Two- and three-point functions of Landau gauge Yang-Mills theory in two dimensions

Markus Q. Huber, Axel Maas, Lorenz von Smekal

Institute of Nuclear Physics, Technical University Darmstadt

Sept. 20, 2012

62nd annual meeting of the Austrian Physical Society

arXiv:1207.0222

Unterstützt von / Supported by

Alexander von Humboldt Stiftung/Foundation

TECHNISCHE UNIVERSITÄT DARMSTADT

Non-perturbative Landau gauge Green functions

Non-perturbative propagators of Landau gauge Yang-Mills theory:

- information about confinement, input for phenomenological calculations (QCD phase diagram, bound states, . . .)
- methods: functional equations, lattice; non-perturbative methods!

Non-perturbative Landau gauge Green functions

Non-perturbative propagators of Landau gauge Yang-Mills theory:

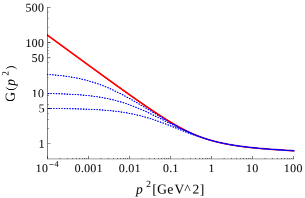
- information about confinement, input for phenomenological calculations (QCD phase diagram, bound states, . . .)
- methods: functional equations, lattice; non-perturbative methods!

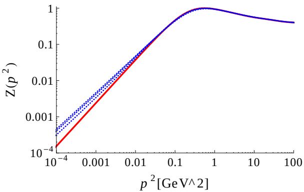
Solutions:

- 4 dimensions: two types of solutions with functional methods that differ only in deep IR [Boucaud et al., JHEP 0806, 012; Fischer, Maas, Pawlowski, AP 324]:

  scaling [von Smekal, Alkofer, Hauck PRL97],

  decoupling [Aguilar, Binosi, Papavassiliou PRD78]
- Lattice calculations find only decoupling type solution for $d = 3, 4$ and scaling for $d = 2$





Why are two dimensions interesting?

- larger lattices $\rightarrow$ lower momenta
  lower dimensions require (much) less computer power, e.g.:
  $d=4$: 128^4 ($L \approx 27\,fm$) [Cucchieri, Mendes, Pos LAT2007, 297],
  $d=2$: 2560^2 ($L \approx 460\,fm$) [Cucchieri, Mendes, AIP CP 1343, 185]
- $\rightarrow$ good lattice results exist even for three-point functions
- Ambiguity of solutions?
- Gribov problem also present

Why are two dimensions interesting?

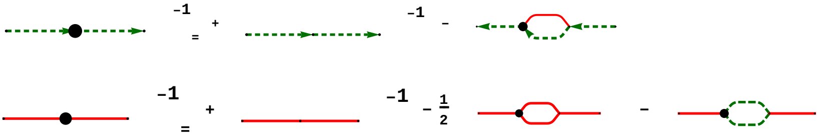
- larger lattices → lower momenta
  lower dimensions require (much) less computer power, e.g.:
  $d = 4$: 128^4 ($L \approx 27\,fm$) [Cucchieri, Mendes, Pos LAT2007, 297],
  $d = 2$: 2560^2 ($L \approx 460\,fm$) [Cucchieri, Mendes, AIP CP 1343, 185]
- → good lattice results exist even for three-point functions
- Ambiguity of solutions?
- Gribov problem also present

Yang-Mills theory for $d = 2$

- Perturbation theory does not work because of IR divergences.
- Gluons have no transverse polarization → no physical degrees of freedom, but we can investigate correlation functions, the Gribov problem, . . .

Dyson-Schwinger equations

Truncated Dyson-Schwinger equations (DSEs) of gluon and ghost propagators:



- Coupled integral equations.
- Contain three-point functions:
  ghost-gluon vertex, three-gluon vertex.

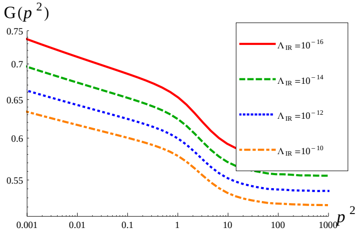
Standard ansätze in 4 dimensions: bare ghost-gluon vertex, three-gluon vertex appropriately dressed to obtain correct UV behavior.

Existence of decoupling solution

- Analytical:
  For $d = 2, 3, 4$ two possible scaling solutions, of which one is unphysical.
  Specific to $d = 2$: One can show analytically which one is unphysical. Coincides with decoupling type.
- Numerical:
  Ghost equation contains IR singularities for decoupling type.

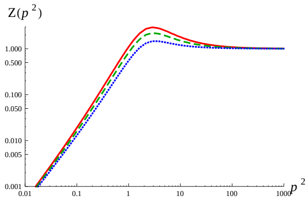
$\Rightarrow$ No decoupling type solution in two dimensions.

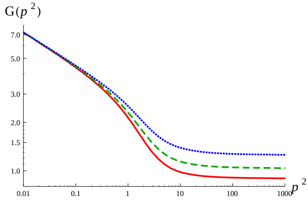
In agreement with Cucchieri, Dudal, Vandersickel, PRD85.



Aspects of $d = 2$ Dyson-Schwinger equations

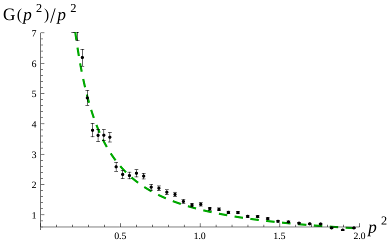
- Different momentum regimes mix,
  e.g., mid-momentum influences UV.

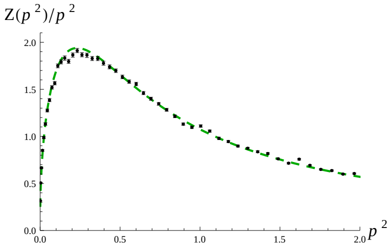




- Ghost dressing must approach 1 in the UV,
  but difficult to achieve due to mixing.
  $\rightarrow$ Increased vertex dependence.
- Remaining logarithmic divergences:
  Different subtraction methods available.

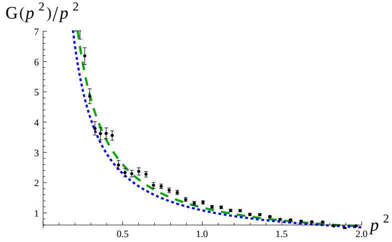
Propagator results

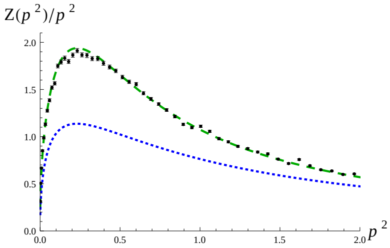




- bare ghost-gluon vertex, three-gluon vertex ansatz (1 parameter),
- lattice results [Maas, 1106.3942]

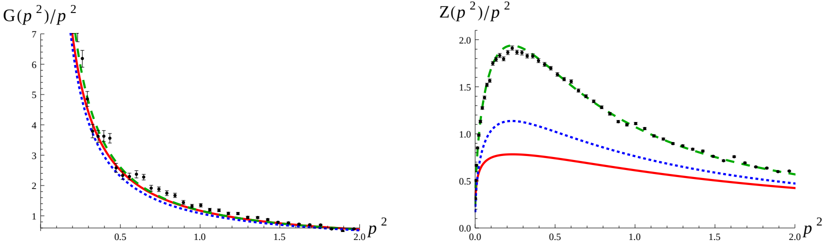
Propagator results





- bare ghost-gluon vertex, three-gluon vertex ansatz (1 parameter),
- lattice results [Maas, 1106.3942]
- lattice inspired models for both vertices,

Propagator results



- bare ghost-gluon vertex, three-gluon vertex ansatz (1 parameter),
- lattice results [Maas, 1106.3942]
- lattice inspired models for both vertices,
- dynamic ghost-gluon vertex, lattice inspired three-gluon vertex

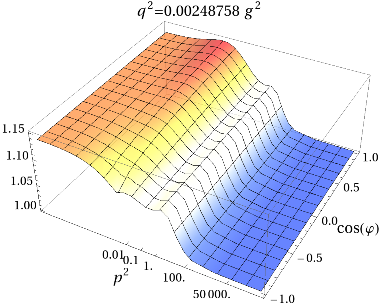
$\Rightarrow$ Good agreement with lattice can be obtained,
but strong dependence on vertices.

Results have been obtained with *DoFun* [MQH, Braun, CPC183] and *CrasyDSE* [MQH, Mitter, CPC183].

Ghost-gluon vertex results

1 (transverse) dressing, 3 variables:
(anti-)ghost momentum squared $(q^2)p^2$, angle between them φ

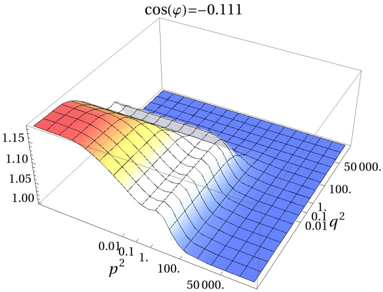
Fixed momentum:



$\longrightarrow$ 1 in the UV

$\longrightarrow$ IR constant

Fixed angle:

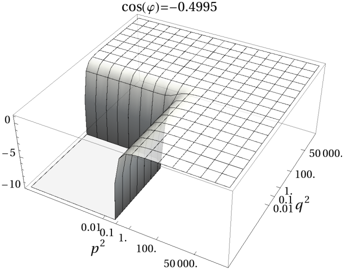


$\longrightarrow$ Almost no dependence on angle

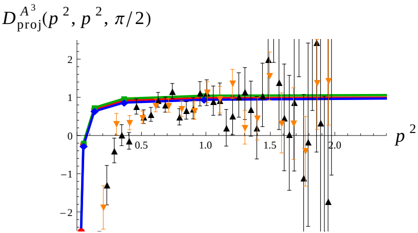
Three-gluon vertex

Three-gluon vertex from propagators and ghost-gluon vertex:

Fixed angle:



Orthogonal configuration:



red, green, blue: DSE calculation with different truncations
black (orange): lattice with $L = 21(12) fm^{-1}$

$\Rightarrow$ Leading diagrams reproduce lattice results.

Summary & Conclusions

- No decoupling solution in 2 dimensions.
- Mixing of different momentum regimes.
- Quantitative importance of two-loop diagrams.
- Ghost UV behavior very sensitive to truncations
  $\longrightarrow$ restrictions on vertices.
- First full dynamic calculation of propagators and ghost-gluon vertex.

Summary & Conclusions

- No decoupling solution in 2 dimensions.
- Mixing of different momentum regimes.
- Quantitative importance of two-loop diagrams.
- Ghost UV behavior very sensitive to truncations
  $\longrightarrow$ restrictions on vertices.
- First full dynamic calculation of propagators and ghost-gluon vertex.

Thank you very much for your attention.