Ongoing research work on Quark-Gluon Plasma and relativistic matter

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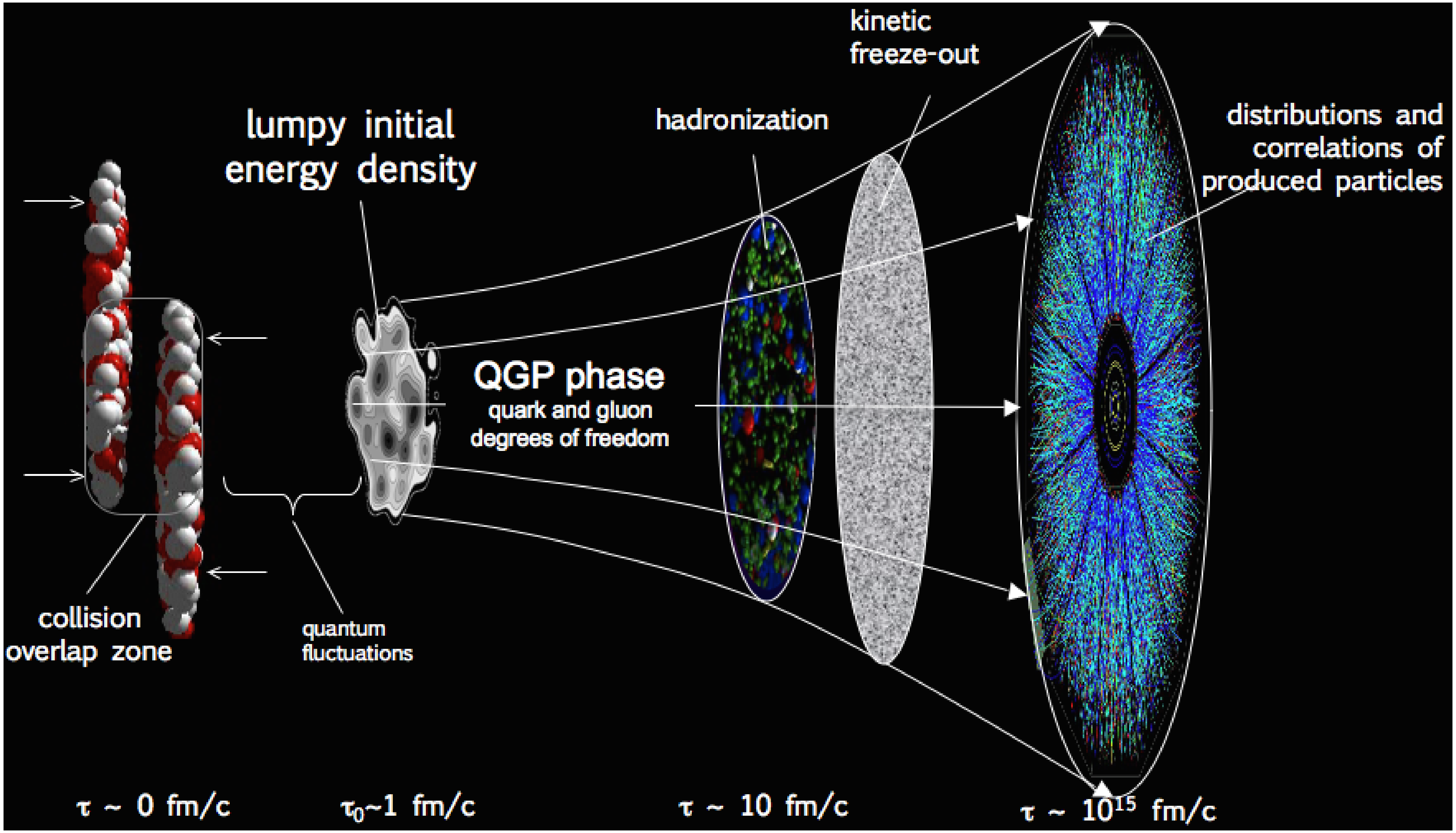
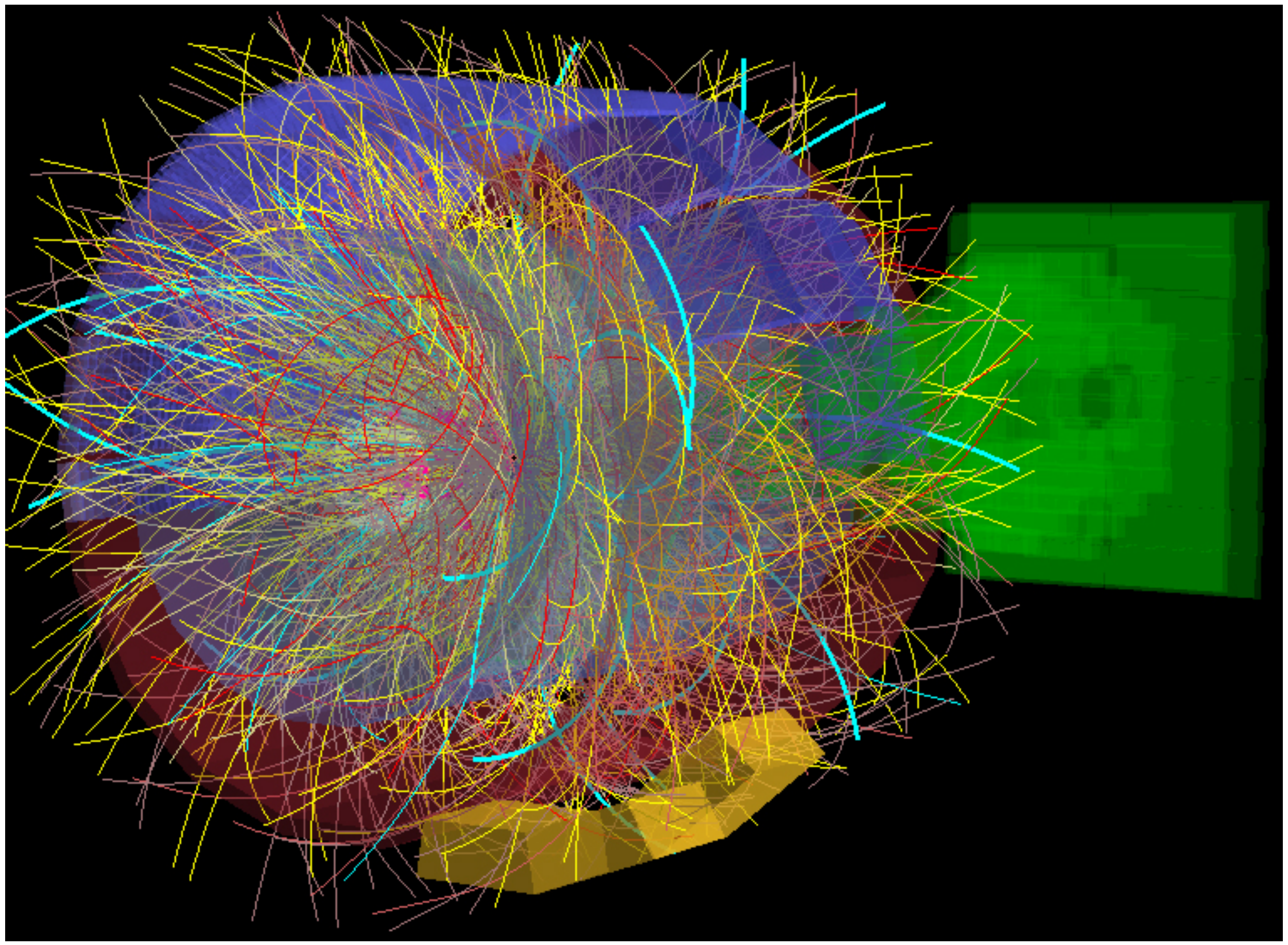
Heavy ion Collision

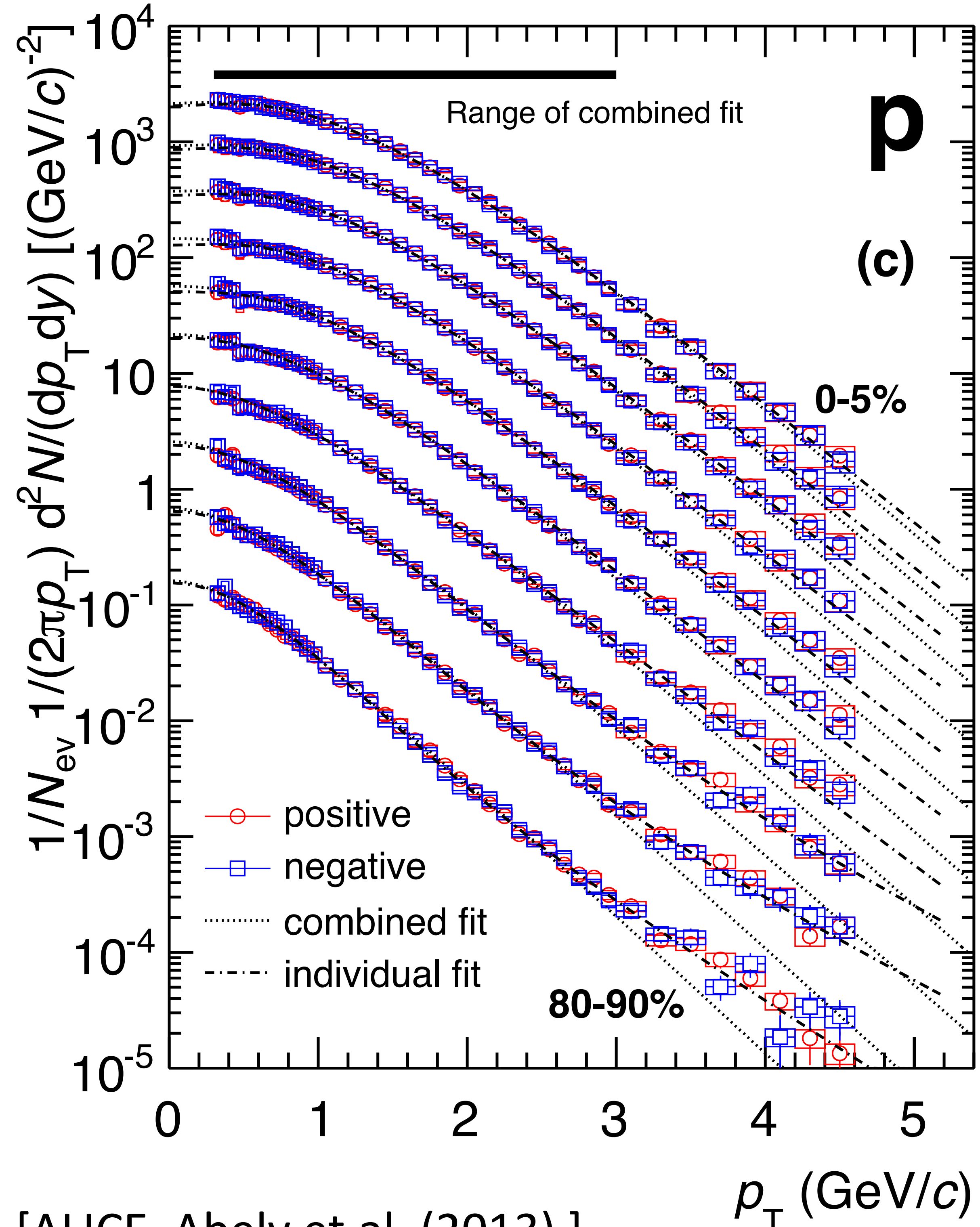


Spectra of identified particles



Events recorded by ALICE from the first lead ion collisions in 2011

Pt : Transverse momenta to the beam axis



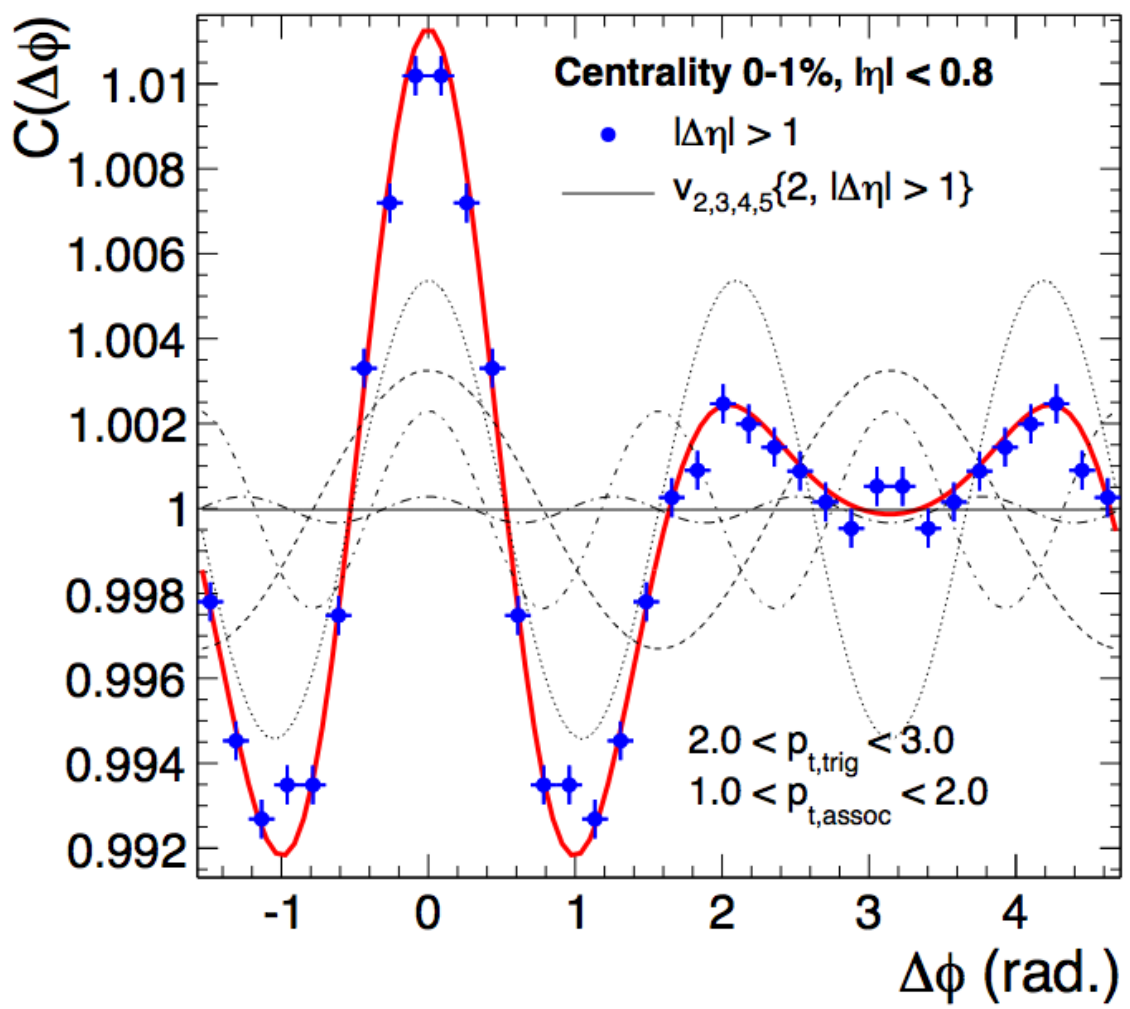
[ALICE, Abelv et.al. (2013)]

Two particle correlation function

- Normalized Correlation function

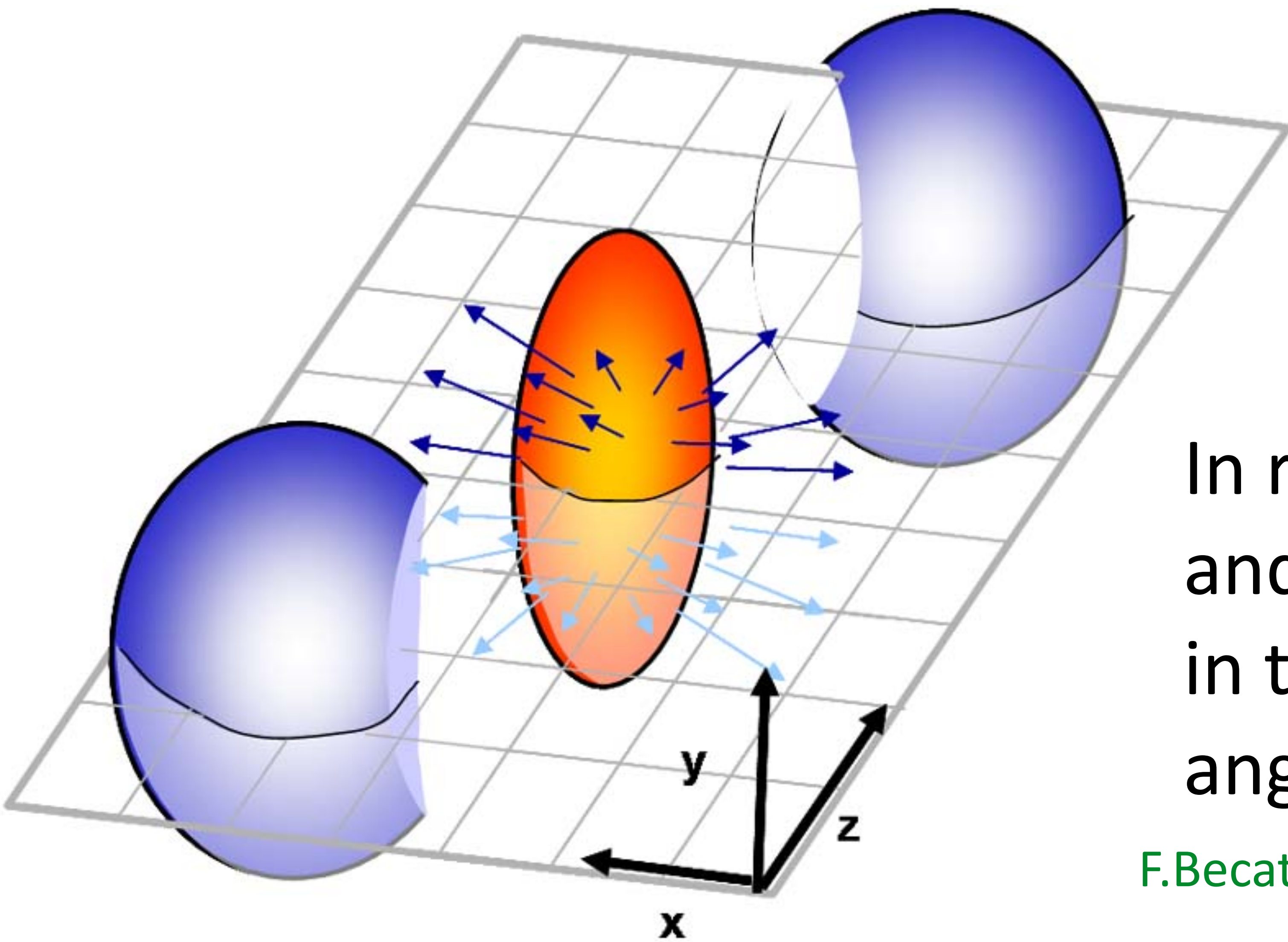
$$C(\phi_1, \phi_2) = \frac{\langle \frac{dN}{d\phi_1} \frac{dN}{d\phi_2} \rangle_{\text{events}}}{\langle \frac{dN}{d\phi_1} \rangle_{\text{events}} \langle \frac{dN}{d\phi_2} \rangle_{\text{events}}} = 1 + 2 \sum_m v_m^2 \; \cos(m\,(\phi_1 - \phi_2))$$

- The modulation in angles are signals of the initial state shape



[ALICE 2011, similar results from CMS, ATLAS, Phenix, Star]

Polarization In HIC



In rotating gas the particle, and antiparticle get polarized in the direction of the angular momentum.

F.Becattini, V.Chandra, L.Del Zanna and E.G (2013)

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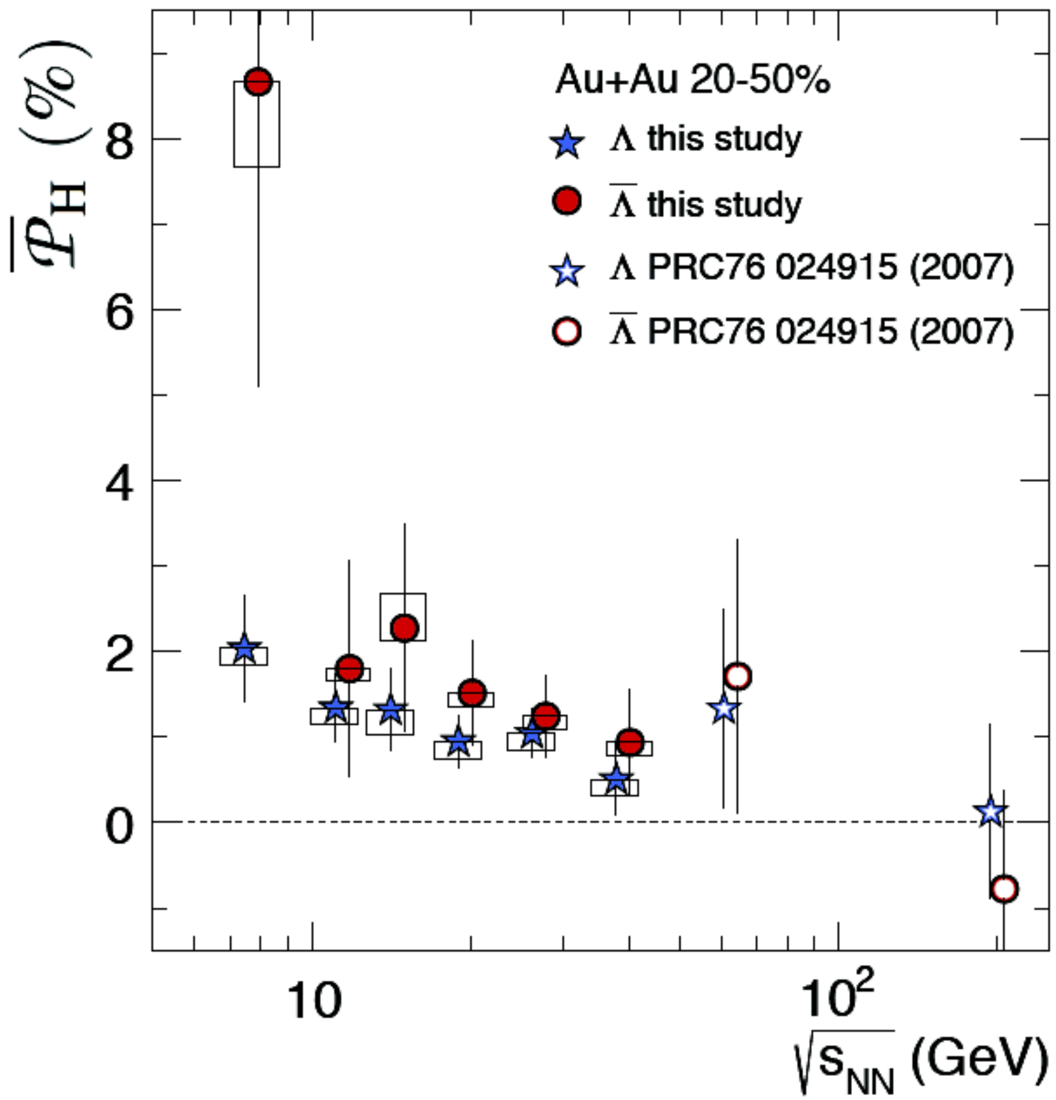
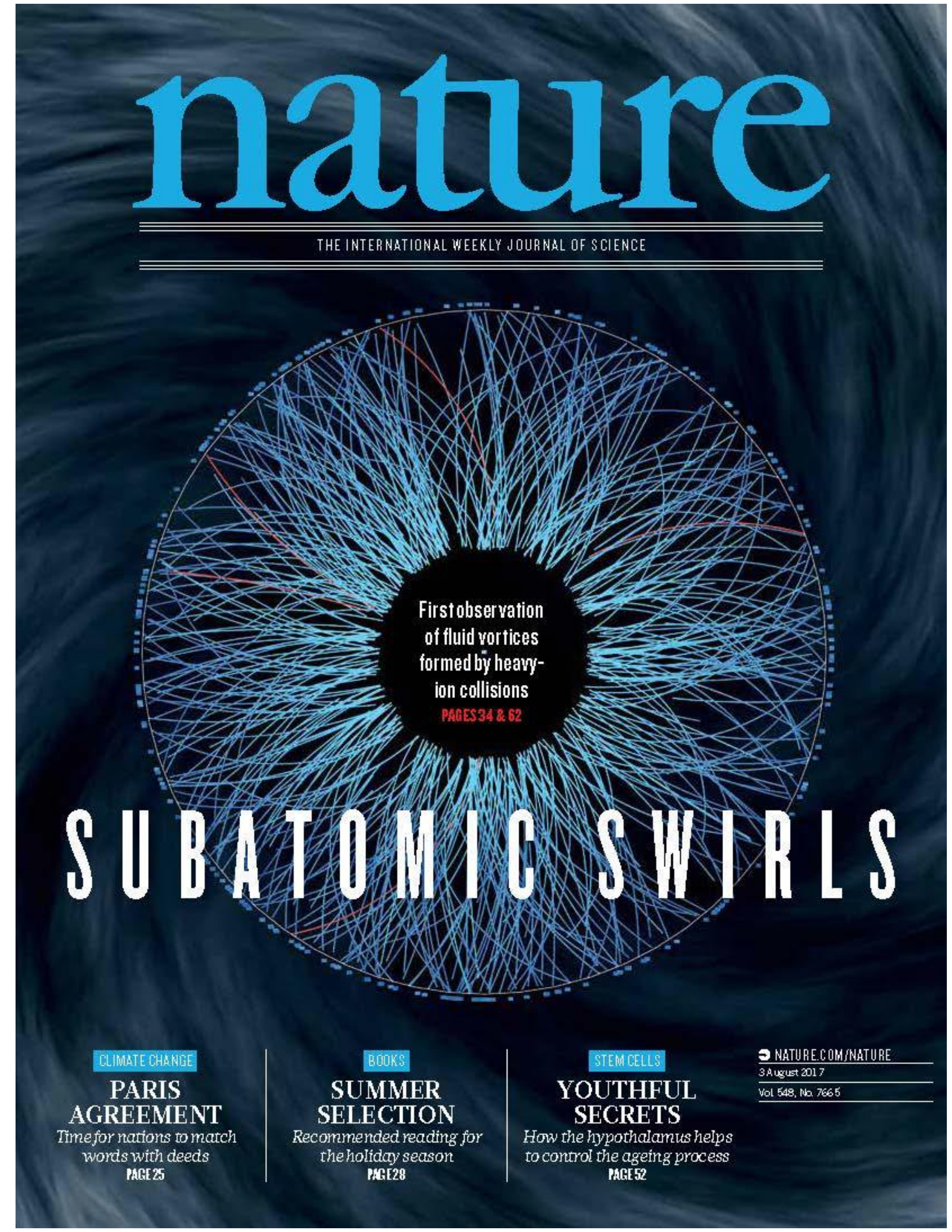
In peripheral high energy heavy ion collisions the system has a large angular momentum and may manifest itself in the polarization of secondary produced particles

STAR measurement

STAR Collaboration, Global Lambda hyperon polarization in nuclear collisions, Nature 548 62-65, 2017





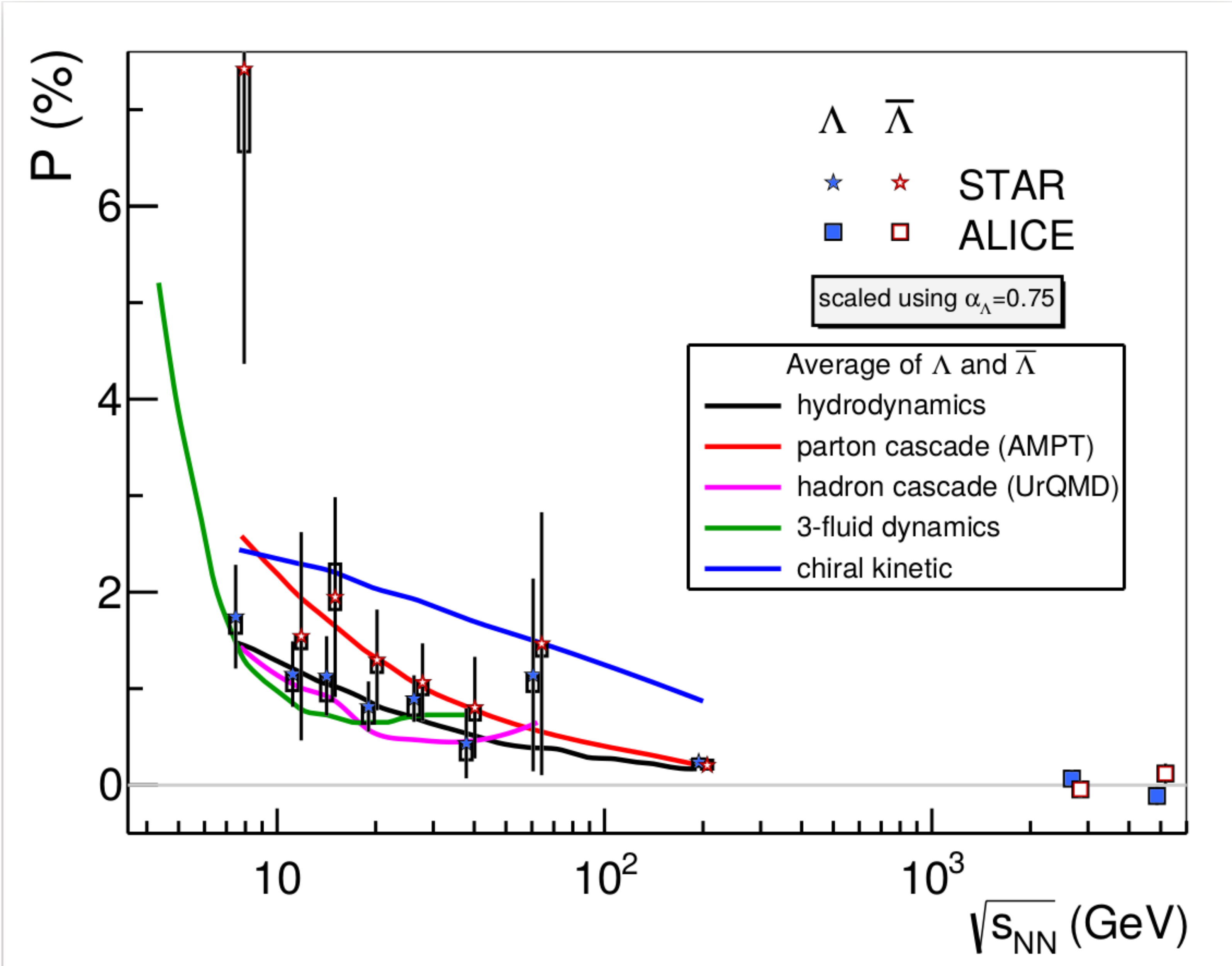
Particle and antiparticle have the same polarization sign.

Not driven by a EM field

Definitely favours the thermodynamic (equipartition) interpretation

Comparison with the data

Becattini, Lisa, Polarization and vorticity in the QGP, Ann. Rev. Part, Nucl. Sc. 70, 395 (2020)

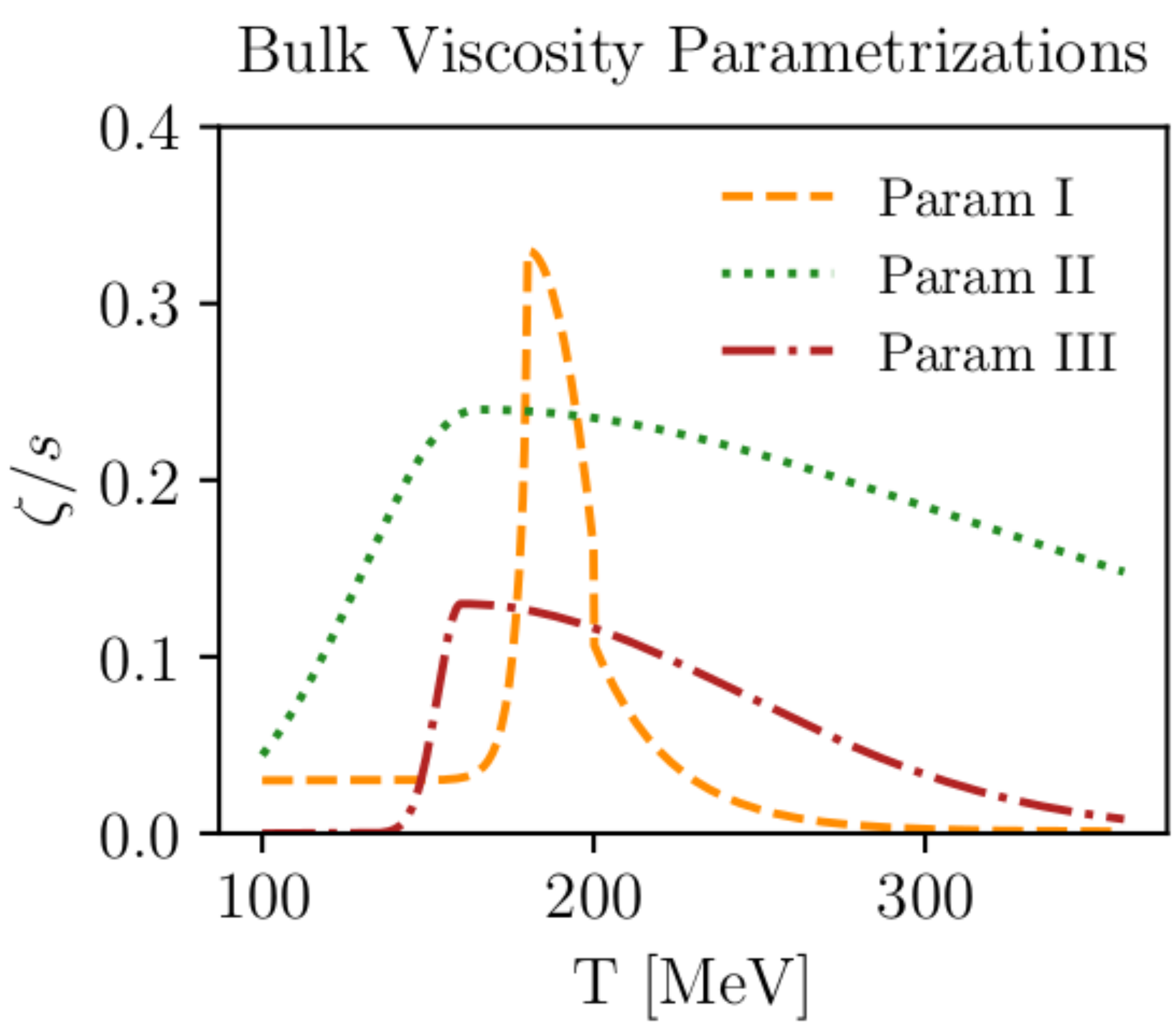


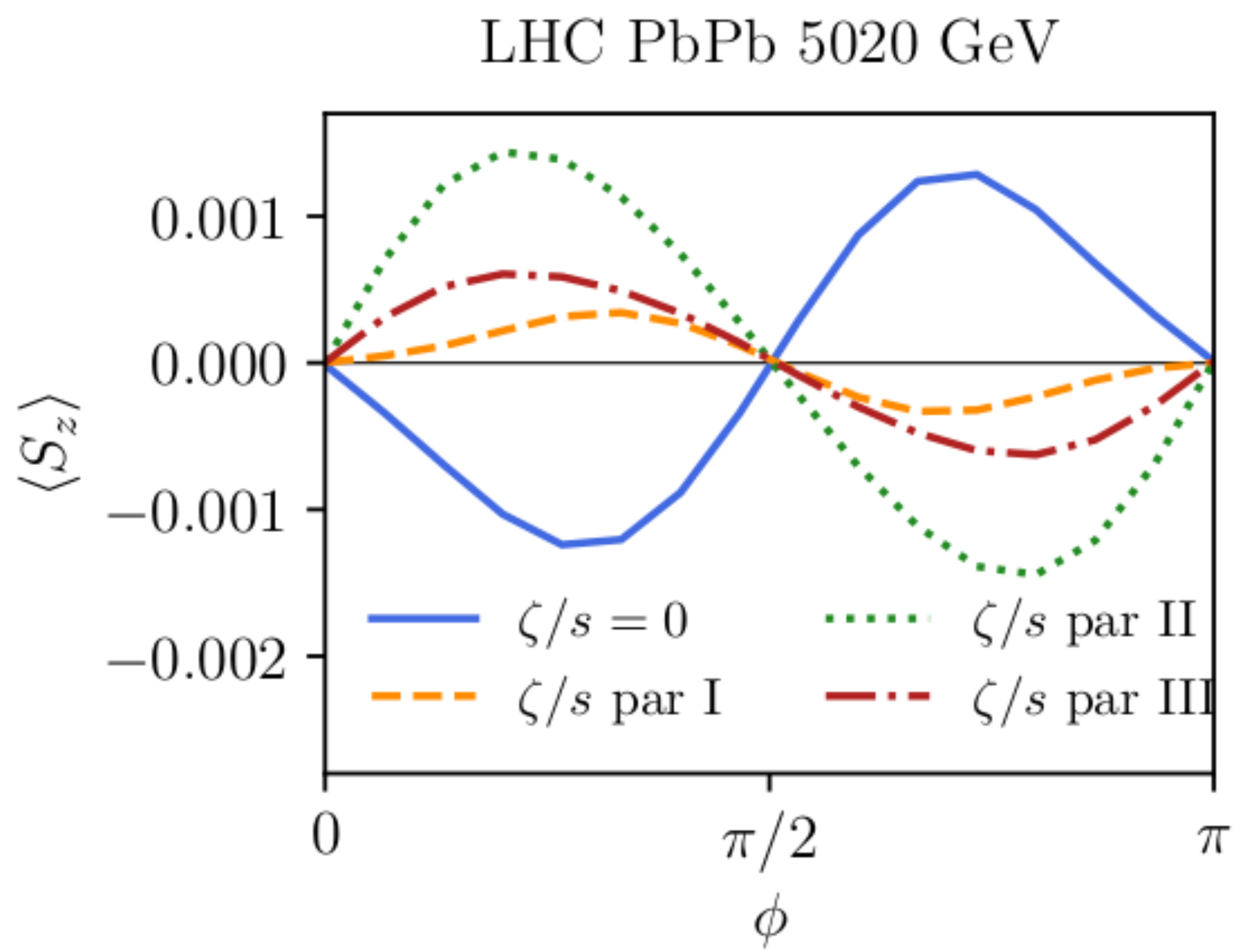
$$S^\mu(p) = \frac{1}{8m}\epsilon^{\mu\nu\rho\sigma}p_\sigma \frac{\int_\Sigma \mathrm{d}\Sigma_\tau p^\tau n_F(1-n_F)\partial_\nu\beta_\rho}{\int_\Sigma \mathrm{d}\Sigma_\tau p^\tau\ n_F}$$

Different models of the collision, same formula for polarization

Bulk viscosity

A.Palermo, E.G, I.Karpenko and F.Becattini EPJC (2024)

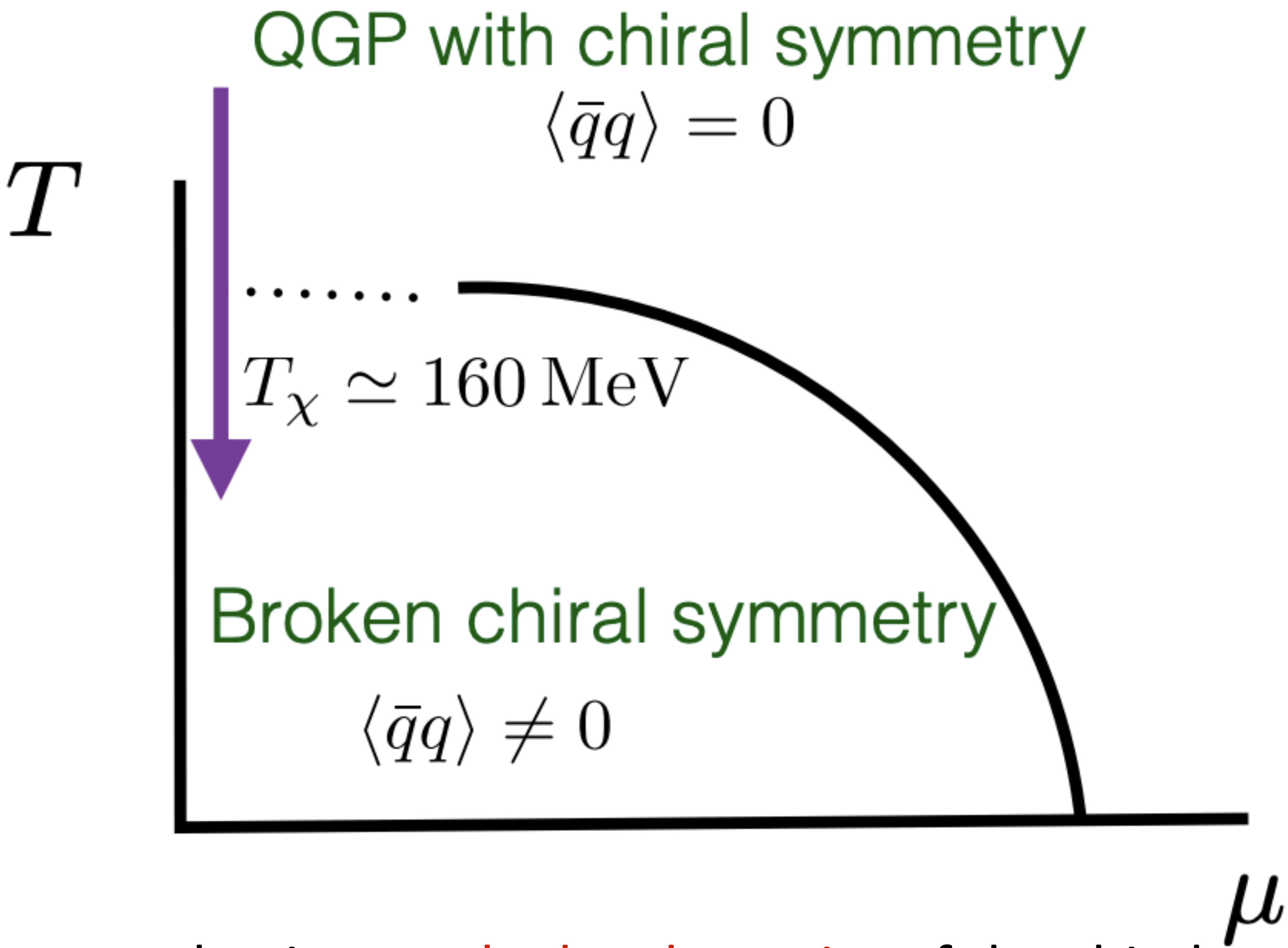




The polarization along the bean axis is really sensitive to the bulk viscosity coefficient of the fluid

Work in progress with Sushant Kumar Singh…

Motivation



We are neglecting any hydro-dynamics of the chiral condensate !

Equation of motion (Model G)

A. Florio, E.G., A. Soloviev, D, Teaney PRD (2022)
A. Florio, E.G., D, Teaney (2023)

Chiral condensate ϕ_a + Axial and Vector charge $n_{ab} = \chi_0 \mu_{ab}$

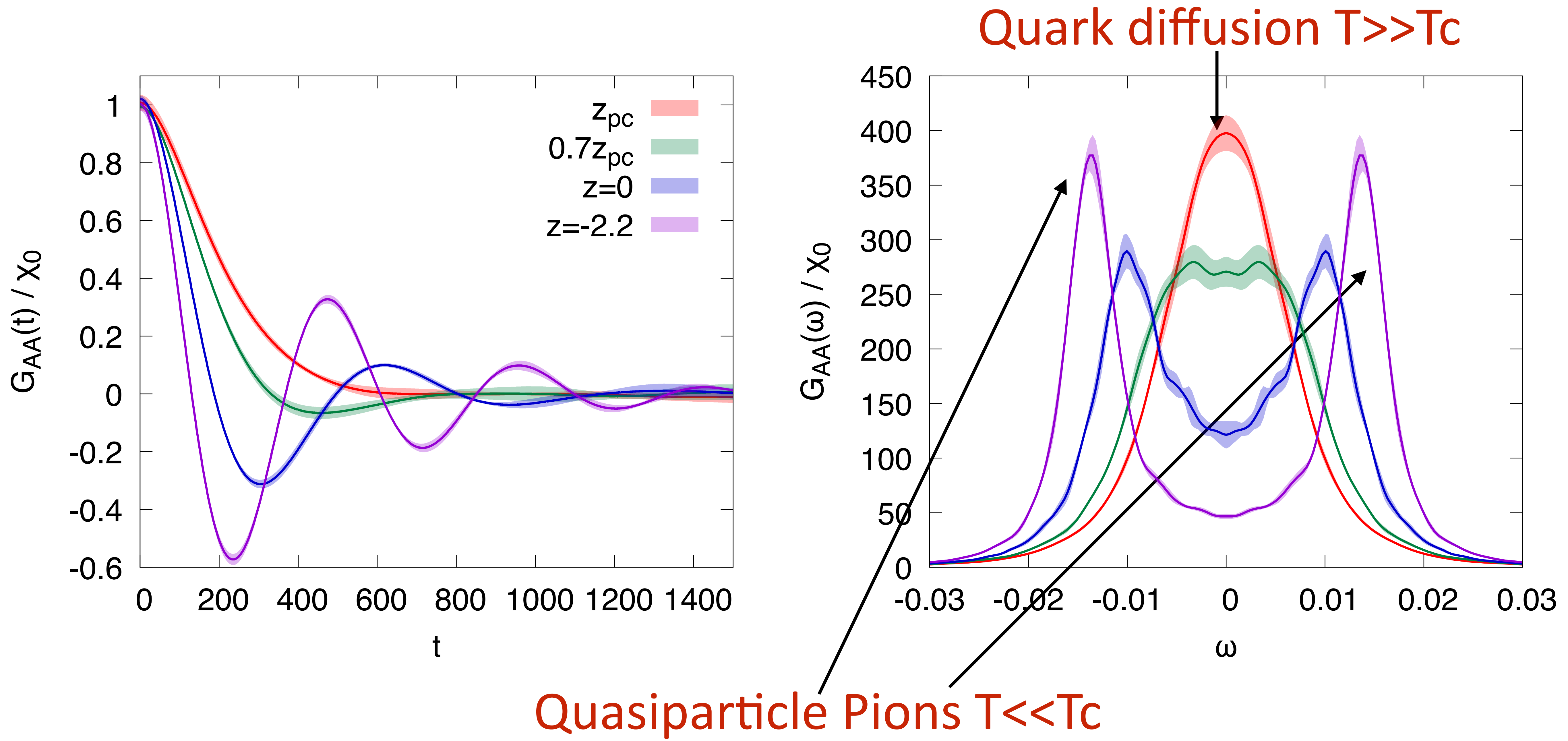
$$\underbrace{\partial_t \phi_a + g_0\, \mu_{ab}\phi_b}_{\text{Ideal part}} = \underbrace{\Gamma_0 \nabla^2 \phi_a - \Gamma_0 (m_0^2 + \lambda\phi^2)\phi_a + \Gamma_0 H_a}_{\text{Dissipative part}} + \theta_a\,,$$

$$\underbrace{\partial_t n_{ab} + g_0\, \nabla\cdot(\nabla\phi_{[a}\phi_{b]}) + H_{[a}\phi_{b]}}_{\text{Ideal part}} = \underbrace{D_0 \nabla^2 n_{ab}}_{\text{Dissipative part}} + \underbrace{\partial_i \Xi^i_{ab}}_{\text{Gaussian Noise}}\,.$$

- The ideal part is charge conservation and Josephson constraint
- Two dissipative coefficient Γ_0 and D_0 and noise
- The simulation of the stochastic process is done with an ideal step and metropolis update.

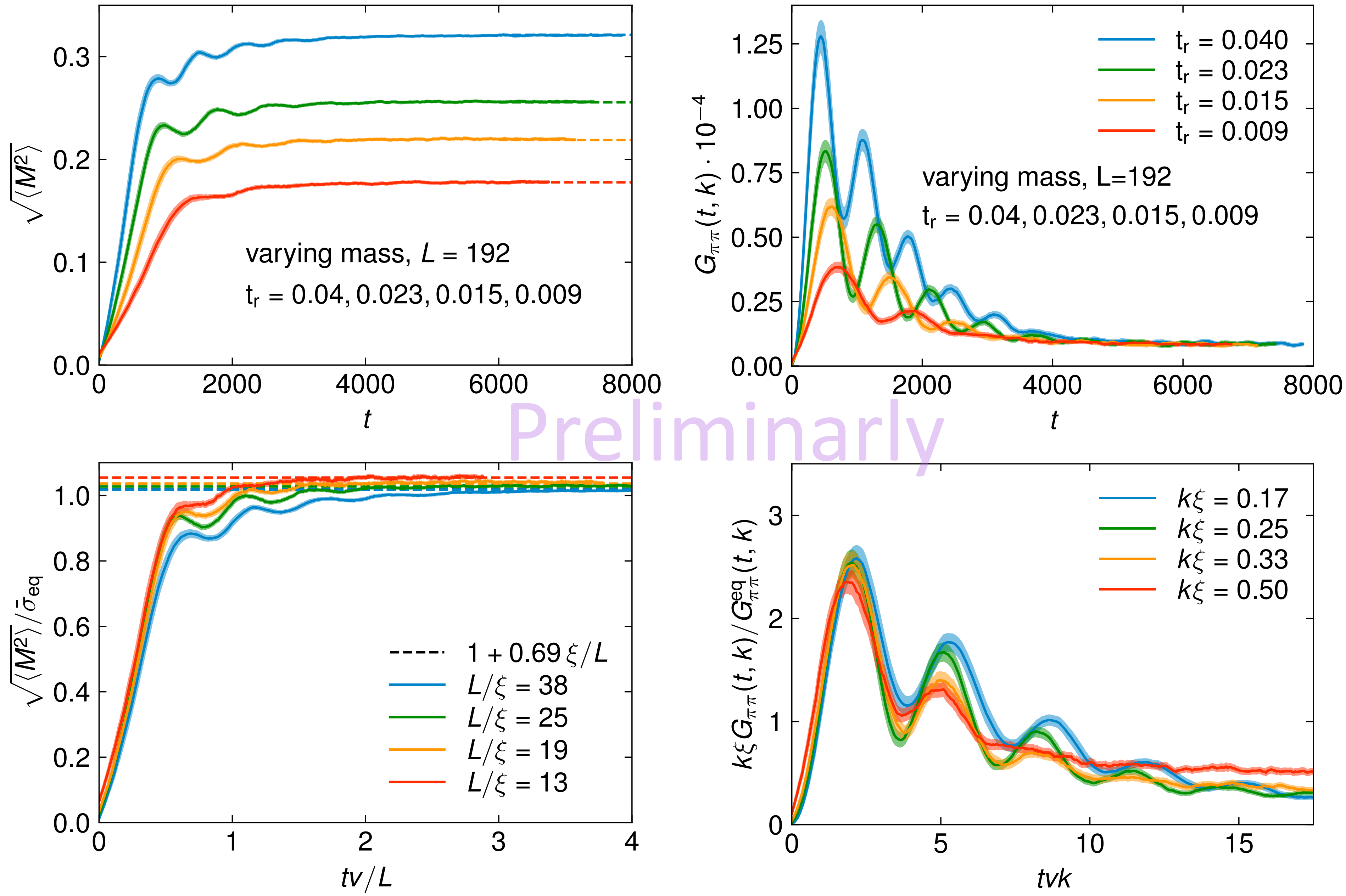
Diffusion at high temperature, pion propagation at low temperature as the vev develops

Propagation of axial charge across the transition



Around T_{pc} the axial charge start changing form a diffusive form to a quasiparticle one

Quench in the broken phase



Consisted with non equilibirum scaling form and huge production of soft pions!

$$G_{\pi\pi}(t,\xi,k) = \frac{\xi^{2-\eta}}{(k\xi)^d}\mathcal{F}(vkt) \qquad \frac{G_{\pi\pi}(t,k)}{G^{\rm eq}_{\pi\pi}(k)} \underset{t\sim 1/vk}{\sim} \begin{cases} 1/k\xi & , \; k \gg m_\pi \\ 1/m_\pi\xi \; , & k \ll m_\pi \end{cases}$$

A. Florio, E.G., A.Mazeliauskas,A. Soloviev, D, Teaney in preparation