The Sextet Model

An overview of the phase structure with Wilson fermions

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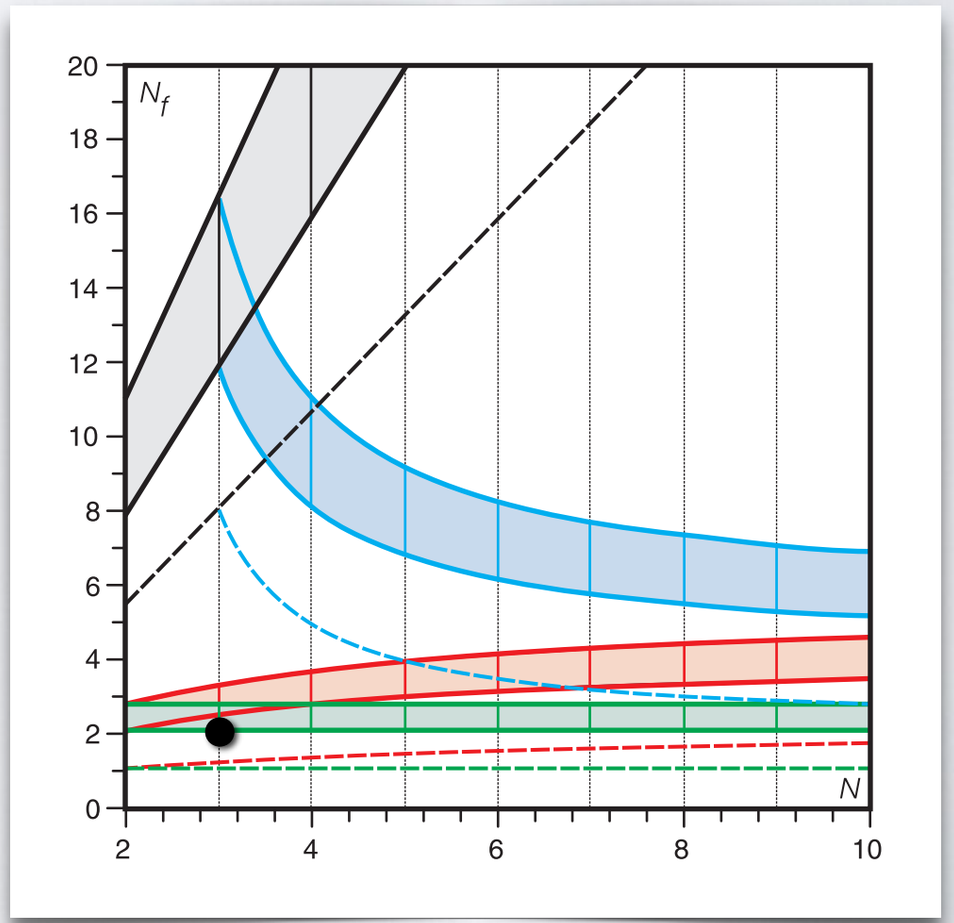
SDU

CP³ Origins
Cosmology & Particle Physics

Motivation

- Minimal Walking Technicolor model
  - SU(3) with two flavors of two-index symmetric fermions
- Near the conformal window
  - Possible walking behavior
  - Might have a light scalar
    - This would be the Higgs particle
- Small ***S*** parameter

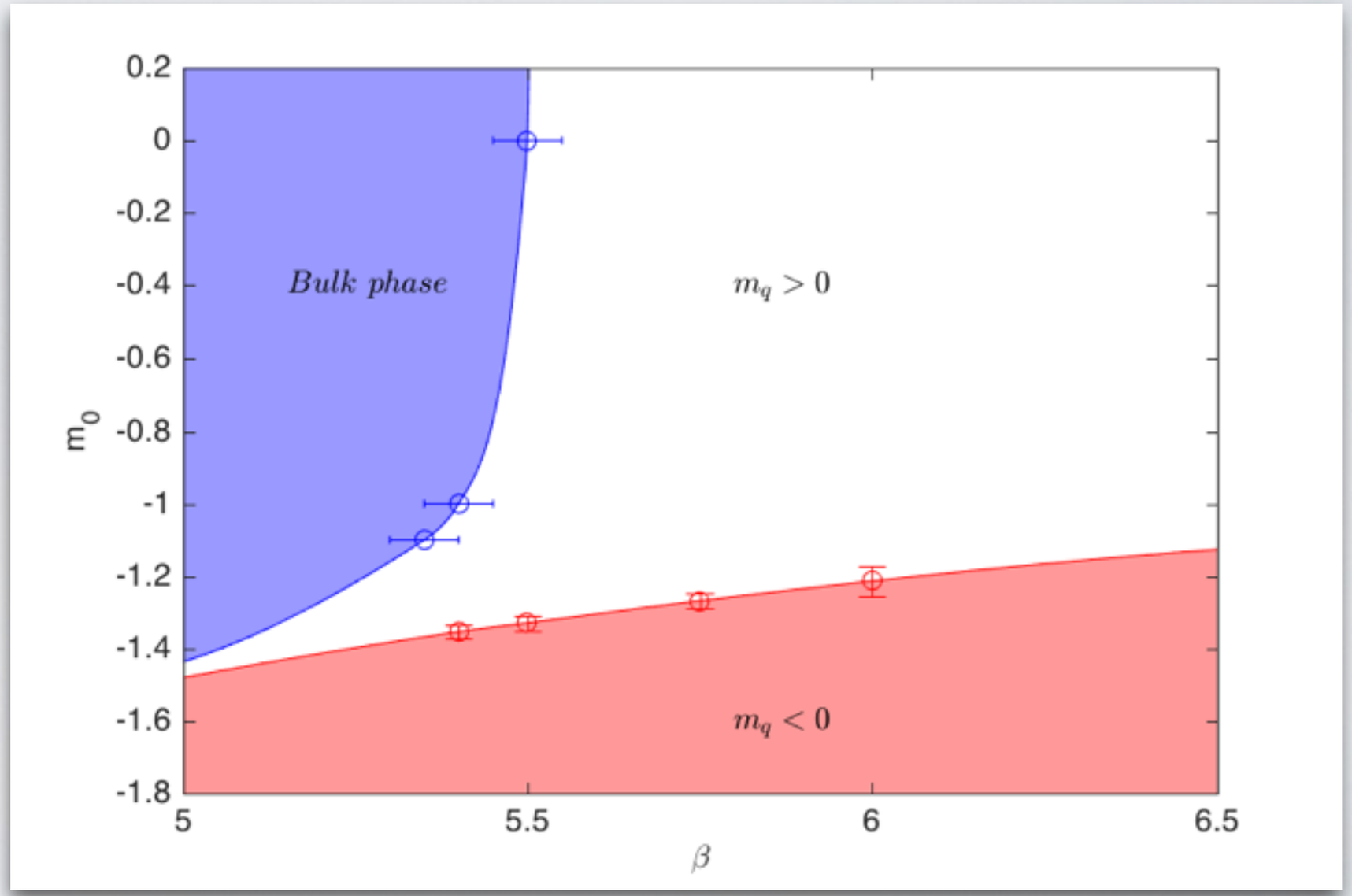
Dietrich, Sannino 2006



Old phase diagram

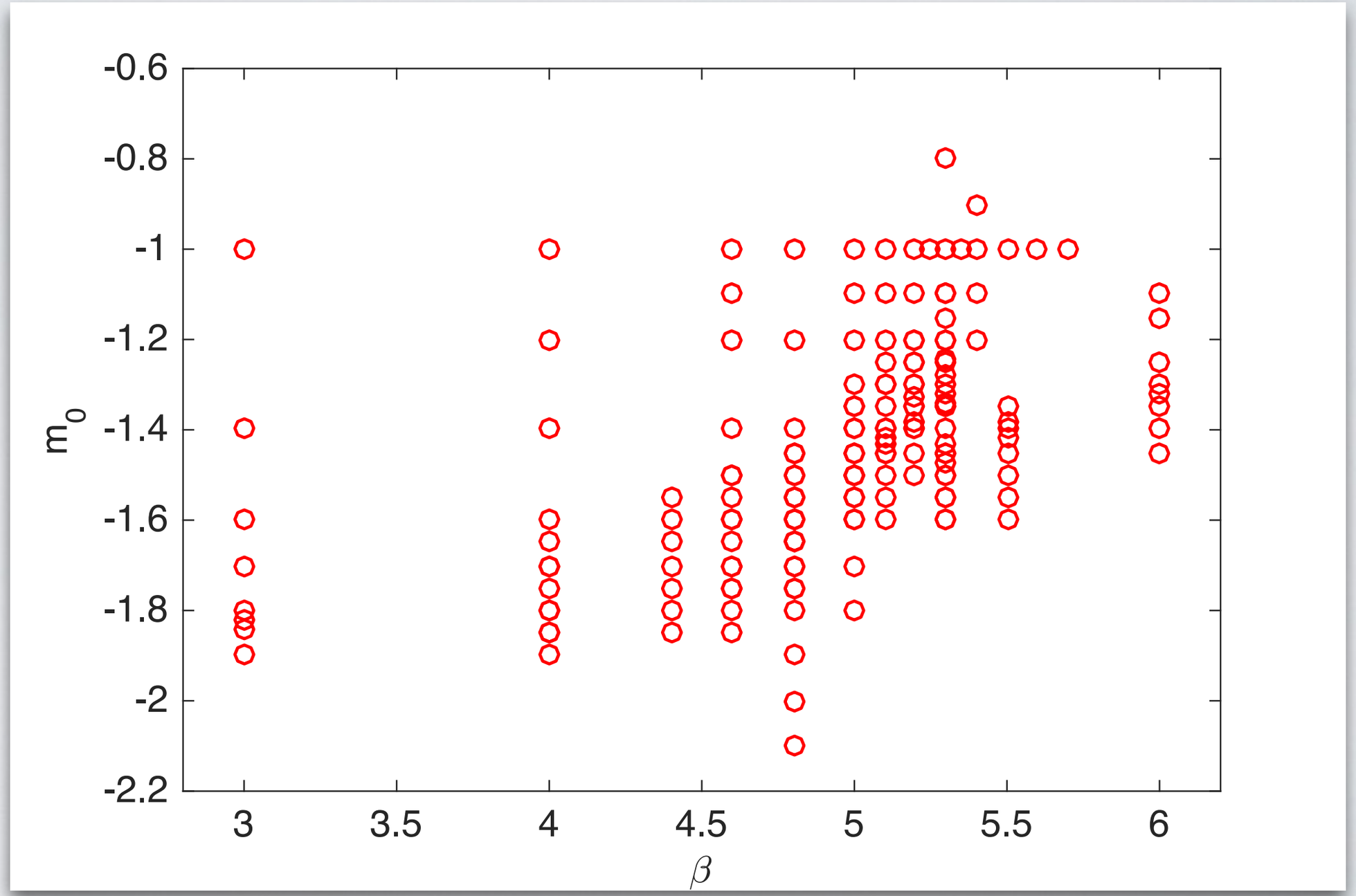
- Bulk phase identified from peak in plaquette susceptibility
- Chiral line identified from PCAC relation

Wilson fermions
+
Plaquette gauge



New simulations

- Large number of new simulations (around 150)



New phase diagram

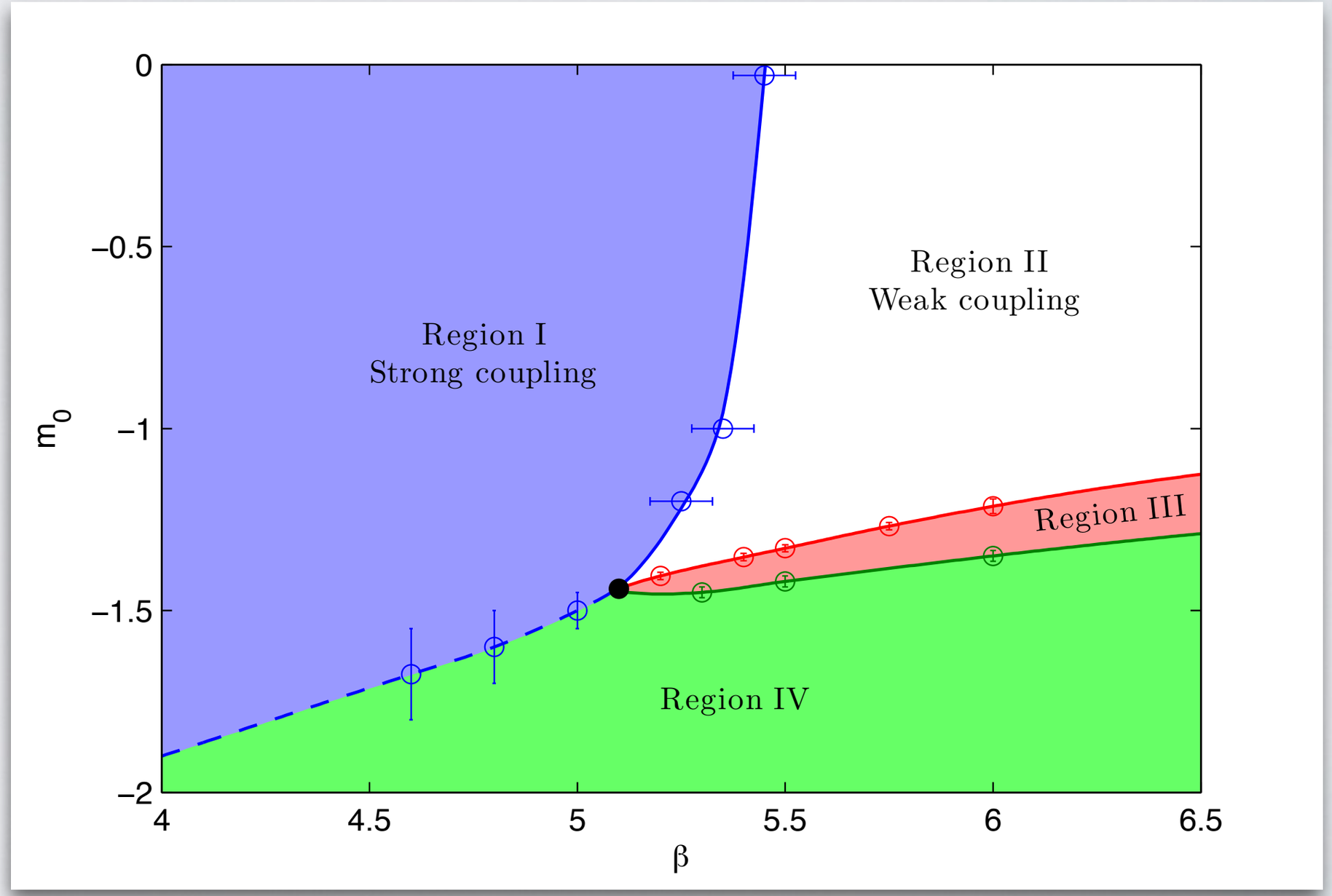
- Phase diagram with 4 regions of interest

Region I, II, III

$$\frac{dm_q}{dm_0} > 0$$

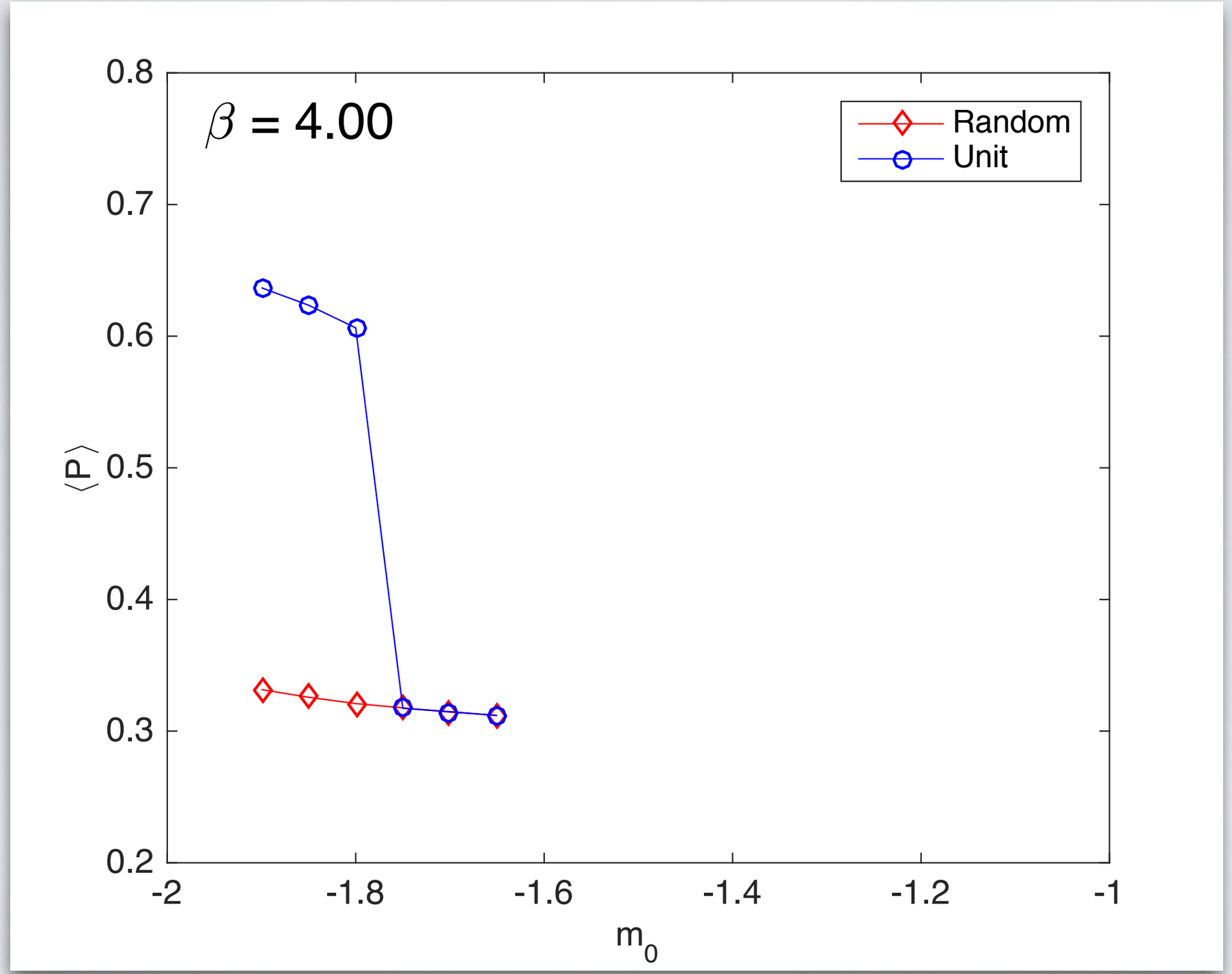
Region IV

$$\frac{dm_q}{dm_0} < 0$$

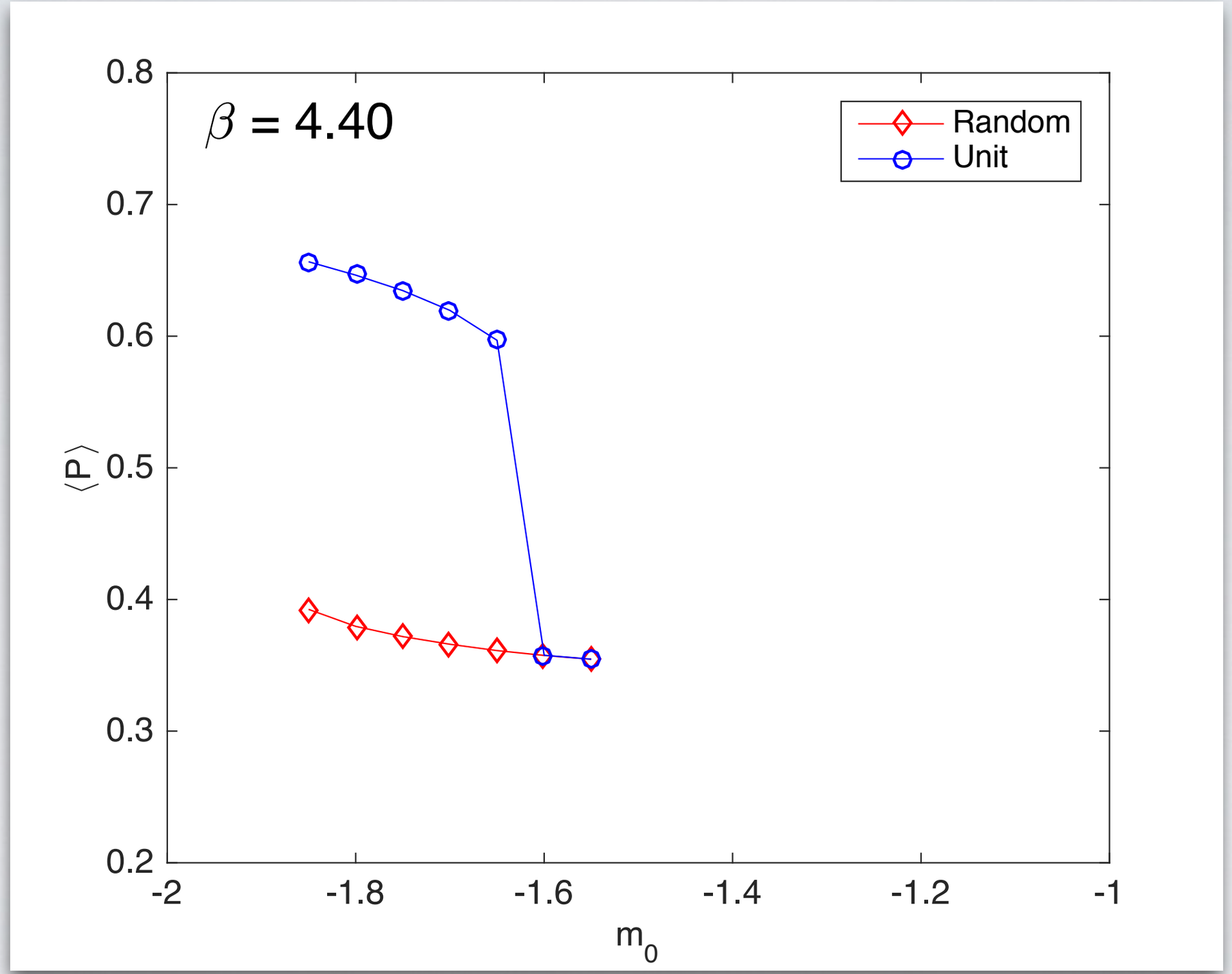


I st order transition

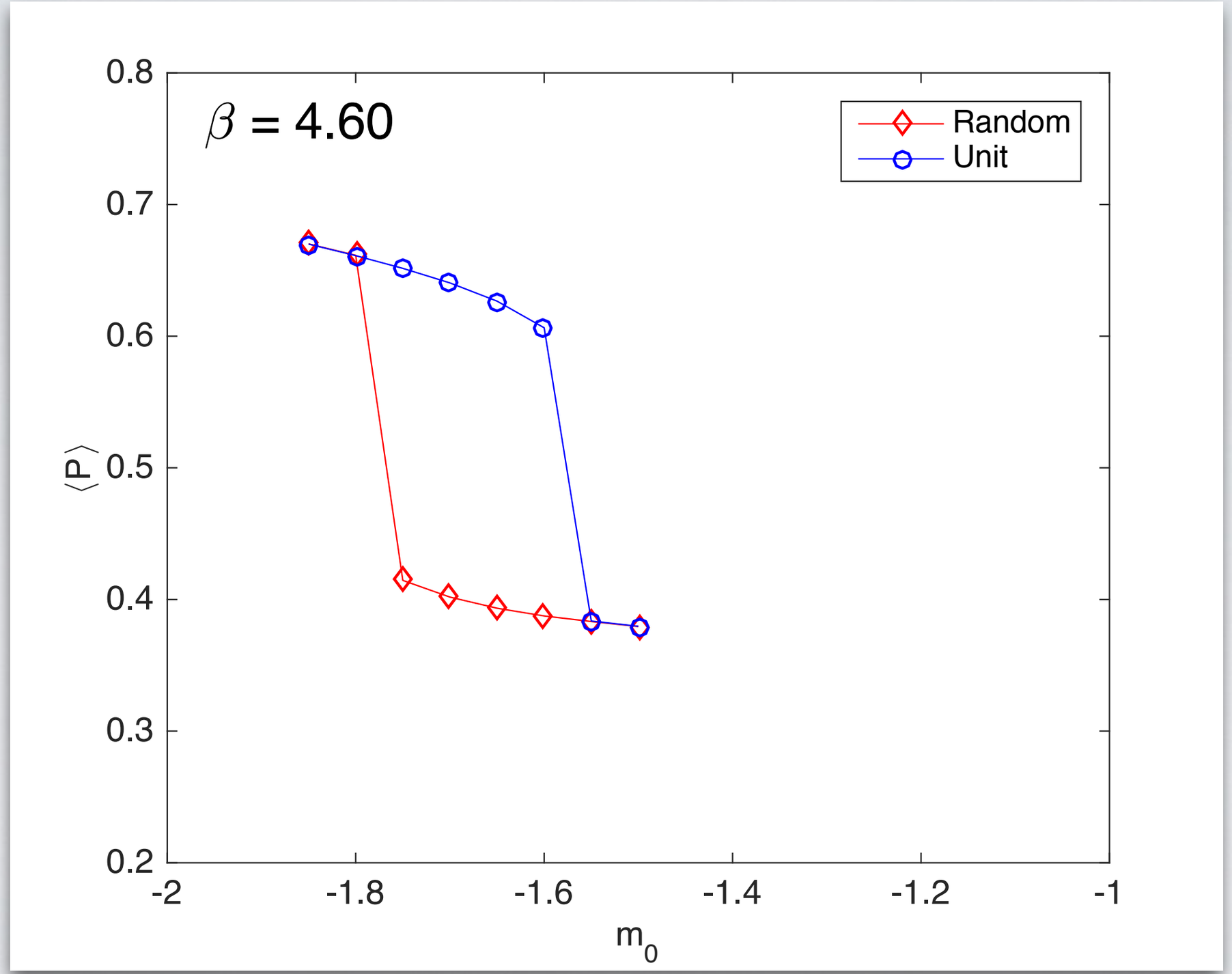
Hysteresis


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

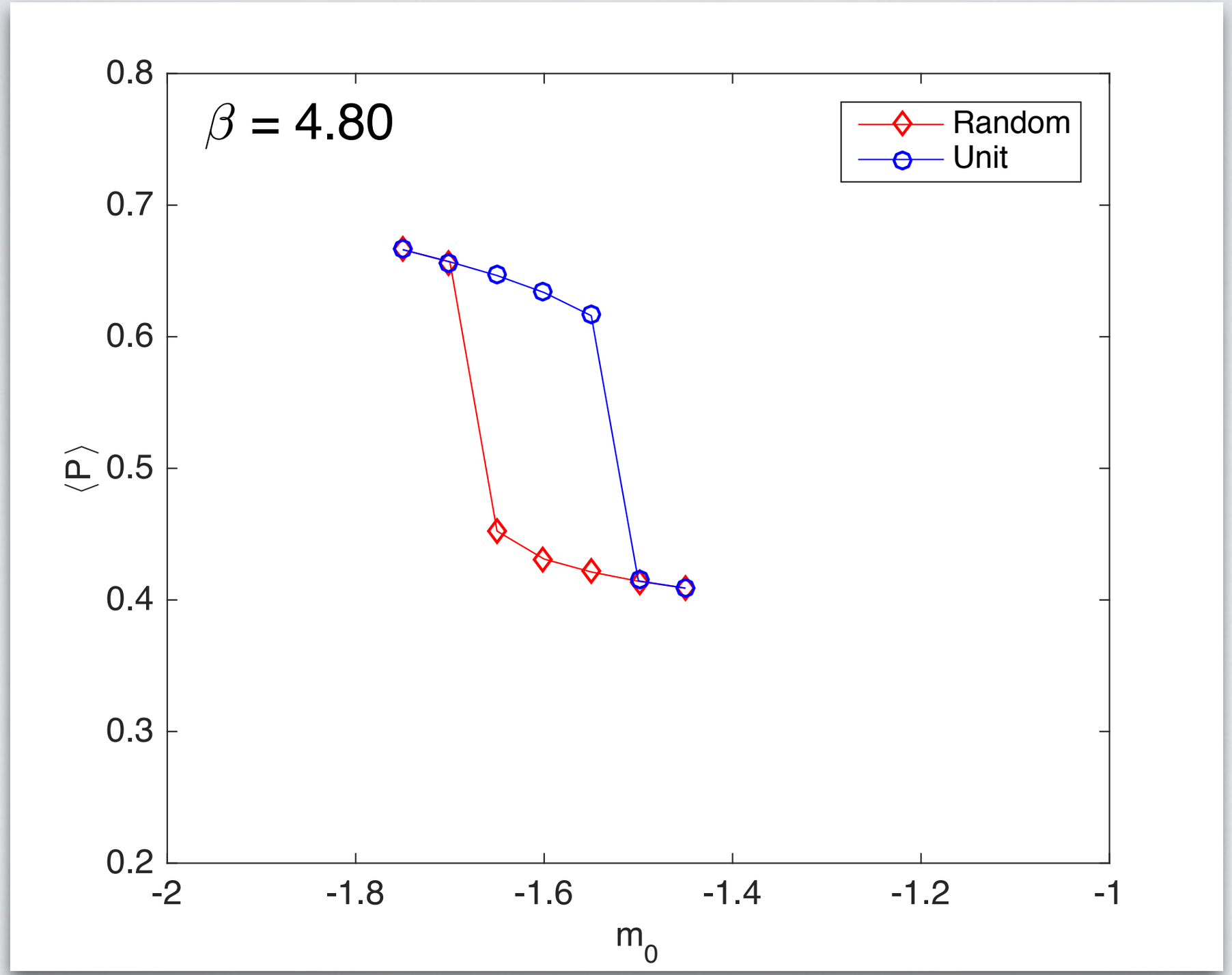
Hysteresis


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

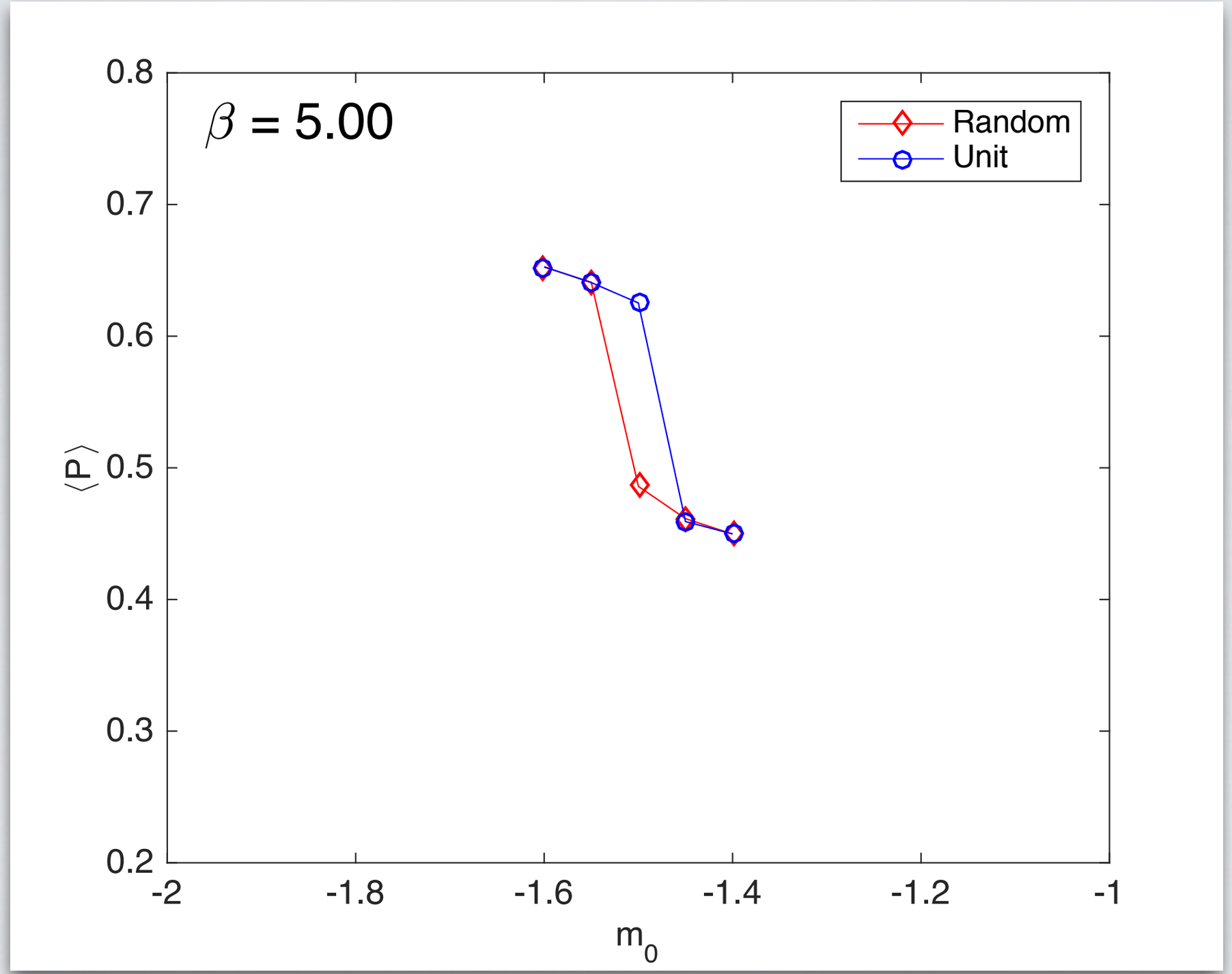
Hysteresis


β = 4.60
Random
Unit
0.8
0.7
0.6
0.5
0.4
0.3
0.2
$\langle \hat{p} \rangle$
-2
-1.8
-1.6
-1.4
-1.2
-1
m_0

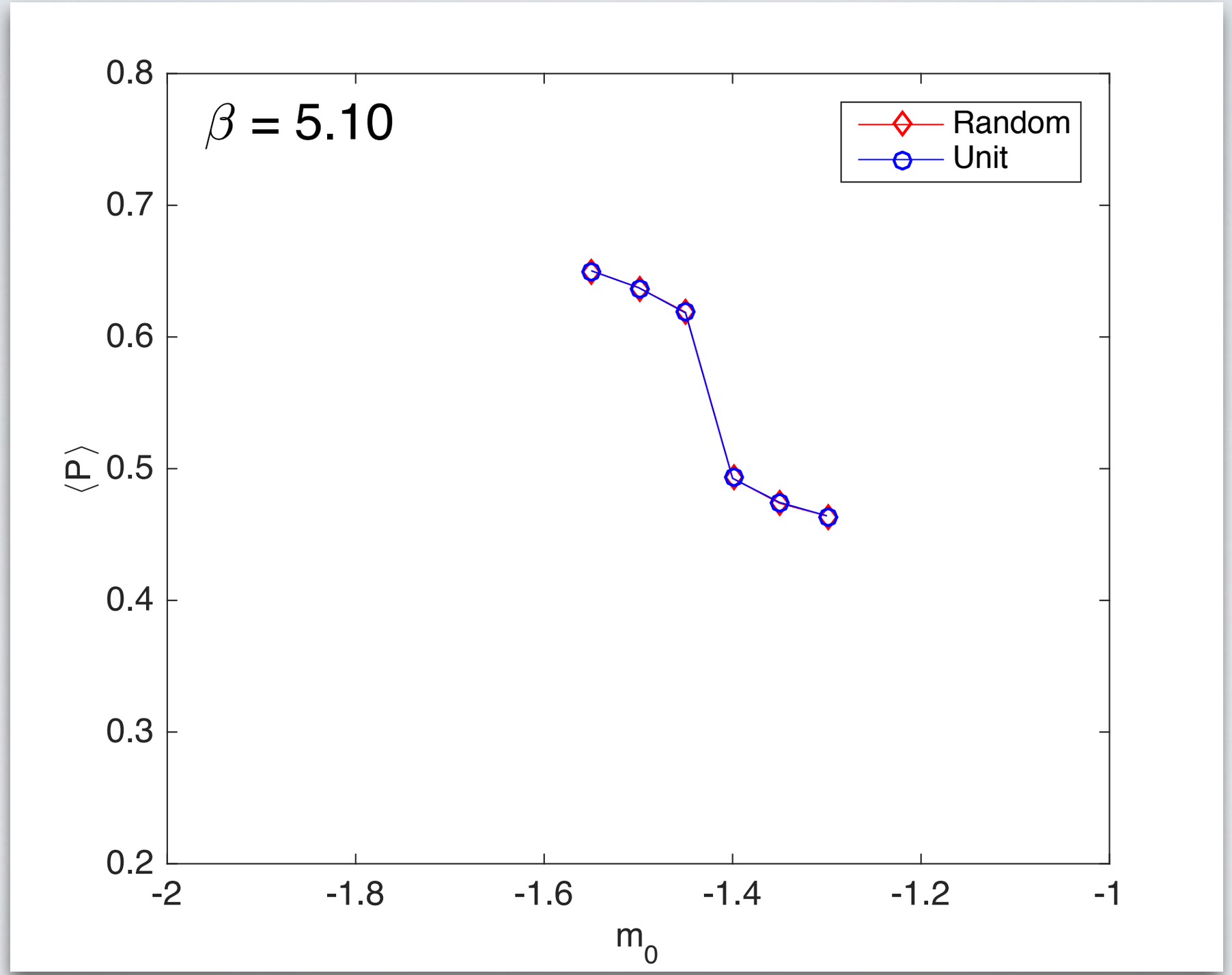
Hysteresis


β = 4.80
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

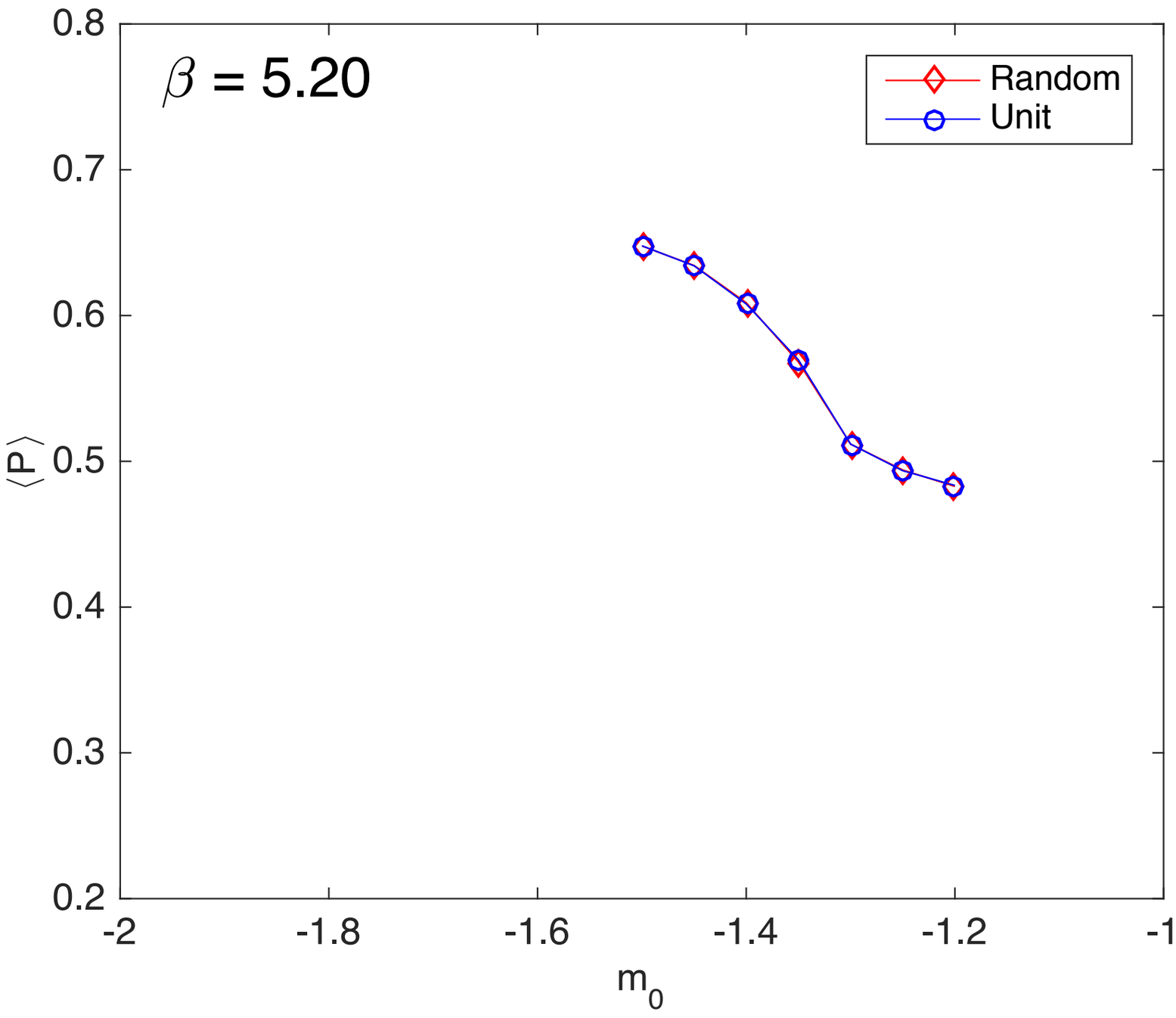
Hysteresis


β = 5.00
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

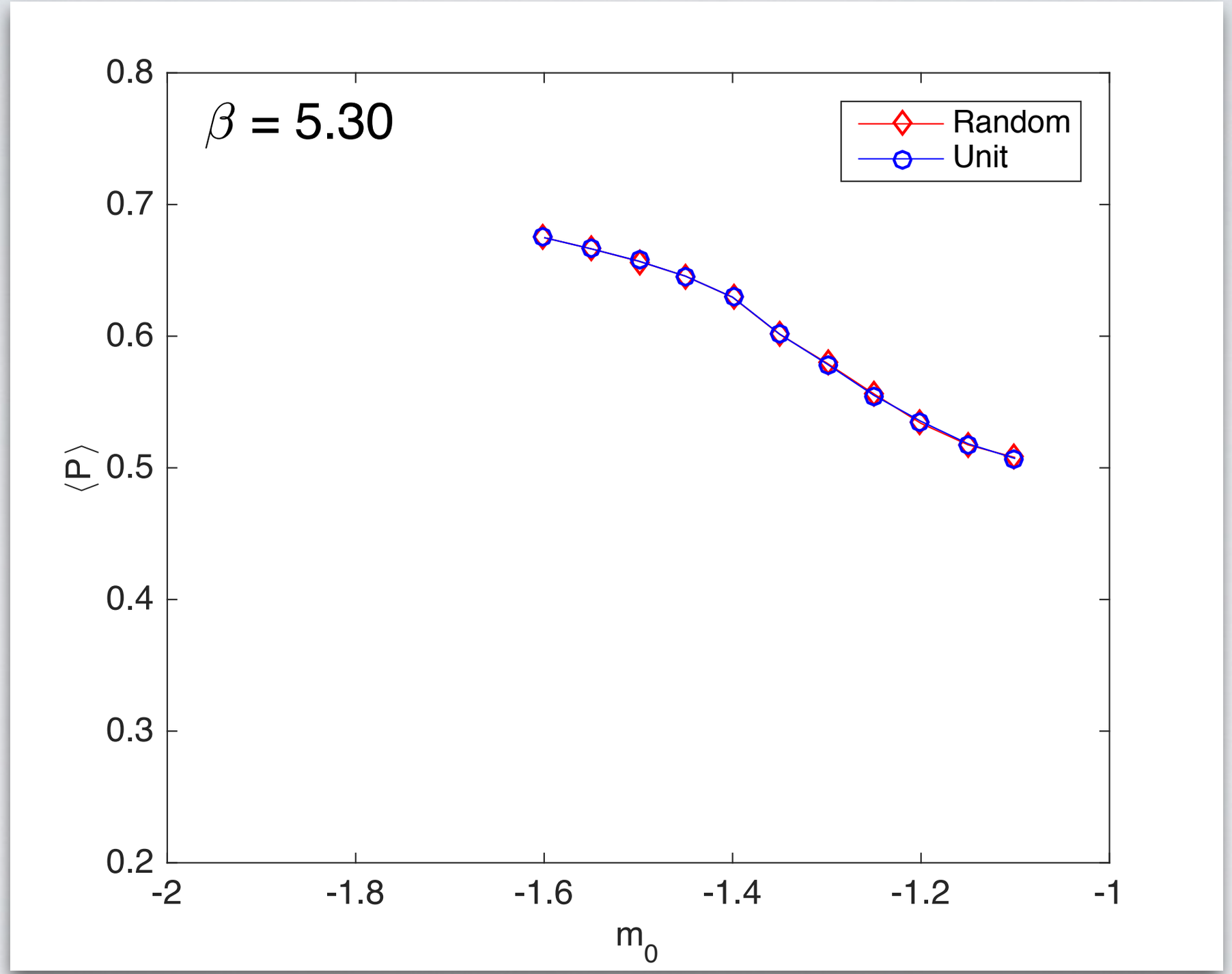
Hysteresis


β = 5.10
Random
Unit
0.8
0.7
0.6
0.5
0.4
0.3
0.2
$\widehat{p}$
-2
-1.8
-1.6
-1.4
-1.2
-1
m_0

Hysteresis

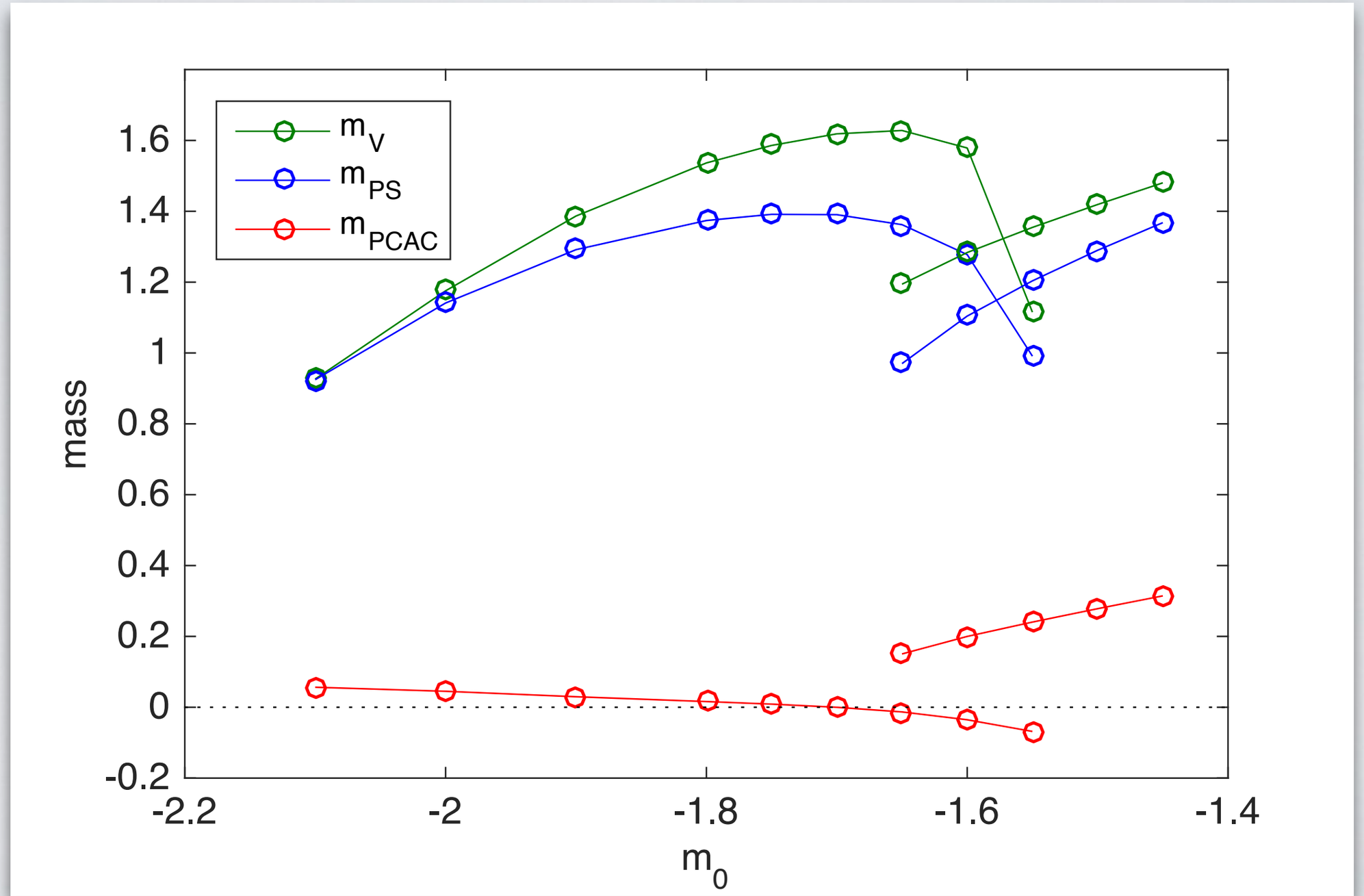

β = 5.20
Random
Unit
0.8
0.7
0.6
0.5
0.4
0.3
0.2
$\langle P \rangle$
-2
-1.8
-1.6
-1.4
-1.2
-1
m_0

Hysteresis


β = 5.30
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

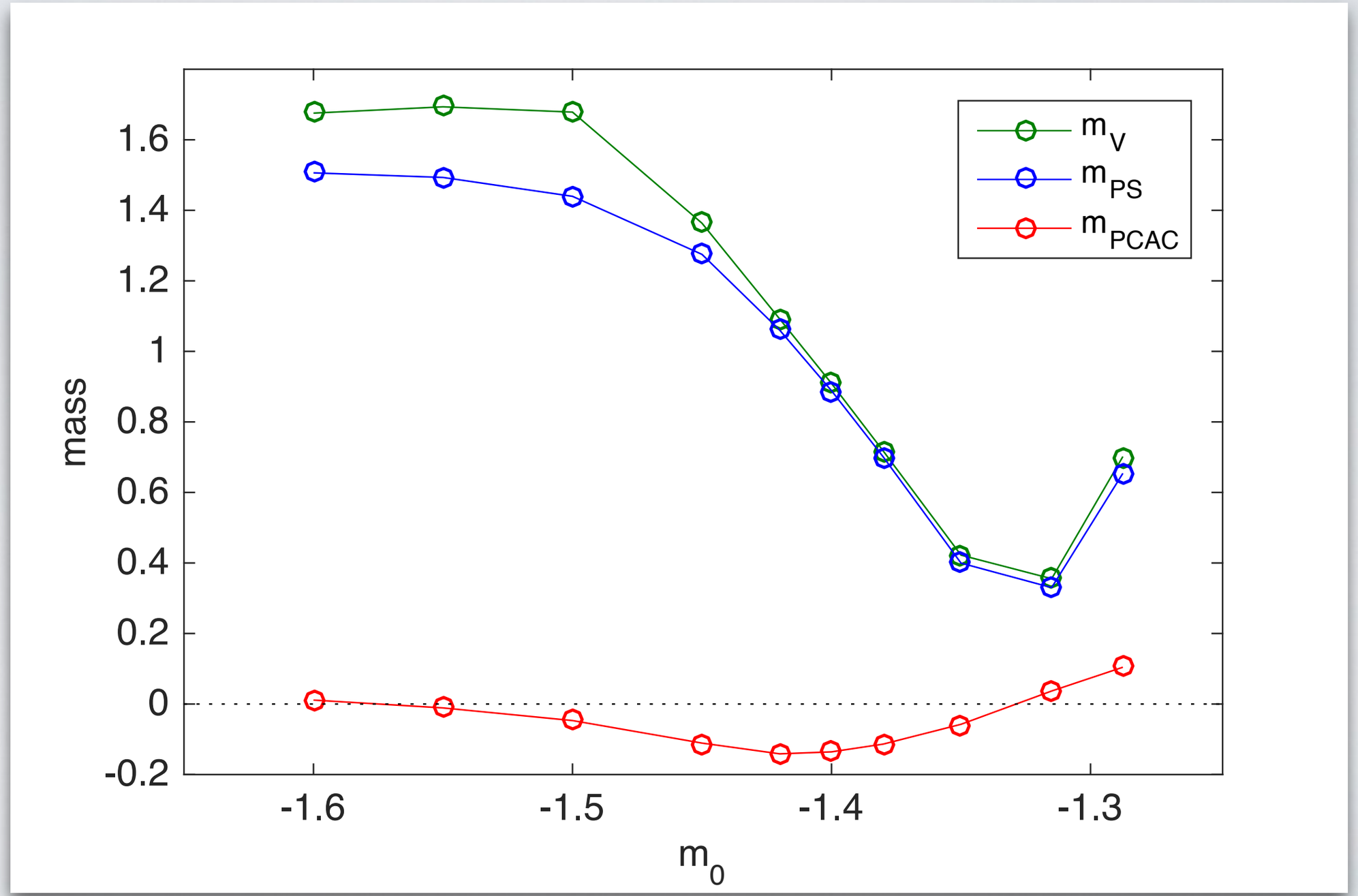
Spectrum

- Spectrum across transition at $\beta = 4.8$



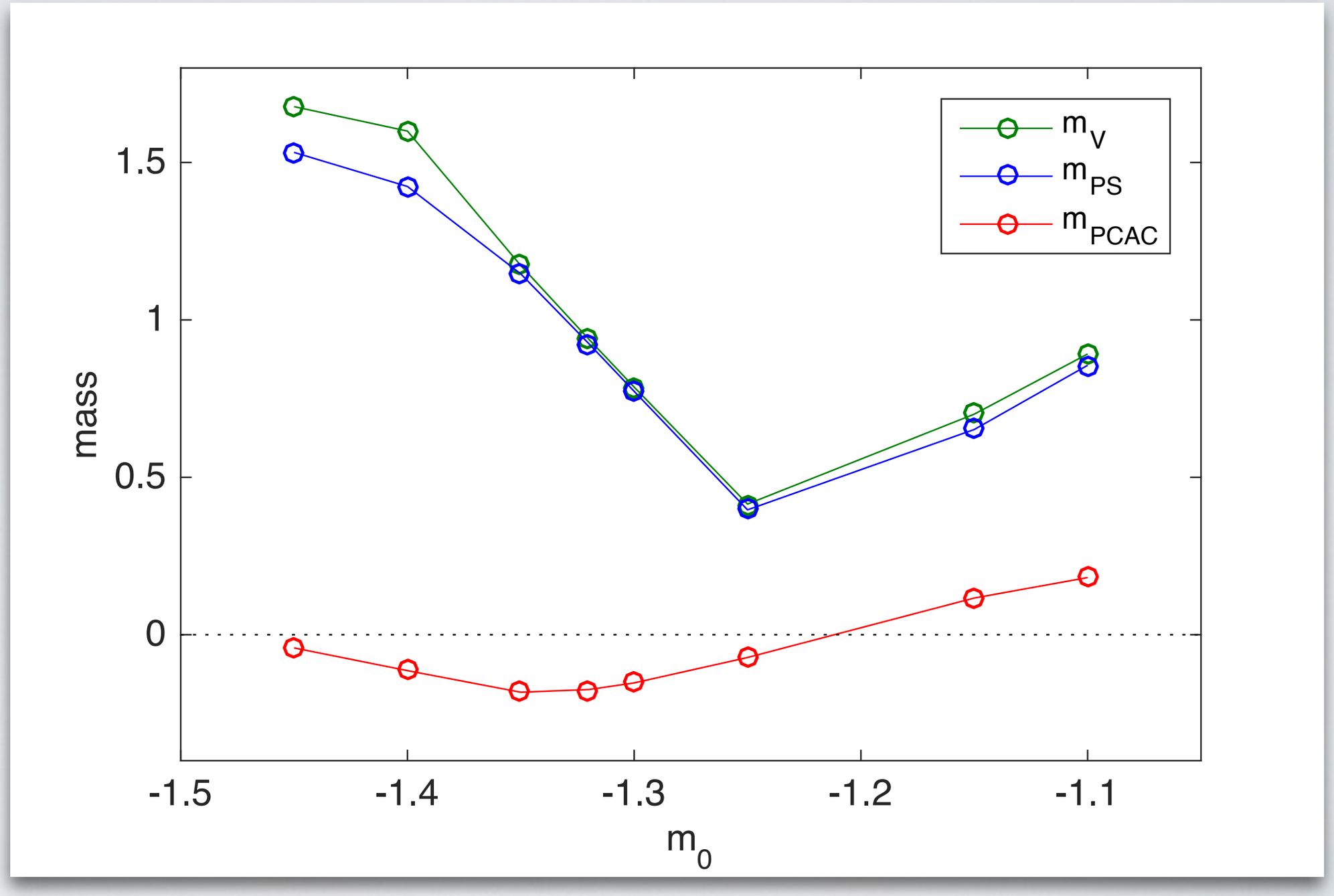
Spectrum

- Spectrum across transition at $\beta = 5.5$

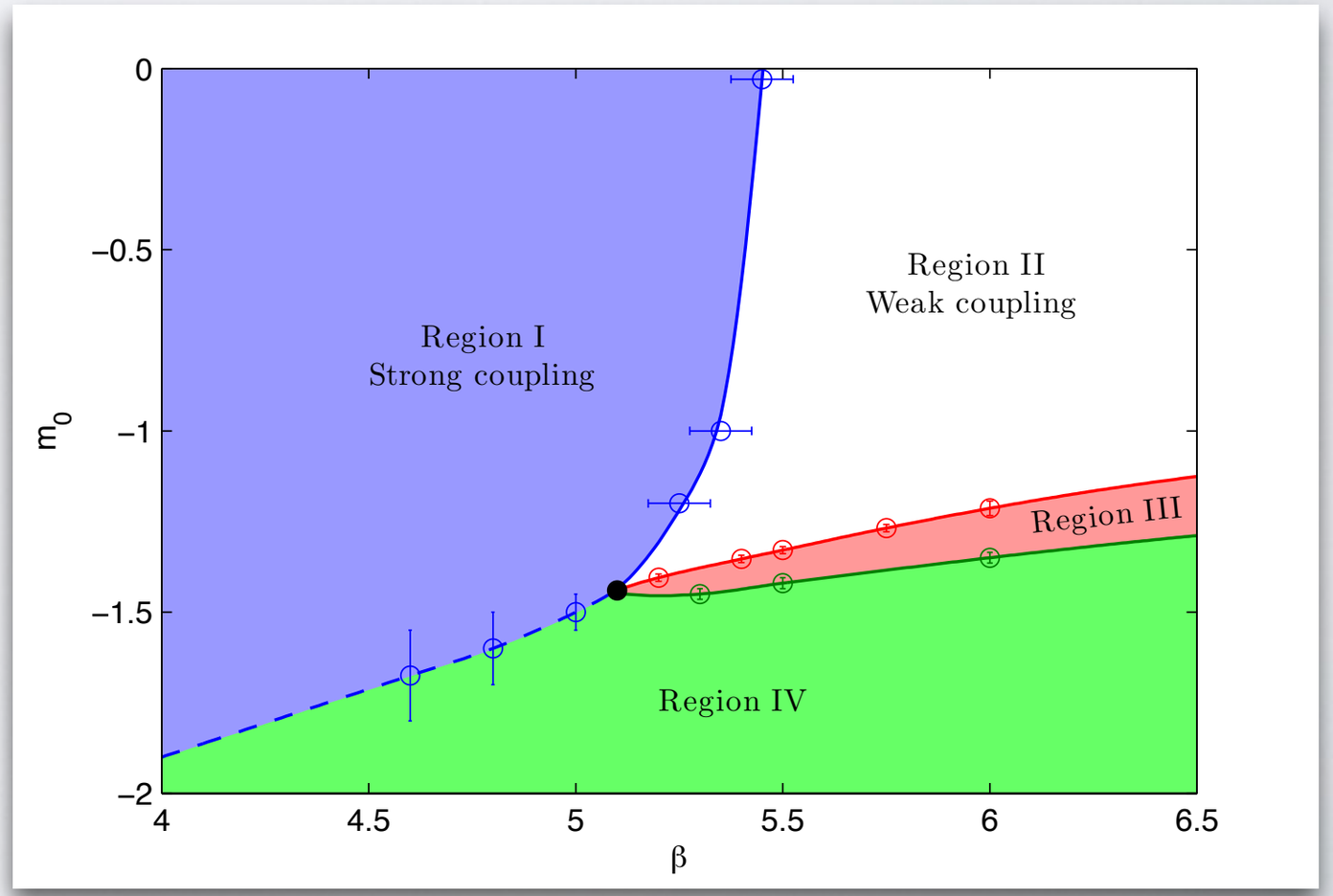


Spectrum

- Spectrum across transition at $\beta = 6.0$

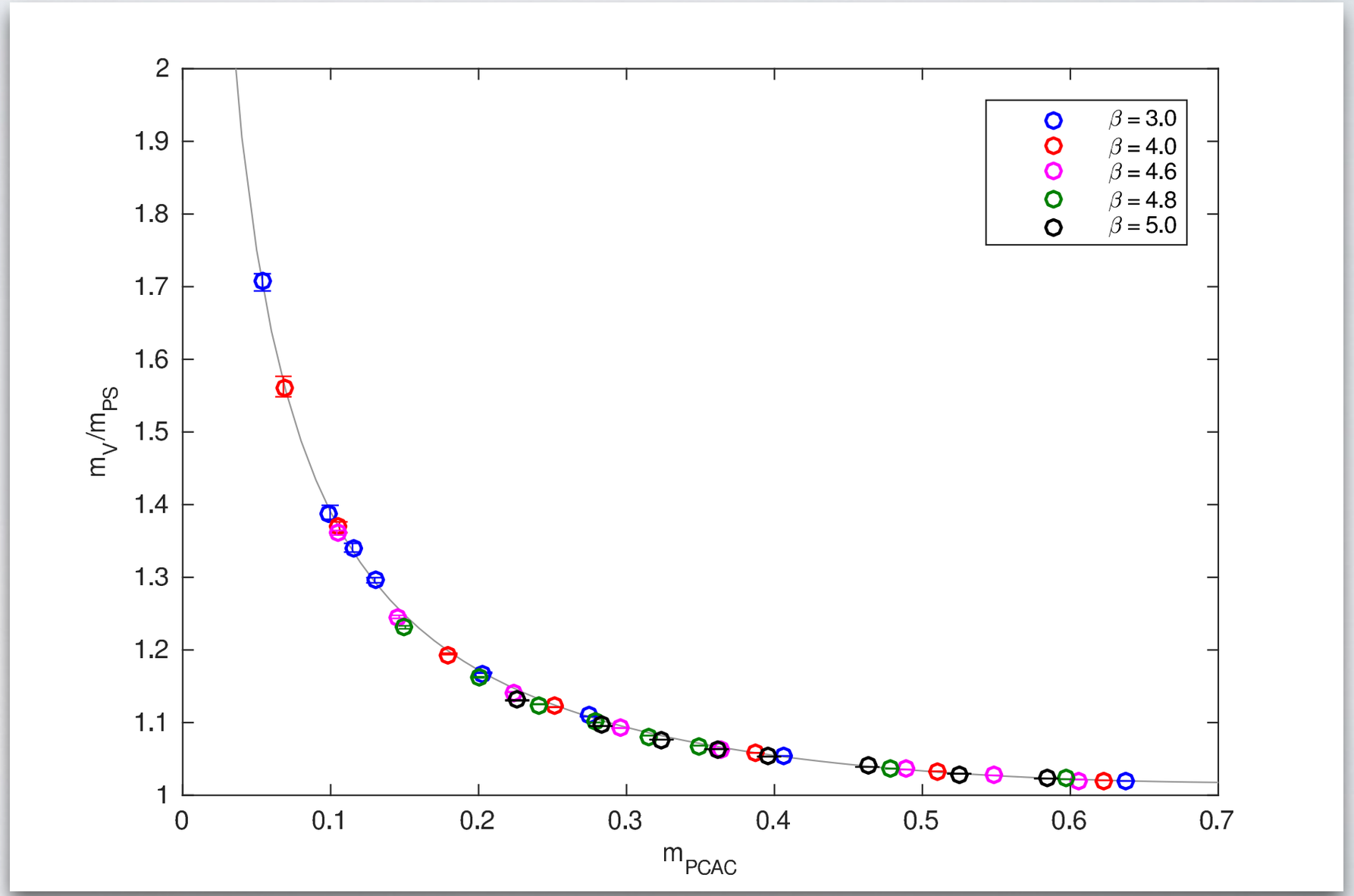


Region I → II


Region I
Strong coupling
Region II
Weak coupling
Region III
Region IV
m_0
β
0
−0.5
−1
−1.5
−2
4
4.5
5
5.5
6
6.5

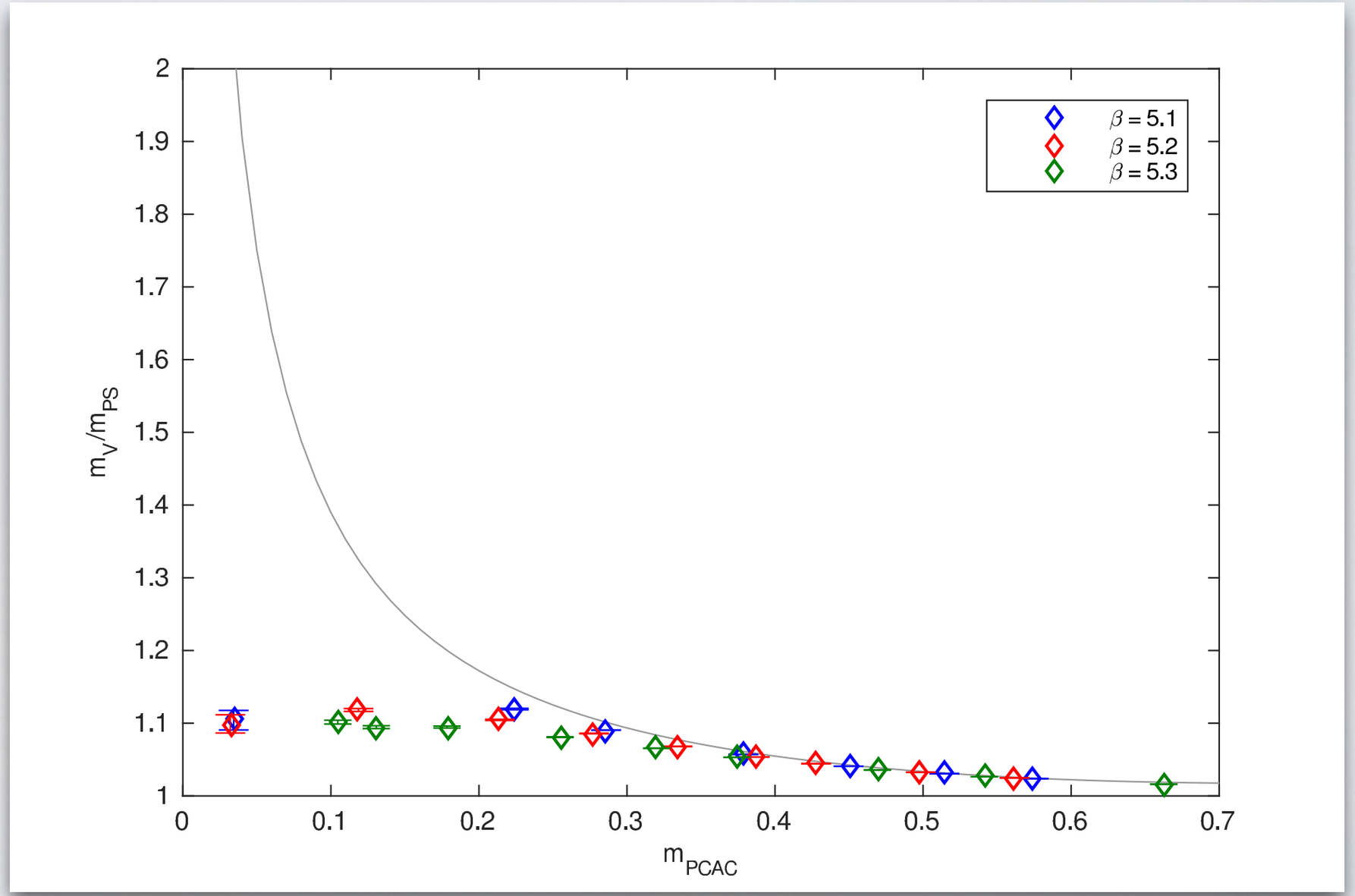
Ratio

- Ratio between M_V and M_{PS} for $\beta = \{3.0, 4.0, 4.6, 4.8, 5.0\}$
- This is in the strong coupling phase (Region I)



Ratio

- Ratio between M_V and M_{PS} for $\beta = \{5.1, 5.2, 5.3\}$
- This is in the weak coupling region (Region II)



Gradient flow

- Use gradient flow to measure change in lattice spacing

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

$$\mathcal{W}(t) = t \frac{d\mathcal{E}(t)}{dt}$$

$$\mathcal{E}(t_0) = \mathcal{E}_{\rm ref}$$

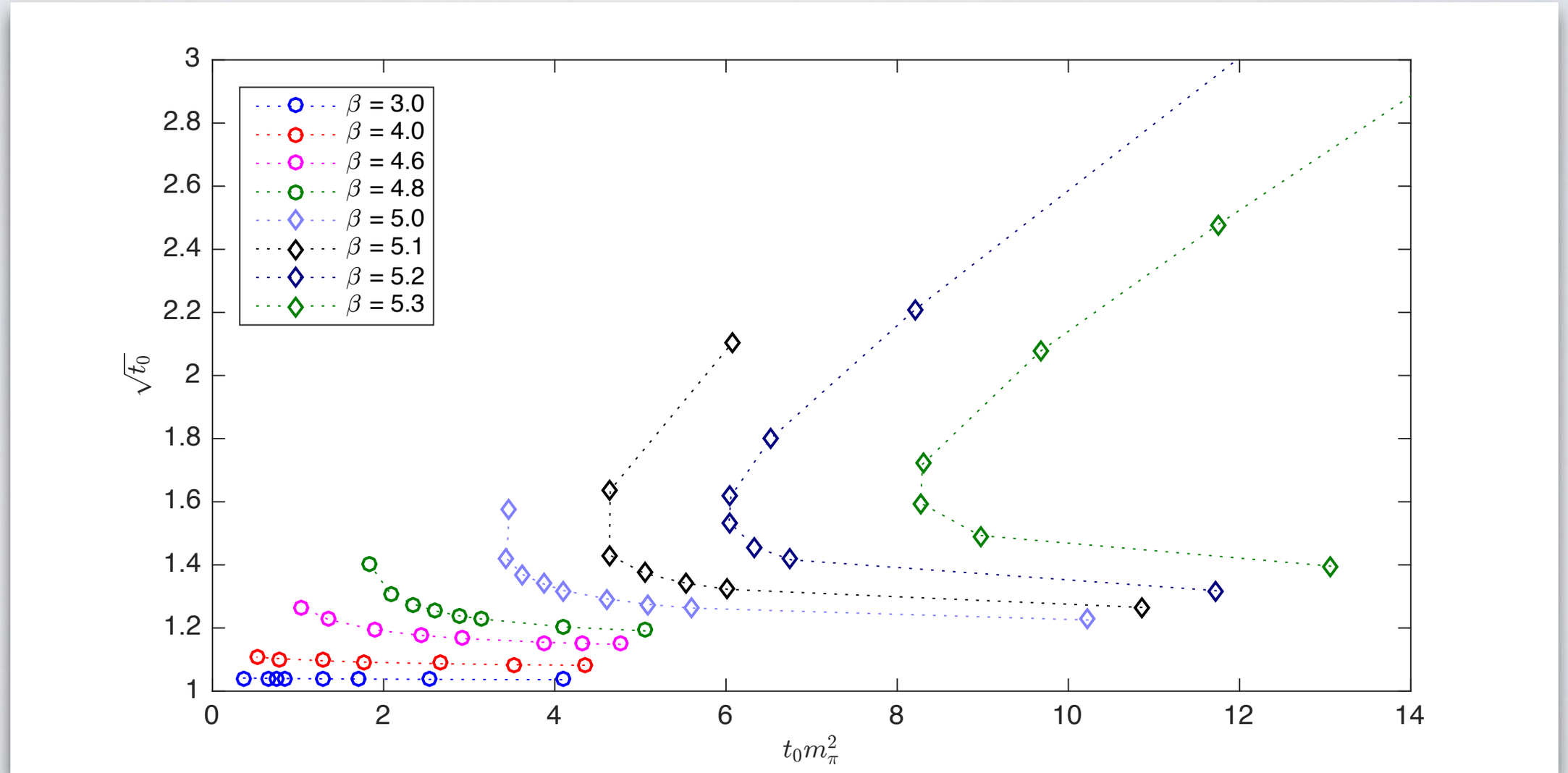
$$\mathcal{W}(w_0^2) = \mathcal{W}_{\rm ref}$$

Lüscher 2010

BMW Collaboration 2012

Gradient flow

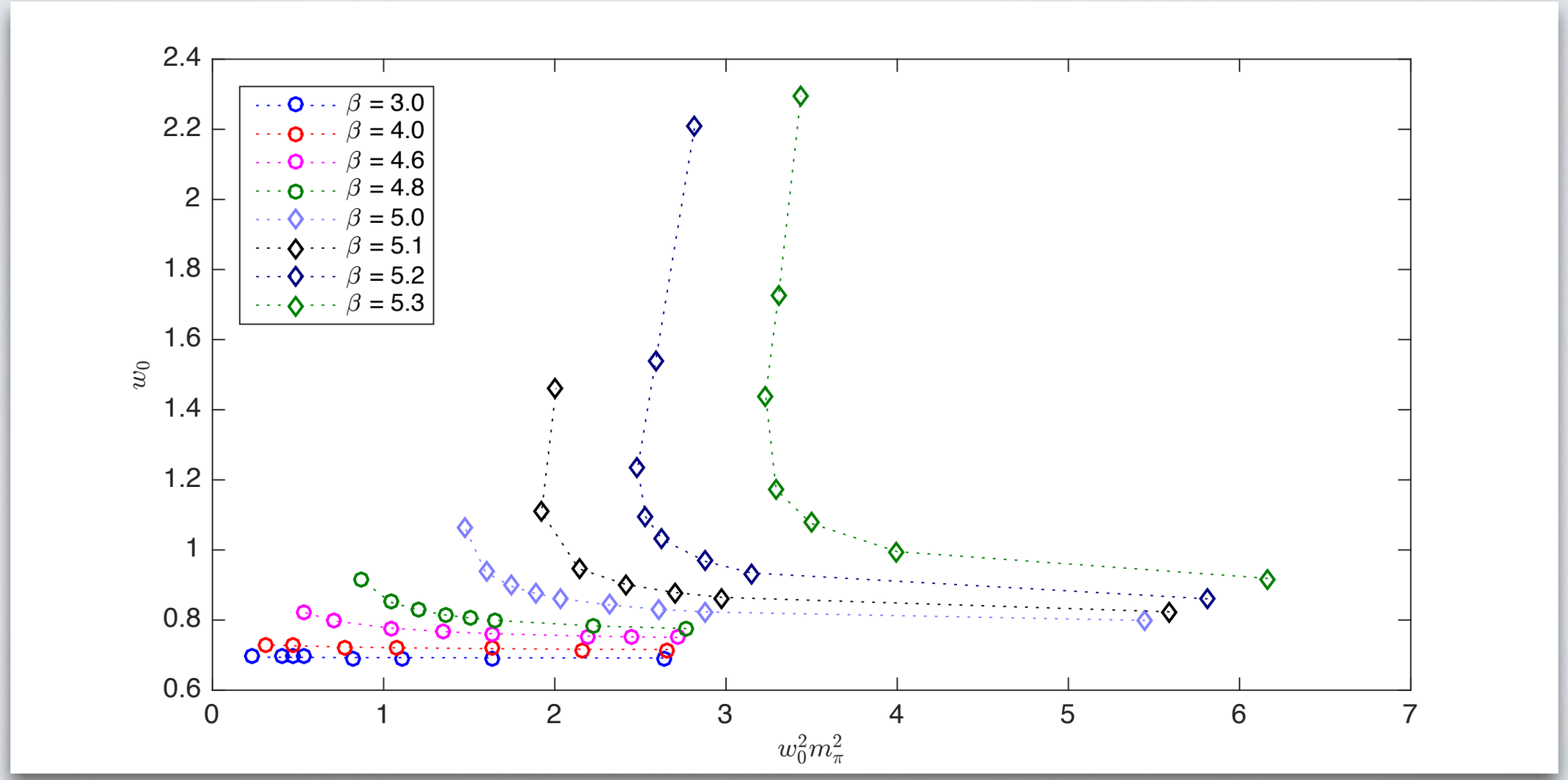
- Chiral limit with t_0 observable.



Gradient flow

- Chiral limit with w_0 observable.

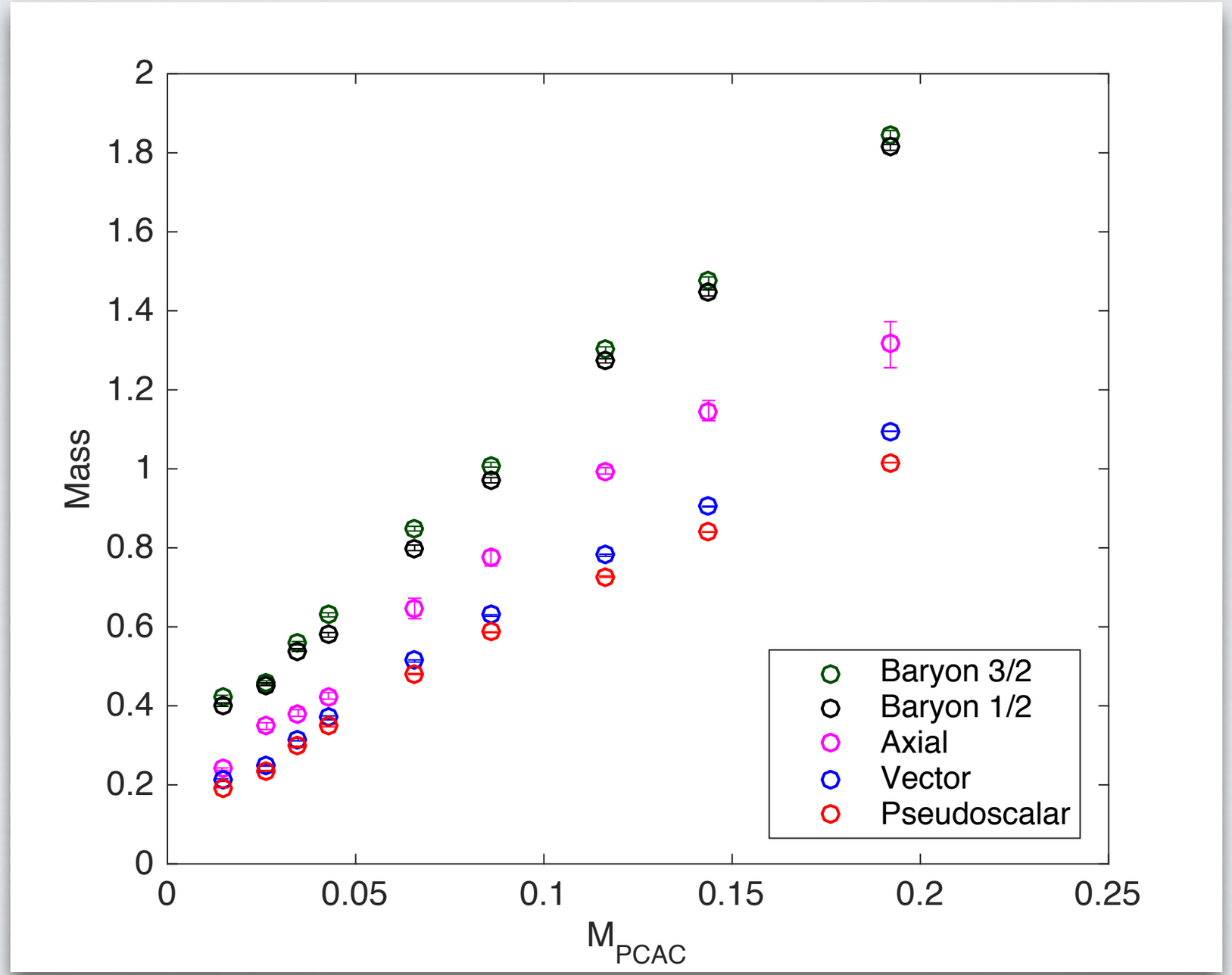
$$w_0^2 \sim \frac{1}{m_\pi^2}$$



Large Volume Runs

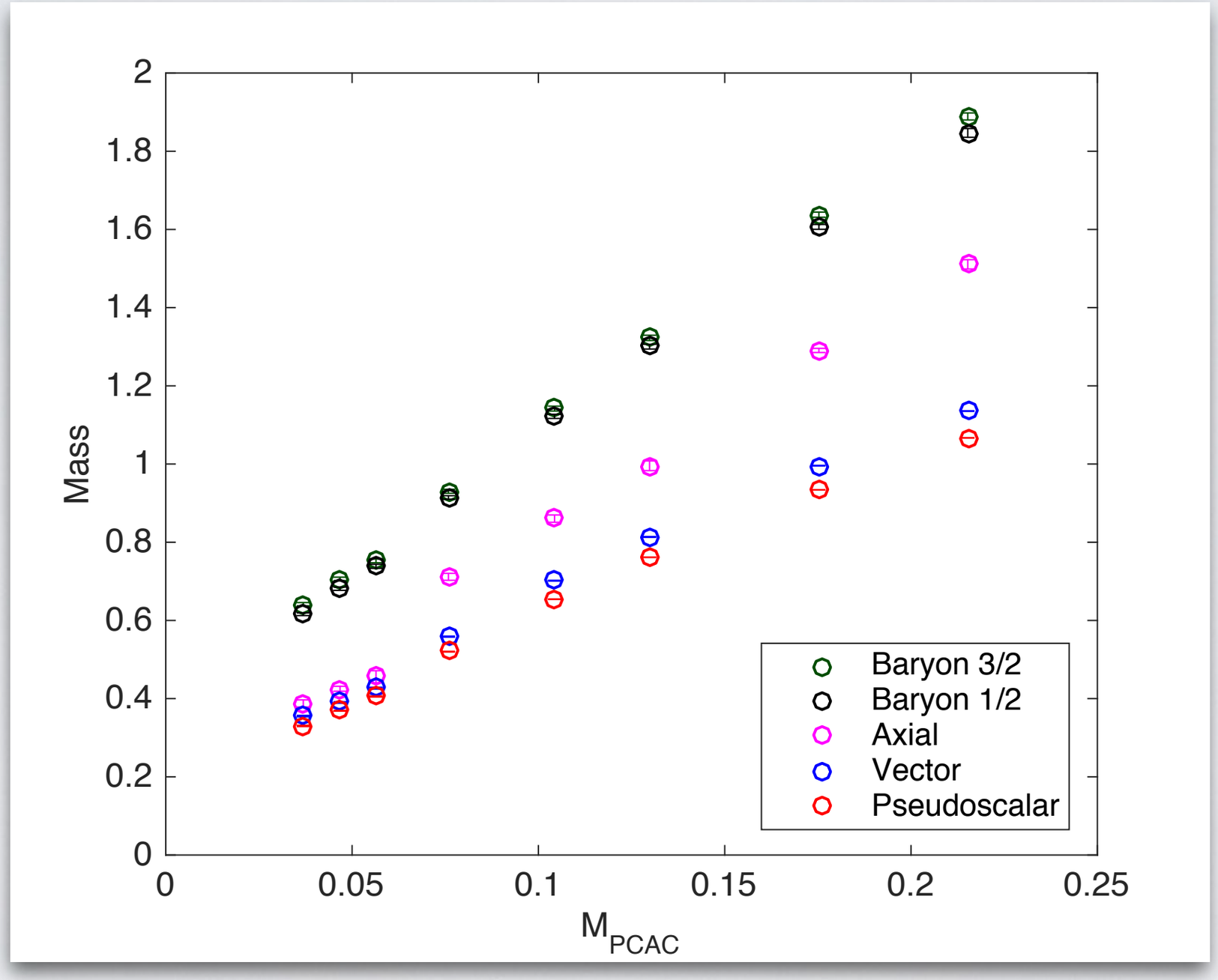
Spectrum

- Meson and baryon spectrum for $\beta = 5.4$



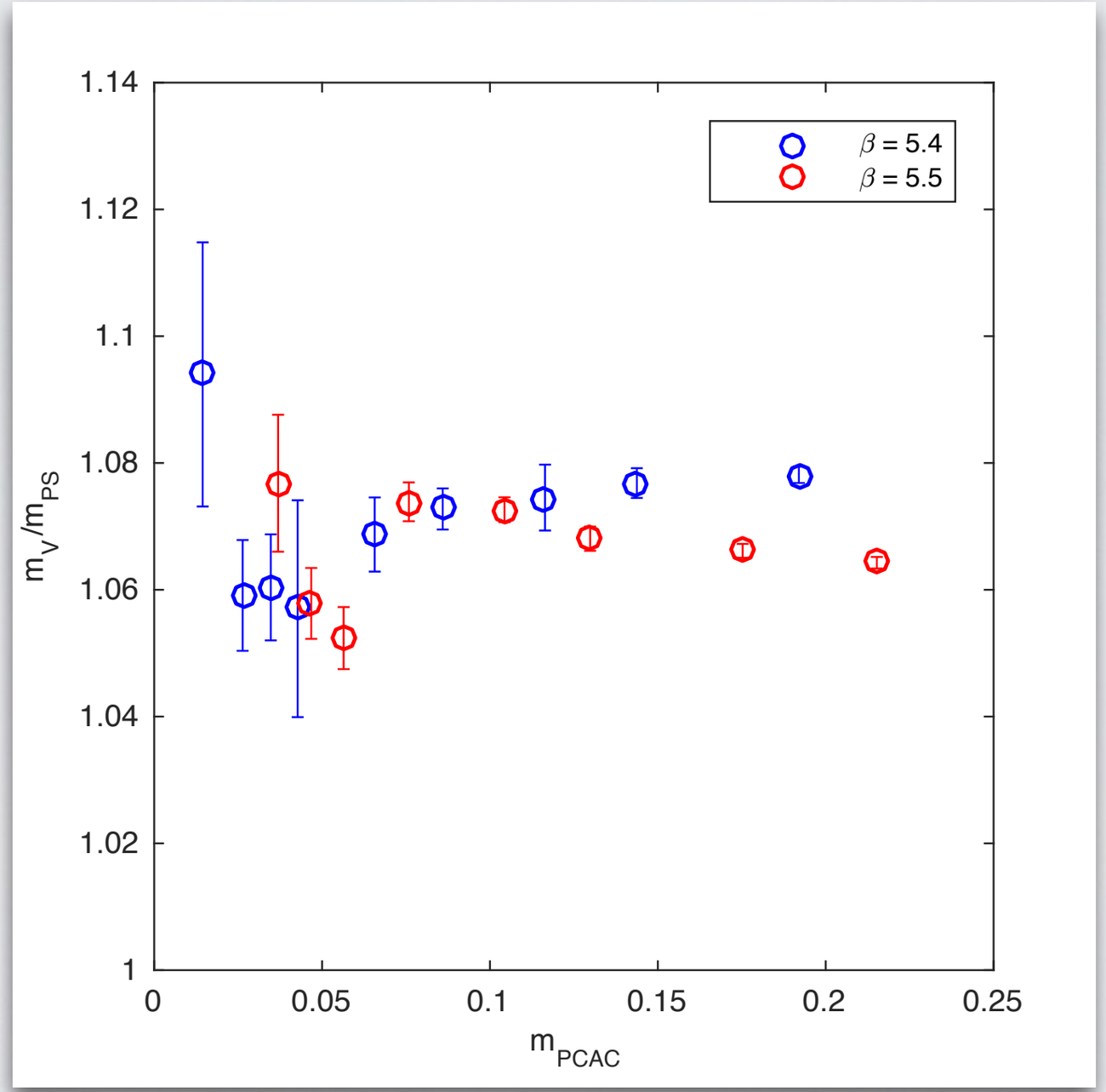
Spectrum

- Meson and baryon spectrum for $\beta = 5.5$



Ratio

- Ratio between M_V and M_{PS} for $\beta = \{5.4, 5.5\}$



Chiral behavior

- Conformal fits

$$M_x = A_x m^{\frac{1}{1+\gamma}} + \tilde{A}_x m^{\frac{1}{1+\alpha_x}}$$

$$F_x = B_x m^{\frac{1}{1+\gamma}} + \tilde{B}_x m^{\frac{1}{1+\beta_x}}$$

- Chiral fits

$$M_\pi^2 = M^2 + \frac{M^4}{F^2}(a_M L + b_M) + \cdots$$

$$F_\pi = F + \frac{M^2}{F}(a_F L + b_F) + \cdots$$

Fixed in continuum

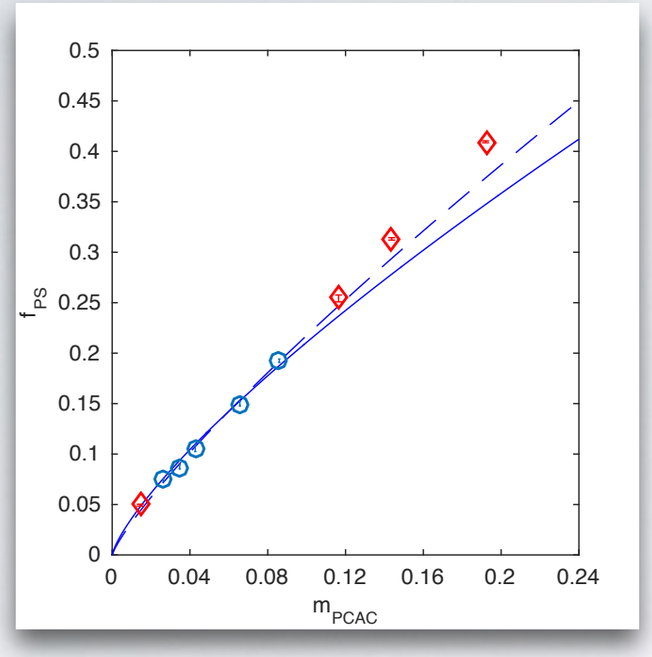
- Leading order pion mass and log term

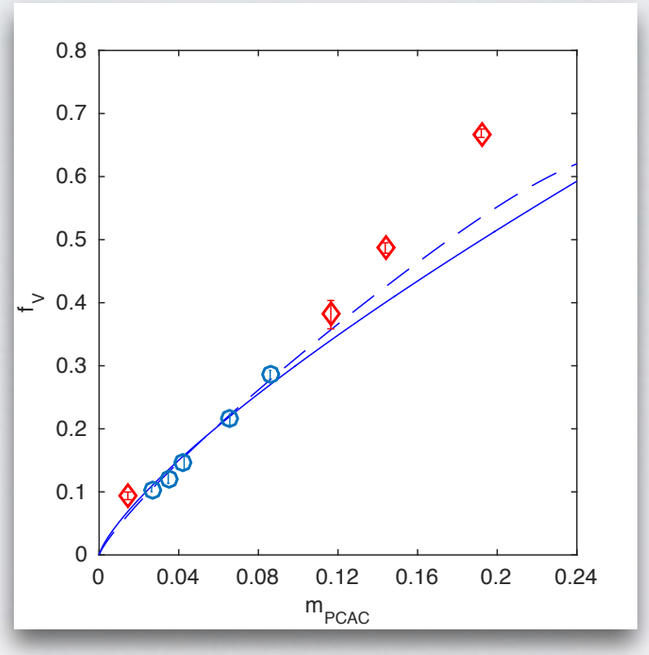
$$M^2 = 2Bm, \qquad L = \frac{1}{16\pi^2}\log\left(\frac{M^2}{\mu^2}\right)$$

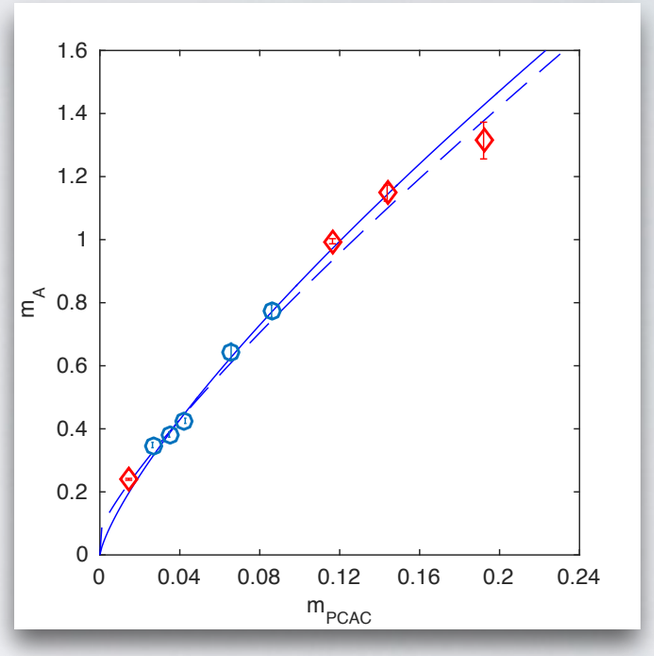
Conformal fits

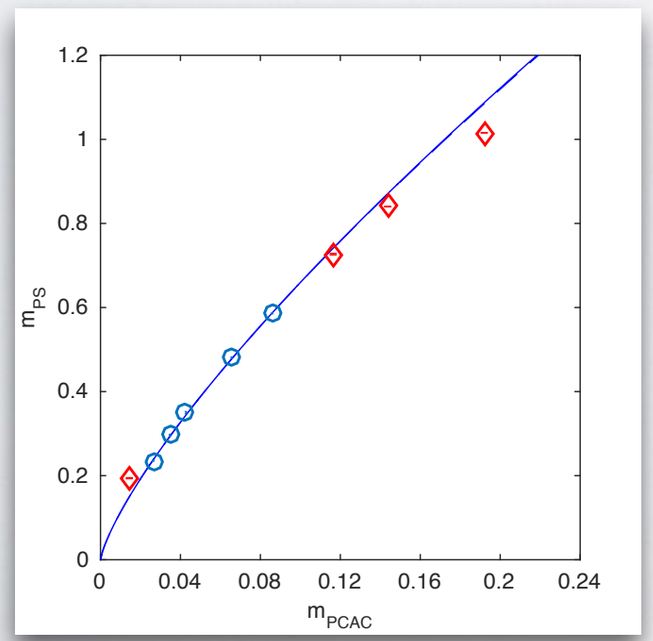
- Combined fit to 6 channels for $\beta = 5.4$

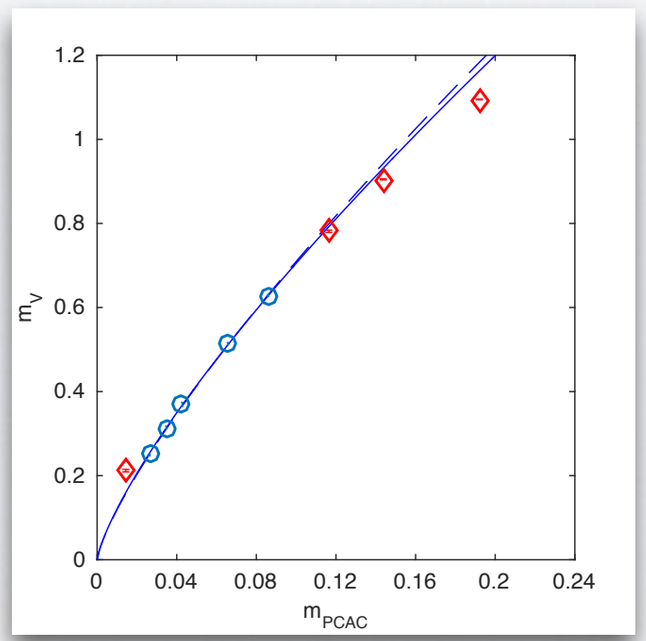
$\chi^2/\mathrm{dof} = \{7.04, 2.62\}$

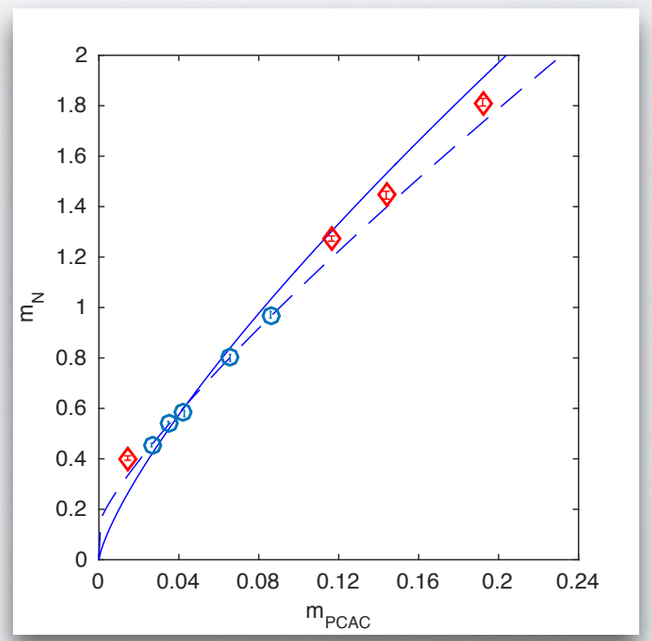








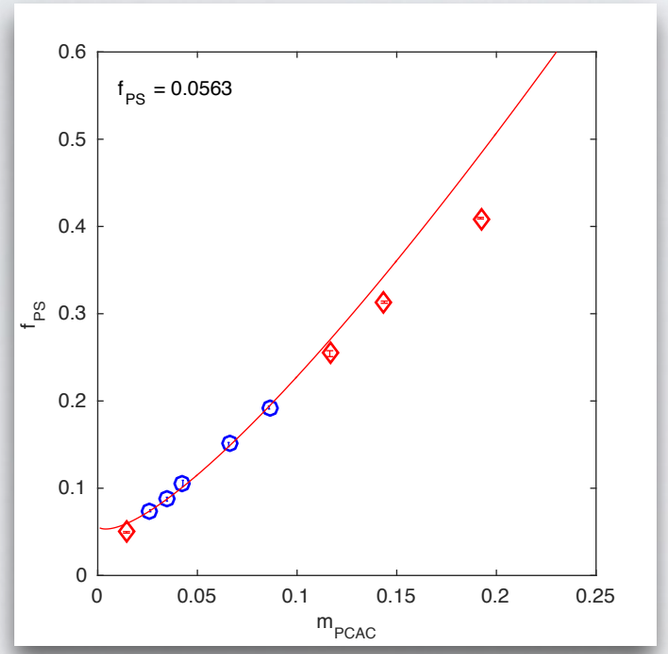


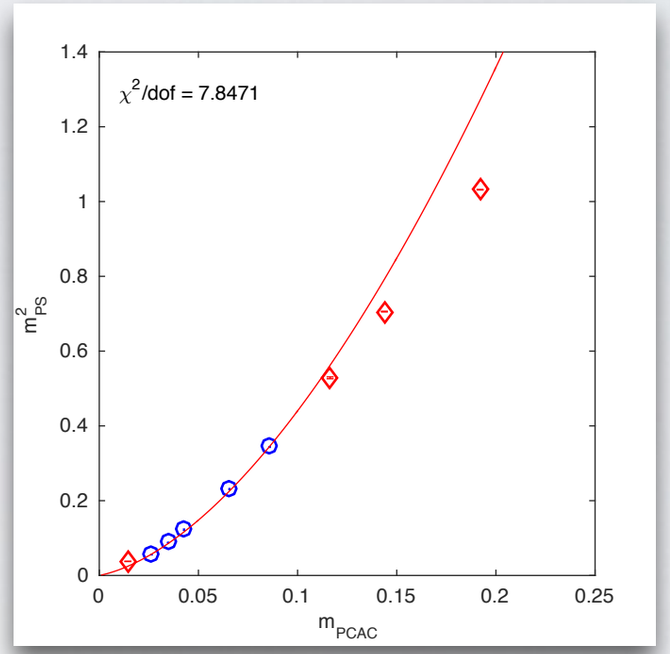


Chiral fits

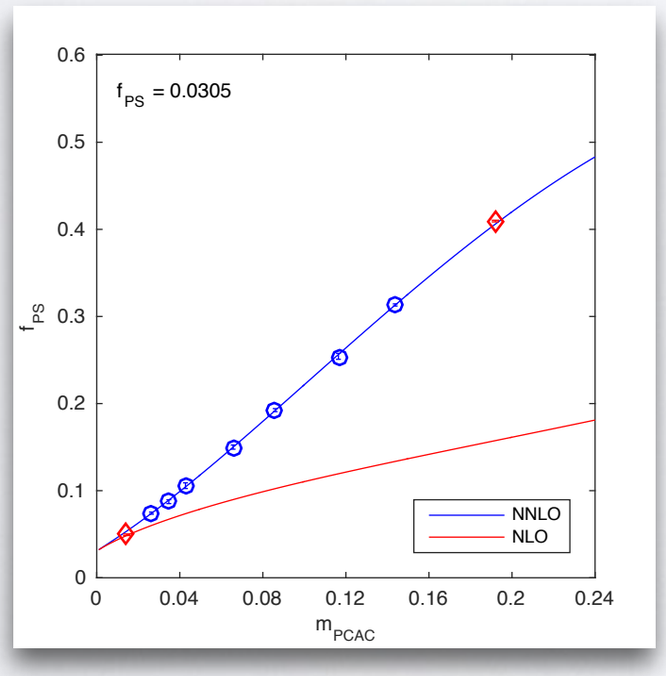
- Combined fit to f_{PS} and m_{PS} for $\beta = 5.4$

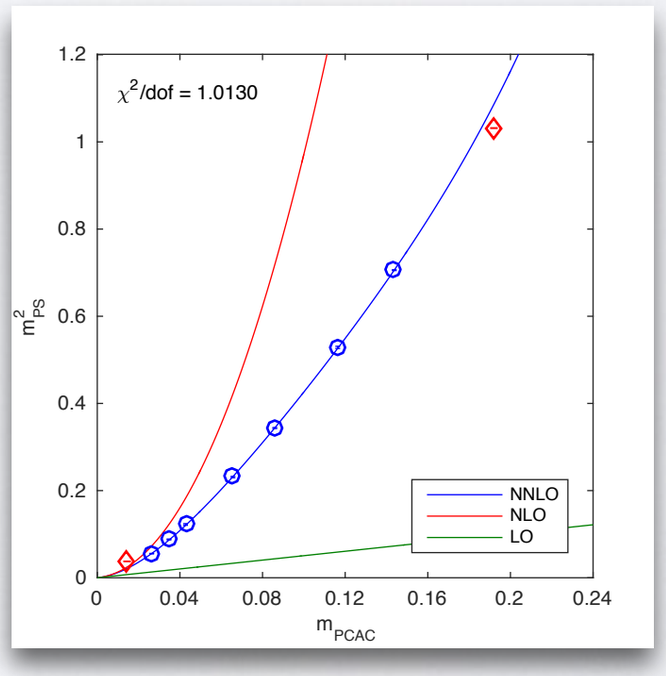
$\chi^2/\mathrm{dof} = \{7.85, 1.01\}$





NLO





NNLO

Conclusions

- The phase structure is non-trivial
- Different behavior in different regions of the parameter space
- The model looks conformal in the weak coupling phase
- Things to consider includes:
  - Open boundary conditions
  - Finite volume effects

Thank you!