Understanding the path-entangled communications device

- View my website: http://webspace.qmul.ac.uk/rocornwall/#Entanglement
- Concerns this one-photon device: http://webspace.qmul.ac.uk/rocornwall/QSE_Flyer2.jpg
- (Also two-photon H-V polarisation device is more easy to understand but less practical): http://webspace.qmul.ac.uk/rocornwall/protocol.jpg

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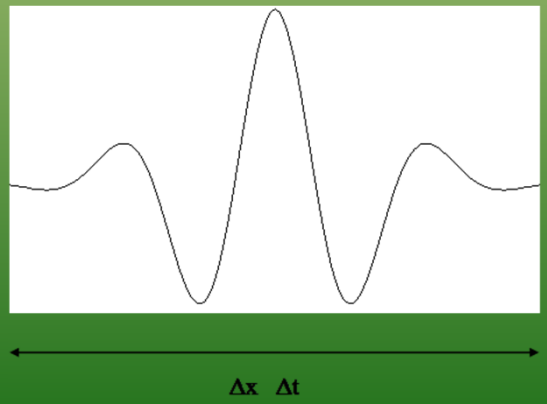
How wave-particle duality really looks

A single particle is essentially a wavepacket.

This is easy to prove from de Broglie relations: $E = \hbar\omega$ and $\mathbf{p} = \hbar\mathbf{k}$

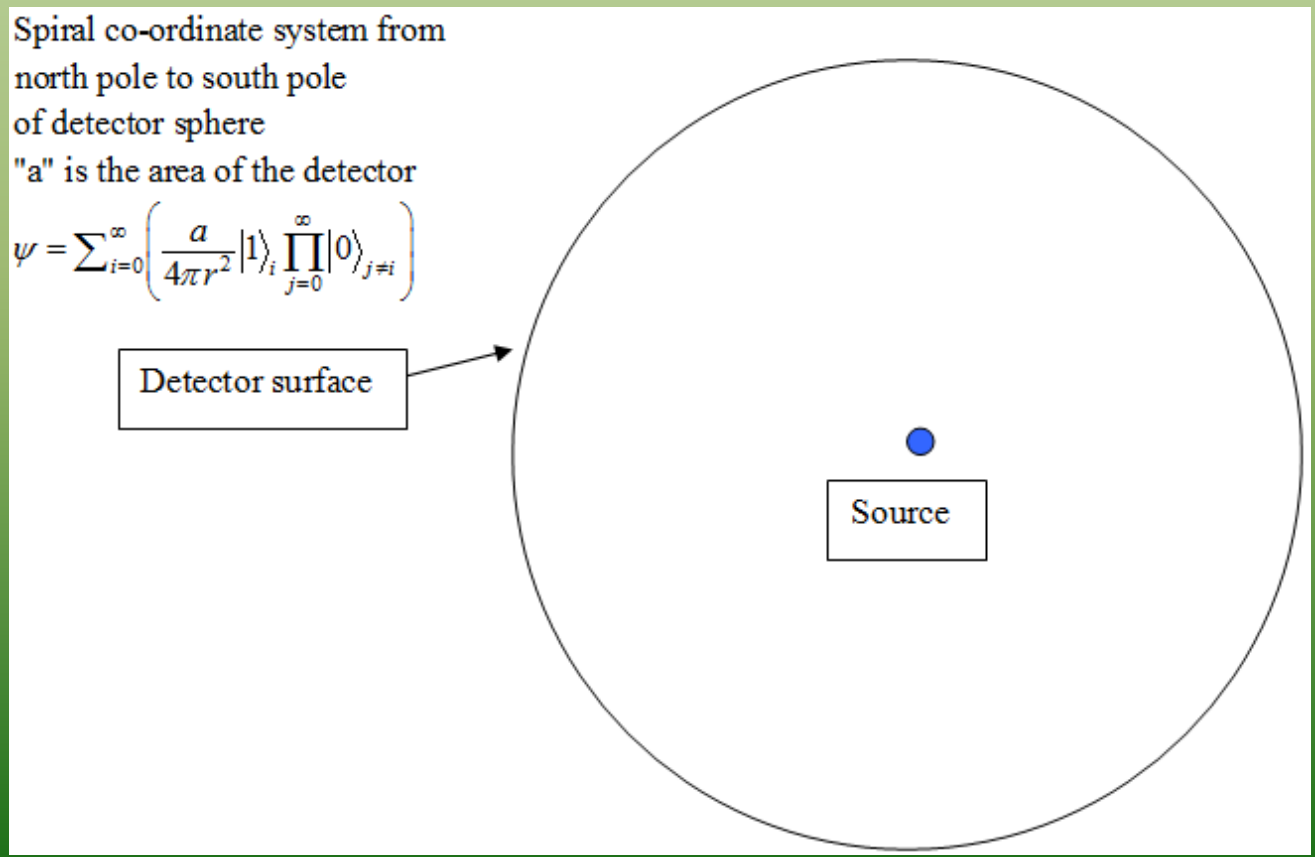
And uncertainty relations: $\Delta E \Delta t \geq h$ and $\Delta p \Delta x \geq h$

It is easy to take ratio of Δx to the wavelength and Δt to the period to obtain an invariant w.r.t. to frequency, i.e. all single particles have the same wavepacket shape (in this particular case below a Gaussian envelope for a non-squeezed state).



Retrocausality or a Realist view of the wavefunction?

Imagine a spherical source of single photons produced at regular intervals. The wavefunction travels through space and is path entangled; it travels towards a spherical source of detectors a long way away (say even light years),



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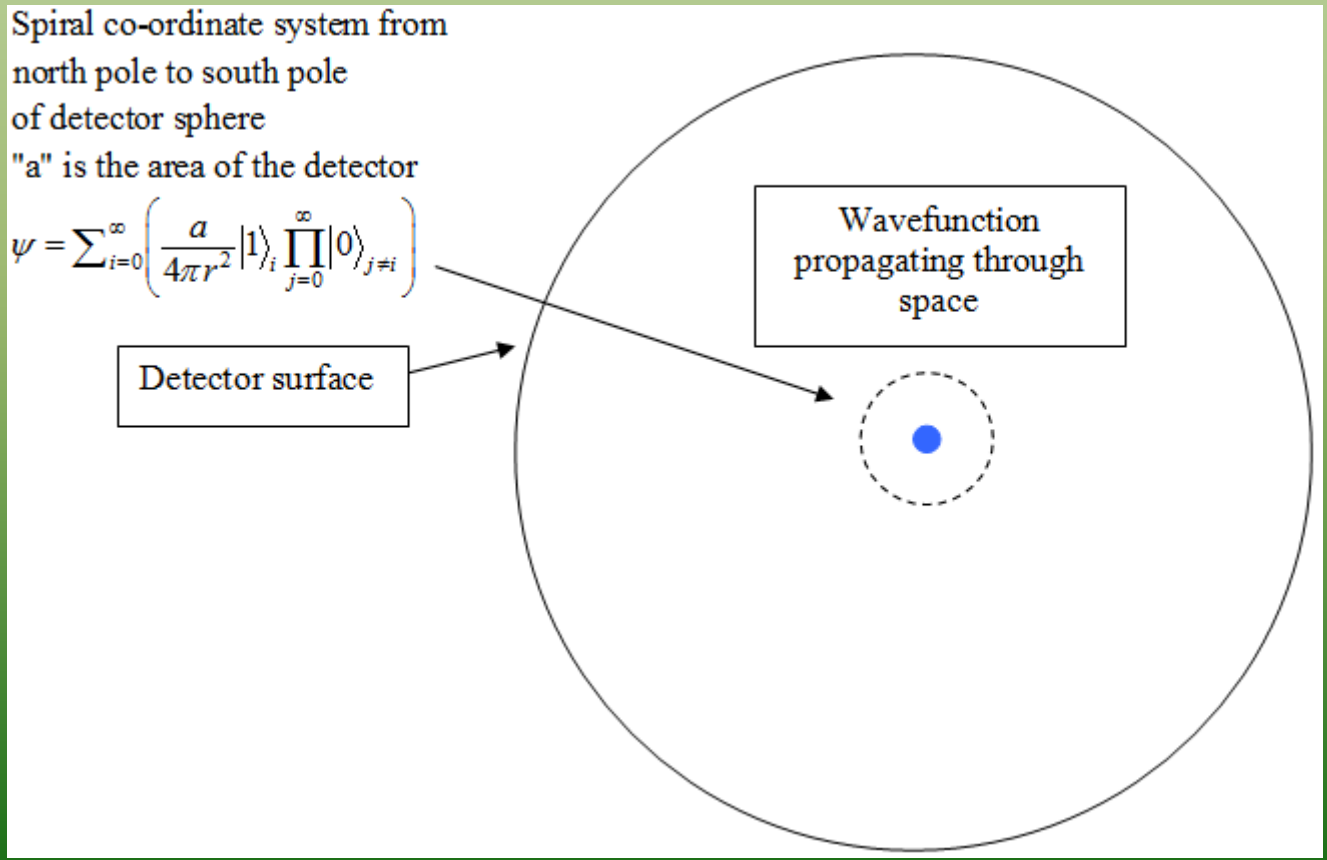

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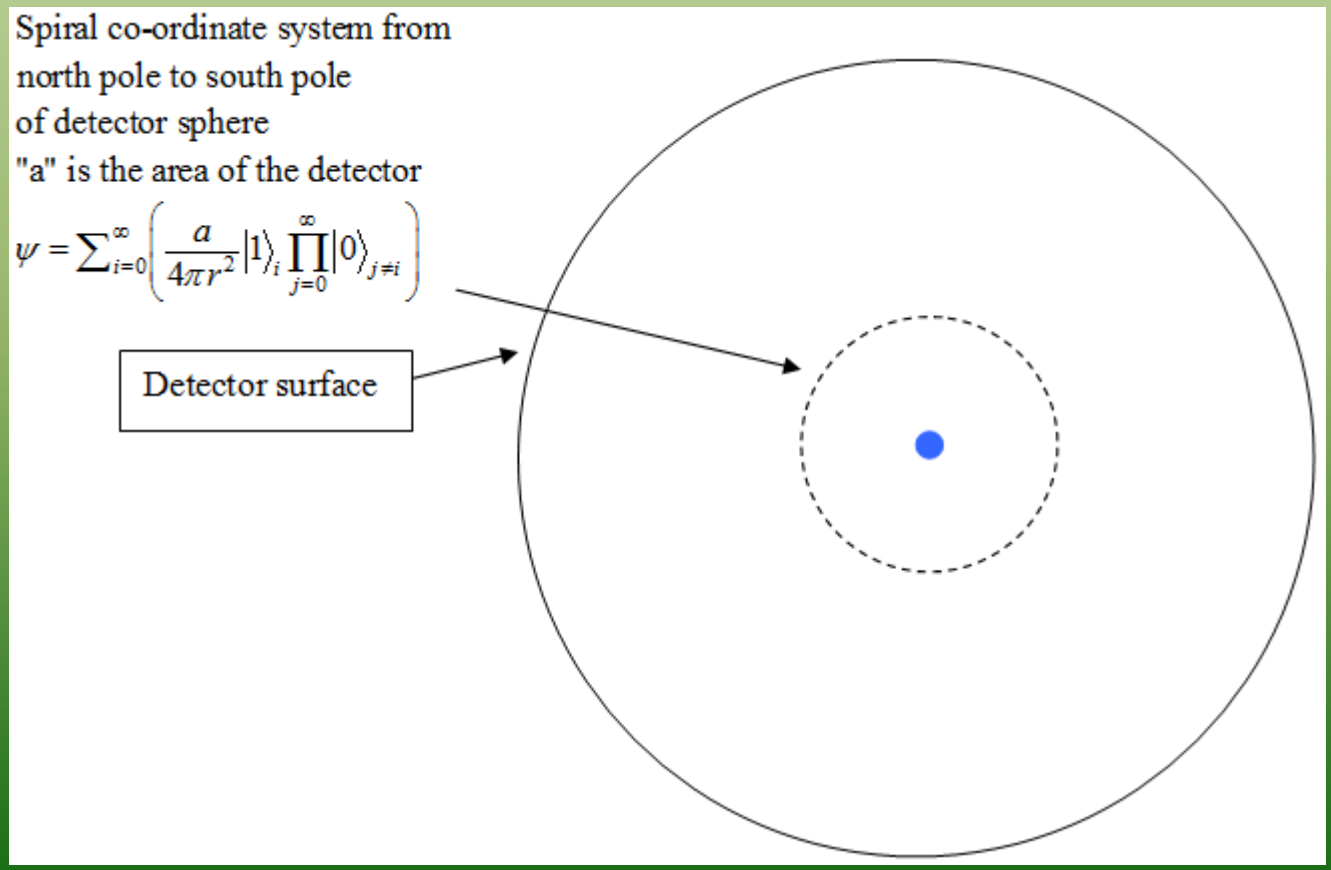

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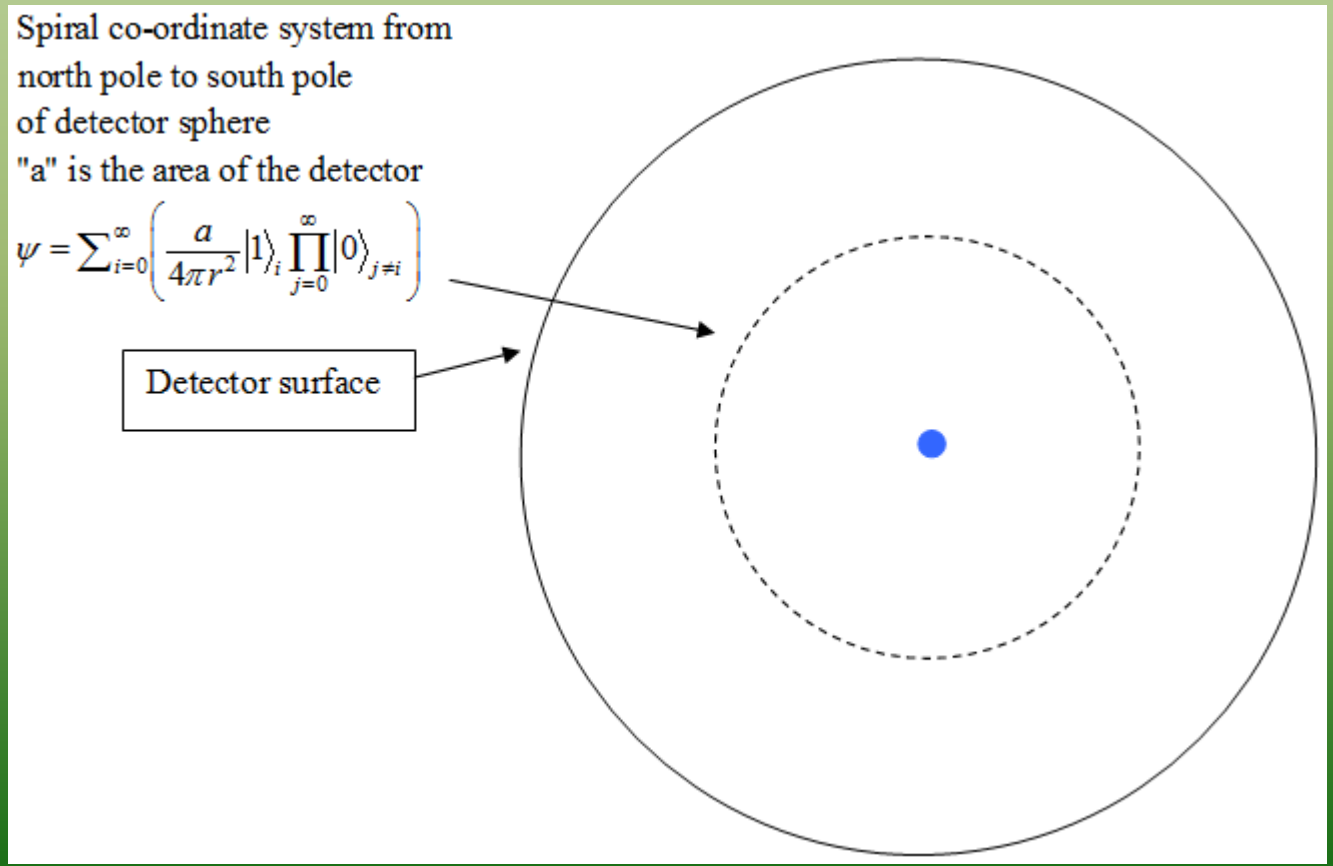

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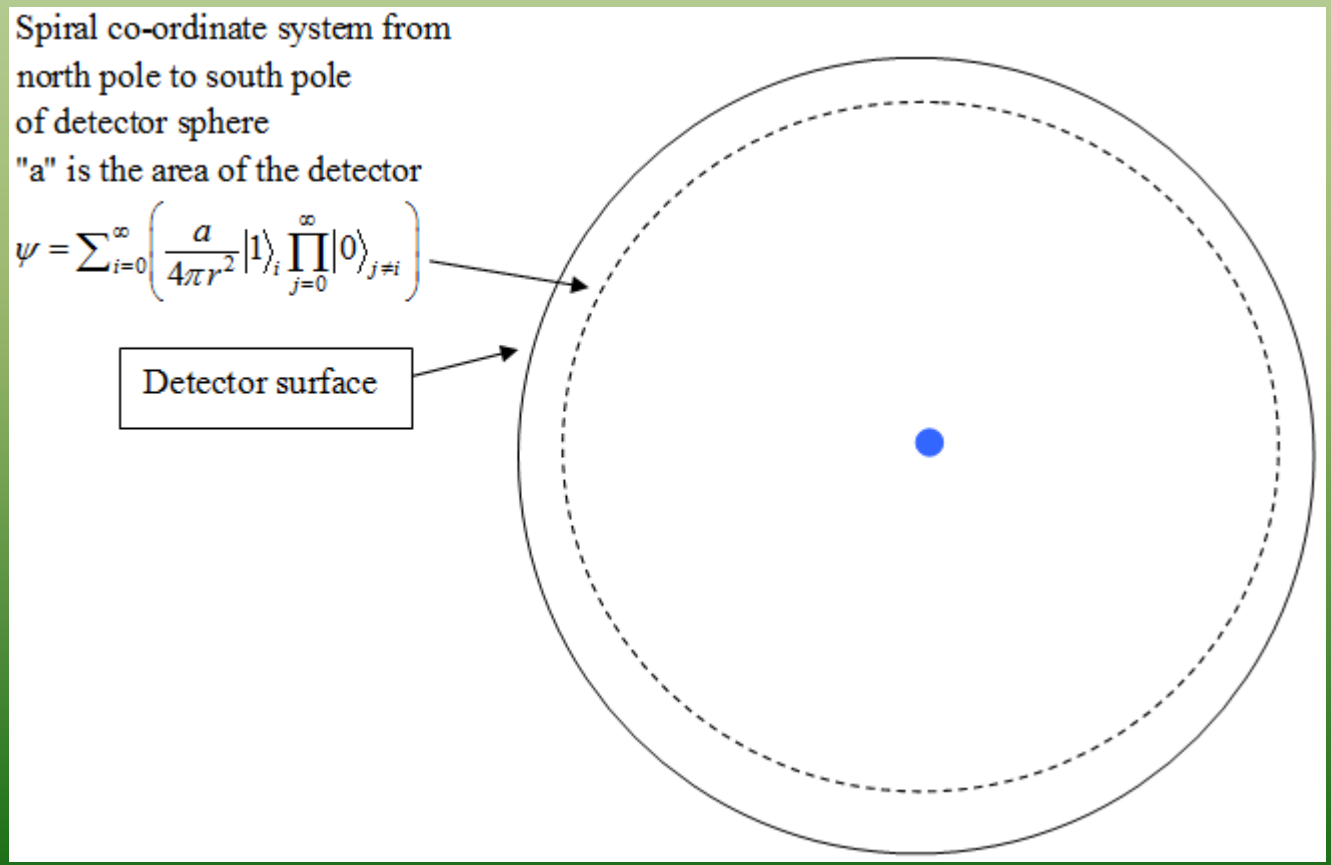

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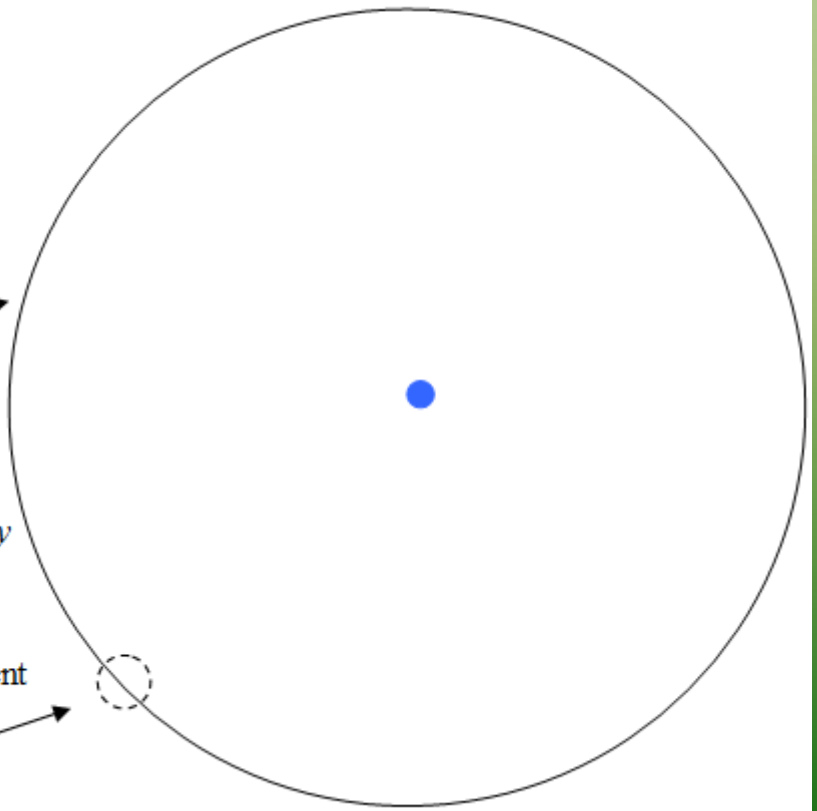
Spiral co-ordinate system from north pole to south pole of detector sphere
"a" is the area of the detector

$$\psi = \sum_{i=0}^{\infty}\left(\frac{a}{4\pi r^2}|1\rangle_i \prod_{j=0}^{\infty}|0\rangle_{j\neq i}\right)$$

Detector surface



Wavefunction "collapses" in other words, becomes localised *randomly* at one detector instantaneously (conservation of probability) and nowhere else. Path entanglement is lost.

$$\psi_i = \frac{a}{4\pi r^2}|1\rangle_i \prod_{j=0}^{\infty}|0\rangle_{j\neq i}$$

What really happened?

- Did the particle really travel through all of the space between the source and detector and not as a “ray”?
- Did the Universe “fork” into an infinite number of worlds where each ray scenario happened?
- Did the detector send a retrocausal signal back to the source so that the particle only went along a ray (or some kind of Bohm pilot wave)?

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  - No. We know the particle behaves as a wave (see start of animation) because it can interfere. An interferometer just limits the continuum of paths in this example here to a few paths and interferes them (more on this later).
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- Did the detector send a retrocausal signal back to the source so that the particle only went along a ray (or some kind of Bohm pilot wave)?
  - There's good grounds for thinking that retrocausality is just nuts (I've written on this point**) for the paradoxes it would create. Besides, what is the mechanism for all this machinery to do this trick (OK, they talk of two-state vector treatment) and how does it distinguish between measurement and non-measurement? The trick to physics is: rules - no intelligent beings and no magical thinking.

** https://ulondon.academia.edu/RemiCornwall "The Impossibility of Large-scale Retrocausal Signalling"

What really happened?

It's easier to accept the reality of the wavefunction and wavefunction collapse as a *real physical phenomenon* along with conventional quantum mechanics and Decoherence Theory.

The Entanglement Communications Apparatus

- It's on the website

http://webspace.qmul.ac.uk/rocornwall

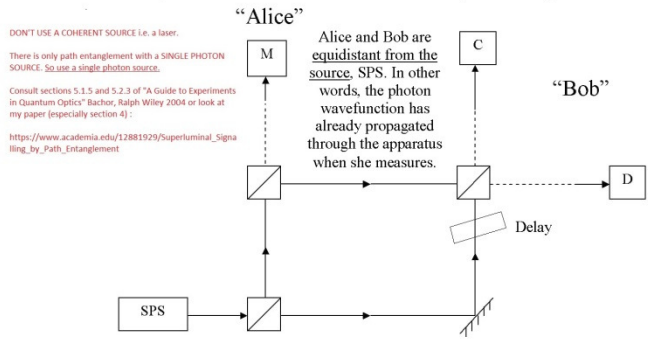
A single photon source (SPS) is incident on a Mach-Zehnder type interferometer with 50:50 beamsplitters. Alice's measurements discerned over space-like separations by Bob at his detectors C (constructive) or D (destructive). Many single photons (a spot from a beam-expander is used with an attenuator on a laser source) are used to represent one bit.

DON'T USE A COHERENT SOURCE i.e. a laser.

There is only path entanglement with a SINGLE PHOTON SOURCE. So use a single photon source.

Consult sections 5.1.5 and 5.2.3 of "A Guide to Experiments in Quantum Optics" Bachor, Ralph Wiley 2004 or look at my paper (especially section 4) :

https://www.academia.edu/12881929/Superluminal_Signalling_by_Path_Entanglement



This is the fundamental law of Quantum Mechanics:-

If the paths can be distinguished then add probabilities

else if the paths can't be, then add amplitudes before calculating probabilities

Thus when Alice measures, both of Bob's paths to his detectors become distinguishable.

Alice sends	Bob receives
Binary 0: No measurement	Binary 0: Min signal, destructive interference from pure state at D
Binary 1: Measurement	Binary 1: Max signal from mixed state at D

$$P(\textit{Bob few photons, binary } 0 \mid \textit{Alice no measurement}) = \left|\frac{i}{\sqrt{2}}\right|^2 + \left|\frac{e^{i\theta}}{\sqrt{4}}\right|^2 + 2\left|\frac{i}{\sqrt{2}}\right|\left|\frac{e^{i\theta}}{\sqrt{4}}\right|\cos\theta$$

$$= 0.5 + 0.25 + \frac{1}{\sqrt{2}}\cos\theta$$

$$\simeq 0.75 \pm 0.707\cos\theta$$

$$\simeq 0.043 \text{ minimum}$$

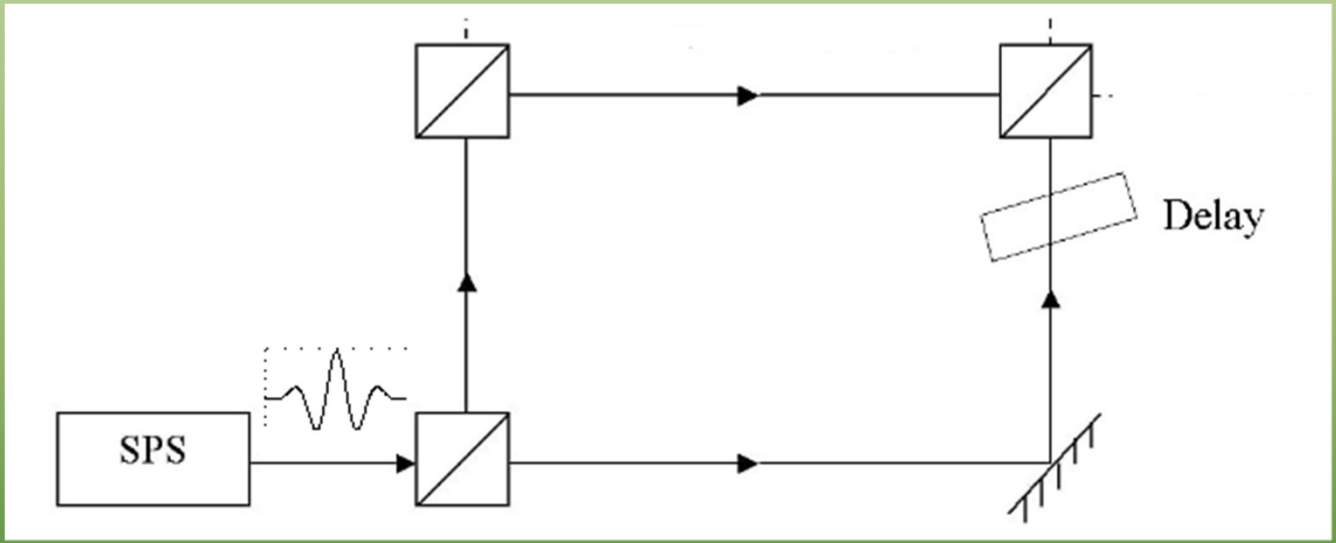
$$P(\textit{Bob lots of photons, binary } 1 \mid \textit{Alice measurement}) = \left|\frac{i}{\sqrt{2}}\right|^2 + \left|\frac{i}{\sqrt{4}}\right|^2$$

$$= 0.5 + 0.25$$

$$= 0.75$$

A single particle (wavepacket) through the interferometer,

No measurement case



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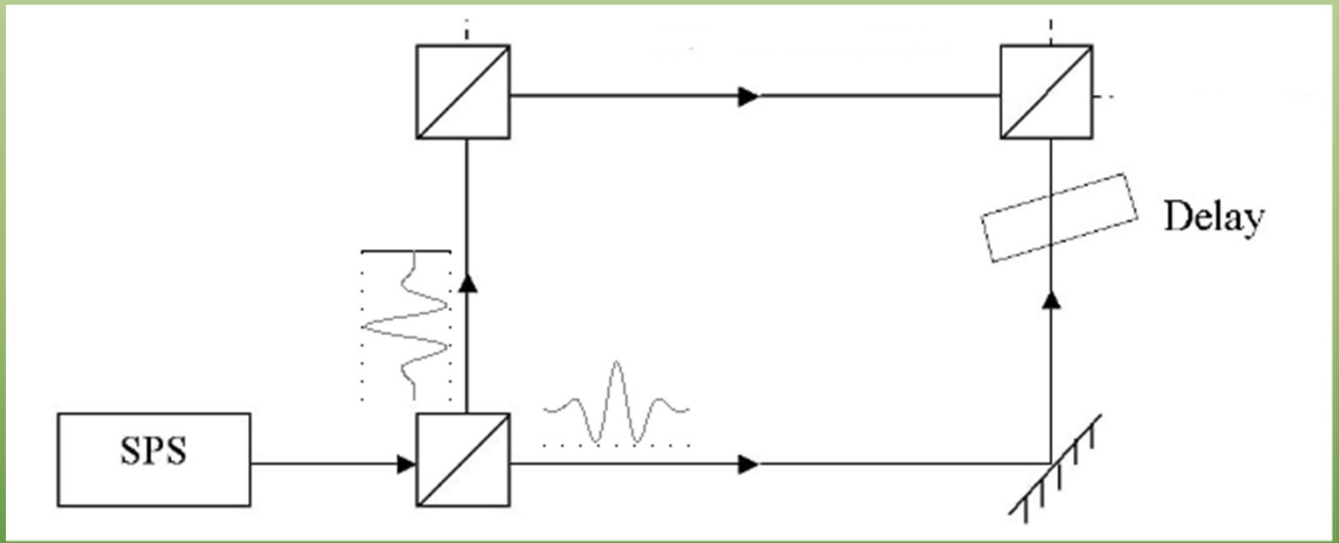

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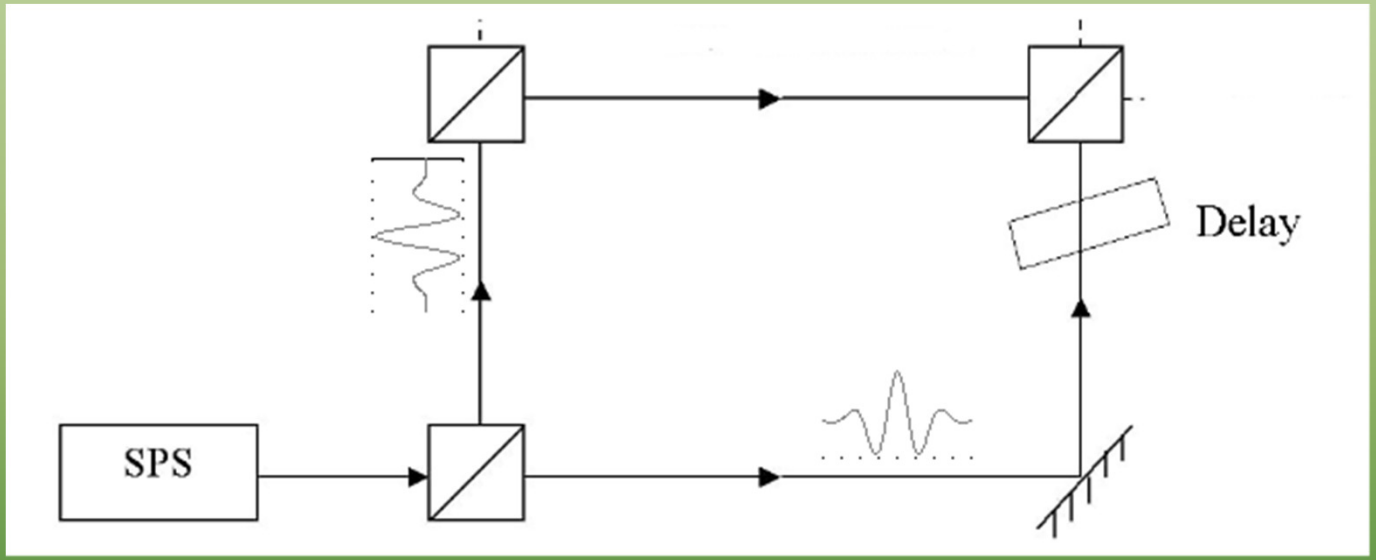

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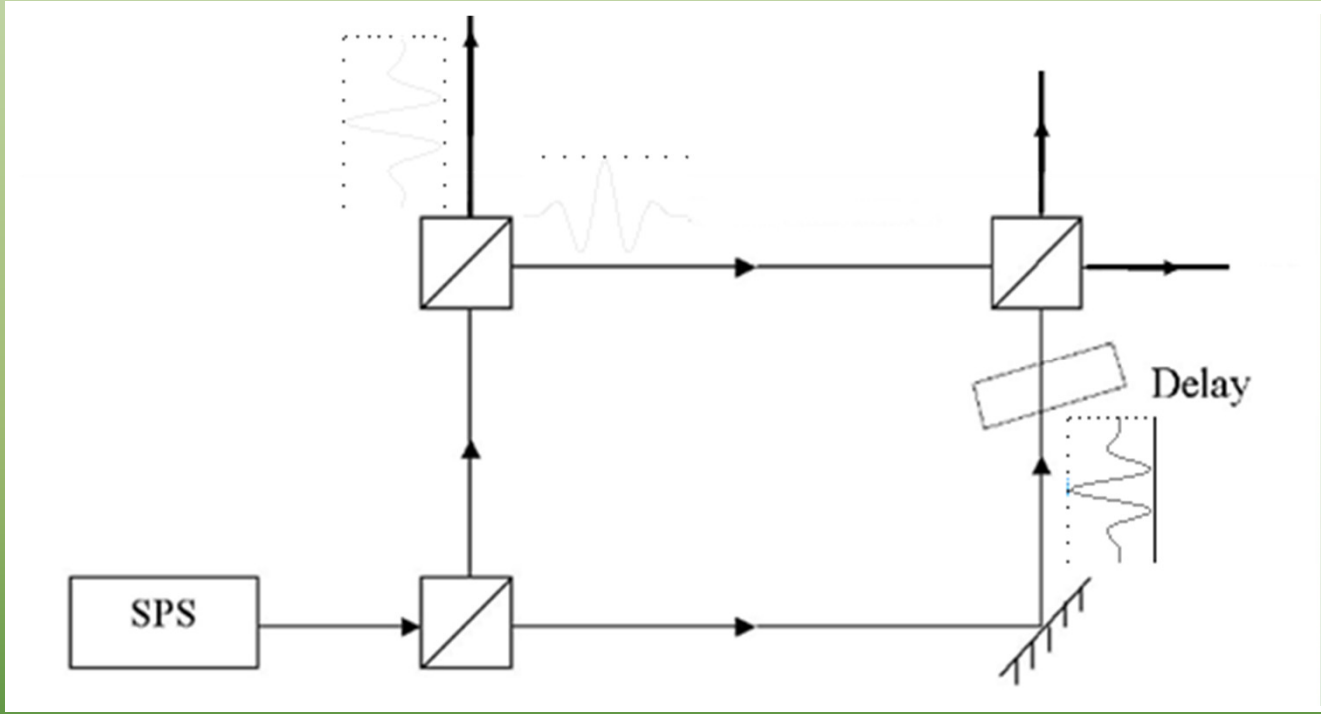

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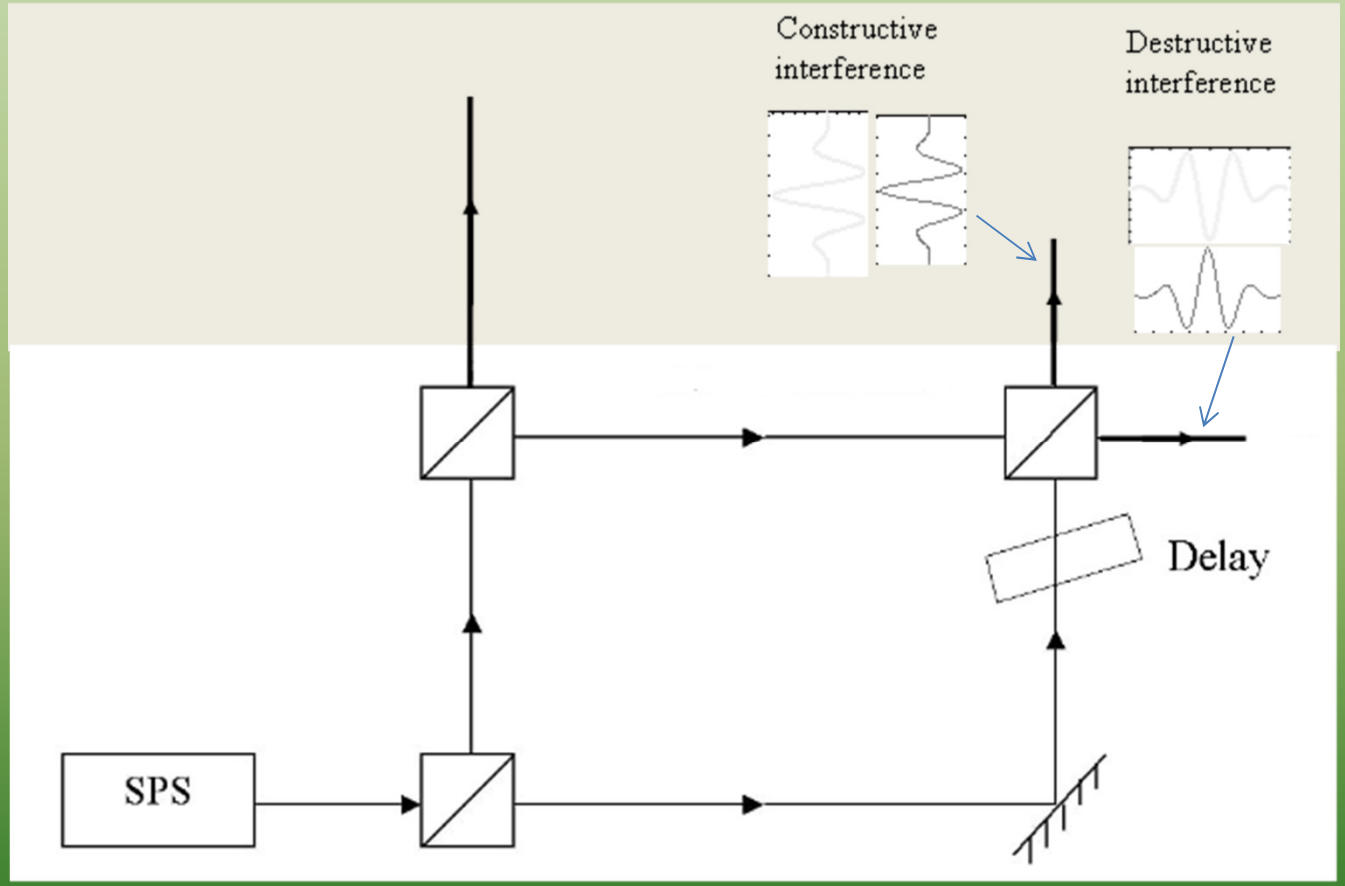

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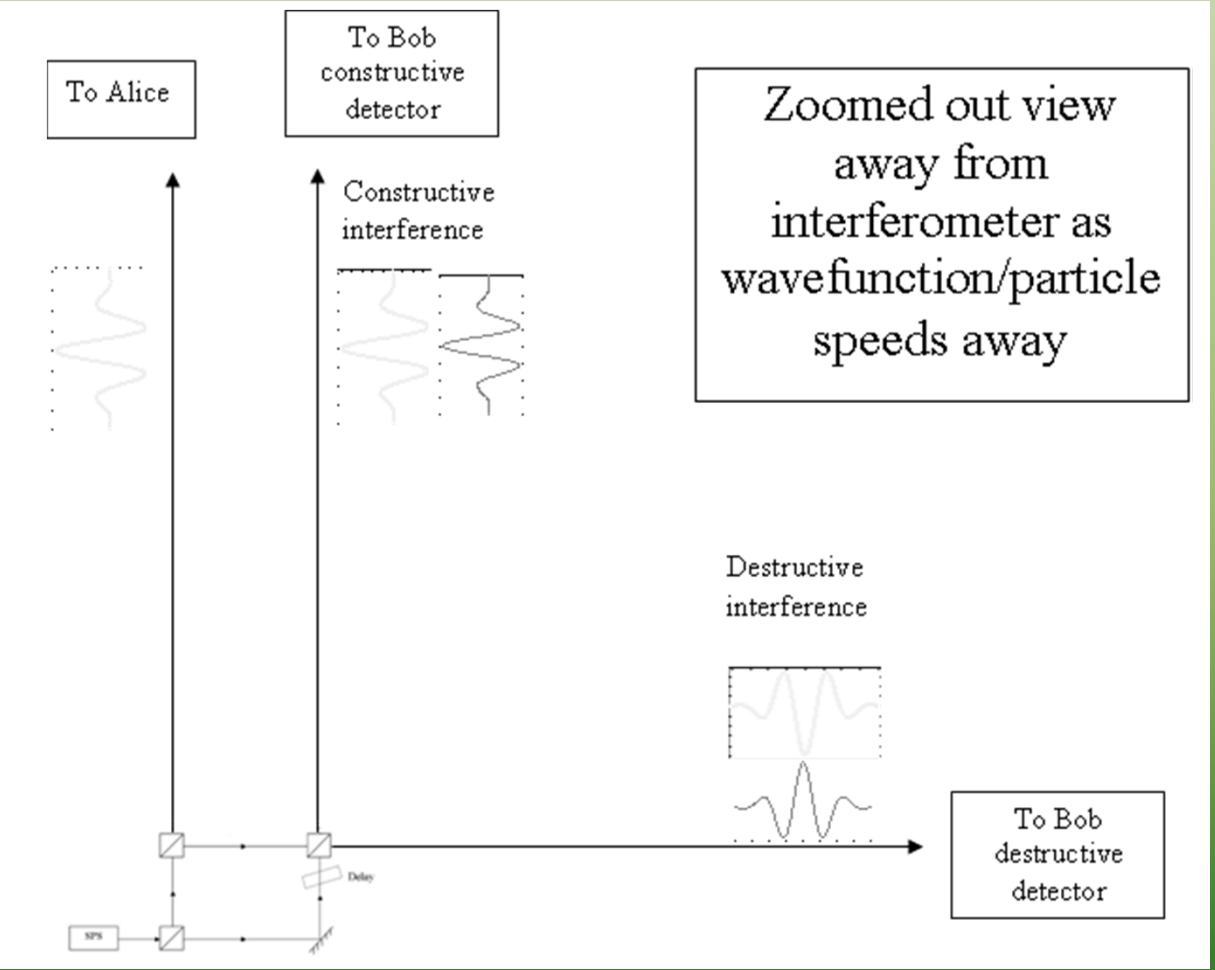
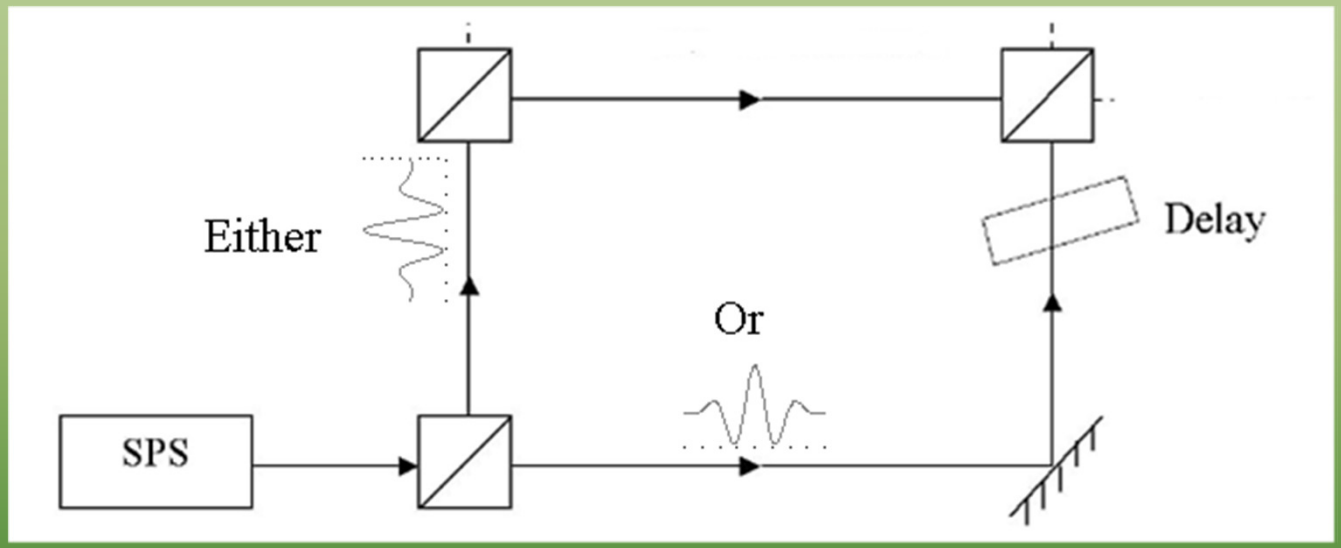


A single particle (wavepacket) through the interferometer,

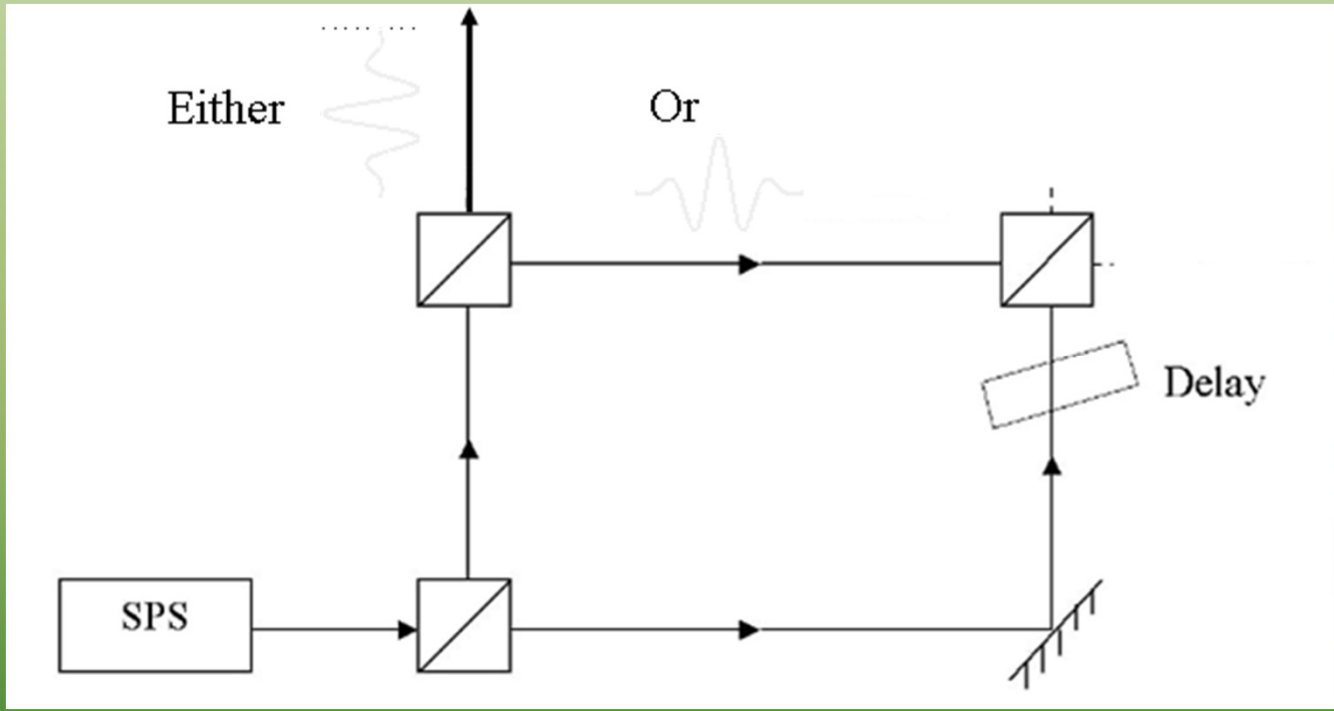
Measured (by Alice) case

Wavefunction goes along mutually exclusive paths



A single particle (wavepacket) through the interferometer,
Measured (by Alice) case
Wavefunction goes along mutually exclusive paths

Then…



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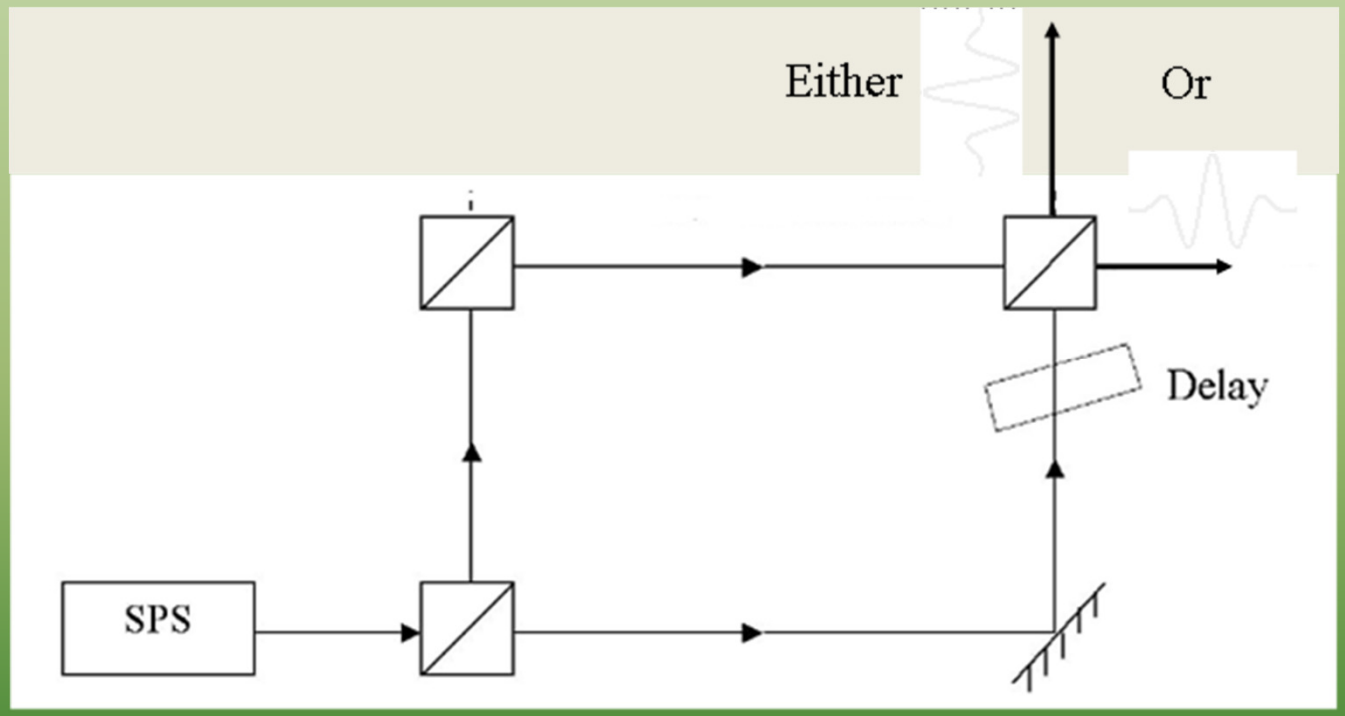

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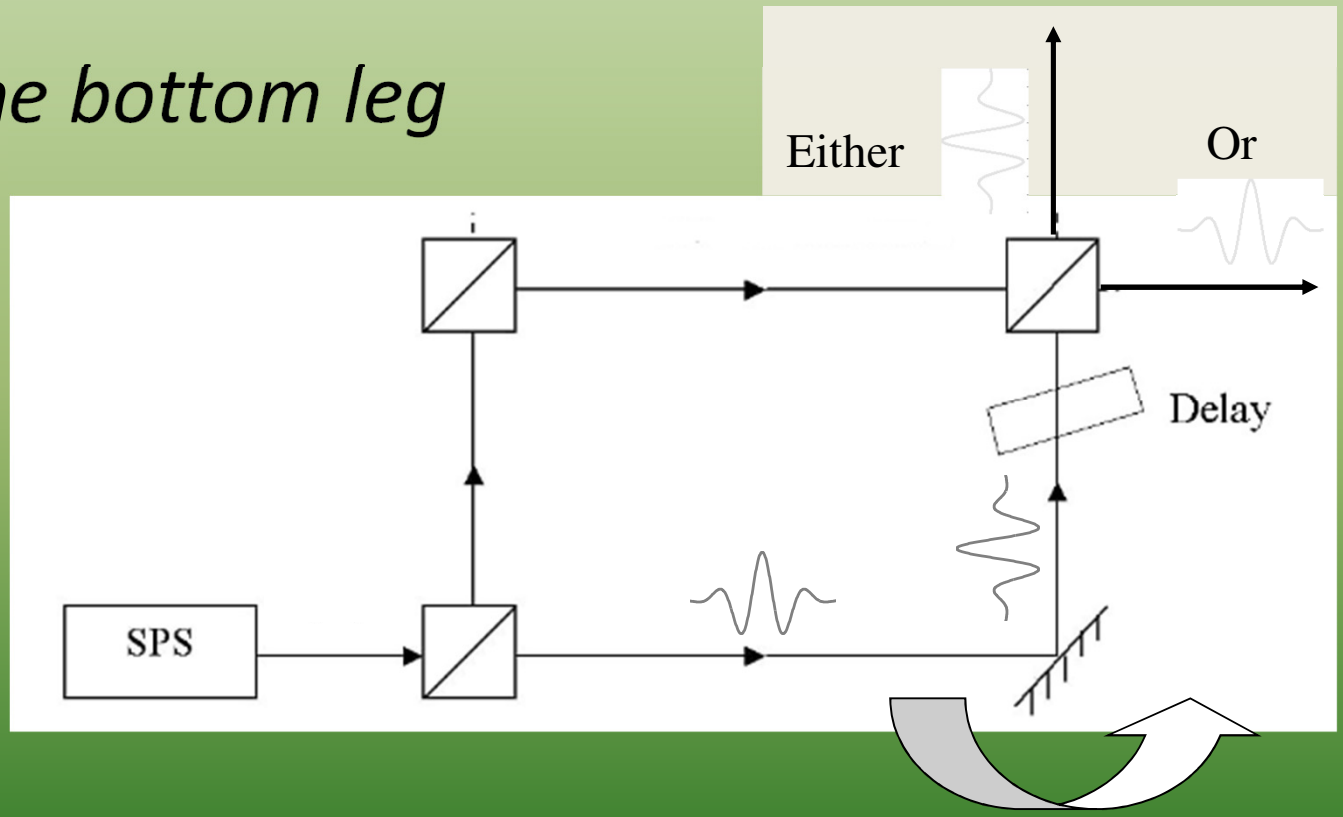
On the bottom leg



What really happened in this measured case (remember Alice can be a long, long way from the interference apparatus) ?

Scenario 1

All either/or events did happen, just not in the same universe!

This is *just one* little experiment. Just imagine one cubic centimetre of gas under standard conditions with some 3 x 10^{19} molecules scattering per second… This forking off of universes is getting silly. One couldn't even detect these other universes so the scenario is metaphysical – "non-science".

- Hypothesis non-fingo! Occam's Razor!

What really happened in this measured case (remember Alice can be a long, long way from the interference apparatus) ?

Scenario 2

Some kind of *intelligent influence* (give it a fancy smancy name, call it "retrocausal back-propagation") ***reached back in time*** to the source (SPS) and told it to produce *wavepackets that can't split* and also told the beamsplitters to join in with the *conspiracy* – and furthermore, to let the wavepacket go through port 3 or 4 of the beamsplitter correctly, so that the statistics turn out just right.

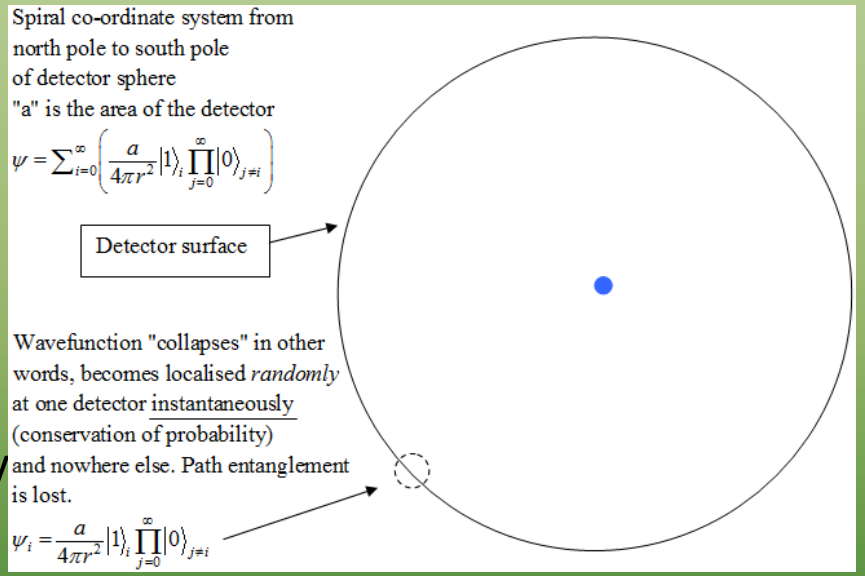
- Hypothesis non-fingo! Occam's Razor! (Magical thinking, B.S. in other words.)

What really happened in this measured case (remember Alice can be a long, long way from the interference apparatus) ?

Scenario 3

The interference apparatus for the communication device is surprisingly similar to the opening argument.

Whereas the communication device has discreet entangled paths, with Bob's paths superimposed, precisely the same argument applies as to the reality of wavefunction collapse at the "surface" of the wavefunction, with regard to the conservation of probability



- It is by far the easiest way to explain things.