$B \to K\ell^+\ell^-$ at Low Hadronic Recoil

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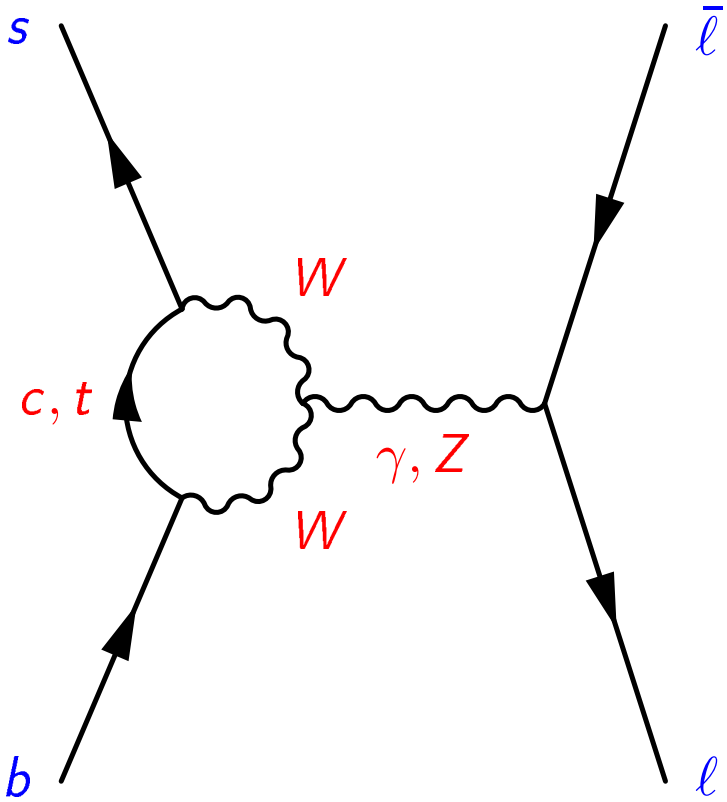
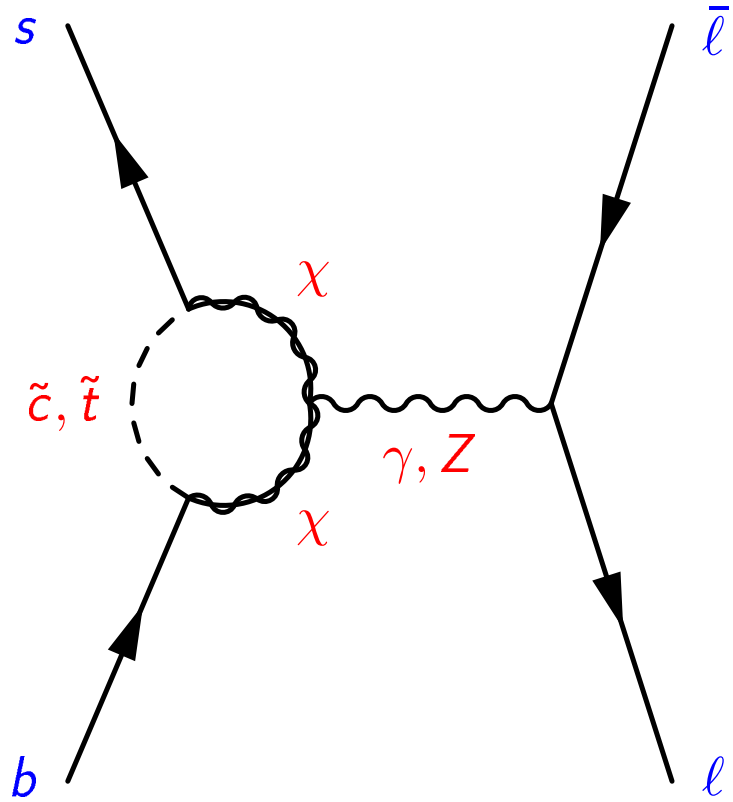
Introduction to $B \to K\ell^+\ell^-$

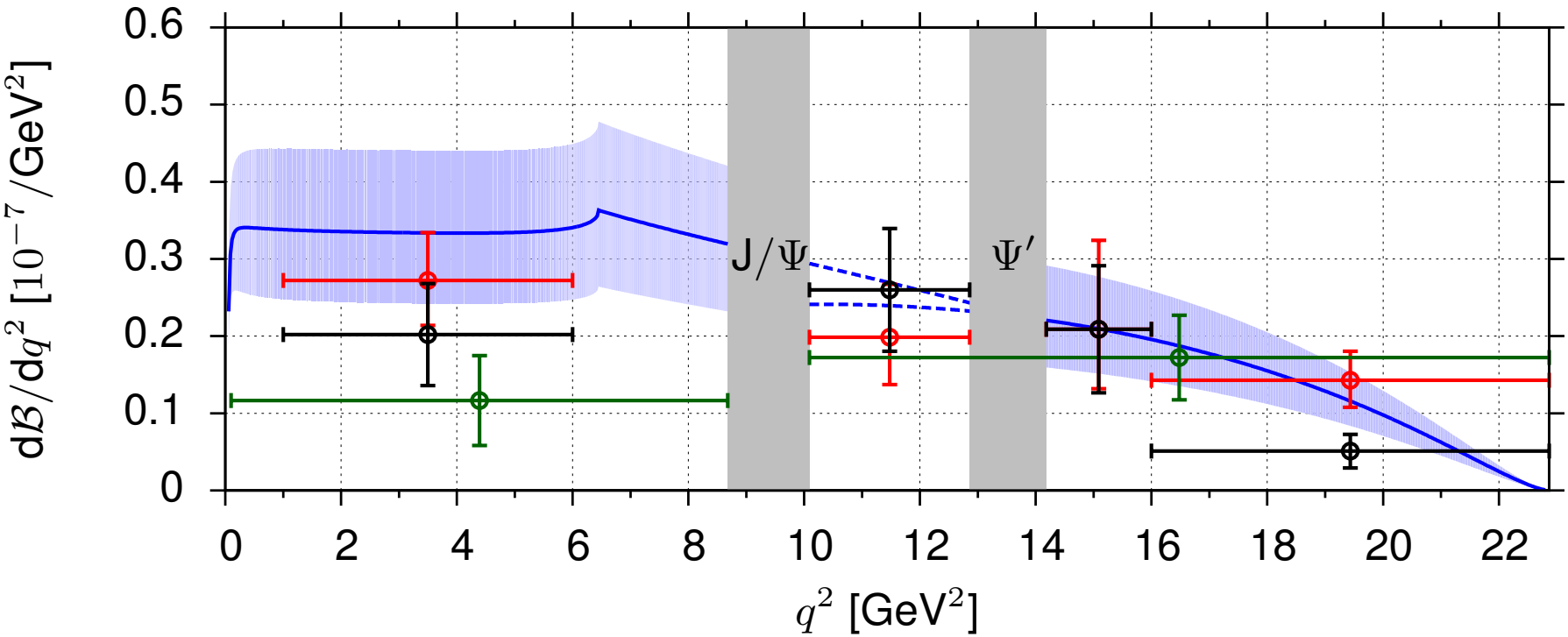
- $b \to s$ transitions mediated by Flavor Changing Neutral Currents (FCNCs)
- FCNCs forbidden at tree level in SM, but not through loops
- New Physics contributions can enter via extended particle content





Branching Fraction $\mathrm{d}\mathcal{B}/\mathrm{d}q^2$ of $B \to K\ell^+\ell^-$

- $\sqrt{q^2}$ = dilepton invariant mass
- SM prediction with form factors from Khodjamirian et al. (2010)
- experimental data from **BaBar** (2006), **Belle** (2009) and **CDF** (2011)



large recoil
$q^2 \ll m_b^2$

$c\bar{c}$-veto

low recoil
$q^2 \approx m_b^2$

Low Recoil Framework by Grinstein, Pirjol (2004)

Form Factors

$$\langle K\,|\bar{s}\,\gamma^\mu\,b|\,B\rangle \sim f_+, f_0 \qquad \langle K\,|\bar{s}\,\sigma^{\mu\nu}\,b|\,B\rangle \sim f_T$$

Results

- improved Isgur-Wise form factor relation:

$$f_T(q^2) = \frac{(m_B + m_K)m_B}{q^2}\,\kappa\, f_+(q^2) + \mathcal{O}\left(\alpha_s, \frac{\Lambda}{m_b}\right)$$

$$\kappa = 1 + \mathcal{O}\left(\alpha_s^2\right) \text{ for } \mu = m_b$$

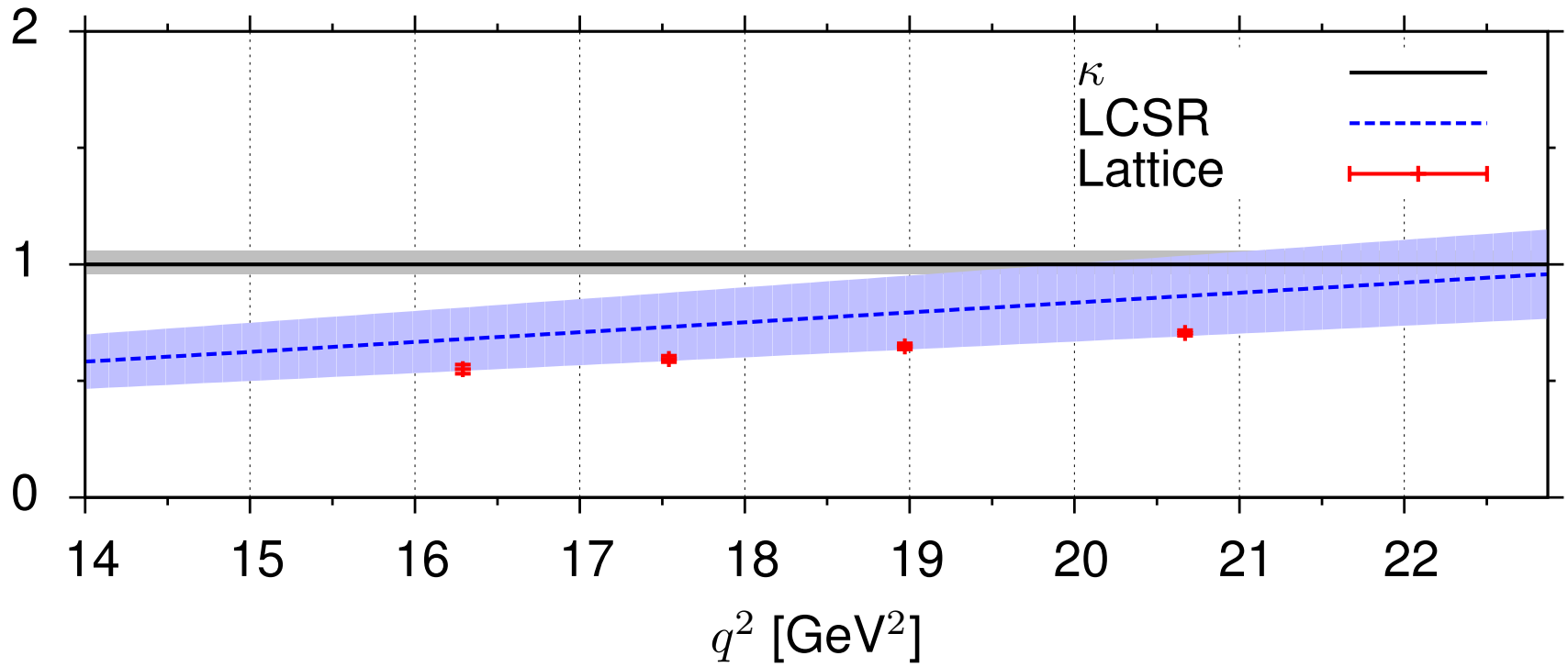
  reduction of independent form factors: $3 \to 2$
- better control of non-perturbative matrix elements of operators $(\bar{s}\,b)(\bar{q}\,q)$

Derivation

- express QCD matrix elements through an Operator Product Expansion (OPE) in $1/Q$, $Q \in \{m_b, \sqrt{q^2}\}$ using Heavy Quark Effective Theory (HQET) fields
- relate HQET currents to quark currents

Performance of Improved Isgur-Wise Relation at Low Recoil

$$R_T(q^2) \equiv \frac{q^2\, f_T(q^2)}{m_B^2\, f_+(q^2)}$$



Form Factors

- Light Cone Sum Rules (LCSR): Khodjamirian et al. (2010)
- Lattice (preliminary): Liu et al. (2011)

Effective Framework

- effective Hamiltonian for $b \to s\,\ell^+\ell^-$

$$\mathcal{H}_{\text{eff}} = -\frac{4\,G_F}{\sqrt{2}}\,V_{tb}\,V_{ts}^*\sum_{i=1}^{10}\mathcal{C}_i(\mu)\,\mathcal{O}_i(\mu) + O(V_{ub}\,V_{us}^*)$$

- renormalization scale $\mu = m_b$
- most relevant operators

$$\mathcal{O}_7 \propto [\bar{s}\,\sigma^{\mu\nu}\,P_R\,b]\,F_{\mu\nu} \qquad \mathcal{O}_{9(10)} \propto [\bar{s}\,\gamma^\mu\,P_L\,b][\bar{\ell}\,\gamma_\mu\,(\gamma_5)\,\ell]$$

- Wilson coefficients $\mathcal{C}_i$
- effective coefficients

$$\mathcal{C}_7^{\text{eff}} = \mathcal{C}_7 + \mathcal{O}\left(\mathcal{C}_{3\ldots6}, \alpha_s\,\mathcal{C}_{1,2,8}, \frac{m_c^2}{q^2}\right)$$

$$\mathcal{C}_9^{\text{eff}} = \mathcal{C}_9 + \left(\frac{4}{3}\mathcal{C}_1 + \mathcal{C}_2\right)h\,(q^2) + \mathcal{O}\left(\mathcal{C}_{3\ldots6}, \alpha_s\,\mathcal{C}_{1,2,8}, \frac{m_c^2}{q^2}\right)$$

Universal Short Distance Couplings

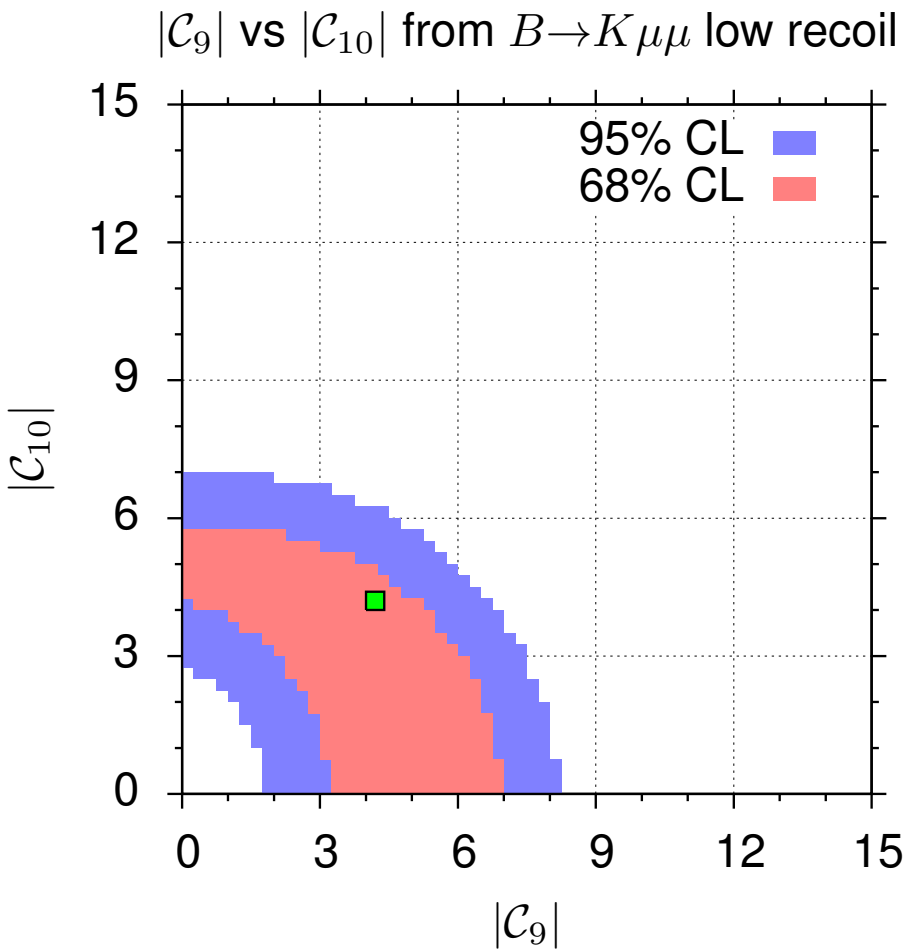
if lepton masses negligible ($\ell = e, \mu$)

- amplitude for $B \to K\ell^+\ell^-$ depends only on ρ_1
  ρ_1: bilinear combination of Wilson coefficients

$$\rho_1 = \left| \kappa \frac{2\, m_b\, m_B}{q^2} \mathcal{C}_7^{\text{eff}} + \mathcal{C}_9^{\text{eff}} \right|^2 + |\mathcal{C}_{10}|^2$$

- ρ_1 known from $B \to K^*\ell^+\ell^-$, Bobeth et al. (2010)
- same sensitivity on ρ_1 in both decays
- reduced uncertainties due to possibility of global fit (in preparation)

Constraining Wilson Coefficients



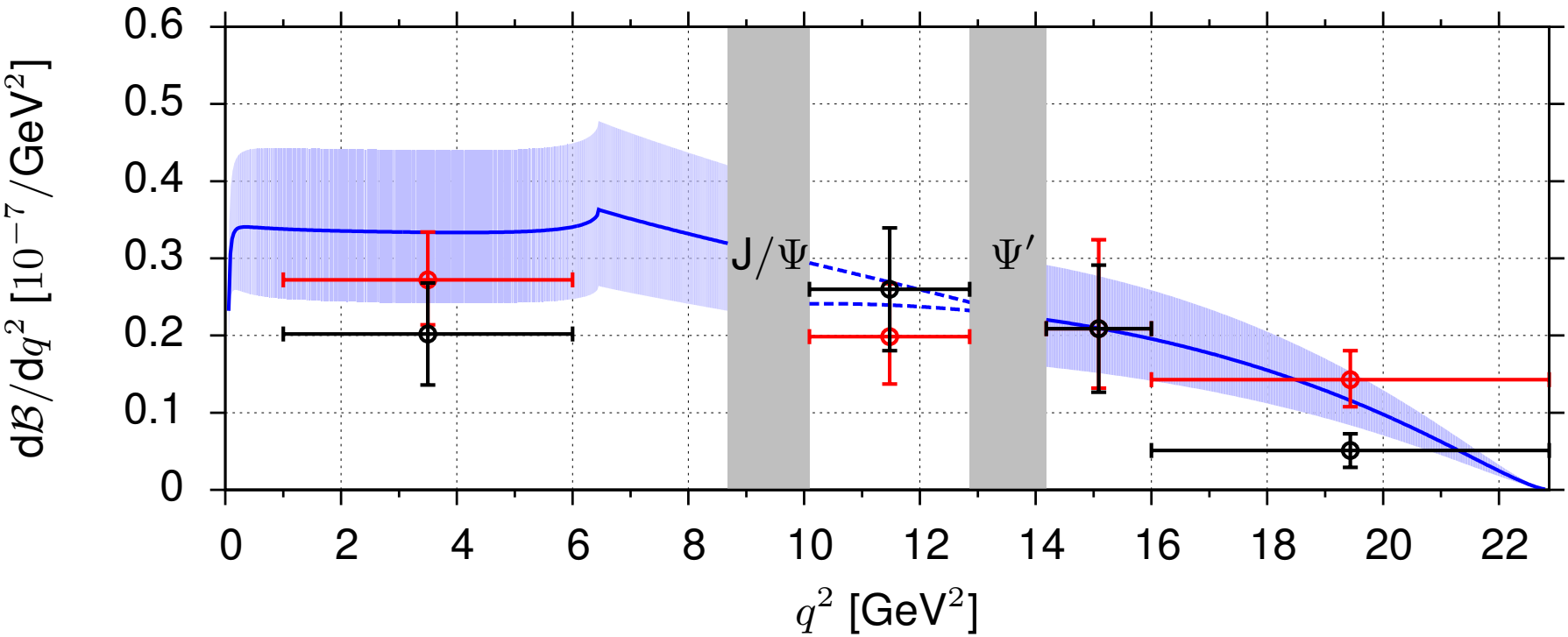
Parameter-Scan

- vary $\mathcal{C}_{7,9,10}$
- $\mathcal{C}_{1\ldots6,8}$ fixed on SM
- goodness-of-fit for every scan-point
- based on low recoil data from Belle and CDF
- numerical analysis with EOS
- green mark represents SM prediction
- results compatible with $B \to K^* \ell^+ \ell^-$

EOS: http://project.het.physik.tu-dortmund.de/eos/

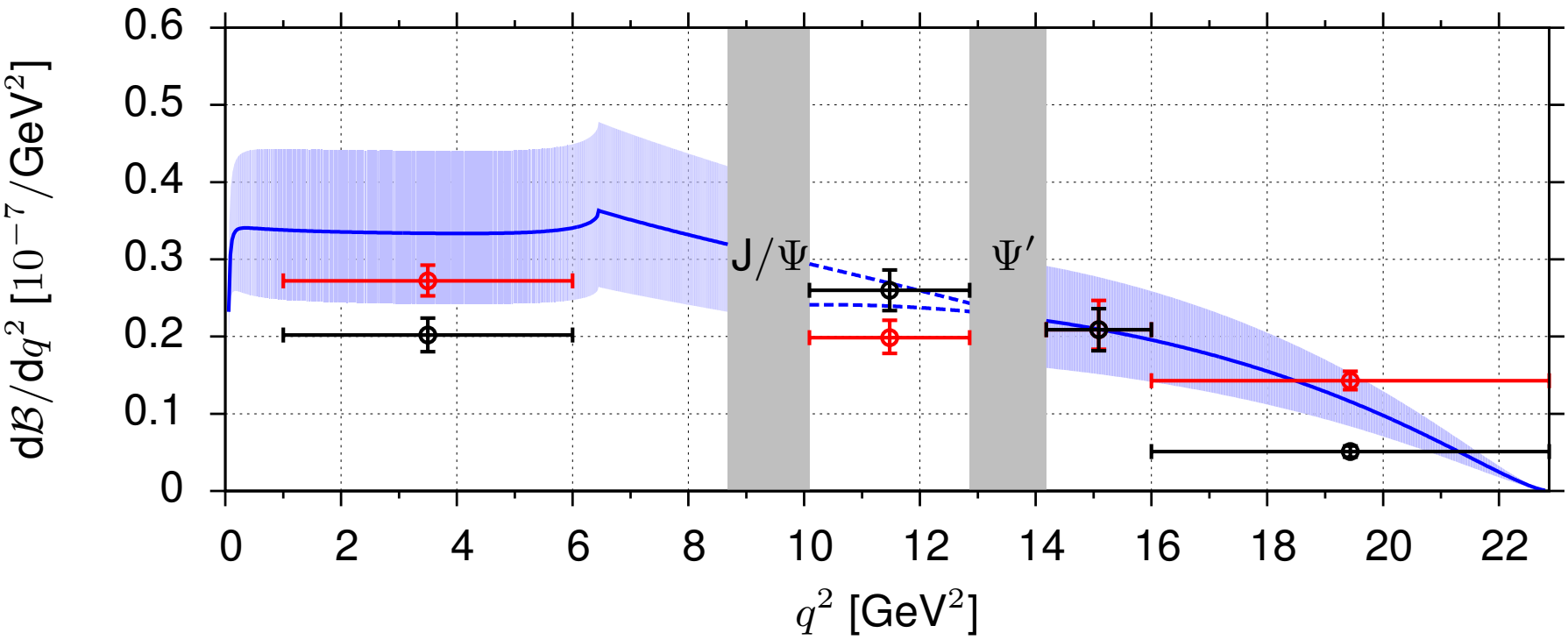
Current Situation for $B \to K\mu^+\mu^-$

- combined **Belle** and **CDF** data: $\sim$ 250 events
- LHCb: 35 events at 37 pb^{-1}
  (talk by A. Golutvin, La Thuile, 2011)



Estimation for LHCb Run in 2011

- 900-1800 $B \to K\mu^+\mu^-$ events at 1-2 fb^{-1} (talk by A. Golutvin, La Thuile, 2011)
- **hypothetical** error reduction



Summary and Outlook

Summary

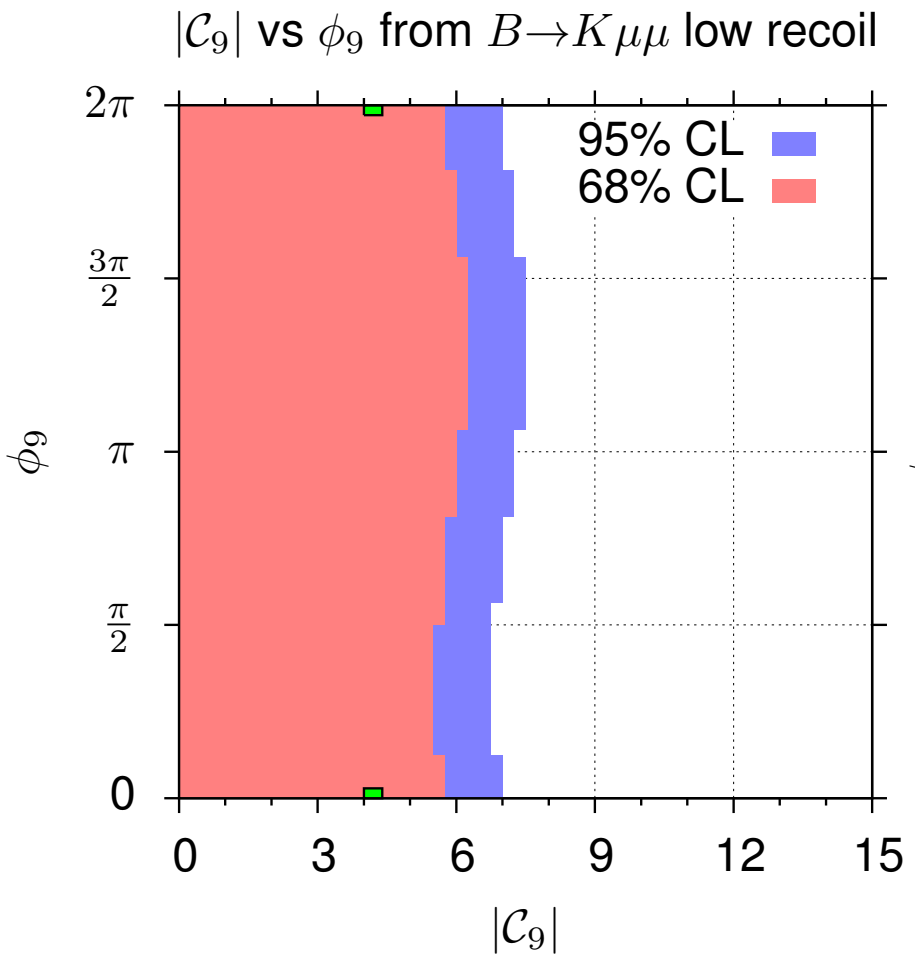
- analysis of $B \to K\ell^+\ell^-$ at low recoil with heavy quark OPE by Grinstein and Pirjol
- same short distance coupling for $B \to K\ell^+\ell^-$ as in $B \to K^*\ell^+\ell^-$
- present $B \to K\ell^+\ell^-$ data already probes New Physics

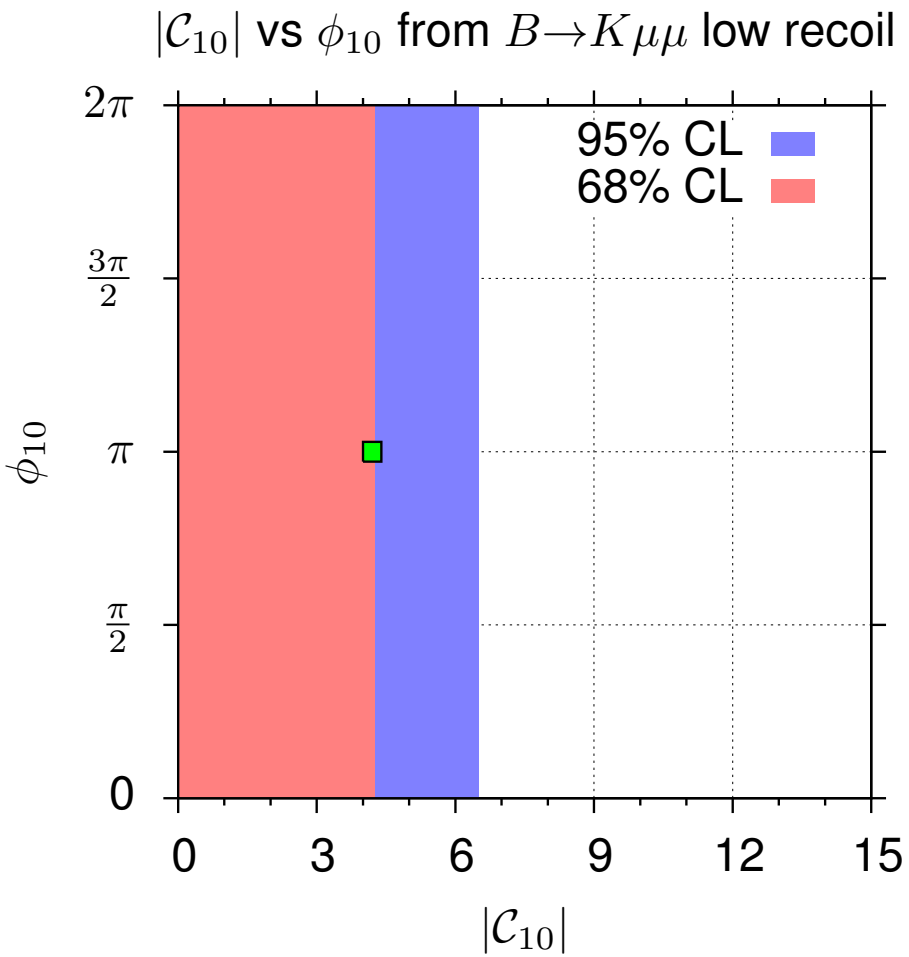
Outlook

- global $B \to \{K, K^*, X_s\}\ell^+\ell^-$ scan allowing for CP violation via complex-valued Wilson coefficients
- LHCb prediction for 2011: 900-1800 $B \to K\mu^+\mu^-$ events

Backup

Constraining Wilson Coefficients





- no sensitivity on ϕ_{10}
- no correlation between ϕ_9 and ϕ_{10}