An Unbinned Angular Analysis of $B^{\pm} \to K^{\pm}\mu\mu$ Decays

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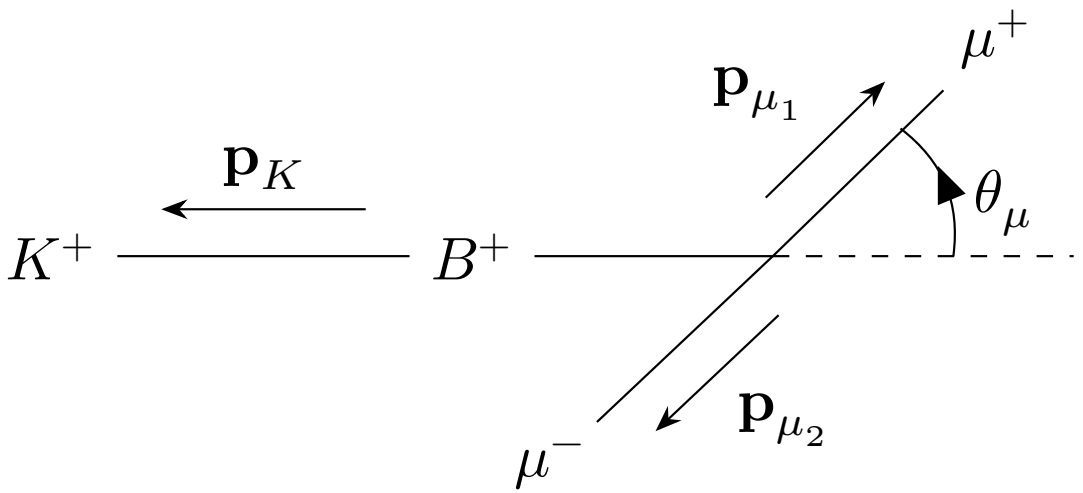
$B \to K\mu\mu$

- $1 \to 3$ body decay: phasespace can be entirely modelled by dependence on the angular $\cos\theta_\mu$, and the dimuon pair invariant mass, $q^2 (\equiv m^2_{\mu\mu})$.
- My goal is to fit the model $\frac{d^2\Gamma}{dq^2 d\cos\theta_\mu}$ [1] to the unbinned distribution of events in this phase space.

$$q^2 = (p^\alpha_{\mu_1} + p^\alpha_{\mu_2})^2$$

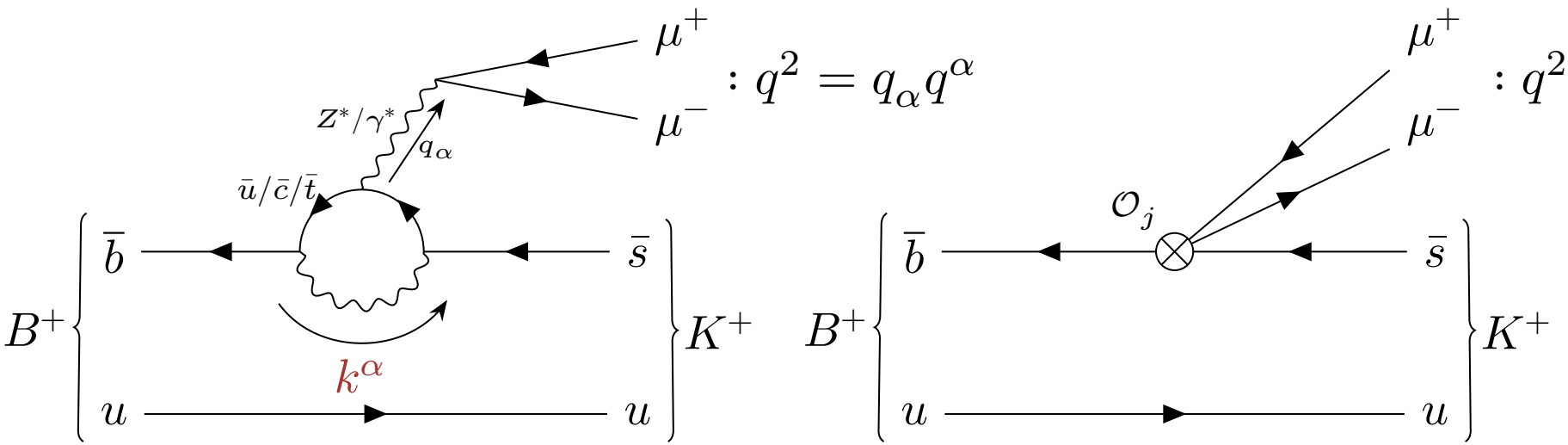
$$\cos\theta_\mu = -\frac{\mathbf{p}_{\mu_1}\cdot\mathbf{p}_K}{|\mathbf{p}_{\mu_1}||\mathbf{p}_K|}$$



[1] J. Gratrex, M. Hopfer, R. Zwicky. *Generalised helicity formalism, higher moments, and* $B \to K_{J_K}(\to K\pi)\bar{\ell}_1\ell_2$ *angular distributions.* 2015. arXiv: 1506.03970

Effective Field Theory

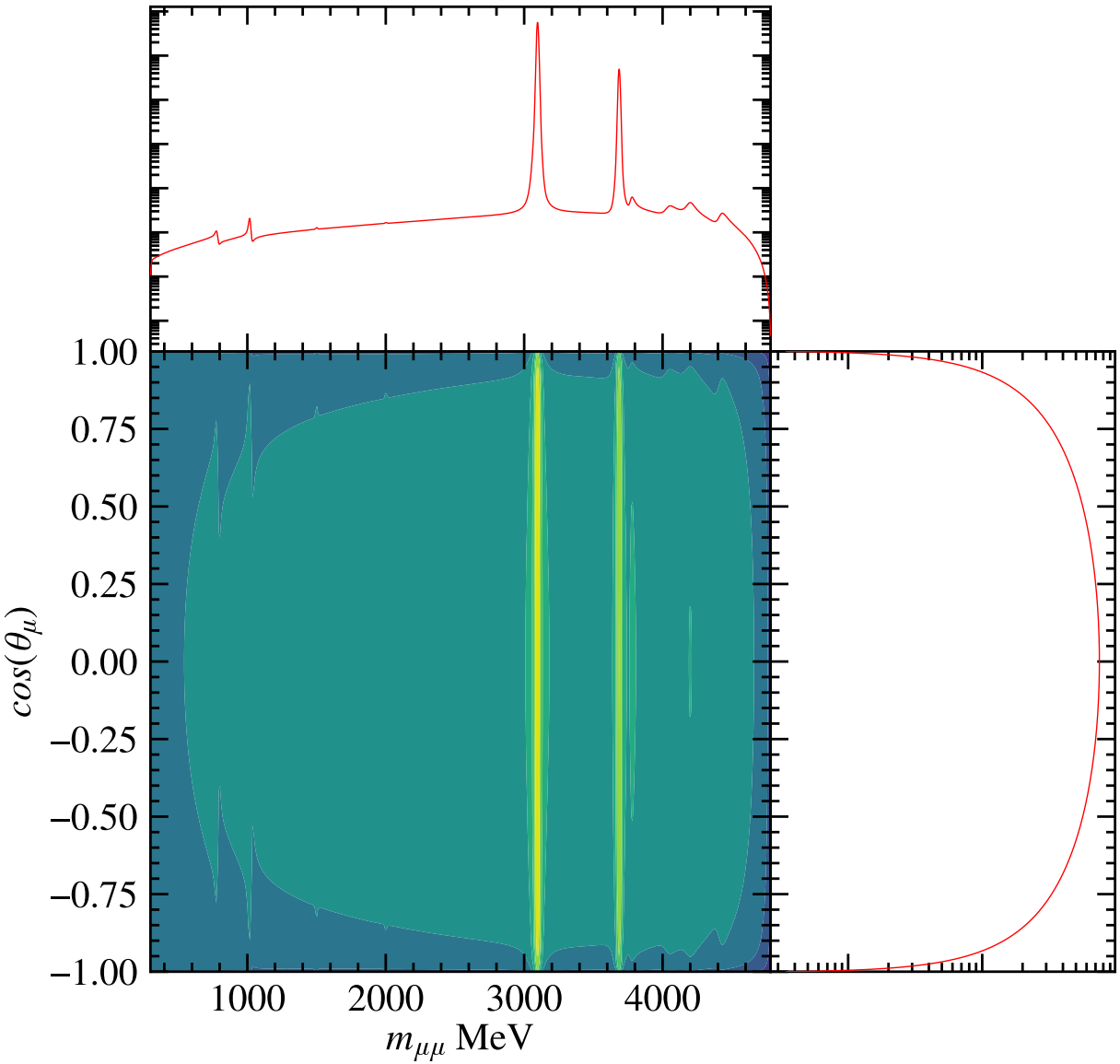
- $b \to s$ is loop and CKM suppressed: NP rates highlighted
- Effective Field Theory integrates over uncontrained virtual k^α, contracting the loops into single point interactions:



- $b \to s$ decays can probe contributions from arbitrarily massive NP, limited only by precision.
- An operator $\mathcal{O}_j$ contains many loop diagrams, grouped together by their J^P number. Contribution $\langle s\mu\mu|\mathcal{O}_j|b\rangle$ is quantified by $\boldsymbol{C_j}$.

Effective Field Theory - Model

- Broad contributions to $\frac{d^2\Gamma}{dq^2 d\cos\theta_\mu}$ are produced by each possible $|C_j|^2$, $C_j C_k^*$ combination. Each with a distinct shape in $(q^2, \cos\theta_\mu)$ space.
- Only $C_{7/9/10}$ ($J^P = 1^{-/-/+}$) are non-zero in the SM.
- The sharp peaks in $m_{\mu\mu}$ are from non-locals that escape the virtual loop, then decay.



$b \to s\ell\ell$ (Flavor) Anomalies

- $b \to s\ell\ell$ decays have turned over a host of measurements of $> 2\sigma$ over a range of final states.[2]
- Collectively, these all point to new physics in the C_9 loop vector coupling at the $> 4\sigma$ level.

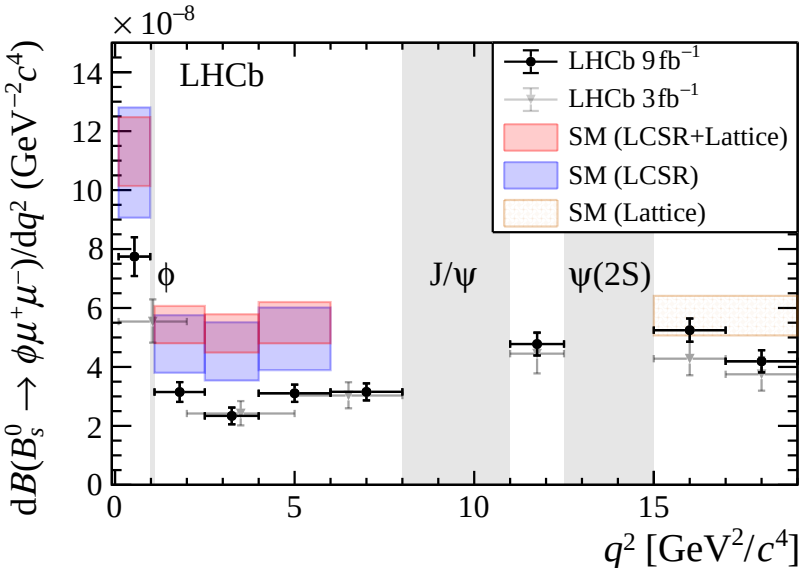


Figure: A 3.6σ SM flavor contention in the most common analysis type, an exclusive $\left(\frac{dB}{dq^2}\right)$ binned measurement. Note the absence of non-local q^2.[3]

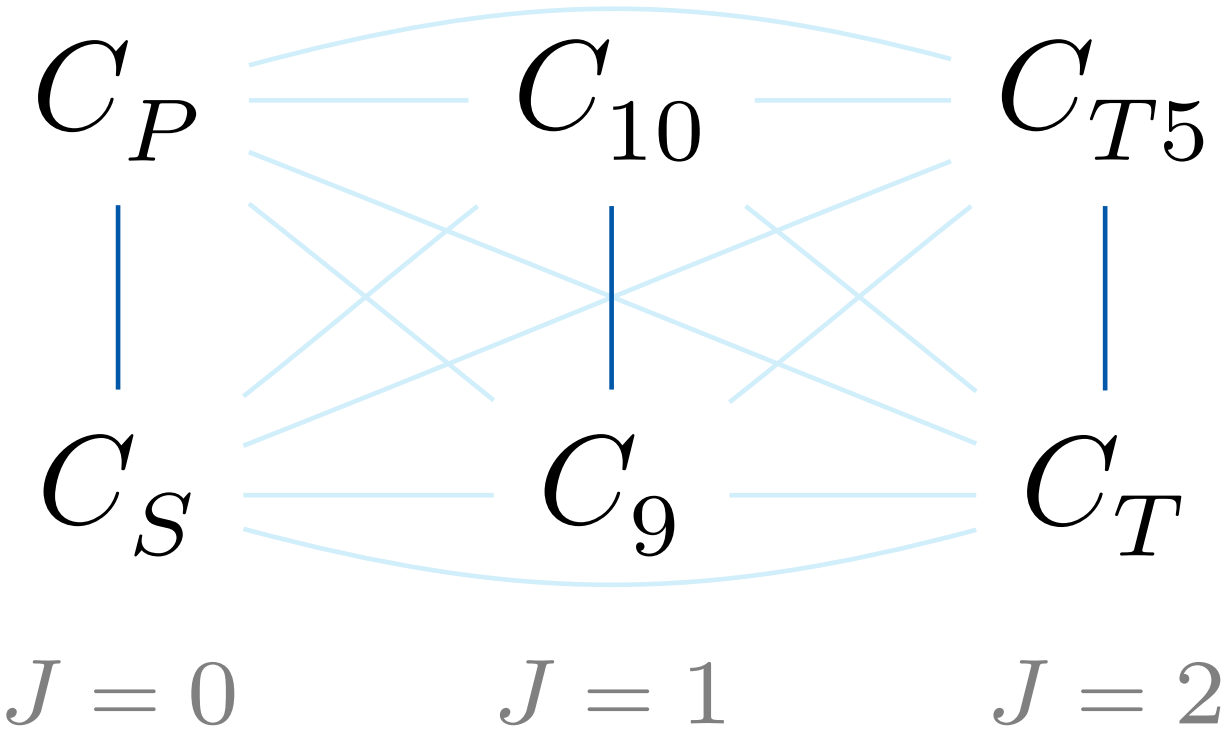
[2] Andersson, M.; Marshall, A.M.; Petridis, K.A.; Smith, E. Strange Things in Bottom-to-Strange Decays: The Standard Model Turned Upside Down? Symmetry 2024, 16, 638. https://doi.org/10.3390/sym16060638

[3] Aaij, R.; et al. Branching Fraction Measurements of the Rare $B_s^0 \to \phi\mu^+\mu^-$ and $B^0 \to f_2'(1525)\mu^+\mu^-$ Decays. Phys. Rev. Lett. 2021, 127, 151801.

My goal is to simultaneously fit $\underbrace{C_S}_{\text{scalar}}, \underbrace{C_P}_{\text{pseudoscalar}}, \underbrace{C_9}_{\text{vector}}, \underbrace{|C_{10}|}_{\text{axial-vector}}, \underbrace{C_T, \text{ and } C_{T5}}_{\text{tensor}}$.

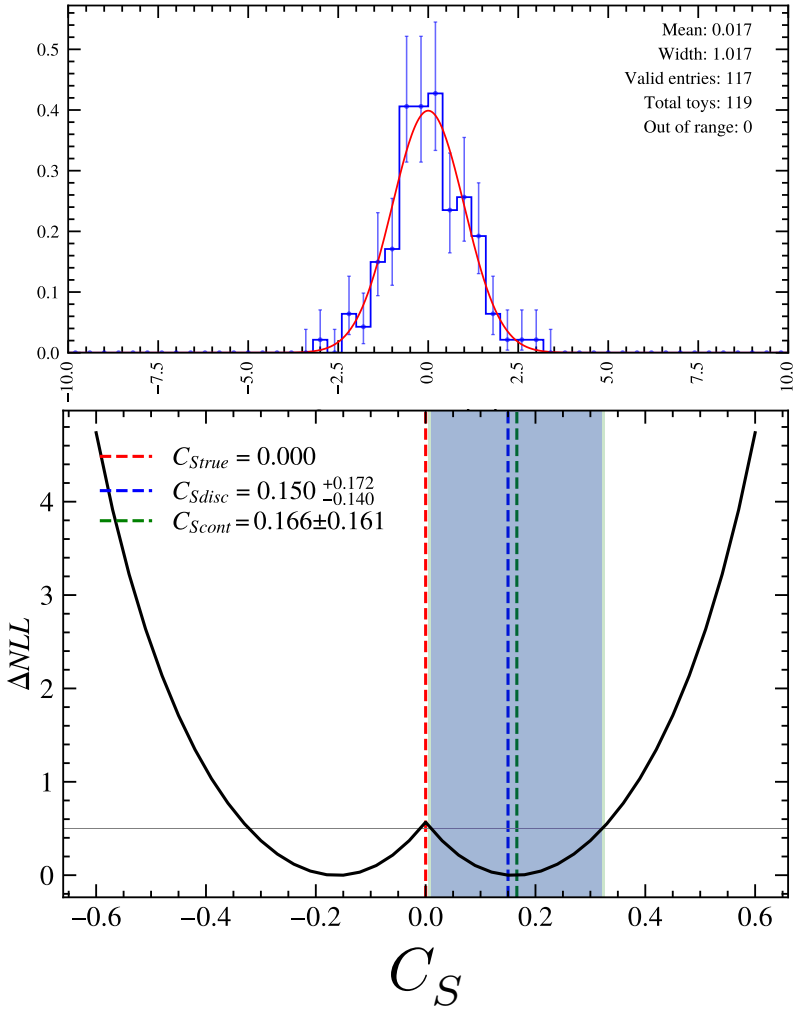
Motivations for our methodology

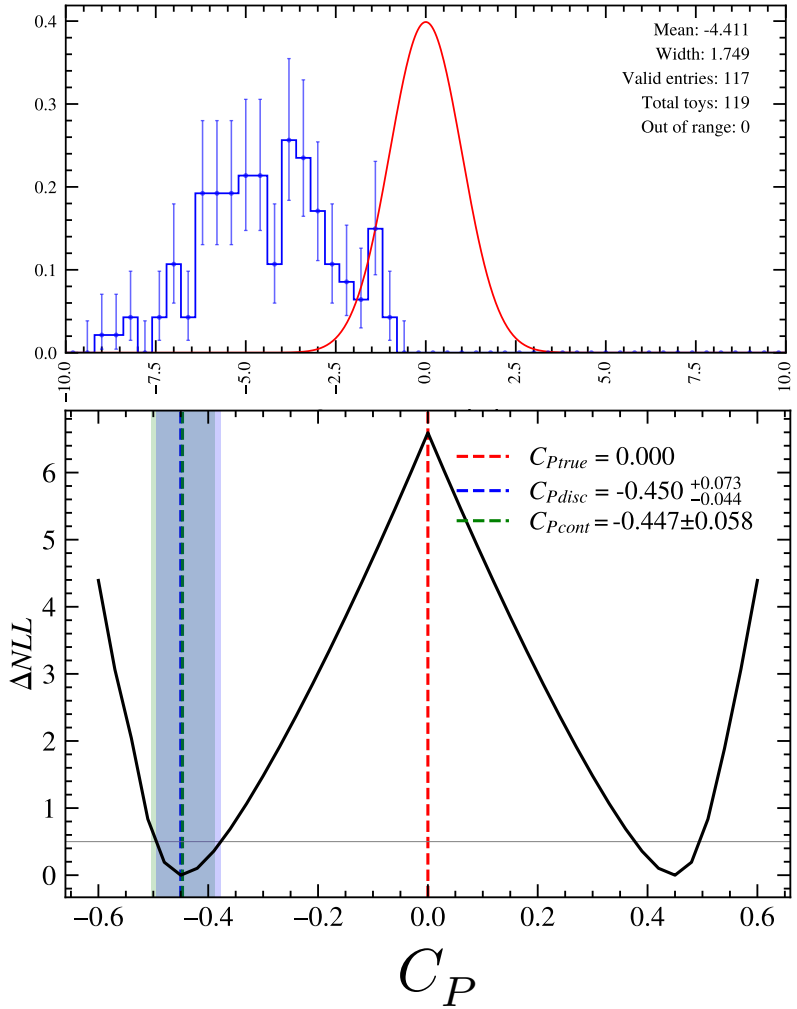
- Including non-local q^2 accounts for non-local tails (and provides more information)
- Angular dimension completely breaks the $\Delta J > 0$ degeneracies
- Unbinned preserves all the information from the data
- High and low q^2 limits help break the $\Delta J = 0$ degeneracies
- Floating all C_j means a reduced model dependence.



Pseudodata Toy (assessing fit quality):

- Fit quality is good, with the exception of C_P...





Next Steps:

- Modelling combinatorial background with a non-parametric approach

Overview

- $b \to s\ell\ell$ loops offer effective NP probes
- NP is strongly suggested in the C_9 sector of $b \to s\ell\ell$ loops by a variety of past results.
- I aim to simultaneously fit C_S, C_P, C_9, $|C_{10}|$, C_T, and C_{T5}.
- This fit will be unbinned, include an angular dimension, and incorporate typically excluded non-local peak regions.