Full QCD in external chromomagnetic field

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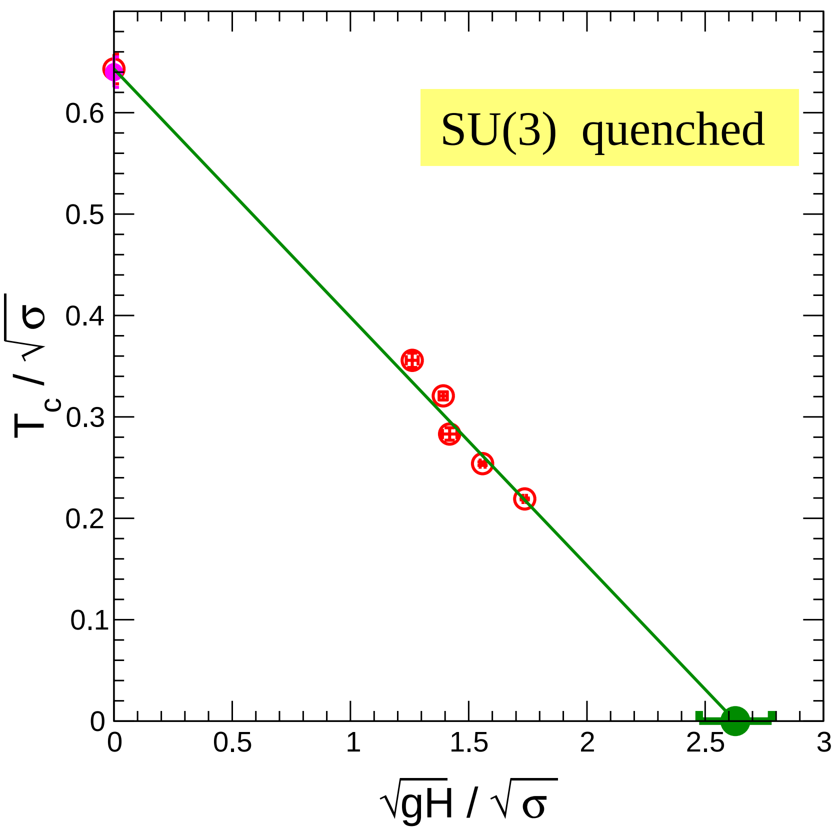
Introduction

In a previous study [Cea-Cosmai, JHEP08(2005)079] on the vacuum dynamics of ***non abelian gauge theories*** we found that

the deconfinement temperature depends on the strength of an external abelian chromomagnetic field.

And in particular:

the deconfinement temperature decreases when the strength of the applied field is increased and eventually goes to zero (vacuum color Meissner effect).



- **Aim of the present work** is to understand ***if***

  the deconfinement temperature depends on the strength of an external abelian chromomagnetic field

  even in the case of **full QCD**.

- **To this purpose** we performed **numerical simulations for finite temperature N_f=2 QCD in an external abelian chromomagnetic field**.

  Simulations have been done using APEmille crate in Bari and the recently installed computer facilities at
  INFN apeNEXT Computing Center

Method

To investigate the QCD dynamics in presence of a external background field at ***finite temperature*** we use the following ***lattice thermal partition functional*** [Cea-Cosmai-Polosa, PLB3929(1997)177; Cea-Cosmai PRD60(1999)094506; Cea-Cosmai-D'Elia, JHEP02(2004)018]

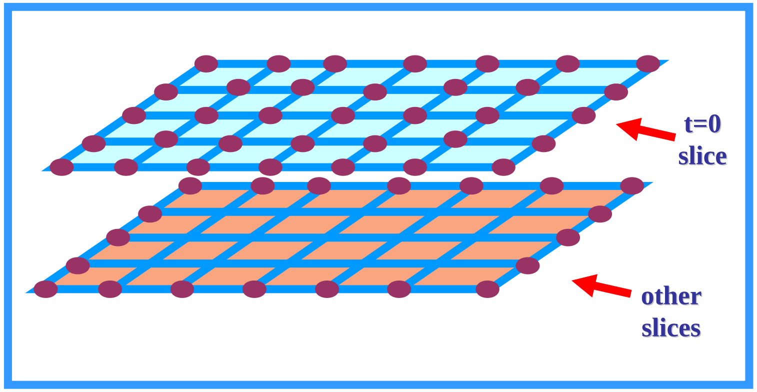
$$\mathcal{Z}_T\left[\vec{A}^{\rm ext}\right] = \int_{U_k(L_t,\vec{x})=U_k(0,\vec{x})=U_k^{\rm ext}(\vec{x})} \mathcal{D}U\,\mathcal{D}\psi\,\mathcal{D}\bar{\psi}\,e^{-(S_W+S_F)}$$

$$= \int_{U_k(L_t,\vec{x})=U_k(0,\vec{x})=U_k^{\rm ext}(\vec{x})} \mathcal{D}U\,e^{-S_W}\,\det M\,,$$

- S_W :Wilson action
- S_F :fermionic action
- M :fermionic matrix

Integration constraint on gauge fields

- ***spatial links*** are **constrained** to values corresponding to the external background field
- ***fermionic fields*** are **not** constrained



- The relevant quantity is ***the free energy functional*** defined as

$$\mathcal{F}[\vec{A}^{\text{ext}}] = -\frac{1}{L_t} \ln \left\{ \frac{\mathcal{Z}_T[\vec{A}^{\text{ext}}]}{\mathcal{Z}_T[0]} \right\}$$

- We can evaluate by numerical simulations the ***derivative*** of the free energy functional with respect to the gauge coupling

$$F'(\beta) = \frac{\partial \mathcal{F}(\beta)}{\partial \beta} = V \left[< U_{\mu\nu} >_{\vec{A}^{\text{ext}}=0} - < U_{\mu\nu} >_{\vec{A}^{\text{ext}}\neq 0} \right]$$

- ***Abelian chromomagnetic field on the lattice:***

$$a^2 \frac{gH}{2} = \frac{2\pi}{L_1} n_{\text{ext}} \quad , n_{\text{ext}} \ \text{integer}$$

quantization of the field strength due to the lattice toroidal geometry

$$U_1^{\text{ext}}(\vec{x}) = U_3^{\text{ext}}(\vec{x}) = \mathbf{1} \,,$$

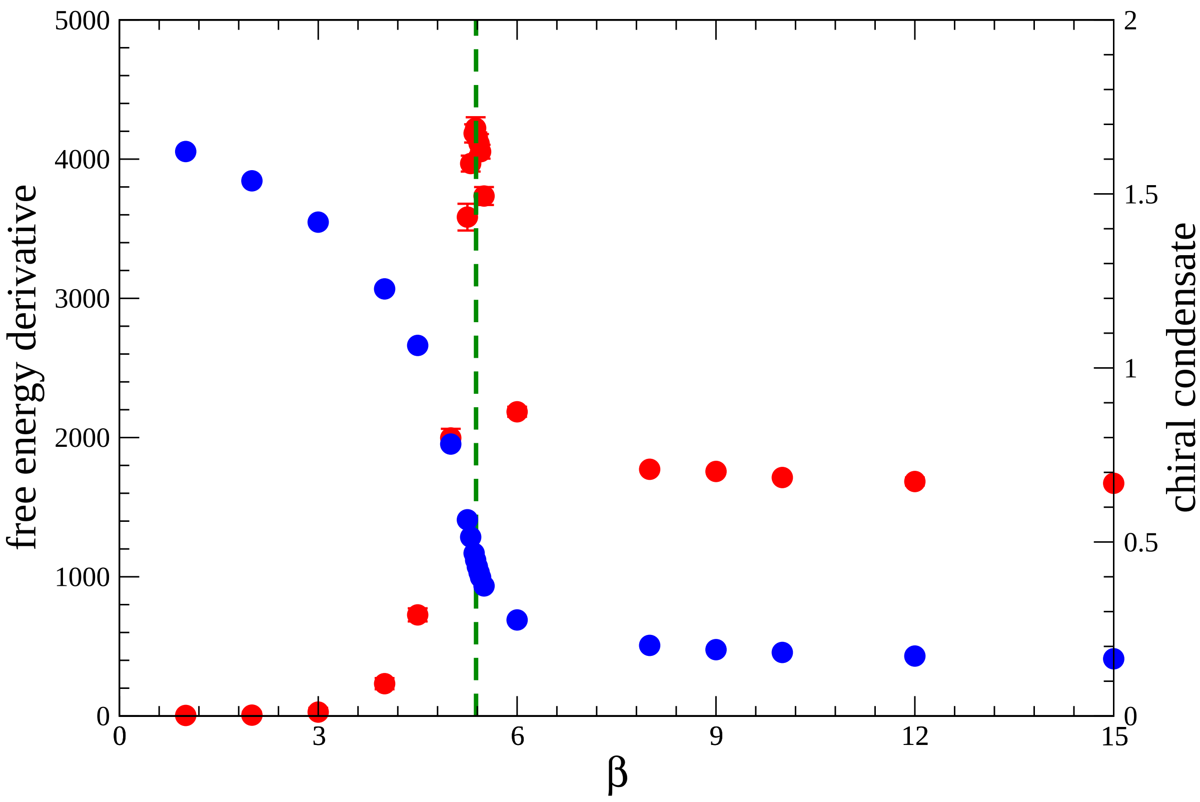
$$U_2^{\text{ext}}(\vec{x}) = \begin{bmatrix} \exp(i\frac{gHx_1}{2}) & 0 & 0 \\ 0 & \exp(-i\frac{gHx_1}{2}) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

SU(3) constrained lattice links for a constant abelian chromomagnetic directed along direction 3 in space and direction 3 in color space

Results

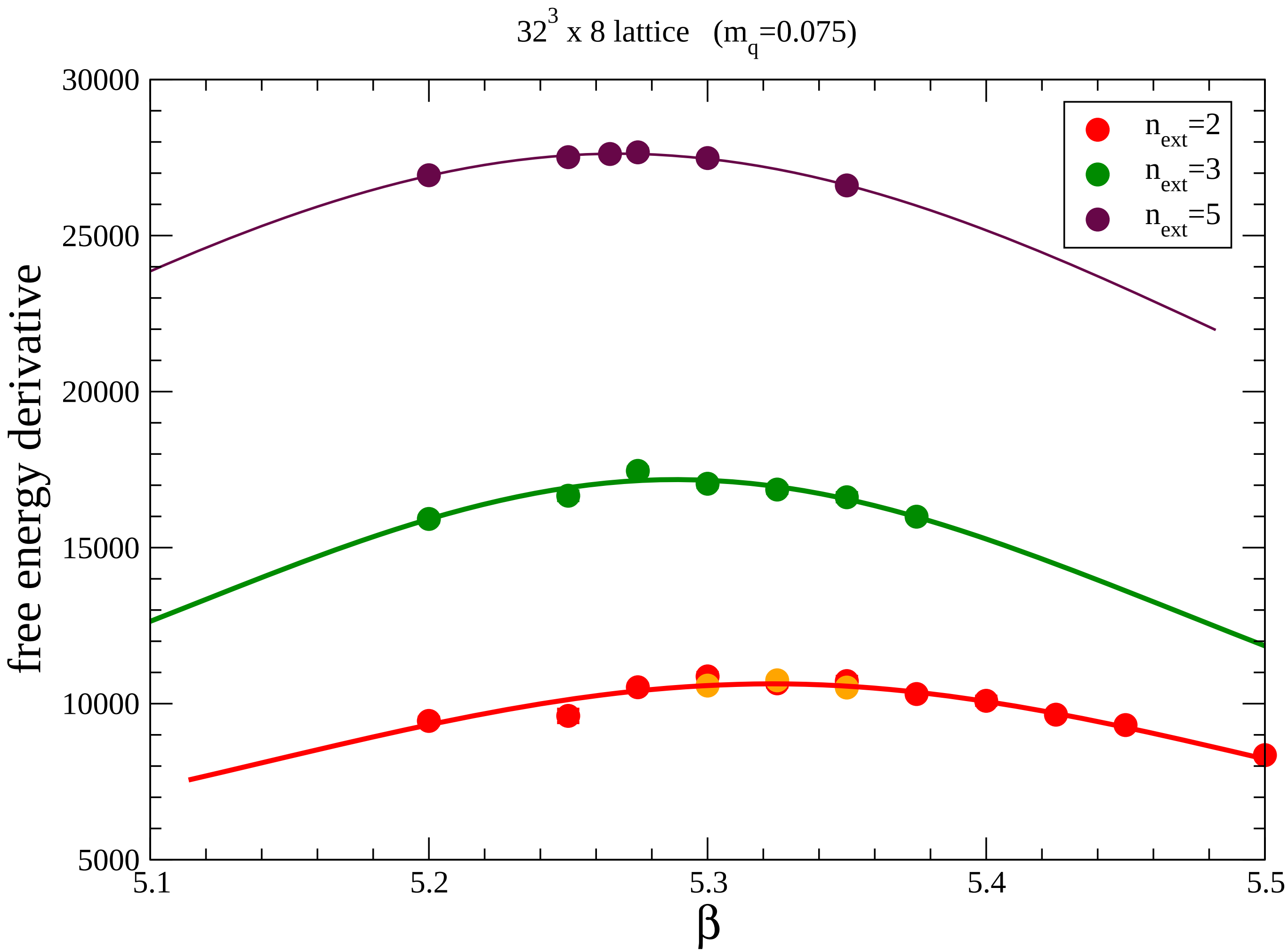
- The ***derivative of the free energy*** and the ***chiral condensate*** at fixed external field strength

$32^3 \times 8 \quad n_{ext}=1 \qquad am_q = 0.075$



The **peak** in the ***derivative of the free energy*** correlates to the **drop** in the ***chiral condensate***

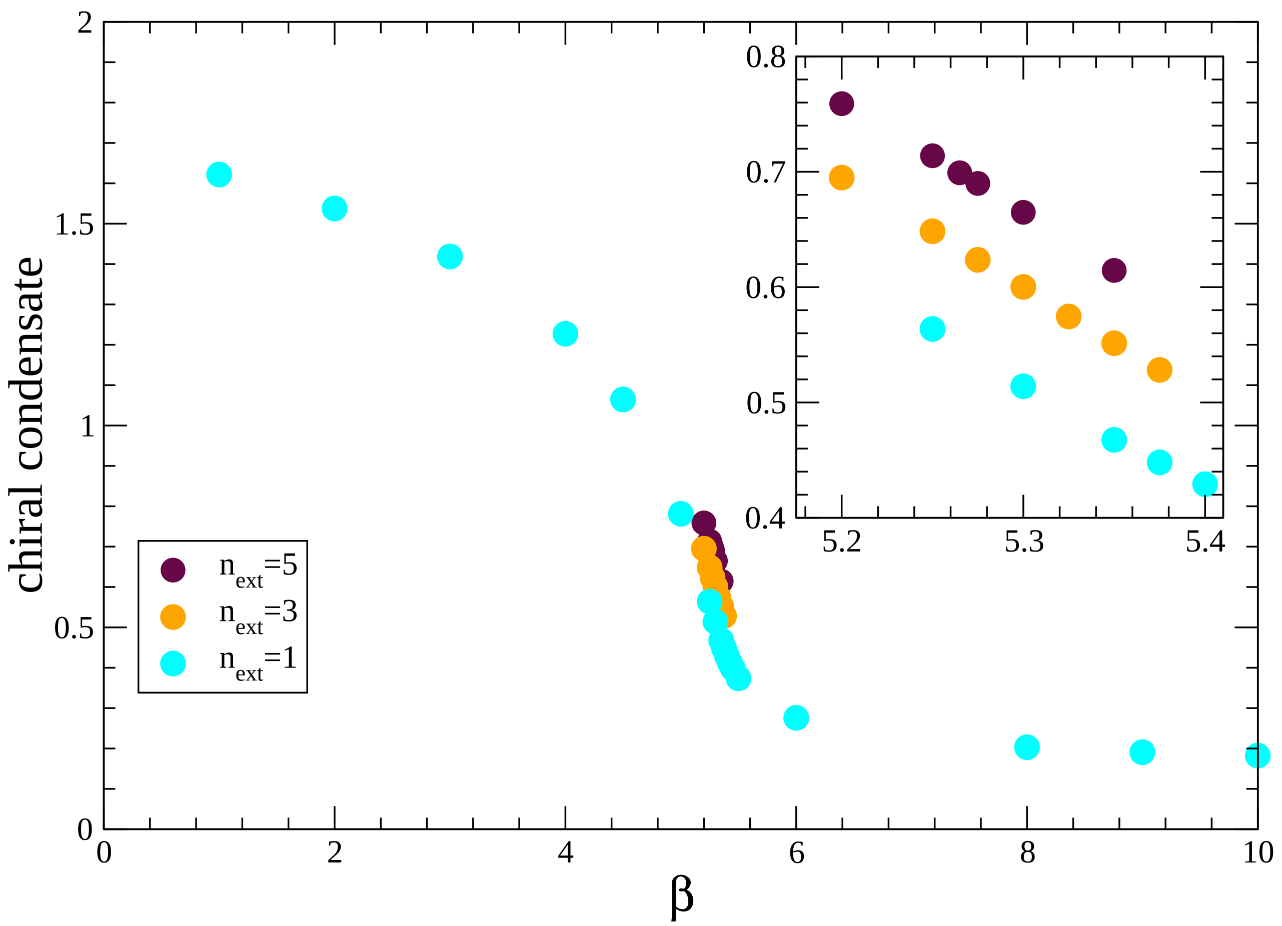
The ***peak of the free energy*** by varying the strength of the external field



The peak position in the derivative of the free energy depends on the strength of the applied field

The ***chiral condensate*** by varying the strength of the external field

$32^3 \times 8$ lattice $am_q = 0.075$

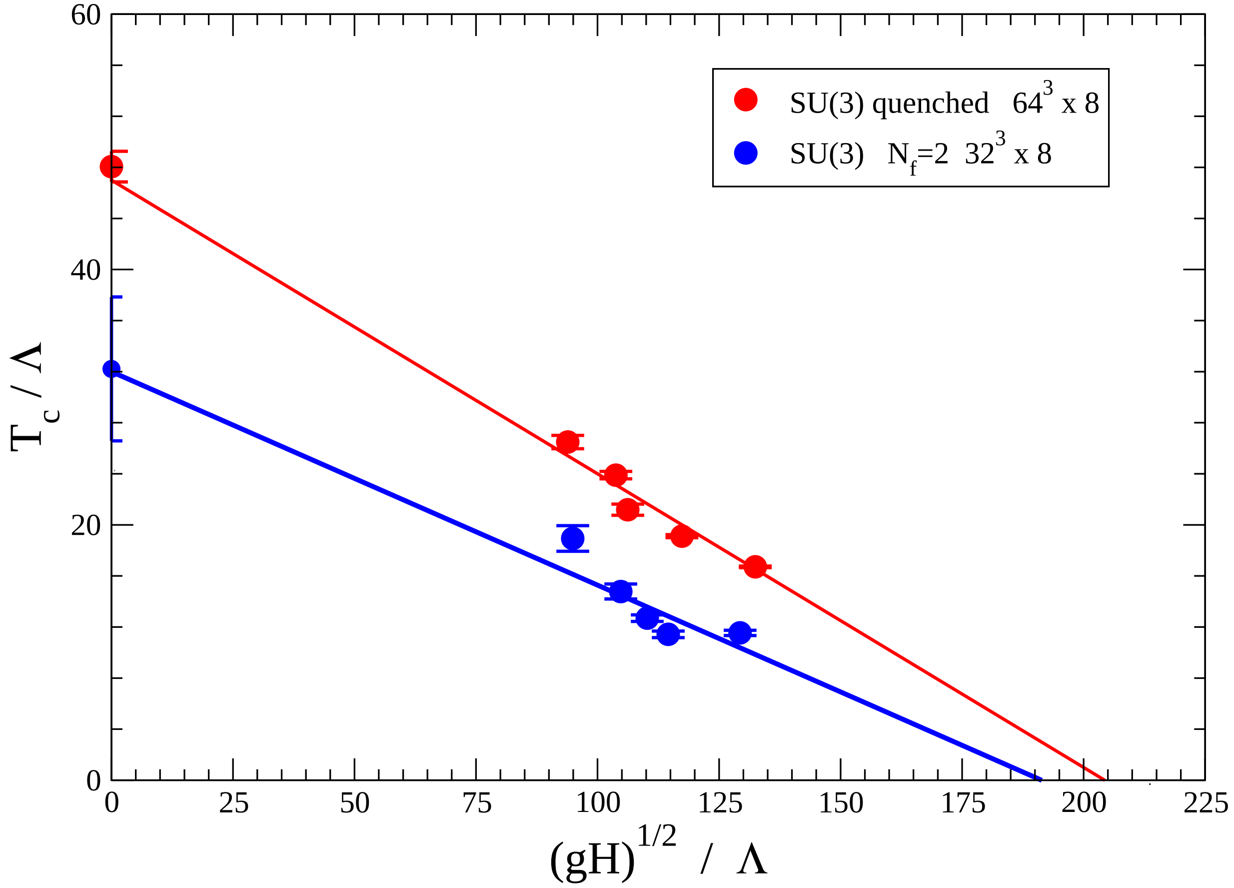


The value of the chiral condensate depens on the strength of the applied field

- The ***critical temperature*** versus the strength of the external field

$$\Lambda = \frac{1}{a} f(g^2)(1 + c_2 \hat{a}(g)^2 + c_4 \hat{a}(g)^4) \qquad \hat{a}(g)^2 \equiv \frac{f(g^2)}{f(g^2=1)}$$

two-loop scaling function with N_f=2



Preliminary analysis using the scale Λ introduced in
[C.Allton, hep-lat/9610016; Edwards-Heller-Klassen, NPB517(19980377]

Conclusions

- Evidence for *vacuum color Meissner effect* even in full QCD.
  Assuming a *linear dependence* on $\sqrt{gH}$ as in the quenched case:

$$\frac{T_c(gH)}{T_c(0)} = 1 - \frac{\sqrt{gH}}{\sqrt{gH_c}}$$

we find: $\sqrt{gH_c}(N_f = 2) < \sqrt{gH_c}(\text{quenched}) \simeq 1.1\,\text{GeV}$

- The *chiral critical temperature* seems to be consistent with the *deconfinement temperature* and both depend on the strength of the external chromomagnetic field

- The *chiral condensate* increases with the strength of the external chromomagnetic field