Toward Breakthrough in Quantum Devices realizing Fault Tolerant Quantum Computers

Modern computers have transformed our lives, yet there are many problems—such as simulating complex quantum materials or breaking certain cryptographic codes—that remain beyond the reach of even the most powerful classical supercomputers. Quantum computers offer a radically different approach: instead of using classical bits of 0 and 1, they process information using quantum states of a superpotion of 0 and 1. But there is a major challenge that quantum information is extremely delicate. Even tiny disturbances from the surrounding environment can introduce errors, making it difficult to build reliable quantum machines: being faster is good, but it has to be correct!

In this talk, I will explore how fundamental physics can help us overcome the challenge of being correct despite errors, i.e., fault-tolerant quantum computer. I will introduce interesting and exotic quasiparticles, emergent in topological superconductors and how the quasiparticle can resolve the seemingly fundamental dilemma between being fast and correct by storing quantum information nonlocally and are naturally protected from noise. If time allows, I will also discuss how the existence of such topological superconductors may be revealed through an unexpected route—by probing the "shape" of a Cooper pair, the fundamental building block of superconductivity, whose spatial structure has never been directly measured so far. By combining theoretical insight with experimental collaboration, we aim to move quantum technologies from basic understanding toward practical, fault-tolerant quantum computers.