The Chiral Magnetic Effect and symmetry breaking in SU(3) quenched theory

V. Braguta, P. Buividovich,
T. Kalaydzhyan, S. Kuznetsov,
M. Polikarpov

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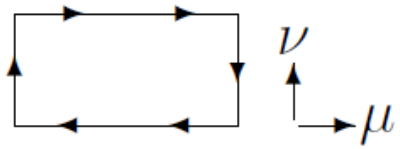
Some effects of the strong magnetic field

- Growing of the chiral condensate
- Vacuum magnetization
- Enhancement of the current/charge fluctuations (CME evidences)
- Quark electric dipole moment
- Conductivity induced along the field (P.Buividovich presentation tomorrow!)

Step 1. The action

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

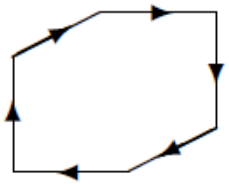
$$R_{\mu\nu} = \frac{1}{3} \mathrm{Re\,Tr}$$



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

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

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



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

Step 2. Monte Carlo

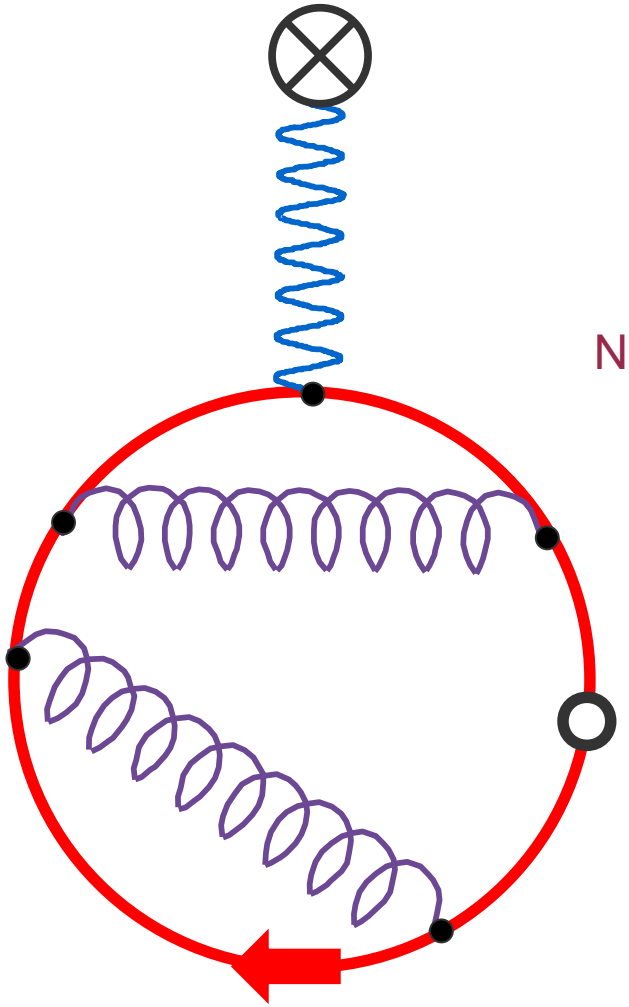
- Heat bath for SU(2)

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

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

- Overrelaxation. Adler (1981)

Step 3. Fermions and Ext.Field



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

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

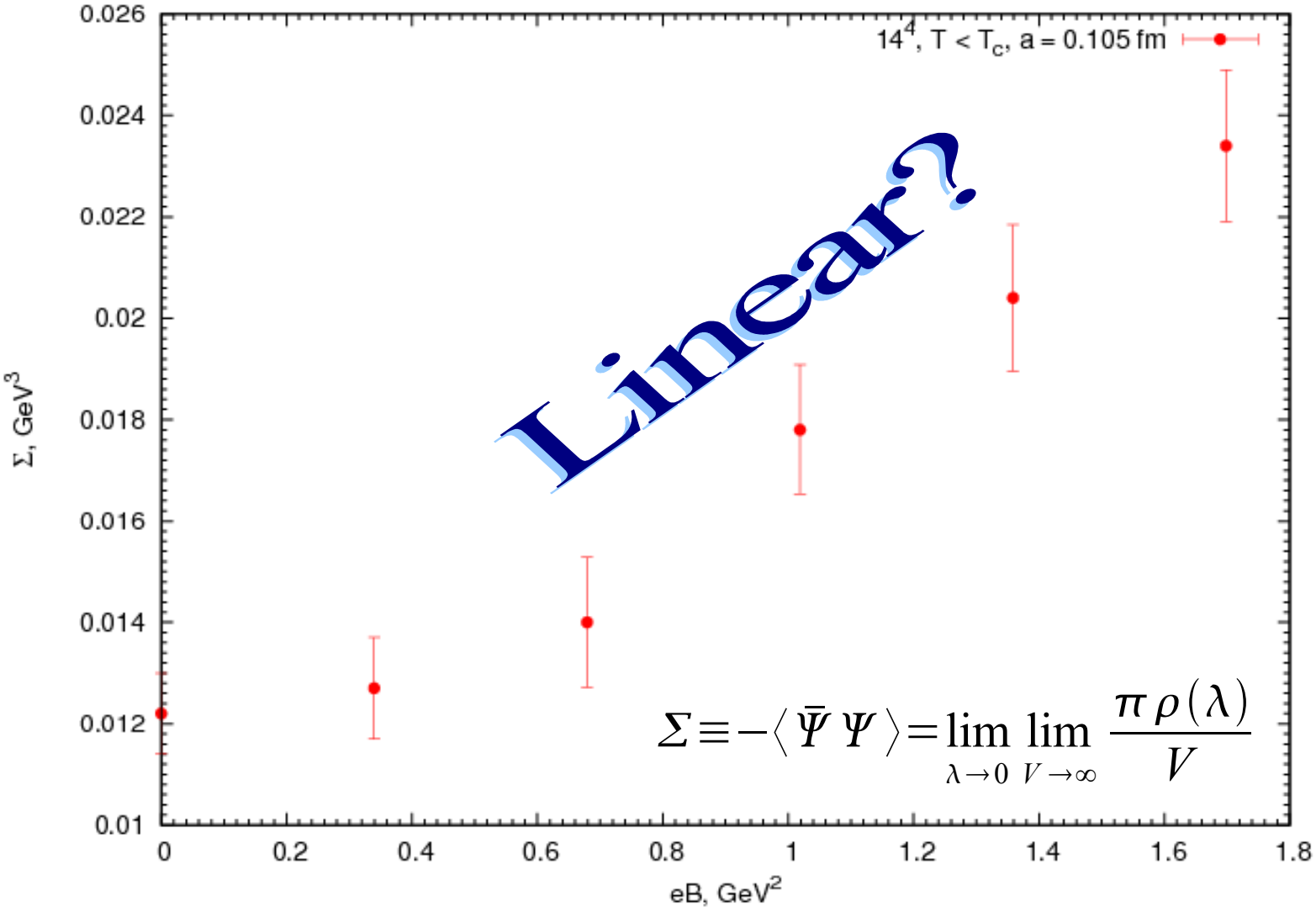
Neuberger overlap operator (1998)

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

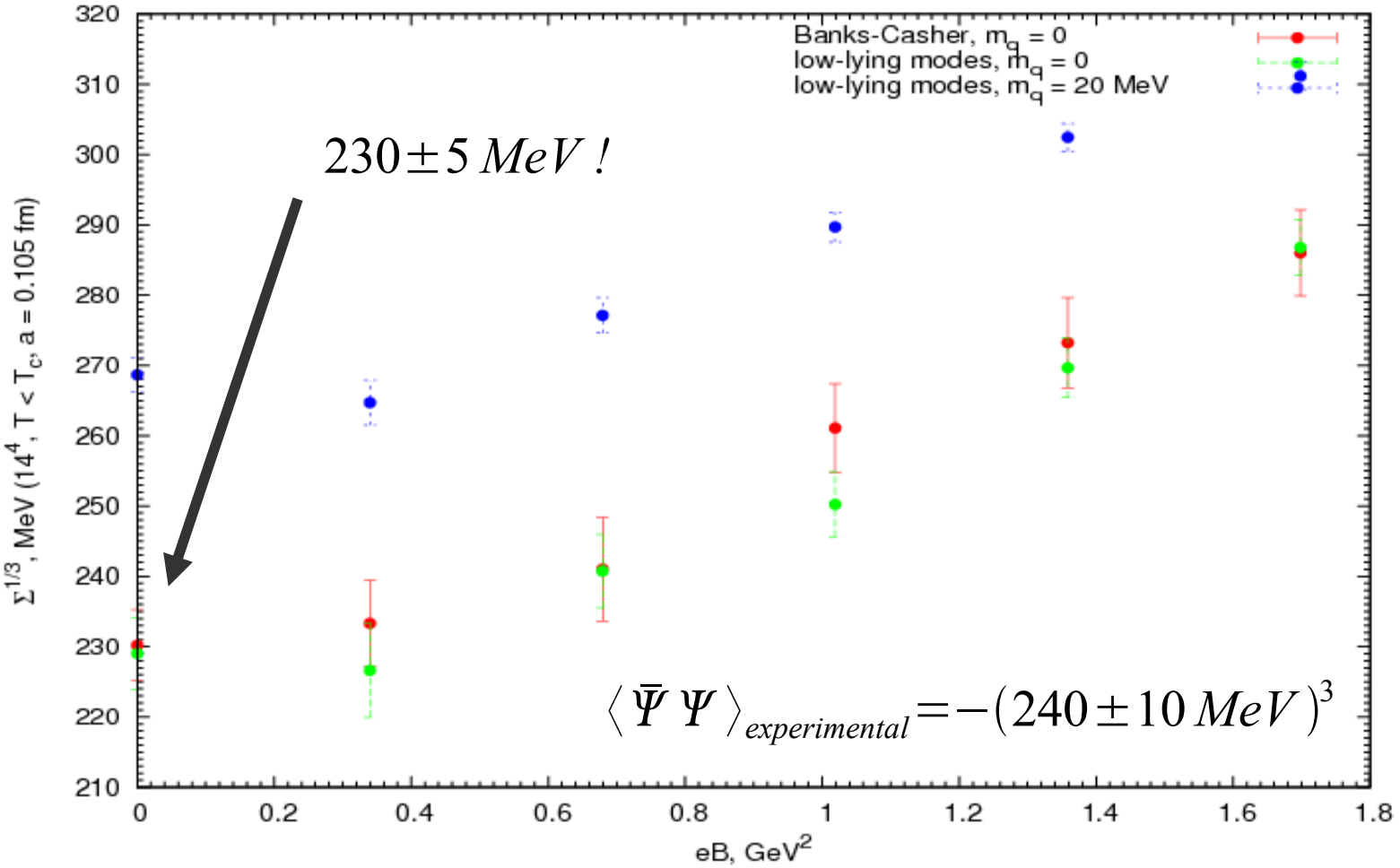
$$\hat{\Gamma} \in \left\{1, \gamma^5, \gamma^{\mu}, \sigma_{\mu\nu} \ldots\right\}$$

ArXiv:0907.0494

Chiral Condensate



Chiral Condensate (MeV)



Magnetization & Polarization

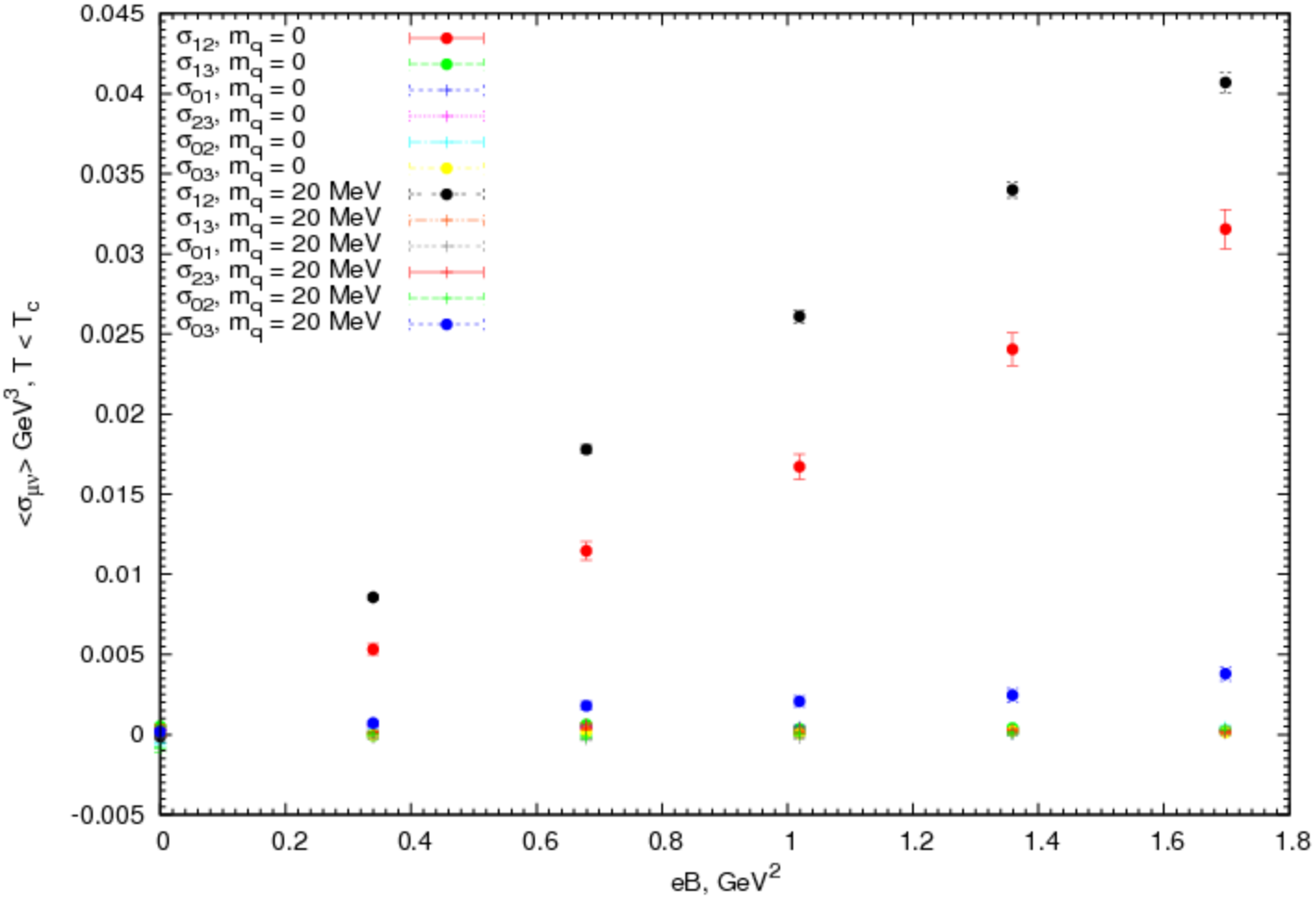
$$\langle \bar{\Psi}\, \sigma_{\mu\nu} \Psi \rangle = \chi \langle \bar{\Psi}\, \Psi \rangle\, q\, F_{\mu\nu}$$

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

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

ArXiv:0909.2350
ArXiv:0906.0488

Magnetization



Magnetization & Susceptibility

$$-\chi\langle\bar{\Psi}\Psi\rangle_{our}=55.2\,MeV$$

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

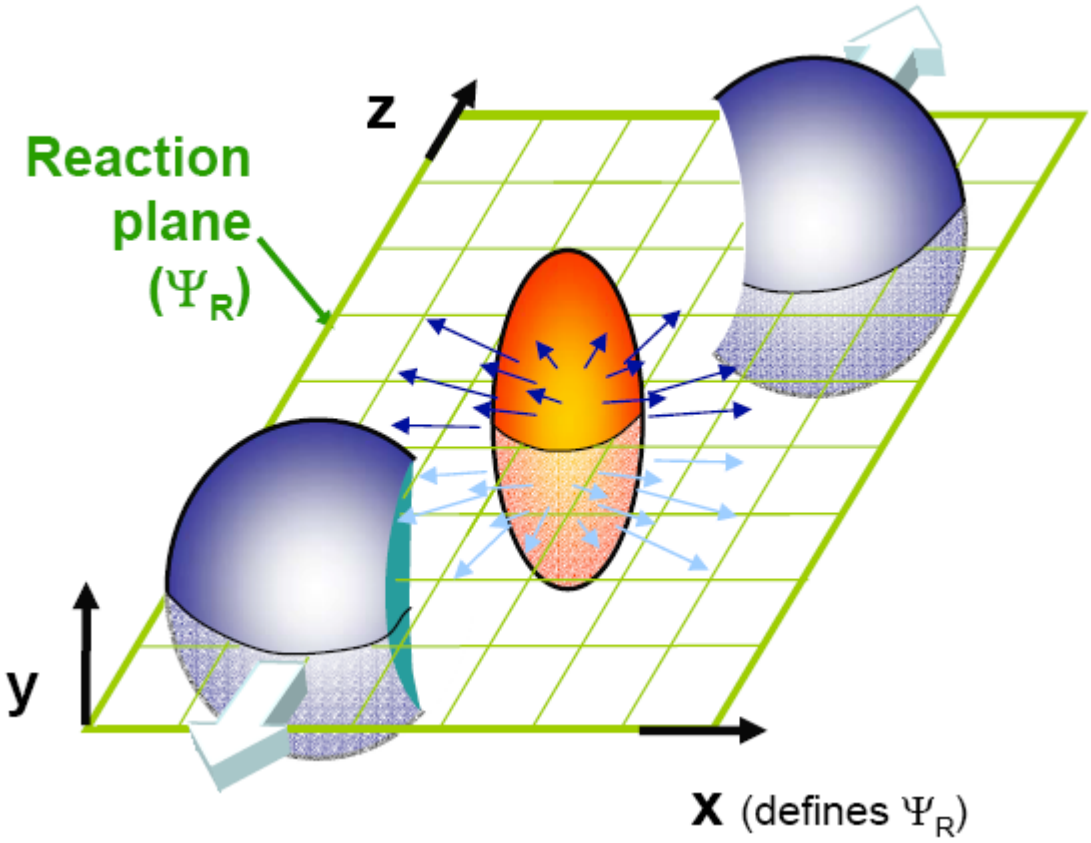
ArXiv:hep-ph/0207307
Ball, Braun, Kivel(2003)

$$\chi_{our}(T=0)=-4.6\,GeV^{-2}$$

ArXiv:hep-ph/0212231
Vainstein (2003)

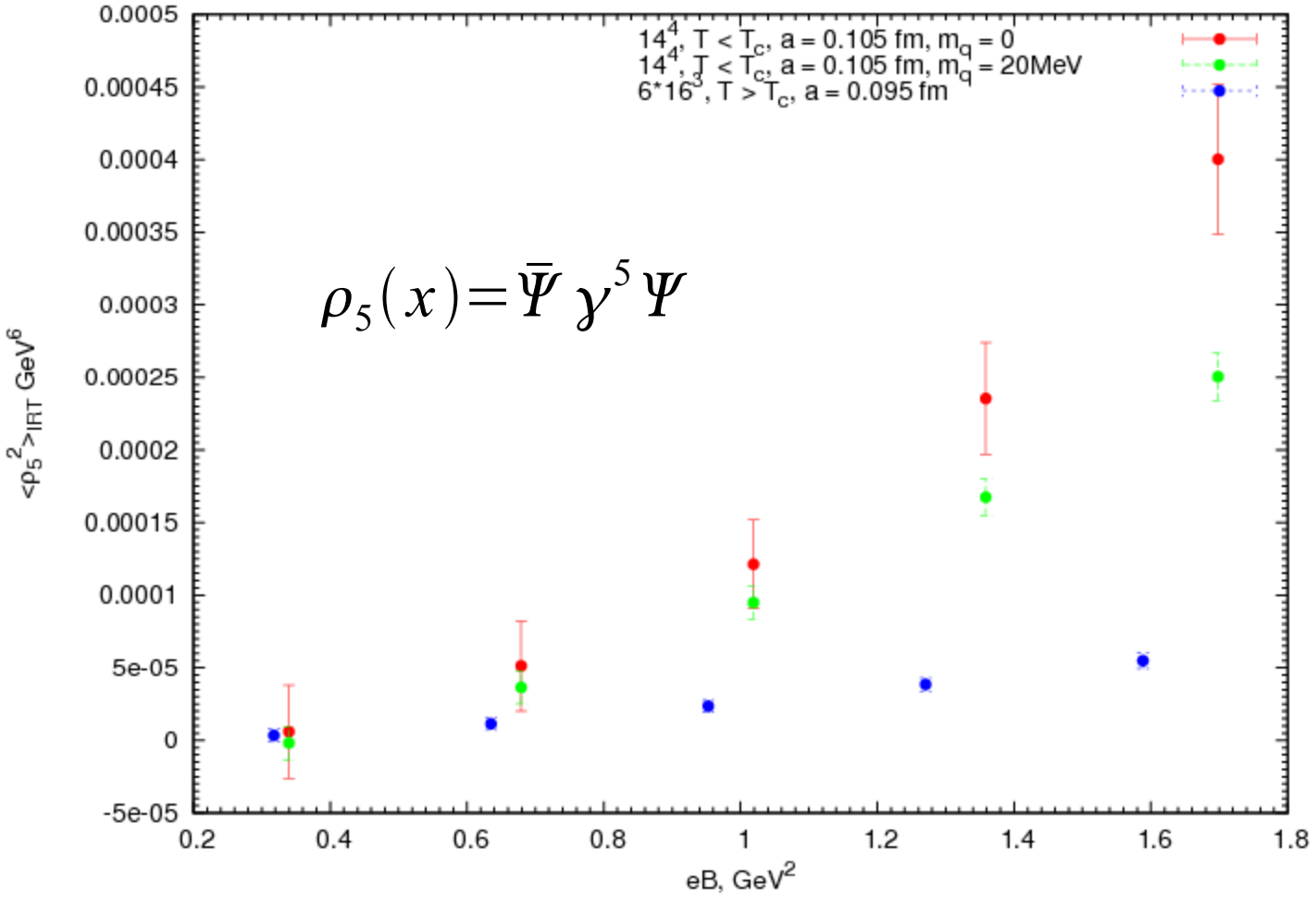
$$\chi_{th}=-\frac{c_\chi N_c}{8\pi^2 f_\pi^2}=-4.5\,GeV^{-2}$$

Chiral Magnetic Effect

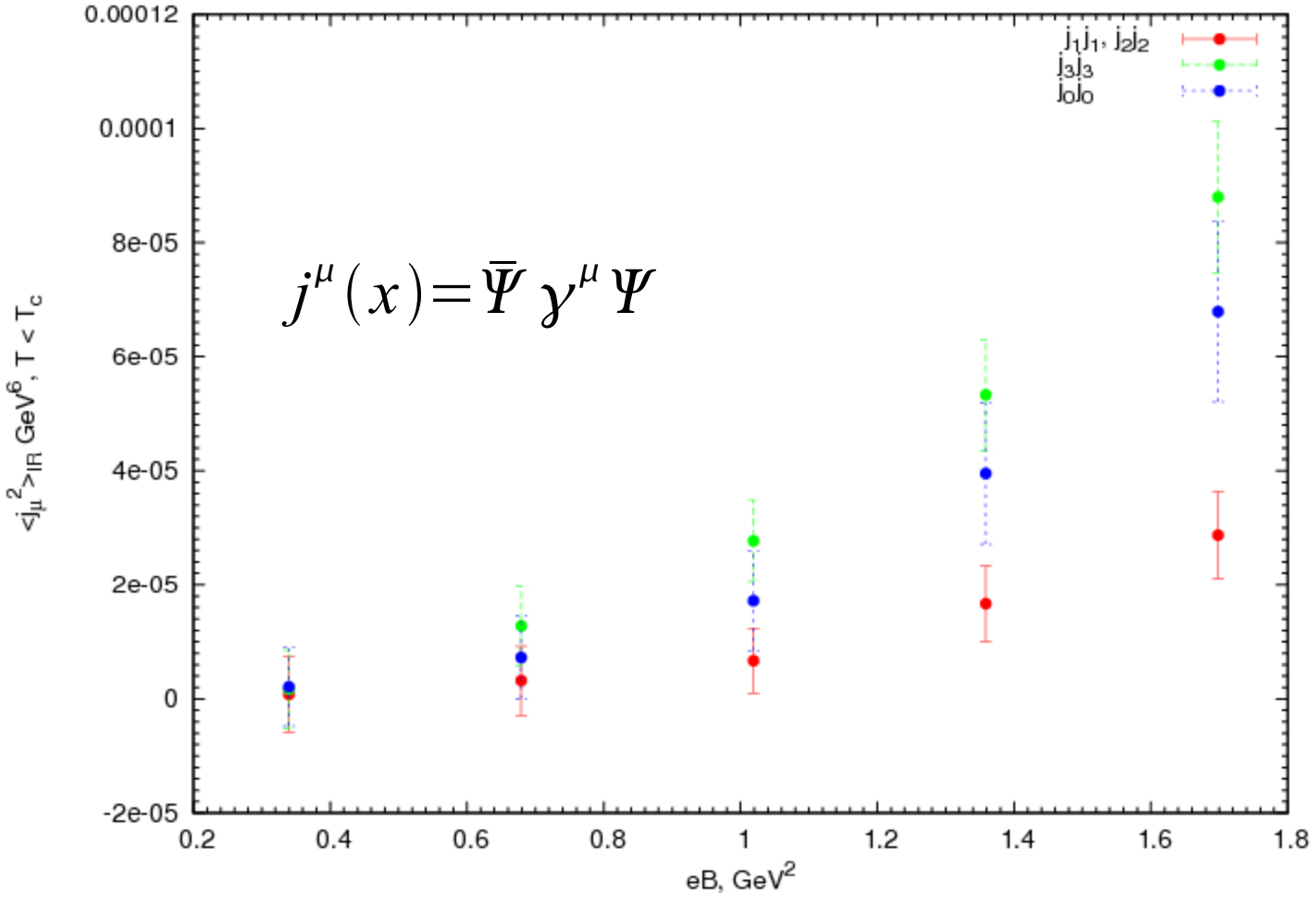


ArXiv:0711.0950

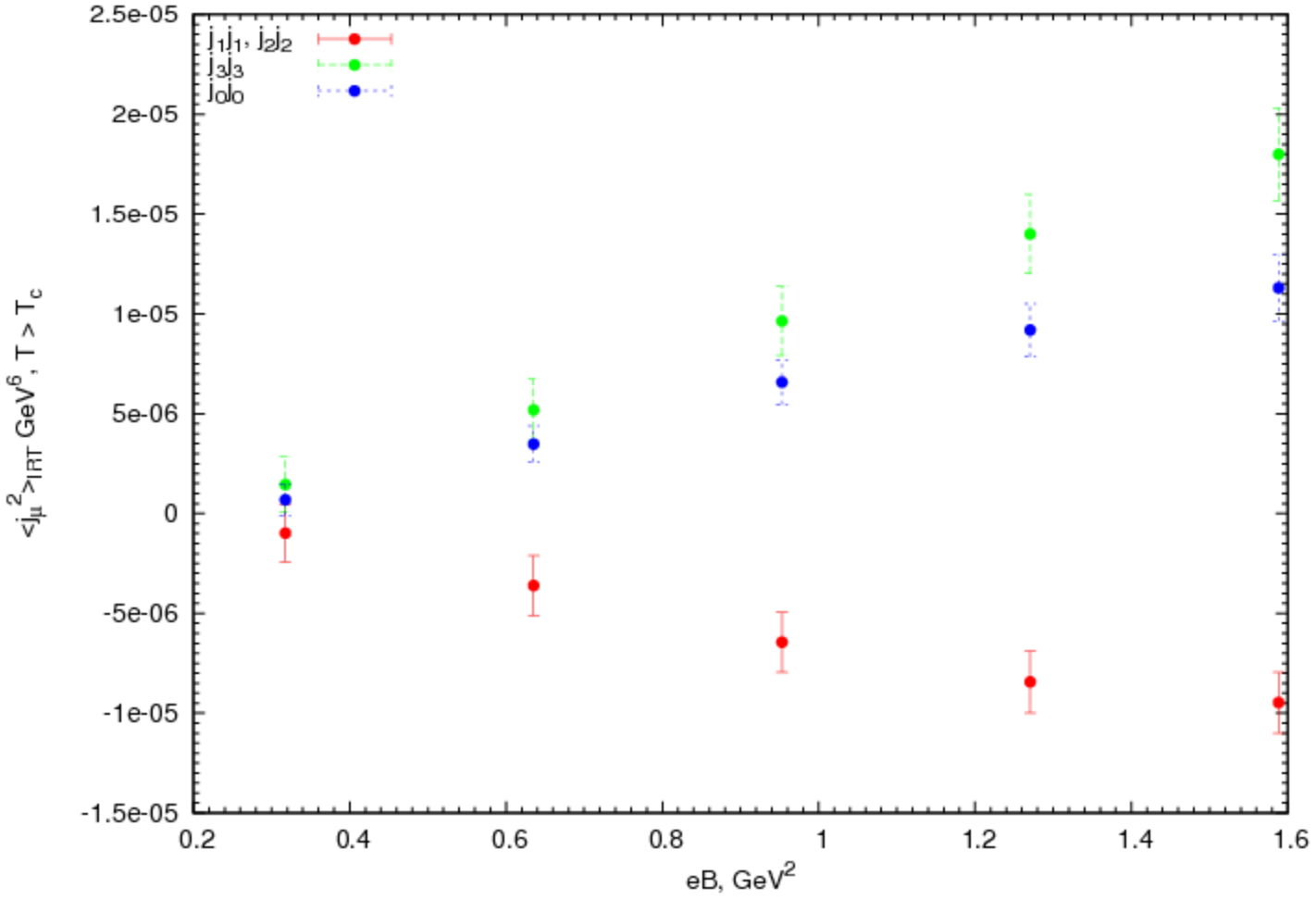
Chirality fluctuations



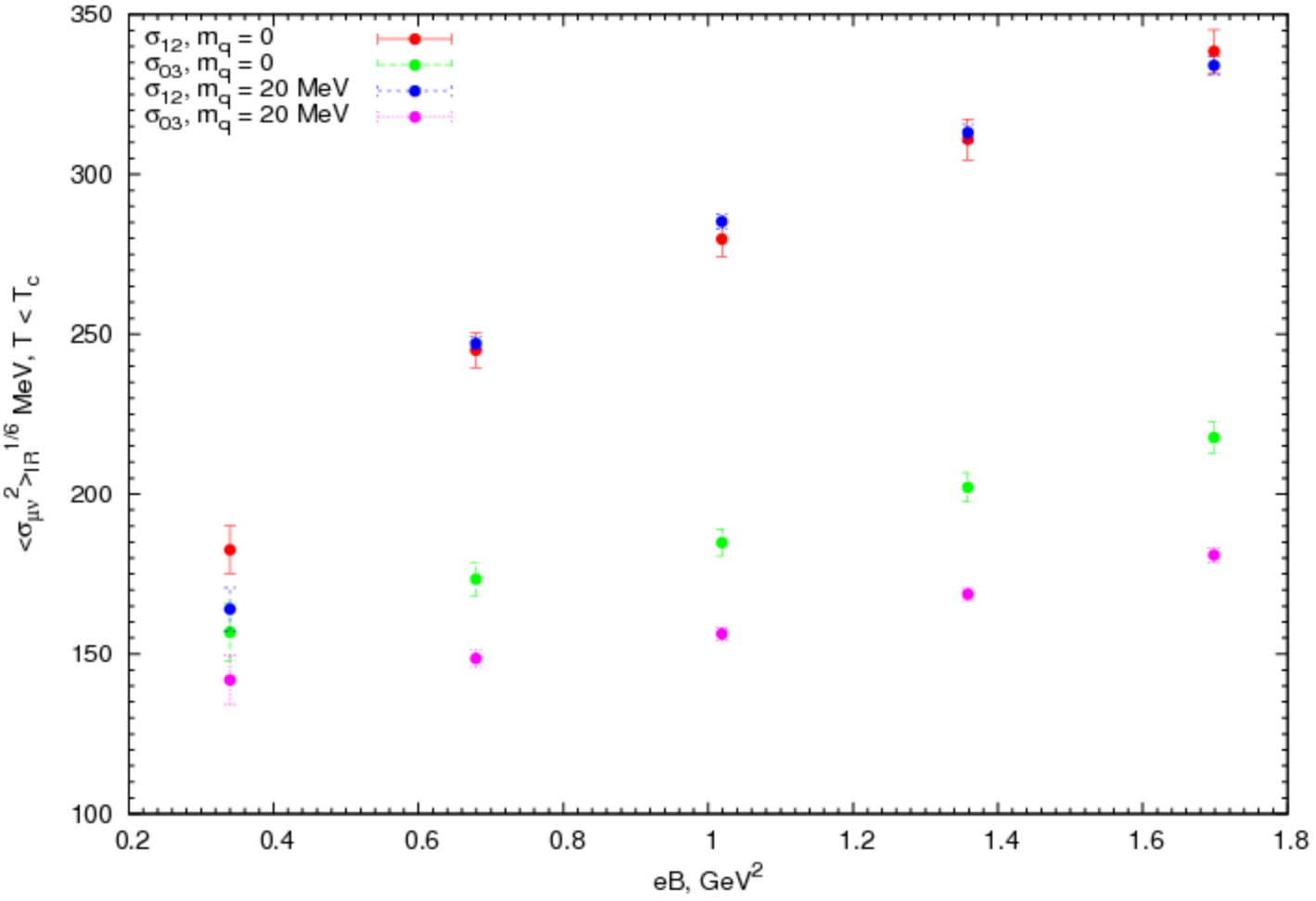
Current fluctuations ($T<T_c$)



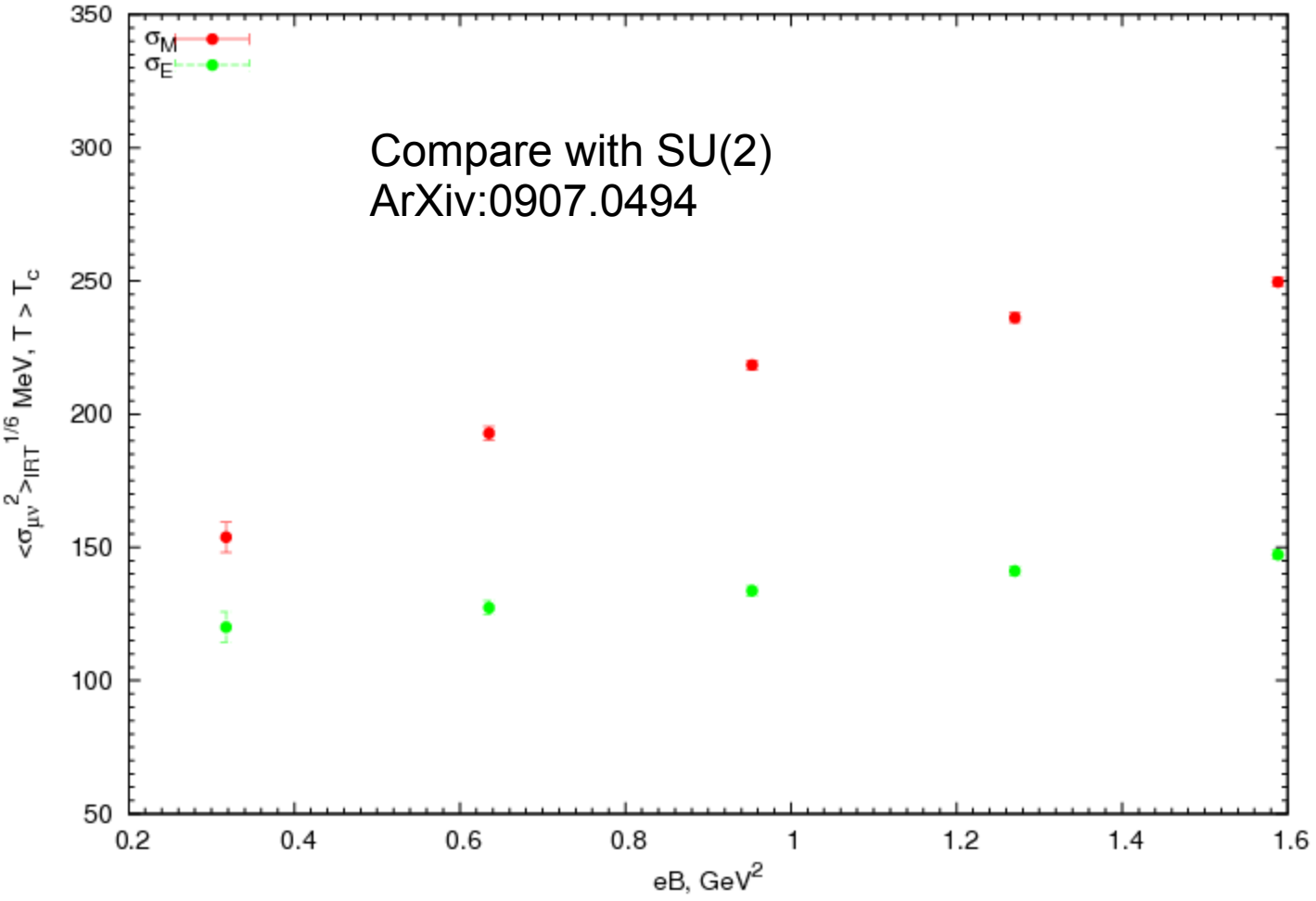
Current fluctuations ($T>T_c$)



Magnetization fluctuations ($T<T_c$)



Magnetization fluctuations ($T>T_c$)



Thank you for the attention!
and
Have a good time!

Appendix. Testing Monte Carlo