A Critical History of Quantum Mechanics and Wave-Particle Duality

By Eric Reiter, February 4, 2022

See **Thresholdmodel.com**

We will re-visit arguments for and against quantum mechanics and reveal some assumptions.

The incomprehensible nature of quantum mechanics will be explained such that it is indeed incomprehensible.

Repair of quantum mechanics can render nature comprehensible.

We will concentrate mostly on ideas that led to wave-particle duality. Early experiments found that matter and light each seemed to have wave and particle properties: a contradiction. Here you will see how our greatest physicists struggled over those ideas. Many physicists will admit that this wave-particle problem has not been resolved to this day. The double-slit test is a popular way to express the wave-particle problem, but a far better test is the beam-split coincidence test. The history of that test will be shown, starting from the thought experiment of Einstein in his definition of the photon, leading to modern actualizations. This critical history includes objections and alternatives that were rejected. From the original offprints, you can judge the assumptions that IMHO led us astray. After you see my other writings and videos of experiments and theory, you might understand how these historical components lead to the resolution of wave-particle duality.

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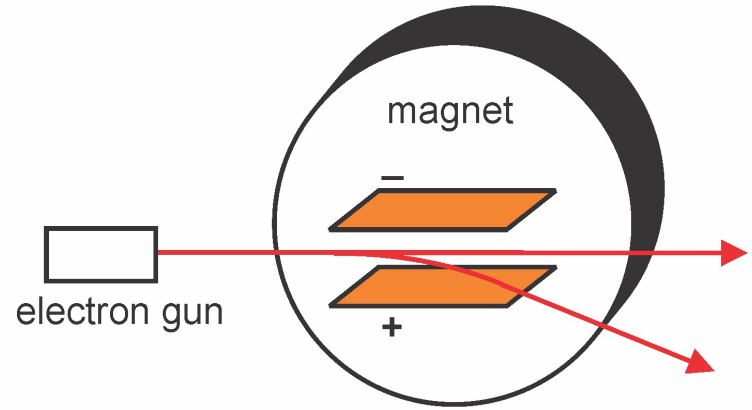
. In red, not accepted by mainstream.

1897 JJ Thomson used the particle model in experiment and theory to reveal

e/m ratio

Components of derivation have e/m.

Phil Mag XLIV (1897) 298.

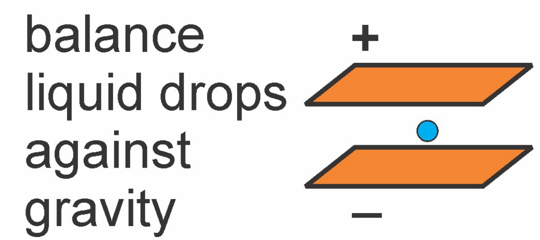


Charge in free space

1898 Townsend and JJ balanced liquid drops to reveal the charge constant

e

Phil Mag XLVI (1898) 528, Townsend's paper.



Charge in bulk matter

Assumption: Charge is thought to be quantized and particle-like in bulk matter and in free space, even though in free space our experiments only reveal ratios, like e/m.

Here is a preview of my hypothesis: Consider that charge is not quantized in free space, but is thresholded. In bulk matter an ensemble effect obscures sub-threshold detection. We propose it is only the e/m ratio that is quantized. We also maintain that the proportion is maintained in their sub-threshold state in sections of space. If this were the case our experiments would give the illusion of quantization. At www.thresholdmodel.com you will see how beam-split coincidence tests verify this model.

1900. Planck, *On the Theory of the Energy Distribution Law of the Normal Spectrum*,

Meeting of 14 December 1900. In *Planck's Original Papers in Quantum Physics*, Kangro, Brush, 1972. Resonator energy is proportional to frequency. Resonators were in matter, not light. Energy is not really quantized because there can be any frequency; it is proportionalized. Planck's constant is more like an energy shaping function of charge.

First appearance of *h*

Let us consider a large number of linear, monochromatically vibrating resonators—N of frequency ν (per second),[28] N' of frequency ν', N'' of frequency ν'', ..., with all N large numbers—which are properly separated and are enclosed in a diathermic[27] medium with light velocity c and bounded by reflecting walls. Let the system contain a certain amount of energy, the total energy E_t(erg) which is present partly in the medium as travelling radiation and partly in the resonators as vibrational energy. The question is how in a stationary state this energy is distributed over the vibrations of the resonators and over the various colours of the radiation present in the medium, and what will be the temperature of the total system.

To answer this question we first of all consider the vibrations of the resonators[29] and try to assign to them certain arbitrary energies, for instance, an energy E to the N resonators ν, E' to the N' resonators ν', ... The sum

$$E+E'+E''+\ldots=E_0$$

must, of course, be less than E_t. The remainder E_t-E_0 pertains then to the radiation present in the medium. We must now give the distribution of the energy over the separate resonators of each group, first of all the distribution of the energy E over the N resonators of frequency ν. If E is considered to be a continuously divisible quantity, this distribution is possible in infinitely many ways. We consider, however—this is the most essential point of the whole calculation—E to be composed of a well-defined number of equal parts and use thereto the constant of nature $h=6{\cdot}55\times10^{-27}$ erg sec.[30] This constant multiplied by the common frequency ν of the resonators gives us the energy element[31] ϵ in erg, and dividing E by ϵ we get the number P of energy elements which must be divided over the N resonators. If the ratio thus calculated is not an integer, we take for P an integer in the neighbourhood.[32]

1902 Lenard, *Uber die Lichtelektrische Wirkung*, Annalen der Physik, 313(5), pg 149. His photoelectric effect paper.

Discovered emitted electron kinetic energy not a function of light intensity. He thought (erroneously) photoelectron's kinetic energy came from stored energy in response to light in a trigger hypothesis. He understood that stopping voltage was a function of light frequency but did not state a linear relationship.

The trigger hypothesis was obviously flawed but his experimental results were a great achievement.

> ...concluded that the energy at escape does not come from the light at all, but from the interior of the particular atom. The light only has an initiating action, rather like that of a of the fuse in firing a loaded gun.
>
> From *On cathode rays Nobel Lecture*, May 28, 1906

The velocity at escape we have already mentioned as very low. I have also found that the velocity is independent of the ultraviolet light intensity (M), and thus concluded that the energy at escape does not come from the light at all, but from the interior of the particular atom. The light only has an initiating action, rather like that of the fuse in firing a loaded gun. I find this conclusion important since from it we learn that not only the atoms of radium - the properties of which were just beginning to be discerned in more detail at that time - contain reserves of energy, but also the atoms of the other elements; these too are capable of emitting radiation and in doing so perhaps completely break down, corresponding to the disintegration and roughening of the substances in ultraviolet light. This view has quite recently been corroborated at the Kiel Institute by special experiments which also showed that the photoelectric effect occurs with unchanged initial velocities even at the temperature of liquid air.

1905. Einstein, *On a Heuristic Point of View About the Creation and Conversion of Light*. Annalen der Physik, 17 (1905) 132. Translated excerpts in black:

According to this picture, the energy of a light wave emitted from a point source is not spread continuously over ever larger volumes, but consists of a finite number of energy quanta that are spatially localized at points of space, move without dividing and are absorbed or generated only as a whole.

Predicts the Compton effect (good).

of electrons. The simplest possibility is that a light quantum transfers its entire energy to a single electron; we will assume that this can occur. However, we will not exclude the possibility that the electrons absorb only a part of the energy of the light quanta. An electron provided with kinetic energy in the interior of the body will have lost a part of its kinetic energy by the time it reaches the surface. In addition, it will have to be assumed that in leaving the body, each electron has to do some work P (characteristic for the body). The greatest perpendicular velocity on leaving the body will be that of electrons located directly on the surface and excited perpendicular to it. The kinetic energy of such electrons is

kinetic energy = $mv^2/2$ = $h\nu$ – escape energy

Applying the particle model.

$$\frac{R}{N}\beta\nu - P .$$

3 symbols reduce to Planck's constant. He derived $E = (R\beta/N)\nu$ his own way.

$(R\beta/N) = h$

If the body is charged to the positive potential Π and is surrounded by conductors of zero potential, and if Π is just sufficient to prevent a loss of electricity of the body, we must have

electron volts = $\Pi\epsilon = \frac{R}{N}\beta\nu - P$

1910 Lorentz

Die Hypothese der lichtquanten,

P. Zeit. 1910 page 349. His last line:

"Das Gesagte dürfte genügen, um zu zeigen, dass von Lichtquanten, die bei der Fortbewegung in kleinen Räumen konzentriert und stets ungeteüt bleiben, keine Rede sein kann."

"What has been said should suffice to show that light quanta concentrated in small spaces and always undivided when moving are not to be considered."

Similar objections and alternative theories to Einstein's were expressed by Lenard, Planck, JJ Thomson, OW Richardson, Sommerfeld, and Debye (see RH Stuewer).

1911. Planck.

From *Theory of Heat Radiation*, Dover book 1959.

"Planck's second theory of 1911." Continuous absorption, explosive emission.

Here energy is not quantized.
It is thresholded.

150. Whereas the absorption of radiation by an oscillator takes place in a perfectly continuous way, so that the energy of the oscillator increases continuously and at a constant rate, for its emission we have, in accordance with Sec. 147, the following law: The oscillator emits in irregular intervals, subject to the laws of chance; it emits, however, only at a moment when its energy of vibration is just equal to an integral multiple n of the elementary quantum $\epsilon = h\nu$, and then it always emits its whole energy of vibration $n\epsilon$.

We may represent the whole process by the following figure in which the abscissæ represent the time t and the ordinates the energy

$$U = n\epsilon + \rho, \; (\rho < \epsilon) \tag{251}$$

Here h was kept constant but he used a loading term ρ. It is easy to adjust the algebra to make action = $h + \rho$.

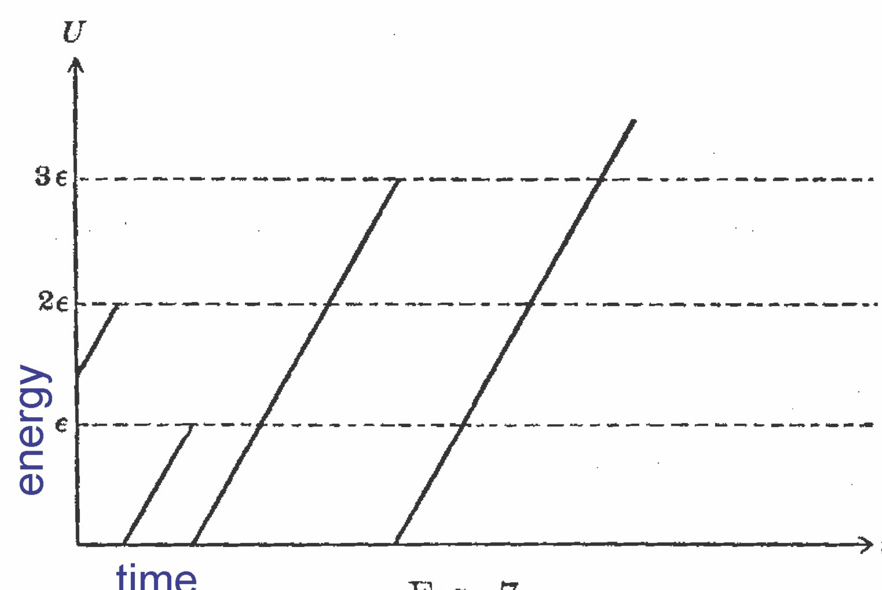


FIG. 7

1913 Sommerfeld and Debye had a loading theory.

Annalen Der Physik, pg 872, vol 41

Here ***h*/2π is marked as a threshold of action**. Action loads-up in their theory of atomic absorption and emission.

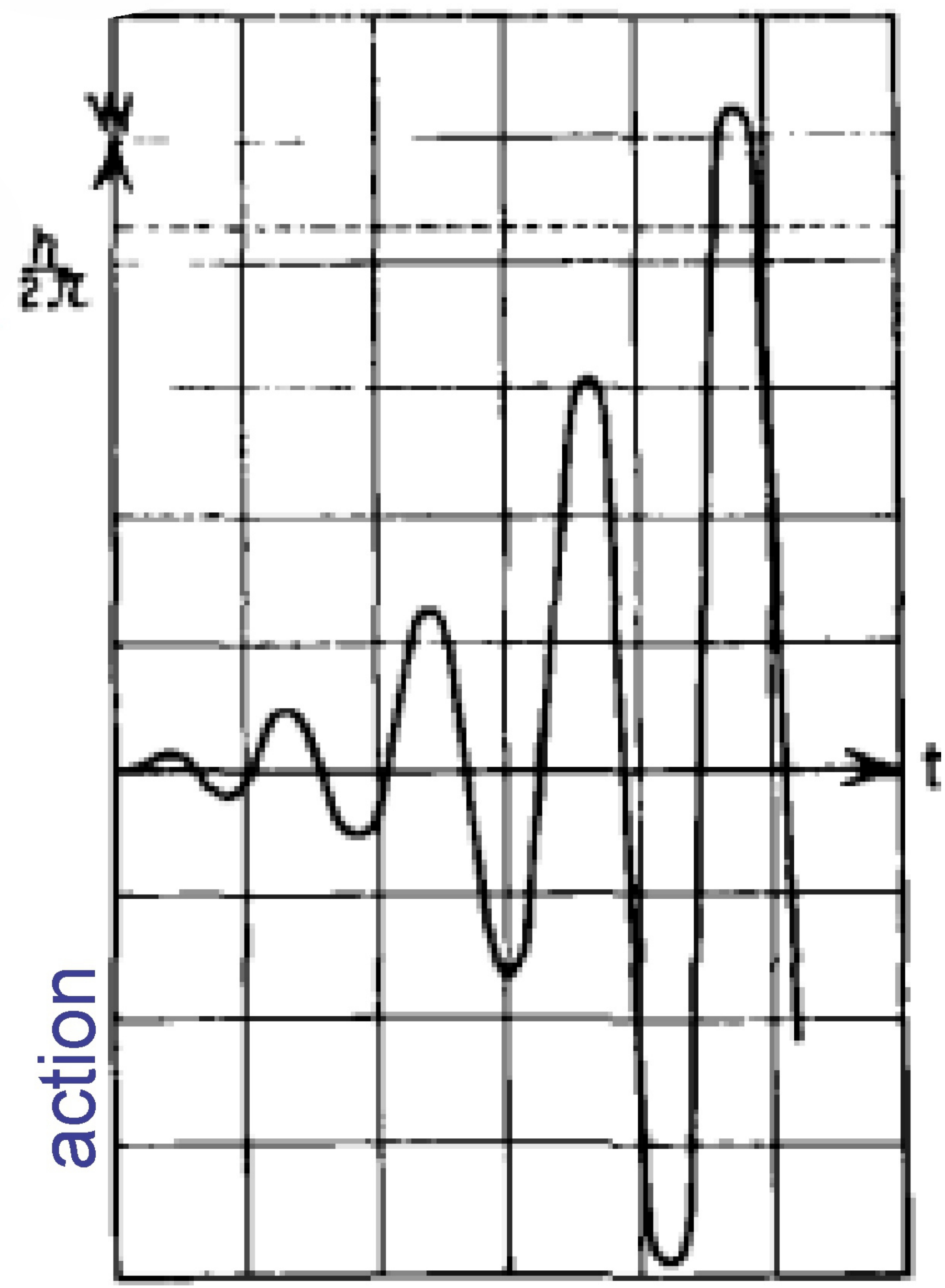


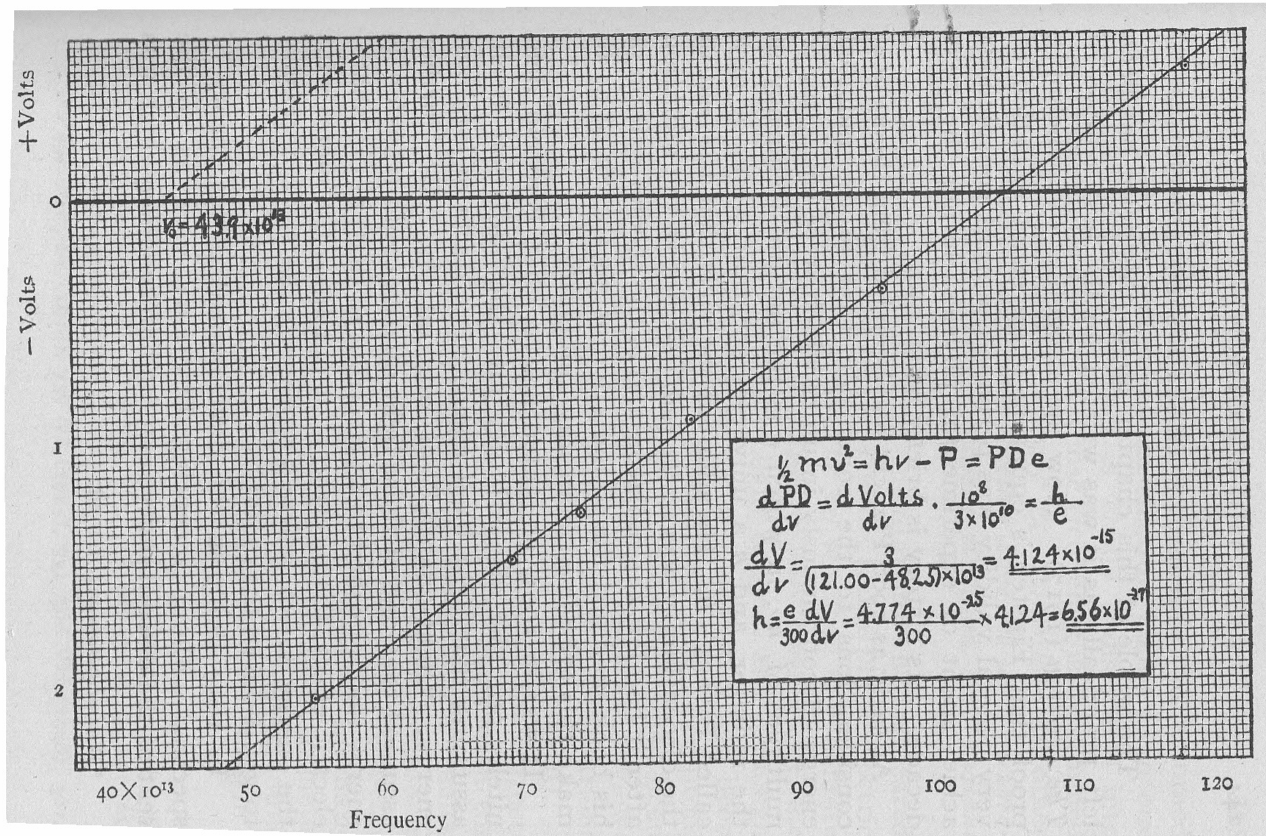
Fig. 1.

1916. Millikan, *A Direct Photoelectric Determination of Planck's "h."* Physical Review, 7 (3), pp. 355-388.

First clear confirmation of Einstein's linear photoelectric equation.

Millikan argued against the photon model and even preferred the loading theory,

Experiment determined ***h/e*** ratio, not *h*. Excerpt from *Electrons (+and-)...* page 238.



paper may be consulted.[1] Suffice it here to say that Einstein's equation demands a linear relation between the applied positive volts and the frequency of the light, and it also demands that the slope of this line should be exactly equal to $\left(\frac{h}{e}\right)$. Hence from this slope, since e is known, it should be possible to obtain h. How per-

1917 Millikan predicts the Unquantum Effect, *The Electron, Its Isolation and Measurement and the Determination of Some of its Properties.* 1917. Page 233

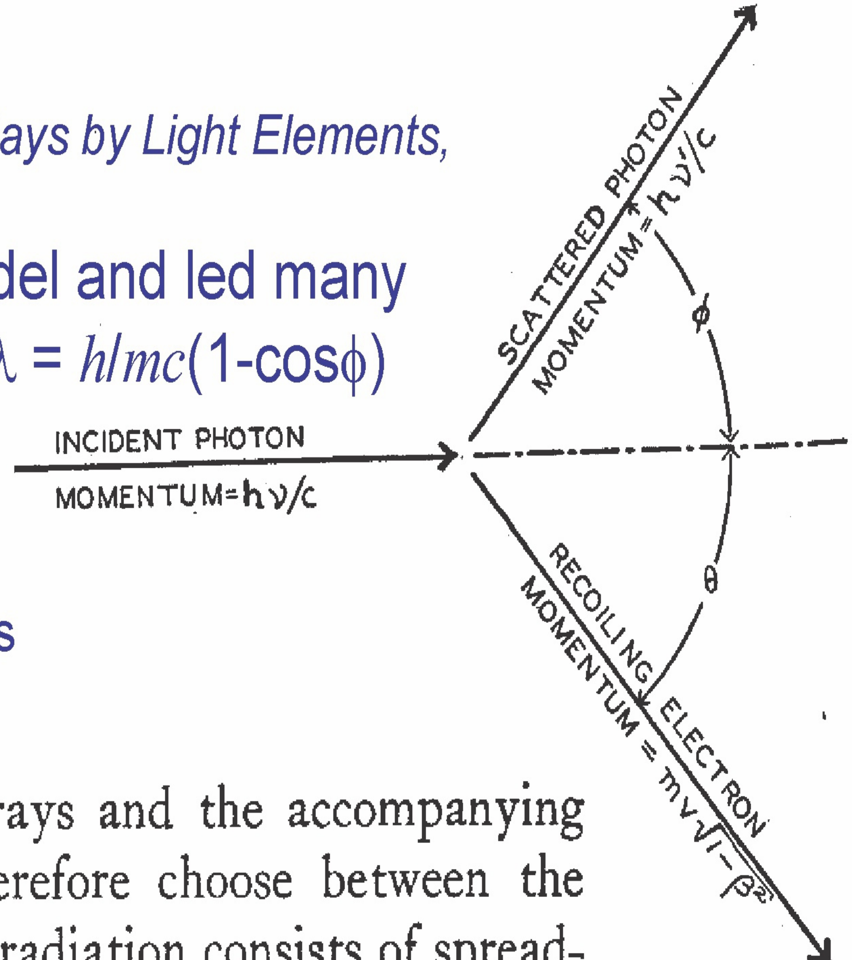
This shows that if we are going to abandon the Thomson-Einstein hypothesis of localized energy, which is of course competent to satisfy these energy relations, there is no alternative but to assume that at some previous time the corpuscle had absorbed and stored up from light of this or other wave-length enough energy so that it needed but a minute addition at the time of the experiment to be able to be ejected from the atom with the energy $h\nu$.

1921 Einstein wins Nobel prize for Photoelectric equation.
However, Millikan and others were still arguing over the validity of the photon model.

1923 Compton,

A Quantum Theory of the Scattering of X-Rays by Light Elements,
Phys Rev V21 #5 page 483 May 1923.

The derivation used the photon model and led many to embrace photons. Its equation $\Delta\lambda = h/mc(1\text{-}\cos\phi)$ measures an ***h/m*** ratio.



Assumption: Energy conservation is thought to require particles.

From Compton's later book:

> If this work on the scattering of x-rays and the accompanying recoil electrons is correct, we must therefore choose between the familiar hypothesis that electromagnetic radiation consists of spreading waves, on the one hand, and the principles of the conservation of energy and momentum on the other. We cannot retain both.

From *X-Rays in Theory and Experiment*, Compton and Allison.1935, Page 221. The idea was dominant, then and is now. ER says, energy need not be quantized to understand its conservation.

Notice in the equation, whole h and whole m are not required. The ratio is quantized.

1924. DeBroglie theory has problems but was accepted.

An Introduction to the Study of Wave Mechanics. deBroglie, 1930

$$W = \frac{mc^2}{\sqrt{1-\beta^2}}, \quad p = \frac{mv}{\sqrt{1-\beta^2}} = \frac{Wv}{c^2}, \quad \left(\beta = \frac{v}{c}\right), \qquad (1)$$

being the velocity of light in empty space.

According to the new conception it is necessary to associate with this particle a wave travelling in the direction of motion of which the frequency is:

$$\nu = \frac{W}{h} \qquad (2)$$

of which the phase velocity is:

$$V = \frac{c^2}{v} = \frac{c}{\beta}, \qquad (3)$$

$$\frac{h\nu}{V} = \frac{W}{c^2}v = p \qquad (4)$$

$$h\nu = \gamma mc^2$$

True for annihilation radiation. Easily misused below that threshold. Requires *delta m*.

$$V\upsilon = c^2$$

Super c phase velocity V implies probabilistic ghost wave. Questionable derivation.

$$\boxed{\begin{aligned} hV/\lambda &= \gamma m\upsilon V \\ h/\lambda &= \gamma m\upsilon \\ \lambda &= h/\gamma m\upsilon \end{aligned}}$$

Above steps can derive deBroglie's famous wave equation. It was used by Schrodinger and fits experiment. However, its derivation implies that λ is of a probability wave.

An alternative derivation by ER removes that problem.

1924. Bohr-Kramers-Slater paper (BKS). An alternative to the kind of energy quantization proposed by Einstein. BKS had energy conserved in a statistical sense that predicted no coincident (e, x-ray) clicks from Compton scattering.

1924. Bothe-Geiger experiment. This was the first beam-split coincidence test. It tested timing between e & x-ray in Compton scattering. It convinced Bohr to abandon the BKS alternative. Coincident pairs were thought to be evidence of a particle effect, not predicted by BKS. This encouraged accepting QM despite its conceptual difficulty. I call this the "shortest time blunder." It stems from not considering a workable loading theory as explored by Planck, Sommerfeld and Debye.

1926. GP Thomson and Davisson & Germer discover charge diffraction. This was very great.

1926. Schrodinger, *Collected Papers on Wave Mechanics.*

His first famous paper of 1926.

He understood that light interacts with beats of his Ψ-wave.

Threshold model of ER expands on this idea.
Charge is the envelope of Ψ.

change in the zero level of E. Consequently, we have to correct our anticipations, in that not E itself—continuing to use the same terminology—but E increased by a certain constant is to be expected to be proportional to the square of the frequency. Let this constant be now *very great* compared with all the admissible negative E-values (which are already limited by (15)). Then firstly, the frequencies will become *real*, and secondly, since our E-values correspond to only relatively small frequency *differences*, they will actually be very approximately proportional to these frequency differences. This, again, is all that our "quantum-instinct" can require, as long as the zero level of *energy* is not fixed.

The view that the frequency of the vibration process is given by

$$\nu = C'\sqrt{C+E} = C'\sqrt{C} + \frac{C'}{2\sqrt{C}}E + \ldots, \tag{22}$$

where C is a constant very great compared with all the E's, has still another very appreciable advantage. *It permits an understanding of the Bohr frequency condition.* According to the latter the *emission frequencies* are proportional to the E-*differences*, and therefore from (22) also to the differences of the proper frequencies ν of those hypothetical vibration processes. But these proper frequencies are all very great compared with the emission frequencies, and they agree very closely among themselves. The emission frequencies appear therefore as deep "difference tones" of the proper vibrations themselves. It is quite conceivable that on the transition of energy from one to another of the normal vibrations, *something*—I mean the light wave—with a *frequency* allied to each frequency *difference*, should make its appearance. One only needs to imagine that the light wave is causally related to the *beats*, which necessarily arise at each point of space during the transition; and that the frequency of the light is defined by the number of times per second the intensity maximum of the beat-process repeats itself.

It may be objected that these conclusions are based on the relation (22), in its *approximate* form (after expansion of the square root), from which the Bohr frequency condition itself seems to obtain the nature of an approximation. This, however, is merely apparently so, and it is wholly avoided when the *relativistic* theory is developed and makes a profounder insight possible. The large constant C is naturally very intimately connected with the rest-energy of the electron (mc^2). Also the seemingly *new* and *independent* introduction of the constant h (already brought in by (20)), into the frequency condition, is cleared up, or rather avoided, by the relativistic theory. But unfortunately the correct establishment of the latter meets right away with certain difficulties, which have been already alluded to.

It is hardly necessary to emphasize how much more congenial it would be to imagine that at a quantum transition the energy changes over from one form of vibration to another, than to think

appearance. One only needs to imagine that the light wave is causally related to the *beats*, which necessarily arise at each point of space during the transition; and that the frequency of the light is defined by the number of times per second the intensity maximum of the beat-process repeats itself.

Schrodinger hated quantum mechanics.

His original wave function was about a charge density.
Max Born changed it to a probability density.
From *The Interpretation of Quantum Mechanics, Dublin Lectures* book 1995.

JULY 1952 COLLOQUIUM

1 • Introduction

Let me say at the outset, that in this discourse, I am opposing not a few special statements of quantum mechanics held today, I am opposing as it were the whole of it, I am opposing its basic views that have been shaped 25 years ago, when Max Born put forward his probability interpretation, which was accepted by almost everybody. It has been worked out in great detail to form a scheme of admirable logical consistency that has been inculcated ever since to every young student of theoretical physics.

1928 *The Element of Time in the Photoelectric Effect*
Lawrence and Beams,
Physical Review 32, 482.

A good experiment, but falsely represented in our textbooks.

Later, textbooks will quote only this shortest 3 ns response time, and say it is the only response time.

Students are taught that any accumulation hypothesis is wrong.

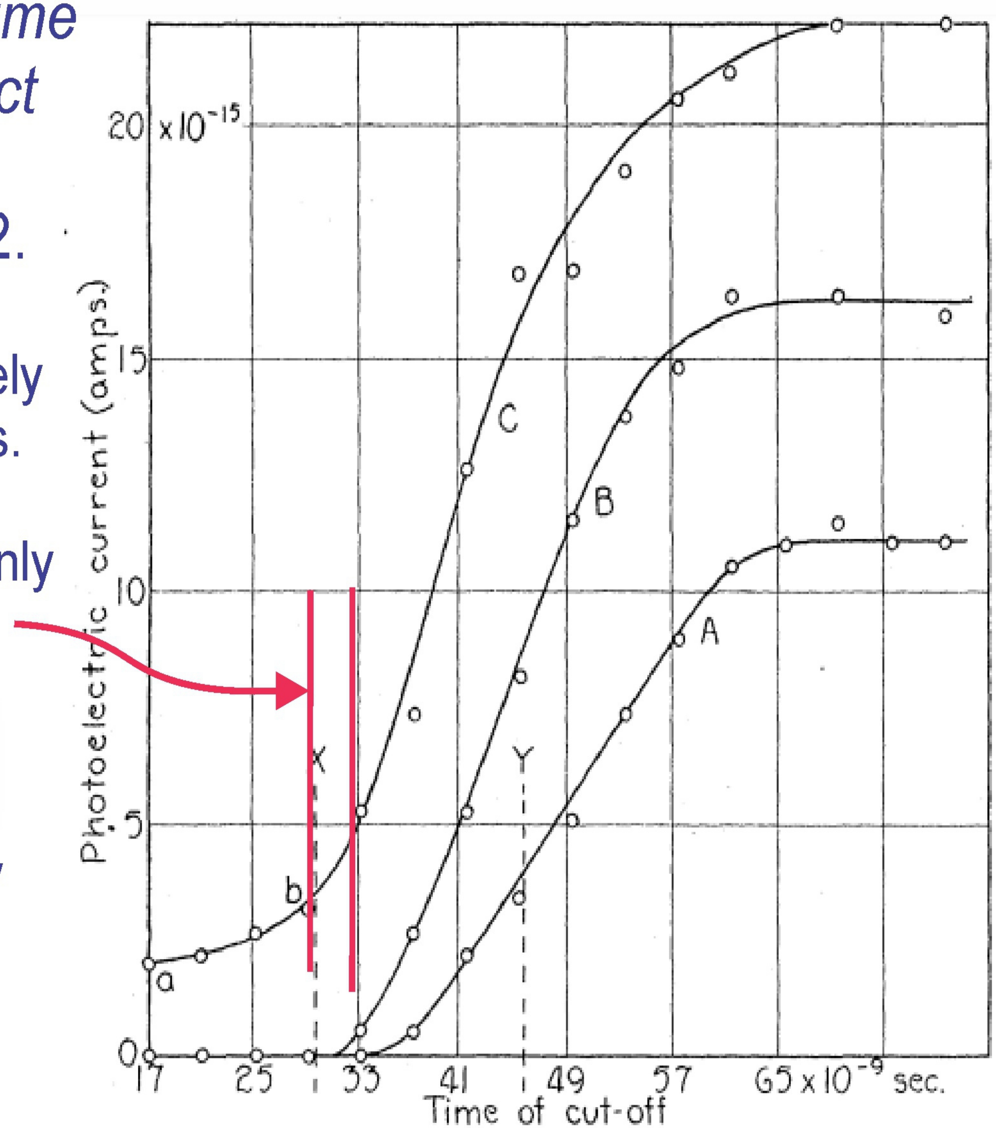


Fig. 4. Photoelectric currents to the collector for various times of cut-off af
ginning of the spark.

1929 Estermann and Stern. *Diffraction of Molecular Rays.*

Helium atoms diffract by the de Broglie equation. The experiment says helium can propagate as a matter-wave. It should be obvious that particles do not diffract. Yet, physics adopted the probability-wave model of quantum mechanics. This is because most physicists assume the principle of energy conservation excludes matter-wave loading models.

(Untersuchungen zur Molekularstrahlmethode aus dem Institut für physikalische Chemie der Hamburgischen Universität, Nr. 15.)

Beugung von Molekularstrahlen.

Von **I. Estermann** und **O. Stern** in Hamburg.

Mit 30 Abbildungen. (Eingegangen am 14. Dezember 1929.)

Trifft ein Molekularstrahl (H_2; He) auf eine Kristallspaltfläche (Li F) auf, so zeigen die von ihr gestreuten Strahlen in allen Einzelheiten eine Intensitätsverteilung, wie sie den von einem Kreuzgitter entworfenen Spektren entspricht. Die aus der Gitterkonstante des Kristalls berechnete Wellenlänge hat für verschiedene m und v den von de Broglie geforderten Wert $\lambda = \frac{h}{m \cdot v}$.

Photon Definition

Bohr, *Atomic Physics and Human Knowledge*. 1958

DISCUSSION WITH EINSTEIN

The extent to which renunciation of the visualization of atomic phenomena is imposed upon us by the impossibility of their subdivision is strikingly illustrated by the following example to which Einstein very early called attention and often has reverted. If a semi-reflecting mirror is placed in the way of a photon, leaving two possibilities for its direction of propagation, the photon may either be recorded on one, and only one, of two photographic plates situated at great distances in the two directions in question, or else we may, by replacing the plates by mirrors, observe effects exhibiting an interference between the two reflected wave-trains. In any attempt of a pictorial representation of the behaviour of the photon we would, thus, meet with the difficulty: to be obliged to say, on the one hand, that the photon always chooses *one* of the two ways and, on the other hand, that it behaves as if it had passed *both* ways.

to paraphrase:

A photon goes one way or another at a beam-splitter, but must also go both ways to display interference.

A contradiction.

Incomprehensible.

1930. Heisenberg, *Quantum Theory*.

Here Heisenberg describes Einstein's photon and its implied wave-function collapse.

This model was accepted long before it was directly tested.

It has been tested, and convinced most physicists that this idea accurately describes nature.

My tests say otherwise (ER).

In relation to these considerations, one other idealized experiment (due to Einstein) may be considered. We imagine a photon which is represented by a wave packet built up out of Maxwell waves.[1] It will thus have a certain spatial extension and also a certain range of frequency. By reflection at a semi-transparent mirror, it is possible to decompose it into two parts, a reflected and a transmitted packet. There is then a definite probability for finding the photon either in one part or in the other part of the divided wave packet. After a sufficient time the two parts will be separated by any distance desired; now if an experiment yields the result that the photon is, say, in the reflected part of the packet, then the probability of finding the photon in the other part of the packet immediately becomes zero. The experiment at the position of the reflected packet thus exerts a kind of action (reduction of the wave packet) at the distant point occupied by the transmitted packet, and one sees that this action is propagated with a velocity greater than that of light. However, it is also obvious that this kind of action can never be utilized for the transmission of signals so that it is not in conflict with the postulates of the theory of relativity.

1935 Millikan, *Electrons (+and-)...*, 1947 page 235.

Millikan abandons the loading theory. This is the last mention I could find of a loading theory that acknowledged the idea of a pre-loaded state. After this book, all accounts of a loading or accumulation hypothesis cripple the idea by acknowledging only the shortest measurable accumulation time.

assume that at some previous time the electron had absorbed and stored up from light of this wave-length enough energy so that it needed but a minute addition at the time of the experiment to be able to be ejected from the atom with the energy $h\nu$. What sort of an absorbing and energy-storing mechanism an atom might have which would give it the weird property of storing up energy to the value $h\nu$, where ν is the frequency of the *incident* light, and then shooting it all out at once, is terribly difficult to conceive. Or, if the absorption is thought of as due to resonance it is equally difficult to see how there can be, in the atoms of a solid body, electrons having all kinds of natural frequencies so that some are always found to absorb and ultimately be ejected by impressed light of any particular frequency.

1935 Compton and Allison, *X-Rays in Theory and Experiment,* page 233.

Compton derives the equation of his effect with waves.

He used Bragg scattering and Doppler effect. Not well known or accepted.

Photons are not necessary.

incident electron by a continuous train of ψ waves of length $\Lambda = h/(mv/2)$ moving along $-Y$, and the recoil electron by a similar train of the same wave-length moving along $+Y$, the two trains together will form standing waves for which the electric charge density is proportional to $\psi_{\text{inc}}\psi^*_{\text{rec}}$, and for which the distance from node to node is $\frac{1}{2}\Lambda = h/mv$. The de Broglie waves representing the electron thus form a Bragg grating of grating space $d = h/mv$. This grating will diffract the incident x-ray waves according to the usual equation

$$n\lambda = 2d \sin(\phi/2)$$

1935 EPR.

Einstein Pedolsoky and Rosen challenge quantum mechanics.

1935, Max Born, Shortest time blunder in the photoelectric effect. *Atomic Physics*, Max Born, 5th edition, 1951, pg 82.

If we start from the hypothesis that the incident light actually represents an electromagnetic alternating field, we can deduce from the size of the particles the time that must elapse before a particle of metal can have taken from this field by absorption the quantity of energy which is required for the release of an electron. These times are of the order of magnitude of some seconds; if the classical theory of light were correct, a photoelectron could in no case be emitted before the expiry of this time after starting the irradiation. But the experiment when carried out proved on the contrary that the emission of photoelectrons set in immediately the irradiation began—a result which is clearly unintelligible except on the basis of the idea that light consists of a hail of light quanta, which can knock out an electron the moment they strike a metal particle.

1956 Bernstein and Mann, review on Compton effect repeats.

They only look for evidence of quanta by seeking the shortest time between coincident clicks (e, γ). There were longer click pair times, as seen by Bothe and Geiger. Those longer time pairs are evidence of a semiclassical model. They do not look for or publish evidence against quantization.

1964, Bell proposes test of EPR-challenge.

1972

Basic Concepts in Relativity and Early Quantum Theory, Resnick, page 138.

Most textbooks teach this **shortest-time blunder**.

It misleads students away from considering a pre-loaded state.

However, no time lag has been detected under any circumstances, the early experiments setting an upper limit of 10^{-9} sec on any such possible delay!

Example 1. A foil of potassium is placed 3 meters from a weak light source whose power is 1.0 watt. Assume that an ejected photoelectron may collect its energy from a circular area of the foil whose radius is, say, one atomic radius ($r \simeq 0.5 \times 10^{-10}$ meter). The energy required to remove an electron through the potassium surface is about 1.8 ev; how long would it take for such a "target" to absorb this much energy from such a light source? Assume the light energy to be spread uniformly over the wave front.

The target area is $\pi(0.5 \times 10^{-10}\text{ meter})^2$; the area of a 3-meter sphere centered on the light source is $4\pi(3\text{ meters})^2$. Thus if the light source radiates uniformly in all directions—that is, if the light energy is uniformly distributed over spherical wavefronts spreading out from the source, in agreement with classical theory—the rate P at which energy falls on the target is given by

$$P = (1.0\text{ watt})\left(\frac{(\pi/4) \times 10^{-20}\text{ meter}^2}{36\pi\text{ meter}^2}\right) = 7 \times 10^{-23}\text{ joule/sec.}$$

Assuming that all this power is absorbed, we may calculate the time required for the electron to acquire enough energy to escape; we find

$$t = \left(\frac{1.8\text{ ev}}{7 \times 10^{-23}\text{ joule/sec}}\right)\left(\frac{1.6 \times 10^{-19}\text{ joule}}{1\text{ ev}}\right) \simeq 4000\text{ secs}$$

Of course, we could modify the above picture to reduce the calculated time by assuming a much larger effective target area. The most favorable assumption, that energy is transferred by a resonance process from light wave to electron, leads to a target area of λ^2, where λ is the wavelength of the light. But we would still obtain a finite time lag that is within our ability to measure experimentally. (For ultraviolet light of $\lambda = 100$ Å, for example, $t \simeq 1$ second). However, no time lag has been detected under any circumstances, the early experiments setting an upper limit of 10^{-9} sec on any such possible delay!

1974 Clauser. Particle component of photon model tested.

PHYSICAL REVIEW D VOLUME 9, NUMBER 4 15 FEBRUARY 1974

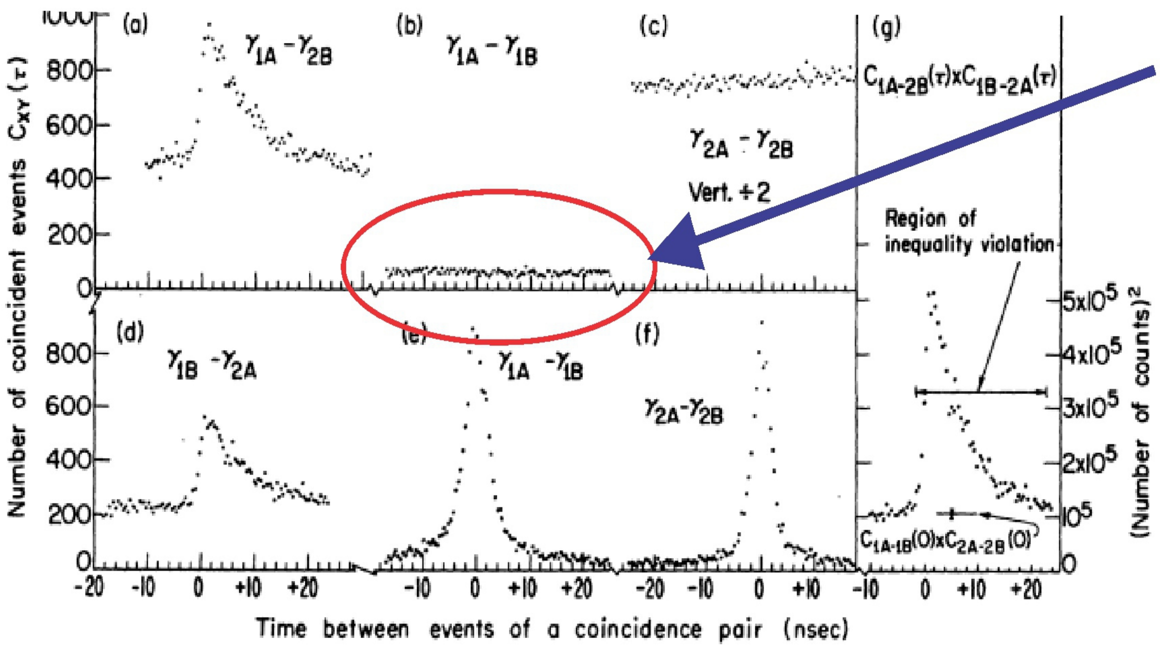
Experimental distinction between the quantum and classical field-theoretic predictions for the photoelectric effect*

John F. Clauser

Department of Physics and Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

(Received 30 October 1973)

We have measured various coincidence rates between four photomultiplier tubes viewing cascade photons on opposite sides of dielectric beam splitters. This experimental configuration, we show, is sensitive to differences between the classical and quantum field-theoretic predictions for the photoelectric effect. The results, to a high degree of statistical accuracy, contradict the predictions by any classical or semiclassical theory in which the probability of photoemission is proportional to the classical intensity.



Any peak here says the time between beam-split clicks exceeds accidental chance. No peak; therefore they say QM is upheld.

FIG. 3. (a)–(d) Time-delay coincidence spectra of the four monitored channels: C_{1A-2B}, C_{1A-1B}, C_{2A-2B}, and C_{1B-2A}. (e)–(f) C_{1A-1B} and C_{2A-2B} coincidence spectra in response to short pulses of light incident upon beam splitters produced by a barium titanate source. (g) Product of C_{1A-2B} and C_{1B-2A} versus time delay. For small times this clearly exceeds the indicated value of the product C_{2A-2B} and C_{1A-1B} evaluated at zero delay.

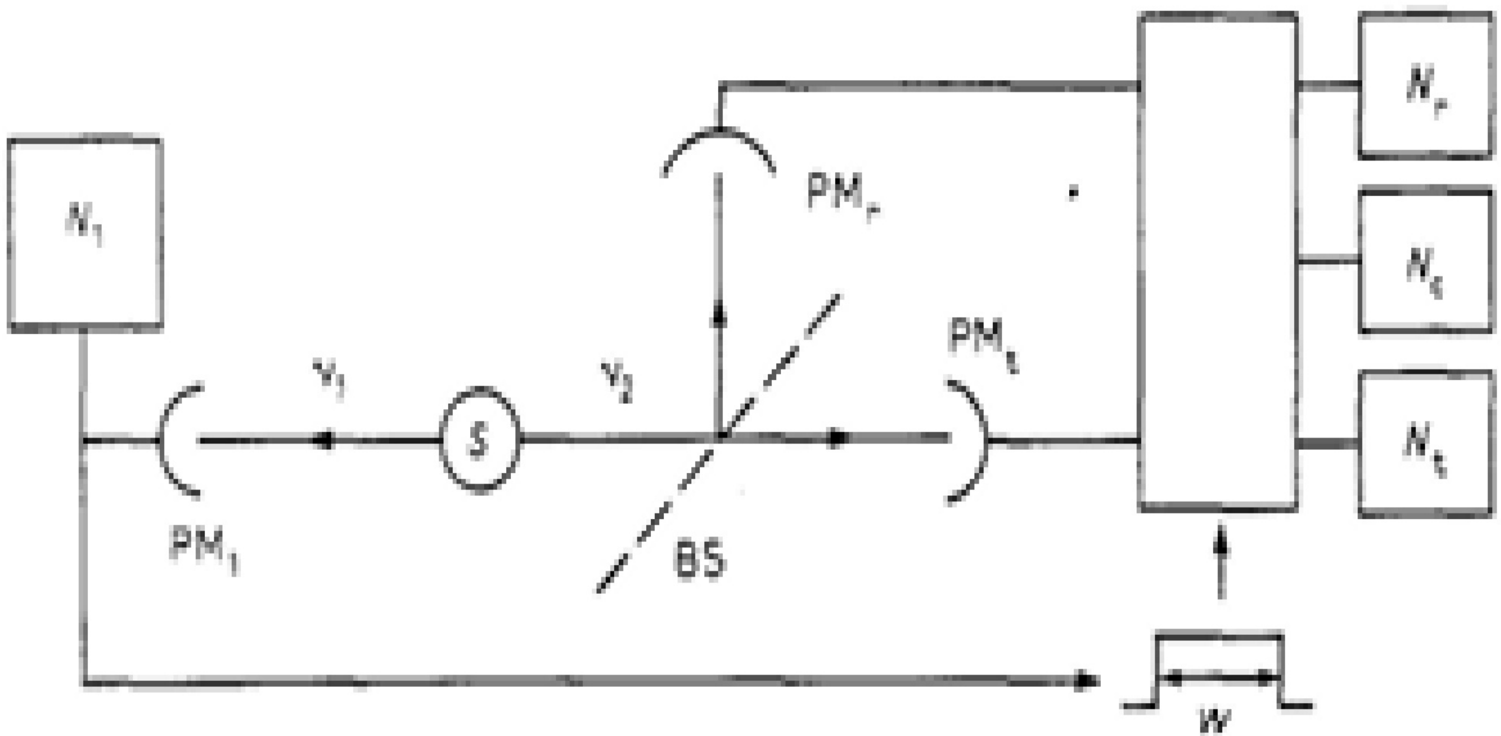
1985 Aspect. Test of wave and particle properties.

Experimental Evidence for a Photon Anticorrelation Effect on a Beam Splitter: A New Light on Single-Photon Interferences.

P. Grangier, G. Roger and A. Aspect (*)

Institut d'Optique Théorique et Appliquée, B.P. 43 - F 91406 *Orsay, France*

(received 11 November 1985; accepted in final form 20 December 1985)



Objections by ER:

polarized beam splitters,

only seeing chance is really just seeing noise,

detector dead time,

inadequate pulse-height resolution.

1981

PHYSICAL REVIEW LETTERS 17 AUGUST 1981

Experimental Tests of Realistic Local Theories via Bell's Theorem

Alain Aspect, Philippe Grangier, and Gérard Roger

It is confusing. **In this case** experimental data, classical theory of Malus, and QM all agree. QM usually works and **in this case** its result is reasonable. However Bell's theory predicts straight lines instead of the sine curve from this experiment (and classical and QM). This convinces many that nature is weird by agreeing with QM, which is weird. Nature need not be weird because **in this case** QM and classical agree, the way it should. The theoretical backgound Bell applied to this EPR test-idea has caused endless confusion to this day.

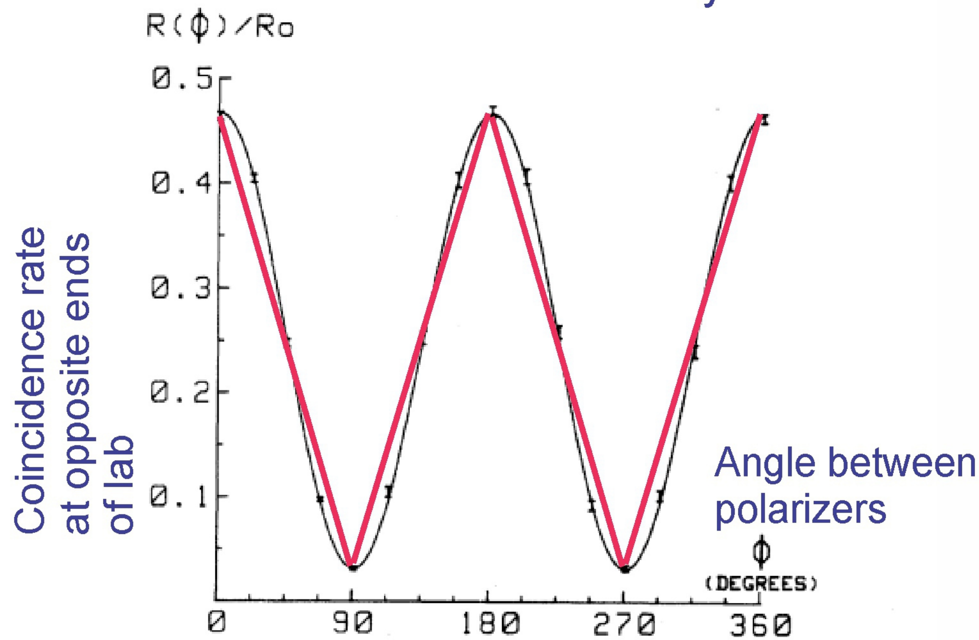


FIG. 4. Normalized coincidence rate as a function of the relative polarizer orientation. Indicated errors are ± 1 standard deviation. The solid curve is not a fit to the data but the prediction of quantum mechanics.

1985 *QED*, Feynman

Highly influential. Denial of wave properties. Photomultiplier clicks are not all the same from monochromatic light; experimentalists avoid this issue.

a photon of a given color hits the photomultiplier, a click of uniform loudness is heard.

If you put a whole lot of photomultipliers around and let some very dim light shine in various directions, the light goes into one multiplier or another and makes a click of full intensity. It is all or nothing: if one photomultiplier goes off at a given moment, none of the others goes off at the same moment (except in the rare instance that two photons happened to leave the light source at the same time). There is no splitting of light into "half particles" that go different places.

I want to emphasize that light comes in this form—particles. It is very important to know that light behaves like particles, especially for those of you who have gone to school, where you were probably told something about light behaving like waves. I'm telling you the way it *does* behave—like particles.

You might say that it's just the photomultiplier that detects light as particles, but no, every instrument that has been designed to be sensitive enough to detect weak light has always ended up discovering the same thing: light is made of particles.

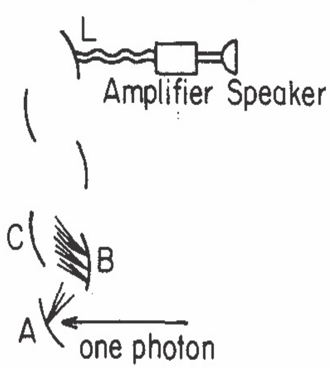
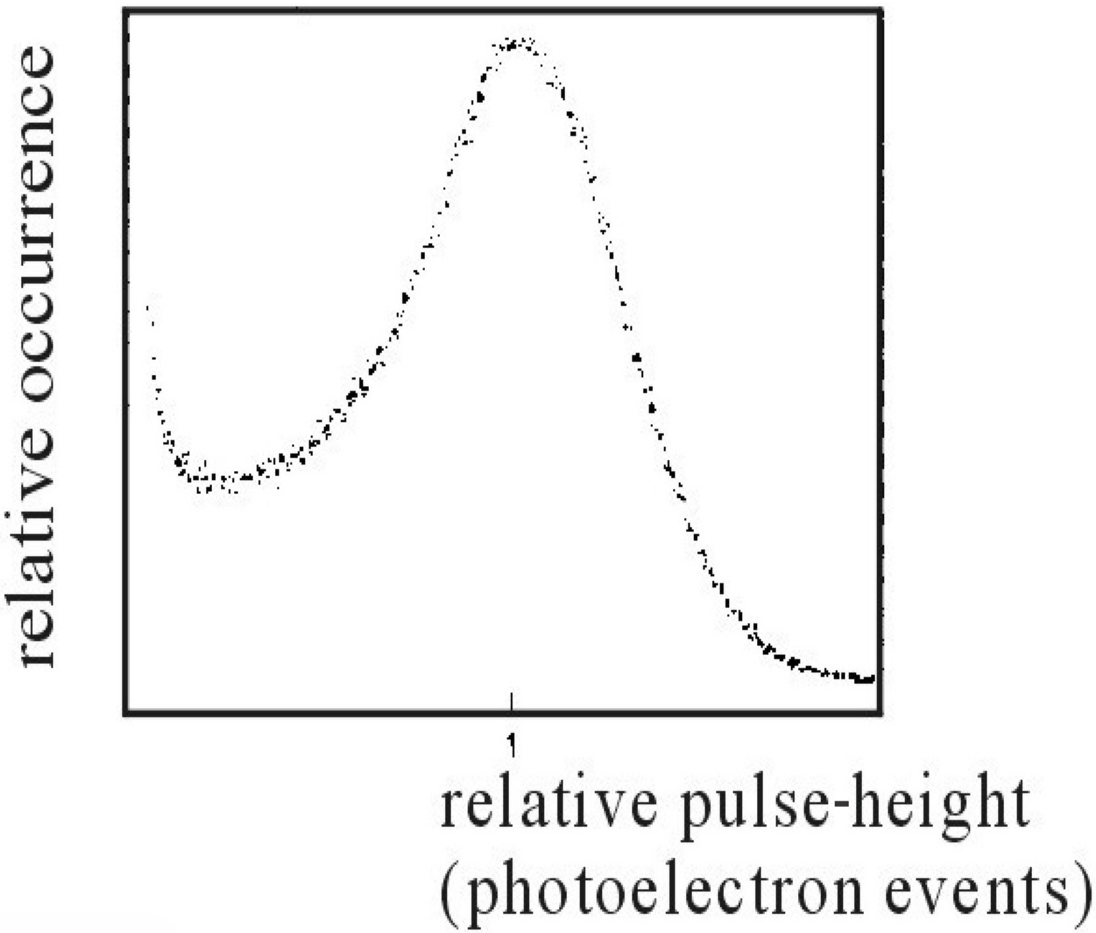


FIGURE 1. *A photomultiplier can detect a single photon. When a photon strikes plate A, an electron is knocked loose and attracted to positively charged plate B, knocking more electrons loose. This process continues until billions of electrons strike the last plate, L, and produce an electric current, which is amplified by a regular amplifier. If a speaker is connected to the amplifier, clicks of uniform loudness are heard each time a photon of a given color hits plate A.*

Photomultiplier pulse-height



Typical "single electron spectrum." Resolution 67% FWHM. Peak to valley ratio 2.8:1. From *Photomultiplier tubes principles and applications*, Philips Photonics, pg 2-8 (1994).

Pulse-height filters are always used in these tests.
The range of pulse-heights for any visible light detector is too wide to make the distinction between quantum or loading theory.

If the filter gate is too low, small pulses can cause pulse-pairs that favor loading. Against quantum mechanics.

If the filter gate is high, it eliminates pulses that would favor a loading. For quantum mechanics.

Papers that test the photon never* say how they set the gate.

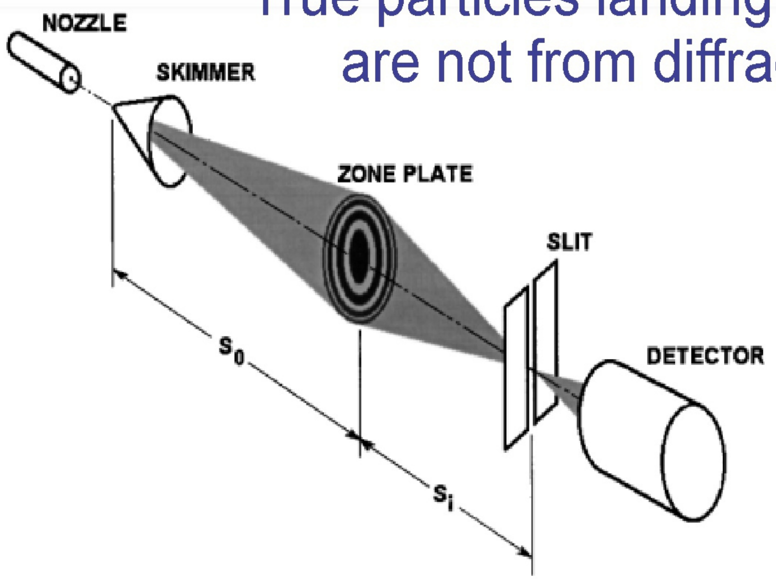
* in all my search.

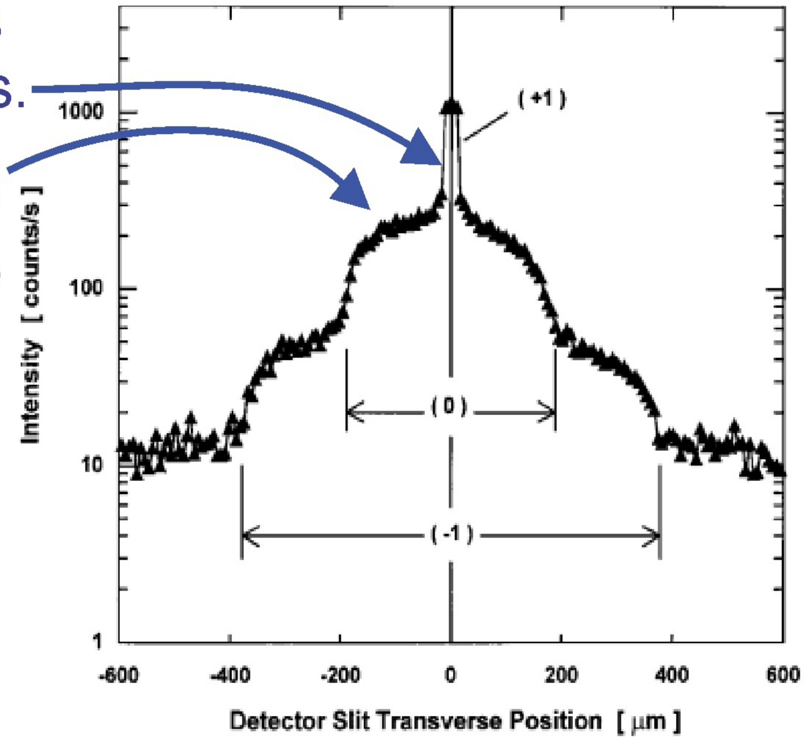
1999 Doak

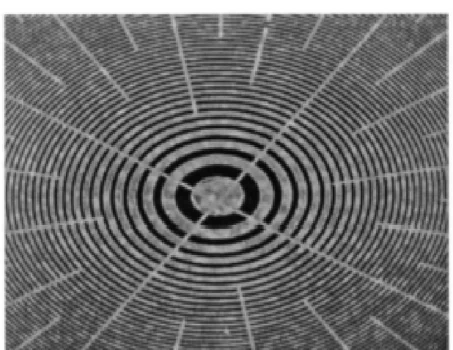
Towards Realization of an Atomic de Broglie Microscope: Helium Atom Focusing Using Fresnel Zone Plates

Effect of focused helium waves cannot happen by true particles.

True particles landing here are not from diffraction.







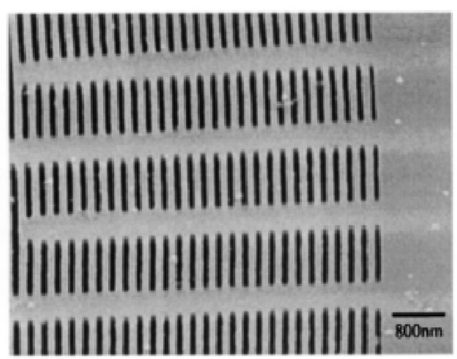


FIG. 2. Transverse scan of detector slit in steps of 6.9 μm through the focused He atom beam. The nozzle temperature was $T_0 = 124$ K to yield a de Broglie wavelength $\lambda = 0.88$ Å, giving a zone plate focal length of 307 mm. Under these conditions the 4 μm diameter beam skimmer should be optimally focused onto the 25 μm detector slit. The central peak is due to the focused (+1) diffraction channel. Underlying plateaus corresponding to the undiffracted (0) channel and defocused (−1) channel are identified on the basis of the expected widths of these features, as marked.

For matter, this is the first clear display of both wave and particle effects in the same experiment.

We Conclude that our history supports an alternative view

In free space our experiments tell us that our ratios are quantized. Our constants express thresholds in a manner similar to Planck's second theory.

e/m Lorentz force
e/h Photoelectric effect
h/m Compton effect, matter-wave diffraction

These assumptions are questionable:
Charges in free space are particles.
Energy conservation requires particles.
If an experiment fits an equation, the assumptions behind its derivation are valid.
A short response time eliminates the semi-classical alternative.
Absence of coincident click-rate exceeding chance confirms QM, with visible light.
PMT & detectors have adequate pulse-height resolution for beam-split coincidence tests.

In my theory we apply our ratios and adjust those stated assumptions. We maintain it is obvious that particles cannot explain wave effects, as argued by Planck, Lorentz, Schrodinger, and Millikan. We explain the particle effect by thresholds in atomic structures that hold the waves together. My experiments substantiate the theory.