Observation of approximate $\mathrm{SU}(2)_{CS}$ and $\mathrm{SU}(2n_f)$ symmetries in high temperature lattice QCD

C. Rohrhofer, Y. Aoki, G. Cossu, H. Fukaya, L. Glozman, S. Hashimoto, C.B. Lang, S. Prelovsek

Quark Matter 2018, Venice

Der Wissenschaftsfonds.

Motivation: a numerical experiment

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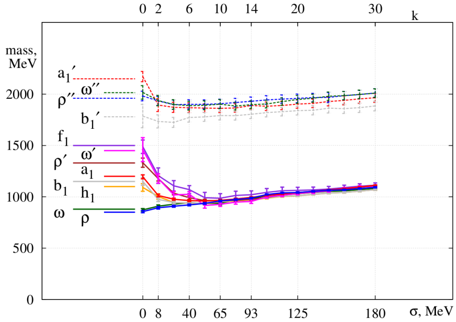
Numerical studies of Hadron spectrum upon Dirac low-mode truncation

(Chiral condensate ↔ Banks-Casher ↔ low modes)



Chiral spin $SU(2)_{CS}$ and $SU(2n_f)$ symmetries derived

similarity due to suppression of low modes in high T QCD?

M.Denissenya,L.Glozman,C.B.Lang, Phys.Rev.D91, 034505

High T study: Vector channel spatial correlators

CR, Y.Aoki, G.Cossu, H.Fukaya, L.Glozman, S.Hashimoto, C.B.Lang, S.Prelovsek (Phys.Rev.D96,094501)

G.Cossu *et al.* hep-lat/1510.07395, A.Tomiya *et al.* hep-lat/1612.01908

High T study: Vector channel spatial correlators

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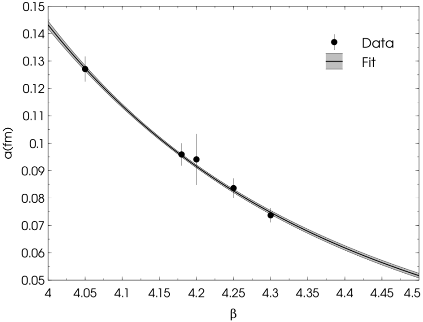
- $n_f = 2$ Möbius DW fermions, Symanzik gauge action
- $32^3 \times 8$ lattices, $T_c = 175$MeV
- local isovectors $\mathcal{O}_\Gamma(x) = \bar{q}(x)\Gamma q(x)$
- measuring spatial correlations in $z-$direction



β	m_{ud}	T [MeV]	
4.10	0.001	220	$1.3T_c$
4.18	0.001	260	$1.5T_c$
4.30	0.001	330	$1.9T_c$
4.37	0.005	380	$2.2T_c$

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Components of the Dirac algebra

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Fix direction of propagation (*z-direction*):

$$C_\Gamma(n_z) = \sum_{n_x, n_y, n_t} \langle \mathcal{O}_\Gamma(n_x, n_y, n_z, n_t) \mathcal{O}_\Gamma(0, 0, 0, 0)^\dagger \rangle$$

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Using $\partial_\mu j^\mu = \partial_\mu j_5^\mu = 0$ we identify the Gamma structures for the Vectors:

$$\mathbf{V} = \begin{pmatrix} \gamma_1 & = Vx \\ \gamma_2 & = Vy \\ \gamma_4 & = Vt \end{pmatrix} \quad \mathbf{A} = \begin{pmatrix} \gamma_1\gamma_5 & = Ax \\ \gamma_2\gamma_5 & = Ay \\ \gamma_4\gamma_5 & = At \end{pmatrix}$$

$$\mathbf{T} = \begin{pmatrix} \gamma_1\gamma_3 & = Tx \\ \gamma_2\gamma_3 & = Ty \\ \gamma_4\gamma_3 & = Tt \end{pmatrix} \quad \mathbf{X} = \begin{pmatrix} \gamma_1\gamma_3\gamma_5 & = \gamma_2\gamma_4 & = Xx \\ \gamma_2\gamma_3\gamma_5 & = \gamma_4\gamma_1 & = Xy \\ \gamma_4\gamma_3\gamma_5 & = \gamma_1\gamma_2 & = Xt \end{pmatrix}$$

γ_3 & $\gamma_3\gamma_5$ no propagation due to current conservation!

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What to expect from $\mathcal{L}_{QCD}$ and χS?

PS	*Pseudoscalar* $\bar{q}(\vec{\tau} \otimes \gamma_5)q$	**S**	*Scalar* $\bar{q}(\vec{\tau} \otimes \mathbb{1}_D)q$
V	*Vector* $\bar{q}(\vec{\tau} \otimes \gamma_k)q$	**A**	*Axial Vector* $\bar{q}(\vec{\tau} \otimes \gamma_5\gamma_k)q$
T	*Tensor Vector* $\bar{q}(\vec{\tau} \otimes \gamma_3\gamma_k)q$	**X**	*Axial Tensor V.* $\bar{q}(\vec{\tau} \otimes \gamma_5\gamma_3\gamma_k)q$

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- $U(1)_A$ broken: *spontaneously, explicitly and anomalously*
- $SU(2)_L \times SU(2)_R$ broken: *spontaneously, explicitly*

Finite T. spatial correlations

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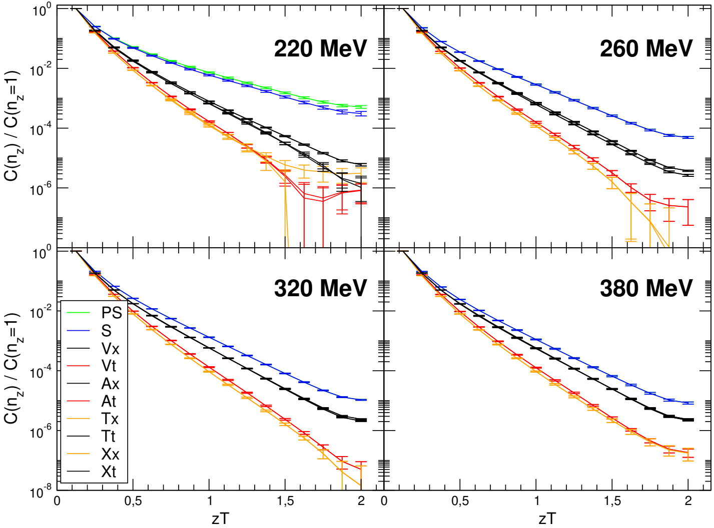
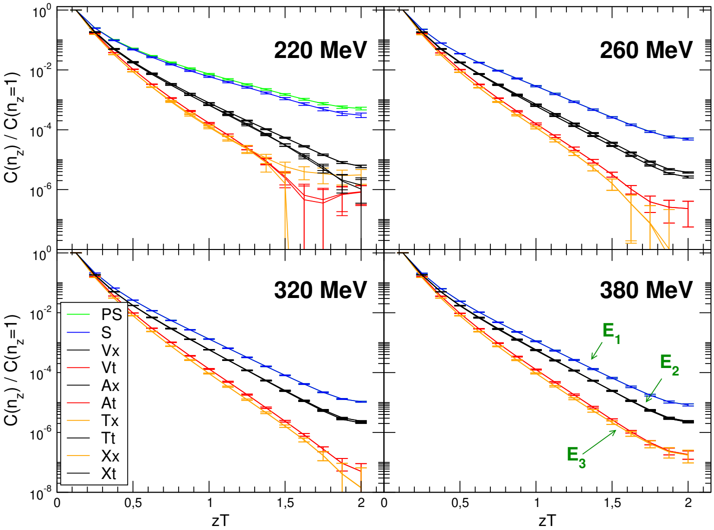


Finite T. spatial correlations



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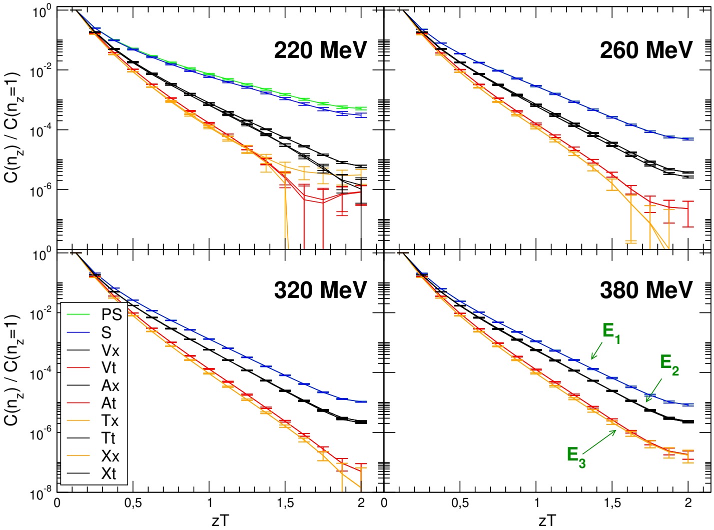

Well pronounced multiplet structure: hint at symmetry?

E_1 and E_2 multiplets

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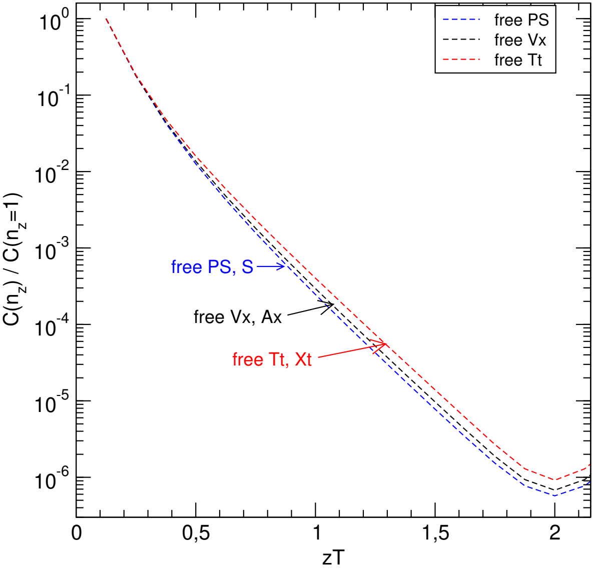
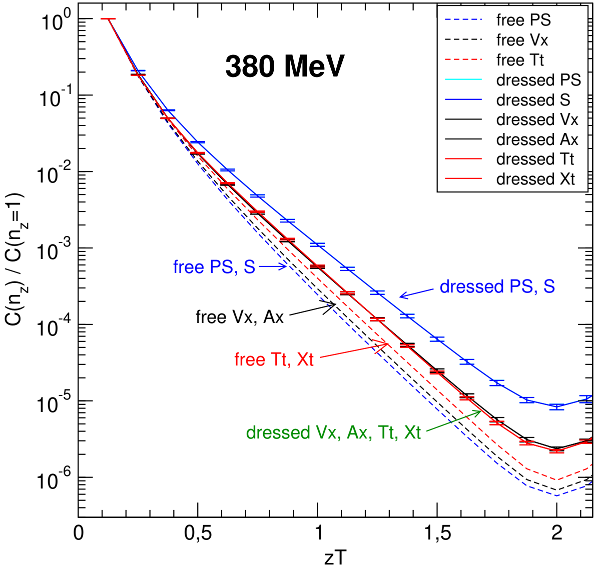


free ($U(x)_\mu = \mathbb{1}$),
non-interacting
quarks:
chiral symmetry

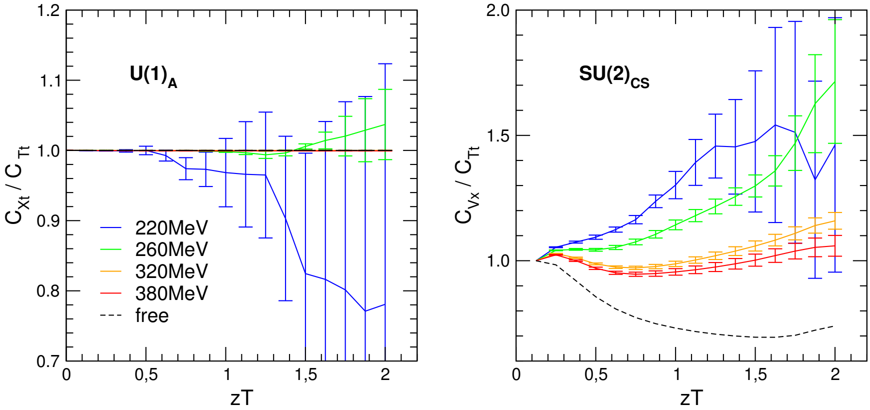
E_1 and E_2 multiplets



free $(U(x)_\mu = \mathbb{1})$, non-interacting quarks: ***chiral symmetry***

dressed meson correlators: ***larger symmetry***

$U(1)_A$ and $SU(2)_{CS}$ detailed ratios



$SU(2)_{CS}$ breaking at 5% level for $\sim 2T_c$

$SU(2)_{CS}$ and $SU(4)$ symmetries

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◇ for spatial $z-$correlators generated by representations:

$$\begin{array}{lll} A_1: & \{\gamma_1, -i\gamma_5\gamma_1, \gamma_5\} & \\ & & \Rightarrow \\ A_2: & \{\gamma_2, -i\gamma_5\gamma_2, \gamma_5\} & \end{array} \quad \begin{array}{l} V_y \leftrightarrow T_t \leftrightarrow X_t \\ V_x \leftrightarrow T_t \leftrightarrow X_t \end{array}$$

◇ Minimal group containing $SU(2)_{CS}$ and χS is $SU(4)$:

$$\left.\begin{array}{l} V_x \leftrightarrow T_t \leftrightarrow X_t \leftrightarrow A_x \\ V_y \leftrightarrow T_t \leftrightarrow X_t \leftrightarrow A_y \end{array}\right\} E_2$$

$$\left.\begin{array}{l} V_t \leftrightarrow T_x \leftrightarrow X_x \leftrightarrow A_t \\ V_t \leftrightarrow T_y \leftrightarrow X_y \leftrightarrow A_t \end{array}\right\} E_3$$

◇ Physical interpretation: $\begin{pmatrix} u_L \\ u_R \\ d_L \\ d_R \end{pmatrix}$ *all components of fundamental vector mix!*

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- ◇ approximate $SU(2)_{CS}$ symmetric region $\rightarrow SU(4)$

$\Rightarrow$ interquark interaction above chiral transition

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color-electric and *color-magnetic* contributions

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$\Rightarrow$ $SU(2)_{CS}$ a tool to distinguish

color-electric and *color-magnetic* contributions

chiral quarks connected by color-electric field
as elementary objects!