First measurement of branching ratio and g_1/f_1 of the neutral cascade hyperon using final state polarization

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The KTeV collaboration has made a first observation of neutral cascade beta decay ($\Xi^0 \rightarrow \Sigma^+ e^- \overline{\nu}$). We present measurements of the branching ratio and form factors for this semi leptonic process. The results agree well with the Cabibbo $SU(3)_f$ theory and do not favor attempts to include symmetry breaking effects.

1. INTRODUCTION

Since the bare quarks are not accessible for carrying out direct measurements, the Hyperon Octet affords the best available laboratory for studying the weak interactions between the light quarks, u,d,s and the leptons (Fig. 1). Up to now, neutral cascade beta decay was the last missing entry of the obviously accessible processes. This decay is of particular interest because it is the $SU(3)_f$ analog of the well-studied neutron decay. This is therefore an excellent case for probing $SU(3)_f$ symmetry breaking effects. The KTeV collaboration has now observed this decay and reports results on both branching and form factors.

2. EXPERIMENTAL METHOD

The KTeV apparatus is designed to study CP violation in neutral kaon decay as well as rare kaon decays. In addition, there is a sufficient flux of neutral cascade Hyperon to also study semi-leptonic and radiative decays. To study the hyperons, we instrumented the beam region in order to trigger on the high momentum forward proton characteristic of all decay channels of interest.

Our events of interest are neutral cascades that decay to Σ^+, electron, antineutrino followed by the subsequent decay of $\Sigma^+ \rightarrow p\,\pi^0$. The decay $\Sigma^+ \rightarrow p\,\pi^0$ has a decay asymmetry of 98% making this the equivalent of an essentially fully polarized beta decay measurement. Only the semileptonic decay produces a Σ^+which thereby serves as a unique signature.

3. BRANCHING RATIO

Fig. 2 shows our two-body and beta decay event samples. The back ground is about 10% and well simulated as resulting from neutral kaon decays. Our result is: B.R. =

$2.54 \pm 0.11(stat) \pm 0.16(sys) \times 10^{-4}$ which agrees well with the $SU(3)_f$ value of $2.61 \pm 0.11 \times 10^{-4}$.

4. FORM FACTORS

The observables in our beta decays in addition to branching ratios and energy spectra are several angular correlations: electron neutrino, electron proton and neutrino proton. To interpret these in terms of the form factors of the hadron current, f_1, g_1 requires expressing the angular distribution in terms of the polarization of the final state baryon. Accordingly we have derived highly transparent expressions which are accurate to second order in q/M of the decay, that is to a few percent. (S. Bright et al, to be published in Phys Rev D) To demonstrate our ability to measure angular correlations we show the proton lambda spin correlation for the 2-body mode (figure 3). Our result $\alpha_{\Xi^0}\alpha_\Lambda = -.288 \pm 0.007(stat) \pm 0.016(sys)$ agrees well with the accepted PDG value of -0.264 ± 0.013. Our beta decay events are remarkably low in background (only 2 %) and the background is well simulated from $K_L$decays. We study our beta decay correlations in the Σ^+rest frame. Our electron correlation is as large as possible. Combining all observed correlations with the branching ratio provides a 2-dimensional fit to f_1 and g_1 (figures 4,5).

5. DISCUSSION

Our results are in better agreement with the Cabibbo $SU(3)_f$ value (same as neutron decay) than with any of the various models that attempt to include $SU(3)_f$ breaking effects. While we await more data from our ongoing experiment to sharpen the precision one may already observe that the beta decays of the octet of hyperons agree remarkably well with the original Cabibbo $SU(3)_f$ predictions.

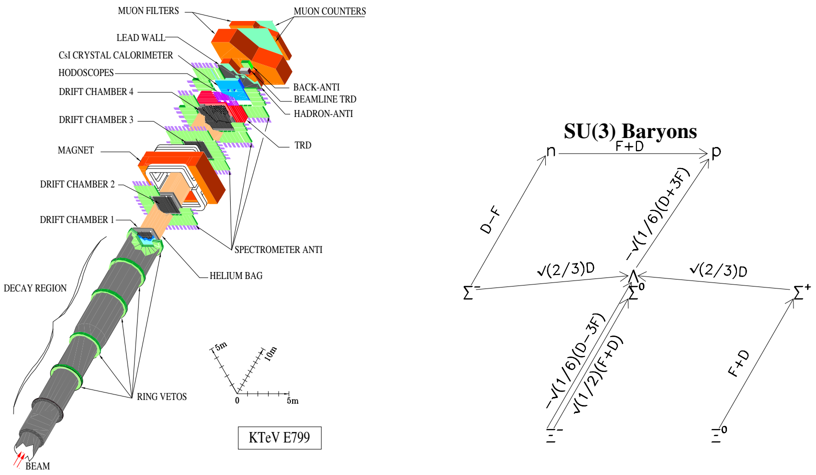

Figure 1. The KTeV detector (left) and a diagram of the octet baryons, with the F and D coefficients for the observed hyperon beta decays (right).

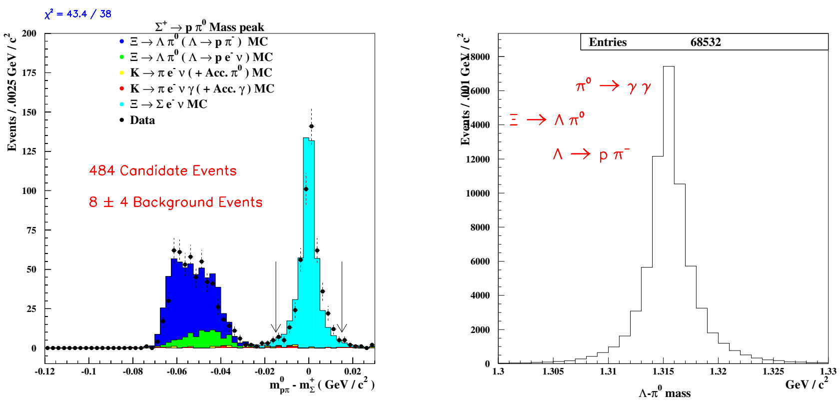

Figure 2. Mass peaks for the signal $\Xi^0 \rightarrow \Sigma^+ e^- \overline{\nu}$ (left) and normalization mode $\Xi^0 \rightarrow \Lambda\pi^0$ with $\Lambda \rightarrow p\pi^-$(right) .

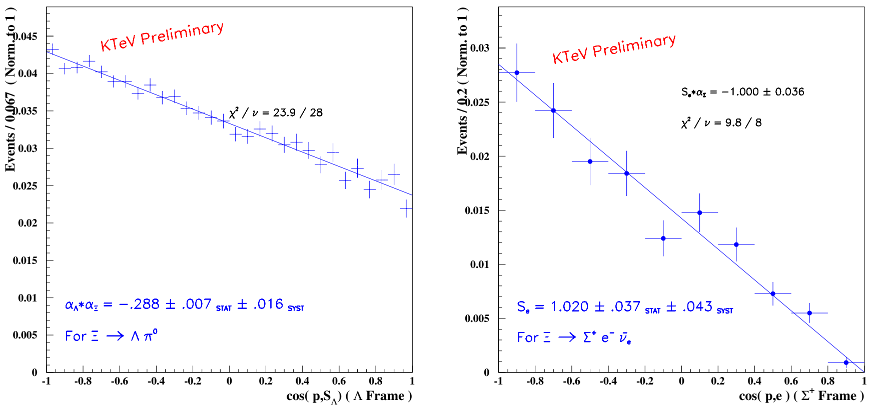

Figure 3. Acceptance corrected proton-electron correlation for $\Xi^0 \to \Sigma^+ e^- \overline{\nu}$ (left), and Acceptance corrected longitudinal Λ polarization for$\Xi^0 \to \Lambda\pi^0$ with $\Lambda \to p\pi^-$(right).

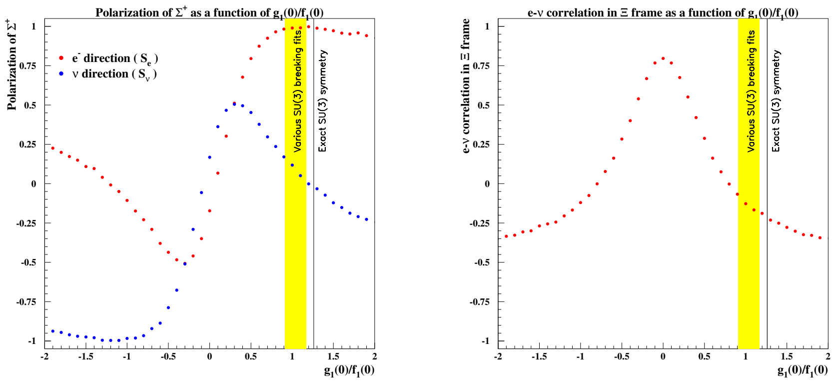

Figure 4. The polarization of the Σ^+in the electron and neutrino directions (left) and the electron-neutrino correlation (right) for $\Xi^0 \to \Sigma^+ e^- \overline{\nu}$.

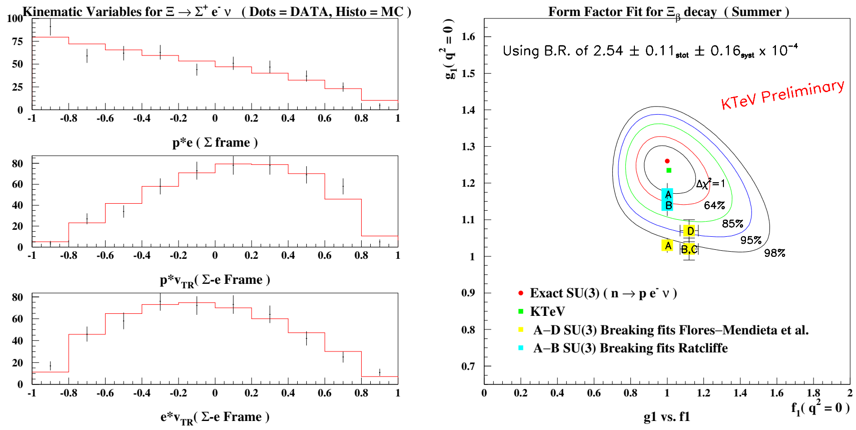

Figure 5. Kinematic distributions used in obtaining g_1/f_1(left) and fit for f_1 and g_1 using measured $g_1/f_1$and rate (left).