Angular distribution of $\Lambda_b \to pK^-l^+l^-$ decays comprising Λ resonances with spin ≤ 5/2

Michal Kreps

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Based on A. Beck, T. Blake and MK, JHEP 02 (2023) 189

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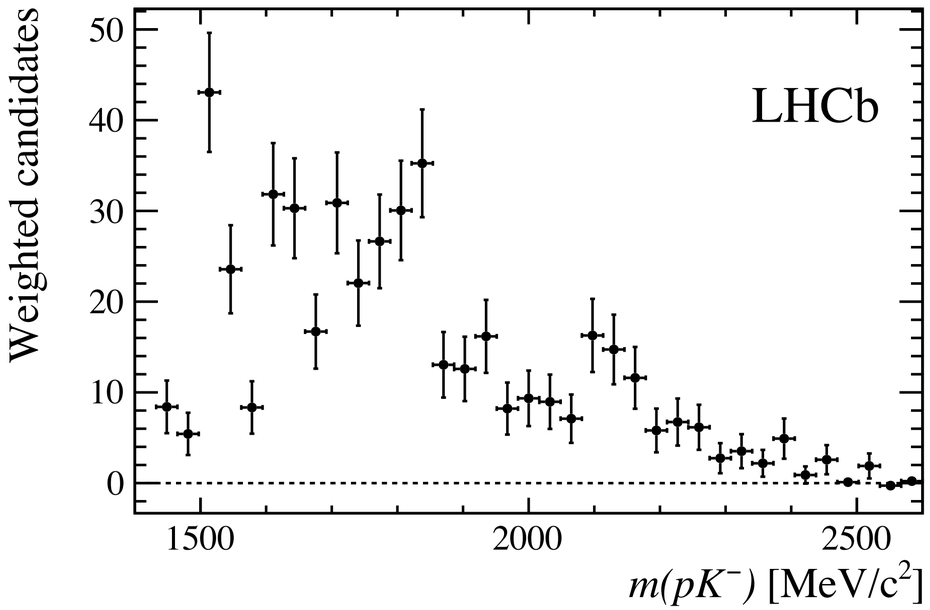
Introduction

- Decays governed by $b \to sll$ transitions are sensitive probes for new physics
- Well studied for meson decays
- Baryon decays provide complementary information
  - Different spin structure
  - Differences in hadronic structure
- Decays $\Lambda_b \to \Lambda^* \mu\mu$ with spin 1/2 and 3/2 Λ^* studied previously (1903.10553, JHEP 07 (2020) 002, JHEP 06 (2019) 136, Eur. Phys. J. Plus 136 (2021) 614)
- In reality several interfering resonances
  - Study effects on angular distributions and observables

LHCb-PAPER-2019-040

Background subtracted $\Lambda_b \to pK\mu\mu$ in $0.1 < q^2 < 6.0$ GeV^2



Interference

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- The full angular distribution with several interfering spin states can be easily written in the helicity formalism
- Full decay rate

operators

spin states

$$\frac{\mathrm{d}^7\Gamma}{\mathrm{d}q^2\,\mathrm{d}m_{pK}\mathrm{d}\vec{\Omega}} = \frac{1}{m_{\Lambda_b}^2}\frac{N_1^2}{2^6(2\pi)^7}\frac{|\vec{k}||\vec{k}_1||\vec{q}_1|}{\sqrt{q^2}}\sum_{\lambda_b}\mathcal{P}_{\lambda_b}\sum_{\lambda_1,\lambda_2,\lambda_p}\Bigg|\sum_{\mathcal{O}_i}\sum_{\Lambda}\sqrt{J_\Lambda+\frac{1}{2}}\sum_{\lambda_\Lambda}g_{\lambda_V\lambda_V}$$

Λ_b decay amplitudes $\times\, \mathcal{H}^{\Lambda,\mathcal{O}_i}_{\lambda_\Lambda,\lambda_V}(q^2,m_{pK})\, d^{1/2}_{\lambda_b,\lambda_\Lambda-\lambda_V}(\theta_b)$

dimuon system amplitudes $\times\, \tilde{h}^{\mathcal{O}_i,\lambda_V}_{\lambda_1,\lambda_2}(q^2)D^{J_V}_{\lambda_V,\lambda_1-\lambda_2}(\phi_\ell,\theta_\ell,-\phi_\ell)^*$

Λ^* decay amplitudes $\times\, h^{\Lambda}_{\lambda_\Lambda,\lambda_p}(m_{pK})D^{J_\Lambda}_{\lambda_\Lambda,\lambda_p}(\phi_p,\theta_p,-\phi_p)^*\Bigg|^2,$

Wigner d-functions

- Several terms will have same angular term, so want to group them

Angular basis

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- No unique option how to group terms, pick one based on associated Legendre polynomials
  - Related to angular momentum and makes it easy to keep track of terms
  - Resulting functions are orthogonal (own weights for the method of moments)
- Final basis: $$f(\vec{\Omega}; l_{\rm lep}, l_{\rm had}, m_{\rm lep}, m_{\rm had}) = 2 n_{l_{\rm lep}}^{m_{\rm lep}} n_{l_{\rm had}}^{m_{\rm had}} P_{l_{\rm lep}}^{|m_{\rm lep}|}(\cos\theta_\ell) P_{l_{\rm had}}^{|m_{\rm had}|}(\cos\theta_p) \times \begin{cases} \sin(|m_{\rm lep}|\phi_\ell + |m_{\rm had}|\phi_p) & m_{\rm lep} \leq 0 \text{ and } m_{\rm had} \leq 0 \\ \cos(|m_{\rm lep}|\phi_\ell + |m_{\rm had}|\phi_p) & m_{\rm lep} \geq 0 \text{ and } m_{\rm had} \geq 0 \end{cases}$$
- The angular distribution takes form

$$\frac{32\pi^2}{3} \frac{\mathrm{d}^7\Gamma}{\mathrm{d}q^2\, \mathrm{d}m_{pK}\, \mathrm{d}\vec{\Omega}} = \sum_{i=1}^{178} K_i(q^2, m_{pK}) f_i(\vec{\Omega})$$

$K_i(q^2, m_{pK})$ are bilinear combinations of products of amplitudes

Anatomy of angular distribution

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- There are 178 terms when polarisation is allowed to be non-zero
  - 46 of these present also with zero polarisation and have no θ_b dependence ($m_{\text{lep}}=m_{\text{had}}$)
  - For polarised case, 46 terms have cos θ_b dependence while rest of the angles are same as unpolarised case
  - Remaining terms have sin θ_b dependence with basis functions where $m_{\text{lep}}\neq m_{\text{had}}$

i	parity combination	$J_\Lambda + J'_\Lambda$	single states 1/2	3/2	5/2	Re/Im	V/A	helicity combinations	Eq.
1	same	≥ 1	✓	✓	✓	Re		$J_\Lambda = J'_\Lambda, (\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(62)
2	same	≥ 1	✓	✓	✓	Re	✓	$J_\Lambda = J'_\Lambda, \lambda_V \neq 0, (\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(63)
3	same	≥ 1	✓	✓	✓	Re		$J_\Lambda = J'_\Lambda, (\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(64)
4	opposite	≥ 1				Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(66)
5	opposite	≥ 1				Re	✓	$\lambda_V \neq 0, (\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(117)
6	opposite	≥ 1				Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(118)
7	same	≥ 2		✓	✓	Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(119)
8	same	≥ 2		✓	✓	Re	✓	$\lambda_V \neq 0, (\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(120)
9	same	≥ 2		✓	✓	Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(121)
10	opposite	≥ 3				Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(122)
11	opposite	≥ 3				Re	✓	$\lambda_V \neq 0, (\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(123)
12	opposite	≥ 3				Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(124)
13	same	≥ 4			✓	Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(125)
14	same	≥ 4			✓	Re	✓	$\lambda_V \neq 0, (\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(126)
15	same	≥ 4			✓	Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(127)
16	opposite	≥ 5				Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(128)
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18	opposite	≥ 5				Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(130)
19	opposite	≥ 1				Re			(131)
20	opposite	≥ 1				Re	✓		(132)
21	same	≥ 2		✓	✓	Re			(133)
22	same	≥ 2		✓	✓	Re	✓		(134)
23	opposite	≥ 3				Re		$\lambda_V = 0, \lvert\lambda'_V\rvert = 1$ (all possible $\lambda_\Lambda^{(\prime)}$)	(135)
24	opposite	≥ 3				Re	✓		(136)
25	same	≥ 4			✓	Re			(137)
26	same	≥ 4			✓	Re	✓		(138)
27	opposite	≥ 5				Re			(139)
28	opposite	≥ 5				Re	✓		(140)

Anatomy of angular distribution

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- 1D distribution in θ_l has usual form, K_2 generates lepton A_{FB}
  - Usual contributions, just adds Λ^* helicity 3/2 in addition to 1/2
- 1D distribution in θ_p gets larger number of terms
  - Includes odd terms in cos θ_p which vanish for single resonance
  - With interference, A_{FB} generated also on hadron side with K_4, K_{10} and K_{16} contributing

$$\frac{\mathrm{d}^3\Gamma}{\mathrm{d}q^2\,\mathrm{d}m_{pK}\,\mathrm{d}\cos\theta_\ell} = \frac{\sqrt{3}}{2}K_1 + \boxed{\frac{3}{2}K_2\cos\theta_\ell} + \frac{\sqrt{15}}{4}K_3(3\cos^2\theta_\ell - 1)$$

$$\begin{aligned}\frac{\mathrm{d}^3\Gamma}{\mathrm{d}q^2\,\mathrm{d}m_{pK}\,\mathrm{d}\cos\theta_p} = {} & \frac{\sqrt{3}}{2}K_1 - \frac{\sqrt{15}}{4}K_7 + 9\frac{\sqrt{3}}{16}K_{13} \\ & + \boxed{\left(\frac{3}{2}K_4 - 3\frac{\sqrt{21}}{4}K_{10} + 15\frac{\sqrt{33}}{16}K_{16}\right)\cos\theta_p} \\ & + \left(3\frac{\sqrt{15}}{4}K_7 - 45\frac{\sqrt{3}}{8}K_{13}\right)\cos^2\theta_p \\ & + \boxed{\left(5\frac{\sqrt{21}}{4}K_{10} - 35\frac{\sqrt{33}}{8}K_{16}\right)\cos^3\theta_p} \\ & + \frac{105\sqrt{3}}{16}K_{13}\cos^4\theta_p + \boxed{\frac{63\sqrt{33}}{16}K_{16}\cos^5\theta_p}\,.\end{aligned}$$

Numerical studies

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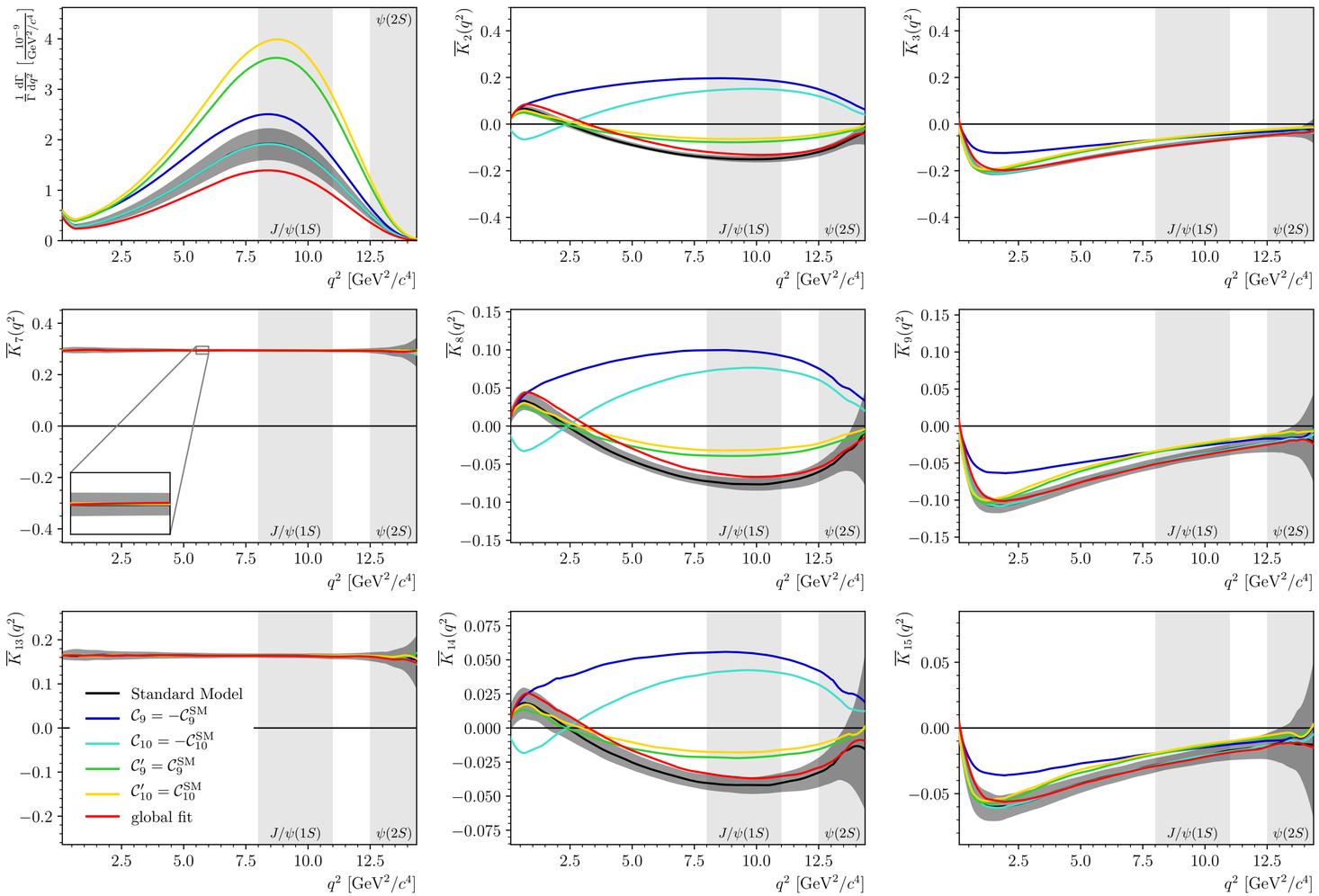
- Use SM Wilson coefficients used in JHEP 05 (2013) 137
- Use all well established states for which prediction for form-factors exists
  - Form-factors based on quark-model from Int. J. Mod. Phys. A 30 (2015) 1550172
- Most of the resonances modelled by relativistic Breit-Wigner
- $\Lambda(1405)$ uses Flattè model
- Investigated scenarios:
  - Flip C_9/C_{10} or add right C_9'/C_{10}'
  - Global fit in Eur. Phys. J. C 82 (2022) 326

resonance	m_Λ [GeV/c^2]	Γ_Λ [GeV/c^2]	$2J_\Lambda$	P_Λ	$\mathcal{B}(\Lambda \to N\overline{K})$
$\Lambda(1405)$	1.405	0.051	1	$-$	0.50
$\Lambda(1520)$	1.519	0.016	3	$-$	0.45
$\Lambda(1600)$	1.600	0.200	1	$+$	0.15 – 0.30
$\Lambda(1670)$	1.674	0.030	1	$-$	0.20 – 0.30
$\Lambda(1690)$	1.690	0.070	3	$-$	0.20 – 0.30
$\Lambda(1800)$	1.800	0.200	1	$-$	0.25 – 0.40
$\Lambda(1810)$	1.790	0.110	1	$+$	0.05 – 0.35
$\Lambda(1820)$	1.820	0.080	5	$+$	0.55 – 0.65
$\Lambda(1890)$	1.890	0.120	3	$+$	0.24 – 0.36
$\Lambda(2110)$	2.090	0.250	5	$+$	0.05 – 0.25

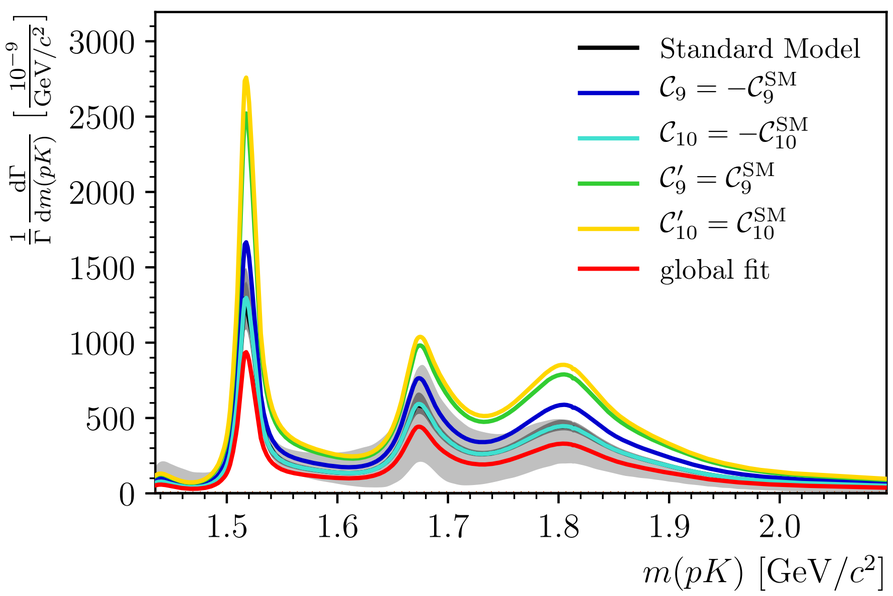
Isolated spin 5/2 resonance

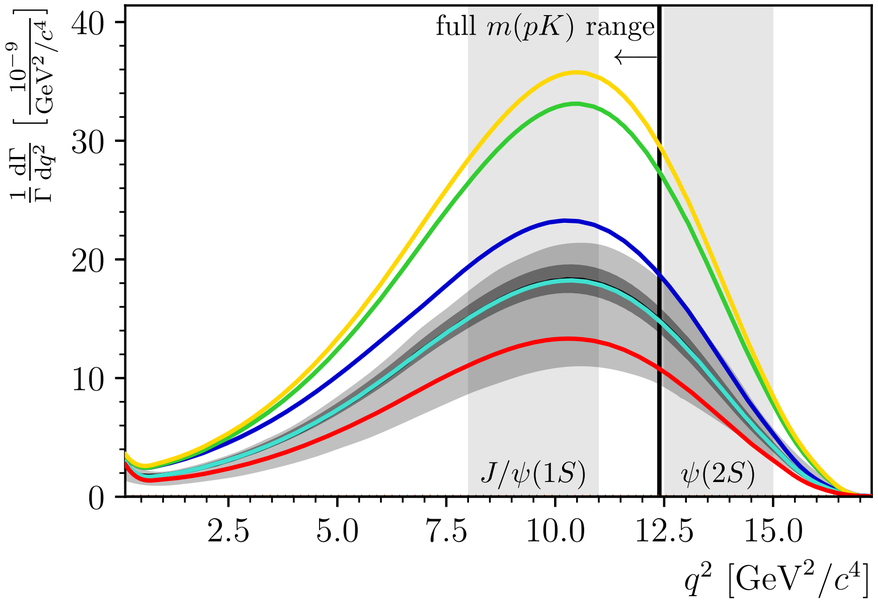
- Only isolated $\Lambda(1820)$
- Grey band shows uncertainty from:
  - Form-factor
  - Widths etc.
  - Non-factorisable corrections
- Often need rather large change in Wilson coefficients for effects larger than uncertainties



Ensemble of resonances

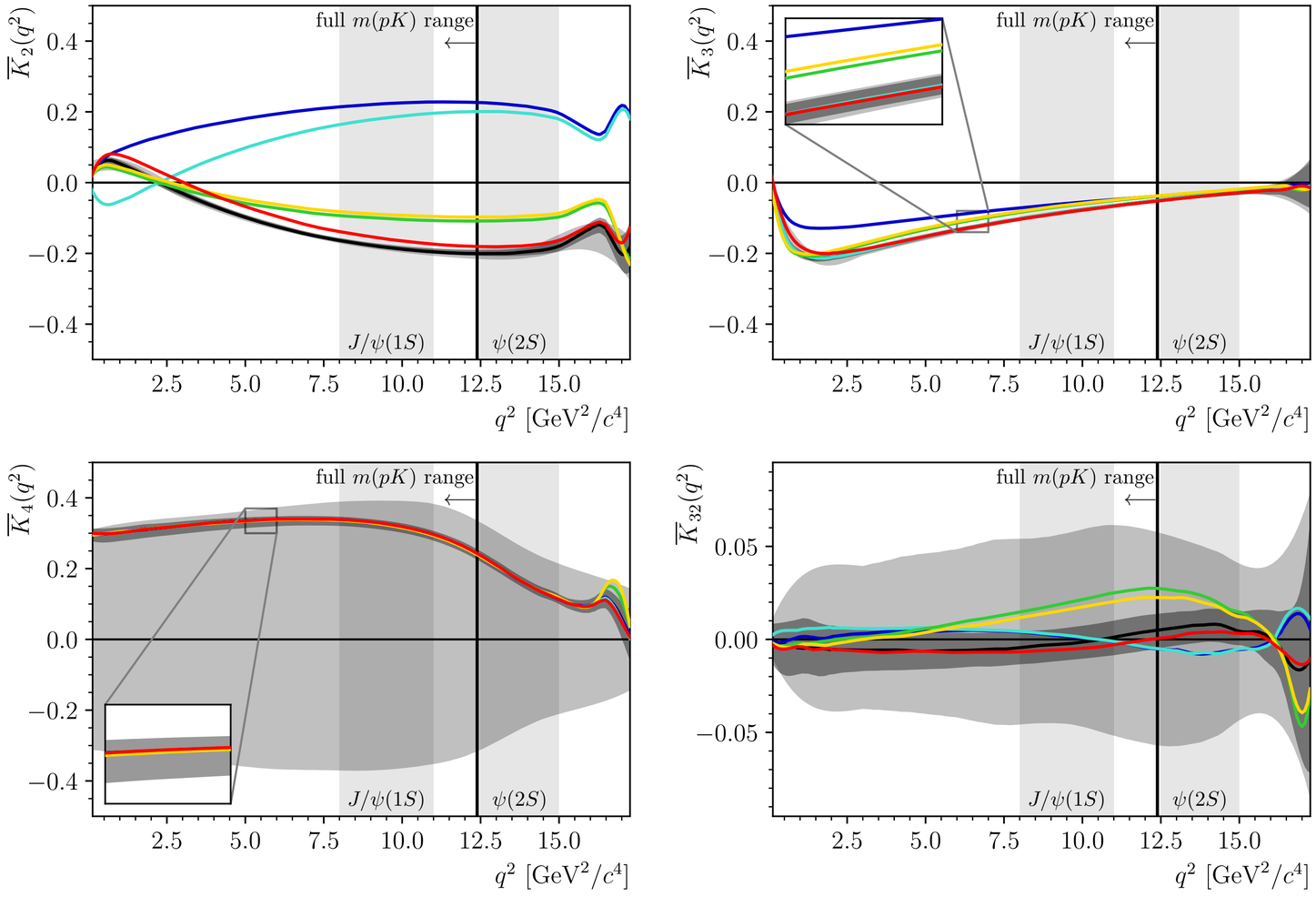
- Investigate sensitivity of observables with ensemble of different Λ resonances
- Strong phases of all Λ resonances set to 0 ($\pi/2$ at the pole)
- Additional uncertainty from strong phases by varying them between -π and π





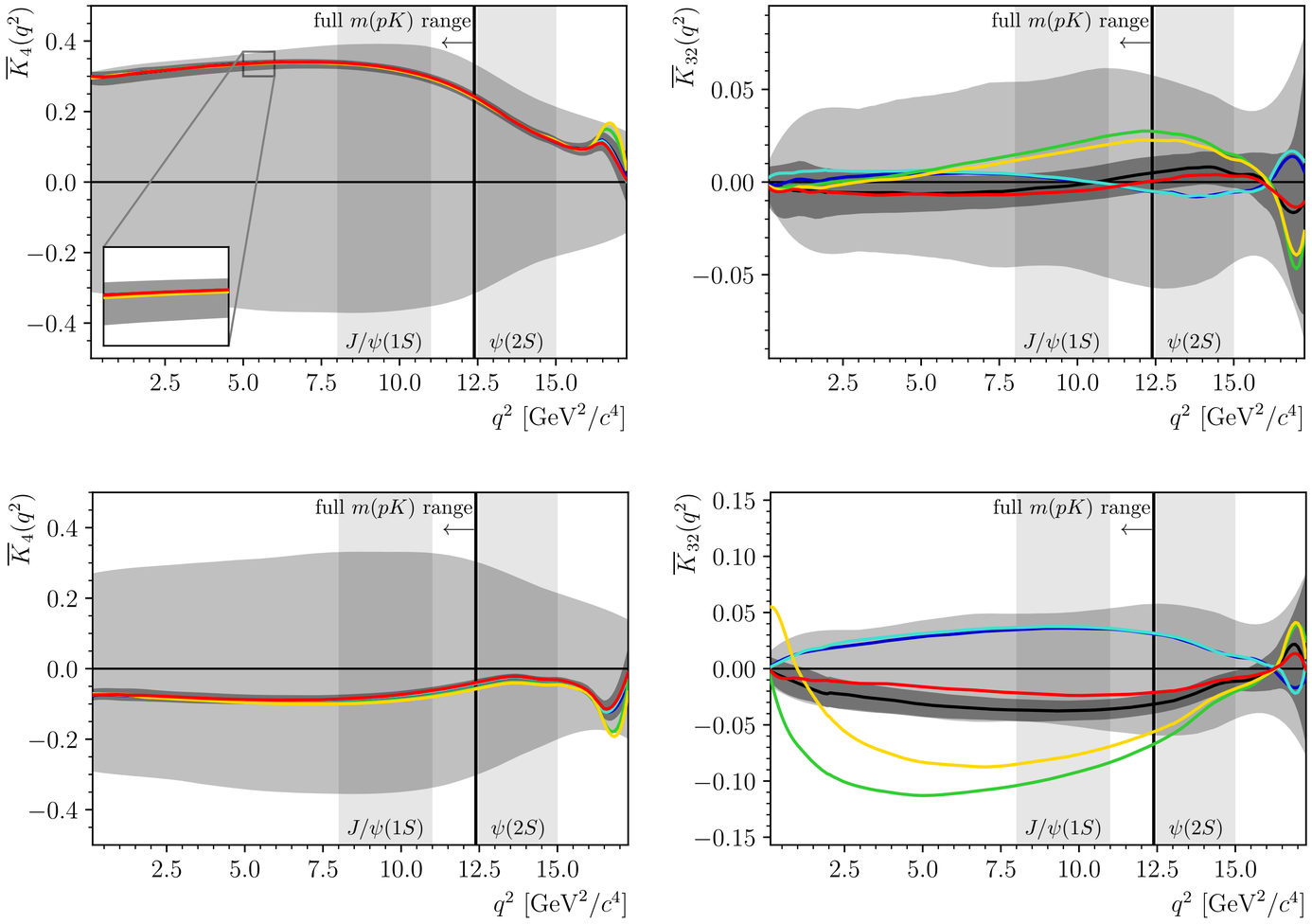
Ensemble of resonances

- Some cases give good sensitivity to new physics without effects from strong phases
- Some observables like K_4 has little sensitivity to new physics, but large effect from strong phases
- Several observables like K_{32} sensitive to new physics but require knowledge of strong phases



Ensemble of resonances

- Particular example of effect of strong phases
- Set strong phase of spin-3/2 resonances to π while keeping rest to 0
- Very large effects on K_4 and K_{32}
  - K_{32} shows significantly different behaviour



Summary

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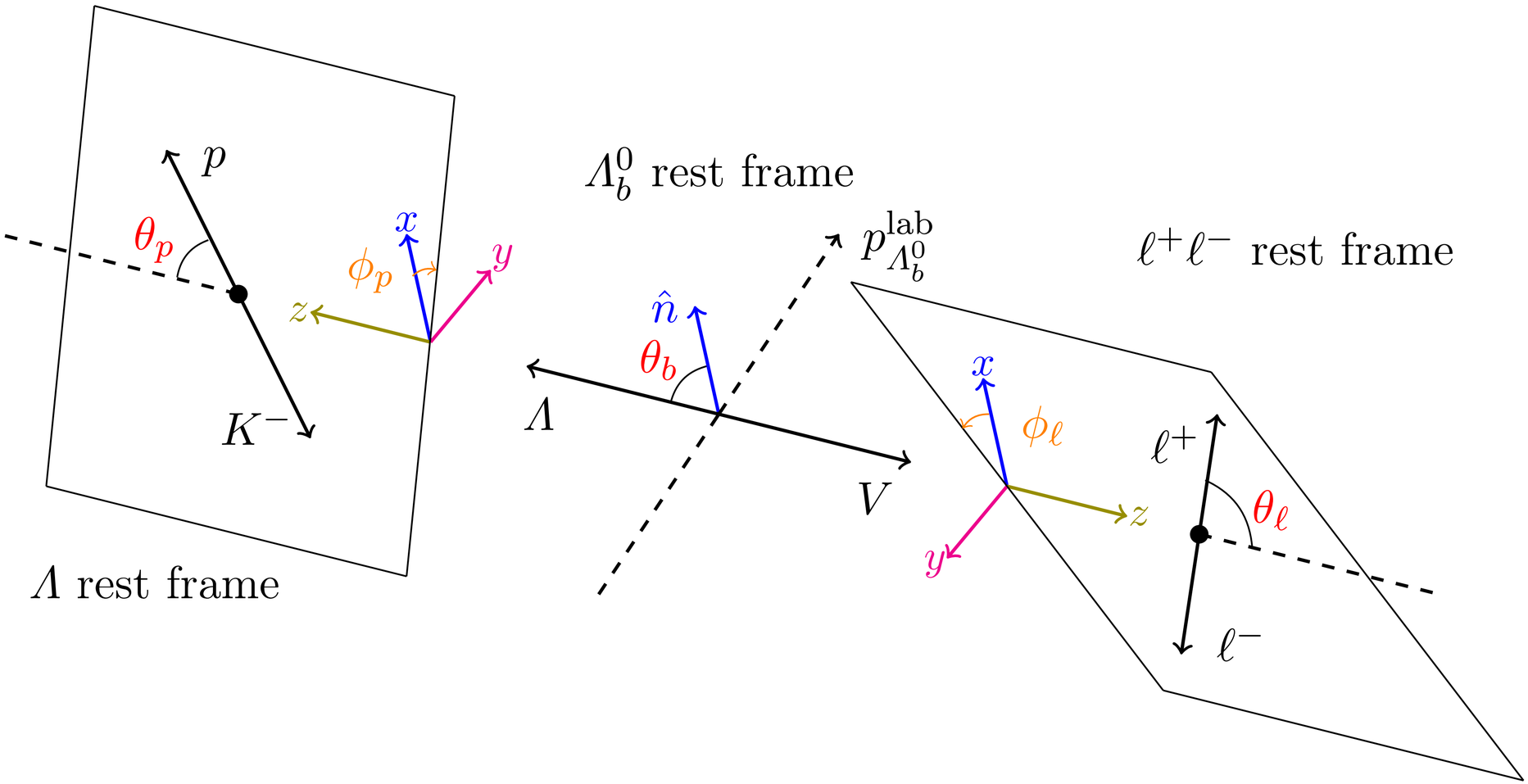
- For the first time looked into angular distribution of $\Lambda_b \to pK\mu\mu$ with interfering pK resonances up to spin 5/2
- Rich set of observables, 46 (178) in unpolarised (polarised) case
  - Some only due to interference between resonances with different spin-parity
  - Some exhibit sensitivity to Wilson coefficients independent of strong phases
  - For some observables, sensitivity to Wilson coefficients is present, but strong phases need to be known
- Provided distribution in the angular basis suitable for the method of moments useful for future measurements

Backup

Definition of angles



Helicity amplitudes

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$$\mathcal{H}^{\Lambda,7^{(\prime)}}_{\lambda_\Lambda,\lambda_V}(q^2,m_{pK}) = -\frac{2m_b}{q^2}\frac{\mathcal{C}^{\rm eff}_{7^{(\prime)}}}{2}\, e^{i\delta_\Lambda}\left(H^{\Lambda,T}_{\lambda_\Lambda,\lambda_V} \mp H^{\Lambda,T5}_{\lambda_\Lambda,\lambda_V}\right)$$

$$\mathcal{H}^{\Lambda,9^{(\prime)}}_{\lambda_\Lambda,\lambda_V}(q^2,m_{pK}) = \frac{\mathcal{C}^{\rm eff}_{9^{(\prime)}}}{2}\, e^{i\delta_\Lambda}\left(H^{\Lambda,V}_{\lambda_\Lambda,\lambda_V} \mp H^{\Lambda,A}_{\lambda_\Lambda,\lambda_V}\right)$$

$$\mathcal{H}^{\Lambda,10^{(\prime)}}_{\lambda_\Lambda,\lambda_V}(q^2,m_{pK}) = \frac{\mathcal{C}_{10^{(\prime)}}}{2} e^{i\delta_\Lambda}\left(H^{\Lambda,V}_{\lambda_\Lambda,\lambda_V} \mp H^{\Lambda,A}_{\lambda_\Lambda,\lambda_V}\right)$$

$$H^{\Lambda,\Gamma^\mu}_{\lambda_\Lambda,\lambda_V} = \varepsilon^*_\mu(\lambda_V)\langle\Lambda|\bar{s}\Gamma^\mu b|\Lambda_b^0\rangle$$

$$\langle\Lambda|\bar{s}\Gamma^\mu b|\Lambda_b^0\rangle = \bar{u}(k,\lambda_\Lambda)\left[X_{\Gamma1}(q^2)\gamma^\mu + X_{\Gamma2}(q^2)v_p^\mu + X_{\Gamma3}(q^2)v_k^\mu\right]u(p,\lambda_b)$$ Spin 1/2

$$\langle\Lambda|\bar{s}\Gamma^\mu b|\Lambda_b^0\rangle = \bar{u}_\alpha(k,\lambda_\Lambda)\left[v_p^\alpha\left(X_{\Gamma1}(q^2)\gamma^\mu + X_{\Gamma2}(q^2)v_p^\mu + X_{\Gamma3}(q^2)v_k^\mu\right) + X_{\Gamma4}(q^2)g^{\alpha\mu}\right]u(p,\lambda_b)$$ Spin 3/2

$$\langle\Lambda|\bar{s}\Gamma^\mu b|\Lambda_b^0\rangle = \bar{u}_{\alpha\beta}(k,\lambda_\Lambda)v_p^\alpha\Big[v_p^\beta\left(X_{\Gamma1}(q^2)\gamma^\mu + X_{\Gamma2}(q^2)v_p^\mu + X_{\Gamma3}(q^2)v_k^\mu\right) + X_{\Gamma4}(q^2)g^{\beta\mu}\Big]u(p,\lambda_b)\,.$$ Spin 5/2

Amplitude combinations

i	parity combination	$J_\Lambda + J'_\Lambda$	single states 1/2	3/2	5/2	Re/Im	V/A	helicity combinations	Eq.
1	same	≥ 1	✓	✓	✓	Re		$J_\Lambda = J'_\Lambda, (\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(62)
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15	same	≥ 4			✓	Re		$(\lambda_\Lambda, \lambda_V) = (\lambda_\Lambda, \lambda_V)'$	(127)
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Amplitude combinations

19	opposite	≥ 1			Re			(131)
20	opposite	≥ 1			Re	✓		(132)
21	same	≥ 2	✓	✓	Re			(133)
22	same	≥ 2	✓	✓	Re	✓		(134)
23	opposite	≥ 3			Re		$\lambda_V = 0, \lvert\lambda'_V\rvert = 1$ (all possible $\lambda_\Lambda^{(\prime)}$)	(135)
24	opposite	≥ 3			Re	✓		(136)
25	same	≥ 4		✓	Re			(137)
26	same	≥ 4		✓	Re	✓		(138)
27	opposite	≥ 5			Re			(139)
28	opposite	≥ 5			Re	✓		(140)

Amplitude combinations

29	opposite	≥ 1			Im			(141)
30	opposite	≥ 1			Im	✓		(142)
31	same	≥ 2	✓	✓	Im			(143)
32	same	≥ 2	✓	✓	Im	✓		(67)
33	opposite	≥ 3			Im		$\lambda_V = 0, \lvert\lambda'_V\rvert = 1$ (all possible $\lambda_\Lambda^{(\prime)}$)	(144)
34	opposite	≥ 3			Im	✓		(145)
35	same	≥ 4		✓	Im			(146)
36	same	≥ 4		✓	Im	✓		(147)
37	opposite	≥ 5			Im			(148)
38	opposite	≥ 5			Im	✓		(149)
39	same	≥ 2	✓	✓	Re			(150)
40	opposite	≥ 3			Re			(151)
41	same	≥ 4		✓	Re			(152)
42	opposite	≥ 5			Re		$\lvert\lambda_V^{(\prime)}\rvert = 1,\ \lambda_\Lambda = \pm 1/2, \lambda'_\Lambda = \mp 3/2$	(153)
43	same	≥ 2	✓	✓	Im			(154)
44	opposite	≥ 3			Im			(155)
45	same	≥ 4		✓	Im			(156)
46	opposite	≥ 5			Im			(157)

Explicit expressions for observables

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$$\mathcal{A}^{Q,V}_{\lambda_\Lambda,\lambda_V} = N \sum_{\Lambda} \sum_{i=7^{(\prime)},9^{(\prime)}} \mathcal{H}^{\Lambda,\mathcal{O}_i}_{\lambda_\Lambda,\lambda_V} h^{\Lambda}_{\lambda_\Lambda,1/2} \,,$$

$$\mathcal{A}^{Q,A}_{\lambda_\Lambda,\lambda_V} = N \sum_{\Lambda} \sum_{i=10^{(\prime)}} \mathcal{H}^{\Lambda,\mathcal{O}_i}_{\lambda_\Lambda,\lambda_V} h^{\Lambda}_{\lambda_\Lambda,1/2} \,,$$

$$K_1 = \frac{1}{\sqrt{3}} \sum_{Q} \sum_{\lambda_\Lambda,\lambda_V} \left(\left| \mathcal{A}^{Q,V}_{\lambda_\Lambda,\lambda_V} \right|^2 + V \longleftrightarrow A \right)$$

$$K_2 = -\sum_{Q} \sum_{\lambda=\pm1} \lambda \cdot \mathrm{Re} \left[\mathcal{A}^{Q,A*}_{\frac{3}{2}\lambda,\lambda} \mathcal{A}^{Q,V}_{\frac{3}{2}\lambda,\lambda} + \mathcal{A}^{Q,A*}_{\frac{1}{2}\lambda,\lambda} \mathcal{A}^{Q,V}_{\frac{1}{2}\lambda,\lambda} \right]$$

$$K_3 = \frac{1}{2\sqrt{15}} \sum_{Q} \sum_{\lambda=\pm1} \left(\left| \mathcal{A}^{Q,V}_{\frac{3}{2}\lambda,\lambda} \right|^2 + \left| \mathcal{A}^{Q,V}_{\frac{1}{2}\lambda,\lambda} \right|^2 - 2 \left| \mathcal{A}^{Q,V}_{\frac{1}{2}\lambda,0} \right|^2 \right) + V \longleftrightarrow A$$

$$\begin{aligned}
K_4 = \frac{1}{105} \sum_{\lambda=\pm1} \mathrm{Re} \Big[&+ \lambda \Big(+35 \mathcal{A}^{\frac{1}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{1}{2}^-,V}_{\frac{1}{2}\lambda,0} + 35 \mathcal{A}^{\frac{1}{2}^+,V*}_{\frac{1}{2}\lambda,\lambda} \mathcal{A}^{\frac{1}{2}^-,V}_{\frac{1}{2}\lambda,\lambda} \\
&+ 21 \mathcal{A}^{\frac{3}{2}^+,V*}_{\frac{3}{2}\lambda,\lambda} \mathcal{A}^{\frac{3}{2}^-,V}_{\frac{3}{2}\lambda,\lambda} + 7 \mathcal{A}^{\frac{3}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{3}{2}^-,V}_{\frac{1}{2}\lambda,0} + 7 \mathcal{A}^{\frac{3}{2}^+,V*}_{\frac{1}{2}\lambda,\lambda} \mathcal{A}^{\frac{3}{2}^-,V}_{\frac{1}{2}\lambda,\lambda} \\
&+ 3 \mathcal{A}^{\frac{5}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{5}{2}^-,V}_{\frac{1}{2}\lambda,0} + 3 \mathcal{A}^{\frac{5}{2}^+,V*}_{\frac{1}{2}\lambda,\lambda} \mathcal{A}^{\frac{5}{2}^-,V}_{\frac{1}{2}\lambda,\lambda} + 9 \mathcal{A}^{\frac{5}{2}^+,V*}_{\frac{3}{2}\lambda,\lambda} \mathcal{A}^{\frac{5}{2}^-,V}_{\frac{3}{2}\lambda,\lambda} \Big) \\
&+ 84 \mathcal{A}^{\frac{3}{2}^+,V*}_{\frac{3}{2}\lambda,\lambda} \mathcal{A}^{\frac{5}{2}^-,V}_{\frac{3}{2}\lambda,\lambda} + 70\sqrt{2} \mathcal{A}^{\frac{1}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{3}{2}^-,V}_{\frac{1}{2}\lambda,0} + 70\sqrt{2} \mathcal{A}^{\frac{1}{2}^+,V*}_{\frac{1}{2}\lambda,\lambda} \mathcal{A}^{\frac{3}{2}^-,V}_{\frac{1}{2}\lambda,\lambda} \\
&+ 42\sqrt{6} \mathcal{A}^{\frac{3}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{5}{2}^-,V}_{\frac{1}{2}\lambda,0} + 42\sqrt{6} \mathcal{A}^{\frac{3}{2}^+,V*}_{\frac{1}{2}\lambda,\lambda} \mathcal{A}^{\frac{5}{2}^-,V}_{\frac{1}{2}\lambda,\lambda} \Big] \\
&+ (V \longleftrightarrow A) + (P_\Lambda \longrightarrow -P_\Lambda) \,,
\end{aligned}$$

$$\begin{aligned}
K_{32} = -\frac{1}{7\sqrt{10}} \sum_{\lambda=\pm1} \mathrm{Im} \Big[&+ 4\sqrt{3} \mathcal{A}^{\frac{5}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{5}{2}^+,A}_{\frac{3}{2}\lambda,\lambda} + 7\sqrt{2} \mathcal{A}^{\frac{3}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{3}{2}^+,A}_{\frac{3}{2}\lambda,\lambda} \\
&- \lambda \left(3\sqrt{3} \mathcal{A}^{\frac{5}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{3}{2}^+,A}_{\frac{3}{2}\lambda,\lambda} + \sqrt{2} \mathcal{A}^{\frac{3}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{5}{2}^+,A}_{\frac{3}{2}\lambda,\lambda} \right) \\
&+ 5\lambda \left(\mathcal{A}^{\frac{3}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{5}{2}^+,A}_{-\frac{1}{2}\lambda,-\lambda} + \left(\frac{3}{2} \longleftrightarrow \frac{5}{2} \right) \right) \\
&+ 7\sqrt{2} \left(\mathcal{A}^{\frac{1}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{5}{2}^+,A}_{-\frac{1}{2}\lambda,-\lambda} + \sqrt{2} \mathcal{A}^{\frac{1}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{5}{2}^+,A}_{\frac{3}{2}\lambda,\lambda} - \left(\frac{5}{2} \longleftrightarrow \frac{1}{2} \right) \right) \\
&+ 7\lambda \left(\sqrt{3} \mathcal{A}^{\frac{1}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{3}{2}^+,A}_{-\frac{1}{2}\lambda,-\lambda} + \mathcal{A}^{\frac{1}{2}^+,V*}_{\frac{1}{2}\lambda,0} \mathcal{A}^{\frac{3}{2}^+,A}_{\frac{3}{2}\lambda,\lambda} + \left(\frac{3}{2} \longleftrightarrow \frac{1}{2} \right) \right) \Big] \\
&+ (V \longleftrightarrow A) + (P_\Lambda \longrightarrow -P_\Lambda) \,.
\end{aligned}$$

Wilson coefficients

- SM Wilson coefficients used in JHEP 05 (2013) 137
- Global fit from Eur. Phys. J. C 82 (2022) 326
  - Consistent with existing measurements in $b \to s\ell\ell$

	Standard Model	global fit
$\mathcal{C}_1$	-0.2632	
$\mathcal{C}_2$	1.0111	
$\mathcal{C}_3$	-0.0055	
$\mathcal{C}_4$	-0.0806	
$\mathcal{C}_5$	0.0004	
$\mathcal{C}_6$	0.0009	
$\mathcal{C}_7$	-0.3120	-0.3120
$\mathcal{C}_9$	4.0749	2.9949
$\mathcal{C}_{10}$	-4.3085	-4.1585
$\mathcal{C}_{7'}$	0.0000	0.0000
$\mathcal{C}_{9'}$	0.0000	0.1600
$\mathcal{C}_{10'}$	0.0000	-0.1800