Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ERC funding

Superconducting Higgs mode

When a spontaneous breaking of a continuous symmetry takes place, for instance when crossing the normal to **superconducting** transition, collective excitations of the order parameter emerge: They are the phase modes and the massive **amplitude Higgs mode** (red arrow in Fig.1).

A mode of Higgs type, of crucial importance in the standard model of elementary particle physics, is also a fundamental collective mode in quantum many-body systems. It is remarkable that such collective Higgs modes predicted by theory many years ago, and lying at the core of the electronic properties of several classes of materials (cold atoms, superconductor, magnetic materials ...) still remain elusive to experimental validation. Even though a theoretical textbook mode, experimental observations of the collective amplitude mode in superconducting materials are scarce and still controversial. Besides, in superconductors, many outstanding and still open questions can be addressed through the study of these Higgs modes. Our purpose is to search for and to reveal the nature of new Higgs mode in condensed matter compounds. It will provide some textbook **experimental** examples and will help to address fundamental questions in the field of superconductivity and beyond

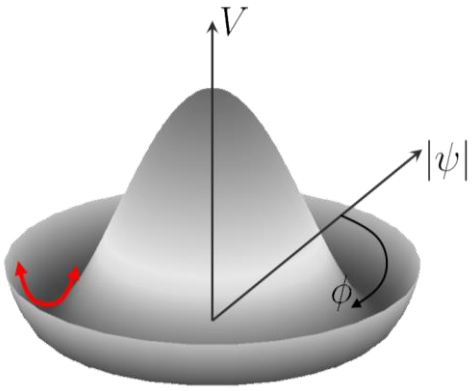

Fig.1*: Mexican-hat-shaped potential of the free energy as a function of the complex order parameter. There are two types of fundamental collective mode around the new equilibrium state taken spontaneously in the line of minima. One, the amplitude mode in red, is known as a "dark" mode and is the analogous of the Higgs boson. In superconductor, it corresponds to coherent oscillatory pairings and depairings of the Cooper pairs of electrons. Quest of such Higgs mode is at the heart of the Master2-PhD project.*

Research topic and facilities available:

Circumstances of observability of Higgs modes in Superconductors mainly include the presence of an electron-phonon-coupled quantum order, such as charge density wave, coexisting with superconductivity and whose collective mode couples to the Higgs one and makes it Raman active. Up to now, measurements are limited to few compounds in the $NbSe_2$ family. The Master 2 student will investigate new family of compounds thanks to **state-of-the-art Raman spectroscopy experiments** under extreme conditions of low temperature and high pressure. The facilities will include a new Raman set-up, cryogenics systems and high pressure Diamond Anvils cells. The student will be encompassed in a new ERC project, starting in December 2020. He/she will participate to new technical developments while being able to use present apparatus.

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	NO