Study of unquenching effects on meson masses and decay constants

Nazario Tantalo

INFN sez. "Tor Vergata"

Centro Ricerche e Studi "E. Fermi"

July 24, 2006

outline

- the sap algorithm
- simulation parameters
- plateau analysis
- partially quenched QCD reference point
- full QCD reference point
- conclusions

the SAP procedure is based on a "geometric" separation of UV and IR modes [Lüscher 04]

- Dirichlet b.c. within the blocks provide $q \geq \pi/L$
- block interactions are small $S(x,y) \sim 1/|x-y|^3$

- the Wilson Dirac operator can be decomposed as

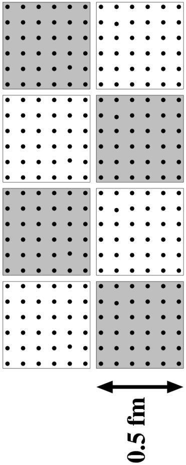
$$D = \frac{1}{2}\left\{\gamma_\mu\left(\nabla^\star_\mu + \nabla_\mu\right) - \nabla^\star_\mu\nabla_\mu\right\} + m$$

$$= D_{\Omega^\star} + D_\Omega + D_{\partial\Omega^\star} + D_{\partial\Omega}$$

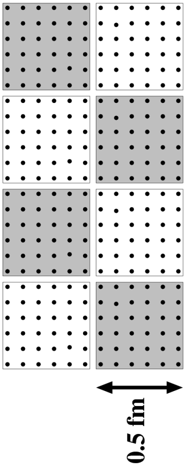
- where

$$D_{\Omega^\star} = \sum_{\text{white } \Lambda} D_\Lambda \qquad D_\Omega = \sum_{\text{black } \Lambda} D_\Lambda$$

- $\Omega^\star$ contains the white blocks while Ω contains the black ones
- $\partial\Omega^\star$ and $\partial\Omega$ are the "exterior boundaries"



the algorithm: domain decomposition (ii)



- the determinant of the full operator can be decomposed as

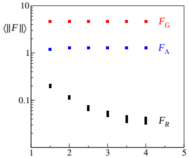
$$\det D = \det \hat{D}_\Lambda \, \det R$$

where

$$R = 1 - P_{\partial\Omega^\star} D_\Omega^{-1} D_{\Omega^\star}^{-1} D_{\partial\Omega}$$

- two flavor QCD can be simulated by introducing two scalar fields

$$S_{N_f=2} = \sum_{\text{all } \Lambda} \| \hat{D}_\Lambda^{-1} \phi_\Lambda \|^2 + \| R^{-1} \chi_{\partial\Omega^\star} \|^2$$



- as a consequence, there is a "natural" hierarchy of the forces

$$\epsilon_G \| F_G \| \sim \epsilon_\Lambda \| F_\Lambda \| \sim \epsilon_R \| F_R \|$$

simulation's parameters

nick	β	lattice	c_{SW}	k	N_{conf}
A_1	5.6	32×24^3	0.0	0.15750	64
A_2				0.15800	109
A_3				0.15825	100
A_4				0.15835	100
B_1	5.8	64×32^3	0.0	0.15410	100
B_2				0.15440	101
B_3				0.15455	104
B_4				0.15462	102
D_1	5.3	48×24^3	1.90952	0.13550	104
D_2				0.13590	171
D_3				0.13610	168
D_4				0.13620	168
D_5				0.13625	151

All the results presented in this talk have been obtained in **collaboration** with:

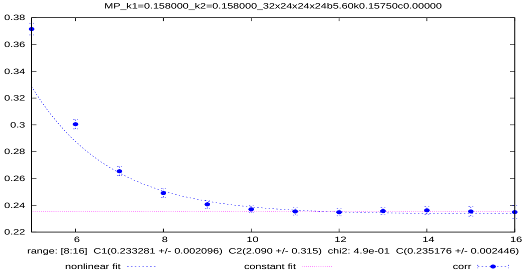
Luigi Del Debbio
Leonardo Giusti
Martin Lüscher
Roberto Petronzio

plateau analysis: pseudoscalar masses

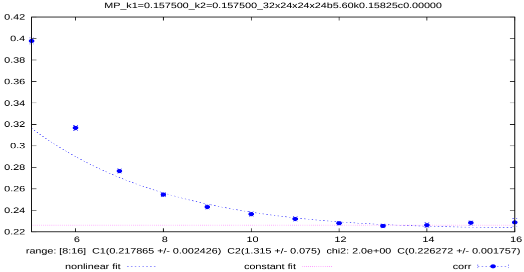
$N_f = 2$ QCD is more subtle than $N_f = 0$ QCD ...excited states contain multi-pion states

$$M_{12}^{\rm eff}(t) \simeq M_{12} + c\, e^{-(M_{12}+2M_\pi)t}$$

- A_1 **lattice**: $k_1 = k_2 \neq k_{\rm sea}$



- A_3 **lattice**: $k_1 = k_2 \neq k_{\rm sea}$
- the two ground states practically coincide while in the up plot the pion is heavier

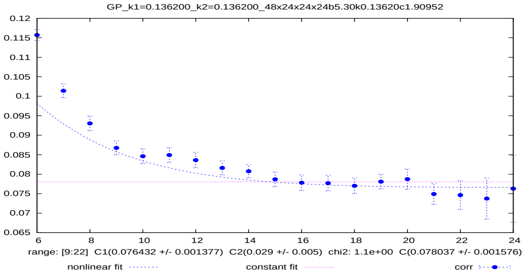


plateau analysis: pseudoscalar residue

the $< P(t)P(0) >$ residue is related to the pseudoscalar decay constant through the PCAC relation

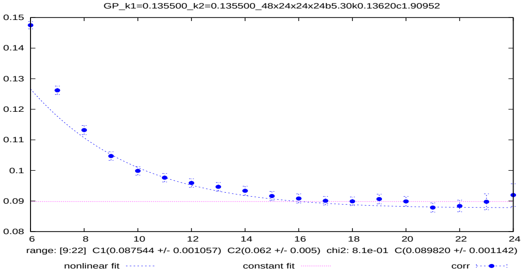
- D_4 **lattice**: $k_1 = k_2 = k_{\text{sea}}$

$$G_{\pi}^{\text{eff}}(t) \simeq G_{\pi} + c\, e^{-3M_{\pi}\, t}$$



- D_4 **lattice**: $k_1 = k_2 \neq k_{\text{sea}}$

$$G_{12}^{\text{eff}}(t) \simeq G_{12} + c\, e^{-(M_{12}+2M_{\pi})t}$$



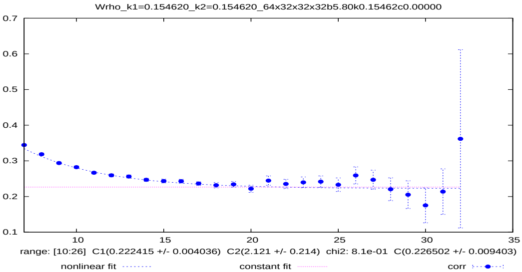
plateau analysis: vector mass

we have used a variational technique (correlation matrix with different Jacobi smearing steps)

- B_4 **lattice**: $k_1 = k_2 = k_{\mathrm{sea}}$

$$W_\rho^{\mathrm{eff}}(t) \simeq W_\rho + c\, e^{-E_1 t}$$

$$E_1 = \sqrt{M_\pi^2 + \left(\frac{2\pi}{L}\right)^2}$$



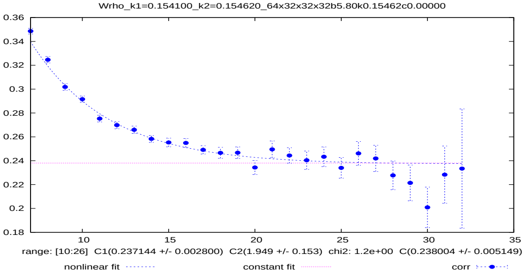
- B_4 **lattice**: $k_1 \neq k_2$

$$W_{V12}^{\mathrm{eff}}(t) \simeq W_{V12} + c\, e^{-E_1 t}$$

$$E_1 = E_{1sea} + E_{sea2}$$

$$E_{1sea} = \sqrt{M_{1sea}^2 + \left(\frac{2\pi}{L}\right)^2}$$

$$E_{sea2} = \sqrt{M_{sea2}^2 + \left(\frac{2\pi}{L}\right)^2}$$



partially quenched reference point

- on each lattice we study the ratio:

$$\left[\frac{M_P(k_{\text{sea}}, k_1)}{M_V(k_{\text{sea}}, k_1)}\right]^2 \qquad \text{v.s.} \qquad \frac{1}{k_1}$$

and we find the value $k1 = k_{\text{ref}}$ such that

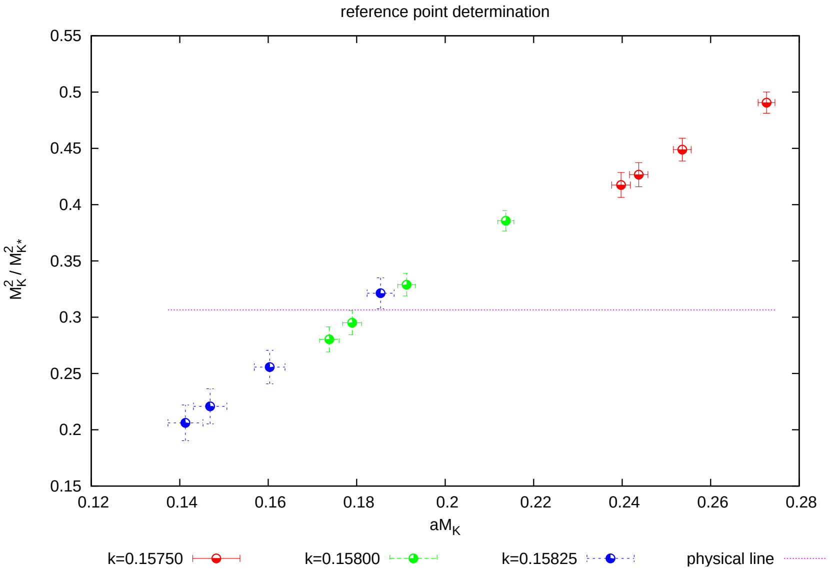
$$R(k_{\text{sea}}) = \left[\frac{M_P(k_{\text{sea}}, k_{\text{ref}})}{M_V(k_{\text{sea}}, k_{\text{ref}})}\right]^2 = \left[\frac{M_K}{M_{K^\star}}\right]^2$$

- then, at fixed β, we study

$$\mathcal{O}(k_{\text{sea}}, k_{\text{ref}}) \qquad \text{v.s.} \qquad \frac{1}{k_{\text{sea}}}$$

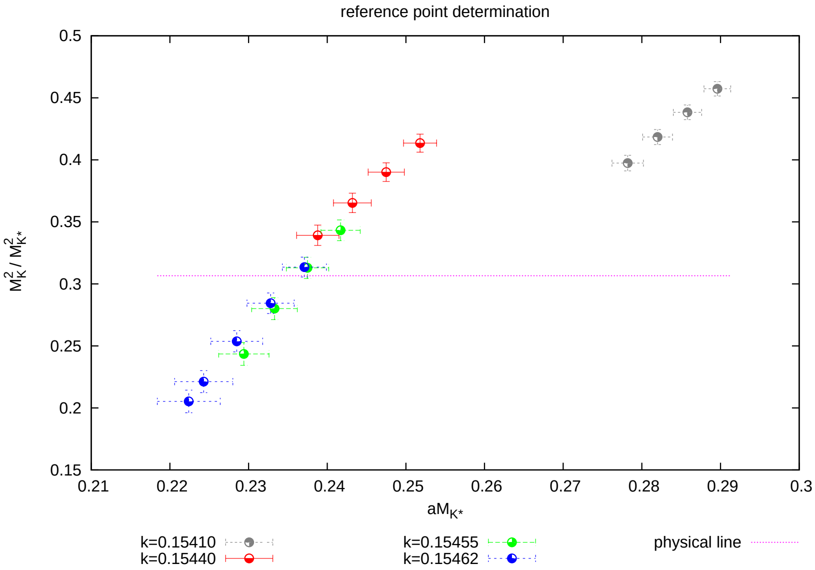
obtaining that for sufficiently small sea quark masses the observable is flat

- in this way we have a possible definition of m_{strange}, M_K, $M_{K^\star}$ and F_K



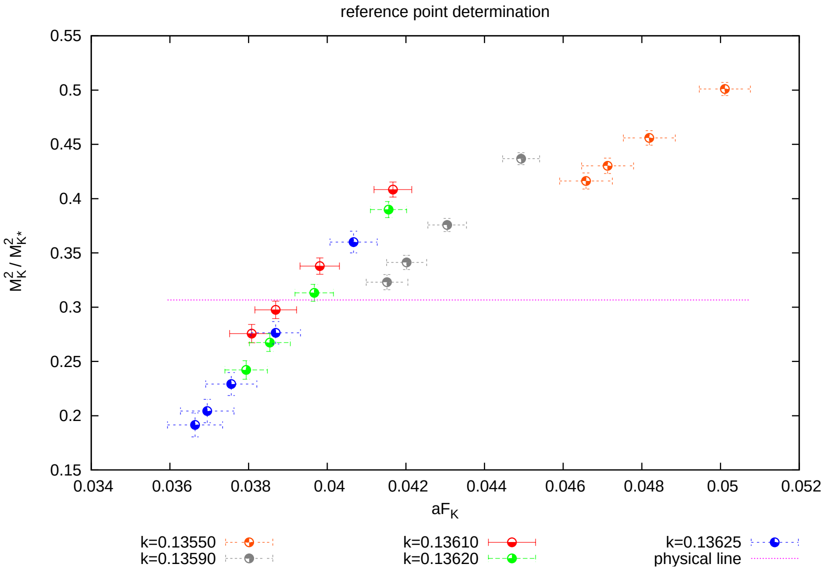
the physical volume is $L \simeq 1.7$ fm

partially quenched reference point: **B* lattices**



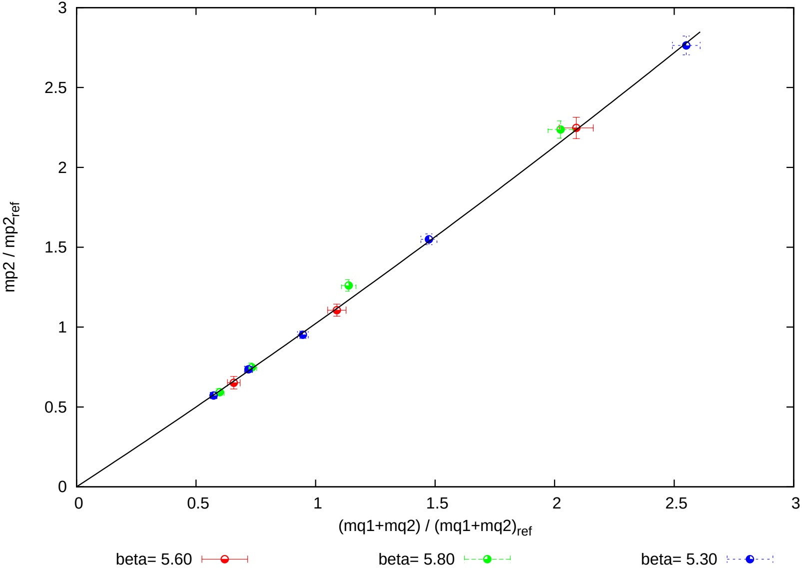
the physical volume is $L \simeq 1.7$ fm

partially quenched reference point: **D* lattices**

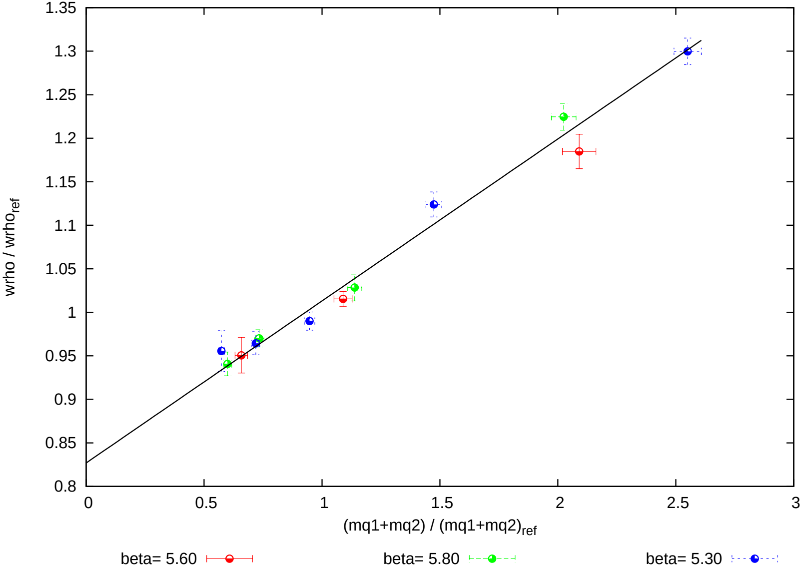


the physical volume is $L \simeq 1.9$ fm

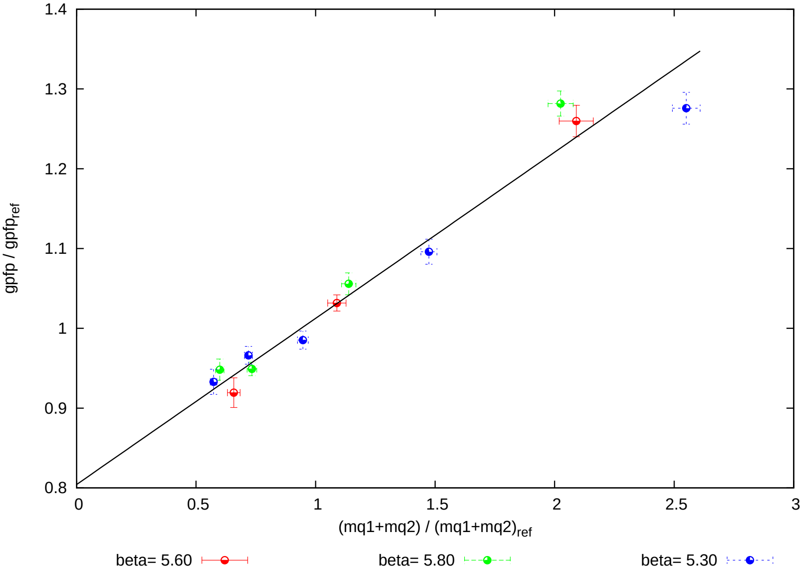
universality: pseudoscalar meson masses



universality: vector meson masses



universality: pseudoscalar meson decay constants



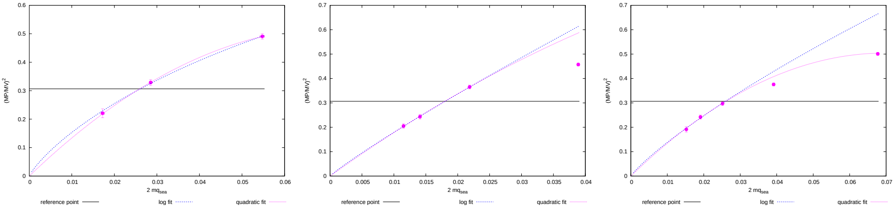
full QCD reference point

another possibility to fix the reference point is:

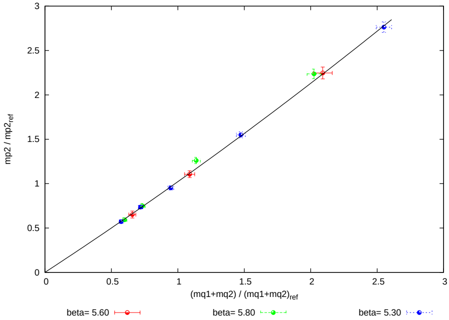
- at fixed bare coupling we consider only the full QCD observables $\mathcal{O}(m_{\rm sea}, m_{\rm sea})$ and we find the value $m_{\rm ref}$ such that

$$R(m_{\rm ref}) = \left[\frac{M_P(m_{\rm ref}, m_{\rm ref})}{M_V(m_{\rm ref}, m_{\rm ref})}\right]^2 = \left[\frac{M_K}{M_{K^\star}}\right]^2$$

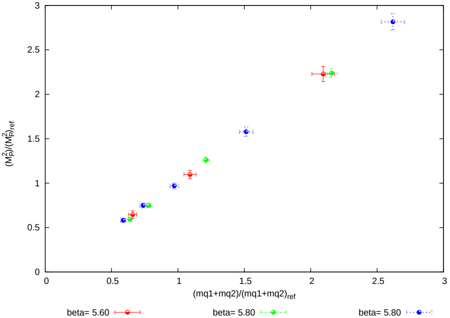
- then we interpolate $\mathcal{O}(m_{\rm sea}, m_{\rm sea})$ in order to get $\mathcal{O}(m_{\rm ref}, m_{\rm ref})$



reference points comparison: pseudoscalar meson masses

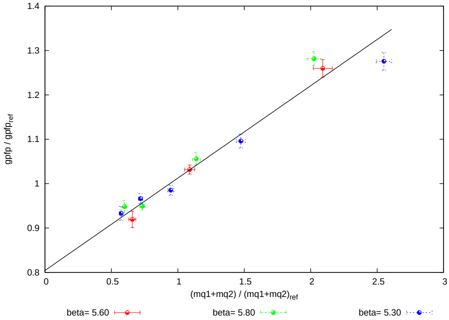


partially quenched reference point

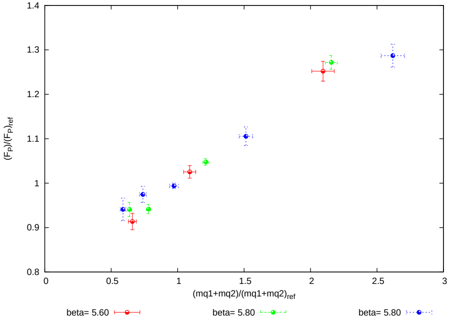


full QCD reference point

reference points comparison: pseudoscalar meson decay constants



partially quenched reference point



full QCD reference point

conclusions

- we are able to simulate with reasonable volumes and reasonable lattice spacings pions of masses from 500 MeV down to 300 MeV.

- the inclusion of the sea quarks complicates the extraction of the hadronic observables
  - multi hadron states contaminate 2pt correlation functions
  - previous results for the vector meson masses could have been over estimated

- masses and decay constants of the mesons containing a light and a "non–light" quark can be computed with good precision (in the "chiral limit")
  - unquenching effects saturate

- as a consequence, the p.q. reference point can be extracted with good precision
  - note: we use p.q. **only** to set the scale

- to check possible systematics due to finite volume effects we are currently simulating a volume of about 2.5 fm.