SU(3) Sextet model with Wilson fermions

Claudio Pica

in collaboration with M. Hansen and V. Drach

based on arXiv:1705.11010

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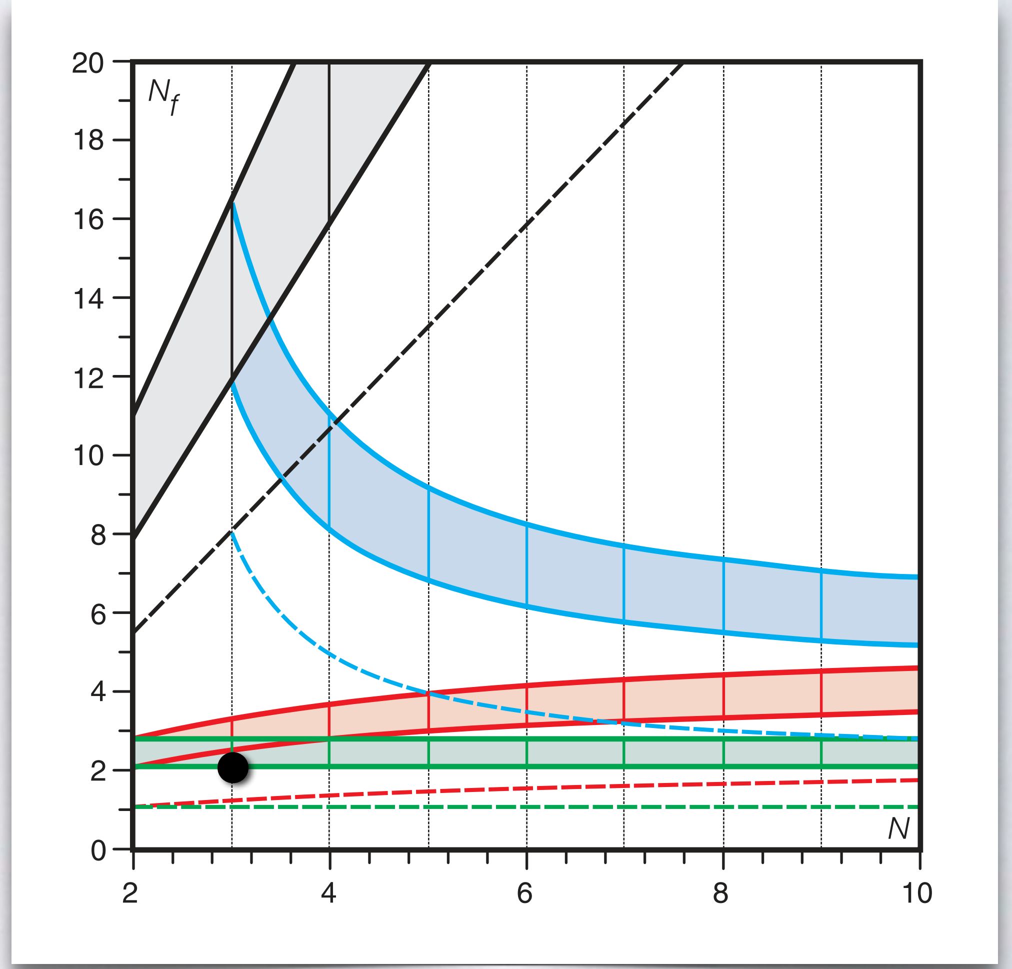
Outline

- the SU(3) sextet model
- Lattice phase diagram
  - spectral observables
  - gradient flow
- Weak coupling phase
  - spectrum: IR conformal vs ChSB
- Conclusions

SU(3) Sextet Model

- Minimal Vanilla Walking TC model (if chiral symmetry is SB)
- Apparent tension between studies with staggered and Wilson fermions
- We focus on the spectrum, i.e. no (gradient flow) running couplings
- Map phase diagram of lattice model



Lattice setup

- SU(3) plaquette gauge action
- Unimproved Wilson fermions
- Two flavors of sextet (2-index symmetric) fermions
- Spectral quantities for mesons and baryon from point sources
- For gradient flow observable we use the symmetric clover discretization for the gauge field action density
- Severe topological freezing problem: simulations at zero topology

$$\psi^{ab} = \psi^{ba}$$

$$\psi \to U \psi U^T$$

(see arXiv:1705.11010 for details)

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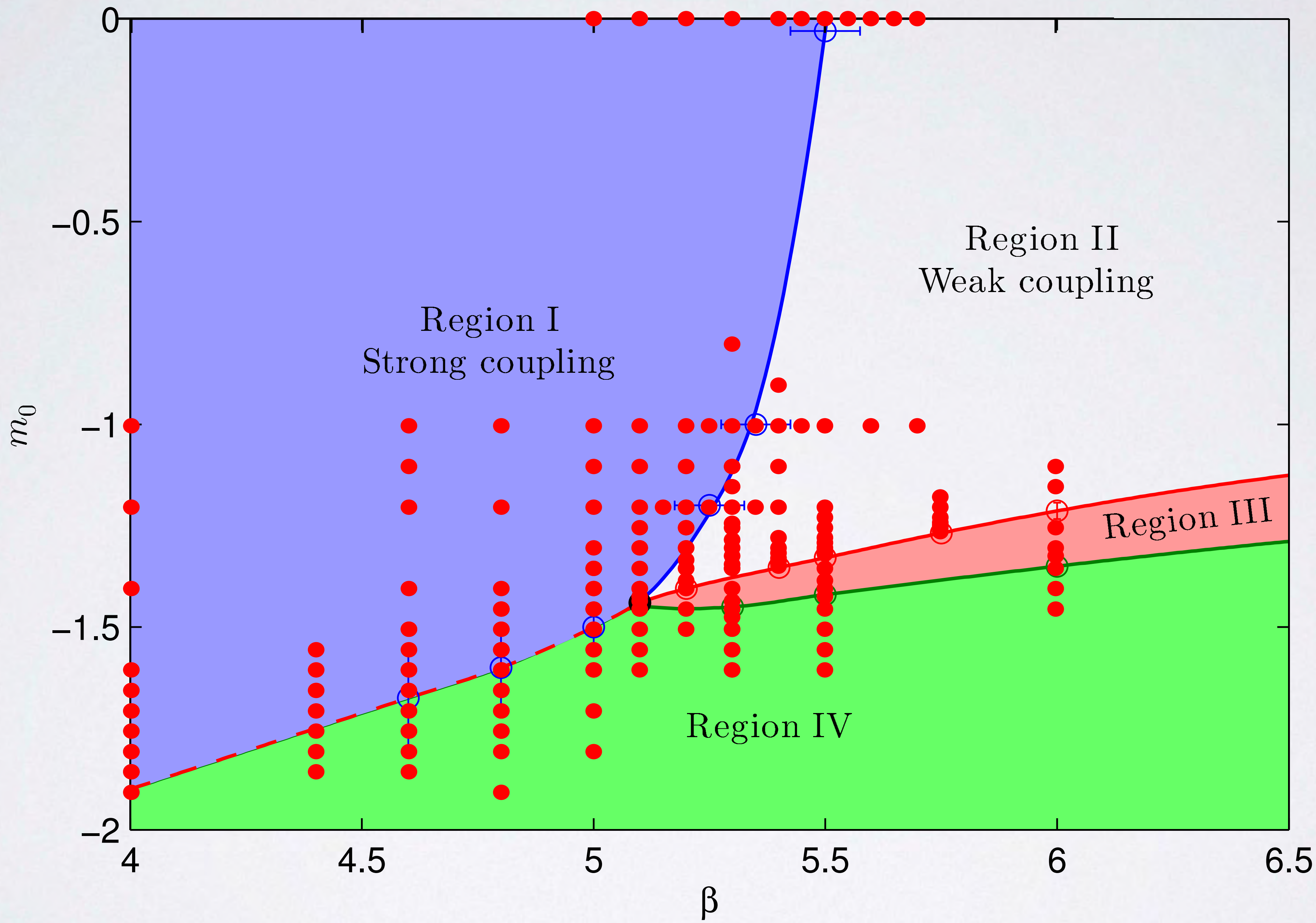
Lattice Phase Diagram



Mostly on 16^3x32 (some 24^3x48 to check for finite volume effects)

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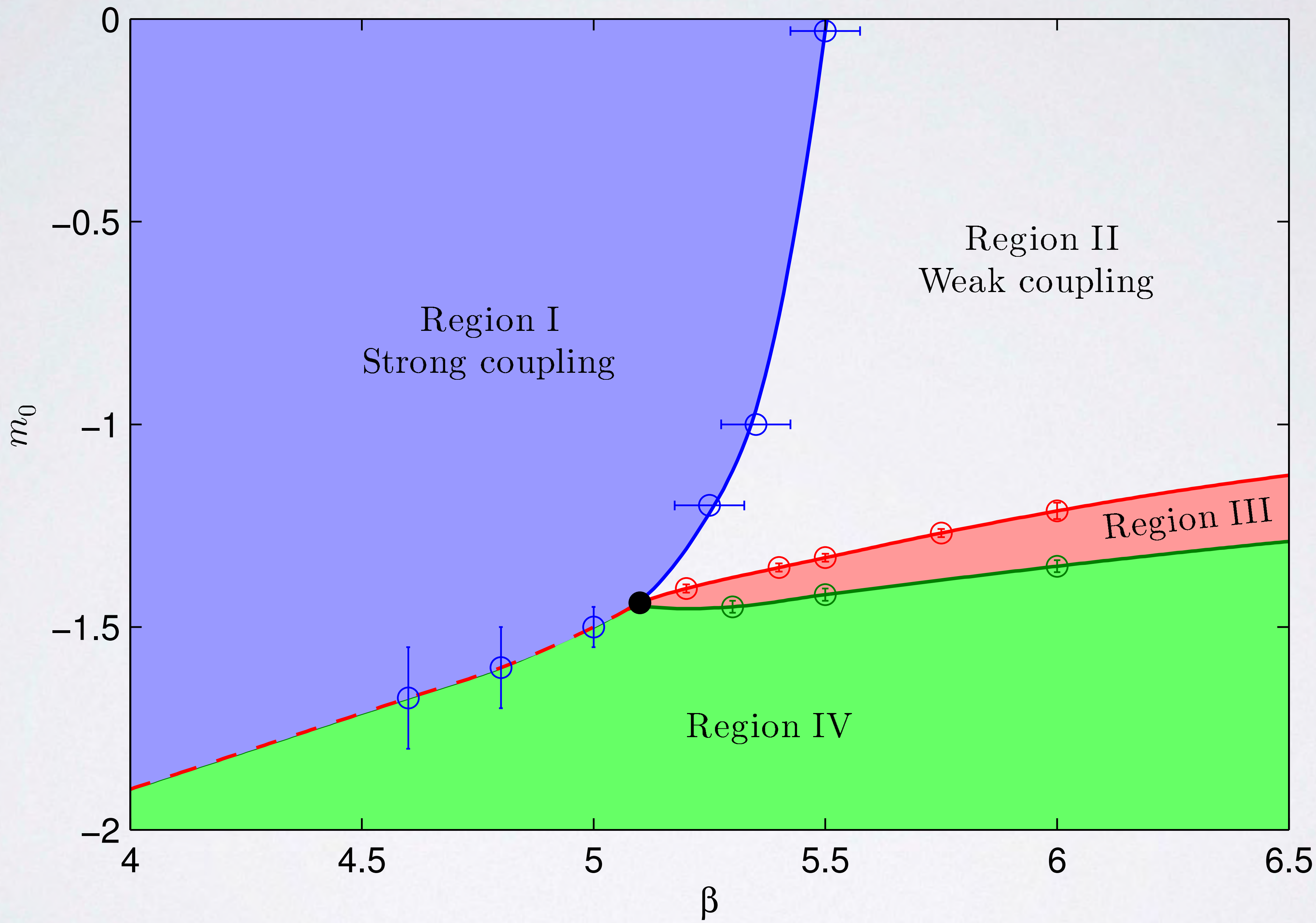
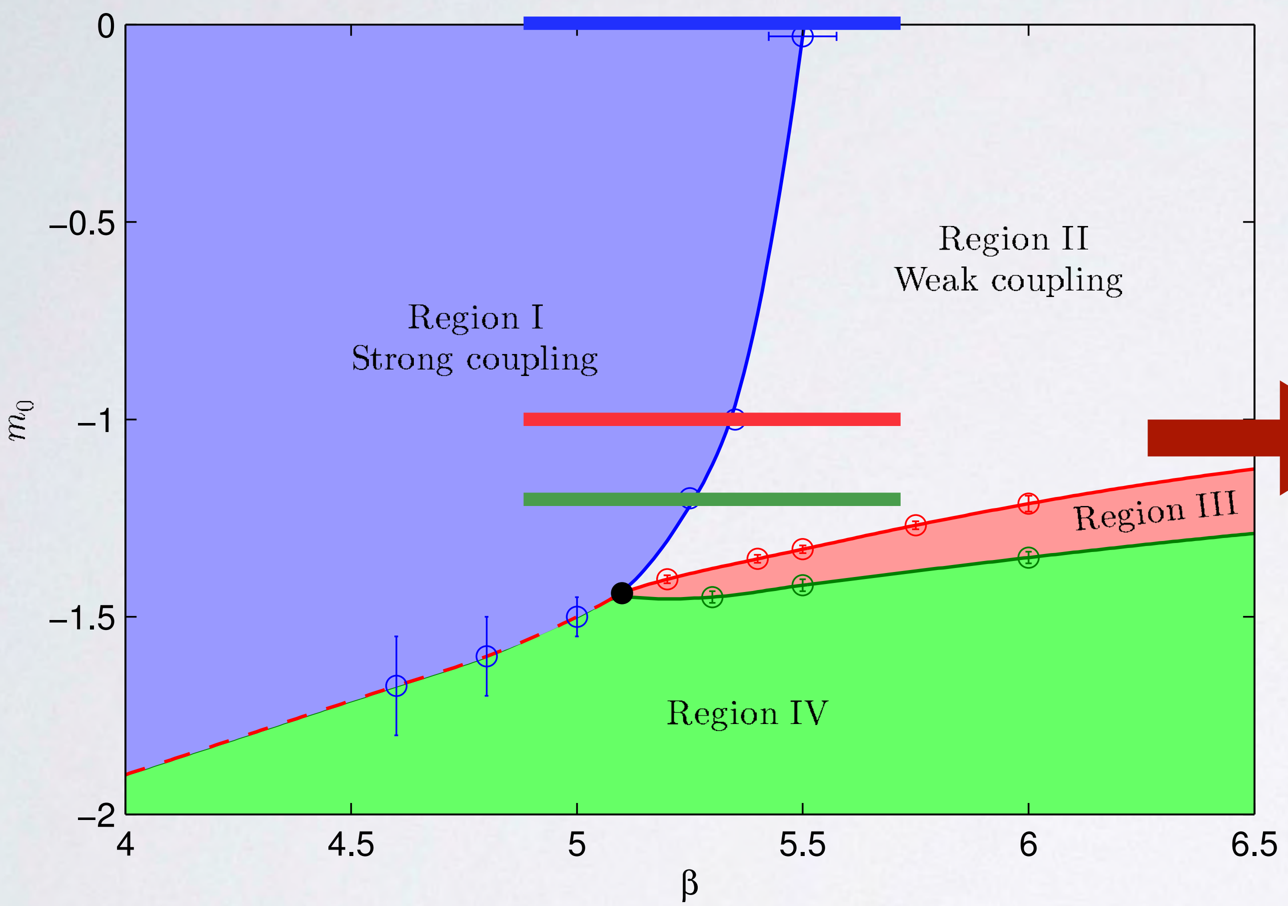
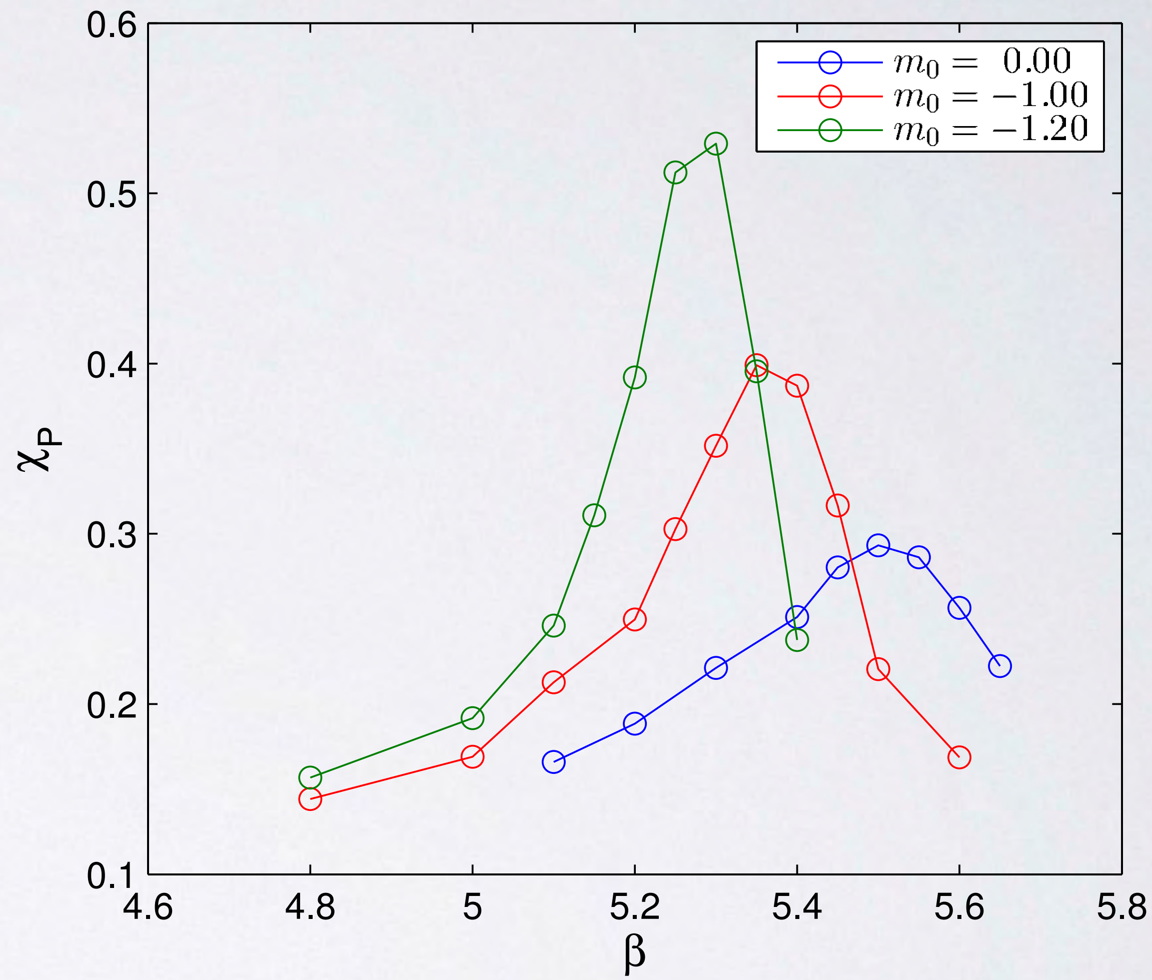
Lattice Phase Diagram



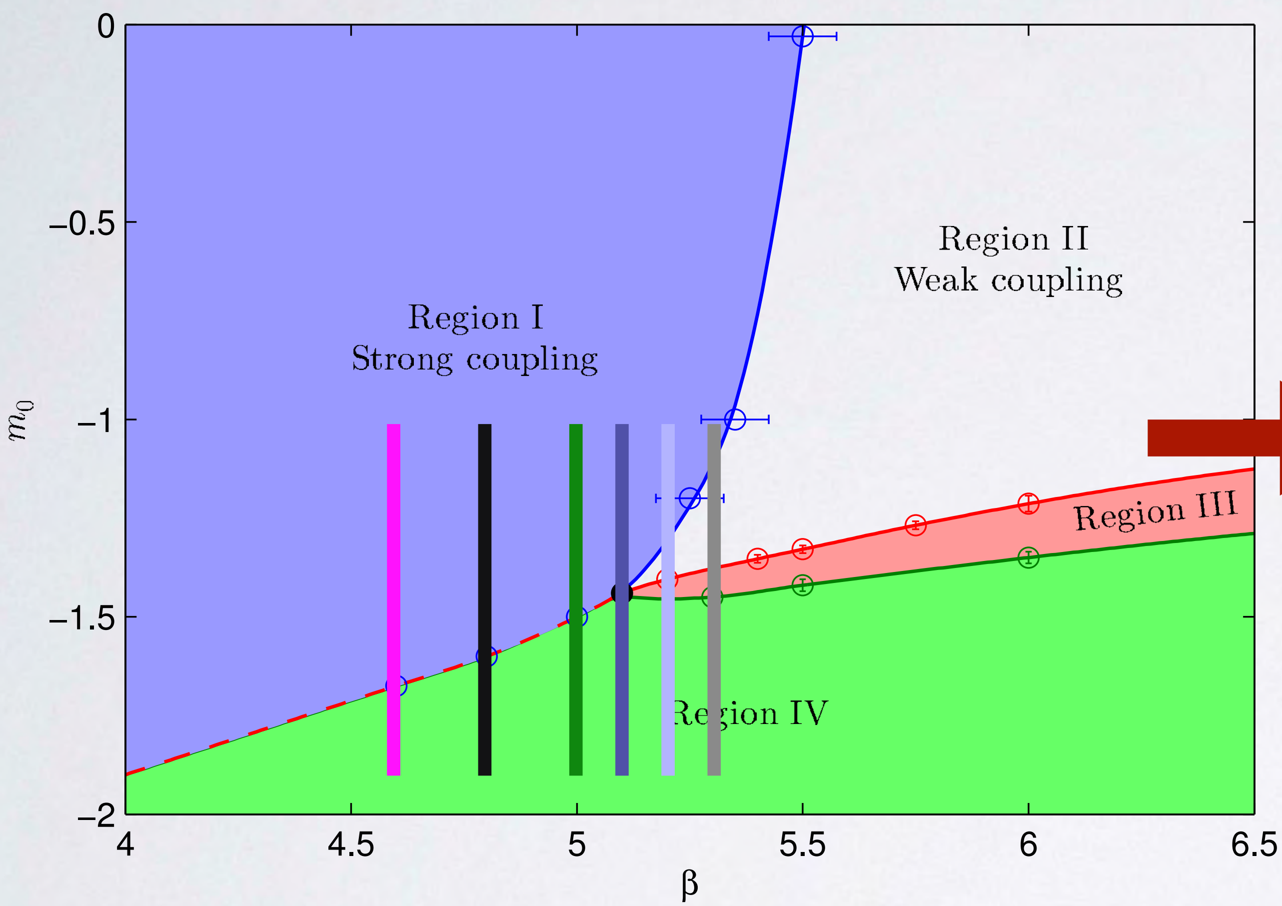
Lattice Phase Diagram

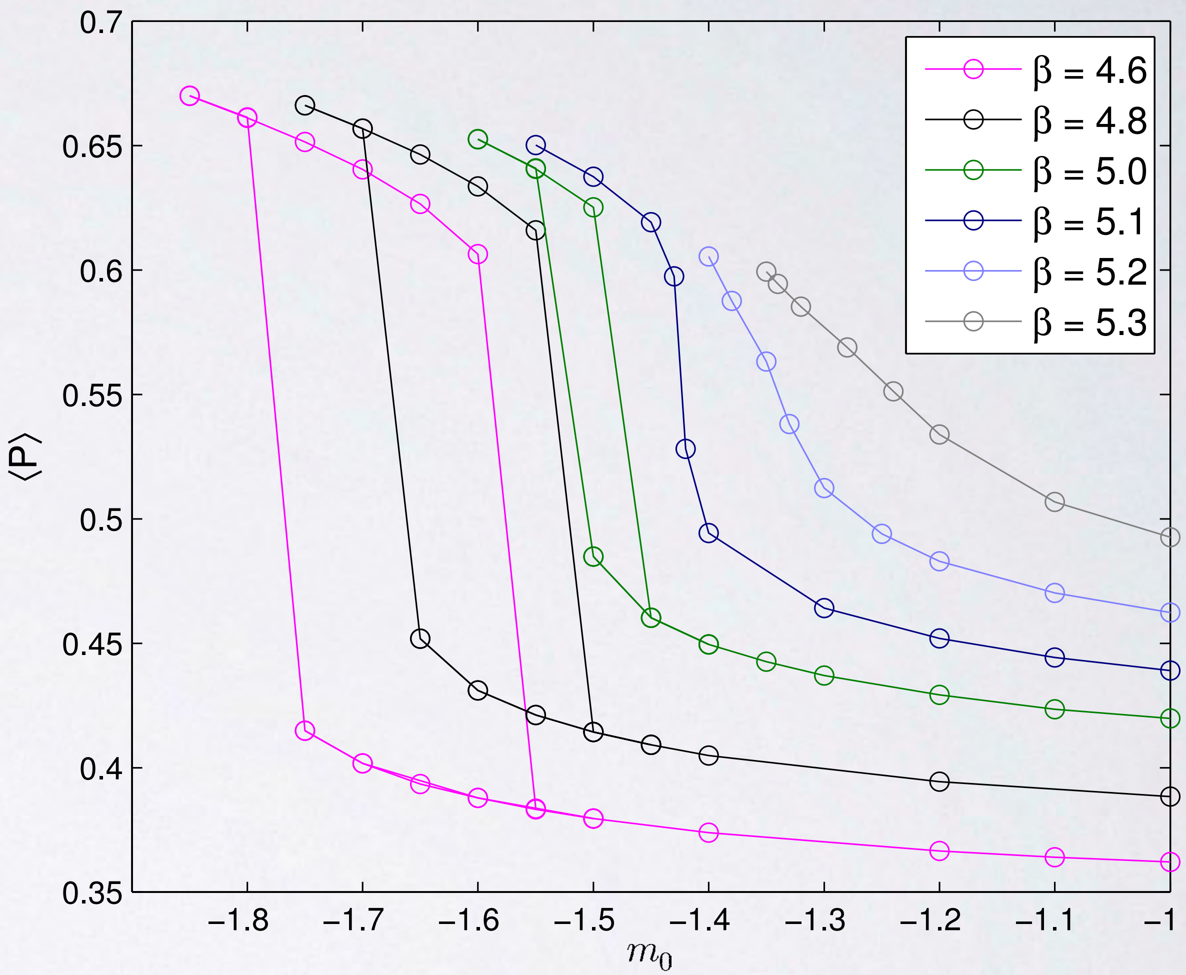




$$\chi_P = \frac{\partial \langle P \rangle}{\partial \beta}$$

Lattice Phase Diagram





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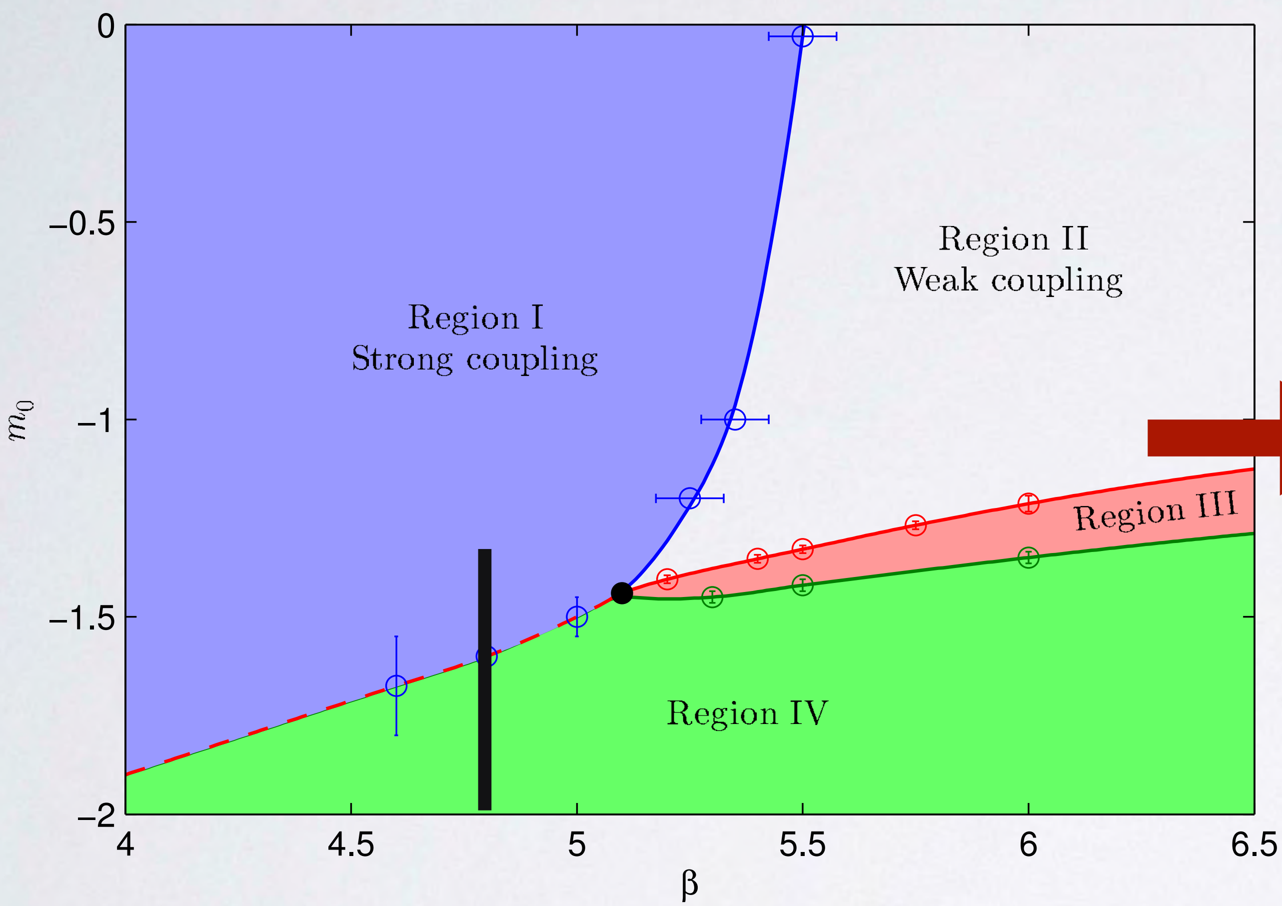
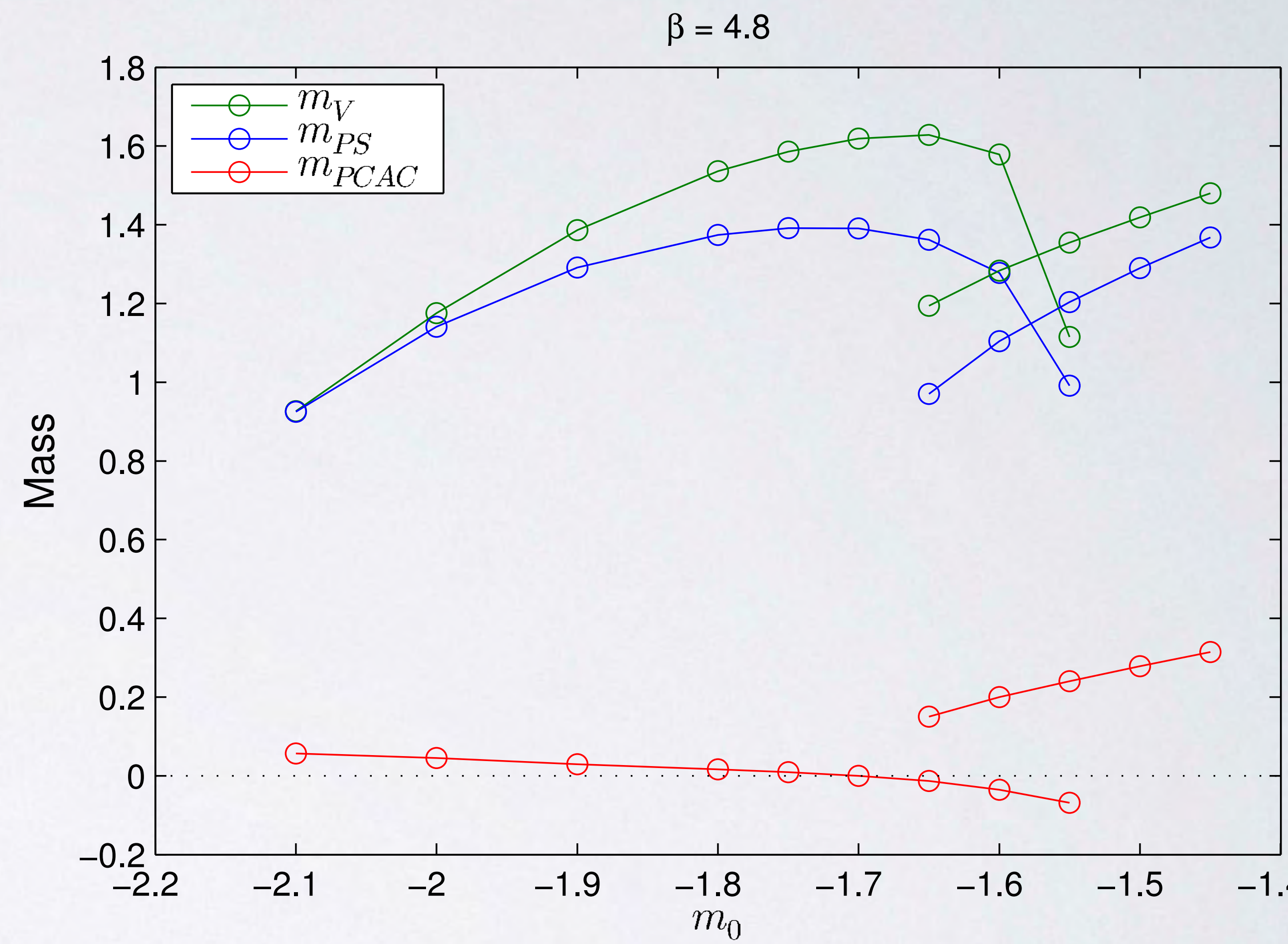
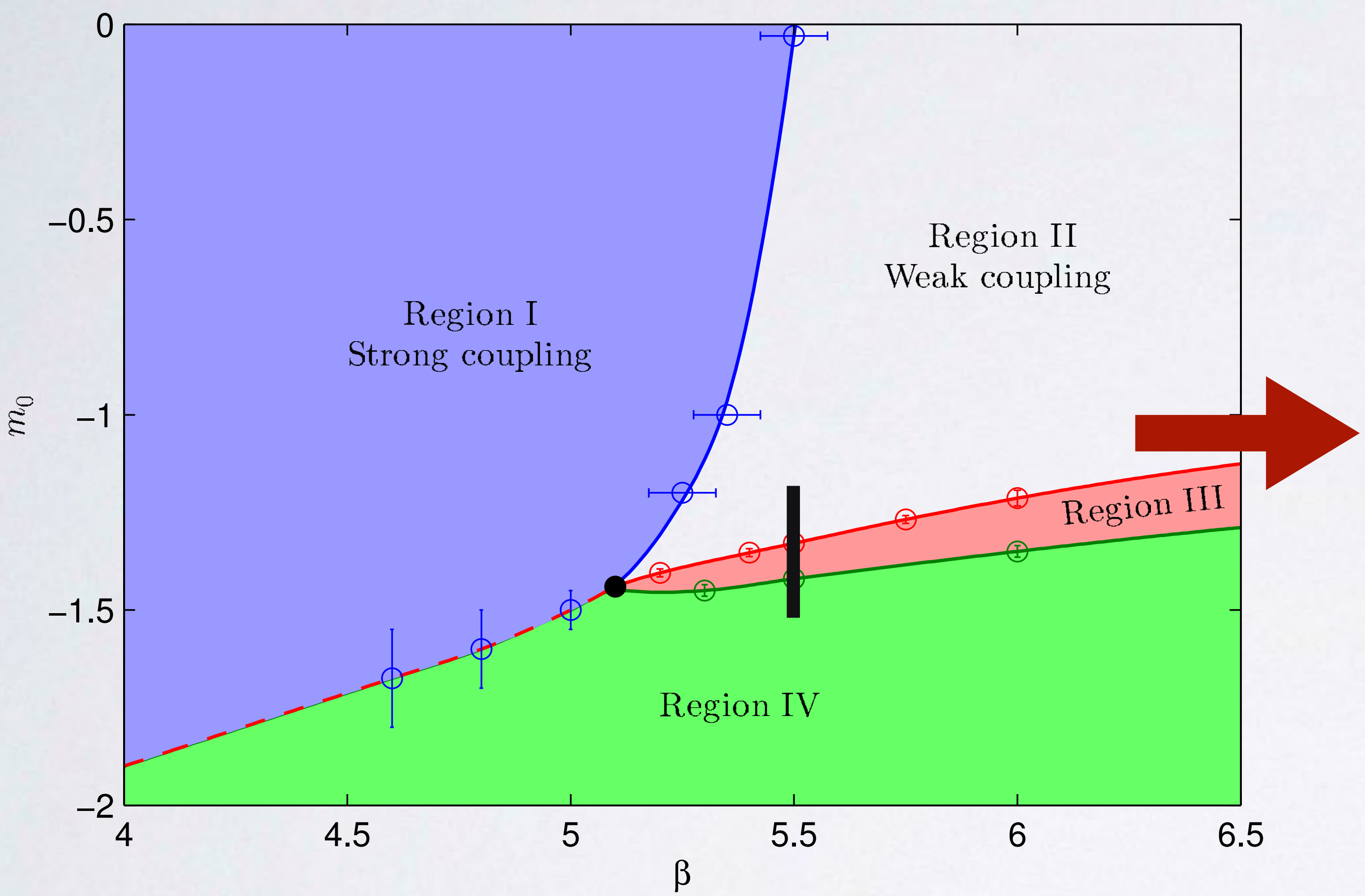
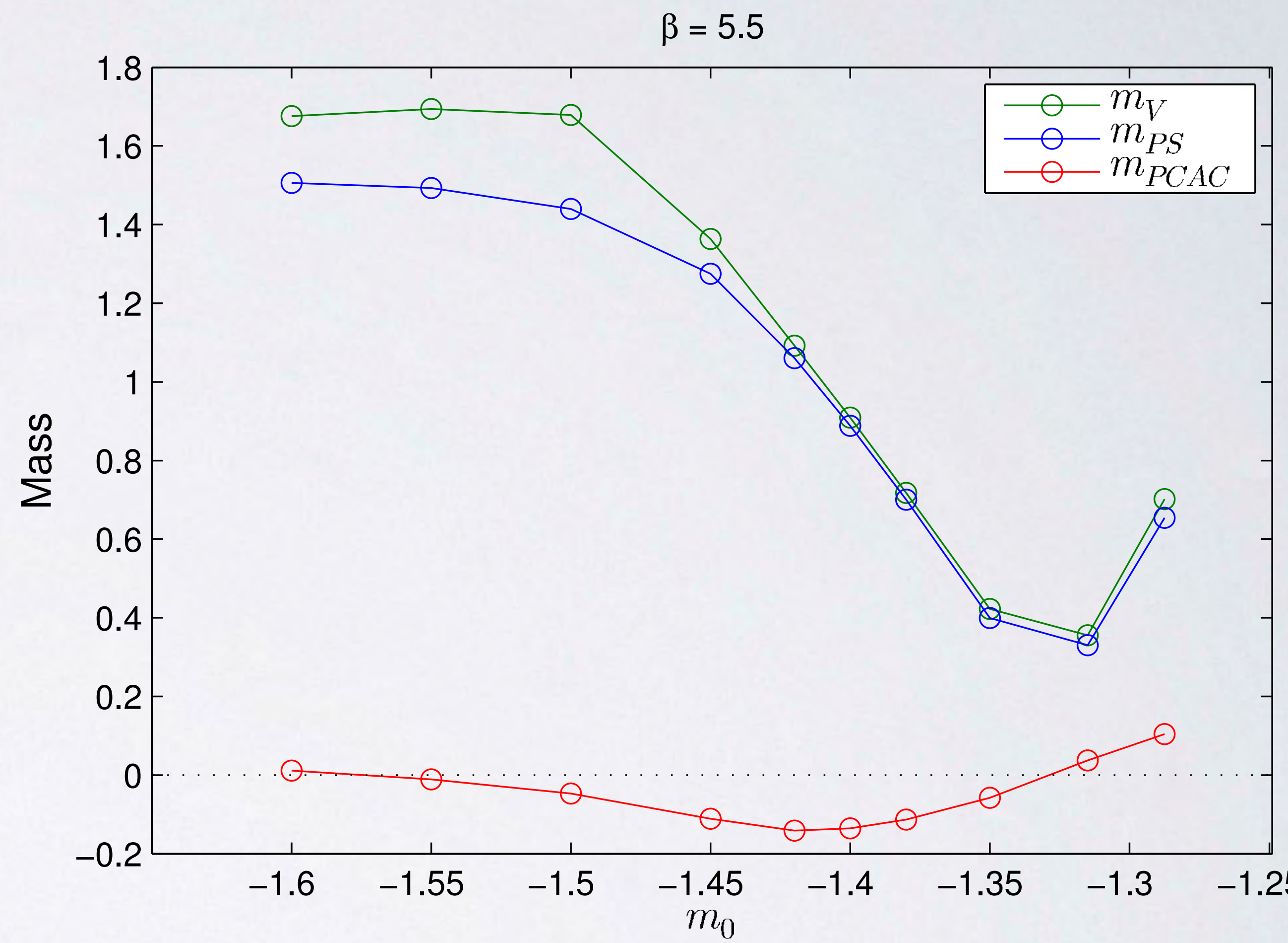
Spectrum @ Strong Coupling



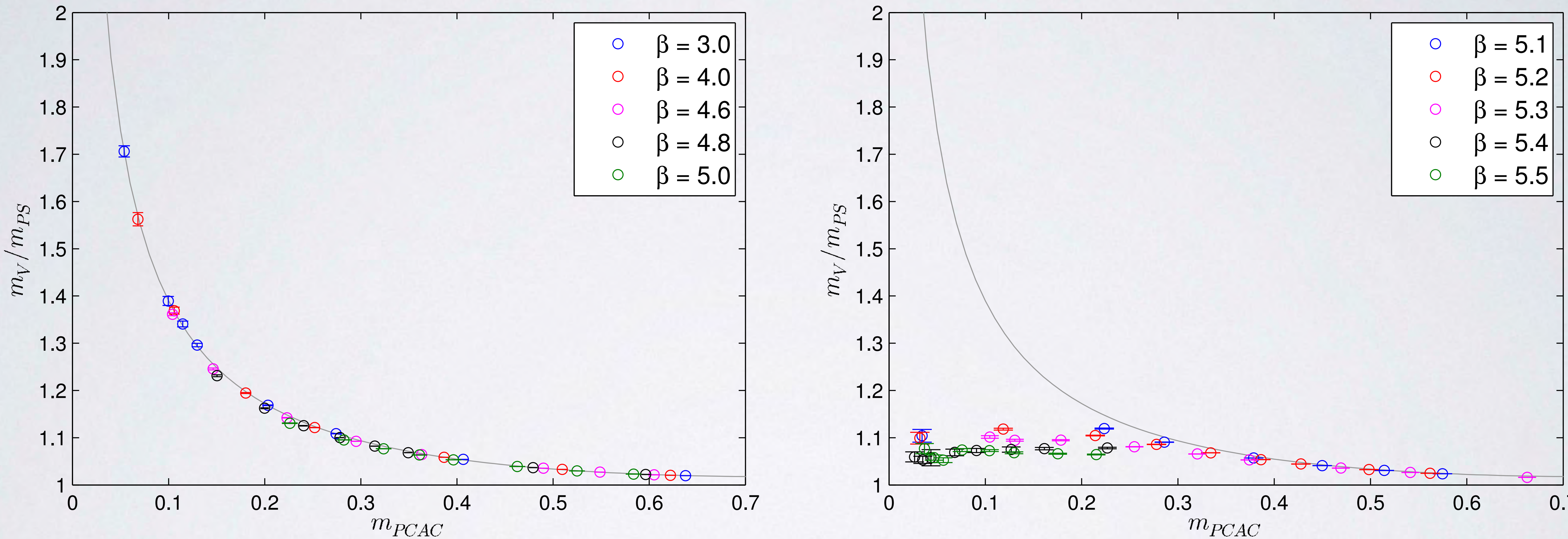


Spectrum @ Weak Coupling



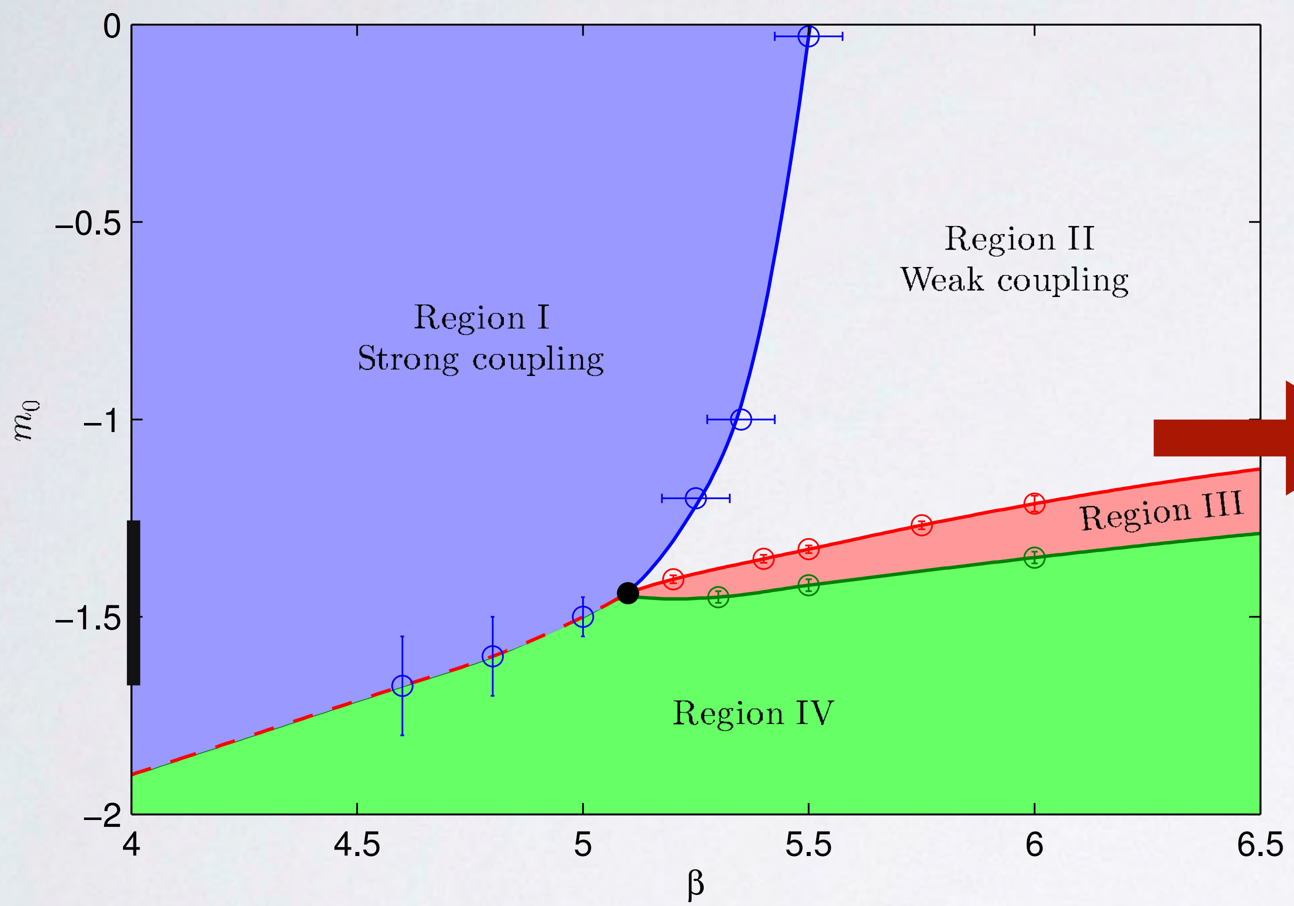


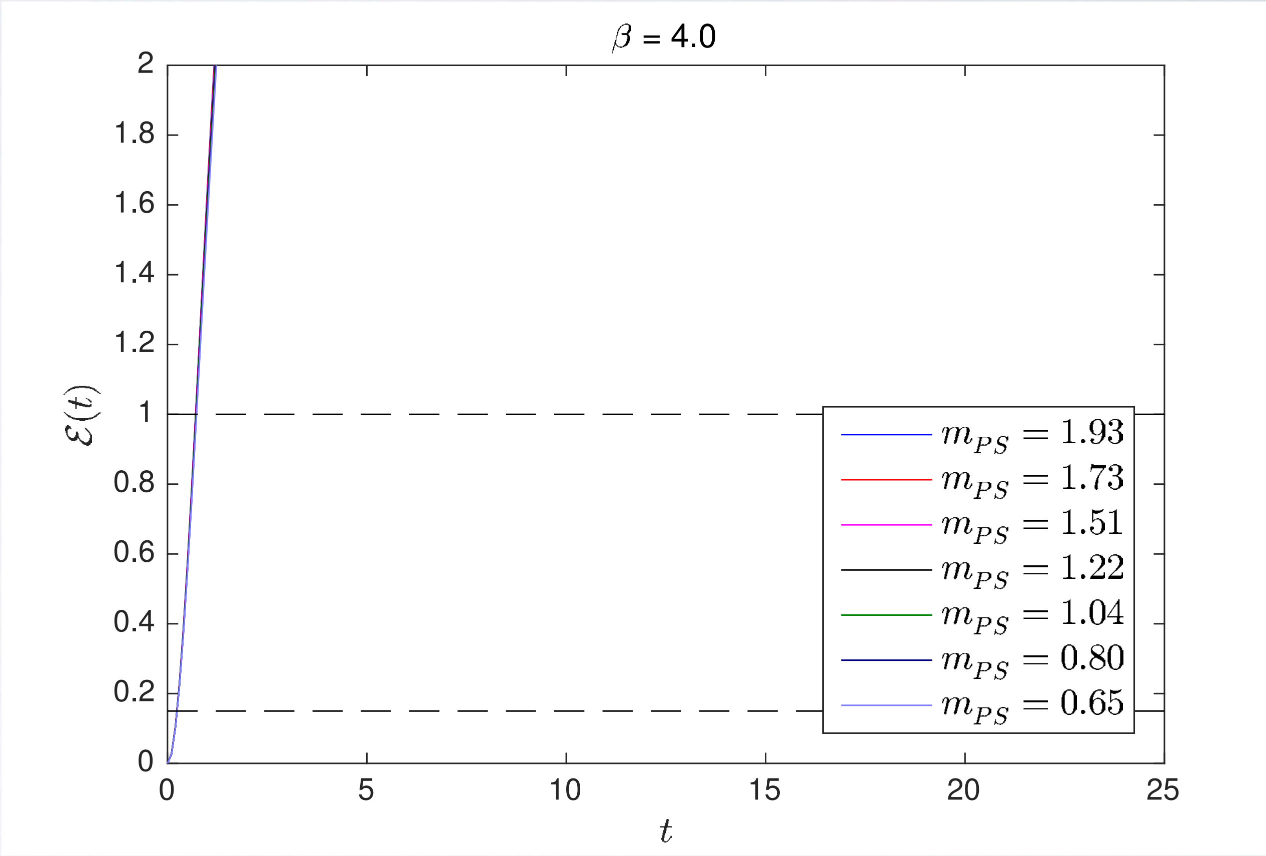
Spectrum: Strong vs Weak Coupling



Mostly on 16^3x32, except at b=5.4, 5.5

GF @ Strong Coupling





$$\mathcal{E}(t) = \langle t^2 E(t) \rangle$$

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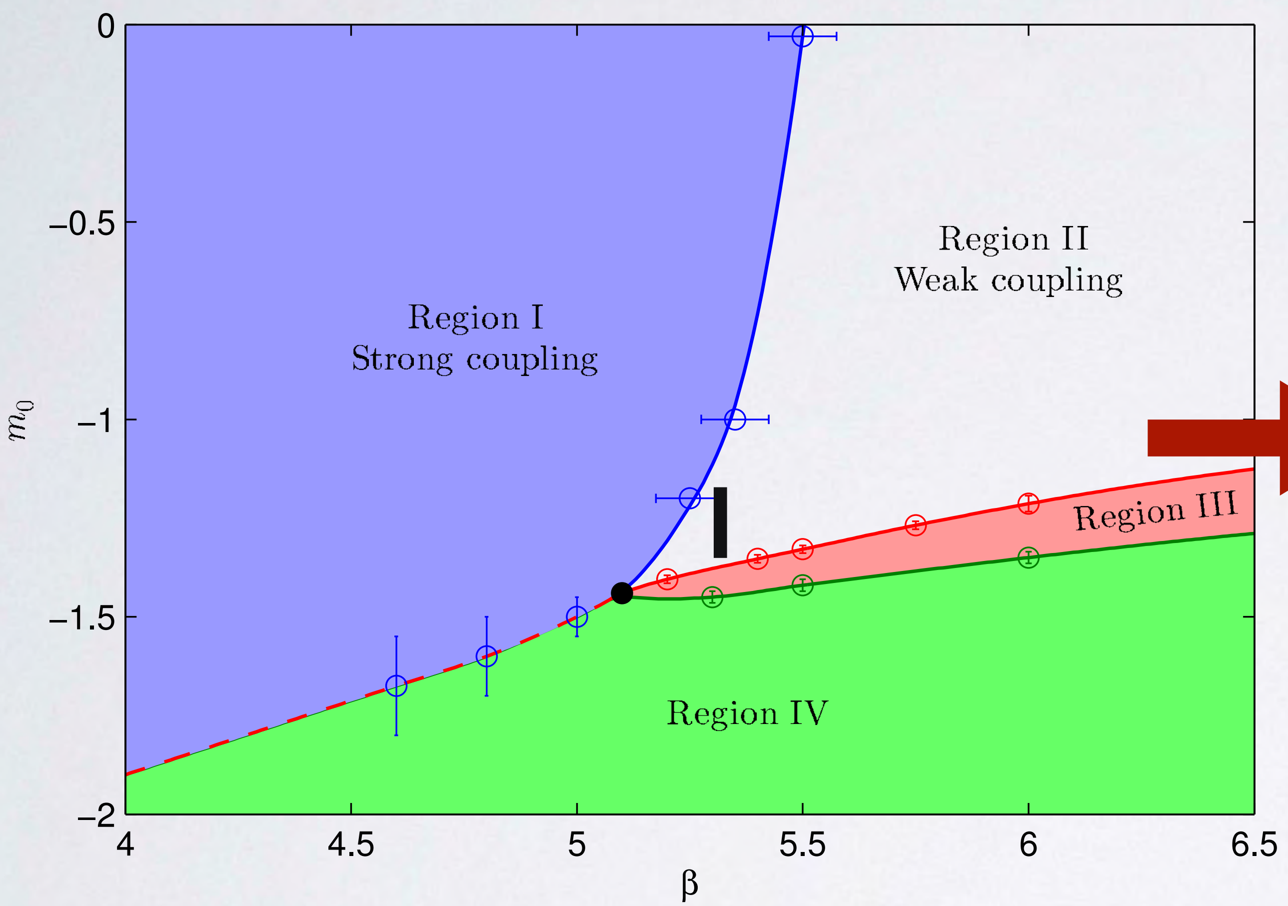
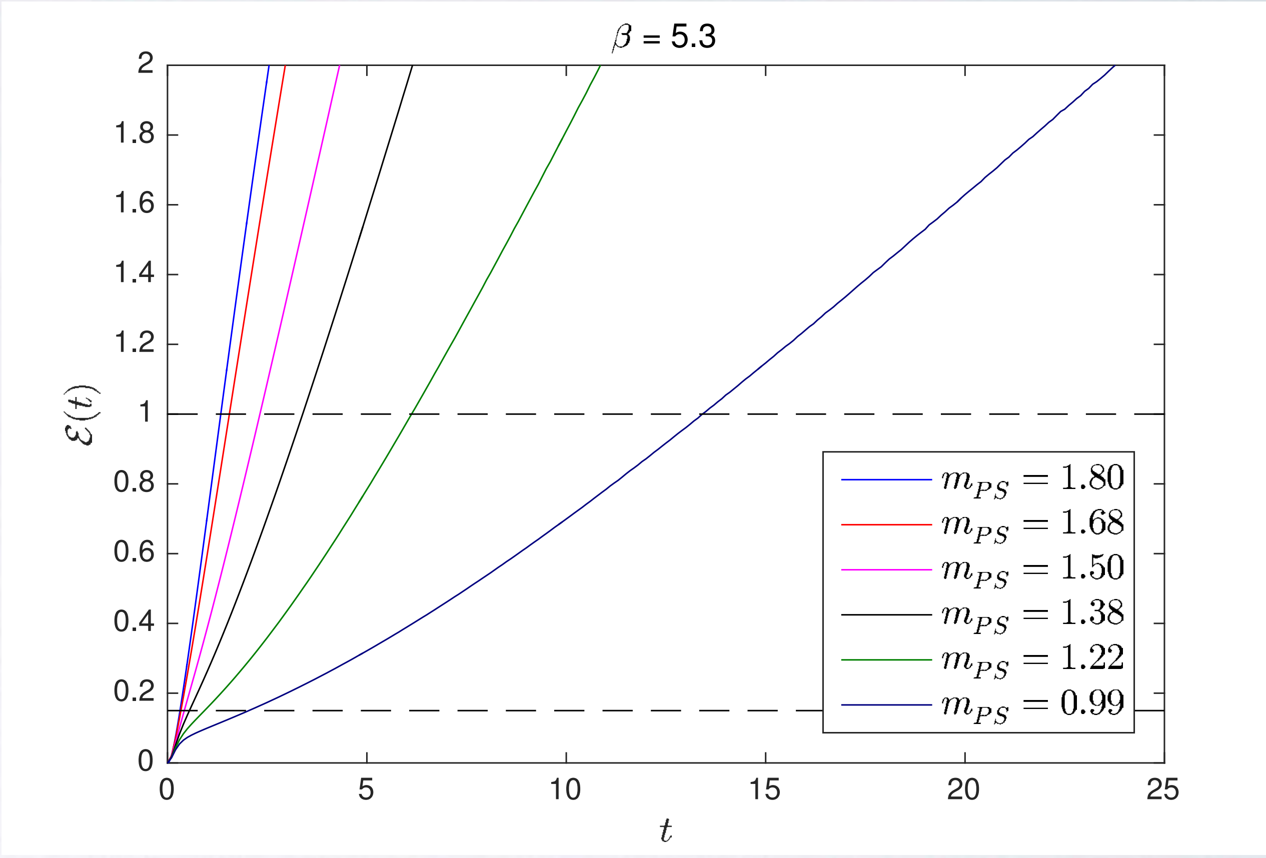
GF @ Weak Coupling





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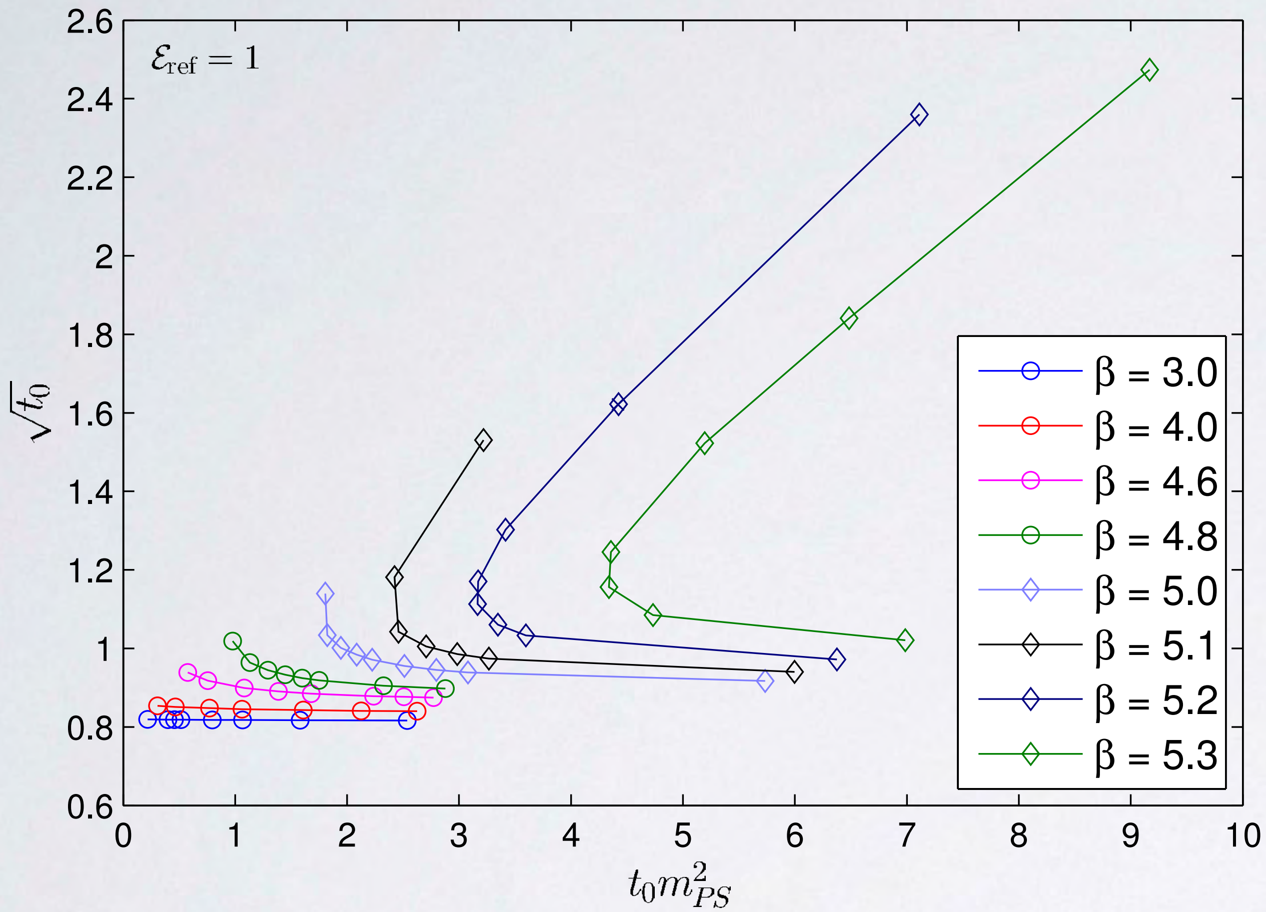

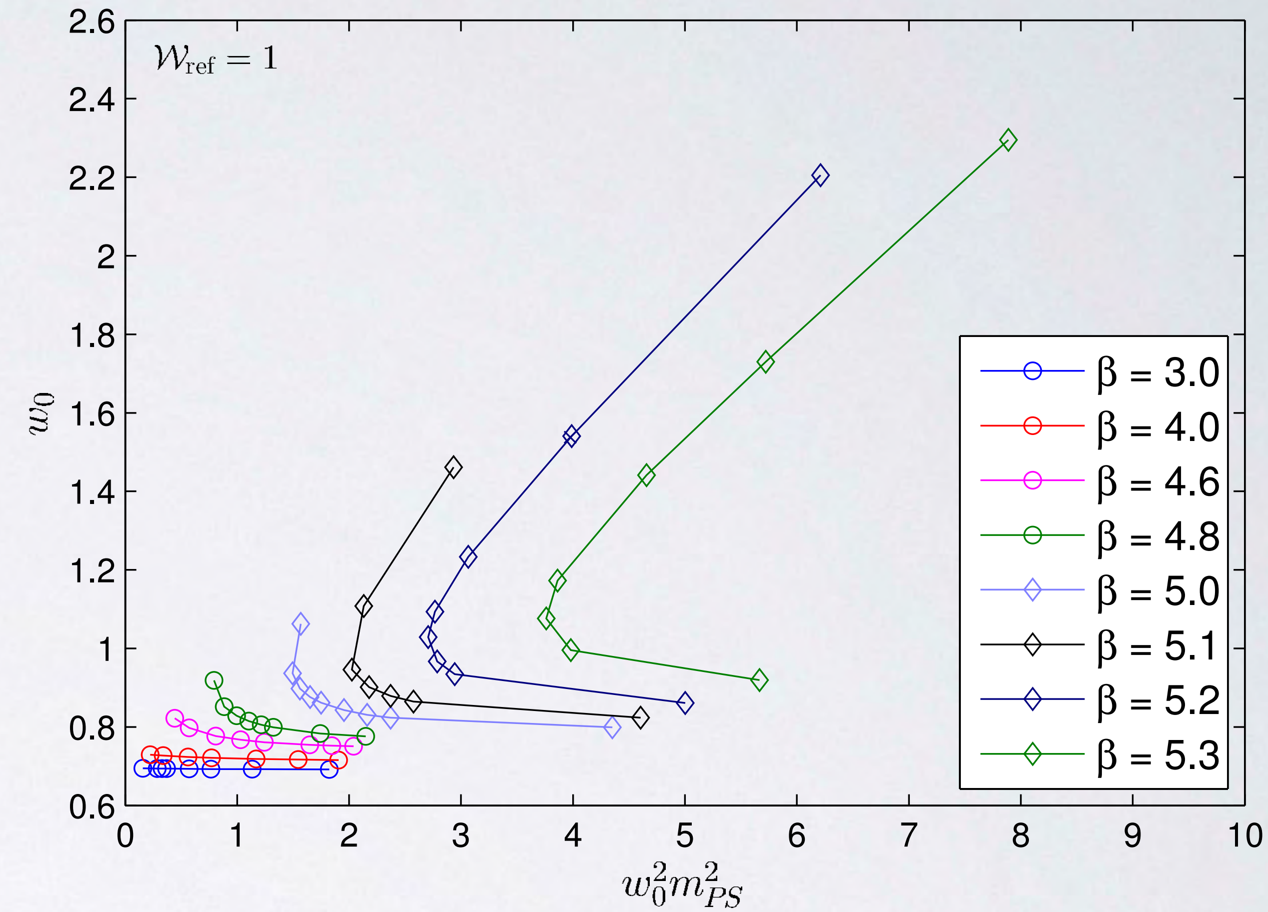

$$\mathcal{E}(t) = \langle t^2 E(t) \rangle \, , \mathcal{W}(t) = t \frac{d\mathcal{E}(t)}{dt}$$

$$\mathcal{E}(t_0) = \mathcal{E}_{\text{ref}} \, , \mathcal{W}(w_0^2) = \mathcal{W}_{\text{ref}}$$

No finite volume effects

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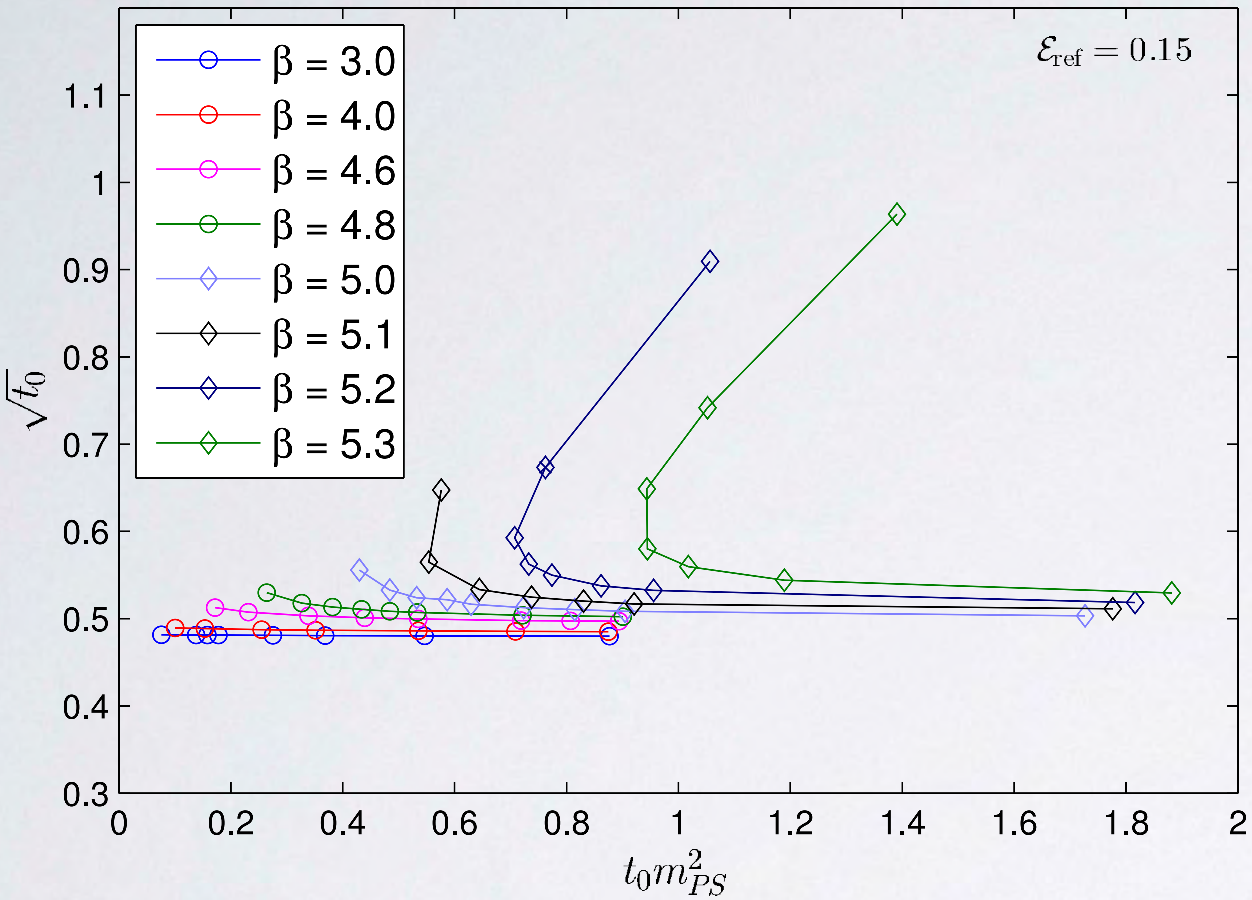
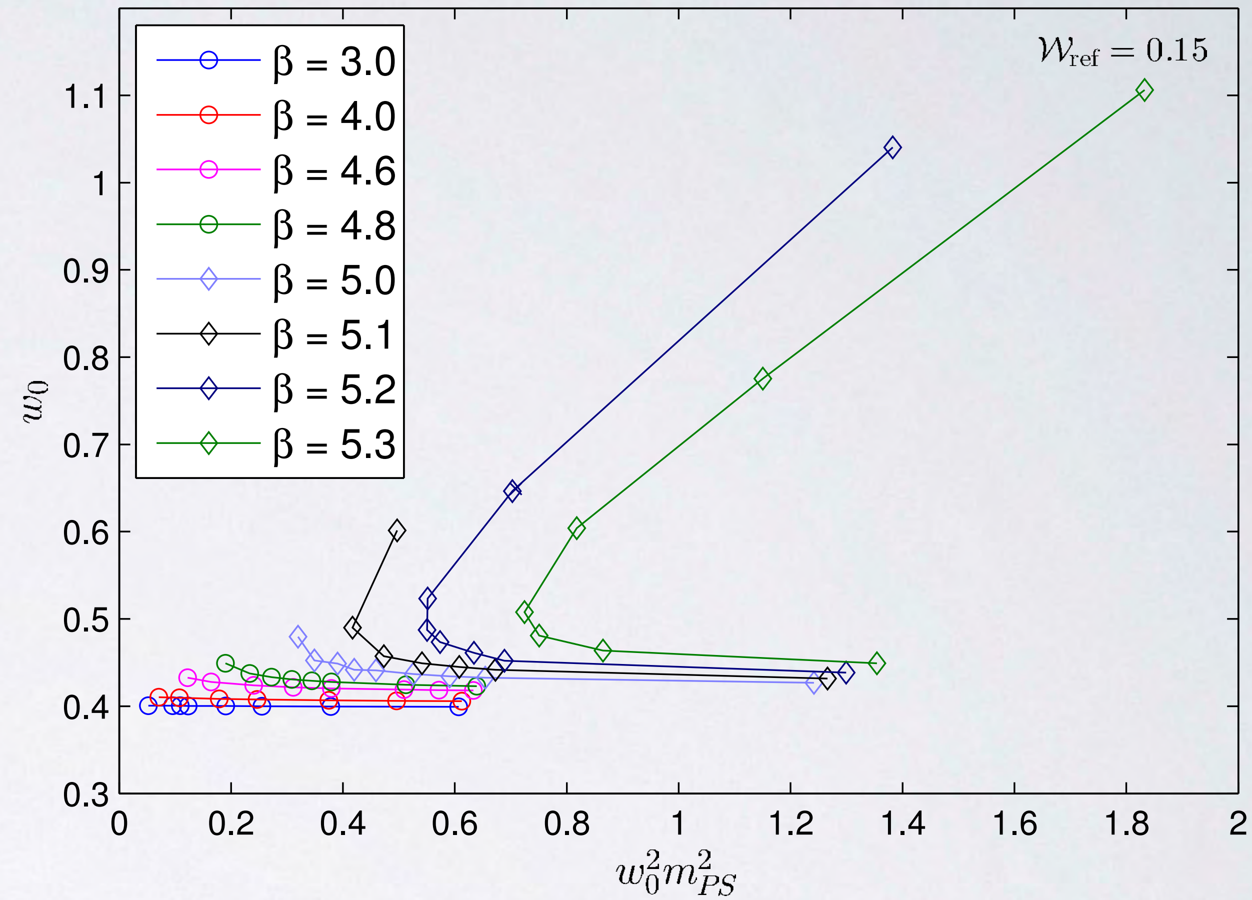
GF: Strong vs Weak Coupling





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$$\mathcal{E}(t_0) = \mathcal{E}_{\rm ref} \,, \mathcal{W}(w_0^2) = \mathcal{W}_{\rm ref}$$

No finite volume effects

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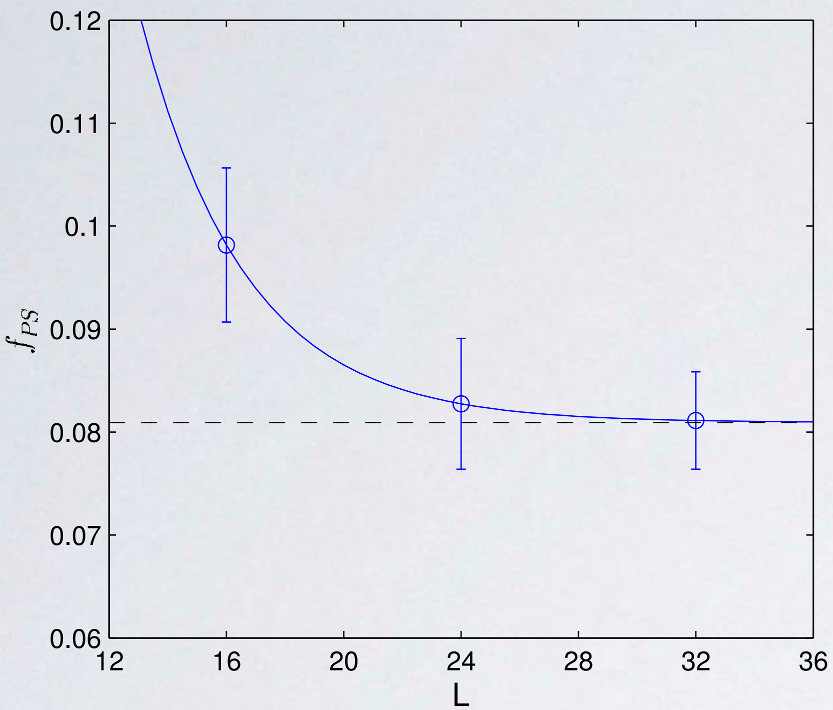
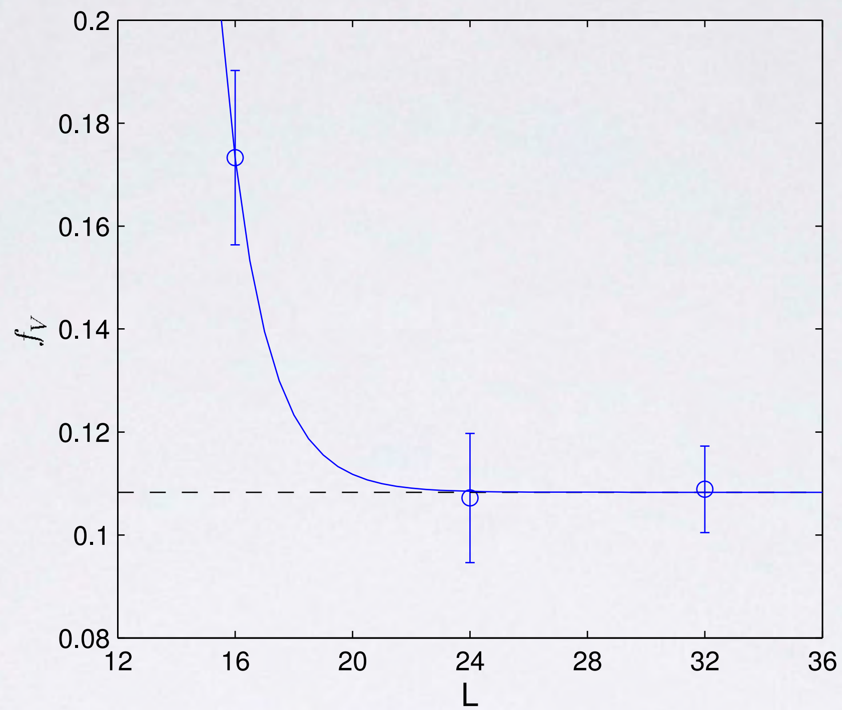
Spectrum @ Weak Coupling

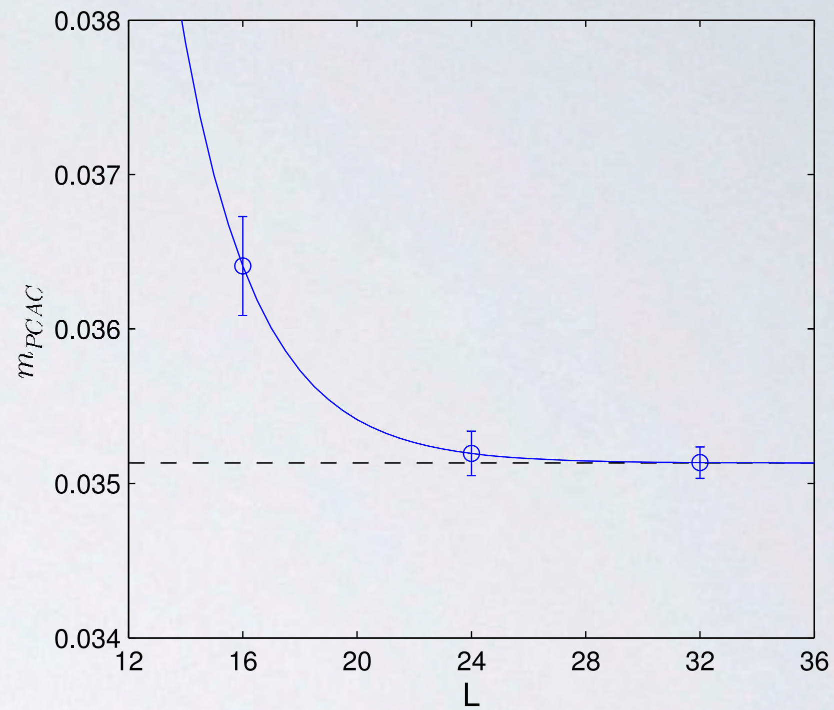
Strategy

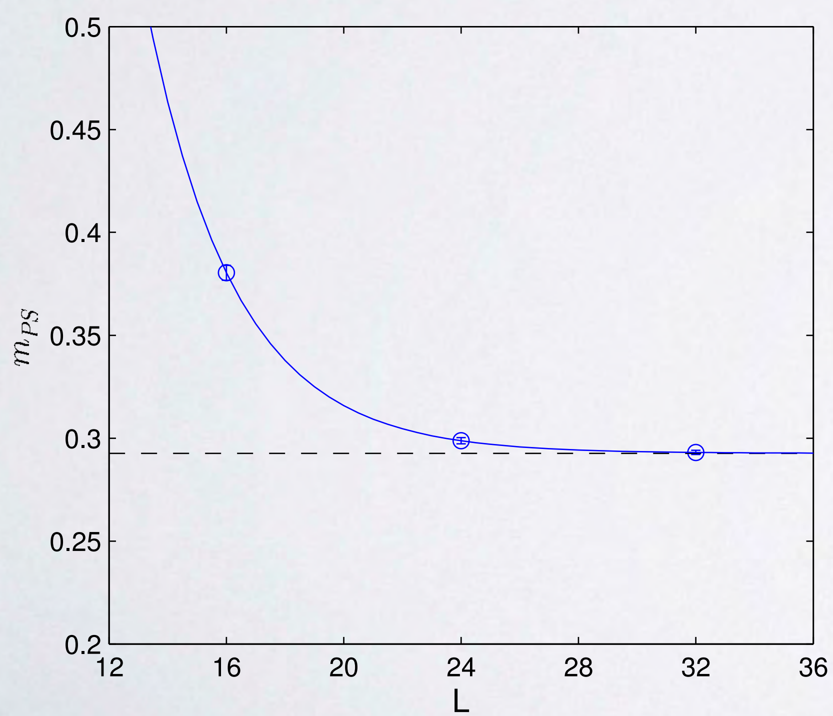
- Focus at weak coupling b=5.4
- Look at spectral observables: $m_{PCAC}, f_{PS}, m_{PS}, f_V, m_V, m_N$
- Use "infinite volume" data
- Go as chiral as possible
- Test IR conformality vs ChSB

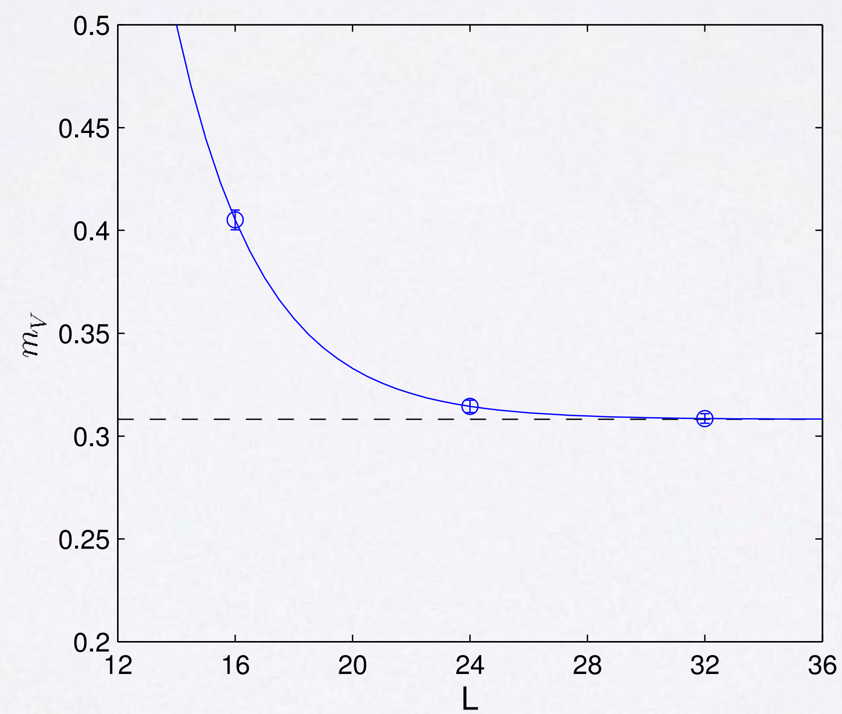
Finite Volume effects







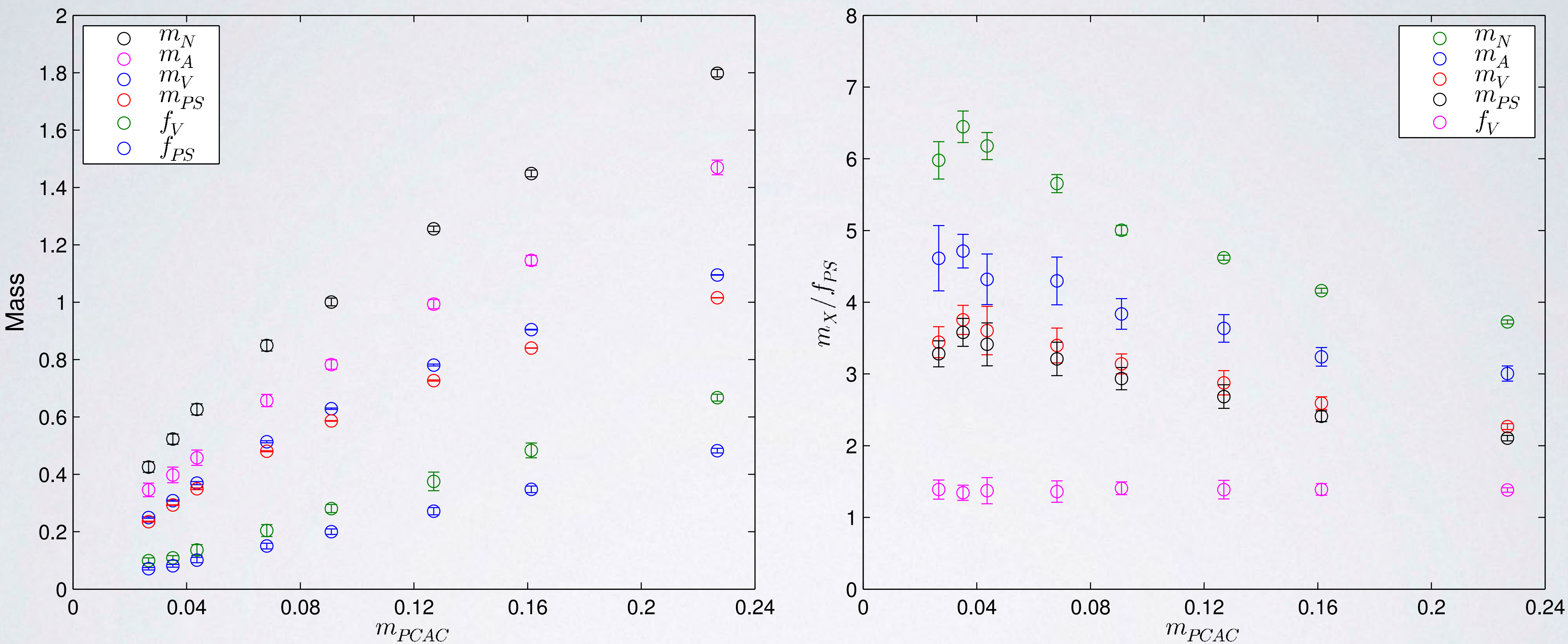




$$m(L) = m_\infty + a\exp(-bL)$$

$$m_{PS} = 0.293(1)$$

Spectrum



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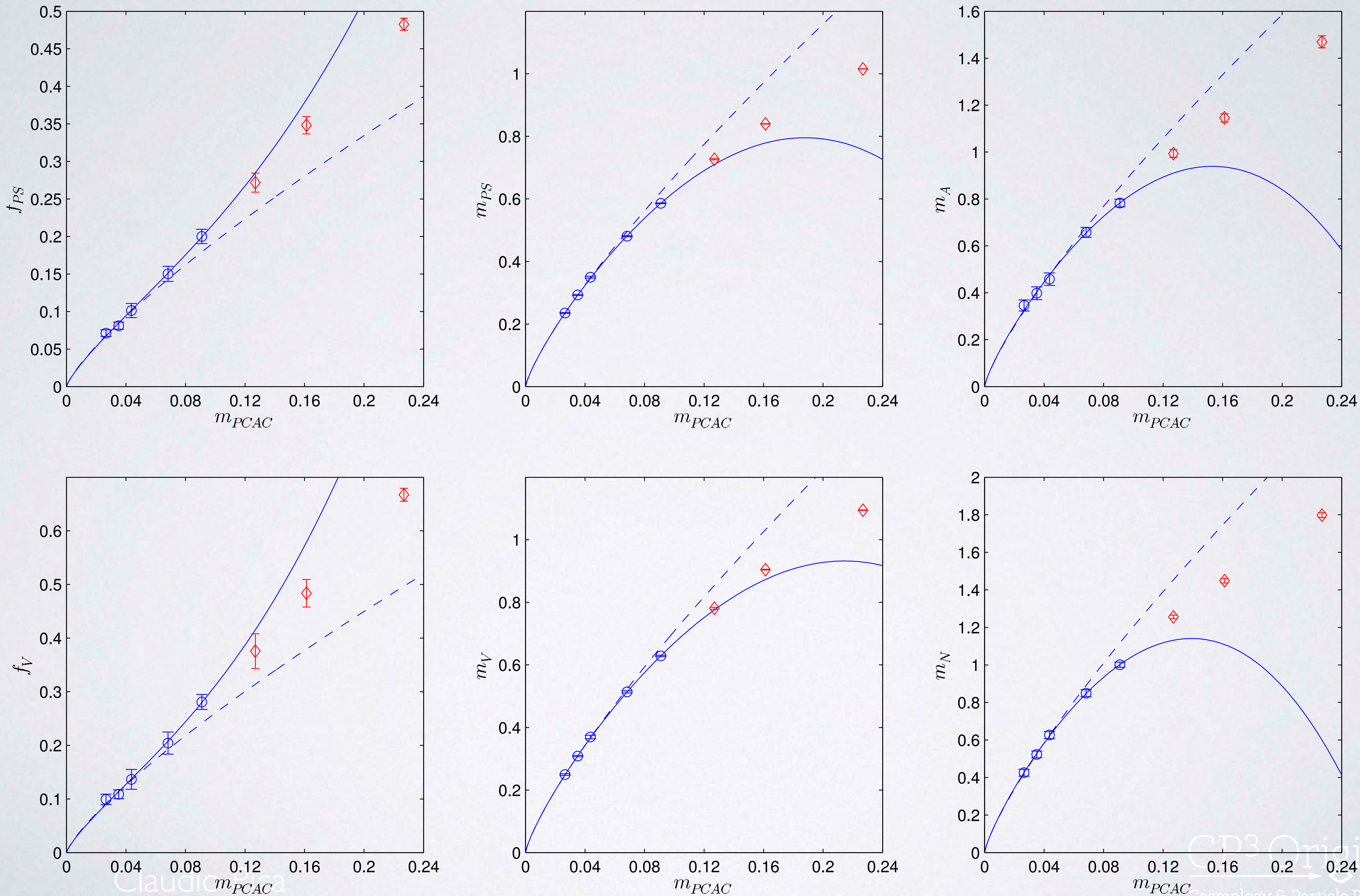
Spectrum: IR conformal scaling



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Spectrum: IR conformal scaling

$$M_X = A_X m^{1/(1+\gamma)} + \tilde{A}_X m^{\omega},$$
$$F_X = B_X m^{1/(1+\gamma)} + \tilde{B}_X m^{\omega},$$

	$\chi^2/d.o.f.$	γ	ω
$m_{PCAC} < 0.1$	7.1/16	0.25(3)	2.71(76)
$m_{PCAC} < 0.05$	4.6/11	0.27(3)	-

Spectrum: ChSB

$$M_\pi^2 = M^2 \left[1 + \frac{M^2}{F^2}(a_M L + b_M) + \frac{M^4}{F^4}(c_M L^2 + d_M L + e_M) \right]$$

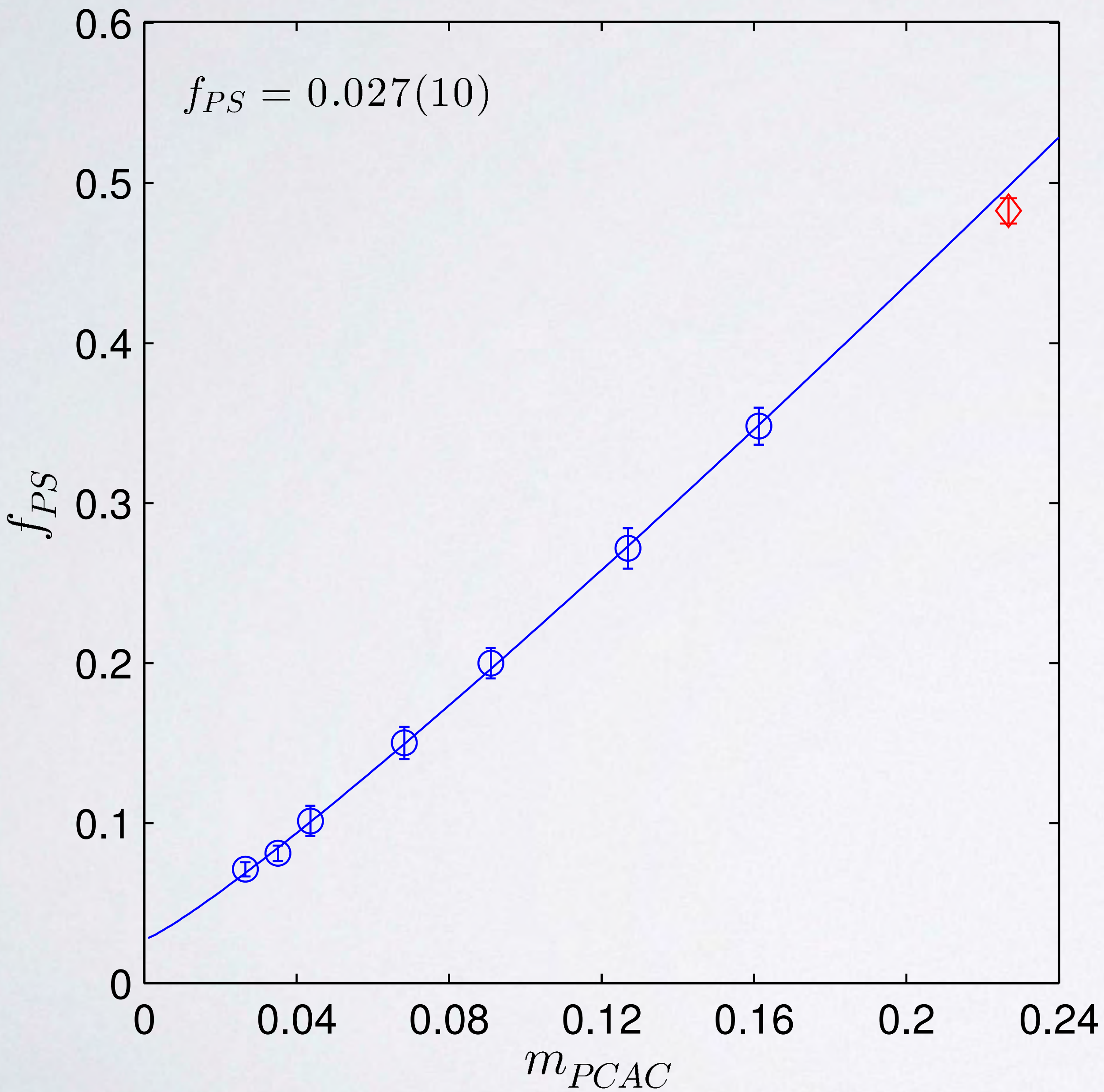
$$F_\pi = F \left[1 + \frac{M^2}{F^2}(a_F L + b_F) + \frac{M^4}{F^4}(c_F L^2 + d_F L + e_F) \right]$$

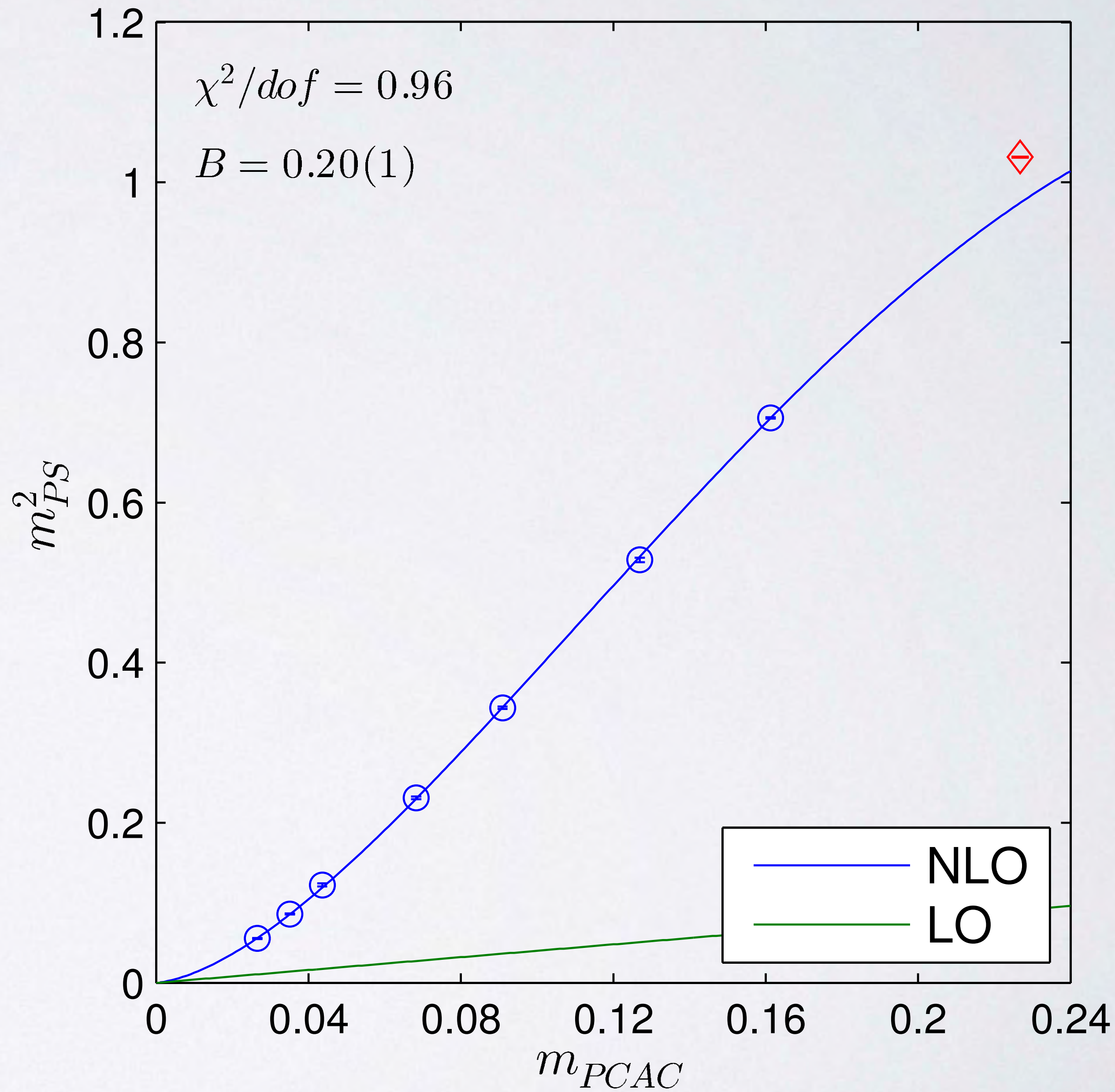
$$M^2 = 2Bm \qquad L = \frac{1}{16\pi^2} \log\left(\frac{M^2}{\mu^2} \right)$$

$$a_M = \frac{1}{2},\ a_F = -1,\ c_M = \frac{17}{8},\ c_F = -\frac{5}{4}$$ Continuum coefficients

Spectrum: ChSB

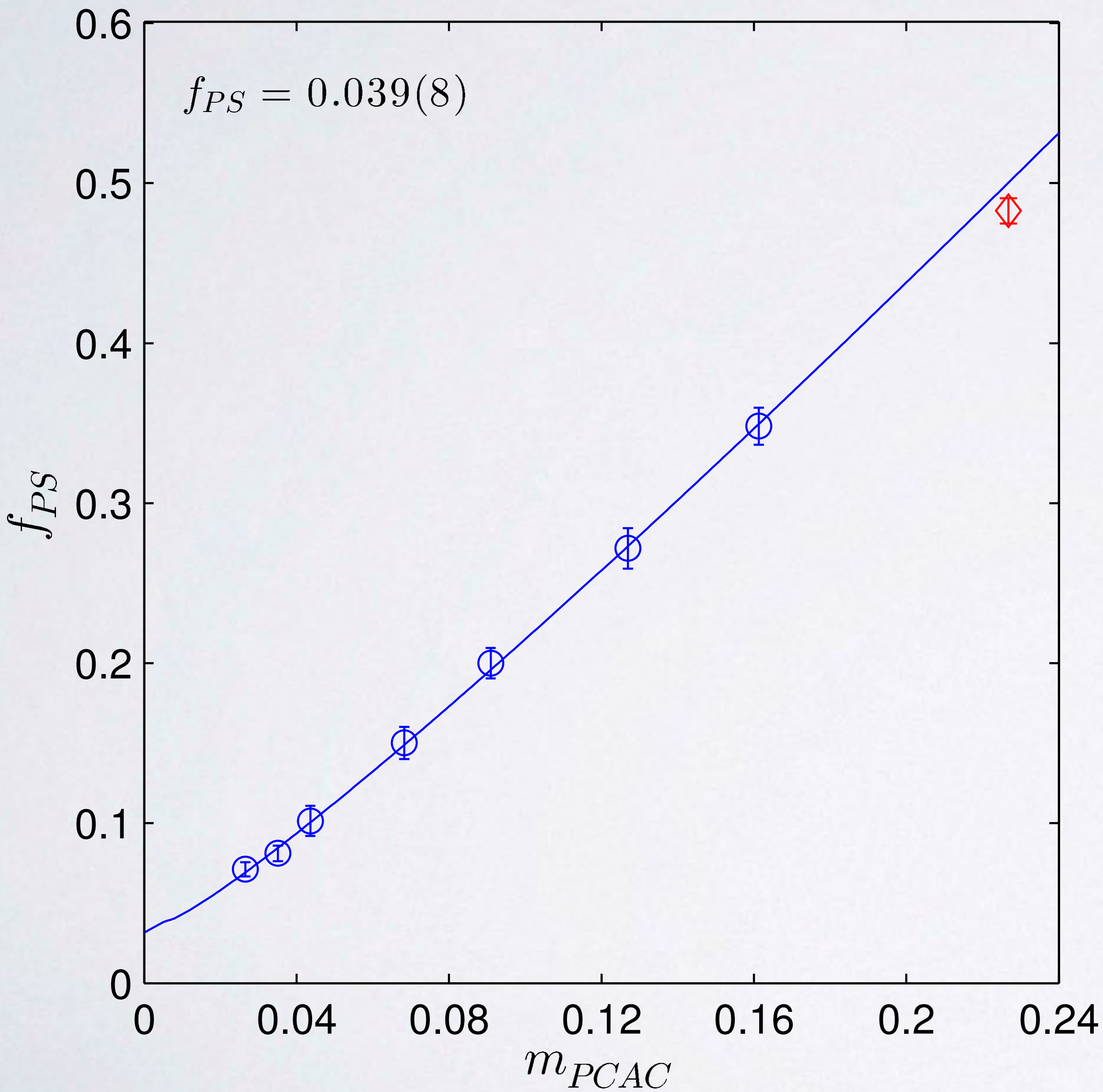
NLO - free log coefficients   d.o.f=6

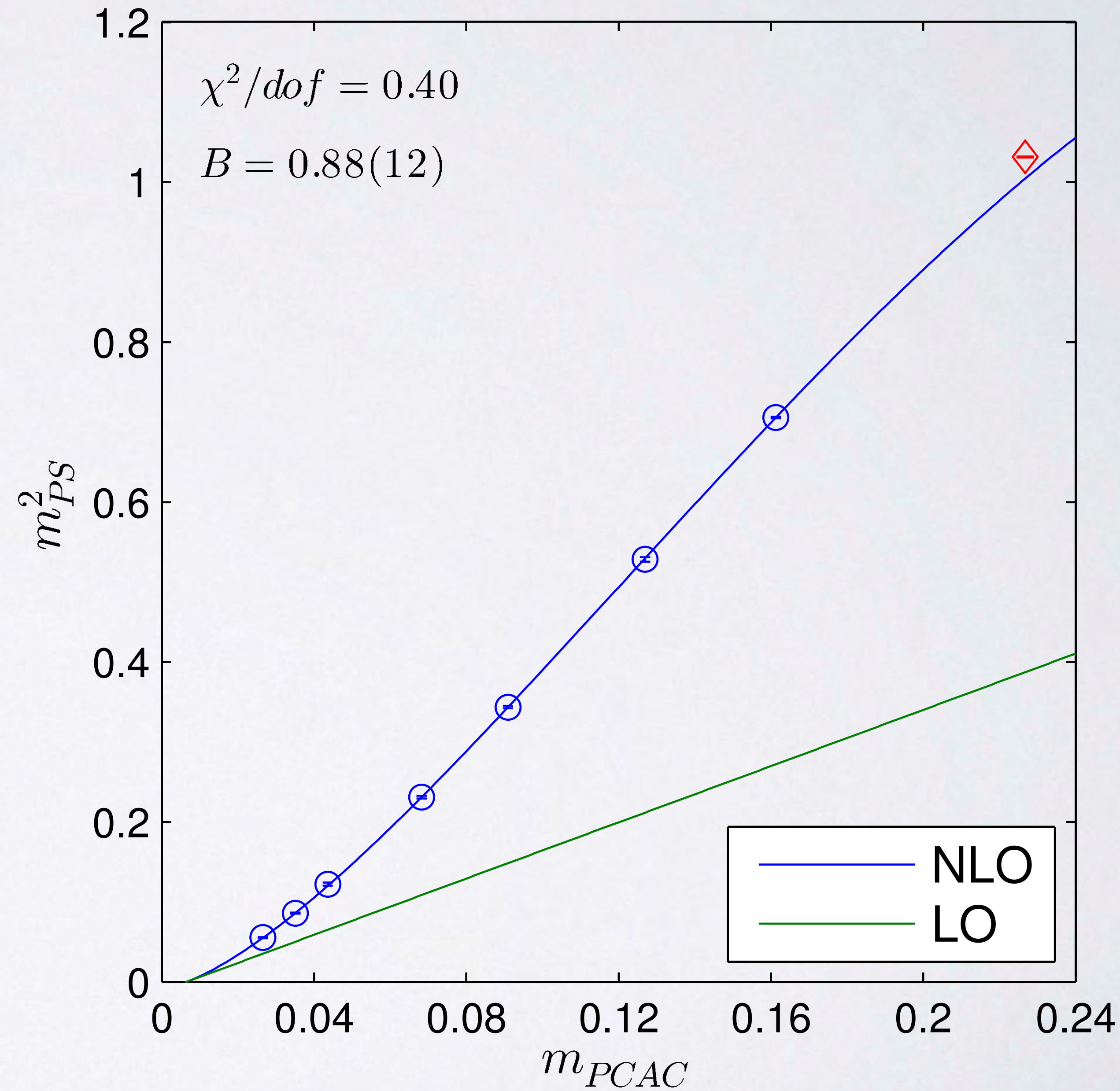




Spectrum: ChSB

NLO - free log coefficients $M^2 = 2Bm + \delta$ d.o.f=5





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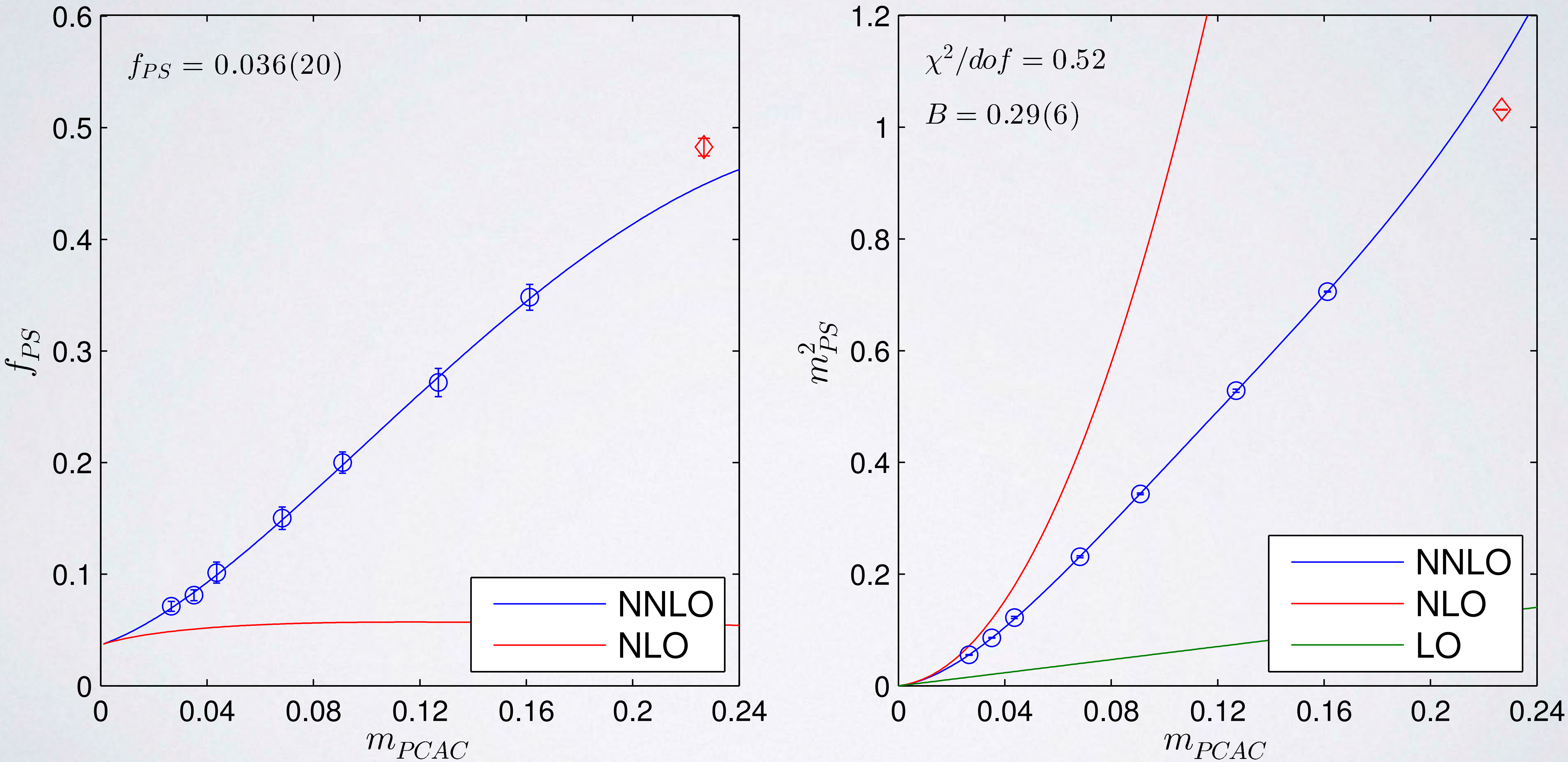
Spectrum: ChSB

NNLO - continuum log coefficients d.o.f=4



Conclusions

- Different qualitative behaviour in strong and weak phases:
  - "chiral" line has a first order transition vs continuous
  - splitting of m_{PS}/m_V vs near degenerate states
  - t_0, w_0^2: mild m_{PCAC} dependence vs divergence > than $1/m_{PS}^2$

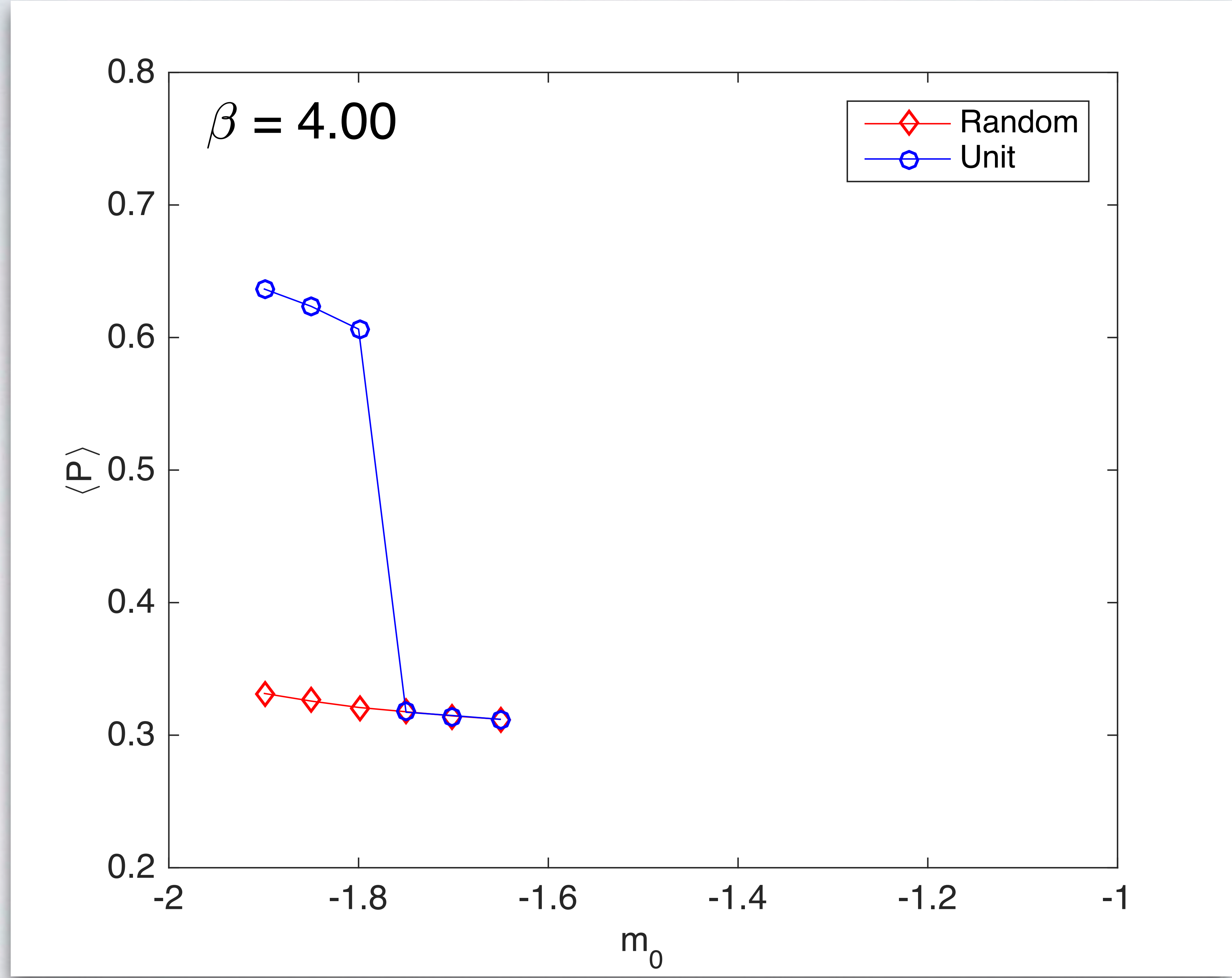
At weak coupling:

- IR conformal scaling compatible with data
- ChSB test: can fit the data, but very far from LO behaviour. But does it make sense at all?

Simplest interpretation of our data: IR conformal

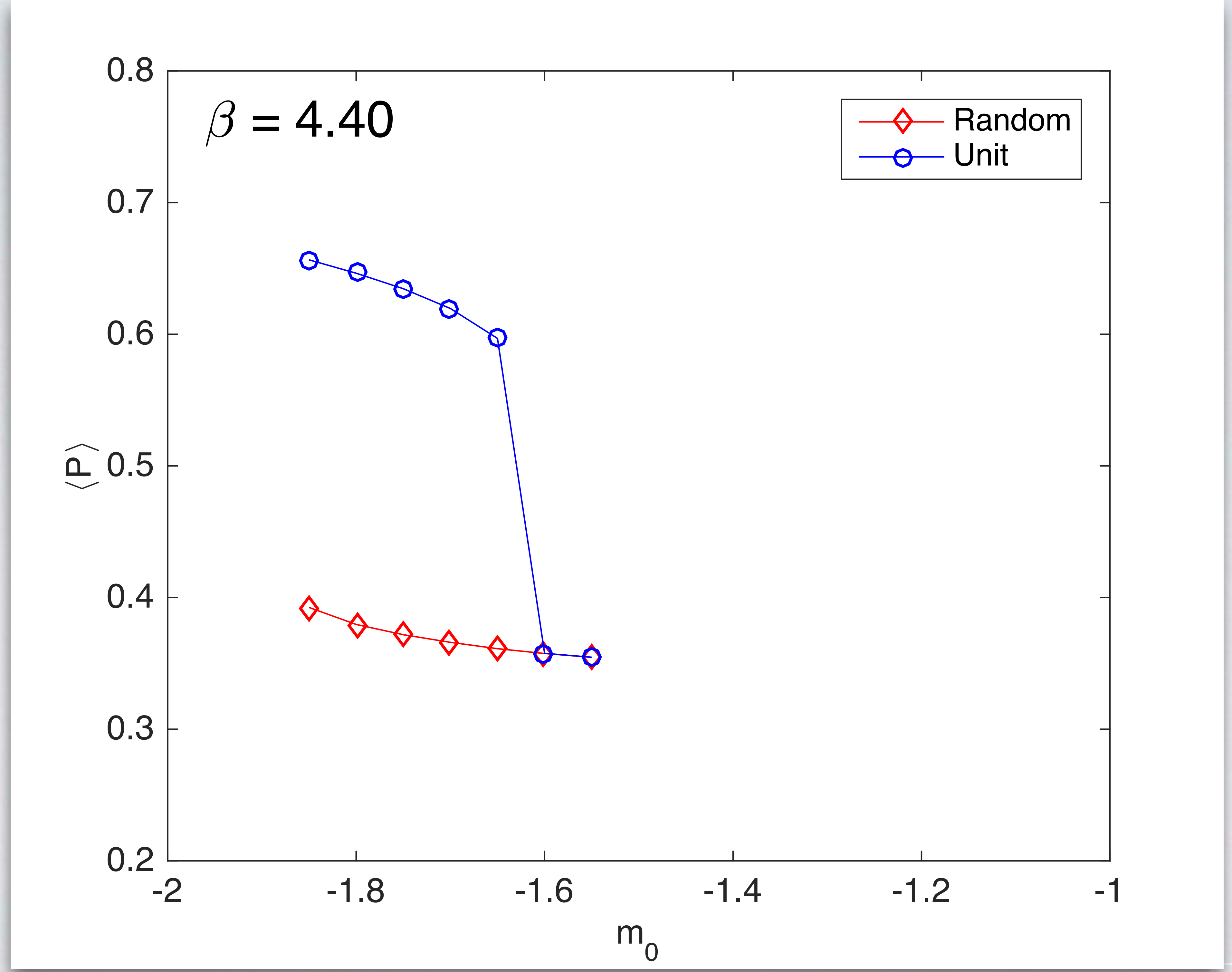
Backup

Hysteresis



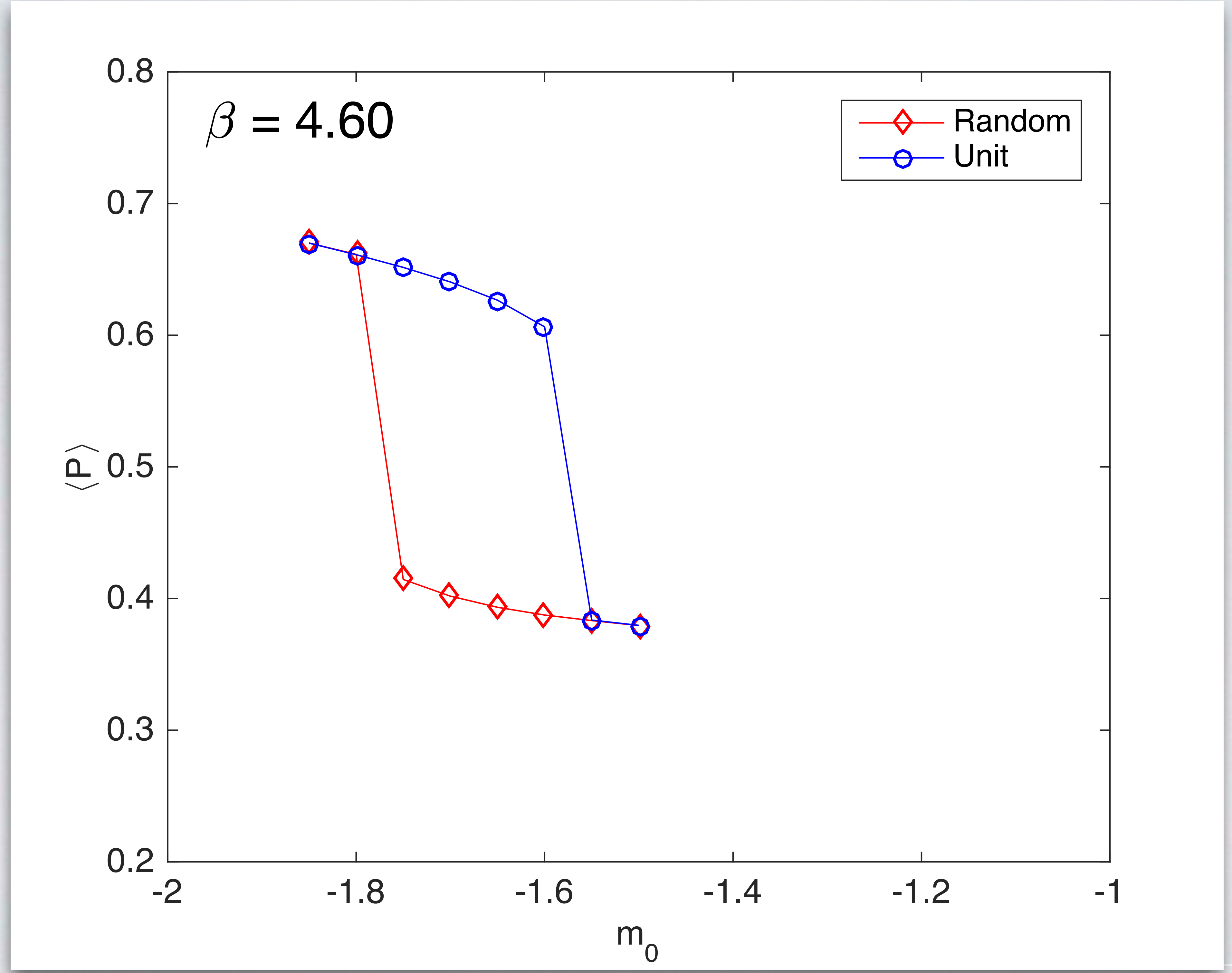
β = 4.00
Random
Unit
0.8
0.7
0.6
0.5
0.4
0.3
0.2
$\langle P \rangle$
-2
-1.8
-1.6
-1.4
-1.2
-1
m_0

Hysteresis

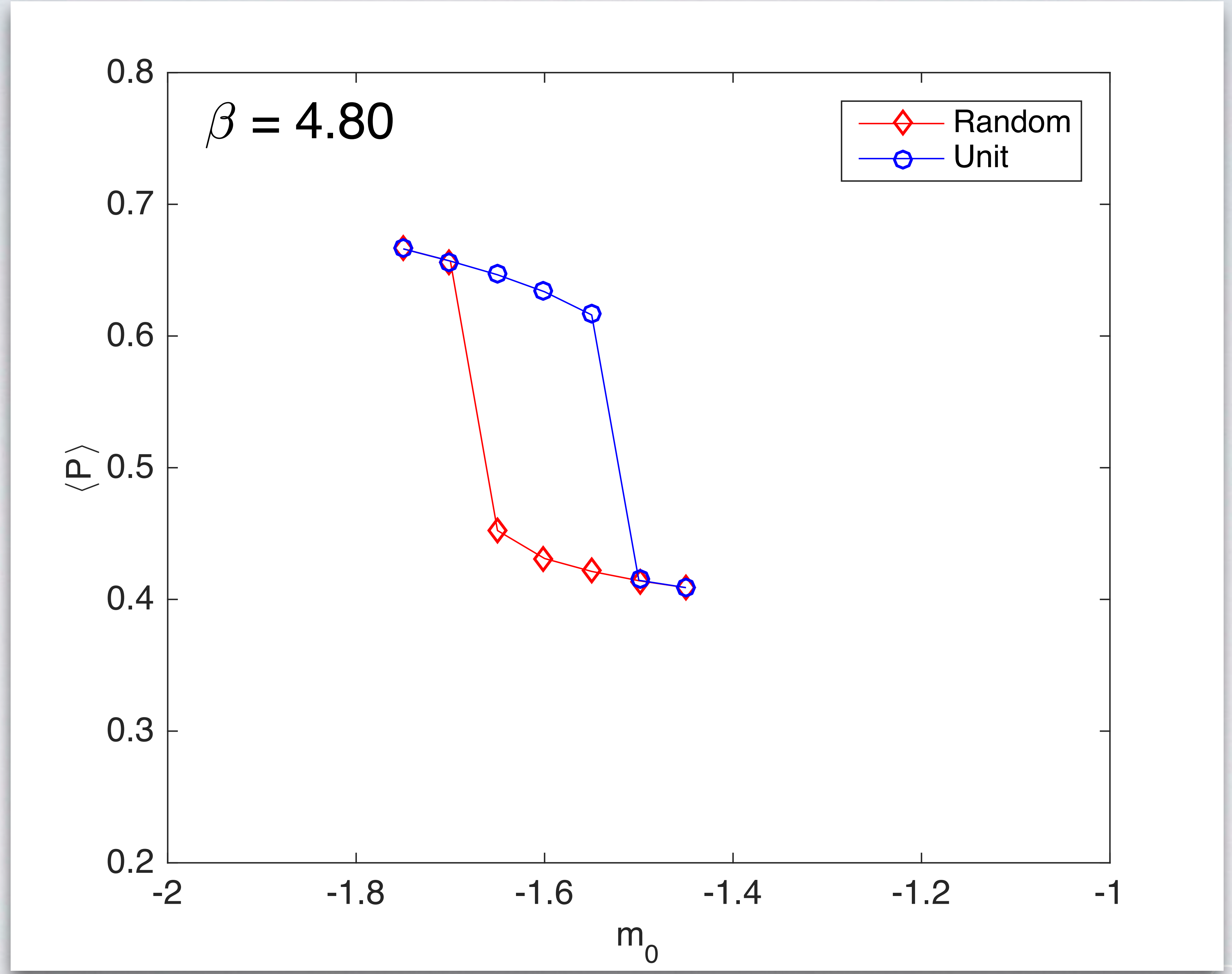


β = 4.40
Random
Unit
0.8
0.7
0.6
0.5
0.4
0.3
0.2
$\langle P \rangle$
-2
-1.8
-1.6
-1.4
-1.2
-1
m_0

Hysteresis



Hysteresis



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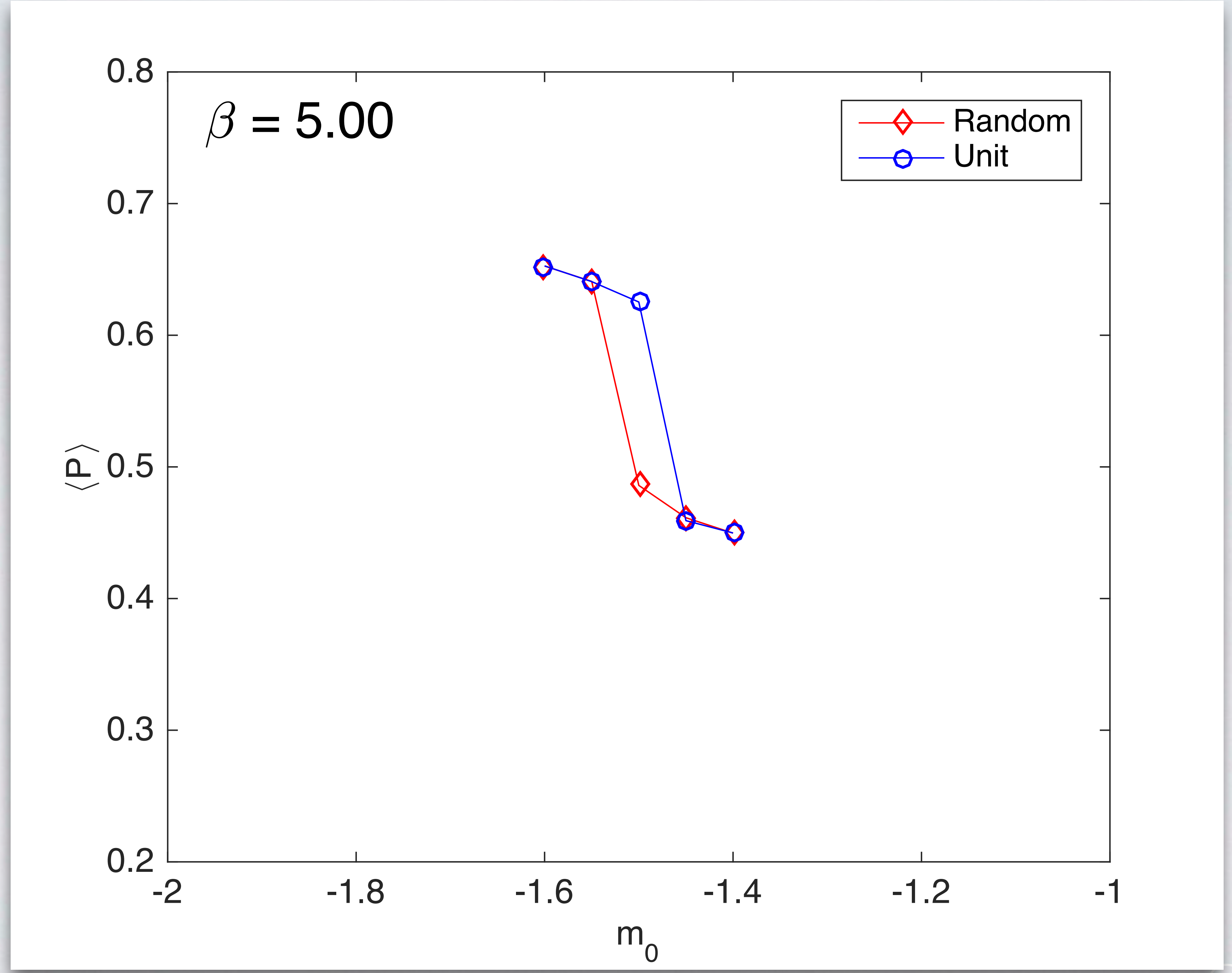
Hysteresis



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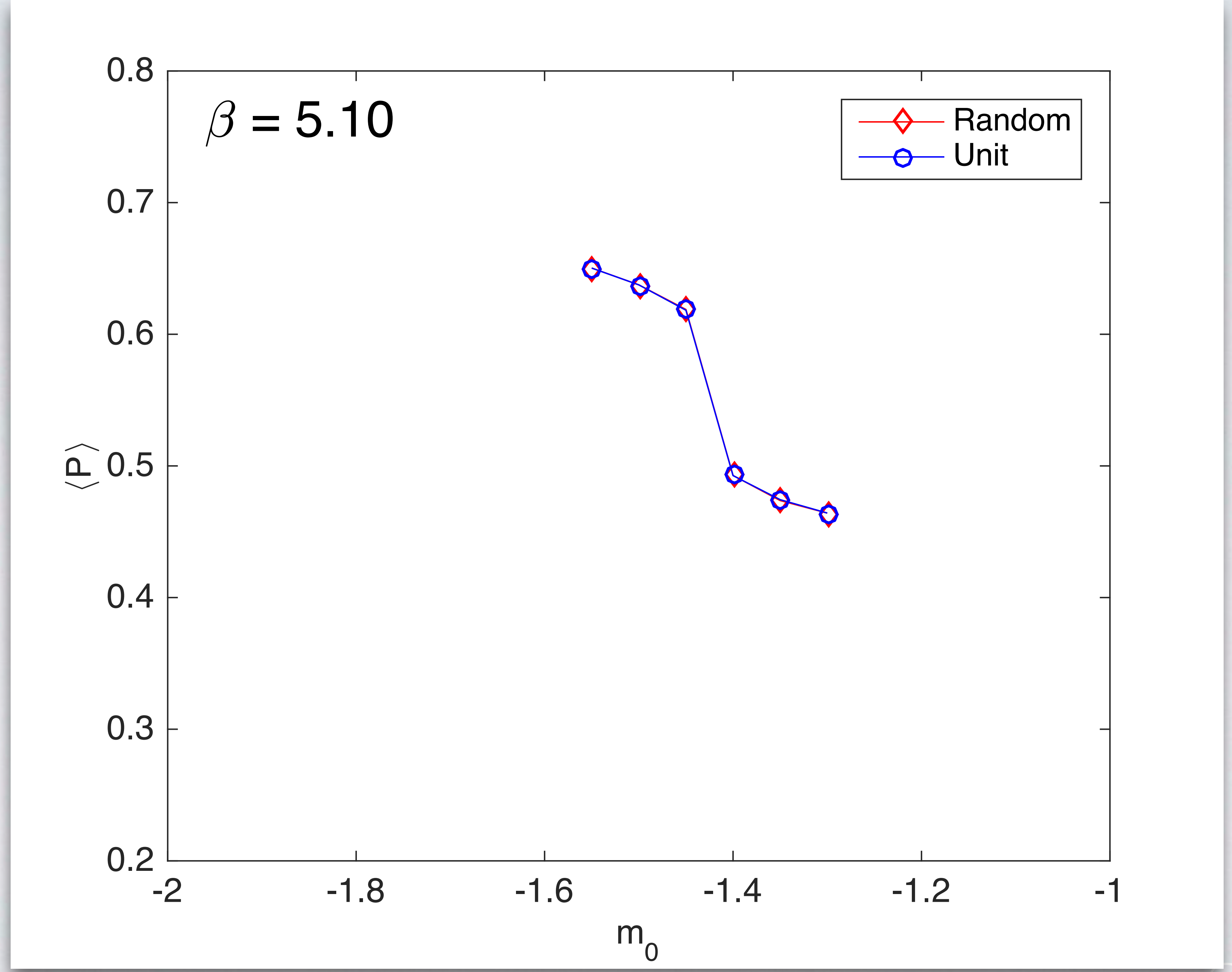

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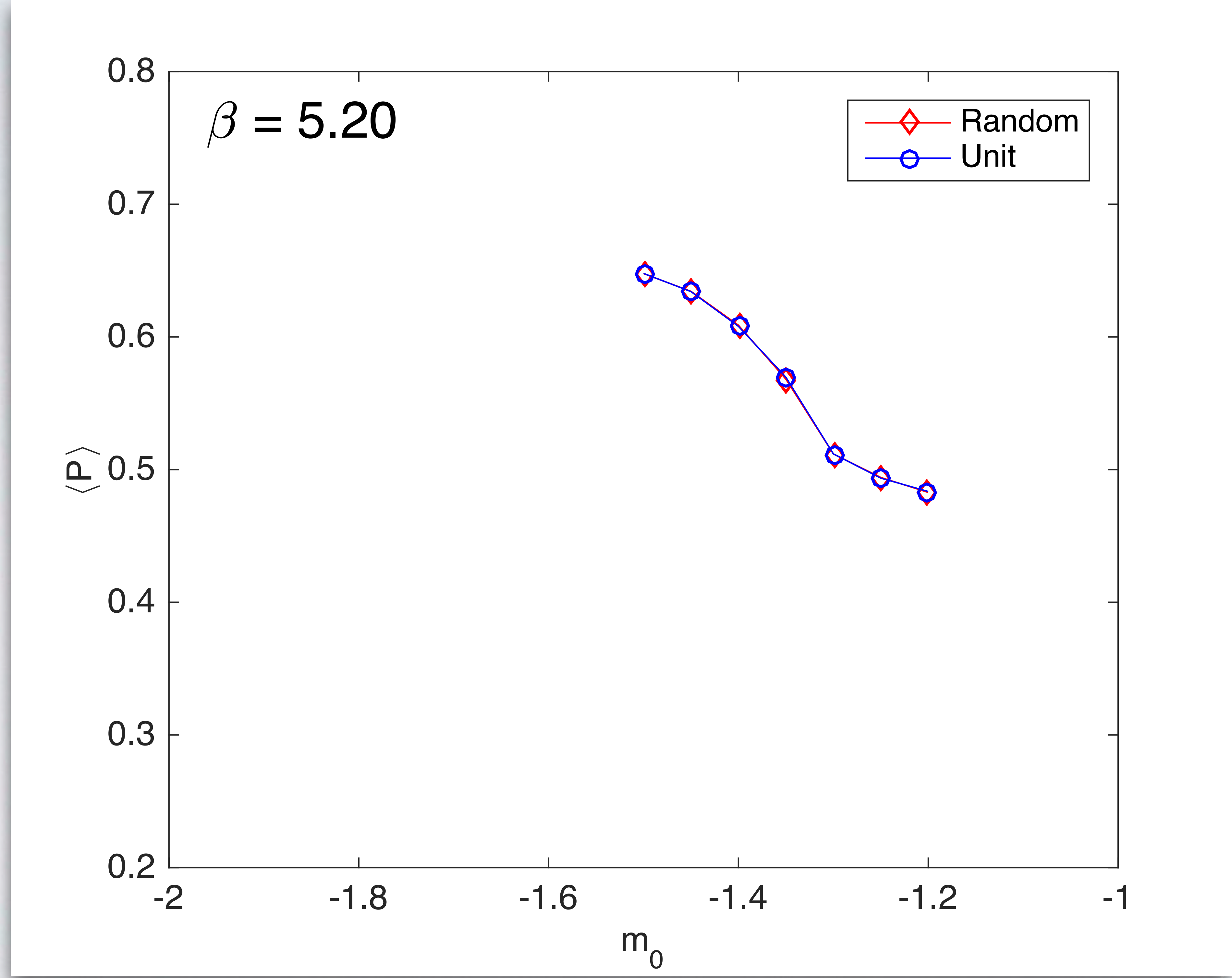
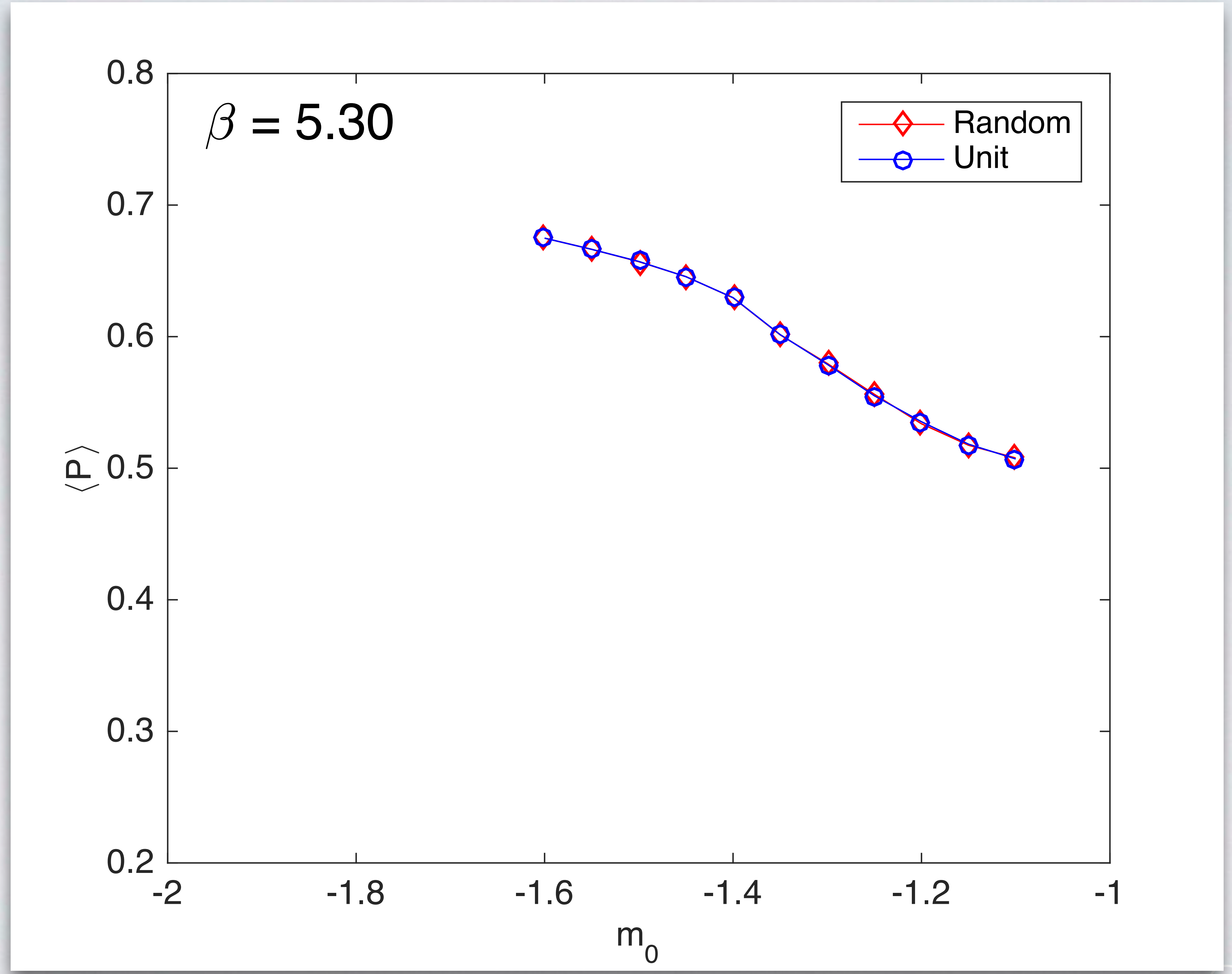
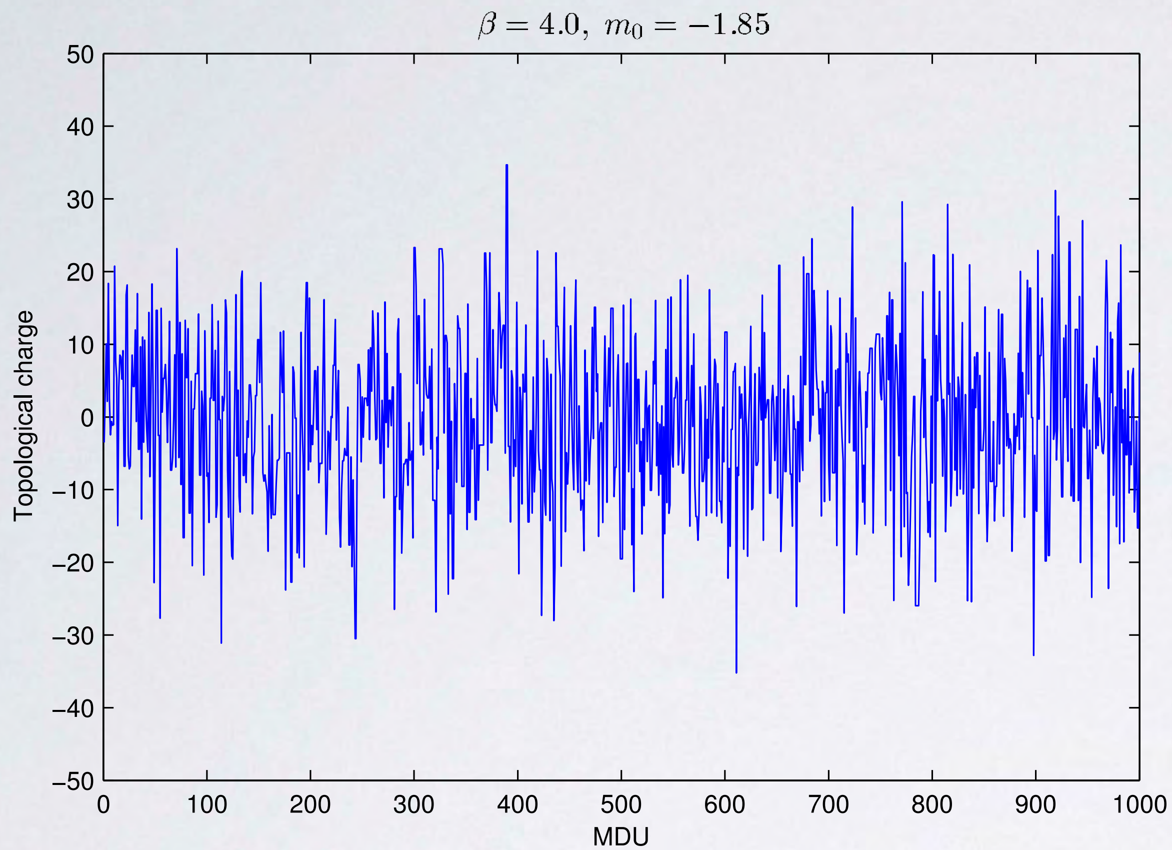
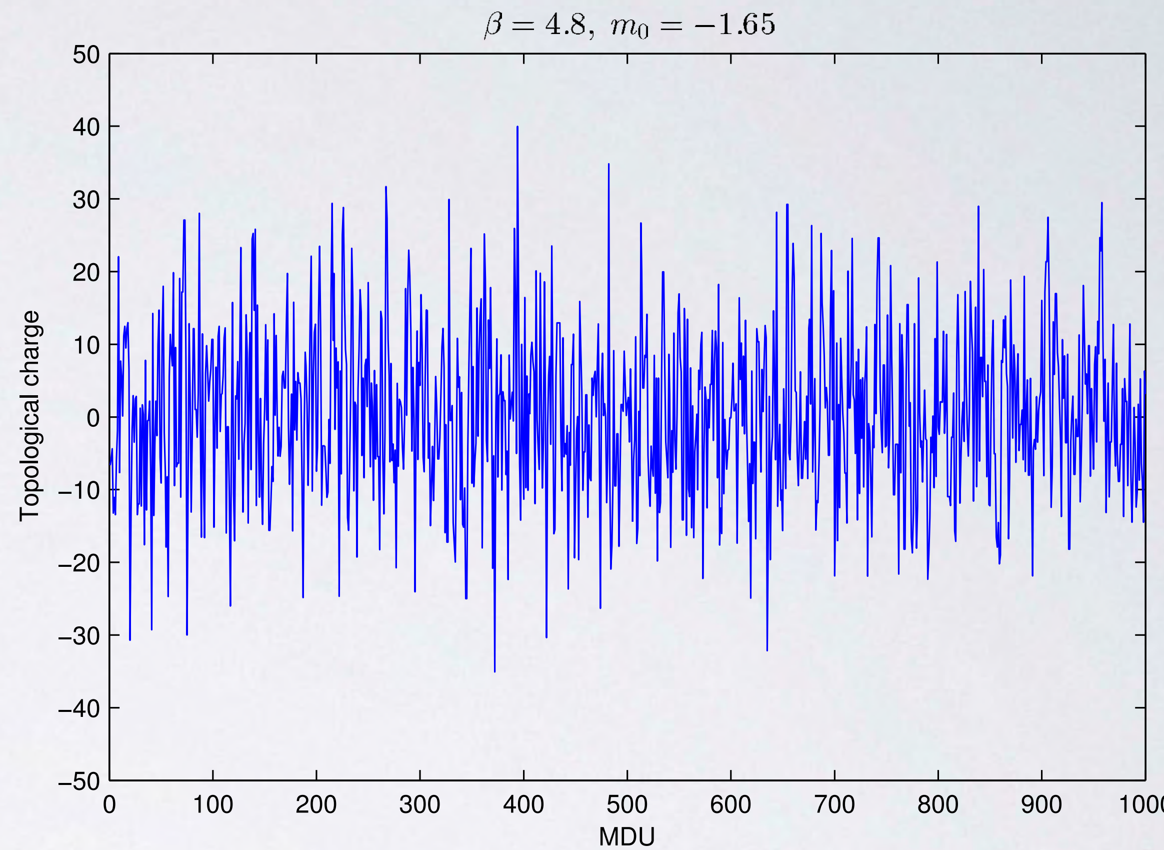


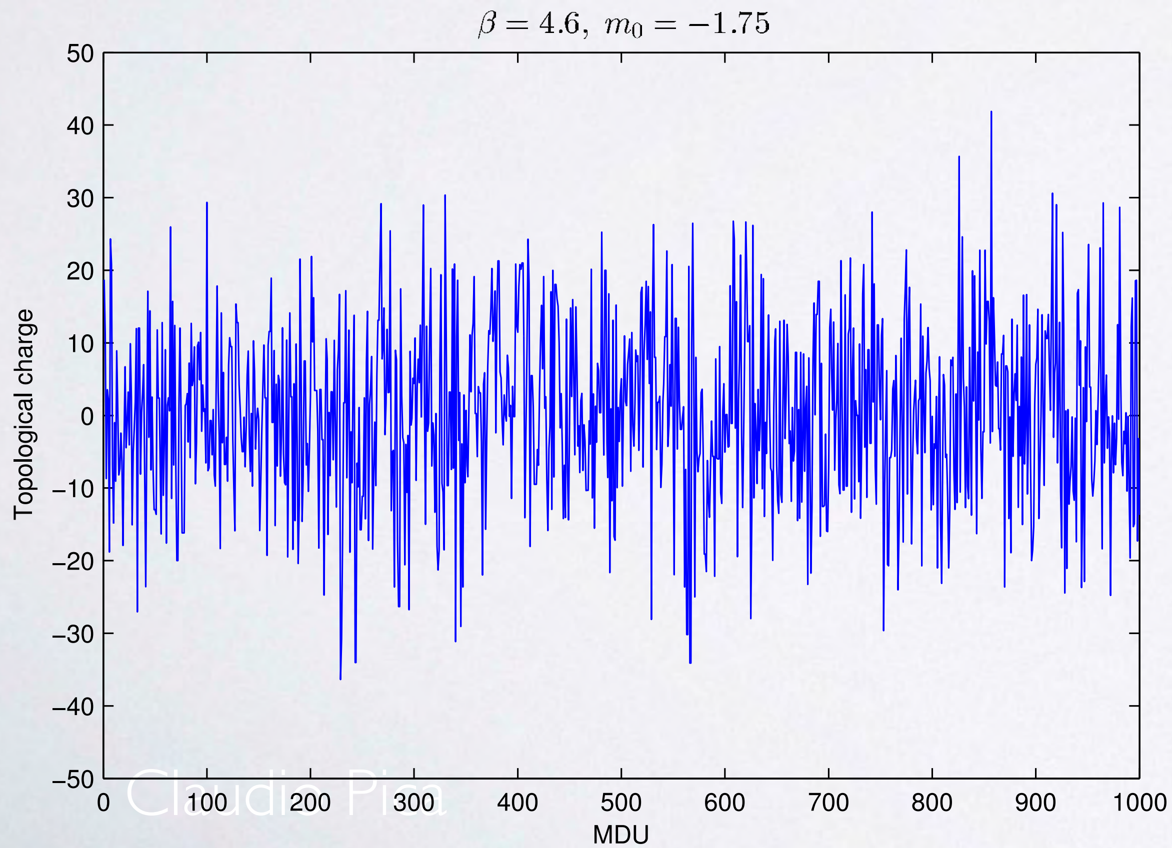
Hysteresis



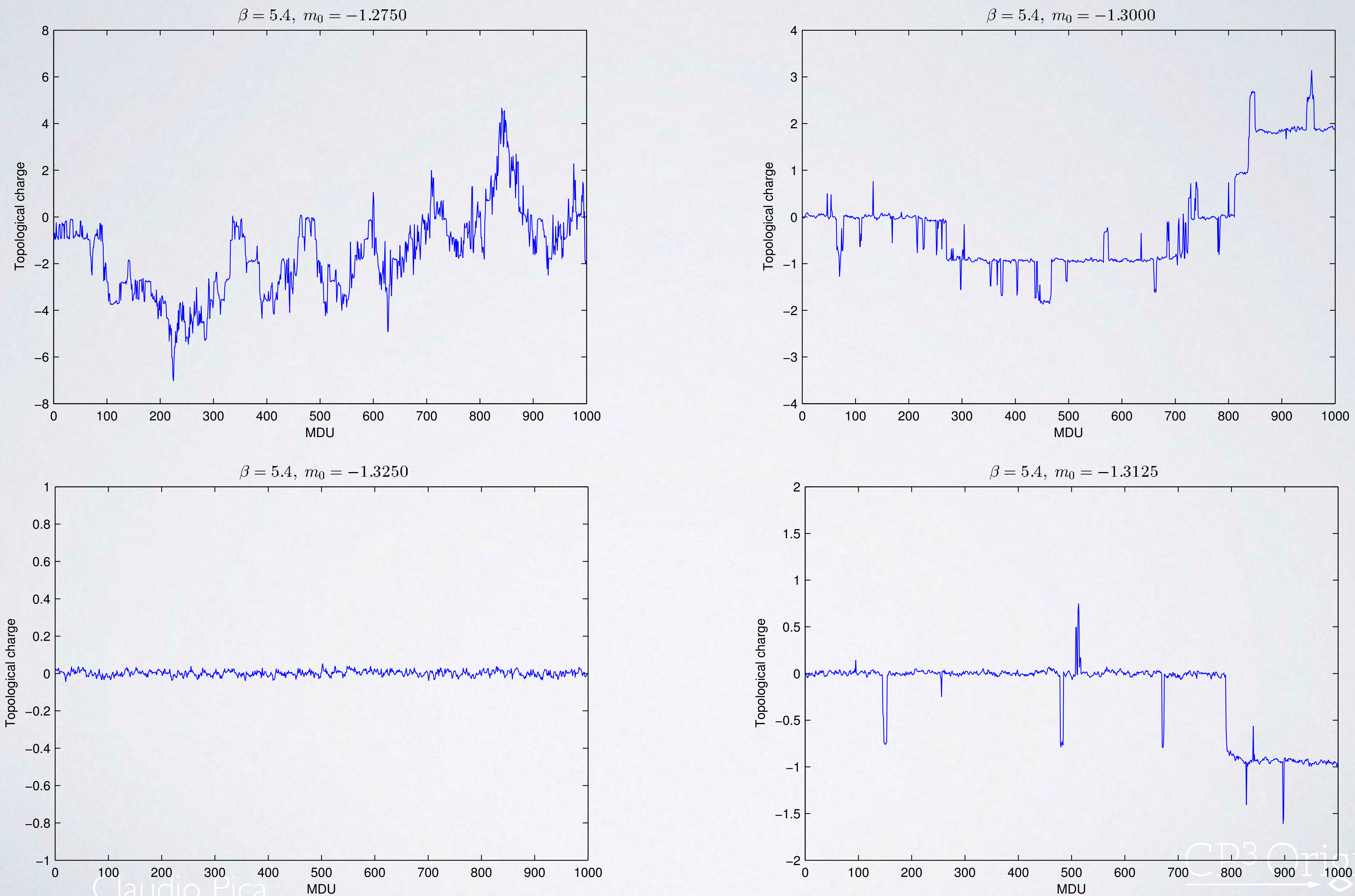
Topology: strong coupling



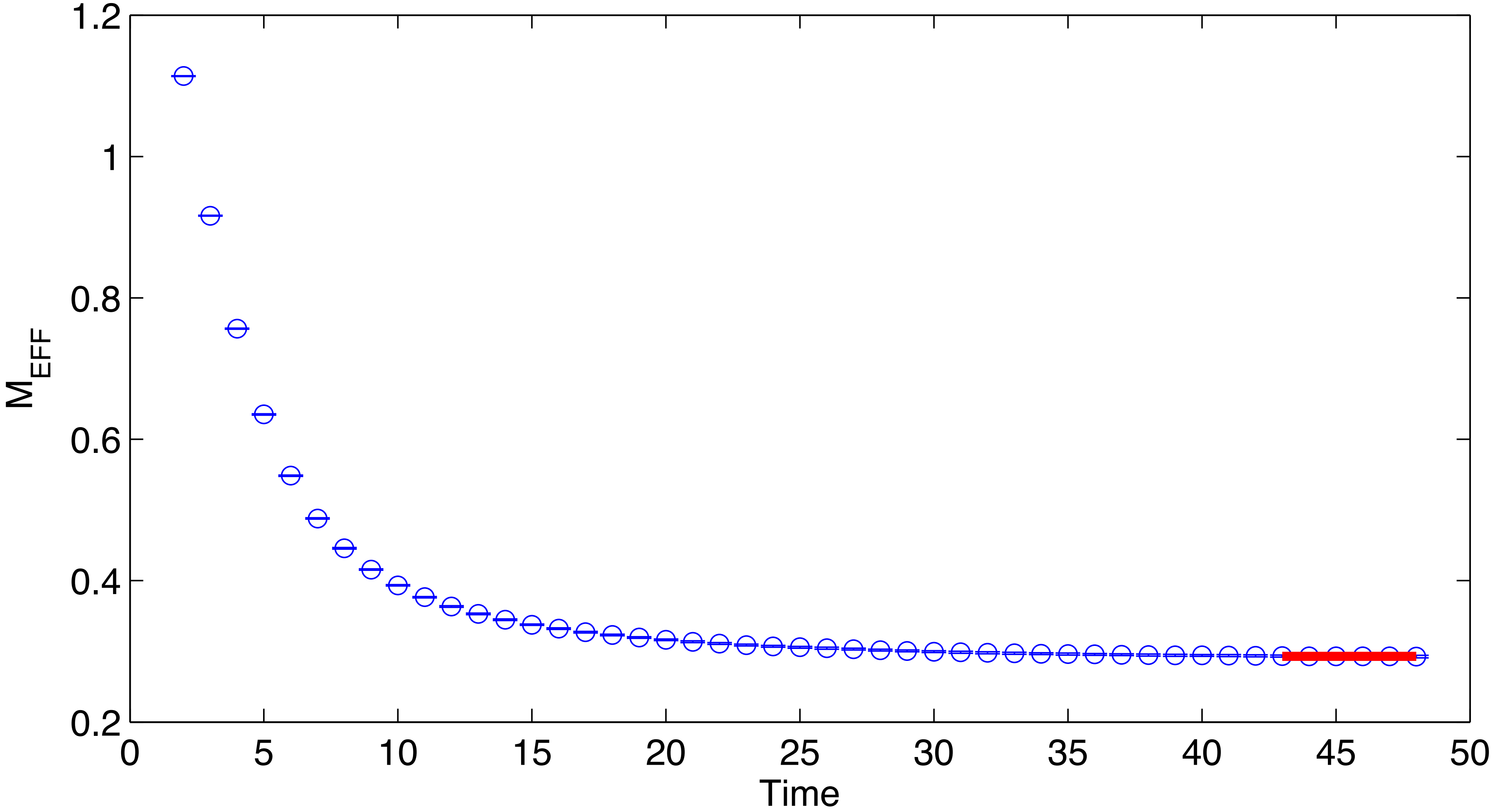




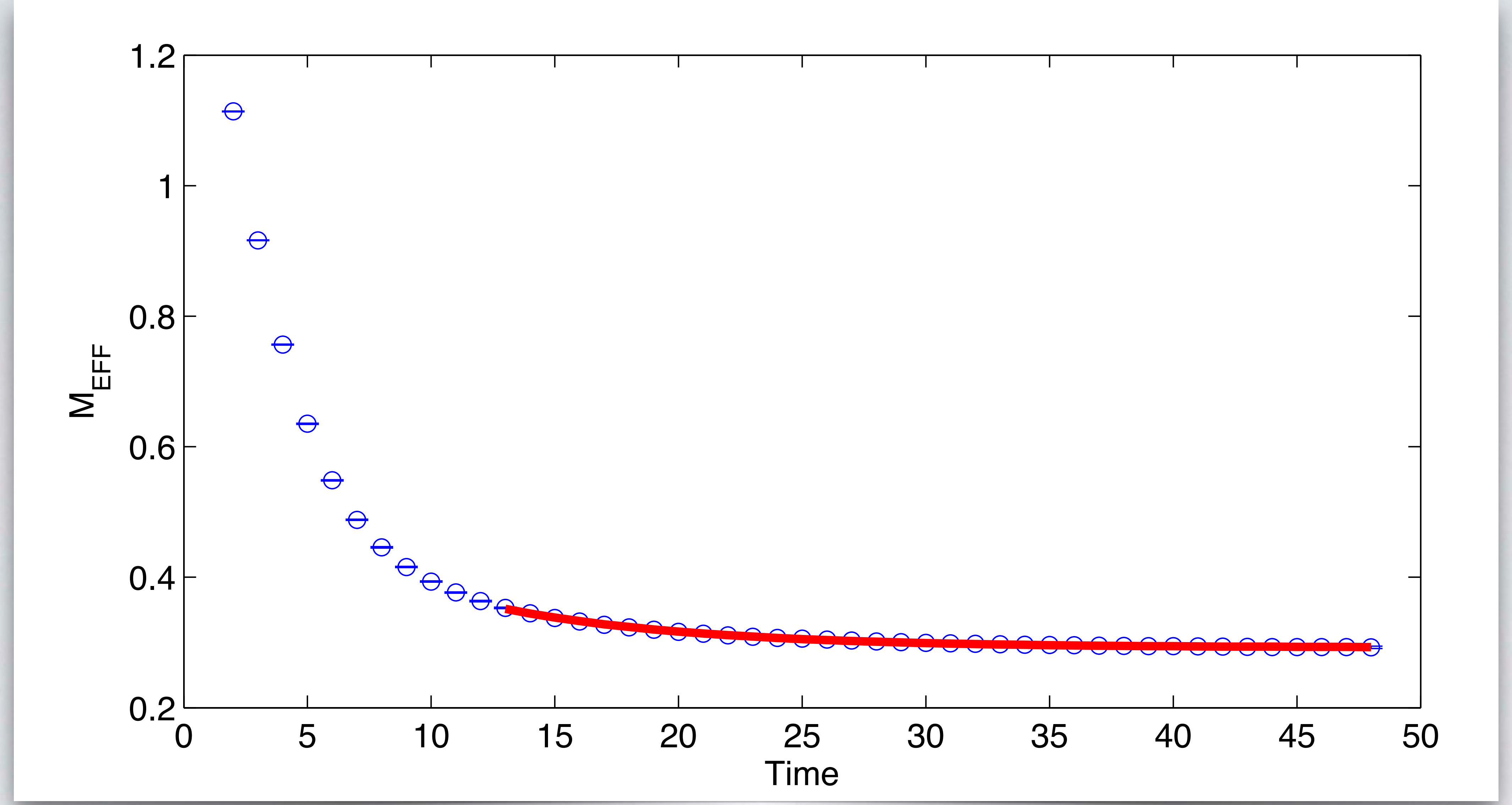
Topology: weak coupling



Effective masses

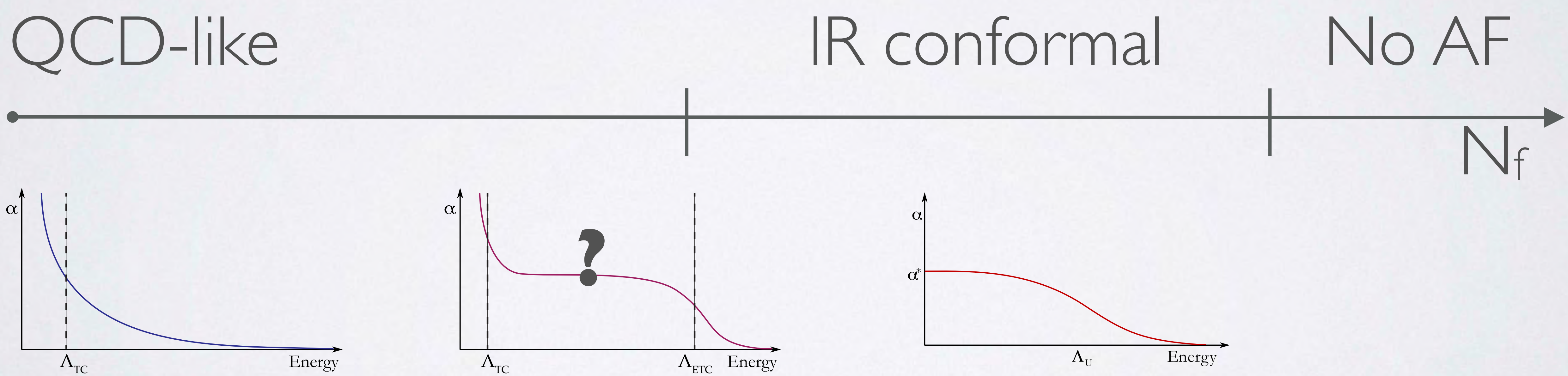


Effective masses



Conformal Window

- Gauge Group: SU, SO, SP, Exceptional
- Matter Representation(s)
- # of Flavors per Representation



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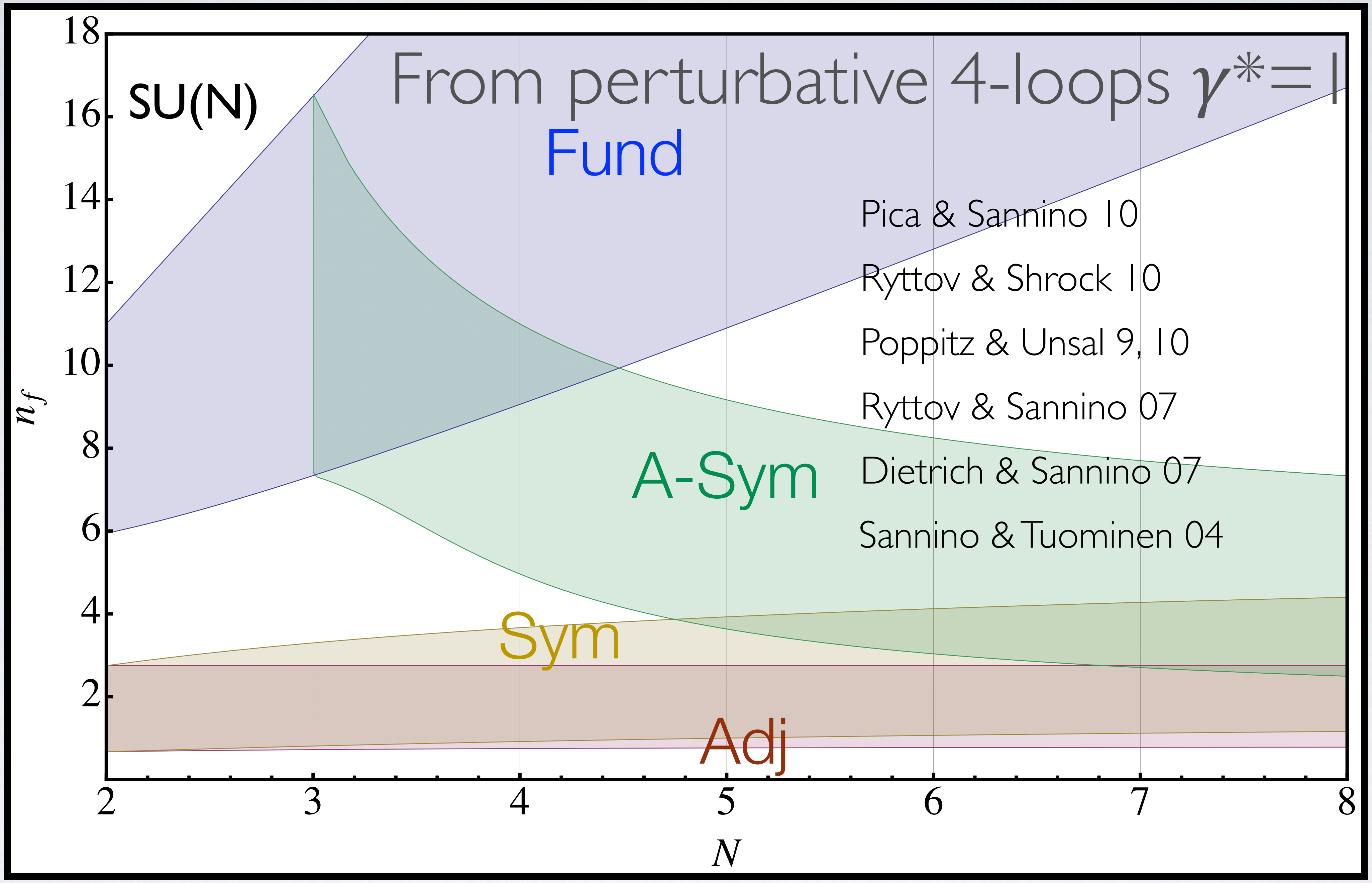
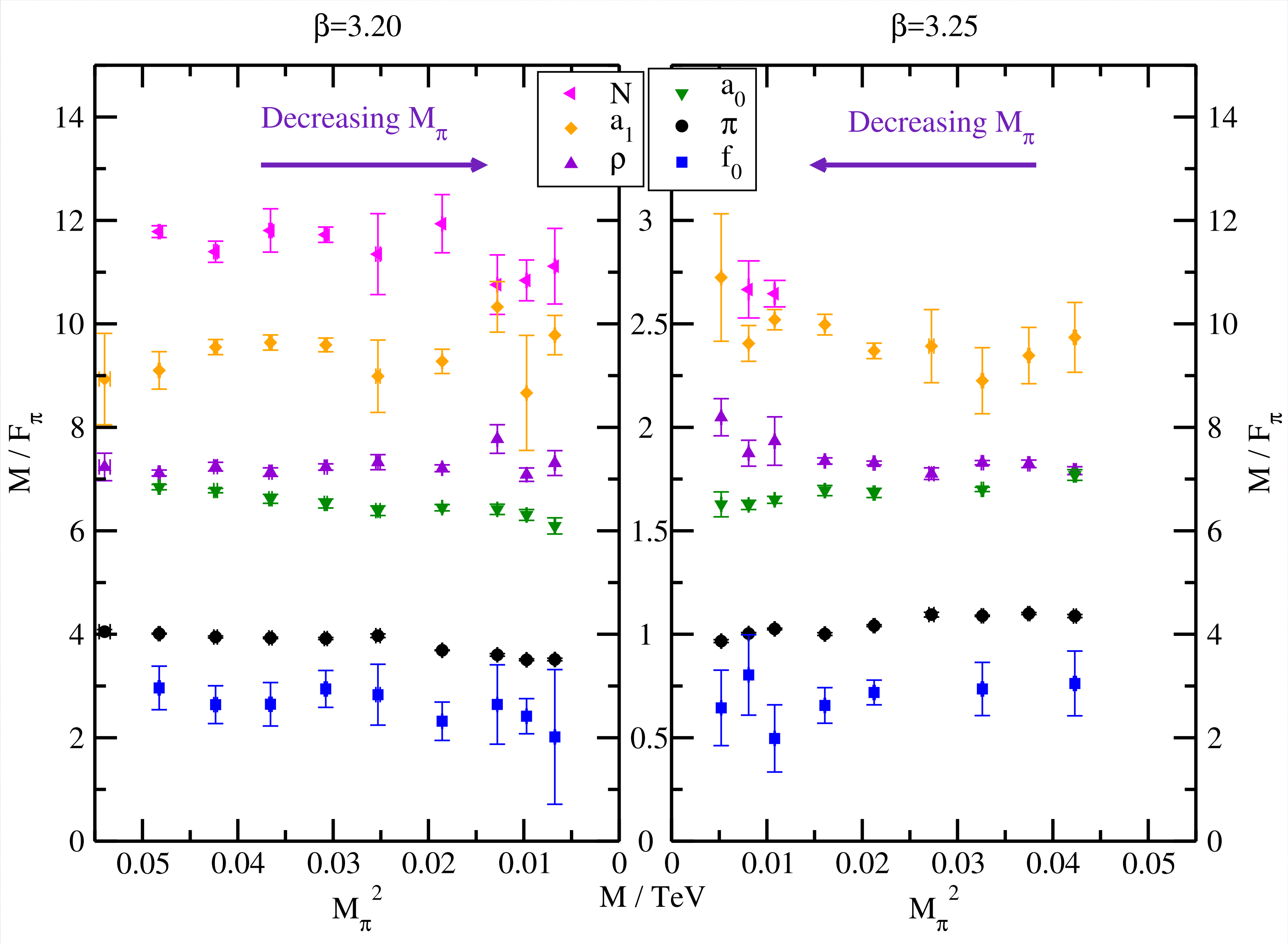
SU(N)



Other methods to estimate the lower boundary available: Schwinger–Dyson eq, counting of thermal d.o.f.,

not all in agreement ➙ **NEED non-perturbative Lattice determination**

SU(3) Sextet N_f=2 Staggered



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