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STATUS AND FUTURE OF EXPERIMENT PS185 ($\bar{p}p \rightarrow \bar{Y}Y$) AT CERN

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Abstract: The LEAR Experiment PS185 at CERN measures total and differential cross-sections as well as polarizations and spin correlations in the reaction $\bar{p}p \rightarrow \bar{Y}Y$. The aim is to try to isolate the dynamics of the strange $\bar{s}s$ quark pair from the $\bar{Y}Y$ observables.

Data were taken for the first time in May 1984 at two $\bar{p}$ momenta (1477 and 1508 MeV/c), and some results from a preliminary evaluation are discussed. The forthcoming program of PS185 is outlined together with a discussion of physics questions that can be addressed within the framework of this experiment.

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1. INTRODUCTION

Although free quarks and their interaction have never been seen, properties of individual quarks and their interaction can be studied. It is the purpose of experiment PS185 [1)] to extract information on quantum numbers and spin dynamics in the creation process of the $\bar{s}s$ pair from the reaction $\bar{p}p \rightarrow \bar{Y}Y$ in the threshold region.

The spin S and isospin I of a light diquark in the baryon 56-plet are related by a symmetry condition: a diquark (qq) has $S = 0$ (1), if $I = 0$ (1). The situation for the hyperons within reach at LEAR is given in Tables 1a and 1b.

Table 1a

Hyperon-pairs within reach at LEAR

$\bar{Y}Y$	Threshold momentum (MeV/c)
$\bar{\Lambda}\Lambda$	1435.1
$\bar{\Lambda}\Sigma^0$ + c.c.	1652.7
$\bar{\Sigma}^+\Sigma^+$	1853.0
$\bar{\Sigma}^0\Sigma^0$	1870.6
$\bar{\Sigma}^-\Sigma^-$	1898.4

Table 1b

Spin and isospin of the light diquark in Λ and Σ

Hyperon Y	Light diquark in Y	
	I	S
$\Lambda\ (I = 0)$	0	0
$\Sigma\ (I = 1)$	1	1

Therefore the hyperons reveal spin quantities of their strange quark, and also the reaction dynamics of the effective quark interaction ($\bar{q}q \rightarrow \bar{s}s$) embedded in the $\bar{p}p \rightarrow \bar{Y}Y$ reaction (Fig. 1).

In fact, experimentally a large negative polarization is found for Λ's produced with $|t'| \geq 0.25\ (\mathrm{GeV/c})^2$ in the reaction $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ [2,3)] and in other reactions[4)] where an $\bar{s}s$ pair is created (Fig. 1). Even inclusive Λ production at high energies exhibits this behaviour[5)].

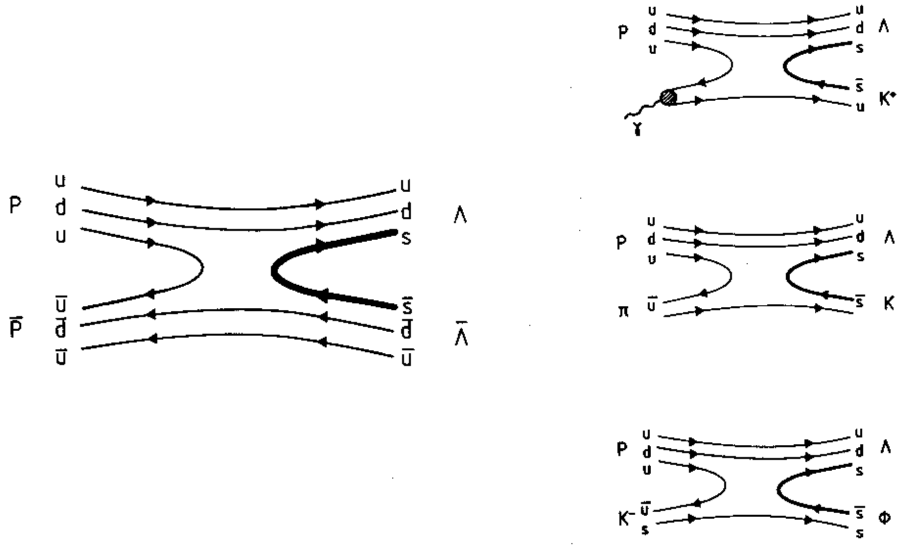

Fig. 1 Quark line diagrams for the $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ reaction and a few other reactions which involve an $\bar{s}s$ pair creation.

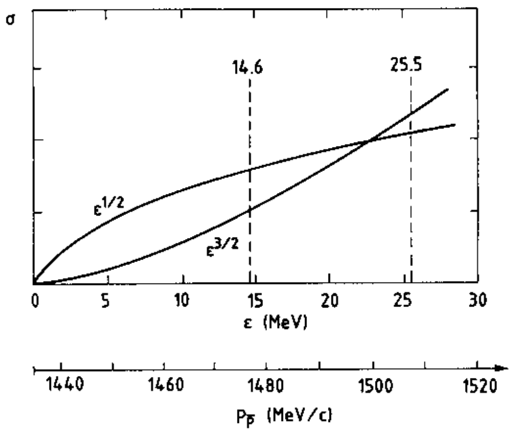

Fig. 2 The total cross-section behaviour for the reaction $\bar{p}p \to \bar{\Lambda}\Lambda$ for the S-wave ($\sigma \propto \epsilon^{1/2}$) and P-wave ($\sigma \propto \epsilon^{3/2}$) as a function of the excess energy. Also indicated are the two energies at which data have been taken in 1984.

In the two-body reaction channel the spin correlation between the hyperon–antihyperon pair can also be measured. This provides information on the relative singlet–triplet strength of the $\bar{Y}Y$ system. So far, experiments indicate that the $\bar{\Lambda}\Lambda$ pairs ($\bar{s}s$ pairs) are always created in a relative triplet state[2,3] — a non-trivial fact.

Working in the threshold region, we have the advantage that the number of partial waves involved is strongly restricted, and very close to threshold we are dealing with almost only S- and P-waves. The relative strength of these can be determined from the shape of the differential cross-section or of the total cross-section. The latter, as a function of the excess energy $\epsilon = \sqrt{s} - m_{\bar{\Lambda}} - m_{\Lambda}$, is shown in Fig. 2 for S- and P-waves.

Putting all these pieces together, it should be possible to pin down the quantum numbers involved in the $\bar{u}u$-annihilation/$\bar{s}s$-creation process. For example, a relative triplet state of the $\bar{\Lambda}\Lambda$ system implies that if the reaction proceeds in S-waves, gluon quantum numbers 1^- are exchanged, whereas P-waves imply vacuum quantum number 0^+, or 1^+, 2^+ in the direct channel.

Theoretical work is at present in progress in view of the expected results from this experiment. Andersson et al.[6] have predicted polarizations using the additive quark model and colour confinement. Tabakin and Eisenstein[7] have developed a one-boson t-channel exchange model, predicting cross-sections, polarizations, and spin correlations, and an s-channel exchange approach has been adopted by Genz and Tatur[8] and further elaborated by Brix[9].

2. THE EXPERIMENT

The experimental set-up is shown in Fig. 3a together with a $\bar{\Lambda}\Lambda$ event in the multiwire proportional chambers (MWPCs) (Fig. 3b). The $\bar{p}$ beam is defined by the thin S_1 counter, and the target consists of a piece of 2.5 mm thick CH_2 surrounded by a scintillator veto box (S_2 and S_3) in order to select the neutral final state. The delayed hyperon hadronic charged decay is then recorded in a forward detector consisting of a stack of 10 MWPCs and 13 drift chamber planes, followed by a scintillator hodoscope (H) and a magnet with three drift chambers for the baryon number identification. The final on-line trigger is given by $S_1 \times \bar{S}_2 \times \bar{S}_3 \times H$.

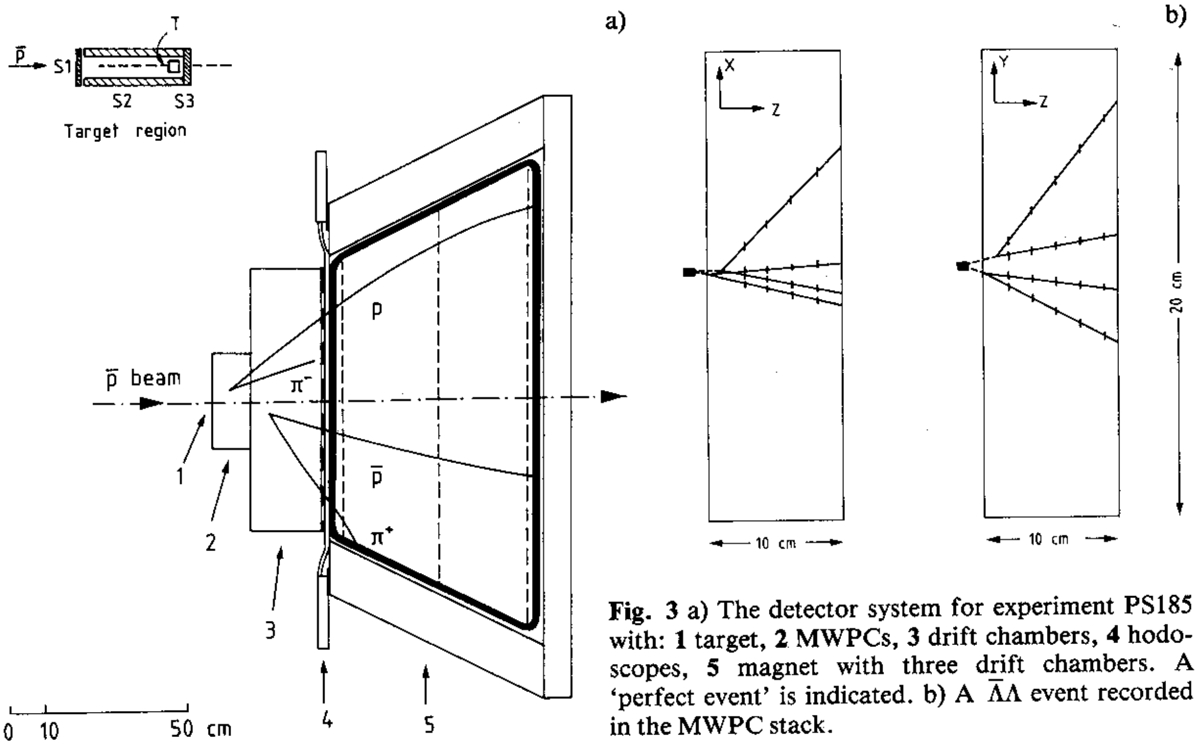

Fig. 3 a) The detector system for experiment PS185 with: **1** target, **2** MWPCs, **3** drift chambers, **4** hodoscopes, **5** magnet with three drift chambers. A 'perfect event' is indicated. b) A $\bar{\Lambda}\Lambda$ event recorded in the MWPC stack.

Within the LEAR range ($p_{\bar{p}} \leq 2$ GeV/c) the hyperons are always emitted into a narrow forward cone. In fact, also the decay protons are confined within a limited forward cone of $\theta < 42°$, and since our detector can cover a solid angle of $\geq 45°$ we have a 100% acceptance for these decay protons in the trigger.

Until now, experiment PS185 has had 1.7×10^{10} $\bar{p}$'s on target at 1508 MeV/c and 2.4×10^{10} $\bar{p}$'s at 1477 MeV/c. The beam was focused down to a remarkably small spot of 1.2×0.4 mm^2 FWHM on the target. In a preliminary analysis ~ 500 $\bar{\Lambda}\Lambda$ events have been extracted from the raw data at each energy, but it is expected that in the final analysis this number will be doubled. These figures should be compared with the published total world statistics of 37 events[2,10] in this momentum region.

The extracted events have been fed through a fitting procedure, optimizing the kinematic variables. There are enough constraints, for example, to calibrate the $\bar{p}$ momenta of the LEAR beam to a remarkable accuracy (see Table 2). The 1.0 MeV/c added to the fitted value is the momentum loss coming from the

Table 2

A comparison of the $\bar{p}$ momenta given by the LEAR machine and the kinematical fitting

LEAR	$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ kinem. fitting	Δ
1480	1476.5 + 1.0	1.7×10^{-3}
1509	1507.5 + 1.0	0.3×10^{-3}

passage through the vacuum exit window, air, and half of the target. Also, the interaction region in the target plane is reconstructed to the size of the beam spot (the decay points being typically $\leq$ 10 cm downstream from the target).

It is too early to give absolute values for the cross-sections, but a relative comparison can be made since the extraction and reconstruction efficiencies should be similar for the two energies. We find a cross-section ratio of

$$\sigma(1508)/\sigma(1477) = 2.01 \pm 0.17\,,$$

to be compared with the predictions for undisturbed S- and P-waves alone:

$$\sigma(\epsilon_1)/\sigma(\epsilon_2) = \begin{cases} (\epsilon_1/\epsilon_2)^{-1/2} = 1.32 & \text{S-wave}\,, \\ (\epsilon_1/\epsilon_2)^{-3/2} = 2.31 & \text{P-wave}\,. \end{cases}$$

This indicates that there is still a strong $\ell > 0$ contribution at an excess energy of 25 MeV, which can also be seen from the non-isotropic angular distribution shown in Fig. 4.

To study the influence of the ^{12}C content in the CH_2 target, a dedicated run was performed at 1477 MeV/c with 3.4×10^9 $\bar{p}$'s on a pure ^{12}C target of 2 mm thickness. The collected data have been fed through the same evaluation procedure as for $\bar{p}p \to \bar{\Lambda}\Lambda$, and, after the kinematic fitting, two events survive. This shows that there is a negligible contamination of the order of < 1% from events coming from ^{12}C.

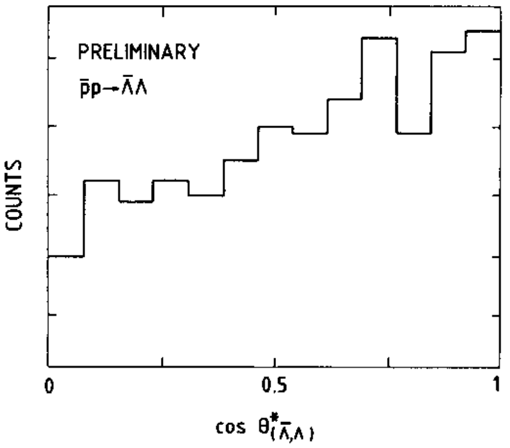

Fig. 4 Symmetrized c.m. angular distribution for $\bar{\Lambda}$ and Λ at 1508 MeV/c.

3. FUTURE PLANS

For 1985 our plans are to take data at momenta close to the $\Lambda\bar{\Lambda}$ threshold (1435 MeV/c) and around the $\Lambda\Sigma$ threshold (1653 MeV/c). Provided we can collect enough statistics, this should give rich physics information, especially on the $\bar{\Lambda}\Lambda$ and $\bar{\Lambda}\Sigma^0$ + c.c. spin correlations at threshold and their energy dependence (in the $\bar{\Lambda}\Lambda$ case). A first comparison of the isospin 0 and 1 channels ($\bar{\Lambda}\Lambda$ and $\bar{\Lambda}\Sigma^0$ + c.c.) could be done, as well as a first search for threshold effects.

A sandwich target consisting of five 2 mm CH_2 pieces stacked together between 0.1 mm thick scintillator sheets will be installed, increasing the count rate by a factor of 4 with respect to the present target.

3.1 Reaction $\bar{p}p \rightarrow K_SK_S$

We will add position-sensitive counters around the target to enable us to measure the reaction $\bar{p}p \rightarrow K_SK_S$ ($K_S \rightarrow \pi^+\pi^-$) in parallel with the $\bar{Y}Y$ measurement. This reaction is of particular interest with respect to the narrow $\xi(2220)$ resonance[11)]—glueball candidate[12)]—observed at SPEAR, since it has been seen in the K_SK_S decay channel; it could thus be studied at $\bar{p}$ momenta close to the $\bar{\Lambda}\Lambda$ threshold and measured with unprecedented precision[13)].

3.2 Reactions $\bar{p}p \rightarrow \bar{\Lambda}\Sigma$ + c.c., $\bar{\Sigma}\Sigma$

We also intend to measure total and differential cross-sections, polarizations, and spin correlations for these reactions. For the case of Σ's, a thin-walled Cherenkov active LH_2 target is being developed[14)].

In parallel with these main activities, information on many different aspects of hyperon physics will be collected parasitically:

i) Comparison of hyperon and antihyperon properties: The hyperons and antihyperons are always created in pairs and detected in the same apparatus, therefore many systematic errors will cancel.
CPT invariance[15)]: The equality of the $\bar{\Lambda}$ and Λ decay lengths can be tested with a significantly better precision than the present 10% accuracy[16)].
CP violation[17)]: A difference in the partial decay ratio $\bar{\Lambda} \rightarrow \bar{p}\pi^+/\Lambda \rightarrow p\pi^-$ or in the decay asymmetry parameter $\alpha_{\bar{\Lambda}}/\alpha_{\Lambda}$ (or $\alpha_{\bar{\Sigma}}/\alpha_{\Sigma}$) would signal a CP violation in the hyperon/antihyperon system. Experiment PS185 will give limits on these effects and provide the necessary information for future CP violation searches in these channels.

ii) Secondary scattering of $\bar{\Lambda}$'s and Λ's[18)]. Using a sandwich target, we will get data on (secondary) scattering of polarized $\bar{\Lambda}$ and Λ on protons and ^{12}C.

iii) Thresholds. The sandwich target allows for a precise energy scan with good luminosity. Together with an accurate measurement of the interaction vertex, this will enable us to use one or only a few LEAR settings close to the threshold in order to search for effects from final-state interaction, cusps, and perhaps super-exotic systems such as $\bar{\Sigma}\Sigma$ atoms.

It should be noted that the concept of the PS185 detector is adapted for threshold studies in general[19)]. It could be used especially for a comparison of threshold production of pions with protons and antiprotons[20)].

In the long-term future, one would clearly like to study the $\bar{p}p \rightarrow \bar{Y}Y$ reaction using an *internal polarized target*[21)]. Finally, complete polarization measurements could be done if polarized antiprotons could be stored in LEAR[21,22)].

4. CONCLUSIONS

The concept of the PS185 experiment works and the physics data are starting to emerge. However, there are still many $\bar{p}$'s needed to fulfil even a part of the program outlined in the original proposal. There are many fascinating questions that are open to investigation, and only some of them can be tackled before the ACOL shutdown in 1986. We therefore feel confident that there is a rich field of physics to be explored with a threshold-type detector in the ACOL era.

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