Two dimensional N=2 Super Yang Mills theory

Daniel August
in collaboration with: Björn Wellegehausen, Andreas Wipf

Theoretisch-Physikalisches Institut
Friedrich-Schiller-Universität Jena

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Research Training Group
Quantum and Gravitational Fields

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Motivation

Many interesting non-perturbative aspects of SUSY

confinement, massless composite fermions,
spontaneous chiral symmetry breaking,...

Our focus: N=2 SYM in d=2

dimensional reduction of N=1 d=4 SYM
gauge group SU(2) [DESY-Münster Collaboration]

Restoration of SUSY via parameter fine-tuning

SUSY on the lattice

Problem

$\left\{ Q^I, (Q^I)^\dagger \right\} \sim P^\mu \rightarrow$ SUSY must be broken on the lattice
or: Leibniz rule is violated $\rightarrow$ Action not invariant under SUSY

two possible solutions

Accidental Symmetry

Preserve subset of SUSY

Model

N=2 SYM in d=2

Reducible Model

$$\mathcal{L} = \frac{1}{g^2}\mathrm{tr}\left\{-\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{i}{2}\overline{\lambda}\Gamma_\mu D^\mu \lambda - \frac{1}{2}D_\mu\phi_m D^\mu\phi^m + \frac{1}{2}\overline{\lambda}\Gamma_{1+m}\left[\phi^m,\lambda\right] + \frac{1}{4}\left[\phi_m,\phi_n\right]\left[\phi^m,\phi^n\right]\right\}$$

Field Content

- g dimensionful coupling constant
- A_μ gauge fields in two dimensions
- ϕ^m two scalars in the adjoint representation
- λ Majorana fermion with four spin indices in the adjoint representation

Model
N=2 SYM in d=2

Reducible Model

$$\mathcal{L} = \frac{1}{g^2}\mathrm{tr}\left\{-\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{i}{2}\overline{\lambda}\Gamma_\mu D^\mu\lambda - \frac{1}{2}D_\mu\phi_m D^\mu\phi^m + \frac{1}{2}\overline{\lambda}\Gamma_{1+m}\left[\phi^m,\lambda\right] + \frac{1}{4}\left[\phi_m,\phi_n\right]\left[\phi^m,\phi^n\right]\right\}$$

Wilson Fermions

- introduce Wilson term for λ
- breaks chiral symmetry
- preserves the R symmetry
- different lattice momenta for bosons and fermions
- requires fine tuning

Fine-tuning
General Considerations

Loop Expansion

- super renormalizable
- only relevant operator $m_s^2 \phi^m \phi_m$
  continuum limit and value for our simulation:
  $m_s^2 = 0.65948255(8)$ [Suzuki and Taniguchi,2005]

Chiral Limit

- in the continuum limit: chiral symmetry restored
- improve lattice results with additional fine tuning
- introduce the operator $m_F \overline{\lambda} \lambda$
- use chiral susceptibility for fine-tuning (later pion)

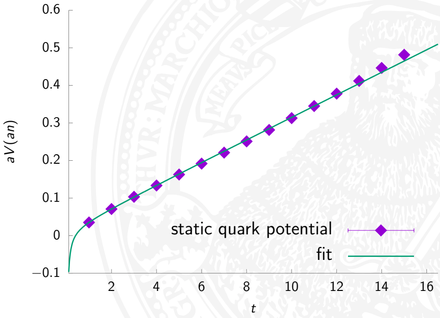
Continuum Limit

Theory

$$\beta = \frac{1}{a^2 g^2} \xrightarrow[\text{limit}]{\text{Continuum}} \infty$$

Static Potential

β	$a[fm]$	$\beta a^2[fm]$
17.0	0.0591(16)	0.0595(31)
15.5	0.0618(18)	0.0592(35)
14.0	0.0650(25)	0.0592(46)



Lattice setup

- RHMC algorithm
- Symanzik improved action
- Wilson fermions
- $N_t x N_s$: 16x8, 32x16, 64x32, 96x48
- $\beta = 14, 15.5, 17, 18, 18.5, 19$

Ward Identities
Continuum

- Ward identities are derived from

$$\langle \mathcal{Q}\mathcal{O} \rangle$$

- we choose the operator

$$\mathcal{O}(x) = \mathrm{Tr}_c \left\{ \overline{\lambda}_b\,(x)\,(\gamma_{\mu\nu})_a^b\,F^{\mu\nu}\,(x) \right\}$$

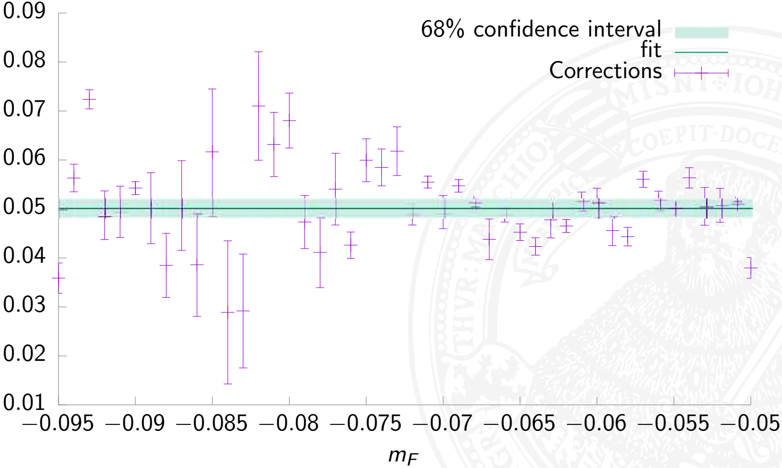
Bosonic Ward Identity

$$\beta \langle S_B \rangle = -\frac{3}{8} \left\langle \frac{i}{2} \overline{\lambda}(x) \not{D} \lambda(x) \right\rangle = 4.5V$$

Ward Identities
Lattice

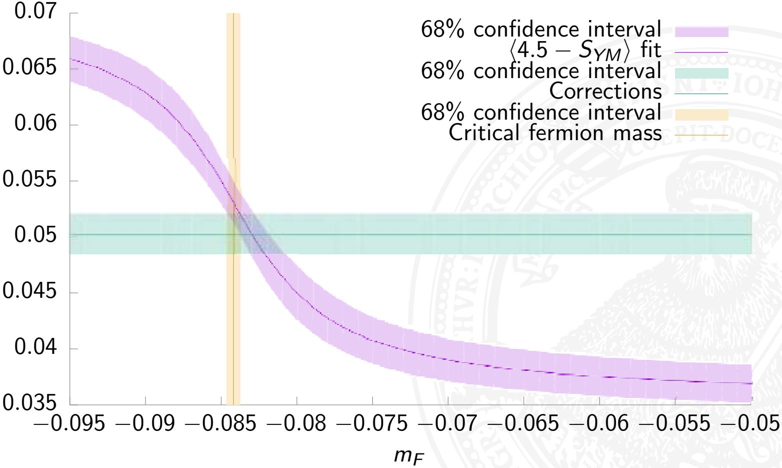
- lattice regularisation breaks super symmetry
  continuum $\rightarrow$ lattice
  $\langle \mathcal{Q}\mathcal{O} \rangle$ $\quad$ $\langle \mathcal{Q}\mathcal{O} \rangle + \langle \mathcal{O}\chi_f \rangle + \langle \mathcal{O}\chi_s \rangle + \langle \mathcal{O}\chi_L \rangle$
- at tree-level: $\langle \mathcal{O}\chi_L \rangle$ vanishes in the continuum limit
- at one-loop: $\langle \mathcal{O}\chi_L \rangle$ contributes via mixing
  only mass subtractions (preliminary)

Ward Identities on the lattice
Corrections for Bosonic Action



Ward Identities on the lattice

BosonicAction



Mass spectrum
Expectations from four dimensions

Veneziano and Yankielowicz

particle	spin	name
$\overline{\lambda}\Gamma_5\lambda$	0	a-η'
$\overline{\lambda}\lambda$	0	a-f_0
$F_{\mu\nu}\Sigma^{\mu\nu}\lambda$	$\frac{1}{2}$	gluino-glueball

[Veneziano and Yankielowicz, 1982]

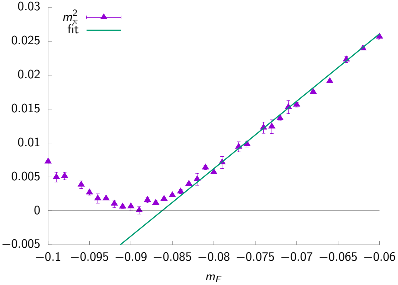
Farra,Gabadadze and Schwetz

particle	spin	name
$F_{\mu\nu}\epsilon^{\sigma\rho}_{\mu\nu}F^{\sigma\rho}$	0	0^--glueball
$F_{\mu\nu}F^{\mu\nu}$	0	0^+-glueball
$F_{\mu\nu}\Sigma^{\mu\nu}\lambda$	$\frac{1}{2}$	gluino-glueball

[Farra,Gabadadze and Schwetz, 1998]

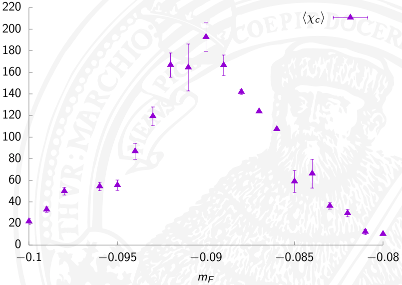
Mass spectrum
Pion

- gaugino mass related to pion mass $m_g \sim m_\pi^2$ [Donini et al. 1998]
- connected part of $\eta' \sim \pi$ [Veneziano and Yankielowicz, 1982]



pion mass

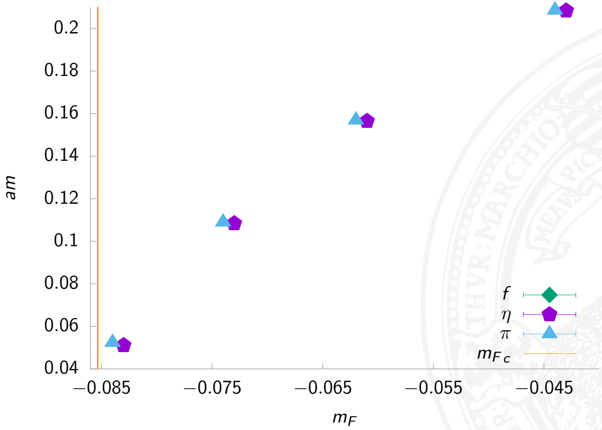
$m_{F\,crit} \approx -0.086$



chiral Susceptibility

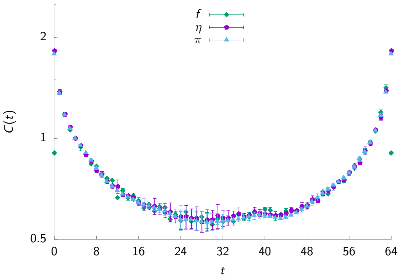
$m_{F\,crit} \approx -0.090$

Mass spectrum
Mesons, ground states

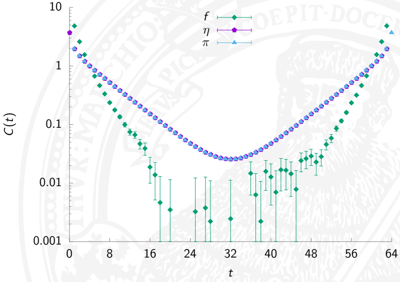


Mass Spectrum
Chiral Limit

Meson Correlators for different fermion mass

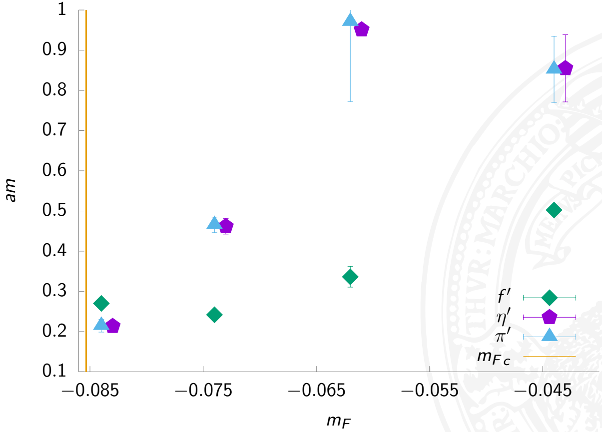


critical fermion mass



noncritical fermion mass

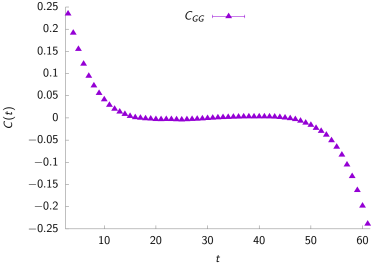
Mass spectrum
Mesons, excited states



Mass spectrum
Gluino Glue

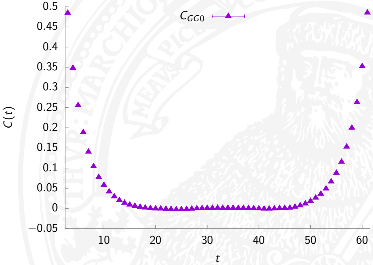
$$\mathcal{O} = F_{\mu\nu}\Gamma_{\mu\nu}\lambda$$

$$C_{GG}(x,y) = \langle \overline{\mathcal{O}}(x)\mathcal{O}(y)\rangle$$



$$m_{GG} = 0.231(8)$$

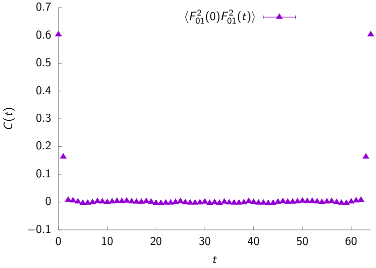
$$C_{GG0}(x,y) = \langle \overline{\mathcal{O}}(x)\Gamma_0\mathcal{O}(y)\rangle$$



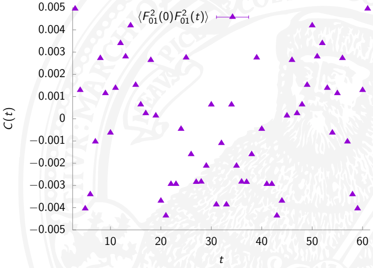
$$m_{GG0} = 0.297(7)$$

Mass spectrum
Glueball

only contact interaction for Glueball operators



full correlator



zoom into region $t \in [3, 61]$

Spectrum

$\beta = 17, m_F = -0.084, V = 64 \times 32$

particle	m_0	m_1
π	0.052(1)	0.215(16)
η	0.051(1)	0.213(15)
f	≈ 0.05	0.270(13)
GG	–	0.231(8)
$GG0$	–	0.297(7)
glueball, scalarball, glue scalarball	∞	-

Summary

Conclusion

- We simulated N=1 SYM domensional reduced to two dimensions on the lattice in the chiral limit
- Bosonic Ward identity satisfied in chiral limit
- massless Mesons, mass degenerate
- glue balls with contact interaction
- gluino glue balls could be mass degenerate with excited Mesons

Outlook

- perform the chiral and continuum limit