. A, 196, 325, 1949.
13.	Heavy Nuclear Splinters (with P.E. Hodgson)	Nature 163,439, 1949.

1949-64, University of Bristol

14.	Emission of Heavy Fragments in nuclear explosions	Proc. Roy. Soc. A, 206, 399, 1950.
15.	Ionization at the origin of electron pairs, and the lifetime of the neutral pion	Phil.Mag.46,1146, 1955.
16, and 17.	Nuclear Transmutations produced by Cosmic Ray Particles of great energy, Parts VI and VII (with Camerini, Davies, Fowler, Franzinetti, Lock & Yekutieli)	Phil.Mag.42,1241, 1951.
18.	Production of K-mesons by cosmic ray particles of great energy (with Daniel, Davies & Mulvey)	Phil.Mag.43, 753, 1952.
19.	Production of Heavy Mesons by Protons of energy 2 GeV - 3000 GeV (with R. Daniel)	Proc.Roy. Soc. A, 221, 351, 1954.
20.	Measurement of Ionization in Nuclear Emulsions (with P.H. Fowler)	Phil.Mag.46, 587, 1955.
21.	On the nature of Particles produced in extremely energetic nuclear encounters (with Brisbout, Dahanayake, Engler and Fujimoto)	Phil.Mag.[illegible], 605, 1956.
22.	On the masses and modes of decay of heavy mesons produced by cosmic radiation (G-stack collaboration with 35 co-authors)	Nuo.Cim.2, 1063, 1955.

"King-Perkins-Chudakov effect" in QED – Close to the production of e^+e^- pair, screening of other charge leads to reduced ionization.

Bristol

- Don's publications while at IC & Bristol.

LIST OF PUBLICATIONS : D.H. PERKINS

1946-49, University of London

1. Nuclear Disintegration by Meson Capture — Nature 159,126, 1947.
2. 'Evaporation' of Heavy Nuclei — Nature 160,299, 1947.
3. Origin of Cosmic Ray Stars at sea-level — Nature 160,707, 1947.
4. Disintegration of Highly Excited Nuclei — Nature 161,486, 1948.
5. Nuclear Capture of Mu-mesons — Nature 163,682, 1949.
6. Mechanism of Pi-meson Disintegrations — Phil.Mag. 40,601,1949.
7. Emission of Protons and Alpha-particles in High Energy Cosmic Ray Stars — Phil.Mag.41,138, 1950.
8. Double Stars (with T.T. Li) — Nature 161,844, 1948.
9. Measurement of Neutron Fluxes by a new method (with R.D. Lowde) — Unpublished AERE Report 1946.
10. Production of Heavy Mesons in Cosmic Ray Stars (with J.B. Harding) — Nature 164,285, 1949.
11. Absorption of star-producing radiation in Ice (with J. Harding, S. Lattimore and T.T. Li) — Nature 163,319, 1949.
12. Nuclear Disintegrations produced by Cosmic Radiation (with J. Harding and S. Lattimore) — Proc. Roy. Soc. A, 196, 325, 1949.
13. Heavy Nuclear Splinters (with P.E. Hodgson) — Nature 163,439, 1949.

1949-64, University of Bristol

14. Emission of Heavy Fragments in nuclear explosions — Proc. Roy. Soc. A, 206, 399, 1950.
15. Ionization at the origin of electron pairs, and the lifetime of the neutral pion — Phil.Mag.46,1146, 1955.
16, and 17. Nuclear Transmutations produced by Cosmic Ray Particles of great energy, Parts VI and VII (with Camerini, Davies, Fowler, Franzinetti, Lock & Yekutieli) — Phil.Mag.42,1241, 1951.
18. Production of K-mesons by cosmic ray particles of great energy (with Daniel, Davies & Mulvey) — Phil.Mag.43, 753, 1952.
19. Production of Heavy Mesons by Protons of energy 2 GeV - 3000 GeV (with R. Daniel) — Proc.Roy. Soc. A, 221, 351, 1954.
20. Measurement of Ionization in Nuclear Emulsions (with P.H. Fowler) — Phil.Mag.46, 587, 1955.
21. On the nature of Particles produced in extremely energetic nuclear encounters (with Brisbout, Dahanayake, Engler and Fujimoto) — Phil.Mag. 1, 605, 1956.
22. On the masses and modes of decay of heavy mesons produced by cosmic radiation (G-stack collaboration with 35 co-authors) — Nuo.Cim.2, 1063, 1955.
23. Analysis of Nuclear Interactions of Energies between 1000 and 100,000 BeV (with Edwards, Losty, Pinkau & Reynolds) — Phil.Mag. 3, 237, 1958.
24. Observation of the Suppression Effect on Bremsstrahlung (with P.Fowler & K.Pinkau) — Phil.Mag. 4,1030, 1959.
25. Studies of the Spectrum of Cascades and Nuclear active component of Air showers at 10,000 m. altitude (with Duthie, Fowler, Fisher, Kaddoura, Pinkau & Wolter) Pts. I & II — Phil.Mag. 6, 89, 1961.
26. The Possibility of Therapeutic Applications of Beams of Negative Pions (with P.H. Fowler) — Nature 189, 524, 1961.
27. Neutrino Fluxes at Nimrod(" " ") — U.of Bristol Report (unpublished) 1962.
28. The Flux of Gamma Rays at High Altitude, and Comparison with the Muon Flux at Sea-Level (with Duthie, Fowler, Kaddoura & Pinkau) — Nuov.Cim.24,122, 1962.
29. Production of Pions and Hyperons in Nuclear Interactions of Very High Energy (with M. Bowler and P. Fowler) — Nuov.Cim.26,1182, 1962.
30. Physics at Ultra High Energy — New Scient.17,21, 1963.
31. Cosmic Radiation and Solar Particles at Aircraft Altitudes (with P.H. Fowler) — Air Registration Board Report SAAC/20 Sept. 1962.
32. Conf.of IPPS on High Energy Physics(Bristol) — Brit.Jour.App.Phys.14, 1963.
33. Nuclear Interactions from 30 to 10^6 GeV (with P.H. Fowler) — Proc. Roy. Soc. A, 278, 401, 1964.
34. ~~Present status of neutrino experiments at accelerators — Proc.IUPAP Conf.Jaipur, Dec.1963.~~
35. ~~CERN Neutrino Experiment - Bubble Chamber Results (with 14 co-authors) — Proc.Sienna Conf. Sept. 1963.~~
36. ~~Neutrino Interactions in the CERN Heavy Liquid Bubble Chamber (with 18 co-authors) — Phys. Lett.12,281,1964.~~
37. ~~High Energy Neutrino Experiments — Proc.Roy.Soc. 1965 (in press)~~

1960, University of Bari

34. Observations on the long range interactions of Pions (with 17 co-authors) — Nuov.Cim.21,459, 1961.

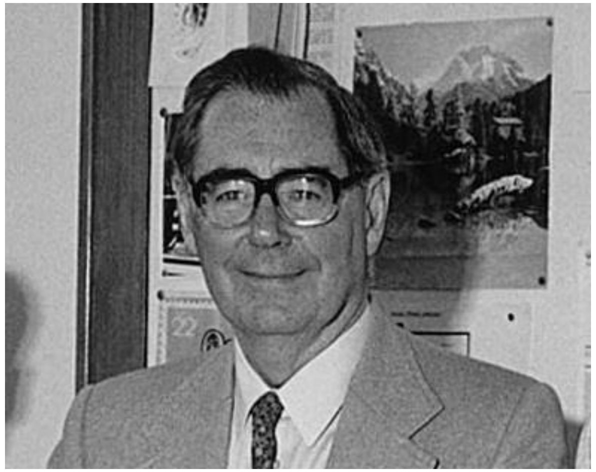
1955-6 and 1961, University of California

35 ~~39~~. Decay Characteristics and Masses of Positive K-mesons produced by the Bevatron (with Birge, Peterson, Stork and Whitehead) — Nuov.Cim. 4, 834, 1956.
36 ~~40~~. Antiproton-Nucleon Annihilation Process (with 17 co-authors) — Phys.Rev.105,1037, 1957.

Oxford

- By the late 1950s, Don could see that emulsions were coming to the end of their development. He turned increasing to the use of accelerators rather than cosmic rays and to a new field, that of the properties of neutrinos – and came to Oxford in 1965.
- His IC & Bristol work was the basis for his election as FRS in 1966.

- Sir Denys Wilkinson, FRS



- Ken Allen

40th Anniversary of π Conference@ Bristol

John Malos retirement ~ 1993

Final words – again from Don

basic research cannot possibly be predicted.

But some things have not changed at all. Fifty years ago, Cecil Powell described his feelings on finding all those wonderful new processes in nuclear emulsions. He said it was "as if, suddenly, we had broken into a walled orchard, where protected trees flourished and all kinds of exotic fruits had ripened in great profusion". Well, the walled orchards still exist today. Perhaps they are not so easy to find, but they *are* there and it is for the new generation of physicists to find them, as I am sure they will.