Spectrum Study of Nf=2 QCD with Overlap Fermions

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New JLQCD's project: Dynamical simulation with overlap fermions

- Powerful approach to low energy QCD
  - Exact chiral symmetry
    - → No contamination in data
  - Any #flavor purchusable

Neuberger, 1998

$$D_{\text{ov}} = \frac{1}{R}\left[1 + \gamma_5 \epsilon(H_W)\right]$$

- State of the art

Hashimoto's talk; Kaneko's talk

  - Extremely light quarks
  - High statistics like never before (57Tflops!)
  - New techniques in gauge generation/measurement
    - → Significant leap of LQCD

- **Current status:** $N_f=2,\ 16^3\times 32,\ S_{\rm ov}+S_{\rm exWilson}+S_{\rm Iwasaki\ gauge}$
  - ~10,000trajs for each
  - 6 sea X 9 valence: $280\ \text{MeV} < m_{\rm PS} < 740\ \text{MeV}$
  - $a^{-1} \simeq 1.63\,\text{GeV}\ \ (r_0 = 0.50\,\text{fm})$
  - Fixed topological charge: $Q=0$
- **This talk-**
  - Meson spectrum $m_\pi,\ f_\pi$ ➡ Chiral log
  - NPR for bilinear $Z_A,\ Z_S = Z_m^{-1}$ ➡ Strange mass
  - Kaon B-parameter Yamada's talk

Improvements with low eigenmodes

DeGrand and Schaefer, 2004; Giusti et al., 2004

- Lowest 50 eigenmodes

$$D_{ov} u_i = \lambda_i u_i$$

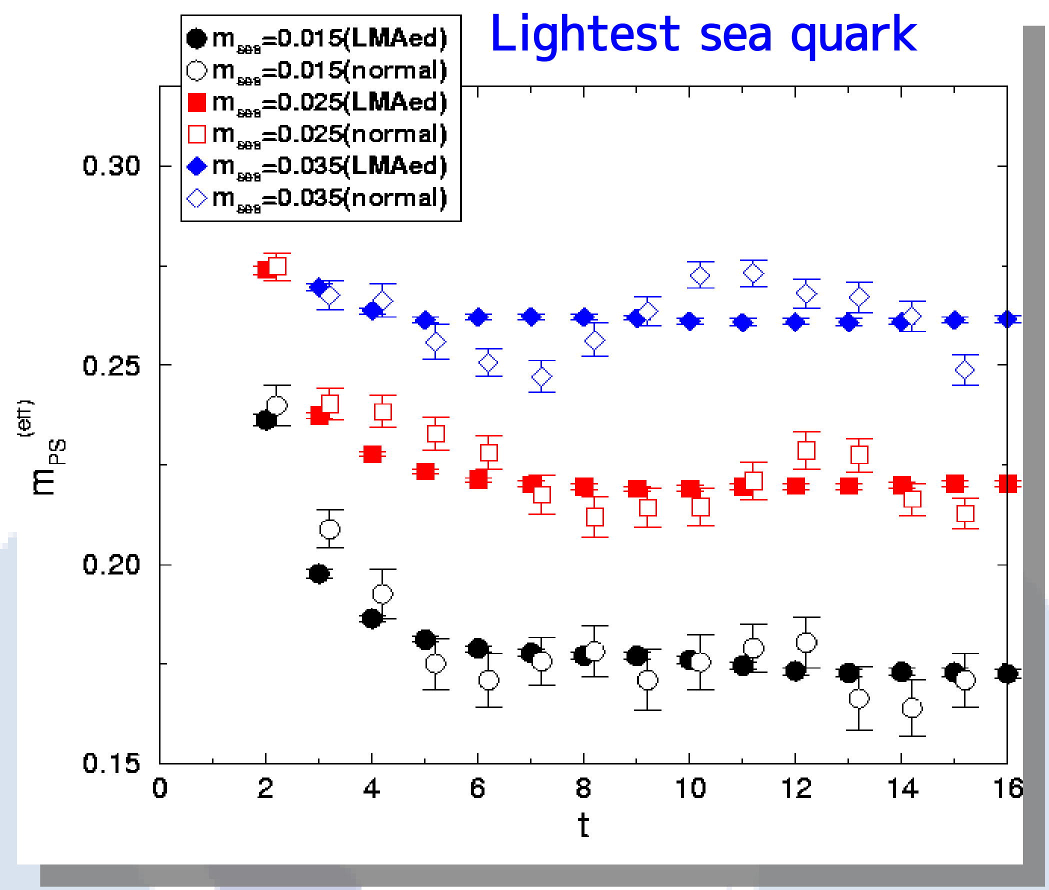
- Low mode preconditioned quark propagator

$$S_q(x,y) = \frac{\sum_{i=1}^{50} u_i(x) u_i(y)}{\lambda_i + m_q} + S_q^{\text{Higher}}(x,y)$$

- Low mode averaged meson correlator

$$C(t) = C^{\text{HH}}(t) + C^{\text{LH}}(t) + C^{\text{HL}}(t) + C^{\text{LL}}(t)$$

Average over space



Meson mass & decay constant

- Lattice data

$$\langle P(t)^{\text{pts}} P(0)^{\text{pts}} \rangle, \ \langle P(t)^{\text{pts}} P(0)^{\text{smr}} \rangle$$

$$\Rightarrow \quad m_\pi, \ \langle 0|P|\pi\rangle = \frac{m_\pi}{2m_q} f_\pi^{(\text{ren})}$$

- NLO ChPT

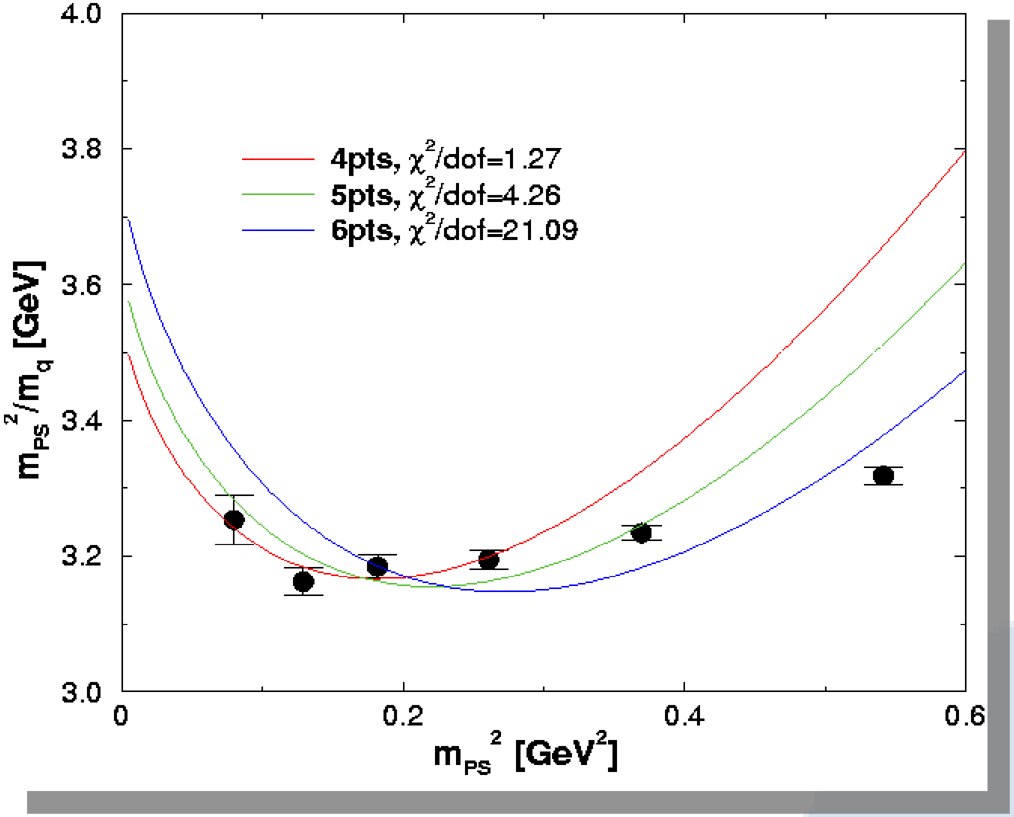
4 param. fit

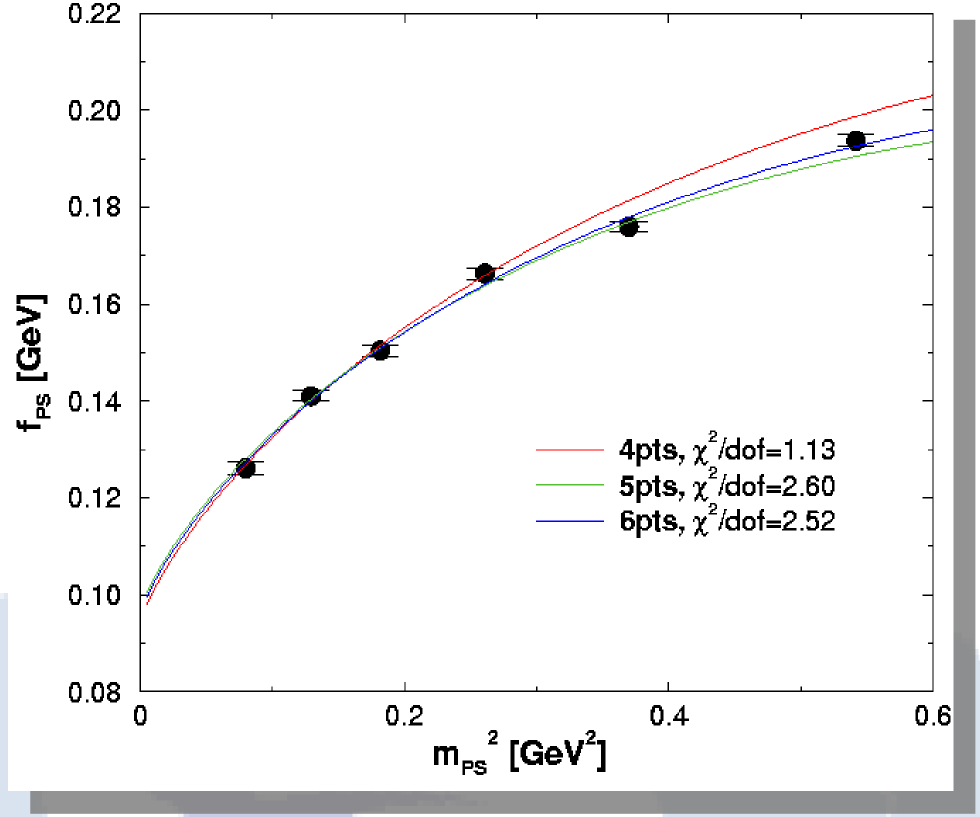
$$\frac{m_\pi^2}{m_q} = 2B_0\left[1 + \frac{2}{N_f}\frac{1}{(4\pi f)^2} m_\pi^2 \log m_\pi^2\right] + \eta\, m_\pi^2$$

$$f_\pi = f\left[1 - \frac{N_f}{(4\pi f)^2} m_\pi^2 \log m_\pi^2\right] + \zeta\, m_\pi^2$$

Dinamical point data

$m_{\mathrm{valence}} = m_{\mathrm{sea}}$



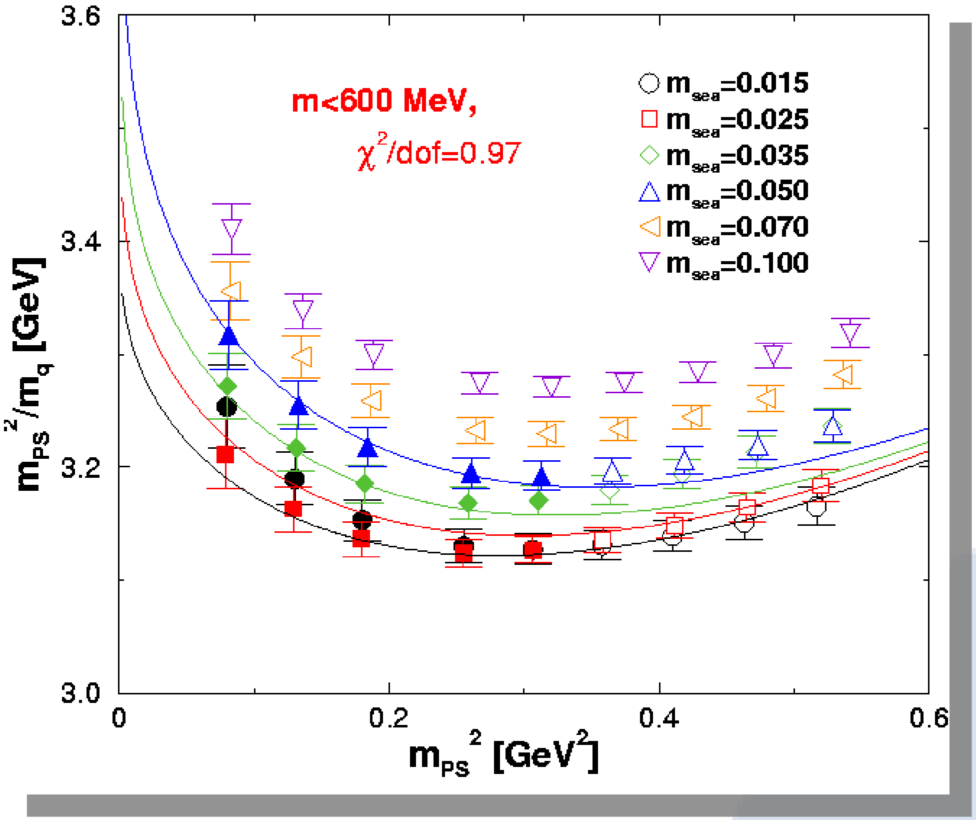


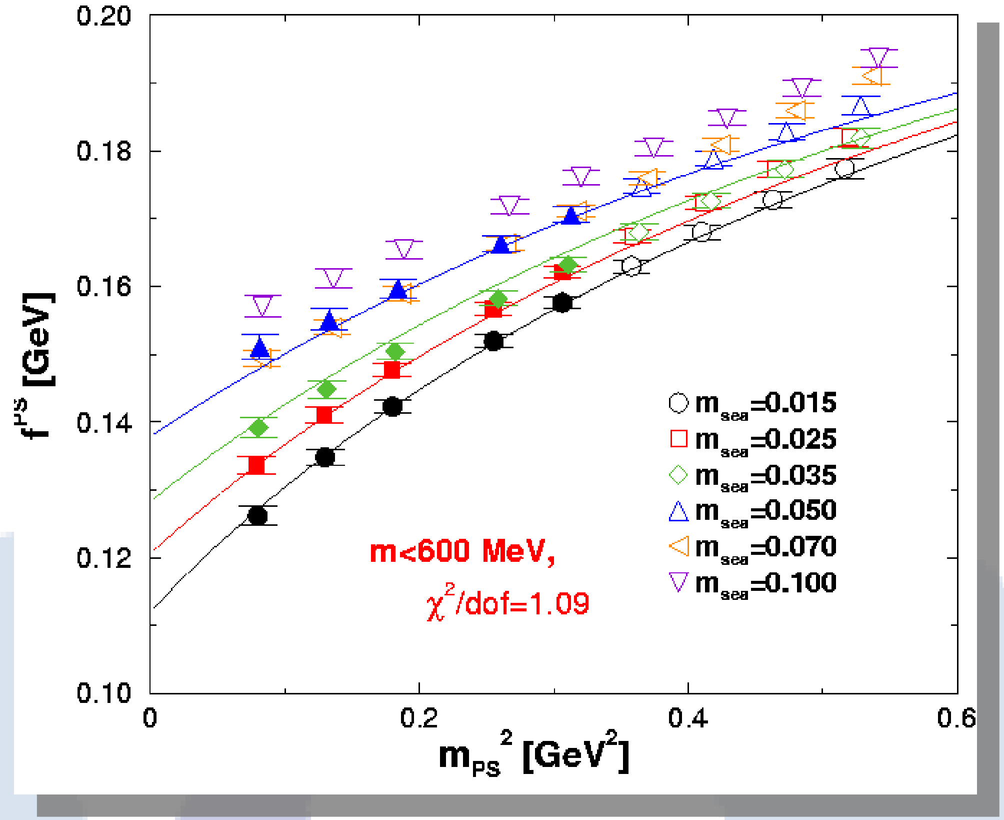
- $f = 94.4(1.4)$ MeV : 4pts fit
- FSE: ~3% /~+5% for the lightest mass

Gasser and Leutwyler, 1987; Colangelo et al., 2005

Partially quenched data

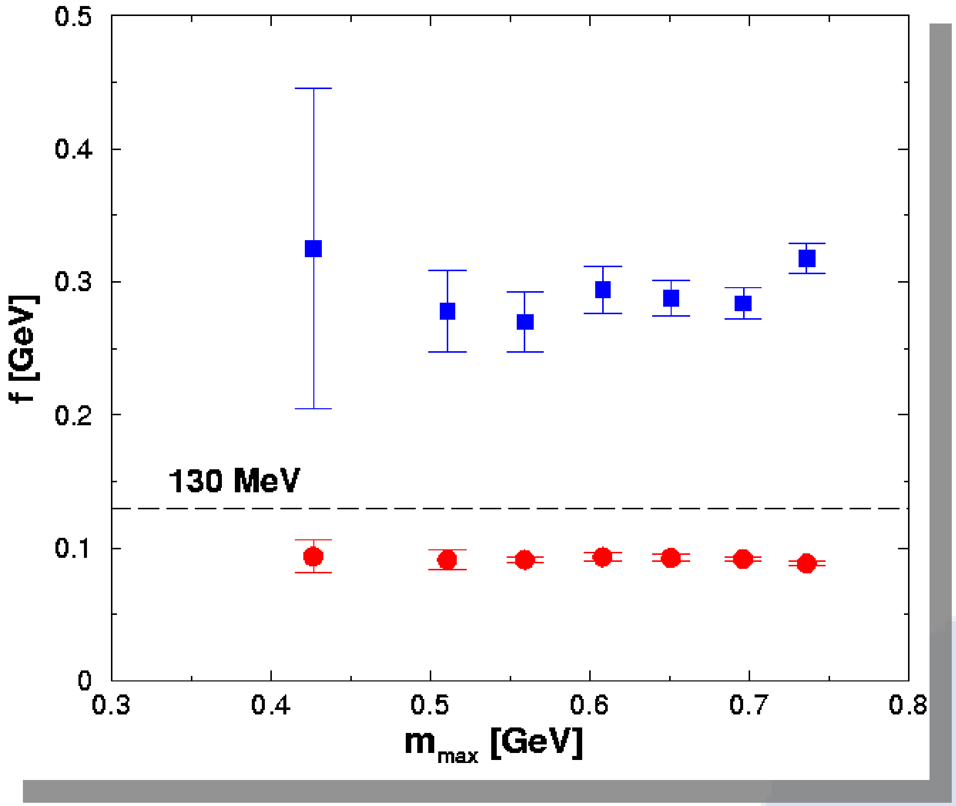
Sharpe, 1997; Golterman and Leung, 1997





- Fit with common f is impossible
- Independent fits are done

Test of (Pq)ChPT



- Rather stable result
  - ➡ FSE does not fill the gap.

Bernard-Golterman ratio

$$\frac{f_{VS}}{\sqrt{f_{VV} f_{SS}}} - 1 = -\frac{1}{2} \cdot \frac{m_{SS}^2}{N_f (4\pi f)^2} \cdot \tau$$

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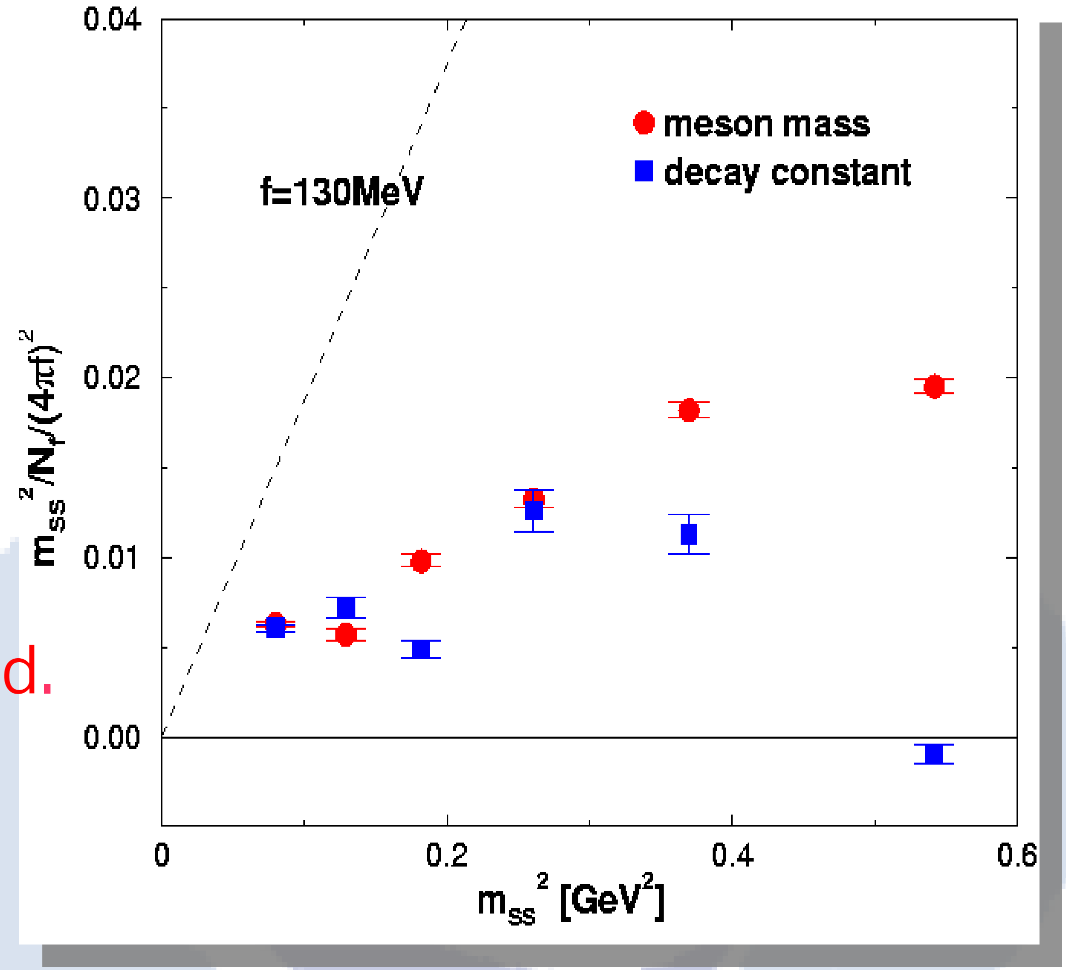
NNLO for meson mass is needed.

Effect of fixed topology ?



NPR for quark mass

Martinelli et al., 1995

- Renormalization condition

$$Z_q^{-1} Z_\Gamma \Lambda_\Gamma^{(\mathrm{latt})}(p) = \Lambda_\Gamma^{(\mathrm{tree})}$$

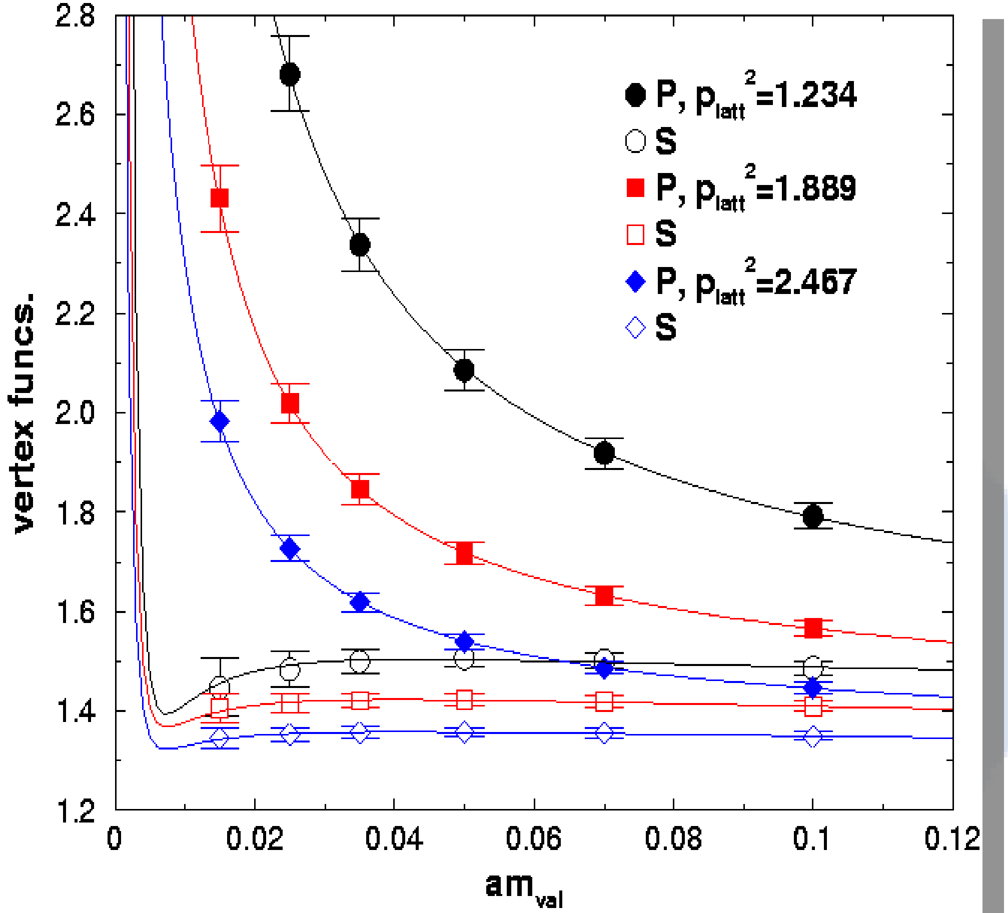
(Landau gauge)

- OPE + WTI

$$\Lambda_P(p) = A \cdot \frac{\langle \bar{\psi}\psi \rangle}{m_q} + \underline{Z_q Z_m} + B_P \cdot m_q^2$$

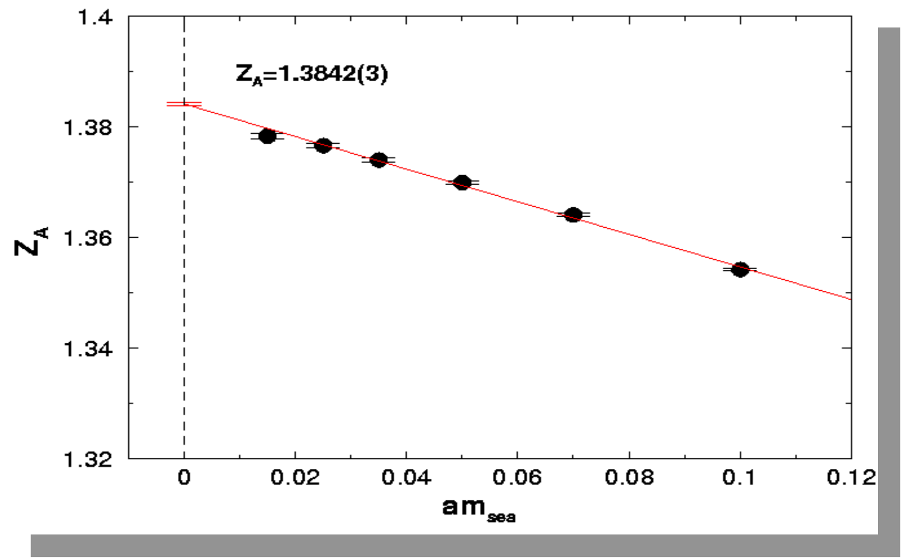
$$\Lambda_S(p) = A \cdot \frac{\partial}{\partial m_q} \langle \bar{\psi}\psi \rangle + \underline{Z_q Z_m} + B_S \cdot m_q^2$$

$$\langle \bar{\psi}\psi \rangle = \langle \frac{1}{V_L} \sum_{i=1}^{50} \frac{2 m_q}{m_q^2 + \lambda_i^2} \rangle$$



- Axial vector

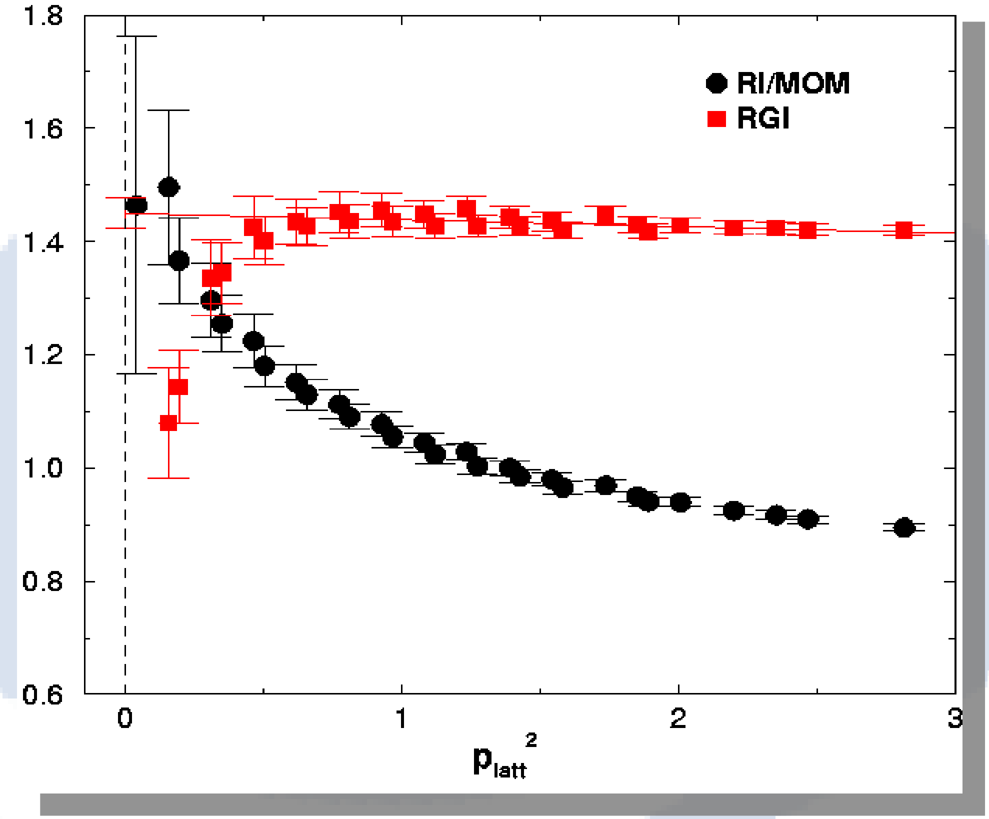
$$Z_A = \frac{\langle P(t)\,X(0)\rangle}{2m_q \Delta_t \langle A_4(t)\,X(0)\rangle}$$



- Matching

$$Z_m^{\mathrm{RI/MOM}} = Z_A \cdot \frac{Z_q Z_m}{\Lambda_A}$$

$$Z_m^{\mathrm{RGI}} = w_{\mathrm{RI/MOM}}(p)\, Z_m^{\mathrm{RI/MOM}}(p)$$

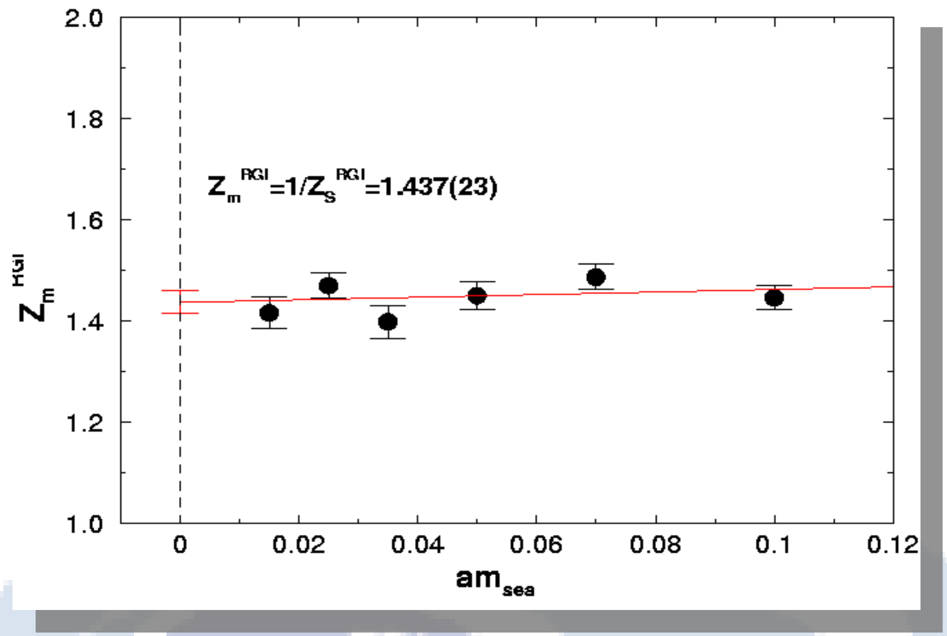


3-loop perturbation result is used

Strange quark mass

- Dynamical limit

$$Z_m^{\overline{\text{MS}}}(2\,\text{GeV}) = w_{\overline{\text{MS}}}^{-1}(2\,\text{GeV}) \cdot Z_m^{\text{RGI}} = 0.742(12)$$



- PCAC rel.

$$m_K = 0.495\,\text{MeV} \Rightarrow a \cdot m_s^{(\text{bare})}/2 \simeq 0.050$$

$$m_s^{\overline{\text{MS}}}(2\,\text{GeV}) = 117(2)(\text{sys.})$$

Summary

New era has come.