Light hadrons from N_f=2+1+1 dynamical twisted mass fermions

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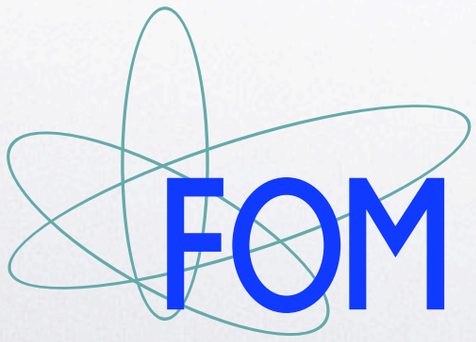

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Outline

- ★ Twisted mass lattice action recap
- ★ Ensemble overview
- ★ Status and strategy of tuning
- ★ NLO SU(2) pion χPT fits
- ★ Preliminary new lattice spacing

Not in this talk

- ★ Baryon spectrum: Drach, P22 (Tuesday)
- ★ Nucleon matrix elements: Dinter, P2
- ★ N_f=4 setup for renormalization constants: Palao (an hour ago)
- ★ Pseudoscalar decay constants: Urbach, next
- ★ Extraction of m_K and m_D: Pallante, poster

Action

- ★ 4 flavour twisted mass fermion action: mass degenerate light doublet, mass split heavy doublet: $N_f=2+(1+1)$
- ★ Iwasaki gauge action
- ★ PHMC algorithm
- ★ See also arXiv:1004.5248v1

Light doublet

★ N_f=2+1+1 twisted mass Wilson fermions: arXiv:hep-lat/0606011v1 (Chiarappa et al.)

★ $S_l = a^4 \sum_x \{\bar{\chi}_l(x) [D[U] + m_{0,l} + i\mu_l \gamma_5 \tau_3] \chi_l(x)\}$

★ Twisted basis: $\chi_l = \begin{pmatrix} \chi_u \\ \chi_d \end{pmatrix}$

★ $\psi_l^{phys} = e^{\frac{i}{2}\omega_l \gamma_5 \tau_3} \chi_l \quad \omega_l = \frac{\pi}{2}$

★ $am_{0,l} \equiv 1/2\kappa - 4$

Heavy doublet

★ Mass-split heavy doublet, details: arXiv:hep-lat/0311008v2 (Frezzotti, Rossi)

★ $S_h = a^4 \sum_x \{\bar{\chi}_h(x) \left[D[U] + m_{0,h} + i\mu_\sigma \gamma_5 \tau_1 + \mu_\delta \tau_3\right] \chi_h(x)\}$

★ Twisted basis: $\chi_h = \begin{pmatrix} \chi_c \\ \chi_s \end{pmatrix}$

★ $\psi_h^{phys} = e^{\frac{i}{2}\omega_h \gamma_5 \tau_1} \chi_h \quad \omega_h = \frac{\pi}{2}$

★ $am_{0,l} = am_{0,h} \equiv 1/2\kappa - 4$

Ensemble updates

- New since last year:
  - Some runs have extended statistics
  - Runs to tune m_s and m_c
  - Finite size effects checks
  - New, smaller lattice spacing with lighter pion masses, currently down to 230 MeV

Ensembles at β=1.90

Label	κ	aμ$_l$	aμ$_\sigma$	aμ$_\delta$	L/a	T/a	m$_\pi$L
A30.32	0.1632720	0.0030	0.150	0.190	32	64	4.0
A40.32	0.1632700	0.0040	0.150	0.190	32	64	4.5
A40.24	0.1632700	0.0040	0.150	0.190	24	48	3.5
A40.20	0.1632700	0.0040	0.150	0.190	20	48	3.0
A50.32	0.1632670	0.0050	0.150	0.190	32	64	5.1
A50.24	0.1632670	0.0050	0.150	0.190	24	48	
A60.24	0.1632650	0.0060	0.150	0.190	24	48	4.2
A80.24	0.1632600	0.0080	0.150	0.190	24	48	4.8
A80.24s	0.1632040	0.0080	0.150	0.197	24	48	4.8
A100.24	0.1632550	0.0100	0.150	0.190	24	48	5.4
A100.24s	0.1631960	0.0100	0.150	0.197	24	48	5.3
A100.24s2		0.0100	0.13	0.17	24	48	

Done

Running

β=1.95, β=2.10

Label	β	κ	$a\mu_l$	$a\mu_\sigma$	$a\mu_\delta$	L/a	T/a	$m_\pi L$
B25.32	1.95	0.1612410	0.0025	0.135	0.170	32	64	3.4
B35.32	1.95	0.1612400	0.0035	0.135	0.170	32	64	4.0
B55.32	1.95	0.1612360	0.0055	0.135	0.170	32	64	5.0
B75.32	1.95	0.1612320	0.0075	0.135	0.170	32	64	5.8
B85.32	1.95	0.1612312	0.0085	0.135	0.170	24	48	4.7
D115.64	2.10		0.00115	0.120	0.1385	64	128	
D15.48	2.10	0.1563610	0.0015	0.120	0.1385	48	96	3.4
D20.48	2.10	0.1563570	0.0020	0.120	0.1385	48	96	3.9
D30.48	2.10	0.1563550	0.0030	0.120	0.1385	48	96	4.7

Running

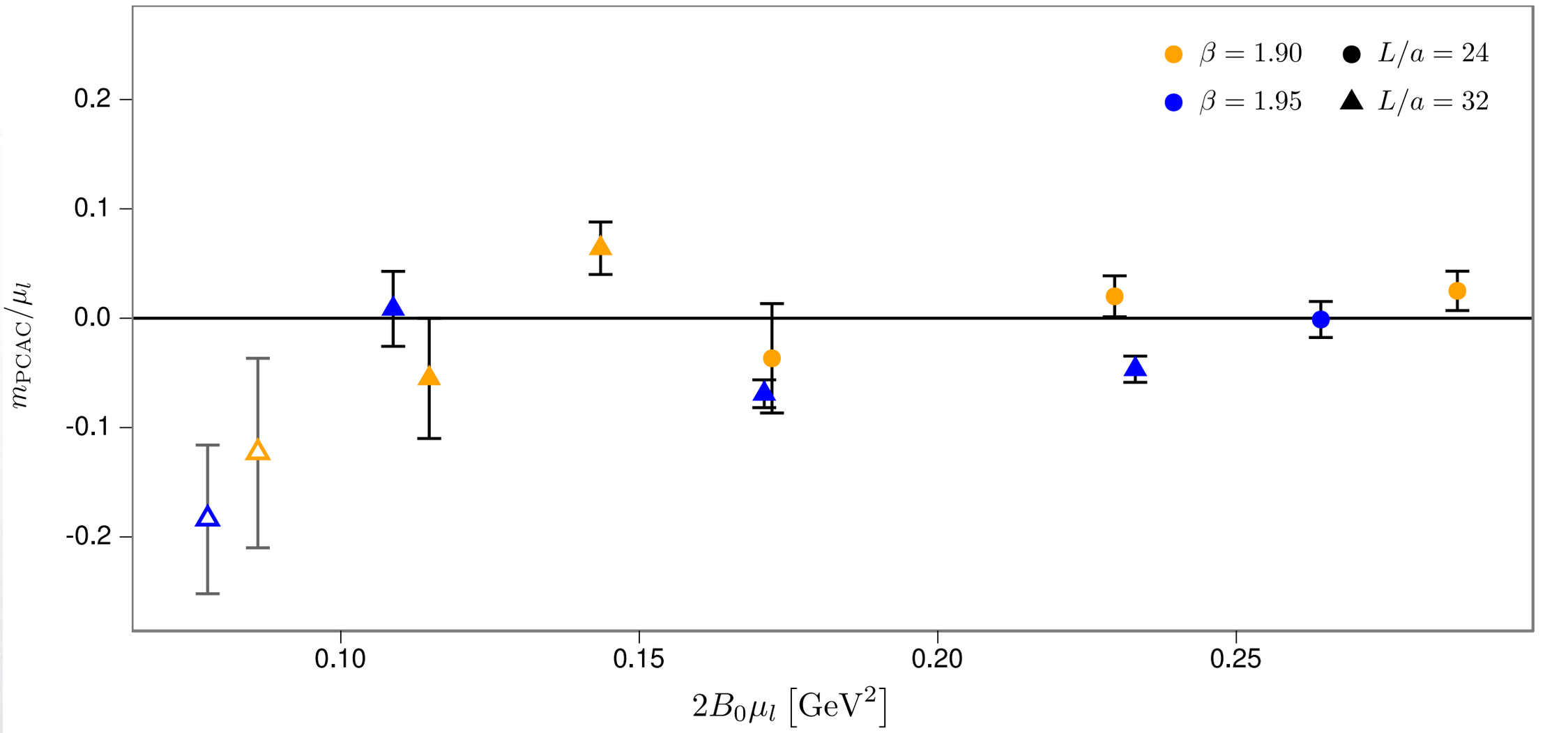
Done

★ Not including N_f=4 runs

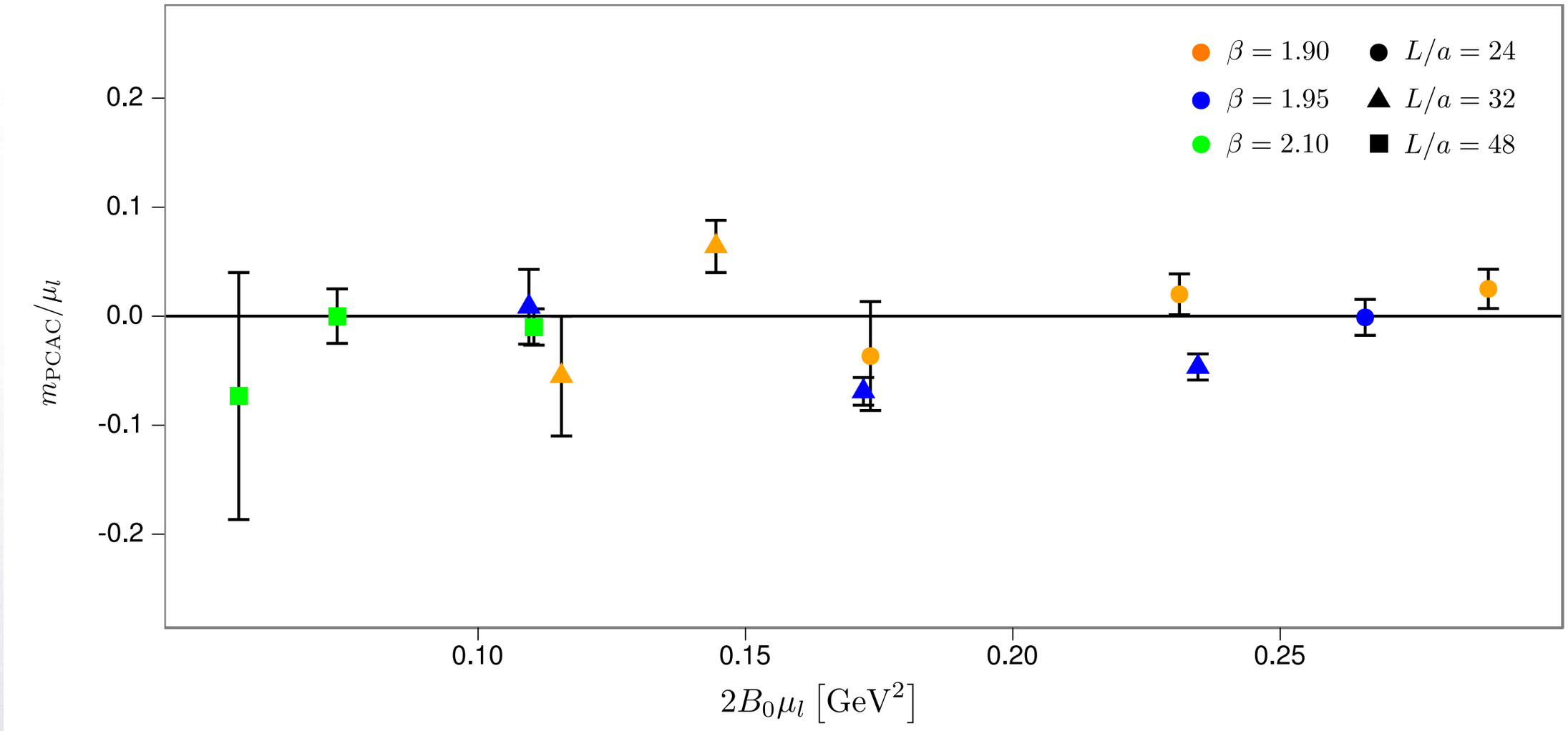
Tuning

- ★ Automatic O(a) improvement at (or near) maximal twist: $am_{\mathrm{PCAC},l} = 0$
- ★ Tune independently to maximal twist at every $\mu_l, \mu_\sigma, \mu_\delta$ combination
- ★ Follow criterium: $\left| \frac{Z_A m_{\mathrm{PCAC}}}{\mu_l} \right| \lesssim 0.1$
  - ★ $Z_A \sim 0.75$ (preliminary)

Tuning status



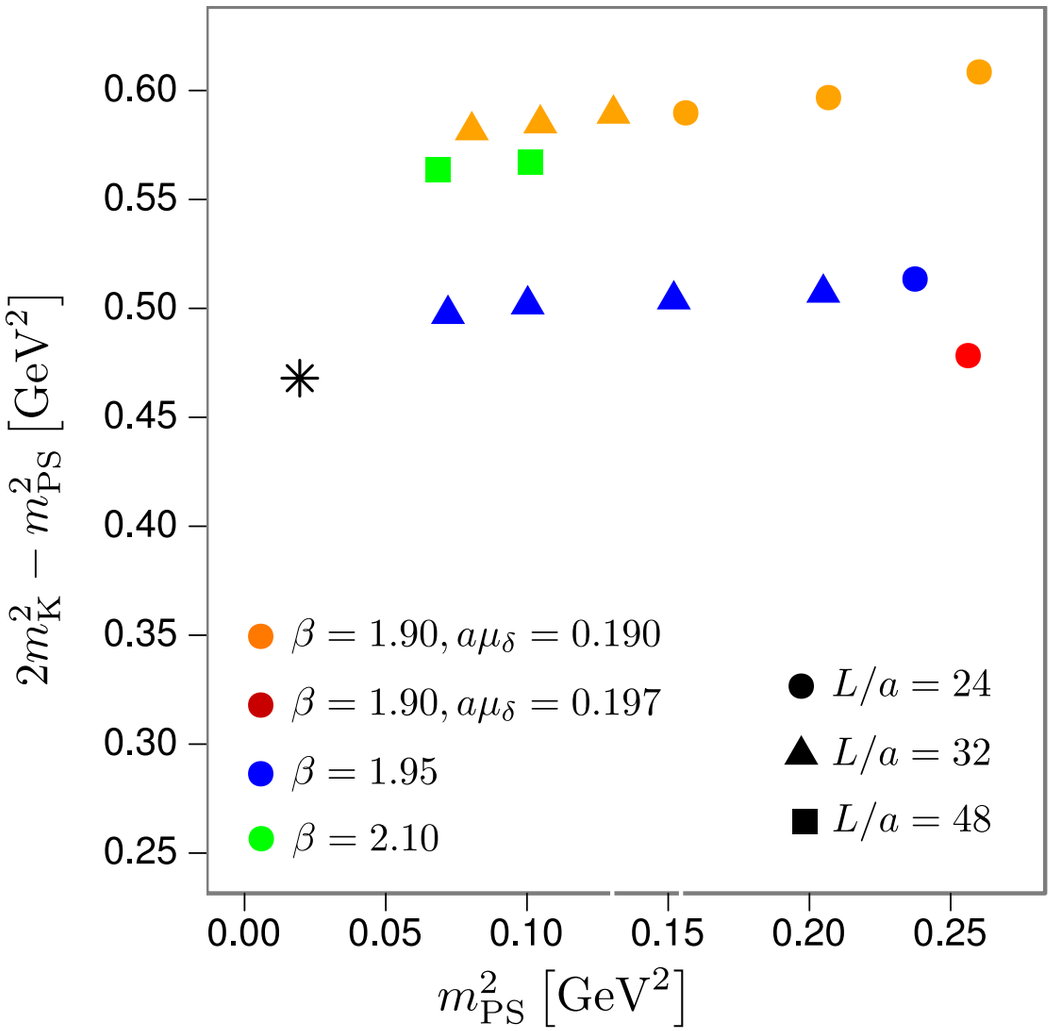
Tuning status

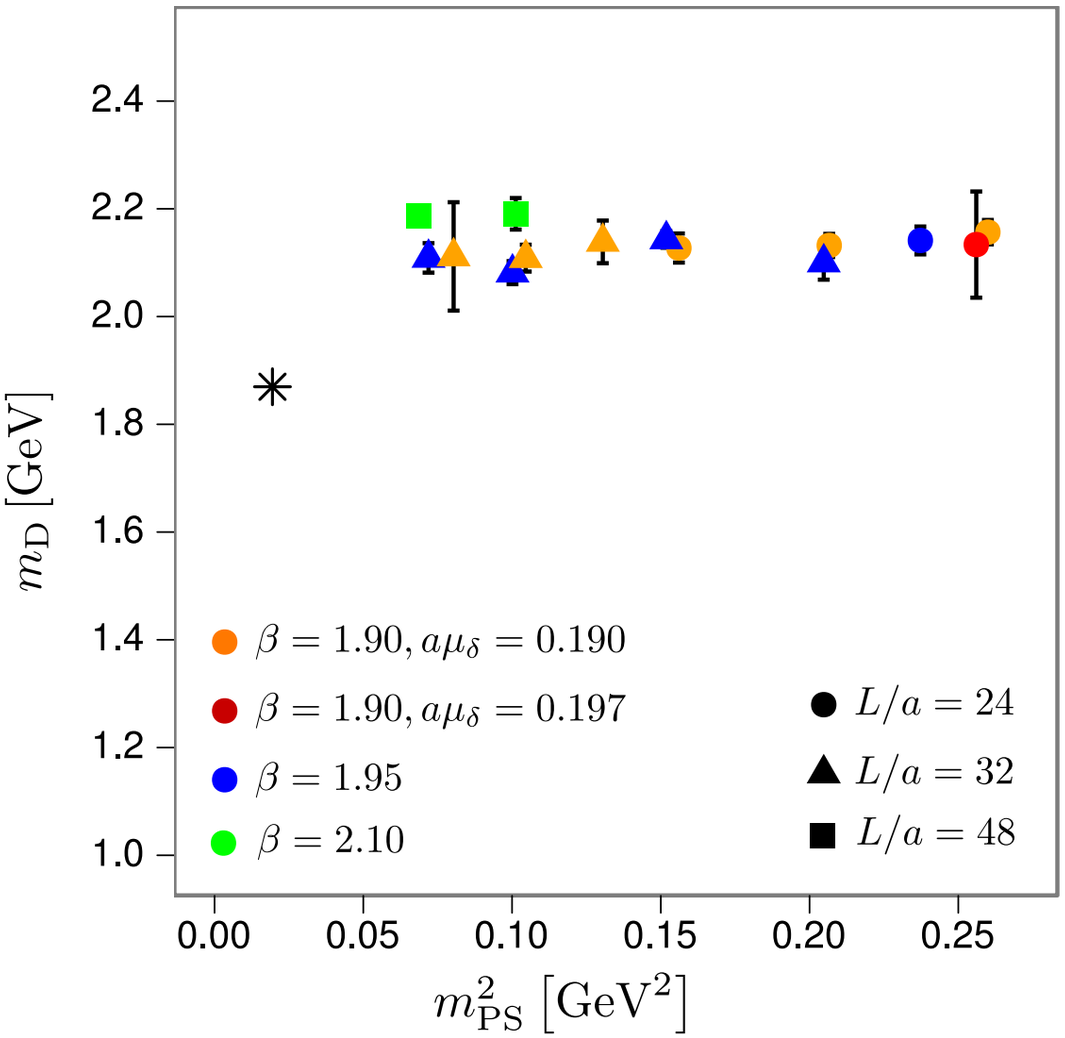


Heavy doublet tuning

- ★ Measure kaon mass and D-meson mass
- ★ We now have several reliable ways to extract the D-meson mass
- ★ Also measure e.g. m_{K^*}, m_{D^*}, f_K, (decuplet)
- ★ Mixed action approach (Urbach, next talk)

Kaon & D-meson mass





Chiral fits

- ★ Pion NLO, some tests of NNLO, $O(a^2)$
- ★ Other decay constants covered by Urbach (next), baryons covered by Drach (P22)
- ★ Consistency checks: combine spacings, separate check of r_0/a, estimate scaling
- ★ Preliminary renormalization factors available at $\beta=1.95$

Chiral fits

- ★ Finite size effects using Colangelo, Dürr, Haefeli (CDH) resummed expression
- ★ Use only largest volumes at each mass
- ★ Do not use new strange/charm sets (yet)
- ★ Fit a ratio of Z_P for other lattice spacings
- ★ Set lattice spacing by finding where f_π/m_π obtains its physical value

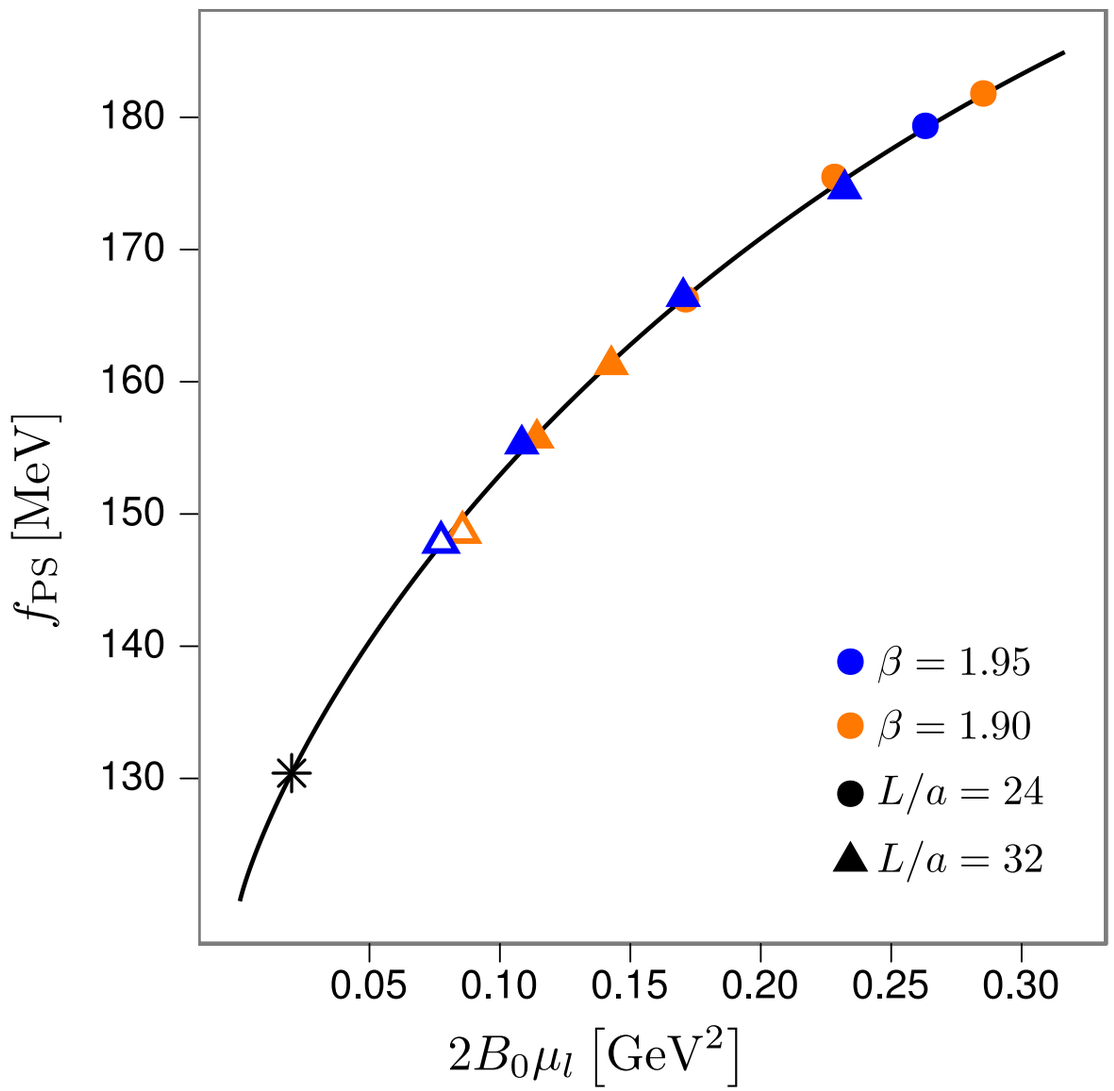
Fits (check)

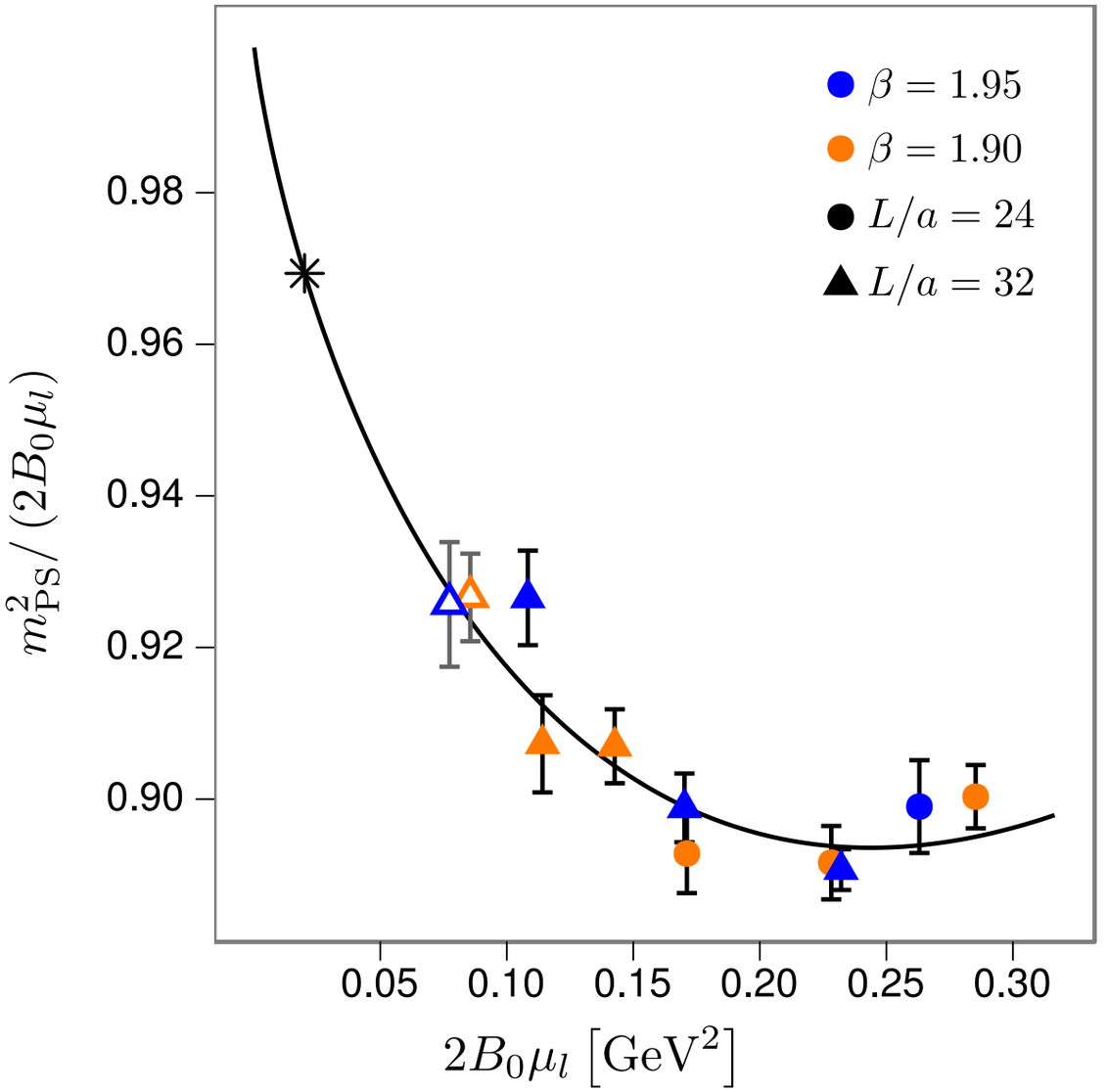
★ A: β=1.90, B: β=1.95, D: β=2.10

Set	A	A,D	B	B,D	A,B	A,B,D	D
f_0	121.0	121.0	121.1	121.2	121.0	121.0	121.7
l_3	3.44	3.43	3.70	3.70	3.54	3.53	3.45
l_4	4.77	4.76	4.67	4.66	4.74	4.73	4.43
f_π/f_0	1.078	1.078	1.076	1.076	1.077	1.077	1.072
a_A (fm)	0.086	0.086			0.086	0.086	
a_B (fm)			0.078	0.078	0.078	0.078	
a_D (fm)		0.061		0.061		0.061	0.062

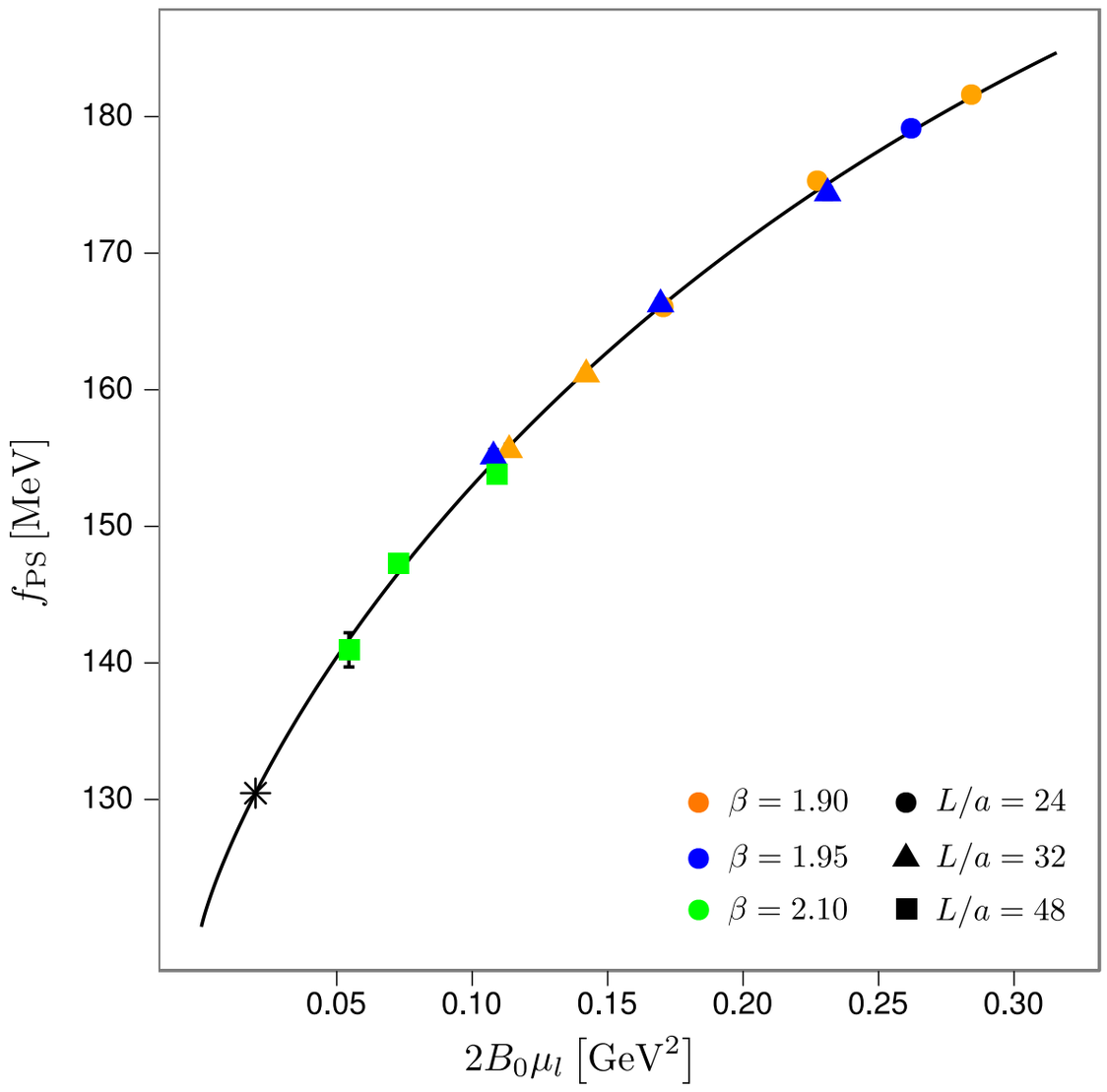
★ β=2.10 data does not constrain combined fits yet

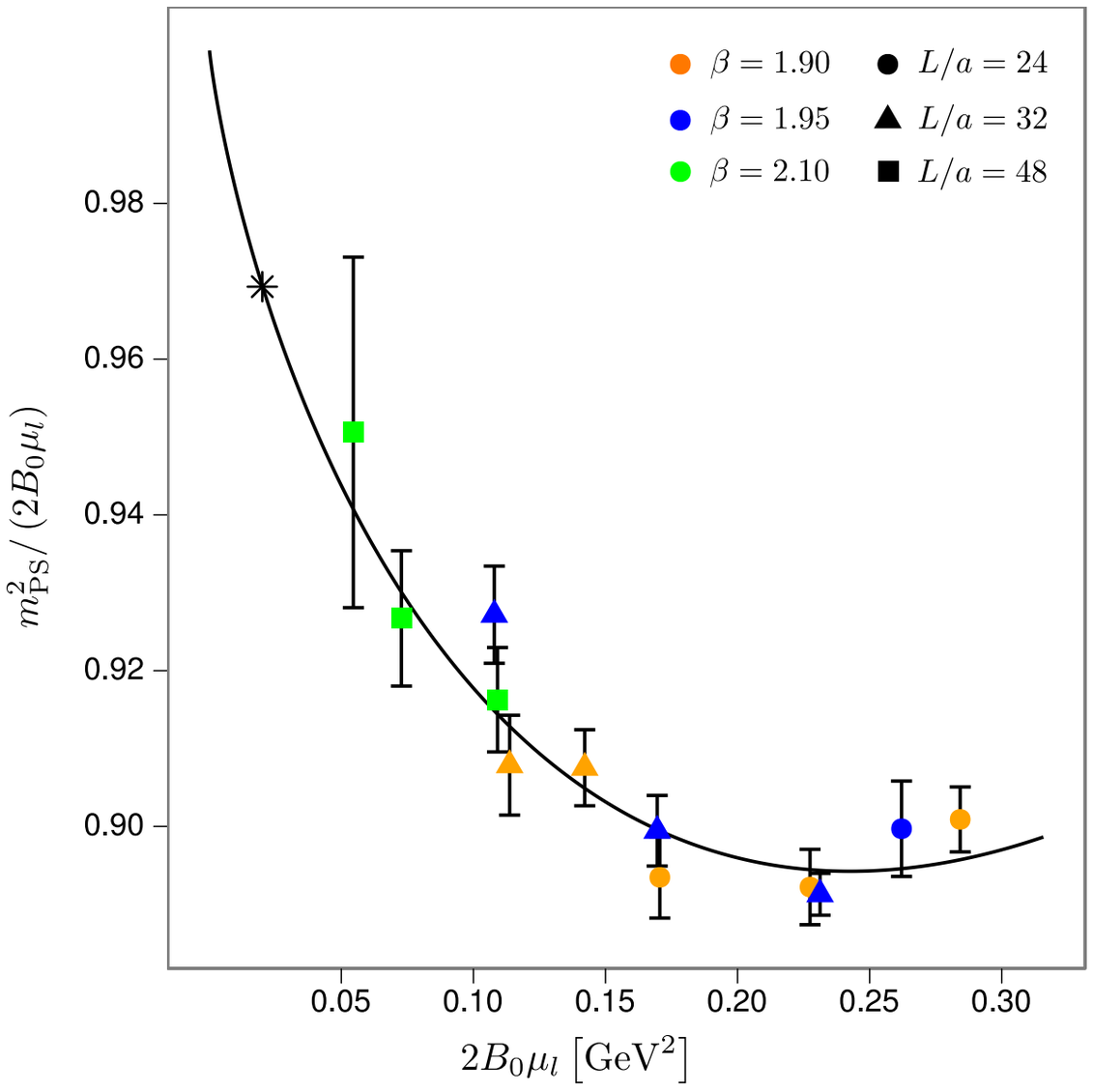
Combined fit





Combined fit

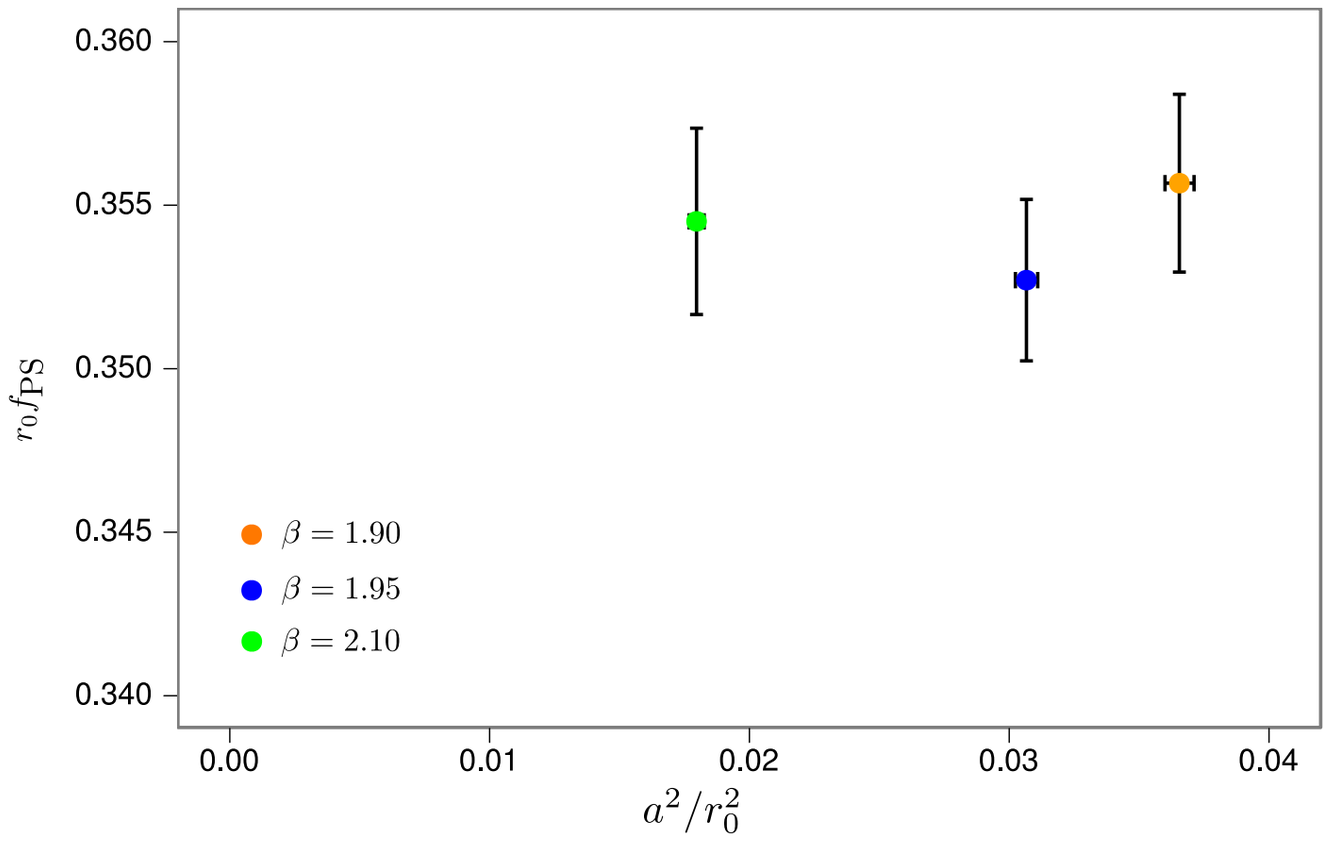




r_0/a & scaling

- ★ Separate fits
- ★ β=2.10 few points

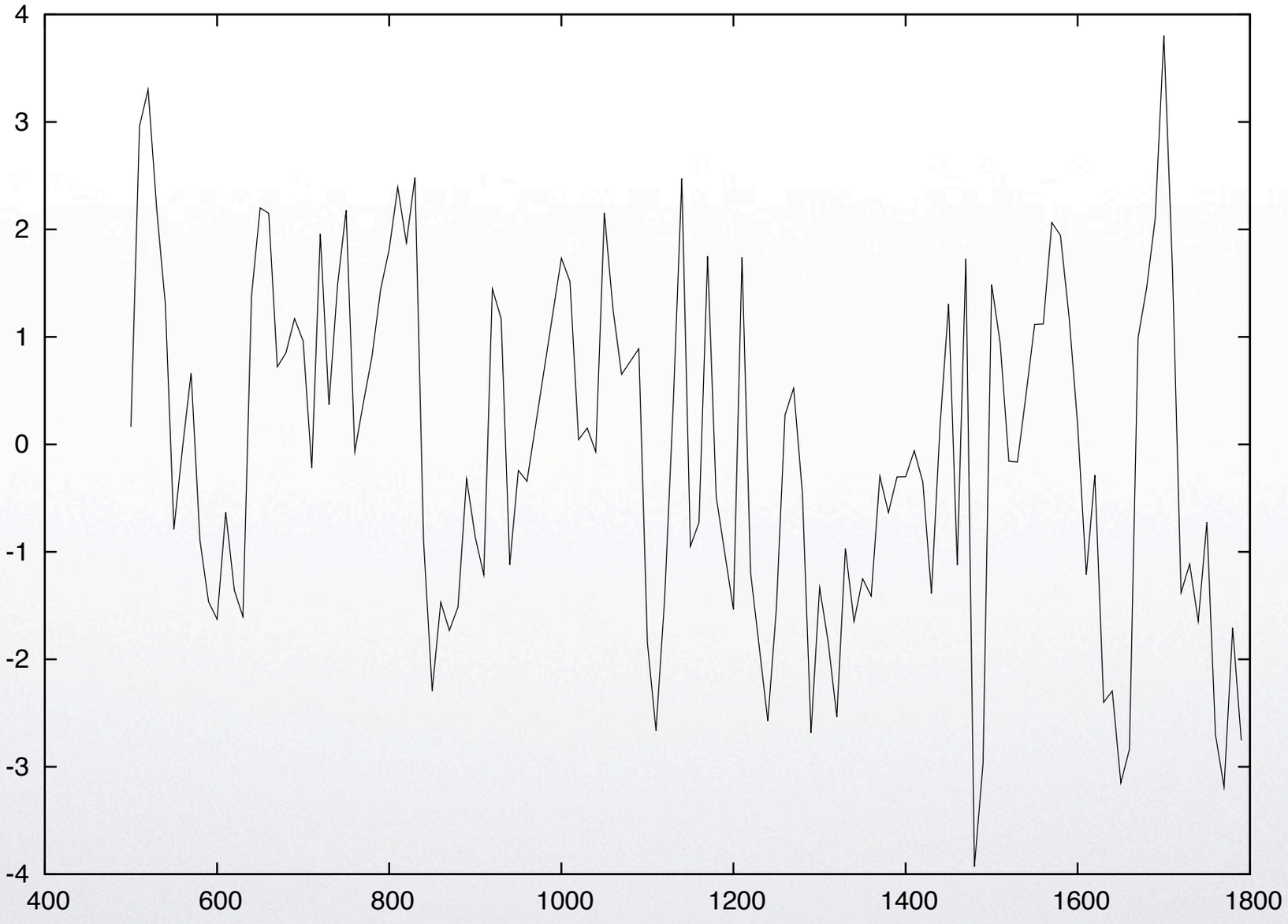
β	1.90	1.95	2.10
a (fm)	0.0859(5)	0.0782(6)	0.061(1)
r_0/a	5.23(4)	5.71(4)	7.46(6)
r_0 (fm)	0.449(4)	0.447(5)	0.45(1)



Conclusions

- ★ Substantial increase in number of ensembles (new lattice spacing, heavy sector, FSE)
- ★ Results in light sector so far appear consistent and indicate good scaling
- ★ Several interesting results and checks coming soon: e.g. lighter mass, Z's at all β
- ★ Other observables: other talks

Topological charge D20.48



Finite size effects