Hyperon Decay 2007

- CP violation in kaon decay measured
  - both ϵ and ϵ' have been measured
- Rare kaon decay $K \to \pi\, \nu\, \nu$ program ongoing
- Hyperon weak decay occurs through the same effective transition as kaon weak decay:

$$s \longrightarrow d$$

- So why is hyperon decay still interesting?

- Because the hyperon decay amplitude is simultaneously sensitive to both parity conserving and parity violating weak interactions.
- CP violation in hyperon decay within the SM is correlated to ϵ' *and* it is small.
- CP violation in hyperon decay beyond SM is limited by theoretical uncertainty in ϵ, *and* can be much larger.

CP Violation in hyperon decay

- Compare hyperon and anti-hyperon decay
- Each decay of the form B′ → B π has s-wave and p-wave amplitudes which could be ΔI=1/2 or ΔI=3/2.
- The angular distribution with polarized B′ is

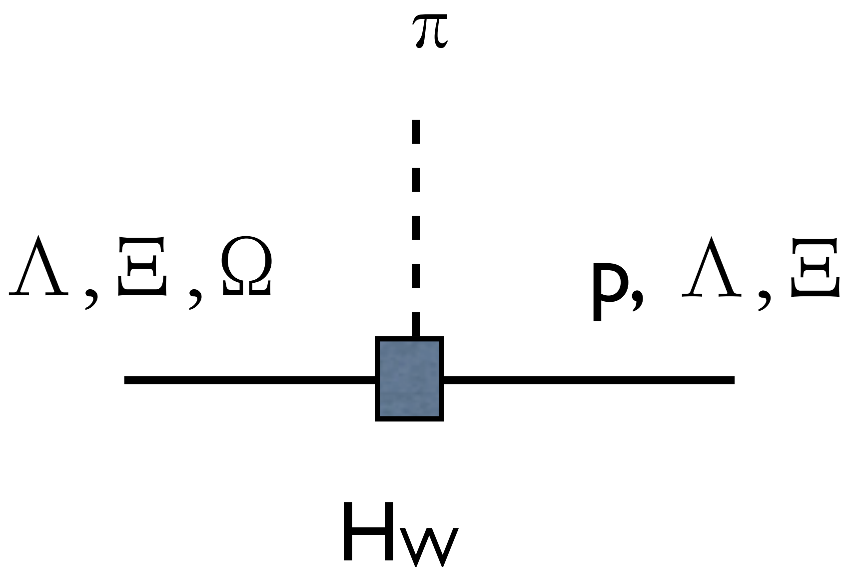
$$\Lambda \to p\pi^-: \qquad \frac{d\mathrm{N(p)}}{d\cos\theta} = \frac{\mathrm{N}_0}{2}(1+\alpha_\Lambda P_\Lambda \cos\theta) \qquad \alpha = \frac{2\mathrm{Re}(S^*P)}{|S|^2+|P|^2}$$

- Two CP odd observables are

$$\Delta \equiv \frac{\Gamma-\bar{\Gamma}}{\Gamma+\bar{\Gamma}} \sim \sqrt{2}\frac{S_3}{S_1}\sin(\delta_3^S-\delta_1^S)\sin(\phi_3^S-\phi_1^S)$$

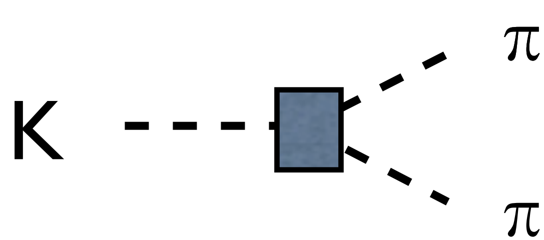
$$A(\Lambda_-^0) \equiv \frac{\alpha+\bar{\alpha}}{\alpha-\bar{\alpha}} \sim -\sin(\delta_1^P-\delta_1^S)\sin(\phi_1^P-\phi_1^S) \sim 0.12\sin(\phi_1^P-\phi_1^S)$$

S (or D) waves

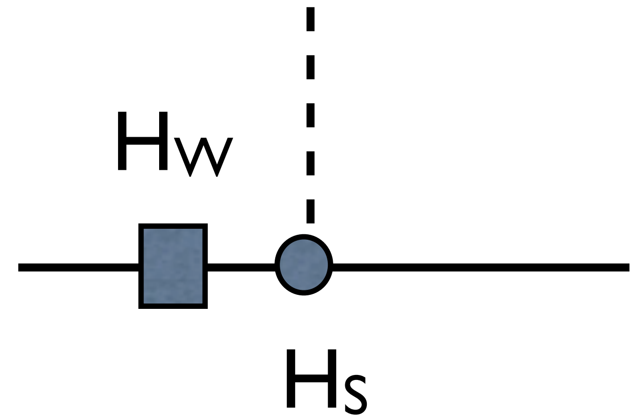


H_W parity violating

CP constraint from ϵ'

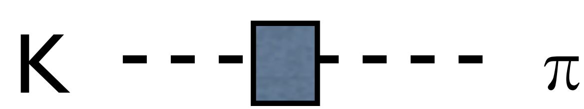


P waves



parity conserving

constraint from ϵ

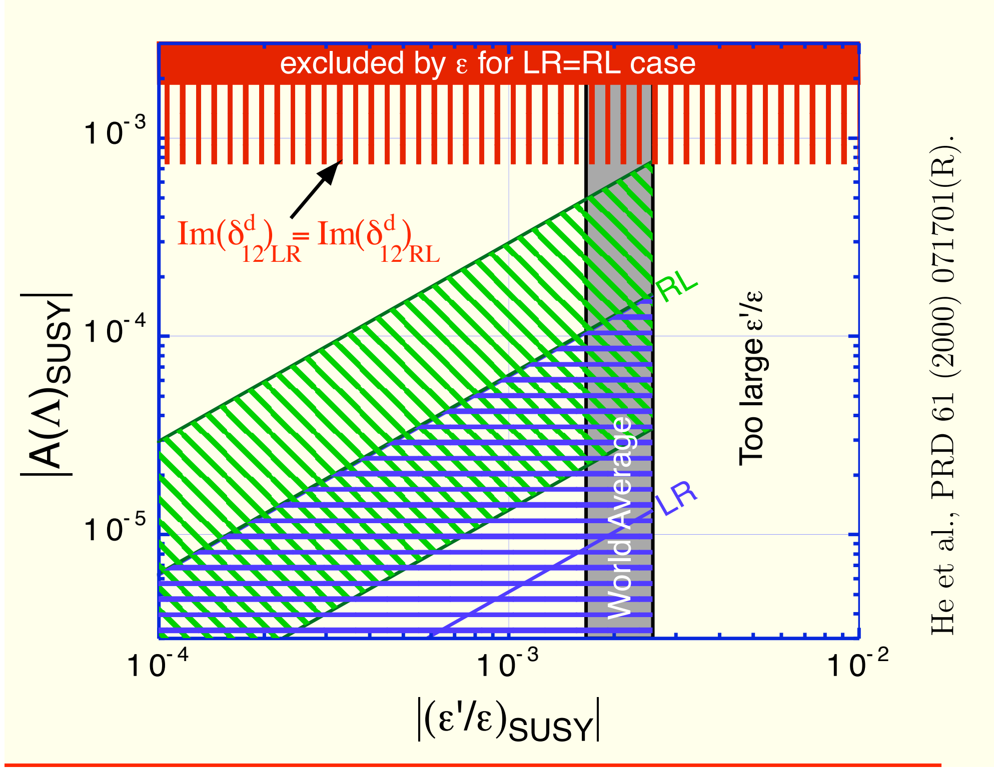


HyperCP looked for asymmetry in $\Xi^- \rightarrow \Lambda\pi^- \rightarrow p\pi^-\pi^-$

Most recent SM prediction $-0.5\times10^{-4} < A_{\Xi\Lambda} < +0.5\times10^{-4}$

Beyond the SM, bounds from ϵ allow up to 10^{-3}

SUSY example:



HyperCP result $A_{\Xi\Lambda} = [0.0\pm5.1(\mathrm{stat})\pm4.4(\mathrm{syst})]\times10^{-4}$

Phys.Rev.Lett.93:262001,2004.

CP Violation in Ω Decay

$$\mathrm{i}\mathcal{M}_{\Omega^-\to\Xi\pi} = G_{\rm F} m_\pi^2\, \bar{u}_\Xi\, \mathcal{A}^{(\rm P)}_{\Omega^-\Xi\pi}\, k_\mu\, u_\Omega^\mu \equiv G_{\rm F} m_\pi^2\, \frac{\alpha^{(\rm P)}_{\Omega^-\Xi}}{\sqrt{2}\, f_\pi}\, \bar{u}_\Xi\, k_\mu\, u_\Omega^\mu \,,$$

$$\begin{aligned}\Delta(\Xi^0\pi^-) &\equiv \frac{\Gamma(\Omega^-\to\Xi^0\pi^-) - \Gamma(\overline{\Omega}^-\to\overline{\Xi}^0\pi^+)}{\Gamma(\Omega^-\to\Xi^0\pi^-) + \Gamma(\overline{\Omega}^-\to\overline{\Xi}^0\pi^+)} \\ &\approx \sqrt{2}\,\frac{\alpha_3^{(\Omega)}}{\alpha_1^{(\Omega)}}\, \sin(\delta_3-\delta_1)\, \sin(\phi_3-\phi_1) \,,\end{aligned}$$

P-wave dominance (predominantly parity conserving)

SM ~ 2 x 10^{-5} much larger than other rate asymmetries

Beyond SM could be 10-100(?) times larger

Tandean 04: $\Delta_{\Omega\to\Lambda K} < 10^{-3}$ (but new constraints now)

Phys.Rev.D70:076005,2004.

Why is it larger in SM?

- The $\Delta I=3/2/\Delta I=1/2$ amplitude ratio is about 7% from data (50% error?)
- The strong $\Xi\pi$ scattering phases estimated in lowest order χPT $(\delta_1-\delta_3)\sim-14^\circ$ (error?)
- The weak phases are estimated in vacuum saturation to be $(\phi_1-\phi_3)\sim 0.001$ (tree

  operator suppressed, phase closer to phase of penguin >> other hyperon decays)

from Tandean, Valencia **Phys.Lett.B451:382-387,1999,**

Phys.Lett.B452:395-401,1999