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Numerical study of stable classical solutions of Quantum Field Theory

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The central issue of the project has been the study of the behavior of electromagnetic fields coupled with scalar fields in the presence of background fields or anisotropic couplings.

1. Anisotropic abelian higgs model

So far it has been found, using lattice techniques, that in the anisotropic five-dimensional Abelian Higgs model, a layered Higgs phase exists in addition to the expected five-dimensional one. The exploration of the phase diagram has shown that the two Higgs phases are separated by a phase transition from the confining phase. This transition is known to be first order. In this paper we explore the possibility of finding a second order transition point in the critical line which separates the first order phase transition from the crossover region. This is shown to be the case only for the four--dimensional Higgs layered phase whilst the phase transition to the five--dimensional broken phase remains first order. The layered phase serves as the possible realisation of four-dimensional space-time dynamics which is embedded in a five--dimensional space-time. These results are due to gauge and scalar field localisation by confining interactions along the extra fifth direction.

(a) Mean field theory

Beginning with the anisotropic couplings one encounters immediately a very large parameter space, so the first step is an approximate method permitting an orientation and localization of the interesting regions. This is done using the mean field approach [1]. Up to now only the tree level calculations have been done. However, this approximation is not sufficient, so it would be interesting to proceed with one-loop calculations. The methodology is described in publication [1].

(b) Hysteresis loops

Figures 1a and 1b concern the transition S-H4, where S is the strong coupling phase and H4 a layered higgs phase.

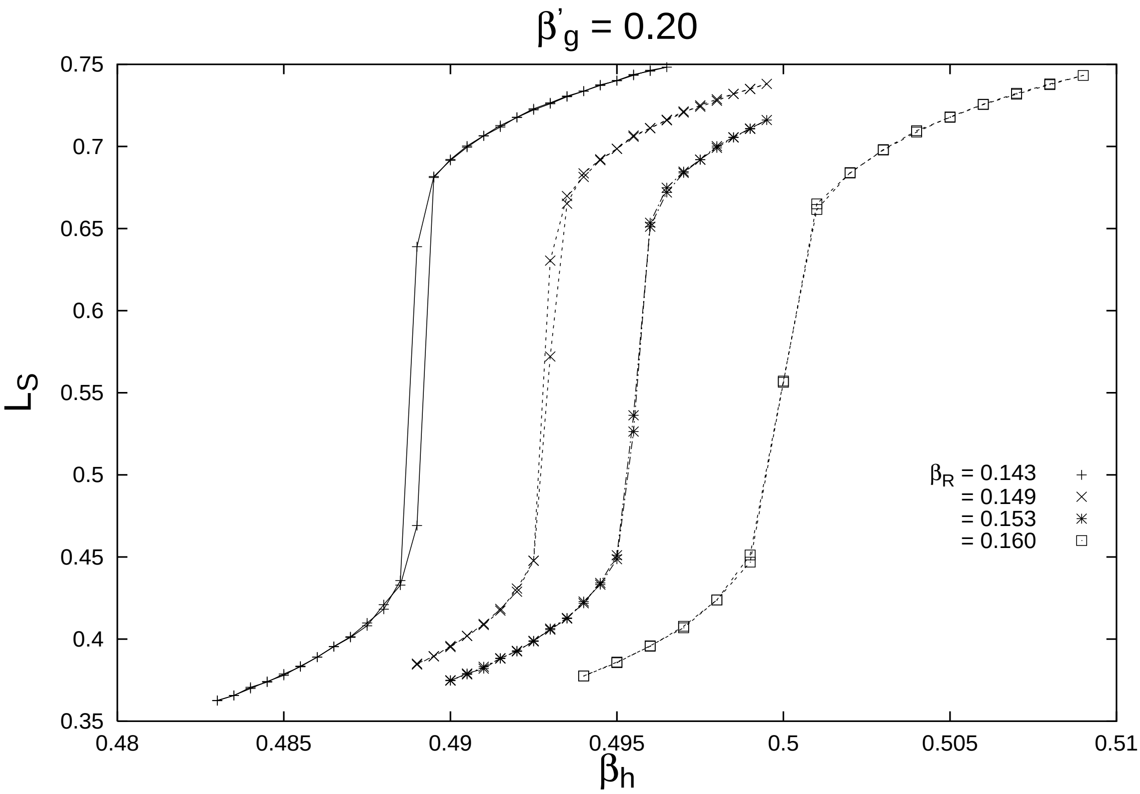

Figure 1: Hysteresis loops for the S-H4 transition.

In figure 1 we show a hysteresis loop for a space-like link. It seems that the loops disappear for self-coupling equal to 0.153. The transverse link has a very small value (not shown in the figure).

In figures 2a and 2b we consider the plaquettes for both the S-H4 and S-H5 transitions for a large value of the self-coupling, where for S-H4 we just saw that the links have no sign of singularity. The new order parameter for S-H4 (figure 2a) shows the same behaviour as the link. However, for S-H5 (figure 2b) the phase transitions appear to be of first order.

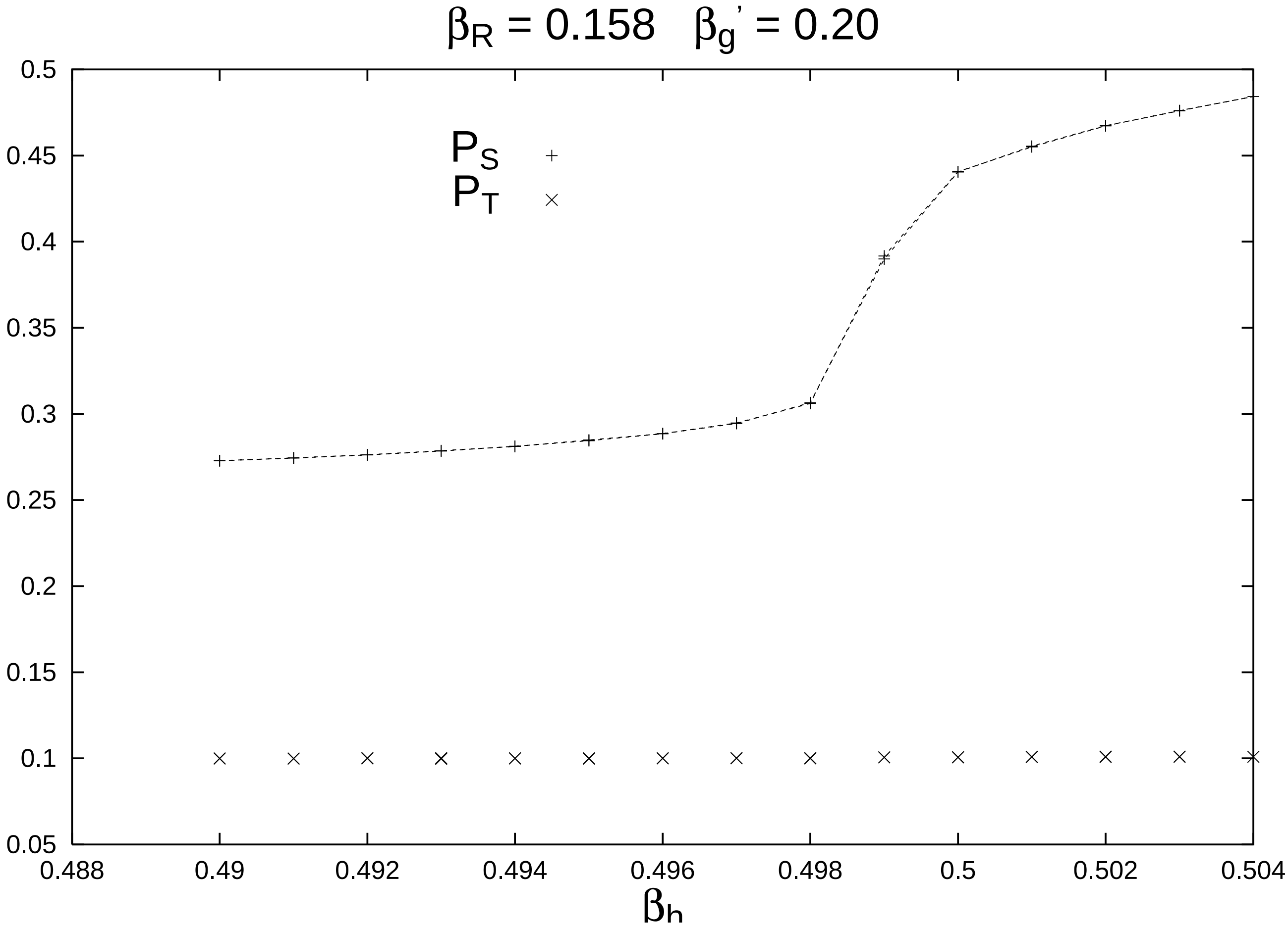

Figure 2a: Plaquette hysteresis loops for the S-H4 transition.

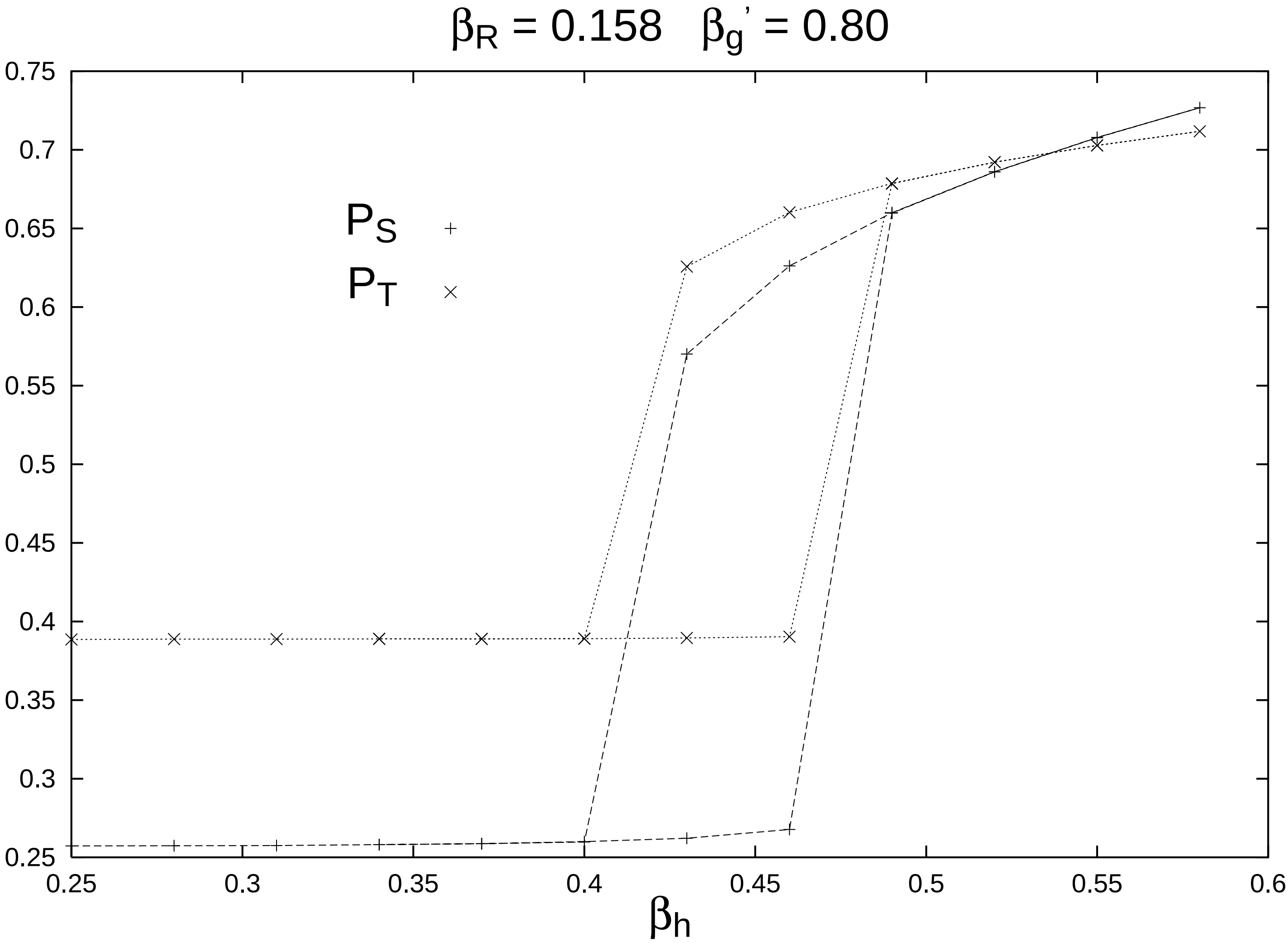

Figure 2b: Plaquette hysteresis loops for the S-H5 transition.

(c) Correlation functions

Figure 3 and contains the space-like and transverse correlation functions. The transverse correlation function falls very rapidly to zero, a signal that the layered phase has set in. On the contrary the space-like correlation function shows that within each layer we have a genuine four-dimensional behaviour. In addition, for increasing self-coupling, the mass parameter decreases and we approach the behaviour of a second order phase transition, with infinite correlation length.

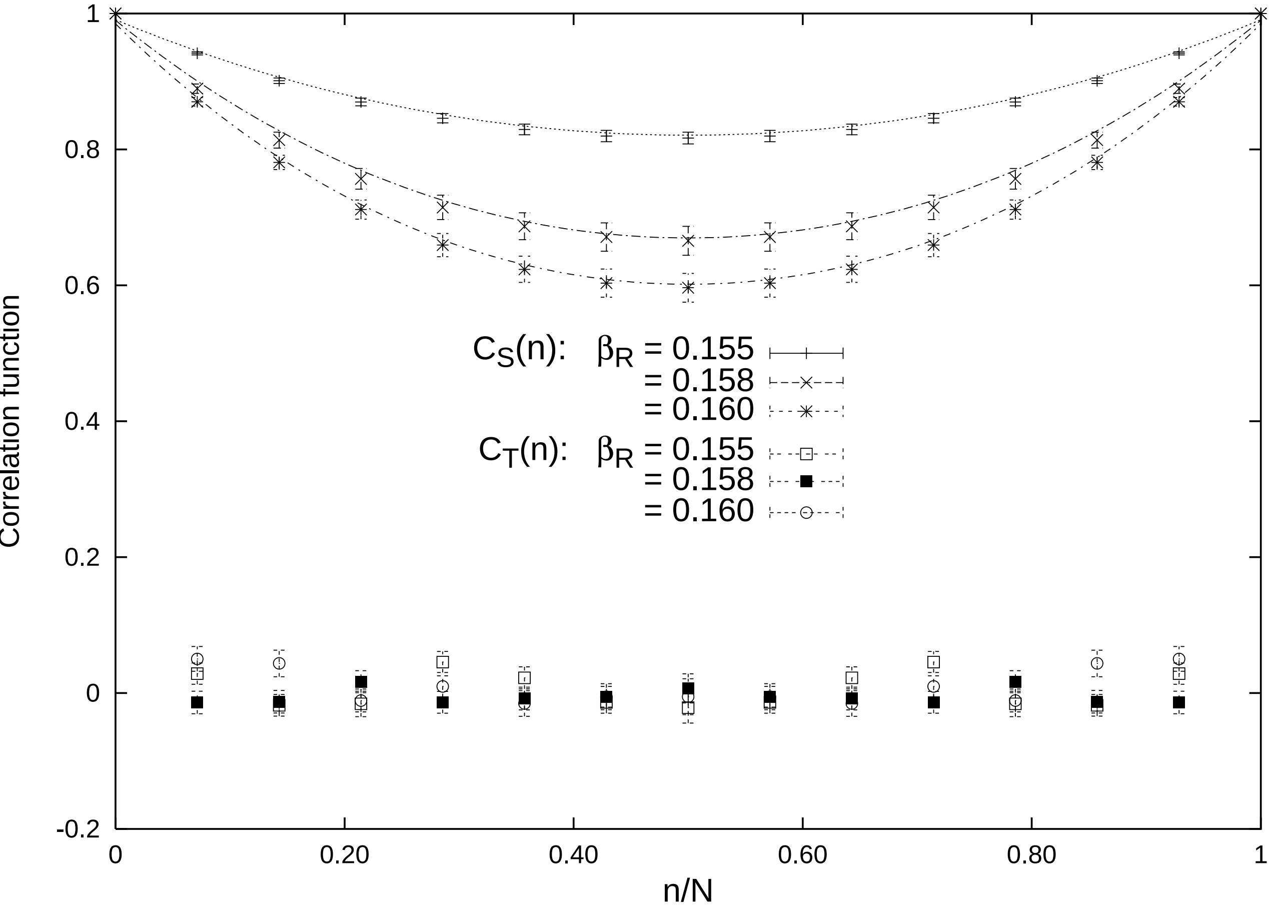

Figure 3: Correlation functions

(d) Conclusion

The model tries to represent a 4-D space-time embedded in a 5-D continuum and the results we found probably signal localization of gauge and scalar fields within the 4-D space-time, due to confining interactions in the transverse direction.

2. Randall-Sundrum background

The spectrum of a massless bulk scalar field Φ with a possible interaction term of the form $-\xi R \Phi^2$ is investigated in the case of Randall-Sundrum geometry. We show that the zero mode for $\xi=0$ turns into a tachyon mode, in the case of a nonzero negative value of ξ. As we see, the existence of the tachyon mode destabilizes the Φ=0 vacuum, against a new stable vacuum with nonzero Φ near the brane, and zero in the bulk. By using this result, we can construct a simple model for the gauge field localization, according to the philosophy of Dvali and Shifman (Higgs phase on the brane, confinement in the bulk).

3. Q-ball background

In publication [4] we have studied Einstein-Yang-Mills equations in the presence of gravitating non-topological soliton field configurations, of q-ball type. We produced numerical solutions, stable with respect to gravitational collapse and to fission into free particles, and we study the effect of the field strength and the eigenfrequency to the soliton parameters. We also investigated the formation of such soliton stars when the space-time is asymptotically anti de Sitter.

References

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3. K.Farakos, P.Pasipoularides: “Gravity induced instability and gauge-field localization”, April 2005, e-print archive: hep-th/0504014.

4. A.Prikas: “EYM equations in the presence of Q-stars”, Phys.Rev. D70: 045008, 2004, e-print archive: hep-/0406088.