Accessing the properties of an elementary Higgs beyond perturbation theory

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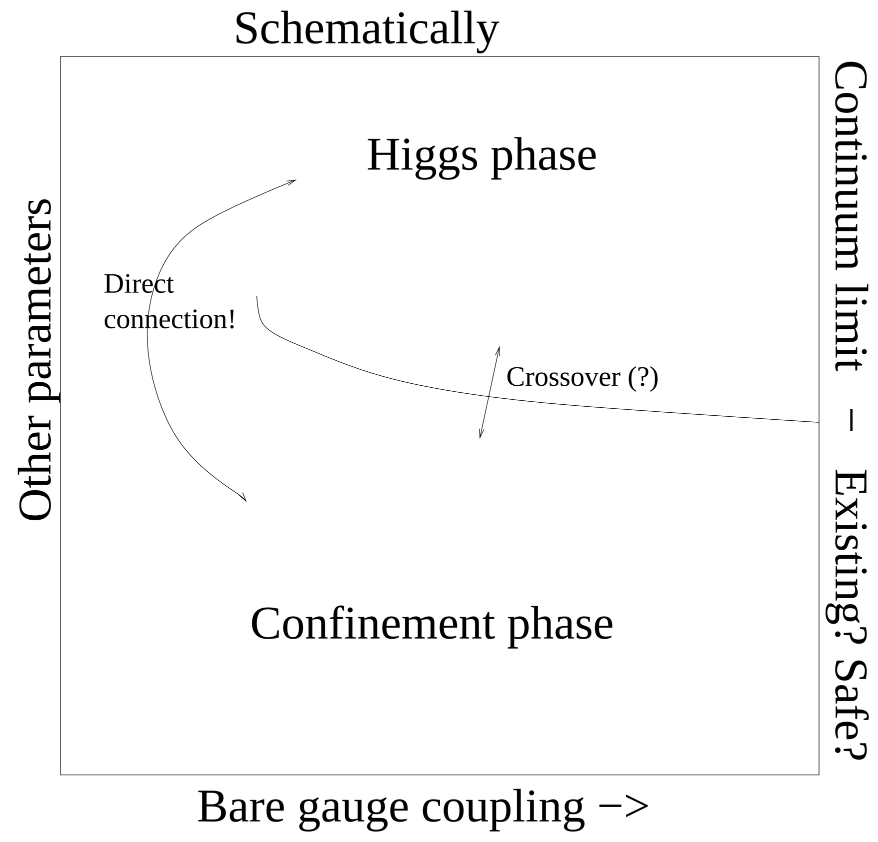
Introduction

√ Study of the weak isospin SU(2) × Higgs sector

○ Questions beyond perturbation theory [1,2]:
○ Is the theory non-trivial and without Landau pole?
○ Is there a mechanism for symmetry breaking in the theory?
○ Can the Higgs mass be stabilized non-perturbatively?
○ What happens if the Higgs is heavy - about a TeV or more?
○ Higgs and confinement phase are continuously connected [2]!

Schematically



√ Answers could be obtained from Higgs and W/Z properties
√ Encoded in correlation functions - propagators, vertices,...

○ These are gauge-dependent!

○ Requires a fixed gauge
Here: Landau-limit of 't Hooft gauge: $\xi \to 0 \to \partial_\mu W^\mu = 0$

Higgs condensate is then zero, $<\phi>=0$ [2]

Techniques

Non-perturbative methods to obtain correlation functions

√ Developed and tested for QCD [3], e. g.

√ Renormalization group methods
√ Dyson-Schwinger equations
√ Lattice calculations

√ Successfully describe confinement, chiral symmetry breaking, finite temperature phase transition, hadronic bound states,...

○ Apply to the weak isospin-Higgs system [1]:
Lattice calculation on a 24^4 lattice

Three bare parameters: gauge coupling g, Higgs mass m_0, and scalar self-coupling λ

√ Compare three cases:
Quenched with $g = 1.35$ (no Higgs dynamics)
Confinement phase with $g = 1.41$, $m_0^2 = -(250\text{ GeV})^2$, $\lambda = 1/2$
Higgs phase with $g = 1.32$, $m_0^2 = -(900\text{ GeV})^2$, $\lambda = 1$

√ Scale is set by 0^{++} Higgsonium mass to be 250 GeV [4]
Agrees with a constituent Higgs model for a 125 GeV Higgs [1]

○ Simplest correlation function: Propagators
Three in Landau gauge: Higgs, W/Z, ghost

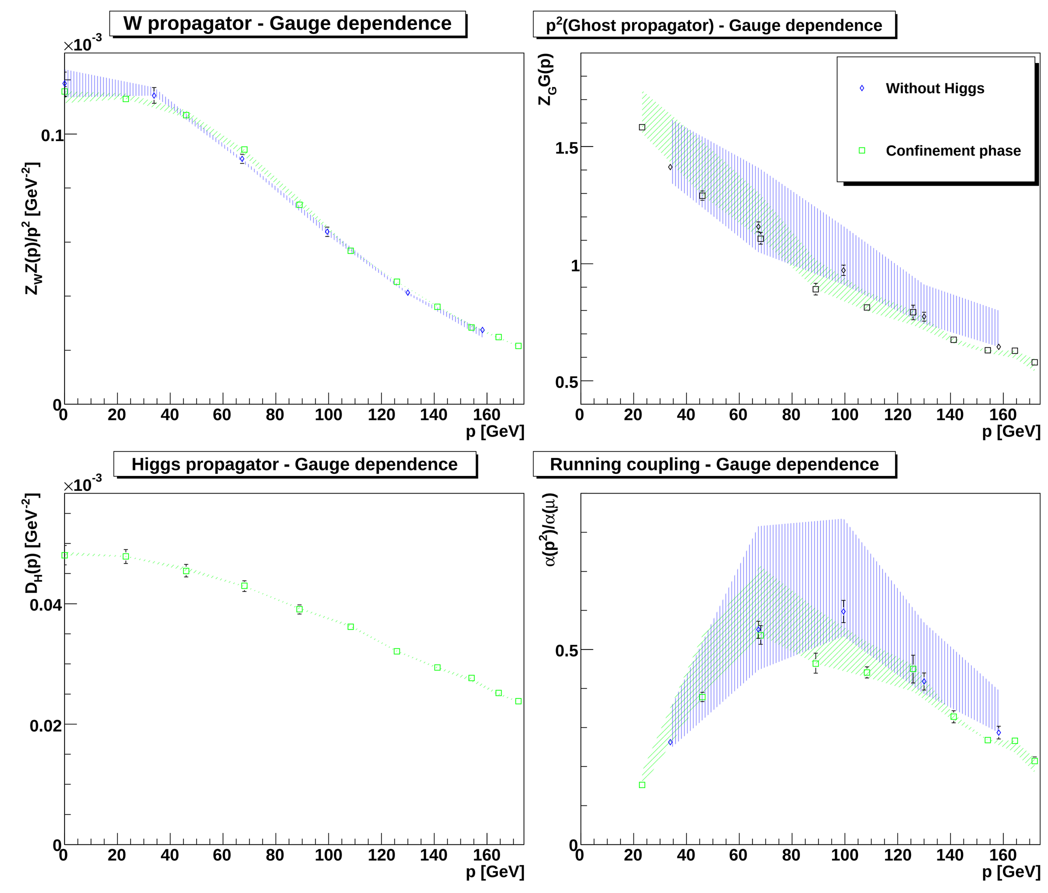
○ Non-perturbative: Local gauge condition not sufficient! [5]

Reason: Gribov copies, and the Gribov-Singer ambiguity

√ Has been understood in Yang-Mills theory and QCD [6,7]
Yields a family of gauges for the Landau gauge

Non-perturbative gauge dependence

○ Non-perturbative different realizations of Landau gauge [7]
Lead to a non-perturbative gauge-dependence of the propagators
○ Not an artifact - inherent property of the propagators!



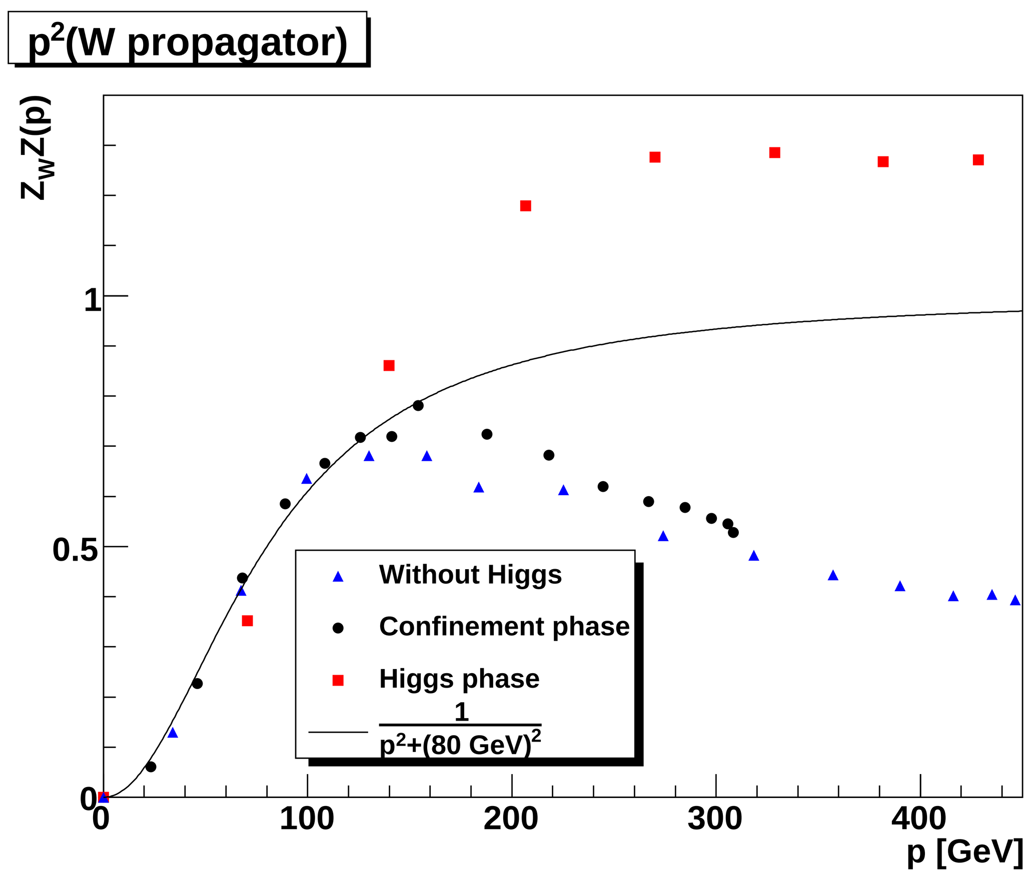
Gives only a lower limit of the gauge dependence [1]

Affects in this case mostly the ghost propagator and the running coupling

W weaker affected

Higgs essentially not affected

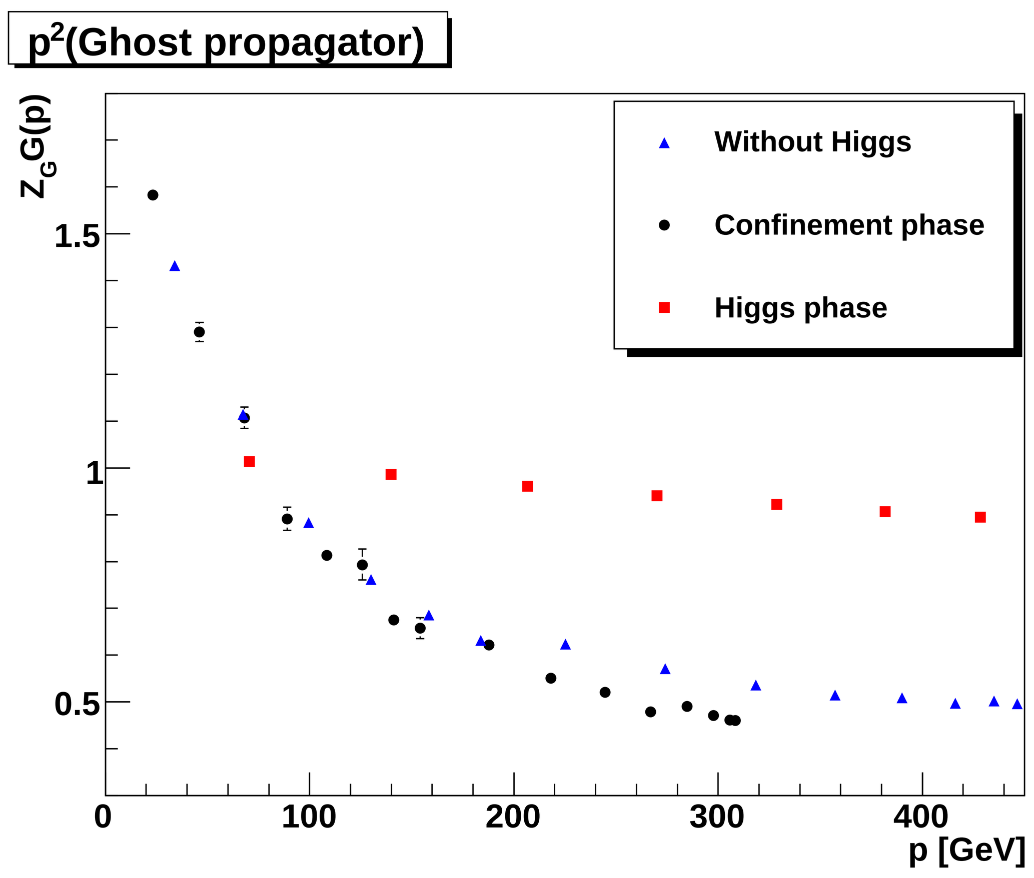
○ Essentially no Gribov copies in the Higgs phase! Lattice artifact?
○ Effect on Higgs possibly stronger in general 't Hooft gauges



√ Dynamical generation of a screening mass
√ Dynamical Higgs effect at work

○ Confinement phase very similar

○ No pole mass in the confinement phase!



√ Drastic difference between confinement and Higgs phase
○ Infrared behavior associated with confinement [3,6]

√ Agrees with other results [8,9]
√ Difference between both phases mainly gauge-dependent

Propagators

○ Without mixing with QED, W and Z are the same

○ W propagator is given by:
○ $D_{\mu\nu} = \left(\eta_{\mu\nu} - \frac{p_\mu p_\nu}{p^2}\right)\frac{Z_W Z(p^2)}{p^2}$

Renormalized as $Z_W Z(\mu^2) = \mu^2/(\mu^2 + (80\text{ GeV})^2)$ at $\mu = 80$ GeV
√ Implements perturbative would-be pole mass

○ Faddeev-Popov ghost propagator is given by:
○ $D_G = \frac{Z_G G(p^2)}{p^2}$

Renormalized as $Z_G G(\mu^2) = 1$ at $\mu = 80$ GeV
Implements perturbative masslessness

○ Running gauge coupling is given by the propagators [3]
○ $\alpha(p^2) = \alpha(\mu^2) Z_W Z(p^2, \mu^2)(Z_G G(p^2, \mu^2))^2$

○ Higgs propagator
○ $D_H = \frac{1}{Z_H(p^2 + m_0^2) + \Sigma(p^2) + \delta m^2}$

Renormalization condition is a pole mass of 125 GeV at μ =125 GeV and agreement of derivatives

Conclusions

√ Higgs and W propagator similar in confinement and Higgs phase
√ Dynamical Higgs effect observed
√ Connection to gauge-invariant states can be established
√ Main difference between Higgs and confinement phase in the gauge-fixing sector

This poster is based on [1]

References

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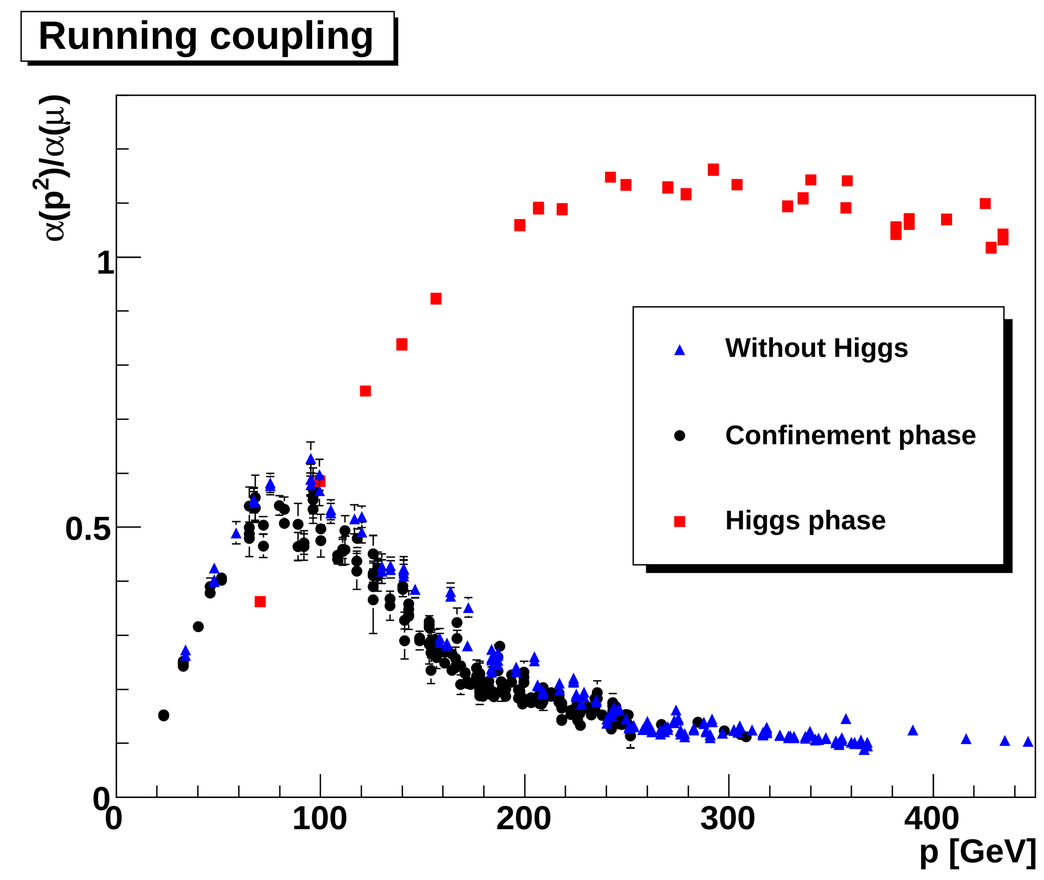
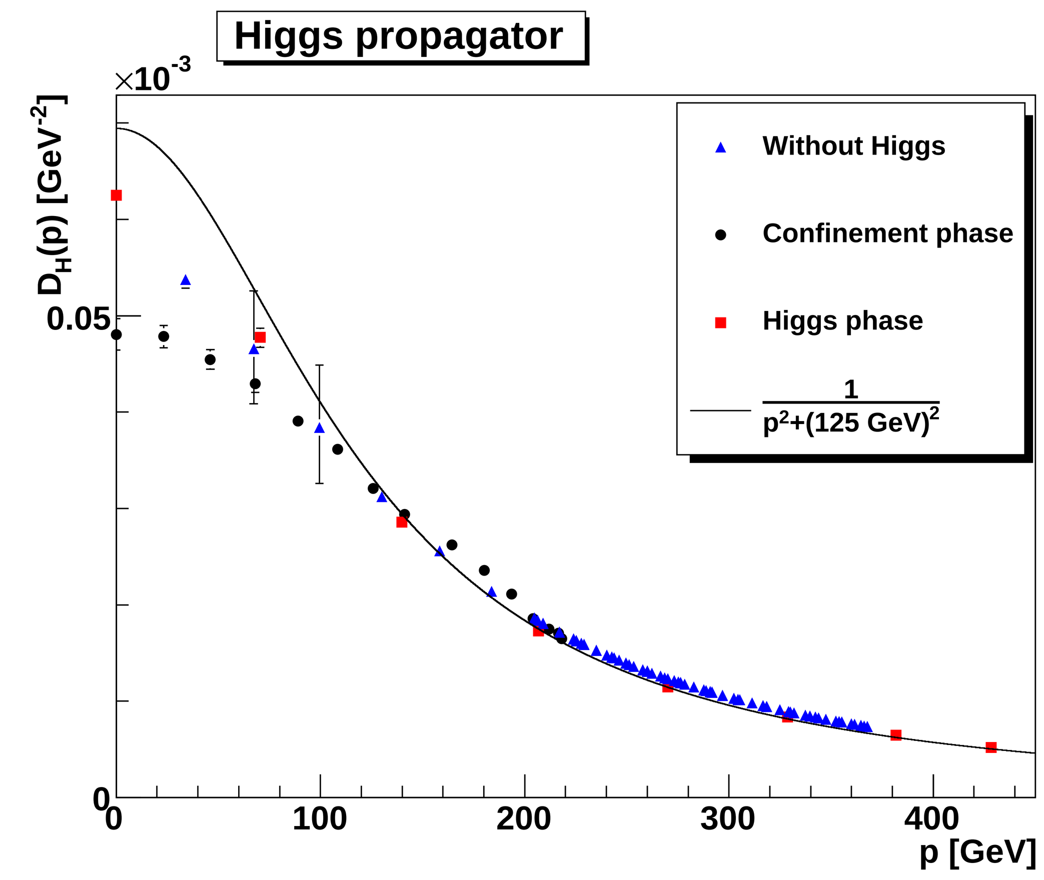


√ No Landau pole in both phases

○ No fundamental difference between the confinement and the Higgs phase

○ Higgs and confinement physics indeed very similar?



√ Screening mass different from would-be pole mass
√ Little difference between Higgs and confinement phase
√ Close to tree-level
○ Can yield screening mass and pole mass as a function of the tree-level mass