Preface

This work covers the material of a two-semester course of quantum field theory (QFT) that I taught for more than 20 years at the Charles University and Czech Technical University in Prague. For years, I was reluctant to write up such a set of lecture notes, since the current literature in this area is quite rich and there are dozens of books on the subject. However, eventually I was forced to do it, because of the pandemy of the infamous coronavirus that has broken out in spring 2020. I comment on this in more detail below. Conceptually, my approach is traditional, starting with several introductory chapters on the relativistic quantum mechanics. Then, after a brief interlude on the classical field theory, one proceeds to the quantization of free fields and to some elementary examples of field interactions, the basic tool being the Dyson perturbation expansion of the S-matrix in the interaction representation. The pragmatic aim of the first half of the text (chapters 1–25) is to arrive at the basic techniques for calculations of Feynman diagrams in the lowest perturbative order, as well as for the computation of the particle decay rates and scattering cross sections. This is just the matter that should be ideally explained during the first (winter) semester, since a part of the curriculum in the second (summer) semester, at least for some students, is a course on the standard model of particle physics, where a Feynman diagram calculation is an everyday occurrence. The second half (chapters 26–50) represents topics to be explained during the second semester and the main theme here is quantum electrodynamics at the level of one-loop diagrams, including techniques of regularization of ultraviolet divergences and renormalization. In this way, the whole material of the present lecture notes is divided into 50 chapters and each of them corresponds, roughly, to a 90 min. lecture (the total number of QFT lectures in a given academic year is about fifty). I would like to stress that the text is really intended to have the character of lecture notes, which means that, among other things, some explicit calculations are shown here in greater detail than in most of the representative monographs and textbooks, so as to make the life of a QFT beginner easier. Throughout the text one also encounters numerous hints to possible independent calculations, addressed to interested diligent readers; some of the problems in question may also serve as appropriate topics for tutorials. Admittedly, readers that are not quite fond of performing independent calculations may find the repeated offers of problems left to them as "instructive exercises" somewhat disturbing (or even annoying); anyway, there are just about three dozen of such hints in the whole text, i.e. less than one per chapter on average.

As I have indicated above, these lecture notes have been written under rather special circumstances, during the protracted coronavirus (COVID-19) crisis in 2020 and 2021. It was a situation that people of my generation have experienced never before, so let me add some personal recollection (which is, admittedly, somewhat emotional). The outbreak of the pandemy was officially announced in March 2020. Thus, on Wednesday, March 11, the personal attendance of students in the lecture rooms was banned "until further notice" and I decided to write immediately the text of a lecture scheduled for Thursday, to be able to send it to students via e-mail. Such a procedure seemed to me more efficient than a system of videoconferences or so, and I hoped

also that the students' opinion would coincide with that of the aspiring student in Goethe's Faust, expressed in a dialogue with Mephistopheles, namely, "You won't need to tell me twice! I think, myself, it's very helpful, too, that one can take back home, and use, what someone's penned in black and white".[1] In any case, it is obvious that a carefully written text is more durable than lectures presented on a blackboard and erased immediately after the classes. Thus I went on in this manner, sticking to the maxim "nulla dies sine linea", till the end of May when the semester terminates. When the summer semester and the students' exams were over, I returned to the material of the envisaged next winter semester and continued writing down the relevant lectures so as to have a complete set (in musical terms, "da capo al fine"). In the meantime, I had to put together a collection of lectures for another course, aimed at a more advanced audience (25 chapters as well). In this way, the whole work has been basically completed in May 2021, with the nasty virus still around. Then there followed a period of transforming the manuscript full of handwritten formulae into a user-friendly electronic file, as well as gradual detailed proofreading of the text, mostly during the academic year 2021/2022. This was largely finished in autumn 2022, when the pandemy was fading away, but was overshadowed by even more tragic events — of course, I have in mind the absurd criminal war that Russia started against Ukraine.

When I started writing the lecture notes, in the gloomy atmosphere of the covid calamity on the rise, it came to my mind that there is a famous work of the world literature that was created under similar circumstances and survived over centuries. Yes, you guessed right; it is the Decameron by Giovanni Boccaccio. Its origin is widely known. It represents a collection of one hundred tales told by a group of ten young people who escaped from Florence, where the epidemic of plague broke out in 1348, and stayed in a hideout in the countryside to avoid the dangerous infection. Concerning my text, I have also written the lecture notes partly in a hideout (the "home office"). These consist of only fifty tales told by myself (not young anymore), concerning topics not so easily accessible to a general public and I certainly do not expect that my opus will become so famous as the Boccaccio's Decameron, or that it could survive through centuries. Nevertheless, I believe that it may have an appropriate (though inevitably limited) lifetime and may be useful for at least some students and other potentially interested scientifically minded readers. My primary aim has been to make it a comprehensible and digestible introduction to the rather difficult subject of quantum field theory, which, among others, forms a basis of the contemporary particle physics.

One last remark is perhaps in order here. In view of the above-mentioned origin of these lecture notes, it is to be expected that most of the potential readers will be university students fluent in Czech. Thus, I could not resist the temptation to include, occasionally, some notes concerning the Czech equivalents of the international English terminology, or even some elements of a common literary folklore. Hopefully, this might add some cheering moments to the serious scholarly style of the whole opus.

Acknowledgements

From what I have written above it might seem that I should thank the malicious coronavirus in the first place, for stimulating me to write up these lecture notes. But I will not, taking into account that, apart from the positive impact mentioned above, this dangerous invisible bug did also so much harm to so many people all over the world. Needless to say, my acknowledgements are aimed in a completely different, genuinely positive, direction. In particular, I recognize the work of my younger colleagues who conducted and supervised, during the previous years, the

[1] A translation into English by A. S. Kline, 2003. In Czech (in the classic translation by O. Fischer) it reads: "Tot' praktické, i heled'me se! To tělem duší při tom jsem. Neb co je černé na bílém, to vesele se domů nese."

tutorials related to my lectures. They are, in alphabetical order: Karol Kampf, Karel Kolář, Jiří Novotný and Martin Zdráhal. Further, I appreciate questions and comments that the students made throughout the years; this certainly led to many improvements of the style and contents of the lectures. Actually, I have also received some useful remarks from other colleagues; for instance, Walter Grimus from Vienna University has drawn my attention to the fact that the frequently cited "Lorentz condition" in electromagnetism is in fact "Lorenz condition". Finally, my great thanks are due to Tomáš Husek and Tomáš Kadavý, who recast my manuscript in LaTeX and thus made it ready for publication; the whole work matured to its present form in spring 2023.

Prague, May 2023 J. Hořejší