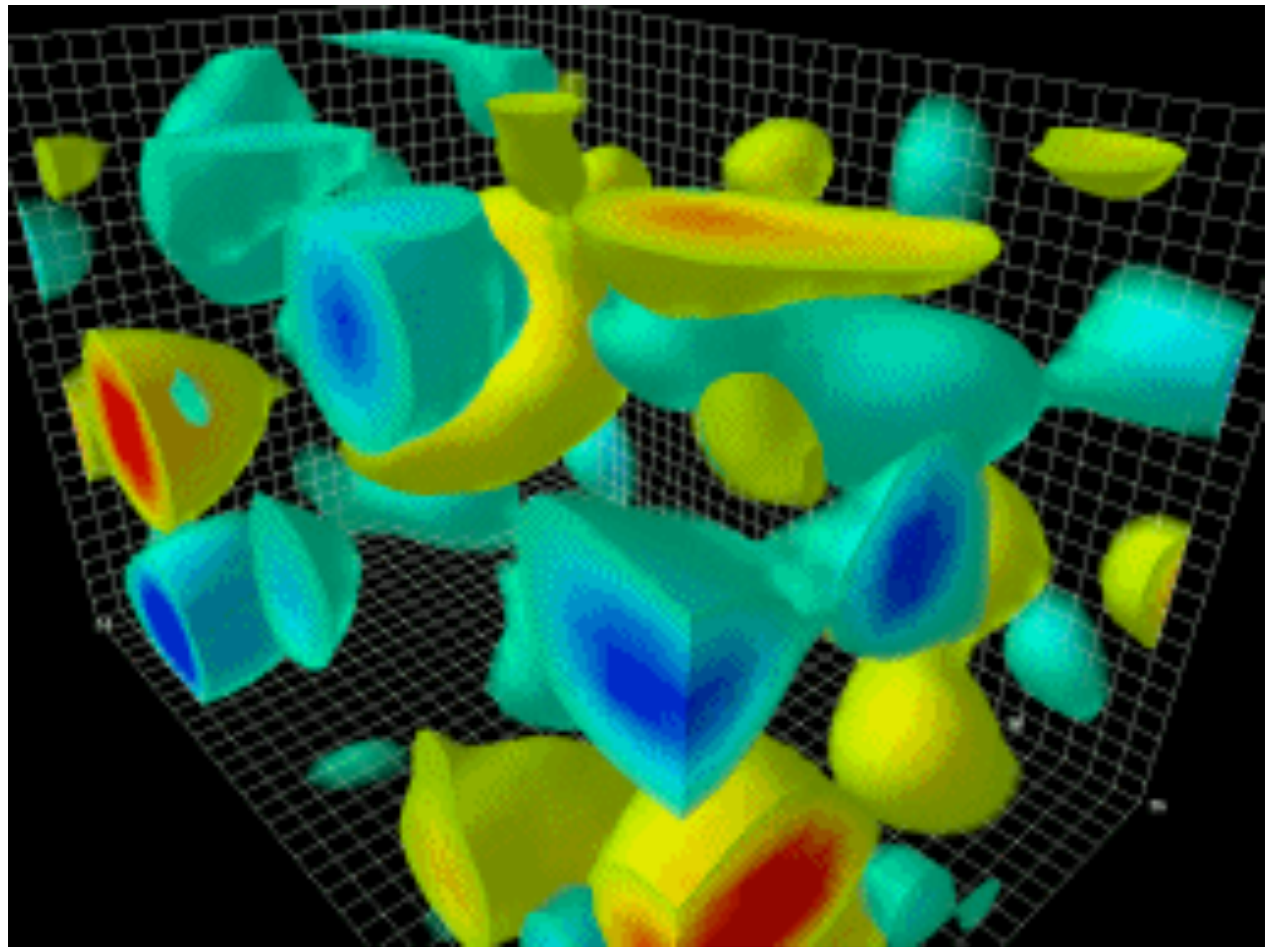
The 22nd International Conference on
Strangeness in Quark Matter
22-27 March, 2026, Los Angeles, CA

Chirality, Polarization, and Spin Alignment in Heavy-Ion Collisions

Shuzhe Shi (施舒哲)
Tsinghua Univ.

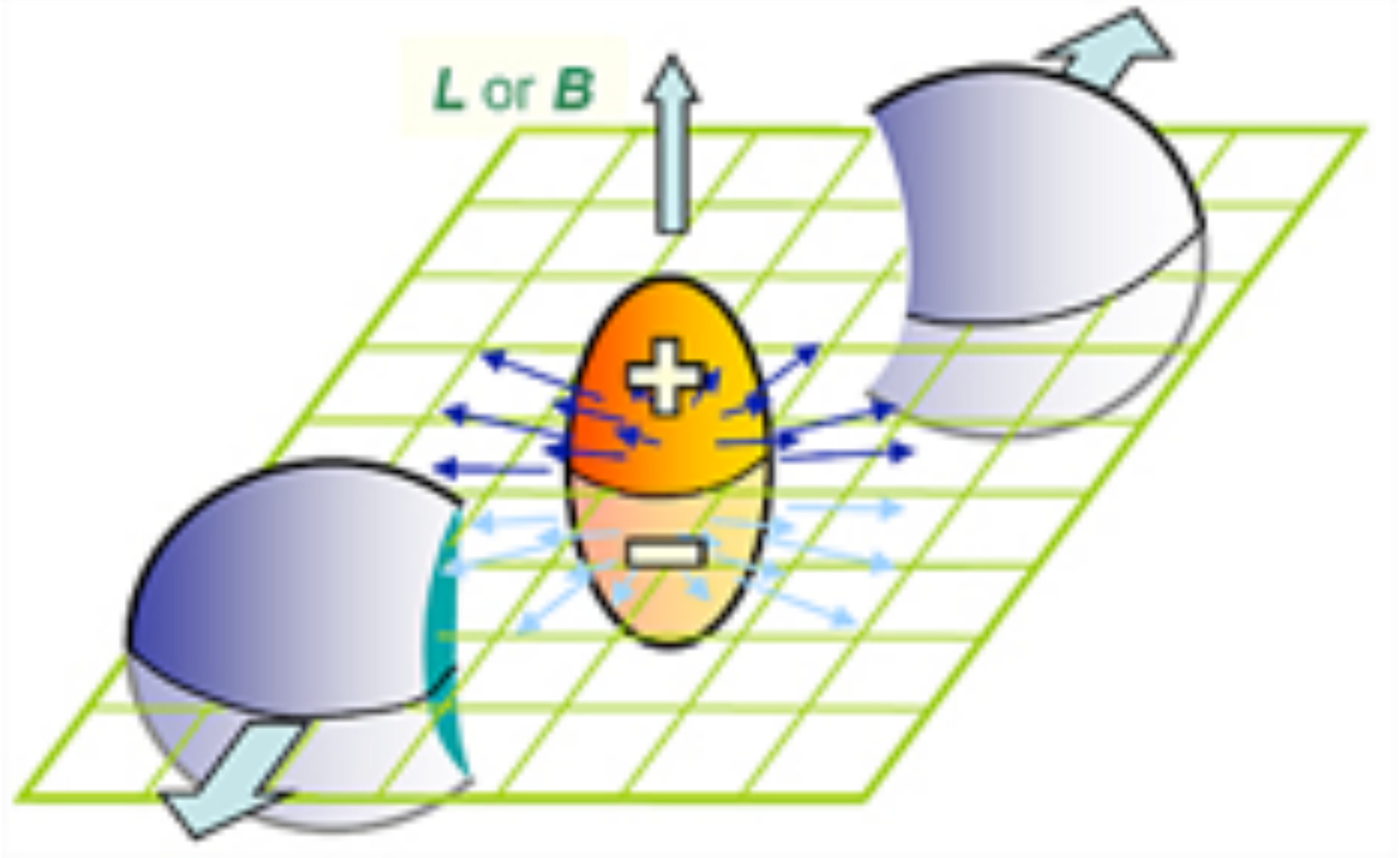
Chirality in QCD

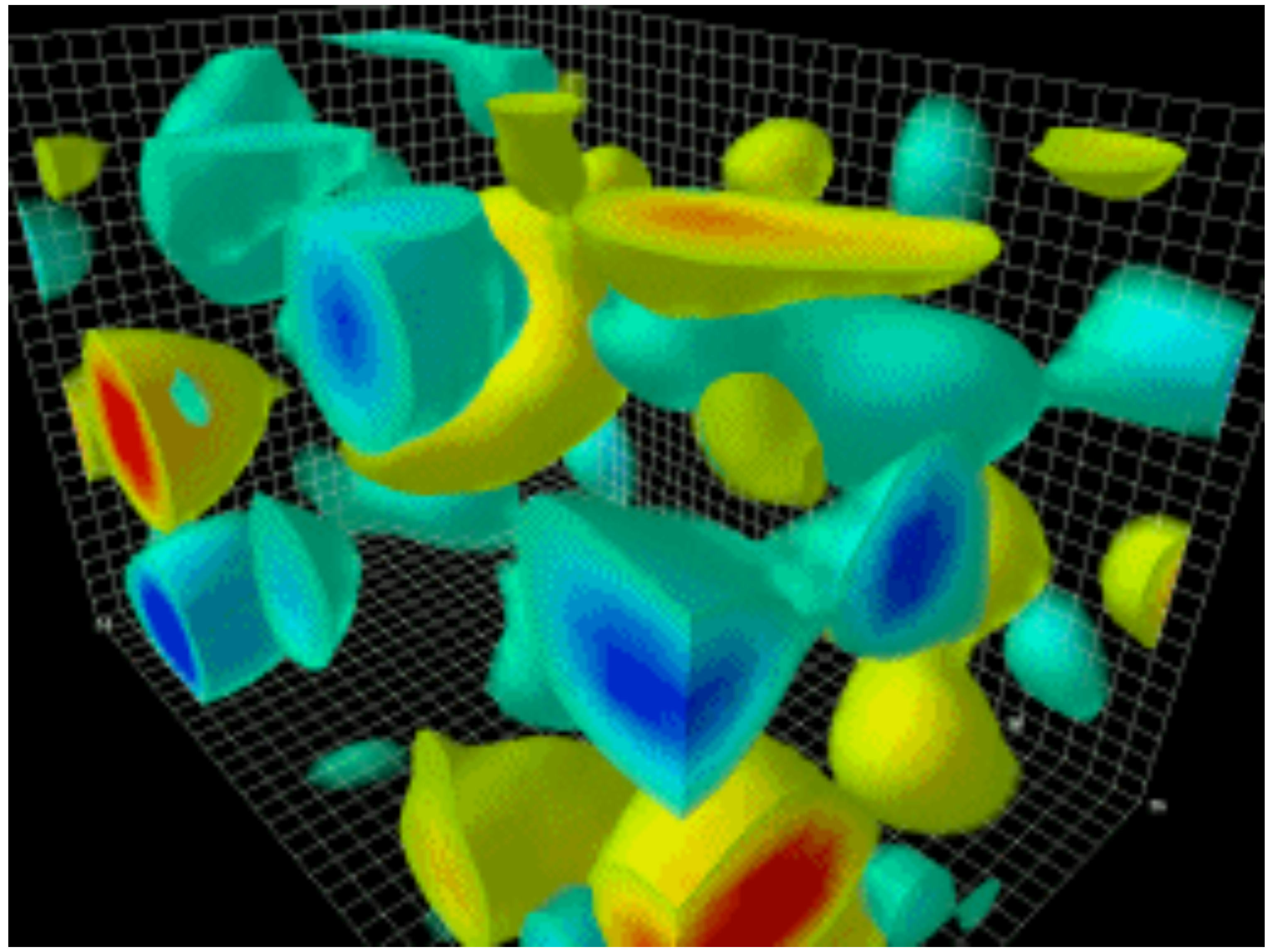


Topology
⊗ Chiral
⊗ Anomaly

$$Q_W = \frac{g^2}{32\pi^2}\int d^4x\, F^a_{\mu\nu}\tilde{F}^{\mu\nu}_a$$

Chiral Magnetic Effect





Magnetic Field

B ~ γ Z Q b / R^3

(10^{15} T @ 200 GeV Au-Au)

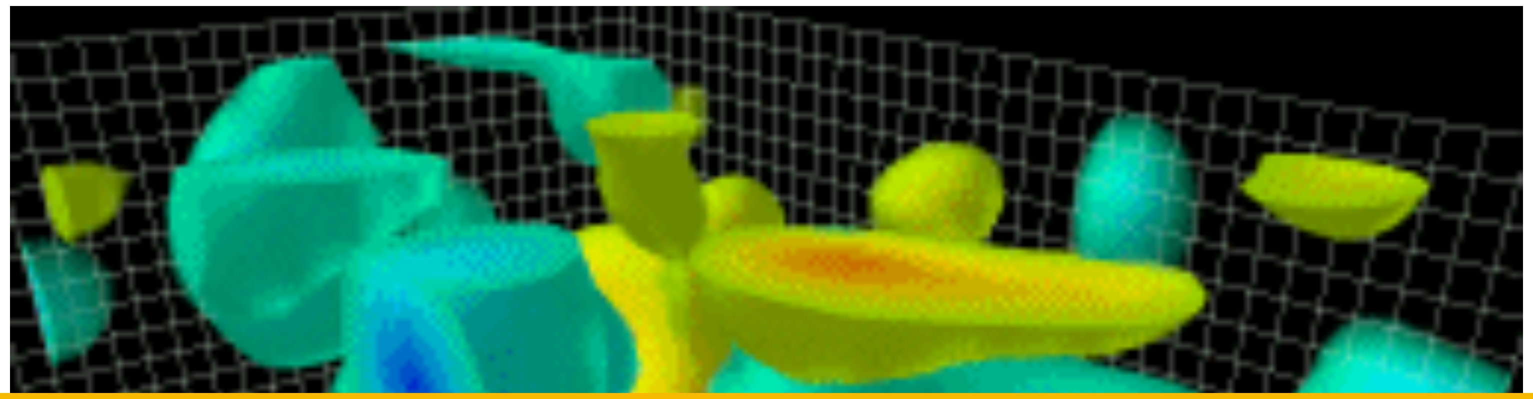
$\otimes$

Topology

$\otimes$ Chiral

$\otimes$ Anomaly

$$Q_w = \frac{g^2}{32\pi^2} \int d^4x \, F^a_{\mu\nu} \tilde{F}^{\mu\nu}_a$$



The Chiral Magnetic Effect

Kenji Fukushima, Dmitri Kharzeev, H.Warringa, PhysRevD.78.074033

recent reviews:

Chiral magnetic effect reveals the topology of gauge fields in heavy-ion collisions

Dmitri Kharzeev, Jinfeng Liao, Nature Review Physics 3 (2021) 1, 55-63

Chapter in QGP6

Dmitri Kharzeev, Jinfeng Liao, Prithwish Tribedy, 2405.05427

$B \sim \gamma$ Z Q b / R^3

(10^{15} T @ 200 GeV Au-Au)

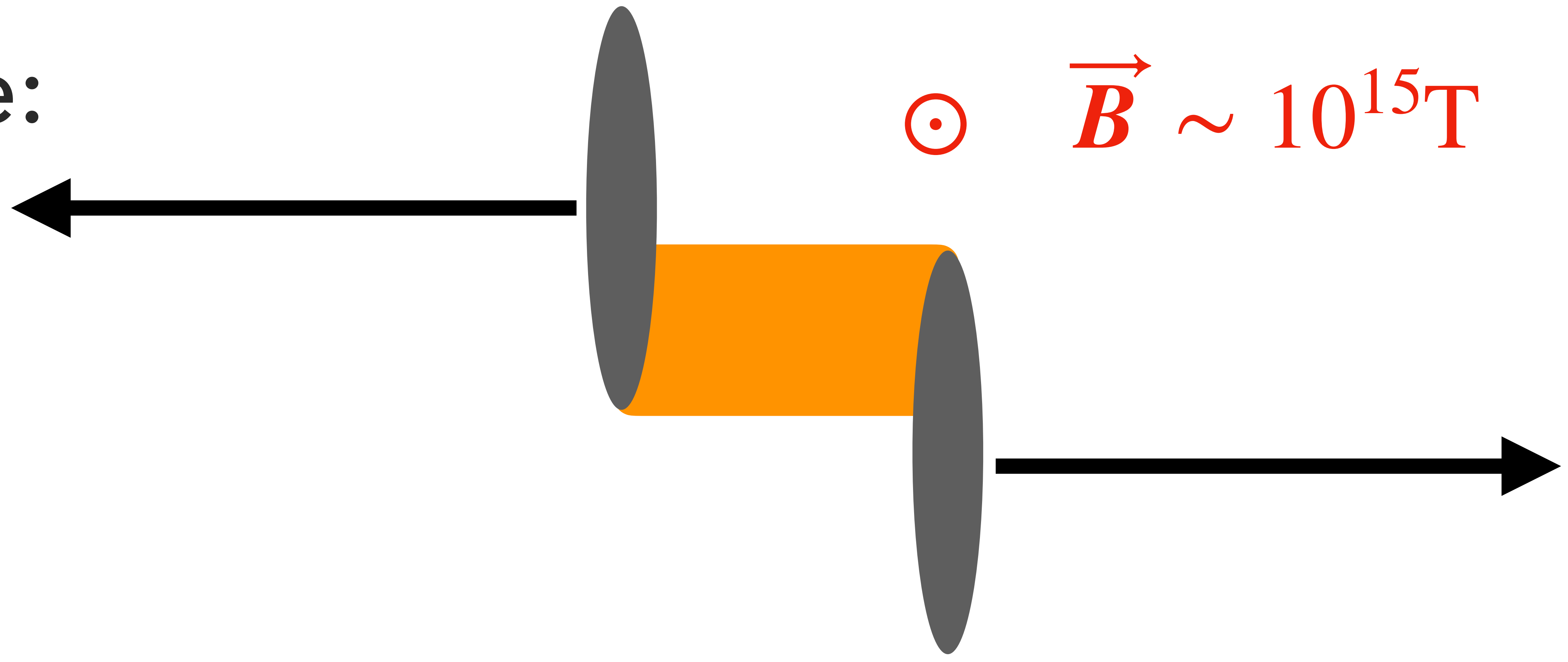
⊗ Anomaly

$$Q_w = \frac{g^2}{32\pi^2}\int d^4x\, F^a_{\mu\nu}\tilde{F}^{\mu\nu}_a$$

Chiral Magnetic Effect

For right-handed particles w/ positive charge:

1. $\vec{p} \parallel \vec{S} \parallel \vec{\mu}$
2. $\text{Energy} = -\vec{\mu} \cdot \vec{B} \propto -\vec{p} \cdot \vec{B}$



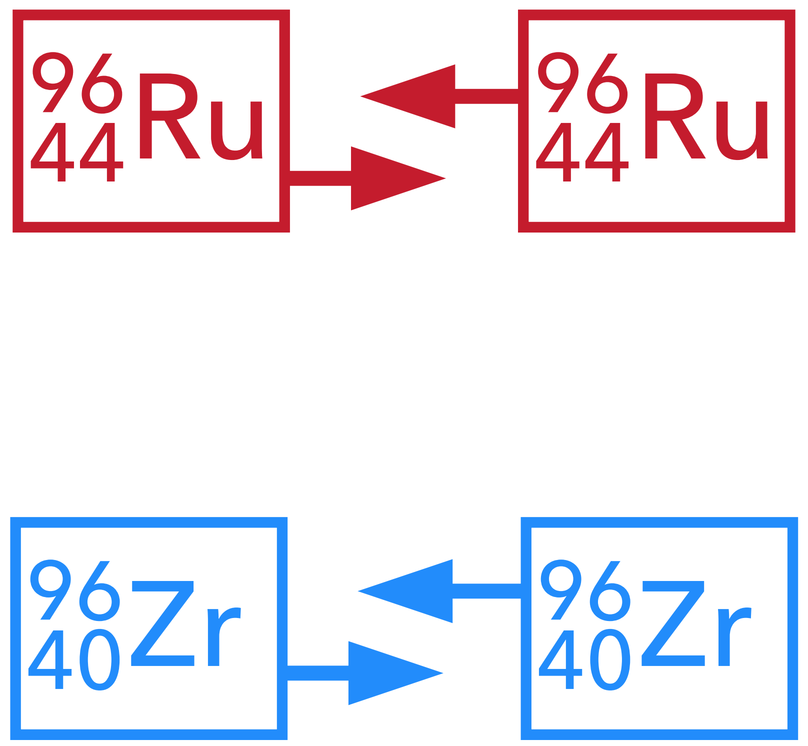
⇒ lower energy if moving along B field direction

$$\vec{J} = \sigma_A \mu_A \vec{B}$$

expectation before the isobar collisions:

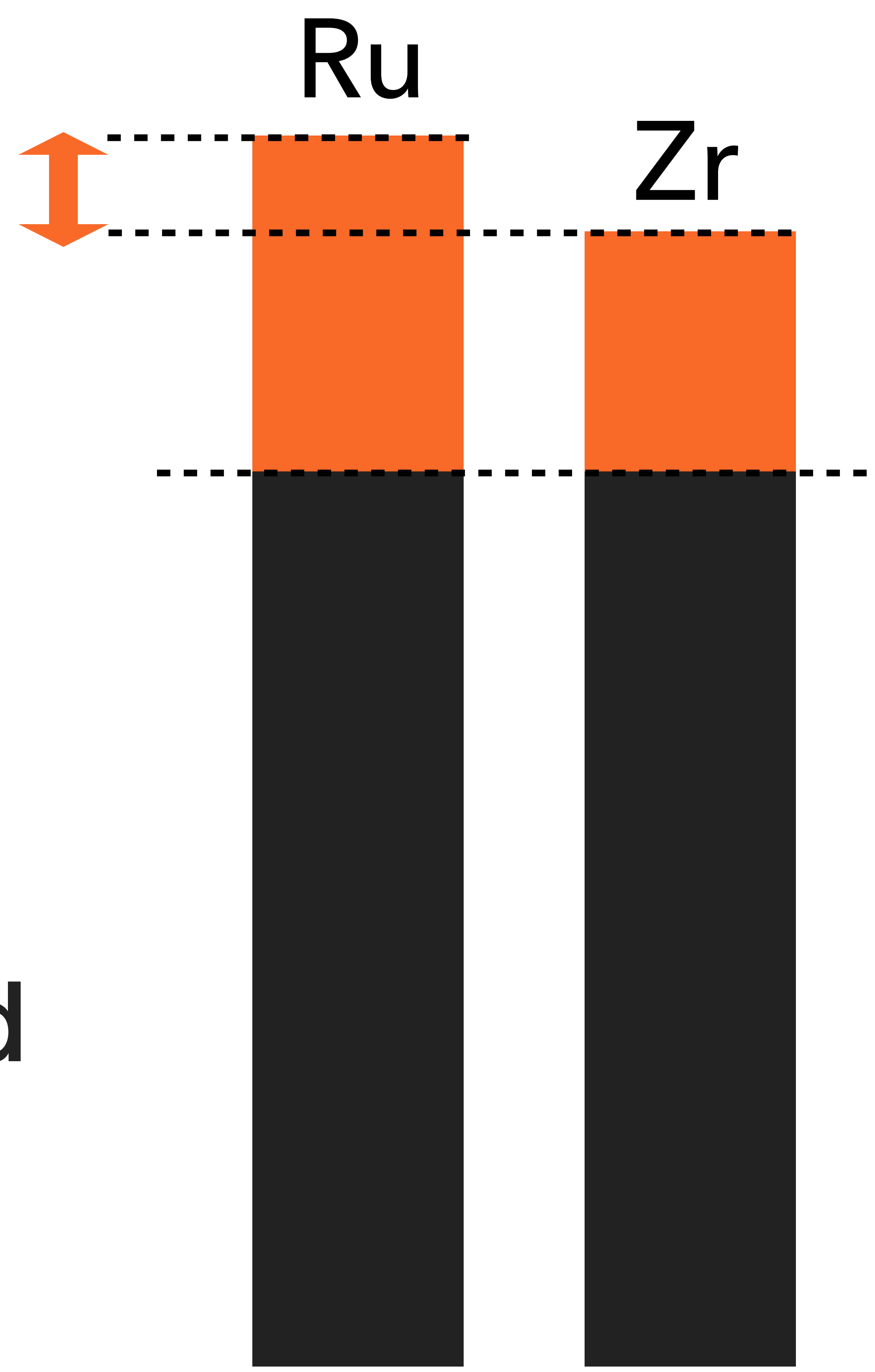
Correlator[Ru] > *Correlator*[Zr] → **CME**

Correlator[Ru] = *Correlator*[Zr] → **no CME**



Different Proton # → **Different CME Signal**

Same Baryon # → **Same Background**

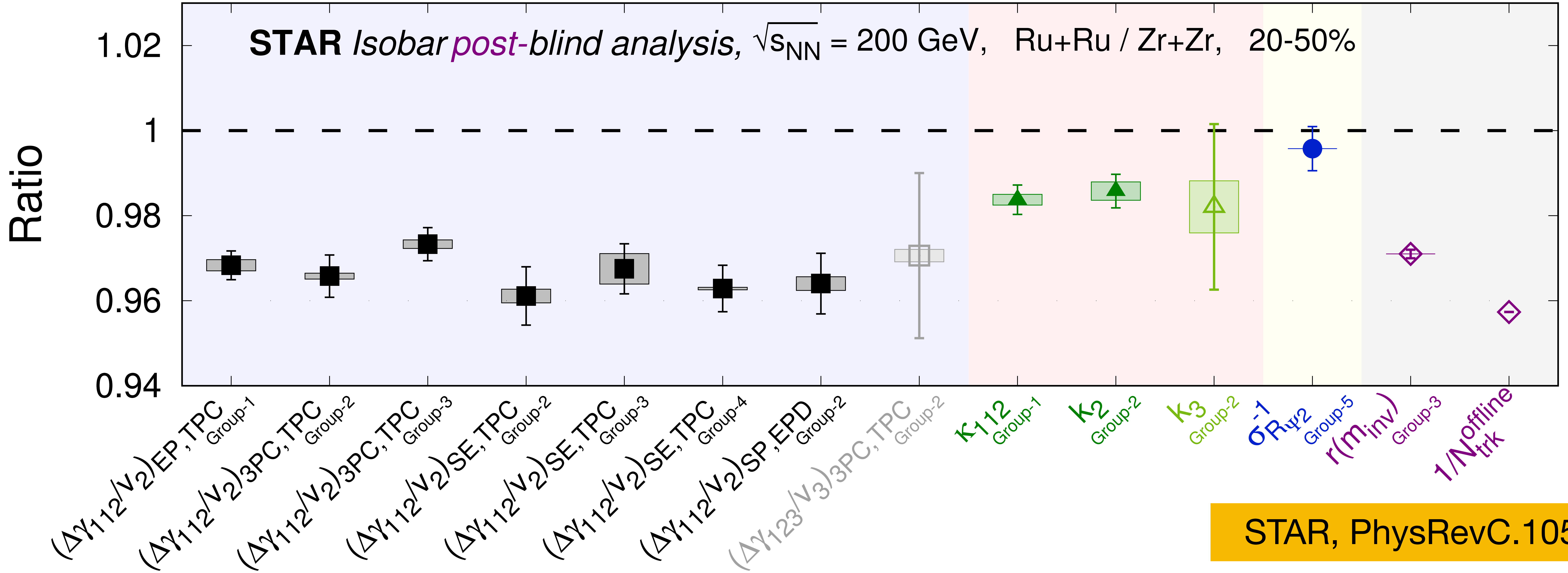


expectation before the isobar collisions:

Correlator[Ru] > *Correlator*[Zr] → **CME**

Correlator[Ru] = *Correlator*[Zr] → **no CME**

measurement: *Correlator*[Ru] < *Correlator*[Zr]



STAR, PhysRevC.105.014901

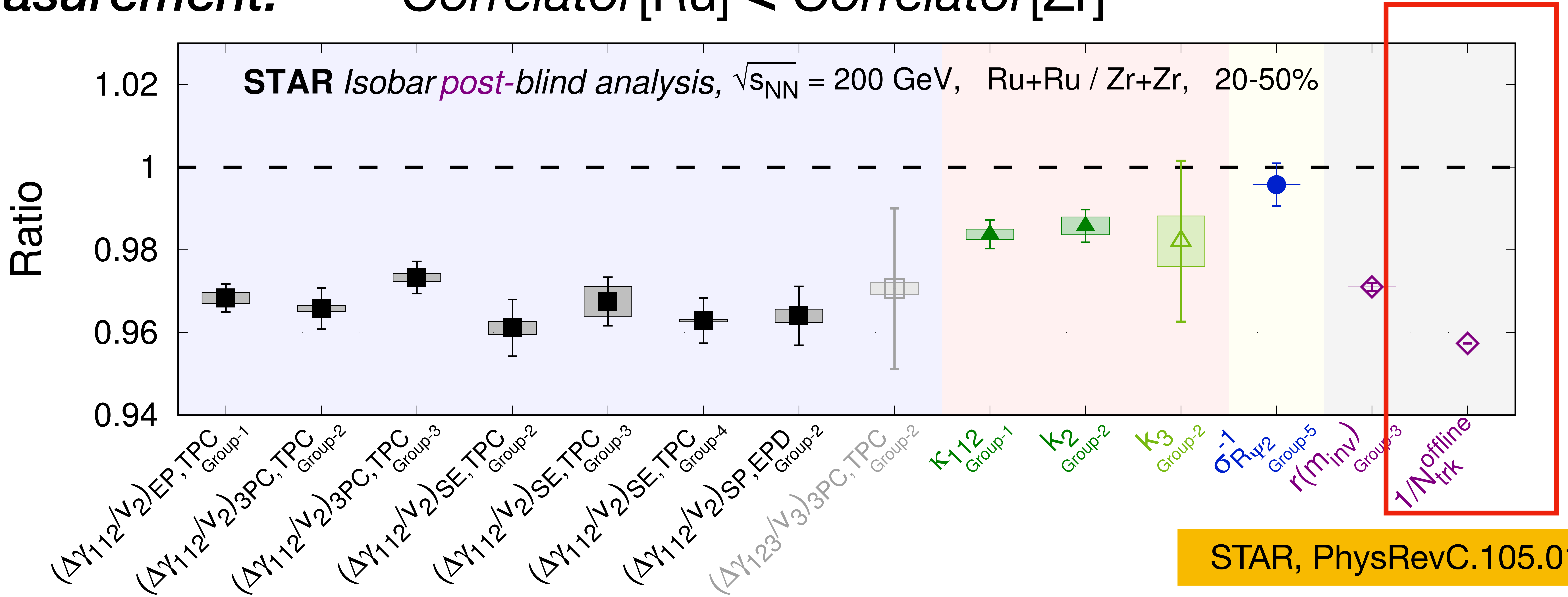
measuring CME in isobar

expectation before the isobar collisions:

Correlator[Ru] > *Correlator*[Zr] → **CME**

Correlator[Ru] = *Correlator*[Zr] → **no CME**

measurement: *Correlator*[Ru] < *Correlator*[Zr]



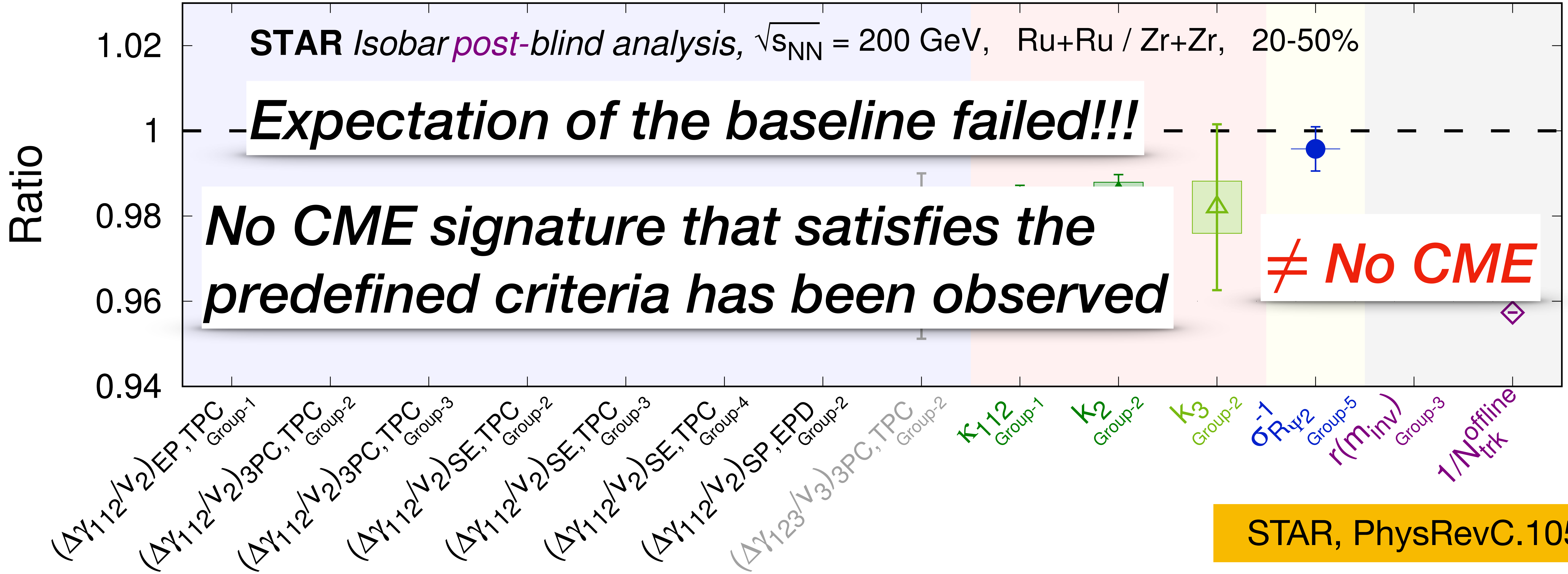
STAR, PhysRevC.105.014901

expectation before the isobar collisions:

Correlator[Ru] > *Correlator*[Zr] → **CME**

Correlator[Ru] = *Correlator*[Zr] → **no CME**

measurement: *Correlator*[Ru] < *Correlator*[Zr]



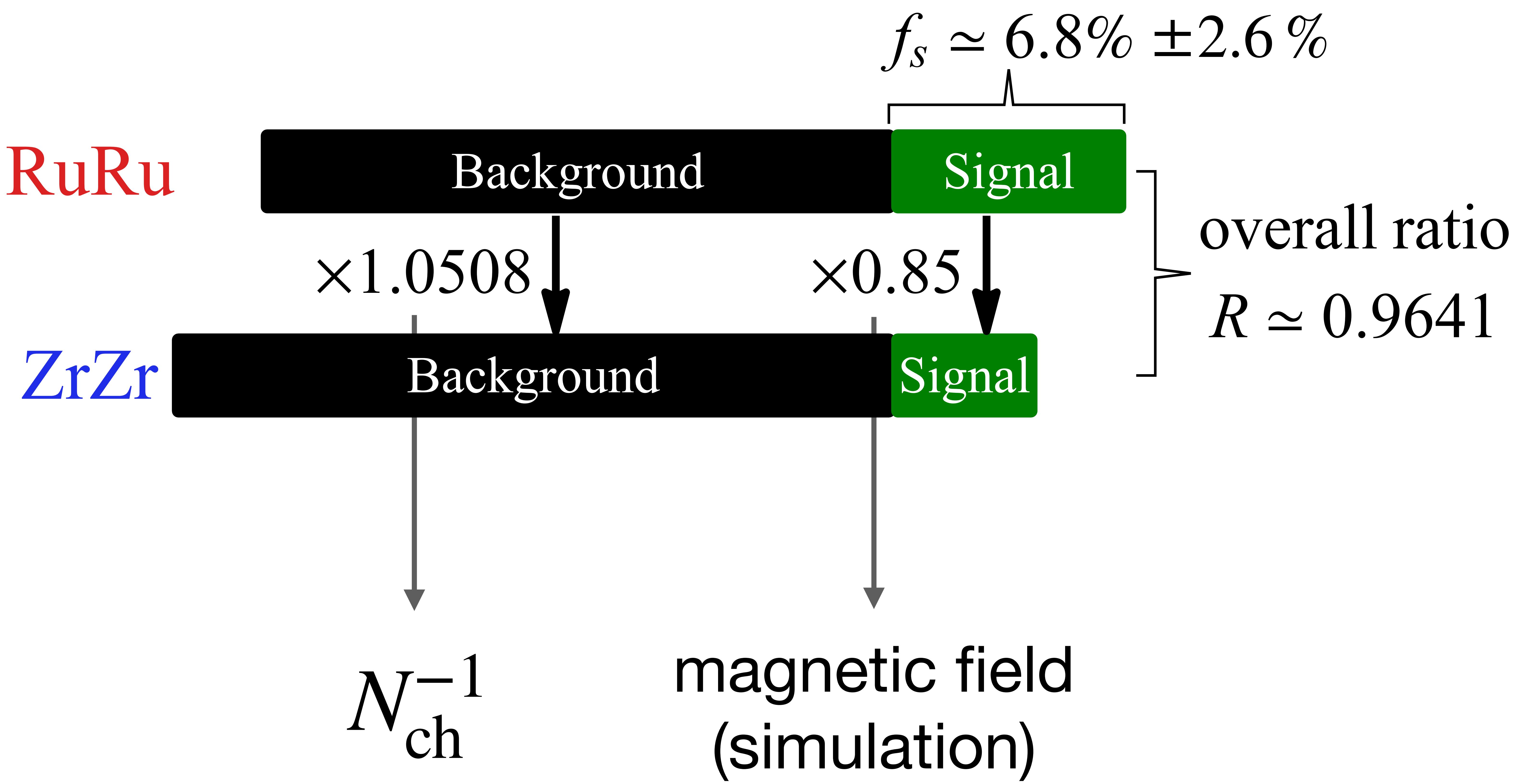
Expectation of the baseline failed!!!

No CME signature that satisfies the predefined criteria has been observed

≠ No CME

STAR, PhysRevC.105.014901

possible CME signal in isobar?



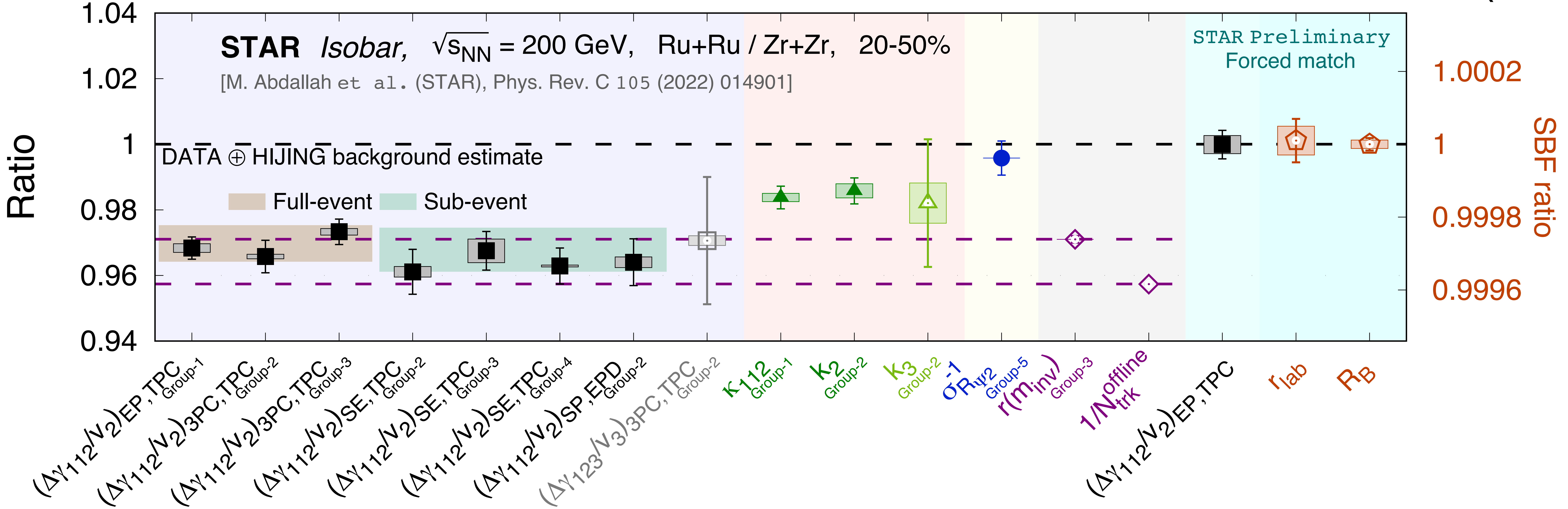
Dmitri Kharzeev, Jinfeng Liao, SS, PhyRevC.106.L051903

possible CME signal in isobar?

updates in experiment: controlling background

Tang, QM2023

EPJ Web of Conferences 296, 01024 (2024)



N_{ch}^{-1}

magnetic field
(simulation)

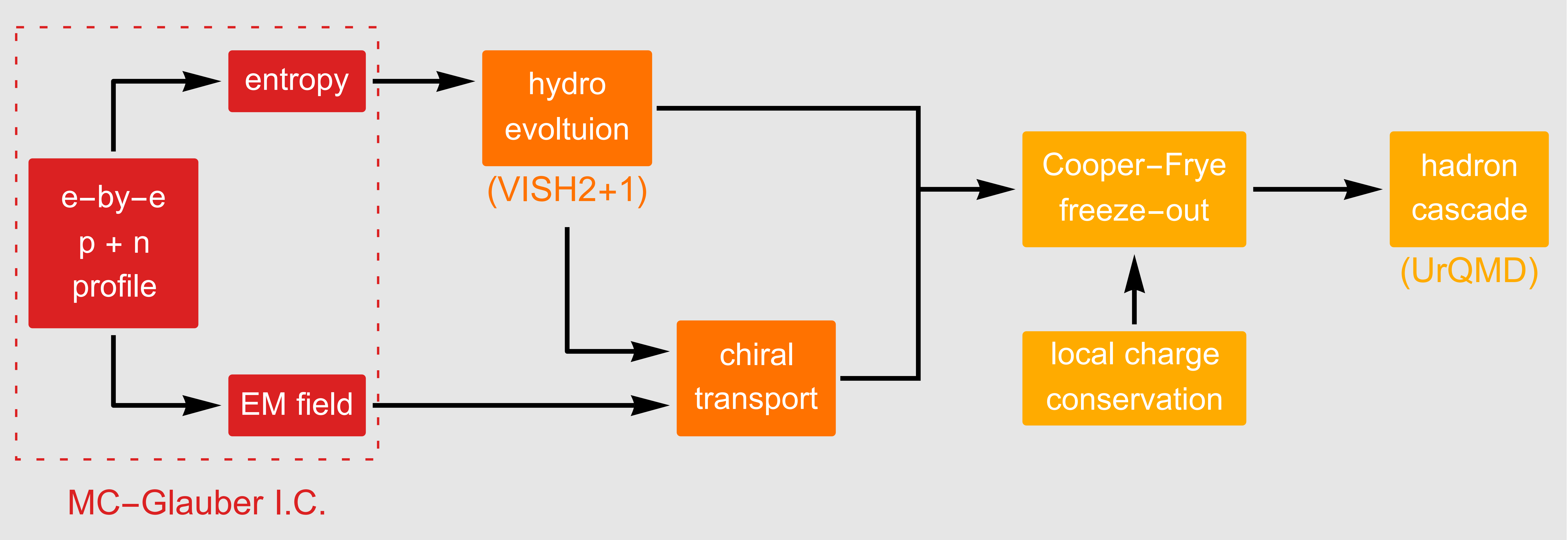
Dmitri Kharzeev, Jinfeng Liao, SS, PhyRevC.106.L051903

challenges in accurate, first-principle calculation

axial charge

$$\vec{J} = \sigma_A \mu_A \vec{B}$$

magnetic field: life time $\sim R/\gamma_{\text{beam}}$ + medium feedback



AVFD model: Jinfeng Liao, SS + Hou, Jiang, Lilleskov, Yin, Zhang, ChinPhysC.42.011001, Annals Phys.394.50, PhysRevLett.125.242301

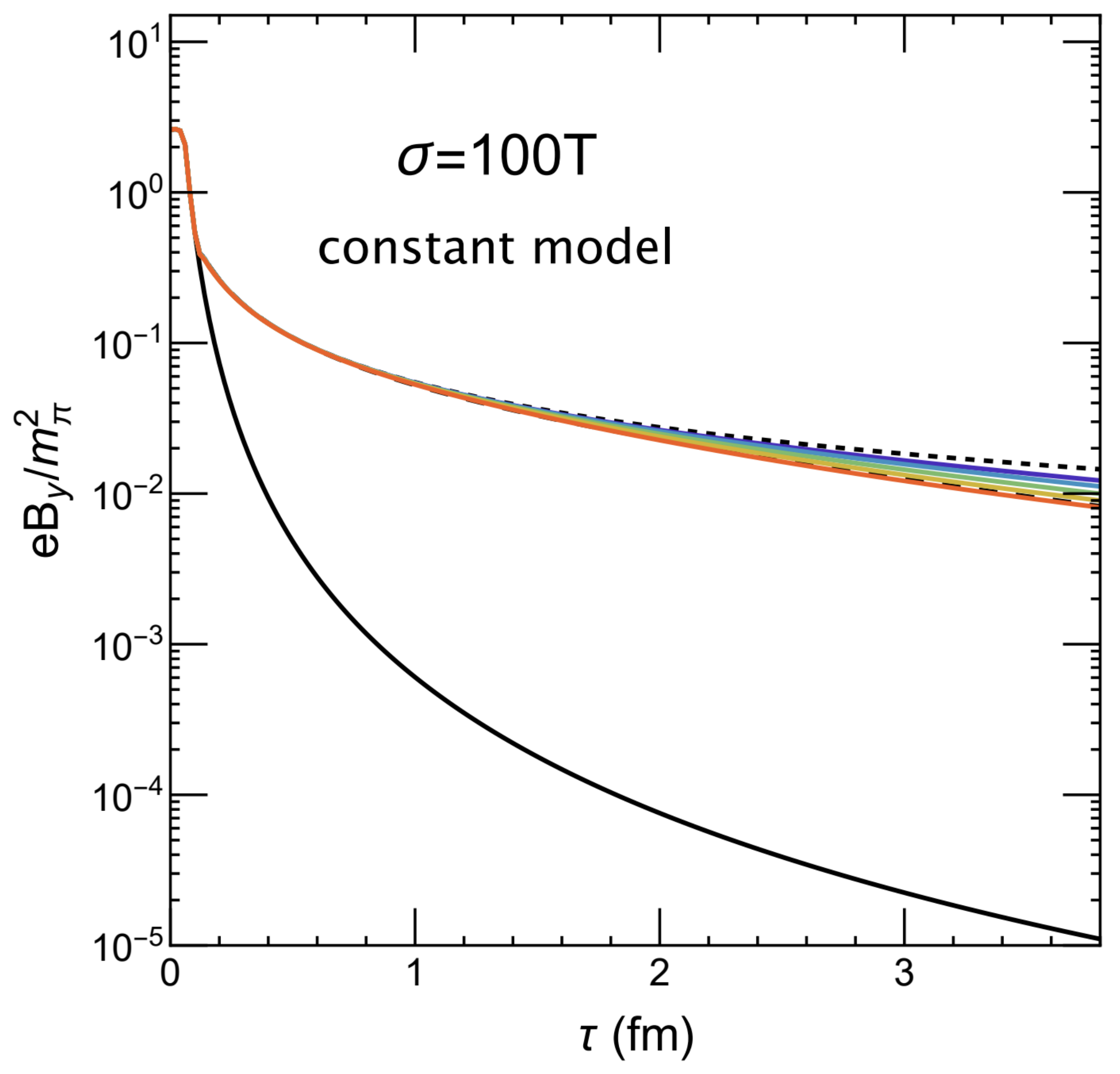
challenges in accurate, first-principle calculation

$$\vec{J} = \sigma_A \mu_A \vec{B}$$

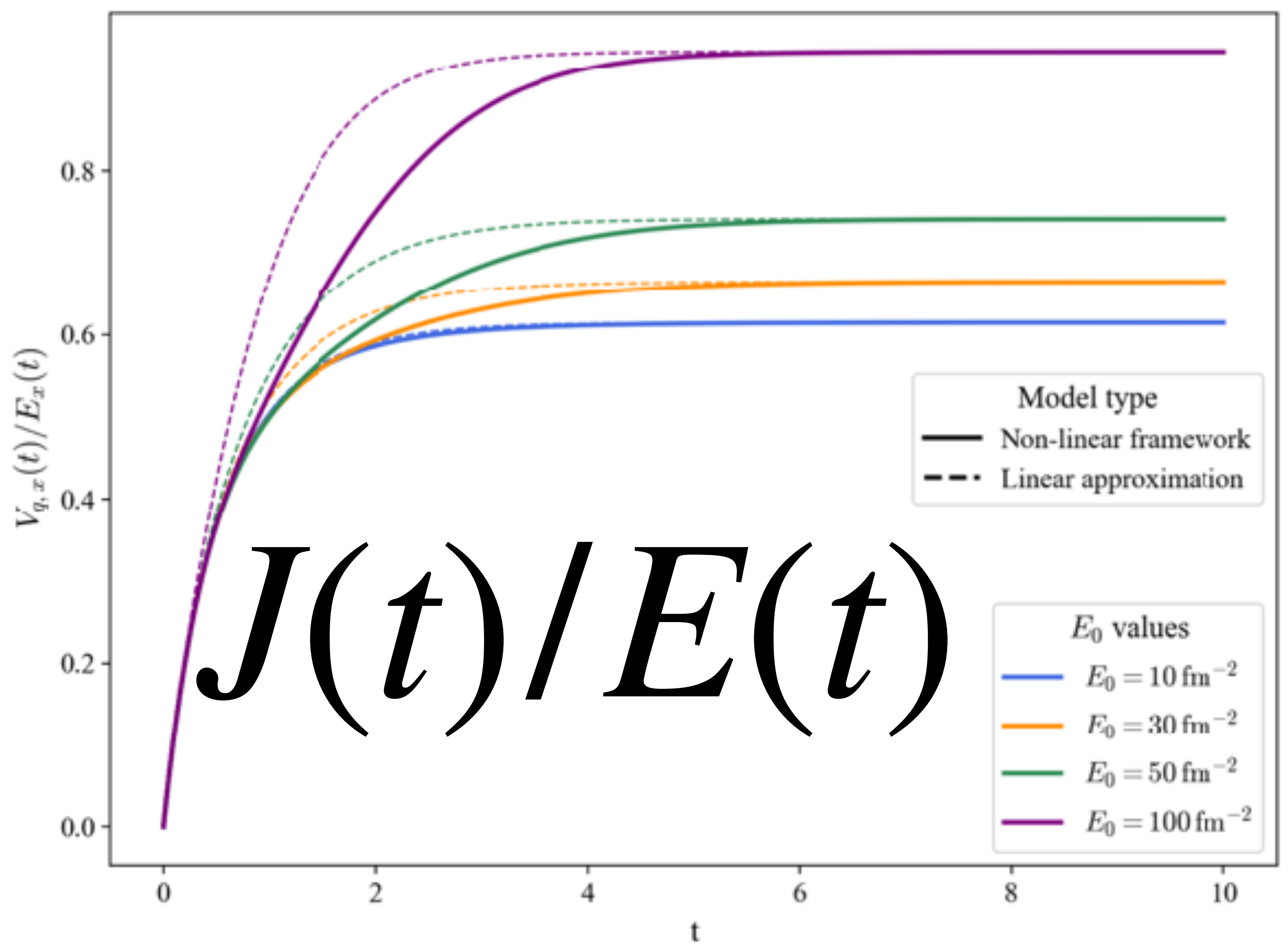
axial charge

magnetic field: life time $\sim R/\gamma_{\rm beam}$ + medium feedback

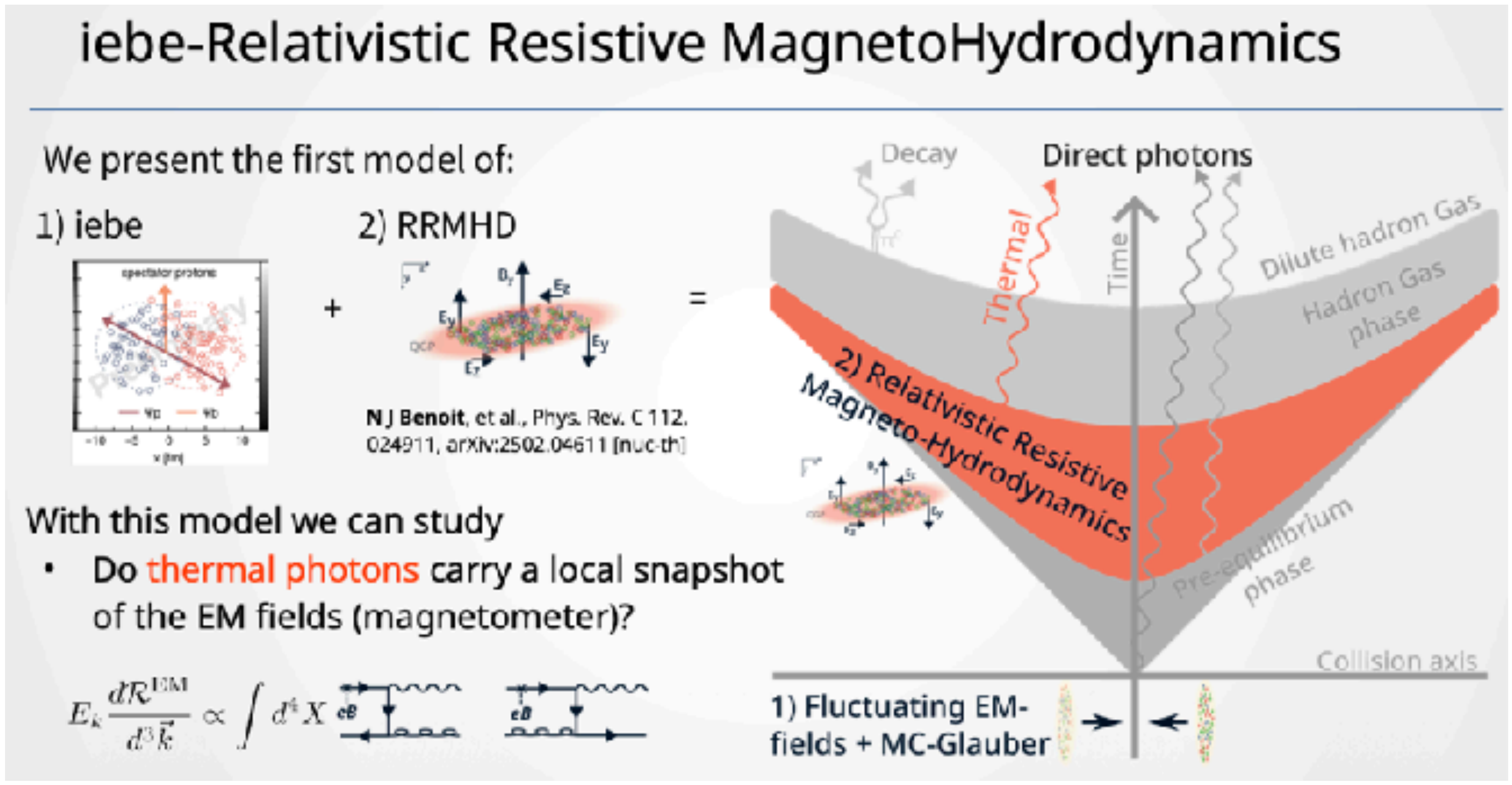
Maxwell equation / Magnetohydrodynamics



Huang, She, SS, Huang, Liao, PhysRevC.107.034901



N. Benoit, TUE 12:15, Parellel IV



K. Kushwah, TUE 11:35, Parellel IV

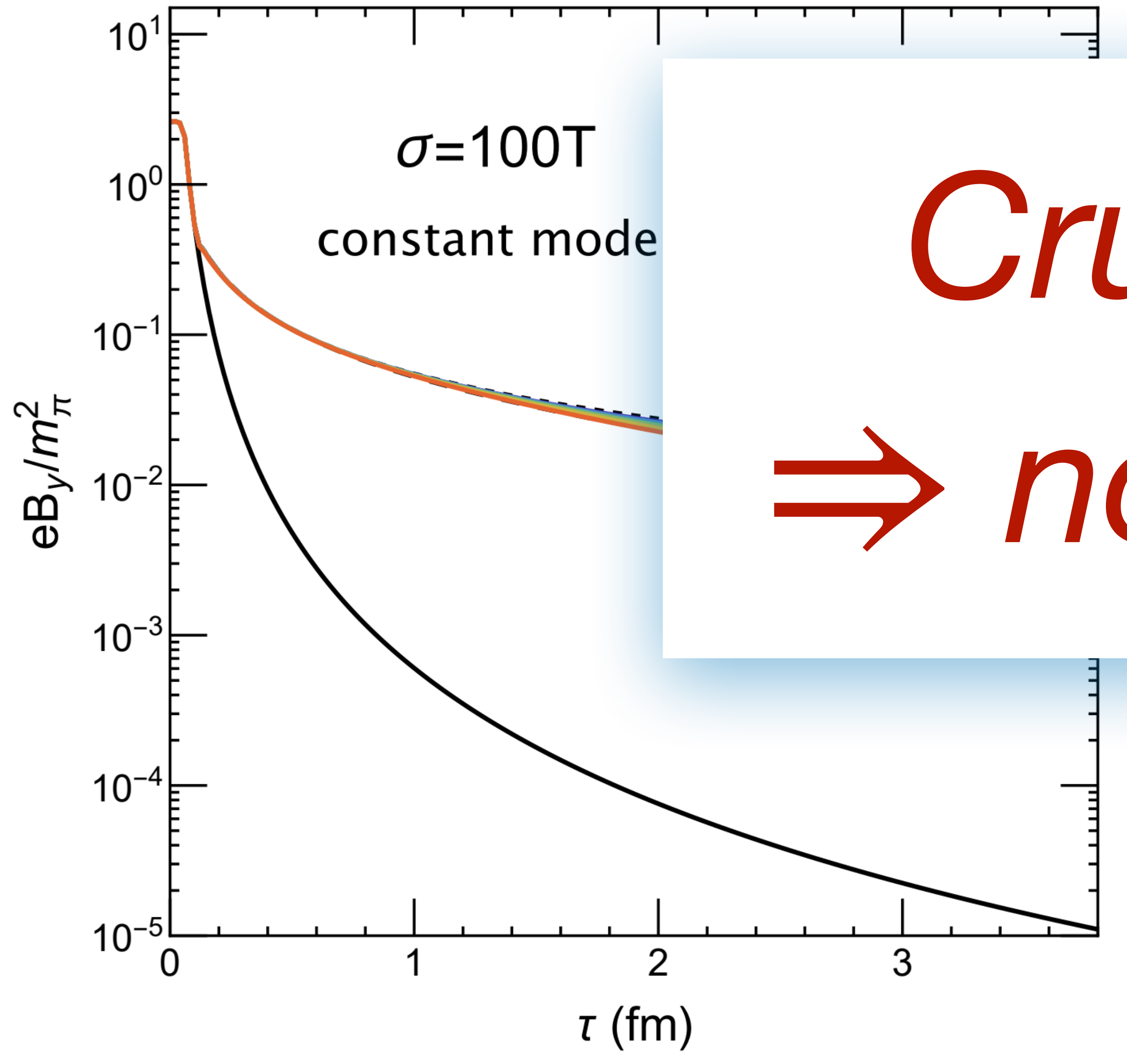
challenges in accurate, first-principle calculation

$$\vec{J} = \sigma_A \, \mu_A \, \vec{B}$$

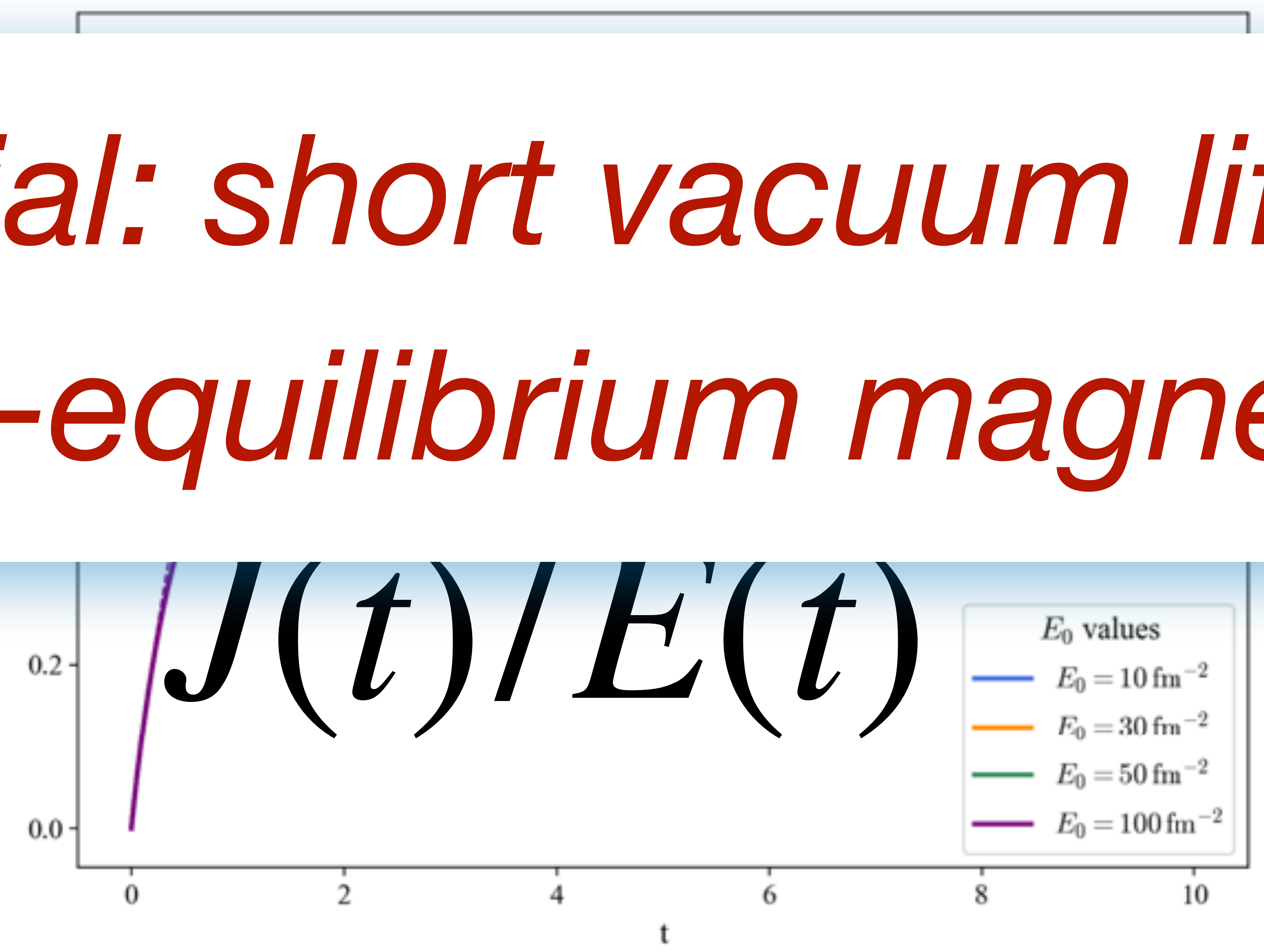
μ_A → axial charge

$\vec{B}$ → magnetic field: life time $\sim R/\gamma_{\rm beam}$ + medium feedback

Maxwell equation / Magnetohydrodynamics

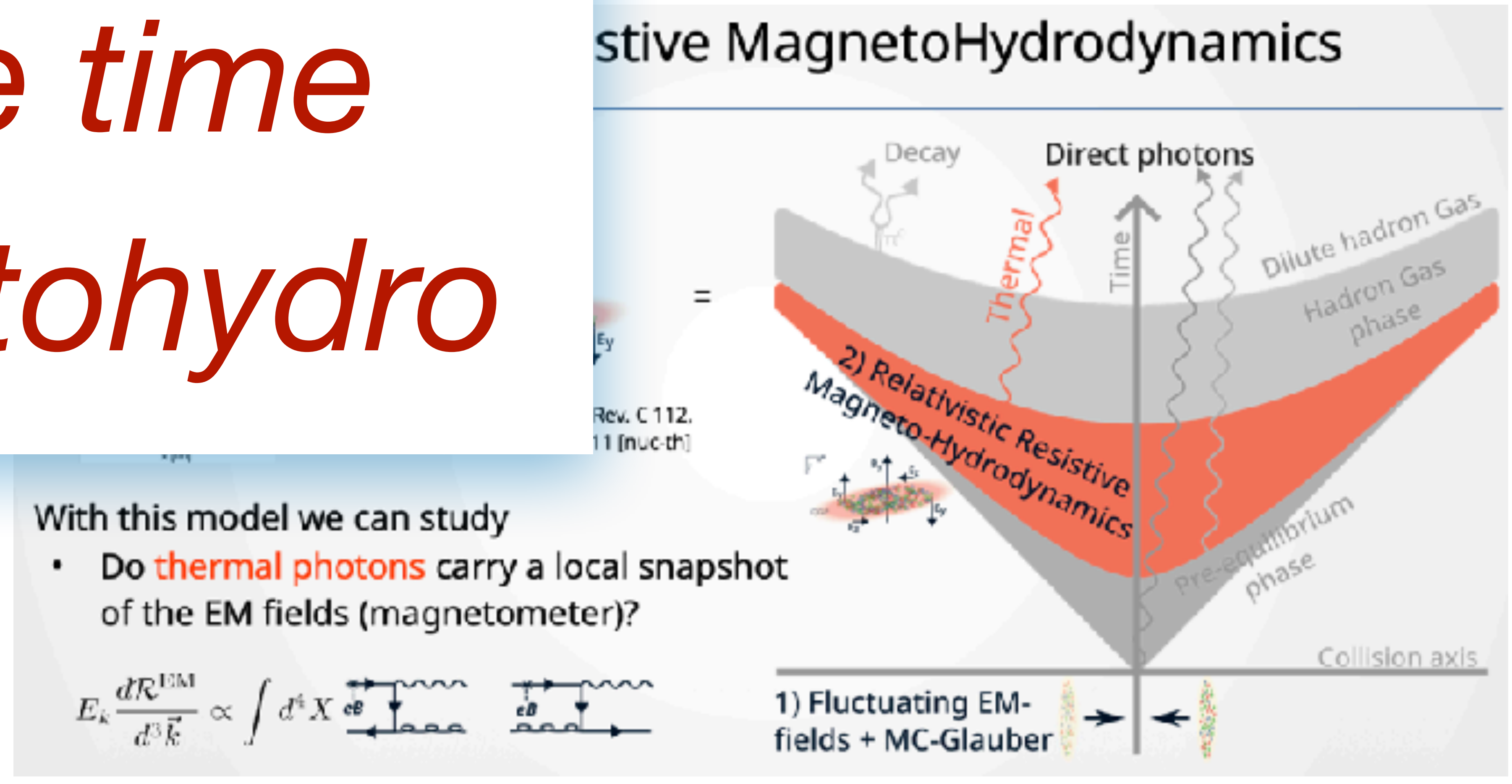


Huang, She, SS, Huang, Liao, PhysRevC.107.034901



K. Kushwah, TUE 11:35, Parellel IV

N. Benoit, TUE 12:15, Parellel IV

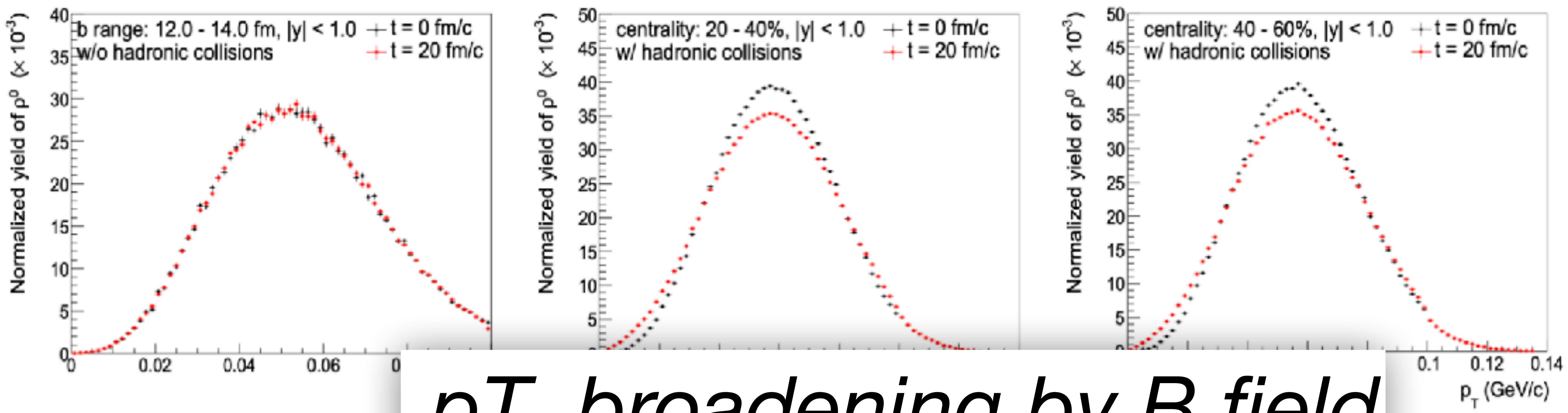


Crucial: short vacuum life time

⇒ non-equilibrium magnetohydro

independent probes of magnetic field

Effect on pair p_T spectrum



pT broadening by B field (in photonuclear process)

- The magnetic field als[…]
- Some methods for extracting nuclear shape parameters are highly sensitive to the peak position in the p_T spectrum, so this broadening effect may also need to be taken into account.

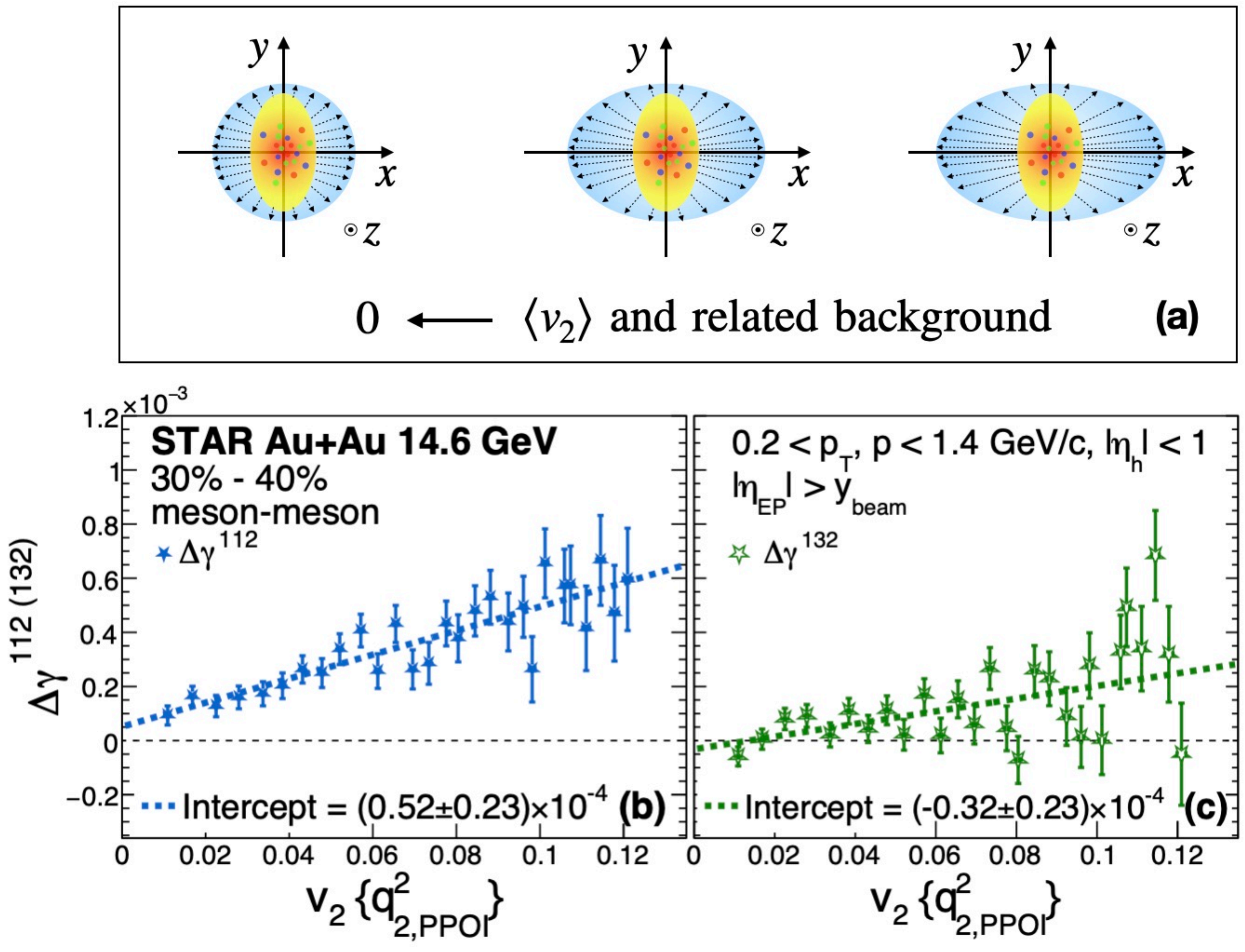
24/03/2026 SQM2026, ZHAN ZHANG 12

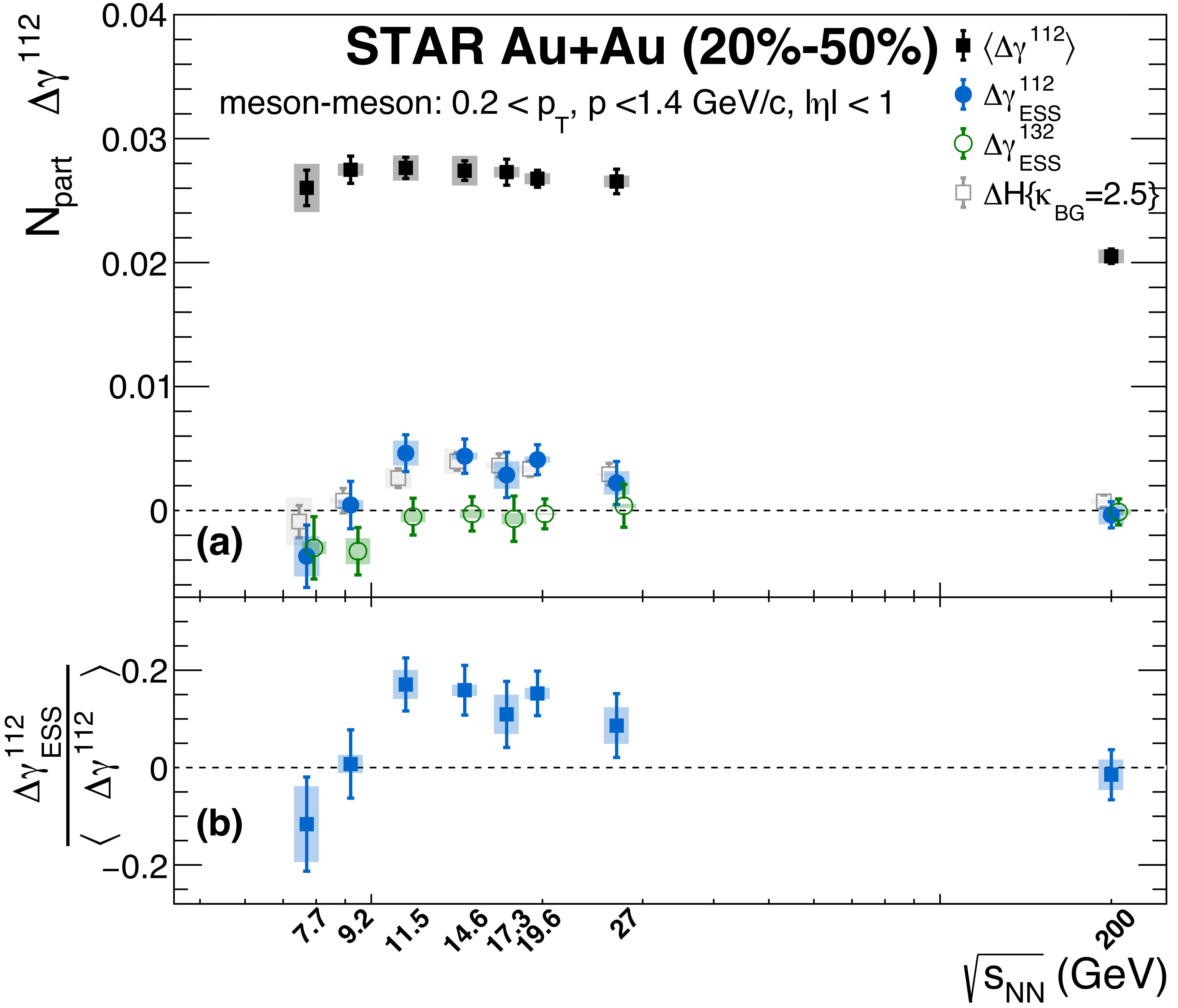
Zhan Zhang, TUE 11:15, Parellel IV
+ K. Kushwah, TUE 11:35, Parellel IV
+ N. Benoit, TUE 12:15, Parellel IV

can independent probes nail down uncertainties in B field?

lower beam energy — long lifetime

STAR, 2506.00265+PhysRevC.113.014912





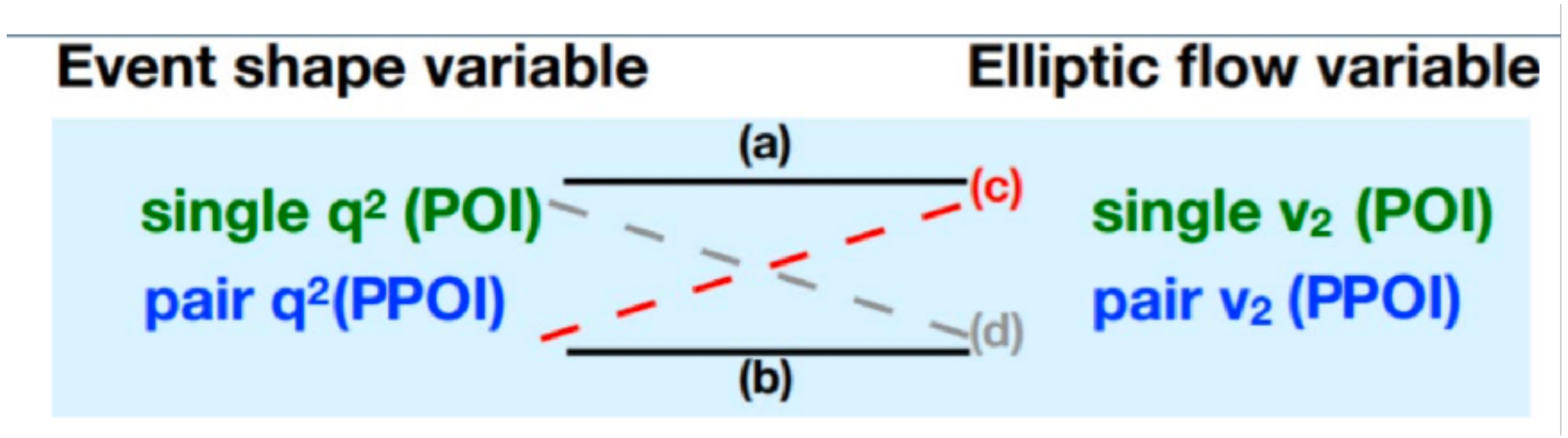
STAR: $\sim 3\sigma$ significance @ 11.5-19.6 GeV

lower beam energy — long lifetime

STAR, 2506.00265+PhysRevC.113.014912

background subtraction methods in experiment: shape engineering

(I)



(II) Event Plane vs Spectator Plane comparison

Test background in no-CME experiments? e.g. 5.02 TeV PbPb

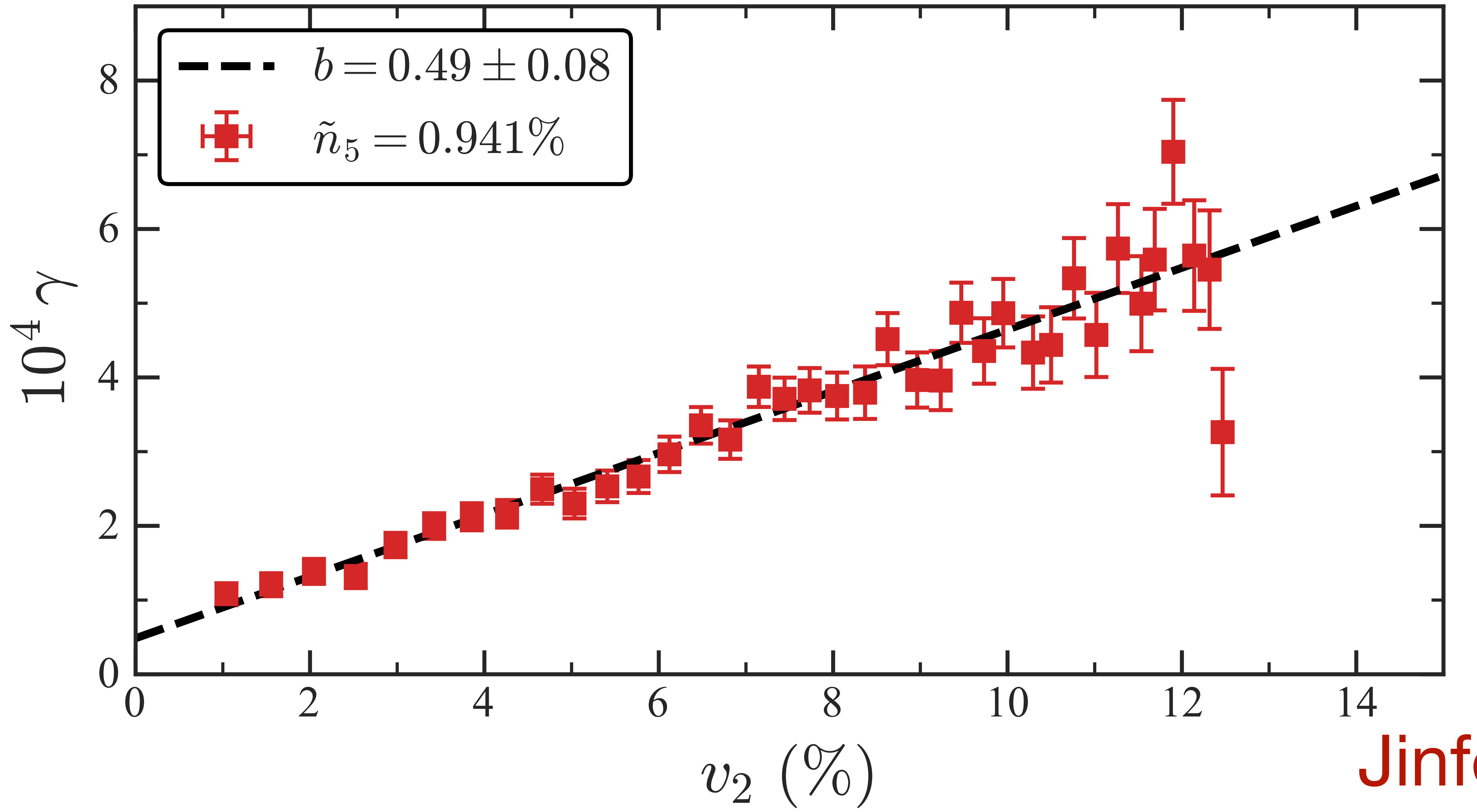
STAR: $\sim 3\sigma$ significance @ 11.5-19.6 GeV

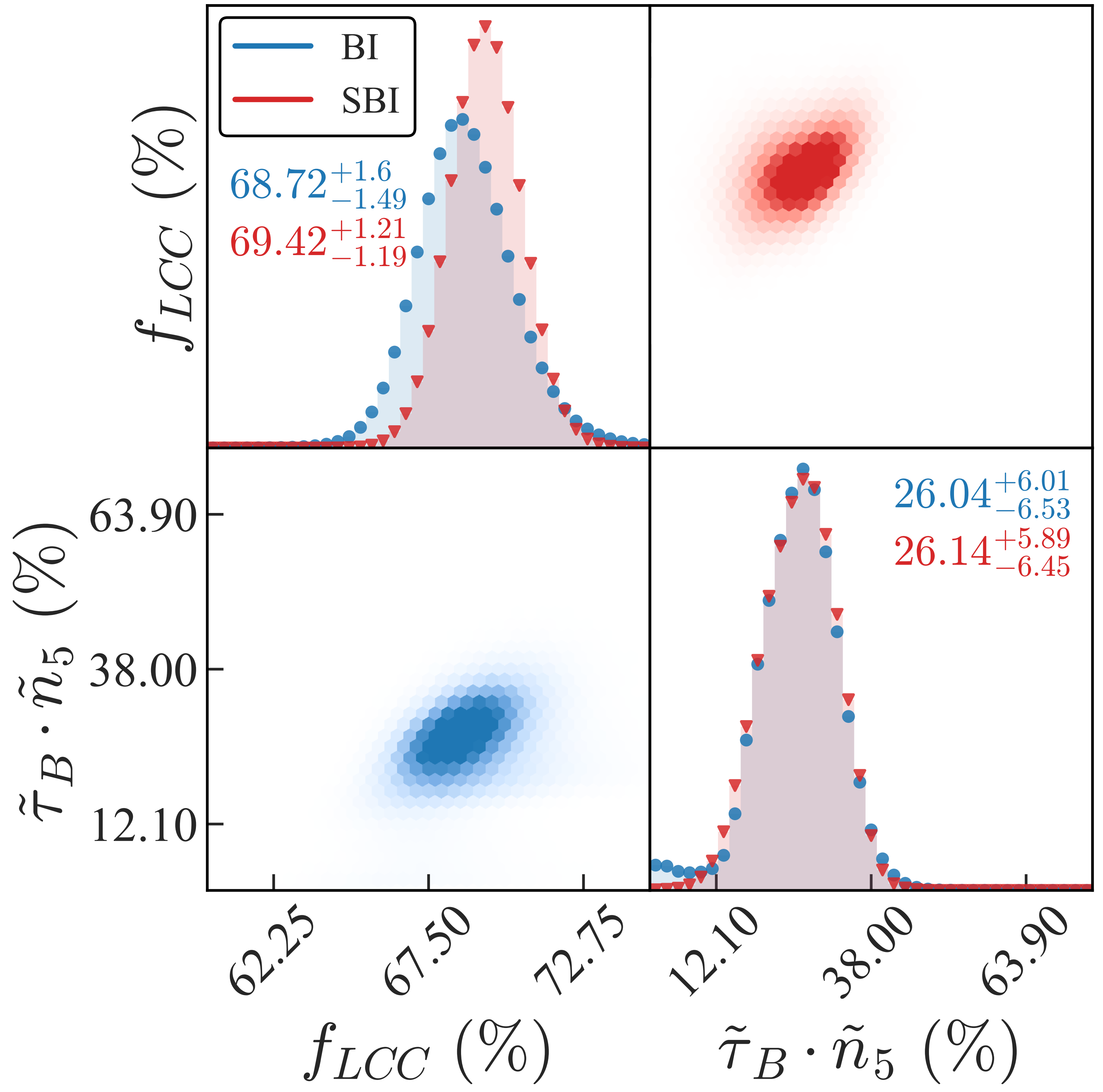
lower beam energy — long lifetime

STAR, 2506.00265+PhysRevC.113.014912

A machine-learning extraction

$$\Delta\gamma, \Delta\delta \rightarrow f_{\rm LCC}, \tau_B, n_5$$





Jinfeng Liao, TUE 15:15, Parellel IV

Alex Akridge, Yu Guo, J. Liao, SS, Hongxi Xing, Hui Zhang, in prep.

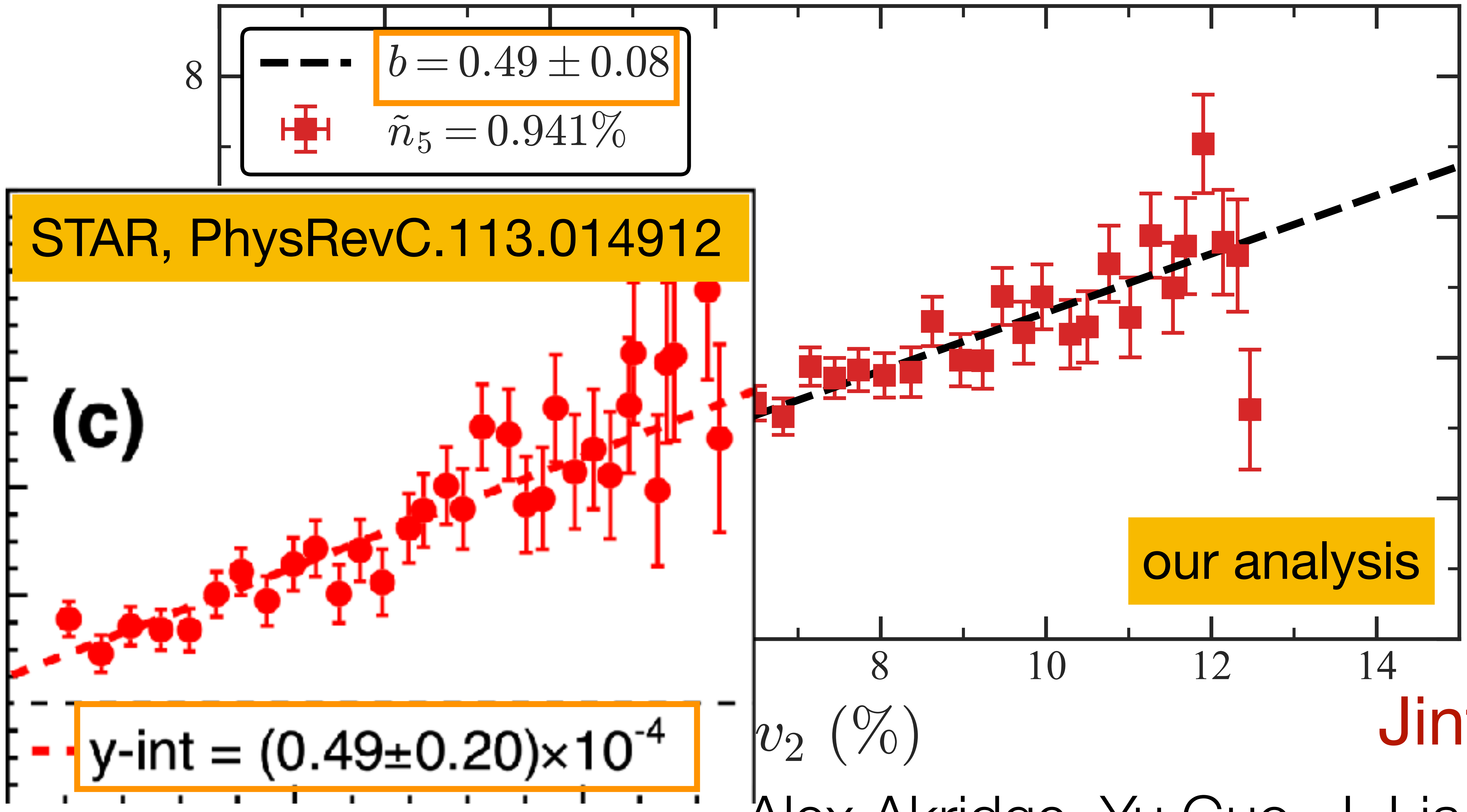
STAR: $\sim 3\sigma$ significance @ 11.5-19.6 GeV

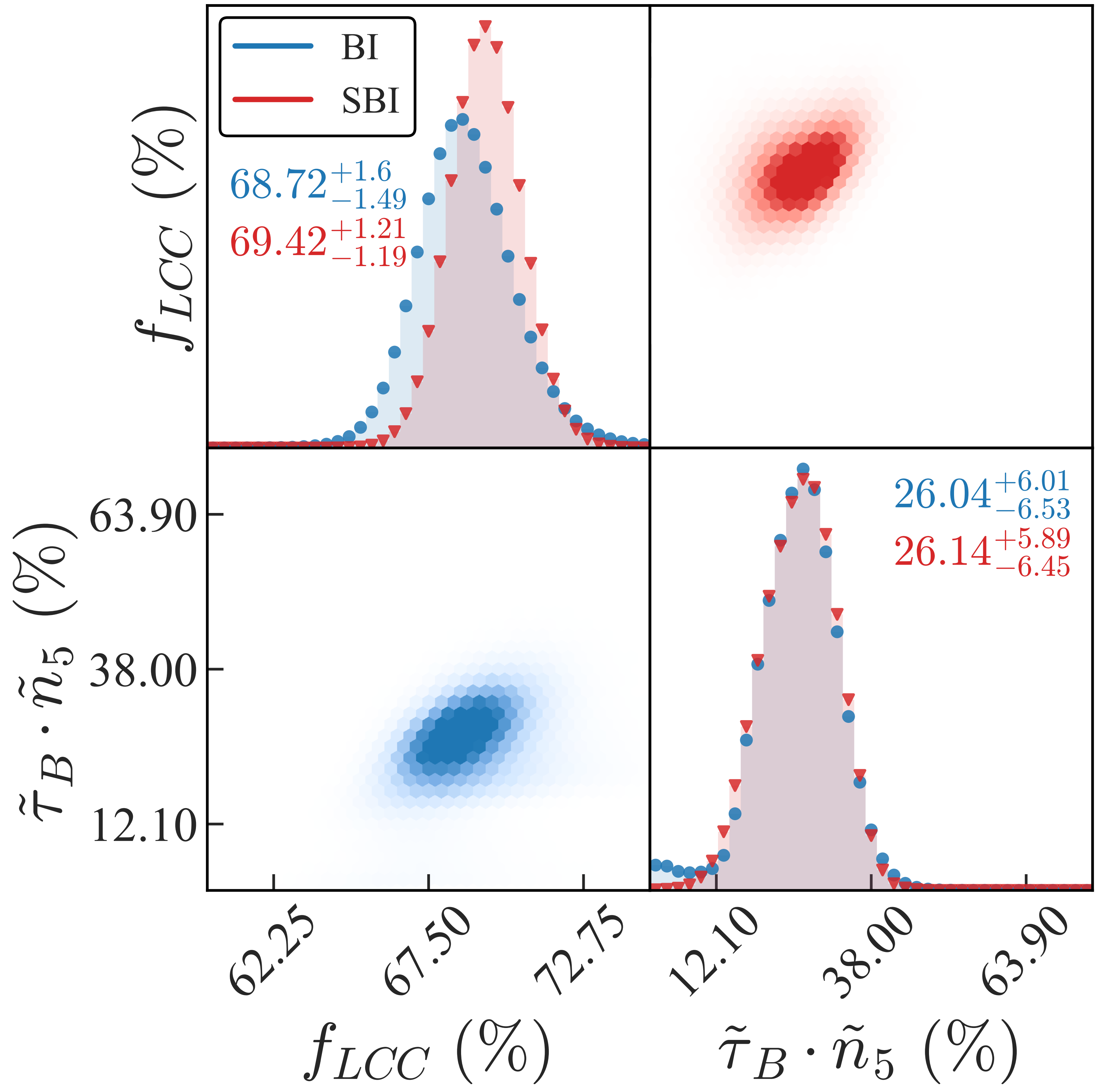
lower beam energy — long lifetime

STAR, 2506.00265+PhysRevC.113.014912

A machine-learning extraction

$$\Delta\gamma, \Delta\delta \rightarrow f_{\mathrm{LCC}}, \tau_B, n_5$$





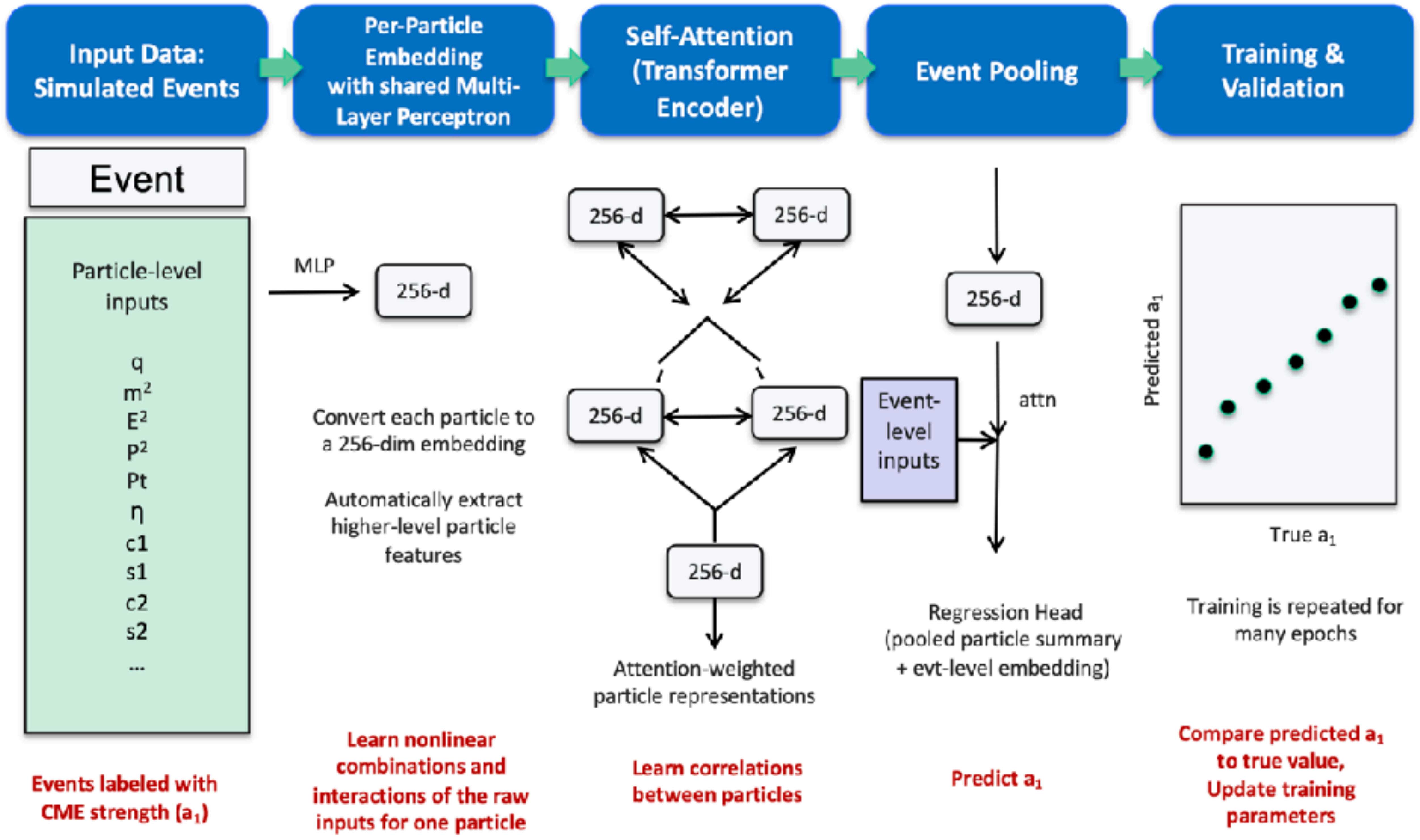
Jinfeng Liao, TUE 15:15, Parellel IV

Alex Akridge, Yu Guo, J. Liao, SS, Hongxi Xing, Hui Zhang, in prep.

STAR: $\sim 3\sigma$ significance @ 11.5-19.6 GeV

more opportunities from machine learning

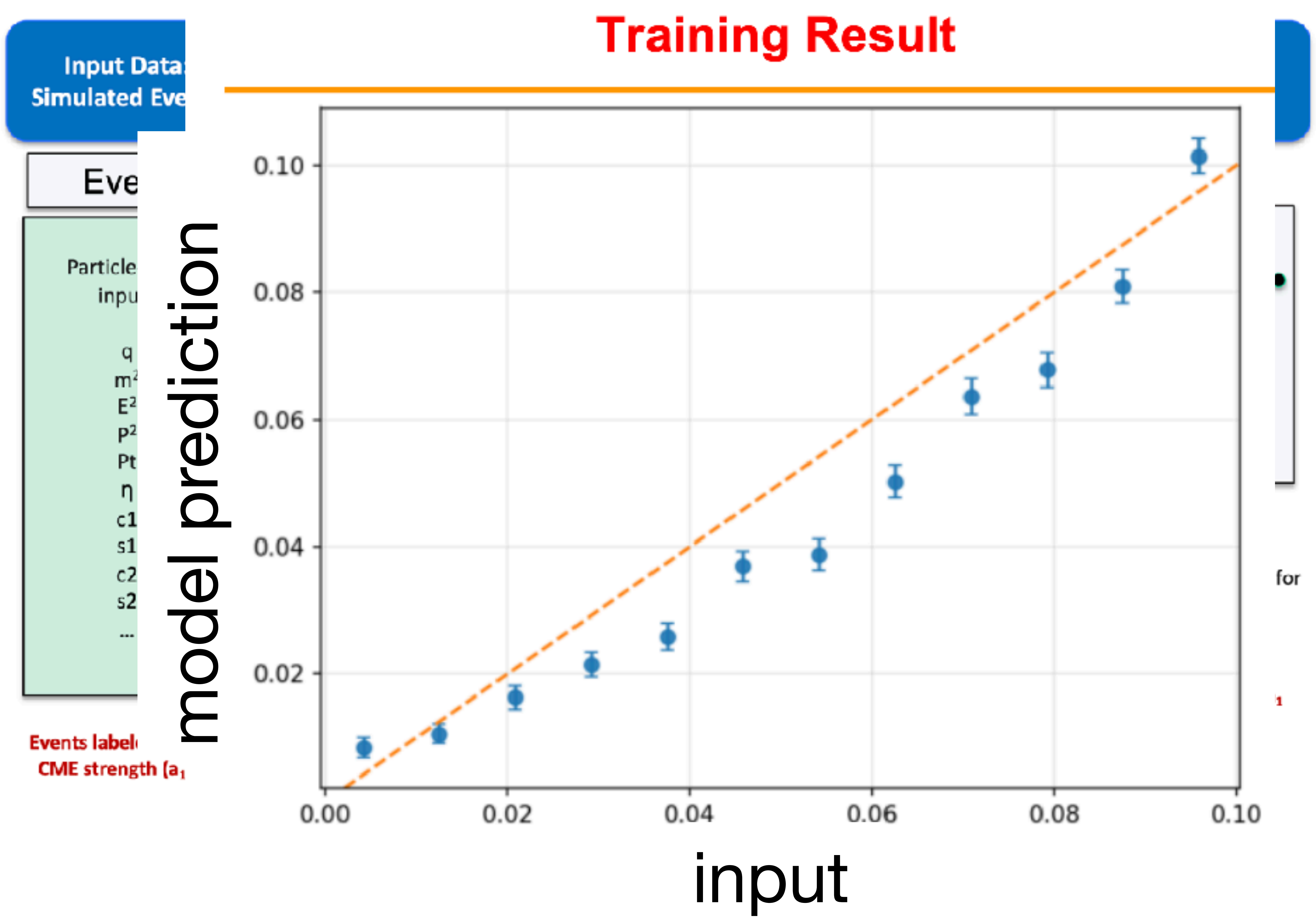
signal extraction w/ Transformer



Aihong Tang, TUE 14:35, Parellel IV

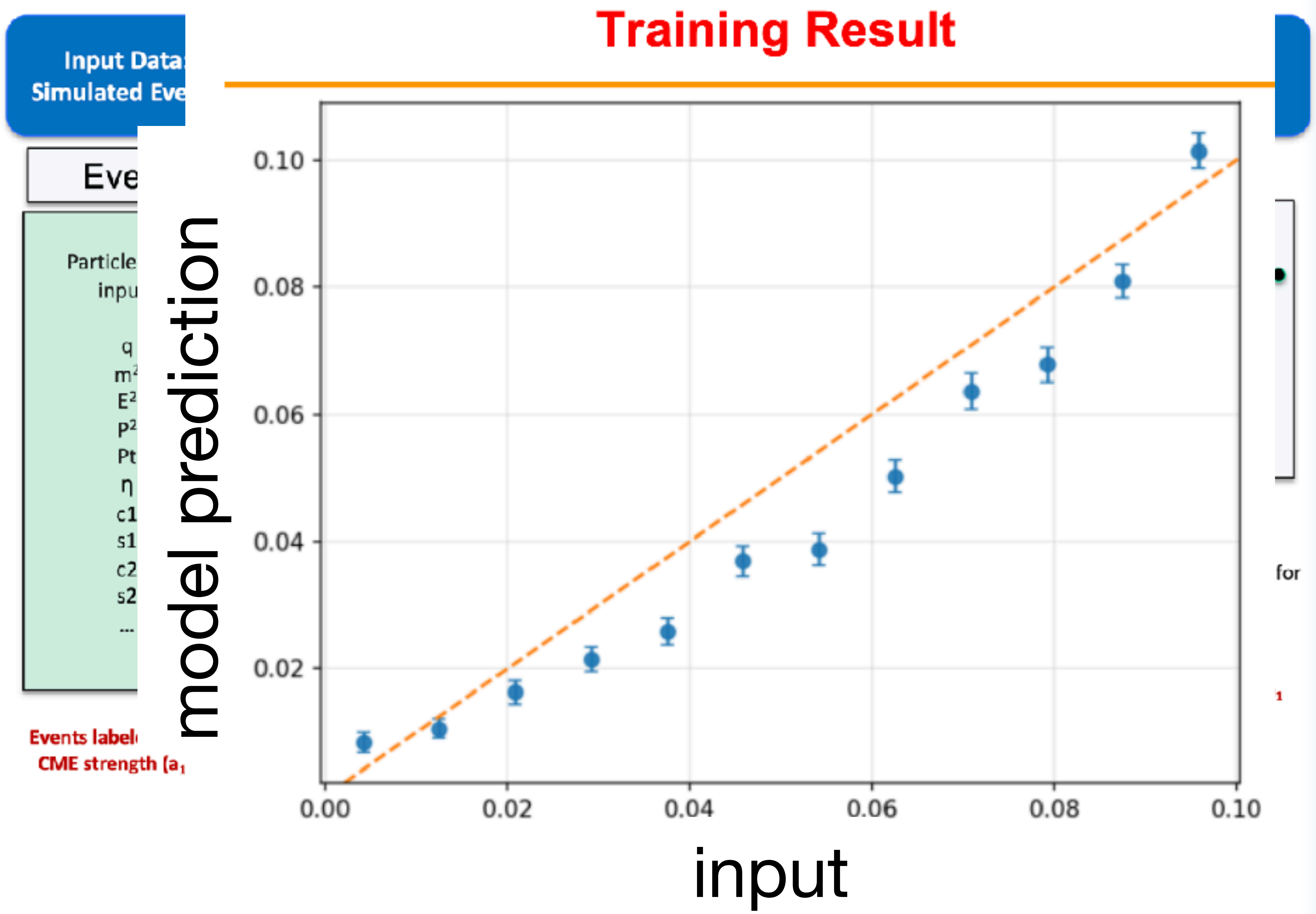
more opportunities from machine learning

signal extraction w/ Transformer



Aihong Tang, TUE 14:35, Parellel IV

signal extraction w/ Transformer



Aihong Tang, TUE 14:35, Parellel IV

“optimal” obs. trained w/ exp.

harmonic coefficients

$$O = L_{2i}\, c_{2i} + B_{i,j}\, c_i\, c_j$$

param. to be trained

$$O_{\mathrm{Pb+Pb@5.02TeV}} \to 0$$

maximize $O_{\mathrm{RuRu}} - O_{\mathrm{ZrZr}}$

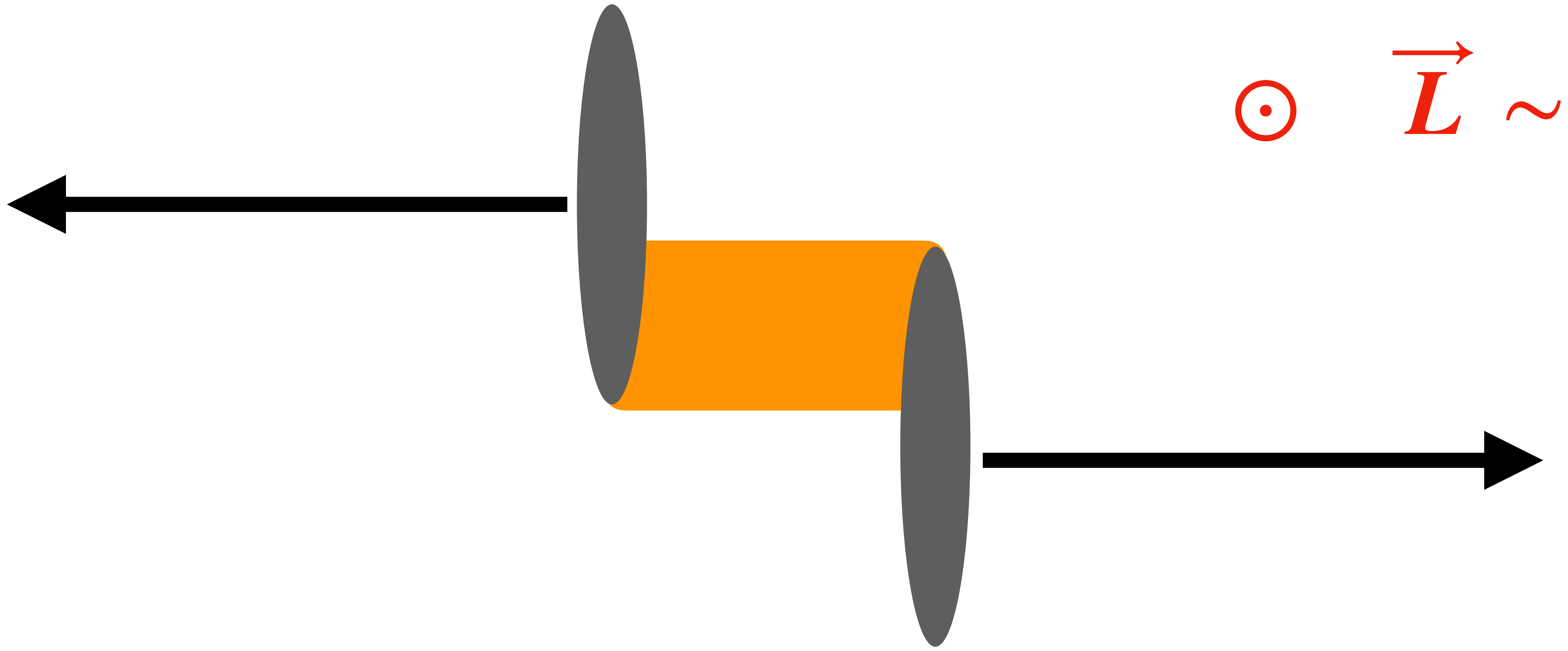
check: $O_{\mathrm{RuRu}} \approx 1.2\, O_{\mathrm{ZrZr}}$?

Hirono, Ikeda, Kharzeev, Ziyi Liu, SS,
PhyRevC.112.L051904

$$a_1^+ \propto \mu_5$$

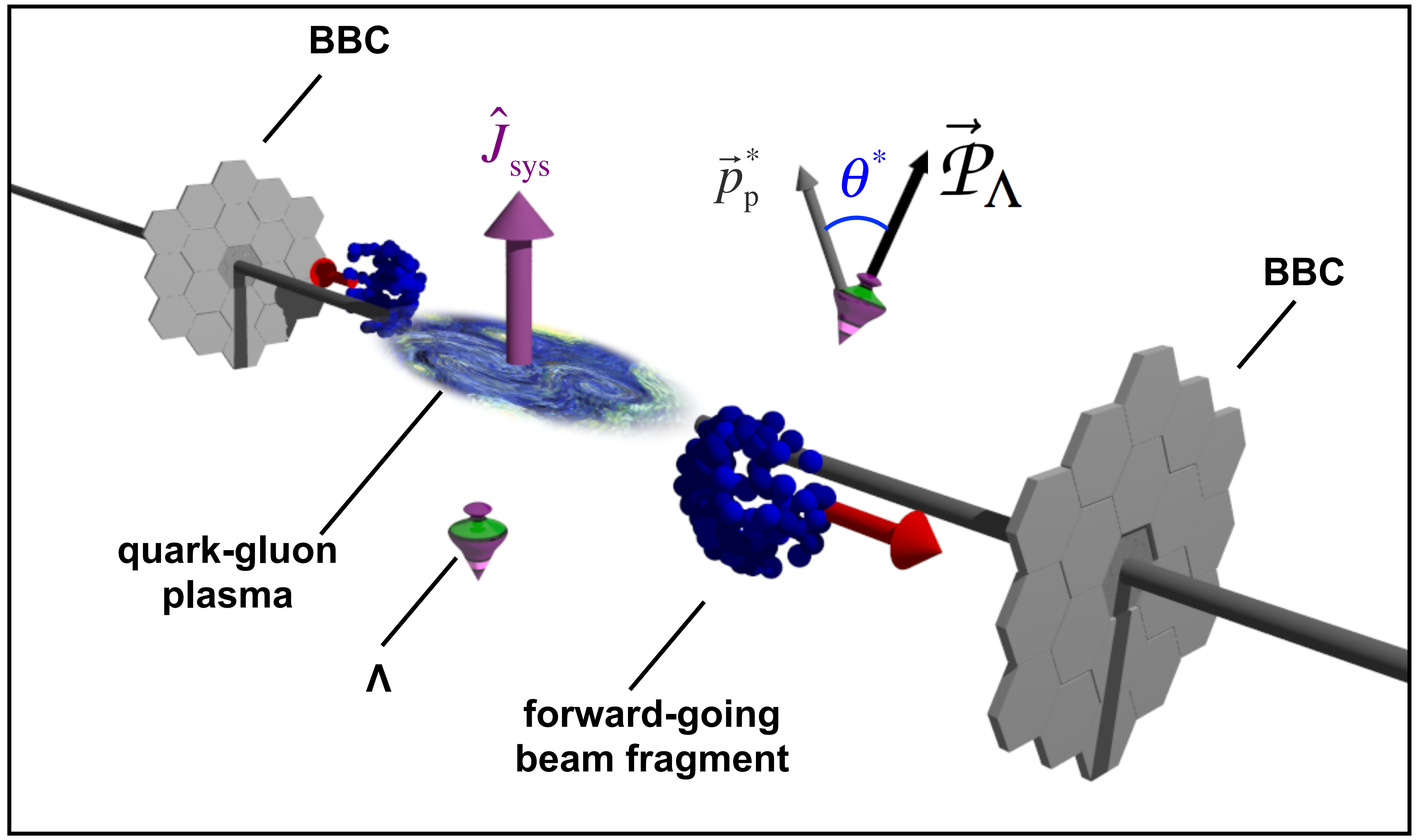
correlation between a_1^+ and Λ helicity?

spin polarization



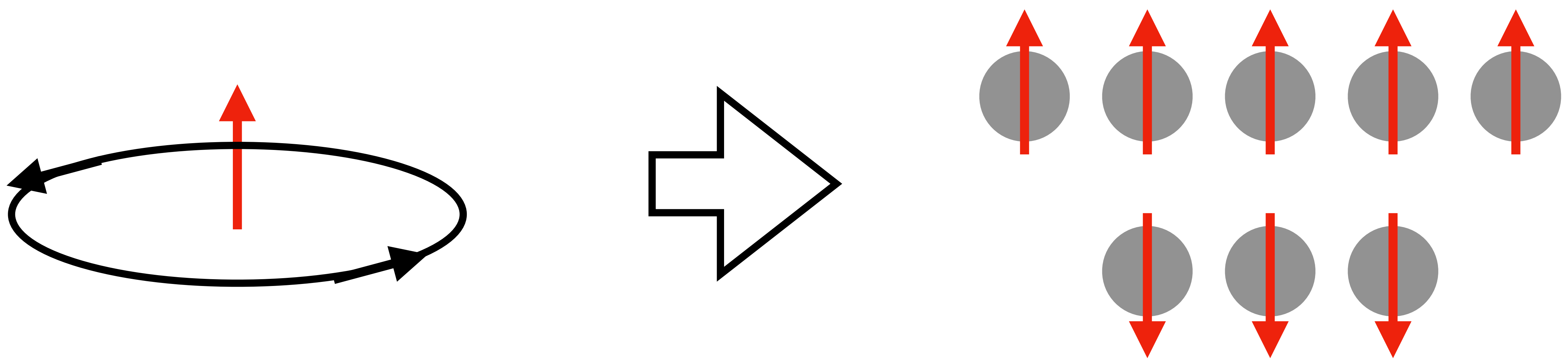
$\odot \quad \vec{L} \sim 10^{4-5}\hbar$

Angular Velocity: $\omega \sim 10^{21}$ Hz



rotation

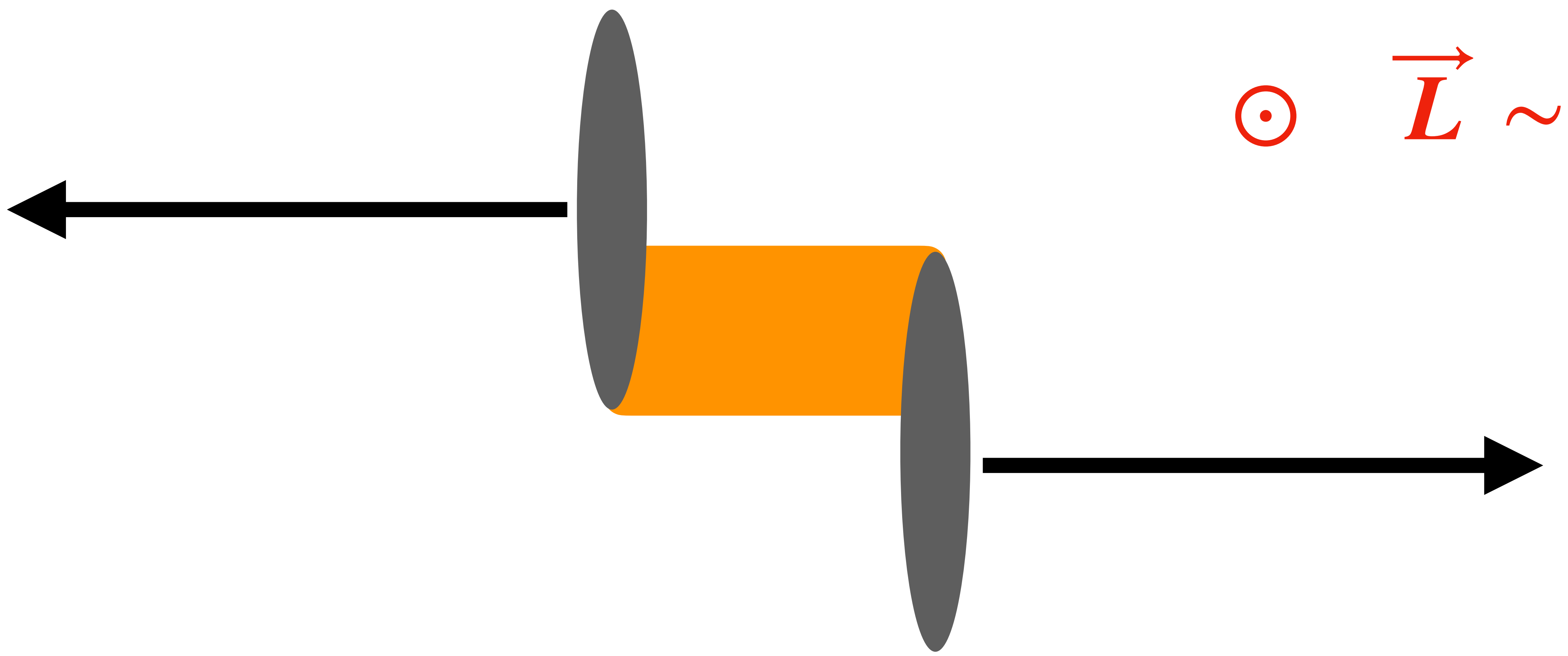
spin



Zuo-Tang Liang, Xin-Nian Wang, PhysRevLett.94.102301

STAR, Nature 548 (2017) 62-65

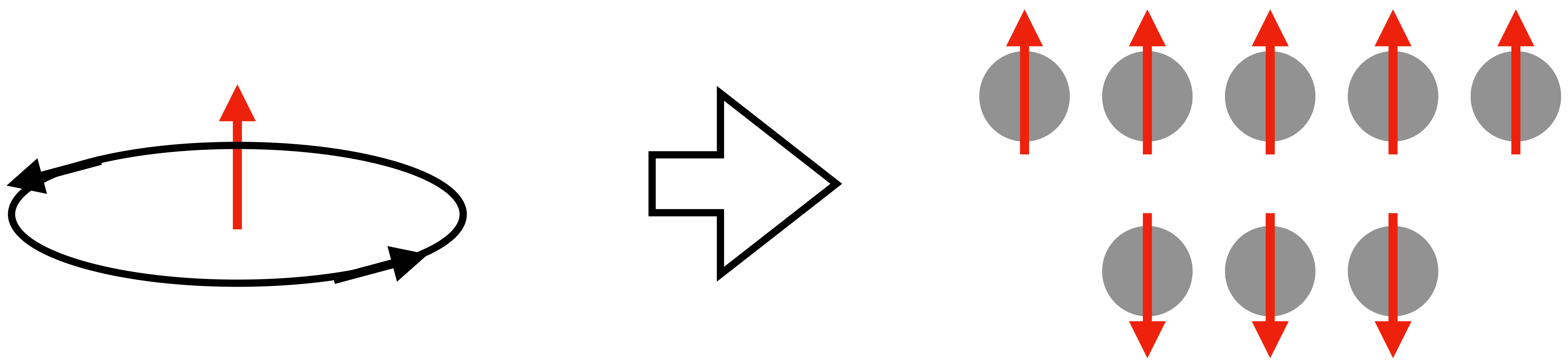
spin polarization

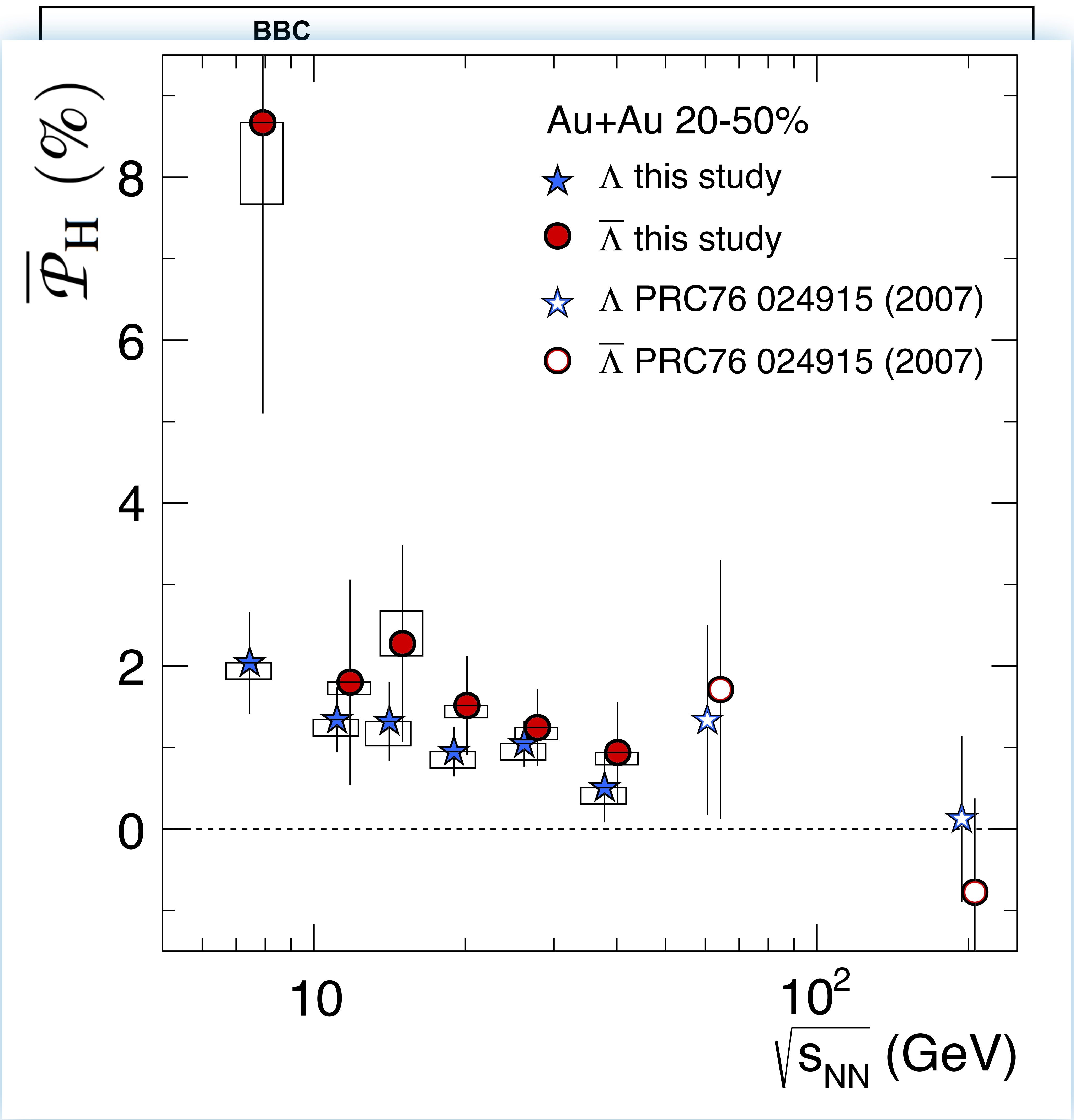


$\odot \quad \vec{L} \sim 10^{4-5}\hbar$

Angular Velocity: ω ~ 10^{21} Hz

rotation   spin

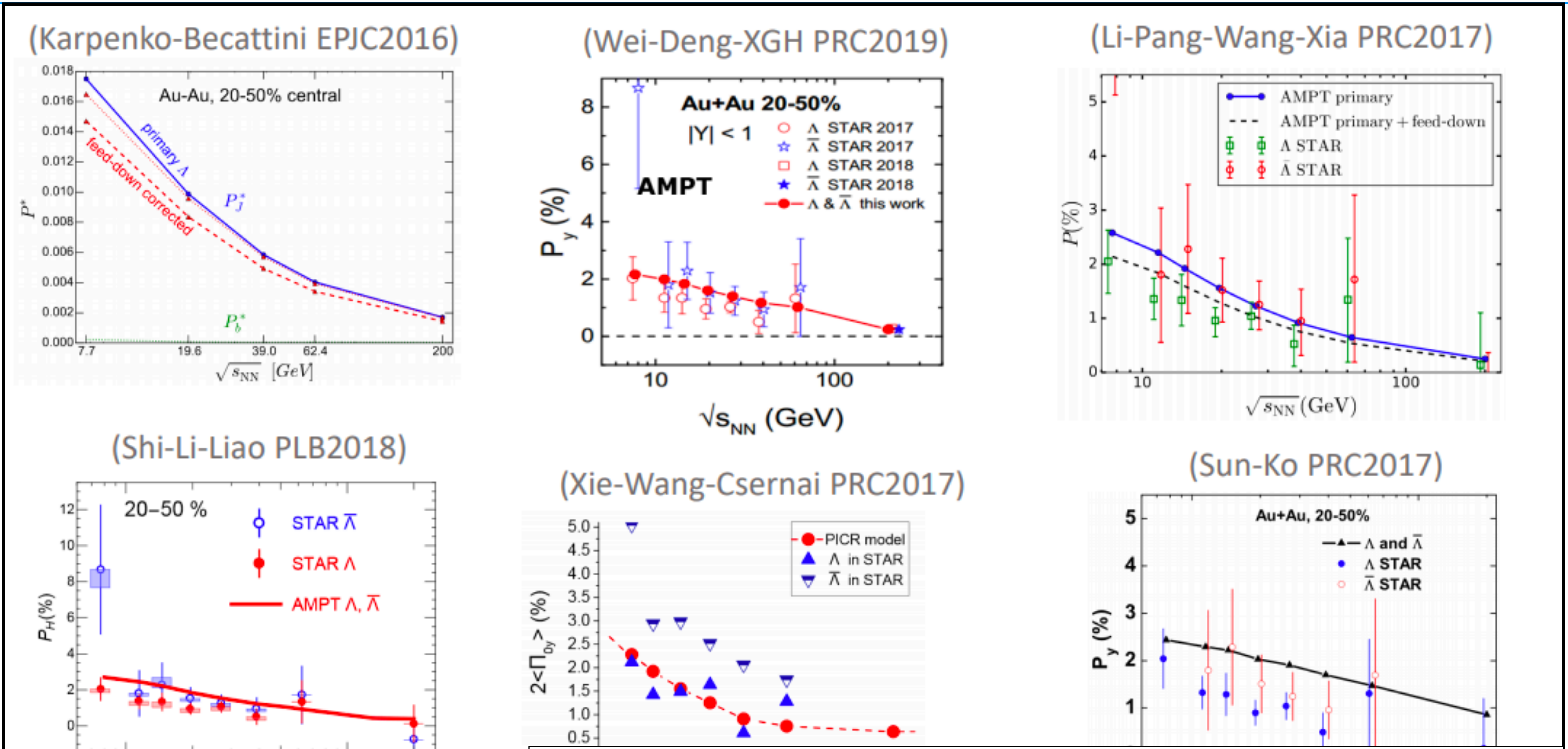




Zuo-Tang Liang, Xin-Nian Wang, PhysRevLett.94.102301

STAR, Nature 548 (2017) 62-65

polarization along out-of-plane direction



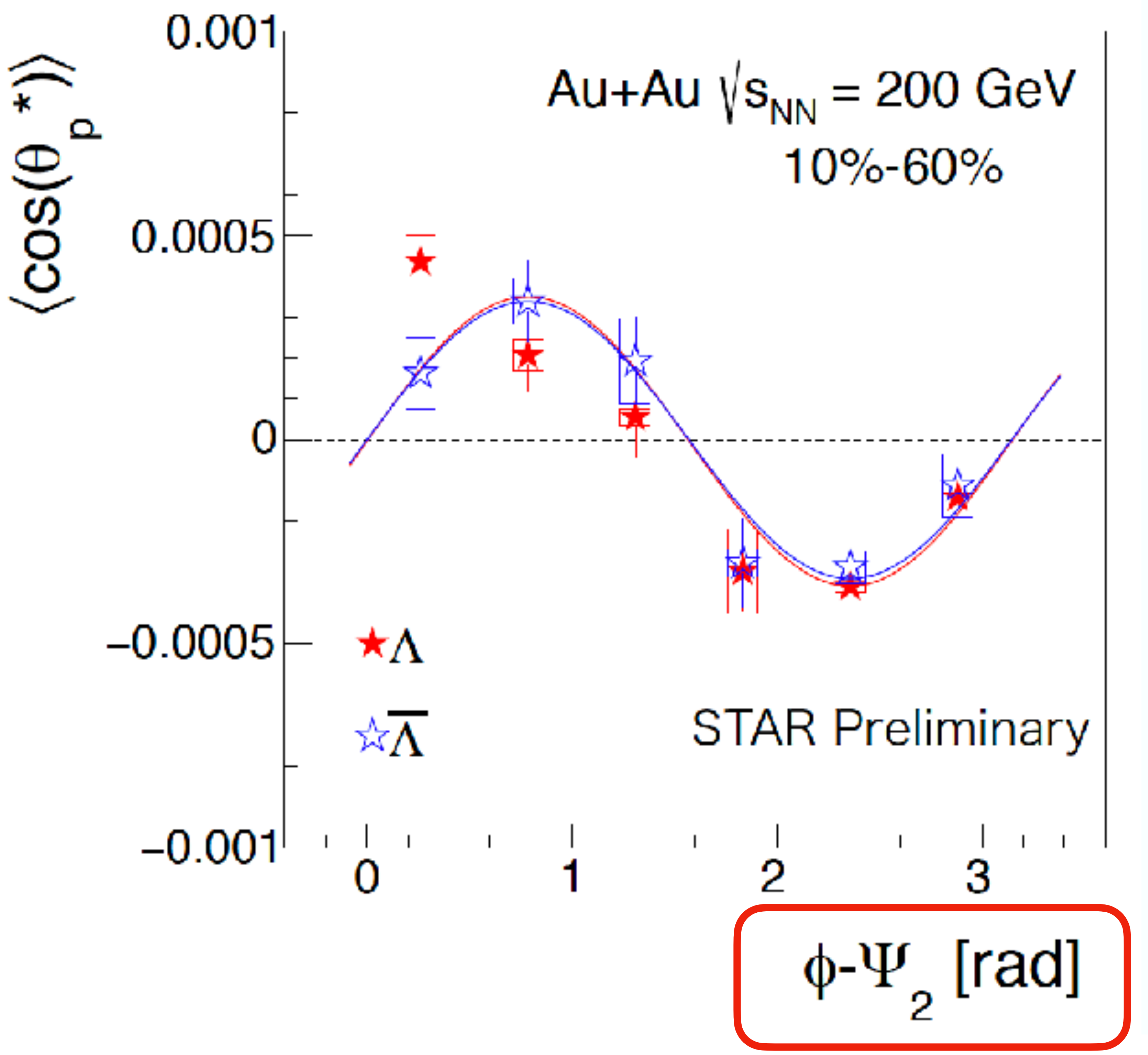
Slide from Xu-Guang Huang's QM19 Plenary Talk

Assuming equilibrium of the spin degrees of freedom,
global polarization rate can be well understood by theo. models.

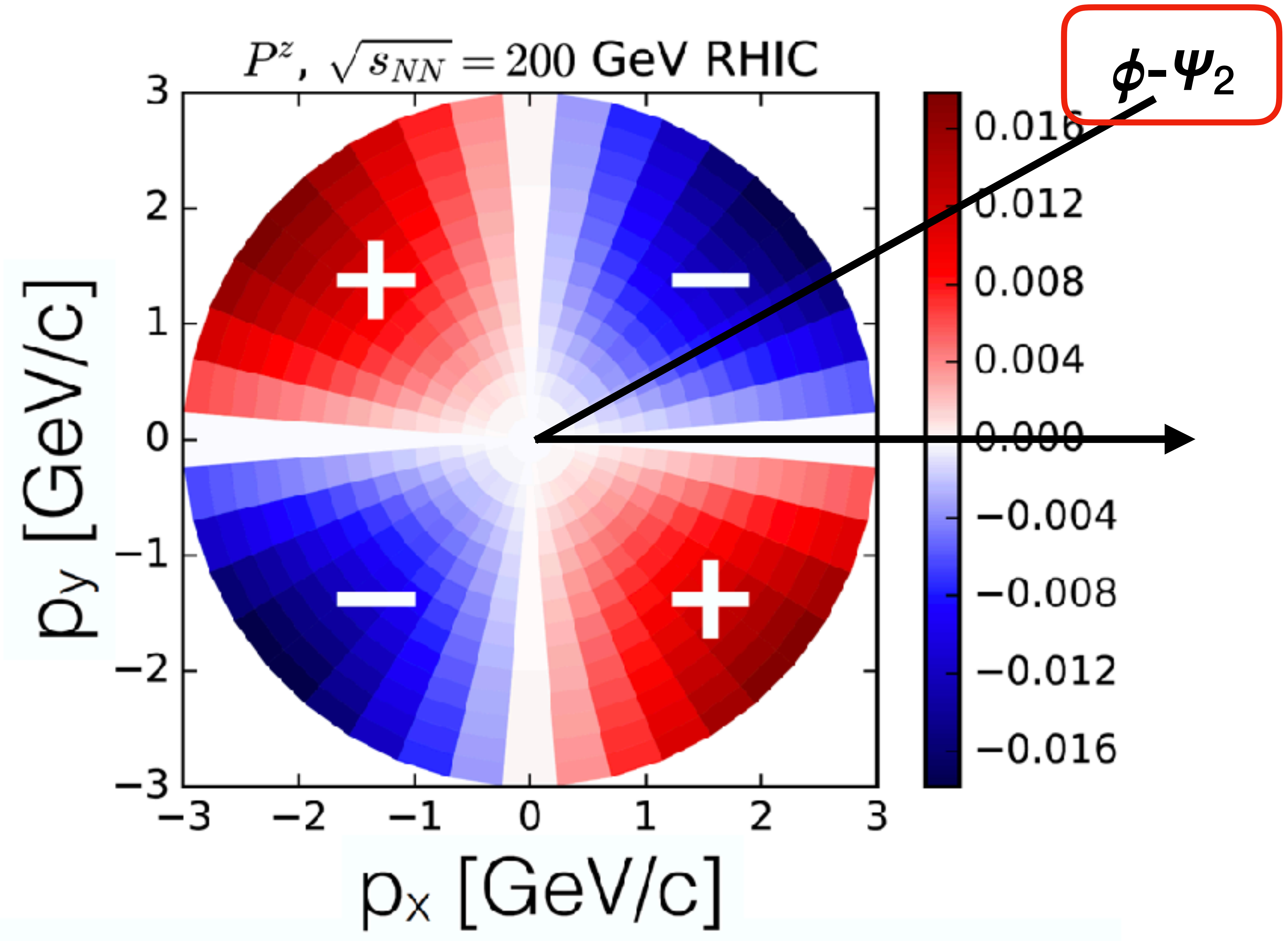
$$\varpi^{\mu\nu} \equiv \frac{1}{2}\left(\partial_\nu \frac{u_\mu}{T} - \partial_\mu \frac{u_\nu}{T}\right)$$

polarization along beam direction

Local longitudinal polarization due to collective flow



STAR



- (Hydro) F. Becattini & I. Karpenko, PRL 2018

Similarly in other models

transport of spin dof: macroscopic

macroscopic approach: conservation law + second law of thermodynamics

Fate of spin polarization in a relativistic fluid: An entropy-current analysis
Koichi Hattori, M.Hongo, Xu-Guang Huang, M.Matsuo, H.Taya, Phys.Lett.B 795 (2019) 100-106

Spin hydrodynamics and symmetric energy-momentum tensors – A current induced by the spin vorticity
Kenji Fukushima, Shi Pu, Phys.Lett.B 817 (2021) 136346

Cross effects in spin hydrodynamics: Entropy analysis and statistical operator
Jin Hu, PhysRevC.107.024915

Relativistic viscous hydrodynamics with angular momentum
Duan She, Anping Huang, Defu Hou, Jinfneg Liao, *Sci.Bull.* 67 (2022) 2265

Transport coefficients are sensitive to microscopic details

Microscopic:

Macroscopic:

distribution function

$\int_p$

conserved (hydrodynamic) currents

$$W_{ab}(x,p) \equiv \left\langle \int \mathrm{d}^4 y \, e^{i\frac{p\cdot y}{\hbar}} \bar{\psi}_b(x+\frac{y}{2})\psi_a(x-\frac{y}{2}) \right\rangle ,$$

$$J^\mu(x), \quad T^{\mu\nu}(x), \quad S^{\mu\nu\lambda}(x)$$

Vortical+Magnetic Effect

Non-Equilibrium Effect

transport of spin dof: microscopic

Wigner Function

$$W_{ab}(x,p) \equiv \left\langle \int \mathrm{d}^4y\, e^{i\frac{p\cdot y}{\hbar}} \bar{\psi}_b(x+\frac{y}{2})\psi_a(x-\frac{y}{2}) \right\rangle ,$$

a 4×4 matrix, decomposed in Clifford basis

$$W = \frac{1}{4}\left(\mathscr{F} + i\mathscr{P}\gamma^5 + \mathscr{V}_\mu \gamma^\mu + \mathscr{A}_\mu \gamma^5 \gamma^\mu + \frac{1}{2}\mathscr{L}_{\mu\nu}\sigma^{\mu\nu} \right),$$

transport of spin dof: microscopic

Wigner Function

$$W_{ab}(x,p) \equiv \left\langle \int d^4y\, e^{i\frac{p\cdot y}{\hbar}} \bar{\psi}_b(x+\frac{y}{2})\psi_a(x-\frac{y}{2}) \right\rangle ,$$

a 4×4 matrix, decomposed in Clifford basis

$$W = \frac{1}{4}\left(\mathscr{F} + i\mathscr{P}\gamma^5 + \mathscr{V}_\mu\gamma^\mu + \mathscr{A}_\mu\gamma^5\gamma^\mu + \frac{1}{2}\mathscr{S}_{\mu\nu}\sigma^{\mu\nu} \right),$$

- Boltzmann equation
- Lorentz force
- chiral vortical effect + spin polarization
- chiral magnetic effect

Dirac Equation

$$\gamma^\mu(i\hbar\partial_\mu - QA_\mu)\,\psi(x) = 0$$

$$\mathscr{J}^\mu_\pm \equiv \frac{\mathscr{V}^\mu \pm \mathscr{A}^\mu}{2} = \left[p^\mu\delta(p^2) \pm \hbar\delta(p^2)\frac{\epsilon^{\mu\nu\lambda\rho}p_\nu n_\lambda}{2p\cdot n}\nabla_\rho \pm \hbar Q\delta'(p^2)\widetilde{F}^{\mu\nu}p_\nu \right] f_\pm ,$$

$$0 = \delta\left(p^2 \mp \hbar Q\frac{p\cdot B}{p\cdot n}\right)\left[p\cdot\partial - Qp^\mu F_{\mu\nu}\partial_p^\nu \pm \hbar\left(\partial_\mu\frac{\epsilon^{\mu\nu\lambda\rho}p_\nu n_\lambda}{2p\cdot n}\right)\nabla_\rho \mp \hbar Q\frac{\epsilon^{\mu\nu\lambda\rho}E_\mu n_\nu p_\lambda}{2(p\cdot n)^2}\nabla_\rho \pm \hbar\frac{Q}{2p\cdot n}p_\lambda\left(\partial_\sigma\widetilde{F}^{\lambda\nu}\right)n_\nu\partial_p^\sigma \right] f_\pm .$$

Huang, *SS*, Jiang, Liao, and Zhuang, PhysRevD.98.036010

transport of spin dof: macroscopic

Wigner Function

$$W_{ab}(x,p) \equiv \left\langle \int \mathrm{d}^4 y \, e^{i\frac{p\cdot y}{\hbar}} \bar{\psi}_b(x+\frac{y}{2}) \psi_a(x-\frac{y}{2}) \right\rangle ,$$

a 4×4 matrix, decomposed in Clifford basis

$$W = \frac{1}{4}\Big(\mathscr{F} + i\mathscr{P}\gamma^5 + \mathscr{V}_\mu \gamma^\mu + \mathscr{A}_\mu \gamma^5 \gamma^\mu + \frac{1}{2}\mathscr{L}_{\mu\nu}\sigma^{\mu\nu} \Big),$$

Hydrodynamic Quantities:

$$J^\mu \equiv \langle \bar{\psi}\gamma^\mu \psi \rangle = \int \frac{\mathrm{d}^4 p}{(2\pi)^4} \mathscr{V}^\mu ,$$

$$T^{\mu\nu} \equiv \langle \bar{\psi}(i\gamma^\mu \partial^\nu)\psi \rangle = \int \frac{\mathrm{d}^4 p}{(2\pi)^4} p^\mu \mathscr{V}^\nu ,$$

$$S^{\lambda\mu\nu} \equiv \frac{1}{4}\langle \bar{\psi}\{\gamma^\lambda, \sigma^{\mu\nu}\}\psi \rangle = \frac{\epsilon^{\lambda\mu\nu\sigma}}{2} \int \frac{\mathrm{d}^4 p}{(2\pi)^4} \mathscr{A}_\sigma ,$$

transport of spin dof: macroscopic

Wigner Function

$$W_{ab}(x,p) \equiv \left\langle \int \mathrm{d}^4 y\, e^{i\frac{p\cdot y}{\hbar}} \bar{\psi}_b(x+\frac{y}{2})\psi_a(x-\frac{y}{2}) \right\rangle ,$$

a 4×4 matrix, decomposed in Clifford basis

$$W = \frac{1}{4}\Big(\mathscr{F} + i\mathscr{P}\gamma^5 + \mathscr{V}_\mu\gamma^\mu + \mathscr{A}_\mu\gamma^5\gamma^\mu + \frac{1}{2}\mathscr{L}_{\mu\nu}\sigma^{\mu\nu}\Big),$$

Hydrodynamic Quantities:

$$J^\mu \equiv \langle \bar{\psi}\gamma^\mu\psi\rangle = \int \frac{\mathrm{d}^4 p}{(2\pi)^4}\mathscr{V}^\mu ,$$

$$T^{\mu\nu} \equiv \langle \bar{\psi}(i\gamma^\mu\partial^\nu)\psi\rangle = \int \frac{\mathrm{d}^4 p}{(2\pi)^4} p^\mu \mathscr{V}^\nu ,$$

$$S^{\lambda\mu\nu} \equiv \frac{1}{4}\langle \bar{\psi}\{\gamma^\lambda,\sigma^{\mu\nu}\}\psi\rangle = \frac{\epsilon^{\lambda\mu\nu\sigma}}{2}\int \frac{\mathrm{d}^4 p}{(2\pi)^4}\mathscr{A}_\sigma ,$$

SHI, GALE, AND JEON

Substituting the distribution function in the definitions (13)–(15), we find the RH and LH particle currents and energy-momentum stress tensor,

Chiral-viscous hydrodynamic equations

$$\pm\frac{\hbar}{2}\epsilon^{\mu\rho\sigma\lambda}u_\rho\partial_\sigma\left(\frac{G^{(1),\pm}_{4,1}}{D^{\pm}_{3,1}}\nu_{\pm,\lambda}\right)$$

$$\pm\frac{\hbar J^{\pm}_{2,2}}{4J^{\pm}_{4,2}}(\epsilon^{\mu\rho\sigma\lambda}u_\rho\sigma_\sigma{}^\xi\pi_{\lambda\xi} - \pi^{\mu\lambda}\omega_\lambda)$$

$$\equiv n_\pm u^\mu + \nu^\mu_\pm + \hbar J^\mu_{\text{quantum},\pm}, \qquad (67)$$

$$T^{\mu\nu} = \varepsilon u^\mu u^\nu - P\Delta^{\mu\nu} + \pi^{\mu\nu} + \frac{4\hbar}{5}\omega^\mu(\nu^\nu_+ - \nu^\nu_-)$$

$$+\frac{\hbar n_A}{4}(8\omega^\mu u^\nu + T\epsilon^{\mu\nu\sigma\lambda}\varpi_{\sigma\lambda})$$

$$+\frac{\hbar}{2}\epsilon^{\mu\rho\sigma\lambda}u_\rho u^\nu\partial_\sigma(\nu^+_\lambda - \nu^-_\lambda)$$

$$-\frac{\hbar}{10}\epsilon^{\mu\nu\rho\sigma}u_\rho(\partial_\sigma u^\lambda)(\nu^+_\lambda - \nu^-_\lambda)$$

$$+\frac{2\hbar}{[illegible]}\epsilon^{\mu\lambda\rho\sigma}u_\rho(\partial_\sigma u^\nu)(\nu^+_\lambda - \nu^-_\lambda)$$

SS, Gale, and Jeon, PhysRevC.103.044906

Wigner Function

$$W_{ab}(x,p) \equiv \left\langle \int \mathrm{d}^4y\, e^{i\frac{p\cdot y}{\hbar}} \bar{\psi}_b(x+\frac{y}{2})\psi_a(x-\frac{y}{2}) \right\rangle,$$

a 4×4 matrix, decomposed in Clifford basis

$$W = \frac{1}{4}\left(\mathscr{F} + i\mathscr{P}\gamma^5 + \mathscr{V}_\mu\gamma^\mu + \mathscr{A}_\mu\gamma^5\gamma^\mu + \frac{1}{2}\mathscr{L}_{\mu\nu}\sigma^{\mu\nu}\right),$$

Hydrodynamic Quantities:

$$J^\mu \equiv \langle \bar{\psi}\gamma^\mu\psi\rangle = \int \frac{\mathrm{d}^4p}{(2\pi)^4}\mathscr{V}^\mu,$$

$$T^{\mu\nu} \equiv \langle \bar{\psi}(i\gamma^\mu\partial^\nu)\psi\rangle = \int \frac{\mathrm{d}^4p}{(2\pi)^4} p^\mu \mathscr{V}^\nu,$$

$$S^{\lambda\mu\nu} \equiv \frac{1}{4}\langle \bar{\psi}\{\gamma^\lambda, \sigma^{\mu\nu}\}\psi\rangle = \frac{\epsilon^{\lambda\mu\nu\sigma}}{2}\int \frac{\mathrm{d}^4p}{(2\pi)^4}\mathscr{A}_\sigma,$$

SHI, GALE, AND JEON

Substituting the distribution function in the definitions (13)–(15), we find the RH and LH particle currents and energy-momentum stress tensor,

$$T^{\mu\nu} = \varepsilon u^\mu u^\nu - P\Delta^{\mu\nu} + \pi^{\mu\nu} + \frac{4\hbar}{5}\omega^\mu(\nu_+^\nu - \nu_-^\nu) + \frac{\hbar n_A}{4}(8\omega^\mu u^\nu + T\epsilon^{\mu\nu\sigma\lambda}\varpi_{\sigma\lambda})$$

many other references:

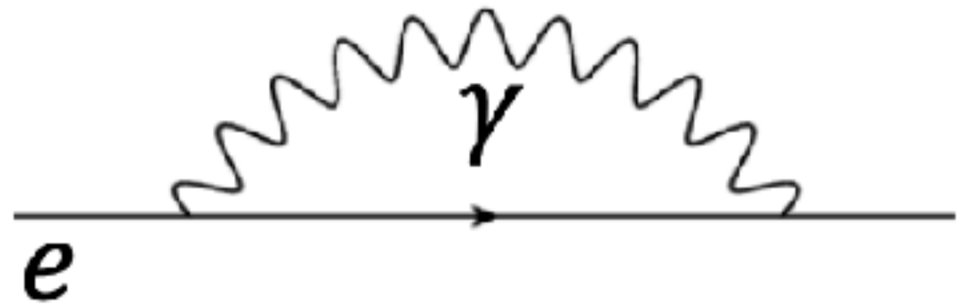
Cracow, Florence, Frankfurt, Fudan,

Shandong Univ., SYSU, Tsinghua, USTC, ...

transport of spin dof: macroscopic

W

➢ changing onshell condition : $q^2 = 0 \to q^2 = 2q \cdot \bar{\Sigma} = m_{\rm th}^2$



a

$\propto e^2$ $\propto e^4$

➢ KB equation : $(\not{\Pi} - m)S^< + \gamma^\mu \frac{i\hbar}{2}\nabla_\mu S^< + \bar{\Sigma} \star S^< = \frac{i\hbar}{2}\left(\Sigma^< \star S^> - \Sigma^> \star S^<\right)$

■ QKT with the self-energy corrections :

N. Yamamoto, DY ,PRD 109, 056010 (2024)
S. Fang, S. Pu, DY, PRD 109, 034034 (2024)

❖ For $\bar{\Sigma}^\mu_V \neq 0$ ➡ $F^{eff}_{\mu\nu}$: $\bar{F}_{\mu\nu} = \partial_{[\mu}\bar{\Sigma}_{V\nu]}$ effective background EM fields

⇒ *spin polarization*

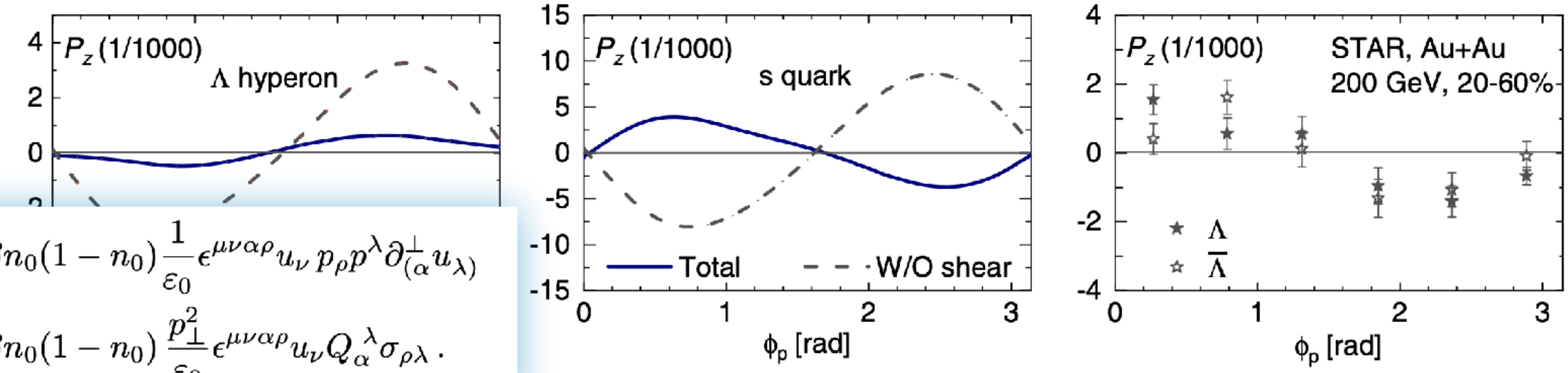
Di-Lun Yang, TUE 11:55, Parellel IV

energy-momentum stress tensor,

many other references:

Cracow, Florence, Frankfurt, Fudan,
Shandong Univ., SYSU, Tsinghua, USTC, …

a possible explanation: shear-induced polarization



$$\mathcal{A}^{\mu}_{\text{SIP}} = -\beta n_0(1-n_0)\frac{1}{\varepsilon_0}\epsilon^{\mu\nu\alpha\rho}u_\nu\, p_\rho p^\lambda \partial^\perp_{(\alpha}u_{\lambda)}$$
$$= -\beta n_0(1-n_0)\frac{p_\perp^2}{\varepsilon_0}\epsilon^{\mu\nu\alpha\rho}u_\nu Q_\alpha^{\ \lambda}\sigma_{\rho\lambda}\,.$$

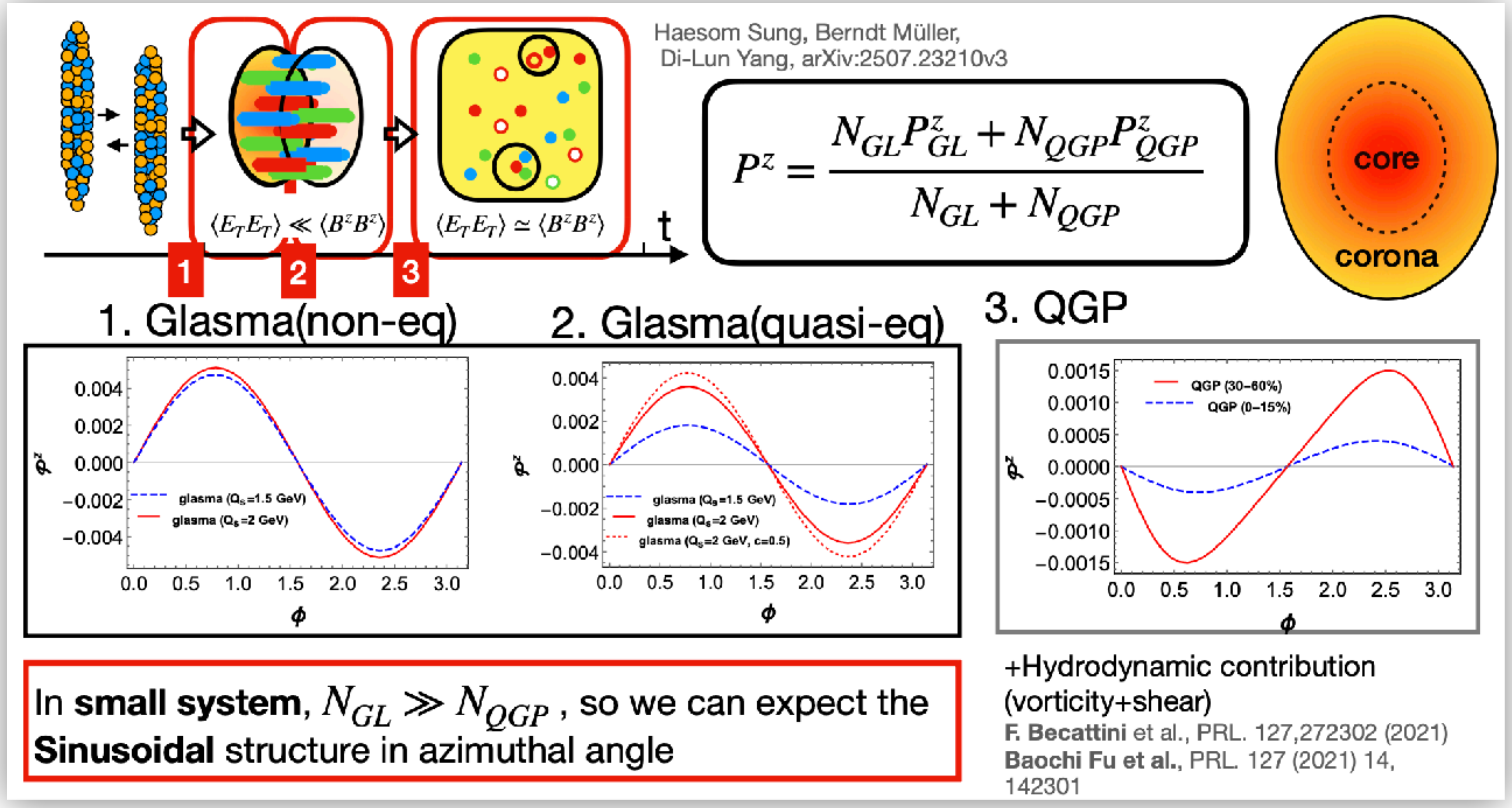
Spin polarization induced by the hydrodynamic gradients
Shuai Y.F. Liu, Yi Yin, JHEP 07 (2021) 188

Shear-Induced Spin Polarization in Heavy-Ion Collisions
Baochi Fu, Shuai Y.F. Liu, Long-Gang Pang, Huichao Song, Yi Yin, PhysRevLett.127.142301

Local Polarization and Isothermal Local Equilibrium in Relativistic Heavy Ion Collisions
F. Becattini, M. Buzzegoli, G. Inghirami, I. Karpenko, A. Palermo, PhysRevLett.127.272302

Spin-thermal shear coupling in a relativistic fluid
F. Becattini, M. Buzzegoli, A. Palermo, Phys.Lett.B 820 (2021) 136519

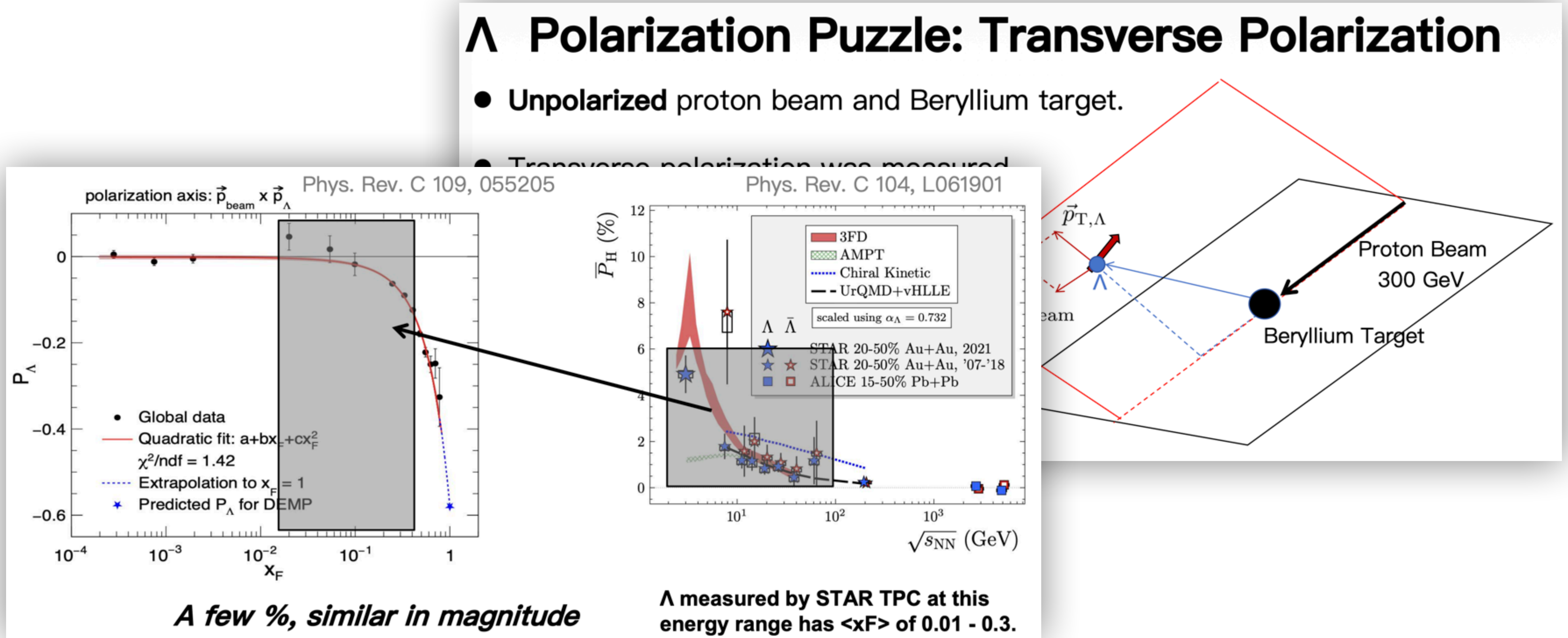
coherent gluons in local spin polarization?



color-glasma field polarize the quark spin with sinusoidal structure

Haesom Sung, TUE 10:05, Parellel IV

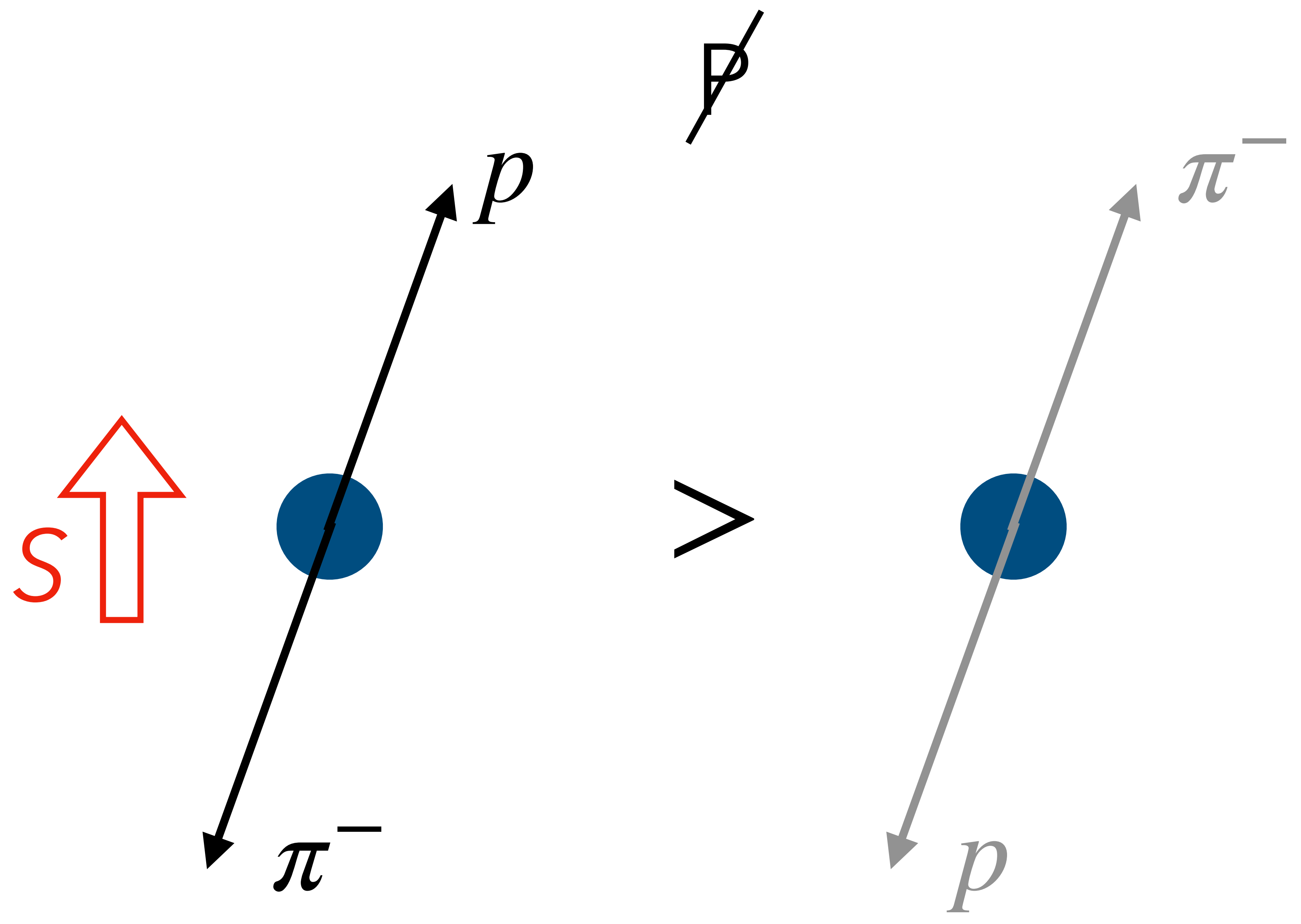
connection with polarization in pA?



Feng Liu, TUE 10:05, Parellel IV

vector meson spin alignment

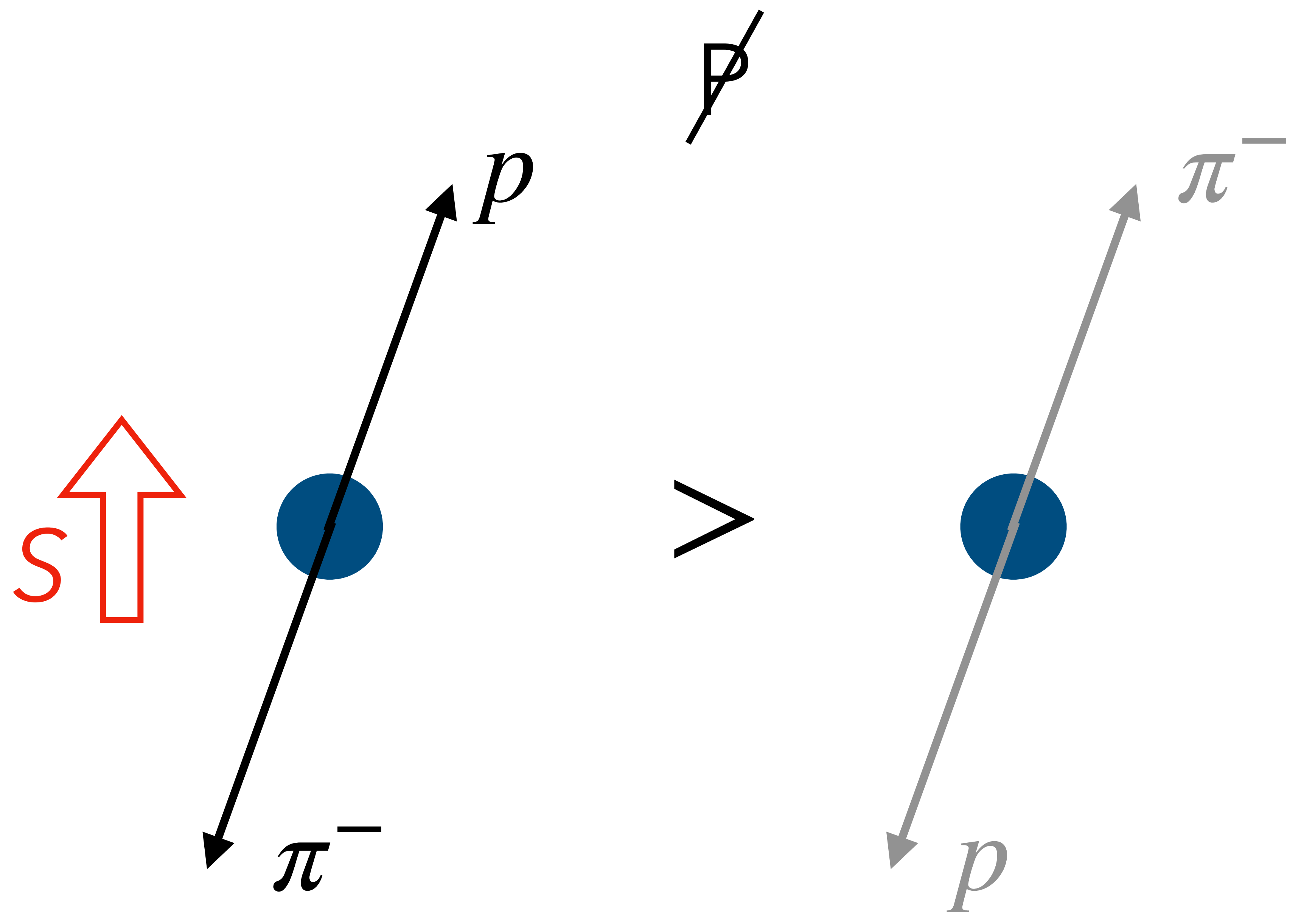
weak decay (Λ)



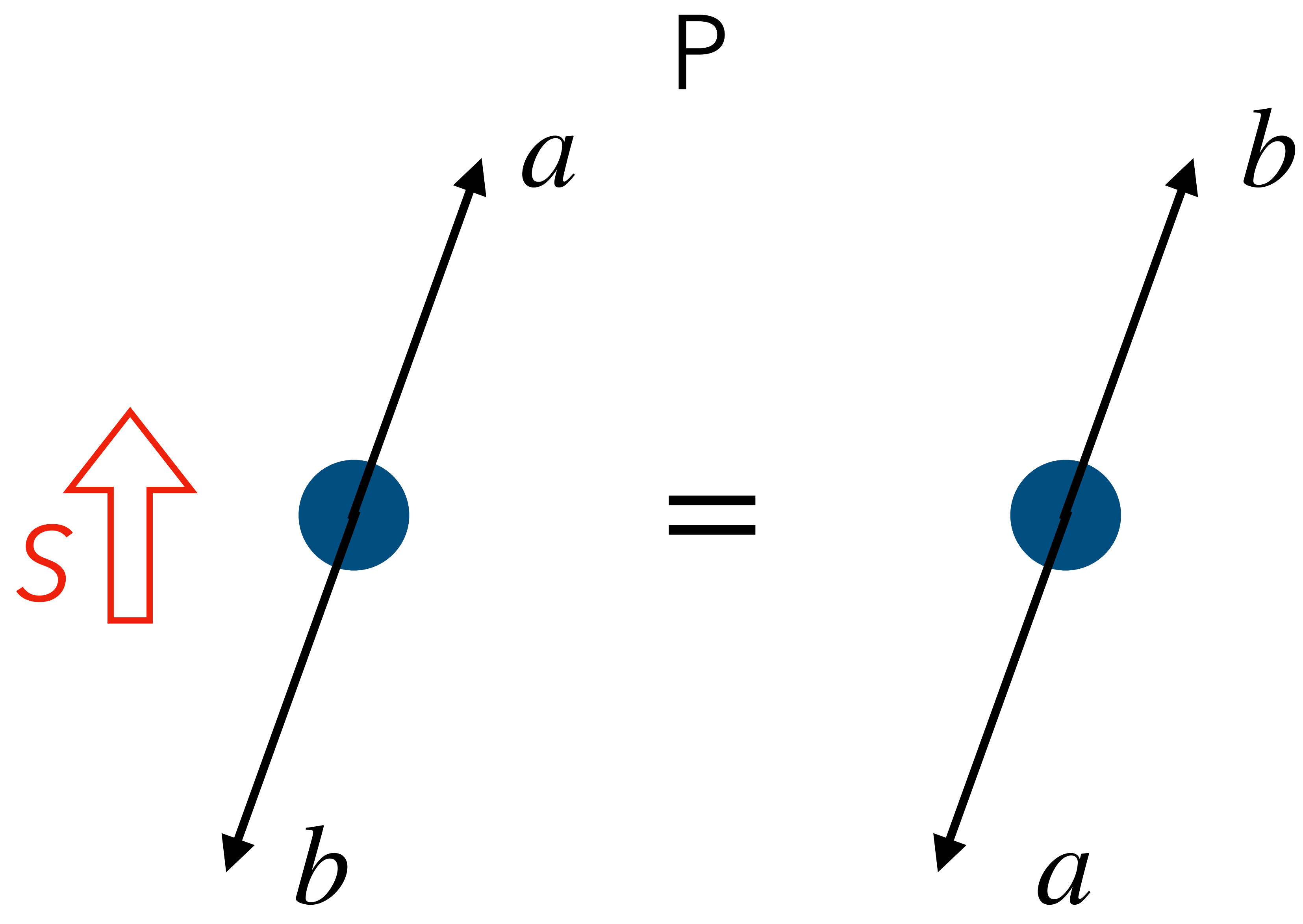
$$P \propto \frac{\omega}{T}$$

vector meson spin alignment

weak decay (Λ)



strong/EM decay $(\phi, \rho, K^*, J/\psi)$

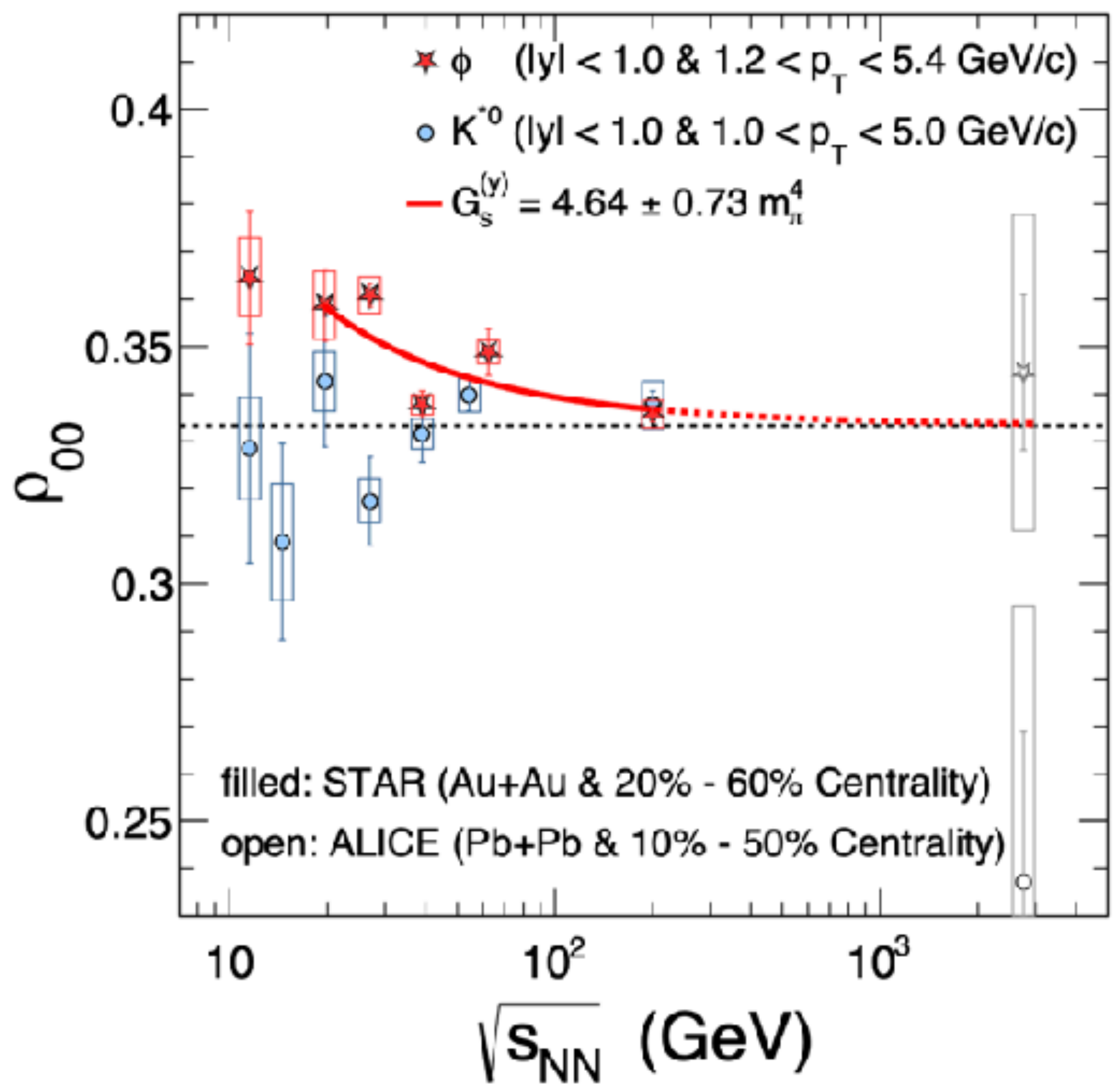


$$P \propto \frac{\omega}{T}$$

$$\hat{\rho} = \sum_{i,j=-1}^{+1} \rho_{ij} |i\rangle\langle j|$$

$$\Delta\rho_{00} \propto \left(\frac{\omega}{T}\right)^2$$

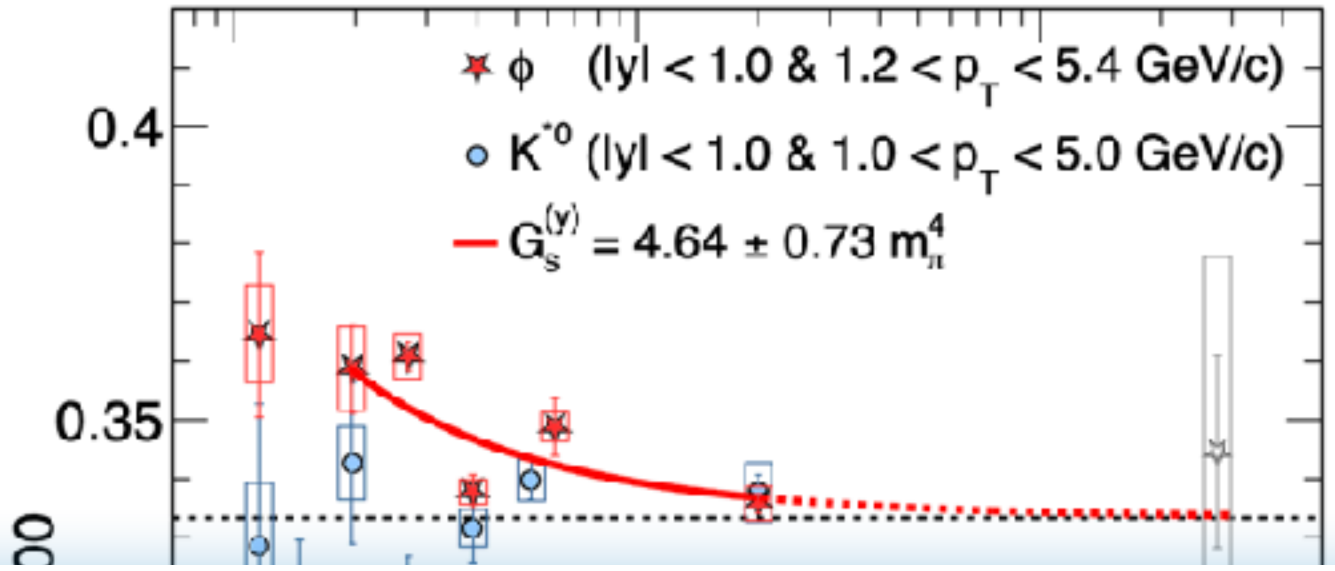
vector meson spin alignment/polarization



$$\Delta\rho_{00} \gg \left(\frac{\omega}{T}\right)^2$$

STAR, Nature 614 (2023) 244

vector meson spin alignment/polarization



$$\Delta\rho_{00} \gg \left(\frac{\omega}{T}\right)^2$$

meson field:

Spin Alignment of Vector Mesons in Heavy-Ion Collisions
Xin-Li Sheng, Lucia Oliva, Zuo-Tang Liang, Qun Wang, Xin-Nian Wang, PhysRevLett.131.042304

shear-induced modification of polarization tensor:

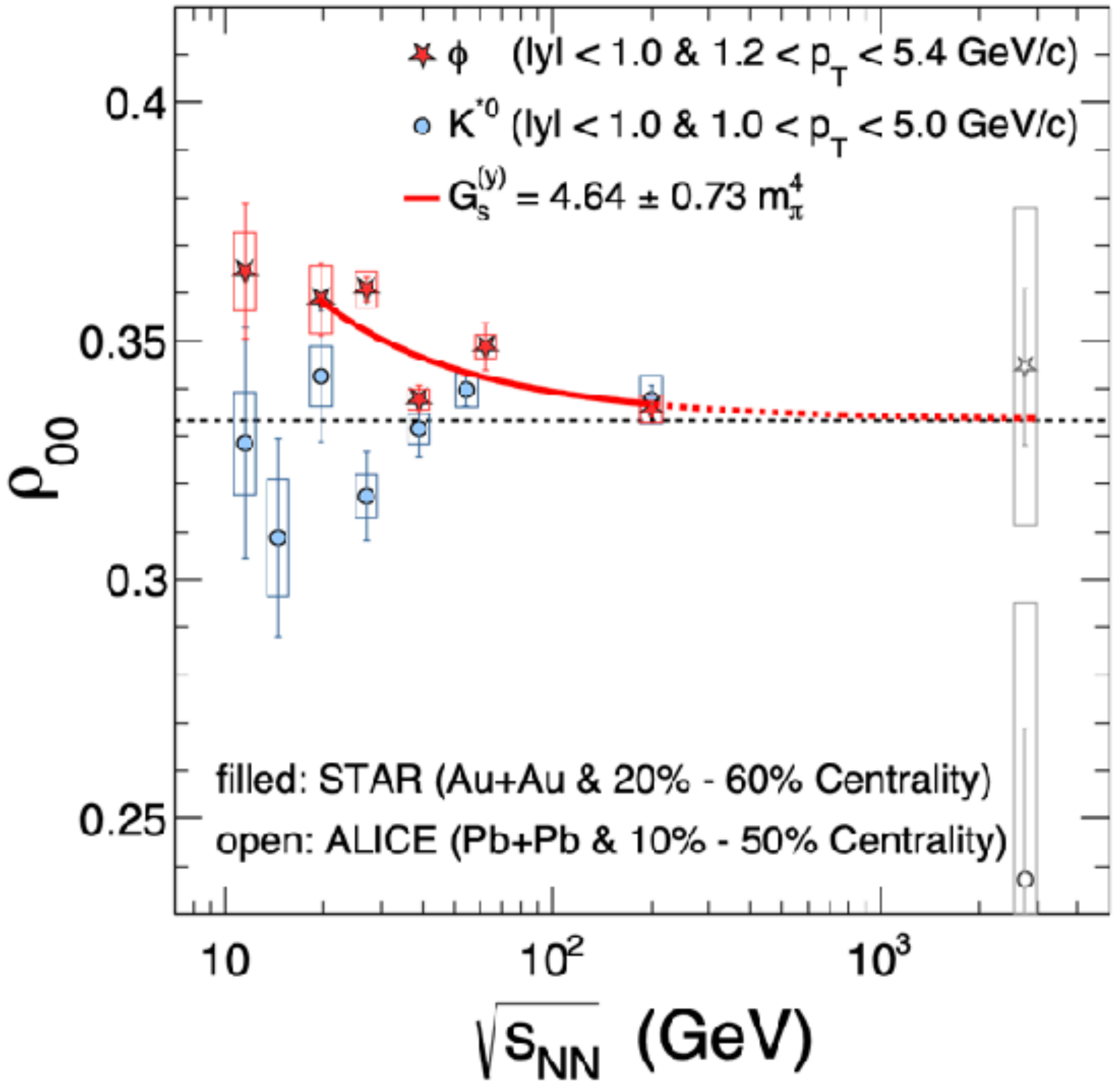
Tensor Polarization and Spectral Properties of Vector Meson in QCD Medium
Feng Li, Shuai Y.F. Liu, 2206.11890

color field correlators:

Tensor Polarization and Spectral Properties of Vector Meson in QCD Medium
Avdhesh Kumar, Berndt Müller, Di-Lun Yang, PhysRevD.107.076025

⋮

summary



- non-equilibrium magnetohydrodynamics

- background models of CME can/shall be tested

- systematic understanding vector meson spin alignment