The magnetic polarizabilities and g-factor of the neutral and charged ρ mesons in a strong magnetic field on the lattice

Solovjeva Olga*,Luschevskaya Elena,Teryev Oleg

ITEP
NRNU "MEPhI"

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Outline:

- Calculations
- Correlators
- The ground state energy of neutral ρ meson
- Magnetic polarizability of neutral ρ meson
- The ground state energy of charged ρ meson
- The g-factor of ρ meson
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Calculations

$$D\psi_k = i\lambda_k\psi_k, \quad D = \gamma^\mu(\partial_\mu - iA_\mu)$$

$$A_{\mu\, ij} \to A_{\mu\, ij} + A^B_\mu \delta_{ij}$$

$A^B_\mu(x) = \frac{B}{2}(x_1\delta_{\mu,2} - x_2\delta_{\mu,1})$ - Abelian magnetic field

$$D^{-1}(x,y) = \sum_{k<M} \frac{\psi_k(x)\psi_k^\dagger(y)}{i\lambda_k + m}$$

Calculations

$$\langle \psi^\dagger(x) O_1 \psi(x) \psi^\dagger(y) O_2 \psi(y) \rangle_A$$

$$\langle \bar{\psi} O_1 \psi \bar{\psi} O_2 \psi \rangle_A = -[O_1 D^{-1}(x,y) O_2 D^{-1}(y,x)]$$

$$\tilde{C}(n_t) = \langle \psi^\dagger(\mathbf{0}, n_t) O_1 \psi(\mathbf{0}, n_t) \psi^\dagger(\mathbf{0}, 0) O_2 \psi(\mathbf{0}, 0) \rangle_A =$$

$$\sum_k \langle 0|O_1|k\rangle \langle k|O_2^\dagger|0\rangle e^{-n_t a E_k}$$

$$\tilde{C}_{fit}(n_t) = A_0 e^{-n_t a E_0} + A_0 e^{-(N_T - n_t) a E_0} =$$

$$2A_0 e^{-N_T a E_0/2} \cosh((\frac{N_T}{2} - n_t) a E_0$$

$$E_0 - ?$$

Correlators

$$C_{xx}^{VV} = \langle \bar{\psi}(\mathbf{0}, n_t)\gamma_1\psi(\mathbf{0}, n_t)\bar{\psi}(\mathbf{0}, 0)\gamma_1\psi(\mathbf{0}, 0)\rangle, \quad (1)$$

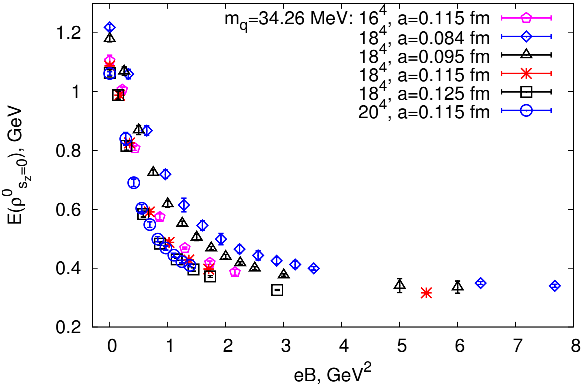
$$C_{yy}^{VV} = \langle \bar{\psi}(\mathbf{0}, n_t)\gamma_2\psi(\mathbf{0}, n_t)\bar{\psi}(\mathbf{0}, 0)\gamma_2\psi(\mathbf{0}, 0)\rangle, \quad (2)$$

$$C_{zz}^{VV} = \langle \bar{\psi}(\mathbf{0}, n_t)\gamma_3\psi(\mathbf{0}, n_t)\bar{\psi}(\mathbf{0}, 0)\gamma_3\psi(\mathbf{0}, 0)\rangle. \quad (3)$$

ρ^0 meson with $s_z = 0 \longleftarrow C_{zz}^{VV}$

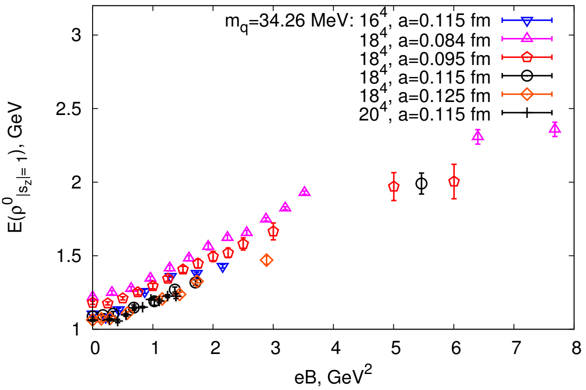
$$C^{VV}(s_z = \pm 1) = C_{xx}^{VV} + C_{yy}^{VV} \pm i(C_{xy}^{VV} - C_{yx}^{VV}). \quad (4)$$

The ground state energy of neutral ρ meson



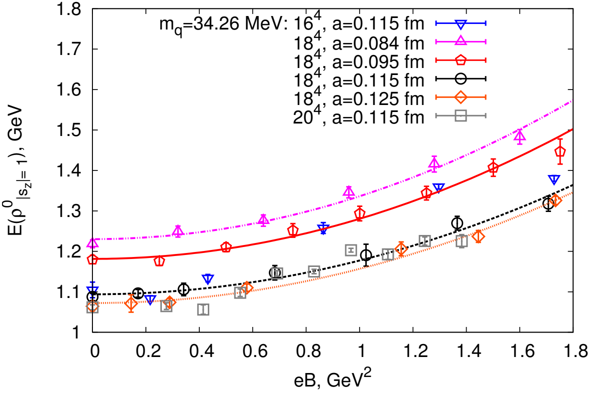
$$E = E(B=0) - 2\pi\beta_m(eB)^2$$

The ground state energy of neutral ρ meson



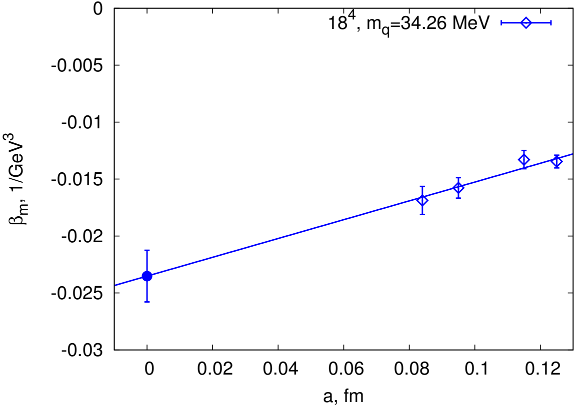
$$E = E(B=0) - 2\pi\beta_m(eB)^2$$

The ground state energy of neutral ρ meson



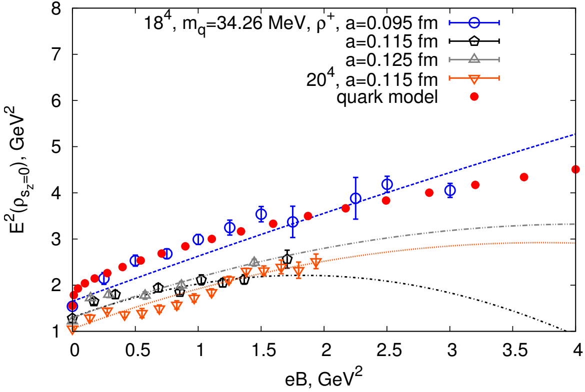
$$E = E(B=0) - 2\pi\beta_m(eB)^2$$

Magnetic polarizability of neutral ρ meson



$$\beta_m^{|s|=1}(\rho^0) = (-1.86 \pm 0.18)\ 10^{-4} fm^3$$

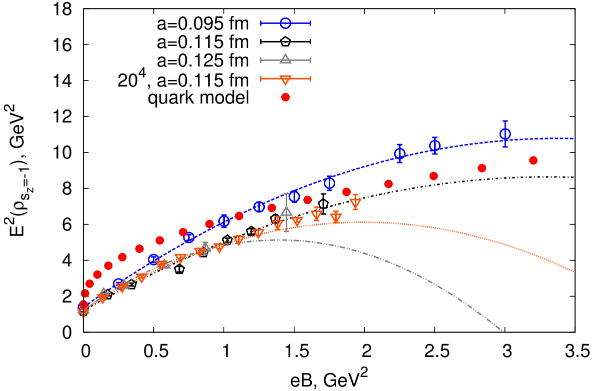
The ground state energy of charged ρ meson



$$E^2 = |qB| - g s_z qB + m^2 - 4\pi m \beta (qB)^2$$

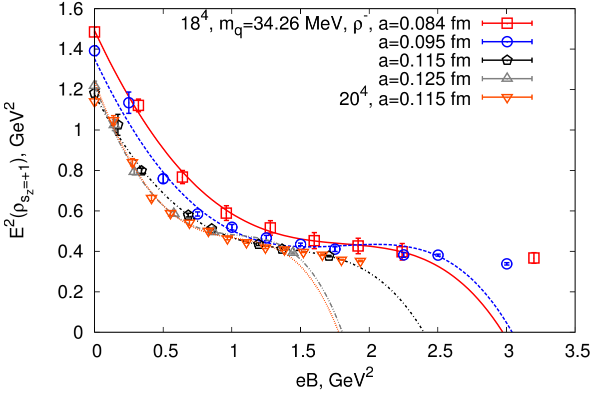
ITEP Lattice

The ground state energy of charged ρ meson



$$E^2 = |qB| - g s_z qB + m^2 - 4\pi m \beta (qB)^2$$

The ground state energy of charged ρ meson



$$E^2 = |qB| - g s_z qB + m^2 - 4\pi m \beta (qB)^2 + k(qB)^4$$

The g-factor of ρ meson

$$g = \frac{E^2(s=+1) - E^2(s=-1)}{2(eB)}$$

$m_q \longrightarrow 0 : g = 2.4 \pm 0.2$ lattice 18^4 $a = 0.115 fm$
experiment: $g_{exp} = 2.1 \pm 0.5$
D. G. Gudino and G. T.Sanchez, (2013), arXiv: 1305.6345 [hep-ph]
$g \approx 2.37$ Relativistic quark model
$g \approx 2.4$ F.X.Lee at al., Phys.Rev. D,78,094502(2008)

Conclusions:

- Magnetic polarizability was found for neutral ρ meson :

$$\beta_m^{|s|=1}(\rho^0) = (-1.86 \pm 0.18)\ 10^{-4} fm^3$$

- Magnetic polarizability depends on spin projections
- No evidences in favour of charged ρ mesons condensation or tachyonic mode existence at large magnetic fields.
- The g-factor of ρ meson is estimated in the chiral limit : $g = 2.4 \pm 0.2$

Future work:

- Mixing between π and ρ mesons
- Magnetic polarizability for charged π and ρ mesons(large lattices and increasing statistics)
- Increase in accuracy of g-factor determination
- Magnetic polarizability , g-factor, ground state energy for K mesons
- Electric polarizability for mesons

Thank you for your attention!

oesolovjeva@gmail.com