Update on semileptonic B-decays with HISQ light quarks and clover b-quarks in Fermilab interpretation

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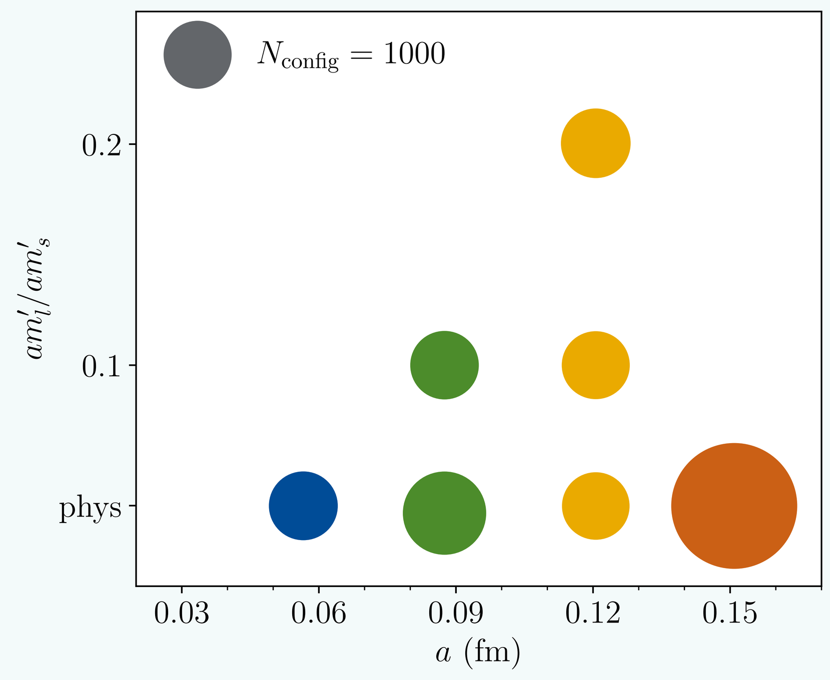
Abstract

- This work is an update on ongoing project [1, 2, 3]
- We compute the vector, scalar, and tensor form factors for the $B \to \pi$, $B \to K$, and $B_s \to K$ amplitudes.
- We use the highly improved staggered quark (HISQ) action for the sea and light valence quarks.
- We use the clover action in the Fermilab interpretation for the bottom quark.
- We carry out simulations on N_f=2+1+1 MILC HISQ ensembles.

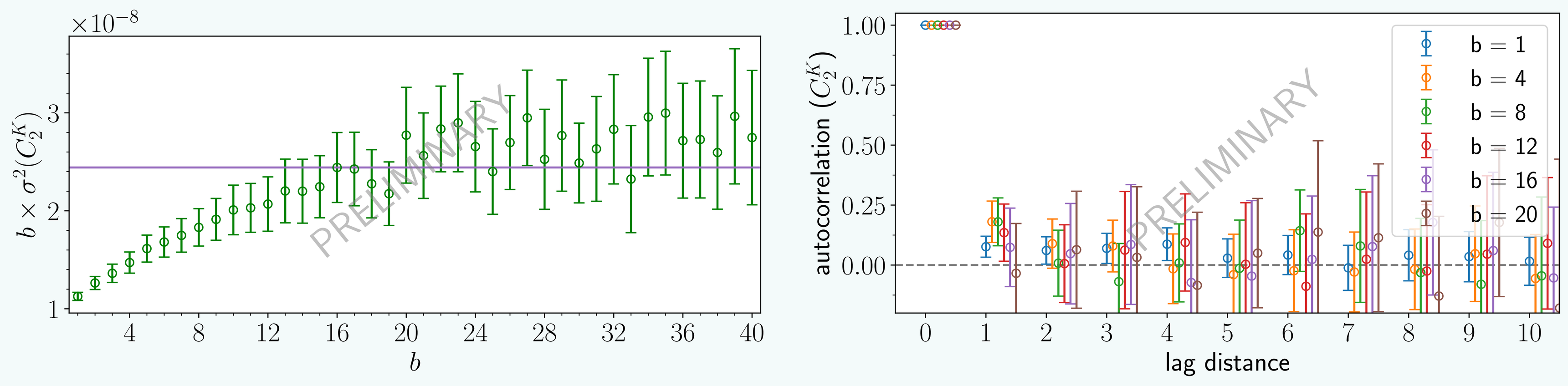
FNAL-HISQ campaign

- Valence quarks: **HISQ light** + **clover bottom in Fermilab interpretation**
- MILC HISQ gauge ensembles [4] : $\boldsymbol{N_f}$**=2+1+1 HISQ sea**
  - Lattice spacings : 0.15 fm to 0.057 fm
  - M_π: 130 MeV to 310 MeV



Binning

- We apply binning (or blocking) on our correlators to mitigate the autocorrelation.
- The bin sizes are chosen by monitoring the variance of the two-point correlation function C_2 while varying bin sizes.

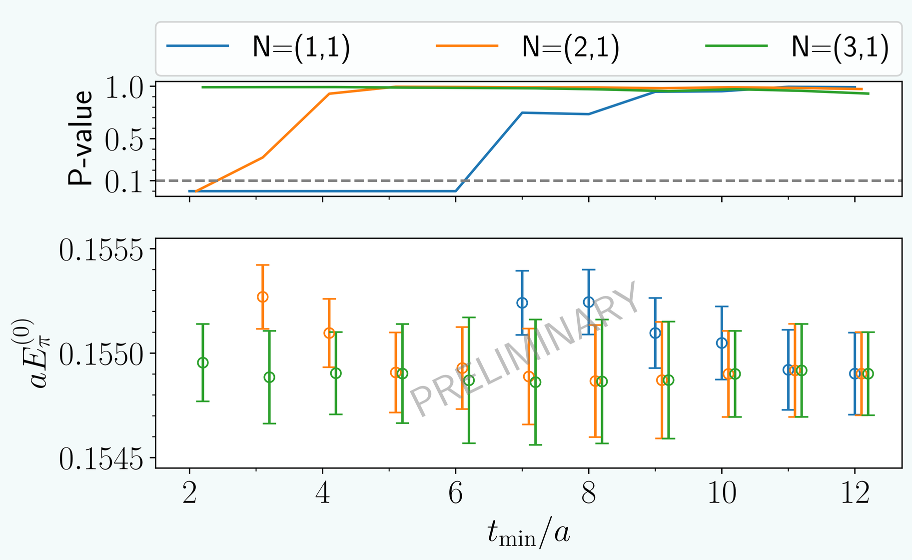


- With the reduced number of samples after binning, we use a rescaled approximation of the covariance matrix.

$$\mathrm{cov}[\widetilde{C}_i, \widetilde{C}_j] \sim \mathrm{cov}[C_i, C_j]\,\frac{\sigma[\widetilde{C}_i]\,\sigma[\widetilde{C}_j]}{\sigma[C_i]\,\sigma[C_j]} \tag{1}$$

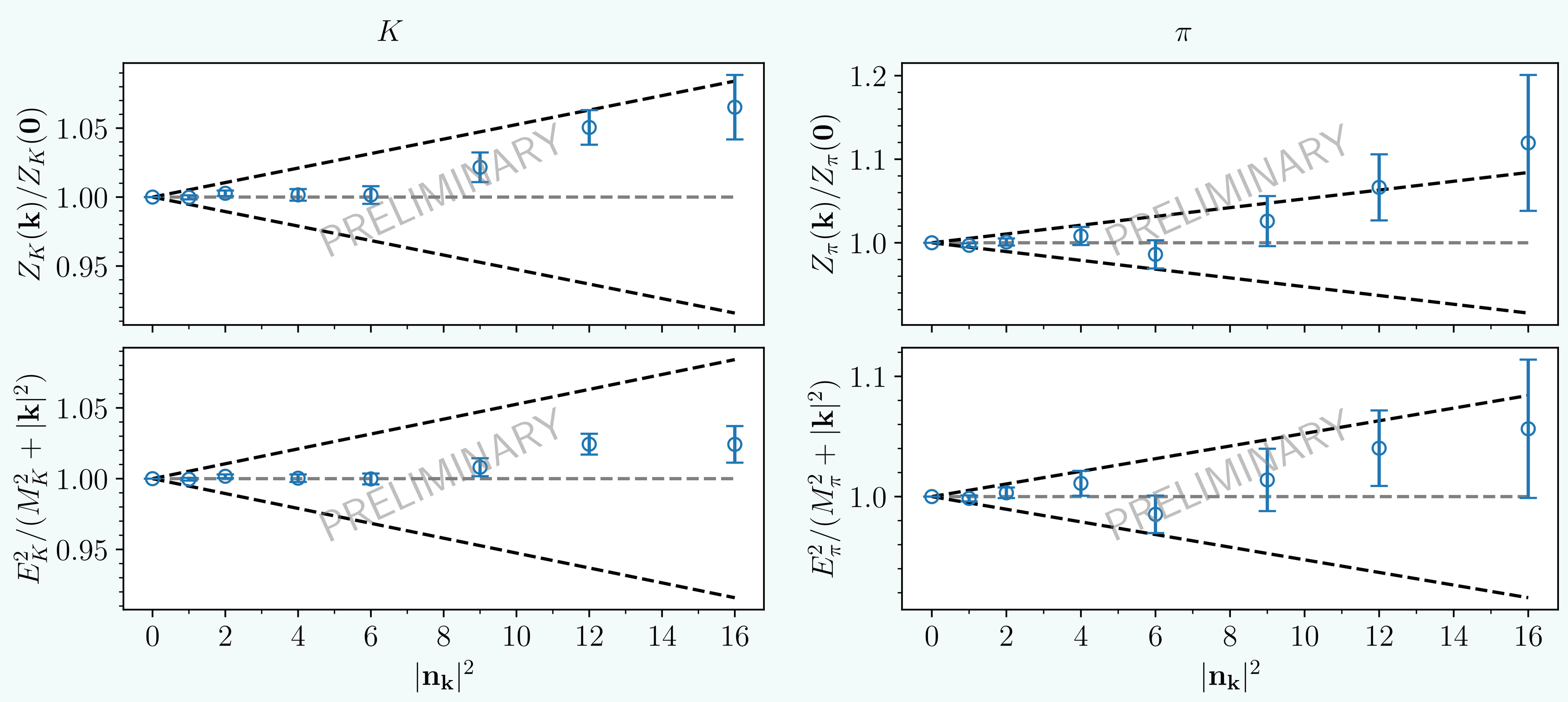
Two-point function analysis

- We analyze the two-point correlation function data to extract primarily the ground state energies.



- Find **ground state energy consistent** for different numbers of states $N = (N_{\text{non-osc}}, N_{\text{osc}})$ and **stable** over varying fit range.
- All data within the fit range have errors $< 5\%$.
- P-value: computed by removing augmented term from χ^2

- We use the dispersion relation instead of directly measured values.



Three-point function (or Ratio) analysis

- For B ($\in B, B_s$) mesons and L ($\in \pi, K$) mesons, we compute the ratio

$$\overline{R}(t,T) = \frac{\overline{C}_3^{B\to L}(t,T)}{\sqrt{\overline{C}_2^L(t)\overline{C}_2^B(T-t)}}\sqrt{\frac{2E_L^{(0)}}{e^{-E_L^{(0)}t}e^{-E_B^{(0)}(T-t)}}} \tag{2}$$

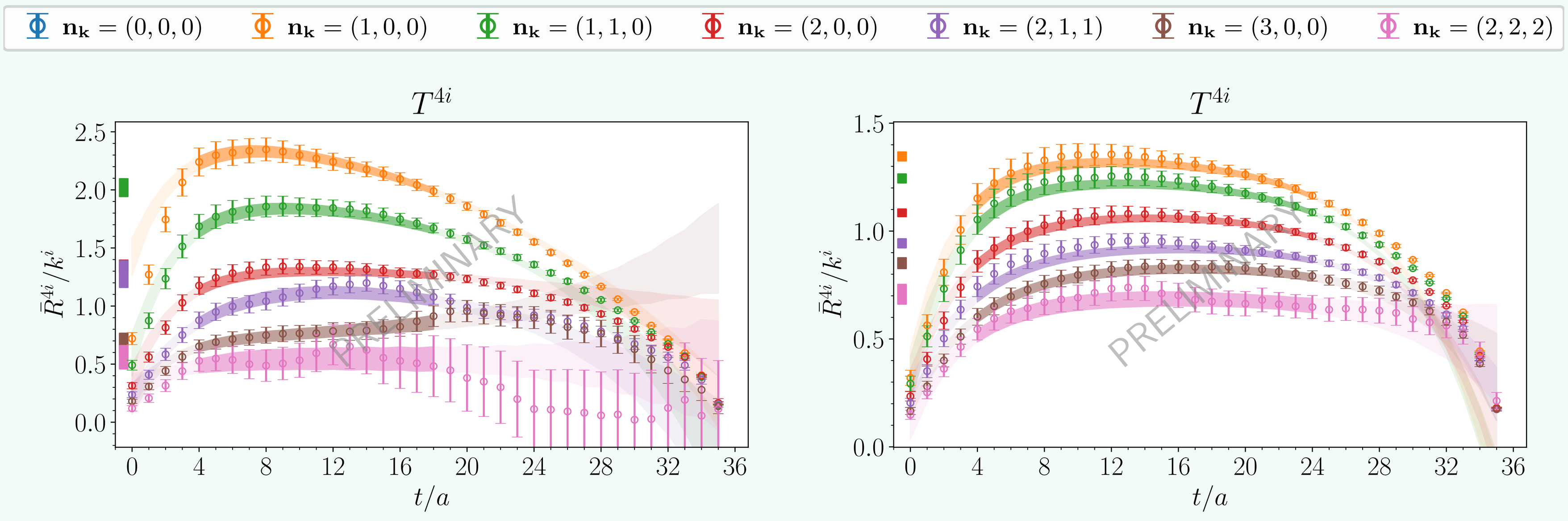
  where $\overline{C}_{2,3}$ are averaged (or smeared) to reduce the oscillating contribution [5].

- Our choice of fit model: describes data well with the least number of terms

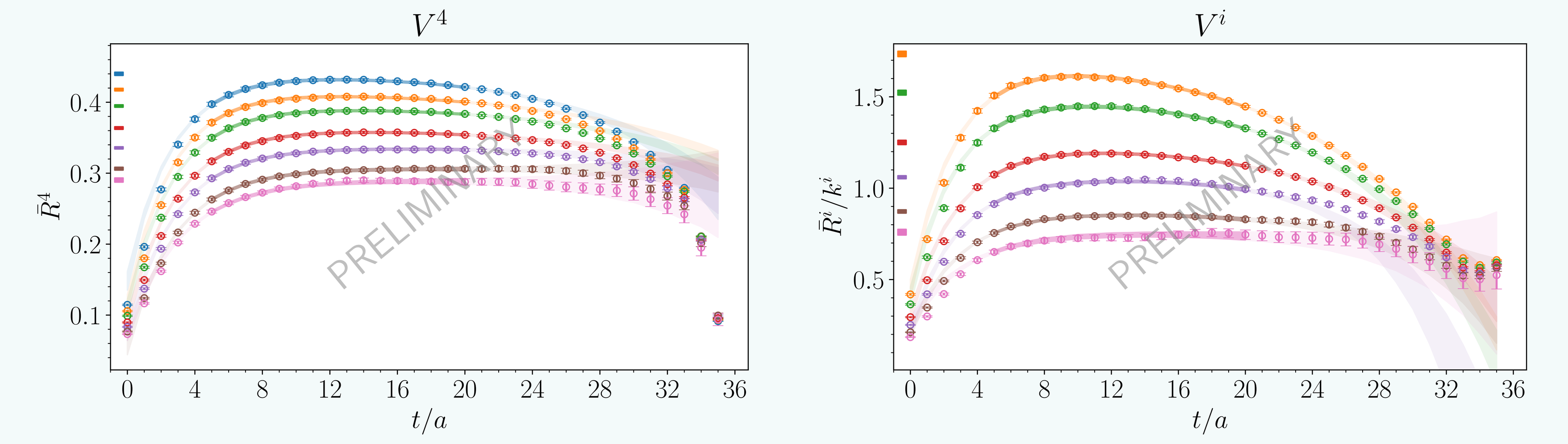
$$\overline{R}(t,T) \sim F^{(0)}\Big[1 + (-1)^{t+1}F_L^{(1)}e^{-\delta E_L^{(1)}t} + F_L^{(2)}e^{-\delta E_L^{(2)}t} + (-1)^{T-t-1}F_B^{(1)}e^{-\delta M_B^{(1)}(T-t)} + F_B^{(2)}e^{-\delta M_B^{(2)}(T-t)}\Big] \tag{3}$$

  Here, oscillating contribution from L (gray) is included only for the $B_s \to K$ decay.

- By fitting $\overline{R}$ to Eq.(3), we extract $F^{(0)}$ and corresponding form factors. The leftmost colored box in the plots represents the fit posterior for $F^{(0)}$.



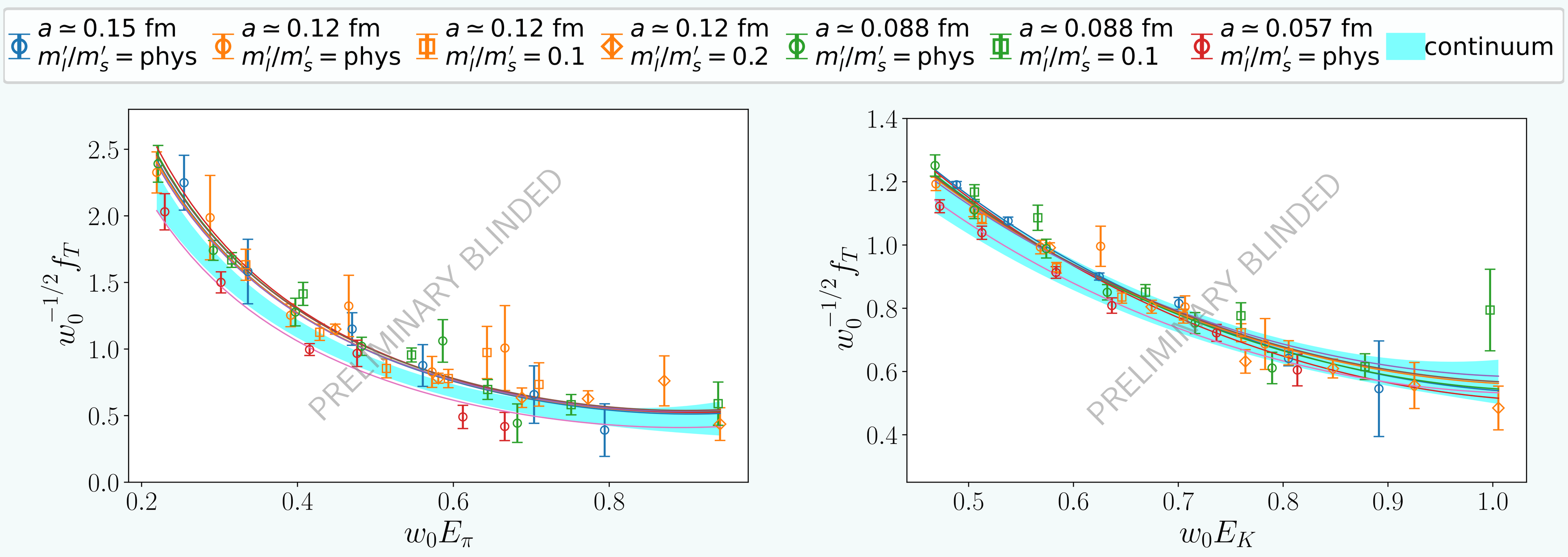
(a) $B \to \pi$ (b) $B \to K$



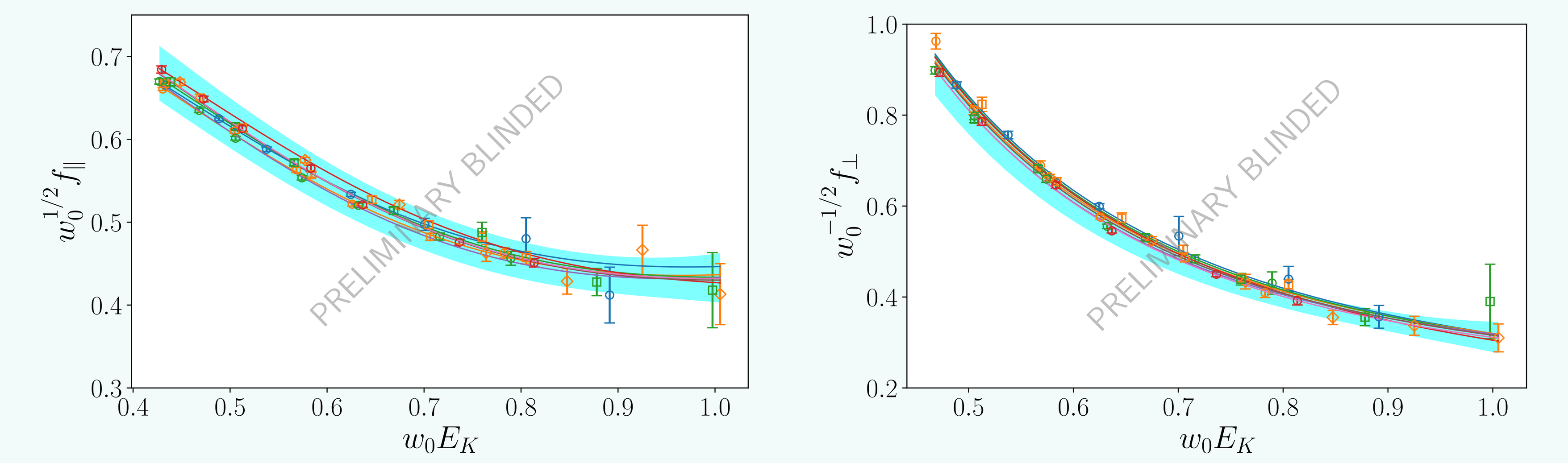
(c) $B_s \to K$ (d) $B_s \to K$

Form factors and chiral-continuum extrapolation

- Form factors and fitting to SU(2) HMrSχPT up to NNLO



(a) $B \to \pi$ (b) $B \to K$



(c) $B_s \to K$ (d) $B_s \to K$

Conclusion & Plan

- We have computed the form factors on the lattice.
- We are testing other variations of χPT and working on improving the result.
- We will extrapolate to the full kinematic range by the z expansion.
- We will compute the decay rates, $|V_{ub}|$ and $|V_{ub}|/|V_{cb}|$.

References

[1] Zechariah Gelzer et al. *EPJ Web Conf.*, 175:13024, 2018.
[2] Z. Gelzer et al. *PoS*, LATTICE2019:236, 2019.
[3] Hwancheol Jeong et al. *PoS*, LATTICE2023:253, 2024.
[4] A. Bazavov et al. *Phys. Rev. D*, 87(5):054505, 2013.
[5] Jon A. Bailey et al. *Phys. Rev. D*, 79:054507, 2009.

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