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 $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ Reactions Near Threshold

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AN INVESTIGATION OF THE $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ AND $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ REACTIONS NEAR THRESHOLD

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Experiment PS185 studies the production of antihyperon-hyperon pairs in antiproton-proton collisions at LEAR in the near-threshold energy region. The $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ reaction has been thoroughly studied by PS185 and many high-quality data have been reported. New results, including total and differential cross sections along with spin observables, are presented here for the channels $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ and $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ at incident lab antiproton momenta of 1.726 and 1.771 GeV/c. The data from the relatively unstudied and complementary $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ channel is compared to that from $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ at similar energies above the reaction threshold.

1 Introduction

Experiment PS185 studies strangeness production in $\bar{p}p$ collisions using the LEAR facility at CERN. This is accomplished via the reactions $\bar{p}p \rightarrow \bar{Y}Y$ where Y is a Λ or Σ hyperon. These reactions are investigated in the near-threshold region, where the energy available to the final-state hyperons is low and the number of partial waves needed to describe the process is limited thereby simplifying subsequent interpretations. The excellent characteristics of the LEAR \bar{p} -beam combined with the delayed weak decays of the final-state hyperons allow for high-precision measurements of the reaction cross sections and spin observables.

Over the last 10 years, PS185 has accumulated a large data set on the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ reaction.¹ These data show strongly forward-peaked differential cross sections along with sizable hyperon polarizations down to quite near the reaction threshold. The spin correlations show that the $\bar{\Lambda}\Lambda$ pair is produced almost exclusively in a triplet state throughout the PS185 kinematic range. These data have provoked numerous theoretical efforts employing a variety of methods (a sampling of

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these may be found in Ref. 2). However, it is generally agreed that these features of the data are the manifestation of the strong effects of annihilation in this channel and the presence of a tensor interaction.

A next step towards further understanding of this aspect of strangeness production would be study of the (isospin 1) $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda + \text{c.c.}$ reaction, a reaction quite complementary to (isospin 0) $\bar{p}p \rightarrow \bar{\Lambda} \Lambda$. The first results provided by PS185 from the $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda + \text{c.c.}$ reaction³ at 1.695 GeV/c, corresponding to an excess energy (the energy above the reaction threshold), ε , of approximately 15 MeV, showed a differential cross section with the familiar forward-peaking. However, this close to the reaction threshold, the cross section is relatively small and there were not enough accepted events to allow for a precise measurement of the spin observables.

The data presented here are the result of an effort to further extend the PS185 program to provide more high-quality data on the $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda + \text{c.c.}$ reaction. Due to the kinematic and topological similarities of the $\bar{p}p \rightarrow \bar{\Lambda} \Lambda$ and $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda + \text{c.c.}$ reactions as seen in the PS185 apparatus, data for the $\bar{p}p \rightarrow \bar{\Lambda} \Lambda$ reaction is collected in parallel and extracted by analysis. Therefore, new results for the $\bar{p}p \rightarrow \bar{\Lambda} \Lambda$ channel are reported as well. For details on the PS185 experimental apparatus, see Ref. 1.

2 Results and Discussion

These results are from data taken at two LEAR momentum settings and correspond to mid-target momentum values of 1.726 ± 0.001 and 1.771 ± 0.001 GeV/c. The error on these values is dominated by the absolute uncertainty in the LEAR extraction momentum. The total cross section values measured for the $\bar{p}p \rightarrow \bar{\Lambda} \Lambda$ reaction are 74.36 ± 2.67 and 79.90 ± 2.89 μb at 1.726 and 1.771 GeV/c, respectively. The values for the $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda + \text{c.c.}$ reaction at the same momentum values are 14.60 ± 0.70 and 21.22 ± 1.00 μb . These errors include both statistical and systematic contributions. The differential cross sections at these momenta for the $\bar{p}p \rightarrow \bar{\Lambda} \Lambda$ and $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda + \text{c.c.}$ reactions as a function of $\cos \theta^*$, where θ^* is the c.m. scattering angle, are shown in Fig. 1.

With these $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda + \text{c.c.}$ data and those collected at 1.695 GeV/c,³ PS185 now has $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda + \text{c.c.}$ results at excess energy values of approximately 15, 25, and 40 MeV. Not

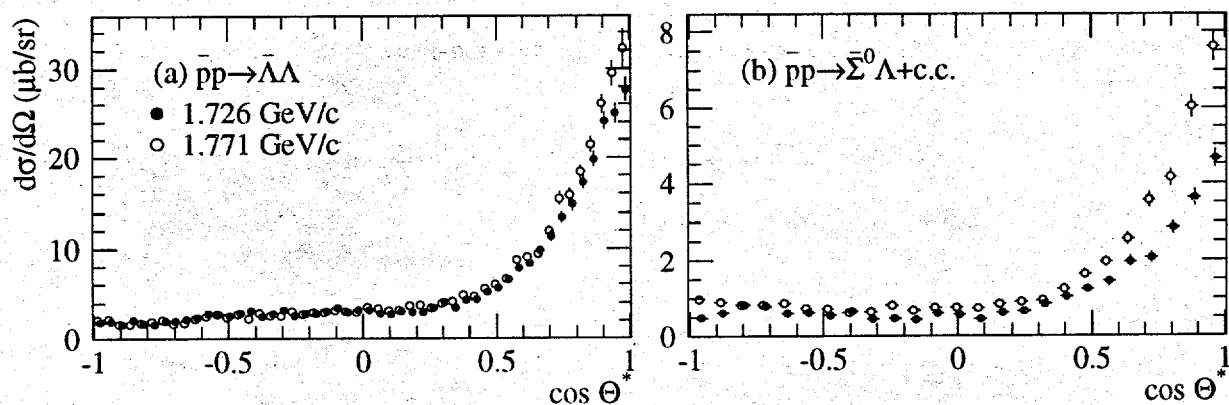


Fig. 1. Differential cross section results for the (a) $\bar{p}p \rightarrow \bar{\Lambda} \Lambda$ and (b) $\bar{p}p \rightarrow \bar{\Sigma}^0 \Lambda + \text{c.c.}$ reactions at 1.726 ± 0.001 and 1.771 ± 0.001 GeV/c. The data points have been offset slightly to avoid overlap.

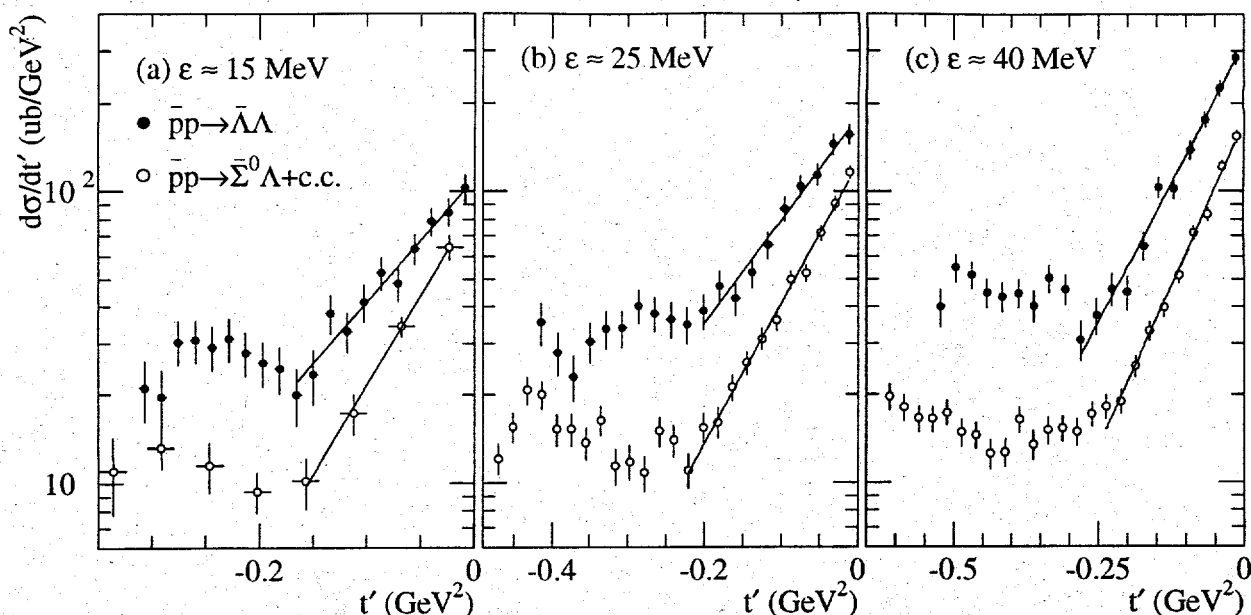


Fig. 2. The differential cross section for the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ and $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ reactions as a function of t' for $\epsilon \approx$ (a) 15, (b) 25, and (c) 40 MeV. The lines indicate the results of a fit to an exponential form in the forward region.

coincidentally, PS185 has reported results¹ for the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ reaction at similar values of ϵ , corresponding to antiproton momenta of 1.477, 1.508, and 1.546 GeV/c. It is instructive to compare data from the two reactions at these similar values of ϵ to (at least partially) remove the effects of phase space differences and more easily see the differences in the reaction dynamics.

The ratio of total cross sections for the two reactions, $\sigma(\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.})/2\sigma(\bar{p}p \rightarrow \bar{\Lambda}\Lambda)$ (the factor of 2 customarily appears in this ratio), is nearly constant at approximately 0.3 for all three values of ϵ . In other words, in this energy range, the reaction cross sections "turn-on" in very nearly the same way. What about the angular distributions? They are perhaps best compared as in Fig. 2, where the differential cross sections as a function of the squared reduced 4-momentum transfer, t' , are plotted for the two reactions for the same three values of ϵ . The fits, indicated by the superimposed solid lines, are of the exponential form, $e^{-bt'}$. The data are fairly well-described in the forward region by this simple form. This form arises in the context of a simple black disk model and the slope b is related to the radius of the black disk, R , by $b = R^2/4$. It is interesting to note, as can be seen in Fig. 2, that the differential cross section for $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ is consistently more forward-peaked (steeper slope) than $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ for all of these values of ϵ . In terms of the black disk model, the $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ data yield black disk radii of 1.3–1.5 F, while the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ data yield radii of 1.1–1.2 F.

The complete set of spin-observable data measured at these two momentum values, which includes the hyperon polarizations and spin correlation coefficients, are too numerous to show here. However, it is interesting to look at a derived quantity, the singlet fraction, which is a measure of the combined $\bar{Y}Y$ spin state. This quantity is shown for the two reactions at the two momentum values in Fig. 3. The singlet fraction yields a value of 1 for a $\bar{Y}Y$ in a pure singlet state, 0 for pure triplet, and 1/4 for no correlation between the two spins. As is readily seen in Fig. 3(a), the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ data at these momenta yield a singlet fraction consistent with zero throughout

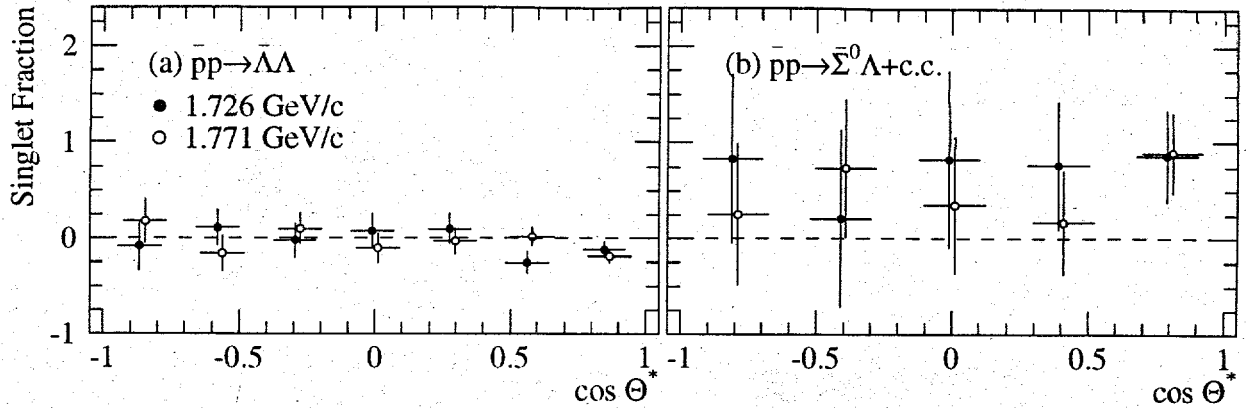


Fig. 3. Singlet fraction results for the (a) $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ and (b) $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ reactions at 1.726 ± 0.001 and 1.771 ± 0.001 GeV/c. The data points have been offset slightly to avoid overlap.

the entire $\cos\theta^*$ range. The weighted average over $\cos\theta^*$ is -0.08 ± 0.05 and -0.07 ± 0.05 at 1.726 and 1.771 GeV/c, respectively. This is consistent with previously reported PS185 $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ data. However, as can be seen in Fig. 3(b), there is indication that this triplet dominance may not hold in the $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ channel. The weighted average values are 0.76 ± 0.31 and 0.56 ± 0.26 at these same momenta.

3 Conclusions

New results, including total and differential cross section along with spin observables have been obtained for the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ and $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ reactions at 1.726 and 1.771 GeV/c. The total cross section, when compared at the same excess energy values, seems to rise from zero with a similar shape for the two reactions. However, the differential cross section is more strongly peaked in the $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ channel. The singlet fraction is measured to be consistent with zero for the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ channel as has been seen in previous PS185 data. However, there is a hint that this triplet fraction dominance does not obtain in the $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ channel, as can be seen from the spin observable data reported here. It will be interesting to see the incorporation of this new data on the $\bar{p}p \rightarrow \bar{\Sigma}^0\Lambda + \text{c.c.}$ reaction into the various theoretical works that have been developed and have, fairly successfully, described the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ data.

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