PHASE STRUCTURE OF U(1) GAUGE-HIGGS THEORY ON $D = 4$ LATTICES ☆

K. JANSEN [a], J. JERSÁK [a], C.B. LANG [b], T. NEUHAUS [a] and G. VONES [b]

[a] *Institut für Theoretische Physik E, Technische Hochschule Aachen, D-5100 Aachen, Fed. Rep. Germany*
[b] *Institut für Theoretische Physik, Universität Graz, A-8010 Graz, Austria*

Received 30 January 1985

We describe a rich phase structure observed in Monte Carlo simulations of the $d = 4$ U(1) gauge-Higgs system on lattices up to size 8^4. The charge-one Higgs field has a dynamical radial degree of freedom. The phase transition between the Coulomb and the Higgs phases is of first order for small values of the quartic coupling λ and weakens when either λ or the inverse gauge field coupling β increase. The confinement-Higgs transition approaches with decreasing λ the two frustration phases found for $\beta < -1$ and might be analogous to a spin-glass transition.

Gauge-Higgs systems formulated on an euclidean lattice provide us with the possibility to study in a non-perturbative approach dynamical effects of confinement and symmetry breaking [1]. The bosonic nature of the Higgs fields allows a direct implementation in Monte Carlo (MC) simulations. This is straightforward for a Higgs field Φ with frozen radial degree of freedom, i.e. $|\Phi| = 1$. Most of the contributions to this topic up to now are for this case. In ref. [2] we give a list of references for MC-investigations of fixed length gauge-Higgs systems for abelian gauge groups on a four-dimensional euclidean lattice.

We investigate the U(1) gauge-Higgs system with a Higgs field in the fundamental (charge-one) representation having dynamical radial degree of freedom controlled by a quartic coupling term. The euclidean lattice action may be written

$$S = -\beta \frac{1}{2} \sum_{p \in \Lambda} (U_p + U_p^*) + \lambda \sum_{x \in \Lambda} (\Phi_x^* \Phi_x - 1)^2 + \sum_{x \in \Lambda} \Phi_x^* \Phi_x - \kappa \sum_{x \in \Lambda} \sum_{\mu=1}^{4} (\Phi_x^* U_{x,\mu} \Phi_{x+\mu} + \text{c.c.}) \quad (1)$$

with the U(1) gauge field link variables $U_{x,\mu}$, their product around plaquettes U_p and with Higgs site variables Φ_x on the lattice Λ. Our study of the phase structure of this model for finite λ is motivated by the following observations:

– Variable coupling λ is desirable for the construction of a continuum limit of the model. The knowledge of the three-dimensional (β, κ, λ) phase diagram is important for future renormalization group (RG) studies of the model.

– Earlier Monte Carlo results for Z(2) [3], U(1) [4–6] and SU(2) [7] lattice Higgs models with finite λ indicated that the phase structures of Higgs models depend substantially on λ.

– Several investigations of the model (1) both for $\lambda = \infty$ [2] and finite λ [4,5] have revealed the existence of a massless Coulomb phase for $\beta > 1$ and κ small enough, separated by two phase transition (PT) lines both from the confinement and from the Higgs regions of the confinement-Higgs phase. The latter PT is a prototype for the mechanism of spontaneous mass generation of the gauge boson. Earlier calculation on a 4^4 lattice by Munehisa [4] indicated that the order of this PT depends on λ and is of first order for small λ. A confirmation of this result on larger lattices would give a non-perturbative support to the Coleman–Weinberg mechanism [8].

In this letter we present a brief summary of our large statistics study on lattices up to 8^4 to determine

☆ Supported by Fonds zur Förderung der Wissenschaftlichen Forschung in Österreich, project P5125, by Deutsches Bundesministerium für Forschung und Technologie. Studienstiftung des Deutschen Volkes, and by Deutsche Forschungsgemeinschaft.