The renormalisation group in particle physics (and the solid state analogy)

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Summary

The principle aim of these lectures is to introduce the concepts of renormalisation and renormalisation group as initially formulated and applied in the realm of elementary particle physics. The general context will thus be that of four dimensional renormalisable relativistic quantum field (gauge) theories. However, greater insight is gained into the meaning of the renormalization group when considered from the point of view of critical phenomena in statistical and solid state physics. We will present both approaches, discuss their merits, the complementary physical interpretations they sustain, the approximations they involve, as well as the misconceptions they sometimes carry along when applied to particle physics. The main issue, namely the energy/momentum scaling properties of physical systems, lies at the heart of the quest for possible new physics beyond the Standard Model at scales that are being probed at the LHC.

Tentative contents

After a brief general introduction to the prerequesite theoretical tools and to the history of infinities in field theory (1h), the central ideas will be presented mainly in the simple setting of scalar fields, and organized in four chapters as follows:

1/ *the origin of the ultra-violet divergences:* -free scalar field -interacting scalar field ('$\lambda\phi^4$' theory) -renormalisation or fine-tuning? -the role of symmetries and generalisation to gauge theories. ($\sim$ 4h)

2/ *renormalisation group à la Stueckelberg-Petermann/Gell-Mann-Low:* -general derivation of the renormalisation group equations -physical meaning of the 'running' quantities, and renormalisation scheme dependence -the resummation theorem -the effective potential case -multi-scale difficulties. ($\sim$ 4h)

3/ *renormalisation group à la Wilson:* -critical phenomena and Kadanoff blocking -scaling and renormalisation group flows, the general idea. - ϵ-expansion in '$\lambda\phi^4$' theory. ($\sim$ 4h)

4/ *in a nutshell: uses and misuses in particle physics:* - running couplings and masses in QED and QCD - the solid state analogy and the meaning of the cut-off - the hierarchy and fine-tuning 'problems' in the Higgs sector of the Standard Model - inclusion of gravity or new physics? grand unification, supersymmetry,...? ($\sim$ 3h)

Time: 3, 4, 5, 6, 7, 12, 13, 14 February 16h00-18h00
Place: Amphi, Grünewald, IPHC