V.V. Braguta, P.V. Buividovich, T.K., S.V. Kuznetsov and M.I. Polikarpov. ArXiv:1011.3795 [hep-lat]

CME and chiral symmetry breaking in SU(3) quenched lattice theory

Tigran Kalaydzhyan

Workshop "Chiral magnetic effect and QCD with magnetic fields from the lattice"

December 13 – 15, 2010. Universität Regensburg, Germany

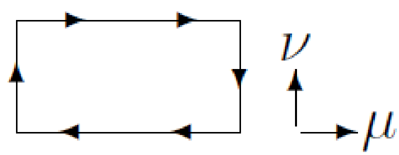
Some effects of the strong magnetic field

- Growing of the chiral condensate
- Vacuum paramagnetic polarization
- Quark electric dipole moment
- Enhancement of the current/charge fluctuations (CME manifestations)
- Conductivity along the field (magnetic field turns the vacuum into an anisotropic conductor)

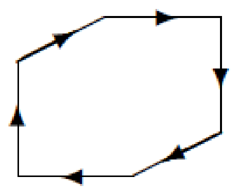
Step 1. The action

$$S = -\beta \sum_{x,\mu>\nu} \left\{ \frac{5}{3}\frac{P_{\mu\nu}}{u_0^4} - r_{\rm g} \frac{R_{\mu\nu}+R_{\nu\mu}}{12\, u_0^6} \right\} + c_{\rm g}\, \beta \sum_{x,\mu>\nu>\sigma} \frac{C_{\mu\nu\sigma}}{u_0^6},$$

$$R_{\mu\nu} = \frac{1}{3}\mathrm{Re\,Tr}$$



$$C_{\mu\nu\sigma} \equiv \frac{1}{3}\mathrm{Re\ Tr}$$



$$r_{\rm g} = 1 + .48\, \alpha_s(\pi/a)$$
$$c_{\rm g} = .055\, \alpha_s(\pi/a)$$

Lüscher and Weisz (1985), see also
Lepage hep-lat/9607076

Step 2. Monte Carlo for SU(3)

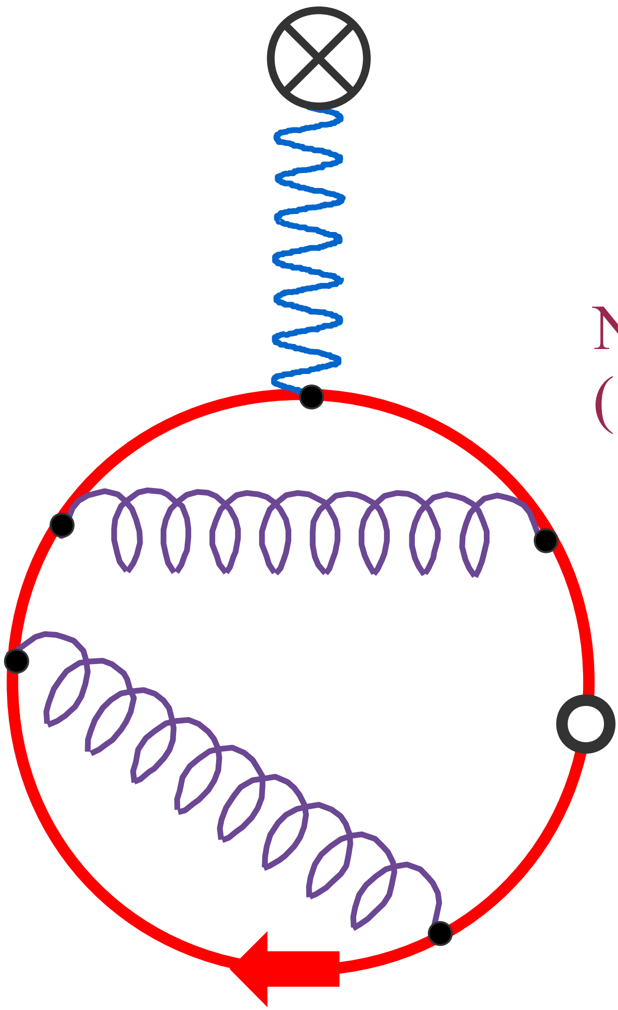
- Heat bath for SU(2)

- Using the standard algorithm for each subgroup. Cabibbo & Marinari (1982)

$$a_1 = \begin{pmatrix} \alpha_1 & \\ & 1 \end{pmatrix} \qquad a_2 = \begin{pmatrix} 1 & \\ & \alpha_2 \end{pmatrix} \qquad a_3 = \begin{pmatrix} \alpha_{11} & & \alpha_{12} \\ & 1 & \\ \alpha_{21} & & \alpha_{22} \end{pmatrix}$$

- Over-relaxation method. Adler (1981)

Step 3. Fermions and Ext. Field



$$D_{ov}(0) = \frac{1}{a}\left(1 - A\left(A^\dagger A\right)^{-1/2}\right)$$

$$A = 1 - aD_W(0)$$

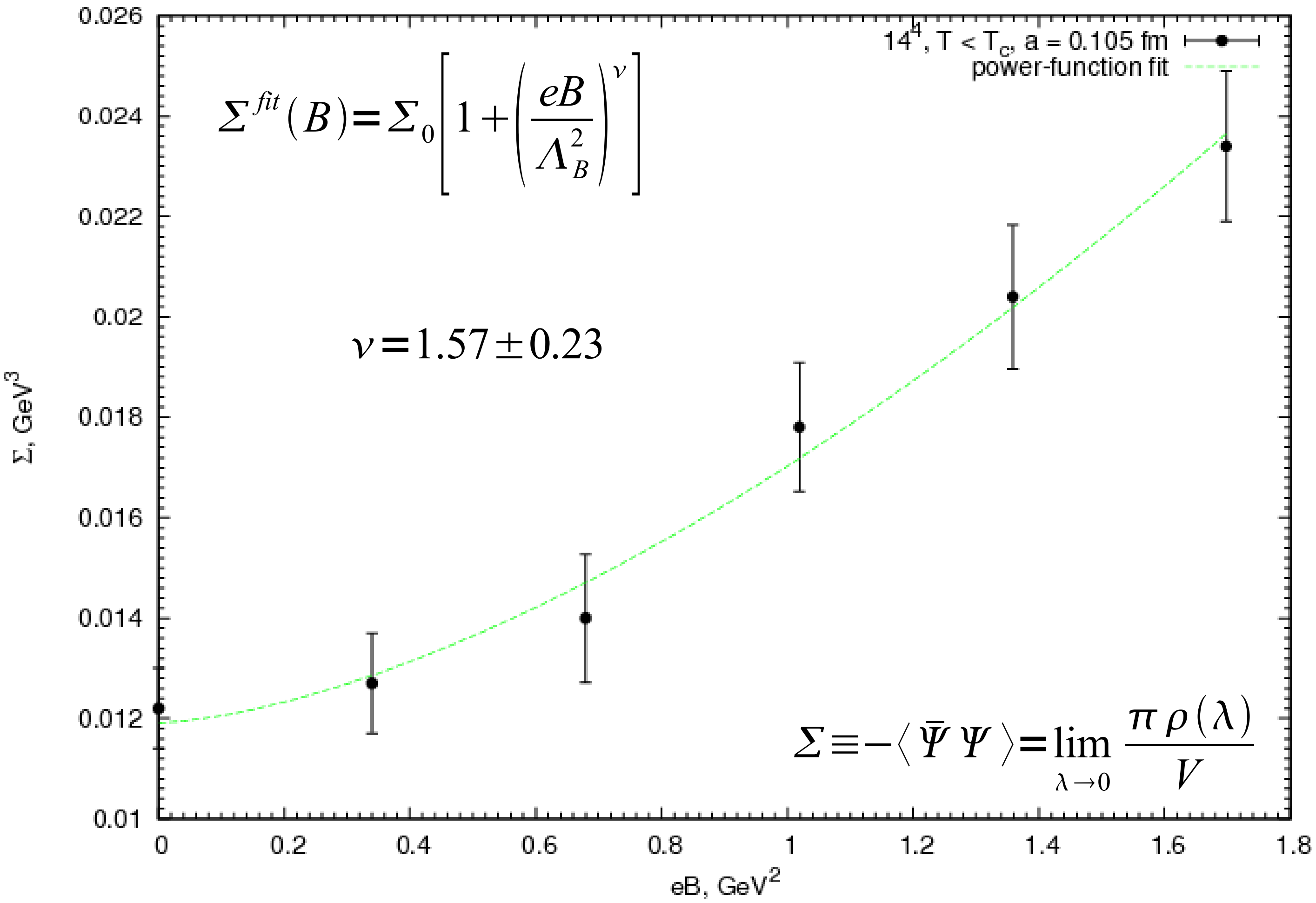
Neuberger overlap operator (1998)

$$\langle \bar{\Psi}\hat{\Gamma}\Psi\rangle \sim Tr[\hat{\Gamma} D_{ov}^{-1}]$$

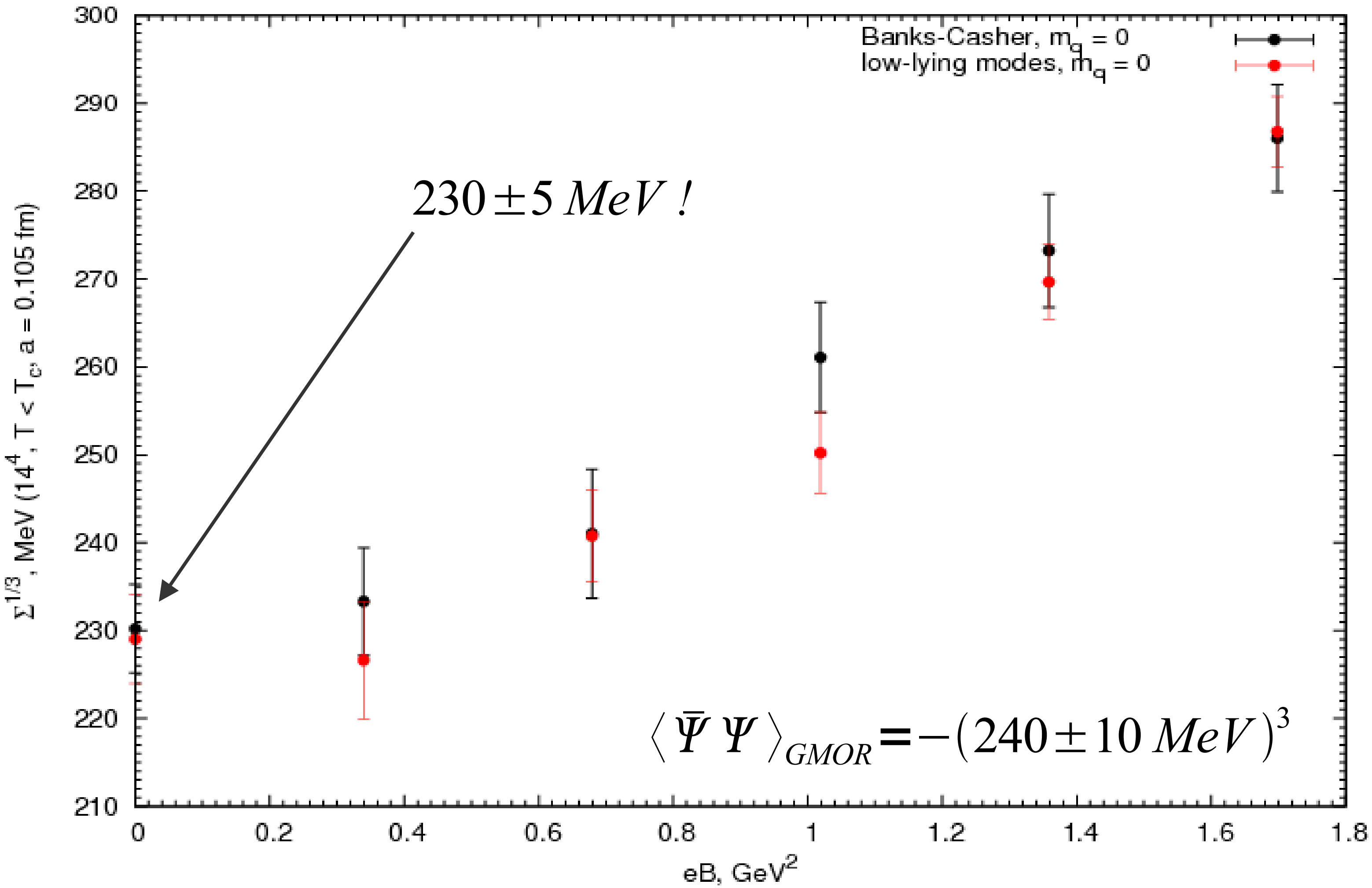
$$\hat{\Gamma} \in \{1, \gamma^5, \gamma^\mu, \sigma_{\mu\nu} \dots\}$$

ArXiv: 0907.0494

Chiral Condensate



Chiral Condensate (MeV)



Magnetization & Polarization

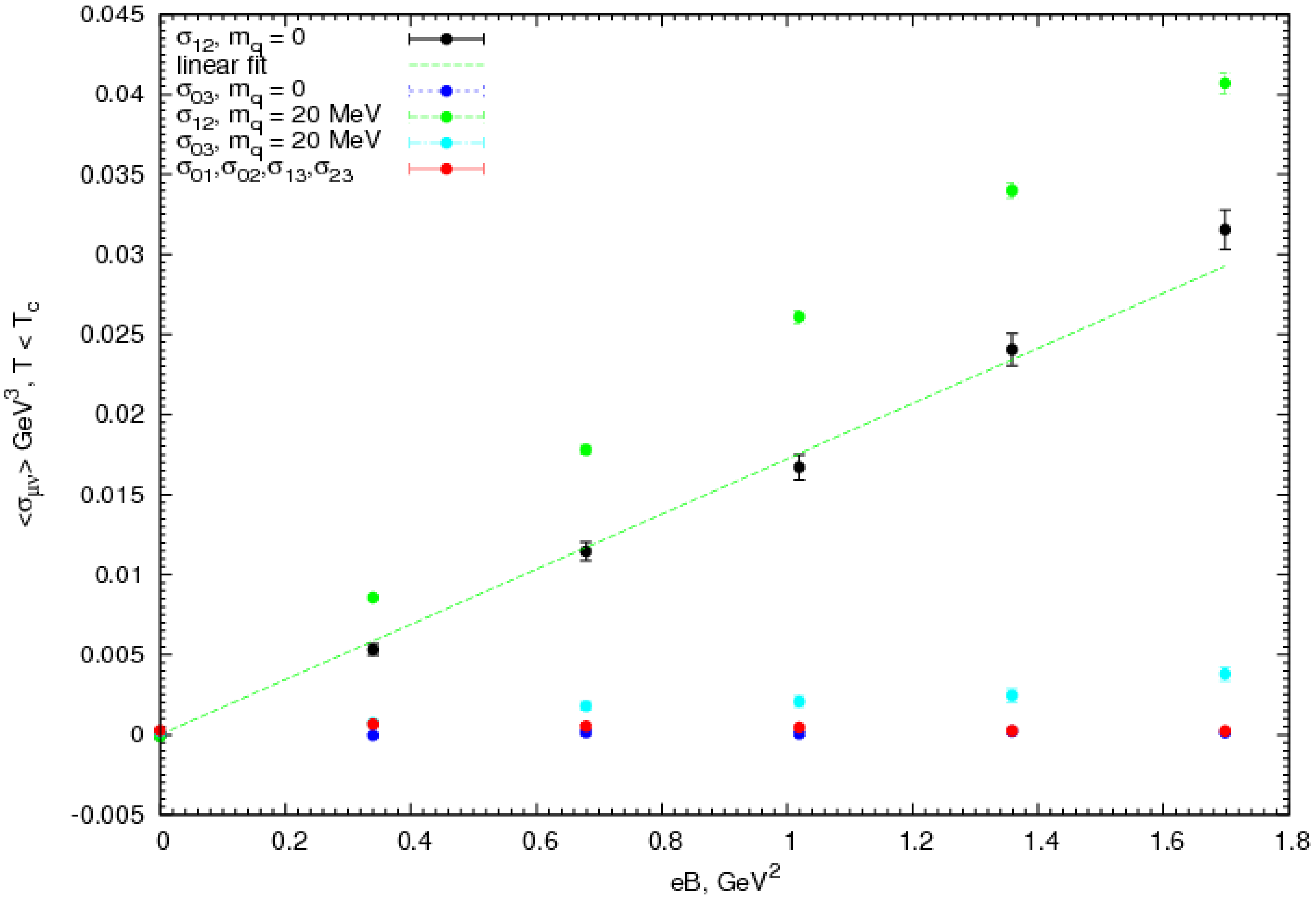
$$\langle \bar{\Psi} \sigma_{\mu\nu} \Psi \rangle = \chi \langle \bar{\Psi} \Psi \rangle q F_{\mu\nu}$$

$$\langle \bar{\Psi} \sigma_{12} \Psi \rangle = \mu_z (qB) \langle \bar{\Psi} \Psi \rangle$$

$$\langle \bar{\Psi} \sigma_{03} \Psi \rangle = \epsilon_z (qB) \langle \bar{\Psi} \Psi \rangle$$

arXiv: 0909.2350
arXiv: 0906.0488

Magnetization



Magnetization & Susceptibility

$$-\chi\langle\bar{\Psi}\Psi\rangle_{our}=52\,MeV$$

arXiv: hep-ph/0207307
Ball, Braun, Kivel(2003)

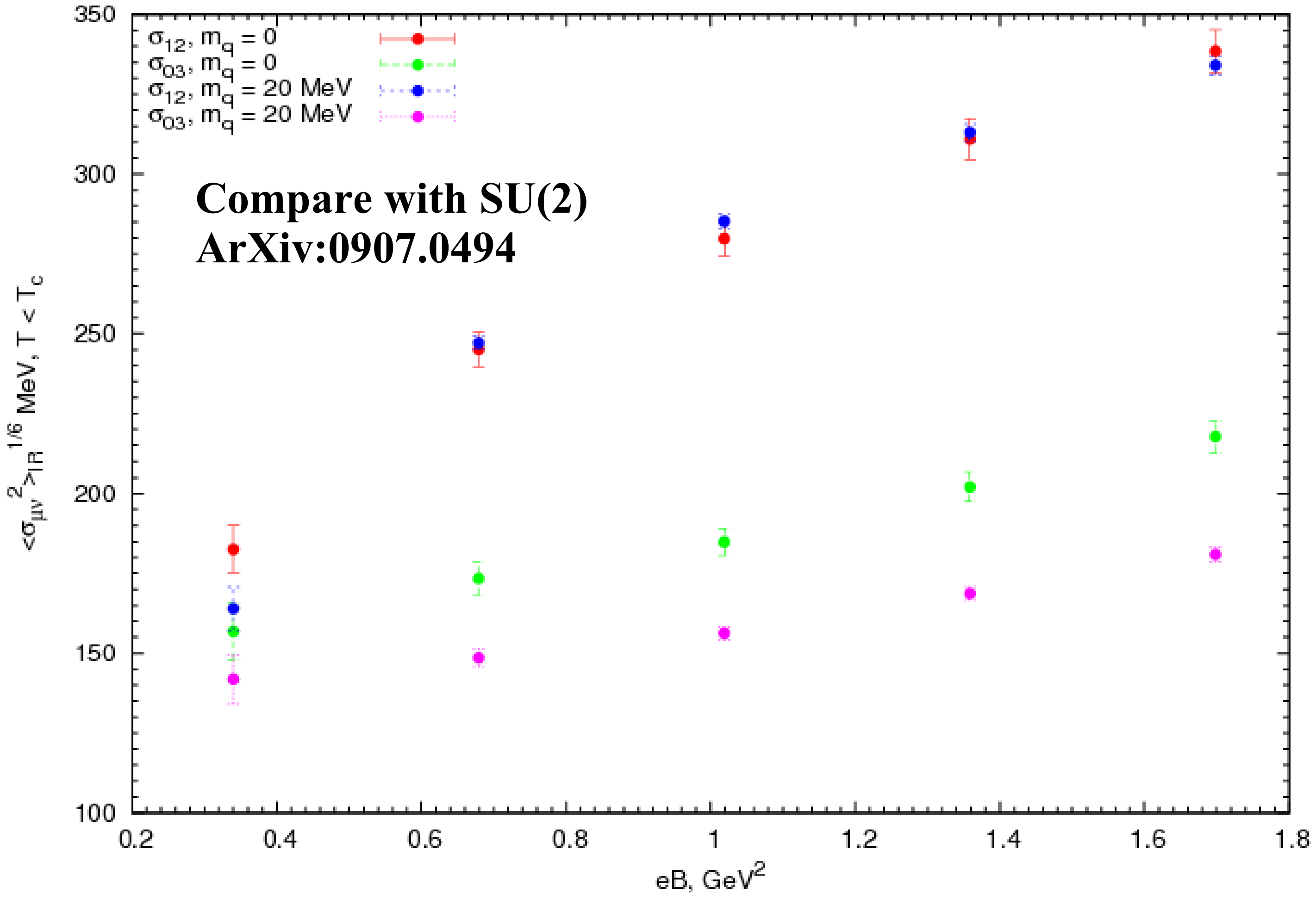
$$-\chi\langle\bar{\Psi}\Psi\rangle_{SumRules}\simeq 50\,MeV$$

$$\chi_{our}(T=0)=-4.24\,GeV^{-2}$$

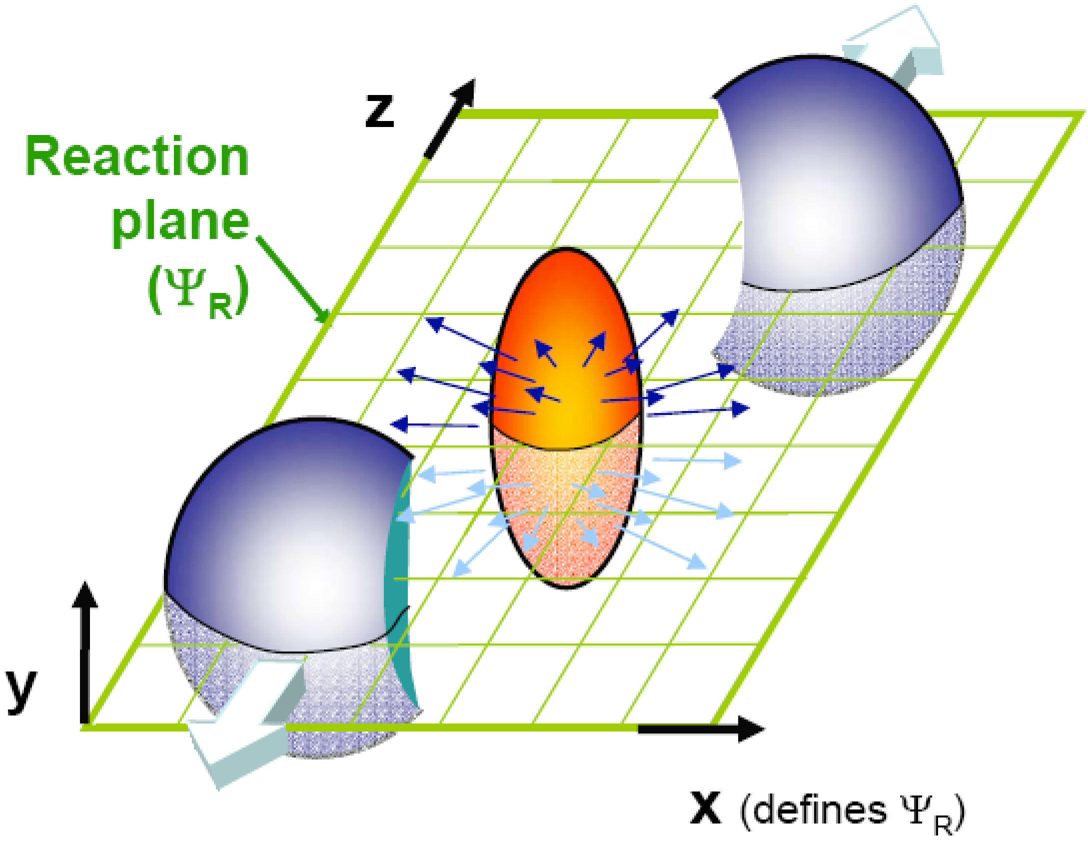
arXiv: hep-ph/0212231
Vainstein (2003)

$$\chi_{th}=-\frac{c_\chi N_c}{8\pi^2 f_\pi^2}=-4.46\,GeV^{-2}$$

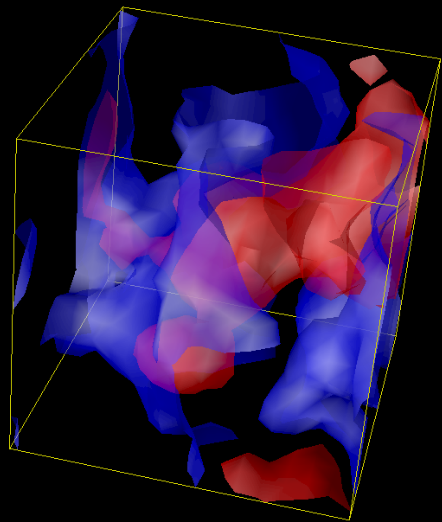
Magnetization fluctuations (T<Tc)

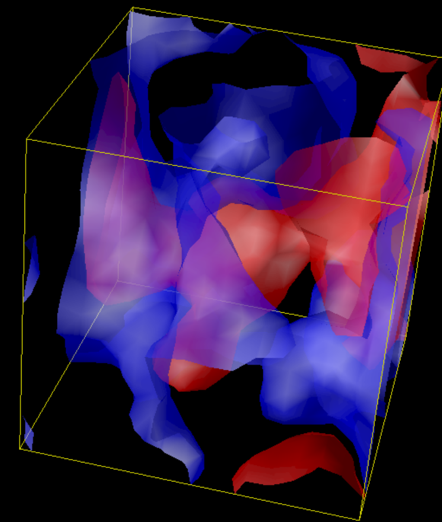


Chiral Magnetic Effect



ArXiv:0711.0950

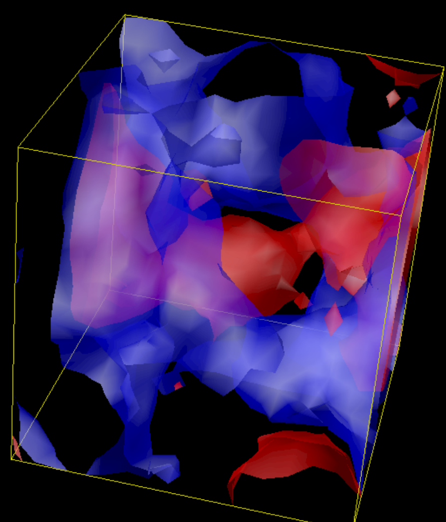


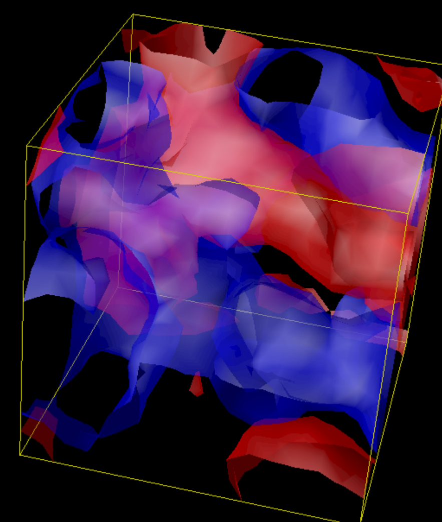


Negative topological charge density

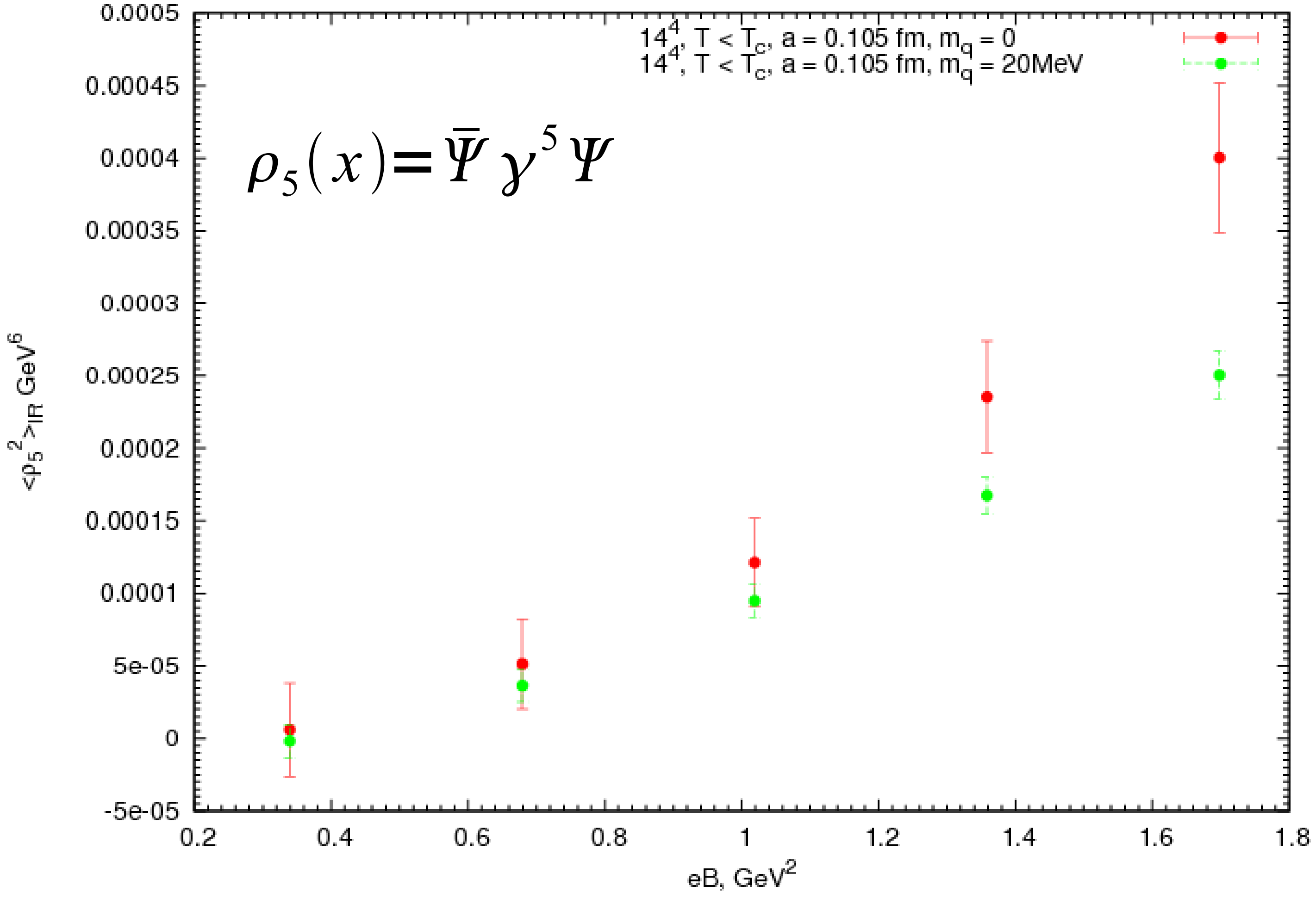
QCD Vacuum

Positive topological charge density

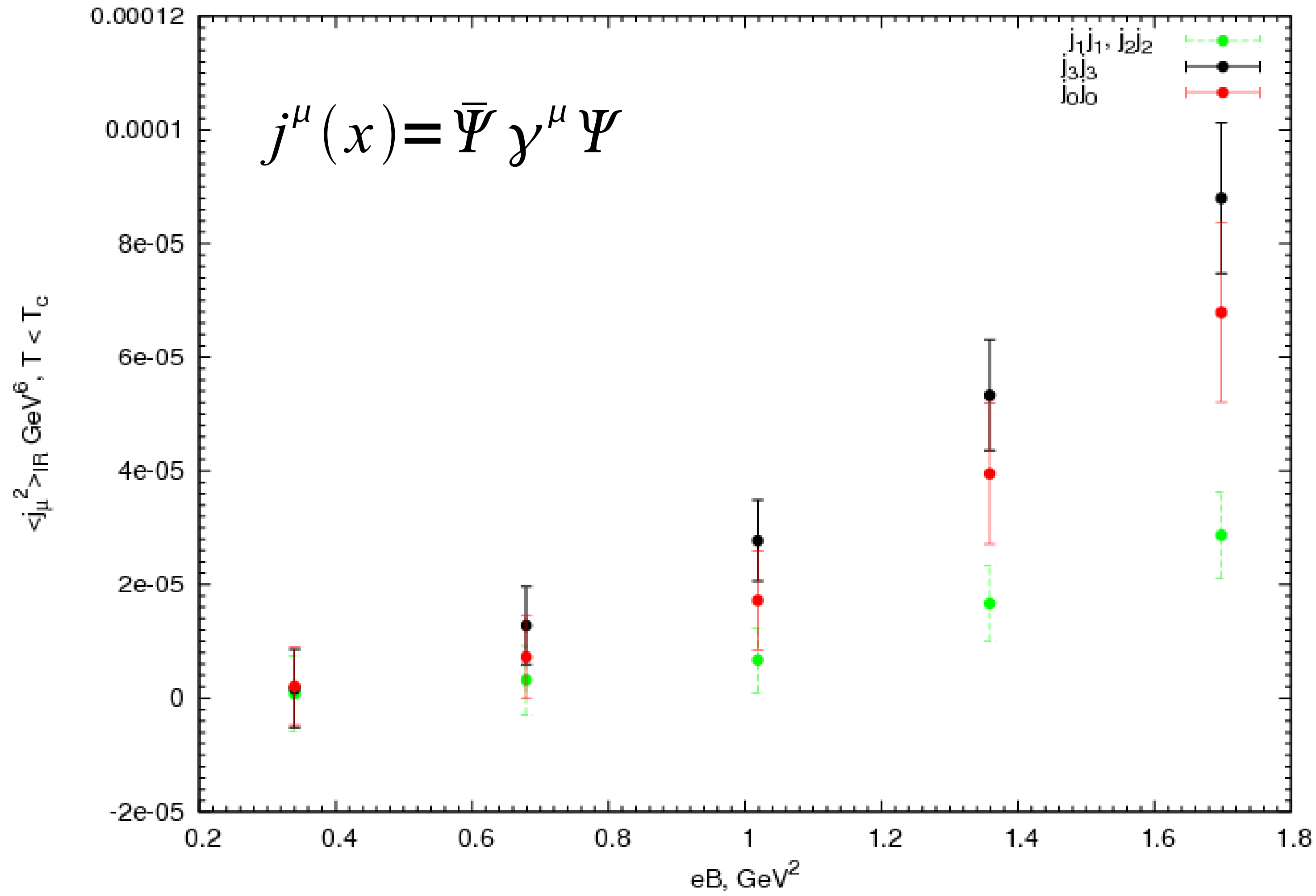




Chirality fluctuations (T<Tc)



Current fluctuations (T<Tc)

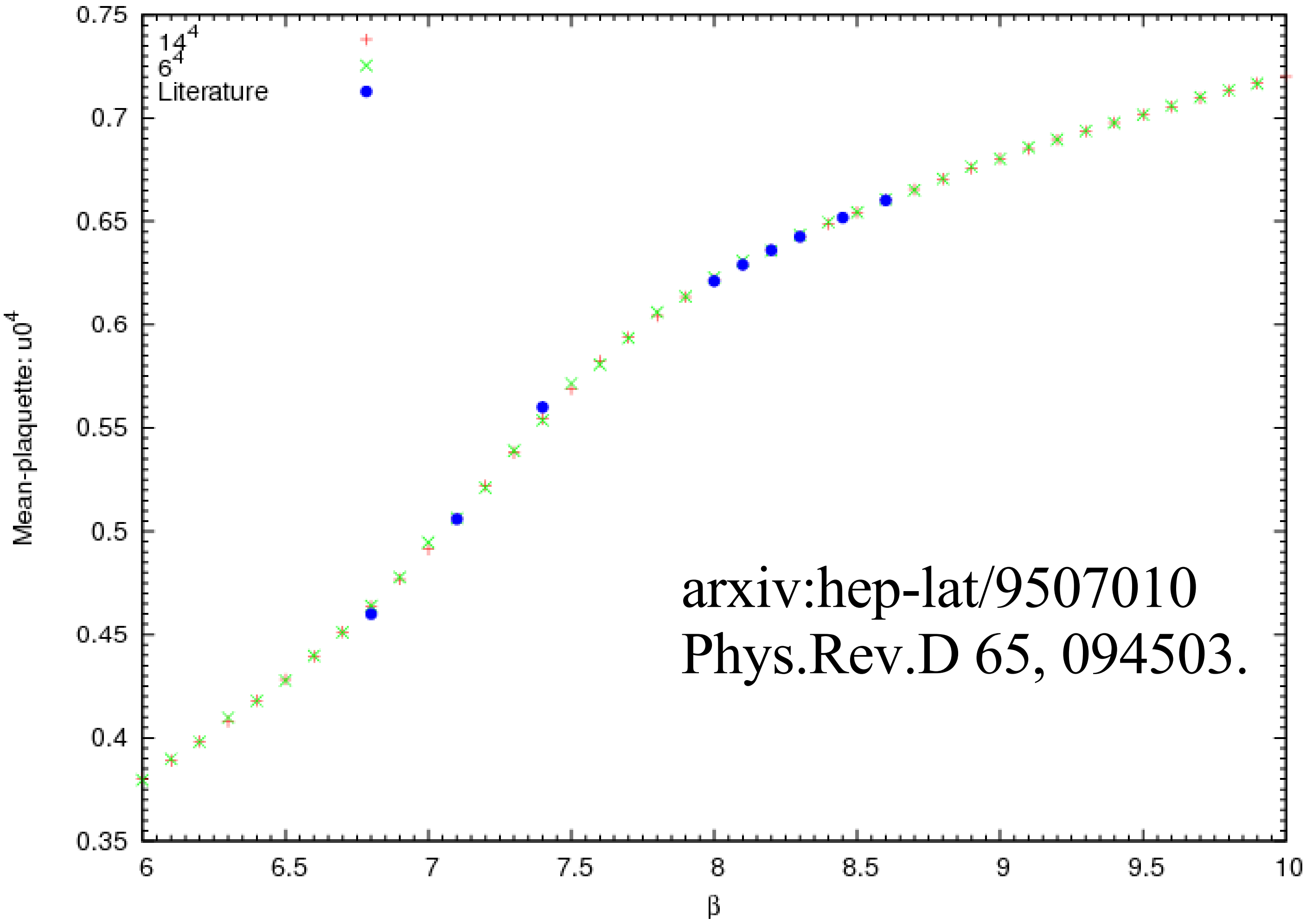


Thank you for the attention!

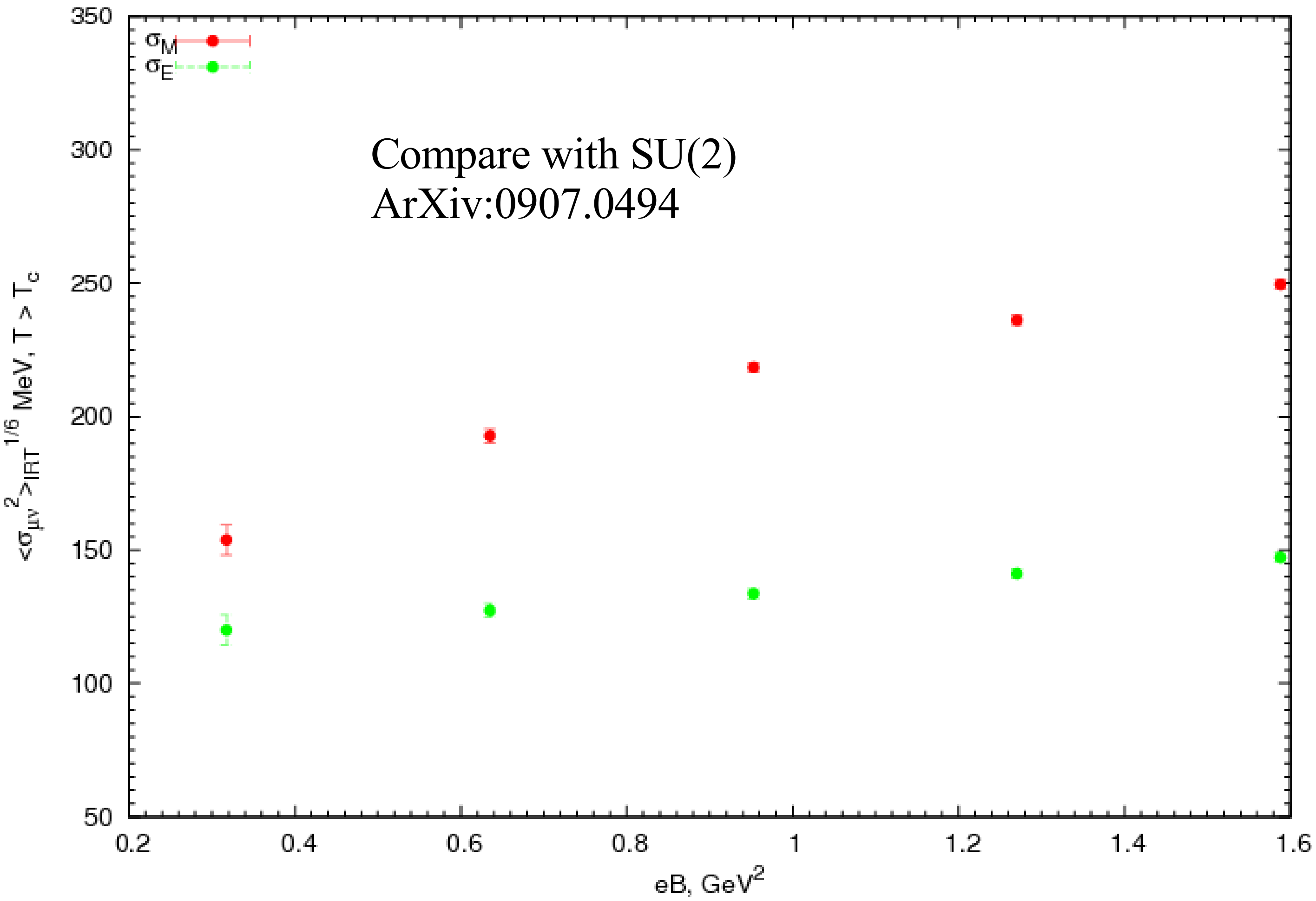
and

Have a good time!

Appendix. Testing Monte Carlo



Appendix. Magnetization fluctuations ($T>T_c$)



Appendix. Current fluctuations ($T>T_c$)