Particles and Gravity

Gravitational interactions are often considered to be extremely feeble at energies accessible in contemporary particle accelerators, hence they are usually neglected in quantitative discussions of particle physics near the electroweak scale. However, there are good reasons to go beyond this standard approach. Firstly, cosmological applications of particle physics become increasingly relevant, and their better theoretical understanding turns out to be a pressing and demanding challenge. Secondly, theories unifying elementary interactions, like the string theory and local supersymmetry, necessarily include gravity and electroweak and strong interactions at equal footing. Incorporation of gravity into unified picture of fundamental interactions always leads to modifications of 4-dimensional Einstein gravity. Often the electroweak interactions are also influenced by modifications of gravity and mixing between electroweak and gravitational degrees of freedom emerges. It opens up a fascinating new perspective for going beyond the Standard Model of electroweak interactions. This lecture is intended to provide a basic link between the high-energy physics thought of as a quantum field theory and gravity understood as a theory of fluctuations of a graviton field around certain background. We shall try to introduce at elementary level tools allowing consistent description of Standard Model degrees of freedom interacting with gravity within the framework of field theory, and at the same time to discuss most interesting phenomena in the realm of particle physics that are sensitive to gravitational interactions.

The lecture will be held in English. It requires some knowledge of quantum mechanics and basics of special relativity. The language of a classical field theory will be adopted, so its knowledge will also be helpful, though not necessary. The lecture should be accessible already to 3rd year students, and fully understandable to 4th and 5th year students.

The outline of the lecture:

1. Brief introduction to classical and quantum field theory
2. Gravity as a field theory of spin-2 gravitons
3. Elementary particles in a curved spacetime
4. Perturbation expansion and Feynman rules for gravitons
5. Experimental tests of general relativity
6. Extra dimensions and Kaluza–Klein theories
7. Gravity at high-energy accelerators
8. The cosmological constant problem and its possible solutions
9. Tunneling in the presence of gravity
10. Quantum mechanics of inflation

Bibliography:

- S. Weinberg, “Gravitation and cosmology : principles and applications of the general theory of relativity”,
- A. Zee, “Quantum field theory in a nutshell”,
- R. Feynman, F. Moringo and W. Wagner, “Feynman Lectures on Gravitation”,
- Journal papers recommended by the lecturers.

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