Screening mass of gluons in presence of external Abelian chromomagnetic field

N. V. Kolomoyets, V. V. Skalozub

Dnepropetrovsk National University
Ukraine

December 5, 2018

Magnetic Mass

Magnetic (electric) mass shows how fast magetic (electric) field decreases with distance in plasma.

$$F_{\mu\nu} = C(r)\, \mathrm{e}^{\,-m^k r^k} \tag{1}$$

$$m = \frac{1}{\lambda}, \qquad \lambda \text{ – screening length} \tag{2}$$

Example: QED

$$m_{\text{el}}^2 = \frac{1}{3} e^2 T^2 \qquad \text{– electric (Debye) mass} \tag{3}$$

$$m_{\text{magn}}^2 = 0 \qquad \text{– magnetic mass} \tag{4}$$

Screened

Long range

Magnetic Mass in SU(N) Gauge Theory

$$F_{\mu\nu} = \sum_{a=1}^{3} F_{\mu\nu}^{(a)}\, t_a, \qquad t_a \text{ – generators of SU(N) group} \tag{5}$$

// D. Gross, R. Pisarski, and L. Yaffe, Rev. Mod. Phys. **53**, 43 (1981)

1-loop calculations:

$$m_{\text{el}}^2 = \frac{1}{3}\, g^2 T^2 \left(N + \frac{N_f}{2}\right) \tag{6}$$

$$m_{\text{magn}}^2 = 0 \tag{7}$$

Higher orders, nonperturbative calculations:

$$m_{\text{magn}}^2 \sim g^4 T^2 \tag{8}$$

$m_{\text{magn}} = 0$ is not excluded

Hypothesis: not all color components of chromomagnetic field contribute to the magnetic mass

Magnetic Mass in the Presence of External Field

External chromomagnetic field: $H^a_\mu = H\delta_{\mu 3}\delta^{a3}$

$SU(2)$

High temperature: $gH/T^2 << 1$

Neutral gluon field:

$$m^2_{\text{el}} \sim g^2T^2\left(1 - C\sqrt{gH}/T\right), \qquad m^2_{\text{magn}} = 0 \qquad (9)$$

// M. Bordag and V. Skalozub, Phys. Rev. D **75**, 125003 (2007) [hep-th/0611256]

// S. Antropov, M. Bordag, V. Demchik and V. Skalozub, Int. J. Mod. Phys. A **26**, 4831 (2011) [arXiv:1011.3147 [hep-ph]]

Color-charged gluon fields:

$$m^2_{\text{el}} \sim g^2T^2\left(1 - C\sqrt{gH}/T\right), \qquad m^2_{\text{magn}} \sim g^2T\sqrt{gH} \qquad (10)$$

// M. Bordag and V. Skalozub, Phys. Rev. D **77**, 105013 (2008) [arXiv:0801.2306 [hep-th]]

// M. Bordag and V. Skalozub, Phys. Rev. D **85**, 065018 (2012) [arXiv:1201.1978 [hep-th]]

$$\sqrt{gH} \sim g^2T \qquad \Rightarrow \qquad m^2_{\text{magn}} \sim g^4T^2$$

Spontaneous field generation

Magnetic Mass on the Lattice

$SU(2)$

1. T. A. DeGrand and D. Toussaint, "The Behavior of Nonabelian Magnetic Fields at High Temperature," Phys. Rev. D **25**, 526 (1982)
    - Screening of the chromomagnetic field of the monopole-antimonopole string was shown
    - Color structure could not be clarified by this method
2. S. Antropov, M. Bordag, V. Demchik and V. Skalozub, "Long range chromomagnetic fields at high temperature," Int. J. Mod. Phys. A **26**, 4831 (2011) [arXiv:1011.3147 [hep-ph]]
    - Zero magnetic mass of the Abelian chromomagnetic field was shown
    - Non-Abelian components of the chromomagnetic field were not investigated

Magetic Mass: Analytical Calculations vs Lattice

$m \neq 0$

$m^2 \sim g^4 T^2$

Perturb. On the lattice

$m_{\text{neut}} = 0$

Perturb. On the lattice

$m_{\text{ch}} \neq 0$

$m_{\text{ch}}^2 \sim g^2 T \sqrt{gH}$

Perturb.

The aim of this investigation: to show that m_{magn} is produced by the charged components of the gluon field on the lattice

Quantum Gluodynamics on the Lattice

Continuous Minkovsky space-time	$\longrightarrow$	Euclidean 4D discrete lattice
Continuous operators	$\longrightarrow$	Discrete operators on the lattice
Gluon fields	$\longrightarrow$	SU(N) matrices at the links of the lattice

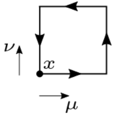
---

Expectation value of a measured quantity $\mathcal{O}$:

$$\langle \mathcal{O} \rangle = \frac{1}{\mathcal{Z}} \int \mathcal{D}U \, \mathcal{O}[U] e^{-S[U]} \quad \longrightarrow \quad \langle \mathcal{O} \rangle \approx \frac{1}{K} \sum_{U_k} \mathcal{O}[U_k] \tag{11}$$

$\mathcal{Z} = \int \mathcal{D}U \, e^{-S[U]}$, $\int \mathcal{D}U = \prod_{x,\mu} \int dU_\mu(x)$, **configurations U_k are distributed with probability $\propto e^{-S[U_k]}$.**

Lattice Wilson action: $$S_W = \beta \sum_{\mu>\nu} \sum_x \left[1 - \frac{1}{N} \mathrm{Re}\,\mathrm{Tr}\, U_{\mu\nu} \right] \tag{12}$$



$$S_W \xrightarrow{a \to 0} \frac{1}{4g^2} \int d^4x \, F^{(c)}_{\mu\nu}(x) F^{(c)}_{\mu\nu}(x) \tag{13}$$

$$U_{\mu\nu}(x) = U_\mu(x) U_\nu(x+\hat{\mu}) U^\dagger_\mu(x+\hat{\nu}) U^\dagger_\nu(x) \text{ – plaquette.} \tag{14}$$

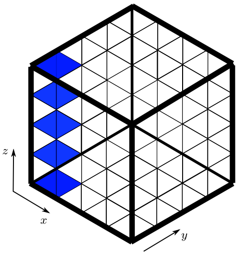
Idea of the investigation:

Two external chromomagnetic fields are introduced on the lattice:

- field of monopole-antimonopole string;
- Abelan field flux.

Screening of combination of that fields is investigated.

Monopole-Antimonopole String on the Lattice



// T. A. DeGrand and D. Toussaint

// M. Srednicki and L. Susskind, Nucl. Phys. **B179**, 239 (1981)

$$S = \beta \sum_n \sum_{\mu>\nu} \left[1 - \frac{1}{N} \mathrm{Re}\,\mathrm{Tr}\, U_{\mu\nu}(n) \Xi_{\mu\nu}(n) \right],$$

$$\Xi_{\mu\nu}(n) \in Z(N)$$

Center of the SU(N) group:

$$Z(N) = \{ \sqrt[N]{1} \cdot I \}$$

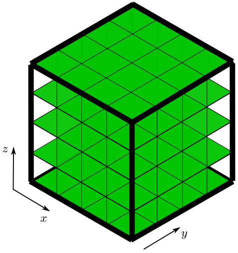
SU(2) case: $Z(2) = \{1 \cdot I,\ -1 \cdot I\}$

SU(3) case: $Z(3) = \{ \mathrm{e}^{-\frac{2}{3}\pi i} \cdot I, 1 \cdot I, \mathrm{e}^{\frac{2}{3}\pi i} \cdot I\}$

$\Xi_{\mu\nu}(n) \neq I$ if string $\cap\, U_{\mu\nu}(n)$

$\Xi_{\mu\nu}(n) = -I$ if $x = 0,\ y = 0,\ \forall z, t$

Abelian Field Flux on the Lattice



Plaquette:

// S. Antropov *et al.*

$$\left.\begin{aligned} U_{\mu\nu}(x) &= U_\mu(x)U_\nu(x+\hat{\mu})U_\mu^\dagger(x+\hat{\nu})U_\nu^\dagger(x) \\ U_\mu(n) &= e^{\,iaA_\mu(n)} \end{aligned}\right\} \Rightarrow U_{\mu\nu}(n) = e^{\,ia^2F_{\mu\nu}(n)}$$

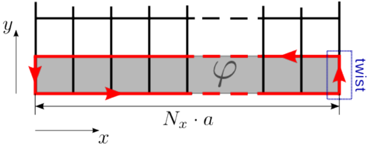
$$U'_{xy} = e^{\,ia^2(H_z+H_z^{\text{ext}})} = U_{xy}\, e^{\,ia^2H_z^{\text{ext}}}$$

$$U'_y(0,n_y,n_z,n_t) = U_y(0,n_y,n_z,n_t)\, e^{\,i\varphi}$$

$$\varphi = a^2N_xH_z^{\text{ext}}$$

Twisted boundary conditions:

$$\begin{cases} U_y(N_x,n_y,n_z,n_t) = U_y(0,n_y,n_z,n_t)\, e^{\,i\varphi}, \\ U_\mu(N_x,n_y,n_z,n_t) = U_\mu(0,n_y,n_z,n_t), \qquad \mu \neq y, \\ \\ U_\mu(n_x,N_y,n_z,n_t) = U_\mu(n_x,0,n_z,n_t), \\ U_\mu(n_x,n_y,N_z,n_t) = U_\mu(n_x,n_y,0,n_t), \\ U_\mu(n_x,n_y,n_z,N_t) = U_\mu(n_x,n_x,n_z,0). \end{cases}$$



$$e^{\,i\varphi} = e^{\,i\varphi_3\sigma_3/2} = \begin{pmatrix} e^{\,i\varphi_3/2} & 0 \\ 0 & e^{-i\varphi_3/2} \end{pmatrix}$$

Abelian Field Flux on the Lattice

$\boxed{SU(3)}$

$$e^{\,i\varphi} = e^{\,i(\varphi_3\lambda_3+\varphi_8\lambda_8)/2} = \begin{pmatrix} e^{\,i(\varphi_3+\varphi_8/\sqrt{3})/2} & 0 & 0 \\ 0 & e^{\,i(-\varphi_3+\varphi_8/\sqrt{3})/2} & 0 \\ 0 & 0 & e^{\,-i\varphi_8/\sqrt{3}} \end{pmatrix} \tag{15}$$

Ext. Field through the Flux vs Ext. Field through the Strength

TBC

$$U_{\mu\nu}(n) = \mathrm{e}^{\,ia^2 F_{\mu\nu}(n)}$$

$$a^2 F_{xy}(n) \to a^2 \left[F_{xy}(n) + H_z^{\text{ext}}\right]$$

Cosmai & Cea

// P. Cea and L. Cosmai, Phys. Rev. D **60**, 094506 (1999) [hep-lat/9903005]

$$U_{\mu}(n) = \mathrm{e}^{\,iaA_{\mu}(n)}$$

$$A_{\mu}(n) \to A_{\mu}(n) + H_z^{\text{ext}} x \delta_{\mu 2} t_3/2$$

$$U_{\mu}(x + N_x, y, z, t) = U_{\mu}(x, y, z, t)$$

$$\Downarrow$$

$$\frac{H_z^{\text{ext}} N_x a}{2} = 2\pi k, \quad k \in Z$$

Outline of the Investigation

Lattices: $N_t \times N^3$, $N_t = \text{const}$

Measured quantity: $\langle U \rangle = \langle \mathrm{Re}\,\mathrm{Tr}\, U_{\mu\nu} \rangle$ Investigated quantity: $f(N) = |\langle U \rangle_{\text{field}} - \langle U \rangle_0|$

$$U_{\mu\nu}(n) = \mathrm{e}^{\,ia^2 F_{\mu\nu}(n)} \approx 1 + ia^2 F_{\mu\nu}(n), \qquad a \to 0 \tag{16}$$

$$\Delta U_{\mu\nu}(n) \approx ia^2 \Delta F_{\mu\nu}(n) \tag{17}$$

$$F(\varphi) = -T \ln \frac{\mathcal{Z}(\varphi)}{\mathcal{Z}(0)}, \quad - \quad \text{free energy}, \qquad \mathcal{Z}(\varphi) = \int \mathcal{D}U\, \mathrm{e}^{-S(\varphi)} \tag{18}$$

$$S(\varphi) = S(0) + \sum_n \frac{1}{n!} \left.\frac{\partial^n S(\varphi)}{\partial \varphi^n}\right|_{\varphi=0} \varphi^n = S(0) + S_\varphi(\varphi) \tag{19}$$

$$\mathcal{Z}(\varphi) = \int \mathcal{D}U\, \mathrm{e}^{-S(0)}\, \mathrm{e}^{-S_\varphi(\varphi)} \qquad \frac{\mathcal{Z}(\varphi)}{\mathcal{Z}(0)} = \mathrm{e}^{-\overline{S}_\varphi(\varphi)} \tag{20}$$

$$F(\varphi) = T\overline{S}_\varphi(\varphi) = T(\overline{S}(\varphi) - \overline{S}(0)) \qquad f(n) \sim \frac{\partial F(n)}{\partial \beta} \tag{21}$$

Outline of the Investigation

Lattices: $N_t \times N^3$, $N_t = \text{const}$

Measured quantity: $\langle U \rangle = \langle \mathrm{Re}\,\mathrm{Tr}\, U_{\mu\nu} \rangle$ Investigated quantity: $f(N) = |\langle U \rangle_{\text{field}} - \langle U \rangle_0|$

Possibilities for f:

- $f \sim 1/N^2$ – flux tubes, the flux is conserved;
- $f \sim 1/N^4$ – Coulombic behavior, flux spreads out over the available area;
- $f \sim \mathrm{e}^{-kN^2}$ – screening of the field; $k = m^2_{\text{magn}}$;
- $f \sim 1/N$ – spontaneous field generation, flux increases with distance.

Simulations are performed

- in absence of external Abelian field flux φ;
- in presence of external Abelian field flux φ:

  φ is directed parallel to the monopole-antimonopole string.

Simulations Setup; SU(2)

Lattices used: $4 \times N^3$, $N = 6, 8, \ldots, 72$

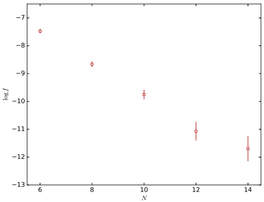
External Abelian field flux $\varphi = 0.08$ ($\sim 10^4$ MeV^2)

$\beta = 2.835$ ($T \sim 1.2$ GeV)
$\beta = 3.020$ ($T \sim 1.9$ GeV)
$\beta = 3.091$ ($T \sim 2.3$ GeV)

Simulations are performed with the QCDGPU program
(`https://github.com/vadimdi/QCDGPU`, V. Demchik, N. K., Comp. Sc. and Appl.,**1**, 1 (2014) [arXiv:hep-lat/1310.7087])

hYBRI LIT/JINR

χ^2-analysis of the Data



$$f_i = |\langle U \rangle_{\text{field}} - \langle U \rangle_0|_i$$

The data are fitted through minimization of χ^2 function:

$$\chi^2(a) = \sum_{i=1}^{K} \frac{[y_i - \log f(N_i; a)]^2}{\sigma_i^2}, \tag{22}$$

$$y_i = \log f_i, \qquad f(N_i; a) = \frac{A}{N^b}\, \mathrm{e}^{-kN^q}.$$

$\chi^2_{min} = \chi^2(\hat{a}) \sim \chi^2_\nu; \qquad \nu = K - L; \qquad L = \text{Length}\, a$

Hypothesis testing:

- H_0: $f(N_i; a)$ describes the data; $\Leftrightarrow \quad \chi^2_{min} \leq \chi^2_{\nu;0.05}$
- H_1: $f(N_i; a)$ does not describe the data. $\Leftrightarrow \quad \chi^2_{min} > \chi^2_{\nu;0.05}$

Functions describing the data

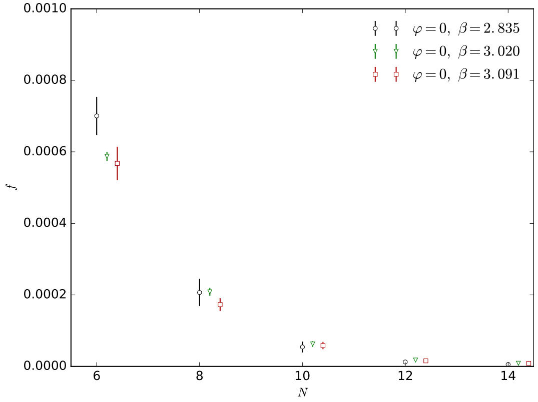
$\Delta\chi^2 = \chi^2(a) - \chi^2_{min} \sim \chi^2_L$

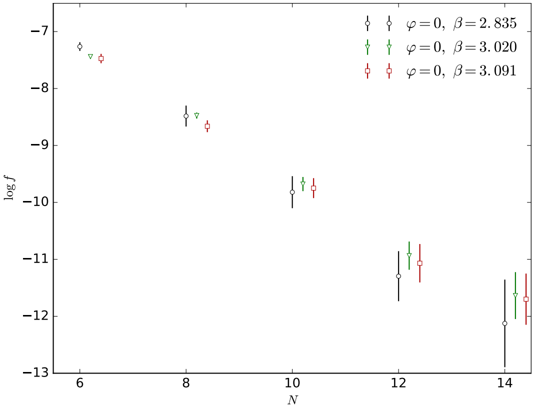
$\chi^2(a) \leq \chi^2_{min} + \chi^2_{L;0.05} \qquad \Rightarrow$ 95% CIs for a

CIs for screening parameters

SU(2) Results: Data at $\varphi = 0$

$$f(N) = |\langle U \rangle_{\text{field}} - \langle U \rangle_0|$$





SU(2) Results: Fitting at $\varphi = 0$

Function	$\beta = 2.835$: χ^2_{min}	$\chi^2_{\nu;0.05}$	$^a/_r$	$\hat{k} \pm 2\sigma$ CI $\times 10^{-2}$	$\beta = 3.020$: χ^2_{min}	$\chi^2_{\nu;0.05}$	$^a/_r$	$\hat{k} \pm 2\sigma$ CI $\times 10^{-2}$	$\beta = 3.091$: χ^2_{min}	$\chi^2_{\nu;0.05}$	$^a/_r$	$\hat{k} \pm 2\sigma$ CI $\times 10^{-2}$
A/N	137	9.49	✗	–	509	9.49	✗	–	190	9.49	✗	–
A/N^2	80.4	9.49	✗	–	247	9.49	✗	–	102	9.49	✗	–
A/N^4	14.0	9.49	✗	–	19.5	9.49	✗	–	9.53	9.49	✗	–
$A\,e^{-kN}$	0.40	7.81	✓	63.9 ± 10.9	2.19	7.81	✓	54.4 ± 4.5	0.98	7.81	✓	56.8 ± 8.0
$A\,e^{-kN^2}$	3.18	7.81	✓	3.68 ± 0.63	11.8	7.81	✗	3.33 ± 0.28	10.3	7.81	✗	3.18 ± 0.45
$(A/N)\,e^{-kN}$	0.60	7.81	✓	51.7 ± 10.9	4.14	7.81	✓	41.5 ± 4.5	0.64	7.81	✓	44.8 ± 8.0
$(A/N)\,e^{-kN^2}$	1.49	7.81	✓	2.99 ± 0.63	4.09	7.81	✓	2.55 ± 0.28	5.10	7.81	✓	2.52 ± 0.45
$(A/N^2)\,e^{-kN}$	0.99	7.81	✓	39.5 ± 10.9	7.29	7.81	✓	28.6 ± 4.5	0.77	7.81	✓	32.7 ± 8.0
$(A/N^2)\,e^{-kN^2}$	0.63	7.81	✓	2.30 ± 0.63	2.16	7.81	✓	1.78 ± 0.28	1.89	7.81	✓	1.85 ± 0.45
$(A/N^4)\,e^{-kN}$	2.32	7.81	✓	15.1 ± 10.9	17.2	7.81	✗	2.80 ± 4.52	2.45	7.81	✓	8.65 ± 7.96
$(A/N^4)\,e^{-kN^2}$	1.36	7.81	✓	0.91 ± 0.63	15.5	7.81	✗	0.23 ± 0.28	1.58	7.81	✓	0.52 ± 0.45

SU(2) Results: Fitting at $\varphi = 0$

$\beta = 2.835$

Function	χ^2_{min}	$\chi^2_{\nu;0.05}$	a/r	$\hat{k} \pm 2\sigma$ CI $\times 10^{-2}$
A/N	137	9.49	✗	–
A/N^2	80.4	9.49	✗	–
A/N^4	14.0	9.49	✗	–
$A\,\mathrm{e}^{-kN}$	0.40	7.81	✓	63.9 ± 10.9
$A\,\mathrm{e}^{-kN^2}$	3.18	7.81	✓	3.68 ± 0.63
$(A/N)\,\mathrm{e}^{-kN}$	0.60	7.81	✓	51.7 ± 10.9
$(A/N)\,\mathrm{e}^{-kN^2}$	1.49	7.81	✓	2.99 ± 0.63
$(A/N^2)\,\mathrm{e}^{-kN}$	0.99	7.81	✓	39.5 ± 10.9
$(A/N^2)\,\mathrm{e}^{-kN^2}$	0.63	7.81	✓	2.30 ± 0.63
$(A/N^4)\,\mathrm{e}^{-kN}$	2.32	7.81	✓	15.1 ± 10.9
$(A/N^4)\,\mathrm{e}^{-kN^2}$	1.36	7.81	✓	0.91 ± 0.63

$\beta = 3.020$

Function	χ^2_{min}	$\chi^2_{\nu;0.05}$	a/r	$\hat{k} \pm 2\sigma$ CI $\times 10^{-2}$
A/N	509	9.49	✗	[illegible]
A/N^2	247	9.49	✗	[illegible]
A/N^4	19.5	9.49	✗	–
$A\,\mathrm{e}^{-kN}$	2.19	7.81	✓	54.4 ± 4.5
$A\,\mathrm{e}^{-kN^2}$	11.8	7.81	✗	3.33 ± 0.28
$(A/N)\,\mathrm{e}^{-kN}$	4.14	7.81	✓	41.5 ± 4.5
$(A/N)\,\mathrm{e}^{-kN^2}$	4.09	7.81	✓	2.55 ± 0.28
$(A/N^2)\,\mathrm{e}^{-kN}$	7.29	7.81	✓	28.6 ± 4.5
$(A/N^2)\,\mathrm{e}^{-kN^2}$	2.16	7.81	✓	1.78 [illegible]
$(A/N^4)\,\mathrm{e}^{-kN}$	17.2	7.81	✗	2.80 [illegible]
$(A/N^4)\,\mathrm{e}^{-kN^2}$	15.5	7.81	✗	0.23 [illegible]

$\beta = 3.091$

Function	χ^2_{min}	$\chi^2_{\nu;0.05}$	a/r	$\hat{k} \pm 2\sigma$ CI $\times 10^{-2}$
A/N	[illegible]	[illegible]	[illegible]	[illegible]
A/N^2	[illegible]	[illegible]	[illegible]	[illegible]
A/N^4	9.53	[illegible]	[illegible]	[illegible]
$A\,\mathrm{e}^{-kN}$	0.98	[illegible]	[illegible]	[illegible]
$A\,\mathrm{e}^{-kN^2}$	10.3	[illegible]	[illegible]	[illegible]
$(A/N)\,\mathrm{e}^{-kN}$	0.64	[illegible]	[illegible]	[illegible]
$(A/N)\,\mathrm{e}^{-kN^2}$	5.10	[illegible]	[illegible]	[illegible]
$(A/N^2)\,\mathrm{e}^{-kN}$	0.77	[illegible]	[illegible]	[illegible]
$(A/N^2)\,\mathrm{e}^{-kN^2}$	[illegible]	[illegible]	[illegible]	[illegible]
$(A/N^4)\,\mathrm{e}^{-kN}$	[illegible]	[illegible]	[illegible]	[illegible]
$(A/N^4)\,\mathrm{e}^{-kN^2}$	[illegible]	[illegible]	[illegible]	[illegible]

PHYSICAL REVIEW D VOLUME 25, NUMBER 2 15 JANUARY 1982

Behavior of non-Abelian magnetic fields at high temperature

T. A. DeGrand* and D. Toussaint

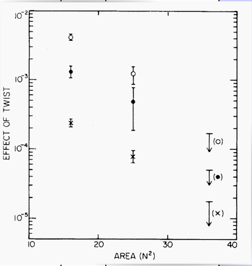
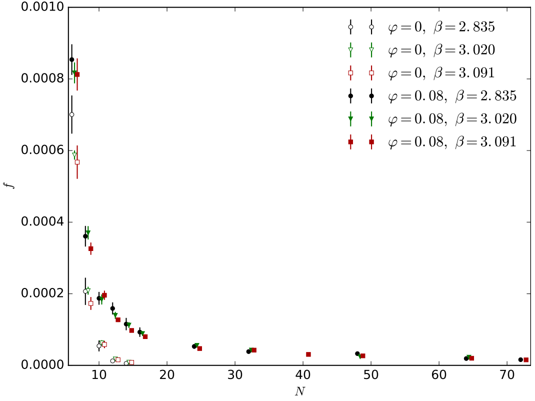


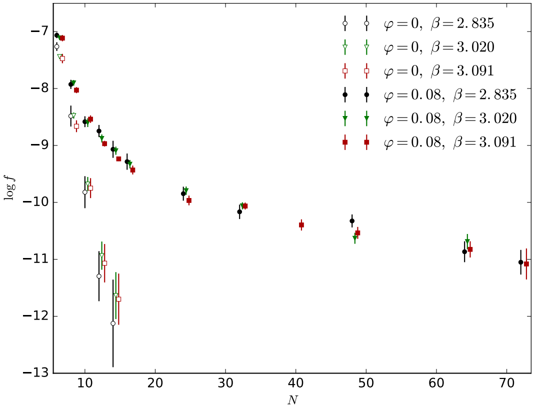
TABLE II. Fits to quantities to a/N^2, b/N^4, or Ce^{-kN^2}, with χ^2.

Quantity	a	χ^2	b	χ^2	c	k	χ^2
$\langle U_{xy} - \frac{1}{2}(U_{xz}+U_{yz})\rangle_{tw}$	0.0216 ± 0.0027	26.5	0.53 ± 0.06	7.5	0.021	0.136 ± 0.021	1.1
$\langle U\rangle_{tw} - \langle U\rangle_{no}$	0.0112 ± 0.0028	12.6	0.28 ± 0.06	5.1	0.0187	0.165 ± 0.054	1.3
$\langle U_{xy}\rangle_{tw} - \langle U_{xy}\rangle_{no}$	0.0367 ± 0.045	38.6	0.89 ± 0.09	12.3	0.0507	0.157 ± 0.031	1.5

SU(2) Results: Data at $\varphi = 0.08$

$$f(N) = |\langle U \rangle_{\text{field}} - \langle U \rangle_0|$$





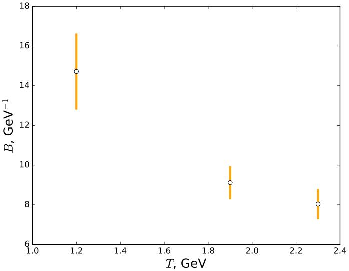
SU(2) Results: Fitting at $\varphi = 0.08$

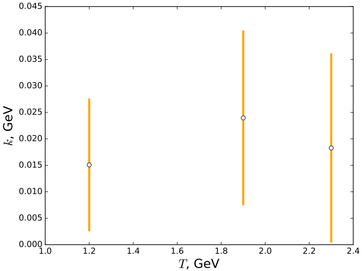
Function	$\beta = 2.835$: χ^2_{min}	$\beta = 2.835$: $\chi^2_{\nu;0.05}$	$\beta = 2.835$: $^a/_r$	$\beta = 3.020$: χ^2_{min}	$\beta = 3.020$: $\chi^2_{\nu;0.05}$	$\beta = 3.020$: $^a/_r$	$\beta = 3.091$: χ^2_{min}	$\beta = 3.091$: $\chi^2_{\nu;0.05}$	$\beta = 3.091$: $^a/_r$
A/N^b	91.2	16.9	✗	170	15.5	✗	223	18.3	✗
$(A/N^b)\,\mathrm{e}^{-kN}$	30.0	15.5	✗	44.9	14.1	✗	69.0	16.9	✗
$(A/N^b)\,\mathrm{e}^{-kN^2}$	47.2	15.5	✗	73.7	14.1	✗	118	16.9	✗
$A\,\mathrm{e}^{B/N}\,\mathrm{e}^{-kN}$	5.33	15.5	✓	7.14	14.1	✓	7.00	16.9	✓

$\beta = 2.835$: $B = 20.3 \pm 2.64$, $k = (1.09 \pm 0.91) \times 10^{-2}$

$\beta = 3.020$: $B = 20.1 \pm 1.84$, $k = (1.08 \pm 0.75) \times 10^{-2}$

$\beta = 3.091$: $B = 21.3 \pm 2.01$, $k = (6.90 \pm 6.76) \times 10^{-3}$

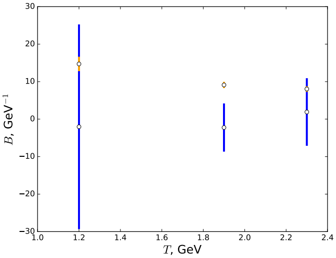


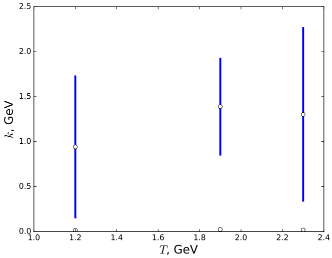


Comparison of the results

$f(N) = A\,e^{B/N}\,e^{-kN}$

	$\beta = 2.835$			$\beta = 3.020$			$\beta = 3.091$		
	χ^2_{min}	$\chi^2_{\nu;0.05}$	$^a/_r$	χ^2_{min}	$\chi^2_{\nu;0.05}$	$^a/_r$	χ^2_{min}	$\chi^2_{\nu;0.05}$	$^a/_r$
$\varphi = 0$	0.36	5.99	✓	1.34	5.99	✓	0.64	5.99	✓
	$B = -2.81 \pm 37.6$ $k = (6.83 \pm 5.76) \times 10^{-1}$			$B = -4.95 \pm 14.2$ $k = (6.29 \pm 2.46) \times 10^{-1}$			$B = 5.04 \pm 23.9$ $k = (4.92 \pm 3.66) \times 10^{-1}$		
$\varphi = 0.08$	5.33	15.5	✓	7.14	14.1	✓	7.00	16.9	✓
	$B = 20.3 \pm 2.64$ $k = (1.09 \pm 0.91) \times 10^{-2}$			$B = 20.1 \pm 1.84$ $k = (1.08 \pm 0.75) \times 10^{-2}$			$B = 21.3 \pm 2.01$ $k = (6.90 \pm 6.76) \times 10^{-3}$		





$m_0 = 1.26 \pm 0.41$ GeV

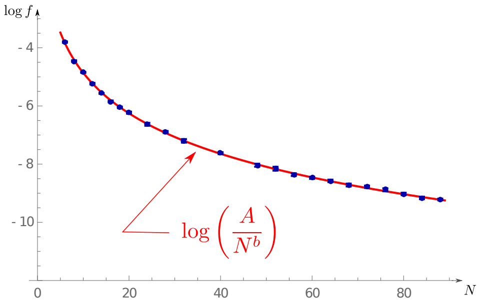
$m_{0.08} = (1.83 \pm 0.87) \times 10^{-2}$ GeV

at 95% CL

SU(3) Results: Data at $\varphi = 0$

$4 \times N^3$ lattices, $N = 6, \ldots, 88$

$\beta = 6.4$ ($T \sim 580$ MeV)



$\chi^2 = 20.2 \qquad \chi^2_{\nu;0.05} = 32.7$

$b = 2.00 \pm 0.02$

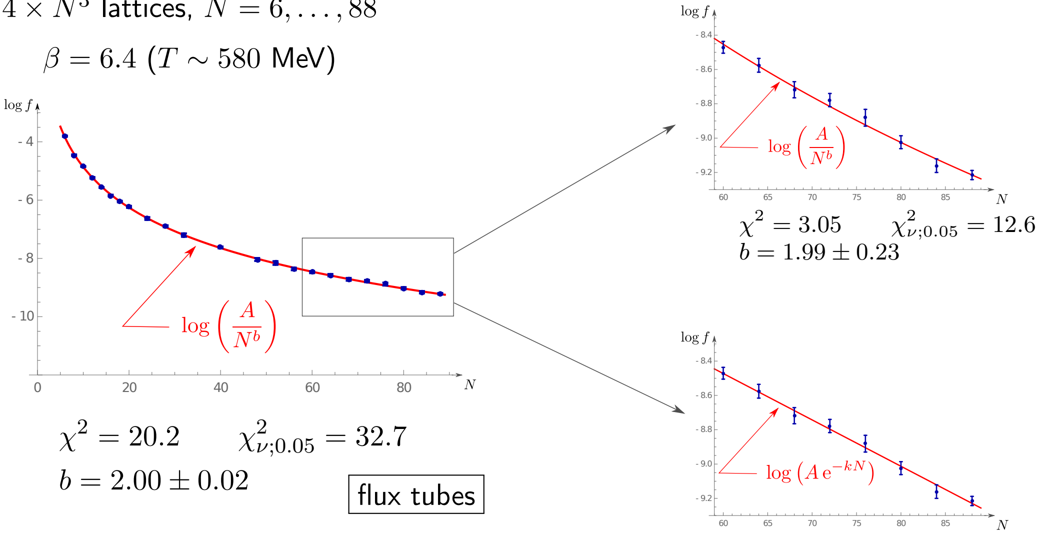
flux tubes

$\chi^2 > \chi^2_{\nu;0.05} \Rightarrow$ rejection at 95% CL

SU(3) Results: Data at $\varphi = 0$

$4 \times N^3$ lattices, $N = 6, \ldots, 88$

$\beta = 6.4$ ($T \sim 580$ MeV)



$\chi^2 = 20.2 \qquad \chi^2_{\nu;0.05} = 32.7$

$b = 2.00 \pm 0.02$

flux tubes

$\chi^2 = 3.05 \qquad \chi^2_{\nu;0.05} = 12.6$

$b = 1.99 \pm 0.23$

$\chi^2 = 2.24 \qquad \chi^2_{\nu;0.05} = 12.6$

$b = (2.70 \pm 0.32) \times 10^{-2}$

$\chi^2 > \chi^2_{\nu;0.05} \Rightarrow$ rejection at 95% CL

Comparison with Literature

$SU(3)$

- B. Grossman, S. Gupta, U. M. Heller and F. Karsch, "Glueball - like screening masses in pure SU(3) at finite temperatures," Nucl. Phys. B **417**, 289 (1994) [hep-lat/9309007].
  - External field sources are not introduced
  - m_{el} and m_{magn} are measured through Plyakov loop correlators
  - $2m_{\text{magn}} = 5.8(4)T$ @ $T = 1.5T_c$

Conclusions

- Both monopole-antimonopole string and external Abelian field flux are introduced on the lattice.
- Results of the previous investigations for SU(2) gauge group are reproduced.
- In SU(2) it is shown that adding of the Abelian field flux weakens the screening of the string field. This confirms that
  - for the Abelian field $m_{\mathrm{magn}} = 0$;
  - m_{magn} of the monopole-antimonopole string field is produced by its non-Abelian components.
- In SU(3) formation of flux tubes is obtained.

Conclusions

- Both monopole-antimonopole string and external Abelian field flux are introduced on the lattice.
- Results of the previous investigations for SU(2) gauge group are reproduced.
- In SU(2) it is shown that adding of the Abelian field flux weakens the screening of the string field. This confirms that
  - for the Abelian field $m_{\mathsf{magn}} = 0$;
  - m_{magn} of the monopole-antimonopole string field is produced by its non-Abelian components.
- In SU(3) formation of flux tubes is obtained.

Thank you for your attention!