A Case Study in the Philosophy of Scientific Experimentation: Electron-Proton Inelastic Scattering Program in High Energy Particle Physics

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Until the early 1980s, the philosophy of scientific experimentation was largely framed by the thesis of theory-ladenness of experimentation (TLE), as advanced in the works of philosophers such as Popper, Hanson, and Kuhn, and this theory-dominated view was accepted as the received view of scientific experimentation. Hacking's rejection of the received view in his Representing and Intervening opened the door to a new conception of scientific experimentation often dubbed the "New Experimentalism." The central tenet of New Experimentalism, as promoted by Hacking, Galison, Franklin, Ackermann and others, has been the acceptance of the view that experimentation is a field of study on its own right. In this new context, the relation between theory and experiment has received more attention from philosophers of science, the question being whether "theory-free" experimentation exists. In more recent years, the theory-experiment relation has been examined in somewhat more detail. Steinle (1997, 2002) has argued that TLE as conceived in the received view of scientific experimentation falls short in capturing the complex nature of the relationship that exists between theory and experiment in the case of particular experimentation which he calls "exploratory experimentation." Steinle's work has revived the old debate about the (im)possibility of "theory-free" experimentation. Heidelberger (1998, 2003) has offered an account for the possibility of theory-free experimentation by distinguishing TLE due to causal understanding and TLE due to theoretical interpretation. In the light of this distinction, he has argued that certain types of experiments proceed only at the causal level without having any recourse to a theoretical framework. In contrast to Heidelberger's account, Carrier (1998) has argued that both the data acquisition and the instrumentation in experimentation require what he calls "observation theories."

In this paper, I address the issue of to what extent the theory-dominated view of experimentation describes scientific practice. I rely on a case study in which I focus on a time period from the history of HEP, which spans from early 1960s to early 1970s. What makes this historical episode interesting for the philosophy of scientific experimentation is that it displays how the ways of theorizing and those of experimenting in HEP changed dramatically over time. The time period that I examine started with the hegemony of a HEP theory -namely, the scattering-matrix theory - which later faced a number of theoretical and experimental challenges that came out from a series of unprecedentedly large-scale experiments. The era eventually culminated in the emergence of a new and widely accepted theory of physics which is today known as the theory of quantum chromodynamics (QCD).

I bring out an important characteristic inherent to the scientific practice of HEP, namely, the "theory-phenomenology distinction." I argue that the theory-phenomenology distinction in HEP illustrates the distinction held for a quite long time by philosophers such as Cartwright and Suppe between "background theories", which embody fundamental laws of nature, and models -or "forefront theories" -, which contain phenomenological laws, namely, laws which are derived from fundamental laws, and which relate to phenomena under scrutiny. I examine the nature of the theory-phenomenology distinction, and use it to correctly identify what is at work on the theory side of the relationship between theory and experiment in the case of HEP experiments. I argue that the theory part of this distinction refers to background theories of HEP, while the phenomenology part refers to various models that enter into experiments. I further assert that experimentation in HEP is typically carried out in terms of models which are called phenomenological models, rather than background theories of HEP.

In the light of the case study I present, I argue that TLE, which grounds theory-dominated conception of experimentation, is too coarse-grained inasmuch as it prevents us from seeing the correct relationship that exists between theorizing and experimenting. I articulate that in order to be able to get a better understanding of scientific practice, a revision needs to be made in the general conception of TLE. I propose that such a revision is possible if we abandon the commitment that experimentation is always driven by theory. In this sense, I consider what I call "theory-drivenness" of experimentation (TDE) as a form of theory-ladenness, which amounts to the claim that experiments, from their initial design up to their final stage, are carried out and interpreted under the framework of a prevailing theory for the purpose of providing definite answers to specific questions already posed by the same theory. I argue that electron-proton inelastic scattering experiments in HEP were firstly carried out without having any recourse to a phenomenological model. From here, I claim that these experiments are not theory-laden in the sense implied by TDE. On the other hand, I argue, inelastic scattering experiments are theory-laden due to the fact that the scientists who perform them are committed to background theories of HEP. That is, I admit the validity of TLE as a philosophical claim, but I attribute a weaker status to it as opposed to its general conception. I propose to differentiate TDE from TLE by claiming that TLE does not entail TDE.

Moreover, with reference to the practice of HEP, I explain and stress the usefulness of the differentiation of TDE from TLE, and discuss its consequences for other philosophical debates on the relation between theory and experiment. Also, I elaborate on Steinle's view that exploratory experimentation is typical to the opening up of new research fields. I argue that the epistemic appropriateness of exploratory experimentation is not restricted to those fields in which there is no well-established theory, but also valid in domains of research which are occupied by well-established theories, or so to speak, mature theories.