

Charmed meson decay constants with overlap fermions on 2+1-flavor domain wall fermion configurations

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Decay constants of pseudoscalar and vector mesons are calculated on 2+1-flavor domain wall fermion configurations for D, D^*, D_s, D_s^* . Overlap fermions are used for the valence quarks. The lattice is of size $32^3 \times 64$ and the inverse lattice spacing is $1/a = 2.383(9)$ GeV. Decay constants of vector mesons defined by both the vector and tensor currents are computed and the results are given in the $\overline{\text{MS}}$ scheme at 2 GeV.

① Motivation

Charmed meson decay constants $f_{D(s)}$, $f_{D(s)^*}$ are important nonperturbative quantities for the study of meson weak decays. $f_{D(s)}$ can be used to determine the Cabibbo-Kobayashi-Maskawa (CKM) matrix elements V_{cs} and V_{cd} from leptonic D meson decays. $f_{D(s)^*}$ play an indispensable role for studies of charmed nonleptonic and semi-leptonic B meson decays, which are important for the searching of new physics and extracting of V_{cb} .

Our previous work of the decay constants were computed at a lattice spacing $1/a = 1.730(4)$ GeV [1], we now present the results on a finer lattice $1/a = 2.383(9)$ GeV to constrain the discretization errors.

[1] Ying Chen, et al. Chin. Phys. C 45 (2021) 023109

③ Numerical Analyses

We calculate the related point source two-point correlation functions and apply one state fitting strategy to derive the meson decay constants, $C(t) = A[e^{-mt} + e^{-m(T-t)}]$ with $T=64$.

After collecting the masses and decay constants at our valence quark masses, we use the linear interpolation/extrapolation form:

$$m_{D^*}^{\text{fit}} - m_{D^*}^{\text{data}} = b_1 \Delta m_{D_s} + b_2 \Delta m_{ss}^2 + b_3 \Delta m_{\pi}^{2, \text{val}} + b_4 \Delta m_{\pi}^{2, \text{sea}},$$

where $\Delta m = m^{\text{data}} - m^{\text{phy}}$, $m_{ss}^2 = 2m_K^2 - m_{\pi}^2$, and we use

$m_{\pi, K, D_s}^{\text{phy}} = 139.6, 493.7, 1969$ MeV as inputs to extract the physical predictions of charmed meson decay constants. For our overlap fermions, the quark mass and pseudoscalar density $\bar{\psi}_1 \gamma_5 \psi_2$ renormalization constants cancel each other out due to chiral symmetry. The matching factors to the $\overline{\text{MS}}$ scheme for vector and tensor current,

$$Z_V = 1.0789(10) \quad Z_T(2 \text{ GeV}) = 1.157(11),$$

are given by [3].

[3] χ QCD Collaboration, Phys. Rev. D 108 (2023) 054506

② Definitions and Lattice Setup

The decay constant f_P , f_V and f_V^T are given by the matrix element defined as

$$(m_1 + m_2) \langle 0 | \bar{\psi}_1 \gamma_5 \psi_2 | P(p) \rangle = m_P^2 f_P,$$

$$\langle 0 | \bar{\psi}_1 \gamma_{\mu} \psi_2 | V(p) \rangle = m_V f_V \epsilon_{\mu}(p),$$

$$\langle 0 | \bar{\psi}_1 \sigma_{\mu\nu} \psi_2 | V(p) \rangle = i f_V^T (\epsilon_{\mu} p_{\nu} - \epsilon_{\nu} p_{\mu}).$$

The gauge configurations used in this work were generated by the RBC/UKQCD collaborations [2].

am_l/am_s	$m_{\pi}(\text{MeV})$	$N_{\text{conf}} \times N_{\text{src}}$
0.004/0.03	302	628×1
0.006/0.03	360	42×16
0.008/0.03	412	49×16

Table. 1 The dynamical quarks are domain-wall fermions with three different light (u/d) quark masses, labeled f004, f006 and f008. The spacial extension is ~ 2.7 fm, with $L^3 \times T = 32^3 \times 64$ and $a \sim 0.08$ fm. N_{conf} is the number of configurations and N_{src} the number of point sources on each configuration.

$am_l^{(\text{val})}$	0.00460, 0.00585, 0.00677, 0.00765, 0.00885 0.01120, 0.01290, 0.01520, 0.01800, 0.02400
m_{π}	220 MeV $\sim$ 500 MeV
$am_s^{(\text{val})}$	0.037, 0.040, 0.043, 0.046, 0.049, 0.052
$am_c^{(\text{val})}$	0.450, 0.492, 0.500, 0.550

Table. 2 The valence quark is overlap fermion, and the physical charm/strange mass $am_{c/s}^{\text{phy}}$ is estimated to be around 0.492/0.043.

[2] RBC and UKQCD Collaborations, Phys. Rev. D 93(2016) 074505

Mass(GeV)	D	D^*	D_s	D_s^*
PDG	1.8695	2.010	1.969	2.112
48I	1.873(5)	2.026(5)	-	2.116(6)
32I	1.869(8)	2.004(8)	-	2.119(9)

④ Preliminary Results

Table. 3 Masses and decay constants. Here 48I and 32I represent the results from previous work and this work respectively. Errors form statistics, lattice spacing and renormalization are taken into account in this work.

Decay constant(MeV)	D	D^*	D_s	D_s^*
FLAG review	209.0(2.4)		248(2)	
48I $f_{P/V}$	213(5)	234(6)	249(7)	274(7)
48I f_V^T/f_V	-	0.91(4)	-	0.92(4)
32I $f_{P/V}$	214.0(1.0)	228.7(1.2)	253.5(1.6)	281.0(1.7)
32I f_V^T/f_V	-	0.91(1)	-	0.91(2)

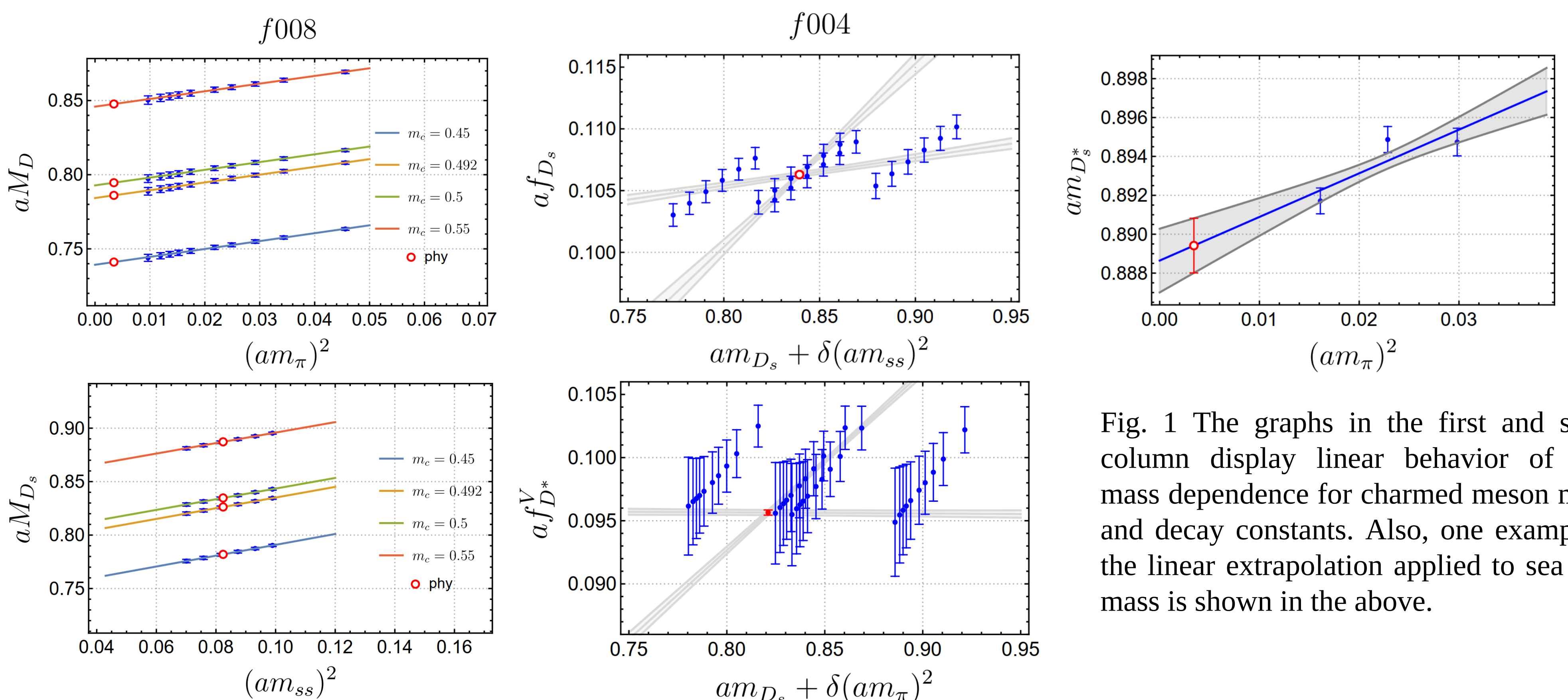


Fig. 1 The graphs in the first and second column display linear behavior of quark mass dependence for charmed meson masses and decay constants. Also, one example for the linear extrapolation applied to sea quark mass is shown in the above.