From CUDOS to PLACE
Gardeners and Hunters in the Transition from the Academic to the Post Academic Science
Reflections on Fraud and the Structure of Scientific Research

Stefano Ossicini
INFM- S^3 - Physics and DISMI Departments
PHD School Nano- and Physical Sciences
Università di Modena e Reggio Emilia - Italy
What ever happened to Dr. Rupp?
or
The resistible rise of Emil Rupp
LOUIS DE BROGLIE

The wave nature of the electron

Nobel Lecture, December 12, 1929

Now, experiment which is the final judge of theories, has shown that the phenomenon of electron diffraction by crystals actually exists and that it obeys exactly and quantitatively the laws of wave mechanics. To Davisson and Germer, working at the Bell Laboratories in New York, falls the honour of being the first to observe the phenomenon by a method analogous to that of von Laue for X-rays. By duplicating the same experiments but replacing the single crystal by a crystalline powder in conformity with the method introduced for X-rays by Debye and Scherrer, Professor G. P. Thomson of Aberdeen, son of the famous Cambridge physicist Sir J. J. Thomson, found the same phenomena. Then Rupp in Germany, Kikuchi in Japan, Ponte in France and others reproduced them, varying the experimental conditions. Today, the existence of the phenomenon is beyond doubt and the slight difficulties of interpretation posed by the first experiments of Davisson and Germer appear to have been satisfactorily solved.

Rupp has even managed to bring about electron diffraction in a particularly striking form. You will be familiar with what are termed diffraction gratings in optics: these are glass or metal surfaces, plane or slightly curved, on which have been mechanically traced equidistant lines, the spacing between which is comparable in order of magnitude with the wavelengths of light waves. The waves diffracted by these lines interfere, and the inter-
1. Über die Winkelverteilung langsamer Elektronen beim Durchgang durch Metallhäute;
von E. Rupp
(Hierzu Tafel XXII bis XXIV)

§ 1. Einleitung

Tritt ein eng begrenzter Elektronenstrahl einheitlicher Geschwindigkeit, aus dem Hochvakuum kommend, in ein Medium $M$ ein, so findet man auf der Austrittsseite des Med.-

... (Text fortgesetzt)
1930

b) Diffraction of matter waves (Davisson and Germer,¹
Thomson,² Rupp³).—After the conception of β-rays as
streams of particles had remained unchallenged for more
than fifteen years, another series of experiments was per-

§ 3. THE EXPERIMENT OF EINSTEIN AND RUPP⁴

Another paradox was thought to be presented by the
following experiment: An atom (canal ray) is made to
pass a slit $S$ of width $d$ with the velocity $v$, and emits light
while doing so. This light is analyzed by a spectroscope
behind $S$. Since the light can reach the spectroscope only
during the time $t = d/v$, the train of waves to be analyzed
has a finite length, and the spectroscope will show it as a
line whose width corresponds to a frequency range

$$\Delta \nu = \frac{1}{t} = \frac{v}{d}.$$  

On the other hand, the corpuscular theory seems to pro-
hibit such a broadening. The atom emits monochromatic
radiation, the energy of each particle of which is $hv$, and
the diaphragm (because of its great mass) will not be able
to change the energy of the particles.

The fallacy lies in neglecting the Doppler effect and the
diffraction of the light at the slit. Those photons which
reach $P$ from the atom are not all emitted perpendicularly

¹ A. Einstein, Berliner Berichte, p. 334, 1926; A. Rupp, ibid., p. 341,
1926.
Emil Rupp 1931

Für einen ruhenden Elektronenkreislauf, auf dem während der Zeit $t$ ein Magnetfeld $H$ einwirkt, wäre die Winkelverdrehung $\varphi$ infolge der Präzessionsbewegung gegeben durch

$$\varphi = \frac{2 \pi f}{T_p}$$

$T_p$ ist die Präzessionsperiode. Ihr Wert ist gegeben durch

$$\tau = \frac{2 \pi m_e}{\gamma}$$

transversale Magnetfelder anwenden. Am besten verwendet man ein gekreuztes elektrisches und magnetisches Feld, die aufeinander so abgestimmt sind, daß, vom mittlere Magnetfeld aus betrachtet, kein elektrischen Feld vorhanden ist. Der Kathodenstrahl erfährt dann keine Abweichung im Feld. Solche Versuche sind in Vorbereitung.

E. Rupp. L. Schall.
The Nobel Prize in Physics 1937
"for their experimental discovery of the diffraction of electrons by crystals"

Clinton Joseph Davisson

George Paget Thomson

The discovery of electron waves
Nobel Lecture, December 13, 1937

Electronic Waves
Nobel Lecture, June 7, 1938

What Ever Happened To Dr. Rupp?
S. Ossicini
The resistible rise of Emil Rupp (1926-1935)

Emil Rupp (1898) - “PhD summa cum laude” 1922
Philipp Lenard (Nobel Prize 1905)
Heidelberg

- “Habilitation” 1926

JANUARY
1926.
ANNALEN DER PHYSIK.
VIERTE FOLGE. BAND 79.

1. Interferenzuntersuchungen an Kanalstrahlen;
von E. Rupp.

and Abklingzeit des leuchtenden Atoms zu kommen. Untersucht wurden Wasserstoff- und Quecksilberkanalstrahlen mittels der Michelsonschen Interferometeranordnung.

Nach Ermittlung des Verschwindens der Interferenzstreifen aus spektralen und apparativen Gründen wurde als größterreichte Interferenzweglänge gefunden

für H₂ 15,2 cm,
für Hg 546 μ 62 cm.

Anfangswert \( A_0 \) nach dem Gesetz \( A = A_0 \cdot e^{-at} \) zeitlich ab.
Der e-te Betrag der Anfangsamplitude wird nach einer bestimmten Zeit, der Abklingzeit \( t = \frac{1}{a} \) erreicht.

“Interference Experiments with Canal Rays”
Einstein thinks that it is possible to distinguish between quantum (instantaneous) and classical (extended in time) light emission.

A canal-ray beam passes at right angles to the optical axis of a lens. Light emitted by the individual atoms in the beam is refocused on a grid of parallel wires at an equal distance from the lens. Because of the transverse motion of radiating atoms, the light coming from any individual atom will be alternately passed and blocked by the grid, thus producing successive short wave-trains. By changing the velocity of the canal-rays, or using different grid spacing, one could control the length and separation of the interfering wave-trains distinguishing between classical and quantum pictures of the emission process.

Einstein corresponds with Rupp on the matter of doing the experiment.
Few months later Einstein had changed his mind about the possibility of distinguishing between quantum and classical light emission, because of Doppler effect.

Einstein envisioned a new experiment. Because self-interference can occur only for light emitted from one and the same atom, light emitted at different times (therefore at different places) can produce interference fringes only if one of the mirrors in the interferometer is slightly tilted. The rotation of the mirror corresponds to a compensation for the Doppler effect of the moving atoms.

Einstein corresponds with Rupp on the matter of doing the experiment.
“Wire Grid and Rotating Mirror Experiments”

Rupp reported (May-August) experiments using a grid and with the rotated-mirror.

In the first case he showed graphs indicating a periodic variation of fringe sharpness as a function of the path difference between the two arms of the interferometer.

In the second, he reported maximum fringe visibility, for a given path difference between the two interferometer beams, when the rotatable mirror was turned through the angle called for Einstein’s theory.

Einstein to Ehrenfest, 12 April 1926:

“Rupp should do an experiment about [the extended time of emission]. He has probably already done it, but—he does not know it yet.”

S. Ossicini
Philipp Lenard (Nobel Prize 1905)

Johannes Stark
(Nobel Prize 1919)

S. Ossicini
Rupp first does the Grating Experiment.

May 14: “I have come to a certain conclusion of the Grating Experiment.”

“Grating 0.1 mm distance”

18 May: Einstein replies.

Graph for finer grating? “Flagrant contradiction with the theory. Fully incomprehensible.”

“It would be a very good idea if you studied my theoretical considerations better.”

“The experiments have not been concluded at all.”
20 May: **Rupp sends new results** (within 2 days!).

“I can now send you results that are in full agreement with the theory.”

21 May: **Einstein replies** (he has now calculated the max & min).

“The results can still not be regarded as a confirmation of the theory.”

“1) The separation between the points of optimal interference should, for the 0.02 mm grating, be *five times* smaller than with the 0.1 mm grating. (In your experiments it is only two times smaller.)”

“2) The value for the separation of the optimal interference is also incorrect. With \( b \) the distance between neighboring lines of the grating, \( v \) the speed of the canal rays, then that separation has to be \( b^2 \), i.e. in your first experiment \( 0.01 \cdot \frac{3 \times 10^{10}}{1.9 \times 10^7} = 16 \text{ cm} \), while it is 30 cm according to your experiment.”
May 31: Rupp sends yet again new data.

"Regrettably, I must first correct the information about the grating I used. The first grating contains 100 clear and dark parts on 1 cm, i.e. the distance center clear-clear is $2 \cdot 0,01$ cm."

"The other grating has 200 parts/cm [Teile/cm], so the distance between two lines is $2 \cdot 0,05$ [sic!] cm (not 0,02 cm as I inaccurately miswrote)."

"May you decide how these results compare to the theory."

3 June: Einstein replies.

"The experiments, that you reported me in your letter of May 31st, are fully satisfying and can be considered a convincing confirmation of the theory. [...]"

If the experiment with the lens [i.e. Rotating Mirror Experiment] also succeeds, then there is no doubt that the theory is correct; actually, that can already not be questioned."
Rotating Mirror Experiment:

15 June: **Rupp reports results.**

Interferences at 0 degrees most unclear, become more clear near +15 degrees, bright and sharp between 30 and 40 degrees, then however, the clarity declines rapidly, at 45 degrees there are hardly any [fringes] visible.

18 June: **Atkinson’s article comes out.**

21 August, Rupp to Einstein:

“**I added something in my manuscript—against Atkinson—that shows that in my earlier paper I had unknowingly and unconsciously carried out the Rotating Mirror Experiment, and in this way arrived at interferences at 15 cm path difference.**”

27 August, Einstein:

“The interference of your earlier experiment can only be explained by an unconscious rotation of the mirror.”

"Über Interferenz von Kanalstrahlenlicht."


R. d’E. Atkinson.
Über die Interferenz-Eigenschaften des durch Kanalstrahlen emittierten Lichtes.

Von A. Einstein.

Nachtrag.


E. Rupp, “Über die Interferenz-Eigenschaften des Kanalstrahllichtes”
S. B. Preuss. 25 (1926) 341

“...One cannot easily underestimate its effect: see e.g. L. Bohnenkamp to Rupp: “Thank you for sending the reprints, that I study carefully. Hopefully you will not immediately become Geheimratlich because of the new symbiosis with the persona gratissima Einstein.” 16 Dec 1926, MFWG.
Rupp responded, but von Hirsch found the response unsatisfactory. “If, in a difficult area of experimental research, differences of interpretation arise, only unsparing criticism of the experiment can provide the clarity that secures the basis for future work.”

Rupp had mentioned that the sets of figures in his paper were not the originals, but had been assembled from separate photographs, superimposed and then recopied. Hirsch remarked: “If an observation, which at the best is at the extreme limits of measurability, is communicated without giving the actual measured values, but only in a copied and converted form, without review of errors, so that there is no standard for exactness and certainty of the result, then this procedure is inconsistent with the established principles of experimental physics.”

H. Straub (PhD Student of Gerlach-1930) failed to find evidence for a coherence length as large as 2 mm (the minimum for his apparatus) for the Rotating Mirror experiment and rotation of one mirror had no effect. He concluded that the experiment proposed by Einstein would be impossible unless canal rays homogeneous in velocity could be produced.
Über Elektronenbeugung an nichtmetallischen Einkristallen
Von M. v. Laue und E. Rupp
(Aus dem Forschungs-Institut der AEG.)
(Mit 7 Figuren)

Über die ersten dieser Versuche hat der eine von uns schon an dieser Stelle berichtet. 1) Neuerdings hat er diese und weitere Messungen derselben Art an zugefügt. Während die Wiederholungen resultierende Vorgänge voll aus bestätigen, hat und wohl einfachere Deutung dafür gen genan den neuen Messungen immer wieder das. Sie schreibt jedem dieser

M. v. Laue (Nobel Prize 1914)

Notiz zur Dynamik der Randschichten eines Kristalls vom NaCl-Typus
Zusatz zu der vorhergehenden Arbeit von M. v. Laue und E. Rupp
Von M. v. Laue

In der im Titel genannten Untersuchung zeigt sich an den Versuchen über Elektronenbeugung, daß der dabei in Betracht kommende Netzebenenabstand \( d \) innerhalb der freilich ziemlich weiten Fehlergrenzen denselben Wert hat, den man aus röntgenographischen Untersuchungen kennt. 1) Das scheint zunächst sehr sonderbar; denn für die Beugung von Röntgenstrahlen spielen stets Hunderte, wenn nicht Tausende von Netzebenen eine Rolle, während nach der erwähnten Untersuchung (§ 1) dafür höchstens die ersten 20 zusammenwirken.

Emil Rupp moves from Göttingen to Berlin

VERY STRANGE!

S. Ossicini
Bemerkung zur Arbeit von E. Rupp „Über die Gültigkeit der de Broglieschen Beziehung für sehr schnelle Elektronen“.


$$V = \frac{1}{e} \left( \frac{1}{\sqrt{1 - \beta^2}} - 1 \right) m_0 c^2$$

einsetzt, und es mit der richtigen Formel (1) vergleicht. Wenn man also direkt aus (1) den Wert von λ für 220 K.V. Elektronen (β = 0,715) berechnet, so bekommt man λ = 2,35 \cdot 10^{-10} \text{ cm}, während RUPP aus (2) λ = 2,183 \cdot 10^{-10} \text{ cm} erhalten hat. Aus den Beugungsringen hat er andererseits λ = (2,162 ± 0,013) \cdot 10^{-10} \text{ cm} bekommen. Die Diskrepanz beträgt also etwa 9\%, was weit über der von ihm angegebenen Meßgenauigkeit liegt. Wenn also seine Ergebnisse richtig sind, so muß man daraus schließen, daß die de Brogliesche Beziehung für sehr schnelle Elektronen nicht mehr gilt!

In 1928, Dirac published his theory of electron, and the question was raised whether the effects of the magnetic moment associated with the electron spin could be observed for free electrons.
A TEST FOR POLARIZATION OF ELECTRON WAVES BY REFLECTION

By C. J. Davisson and L. H. Germer

Abstract

A homogeneous beam of electrons is directed at 45° incidence against a \{111\}—face of a nickel crystal. The beam regularly reflected from this face impinges upon a second similar face at the same incidence angle. A Faraday collector is set to receive electrons regularly reflected from the second crystal, but only such electrons are accepted into the collector as have survived the two reflections without appreciable loss of kinetic energy. The collector and second crystal are rigidly joined, and may be rotated about the axis of the beam proceeding from the first to the second crystal. Measurements of the intensity of the twice reflected beam have been made at bombarding potentials from 10 to 200 volts. Within this range selective reflections (intensity maxima) are observed at 20, 55, 77, 103 and 120 volts. These five selectively reflected beams have been separately tested for polarization by measuring the current received by the collector as a function of the azimuth of the movable system. If electron waves are polarized by reflection the intensity of the twice reflected beam should be greatest when the planes of incidence of the two reflections coincide, and least when they stand normal to one another. No such variation of the current to the collector is observed within the limits of error of the measurements—about one half of one percent of the total current. Our observation is that electron waves are not polarized by reflection.
The Scattering of Fast Electrons by Atomic Nuclei.

By N. F. Mott, B.A., St. John’s College, Cambridge.

(Communicated by N. Bohr, For. Mem. R.S.—Received April 25, 1929.)

Section 1. The hypothesis that the electron has a magnetic moment was, as is well known, first introduced to account for the duplicity phenomena of atomic spectra. More recently, however, Dirac has succeeded in accounting for these same phenomena by the introduction of a modified wave equation, which conforms both to the principle of relativity and to the general transformation theory. Formally, at least, on the new theory also, the electron has a magnetic moment of \( \hbar/e \), but when the electron is in an atom we cannot observe this magnetic moment directly; we can only observe the moment of the whole atom, or, of course, the splitting of the spectral lines, which we may say is “caused” by this moment. The question arises, has the free electron “really” got a magnetic moment, a magnetic moment that we can by any conceivable experiment observe? The question is not so simple as it might seem, because a magnetic moment \( \hbar/e \) can never be observed directly, e.g., with a magnetometer; there is always an uncertainty in the external electromagnetic field, due to the uncertainty in the position and
Mott (1929, and later 1931, 1932) calculated, on the basis of Dirac’s theory of the electron, that there would be a forward-backward asymmetry of approximately 10% in the double scattering of electrons from heavy nuclei. Mott clearly specified the conditions that would have to be satisfied in order to observe this effect. One had to double scatter relativistic electrons at large angles (90°) from heavy nuclei (most calculations assumed a nuclear charge $Z$ approximately 80). The first scatter would polarize the electrons and the second scatter would analyze the produced polarization, giving rise to an asymmetry.

The earliest experiment that discussed Mott’s calculation was performed by Chase (1929). He observed a 4% asymmetry in the double scattering but attributed it to a difference in the electrons path.
Rupp promptly picked upon this question.

Positive results were provided by experiments done by Rupp.

i) 1929 Rupp reported for double scattering at very small angles that the polarization increased with increasing energy and that while gold have an effect, beryllium did not; Chase noted that Mott’s theory applied only to large-angle scattering.

ii) 1930 Rupp and Rupp and Szilard reported a positive result for a single 90° scatter followed by diffraction from a foil.

iii) Rupp’s 1932 experiment first scattered electrons at 90° from a gold foil, followed by a 90° scatter from a gold wire. He found a 3-4% asymmetry at an electron energy of 130 keV and an asymmetry of 9-10% at 250 keV.

iv) Dymond (1931) also reported a positive result, but one that was five times smaller than the theoretical prediction.
München, den 30.1.1930.

Sehr geehrter Herr Rupp!

Ihren Bericht über den photographischen Nachweis der un-
symmetrischen Winkelverteilung der zweifach reflektierten Elektronen
haben wir mit grossem Interesse gelesen. Da wir selbst seit längerer
Zeit mit ähnlichen Versuchen (allerdings mit ausgesprochen negativen
Ergebnis) beschäftigt sind, würden wir Ihnen zu Dank verpflichtet sein,
wenn Sie uns mitteilen würden, mit welcher Stromstärke und mit
welchen Expositionsszeiten Sie bei 220 KV gearbeitet haben. Nach
unseren Erfahrungen müssen Sie recht hohe Expositionszeiten verwenden
haben. Besonders sind wir überrascht über die Linienstärke, die ja
trotz der zweieinhalbachen Vergrösserung ausserordentlich gross
ist (Fig.2). Oder haben Sie vielleicht noch stärkere Ausblendung
Verwendet, als in Fig.1 angegeben? Dann müsten Sie aber ganz
unwahrscheinlich hohe Expositionszeiten gehabt haben. (Ihre Fig.1 ist
doch wohl so zu verstehen, dass der Abstand zwischen A und B2 50mm,
und der zwischen B2 und P 450 mm beträgt – in der Zeichnung erscheint
der Abstand B2P nur doppelt so gross wie B2P !).

Schliesslich möchten wir Sie noch um die Angabe bitten, wie dick
die verwendete Goldschicht bei A war; nach unseren Erfahrungen mit
können Schichten muss Ihre Schicht sehr dick gewesen sein, da Sie
Einst unbedingt zu wochenlangen Expositionen kommen müssten.

In Interesse einer baldigen Klärung des Unterschiedes zwischen
Ihrem Ergebnis und dem unserigen wären wir Ihnen für eine baldige
Antwort sehr dankbar.

Mit besten Grüssen

Arnold Sommerfeld
SEGUE...

- **G.P. Thomson** (1933), found no effect.

- **Rupp** (1934), this time using thallium vapor rather than gold targets, again found a positive result.

- **Dymond** (1934) published a full repudiation of his earlier positive results. He concluded, "We are driven to the conclusion that the theoretical results are wrong. There is no reason to believe that the work of Mott is incorrect;... It seems not improbable, therefore, that the divergence of theory from experiment has a more deep-seated cause, and that the Dirac wave equation needs modification in order to account successfully for the absence of polarization".

- **G.P. Thomson** (1934) published a comprehensive review of the field. He reported no effects of the type found by Rupp and he found a forward-backward ratio of \((0.996 \pm 0.01)\) in comparison to Mott’s prediction of \((1.15)\). Thomson also concluded that there was a serious discrepancy between theory and experiment.
Rupp continued to be quick to seize on the newest developments, and after doing his work on electron scattering he soon turned his attention in other directions. 1932 saw the discovery of the neutron by Chadwick and of the positron by C. D. Anderson. In 1933, I. Curie and F. Joliot, L. Meitner, Chadwick, Blackett and Occhialini observed the emission of positrons from certain elements when bombarded by alpha particles, neutrons and gamma rays from laboratory sources. Rupp described in details, 1934 in several papers, how he have made positrons by bombarding lithium with energetic protons, producing alpha particles, and allowing these to strike an aluminium foil from which positrons emerged on the far side. He claimed to have accelerated a beam of protons of 1 mA across a vacuum gap of only 3mm at potential differences up to 500 kV. Results better than those obtained in Rutherford’s laboratory at Cambridge, the only place at the time that had an high-voltage accelerator. Rupp claimed also the first test of the De Broglie relationship for protons!
Lange and Brasch at AEG Berlin discovered that the discharge tube used in the Rupp's experiment for positron showed no sign of use! Rupp sought protection by the Director Ramsauer, who appointed a small committee to supervise Rupp's repetition of experiments, but shortly thereafter Rupp said the discharge tube, oops!, had been broken. Rupp is expelled from the Institute and obliged to make the matter public in some way.

Mitteilung.

Infolge einer Erkrankung, über die das unten aufgeführte ärztliche Gutachten\(^1\) Auskunft gibt, sehe ich mich veranlaßt, die folgenden Veröffentlichungen aus dem Jahre 1934 zurückzuziehen:

- Polarisation der Elektronen in magnetischen Feldern. ZS. f. Phys. 90, 166, 1934.

Es besteht keine Veranlassung, frühere Arbeiten ganz oder teilweise zurückzuziehen.

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\(^1\) Aus dem Gutachten des Arztes, Dr. E. Freiherr von Gebsattel, Fürstenberg (Meckl.): Die Untersuchung ergab, daß Dr. Rupp seit 1932 an einem mit psychogenen Dämmerzuständen verbundenen seelischen Schwächezustand (Psychasthenie) erkrankt war. Während dieser Erkrankung und durch sie bestimmt, hat er, ohne sich dessen bewußt zu sein, Mitteilungen über physikalische Phänomene (Positronen, Atomzertrümmerung) veröffentlicht, die den Charakter von „Fiktionen“ an sich tragen. Es handelt sich um einen Einbruch von traumartigen Zuständen in das Gebiet seiner Forschertätigkeit. Seine völlige Wiederherstellung wird mit völliger Sicherheit erfolgen.
Announcement

As the result of an illness, about which the medical opinion below* gives information, I find myself obliged to retract the following publications from the year 1934:

Polarization of electrons by free atoms, Z. Phys. 88, 242 (1934)
Polarization of electrons in magnetic field, Z. Phys. 90, 166 (1934)
Investigations with artificially produced positrons, Z. Phys. 92, 485 (1934)
Investigations with artificially produced positrons, Z. tech. Phys. 15, 575 (1934)
Measurements of high voltages by means of electron scattering, Ann. Phys. 20, 594 (1934)

There exists no cause to retract earlier works either wholly or partially.

*Dr. E. Freiherr von Gebsattel:”The investigations showed that Dr. Rupp had been ill since 1932 with an emotional weakness (Psychastenia) linked to psychological semiconsciousness. During this illness, and under its influence, he has, without being himself conscious of it, published papers on physical phenomena (positrons, atomic disintegrations) that have the character of ‘fictions’. It is a matter of the intrusion of dreamlike states into the area of his scientific activity. His complete recovery will certainly ensue”
Einstein had given the wrong sense of orientation for the tilted mirror. Error repeated by Rupp in his arrangement, but which, he said, brought the fringes into view!
Anmerkung der Redaktion:


Wir beabsichtigen nicht, weitere Einzelheiten darüber zu bringen, müssen vielmehr den Lesern die angemessene Vorsicht überlassen.

Die Redaktion.
H. Billing (Gerlach PhD Student) stated that, when sufficiently homogeneous and parallel canal rays are available, one could see interferences to some 1.5 mm path difference (two orders of magnitude less than Rupp) using the rotation angle (with the right direction) dependence predicted by Einstein. So the Munich group ended up confirming Einstein’s theory!
Thus, at the end of 1939 there was a clear discrepancy between Dirac theory, as used by Mott, and the experimental results on the double scattering of electrons. Yet the theory was not regarded as refuted. Why was this? The reason is that, at the time, Dirac theory, and only Dirac theory, predicted the existence of the positron (a positive electron). This particle had been discovered in 1932 and had provided very strong support for Dirac theory. In comparison with this success, the discrepancy in electron scattering, along with another small discrepancy in the spectrum of hydrogen, just did not have sufficient evidential weight. The unique, and confirmed, prediction of the positron outweighed these discrepancies.

**It isn’t easy to refute a strongly confirmed theory.**

Interestingly, it was the experimental results that were wrong. In the early 1940s experimental work showed that the way in which the experiments were performed during the 1930s had precluded the possibility of observing the polarization effects predicted by Mott. In order to avoid problems with multiple scattering the experimenters had scattered the electrons from the front surface of the targets. Unfortunately this made the effects of plural scattering, a few large scatters rather than just one as required by Mott, very large.

*The symmetric plural scattering swamped the predicted polarization effect.* When the experimental apparatuses were changed to eliminate this problem the discrepancy disappeared. Mott’s theory was then supported by the experimental evidence 14 years later!