

The 2022 Physics Nobel Prize



Alexander Rothkopf
(University of Stavanger)
[@rothkopfAK](https://twitter.com/rothkopfAK)

Awarded

to
**Alain Aspect,
John F. Clauser
Anton Zeilinger**



Awarded

to
Alain Aspect,
John F. Clauser
Anton Zeilinger

"for experiments with
entangled photons,
establishing the violation
of Bell inequalities and
pioneering quantum
information science"



Awarded

to

Alain Aspect,
John F. Clauser
Anton Zeilinger

"for experiments with
entangled photons,
establishing the violation
of **Bell inequalities** and
pioneering quantum
information science"

A tale of two types of randomness:

**Randomness
of ignorance**

**Quantum
Randomness**

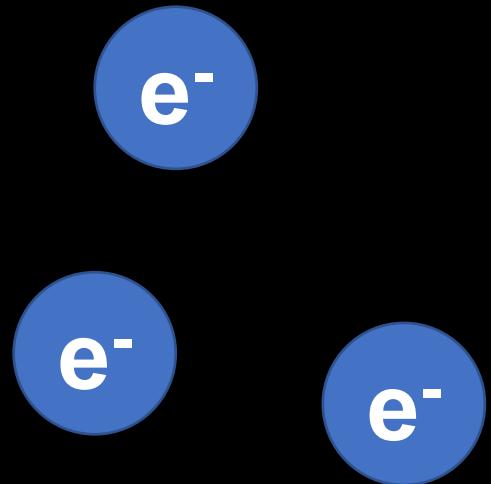
Randomness of ignorance

Flipping a coin:

Hard to predict – appears random

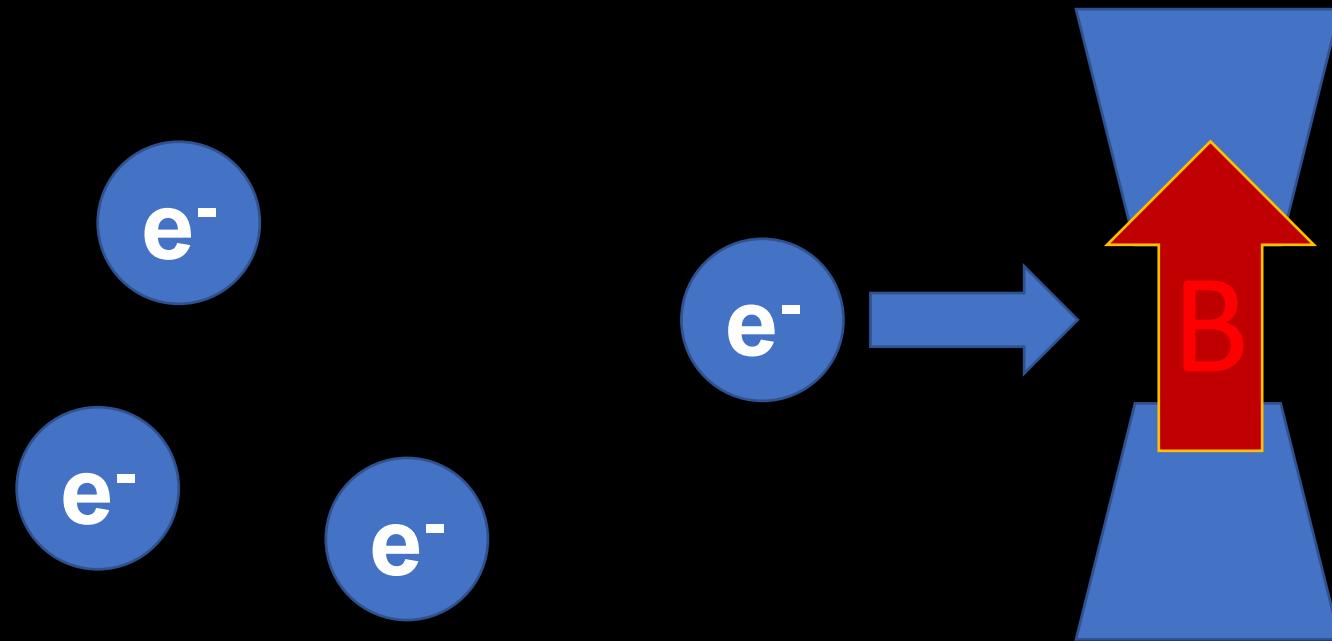


Quantum Randomness



Elementary particles
are small magnets

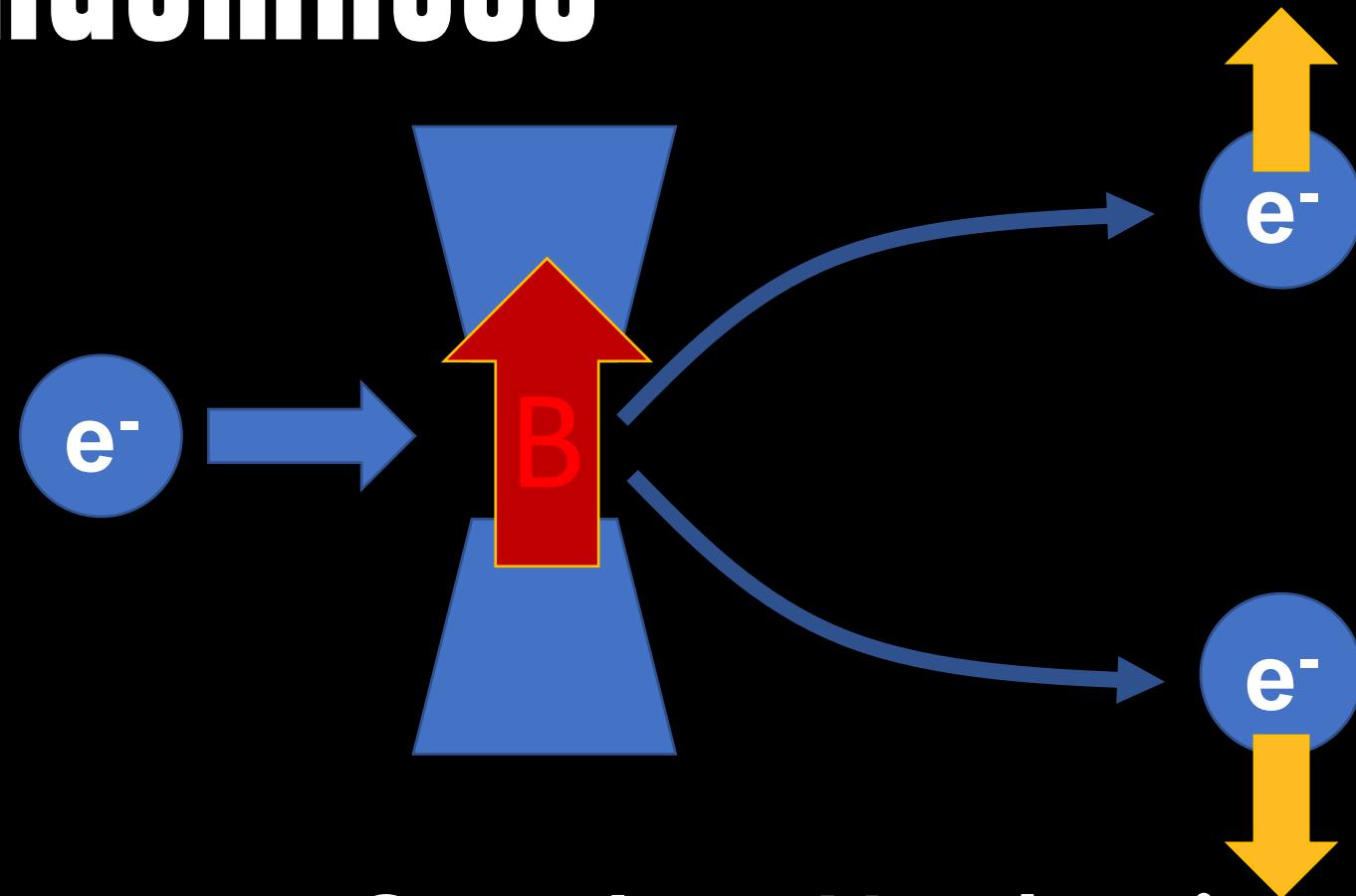
Quantum Randomness



Elementary particles
are small magnets

Quantum Randomness

e^-
 e^-
 e^-

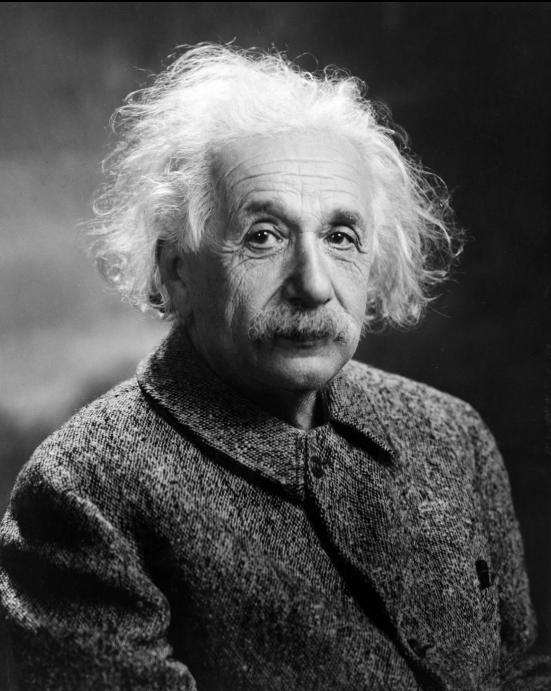


Elementary particles
are small magnets

Quantum Mechanics: Ran-
dom in or opposite to B 😐

What is Quantum Randomness

A. Einstein, B. Podolsky and N. Rosen,
Phys. Rev. 47, 777 (1935)



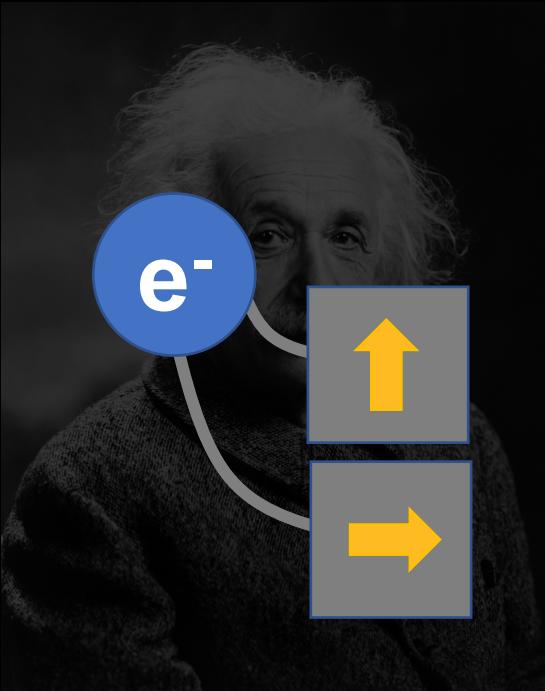
Albert Einstein



Niels Bohr

What is Quantum Randomness

A. Einstein, B. Podolsky and N. Rosen,
Phys. Rev. 47, 777 (1935)



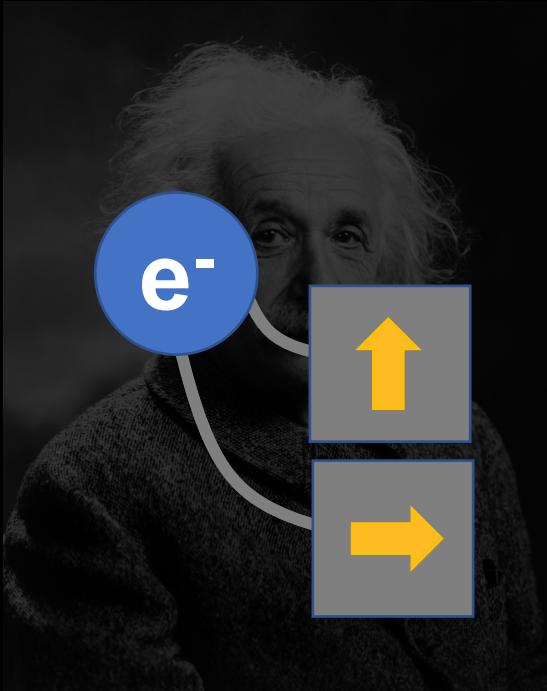
**Quantum Mechanics ignorant
of the true state of a particle
(Local hidden variable)**



Niels Bohr

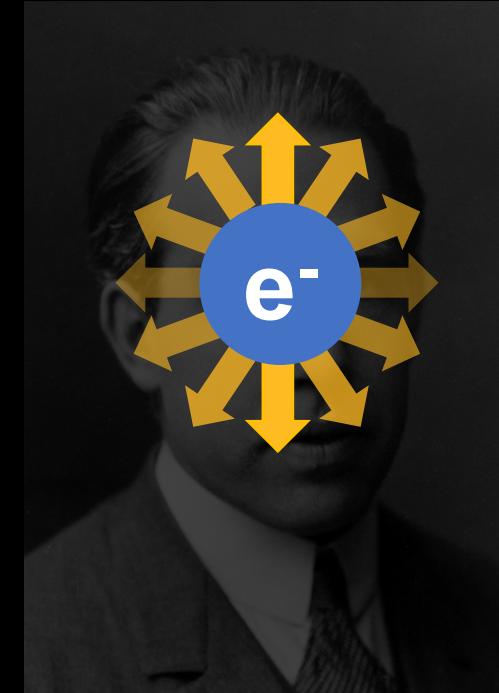
What is Quantum Randomness

A. Einstein, B. Podolsky and N. Rosen,
Phys. Rev. 47, 777 (1935)



Quantum Mechanics ignorant
of the true state of a particle
(Local hidden variable)

Particles do not have a defined
property until measured
(Quantum Indeterminism)

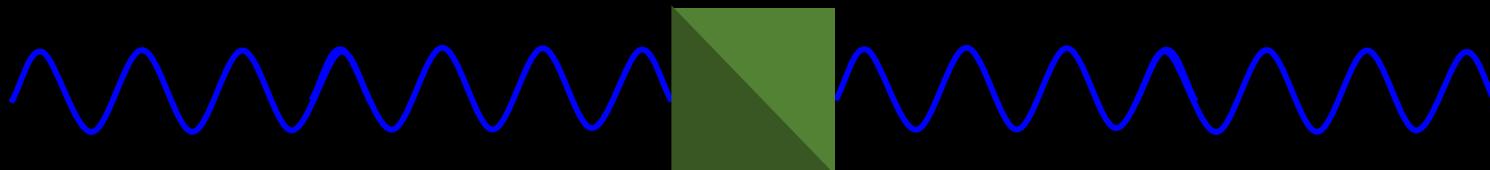


Deciding Philosophy with Physics

John Bell: a clever thought experiment

J.S. Bell, *Physics* 1, 195 (1964)

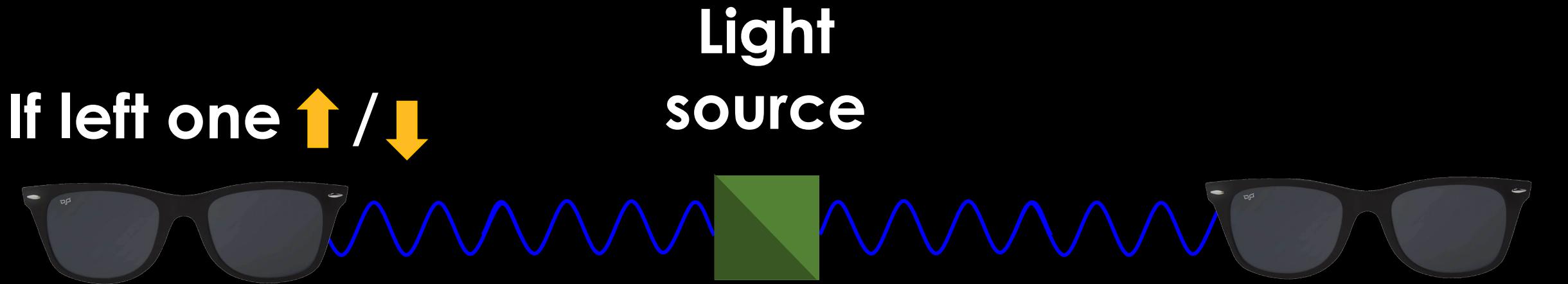
Light
source



Deciding Philosophy with Physics

John Bell: a clever thought experiment

J.S. Bell, *Physics* 1, 195 (1964)

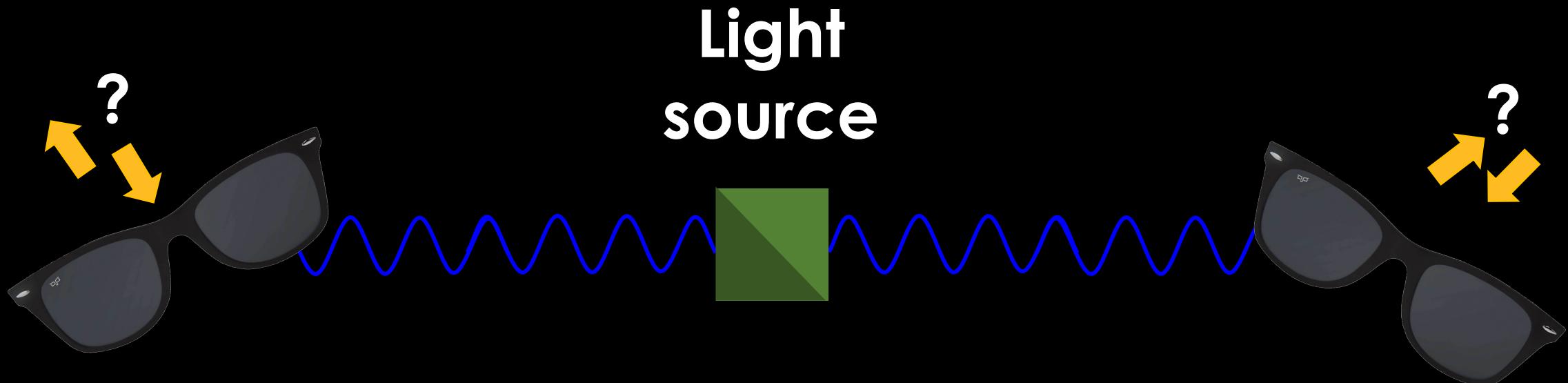


“entangled” photons:
share information so that
opposite random outcomes

Deciding Philosophy with Physics

John Bell: a clever thought experiment

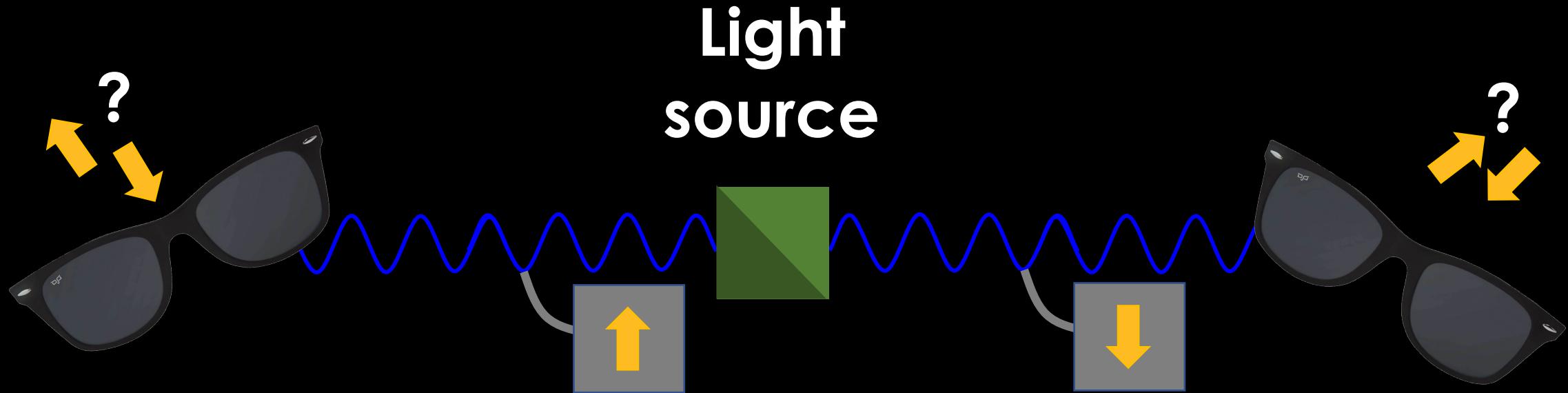
J.S. Bell, *Physics* 1, 195 (1964)



Deciding Philosophy with Physics

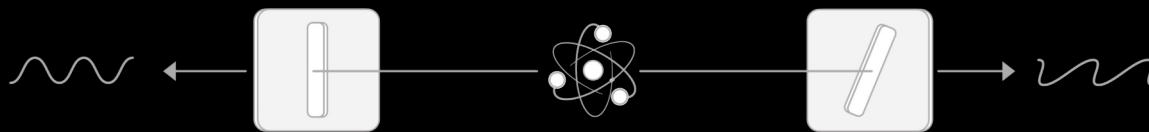
John Bell: a clever thought experiment

J.S. Bell, *Physics* 1, 195 (1964)

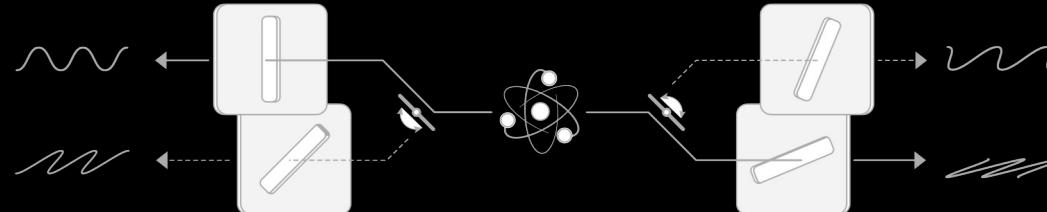


Bell inequality: experiment result if Einstein is right

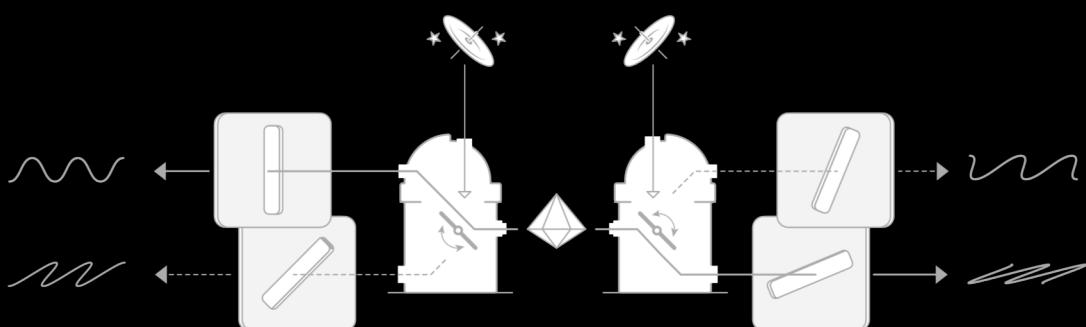
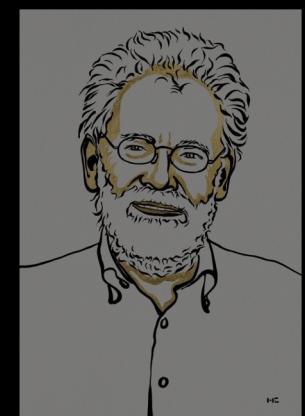
From thought to actual experiment



S.J. Freedman and J.F. Clauser, *Phys. Rev. Lett.* 28, 938 (1972)

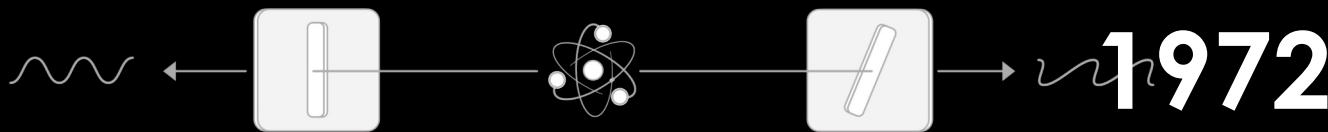


A. Aspect, P. Grangier and G. Roger, *Phys. Rev. Lett.* 49, 91 (1982)

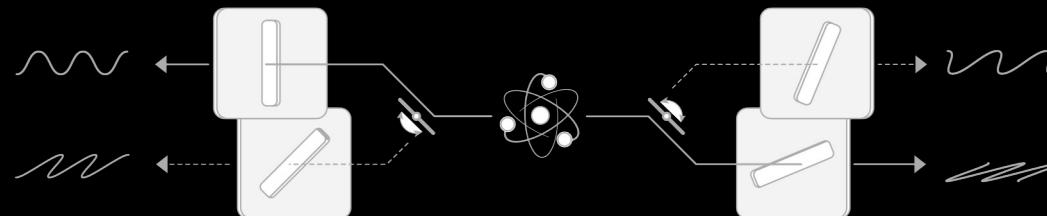


G. Weihs, T. Jennewein, C. Simon, H. Weinfurter & A. Zeilinger, *Phys. Rev. Lett.* 81 (23), 5039 (1998)

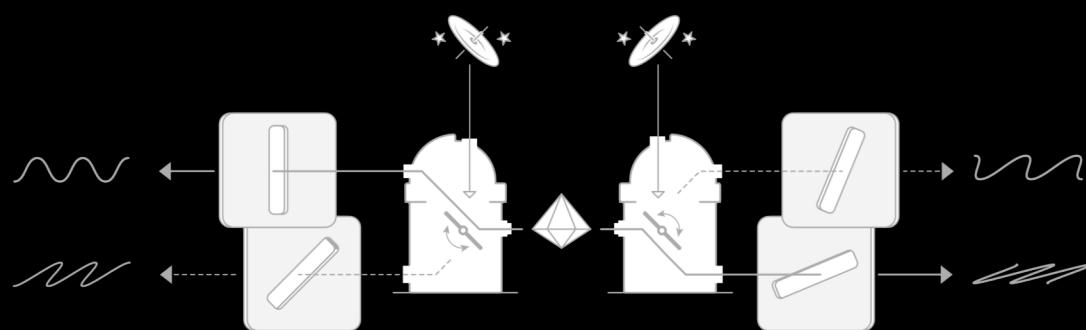
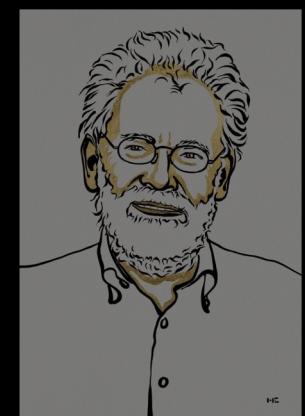
From thought to actual experiment



S.J. Freedman and J.F. Clauser, *Phys. Rev. Lett.* 28, 938 (1972)

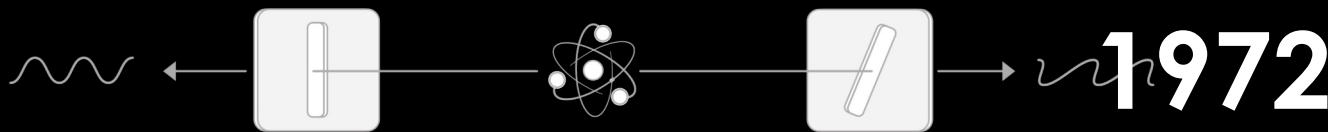


A. Aspect, P. Grangier and G. Roger, *Phys. Rev. Lett.* 49, 91 (1982)

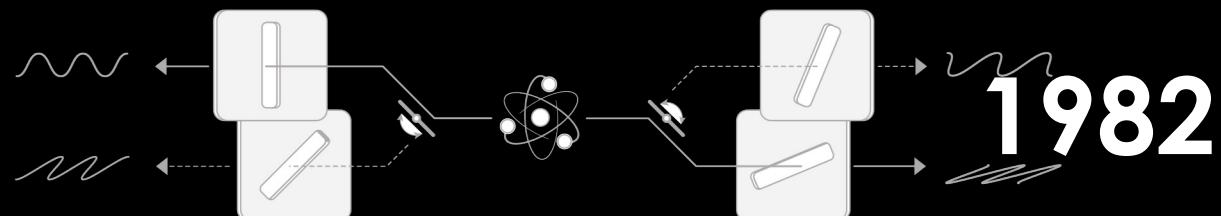


G. Weihs, T. Jennewein, C. Simon, H. Weinfurter & A. Zeilinger, *Phys. Rev. Lett.* 81 (23), 5039 (1998)

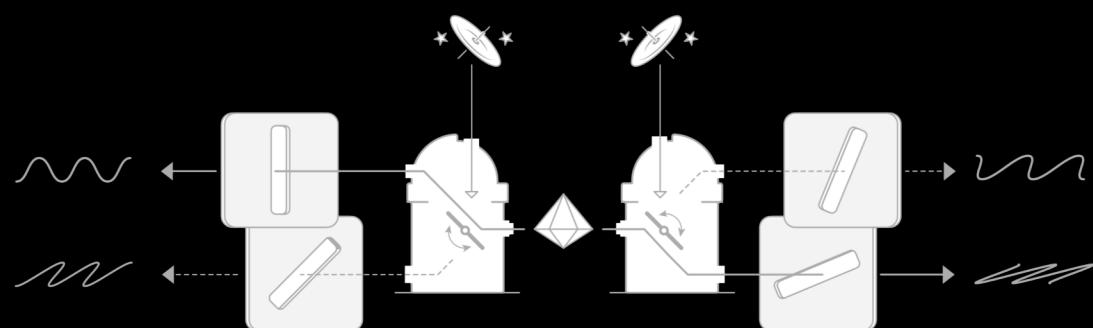
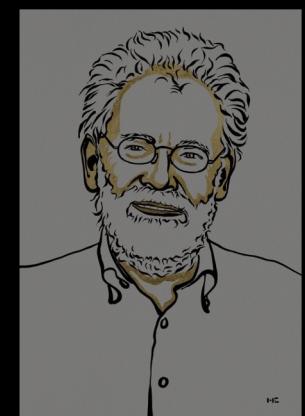
From thought to actual experiment



S.J. Freedman and J.F. Clauser, *Phys. Rev. Lett.* 28, 938 (1972)

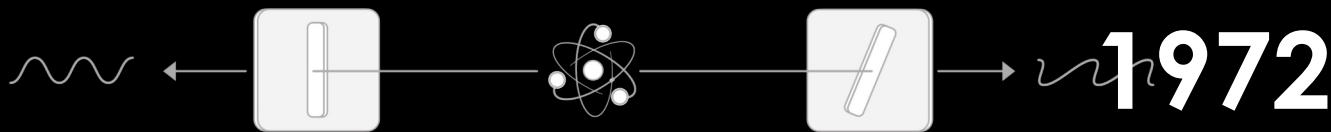


A. Aspect, P. Grangier and G. Roger, *Phys. Rev. Lett.* 49, 91 (1982)

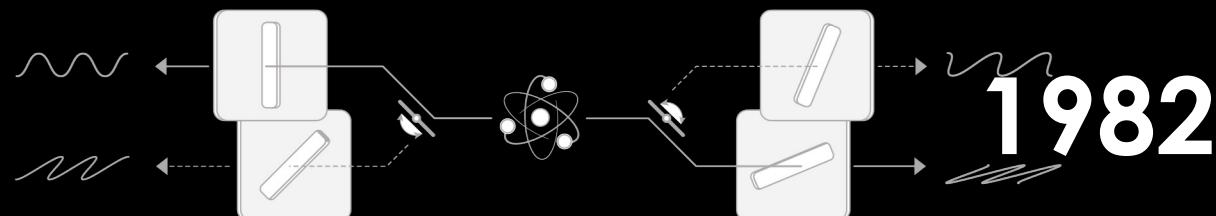


G. Weihs, T. Jennewein, C. Simon, H. Weinfurter & A. Zeilinger, *Phys. Rev. Lett.* 81 (23), 5039 (1998)

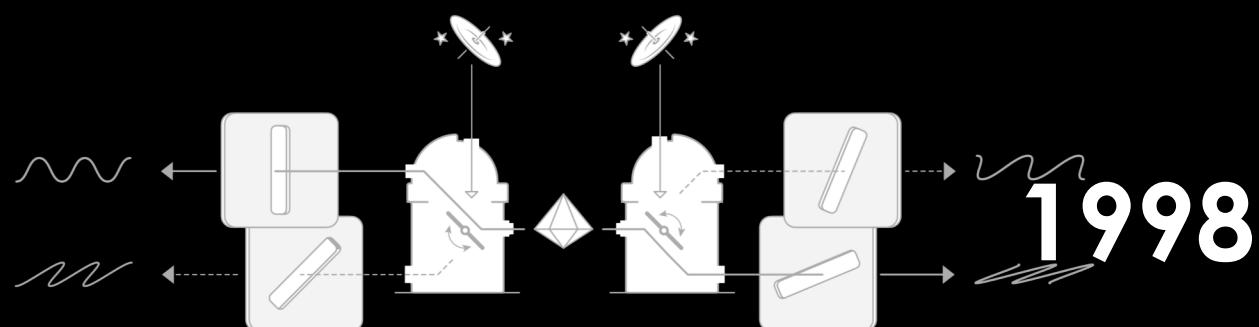
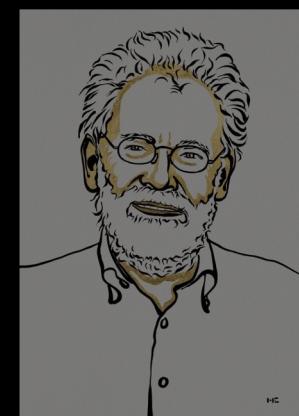
From thought to actual experiment



S.J. Freedman and J.F. Clauser, *Phys. Rev. Lett.* 28, 938 (1972)

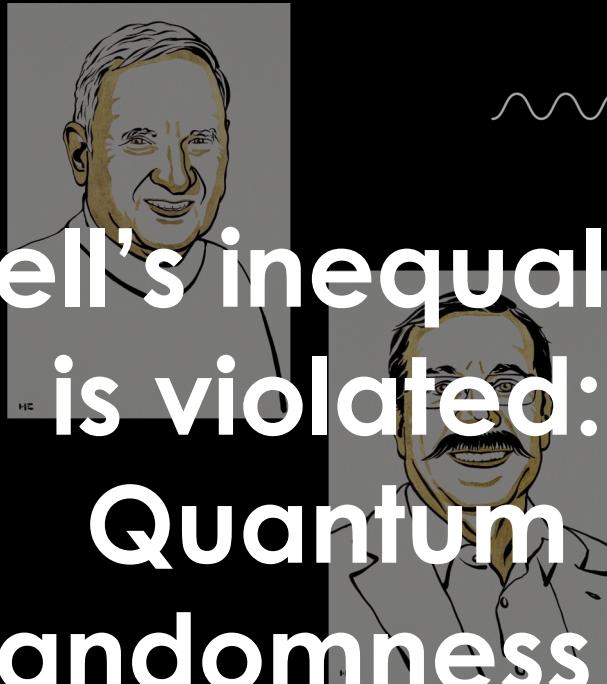


A. Aspect, P. Grangier and G. Roger, *Phys. Rev. Lett.* 49, 91 (1982)

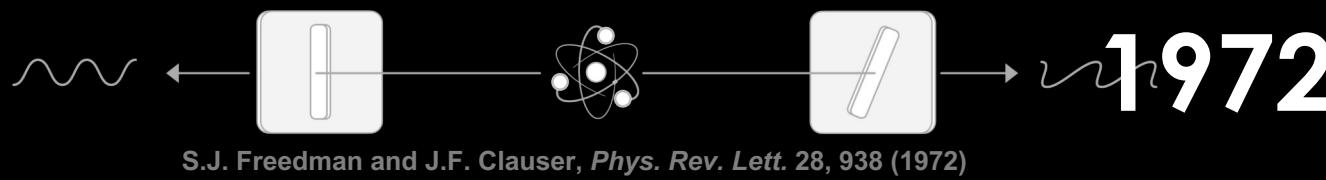


G. Weihs, T. Jennewein, C. Simon, H. Weinfurter & A. Zeilinger, *Phys. Rev. Lett.* 81 (23), 5039 (1998)

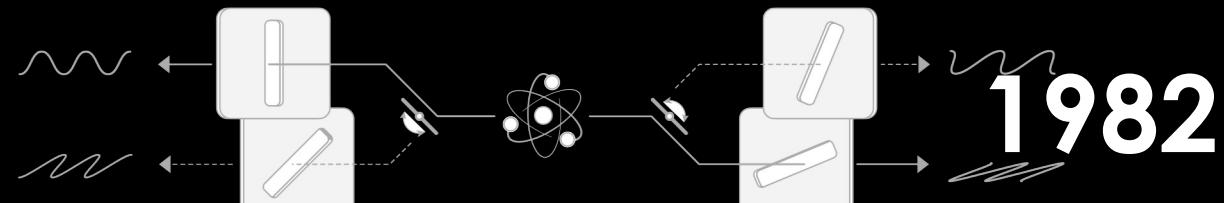
From thought to actual experiment



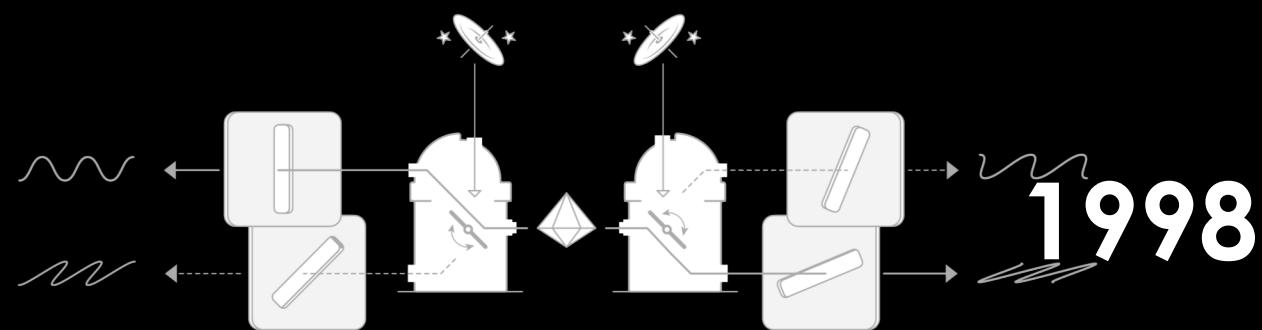
Bell's inequality
is violated:
Quantum
randomness is
NOT mere
ignorance



S.J. Freedman and J.F. Clauser, *Phys. Rev. Lett.* 28, 938 (1972)



A. Aspect, P. Grangier and G. Roger, *Phys. Rev. Lett.* 49, 91 (1982)



G. Weihs, T. Jennewein, C. Simon, H. Weinfurter & A. Zeilinger, *Phys. Rev. Lett.* 81 (23), 5039 (1998)

The 2022 Physics Nobel Prize

"for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science"



Einstein was wrong,
Bohr was right:

The measurement of
a microscopic
particle will be
inherently random.