Article ID: 1007-4627(2001)03-0197-04

HBT λ-parameter in Relativistic Heavy-ion Collisions*

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Abstract: Using the dynamical transport model RQMD with a correlation after-burner, the behavior of two-pion HBT λ-parameter is studied in Au+Au central collisions at RHIC energy $\sqrt{s}=200$ AGeV. The λ-parameter is found to be sensitive to the sequential freeze-out in heavy-ion collisions.

Key words: relativistic heavy-ion collision; HBT correlation; correlation function

CLC number: O572 **Documber code**: A

The space-time evolution information of heavy-ion collisions can be extracted by two-particle intensity interferometry[1]. The strength parameter λ of HBT correlation has the value of one in the ideal case[2]. Experimental results[3], as well as model calculations[4], often show that the value of λ is less than one. A familiar interpretation for the effect is the partial quantum coherent. Sometimes the final-state interactions, the finite resolution of momentum difference in experiment, and the particle identification are also blamed for the λ-parameter smallness[5]. More importantly, it is believed that resonances, especially those decaying with long lifetimes, will reduce the value of the λ-parameter.

In this letter, we study the behavior of two-pion HBT λ-parameter in Au+Au collisions at center-of-mass energy $\sqrt{s}=200$ AGeV. The dynamical transport approach RQMD is used as a event generator[6] and a correlation after-burner (CRAB) code is used to calculate the two-pion correlation functions. The 3-dimensional correlation functions are fitted with the standard Gaussian form[7],

$$C_2(q) = 1 + \lambda \exp(-R_o^2 q_o^2 - R_s^2 q_s^2 - R_l^2 q_l^2) . \quad (1)$$

where the components of relative momentum q of a pair of pions are defined parallel to the beam (l = longitudinal), parallel to the transverse momentum (o=out), and perpendicular to the transverse momentum (s=side), respectively. The $R_i (i=o,s,l)$ is the homogeneity length in the i-direction.

The two-pion HBT parameters as a function of pair transverse momentum p_t are plotted as solid lines in Fig. 1 for Au + Au central collisions at $\sqrt{s}=200$ AGeV. All size parameters, R_o, R_s and R_l, decrease dramatically as p_t goes up. The λ-parameter also changes as a function of pair transverse momentum. The HBT size parameters are compared to the pion space-time distributions at freeze-out. Distances of pion pairs selected randomly are calculated in the i-direction and fitted with the static Gaussian formalism to a range of ±1.5 RMS value of the distribution (dashed

Received date: 05 July 2001

* **Foundation item**: National Natural Science Foundation of China (19875012); Scientific Research Foundation of Harbin Institute of Technology (HIT. 2000. 08)

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lines). Due to the non-Gaussian shape in the distance distributions, the Gaussian fit results will depend on the fitting range. In Fig. 1, the dashed-dot lines represent the uncertainties of the fitting range from 1.0 to 2.0 RMS value of the distribution. It is clear that most of non-Gaussian appears in the low p_t region. While the radii directly from pion space-time distributions are consistent with the HBT values in the l-and s-direction, a clear difference appears in the o-direction between the two approaches.

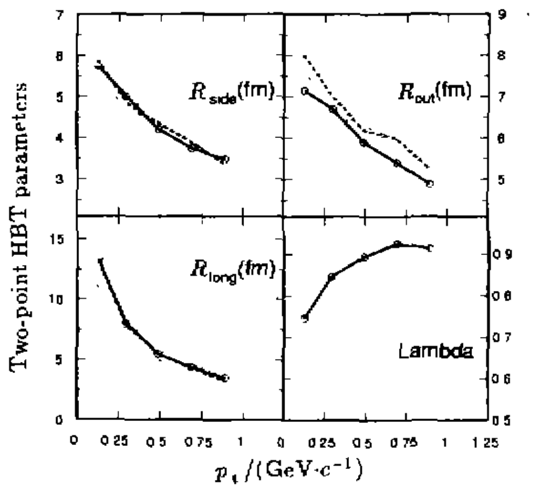

Fig. 1 The two-pion HBT parameters as a function of pair transverse momentum p_t for Au + Au collisions at $\sqrt{s}=200$ AGeV.

As can be seen in Fig. 1, while the size parameters decrease as p_t increases, the λ-parameter increases gradually. The p_t-dependence of λ-parameter was attributed mostly to the resonance decays. The finite resolution in relative momentum does also play a role for large size source. However, the hot and dense system formed in heavy-ion collisions will expand and freeze-out continuously. One may imagine that particles located closer to the edge will freeze-out earlier than those near the center of the hot zone. Matter initiating at the center of the collision zone where the density is high will have to expand first, till the system becomes dilute enough to freeze-out. Then the freeze-out will be continuous and sequential, i.e. the particles which come out of the system at early time will be from relatively smaller source compared to those at late time. Assuming the source is Gaussian at each time interval, the total source integrated over the whole time evolution is not necessarily Gaussian due to the change of the source size as a function of collision time. Such non-Gaussian shape will lead to the non-unity of λ-parameter if it is extracted by using Eq. (1) to fit the correlation functions.

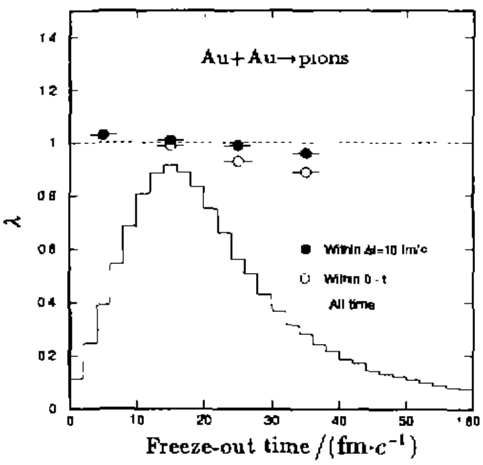

Fig. 2 The HBT λ-parameters as a function of pion freeze-out time for Au+Au collisions at $\sqrt{s}=200$ AGeV.

The two-pion HBT λ-parameters as a function of pion freeze-out time are shown in Fig. 2 for Au+Au central collisions at $\sqrt{s}=200$ AGeV. Due to expansion and/or resonance decay, the correlation functions are not in a perfect Gaussian shape and the λ-parameter extracted from Eq. (1) is less than one. However, within the time window of $\Delta t=10$ fm/c, the correlation functions are much closer to the Gaussian shape and the λ is unity (solid circle). In Fig. 2, the shaded bar represents the λ value (~0.8) under the total freeze-out time integrated. In a time integrated window, ($\Delta t=0-t_i$, $t_i=10$, 20, 30, 40 fm/c), the λ-parameter (open circle) also decreases and it eventually reaches the total time integrated value. This means that whence sequential freeze-out occurs, whether due to resonance decay or expansion, the summed source is not a Gaussian even it is at a given time interval. As a result, the correlation function is destroyed and the λ-parameter from the HBT measurement becomes less than one. The sequential freeze-out, at least from the model used here, is more general than either resonance decay or expansion. The experimental measured λ-parameter less than one may be interpreted as an evidence of sequential freeze-out in heavy-ion collisions.

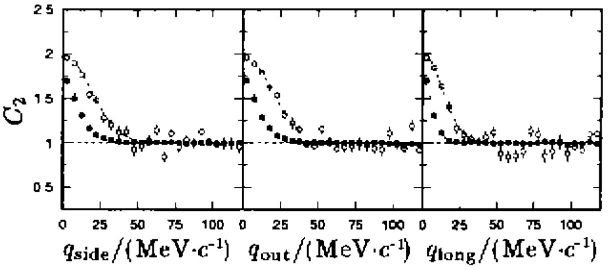

Fig. 3 Projections of 3-dimensional correlation functions constructed from the ω meson decayed pions in Au+Au collisions at $\sqrt{s}=200$ AGeV.

Up to now, we have used only the directly produced pions to construct the correlation functions and demonstrate that the non-unity of the λ-parameter is the result of the sequential freeze-out of the source produced in the heavy-ion collisions. We argue that the effect of the resonance decay is part of the story here. In order to show this, we study resonance contributions by investigating the correlation functions of pions from the ω meson decays. With full decay width 8.41 MeV/c^2 and lifetime 23 fm/c, the ω meson is the moderately long-lived resonance. It is expected to be produced in significant numbers in relativistic heavy-ion collision, and the effect on correlation functions has been studied by several authors[8,9]. As shown in Fig. 3, the correlation functions (solid circle) are not perfect Gaussian shape and the λ-parameter is less than one. However, within the time window, $10<t<30$ fm/c, the correlation functions (open circle) are much closer to the Gaussian shape and the λ is unity. This result means that whence sequential freeze-out occurs, whether due to decay or expansion, or due to other mechanism, the correlation function is different from a Gaussian and the λ-parameter becomes less than one. This effect is particularly important if one wants to draw conclusions from the λ-parameter about a possible contribution of a coherent component in multiparticle production.

In summary, we have studied the behavior of the pion HBT λ-parameter in Au—Au central collisions at RHIC energy $\sqrt{s}=200$ AGeV. Within a given narrow freeze-out time window, $\Delta t=10$ fm/c, the λ-parameter is unity while the total time integrated value is about 0.8. This is also true even for the pions from the ω resonance decays. Pions emitted at different freeze-out times with different size parameters or resonance decays will distort the correlation functions from ideal Gaussian shape and thus reduce the value of the λ.

References:

[1] Pratt S. Pion Interferometry for Exploding Sources[J]. Phys Rev Lett, 1984, 53(13): 1 219—1 221.

[2] Gyulassy M, Kauffmann S K, Lance W W. Pion Interferometry of Nuclear Collisions I Theory[J]. Phys Rev C, 1979, 20(6): 2 267—2 292.

[3] Bearden I G, BΦggild H, Boissevain J, *et al*. High Energy Pb+Pb Collisions Viewed by Pion Interferometry[J]. Phys Rev C, 1998, 58(3): 1 656—1 665.

[4] Fields D E, Sullivan J P, Simon-Gillo J, *et al*. Relationship Between Correlation Function fit Parameters and Source Distributions[J]. Phys Rev C, 1995, 52(2): 986—994.

[5] Bolz J, Ornik U, Plumer M, *et al*. Resonance Decays and Partial Coherence in Bose-Einstein Correlations[J]. Phys Rev D, 1993, 47(9): 3 860—3 870.

[6] Sorge H. Flavor Production in Pb(160 AGeV) on Pb Collisions: Effect of color ropes and hadronic rescattering[J]. Phys Rev C, 1995, 52(6): 3 291—3 314.

[7] Sullivan J P, Berenguer M, Jacak B V, *et al*. Bose-Einstein Correlations of Pion Pairs and Kaon Pairs From Relativistic Quantum Molecular Dynamics[J]. Phys Rev Lett, 1993, 70(20): 3 000—3 003.

[8] Nickerson S, Csörgő T, Kiang D. Testing the Core-halo Mod-

el on Bose-Einstein Correlation Functions [J]. Phys Rev C, 1998, 57(6): 3 251—3 262.
[9] Wiedemann U A, Heinz U. Resonance Contributions to Hanbury-Brown-Twiss Correlation radii[J]. Phys Rev C, 1997, 56(6): 3 265—3 286.

相对论重离子碰撞中 HBT 关联 λ 参数分析*

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摘　要: 利用相对论量子分子动力学模型 RQMD, 对 RHIC 能区 $\sqrt{s}=200$ AGeVAu+Au 中心碰撞进行了2π干涉学分析, 对 HBT 关联相干因子 λ 的行为进行了研究. 研究表明, 参数 λ 一般小于理想混沌源时的值, 这反映了源的部分相干特性外, 还与源的膨胀和持续冻结有关, 体现为 λ 参数对粒子的冻结时间较为敏感.

关 键 词: 相对论重离子碰撞; HBT 关联; 关联函数

《原子核物理评论》简介

本刊是核科学领域的综合性学术刊物, 是中国核物理学会会刊. 它由科学出版社出版, 国内外公开发行. 本刊主要刊登反映本学科及相关各交叉学科领域最新进展的评述性文章, 报道原子核物理基础研究及其应用研究, 以及与此有关的交叉学科研究领域的最新重要研究成果和发展趋势, 同时及时发表最新重要研究成果的学术论文. 栏目有: 核物理、加速器物理、核技术、交叉学科、核能与核数据库及不定期栏目**"快报"(英文, 2—4个月内出版)**等. 读者对象为: 广大科研人员、技术人员、大专院校师生以及工农矿医的有关人员.

在核物理学会和全体同仁的关心和支持下, 在编委会的领导下, 经过编辑部工作人员的努力, 近年来本刊水平有较大提高, 已被《中文核心期刊要目总览》(2000年版)编委会确定为**核心期刊**. 该刊物的国内外影响日益增大, 在促进核物理学科及相关交叉学科的发展方面起了一定的作用.

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* 基金项目: 国家自然科学基金资助项目(19875012); 哈尔滨工业大学校基金资助项目(HIT.2000.08)