The weak magnetic effect from quark-gluon plasma

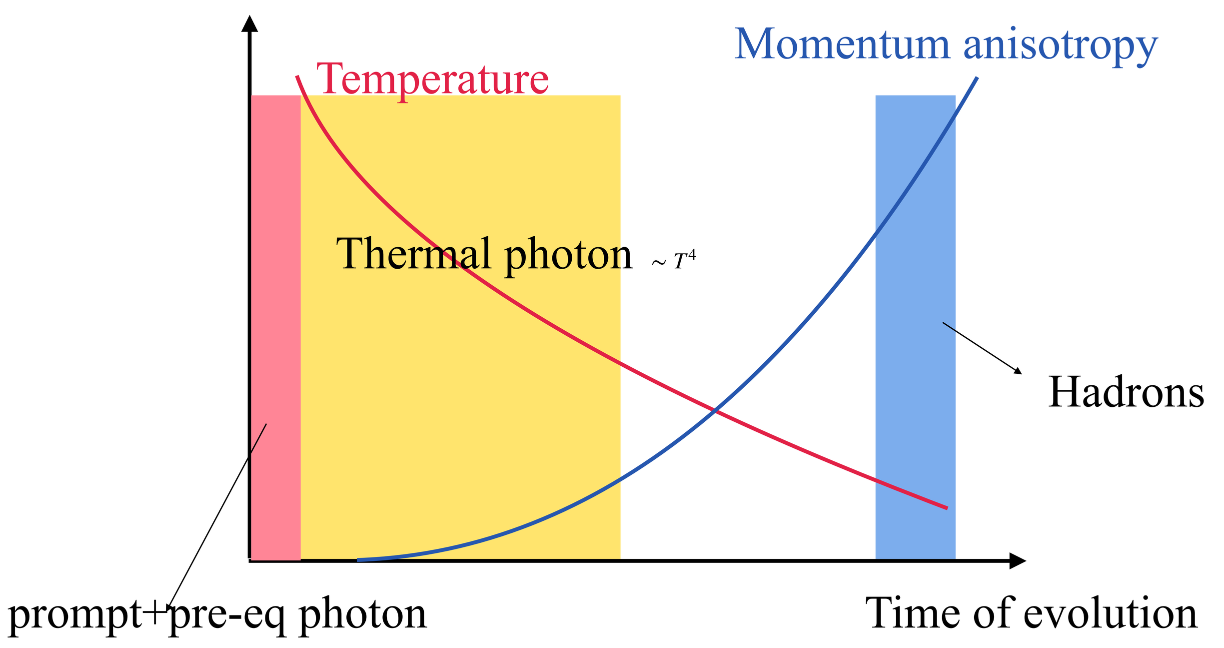
Jing-An Sun, Li Yan

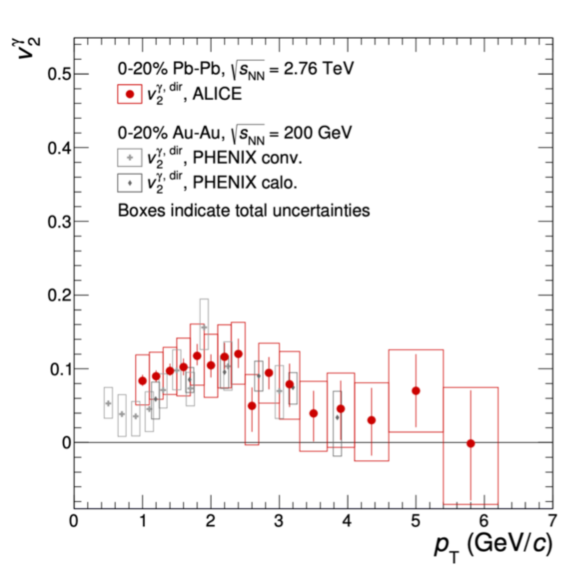
arXiv: 2302.07696

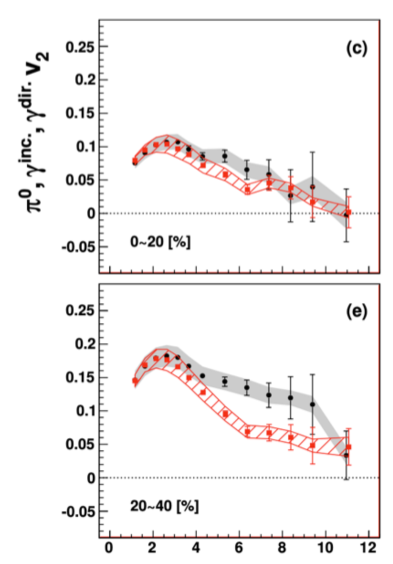
QM2023@Houston

Introduction

No theory predict the observation of **large yields** and **large v_2** for direct photons!

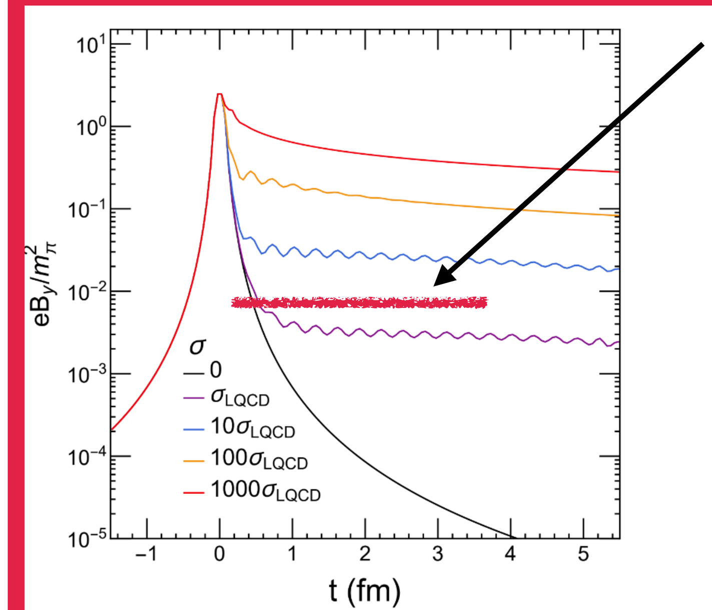


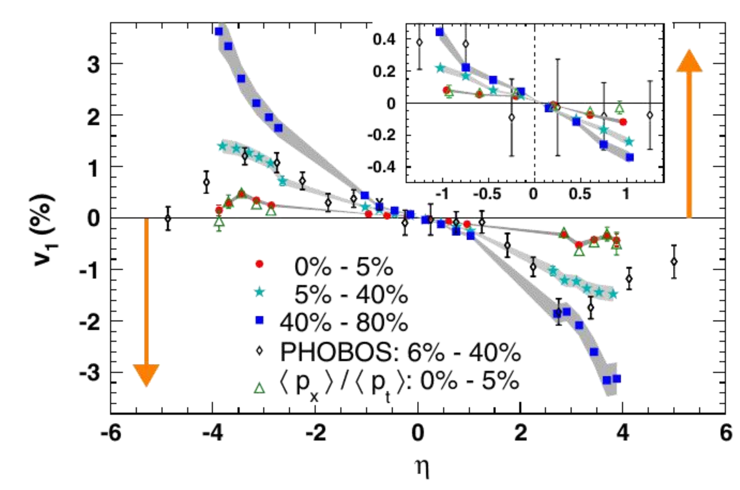




Theory: $v_2^{\gamma} \ll v_2^{hadron}$ ← **Puzzle!** → Experiment: $v_2^{\gamma} \approx v_2^{hadron}$

Methodology





EM field is Weak at hydro-evolution! $eB \ll T\nabla \sim m_\pi^2$

Weak magnetic non-equilibrium correction.

$$f_q = n_q + \delta f + f_{EM}$$

$$f_{\rm EM} = \frac{c}{8\alpha_{\rm EM}} \frac{\sigma_{\rm el} n_{\rm eq}(1-n_{\rm eq})}{T^3 p\cdot u} eQ_f F^{\mu\nu} p_\mu u_\nu$$

$[\ldots\cos\phi + \ldots\cos 2\phi + \ldots]\ \cos\phi$

v_1^{hadron} — v_2^{hadron} — weak magnetic non-eq

$v_1^{odd}(\eta)$ is required for non-zero v_2^{EM}!

A new $\cos(2\phi)$ term v_2^{EM}!

Hydrodynamic simulation

- A "tilted" fireball : single-shot simulation
  - **Use a tilted fireball configuration to capture the rapidity-odd v_1 of charged hadrons**
- Trento3D initial condition : event-by-event simulation — **Realistic collisions !**

Magnetic field profile

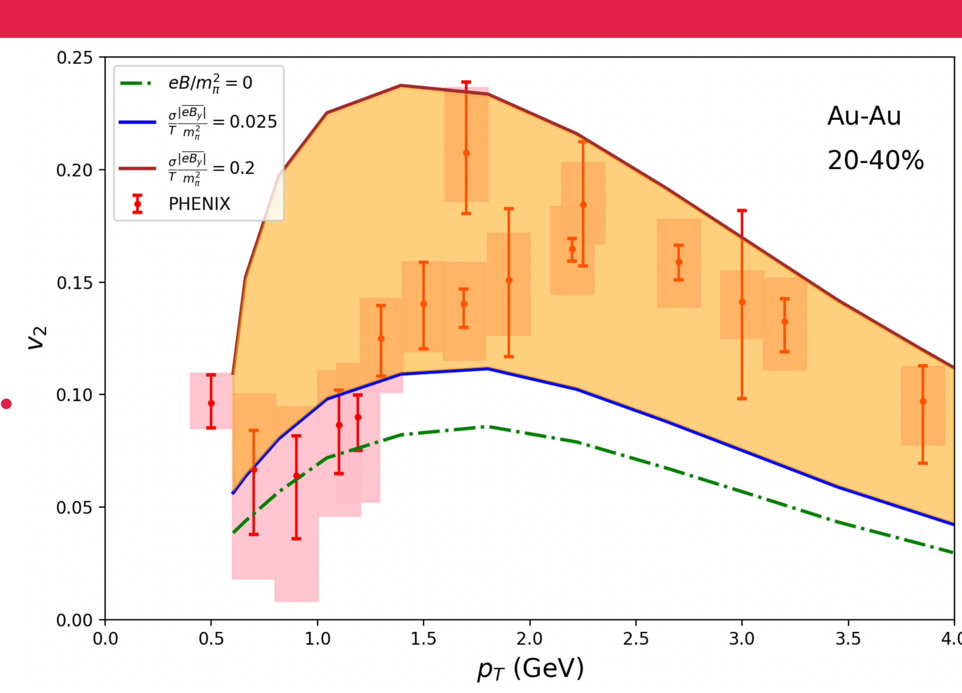
- Electrical conductivity: LO pQCD evaluation (AMY)
- η_s dependence is used as in vacuum and the time average B field $e\bar{B}$ is extracted.

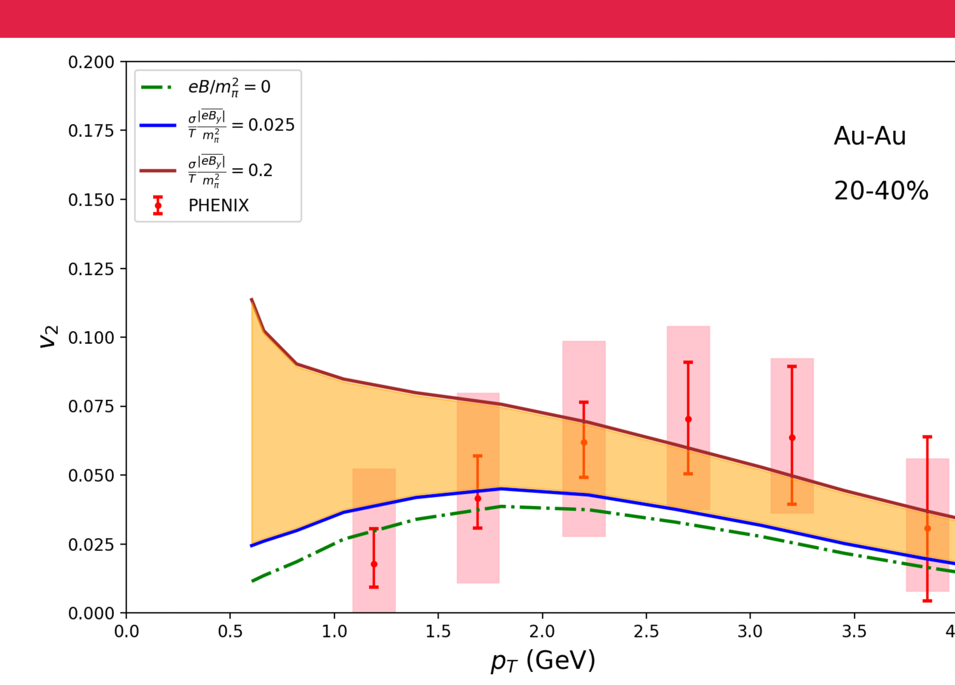
$$e\bar{B}\frac{eB(\tau_0,\eta)}{eB(\tau_0,0)}$$

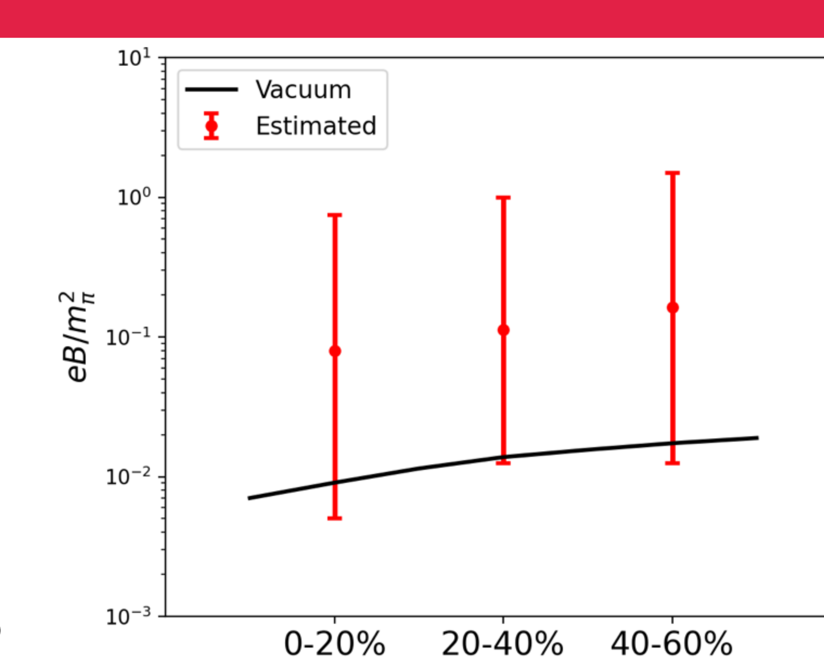
NEW CONCEPT: Non-trivial coupling effect between the weak magnetic field and the longitudinal dynamics of the fireball!

Results

- The **experimental data are reproduced** for all centralities.
- Averaged B field is extracted and is **under weak magnetic assumption.**
- The B field magnitude grows as centrality increases: **correct trend**!







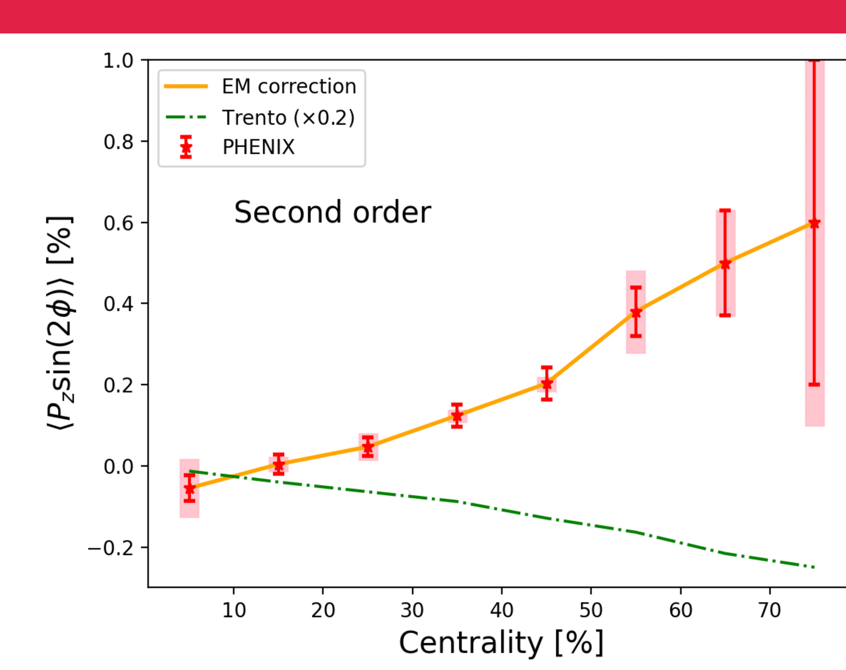
How about spin polarization?

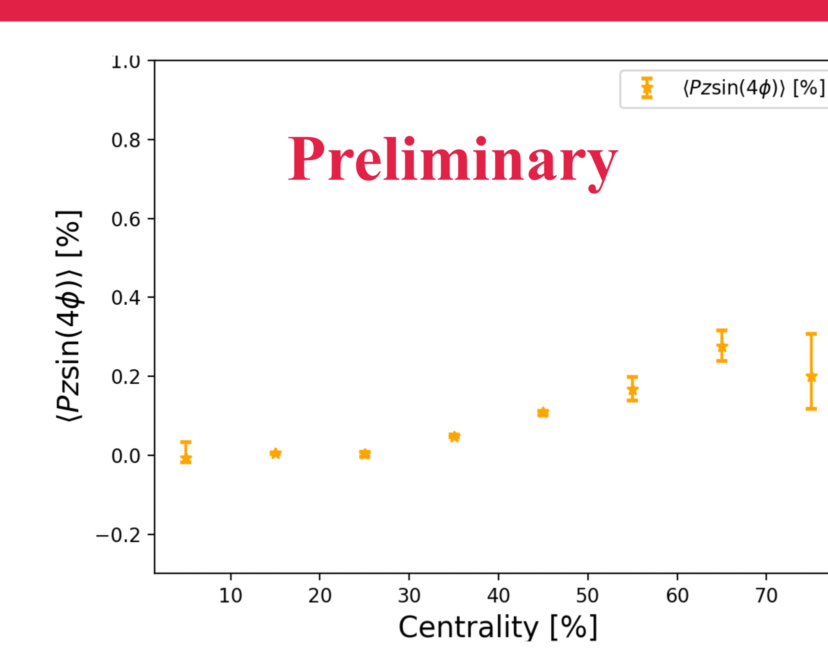
- Opposite **sign** of the $P^z(\phi)$
- Opposite trend on the **centrality dependence**
- With SIP term, the sign can be flipped but the magnitude is almost centrality-independent.

Only thermal vorticity!

- Trento3D is used to generate the smooth initial conditions: **Rapidity-odd** $v_1(\eta)$
- S-quark memory: $P_\Lambda^z = P_s^z$
- Constant eB

$n_{\rm eq}$(with spin) → $(n_{\rm eq} + f_{EM}) \otimes$ spin





- B field **flips the $P^z(\phi)$ sign** successfully and the **centrality dependence** is reproduced.
- The B field used to fit the experimental data is still weak and follows the centrality trend.
- The **$\sin(4\phi)$ structure** in $P^z(\phi)$ is expected.

Summary

- **Weak magnetic photon emission: Weak magnetic field + the non-trivial longitudinal dynamics of fireball.**
- The **elliptic and triangle flow of direct photon** both get significant increments, which confronts the experimental data.
- The sign of $P_\Lambda^z(\phi)$ is flipped and the centrality dependence are reproduced.
- The **$\sin(4\phi)$ structure** in $P^z(\phi)$ is expected.

Acknowledgement

We are grateful for very helpful discussions with Charles Gale and Xu-Guang Huang. This work is supported in part by the NSFC Grants through No. 11975079.