Quo Vadis P_5' ?

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on behalf of the $B \to K^* \mu\mu$ team

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The road (towards NP ?)

$\Rightarrow$ Several theory authors proposed to measure a "clean" observable:

$$\mathrm{P}_5' = \frac{S_5}{\sqrt{F_L(1-F_L)}}$$

$\Rightarrow$ At leading order of α_s and m_b expansion the form factors cancel arxiv::1207.2753

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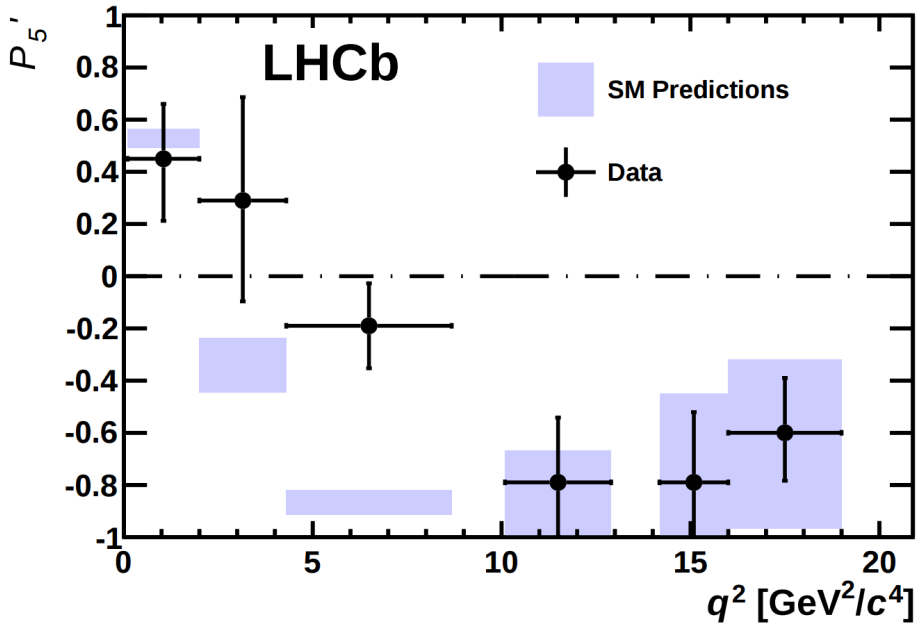
⇛ LHCb: arXiv::1308.1707 ($1\ \mathrm{fb}^{-1}$)



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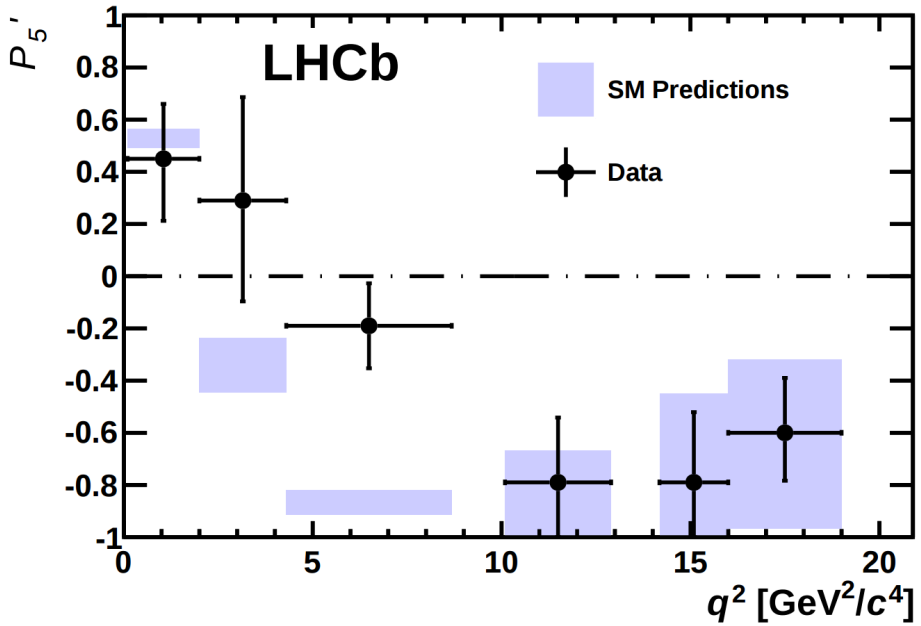
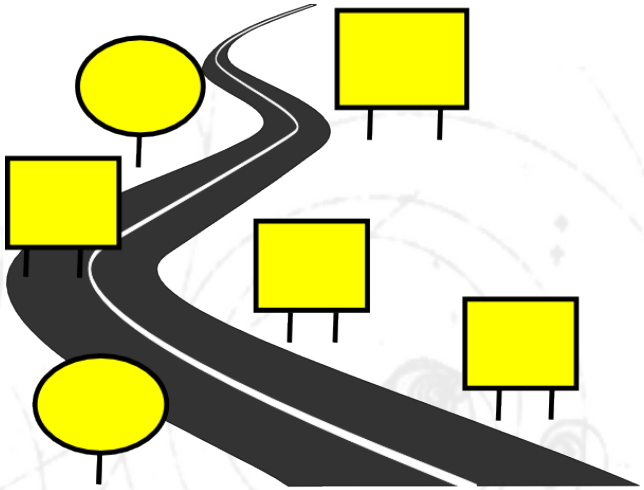


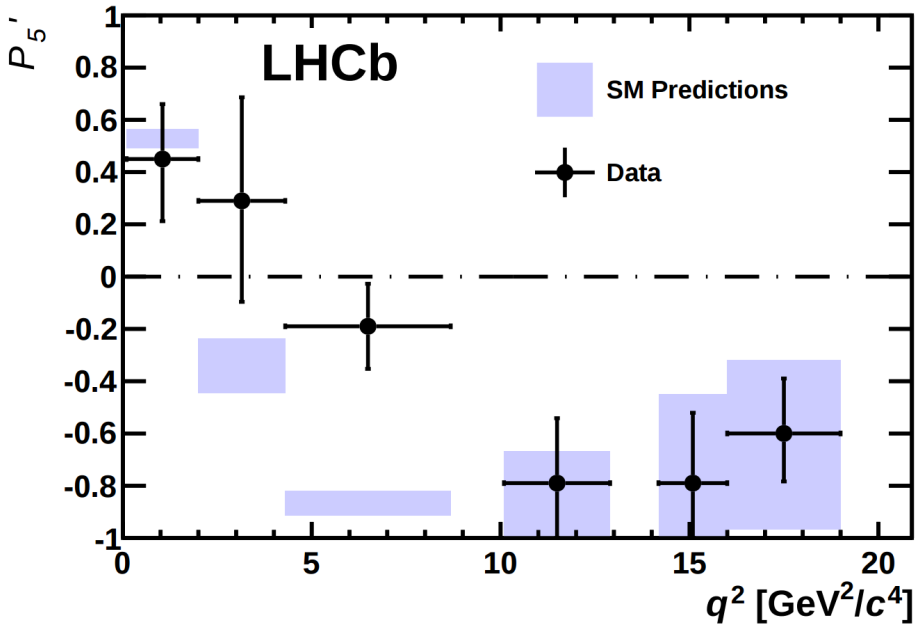
What we were promised:

What we got:



The history of P_5'

$\Rightarrow$ 2013 LHCb:
arXiv::1308.1707



The history of P_5'

⇛ 2013 LHCb:
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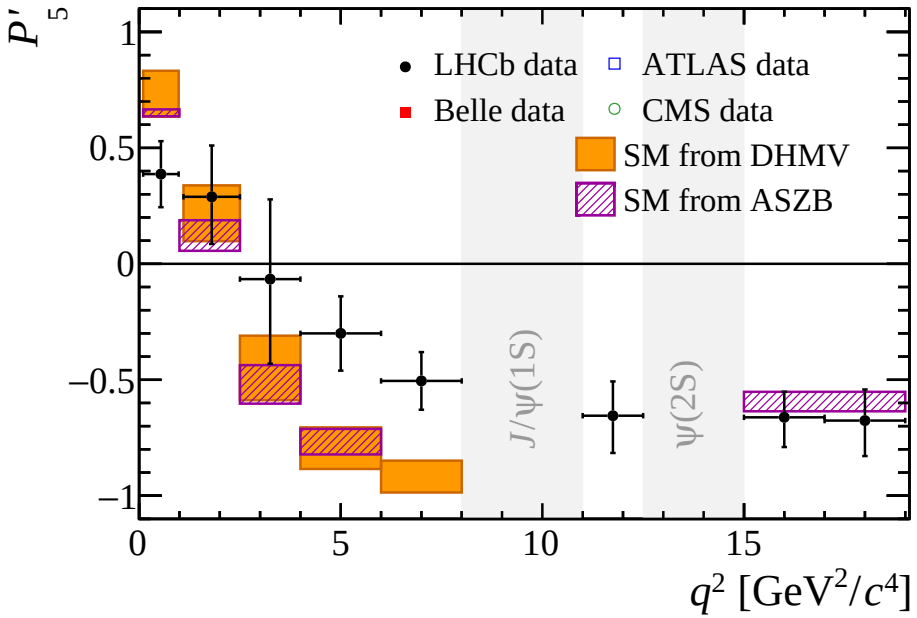
⇛ 2015 LHCb:
arXiv::1512.0444

⇛ Theory: DHMV: arXiv::1407.8526
ASZB: arXiv::1411.3161



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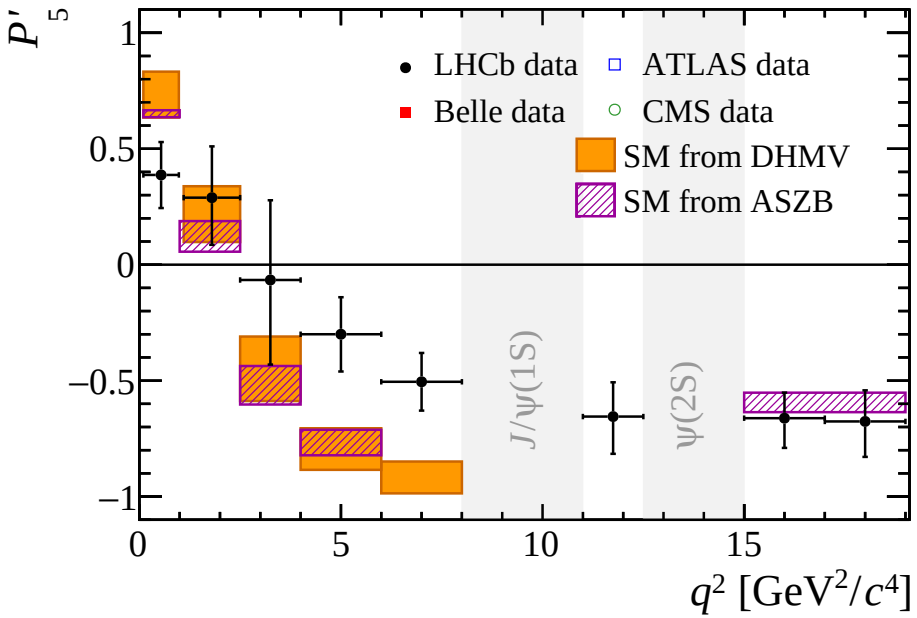

⇛ We generated a lot of interest :) The paper has now 115 citations!
⇛ Two alliances were formed:

⇛ We have new physics:

⇛ We have QCD effects:

arXiv::1611.04338 L.Silvestrini,

The history of P_5'

⇛ 2013 LHCb: arXiv::1308.1707

⇛ 2015 LHCb: arXiv::1512.0444

⇛ 2016 Belle: arXiv::1604.04042

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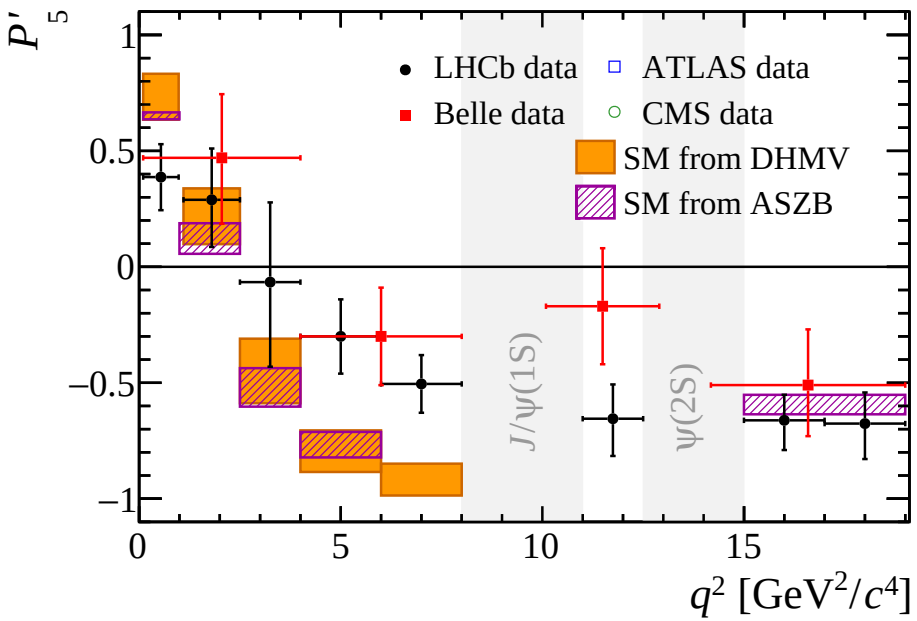


The history of P_5'

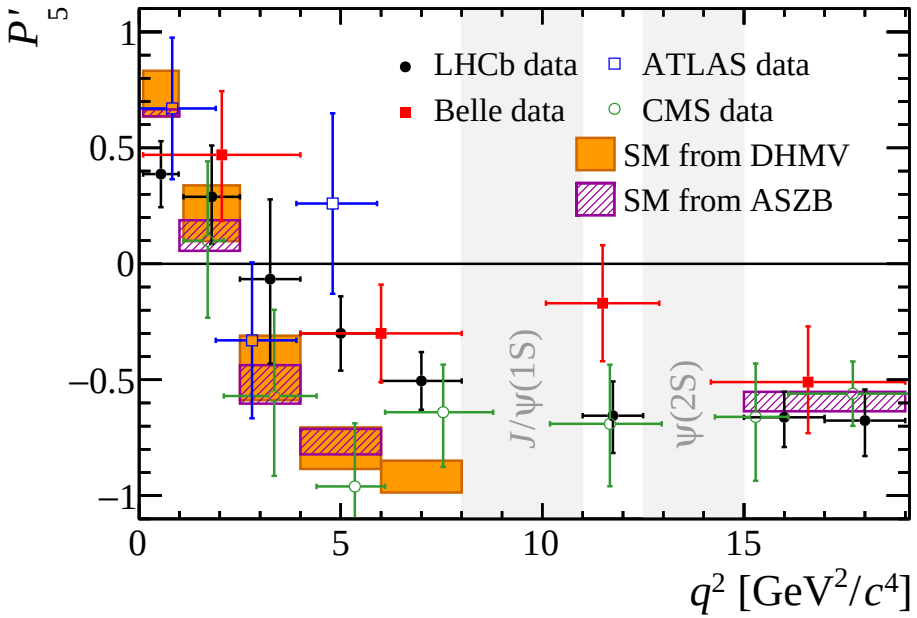
⇛ 2013 LHCb: arXiv::1308.1707

⇛ 2015 LHCb: arXiv::1512.0444

⇛ 2016 Belle: arXiv::1604.04042

⇛ 2017: ATLAS-CONF-2017-023 $(20.5\ \mathrm{fb}^{-1})$ and CMS-PAS-BPH-15-008 $(20.8\ \mathrm{fb}^{-1})$

⇛ Theory: DHMV: arXiv::1407.8526 ASZB: arXiv::1411.3161



Details about their ATLAS & CMS analysis 1/2

$\Rightarrow$ The results are based on Run1 data.

$\Rightarrow$ The measurement of P_5' is possible knowing the B flavour.

$\Rightarrow$ In LHCb we have the RICH, but ATLAS and CMS don't, so the flavour is assigned by checking two possible mass hypothesis for K^* and choosing the one closer to the SM value (13% for CMS and 11% for ATLAS).

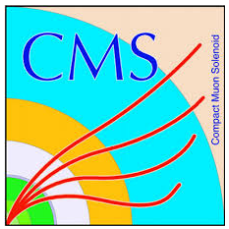
$\Rightarrow$ The analysis follows our LHCb results from $1\ \mathrm{fb}^{-1}$:

- Not enough events to perform the full angular fit.
- Fold the angles to reduce the number of observables
- In this procedure you lose correlations between the observables

$\Rightarrow$ The acceptance corrections both in CMS and ATLAS parametrized as $\epsilon(\cos\theta_l, \cos\theta_k, \phi, m)$ in each of the q^2 bin.

Details about their ATLAS & CMS analysis 2/2

⇛ Angular acceptance parametrized by polynomial functions.
⇛ Determination of F_L, P_1, P_4', P_5', P_6', P_8' and/or S_i $i = 3, 4, 5, 7, 8$.
⇛ Systematic for S-wave (small)
⇛ Main systematics: background: charm, partRECO, fake K^*.
⇛ $\mathrm{B} \to \mathrm{K}^* \mathrm{J}/\psi$ used ONLY for mass PDF.



⇛ Angular acceptance parametrized by KDE and sampled histograms.
⇛ Determination of only P_1 and P_5'.
⇛ Swave fraction inferred from previous measurement.
⇛ Main systematics: Control channel differences.
⇛ $\mathrm{B} \to \mathrm{K}^* \mathrm{J}/\psi$ used for systematics.

Global analysis

$\Rightarrow$ Two main players on the market:

$\Rightarrow$ J. Matias, et. al.

$\Rightarrow$ Measurements taken into the analysis:

- Angular and Br of $\mathrm{B} \to \mathrm{K}^* \mu\mu$
- Angular and Br of $\mathrm{B}_\mathrm{s}^0 \to \phi\mu\mu$
- Angular and Br of $\mathrm{B} \to \mathrm{K}\mu\mu$
- Br $\mathrm{B} \to X_s\mu\mu$ and $\mathrm{b} \to \mathrm{s}\gamma$
- $\mathrm{B}_\mathrm{s}^0 \to \mu\mu$

$\Rightarrow$ D. Straub, et. al.

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- Angular and Br of $\mathrm{B} \to \mathrm{K}^* \mu\mu$
- Angular and Br of $\mathrm{B}_\mathrm{s}^0 \to \phi\mu\mu$
- Angular and Br of $\mathrm{B} \to \mathrm{K}\mu\mu$
- Br $\mathrm{B} \to X_s\mu\mu$

$\Rightarrow$ There are also subtle difference in the theory treatment of form factors.

So what is the significance? J. Matias, et. al.

$\Rightarrow$ LHCb ($3\ \mathrm{fb}^{-1}$):

Coefficient	Best Fit	$\mathrm{Pull}_{\mathrm{SM}}$
C_9	-1.09	4.5
$C_9 = -C_{10}$	-0.68	4.2
$C_9 = -C_9'$	-1.06	4.8
$C_9 = -C_{10}$ and $C_9' = -C_{10}'$	-0.69	4.1

So what is the significance? J. Matias, et. al.

$\Rightarrow$ LHCb ($3\ \mathrm{fb}^{-1}$) + Belle:

Coefficient	Best Fit	$\mathrm{Pull}_{\mathrm{SM}}$
C_9	-1.12	5.0 (!!!)
$C_9 = -C_{10}$	-0.61	4.4
$C_9 = -C_9'$	-1.05	4.5
$C_9 = -C_{10}$ and $C_9' = -C_{10}'$	-0.66	4.6

So what is the significance? J. Matias, et. al.

$\Rightarrow$ LHCb ($3\ \mathrm{fb}^{-1}$) + Belle + ATLAS:

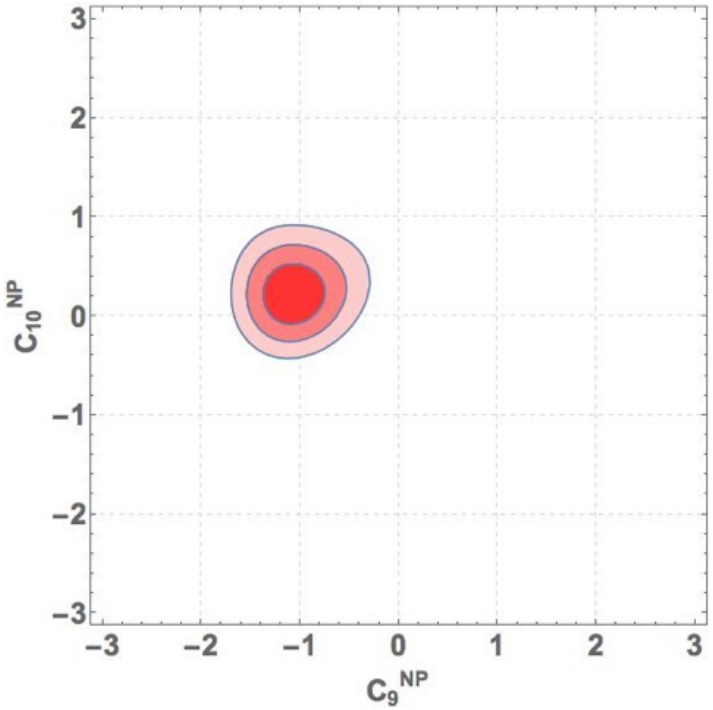
Coefficient	Best Fit	$\mathrm{Pull}_{\mathrm{SM}}$
C_9	-1.14	5.2 (!!!)
$C_9 = -C_{10}$	-0.60	4.4
$C_9 = -C_9'$	-1.08	4.9
$C_9 = -C_{10}$ and $C_9' = -C_{10}'$	-0.67	4.6

So what is the significance? J. Matias, et. al.

$\Rrightarrow$ LHCb ($3\ \mathrm{fb}^{-1}$) + Belle + ATLAS + CMS:

Coefficient	Best Fit	$\mathrm{Pull}_{\mathrm{SM}}$
C_9	-1.07	4.9
$C_9 = -C_{10}$	-0.58	4.3
$C_9 = -C_9'$	-1.01	4.6
$C_9 = -C_{10}$ and $C_9' = -C_{10}'$	-0.61	4.3

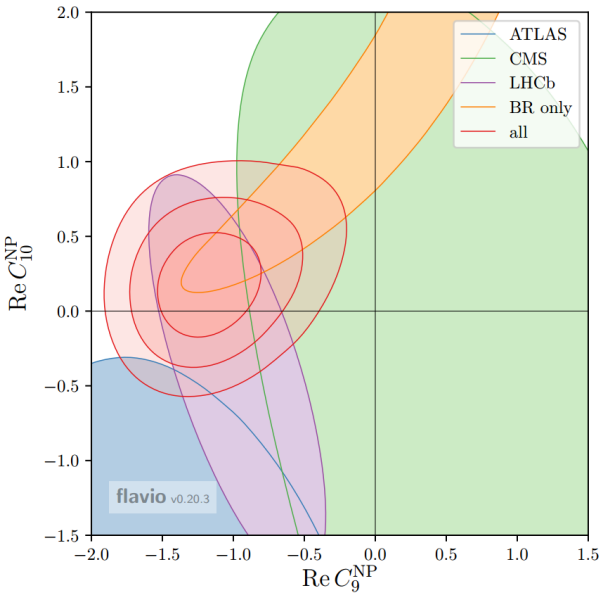
So what is the significance? J. Matias, et. al.

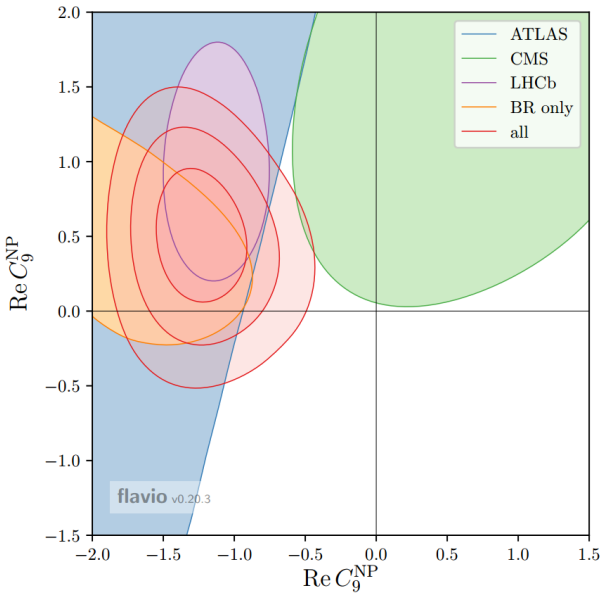


So what is the significance? D. Straub, et. al. [1703.09189]

⇛ LHCb ($3\ \mathrm{fb}^{-1}$) + CDF + ATLAS + CMS:

Coefficient	Best Fit	$\mathrm{Pull}_{\mathrm{SM}}$
C_9	-1.21	4.9
$C_9 = -C_{10}$	-0.62	4.2





⇛ Both groups came to a similar conclusion!

~~Quo Vadis~~ P_5' ?
Status Quo P_5' !

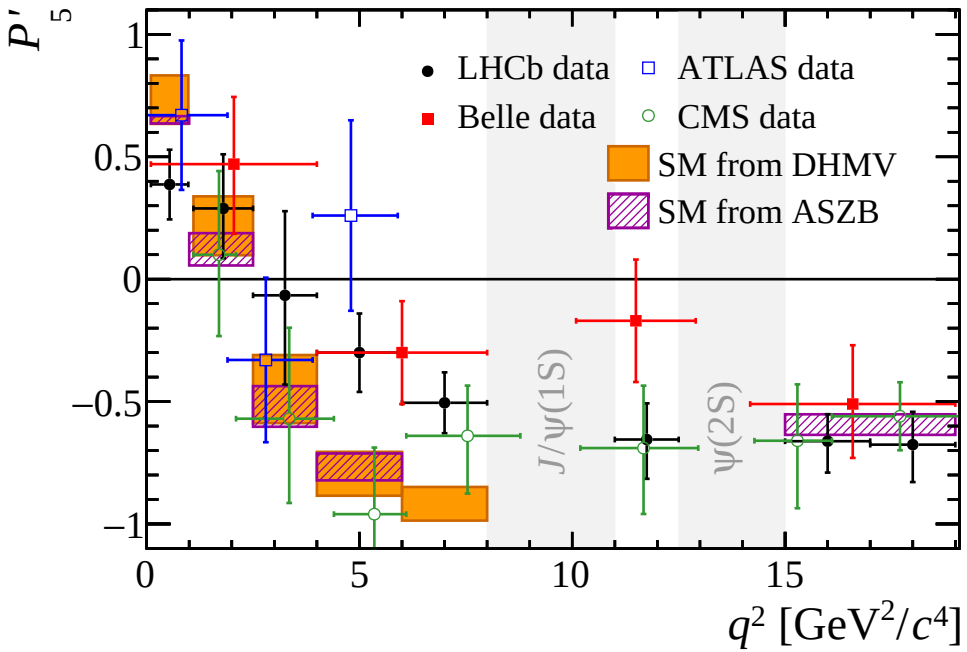
Comments about the CMS result 1/4

⇛ Both ATLAS and CMS use our folding technique that was used in the $1\ \mathrm{fb}^{-1}$ analysis. ⇛ CMS when performing the angular fit fixes the F_L, F_S and A_s from the previous analysis on the same data!

⇛ They claim that they check with TOYMC that it is correct. However some doubts remain.

⇛ Feldman-Cousin procedure can underestimate the errors in this case.

⇛ More details on toy validation and or bootstrapping the data would be nice!

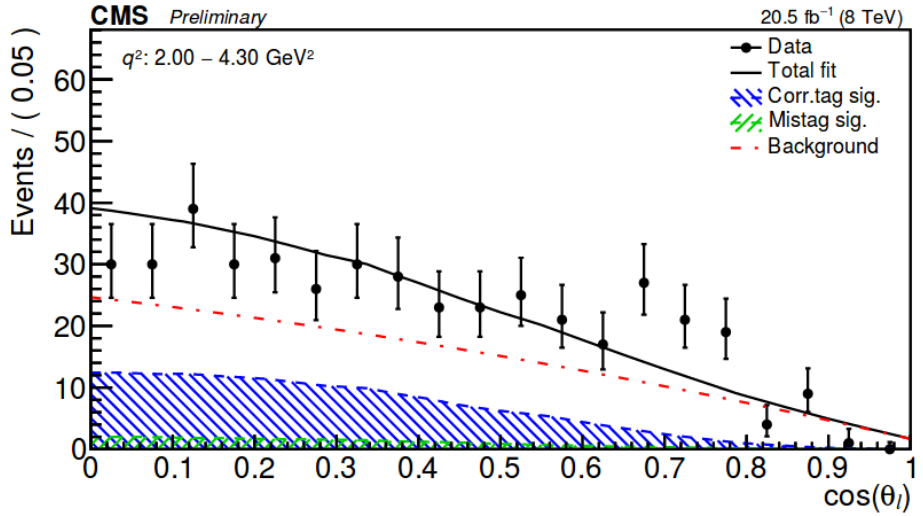


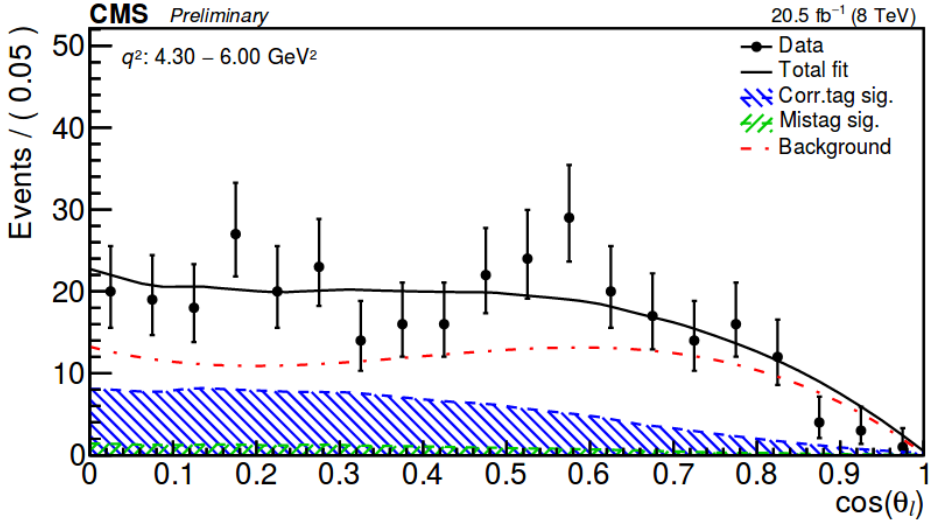
Comments about the CMS result 2/4

⇛ There seems to be a structure in the $\cos\theta_l$ distribution.

⇛ A.Bevan suggested this might be due to a $\mathrm{B} \to \mathrm{D}(\mathrm{K}\pi\pi)\pi$

⇛ Can be easily checked with MC.





Comments about the CMS result 3/4

⇛ In the decay of $\mathrm{B} \to \mathrm{K}^* \mathrm{J}/\psi$ they fail to reproduce the value of F_L.

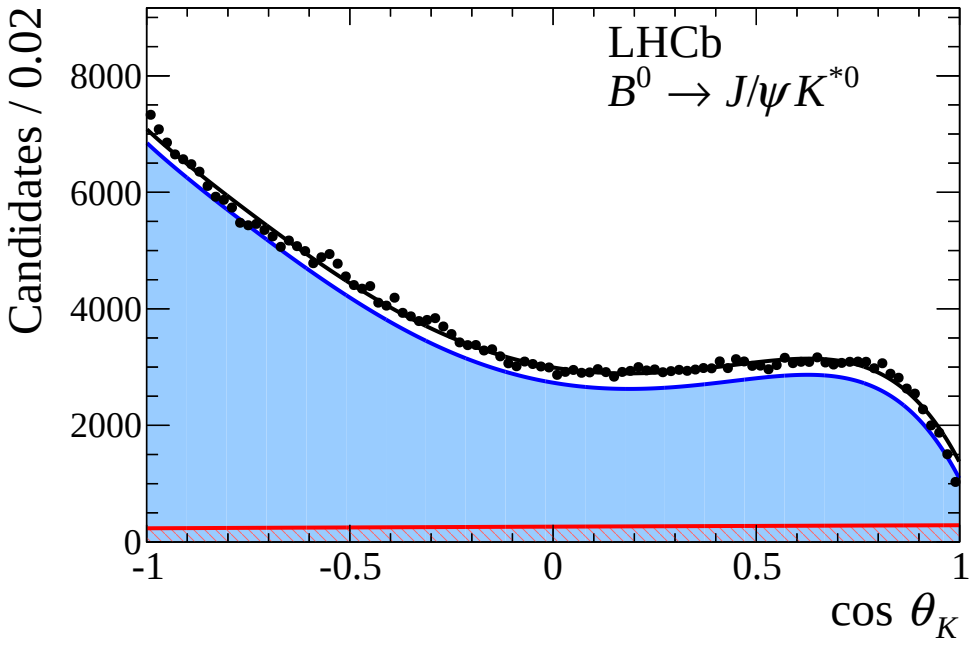
⇛ They assign the difference as a systematic uncertainty.

⇛ There is no guarantee that this has no q^2 dependence.

⇛ They tag the K^* via which of the configurations: $\mathrm{K}^+\pi^-$, $\mathrm{K}^-\pi^+$ is closer to the nominal K^* mass.

⇛ They model the mis-tag fractions from MC.

⇛ The mis-tag is modelled by MC. Systematic assign from $\mathrm{B} \to \mathrm{K}^* \mathrm{J}/\psi$ (no q^2 dependence assumed).

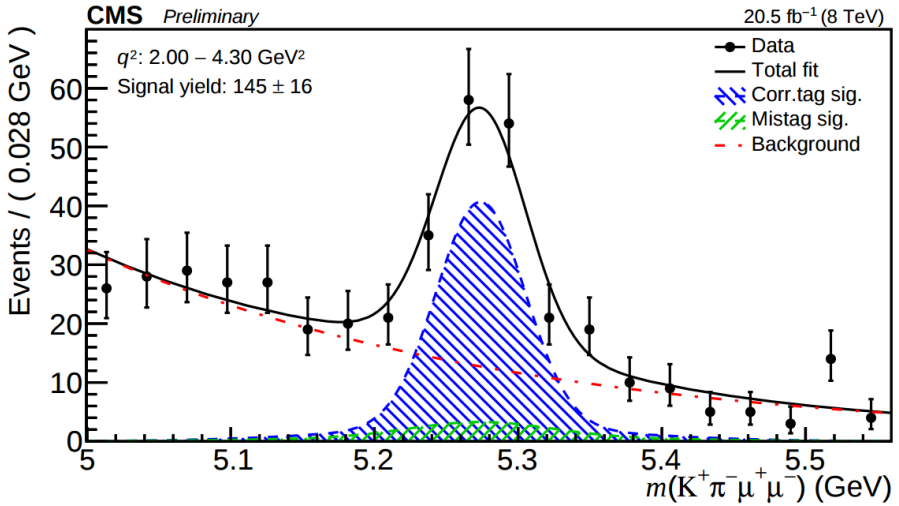


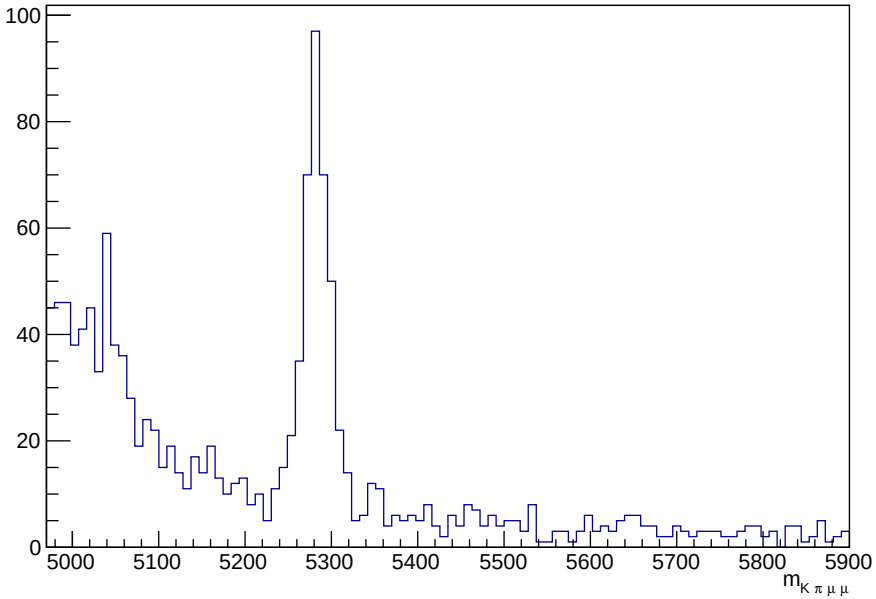
Comments about the CMS result 4/4

⇛ CMS uses a long range mass window in the $m_{\mathrm{K}\pi\mu\mu}$ fits.

⇛ In LHCb we saw non negligible amount of PARTRECO events.

⇛ In their fits they don't account for it.



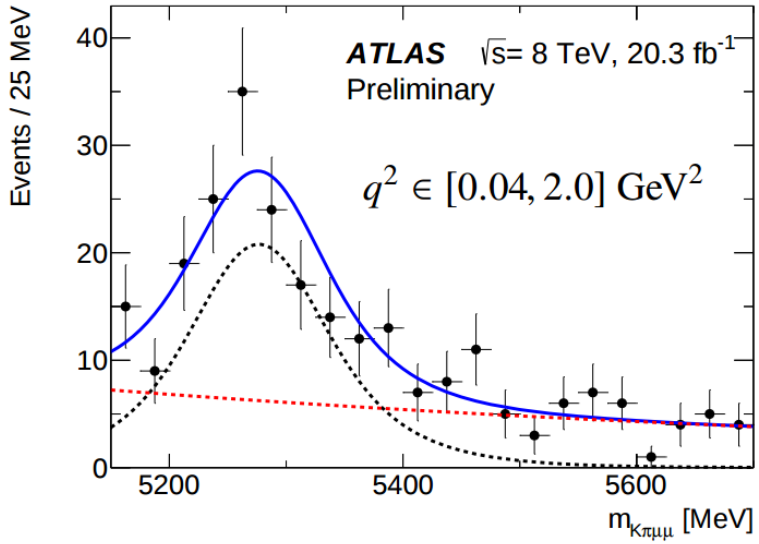


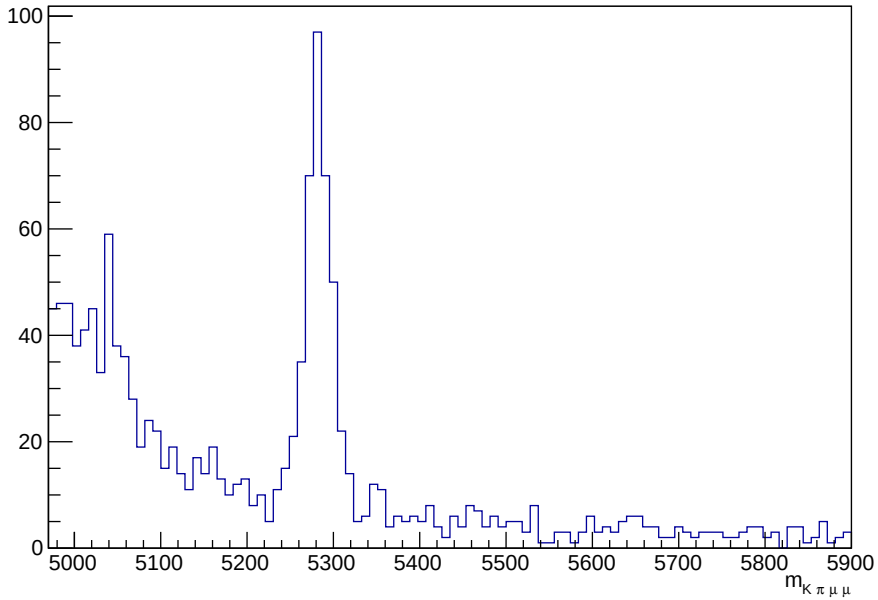
Comments about the ATLAS result

⇛ ATLAS has much worse mass resolution compared to CMS and LHCb.

⇛ They cut tight on the $m_{\mathrm{K}\pi\mu\mu}$ as we did.

⇛ How ever it is not obvious that they are not affected because of the resolution.





Conclusion

$\Rightarrow$ The anomaly is alive and well!

$\Rightarrow$ Inclusion of new results increases the significance.

$\Rightarrow$ Tension with SM seen in P_5' by Atlas, Belle and LHCb. CMS result in good agreement with SM, but consistent with our results.

$\Rightarrow$ Some discussion on aspects of the CMS analysis ongoing.

$\Rightarrow$ Run2 data will confirm or disprove the anomaly (of course the nature of the anomaly is a different question).

$\Rightarrow$ The corrected measurement of $Br(\mathrm{B} \to \mathrm{K}^* \mu\mu)$ [see Kostas slides] will increase the tension with SM further, will agree better with $Br(\mathrm{B}_\mathrm{s}^0 \to \phi\mu\mu)$ and $Br(\mathrm{B} \to \mathrm{K}\mu\mu)$

Backup