SU(3) Breaking in Hyperon Beta Decays: a Prediction for $\Xi^0 \to \Sigma^+ e\bar{\nu}$

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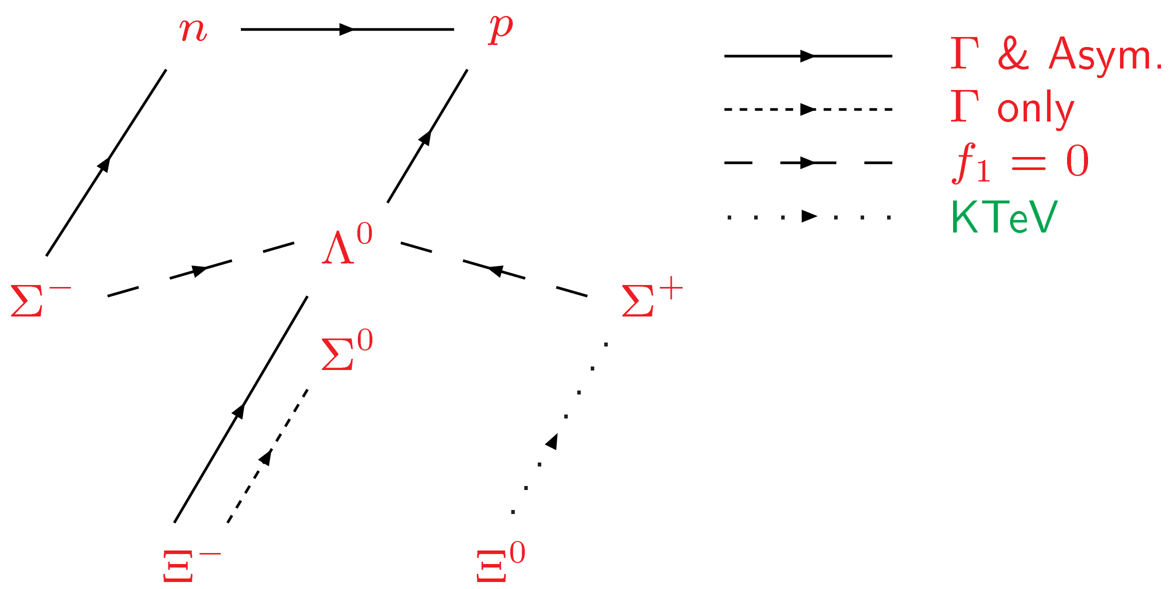
Outline

- The HSD Data: rates & angular correlations
- SU(3) Breaking: models for mass effects
- Fit Results: SU(3) parameters F and D
- A Prediction: comparison with another approach
- Conclusions: a satisfactory picture is emerging
  but there is still a need for testing

The HSD Data



The present world data (the values for g_1/f_1 are extracted from angular correlations).

Decay	$\Gamma \quad (10^6\,\mathrm{s}^{-1})$		g_1/f_1	
$B \quad \to B'\ell\nu$	$\ell = e^-$	$\ell = \mu^-$	$\ell = e^-$	SU(3)
$n \quad \to p$	1.1274 ± 0.0025		1.2601 ± 0.0025	$F + D$
$\Lambda^0 \to p$	3.161 ± 0.058	0.60 ± 0.13	0.718 ± 0.015	$F + D/3$
$\Sigma^- \to n$	6.88 ± 0.23	3.04 ± 0.27	-0.340 ± 0.017	$F - D$
$\Sigma^- \to \Lambda^0$	0.387 ± 0.018			$-\sqrt{\frac{2}{3}}\,D$
$\Sigma^+ \to \Lambda^0$	0.250 ± 0.063			$-\sqrt{\frac{2}{3}}\,D$
$\Xi^- \to \Lambda^0$	3.35 ± 0.37	2.1 ± 2.1	0.25 ± 0.05	$F - D/3$
$\Xi^- \to \Sigma^0$	0.53 ± 0.10			$F + D$

1. Γ for $n \to p$ in units of $10^{-3}\,\mathrm{s}^{-1}$.
2. Scale factor 2 for error on Γ in $\Xi^- \to \Lambda^0$ (PDG practice for discrepant data).
3. Absolute expression for g_1 in $\Sigma^\pm \to \Lambda^0$ given as $f_1 = 0$.
4. $\Xi^- \to \Lambda^0$ μ-mode data are not used in fits.
5. Values in green have precision 5% or better.

SU(3) Breaking

SU(3) breaking is well described using centre-of-mass (CoM), or recoil, corrections [Donoghue, Holstein and Klimt (DHK)].

Approach A: CoM corrections to g_1 for $A \to B\ell\nu$. Momentum smearing describing an extended object leads to:

$$g_1 = g_1^{\mathrm{SU(3)}} \left[1 - \frac{\langle p^2 \rangle}{3 m_A m_B} \left(\frac{1}{4} + \frac{3 m_B}{8 m_A} + \frac{3 m_A}{8 m_B} \right) \right]$$

Approach B (similar): breaking ascribed to mass effects in the interaction hamiltonian via first-order PT [Ji & PGR].

The result is equivalent to a linearised version of the above:

$$g_1 = g_1^{\mathrm{SU(3)}} \left[1 - \epsilon (m_A + m_B) \right]$$

Comments:

- Both normalised to the reference-point correction for $g_1^{n \to p}$.
- Corrections to f_1 are negligible (Ademollo-Gatto).
- Residual $\sim$2% correction to $|\Delta S{=}1|$ decays marginally improves the fit without altering the results. DHK used a much larger value $\sim$8%.

Fit Results

Results of three fits: Sym., A and B.

SU(3) symmetric and breaking fits, including V_{ud} & V_{us} from nuclear ft and $K_{\ell 3}$ analyses.

Fit	Parameters			χ^2/DoF	F/D
	V_{ud}	F	D		
Sym.	0.9749 ± 0.0003	0.465 ± 0.006	0.798 ± 0.006	2.3	0.582
A	0.9743 ± 0.0004	0.460 ± 0.006	0.806 ± 0.006	1.2	0.571
B	0.9744 ± 0.0004	0.459 ± 0.006	0.807 ± 0.006	1.2	0.571

Notes:

- The value of V_{ud} (and hence V_{us}) is fixed mainly by ft and $K_{\ell 3}$ analyses.
- If V_{ud} and V_{us}) are determined from HSD data alone, all central values are very similar.
- F and D are insensitive to the breaking.
- The data demand corrections and CoM or mass-driven breaking is sufficient.
- The angular-correlation data alone require no breaking.

A Prediction

The axial coupling, rate and branching fraction (B) for $\Xi^0 \to \Sigma^+ e\bar{\nu}$. The errors are those returned by the fitting routine.

Fit	g_1/f_1	Γ ($10^6\,\mathrm{s}^{-1}$)	B (10^{-4})
Sym.	1.26	0.89 ± 0.01	2.58 ± 0.05
A	1.17 ± 0.03	0.80 ± 0.03	2.32 ± 0.10
B	1.14 ± 0.03	0.78 ± 0.03	2.26 ± 0.12

No error is assigned to g_1/f_1 in the symmetric fit; it would be that of neutron β-decay.

A $1/N_c$ expansion approach [Flores-Mendieta, Jenkins and Manohar]: leads to g_1/f_1 considerably smaller than here.

$$f_1 = 1.12 \text{ and } g_1 = 1.02, \text{ or } g_1/f_1 = 0.91 \text{ (their fit B)},$$

leading to $\Gamma = 0.68 \times 10^6\,\mathrm{s}^{-1}$; they also obtain $F/D = 0.46$.

Both g_1/f_1 and Γ are smaller than those presented here, which are in turn smaller than the naïve SU(3) fit.

Thus, all possibilities should be distinguishable in an experiment with good statistics, such as KTeV.

N.B. The Flores-Mendieta *et al.* fit includes baryon-decuplet non-leptonic decay data, which dominate. The overall fit (*i.e.*, χ^2) is poor. However, their approach applied to the HSD data alone produces results similar to those reported here.

Conclusions

We are still far from a complete and reliable picture of SU(3) breaking in this sector (witness the octet-decuplet discrepancy and the $|\Delta S{=}1|$ uncertainties).

The system is still not really over-constrained.

Another decay for which large corrections to rates and angular correlations are expected is $\Xi^- \to \Sigma^0 e\nu$.
There too $g_1/f_1 = F + D$, allowing for sensitive cross checks.

N.B. Despite being easier to analyse, the angular correlation data alone do not require SU(3) breaking: only full analyses display the true picture.

The present situation:

- The data display significant breaking effects.
- Mass-breaking driven schemes are satisfactory.
- There is still much to be understood.
- As usual . . . we do need more data!