

The Low-Energy Frontier of Particle Physics

Monday, 10 February 2025 - Wednesday, 12 February 2025

INFN-LNF

Book of Abstracts

Contents

Lunch at LNF canteen	1
Fifth Force and Fundamental Constants	1
The Low Energy Frontier of Particle Physics	1
Opto-mechanical Resonators	1
The Archimedes Experiment: a way for exploring the Vacuum-Gravity Interaction	1
Quantum effects in gravity from a delocalised quantum source	1
Atomic fountain	2
Discussion	2
VIP Experiment	2
Probing the electron's EDM using cold and slow molecules	2
Theory Talk 1	3
Theory Talk 2	3
Discussion on Symmetry Violations	3
Fundamental physics with levitated micromagnets	3
New Detection of Dark Matter	3
ANDROMeDa	3
DELight	4
New Frontiers	4
Axion Experiments	4
Discussion on Light Dark Matter	4
Overview of ^{229m}Th based nuclear clock	4
Frequency metrology of buffer-gas-cooled molecular spectra for fundamental Physics research	4
Long range forces: A theory review	5

Discussion on 5th force and variation of fundamental constants 5

1

Lunch at LNF canteen

2

Fifth Force and Fundamental Constants

3

The Low Energy Frontier of Particle Physics

Corresponding Author: budker@uni-mainz.de

opening Talk

Gravity and Quantum Mechanics / 4

Opto-mechanical Resonators

Corresponding Author: francesco.marin@fi.infn.it

Gravity and Quantum Mechanics / 5

The Archimedes Experiment: a way for exploring the Vacuum-Gravity Interaction

Corresponding Author: paola.puppo@roma1.infn.it

The Archimedes experiment has the goal to measure the vacuum fluctuations interaction with Gravity. A high sensitive balance is employed to measure the small weight variations of high Tc superconducting samples when they pass to their superconductive status.

We describe the challenging experimental solutions adopted for having a very efficient heat exchange with the samples only through the radiation mechanism and we present the first promising results to reach the goal of this experiment.

Gravity and Quantum Mechanics / 6

Quantum effects in gravity from a delocalised quantum source

Corresponding Author: fgiacomini@phys.ethz.ch

Understanding the fundamental nature of gravity at the interface with quantum theory is a major open question in theoretical physics. Recently, the study of gravitating quantum systems, for instance a massive quantum system prepared in a quantum superposition of positions and sourcing a gravitational field, has attracted a lot of attention: quantum optics experiments are working towards realising such a scenario in the laboratory, and measuring the gravitational field associated to a quantum source is expected to give some information about the nature of gravity. On the theory side, quantum information tools are used to interpret the results. However, there are still open questions concerning the precise conclusions that these experiments could draw on the quantum nature of gravity, such as whether experiments in this regime will be able to test more than the Newtonian part of the gravitational field.

In my talk, I will present a new result, where a delocalised quantum source gives rise to effects that cannot be reproduced using the Newton potential nor as a limit of classical General Relativity. These effects can in principle be measured by performing an interference experiment, and are independent of graviton emission.

Identifying stronger quantum aspects of gravity than those reproducible with the Newton potential is crucial to prove the nonclassicality of the gravitational field and to plan a new generation of experiments testing quantum aspects of gravity in a broader sense than what proposed so far.

Gravity and Quantum Mechanics / 7

Atomic fountain

Corresponding Author: poli@lens.unifi.it

Gravity and Quantum Mechanics / 8

Discussion

Symmetry Violation / 9

VIP Experiment

Corresponding Author: napolitano.fabrizio@lnf.infn.it

Symmetry Violation / 10

Probing the electron's EDM using cold and slow molecules

Precision measurements on molecular quantum systems have developed into a powerful way to explore new physics. Such measurements are currently the most sensitive way to probe an effective asymmetry in the charge distribution of the electron - its electric dipole moment. Through a measurement of this property, limits can be set on possible extensions of the Standard model of particle physics. In this talk we will present the context, methods and latest developments in this field where the precision techniques of atomic and molecular physics are used to probe the frontiers of particle

physics. A particular focus is put on our work to produce slow beams and trapped samples of suitable molecules.

Symmetry Violation / 11

Theory Talk 1

Corresponding Author: joerg.jaeckel@cern.ch

Symmetry Violation / 12

Theory Talk 2

Symmetry Violation / 13

Discussion on Symmetry Violations

Light Dark Matter / 14

Fundamental physics with levitated micromagnets

Corresponding Author: anvinante@fbk.eu

Macroscopic and mesoscopic ferromagnets levitated by Meissner effect in vacuum behave as multimode mechanical systems with ultrahigh quality factor and high sensitivity to external magnetic fields. Furthermore, they can be easily coupled to superconducting quantum devices. This suggests the possibility of using this experimental platform for a variety of measurements in the context of fundamental and quantum physics. In this talk I will review our recent experimental work on levitated micromagnets with SQUID-based detection. Among various results, we have recently demonstrated magnetic field resolution beyond the energy resolution limit, atomic-like gyroscopic effects, and ultrafast spinning at MHz frequencies. I will discuss potential applications to fundamental physics, including the search for ultralight dark matter, fifth force measurements, and more speculative investigations on the macroscopic limits of quantum mechanics.

Light Dark Matter / 15

New Detection of Dark Matter

Light Dark Matter / 16

ANDROMeDa

Corresponding Author: francesco.pandolfi@roma1.infn.it

Light Dark Matter / 17

DELight

Corresponding Author: eleanor.fascione@kip.uni-heidelberg.de

Light Dark Matter / 18

New Frontiers

Corresponding Author: angelo.esposito@roma1.infn.it

Light Dark Matter / 19

Axion Experiments

Light Dark Matter / 20

Discussion on Light Dark Matter

Fifth Force and Variation of Fundamental Constants / 21

Overview of ^{229m}Th based nuclear clock

Corresponding Author: mikhail.osipenko@ge.infn.it

Nuclear transitions have energy scale a few orders of magnitude larger than atomic ones. This mismatch of energy scales prevented to use laser sources for excitation of nuclear levels. In the 70th it was deduced that ^{229}Th isotope might have an isomeric state at the energy of a few eVs. Recently, with development of the optical frequency combs, this state stimulated a broad interest, in particular regarding a possible nuclear clock application, allowing to enhance the atomic clock precision and test correlations between fundamental forces. In the last decade many experiments on the ^{229m}Th isomer were performed, including TORIO-229 experiment of INFN, confirming the past expectations. In this presentation an overview of the current knowledge on the lowest nuclear isomer ^{229m}Th will be presented as well as its possible future applications.

Fifth Force and Variation of Fundamental Constants / 22

Frequency metrology of buffer-gas-cooled molecular spectra for fundamental Physics research

Corresponding Author: pasquale.maddaloni@cnr.it

Based on the production of molecular samples at cryogenic temperatures by the buffer-gas-cooling technique and their combination with cavity-enhanced spectroscopy in the Lamb-dip regime, we present a new generation of high-accuracy physics tests beyond the Standard Model at the eV energy scale. Examples include searching for putative fifth-force interactions and assessing the space-time stability of the proton-to-electron mass ratio.

Fifth Force and Variation of Fundamental Constants / 23

Long range forces: A theory review

Corresponding Author: philip.soerensen@pd.infn.it

Various types of BSM physics, in particular new light particles, can lead to long-range forces. We can search for such “fifth force” interactions by sensitivity measuring gravity on various scales. In this talk, I will review how such long-range forces can be generated and how they lead to apparent violations of the inverse-square law and the equivalence principle of gravity. I will also discuss the of different types of long-range forces and give an overview of which kinds of BSM physics that long-range forces can be used to test.

Fifth Force and Variation of Fundamental Constants / 24

Discussion on 5th force and variation of fundamental constants