

# First results with two light flavours of twisted mass quarks

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Lattice 2006, Tucson

# European Twisted Mass Collaboration

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# Outline

Introduction

Results

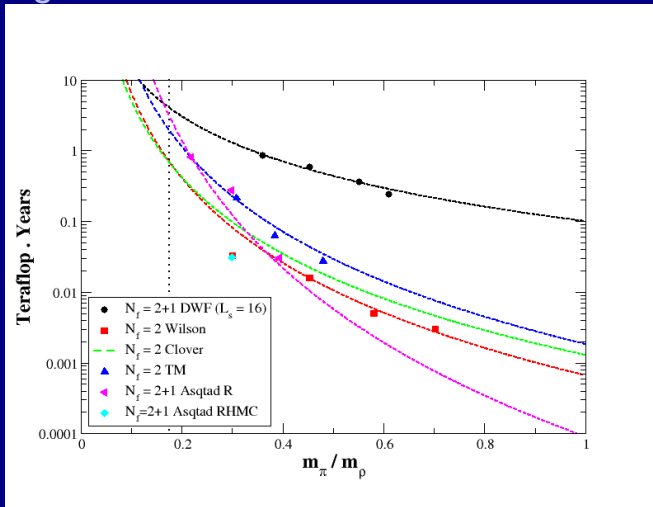
Setup

First Results

Scaling

Conclusion

There we go...



# Twisted Mass fermions

- ▶ the twisted mass Dirac operator:

$$D_{\text{tm}} = D_{\text{W}} + m_0 + i\mu\gamma_5\tau_3.$$

(Frezzotti, Grassi, Sint, Weisz, 1999)

- ▶ Wilson Dirac operator  $D_{\text{W}}$  with bare mass  $m_0$ .
- ▶ twisted mass parameter  $\mu$ .
- ▶  $\tau_3$  third Pauli matrix acting in flavour space
- ▶  $D_{\text{tm}}$  is protected against unphysically small eigenvalues

# Automatic $\mathcal{O}(a)$ improvement

If  $m_0$  is tuned to its critical value  $m_{\text{crit}}$  (maximal twist) then ...

- ▶ observables are automatically  $\mathcal{O}(a)$  improved.

(Frezzotti, Rossi, 2003)

Shown to work in practice for various observables in the quenched approximation (Jansen et al., 2004, 2005; Abdel-Rehim et al., 2004, 2005)

- ▶ Simplifies mixing during renormalisation
- ▶ Only one parameter ( $m_0$ ) must be tuned

but...

- ▶ parity and flavour symmetry explicitly broken

# Setup

- ▶ We are using the tree-level Symanzik improved gauge action (Weisz, 1983)
- ▶  $N_f = 2$  mass-degenerate flavours of maximally twisted mass quarks
- ▶ Algorithm: HMC with multiple time scales and mass preconditioning (Urbach et al., 2005)
- ▶ Plan:
  - ▶ 3 lattice spacings: 0.075 – 0.125 fm
  - ▶ pseudo scalar masses in the range 250 – 550 MeV
  - ▶ volumes  $\geq 2$  fm
- ▶  $m_0$  tuned to  $m_{\text{crit}}$  at the lowest mass at each lattice spacing

# Setup

| $\beta$ | $L^3 \times T$   | $a$ [fm]        | $m_{\text{PS}}$ [MeV] | $N_{\text{therm}}$ | $N_{\text{traj}}$ |
|---------|------------------|-----------------|-----------------------|--------------------|-------------------|
| 3.9     | $24^3 \times 24$ | $\approx 0.095$ | $\approx 280$         | 1500               | 5000              |
|         |                  |                 | $\approx 350$         | 1500               | 5000              |
|         |                  |                 | $\approx 430$         | 1500               | 5000              |
|         |                  |                 | $\approx 510$         | 1500               | 5000              |
| 4.05    | $32^3 \times 64$ | $\approx 0.075$ | $\approx 280$         | 1500               | 1200              |
|         |                  |                 | $\approx 350$         | 1500               | 500               |

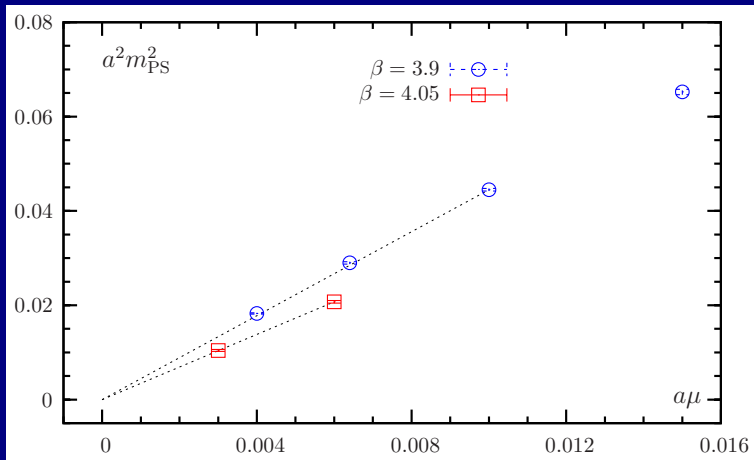
$\beta = 4.05$  very preliminary!

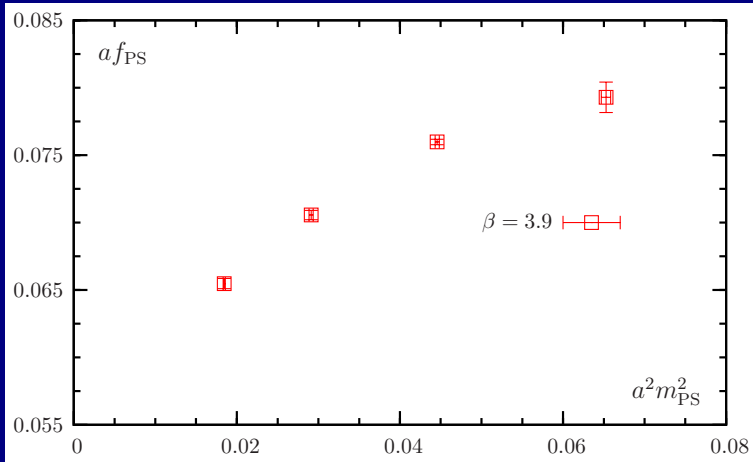
# Some simple observables

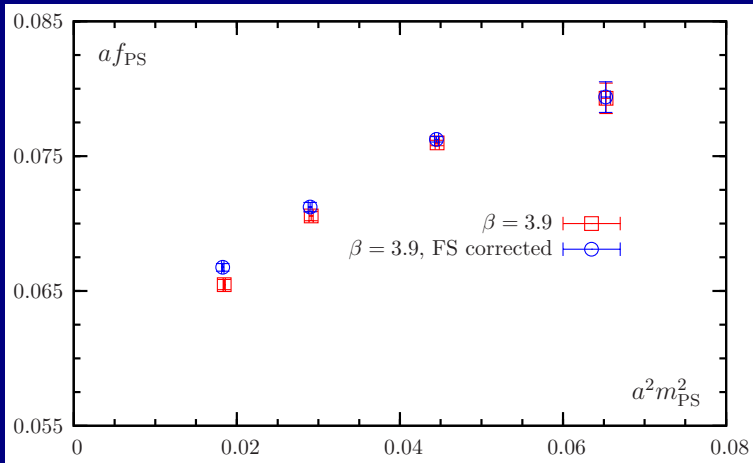
- ▶ First quantities to look at are  $m_{\text{PS}}$  and  $f_{\text{PS}}$
- ▶  $f_{\text{PS}}$  at maximal twist can be obtained from

$$f_{\text{PS}} = \frac{2\mu}{m_{\text{PS}}^2} |\langle 0 | P^1(0) | \pi \rangle|$$

- ▶ Note that at maximal twist  $f_{\text{PS}}$  does not need to be renormalised
- ▶ We estimate finite size (FS) effects with NLO ChPT formula from Gasser and Leutwyler (Gasser, Leutwyler, 1987)
- ▶ Checked against resummed Lüscher formula (Lüscher, 1986; Colangelo, Dürr, Haefeli, 2005)
- ▶ We use spin diluted random time slice sources, fuzzing (Michael) and variational methods (Michael, 1985 ;Lüscher, Wolff, 1990)

$am_{\text{PS}}$  versus  $a\mu$  at  $\beta = 3.9$ 

$f_{\text{PS}}$  at  $\beta = 3.9$ 

$f_{\text{PS}}$  at  $\beta = 3.9$ 

## $f_{\text{PS}}$ at $\beta = 3.9$

- ▶ Fits to the data with ChPT formulae in progress
- ▶ when the data is extrapolated linearly to the physical point we obtain:

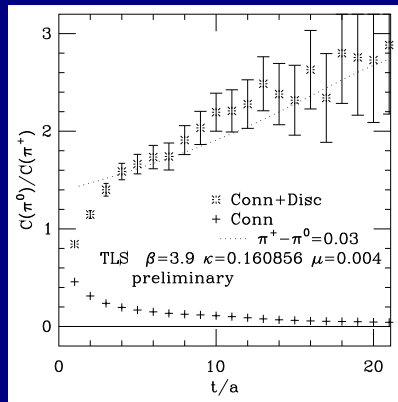
$$f_{\pi} = 126.3 \pm 0.8 \pm 0.7 \text{ MeV}$$

- ▶ First error comes from  $m_{\text{PS}}, f_{\text{PS}}$  and extrapolation, the second from  $r_0/a$
- ▶  $r_0 = 0.5 \text{ fm}$  was used
- ▶ In our normalisation  $f_{\text{PS}} = 131 \text{ MeV}$

# Effects of Isospin breaking

Flavour symmetry explicitly broken by twisted mass term at finite  $a$

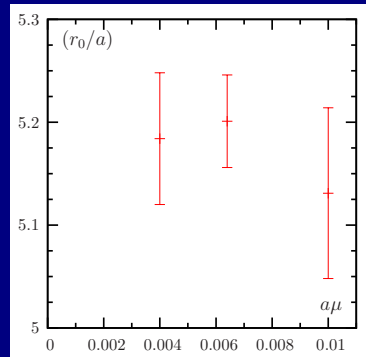
- ▶ Expected to be largest in  $m_{\text{PS}}^{\pm} - m_{\text{PS}}^0$
- ▶  $\beta = 3.9$ ,  $a\mu = 0.004$ ,  $am_{\text{PS}} = 0.1358(5)$ :  
 $m_{\text{PS}}^{\pm} - m_{\text{PS}}^0 = 0.03(1)$
- ▶ A factor of 2 smaller than quenched
- ▶ Splitting in the vector mass compatible with 0



# Setting the scale

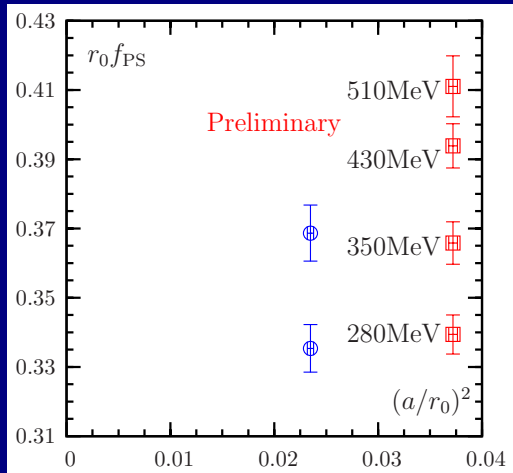
- ▶ Using the Sommer scale  $r_0$
- ▶ Value of  $r_0$  not very well known
- ▶ Scale setting with f.i.  $f_K$ ,  $m_{K^*}$  etc. in progress
- ▶ Here I use  $r_0 = 0.5$  fm
- ▶  $\mu$  dependence seems to be weak

$$\beta = 3.9$$



# Preliminary continuum scaling

- ▶  $r_0/a$  value at the lowest  $\mu$  value
- ▶ masses not yet exactly matched



# Conclusion

- ▶ First encouraging results with  $N_f = 2$  flavours of maximally twisted mass quarks
- ▶ We can reach values for  $m_{\text{PS}}$  as low as 280 MeV
- ▶ Flavour symmetry breaking effects are visible, but significantly smaller than quenched
- ▶ Lattice artifacts in  $f_{\text{PS}}$  seem to be small