The Thematic Grant is related to the general research title Advanced Metrology. This includes eight research Topics (listed below), each of them with a specific title and proponent Supervisor/s. The applicants have the possibility to identify the specific topic they are interested in.

**Topic 1: Transition-Edge Sensors: towards dark photons and electron detection**

Transition-Edge Sensors (TESs) are microcalorimeters based on the steep resistive transition of a superconducting material. TESs are at the leading-edge as quantum detectors and INRIM has a long experience on TESs as single photon detectors in the visible and near-infrared wavelength region. The aim of the PhD proposal is to extend the development of TESs for experiments of fundamental physics, pushing their performances to the limit. Effort will be addressed to improve the quantum efficiency of the devices, their energy resolution and to reduce their dark counts rate.
Objectives

parameters are fundamental to develop a TES suitable for the search of dark matter and in particular of dark photons through a dielectric haloscope. The excellent performances of TESs can also be applied to demonstrate the feasibility to measure the energy of electrons accelerated in vacuum, as requested by the PTOLEMY collaboration, which aims to detect relic neutrinos from the Big Bang.

Topic 2: Quantum correlations fingerprint of microwave signals for illumination protocols beating classical limits - Quantum Radar
Quantum illumination based on entangled radiation sources is capable of exponentially reducing the probability error in the detection of a target compared to the case of traditional sources, precisely in the limit of low signal to noise ratio (SNR = 0.01). An ideal quantum source generates entangled states such as "two-mode squeezed vacuum states", which can be produced by adjusting the parameters of a quantum limited amplifier (either optical or exploiting the Josephson effect in the microwave regime). By appropriately manipulating signal generation and measurement, the candidate will develop and characterize experimental setups for robust quantum-enhanced detection in the microwave regime.

The research activity will be located in the Quantum Circuits for Metrology Laboratory, where the candidate will treat signals composed by single-photon microwave radiation in a cryogenic environment, exploiting state-of-the-art techniques revealing their quantum fingerprints.

Topic 3: Ultra-high Precision Absolute Earth Gravity Measurements
The value of the local acceleration due to gravity and its variations with time is of interest in a wide field of physical sciences and is measured by ballistic and quantum absolute gravimeters, traceable to the units of length and time. INRIM developed a transportable ballistic rise-and-fall absolute gravimeter (IMGC-02), which is the current Italian primary standard, but is overperforming for the uncertainty levels (around 10^{-5}) required by calibration laboratories, thus a new transportable and more suitable absolute gravimeter has to be developed. The PhD activity will be mainly focused on such task. The PhD candidate will be also involved in in-situ measurements, comparisons and relevant activities aimed at realizing a reference network for absolute gravity and at establishing the International Height Reference System/Frame (IHRS/IHRF) in the Italian area. Such a task is part of a research project of relevant national interest funded by MUR.

Topic 4: Metrology for soil properties and ground base system in environmental and climate research
The World Meteorological Organization has clearly expressed interest in implementing a metrological approach for cryosphere observations. Permafrost is a key component of the cryosphere, influencing energy exchanges, hydrological processes, CO2 and methane emissions. Soil moisture is one of the Essential Climate Variables influencing the land–atmosphere interactions at weather and climate timescales. Several soil moisture observation systems exist, but metrological tools are needed to ensure traceability and measurement methods' harmonization.

Objective of this research proposal is to:
• Develop novel metrological tools for soil moisture measurements, and harmonize different measurement methods.
• Improve measurements techniques and advance knowledge in calibration and overall measurement uncertainties for soil moisture and permafrost temperature.
• Apply machine-learning techniques for the generation of “virtual sensors” in
ground-based meteorological networks.

Topic 5: Design and characterization of a measurement system for Scattering Parameters at cryogenic temperatures for the characterization of microwave quantum devices
Quantum microwave devices (QMD) play a key role in different fields, e.g.: quantum computation and communication, radio-astronomy and biomedical imaging. New stringent demands are set on, e.g.: signal generation and detection, insertion loss and spectral characteristics of components. Microwave (MW) calibration capabilities exist at room temperature, but they are of limited use in cryogenics due to the major changes the components undergo. Even if QMDs should enable dramatically better accuracy, cryogenic MW measurements still lack in trace.

Skills and competencies for the development of the activity

Topic 1
Strong interest in research activities is required. In particular, it will constitute factors of preference:
• the attitude for experimental work;
• knowledge in one or more of the following fields: thin film fabrication, optics, cryogenics, superconducting devices;
• experience with one or more of the following programming languages: Labview, Matlab, Python, Comsol

Topic 2
- Data acquisition (transducers, digitalization)
- Microwave signals manipulation (waveguides, spectrum analysis, network analysis)
- Data processing (FPGA, post-processing)

Topic 3
Master degree in Physics or Engineering.
Skills on mechanical measurements, optical-interferometric systems, measurement uncertainty assessment, Finite Element Method (FEM) programs, LabVIEW and C++ development environment are appreciated, but not mandatory.

Topic 4
The candidate is required to have skill in environmental physics, physical engineering, mathematical models, electronics and machine learning

Topic 5
Required Skills: microwave design and measurements (active and passive devices, network analysis, spectrum analysis), data acquisition and analysis
Appreciated Skills: Python language programming, cryogenics

Topic 6
Basic skills and competences:
- Knowledge of the basis of quantum mechanics proven by the pass of the specific university exams.
Preferred skills and competences:
- Experience in Magnetic field sensing
- Knowledge of the basic optical components used in quantum optics experiments
- Capability to operate and program (preferably via Python language) remotely controlled measurement lab equipment
- Excellent knowledge of the English language.
Topic 7
The candidate is expected to have one or more of the following competences:
- mechanical engineering, to design the delicate flexible structure able to sense piconewton forces;
- electrical engineering to design the electrode structure and to set-up the measurement chain with microvolt accuracy;
- finite element analysis to model the elastic hinges and the electrostatic fields;
- informatics, to manage the whole instrumentation and for data analysis.

Topic 8
Master degree in Physics, or Electronic Engineering or Energy and Nuclear Engineering
- Basic electronics
- Familiarity with at least one programming language
- Interest for laboratory/experimental physics work