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ABSTRACT

Within 4d SU(2) lattice gauge theory the 2^+ glueball is investigated. Using a recently proposed source we carry out a high statistics Monte Carlo calculation at $\beta = 2.25$ and $\beta = 2.40$. We obtain correlations up to distance $t = 3$. For increasing distances we find a significantly decreasing $m(2^+)$ mass.

Source methods play an important role for investigating the spectrum of pure lattice gauge theories. For a partial reference list see /1,2/. Most investigations /1/ concentrate on the 0^{++} mass gap. In Ref. /2/ sources for the SU(2) 2^+ and the SU(2) 0^- spin state *) were proposed and preliminary Monte Carlo (MC) calculations indicated a reasonable signal in case of the 2^+ state, whereas the signal for the 0^- state disappeared already at distance $t = 1$ rapidly into the statistical noise.

In the present letter we use the 2^+ source and report MC results relying on the high statistics of table 1. In case of measurements the first number gives the

	EQUI	MEAS	BINS
2.15	1250	3 · 5 000	20
2.25	1250	2 · 100 000	40
2.40	1250	2 · 50 000	20

Table 1

MC statistics: Number of sweeps for reaching equilibrium (EQUI) and for measurements (MEAS). Error bars calculated with respect to the given number of bins (BINS).

sweeps performed for one measurement and second number gives the total number of measurements performed. The lattice size is always 8^4. As in Ref. /2/ we calculate expectation values of 6 different operators in the E + representation of the cubic group. This corresponds to spin 2 + in the continuum limit; see Ref. /3/. The considered 6 operators are depicted in figure 1. Error bars are obtained by dividing all data into the number of bins given in table 1.

In this letter we report only results from operators which give

$$r = \text{signal} / \text{noise} > 3 \tag{1}$$

for correlations at distance $t = 3$, (β = 2,25, 2.40). The signal to noise ratio is defined as mean value/error bar. For the sake of stability at $t = 2$, 3 also no

*) The definition of spin states on the lattice is discussed in Ref. /3/.

correlations with a sign change at distance t ≥ 2 are considered. With our data at β = 2.15 a ratio r $>$ 3 is never obtained at distance t = 3 and the correlations with the two highest r-ratios are taken into accound up to t = 2. At this β -value correlations at distance t = 2 are argued to give already rather reliable results.

The thus selected results are presented in table 2. A detailed discussion of all results will be given in Ref. /4/. In table 2 the mass gap definitions

$$m(t_1, t_2) = \frac{-1}{t_2 - t_1} \ln \frac{\langle \Psi | O_i(t_2) | 0 \rangle}{\langle \Psi | O_i(t_1) | 0 \rangle} \qquad (2)$$

are used. The operators O_i (i = 1, ..., 6) are taken in the indicated E + representation (for details see Ref. /3/).

In the strong coupling limit /5/ as well as in the finite volume weak coupling limit /6/ a mass ratio

$$m(2^+) \,/\, m(0^+) \approx 1 \qquad (3)$$

is obtained. In contrast high statistics MC variational calculations /7/ give the order of magnitude

$$m(2^+) \,/\, m(0^+) \approx 1.8. \qquad (4)$$

Qualitatively the thus obtained behaviour of the mass ratio on a finite lattice is depicted in figure 2. The present work indicates that the ratio (4), i.e. the peak in figure 2, may lower further down. Averaging our source method MC results gives (in lattice units) $m(2^+) \approx 1.9$ at β = 2.25 and $m(2^+) \approx 0.93$ at β = 2.40. With the estimate /7/ $m(0^+) \approx 190\,\Lambda_L$ this yields

$$m(2^+) \,/\, m(0^+) \approx 1.5 \qquad (\beta = 2.25). \qquad (5)$$

At β = 2.40 the ratio is even down to $m(2^+) / m(0^+) \approx 1.1$ ($\pm$ 40%). However, at this β -value the lattice is presumably already too small to reflect true continuum limit behaviour. Instead the result may reflect the decreasing tendency of the mass ratio curve in figure 2 for $\beta \to \infty$.

Finally the reliability of our results in the $t \to \infty$ limit (β, volume fixed) has to be discussed critically. An advantage of the E + correlations /2/, as compared with the A1 + correlations /1/, is that the vacuum expectation value is known to be exactly zero. Therefore we have one parameter less than for instance in the work of De Forcrand et al. /1/. On the other hand we only obtain reasonable signals up to the rather short distance t = 3 and by this reason the extrapolation to large t is questionable. Table 2 gives an unstable tendency: Mass ratios are lowering systematically and at β = 2.40 even in a rather drastic way. The relation to the asymptotic value cannot really be clarified: In contrast to MC variational calculations /7/ the source method does not give upper bounds. The analysis of all data /4/ exhibits further warnings related to this point. What one needs would be consistency over several steps in t, but the signal dies away too fast.

In conclusion our 2^+ glueball calculation improves considerably previous results /7/. The final aim of a reliable continuum limit extrapolation is, however, not reached.

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	OP	E+ repr.	E+ comp.	m(0,1)	m(0,2)	m(1,2)	m(0,3)	m(1,3)	m(2,3)	r
2.15	1	1	1	3.75(1)	3.64(8)	3.54(16)				
2.15	5	1	1	4.02(1)	3.62(10)	3.22(19)				
2.25	1	1	1	3.72(1)	3.62(2)	3.52(5)	3.12(7)	$2.81(^{+12}_{-9})$	2.11(25)	4.8
2.25	2	1	1	3.92	3.45(2)	2.98(5)	2.92(8)	$2.41(^{+13}_{-10})$	$1.85(^{+29}_{-24})$	4.6
2.25	3	2	1			2.86(5)		$2.37(^{+16}_{-11})$	$1.89(^{+34}_{-28})$	3.8
2.25	4	2	1			2.87(5)		$2.33(^{+13}_{-10})$	$1.79(^{+31}_{-25})$	4.3
2.25	5	1	1	3.92	3.47(3)	3.03(5)	2.97(10)	$2.49(^{+15}_{-11})$	$1.96(^{+33}_{-28})$	4.0
2.40	3	1	2	4.59	4.00(7)	3.42(12)	2.98(11)	$2.18(^{+16}_{-12})$	$0.95(^{+42}_{-37})$	3.8
2.40	6	1	2	4.94(1)	3.42(7)	1.90(16)	2.57(10)	$1.40(^{+15}_{-12})$	$0.90(^{+42}_{-37})$	4.1

Table 2

Selected MC results. The E+ representations (repr.) are defined in Ref. /3/ and the selected component (comp.) of these 2d representations is also indicated. Finally the signal to noise ratio r for correlations at distance t = 3 is given.

Figure captions

Figure 1: Operators as considered in the present MC calculation.

Figure 2: Qualitative behaviour of the $m(2^+)$ / $m(0^+)$ ratio on a finite lattice.

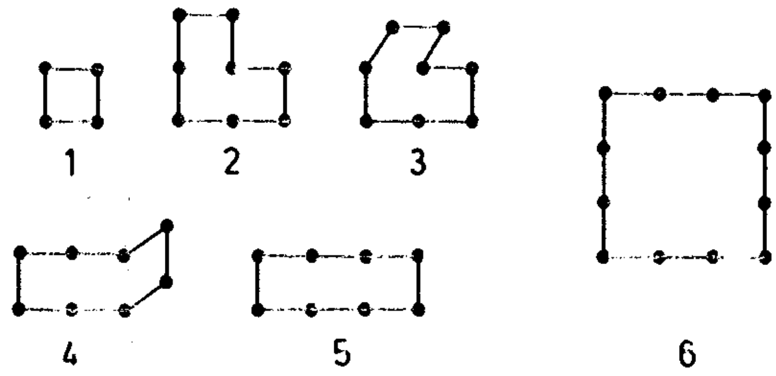

Figure 1

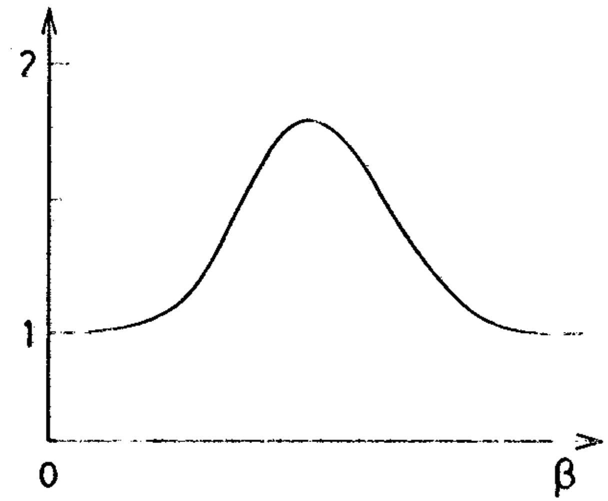

Figure 2