

# Proposed Double-Slit Experiments Colliding Antimatter with Matter, and Live Spores with Protons

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**How to cite this paper:** Russell, D.N. (2025) Proposed Double-Slit Experiments Colliding Antimatter with Matter, and Live Spores with Protons. *Open Journal of Microphysics*, 15, 43-51.

<https://doi.org/10.4236/ojm.2025.153003>

**Received:** April 29, 2025

**Accepted:** July 29, 2025

**Published:** August 1, 2025

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## Abstract

The purpose of this paper is to stimulate researchers to do the following proposed experiments, based on the well-known double-slit experiments and the resulting experimentally established wave-particle duality that all particles of matter have a wavelength and a wave-nature. It is proposed to form a low-density stream of antimatter particles and to pass them through a double-slit, and to form a low-density stream of their matter counterparts intersecting with the antimatter stream, just after they pass through double-slits. Calculated de Broglie wavelengths and slit widths are provided for chosen beam velocities. Objectives are to determine if antimatter annihilates with intersecting matter, and if radioactive emission is neutralized, while they are expressing their wave-natures, or if interference patterns of light and dark stripes appear on detection screens, which would indicate that no annihilation had occurred and that the particles had re-materialized at detection screens. It is proposed to pass bacterial spores through a double-slit and collide them with a beam of protons with an objective to open a new field, Quantum Biophysics, to learn about the quantum nature and behavior of de Broglie waves of living cells. Engineering applications in the natural vacuum of space are discussed. These proposed experiments present a novel way to gather information about the nature and behavior of these de Broglie wave forms, about which almost nothing is known, and a way to confirm the quantum delocalization of bacterial spores and viruses into energy waves, which has bio-medical importance.

## Keywords

Antimatter, Positron, Tritium, De Broglie Waves, Double Slit, Annihilation,

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## 1. Introduction

The well-known double-slit experiment was first carried out in 1801 by British polymath, Thomas Young, in which he demonstrated that wave interference by light produced a pattern of light and dark stripes on a wall. This provided solid evidence that light was a wave. In 1927, Clinton Davisson and Lester Germer, and, separately, George Thomson with his student, Alexander Reid, demonstrated that electrons show the same interference behavior, when they pass through a double-slit, as light does [1], which verified the hypothesis by Louis de Broglie in 1924 of wave-particle duality, and established the experimental basis for quantum mechanics. Since then, it has been demonstrated that atoms and even large molecules made of thousands of atoms interfere with themselves and exist as waves, known as de Broglie waves, and exist in two places at once, when they pass through double-slits. Stable, large-mass molecules have been shown to extend the complexity range of demonstrations of molecular de Broglie wave interference to masses in excess of 10,000 amu having 810 atoms in a single particle, and fully coherent quantum delocalization of such particles composed of 5000 protons, 5000 neutrons and 5000 electrons has been confirmed [2]. In 2019 positrons have been demonstrated to have a wave nature and produce interference effects exactly like electrons [3], when passing through a double-slit made with gold-coated silicon nitride gratings with periodicity of 1.21 microns. For that experiment, they designed, built, and used a Talbot-Lau interferometer, because it is suited to low-energy positron beams [4]. Positron waves propagated out to a nuclear emulsion detector screen, where they changed the structure of silver bromide crystals. Developing this nuclear emulsion film revealed an interference pattern of alternating stripes of high and low positron density. The method of controlling charged particle beams by magnetic and electric fields is well-known, since it was refined and perfected in 1950.

While we know that in photons it is electric and magnetic fields that are oscillating or waving, we do not know what is waving in the wave-nature of particles having rest mass. Therefore, there is a great need to discover what is waving in de Broglie matter waves. There is also a need to develop means of exploiting the advantages of matter and antimatter, while they are expressing their de Broglie wave-natures.

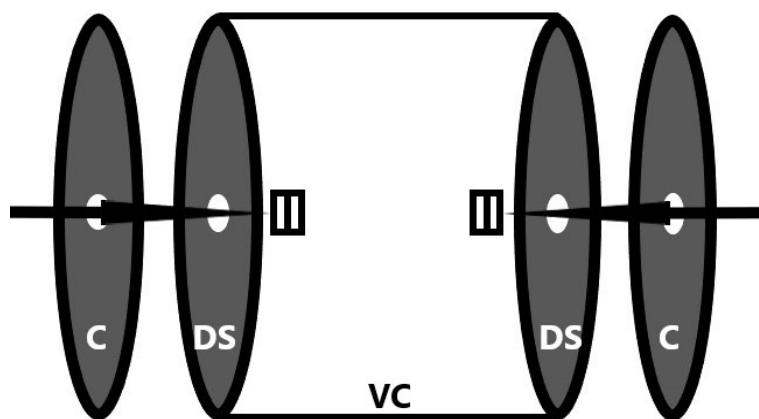
## 2. Proposed Experimental Methods

For all of the following experiments proper and sufficient shielding should be used with all radioactive samples, and all parts of the human anatomy should remain clear of positron beams and electron beams. OSHA radiation exposure limits must not be exceeded, radiation surveys should be conducted, personnel should be mon-

itored, caution signs should be posted in highly visible locations, and instruction should be provided to personnel, as outlined in the Ionizing Radiation Standard according to 29 CFR 1910.1096. Appropriate personal protective equipment should be used. All experiments should be conducted under sufficient vacuum conditions to avoid collisions of the various particles making up the beams with air molecules. Positron beam experiments require high vacuum to minimize such collisions that would scatter the beam, annihilate positrons, and bring down its intensity. Recommended vacuum pressure is in the micro-Torr to nano-Torr range, so that the mean free path of the positrons would be longer than the total beam path length from the source to the detection screen. The vacuum chamber should be air-tight enough to maintain such low pressures over the many hours or days needed to accumulate sufficient data on the detector screens. Vacuum chambers and vacuum pumps are not needed for these experiments and applications in the vacuum of space. Particle densities in all proposed experiments must be low enough so that charge repulsion between particles would not be significant, and so that a particle passing through a double-slit can be confirmed to have interfered with itself. The surface area of the detector screens should be at least a thousand times that of the rectangles housing the double-slits, so that they do not significantly obstruct the de Broglie waves from reaching the detector screens. Collimation holes and rectangles representing double-slits would be microscopic and much smaller relative to the size of the detector screens, than they appear in **Figure 1**.

In a first experiment it is proposed that a low-density, preferably one at a time single-file, stream of positrons is formed by collimation and made to pass through a double-slit toward a detection screen, and that a collimated low-density, preferably one at a time single-file, stream of electrons is formed with the same velocity intersecting with the positron stream, and made to pass through a separate double-slit toward a separate detection screen. The intersection angle of the opposing streams should be 180 degrees or as close as possible to head-on collision to cancel out the kinetic energies of opposing particles. Detection screens should be located on opposite sides of a preferably cylindrical vacuum chamber with a small hole in the center of each screen to allow the streams to enter. These small holes serve to better collimate and align the beams, as shown in **Figure 1**. A positron stream can be obtained from isotopes, such as sodium-22, which emits positrons with kinetic energy of about 3 eV. A monochromatic and continuous beam results, and gold-coated silicon nitride gratings were proven to be an excellent substrate from which to make the slits [3]. An electron stream can be obtained by heating a filament and accelerating the resulting free electrons with an electric field oriented along the direction of the beam by a cathode spaced apart from an anode. Silver bromide can be used in a nuclear emulsion as a detection screen for positrons and the positron particle stream may be controlled and measured by the method reported previously [3]. Phosphor screens made of ZnS:Ag, are commonly used as electron detection screens by converting electron energy into visible light. Electrons and positrons may be accelerated or decelerated by establishing electric fields with an-

ode and cathode electrodes placed apart along the respective stream directions, thus producing an electric force either in the direction of motion or against the direction of motion of the particles. The velocity of the particles is controlled by finely adjusting the voltage between the electrodes. In these experiments the particle density would be very low, so there would not be any problem with charge repulsion between particles. The slower the particle velocities, the larger are their de-broglie wavelengths and the easier it is to manufacture required slits, whose sizes for various particles are calculated below. Although there may be a distribution of particle velocities created by the electric fields, only those particles with velocities corresponding to their de Broglie wavelengths and slit-widths will pass through the slits. Thus, the slit-width finely controls the particle velocity. The objectives are to learn, just by examining the detection screens, if electrons annihilate with positrons, and if there is resulting gamma-ray emission, while both are expressing their wave-natures after having passed through double-slits. Each annihilation should result in 2 gamma-rays being emitted and, in that case, there should be no interference pattern of light and dark stripes appearing on the detection screens. Incomplete annihilation should result in faint light and dark stripes on the detection screens. However, no annihilation would result in a vivid pattern of light and dark stripes forming on the detection screens caused by the positrons and electrons re-materializing on their respective detection screens.



**Figure 1.** Side perspective view of double-slit collision experimental device, where C means collimator, DS means detection screen, VC means vacuum chamber, and arrows indicate direction of particle motion through collimator holes and double-slits, which are microscopic and much smaller than they appear in the drawing.

In a second experiment it is proposed that tritium atoms or ions, preferably one at a time in single file, be made to pass via collimation holes through a double-slit toward a detection screen, and that a low-density, preferably one at a time single-file, stream of positrons is formed by collimation and by means of an electric field generated by spaced apart cathode and anode electrodes with the same energy as beta particles being emitted from the tritium and made to pass through a separate double-slit intersecting with the tritium atoms or ions and travelling toward a sep-

arate nuclear emulsion detection screen. The intersection angle of the opposing streams should be 180 degrees. Detection screens should be located on opposite sides of a preferably cylindrical vacuum chamber with a small hole in the center of each screen to allow the streams to enter. These small holes also serve to better collimate and align the streams, as shown in **Figure 1**. Positrons can be obtained from isotopes, such as sodium-22. Positron velocity may be controlled by finely adjusting the voltage between cathode and anode electrodes. A monochromatic and continuous beam can be made, and gold-coated silicon nitride gratings were proven to be an excellent substrate from which to make the slits [3]. Tritium atoms may be ionized so that the same method may be used to achieve and to control their velocity. The slit width would act as a velocity filter to further control velocity, as explained above. Most radiation-detection instruments, such as Geiger counters, are not capable of detecting tritium beta particles, because of their low average energy of 5.685 keV. Instead, a good, reliable method for detecting tritium is liquid scintillation counting. Since tritium emits electrons, called beta particles, a phosphor, such as ZnS:Ag, can be used for the tritium detection screen. A nuclear emulsion screen, as in the first experiment above and as reported previously [3], is suggested to be used to detect positrons. The objectives are to learn, just by examining the detection screens, if the positron beam annihilates with the beta particle radiation from the tritium atoms, and if gamma ray emission results from such annihilation, while both tritium and positrons are expressing their wave-natures after having passed through their respective double-slits. Annihilation should result in gamma-ray emission and no light and dark stripes forming on the detection screen for the positrons. Incomplete annihilation should result in faint light and dark stripes on the detection screens. However, vivid light and dark patterns forming on both detection screens would indicate wave interference and that no annihilation had occurred.

In a third experiment it is proposed to send small bacterial spores, such as those of *Bacillus atrophaeus* and of *Bacillus subtilis*, one at a time in single-file through a double-slit to demonstrate and learn about the wave-nature of life forms, and to transmit such life-forms through the vacuum of space to re-materialize at a detection screen, intact. Such spores are able to withstand vacuum, extreme cold and heat, desiccation, and intense ionizing radiation levels. Their surfaces may be weakly ionized to facilitate directing them through the double-slit by means of an electric field set up by spaced apart anode and cathode electrodes. Since the mass of such spores is 0.01 picograms, their velocity must be reduced to 10 nanometers/second to allow feasible creation of slit-widths in the nanometer range. Cryogenic cooling may be needed to reduce random thermal vibrations, which become significant at such low velocities. Conventional optical tweezers may be used to manipulate and guide the bacterial spores through the double-slit exactly at the chosen velocity. Single atoms of lithium can be held in three straight rows by a fractal array of highly focused laser beams, as explained by the present author [5], to form the required nanometer-scale double-slit, and to reduce random thermal vibrations of atoms making up the slits. This fractal array of highly focused laser

beams, invented and explained by the present author [5], may also be used to manipulate and guide the bacterial spores through the double-slit one at a time exactly at the chosen velocity. Lithium atoms are recommended to form the slits, because they have a high polarizability of 164 atomic units (36.5 times higher than that for hydrogen), which is required for optical tweezers to work. The fact that the spore size is 452 times the slit width, calculated above, through which they would pass assures that they pass as quantum waves, rather than as particles. The detection screen for living bacterial spores would be a nutrient gel favorable to the growth of the chosen species. After exposure, the detection screen would be grown out, under optimal conditions for the chosen species. A characteristic pattern of stripes of bacterial growth would indicate that interference had occurred. In a second part to this experiment a low-density, preferably one at a time single-file, proton stream is proposed to be introduced through a separate double-slit at the opposite end of the vacuum chamber at 180 degrees against the direction of the spores in their wave-state at a velocity of 0.01 meter/second. The velocity of the protons would be controlled via an electric field set up by spaced apart electrodes and by finely adjusting the voltage between the electrodes. If they behave as particles, the electrons should scatter and ionize the spores, thus showing that no interference had occurred. But, if they act as waves, then they should pass through each other and re-materialize at their detection screens showing the characteristic striped pattern that indicates that interference had occurred. Similar experiments are proposed passing virus particles through a double-slit, by the same means as for bacterial spores (above), toward a detection screen comprised of a layer of host cells best suited for a chosen virus to infect. In this case stripes indicating the deposition of virus would appear as blank stripes where host cells had been lysed and killed, and would indicate that interference had occurred.

It is further proposed that the first, second, and third experiments, above, be performed on a space-based platform, such as a space station or a spacecraft, where confining vacuum chambers and vacuum pumps are not needed. Since particles would not be scattered or absorbed in the natural vacuum of space, these experiments would be best suited to find application there. The detection screens could be placed much farther away on another spacecraft or satellite, for example, since they would not need to be inside a vacuum chamber. The velocity of particles travelling through space, as de Broglie waves after having passed through a double-slit, could be calculated and compared with known particle velocities before passing through the double-slit. Experiments in orbit should be done on the dark side of Earth, facing away from the Sun, to eliminate the need to use cryogenic cooling to reduce the effect of thermal vibration on particle velocities. This would reduce random variations in de Broglie wavelengths.

### **3. Theoretical Calculated Results of Slit Widths**

The de Broglie wavelength is  $h/mv$ , where  $h$  is Planck's constant,  $m$  is mass, and  $v$  is velocity. Since velocity,  $v$ , is in the denominator, one may increase this wave-

length and, therefore, the slit-width by decreasing the particle velocity. The slit-width may be fine-tuned by moving a slotted covering mask over the slits, which partially covers the slits.

For a chosen electron and positron velocity of 100 meters/second, for example, the de Broglie wavelength is 7.28 microns. Since this wavelength should encompass two slits and the partition between them, the slit-width should be one third of the de Broglie wavelength, which is 2.43 microns.

For a chosen tritium velocity of 0.01 meter/second, the de Broglie wavelength is 13 microns, and the slit-width should be one third of that, which is 4.33 microns.

For a chosen proton velocity of 0.01 meter/second, the de Broglie wavelength is 39 microns, and the slit-width should be one third of that, which is 13 microns.

For bacterial spore or virus particle mass of 0.01 picograms and a chosen velocity of 10 nanometer/second, the de Broglie wavelength is 6.63 nanometers, and the slit-width should be one third of that, which is 2.21 nanometers. The diameter of such spores and virus particles is about 1 micron, which is 452 times larger than this calculated slit width.

#### 4. Discussion

If there is any attempt to measure or detect de Broglie wave forms at any point between double-slits and detection screens, the particles would re-materialize at that point of detection, and they retroactively would give experimental evidence that they had always been particles and had never existed as wave forms at all. Therefore, all measurements in all of the above proposed experiments must be done only by examining the patterns formed on the detector screens. Experimental outcomes cannot be predicted, since the behavior and nature of de Broglie waves have never been measured in such interactions, as they travel between double-slits and detection screens. These proposed experiments present a novel way to gather information about these matter wave forms, without placing any detector between double-slits and detector screens. According to the Theory of Relativity, quantum de Broglie waves must propagate through all four dimensions of space and time. So, subtracting the number of particles re-materializing on a detector screen from the number of particles hitting a double-slit would provide evidence that some of the particles may have propagated out to another time. This would add to our understanding of the quantum wave-nature of matter. Results from these proposed experiments would teach us the wave-nature and behavior of particles colliding with anti-particles with rest mass, once they have de-materialized into waves upon passing through a double-slit. It will be discovered if matter waves annihilate or neutralize their counterpart antimatter waves upon intersecting with each other, after passing through double-slits, and if radioactive emissions of isotopes expressing their wave-natures are annihilated or neutralized by their antimatter counterparts, after both have passed through double-slits, or if they pass through each other as waves, without annihilation. It will be learned whether or not radioactive isotopes continue to emit radiation, while expressing their wave-natures after passing through double-slits, before re-materializing upon

hitting a detection screen. It will be learned if living bacterial spores and viruses survive passing through a double-slit, and if they survive head-on collision with much higher speed protons, also in their wave-natures, after having passed through a separate double-slit. *Bacillus atrophaeus* is recommended, because it is easy to grow and quite hardy and, therefore, in wide use as an indicator of successful biomedical sterilization. *Bacillus subtilis* is recommended, because it is a harmless and beneficial probiotic, and because it produces spores less than 1 micron in diameter. These experiments should confirm the quantum delocalization of bacterial spores and viruses into de Broglie energy waves, and that living cells work by quantum mechanical rules. The bio-medical significance is that it would explain how spores and virus particles with the correct velocity travel through spaces (slit widths) between fibers of filter-masks that are hundreds of times smaller than the diameter of those particles, and it would guarantee that these spores and viruses could only have gone through such narrow slits as energy waves.

Potential future engineering applications are: 1) Replacing filter masks with isolation suits with helmets having separate air supply to stop transmission of dangerous bacterial spores and viruses, since quantum de Broglie waves can pass through any air filter; 2) Developing means to neutralize particle beams of both matter and antimatter in the vacuum of space; 3) Developing means to transmit beams of antimatter through matter in their wave states, without annihilation; 4) Developing means to transmit radioactive isotopes, like tritium and sodium-22, through the vacuum of space with their beta and positron radioactivity suppressed in their de Broglie wave states, which then re-materialize into radioactive particles at a chosen location; and 5) Developing means to transmit bacterial spores and viruses through space in their de Broglie wave states, which then re-materialize and grow on appropriate growth media at a chosen location.

### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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