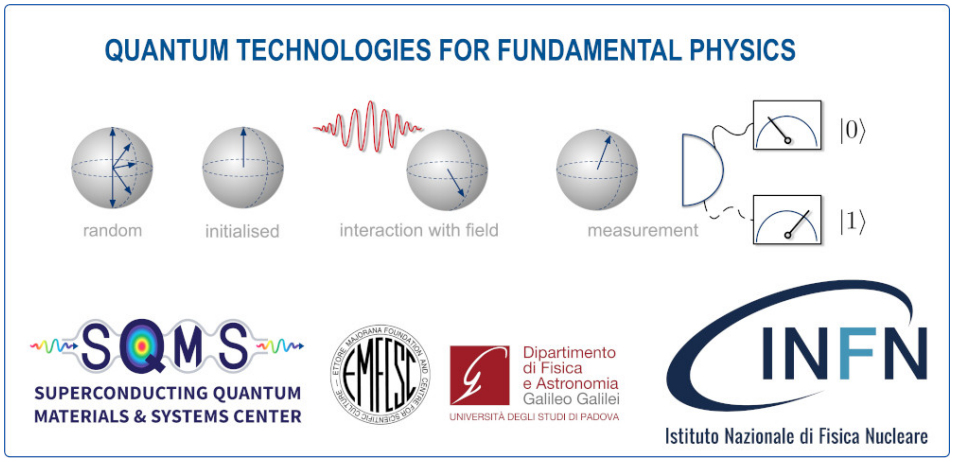
Quantum Technologies for Fundamental Physics



Report of Contributions

https://agenda.infn.it/e/sqmsworkshop2023

Contribution ID: **2** Type: **not specified**

History and frontiers of SRF technology and application.

SRF (Superconducting Radio Frequency) science and technology has taken the accelerator world by storm. Steady advances in SRF performance have enabled, and continue to enable, a large variety of SRF-based accelerators for applications in materials science, nuclear physics, nuclear astrophysics, and high energy physics. The total installed voltage has risen from 7 GeV in the year 2000 to 25 GeV installed and operating by 2020. In another decade the total is expected to rise to 40 GeV. There has been spectacular progress in performance, in scientific understanding of improvements, and innovative cavity designs for new applications. A large fraction of the progress is a testament to the creativity and success of imaginative researchers who have pursued efforts to gain understanding, worked on inventive treatments, and opened the door to new applications. An exciting new development is the use of SRF cavities for Quantum Computing. Nb cavities offer a transformative vehicle for increasing the coherence times of qubits from sub-milliseconds to seconds, promising to bring the quantum computing field to Quantum Advantage over classical computers. SRF is an active and exciting field with many more breakthroughs ahead!

Presenter: PADAMSEE, Hasan

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **18** Type: **not specified**

INFN Present and Future Perspectives

Saturday, 2 September 2023 09:30 (30 minutes)

Presenter: PALLAVICINI, Marco (INFN Genova)

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **19** Type: **not specified**

SQMS - Welcome Remarks and Introduction

Saturday, 2 September 2023 09:00 (10 minutes)

Presenter: GRASSELLINO, Anna

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **20** Type: **not specified**

SQMS Italy - Welcome Remarks and Introduction

Saturday, 2 September 2023 09:10 (10 minutes)

Presenter: BONVICINI, Valter (Istituto Nazionale di Fisica Nucleare)

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **21** Type: **not specified**

DOE Introductory Remarks

Saturday, 2 September 2023 09:20 (10 minutes)

Presenter: PATWA, Abid (Department of Energy, Office of High Energy Physics)

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **22** Type: **not specified**

The Case for Testing the Modifications of Quantum Mechanics

We discuss the case for potential extensions to and motivate tests of quantum mechanics. We then argue that most extensions of quantum mechanics inherently include state-dependent time evolution. We then present a causal modification of quantum mechanics by adding non-linear (state-dependent) terms to the Schrodinger Equation. We find that, until recently, experimental bounds on these non-linearities are weak and discuss the types of experiments that are testing this modification. If time, we will discuss the potential dilution of laboratory effects due to amplification of quantum fluctuation in the past history of the universe, and then point out additional cosmological and astrophysical signals if such a dilution occurred.

Presenter: KAPLAN, David (Johns Hopkins University)

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **23** Type: **not specified**

Performance and scalability tradeoffs in a superconducting qubit processor architecture

Saturday, 2 September 2023 12:30 (30 minutes)

Rigetti Computing's QPU roadmap projects scaling to large systems by lateral tiling of many individual superconducting qubit chips in a multi-die assembly. Each chip in the assembly, meanwhile, has a dense array of qubits and tunable couplers with 3D signalling. This talk will discuss the challenges of engineering such a QPU to have long coherence times, fast control, and strong qubit-qubit interactions while maintaining scalability. In particular, it will cover strategies for mitigating the additional loss channels introduced by the high density of signal lines needed for fast operation of Rigetti's circuit architecture.

Presenter: BESTWICK, Andrew (Rigetti)

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **24** Type: **not specified**

Quantum noise in interferometric gravitational wave detectors

Saturday, 2 September 2023 15:30 (30 minutes)

Quantum noise plays an important role in limiting the sensitivity of current interferometric gravitational (GW) wave detectors. For this reason, in recent years all international collaborations have undertaken an R&D campaign aimed at overcoming the Standard Quantum Limit for GW detectors. The strategy employed is based on the use of squeezed vacuum states injected in to the detector port of the interferometers. This presentation will deal with the current state of these researches with particular emphasis on the main experimental difficulties to be faced in order to achieve a significant sensitivity improvement. Finally some recently proposed alternative methods for the reduction of quantum noise will be briefly discussed.

Presenter: ZENDRI, Jean-Pierre (INFN Padova)

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **25** Type: **not specified**

Loophole-free Bell Inequality Violation with Superconducting Circuits*

Superposition, entanglement, and non-locality constitute fundamental features of quantum physics. Remarkably, the fact that quantum physics does not follow the principle of locality can be experimentally demonstrated in Bell tests performed on pairs of spatially separated, entangled quantum systems. While Bell tests were explored over the past 50 years, only relatively recently experiments free of so-called loopholes succeeded. Here, we demonstrate a loophole-free violation of Bell's inequality with superconducting circuits [1]. To evaluate a CHSH-type Bell inequality, we deterministically entangle a pair of qubits and perform fast, and high-fidelity measurements along randomly chosen bases on the qubits connected through a cryogenic link spanning 30 meters. Evaluating more than one million experimental trials, we find an average S-value of 2.0747 ± 0.0033, violating Bell's inequality by more than 22 standard deviations. Our work demonstrates that non-locality is a viable new resource in quantum information technology realized with superconducting circuits with applications in quantum communication, quantum computing and fundamental physics.

[1] S. Storz, J. Schär, A. Kulikov, P. Magnard, P. Kurpiers, J. Lütolf, T. Walter, A. Copetudo, K. Reuer, A. Akin, J-C. Besse, M. Gabureac, G. J. Norris, A. Rosario, F. Martin, J. Martinez, W. Amaya, M. W. Mitchell, C. Abellán, J-D. Bancal, N. Sangouard, B. Royer, A. Blais, and A. Wallraff, Nature 617, 265-270 (2023)

- Work done in collaboration with Simon Storz, Josua Schaer, Anatoly Kulikov, Paul Magnard, Philipp Kurpiers, Janis Luetolf, Theo Walter, Adrian Copetudo, Kevin Reuer, Abdulkadir Akin, Jean-Claude Besse, Mihai Gabureac, Graham J. Norris, Andres Rosario, Ferran Martin, Jose Martinez, Waldimar Amaya, Morgan W. Mitchell, Carlos Abellan, Jean-Daniel Bancal, Nicolas Sangouard, Baptiste Royer, Alexandre Blais, and Andreas Wallraff

Presenter: WALLRAFF, Andreas (ETH Zurich)

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **26** Type: **not specified**

Quantum sensing with a microwave photon counter

Saturday, 2 September 2023 16:00 (30 minutes)

Presenter: BERTET, Patrice (CEA)

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **27** Type: **not specified**

Introduction

Sunday, 3 September 2023 09:00 (10 minutes)

Presenter: KHAN, Yoni (University of Illinois at Urbana-Champaign)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **28** Type: **not specified**

Quantum sensing with cavities and more

Sunday, 3 September 2023 12:30 (20 minutes)

Quantum sensors offer the most promising way to detect a number of light, weakly coupled particles, such as gravitons or axions. Cavities, as well as other optomechanical systems, are current realizations of such sensors in operation. I will discuss how a theoretical tool from quantum optics, the input-output formalism, allows calculation and understanding of the sensitivity of these different systems. I will further comment on how quantum-enhanced techniques may be used to reduce the quantum mechanical noise of these systems, allowing for unprecedented new physics sensitivities.

Presenter: MAROCCO, Giacomo (Lawrence Berkeley Lab)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **29** Type: **not specified**

Enabling role of SRF cavities as physics detectors: example of DarkSRF

Sunday, 3 September 2023 09:30 (15 minutes)

Presenter: ROMANENKO, Alexander (Fermilab)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **30** Type: **not specified**

Novel Materials for High Coherence Superconducting Quantum Devices

Sunday, 3 September 2023 11:35 (15 minutes)

The SQMS Center has launched a systematic investigation to help identify sources of microwave loss and decoherence in superconducting quantum devices, and converge on materials/passivations to mitigate these loss mechanisms. In a Center wide effort, the surface oxides of Nb, singled out to be a significant source of decoherence, is replaced by a passivation layer. A wide range of materials has been explored as the passivation layer to include Al, Ta, and TiN, to name a few. Our results show that the coherence time of transmon qubits is significantly improved for devices on Nb with Ta encapsulation, by a factor of 3 to 5, compared to devices on bare Nb with surface oxide. Our best T1 reaches ~200 us (450 us) for devices fabricated on sapphire (Si) substrates. These results firmly establish the SQMS Center amongst the leading teams capable of fabricating high coherence quantum devices. Superconducting qubits and quantum sensors with reduced decoherence could potentially be useful in the search of weakly coupled particles.

Presenter: BAL, Mustafa (Fermilab)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **31** Type: **not specified**

Advances in SRF cavity architectures for quantum computing and sensing

Sunday, 3 September 2023 10:00 (15 minutes)

Superconducting radio frequency (SRF) cavities offer an excellent platform for storing and processing quantum information due to their exceptionally long lifetimes and large accessible Hilbert spaces. A common strategy to manipulate the quantum states is to use a nonlinear element like a transmon. Nevertheless, constructing a 3D SRF architecture with sustained cavity lifetimes presents several challenges. In this talk, we present our successful integration of transmons with single-cell Nb SRF cavities, enabling the preparation of several non-classical states. Preliminary results reveal the potential of this platform to build a qudit-based quantum computer, departing from traditional qubit-based architectures. We discuss strategies to enhance coherence times, develop high-fidelity gate schemes, and expand the system for constructing a multi-qudit quantum processor. Furthermore, we explore how this architecture can bolster dark matter detection efficiency through multi-photon quantum state preparation.

Presenter: ROY, Tanay (Fermilab)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **32** Type: **not specified**

Search for sub-GeV Dark Matter using superfluid 3He at ultralow temperatures

Sunday, 3 September 2023 10:15 (20 minutes)

At ultra-low temperatures (ULT) macroscopic quantum states form, such as superfluids, that have unique potential as quantum sensors for rare interactions. The QUEST-DMC QTFP project is deploying this technology at two sites capable of reaching ULT, Royal Holloway (RHUL) and Lancaster University (ULANC), both members of the European Microkelvin Platform, EMP (https://emplatform.eu/). QUEST-DMC employs a superfluid helium-3 target for "laboratory cosmology", studying phase transitions relevant for understanding inflation and searching for light Dark Matter candidates. The Dark Matter search will be based on a small 3He target constructed as a bolometer. A nanowire sensor will be used to detect the quasi-particles produced when a Dark Matter interaction breaks the fragile 3He Cooper pairs.

Presenter: CASEY, Andrew (Royal Holloway, University of London)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **33** Type: **not specified**

Opportunities for SRF Cavities in the ADMX-EFR Project

Sunday, 3 September 2023 09:10 (20 minutes)

The axion is a hypothetical particle that may solve two problems in particle physics & cosmology, the Strong-CP problem and the nature of dark matter. The Axion Dark Matter Experiment (ADMX), which started at LLNL in the mid-1990s, is the DOE Flagship search for these particles. The experiment uses tunable resonant cavities in a large static magnetic field to enhance the conversion of axions to detectable microwaves. Quantum-limited amplifiers based on superconducting Josephson Junction circuits are critical to allow the search to be sensitive enough to rapidly scan the frequencies where the axion may exist. Here I will describe the detection strategy of ADMX along with outlining the next phase of the experiment dubbed ADMX-Extended Frequency Range (ADMX-EFR) which aims to cover 2-4 GHz in frequency range at below DFSZ sensitivity. I will discuss the opportunities that strong B-field tolerant high Q SRF cavities will allow for ADMX-EFR anticipated sensitivity.

Presenter: CAROSI, Gianpaolo (Lawrence Livermore National Laboratory)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **34** Type: **not specified**

How to detect axion dark matter ⋯for real

Sunday, 3 September 2023 11:50 (20 minutes)

Presenter: CHOU, Aaron (Fermilab)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **35** Type: **not specified**

Entering the quantum utility era: how to best mitigate noise on quantum computers?

Sunday, 3 September 2023 12:50 (20 minutes)

Until fault-tolerance becomes implementable at scale, quantum computing will heavily rely on noise mitigation techniques. Entering the era of quantum utility and performing complex enough quantum simulation requires the use of efficient and scalable noise mitigation strategies.

While methods such as zero noise extrapolation with probabilistic error amplification (ZNE-PEA) and probabilistic error cancellation (PEC) have been successfully tested on hardware recently, their scalability to larger circuits may be limited.

In this talk I will present our recently introduced tensor-network error mitigation (TEM) algorithm [1], which acts in post-processing to correct the noise-induced errors in estimations of physical observables.

The method consists of the construction of a tensor network representing the inverse of the global noise channel affecting the state of the quantum processor, and the consequent application of the map to informationally complete measurement outcomes obtained from the noisy state.

The key advantage of TEM is that the measurement overhead is quadratically smaller than in PEC. We test TEM extensively in numerical simulations in different regimes. By using Clifford circuits, we explore the capabilities of the method in wider and deeper circuits with lower noise levels. We find that in the case of 100 qubits and depth 100, both PEC and ZNE fail to produce accurate results, while TEM succeeds.

[1] "Scalable tensor-network error mitigation for near-term quantum computing", arXiv:2307.11740v2.

Presenter: MANISCALCO, Sabrina (Algorithmiq and Aalto University, Finland)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **36** Type: **not specified**

Dark matter detection with trapped ions

Sunday, 3 September 2023 12:10 (20 minutes)

Axion Dark Matter, Dark Photon Dark matter and Millicharged particle dark matter are some of the simplest and popular models of dark matter and are looked for in various experiments. Yet, there continue to exist inaccessible regions in interaction and mass parameter space for these models. In this talk I propose a new way to detect the tiny electric fields produced by these dark matter candidates: the remarkably stable trapped ions, tools developed in the context of quantum metrology and quantum computing. I present preliminary data from pilot experiments as well as steps to improve sensitivity in the future.

Presenter: RAMANI, Harikrishnan (Stanford University)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **37** Type: **not specified**

SERAPH: Wavelike Dark Matter Searches with SRF Cavities

Sunday, 3 September 2023 09:45 (15 minutes)

Haloscopes consisting of a microwave cavity with a high quality factor (Q) connected to low-noise electronics have been deployed to detect wavelike axions and dark photons. But the dark matter mass is unknown, so haloscopes must be tunable to search through the photon coupling vs. mass parameter space. Therefore, the scan rate for haloscope experiments is a crucial figure of merit and is proportional to the cavity's quality factor. State-of-the-art experiments like ADMX currently use copper cavities with ~80000. However, implementing superconducting cavities with ~1010can increase the instantaneous scan rate by possibly a factor of 105.
This presentation will report progress on the SERAPH experiment, a family of superconducting haloscopes being developed by the Superconducting Quantum Materials and Systems (SQMS) Center. In this presentation, I will first discuss the principles behind operating a haloscope whose bandwidth is much narrower than the dark matter halo energy distribution. I will then describe the first SERAPH experiments implementing a 1.3 GHz Niobium cavity with an ultra-high quality factor (Q~1010) that has achieved the best sensitivity and deepest exclusion to wavelike dark photon dark matter by almost an order of magnitude. Next, I will discuss progress on the next phase of SERAPH, which will search dark photon dark matter using a widely-tunable SRF cavity (4-7 GHz). I will finally describe plans for subsequent SERAPH experiments to search for dark photons and axions with tunable SRF cavities tolerant to multi-Tesla magnetic fields and quantum sensors that subvert the Standard Quantum Limit.

Presenter: CERVANTES, Raphael (Fermilab)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **38** Type: **not specified**

A search for dark matter axions with a transmon-based single photon counter

Sunday, 3 September 2023 15:00 (15 minutes)

I will report about a haloscope experiment in which a hybrid surfaced (copper-NbTi) cavity immersed in a 2 T-magnetic field has been readout by a transmon-based single microwave photon detector (SMPD). The cavity frequency could be varied to probe for different axion masses around 30.5 microelectronvolt by means of a nanopositioner, and I will report about the upper limit that we obtained on the axion-photon coupling in a range of a few hundred kHz.

Presenter: BRAGGIO, Caterina (Istituto Nazionale di Fisica Nucleare)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **39** Type: **not specified**

Axion dark matter search with high-temperature superconducting cavities

Sunday, 3 September 2023 15:15 (20 minutes)

The pursuit of axion dark matter search has long been a daunting task, but recent advances in superconducting materials research have brought physicists closer than ever to unlocking the secrets of this elusive particle. At the forefront of this search is the Center for Axion and Precision Physics research (CAPP), which has established a state-of-the-art detector facility in Korea featuring multiple dilution refrigerator systems and a newly added 12 T big bore (32 cm) Nb3Sn magnet, along with quantum noise-limited amplifiers capable of collecting axion dark matter physics data with a DFSZ level sensitivity. With a total system noise temperature of around 200 mK, the facility is now able to scan more than 1 GHz per year. CAPP is currently engaged in critical R&D efforts aimed at improving the sensitivity of the haloscope detector system, including the development of superconducting cavities that can sustain a high Q-factor (more than 10 million) even at 12T. The utilization of the newly developed HTS cavities has resulted in promising and encouraging results, which augments our ability to search for axion dark matter with an enhanced scanning speed. Overall, our findings highlight the pivotal role of HTS cavities in revolutionizing axion haloscope experiments, accelerating the quest for understanding the elusive nature of dark matter, and unlocking new possibilities in the field of particle physics.

Presenter: CHUNG, Woohyun (IBS-CAPP)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **40** Type: **not specified**

Nb3Sn for axion searches

Sunday, 3 September 2023 15:35 (15 minutes)

Presenter: POSEN, Sam (Fermilab)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **41** Type: **not specified**

First Results from BREAD Dark Photon Search

Sunday, 3 September 2023 15:50 (20 minutes)

We introduce the Broadband Reflector Experiment for Axion Detection (BREAD) conceptual design and science program. BREAD is a dish antenna experiment based on a coaxial cylindrical reflector design which converts axions or dark photons into ordinary photons and focuses them onto a small sensor. This unique geometry is well matched to the requirements of superconducting quantum sensors since it is compatible with the use of standard cryostats and high-field solenoids. The BREAD technology may be used to search for bosonic dark matter across frequencies ranging from the microwave to visible light, corresponding to masses between ~40 micro-eV to 1 eV. We will show initial results from a dark photon search conducted with a 0.7 m2 reflector at room temperature in the 10-13 GHz frequency range. Sensitivity to the KSVZ and DFSZ axions will require new generations of photon-counting quantum sensors in combination with large reflector areas and high-field magnets. We project BREAD sensitivity for various sensor technologies and discuss future prospects.

Presenter: SONNENSCHEIN, Andrew (Fermilab)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **42** Type: **not specified**

Discussion

Sunday, 3 September 2023 16:10 (20 minutes)

Session Classification: Superconducting cavities, materials, and quantum technology for detection of weakly-coupled particles

Contribution ID: **43** Type: **not specified**

Introduction

Monday, 4 September 2023 09:00 (10 minutes)

Presenter: HARNIK, Roni (Fermilab)

Session Classification: Cavities and Quantum Technologies for Gravitational Waves

Contribution ID: **44** Type: **not specified**

Francesco Muia

Presenter: MUIA, Francesco (University of Cambridge)

Session Classification: Cavities and Quantum Technologies for Gravitational Waves

Contribution ID: **45** Type: **not specified**

Resonant Cavities for Gravitational Waves

Monday, 4 September 2023 09:10 (35 minutes)

Presenter: ELLIS, Sebastian (University of Geneva)

Session Classification: Cavities and Quantum Technologies for Gravitational Waves

Contribution ID: **46** Type: **not specified**

MAGO 2.0: Detecting Gravitational Waves with Superconducting Cavities

Monday, 4 September 2023 09:45 (35 minutes)

Presenter: BERLIN, Asher (Fermilab)

Session Classification: Cavities and Quantum Technologies for Gravitational Waves

Contribution ID: **47** Type: **not specified**

Status of the MAGO cavity and the plan of high-f GW detection in Hamburg

Monday, 4 September 2023 11:30 (25 minutes)

We prepare to set up a new project to detect high frequency GW, starting with the existing cavity from the MAGO collaboration, which will be used for R&D studies and for a first measurement together with Fermilab. We will present the status of the first inspection of the cavity fabricated about 15years ago. In addition, we will show our current results of our theoretical analysis of the interaction of the GW with the cavity. This is necessary to further optimize a future cavity geometry and to better understand the boundary requirements for the experimental infrastructure. We also develop a new cavity control system for this experiment, with the aim to reach the fundamental limit in the sensitivity of this detection principle.

Presenters: PETERS, Krizstian (DESY); WENSKAT, Marc (Universität Hamburg)

Session Classification: Cavities and Quantum Technologies for Gravitational Waves

Contribution ID: **48** Type: **not specified**

MAGO activities at Fermilab and Frequency stability of SRF cavities (microphonics).

Monday, 4 September 2023 11:55 (25 minutes)

At Fermilab we are working with DESY and INFN to revive the MAGO experiment. We started several activities in preparation for the arrival of the cavity onsite in order to be able to successfully cold test the cavity and successively conduct a GW search.

There are several proposed experiments to search for Dark Matter that will utilize SRF cavities submerged into liquid Helium. Extremely narrow bandwidth of SRF cavities (<1 Hz) and requirements for cavity frequency stability will be obligated special measures to mitigate any vibrations from external sources that will be penetrated and re-tuned cavity. In the talk recent FNAL experience of measuring microphonics of SRF cavities used for Dark Photon experiment will be presented. FNAL' s program to mitigate SRF cavity microphonics (in passive and active way) will be presented

Presenters: GIACCONE, Bianca; PISCHALNIKOV, Yuriy (Fermilab)

Session Classification: Cavities and Quantum Technologies for Gravitational Waves

Contribution ID: **49** Type: **not specified**

Discussion

Monday, 4 September 2023 12:20 (40 minutes)

Session Classification: Cavities and Quantum Technologies for Gravitational Waves

Contribution ID: **50** Type: **not specified**

Quantum sensor networks with high efficiency transduction

Monday, 4 September 2023 15:00 (20 minutes)

Quantum transducers facilitate the conversion of quantum information and signals across various physical platforms. In the field of sensing, microwave-optical quantum transducers hold particular significance in enhancing the capabilities of superconducting quantum sensors by harnessing the strengths of both microwave and optical photons. Here, we will address crucial technological aspects related to high-efficiency microwave-optical quantum transduction. The objective is to advance the development of quantum sensors and distributed sensor networks for fundamental physics experiments like haloscopes and dark matter investigations.

Presenter: ZORZETTI, Silvia (Fermilab)

Session Classification: Quantum Networks and Testbeds

Contribution ID: **51** Type: **not specified**

Quantum sensing applied to dark matter search

Monday, 4 September 2023 15:20 (20 minutes)

I will summarize recent proposals of applying quantum sensing technology, such as squeezing, entanglement and transduction to dark matter search. The sensing platform includes microwave cavities and optomechanical sensors.

Presenter: ZHUANG, Quntao (USC)

Session Classification: Quantum Networks and Testbeds

Contribution ID: **52** Type: **not specified**

Lithium Niobate Waveguides for quantum applications

Monday, 4 September 2023 15:40 (20 minutes)

Lithium niobate is a leading material for integrated optics for quantum and classical applications. Because of its nonlinearity, it supports the fabrication of electro-optical devices for quantum state generation and manipulation. Using this material platform, I will show our experimental results on the generation of squeezed vacuum state on chip, frequency conversion of single photons, and integration of multiple components on chip. The monolithic nature of these devices means that the correct phase can be stably realized in what would otherwise be an unstable interferometer, greatly simplifying the task of implementing sophisticated photonic quantum circuits.

Presenter: LOBINO, Mirko (Università di Trento - TIFPA)

Session Classification: Quantum Networks and Testbeds

Contribution ID: **53** Type: **not specified**

The underground Round Robin

Monday, 4 September 2023 16:00 (20 minutes)

The Laboratori Nazionali del Gran Sasso (LNGS) is a deep-underground research facility located in Italy. The facility is surrounded by 1.4 kilometers of rock, which acts as a natural shield against cosmic rays. In this talk, I will present the "Round Robin" project, in which we aim to circulate the same qubit prototype in multiple SQMS testbeds to disentangle the sources of decoherence. I will discuss the preliminary results obtained in the characterization of the Round Robin in the LNGS cryogenic facility.

Presenter: COLANTONI, Ivan (CNR Nanotec)

Session Classification: Quantum Networks and Testbeds

Contribution ID: **54** Type: **not specified**

Discussion

Monday, 4 September 2023 16:20 (10 minutes)

Session Classification: Quantum Networks and Testbeds

Contribution ID: **55** Type: **not specified**

Test of Causal Non-Linear Quantum Mechanics by Ramsey Interferometry on the Vibrational Mode of a Trapped Ion

Tuesday, 5 September 2023 09:00 (25 minutes)

Kaplan and Rajendran have recently demonstrated that non-linear and state-dependent terms can be consistently added to quantum field theory to yield causal non-linear time evolution in quantum mechanics. Causal non-linear theories have the unavoidable feature that their quantum effects are dramatically sensitive to the full physical spread of the quantum state of the system. As a result, such theories are not well tested by conventional atomic and nuclear spectroscopy. By using a well-controlled superposition of vibrational modes of a 40Ca+ ion trapped in a harmonic potential, we set a stringent limit of 5.4×10−12 on the magnitude of the unitless scaling factor ϵ̃γ for the predicted causal, non-linear perturbation.

Presenter: RAJENDRAN, Surjeet (The Johns Hopkins University)

Session Classification: Tests of Quantum Mechanics

Contribution ID: **56** Type: **not specified**

Towards tests of causal nonlinear quantum mechanics using light-pulse atom interferometry

Tuesday, 5 September 2023 09:25 (25 minutes)

Long-baseline light-pulse atom interferometry (LPAI) is a powerful tool for performing tests of fundamental physics (see [1] and reference therein). Using state-of-the-art technology for coherent manipulation of ultracold (picoKelvin) atoms, LPAI is capable of creating quantum superpositions over tens of meters. Moreover, due to acceleration sensitivities close to 10-14 m/s2, using (say) a 100 meter tall LPAI, gravitational phenomena can be studied in conjunction with quantum mechanics (QM). In this talk, I'll discuss our efforts in the construction of two such LPAIs at the Fermi National Accelerator Laboratory (Fermilab) and Northwestern University.

Following recent theoretical investigation of implications of causal nonlinear QM [2], experimental bounds were set on the nonlinear parameter, ε, of said theory using nuclear spins and ions [3,4]. I will discuss proposed tests of this theory using LPAI. Such a measurement involves sensing gravity from well-controlled terrestrial source masses placed at different positions relative to the LPAI. According to the Everett many-worlds interpretation of QM, LPAI can infer a nonlinear coupling, ε, between different branches of the universal wave function with the source mass in different locations. I will discuss measurement schemes for setting new bounds on ε using LPAI.

[1] Abe et al. (2021). Quantum Sci. Technol. 6, 044003.
[2] Kaplan and Rajendran. (2022). Phys. Rev. D 105, 055002
[3] Polkovnikov et al. (2023). Phys. Rev. Lett. 130, 040202
[4] Broz et al. (2023) . Phys. Rev. Lett. 130, 200201

Presenter: MAKARAND DESHPANDE, Tejas (Northwestern University)

Session Classification: Tests of Quantum Mechanics

Contribution ID: **57** Type: **not specified**

Cryogenic test runs in preparation for NLQM searches

Tuesday, 5 September 2023 09:50 (25 minutes)

"Following the ideas in [1] and [2] we are building an experiment for searching for the quantum mechanics non-linearity signal
at the cryogenic cavity vertical test facility at Fermlab. The experiment will employ quantum bit sequence generated
on "Aspen-M"80-qubit quantum computer at Rigetti Computing, Inc [3]. The novelty of this experiment lies in using cryogenic temperature setup which would
allow to suppress background noise. The experiment will be run in an automated way by a computer that communicates with the several devices needed in the experiment.
The experimenter's involvement in running the experiment is only launching the execution of the script the runs the experiment in an automated way from start to end.
This was approach was chosen to avoid a problem of quantum dilution [1]. So far a test run was run was conducted using classically generated bits rather then quantumly generated.
Details of the test run will be described.
[1] https://arxiv.org/pdf/2106.10576.pdf
[2] arXiv:2204.11875 (2022)
[3] https://www.rigetti.com/"

Presenter: MELNYCHUK, Alex (Fermilab)

Session Classification: Tests of Quantum Mechanics

Contribution ID: **58** Type: **not specified**

Discussion

Tuesday, 5 September 2023 10:15 (15 minutes)

Session Classification: Tests of Quantum Mechanics

Contribution ID: **59** Type: **not specified**

Experimental measurement of the Bell parameter with a Single entangled pair

Tuesday, 5 September 2023 11:30 (25 minutes)

Bell inequalities are one of the cornerstones of quantum foundations and fundamental tools for quantum technologies.
Recently, the scientific community worldwide has put a lot of effort towards them, which culminated with loophole-free experiments [1]. Nonetheless, none of the experimental tests so far was able to extract information on the whole inequality from each entangled pair, since the wave function collapse forbids performing, on the same quantum state, all the measurements needed for estimating the entire Bell parameter.
After a general introduction to quantum optics experiments addressing fundamental issues, we present here the first single-pair Bell inequality test able to obtain a Bell parameter value for every entangled pair detected [2]. This is made possible by exploiting sequential weak measurements [3], allowing to perform non-commuting measurements in sequence on the same state, on each entangled particle. Such a feature not only grants unprecedented measurement capability, but also removes the need to choose between different measurement bases, intrinsically eliminating the counterfactual definiteness hypothesis.
We also demonstrate how, after the Bell parameter measurement, the pair under test still presents a noteworthy amount of entanglement, providing evidence of the absence of the wave function collapse. This, on the one hand, provides new insights into the concept of quantum measurement and, on the other hand, allows us to exploit this quantum resource for further protocols.

[1] https://plato.stanford.edu/entries/bell-theorem/
[2] Salvatore Virzì, Enrico Rebufello, Francesco Atzori, Alessio Avella, Fabrizio Piacentini, Rudi Lussana, Iris Cusini, Francesca Madonini, Federica Villa, Marco Gramegna, Eliahu Cohen, Ivo Pietro Degiovanni, Marco Genovese arXiv:2303.04787
[3] F. Piacentini, et al.; Phys. Rev. Lett. 117 (2016) 170402

Presenter: GENOVESE, Marco (INRIM)

Session Classification: Tests of Quantum Mechanics

Contribution ID: **60** Type: **not specified**

Quantum metrology of noisy spreading channels

Tuesday, 5 September 2023 11:55 (25 minutes)

We provide the optimal measurement strategy for a class of noisy channels that reduce to the identity channel for a specific value of a parameter (spreading channels). We provide an example that is physically relevant: the estimation of the absolute value of the displacement in the presence of phase randomizing noise. This channel is useful to model axion dark matter search.

Surprisingly, this noise does not affect the effectiveness of the optimal measurement. We show that, for small displacement, a squeezed vacuum probe field is optimal among strategies with same average energy. A squeezer followed by photodetection is the optimal detection strategy that attains the quantum Fisher information, whereas the customarily used homodyne detection becomes useless in the limit of small displacements, due to the same effect that gives Rayleigh's curse in optical superresolution. There is a quantum advantage: a squeezed or a Fock state with N average photons allow to asymptotically estimate the parameter with a N better precision than classical states with same
energy.

Presenter: MACCONE, Lorenzo (Universita' di Pavia)

Session Classification: Tests of Quantum Mechanics

Contribution ID: **61** Type: **not specified**

Discussion

Tuesday, 5 September 2023 12:45 (15 minutes)

Session Classification: Tests of Quantum Mechanics

Contribution ID: **62** Type: **not specified**

Quantum computing for HEP application

Wednesday, 6 September 2023 09:00 (25 minutes)

We start from a description of the current challenges in quantum computing for simulation and quantum hardware control in view of applications in HEP. We discuss the role of middleware development for quantum computing. We describe recent applications of quantum computing to high-energy physics for parton distribution functions determinations and Monte Carlo simulation. We conclude by identifying the major points to improve and achieve in the next years.

Presenter: CARRAZZA, Stefano (Istituto Nazionale di Fisica Nucleare)

Session Classification: Quantum Computation and Simulation

Contribution ID: **63** Type: **not specified**

Quasiprobabilistic approaches for quantum error mitigation and open system dynamics simulation

Wednesday, 6 September 2023 09:25 (25 minutes)

We present quasiprobability methods that are aimed at effectively reducing or tailoring the quantum noise present in the output of noisy hardware simulations. These methods rely on a tomographic characterization of noisy quantum channels and then proceed by decomposing the desired quantum channels in terms of the noisy implementable ones. We discuss applications of these techniques to quantum error mitigation beyond probabilistic error cancellation (PEC) and to the simulation of open quantum systems.

[1] Benjamin McDonough, Andrea Mari, Nathan Shammah, Nathaniel T. Stemen, Misty Wahl, William J. Zeng, Peter P. Orth, Automated quantum error mitigation based on probabilistic error reduction, 2022 IEEE/ACM Third International Workshop on Quantum Computing Software (QCS), Dallas, TX, USA, 2022, pp. 83-93.

Presenter: ORTH, Peter (Saarland University and Ames National Laboratory)

Session Classification: Quantum Computation and Simulation

Contribution ID: **64** Type: **not specified**

The Quantum Price of Particle Physics

Wednesday, 6 September 2023 09:50 (25 minutes)

Fundamental obstacles are believed to prevent classical computers from ever producing /ab initio /theoretical predictions for certain cross-sections and transport coefficients at particle colliders and in the early universe. While quantum computers could overcome these obstacles, the current resources estimates for /quantum practicality/ in particle physics are large. In this talk, we will review these estimates and state-of-the-art calculations. A small discussion of possible hardware and algorithmic methods for reducing these costs – and thus accelerating the timeline for quantum practicality – will be had.

Presenter: LAMM, Hank (Fermilab)

Session Classification: Quantum Computation and Simulation

Contribution ID: **65** Type: **not specified**

Discussion

Wednesday, 6 September 2023 10:15 (15 minutes)

Session Classification: Quantum Computation and Simulation

Contribution ID: **66** Type: **not specified**

Making the case for a quantum computer for quantum gravity

Wednesday, 6 September 2023 11:30 (25 minutes)

There are many directions to explore in fundamental physics. I will tell why quantum gravity is the most promising and urgent, and will point to specific theoretical open issues, related to black hole entropy, that need to be settled with an experiment. This can eventually open the doors to the next era.

Then I will discuss why this program can be pursued by using equivalences between different quantum systems. This approach, opened-up by Feynman in two seminal pieces of work, one on analogs and one on quantum computers, today reached the necessary level of maturity.

I will close by pointing to a couple of concrete cases, to measure black hole entropy or related quantities, where graphene plays a prominent role: the analog of a BTZ black hole and the SYK model with its AdS/CFT-corresponding JT gravity.

A properly conceived quantum computer should be able to realize these scenarios and more, becoming a CERN-like facility for the next generation of experiments in fundamental physics.

Presenter: IORIO, Alfredo (Charles University in Prague)

Session Classification: Quantum Computation and Simulation

Contribution ID: **67** Type: **not specified**

Hypergraph states and quantum neural networks

We describe the class of hypergraph states, that generalise the notion of graph states and are employed in several known quantum algorithms, and show how they can be profitably used to realise a quantum computing model of artificial neuron. We describe the implementation of an artificial neural network based on this model and the application to entanglement witnessing and to an industrial case study.

Presenter: MACCHIAVELLO, Chiara (Universita' di Pavia)

Session Classification: Quantum Computation and Simulation

Contribution ID: **68** Type: **not specified**

Hybrid Photonics Platform for Quantum Information Processing

Wednesday, 6 September 2023 12:20 (25 minutes)

The development of optical quantum technologies allows for quantum-enhanced metrology, secure quantum communication, and quantum computing and simulation in highly increased dimensions. Maturing quantum photonics requires efficient generation and detection of single photons, as well as their scalable manipulation. We merge highly efficient multi-photon sources and integrated waveguide components. In particular, we interface these scalable platforms, demonstrating high-rate multi-photon interference with a quantum dot based multi-photon source and a reconfigurable photonic chip on glass. We will then review applications of this platform to quantum computing and quantum metrology.

Presenter: SCIARRINO, FABIO (Dipartimento di fisica)

Session Classification: Quantum Computation and Simulation

Contribution ID: **69** Type: **not specified**

Discussion

Wednesday, 6 September 2023 12:45 (15 minutes)

Session Classification: Quantum Computation and Simulation

Contribution ID: **70** Type: **not specified**

Operational Quantum Mereology

Wednesday, 6 September 2023 15:00 (25 minutes)

In this talk I will outline a novel approach to quantum mereology based on minimal information scrambling. Generalized quantum subsystems are defined by pairs of von Neumann algebras and their scrambling in terms of an Algebraic Out of Time Order Correlation (A-OTOC) function. The short time expansion of the A-OTOC allows one to define a notion of Gaussian Scrambling rate. The latter has a simple geometrical interpretation, and its local minima provide an operational criterion for the selection of emergent quantum subsystems.

References:
P. Zanardi, E. Dallas, S. Lloyd, Operational Quantum Mereology and Minimal Scrambling, arXiv:2212.14340

Presenter: ZANARDI, Paolo (University of Southern California, Los Angeles, USA)

Session Classification: Quantum Computation and Simulation

Contribution ID: **71** Type: **not specified**

Quantum reservoir computing and Quantum Extreme Learning machines

Wednesday, 6 September 2023 11:55 (25 minutes)

In the past few years we have witnessed a growing interest computational paradigms beyond the gate paradigm. Among these Extreme learning machines and Reservoir computers are two particularly interesting new computational paradigms. They key feature is the use of a fixed, nonlinear dynamics to efficiently extract information from a given dataset. Such goal, in the classical scenario, is achieved by processing the data as input of some fixed nonlinear dynamics of a suitable (neural) network –the reservoir - which enlarge the dimensionality of the data, making it easier to extract the properties of interest. The difference between Extreme learning machines and Reservoir computers is whether whether the reservoir being used can deploy an internal memory. More precisely, reservoir computers hold memory of the inputs seen at previous iterations, a feature which plays a crucial role when processing time sequences. Extreme machine learning on the other hand use memoryless reservoirs. Although this makes the training of ELMs easier, it also makes them unsuitable for temporal data processing. We will review some recent theoretical and experimental results on the quantum counterpart of the above.

Presenter: PALMA, Massimo (Universita' di Palermo)

Session Classification: Quantum Computation and Simulation

Contribution ID: **72** Type: **not specified**

An invitation to quantum estimation theory

Wednesday, 6 September 2023 15:25 (25 minutes)

Several quantities of interest in physics are non-linear functions of the density matrix and cannot, even in principle, correspond to proper quantum observables. Any method aimed to determine the value of these quantities should resort to indirect measurements and thus corresponds to a parameter estimation problem whose solution, i.e. the determination of the most precise estimator, unavoidably involves an optimization procedure. In this talk, I review local quantum estimation theory, which provides tools to address the above issue and characterize signals and devices in quantum technology. In particular, I will try to address the following points
- Why estimation theory is relevant?
- Classical and quantum Cramer-Rao bound
- Application: quantum probing
- Application: is that theory not even wrong?
- Current problems: multiparameter estimation and going beyond the Cramer-Rao.

Presenter: PARIS, Matteo (Istituto Nazionale di Fisica Nucleare)

Session Classification: Quantum Computation and Simulation

Contribution ID: **73** Type: **not specified**

Discussion

Wednesday, 6 September 2023 15:50 (15 minutes)

Session Classification: Quantum Computation and Simulation

Contribution ID: **74** Type: **not specified**

History and frontiers of SRF technology and application.

Saturday, 2 September 2023 11:30 (30 minutes)

SRF (Superconducting Radio Frequency) science and technology has taken the accelerator world by storm. Steady advances in SRF performance have enabled, and continue to enable, a large variety of SRF-based accelerators for applications in materials science, nuclear physics, nuclear astrophysics, and high energy physics. The total installed voltage has risen from 7 GeV in the year 2000 to 25 GeV installed and operating by 2020. In another decade the total is expected to rise to 40 GeV. There has been spectacular progress in performance, in scientific understanding of improvements, and innovative cavity designs for new applications. A large fraction of the progress is a testament to the creativity and success of imaginative researchers who have pursued efforts to gain understanding, worked on inventive treatments, and opened the door to new applications. An exciting new development is the use of SRF cavities for Quantum Computing. Nb cavities offer a transformative vehicle for increasing the coherence times of qubits from sub-milliseconds to seconds, promising to bring the quantum computing field to Quantum Advantage over classical computers. SRF is an active and exciting field with many more breakthroughs ahead!

Presenter: PADAMSEE, Hasan

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **75** Type: **not specified**

Introduction to superconducting qubits for QIS & beyond

Saturday, 2 September 2023 10:00 (30 minutes)

This talk will provide a brief overview and introduction to superconducting qubits: their historical development, their current use, and future prospects.

Presenter: KOCH, Jens

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **76** Type: **not specified**

Loophole-free Bell Inequality Violation with Superconducting Circuits*

Saturday, 2 September 2023 12:00 (30 minutes)

Superposition, entanglement, and non-locality constitute fundamental features of quantum physics. Remarkably, the fact that quantum physics does not follow the principle of locality can be experimentally demonstrated in Bell tests performed on pairs of spatially separated, entangled quantum systems. While Bell tests were explored over the past 50 years, only relatively recently experiments free of so-called loopholes succeeded. Here, we demonstrate a loophole-free violation of Bell's inequality with superconducting circuits [1]. To evaluate a CHSH-type Bell inequality, we deterministically entangle a pair of qubits and perform fast, and high-fidelity measurements along randomly chosen bases on the qubits connected through a cryogenic link spanning 30 meters. Evaluating more than one million experimental trials, we find an average S-value of 2.0747 ± 0.0033, violating Bell's inequality by more than 22 standard deviations. Our work demonstrates that non-locality is a viable new resource in quantum information technology realized with superconducting circuits with applications in quantum communication, quantum computing and fundamental physics.

[1] S. Storz, J. Schär, A. Kulikov, P. Magnard, P. Kurpiers, J. Lütolf, T. Walter, A. Copetudo, K. Reuer, A. Akin, J-C. Besse, M. Gabureac, G. J. Norris, A. Rosario, F. Martin, J. Martinez, W. Amaya, M. W. Mitchell, C. Abellán, J-D. Bancal, N. Sangouard, B. Royer, A. Blais, and A. Wallraff, Nature 617, 265-270 (2023)

- Work done in collaboration with Simon Storz, Josua Schaer, Anatoly Kulikov, Paul Magnard, Philipp Kurpiers, Janis Luetolf, Theo Walter, Adrian Copetudo, Kevin Reuer, Abdulkadir Akin, Jean-Claude Besse, Mihai Gabureac, Graham J. Norris, Andres Rosario, Ferran Martin, Jose Martinez, Waldimar Amaya, Morgan W. Mitchell, Carlos Abellan, Jean-Daniel Bancal, Nicolas Sangouard, Baptiste Royer, Alexandre Blais, and Andreas Wallraff

Presenter: WALLRAFF, Andreas

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **77** Type: **not specified**

The Case for Testing the Modifications of Quantum Mechanics

Saturday, 2 September 2023 15:00 (30 minutes)

We discuss the case for potential extensions to and motivate tests of quantum mechanics. We then argue that most extensions of quantum mechanics inherently include state-dependent time evolution. We then present a causal modification of quantum mechanics by adding non-linear (state-dependent) terms to the Schrodinger Equation. We find that, until recently, experimental bounds on these non-linearities are weak and discuss the types of experiments that are testing this modification. If time, we will discuss the potential dilution of laboratory effects due to amplification of quantum fluctuation in the past history of the universe, and then point out additional cosmological and astrophysical signals if such a dilution occurred.

Presenter: KAPLAN, David

Session Classification: Physics Case for Quantum Technologies

Contribution ID: **78** Type: **not specified**

Francesco Muia - GW

Tuesday, 5 September 2023 12:20 (25 minutes)

Presenter: MUIA, Francesco (University of Cambridge)

Session Classification: Tests of Quantum Mechanics

Contribution ID: **79** Type: **not specified**

Discussion

Monday, 4 September 2023 10:20 (10 minutes)

Session Classification: Cavities and Quantum Technologies for Gravitational Waves

Contribution ID: **80** Type: **not specified**

Closing remarks

Wednesday, 6 September 2023 16:05 (20 minutes)

Contribution ID: **81** Type: **not specified**

Comparing Quantum and Classical Machine Learning for Vector Boson Scattering Background Reduction at the Large Hadron Collider

Saturday, 2 September 2023 16:30 (5 minutes)

Presenter: CUGINI, Davide

Session Classification: .

Contribution ID: **82** Type: **not specified**

A protocol for global multiphase estimation

Saturday, 2 September 2023 16:35 (5 minutes)

Presenter: CHESI, Giovanni (Istituto Nazionale di Fisica Nucleare)

Session Classification: .

Contribution ID: **83** Type: **not specified**

Overview of available piezo-based nano-positioners for operation into mK range

Saturday, 2 September 2023 16:40 (5 minutes)

Presenter: PISCHALNIKOV, Yuriy (Fermilab)

Session Classification: .

Contribution ID: **84** Type: **not specified**

Best Sensitivity to Wavelike Dark Photon Dark Matter with SRF Cavities

Saturday, 2 September 2023 16:45 (5 minutes)

Presenter: CERVANTES, Raphael

Session Classification: .

Contribution ID: **85** Type: **not specified**

A cryogenic muon veto for superconducting quantum bits

Saturday, 2 September 2023 16:50 (5 minutes)

Presenter: MARIANI, Ambra (Istituto Nazionale di Fisica Nucleare)

Session Classification: .

Contribution ID: **86** Type: **not specified**

Native 3-body interactions for quantum annealing with trapped ions

Saturday, 2 September 2023 16:55 (5 minutes)

Primary author: NAGIES, Sebastian

Co-authors: GEIER, Kevin; HAUKE, Philipp

Presenter: NAGIES, Sebastian

Session Classification: .

Contribution ID: **87** Type: **not specified**

Design, fabrication and characterization of a ultra-high-Q resilient Nb3Sn resonant cavity

Saturday, 2 September 2023 17:00 (5 minutes)

Presenter: Dr RETTAROLI, Alessio (Istituto Nazionale di Fisica Nucleare)

Session Classification: .

Contribution ID: **88** Type: **not specified**

NbTi Thin Film SRF Cavities for Dark Matter Search

Saturday, 2 September 2023 17:05 (5 minutes)

Presenter: MARCONATO, Giovanni (Istituto Nazionale di Fisica Nucleare)

Session Classification: .

Contribution ID: **89** Type: **not specified**

A SRF Cavity Detector for Gravitational Waves

Saturday, 2 September 2023 17:10 (5 minutes)

Primary author: FISCHER, Lars

Co-authors: MOORTGAT-PICK, Gudrid; PETERS, Krisztian; WENSKAT, Marc; PAULSEN, Michel; LÖWENBERG, Robin

Presenter: FISCHER, Lars

Session Classification: .

Contribution ID: **90** Type: **not specified**

Formulation of the Electric Vehicle Charging and Routing Problem for a Hybrid Quantum-Classical Search Space Reduction Heuristic

Saturday, 2 September 2023 17:15 (5 minutes)

Primary author: BOTTARELLI, Alberto

Presenter: BOTTARELLI, Alberto

Session Classification: .

Contribution ID: **91** Type: **not specified**

Loophole-free Bell Inequality Violation with Superconducting Circuits

Saturday, 2 September 2023 17:20 (5 minutes)

Primary author: KULIKOV, Anatoly (JINR, Dubna)

Presenter: KULIKOV, Anatoly (JINR, Dubna)

Session Classification: .