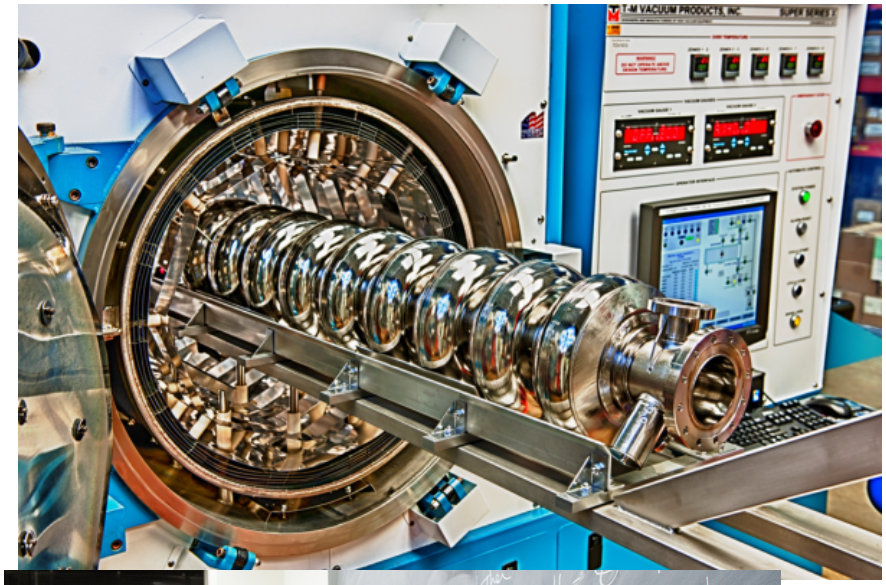
Fermilab and Quantum Sensors

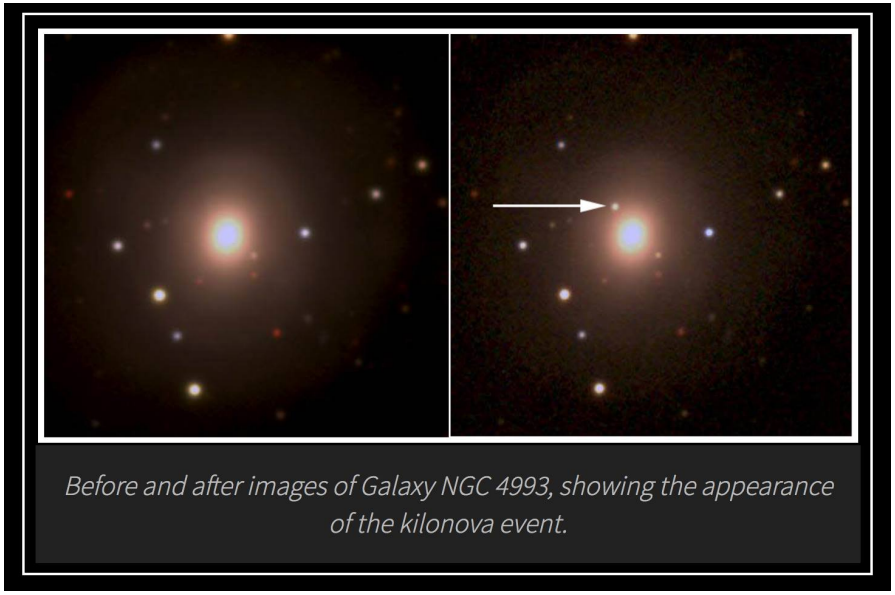
Joe Lykken

CPAD Workshop on Quantum Sensing

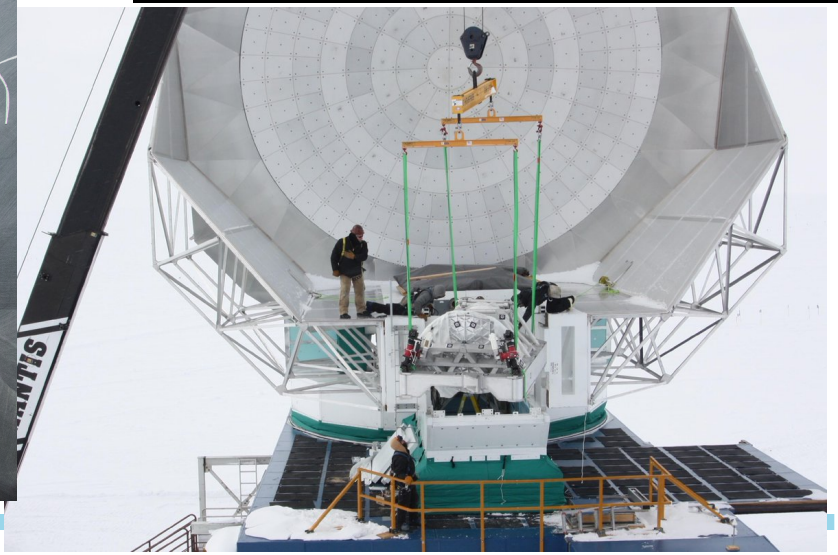
Dec 12, 2017

Fermilab develops cutting-edge accelerators, detectors, computing, and theory for fundamental physics experiments





Before and after images of Galaxy NGC 4993, showing the appearance of the kilonova event.

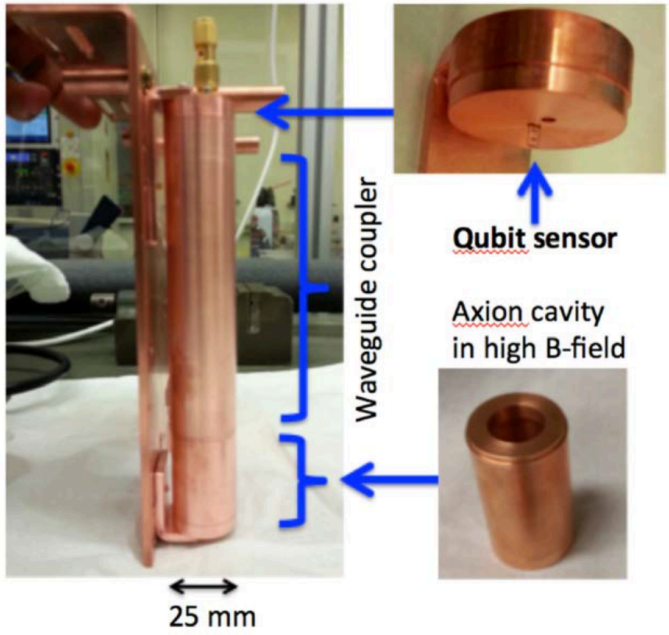


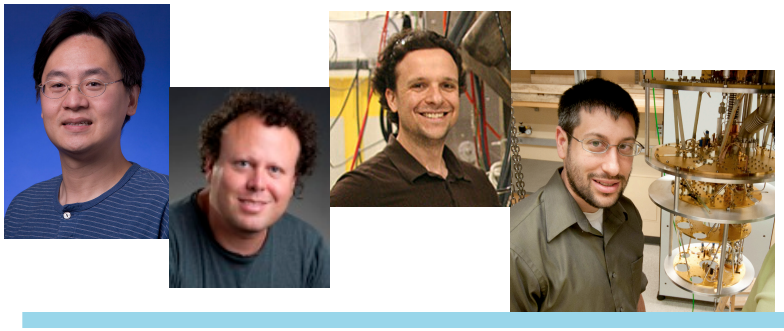
Fermilab

Qubit-based axion dark matter detectors

Collaboration between Fermilab and U. Chicago, with support from the Heising-Simons Foundation

Goal is to put a microwave cavity coupled to superconducting qubits in a strong magnetic field, and demonstrate sensitivity to dark matter axions in the cosmologically-preferred mass range.





Aaron Chou, Andrew Sonnenschein, Daniel Bowring, Fermilab

David Schuster U. Chicago

MAGIS-100 Cold Atom Interferometer

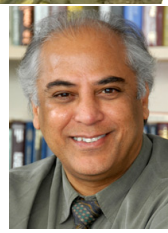
MINOS shaft
Fermilab

MAGIS-100 will be a 100 meter cold atom interferometer, sensitive to space-time distortions in the laboratory

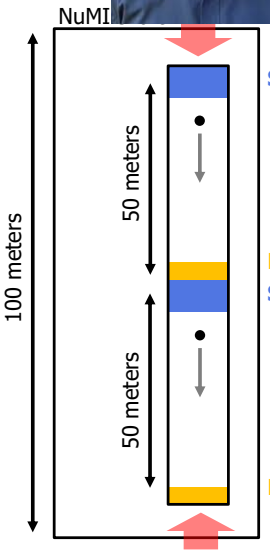
Jason Hogan
Peter Graham
Stanford

Rob Plunkett
Fermilab

Jon Coleman
U. Liverpool



Swapan
Chattopadhyay
NIU/FNAL



- 100 m atom interferometer (accelerometer) drop tower
- >3 s drop time to split and recombine atomic wavefunctions
- Detect dark matter through oscillatory force
- Also gravitational waves from unknown sources
- Lead to ~km scale detector for GW's (e.g. BH mergers) and DM, opens band below LIGO and above LISA (~ 0.1 - 10 Hz)

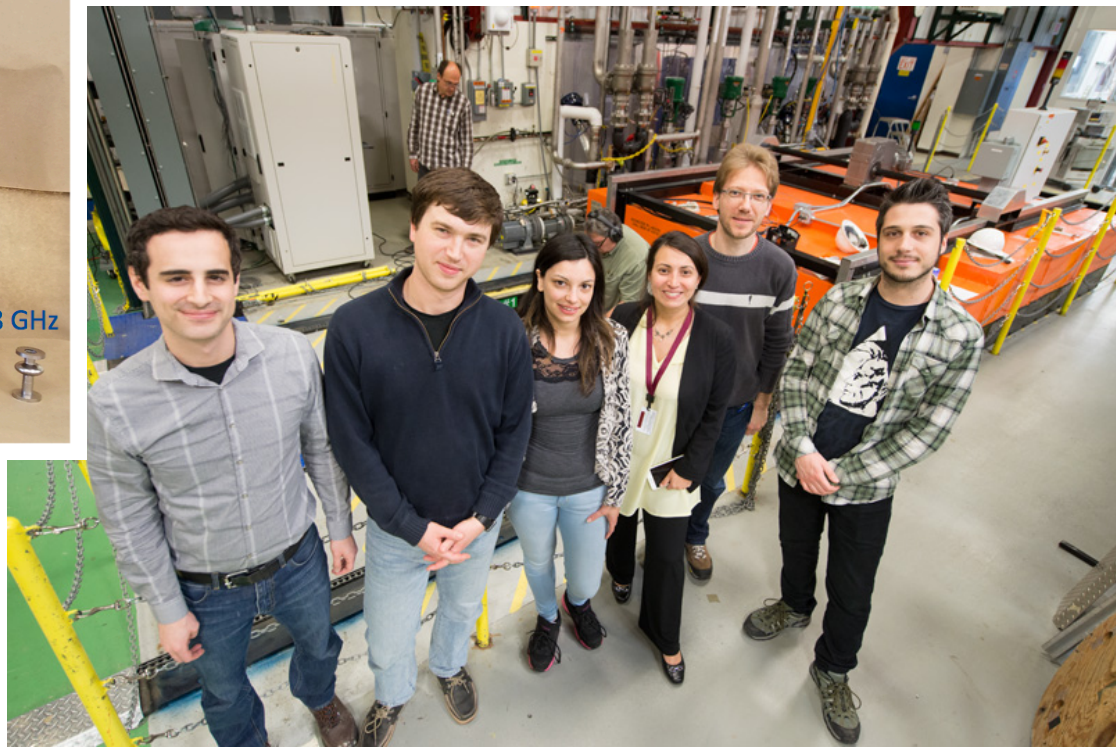
Roni Harnik
Fermilab

Fermilab

Superconducting Quantum Systems

- Fermilab has world leading SRF/superconducting materials effort
- Fermilab has relevant expertise in subkelvin cryogenics, controls, readout and systems engineering for scaling up superconducting quantum computers

From PIP-2, LCLS-2 to Quantum Computing



Fermilab SRF team includes 3 DOE Early Career Awardees, 2017 Presidential Early Career Awardee, two Peoples Fellows

Superconducting Quantum Systems

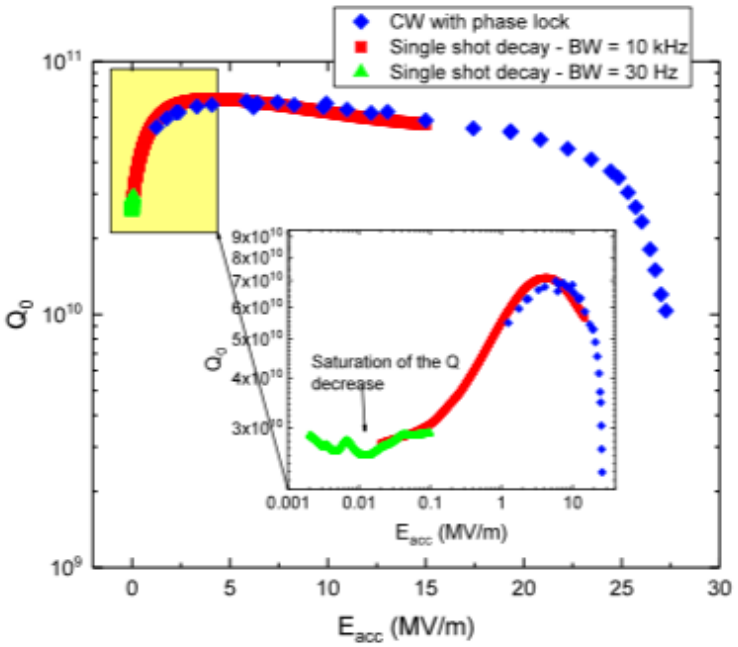
We have begun R&D toward higher Q cavities for quantum computers, which translates to longer coherence times and other good things

Nature of the Low Field Q Degradation in Superconducting Niobium Cavities*

A. Romanenko†
Fermi National Accelerator Laboratory, Batavia, IL 60510, USA

D. I. Schuster‡
The James Franck Institute and Department of Physics, University of Chicago, Chicago, Illinois 60637, USA
(Dated: May 31, 2017)

In niobium superconducting radio frequency (SRF) accelerating cavities a decrease of the quality factor at lower fields - a so called *low field Q slope or LFQS* - has been a long-standing unexplained effect. By extending the high Q measurement techniques to ultralow fields we discover two previously unknown features of the effect: i) saturation at rf fields lower than $E_{acc} \sim 0.1$ MV/m; ii) strong degradation enhancement by growing thicker niobium pentoxide. Our findings suggest that the LFQS may be caused by the two level systems in the natural niobium oxide on the inner cavity surface, thereby identifying a new source of residual resistance and providing guidance for potential non-accelerator low field applications of SRF cavities.



A. Romanenko and D. I. Schuster, ''Nature of the low field Q degradation in superconducting niobium cavities'', https://arxiv.org/abs/1705.05982, about to appear in Physical Review Letters.

Partnerships

Fermilab strategy in quantum science is to maximize partnerships with university groups, industry, and other labs

Chicago Quantum Exchange
with U. Chicago and Argonne

INQNET Program
with Caltech and AT&T