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# Hyperon Static Properties

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# Hyperon Static Properties

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I review the static properties of the hyperons including masses, lifetimes, magnetic moments and CPT test from the asymmetries of these quantities for hyperon and anti-hyperon.

## 1. INTRODUCTION

The static properties of the hyperons include masses, lifetimes, magnetic moments and CPT test from the asymmetries of these quantities for hyperon and anti-hyperon. I will review the present status of these measurements with an eye toward identifying places where new or improved measurements can have a significant physics impact. Most of these measurements are from the PDG [1] where there have been only two new measurements quoted since 1995. I also report two new measurements not yet published.

## 2. CPT TESTS

All the hyperon static properties have invariant magnitudes under CPT, or hyperon, anti-hyperon transformations. The masses and lifetimes should be the same while the magnetic moments should change sign under CPT. If the mass of particle and anti-particle differ under CPT then the lifetimes will also differ just from the difference in available phase space. There are no real models for CPT violation. The $K^0$ system is probably the most sensitive place to look for such violations. Nonetheless, there are high precision measurements available in the baryon sector so we can, and therefore must, look. In Figure 1 I plot the asymmetries (absolute value of the difference over the average) for the measured hyperon masses, lifetimes and the $\Sigma^+$ magnetic moment. I also include the proton and neutron mass asymmetries since the proton mass asymmetry is by far the most precise test in this sector. All these measurements are consistent with zero to within their errors.

A new measurement of the lifetimes of the $\Sigma^+$ and $\overline{\Sigma}^-$ comes from E761, our old $\Sigma^+$ radiative decay experiment which took data in 1990.

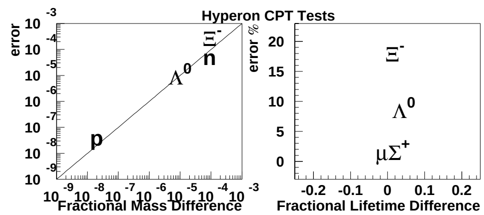


Figure 1. Hyperon mass, lifetime and magnetic moment CPT tests

This experiment was originally mounted to make precise measurements of the branching ratio and asymmetry parameter in the hyperon weak radiative decays $\Sigma^+ \to p\gamma$ and $\Xi^- \to \Sigma^-\gamma$. In the course of this run a sample of data was taken with all the magnetic fields reversed yielding a matched set of positive and negative hyperon beam data in the same apparatus. A lifetime analysis of these data [2] yield $\tau[\Sigma^+] = 80.38 \pm 0.40 \pm 0.14$ psec and $\tau[\overline{\Sigma}^-] = 80.43 \pm 0.80 \pm 0.14$ psec based upon 640K and 132K events respectively. The $\Sigma^+$ lifetime asymmetry is $\Delta\tau/<\tau>$ $= -0.06 \pm 1.12\%$ making this measurement the best baryon lifetime CPT test.

## 3. MAGNETIC MOMENTS

The hyperon magnetic moments are major experimental success story. Since the advent the polarized hyperon beams in 1976 all the accessible magnetic moments in the baryon octet have been measured with high precision.

The traditional first level description of the hyperon magnetic moments is the simple $SU_6$ additive quark model which assumes fixed moments for each flavor of quark and no orbital angular

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momentum. It predicts all the moments in terms of the measured moments of (p, n, $\Lambda^0$) which fix the (u, d, s) quark moments. The PDG [1] averages for the moments are shown in Table 1. The deviations from the $SU_6$ model are at the $5-10\%$ level as expected for an $SU_3$ based model. These deviations are very well measured. Many models have been advanced in the past 30 years to go beyond simple $SU_6$. However, no more advanced model seems to do substantially better than simple $SU_6$. This is an experimentally finished program until somebody can build a better baryon model which challenges the precisions of the present measurements.

## 4. LIFETIMES

The present status of the measurements of the lifetimes of the hyperons from the PDG [1] are shown in Figure 2. All are measured to better than 1% except $\tau_{\Xi^0}$ and $\tau_{\Omega^-}$. Both KTeV at Fermilab and NA48 at CERN are collecting large samples of $\Xi^0$. It is reasonable to project that this lifetime should be improved to the 1% level in the near future. Likewise HyperCP at Fermilab is collecting a large samples of $\Omega^-$ from which they should be able to improve this lifetime measurement to the 1% level.

Precision lifetime measurements require an apparatus with good resolution and excellent simulation of acceptance and resolution smearing effects. These are particular strengths of experiments like KTeV, NA48 and HyperCP. While it is difficult to foresee the systematic limitations of a given measurement in one of these experiments I have no doubt that each can make significant improvements to these measurements given the will to undertake the analysis.

A most important use of precision lifetimes is in the analysis of the hyperon semi-leptonic decays. The relationship between the directly measured semi-leptonic branching ratio [B] and the decay rate predicted by theory [$\Gamma$] is B=$\Gamma\tau$. The lifetime must be known more precisely, fractionally, than the branching ratio in order to fully exploit the semi-leptonic branching ratio measurements in testing the theory. This is particularly important in exploiting the recent $\Xi^0$ semi-leptonic decays observed by KTeV and NA48. This should provide the motivation for them to improve the lifetime measurement of this state.

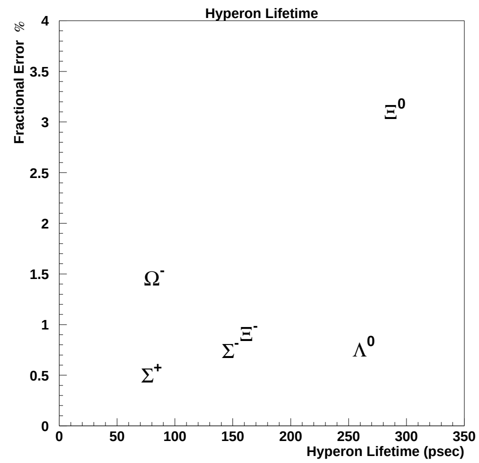


Figure 2. Present PDG values of the hyperon lifetimes and fractional precisions

## 5. MASSES

The mass spectrum of the baryons is an enduring subject. An early and seminal contribution is the Coleman-Glashow mass relation [3] which relates the the isopsin splittings of the three I spin multiplets of the baryon octet:

$$M_n - M_p + M_{\Xi^-} - M_{\Xi^0} + M_{\Sigma^+} - M_{\Sigma^-} = 0 \quad (1)$$

More recent work is this area includes papers by Jon Rosner [5] and Elizabeth Jenkins [4] and references therein. There are many sum rules of this type. All the others involve the masses of decuplet, charm or beauty baryons. Beyond 100 $KeV/c^2$ the precision of these sum rules should be limited by the theory.

The present status of the measurements of the masses of the hyperons from the PDG [1] are shown in Figure 3. All are known to the 100 $KeV/c^2$ level or better save the $\Xi^0$ and $\Omega^-$. NA48 has recently reported [6] a preliminary new measurement of the $\Xi^0$ mass with a precision of 200 $KeV/c^2$. The error given is dominated by systematics uncertainties which they may be able to improve further with a complete analysis of all their data. KTeV may also be able to improve this measurement. HyperCP at Fermilab has enormous samples of both $\Xi^-$ and $\Omega^-$ decays. In principle they ought to be able to significantly improve the mass measurements for both of these states.

Table 1
Hyperon Magnetic Moments (NM)

| Hyperon | Moment | Quark Model | Difference |
|---|---|---|---|
| p | $+2.792847$ | fixed | ——- |
| n | $-1.913043$ | fixed | ——- |
| $\Lambda^0$ | $-0.613(04)$ | fixed | ——- |
| $\Sigma^+$ | $+2.458(10)$ | $+2.67$ | $-0.210(10)$ |
| $\Sigma^0 \to \Lambda^0$ | $-1.610(80)$ | $-1.63$ | $+0.020(80)$ |
| $\Sigma^-$ | $-1.160(25)$ | $-1.09$ | $-0.070(25)$ |
| $\Xi^0$ | $-1.250(14)$ | $-1.43$ | $+0.177(14)$ |
| $\Xi^-$ | $-0.6517(25)$ | $-0.47$ | $-0.161(03)$ |
| $\Omega^-$ | $-2.024(56)$ | $-1.84$ | $-0.184(56)$ |

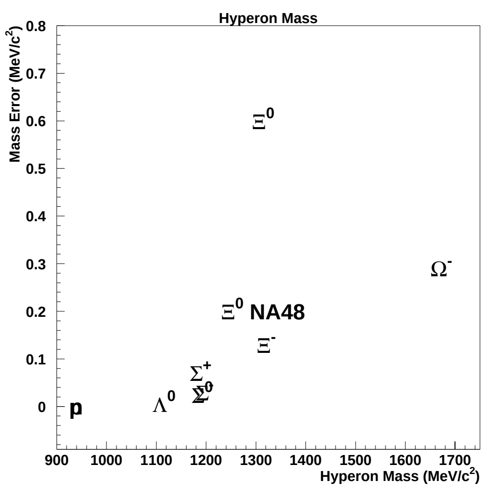


Figure 3. Present PDG values of the hyperon masses and precisions

The present experimental value for the Coleman-Glashow sum rule is $-0.37 \pm 0.62$ dominated by the uncertainty on $M_{\Xi^0}$. Using the preliminary NA48 value of $M_{\Xi^0}$ improves this the test of this sum rule to $-0.30 \pm 0.25$. The next biggest uncertainty is in $M_{\Xi^-}$ which HyperCP may be able to improve.

## 6. CONCLUSIONS

With the anticipated new results from NA48, KTev, HyperCP, and perhaps some older experiments like E761, typical precisions on the static properties of the hyperon will approach:

| | |
|---|---|
| mass | $100\ KeV/c^2$ |
| life time | 1% |
| magnetic moment | 0.025 NM |

In all three cases these precisions are higher than that expected from present theory and models. There does not appear to be a compelling reason to mount a new experiment to significantly improve any of these measurements at this time.

This body of work is an operational definition of precision particle physics. These measurements are all now sufficiently precise to present serious challenges to model builders. However in the tennis game between experiment and theory we experimentalists will have to wait for them to hit this ball back over the net before it is worth having another swing at it.

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