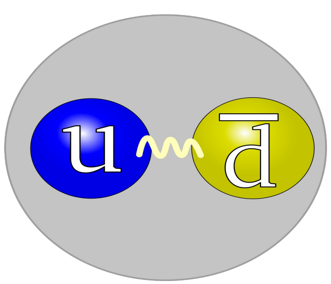
The magnetic polarizabilities of mesons in external magnetic field in SU(3) lattice gauge theory



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PANDA Russia Workshop

Calculations

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

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

Abelian magnetic field

SU(3) gluon field

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

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

Calculations

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

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

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

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

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

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

E_0-?

Correlators

π mesons

$$C^{PSPS} = \langle \bar{\psi}_u(\mathbf{0}, n_t)\gamma_5\psi_u(\mathbf{0}, n_t)\bar{\psi}_d(\mathbf{0}, 0)\gamma_5\psi_d(\mathbf{0}, 0)\rangle$$

ρ mesons

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

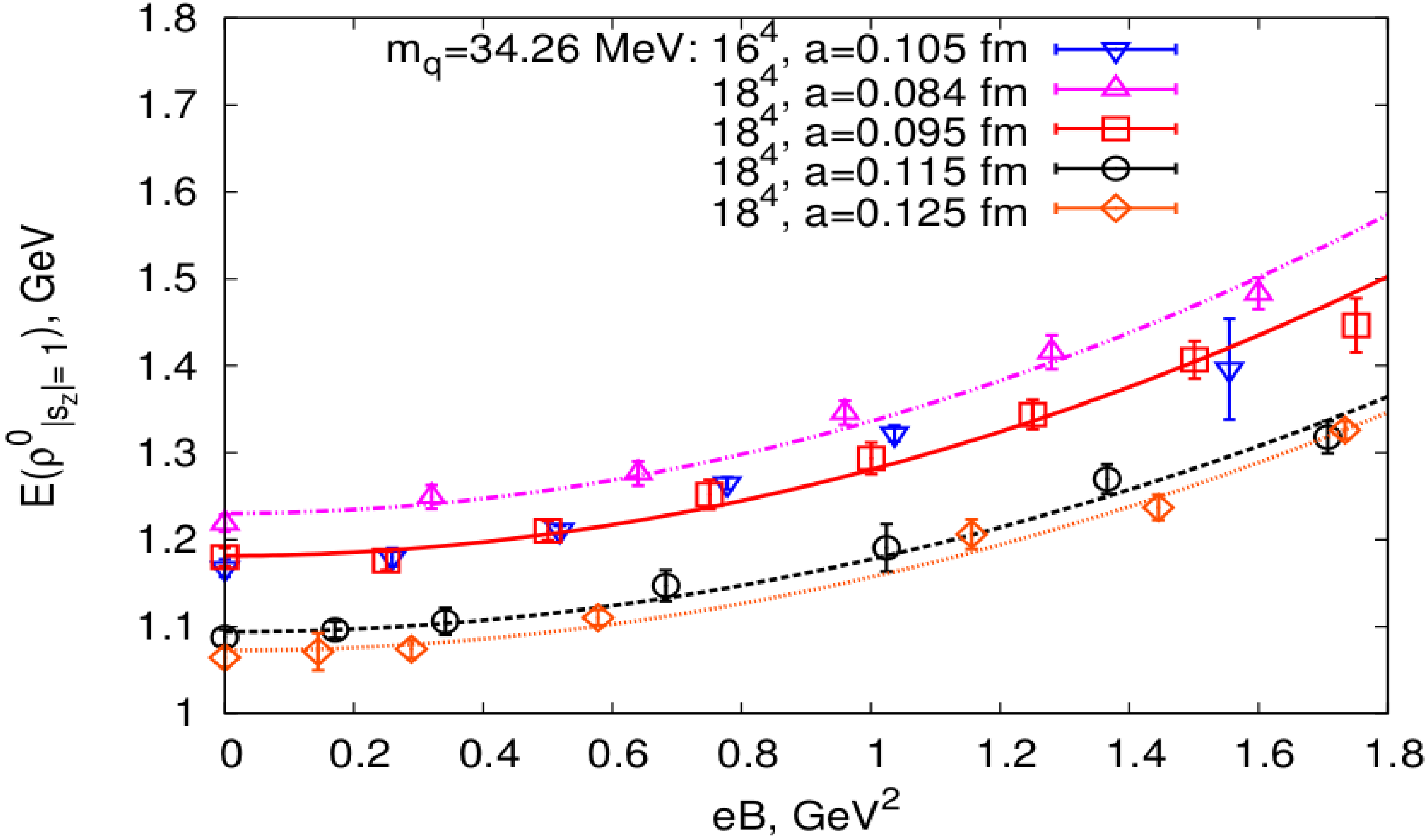
$$C^{VV}_{xx} = \langle \bar{\psi}(\mathbf{0}, n_t)\gamma_1\psi(\mathbf{0}, n_t)\bar{\psi}(\mathbf{0}, 0)\gamma_1\psi(\mathbf{0}, 0)\rangle$$

$$C^{VV}_{yy} = \langle \bar{\psi}(\mathbf{0}, n_t)\gamma_2\psi(\mathbf{0}, n_t)\bar{\psi}(\mathbf{0}, 0)\gamma_2\psi(\mathbf{0}, 0)\rangle$$

$$C^{VV}_{zz} = \langle \bar{\psi}(\mathbf{0}, n_t)\gamma_3\psi(\mathbf{0}, n_t)\bar{\psi}(\mathbf{0}, 0)\gamma_3\psi(\mathbf{0}, 0)\rangle$$

ITEP Lattice

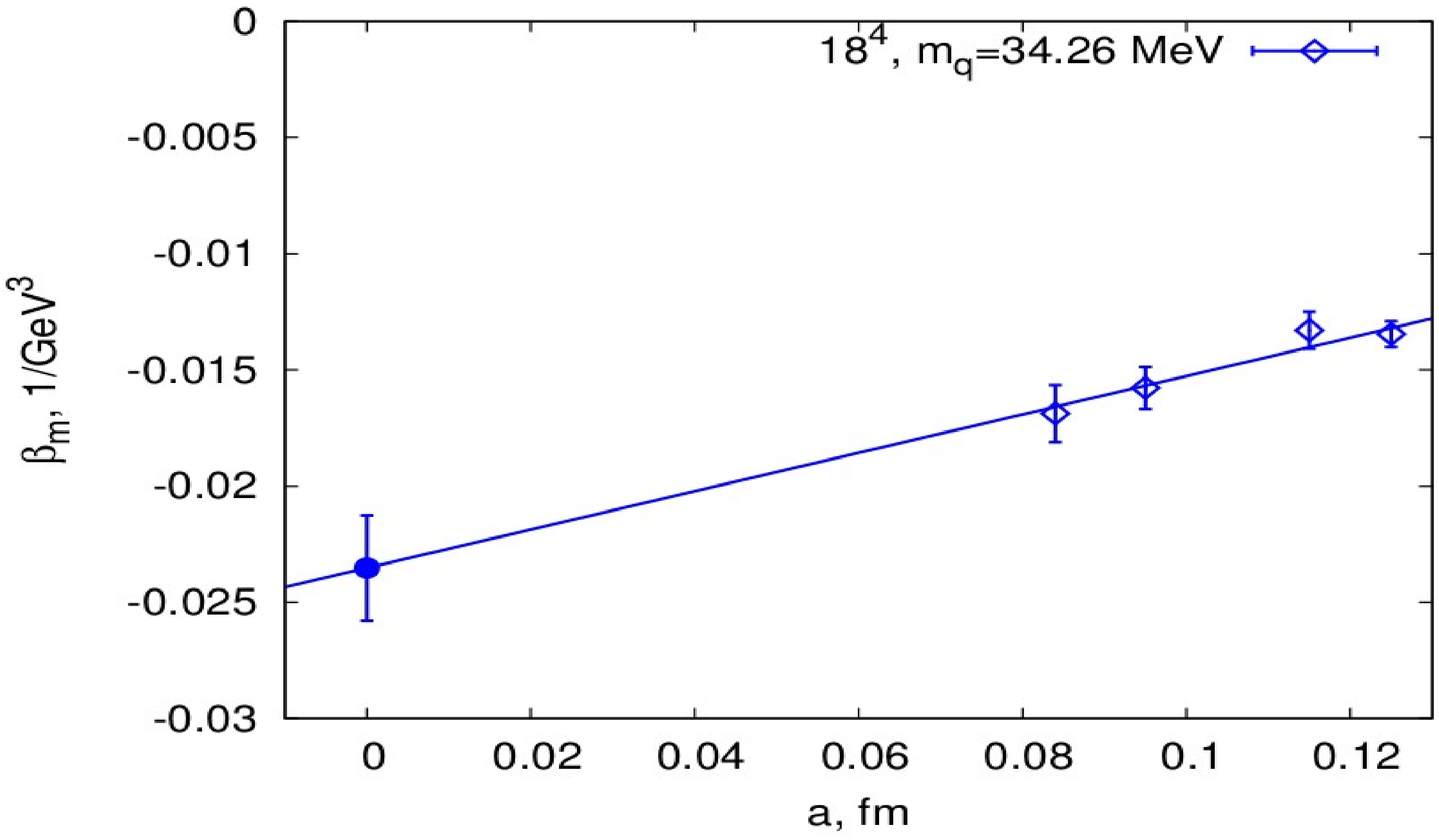
The ground state energy of ρ mesons



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

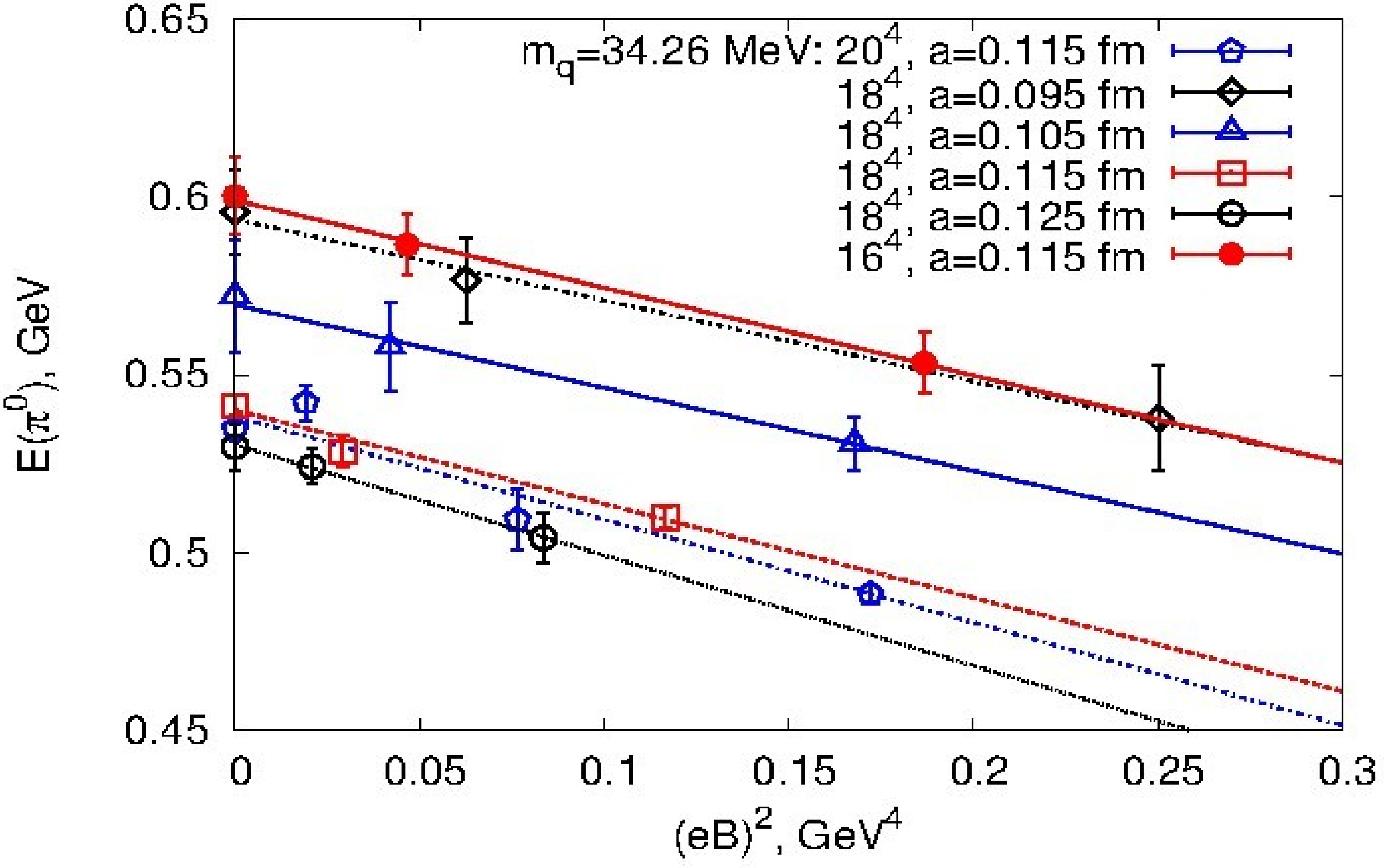
ITEP Lattice

Magnetic polarizability of ρ mesons



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

The ground state energy of π mesons



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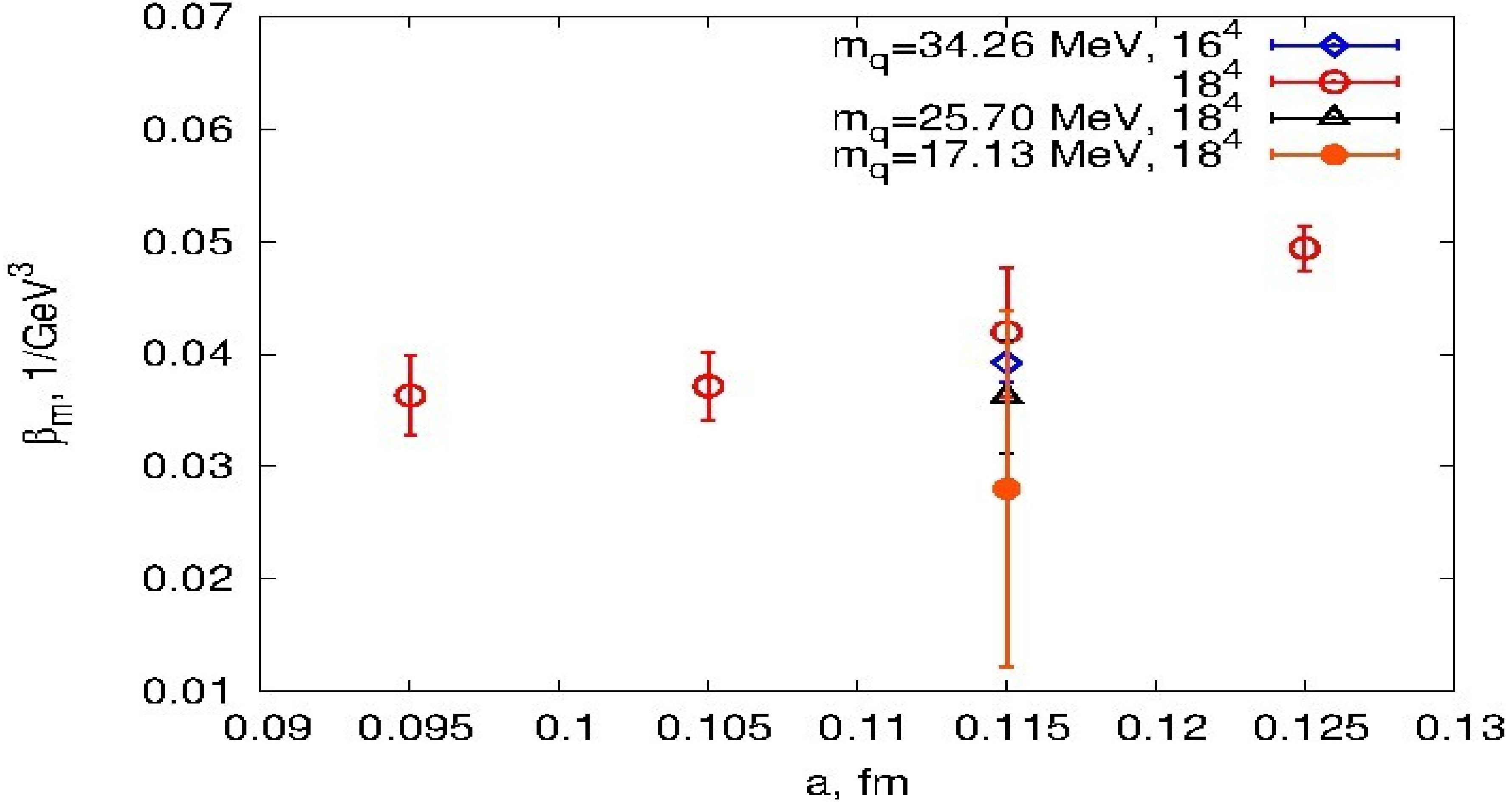
Magnetic polarizability of π mesons



$$\beta_m(\pi^0) = (2.8 \pm 0.3) * 10^{-4}\ fm^3$$

ITEP Lattice

Magnetic polarizability of π mesons

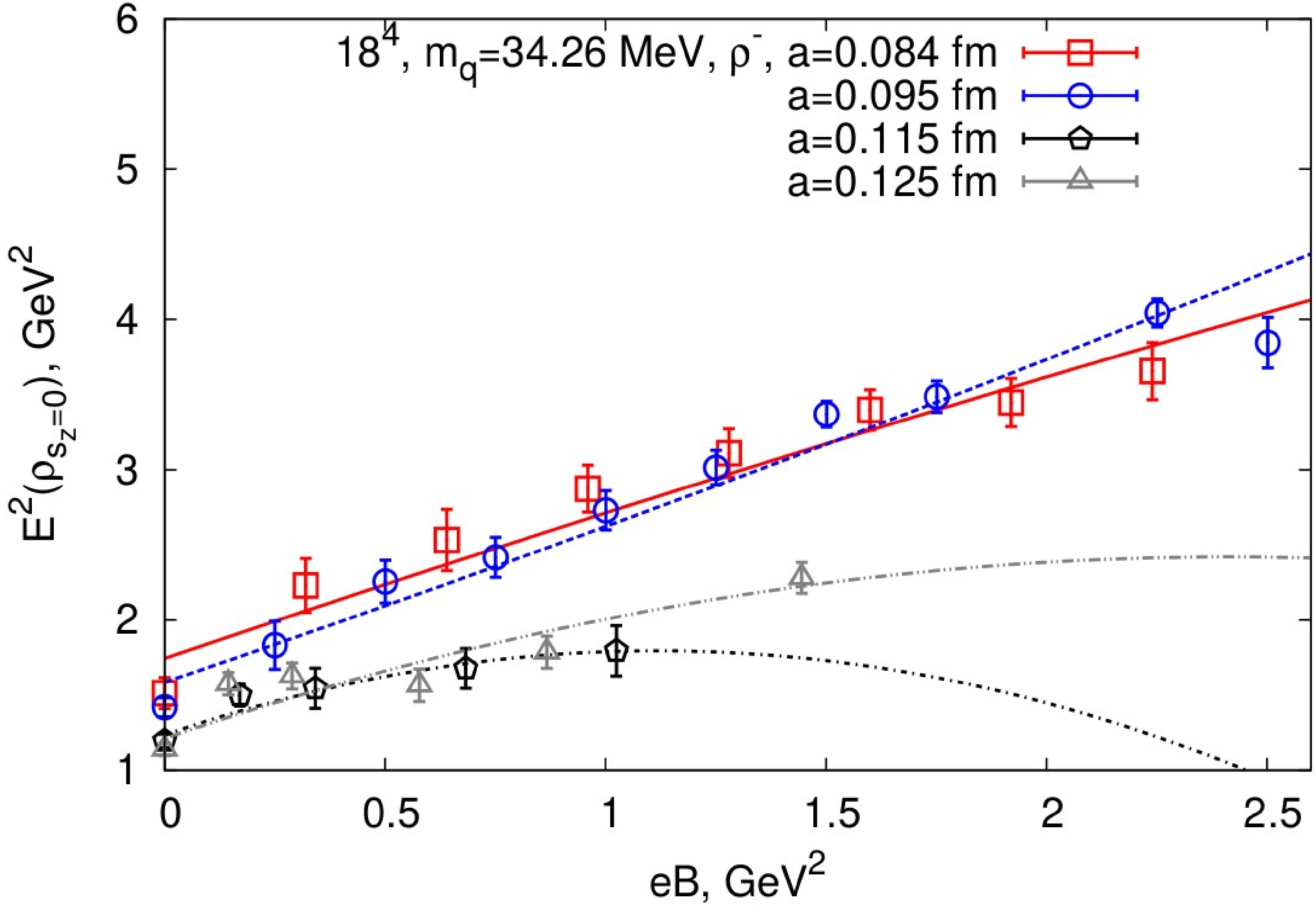
$$\beta_m(\pi^0) = (2.14 \pm 1.22) * 10^{-4}\ fm^3\ m_q = 17 Mev$$
$$\beta_m(\pi^0) = (2.8 \pm 0.3) * 10^{-4}\ fm^3\ m_q = 25 Mev$$

Chiral perturbation theory : 2 loops corrections

	ChPT to one loop	ChPT to two-loops
$(\alpha - \beta)_{\pi^0}$	-1.0	-1.9 ± 0.2
$(\alpha + \beta)_{\pi^0}$	0	1.1 ± 0.3

Charged ρ meson

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



Charged ρ meson

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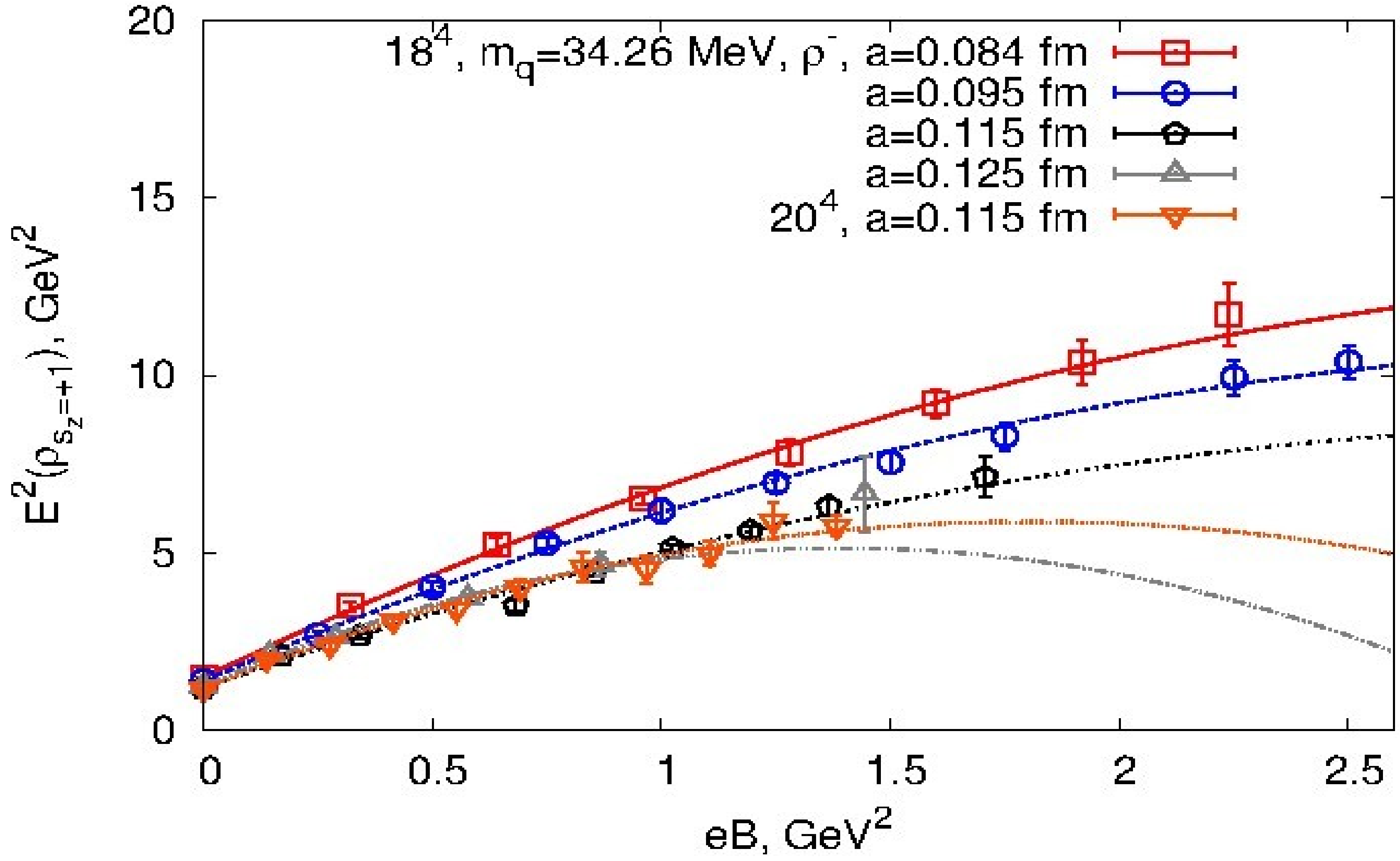
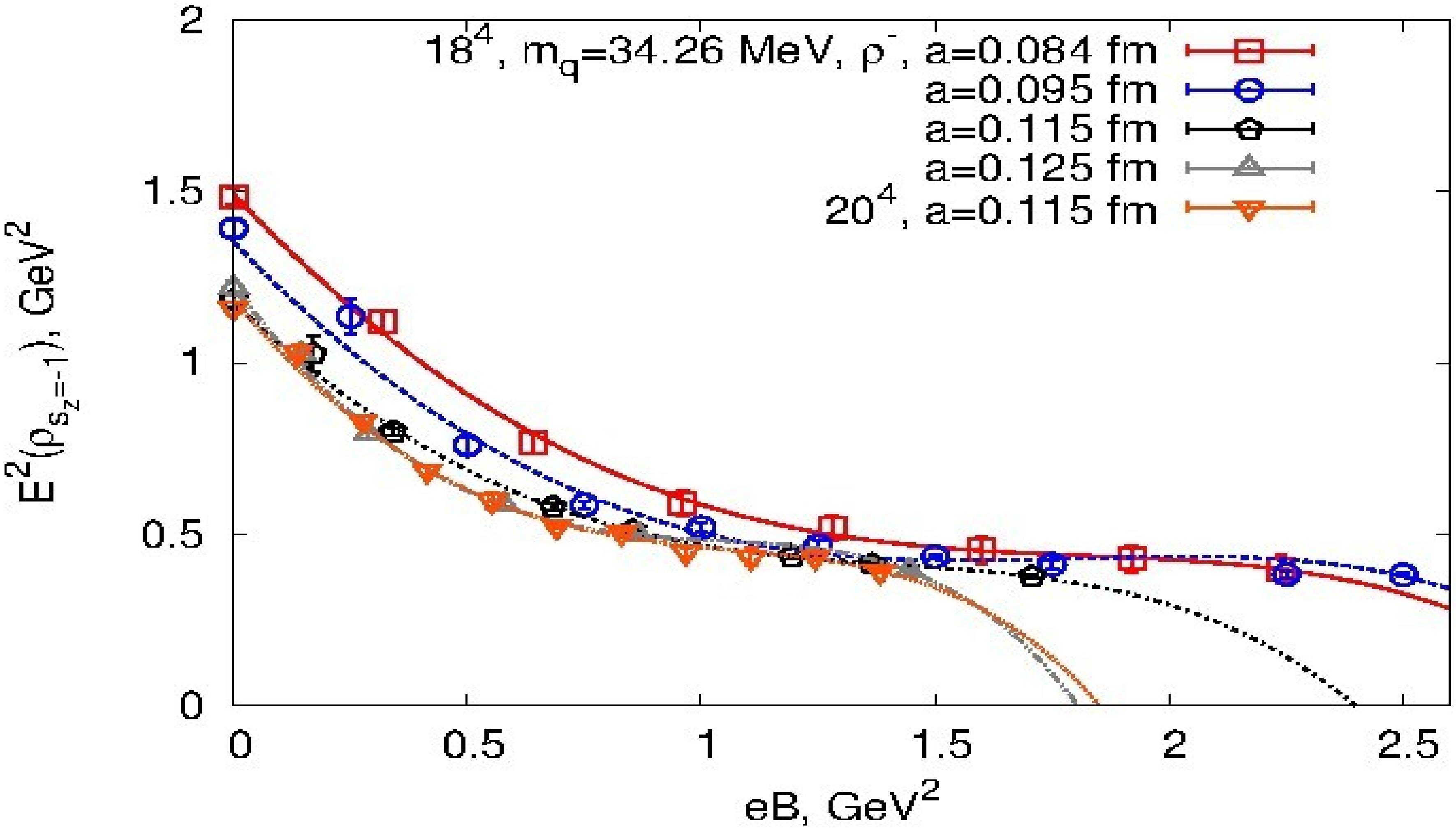


Charged ρ meson

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



The g-factor of ρ mesons

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

$m_q \longrightarrow 0$

$g \ = \ 2.4 \pm 0.2$ lattice 18^4 and $a = 0.115$ fm

$g_{exp} = 2.1 \pm 0.5$

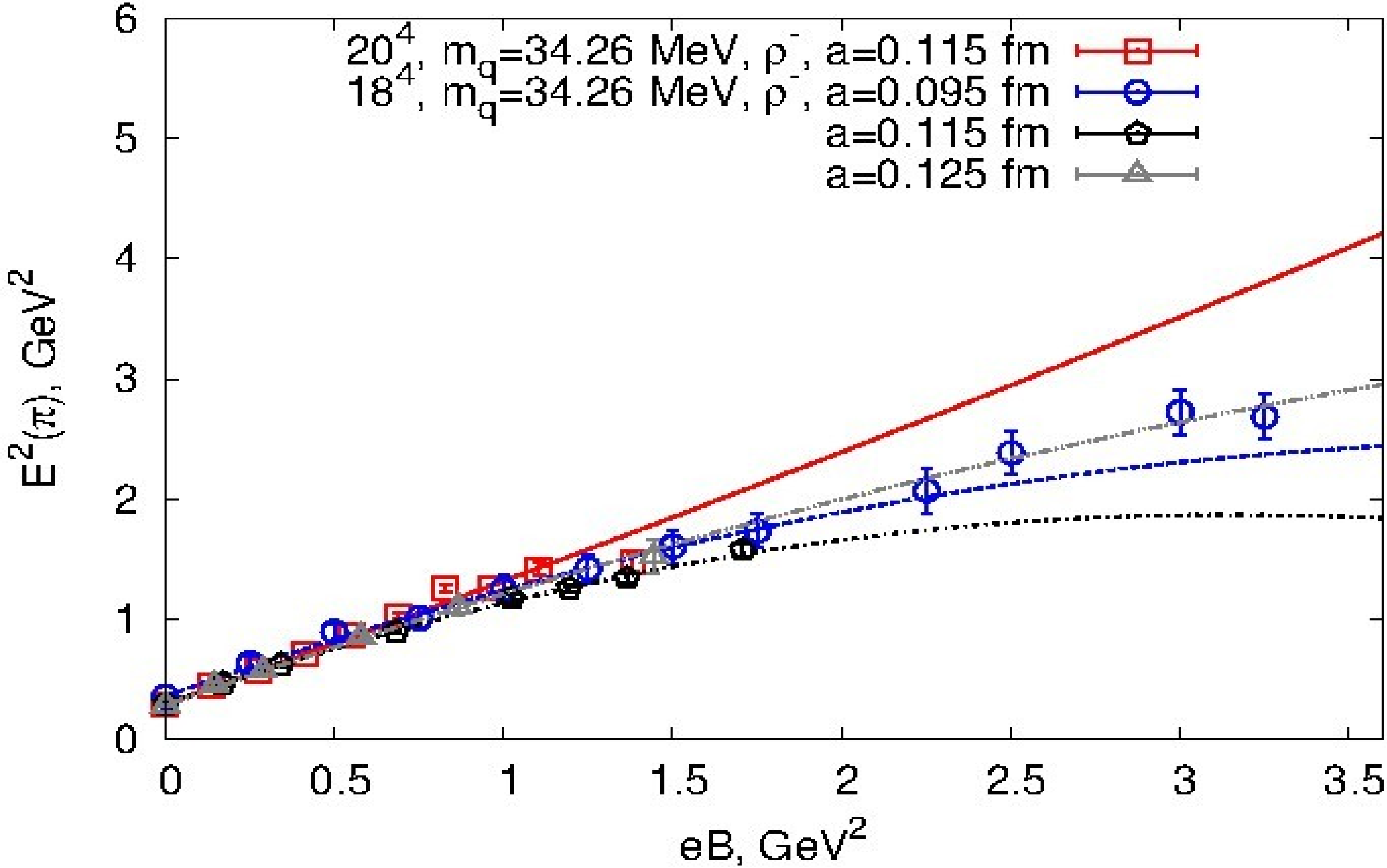
D. G. Gudino and G. T.Sanchez, (2013), arXiv: 1305.6345 [hep-ph]

$g \approx 2.37$ Relativistic quark model

$g \approx 2.4$ F. X. Lee et.al., Phys. Rev. D 78, 094502(2008)

Charged π meson

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

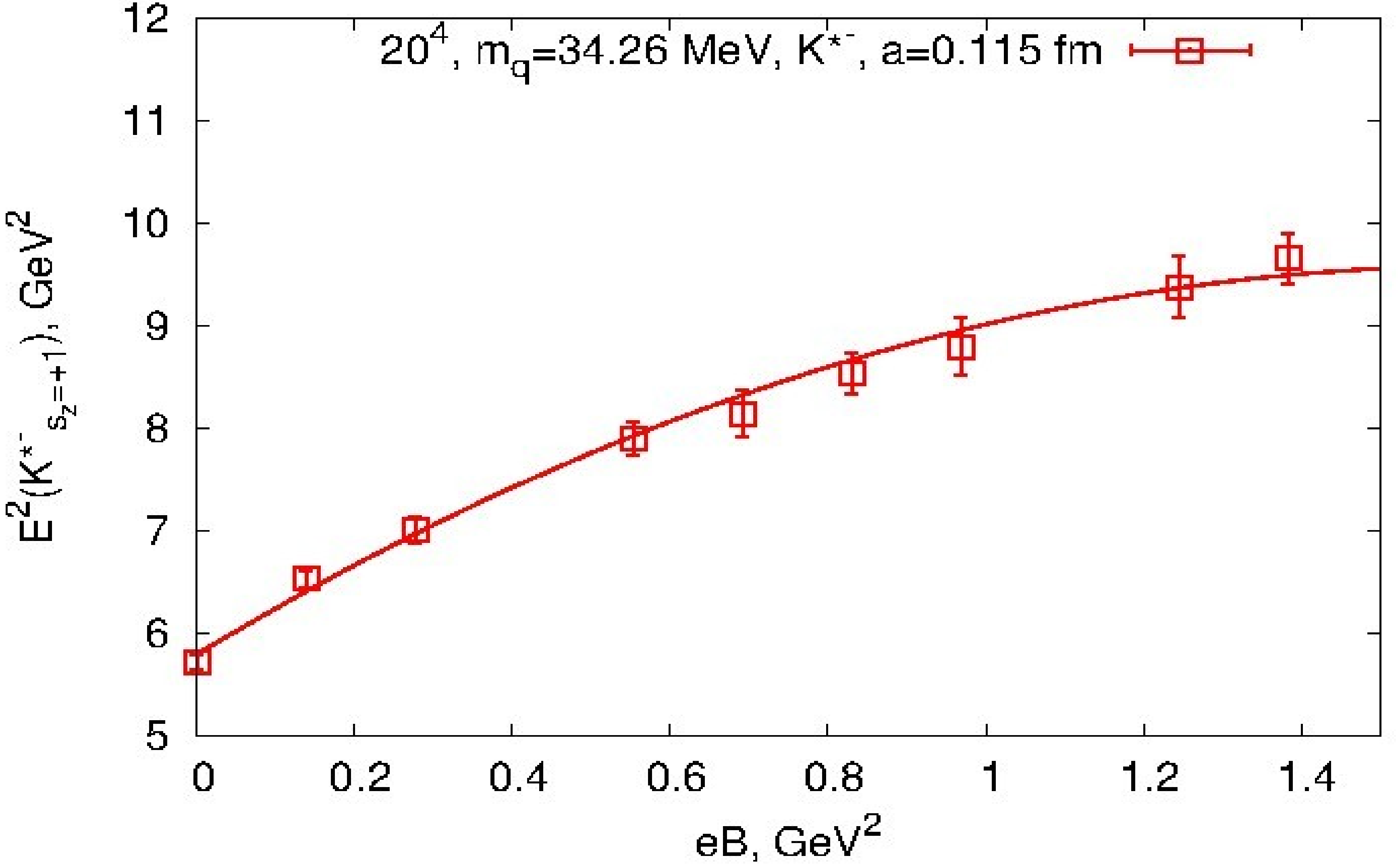


Charged π meson

V_{latt}	$a\ (fm)$	χ^2/dof	$\beta_m, (10^{-4} fm^3)$
18^4	0.095	0.22	1.2 ± 0.2
18^4	0.115	0.28	1.8 ± 0.1
18^4	0.125	0.04	0.8 ± 0.4

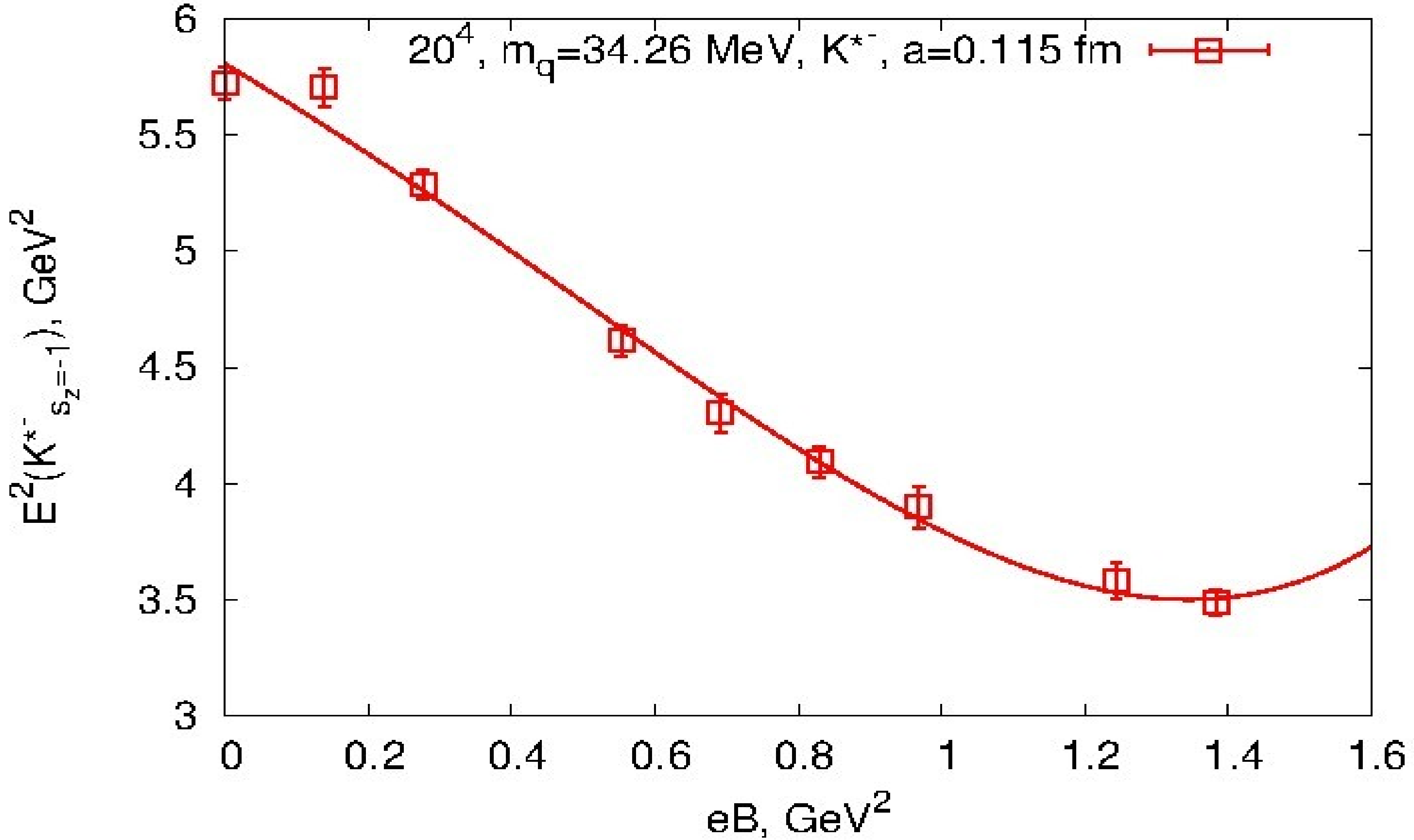
Charged K* meson

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

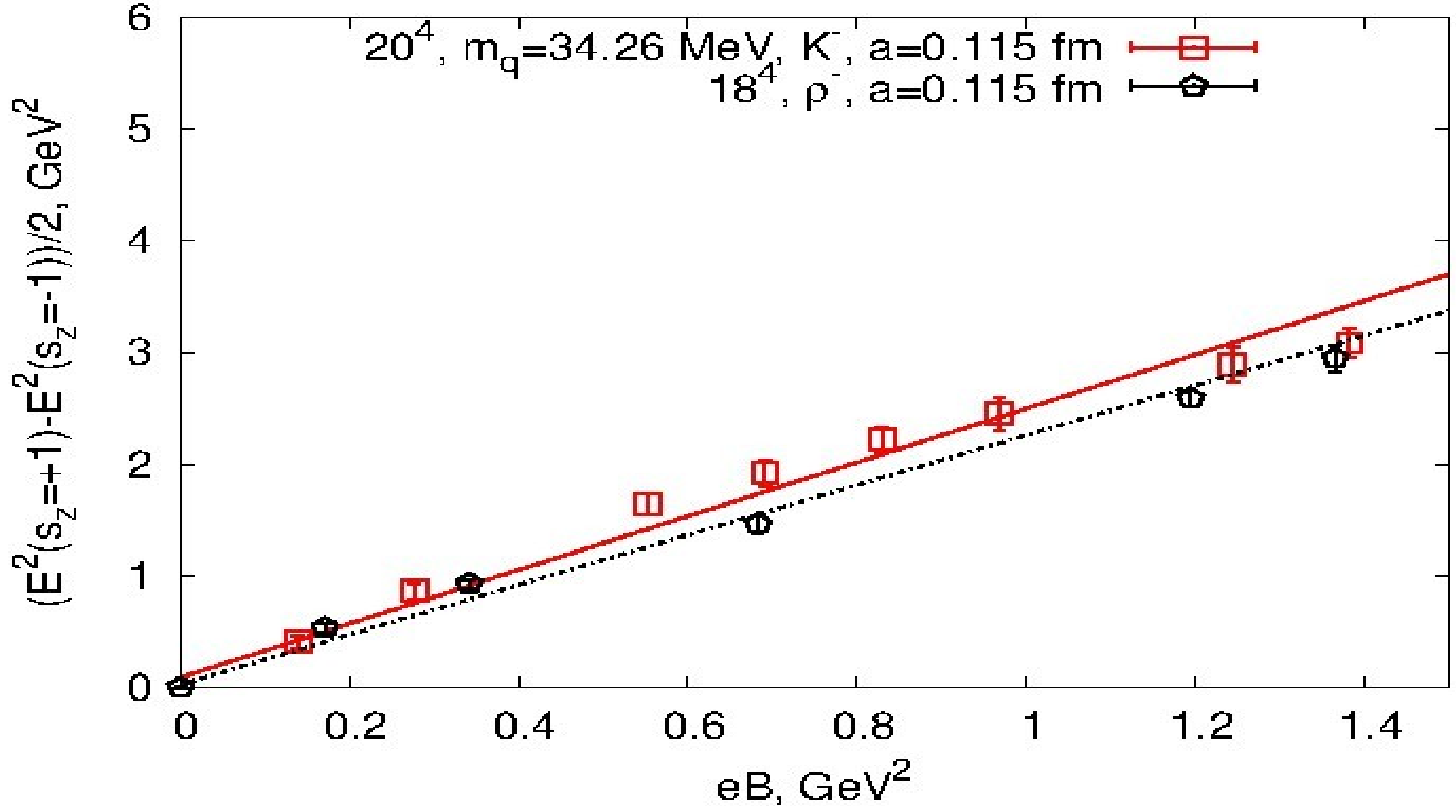


Charged K* meson

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



The g-factor of K* and ρ mesons



$g = 2.41 \pm 0.13$ K* meson

$g = 2.23 \pm 0.12$ **ρ** meson

Conclusions

Magnetic polarizability was found for neutral π and ρ mesons :

$$\beta_m(\pi^0) = (2.14 \pm 1.22) * 10^{-4}\ fm^3\ m_q = 17Mev$$

$$\beta_m(\pi^0) = (2.8 \pm 0.3) * 10^{-4}\ fm^3\ m_q = 25Mev$$

$$\beta_m^{|s|=1}(\rho^0) = (-1.86 \pm 0.18) * 10^{-4}\ fm^3\ m_q = 36Mev$$

Magnetic polarizability depends on spin projections.

g-factor for ρ meson $g = 2.4 \pm 0.2$

Magnetic polarizability was found for charge π mesons

The ground state energy was found for charged, neutral π and ρ and K* mesons

Future works

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

Magnetic moments and polarizabilities of heavy quarkonia

Thank you for your attention!

For more information welcome to arXiv: 1411.4284[hep-lat]

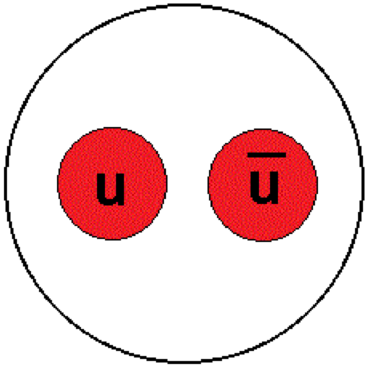
ITEP Lattice

For gauge confiuractions: Symanzik action

$$S = \beta_{imp} \sum_{\rm pl} S_{\rm pl} - \frac{\beta_{imp}}{20 u_0^2} \sum_{\rm rt} S_{\rm rt}$$

$$S_{\rm pl,rt} = \frac{1}{3} {\rm Tr}\,(1 - U_{\rm pl,rt})$$

$$u_0 = (W_{1\times 1})^{1/4} = \langle (1/3) {\rm Tr}\, U_{\rm pl} \rangle^{1/4}$$



$$qB = \frac{2\pi k}{(aL)^2}, \quad k \in \mathbb{Z}$$

$$\sqrt{eB_{min}} = 380 \text{ MeV}$$