PARTICLE VIOLATION SPECTROSCOPY

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ABSTRACT

A quantum mechanical particle should go one way or the other at a beam-splitter. We test this notion using the singly emitted 5.5 MeV alpha-ray (He++) from Americium-241 in spontaneous decay. We use a thin gold-foil beam-splitter and two surface barrier detectors. According to quantum mechanics, coincident detection to these two detectors should only occur by chance at an easily calculated rate. However, the method at hand shows coincident pulse rates greatly exceeding chance. In most cases the pulse-heights in the two detectors past the beam-splitter will add to the full height of an un-split alpha-ray. One might think the alpha was split into components. However, the available kinetic energy is far below the binding energy threshold required to perform such a split in either helium or gold. We conclude the alpha matter-wave was split like a wave, in violation of quantum mechanics. The degree above chance was found to be a function of the gold alloy.

Background

Well known experiments have revealed wave properties of so-called particle beams. C Davison and L H Germer published "Diffraction of electrons by a crystal of nickel," (1927) *Physical Review,* volume 30, No. 6, pages 705 to 740. Within two months, G P Thompson published his electron diffraction experiment, as described in J J Thompson's book *Recollections and Reflections* (1937) page 347. G P Thomson's work is best described in his book *The Wave Mechanics of the Free Electron* (1930). Molecular wave diffraction was clearly demonstrated in the experiments of I Estermann, R Frisch and O Stern in "Monochromasierung der de Broglie-Wellen von Molekularstrahlen," *Zeitschrift für Physik A* (1932) volume 73, pages 348 to 365. In modern physics, these experiments have been described in terms of quantum mechanical particles influenced by a purely mathematical probability wave. Physicists realize that classical particles do not diffract, but somehow, they think a quantum mechanical particle can diffract. So-called particle diffraction experiments have always posed a conceptual problem. Attempts to understand how a particle can have wave properties usually resort to a probability-wave that somehow guides the particle. It is well known that a classical particle model cannot be adjusted to explain wave cancellation or diffraction effects, especially when detection rates are adjusted to one-at-a-time. Furthermore, there is no reasonable way to understand how the energy of a wave could spread through macroscopic space, and then collapse to cause a particle-like detection event. This problem, often called a paradox, is known as wave-particle duality. The term "quantum mechanical particle" implies paradoxical wave-particle duality.

Predating wave-particle duality for matter was wave-particle duality for light, originating in Einstein's famous photoelectric effect paper of 1905, "On a Heuristic Point of View

Concerning the Production and Transformation of Light." It was a paradox. Experimental evidence for my method of solving the wave-particle paradox for light is fully described in *Photon Violation Spectroscopy,* PVS, (US patent pending US 2005/0139776 published June 30, 2006). In PVS I describe the method and theory of how the principle of the photon can be overturned. PVS shows how light must be spreading classically, and that it must not hold together as anything resembling a particle. I use the loading theory to reinterpret experiments famous for showing that light is particles. The loading theory and the theory of quantum mechanics make opposite predictions in a beam-split tests. My theoretical work in PVS enabled me to predict these *unquantum* alpha-ray experiments. At the time of my writing PVS, there was no experimental evidence to demonstrate that matter likewise could split as a wave to cause detection coincidences beyond chance. The phenomenon is best described as a threshold in a loading theory. Both classical and quantum mechanical understandings of the word "particle" presume that such a particle would hold itself together as an intact package incident upon a microscopic absorber.

My tests record detector pulses in coincidence at rates beyond the chance rate predicted by quantum mechanics. Test results indicate that a resonant precursor of the nuclear wave function, known as the atomic nucleus, must exist in a partially loaded state. The level of a partially loaded state determines the probability that an incident pulse of matter-wave energy can complete this partially loaded state to a threshold and trigger multiple detectable absorption events in coincidence.

Here we employ alpha-rays, high speed helium nuclear matter-waves emitted in spontaneous nuclear decay. In mainstream physics, energy conservation is treated in terms of particles emitted, processed, and absorbed, with no accounting for a pre-loaded state. Mainstream physics commonly assumes that even a quantum mechanical particle is just a shrunken down classical particle that is associated with a guiding wave function, and that a particle makes a crash landing to cause an absorption event. It would be misleading to explain my discovery in terms of "alpha-particle." I warn that words like "atom" and "electron" should instead refer to their experimentally associated phenomena, not tiny spheres leading to a paradoxical world.

Here we model solid state matter as atomic particles. However, when an elemental wave function in its particle-like state is released to travel across space it can lose this particle property and can spread longitudinally and transversely as a matter-wave to account for interference effects. In the solid state, a stable matter-wave may shape space with centers of its mass distribution described by particles, but such a mass can be released to convert its standing wave energy into a traveling spreading matter-wave. In these experiments I call it *heliumness*. The wave is understood to load-up in a standing wave system, up to a threshold that can suddenly be released, to give the illusion that a particle hit there.

Prior physics considered the loading theory for light, but never considered the loading theory for matter (atoms). The loading theory was first introduced in 1911 by Max Planck in his paper "Eine neue Strahlungshypothese," found in a collection of his works *Physikalische Abhandlungen und Vorträge.* Here Planck described continuous emission and explosive absorption, and theorized an energy E in the inequality $0 < E < h\nu$, where h is his action constant, and ν (Greek letter nu) is electromagnetic frequency. Planck also used ν for the same frequency of a material oscillator as I do. In this 1911 paper, Planck used the average energy $h\nu/2$ to derive his famous black body heat distribution equation. Planck's inequality algebraically implies that action can be any value between 0 and *h*. The loading theory was described in T Kuhn's *Black Body Theory and the Quantum Discontinuity 1894-1912* (1978) as Planck's second theory. The only other works to be found on the loading theory are by P Debye and A Sommerfeld, one of which is "Theorie des Lichtelektrischen Effektes vom Standpunkt des Wirkungsquantums," *Annalen der Physik* (1913) volume 346, issue 10, pages 873-930. Planck's second theory with continuous absorption in black body radiation was well described in O W Richardson's book, *The Electron Theory of Matter* (1914) first edition, page 350.

The research of E O Lawrence and J W Beams, "The Element of Time in the Photoelectric Effect," *Physical Review* 32, page 478 (1928), gave curves of current verses time to clearly show there are minimum, average, and maximum times to be considered. Early authors discredited the idea of the pre-loaded state. Examples are M Born, *Atomic Physics* (1935), and Hughes and DuBridge, *Photoelectric Phenomena* (1932), chapter 2-9, pages 32-33. The loading theory was considered in A H Compton and S K Allison's book *X-Rays in Theory and Experiment* (1935), page 47, and in R A Millikan's book *Electrons (+ and –)* (1947), page 253. To their credit, Compton and Millikan understood that the loading theory includes a pre-loaded state, but they did not embrace it. In all publications thereafter, in all my long search for it, writing on any form of loading theory, otherwise known as the accumulation hypotheses, was crippled by confusion over the issue of response time. Contrary to popular teachings there is indeed a time-lag in photoelectric current, as shown the data of Lawrence and Beams. Our textbooks will often show a calculation of the loading time. However, they unfairly compare a calculated <u>maximum</u> loading time to an experimentally observed <u>minimum</u> response time. The average loading time does change with intensity, but this is not acknowledged when only the minimum time is given to consider. These faulty arguments are the norm in physics and are still taught, most notably in Halliday and Resnick, *Physics*, sub-chapter on Photoelectric Effect.

There are many similar textbook errors. In Halliday and Resnick's chapter on the Compton effect they write: "The presence of a scattered wave of wavelength λ cannot be understood if the incident X-rays are an electromagnetic wave." It is very easy to go to Compton and Allison's book page 232 to find an electromagnetic wave explanation. A similar explanation was described by E Schrödinger, *Ann der Phys* (1927), 82, page 257.

In the loading theory, the alternative to the concept of the particle is the threshold. Planck's second theory of 1911 introduced a threshold of energy concept: emission is quantized, and absorption is continuous up to a threshold. Experiments predating mine have never shown quantized absorption to fail. After Max Born criticized Schrödinger's wave packet interpretation, in Born's book *Atomic Physics*, the particle/probability model dominated mainstream physics and our textbooks.

The first coincidence experiment was by W Bothe and H Geiger, "Uber das Wasen des Comptoneffekts," *Zeitschrift fur Physik* (1925) pages 639-663, vol. 32, where a Coolidge tube made x-rays interact with hydrogen surrounded by an electron detector and a Geiger counter. Their coincidence rate was 11 times greater than chance. This is what you would expect from two different kinds of detectors detecting two different kinds of "particles." It would seem foolish to attempt to split the alpha if you thought it was a quantum mechanical particle. It is not obvious to test the loading theory, especially since such a vast amount of prior literature claims to have already tested and discredited it. We know from this document and PVS that the patent office does not grant patents on methods that contradict quantum mechanics. I have described in PVS major mistakes of past attempted to test alternatives to quantum mechanics. Evidence here compels a major revision or replacement of quantum mechanics. Concerning experiments similar to that of Bothe-Geiger, tests done to repeat their effect were only examined in a manner towards strengthening quantum mechanics. They searched for how close together in time the coincidences have occurred, not the more important idea of exceeding chance-coincidence rates. The idea of seeking a loading alternative to quantum mechanics is routinely side-stepped.

All previous beam-split tests of the loading theory employed electromagnetic light. Previous beam-split tests with light did not defy quantum mechanical chance. It would therefore seem a waste of time to try to defy chance with material particles. The idea behind our beam-split tests might have originated from a thought experiment of Einstein's, recalled by N Bohr in his book *Atomic Physics and Human Knowledge* (1958):

> "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."

It is the first half of this quote/definition that my experimental results conflict with. A beam-splitter test has been previously performed using x-rays and visible light, and only chance coincidence rates were found, consistent with quantum mechanics. By these prior tests, a physicist would predict that any quantum mechanical particle would behave similar to the photon: it would go one way or another at a beam-splitter. I know of no prior attempt to split material particles into two beams of the same particle type, and then go on to search for coincident pulses of that same particle type. So called particle telescopes have been developed to detect particle type, but they have never been used to see if one particle, could become two. The way to think about such a thing is to give up the idea of particle-like absorption, and embrace the loading theory.

The way to make sense of the loading theory is to make the action constant *h*, the electronic charge constant *e*, and the electronic mass constant *m*, all maximum thresholds. This way, the ratio of any two of these three measures would stay unchanged as a wave thins-out in space. Measurements will not show a lower action, charge, or mass because only a ratio, such as action/mass, will be conserved and expressed in our measurements.

Of course, with matter, and particularly the alpha, there is a binding energy issue that must be addressed. If an alpha has a kinetic energy greater than its own binding energy, it can split into subatomics. Similarly, if an incident "alpha particle" has kinetic energy exceeding the binding energy of a target atom, the target can be split into subatomics. See R D Evans' book *The Atomic Nucleus,* page 299. However, conventional physics will not understand a way for these splittings to occur if the incident kinetic energy is below its binding energy threshold. Therefore conventional physics will predict that a material particle with insufficient kinetic energy to cause a split, will go one way or another at a point of reflection. By conventional physics, such an experiment would predict coincident detection events only at the accidental chance rate. A conventional physicist would predict a particle would always go one way or another at a beam-splitter, never both ways at once.

This kind of beam-split test requires knowing that emissions are not simultaneous. This test for a singly emitted particle is called a true coincidence test, and is well known in physics. Nevertheless a patent on a method of testing for true coincidences was granted to Drukier, US 5,866,907. The detectors are arranged in an opposed orientation so that each detector receives a substantial flux of non-overlapping solid angle radiation. By non-overlapping solid angles, I mean there was no beam-splitter, and the radiation went in different directions. A true coincidence test is designed to see if a quantized emission sends energy in different directions at once. If the radiation obeys the equation for matter-wave wavelength, $h = m\upsilon\lambda$, or the equation for electromagnetic frequency, $\varepsilon = h\nu$, a conventional physicist will called it a quantum mechanical particle. Two such quantum mechanical particles simultaneously emitted in different directions will create true coincidences. A true coincidence source is usually avoided in *Particle Violation Spectroscopy*

It is important to point out certain experiments that seem to support the probability-wave interpretation, in conflict with my method. There have been many attempts to confirm the probability-wave interpretation of quantum mechanics. Examples are experiments that report diffraction effects using molecules as large as carbon-60, so called "fullerene molecules." Those "fullerene" experiments were performed in the laboratory of Anton Zeilinger, Universität Wien, Austria. None of their experiments report fringe shift data from the same apparatus as a function of different velocities. Such a comparison would have been straightforward because their apparatus included a rotating wheel velocity selector. Fringe shift as a function of velocity has not been reported in any of their published papers. Velocity relates to de Broglie's wave equation h = (mass)(velocity)(wavelength), at the heart of quantum mechanics. A good example of the Austrian team's work is: O Nariz, M Arndt and A Zeilinger, "Quantum interference experiments with large molecules" (2003), *American Journal of Physics*, American Association of Physics Teachers, vol. 71 pages 319 to 325. Such a comparison of fringe shifts with velocity was indeed performed properly by Estermann, Frisch, and Stern in the reference previously cited on page 362. This 1932 work sets the obvious experimental standard that was not attempted by the Austrian team. The theory used by the Austrian team was not fully written, and contained many unnecessary assumptions. For these reasons, reports by Zeilinger et-al claiming that large molecules diffract according to a probabilistic de Broglie wave cannot be held as evidence against the validity of my method. My work says particles, quantum mechanical or not, do not diffract. When dealing with low count rates, only load-up mechanisms will display diffraction. But quantum mechanics assumes no size limit upon its "particle diffraction" effects. Publishers have routinely denied a paradox and do not encourage its resolution. *Particle Violation Spectroscopy* and *Photon Violation Spectroscopy* demonstrate that modern physics has been in error by accepting that particles guided by a probability-waves are the reality of nature.

A commercially viable utility of my method is a material science spectroscopy applied to gold, carbon, silicon and other materials. Another utility is to demonstrate the physics discovery with an apparatus to be sold to school labs. A low cost apparatus can be produced utilizing: americium-241 as a low level alpha-ray source, two semiconductor alpha-ray detectors with their output pulses digitized by high speed analog to digital converters, and an interface to a personal computer. Pulse-amplitude windowing and time coincidence functions can be accomplished in digital signal processing software. For alpha-rays, if the source and detectors are placed closer than a centimeter, a vacuum chamber is not necessary.

Data presented here are from actually constructed apparatus. Figures presented here are representing actually constructed apparatus. The drawings and description have been properly simplified but are more than adequate for any physicist to understand and reproduce this work. Multiple tests were done to insure against artifact, procedural error, and instrumentation error.

Description of Figures

Figure 1 describes an embodiment for splitting alpha-rays with thin foils.

Figure 2 is a composite of data using 24 carat gold leaf as a beam-splitter of alpha-rays.

Figure 3a is a coincidence histogram for the same experiment as for fig. 2.

Figure 3b is a coincidence histogram using 23 carat gold leaf as a beam-splitter of alpha-rays.

Figure 3c is a coincidence histogram using a surface barrier detector to detect and split alpha-rays.

Figure 3d is a coincidence histogram with alpha-rays and no beam-splitter, showing no true coincidences.

Figure 4 describes the arrangement for splitting alpha-rays from a diamond powder coated surface.

Figure 5 is an annotated screen capture of a computer automated test of a diamond powder coated surface splitting alpha-rays.

Figure 6a is a pulse amplitude histogram from a surface barrier detector receiving alpha-rays.

Figure 6b is a pulse amplitude histogram of alpha-rays reflecting from a surface of diamonds.

Figure 7a describes supporting physics evidence from *Photon Violation Spectroscopy*.

Figure 7b is a digital oscilloscope graphic for the experiment of fig. 7a.

Description of Preferred Embodiment

The radiation source for all of my matter-wave splitting experiments are 2 mm diameter foil disks plated with one microcurie of americium-241. An atom of Am-241 in spontaneous decay emits a 5.5 MeV alpha-ray and a 66 keV gamma-ray. Electron volts, eV, is a particle model energy unit, here relating to kinetic energy.   I use this energy unit for convenience, and is not to be construed as embracing an always applicable particle picture. The alpha-ray is related in physics to the helium nucleus with chemical formula He^{++}. This might seem confusing that I talk of particles and not-particles. There surely are particles, but we are revealing a non-particle state of an element.

My earliest strong evidence for splitting the alpha-ray as a wave was on April 17, 2005 using a gold leaf beam-splitter and two ORTEC brand DIAD (discriminating industrial alpha detector) surface barrier detectors. This revealed coincident detection events at 538 times chance. My detailed experimental description and evidence employed different detectors and a more refined method. Many scattering material types, geometries, and detector types were tested. My most robust evidence employed beam-splitter foils of gold and alloys of gold. Commercial surface barrier detectors are constructed two ways: (1) the front surface may be electrically isolated (non-grounded detector surface) from the casing such as those manufactured by CANBERRA, or (2) the front surface may be electrically bonded (grounded detector surface) to the casing such as those manufactured by ORTEC. It was found from careful measurement that the electrically isolated active surface of CANBERRA detectors were vulnerable to cosmic ray interference. Cosmic rays can cause artifact coincidences when two CANBERRA detectors are used. In control tests with the Am-241 source removed, it was found that the one inch detectors from ORTEC were the quietest. A no-source control test was arranged as in **fig.1** with one of the two detectors being a 1 inch ORTEC, and the second detector a CANBERRA detector. My best no-source control test ran continuously for 3 days with zero coincidences measured.

Referring to **fig. 1**, Am-241 source **10** is surrounded by cylindrical collimator **11** to prevent alpha-rays from directly encountering the surface of reflection-detector **13**. The source and collimator are typically supported on the outer edges of reflection-detector **13** by a thin bar **12** so as to obscure detector **13** as little as possible. A typical alpha-ray from spontaneous decay from the source will follow path **14** to encounter beam-splitter **15** on mounting ring **16** that fits over transmission-detector **18**. Beam-splitter **15** is typically a thin foil of gold; two layers of artist's 24 carat gold leaf stacked together were found to work best. Most often the alpha-ray will continue with most of its kinetic energy intact along typical path **17** toward transmission-detector **18**. In some cases a component of the initial alpha-ray will be reflected along typical path **19** toward reflection-detector **13**. This reflection from the gold foil is the same phenomenon as observed in the famous experiment of Geiger and Marsden, and whose data was used by Rutherford to show evidence of a particle-like nucleus of gold. The effects to be observed here occur when the alpha-ray splits and travels simultaneously along typical paths **17** and **19** to cause simultaneous pulses from both detectors **13** and **18**.

The bias and amplification of detectors **13 18** are performed by conventional means. The output terminals of detectors **13 18** are provided with a DC bias voltage via resistors **20 21,** typically 10 megaOhms, to bias the detectors with negative 40 volts from DC power supply **22**. The detector's output current pulse is coupled via capacitors **23 25,** typically 1 microfarad, to preamplifiers **27 29**. The preamplifiers used were Linear Technology LT1222 op amps with a 155 kOhm resistor and 1 pf capacitor in parallel (not shown) for the inverting amplifier feedback network, and with the op amp's positive input grounded via a 1 kOhm resistor (not shown). The detectors and amplifiers are housed in a vacuum chamber constructed from cylinder **31** with removable end caps **33 35**. With detector **18** on support **36**, the end cap **35** can be rotated to orient detector **18** at different angles for reflection studies described in **fig. 4**. The chamber is evacuated of air with vacuum pump **37** to a modest vacuum of approximately 100 millitorr. Ultra high vacuum technique is not required for alpha work. I tested the alpha-split effect using both a roughing pump and, at a better vacuum using a turbomolecular pump, and found no difference. The bias and detector signal wires connect by feedthrough **39** to outside the vacuum chamber. The pre-amplifiers require power wires, not shown, and use additional pins on feedthrough **39**.

Amplifiers **41 43** were commercial modules from ORTEC designed to work with ORTEC single channel analyzer (SCA) modules **45 47.** This amplifier/SCA pair is specified by ORTEC to minimize "walk" timing errors that vary with pulse amplitude. Amplifiers were ORTEC model 460, and SCA modules were ORTEC model 551. Although there are many ways to set up a coincidence circuit, the easiest and most convincing method is to use a Lecroy digital storage oscilloscope **DSO** with histogram software; I used model LT344. Channels 1 and 2 of **DSO**, **Ch1 Ch2,** monitor output of amplifiers **41 43**. Channels 3 and 4 of **DSO**, **Ch3 Ch4,** monitor square wave timing pulse output of SCAs **45 47**. **Ch1 Ch2** are useful for seeing that pulses **49 51** are not misshapen due to noise or pulse overlap. **Ch3 Ch4** are used by the LT344 smart trigger mode that triggers when SCA pulses **53 55** are within a preset time, typically 100 nanoseconds; this is the coincidence circuit. The lower level settings **LL1 LL2** of the SCAs must be set high enough to eliminate noise. Here I set these levels to 1/3 of the characteristic pulse amplitude of the 5.5 MeV alpha-ray. The SCA upper levels **UL1 UL2** were set to its maximum. The range of pulse amplitudes between **LL1** and **UL1** is window number 1, and the range of pulse amplitudes between **LL2** and **UL2** is window number 2. The time between **Ch3 Ch4** timing pulses is plotted in coincidence histogram **H** by the **DSO**. A time delay feature in the SCA is used to make the channel 1 pulse record first so that histogram display **H** is centered on the screen. Coincidence histogram **H** is the most important output of the experiment. Quantum mechanics would predict a Poisson. On our scales the histogram would have an imperceptible slope, essentially a flat band of noise like that of **fig. 3d**. Any peak in this histogram indicates there is a mechanism other than noise to be analyzed. **DSO** outputs a trigger pulse wired to counter **57** to count coincidences. Counters **59 61** record outputs of the SCAs for singles rate calculations. The time duration of the experiment is obtained from the **DSO** or a separate timer (not shown). The time duration and data from the counters provide for a calculation of singles rates from each detector. An enhancement to the data acquisition was employed in some of my tests employing computer **63** connected to **DSO**, and counters **57 59 61** through bus **GPIB.** GPIB is a popular instrument communication system. Computer **63** is optional to show the *unquantum* effect, but was found necessary to obtain ordered pulse pairs. Future implementations will likely employ a two channel high speed analog to digital converter with dual port ram interfaced to a host computer to digitize pulse shapes from each preamplifier **27 29**, and will perform windowing and coincidence operations in software.

Additional features of the apparatus are required for calibration or various studies. Test source **65** mounted on rod **67** can be manipulated through linear-rotary seal **69** to illuminate each detector with alpha-rays, or to illuminate both detectors simultaneously. Detector **13** is mounted on rod **71** supported by linear seal **73** so the optimum spacing between the two facing detectors **18 13** can be adjusted. A spacing of 4 mm between source **10** and gold foil beam-splitter **15** was found to be optimal.

In a pulse amplitude histogram, for example **fig. 2 RE** for the alpha-ray, a characteristic pulse amplitude is revealed as a peak in the histogram at 5.5 MeV. The alpha-ray can cause pulses over a wide amplitude range. It is known from nuclear physics books and my own tests that an Am-241 source only emits one alpha in atomic spontaneous decay, and that this source does not cause detector pulses in a surface barrier detector from anything but the alpha-ray. The pulse amplitudes are known to be smeared over a histogram by two dominant mechanisms: there are different velocity alphas produced in escaping the solid of the source, and the detector can distort the pulse amplitude. The SCA window for each detector was set to include a wide range of pulse amplitudes, the smallest being 1/3 of its 5.5 MeV characteristic, set by **LL1** and **LL2**, and ranging to an upper limit set beyond what the monitoring oscilloscope **DSO** was able to acquire without clipping.

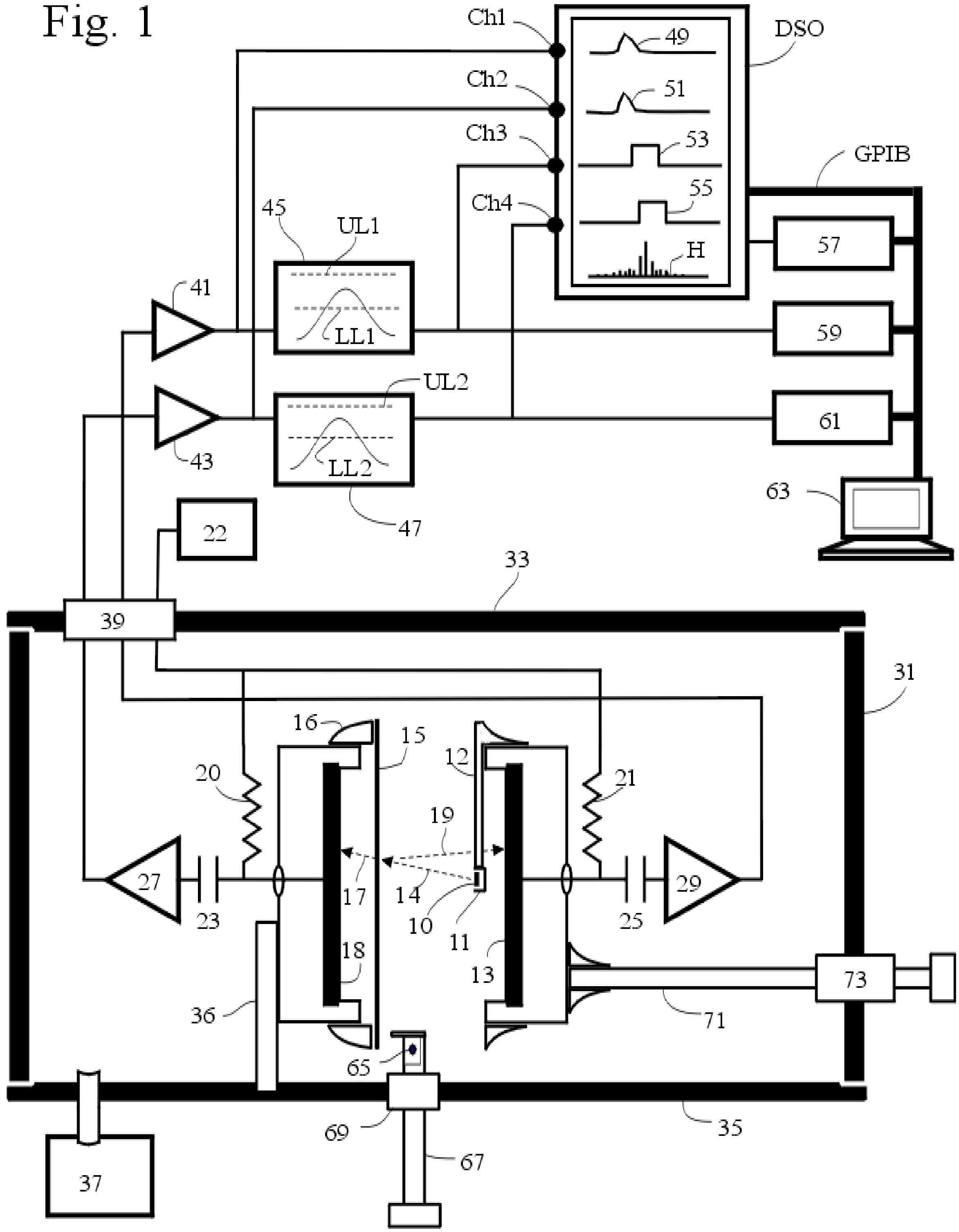
Figure 2 is data from an experiment performed November 13, 2006 that used essentially the same hardware as described in **fig. 1**. The data of **fig. 2** is from **fig. 1** coincidence histogram **H**. The source was one Am-241 disk **10** which emits approximately 1 microcurie of alpha-rays. The surfaces of the two surface barrier detectors **13 18** were approximately 9 mm from each other, and the detector's working diameter was approximately 2 cm. The beam-splitter consisted of two layers of 24 carat gold leaf imported from Thailand and held to aluminum ring **16** with a thin layer of vacuum grease. The histograms of **fig. 2** labeled **RE** and **TR** are the reflected and transmitted singles spectra respectively. Data of **RE TR** was collected with the gold in place and no coincidence gating applied. Pulse amplitude histograms **RE TR** were collected by a pulse-maximum feature in the LT344 **DSO.** The reflected pulse amplitude histogram **RE** was taken using test source **65** centered to aim at detector **13**. The positioning and scaling of **fig. 2** component spectra were determined from test pulses and by noting the voltages on **DSO**. The peak of each **RE TR** histogram is assumed to correspond to 5.5 MeV and is designated 1 on pulse amplitude scales **Ch1 Ch2** of **fig. 2**. Position 0.33 for each pulse amplitude histogram was determined by SCA settings **LL1** and **LL2**. The points in the **Ch1 Ch2** plane are from coincidences within τ = 100 ns, as measured from detector pulses **49 51.** These points were digitized by **DSO**, and transmitted to computer **63** for analysis and plotting.

This **Ch1 Ch2** way of plotting was accomplished by interfacing **DSO** to host computer **63** running a QUICKBASIC program of my own development. It was necessary to develop this xy plot of pulse-pairs to see if particle-energy conservation was broken. It is easy to visualize from **fig. 2** that the average pulse-pairs occur at about half the 5.5 MeV point. This is what would be expected if an alpha-particle were to split into two particles, each of half its initial kinetic energy. However in R D Evans' book he clearly describes that it takes over 7 MeV per nucleon to split a helium nucleus, and even more to split off a component of gold. The kinetic energy spectrum of Am-241 is published in *Radiation Detection and Measurement* by Knoll page 398 first edition, and shows the maximum initial kinetic energy at 5.545 MeV. Therefore, there is not enough kinetic energy to split the alpha by conventional theory. The detectors and count rates are responding to alpha-waves, not alpha-particles.

It is important to understand that the coincidence xy points plotted in **fig. 2** do not occur below about 0.45 of the characteristic average pulse amplitude. This was not due to the SCA settings which were set at 0.33, it is due to the phenomenon. If there were some phenomenon at play other than what I describe, smaller pulse amplitude pairs would be detected in coincidence.

The experiment of **fig. 2** of November 13, 2006 had a reflected singles rate R_{re} = 0.042/sec from the 24 carat gold and a transmitted singles rate R_{tr} = 2314/sec through the gold. For each coincidence histogram in **fig. 3** the window of times between plotted coincidences was

Fig. 1



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set at τ = 100 ns. The chance rate of coincidences is calculated $R_c = R_{re}R_{tr}\tau$ = (0.042)(2314)(100ns) = 9.8 x 10^{-6}/sec. The experimentally measured rate was R_e = (159 coincidences)/(154ks) = 1.04 x 10^{-3}/sec, making the ratio R_e/R_c = 105 times chance. Any ratio greater than 1 and surpassing error margins is significant, because quantum mechanics predicts R_e/R_c to not surpass unity.

A time difference (Δdly) coincidence histogram for the experiment of **fig. 2** is plotted at **fig. 3a** by means of the LT344 **DSO** Δdly histogram and smart qualified trigger features, depicted in **fig. 1 H**.

From an earlier experiment of November 10, 2006 comes the Δdly histogram of **fig. 3b**. Everything except for the beam-splitter material was kept unchanged for a good comparison to the experiment of November 13, 2006. Beam-splitter **15** was two layers of an Italian brand of 23 carat gold leaf. The transmitted singles rate here was R_{tr} = 2434/sec, nearly identical to the test of November 13. Singles rates are calculated by the total singles counts per experiment duration, 895 minutes. The similar transmitted singles rates indicate the gold leaves were very similar in their ability to attenuate alpha, indicating that thickness by stopping power of 23 carat gold of **fig. 3b** was similar to 24 carat gold of **fig. 3a**. The reflected singles rate was markedly different at R_{re} = 0.0793/sec. Alphas were reflected from this less pure 23 carat gold nearly twice as often One might expect the alpha-split effect to work better with the 23 carat gold given these singles rates. The chance rate was R_c = (0.0793)(2434)(100ns) = 1.95 x10^{-5}/sec and R_e = (40 coincidences)/(53.7ks) = 7.45 x10^{-4}/sec, R_e/R_c = 38 times chance, 2.7 times worse than with the 24 carat gold. Conventional theory and singles rates would not so easily measure our 1/24 difference in gold purity. The ratio above chance is therefore an interesting measure indicating something in the metallurgy that could not be measured by prior art alpha-ray physics.

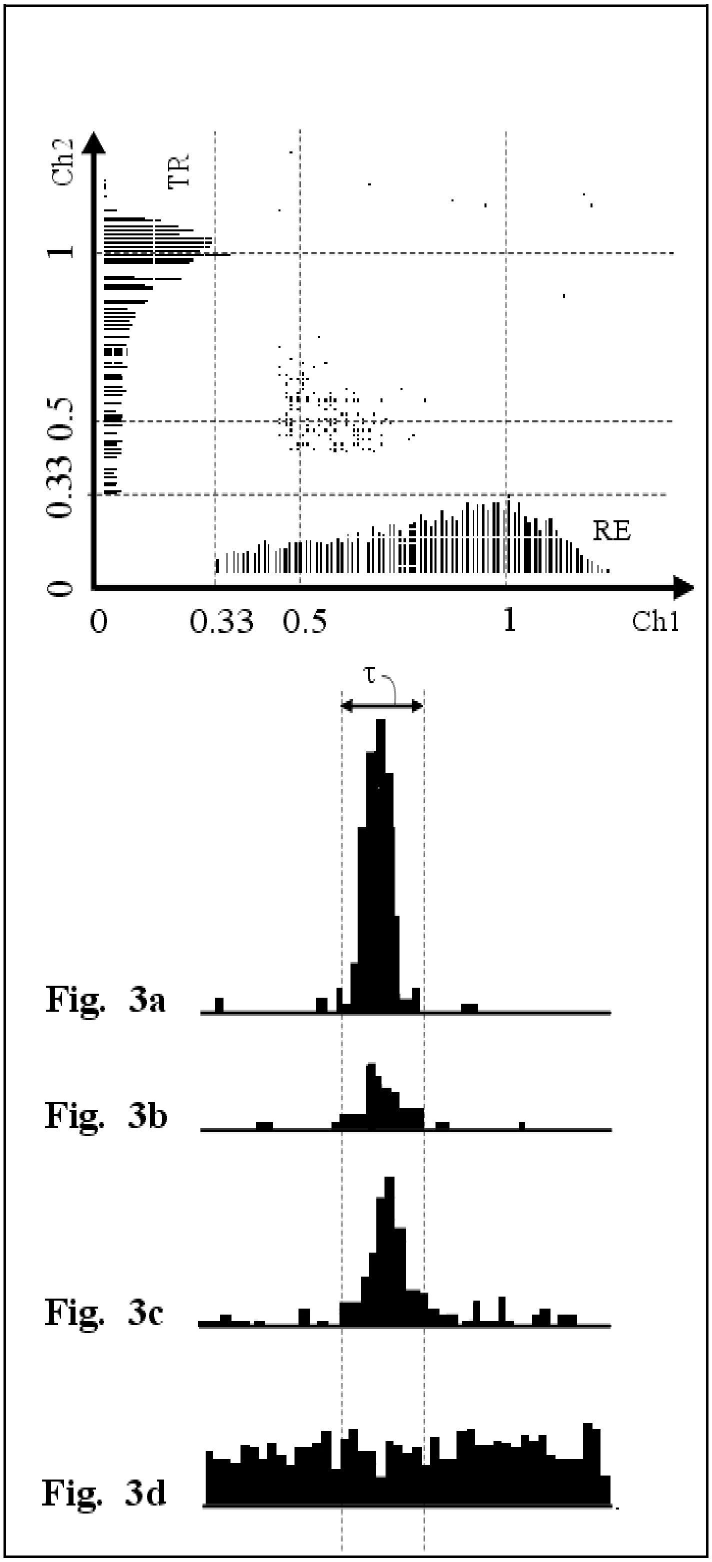
Gold is not necessary as a beam-splitter. **Figure 3c** shows a Δdly histogram using only the transmission detector surface itself as a beam-splitter. This experiment of November 8, 2006 used the same SCA settings and detectors, but with a stronger Am-241 source than in the previously described experiments. There were 10 disks of Am-241: 9 at the periphery of the reflection detector, and one suspended at the center. The strength of the source only changes the time duration of the experiment. It has been found that the strength of the source does not affect the degree above chance. The experimental duration was 6.64 hours, R_{re} = 0.15/sec, R_{tr} = 8527/sec, R_c = 4.8 x 10^{-4}/sec, R_e = 0.0044/sec, R_e/R_c = 9.3 times chance. The detector surface has a thin layer of aluminum vacuum-deposited over silicon, designed for the alpha-ray to pass through. Copper leaf as a beam-splitter material under study also revealed a small positive *unquantum* effect, but tests with palladium and silver leaf foils, plastic, and mica did not surpass chance. The method of *Particle Violation Spectroscopy* will undoubtedly be useful in measuring properties of atomic structure of silicon and other materials in the semiconductor industry. The fact that not any beam-splitter material is capable of revealing an *unquantum* effect is evidence of its material specificity. The tests mentioned with palladium and silver leaf foils produced a coincidence histogram of noise resembling **fig. 3d**. Gasses were also tested as a beam-splitter in March of 2005 using butane (2.3 x chance), propane (chance), and oxygen (chance).

Many control tests were performed. A test for true coincidences (simultaneously emitted quanta) of December 7, 2006, shown in **Fig. 3d**, was performed for 2 hours with a single Am-241 source disk present. The detectors were at right angles to each other with no beam-splitter leaving the detectors to receive non-overlapping solid angles of radiation from a relatively small source. The SCA window settings were the same for all experiments of **fig. 2** and **fig. 3**. If there were true coincidences there would be a peak within section τ of **fig. 3**, the center of which is 0 ns between timing pulses. However, the relatively flat coincidence histogram shows that my Am-241 source disk contained no impurity true-coincidence source. The detectors, window SCA settings, and detector positioning within the vacuum chamber for the non-beam-splitter (true coincidence) control test, were also the same as used for testing reflection of alpha-rays on diamonds described for **fig. 4**. This true coincidence test applies for both matter-rays and gamma-rays.

It is still possible to perform my method using a source that does produce true coincidences. A third detector must be placed outside the path heading to the beam-splitter, and its pulse put in anti-coincidence. Detection schemes employing greater numbers of detectors or arrays of detectors are obvious, so long as a set of coincident detections are utilized to defy quantum mechanical chance.

To accompany experiments testing a diamond-split effect of **fig. 4** a no-source background coincidence test was performed for 48 hours with everything else unchanged. This background test used a 1 inch diameter ORTEC and a 1.5 inch diameter CANBERRA PIPS detector at right angles to each other with an Am-241 disk centrally located. This kind of background test was repeated several times with different geometries. In none of these background tests was a single coincidence found, even by chance. This indicates that cosmic rays were not interfering with the experiments. Cosmic rays were indeed found to interfere and cause coincidences when two CANBERRA PIPS detectors were employed, and coincidences occurred at an average rate of about 3/day, with the amplitudes of pulses being irregular. One fully ORTEC detector was therefore shown to protect from recording artifact coincidences of cosmic origin.

Figure 4 describes the arrangement used for splitting alpha-rays from diamonds. I suspected an unquantum effect with diamond because a resonant reflection of 5.5 MeV alpha-rays with carbon was found by Ferguson and Walker, "The Scattering of Alpha-Particles by Carbon and Oxygen," *Physical Review* (1940), vol. 58, page 666. In this resonant reflection helium (alpha) joins carbon to make oxygen in an unstable form that quickly decays to return the helium in a retro reflection. It was fortunate that Am-241 ejects an alpha-ray at just the right kinetic energy to stimulate this resonant reaction. Ferguson and Walker found that the alpha retro-reflects from carbon at a greater rate than calculated by Rutherford's method; this inspired me to experiment with diamonds as a beam-splitter to see if different orders of reflected components of the alpha-ray could be detected in coincidence. The experiment of **fig. 4** of November 28, 2006 used 10 Am-241 source disks **111** in two rows of 5, mounted in collimator tubes **113**, to aim alpha-rays **114** toward a set of diamond powder coated machinist's files **115**. Beam-splitter **115** is a 1 inch square surface of a commercial diamond file. Alpha-rays that were predominantly specularly reflected **117** were captured by a 1 inch ORTEC surface barrier detector **119**, and alpha-rays predominantly retro-reflected **121** were captured by a 1.5 inch CANBERRA PIPS surface barrier detector **123**. I discovered that to make the effect work, a low level alpha-



ray ambient source **125** of Am-241 was needed to leak a low level to both detectors without reflecting from the diamonds. Shutter **126** adjusts the flux of matter-wave. I assume this is necessary to enhance the pre-loaded state of resonant atomic He++ domains in the detector; but I'm not sure. The *unquantum* effect in this diamond reflection test was found to disappear without source **125**, and ambient source **125** alone does not cause coincidences. No correction in the chance calculation was needed because the singles rate measurements read from diamond-reflection and from ambient source **125**. The duration of the experiment was 6.56 days. The singles rates were calculated in computer **63** by taking the ratio of singles counts and the sum of all time durations between each coincidence event.

Experimental results of November 28, 2006 are from the arrangement of **fig. 4** and are shown in **fig. 5**, which is an annotated screen capture of the QUICKBASIC program I wrote for automating the experiment. There is nothing in my QUICKBASIC program that could not be reproduced from the information in this disclosure by a programmer skilled in BASIC and GPIB interfacing. The appendix QUICKBASIC program is titled alpha19.txt. The chance rate R_c, experimental coincidence rate R_e, and degree above chance R_e/R_c = 8.84, are displayed at the bottom of **fig. 5,** and are calculated using only the valid pulse pairs that were within 160 ns of each other, as set in the program by adjustable vertical line cursors **141 143**. There are 16 pulse pairs bracketed in the 160 ns window. The analog shapes of these chosen pulse pairs **PULSES** are in the computer display. It is readily seen that **PULSES** are all undistorted, and in coincidence. On the same time scale and to the right of the analog **PULSES** are timing pulses number 1 and timing pulses number 2 from SCA **45** and SCA **47** respectively. The timing pulses are digitized in **DSO** in **fig. 1** as **53 55**, and re-displayed in computer **63**. These timing pulses are 500 ns wide, and their vertical offset in **fig. 5** is artificial. Analog and digital pulses that were from pulse pairs beyond cursors **141 143** were eliminated from the calculation and the x-y display. A base line **151** of the analog pulse for one channel is positioned at the keyboard, and is done similarly for the other channel, not shown. These base lines determine the zero of the **Ch1 Ch2** coordinate system. The software creating the **fig. 5** display is the same software used for the **Ch1 Ch2** plot in the **fig. 2** composite. There were 16 pulse pairs plotted in **fig. 5.** The spectacular discovery from this test is that some pulses were big. Diagonal line **153** was calibrated from separate tests and inserted in **fig. 5**; this is the line upon which two pulses would add to twice the characteristic 5.5 MeV alpha-ray. If a point were plotted on the center of this line it would be from pulses that each had the full characteristic pulse amplitude of 5.5 MeV, as described for **Fig. 2**. Such a point on line **153** would have broken particle-energy conservation by a factor of 2; only one such point is displayed here. Breaking particle-energy conservation is not breaking the law of energy conservation, it breaks the particle model. I uphold energy conservation. Line **155** is where particle-energy is conserved; a point plotted on the center of this line would be from two (5.5 MeV)/2 detector pulses. Points to the right of line **155** break what I call particle-energy conservation. This method of violating the principle of the particle here is similar to the way I broke particle-energy conservation in *Photon Violation Spectroscopy*. *Particle Violation Spectroscopy* reveals a two-for-one effect, and is predicted by the loading theory.

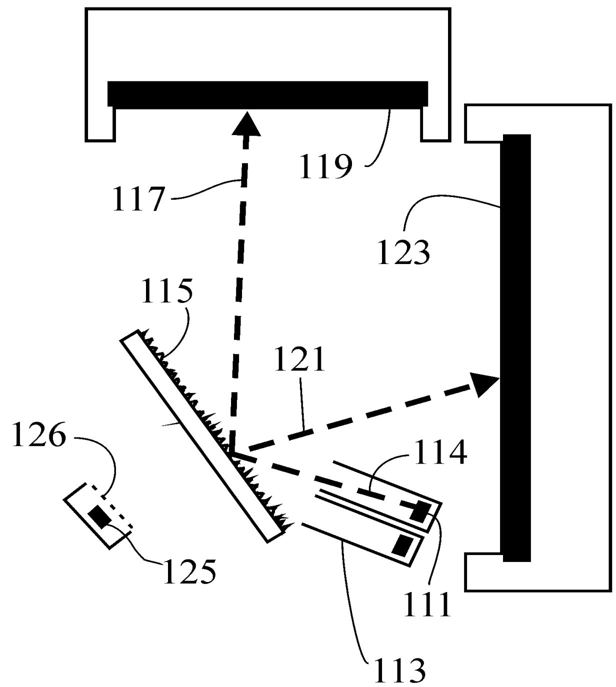
I performed several tests with the apparatus and method describing **fig. 4**, but substituted for beam-splitter (reflector) **115** surfaces of graphite, quartz, gold, and cubic zirconium. None of these materials revealed an *unquantum*t effect. The fact that the *unquantum* effect was revealed analyzing carbon in the diamond chemical state but not in the graphite chemical state, is evidence that the method of *Particle Violation Spectroscopy* is sensitive to the chemical state of the beam-splitter, at least for carbon. There are several known alpha spectroscopy techniques employed for material analysis, but they are not coincidence tests.

There is yet another mode of *particle violation spectroscopy* that I have discovered. My earliest success with finding an *unquantum* splitting the alpha with diamond were obtained as early as October 12, 2005, and those tests did not require a second tickler-field source. The test of November 28 did require a tickler field. In a 6.6 ksec test with two Am-241 disks and two jewel diamonds, with singles rates of 1/155 sec and 1/76/sec, there were 5 coincident detections within 75 ns and no others, to give R_e/R_c = 6 million times chance. This test used two of the shielded DIAD ORTEC detectors found to be immune to cosmic caused coincident events. The function of the tickler field may have been expressed by an unknown ambient source of the chamber's metal. The chamber was built from parts from a discarded coating machine from Stanford University, and was undoubtedly contaminated. However, control tests in the Stanford machine revealed no background coincident detections that would have confounded the measurement. The data of **figs. 2**, **3**, **5**, **6**, and **7** were not obtained from the Stanford machine. It is an important discovery in itself that the *unquantum* effect can be modulated by an ambient or a controlled source, as verified by the data of **fig. 5**. My alpha-ray *unquantum* effect was tested in three different vacuum chambers. My series of tests also employed different detectors and amplifiers as well. Tests searching for electronic cross talk were also carefully undertaken. It took me two years of rebuilding and testing to convince me the alpha-split effects for diamond and gold were real and were in contradiction to prior art particle physics. The discovery of an ambient field influencing the *unquantum* effect from the data of **fig. 5** is additional evidence of a pre-loaded state.

Figure 6a is a conventional pulse amplitude spectrum of alphas aimed straight toward a single ORTEC detector, of 2 cm diameter active surface. The source was ten Am-241 disks (1 microcurie per disk) mounted in brass collimator tubes similar to **114** of **fig. 4**. Vertical scale **171** is logarithmic and horizontal scale **173** is pulse amplitude with "1" marked at the characteristic pulse amplitude and "2" marked at the expected sum-peak position. The lower level **LL** cut-off in these histograms is from the SCA setting. A characteristic peak section **187,** had a detection rate of 23.3k/253 sec = 92 pulses/sec. From observing the analog pulses on the **DSO,** an estimate can be made of the time that two pulses would need to overlap to create a sum-peak, and this estimate was made to err in favor of quantum mechanics. This estimate is τ_S = 200ns. Sum-peak **177** has 2 pulses/253sec= 1/126sec. Calculation of the expected chance rate for the sum-peak region would be $R_c = (92/sec)^2(200ns)$ = 1/589sec. The ratio R_e/R_c is approximately 4, for such a low count rate in the sum-peak can be taken as a good match between theory and experiment, for what is expected for sum peak **177**. We defy chance, but not by much.

Figure 6b is a pulse amplitude spectrum of alphas now reflecting from a set of diamonds. These diamonds were a pair of diamond earrings and a mosaic of 1 mm triangular diamond macles that added up to a surface of approximately 1 cm^2. The detector was the same as used for **fig. 6a**. The alpha source and detector were both placed approximately 45 degrees above the diamond reflecting surface. Vertical scale **177** and horizontal scale **179** are the same as for **fig. 6a**. The range of pulse heights **181** was the same as used for **fig. 6a** and had 668 pulses/41 ksec = 1.63 $x10^{-2}$/sec = R_1. Region **183** on scale **179** at 2 times the characteristic, had 8 pulses/41 ksec = 195 $x10^{-6}$/sec = R_e. The chance rate R_c for this region would be $R_c = R_1^2\ \tau_s$ = 5.3 x 10^{-11}/sec. R_e/R_c = 3.6 million times chance, reflected from the diamonds indicating a substantially enhanced sum-peak. This is strong evidence for an *unquantum* effect enhanced by reflecting alphas from diamonds as measured with a single detector. The unusual dip **185** in reflected spectrum **179** implies that a large fraction of the alpha matter-wave was not reflected in any omnidirectional sense, but instead implies that a large fraction was either retro-reflected or sent in two directions at once, and was not picked up by the single detector because the source/ detector arrangement was not adjusted to receive retro-reflection. Dip **185** sits exactly in the center of the 5.5 MeV characteristic peak **187** of the non-reflected spectrum of **fig. 6a**. Here we see consistency between the two-detector beam-split test of **fig. 5** and the single detector reflection test of **fig. 6b**, which both used diamonds and broke chance. Either the released alpha waves from the diamond reaction were more coherent so as to more readily trigger detection, or energy was released from the diamond; either case is an *unquantum* effect. I conclude that these alpha diamond *unquantum* effects are enhanced by the 5.5 MeV alpha resonance with carbon

Fig. 4



119
117
123
115
121
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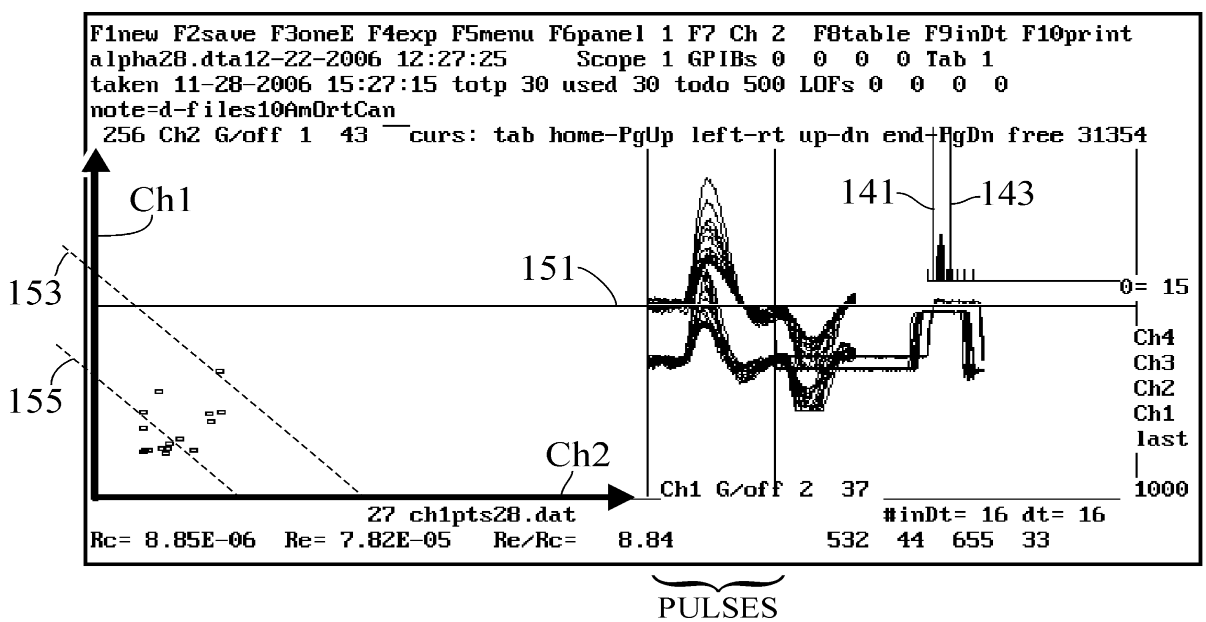
114
125
111
113

Fig. 5



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alpha28.dta12-22-2006 12:27:25 Scope 1 GPIBs 0 0 0 0 Tab 1
taken 11-28-2006 15:27:15 totp 30 used 30 todo 500 LOFs 0 0 0 0
note=d-files10AmOrtCan
256 Ch2 G/off 1 43 curs: tab home-PgUp left-rt up-dn end-PgDn free 31354
Ch1
141
143
151
153
155
0= 15
Ch4
Ch3
Ch2
Ch1
last
Ch2
Ch1 G/off 2 37
1000
27 ch1pts28.dat
#inDt= 16 dt= 16
Rc= 8.85E-06 Re= 7.82E-05 Re/Rc= 8.84
532 44 655 33
PULSES

discovered by Ferguson and Walker. Coincidence data of **fig. 5** are due to a retro-reflection of the single alpha-ray from diamond that took place simultaneously with an omnidirectional reflection of the same single alpha-ray. Such a simultaneous splitting of the alpha-ray has never been reported in prior art and is clear evidence of the usefulness of *Particle Violation Spectroscopy*.

Recent Support from Photon Violation Spectroscopy

Useful results from the method of *Photon Violation Spectroscopy* are additional evidence for the importance and usefulness of *Particle Violation Spectroscopy*. The physics behind the method of *Photon Violation Spectroscopy* must be valid for the method of *Particle Violation Spectroscopy* to be valid. Newly tested evidence refuting the photon model, similar to my evidence given in US 2005/0139776, is emphasized here to show due diligence in developing the physics underlying *Particle Violation Spectroscopy* and *Photon Violation Spectroscopy*. I have discovered in September 2007 that annihilation radiation, a well studied form of gamma radiation from electron-positron collision, produces a notably strong *unquantum* effect. Three detectors were used to remove a possible artifact from a third gamma-ray emitted in true-coincidence upon decay from **Na22**. Here the coincident detection rate is 321 times quantum mechanical chance. The third detector acts as a trigger to record the splitting of only one of the two annihilation gammas.

Referring to **fig. 7a**, source **Na22** of gamma-rays are sodium-22 (Na-22) atoms in spontaneous decay. Na-22 can suddenly emit a unit of positive charge, an anti-electron. The anti-electron meets an ambient negative electron. The two charge-waves cancel, and two oppositely directed gamma-rays **γ1** and **γ2** are produced. A higher frequency gamma ray **γ3** is also produced in the radioisotope decay. Sodium iodide scintillator crystal **NaI**, is incorporated to respond to gamma ray **γ3**. Labels **γ1 γ2 γ3** represent a typical set of rays. The gamma detectors are scintillator crystals that emit a classical pulse of visible light energy proportional to a captured gamma-ray's electromagnetic frequency. Detector **NaI** responds with typical scintillator pulse **PNaI**. Two bismuth germinate scintillator crystals **BGO1 BGO2** are incorporated to respond to **γ1**. Detector **BGO3** responds with typical scintillator pulse **P3**, and detector **BGO4** responds with typical scintillator pulse **P4**. The scintillator light is converted to an electrical pulse by photomultiplier tubes **PMT2 PMT3 PMT4**. The single channel analyzer circuits **SCA2 SCA3 SCA4** are set to allow electrical pulse amplitudes that are characteristic of their respective scintillation-captured gamma-ray, and generate timing pulses delivered to counters **ctr2 ctr3 ctr4** and digital oscilloscope **DSO2** channels **2 3 4**. The time interval between timing pulses is measured and plotted in typical histograms **Dt23**, **Dt34**, the real data of which are plotted in **fig. 7b**. Any peak in these histograms indicates coincident gamma-ray events surpassing what can be caused by chance overlap. The signals from **SCA2 SCA3 SCA4** are used in triple coincidence to remove any possible artifact. The rate of overlapping pulses **2 3 4**, after subtracting a background coincidence rate, was measured at coincidence histogram **Dt23** to be a rate 321 times the chance rate, from my experiment of September 27, 2007. For the **BGO3 BGO4** pair, the rate of overlapping pulses **3 4**, after subtracting a background coincidence rate, was measured at coincidence histogram **Dt34** to be a rate 29 times the chance rate, from my experiment of September 27, 2007. The chance equation used was R_c=

$3R_2R_3R_4\tau_{23}\tau_{34}$. Mechanism **DC** of producing the double coincidence histogram **Dt34** was the smart trigger feature in the LT344 scope. Mechanism **TC** of producing the triple coincidence histogram **Dt23** was accomplished in the LT344 using its Δdly parameter feature. **Figure 7b** is a screen capture of the LT344, graphing the most convincing picture on September 27, 2007. The counter rates were calculated at ctr2 = 60 /sec for the NaI, ctr3 = 193 /sec for the first BGO, and ctr4 = 129 /sec for the second BGO, respectively. The background coincidence rate was 2.075×10^{-5} /sec. Channel B is the first BGO spectrum vertical logarithmic, and channel D is the NaI spectrum vertical linear, with different pre-amplifier gains. Channel A is **Dt34** and channel C is **Dt23**.

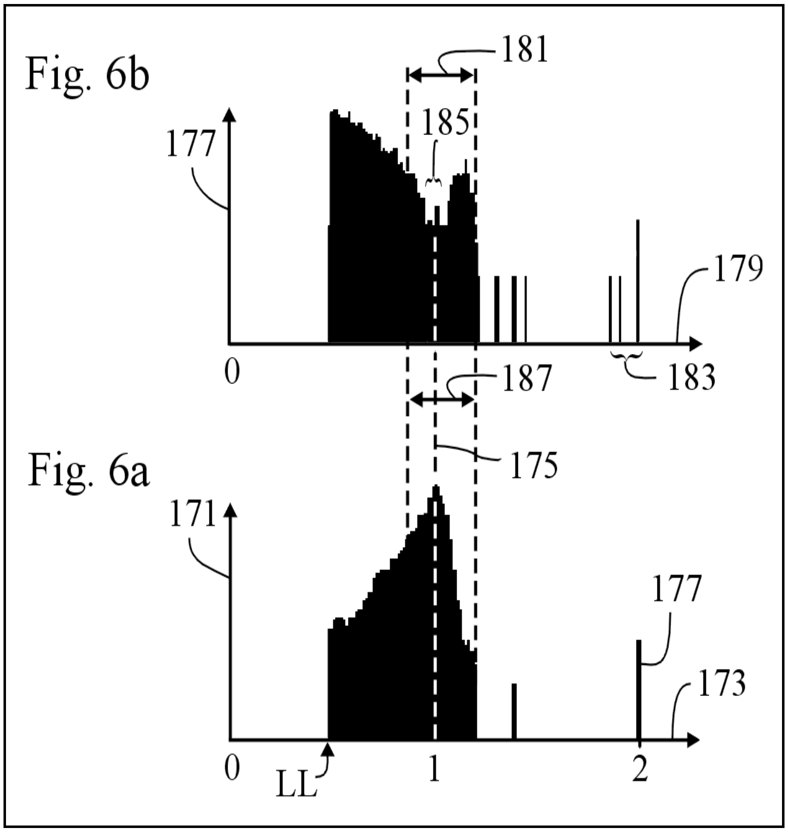
In another similar test of August 23, 2007, using the same **BGO3 BGO4** detectors and electronics, Cs-137 with its single gamma-ray, is used as a source. The Cs-137 660 keV gamma ray is close in frequency to that of 551 keV annihilation radiation, but no coincidences were detected beyond chance, in a 1.6 hour test. In yet another similar test of August 29, 2007, Mn-54 with its single gamma-ray, is used as a source. The Mn-54 700 keV gamma ray gave 3.75 times chance in a test spanning 1.9 days and a background test spanning 25 hours. The data from tests with Cs-137 and Mn-54 as compared with data from the test with Na-22 indicate an extra factor other than electromagnetic frequency, such as resonance or coherence, is at play to cause the *unquantum* effect. These extra factors are yet another discovery made using the method of *Photon Violation Spectroscopy*. Discoveries made with *Photon Violation Spectroscopy* reinforce the validity of *Particle Violation Spectroscopy*.

Conclusions, Ramifications, and Scope

In the history of physics, light was thought to be a particle because the electron was thought to be a particle. I show light is not a particle, and this is shown in the same kind of test others have used to show that light is a particle. If light is not quantized it implies charge is not quantized. We conclude that charge is thresholded.

In the nomenclature of *Particle Violation Spectroscopy*, the helium nucleus would be termed the helium nuclear matter wave. In my previous disclosure of *Photon Violation Spectroscopy*, the underlying mechanism implies electrons do not act like quantum mechanical particles either. The electron should be able to split similarly to alpha-ray. When a gamma is emitted in spontaneous decay it will often generate an internal photoelectric conversion electron with its full kinetic energy preserved. A bare source of conversion electrons such as Cd-109 in a vacuum chamber should produce double-high pulses in a single surface barrier detector. In other words, the physics behind the method predicts that two electrons can be loaded to threshold by one incident electron, to show itself in an anomalously high sum-peak.

It is obvious to apply the method of *Particle Violation Spectroscopy* to charge waves, neutron waves, proton waves, atomic waves, and to any particle-like micro-phenomenon that also displays wave properties. The object of the disclosure at hand is to provide evidence, methodology, and apparatus concerning the violation of quantum mechanics for rays associated with a rest mass, such as alpha-rays and electronic rays. If a phenomenon displays diffraction, the phenomenon is not due to particles, and the probability interpretation can be shown to fail in a beam-splitter test. My evidence for splitting the alpha could not be due to breaking an incident particle into sub-particles, because the binding energy of the incident ray and the target element



exceeds the kinetic energy of the incident matter-wave.

Spectroscopic, material science, and probe applications of my method are obvious. A tested commercially viable application for future manufacture is a miniature gold purity analyzer. More elaborate schemes with arrays of detectors are obvious. It is also obvious to perform *Particle Violation Spectroscopy* with only one detector to measure sum-peaks occurring at rates surpassing a chance calculation. Such a new fundamental measurement will undoubtedly be useful in monitoring the flow of electric charge within a material under study in superconductivity research.

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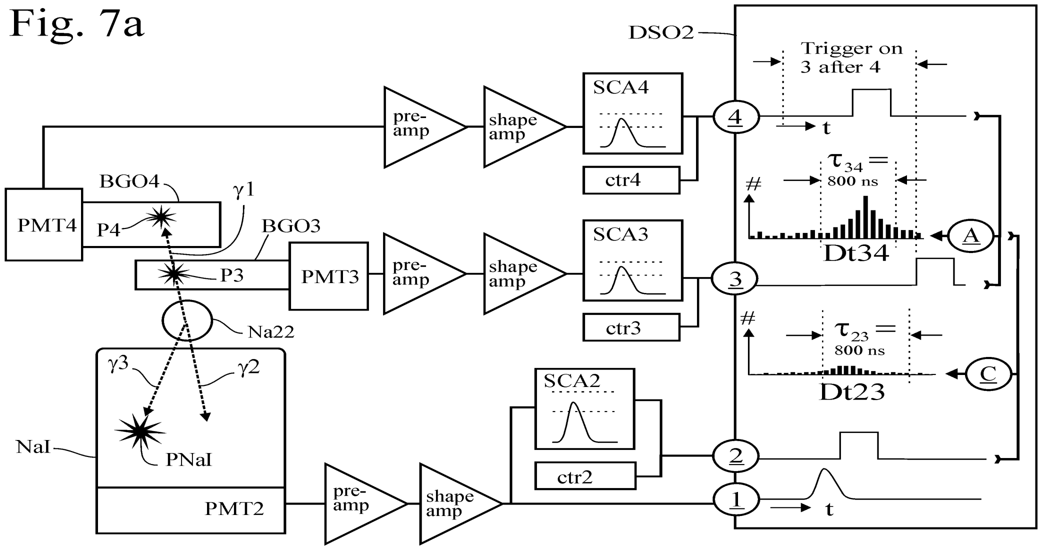
Fig. 7a


DSO2
Trigger on
3 after 4
SCA4
pre-
amp
shape
amp
ctr4
PMT4
BGO4
P4
γ1
BGO3
P3
PMT3
SCA3
ctr3
Na22
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NaI
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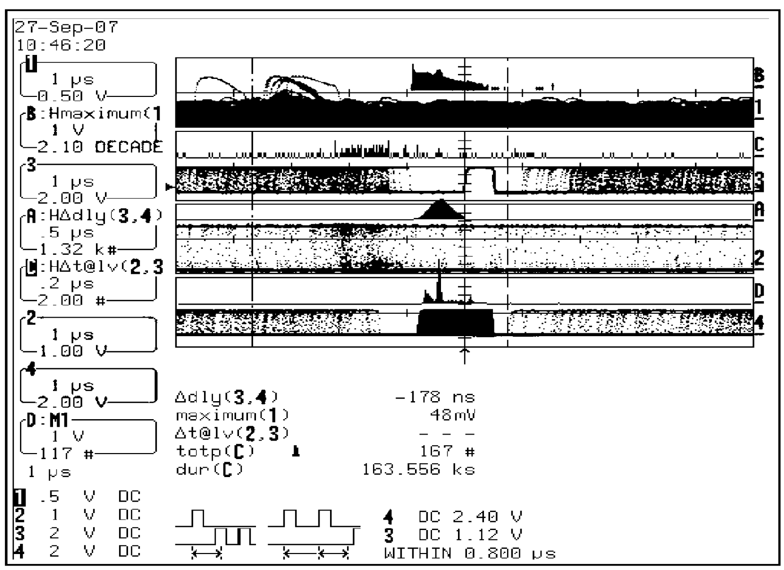
Fig. 7b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maximum(1) 48mV
Δt@lv(2,3) - - -
totp(C) 167 #
dur(C) 163.556 ks
4 DC 2.40 V
3 DC 1.12 V
WITHIN 0.800 μs