Strange Particle Decays

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Abstract

Recent results on strange particles decays from Brookhaven and Fermilab are reviewed. Detailed attention is given to the following topics: a search for the decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ from Brookhaven Experiment 787, a search for $K_L \rightarrow \mu e$ from Brookhaven Experiment 791, a measurement of the $\Sigma^+$ magnetic moment from Fermilab Experiment 761, and a measurement of the decay $K_L \rightarrow e^+ e^- e^+ e^-$ from Fermilab Experiment 799.

1. Introduction

Starting from their discovery in cosmic rays in 1947,1 the study of strange particles has made major contributions to our understanding of elementary particles. An understanding of associated production, the τ-θ puzzle, Cabibbo mixing, $K^0$-$\bar{K}^0$ mixing, baryon magnetic moments, and the discovery of $CP$ violation all came from experiments using strange particle beams and, especially when considered historically, all underpin important components of the Standard Model. The strange quark was key in these discoveries because it is the lightest quark not seen in ordinary matter. Its relatively low mass allows copious production at accelerators and limits both the number of channels and phase space for decay. These facts along with its resistance to strong decay allow formation of strange beams, which in turn allow study of decays far from the harsh environment near a production target. The long lifetime of strange particles also allows study of reactions with very low rates. With all of these advantages and with advances in accelerator and detector technology over the years, there are still many active or recently active programs trying to refine our understanding of the standard model or discover new physics using strange particles.

Table 1.1: Recent results in strange particle decays. The physics issues addressed are flavor-changing neutral current decays (FCNC), tests of chiral perturbation theory (XPT), separate lepton family number conservation, hyperon production polarizations, hyperon magnetic moments and decay asymmetries in hyperon radiative decays and direct $CP$ violation.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Decay</th>
<th>Physics Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNL E787</td>
<td>$K^+ \rightarrow \pi^+\nu\bar{\nu}$</td>
<td>FCNC $^2$</td>
</tr>
<tr>
<td>BNL E791, 871</td>
<td>$K_L \rightarrow \mu e$</td>
<td>$\mu^+\mu^-, e^+e^-$</td>
</tr>
<tr>
<td>FNAL E761</td>
<td>$\Sigma^+ \rightarrow p\pi^0$</td>
<td>polarization, mag. mom. $^7-^8$</td>
</tr>
<tr>
<td>FNAL E799</td>
<td>$K_L \rightarrow \pi^0e^+e^-$</td>
<td>dir. $CP$ viol., FCNC $^12$</td>
</tr>
</tbody>
</table>

These programs have produced a long list of recent results on strange particles which are listed in Table 1.1. This review will concentrate on a few of them, in particular a new limit on the decay $K^+ \rightarrow \pi^+\nu\bar{\nu}$ from BNL E787, a limit on the lepton family number violating decay $K_L \rightarrow \mu e$ from BNL 791, a measurement of the $\Sigma^+$ magnetic moment from
FNAL E761, and a new investigation of the quantum numbers of the $K_L$ via its decay $K_L \rightarrow e^+e^-e^+e^-$ from FNAL E799.

2. **BNL E787: $K^+ \rightarrow \pi^+\nu\bar{\nu}$**

Fig. 2.1 shows one of the diagrams that contributes to the decay $K^+ \rightarrow \pi^+\nu\bar{\nu}$. Even at the one-loop level, the rate would vanish if not for the differences in the quark masses which upset the cancellation of the diagrams. Many authors have estimated the rate of $K^+ \rightarrow \pi^+\nu\bar{\nu}$ in the context of the Standard Model. The branching ratio is most sensitive to the values of the CKM matrix elements and the top quark mass. Uncertainties in the hadronic matrix element have been largely eliminated by relating this rate to that of $K^+ \rightarrow \pi^0e^+\nu_e$ and long distance effects have been shown to be negligible for $K^+ \rightarrow \pi^+\nu\bar{\nu}$. Assuming three generations of neutrinos and a top quark mass less than 200 GeV/$c^2$, the expectation is that

$$\text{BR}(K^+ \rightarrow \pi^+\nu\bar{\nu}) = (0.6 - 6) \times 10^{-10}. \quad (2.1)$$

Most of the uncertainty comes from the CKM matrix element $V_{td}$. This process is therefore one of the best ways to get at this element. The best previous experimental upper limit on this process is $1.4 \times 10^{-7}$ at the 90% confidence level.

This leaves a large window in which to search for new physics. An experiment sensitive to $K^+ \rightarrow \pi^+\nu\bar{\nu}$ will detect the charged pion coming from the $K^+$ decay recoiling against a weakly interacting system of particles. Hence it will be sensitive to certain types of new particles which include the familon, and supersymmetric particles. In addition, the standard model rate may can also be altered with the addition of new virtual particles. For example in models with non-minimal Higgs sectors a virtual charged Higgs can change the flavor of the $s$ quark. Diagrams like these can add to or subtract from the rate for $K^+ \rightarrow \pi^+\nu\nu$.

The main backgrounds to a measurement of $K^+ \rightarrow \pi^+\nu\bar{\nu}$ come from the decays $K^+ \rightarrow \mu^+\nu (K_{\mu2})$ with a branching ratio of 64% and $K^+ \rightarrow \pi^+\pi^0 (K_{\pi2})$ with a branching ratio of 21%. These are both topologically similar to the decay of interest, with one charged track in the final state. In order to deal with the background there are three broad areas.
of attack. First, one must be able to distinguish pions from muons. One way to do this is to observe the unique decay sequence $\pi^+ \rightarrow \mu^+ \nu, \mu^+ \rightarrow e^+ \nu \bar{\nu}$. Second, the detector must efficiently veto the photons from $\pi^0$ decay. This requires a $4\pi$ photon detector. And third, one must exploit the differences between the kinematics of the decay and those of the background.

![Momentum spectrum for charged particles from $K^+$ decay.](image)

Figure 2.2: Momentum spectrum for charged particles from $K^+$ decay. Branching ratios are given in parentheses.

Fig. 2.2 shows the momentum spectrum of the daughter charged particles from $K^+$ decay measured in the kaon rest frame. The two-body modes have a unique range. The three-body decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ peaks at its end point and has a significant fraction of its phase space between the $K_{e2}$ and $K_{\mu3}$ peaks. The data analysis focuses on the areas of phase space above and below the $K_{e2}$ peak. As discussed below, the detector provides three independent measurements of the decay kinematics: momentum, range, and energy. This redundancy guards against mismeasurement of a single quantity and provides a means of particle identification.

The detector is shown in Fig. 2.3. It is located at the end of a 775 MeV/c separated beamline at the Brookhaven AGS. The beam was instrumented with a Čerenkov counter, several scintillator hodoscopes, and a small MWPC. The beam passed through a beryllium oxide degrader and kaons were ranged out in a scintillating fiber target. Surrounding the target was a cylindrical drift chamber which provided a momentum measurement of the decay particle. The decay particle entered and was brought to rest in a plastic scintillator range stack. In addition to the range measurement, the kinetic energy was measured by summing the pulse height in struck range stack counters. Outside of the range stack was a lead-scintillator barrel photon veto. Completing the solid angle coverage of the photon veto were lead-scintillator endcaps. Surrounding the entire detector was a conventional
copper-coil magnet which provided a 1 T field. The tagging of the $\pi \rightarrow \mu \rightarrow e$ decay sequence is accomplished by instrumenting the range stack with 180 channels of 500 MHz, 8-bit transient digitizers.

The most recent result from E787 on $K^+ \rightarrow \pi^+ \overline{\nu} \nu$ is from data collected in 1989, 1990 and 1991. A preliminary analysis of the data from these years uses a total exposure of $3.47 \times 10^{11}$ stopped $K^+$s. Fig. 2.4 shows the candidate events before the final cuts on range and kinetic energy have been applied. The events below the accepted region are consistent with $K_{\pi 2}$ decays where both photons from the $\pi^0$ have been missed. There are several events above the accepted box consistent with $K_{\pi 2}$ events. No events are seen in the signal region. The acceptance for $K^+ \rightarrow \pi^+ \nu \overline{\nu}$ is 0.18%. The acceptance for a two-body decay $K^+ \rightarrow \pi^+ X^0$ is 1.1%. Preliminary branching ratio limits are:

$$\text{BR}(K^+ \rightarrow \pi^+ \nu \overline{\nu}) < 3.7 \times 10^{-9}$$
$$\text{BR}(K^+ \rightarrow \pi^+ X^0) < 6.1 \times 10^{-10}$$

at the 90% confidence level.

The experiment took data during the summer of 1994 with several improvements. The most important of these was a new separated beam line which increases the $K^+$ flux by a factor of about 2.5 per incident proton, and which dramatically improves the purity of the beam, giving a $K^+/\pi$ ratio of 4:1. The ratio was formerly 1:2. Also installed were a new scintillating fiber target, a completely rebuilt trigger system, a new data acquisition computer with associated control software, a new central tracking chamber, new $z$-tracking chambers in the range stack, cesium iodide crystal endcap detectors, and finer segmentation of the inner layers of the range stack.
Figure 2.4: Final sample of candidates from the 1989-91 data before range and kinetic energy cuts have been applied. The box shows the accepted regions for the final cuts. The histograms at the top and left margins are projections of the data.

The AGS booster will started to increase the intensity of the proton beam in 1994. Eventually, the increase will be a factor of about four over the intensity performance of the recent past. Major detector improvements are being contemplated, including an upgrade of the barrel photon detector and further segmentation of the range stack to deal with potential backgrounds from accidentals in the new high rate environment. The ultimate goal of E787 is to see a handful of events if they occur at the Standard Model rate.

3. BNL E791 and E871: $K_L \rightarrow \mu e$

The decay $K_L \rightarrow \mu e$ violates separate lepton number conservation. There is no known symmetry principle to enforce conservation of this quantum number, yet so far, searches in many different reactions have failed to find any violation of this law. If these types of decays exist, they may probe very high mass scales. For the common and rare decay modes shown in Fig. 3.1, where the rare reaction is mediated by a particle $z$, then naively,

$$\Gamma_{\text{common}} \propto \frac{g^4 \sin^2 \theta_C}{M_W^4} \quad \text{and} \quad \Gamma_{\text{rare}} \propto \frac{g_z^4}{M_z^4}$$

This would imply that

$$M_z = (100 \text{ TeV}/c^2) \frac{g_z^2}{g} \left[ \frac{10^{-11}}{\text{BR}(K_L \rightarrow \mu e)} \right]^{1/4}$$
Figure 3.1: Common and rare $K$ decay modes.

Figure 3.2: The E791 detector.

The E791 detector is shown in Fig. 3.2. Two analyzing magnets give redundancy in the momentum and direction measurements and help guard against decays-in-flight. Čerenkov counters and a lead glass array provide electron identification and a muon rangefinder backs up the entire detector.
The kinematic analysis hinges on two quantities, the two-body invariant mass $M_{\mu e}$ and the transverse momentum $P_T$, which is defined as the component of the two-body momentum transverse to the direction defined by the production target and the reconstructed decay vertex.

Particle identification is important to suppress background due to $K_L \rightarrow \pi e\nu$. A single-misidentified background can come from pion decay providing a muon ($\pi \rightarrow \mu \nu$) or a real pion faking a muon in the detector. Double-misidentified background events can also occur, with the pion faking an electron and the electron faking a muon.

![Figure 3.3: Final events from E791, showing $P_T^2$ vs. $M_{\mu e}$. Plus signs are 1989 data and circles are 1990 data.](image)

The experiment is normalized to the (CP-violating) rate of $K_L \rightarrow \pi^+\pi^-$. The trigger for these events were prescaled and taken along with the rare decay triggers. The final result from E791 on $K_L \rightarrow \mu e$ is from data taken in 1989 and 1990. The normalization sample is 46,500 $K_L \rightarrow \pi^+\pi^-$ decays. The data is shown in Fig. 3.3, which shows events passing all particle identification cuts in the plane of $P_T^2$ vs. $M_{\mu e}$. No events are seen in the final accepted region indicated by the box. The result is

$$\text{BR}(K_L \rightarrow \mu e) < 3.9 \times 10^{-11}$$

at the 90% confidence level. If combined with a previous result from 1988 data the limit is

$$\text{BR}(K_L \rightarrow \mu e) < 3.3 \times 10^{-11}$$

at the 90% confidence level.

Experiment 871 will continue the search for rare two-body decays of the $K_L$. Improvements over the previous experiment include a beam plug to help with the accidental rates in the downstream portions of the detector and straw chamber tracking planes. The goal of the experiment is a single event sensitivity to $K_L \rightarrow \mu e$ of about $10^{-12}$. In addition, they hope to collect of order 10,000 $K_L \rightarrow \mu^+\mu^-$ decays (of which E791 already has the world’s largest sample) and perhaps see a few $K_L \rightarrow e^+e^-$ events.
4. FNAL E761: $\Sigma^+$ and $\bar{\Sigma}^-$ Magnetic Moment

The measurements of baryon magnetic moments have historically supported the picture of hadrons given in the static quark model. Over the years the improved precision of these experiments have shown discrepancies with the model, and the need for a deeper understanding of hadron structure. E761 has recently reported a precise measurement of the $\Sigma^+$ magnetic moment. The last two experiments that measured $\mu_{\Sigma^+}$ disagreed by a little over two standard deviations. Also, in addition to hyperon magnetic moments, E761 has also measured asymmetry parameters in radiative hyperon decays.

![Diagram of E761 detector](https://example.com/diagram.png)

**Figure 4.1: Plan view of the E761 detector.**

The detector is shown in Fig. 4.1. Protons of 800 GeV/c were incident on a target inside the upstream end of a 7.3-m-long, 3.5-T magnet, which precessed the hyperons. The targeting angle was variable in both the horizontal and vertical directions, giving control over the direction of the hyperon polarization. Following that were two magnetic spectrometers, a hyperon spectrometer and a baryon spectrometer, the latter to measure the decay proton from $\Sigma^+ \rightarrow p\pi^0$. Currents of all magnets in the experiment could be reversed to select and analyze a positive or negative beam. One of the major experimental difficulties of the experiment was making an accurate measurement of the field integral of the conventional hyperon magnet.

The decays $\Sigma^+ \rightarrow p\pi^0$ and $\bar{\Sigma}^- \rightarrow \bar{p}\pi^0$ are seen by measuring the hyperon momentum, detecting the decay proton or antiproton and reconstructing the missing mass of the decay. Fig. 4.2 shows signals for $\Sigma^+ \rightarrow p\pi^0$ and $\bar{\Sigma}^- \rightarrow \bar{p}\pi^0$. Since the direction of the initial polarization is known, a measurement of the direction of the polarization at decay gives the magnetic moment (the total precession angle is of course only measured modulo $2\pi$, but the magnetic moment is known more than well enough to resolve the ambiguity).

The final result for the $\Sigma^+$ and $\bar{\Sigma}^-$ magnetic moments are $(2.4613 \pm 0.0034 \pm 0.0040)\mu_N$ and $(−2.428 \pm 0.036 \pm 0.007)\mu_N$ respectively. The agreement in magnitude and difference in sign are consistent with CPT invariance. Table 4.1 shows the history of the $\Sigma^+$ magnetic moment, including this measurement.

Table 4.2 summarizes the present experimental situation in hyperon magnetic moments. Comparison is made with a typical fit to the $SU(6)$ quark model. This level of
Figure 4.2: Distributions of mass squared of the missing neutral particle ($X^0$) for (a) $\Sigma^+ \rightarrow pX^0$ for positive beam candidates and (b) $\Sigma^- \rightarrow \bar{p}X^0$ for negative beam candidates.

Table 4.1: Measurements of the $\Sigma^+$ magnetic moment.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Magnetic moment</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settles et al.²⁹</td>
<td>2.3000</td>
<td>0.1400</td>
</tr>
<tr>
<td>Ankenbrandt et al.³⁰</td>
<td>2.4040</td>
<td>0.0198</td>
</tr>
<tr>
<td>Wilkinson et al.³¹</td>
<td>2.4790</td>
<td>0.0251</td>
</tr>
<tr>
<td>Moreles et al.⁸ (E761)</td>
<td>2.4613</td>
<td>0.0052</td>
</tr>
</tbody>
</table>

accuracy along with measurements of other hyperon magnetic moments provide a severe challenge to dynamical calculations of hadron structure.

5. FNAL E799: $K_L \rightarrow e^+e^-e^+e^-$

The main diagram for the decay $K_L \rightarrow e^+e^-e^+e^-$ is shown in Fig. 5.1. One expects that the rate is down by a factor of $\alpha^2$ from that of $K_L \rightarrow \gamma\gamma$, which has a branching ratio of $(5.7 \pm 0.3) \times 10^{-4}$. This decay allows a determination of the $CP$ parameters of the $K_L$ in a purely leptonic final state. Before the result reported here, there were a total of only 8 fully reconstructed events seen in other experiments.²⁵⁻³⁷

The E799 apparatus is essentially the same as that used for E731, whose goal was a measurement of $\epsilon'/\epsilon$. The detector is shown in Fig. 5.2. 800 GeV protons incident on a Be target produced the $K_L$ beam. Drift chambers and an analyzing magnet provide the momentum of the electrons. The lead glass array gives particle identification information.
Table 4.2: Baryon magnetic moments. Moments are in units of nuclear magnetons.

<table>
<thead>
<tr>
<th>Baryon</th>
<th>Moment$^{22}$</th>
<th>QuarkModel</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p$</td>
<td>+2.792847</td>
<td>fixed</td>
<td>—</td>
</tr>
<tr>
<td>$n$</td>
<td>-1.913043</td>
<td>fixed</td>
<td>—</td>
</tr>
<tr>
<td>$\Lambda$</td>
<td>-0.613(04)</td>
<td>fixed</td>
<td>—</td>
</tr>
<tr>
<td>$\Sigma^+$</td>
<td>+2.461(05)</td>
<td>+2.67</td>
<td>-0.207(05)</td>
</tr>
<tr>
<td>$\Sigma^0 \rightarrow \Lambda$</td>
<td>-1.610(80)</td>
<td>-1.63</td>
<td>+0.020(80)</td>
</tr>
<tr>
<td>$\Sigma^-$</td>
<td>-1.160(25)</td>
<td>-1.09</td>
<td>-0.070(25)</td>
</tr>
<tr>
<td>$\Xi^0$</td>
<td>-1.250(14)</td>
<td>-1.43</td>
<td>+0.177(14)</td>
</tr>
<tr>
<td>$\Xi^-$</td>
<td>-0.651(03)</td>
<td>-0.47</td>
<td>-0.161(03)</td>
</tr>
<tr>
<td>$\Omega^-$</td>
<td>-1.940(220)</td>
<td>-1.84</td>
<td>-0.100(220)</td>
</tr>
</tbody>
</table>

Figure 5.1: Diagram for $K_L \rightarrow e^+e^-e^+e^-$. 

The kinematic variables of interest are the four-electron mass $M_{eeee}$ and $P_t^2$, the square of the momentum transverse to the $K_L$ line of flight (defined by the production target and the reconstructed decay vertex).

Fig. 5.3 shows the results of a Monte Carlo simulation of the signal and the kinematic cuts. The data before cuts on $M_{eeee}$ and $P_t^2$ are shown in Fig. 5.4. There are 27 events observed in the signal box. The main backgrounds are due to the decays $K_L \rightarrow e^+e^-\gamma$ with external photon conversion and $K_L \rightarrow \pi^\pm e^\mp \nu e^-e^-$ (a. k. a. radiative $K_{e3}$ with internal photon conversion. The $K_L \rightarrow e^+e^-\gamma$ background is estimated at 0.36 ± 0.7 events in the signal region. Most of the events populating the region outside the signal box are due to $K_L \rightarrow \pi^\pm e^\mp \nu e^-e^-$ with the charged pion misidentified as an electron. The reconstructed mass in these events should be less than 476 MeV/c. The rate from this source in the signal box is estimated at less than 0.01 event.
Figure 5.2: The E799 detector.

Figure 5.3: The $P_t^2$ vs. $M_{eeee}$ distribution from Monte Carlo simulation of $K_L \rightarrow e^+e^-e^+e^-$. The box defines the signal region.

Figure 5.4: The $P_t^2$ vs. $M_{eeee}$ distribution for candidate events from data.
Figure 5.5: The $\phi$ distribution of the data (points) corrected for acceptance and folded into $0^\circ$ to $90^\circ$. The fitted function is also shown.

Normalization was done using the decay $K_L \rightarrow \pi^0 \pi^0 \pi^0$ where two of the pions undergo Dalitz decay. The same trigger was used for normalization and signal events. The relative acceptance correction was dominated by the difference in the geometric acceptance between the eight-body normalization channel and the four-body signal channel, giving a factor of 40.2 ± 1.1 better acceptance for the signal. 1540 normalization events were observed. The result is that

$$\text{BR}(K_L \rightarrow e^+e^-e^+e^- (\gamma)) = (3.96 \pm 0.78 \pm 0.32) \times 10^{-8},$$

where the relative acceptance calculation takes into account the possibility of a radiated photon in both signal and normalization events.

With sufficient statistics, this leptonic decay could be used to look for evidence of $CP$ violation independent of hadronic decay modes. If the $CP$ eigenstates of the neutral kaon are $K_1$ (even) and $K_2$ (odd), with

$$K_L = \frac{K_2 + eK_1}{\sqrt{1 + |e|^2}}$$

then from hadronic decays it is known that $e$ has the value $2.3 \times 10^{-3}$. In fact, if the admixture of $CP$ even and odd in the leptonic final state were different than that of the $K_L$, that would be evidence for direct $CP$ violation. Putting aside direct $CP$ violation however, the distribution of the angle $\phi$ between the two decay planes of the $e^+e^-$ pairs is given by

$$\frac{dn}{d\phi} = A \left[ 1 + \frac{1 - |er|^2}{1 + |er|^2} B \cos 2\phi + \frac{2\text{Re}(er)}{1 + |er|^2} C \sin 2\phi \right]$$

where $A$, $B$ and $C$ are constants and $r$ is the ratio of the amplitude for $K_1 \rightarrow e^+e^-e^+e^-$ to that for $K_2 \rightarrow e^+e^-e^+e^-$. It is expected to be of order unity. If the distribution from $90^\circ$ to $180^\circ$ is folded over on to that from $0^\circ$ to $90^\circ$, then the term proportional to $C$ drops out. $B$ has been calculated to be $-0.20$ using a Monte Carlo simulation based on the Kroll-Wada formula. A fit to the data is shown in Fig. 5.5. The result is that $|er|^2 = -0.036^{+0.45}_{-0.36}$. 
Figure 5.6: The Monte Carlo distribution of the log of the likelihood ratio $\ln \lambda$ for $CP = -1$ (solid line) and $CP = +1$ (dashed line). The location of the value of $\ln \lambda$ from the data is also shown.

If $CP$ is assumed to be conserved, then this decay can be used to check whether the $K_L$ is $CP$ even or odd. In this case the probability distribution is

$$
\frac{dn}{d\phi} = A(x_1, y_1, x_2, y_2)[1 \pm \alpha(x_1, y_1, x_2, y_2) \cos 2\phi]
$$

where $x$ and $y$ are kinematic quantities given by $x^2 = (E_+ + E_-)^2 - (p_+ + p_-)^2$ and $y = |E_+ - E_-|/|p_+ + p_-|$ with subscripts 1 and 2 referring to the two $e^+e^-$ pairs. The plus sign corresponds to the $CP$ even case and the minus sign to the $CP$ odd case. Using the 27 observed signal events, the product of likelihood ratios

$$
\lambda = \prod_{i=1}^{27} \frac{1 - \alpha_i \cos 2\phi_i}{1 + \alpha_i \cos 2\phi_i}
$$

is calculated to be 2392. The same product is calculated for an ensemble of Monte Carlo experiments where in each, 27 events are detected, separately for $CP$ even and odd assumptions. The resulting distributions of $\lambda$ are shown in Fig. 5.6 along with the value from the data. The probability of obtaining a value of $\lambda$ greater that that of the data is 14% and 0.04% for $CP$ odd and even distributions respectively, supporting the $CP$ odd hypothesis. So indeed, we should expect the $K_L$ to decay to three pions!
References

2. Preliminary result.
3. Analysis in progress.
5. A. Heinson et al., submitted to Phys. Rev. D.
15. Accepted for publication in Phys. Rev. Lett.
16. Submitted for publication.
30. C. Ankenbrandt et al., Phys. Rev. Lett. 51, 863 (1983). The authors of Ref. 8 have re-measured the field integral of the hyperon magnet used in this experiment. The value report in the table has been corrected to reflect this re-measurement.