Latest results from the LSD collaboration

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The Lattice Strong Dynamics collaboration

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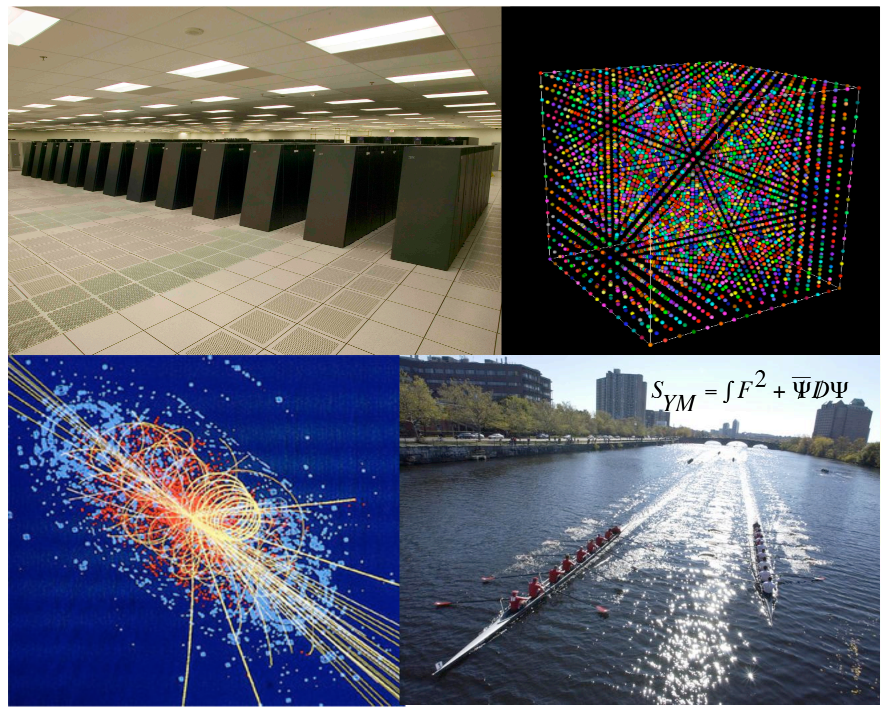


LHC
TeV physics

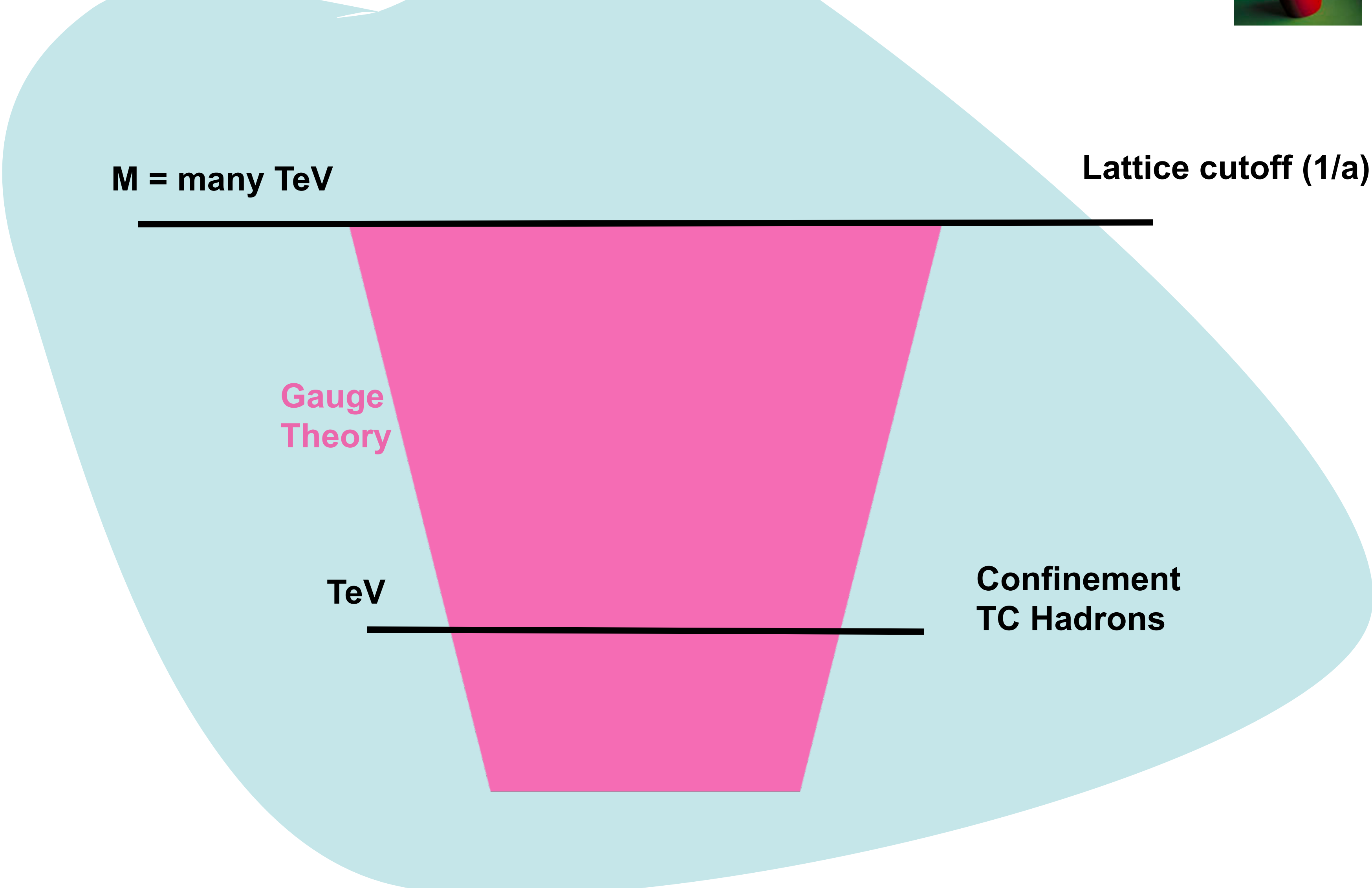
Our first thoughts

- TC and ETC models can use lattice non-perturbative input.
  - How do the properties of gauge theory change with N_f, N_C and R ?

- Chiral condensate enhancement $\frac{\langle \overline{\psi}\psi \rangle}{F^3}$
- S parameter
- Particle spectrum
- Dirac operator eigenvalue spectrum

How should we proceed?

A slice of ETC



Choices

- ETC is complicated enough:
  stay with fundamental reps
- Start from something we know:
  lattice QCD -- SU(3) color
- Move slowly away from QCD and not too close to N_{fc}:
  first do 6 flavors
- Chiral and flavor symmetries are crucial:
  use DWF
- To be able to observe enhancement:
  use large cutoff (small a)
- To be able to make direct comparisons:
  Do a 2-flavor simulation at the same cutoff

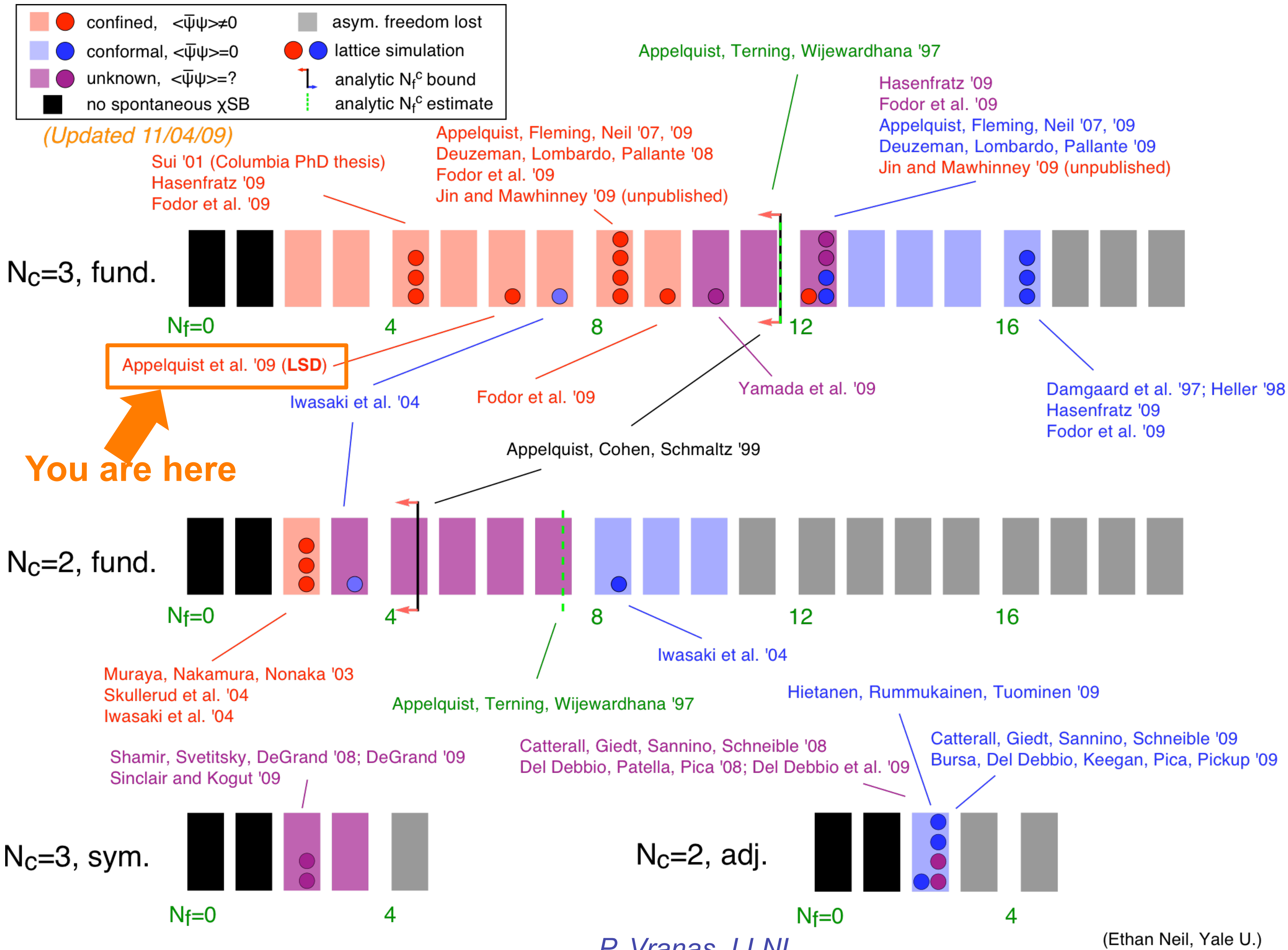
Higher demands

- Computing cost increases as $N_f^{3/2}$

- The lattice must have cutoff much larger than the confinement scale to take advantage of slower running. Larger lattice needed as we approach the IRFP.

- We do not know the answer

Current landscape



Simulations

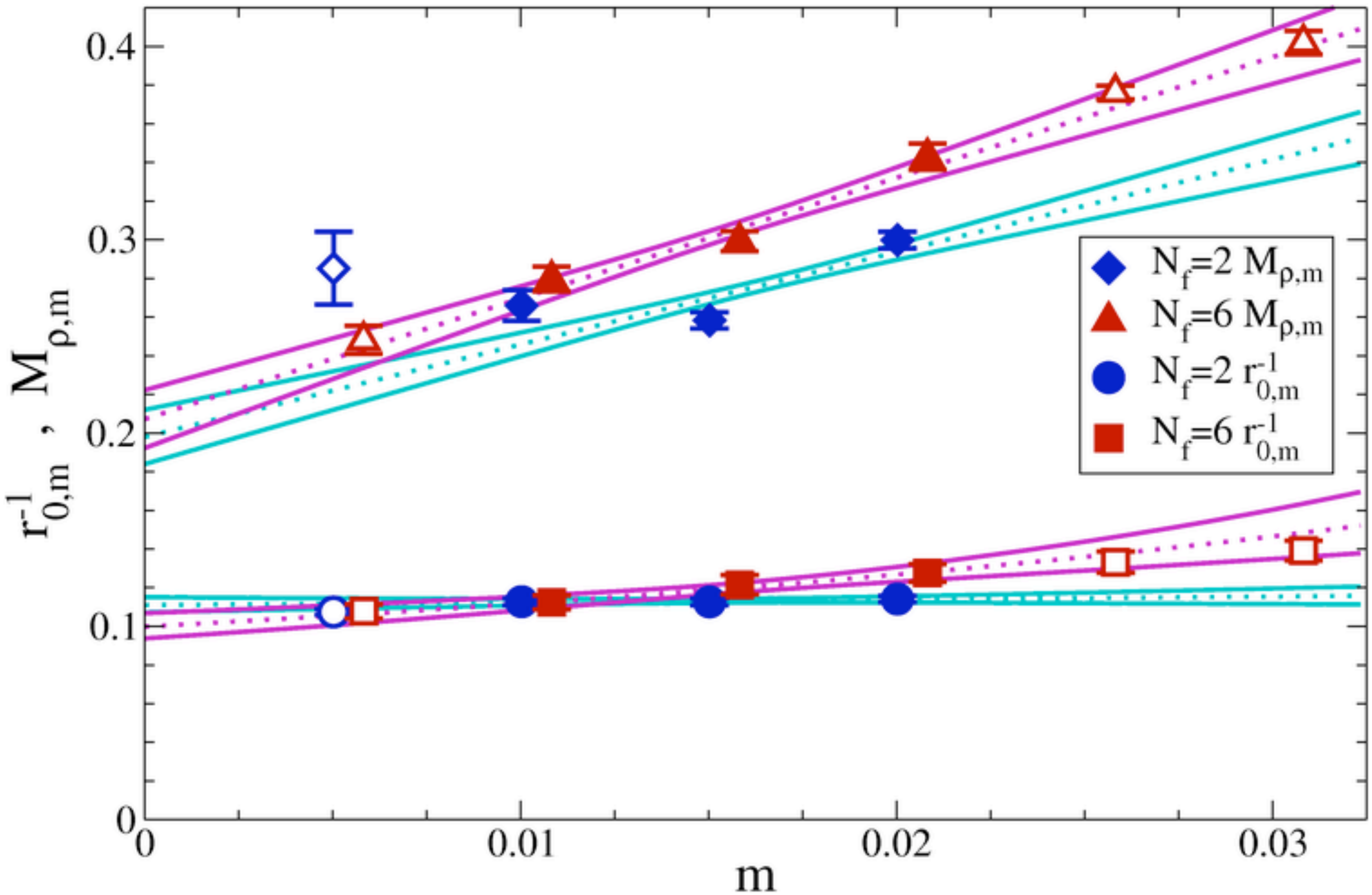
- Lattice Volume is 32^3 x 64
- Iwasaki gauge action with DWF at $L_s = 16$
- Input fermion masses $m_f = 0.005$ to 0.03
- $m_{res} \sim 8\text{x}10^{-4}$ (6f), $3\text{x}10^{-5}$ (2f) ➔ $m = m_f + m_{res}$
- $M_m L > 4$
- HMC, multi-level simplectic integrator

  mass preconditioning

  chronological inversion

  CPS
- 6-flavor $\beta = 2.1$ ←➔ 2-flavor $\beta = 2.7$
- About 1,000 configurations per point

Scales



Reasonable distance from cutoff with M_ρ~ cutoff / 5

Chiral perturbation theory

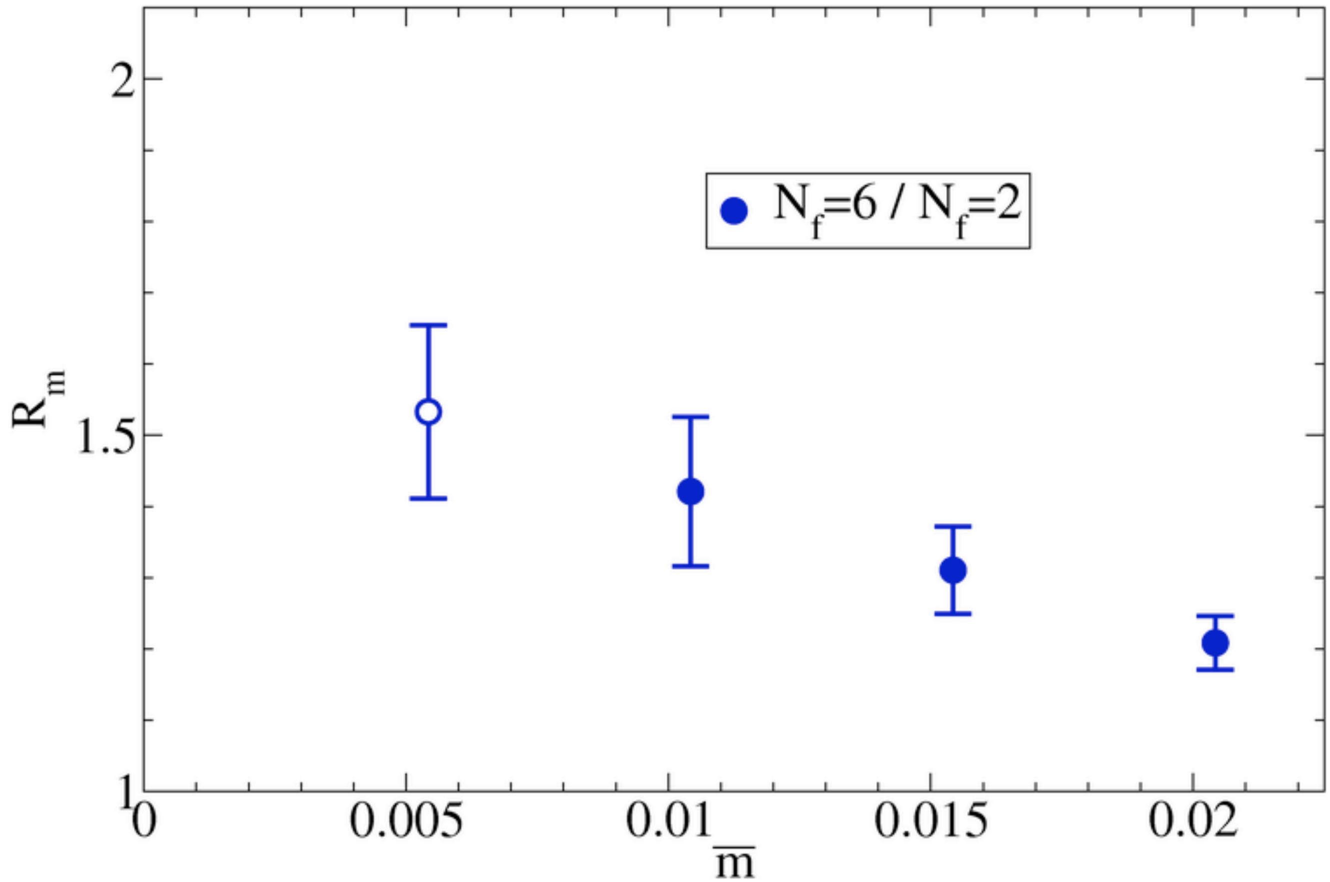
$$M_m^2 = \frac{2m\langle\bar\psi\psi\rangle}{F^2}\left\{1 + zm\left[\alpha_M + \frac{1}{N_f}\log(zm)\right]\right\}$$

$$F_m = F\left\{1 + zm\left[\alpha_F - \frac{N_f}{2}\log(zm)\right]\right\}$$

$$\langle\bar\psi\psi\rangle_m = \langle\bar\psi\psi\rangle\left\{1 + zm\left[\alpha_C - \frac{N_f^2-1}{N_f}\log(zm)\right]\right\}$$

- ★ Log coefficients of $F_m, \langle\bar\psi\psi\rangle_m \sim N_f$
- ★ $\alpha_C \sim 1/a^2 \rightarrow \langle\bar\psi\psi\rangle_m$ difficult to measure
- ★ Instead measure (GMOR) $\dfrac{M_m^2}{2mF_m} \rightarrow \dfrac{\langle\bar\psi\psi\rangle}{F^3} \quad \text{at} \quad m \rightarrow 0$

6-flavor vs. 2-flavor enhancement

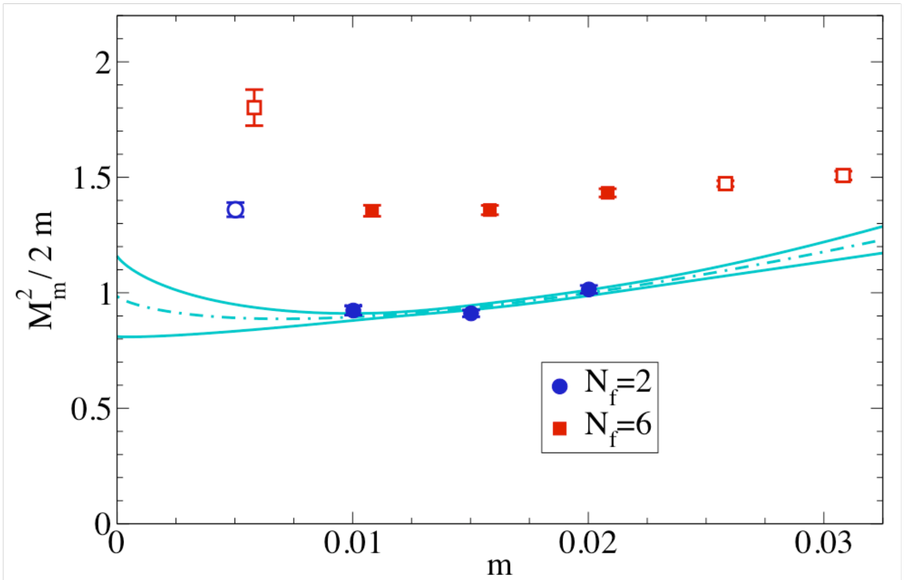


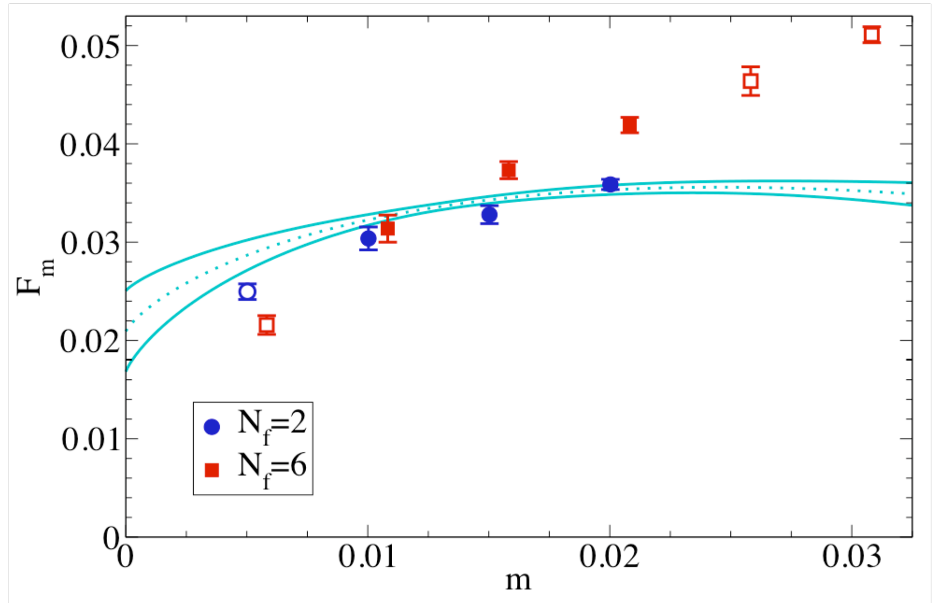
★ $R_m = [M_m^2/2mF_m]_{6f} \ \ / \ \ [M_m^2/2mF_m]_{2f}$

★ Can compare directly 6f to 2f because they have same cutoff

★ Observing **~ 50% enhancment**

xPT fits and bound



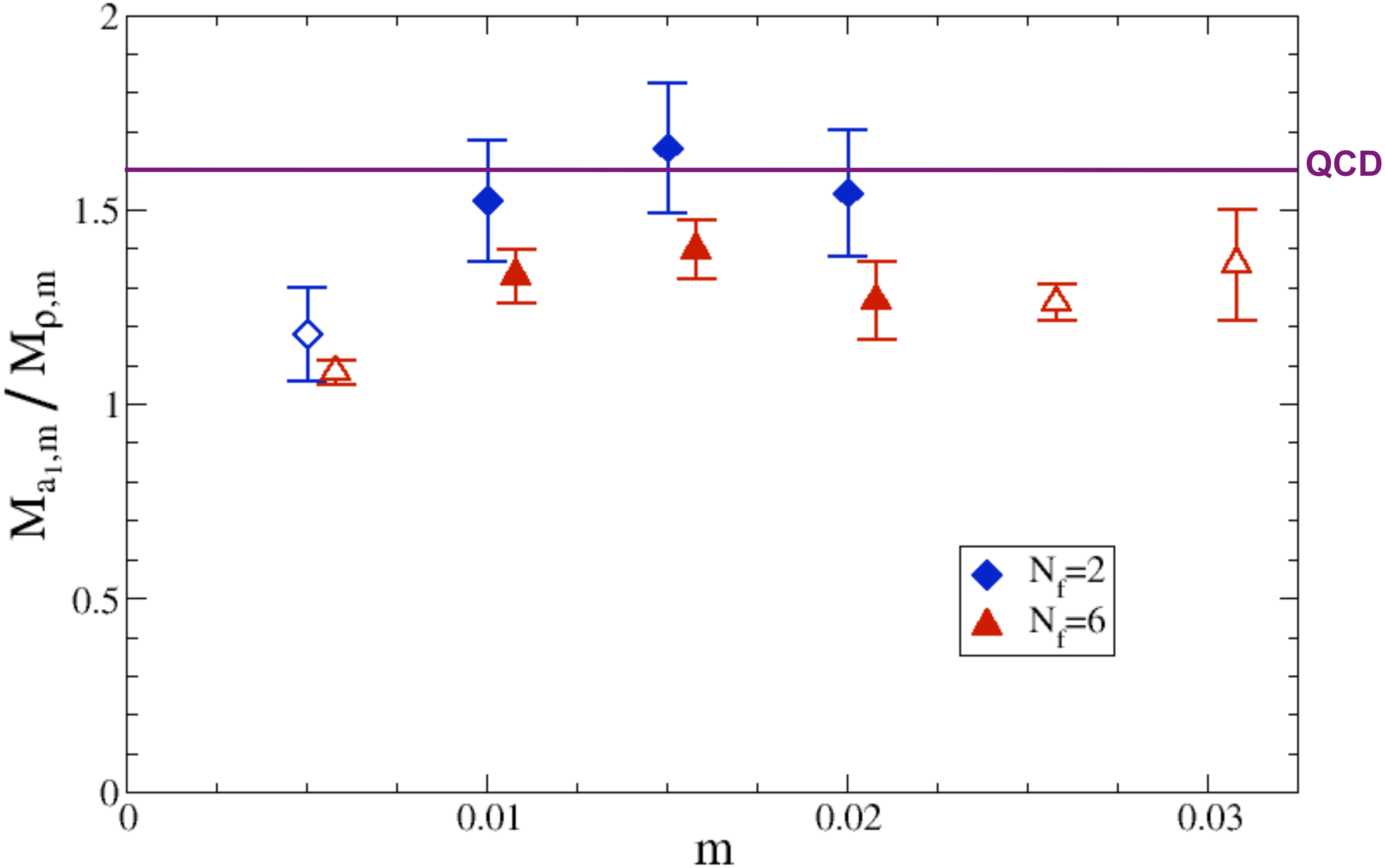


- ★ 2f give a reasonable combined fit for $M_m^2/2mF_m,\ F_m,\ \langle\bar\psi\psi\rangle_m$
- ★ 2f agree with phenomenology: $\langle\bar\psi\psi\rangle/F^3 = 47.1(17.6)_{\rm latt} = 36.2(6.5)_{\overline{\rm MS}}$
- ★ 6f because of larger slope need smaller masses (➔ larger lattices)
- ★ Linear fits on the 6-flavor data give a bound:

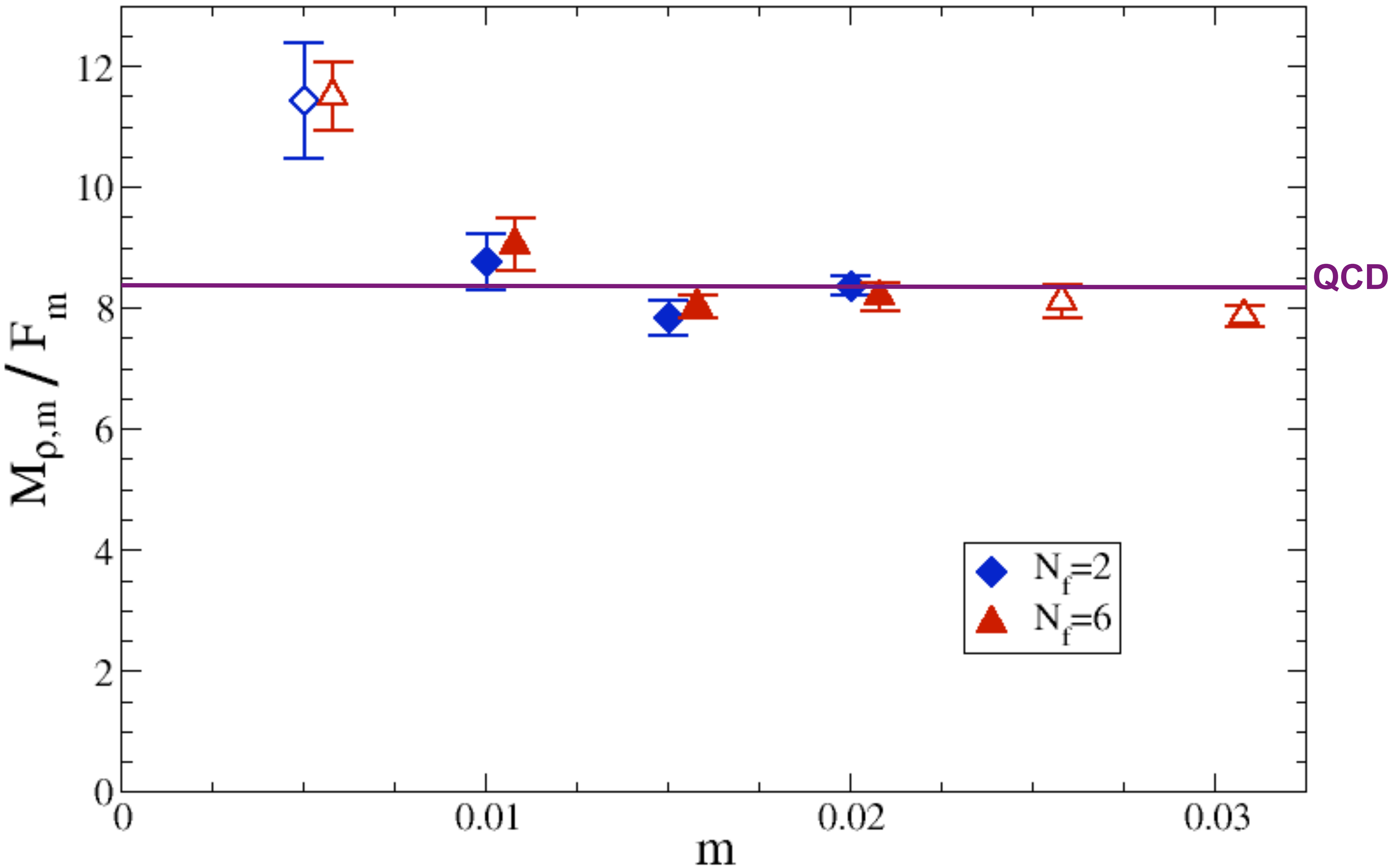
  28% increase: [= 47.1(17.6)]$_{2f}$ [> 60.0(8.0)]$_{6f}$

  absence of enhancement excluded at 73% confidence level

Hadron spectrum



Hadron spectrum



Salient features: Topology

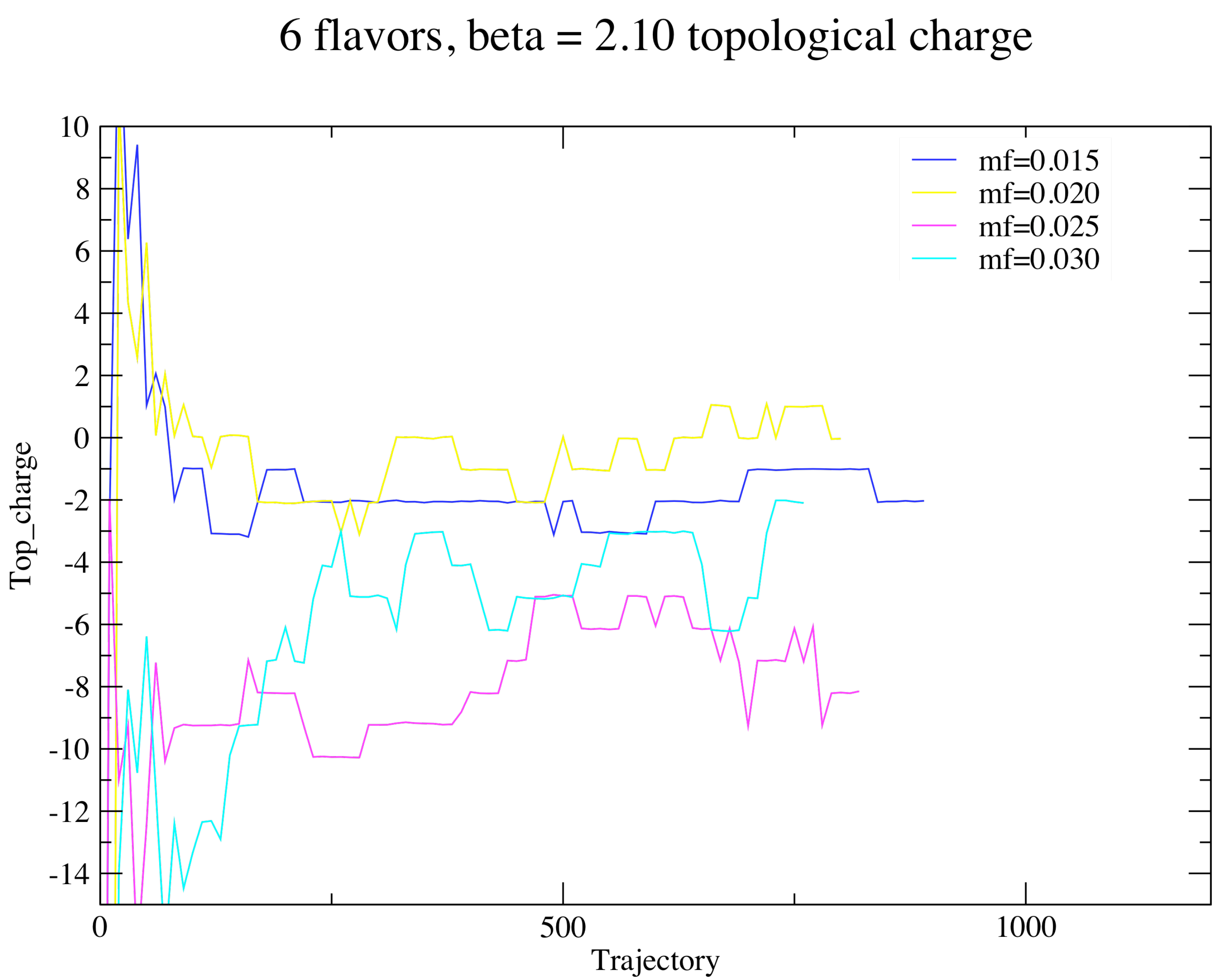
⌘ At small lattice spacing the barriers between TC sectors are large

⌘ At small m DWF HMC encounter barriers in changing global topology Q

⌘ At large volume Q is irrelevant but for us it is a finite size effect

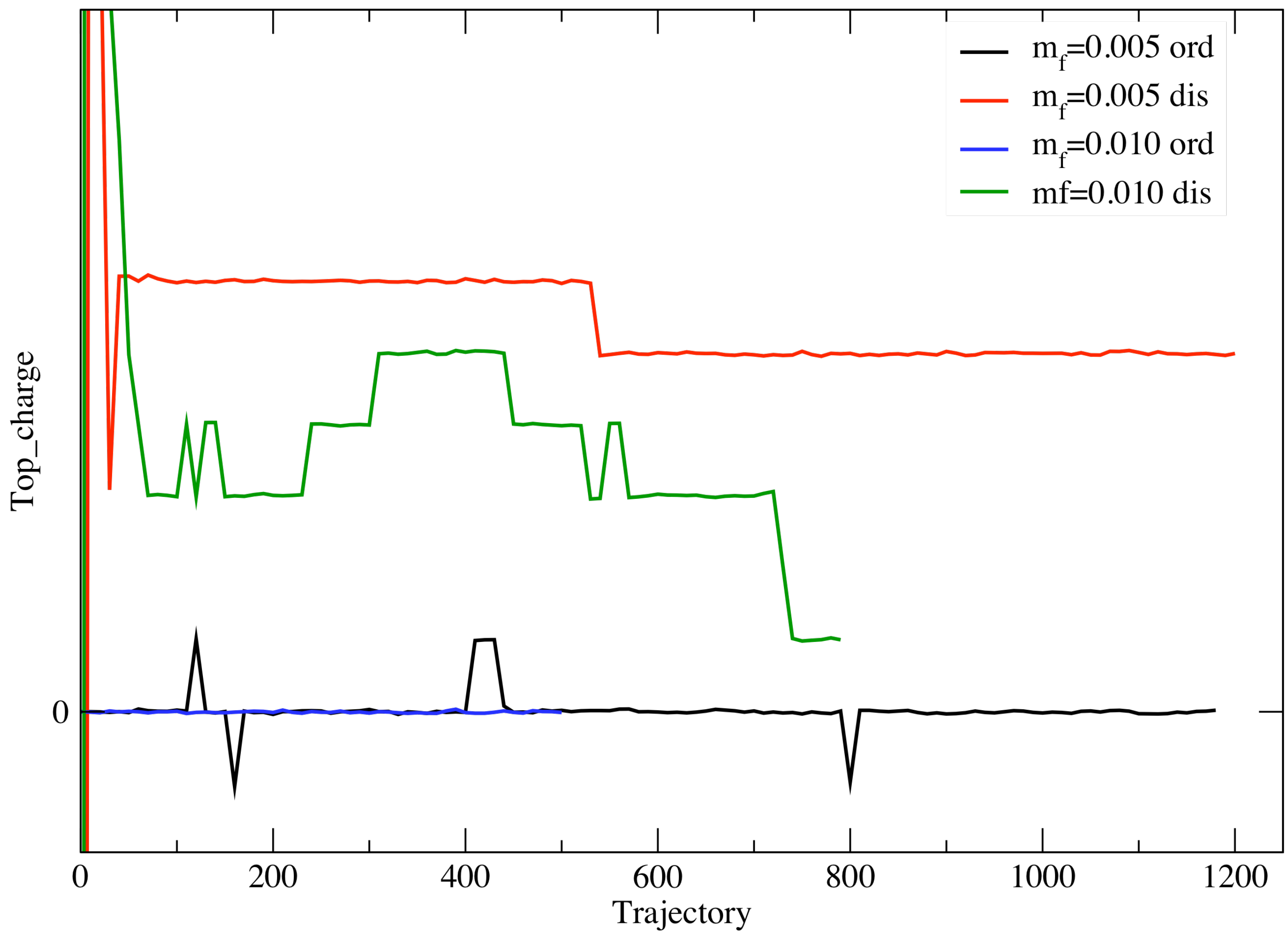
⌘ For $0.01 \leq m$, Q evolves sufficiently: for $m = 0.005$ it does not

Topology (preliminary)



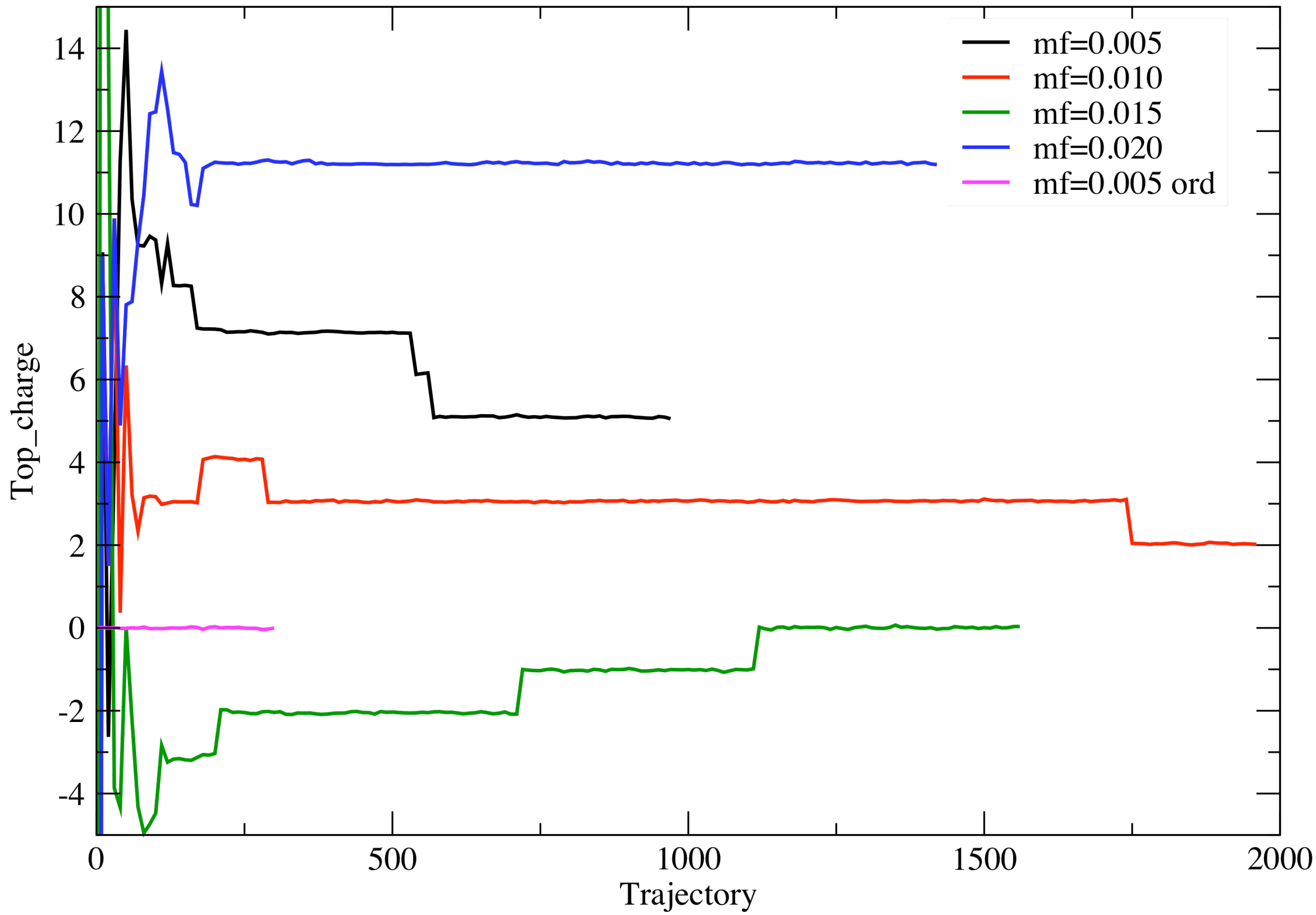
Topology (preliminary)

6 flavors, beta = 2.10 topological charge



Topology (preliminary)

2 flavors, beta = 2.70 topological charge



150 million core hours on LLNL BG/L

Near term LSD plans

- 9-flavors $SU(3)_c$ fundamental at the same lattice spacing
- Measure S at 2, 6 and 9 flavors
- Measure Dirac spectrum at 2, 6 and 9 flavors
- Fundamental $SU(2)_c$

Conclusions

- 2 and 6 flavors $SU(3)_c$ fundamental at same lattice spacing
- Condensate enhancement larger than 50%
  Excluded no-enhancement at 73% confidence level
- Hadron spectrum deviations