A Joint Approach to Teaching Quantum Field Theory

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ABSTRACT

In Spring 2024, the Math and Physics departments at GMU introduced a joint course on Quantum Field Theory (MATH 689/PHYS 786), aimed at bridging the gap between the disciplines. The course, with over 20 participants, inspired new initiatives like the "QFT hour" and a summer seminar on String Theory, led by Dr. Casey Blacker.

We will explain how quantum field theory exemplifies the excitement and importance of such collaborative endeavors. It has not only driven key advances in understanding fundamental physics—such as the development of gauge theory and the Standard Model, which used mathematical tools like differential topology and group theory to classify elementary particles and predict the Higgs boson—but has also inspired breakthroughs in mathematics. These include geometric quantization, the discovery of new manifold invariants, such as those from Chern-Simons theory, and significant advancements in analysis, including the development of operator algebras, von Neumann algebras, and C*-algebras, which have become foundational in both mathematical physics and functional analysis. Despite these successes, quantum field theory still lacks a fully rigorous mathematical formalism, leaving much to explore, and its unification with gravity remains a major open problem. This underscores the importance of continued collaboration between mathematicians and physicists to tackle these challenges and push both fields forward. Such collaborations are not only essential to the intellectual growth of our students but also to the research programs in both departments and to the progress of both disciplines as a whole.

We will report on how our experiment began, the challenges we faced in coordinating and adjusting the content on the fly, and the feedback from participants—the good, the bad, and the ugly. This experience highlighted the need for more collaborative teaching efforts to ensure that both physics and mathematics students have the necessary background for such courses. The lessons learned will be invaluable in shaping a more refined, multi-course sequence.