Azimuthal Angle Dependence of HBT Interferometry with respect to Event Planes in Au+Au collisions at PHENIX

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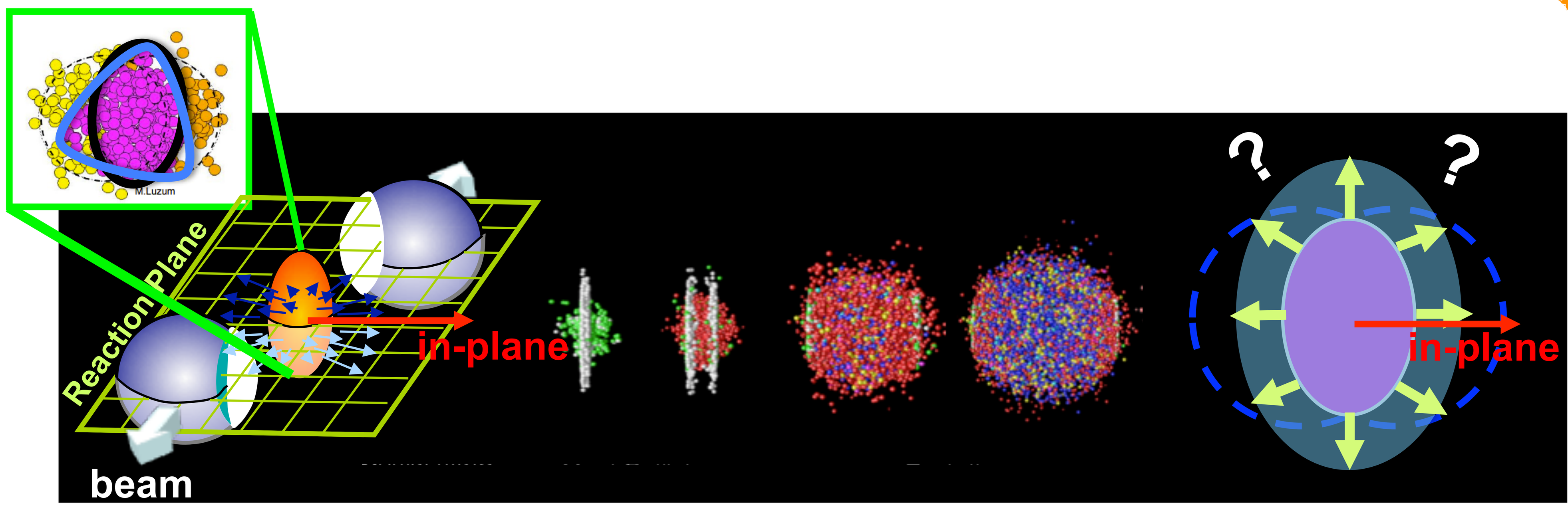
Introduction

Higher order flow anisotropies (v_n) are considered to be originated from initial geometrical fluctuation of participating nucleons followed by the collective expansion of the hot and dense medium created in a heavy ion collision.

The higher order final spatial anisotropies (ε_n) can be accessible by Hanbury Brown and Twiss (HBT) interferometry with respect to higher order event planes (Ψ_n), which reflects the geometrical size and shape at kinetic freeze-out.

This measurement provides detailed information on the system evolution, and could be also a unique probe to the initial-state fluctuation.

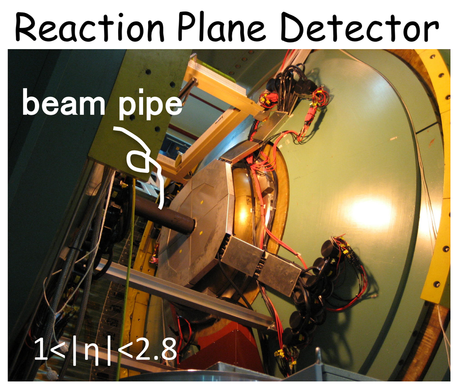


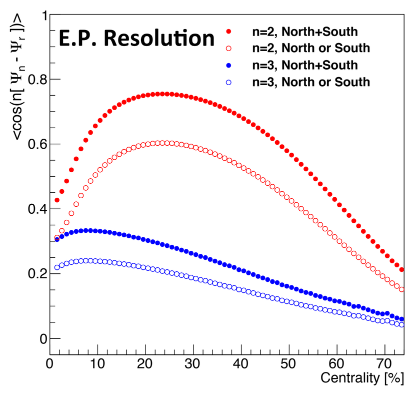
Analysis Method

✓Event planes determined by Reaction Plane Detector

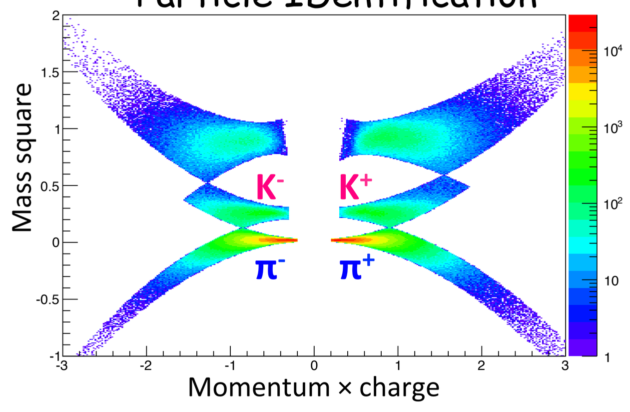
✓PID based on time-of-flight from collision vertex to Electromagnetic Calorimeter

Reaction Plane Detector





Particle IDentification



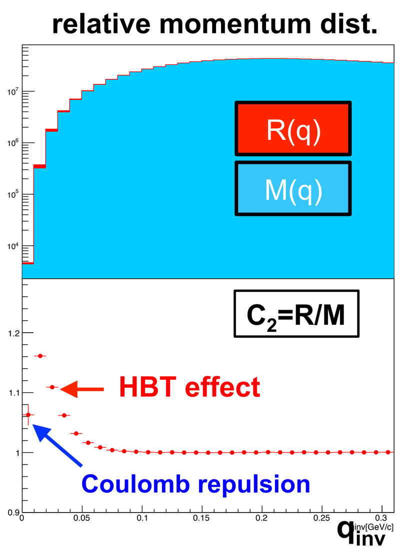
$$\Psi_n = \frac{1}{n}\tan^{-1}\left(\frac{\Sigma w_i \cos(n\phi_i)}{\Sigma w_i \sin(n\phi_i)}\right)$$

$$\mathrm{Res}\{\Psi_n\} = \langle \cos[n(\Psi_n^{obs} - \Psi_n^{true})] \rangle$$

$$m^2 = \frac{p^2}{c^2}\left[\left(\frac{ct}{L}\right)^2 - 1\right]$$

t: time-of-flight
L: path length

Correlation function $C_2 = \frac{A(q)}{B(q)}$



✓ A(q): pairs within the same event

✓ B(q): pairs within the different events made by event-mixing

✓ Corrections on the event plane and momentum resolutions were performed.

Fitting function

$$\vec{k}_T = \frac{1}{2}(\vec{p}_{T1} + \vec{p}_{T2})$$

$$\vec{q}_o \parallel \vec{k}_T,\ \vec{q}_s \perp \vec{k}_T$$

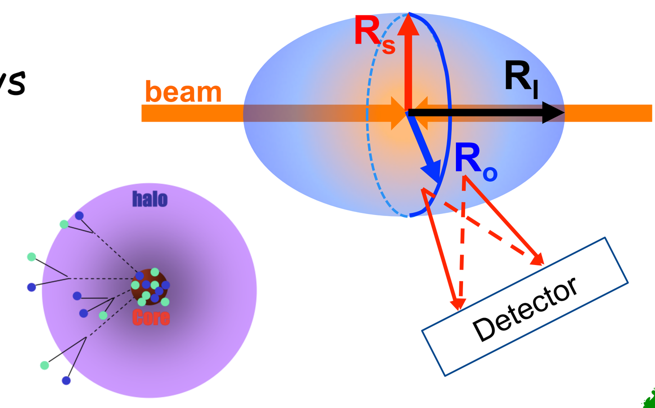
$$C_2 = C_2^{core} + C_2^{halo} = [\lambda(1+G)F_c] + [1-\lambda]$$

$$G = \exp(-R_s^2 q_s^2 - R_o^2 q_o^2 - R_l^2 q_l^2 - 2R_{os}^2 q_o q_s)$$

✓ Fitting function based on "Core-halo" picture to take into account the long-lived resonance decays

✓ 3D-analysis with "Out-Side-Long" system

✓ Including Coulomb repulsive effect

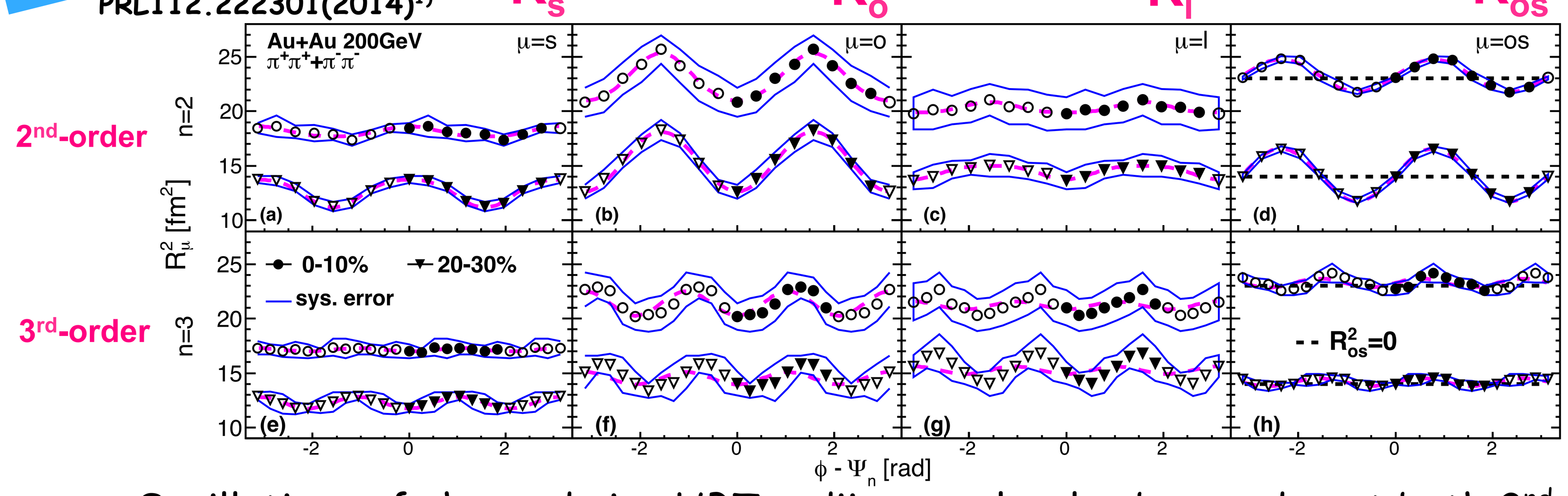


Azimuthal angle dependence of HBT radii (R_μ) was measured w.r.t Ψ_2 and Ψ_3.

HBT radii w.r.t 2nd/3rd-order Event Planes

Published!!

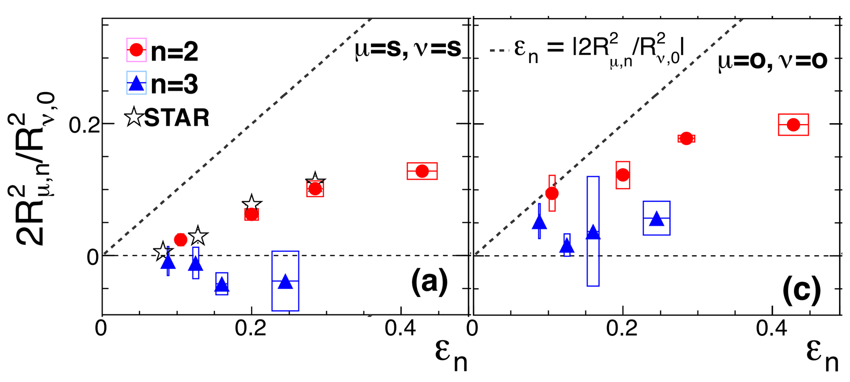
PRL112.222301(2014)[1]



Oscillations of charged pion HBT radii were clearly observed w.r.t both 2nd and 3rd-order event planes.

✓ Opposite sign of R_s and R_o for 2nd-order

✓ Same sign of R_s and R_o for 3rd-order



w.r.t Ψ_2

✓ $\varepsilon_{final} \sim \varepsilon_{init}/2$ due to medium expansion

✓ Consistent with STAR experiment

w.r.t Ψ_3

✓ Negative $R_{s,3}^2$ and positive $R_{o,3}^2$

✓ **Oscillation driven by triangular flow** (see below)

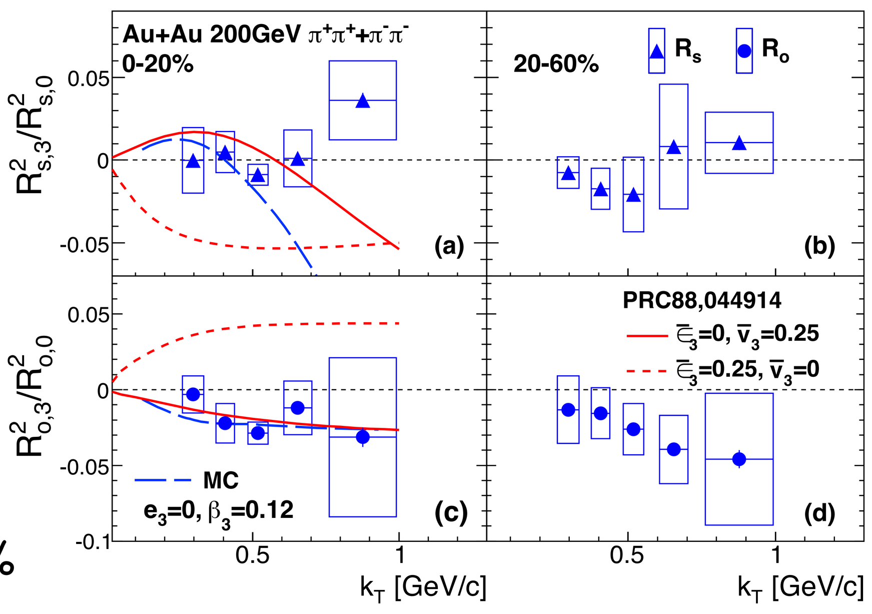
For 3rd-order dependence, comparison with two calculations:

✓Gaussian source model[2]

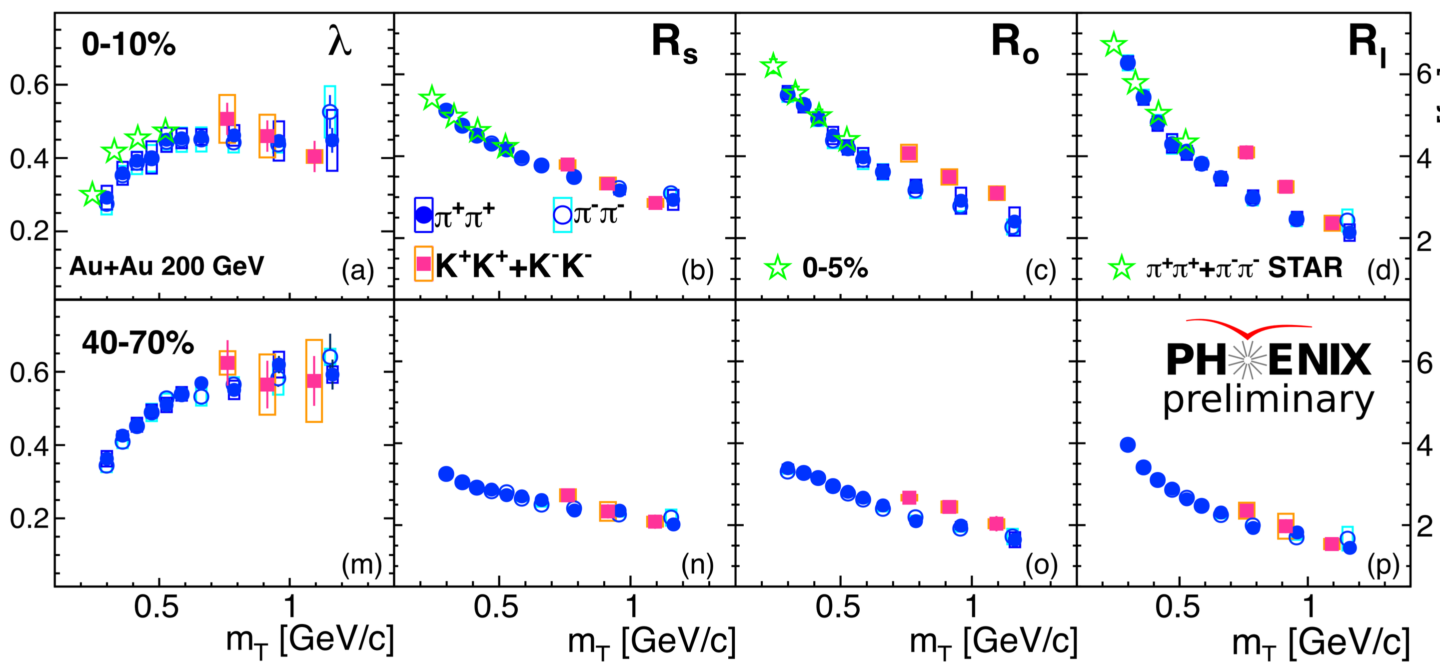
✓Monte-Carlo simulation[1]

Qualitatively consistent with the case of **finite triangular flow without spatial deformation** !!

Possible indication of reversed triangular spatial anisotropy[1] in 20-60%



Particle Species Dependence

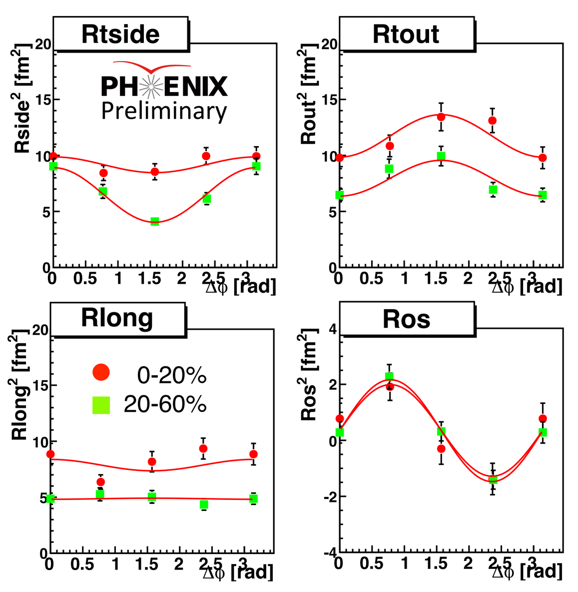


✓ **Visible differences of R_o and R_l** in central collisions

✓ The difference decreases with centrality

✓ Ψ_2 dependence was observed as well as π

kaon HBT w.r.t Ψ_2



Possible indication/interpretation

✓ Similar trend to hydrokinetic model[3]

– Breaking of m_T scaling for R_l may be explained by strong transverse flow

✓ Blast-wave model study suggests faster freeze-out but longer emission duration of K compared to π (Thesis result)

✓ Need realistic model study to justify the scenario

Conclusion & Outlook

✓PHENIX has performed a first measurement of HBT w.r.t 3rd-order event plane

✓Source eccentricity is diluted due to medium expansion but still retain initial shape, while triangularity seems to vanish at kinetic freeze-out

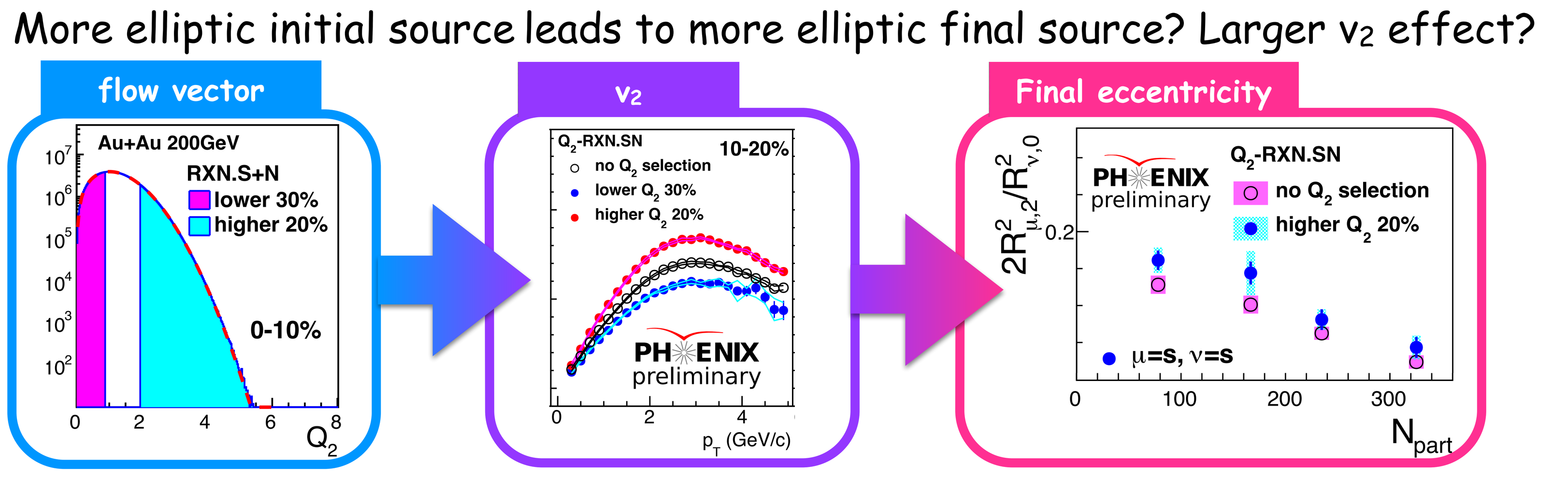
✓Charged kaon HBT shows similar but slight different trends to charged pions with possible indication of different freeze-out mechanism

Toward event-by-event study with event shape engineering[4]

✓Larger/smaller **flow vector** ->larger/smaller v_2 event (->**control initial** ε_2?)

✓How about final ε_2 possibly controlling initial shape?

- More elliptic initial source leads to more elliptic final source? Larger v_2 effect?



✓Could select large ε_3 event with small ε_2, maybe applicable for U+U and Cu+Au

References

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2) C. J. Plumberg, C. Shen and U. Heinz, Phys. Rev. C**88**, 044914 (2013)
3) I. A. Karpenko and Y. M. Sinyukov, Phys. Rev C**81**, 054903 (2010)
4) J. Schukraft, A. Timmins and S. A. Voloshin, Phys. Lett. B**719**, 394 (2013)