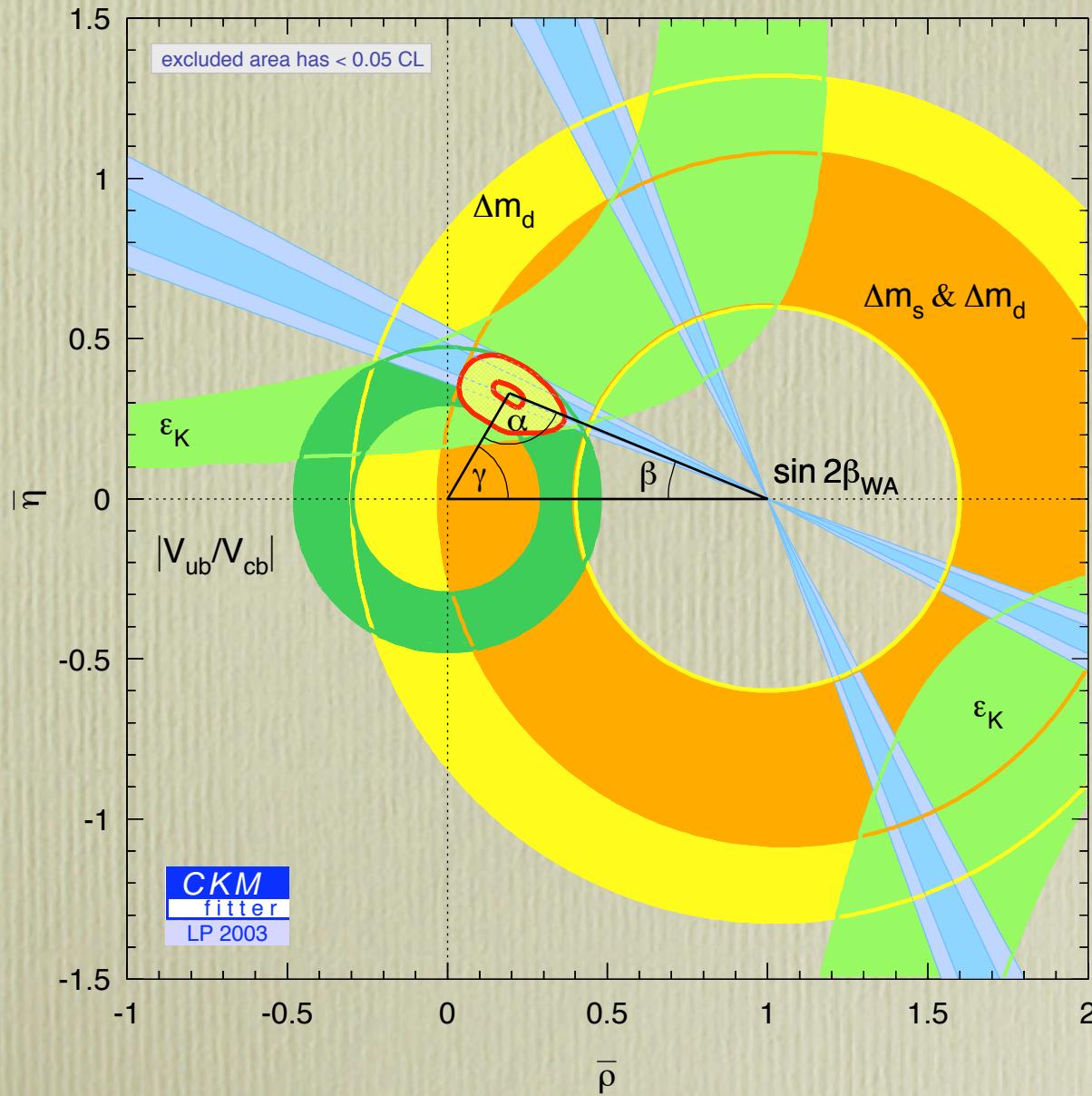


B and *D* Mesons NRQCD and FNAL heavy quarks

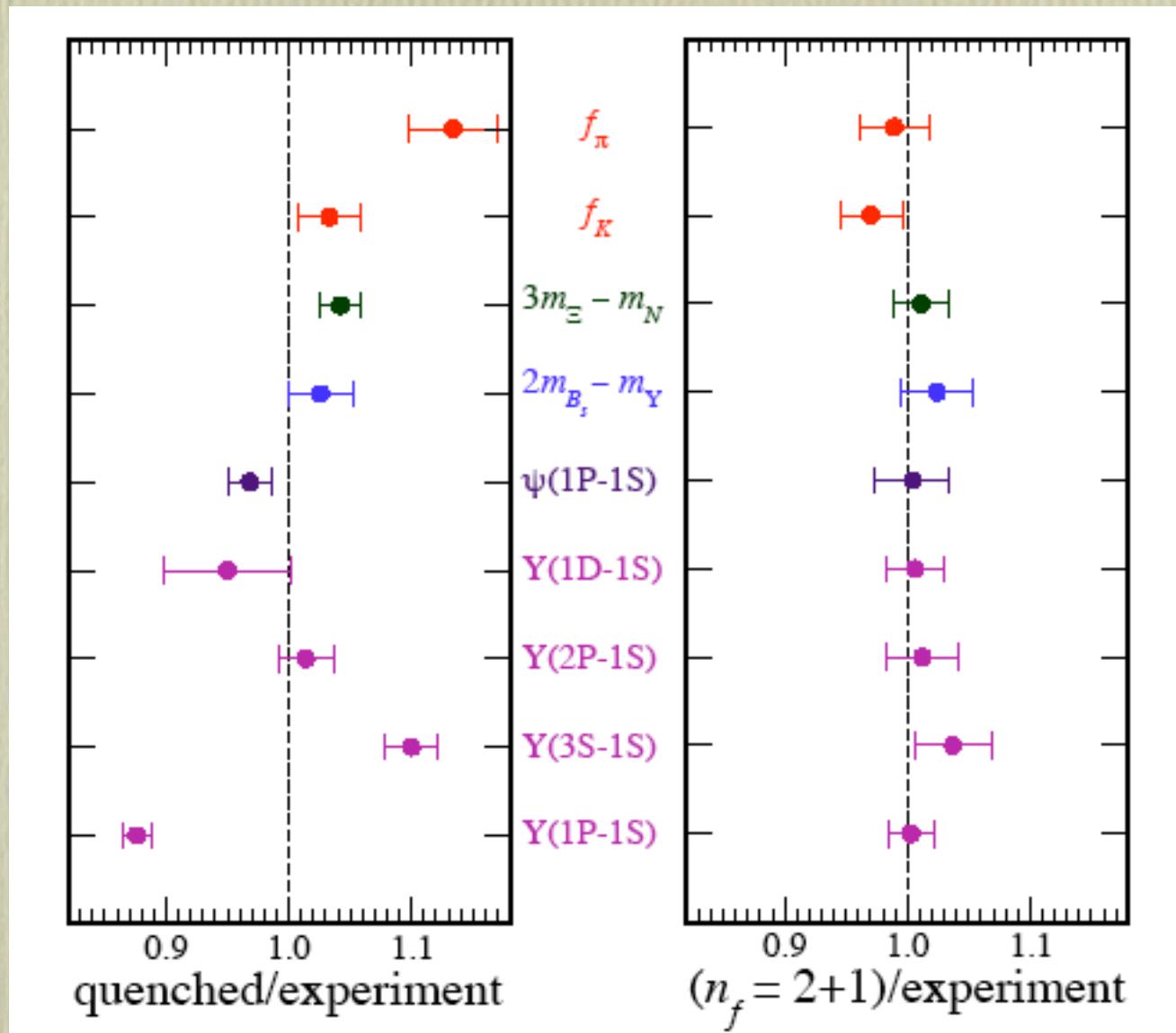
Matthew Wingate (Univ. of Washington)
for the
NRQCD/FNAL/MILC Collaborations

Constrain CKM parameters



- Assume S.M.
- Over-constrain
- Expt. & Theory
- Lattice

Quenched vs. Light Improved Staggered



Not QCD. Empirically wrong

QCD? Empirically OK (so far)

2+1 flavor MILC lattices

C. Bernard, et al, PRD, 64, 054506 (2001)

- Symanzik-improved staggered action
- Spacings: 0.09 fm & 0.12 fm
- Spatial lengths: 2.5 fm
- 2 light flavors down to $m_s/8$
- Bare parameters set using

$\Upsilon' - \Upsilon$	$\{m_\pi, m_K\}$	m_{D_s}	m_Υ
a	$\{m_{ud}, m_s\}$	m_c	m_b

Outline

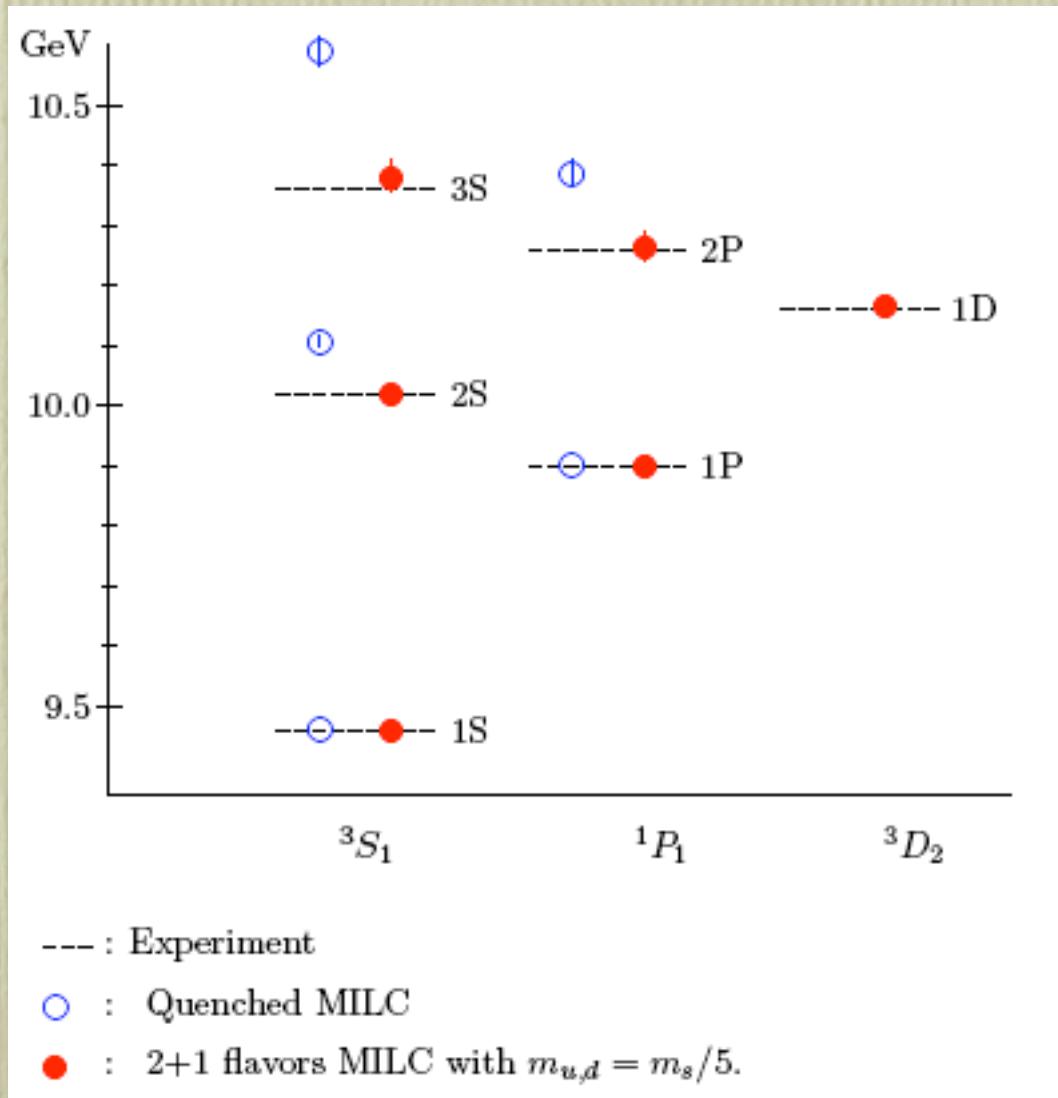
- Quarkonium and B_c masses
- Heavy-strange decay constants f_{B_s} and f_{D_s}
- Decay constants toward the chiral limit
- Semileptonic decay form factors

WARNING!

All data and fits are PRELIMINARY

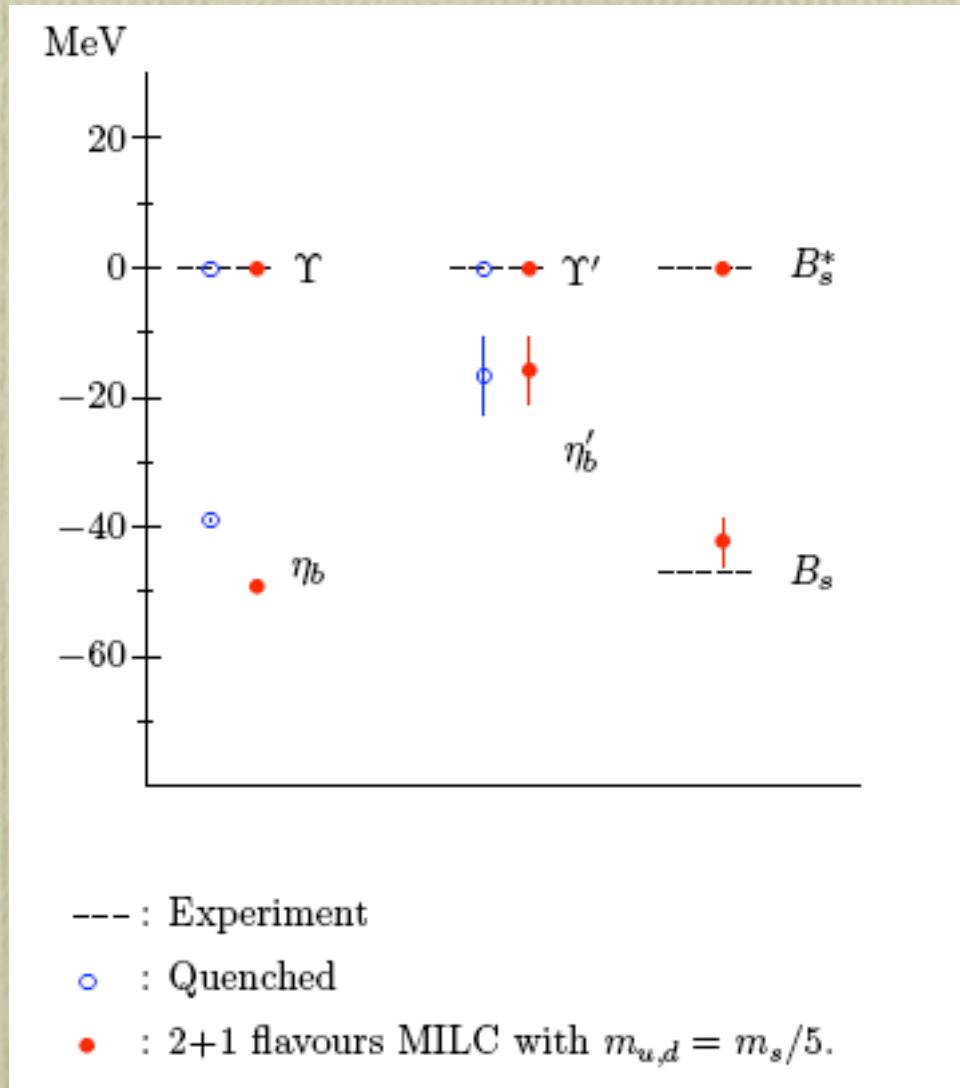
unless explicitly stated otherwise

Bottomonium

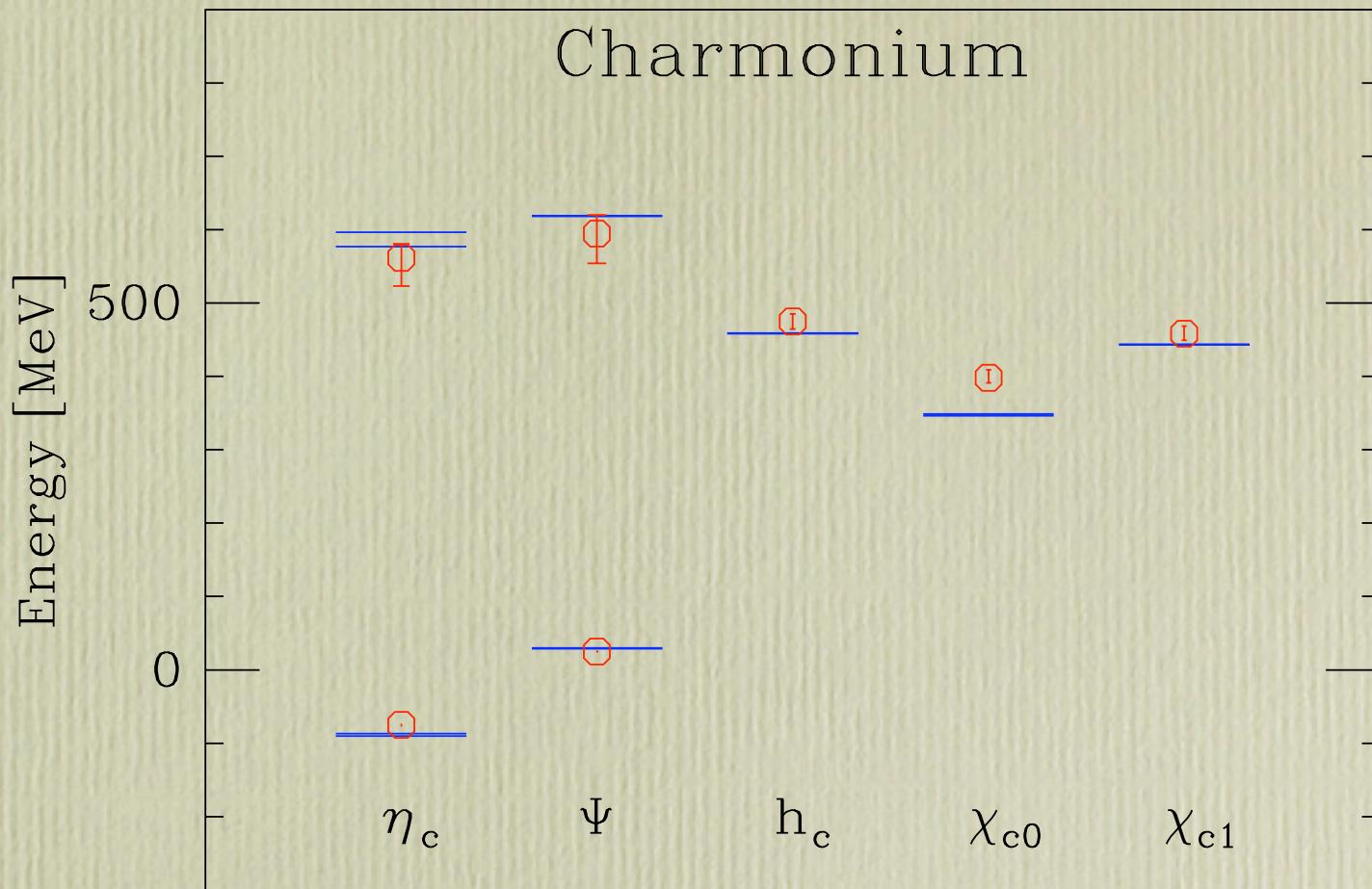


- Coarser lattice
- $1P - 1S$ splitting used to set scale in this plot
- $m_{u,d} = m_s^{\text{phys}}/4$
- Negligible change for $m_{u,d} = m_s^{\text{phys}}/2$

Hyperfine splittings



- Predictions for η_b and η'_b
- Splitting in B_s is order $1/M$ in HQET



- Zero is spin average of **1S** states
- Results in physical sea quark mass limit (mild dependence)

B_c meson

- Observed in 1998 by CDF $B_c^+ \rightarrow J/\psi \ell^+ \nu$

$$m_{B_c} = 6.4 \pm 0.5 \text{ GeV}$$

- “Golden” quantities:

$$m_{B_c} - \frac{1}{2}(m_\psi + m_\Upsilon)$$

$$m_{B_c} - (m_{D_s} + m_{B_s})$$

B_c meson

- Quarkonium baseline

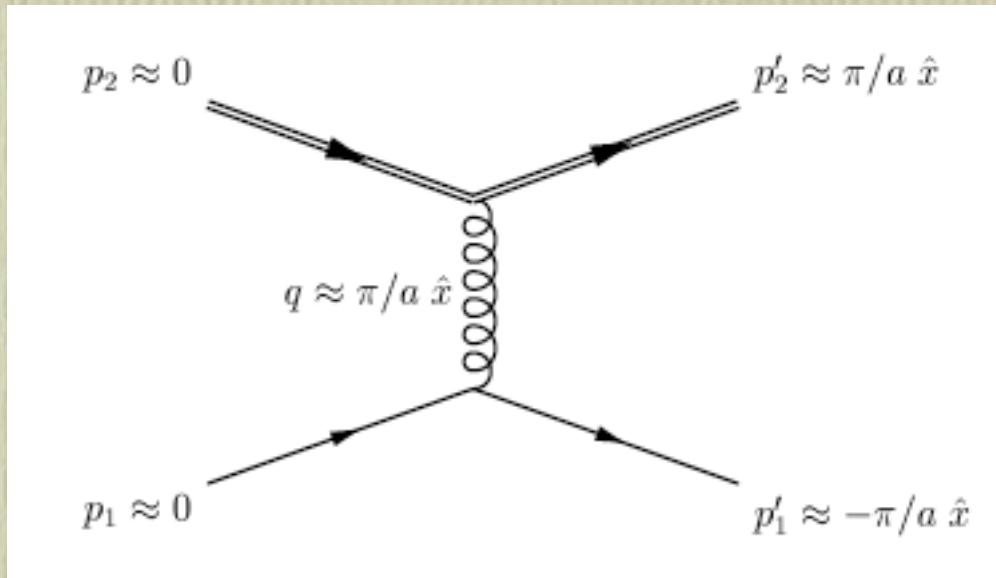
$$m_{B_c} = 6.307 \pm 0.002 \begin{array}{l} +0.000 \\ -0.010 \end{array} \text{ GeV}$$

- Heavy-light meson baseline

$$m_{B_c} = 6.253 \pm 0.017 \begin{array}{l} +0.030 \sim 50 \\ -0.000 \end{array} \text{ GeV}$$

- Further study of m_{sea} and a dependence underway

Heavy-staggered mesons

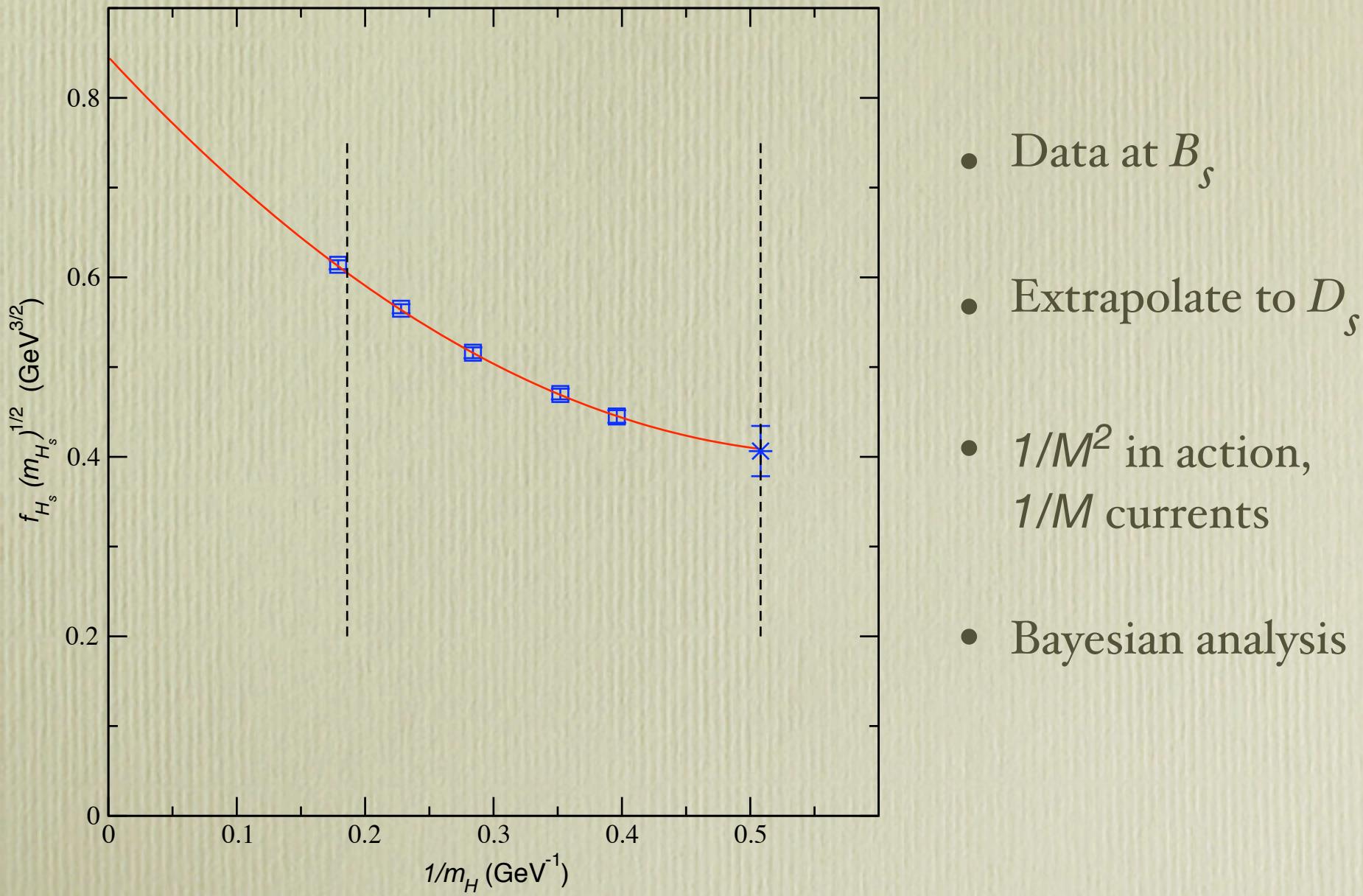


$$\left\langle \bar{\Psi}(x)\gamma_5\psi(x) \bar{\psi}(0)\gamma_5\Psi(0) \right\rangle$$

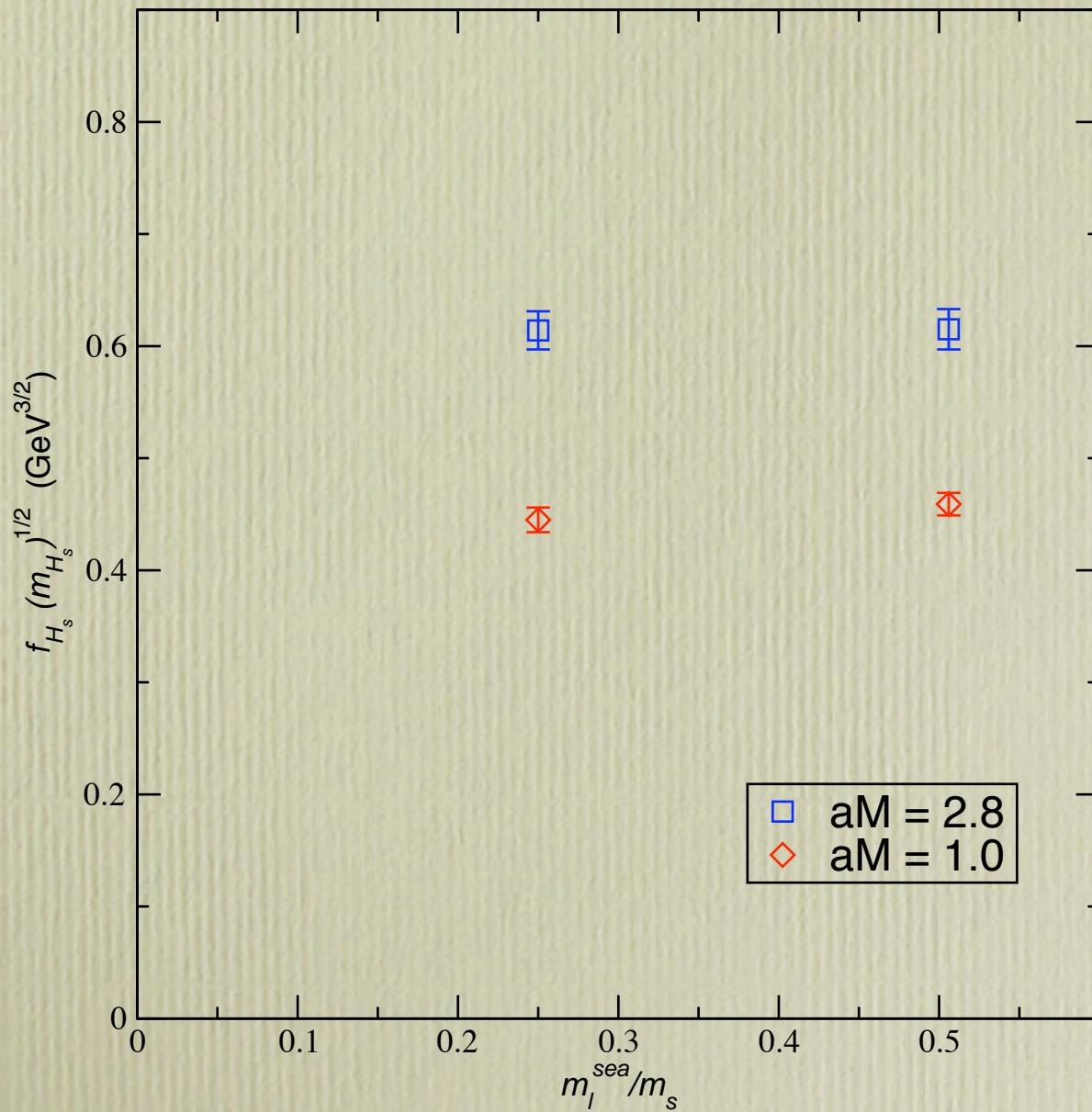
$$G_\psi(x, y) = g_\chi(x, y) \prod_\mu \gamma_\mu^{x_\mu} \gamma_{4-\mu}^{y_{4-\mu}}$$

- NRQCD/FNAL
heavy quarks are not doubled
- Taste-breaking is negligible
- Compute corr'n fns
using naive light fermions

Heavy-strange decay constant



Sea quark mass dependence



- No stat. significant sea quark mass dependence
- No log divergences in chiral pert. th.

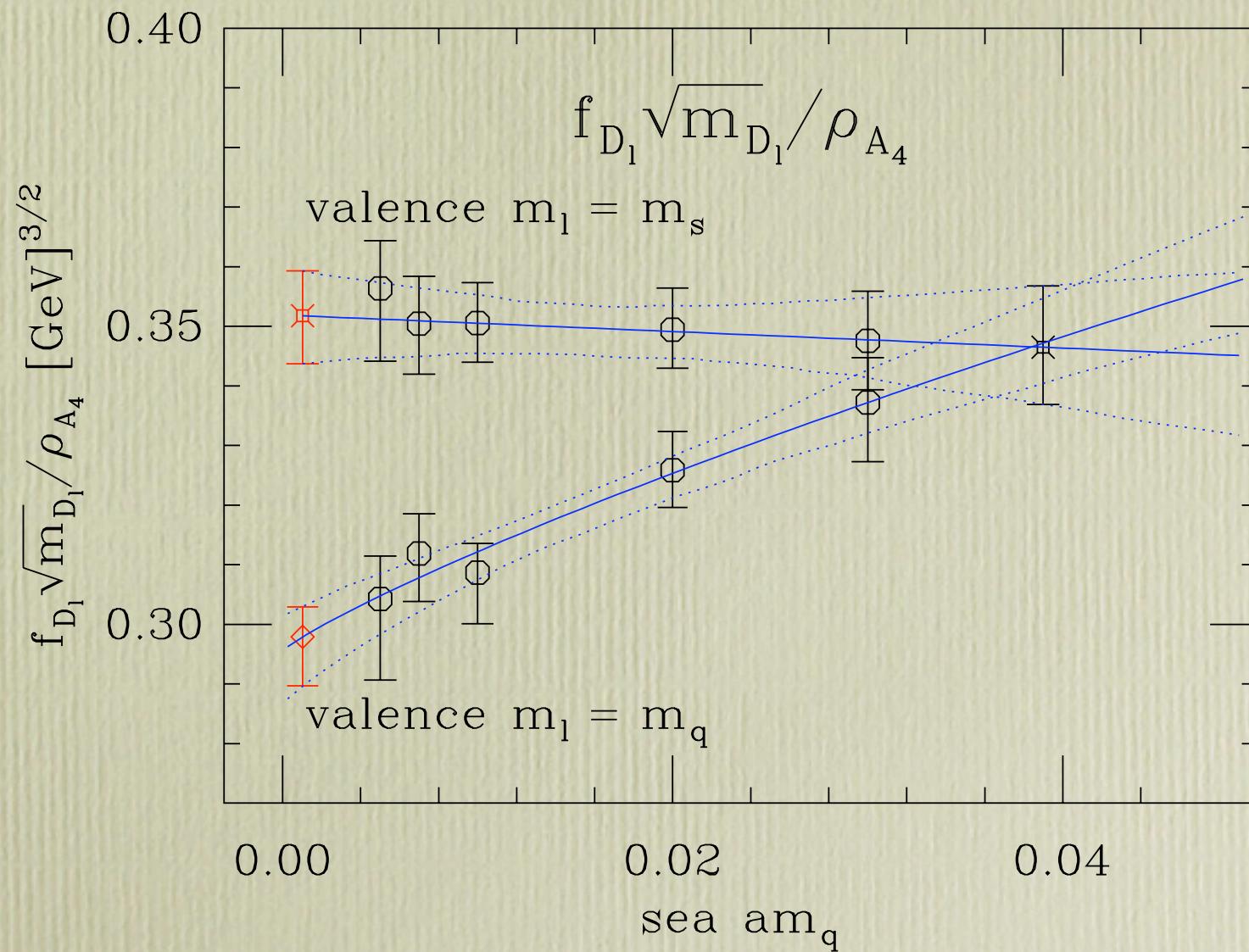
Systematic Uncertainties

source	order	B_s	D_s
perturbation th.	$O(\alpha_s^2)$	10%	10%
NRQCD	$O(\alpha_s \Lambda_{QCD} / m_Q)$	3%	10%
finite spacing	$O(\alpha_s a^2 \Lambda_{QCD}^2)$	2%	2%
sea quark	--	< 3%	< 5%

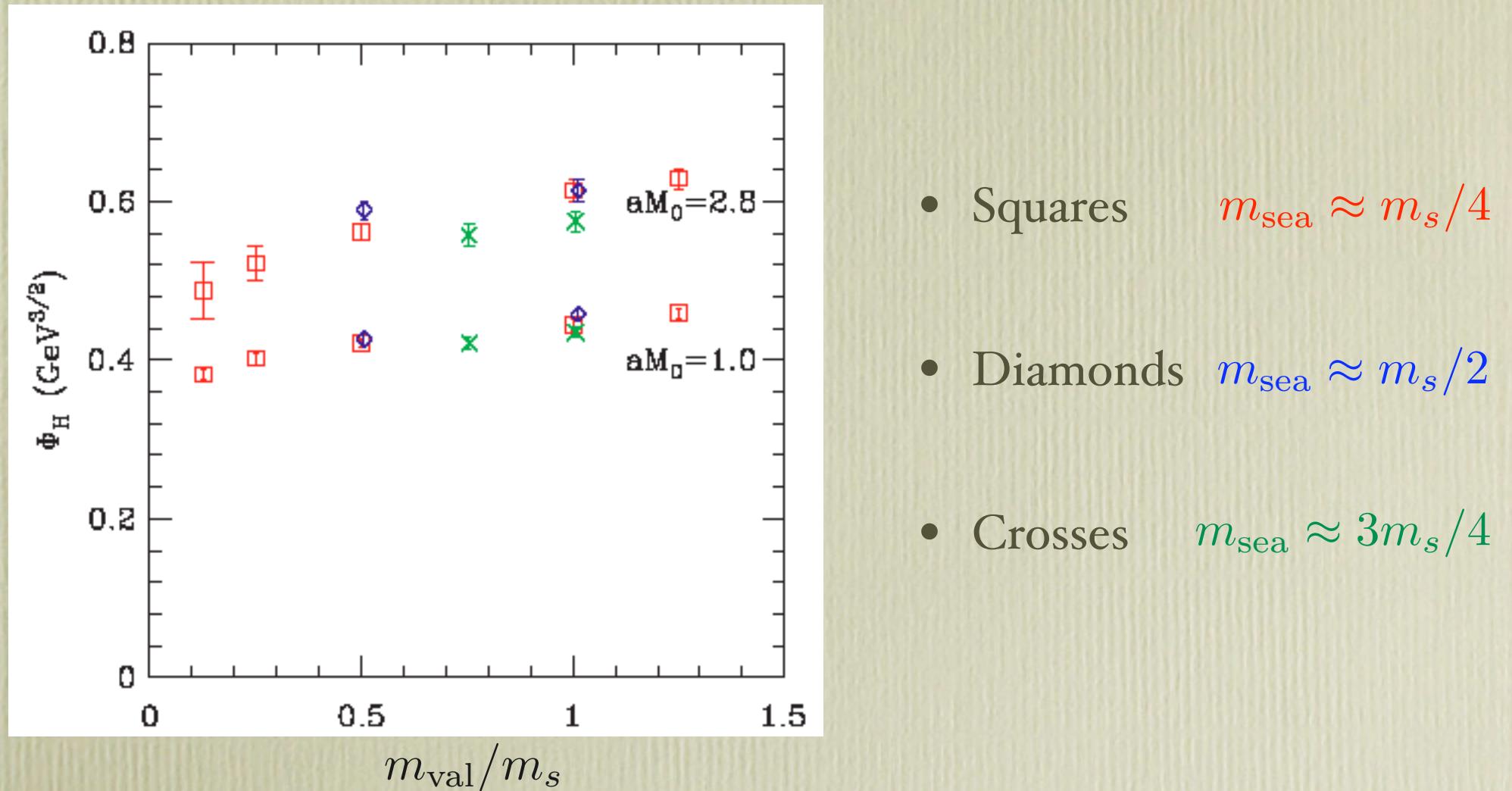
$$f_{B_s} = 260 \pm 7 \pm 26 \pm 8 \pm 5 \text{ MeV}$$

$$f_{D_s} = 290 \pm 20 \pm 29 \pm 29 \pm 6 \text{ MeV}$$

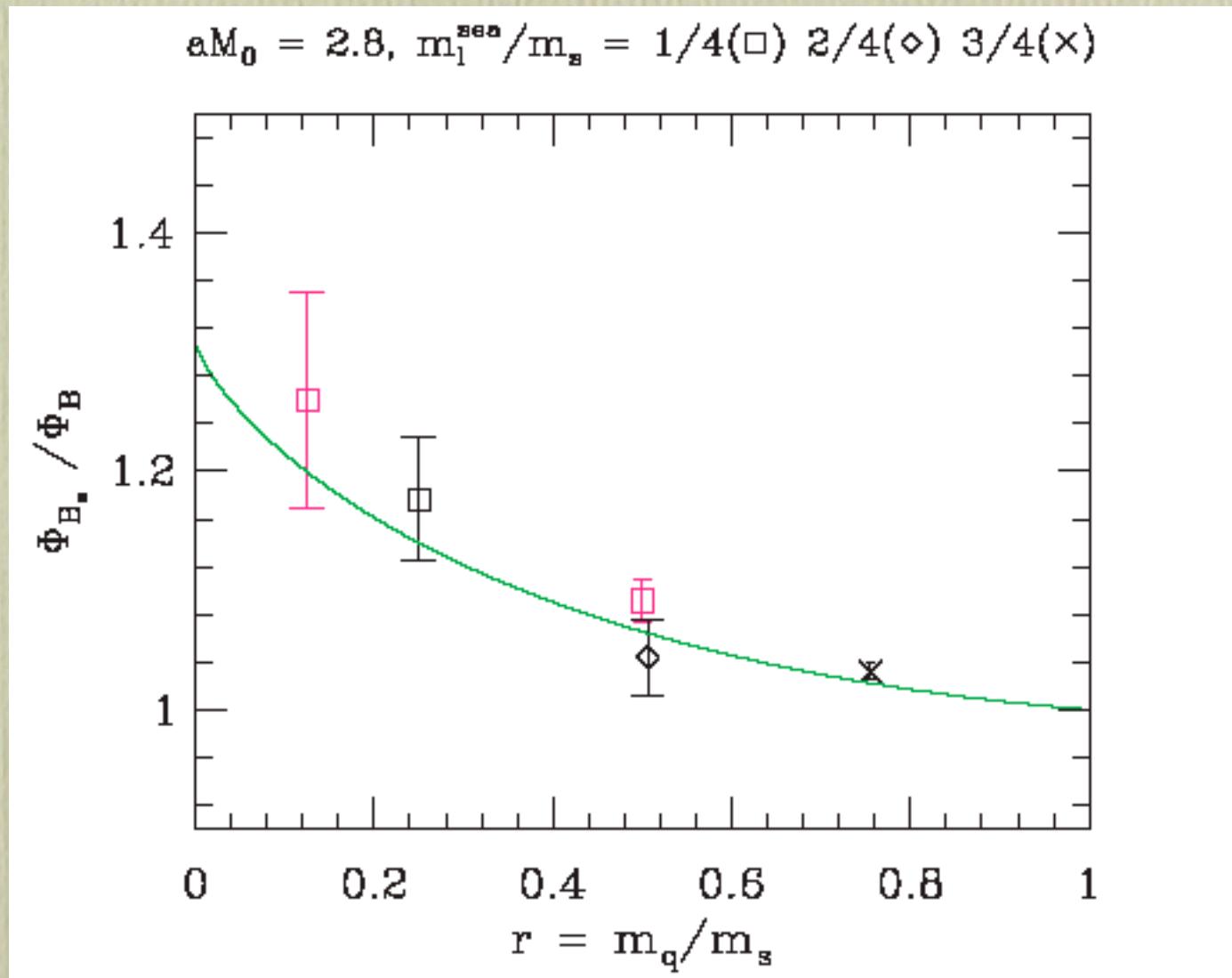
D, D_s meson decay constants (Fermilab)



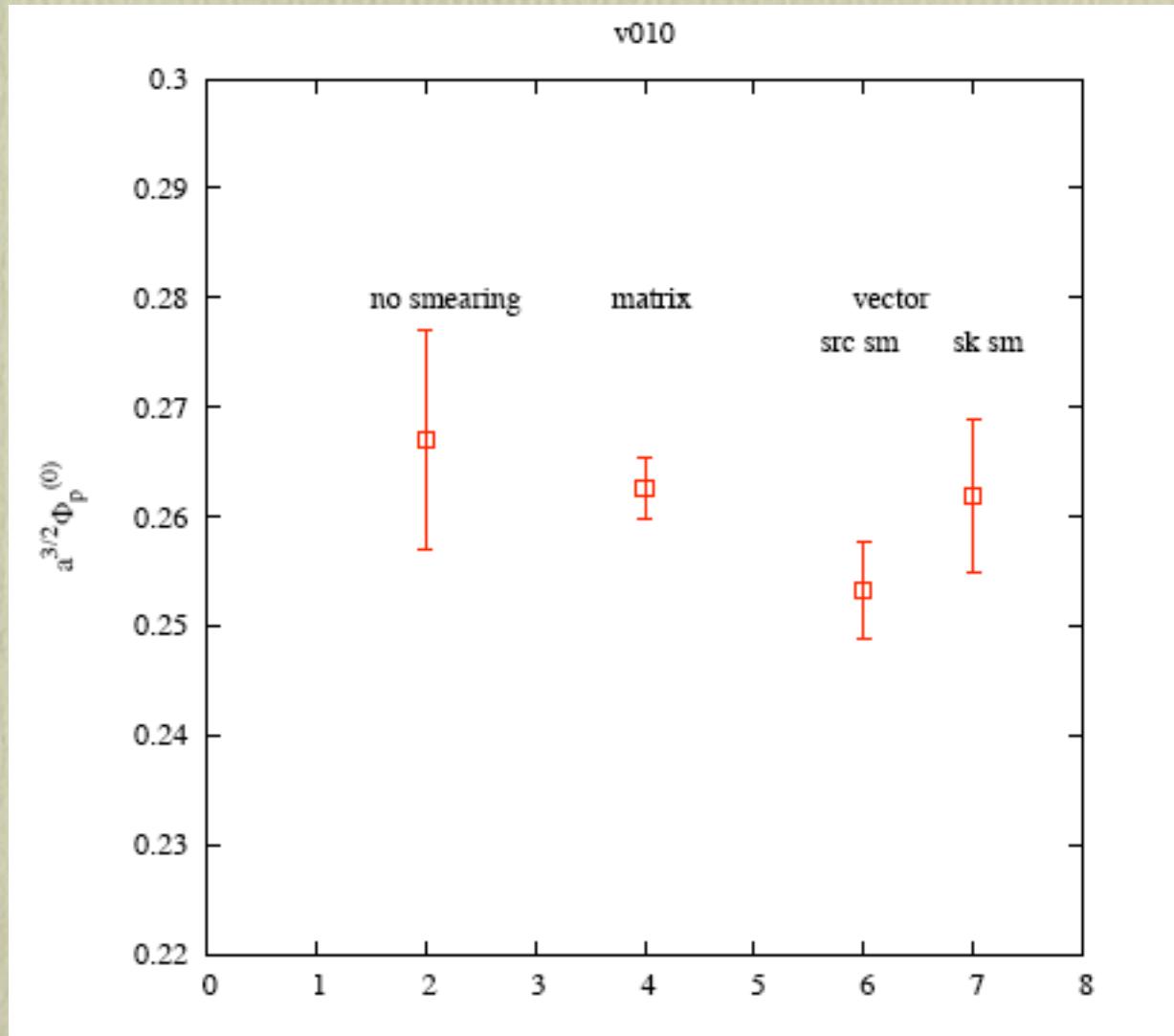
Toward f_B - summary plot



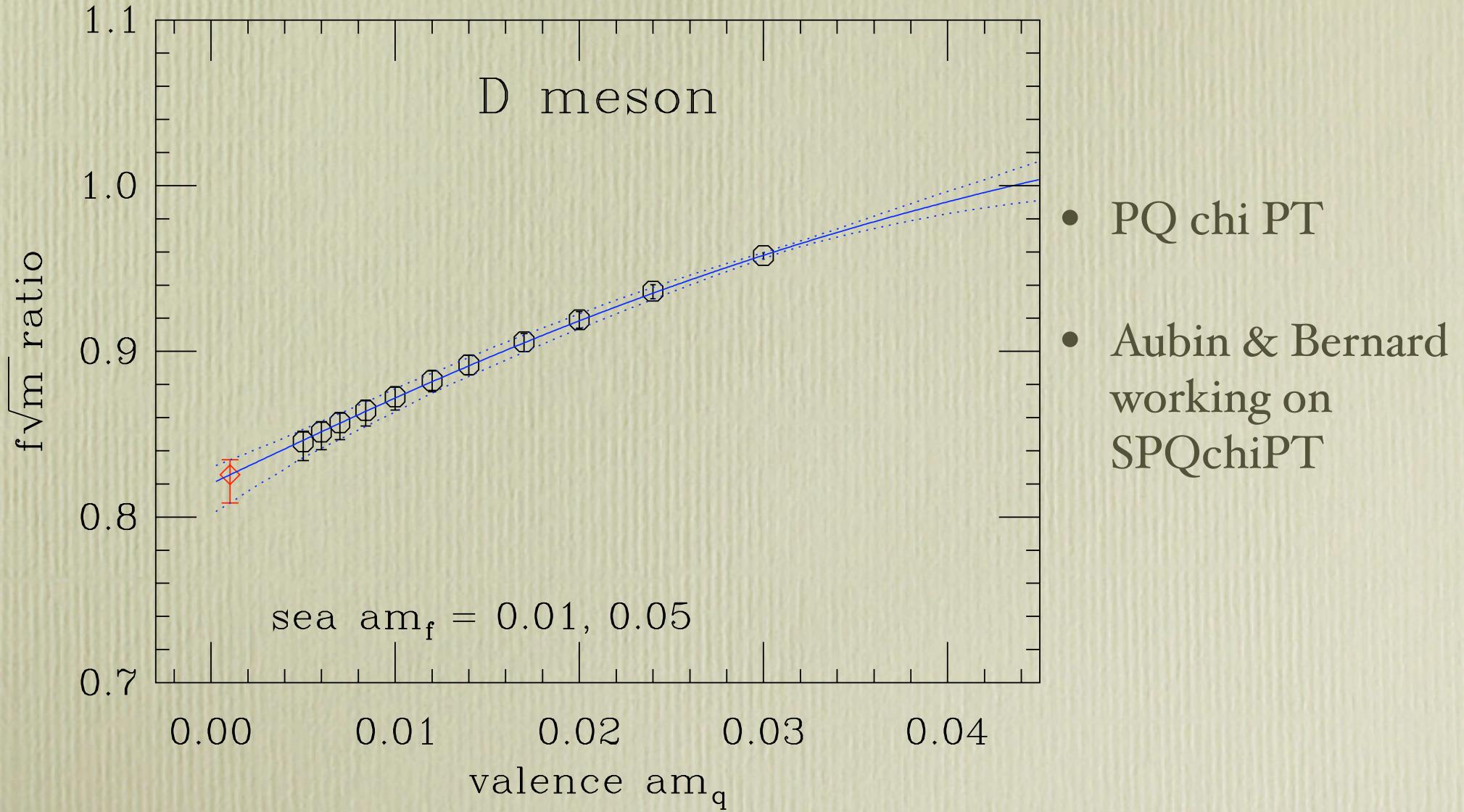
$$\frac{f_{B_s} \sqrt{m_{B_s}}}{f_B \sqrt{m_B}}$$



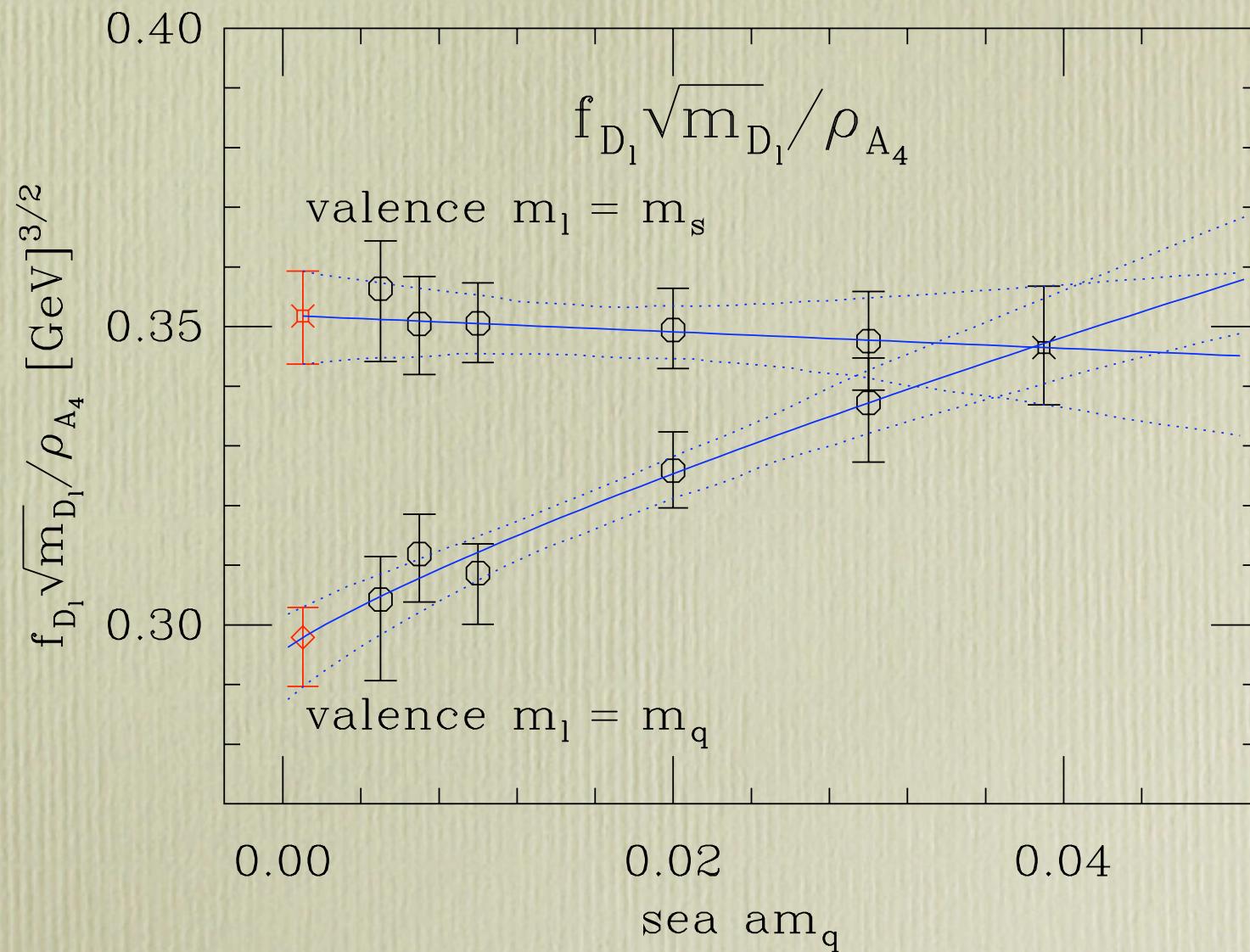
Smearing the heavy quark source/sink



Chiral extrapolations



D, D_s meson decay constants (Fermilab)



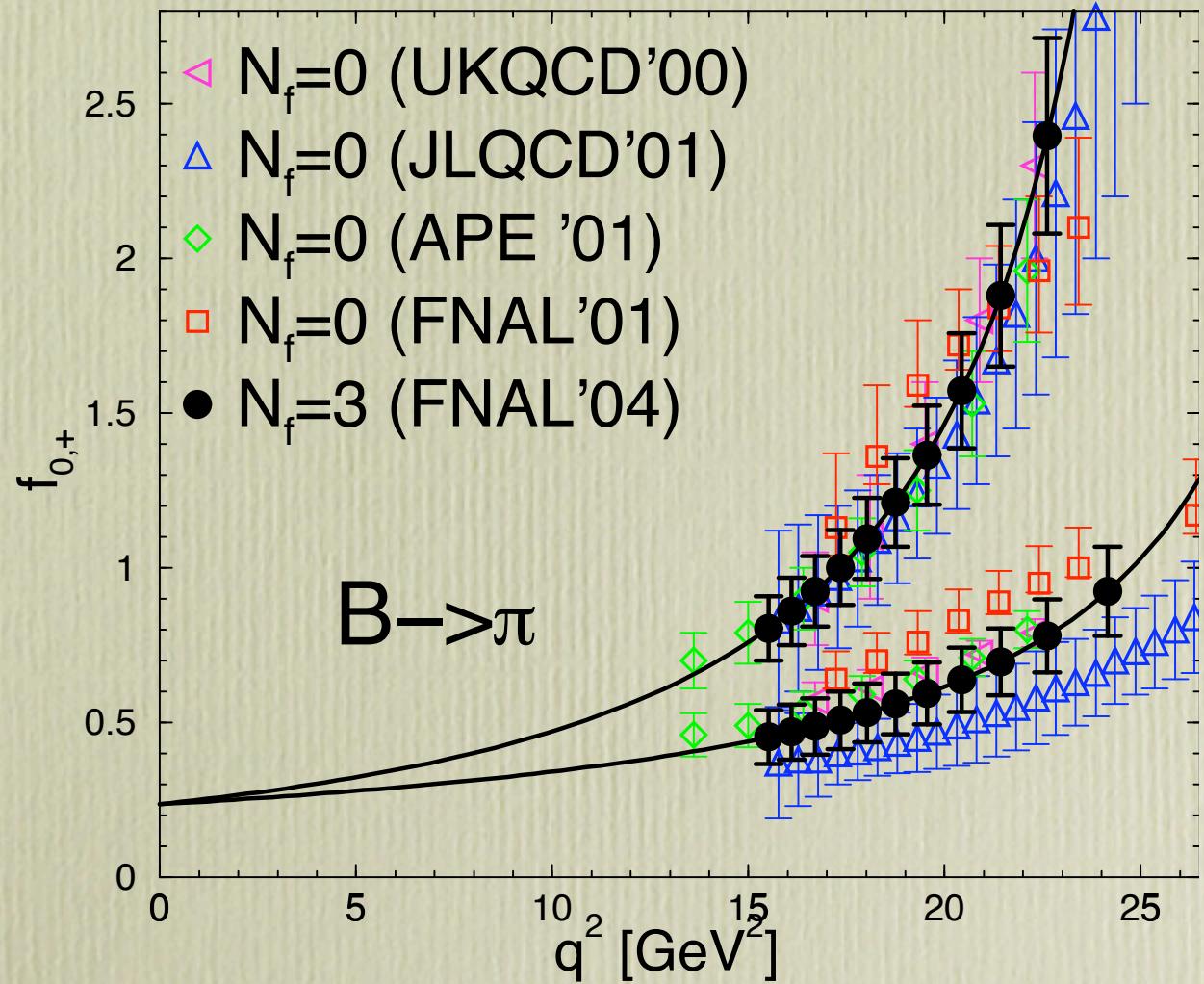
Semileptonic decays $H \rightarrow \pi \ell \nu$

$$\langle \pi | V_\mu | H \rangle \; \equiv \; f_+(q^2) \left(p_\pi + p_H - \frac{m_H^2 - m_\pi^2}{q^2} q \right)_\mu$$

$$+ \; f_0(q^2) \; \frac{m_H^2 - m_\pi^2}{q^2} \; q_\mu$$

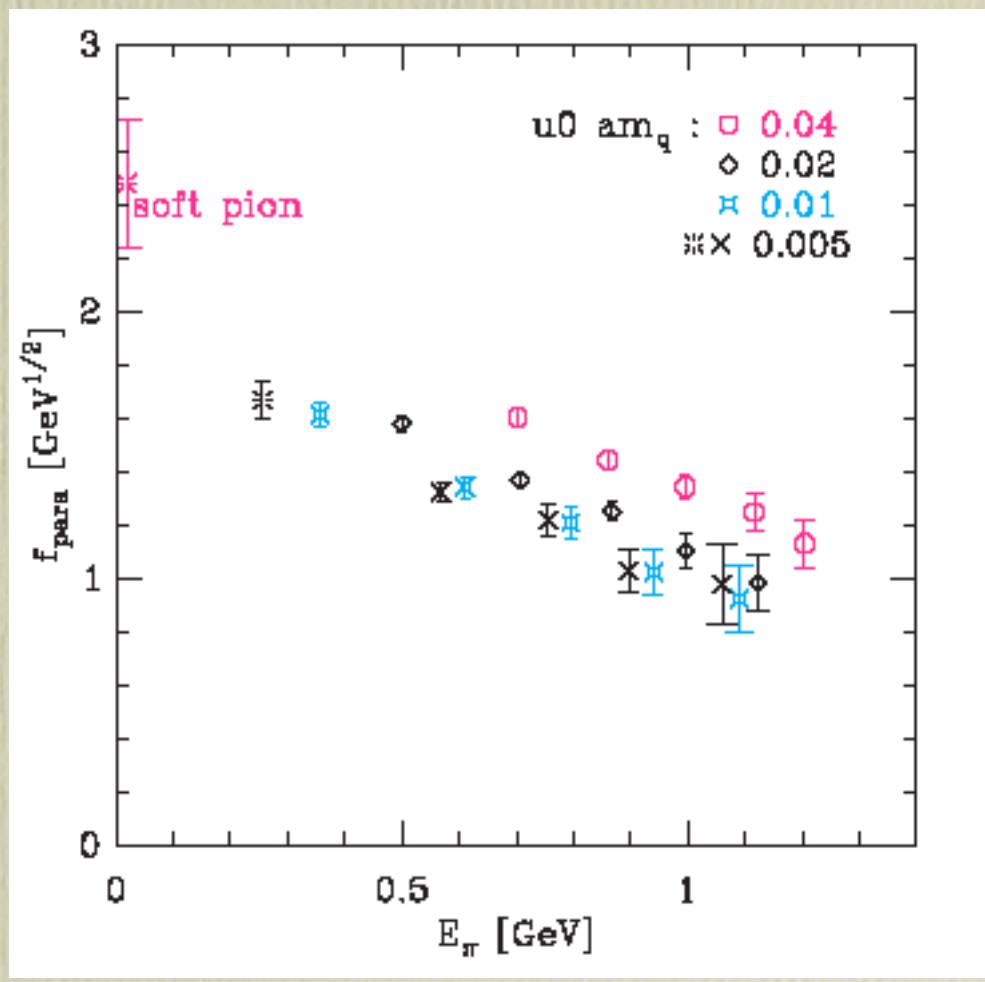
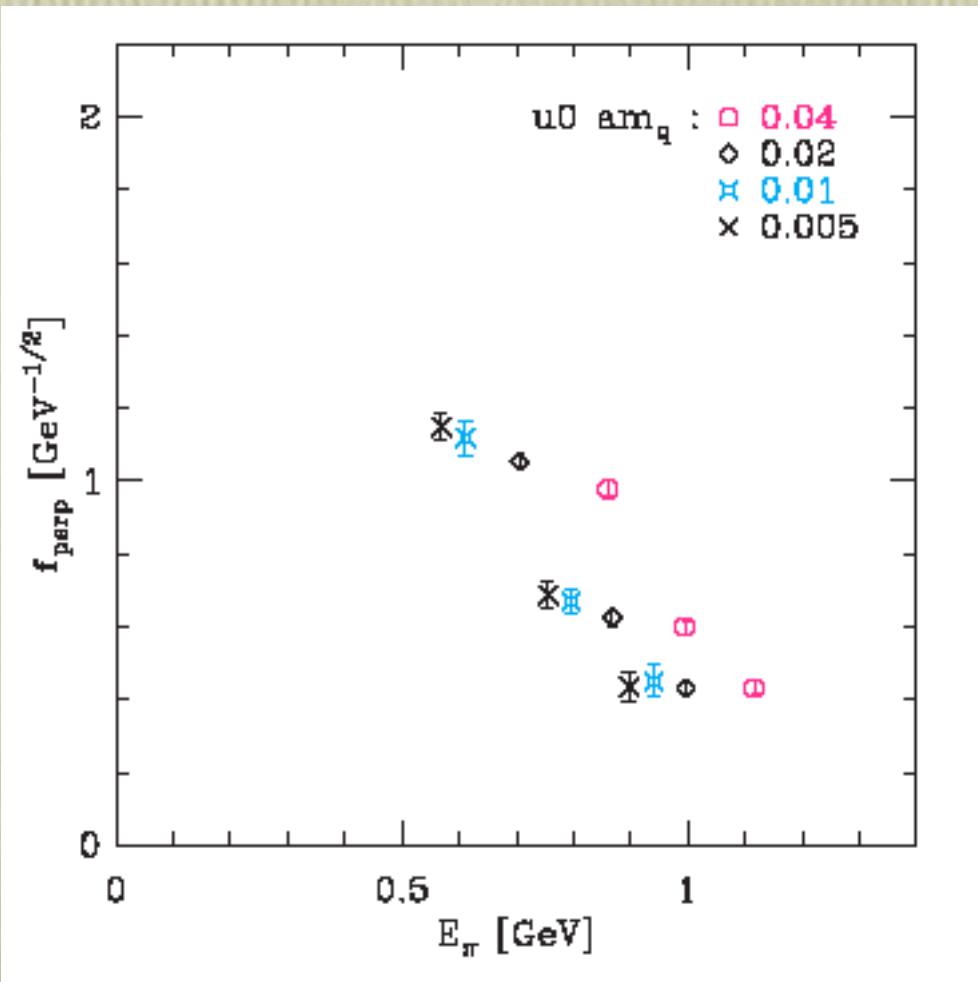
$$\equiv \; \sqrt{2m_H} \bigg(\; \textcolor{violet}{f}_{||}(E_\pi) v_\mu \; + \; f_\perp(E_\pi) \; p_{\perp,\mu} \bigg)$$

$B \rightarrow \pi \ell \nu$ with Fermilab HQ



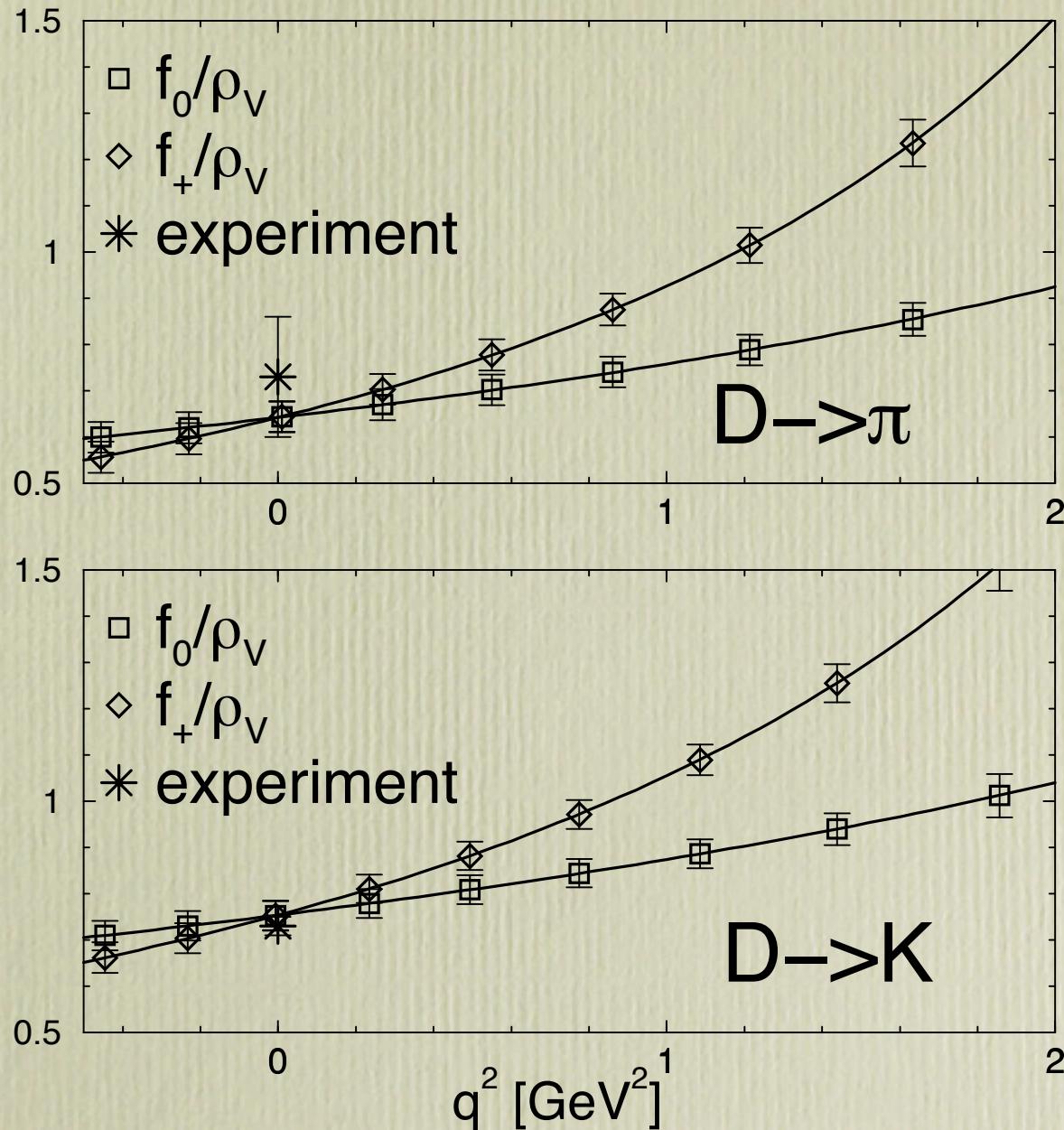
Masataka Okamoto, et al.

$B \rightarrow \pi \ell \nu$ with NRQCD

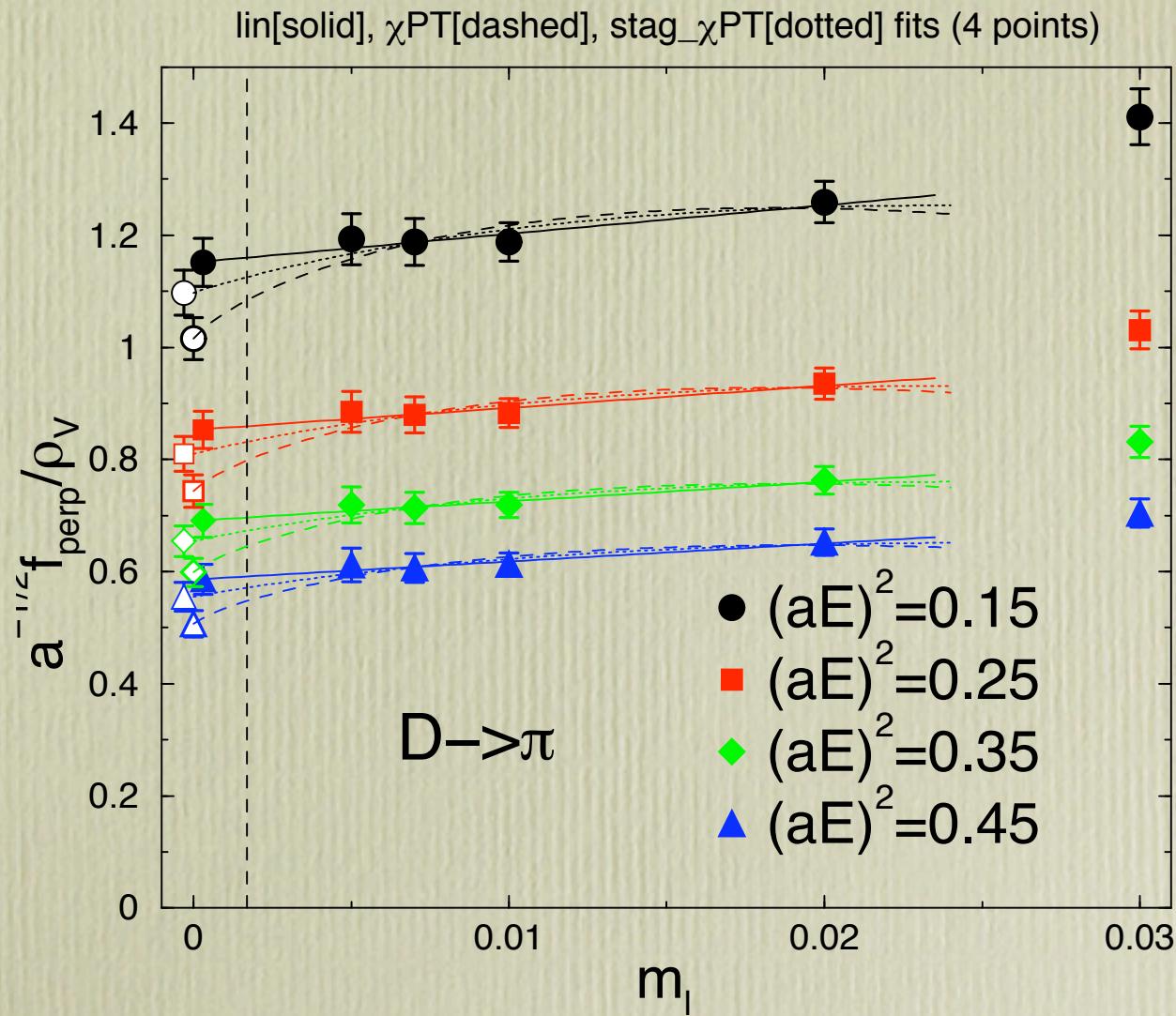


Junko Shigemitsu, et al.

Semileptonic D decays



Chiral extrapolation of f_\perp



Final Remarks

- Staggered chiral perturbation theory
- Moving NRQCD (K. Foley, et al) $B \rightarrow D\ell\nu$
- Neutral B mixing matrix elements

Nicholas Wingate



born 23 Dec 2003

Final Remarks

- Staggered chiral perturbation theory
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