Testing Superdeterministic Conspiracy

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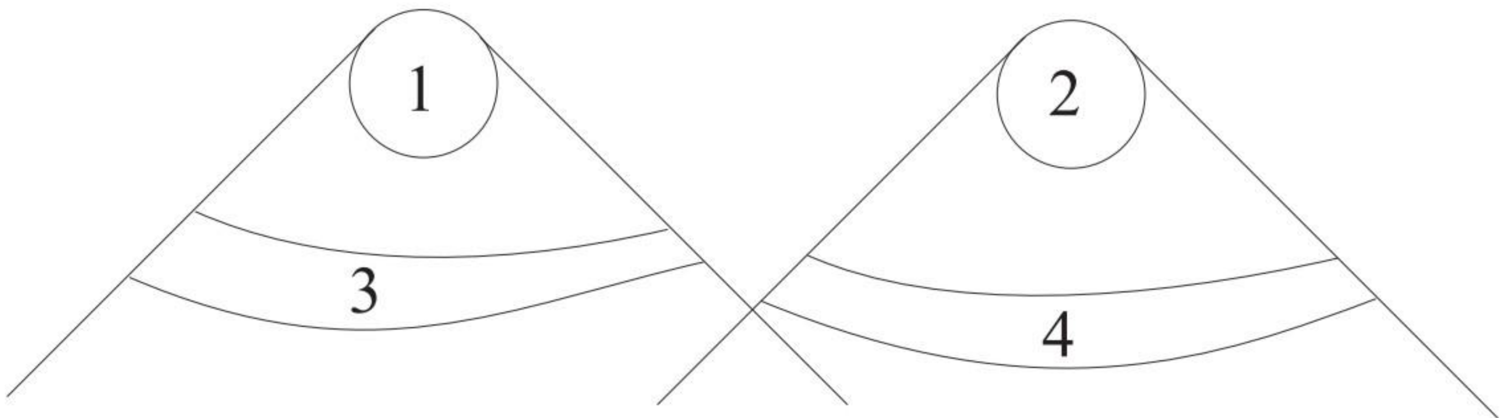
What is Superdeterminism?

- No free will: Not possible to chose detector settings independent of prepared state.
- "Conspiracy" theories: misleading expression.
- Really: Nonlocal correlations necessary, but
- Not necessarily spooky at a distance.
- Hidden variables, yes, but not necessarily realist.

Nonlocality



"A theory will be said to be locally causal if the probabilities attached to values of local beables in a space-time region 1 are unaltered by specification of values of local beables in a space-like separated region 2, when what happens in the backward light cone of 1 is already sufficiently specified, for example by a full specification of local beables in a space-time region 3…"

~ J. S. Bell

Why Superdeterminism?

- Because I like it.
- Because it’s possible and hasn’t been ruled out since Bell’s theorem can’t be used.
- Logically: Can never be ruled out, but certain models can be ruled out.
- Try to be as model-independent as possible.

What kind of Superdeterminism?

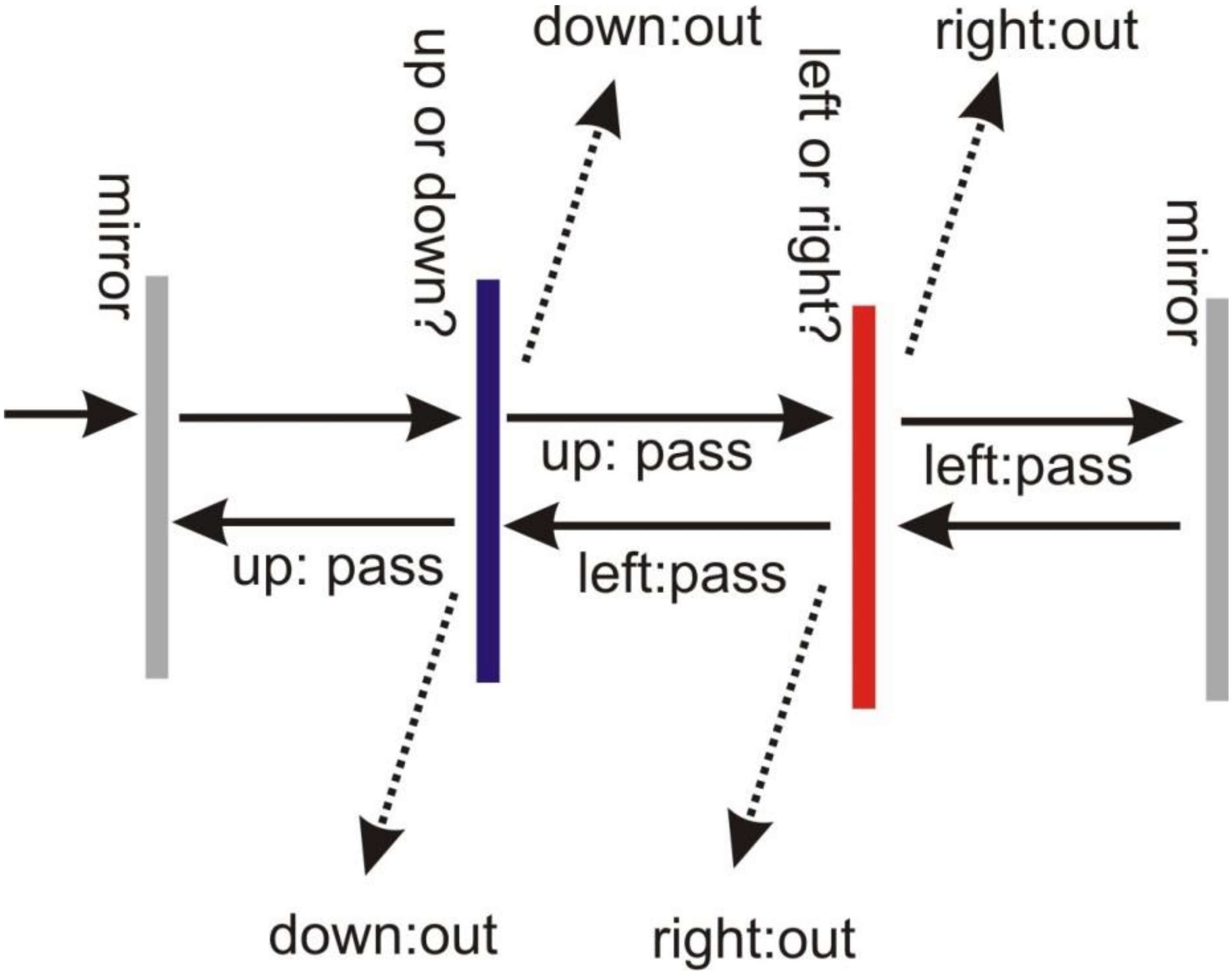
- Assume: Hidden variables come from environment.
- Assume: dofs beyond experiment’s scale decouple.
- Assume: Born rule fulfilled.
- No assumptions about collapse or likewise.

How to test Superdeterminism?

- Main difference to standard QM: The same initial state will lead to the same outcome. No indeterminism.
- But “the same state” now means “the same hidden variables”. So we don’t know how to prepare the “same” state twice.
- Avoid problem by repeating measurements on one state. Use non-commuting variables.

Testing Superdeterminism

- Repeatedly measure non-commuting variables on one state.
- Time needs to be so short that environmental hidden variables don’t change.
- If they do: indeterminism comes back



Measure: time elapsed before particle is out

Experimental Requirements

- Noise free: Cool, small, well isolated.
- Quick: Rapid succession of measurements.
- Measure: Correlation time between subsequent measurement outcomes or the lack of correlation respectively.

$$\mathrm{Corr}_\kappa = \frac{E(\phi, O, t = 0 \wedge \phi, O, t = \kappa)}{E(\phi, O^2)}$$

- Ansatz: $\mathrm{Corr}_\kappa = \exp\left(-\kappa/\tau\right)$

Estimate

- Photodetector with N atoms and energy gap ΔE at temperature T

$$\tau \approx \frac{\exp(\Delta E/T)}{N} \tau_{\mathrm{r}}$$

- $\tau_{\mathrm{r}} \approx 1\mathrm{ns}$, electron-hole recombination time
- For $N \approx 10^{15}$, $T \approx 300$ K and $\Delta E \approx$ eV one has $\tau \approx 10^{-6}$ sec → not hopeless!

Historical Footnote

"Von Neumann often discussed the measurement of the spin component of a spin-1/2 particle in various directions. Clearly, the possibilities for the two possible outcomes of a single such measurement can be easily accounted for by hidden variables [...] However, **Von Neumann felt that this is not the case for many consecutive measurements of the spin component in various different directions**. The outcome of the first such measurement restricts the range of values which the hidden parameters must have had before that first measurement was undertaken. The restriction will be present also after the measurement so that the probability distribution of the hidden variables characterizing the spin will be different for particles for which the measurement gave a positive result from that of the particles for which the measurement gave a negative result." [emphasis added]

~ E. P. Wigner, Footnote in Am. J. Phys. 38, 1005 (1970)

Takeaway

- Superdeterministic hidden variables theories cannot be tested using Bell's theorem
- To test these theories: Use repeated measurements on non-commuting observables
- If hidden variables exist: Measurement outcomes should be correlated
- Correlation time short in noisy systems, need small and cool system and accurate time measurement.