

# Particle-counting statistics of time- and space-dependent fields

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The counting statistics give insight into the properties of quantum states of light and other quantum states of matter such as ultracold atoms or electrons. The theoretical description of photon counting was derived in the 1960s and was extended to massive particles more recently. Typically, the interaction between each particle and the detector is assumed to be limited to short time intervals, and the probability of counting particles in one interval is independent of the measurements in previous intervals. There has been some effort to describe particle counting as a continuous measurement, where the detector and the field to be counted interact continuously. However, the formalism based on continuous measurements does not provide a formula applicable to general time- and space-dependent fields. In our work, we derive a fully time- and space-dependent description of the counting process for linear quantum many-body systems, taking into account the back-action of the detector on the field. We apply our formalism to an expanding Bose-Einstein condensate of ultracold atoms, and show that it describes the process correctly, whereas the standard approach gives unphysical results in some limits. The example illustrates that, in certain situations, the back-action of the detector cannot be neglected and has to be included in the description.

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