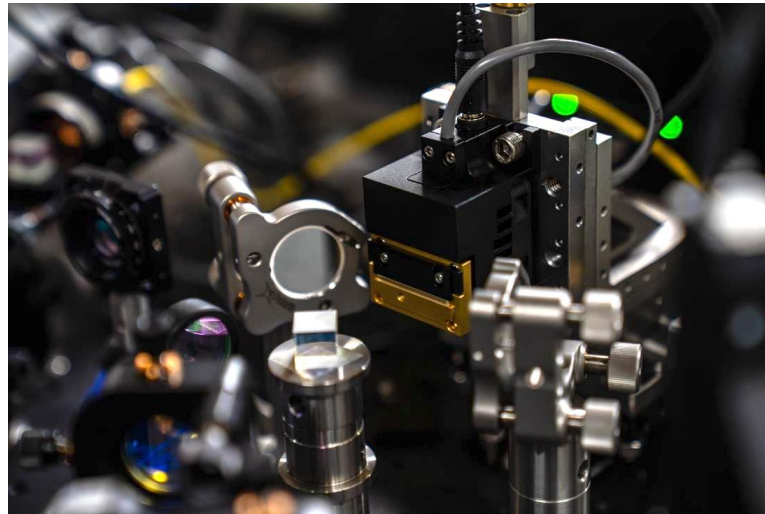


QUANTUM TECH IS IN YOUR PUBLIC LIBRARY



Gina Lorenz
University of Illinois Urbana-Champaign
PHYS403, 11/18/25



UNIVERSITY OF
ILLINOIS
URBANA-CHAMPAIGN



NATIONAL QUANTUM INITIATIVE

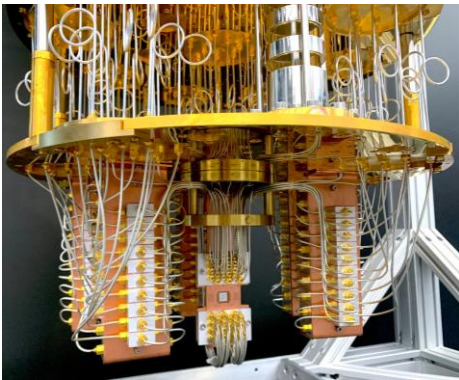
THE FEDERAL SOURCE AND GATEWAY TO QUANTUM R&D ACROSS THE U.S. GOVERNMENT

- The National Quantum Initiative Act was signed into law on December 21, 2018. The law gives the United States a plan for advancing quantum technology.
- This act has spurred a tsunami of funding for quantum research and industry, much of it centered around “Quantum 2.0” technology.

WHAT IS QUANTUM 2.0?

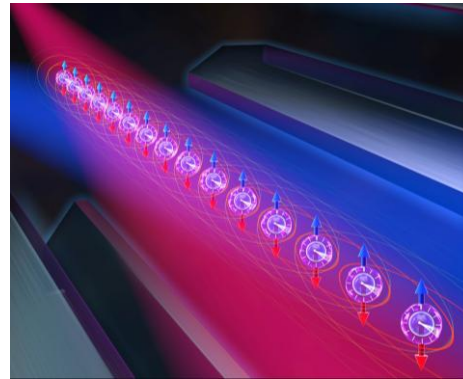
Quantum 1.0: semiconductor junctions, transistors, lasers, etc.

Quantum 2.0 tech uses phenomena like **superposition** and **entanglement** for



Quantum Computers

- break encryption
- perform calculations impossible for regular computers
- simulate quantum systems for e.g. drug discovery



Quantum Sensors

- synchronize clocks better
→ better GPS
- improve sensitivity of probes in medicine, transportation, and fundamental science

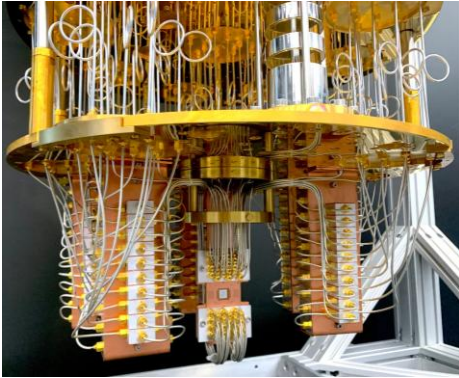


Quantum Networks

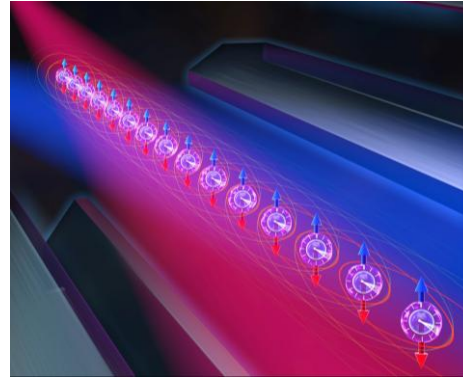
- connect quantum computers in a “quantum internet”
- communicate securely
- improve astronomical observation



HANDS-ON QUANTUM 2.0



quantum cloud computing:
over a dozen companies



entanglement-based sensors
still in the lab



quantum networks: a few in the
world, but not publicly accessible

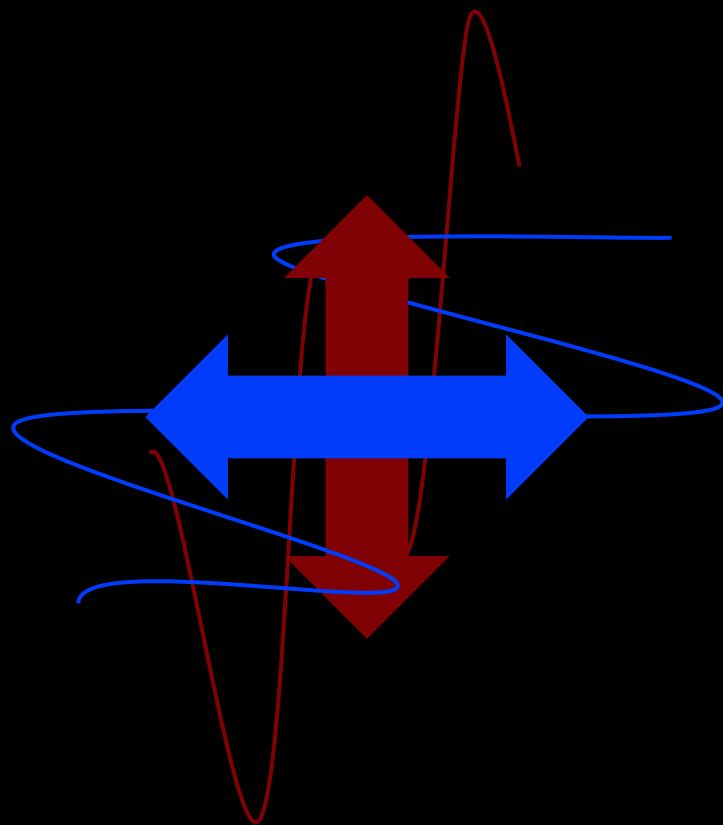
In the history of quantum entanglement, **quantum light** was and remains one of the most “accessible” hands-on quantum 2.0 technologies.

To see why this is, let’s dive right in...

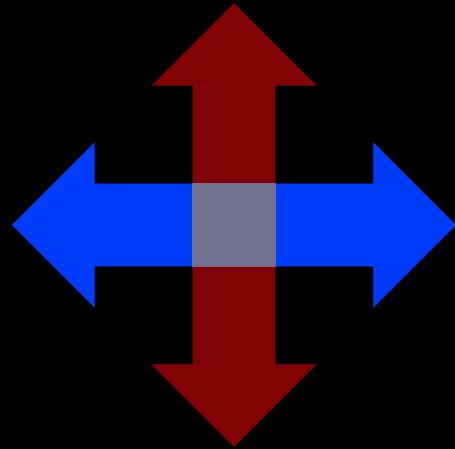
Quantum

The smallest quantity of light is a photon.
Quantum science describes how photons and other quantum particles behave.

Superposition



Superposition



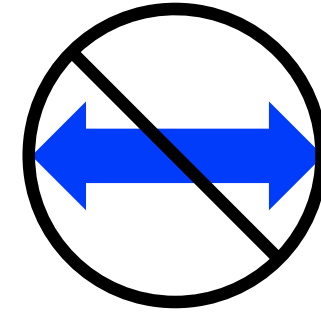
Measurement



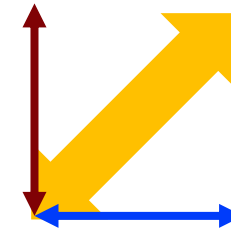
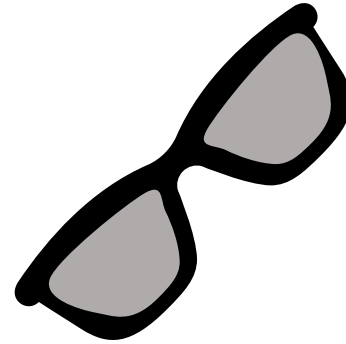
Polarizers only let through photons that wave a certain direction.



The polarizers block photons waving horizontally.



Diagonal: superposition of vertical and horizontal

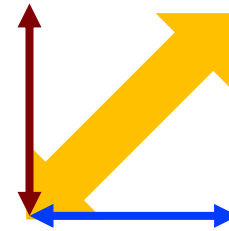
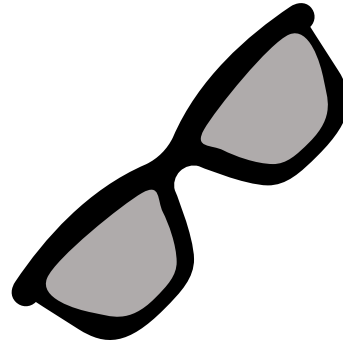
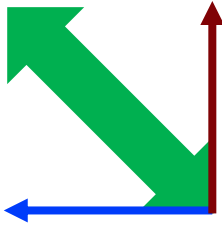
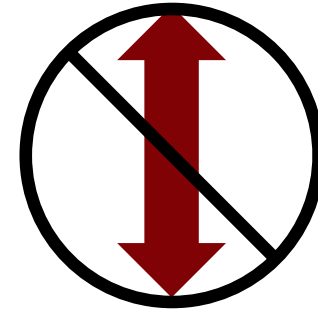
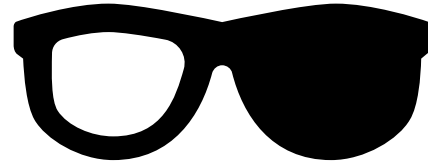


Some horizontally polarized photons get through because their polarizations *changed* into a superposition after the diagonal polarizer.





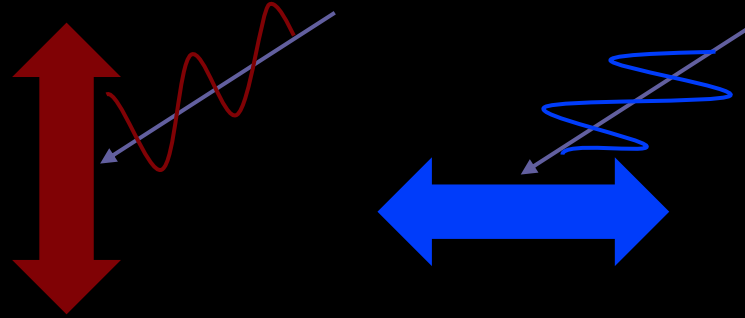
IMAX glasses



Note: some IMAX glasses use circular polarization and this won't work

Superposition

Photons can be polarized



Photons can be in a superposition of two possibilities

possibility

P $| \uparrow \rangle$ $| \downarrow \rangle$

$$| \uparrow \rangle + | \downarrow \rangle$$



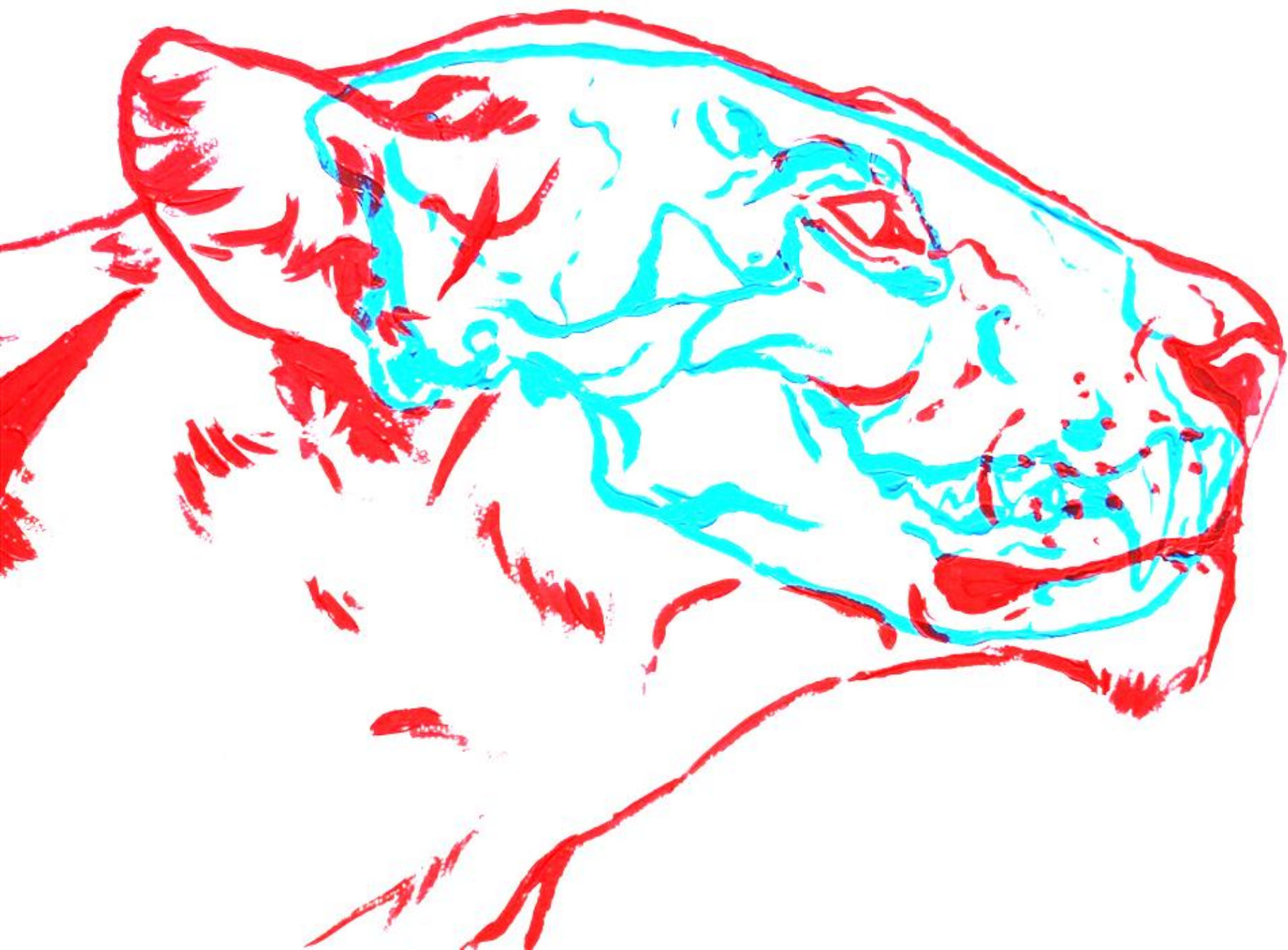
We write a superposition using symbols called “kets” (last part of “bracket”)

Quantum science challenges commonly held beliefs

Belief: “Objects have definite states before measurement.”

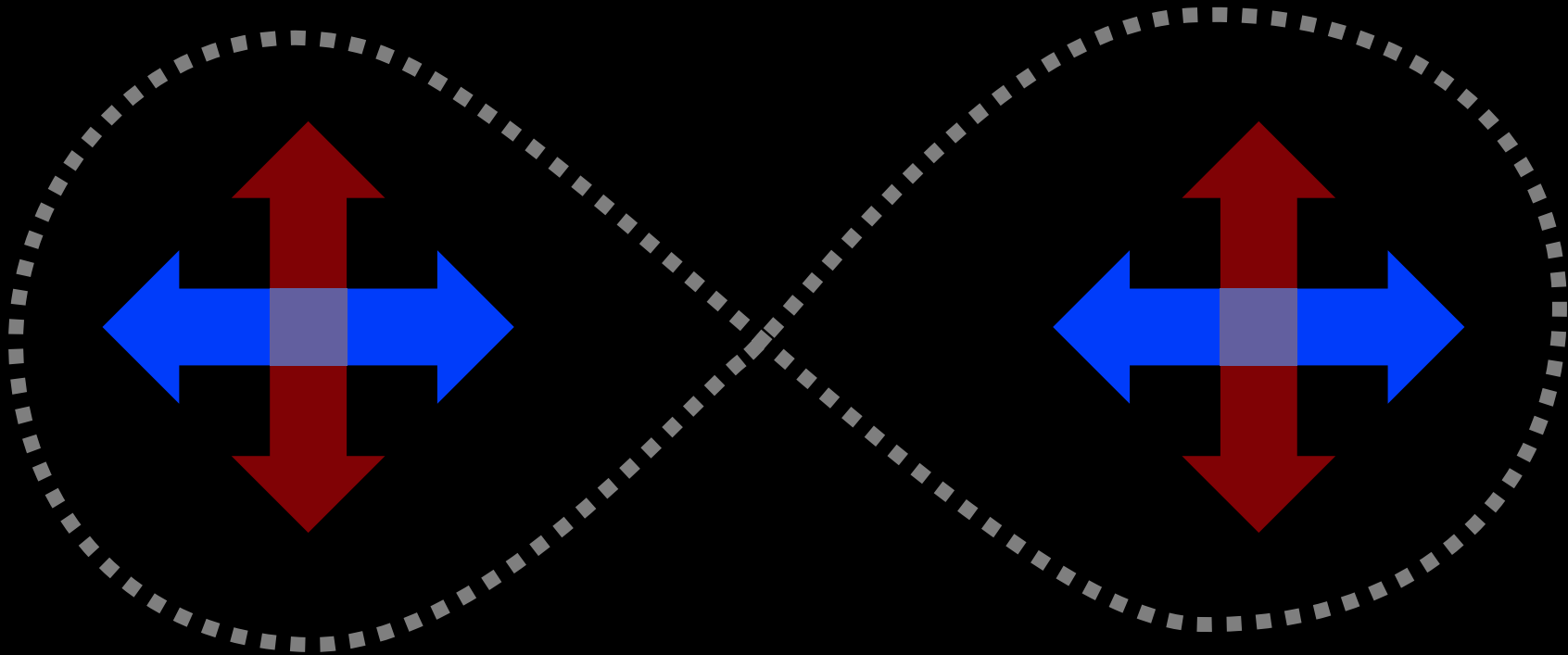
Superposition implies quantum particles may not.

Then is there an objective **reality** before measurement?

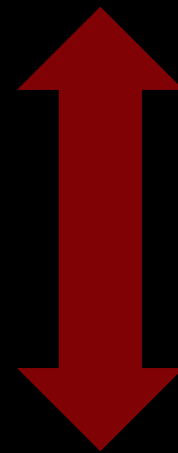
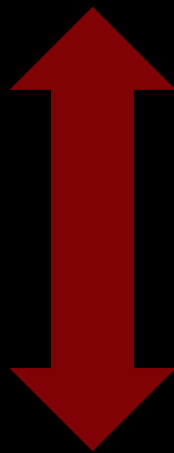


Entanglement

Entanglement



Measurement



Polarization Entanglement

- Photons can be in a **superposition** of two polarizations

$$| \updownarrow \rangle + | \leftrightarrow \rangle$$

- Two photons can be **entangled** such that when one of them is measured, they always end up being the same polarization

$$| \updownarrow \updownarrow \rangle + | \leftrightarrow \leftrightarrow \rangle$$

- This property allows them to behave as if they were one object no matter the distance

Why is this not entanglement?

- Consider socks in a box
- There are two boxes of socks. The socks can be red or green.
- Which color they are is determined randomly by a machine, but the two boxes always have the same color socks.
- The socks are sent to distant locations, like Timbuktu and Wananiffee.
- The recipients open the boxes simultaneously.
- Great fox! They always find the same color socks in the box!

With photons

- We don't know what color the photons are, not because it's hidden, but because the photons are in a superposition of colors
- Their color won't be determined until the recipient sees the color.
- At the instant the color is measured, the color of the other photon becomes the same.
- So the key differences are:
 - The colors are not predetermined (violating realism)
 - Measuring the color of one instantaneously sets the color of the other (violating locality)

Quantum Analogies

“Every analogy is limited, otherwise it would be the real thing and not an analogy.”

- David Bohm

So what is the real quantum understanding?

Unlike most other science concepts, at the root we do not have an intuitive understanding of quantum phenomena.

Quantum interpretations are used to provide a sense of intuition. They are not yet proven.

Quantum analogies are based on quantum interpretations.

Probing the Connection between Entangled Particles and Wormholes in General Relativity

Ben Kain^{*}

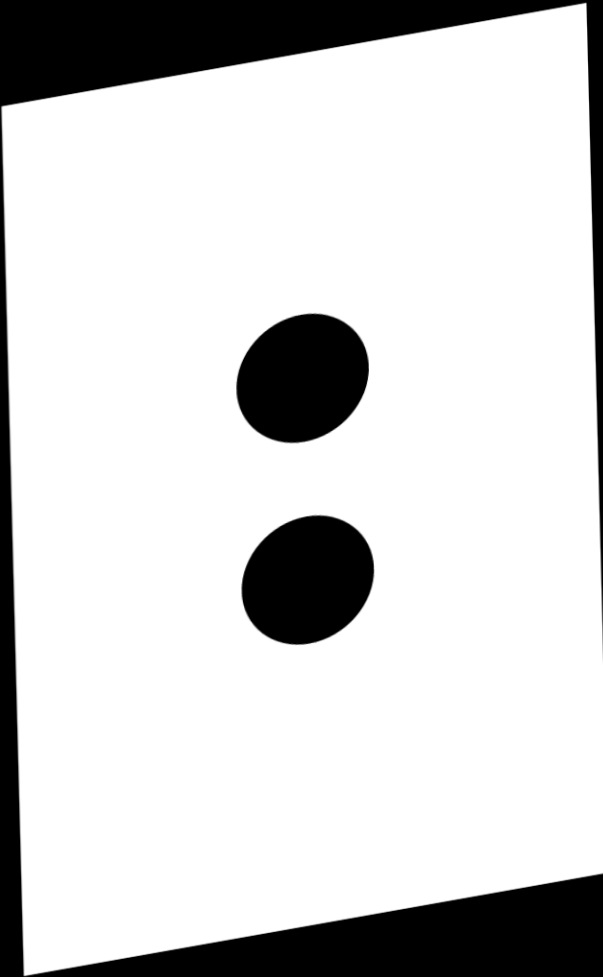
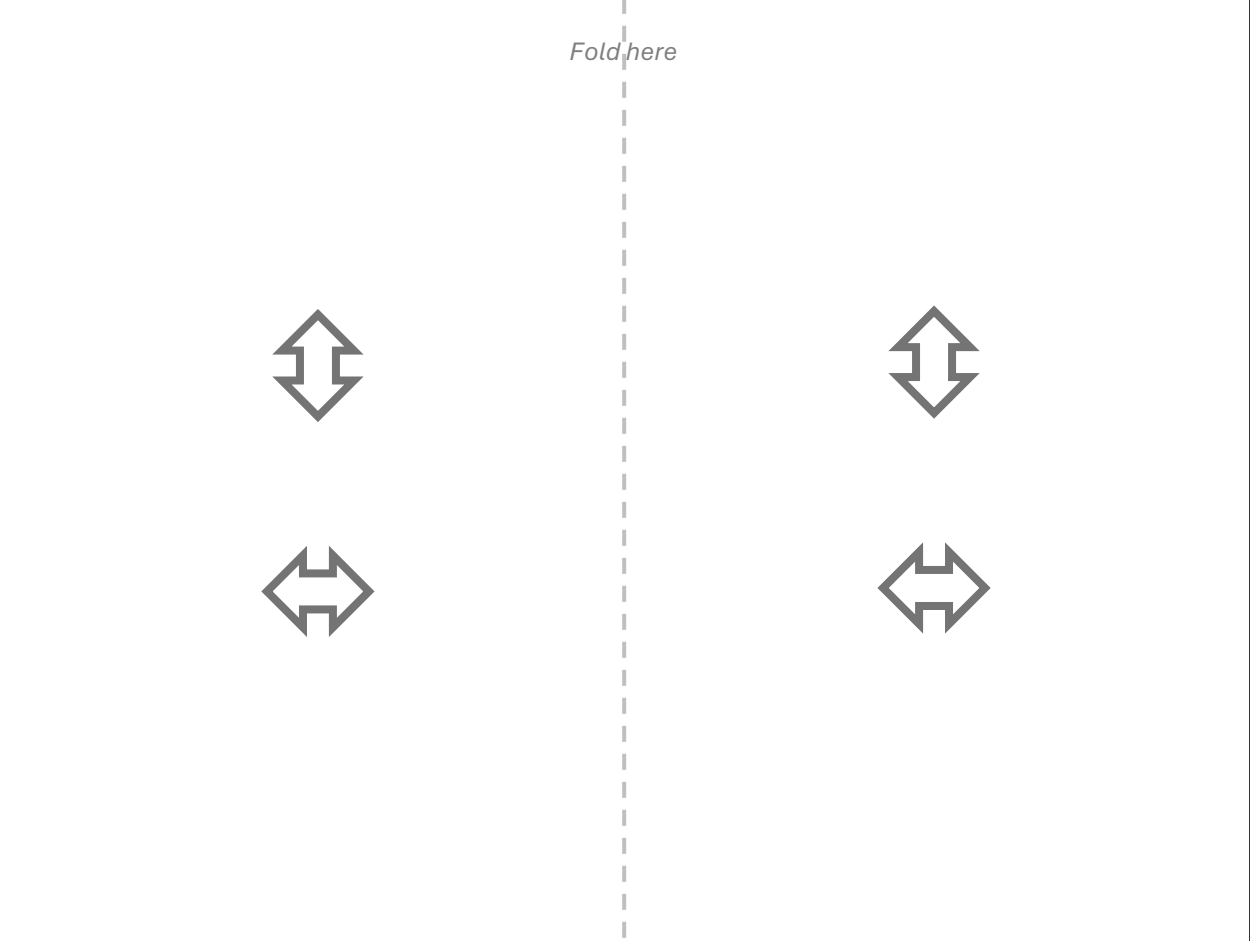
Department of Physics, College of the Holy Cross, Worcester, Massachusetts 01610, USA

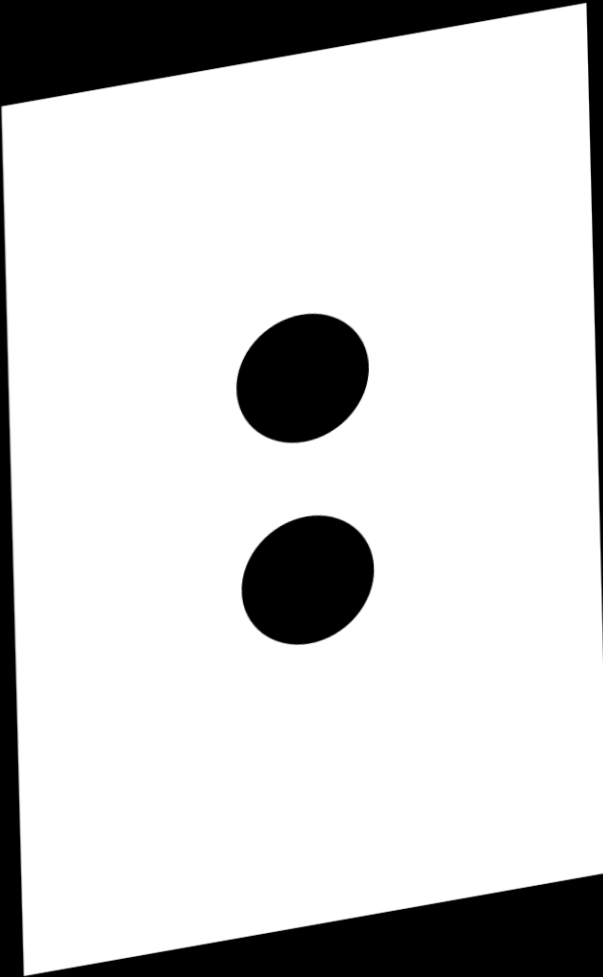
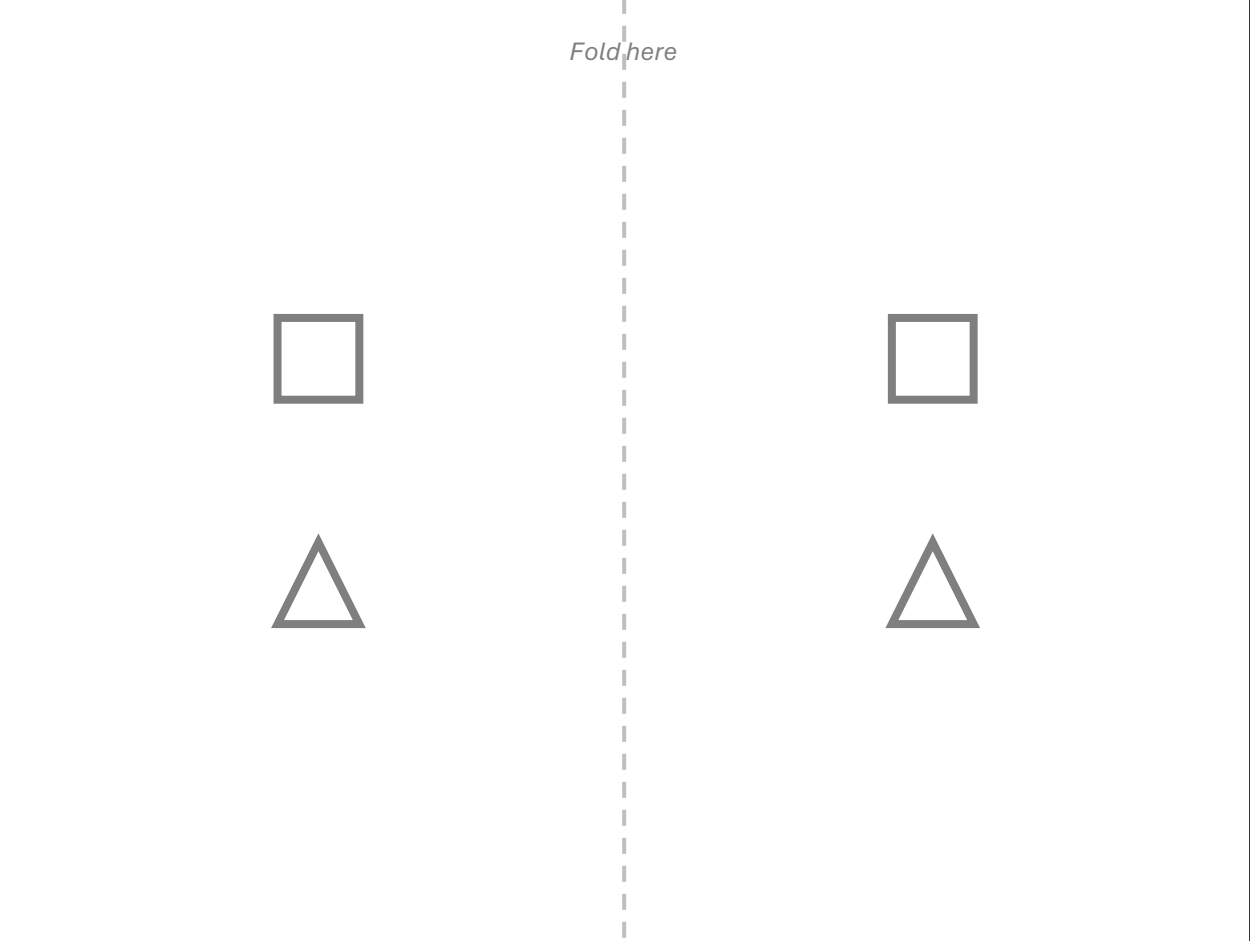


(Received 4 January 2023; accepted 26 July 2023; published 5 September 2023)

Maldacena and Susskind conjectured that two entangled particles, which can be thought of as forming an Einstein-Podolsky-Rosen (EPR) pair, are connected by a nontraversable wormhole or Einstein-Rosen (ER) bridge. They named their conjecture $ER = EPR$. We present a concrete quantitative model for $ER = EPR$, in which two spin-1/2 particles in a singlet state are connected by a nontraversable wormhole in asymptotically flat general relativity. In our model, the fermions are described by the charged Dirac equation minimally coupled to gravity. This system has static wormhole solutions. We use these solutions as initial data and numerically evolve them forward in time. Our simulations show that black holes form, which are connected by the wormhole and which render the wormhole nontraversable. We also find that the wormhole throat shrinks, which places the particles in close proximity to one another and suggests an explanation for how the wormhole facilitates the nonlocal communication required by entanglement.

DOI: [10.1103/PhysRevLett.131.101001](https://doi.org/10.1103/PhysRevLett.131.101001)





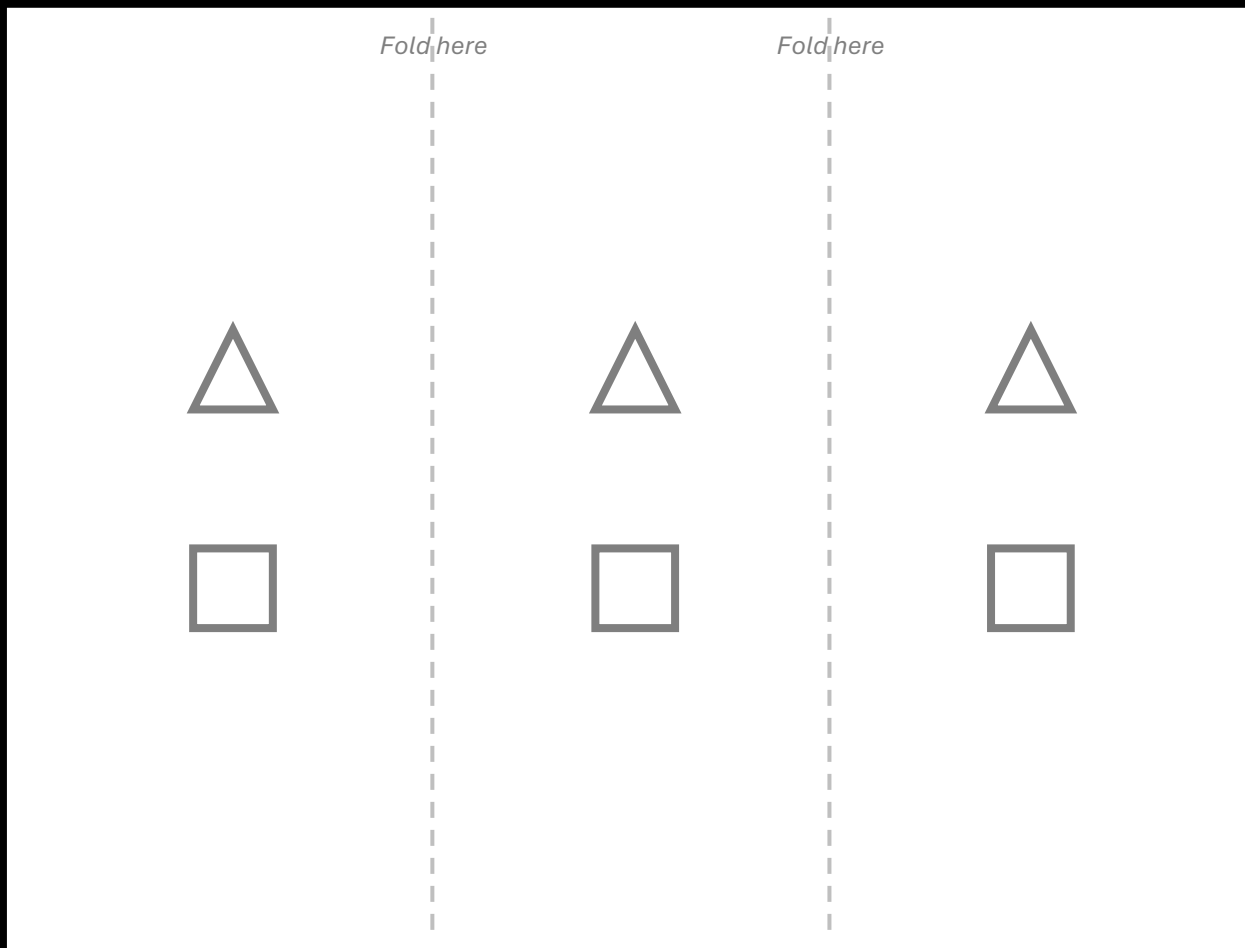
Fold here





Fold here

Fold here



$$|\triangle \triangle \triangle\rangle + |\square \square \square\rangle$$

Properties of Entanglement

at least
“It takes ^Vtwo to tangle.”
J. Eberly, 2015

$$\psi_{pair} \propto |HH\rangle + |VV\rangle \quad \text{Entangled}$$

1935: Entanglement is

“*the* characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought”
—E. Schrödinger

$$\psi_1 \propto |H\rangle + |V\rangle$$

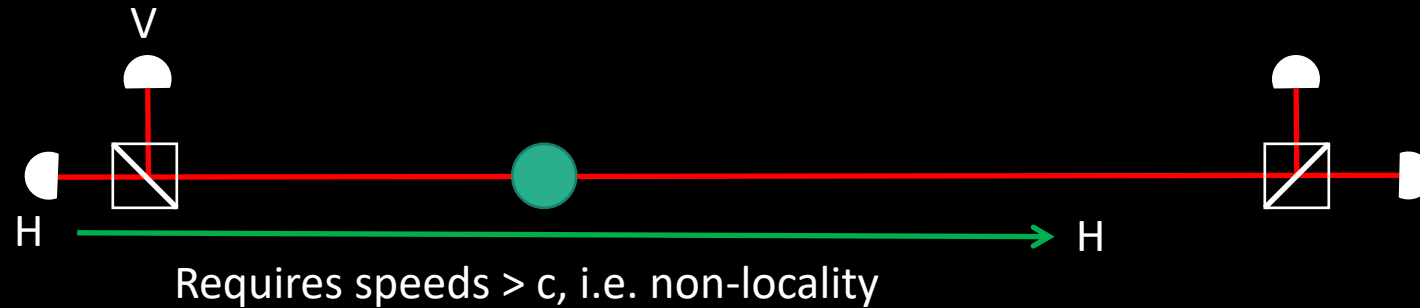
$$\psi_2 \propto |H\rangle + |V\rangle$$

$$\psi_{12} = \psi_1 \psi_2 \propto |HH\rangle + |VV\rangle + |HV\rangle + |VH\rangle \quad \text{Not Entangled}$$

In an **entangled** state, neither particle has definite properties alone.

⇒ All the information is stored in the *joint* properties.

1935: Einstein, Podolsky, Rosen (EPR) Paradox

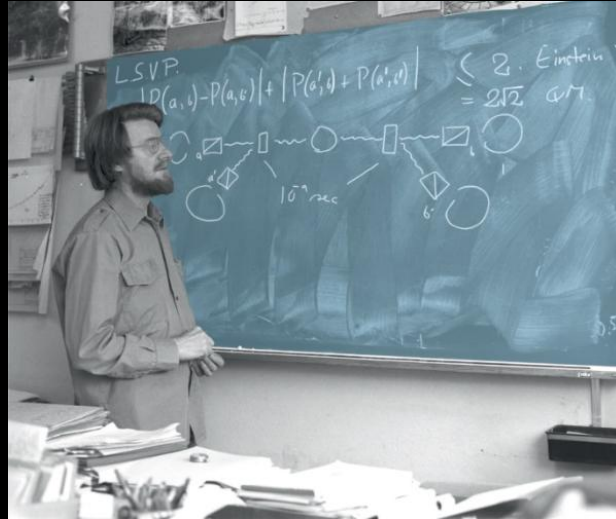


*spooky action
at a distance*

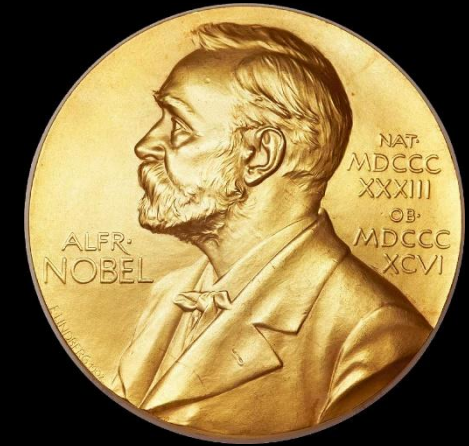
Quantum mechanics challenges two commonly held beliefs:

1. “Objects have definite states before measurement.” Superposition implies quantum particles do not. (Then is there an objective **reality** before measurement?)
2. “Physical changes can only be caused locally.” Entanglement implies **nonlocal** correlations exist. (Does this allow faster-than-light communication? No, because results are random.)

EPR: Maybe correlations are due to some local element of reality that we haven’t detected yet (“local hidden variables”)?



1930's



1970's to present

1960's

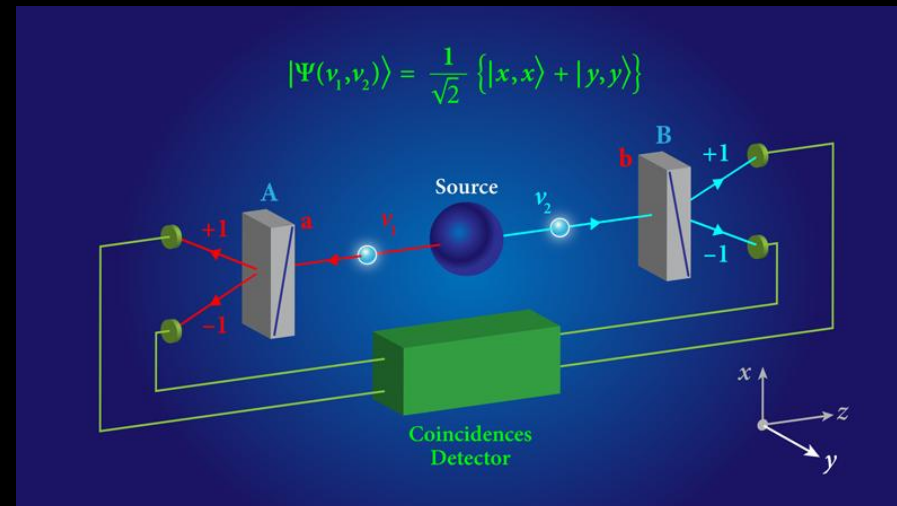
2022

EINSTEIN ATTACKS QUANTUM THEORY

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

SEE FULLER ONE POSSIBLE

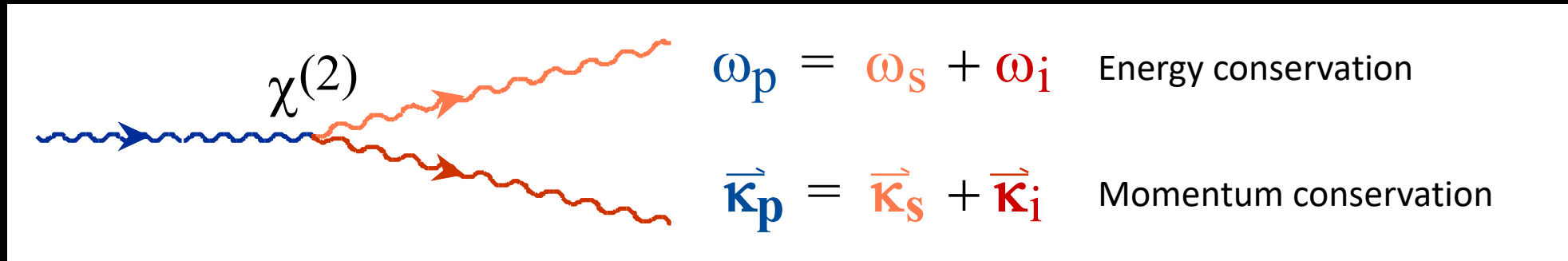
Believe a Whole Description of
'the Physical Reality' Can Be
Provided Eventually.



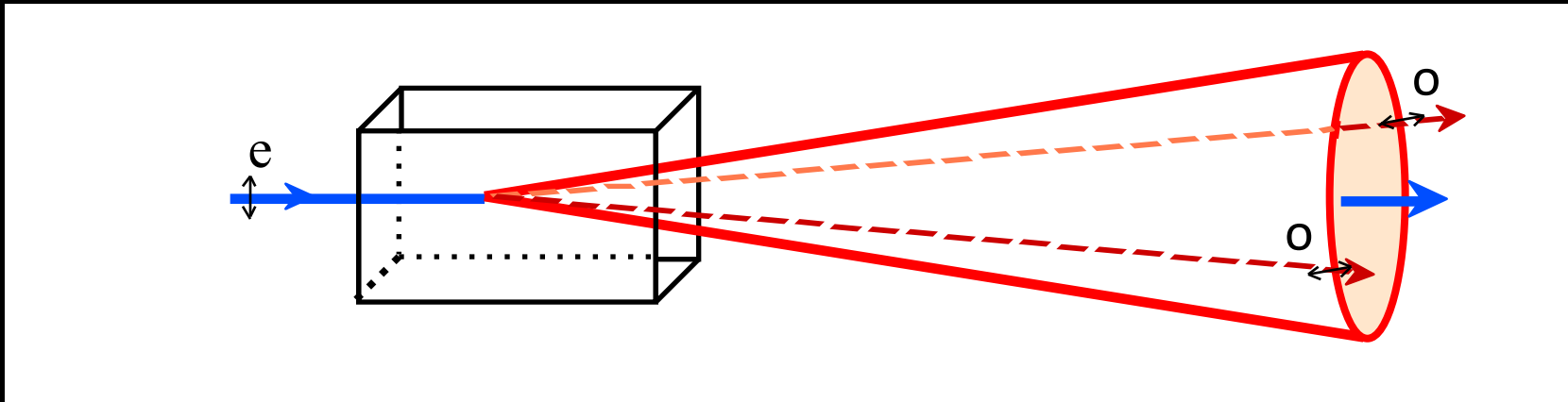
Such experiments
are now regularly
incorporated in
undergraduate
laboratories

We can create photons in pairs

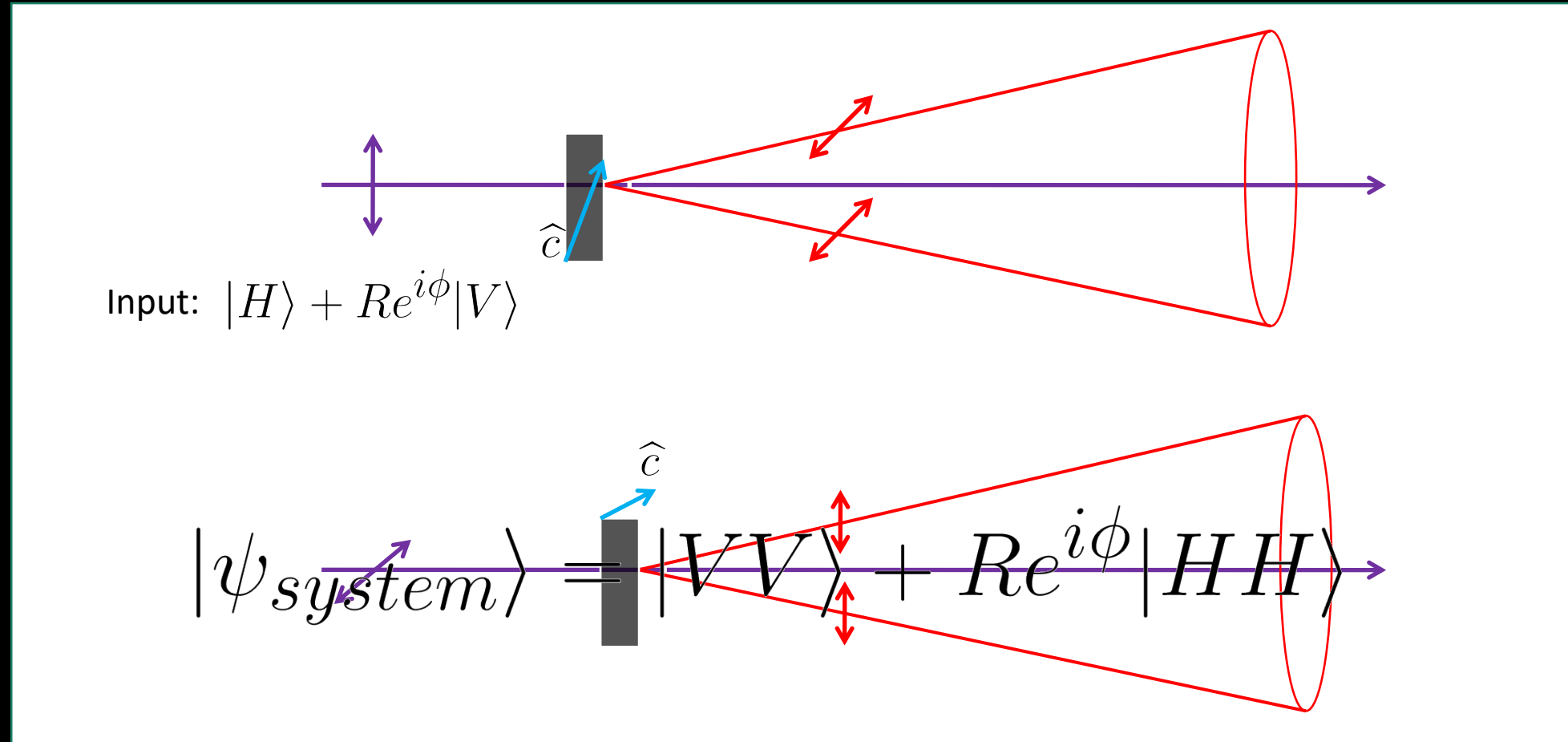
In 1970, the theory for spontaneous parametric down-conversion showed we can create photons in pairs



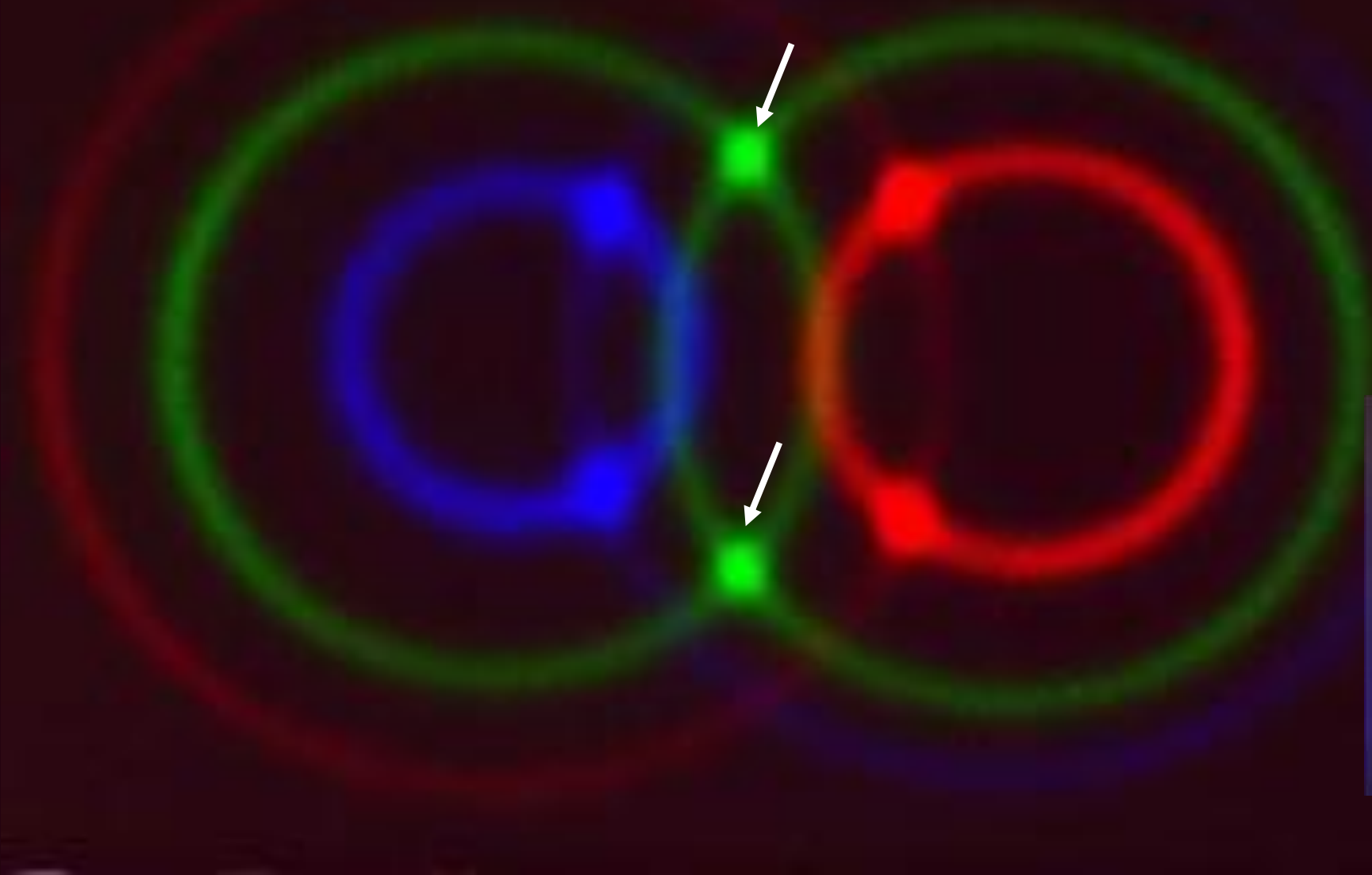
We can choose an orientation so that the photons have identical polarizations:



Using two crystals, we can create polarization-entangled photon pairs



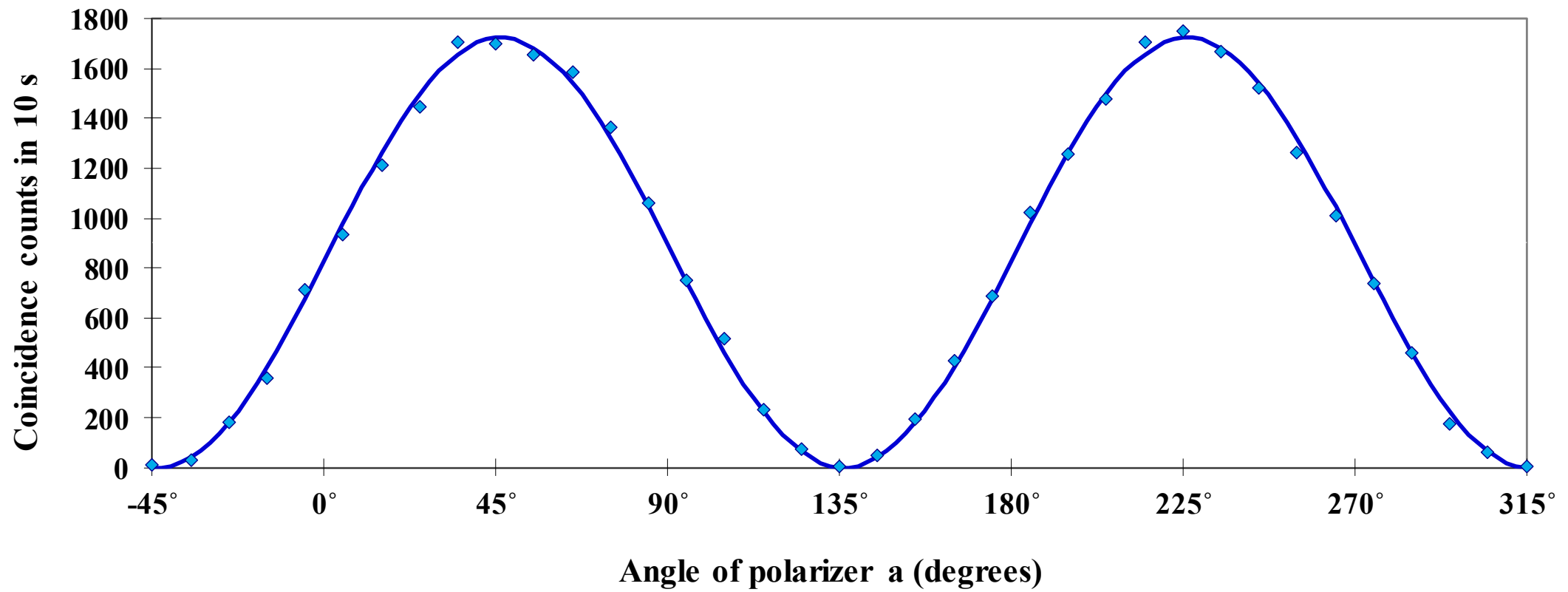
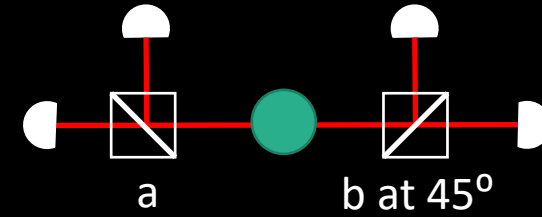
$$|\psi_{system}\rangle = |VV\rangle + Re^{i\phi}|HH\rangle$$



Paul Kwiat

Phys. Rev. Lett. 75, 4337 (1995).

Measuring the photons with polarizers shows near-perfect quantum correlation

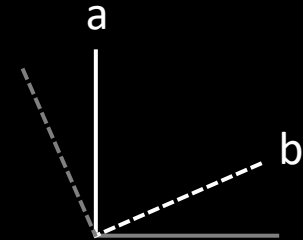
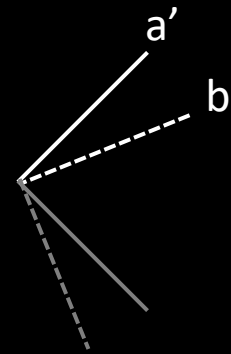
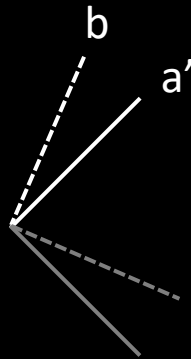
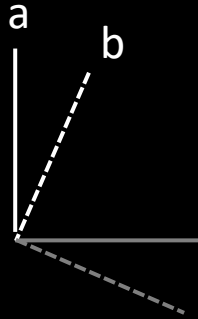


Bell's theorem tests for entanglement

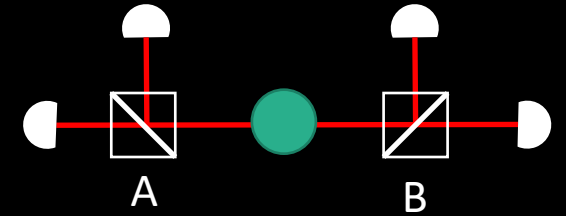
- Bell's theorem gives an inequality that would hold if local realism were true
 - The measurements are taken over many entangled pairs and thus are statistical
 - The angles are chosen to maximize violation of the inequality

$$[E(a,b) + E(a',b) + E(a',b') - E(a,b')] \leq 2$$

First 3 terms ~ likelihood the results are more similar than different



The last term ~ likelihood more different than similar



With entanglement, the correlations are stronger, resulting in a larger value



Strong Loophole-Free Test of Local Realism*

Lynden K. Shalm,^{1,†} Evan Meyer-Scott,² Bradley G. Christensen,³ Peter Bierhorst,¹ Michael A. Wayne,^{3,4} Martin J. Stevens,¹ Thomas Gerrits,¹ Scott Glancy,¹ Deny R. Hamel,⁵ Michael S. Allman,¹ Kevin J. Coakley,¹ Shellee D. Dyer,¹ Carson Hodge,¹ Adriana E. Lita,¹ Varun B. Verma,¹ Camilla Lambrocco,¹ Edward Tortorici,¹ Alan L. Migdall,^{4,6} Yanbao Zhang,² Daniel R. Kumor,³ William H. Farr,⁷ Francesco Marsili,⁷ Matthew D. Shaw,⁷ Jeffrey A. Stern,⁷ Carlos Abellán,⁸ Waldimar Amaya,⁸ Valerio Pruneri,^{8,9} Thomas Jennewein,^{2,10} Morgan W. Mitchell,^{8,9} Paul G. Kwiat,³ Joshua C. Bienfang,^{4,6} Richard P. Mirin,¹ Emanuel Knill,¹ and Sae Woo Nam^{1,‡}

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³Department of Physics, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, USA

⁴National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, Maryland 20899, USA

⁵Département de Physique et d'Astronomie, Université de Moncton, Moncton, New Brunswick E1A 3E9, Canada

⁶Joint Quantum Institute, National Institute of Standards and Technology and University of Maryland, 100 Bureau Drive,
Gaithersburg, Maryland 20899, USA

⁷Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, California 91109, USA

⁸ICFO-Institut de Ciències Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain

⁹ICREA-Institució Catalana de Recerca i Estudis Avançats, 08015 Barcelona, Spain

¹⁰Quantum Information Science Program, Canadian Institute for Advanced Research, Toronto, Ontario, Canada

(Received 10 November 2015; published 16 December 2015)

We present a loophole-free violation of local realism using entangled photon pairs. We ensure that all relevant events in our Bell test are spacelike separated by placing the parties far enough apart and by using fast random number generators and high-speed polarization measurements. A high-quality polarization-entangled source of photons, combined with high-efficiency, low-noise, single-photon detectors, allows us to make measurements without requiring any fair-sampling assumptions. Using a hypothesis test, we compute p values as small as 5.9×10^{-9} for our Bell violation while maintaining the spacelike separation of our events. We estimate the degree to which a local realistic system could predict our measurement choices. Accounting for this predictability, our smallest adjusted p value is 2.3×10^{-7} . We therefore reject the hypothesis that local realism governs our experiment.

Does this mean we can communicate faster than light?

- Because the state the photons end up in is random, knowing that you share the same state cannot be used to communicate – although it can be used as a resource called “shared randomness”

SPOOKY ACTION AT A DISTANCE

A SOURCE OF PHOTONS SENDS OUT A PAIR OF **ENTANGLED** PHOTONS...



...ONE TO ALICE...

To Alice's

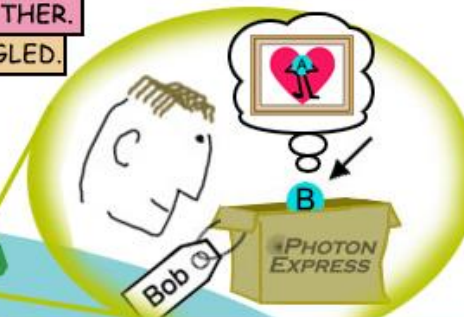
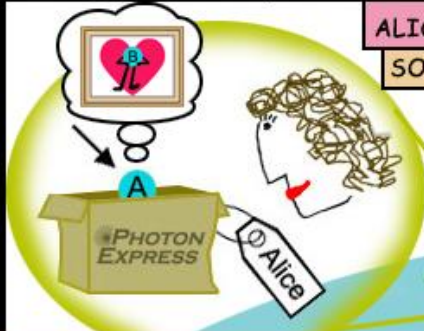


...AND ONE TO BOB.

To Bob's



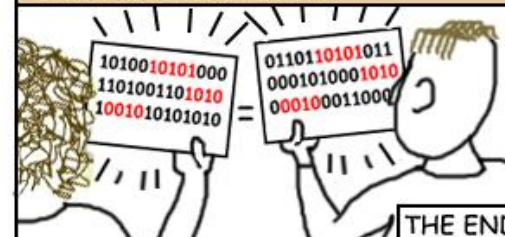
ALICE AND BOB ARE **QUITE DISTANT** FROM EACH OTHER.
SO ARE THE PHOTONS, BUT THEY REMAIN **ENTANGLED**.



ALICE RANDOMLY CHOOSES HOW TO MEASURE THE **POLARIZATION** OF HER PHOTON (AND DOESN'T TELL BOB).

BOB ALSO RANDOMLY CHOOSES A WAY TO MEASURE THE **POLARIZATION** OF HIS PHOTON (AND DOESN'T TELL ALICE).

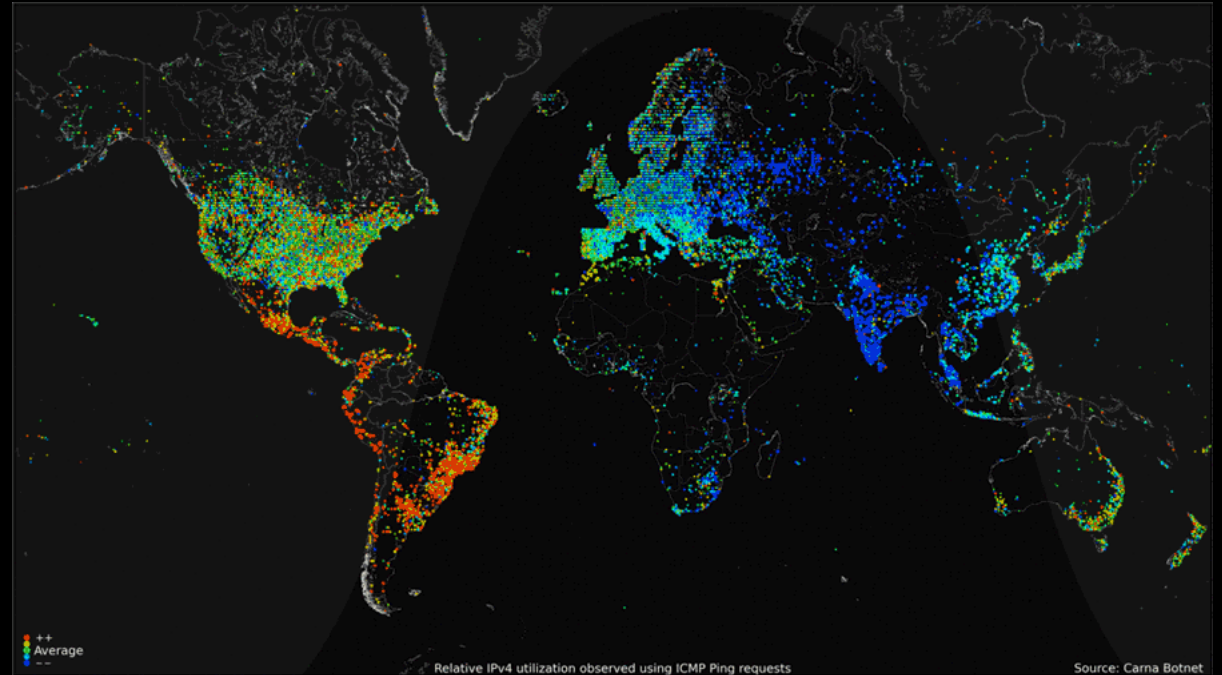
ALICE AND BOB REALIZE THAT THE **RESULTS** OF THEIR MEASUREMENTS ARE **CORRELATED**, BECAUSE THE PHOTONS--EVEN FAR APART--ARE STILL INTIMATELY LINKED -- THAT IS, **ENTANGLED**.



THE END

Quantum networks: a new type of internet

- Genuinely secure communication through detection of eavesdropping
- Connections with real-world quantum computers (once they are ready)
 - Fundamentally new ways of solving computational problems
- Improved sensing of astronomical objects
- Unforeseen applications of the technology
- There are a handful of few-node and many (~40) node quantum networks in the world.



Why are entangled states important?

- Responsible for quantum measurements and decoherence
- Central to demonstrations of quantum nonlocality (e.g., Bell's inequality)
- **Quantum computation** – intermediate states are all complex entangled states
- **Quantum cryptography** – separated particles' correlations allow sharing of secret random key
- **Quantum teleportation** – transmit unknown quantum state without sending the state itself

Entanglement, and the scaling that results, is the key to the power of quantum computing

- Classically, information is stored in a bit register:

1	0	1
---	---	---

- A 3-bit register can store **one** number, from 0-7
- Quantum Mechanically, a register of 3 qubits can store all of these numbers in superposition:

$$|000\rangle + |001\rangle + |010\rangle + |011\rangle + |100\rangle + |101\rangle + |110\rangle + |111\rangle$$

Result:

- Classical: one N-bit number
- Quantum: 2^N (all possible) N-bit numbers
 - N.B. A 300-qubit register can simultaneously store more combinations than there are particles in the universe.
- Acting on the qubits simultaneously affects all the numbers:

$$(|0\rangle + |1\rangle + \dots + |7\rangle) \otimes |f(x)\rangle \Rightarrow |0\rangle|f(0)\rangle + |1\rangle|f(1)\rangle + \dots + |7\rangle|f(7)\rangle$$

- Some important problems benefit from this entanglement, enabling solutions of otherwise insoluble problems.

Quantum Logic

Controlled-Not Gate:

$$|0\rangle_c |0\rangle_t \rightarrow |0\rangle_c |0\rangle_t$$

$$|0\rangle_c |1\rangle_t \rightarrow |0\rangle_c |1\rangle_t$$

$$|1\rangle_c |0\rangle_t \rightarrow |1\rangle_c |1\rangle_t$$

$$|1\rangle_c |1\rangle_t \rightarrow |1\rangle_c |0\rangle_t$$

$$(|0\rangle_c + |1\rangle_c) |0\rangle_t \xrightarrow{CNOT} |0\rangle_c |0\rangle_t + |1\rangle_c |1\rangle_t$$

2-Qubit interactions lead to entangled states.

Classical Cryptography



<http://en.wikipedia.org>

RSA Algorithm (1978): Generate random prime numbers p & q .
Compute $n = pq$, $\phi(n) = (p-1)(q-1)$, e co-prime with ϕ , $d = e^{-1} \bmod \phi(n)$
Release e , n as public key. Encrypt: $c = \text{message}^e \bmod n$
Keep d as private key. Decrypt: $\text{message} = c^d \bmod n$

9AFGJI4JT09RKSP

From: UIUC
Sent: Friday, March 2, 2017 11:40 AM
To: 'Virginia Lorenz'
Subject: Physics

Hi Virginia,
...

Security relies on computational difficulty of factoring the public key

Quantum Key Distribution

$$|\uparrow\uparrow\rangle + |\leftrightarrow\leftrightarrow\rangle$$

Security is guaranteed by the laws of quantum physics

Ekert Protocol (1991): Generate entangled photon pair.

Cerberis QKD Server



Cerberis from IDQ is a standalone rack-mountable QKD server; providing secure quantum keys based on the BB84 and SARG protocols. Integrated with IDQ's Centauris Ethernet and Fiber Channel encryptors, Cerberis has been deployed by governments, enterprises and financial institutions since 2007.

<http://www.idquantique.com/quantum-safe-crypto/>

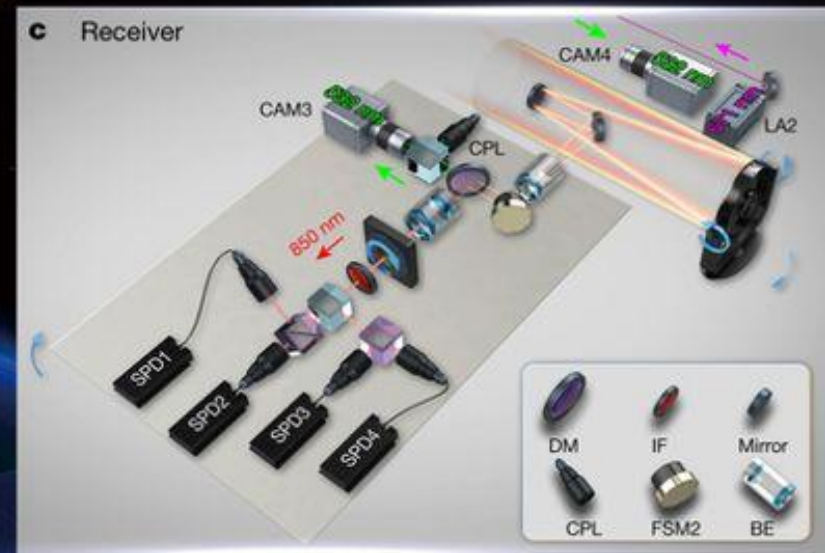
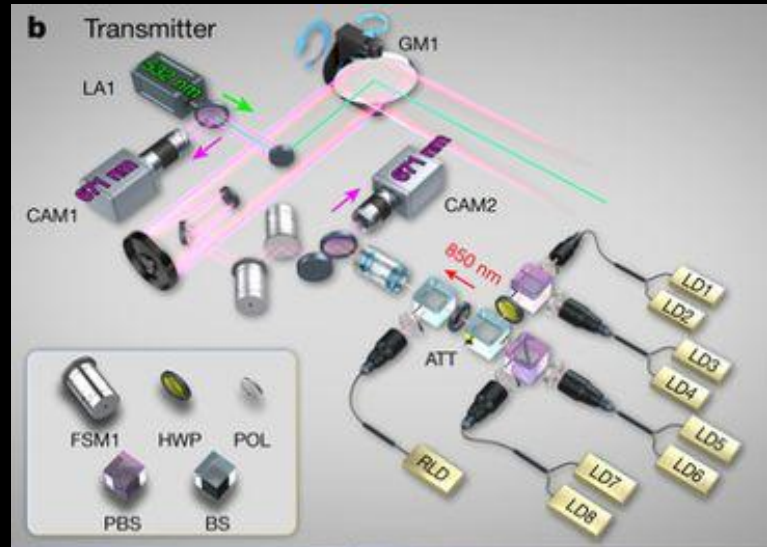
Everitt Laboratory
Electrical and...

Engineering Hall

Laboratory
Of Physics,
University...

Eavesdropping without being detected is impossible
because measurement changes the correlations

Satellite-to-ground QKD



nature
International journal of science

Article | Published: 09 August 2017

Satellite-to-ground quantum key distribution

Sheng-Kai Liao, Wen-Qi Cai [...] Jian-Wei Pan

Nature **549**, 43–47 (07 September 2017) | [Download Citation](#)



DIGITAL SINGLE MARKET

Digital Economy & Society

[European Commission](#) > [European Commission will launch €1 billion quantum technologies flagship](#)



[The strategy](#)

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European Commission will launch €1 billion quantum technologies flagship

Published on 17/05/2016

Günther H. Oettinger, Commissioner for the Digital Economy and Society outlined the Commission's plan to launch a €1 billion flagship initiative on quantum technology.

Speaking at the [Quantum Europe Conference](#) organised by The Dutch presidency of the EU, the European Commission and the QuTech center in Delft, the Commissioner outlined his objective to reinforce European scientific leadership and excellence in quantum research and in quantum technologies.



Share



NATIONAL QUANTUM INITIATIVE

THE FEDERAL SOURCE AND GATEWAY TO QUANTUM R&D ACROSS THE U.S. GOVERNMENT

- The National Quantum Initiative Act was signed into law on December 21, 2018. The law gives the United States a plan for advancing quantum technology.
- This act has spurred a tsunami of funding for quantum research and industry, much of it centered around “Quantum 2.0” technology.

NEW CENTER AWARDED \$12.6M BY DOE

 Jul 13, 2020

A team from the University of Illinois at Urbana-Champaign's Grainger College of Engineering was awarded an Energy Frontier Research Center by the Department of Energy (EFRC).

The new center is highly-collaborative spanning three institutions, with additional team members and leadership from University of Illinois-Chicago and the SLAC National Accelerator Laboratory. On campus, the program draws together experts in quantum information science, physics and materials science from the [Illinois Quantum Information Science and Technology Center \(IQIIST\)](#), from the Physics Department, Materials Science and Engineering, and the Materials Research Laboratory.

U.S. Department of Energy Unveils Blueprint for the Quantum Internet at 'Launch to the Future: Quantum Internet' Event

JULY 23, 2020



[Home](#) » U.S. Department of Energy Unveils Blueprint for the Quantum Internet at 'Launch to the Future: Quantum Internet' Event

Nationwide Effort to Build Quantum Networks and Usher in New Era of Communications

CHICAGO, IL – In a press conference today at the University of Chicago, the U.S. Department of Energy (DOE) unveiled a report that lays out a blueprint strategy for the development of a national quantum internet, bringing the United States to the forefront of the global quantum race and ushering in a new era of communications. This report provides a pathway to ensure the development of the [National Quantum Initiative Act](#), which was signed into law by President Trump in December of 2018.

Around the world, consensus is building that a system to communicate using quantum mechanics represents one of the most important technological frontiers of the 21st century. Scientists now believe that the construction of a prototype will be within reach over the next decade.

In February of this year, DOE National Laboratories, universities, and industry met in New York City to develop the blueprint strategy of a national quantum internet, laying out the essential research to be accomplished, describing the engineering and design barriers, and setting near-term goals.

"The Department of Energy is proud to play an instrumental role in the development of the national quantum internet," said U.S. Secretary of Energy Dan Brouillette. "By constructing this new and emerging technology, the United States continues with its commitment to maintain and expand

[Home](#) / [News](#)

MIDWEST COLLABORATION, LED BY IQUIST, AWARDED \$25 MILLION QUANTUM INFORMATION INSTITUTE

7/21/2020 9:53:05 AM

Michelle Huls Rice for

[f](#) [t](#) [in](#)

Grainger Engineering

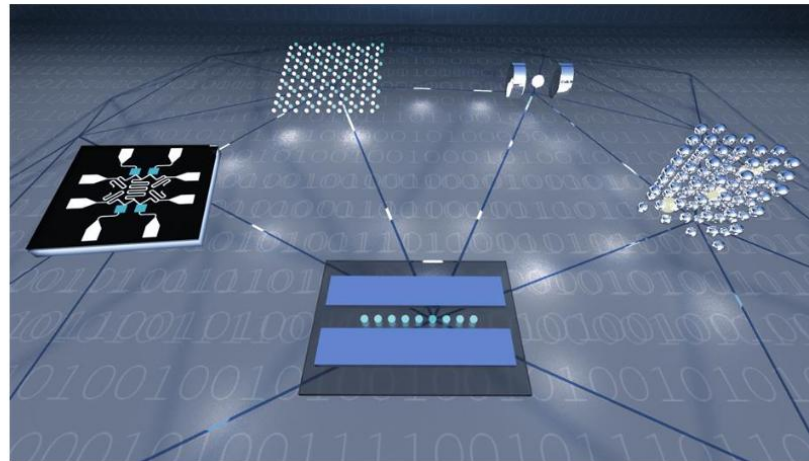
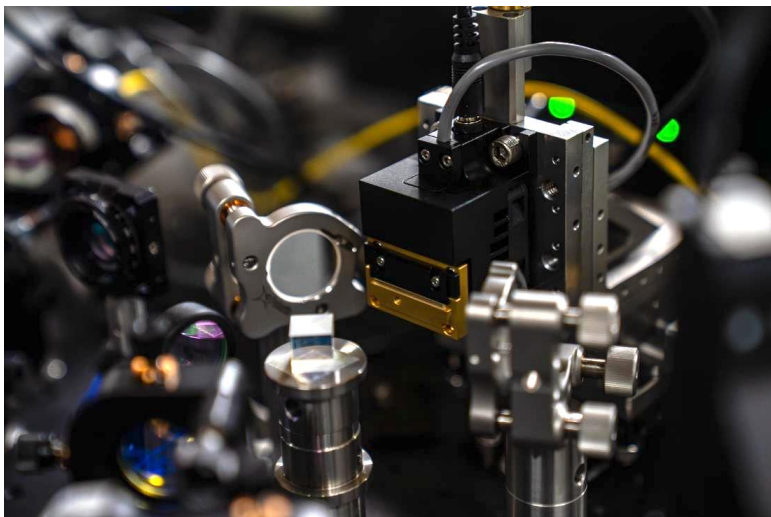


Image by Emily Edwards, IQUIST

The Grainger College of Engineering's Illinois Quantum Information Science and Technology Center (IQIUST) will launch a National Science Foundation Quantum Leap Challenge Institute for Hybrid Quantum Architectures and Networks (HQAN). The collaborative institute spans three Midwest research powerhouses, all of which are members of the Chicago Quantum Exchange: The University of Illinois, University of Chicago, and the University of Wisconsin. HQAN also includes partnerships with industry and government labs.

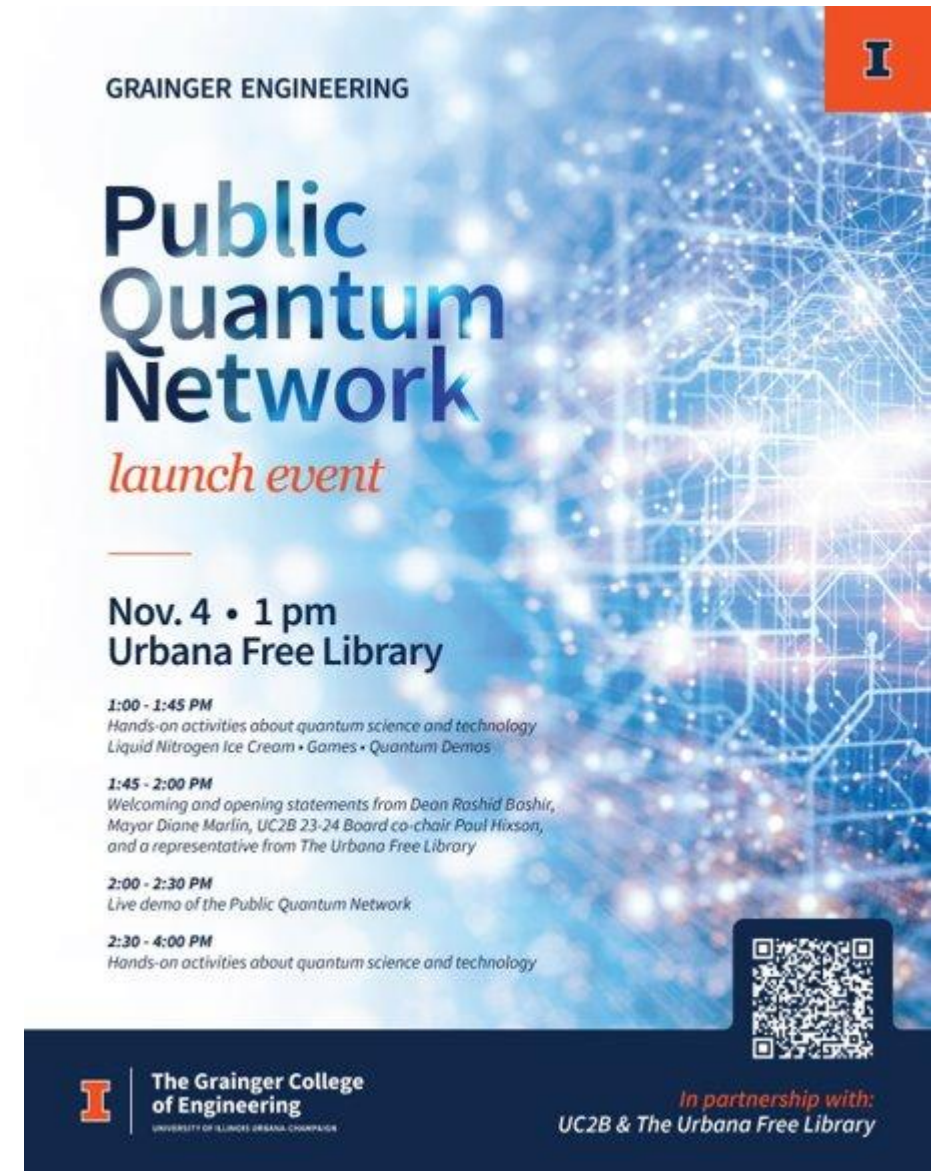
Established with a \$25 million, five-year NSF award, the HQAN institute will be one of only three Quantum Leap Challenge Institutes in the country. Quantum Leap Challenge Institutes will bring together multidisciplinary researchers and diverse partners to advance scientific, technological, and workforce development goals.



THE IDEA

Enable the public to make measurements on a real quantum network that transmits entangled photons, for

- Extensive public engagement
 - Hands-on public participation in quantum technologies
 - Quantum curricula (K-12 & community college)
- Fundamental research
 - State-of-the-art quantum protocols
 - Fundamental tests at scale
- Quantum technology innovation
 - Involvement of industry partners



GRAINGER ENGINEERING

Public Quantum Network
launch event

Nov. 4 • 1 pm
Urbana Free Library

1:00 - 1:45 PM
Hands-on activities about quantum science and technology
Liquid Nitrogen Ice Cream • Games • Quantum Demos

1:45 - 2:00 PM
Welcoming and opening statements from Dean Rashid Bashir, Mayor Diane Marlin, UC2B 23-24 Board co-chair Paul Hixson, and a representative from The Urbana Free Library

2:00 - 2:30 PM
Live demo of the Public Quantum Network

2:30 - 4:00 PM
Hands-on activities about quantum science and technology



 **The Grainger College of Engineering**
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

In partnership with:
UC2B & The Urbana Free Library



Quantum Secure Communication



Quantum Teleportation



The Quantum Internet

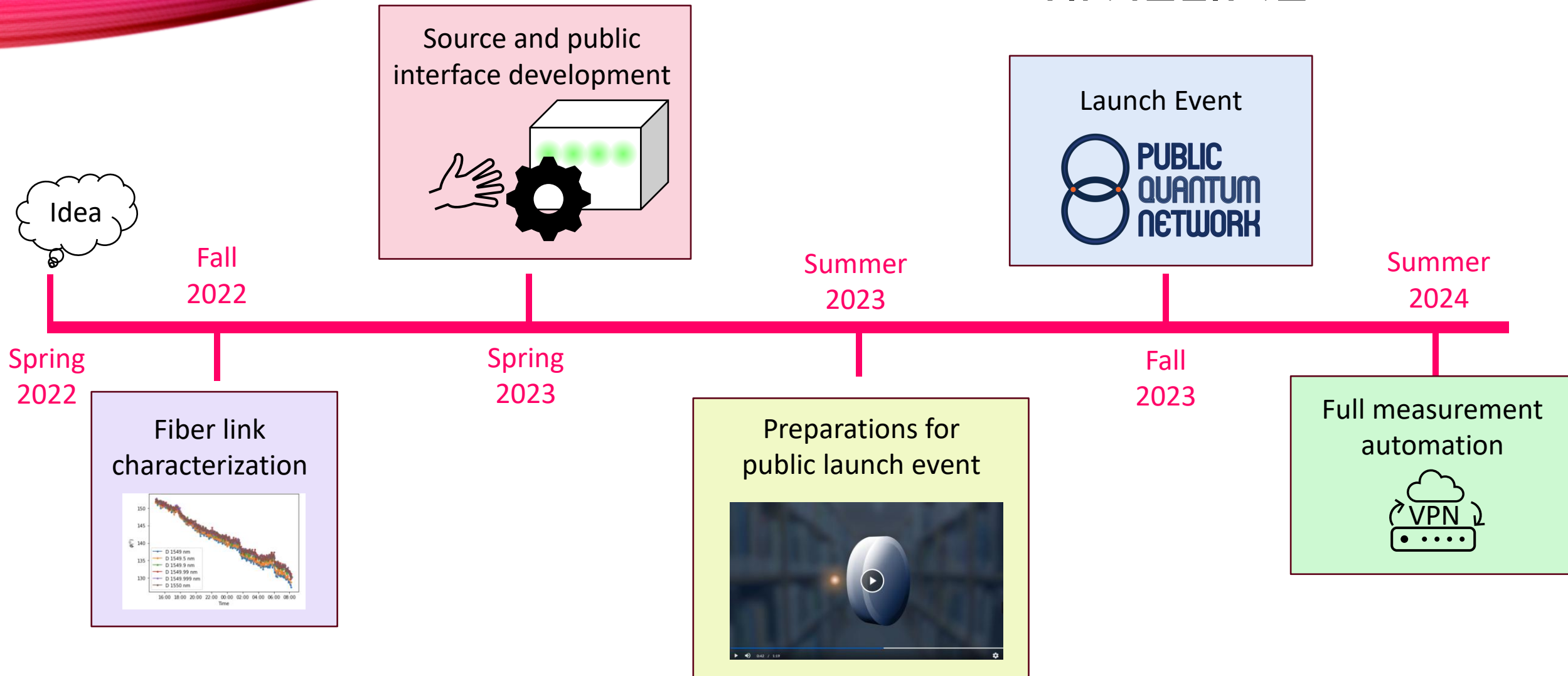
Fault-tolerant quantum memories are used to build repeaters and switches for high-fidelity high-rate quantum communications over 1000s of km

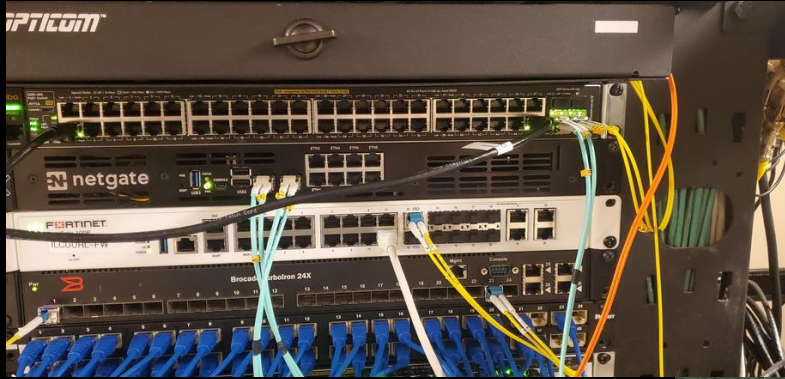


Unforeseen
applications
from the
public

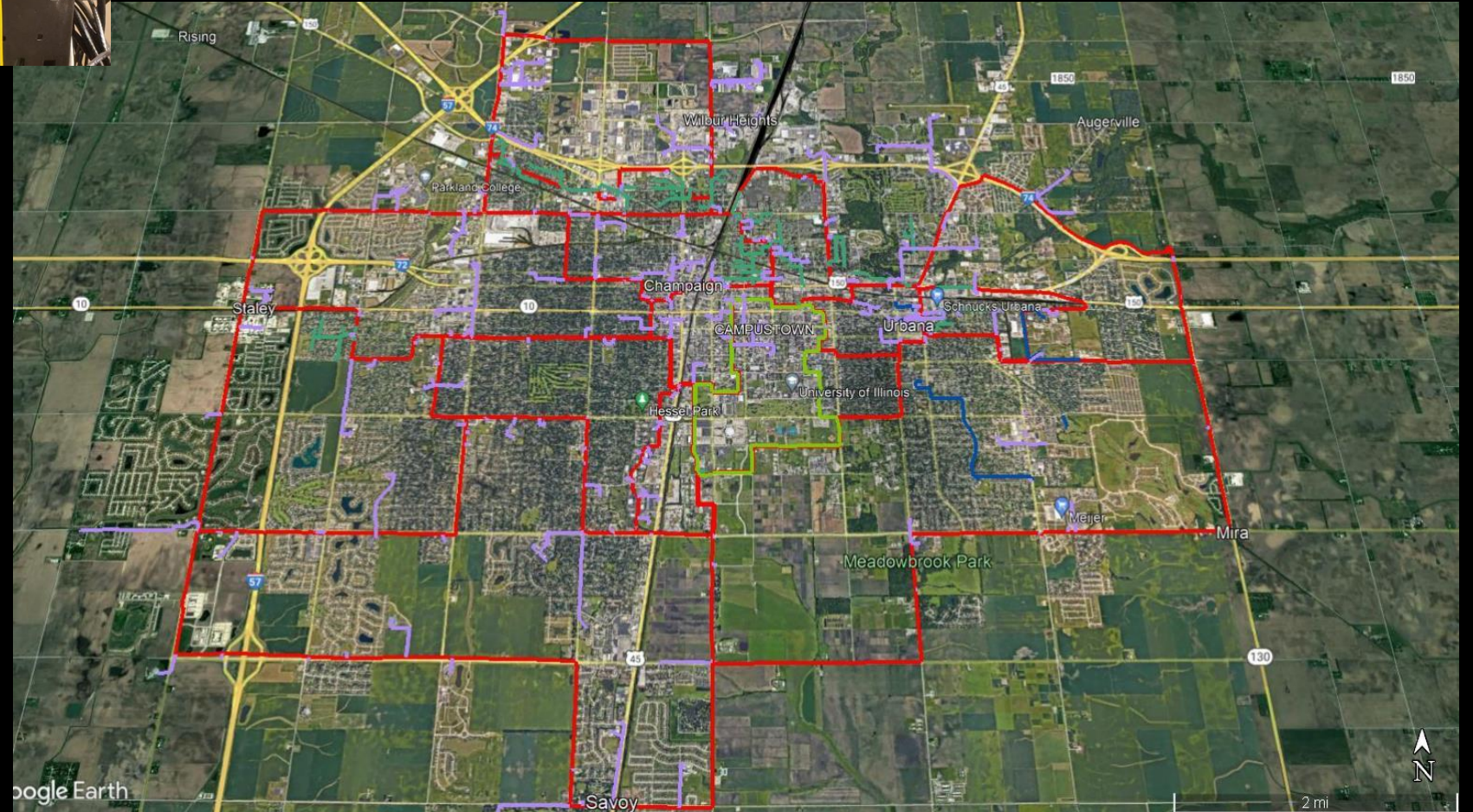


TIMELINE





THE LINK





Loomis
Laboratory
Of Physics,
University...

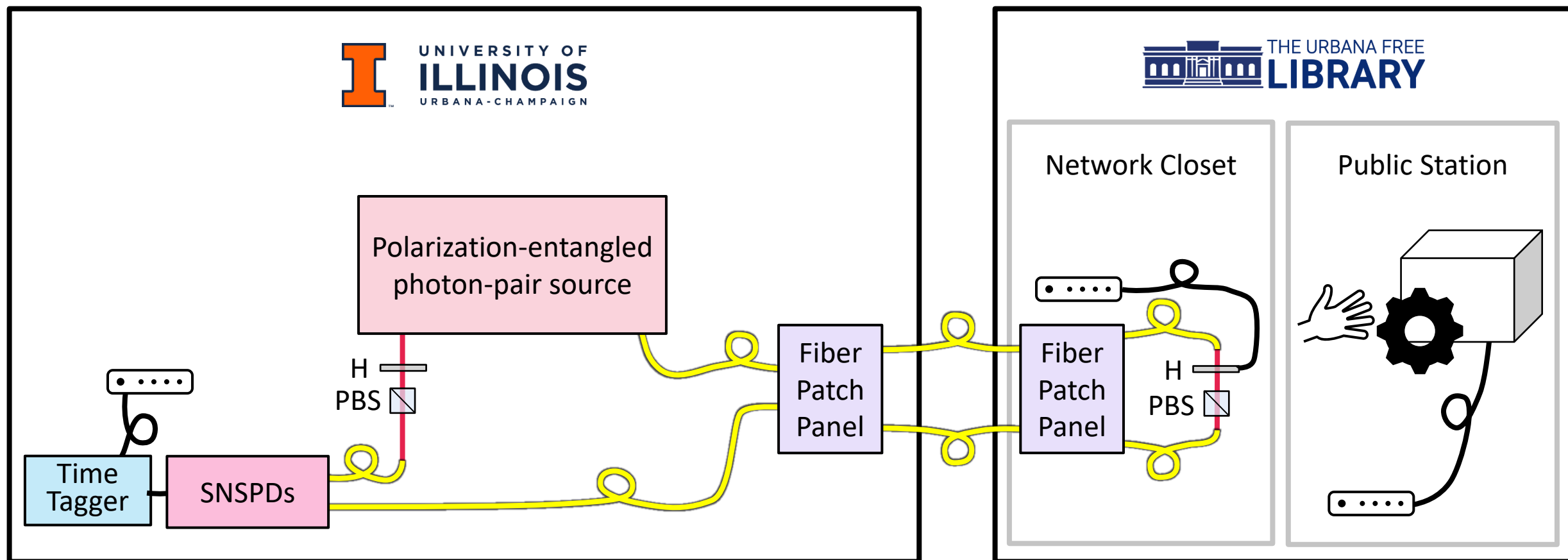


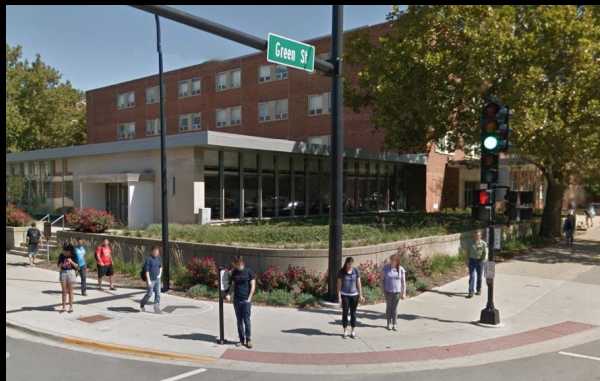
The Urbana Free Library



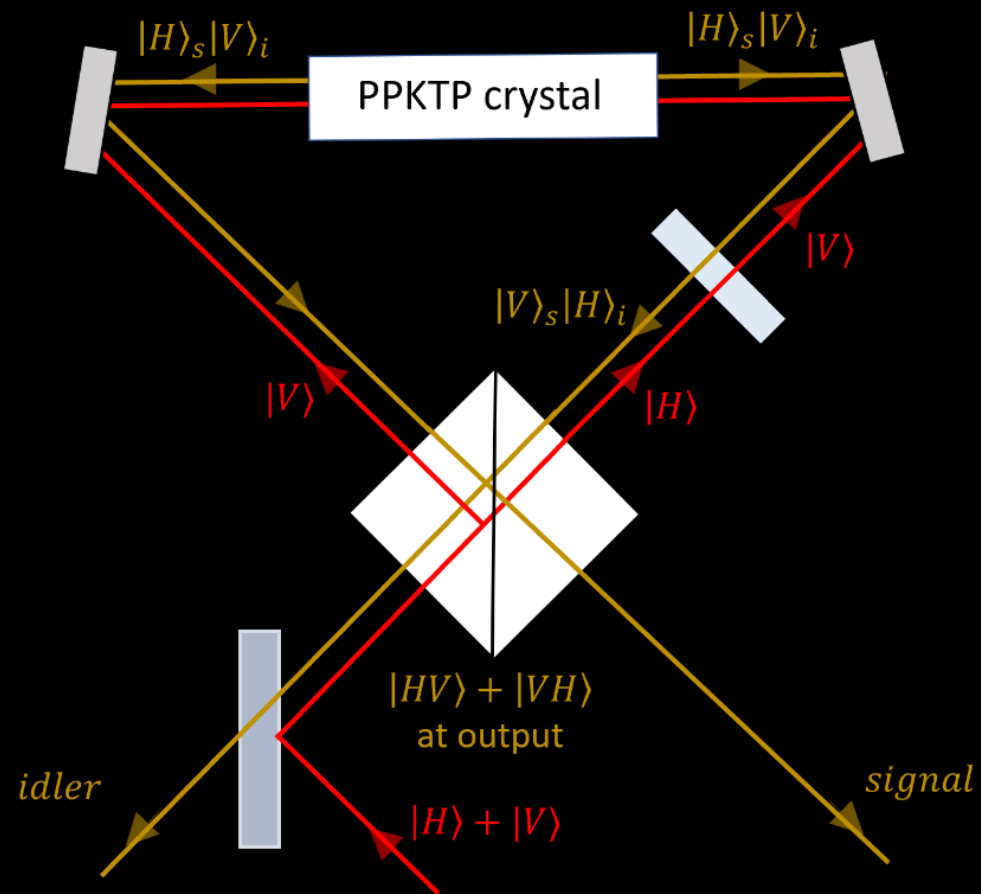
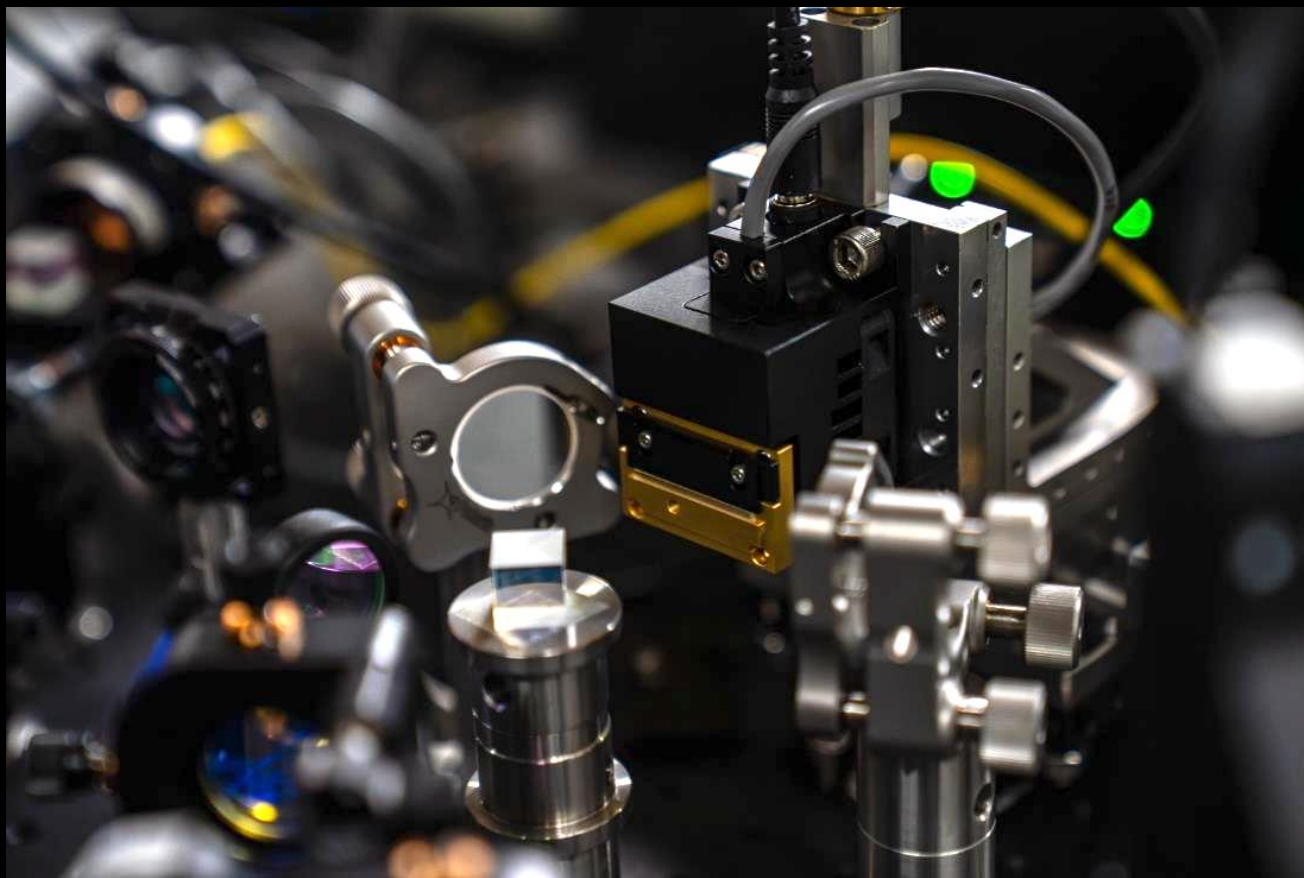
THE VISION

Send one photon from each pair of polarization-entangled photons in a loop to the library, where users can perform a Bell test (CHSH inequality)





THE ENTANGLEMENT SOURCE



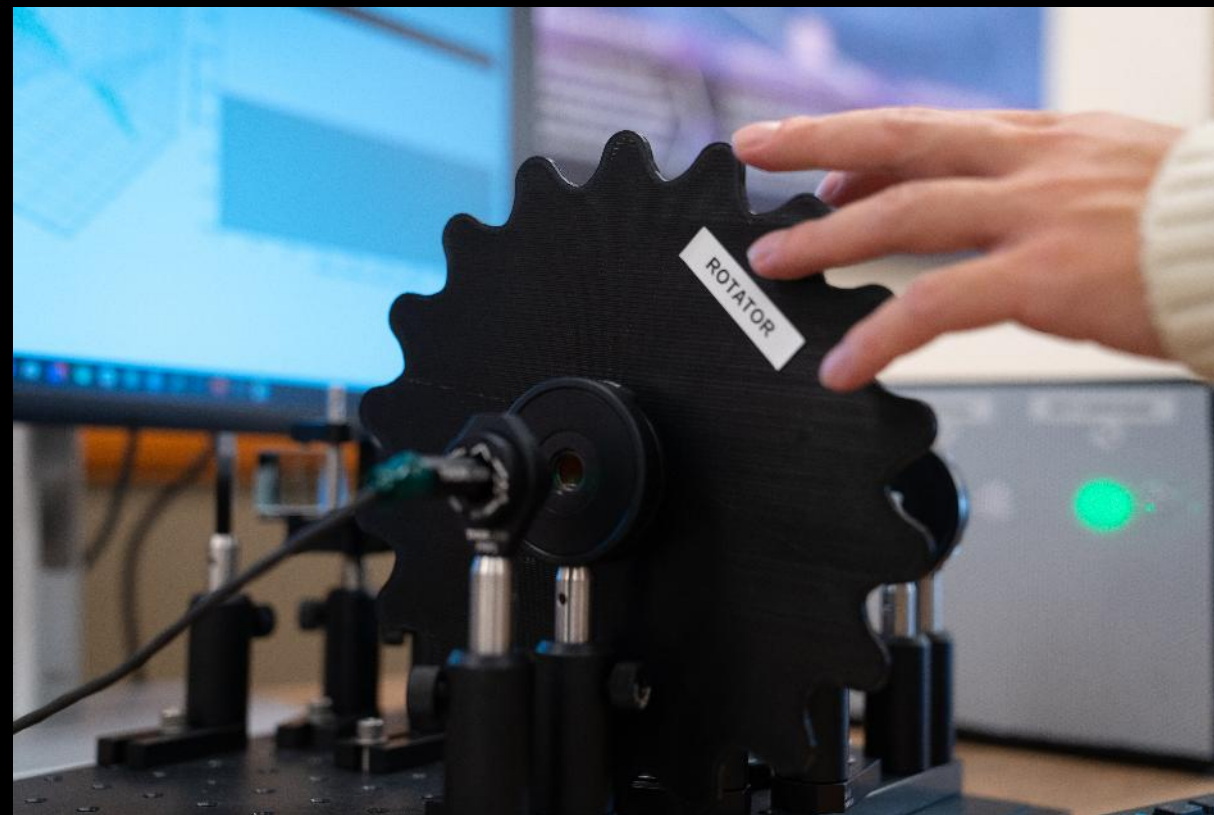
An aerial photograph of the University of Illinois at Urbana-Champaign campus during autumn. The image shows a dense cluster of red brick academic buildings, interspersed with green lawns and trees displaying vibrant orange, yellow, and red foliage. A prominent church steeple is visible in the lower right quadrant. A multi-lane road with a green-painted bike lane runs diagonally through the center of the campus. Numerous parking lots filled with cars are scattered throughout the scene. The overall atmosphere is serene and picturesque, capturing the peak of fall colors.

LOOMIS LABORATORY

UNIVERSITY OF ILLINOIS
URBANA-CHAMPAIGN



THE PUBLIC INTERFACE

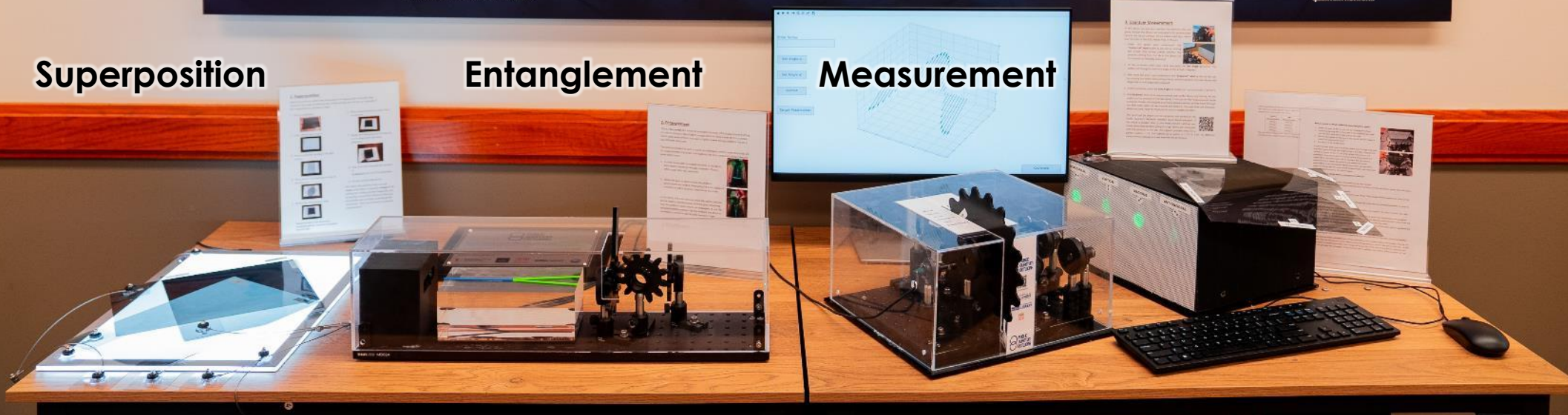




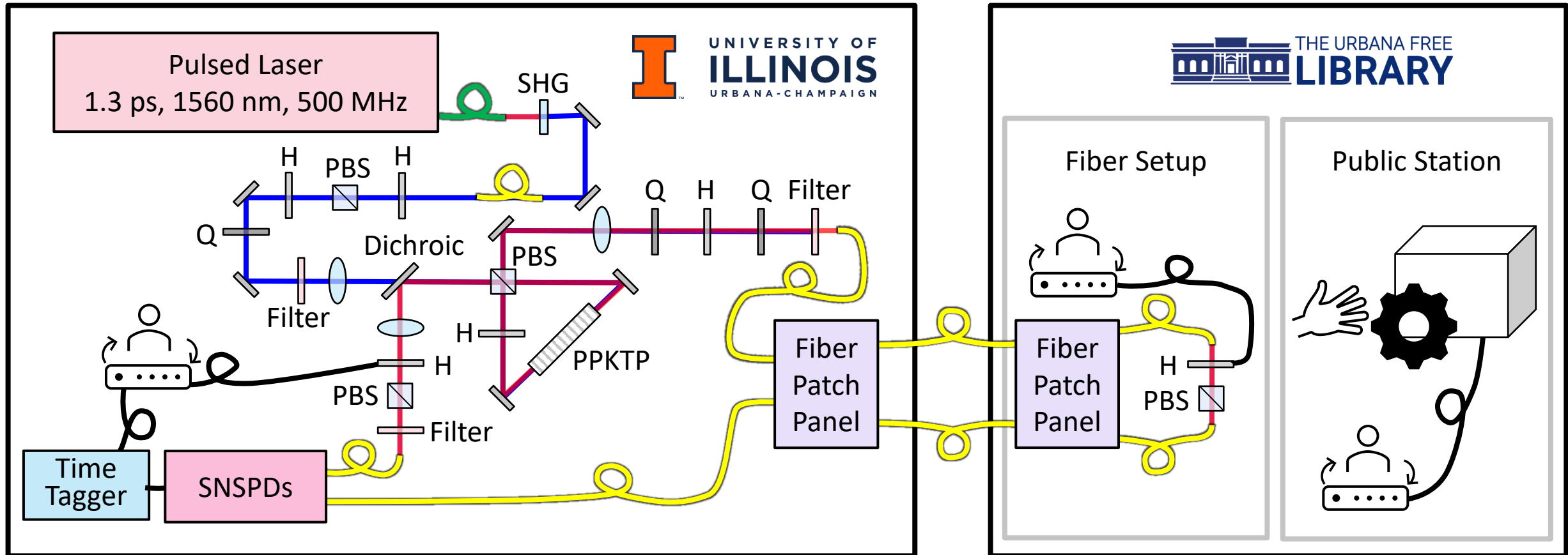
Superposition

Entanglement

Measurement



THE QUANTUM NETWORK V.1



Measurements facilitated by communication amongst researchers

Public Quantum Network Launch Event

Saturday, November 4, 1:00 - 4:00 p.m.
The Urbana Free Library | For all ages.

Celebrate the launch of the first publicly accessible quantum network in the nation!

*Where everyone can
play with quantum particles.
Come explore with us!*

Quantum activities for all ages

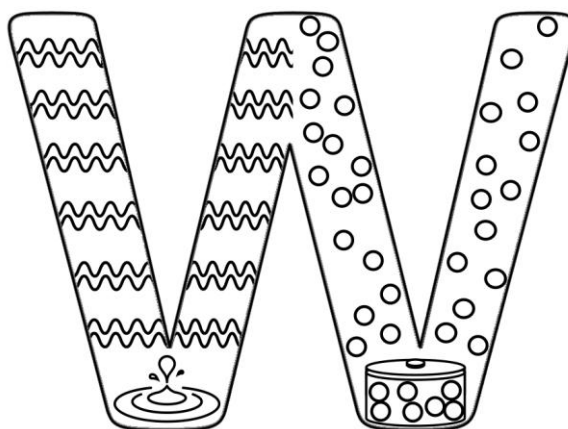
Liquid nitrogen ice cream





Print out a coloring book!

iquist.illinois.edu/outreach/pqn/coloring-book



Wave-Particle Duality

Do you ever feel sleepy and hungry at the same time? Quantum particles can be two things at the same time, too. They can act as both waves and particles.



ABCs of Quantum Networks



A coloring & activity book for the



Public Quantum Network
<https://iquist.illinois.edu/pqn>





GRAINGER
ENGINEERING



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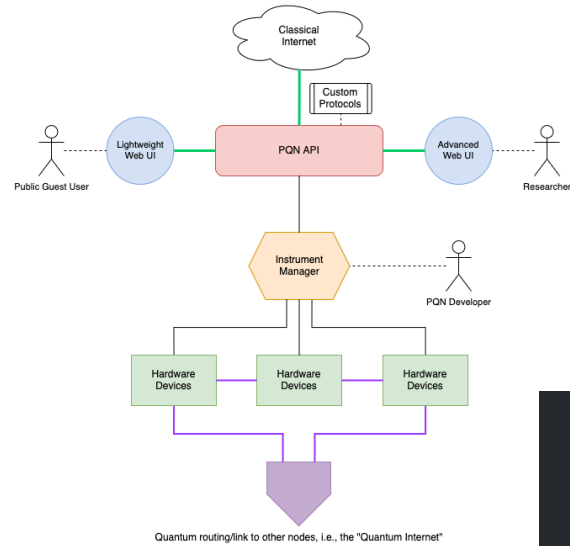
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THE SOFTWARE



Product ▾

Solutions ▾

Resources ▾

Open Source ▾



PublicQuantumNetwork / **pqn-stack**

Public

<> Code



Issues

26



Pull requests

3



Discussions



master ▾



10 Branches



2 Tags

Hardware-level example

Feynman Computing Center

3. Gets the measurement request
4. Runs the measurement
6. Sends the result to LSC

Controls motor via
USB cable



Gets detection
counts

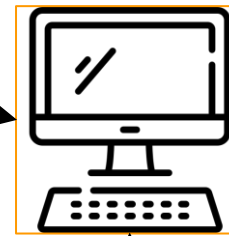


Communication via
wireless connection

Lederman Science Center

Public Measurement Setup

1. PC runs GUI
2. Sends the measurement request
7. Gets and displays the result



Network Closet



5. Controls motor via
USB cable



The PQN GitHub repository is now public

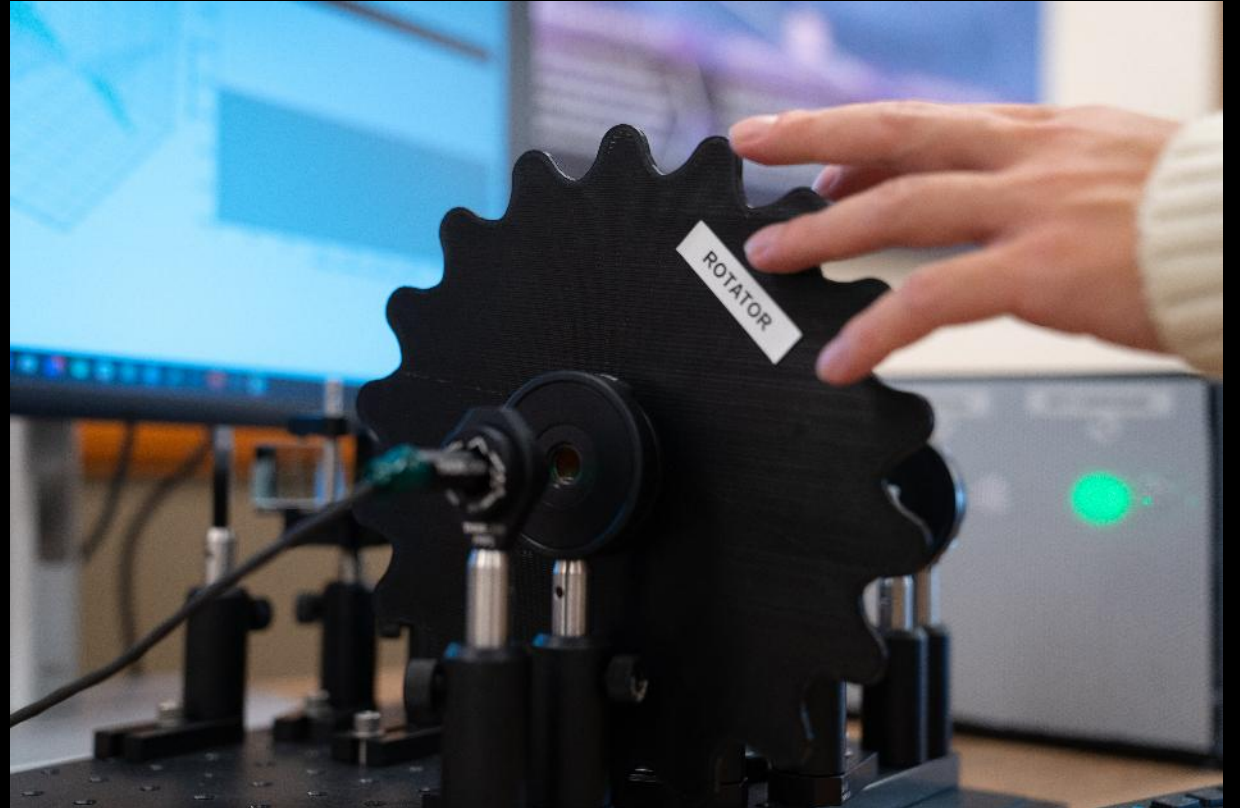
github.com/PublicQuantumNetwork/pqn-stack

- Raw code, loose structure in place
- Refining and polishing as we go

Next steps:

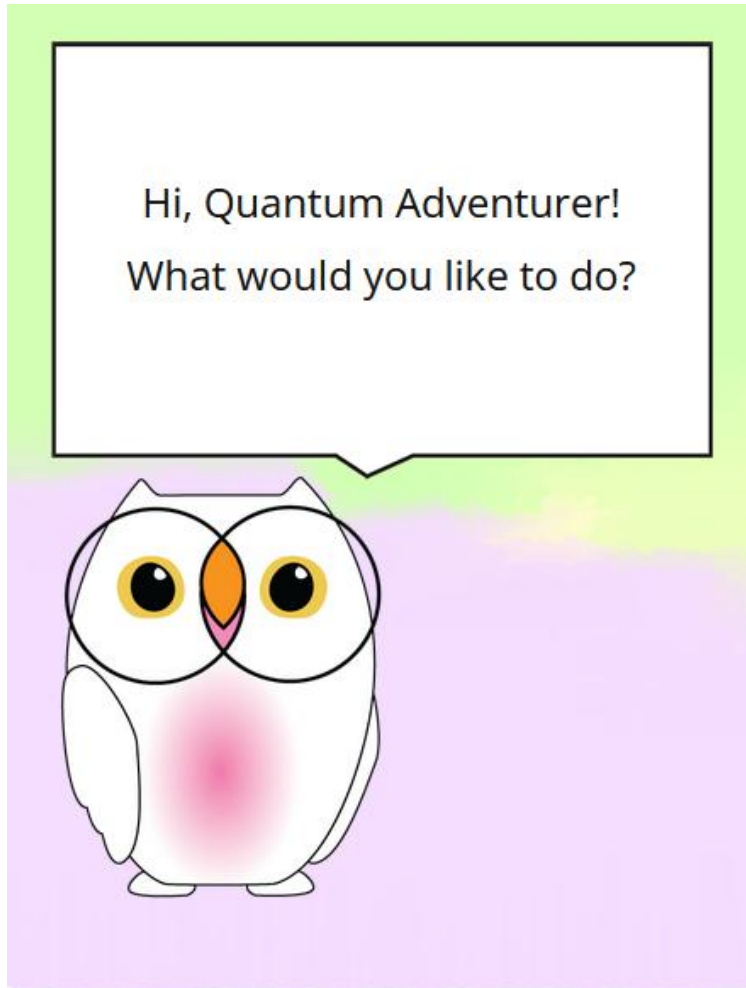
- Complete two-player codebase and test at UIUC
- Test at Fermilab

THE PUBLIC INTERFACE



Public Interaction Activities

Graphical user interface features PQN mascot “Whobit,” who guides 4 possible games



Game	Approximate protocol
Verify Quantum Link	CHSH
Quantum Fortune	random number generation
Get to Know Someone	quantum voting
Send a Secret Message	QKD

Can see interface at <https://pqnetwork.web.illinois.edu>

Quantum fortune examples

- Give the world the best you've got. And you will get kicked in the teeth. Give the world the best you've got anyway. - Hedy Lamarr
- The only sure way to avoid making mistakes is to have no new ideas. - Albert Einstein
- Once you can accept the universe as matter expanding into nothing that is something, wearing stripes with plaid comes easy. - Albert Einstein
- The best way to cheer yourself is to cheer somebody else up. - Albert Einstein
- Everybody is a genius. But if you judge a fish by its ability to climb a tree it will live its whole life believing that it is stupid. - Albert Einstein



Start over

Hi, Quantum Adventurer!
What would you like to do?



Verify Quantum Link (single player)

Share a secret message (multi-player)

Get to know someone (multi-player)

Quantum Fortune (single player)



Examples of two-player questions

- Photons can be undecided (in a superposition) when asked which way they wiggle. What question would your friend be most undecided about? Which book to read / Which movie to watch
- Photons can be in superpositions (undecided) together. Which scenario would your friend prefer being in superposition about with you? Where to go on vacation / Who to invite to a party
- Photons can be entangled so they always choose the same way. What do you think your friend would prefer to always agree with you on? When to leave a party / When to eat dinner
- Quantum networks can share secret messages using entangled photons. What message would your friend send first on such a network? An embarrassing photo / A declaration of love
- If your friend controlled a quantum network, what would they use it for? World domination / World peace

The more they agree, the longer
the key -> higher res emoji



Survey assesses impact

Please read the text and
click yes if you would like to
take the survey.



PQN Consent Cover Letter

The purpose of this research study is to gauge how well quantum concepts are being conveyed at the PQN table at the library. We are doing this study to make quantum concepts better accessible to young people and the general public.

We would like you to complete a survey after you have finished the PQN activities, which we will use to see how well we explained concepts. There are minor loss of confidentiality issues associated with participating in this study, that could arise if the surveys are lost from our staff, but we will make every effort to safeguard your information. You may not

Yes, I agree

No, I changed my mind

I

WHAT'S NEXT?

Links to Chicago: Kankakee Community College



Fermilab Visitor's Center

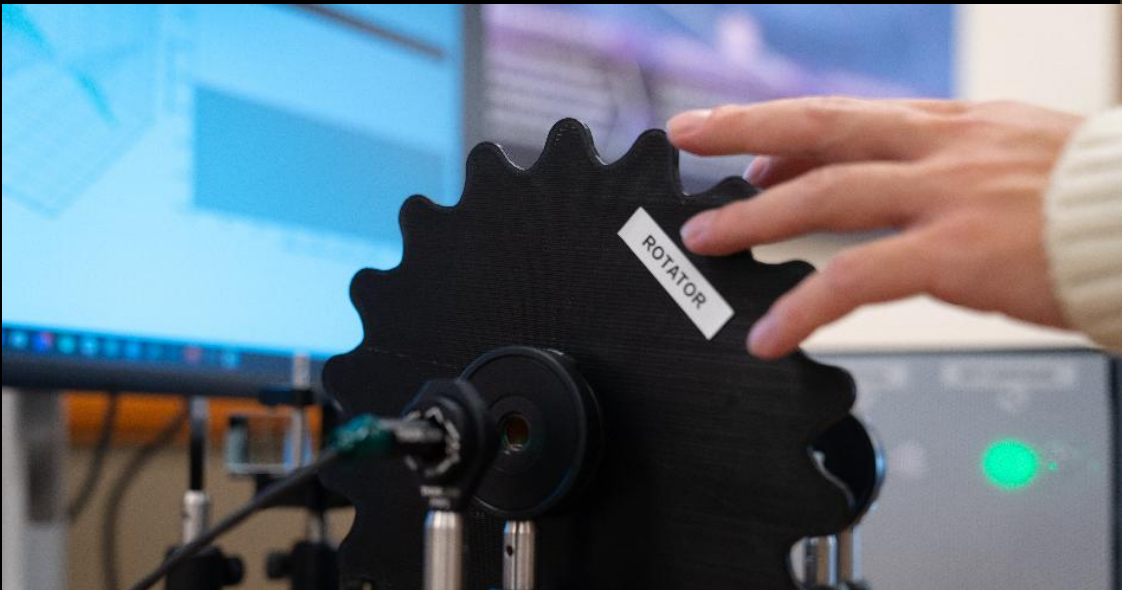


Locally: preparing for next node, ongoing outreach activities

Next summer: build curricula with local high school teachers

Planning public quantum networks in Boulder, Colorado, and Irvine, California

Quantum outreach at UIUC



CASCADE: AN ARTS-
SCIENCE CELEBRATION

LabEscape



NOW OPEN FOR MISSIONS AT OUR NEW LOCATION!

LabEscape Quantum Salvation Mission Center, Rm 1262 Digital
Computing Lab
1304 W. Springfield Ave., Urbana, IL



ACKNOWLEDGEMENTS



Keshav Kapoor
UIUC



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Soroush Hosseini
UIUC



Benjamin Nussbaum
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Marcos Frenkel
NCSA



Kriti Shetty
UIUC



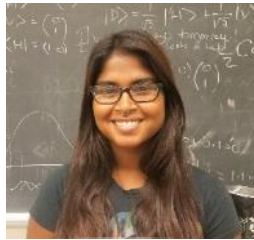
Donggeon Park



Vanessa Zhang



Colin Lualdi
UIUC



Samantha Isaac
UIUC



Brittany Karki
UIUC



Kelsey Ortiz
UIUC



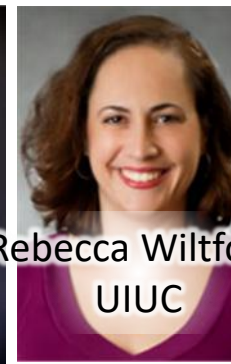
Chris Skaar
UIUC



Virginia Lorenz
UIUC



Paul Kwiat
UIUC



Rebecca Wiltfong
UIUC



Emily Edwards
UIUC



Tracy Smith
UC2B



Paul Hixson
UC2B



Leon Wilson
TUFL



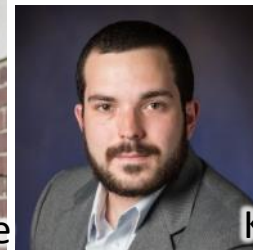
Lauren Chambers
TUFL



Dawn Cassady
TUFL



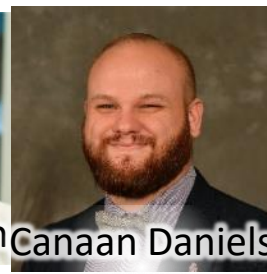
Nicolas Morse
UIUC



Michael O'Boyle
UIUC



Kim Gudeman
UIUC



Canaan Daniels
UIUC



Angela Graham
UIUC



Brian Demarco
UIUC



THANK YOU!



+



Acknowledgements

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