Baryon weak decays - from experiment to lattice QCD

Mar 4 – 5, 2024
Europe/Warsaw timezone

Exploration of new EU projects and collaborations for strange and charm baryons decays (Experiment, Phenomenology, Lattice)

Probing baryon weak decays - from experiment to lattice QCD

6–7 Mar 2023
Warsaw, Pasteura 7
Europe/Warsaw timezone

CPV tests in baryon decays

Conclusions from the first workshop and the scope of this workshop

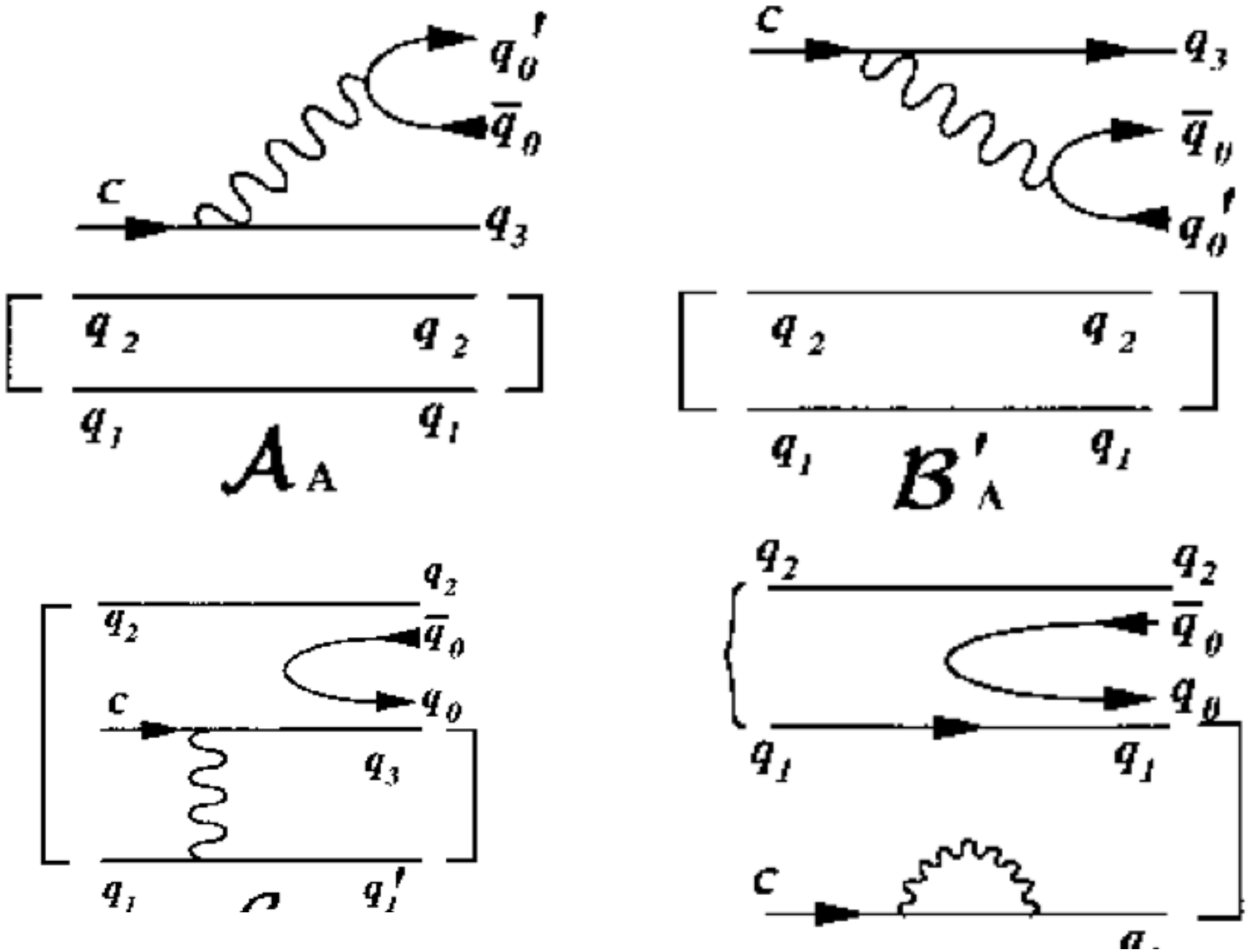
Non-leptonic 2body decays			
(strange) $B_s \rightarrow$B+P	**exp**	**ph**	lattice
(charm) $B_c \rightarrow$B+P	**exp**	**ph**	~~lattice~~
Semi-leptonic decays:			
(strange) $B_s \rightarrow B + l\nu_l$	**exp**	**ph**	lattice
(charm) $B_c \rightarrow B + l\nu_l$	**exp**	**ph**	lattice
Weak radiative/conversion decays			
(strange) $B_s \rightarrow \mathrm{B} + \gamma^{(*)}$	**exp**	ph	**lattice**]
Non-leptonic quasi 2 body and 3 body decays			
(charm) $B_c \rightarrow B^* + P$ or $B_c \rightarrow B + M^*$	**exp**	**ph**	~~lattice~~

$$B_s \to B + P$$

	D	$\mathcal{B}$	$\langle \alpha_D \rangle$	$\langle \phi_D \rangle$ (rad)	A_{CP}	Comment
$\Lambda \to p\pi^-$	[Λp]	64%	**0.755(03)**[a]	**−0.113(61)**[b]	**−0.005(10)**[a]	
			0.754(3)(2)	...	−0.006(12)(7)	BESIII [31]
			0.721(6)(5)[*]	...	...	CLAS [47]
			0.760(6)(3)	...	−0.004(12)(9)	BESIII [32]
$\Lambda \to n\pi^0$	[Λn]	36%	**0.692(17)**[c]	...	...	BESIII [31]
$\Sigma^+ \to p\pi^0$	[Σp]	52%	**−0.994(04)**[d]	**0.63(59)**[g]	**−0.004(37)**[d]	
$\Sigma^+ \to n\pi^+$	[Σn]	48%	**0.068(13)**[*]	**2.91(35)**[*]	...	PDG [28]
$\Sigma^- \to n\pi^-$	[$\Sigma-$]	100%	**−0.068(08)**[*]	**0.17(26)**[*]	...	PDG [28]
$\Xi^0 \to \Lambda\pi^0$	[$\Xi 0$]	100%	**−0.345(08)**[e]	**0.36(21)**[*]	...	AVG [48,49]
$\Xi^- \to \Lambda\pi^-$	[$\Xi-$]	100%	**−0.379(04)**[f]	−0.042(16)[*]	...	AVG [28,50]
			−0.373(5)(2)	0.016(14)(7)	**0.006(13)(6)**	BESIII [32]

$$\Omega^- \to \Lambda + K^-, \Xi^0\pi^-, \Xi^-\pi^0$$

$$B_c \to B + P$$



c
q0'
q̄0
q3
q2
q2
q1
q1
A A
c
q3
q̄0
q0'
q2
q2
q1
q1
B' A
q2
q2
q̄0
c
q0
q3
q1
q1'
q2
q2
q̄0
q0
q1
q1
c

$B_c \to B + P$ measured

Channels	$\mathcal{B}_{\text{exp}}(\%)$	α_{exp}	$\mathcal{B}(\%)$	α	β	γ
$\Lambda_c^+ \to pK_S$	1.59(8)	*0.18(45)	1.55(7)	−0.40(49)	0.32(29)	−0.86(19)
$\Lambda_c^+ \to \Lambda^0\pi^+$	1.30(6)	−0.755(6)	1.29(5)	−0.75(1)	−0.13(19)	−0.64(4)
$\Lambda_c^+ \to \Sigma^0\pi^+$	1.27(6)	−0.466(18)	1.27(5)	−0.47(2)	0.88(2)	−0.05(27)
$\Lambda_c^+ \to \Sigma^+\pi^0$	1.25(10)	−0.48(3)	1.27(5)	−0.47(2)	0.88(2)	−0.05(27)
$\Lambda_c^+ \to \Xi^0 K^+$	**0.55(7)	0.01(16)	0.40(3)	−0.15(14)	−0.29(22)	0.94(7)
$\Lambda_c^+ \to \Lambda^0 K^+$	0.064(3)	−0.585(52)	0.063(3)	−0.56(5)	0.82(5)	0.10(27)
$\Lambda_c^+ \to \Sigma^0 K^+$	0.0382(25)	−0.54(20)	0.0365(21)	−0.52(10)	0.48(24)	−0.71(17)
$\Lambda_c^+ \to n\pi^+$	0.066(13)		0.067(8)	−0.78(12)	−0.63(15)	−0.04(20)
$\Lambda_c^+ \to \Sigma^+ K_S$	0.048(14)		0.036(2)	−0.52(10)	0.48(24)	−0.71(17)
$\Lambda_c^+ \to p\pi^0$	< 0.008		0.02(1)		−0.82(32)	0.57(48)
$\Lambda_c^+ \to \Sigma^+\eta$	0.32(4)	−0.99(6)	0.32(4)	−0.93(4)	−0.32(16)	−0.16(23)
$\Lambda_c^+ \to p\eta$	0.142(12)		0.145(26)	−0.42(61)	0.64(40)	−0.65(20)
$\Lambda_c^+ \to \Sigma^+\eta'$	0.437(84)	−0.46(7)	0.420(70)	−0.44(25)	0.86(6)	0.25(35)
$\Lambda_c^+ \to p\eta'$	0.0484(91)		0.0520(114)	−0.59(9)	0.76(14)	−0.26(33)
$\Xi_c^+ \to \Xi^0\pi^+$	1.6(8)		0.90(16)	−0.94(6)	0.32(21)	−0.07(20)
$\Xi_c^0 \to \Xi^-\pi^+$	****1.43(32)	$^{*}-0.64(5)$	2.72(9)	−0.71(3)	0.36(20)	−0.60(12)
Channels	$\mathcal{R}_X^{\text{exp}}$	α_{exp}	$\mathcal{R}_X$	α	β	γ
$\Xi_c^0 \to \Lambda^0 K_S$	0.225(13)		0.233(9)	−0.47(29)	0.66(20)	−0.58(21)
$\Xi_c^0 \to \Xi^- K^+$	**0.0275(57)		0.0410(4)	−0.75(4)	0.38(20)	−0.55(13)
$\Xi_c^0 \to \Sigma^0 K_S$	0.038(7)		0.038(7)	−0.07(117)	−0.83(28)	0.55(41)
$\Xi_c^0 \to \Sigma^+ K^-$	0.123(12)		0.132(11)	−0.21(18)	−0.39(29)	0.90(13)

$B_c \to B + P$ not measured

TABLE II: Legend as in TABLE I but for unobserved decays.

Channels	$\mathcal{B}(10^{-3})$	α	β	γ	Channels	$\mathcal{B}(10^{-4})$	α	β	γ
$\Lambda_c^+ \to pK_L$	15.20(67)	−0.40(44)	0.33(27)	−0.86(17)	$\Lambda_c^+ \to nK^+$	0.13(2)	−0.90(6)	0.31(20)	−0.32(2)
$\Xi_c^+ \to \Sigma^+ K_S$	0.59(49)				$\Xi_c^+ \to \Lambda^0 \pi^+$	3.24(90)	0.29(29)	−0.47(30)	−0.83(13)
$\Xi_c^+ \to pK_{S/L}$	0.19(2)	−0.37(7)	0.35(18)	−0.86(8)	$\Xi_c^+ \to n\pi^+$	0.34(4)	−0.27(23)	−0.51(35)	0.81(26)
$\Xi_c^+ \to \Sigma^+ \pi^0$	0.21(14)	−0.49(49)	0.83(26)	−0.26(27)	$\Xi_c^+ \to \Sigma^0 K^+$	1.17(4)	−0.68(3)	0.35(19)	−0.65(26)
$\Xi_c^+ \to \Sigma^+ \eta$	0.07(3)	−0.80(69)	−0.41(77)	−0.43(104)	$\Xi_c^+ \to p\pi^0$	0.17(2)	−0.27(23)	−0.51(35)	0.81(26)
$\Xi_c^+ \to \Sigma^+ \eta'$	0.11(24)	−0.44(30)	0.88(23)	−0.19(42)	$\Xi_c^+ \to p\eta$	1.72(37)	−0.41(7)	0.67(15)	−0.62(26)
$\Xi_c^+ \to \Sigma^0 \pi^+$	0.30(1)	−0.59(3)	0.75(7)	−0.29(22)	$\Xi_c^+ \to p\eta'$	0.94(18)	−0.53(5)	0.73(18)	−0.43(26)
$\Xi_c^+ \to \Xi^0 K^+$	0.10(1)	−0.73(12)	−0.59(14)	0.35(17)	$\Xi_c^+ \to \Lambda^0 K^+$	0.37(4)	−0.44(12)	0.63(21)	0.65(26)
$\Xi_c^0 \to \Sigma^0 K_L$	0.97(17)		−0.53(39)	0.84(28)	$\Xi_c^0 \to pK^-$	1.96(19)	−0.26(22)	−0.50(34)	0.83(20)
$\Xi_c^0 \to \Xi^0 \pi^0$	7.10(41)	−0.49(9)	0.46(23)	−0.74(15)	$\Xi_c^0 \to nK_{S/L}$	7.10(62)	−0.44(3)	0.83(8)	−0.36(23)
$\Xi_c^0 \to \Xi^0 \eta$	2.94(97)	0.04(22)	0.83(13)	0.55(21)	$\Xi_c^0 \to \Lambda^0 \pi^0$	0.89(17)	−0.32(50)	−0.40(31)	−0.86(24)
$\Xi_c^0 \to \Xi^0 \eta'$	5.66(93)	−0.58(15)	0.74(6)	0.34(25)	$\Xi_c^0 \to n\pi^0$	0.06(1)	−0.27(23)	−0.51(35)	0.81(26)
$\Xi_c^0 \to \Lambda^0 K_L$	7.07(24)	−0.47(24)	0.71(17)	−0.53(21)	$\Xi_c^0 \to \Lambda^0 \eta$	4.31(1.10)	−0.02(52)	0.12(30)	−0.99(2)
$\Xi_c^0 \to \Sigma^+ \pi^-$	0.21(2)	−0.22(19)	−0.41(30)	0.88(14)	$\Xi_c^0 \to \Lambda^0 \eta'$	6.83(1.32)	−0.67(6)	0.74(8)	−0.09(26)
$\Xi_c^0 \to \Sigma^0 \pi^0$	0.34(3)	−0.33(48)	−0.38(27)	−0.87(23)	$\Xi_c^0 \to \Sigma^- K^+$	0.78(3)	−0.68(3)	0.35(19)	−0.65(26)
$\Xi_c^0 \to \Sigma^0 \eta$	0.12(5)	−0.80(69)	−0.41(77)	−0.43(104)	$\Xi_c^0 \to p\pi^-$	0.11(1)	−0.27(23)	−0.51(35)	0.81(26)
$\Xi_c^0 \to \Sigma^0 \eta'$	0.19(4)	−0.44(30)	0.88(23)	−0.19(42)	$\Xi_c^0 \to n\eta'$	0.31(6)	−0.53(5)	0.73(18)	−0.43(26)
$\Xi_c^0 \to \Sigma^- \pi^+$	1.83(6)	−0.65(3)	0.33(18)	−0.69(9)	$\Xi_c^0 \to n\eta$	0.57(12)	−0.41(7)	0.67(15)	−0.62(26)
$\Xi_c^0 \to \Xi^0 K_{S/L}$	0.43(2)	−0.47(2)	0.88(1)	0.06(26)					

Weak radiative/conversion decays

The LHCb Collaboration, now in a position to repeat that measurement with a much larger event sample, has recently already turned up 4.1σ evidence for the decay [2]. The reported branching fraction,

$$\mathcal{B}(\Sigma^+ \to p\mu^+\mu^-)_{\text{LHCb}} = \left(2.2^{+1.8}_{-1.3}\right) \times 10^{-8}, \tag{1.1}$$

is in agreement with the range implied by the HyperCP observation [1],

$$\mathcal{B}(\Sigma^+ \to p\mu^+\mu^-)_{\text{HyperCP}} = \left(8.6^{+6.6}_{-5.4} \pm 5.5\right) \times 10^{-8}, \tag{1.2}$$

and with the SM prediction [3]

$$1.6 \times 10^{-8} \le \mathcal{B}(\Sigma^+ \to p\mu^+\mu^-)_{\text{SM}} \le 9.0 \times 10^{-8}. \tag{1.3}$$

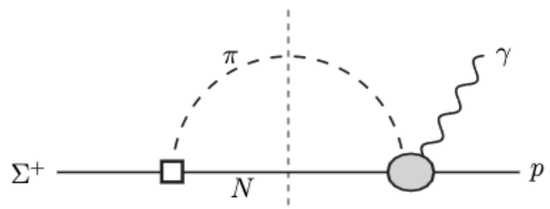


FIG. 1. Unitarity cut.

Prospects for a lattice calculation of the rare decay $\Sigma^+ \to p\ell^+\ell^-$

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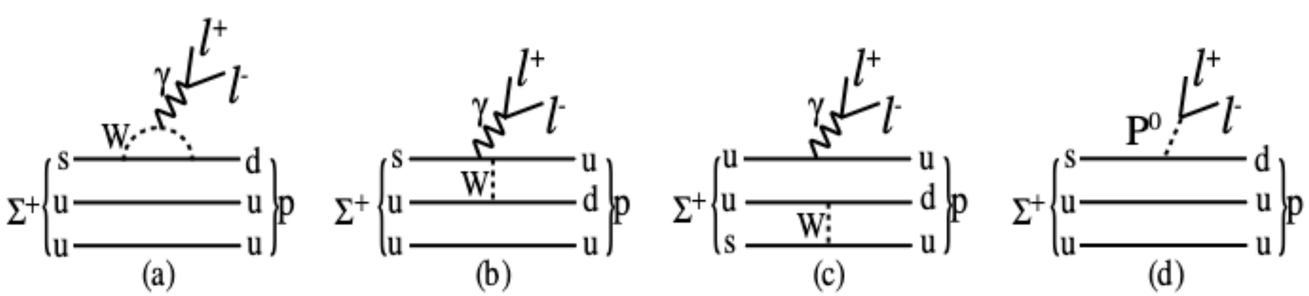


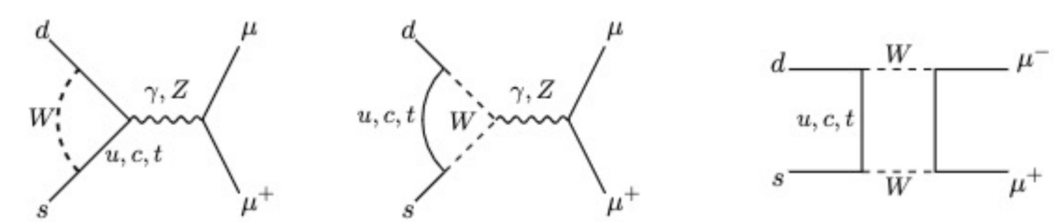
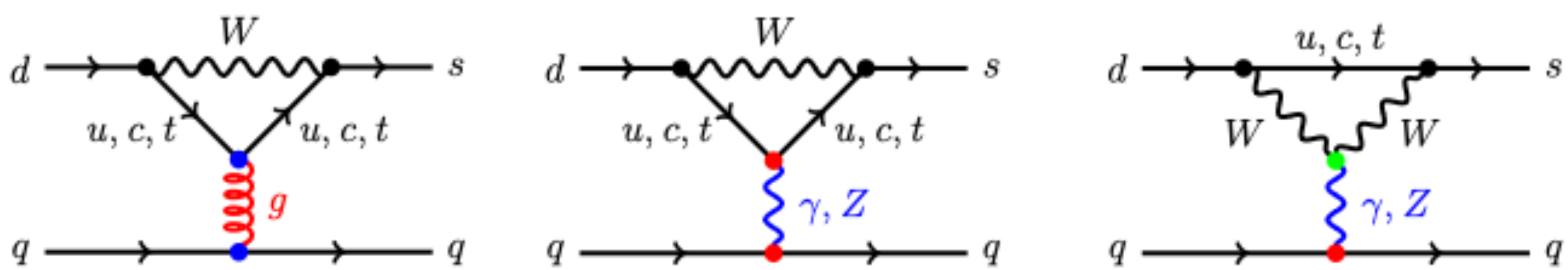


Figure 1. Short-distance Standard Model contributions to the $s \to d$ transition from penguin and box diagrams.

CPV tests in baryon decays



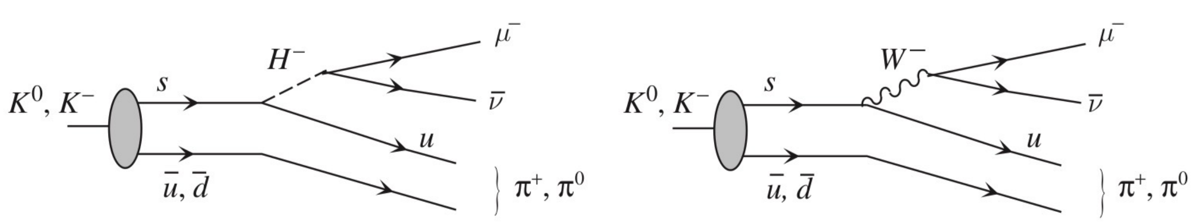


Figure 17.8 A diagram giving rise to muon transverse polarization in $K \to \pi\mu\nu$.

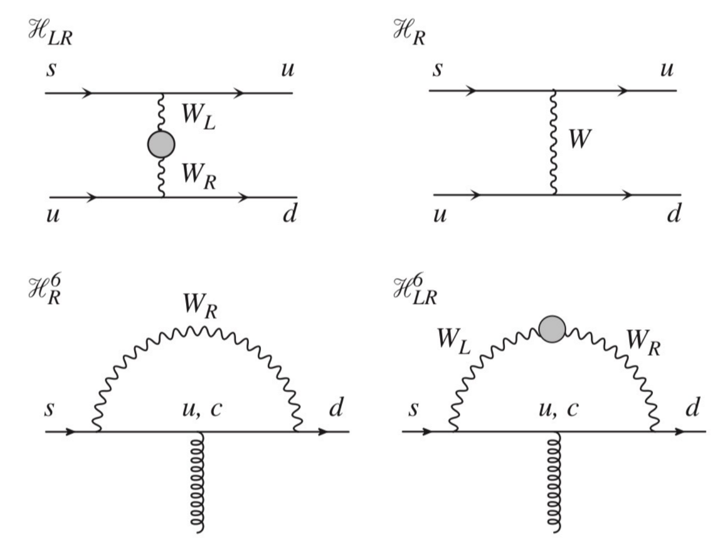


Figure 17.2 Feynman diagrams with new contributions to $\mathcal{H}(\Delta S = 1)$.