Identical pions femtoscopic studies in Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV with STAR at the RHIC

TCHoU Workshop for the Division of Quark Nuclear Matters
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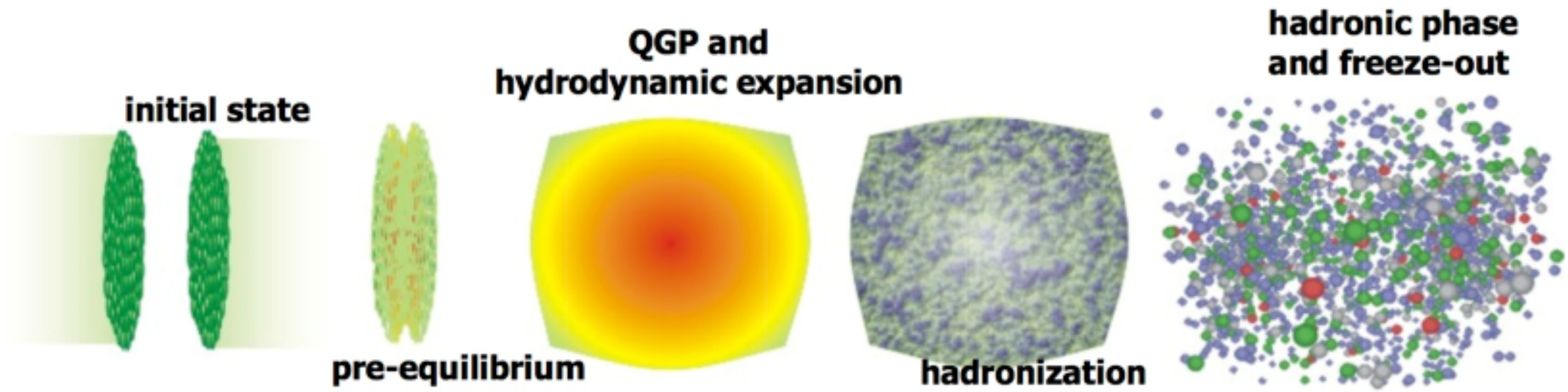
STAR

Introduction

- Big-Bang theory of the universe predicts that matter existed in QGP form after ~1 μs of the universe formation

- Lattice QCD predicts QGP at ~170 MeV temperature



- Very hot and dense QGP like medium formation in heavy-ion collisions due to inelastic collisions between nuclei and conversion of kinetic energy into heat

- To obtain the equation of state, it is important to know the dimensions of fireball which is impossible to measure directly due to its very small size

Introduction (contd.)

- Femtoscopy (or HBT technique) provides a direct tool to measure the source size
- Probe space-time characteristics of the source using particle correlations in momentum space
- Main sources of correlations:

➡ **Quantum statistics (QS)** → **HBT analysis**

- Identical bosons - Bose-Einstein quantum statistics
- Identical fermions - Fermi-Dirac quantum statistics

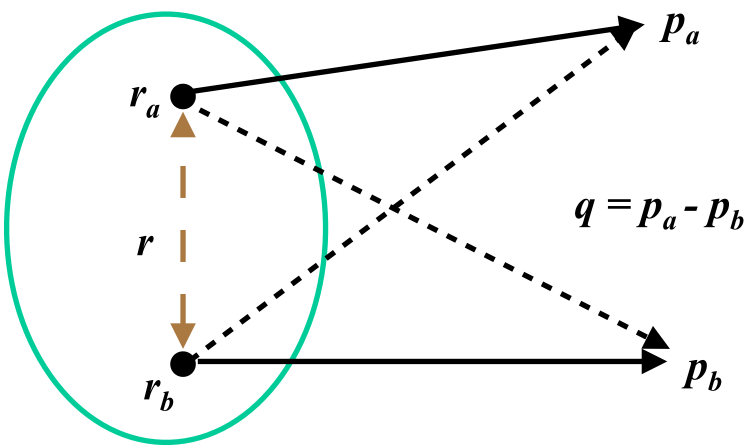
➡ **Final-state interactions (FSI)**

- Strong interaction
- Coulomb interaction (repulsion/attraction)

QS + FSI→ Femtoscopic analysis

Two-particle correlation function

$$C_2 = \frac{P_2(p_a, p_b)}{P_1(p_a)P_1(p_b)}$$



Koonin-Pratt Equation,

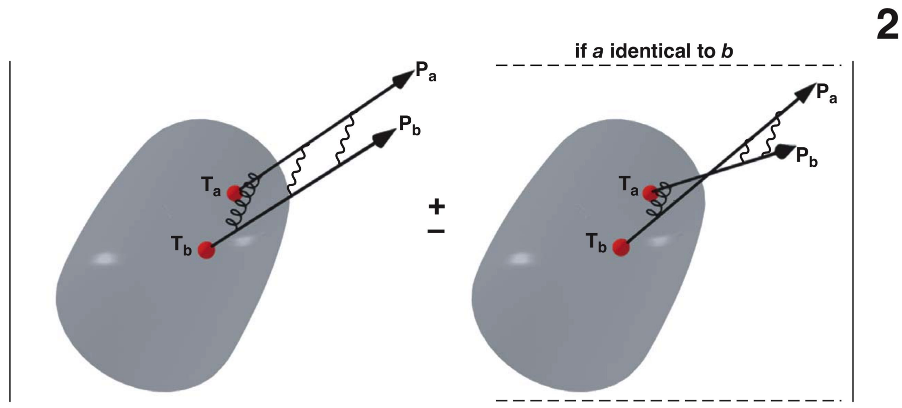
PLB70 (1977) **43**,*S. Pratt et al.*, PRC42 (1990) 2646

Source function

$$\mathbf{C(q)} = \int \mathbf{dr}|\psi(\mathbf{q},\mathbf{r})|^2\mathbf{S(r)}$$

Experimental correlation function

Pair wave function

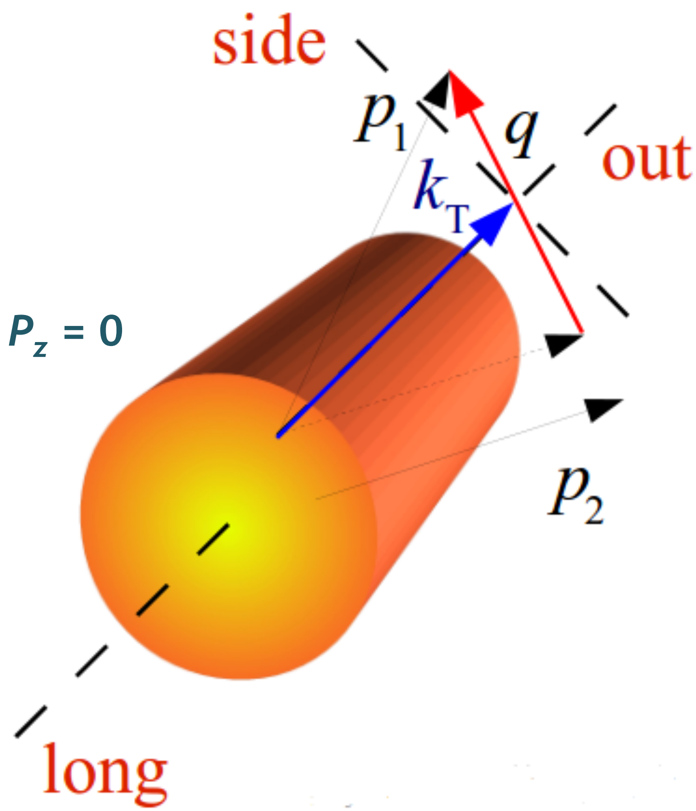


➡ $P_2(p_a,p_b)$ – probability of detection of particles with momenta p_a and p_b

➡ $P_1(p_i)$ – probability of detection of particle with momentum p_i

Bertsch–Pratt 'Out-Side-Long' coordinate system

- **side** is interpreted as **geometric size**
- **out** gives info on **emission process**
- **long** is used for **emission time approx.**



Longitudinal co-moving system (LCMS):

A rest frame moving along the beam direction such that $P_z = 0$

$$V_{long} = (P_0 V_z - P_z V_0)/M_T$$

$$V_{side} = (P_x V_y - P_y V_x)/P_T$$

$$V_{out} = (P_x V_x + P_y V_y)/P_T$$

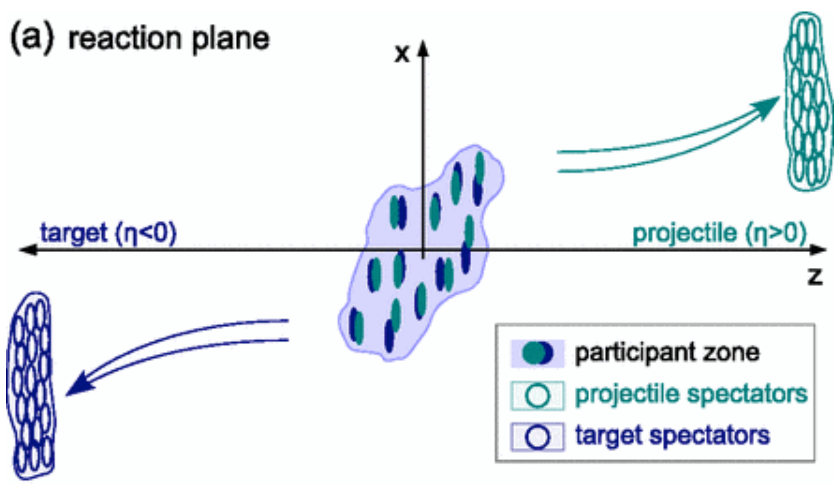
Pair rest frame (PRF):

$$V'_{out} = \frac{M_{inv}}{M_T}\frac{(P_x V_x + P_y V_y)}{P_T} - \frac{P_T}{M_T M_{inv}} P.V$$

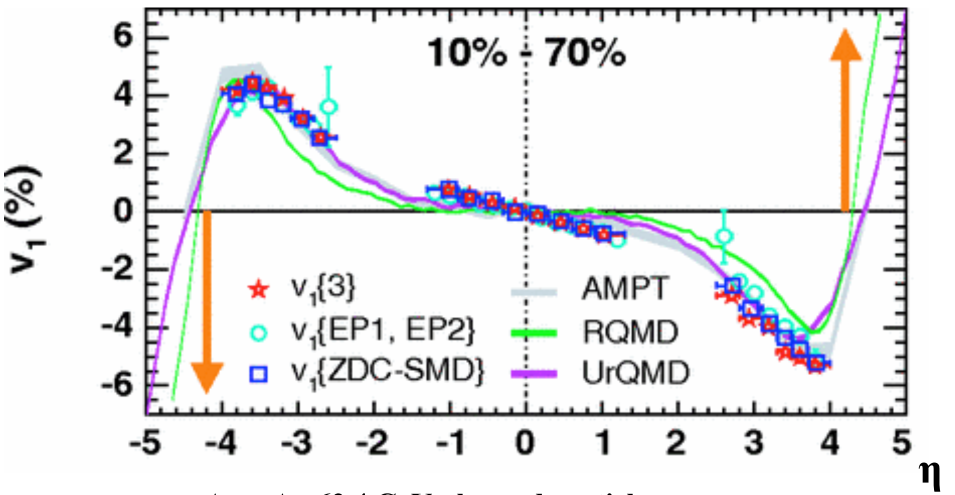
Where $M_T{}^2 = P_0^2 - P_z^2$, $P_T^2 = P_x^2 + P_y^2$ and $M_{inv}^2 = P^2$

Femtoscopic studies w.r.t. Ψ_1

ALICE Collaboration, Phys. Rev. Lett. 111 (2013) 232302



STAR Collaboration, Phys. Rev. C 73 (2006) 34903



Au + Au 62.4 GeV, charged particle v_1

- Directed flow v_1 ($= \langle\cos(\phi - \Psi_1)\rangle$) is produced due to interaction between spectator and participant particles
- $v_1(\eta)$ is zero three times at around mid, forward and backward rapidities : possible signature of phase transition (J. Brachmann et al. Phys. Rev. C 61 (2000) 024909)
- v_1 can't be explained by hydrodynamical models unlike v_2 or v_3

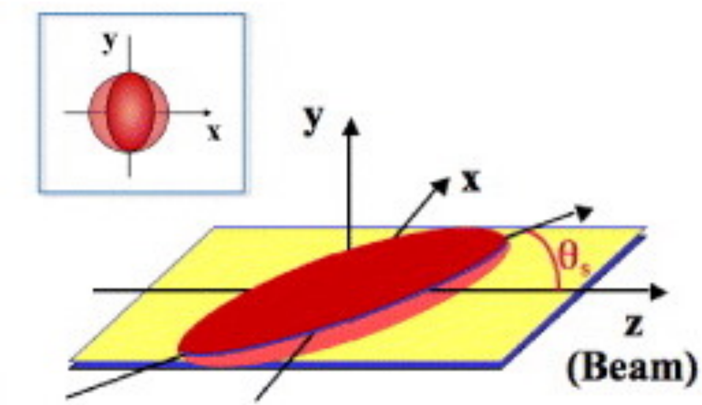
Femtoscopic studies w.r.t. Ψ_1

- v_1 signal can be generated from assuming the "tilted source" initial conditions

- Femtoscopic measurements w.r.t. Ψ_1 can give the information about tilt angle θ_s

- Fit function for identical particles with cross term:

M. A. Lisa et al. New J. Phys. 13 (2011) 065006



$$C(q) = N[(1-\lambda) + \lambda K(q_{inv})(1+G(q))]$$

$$G(q) = exp(-R_{out}^2 q_{out}^2 - R_{side}^2 q_{side}^2 - R_{long}^2 q_{long}^2 - R_{os}^2 q_{out} q_{side} - R_{ol}^2 q_{out} q_{long} - R_{sl}^2 q_{side} q_{long})$$

- Goal: to perform femtoscopic analysis w.r.t. Ψ_1 and extract θ_s which is expected to decrease with energy

$$\theta_s = \frac{1}{2}\tan^{-1}\left(\frac{-4R_{sl,1}^2}{R_{l,0}^2 - R_{s,0}^2 + 2R_{s,2}^2}\right)$$

Fit function

$$\begin{cases} R_{\mu,0}^2 + 2R_{\mu,1}^2 cos(\phi - \Psi_1) + 2R_{\mu,2}^2 cos(2(\phi - \Psi_1)), (\mu = o, s, l, ol) \\ R_{\mu,0}^2 + 2R_{\mu,1}^2 sin(\phi - \Psi_1) + 2R_{\mu,2}^2 sin(2(\phi - \Psi_1)), (\mu = os, sl) \end{cases}$$

THANK YOU