Large volume results in SU(2) with adjoint fermions

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IRFP scaling & spectrum of the theory

Scaling laws for the spectrum in the neighbourhood of a fixed point:

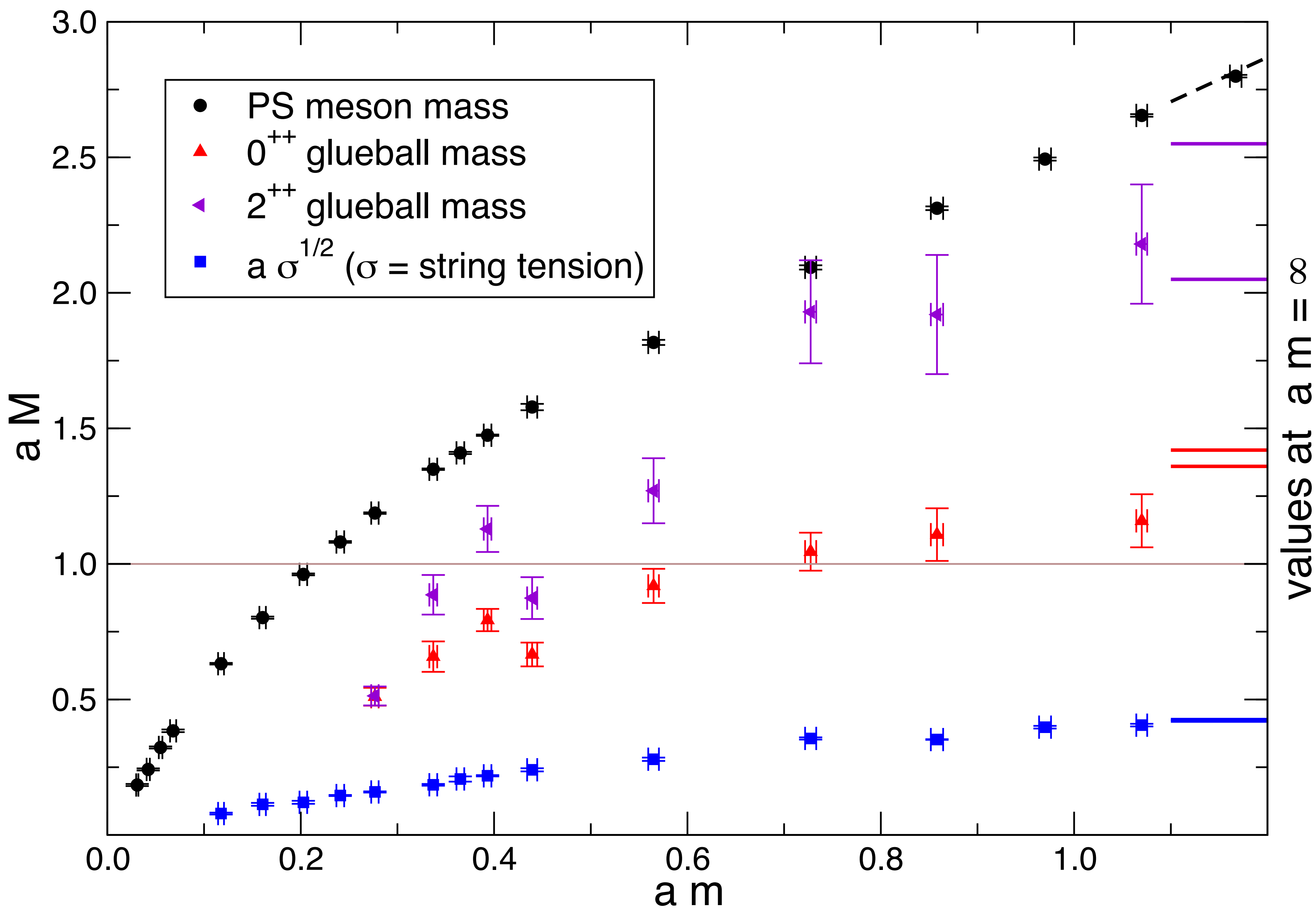
$$\boxed{M_H \propto \mu\, m^{\frac{1}{1+\gamma_*}}}$$

[Luty 08, DeGrand 09, LDD et al 09]

$\mathcal{O}$	def	$\langle 0\vert\mathcal{O}(0)\vert J^{\mathrm{P(C)}}(p)\rangle$	$J^{\mathrm{P(C)}}$	$\Delta_{\mathcal{O}} = d_{\mathcal{O}} + \gamma_{\mathcal{O}}$	$\eta_{G[F]}$
S	$\bar{q}q$	G_S	0^{++}	$3-\gamma_*$	$(2-\gamma_*)/y_m$
S^a	$\bar{q}\lambda^a q$	G_{S^a}	0^{+}	$3-\gamma_*$	$(2-\gamma_*)/y_m$
P^a	$\bar{q}i\gamma_5 q$	G_{P^a}	0^{-}	$3-\gamma_*$	$(2-\gamma_*)/y_m$
V	$\bar{q}\gamma_\mu q$	$\epsilon_\mu(p) M_V F_V$	1^{--}	3	$1/y_m$
V^a	$\bar{q}\gamma_\mu\lambda^a q$	$\epsilon_\mu(p) M_V F_{V^a}$	1^{-}	3	$1/y_m$
A^a	$\bar{q}\gamma_\mu\gamma_5\lambda^a q$	$\epsilon_\mu(p) M_A F_{A^a}\ [ip_\mu F_{P^a}]$	$1^{+}\ [0^{-}]$	3	$1/y_m\ [1/y_m]$

Spectrum for SU(2) + 2 adjoint fermions

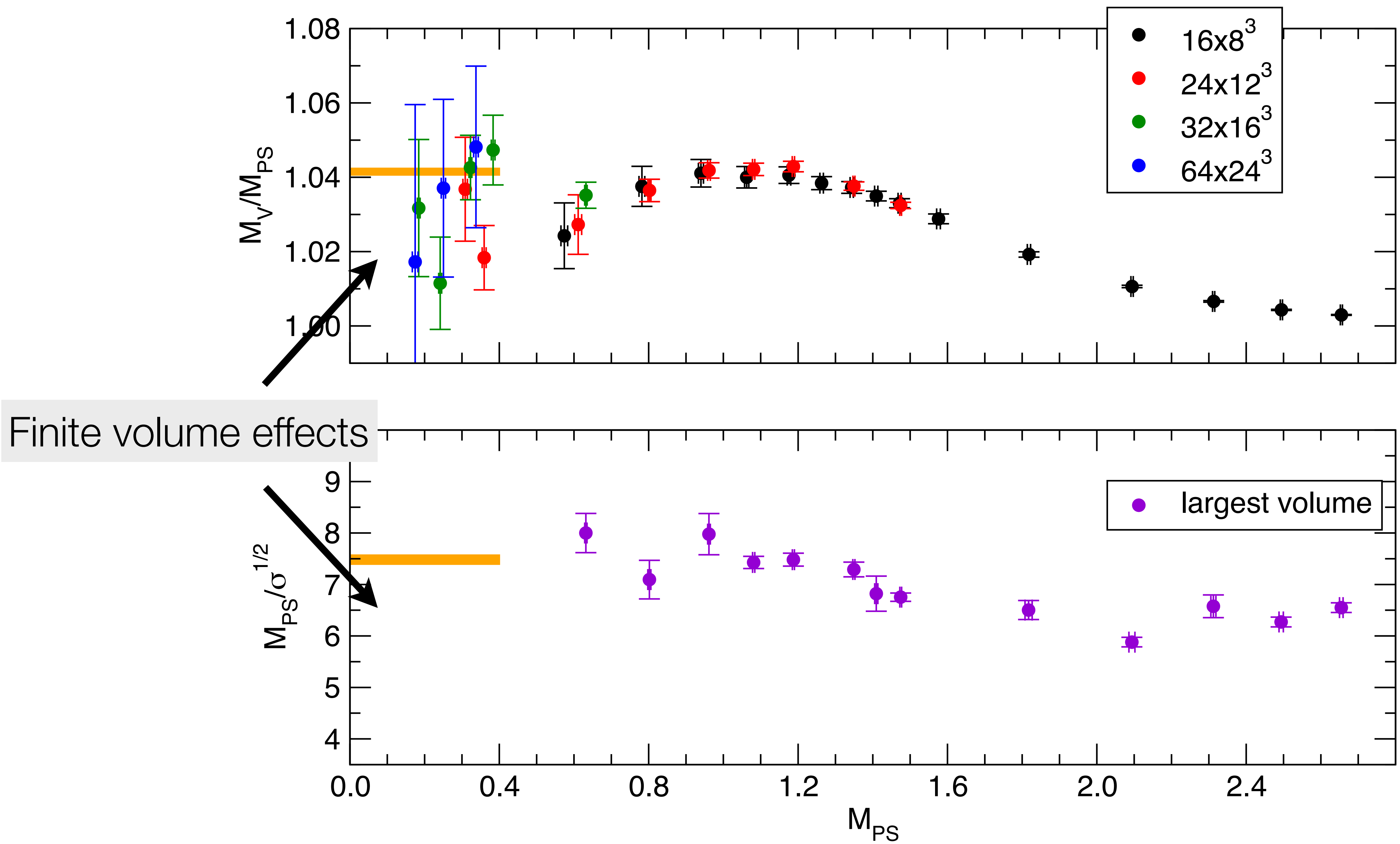
- Overall picture: non-singlet meson states & glue



JK:"*Does the system have a chance to break chiral symmetry?*"

[LDD et al 09]

Finite volume effects?

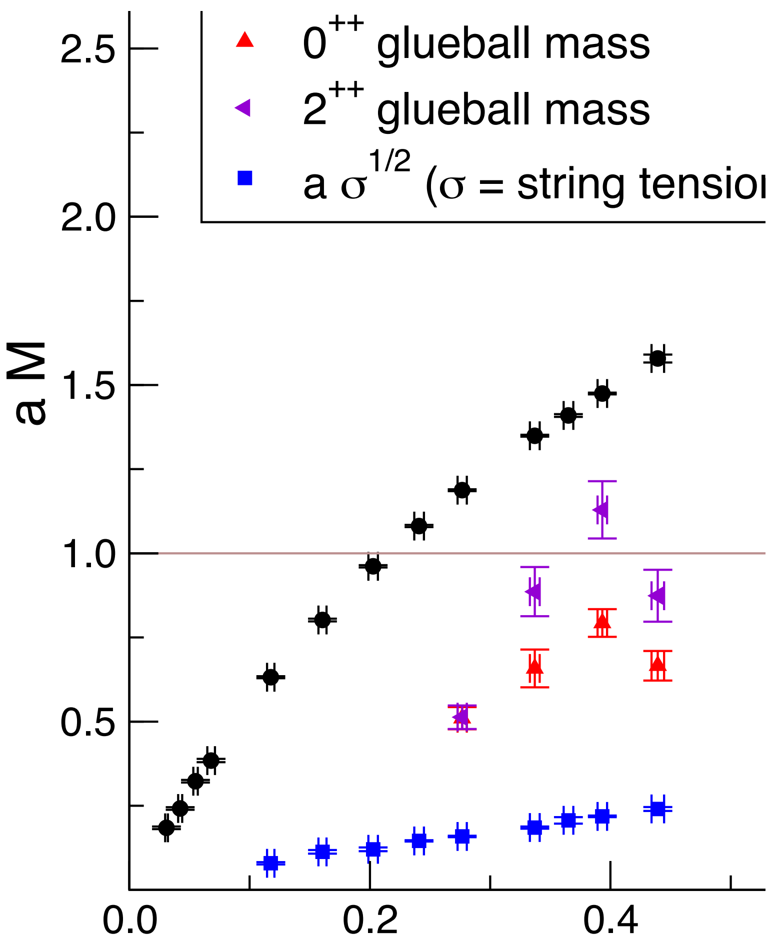


Qualitative evidence for a conformal spectrum

Need large lattices and small masses to control systematic errors

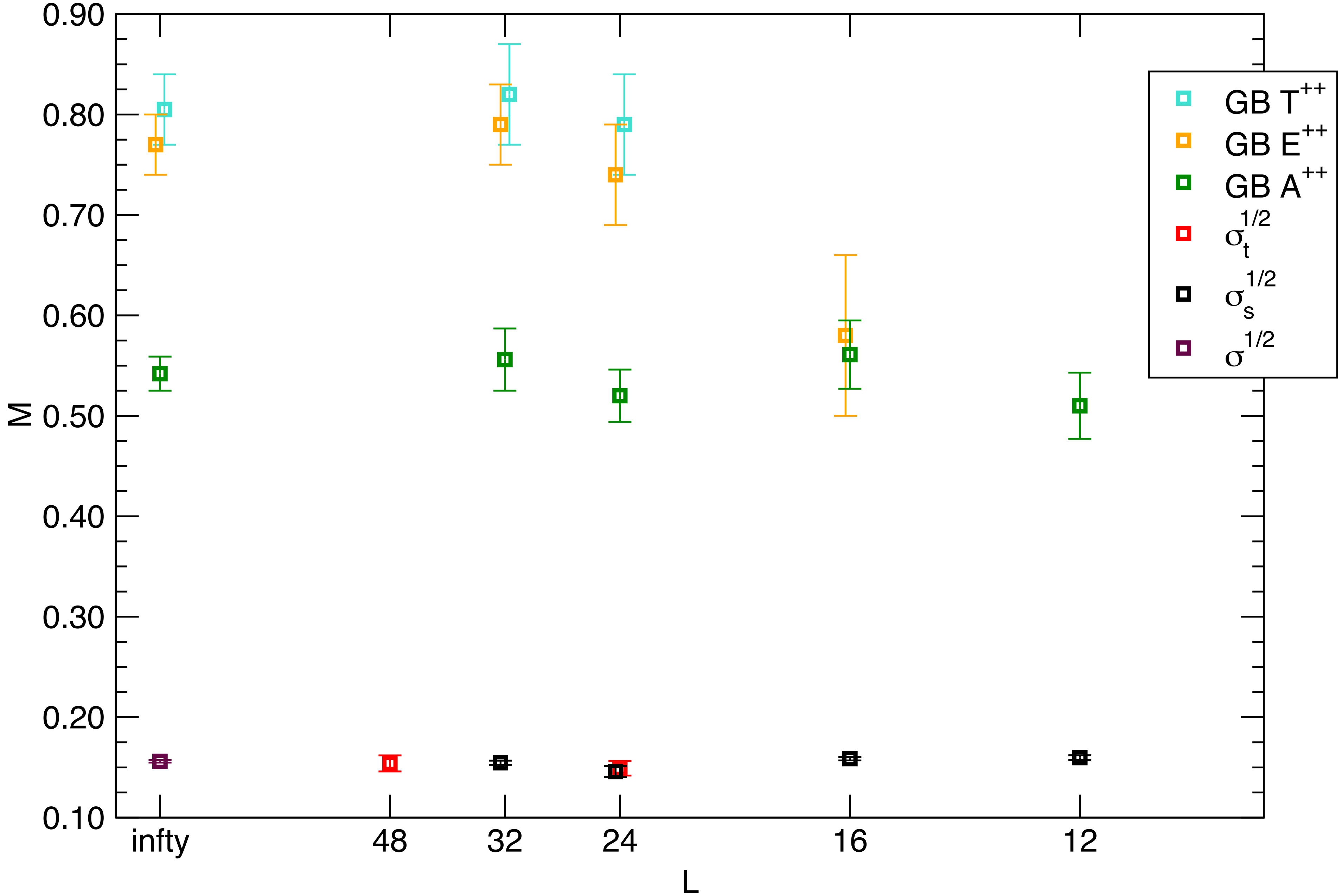
[LDD et al 11]

New lattices



lattice	V	$-am_0$	N_{traj}	t_{traj}	$\langle P \rangle$	τ	λ	τ_λ
A10	64×8^3	1.15	810	3	0.66536(22)	3.6(1.2)	0.2005(58)	1.42(31)
A11	64×12^3	1.15	530	1.5	0.66601(15)	1.93(59)	0.2054(40)	1.54(43)
C5	64×16^3	1.15	1500	1.5	0.665992(61)	2.32(46)	0.2116(16)	2.38(48)
D4	64×24^3	1.15	2387	1.5	0.665927(26)	3.92(79)	0.21478(70)	1.70(24)
F1	64×32^3	1.15	2541	1.5	0.665946(30)	3.37(62)	0.2115(12)	1.06(12)
G1	80×48^3	1.15	2200	1.5	0.665943(17)	5.1(1.2)	0.2237(17)	0.637(58)
B2	24×12^3	1.05	7819	1	0.647633(70)	6.79(99)	1.4936(51)	5.80(78)
C6	64×16^3	1.05	2648	1.5	0.647645(48)	4.63(96)	1.4389(36)	1.26(14)
D5	64×24^3	1.05	4000	1.5	0.647695(37)	3.56(53)	1.3906(45)	0.722(54)
F2	48×32^3	1.05	3590	1.5	0.647680(30)	4.28(74)	1.3708(49)	0.632(45)
TWA1	64×8^3	1.15	565	1.5	0.66665(22)	2.8(1.0)	0.5557(96)	0.85(18)
TWB1	64×12^3	1.15	741	1.5	0.66590(11)	2.96(96)	0.2709(48)	1.93(50)
TWC1	64×16^3	1.15	1162	1.5	0.665990(61)	2.91(73)	0.2484(17)	6.2(2.2)
TWD1	64×24^3	1.15	2701	1.5	0.665912(35)	4.63(95)	0.21840(88)	2.43(37)

Larger volumes - heavier mass



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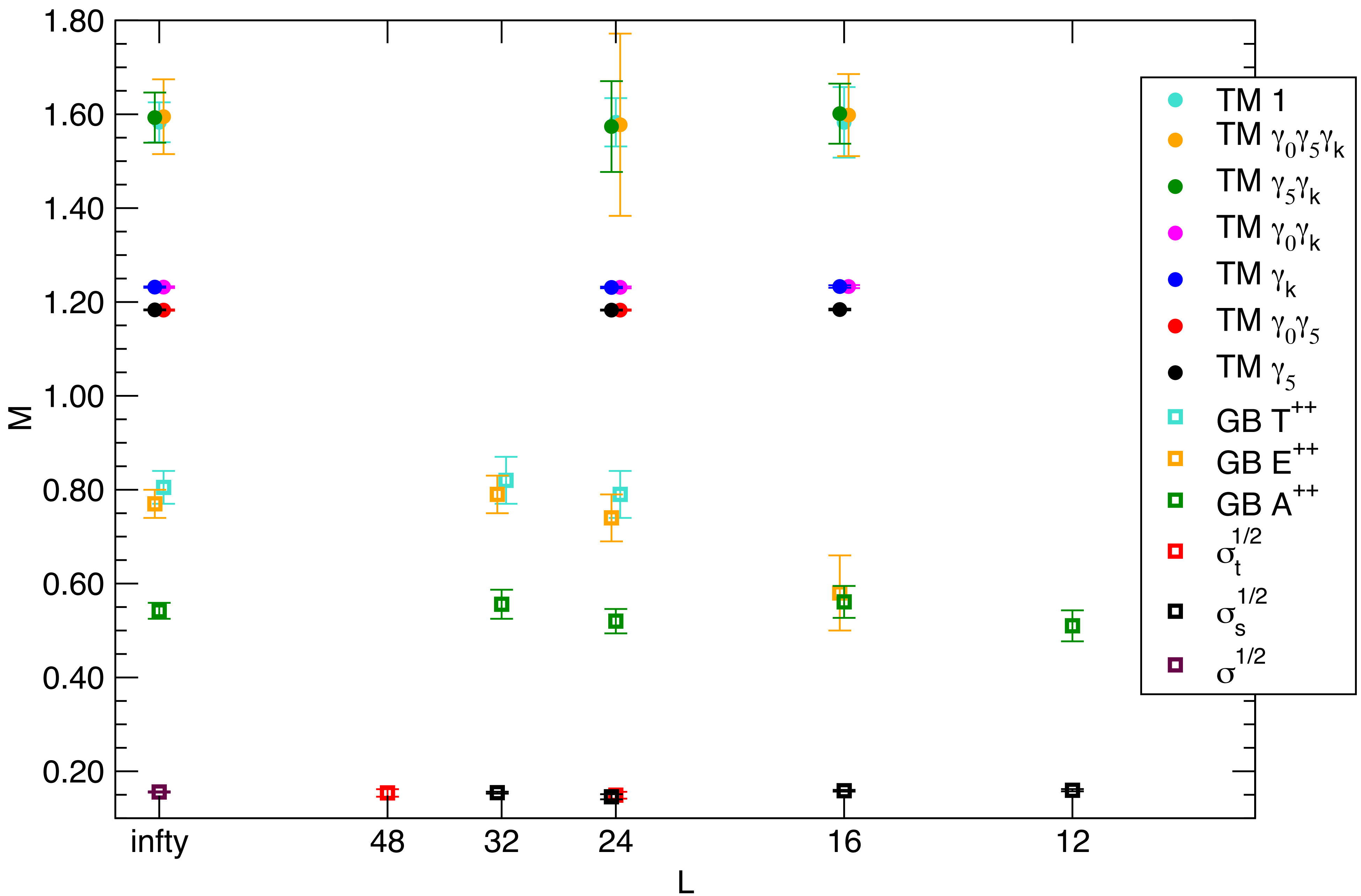
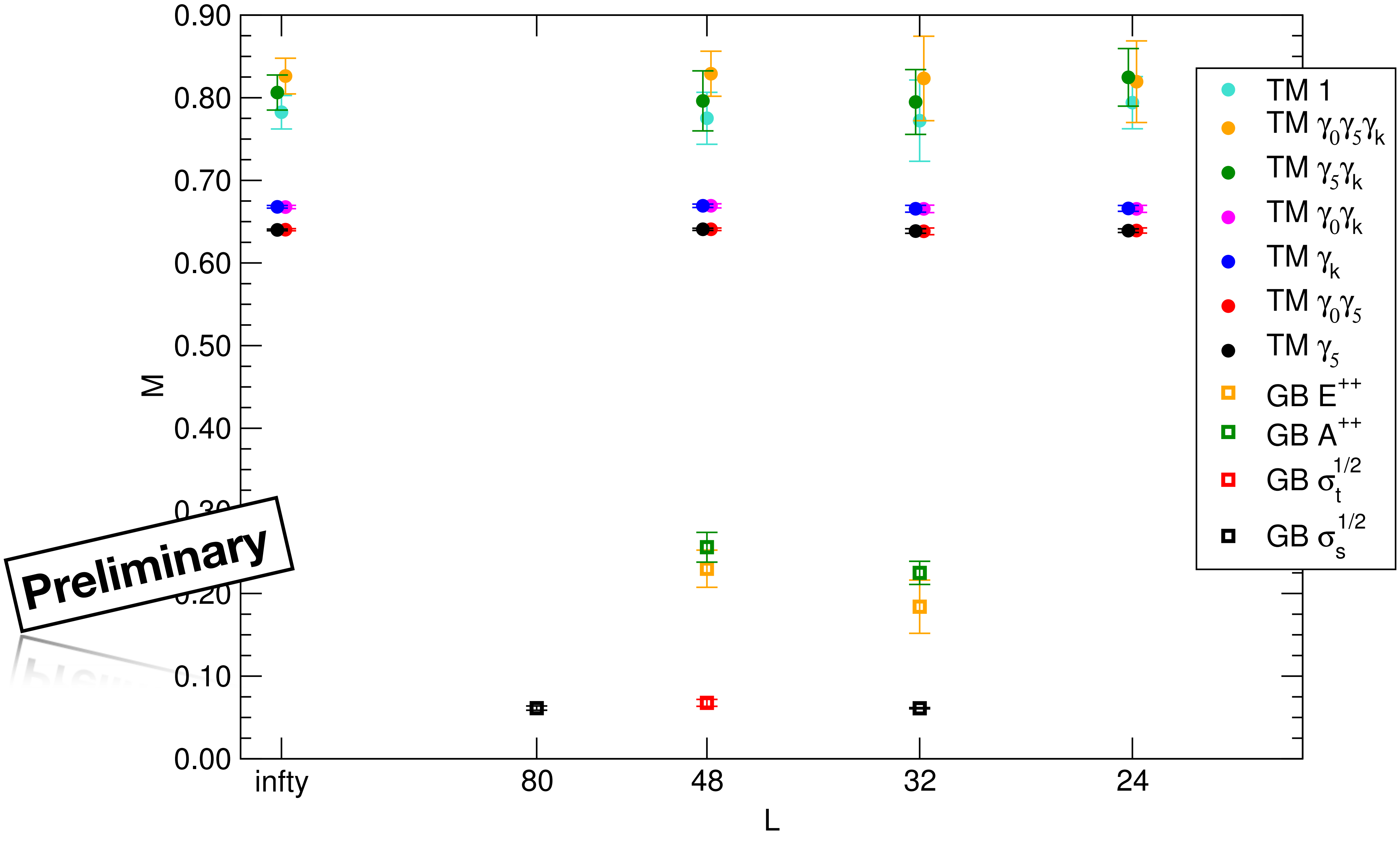
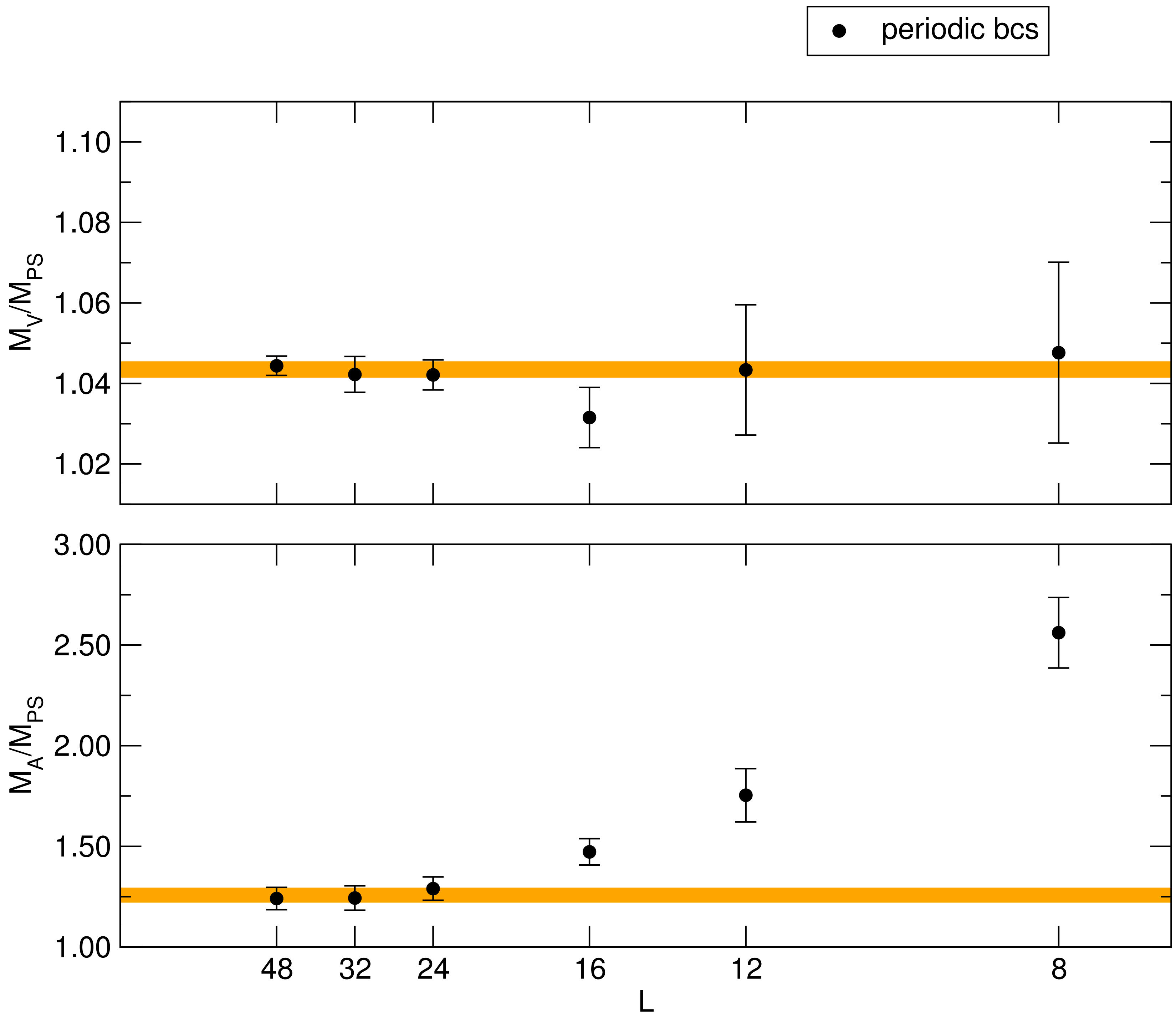


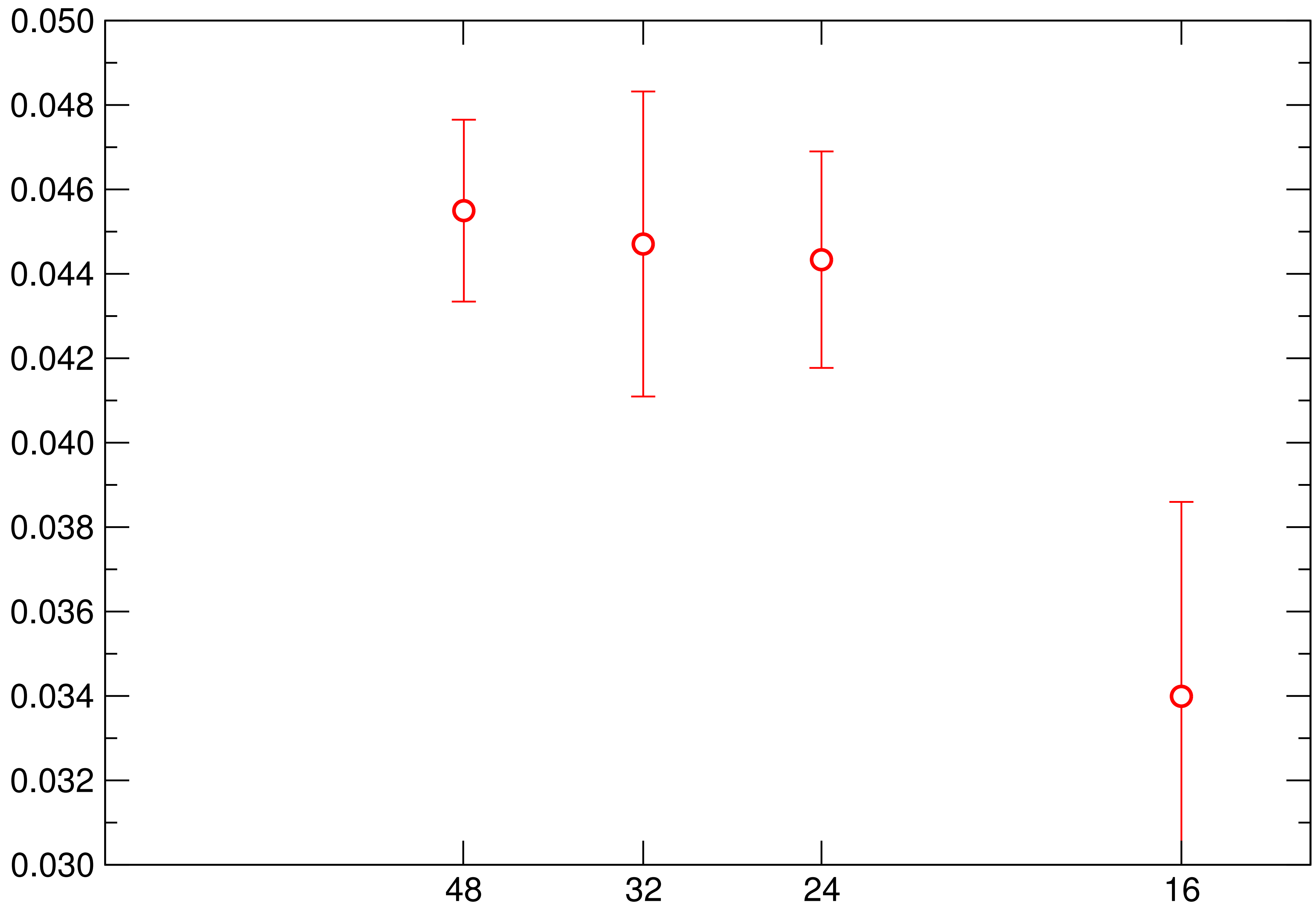
Larger volumes - lighter mass



Mesonic mass ratios - lighter mass



GMOR relation and FSE - lighter mass

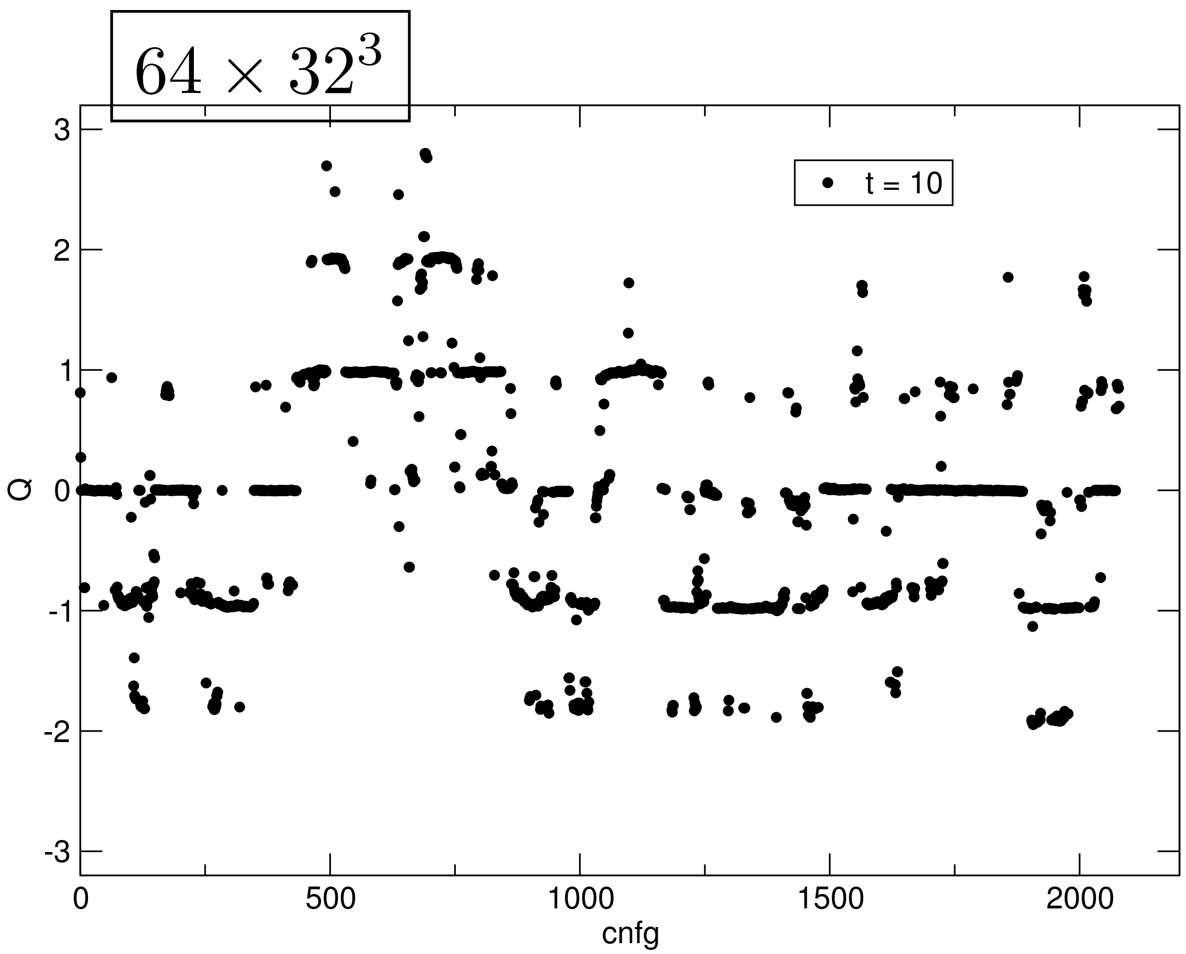


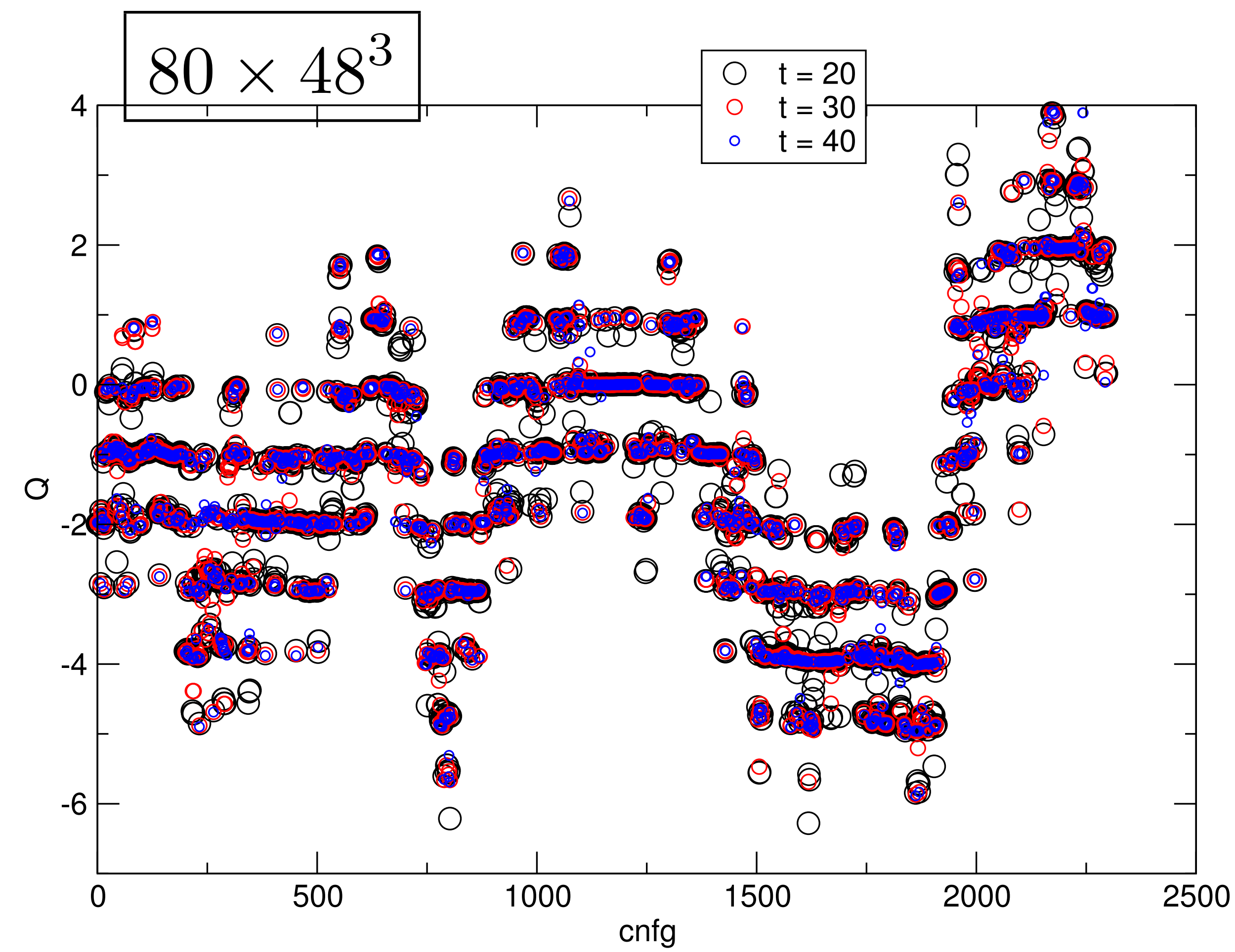
Topology sampling?

$$\partial_t V_t(x,\mu) = Z[V_t](x,\mu)V_t(x,\mu)$$

Topology defined using WF

$$Q = -\frac{a^4}{32\pi^2}\sum_x \epsilon_{\mu\nu\rho\sigma}\,\mathrm{tr}\left[G_{\mu\nu}(x)G_{\rho\sigma}(x)\right]$$





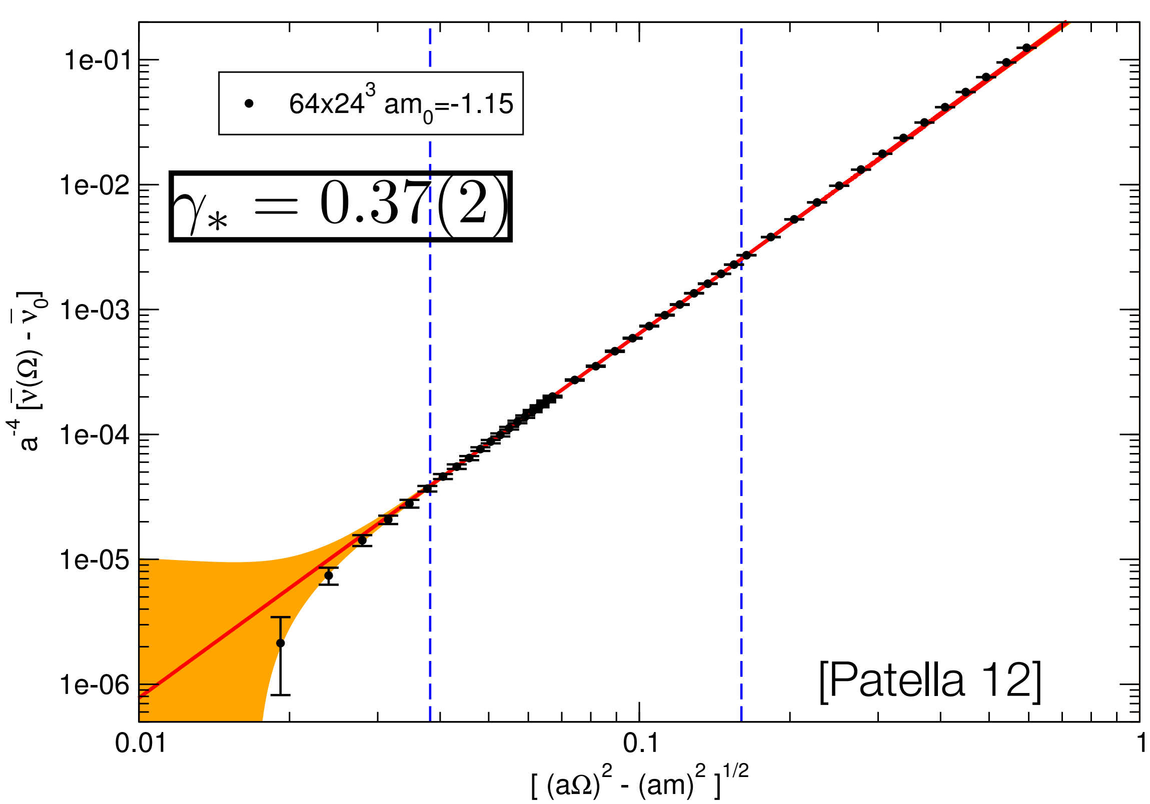
Dirac Eigenvalues

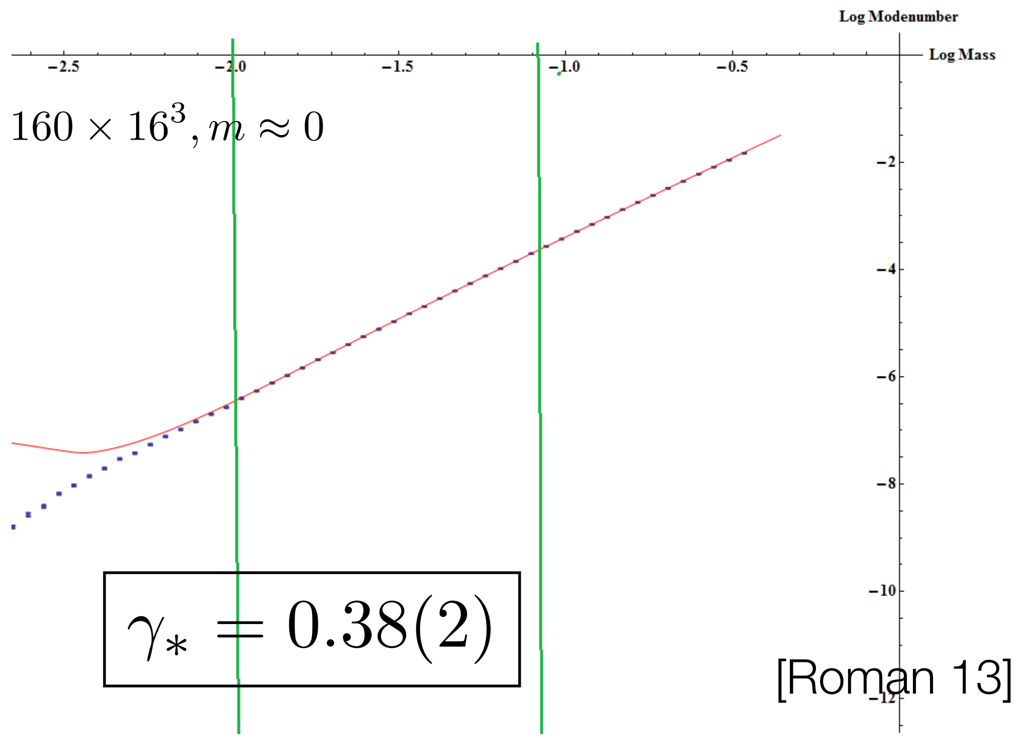
Scaling of the eigenvalue density:

$$\langle \bar{q}q \rangle \overset{m\to 0}{\sim} m^{\eta_{\bar{q}q}} \quad \Leftrightarrow \quad \rho(\lambda) \overset{\lambda\to 0}{\sim} \lambda^{\eta_{\bar{q}q}} \, .$$

[DeGrand 09, LDD & Zwicky 10, Patella 12]

Measure the mode number of $D^\dagger D + m^2 \longrightarrow \nu(M,m) = C + \left(M^2 - m^2\right)^{2/(1+\gamma_*)}$





Finite-size scaling

FSS for the masses in the spectrum:

$$\boxed{M_H = L^{-1} f(x)} \qquad\qquad x = L^{y_m} m$$

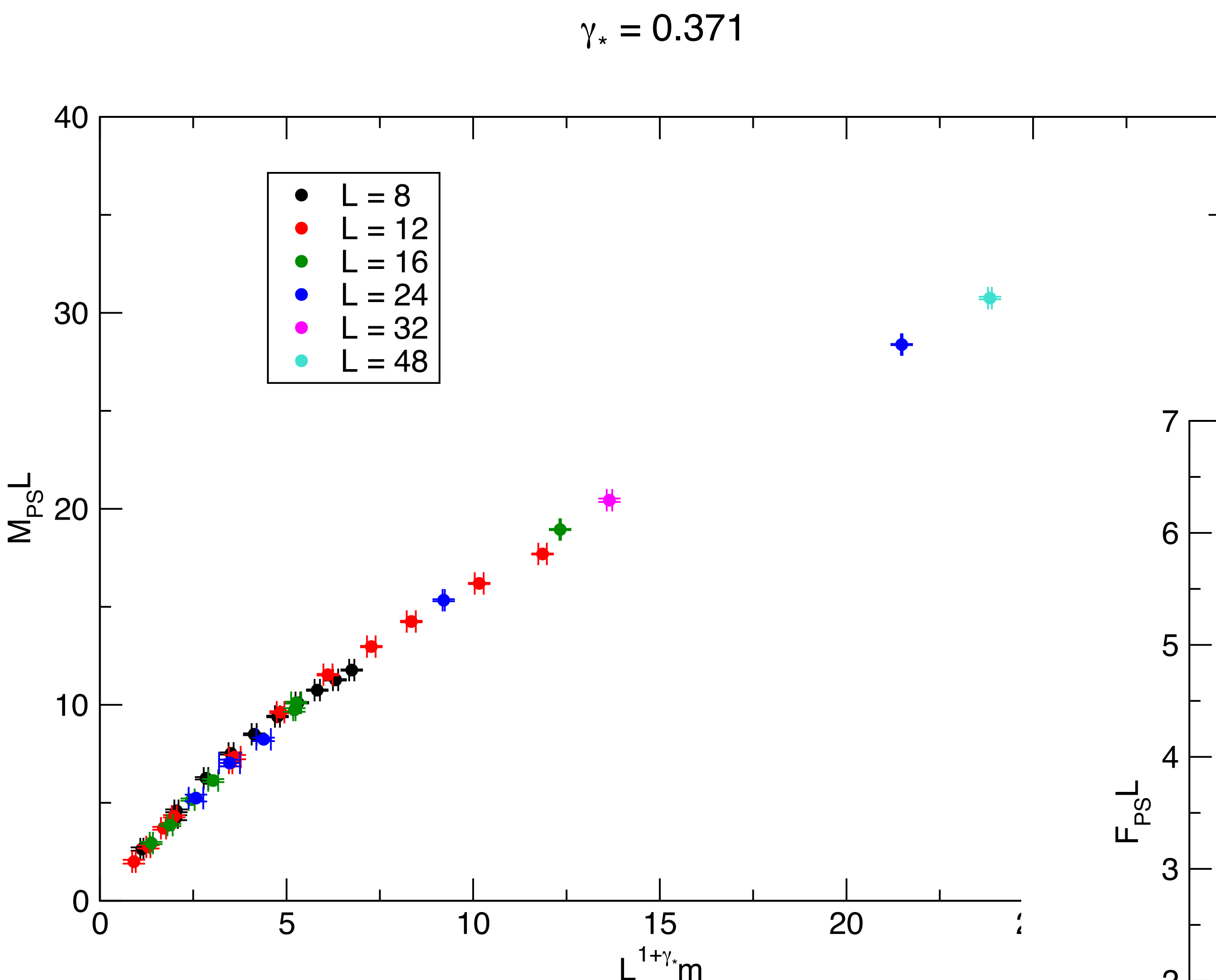
In order to recover the correct scaling with m at **infinite volume**:

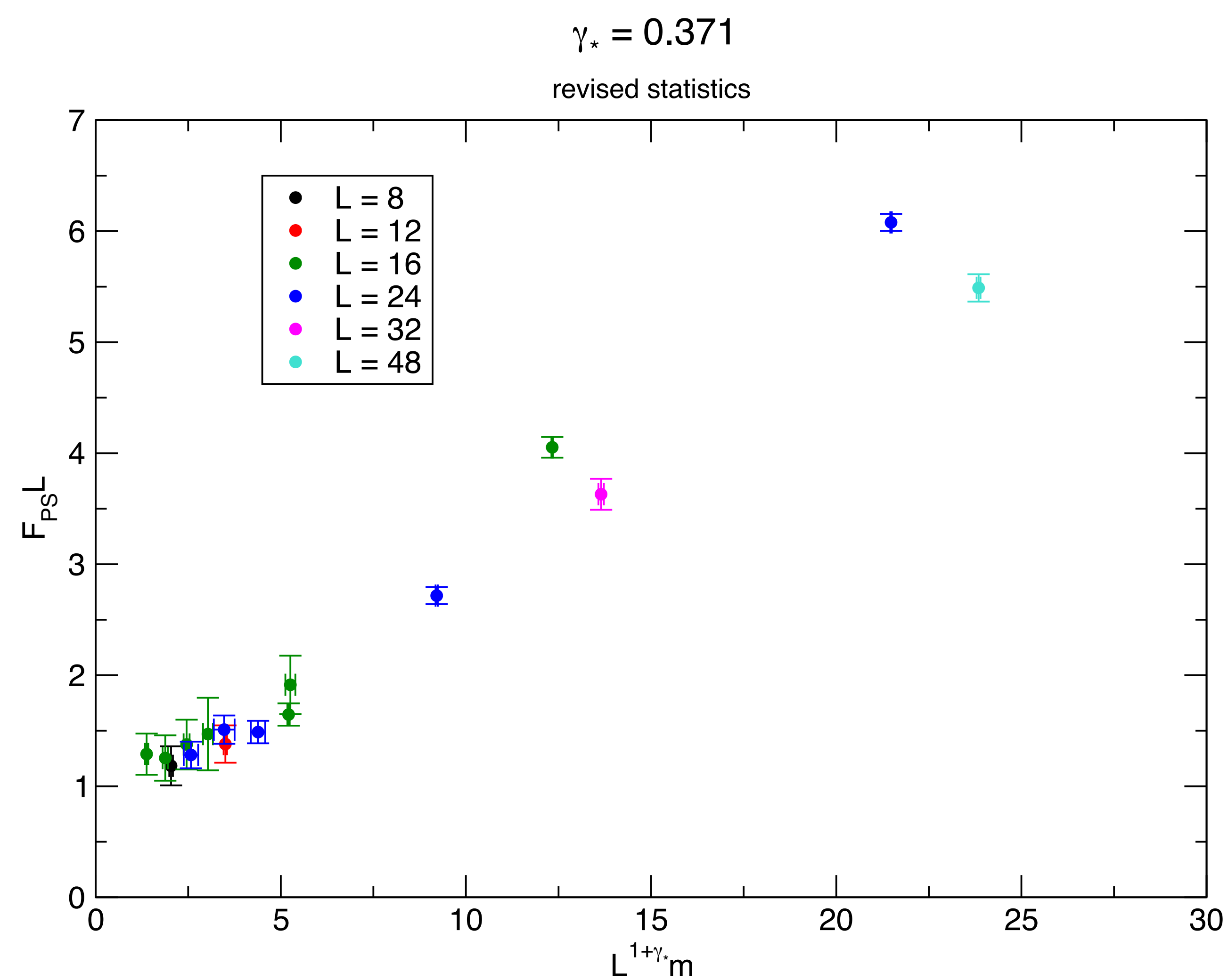
$$f(x) \sim x^{1/y_m}\,, \quad \text{as } x \to \infty$$

If we go to the massless limit, at **fixed** volume and cut-off, the masses of the states in the spectrum of the theory saturate and scale as:

$$M_H \propto L^{-1}$$

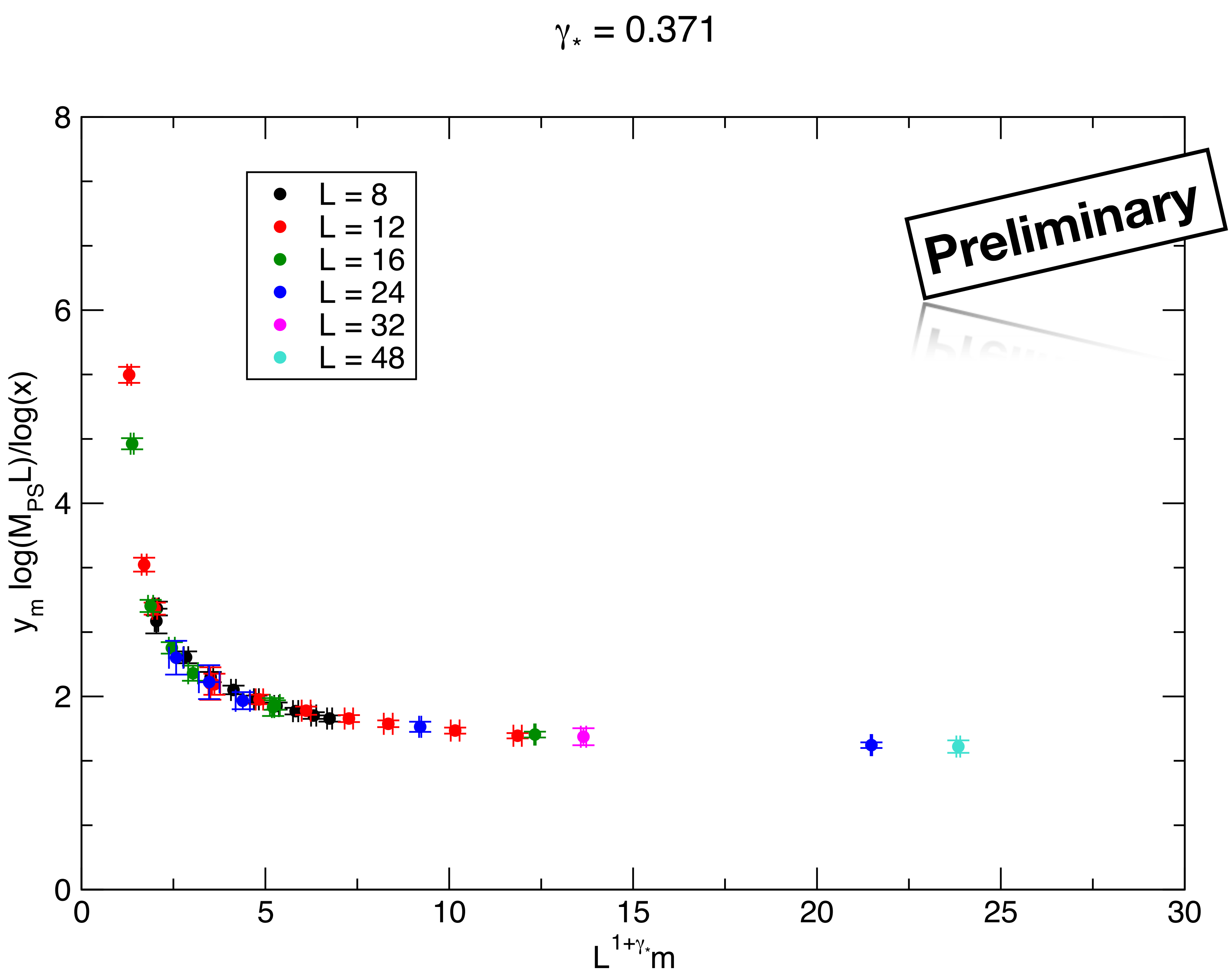
FSS - example





Preliminary

FSS - asymptotic behaviour



Conclusions

Spectrum in the mesonic sector is under control - confirm our earlier observations

Data remain **consistent** with conformal scaling

Lighter states in the gluonic sector are difficult (variational method, centre symmetry)

Topology needs to be monitored

Eigenvalues of Dirac operator yield the best determination of the anomalous dimension

FSS compatible with lattice data