$|V_{ub}|$ Exclusive: Form Factors from Lattice QCD

Jonathan Flynn

University of Southampton

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Outline

$B \to \pi$ Current Calculations: FNAL-MILC and HPQCD

Chiral Extrapolation

Quenched vs Unquenched

Prospects

$B \to \pi$: FNAL-MILC

- $n_F = 2+1$ asqtad staggered light quarks, ~ 500 cfgs
- $m_s/8 < m_l < 3m_s/4$ with $m_{l,\mathrm{val}} = m_{l,\mathrm{sea}}$
- b-quark: tadpole-improved clover action with Fermilab interpretation
- Matching: $Z^{ab}_{V_\mu} = \rho_{V_\mu}(Z^{aa}_V Z^{bb}_V)^{1/2}$
- Local sources/sinks; four source times

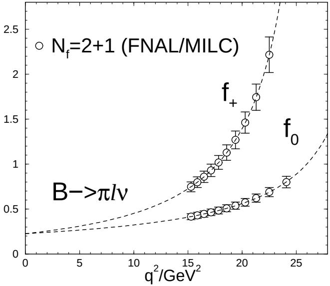
Okamoto et al, npbps140 (2005) 461

Okamoto PoS (LAT2005) 013

Mackenzie et al PoS (LAT2005) 207

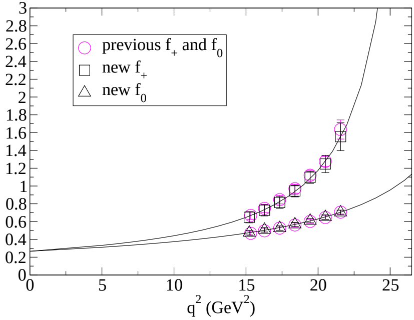
Van de Water LAT2006

- Main errors:
  - discretisation $\sim 9\%$
  - statistical $\sim 8\%$
- Results still preliminary



$B \to \pi$: HPQCD

- $n_F = 2 + 1$ asqtad staggered light quarks
- Use both $m_{l,\text{val}} = m_{l,\text{sea}}$ and $m_{l,\text{val}} \neq m_{l,\text{sea}}$ with $m_s/8 < m_{l,\text{sea}} < m_s/2$
- NRQCD b quark with relativistic and finite-a corrections (tree-level coefficients), tadpole-improved
- Heavy-light current with one-loop corrections: $J_0^{(0,1,2)}$ and $J_k^{(0,1,2,3,4)}$ to $O(\alpha_s \Lambda/M, \alpha_s/(aM), \alpha_s a\Lambda)$



- Main errors:
  - Statistics and chiral extrapolation 8%
  - 2-loop matching 9%

prd73 (2006) 074502

Chiral Extrapolations

- Work with

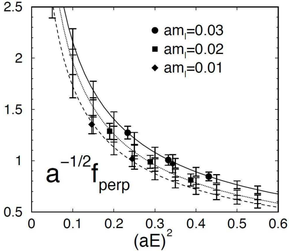
$$\langle \pi(p)|V^\mu|B(m_B v)\rangle = \sqrt{2m_B}(v^\mu f_\| + p^\mu_\perp f_\perp)$$

where $p_\perp = p - (p\cdot v)v$ since in B rest frame

$$\langle \pi|V^0|B\rangle = \sqrt{2m_B} f_\|, \qquad \langle \pi|V^k|B\rangle = \sqrt{2m_B} p^k f_\perp$$

- Both FNAL-MILC and HPQCD use SχPT
- Extrapolation most convenient at fixed E_π
  - Convert to f_+, f_0 for each light mass
  - Interpolate with some ansatz (BK, BZ, ZE, . . .)
  - Convert back to $f_\|$, $f_\perp$ at fixed E_π
  - Extrapolate at fixed E_π
  - Finally convert to physical f_+, f_0

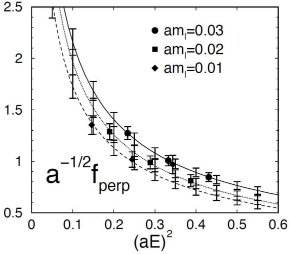
Chiral extrapolation

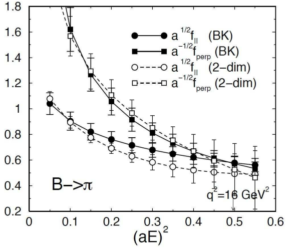


Simulated masses

Mackenzie et al, PoS (LAT2005) 207

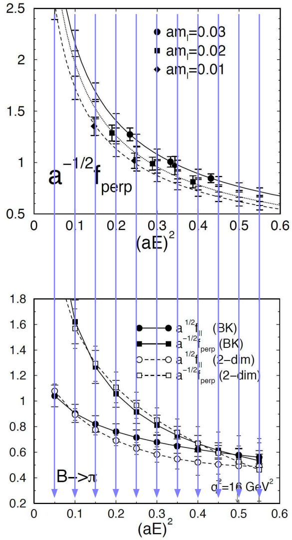
Chiral extrapolation





Mackenzie et al, PoS (LAT2005) 207

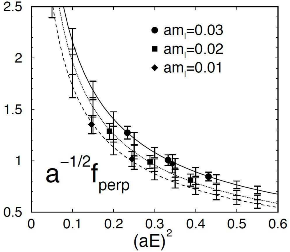
Chiral extrapolation

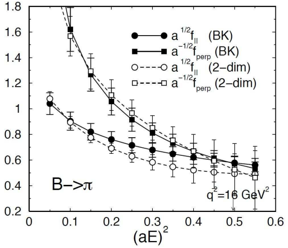


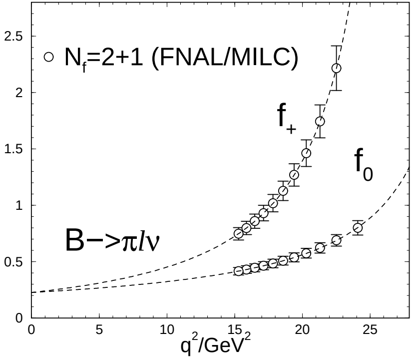
Extrapolate to physical pion mass

Mackenzie et al, PoS (LAT2005) 207

Chiral extrapolation







Mackenzie et al, PoS (LAT2005) 207
Okamoto, PoS (LAT2005) 013

- Choice of interpolation
- Twisted BC

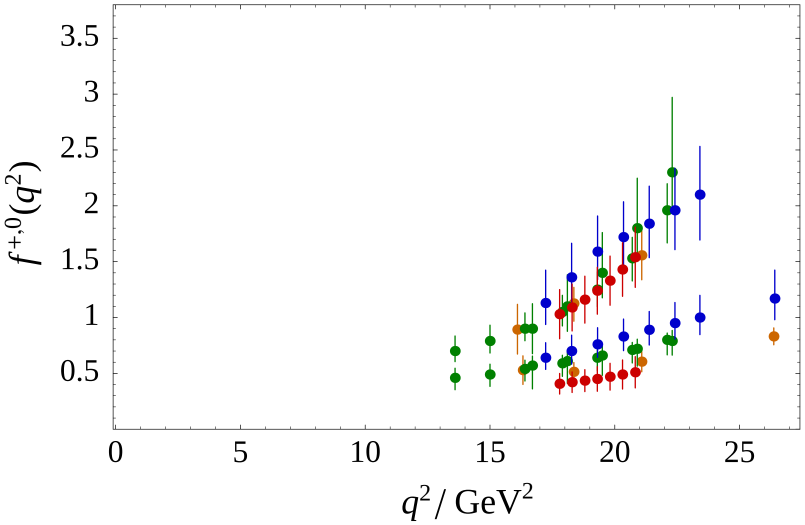
Commentary

- HPQCD and FNAL/MILC use same gauge configurations
  - Correlations?
  - Need confirmation by other groups using same and different sea quark formulations
- Also want checks with same and different heavy quark implementations

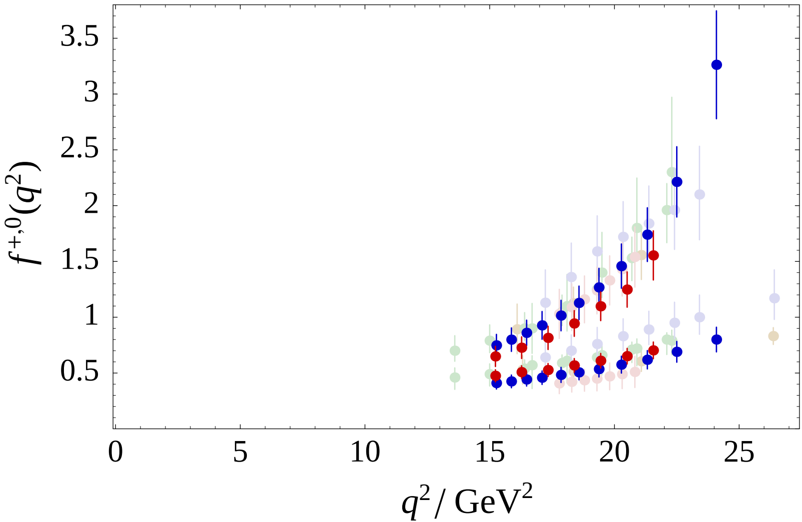
Quenched vs Unquenched

	n_f	Heavy	
UKQCD	0	clover	plb486 (2000) 111
APE	0	clover	npb619 (2001) 565
FNAL	0	Fermilab	prd64 (2001) 014502
JLQCD	0	NRQCD	prd64 (2001) 114505
Shigemitsu et al	0	NRQCD aniso	prd66 (2002) 074506
FNAL prelim	2+1	Fermilab	PoS (LAT2005) 013, 207
HPQCD	2+1	NRQCD	prd73 (2006) 074502

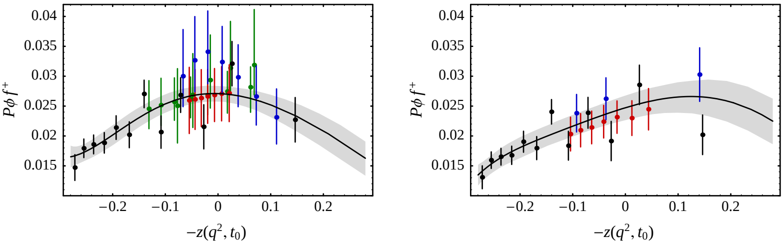
Quenched vs Unquenched



Quenched vs Unquenched

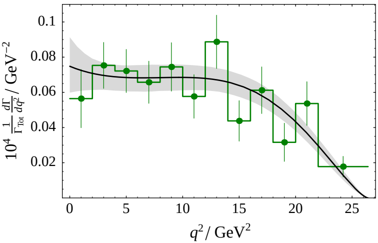


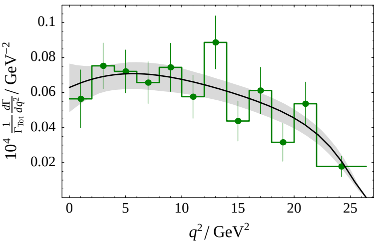
Quenched vs Unquenched with BaBar 12-bins



	$10^3|V_{ub}|$	$f^+(0)$
Unquenched		
HPQCD & FNAL-MILC & LCSR	4.01(34)	0.236(22)
HPQCD & FNAL-MILC	4.16(40)	0.216(29)
HPQCD	4.42(52)	0.207(31)
FNAL-MILC	3.79(49)	0.239(39)
Quenched		
LQCD & LCSR	3.71(27)	0.262(21)
LQCD	3.70(28)	0.265(30)

Quenched vs Unquenched with BaBar 12-bins





- Changes in $|V_{ub}|$

$$\frac{\text{unqenched \& LCSR}}{\text{quenched \& LCSR}} \nearrow 8\%$$

$$\frac{\text{unqenched}}{\text{quenched}} \nearrow 12\%$$

$$\frac{\text{unqenched HPQCD}}{\text{unquenched FNAL-MILC}} \nearrow 17\%$$

- FNAL-MILC numbers as quoted by AGRS prl95 (2005) 071802
- See also Ball hep-ph/0611108

Prospects

- FNAL/MILC
  - MILC ensembles extended: $\sim 500 \to \sim 800$ configs
  - new correlation functions computed; smeared B sources
  - chiral extrapolation
    - BK $\to$ ZE for q^2 interpolation to fixed E_π
    - combined E_π, m fit
    - twisted BC to ensure fixed E_π
  - discretisation error
    - use finer lattice-spacing
    - improve action/operators (Kronfeld-Oktay hep-lat/0610069)
- HPQCD
  - go beyond 1-loop current matching (2-loop pt, high-β MC)
  - better source/sink smearing
  - exploit ratio $B \to \pi / B \to D$
  - mNRQCD to access lower q^2
  - parametrisation: BZ $\to$ ZE

Prospects

- ALPHA/ROME2
  - HQET with nonperturbative accuracy
  - interpolate between HQET and relativistic *after* taking continuum limit
  - Quenched f_{B_s} to $\sim 3\%$ accuracy (hep-lat/0609065), $n_f = 2$ in progress; form factors to follow

Variations

- $B \to \rho$
  - Quenched results available SPQcdR hep-lat/0209116; UKQCD jhep05, 035: good match to LCSR at moderate q^2
  - Problem of $\rho \to \pi\pi$ in unquenched simulations
- $B \to \eta$
  - Disconnected contributions
- $B \to \omega$
  - ω is narrow: more attractive than ρ
  - Ignore disconnected contributions (OZI violations small)
- $B_s \to K$
  - Needs SFF at $\Upsilon(5S)$