



QIS at Fermilab and Workforce development efforts

Silvia Zorzetti, QIS Ecosystem Leader at the DOE SQMS Research Center

Sandra Charles, Chief Equity, Diversity, Inclusion, and Accessibility Officer

Anna Grassellino, SQMS Director

Jens Koch, SQMS Deputy Director

Fermilab at a Glance

- America's particle physics and accelerator laboratory
- Operates the largest US particle accelerator complex
- ~1,900 staff and ~\$600M/year budget
- 6,800 acres of federal land
- Facilities used by 4,000 scientists from >50 countries

As we move into the next 50 years, our vision remains to solve the mysteries of matter, energy, space, and time for the benefit of all.



Fermilab Science Mission – P5 science drivers

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context
Executive Summary



Report of the Particle Physics Project Prioritization Panel (P5)

May 2014



Higgs boson



Neutrinos



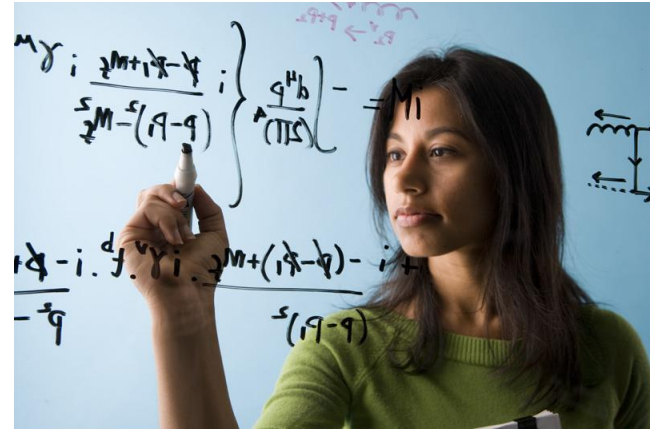
Dark matter



Dark energy and inflation



Exploring the unknown



Fermilab is delivering on the DOE/SC discovery science mission: Major particle physics breakthroughs from Fermilab experiments, major technology breakthroughs from Fermilab research

Quantum computing and sensing at Fermilab

HEP for QIS

Technology expertise and infrastructure for the development of new quantum devices and for the challenges of scaling up quantum systems

QIS for HEP

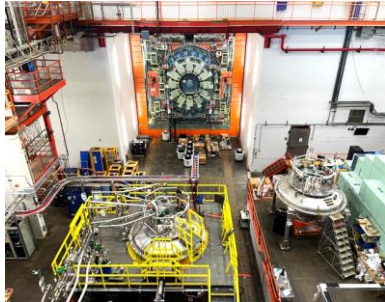
Tackle HEP challenges, such as dark matter detection, quantum computing advantage for field simulations



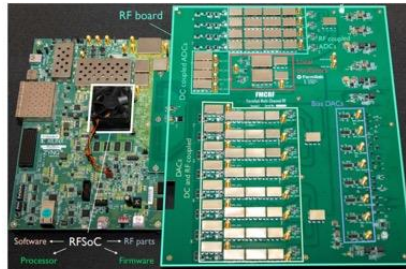
Superconducting technology



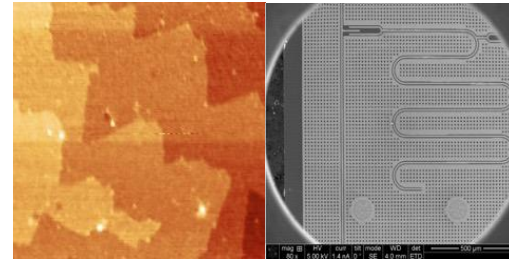
SRF cavities with long coherence time



Cryogenics



Control electronics



Materials and devices

National Quantum Initiative Act (2018)

10 yr plan to accelerate
the development of
**quantum information science
& technology applications.**

“ **Department of Energy (DOE)** shall carry out a **basic research program** in QIS;

DOE Office of Science shall establish and operate **NQI Science Research Centers** to conduct basic research to accelerate scientific breakthroughs in quantum information science and technology. ”

H. R. 6227

One Hundred Fifteenth Congress
of the
United States of America

AT THE SECOND SESSION

*Began and held at the City of Washington on Wednesday,
the third day of January, two thousand and eighteen*

An Act

To provide for a coordinated Federal program to accelerate quantum research and development for the economic and national security of the United States.

*Be it enacted by the Senate and House of Representatives of
the United States of America in Congress assembled,*

SECTION 1. SHORT TITLE; TABLE OF CONTENTS.

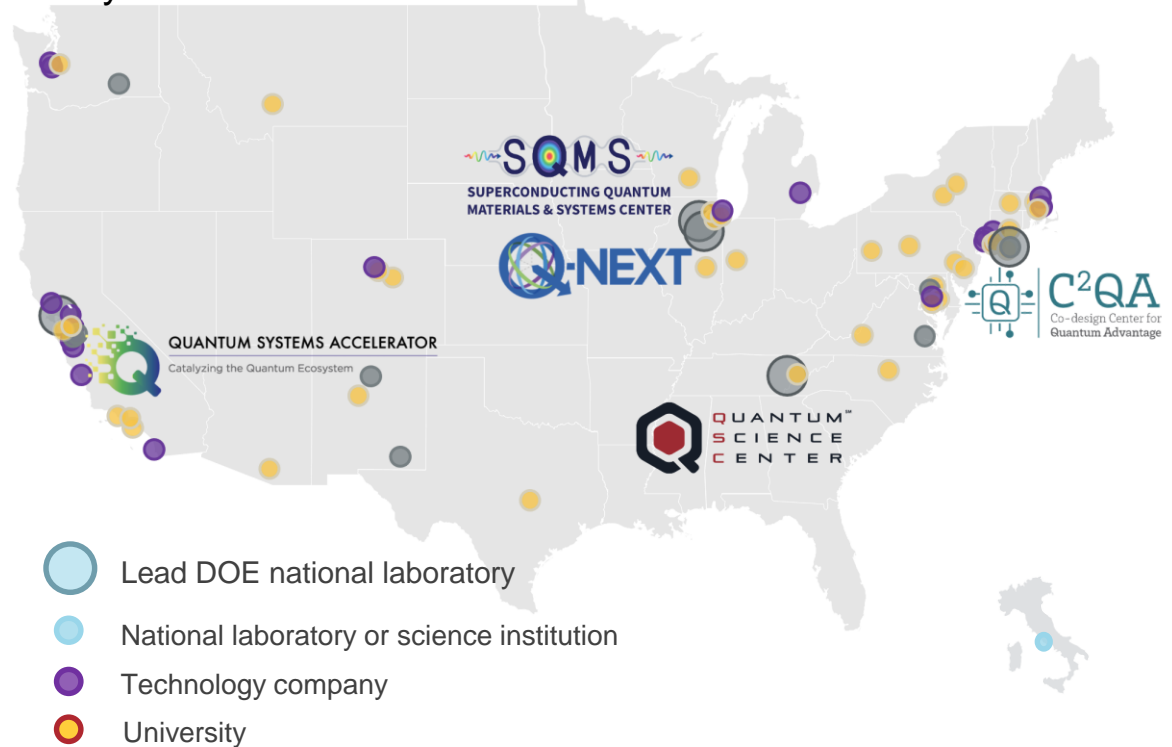
“ Quantum information science is the use of the laws of quantum physics for the storage, transmission, manipulation, or measurement of information. ”

Partnerships across academia, industry and national labs

The DOE centers bring together multidisciplinary collaborations of **1,200** experts, including **600** students and postdocs, across **80** academic, industry and national science institutions in **21** states and DC.

Through institutional partnerships, the centers unite unique capabilities, expertise and facilities.

- Answering fundamental open questions in QIS
- Leveraging DOE user facilities for advanced materials analysis and device fabrication
- Training a new and diverse quantum workforce
- Technology transfer – rapid cycle from discovery to commercialization
- Accelerating scaling up and production
- Developing national standards

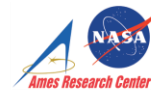




30 Partner Institutions
>500 Collaborators

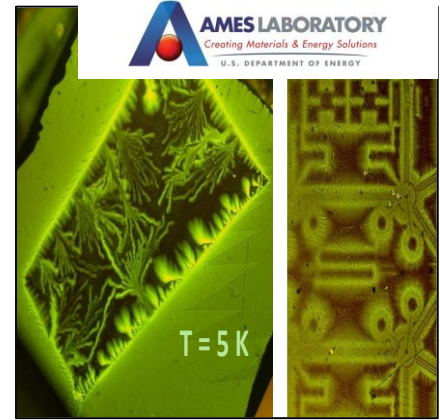
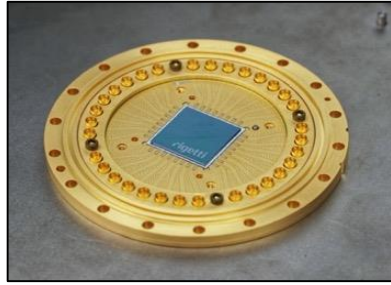
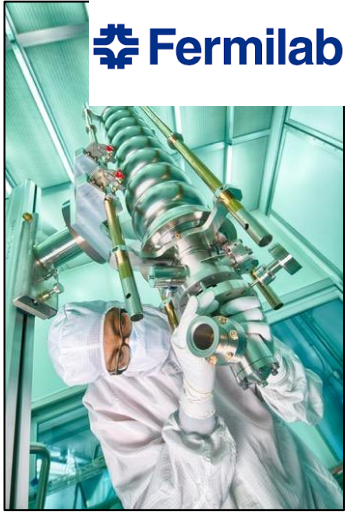
A DOE National Quantum Information Science Research Center, led by

Fermilab



A **mission driven**, multi-institutional and multidisciplinary collaboration **leveraging investments** at DOE national labs, academia, industry and several other federal and **international** entities

Mission: Attacking the Decoherence Cross-Cutting Challenge

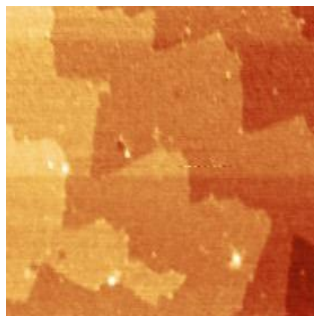


SQMS Mission

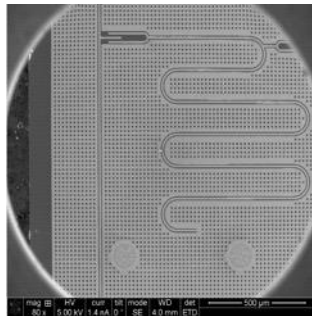
"bring together the power of national labs, industry and academia to achieve transformational advances in the QIS **major cross-cutting challenge** of **understanding** and **eliminating** the **decoherence** mechanisms in superconducting 2D and 3D devices, with the goal of enabling construction and deployment of superior quantum systems for computing and sensing."



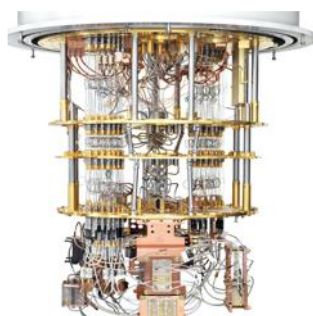
SQMS Goals and Science & Technology Innovation Chain



Developing a full understanding of sources of decoherence via a systematic, fundamental science approach



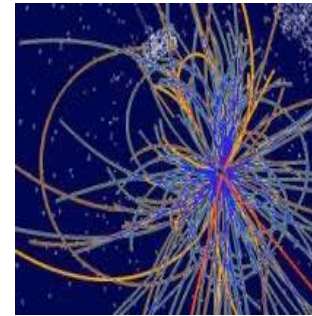
Demonstrating devices with systematically and consistently higher coherence at different SQMS partners



Preserving device high performance through the process of integrating into more complex systems



Deploying quantum computing and sensing facilities of innovative architectures and improved performance

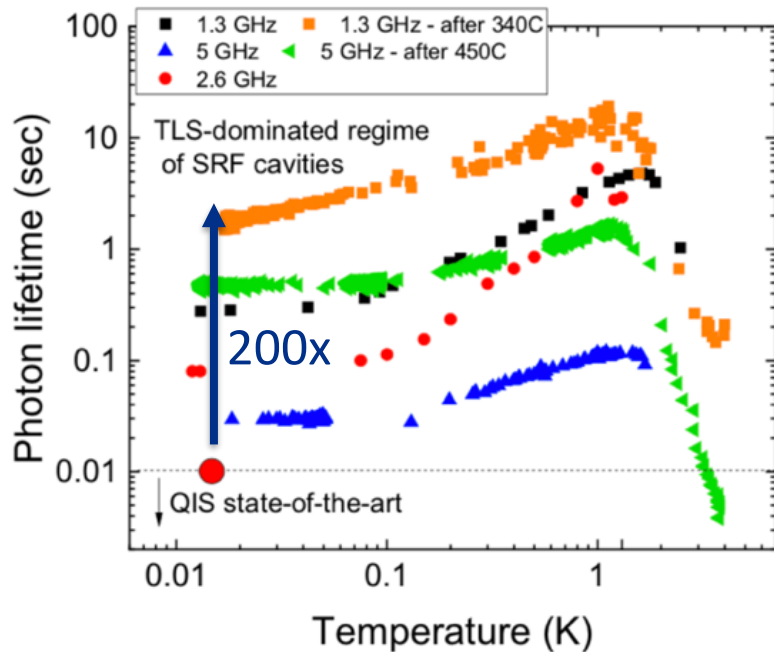


Demonstrating quantum computing and sensing advantage for particle physics and other scientific applications

SQMS bridges the gap between ideas and large-scale realizations via the unique center-wide, multidisciplinary coordinated approaches

Highlight: world record coherence 3D cavities in quantum regime

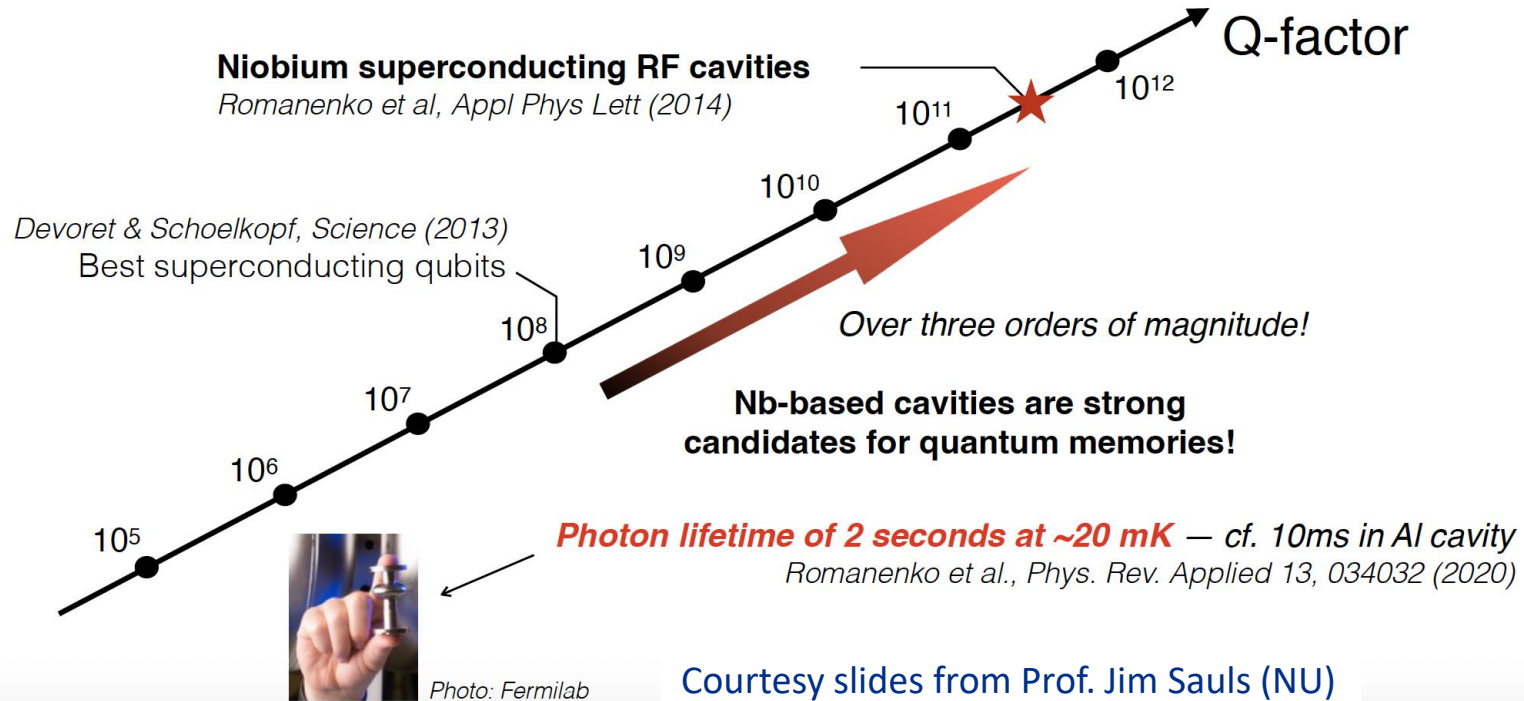
A. Romanenko et al, Phys. Rev. Applied **13**, 034032, 2020



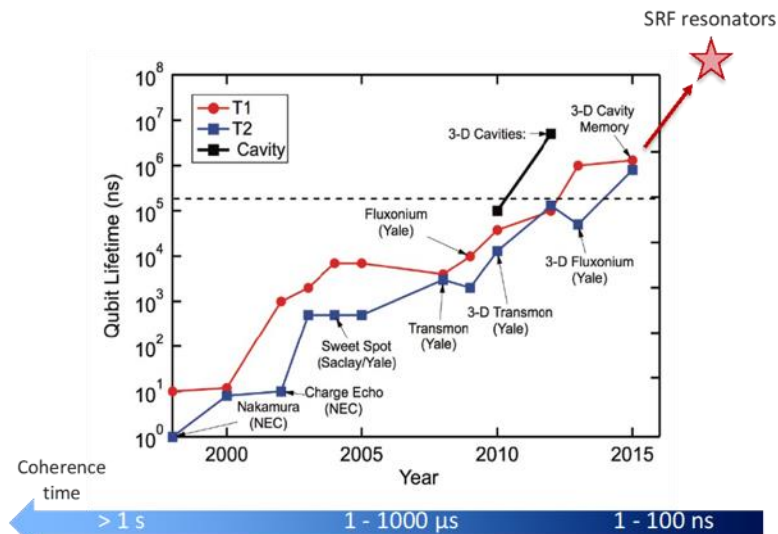
- Technology originally developed for accelerators
- Fermilab is world leader in SRF
- 2 seconds of coherence demonstrated

Improved photon lifetimes by a factor of 1,000

In the quantum regime



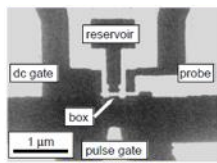
New 3D quantum devices



SRF technology



Transmon 3D architecture
H. Paik *et al.*, Phys. Rev. Lett. (2011)



Cooper-pair box
Y. Nakamura *et al.*, Nature (1999)



SQMS 3D SRF approach – unique benefits of the world’s best coherence

Novel QPU architectures

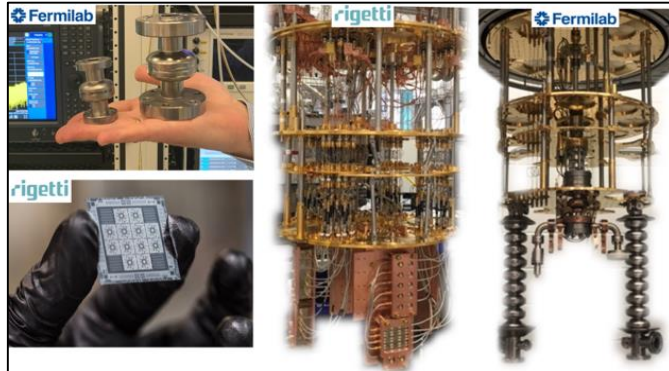
- Long coherence allows going from qubit to “qudit” approach (use **d** energy levels instead of traditional 2)
 - All-to-all qubit connectivity

ONE nine cell SRF cavity + **ONE** transmon =
SQMS 100+ qubits processor



Scalability

- > 100 qubits with just few input/output lines



Science

- Directly probing the quantum to classical transition : “Schroedinger cat” states of record large scales
- New physics (dark photon and axion) searches with orders of magnitude improved sensitivity
- Physics simulations enabled by the all-to-all qubit connectivity

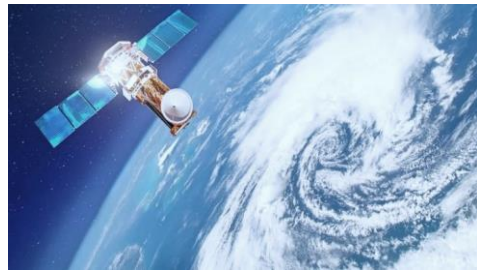
Applications – pilot programs

SQMS provides access to unique infrastructure, capabilities, and expertise

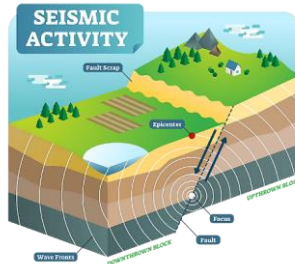
Use these capabilities for commercialization and economic growth

Areas of interest

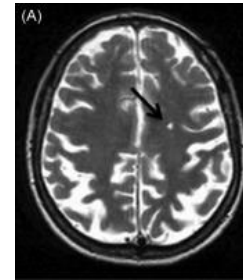
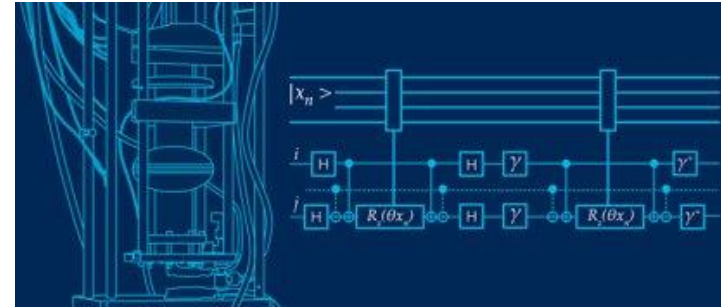
- Open-source software projects for the QIS ecosystem
- Provide a quantum advantage in real-life applications
- Single-photon level material studies



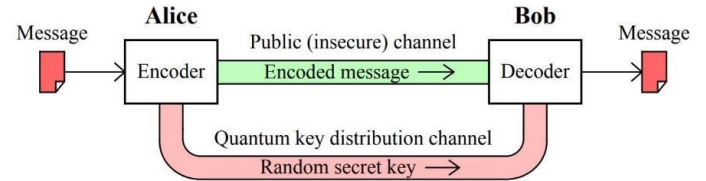
Climate Change



Sensors



SQMS-NYU Langone
Noninvasive estimation
of biophysical and
electrical properties of
biological tissue by
using magnetic
resonance

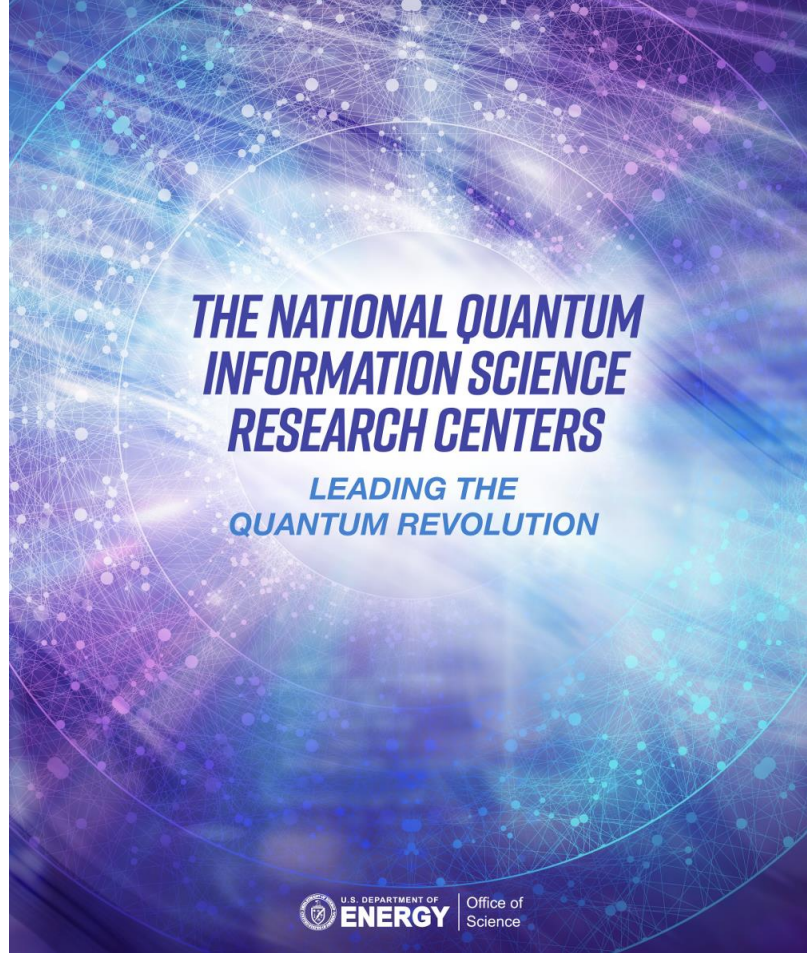


Cryptography

Workforce development at NQI Research Centers

Mission:

Create and implement programs for training the next generation of scientists and engineers in quantum.

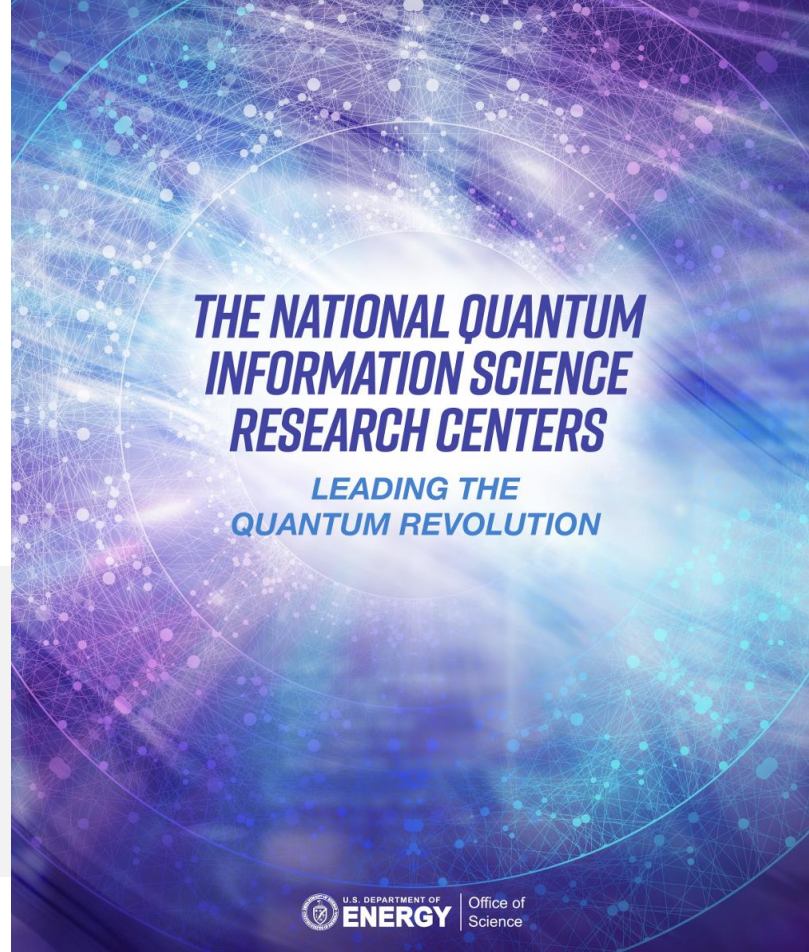


Workforce development at NQI Research Centers

Mission:

Create and implement programs for training the next generation of scientists and engineers in quantum.

DOE is supporting initiatives to address gaps in the workforce through collaboration between national laboratories, academia, and industry to prepare America's next-generation workforce for STEM.



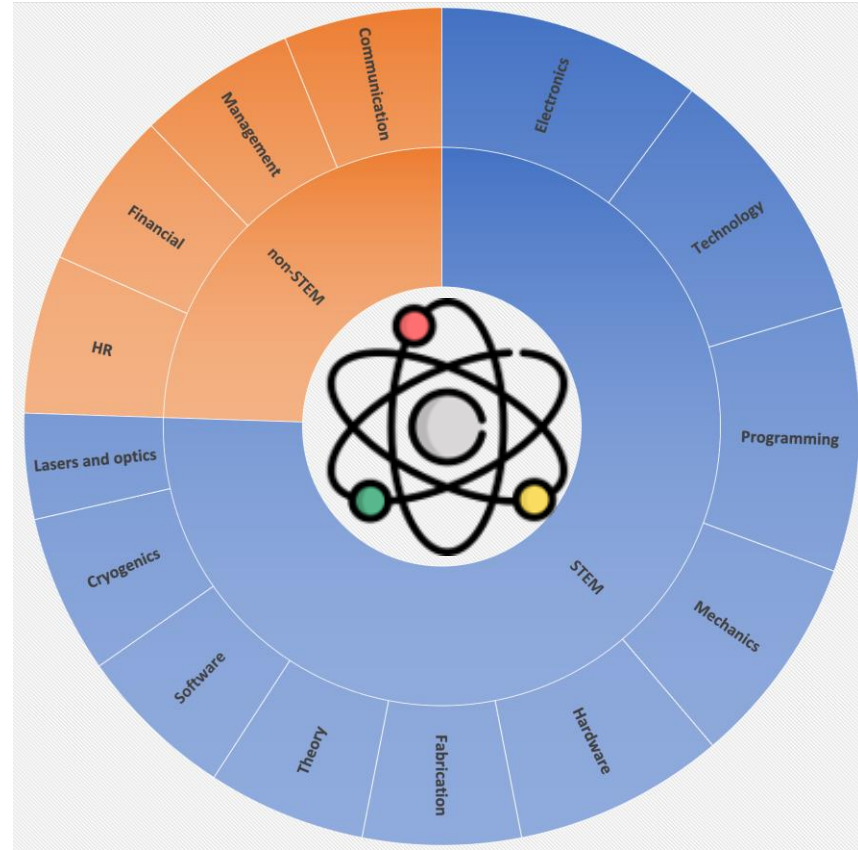
Workforce development at NQI Research Centers

Mission:

Create and implement programs for training the next generation of scientists and engineers in quantum.

Challenges:

- Multidisciplinary field
- Quantum mechanics, programming and hardware



Workforce development at NQI Research Centers

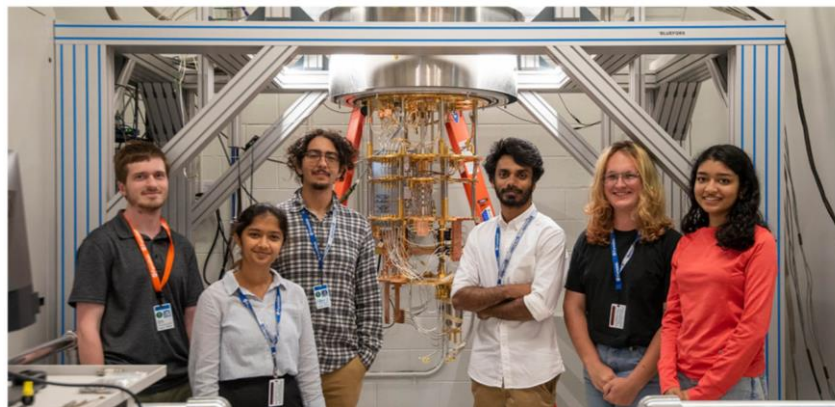
Mission:

Create and implement programs for training the next generation of scientists and engineers in quantum.

Opportunities:

- Cross-functional collaboration between academia, industry, national labs, NQI Research Centers
- Quantum computing as a gateway for a new and diverse workforce in STEM

SQMS engages with more than **400** external students in the first three years of operations



Workforce development at NQI Research Centers

Mission:

Create and implement programs for training the next generation of scientists and engineers in quantum.

Implementation:

Training through research

Workforce development at NQI Research Centers

Mission:

Create and implement programs for training the next generation of scientists and engineers in quantum.

Implementation:

Training through research

Leverage DOE investments

Expose students and early-stage research to state-of-the-art facilities and expertise in a multi-institutional / multi-disciplinary collaboration

Develop and practice research, technical and soft skills (presentation, networking, etc.)



Workforce development at NQI Research Centers

Mission:

Create and implement programs for training the next generation of scientists and engineers in quantum.

Vehicles identified at SQMS:

1. SQMS Summer Internship Program
2. Carolyn B. Parker Fellowship
3. Summer Schools
4. New funding opportunities

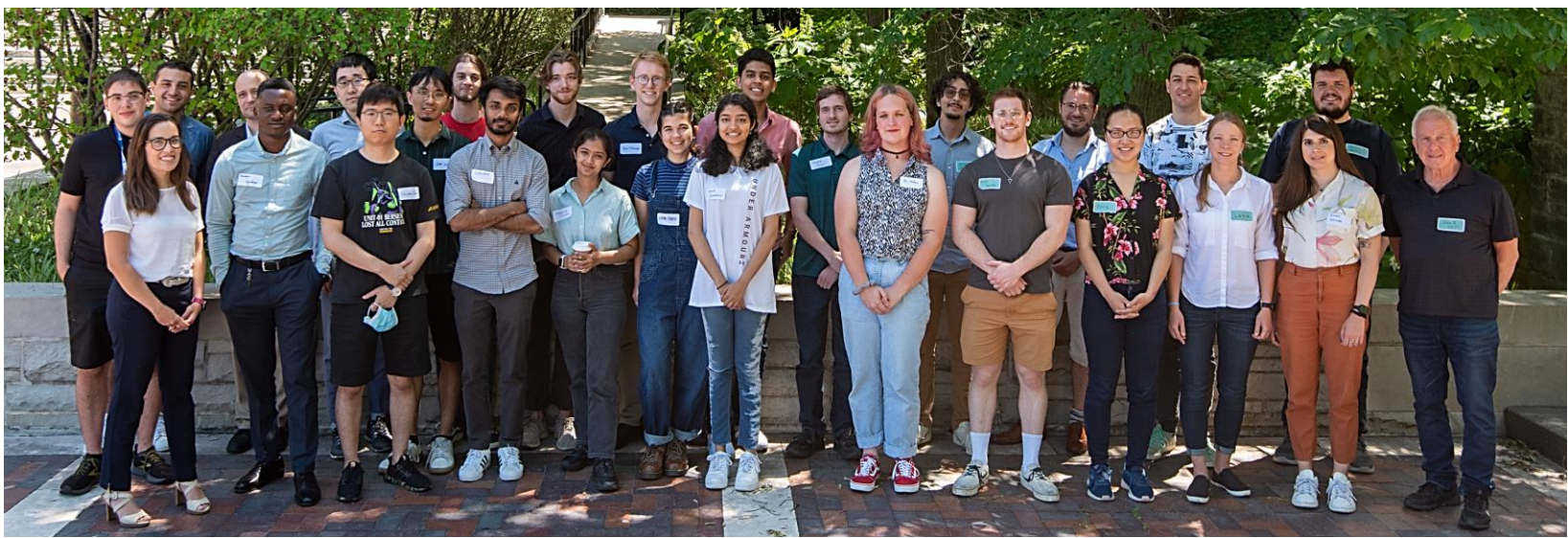
SQMS Timeline for Workforce Development

SQMS: Ecosystem and workforce development activities



Vehicles identified at SQMS:

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Vehicles identified at SQMS:

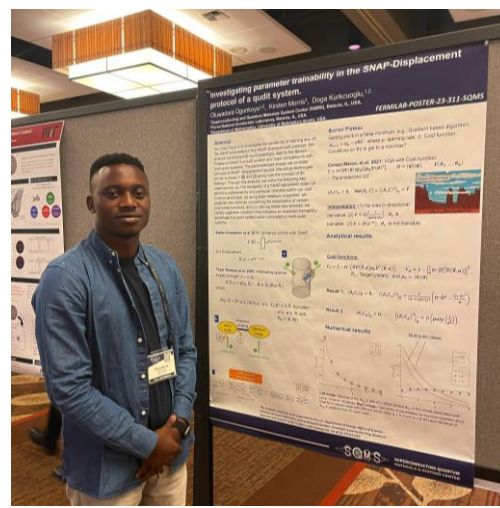
1. SQMS Summer Internship Program
2. Carolyn B. Parker Fellowship
3. Summer Schools
4. New funding opportunities

- 10-week paid internship program
- undergrad interns from across the US
- co-supervised across the center
- dedicated training programs and research activities
- Interim reports and mentoring program
- 50% of interns are female or belong to underrepresented groups in STEM



Carolyn Parker

Parker Fellow
Superconducting Quantum Materials and System Center



Dr. Oluwadara Ogunkoya
1st Parker Fellow

Vehicles identified at SQMS:

1. SQMS Summer Internship Program
2. Carolyn B. Parker Fellowship
3. Summer Schools
4. New funding opportunities

- First fellowship opportunity in QIS to prioritize the representation and inclusion of historically and contemporarily minoritized scholars in STEM.
- Named after the first African American woman to earn a postgraduate degree in physics
- Multi-disciplinary committee to select candidates across with different expertise



Vehicles identified at SQMS:

1. SQMS Summer Internship Program
2. Carolyn B. Parker Fellowship
3. Summer Schools
4. New funding opportunities

2023: Largest U.S. school to educate in quantum information science, including lab experience

- > 300 applicants
- 150 participants : students, professionals from labs and industry
- More than 40 instructors, top national experts in QIS from the 5 quantum centers (DOE, academia, industry)

2023 US QIS Summer School



Hands-on training classes



HEP-RENEW awarded proposal: **Training through research in quantum information science and engineering at the SQMS Center**

Quantum Science focus area of the **RENEW Pathway Summer School** co-organized by Fermilab and Brookhaven national laboratories

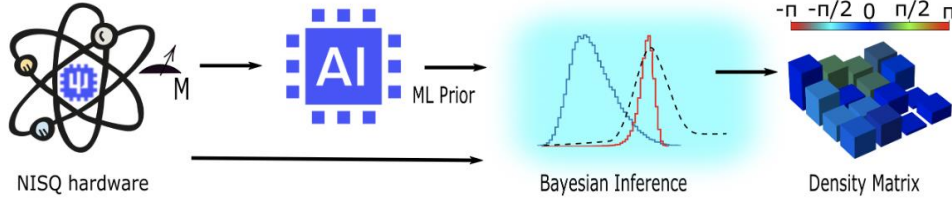
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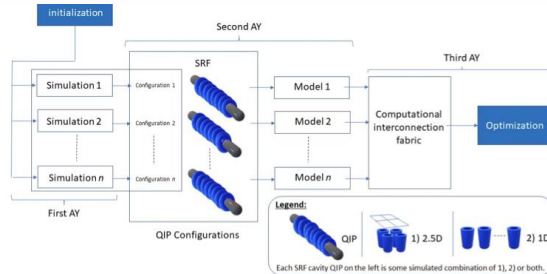
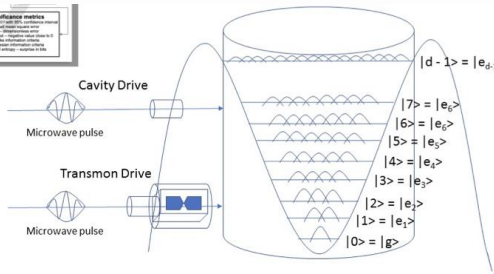
DOE Reaching a New Energy Science Workforce (RENEW)

- Leveraging national laboratories and unique facilities while aiming to include more minority serving institutions (MSIs) in particle physics research
- Students and faculty from MSIs to conduct studies at SQMS
- Build the critical infrastructure and next-generation capabilities for quantum computing and sensing

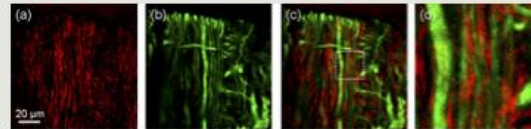
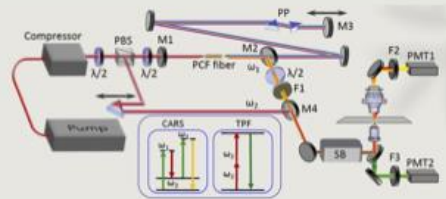
Training through research in quantum information science and engineering at the SQMS Center



Thomas A. Searles
 University of Illinois
 Chicago
 Quantum devices and
 engineering



Stephen Providence
 Coppin State University
 Quantum Algorithms



Yanhua Zhai
 Spelman College
 Quantum materials

Opportunities for ALL at Fermilab



ASPIRE Fellowship

Accelerator Engineering Fellowship
for Underrepresented Minorities

ASPIRE

[Program Details >](#)



SQMS Parker Fellowship

Superconducting Quantum
Materials and System Center

Carolyn B.
Parker

[Program Details >](#)



Sylvester J. Gates, Jr Fellowship

Theoretical Physics: Postdoctoral

Sylvester James
Gates, Jr.

[Program Details >](#)

30+ Fellowships & Internships

DOE Internships

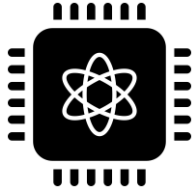
- Minority Education Institutions Student Partnership Program (MEISPP)
- Community College Internship (CCI)
- DOE Omni Technology Alliance Internship Program Summer Undergraduate Laboratory Internship (SULI)
- Visiting Faculty Program (VFP)

Fermilab Programs & Initiatives Flagship

- Programs Graduate Fellowships in Engineering and Science (GEM)
- Summer Internships in Science and Technology (SIST)
- TARGET Program Fermilab Co-Op Program
- VALOR (Veteran Applied Laboratory Occupational Retraining)
- Fermilab Alumni Network –the FAN

Thank you!

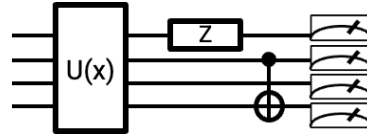
Quantum
Information
Science



Hardware/
Devices



Physics/
Devices



Algorithms/
Applications

*Foundations of
Quantum Mechanics*

*Physics Beyond
Standard Model*

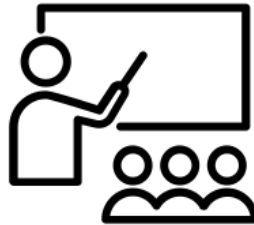
Dark Matter

Quantum Advantage

Ecosystem



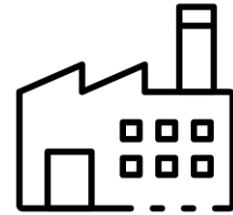
Education



Training



Hands-on research



Industry applications

Workforce Development in STEM

Recommendations to help physics and astronomy departments develop action plans for systemic change

Success or failure of students in physics is attributed to:

- Sense of belonging → Professional network
- Physics identity → Research project
- Academic and financial support
- Leadership and structures

Carrying out research at DOE national laboratories and at research centers such as SQMS to foster a sense of belonging among staff and students while cultivating a collaborative community

AIP | American Institute of Physics

TEAM-UP REPORT

**THE TIME
IS NOW**

Systemic Changes to Increase African Americans with Bachelor's Degrees in Physics and Astronomy



TEAM+UP

www.aip.org/diversity-initiatives/team-up-task-force