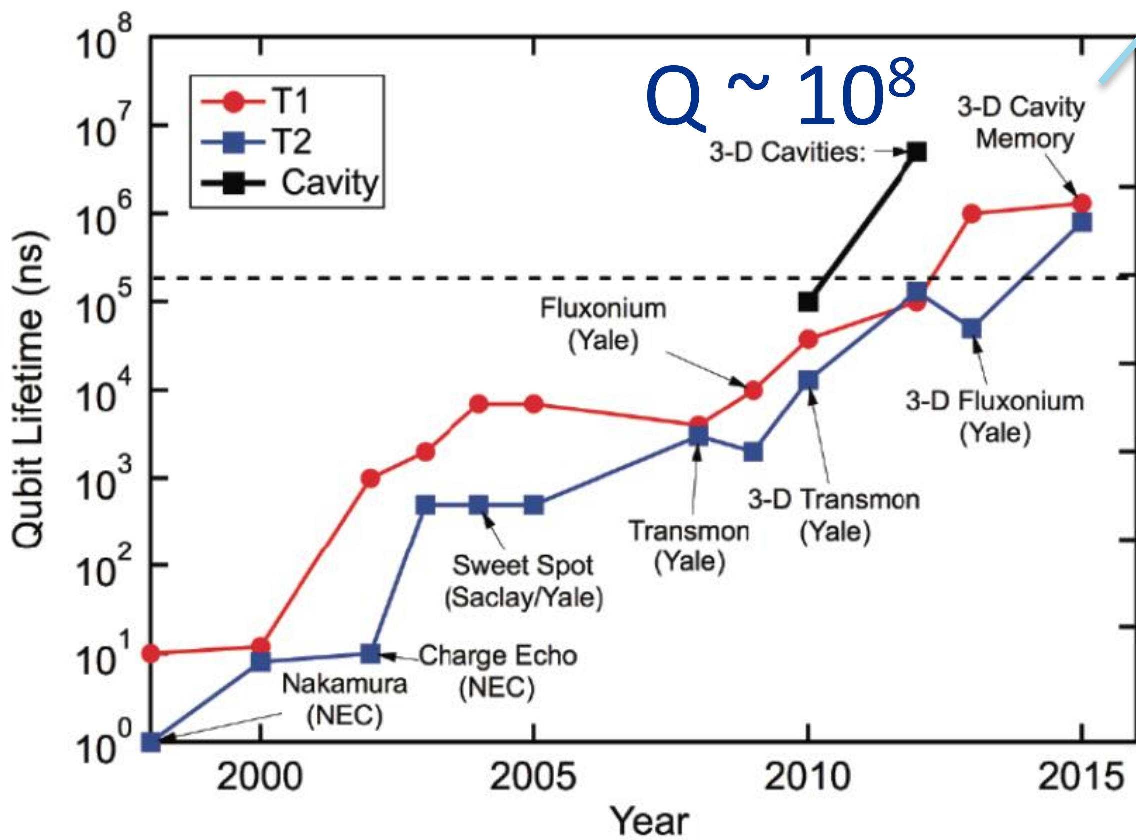
QIS

roni

Theory-treat, Nov 2019

High Q SRF cavities for improved coherence



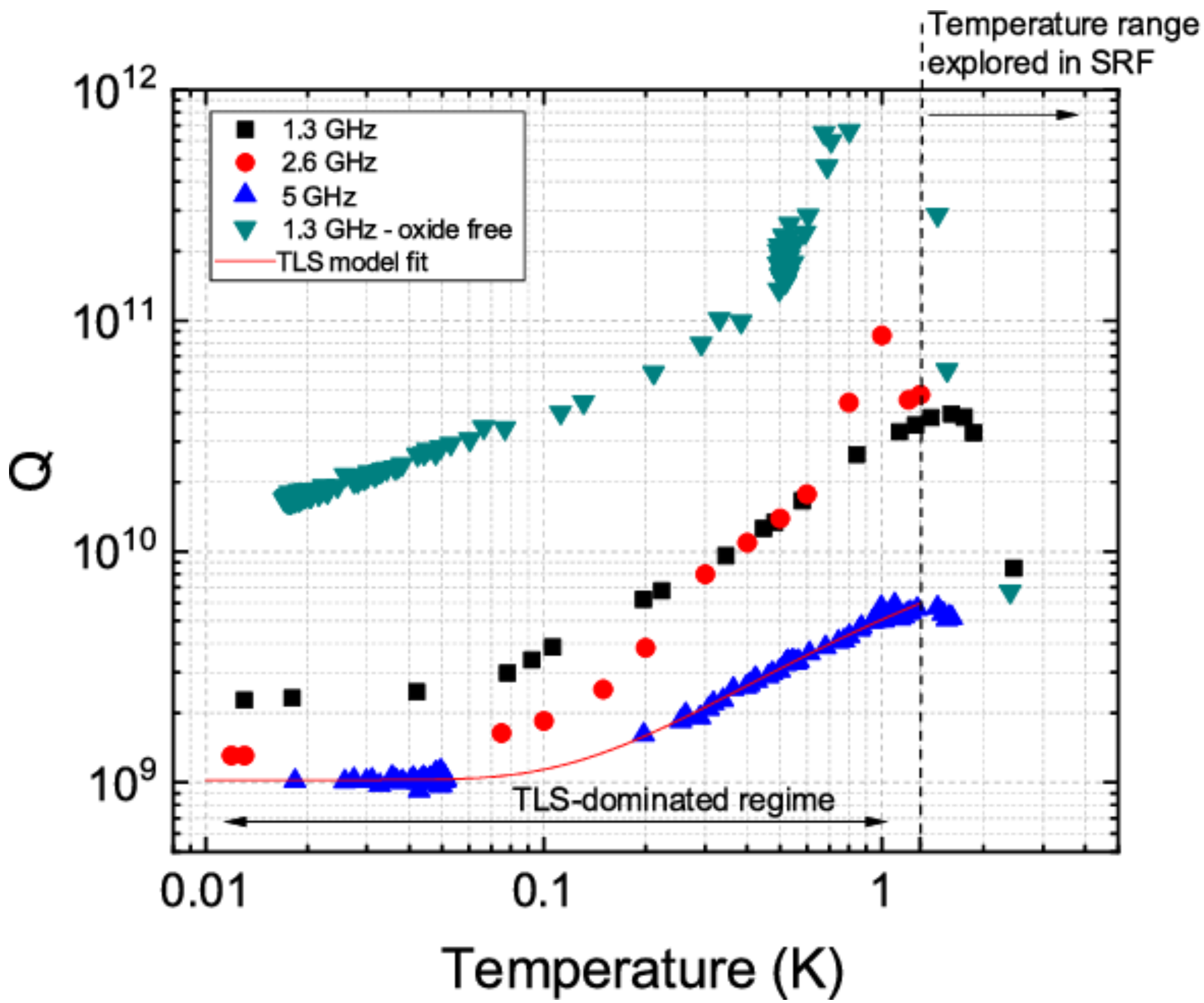
Q > 10^{11}

Potential of up to ~10 <u>seconds</u> of coherence

M. H. Devoret and R. J. Schoelkopf, *Science* 339, 1169–1174 (2013)

1-cell Fermilab cavities of various frequencies

SRF may be a game changer.



A home for qubits?

Accelerator cavities

Fermilab hired Eric Holland - a superconductor transmon expert.

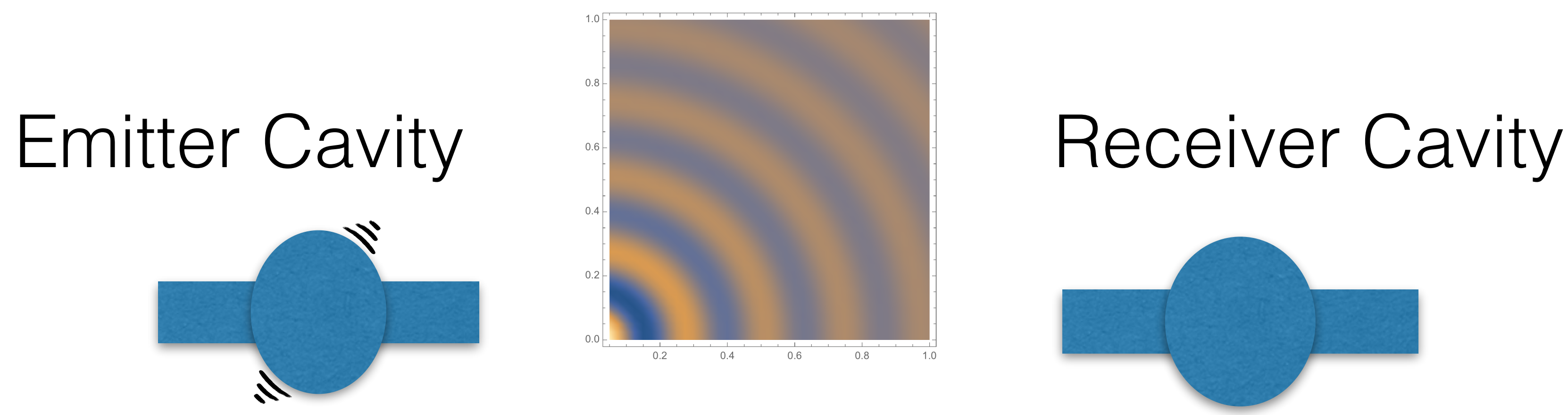
If these guys pull i off, Fermilab may find it self as home to the worlds best quantum computer.

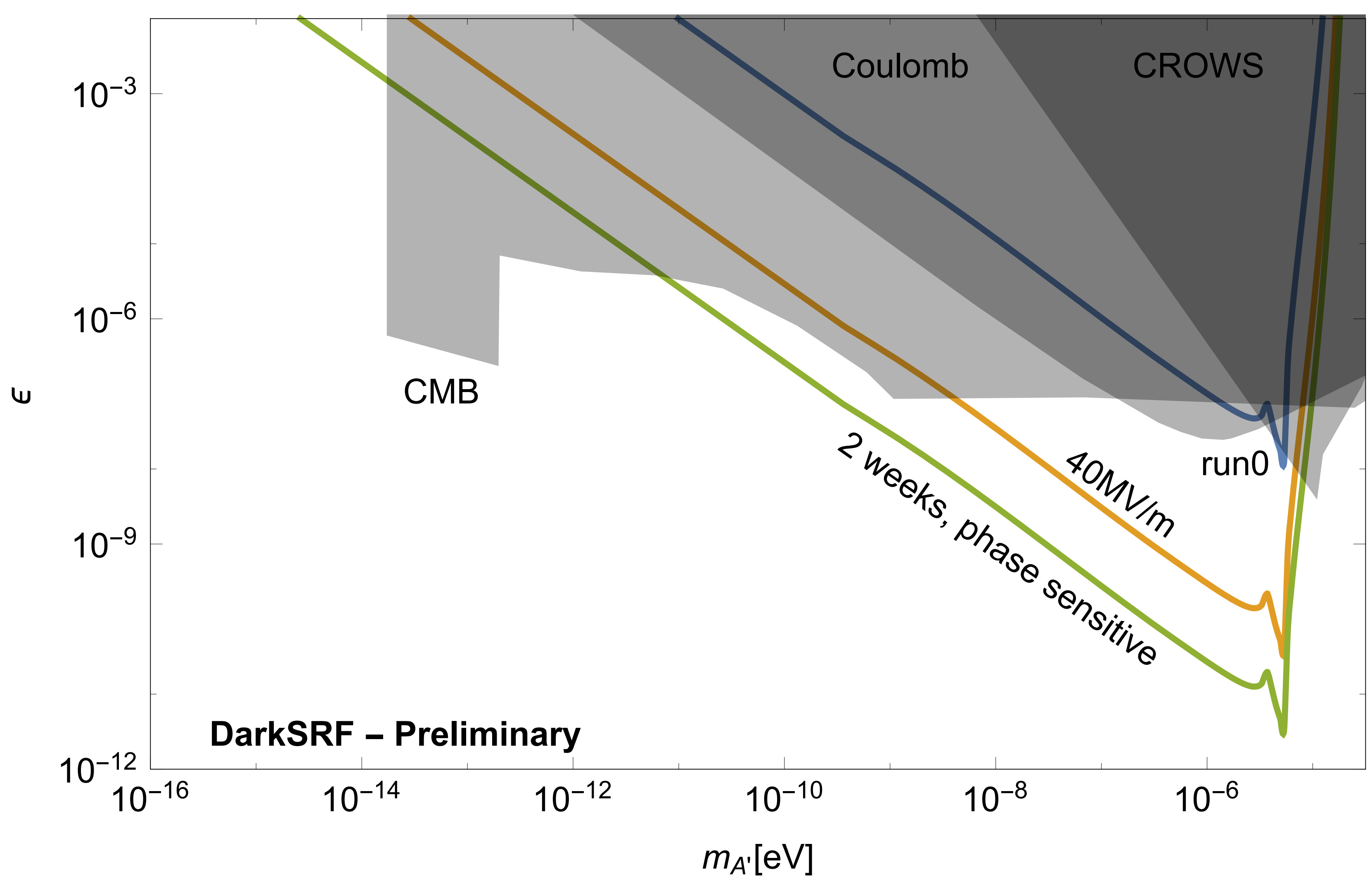
It would be good if it is used to calculate something HEPy.

The hardware will initially be very specialized. Development of the algorithm you want to run may need to happen as the hardware is developed.

Dark SRF

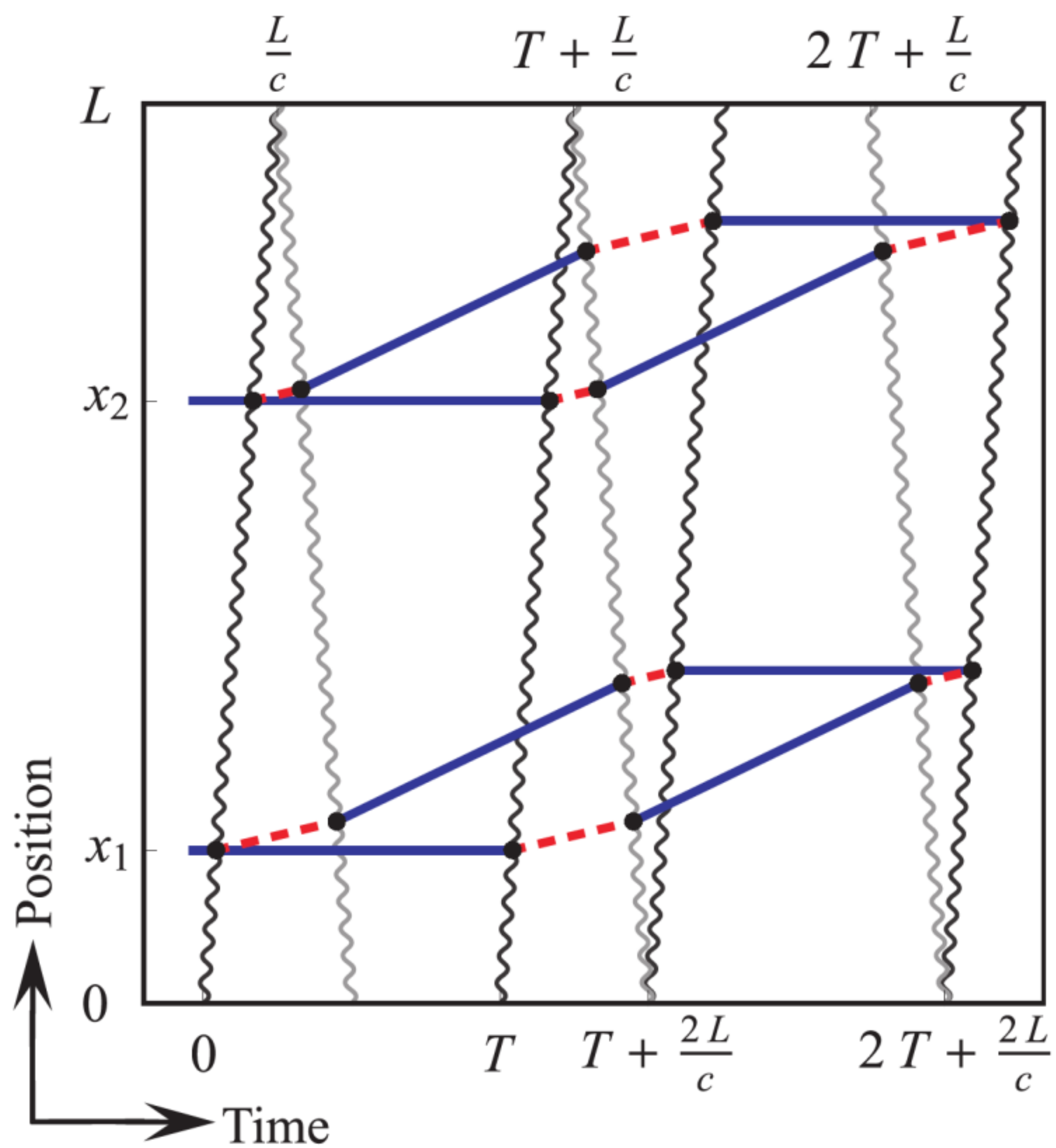
ongoing work w/ APSTD. Also involved: Josh and Zhen.

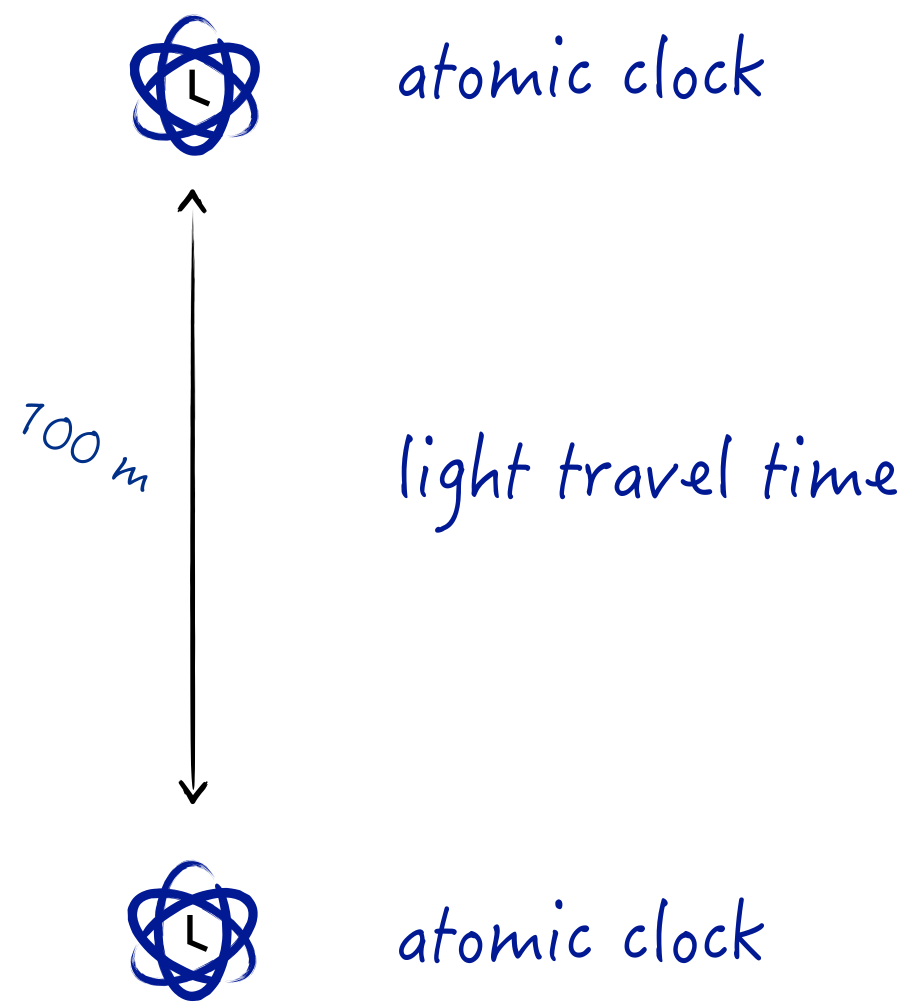




MAGIS 100

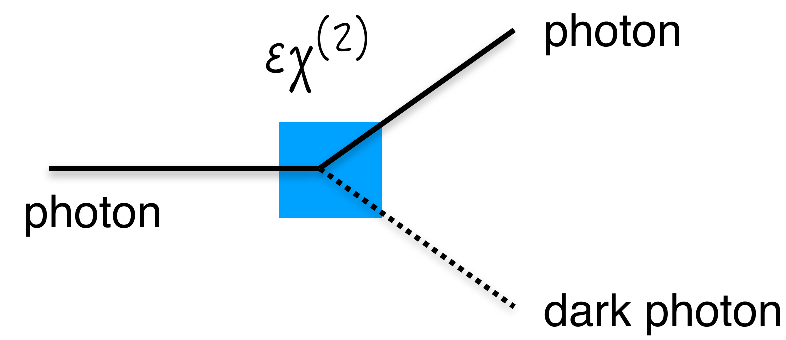
A 3 clock comparison (2 atomic, 1 light travel time):





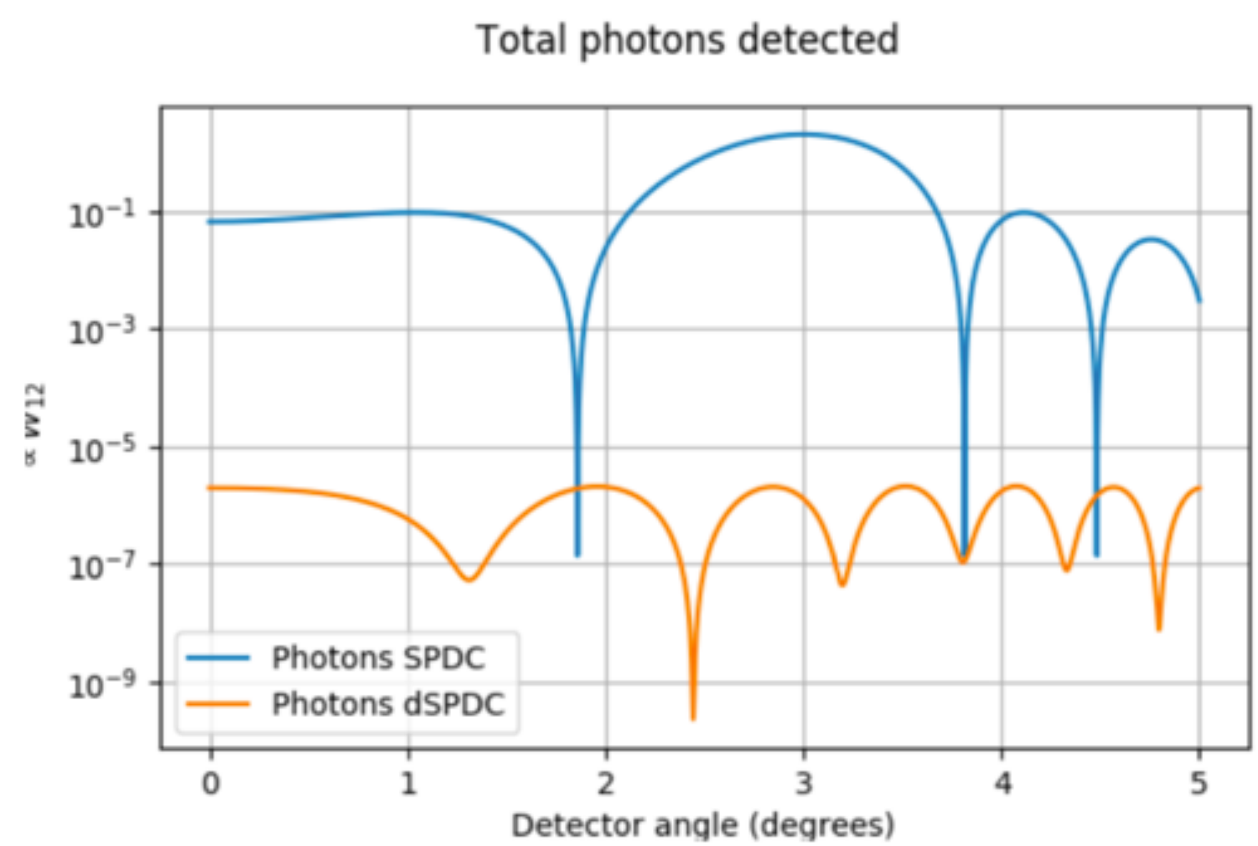
Nonlinear optics: there are crystals with effective 3-photon and 4-photon vertices.

→ associated photon+dark photon production.



Mono-photon on the optics table!

with Estrada's group.



Quantum People: Staff

Roni (28%)

Jime Simone (25%)

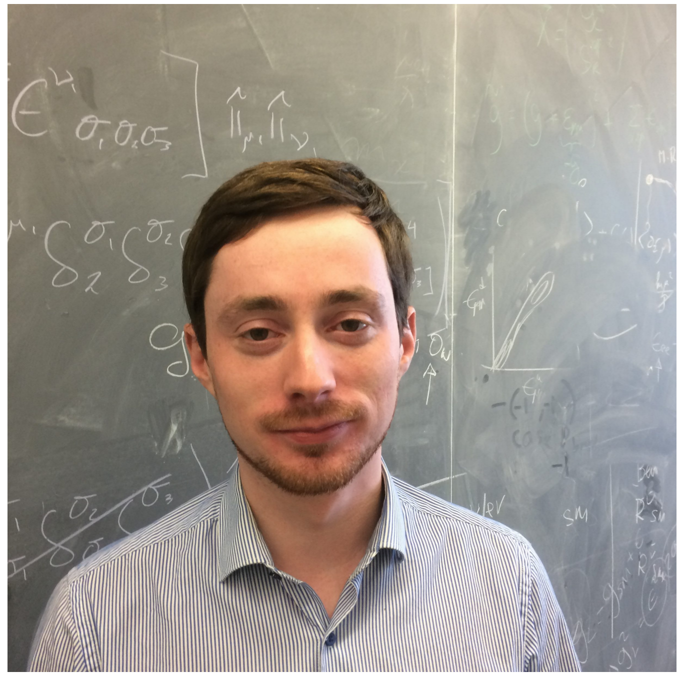
QIS FQI people:

Just moved to our floor:

Alex Macridin (staff)

**Andy Li
(postdoc, 2018-2021?)**

QIS theory postdocs:



Ciaran Hughes

2016-2019 Lattice
2019-2021 quantum

Hank Lamm

2019-2022

We may have funds for more QIS?
Simulation? Sensors?

Ciaran Huges

1. **Exploring S-Wave Threshold Effects in QCD: A Heavy-Light Approach**
   Estia Eichten, Ciaran Hughes. Nov 5, 2019. 10 pp.
   FERMILAB-PUB-19-558-T
   e-Print: **arXiv:1911.02024 [hep-lat] | PDF**
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   ADS Abstract Service
   Detailed record

2. **Quantum Computing as a High School Module**
   Anastasia Perry (Illinois Math. Sci. Acad.), Ranbel Sun (Unlisted, US, MA), Ciaran Hughes, Joshua Isaacson, Jessica Turner (Fermilab). A
   FERMILAB-FN-1077-T
   e-Print: **arXiv:1905.00282 [physics.ed-ph] | PDF**
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   ADS Abstract Service; OSTI.gov Server; Fermilab Library Server (fulltext available); Link to Fulltext
   Detailed record

3. **Improving the kinetic couplings in lattice nonrelativistic QCD**
   Christine T.H. Davies (Glasgow U.), Judd Harrison (Glasgow U. & Cambridge U., DAMTP), Ciaran Hughes (Cambridge U., DAMTP & Ferm
   von Hippel (U. Mainz, PRISMA), Matthew Wingate (Cambridge U., DAMTP). Dec 30, 2018. 19 pp.
   Published in **Phys.Rev. D99 (2019) no.5, 054502**
   MITP/18-129, FERMILAB-PUB-18-698-T
   DOI: 10.1103/PhysRevD.99.054502
   e-Print: **arXiv:1812.11639 [hep-lat] | PDF**
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   ADS Abstract Service; OSTI.gov Server; Link to Article from SCOAP3; Fermilab Library Server (fulltext available); Link to Fulltext
   Detailed record

4. **Digitizing Gauge Fields: Lattice Monte Carlo Results for Future Quantum Computers**
   Daniel C. Hackett (Colorado U.), Kiel Howe, Ciaran Hughes (Fermilab), William Jay (Colorado U. & Fermilab), Ethan T. Neil (Colorado U. &
   pp.
   Published in **Phys.Rev. A99 (2019) no.6, 062341**
   FERMILAB-PUB-18-615-T
   DOI: 10.1103/PhysRevA.99.062341
   e-Print: **arXiv:1811.03629 [quant-ph] | PDF**
   References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
   ADS Abstract Service; OSTI.gov Server; Link to Fermilab Library Server (fulltext available); Link to Fulltext
   Detailed record - Cited by 9 records

Currently working on:
Informing lattice S2N problem with QIS tools.
Initial state prep input from LQCD to Quantum simulation.

Hank Lamm

1. **Precision Model-Independent Bounds from Global Analysis of $b \to c\ell\nu$ Form Factors**
Thomas D. Cohen, Henry Lamm (Maryland U.), Richard F. Lebed (Arizona State U.). Sep 23, 2019. 13 pp.
Published in **Phys.Rev. D100 (2019) no.9, 094503**
DOI: 10.1103/PhysRevD.100.094503
e-Print: **arXiv:1909.10691 [hep-ph] | PDF**
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service; Link to Article from SCOAP3
Detailed record - Cited by 1 record

2. **Parton Physics on a Quantum Computer**
NuQS Collaboration (Henry Lamm *et al.*). Aug 27, 2019. 7 pp.
e-Print: **arXiv:1908.10439 [hep-lat] | PDF**
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service
Detailed record - Cited by 1 record

3. **Nucleon properties from basis light front quantization**
Chandan Mondal (Lanzhou, Inst. Modern Phys.), Siqi Xu, Jiangshan Lan, Xingbo Zhao, Yang Li (Geneva U.), Henry Lamm (Maryland U.), Jame
Published in **PoS DIS2019 (2019) 190**
DOI: 10.22323/1.352.0190
Conference: C19-04-08 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Link to Fulltext
Detailed record

4. **Gluon Field Digitization for Quantum Computers**
NuQS Collaboration (Andrei Alexandru (George Washington U. & Maryland U.) *et al.*). Jun 26, 2019. 5 pp.
e-Print: **arXiv:1906.11213 [hep-lat] | PDF**
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service
Detailed record - Cited by 4 records

5. **General Methods for Digital Quantum Simulation of Gauge Theories**
NuQS Collaboration (Henry Lamm *et al.*). Mar 19, 2019. 14 pp.
Published in **Phys.Rev. D100 (2019) no.3, 034518**
DOI: 10.1103/PhysRevD.100.034518
e-Print: **arXiv:1903.08807 [hep-lat] | PDF**
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service; Link to Article from SCOAP3
Detailed record - Cited by 9 records

6. **σ Models on Quantum Computers**
NuQS Collaboration (Andrei Alexandru (George Washington U. & Maryland U.) *et al.*). Mar 15, 2019. 5 pp.
Published in **Phys.Rev.Lett. 123 (2019) no.9, 090501**
DOI: 10.1103/PhysRevLett.123.090501
e-Print: **arXiv:1903.06577 [hep-lat] | PDF**
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service; Link to Article from SCOAP3
Detailed record - Cited by 5 records

7-14

15. **Simulation of Nonequilibrium Dynamics on a Quantum Computer**
Henry Lamm (Maryland U.), Scott Lawrence (Maryland U., College Park). Jun 18, 2018. 5 pp.
Published in **Phys.Rev.Lett. 121 (2018) no.17, 170501**
DOI: 10.1103/PhysRevLett.121.170501
e-Print: **arXiv:1806.06649 [quant-ph] | PDF**
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service
Detailed record - Cited by 10 records

QIS visitors→staff?:

Martin Savage

Coming mid-february for ~ 1 year.
Potentially staying for good.

Area	Task	Institution(s)
Simulation	Lattice scalar field theory: (state preparation, time-evolution, scattering, topology, phase transitions, entanglement, digitization)	Caltech, Fermilab, UIUC, UW-INT
Simulation	Lattice gauge theory and QCD: (qubit mapping and plaquettes, time evolution, circuits, inelastic processes and fragmentation, entanglement, S-matrix, topology, scattering)	Caltech, Fermilab, Purdue, UIUC, UW-INT
Analysis	Algorithms for event ensembles Hybrid algorithms for preprocessing QIS-inspired classical algorithms	MIT
Sensors	Cavity sensor developement Dark SRF theory support MAGIS-100 long range interactions Dark photon searches w/ nonlin. optics searches DM search w/ photon pairs in nonlin. optics Quantum limited impulse detectors for DM Quantum sensors for dark radiation Spin precession experiments and neutrinos	Fermilab

Table 1.1: Research topics and collaborating institutions. Further details are given in the budget justification.

Year	Milestones
1	State prep. of entangled free lattice scalar QFT with $L \geq 8$ and $n_Q \geq 2$ qubits per site
	State preparation of 2-dim Yang-Mills gauge theory with $n_P \geq 4$ and $j_{\max} \geq \frac{1}{2}$
	Simulations of topological features of 1-dim theories with domain-wall fermions with $L \geq 8$
	Simulations of parton distributions in the Schwinger model with $L \geq 8$
	Analyze matching of HEP-relevant theories to Trotterized time-evolution Hamiltonians
	Map scalar and Abelian QFT onto SRF-cavity qudit devices
	Computation of Circuit complexity in O(2) 3d QFT
	Identify non-trivial constraint on the S-matrix from QIS
	Develop coreset algorithms for compression of collider data for quantum devices
	Support dark SRF in launching search for dark photon
	Develope formalism for dark+visible photon pair in nonlinear optics systems
2	Adiabatic evolution from free to interacting scalar field theory
	Adiabatic evolution from strong coupling to interacting gauge theories in low dimensions
	Detectors and scattering in 2-dim lattice Yang-Mills
	field truncation studies in lattice Yang-Mills theory
	First time-evolved scalar and Abelian QFT with SRF-cavity qudit devices
	Map non-Abelian QFT onto SRF-cavity qudit devices
	Perform loop-level matching of scalar field theory to Hamiltonian lattice
	Inclusion of quarks into lattice Yang-Mills
	Find methods to measure EE in QFT simulators
	Explore classical and quantum clustering algorithms using the metric space approach
	Explore multi-mode running for dark SRF
	Co-development of nonlinear optics based dark photon search
3	State preparation of interacting lattice scalar field theory
	State preparation of 3-dim Yang-Mills
	Perform loop-level matching of Yang-Mills field theory to Hamiltonian lattice
	First time-evolved non-Abelian QFT with SRF-cavity qudit devices
	Identify quantum algorithms that capitalize on linear runtime for multi-particle correlators
	Run protocols for MAGIS-100 to probe long range interactions
	Concepts for direct detection of dark radiation
	Study of nonlinear optics systems for DM detection
4	Two to many scattering in 1-dim lattice scalar field theory
	Time-evolved scalar, Abelian and non-Abelian QFT with SRF-cavity qudit devices
	Develop quantum event clustering algorithms
	Provide theoretical support in analysis of MAGIS-100 data to search for DM
	Assess feasibility of quantum limited impulse detectors for DM detection
	Co-development axion searches with Dark SRF
5	Two to many scattering in 3-dim lattice scalar field theory
	Inelastic scattering processes using SRF-cavity qudit systems
	Implement event clustering algorithms on a quantum computing platform
	Consider feasibility of neutrino detection with spin precision based on state of field
	Assess reach of MAGIS upgrade based on MAGIS-100 performance

Table 1.2: Research milestone organized by the funding cycle year they we expect them to be achieved.