A new insight on the Anomaly

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Based on: J. M. and N. Serra, **arXiv:1402.6855**

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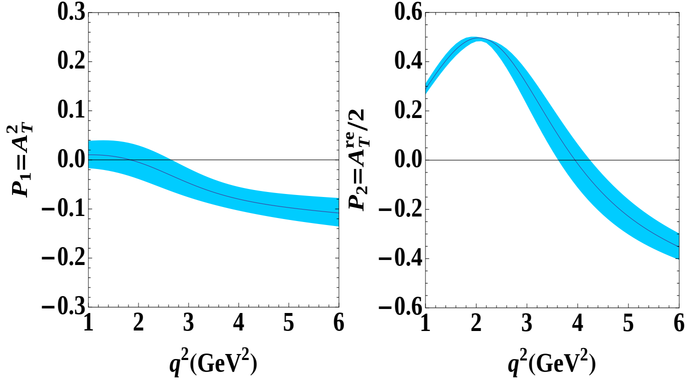
A few properties of the relevant observables $P_{1,2}$ and $P'_{4,5}$

P_1 and P_2 observables function of $A_\perp$ and $A_\|$ amplitudes

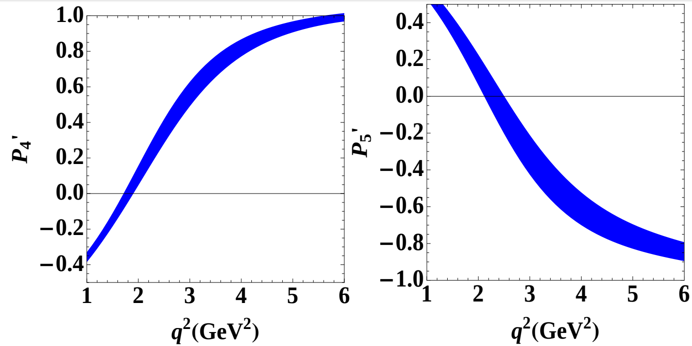
- $\mathbf{P_1}$: Proportional to $|A_\perp|^2 - |A_\||^2$
  - Test the LH structure of SM and/or existence of RH currents that breaks $A_\perp \sim -A_\|$
- $\mathbf{P_2}$: Proportional to $\mathrm{Re}(A_i A_j)$
  - Zero of P_2 at the same position as the zero of A_{FB}
  - P_2 is the clean version of A_{FB}. Their different normalizations offer different sensitivities.



- P_3 and $P'_{6,8}$ are proportional to $\mathrm{Im} A_i A_j$ and small if there are no large phases. All are < 0.1.
- P_i^{CP} are all negligibly small if there is no New Physics in weak phases.

P_4' and P_5' observables function of $A_{\perp,\|}$ and also A_0 amplitudes

- $\mathbf{P'_{4,5}}$: Proportional to $\mathrm{Re}(A_i A_j)$
- $|P_{4,5}| \leq 1$ but $|P'_{4,5}|$ can be > 1.



In the large-recoil limit

$$A^L_{\perp,\|} \propto \left[\mathcal{C}_9^{\text{eff}} - \mathcal{C}_{10} + \frac{2\hat{m}_b}{\hat{s}}\mathcal{C}_7^{\text{eff}}\right]\xi_\perp(E_{K^*}) \qquad A^R_{\perp,\|} \propto \left[\mathcal{C}_9^{\text{eff}} + \mathcal{C}_{10} + \frac{2\hat{m}_b}{\hat{s}}\mathcal{C}_7^{\text{eff}}\right]\xi_\perp(E_{K^*})$$

$$A^L_0 \propto \left[\mathcal{C}_9^{\text{eff}} - \mathcal{C}_{10} + 2\hat{m}_b\mathcal{C}_7^{\text{eff}}\right]\xi_\|(E_{K^*}) \quad A^R_0 \propto \left[\mathcal{C}_9^{\text{eff}} + \mathcal{C}_{10} + 2\hat{m}_b\mathcal{C}_7^{\text{eff}}\right]\xi_\|(E_{K^*})$$

- In the SM $C_9^{SM} \sim -C_{10}^{SM}$, this cancellation strongly suppresses $A^R_{\perp,\|}$ above 4 Gev^2: $A^L_{\perp,\|} >> A^R_{\perp,\|}$. This makes $P_4 \to 1$ and $P_5 \to -1$ for $q^2 \to 8$ GeV^2 quite fast BUT the fact that $|A_\|| > |A_\perp|$ and that $P_4' \propto A_0^{L*}A_\|^L + A_0^R A_\|^{R*}$ and $P_5' \propto A_0^{L*}A_\perp^L - A_0^R A_\perp^{R*}$ makes less efficient the convergence in the case of P_5'.
- In presence of New Physics affecting only C_9 the cancellation $C_9 \sim -C_{10}$ is less efective, consequently $A^R_{\perp,\|}$ is less suppressed and one should expect to see the effect of $C_9 \neq C_9^{SM}$ in P_5'.

Present bins: [0.1,2], [2,4.3], [4.3,8.68], [1,6], [14.18,16], [16,19] GeV^2.

Observable	Experiment	SM prediction	Pull
$\langle P_1\rangle_{[0.1,2]}$	$-0.19^{+0.40}_{-0.35}$	$0.007^{+0.043}_{-0.044}$	-0.5
$\langle P_1\rangle_{[2,4.3]}$	$-0.29^{+0.65}_{-0.46}$	$-0.051^{+0.046}_{-0.046}$	-0.4
$\langle P_1\rangle_{[4.3,8.68]}$	$0.36^{+0.30}_{-0.31}$	$-0.117^{+0.056}_{-0.052}$	$+1.5$
$\langle P_1\rangle_{[1,6]}$	$0.15^{+0.39}_{-0.41}$	$-0.055^{+0.041}_{-0.043}$	$+0.5$
$\langle P_2\rangle_{[0.1,2]}$	$0.03^{+0.14}_{-0.15}$	$0.172^{+0.020}_{-0.021}$	-1.0
$\langle P_2\rangle_{[2,4.3]}$	$0.50^{+0.00}_{-0.07}$	$0.234^{+0.060}_{-0.086}$	**$+2.9$**
$\langle P_2\rangle_{[4.3,8.68]}$	$-0.25^{+0.07}_{-0.08}$	$-0.407^{+0.049}_{-0.037}$	**$+1.7$**
$\langle P_2\rangle_{[1,6]}$	$0.33^{+0.11}_{-0.12}$	$0.084^{+0.060}_{-0.078}$	$+1.8$
$\langle A_{\rm FB}\rangle_{[0.1,2]}$	$-0.02^{+0.13}_{-0.13}$	$-0.136^{+0.051}_{-0.048}$	$+0.8$
$\langle A_{\rm FB}\rangle_{[2,4.3]}$	$-0.20^{+0.08}_{-0.08}$	$-0.081^{+0.055}_{-0.069}$	-1.1
$\langle A_{\rm FB}\rangle_{[4.3,8.68]}$	$0.16^{+0.06}_{-0.05}$	$0.220^{+0.138}_{-0.113}$	-0.5
$\langle A_{\rm FB}\rangle_{[1,6]}$	$-0.17^{+0.06}_{-0.06}$	$-0.035^{+0.037}_{-0.034}$	-2.0

- $\mathbf{P_1}$: No substantial deviation (large error bars).
- $\mathbf{A_{\rm FB}}$-$\mathbf{P_2}$: A slight tendency for a lower value of the second and third bins of $A_{\rm FB}$ is consistent with a $2.9\,\sigma$ ($1.7\,\sigma$) deviation in the second (third) bin of P_2.
- **Zero**: Preference for a slightly higher q^2-value for the zero of $A_{\rm FB}$ (same as the zero of P_2).

Both effects can be accommodated with $\mathcal{C}_7^{\rm NP} < 0$ and/or $\mathcal{C}_9^{\rm NP} < 0$.

Observable	Experiment	SM prediction	Pull
$\langle P_4' \rangle_{[0.1,2]}$	$0.00^{+0.52}_{-0.52}$	$-0.342^{+0.031}_{-0.026}$	$+0.7$
$\langle P_4' \rangle_{[2,4.3]}$	$0.74^{+0.54}_{-0.60}$	$0.569^{+0.073}_{-0.063}$	$+0.3$
$\langle P_4' \rangle_{[4.3,8.68]}$	$1.18^{+0.26}_{-0.32}$	$1.003^{+0.028}_{-0.032}$	$+0.6$
$\langle P_4' \rangle_{[1,6]}$	$0.58^{+0.32}_{-0.36}$	$0.555^{+0.067}_{-0.058}$	$+0.1$
$\langle P_5' \rangle_{[0.1,2]}$	$0.45^{+0.21}_{-0.24}$	$0.533^{+0.033}_{-0.041}$	-0.4
$\langle P_5' \rangle_{[2,4.3]}$	$0.29^{+0.40}_{-0.39}$	$-0.334^{+0.097}_{-0.113}$	$\mathbf{+1.6}$
$\langle P_5' \rangle_{[4.3,8.68]}$	$-0.19^{+0.16}_{-0.16}$	$-0.872^{+0.053}_{-0.041}$	$\mathbf{+4.0}$
$\langle P_5' \rangle_{[1,6]}$	$0.21^{+0.20}_{-0.21}$	$-0.349^{+0.088}_{-0.100}$	$+2.5$
$\langle P_4' \rangle_{[14.18,16]}$	$-0.18^{+0.54}_{-0.70}$	$1.161^{+0.190}_{-0.332}$	-2.1
$\langle P_4' \rangle_{[16,19]}$	$0.70^{+0.44}_{-0.52}$	$1.263^{+0.119}_{-0.248}$	-1.1
$\langle P_5' \rangle_{[14.18,16]}$	$\mathbf{-0.79^{+0.27}_{-0.22}}$	$\mathbf{-0.779^{+0.328}_{-0.363}}$	$+0.0$
$\langle P_5' \rangle_{[16,19]}$	$\mathbf{-0.60^{+0.21}_{-0.18}}$	$\mathbf{-0.601^{+0.282}_{-0.367}}$	$+0.0$

Definition of the anomaly:

- $\mathbf{P_5'}$: There is a striking $4.0\,\sigma$ ($1.6\,\sigma$) deviation in the third (second) bin of P_5'.

  Consistent with large negative contributions in $\mathcal{C}_7^{\rm NP}$ and/or $\mathcal{C}_9^{\rm NP}$.

- $\mathbf{P_4'}$: in agreement with the SM, but within large uncertainties, and it has future potential to determine the sign of $\mathcal{C}_{10}^{\rm NP}$.

- $\mathbf{P_6'}$ and $\mathbf{P_8'}$: show small deviations with respect to the SM, but such effect would require complex phases in $\mathcal{C}_9^{\rm NP}$ and/or $\mathcal{C}_{10}^{\rm NP}$.

Us: $(-0.19-(-0.872))/\sqrt{0.16^2+0.053^2}=4.05$ and **Exp**: $(-0.19-(-0.872+0.053))/\sqrt{0.16^2+0.053^2}=3.73$

Our SM predictions+LHCb data

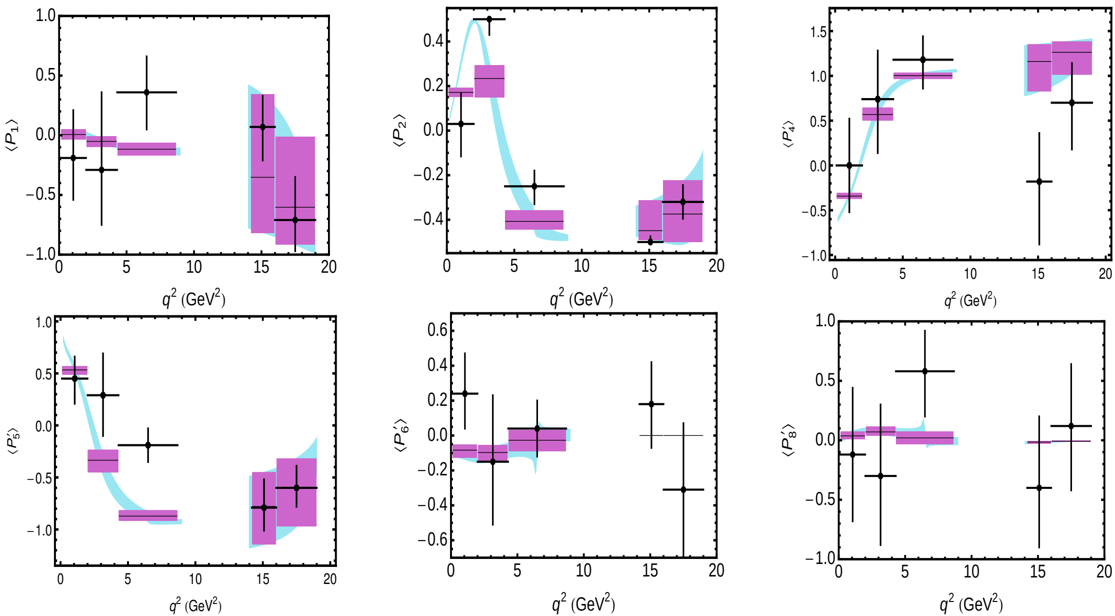


Figure : Experimental measurements and SM predictions for some $B \to K^* \mu^+ \mu^-$ observables. The black crosses are the experimental LHCb data. The blue band corresponds to the SM predictions for the differential quantities, whereas the purple boxes indicate the corresponding binned observables.

General case all WC free

Result of our analysis (large+low recoil data+rad) if we allow **all Wilson coefficients** to vary freely:

Coefficient	$1\,\sigma$	$2\,\sigma$	$3\,\sigma$
$\mathcal{C}_7^{\rm NP}$	$[-0.05, -0.01]$	$[-\mathbf{0.06}, \mathbf{0.01}]$	$[-0.08, 0.03]$
$\mathcal{C}_9^{\rm NP}$	$[-1.6, -0.9]$	$[-1.8, -0.6]$	$[-\mathbf{2.1}, -\mathbf{0.2}]$
$\mathcal{C}_{10}^{\rm NP}$	$[-\mathbf{0.4}, \mathbf{1.0}]$	$[-1.2, 2.0]$	$[-2.0, 3.0]$
$\mathcal{C}_{7'}^{\rm NP}$	$[-\mathbf{0.04}, \mathbf{0.02}]$	$[-0.09, 0.06]$	$[-0.14, 0.10]$
$\mathcal{C}_{9'}^{\rm NP}$	$[-\mathbf{0.2}, \mathbf{0.8}]$	$[-0.8, 1.4]$	$[-1.2, 1.8]$
$\mathcal{C}_{10'}^{\rm NP}$	$[-\mathbf{0.4}, \mathbf{0.4}]$	$[-1.0, 0.8]$	$[-1.4, 1.2]$

Table : 68.3% ($1\,\sigma$), 95.5% ($2\,\sigma$) and 99.7% ($3\,\sigma$) confidence intervals for the NP contributions to WC.

- This table tells you again that there is **strong evidence for a $\mathcal{C}_9^{\rm NP} < 0$, preference for $\mathcal{C}_7^{\rm NP} < 0$** and **no clear-cut evidence** for $\mathcal{C}_{10,7',9',10'}^{\rm NP} \neq 0$.
- *This does not imply that they will be at the end zero but that* **present data** *does not point clearly for a positive or negative value.*

General case all WC free

In conclusion our pattern of [PRD88 (2013) 074002] obtained from an $\mathcal{H}_{eff}$ approach is

$$\mathbf{C_9^{NP}} \sim [\mathbf{-1.6}, \mathbf{-0.9}], \quad \mathbf{C_7^{NP}} \sim [\mathbf{-0.05}, \mathbf{-0.01}], \quad \mathbf{C_9'} \sim \pm\delta \quad \mathbf{C_{10}}, \mathbf{C'_{7,10}} \sim \pm\epsilon$$

where δ is small (at maximum half $|\mathbf{C_9^{NP}}|$) and ϵ is smaller.

A simplified version is $C_9^{NP} = -1.5$

Best fit points:

Large recoil: $\mathbf{C_9^{NP}} = \mathbf{-1.5}$, $C_{7eff}^{\rm NP} = -0.02$

Large recoil: $\mathbf{C_9^{NP}} = \mathbf{-1.6}$, $C_{7eff}^{\rm NP} = -0.02$, $C_{10}^{\rm NP} > 0$, $\mathbf{C_{9\prime}^{\rm NP}} < \mathbf{0}$, $C_{7\prime}^{\rm NP} > 0$, $C_{10\prime}^{\rm NP} < 0$.

Large+Low: $\mathbf{C_9^{NP}} = \mathbf{-1.2}$, $C_{7eff}^{\rm NP} = -0.03$, $C_{10}^{\rm NP} > 0$, $\mathbf{C_{9\prime}^{\rm NP}} > \mathbf{0}$, $C_{7\prime}^{\rm NP} < 0$, $C_{10\prime}^{\rm NP} < 0$

Can we test if the anomaly in P_5' is isolated?

Important test for 3 fb^{-1} data

BUT

already now there are interesting hints...

How do we know that we have a complete description for $B \to K^*(\to K\pi)\mu^+\mu^-$

[Egede, Hurth, JM, Ramon, Reece'10]

An important step forward was the identification of the **symmetries** of the distribution:

Transformation of amplitudes leaving distribution invariant.

Symmetries determine the minimal # observables for each scenario:

$$n_{obs} = 2n_A - n_S$$

Case	Coefficients	Amplitudes	Symmetries	Observables
$m_\ell = 0,\ A_S = 0$	11	6	4	**8**
$m_\ell = 0$	11	7	5	**9**
$m_\ell > 0,\ A_S = 0$	11	7	4	**10**
$m_\ell > 0$	12	8	4	**12**

All symmetries (massive and scalars) were found explicitly later on.

[JM, Mescia, Ramon, Virto'12]

Symmetries $\Rightarrow$ # of observables $\Rightarrow$ determine a **basis**: each angular observable constructed can be expressed in terms of this basis.

[Egede, Hurth, JM, Ramon, Reece JHEP 1010 (2010) 056]

Let's review first the **symmetry formalism** for the massless angular distribution:

$$\mathbf{n}_{\|} = \begin{pmatrix} A_{\|}^{L} \\ A_{\|}^{R*} \end{pmatrix}, \quad \mathbf{n}_{\perp} = \begin{pmatrix} A_{\perp}^{L} \\ -A_{\perp}^{R*} \end{pmatrix}, \quad \mathbf{n_0} = \begin{pmatrix} A_{0}^{L} \\ A_{0}^{R*} \end{pmatrix}.$$

All the coefficients $\mathbf{J_i}$ can be expressed in terms of the products $\mathbf{n_i^\dagger}\,\mathbf{n_j}$ (example):

$$J_3 = \frac{1}{2}\left(|n_\perp|^2 - |n_\||^2\right), \quad J_4 = \frac{1}{\sqrt{2}}\mathrm{Re}(n_0^\dagger\, n_\|), \quad J_5 = \sqrt{2}\,\mathrm{Re}(n_0^\dagger\, n_\perp), \quad J_9 = -\mathrm{Im}(n_\perp^\dagger\, n_\|)$$

A **symmetry** of the angular distribution will be a unitary transformation $n_i \to U n_i$

$$n_i^{'} = U n_i = \begin{bmatrix} e^{i\phi_L} & 0 \\ 0 & e^{-i\phi_R} \end{bmatrix} \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} \cosh i\tilde{\theta} & -\sinh i\tilde{\theta} \\ -\sinh i\tilde{\theta} & \cosh i\tilde{\theta} \end{bmatrix} n_i \,.$$

U defines the **four symmetries** of the massless angular distribution:

- two global phase transformations (ϕ_L and ϕ_R),
- a rotation θ among the real and imaginary components of the amplitudes independently
- another rotation $\tilde{\theta}$ that mixes real and imaginary components of the transversity amplitudes.

Solving the system of equations of $A_{\perp,\|,0}$ in terms of J_i (using three of the symmetries) we found:

$$e^{i(\phi_0^L-\phi_\perp^L)} = \frac{2(2J_{2s}-J_3)(J_5+2iJ_8)-(2J_4+iJ_7)(J_{6s}-2iJ_9)}{\sqrt{16J_{2s}^2-4J_3^2-J_{6s}^2-4J_9^2}\sqrt{2J_{1c}(2J_{2s}-J_3)-4J_4^2-J_7^2}},$$

This equation is related to the freedom associated to the **fourth** unused symmetry transformation $\tilde{\theta}$.

Imposing that its modulo is one we find:

$$\begin{aligned} J_{2c} &= -2\frac{(2J_{2s}+J_3)\left(4J_4^2+\beta_\ell^2J_7^2\right)+(2J_{2s}-J_3)\left(\beta_\ell^2J_5^2+4J_8^2\right)}{16J_{2s}^2-\left(4J_3^2+\beta_\ell^2J_{6s}^2+4J_9^2\right)} \\ &\quad +4\frac{\beta_\ell^2J_{6s}(J_4J_5+J_7J_8)+J_9(\beta_\ell^2J_5J_7-4J_4J_8)}{16J_{2s}^2-\left(4J_3^2+\beta_\ell^2J_{6s}^2+4J_9^2\right)}, \end{aligned}$$

Indeed an identical equation can be written in terms of the $\bar{J}_i$.

[J.M, N. Serra '14]

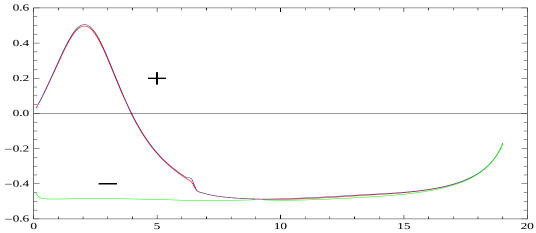
This equation can be expressed in terms of P_i and P_i^{CP} observables to get:

$$\bar{P}_2 = +\frac{1}{2\bar{k}_1}\left[(\bar{P}_4'\bar{P}_5' + \delta_1) + \frac{1}{\beta}\sqrt{(-1+\bar{P}_1+\bar{P}_4'^2)(-1-\bar{P}_1+\beta^2\bar{P}_5'^2)+\delta_2+\delta_3\bar{P}_1+\delta_4\bar{P}_1^2}\right]$$

where

$$\bar{P}_i = P_i + P_i^{CP} \qquad \beta = \sqrt{1-4m_\ell^2/s}$$

The sign in front of the square root is taken "+" everywhere by comparison with exact result in SM, at low-recoil both solutions (+ and -) converge. (Plot with $\delta_i \to 0$)



REMARK:

- **This is an exact equation valid for any q^2 (low, large) and obtained from symmetries.**
- **It involves 6 P_i of the basis plus one redundant.**

An identical equation can be written in terms of $\hat{P}_i = P_i - P_i^{CP}$, substituting $\bar{P}_i \to \hat{P}_i$ everywhere. More importantly all terms inside the δ_i are strongly suppressed (by small strong and weak phases):

$$\delta_i \sim \mathcal{O}((\mathrm{Im}A_i)^2, 1-\bar{k}_1) \quad \text{and} \quad \bar{k}_1 = 1 + F_L^{CP}/F_L$$

Hypothesis: No **New Physics in weak phases** entering Wilson coefficients and **not scalars/tensors**. Both hypothesis can be tested, measuring P_i^{CP} and S_1.

To an **excellent approximation** we have:

$$P_2 = \frac{1}{2}\left[P'_4 P'_5 + \frac{1}{\beta}\sqrt{(-1+P_1+P'^2_4)(-1-P_1+\beta^2 P'^2_5)}\right]$$

This equation can be used in *binned form* if:

- Observables are nearly constant inside the bin
- Or the size of the bin is very small.

We correct for this by $\langle P_2 \rangle \to \langle P_2 \rangle + \Delta^{\rm NP}_{\rm exact-relation}$ where $\Delta^{\rm NP}_{\rm exact-relation}$ is order 10^{-2} except for [0.1-2] bin and [1-6] bin.

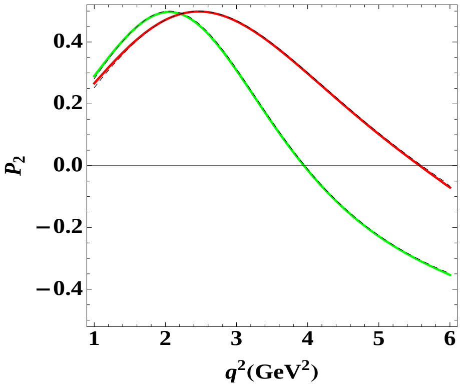


Figure : Green: SM exact, dashed inside approximation, Red: NP $C_9^{NP} = -1.5$ exact, dashed inside approximation

The striking consequence of this equation is that it allows you to use data **to predict** *the* **impact of the anomaly in** P'_5 *in a completely* **different observable***:* P_2

- The terms δ_i has been computed in the SM and in presence of New Physics [constrained range]

$$\begin{aligned} -0.1 &\leq C_7^{NP} \leq 0.1,\ -2 \leq C_9^{NP} \leq 0,\ -1 \leq C_{10}^{NP} \leq 1 \\ -0.1 &\leq C_7' \leq 0.1, \quad -2 \leq C_9' \leq 2, \quad -1 \leq C_{10}' \leq 1 \end{aligned}$$

being always bounded within $10^{-1} - 10^{-2}$.

	δ_1	δ_2	δ_3	δ_4
$\|SM\|$	$\lesssim 0.01$	$\lesssim 0.03$	$\lesssim 0.01$	$\lesssim 0.01$
NP	$[-0.03, 0.01]$	$[-0.09, 0.01]$	$[-0.04, 0.04]$	$[-0.03, 0.02]$

The smaller the size of the bin the smaller the error

Point	[0.1-2]*	[2-4.3]	[4.3-8.68]	[1-6]*	[1-2]	[2-3]	[3-4]	[4-5]	[5-6]
$\Delta^{\rm SM}_{\rm exact-relation}$	-0.14	-0.06	-0.03	-0.21	-0.02	-0.02	-0.01	-0.01	-0.01
$\Delta^{\rm NP}_{\rm exact-relation}$ *upper*	-0.07	-0.02	-0.02	-0.08	$+0.00$	$+0.00$	$+0.00$	$+0.00$	$+0.01$
$\Delta^{\rm NP}_{\rm exact-relation}$ *down*	-0.23	-0.10	-0.09	-0.28	-0.07	-0.04	-0.03	-0.02	-0.04
$\Delta^{\rm C_9^{NP}=-1.5}_{\rm exact-relation}$	-0.11	-0.04	-0.04	-0.16	-0.01	-0.01	-0.01	-0.01	-0.01

Implication I: **A new bound on P_1**

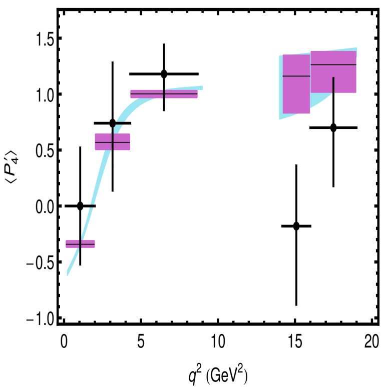
Imposing that the square root is well defined one finds:

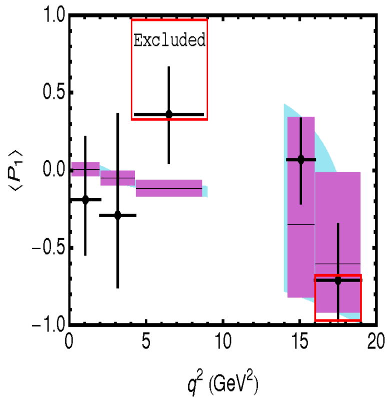
$$P_5'^2 - 1 \leq P_1 \leq 1 - P_4'^2$$

- Indeed this is an exact bound that could be alternatively obtained from

$$|P_4| = |P_4'|/\sqrt{1-P_1} \leq 1 \quad \text{and} \quad |P_5| = |P_5'|/\sqrt{1+P_1} \leq 1$$

$|P_{4,5}| \leq 1$ comes from the geometrical interpretation of those observables in terms of n_i.





- The new upper bound is very stringent for the [4.3,8.68] bin, cutting most of the space for a positive P_1: $P_1^{[4.3,8.68]} < 0.33$
- The lower bound is particularly relevant for the [16,19] bin of P_1: $P_1^{[16,19]} > -0.68$.

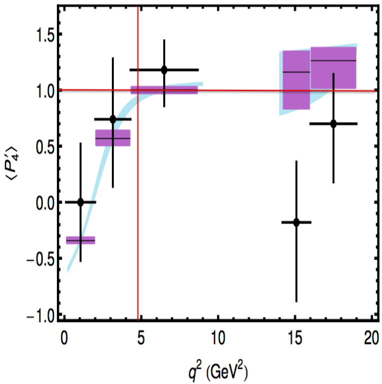
Implication II: **At the position of the zero q_0^2 of P_2 (same as A_{FB}) the following relation holds:**

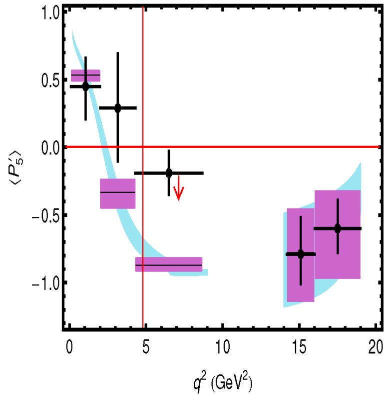
$$[P_4^2 + P_5^2]|_{q^2=q_0^2} = 1 \quad \text{or} \qquad [P_4'^2 + P_5'^2]|_{q^2=q_0^2} = 1 - \eta(q_0^2)$$

where

$$\eta(q_0^2) = P_1^2 + P_1(P_4'^2 - P_5'^2)|_{q^2=q_0^2}$$

SM Zero of A_{FB}: $q_0^{2SM} = 3.95 \pm 0.38$ (our), 3.90 ± 0.12 (Buras'08), 2.9 ± 0.3 (Khodjamirian'10) GeV^2
Experimental LHCb data: $q_0^{2LHCb} = 4.9 \pm 0.9$ GeV^2





Assume that a future precise measurement of the zero confirms $q_0^{2exp} \sim 4.9$ GeV^2 with small error.

If $P_4' \sim 1$ and $P_1 \geq 0$ at $q_0^2 = 4.9$ GeV^2 (like present data seems to suggest) then one should find $P_1(q_0^2) \leq 1 - P_4'^2 \sim 0$, $\eta(q_0^2) \sim 0$ **and** $\mathbf{P_5'(q_0^2) \sim 0}$

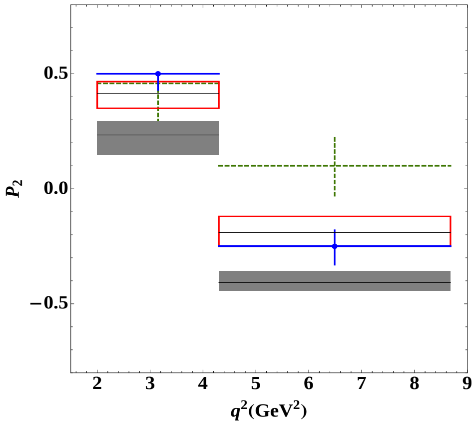
(notice that in SM $P_5'(q_0^2) = -0.75$)

A precise measurement of q_0^2 (zero of A_{FB}) outside the SM region would serve as an indirect confirmation of the anomaly

Implication III: **We can establish a new relation between the anomaly bin in P_5' and P_2:**

$$\langle P_2\rangle = \frac{1}{2}\left[\langle P_4'\rangle\langle P_5'\rangle + \sqrt{(-1+\langle P_1\rangle+\langle P_4'\rangle^2)(-1-\langle P_1\rangle+\langle P_5'\rangle^2)}\right] + \Delta^{bin}_{exact}$$

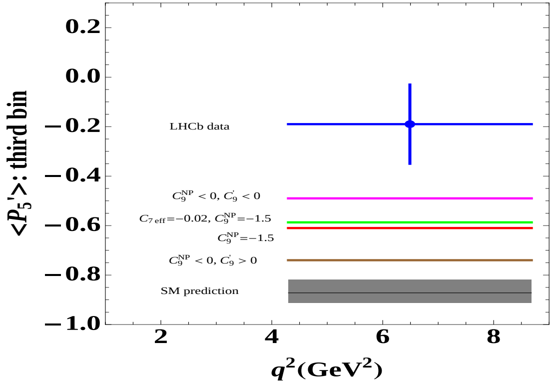
where $\Delta^{bin}_{exact} = -0.04$ for NP best fit point at 2nd and 3rd bin, while $\Delta^{bin}_{exact} = -0.01$ for 1 GeV^2 size.



GRAY band: SM prediction. **BLUE cross**: Measured value of P_2
RED rectangle: $C_9^{NP} = -1.5$ NP prediction.
Green cross is $\langle P_2\rangle$ obtained from combining data of $\langle P_{4,5}'\rangle$, $\langle P_1\rangle$, considering asymmetric errors and bound on P_1

- Bin [2,4.3]: LHCb data:$+0.50^{+0}_{-0.07}$,Relation:$+0.46^{+0}_{-0.19}$
  0.2σ measured (blue cross) versus relation (green cross)
- Bin[4.3,8.68]: LHCb data:$-0.25^{+0.07}_{-0.08}$, Relation:$+0.10^{+0.13}_{-0.13}$
  2.4σ measured (blue cross) versus relation (green cross),
  1.9σ from relation to NP best fit point (red box),
  3.6σ from relation to SM.

Extremely simplified where $P_4' \sim 1$ (if $P_1 \sim 0$): $P_2 \sim \frac{1}{2}P_5'$

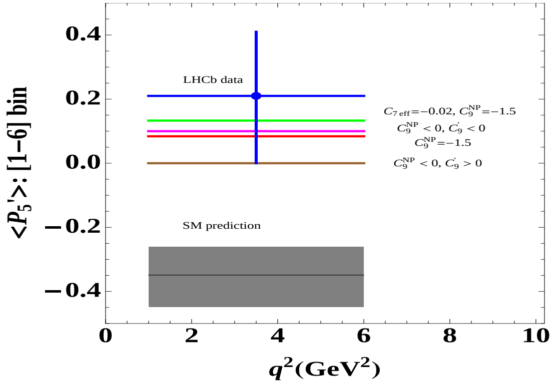


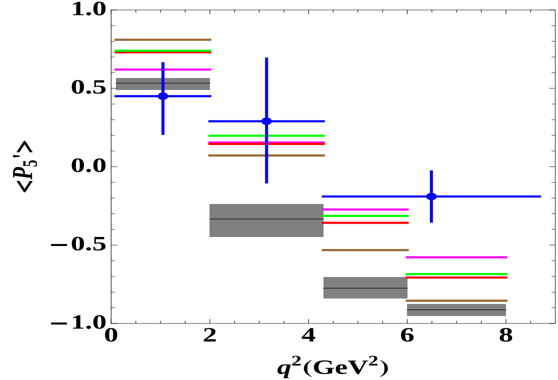
It is not surprising that the second bin in P_2 fits perfectly, while the third bin in P_2 goes on the right direction but does not fit perfectly.

Reason It is very difficult to get excellent agreement with the third bin of P_5' inside a global fit.

- Our large recoil best fit point gives $\langle P_5' \rangle_{[4.3,8.68]} = -0.49$ and reduces tension with data at 1.8σ (from 4σ in SM): $C_9' < 0$ is strongly favored by this bin.
- The best fit point with $C_9^{NP} = -1.5$ gives $\langle P_5' \rangle_{[4.3,8.68]} = -0.61$.
- Any analysis with $C_9' > 0$ provides a much worst disagreement with data in this bin.

Most plausible scenario: Third bin in P_5' will go down (reducing distance with SM) while third bin in P_2 might go up (enlarging distance with SM): *Global picture much more consistent.*





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Most plausible scenario: Third bin in P_5' will go down (reducing distance with SM) while third bin in P_2 might go up (enlarging distance with SM): *Global picture much more consistent.*

Implication IV:

The first low-recoil bin [14.18,16] can also be tested using this equation

LHCb data on P_2 in this bin gives: $-\mathbf{0.50}^{+0.03}_{-0.00}$

LHCb data on P_4', P_1, P_5' implies that P_2 should be: $+\mathbf{0.50}^{+0}_{-0.27}$ (if $+$) or $-\mathbf{0.50}^{+0.33}_{+0}$ (if -)

- This shows a discrepancy of $\mathbf{3.7}\sigma$ if $+$ solution is taken
- Or agreement if - solution is chosen

However both solutions $+$ and - should give same result at low-recoil

Conclusion: The measurement of this first low recoil bin is probably exhibiting a statistical fluctuation or signaling a problem at low recoil.

Implication V:

ALTERNATIVELY **Full fit of the angular distribution with a small dataset**

Under the assumption of real Wilson coefficients one has

- Free parameters F_L, P_1, $P'_{4,5}$.
- P_2 is a function of the other observables and $P'_{6,8}$ are set to zero.

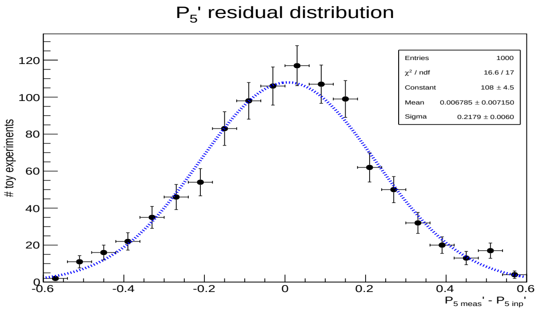

Figure : Residual distribution of P'_5 when fitting with 100 events. The fit of a gaussian distribution is superimosed.

We find testing this fit for values around the measured values: **convergence and unbiased pulls** with as little as 50 events per bin. Gaussian pulls are obtained with only 100 events.

This opens the possibility to perform a full angular fit analysis with small bins in q^2

The main hypothesis (real WC) can be tested measuring P_i^{CP}.

Conclusions

- We have addressed, using symmetries, the question:

Is the anomaly in P'_5 isolated?

  - The anomaly in P'_5 should also appear in P_2 in a specific way: The interesting result is that the deviation observed in P_2 in this same bin goes in the direction predicted by the anomaly.
  - The higher position of the zero of A_{FB} the smaller the value of P'_5 at this point (for a P'_4 SM-like)
  - A strong upper and lower bound on P_1: $P'^2_5 - 1 \leq P_1 \leq 1 - P'^2_4$
  - The first low-recoil bin of P'_4 exhibits a 3.7σ tension between the measured and obtained value using "+" solution, pointing possibly to a statistical fluctuation or a low-recoil problem.
  - The obtained relation among $P_2, P'_{4,5}, P_1$ opens the possibility to perform **now** a full angular fit with a reduced number of events.

BACK-UP slides