NEXSPheRIO results on chaotic and squeezed correlations
混沌與壓制性關聯的NEXSPheRIO結果

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Outline

- Chaotic and squeezed correlations for a hot expanding system
- SPheRIO implementation
- Numerical results

- Conclusion and prespective

Two particle correlation

- Definition

$$R(p_1, p_2) \equiv \frac{\langle N \rangle^2}{\langle N(N-1) \rangle} \frac{P_2(p_1, p_2)}{P_1(p_1) P_1(p_2)} = \frac{\langle N \rangle^2 \sigma_T}{\langle N(N-1) \rangle} \frac{d^6\sigma / d^3p_1 d^3p_2}{(d^3\sigma / d^3p_1)(d^3\sigma / d^3p_2)}$$

in terms of differential cross section

$$\int d^3p_1 d^3p_2 (d^6\sigma / d^3p_1 d^3p_2) = \langle N(N-1) \rangle \sigma_T$$

$$\int d^3p (d^3\sigma / d^3p) = \langle N \rangle \sigma_T$$

Two particle correlation

- Definition

$$R(p_1, p_2) \equiv \frac{\langle N \rangle^2}{\langle N(N-1) \rangle} \frac{P_2(p_1, p_2)}{P_1(p_1) P_1(p_2)} = \frac{\langle N \rangle^2 \sigma_T}{\langle N(N-1) \rangle} \frac{d^6\sigma / d^3 p_1 d^3 p_2}{(d^3\sigma / d^3 p_1)(d^3\sigma / d^3 p_2)}$$

or in terms of particle/pair production

$$P_1(p) = \langle \phi | \hat{n}_p | \phi \rangle = \langle \phi | \hat{a_p}^+ \hat{a_p} | \phi \rangle$$

$$P_2(p_1, p_2) = \langle \phi | \hat{n}_{p_1} \hat{n}_{p_2} | \phi \rangle = \langle \phi | a^+_{p_2} a^+_{p_1} a_{p_1} a_{p_2} | \phi \rangle$$

Two particle correlation in a hot expanding medium

- In the case of systems created at RHIC, in order to calculate

$$P_2(p_1, p_2) = \langle \phi | a^{+}_{p_2} a^{+}_{p_1} a_{p_1} a_{p_2} | \phi \rangle$$

- Two subjects are getting involved

- Finite temperature
- Expansion of the system

Two particle correlation in a hot expanding medium

- Wick's theorem at finite temperature

$$P_2(p_1, p_2) = \langle \phi | a^+_{p_2} a^+_{p_1} a_{p_1} a_{p_2} | \phi \rangle$$

$$\langle | \cdots | \rangle = \mathrm{Tr}(\hat{\rho} \cdots)$$

$$\langle | a^+_{p_1} a^+_{p_2} a_{p_2} a_{p_1} | \rangle = \langle | a^+_{p_1} a_{p_1} | \rangle \langle | a^+_{p_2} a_{p_2} | \rangle + \langle | a^+_{p_1} a_{p_2} | \rangle \langle | a^+_{p_2} a_{p_1} | \rangle + \langle | a^+_{p_1} a^+_{p_2} | \rangle \langle | a_{p_2} a_{p_1} | \rangle$$

- Le Bellac, TFT

Two particle correlation in a hot expanding medium

- Particle emission on freeze-out surface

$$\langle|a^\dagger_{p_1} a_{p_2}|\rangle = \int_{\sigma=T_f} d\sigma_\mu P^\mu f(x,P) e^{iqx} = \sum_j \frac{\nu_j n_{j\mu} P^\mu}{s_j |n_{j\mu} u^\mu_j|} \mathrm{e}^{iq_\mu x^\mu_j} f(u_{j\mu} P^\mu)$$

$$P = (p_1 + p_2)/2$$
$$q = (p_1 - p_2)$$

- Yad. Fiz. 46, 637 (1987); Heavy Ion Phys. 10, 113, (1999)

Two particle correlation in a hot expanding medium with mass shift

- The underlying physics:

Mass shift due to medium effect at finite temperature

$$H = \int d^3x \frac{1}{2}\left[\frac{1}{c^2}\dot{\phi}^2 + (\nabla\phi)^2 + \mu^2\phi^2\right]$$

$$\mu^2 \to \mu^2 + m_1^2$$

$$H = \int d^3x \frac{1}{2}\left[\frac{1}{c^2}\dot{\phi}^2 + (\nabla\phi)^2 + (\mu^2 + m_1^2)\phi^2\right]$$

- Heavy Ion Phys. 4 (1996) 233

Two particle correlation in a hot expanding medium with mass shift

$$\langle | a^{\dagger}_{p_1} a_{p_2} | \rangle \rightarrow a^{\dagger}_{p}, \langle |$$

- To calculate the particle/pair production of free particles out of a locally thermalized expanding system

$$a_k = c_k b_k + s^*_{-k} b^+_{-k}$$
$$a^+_k = c^*_k b^+_k + s_{-k} b_{-k}$$
$$c_k \equiv \cosh(r_k)$$
$$s_k \equiv \sinh(r_k)$$
$$r_k = \frac{1}{2} \log \left[\frac{\omega_k}{\Omega_k} \right]$$

- Two sets of creation and annihilation operators which diagonalize the Hamiltonian w./w.o. mass shift – connected by the Bogoliubov transformation

Two particle correlation in a hot expanding medium with mass shift

- Chaotic and squeezed correlation

$$\langle|a^+_{p_1} a^+_{p_2} a_{p_2} a_{p_1}|\rangle = \langle|a^+_{p_1} a_{p_1}|\rangle\langle|a^+_{p_2} a_{p_2}|\rangle + \langle|a^+_{p_1} a_{p_2}|\rangle\langle|a^+_{p_2} a_{p_1}|\rangle + \langle|a^+_{p_1} a^+_{p_2}|\rangle\langle|a_{p_2} a_{p_1}|\rangle$$

$$R(p_1, p_2) \equiv C_2(p_1, p_2) = 1 + \frac{|G_c(p_1, p_2)|^2}{G_c(p_1, p_1) G_c(p_2, p_2)} + \frac{|G_s(p_1, p_2)|^2}{G_c(p_1, p_1) G_c(p_2, p_2)}$$

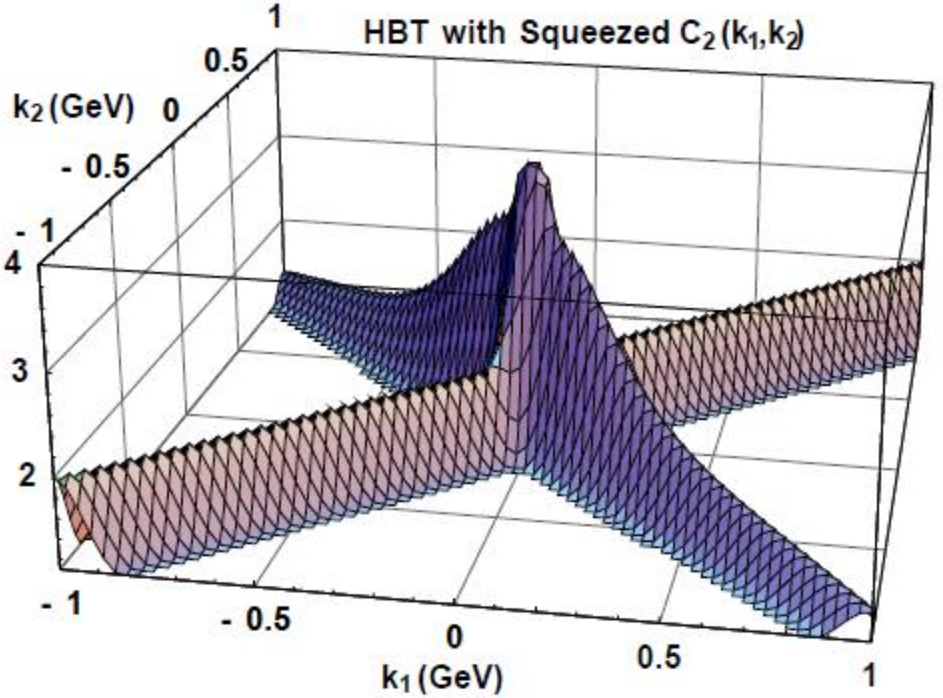
$$G_c(p_1, p_2) = \sqrt{\omega_{p_1}\omega_{p_2}}\left[c^*_{p_1} c_{p_2} \langle|b^+_{p_1} b_{p_2}|\rangle + s_{-p_1} s^*_{-p_2}(\langle|b^+_{-p_2} b_{-p_1}|\rangle + 1)\right]$$

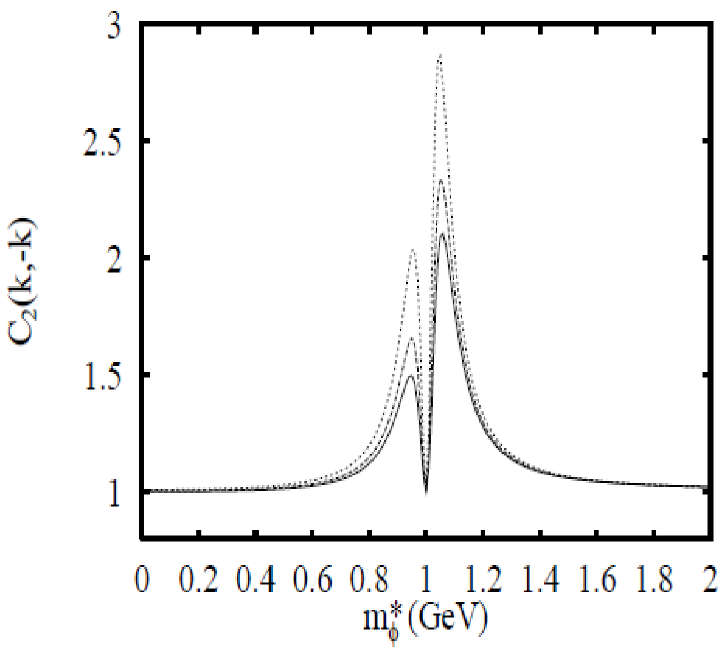
$$G_s(p_1, p_2) = \sqrt{\omega_{p_1}\omega_{p_2}}\left[s^*_{-p_1} c_{p_2} \langle|b^+_{-p_1} b_{p_2}|\rangle + c_{p_1} s^*_{-p_2}(\langle|b^+_{-p_2} b_{p_1}|\rangle + 1)\right]$$

- PRL 83, 4013 (1999); PRC73, 044906, (2006)

Two particle correlation in a hot expanding medium with mass shift

- Chaotic and squeezed correlation





- PRL 83, 4013 (1999); PRC73, 044906, (2006)

SPheRIO implementation

- Chaotic and squeezed correlation

$$\langle|a^+_{p_1}a^+_{p_2}a_{p_2}a_{p_1}|\rangle = \langle|a^+_{p_1}a_{p_1}|\rangle\langle|a^+_{p_2}a_{p_2}|\rangle + \langle|a^+_{p_1}a_{p_2}|\rangle\langle|a^+_{p_2}a_{p_1}|\rangle + \langle|a^+_{p_1}a^+_{p_2}|\rangle\langle|a_{p_2}a_{p_1}|\rangle$$

$$R(p_1,p_2) \equiv C_2(p_1,p_2) = 1 + \frac{|G_c(p_1,p_2)|^2}{G_c(p_1,p_1)G_c(p_2,p_2)} + \frac{|G_s(p_1,p_2)|^2}{G_c(p_1,p_1)G_c(p_2,p_2)}$$

$$G_c(p_1,p_2) = \sqrt{\omega_{p_1}\omega_{p_2}}\left[c^*_{p_1}c_{p_2}\langle|b^+_{p_1}b_{p_2}|\rangle + s_{-p_1}s^*_{-p_2}(\langle|b^+_{-p_2}b_{-p_1}|\rangle + 1)\right]$$

$$G_s(p_1,p_2) = \sqrt{\omega_{p_1}\omega_{p_2}}\left[s^*_{-p_1}c_{p_2}\langle|b^+_{-p_1}b_{p_2}|\rangle + c_{p_1}s^*_{-p_2}(\langle|b^+_{-p_2}b_{p_1}|\rangle + 1)\right]$$

$$G_c(1,2) \equiv G_c(p_1,p_2) = \frac{1}{(2\pi)^3}\int_\sigma d\sigma_\mu P^\mu_{1,2}e^{iq_{1,2}\cdot x}\left[|c_{1,2}|^2 n_{1,2} + |s_{-1,-2}|^2(n_{-1,-2)} + 1)\right]$$

$$G_s(1,2) \equiv G_s(p_1,p_2) = \frac{1}{(2\pi)^3}\int_\sigma d\sigma_\mu P^\mu_{1,2}e^{2iP_{1,2}\cdot x}\left[s^*_{-1,2}c_{2,-1}n_{-1,2} + c_{1,-2}s^*_{-2,1)}(n_{1,-2} + 1)\right]$$

SPheRIO implementation

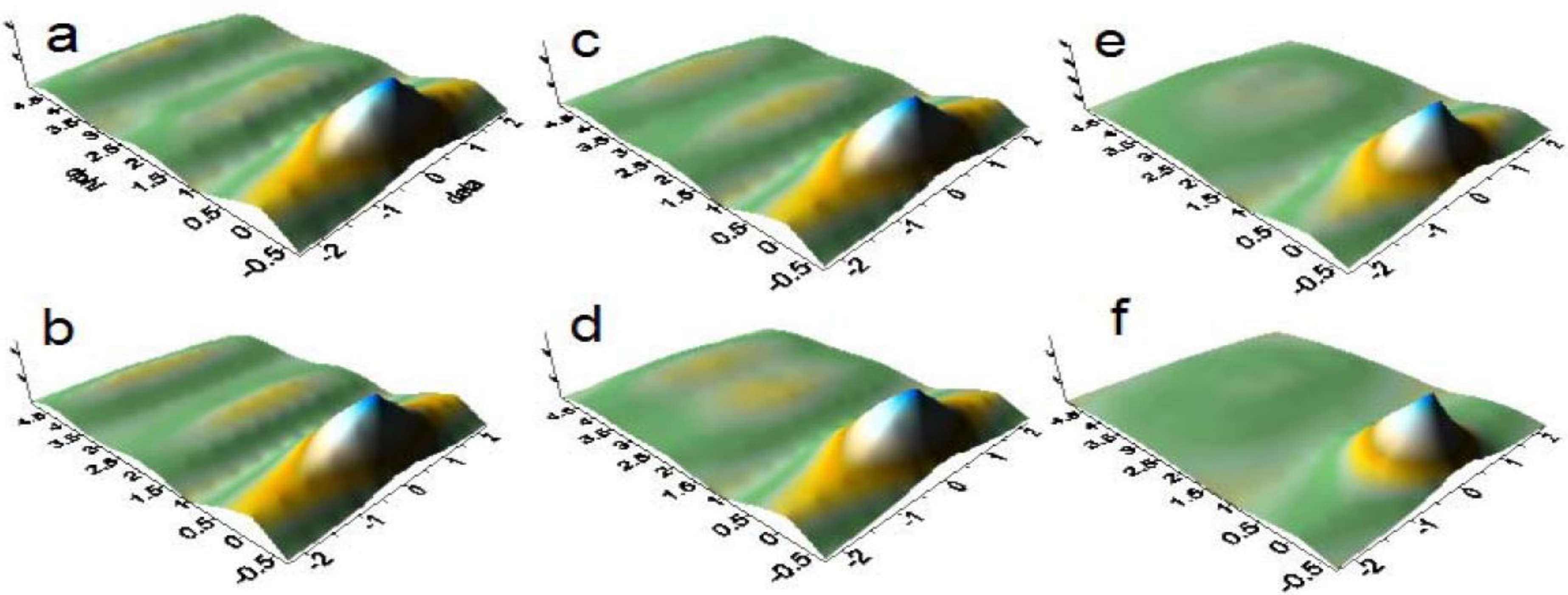
- NEXUS+SPheRIO

- NEXUS
  - H.J. Drescher, F.M. Liu, S. Ostapchenko, T. Pierog and K. Werner, Phys. Rev. C65, 054902 (2002).
  - Event generator
  - Event by event fluctuation
  - In collaboration with K. Werner

- SPheRIO
  - C.E.Aguiar, T.Kodama, T.Osada & Y.Hama., J.Phys. G27(2001)75.
  - 3D hydro code
  - Based on Smoothed Particle Hydrodynamics
  - Robustness to deal with any kind of geometrical structure
  - In collaboration with Ph. Mota, T. Kodama, Y. Hama

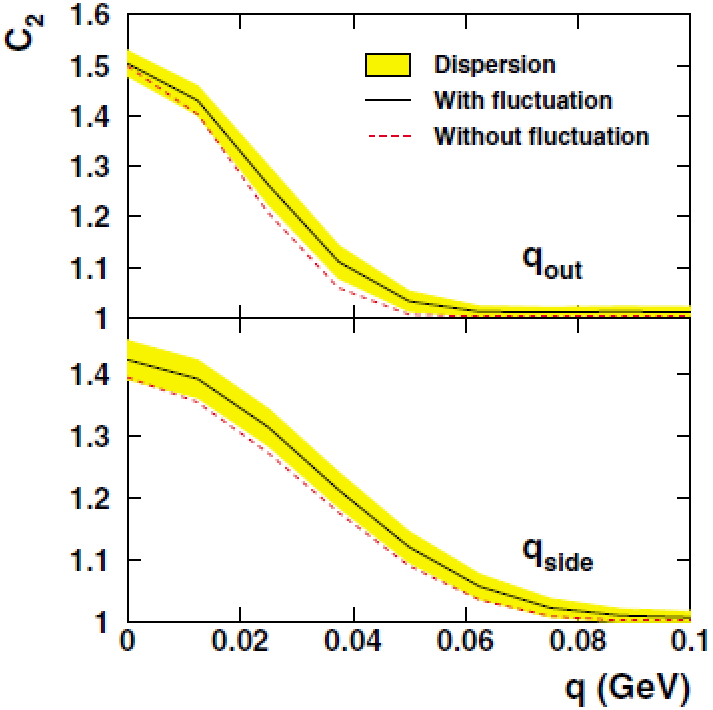
"ridge" observed in RHIC

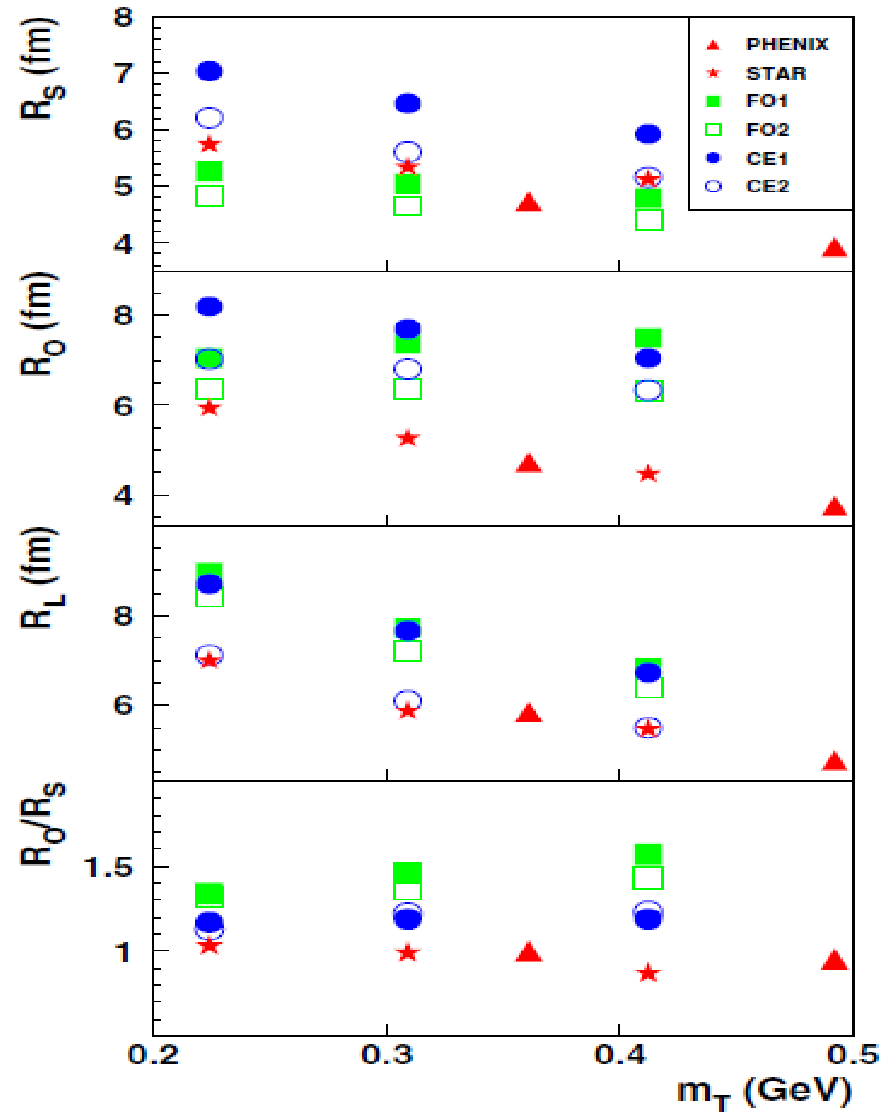
Two particle correlation for different centralities
momentum thresholds 2.5GeV X 1.5GeV
a:0-5% b:5%-10% c:10%-20% d:20%-30% e:30%-40% f:40%-50%



In collaboration with J. Takahashi and Kodama

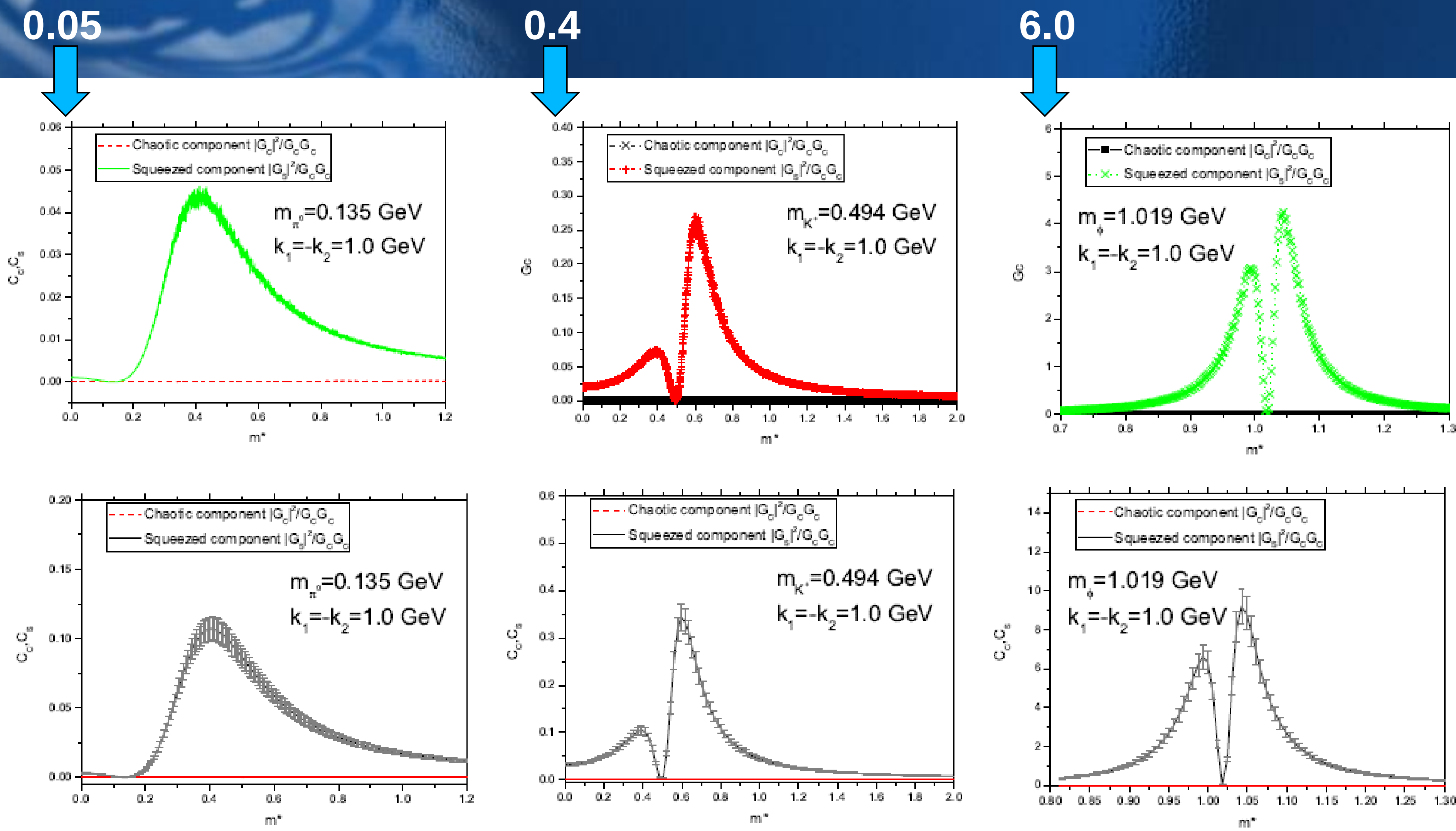
HBT (chaotic) correlation



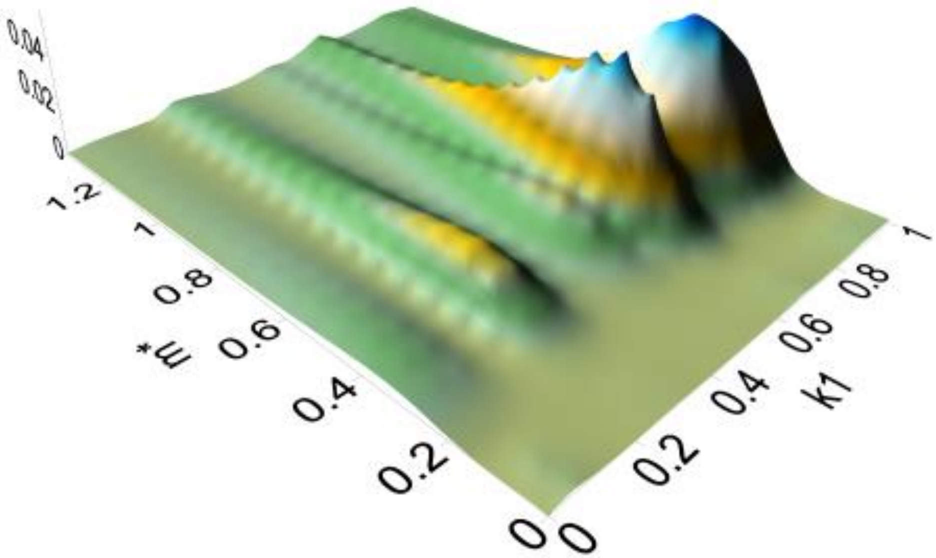


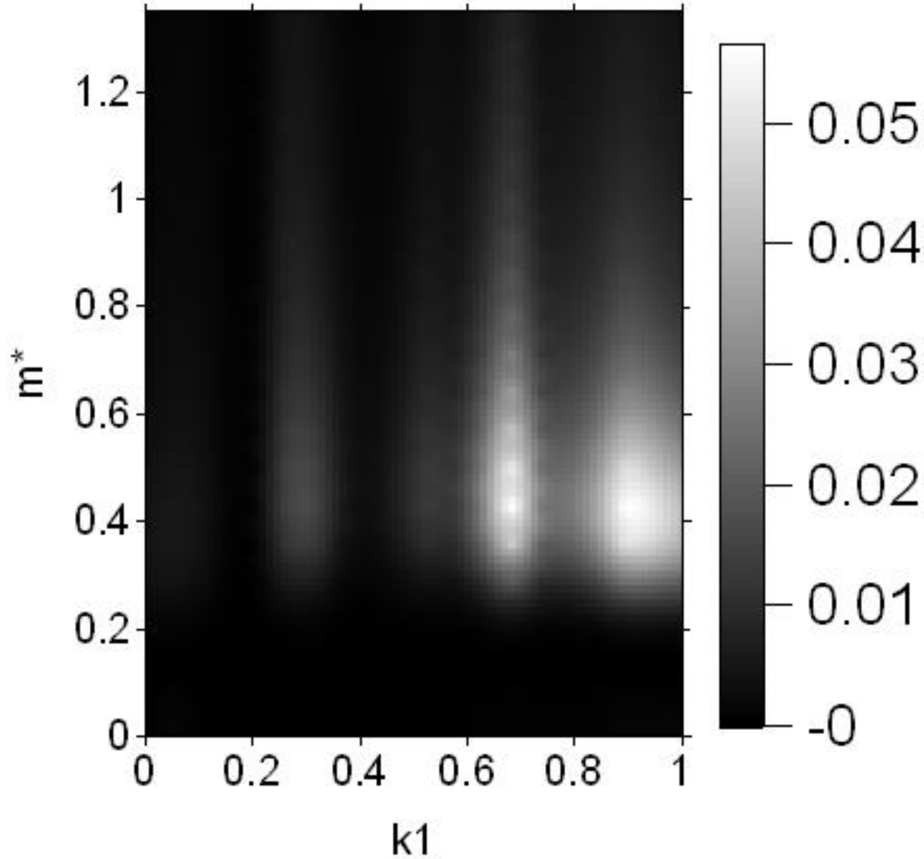
PRL93, 182301, (2004)

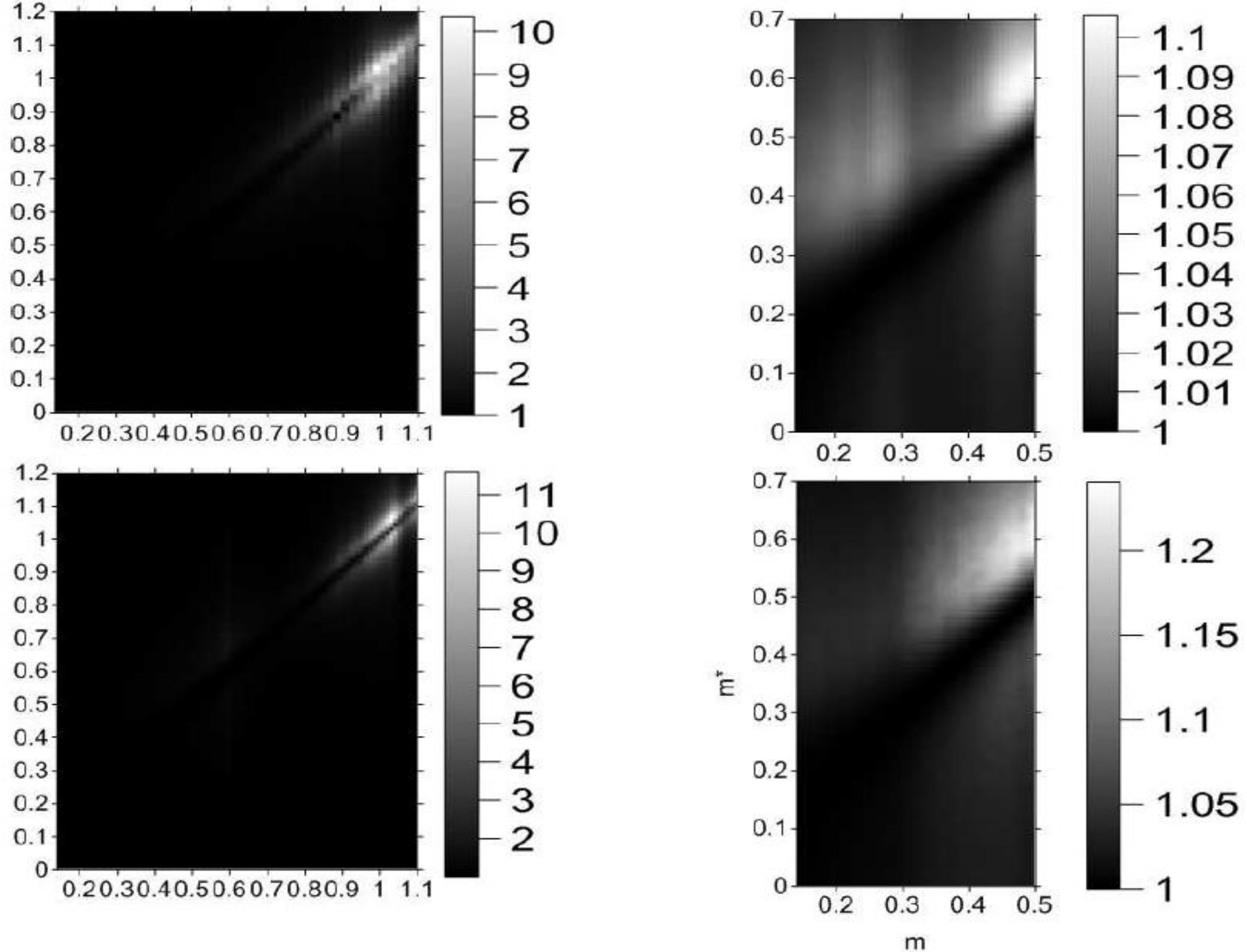
BBC correlations (preliminary)



BBC correlations of pions (preliminary)



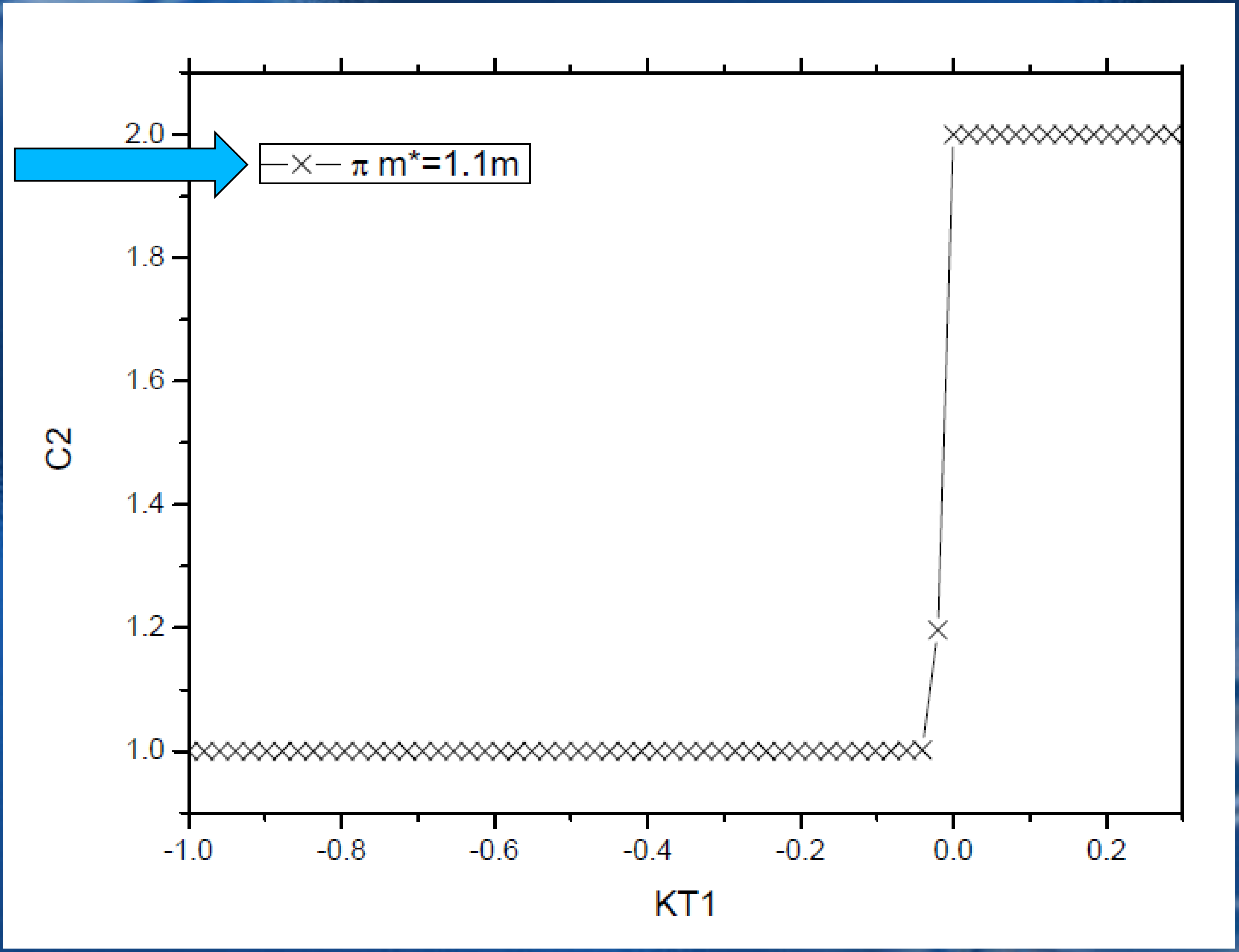




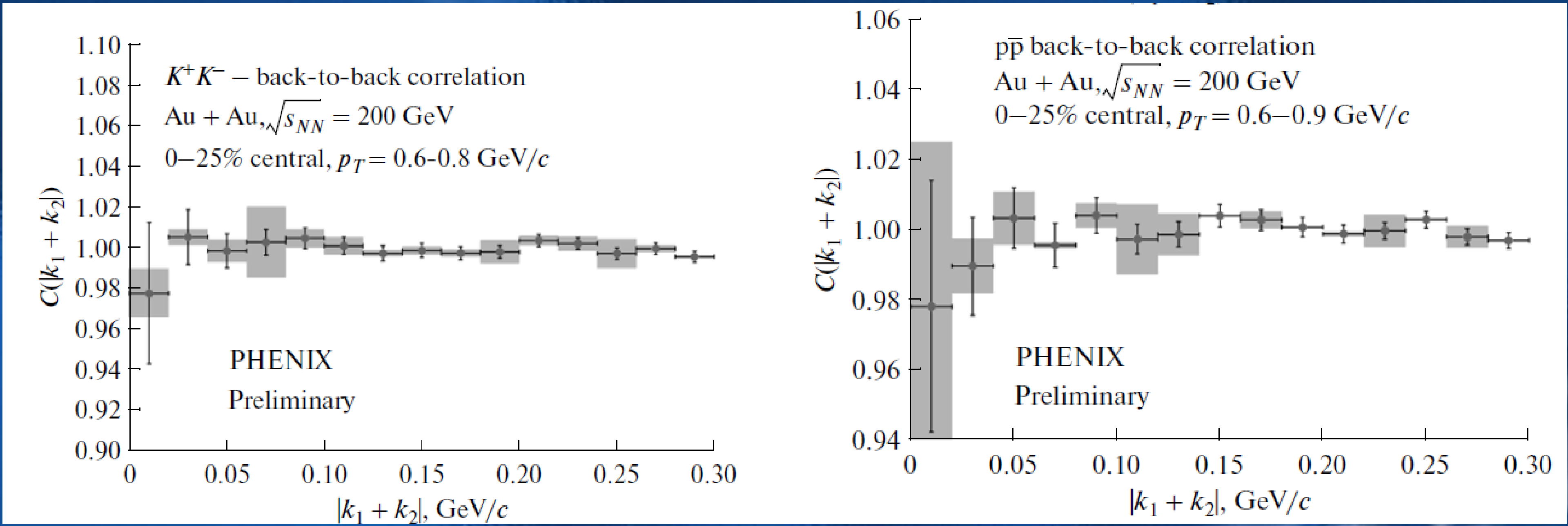
m*
m

BBC correlations (preliminary)

given a small m*



PHENIX data (preliminary)



ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2011, Vol. 8, No. 9, pp. 1033–1036. © Pleiades Publishing, Ltd., 2011.

Conclusion and perspective

- An attempt to use a hydrodynamical model to evaluate the temporal evolution of the system and incorporate it into calculations of squeezed particle correlations

- The part of chaotic particle correlations remains the same as before, which was consistent with the existing experimental data.

- Except the value of mass shift, there is no new parameter in our calculation. In principle, the former can be determined by microscopic model.

- The calculations were done for pion, kaon and phi. The part of squeezed particle correlations is very small for pions, its maximal increases with the particle mass. It might be measurable for kaon and phi mesons.

- When the mass shift is small, the correlations are not measurable for either of the three particles. These results are consistent with the PHENIX preliminary measurements.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backup slides

Thank you!

谢谢!