The ghost-gluon vertex in Landau gauge Yang-Mills theory

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The infrared properties of strong interaction, such as confinement, require a non-perturbative treatment. One possibility to approach this challenging task is to employ the Dyson-Schwinger technique to derive an infinite tower of mutually coupled equations for the Green functions of Yang-Mills theory. The Landau gauge has the intriguing feature that the ghost-gluon vertex $\Gamma_\mu(k;q,p)$ reduces to its tree-level value in the limit of vanishing incoming ghost momentum p [1]. In the ultraviolet, this vertex is expected to yield the perturbative behavior. Therefore, one might be tempted to choose the ghost-gluon vertex bare for all momentum variables. The bare vertex approximation has been applied to Landau gauge Dyson-Schwinger studies to arrive at a gluon propagator that is suppressed in the infrared and an enhanced ghost propagator in the infrared, thus satisfying criteria for confinement in pure Yang-Mills theory [2]. An investigation of the non-perturbative ghost-gluon vertex will test this assumption and, moreover, provide insight into this interesting and non-trivial object.

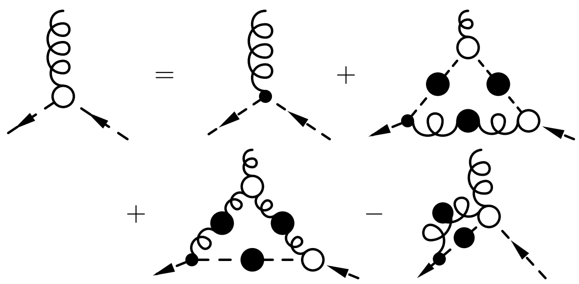

Figure 1: Complete DSE for the ghost-gluon vertex. Curly lines are gluons, dashed lines are ghosts, blobs represent dressed objects.

The complete Dyson-Schwinger equation for the ghost-gluon vertex in the Landau gauge has been derived [3], see Fig. 1. This non-linear equation can be solved by iteration for both four and three Euclidean spacetime dimensions d, employing the non-perturbative propagators calculated in [4, 5]. The contribution of the four-point interaction is neglected in accordance to the truncation applied for the propagators. For the reasons mentioned above, the bare ghost-gluon vertex is a good starting point for the iteration. The three-gluon vertex is set to its tree-level value. After one iteration step the ghost-gluon vertex shows a behavior [3, 6] which is quite close to the input for all momentum variables. The infrared behavior of the result satisfies the constraint imposed by gauge invariance, i.e. the Slavnov-Taylor identity of the vertex. In the ultraviolet asymptotic freedom is observed. The previously unknown limit of vanishing gluon momentum k is shown for $d = 4$ and $SU(2)$ in Fig. 2, where

$$1 + A(k^2; q^2, p^2) = \frac{k^2 q_\mu t_{\mu\nu}(k)}{i g_d (q^2 k^2 - (q \cdot k)^2)} \Gamma_\nu(k; q, p)$$

with the gauge coupling g_d and the transverse projector $t_{\mu\nu}(k) = \delta_{\mu\nu} - k_\mu k_\nu / k^2$. Choosing $d = 3$ and/or $SU(3)$ does not significantly change the results [3, 6]. The deviations from tree-level are in the range of 20%, indicating that the input of the iteration is quite close to the fixed point. The comparison to recently obtained lattice data [7] shows good agreement. Other inputs for the ghost-gluon vertex, motivated by its Slavnov-Taylor identity, have also been used and yielded similar results [3, 6].

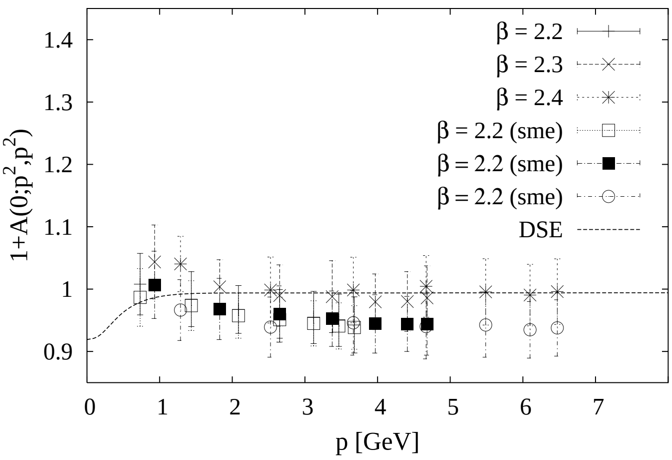

Figure 2: The $d = 4$ ghost-gluon vertex in the limit of vanishing gluon momentum compared to lattice data [7].

These calculations justify the bare vertex approximation a posteriori and provide a more profound confirmation of the features of the propagators, in particular gluon confinement in the four-dimensional vacuum theory [4]. For the three-dimensional investigations, support is given for remnant long-range interactions in the high-temperature phase of Yang-Mills theory [5]. Moreover, the results corroborate the hypothesis that the Green functions of Yang-Mills theory are dominated by ghosts in the infrared and thus strengthen the evidence for the Gribov-Zwanziger confinement scenario [8].

References

[1] J. C. Taylor, Nucl. Phys. B **33** (1971) 436; W. J. Marciano and H. Pagels, Phys. Rept. **36** (1978) 137.

[2] R. Alkofer and L. von Smekal, Phys. Rept. **353** (2001) 281 [arXiv:hep-ph/0007355].

[3] W. Schleifenbaum, diploma thesis, TU Darmstadt, 2004;

[4] C. S. Fischer and R. Alkofer, Phys. Lett. B **536** (2002) 177 [arXiv:hep-ph/0202202].

[5] A. Maas, J. Wambach, B. Grüter and R. Alkofer, Eur. Phys. J. **C37** (2004) 335 [arXiv:hep-ph/0408074].

[6] W. Schleifenbaum, A. Maas, J. Wambach and R. Alkofer, arXiv:hep-ph/0411052.

[7] A. Cucchieri, T. Mendes and A. Mihara, JHEP **0412** (2004) 012 [arXiv:hep-lat/0408034].

[8] D. Zwanziger, Phys. Rev. D **69** (2004) 016002 [arXiv:hep-ph/0303028]; D. Zwanziger, Nucl. Phys. B **412** (1994) 657; V. N. Gribov, Nucl. Phys. B **139** (1978) 1.