Gluon and Ghost Propagators in Landau Gauge on the Lattice

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We study the UV behavior of Gluon and Ghost Propagators in quenched QCD in Landau gauge \( (\partial_\mu A^a_\mu = 0) \)
Motivations:

- non-perturbative study in 2GeV → 6GeV domain
- matching between lattice predictions ↔ perturbation theory
- estimation of $\Lambda_{\text{QCD}}$ (the energy scale of quenched QCD, is related to $\alpha_s$)
- checking the self-consistency of lattice approach
  
  $$
  \left( \Lambda_{\text{QCD}}^\text{ghost} \leftrightarrow ? \Lambda_{\text{QCD}}^\text{gluon} \right)
  $$

- studying non-perturbative power corrections
Simulation Setup

- Euclidean theory on a finite lattice \((L^4, a)\)
- Monte-Carlo evaluation of the functional integral
  \[
  \int [{\cal D}A] A^a_\mu(x) A^b_\mu(y) e^{-S_{\text{QCD}}[A]}
  \]
  \(\Rightarrow\) gluon propagator.
- Numerical inversion of the Faddeev-Popov operator on the lattice:
  \[
  M^{ab}(x, y) = [(\partial + A) \cdot \partial]^{ab}(x, y)
  \]
  \(\Rightarrow\) ghost propagator.
- Controlled extrapolation to the continuum limit \(a \to 0\)
  \[
  \langle \tilde{A}^a_\mu(p) \tilde{A}^b_\nu(-p) \rangle = \frac{G(p^2)}{p^2} \delta^{ab} \left( \delta_{\mu\nu} - \frac{p_\mu p_\nu}{p^2} \right),
  \]
  \[
  \langle c^a(p) \bar{c}^b(-p) \rangle = \frac{F(p^2)}{p^2} \delta^{ab}
  \]
Results (Gluon)

\[ G(p) \text{ vs. } p, \text{ GeV} \]

\[
\begin{array}{cccc}
2 & 4 & 6 & 8 \\
2 & 1 & 1.5 & 2 \\
3 & 3.5 & 3 \text{ MeV} \\
\end{array}
\]

\[ \Lambda^2 \approx 297 \pm 3 \text{ MeV} \]

32^4 \beta=6.4 \#conf 250, Fit scheme \text{ MÖM (3)}, \Lambda^2=297\pm 3 \text{ MeV}
Results (Ghost, preliminary)

$F(p) = 32^4 \beta = 6.4 \text{ conf 250, Fit scheme MÖM(3), } \Lambda = 317 \pm 9 \text{ MeV}$
Results (Summary, preliminary)

Fit at 3 loops in MOM scheme + conversion to $\bar{\text{MS}}$ scheme:

<table>
<thead>
<tr>
<th>$\beta$</th>
<th>$L$</th>
<th>$\Lambda_{\bar{\text{MS}}}^{(3)\text{gluon}}$</th>
<th>$\chi^2$/d.d.l</th>
<th>$\Lambda_{\bar{\text{MS}}}^{(3)\text{ghost}}$</th>
<th>$\chi^2$/d.d.l</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
<td>16</td>
<td>319(3)MeV</td>
<td>0.61</td>
<td>333(7)MeV</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>306(4)MeV</td>
<td>0.42</td>
<td>285(3)MeV</td>
<td>0.11</td>
</tr>
<tr>
<td>6.2</td>
<td>24</td>
<td>313(2)MeV</td>
<td>0.60</td>
<td>342(10)MeV</td>
<td>0.6</td>
</tr>
<tr>
<td>6.4</td>
<td>32</td>
<td>297(2)MeV</td>
<td>0.95</td>
<td>317(9)MeV</td>
<td>0.31</td>
</tr>
</tbody>
</table>
Conclusions

- consistent results for $\Lambda_{QCD}$ at 3 loops for ghost(new) and gluon propagators
- good stable fits at 3 loops in the region $2\text{GeV} \rightarrow 6\text{GeV}$ ($\chi^2 < 1$)
- large value of $\Lambda_{QCD}$ (quenched approximation) : unquenching and (?)power corrections make it lower, $\sim 250\text{MeV}$
Perspectives

- precise study, including ghost-gluon vertex and corresponding $\alpha_s$ analysis
- (preliminary) taking in account of $\langle A^2 \rangle$ condensate leads to coherent results for $\Lambda$ from ghost and gluon propagators
- IR study (Gribov copies, IR-asymptotic behavior, etc.)