NUCLEAR AND PARTICLE PHYSICS ASPECTS
OF HYPERON AND ANTINUCLEON INTERACTIONS

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ABSTRACT

A discussion is given of hyperon (Y) and antinucleon (N) interactions with nucleons and nuclei, emphasizing some of the future prospects for nuclear structure and elementary particle physics studies at LEAR or a future "kaon factory".

1. Introduction

In recent years, there has been a surge of interest in the use of intense kaon and antiproton beams to address a variety of problems of fundamental interest in nuclear and elementary particle physics. The LEAR (Low Energy Antiproton Ring) facility at CERN has recently become operational, and promises to revolutionize the field of low energy antinucleon physics 1). There is active discussion of various proposals 2) for a "kaon factory", a general purpose facility providing intense beams of hadrons (kaons, pions, hyperons, antinucleons, etc.) and leptons (muons, neutrinos). The physics questions which could be addressed with such a facility are very diverse, spanning particle, nuclear and even solid state physics. In this short review, I restrict my attention to the future prospects for strong interaction studies of processes induced by N or strange particle 3) beams. The reader is referred to refs. 2 and 3 for a more comprehensive development. The topics I will address include i) production and decay of strange dibaryons, ii) spectroscopy of strangeness S = -2 many body systems, iii) NN annihilation mechanisms, and iv) inelastic N-nucleus scattering and spin-flip excitations in nuclei.
2. Overview

Until fairly recently, most studies of $\bar{N}$ interactions involved bubble chamber experiments, and were largely concentrated on the $\bar{p}p$ and $\bar{p}d$ systems. Differential cross section data for $NN$ elastic and charge exchange scattering exist at various energies, as well as total cross section measurements. There is data of rather modest precision on the branching ratios for various mesonic channels in $NN$ annihilation. The $NN$ system has long been considered as an attractive hunting ground for meson resonances: the $\rho$, $\omega$, $f$, $A_2$ ... mesons are readily seen in $NN$ annihilation, and there have been many searches for so-called "baryonium" states $B$ in $NN$ elastic scattering, total cross sections and reactions such as $p\bar{p} \rightarrow \pi^- + B$ or $\gamma + B$.

The LEAR facility, which provides unprecedented $\bar{p}$ beam intensities at low momentum, is expected to lead to an explosion of new data on $\bar{N}$ interactions. For example, $NN$ spin observables can now be measured, as well as precise branching ratios for multi-meson annihilations. Theoretical models will be strongly constrained by this new information. For instance, $NN$ spin observables are sensitive to the coherent tensor forces which result from vector meson exchange, while the relative rates for annihilation channels test the topology of quark rearrangement or pair creation/destruction processes in the quark model. Up to now, information on $\bar{p}$-nucleus interactions was very sparse. The first results from LEAR on $\bar{p}$-nucleus elastic and inelastic scattering are now emerging. It will be fascinating to exploit the potentialities of the $\bar{N}$ as a nuclear structure probe. We give some indications of these prospects below.

In the last few years, the spectroscopy of $S = -1$ hypernuclei ($\Lambda$ and $\Sigma$) has been studied via the strangeness exchange ($K^-\pi^+$) reactions at CERN and Brookhaven. The ($K^-\pi^+$) studies with magnetic spectrometers constituted a very important advance, since one was able to explore natural parity excited states as well as the ground states accessible by emulsion techniques. Recently, the unnatural parity part of the $\Lambda$ hypernuclear spectrum has been probed via the
reaction at BNL. Many interesting structure questions arise, some of which will be discussed by A. Gal at this conference. I will focus instead on future prospects for the study of \( S = -2 \) systems, both six quark dibaryon states and more complex nuclei. These can be produced in the \( (K,K) \) reaction, but intense kaon beams are required. Stable or quasi-stable strange six quark states represent one of the most important predictions of the MIT bag model. An extremely important area, which I will not have time to discuss, is that of rare decays of kaons and hyperons, which relates to the search for small violations of various conservation laws; the reader is referred to ref. (2).

3. Strange Six Quark Dibaryons

The subject of dibaryon resonances has been of prime interest in the last few years, with the bulk of the theoretical and experimental effort devoted to the NN sector. However, narrow dibaryons are more likely if \( S \neq 0 \), for several reasons. The color magnetic forces of QCD operate with maximum attraction for an SU(3) flavor singlet configuration of six quarks; this requires \( S = -2 \). The lowest-lying quark configuration, namely ududss with \( J^\pi(I) = 0^+(0) \), called the H, may even be stable with respect to strong decay into \( \Lambda \Lambda, \Xi \Xi \) etc. In LS-coupling, the H couples to \( Q^3 \times Q^3 \) clusters in the \( ^1S_0 \) state. Thus it cannot be produced in the \( d(K^-,K^+) \) reaction, but rather in the process \( ^3\text{He}(K^-,K^+)Hn \). The peak cross section for this reaction, which occurs for a momentum \( k \approx 1.8 \text{ GeV/c} \) where the elementary process \( K^-p \rightarrow K^+\Xi^- \) at \( \Theta_{K^+} = 0^\circ \) is maximum, is predicted to be of order \( \frac{d^2\sigma}{d\Omega_{K^+}d\Omega_n} \approx 30 \text{ nb/sr} \). If \( m_H < 2m_\Lambda \), the \( K^+n \) coincidence measurement is very clean, since the H corresponds to a peak in the missing mass spectrum lying below the quasielastic region. A high momentum \( K^- \) beam of high intensity is required, in view of the small cross section. Note that the H could also be formed in a three step process: i) \( K^-p \rightarrow K^+\Xi^- \), ii) slowing down and capture of the \( \Xi^- \) in an atomic state, and iii) H formation via annihilation. The case \( \Xi^-d \rightarrow Hn \) seems particularly promising, as shown in ref. (6), since the low relative \( \Xi^-p \) momentum in the \( \Xi^-d \) atom favors H formation. On the other hand, a sizable
fraction of the $\Xi$'s are lost through weak decay during the slowing down process. The $^3\text{He}$ and the atomic experiments appear to be comparable; they would deserve a high priority at a "kaon factory".

A six quark system with $S = -1$ cannot be a flavor singlet, but lower dimensional flavor representations are possible than for $S = 0$. Hence dibaryons with $S = -1$ can lie closer to the strong decay threshold than those with $S = 0$. In the bag model, two $S = -1$ six quark "primitives" of cluster structure $D = Q Q$ are of particular interest, namely

$$D_s = \{[3(1/3,1/2)0] \otimes [3^*(2/3,0)0]\}_{1^+_I}, I = 1/2$$

$$D^J_t = \{[3(1/3,1/2)1] \otimes [3^*(2/3,0)0]\}_{3^+_J}, I = 1/2$$

where the notation $f(y,i)$'s refers to the flavor $f$, hypercharge $y$, isospin $i$ and spin $s$ of each cluster. The clusters have a relative orbital angular momentum $L = 1$ between them, and couple to the $1^+_I$ or $3^+_J$ $YN$ channels as indicated. The masses of $D_s$ and $D^J_t$ are estimated to be 2110 and 2150 MeV, respectively, not far from the $\Delta N$ and $\Sigma N$ thresholds of 2050 and 2130 MeV. Many other "primitives" ($P$-matrix poles) exist in the bag model spectrum, but these lie much further above the strong decay thresholds, and have cluster configurations that are unstable with respect to quark "tunneling". The strong decay widths of $D_s$ and $D^J_t$ were recently estimated in a simple model involving wave function rearrangement into $Q Q$ channels, followed by a final state interaction leading to an on-shell $YN$ system. The widths were found to be very small (a few MeV or less), due principally to two factors: i) a very small wave function overlap with the $\Lambda p$ channel, and ii) weaker final state interactions for $YN$ than for NN. Analogous considerations for $S = 0$ dibaryons do not lead to narrow structures which couple to Pauli-allowed NN channels. In the NN case, the flavor representations are of higher dimensionality, and the color magnetic attraction is not strong enough to stabilize the system against quark tunneling.
Production cross sections for $D_s$ and $D_t^J$ have been estimated\textsuperscript{7)} to be of the order of a few $\mu$b/sr at peak. The relevant reactions are $d(K^-,\pi^-)D_t^J$ and $^3\text{He}(K^-,\pi^+)nD_s$; note that $D_s$ is a spin singlet and is not produced with a deuterium target. Since $D_{s,t}$ are P-wave structures, unlike the H, their production requires $\Delta L = 1$ and hence the cross section peaks at non-zero angle, where the dibaryon signal can be more easily distinguished from the background. Such $(K^-,\pi^+)$ experiments are already feasible with existing $K^-$ beams\textsuperscript{8)}, and are extremely important way of searching for narrow dibaryons.

4. **Doubly Strange Hypernuclei**

Hypernuclei with two units of strangeness have occasionally been seen in emulsion experiments, but only a few ground state binding energies are known. The existence of intense kaon beams in the momentum range 1–2 GeV/c would enable us to explore a fascinating and new spectroscopy of $S = -2$ hypernuclei through the $(K^-,K^+)$ and $(K^-,K^0)$ reactions on nuclear targets. The $\Xi^-$ hypernuclei can be produced in the one step $K^-p \rightarrow K^+\Xi^-$ reaction. Because of the sizable momentum transfer, this process emphasizes the formation of high spin $\Xi^-$ states. Some distorted wave estimates\textsuperscript{9)} of $\Xi^-$ hypernuclear production cross sections have been made for $^4\text{He}, ^{12}\text{C}$ and $^{28}\text{Si}$ targets. The $0^0 (K^-,K^0)$ lab cross sections at $k_L \approx 1.8$ GeV/c range from tens of nb/sr to about 1 $\mu$b/sr, the latter for the $^{28}\text{Si}(K^-,K^+)\Xi^{28}\text{Mg}$ reaction, leading to a $\Xi$ particle-proton hole state of structure $(d_{3/2},s_{1/2},d_{5/2})^4$. The width of these high spin $\Xi$ states is not expected\textsuperscript{9)} to exceed a few MeV. Thus, in analogy to the surprisingly narrow $\Sigma$-hypernuclear excitations seen at CERN and Brookhaven, one can also anticipate the existence of relatively long-lived $\Xi$ states.

One also expects a spectrum of bound $\Lambda\Lambda$ hypernuclear states, which are stable against strong decay. These states can be made in a two-step reaction $K^-p \rightarrow \pi^0\Lambda$, followed by $\pi^0p \rightarrow K^+\Lambda$, or by another route, namely $K^-p \rightarrow K^+\Xi^-$ and $\Xi^-p \rightarrow \Lambda\Lambda$. For the former process, cross sections for the formation of states in $^{16}\text{C}$ and $^{40}\text{Ar}$ have been estimated\textsuperscript{10)} in second order DWBA. The $(K^-,K^0)$ cross sections are very
small, of the order of a few nb/sr at 0°, even for states of higher spin, such as \(^{14}\text{C}(2^+)^0\text{p,p}_{\Lambda}\Lambda\Lambda\). The ground states of \(\Lambda\Lambda\) hypernuclei will have very tiny \((K^-,K^+)\) cross sections, due to the large "angular momentum mismatch" (0.2 nb/sr for \(\Lambda\Lambda\text{C (g.s.)}\)). These experiments require the intense flux of a "kaon factory". Here we could access a new domain of strange particle nuclear physics, perhaps leading to an understanding of novel aspects of dynamical symmetries in hypernuclei (vs. nuclei) as well as the essentially unknown properties of the \(\Lambda\Lambda\) and \(\Xi\Xi\) strong interactions.

5. The Nucleon-Antinucleon (NN) Interaction and Baryonium

The \(\bar{\Lambda}\Lambda\) system presents many fascinating problems, only a few of which are mentioned here. Several recent reviews\(^{11, 12}\) and an older classic\(^{13}\) are available for more details. The proceedings of the various \(\bar{\Lambda}\) symposia\(^{14}\) are also valuable sources of information.

A tantalizing possibility is that one can exploit the intimate relation between the longer range (\(\geq 0.8-1\) fm) part of the \(\bar{\Lambda}\Lambda\) and \(\Lambda\Lambda\) meson exchange potentials. If one applies the G-parity transformation, repulsive coherences in \(\bar{\Lambda}\Lambda\) spin-orbit forces are replaced by attractive coherences\(^{15}\) of \(\bar{\Lambda}\Lambda\) tensor forces. That is, all pseudoscalar and vector meson exchanges (\(\pi, \eta, \rho, \omega\)) produce tensor potentials of the same sign for \(\bar{\Lambda}\Lambda\) isospin \(I = 0\); the \(\pi\) and \(\rho\) transition potentials for \(\bar{\Lambda}\Lambda \rightarrow \Delta\Lambda\), \(\Delta\Lambda\) are also of the same sign, whereas they tend to cancel for the \(\Lambda\Lambda\) system. These coherences should show up in \(\bar{\Lambda}\Lambda\) spin observables\(^{16}\), which can be measured in future experiments at LEAR. The spin observables are also crucial in distinguishing between optical models for the \(\bar{\Lambda}\Lambda\) system which have a strong\(^{17}\) or weak\(^{18, 19}\) spin dependence of the absorptive potential \(W(r)\).

The \(\bar{\Lambda}\Lambda\) system provides an ideal entrance channel for producing "baryonium" states \(B\); those above the \(\bar{\Lambda}\Lambda\) threshold should be seen in elastic scattering and those below threshold in reactions like \(\bar{\Lambda}\Lambda \rightarrow \gamma + B\), \(\pi + B\). In \(\bar{\Lambda}\Lambda\) potential models, narrow bound states or resonances can occur near threshold\(^{15, 20, 21}\). In the "color
chemistry" of multiquark systems, numerous baryonium states of \( Q^2Q^2 \) structure are expected, which couple preferentially to the \( N\bar{N} \) channel rather than to mesons. For the past few years, there have been persistent suggestions of narrow structures \( B^0 \) in the \( p\bar{p} \rightarrow \gamma + B^0 \) reaction. Recently, a first study of the \( p\bar{p} \rightarrow \pi^+ + B^+ \) reaction at LEAR has provided striking evidence, of high statistical significance, for the existence of a very narrow meson \( B^+ \) (necessarily \( I = 1 \)) of mass \( m_B \approx 1620 \text{ MeV} \) and width \( \Gamma_B < 5 \text{ MeV} \). Further important experiments on \( \gamma \) and \( \pi^0 \) emission are in progress at LEAR. The systematic comparison of the peaks seen in the \( \gamma, \pi^0 \) and \( \pi^\pm \) spectra is very important in obtaining quantum number constraints on \( B \). Eventually, one would also like to study the branching ratios for \( B \) decay into various mesonic channels, in order to distinguish between theories which imply different topological structure for the baryonium states.

6. Quark Model Mechanisms for \( N\bar{N} \) Annihilation

Nucleon-antinucleon annihilation, even at threshold, is a short range process which necessarily involves significant radial overlap of the \( N \) and \( \bar{N} \). One expects that quark degrees of freedom play a crucial role, and that a consideration of quark symmetries and dynamics is necessary to obtain a more fundamental understanding of the annihilation process.

Most existing data on \( N\bar{N} \) annihilation modes comes from bubble chamber experiments. Although several dozen channels of two meson \( (N\bar{N} \rightarrow M_1M_2) \) or three meson \( (N\bar{N} \rightarrow M_1M_2M_3) \) character have been identified, where \( M_i = \pi, \eta, \rho, \omega \), the relative branching ratios are not well determined. At the LEAR facility, the \( N\bar{N} \) annihilation process can be studied with unprecedented accuracy, providing a data set which would constrain much more strongly any microscopic quark model description.

Several approaches to \( N\bar{N} \) annihilation exist in the literature. Early on, statistical models were introduced to discuss multiplicities, energy spectra, etc. After the advent of \( SU(6) \) symmetry, quark
rearrangement models\textsuperscript{28}) for the process \( \bar{N}N \rightarrow M_1 M_2 M_3 \) process were introduced. A modern version of the rearrangement model has been developed by Maruyama and Ueda\textsuperscript{29}), and incorporates in a phenomenological way the effects of \( \bar{N}N \) initial state interactions and SU(6) symmetry breaking. In this approach, the probability \( P \) for the process \( \bar{N}N \rightarrow M_1 M_2 M_3 \) is written as

\[ P(IS;123) = b(I,S)C(IS;123)g_1g_2g_3V(123;E) \]  

(2)

where \( b(I,S) \) is a set of four parameters reflecting the differing real potentials in \( \bar{N}N \) channels of isospin \( I \) and spin \( S \), \( C(IS;123) \) is an SU(6) recoupling coefficient, \( V \) is a phase space factor and the \( \{g_i\} \) allow the possibility of SU(6) breaking, through the use of different meson wave functions, for instance. The most recent version\textsuperscript{29}) of the model gives

\[ g_1 = \begin{pmatrix} 1 & \pi \\ 13 & \eta \\ 14.5 & \omega \\ 17.5 & \rho \end{pmatrix} \quad b(I,S) = \begin{pmatrix} 1 & (00) \\ 0.68 & (11) \\ 0.58 & (10) \\ 0.53 & (01) \end{pmatrix} \]  

(3)

Except for the strong suppression of direct pion production (as opposed to pions arising from \( \eta, \rho \) or \( \omega \) decay), SU(6) breaking does not seem necessary. This suppression may reflect the special role of the pion as a Goldstone boson. The \( b \)'s are not indicative of qualitatively important initial state effects.

The simple rearrangement model can give a reasonable description of the annihilation branching ratios, at the cost of introducing a number of phenomenological parameters. One might worry that the effects of other quark mechanisms, i.e. processes involving creation/destruction of one or more quark-antiquark (Q\( \bar{Q} \)) pairs, might be masked by this phenomenological procedure. There have even been claims\textsuperscript{30}) (incorrect) that pair annihilation processes dominate, i.e. that those graphs without line crossings are much larger than rearrangement graphs.
The two meson modes $NN \to M_1 M_2$ offer a particularly attractive case for the study of interference effects\textsuperscript{31) between different annihilation mechanisms in the quark model. For instance, the ratio of strange to non-strange meson modes is very revealing, since the production of strangeness requires $ss$ pair creation. If we denote $(\sigma_{pp} \to M_1 M_2)/q^{2L+1}$ by $\sigma_{M_1 M_2}$ (here $q^{2L+1}$ is the final state penetrability), then\textsuperscript{31)

\[
\frac{\sigma_{K+K^-}}{\sigma_{\pi+\pi^-}} = \begin{cases} 
\frac{4}{9} & (L = 0) \\
\frac{4}{9(1 + 2\xi)^2} & (L = 1)
\end{cases}
\]

where $\xi$ is the ratio of "rearrangement" (here involving one $^{13}P_0$ QQ pair annihilating and one line crossing) and "planar" (no line crossings, 3 QQ vertices) amplitudes. For $NN$ S-waves ($L = 0$), the rearrangement graph does not contribute (unless we introduce a $^{13}S_1$ QQ vertex with a subsequent finite momentum transfer to another quark line). The experimental result of Bizzarri et al\textsuperscript{32) is

\[
\frac{\sigma_{K+K^-}}{\sigma_{\pi+\pi^-}} = \begin{cases} 
1/2 & (L = 0) \\
\sim 10^{-2} & (L = 1)
\end{cases}
\]

The dominance of the "rearrangement" process ($\xi \approx 10$) provides a natural dynamical mechanism for the suppression of the $K^+K^-/\pi^+\pi^-$ ratio in the P-wave. The same mechanism helps to explain a long-standing anomaly\textsuperscript{33) relating to a sizable odd-L contribution to the $\pi^+\pi^-$ mode in "at rest" $pp$ annihilation (from the protonium atom).

Some limited information is available on $\eta$ modes. Generally $\eta X/\pi^0 X$ ratios are smaller than unity, an exception being the $\eta\pi^0/\pi^0\pi^0$ ratio "at rest", which is about 1.5, if one accepts the recent experimental results of Backenstoss et al\textsuperscript{34). Simple quark model or baryon exchange considerations give this ratio as less than 1. This qualitative discrepancy may indicate interesting new physics (an $I = 1$...
baryonium state, a sequential process $\bar{p}p \rightarrow \Delta N + \pi^0 \eta$, etc.). For the future, the detailed understanding of the NN annihilation process provides a very important experimental and theoretical challenge.

7. The Antinucleon as a Nuclear Structure Probe

The potentialities of the antinucleon as a nuclear structure probe are largely unexplored, although there are some preliminary results\textsuperscript{35} from LEAR and a few theoretical predictions\textsuperscript{36}. The inelastic scattering process $(\overline{N}, N')$ has a special relationship to $(N, N')$, since it offers the same spin-isospin degrees of freedom ($\Delta S = 0, 1$; $\Delta T = 0, 1$) in the nuclear response. However, because of the significantly different spin dependence of the NN and $\overline{NN}$ real potentials and the presence of a huge annihilation potential $W$ for $\overline{NN}$ (absent for NN), the $\overline{N}$ and $N$ elastic and inelastic scattering display important differences. Due to the very strong absorption, $\overline{N}$ elastic scattering displays a typical diffractive pattern, while $\overline{N}$ inelastic scattering will excite configurations whose wave functions are surface localized. The $\overline{N}$ is thus a more selective probe than the nucleon, which penetrates much farther into the nuclear interior.

If the two-body $\overline{NN}$ absorptive potential $W$ is strongly spin dependent, as in the Paris (P) model\textsuperscript{17}, the spin response of the nucleus is amplified ($\Delta S = 1$), and the $\overline{N}$ would offer an excellent way of exciting isoscalar spin waves in nuclei. If, on the other hand, $W$ is independent of $I$ and $S$, as assumed in the DR model of ref. (18), then the inelastic response of the nucleus to an $\overline{N}$ or $N$ is rather similar, in the sense that Gamow-Teller transitions ($\Delta S = \Delta T = 1$, with $t_{\sigma\tau}$ as the central part of the transition operator) are larger than isobaric analog excitations ($\Delta S = 0, \Delta T = 1$, operator $t_{\tau}$), which in turn exceed the strength of $\Delta S = 1, \Delta T = 0$ transitions (operator $t_{\sigma}$). In principle, once the spin observables have been measured for the two-body $\overline{NN}$ system, one can distinguish between models for $W$ which have a different spin dependence. An even simpler test, however, accessible in the first round of LEAR experiments, consists in looking
at the ratio of $\bar{N}$ inelastic cross sections to isoscalar and isovector spin flip excited states. A good example is provided by the pair of $1^+$ states in $^{12}$C at 12.7 MeV ($\Delta S = 1$, $\Delta T = 0$) and 15.1 MeV ($\Delta S = 1$, $\Delta T = 1$). One predicts\(^{36}\) in distorted wave approximation that

$$R(\theta) = \left\{ \frac{\mathrm{d}\sigma/\mathrm{d}\Omega(1^+, T = 0)}{\mathrm{d}\sigma/\mathrm{d}\Omega(1^+, T = 1)} \right\}$$

(6)

$$= \begin{cases} 
0.44 \ (\text{P}), 
0.05 \ (\text{DR}) & \text{at } \theta = 0^\circ \\
0.38 \ (\text{P}), 
0.15 \ (\text{DR}) & \text{at } \theta = 10^\circ.
\end{cases}$$

At small angles, $R(\theta)$ reflects the ratio $|t_\sigma/t_{\sigma_T}|^2$ of two-body NN amplitudes, and differs by an order of magnitude for the P (ref. 17) and DR (ref. 18) models. For larger angles, the tensor and spin-orbit parts of the $\bar{NN}$ t-matrix dominate, and the two models differ less dramatically, but still substantially. Other spin quantities, such as the elastic polarization P and P-A for spin-flip excitations, are also sensitive\(^{36}\) to the spin dependence of $\bar{N}$, as well as the coherent tensor forces in the $\bar{NN}$ meson exchange potential. One anticipates a complex spin-orbit potential\(^{36}\) for the $\bar{N}$, with the largest contribution from second order two-body tensor forces rather than first order spin-orbit terms. There should also be a significant one-body Lane $\left(\varphi,\varpi\right)$ potential for the $\bar{N}$, which should show up, for instance, in a comparison of angular distributions for the $(\bar{p},\bar{p})$ and $(\bar{p},\bar{n})$ processes.

Most of the notions discussed here relate to $\bar{N}$-inelastic scattering as a reflection of the (as yet poorly determined) spin-isospin dependence of the $\bar{NN}$ two-body interaction. After the effective $\bar{NN}$ interaction has been better determined phenomenologically, one hopes that the uniqueness of the $\bar{N}$ as a nuclear probe will lead to new insights into nuclear structure, through comparative studies of complementary reactions such as $(\bar{p},\bar{p})$, $(p,p')$, $(e,e')$, $(\pi,\pi')$, etc., which have quite distinct properties with respect to spin-isospin, energy dependence, and momentum transfer.
In this cursory review, I have tried to convey some impression of the richness of phenomena which can be explored with intense strange particle and antinucleon beams. For a much broader picture, I invite the reader to consult refs (1-3), or better yet, explore a research problem of his or her own choosing in this emerging and exciting field.

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References

2. For a comprehensive review of the physics questions which could be addressed at a future "kaon factory", see "Physics with LAMPF II", Los Alamos Report LA-9798-P, June, 1983.
3. C.B. Dover and G.E. Walker, Phys. Rep. 89, 1-177 (1982); this is an extensive review of strange particle interactions with nucleons and nuclei.


26. G.A. Smith, private communication and article in preparation by Athens-New Mexico-Penn State-Temple collaboration at LEAR.
29. M. Maruyama and T. Ueda, Nucl. Phys. A364, 297 (1981) and Phys. Lett. 124B, 121 (1983); M. Maruyama, Prog. Theor. Phys. 69, 937 (1983); in eq. (3), we multiply $g_\eta$ by 2, to account for the fact that the real $\eta$ consists of only 50% non-strange quarks, whereas the calculations were done with an ideally mixed $\eta$.

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