Lattice 2008

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for

European Twisted Mass Collaboration

# Pseudoscalar decay constants ($f_K$, $f_D$, $f_{Ds}$) from $N_f = 2$ Twisted Mass QCD


in collaboration with
Benoit Blossier and Vittorio Lubicz

# Simulation Details

**Gauge Action: tree-level improved Symanzik**

- $N_f = 2$ dynamical fermions, degenerate in mass
- three values of $\beta$ : 3.8 ($a \approx 0.10$fm), 3.9 ($a \approx 0.09$fm), 4.05 ($a \approx 0.07$fm)

**Fermionic Action: twisted mass (tm) at maximal twist**

## Advantages:

- Pseudoscalar meson masses and decay constants are automatically O(a)-improved
- Pseudoscalar decay constants do not require renormalization constant: $f_P = 2\mu \frac{|\langle 0|P^1(0)|P\rangle|}{M_P \cdot \sinh(M_P)}$

bare twisted mass

| $\beta$ | 3.8 | 3.9 | 4.05 |
|---|---|---|---|
| V | $24^3$x48 | $24^3$x48 | $32^3$x64 |
| a | 0.10 fm | 0.09 fm | 0.07 fm |
| #confs | {240, 240} | {480, 240, 240, 240} | {128, 128, 128} |
| $a\cdot\mu_l$ | {0.08,0.011} | {0.004,0.0064,0.0085,0.01} | {0.0030,0.0060,0.0080} |
| $a\cdot\mu_s$ | {0.02,0.025,0.03,0.036} | {0.022,0.027,0.032} | {0.015,0.018,0.022,0.026} |
| $a\cdot\mu_c$ | {0.27,0.31,0.355,0.435,0.52} | {0.25,0.32,0.39,0.46} | {0.20,0.23,0.26,0.315} |

$$0.2\cdot m_s^{phys} \le \mu_l \le 0.5\cdot m_s^{phys}$$
$$0.9\cdot m_s^{phys} \le \mu_s \le 1.5\cdot m_s^{phys}$$
$$0.8\cdot m_c^{phys} \le \mu_c \le 1.5\cdot m_c^{phys}$$

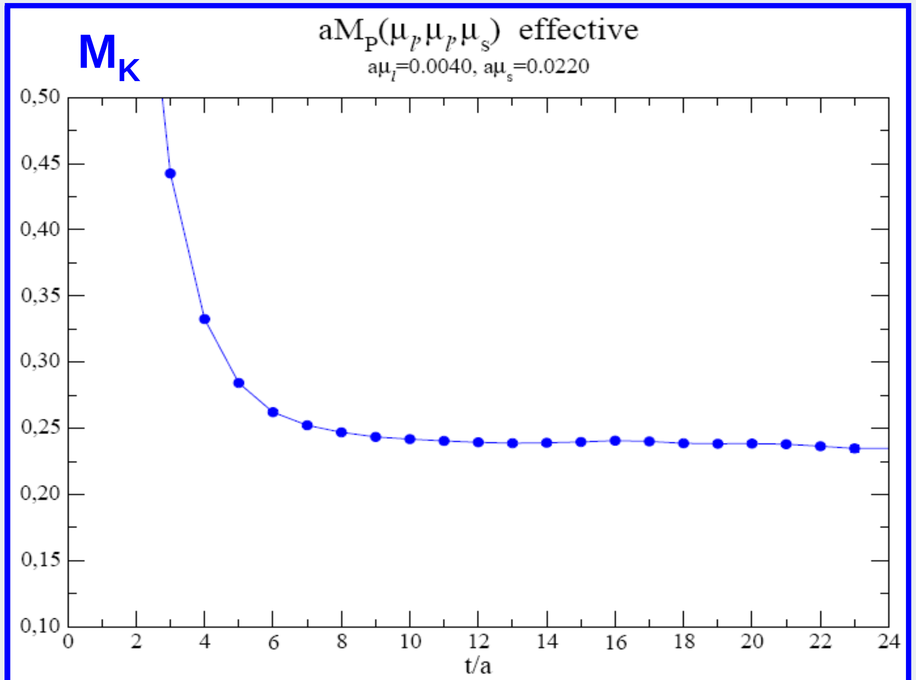
$$M(\mu_{sea},\mu_{val1},\mu_{val2})$$
$$F(\mu_{sea},\mu_{val1},\mu_{val2})$$

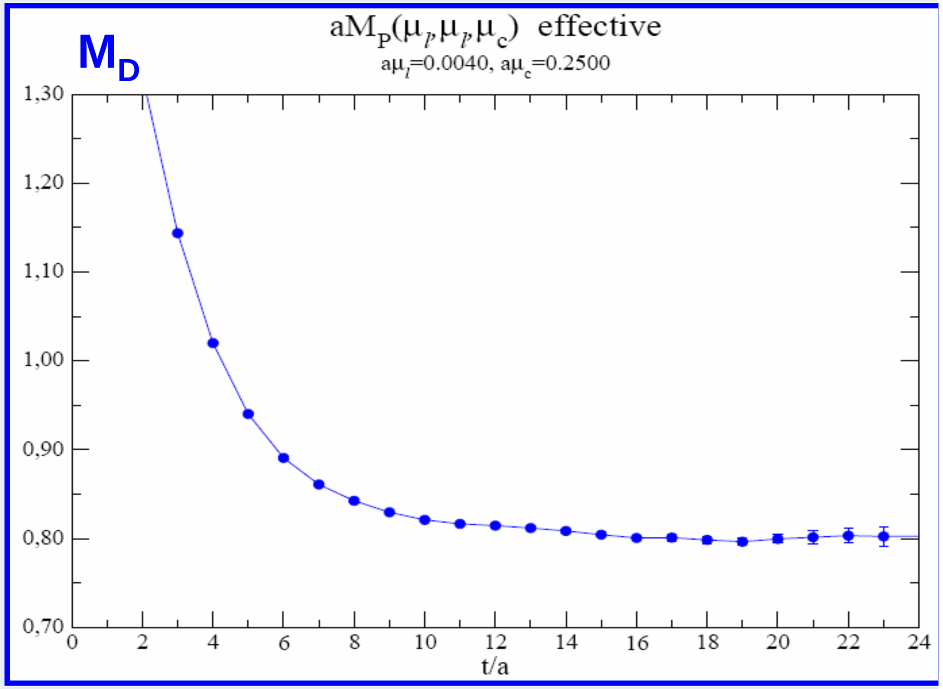
sea valence

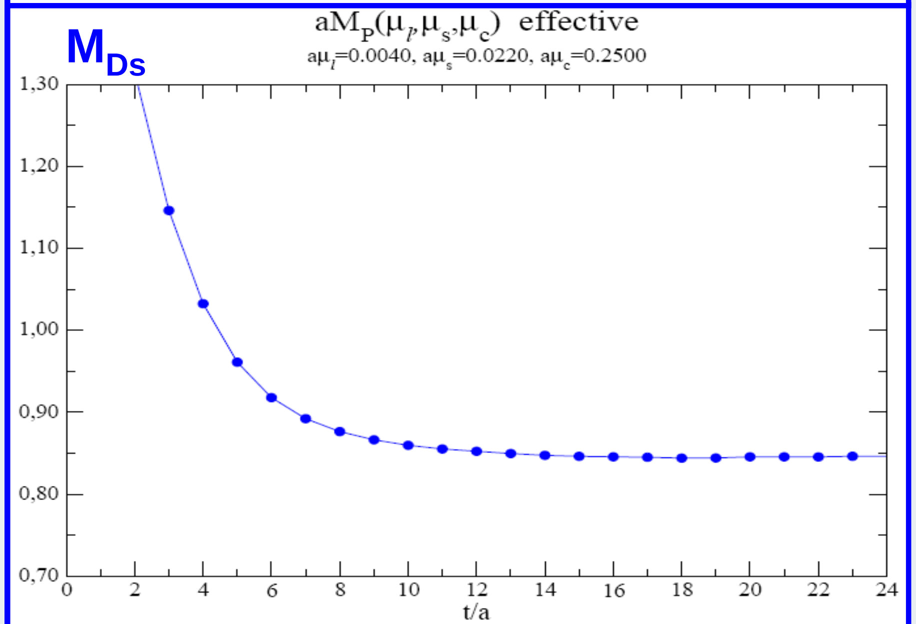
$$f_K \leftrightarrow F(\mu_l,\mu_l,\mu_s)$$
$$f_D \leftrightarrow F(\mu_l,\mu_l,\mu_c)$$
$$f_{D_s} \leftrightarrow F(\mu_l,\mu_s,\mu_c)$$

# Plateaux of effective pseudoscalar masses

e.g. $\beta$=3.9




**The plateau quality of 2-point pseudoscalar corr. functions is very good !**

(Statistical accuracy improved using a stochastic method to include all spatial sources)

C.McNeile and C.Michael [UKQCD], hep-lat/0603007

# KAON SECTOR

# Progress w.r.t. ETMC'07: 0709.4574

| 2007 | 2008 |
|---|---|
| One value of $\beta$: 3.9 | Three values of $\beta$: 3.8,3.9,4.05<br>$\rightarrow$ continuum limit |
| Chiral fit based on SU(3)-ChPT | Chiral fit based on SU(2)-ChPT<br>(SU(3)-ChPT for comparison) |
| Statistics:<br>240 confs for each $\mu_l$, at $\beta$=3.9 | Statistics:<br>480 confs at the lightest $\mu_l$, at $\beta$=3.9 |
| Study of the dependence of $f_K$<br>on quark masses | Study of the dependence of $f_K$<br>on meson masses<br>(with quark masses it is fundamental to have $O(a^2)$ under control in quark mass Renormalization Constants<br>$\longrightarrow$ study in progress) |

# Combined analysis

## Fit of data at various β

At the lowest β (3.8) the tuning of the critical mass is found to be problematic

→O(a) improvement is not guaranteed at the lightest quark mass

→we do not include data at β=3.8 in the analysis

(we consider them only for comparison, finding perfect compatibility)

## The fit formulae for $f_K$ include both:

- the meson mass dependence → chiral limit
- an $O(a^2)$ term → continuum limit

(small but visible)

# The dependence of $f_K$ on meson masses is well described by (NLO) SU(2)-ChPT

**IDEA: in kaons the strange quark is not light enough to apply SU(3)-ChPT**
**⇨ chiral symmetry properties are satisfied only by the light quark**

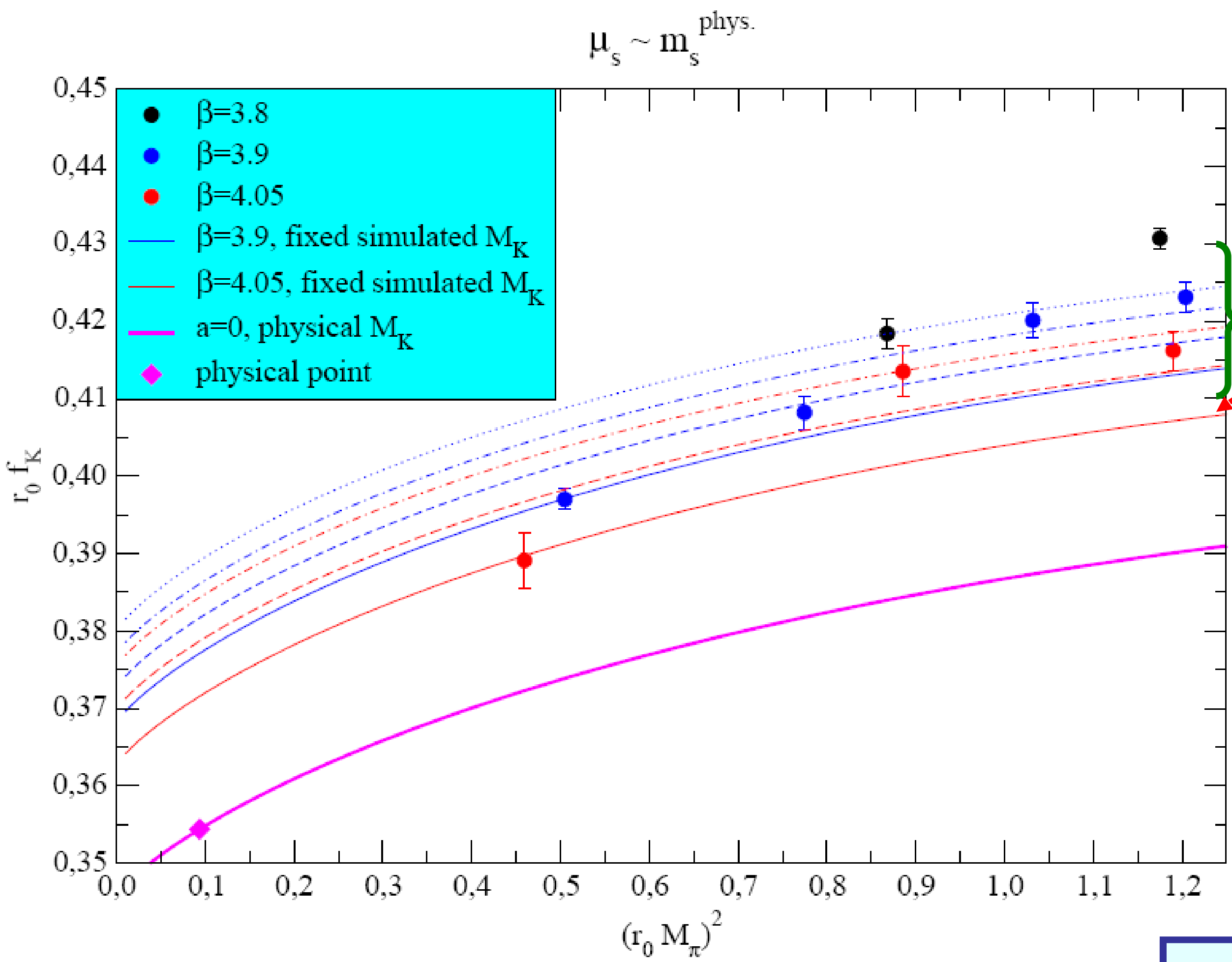
RBC/UKQCD Collaborations, 0804.0473

**The SU(2)-ChPT formulae can be obtained, for the decay constant, from SU(3)-ChPT by expanding in $\mu_l/\mu_s$**

**A fit based on NLO SU(3)-ChPT + quadratic terms is considered for comparison, finding perfect compatibility**

# Chiral Behaviour: dependence of $f_K$ on $m_\pi^2$

**Finite size effects (from 1-loop ChPT)**
**[D. Becirevic,G. Villadoro, hep-lat/0506004]**
**turn out to be negligible in the kaon region**




- **Data with $\mu_s \sim m_s^{phys.}$**
- **Curves at simulated β and $M_K$**
- **Curve with a=0, physical $M_K$**

**The interpolation to the physical $M_K$ is well described by a linear dependence in $M_K^2$**

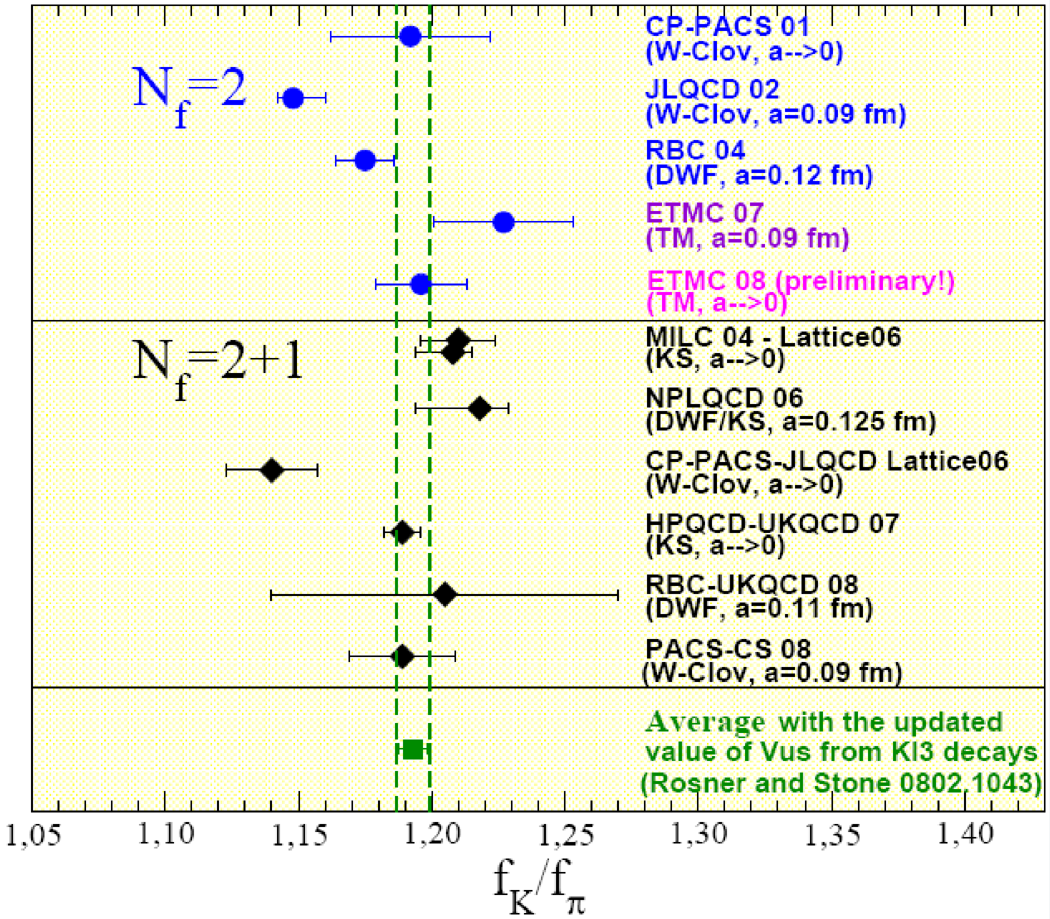
# Results

still preliminary systematic uncertainty!

$f_K \quad = 156.3\,(1.7)(0.9)(1.0)(?)$ MeV

$f_K/f_\pi = 1.196\,(13)\quad(7)\quad(8)\ (?)$

statistics — including $\beta$=3.8 — SU(3)-ChPT




**ETMC**

2007 → 2008

$f_K$: 161.7(1.2)(3.1)→156.3(1.7)(?)MeV

$f_K/f_\pi$:1.227(9)(24) → 1.196(13)(?)

Small decrease due to the continuum limit

# D-SECTOR

# Method for $f_D$, $f_{Ds}$: combined analysis (similarly to the analysis of $f_K$)

**The fit formulae for $f_D$, $f_{Ds}$ include both:**

- the meson mass dependence → chiral limit
- an $O(a^2)$ and an $O(a^2 \cdot M_{Ds})$ term → continuum limit
  (expected and found to be large in this case)
  (data at $\beta$=3.8 considered only for comparison →good compatibility)

S. Sharpe and Y. Zhang, hep-lat/9510037

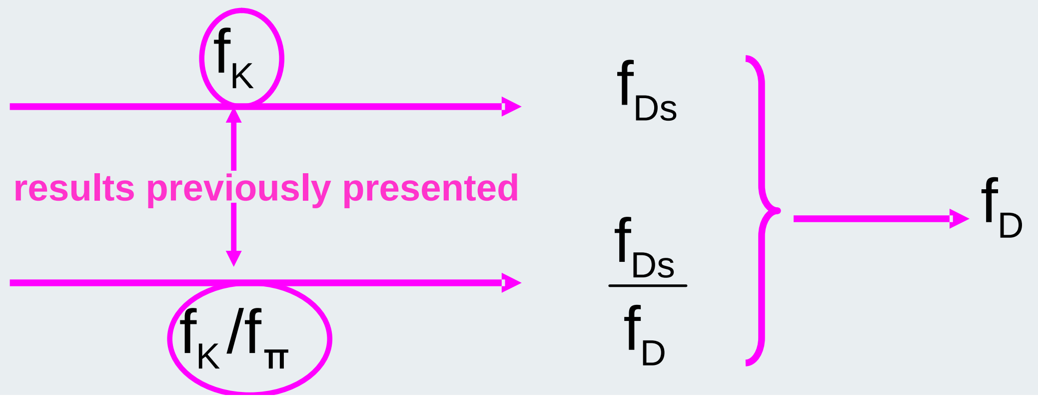
**Chiral Behaviour based on SU(2)-HMChPT**
(i.e. HMChPT formulae expanded in $\mu_l/\mu_s$)

A fit based on HMChPT is considered for comparison, finding perfect compatibility

**We introduce and fit two suitable ratios, where the light meson dependence is softened**

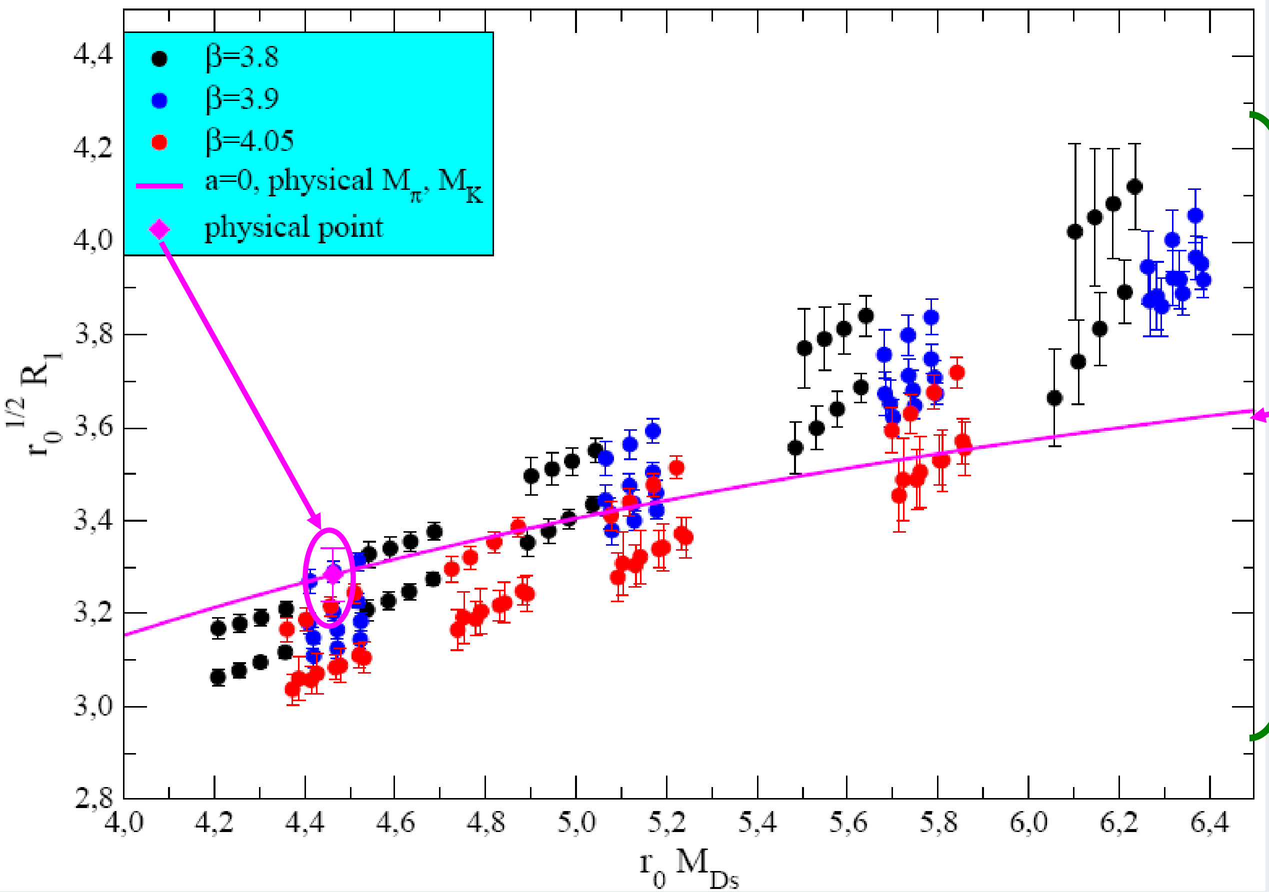
$$R_1 \equiv \frac{f_{Ds}\sqrt{m_{Ds}}}{f_K}$$

$$R_2 \equiv \frac{f_{Ds}\sqrt{m_{Ds}}}{f_K} \cdot \frac{f_\pi}{f_D\sqrt{m_D}}$$



# Dependence on the heavy meson mass: $R_1$ vs $m_{Ds}$

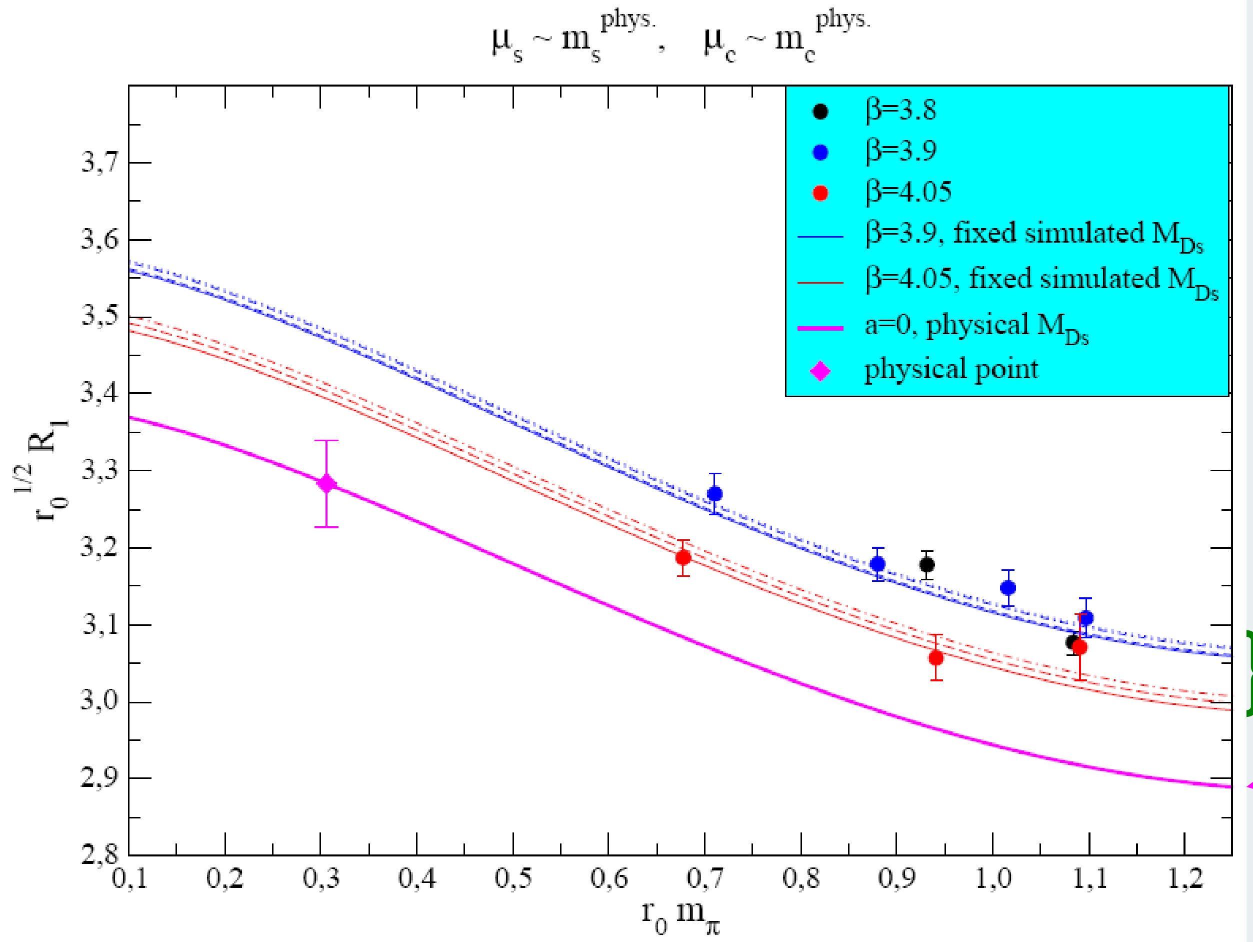
$$R_1 \equiv \frac{f_{Ds}\sqrt{m_{Ds}}}{f_K}$$




- **All data**
- **Curve with a=0 and physical $M_\pi$, $M_K$**

# Chiral Behaviour: dependence of $R_1$ on $m_\pi$

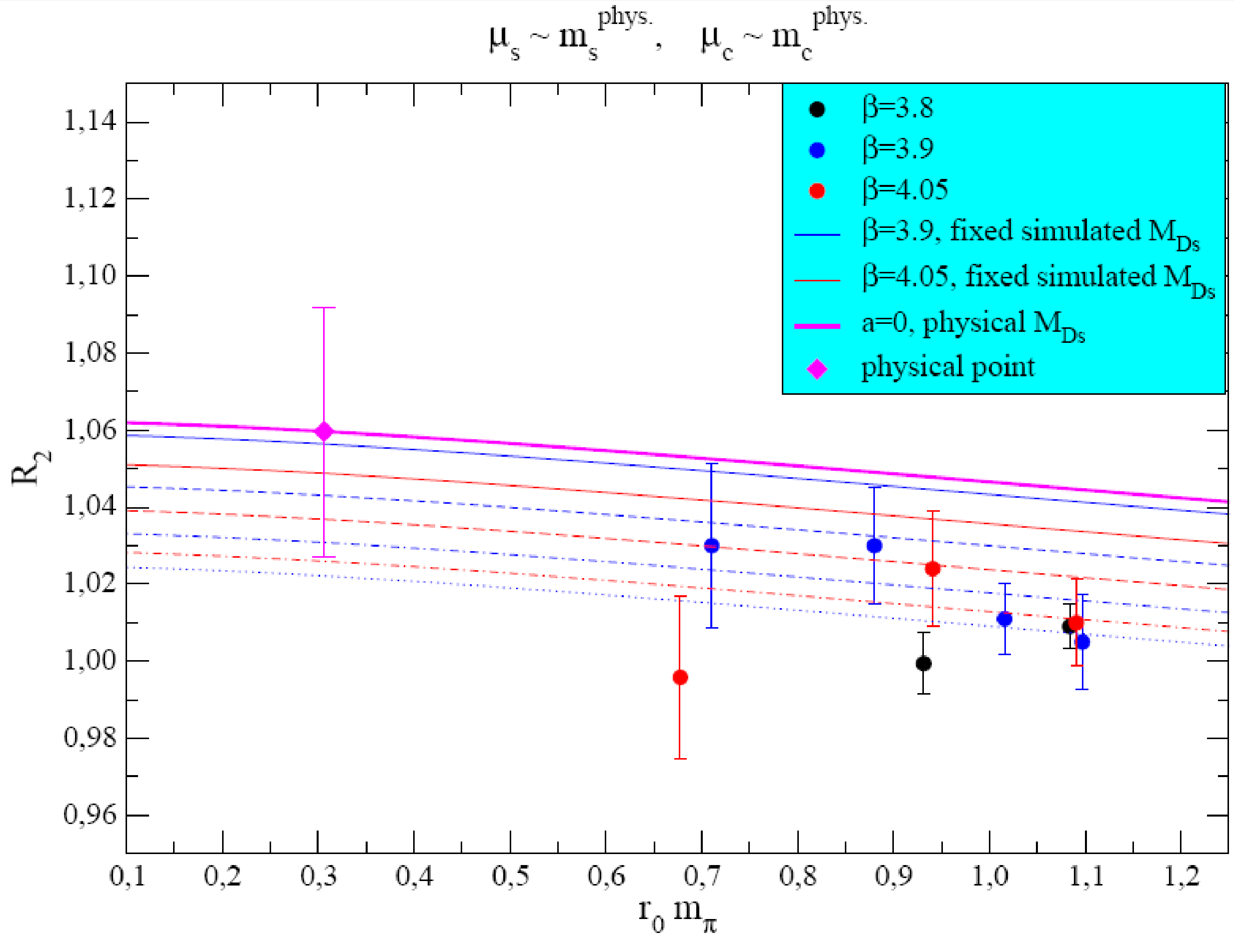
$$R_1 \equiv \frac{f_{Ds}\sqrt{m_{Ds}}}{f_K}$$




- Data with $\mu_s \sim m_s^{phys.}$ $\mu_c \sim m_c^{phys.}$
- Curves at simulated $\beta$ and $M_K$, $M_{Ds}$
- Curve with a=0 and physical $M_K$, $M_{Ds}$

# Chiral Behaviour: dependence of $R_2$ on $m_\pi$

$$R_2 \equiv \frac{f_{Ds}\sqrt{m_{Ds}}}{f_K} \cdot \frac{f_\pi}{f_D\sqrt{m_D}}$$




- Data with $\mu_s$~$m_s^{phys.}$ $\mu_c$~ $m_c^{phys.}$
- Curves at simulated $\beta$ and $M_K$ , $M_{Ds}$
- Curve with **a=0** and physical $M_K$, $M_{Ds}$

# Results

still preliminary systematic uncertainty!

$f_D = 197(7)(4)(0)(11)$ MeV

$f_{Ds} = 244(4)(3)(2)(10)$ MeV

$f_{Ds}/f_D = 1.24(4)(1)(1)(2)$

statistics

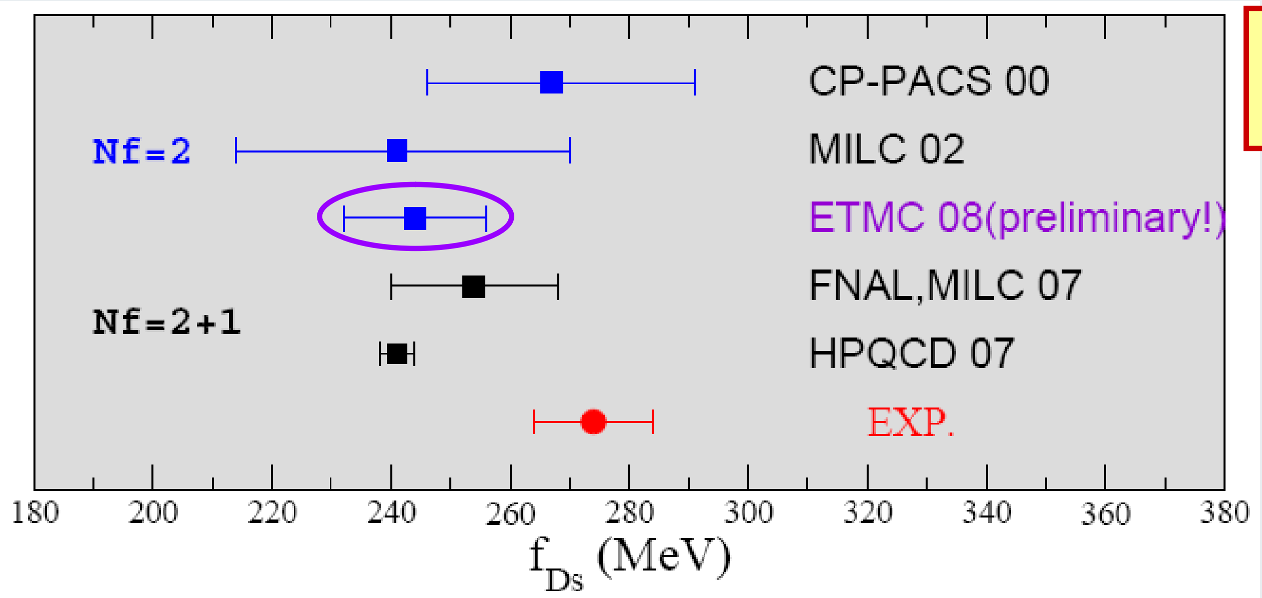
including $\beta$=3.8

SU(3)-HMChPT

only $\beta$=4.05

In agreement with the NEW exper. measurement:
$f_D^{exp.}$ =(205.8 ± 8.5 ± 2.5)MeV
Cleo-c (0806.2112)

Smaller than the exper. average!!!
$f_{Ds}^{exp.}$ =(277 ± 9)MeV
Cleo-c+BaBar+Belle
→(B.A. Dobrescu and A. Kronfeld '08)




Compatible with other recent unquenched results