Study of axial magnetic effect

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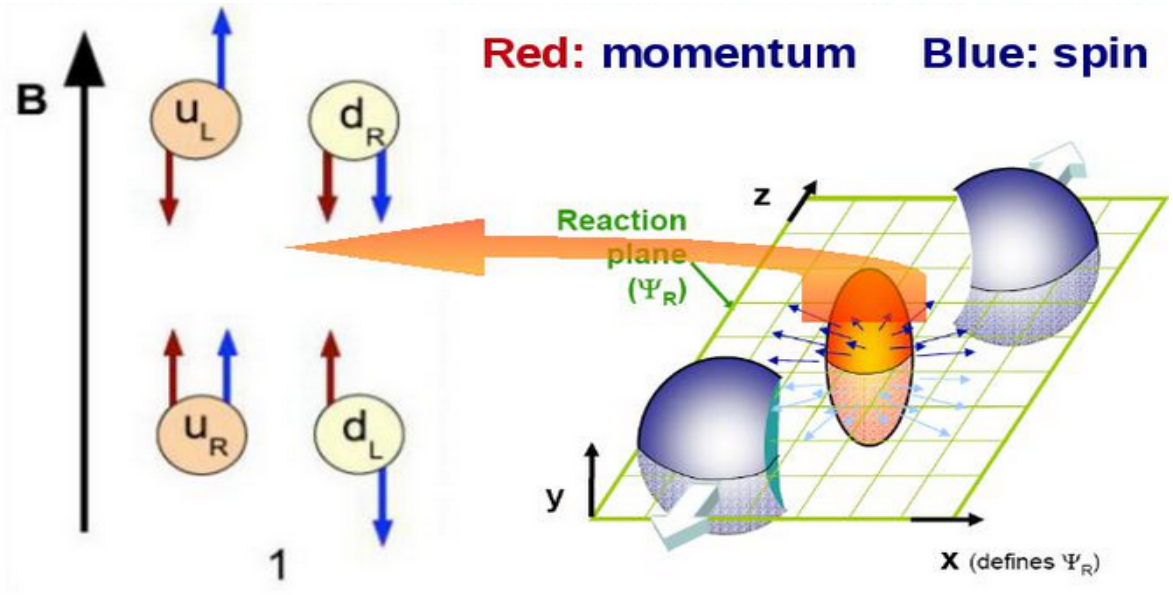
Outline:

- Introduction
- Observation of axial magnetic effect
- Temperature dependence of axial magnetic effect
- Conclusion



Chiral magnetic effect

- Topological charge($n_R \neq n_L$) + magnetic field $\Rightarrow$ chiral magnetic effect (D. Kharzeev, L. McLerran, H. Warringa, NPA 803 ('08) 227)
- Related to axial anomaly
- $J_V = \sigma_{AV} H$ can be studied experimentaly (observed at RHIC and LHC, STAR Collaboration Phys.Rev.Lett. 103 (2009) 251601, ...)

Anomalous transport

- Chiral magnetic effect: $J_V = \sigma_{VV} H, \quad \sigma_{VV} = \frac{\mu_5}{2\pi^2}$
- Axial chiral magnetic effect: $J_A = \sigma_{AV} H, \quad \sigma_{AV} = \frac{\mu}{2\pi^2}$
- Chiral vortical effect: $J_V = \sigma_V \omega, \quad \sigma_V = \frac{\mu_5 \mu}{2\pi^2}$
- Axial chiral vortical effect: $J_A = \sigma_A \omega, \quad \sigma_A = \frac{\mu^2 + \mu_5^2}{4\pi^2} + \frac{T^2}{12}$

Why anomalous transport phenomena are so interesting?

- Can be seen in current heavy ion collision experiments
- Related to the first principles of quantum field theory (anomalies)
- Non-dissipative phenomena

Axial chiral vortical effect:

One can carry out the simulations at $\mu = 0, \ \mu_5 = 0$

Axial chiral vortical effect:

Axial chiral vortical effect: $J_A = \sigma_A \omega, \quad \sigma_A = \frac{T^2}{12} \; (\mu = \mu_A = 0)$

Axial magnetic effect:

- $L = \bar{\psi}\big(\hat{\partial} - ig\hat{A}^a t^a - ie\gamma_5 \hat{A}_5\big)\psi$
- $J^i_\epsilon = \langle T^{0i} \rangle = \sigma H_5, \quad \sigma = \sigma_A = \frac{T^2}{12}$

One can study axial magnetic effect instead of axial chiral vortical effect

From axial magnetic to usual magnetic field

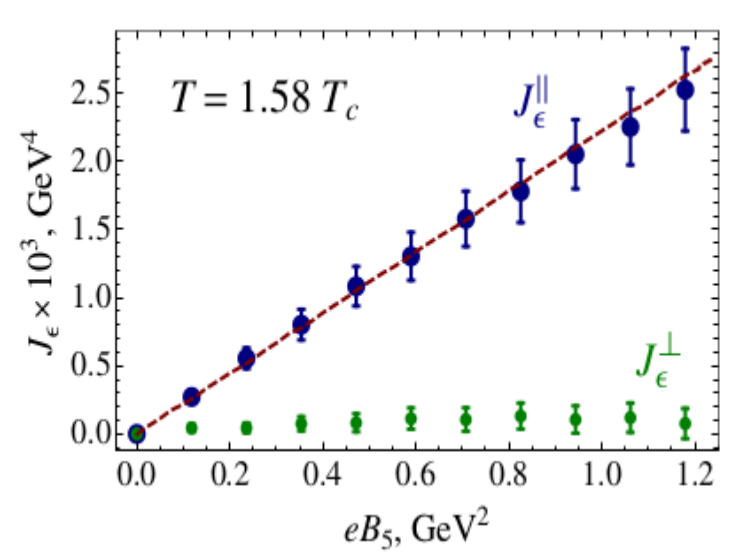
- $J_E = \langle T^{0i} \rangle = \frac{i}{2} \langle \bar{\psi}(\gamma^0 D_5^i + \gamma^i D_5^0)\psi \rangle, D_5^\mu = \partial^\mu - igA^\mu - ie\gamma_5 A_5^\mu$
- $C_\mu(x, y, A_5) = \langle \bar{\psi}(x) U_{xy} \gamma_\mu \psi(y) \rangle = -Tr\big(U\ S_5(A_5)\gamma_\mu\big)$
- $Tr\big[S_5(A_5)\gamma_\mu\big] = Tr\big[(P_R + P_L)S_5(A_5)\gamma_\mu\big] =$
  $Tr\big[P_R S(A_5)\gamma_\mu\big] + Tr\big[P_L S(-A_5)\gamma_\mu\big]$

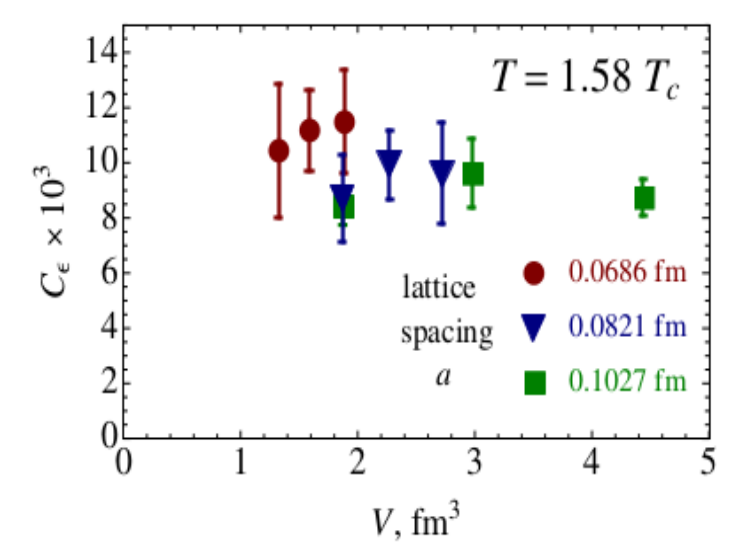
Motion in axial magnetic field can be related to the motion in usual magnetic field

Simulation details

- Tadpole improved action
- SU(2) quenched QCD
- Statistics ~ 3000
- Lattice parameters: $L_s = 14 - 20,\ L_t = 4 - 6,\ \beta = 3.0 - 3.5$

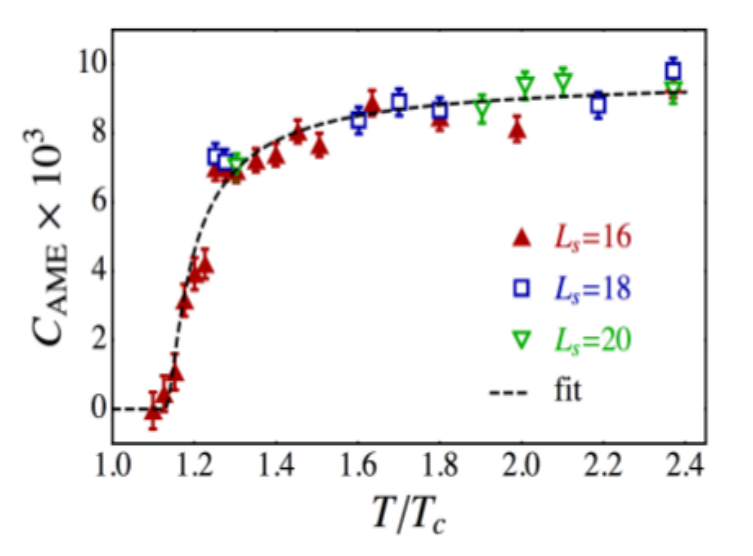
Observation of AME (V. Braguta et. al., Phys.Rev. D88 (2013))





- Observation of non-dissipative phenomenon
- $J_\epsilon^{\parallel} \sim H_5, \quad J_\epsilon^{\perp} \sim 0$

Temperature dependence of AME (V. Braguta et. al., Phys.Rev. D89 (2014))



- $C_{AME} = \frac{J_\epsilon}{eH_5 T^2}$, Good fit: $C_{AME}(T) = C_{AME}^{\infty} \exp\left(-\frac{h}{T-T_c}\right)$
- $J_\epsilon(T \gg T_c) \sim T^2$, $\frac{C_{AME}(T \gg T_c)}{C_{AME}^{th}} \simeq 0.06$
- $C_{AME}(T > T_c) > 0$, $C_{AME}(T < T_c) = 0 \Rightarrow$ clean signature for experiments

Conclusion

- Observation of axial magnetic effect
- Scaling $\sim T^2$ at high temperature
- σ_{lat} is by an order of magnitude smaller than σ_{th}
- AME is observed in deconfinement and is not observed in confinement
- Clean signature of anomalous transport phenomena for heavy ion collision experiments

THANK YOU