Lattice calculation of the $D_s \mapsto X\ell\bar{\nu}_\ell$ inclusive decay rate: an overview

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1. Motivation

- Lattice QCD: non-perturbative study from first principles of strong and weak interactions
- Euclidean space-time with finite lattice spacing a and finite volume V
- Semileptonic decay: access to CKM-matrix elements ⇒ test of Standard Model
- Inclusive decay: no knowledge of final state is necessary
- Comparison to experimental measurements [1, 2]
- Preliminary studies in [3], overview of methods in [4], full paper forthcoming.

2. Simulations

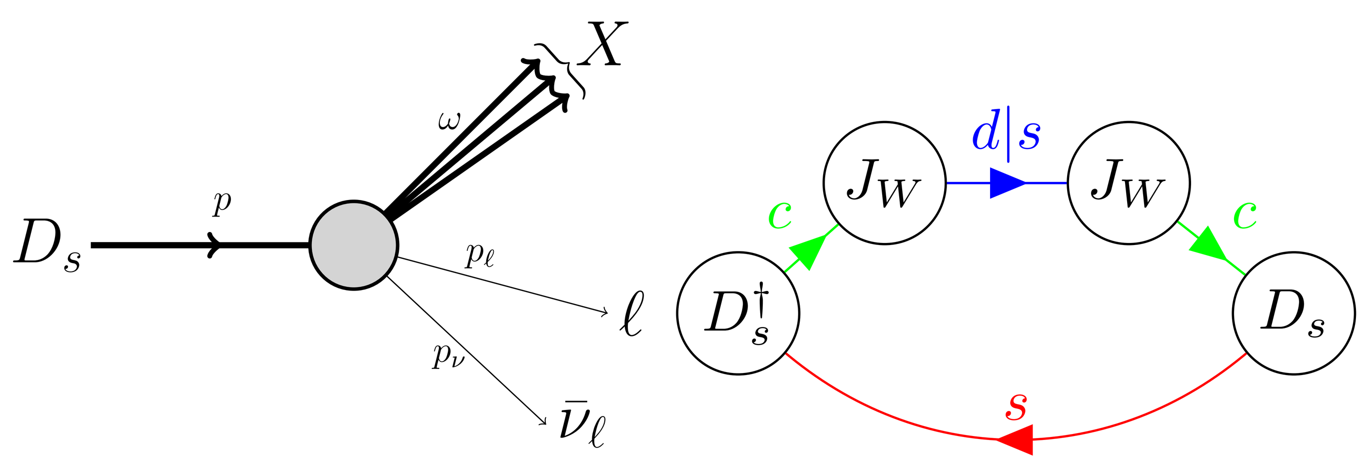

Figure 1: The kinematics of the inclusive $D_s \mapsto X\ell\bar{\nu}_\ell$ semileptonic decay and the computed Wick-contraction.

- Calculate decay rate with $\Gamma_{fg} = \int \frac{d^3p_\nu}{(2\pi)^3 2e_\nu}\frac{d^3p_\ell}{(2\pi)^3 2e_\ell}\frac{1}{m_{D_s}} L_{\mu\nu}(p_\ell, p_\nu) H^{\mu\nu}_{fg}(p, p-p_\ell-p_\nu)$
- Lattice-correlator: $M^{\mu\nu}_{fg}(t, \boldsymbol{\omega}^2) = \int_0^\infty d\omega_0\, H^{\mu\nu}_{fg}(\omega_0, \boldsymbol{\omega}^2) e^{-\omega_0 t}$

→ The hadronic tensor is the spectral density of our measurement

- Calculation of the correlator requires several inversions of the Dirac-matrix
- Solve inverse Laplace-transform with the HLT-algorithm [5] → extract smeared spectral density

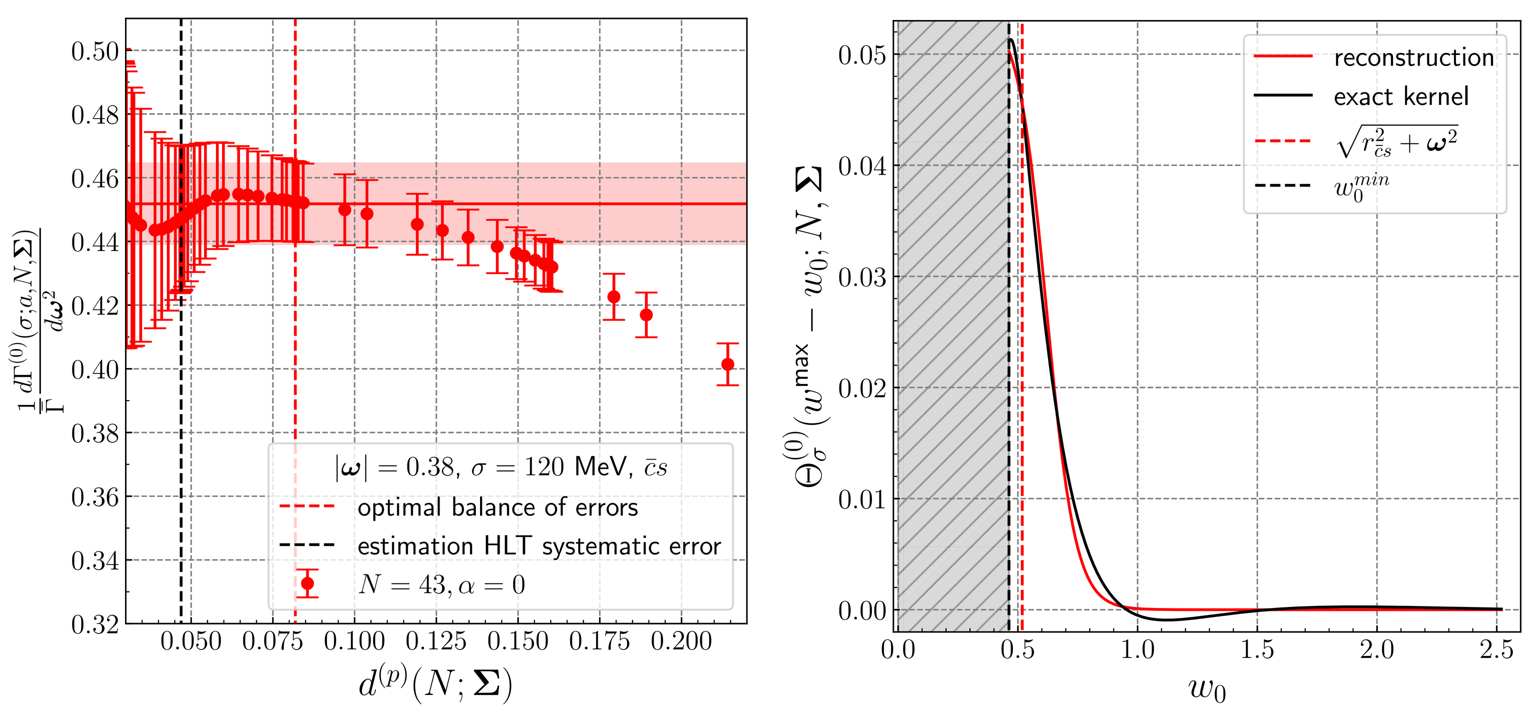

Figure 2: Stability plot showing the balance between systematic and statistical error and reconstructed integration kernel

3. Results

- Simulation with ETMC-ensembles with physical pion mass, four different lattice spacings, three different volumes
- Determine systematic effects from HLT and finite size effects
- Extrapolate to zero lattice spacing

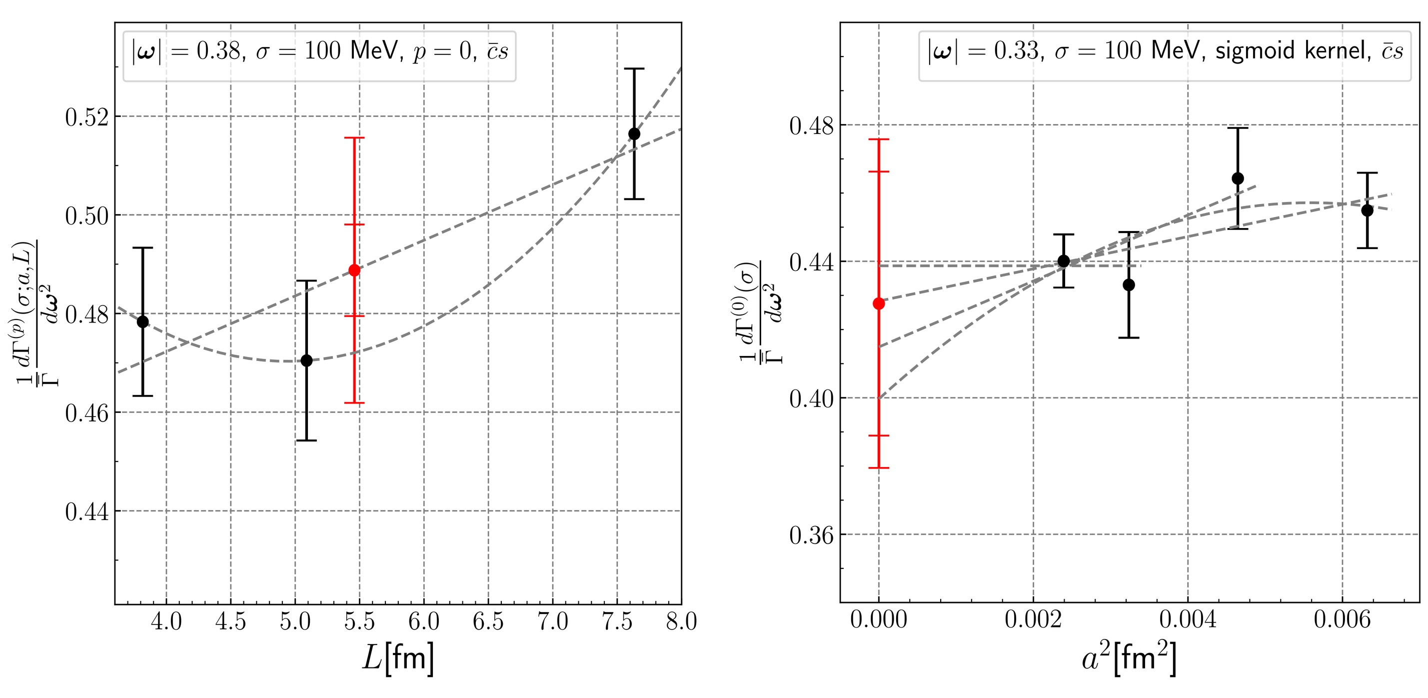

Figure 3: Determination of the finite-size-effects and of the continuum limit $a \to 0$.

- Extrapolate to non-smeared kernel

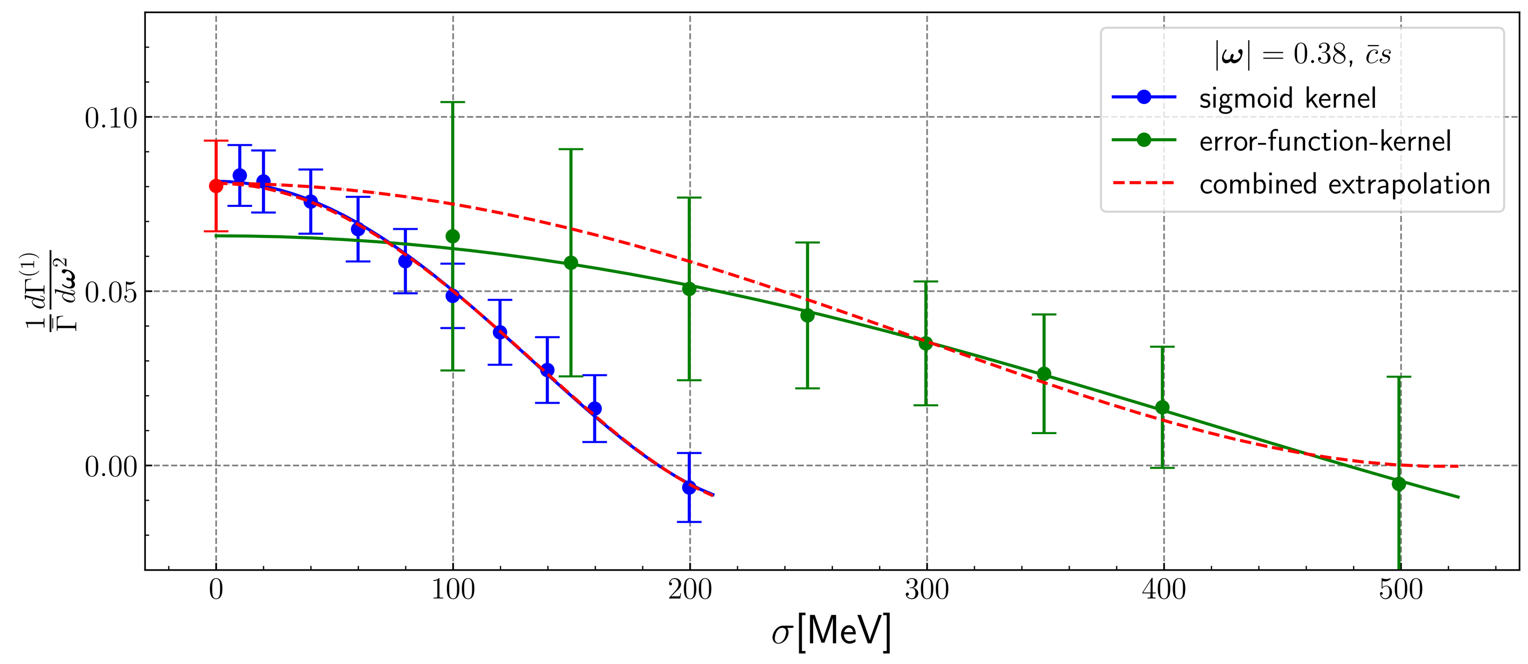

Figure 4: Extrapolation of the smearing parameter for two different integration kernels

- $\Gamma = \int d\boldsymbol{\omega}^2 \left(|V_{cs}|^2 \frac{d\Gamma_{\bar{c}s}}{d\boldsymbol{\omega}^2} + |V_{cd}|^2 \frac{d\Gamma_{\bar{c}d}}{d\boldsymbol{\omega}^2} \right)$
- Perform final integration numerically

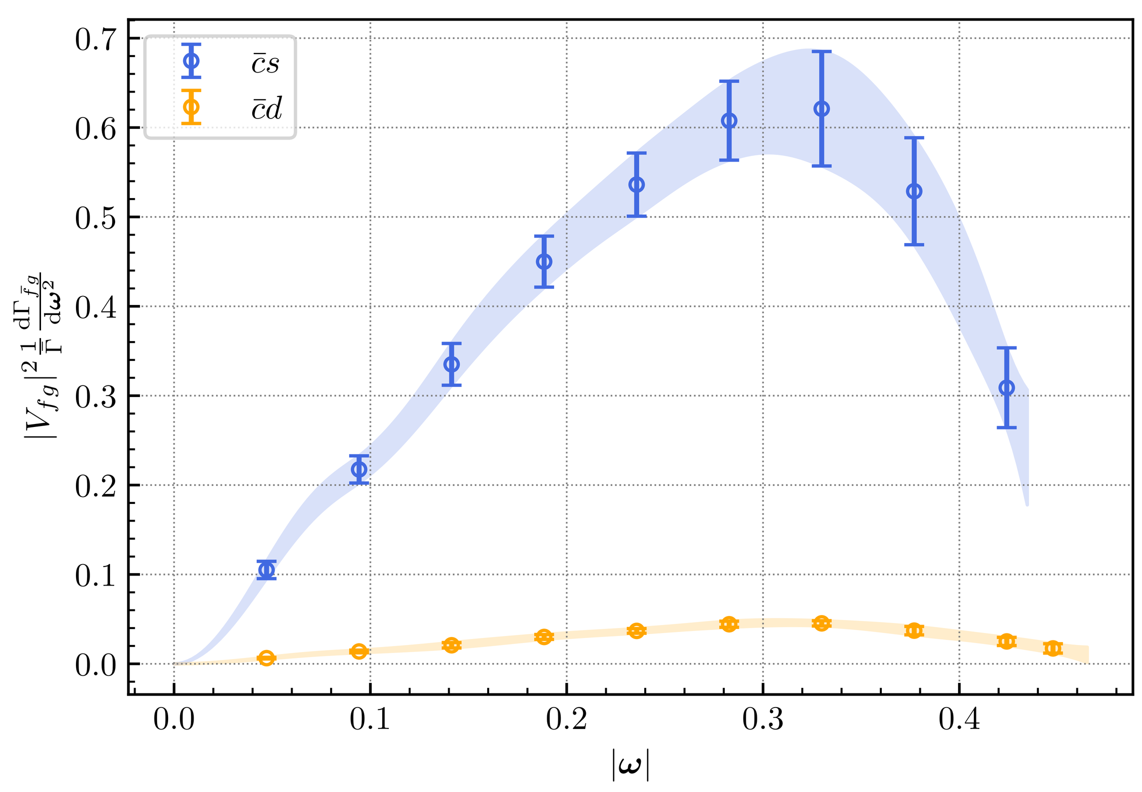

Figure 5: Differential decay rate in the continuum limit

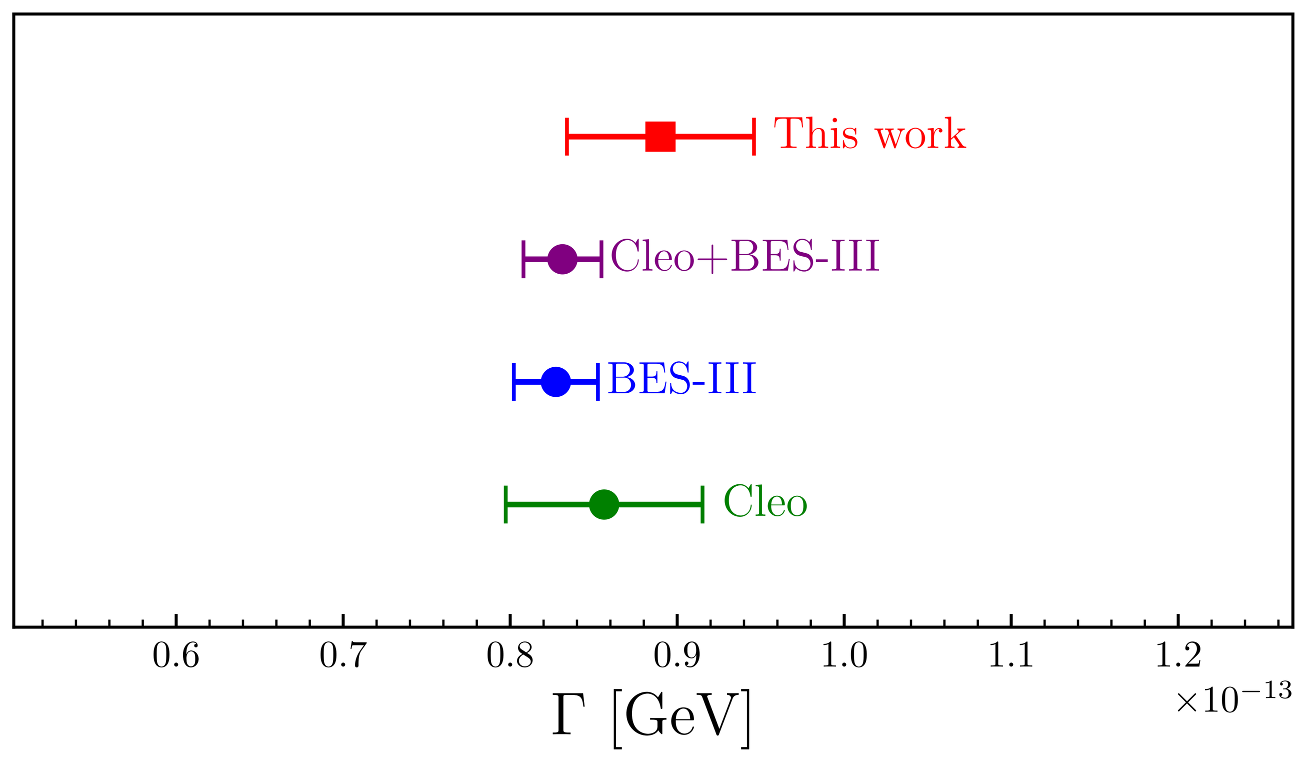

Figure 6: final result

Good agreement between lattice and experimental results

References

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