Setting the stage: Low recoil and physics impact 2018+

First bsll workshop (2011, DESY) was solely on rare b-decays@LoReco https://indico.desy.de/indico/event/4250/

This talk really is about charm-contributions to bsll at lo recoil; recent works by Lyon, Zwicky 1406.0566, Brass, GH, Nisandzic 1606.00775, Blake, Egede, Owen, Pomery, Petridis 1709.03921

Gudrun Hiller, TU Dortmund

The early days...

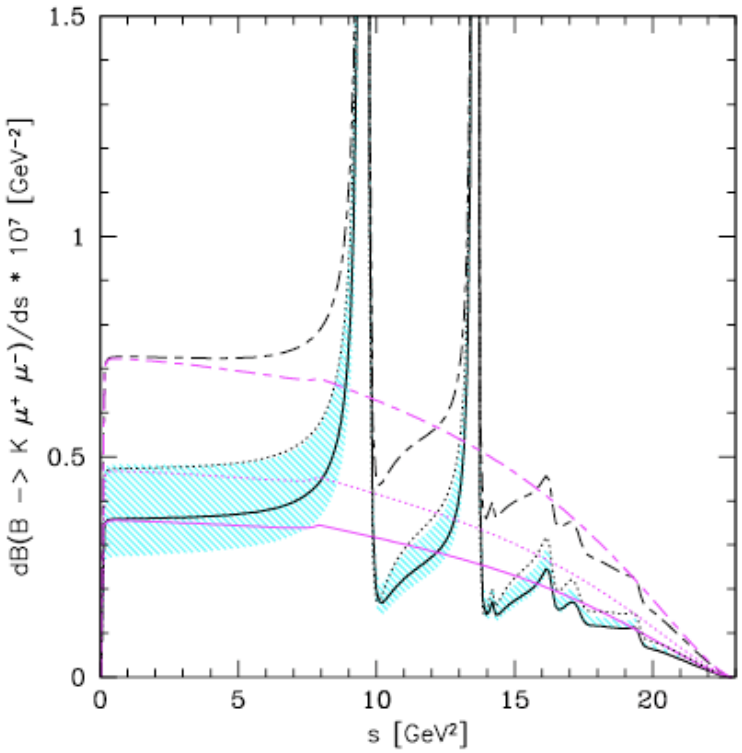


Fig from Ali et al hep-ph/9910221, solid: SM (with bands from FF-uncertainties), dotted and dot-dashed: BSM scenario

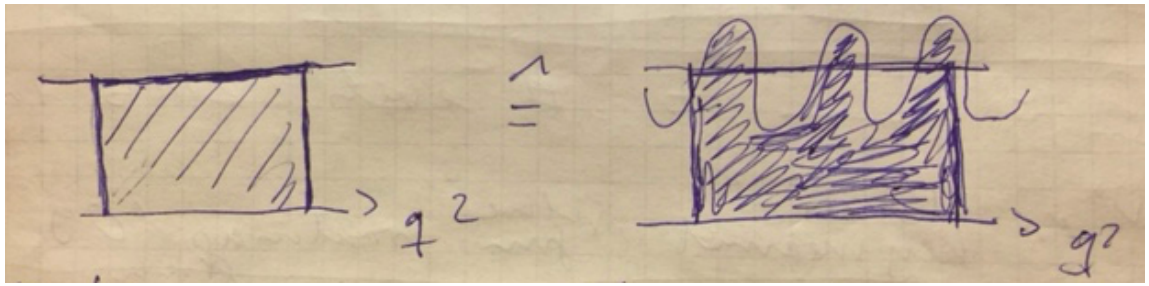
– factorization (one global framework) $\rightarrow$ QCDF, OPE

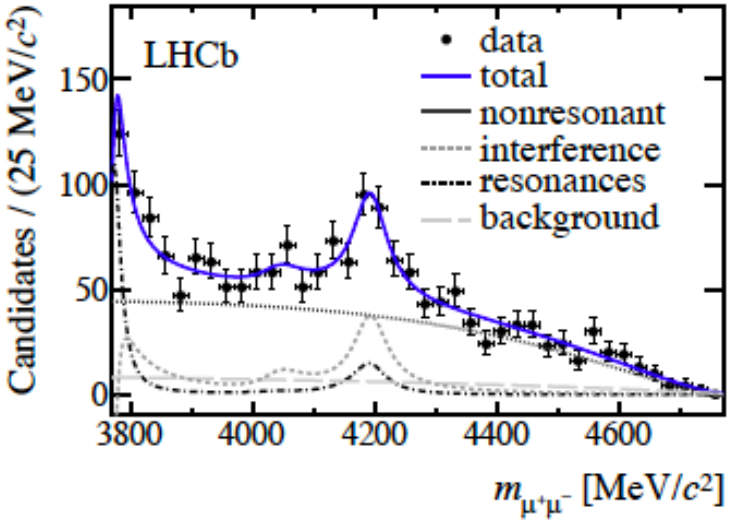
– LCSR form factors (extrapolated) $\rightarrow$ lattice form factors Horgan et al 1310.3722 and FF fits to high and low q^2 1204.4444, 1308.4379, 1503.05534

– $c\bar{c}$ resonances from e^+e^--data a la Krüger, Sehgal hep-ph/9603237 $\rightarrow$??

Low recoil OPE vs data

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





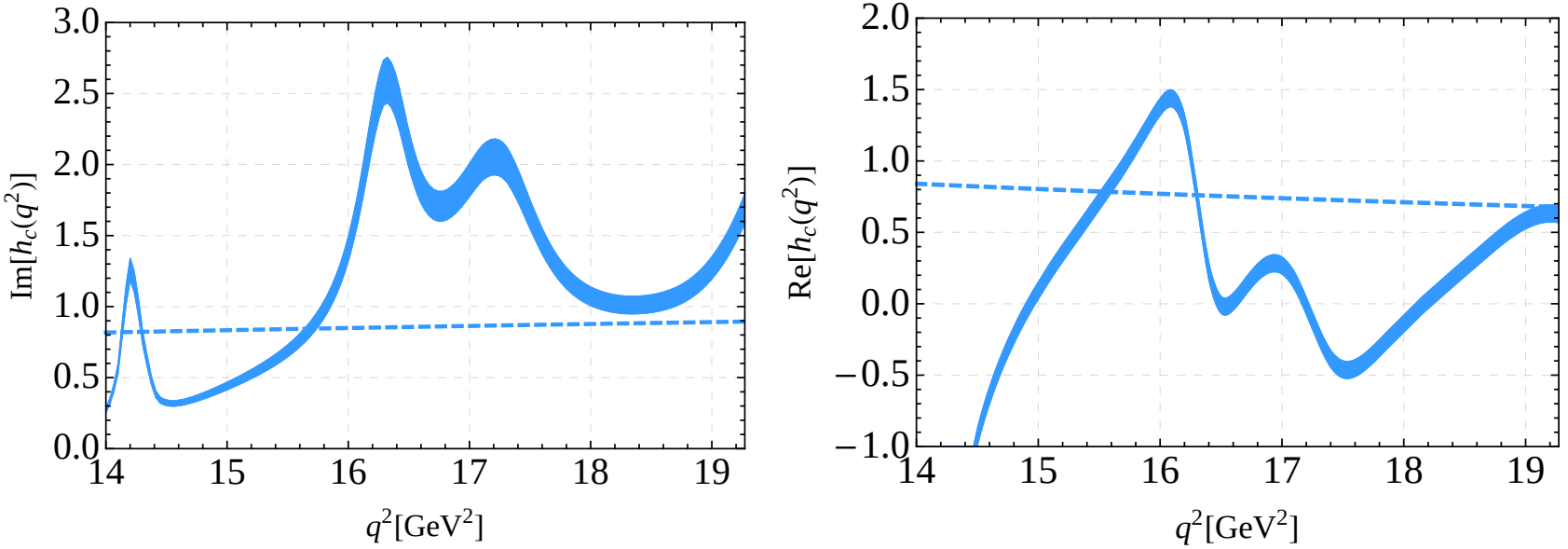
Bin size and position affect how well this works. Beyond-OPE question. Resonance "wiggles" observed in $B \to K\mu\mu$. LHCb 1307.7595

Local spectra wiggle (LHCb)

How good is the OPE (uncertainties) quantitatively, depending on bin size and position?

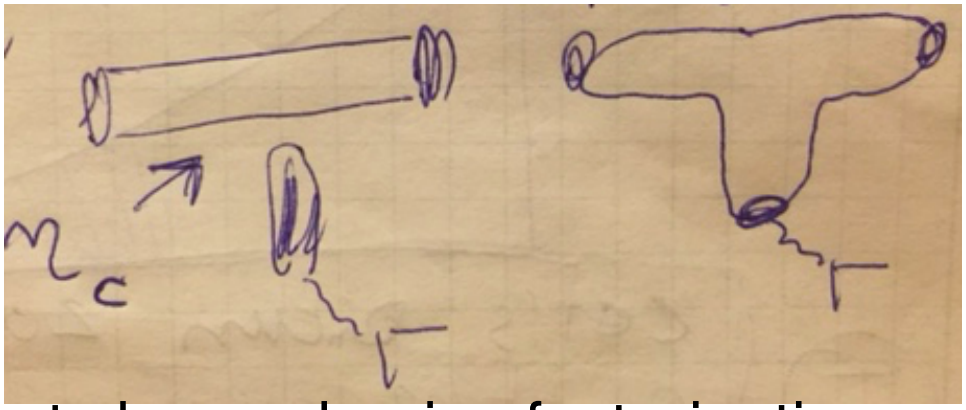
Useful (pheno) local description i) per se Blake et al '17 and ii) as a test case against the OPE Brass et al '16?

Parametrization: $C_9^{\rm eff}(q^2) = C_9 + 3a_2\,\eta_c(..)\cdot h_c(q^2) + penguins$, $3a_2 \simeq 0.6$



$h_c(q^2)$ from e^+e^- data + dispersion relation Krüger, Sehgal with BES-II data '07 Lyon Zwicky Figs from 1606.00775 Brass et al $\eta_c(..)$: "fudge functions"

$\eta_c = \eta_c(q^2)$: "fudge functions" needed for $B \to K^{(*)}\mu\mu$, complex-valued, process-dependent; in principle, also angular Θ_ℓ and Θ_K-dependence 1606.00775 , neglected here.

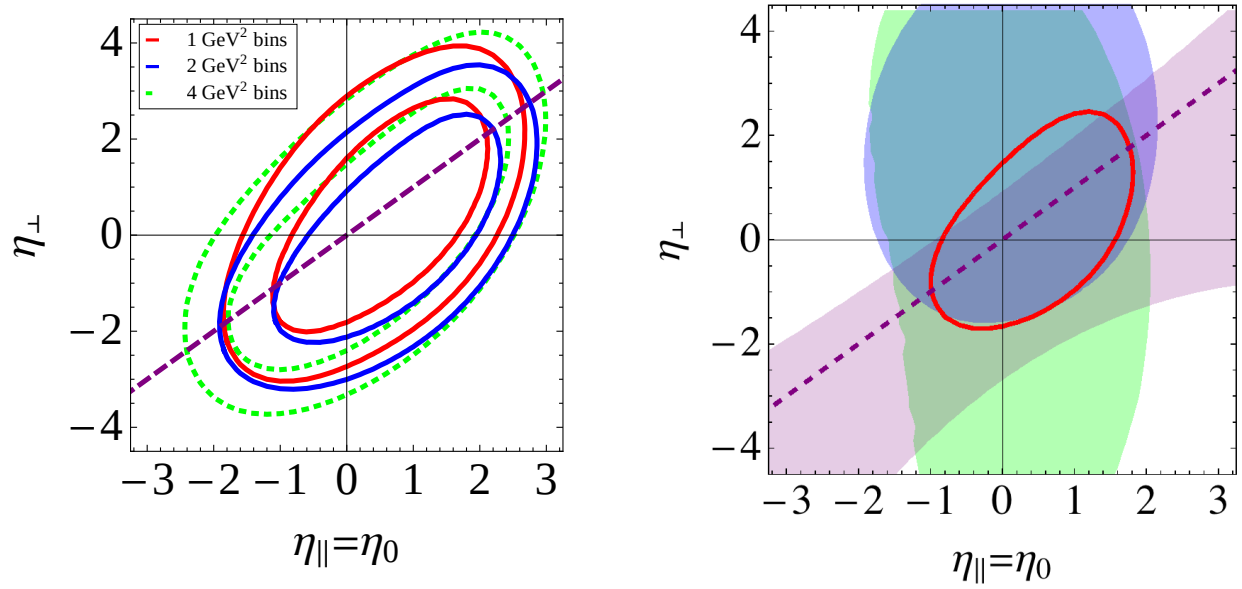


$\eta_c \neq 1$ models effects beyond naive factorization

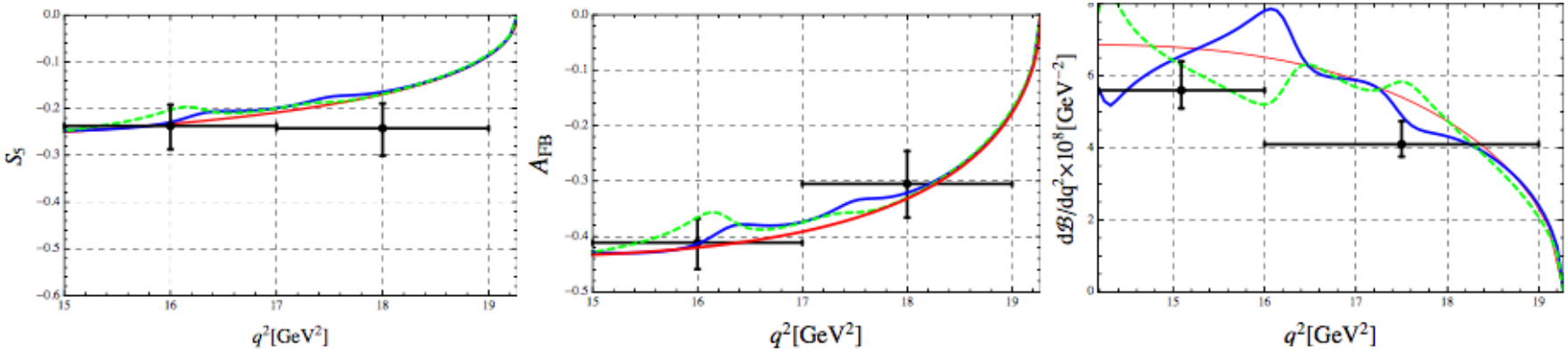
	J/Ψ	$\Psi(2S)$	$q^2 > m^2_{\Psi(2S)}$
K	1.40 ± 0.09	1.72 ± 0.08	$\simeq -2.5$ Lyon, Zwicky
K^* (Br)	0.96 ± 0.06	0.85 ± 0.06	see fits 1606.00775 Brass et al

$\eta_c(K^*_\parallel, q^2_{max}) = \eta_c(K^*_0, q^2_{max})$ universal at endpoint GH, Zwicky '13

$B \to K^* \mu\mu$ @lo recoil



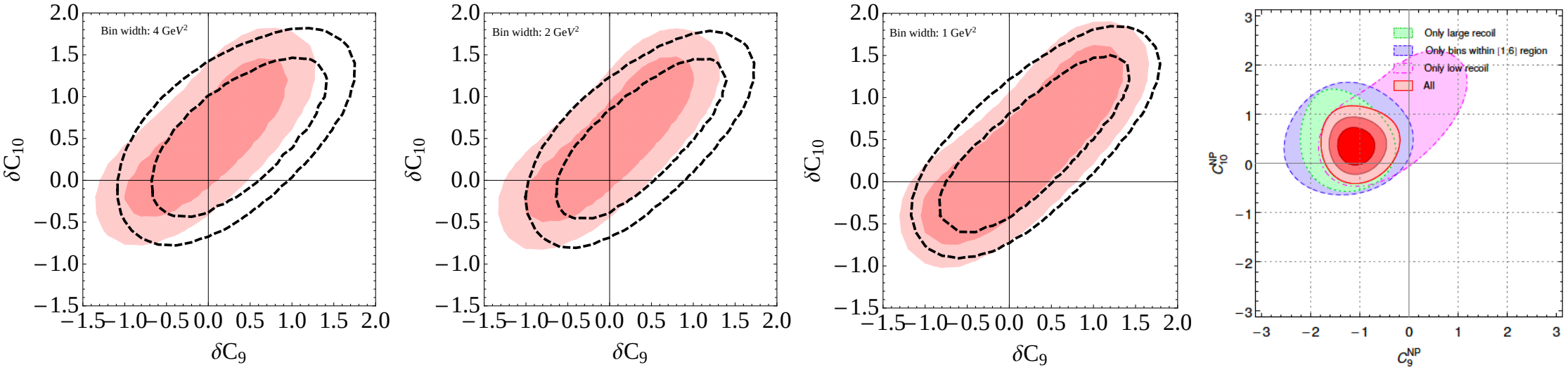
Figs from 1606.00775; Left: simultaneous fit to $C_{9,10}$ and $\eta_\perp$, η_0 Right plot: assuming SM, green: Br, magenta S_8, S_9, blue $A_{\rm FB}$



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 $A_{\rm FB}^{\rm CMS}$.

red: OPE, black: KS-model with $\eta_0 = \eta_{||}$ and $\eta_\perp$ simultaneously fitted, 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.

Existing $B \to K^* \mu\mu$ data barely see "wiggles"; results consistent between all binnings $\Delta q^2 = 1, 2, 4\,\text{GeV}^2$

Summary

– Low recoil 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 Bobeth, GH, van Dyk '13

$$J_7 \simeq -\frac{9}{\sqrt{2}} f_0 f_\parallel \mathcal{C}_{10} a_2 \mathrm{Im}[h_c(q^2)(\eta_c(K_0^*, q^2) - \eta_c(K_\parallel^*, q^2))]\,, \tag{1}$$

$$J_8 \simeq -\frac{9}{2\sqrt{2}} f_0 f_\perp (\tilde{\mathcal{C}}_9^{\rm eff} + \kappa \frac{2 m_b m_B}{q^2} \mathcal{C}_7^{\rm eff}) a_2 \mathrm{Im}[h_c(q^2)(\eta_c(K_0^*, q^2) - \eta_c(K_\perp^*, q^2))]\,, \tag{2}$$

$$J_9 \simeq -\frac{9}{2} f_\parallel f_\perp (\tilde{\mathcal{C}}_9^{\rm eff} + \kappa \frac{2 m_b m_B}{q^2} \mathcal{C}_7^{\rm eff}) a_2 \mathrm{Im}[h_c(q^2)(\eta_c(K_\parallel^*, q^2) - \eta_c(K_\perp^*, q^2))]\,, \tag{3}$$

– SM fits on $B \to K^* \mu\mu$ at low recoil are consistent with the SM, however, large BSM effects $-\delta C_{10} \sim \delta C_9 \sim -0.5$ are also allowed.

Questions/Comments

– Do we need binning at all with the current/future round of data? OPE should be best towards endpoint and larger bins $17-19\,\text{GeV}^2$ Brass et al '16

– More sophisticated, theory-driven approach for fudge functions?

– More data to improve on pheno-approach to fudge functions?

– Form factor uncertainties still major uncertainty at low recoil!

– Fit to low recoil and low q^2 and inclusive/exclusive decays should return same Wilson coefficients/ check of systematics for TH and EXP; lets see in $\approx$ bsll2020