We present a numerical study of spectroscopic observables in the SU(2) gauge theory with two adjoint fermions. We compare our results using improved source and sink operators with previous determinations of masses that used point sources and sinks and investigate possible systematic effects in both cases. We discuss the finite volume effects on the spectrum, incorrigibly by varying the size of the lattice and by changing the boundary conditions.

### Introduction

Minimal walking technicolor (MWT), with gauge group SU(2) and two flavours of adjoint Dirac fermions, is a candidate theory of electroweak symmetry breaking. The evidence accumulated so far for this theory favours a conformal or near-conformal scenario. However, more systematic studies need to be performed before the IR properties of the theory can be determined with confidence.

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### Smearing effects

We systematically compared local, gaussian and wall-smeared sources on our ensembles. At our lightest masses, the wall-smeared sources have the largest overlap with the ground state, which is reflected in the flattest effective masses. In Fig. 1 we show the PS effective masses computed with the three methods.  

![Comparison of the pseudoscalar mass from different smearings at am0 = −1.175, on a 16 × 8 lattice (left) and a 24 × 12 lattice (right).](image)

Smeared sources are more sensitive to the algorithm's autocorrelation time. We study this by grouping the N data into N/b blocks of length b and averaging over each block. A bootstrap analysis is then performed on the reduced datasets. When the block size is big enough, the relative error is given by the block size corresponding to an integrated autocorrelation time of order 1. Our analysis of the autocorrelation is illustrated in Fig. 2 for the PS effective mass.

![Autocorrelation analysis on a 24 × 12 lattice at am0 = −1.175, for the PS effective mass in two temporal points. Left, integrated autocorrelation time; right, relative error. Plateaus of the relative error highlighted with faint rectangles.](image)

We see that the measured autocorrelation times for the smeared results are larger than for the local results, and that the standard deviation increases up to a point where it appears to reach a plateau. The value of b where this plateau sets in is interpreted as the length in simulation time over which the data are uncorrelated. This picture is replicated across our ensembles. We have accounted for this by conducting our bootstrap analyses over appropriately reduced datasets. To quantify the flatness of the effective mass we define the ratio

\[ R(b) = \frac{\text{standard deviation of } M(b)}{\text{standard deviation of } M(\infty)} \]

where \( M(\infty) \) is the PS mass at infinite volume. The value of \( R(b) \) is plotted for pseudoscalar effective masses.

![Effective PS mass on different volumes for am0 = −1.05 (L=local, W=wall).](image)

Having understood the effects of smearing and inadequate plateaux, we have extended our calculations to lighter masses and larger volumes. We show the effective PS mass at am0 = −1.15 in Fig. 6. We see that for Lx ≥ 24 there is good agreement. Furthermore, for Lx = 32 there is a very long plateau which agrees with the plateau for Lx = 64.

### Finite Volume Effects

We have calculated the PS and V masses, their ratio and PS decay constant on the 16 × 8 and 24 × 12 lattices for am0 = −1.05, both from local and wall-smeared sources. We find that the volume dependence appears to strengthen with wall-smeared sources. To clarify this, we look at the effective PS mass in Fig. 4. By comparing the effective masses on the 24 × 12 and 64 × 8 lattices it is clear that the finite volume makes the pseudoscalar meson lighter. On the 16 × 8 lattice the mass estimated with the local sources is affected by two relatively large effects: the finite volume, which decreases the mass and the bad determination of the plateaux, which increases the mass. These two effects almost cancel each other. Therefore the finite volume effects are actually larger than estimated using just the local sources, and they are better estimated using wall-smeared sources at light enough masses. These conclusions are valid also for the vector meson mass and for the ratio M0/M1.

![Effective PS mass for periodic and twisted boundary conditions for various lattice sizes at am0 = −1.15.](image)

Finally, we have investigated finite volume effects in the gluonic sector. These appear to be larger than for mesons. We plot the string tension and glueball masses in Fig. 8. Despite the larger pseudoscalar mass, it appears we need Lx ≥ 52 to control the 2\(^+\) glueball mass.

![Ratio of M0 to M0, with an estimate of the remaining finite-volume errors.](image)

We have found wall-smearing leads to better plateaux, at the cost of larger errors on some points. We plotted the string tension and glueball masses in Fig. 8. Despite the larger pseudoscalar mass, it appears we need Lx ≥ 52 to control the 2\(^+\) glueball mass.

### Summary

We have investigated the effects of both smearing and finite volumes on determinations of the spectrum of minimal walking technicolor. We have found wall-smeared leads to better plateaux, at the cost of larger autocorrelation times. Finite volume effects can be underestimated if only local sources are used. In general, larger volumes (compared to experience from QCD) are needed to control finite volume effects, especially for gluonic observables. Nevertheless, our conclusions regarding the near-conformal dynamics of this theory are robust.

### References
