Workshop on the intersections of Quantum Information Science and Nuclear Physics

Monday, January 12, 2026 - Friday, January 16, 2026

Book of Abstracts

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Real-time Dynamics of fermionic models on Superconducting Quantum Computers at the Utility Scale

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In this talk, we present a large-scale quantum simulation of the one-dimensional Fermi-Hubbard model, a paradigmatic fermionic model, on IBM's superconducting quantum computers with over 100 qubits. By developing first-order and second-order optimized Trotterization circuits, we maintain a constant circuit depth in quantum simulation regardless of system size on superconducting quantum computers with limited qubit connectivity, such as IBM's quantum devices. Such a scalable Trotterization circuit design enables us to precisely investigate the relaxation dynamics in the Fermi-Hubbard model using IBM's quantum computers with over 100 qubits, and we validate our results against the Tensor Network-based method employing the time-dependent variational principle. Thereby, our quantum simulation framework advances beyond exact classical methods in the exploration of large-scale fermionic many-body systems.

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No-go Theorem for Environment-assisted Invariance Symmetry of Entanglement

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In this talk, I will examine the conditions under which quantum operations preserve environment-assisted invariance (envariance), a symmetry of entanglement. While envariance has traditionally been studied in the context of local unitary operations, I extend the analysis to include non-unitary local operations. I will show that, to maintain envariance, such operations must admit Kraus representations with a direct-sum structure, thereby effectively defining decoherence-free subspaces. Finally, I will discuss the broader implications of our main no-go theorem for quantum control.
Reference: A. Sone, A. Touil, K. Maeda, P. Cappellaro and S. Deffner, New J. Phys. 27 064509 (2025)

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Information Processing in Quantum Thermodynamic Systems: an Autonomous Hamiltonian Approach

Author: Shou-I Tang[1]

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Extending the quantum formulation of [Phys. Rev. X 3, 041003 (2013)] to a more general setting for studying the thermodynamics of information processing including initial correlations, we generalize the second law of thermodynamics to account for information processing in such autonomous systems. We consider a composite quantum system consisting of a principal system, heat bath, memory, and work source, and adopt an autonomous Hamiltonian framework. We derive constraints on the total Hamiltonian that ensure the work source to act as a catalyst preserving its original randomness, namely that the total unitary evolution must have a unitary partial transpose. We show that this requirement is equivalent to the commutativity of operators acting on the joint system of the principal system, bath, and memory, which underlies the Hamiltonian structure. Next, we generalize the quantum speed limit for the joint dynamics of system and memory to the quantum thermodynamic speed limit, from which we obtain a dynamical version of Landauer's bound. More importantly, we also interpret this quantum thermodynamic speed limit in the context of quantum hypothesis testing.

Session 2 / 4

Experimental Quantum Simulations of Nuclear and High Energy Phenomena

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I will present recent experiments that simulate several phenomena in nuclear and high-energy physics. This includes of meson scattering 1, string-breaking [2], bubble nucleation across a quantum phase transition [3], and the programming of HaPPY codes related to AdS/CFT holographic duality. These simulations exploit the platform of trapped atomic ions, featuring qubits (spins) with essentially infinite idle coherence times and the highest purity quantum gate operations. Such atomic clock qubits are controlled with laser beams, allowing densely-connected and reconfigurable universal gate sets. In the future, such simulations will rely on scaling to much larger systems, involving concrete architectural paths, from shuttling ions between QPU cores to modular photonic interconnects between multiple QPUs. More broadly, I will summarize the state-of-the-art in ion trap quantum computers in both academic and industrial settings, for both scientific and commercial applications.

1 E. R. Bennewitz, et al., Quantum 9, 1773 (2025).
[2] A. De, et al., arXiv:2410.13815 (2024).
[3] D. Luo, et al., arXiv:2505.09607 (2025).

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Quantum Sensing of Fundamental Symmetry-Violating Nuclear Properties

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This talk will describe three types of experiments that use techniques of single quantum state preparation, state engineering, and projective state readout to measure fundamental symmetry-violating properties of nuclei, often at the standard quantum limit of sensitivity. These are:
1. Ongoing experiments to search for parity (P) and time reversal (T) violating nuclear Schiff moments, which are a powerful probe for CP-violating physics beyond the Standard Model (BSM).
2. Ongoing experiments to measure P-violating (PV) nuclear anapole moments, which are poised to provide a broad new data set for understanding the electroweak structure of nuclei in the SM.
3. New experiments to measure the changes in PV nuclear weak charge and/or neutron radius, across a chain of isotopes of the same element. These can probe for BSM physics and/or provide new information on the nuclear equation of state.

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Quantum Sensing Radiative Decays of Neutrinos and Dark Matter Particles

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We present a new approach to search for radiative decays of very weakly interacting particles using quantum sensors. Superconducting transmon qubits and trapped ion systems can detect extremely small electromagnetic signals produced by decay photons. We study two physics cases: dark matter and the cosmic neutrino background. We show that current quantum devices can already probe radiative decays of dark matter, while reaching sensitivity to neutrino magnetic moments will require larger and more coherent quantum systems.

Session 6 / 7

Single atom tweezer array platform for open quantum system physics

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Understanding decoherence and dissipation remains a central challenge for quantum information science, particularly in many-body systems where system–environment coupling gives rise to rich and not yet fully understood dynamics. Neutral-atom tweezer arrays offer a promising route toward controlled many-body quantum simulators in which local information spreading through an interacting system can be studied in detail. Such a platform enables exploration of how information flows between a quantum system and its environment, including phenomena such as non-Markovian dynamics, information backflow, partial local recovery, and the encoding of local information into global many-body states. Understanding these processes is essential for clarifying the role of decoherence in quantum information processing and for identifying regimes where environmental coupling can be characterized, mitigated, or potentially exploited.

In this talk, I will describe an experimental platform under development based on individually trapped cesium atoms in optical tweezers with Rydberg interactions. The emphasis will be on the experimental framework, the conceptual questions it enables, and the types of open-system phenomena that such a platform is designed to address, with the goal of enabling studies of decoherence in programmable many-body quantum systems.

Session 4 / 8

Quantum Sensing Using a Transportable Optical Lattice Clock

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As Thorium nuclear spectroscopy progresses, it promises to be a unique and powerful quantum senor of the strong nuclear force. In an analogy, once clock errors arising from electromagnetism are understood and quantified, an optical lattice clock may be used as a sensor to measure effects arising from gravity. One application is relativistic geodesy, where earth's geoid can be mapped via relativistic red-shift of the clock frequency. Here, we present efforts at NIST to develop a transportable optical lattice clock capable of state-of-the-art relativistic geodesy. We will summarize systematic clock uncertainties and the stability of the transportable clock laser system. We will conclude with a brief description of a preliminary measurement campaign to measure clock frequency offsets between a laboratory clock in Boulder CO and a remote clock transported to the summit of a 4300 m mountain.

Session 3 / 9

DeMarco Group Research and the Illinois Quantum and Microelectronics Park

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I will give an overview of research in my group at the University of Illinois, including measurements of mobility in optical lattice Hubbard models, photonic cluster state generation using trapped atomic ions, and work to entangle atomic ions with silicon carbide di-vacancy centers. I will also talk about my role as Chief Technology Officer in launching the Illinois Quantum and Microelectronics Park (IQMP). I will link the IQMP to opportunities in science and technology development and the intersection of academic research and private-sector activity.

Session 6 / 10

Addressing the Current Challenges of Quantum Machine Learning through Multi-Chip Ensembles

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Practical Quantum Machine Learning (QML) is challenged by noise, limited scalability, and poor trainability in Variational Quantum Circuits (VQCs) on current hardware. We propose a multi-chip ensemble VQC framework that systematically overcomes these hurdles. By partitioning high-dimensional computations across ensembles of smaller, independently operating quantum chips and leveraging controlled inter-chip entanglement boundaries, our approach demonstrably mitigates barren plateaus, enhances generalization, and uniquely reduces both quantum error bias and variance simultaneously without additional mitigation overhead. This allows for robust processing of large-scale data, as validated on standard benchmarks (MNIST, FashionMNIST, CIFAR-10) and a real-world PhysioNet EEG dataset, aligning with emerging modular quantum hardware and paving the way for more scalable QML.

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Towards hybrid algorithms for hadronization in event generators

Author: Yannick Meurice[1]

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Theory of the Th-229 nuclear clock: from ion-trap concept to solid-state platforms

Author: Andrei Derevianko[1]

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New frontier of quantum computing

Author: Mikhail Lukin[1]

[1] *Harvard University*

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Nuclear Physics with Rare Atoms and Molecules

Author: Ronald Fernando Garcia Ruiz[1]

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From Quantum Circuits to Quantum Agents: Towards Scalable and Self-Programming Quantum AI

Author: Samuel Yen-Chi Chen[1]

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Quantum Control and Cold Chemistry with Diatomic Molecules

Author: Dan McCarron[1]

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Controlling and inducing strong correlations at twisted material interfaces

Author: Pavel Volkov[1]

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Analog Quantum Simulation of Topological Lattice Models with a Parametric Cavity

Author: Christopher Wilson[1]

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Programmable neutral atom quantum computers for nuclear physics

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Can Bose-Einstein condensates modify radioactive decay of atoms

Author: Wolfgang Ketterle[1]

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Author: Jiunn-Wei Chen[1]

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Quantum-amplified global-phase spectroscopy on an optical clock transition

Author: Simone Colombo[1]

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Neutral-atom arrays for cavity QED and quantum computing

Author: Vladan Vuletic[1]

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Quantum Diamond Sensors Best of Both Worlds

Author: Ronald Walsworth[1]

[1] *University of Maryland*

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New tools for resource-efficient quantum simulation of nuclear physics with neutral atom arrays

Author: Jake Covey[1]

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Towards an all solid-state VUV CW Laser at 148.4nm for the 229Th Nuclear Clock

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Author: Olga Kocharovskaya[1]

[1] *Texas A&M University*

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Solid state nuclear clock

Author: Koji Yoshimura[1]

[1] *Okayama University*

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Quantum simulation on curved spacetime

Author: Kazuki Ikeda[1]

[1] *UMass Boston*

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[1] *Michigan State University*

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Nuclear clocks: What now?

Author: Eric Hudson[1]

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Neutral-atom quantum computing with nuclear spin qubits

Author: Matthew Norcia[1]

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Author: Huan-Hsin Tseng[1]

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[1] *Indiana University Bloomington*

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[1] *Jefferson Lab*

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[1] *Harvard University*

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[1] *Johns Hopkins University*

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Author: Ike Chuang[1]

[1] *MIT*

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Portable trapped ion quantum computer/clock system

Author: Robert Niffenegger[1]

[1] *UMass Amherst*

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Author: Eric Holland[1]

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Lattice field theory for superconducting circuits

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In this talk I will present a new, general method for computing properties of superconducting circuits from circuitQED. This method is essentially a direct adaptation of "lattice QCD", a tool commonly used in particle physics to solve the microscopic equations of nuclear physics, to superconducting circuits. I will describe the method, then present applications to fluxonium, a superconducting circuit with promising applications for quantum computing. Connection to experiment is made from a microscopic study of charge noise. Small corrections to the standard coherent quantum phase slip rate formula are seen in the microscopic calculations, and I present a simple modification to the present theory that accounts for the difference.