$B \to K^* \ell\ell$ Contributions

(Zooming in on high q^2)

based on works in progress with Simon Braß and Ivan Nisandzic

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Motivation

$B \to K^*(\to K\pi)\mu\mu$ are FCNC induced and highly sensitive to flavor physics in and beyond SM; lots of diagnozing power in angular distribution regarding CP, Dirac structure and hadronic physics.

Current global $b \to s$ fits exhibit "anomalies", $\to$ talk by Lars Hofer

Studies of $B \to K^*(\to K\pi)\mu\mu$ is key measurement (LHCb roadmap 0912.4179), measurements by CMS, ATLAS and by previous experiments at Tevatron (CDF) and B-factories (Belle, BaBar). Today almost 3000 signal events analyzed (Run I, 7+8 TeV, 3fb^{-1} LHCb); improved precision in Run II and Belle II in nearer term future. $\to$ talk by Johannes Albrecht

New level of precision requires and allows to revisit backgrounds.

Seach windows in $B \to K^{(*)}\mu\mu$

Charmonium contributions $B \to K^{(*)}(\bar{c}c) \to K^{(*)}\mu\mu$; peaks and wiggles

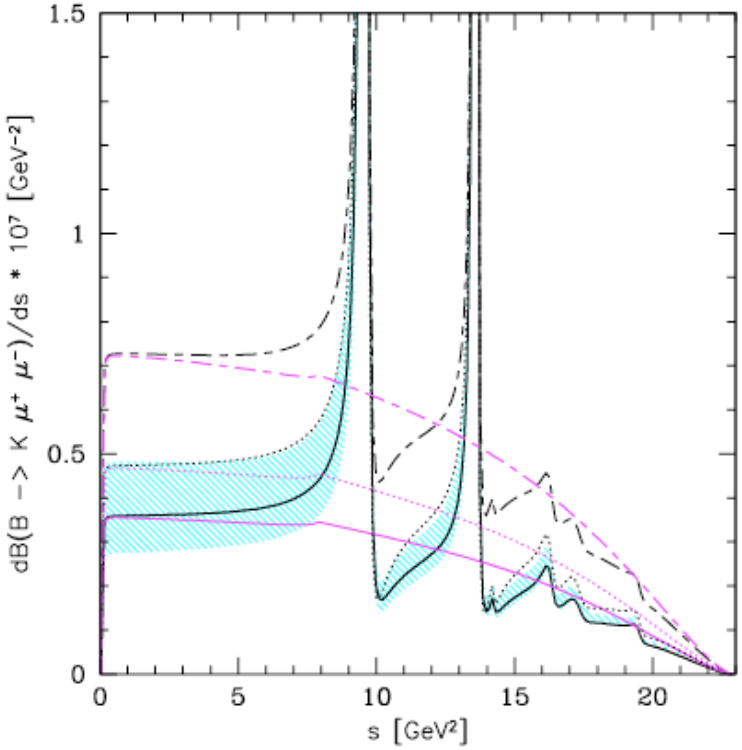


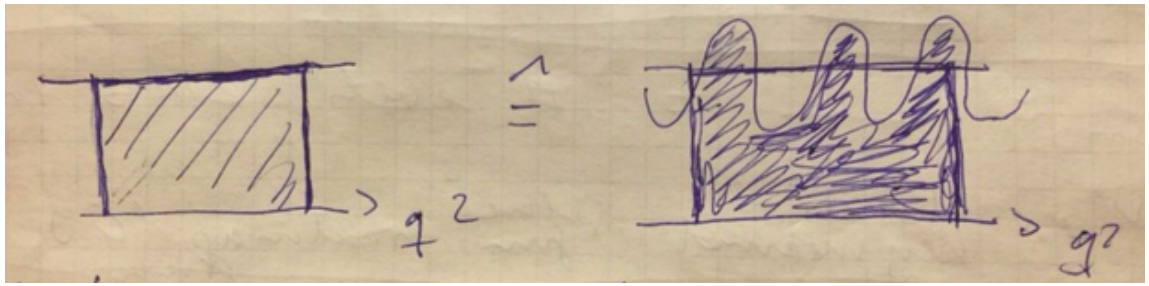
Fig from 9910221, solid: SM, dotted and dot-dashed: BSM scenario

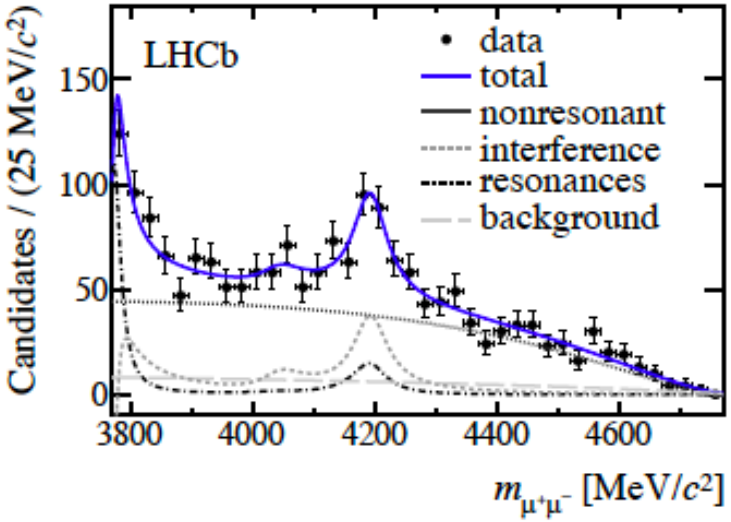
Low dilepton mass window below $J/\Psi \to$ QCD factorization

High dilepton mass window above $\psi(2S) \to$ OPE THIS TALK

High q^2/low recoil OPE

Operator Product Expansion in $1/q^2$, $q^2 \sim \mathcal{O}(m_b^2)$ Buchalla, Isidori,Grinstein,Pirjol, Beylich, Buchalla, Feldmann includes charm effects after binning



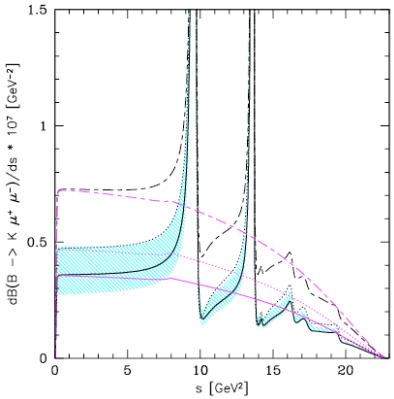


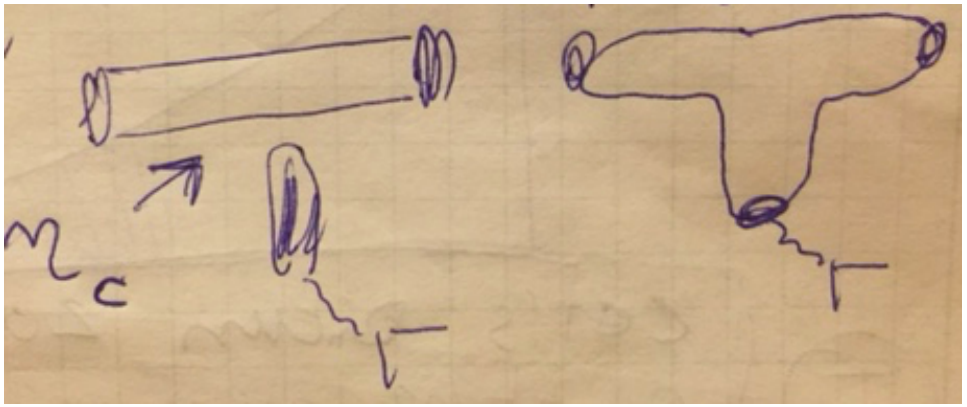
Bin size and position affect how well duality works. Can't tell from OPE within. Resonance "wiggles" observed in $B \to K\mu\mu$. LHCb 1307.7595

$B \to K\mu\mu$ in high q^2 region

To understand uncertainties related to chosen binning quantitatively, model the q^2-distributions locally by a test case model for the OPE:

$e^+e^- \to hadrons$ data + dispersion relation + "factorization assumption" Krüger, Sehgal





$\eta_c \neq 1$ models effects beyond naive factorization; ultimately, $\eta_c = \eta_c(q^2)$ and complex; $|\eta_{J/\psi\, K}| = 1.39 \pm 0.11, |\eta_{\psi(2S)\, K}| = 1.75 \pm 0.10$

Assuming SM $B \to K\mu\mu$ spectrum $\eta_c(K) \simeq -2.5$ gives good fit for $q^2 > m^2_{\Psi(2S)}$ Lyon, Zwicky

$B \to K^* \mu\mu$ transversity amplitudes in low recoil OPE*

$$A_i^{L,R}(q^2) \propto \underbrace{C^{L,R}(q^2)}_{SM/BSM} \cdot \underbrace{f_i(q^2)}_{formfactor} + \text{small param} \times O(1/m_b), \quad i = \perp, ||, 0$$

$C^{L,R} = (C_9^{\text{eff}} \mp C_{10}) + \kappa \frac{2\hat{m}_b}{\hat{s}} C_7^{\text{eff}}$ is universal! Bobeth, GH, van Dyk

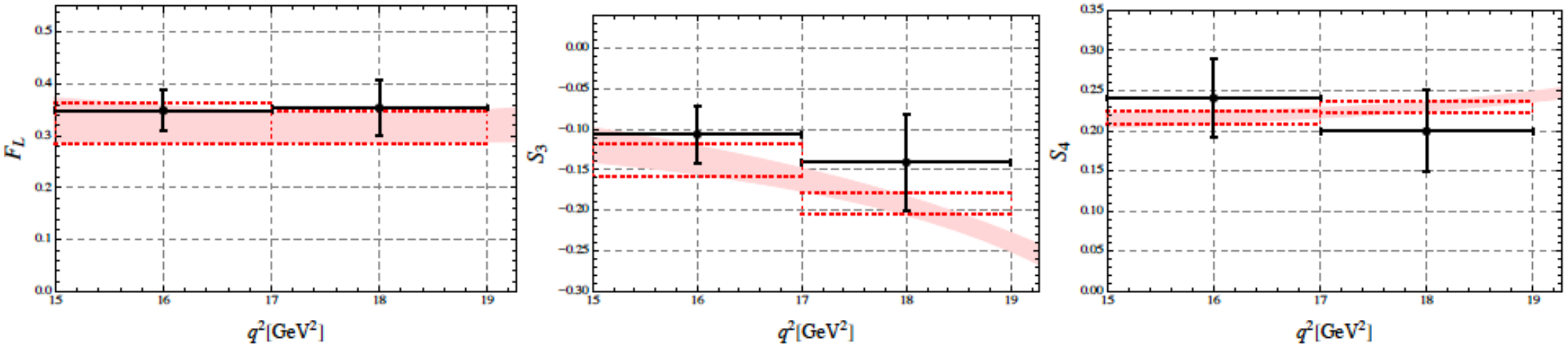
Probe the OPE with its key feature, universality!

To remove model-dependence use "ratio"-observables where $C^{L,R}$: drops out, e.g. $F_L = \frac{|A_0^L|^2 + |A_0^R|^2}{\sum_{X=L,R}(|A_0^X|^2 + |A_\perp^X|^2 + |A_\parallel^X|^2)} = \frac{f_0^2}{f_0^2 + f_\perp^2 + f_\parallel^2}$

In general $\eta_c(K_i^*, q^2)$, i.e., the resonance "wiggles" could be different for each transversity amplitude which does not drop out.

$*$ assuming only V-A operators

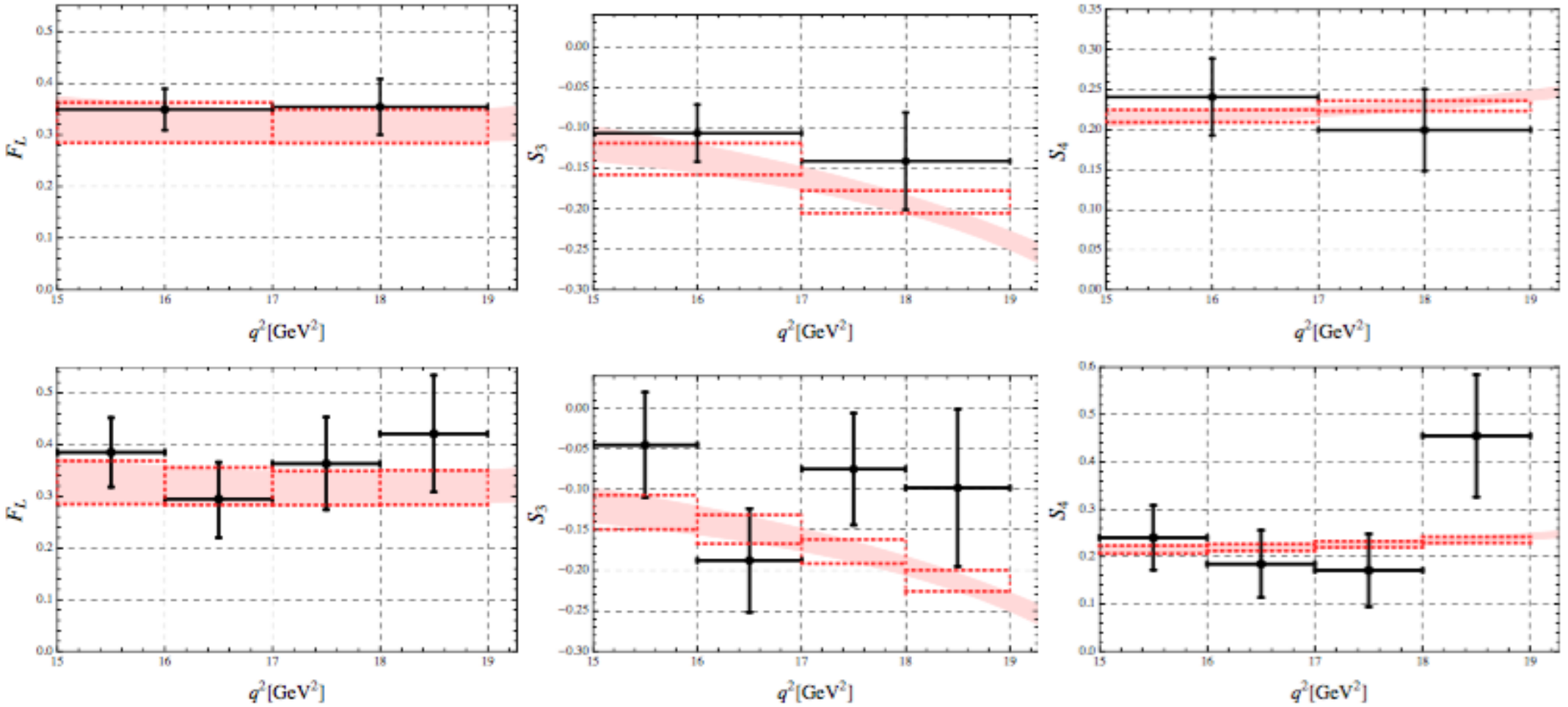
2 GeV^2 bins



black data: LHCb 1512.04442, red boxes: OPE, model-independent

2 GeV^2 bins appear universal; wiggles signal bad bins (for OPE); could show up differently in obs, diagnose transversity structure

Zooming in on high q^2



smaller bins have larger uncertainties, resonances vs statistics?

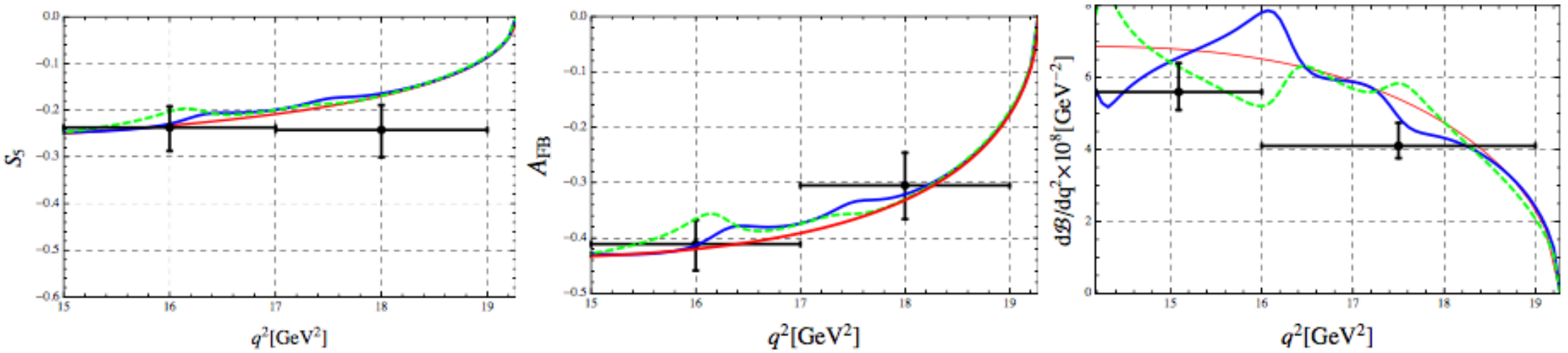
Exact endpoint q^2_{max} predictions $F_L = 1/3, S_3 = -1/4, S_4 = 1/4$

No non-factorizable terms at endpoint: $\eta_c(K_i^*, q^2_{max}) = \eta_c(K^*, q^2_{max})$

2 GeV^2 bins

larger binning data consistent with universality within uncertainties

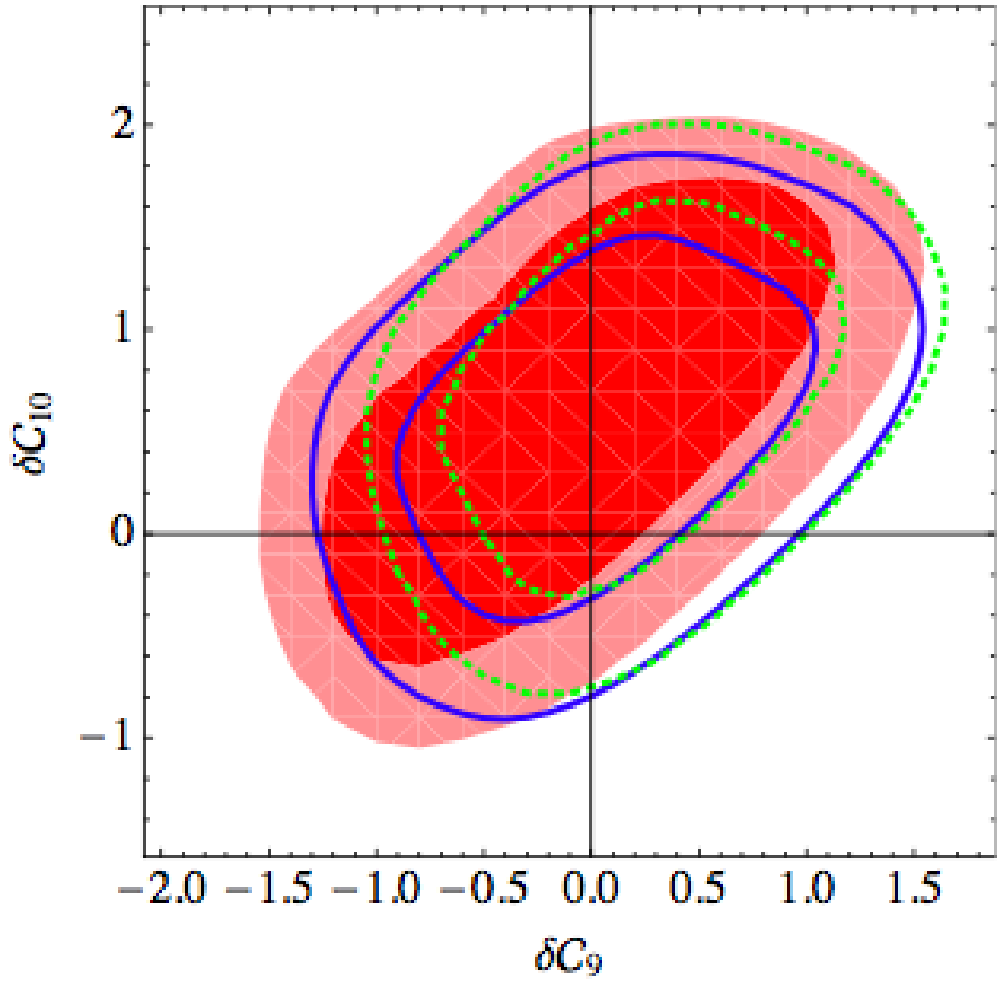
$$|\eta_{J/\psi\, K^*}| = 0.95 \pm 0.07, \quad |\eta_{\psi(2S)\, K^*}| = 0.92 \pm 0.05$$

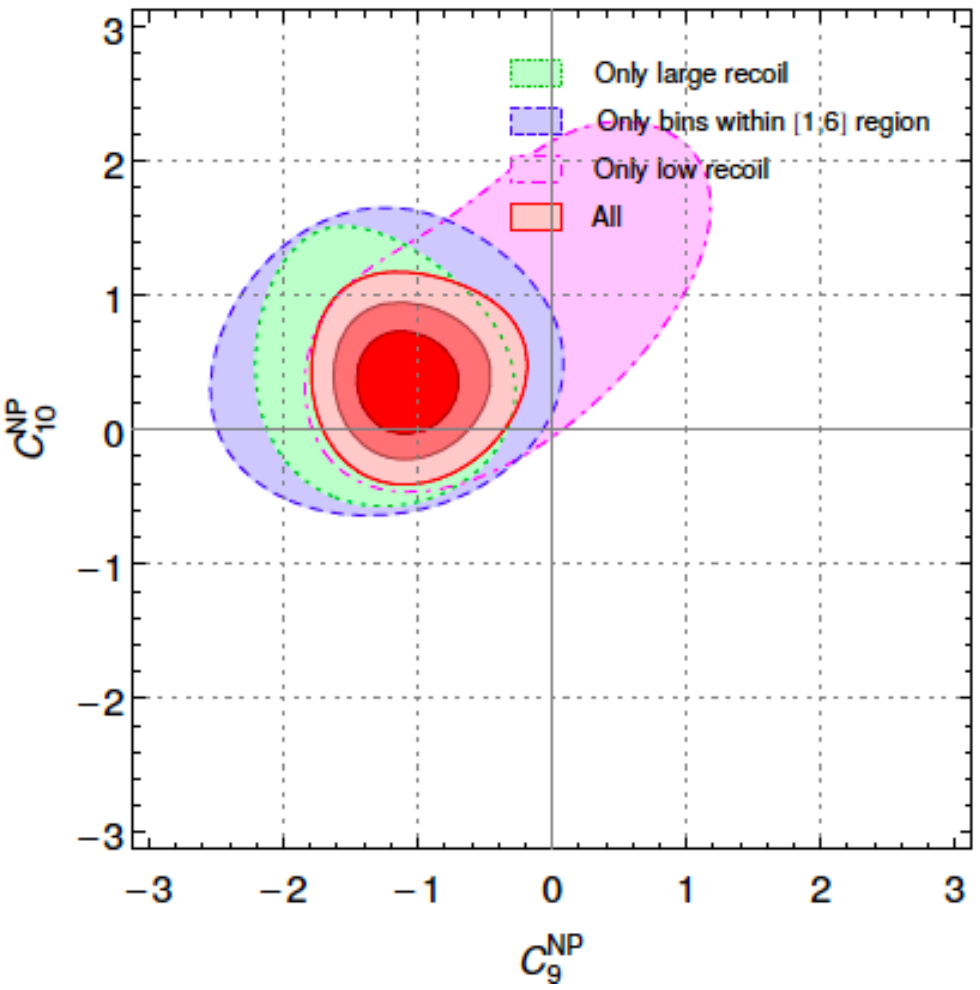


black data: LHCb, vs SM curves red: "unbinned" OPE, blue $\eta_c(K^*) = 1$, green $\eta_c(K^*) = -1$.

$S_5 \propto P_5'$ and A_{FB} less sensitive to local wiggles than branching ratio. Constrain model-parameter $\eta_c(K^*)$ in future from the latter.

Testing the SM





Low recoil fit $B \to K^* \mu\mu$ only, incl. Br, LHCb and A_{FB}^{CMS}.

red: OPE, blue $\eta_c(K^*) = 1$, green $\eta_c(K^*) = -1$, 68 and 95 %CL

Consistent with plot to the right shows 3 σ regions, pink: full high q^2 bin Hofer et al 1510.04239 and SM.

Summary

– High q^2 region in semileptonic rare $|\Delta b| = |\Delta s| = 1$ decays is inhabited by wider charm resonances.

– Using a local model against the OPE provides a data-driven method to test the binning and limitations of the OPE.

– Further tests include Null tests of the angular distribution.

– SM fits on $B \to K^* \mu\mu$ at low recoil are consistent with the SM, however, large BSM effects $\delta C_9 \sim -1$ are also allowed.

- -We look forward to future data.