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Accessing the properties of an elementary Higgs beyond perturbation theory

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In certain gauges, the Higgs sector of the standard model can be very well described by expanding perturbatively around the expectation value of the Higgs field. However, in general the gauge-dependent Higgs expectation value can be zero, and thus a perturbative treatment in these gauges cannot provide an adequate description of experimental results. An example for such a gauge is the Landau limit of the 't Hooft gauge. Such gauges therefore provide an ideal setting to study the non-perturbative origin of the Higgs effect.

Here, these non-perturbative properties are determined using lattice gauge theory for the weak isospin sector of the standard model, i. e., the Higgs and the (in the absence of QED degenerate) W and Z gauge bosons. From the propagators of these particles it is found that the gauge bosons exhibit the spontaneous generation of a screening mass, in close analogy to the confinement phase, and thus show the expected properties without an explicit breaking of the global weak isospin symmetry. At the same time the Higgs is only slightly modified against its renormalized tree-level behavior, and the running gauge coupling is found to be suppressed at small momenta.

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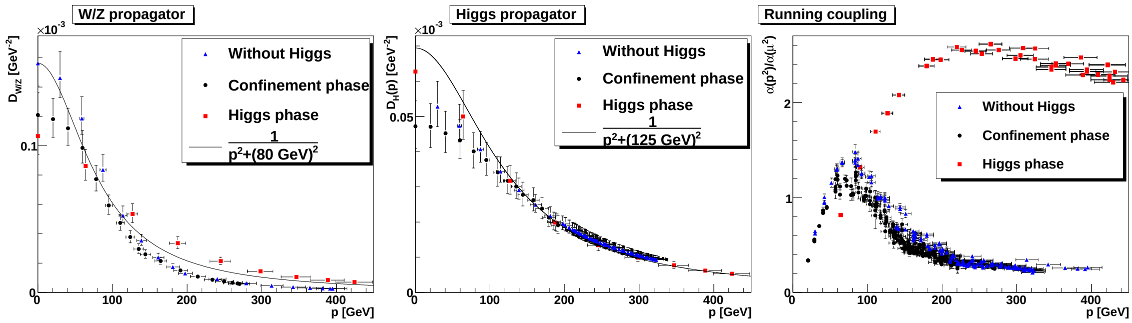

Figure 1: The weak gauge boson propagator (left panel), the Higgs propagator (middle panel) and the running gauge coupling (right panel). The propagators are compared to the (renormalized) tree-level behavior. The renormalization prescription and the details of the simulations can be found in [1].

The vacuum condensate of the Higgs is gauge-dependent, and cannot be used as an order parameter to distinguish the confinement and the Higgs phase of fundamental scalars coupled to Yang-Mills theories [2]. Thus, a perturbative determination of the correlation functions in a gauge with vanishing condensate, here the Landau gauge, is of limited use, and it is necessary to resort to non-perturbative methods. Here, lattice gauge theory is used to determine the elementary correlation functions, in particular the propagators, of the weak isospin sector of the standard model, see [1] for details. The results obtained for the propagator of the (in the absence of QED degenerate) W and Z gauge bosons, the Higgs, and the running gauge coupling are shown in figure 1.

The results show the spontaneous generation of a screening mass for the gauge bosons, and thus the same as in the conventional Higgs mechanism. Thus, in this gauge the mass generation for the gauge bosons is occurring genuinely non-perturbatively. It is hence possible to understand the non-perturbative mechanism for the Higgs effect as a dynamical phenomena rather than a static condensate. At the same time the Higgs itself is only weakly deformed from a renormalized tree-level behavior. Thus, the Higgs is rather inert. In particular, the comparison to the confinement case and to a quenched Higgs, see figure 1, show that the elementary correlation functions exhibit in all cases a rather similar behavior, again emphasizing the qualitative similarity between both phases.

Besides these general field-theoretical aspects, these findings also show that the elementary correlation functions can be determined even in the technically rather advantageous Landau-gauge limit [3]. This paves the way to use a full non-perturbative setting, combining besides these lattice methods also functional continuum calculations [3], to determine the impact of strong interactions at the electroweak scale. This is particular important in the presence of strong initial and final state interactions, as they occur, e. g., in precision low-energy experiments, or if strong interactions, like technicolor, should play a role in the electroweak sector.

References

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