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MODELS OF HIGH ENERGY PROCESSES

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Cambridge University Press
978-0-521-13382-1 - Models of High Energy Processes
J. C. Polkinghorne
Frontmatter
More information

Contents

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Preface

Theoretical physics makes extensive use of models to test and develop intuition. In non-relativistic quantum mechanics the principal source of insight is provided by the study of suitably chosen potentials. However, such an approach can be of little value in relativistic quantum mechanics. Instead the Feynman integrals of perturbation theory have provided a rich testing ground for assessing dynamical conjectures. The method is unashamedly heuristic but it commands respect because Feynman perturbation theory gives a formal solution of the requirements of analyticity and unitarity. These principles are believed to provide the essential kinematic setting for relativistic quantum mechanics. It is true that recent ideas of confinement, and of the role of non-perturbative classical solutions of field theory, have suggested important aspects of relativistic quantum mechanics that are not to be seen in Feynman integrals. Nevertheless the method retains its power to act as a guide to the answer of many dynamical questions. In particular it remains an indispensable tool to investigate the fundamental interactions of quarks and gluons, a role which has been given an enhanced respectability by the elegant notion of asymptotic freedom for non-Abelian gauge theories.

While perturbation theory continues to be an important model, eliciting its guidance is sometimes a formidable analytic task. An important advance was made when Academician Gribov introduced hybrid models, based on Sudakov parameter methods. Not only are these models in many cases easier to calculate but also their largely non-perturbative character makes their conclusions stand on firmer ground. The technique pioneered by Gribov has proved a fruitful source of model making for many physical regimes. One of its most important uses has been to provide a covariant and non-perturbative formulation of the parton model. This model describes the substructure within hadrons which appears to be manifest in deep inelastic scattering reactions of all kinds. Such processes, characterised by high energy and large momentum transfer, probe the constituents out of which hadrons are made. They provide much of the detailed evidence for the quark structure of matter.

This monograph seeks to provide an introduction to these types of model making. Its aim is to explain the basic ideas in a form accessible to graduate students and other readers who have acquired a first knowledge of quantum field theory and basic particle physics, including the elements of Regge theory. I believe that it describes all major calculational techniques together with sufficient physical applications to illustrate their utility. No attempt has been made to be encyclopaedic, for an exhaustive treatment of every application would have created a volume too large for the simple pedagogic purpose intended. For example the parton model is discussed in a way which exhibits its physical structure but which avoids commitment to details which are still a matter of unresolved phenomenological debate. Similarly, on the theoretical side I have been content to illustrate the connection of the ideas presented with Reggeon field theory and with K. Wilson's operator product expansion, without developing either subject in detail since each is really an autonomous discipline in the regime it describes.

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J. C. POLKINGHORNE

Summary of analytical techniques

In this monograph we describe a number of mathematical techniques. They are employed in appropriate physical contexts but often they are capable of much wider application than can be illustrated in a book of this size. The aim of this summary is to give an indication of these techniques, and the sections in which they are developed, in the hope that this will prove useful to a reader in search of a line of attack on a problem.

The basic method for evaluating Feynman integrals is symmetric integration (section 1.2). If numerator factors are present the use of auxiliary momenta as dummy variables is often helpful (section 1.3). A technique for handling logarithmic factors is known (section 3.3, equation (3.3.28)). Sometimes it is convenient to rewrite the loop momentum integrals as integrals over invariants (section 3.7). Ways of handling θ-functions and δ-function constraints are also available (section 4.4).

The asymptotic behaviour of integrals can sometimes be determined by direct integration by means of formulae like (2.1.7) of section 2.1. This section describes the important notions of natural behaviour, end point contributions and pinch contributions.

A powerful general method for treating end point contributions is provided by Mellin transforms (section 2.2). Key ideas are scaling transformations (section 2.3), disconnected scaling sets (section 2.3), independent scaling sets (section 2.3) and singular configurations (section 2.4). Multiple Mellin transforms (section 2.9) can be used to discuss limits in several variables.

Pinch contributions are discussed in section 2.6, where it is also explained how they can be evaluated by using end point techniques. An example of behaviour governed by a mixture of end points and pinches is given in section 2.7.

The treatment of divergences by dimensional regularisation is discussed in section 2.5 and the effect of divergences on asymptotic behaviour illustrated in section 3.3.

The determination of momentum flows associated with scaling sequences is given in section 2.8, where the eikonal approximation is also worked out.

Sudakov parameters are defined in section 3.1. The importance of contour closing arguments in determining the significant range of values of Sudakov parameters in high energy regimes is illustrated in section 3.2. In section 3.3 a modified Sudakov representation with massless momenta is defined (see (3.3.13)) and in section 3.4 an alternative and universally powerful parametrisation for constituent momenta almost parallel to parent hadron momenta is written down ((3.4.3) *et seq.*).

A method by which Fourier transforms can be used to specify general analytic properties is given in section 3.6 (see (3.6.8)). The way iε prescriptions for internal invariants are specified by the iε prescriptions for external invariants is explained in section 4.2.