Key Concepts in Quantum Sensing

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In these lectures I will illustrate key concept of quantum sensing, providing a theoretical basis to understand quantum metrology and entanglement-enhanced interferometry [1]. First, I will discuss sensing based on probabilities (the so-called *classical* sensing), introducing important concepts such as maximum likelihood estimation and Cramer-Rao bound, and illustrate statistical as well as geometrical properties of the Fisher information. I will then discuss sensing based on quantum states (so-called *quantum* sensing) and see how the previously-mentioned classical concepts generalize to the quantum Cramer-Rao bound and quantum Fisher information. In the third part of my lectures I will make pedagogical exampless, from a single qubit to entangled (spin-squeezed and GHZ) states of many qubits, and illustrate the notion of Heisenberg limit and metrologically-useful entanglement. Finally, the last part is devoted to experimentally-relevant strategies to generate useful entangled states based on particle-particle interaction.

[1] Luca Pezzè, Augusto Smerzi, Markus K. Oberthaler, Roman Schmied, and Philipp Treutlein, Quantum metrology with nonclassical states of atomic ensembles, Rev. Mod. Phys. 90, 035005 (2018)