Interesting Quantum R&D Activities

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SCD Projects Meeting

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Fermilab Quantum Institute – reminders of structure

- https://quantum.fnal.gov/
- Two aspects
  - Quantum Science Program: algorithms, theory, controls (networks)
  - Quantum Technology Program: sensors, devices, systems
- We are mainly involved in the science program, but work directly with the technology group
- Many small QuantISED grants are active now
  - Adam Lyon: Large-scale (HPC) open quantum systems simulations (w/ANL)
  - Gabe Perdue: Machine learning and optimization (w/ORNL)
  - Gustavo Cancelo: Controls (w/UChicago)
  - Alex Macridin: Spin systems with VQE (FNAL theory group)
  - Panagiotis: Quantum networking (Caltech, Northwestern)
- Steve Mrenna and I are part of the projects that Gabe and Adam run

Some of the key initiatives

- National Quantum Institute call
  - Fermilab put in a proposal focused on SRF-based qubit systems, QIS, algorithms, and material science led by Anna Grassellino, partnered with NASA and many universities
    - Panagiotis, AlexM, AdamL, myself included and many others from Tech Division and theory
  - Five are in the running, probably three will make it (FNAL/NASA, ORNL/LANL, UofC/ANL, LBNL/Sandia, Brookhaven/others)
    - Steve Mrenna included on the ORNL-led proposal for HEP theory
- Partnerships with industry
  - Rigetti: CRADA is still in the works for linking to HEPCloud to to connect HEP to quantum resources. Several SCD folks involved (Burt, Tony, Andrew, Adam, Farrukh).
  - IBM: We are part of the IBMQ network through ORNL
  - Google
  - Honeywell and AWS Braket are in the works

What's exciting and interesting?

- We can run quantum circuits that
  - Find valid solutions to difficult optimization problems on Dwave and IBMQ
  - Do classification tasks on Google's Sycamore chip using SVMs
  - Show results from Rabi model using Rigetti device and VQE
- Running a program is similar to running a physics experiment.
- Superconducting qubits have short coherence times (10s of microseconds), are noisy (very limited in kinds of gate sequences that can be executed and measured), and can only handle the smallest toy problems.
- The system we (FNAL) are constructing from SRF cavities will be interesting
  - Very long conherence times and very high fidelity expected,
  - qudit capabilities (2^10 levels possible)
  - Adam and I are working to help develop simulation capabilities with Eric Holland
- Current systems can solve (small) problems using hybrid algorithms and variational methods (VQE, QAOA)