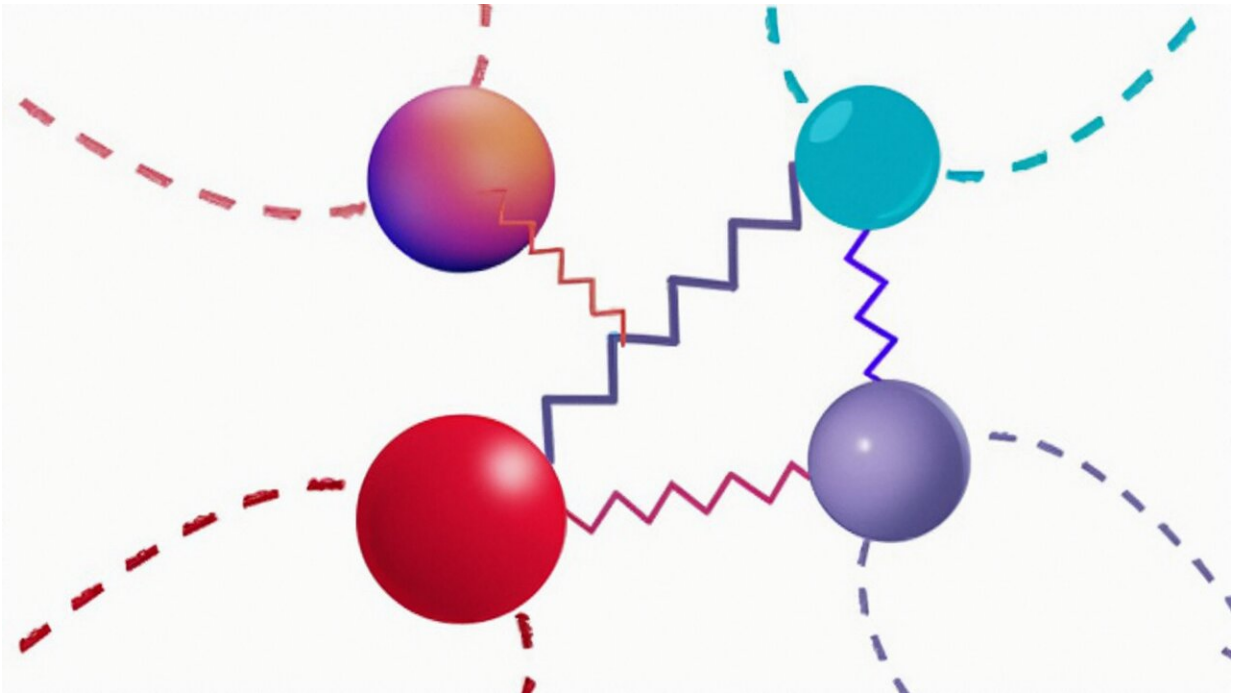
Many-body interactions feel the heat: Introducing thermal field theory

August 2 2023, by Robert Lea



A many-body process at zero temperature which becomes much more complicated when temperature is a factor. Credit: Robert Lea

Quantum field theory is a framework used by physicists to describe a wide range of phenomena in particle physics and is an effective tool to deal with complicated many-body problems or interacting systems.

Conventional quantum field theory describes systems and interactions at

zero temperature and zero chemical potential, and interactions in the real world certainly do occur at non-zero temperatures. That means scientists are keen to discover what effects may arise as a result of non-zero temperature and what new phenomena could arise due to a thermal background. In order to understand this, physicists turn to a recipe for quantum field theory in a thermal background — thermal field theory.

In a paper in *The European Physical Journal Special Topics*, Munshi G. Mustafa, Senior Professor at the Saha Institute of Nuclear Physics, Kolkata, India, introduces a thermal field theory in a simple way weaving together the details of its mathematical framework and its application.

"The goal of thermal field theory is to describe a large ensemble of multiple interacting particles, including gauge interactions, in a thermal environment," Mustafa says. "It also describes the creation and annihilation of new processes in a thermal system that are not present in vacuum or conventional field theory. Thermal field theory is a useful tool by which a complicated many-body system can be addressed only through the thermal averaged properties observed over a long period of time."

Mustafa explains that thermal field theory brings together the well-established realm of statistical mechanics supplemented with conventional quantum field theory to make problems manageable and allow observable characteristics to be expressed in terms of temperature and chemical potential.

"For a better understanding of the matter produced in high energy heavy-ion collisions at the Large Hadron Collider (LHC) and in future experiments, one needs the prescription of thermal field theory in particle and nuclear physics. It is also required for a better understanding of phase transition in condensed matter physics and the evolution of the

universe at early times," Mustafa concludes.

"This pedagogical review will serve as a primer to those who are interested to learn thermal field theory from the basics."

More information: Munshi G. Mustafa, An introduction to thermal field theory and some of its application, *The European Physical Journal Special Topics* (2023). DOI: 10.1140/epjs/s11734-023-00868-8

Provided by Springer

Citation: Many-body interactions feel the heat: Introducing thermal field theory (2023, August 2) retrieved 3 May 2024 from https://phys.org/news/2023-08-many-body-interactions-thermal-field-theory.html

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