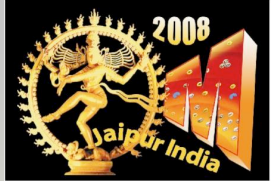


SEARCH FOR SQUEEZED-PAIR CORRELATIONS AT RHIC

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Outline



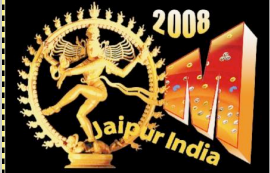
- Introduction and motivation
- Brief review and previous results (infinite systems)
- Focus on finite expanding system, non-relativistic approach → illustration: $\phi\phi$ BBC pairs
- How to search for squeezed BBC pairs in experiments → suitable variables
- Modified-mass effects and squeezing on BBC and HBT correlations
- Summary and conclusions

Brief Introduction



- Late 90's: Back-to-Back Correlations (BBC) among **boson-antiboson pairs** → shown to exist if the **masses** of the particles were **modified** in a hot and dense medium
[Asakawa, Csörög & Gyulassy, P.R.L. 83 (1999) 4013].
- Shortly after → **similar BBC** existed among **fermion-antifermion pairs** with medium modified masses
[Panda, Csörög, Hama, Krein & SSP, P. L. B512 (2001) 49].
- **Some properties:**
 - **Similar formalism** for both bosonic (bBBC) and fermionic (fBBC) Back-to-Back Correlations
 - **Similar** (and unlimited) **intensity** of fBBC and bBBC
 - Expected to appear for $p_T \leq 1-2 \text{ GeV}/c$

Similarities



- Maximum of the squeezed correlation function vs. M_*
→ small mass shifts seem to induce stronger correlations

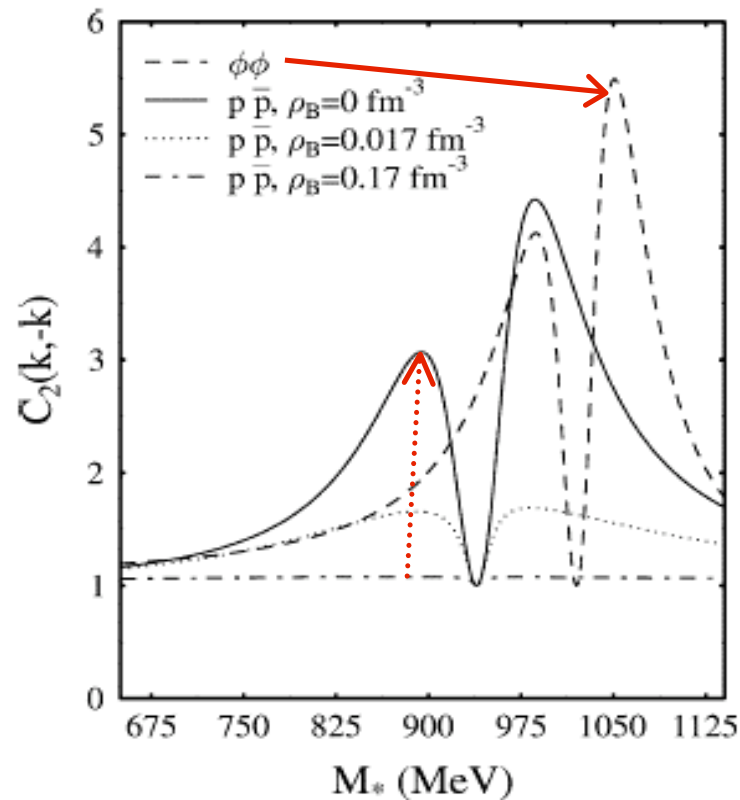
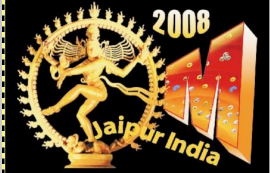


Fig. 1. Back-to-back correlations of proton–anti-proton pairs and ϕ -meson pairs, for $T = 140 \text{ MeV}$, $\Delta t = 2 \text{ fm}/c$ and $|\mathbf{k}| = 800 \text{ MeV}/c$.

Full Correlation Function



$$\langle a_{k_1}^\dagger a_{k_2}^\dagger a_{k_1} a_{k_2} \rangle = \langle a_{k_1}^\dagger a_{k_1} \rangle \langle a_{k_2}^\dagger a_{k_2} \rangle \pm \langle a_{k_1}^\dagger a_{k_2} \rangle \langle a_{k_2}^\dagger a_{k_1} \rangle + \langle a_{k_1}^\dagger a_{k_2}^\dagger \rangle \langle a_{k_1} a_{k_2} \rangle$$

NOTATION

$$N_1(\vec{k}_i) = \omega_{k_i} \frac{d^3 N}{d^3 k} = G_c(\vec{k}_i, \vec{k}_i) \equiv G_c(i, i) = \omega_{k_i} \langle a_{k_i}^\dagger a_{k_i} \rangle \longrightarrow \text{Spectra}$$

$$G_c(\vec{k}_1, \vec{k}_2) \equiv G_c(1, 2) = \sqrt{\omega_{k_1} \omega_{k_2}} \langle a_{k_1}^\dagger a_{k_2} \rangle \longrightarrow \text{Chaotic amplitude}$$

$$G_s(\vec{k}_1, \vec{k}_2) \equiv G_s(1, 2) = \sqrt{\omega_{k_1} \omega_{k_2}} \langle a_{k_1} a_{k_2} \rangle \longrightarrow \text{Squeezed amplitude}$$

$$C_2(\vec{k}_1, \vec{k}_2) = 1 \pm \frac{|G_c(1, 2)|^2}{G_c(1, 1)G_c(2, 2)} + \frac{|G_s(1, 2)|^2}{G_c(1, 1)G_c(2, 2)}$$

HBT

BBC



In-medium & asymptotic operators

- $a_k (a_k^\dagger) \rightarrow$ annihilation (creation) operator of the asymptotic quanta with 4-momentum p^μ ;
- $b_k (b_k^\dagger) \rightarrow$ in-medium annihilation (creation) operator
(a -quanta \rightarrow observed; b -quanta \rightarrow thermalized in medium)

They are related by the Bogoliubov transformation:

$$\begin{cases} a_k^\dagger = c_k^* b_k^\dagger + s_{-k} b_{-k} \\ a_k = c_k b_k + s_{-k}^* b_{-k}^\dagger \end{cases} ; \quad \boxed{c_k = \cosh[f_k]} ; \quad \boxed{s_k = \sinh[f_k]}$$

- $\boxed{f_k = \frac{1}{2} \ln(\omega_k / \Omega_k)}$ \rightarrow squeezing parameter (Bogoliubov transformation is equivalent to a squeezing operation)

bBBC & fBBC - formalism summary



• Bosonic BBC

$$c_k = \cosh[f_k] ; s_k = \sinh[f_k]$$

$$\begin{cases} a^\dagger_k = c_k b^\dagger_k + s_{-k} b_{-k} \\ a_k = c_k b_k + s_{-k}^* b_{-k}^\dagger \end{cases}$$

$$\begin{cases} f_k \equiv r_k^{ACG} = \frac{1}{2} \log \left(\frac{\omega_k}{\Omega_k} \right) \\ \omega_k^2 = m^2 + \vec{k}^2 \\ \Omega_k^2 = \omega_k^2 - \delta M^2(|k|) \\ m_*^2 = m^2 - \delta M^2(|k|) \end{cases}$$

• Fermionic BBC

$$c_k = \cos[f_k] ; s_k = \sin[f_k]$$

$$\begin{pmatrix} a_{\lambda,k} \\ \tilde{a}_{\lambda',-k}^\dagger \end{pmatrix} = \begin{pmatrix} c_k & \frac{f_k}{|f_k|} s_k A \\ -\frac{f_k^*}{|f_k|} s_k^* A^\dagger & c_k^* \end{pmatrix} \begin{pmatrix} b_{\lambda,k} \\ \tilde{b}_{\lambda',-k}^\dagger \end{pmatrix}$$

$$A = [\chi_\lambda^\dagger (\sigma \cdot \hat{k}) \tilde{\chi}_{\lambda'}] ; A^\dagger = [\tilde{\chi}_{\lambda'}^\dagger (\sigma \cdot \hat{k})^\dagger \chi_\lambda]$$

$$\tilde{\chi}_{\lambda'} = -i\sigma^2 \chi_{\lambda'} ; \hat{k} = \vec{k}/|\vec{k}|$$

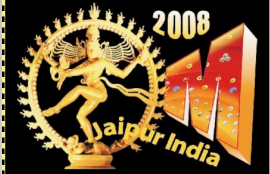
→ is a Pauli spinor

$$\tan(2f_k) = -\frac{|k| \Delta M(k)}{\omega_k^2 - \Delta M(k)M}$$

$$m_*(k) = m - \Delta M(k)$$

$$\omega_k^2 = m^2 + \vec{k}^2 ; \Omega_k^2 = m_*^2 + \vec{k}^2$$

Finite expanding systems



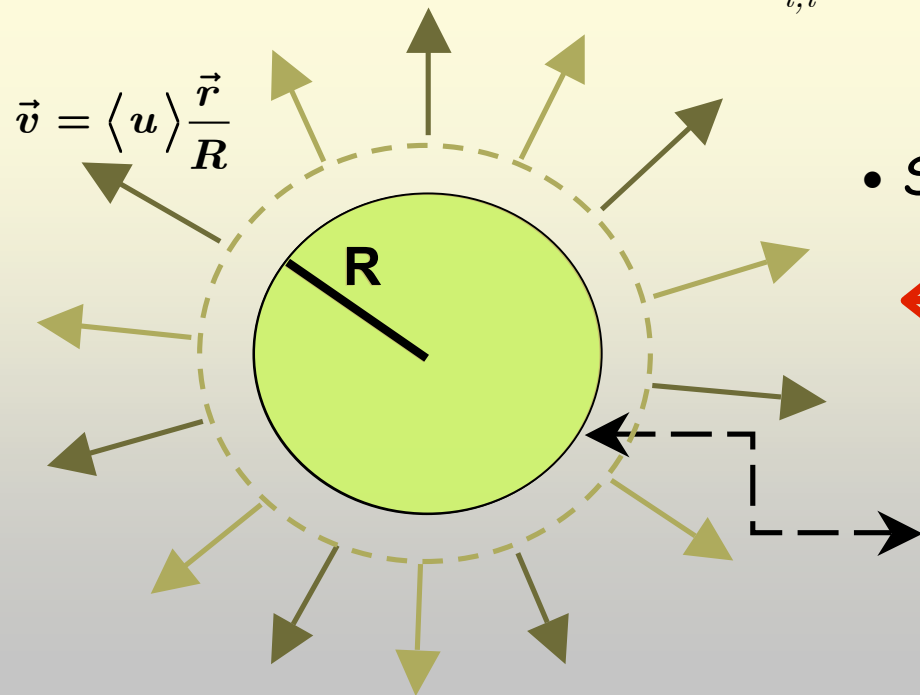
- Does the BBC survive
 - Finite medium (volume V) ?
 - Flow ?
- Squeezed correlations were shown
 - to survive both (more realistic) conditions, still with sizeable strength
 - non-relativistic treatment with flow-independent squeezing parameter $\rightarrow \phi\phi$ squeezed correlations
(partial results shown @ Quark Matter 2005 \rightarrow <http://qm2005.kfki.hu/> ; see also <http://curly.pa.msu.edu/~scottepratt/wpcf2007/agenda.html>)
... brief reminder of main results follows \rightarrow

Expanding non-relativistic finite system



- For large mass m and small mass shifts $[(m_* - m) / m \ll m]$
→ flow effects on squeezing parameter $f_{i,j}$ are negligible :
 $c_{i,j}$ and $s_{i,j} \rightarrow$ flow independent

- Finite volume V
 - $s_{i,i} = 0$ outside mass-shift region ($\Delta M = 0$)



- Simplest V profile → analytical calculations:

← Cross-sectional area → Gaussian
 $\approx \exp[-\vec{r}^2 / (2R^2)]$

→ Region where mass-shift is non-vanishing

Additional hypotheses



- $n_{i,j} \rightarrow$ Boltzmann limit of Bose-Einstein distribution:

$$n_{i,j}(x) \sim \exp \left[- \left(K_{i,j}^\mu u_\mu - \mu(x) \right) / T(x) \right]$$

Hydro parameterization \rightarrow $\frac{\mu(x)}{T(x)} = \frac{\mu_0}{T(x)} - \frac{\vec{r}^2}{2R^2}$

- Freeze-out:

Sudden freeze-out $\rightarrow \int dt E_{i,j} e^{-2iE_{i,j} \cdot \tau} \delta(\tau - \tau_0) d\tau_f = E_{i,j} e^{-2iE_{i,j} \cdot \tau_0}$

Finite emission interval $\rightarrow \int dt E_{i,j} F(\tau_f) e^{-iE_{i,j}(\tau - \tau_0)} d\tau_f = \frac{E_{i,j}}{[1 + (E_{i,j} \Delta\tau)^2]}$

$$F(\tau) = \frac{\theta(\tau - \tau_0)}{\Delta\tau} e^{-(\tau - \tau_0)/\Delta\tau}$$

- Non-relativistic limit:

$$u^\mu = \gamma(1, \vec{v}) \quad ; \quad \vec{v} = \langle u \rangle \frac{\vec{r}}{R}$$

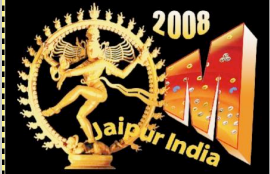
$$\gamma = (1 - \vec{v}^2)^{-1/2} \approx 1 + \frac{1}{2} \vec{v}^2 \quad [O(v^2)]$$

Summary of the previous results



- Previous results showed:
 - $C_s(k, -k)$ survives both
 - Finite emission times ($\Delta t = 2\text{fm}/c$) and system sizes
 - Moderate flow (could enhance signal at smaller \underline{k})
 - However, only the behavior of the maximum value of $C_s(k, -k)$ vs. m_* vs. k was studied before (not useful for looking for the signal)
- Which would be the basic signal to be searched for? \rightarrow better look for different values of k_1, k_2 , i.e., $C_s(k_1, k_2)$

Squeezed Correlation vs. k_1 & k_2



$$2 * \vec{K} = \vec{k}_1 + \vec{k}_2$$

$$\vec{q} = \vec{k}_1 - \vec{k}_2$$

$$G_s(k_1, k_2) = \frac{E_{1,2}}{(2\pi)^{3/2}} c_{12} s_{12} \left\{ \begin{array}{l} R^3 \exp\left(-\frac{R^2(k_1 + k_2)^2}{2}\right) + 2 n_0^* R_*^3 \exp\left(-\frac{(k_1 - k_2)^2}{8m_*T}\right) \times \\ \exp\left[\left(-\frac{im\langle u \rangle R}{2m_*T_*} - \frac{1}{8m_*T_*} - \frac{R_*^2}{2}\right)(k_1 + k_2)^2\right] \end{array} \right\}$$

$$2 * \vec{K} = \vec{k}_1 + \vec{k}_2$$

Remember: $2 * \vec{K} = \vec{k}_1 + \vec{k}_2$, $\vec{q} = \vec{k}_1 - \vec{k}_2$

$$G_c(k_i) = \frac{E_{i,i}}{(2\pi)^{3/2}} \left\{ |s_{ii}|^2 R^3 + n_0^* R_*^3 \left(|c_{ii}|^2 + |s_{ii}|^2 \right) \exp\left(-\frac{k_i^2}{2m_*T_*}\right) \right\}$$

$$R_* = R \sqrt{\frac{T}{T_*}}$$

$$C_s(\vec{k}_1, \vec{k}_2) = 1 + \frac{|G_s(1,2)|^2}{G_c(1,1)G_c(2,2)}$$

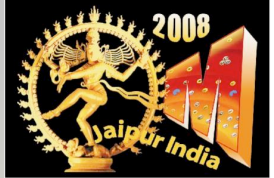
$$T_* = \left(T + \frac{m^2 \langle u \rangle^2}{m_*}\right)$$

Suitable variables



- Two main possibilities:
 1. Combining particle-antiparticle pairs $(k_1, k_2) \rightarrow$ theory \leftrightarrow simulation
 2. Rewriting $C_s(k_1, k_2)$ in terms of K and q :
 - $2 * \vec{K}_{i,j} = (\vec{k}_i + \vec{k}_j) \quad \vec{q}_{i,j} = (\vec{k}_i - \vec{k}_j)$
 - The effect is **maximum** for $\vec{k}_1 = -\vec{k}_2 = \vec{k}$
i.e., for $\vec{K} = 0 \rightarrow$ study for different values of q

Relativistic extension of $2^* \vec{K}_{i,j} = (\vec{k}_i + \vec{k}_j)$



- If we define (suggested by M. Nagy)

$$Q_{inv}^{back} = (\omega_1 - \omega_2, \vec{k}_1 + \vec{k}_2) = (q_{12}^0, 2\vec{K}_{12})$$

- Where

$$2K^\mu = [(k_1^0 + k_2^0), (\vec{k}_1 + \vec{k}_2)] \quad ; \quad q^\mu = [(k_1^0 - k_2^0), (\vec{k}_i - \vec{k}_j)]$$

- However, even better: define a new variable, such as

$$Q_{bbc}^2 = - (Q_{inv}^{back})^2 = 4(\omega_1\omega_2 - K^\mu K_\mu)$$

- Then, its non-relativ. limit ($\omega_i = \sqrt{m^2 + \vec{k}_i^2} \approx m + \frac{\vec{k}_i^2}{2m}$) is

$$Q_{bbc}^2 \approx (2\vec{K}_{12})^2$$

$C_s (K_{12}, q_{12})$ vs. (2^*K_{12}) vs q_{12} - no flow

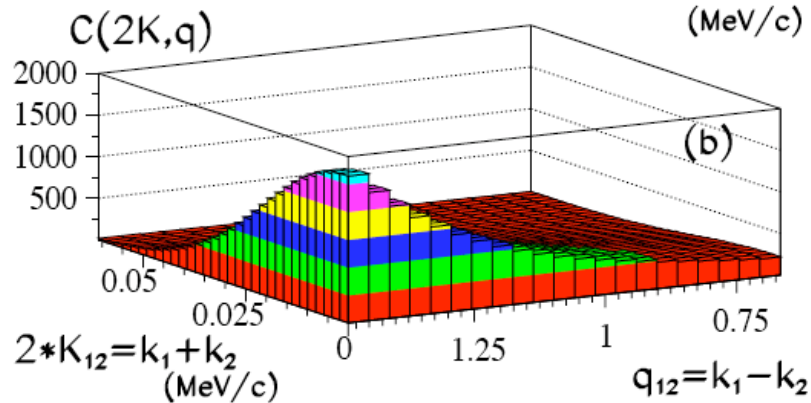
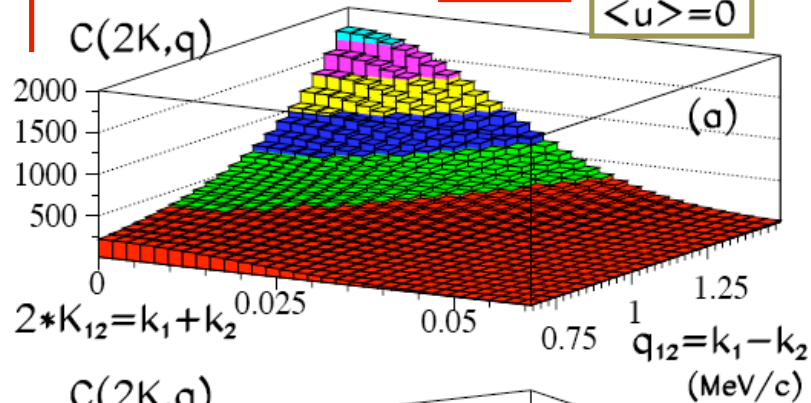


time reduction factor:

$$\frac{E_{i,j}}{[1 + (E_{i,j} \Delta\tau)^2]}$$

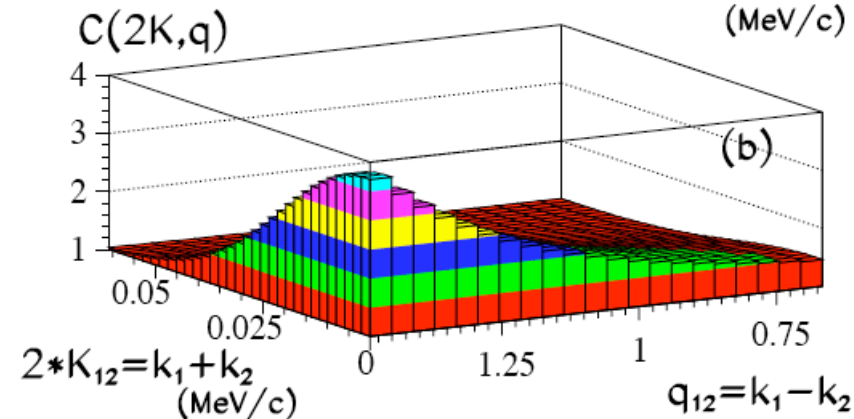
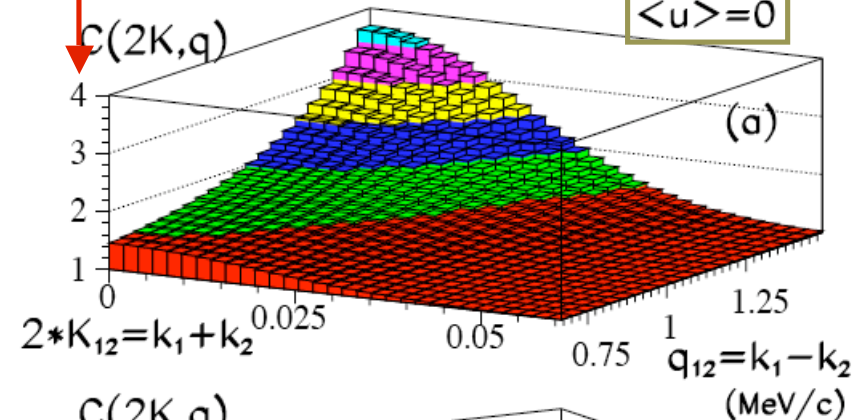
$R=7$ fm, $m_s=1$ GeV, $\Delta t=0$, $T=0.14$ GeV

$\langle u \rangle = 0$

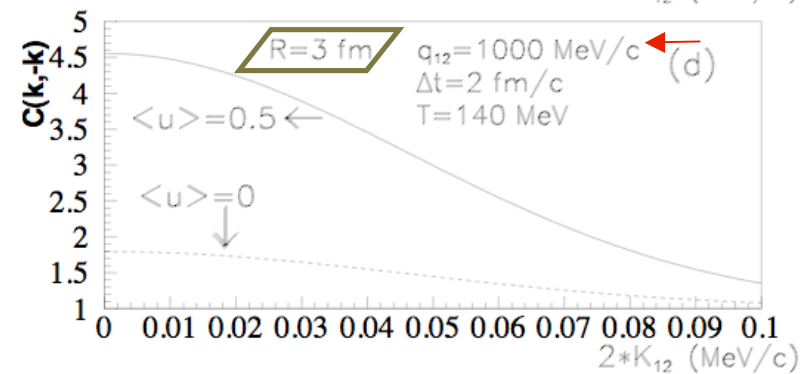
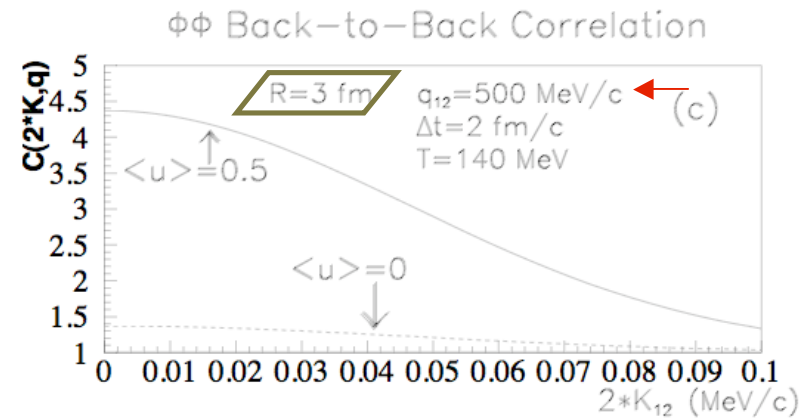
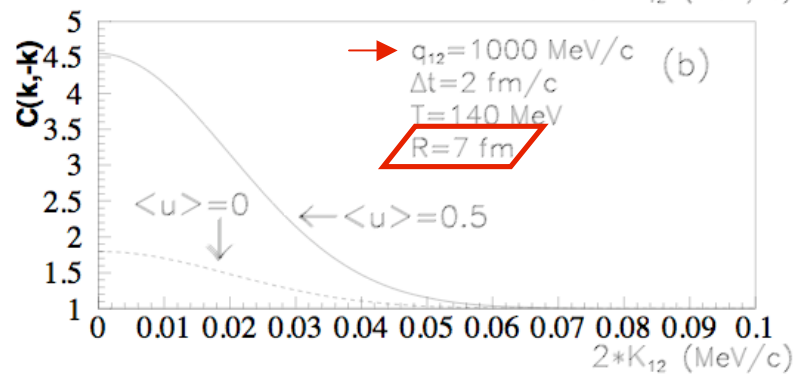
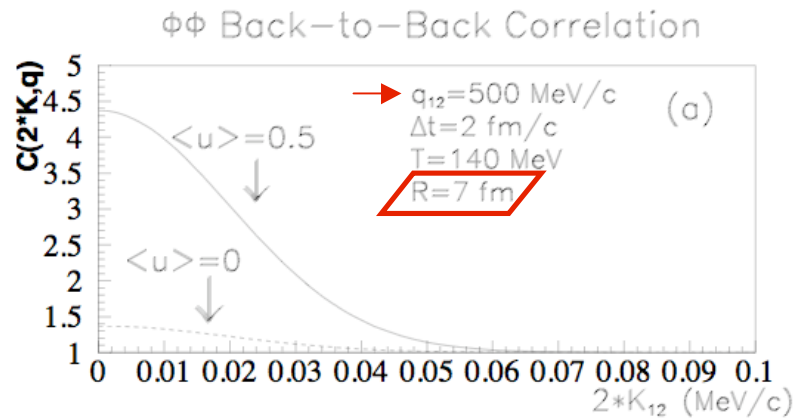
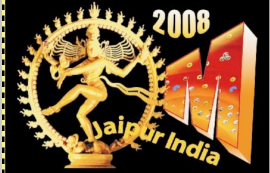


$R=7$ fm, $m_s=1$ GeV, $\Delta t=2$ fm/c, $T=0.14$ GeV

$\langle u \rangle = 0$



Effect of radial flow @ RHIC ($\langle u \rangle \sim 0.5$)

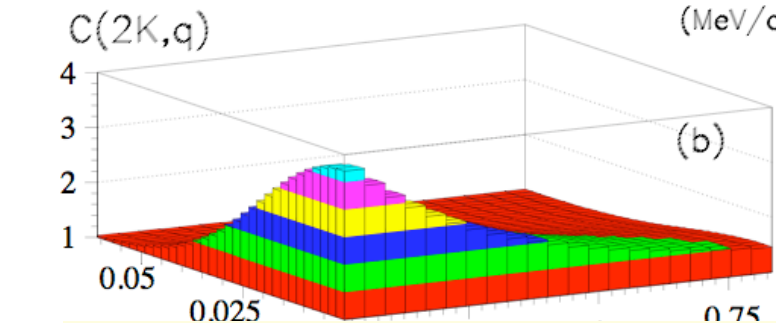
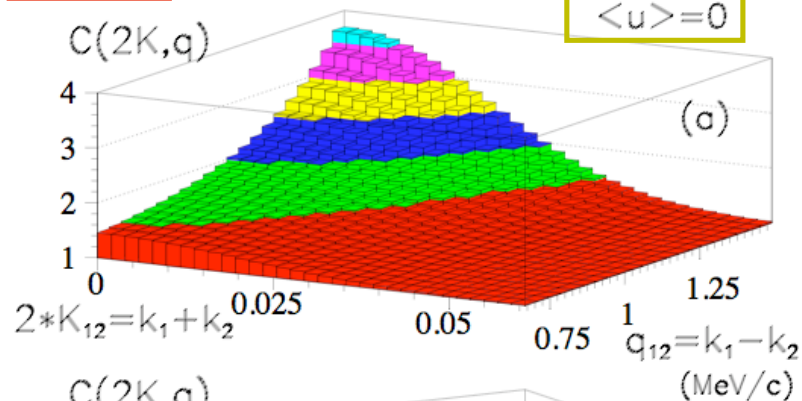


$C_{sq}(K_{12}, q_{12})$ vs. K_{12} vs. q_{12} - flow effects



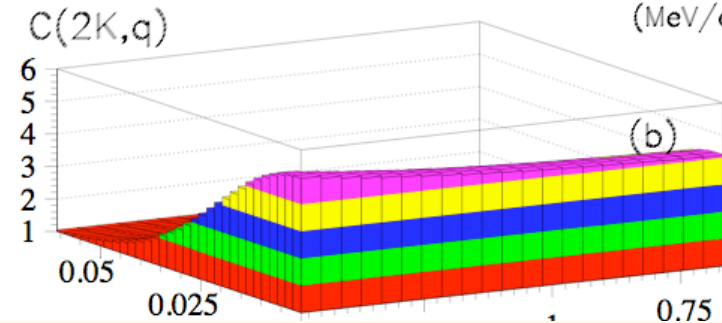
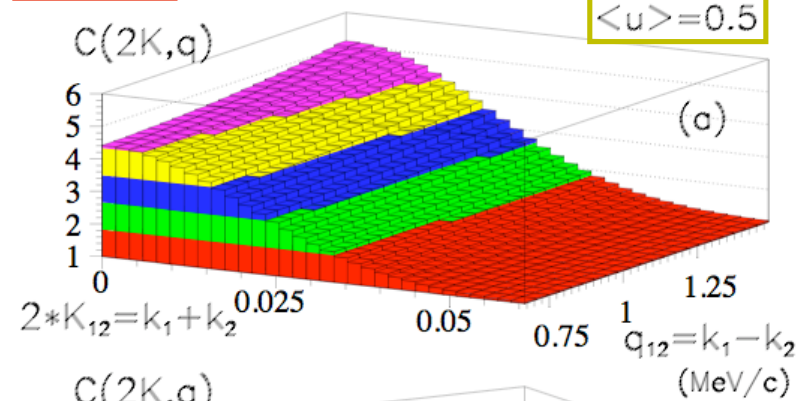
$R=7$ fm, $m_s=1$ GeV, $\Delta t=2$ fm/c, $T=0.14$ GeV

$\langle u \rangle = 0$



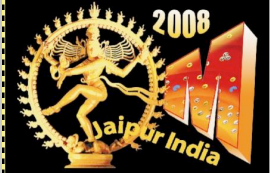
$R=7$ fm, $m_s=1$ GeV, $\Delta t=2$ fm/c, $T=0.14$ GeV

$\langle u \rangle = 0.5$



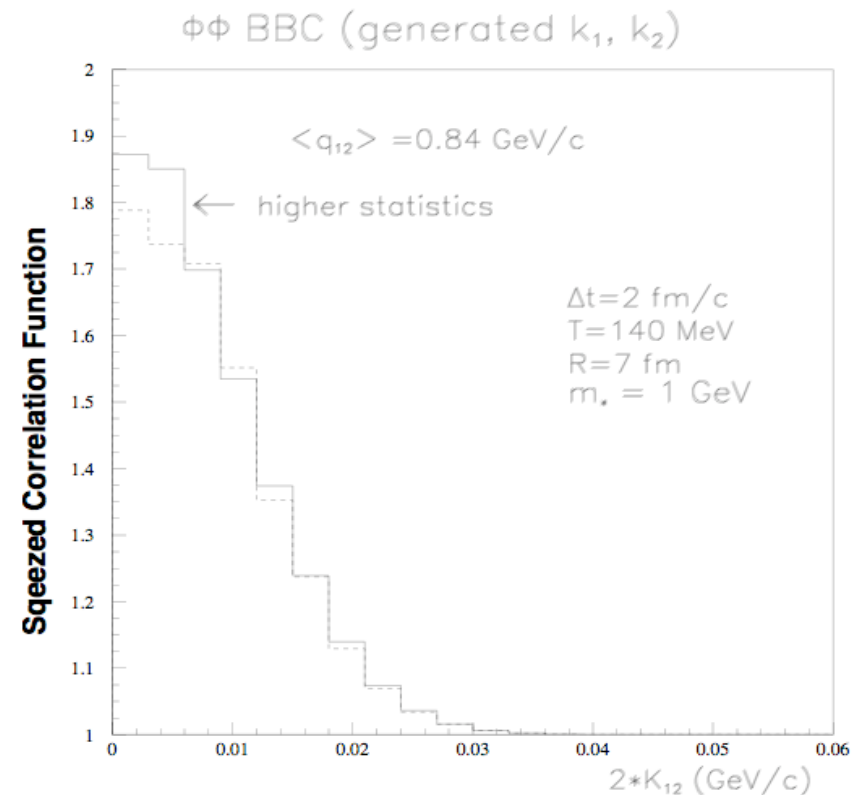
- Flow clearly has an effect:
 - For $\langle u \rangle = 0 \rightarrow C_s$ increases fast for increasing q_{12} ;
 - $\langle u \rangle = 0.5 \rightarrow C_s$ increases more slowly but is significantly higher at lower values of q_{12}
 - Flow **enhances** and **extends** the signal to broader region (K_{12}, q_{12})

Simulation: $C_s(k_1, k_2)$ - preliminary



- Squeezed
Correlation as
function of $2 * K_{12}$:

- $\Delta t = 2 \text{ fm}/c$
- $T = 140 \text{ MeV}$
- $R = 7 \text{ fm}/c$
- m_*



Bose-Einstein Correlations



- The complete correlation function of ϕ 's have an identical-particle term ($\phi \phi$), reflecting their Bose-Einstein nature
- In certain regions of the $(\vec{K}_{12}, \vec{q}_{12}) \rightarrow$ B-E correlation dominates
- Would the mass-shift have any effect in the ϕ - ϕ identical particle correlation? A: **YES!**
(although weaker than in the particle-antiparticle case)

HBT correlation function



- Effects of squeezing on the Chaotic (HBT) Correlation Function

$$\vec{q} = \vec{k}_1 - \vec{k}_2$$

$$2 * \vec{K} = \vec{k}_1 + \vec{k}_2$$

$$G_c(k_1, k_2) = \frac{E_{1,2}}{(2\pi)^{3/2}} \left\{ R^3 |s_{12}|^2 \exp\left(-\frac{R^2(k_1 - k_2)^2}{2}\right) + n_0^* R_*^3 \left(|c_{12}|^2 + |s_{12}|^2\right) \exp\left(-\frac{(k_1 + k_2)^2}{8m_*T_*}\right) \times \right. \\ \left. \exp\left[\left(-\frac{im\langle u \rangle R}{2m_*T_*}\right)(k_1^2 - k_2^2)\right] \exp\left[-\left(\frac{1}{8m_*T} + \frac{R_*^2}{2}\right)(k_1 - k_2)^2\right] \right\}$$

(between \vec{K} and \vec{q}) \ominus \longleftarrow $2 * \vec{K} \cdot \vec{q}$ $\vec{q} = \vec{k}_1 - \vec{k}_2$

$$2 * \vec{K} = \vec{k}_1 + \vec{k}_2, \quad \vec{q} = \vec{k}_1 - \vec{k}_2$$

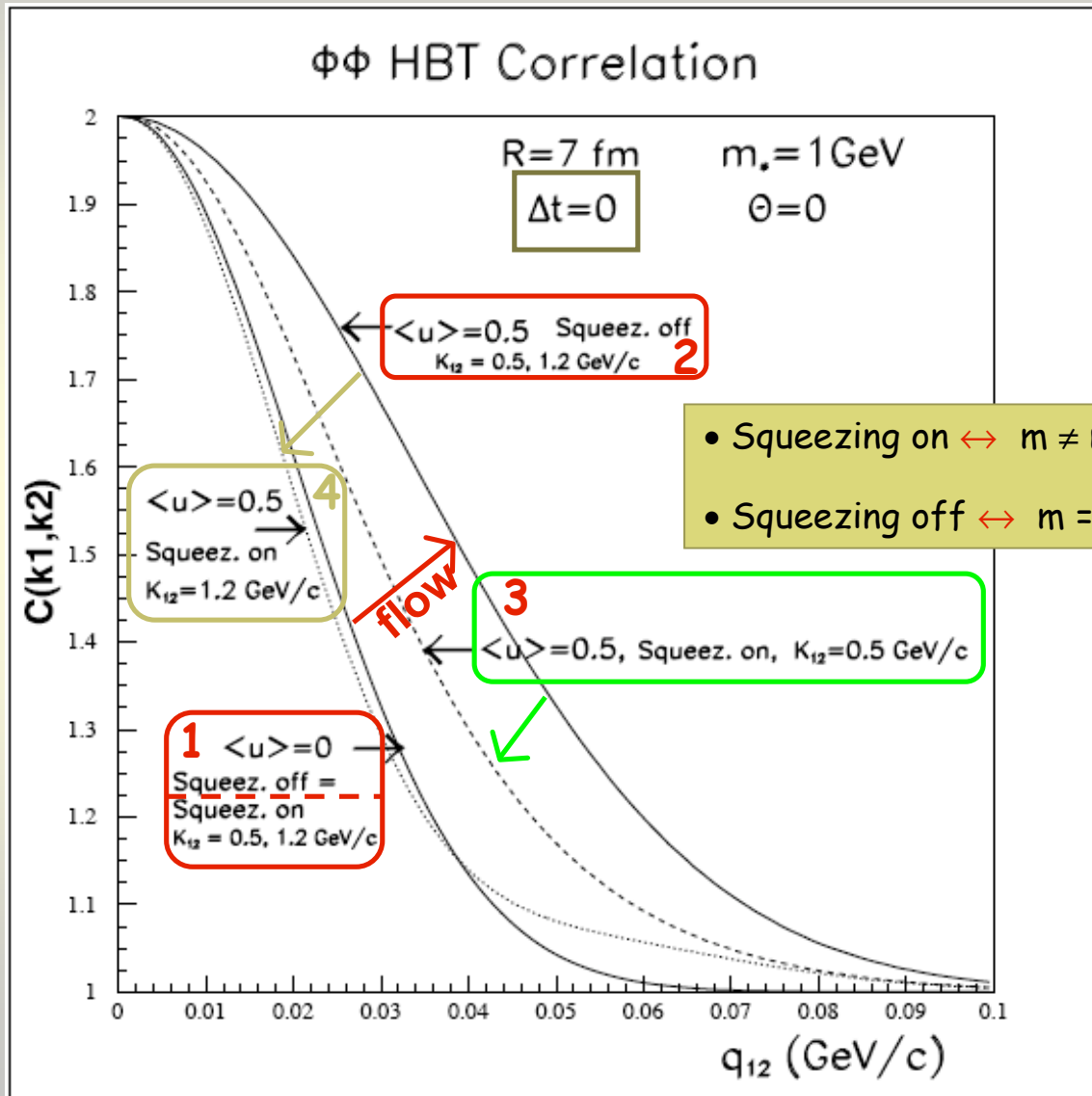
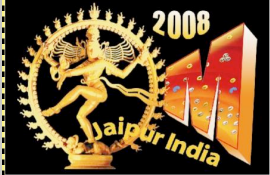
$$G_c(k_i) = \frac{E_{i,i}}{(2\pi)^{3/2}} \left\{ |s_{ii}|^2 R^3 + n_0^* R_*^3 \left(|c_{ii}|^2 + |s_{ii}|^2\right) \exp\left(-\frac{k_i^2}{2m_*T_*}\right) \right\}$$

$$R_* = R \sqrt{\frac{T}{T_*}}$$

$$C_c(\vec{k}_1, \vec{k}_2) = 1 + \frac{|G_c(\vec{k}_1, \vec{k}_2)|^2}{G_c(\vec{k}_1, \vec{k}_1) G_c(\vec{k}_2, \vec{k}_2)}$$

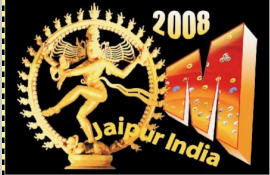
$$T_* = \left(T + \frac{m^2 \langle u \rangle^2}{m_*}\right)$$

$\phi\phi$ -HBT Correlations - $\Delta t=0$ - dependence on the average energy K_{12}

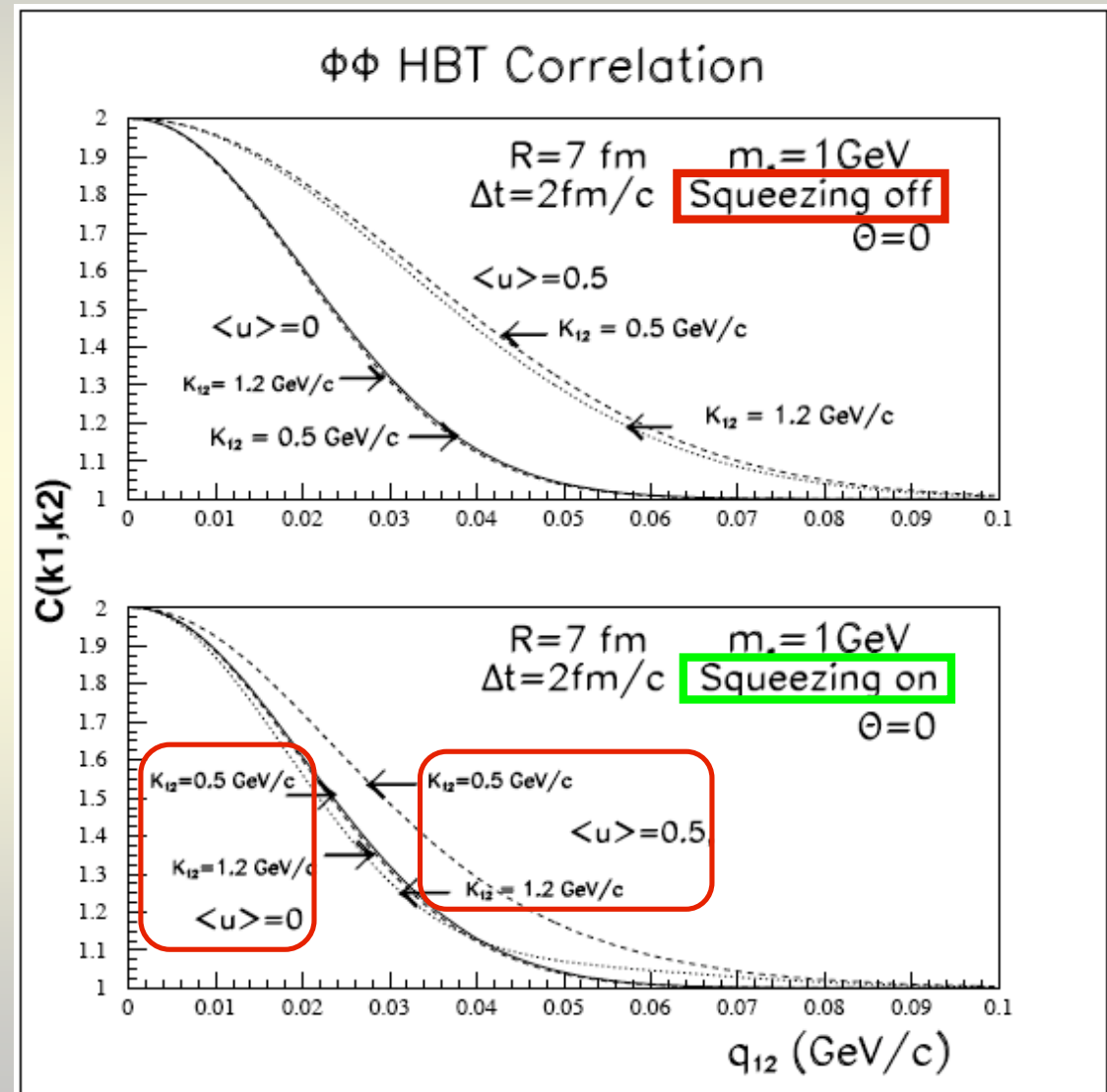


- For illustration:
 - Instant freezout ($\Delta t=0$)
 - No squeezing \rightarrow correlation width increases (curve broadens)
 - Effects of squeezing:
 - Opposes those of flow (curves narrower)
 - effects more pronounced for increasing K_{12}

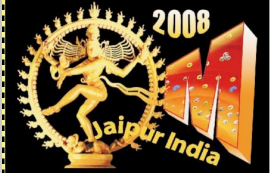
$\phi\phi$ -HBT Correlations - $\Delta t=2$ fm/c - dependence on the average energy K_{12}



- Similar to previous:
 - But finite freezeout ($\Delta t=2$ fm/c)
 - Slight difference even at $\langle u \rangle=0$
 - Same qualitative difference as for $\Delta t=0$: squeezing opposes to the flow effect, reducing the width

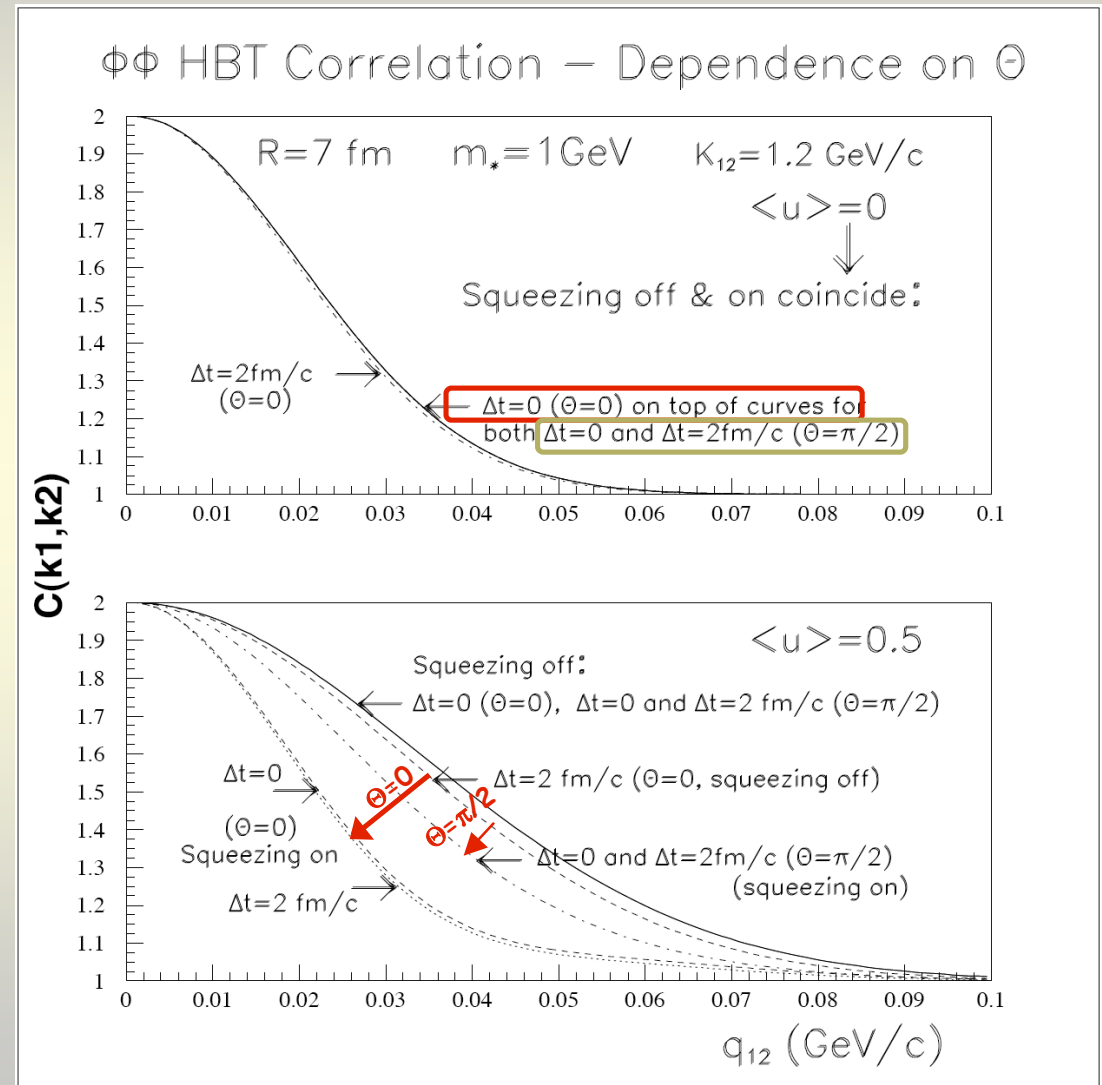


Dependence on Θ - angle($\vec{K}_{12}, \vec{q}_{12}$)

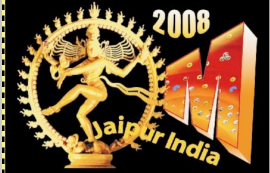


• Conclusions:

- Very small sensitivity to squeezing at $\Theta=0$ and $\langle u \rangle = 0$
- Flow amplifies the differences \rightarrow sizeable for $\langle u \rangle = 0.5$
- No sensitivity to time for $\Theta = \pi/2$ (as expected)
- Average over $\Theta \rightarrow$ significant difference between no squeezing and squeezing on



Summary and Conclusions



- Brief review of squeezed correlations
- And of the most important results of the model (in a non-relativistic treatment of expanding finite systems)
- Suggestion of suitable variables to use in the experimental search of the BBC's:
 $C_s (K_{12}, q_{12})$ vs. (2^*K_{12}) vs q_{12} or in invariant terms:

$$Q_{bbc}^2 = - (Q_{inv}^{back})^2 = 4(\omega_1\omega_2 - K^\mu K_\mu)$$

- Showed some preliminary results on the expected behavior of the $C_s(k_1, k_2)$ & $C_c(k_1, k_2)$ vs. (2^*K_{12}) vs q_{12}

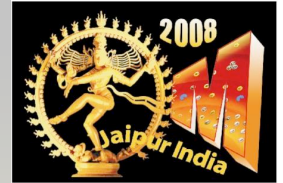
Just a detail missing: **experimental discovery!**

- **Let's find it now! And show it at the next QM 2009!!**

Acknowledgments

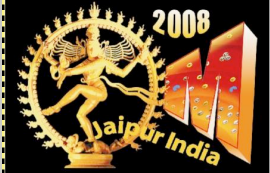


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EXTRAS

Formalism (bosons)



- Infinite medium

$$H = H_0 - \frac{1}{2} \int d\vec{x} d\vec{y} \phi(\vec{x}) \delta M^2(\vec{x} - \vec{y}) \phi(\vec{y}) \longrightarrow \text{In-medium Hamiltonian}$$

$$H_0 = \frac{1}{2} \int d\vec{x} (\dot{\phi}^2 + |\nabla\phi|^2 + m^2\phi^2) \longrightarrow \text{Asymptotic (free) Hamiltonian, in the rest frame of matter}$$

- Scalar field $\phi(x) \rightarrow$ quasi-particles propagating with momentum-dependent medium-modified effective mass, m_* , related to the vacuum mass, m , by

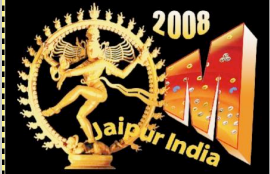
$$m_*^2(|\vec{k}|) = m^2 - \delta M^2(|\vec{k}|)$$

- Consequently:

$\Omega_k \rightarrow$ frequency of the in-medium mode with momentum \vec{k}

$$\Omega_k^2 = m_*^2 + \vec{k}^2 = \omega_k^2 - \delta M^2(|\vec{k}|)$$

Formalism (fermions)



$$H = H_0 + H_I \quad ; \quad H_0 = \int d\vec{x} : \bar{\psi}(x) (-i\vec{\gamma} \cdot \vec{\nabla} + M) \psi(x) :$$

$$\psi(x) = \frac{1}{V} \sum_{\lambda, \lambda', \vec{k}} (u_{\lambda, \vec{k}} a_{\lambda, \vec{k}} + v_{\lambda', -\vec{k}} a_{\lambda', -\vec{k}}^\dagger) e^{i\vec{k} \cdot \vec{x}}$$

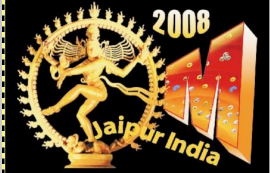
$$\langle a_{k_1}^\dagger a_{k_2}^\dagger a_{k_1} a_{k_2} \rangle = \langle a_{k_1}^\dagger a_{k_1} \rangle \langle a_{k_2}^\dagger a_{k_2} \rangle - \langle a_{k_1}^\dagger a_{k_2} \rangle \langle a_{k_2}^\dagger a_{k_1} \rangle + \langle a_{k_1}^\dagger a_{k_2}^\dagger \rangle \langle a_{k_1} a_{k_2} \rangle$$

- System described by quasi-particles \rightarrow medium effects taken into account through self-energy function
- For spin-1/2 particles under mean fields in a many body system:

$$\boxed{\Sigma^s + \gamma^0 \Sigma^0 + \gamma^i \Sigma^i} \rightarrow \text{to be determined by detailed calculation}$$

- $\Sigma^s \rightarrow$ notation: $\Sigma^s(k) = \Delta M(k)$
- $\Sigma^1 \rightarrow$ very small \rightarrow neglected
- $\Sigma^0 \rightarrow$ weakly-dependent on momentum \rightarrow totally thermalized medium: $\boxed{\mu_* = \mu - \Sigma^0}$
 \rightarrow (results for net barion number)
- Hamiltoniana $H_1 \rightarrow$ describes a system of quasi-particles with mass- dependent momentum $m_* = m - \Delta M(k)$

Correlation for strict BBC pairs



- Momenta of the pair

Remember:

$$k_2 = -k_1 = k$$

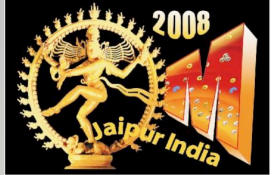
$$2 * K_{i,j}^\mu = (k_i + k_j) \quad ; \quad q_{i,j}^\mu = (k_i - k_j)$$

- Back-to-Back correlation function

$$C_s(k, -k) = 1 + \left\{ |c_0| |s_0| \left[R^3 + 2 \left(\frac{R^2}{\left(1 + \frac{m^2 \langle u \rangle^2}{m_* T}\right)} \right)^{\frac{3}{2}} \exp\left(-\frac{m_*}{T} - \frac{k^2}{2m_* T}\right) \right]^2 \right\} \times$$

$$\left\{ |s_0|^2 R^3 + \left(|c_0|^2 + |s_0|^2 \right) \left(\frac{R^2}{\left(1 + \frac{m^2 \langle u \rangle^2}{m_* T}\right)} \right)^{\frac{3}{2}} \exp\left(-\frac{m_*}{T} - \frac{k^2}{2m_* T} + \frac{m^2 \langle u \rangle^2 k^2 / m_*^2}{\left(1 + \frac{m^2 \langle u \rangle^2}{m_* T}\right) 2T^2}\right) \right\}^{-2}$$

Formalism for treating finite expanding systems



- For a hydrodynamical ensemble \rightarrow amplitudes can be written as
[Makhlin & Sinyukov, N.P. A566 (1994) 598c]

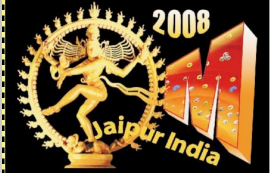
$$G_c(1,2) = \frac{1}{(2\pi)^3} \int d^4\sigma_\mu(x) K_{1,2}^\mu e^{iq_{1,2} \cdot x} \left[|c_{1,2}|^2 n_{1,2} + |s_{-1,-2}|^2 (n_{-1,-2} + 1) \right]$$

$$G_s(1,2) = \frac{1}{(2\pi)^3} \int d^4\sigma_\mu(x) K_{1,2}^\mu e^{i2K_{1,2} \cdot x} \left[s_{-1,2}^* c_{2,-1} n_{-1,2} + c_{1,-2} s_{-2,1}^* (n_{1,-2} + 1) \right]$$

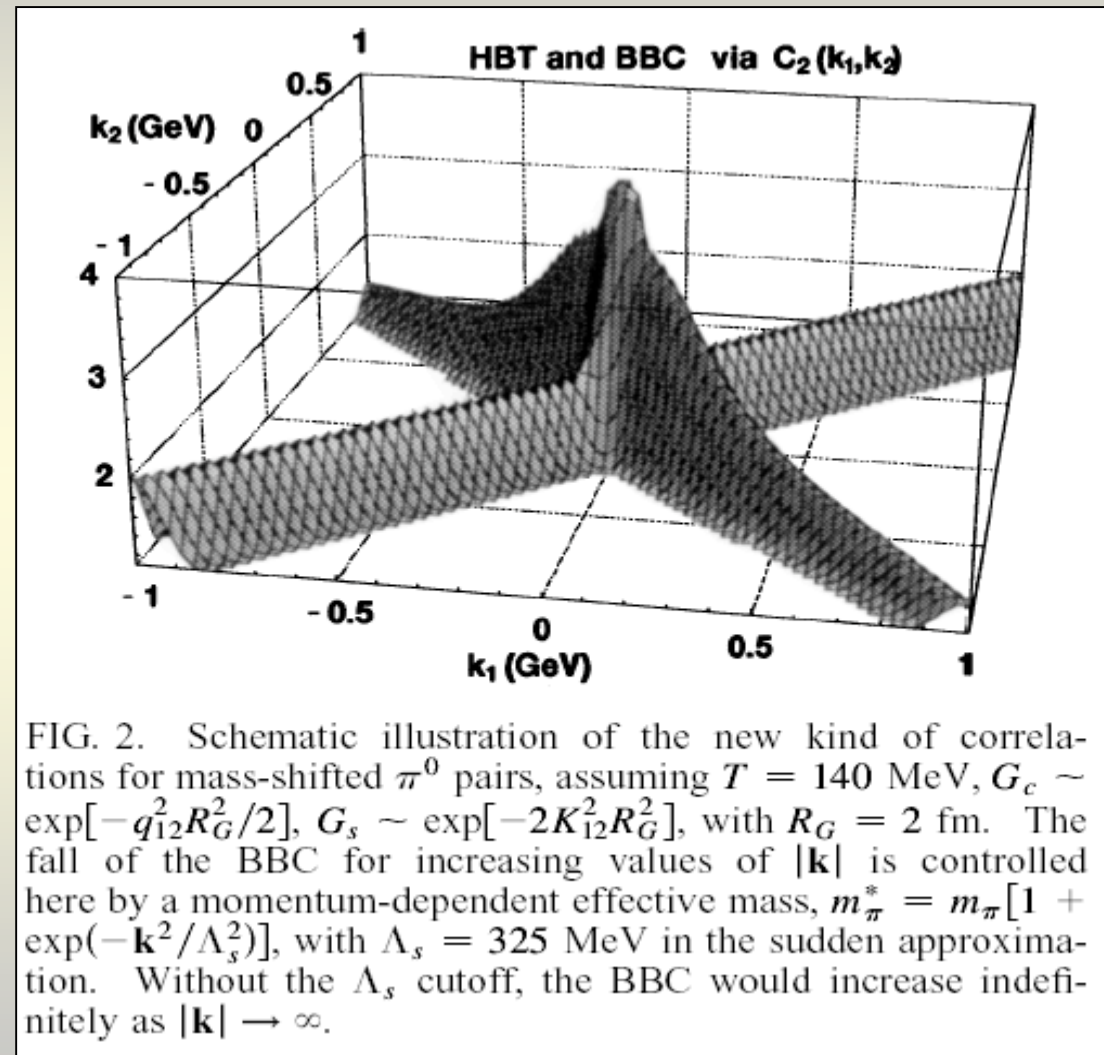
$$2 * K_{i,j}^\mu = (k_i + k_j)$$

$$q_{i,j}^\mu = (k_i - k_j)$$

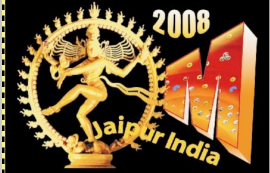
Full correlation function - 1



- Estimate for Gaussian-type momentum-dependent mass shift
(by Asakawa, Csörgő and Gyulassy)



Full correlation function - 2



- Expectation with the simple momentum-independent model discussed here (squeezed correlation is enhanced at large values of the individual momenta)

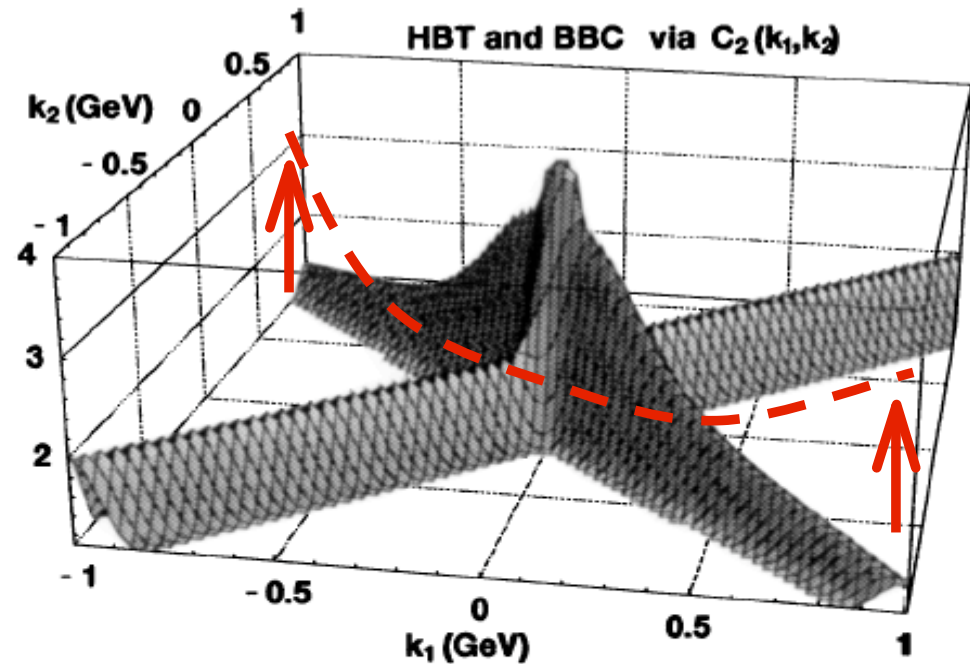
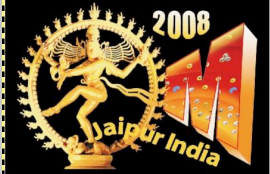
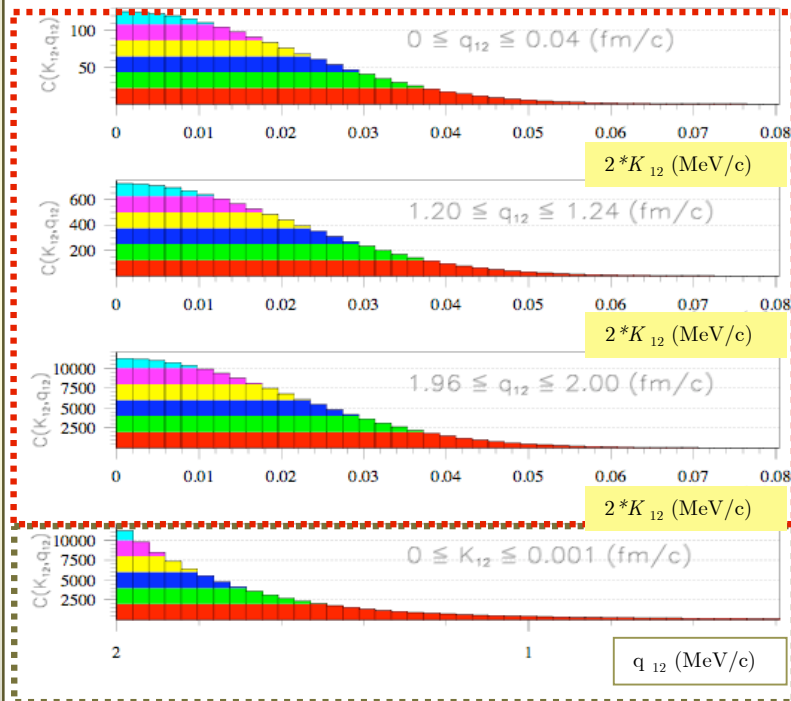


FIG. 2. Schematic illustration of the new kind of correlations for mass-shifted π^0 pairs, assuming $T = 140$ MeV, $G_c \sim \exp[-q_{12}^2 R_G^2/2]$, $G_s \sim \exp[-2K_{12}^2 R_G^2]$, with $R_G = 2$ fm. The fall of the BBC for increasing values of $|\mathbf{k}|$ is controlled here by a momentum-dependent effective mass, $m_\pi^* = m_\pi [1 + \exp(-\mathbf{k}^2/\Lambda_s^2)]$, with $\Lambda_s = 325$ MeV in the sudden approximation. Without the Λ_s cutoff, the BBC would increase indefinitely as $|\mathbf{k}| \rightarrow \infty$.

$C_s(K_{12}, q_{12})$ vs. 2^*K (vs q) slices



$\phi\phi$ BBC: slices for $\Delta t=0$ fm/c



$\phi\phi$ BBC: slices for $\Delta t=2$ fm/c

