Di–V^0 Events in Pb–Pb Collisions at 158 A GeV/c

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Abstract

The first results on V^0-V^0 pairs, namely invariant masses and HBT correlations, obtained by the WA97 experiment in Pb–Pb collisions are presented. There is no evidence for any resonance signal.

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Introduction

A correlation study of pairs of neutral strange particles produced closely in phase space can give information both on the interaction of the pair itself and on the space–time structure of the heavy ion collision [1] [2]. For example, a study of the correlations in the Λ–Λ system can reveal the presence of an exotic resonance H^0 [3]. In addition, HBT interferometry of K^0_s pairs [4] can be a useful complement to charged boson interferometry, since it is not affected by Coulomb effects which tend to distort the correlation between charged particles.

WA97 [5] is a dedicated experiment which aims to study strange particle production with high statistics in a limited acceptance window (about one unit of rapidity around central rapidity and $p_t \geq 0.4$ GeV/c). As a consequence it is well suited to detect strange particle pairs close to each other in phase space.

Data and analysis

The results presented here are based on 110 million events collected in 1995. After event reconstruction, large samples of nearly background-free Λ (~ 450000), K^0_s (~ 550000) and $\overline{\Lambda}$ (~ 66000) were obtained. Details on the experimental layout, analysis procedure and acceptance window are given in [6]. Only V^0s pointing to the target were selected, thus reducing possible feed-down from the cascade particles. Events which could correspond to double interactions in the target or pile-up (about 3%) were removed. No acceptance and efficiency corrections have been applied, but they are of minor importance for this preliminary study.

About 1.0 % of triggered events contain at least one good V^0 and about 0.7 % of these events contain also a second V^0 *i.e.*, less than could be expected from statistically independent V^0 production. This is not surprising as the data are not corrected for efficiency, which is lower in the case of double V^0 events due to higher track multiplicity.

Λ–Λ invariant mass

After applying cuts we are left with 1204 Λ–Λ pairs. Their invariant mass distribution is shown in fig.1. The overall shape of the distribution is influenced by the experimental acceptance window – large invariant masses are suppressed. The background distribution was obtained by mixing lambdas from different events of similar multiplicity. The probability that the two histograms are random samplings of the same (unknown) distribution, comparing only the shape of the two histograms, is found by the Kolmogorov [7] test to be 0.49. There is no evidence for any resonance signal, as illustrated in fig.1 (right) which shows the deviations between the data and background in units of statistical errors. The WA97 trigger selected the most central 40% of the total (geometric) inelastic cross section. In order to check if there is any dependence of the Λ–Λ mass spectrum on collision centrality, we have divided the full sample into *less central* and *more central* events corresponding approximately to a number of participants between 100-250 and 250-400 respectively [5]. The result is shown in fig.2; no significant resonance type structures can be seen in any of the two invariant mass distributions.

Λ–Λ HBT correlation

The Λ–Λ correlations can be studied using particle interferometry, as proposed and discussed by C. Greiner and B. Müller [8]. For this purpose we construct the two–lambda correlation function $C(|\mathbf{q}|)$, where $\mathbf{q}$ is the Λ-Λ relative momentum in the nucleon–nucleon center of mass system, using mixed events as background. The estimated average error on $|\mathbf{q}|$ is 35 MeV/c. The correlation function $C(|\mathbf{q}|)$ is expected to be equal to 1.0 (*i.e.* no correlation) at large $|\mathbf{q}|$ ($|\mathbf{q}| \geq 0.2$ GeV/c) and decrease (Λ is a fermion) down to 0.5 when approaching $|\mathbf{q}| \approx 0$, in the absence of Λ–Λ resonance effects. Note that the correlation strength resulting from the quantum statistics is reduced (roughly by a factor of 2) due to the fact that it is experimentally impossible to distinguish between a directly produced Λ and a Λ originating from a Σ^0 decay.

If the resonance effects are not negligible, as suggested by a double-hyperfragment analysis [9], the correlation function $C(|\mathbf{q}|)$ should be drastically modified, thus offering a unique opportunity to quantify this Λ–Λ interaction.

The measured correlation function is shown in fig.3, where the solid curve shows, as an example, the expected shape for a Λ emitting source of 2 fm radius, in absence of resonances. The limited statistics does not allow us to reach any conclusion.

$\mathrm{K^0_s}$–$\mathrm{K^0_s}$ pairs

We have found 1999 $\mathrm{K^0_s}$–$\mathrm{K^0_s}$ pairs in our data. The experimental acceptance of $\mathrm{K^0_s}$ is similar as for Λ apart from a small shift to higher rapidity [6].

In fig.4 we show the $\mathrm{K^0_s}$–$\mathrm{K^0_s}$ invariant mass distribution together with the corresponding background. The two distributions are compatible as reflected by the Kolmogorov test probability of 0.97. This is consistent with independent $\mathrm{K^0_s}$ production.

Fig.5 shows the experimental correlation function $C(|\mathbf{q}|)$ together with a curve illustrating the expected shape in case of a fireball of 6 fm radius, as obtained from the $\pi - \pi$ correlations [2]. The estimated average error on $|\mathbf{q}|$ is 31 MeV/c. The data are compatible with a large radius of the fireball, at the limit of the $\mathrm{K^0_s}$ momentum resolution.

Other V^0–V^0 pairs

We complete our V^0–V^0 preliminary study with a presentation of the Λ–$\overline{\Lambda}$ and

Λ–K^0_s (fig.6) invariant mass ditributions. In the first case, because of low statistics (391 pairs), the bin size is increased to 20 MeV while it is 10 MeV in all other cases. The Λ–K^0_s pairs (3182 events) are most abundantly represented in our V^0–V^0 sample. In both cases, a visual inspection of the plots does not reveal any significant structure. The corresponding Kolmogorov test probabilities are 0.24 and 0.95.

Conclusions and outlook

We have presented the first results on V^0–V^0 pairs produced in central Pb–Pb collisions at 158 A GeV/c near central rapidity and moderate ($p_t \geq 0.4$ GeV/c) transverse momentum. The invariant mass distributions of Λ–Λ, K^0_s–K^0_s, Λ–$\overline{\Lambda}$ and Λ–K^0_s pairs are compatible with the corresponding background distributions obtained using an event mixing method. No resonance signal is observed.

The available statistics do not allow us to draw any significant conclusion from the HBT momentum correlations of Λ–Λ and K^0_s–K^0_s pairs.

The analysis of WA97 data is in progress and we expect to double the present statistics. Then the NA57 experiment [10] should collect at least two times higher statistics than WA97.

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Figures

- Figure 1: left – Λ–Λ invariant mass distribution for the data (1204 pairs) and the background obtained from mixing events of similar centrality, normalized to the number of Λ–Λ pairs,
  right – difference between signal and background in units of statistical error for each bin.

- Figure 2: The same as fig.1 but split into *less central* (left) and *more central* (right) events, corresponding approximately to a number of participants between 100-250 and 250-400 respectively.

- Figure 3: HBT relative momentum correlation of the Λ–Λ pairs. The bin size is 50 MeV/c. The full curve shows the correlation expected for a fireball of 2 fm radius.

- Figure 4: $\mathrm{K^0_s}$–$\mathrm{K^0_s}$ invariant mass distribution for the data (1999 pairs) and the background.

- Figure 5: HBT relative momentum correlation of the $\mathrm{K^0_s}$–$\mathrm{K^0_s}$ pairs. The bin size is 50 MeV/c. The full curve shows the correlation expected for a fireball of 6 fm radius.

- Figure 6: The invariant mass distributions for: left – 391 Λ–$\overline{\Lambda}$ pairs,
  right – 3182 Λ–$\mathrm{K^0}$ pairs, shown together with the corresponding backgrounds.

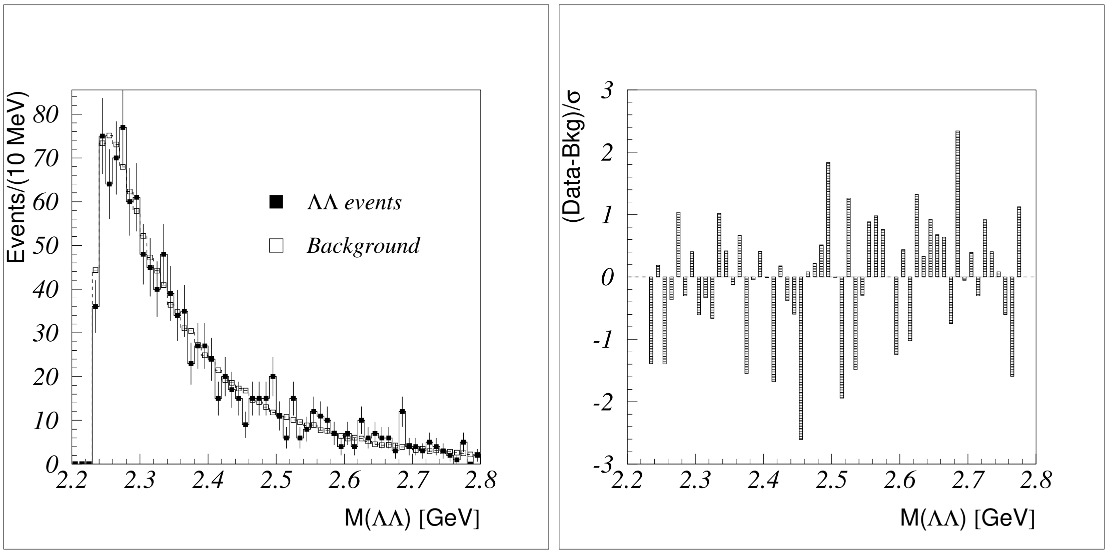

Figure 1.

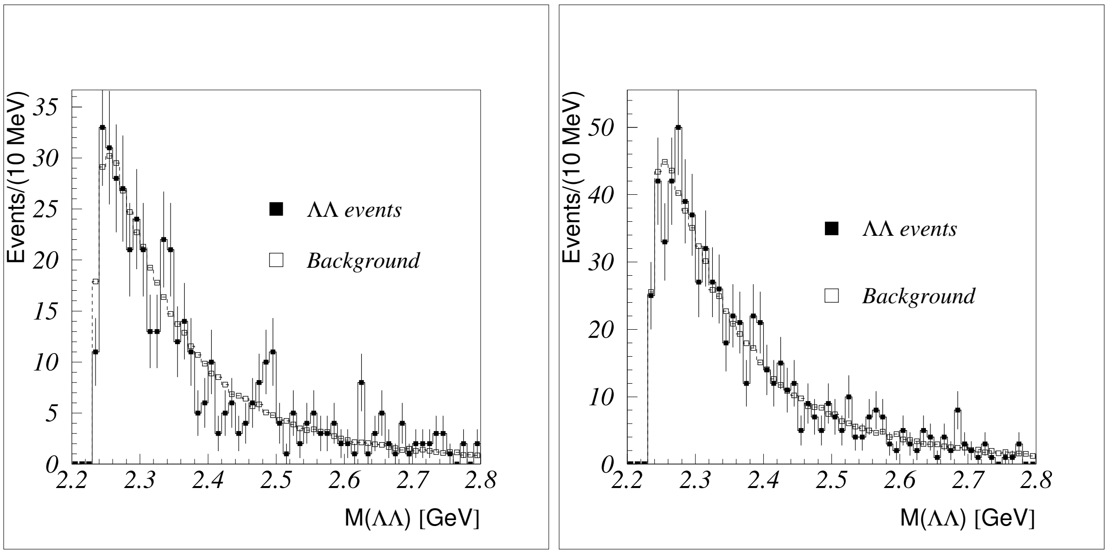

Figure 2.

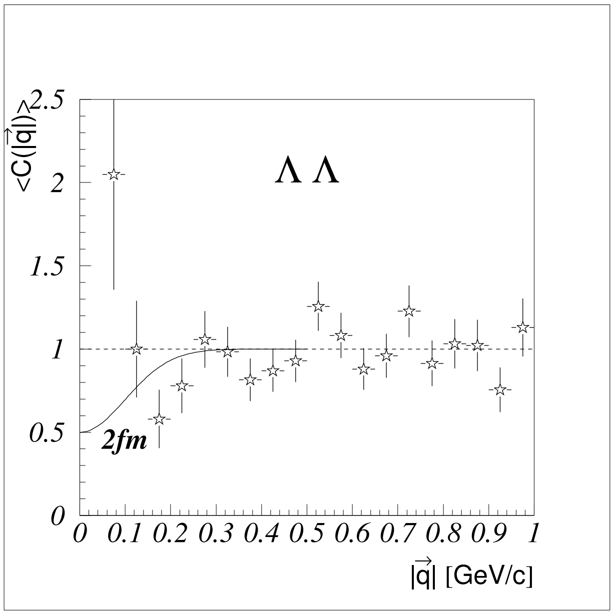

Figure 3.

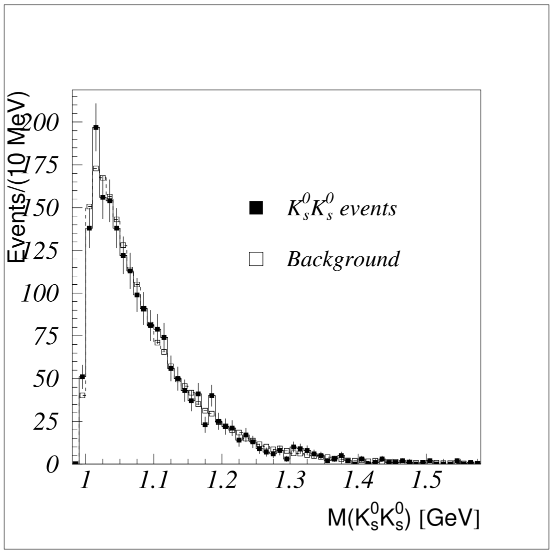

Figure 4.

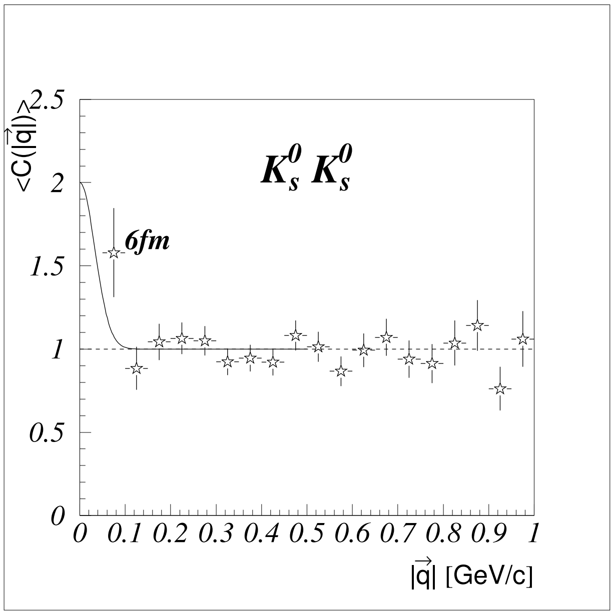

Figure 5.

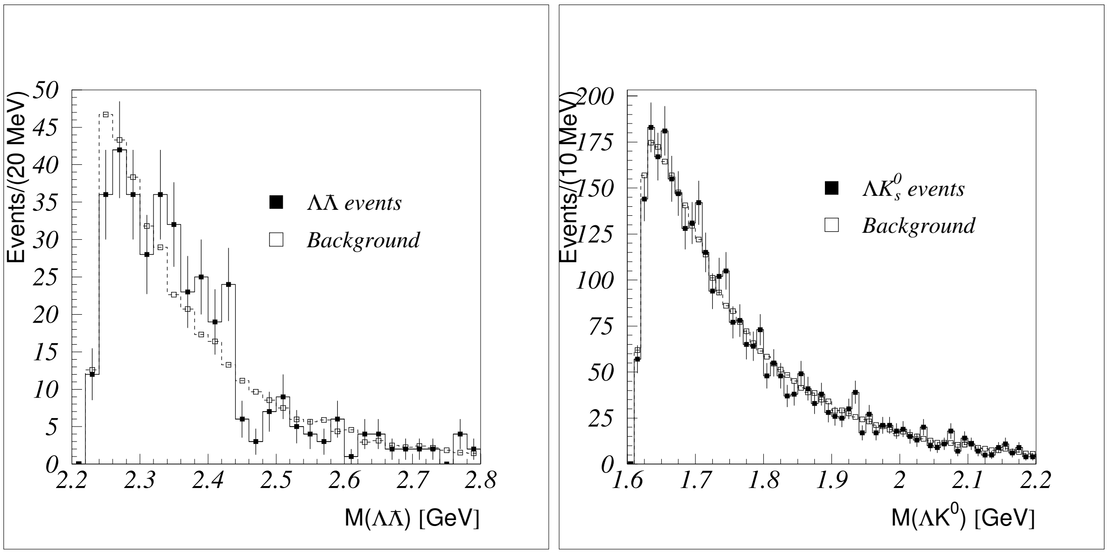

Figure 6.