

Differences between QFT and QM

1. Theoretical Framework and Scope

- **QM**

- **Scope:** Primarily used to study the behavior of microscopic particles such as electrons, protons, and atoms.
- **Objects of Description:** Individual particles' motion, energy, wave functions, etc.
- **Fundamental Principles:** Based on Schrödinger's equation, the probabilistic interpretation of the wave function, and the uncertainty principle.

- **QFT**

- **Scope:** Used to describe interactions between particles, especially in high-energy physics, addressing fundamental particles and forces.
- **Objects of Description:** The relationship between fields and particles, where particles are seen as excitations of the underlying fields.
- **Fundamental Principles** Based on the quantization of fields, covering electromagnetic fields, strong interactions, weak interactions, etc.

2. Mathematical Tools and Methods

- **QM**

- Uses wave functions (or state vectors) to describe particle states.
- Employs Schrödinger's equation or Heisenberg's matrix mechanics to describe the evolution of particles.

- **QFT**

- Utilizes field operators($\Psi(\mathbf{r})$) to describe the quantum states of fields.
- Applies Lagrangians, Hamiltonians, and path integrals to describe the evolution and interactions of fields.

3. Concept of Particles and Fields

- **QM**

- Particles are described by the probability density of wave functions, exhibiting wave-particle duality.
- Focuses on the motion, energy states, and evolution of particles' wave functions.

- **QFT**

- Particles are described as excitations of quantum fields, e.g., the electron field's quantum excitations are electrons.

- Emphasizes the quantization of fields, where different types of fields correspond to different particles.

4. Relativity

- **QM**

- Generally deals with non-relativistic cases, where particles' velocities are much less than the speed of light.
- Relativistic quantum mechanics (like the Dirac equation) is an extension but does not fully encompass relativistic effects.

- **QFT**

- Fully compatible with relativity, handling relativistic particles and interactions at high energies.
- For example, Quantum Electrodynamics (QED) describes electromagnetic interactions within a relativistic quantum field framework.

5. Application Areas

- **QM**

- Mainly applied in atomic physics, molecular physics, condensed matter physics, quantum information, etc.
- Describes the electronic structure and energy levels within atoms, molecules, and solids.

- **QFT**

- Primarily applied in high-energy physics, particle physics, and cosmology.
- Describes the fundamental particles and forces, such as the electromagnetic force, strong force, and weak force.