Rare B decays with moving NRQCD and improved staggered quarks

Stefan Meinel
DAMTP, University of Cambridge

with

R. R. Horgan, L. Khomskii, M. B. Wingate (Cambridge)
A. Hart, E. H. Müller (Edinburgh)

Some experimental results

$$B(B^+ \to K^{*+}\gamma) = (40.3 \pm 2.6) \times 10^{-6}$$

$$B(B \to K l^+ l^-) = (0.39 \pm 0.06) \times 10^{-6}$$

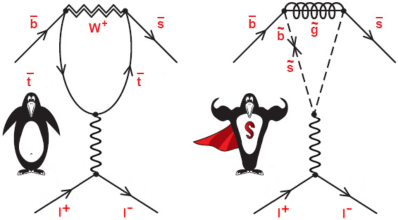
$$B(B \to K^* l^+ l^-) = \left(0.97 \begin{array}{c} +0.17 \\ -0.16 \end{array}\right) \times 10^{-6}$$

[Heavy Flavor Averaging Group, April 2008]

Rare B decays

More interesting than “tree-level decays”

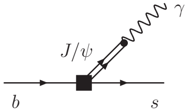
- $b \longrightarrow s$ is FCNC process, very sensitive to new physics



(figure adapted from *SLAC today 9/2006*)

More difficult than “tree-level decays”

- long-distance and spectator effects
- vector meson final states
- large recoil momenta



General framework for weak B decays

Standard Model (or beyond)

$\downarrow$ OPE

$$C_i(M_W)\,\mathcal{Q}_i^{\text{cont}}(M_W)$$

$\downarrow$ RG running

$$C_i(m_b)\,\mathcal{Q}_i^{\text{cont}}(m_b)$$

$\downarrow$ matching

$$C_i(m_b)\,Z_{ij}(am_b)\,\mathcal{Q}_{ij}^{\text{latt}}(a^{-1})$$

$\downarrow$

Non-perturbative lattice computation
of $\langle F|\mathcal{Q}_{ij}^{\text{latt}}|B\rangle$

Parametrization of matrix elements in terms of form factors

$B \to K l^+ l^-$

$$\langle K(p')|\bar{s}\gamma^\mu b|\bar{B}(p)\rangle = f_+(q^2)\left[p^\mu + p'^\mu - \frac{M_B^2 - M_P^2}{q^2} q^\mu\right] + f_0(q^2)\frac{M_B^2 - M_P^2}{q^2} q^\mu ,$$

$$q_\nu \langle K(p')|\bar{s}\sigma^{\mu\nu} b|\bar{B}(p)\rangle = \frac{i f_T(q^2)}{M_B + M_P}\left[q^2(p^\mu + p'^\mu) - (M_B^2 - m_P^2)q^\mu\right]$$

$B \to K^* \gamma$

$$q^\nu \langle K^*(p',\varepsilon)|\bar{s}\sigma_{\mu\nu} b|\bar{B}(p)\rangle = 4\, T_1(q^2)\epsilon_{\mu\nu\rho\sigma}\varepsilon^{*\nu} p^\rho p'^\sigma$$

$$q^\nu \langle K^*(p',\varepsilon)|\bar{s}\sigma_{\mu\nu}\gamma_5 b|\bar{B}(p)\rangle = 2i T_2(q^2)\left[\varepsilon^*_\mu (M_B^2 - M_{K^*}^2) - (\varepsilon^* \cdot q)(p + p')_\mu\right]$$
$$2i T_3(q^2)(\varepsilon^* \cdot q)\left[q_\mu - \frac{q^2}{M_B^2 - M_{K^*}^2}(p + p')_\mu\right]$$

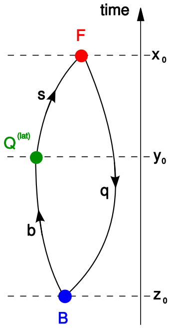
Parametrization of matrix elements in terms of form factors

$B \to K^* l^+ l^-$

$$
\begin{aligned}
q^\nu \langle K^*(p',\varepsilon)|\bar{s}\sigma_{\mu\nu}b|\bar{B}(p)\rangle &= 4\,T_1(q^2)\epsilon_{\mu\nu\rho\sigma}\varepsilon^{*\nu}p^\rho p'^\sigma \\
q^\nu \langle K^*(p',\varepsilon)|\bar{q}\sigma_{\mu\nu}\gamma_5 b|\bar{B}(p)\rangle &= 2iT_2(q^2)\left[\varepsilon^*_\mu(M_B^2 - M_{K^*}^2) - (\varepsilon^*\cdot q)(p+p')_\mu\right] \\
&\quad 2iT_3(q^2)(\varepsilon^*\cdot q)\left[q_\mu - \frac{q^2}{M_B^2 - M_{K^*}^2}(p+p')_\mu\right] \\
\langle K^*(p',\varepsilon)|\bar{s}\gamma^\mu b|\bar{B}(p)\rangle &= \frac{2iV(q^2)}{M_B + M_{K^*}}\,\epsilon^{\mu\nu\rho\sigma}\varepsilon^*_\nu\, p'_\rho p_\sigma, \\
\langle K^*(p',\varepsilon)|\bar{s}\gamma^\mu\gamma_5 b|\bar{B}(p)\rangle &= 2M_{K^*}A_0(q^2)\,\frac{\varepsilon^*\cdot q}{q^2}\,q^\mu \\
&\quad +(M_B + M_{K^*})\,A_1(q^2)\left[\varepsilon^{*\mu} - \frac{\varepsilon^*\cdot q}{q^2}\,q^\mu\right] \\
&\quad -A_2(q^2)\,\frac{\varepsilon^*\cdot q}{M_B + M_{K^*}}\left[p^\mu + p'^\mu - \frac{M_B^2 - M_{K^*}^2}{q^2}\,q^\mu\right]
\end{aligned}
$$

Non-perturbative lattice computation

Interpolating fields for $\langle F(p')|\mathcal{Q}^{\text{latt}}|\bar{B}(p)\rangle$:



$$\Phi_B(x) = \overline{\Psi}_q(x)\gamma_5\Psi_b(x),$$
$$\Phi_F(x) = \overline{\Psi}_q(x)\gamma_F\Psi_s(x), \qquad \gamma_F = \gamma_j,\ \gamma_5$$
$$\mathcal{Q}^{\text{latt}}(x) = \overline{\Psi}_s(x)\Gamma_{\mathcal{Q}}\Psi_b(x)$$

Correlators we need:

$$C_{F\mathcal{Q}B}(\mathbf{p}',\,\mathbf{p},\,x_0,\,y_0,\,z_0) = \sum_{\mathbf{y}}\sum_{\mathbf{z}}\left\langle \Phi_F(x)\ \mathcal{Q}^{\text{latt}}(y)\ \Phi_B^\dagger(z)\right\rangle e^{-i\mathbf{q}\cdot(\mathbf{y}-\mathbf{x})}e^{i\mathbf{p}\cdot(\mathbf{z}-\mathbf{x})}$$

$$C_{BB}(\mathbf{p},\ x_0,\ y_0) = \sum_{\mathbf{x}}\left\langle \Phi_B(x)\ \Phi_B^\dagger(y)\right\rangle e^{-i\mathbf{p}\cdot(\mathbf{x}-\mathbf{y})}$$

$$C_{FF}(\mathbf{p}',\ x_0,\ y_0) = \sum_{\mathbf{x}}\left\langle \Phi_F(x)\ \Phi_F^\dagger(y)\right\rangle e^{-i\mathbf{p}'\cdot(\mathbf{x}-\mathbf{y})}$$

Matrix elements (and energies) from correlators

For large $|x_0 - y_0|$ and $|y_0 - z_0|$

$$\begin{aligned} C_{F\mathcal{Q}B} &\longrightarrow e^{-E_F|x_0-y_0|}e^{-E_B|y_0-z_0|}A_{F\mathcal{Q}B}, \\ C_{BB} &\longrightarrow e^{-E_B|x_0-y_0|}A_{BB}, \\ C_{FF} &\longrightarrow e^{-E_F|x_0-y_0|}A_{FF}, \end{aligned}$$

$$\begin{aligned} A_{F\mathcal{Q}B} &= \begin{cases} \frac{\sqrt{Z_{K^*}}}{2E_{K^*}}\frac{\sqrt{Z_B}}{2E_B}\sum_s \varepsilon_j(p',s)\,\langle K^*\left(p',\varepsilon(p',s)\right)|\,\mathcal{Q}\,|\bar{B}(p)\rangle, & F = K^*, \\ \frac{\sqrt{Z_K}}{2E_K}\frac{\sqrt{Z_B}}{2E_B}\,\langle K\left(p'\right)|\,\mathcal{Q}\,|\bar{B}(p)\rangle, & F = K \end{cases} \\ A_{BB} &= \frac{Z_B}{2E_B} \\ A_{FF} &= \begin{cases} \sum_s \frac{Z_{K^*}}{2E_{K^*}}\,\epsilon_j^*(p',s)\epsilon_j(p',s), & F = K^*, \\ \frac{Z_K}{2E_K}, & F = K. \end{cases} \end{aligned}$$

Fermion Actions

Light quarks (u, d and s): AsqTad or HISQ

- MILC configurations with sea quark masses in chiral regime

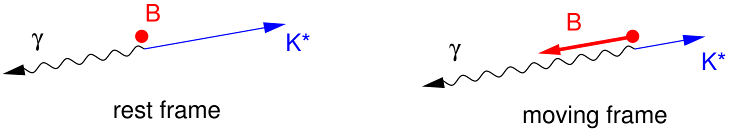
b quark: moving NRQCD

[Mandula & Ogilvie, Hashimoto & Matsufuru, Sloan, Davies-Dougall-Foley-Lepage-Wong]

- allows us to work directly at the physical b quark mass
- allows us to work at lower q^2 compared to standard NRQCD, but $M_B^2 - q^2 \ll M_B^2$ is still required for convergence of heavy-quark expansion
- requires $am_b > 1$
- applicable to both HL and HH mesons

Moving NRQCD: reducing discretization errors at large recoil

- give B meson large momentum to reduce final state momentum
- perform NRQCD expansion in B rest frame, boost to lattice frame and discretize



- momentum of light degrees of freedom in B meson and residual momentum of b quark are of order

$$\gamma(v+1)a\Lambda_{QCD}$$

(v – boost velocity)

moving-NRQCD field redefinition (on Minkowski space)

$$\Psi_b(x) \;=\; S(\Lambda) \;\; T_{\rm FWT} \;\; e^{-im\, u\cdot x\, \gamma^0} \;\; T_{\rm TD} \;\; \frac{1}{\sqrt{\gamma}} \left(\begin{array}{c} \psi_v(x) \\ \xi_v(x) \end{array} \right)$$

with

$$T_{\rm FWT} = \exp\left(\frac{1}{2m}\; i\gamma^j \Lambda^\mu{}_j D_\mu \right) \ldots$$

(FWT transformation in boosted frame),

$$T_{\rm TD} = \exp\left(\frac{i}{4\gamma m} \gamma^0 \left[(\gamma^2 - 1) D_0 + (\gamma^2 + 1) \mathbf{v} \cdot \mathbf{D} \right] \right) \ldots$$

(removes unwanted time derivatives), and $S(\Lambda)$ is Dirac spinor representation of Lorentz boost.

Euclidean mNRQCD Lagrangian correct through $\mathcal{O}(\Lambda_{QCD}^2/m^2)$ (HL) and $\mathcal{O}(v_{NR}^4)$ (HH)

$$\mathcal{L} = \psi_v^+ \left(D_4 + H_0 + \delta H \right) \psi_v + \xi_v^+ \left(D_4 - \overline{H_0} - \overline{\delta H} \right) \xi_v$$

with

$$H_0 = -i\mathbf{v}\cdot\mathbf{D} - \frac{\mathbf{D}^2 - (\mathbf{v}\cdot\mathbf{D})^2}{2\gamma m}$$

$$\begin{aligned}
\delta H = & -\frac{i}{4\gamma^2 m^2}\left(\{\mathbf{D}^2,\ \mathbf{v}\cdot\mathbf{D}\} - 2(\mathbf{v}\cdot\mathbf{D})^3 \right) \\
& + \frac{1}{8\gamma^3 m^3}\left(-\mathbf{D}^4 + 3\left\{\mathbf{D}^2,\ (\mathbf{v}\cdot\mathbf{D})^2\right\} - 5(\mathbf{v}\cdot\mathbf{D})^4 \right) \\
& - \frac{g}{2\gamma m}\boldsymbol{\sigma}\cdot\mathbf{B}' - \frac{g}{8\gamma m^2}\ \boldsymbol{\sigma}\cdot\left(\mathbf{D}\times\mathbf{E}' - \mathbf{E}'\times\mathbf{D}\right) \\
& - \frac{ig}{4\gamma^2 m^2}\left\{\mathbf{v}\cdot\mathbf{D},\ \boldsymbol{\sigma}\cdot\mathbf{B}'\right\}. \\
& + \frac{g}{8(\gamma+1)m^2}\left\{\mathbf{v}\cdot\mathbf{D},\ \boldsymbol{\sigma}\cdot(\mathbf{v}\times\mathbf{E}')\right\} \\
& + \frac{g}{8m^2}\left(i\mathbf{D}^{\mathrm{ad}}\cdot\mathbf{E} + \mathbf{v}\cdot(\mathbf{D}^{\mathrm{ad}}\times\mathbf{B}) \right) \\
& - \frac{(2-\mathbf{v}^2)g}{16m^2}\left(D_4^{\mathrm{ad}} + i\mathbf{v}\cdot\mathbf{D}^{\mathrm{ad}} \right)(\mathbf{v}\cdot\mathbf{E}).
\end{aligned}$$

mNRQCD external momentum renormalisation and energy shift

The residual B momentum is discretized on the lattice,

$$k_j = \frac{2\pi\, n_j}{L}$$

The physical momentum is given by

$$\mathbf{p} = \mathbf{k} + Z_p \mathbf{P}_0$$

with

$$\mathbf{P}_0 = \gamma m \mathbf{v}, \quad Z_p \approx 1.$$

B meson correlators decay with ground state energies

$$E_{\mathbf{v}}(\mathbf{k}) = \underbrace{\sqrt{(Z_p \mathbf{P}_0 + \mathbf{k})^2 + M_B^2}}_{\text{physical energy}} - \Delta_{\mathbf{v}}$$

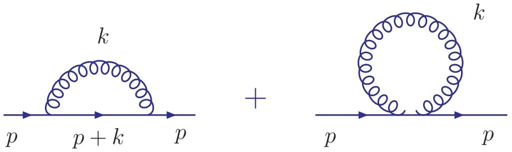
with an energy shift $\Delta_{\mathbf{v}}$. In perturbation theory,

$$\Delta_{\mathbf{v}} = Z_m Z_\gamma \gamma m - E_0.$$

Perturbative computation of renormalization parameters

- E_0, Z_ψ, Z_m, Z_v and Z_p can be extracted from heavy-quark self energy

$\Sigma(p) =$



$$E_0 = 1 + \alpha_s \,\mathrm{Re}\{\Sigma\}|_{p=0}$$

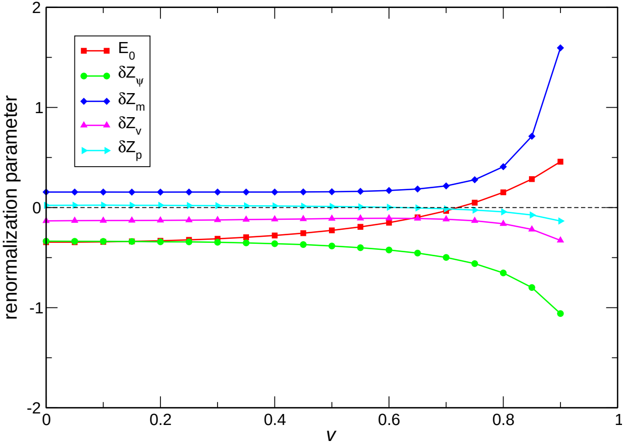
$$Z_\psi = 1 + \alpha_s \left(\mathrm{Re}\{\Sigma\} + \mathrm{Im}\{\frac{\partial \Sigma}{\partial p_0}\} \right) \Big|_{p=0}$$

$$\vdots$$

- computed to 1-loop for full $\mathcal{O}(\Lambda^2_{QCD}/m^2)$ action [Lew Khomskii 2008]

Perturbative computation of renormalization parameters

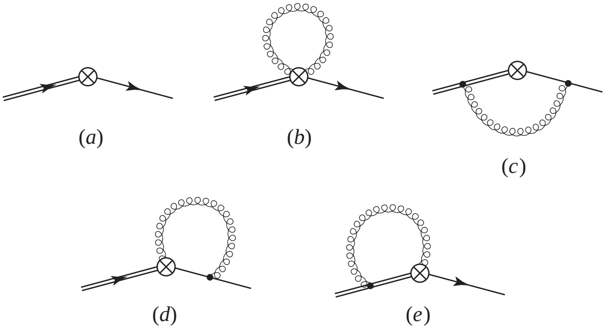
Here, $Z_\psi = 1 + \alpha_s \delta Z_\psi$ etc.



Full improved $\mathcal{O}(\Lambda^2_{QCD}/m^2)$ mNRQCD action with Lüscher-Weisz gluon action, $m = 2.8$, $n = 4$. All errors are $O(10^{-3})$

Preliminary data from [Lew Khomskii 2008]

Perturbative matching of vector and axial vector currents



- Computation of matching coefficients for all lattice operators up to $\mathcal{O}(\Lambda_{QCD}/m)$ is underway [Lew Khomskii 2008]

Lattice operators for temporal axial current [Lew Khomskii 2008]

$$
\begin{aligned}
I_1 &= f_0(1+\gamma_{(0)})\,\bar{q}_0(x)\hat{\gamma}_5 Q_0(x)\,, \\
I_2 &= i f_0 \gamma_{(0)}\,\bar{q}_0(x)\hat{\gamma}_5 \hat{\boldsymbol{\gamma}}\cdot\boldsymbol{v}_0 Q_0(x)\,, \\
I_3 &= -i f_0(1-\gamma_{(0)}^2)\,\frac{1}{2m_0}\,\bar{q}_0(x)\hat{\gamma}_5 \boldsymbol{v}_0\cdot\boldsymbol{D} Q_0(x)\,, \\
I_4 &= -f_0\gamma_{(0)}(1+\gamma_{(0)})\,\frac{1}{2m_0}\,\bar{q}_0(x)\hat{\gamma}_5(\hat{\boldsymbol{\gamma}}\cdot\boldsymbol{v}_0)(\boldsymbol{v}_0\cdot\boldsymbol{D})Q_0(x)\,, \\
I_5 &= \frac{f_0(1+\gamma_{(0)})}{2m_0}\,\bar{q}_0(x)\hat{\boldsymbol{\gamma}}\cdot\boldsymbol{D}\hat{\gamma}_5 Q_0(x)\,, \\
I_6 &= \frac{i f_0\gamma_{(0)}}{2m_0}\,\bar{q}_0(x)(\hat{\boldsymbol{\gamma}}\cdot\boldsymbol{D})\hat{\gamma}_5(\hat{\boldsymbol{\gamma}}\cdot\boldsymbol{v}_0)Q_0(x)\,, \\
I_7 &= -\frac{f_0(1+\gamma_{(0)})}{m_0}\,\bar{q}_0(x)\hat{\boldsymbol{\gamma}}\cdot\overleftarrow{\boldsymbol{D}}\hat{\gamma}_5 Q_0(x)\,, \\
I_8 &= -\frac{i f_0\gamma_{(0)}}{m_0}\,\bar{q}_0(x)(\hat{\boldsymbol{\gamma}}\cdot\overleftarrow{\boldsymbol{D}})\hat{\gamma}_5(\hat{\boldsymbol{\gamma}}\cdot\boldsymbol{v}_0)Q_0(x)\,, \\
I_9 &= i f_0(1+\gamma_{(0)})\,\frac{1}{2m_0}\,\bar{q}_0(x)\boldsymbol{v}_0\cdot\overleftarrow{\boldsymbol{D}}\hat{\gamma}_5 Q_0(x)\,, \\
I_{10} &= -f_0\gamma_{(0)}\,\frac{1}{2m_0}\,\bar{q}_0(x)(\boldsymbol{v}_0\cdot\overleftarrow{\boldsymbol{D}})\hat{\gamma}_5(\hat{\boldsymbol{\gamma}}\cdot\boldsymbol{v}_0)Q_0(x)\,.
\end{aligned}
$$

Perturbative matching of tensor current

- matching coefficients computed to 1 loop for leading order operators [Eike Müller 2008]

$$\mathcal{Q}_{7,1}^{0\ell} = \sqrt{\frac{1+\gamma}{2\gamma}} m \left(\bar{q} \sigma_{0\ell} \tilde{\Psi}_v^{(+)} \right)$$

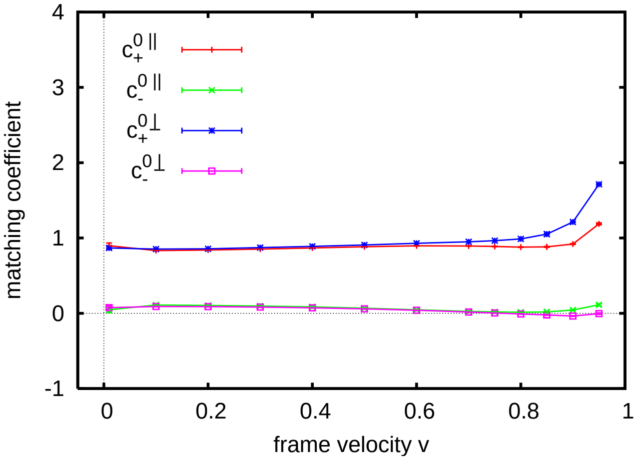
$$\mathcal{Q}_{7,2}^{0\ell} = v \sqrt{\frac{\gamma}{2(1+\gamma)}} m \left(\bar{q} \sigma_{0\ell} \hat{\boldsymbol{v}} \cdot \boldsymbol{\gamma} \gamma_0 \tilde{\Psi}_v^{(+)} \right)$$

$$\mathcal{Q}_7^{(lat)0\ell} = (1 + \alpha_s c_1^{0\ell}) \mathcal{Q}_{7,1}^{0\ell} + (1 + \alpha_s c_2^{0\ell}) \mathcal{Q}_{7,2}^{0\ell}$$
$$= (1 + \alpha_s c_+^{0\ell}) \mathcal{Q}_{7,+}^{0\ell} + \alpha_s c_-^{0\ell} \mathcal{Q}_{7,-}^{0\ell}$$

with $\mathcal{Q}_{7,\pm}^{0\ell} = \mathcal{Q}_{7,1}^{0\ell} \pm \mathcal{Q}_{7,2}^{0\ell}$

Perturbative matching of tensor current (preliminary)

$$\mathcal{Q}_7^{(lat)0\ell} = (1 + \alpha_s c_+^{0\ell})\,\mathcal{Q}_{7,+}^{0\ell} + \alpha_s c_-^{0\ell}\,\mathcal{Q}_{7,-}^{0\ell}$$



Improved $\mathcal{O}(\Lambda_{QCD}/m)$ mNRQCD action with Symanzik improved gluon action, $m = 2.8$, $n = 2$ [Eike Müller 2008]

Tests of lattice mNRQCD from 2-point correlators

- tadpole-improved $\mathcal{O}(v_{NR}^4, \Lambda_{QCD}^2/m_b^2)$ moving NRQCD action
- MILC $20^3 \times 64$, lattice spacing a^{-1} ≈1.6 GeV, sea quark masses $am_u = am_d = 0.007$, $am_s = 0.05$ ($m_\pi \sim 300$ MeV)
- valence quark masses $am_u = am_d = 0.007$, $am_s = 0.04$, $a\,m_b = 2.8$
- $\mathbf{v} = (v, 0, 0)$
- compute heavy-heavy and heavy-light meson energies and decay constants at different boost velocities
- heavy-heavy mesons: smearing with hydrogen wave functions in Coulomb gauge
- heavy-light mesons: use AsqTad valence quarks, Gaussian smearing in Coulomb gauge
- Bayesian multi-exponential fitting

Tests of lattice mNRQCD from 2-point correlators

Recall that

$$E_{\mathbf{v}}(\mathbf{k}) = \underbrace{\sqrt{(Z_p\mathbf{P}_0 + \mathbf{k})^2 + M^2}}_{\text{physical energy}} - \Delta_{\mathbf{v}}.$$

$\Rightarrow$ compute

$$\begin{aligned}
\Delta_{\mathbf{v}} &= \frac{\mathbf{k}_\perp^2 - \left(E_{\mathbf{v}}^2(\mathbf{k}_\perp) - E_{\mathbf{v}}^2(0)\right)}{2(E_{\mathbf{v}}(\mathbf{k}_\perp) - E_{\mathbf{v}}(0))}, \\
Z_p &= \frac{E_{\mathbf{v}}^2(\mathbf{k}_\parallel) - E_{\mathbf{v}}^2(-\mathbf{k}_\parallel) + 2\Delta_{\mathbf{v}}(E_{\mathbf{v}}(\mathbf{k}_\parallel) - E_{\mathbf{v}}(-\mathbf{k}_\parallel))}{4\mathbf{k}_\parallel \cdot \mathbf{P_0}}, \\
M_{\text{kin}} &= \sqrt{(E_{\mathbf{v}}(\mathbf{k}) + \Delta_{\mathbf{v}})^2 - (Z_p\mathbf{P_0} + \mathbf{k})^2}.
\end{aligned}$$

Tests of lattice mNRQCD from 2-point correlators

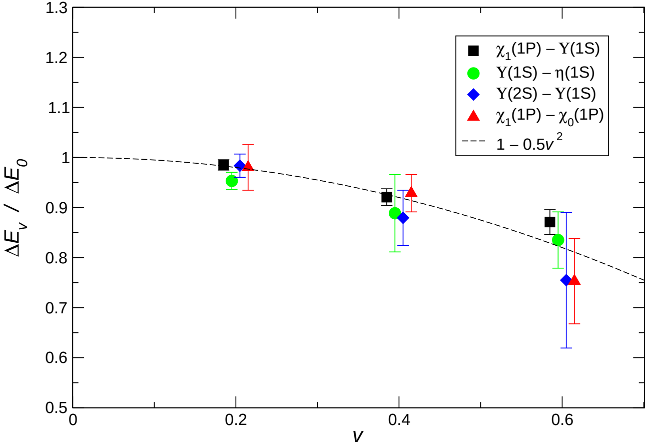
Results for η_b:

v	Z_p	M_{kin}	Δ_v
0		6.240 ± 0.033	5.815 ± 0.033
0.2	1.029 ± 0.015	6.40 ± 0.10	6.09 ± 0.10
0.4	1.014 ± 0.069	6.28 ± 0.42	6.37 ± 0.45
0.6	0.929 ± 0.062	6.47 ± 0.41	7.24 ± 0.49

(lattice units)

Tests of lattice mNRQCD from 2-point correlators

Energy splittings vs boost velocity (points are offset horizontally for legibility)



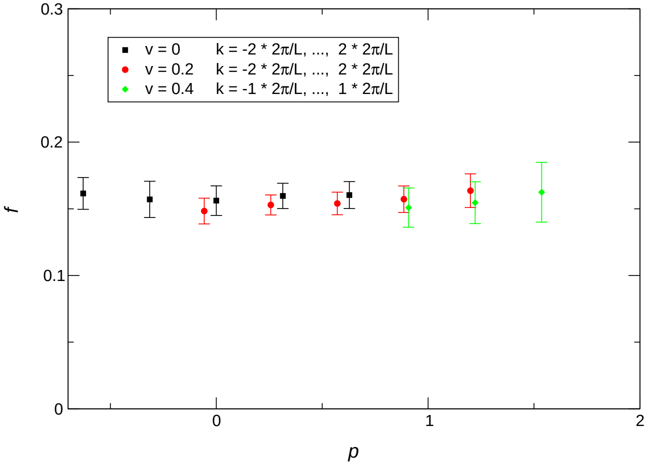
$$E^A_{\mathbf{v}}(0) - E^B_{\mathbf{v}}(0) = \sqrt{(2Z_p\gamma m_b\mathbf{v})^2 + M_A^2} - \sqrt{(2Z_p\gamma m_b\mathbf{v})^2 + M_B^2}$$

$$\frac{E^A_{\mathbf{v}}(0) - E^B_{\mathbf{v}}(0)}{E^A_{\mathbf{0}}(0) - E^B_{\mathbf{0}}(0)} = 1 - \left(\frac{2m_b}{M_A\, M_B}\right)\mathbf{v}^2 + \mathcal{O}(\mathbf{v}^4) \quad \text{for} \quad Z_p = 1$$

Tests of lattice mNRQCD from 2-point correlators

B and B_s decay constants $\langle 0|\mathrm{A}^\mu(0)|\bar{B}_{(s)},\mathbf{p}\rangle = i f_{B_{(s)}}\, p^\mu$ at different boost velocities

f_{B_s} vs. total momentum $\mathbf{p} = \mathbf{k} + Z_p \gamma m \mathbf{v}$ (lattice units, $Z_p \approx 1$)



3-point correlators and form factors

- $\mathcal{O}(\Lambda_{QCD}/m_b)$ moving NRQCD action, leading current operators only
- MILC $20^3 \times 64$, lattice spacing $a^{-1} \approx$1.6 GeV, sea quark masses $am_u = am_d = 0.007$, $am_s = 0.05$ ($m_\pi \sim 300$ MeV)
- valence quark masses $am_u = am_d = 0.007$, $am_s = 0.04$, $a\, m_b = 2.8$
- 3-point functions must be fitted to

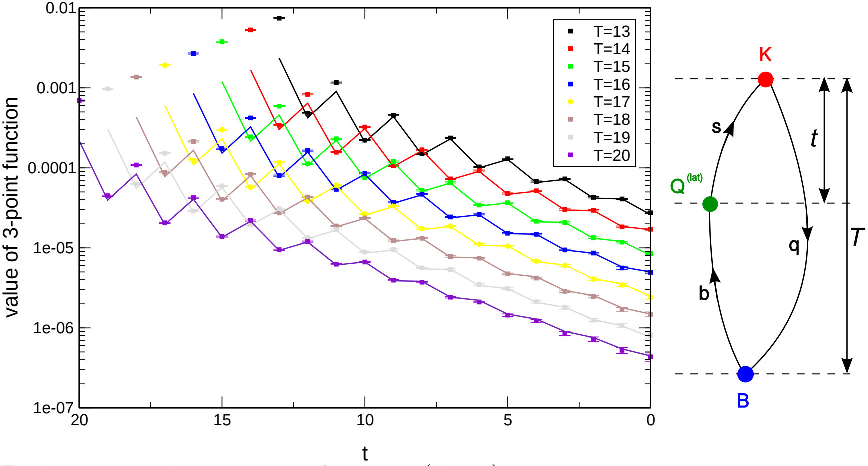
$$C_{FJB}(\mathbf{p}', \mathbf{p}, t, T) \quad \rightarrow \quad \sum_{\substack{k = 0..K, \\ l = 0..L}} A_{kl}^{(FJB)} \cdot (-1)^{k\,t}(-1)^{l(T-t)} e^{-F_k t} e^{-E_l (T-t)}$$

  (oscillating contributions due to use of naive (AsqTad) quarks)
- Bayesian fitting
- 2-variable fits, varying both t and T

3-point correlators and form factors

$\langle\ \Phi_K\ \ \bar{s}\gamma_0 b\ \ \Phi_B^\dagger\ \rangle$ at $\mathbf{k}_{(\mathbf{p})} = \frac{2\pi}{L}(0,0,0)$, $\mathbf{k}_{(\mathbf{q})} = \frac{2\pi}{L}(0,0,0)$, $\mathbf{v} = 0$

very preliminary!

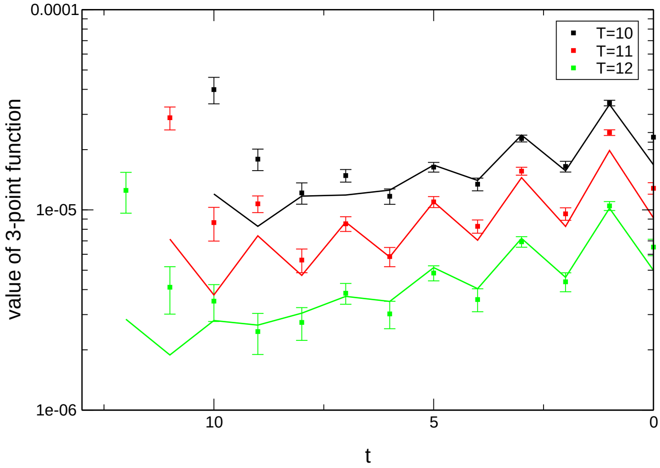


Fitting range: $T = 14 \ldots 18$ and $t = 6 \ldots (T-5)$.

3-point correlators and form factors

$\langle\ \Phi_{K^*}\ \ \bar{s}\sigma_{13}b\ \ \Phi_B^\dagger\ \rangle$at $\mathbf{k_{(p)}} = \frac{2\pi}{L}(0,0,0)$, $\mathbf{k_{(q)}} = \frac{2\pi}{L}(1,0,0)$, $\mathbf{v} = 0$

very preliminary!

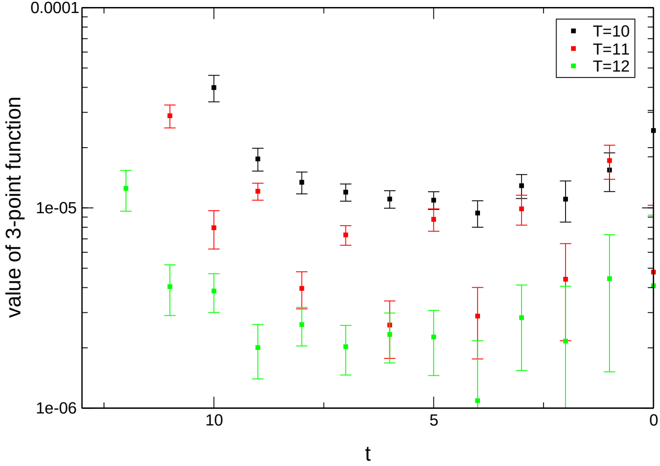


Fitting range $T = 8 \ldots 20$ and $t = 4 \ldots (T-4)$ (not all data shown for clarity)

3-point correlators and form factors

$\langle\ \Phi_{K^*}\ \ \bar{s}\sigma_{13}b\ \ \Phi_B^\dagger\ \rangle$at $\mathbf{k}_{(\mathbf{p})} = \frac{2\pi}{L}(1,0,0)$, $\mathbf{k}_{(\mathbf{q})} = \frac{2\pi}{L}(2,0,0)$, $\mathbf{v} = 0.4$

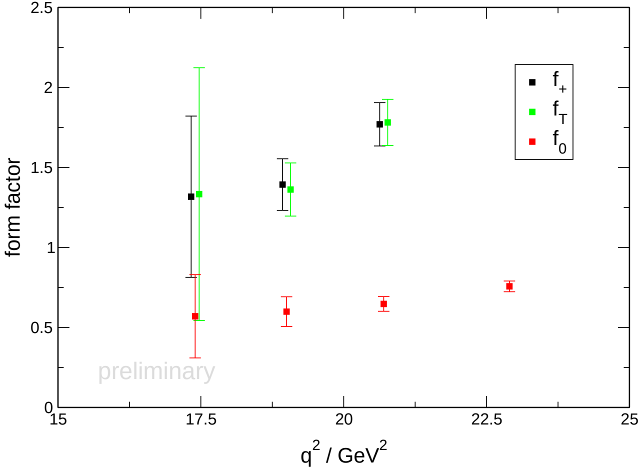
very preliminary!



(not all data shown for clarity)

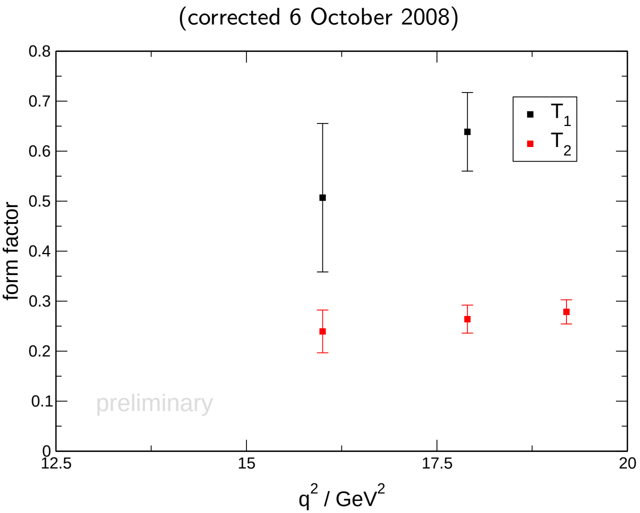
3-point correlators and form factors

(corrected 6 October 2008)



The points at lowest q^2 have $\mathbf{v} = 0.4$, $\mathbf{k}_{(\mathbf{p})} = \frac{2\pi}{L}(1, 0, 0)$, $\mathbf{k}_{(\mathbf{q})} = \frac{2\pi}{L}(2, 0, 0)$

3-point correlators and form factors



The points at lowest q^2 have $\mathbf{v} = 0.2$, $\mathbf{k}_{(\mathbf{p})} = \frac{2\pi}{L}(1,0,0)$, $\mathbf{k}_{(\mathbf{q})} = \frac{2\pi}{L}(2,0,0)$

Outlook

- 3-point fits shown here are just first attempts and can probably be improved
- for more data points and lower q^2, need to work with off-axis lattice momenta and boost velocities
- random wall sources [Kit Wong, Lattice 2007] will improve statistics $\rightarrow$ larger K, K^* momentum and higher $\mathbf{v}$
- smearing will reduce excited state contaminations