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Abstract:
We study the sensitivity of pion interferometry in pp and $\bar{p}p$ collisions at ISR energies to the resonance abundance. We show that those data are not compatible with the full resonance fractions predicted by the Lund model. The preliminary S+S and O+Au data at 200 A GeV are, however, not incompatible with the Lund predictions, although their sensitivity to resonances is significantly weaker than in the $pp/\bar{p}p$ case.

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We study the sensitivity of pion interferometry in pp and $\bar{p}p$ collisions at ISR energies to the resonance abundance. We show that those data are not compatible with the full resonance fractions predicted by the Lund model. The preliminary S+S and O+Au data at 200 A GeV are, however, not incompatible with the Lund predictions, although their sensitivity to resonances is significantly weaker than in the $pp/\bar{p}p$ case.

Second order boson interferometry[1] is a powerful tool to obtain information about the space-time dimensions of emitting sources. Conventional pion interferometry involves fitting the two-particle correlation function with the following ansatz:

$$C(k_1, k_2) \equiv \frac{P_2(k_1, k_2)}{P_1(k_1)P_1(k_2)} = 1 + \lambda|\rho(k_1 - k_2)|^2 \quad ,$$

where P_m denotes the m identical pion inclusive distribution, k_1 and k_2 are the four-momenta of the observed pions, $\rho(q) = \int d^4x e^{iqx}\rho(x)$ is the Fourier transform of the freeze-out space-time density, and λ is the incoherence or chaoticity parameter. Ideally, the space-time dimension of the emitting source could be inferred from the width of the correlation function. However, this simple relation is valid only in the semiclassical limit and for completely decoupled phase-space distribution. In typical situations the underlying dynamics produces strong phase-space correlations which modify the above relation.

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One of the most interesting suggestions[2, 3, 4] concerning interferometry was that it could be used in the search for a signature of the Quark Gluon Plasma (QGP) formation by looking for long time delays. At Quark Matter '88, NA35[5] results on $\pi^-\pi^-$ interferometry generated a great deal of interest because of the apparent large transverse freeze-out radii and proper-time found in their analysis. Of course, it was important to demonstrate that more conventional explanations could not also explain the data. This led us to investigate a hadronic resonance gas model[6, 7], based on the covariant current ensemble formalism and on the ATTILA/LUND model[8]. String models naturally lead to strong-phase space correlations, e.g., between space-time, $\eta = \frac{1}{2}log[(t+z)/(t-z)]$, and momentum, $y = \frac{1}{2}log[(E+p_z)/(E-p_z)]$. In addition, they suggest that a large fraction of the observed final pions could arise from the decay of long lived resonances, such as ω, η and η', which could simulate the effect of long-lived sources and partially coherent fields. There is experimental evidence for such large resonance fractions, at least at ISR energies[9]. Furthermore, distortions caused by the non-uniformity of the rapidity density and by the large spread in freeze-out proper times also have to be taken into account.

We have previously demonstrated[6] that a conventional model was able to fit the existing data as well as a quark gluon plasma model[4]. The coincidental agreement with data of these two distinct models motivated us to search for other means to more clearly differentiate among dynamical possibilities. We suggested the comparison of pion and kaon interferometry to enhance the differences[10]. The calculated curves for kaon interferometry indeed exhibited a much more significant difference between these two models.

From the above mentioned studies, we found that resonances were responsible for the most significant distortions in the correlation function. In the absence of direct resonance measurements, pion interferometry can in fact be thought of as providing an indirect estimate of their abundance! This led us to analyse the behavior of the correlation function of pions produced at AGS 14.6 A GeV, using the predicted Lund resonance fractions. We noted in that study the striking influence of finite q_L on lowering the correlation function intercept: even without the inclusion of resonances, finite binning caused a dramatic decrease of the apparent intercept, stronger for bigger q_L. A clear sensitivity to resonances could also be seen. However, the result of such analysis[11], when compared to the preliminary experimental data of Ref.[12], appeared to suggest the near absence of resonances in AGS range as compared to SPS energies. As pointed out recently by R. Morse[12], resonance cross-sections from pp interactions at 24 GeV/c[13] also suggest much smaller fractions than the ones predicted by the Lund model. Pion interferometry at the AGS is therefore consistent with the resonances as measured in Ref.[13].

The above results motivated the present study of interferometry of pions produced in *pp* and $\bar{p}p$ collisions at ISR[14]. Surprisingly, the result turns out to be neither compatible with the absence of resonance nor with the full resonance fractions predicted by Lund. Instead, the data seem to be best described by resonance fractions that are approximately one half of the Lund prediction. This is shown in Fig. 1. Part (a) shows

$C(Q_{inv})$, where $Q^2_{inv} = \mathbf{q}^2 - q_0^2$. We emphasize that the calculations shown in Fig. 1 correspond to completely chaotic systems, for which $\lambda = 1$. The geometrical source size was taken to be $R_T = 0.75$ fm and $\tau = 1$ fm. The Lund resonance fractions used were $f_{\pi^-/direct} \approx 0.19$, $f_{\pi^-/\rho} \approx 0.40$, $f_{\pi^-/\omega} \approx 0.16$, $f_{\pi^-/K^*} \approx 0.09$. The remaining pion fractions due to long lived resonances do not contribute to interferometry in the range of momenta considered here. The curve in the middle corresponds to reducing $f_{\pi^-/r} \rightarrow \frac{1}{2} f_{\pi^-/r}$ and increasing $f_{\pi^-/direct}$ accordingly. The dashed histogram corresponds to the absence of resonances ($f_{\pi^-/direct}$=1). In these calculations we assumed for simplicity the ideal Bjorken's Inside-Outside picture for the rapidity distribution and the perfect correlation between the space-time rapidity η and the real rapidity y, since previous studies[15] showed that the main distortions were due to resonances.

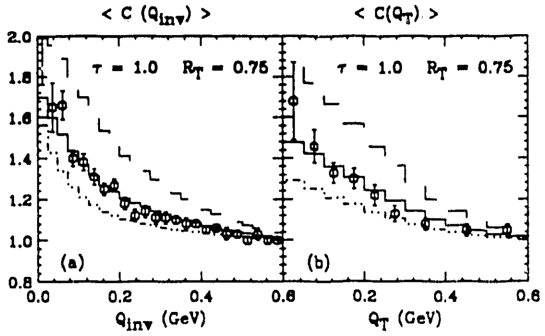

Figure 1: Negative pion correlation in pp and $\bar{p}p$ reactions at ISR energies as a function of Q_{inv} in (a) and q_T ($q_L \leq 0.15$ GeV/c) in (b). Dashed, solid and dot-dashed indicate calculated correlation functions with no, half and full resonance abundance, respectively. The experimental data points are from Ref.[14] in (a) and from Ref.[16] in (b).

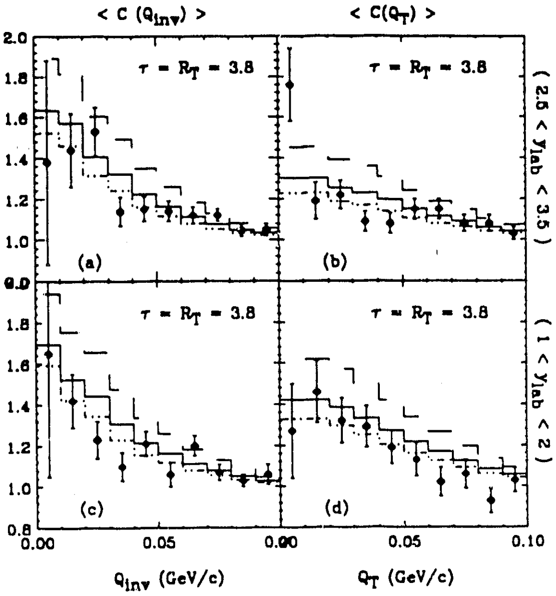

Figure 2: Dependence of the correlation function for S+S at $E_{lab} = 200$ A GeV on resonance fractions. In (a) and (c) the correlation functions versus Q_{inv} are plotted as in Fig. 1; in (b) and (d) they are plotted versus q_T ($q_L \leq 0.10$ GeV/c). The experimental data points are from Ref.[17]. Cases (a) and (b) correspond to rapidity region $2.5 < y_{lab} < 3.5$ while (c) and (d), to $1 < y_{lab} < 2$.

Given the above surprising results, contradicting the conclusion we found in Ref.[6] that the NA35 O+Au data were well fit with the full resonance fractions, we turn next to new data on S+S at 200 A GeV[17]. Here, the same resonance fractions were used as in Fig. 1, as well as the same unity chaoticity parameter. For the S+S analysis we used the same source parameterizations as in Ref.[6] but with $R_T = \tau = R_A \approx 3.8$ fm. The results are in Fig. 2, where parts (a) and (c) show $C(Q_{inv})$. We can see in both cases that the distinction among the overall correlation function behavior is not as large as in Fig. 1. The curves are closer to one another because the increase of the source radius and proper-time reduce the relative importance of the time delay due to resonances.

We also calculate the correlation as a function of q_T, the component of the momentum difference of the pair perpendicular to the beam axis, considering the longitudinal component to be $q_L < q_{L_{min}}$. The results corresponding to the ISR case, with $q_L < 0.15$ GeV/c, are shown in Fig. 1(b). Note that the sensitivity to the resonance fractions is similar to that in Fig. 1(a). The comparison with the corresponding data points of Ref.[16] also seems to favor the fractions corresponding to half of those predicted by the Lund model. For the S+S case we adopted $q_L < 0.10$ GeV/c, as in Ref.[17], and the conclusions are similar to the corresponding analysis in terms of the Q_{inv} variable. Unfortunately, the experimental uncertainties of the data in Ref.[17] are too large to discriminate which curve fits best. Those preliminary data, however, fall systematically below the no resonance curve. NA35 O+Au data in Ref.[5] are also not very sensitive to the actual resonance fractions since in that case we used essentially the same source distributions. In reality, it turns out that the preliminary O+Au data from Ref.[5] and the preliminary S+S data from Ref.[17] are also very similar within error bars, reinforcing the need for higher statistics to disentangle the role played by resonances for A+B collisions at these energies and, in particular, which resonance fraction agrees more closely with data.

We saw at this meeting that the NA35 data changed dramatically from Quark Matter '88 to '91. Final conclusions on AA are thus not yet possible. All that can be said at this point is that AFS/ISR data on pp and $\bar{p}p$ and the AGS/E-802 data on Si+Au at lower energy seem to be indicative of smaller resonance fractions and thus a reduced distortion of $C(q)$ due to such effect. The new Helios data on pBe into $\mu^+\mu^-$ presented at this conference[18], on the other hand, seem to be more consistent with expectations from the Lund model and from Ref.[9]. In any case, it is obvious from the above exercise that it is imperative to get *independent* determination of resonance fractions in A+B reactions before any conclusions on the significance of the deduced geometrical parameters can be claimed. In this regard the use of $\mu^+\mu^-$ to probe the resonance fractions as in the Helios experiment needs to be pursued more vigorously. If Helios results are correct then only the interferometry of $pp/\bar{p}p$ collisions remains a mystery. Perhaps in that case the semi-classical approximations is not applicable or strong final state interactions distort more severely the interference pattern.

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