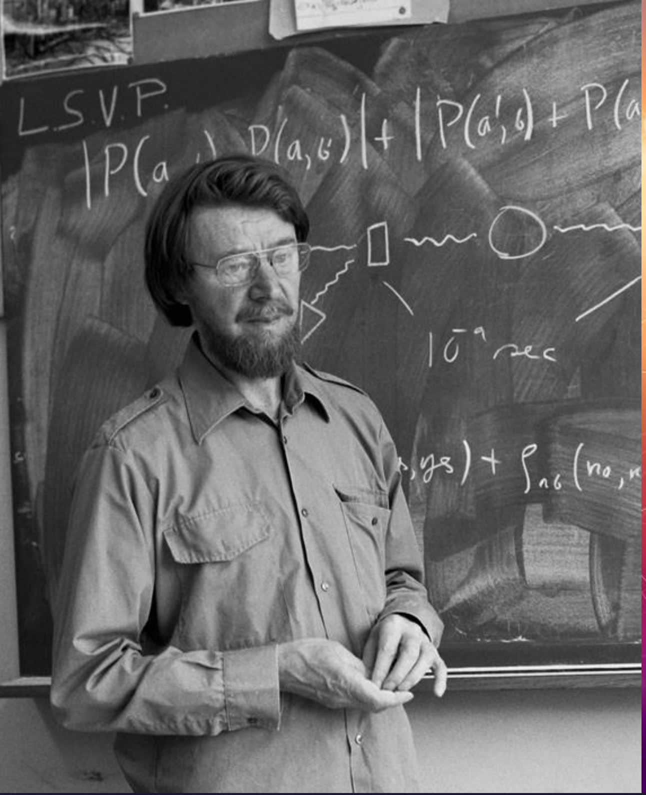
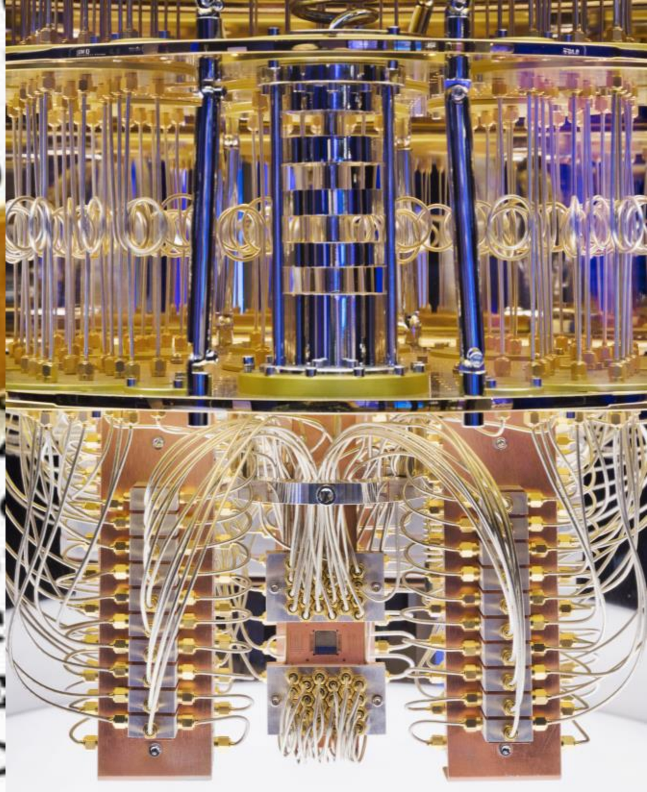
Entanglement

Giovanni Della Lunga



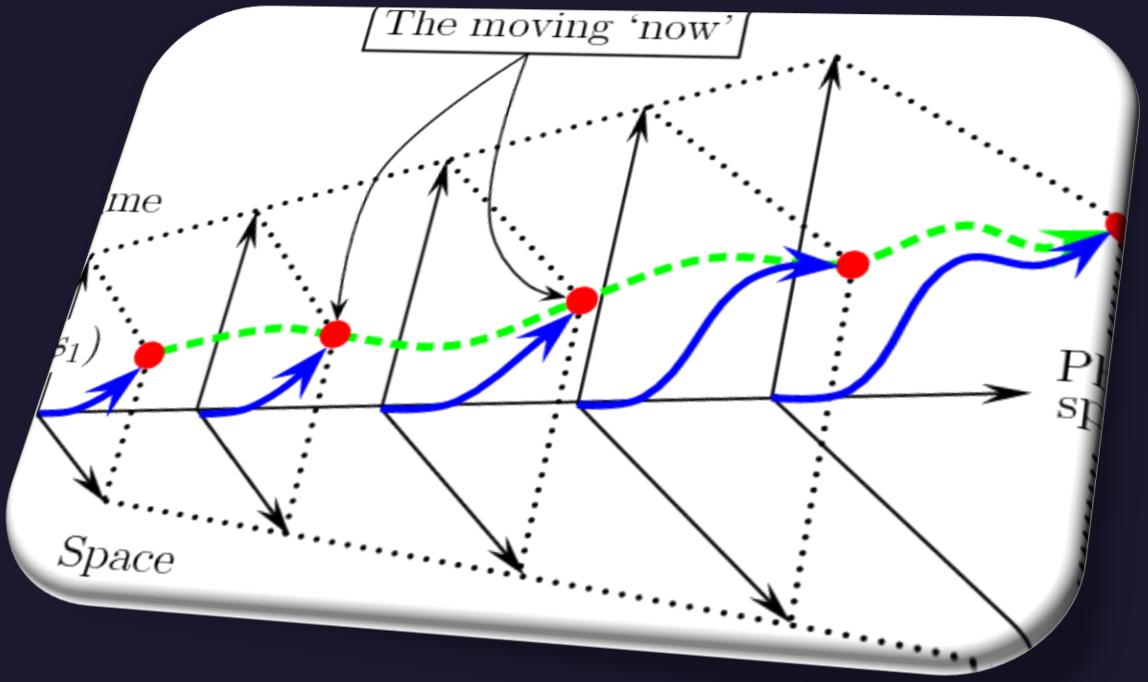
Introduzione

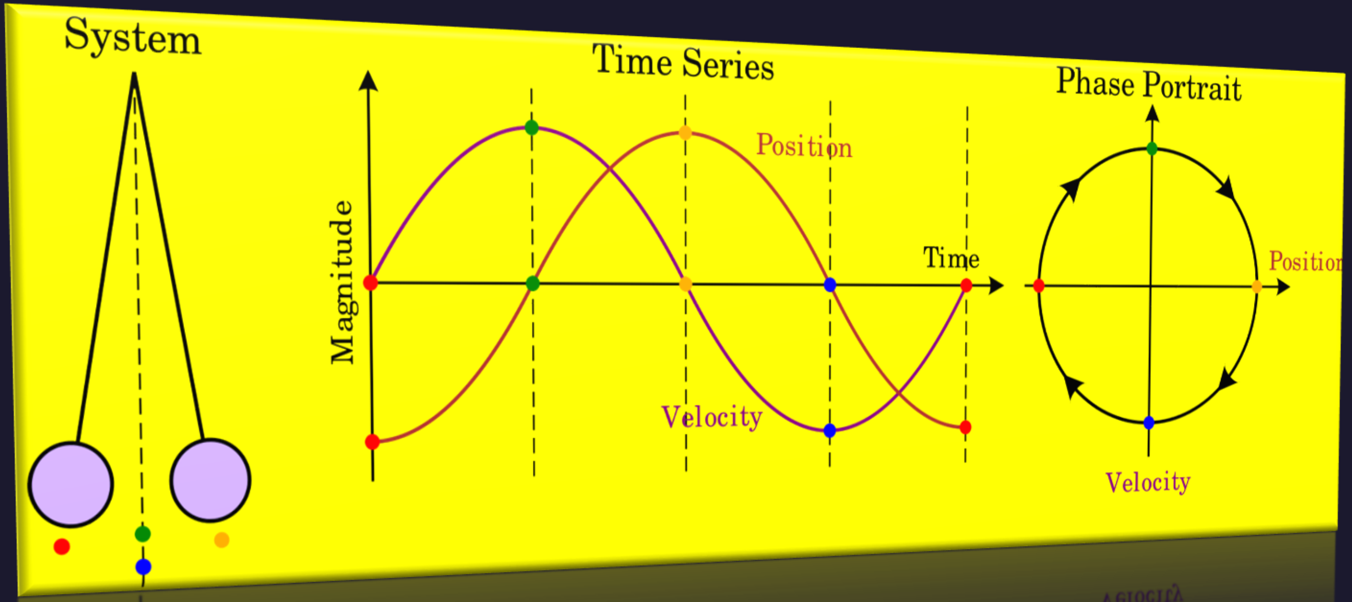
- In italiano entanglement significa semplicemente legato o aggrovigliato attorcigliato.
- In meccanica quantistica entanglement significa una cosa precisa, abbastanza semplice da enunciare, indica che due o più particelle sono connesse tra loro, cioè hanno proprietà che sono correlate. In altre parole, lo stato di ciascuna particella non può essere descritto senza tenere conto dell'insieme delle particelle.

Introduzione

- Proprietà e Stato di un Sistema Fisico

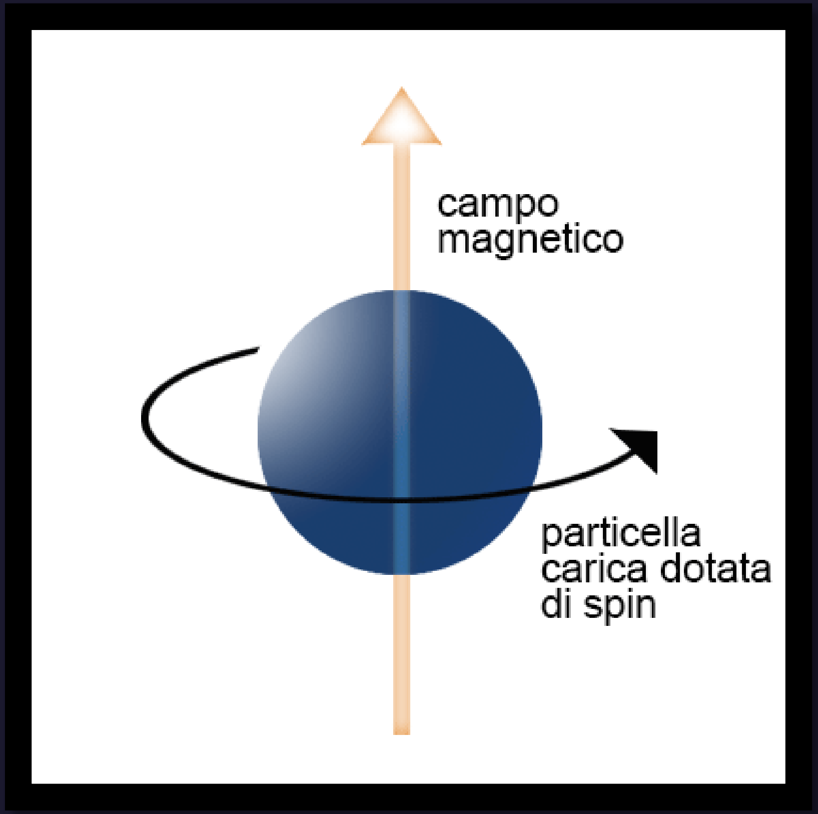
- In generale lo stato di un sistema è la specificazione di tutte le grandezze fisiche caratteristiche del sistema.

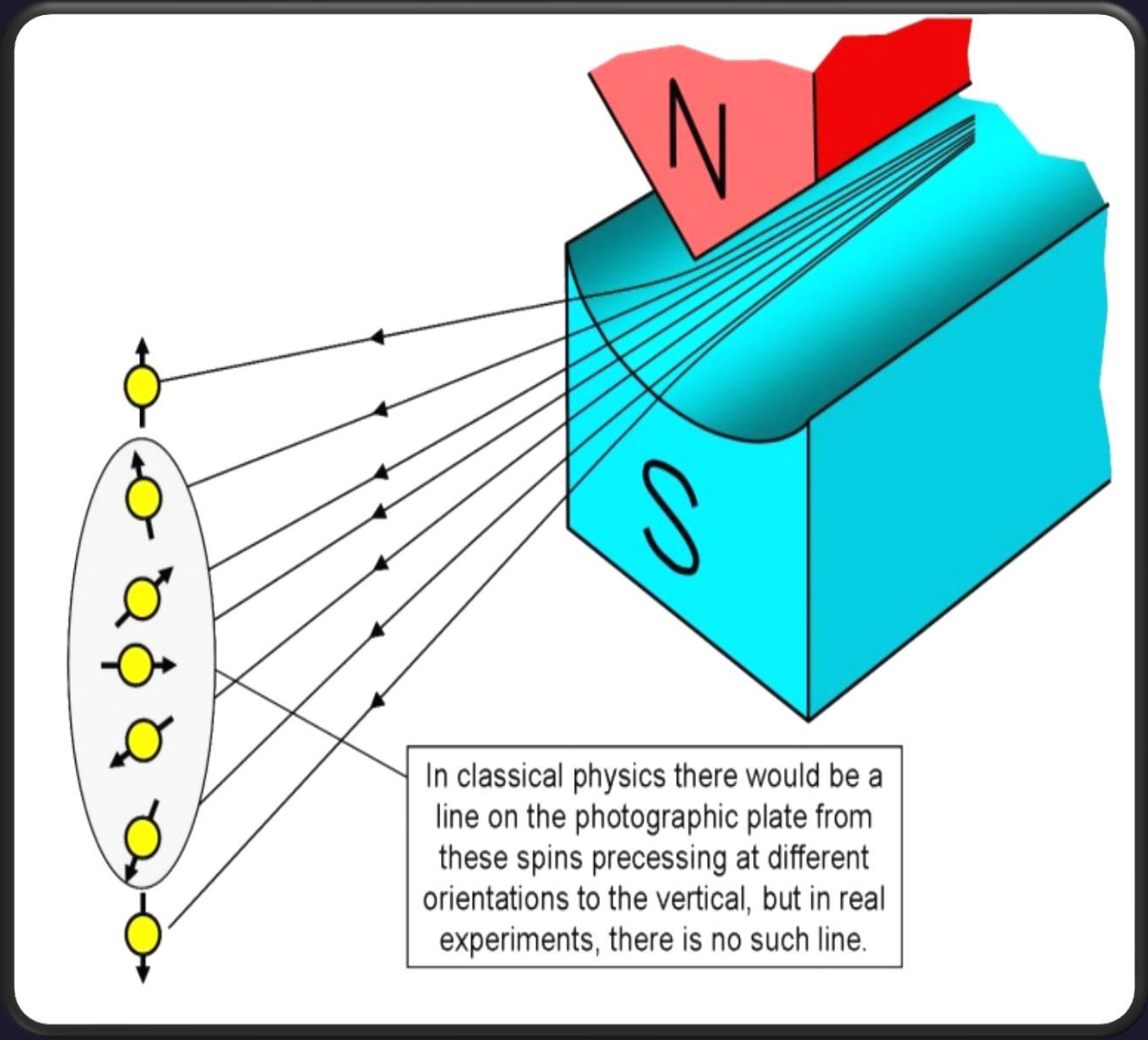




Introduzione

- Gli elettroni hanno una proprietà quantistica che ha una certa somiglianza con la rotazione di un oggetto macroscopico per esempio una trottola e infatti è stata chiamata spin che significa appunto rotazione

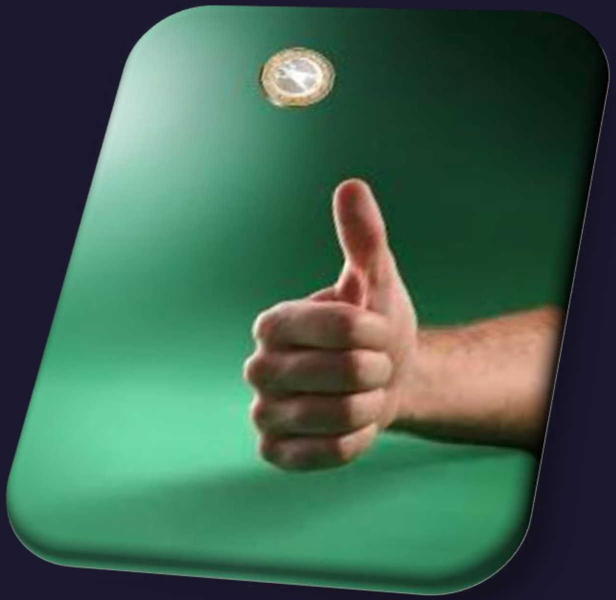


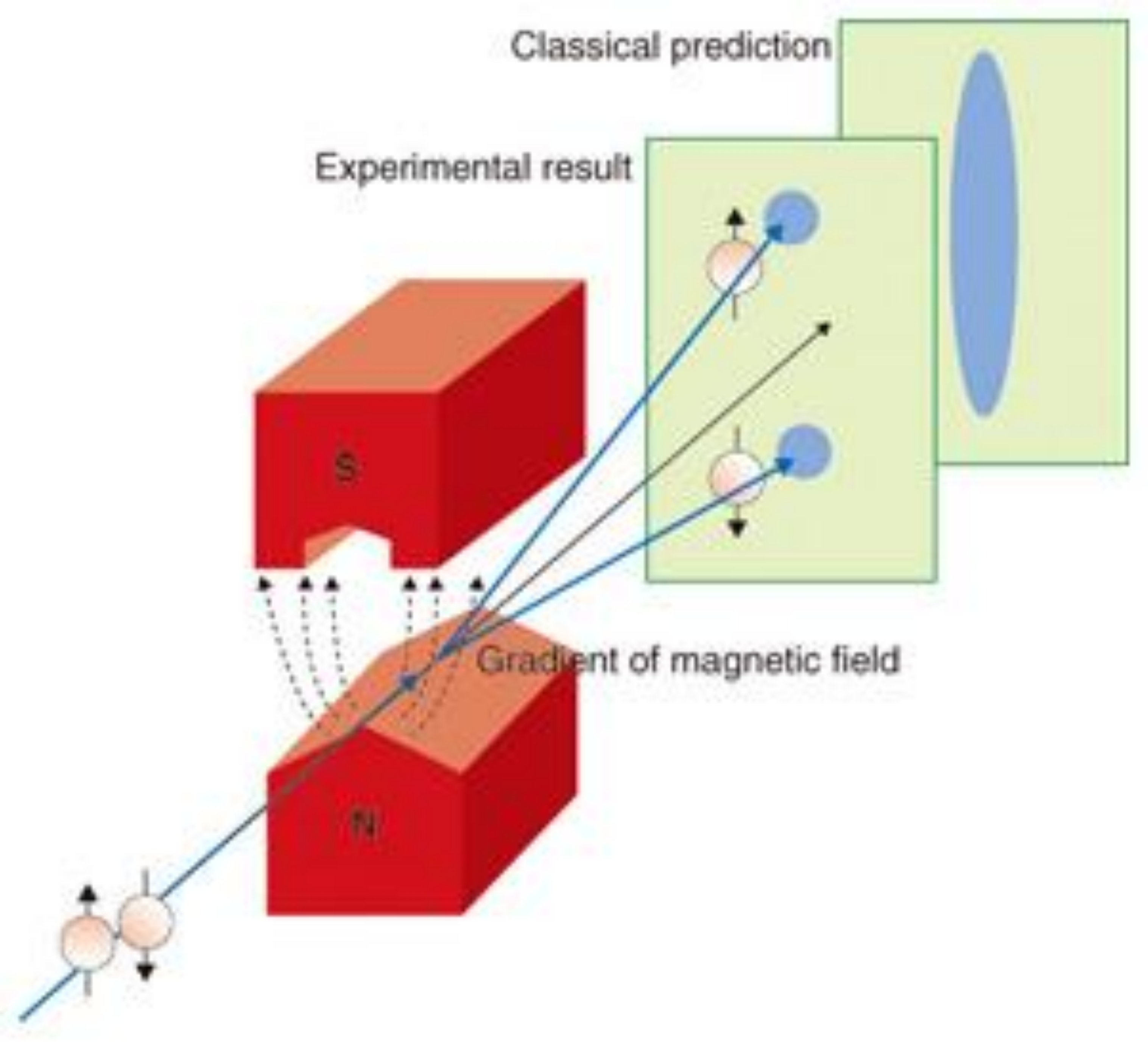


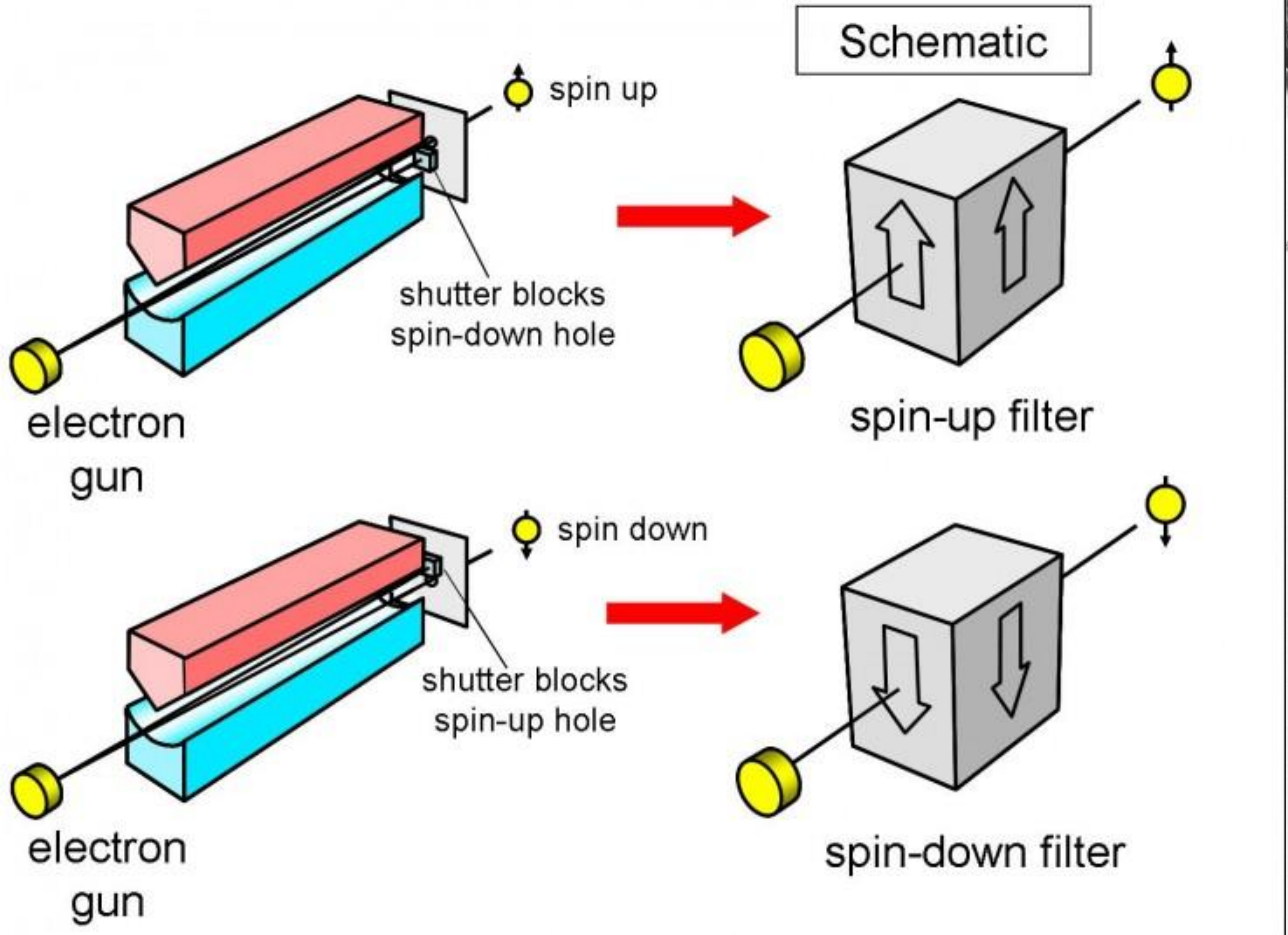
Quantizzazione

Esperimento di Stern-Gerlach

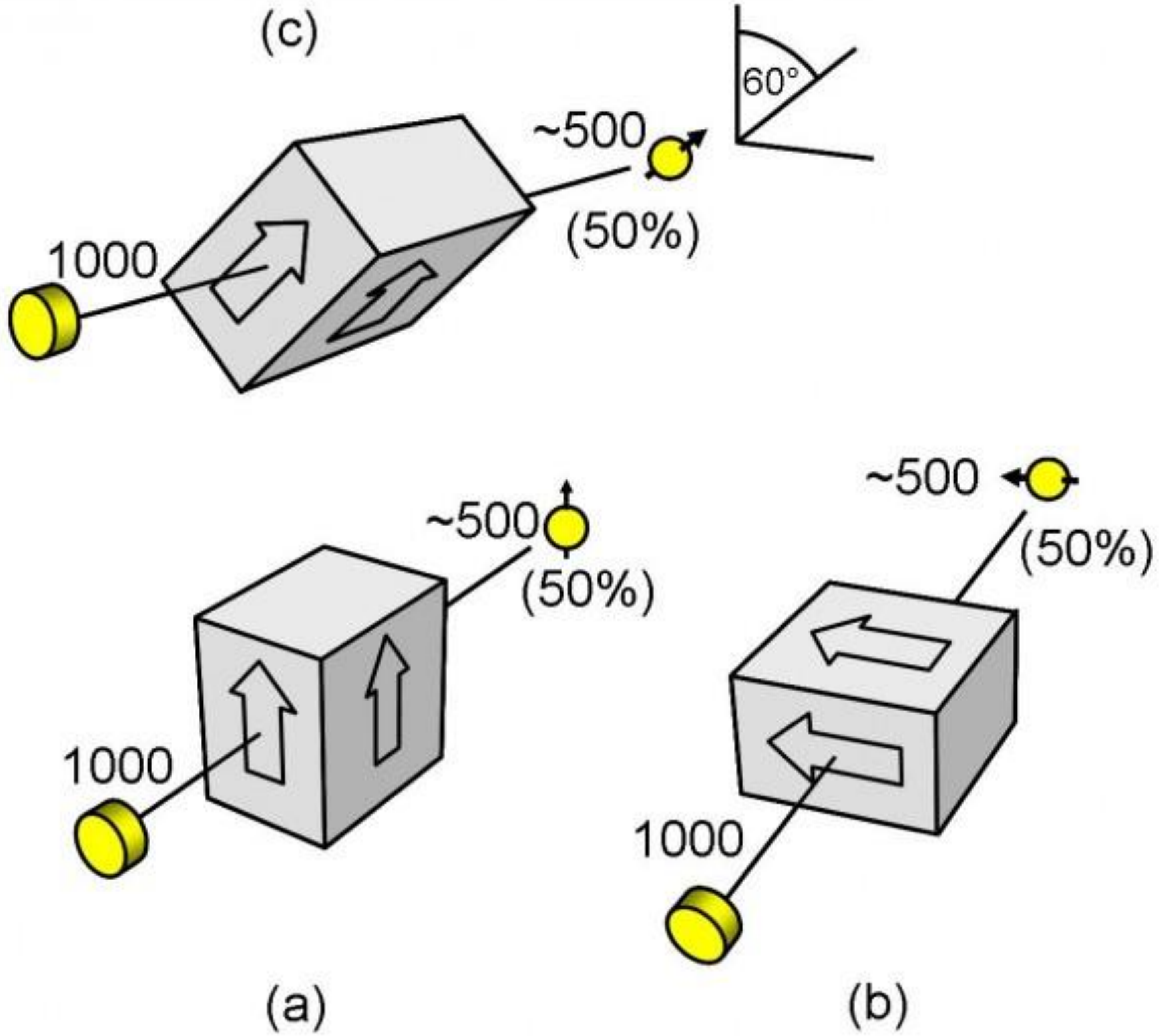
Lo spin degli elettroni può avere solo due valori più o meno un mezzo oppure se vogliamo rendere le cose ancora più semplici su e giù



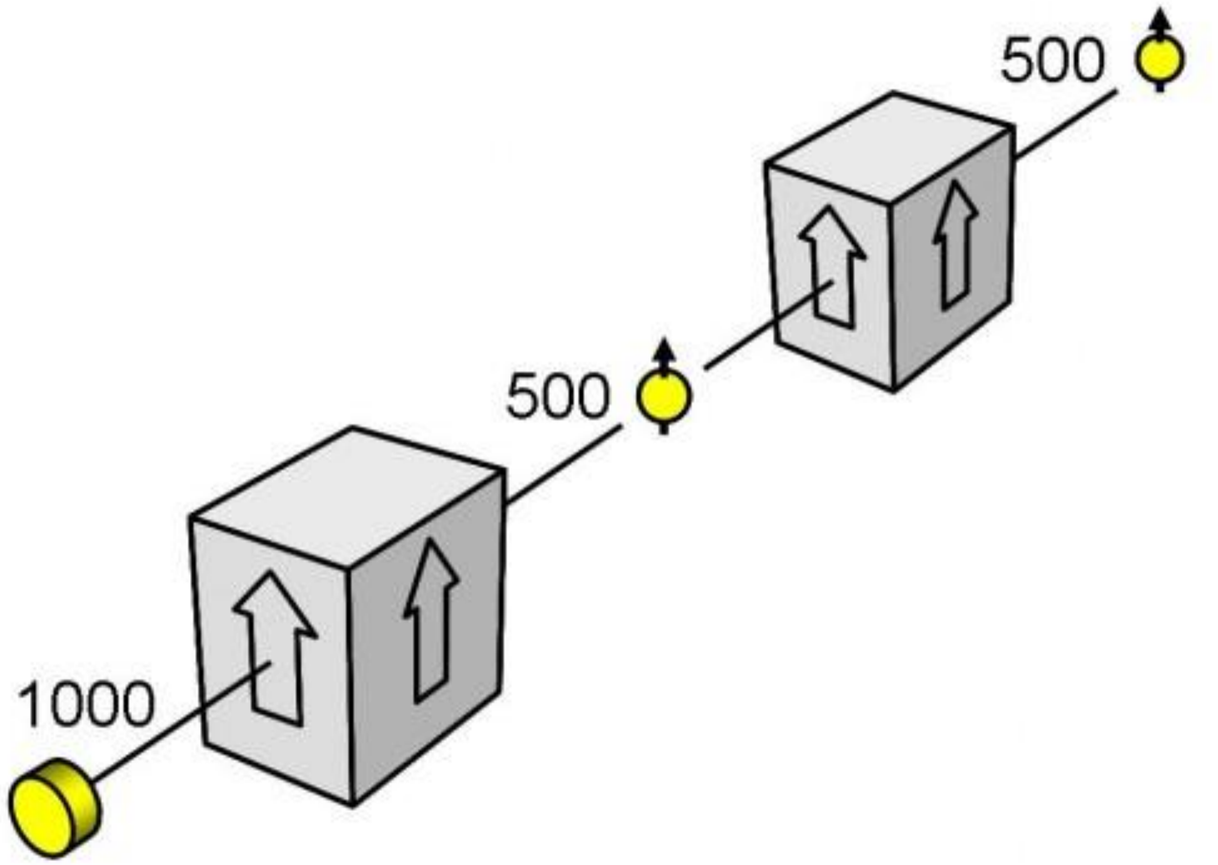


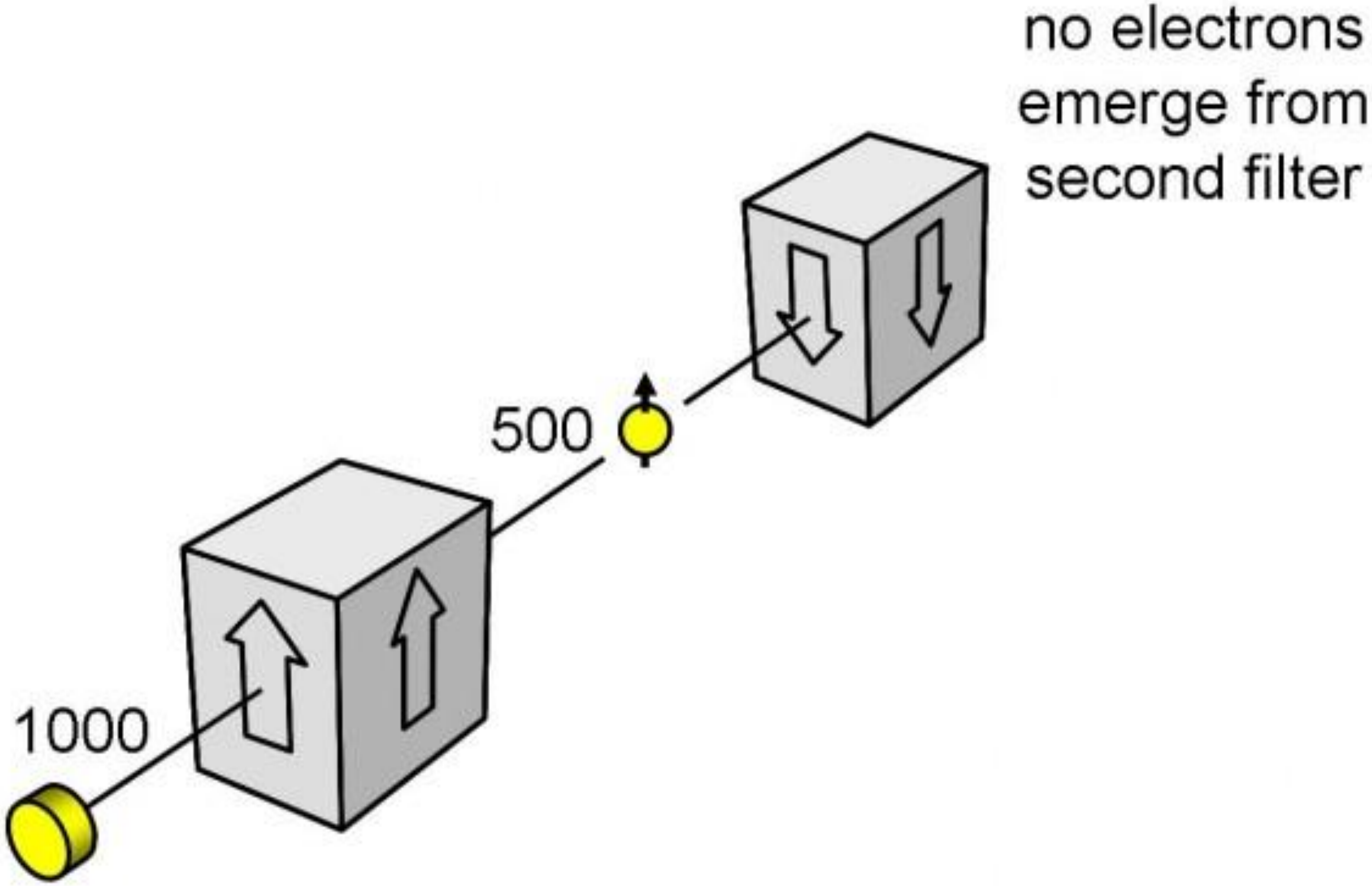

Schematic
spin up
shutter blocks
spin-down hole
electron
gun
spin-up filter
spin down
shutter blocks
spin-up hole
electron
gun
spin-down filter

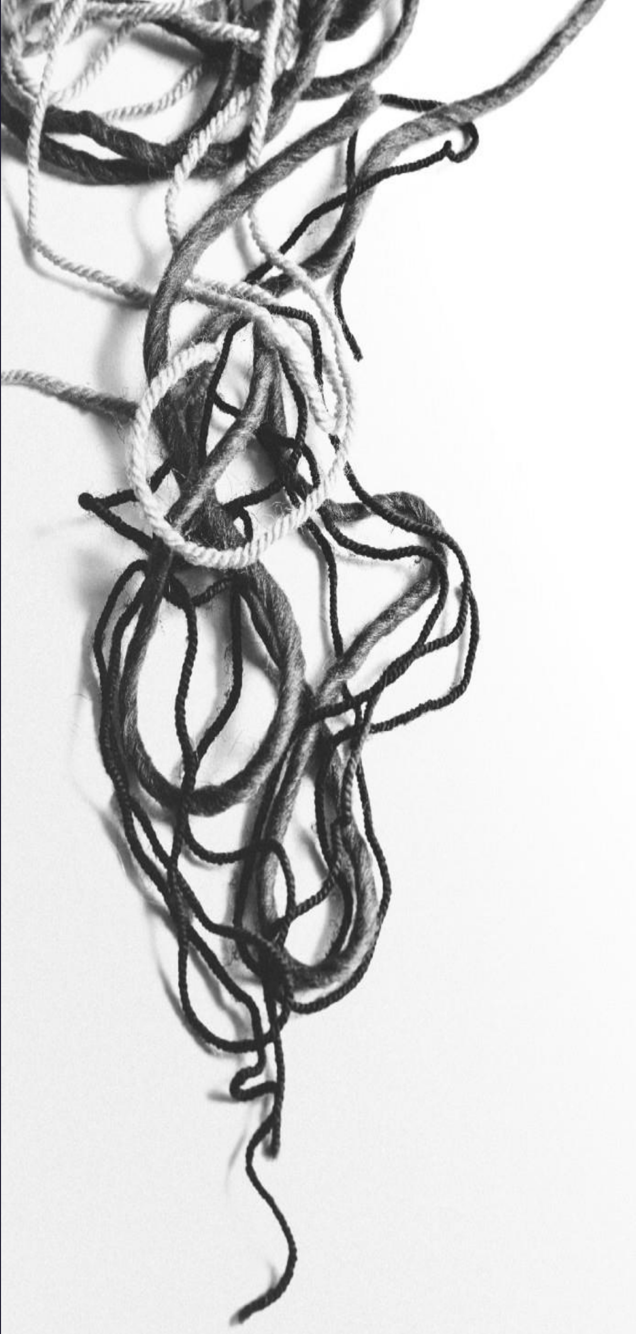
Casualità

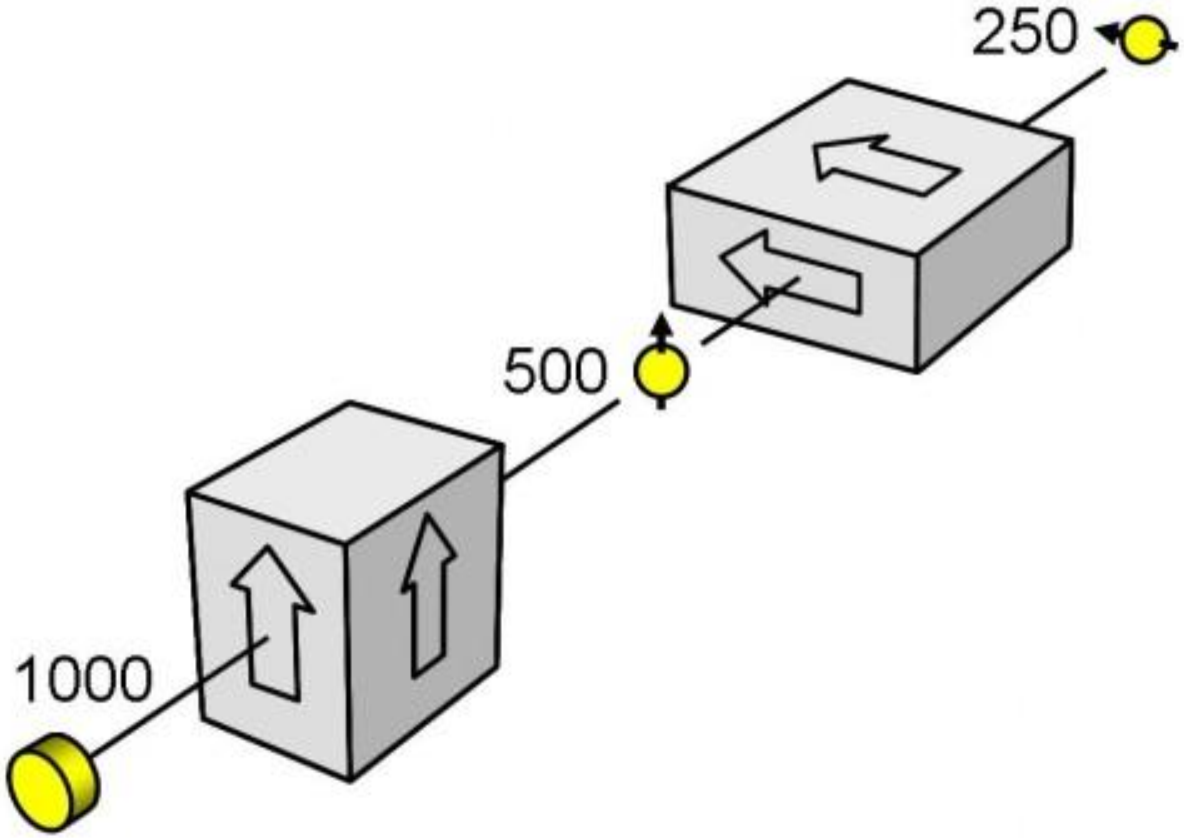


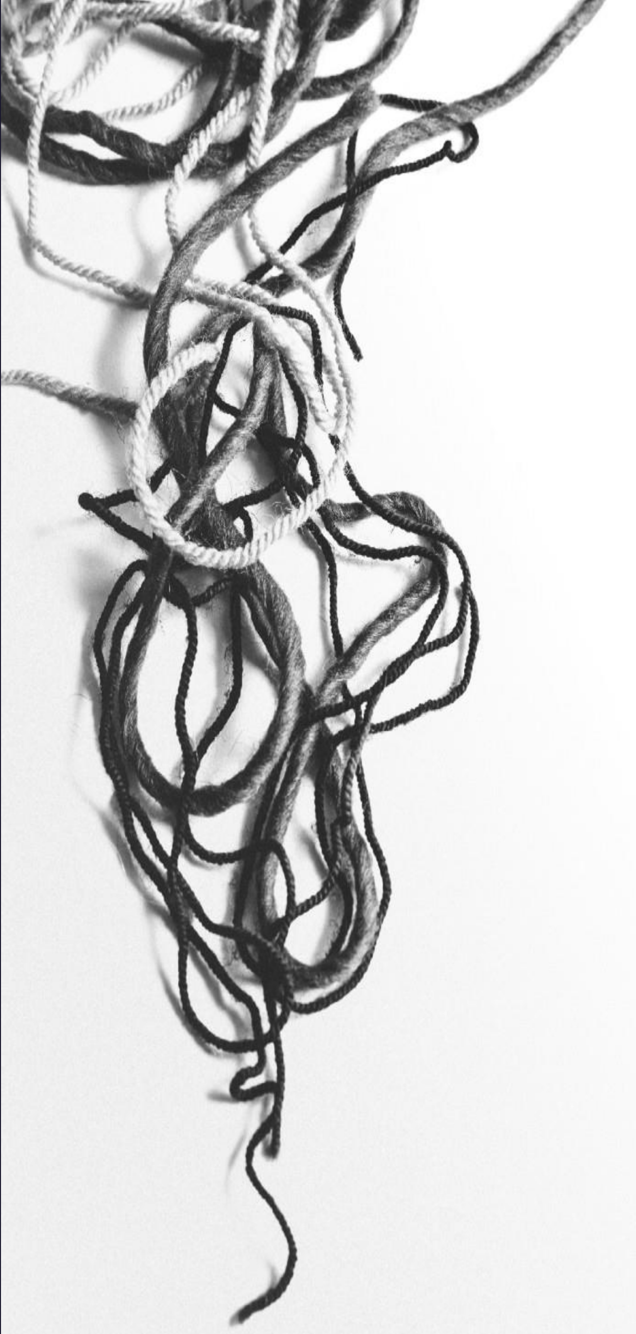
(c)
60°
~500
(50%)
1000
~500
(50%)
1000
~500
(50%)
1000
(a)
(b)

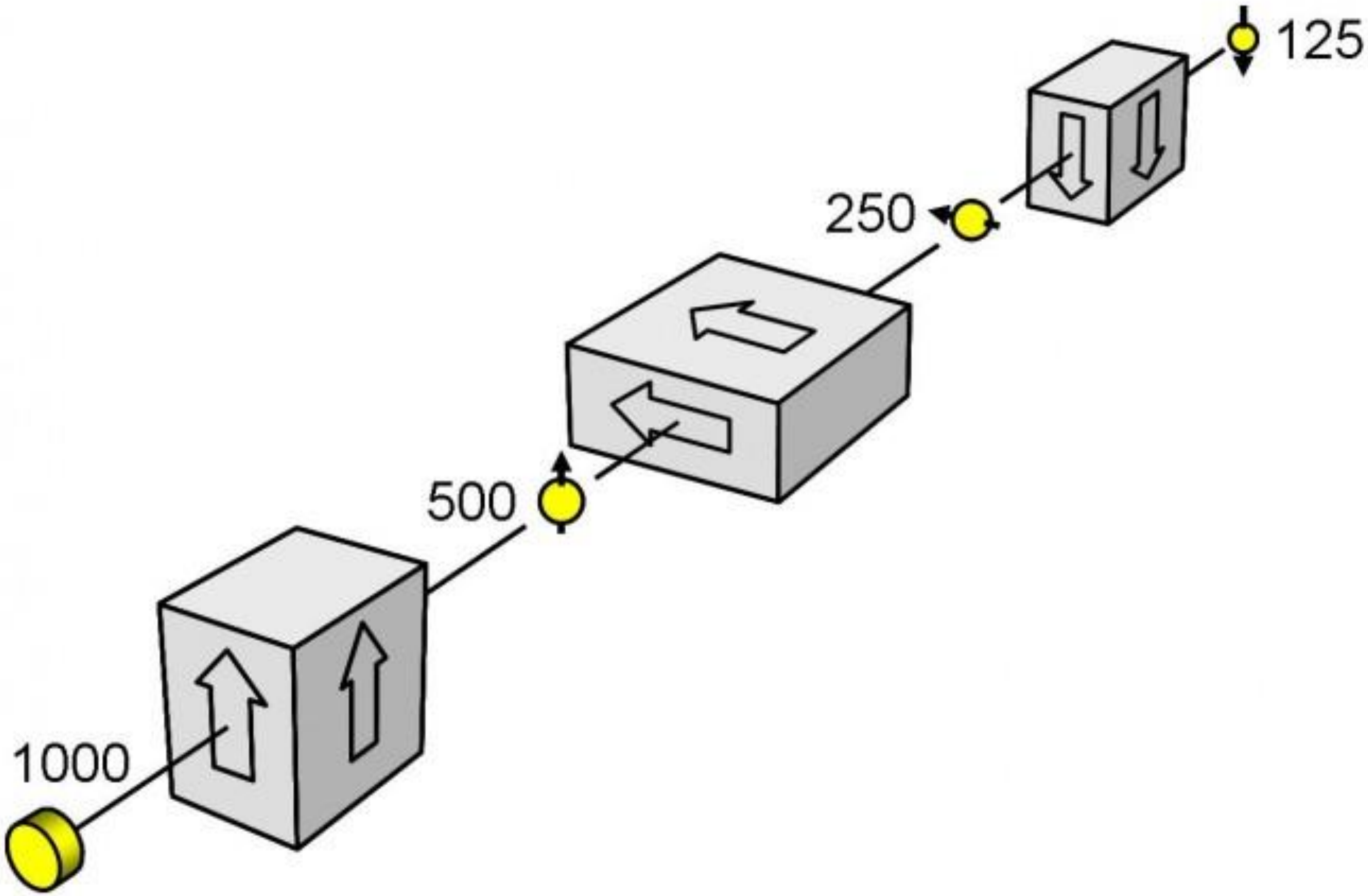

1000
500
500


no electrons
emerge from
second filter
500
1000




250
500
1000



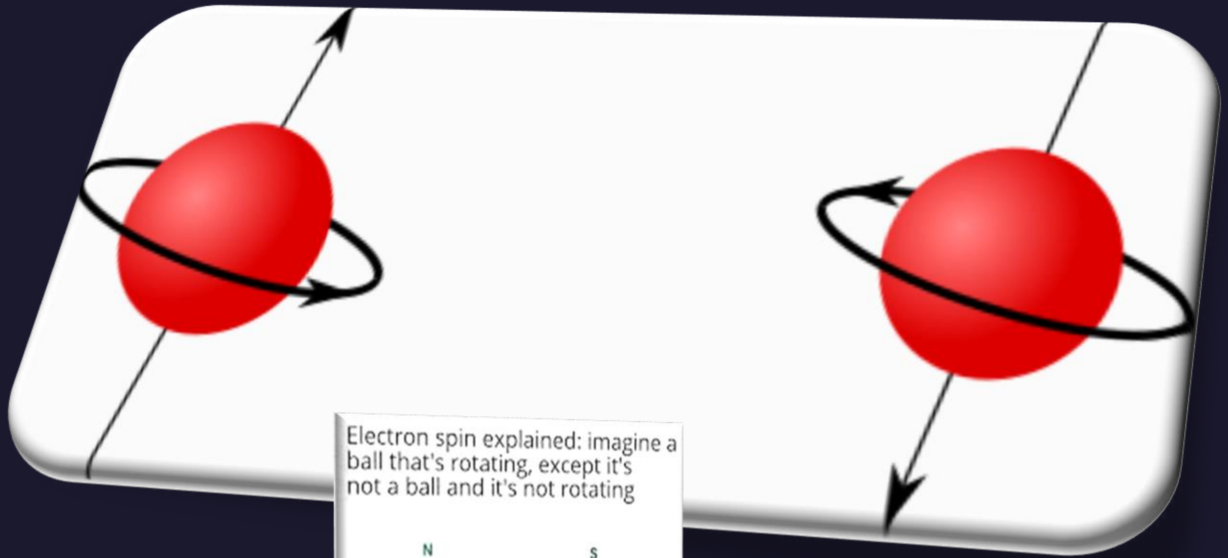

125
250
500
1000

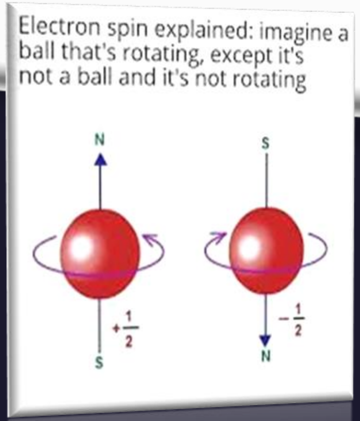
Conservazione


TikTok
@astrosamantha

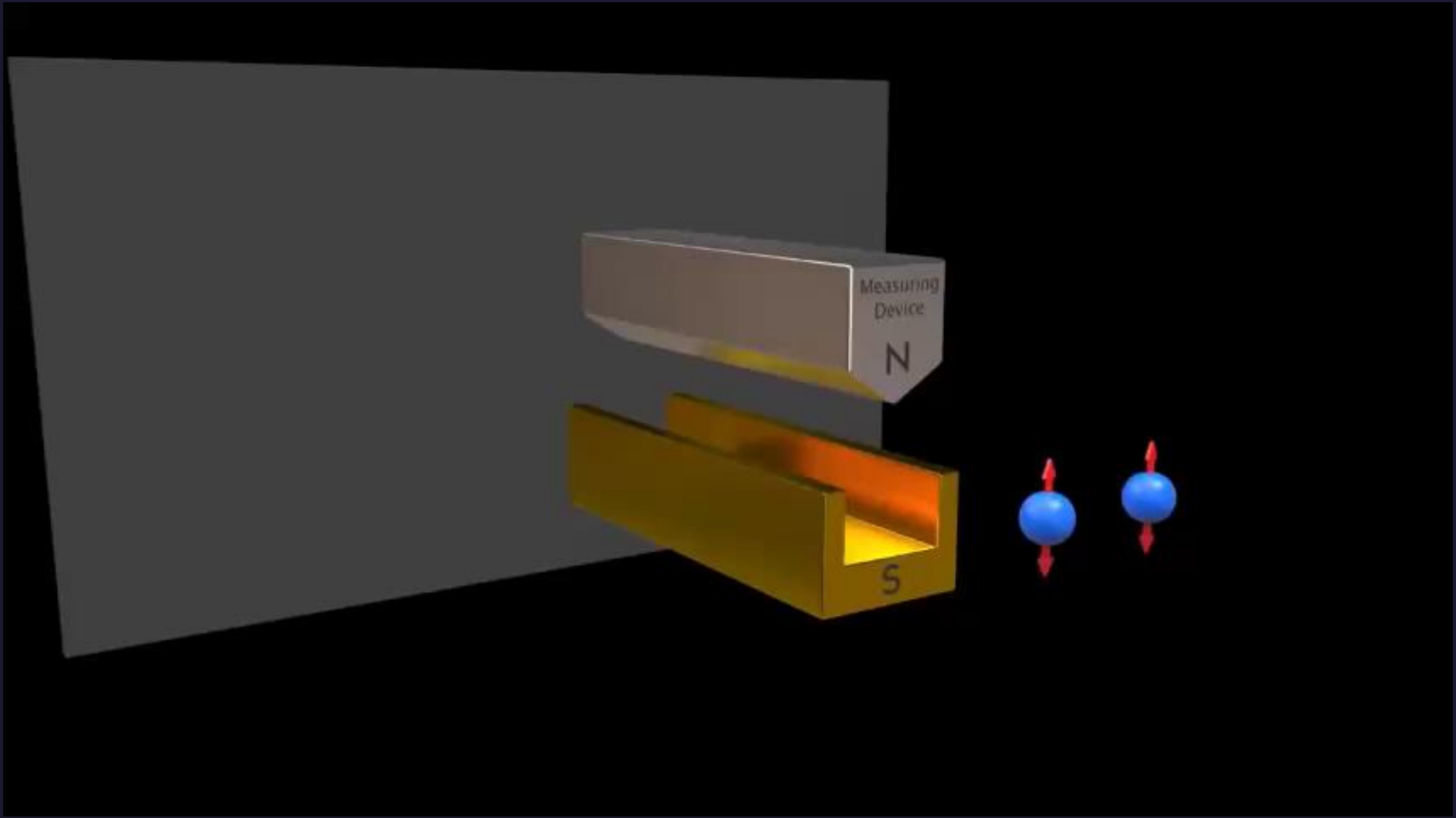

CONSERVATION OF ANGULAR MOMENTUM
TikTok
@astrosamantha

Conservazione - Correlazione





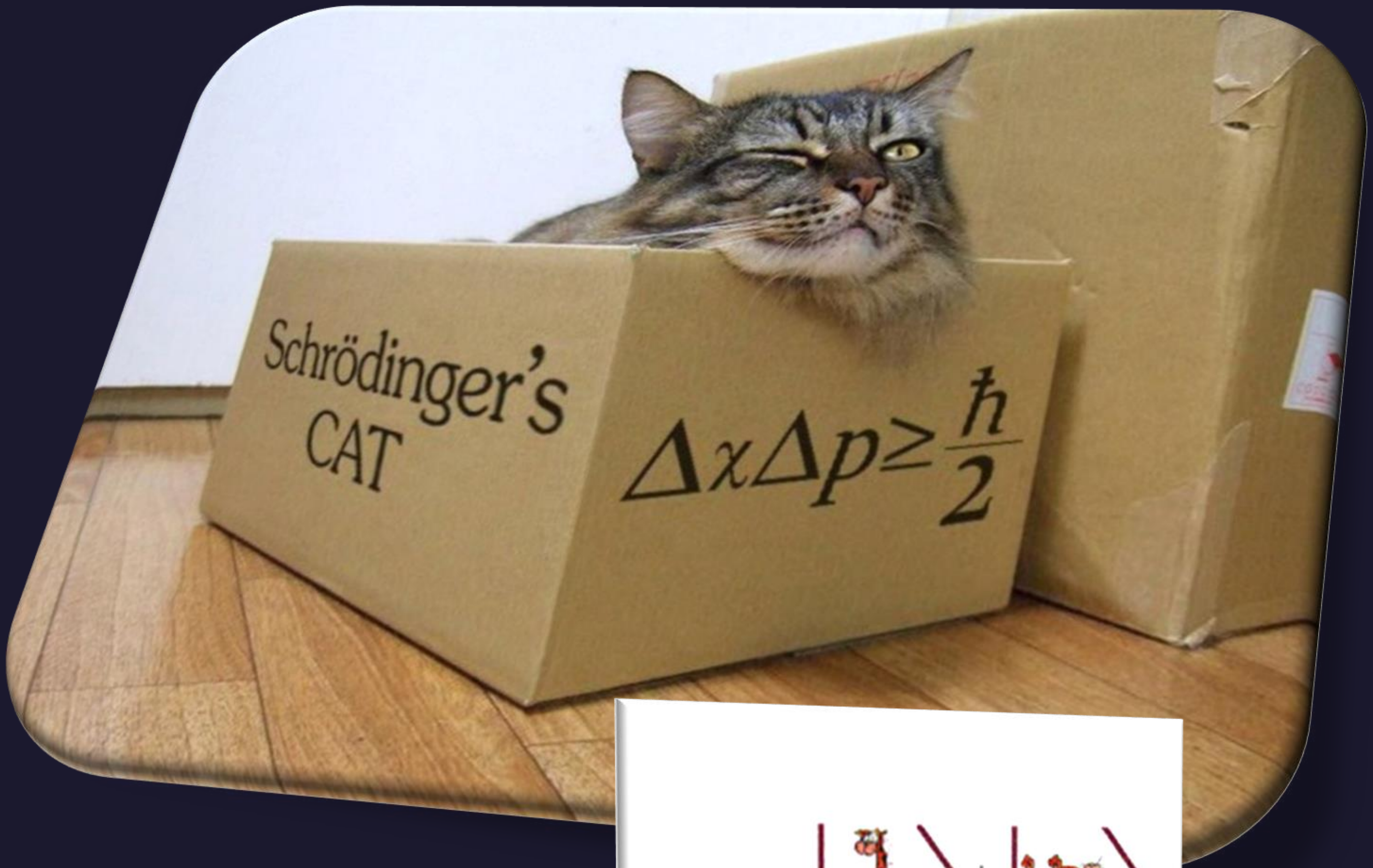
- si possono creare due elettroni in modo che la somma dei loro spin faccia esattamente zero
- non ci interessa sapere esattamente come facciamo questa cosa il punto veramente importante è che una volta che questi due elettroni sono stati creati o preparati in questo modo cioè con la somma dello spin complessivo uguale a zero sono costretti a rimanere in questo stato cioè sono correlati quindi
- se uno dei due spin è più un mezzo l'altro deve essere per forza meno un mezzo la somma deve fare zero qualunque cosa accada

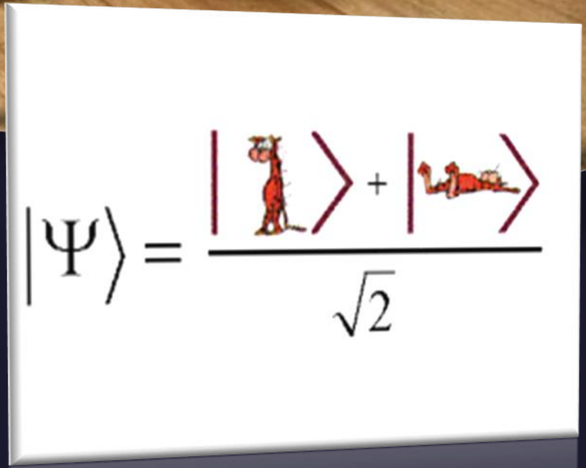

Measuring Device
N
S

Sovrapposizione

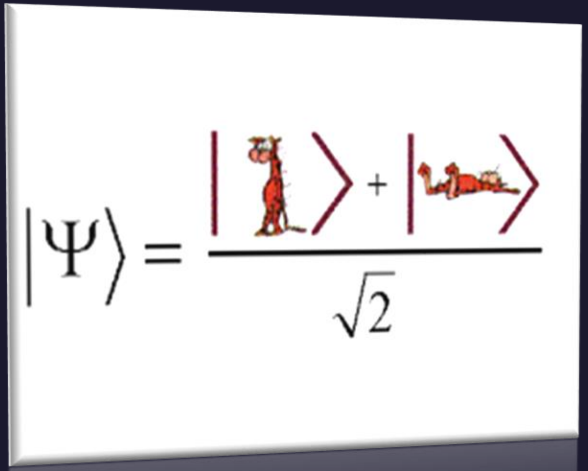
Sovrapposizione

In meccanica quantistica però la cosa è in effetti un po’ più strana perché le particelle quantistiche non hanno proprietà definite fino a quando non andiamo a misurarle quindi lo spin di un elettrone per esempio non è +1/2 o -1/2 un mezzo prima della misura ma in realtà è quello che meccanica quantistica viene chiamato una sovrapposizione





Sovrapposizione

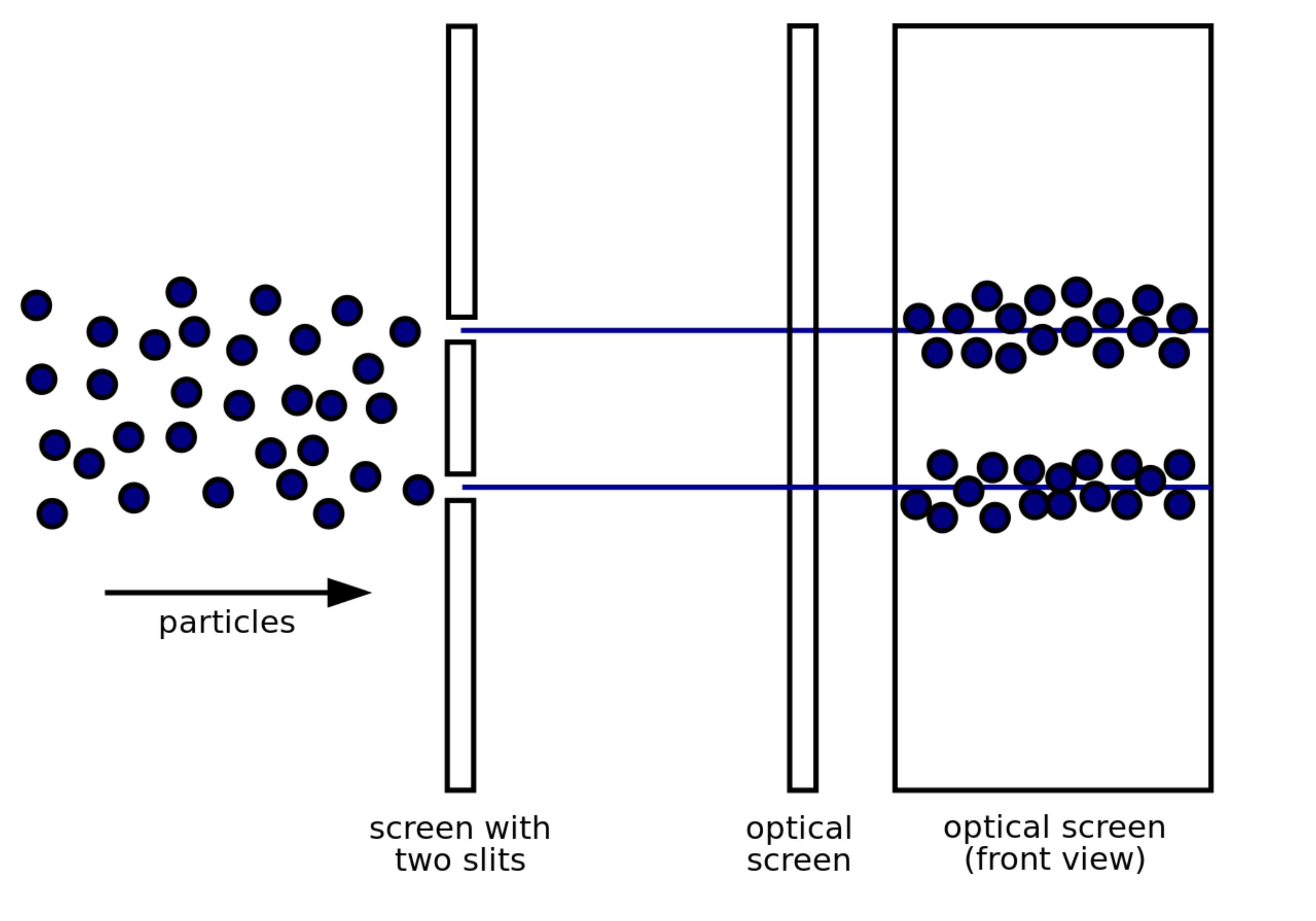


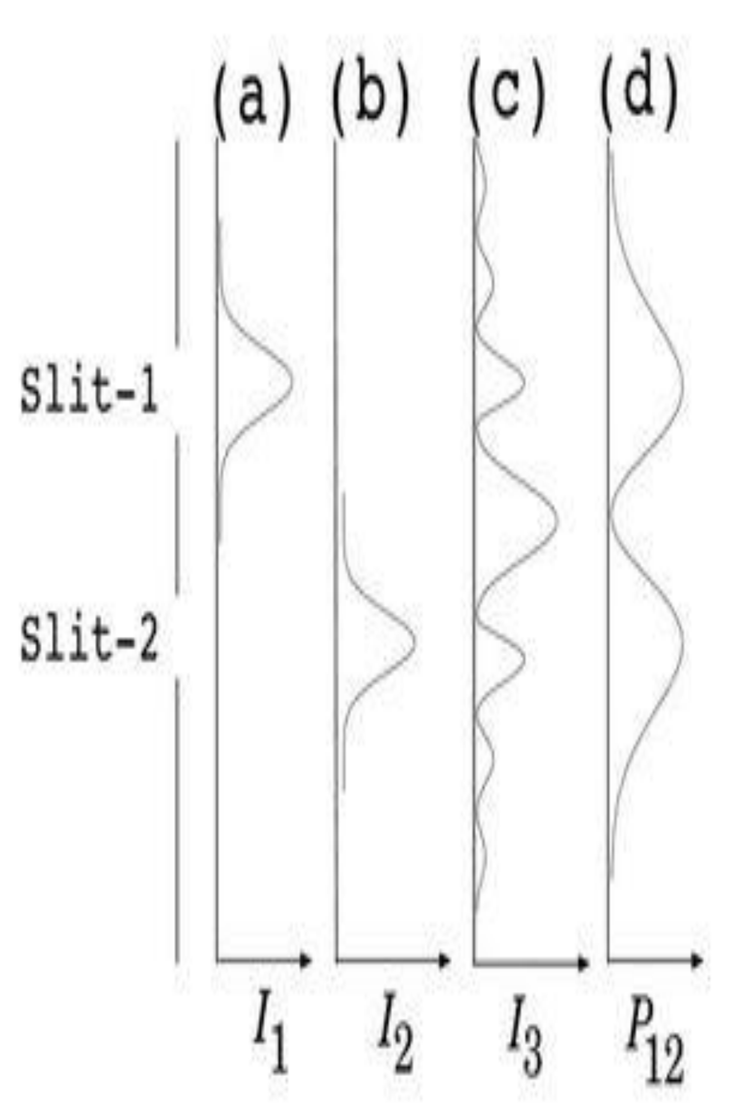
- Anche su questo c'è un po' di confusione perché spesso si legge che fino a quando non facciamo una misura dello spin dell'elettrone sappiamo solo che c'è 50 per cento di probabilità che sia sue 50 per cento probabilità che sia giu!

- Ma questo è vero anche in un sistema classico. Non c'è niente di strano! Se ho una moneta dentro una scatola non so se è testa o croce fino a quando non avrò aperto la scatola so solo che c'è una probabilità del 50 per cento di aprire e trovare che la moneta con la faccia in su che indica testa o il 50 per cento di aprire e vedere croce.

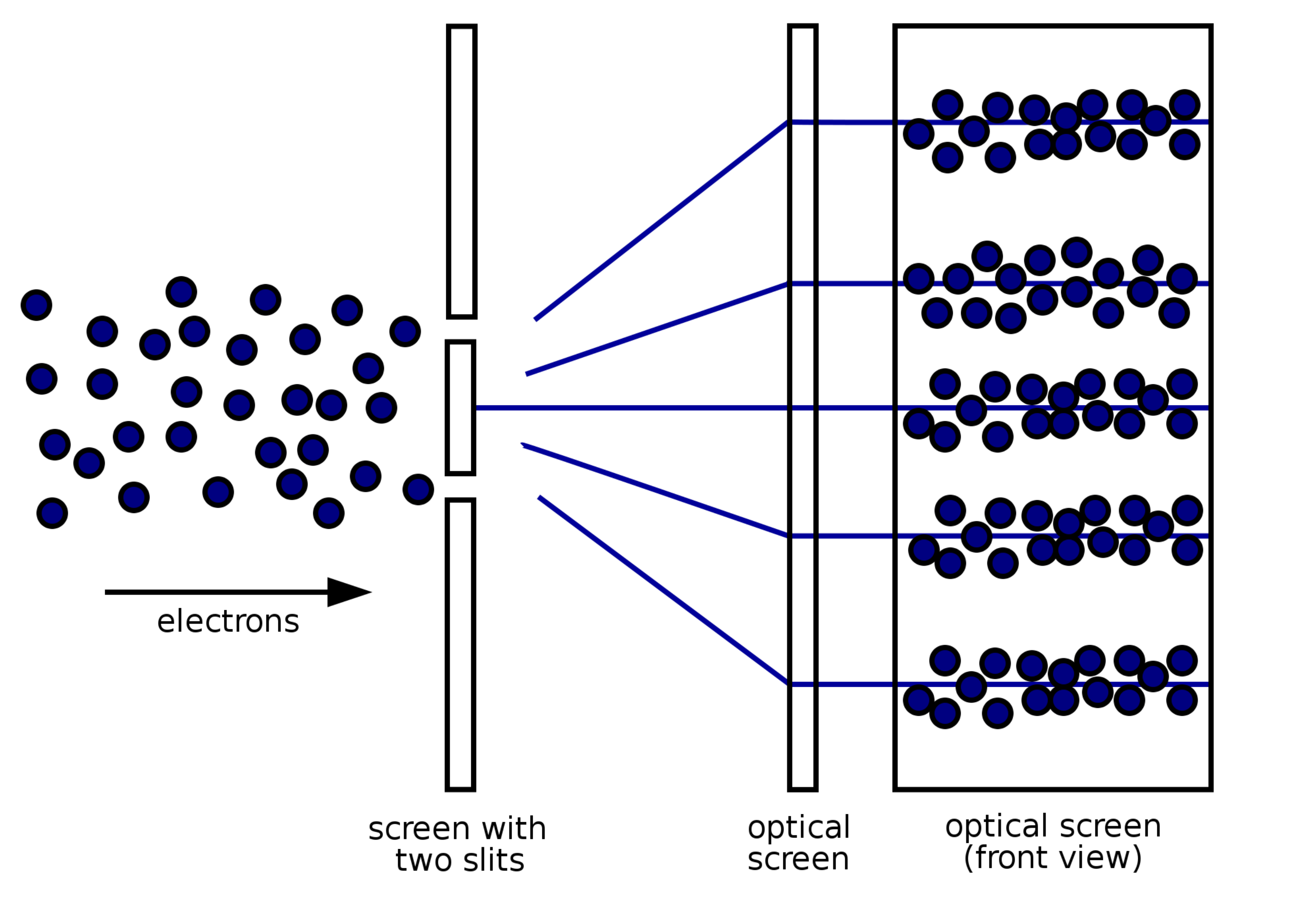
- In meccanica quantistica la faccenda è diversa!

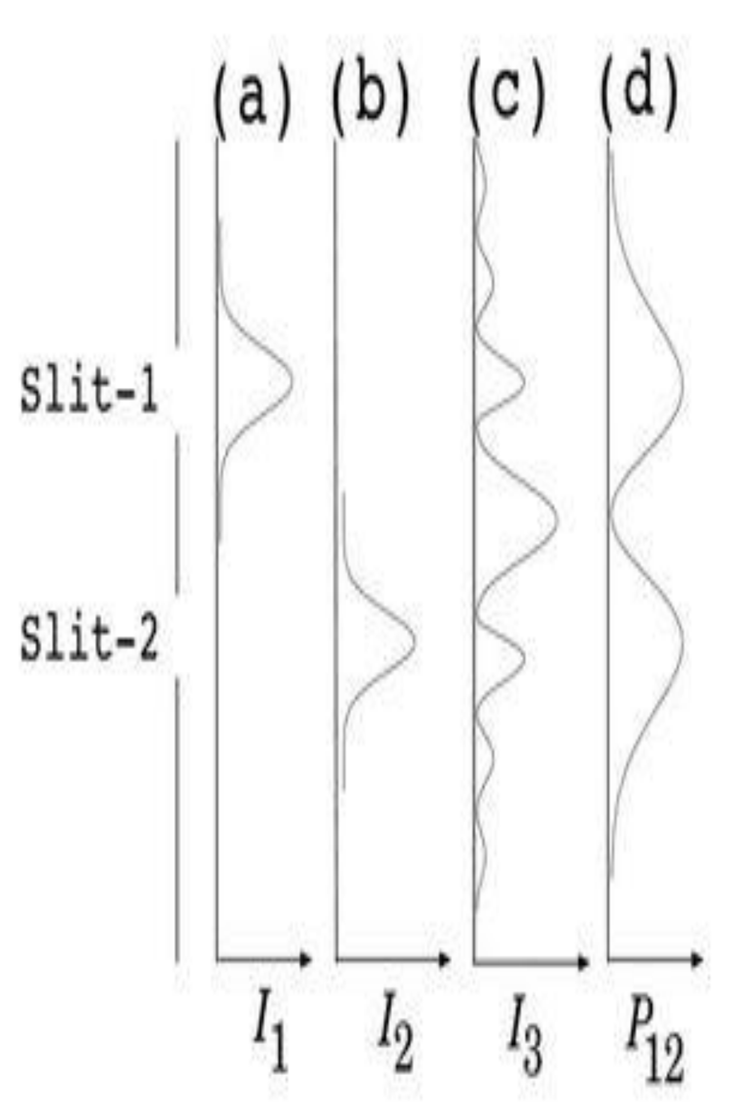
Sovrapposizione



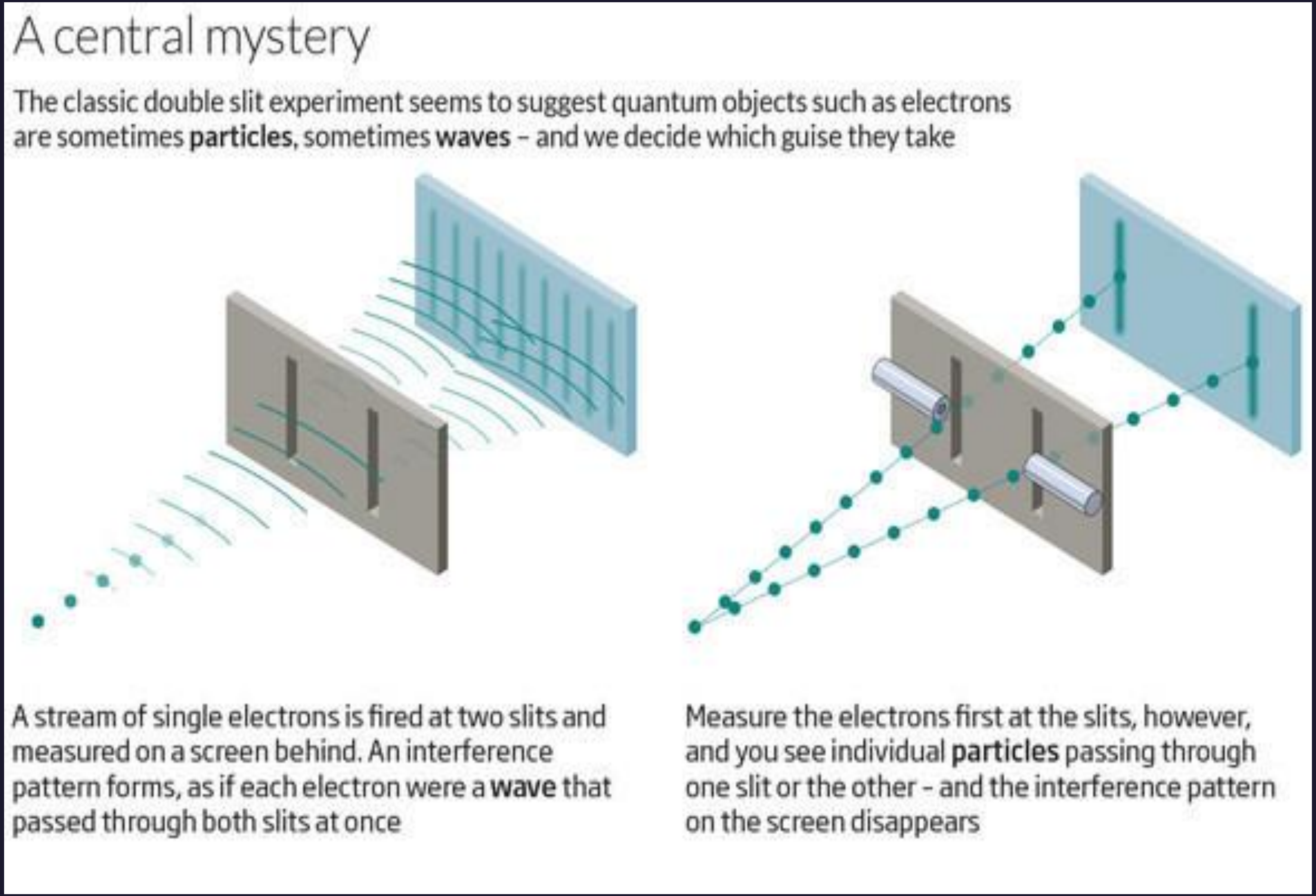


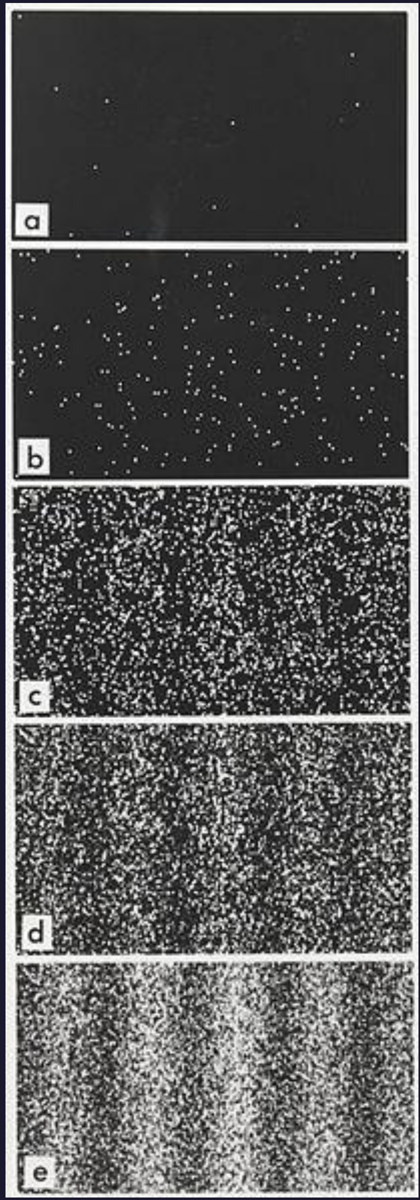
Sovrapposizione





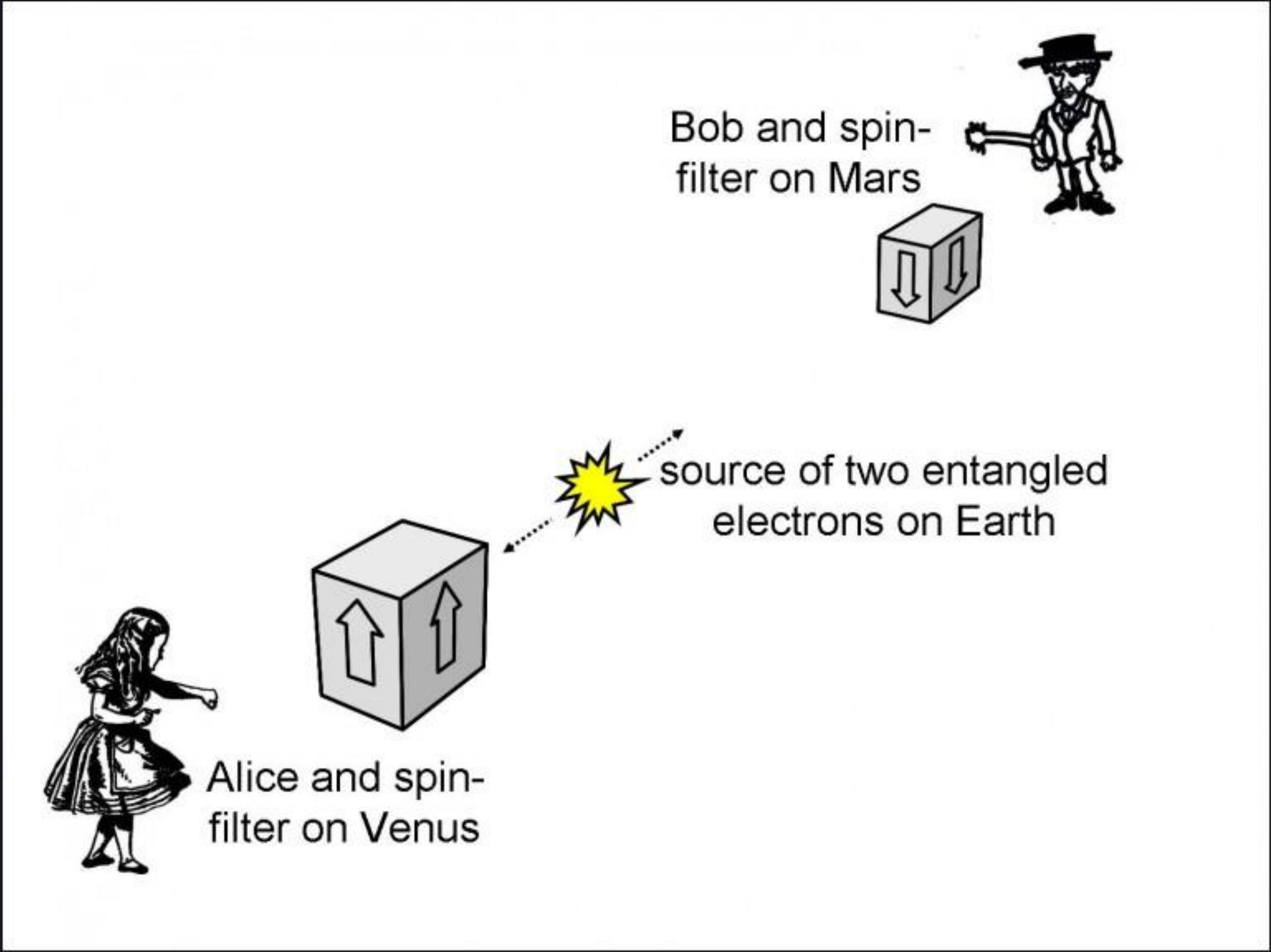
Sovrapposizione



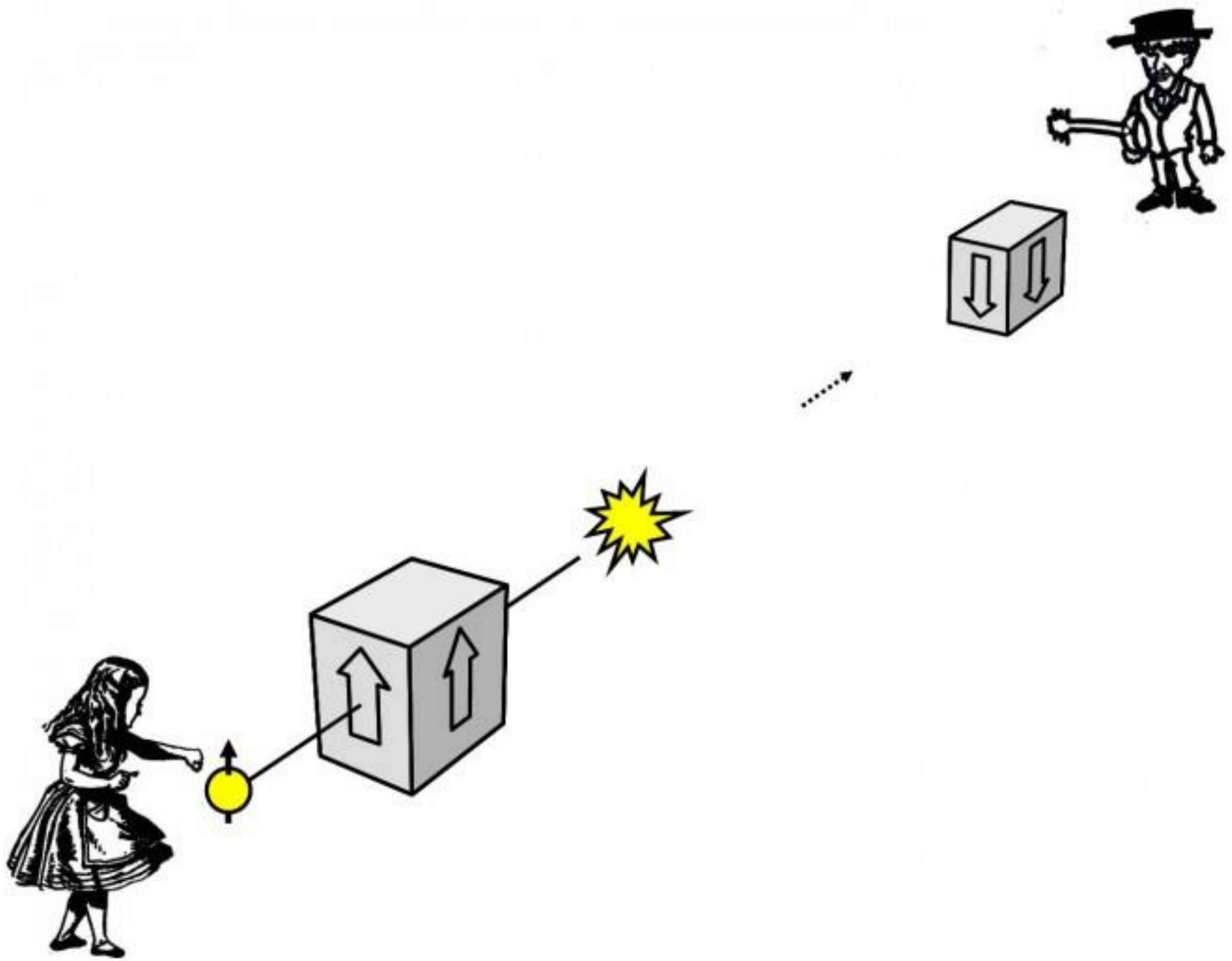


Entanglement

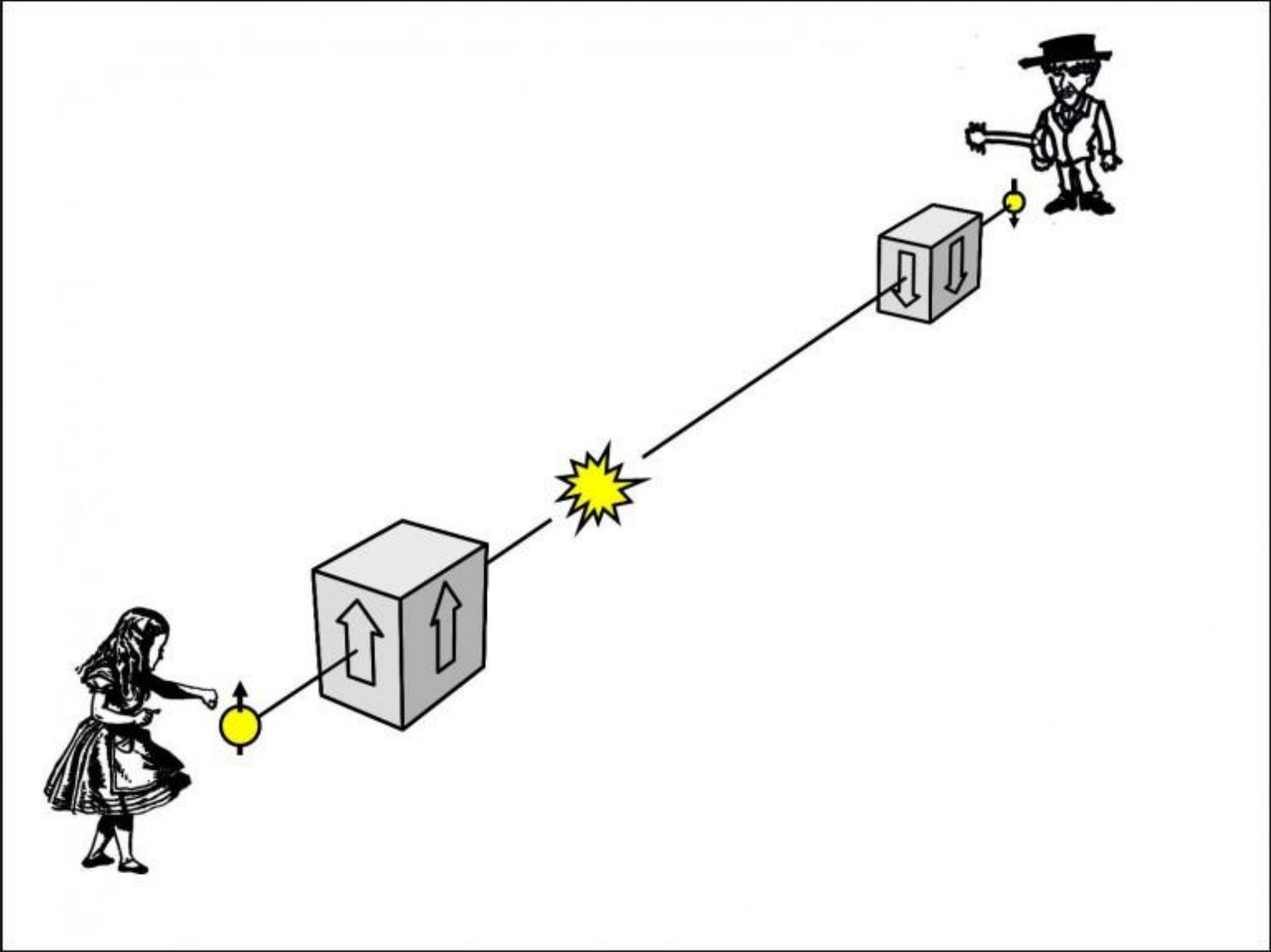
Entanglement



Entanglement

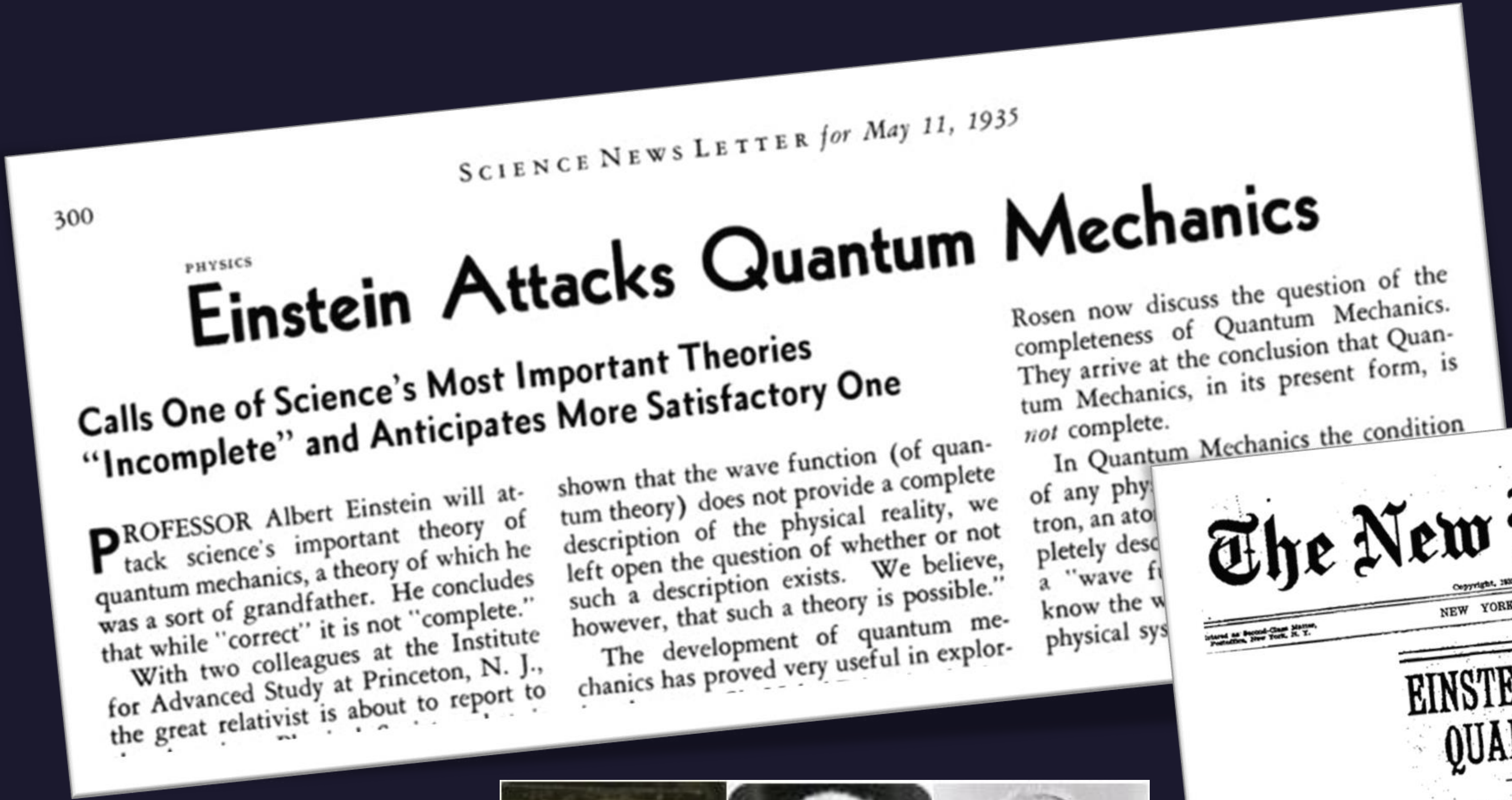


Entanglement



Entanglement: Può la Meccanica Quantistica Ritenersi Completa?

1935



300

SCIENCE NEWS LETTER *for May 11, 1935*

PHYSICS

Einstein Attacks Quantum Mechanics

Calls One of Science's Most Important Theories "Incomplete" and Anticipates More Satisfactory One

PROFESSOR Albert Einstein will attack science's important theory of quantum mechanics, a theory of which he was a sort of grandfather. He concludes that while "correct" it is not "complete."

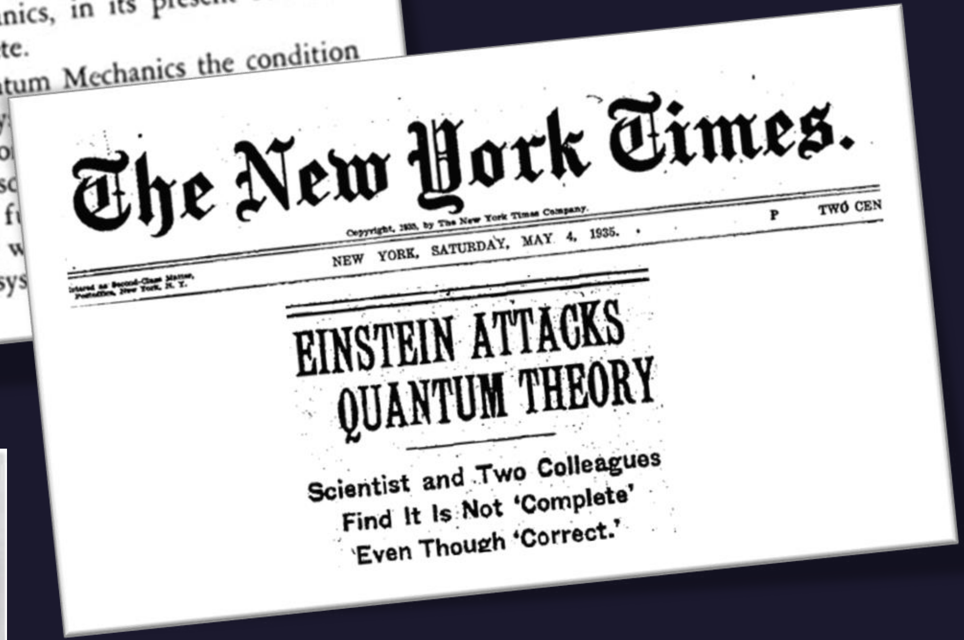
With two colleagues at the Institute for Advanced Study at Princeton, N. J., the great relativist is about to report to

shown that the wave function (of quantum theory) does not provide a complete description of the physical reality, we left open the question of whether or not such a description exists. We believe, however, that such a theory is possible."

The development of quantum mechanics has proved very useful in explor-

Rosen now discuss the question of the completeness of Quantum Mechanics. They arrive at the conclusion that Quantum Mechanics, in its present form, is *not* complete.

In Quantum Mechanics the condition of any phy… tron, an ato… pletely desc… a "wave f… know the w… physical sys…



The New York Times.

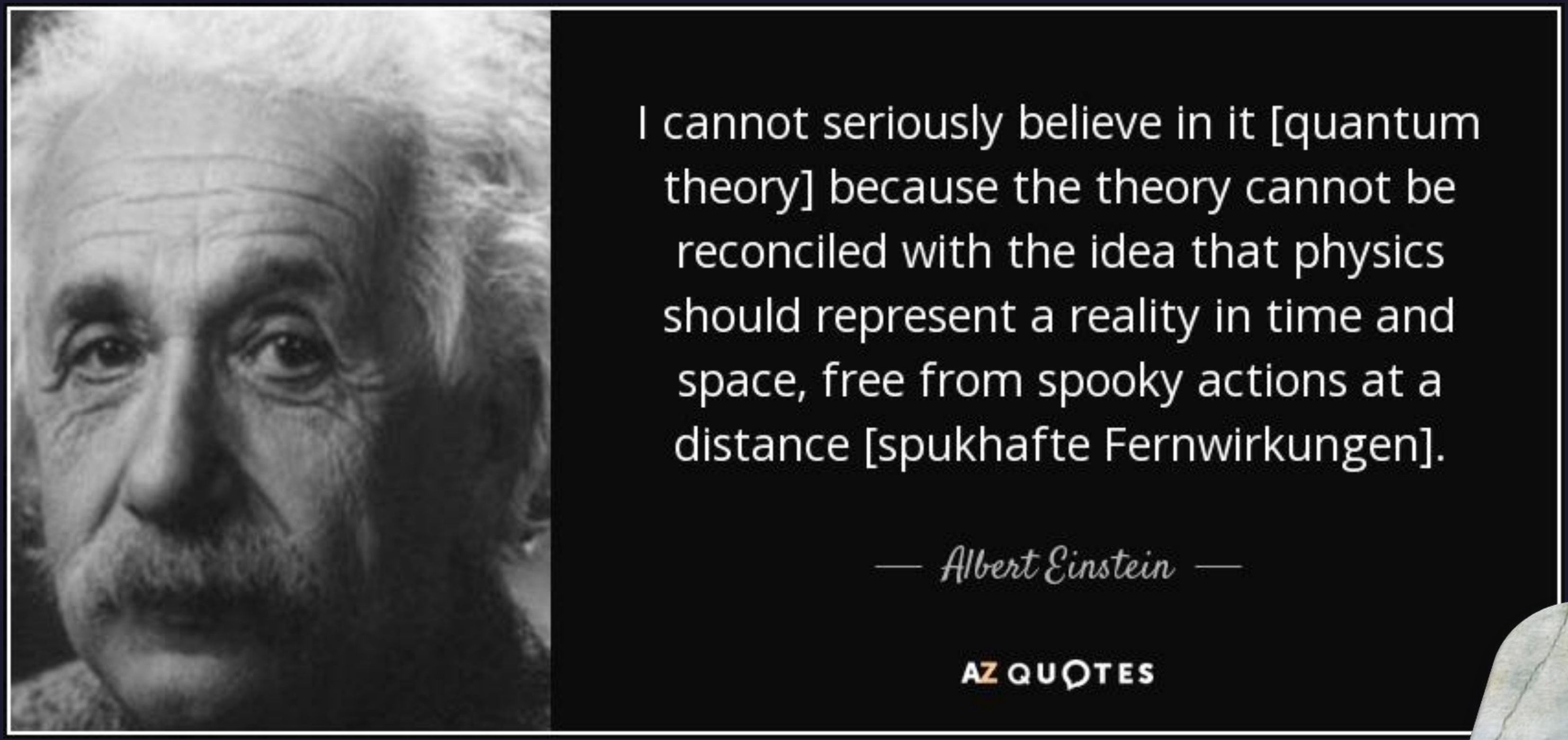
NEW YORK, SATURDAY, MAY 4, 1935.

TWO CEN

EINSTEIN ATTACKS QUANTUM THEORY

Scientist and Two Colleagues Find It Is Not 'Complete' Even Though 'Correct.'

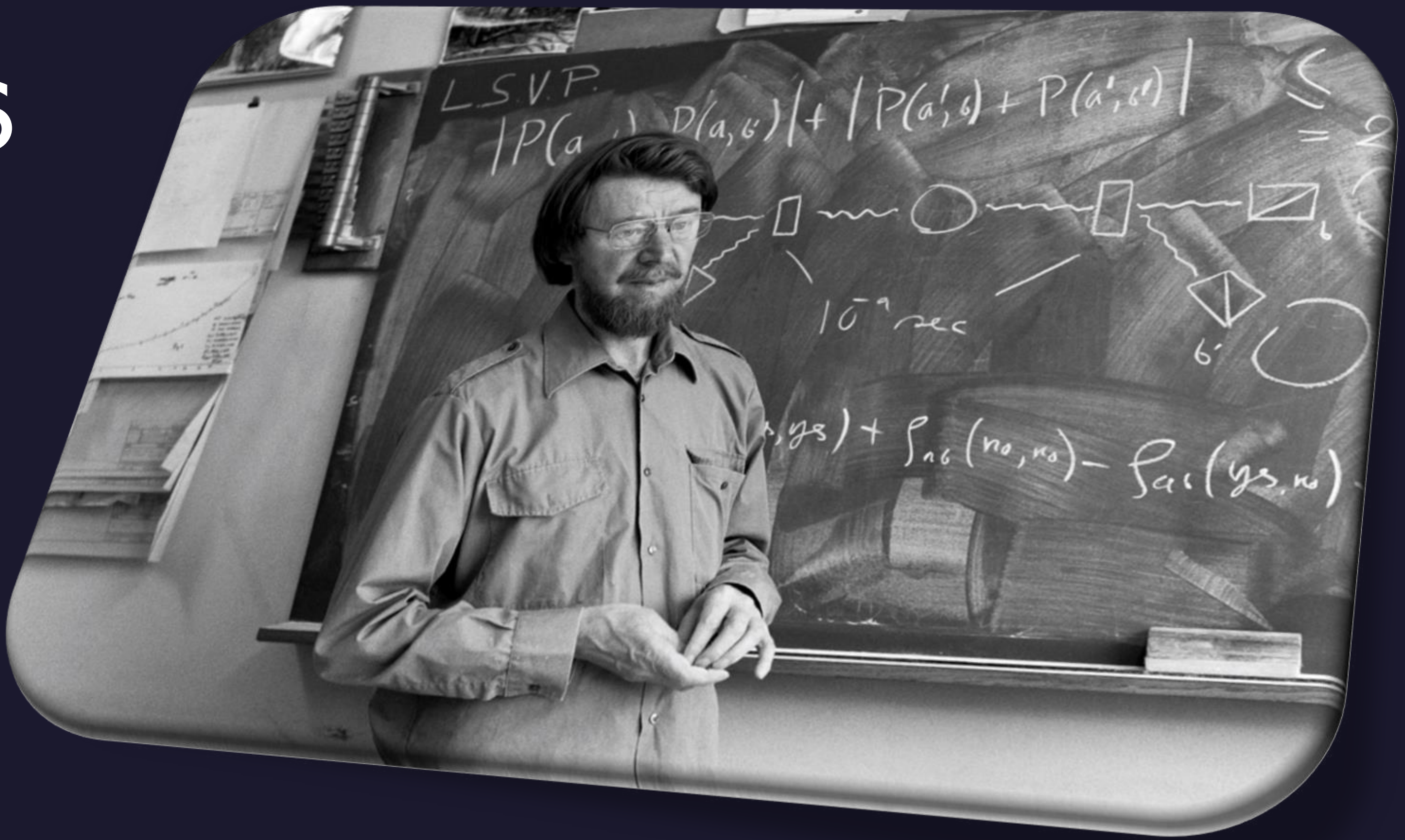
Entanglement: Può la Meccanica Quantistica Ritenersi Completa?



1935

Il Teorema di Bell 1966

- J. Bell riesce a stabilire la possibilità di ciò che nella filosofia della scienza viene chiamato «Esperimento Cruciale»: una nuova situazione sperimentale per la quale la previsione teoria della meccanica quantistica è discrepante con ciò che necessariamente fa qualsiasi teoria che presuppone l'esistenza di elementi di realtà locali;
- L'esperimento ipotizza la misura di 3 proprietà binarie



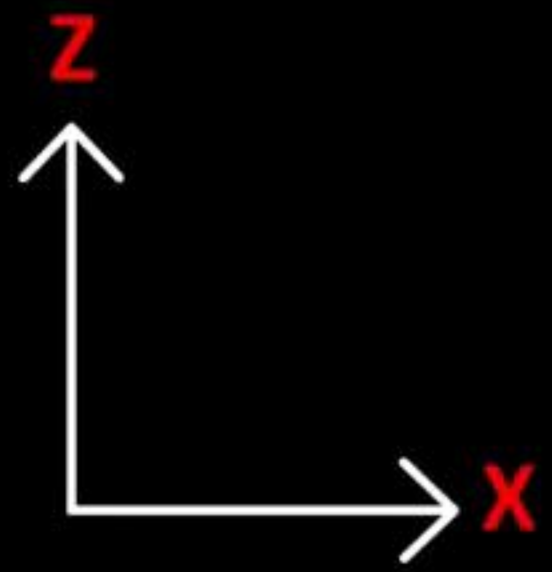
John Stewart Bell (1928-1990)

Il Teorema di Bell

Proprietà 1 : Indossare il Cappello

Proprietà 2 : Indossare gli Occhiali

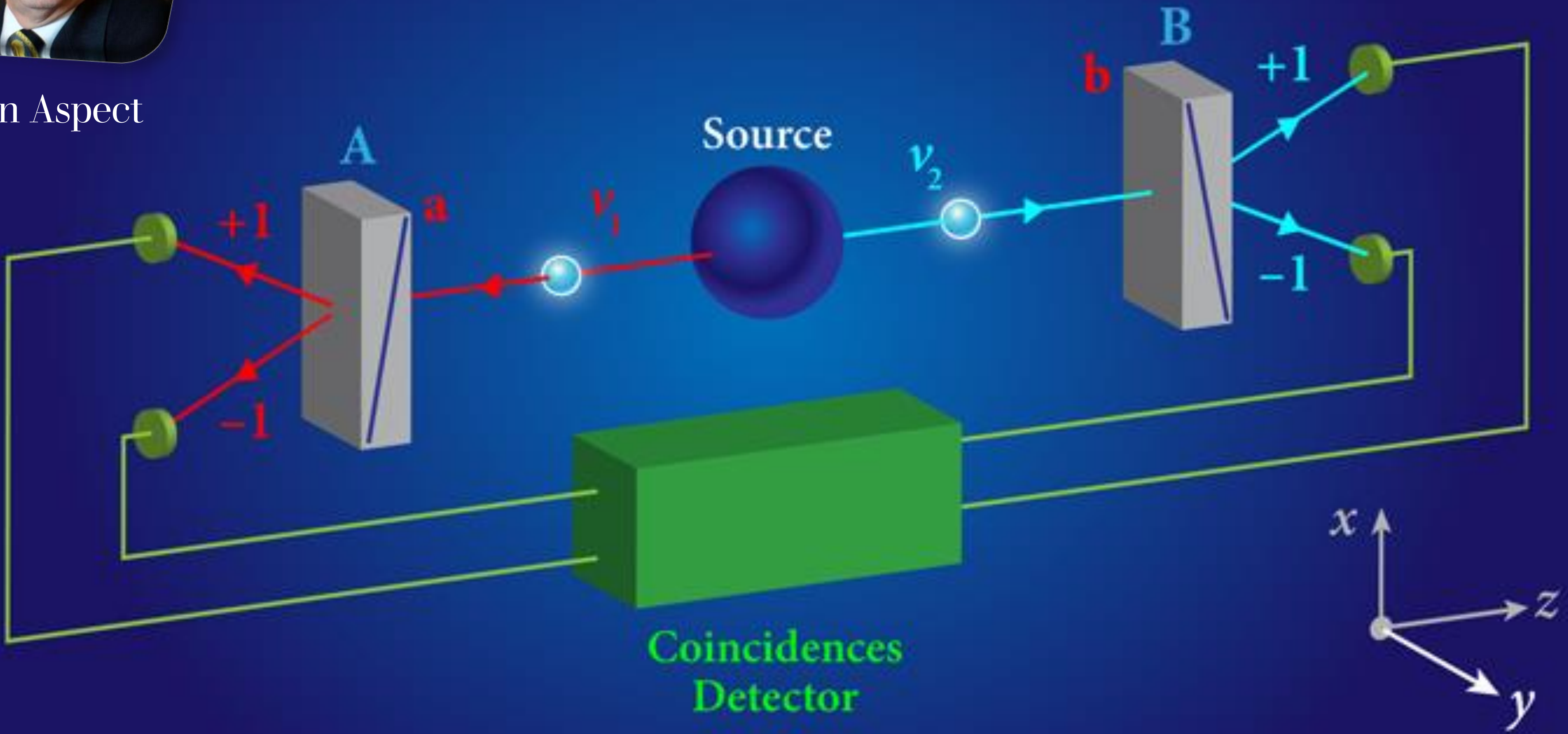
Proprietà 3 : Indossare i Calzini


Z
X

1982

Alain Aspect

$$|\Psi(\nu_1,\nu_2)\rangle = \frac{1}{\sqrt{2}}\left\{|x,x\rangle + |y,y\rangle\right\}$$



80 Anni di Studio!

PHYSICAL REVIEW VOLUME 47
MAY 15, 1935

Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?

A. EINSTEIN, B. PODOLSKY AND N. ROSEN, *Institute for Advanced Study, Princeton, New Jersey*
(Received March 25, 1935)

In a complete theory there is an element corresponding to each element of reality. A sufficient condition for the reality of a physical quantity is the possibility of predicting it with certainty, without disturbing the system. In quantum mechanics in the case of two physical quantities described by non-commuting operators, the knowledge of one precludes the knowledge of the other. Then either (1) the description of reality given by the wave function in

VOLUME 49, NUMBER 2 PHYSICAL REVIEW LETTERS 12 JULY 1982

Experimental Realization of Einstein-Podolsky-Rosen-Bohm *Gedankenexperiment*: A New Violation of Bell's Inequalities

Alain Aspect, Philippe Grangier, and Gérard Roger
Institut d'Optique Théorique et Appliquée, Laboratoire associé au Centre National de la Recherche Scientifique, Université Paris-Sud, F-91406 Orsay, France
(Received 30 December 1981)

The linear-polarization correlation of pairs of photons emitted in a radiative cascade of calcium has been measured. The new experimental scheme, using two-channel polarizers (i.e., optical analogs of Stern-Gerlach filters), is a straightforward transposition of Einstein-Podolsky-Rosen-Bohm *gedankenexperiment*. The present resu... lead to the grea... agreement with the quantum mechanical predictions, ... eralized Bell's inequalities ever achieved.

PACS numbers: 03.65.Bz, 35.80.+s

In the well-known Einstein-Podolsky-Rosen-Bohm *gedankenexperiment*[1] (Fig. 1), a source emits pairs of spin-$\frac{1}{2}$ particles, in a singlet state (or pairs of photons in a similar nonfactorizing state). After the particles have separated, one performs correlated measurements of their spin components along arbitrary directions $\vec{a}$ and $\vec{b}$. Each measurement can yield two results, denoted ±1; for photons, a ... the result +1 if the ... to $\vec{a}$, and −1 if the ... dicular. For a sing... predicts some corr... urements on the tw... $P_{\pm\pm}(\vec{a}, \vec{b})$ the probab... ±1 along $\vec{a}$ (particle... The quantity

http://arxiv.org/abs/1508.05949

Experimental loophole-free violation of a Bell inequality using entangled electron spins separated by 1.3 km

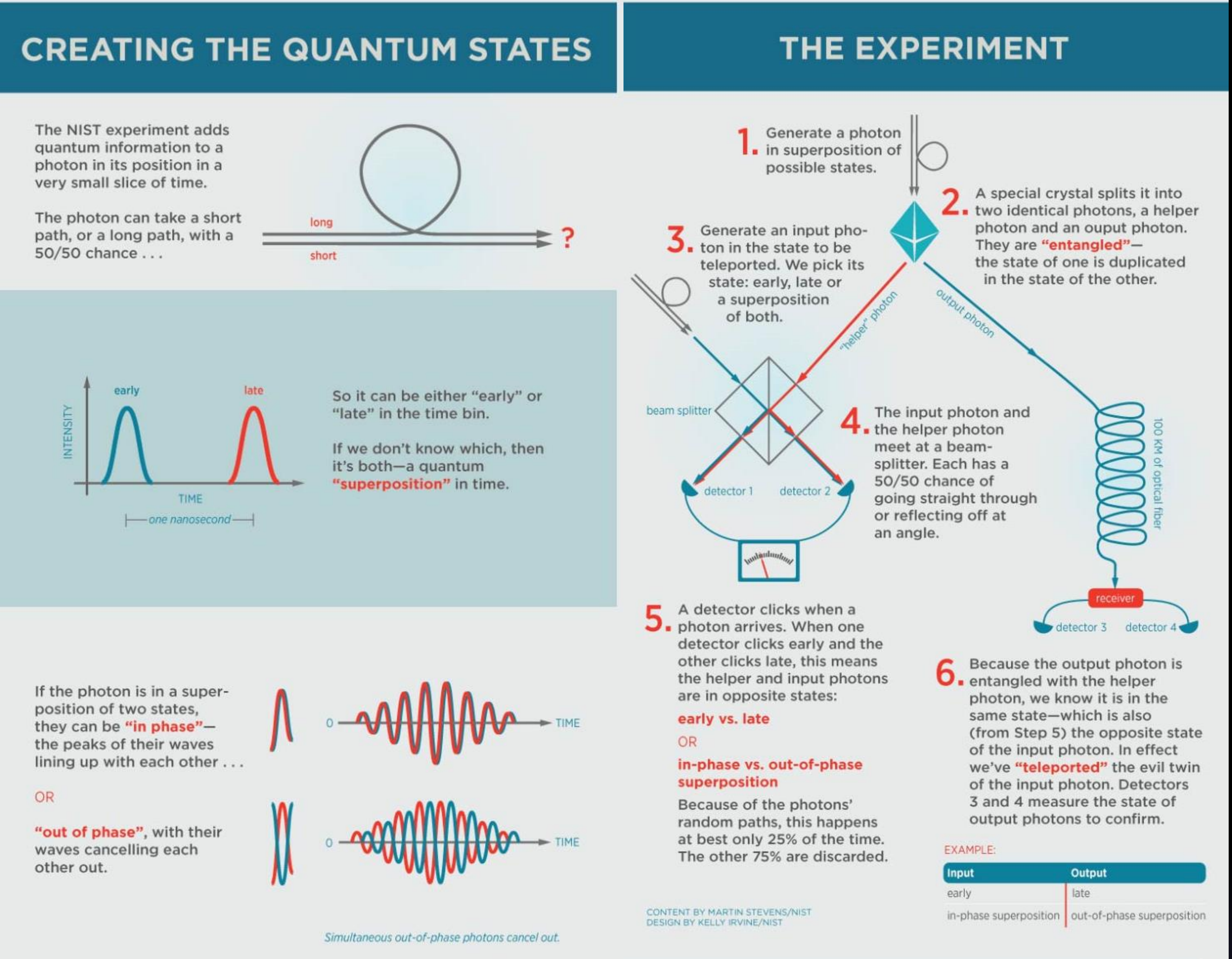
B. Hensen, H. Bernien, A.E. Dréau, A. Reiserer, N. Kalb, M.S. Blok, J. Ruitenberg, R.F.L. Vermeulen, R.N. Schouten, C. Abellán, W. Amaya, V. Pruneri, M. W. Mitchell, M. Markham, D.J. Twitchen, D. Elkouss, S. Wehner, T.H. Taminiau, R. Hanson (Submitted on 24 Aug 2015)

For more than 80 years, the counterintuitive predictions of quantum theory have stimulated debate about the nature of reality. In his seminal work, John Bell proved that no theory of nature that obeys locality and realism can reproduce all the predictions of quantum theory. Bell showed that in any local realist theory the correlations between distant measurements satisfy an inequality and, moreover, that this inequality can be violated according to quantum theory.

Entanglement e Informazione


Teletrasporto

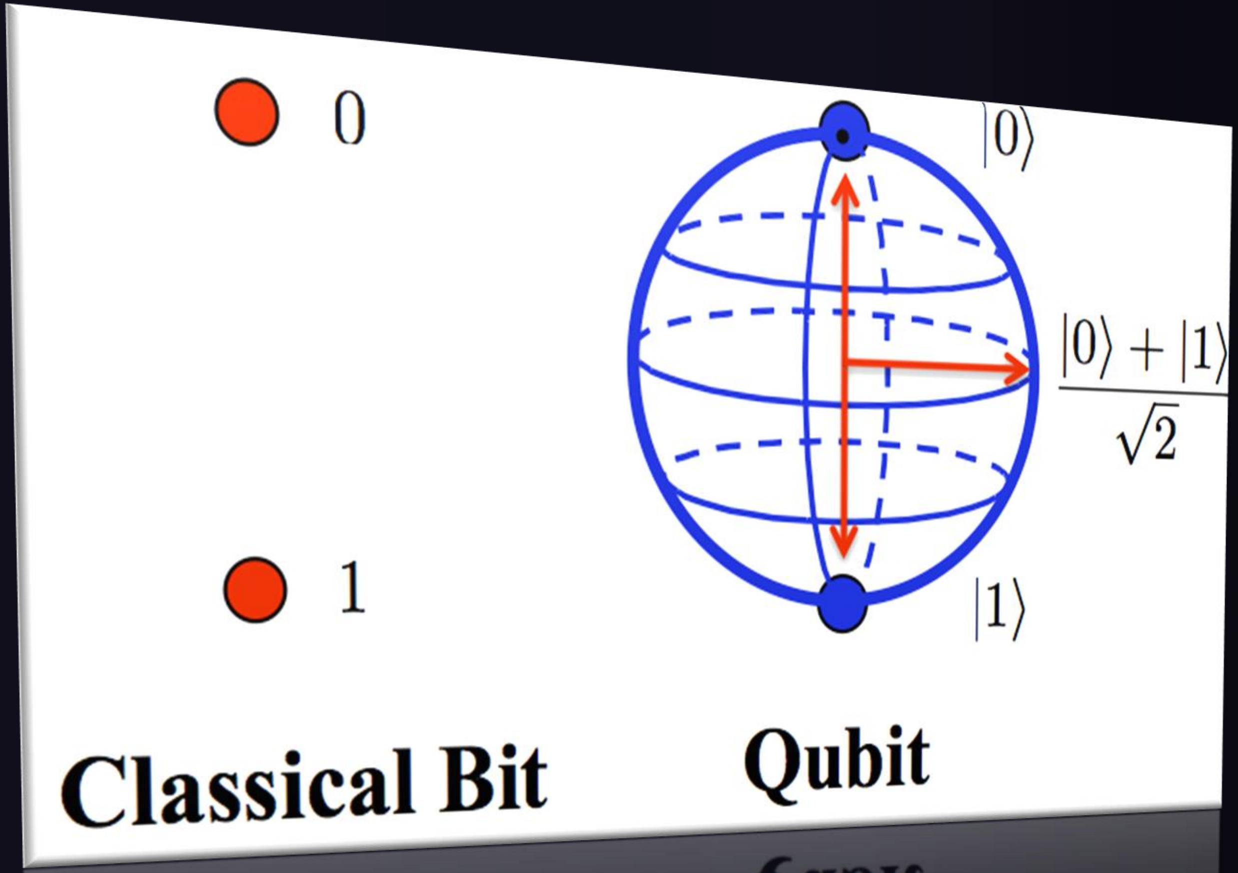
Teletrasporto



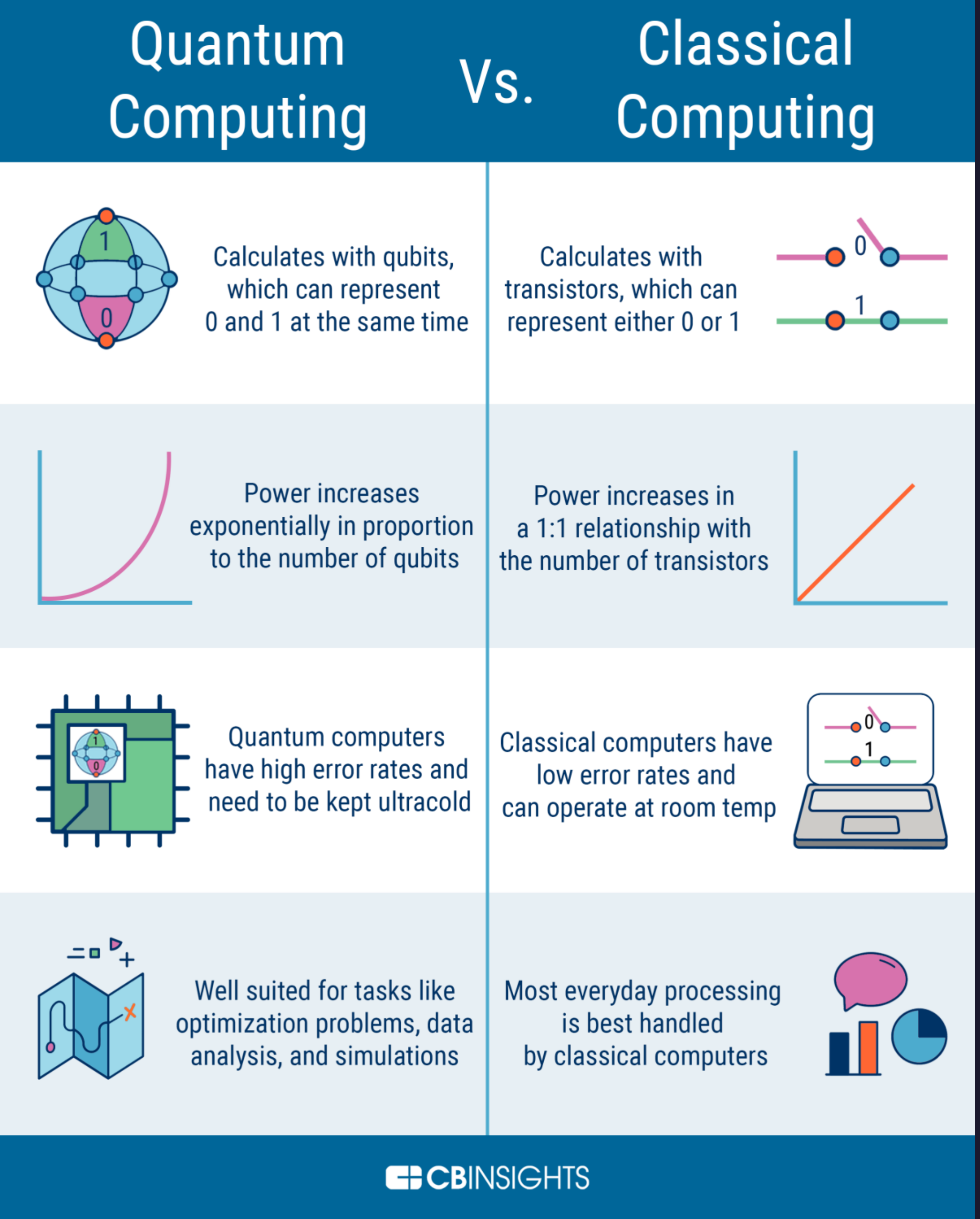
Teletrasporto

QBit

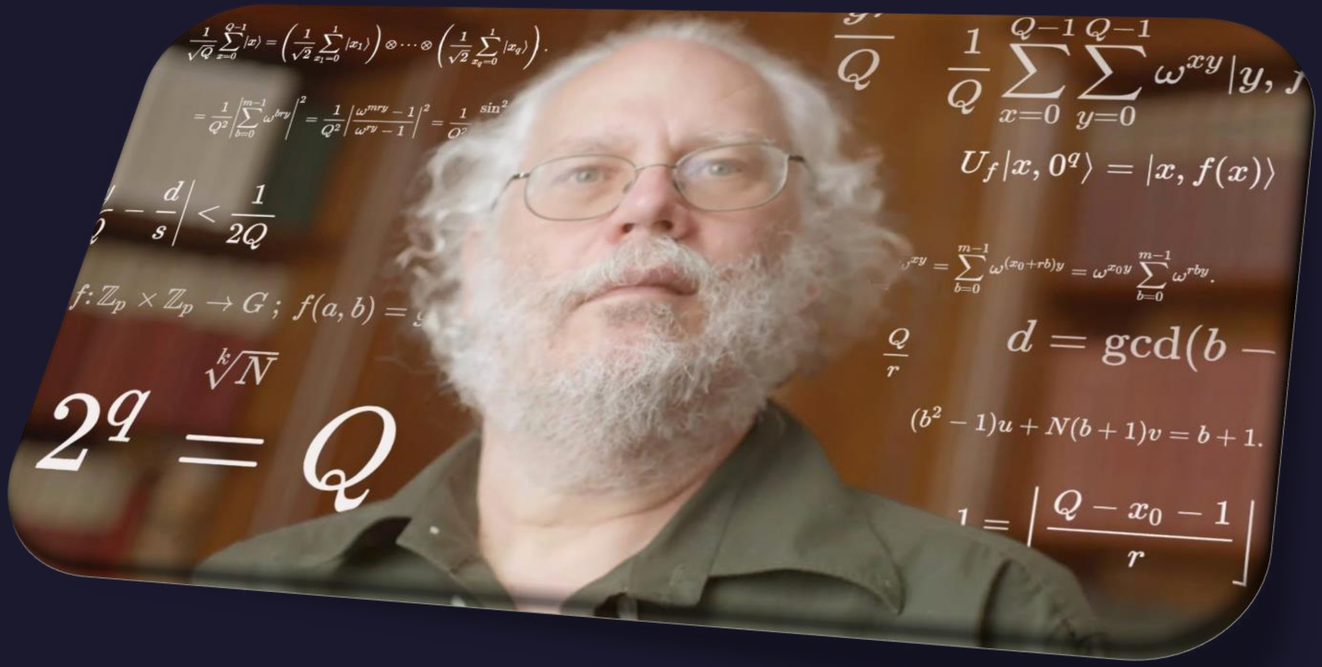
QBit

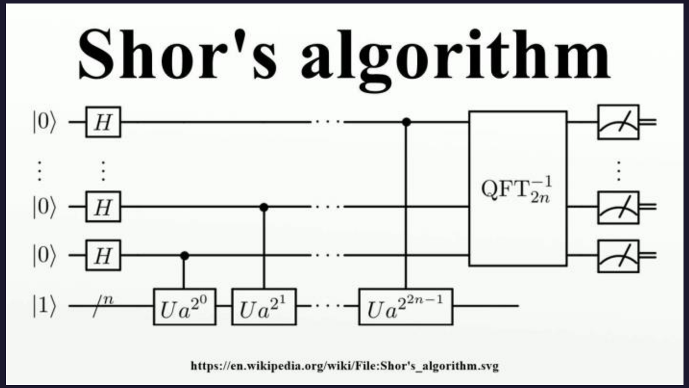


- Rispetto al bit, nella teoria quantistica l’unità di informazione è il Qbit che, in base alla sua natura quantistica, anche se è anch’esso dicotomico per quanto riguarda i valori possibili di una misurazione, può tuttavia occupare stati di sovrapposizione…


Quantum Computing
Vs.
Classical Computing
Calculates with qubits, which can represent 0 and 1 at the same time
Calculates with transistors, which can represent either 0 or 1
Power increases exponentially in proportion to the number of qubits
Power increases in a 1:1 relationship with the number of transistors
Quantum computers have high error rates and need to be kept ultracold
Classical computers have low error rates and can operate at room temp
Well suited for tasks like optimization problems, data analysis, and simulations
Most everyday processing is best handled by classical computers
CBINSIGHTS

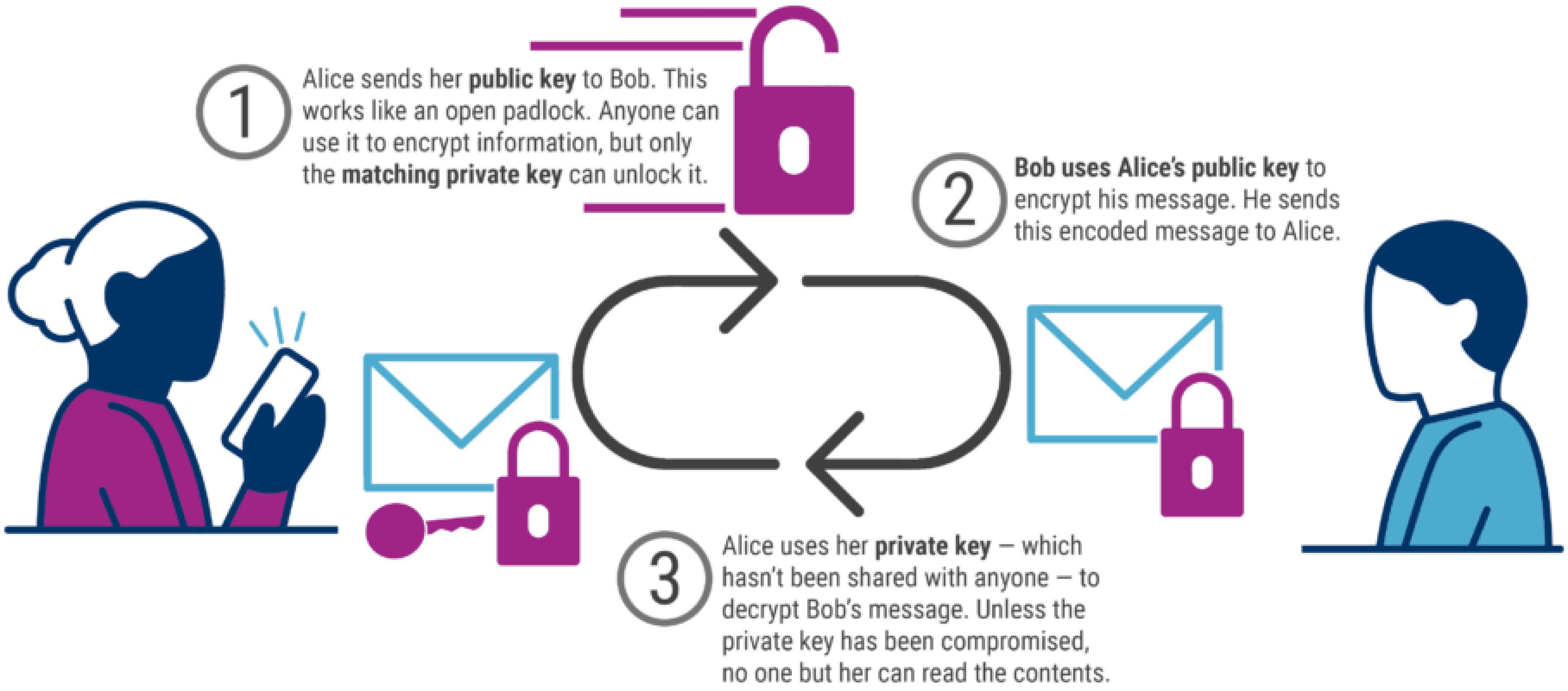
QBit




Shor's algorithm
https://en.wikipedia.org/wiki/File:Shor's_algorithm.svg

Crittografia

How public-key cryptography works

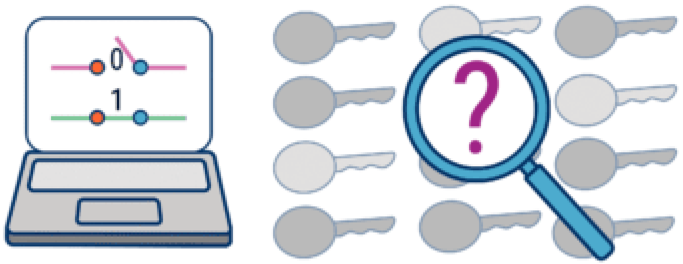


CB INSIGHTS

Why quantum computers threaten today's public-key cryptography

Public-key cryptography is commonly used to communicate online

Bob wants to send a message to Alice. To do this privately, **Alice generates a public key and a private key**. Bob uses the public key to encrypt a message that can only be decoded using Alice's matching private key.

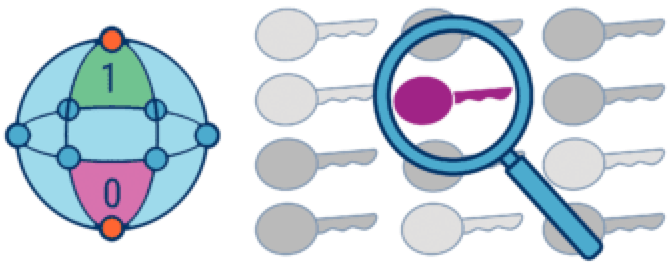


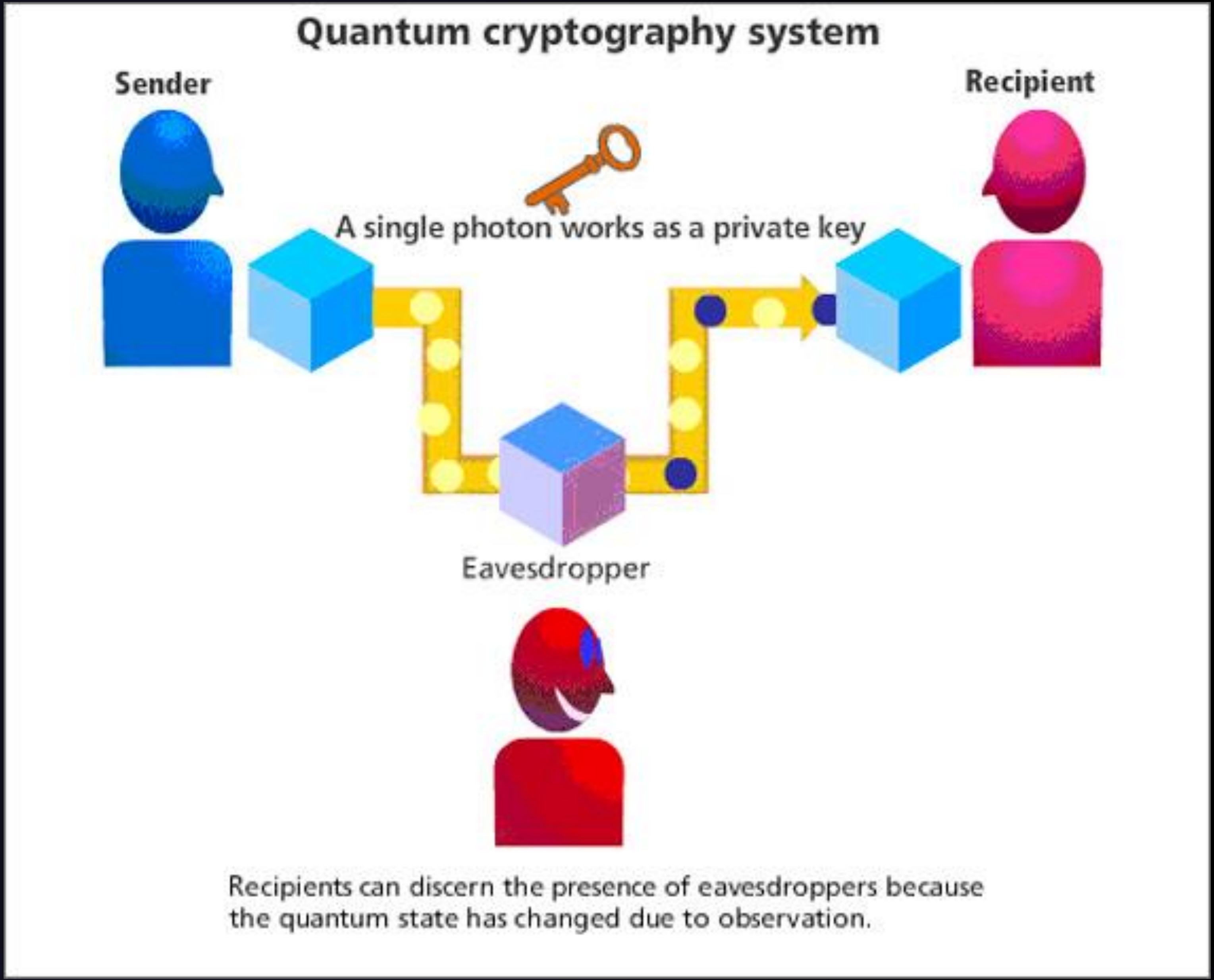
Classical computers find identifying a private key extremely difficult

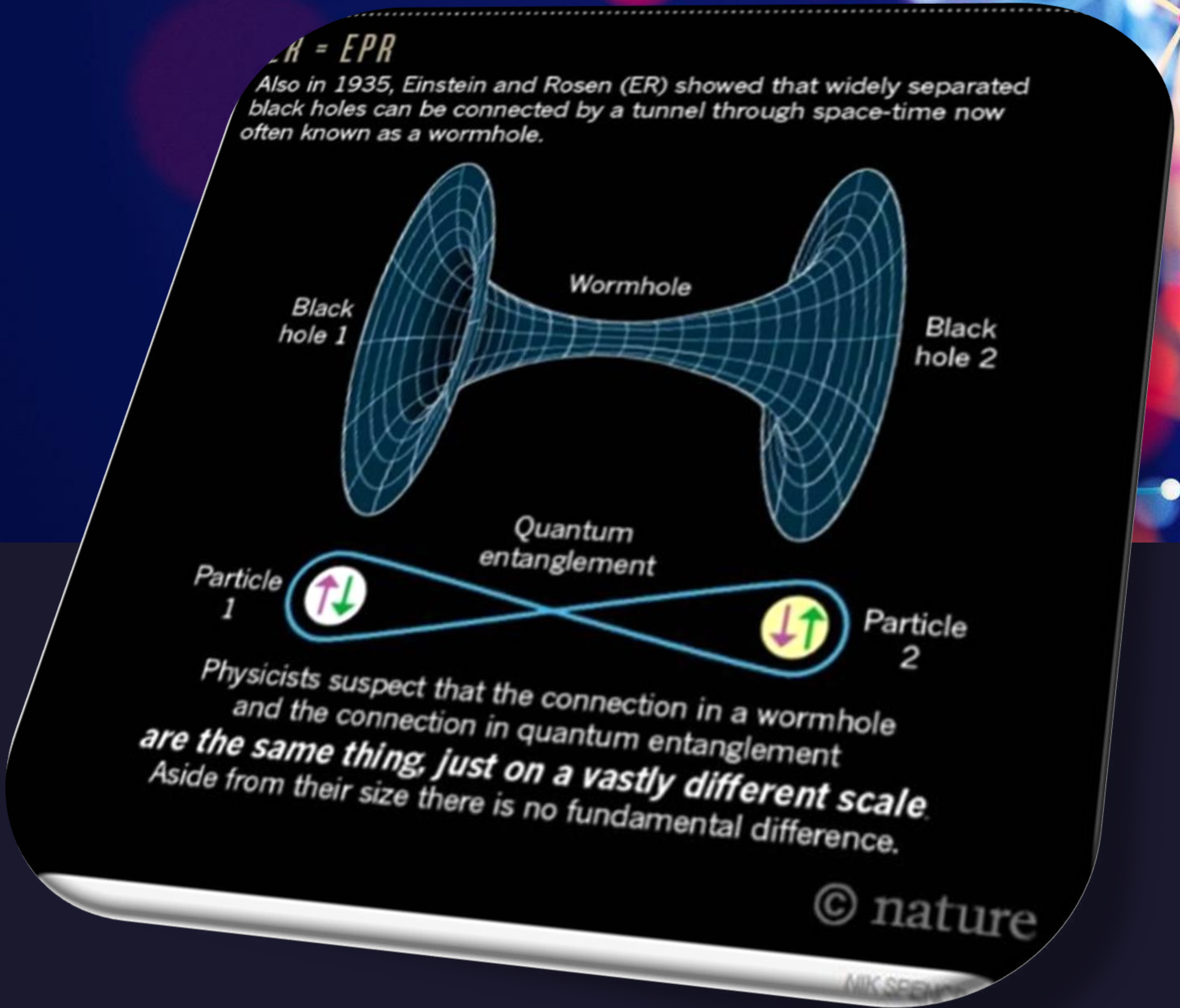
Only Alice has the private key, but **her public key is accessible to anyone**. Classical computers find the current mathematical problems linking private keys to public keys very challenging — minimizing the risk they pose.

But quantum computers can figure out a private key quickly

Quantum computers process information in a different way to conventional computers, allowing new types of calculation. This includes an algorithm that can **quickly figure out a private key purely from a public key** for encryption methods commonly used online.




Quantum cryptography system
Sender
Recipient
A single photon works as a private key
Eavesdropper
Recipients can discern the presence of eavesdroppers because the quantum state has changed due to observation.



Quantum Gravity e oltre ...

Grazie

Giovanni Della Lunga

giovanni.dellalunga@gmail.com

https://github.com/polyhedron-gdl