Dimensional Reduction of 5D YM model

Eliana Lambrou

with R.D.Kenway, L.Del Debbio and E.Rinaldi

September 12, 2012

Layer phase

Fu-Nielsen idea

If in a D-dimensional lattice we define a set of different nearest-neighbor couplings for the gauge fields in an n-dimensional sublattice, this may lead to the formation of an n-dimensional Layer phase ($n < D$). Within this phase the gauge particles can travel freely but they are confined in the remaining dimensions ($d = D - n$).

In 5D YM model:

Layer phase: 4-dimensional hyperplanes in the extra dimension - x_5

Continuum 5D SU(2) Yang-Mills Euclidean Action:

$$S_E = \int d^4x \int dx_5 \frac{1}{2g_5^2} \mathrm{Tr} F_{MN}^2 \qquad {}_{M,N=1\ldots5}$$

Discretize it using anisotropic Wilson Action:

$$\mathrm{S} = \beta_4 \sum_x \sum_{1\le\mu<\nu\le4} \left(1 - \frac{1}{2}\, U_{\mu\nu}(x)\right) + \beta_5 \sum_x \sum_{1\le\mu\le4} \left(1 - \frac{1}{2}\, U_{\mu5}(x)\right)_{\mu,\nu=1\ldots4}$$

where

$$U_{\mu\nu}(x) = U_\mu(x) U_\nu(x + \hat{\mu} a_4) U_\mu^\dagger(x + \hat{\nu} a_4) U_\nu^\dagger(x)$$

$$U_{\mu5}(x) = U_\mu(x) U_5(x + \hat{\mu} a_4) U_\mu^\dagger(x + \hat{5} a_5) U_5^\dagger(x)$$

with $U_\mu = \exp(i g_5 a_4 A_\mu)$ and $U_5 = \exp(i g_5 a_5 A_5)$.

Observables

- Average Plaquette

$$\langle \hat{P} \rangle = \left\langle \frac{1}{10VN_c} \sum_x \sum_{M<N} \mathrm{Tr}(U_{MN}(x)) \right\rangle$$

- Polyakov Loops

$$\mathrm{Poly}_T = \frac{L_T}{N_c V} \left| \sum_{\vec{x},x_5} \prod_{x_1=0}^{(L_T-1)a_4} U_1(x) \right|$$

- Wilson Loops

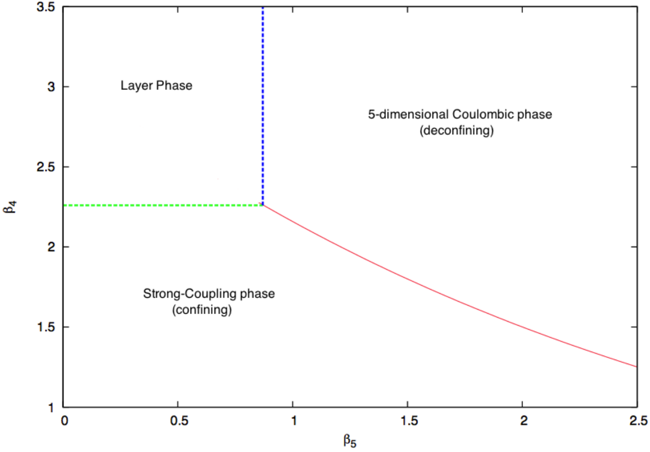
$$W_{\mathcal{L}}[U] = \left\langle \mathrm{Tr}\left[\prod_{(k,M)\in\mathcal{L}} U_M(k) \right] \right\rangle$$

Dimensional Reduction via compactification

- **Creutz - Isotropic lattices**
  First order bulk phase transition
- More recent works - **anisotropic lattices:**
  1. One of the directions small $\Rightarrow$ compactification
  2. Nature of phase transition changes to second order phase transition
  3. Go to the continuum limit
     $\Rightarrow$ 4D YM or 4D YM + adjoint scalar

Dimensional Reduction via localization

- Difference in this work: No compactification
- Nature of phase transition at a specific parameter region changes
- Distinguish different phases from order parameters
- Find if it is of second order by matching critical exponents
- Then can go to the continuum limit


3.5
3
2.5
2
1.5
1
0
0.5
1
1.5
2
2.5
β4
β5
Layer Phase
5-dimensional Coulombic phase
(deconfining)
Strong-Coupling phase
(confining)

Non-trivial field theory in the continuum limit

Next steps:

- Investigate further this 4D interacting theory
- Investigate further its spectrum
- Is it dimensionally reduced to low energy degrees of freedom of a known model?

References

- K. Farakos and S. Vrentzos, *Exploration of the phase diagram of 5d anisotropic SU(2) gauge theory*, Nucl.Phys. B862 (2012) 633649, [arXiv:1007.4442]
- S. Ejiri, J. Kubo, and M. Murata, *A Study on the nonperturbative existence of Yang-Mills theories with large extra dimensions*, Phys.Rev. D62 (2000) 105025, [arXiv:0006.217]
- P. de Forcrand, A. Kurkela, and M. Panero, *The phase diagram of Yang-Mills theory with a compact extra dimension*, JHEP 1006 (2010) 050, [arXiv:1003.4643]
- F. Knechtli, M. Luz, and A. Rago, *On the phase structure of five-dimensional SU(2) gauge theories with anisotropic couplings*, Nucl.Phys. B856 (2012) 7494, [arXiv:1110.4210]
- L. Del Debbio, A. Hart, and E. Rinaldi, *Light scalars in strongly-coupled extra-dimensional theories*, [arXiv:1203.2116]