Status of the Nf=4 RCs project in France

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Methodology

- Non-perturbative hypercubic corrections

$$Z^{latt}(a^2p^2, a^4p^{[4]}, a^6p^{[6]}, ap_4, a^2\Lambda^2_{QCD}) = Z^{hyper\_corr}(a^2p^2, ap_4, a^2\Lambda^2_{QCD}) + R(a^2p^2, a^2\Lambda^2_{QCD})a^2\frac{p^{[4]}}{p^2} + \cdots \quad (1)$$

where

$$p^{[n]}_{H3} \equiv \sum_{\mu=1}^{3} p^n_\mu, \quad n = 2, 4, 6 \quad (2)$$

$$R(a^2p^2, a^2\Lambda^2_{QCD}) = \frac{dZ^{latt}}{d\epsilon}|_{\epsilon=0} \sim c_{a2p4} + c_{a4p4}a^2p^2, \quad \epsilon = a^2\frac{p^{[4]}}{p^2} \quad (3)$$

- Running including the contribution from $\langle A^2 \rangle$

$$Z^{latt}_q(p^2) = Z^{pert}(p^2, \mu^2)\left(1 + \frac{C^Z_{Wilson}(p^2, \mu^2)}{Z^{pert}(p^2, \mu^2)}\langle A^2(\mu^2)\rangle\right) + c_{a2p2}a^2p^2 \quad (4)$$

Analysis procedures

- θ-average $O(a)$

$$Z(M,|\theta|) = \frac{1}{2}[Z(M,\theta^p) + Z(M,\theta^m)]$$

$$M = \sqrt{Z_A^2 m_{PCAC}^2 + \mu^2}, \quad \tan\theta = \frac{Z_A m_{PCAC}}{\mu}$$

- Valence chiral limit (Goldstone-pole subtractions) $O(\frac{1}{M_\pi^2})$

$$\Gamma_P(p^2, m^{val}) = \Gamma_P(p^2, m^{val} = 0) + c_1(p^2) \cdot \left(M_{PS}^{val}\right)^2 + \frac{c_2(p^2)}{\left(M_{PS}^{val}\right)^2} \quad (5)$$

- Hypercubic corrections $O(a^2 \frac{p^{[4]}}{p^2}) \cdots$
- Running $O(a^2 p^2)$ and condensate terms $O(\frac{1}{p^2})$
- Sea chiral limit remnant θ_{sea} dependence

$L^3 \times T = 24^3 \times 48 \quad \beta = 1.95$

Ensemble	κ_{sea}	μ_{sea}	μ_{val}	Index	Stats
1m	0.161739	0.0085	{0.0085, 0.0190, 0.0261, 0.0322, 0.0378}	0120-1370	250
1p	0.160389	0.0085	{0.0085, 0.0190, 0.0261, 0.0322, 0.0378}	0105-1375	250
2m	0.161229	0.0085	{0.0085, 00150, 0.0190, 0.0203, 0.0252, 0.0261, 0.0298, 0.0322, 0.0378}	0105-1650	310
2p	0.160826	0.0085	{0.0085, 00150, 0.0190, 0.0203, 0.0252, 0.0261, 0.0298, 0.0322, 0.0378}	0385-1840	290
3m	0.161229	0.0180	{0.0060, 0.0085, 0.0120, 0.0150, 0.0180, 0.0203, 0.0252, 0.0298}	0185-1655	295
3p	0.160826	0.0180	{0.0060, 0.0085, 0.0120, 0.0150, 0.0180, 0.0203, 0.0252, 0.0298}	0241-1661	356
7m	0.161585	0.0085		1455-2890	290
7p	0.160524	0.0085		0000-1600	320
4m	0.161095	0.0085			
4p	0.160870	0.0085			
5m	0.161000	0.0085			
5p	0.160943	0.0085			

$L^3 \times T = 32^3 \times 64 \quad \beta = 2.1$

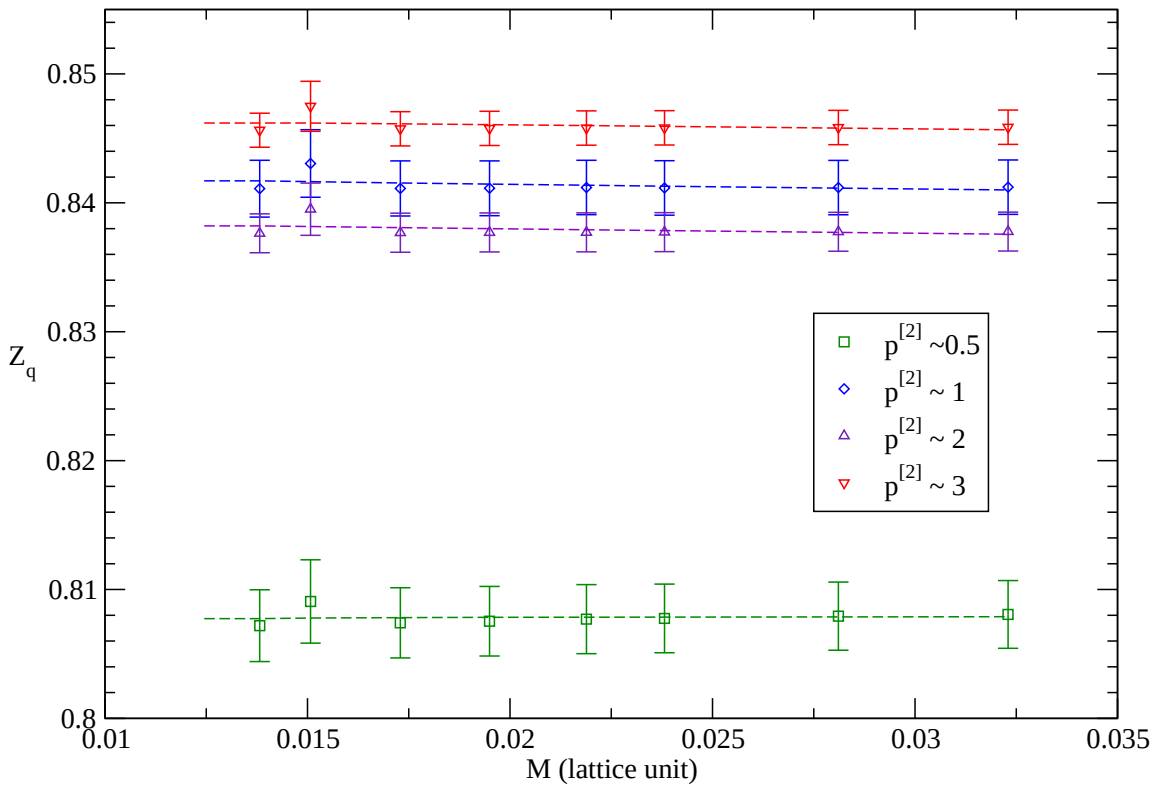
Ensemble	κ_{sea}	μ_{sea}	μ_{val}	index	Stats
D-2ap-L32	0.156042	0.0030	{0.0013, 0.0030, 0.0080, 0.0143, 0.0195, 0.0247, 0.0298}	0500-0700	50
D-2am-L32	0.156157	0.0030	{0.0013, 0.0030, 0.0080, 0.0143, 0.0195, 0.0247, 0.0298}	0716-0896	50
D-3p-L32	0.156017	0.0046	{0.0025, 0.0046, 0.0090, 0.0152, 0.0201, 0.0249, 0.0297}	0220-1240	250
D-3m-L32	0.156209	0.0046	{0.0025, 0.0046, 0.0090, 0.0152, 0.0201, 0.0249, 0.0297}	0114-1522	350
D-4p-L32	0.155983	0.0064	{0.0039, 0.0064, 0.0112, 0.0184, 0.0240, 0.0295}		
D-4m-L32	0.156250	0.0064	{0.0039, 0.0064, 0.0112, 0.0184, 0.0240, 0.0295}	0500-0716	55
D-5p-L32	0.155949	0.0078	{0.0048, 0.0078, 0.0119, 0.0190, 0.0242, 0.0293}	0512-1424	230
D-5m-L32	0.156291	0.0078	{0.0048, 0.0078, 0.0119, 0.0190, 0.0242, 0.0293}	0500-1704	300

Data analysis

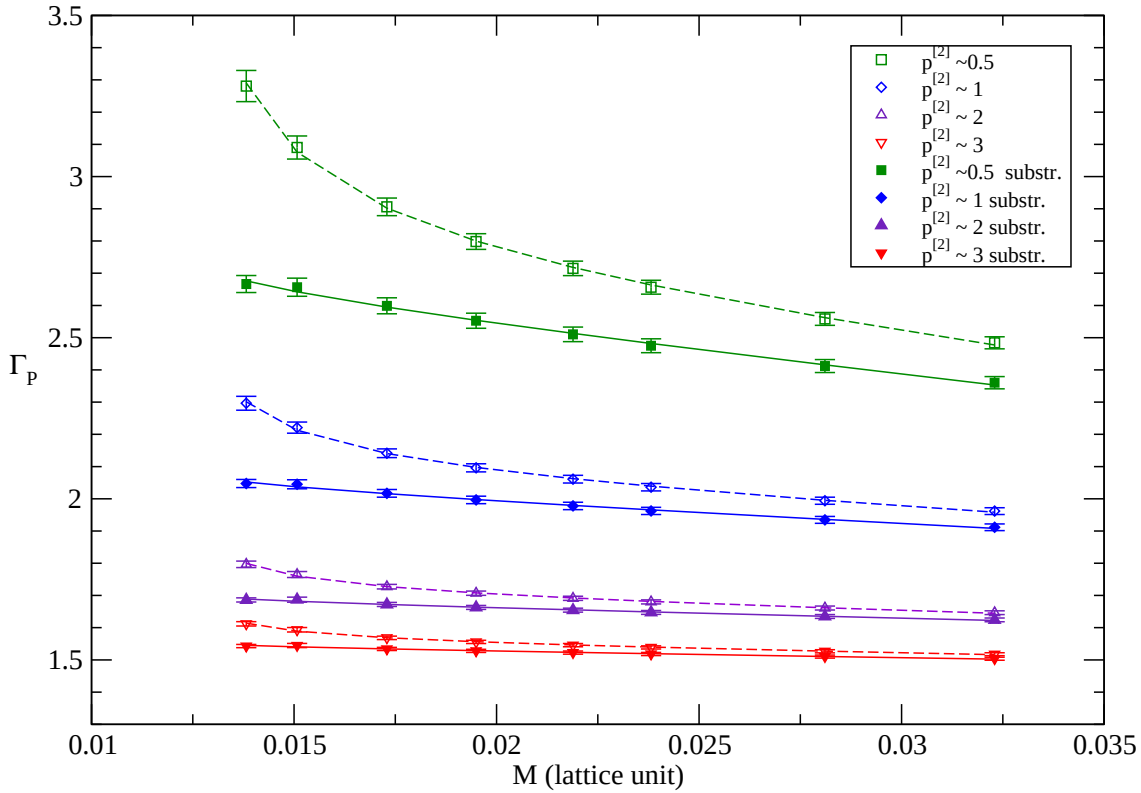
$L^3 \times T = 24^3 \times 48,\ \beta = 1.95,\ a \approx 0.08\text{fm}$

Ensemble	κ_c	μ_{sea}	m_{PCAC}	θ	conf #
3m	0.161229	0.0180	-0.01602(20)	-0.601	295
3p	0.160826	0.0180	+0.01632(21)	+0.609	356

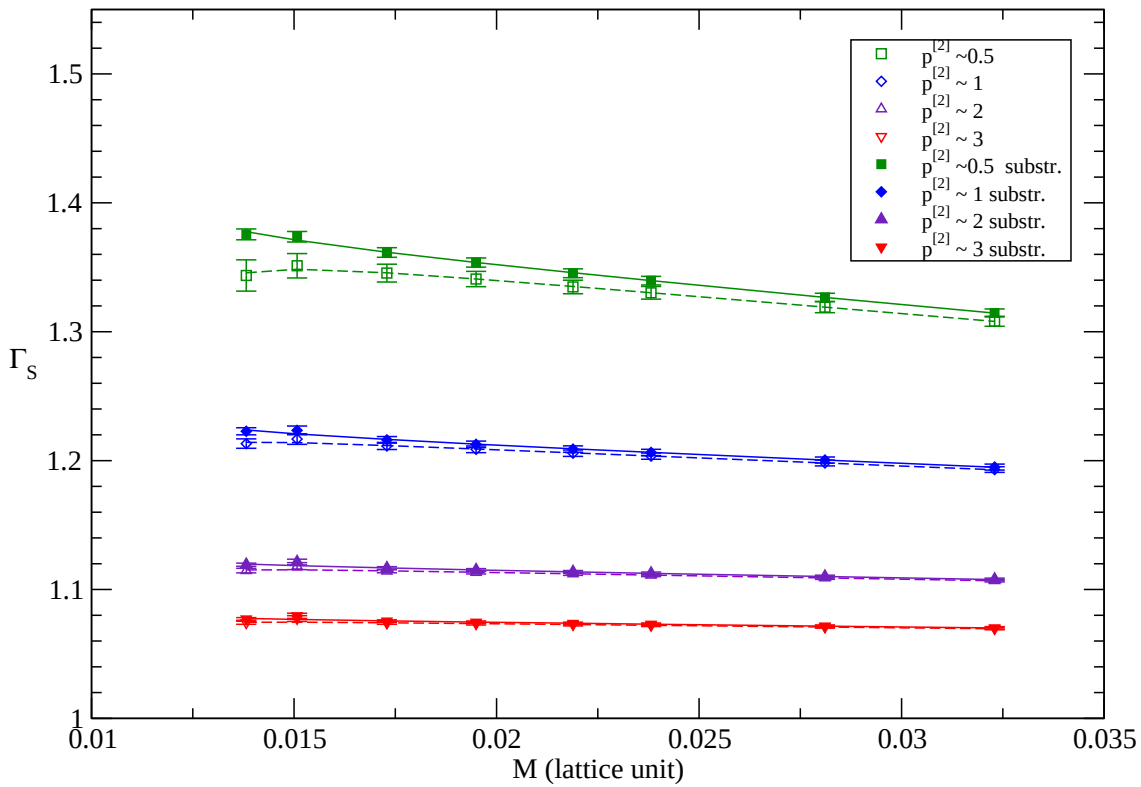
Valence chiral limit for Z_q



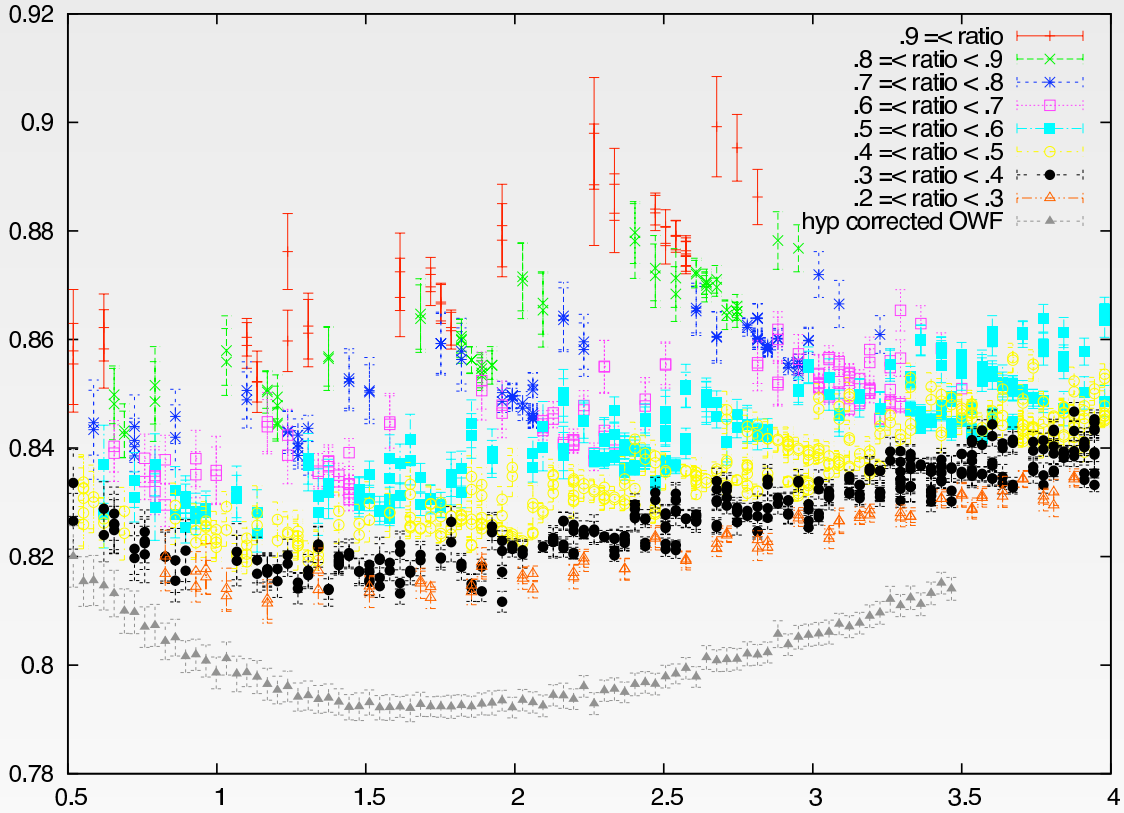
Valence chiral limit for Z_P



Valence chiral limit for Z_S

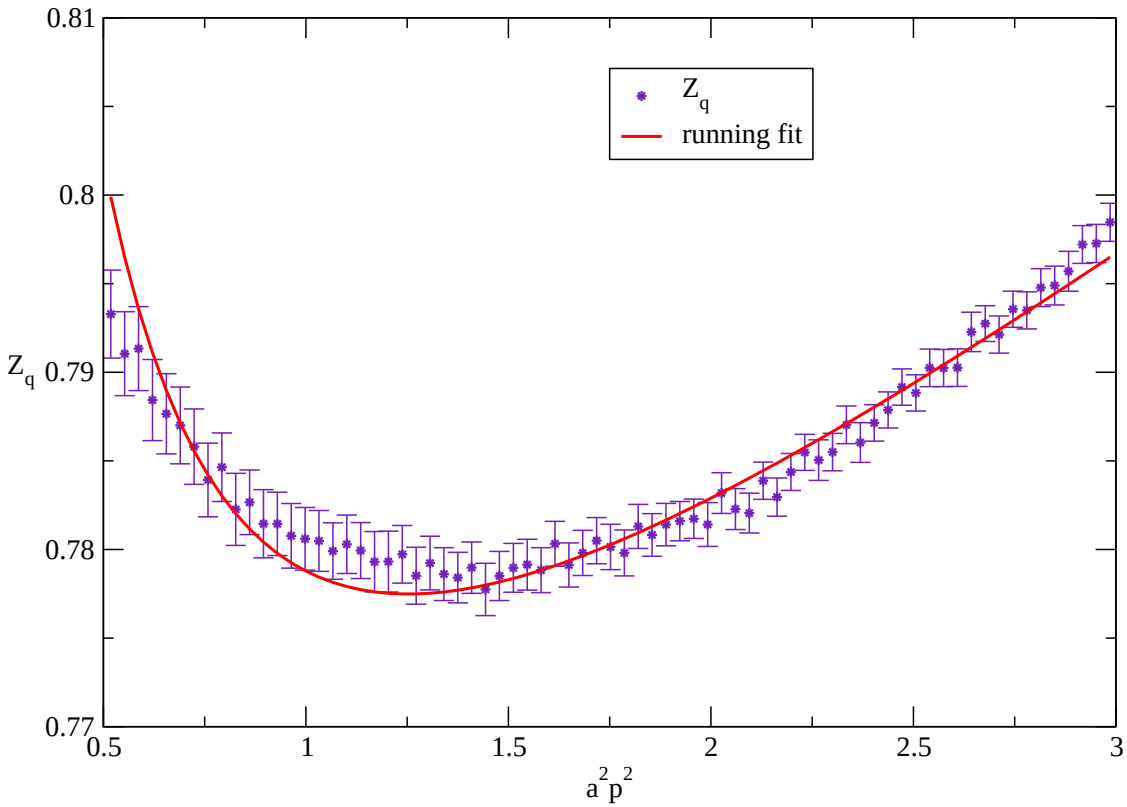


Hypercubic corrections for Z_q

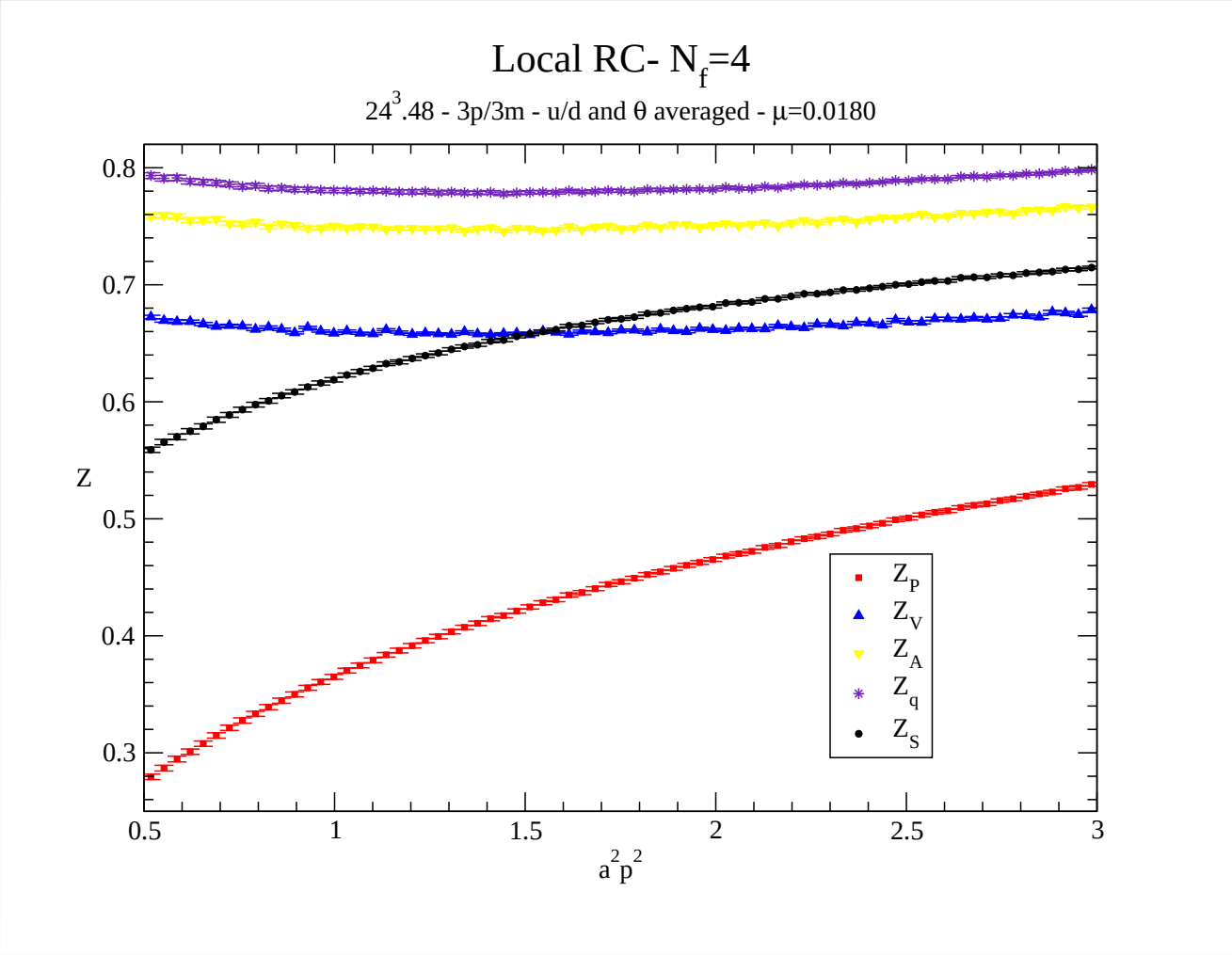


$$p^{[4]} = \sum_{\mu} p_{\mu}^4, \quad 0.25 \leq \text{ratio} = p^{[4]}/(p^2)^2 \leq 1 \tag{6}$$

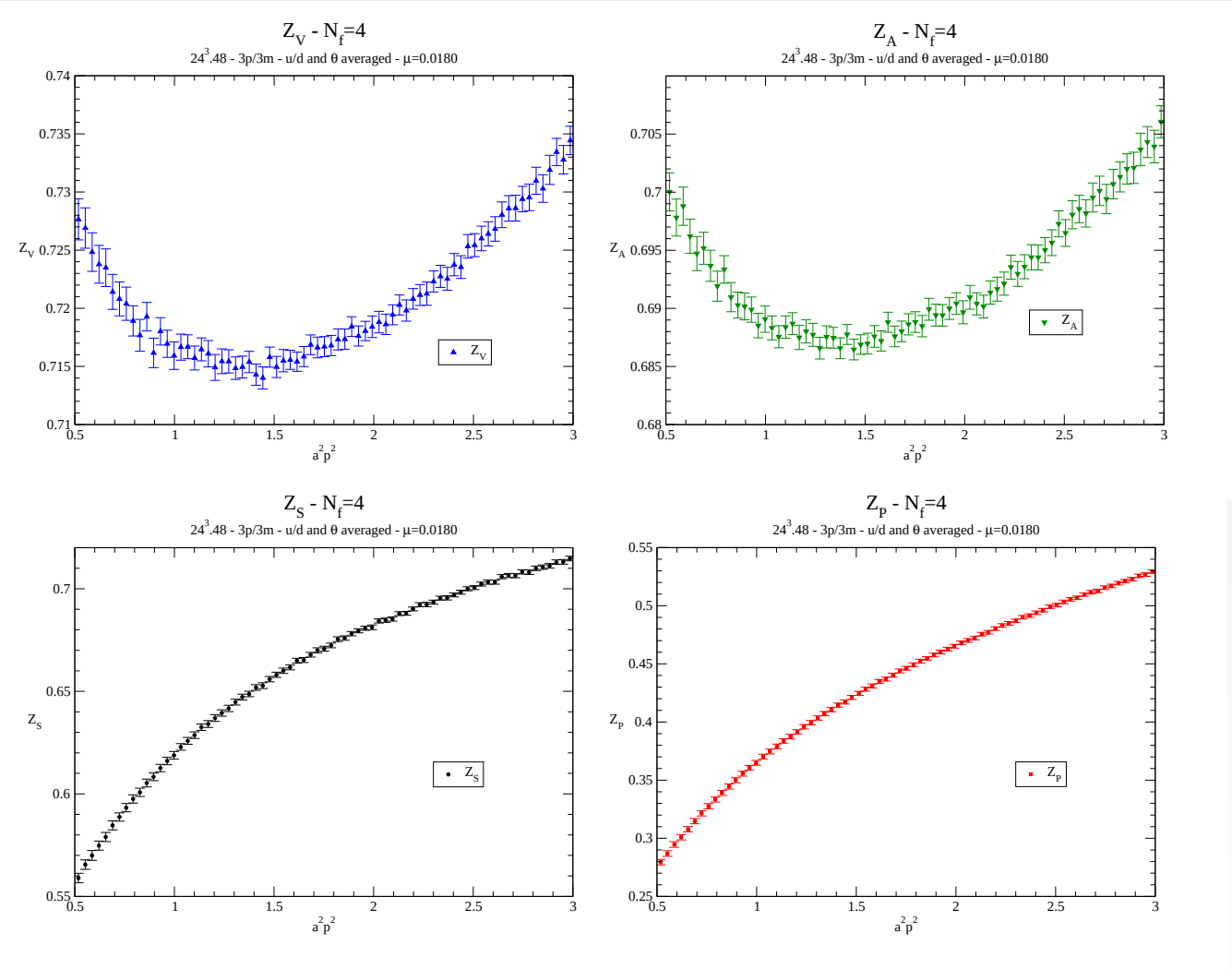
Running of Z_q



Preliminary results for ensemble 3p/3m



Running for Z_S, Z_P, Z_V and Z_A?



Preliminary results

$$Z_q^{pert}(\mu = 10\text{GeV}) = 0.7368 \pm 0.0028,$$
$$g^2\langle A^2\rangle_{CM}\big|_{\mu=10\text{GeV}} = 5.20 \pm 0.16\text{GeV}^2,$$
$$Z_V \simeq 0.6625(5)$$
$$Z_A \simeq 0.7536(6)$$

Systematic errors

- Sliding window fit / one window fit for hypercubic corrections.
- Momentum window for the analysis.
- Order of perturbation theory used for the running.
- Fitting formulae used for subtracting the goldstone-pole.
- Fitting formulae used for chiral extrapolations.
- Check finite volume effects.
- Check cut-off (finite lattice spacing) effects.

Things to do

- Work out (NP) running formulae for all RCs.
- Pion masses for goldstone-pole subtractions.
- Finish inversions for 32^3 ensembles.
- Analysis of RCs for bilinear operators and possibly twist-2 operators.