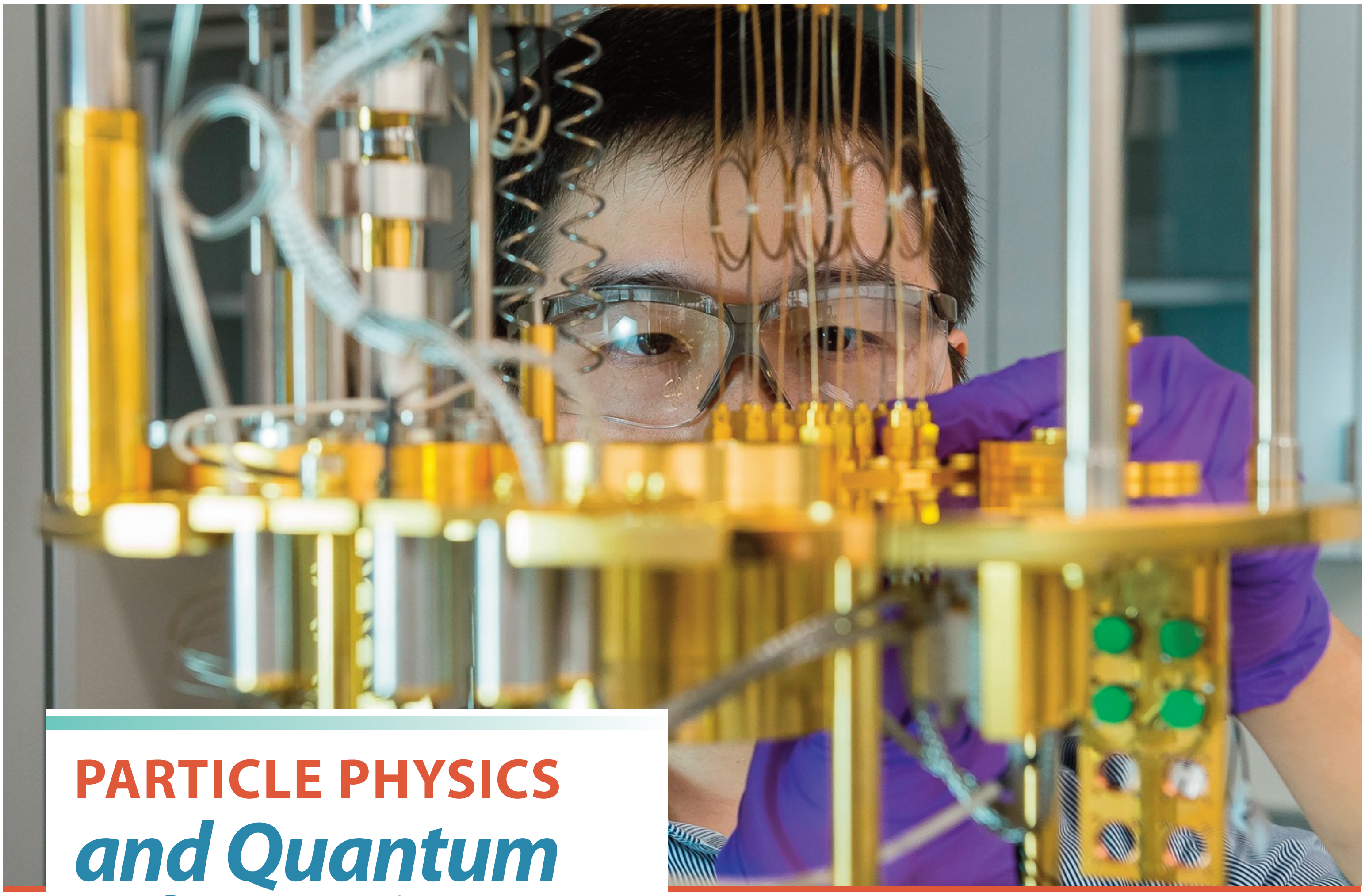
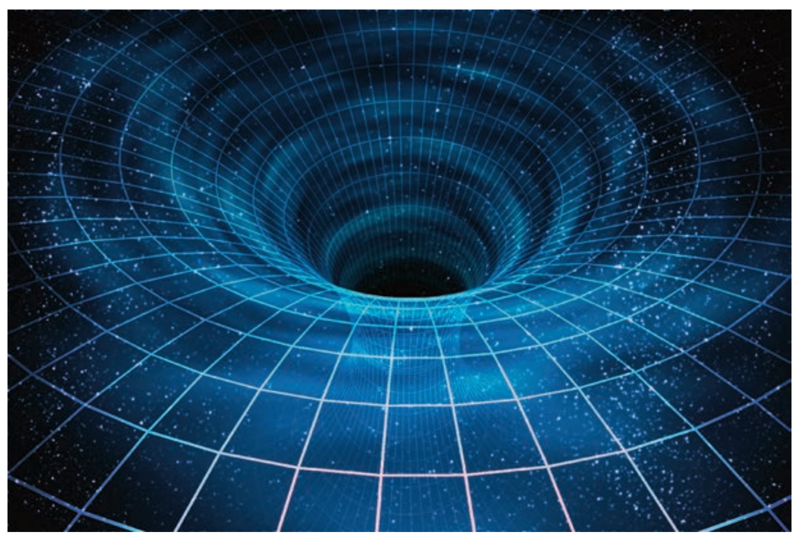
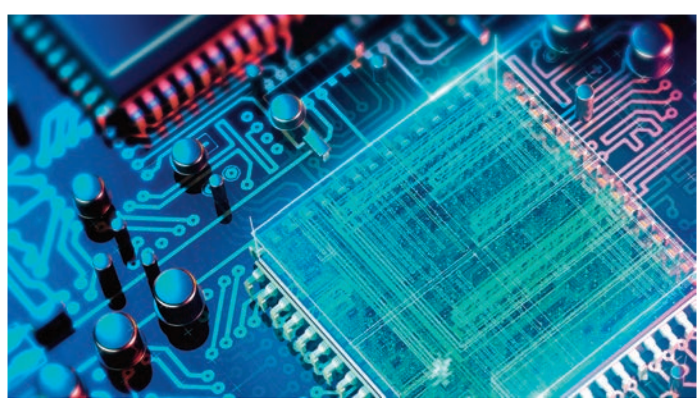


PARTICLE PHYSICS *and Quantum Information Science*

Advances in particle physics and Quantum Information Science (QIS) are tightly connected. The launch of the National Quantum Initiative signals the importance of QIS to the nation's cybersecurity and economic competitiveness. Particle physicists bring to this effort specific technologies, new ideas, and the ability to construct sophisticated, large-scale instruments. QIS, in return, offers solutions to fundamental problems in our science, from the interactions of quarks to the birth and death of black holes.





Demonstration of high-fidelity quantum teleportation on a quantum network.

The Promise of QIS

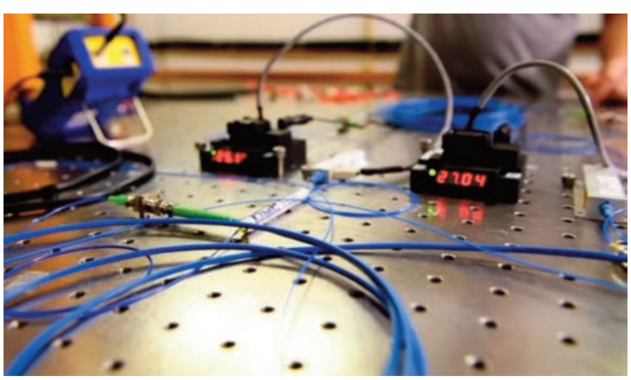
A quantum bit (qubit) extends the simple computer 1 or 0 using the relations of quantum coherence found in atomic physics. These relations allow qubits to carry more information and to process information more powerfully. However, qubits are fragile and short-lived.

By its nature, particle physics deals with quantum coherence at the particle level. We **develop and improve tools** to detect single electrons and photons.

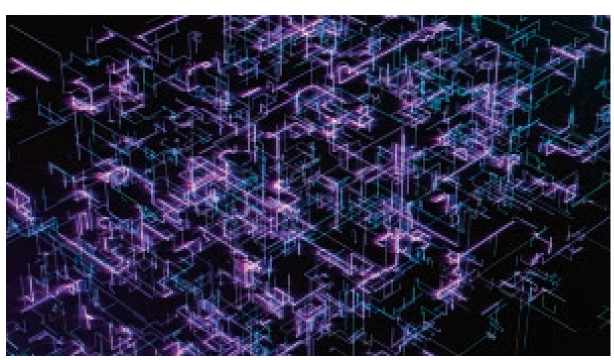
In 2020, we and our partners achieved the **high-fidelity teleportation** of light-particle qubits over a distance of 27 miles using sensors originally developed for cosmological observations.

Particle physicists and collaborators from other fields are **introducing unique approaches inspired by particle physics** applications to help advance QIS.

A qubit is the fundamental element of information for a quantum computer.



Fiber-optic cables connect off-the-shelf devices and state-of-the-art quantum devices.



The quantum internet will rely on the laws of quantum mechanics to control and transmit information.

Particle Physics

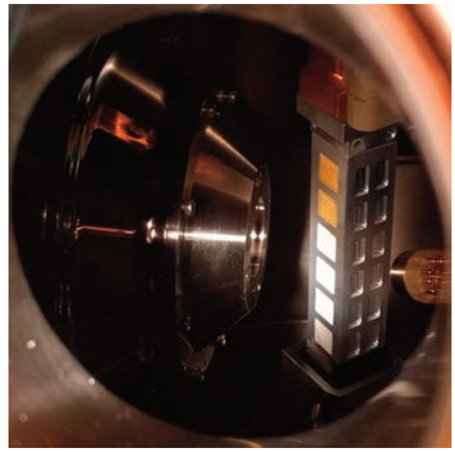
Accelerates QIS Innovation

Superconductivity offers ultra-cold quantum systems that are more stable and easier to manipulate than competing technologies.

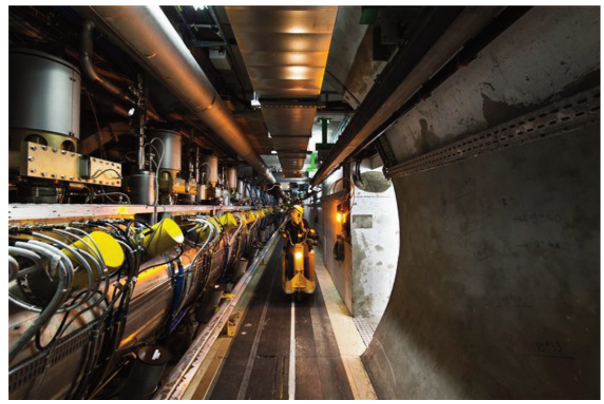
Particle physicists have constructed the world's largest-scale superconducting systems. Fermilab plans to build the world’s largest dilution refrigerator, enabling superconducting radio-frequency cavities to function as qubits in a quantum computer.

Superconducting accelerator cavities have maintained qubits for **world-record times**, seconds instead of 20–30 microseconds.

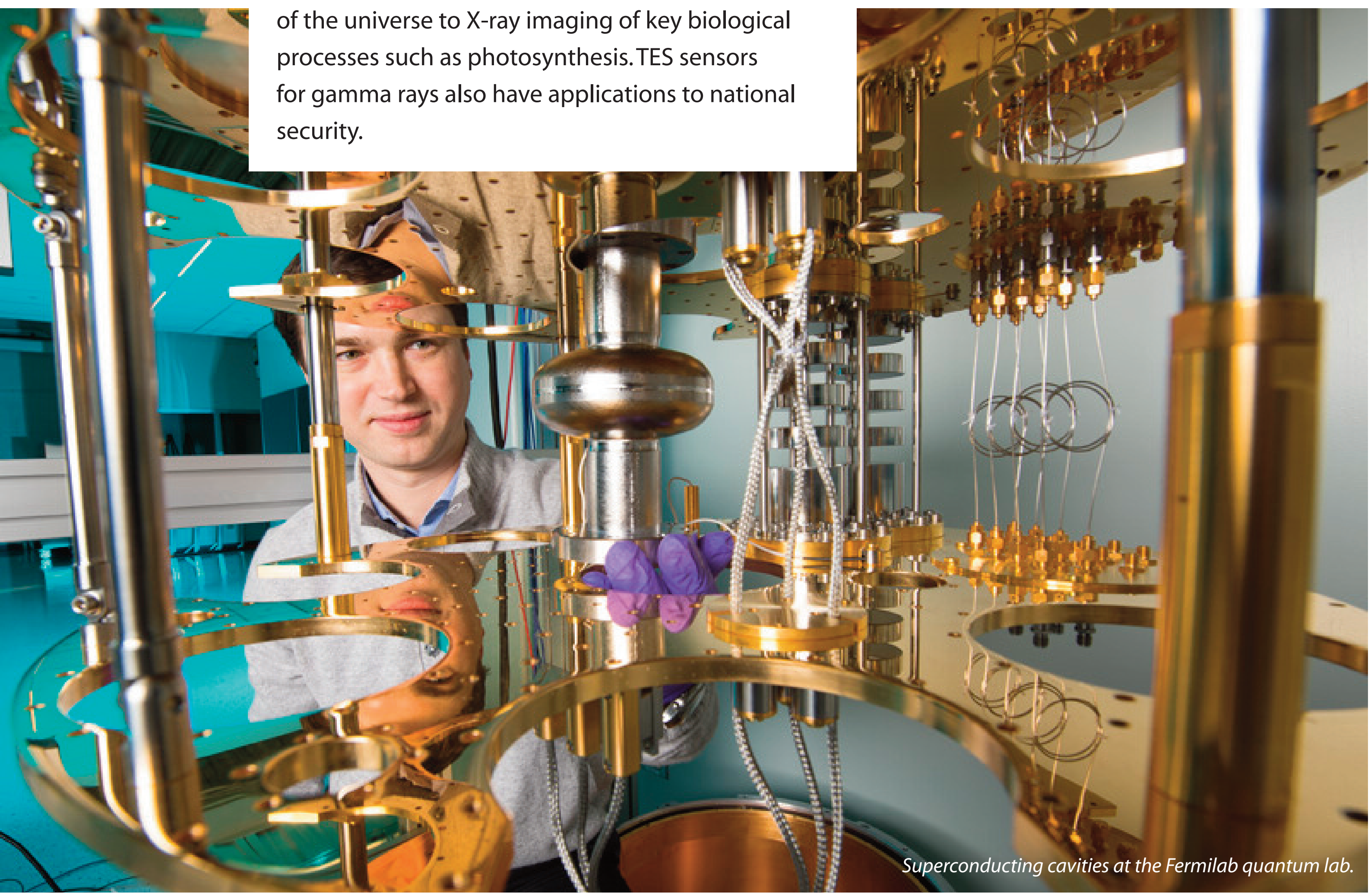
Particle physicists developed the TES, a superconducting quantum sensor, to search for the mysterious dark matter of the universe. These sensors now have **wide applications as detectors** for measurements ranging from the earliest radiation of the universe to X-ray imaging of key biological processes such as photosynthesis. TES sensors for gamma rays also have applications to national security.



A TES sensor mounted at the SLAC X-ray synchrotron.



Superconducting systems at the Large Hadron Collider.



Superconducting cavities at the Fermilab quantum lab.

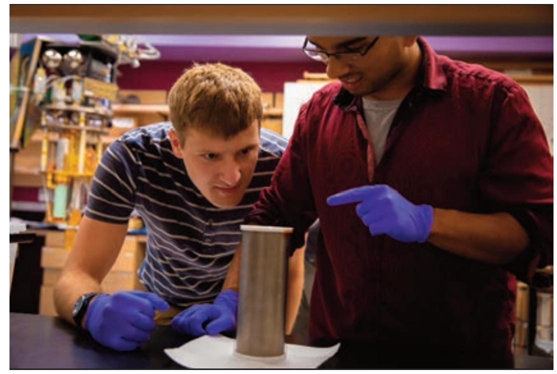
Aaron Chou applies particle physics techniques to test and operate topological qubits.

Particle Physics Resources and Expertise for QIS

Newly established national QIS research centers, led by the national laboratories, **leverage expertise in particle physics** and help grow the QIS workforce.

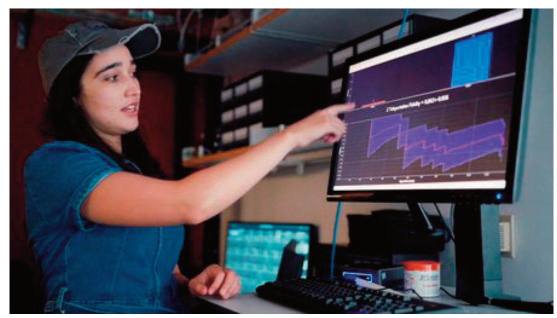
Students already are working on the quantum technologies of tomorrow at each of these centers and at universities.

The **fundamental research of particle physicists and QIS researchers** complements the centers by developing theory and simulations to explore quantum computers, quantum sensors, and novel experiments.

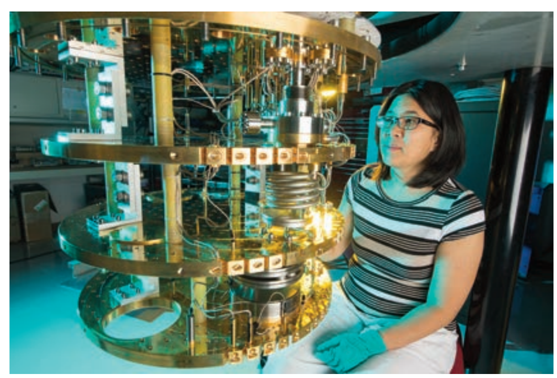


SLAC graduate students Steven Kuenstner (left) and Saptarshi Chaudhuri (right) assembling a TES superconducting sensor.

Postdoctoral fellow Daniil Frolov working in Fermiab's quantum lab.



Caltech graduate student Samantha Davis analyzes quantum teleportation data.



Physicist Lauren Hsu works on a dilution refrigerator for quantum sensors.

Images courtesy Caltech, CERN, Fermilab, SLAC, Getty Images, Shutterstock