Partial quenching and chiral symmetry breaking

Michael Creutz

Pseudoscalar spectrum versus $m_u$ at fixed $m_d \neq 0$
Partial quenching

- generate dynamical lattices with fixed “sea” quark masses

- study quark propagators with different “valence” quark masses.

- from these form “valence” bound states
Usual assumption

- as valence masses go to zero

- a valence condensate $\langle \bar{\psi}_{\text{val}} \psi_{\text{val}} \rangle \neq 0$ forms

- valence pion masses go to zero

In some cases this assumption can fail
Consider two non-degenerate flavors “$u$” and “$d$”

- chiral symmetry for the dynamical pions
  
  \[ M_\pi \sim \frac{m_u + m_d}{2} + O(m_q^2) \]

Fix $m_d \neq 0$ but take $m_u = 0$

- $M_\pi \sim m_d/2 \neq 0$

- no singularity for $m_u$ in the vicinity of zero
  
  \[ \text{“Dashen phase” at } m_u = -m_d + O(m_d^2) \]
Banks and Casher

- small imaginary eigenvalues of the Dirac operator $\rho(0)$
- generate a jump in the condensate $\langle \bar{\psi}\psi \rangle$ as $m_q$ passes through zero

No jump in sea $\langle \bar{u}u \rangle$ at $m_u = 0$ when $m_d$ remains finite

At vanishing $m_u$ the up quark propagator has $\rho_u(0) = 0$
Bring in the valence quarks and take $m_{val}$ to zero

- The valence propagator and the up quark propagator become the same
  - $D_{val} \rightarrow D_u$ as $m_{val} \rightarrow 0$
  - $\rho_{val}(0) \rightarrow \rho_u(0) = 0$

Valence quarks do not condense

- No valence chiral symmetry breaking
- No expectation for massless valence pions
Conclusion

- partially quenched perturbation theory can fail if $\langle m_{val} \rangle < \langle m_s \rangle$

- independent of lattice fermion formulation

- a consequence of the anomaly