LEHIGH UNIVERSITY

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Experimental Implementation of Non-local Hidden Variables

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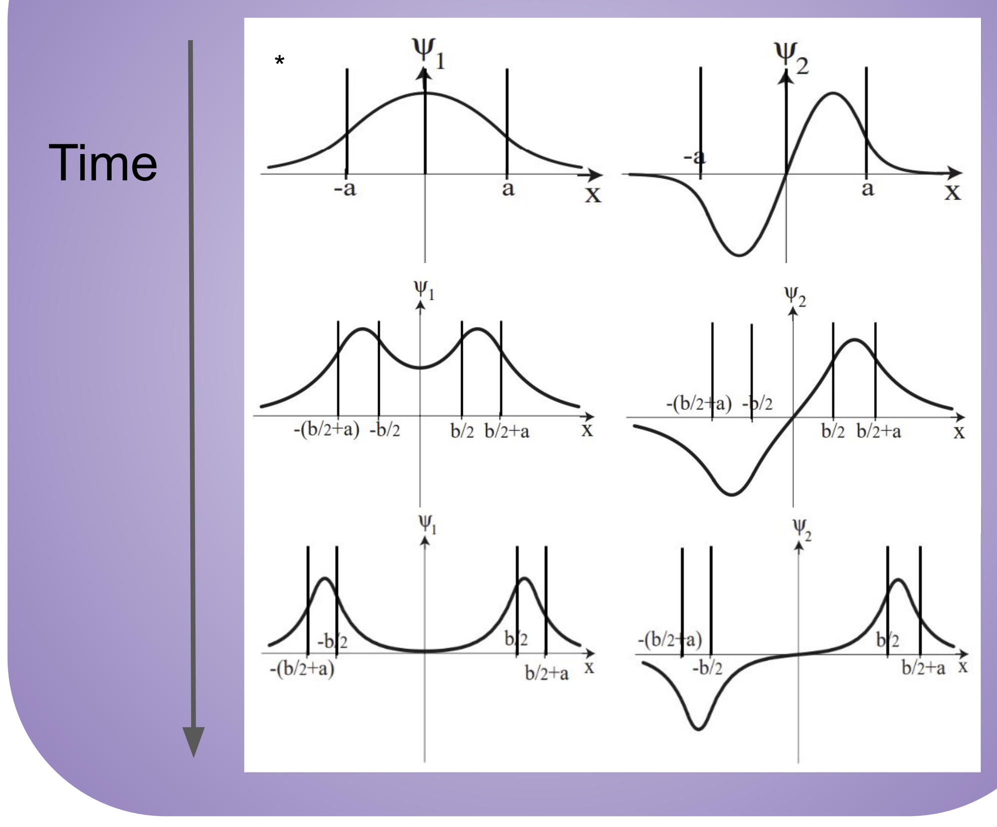
Abstract

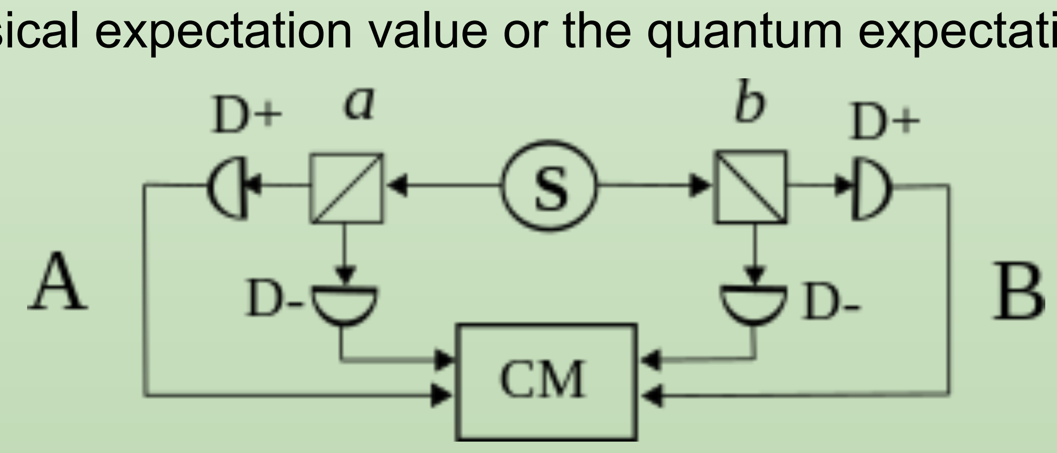
A novel apparatus for creating and maintaining entanglement pairs in the mesoscopic domain has been shown to exhibit behavior outside the classical range of expectation values. It uses the non-local assumption, that two spatially separated elements of reality can maintain influence on each other through a shared wavefunction, and it has been used to create unitary hidden variables. The circuit is a chain of NPN transistors that oscillate the position of a charge between 8 finite square wells. The hidden variable is the position of the charge within the chain of transistors, which can be measured using a seperate circuit. It has been shown using the Clauser, Horne, Shimony, and Holt inequality (CHSH) that these non-local hidden variables are in agreement with quantum mechanics, providing further evidence against local hidden-variable theories.

Quantum Entanglement



Clauser Horne Shimony Holt (CHSH) Test

The CHSH Test was derived from Bell's Inequality, and it gives an experimental method to prove that quantum reality is fundamentally non-local. In this experiment, the CHSH test is turned around to test whether a particular system acts according to the classical expectation value or the quantum expectation value.

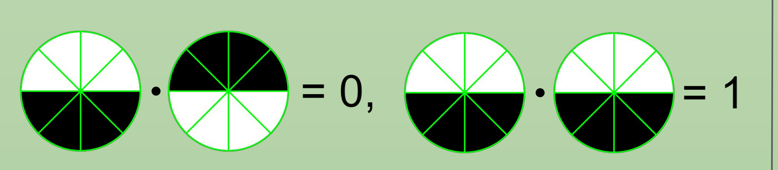


For $a=0$, $b=\frac{\pi}{8}$, $a'=\frac{\pi}{4}$, $b'=\frac{3\pi}{8}$

$E(a,b)=P_{++}+P_{--}-P_{+-}-P_{-+}$

$S=E(a,b)-E(a,b')+E(a',b)+E(a',b')$

Classical Expectation Value



For $|a-b|=\frac{\pi}{8}$

$P_{ww}=P_{bb}=3/8$

$P_{wb}=P_{bw}=1/8$

$E=\frac{1}{2}$

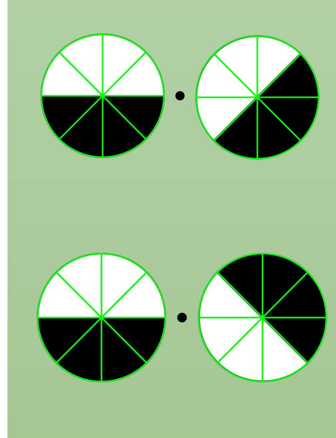
For $|a-b|=\frac{3\pi}{8}$

$P_{ww}=P_{bb}=1/8$

$P_{wb}=P_{bw}=3/8$

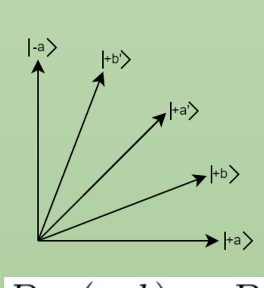
$E=-\frac{1}{2}$

$S=\frac{1}{2}-(-\frac{1}{2})+\frac{1}{2}+\frac{1}{2}$



$$\boxed{S \leq |2|}$$

Quantum Expectation Value



$P_{ww}(a,b)=P_{bb}(a,b)=\frac{1}{2}cos^2(a-b)$

$P_{bw}(a,b)=P_{wb}(a,b)=\frac{1}{2}sin^2(a-b)$

$cos(2x)=cos^2(a-b)-sin^2(a-b)$

$E(a,b)=cos(2(a-b))$

For $|a-b|=\frac{\pi}{8}$

$E=cos(2(\frac{\pi}{8}))=\frac{1}{\sqrt{2}}$

For $|a-b|=\frac{3\pi}{8}$

$E=cos(2(\frac{3\pi}{8}))=-\frac{1}{\sqrt{2}}$

$S=\frac{1}{\sqrt{2}}-(-\frac{1}{\sqrt{2}})+\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{2}}$

$$\boxed{S \leq 2\sqrt{2}}$$

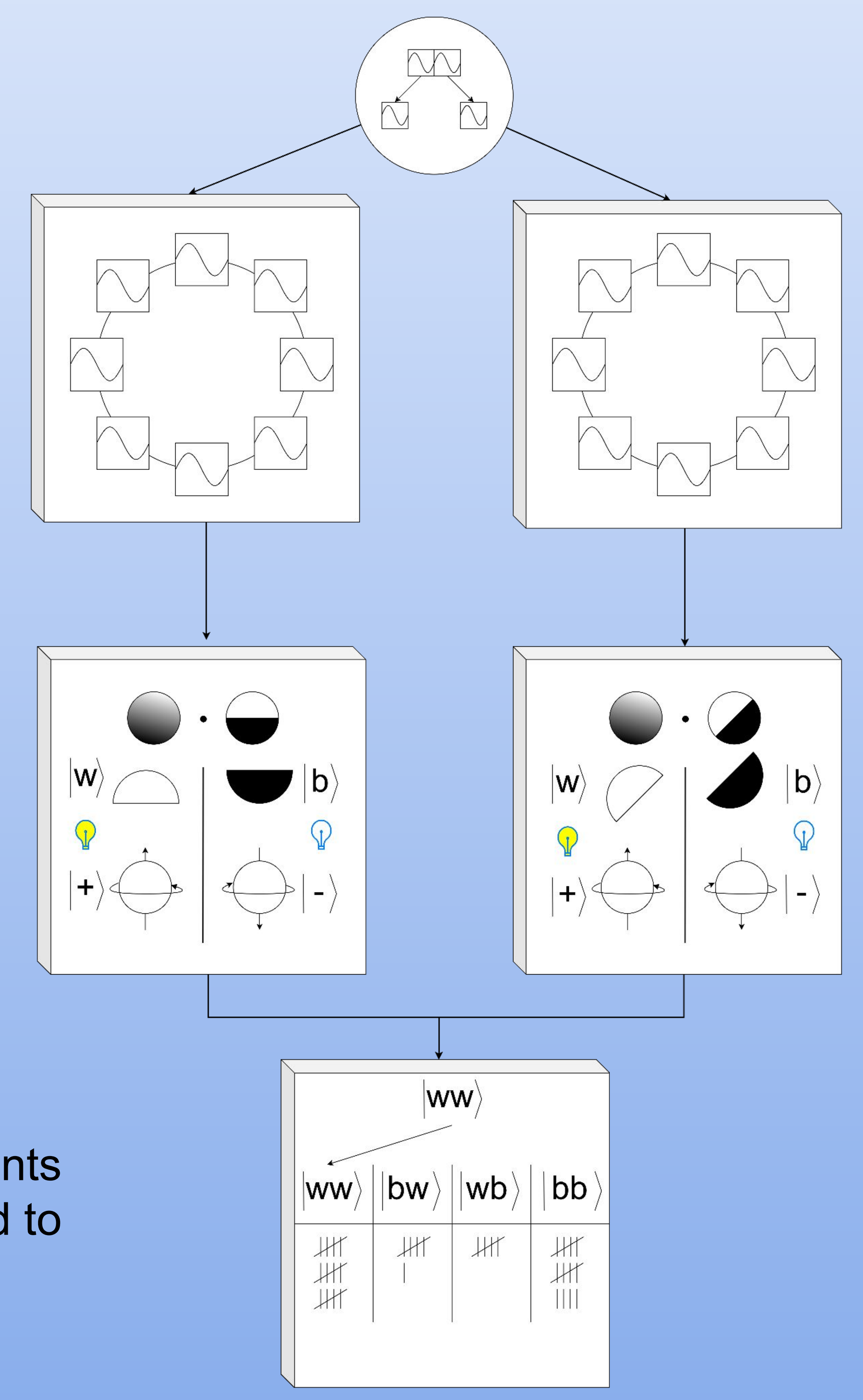
Novel Apparatus

Spin-0 source
A single wave function is divided in half.

Spinners
Evolve the wave function through time

Measurement
Measure the wave function in two different bases

Analysis
The results of measurements are compiled and are used to compute E, and S

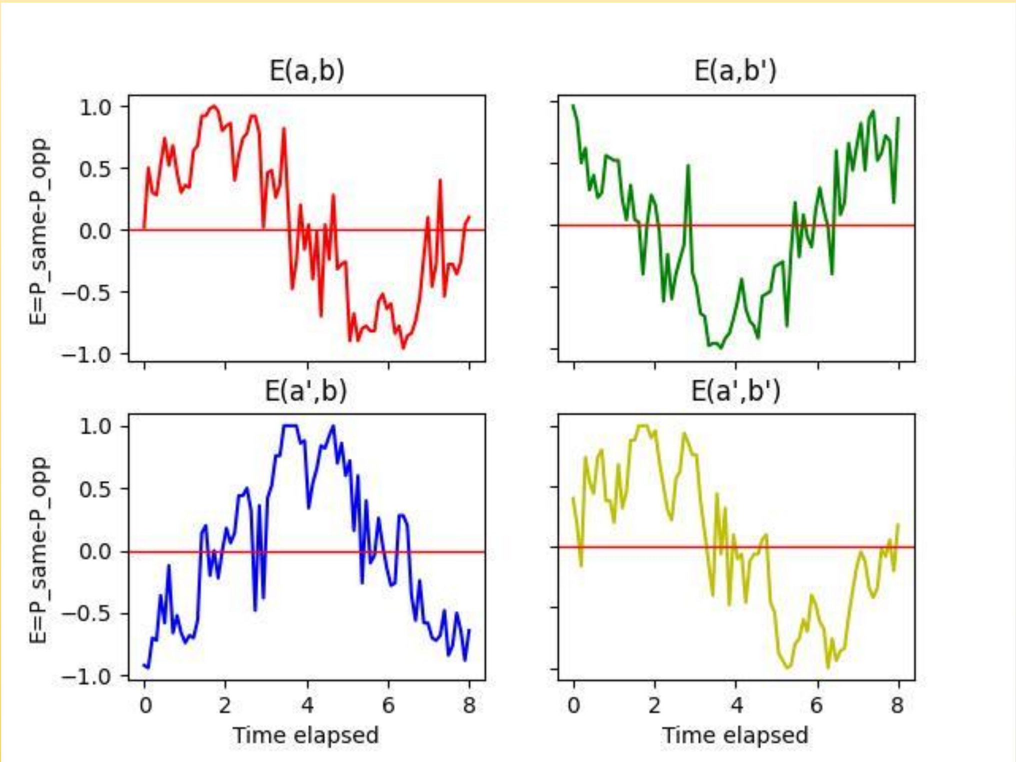


Results and Conclusion

This schematic leads to the bottom right figure, the results exceed the classical expectation value and Bell's Inequality is violated by this apparatus. This indicates that reality cannot be explained using a local realist interpretation, and opens the possibility for a non-local hidden variable theory.

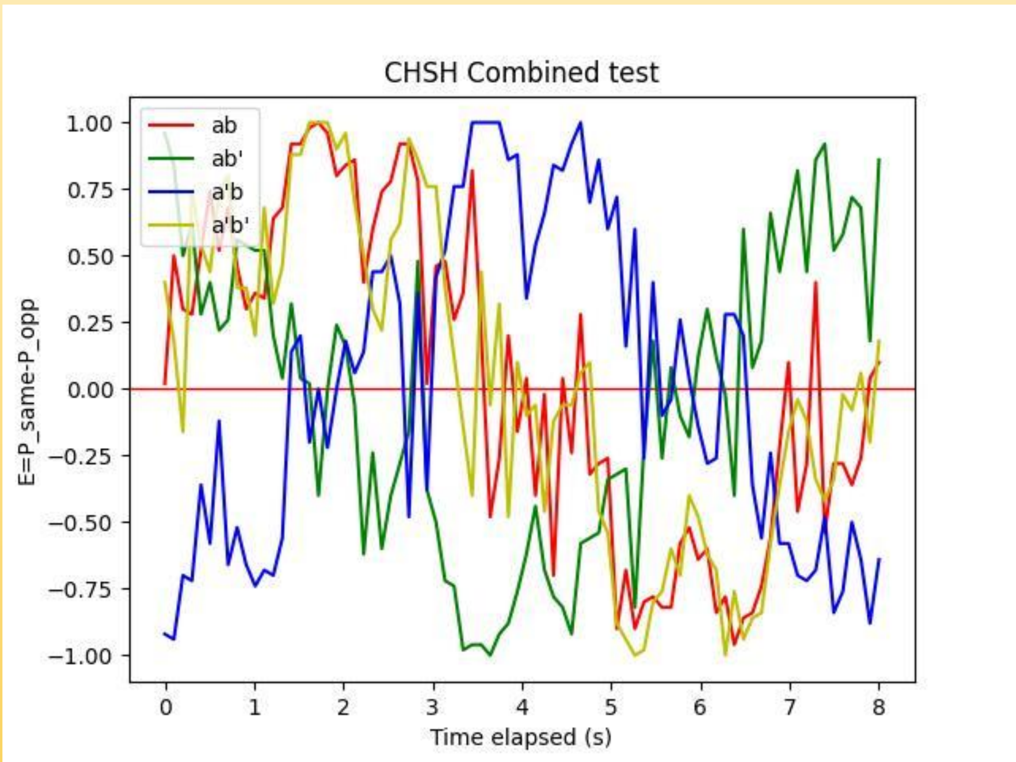
Individual Expectation Values

This quad graph shows the expectation values for 4 configurations of a and b. Each configuration is run independently in time.



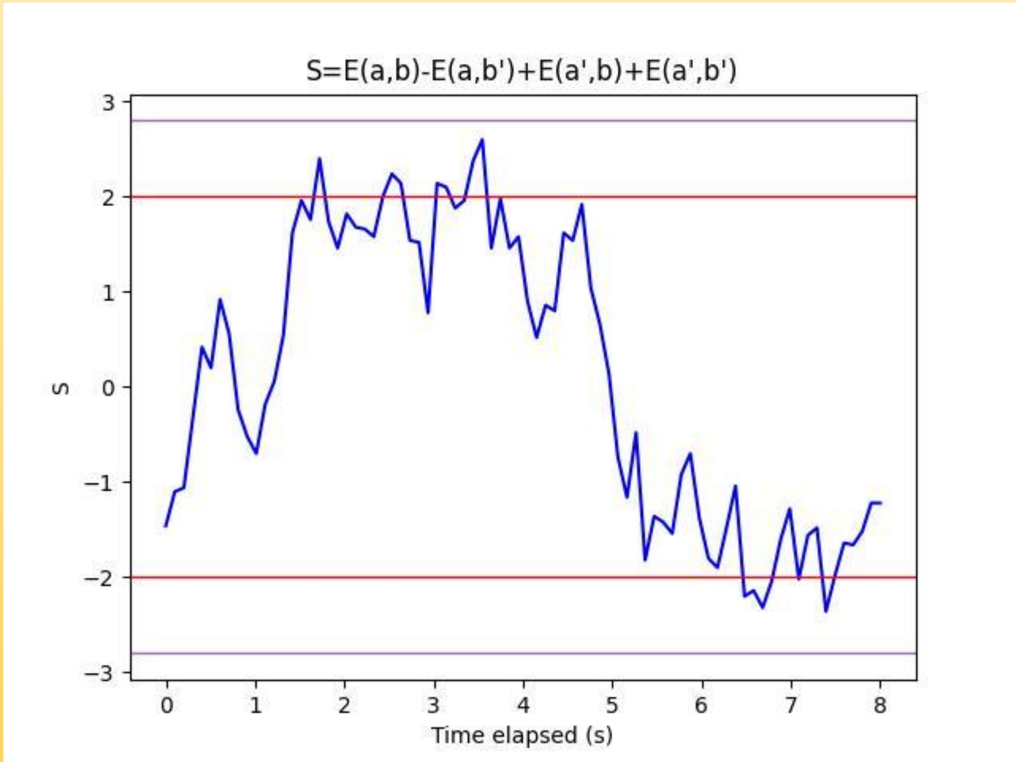
Combined Expectation Values

This graph is an overlay of the 4 individual graphs. The red and yellow lines are in phase, while the blue and green are π out of phase.



S Values

This graph shows the variable S over time elapsed. The red lines represents the classical range, while the purple lines represent the quantum range.



*Graphs found in Quantum Mechanics by Griffiths