INVESTIGATION OF N=1 SUPERSYMMETRIC SU(2) YANG-MILLS THEORY

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Lattice 2019 - Wuhan

based on
arXiv: 1901.02416

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N = 1 SUSY YANG-MILLS THEORY

- Simplest SUSY gauge theory
- Part of every SUSY extension of the Standard Model

$$\mathscr{L} = -\frac{1}{4}F^a_{\mu\nu}F^{a\mu\nu} + \frac{i}{2}\bar{\lambda}^a\gamma^\mu(D_\mu\lambda)^a + \frac{1}{2}m\bar{\lambda}^a\lambda^a$$

- Majorana fermions $\bar{\lambda} = \lambda^T\mathscr{C}$
- Adjoint representation $(D_\mu\lambda)^a = \partial_\mu\lambda^a + gf^{abc}A^b_\mu\lambda^c$
- Gluino mass term breaks SUSY softly

LATTICE ACTION

$$S = S_g + \frac{1}{2}\sum_x \left\{ \bar{\lambda}^a(x)\lambda^a(x) - \kappa \sum_{\mu\pm1}^{\pm4} \bar{\lambda}^a(x+\hat{\mu})(1+\gamma_\mu)V_\mu^{ab}(x)\lambda^b(x) \right\}$$

S_g Symanzik gauge action

Adjoint link $V_\mu^{ab}(x) = \mathrm{Tr}[U_\mu^\dagger(x)T^a U_\mu(x)T^b]$

With one level of Stout smearing

SUSY ON THE LATTICE

Problem:

$$\{Q, Q^\dagger\} \sim P_\mu$$

Lattice discretization breaks SUSY explicitly!

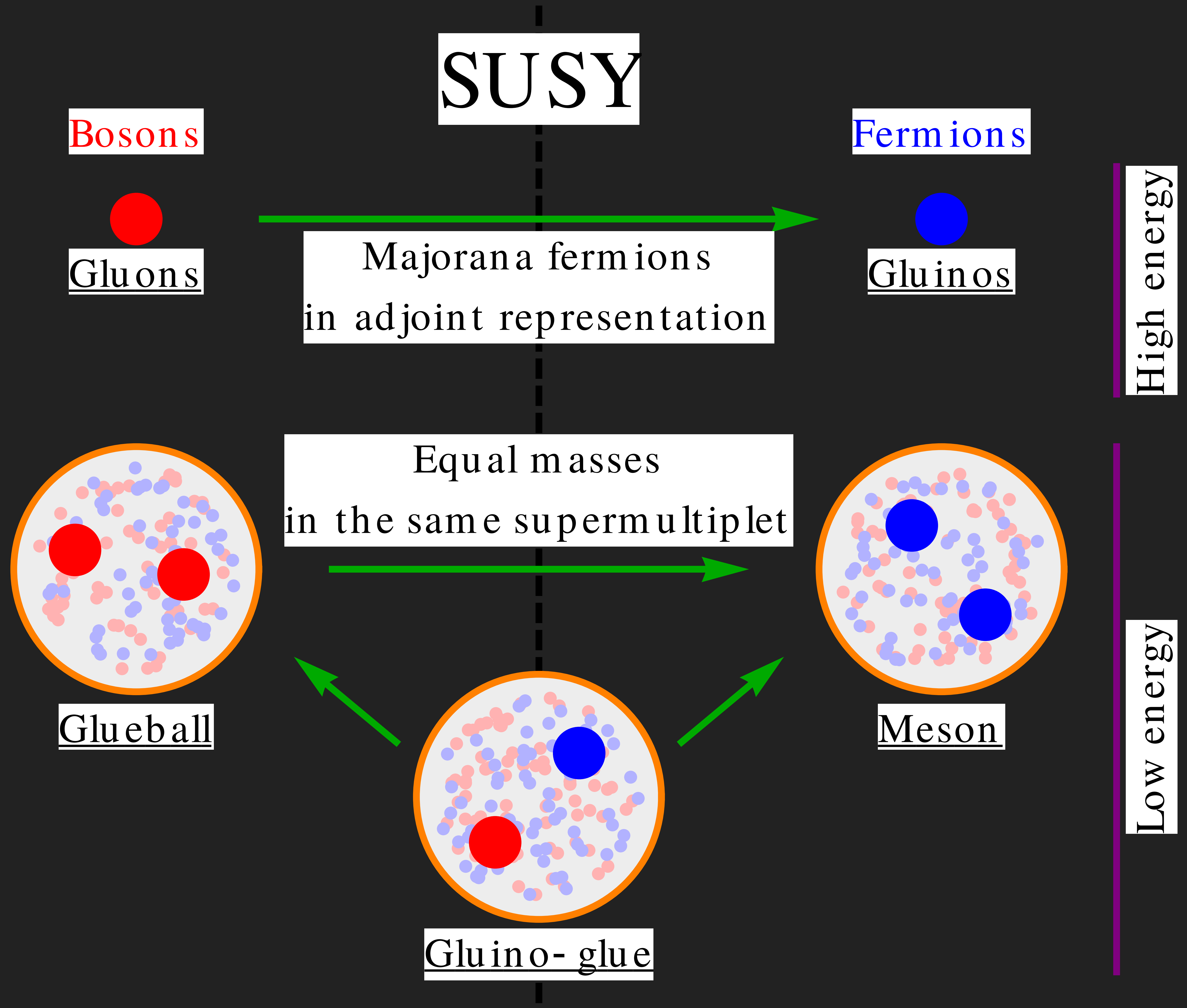
However, if we are in the chiral limit we recover SUSY for $a \to 0$

[Curci, Veneziano Nucl. Phys. B 292]

Check this explicitly by analyzing adjoint pion mass

or SUSY Ward identities

SPECTRUM OF BOUND STATES



SPECTRUM OF BOUND STATES

Color neutral bound states of gluons and gluinos should form supermultiplets

Predictions from effective field theories:

0^+ a-f_0 meson $\sim \bar{\lambda}\lambda$

0^- a-η' meson $\sim \bar{\lambda}\gamma_5\lambda$

spin 1/2 gluino-glue $\sim \sigma_{\mu\nu}\mathrm{Tr}(F_{\mu\nu}\lambda)$

[Veneziano, Yankielowitz PLB 113]

SPECTRUM OF BOUND STATES

Additional Multiplet:

0^+ glueball

0^- glueball

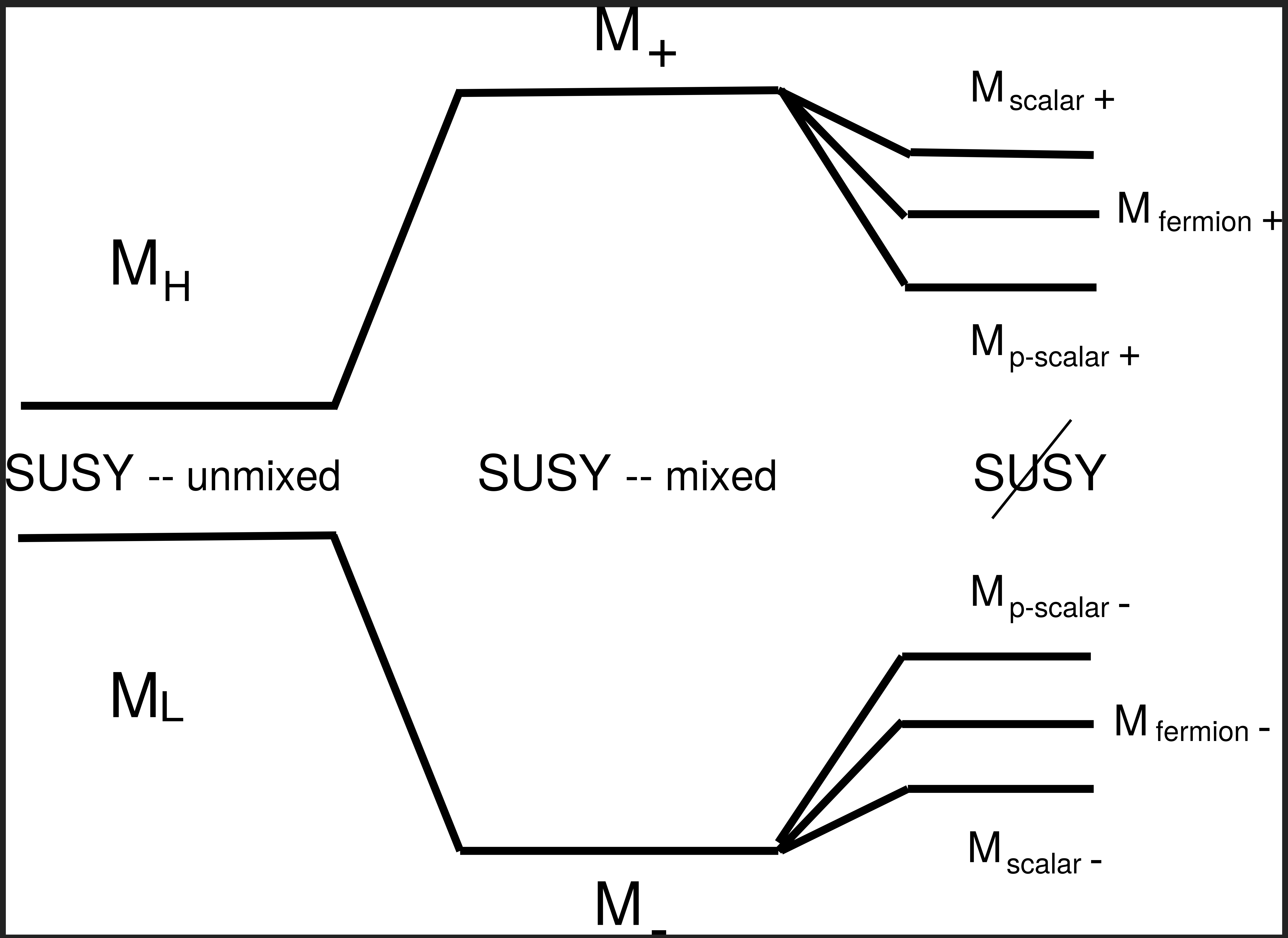
spin 1/2 gluino-glue $\sim \sigma_{\mu\nu}\mathrm{Tr}(F_{\mu\nu}\lambda)$

[Farrar, Gabadatze, Schwetz PRD 60]

Possible mixing between multiplets

mass hierarchy unclear

SPECTRUM OF BOUND STATES



[Farrar, Gabadatze, Schwetz PRD 60]

VARIATIONAL METHOD

Use not a single operator to describe a particle but

a set of operators O_i

$$C_{ij} = \langle O_i(t) O_j^\dagger(0) \rangle$$

Solve generalized Eigenvalue problem to get masses

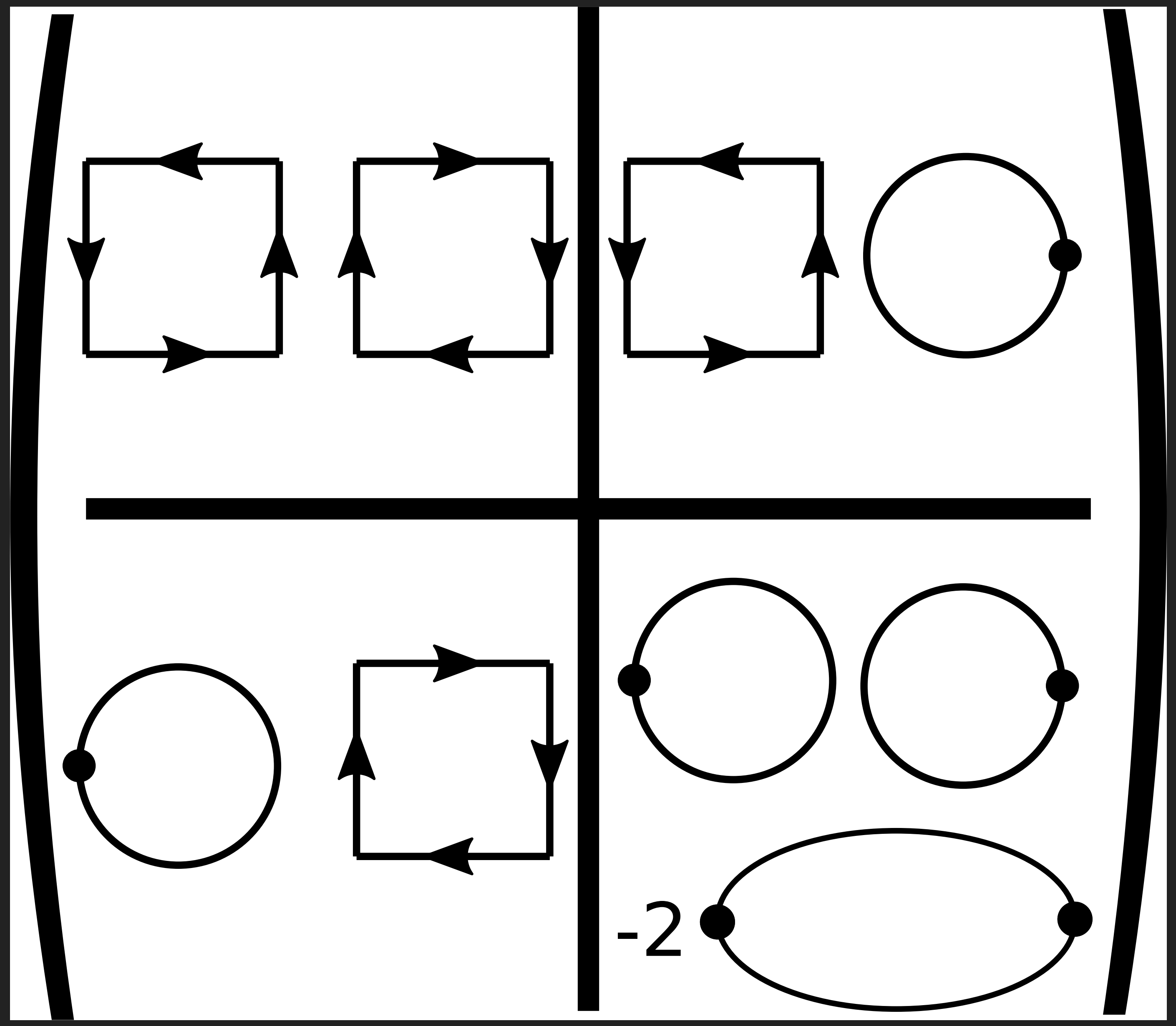
$$C(t)\overrightarrow{v}^{(n)} = \lambda^{(n)}(t, t_0) C(t_0) \overrightarrow{v}^{(n)}$$

with

$$\lim_{t \to \infty} \lambda^{(n)}(t, t_0) \propto e^{-m^{(n)}(t-t_0)} \left(1 + \mathcal{O}(e^{-\Delta m^{(n)}(t-t_0)} \right)$$

WHAT WE DID

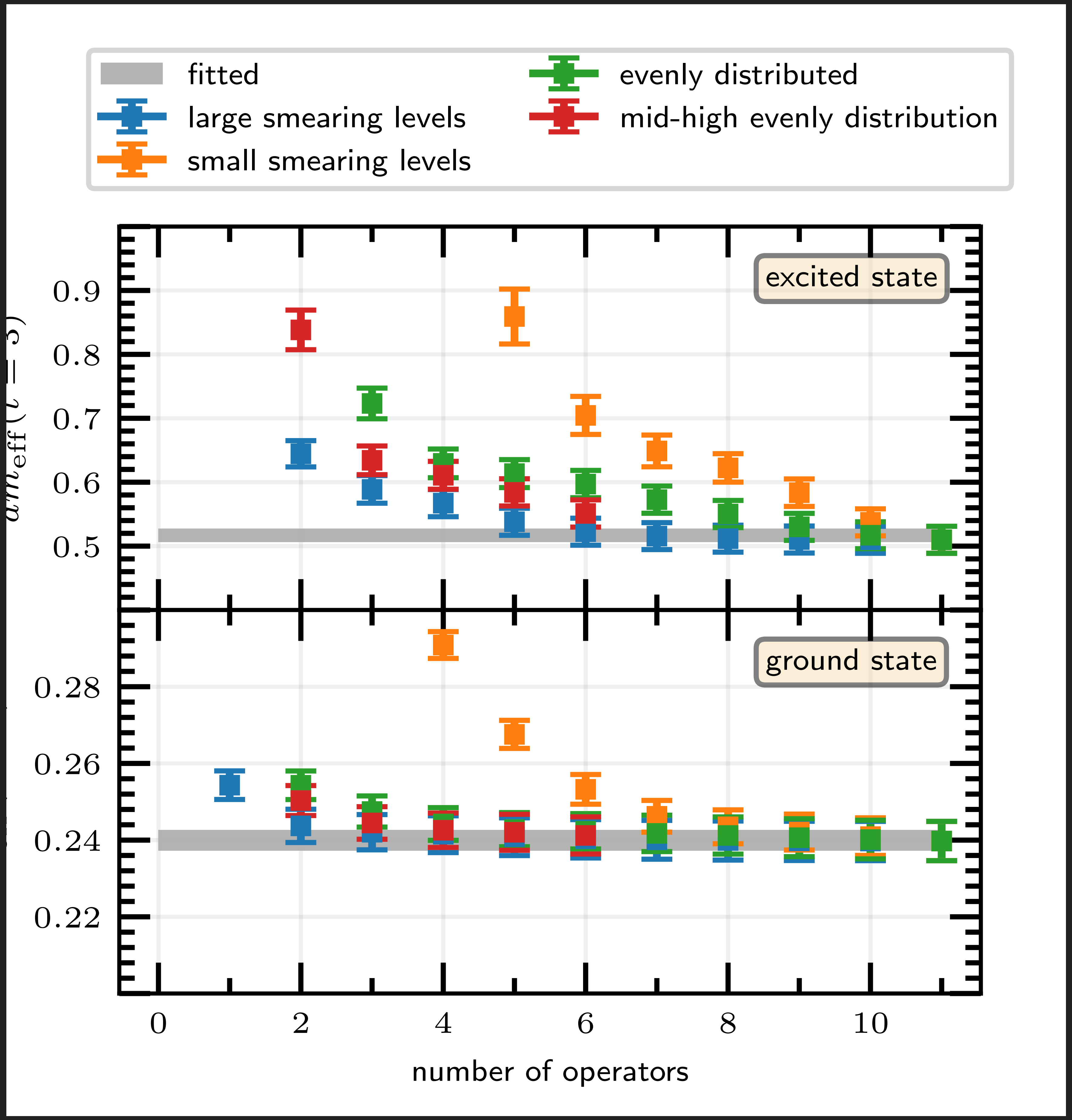
- We reanalzyed old configurations
    - 3 different lattice spacings with 3 - 6 different gluino masses
- With an improved operator basis
    - using „optimized" smearing techniques
    - and taking operator mixing into account



OPERATOR BASIS

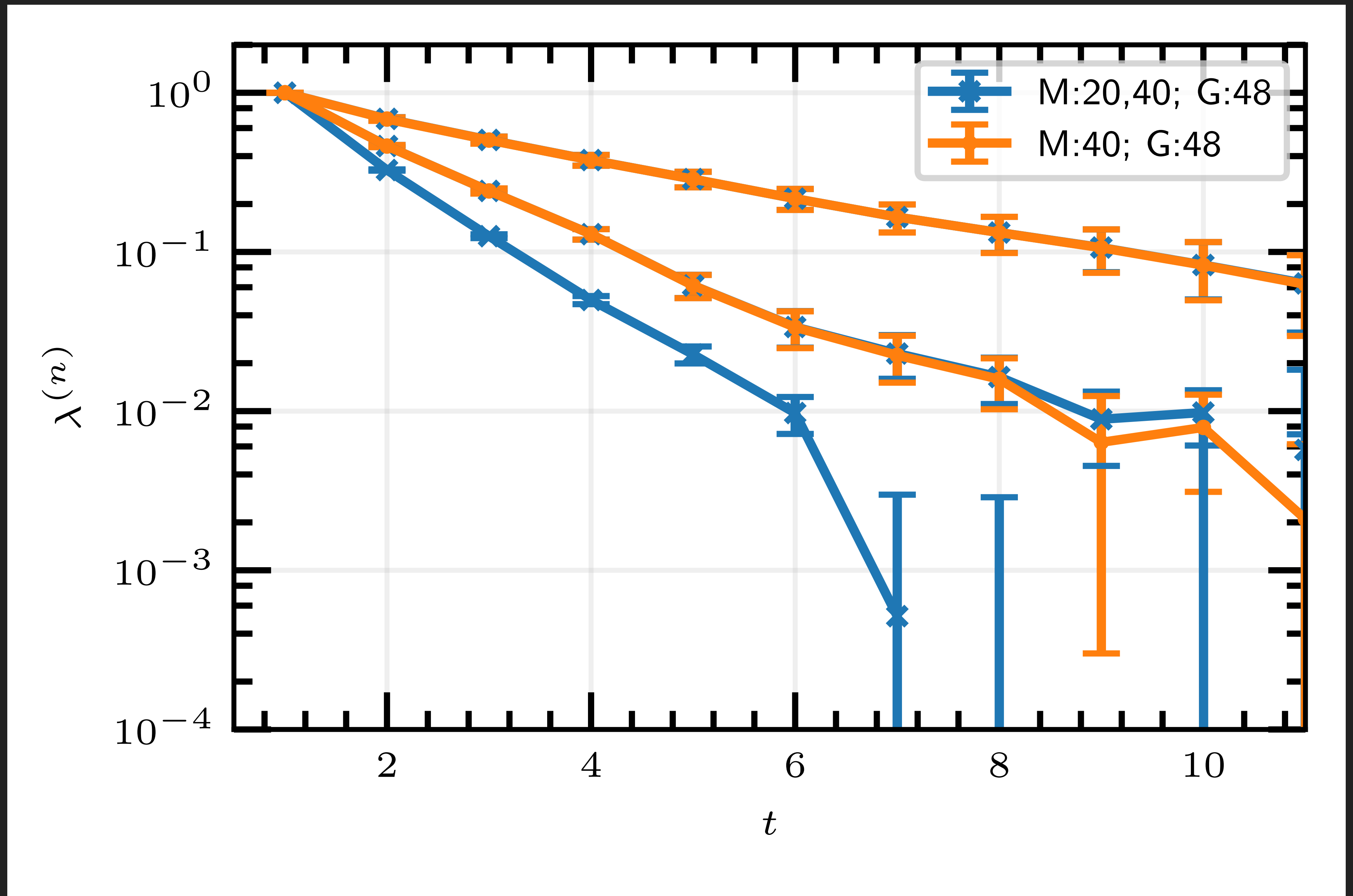
- Use combination of APE and Jacobi smearing
- Include suitable operators
- Different for each particle
- Beware of oversmearing

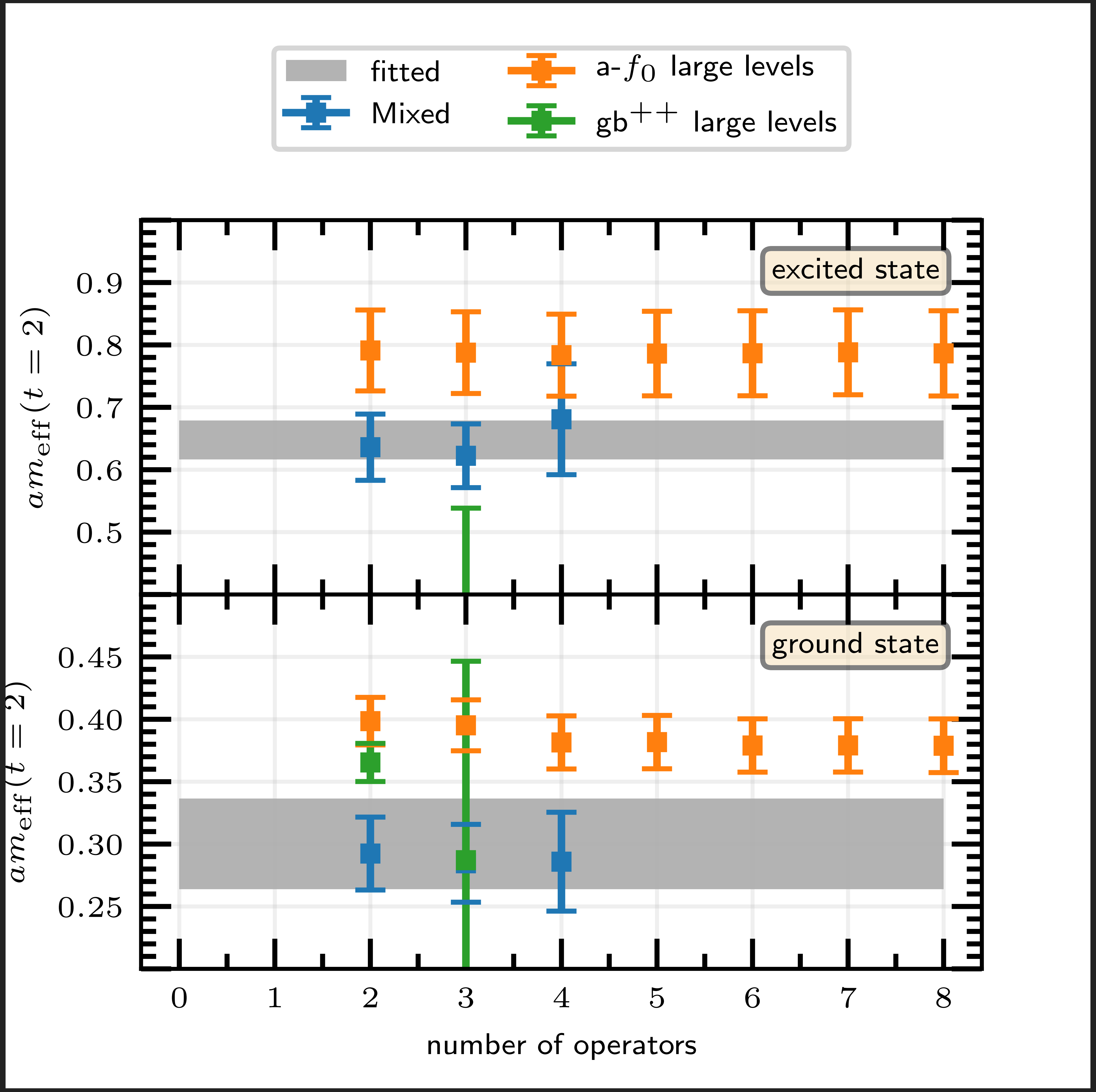
Tedious task, but essential for extracting excited multiplet



OPERATOR BASIS

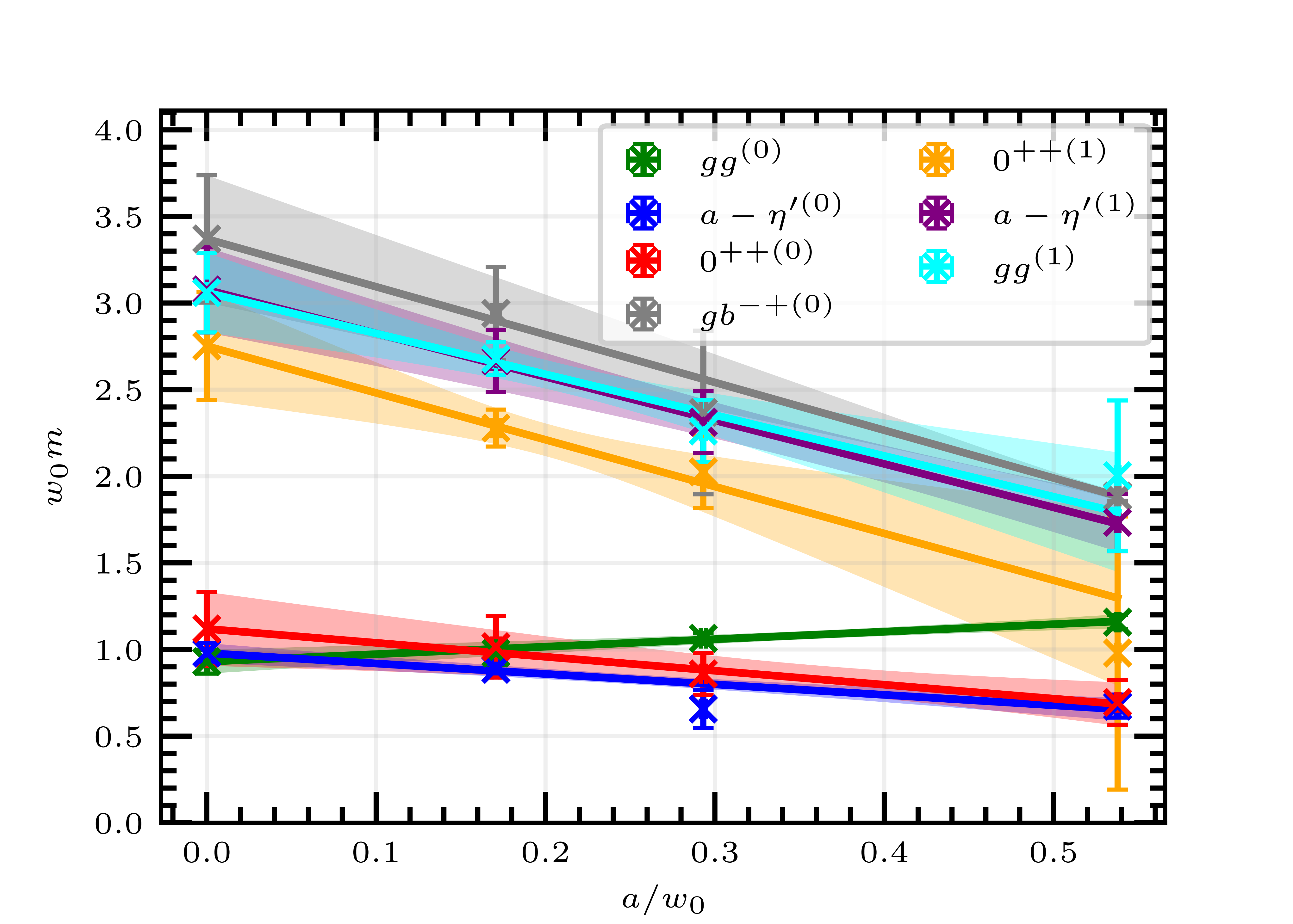
- Importance of mixed basis
- There is an optimal number of operators





CONTINUUM EXTRAPOLATION

- First extrapolate to chiral limit
- Finally extrapolate towards continuum
- Scale setting via w_0
- Clear formation of two supermultiplets

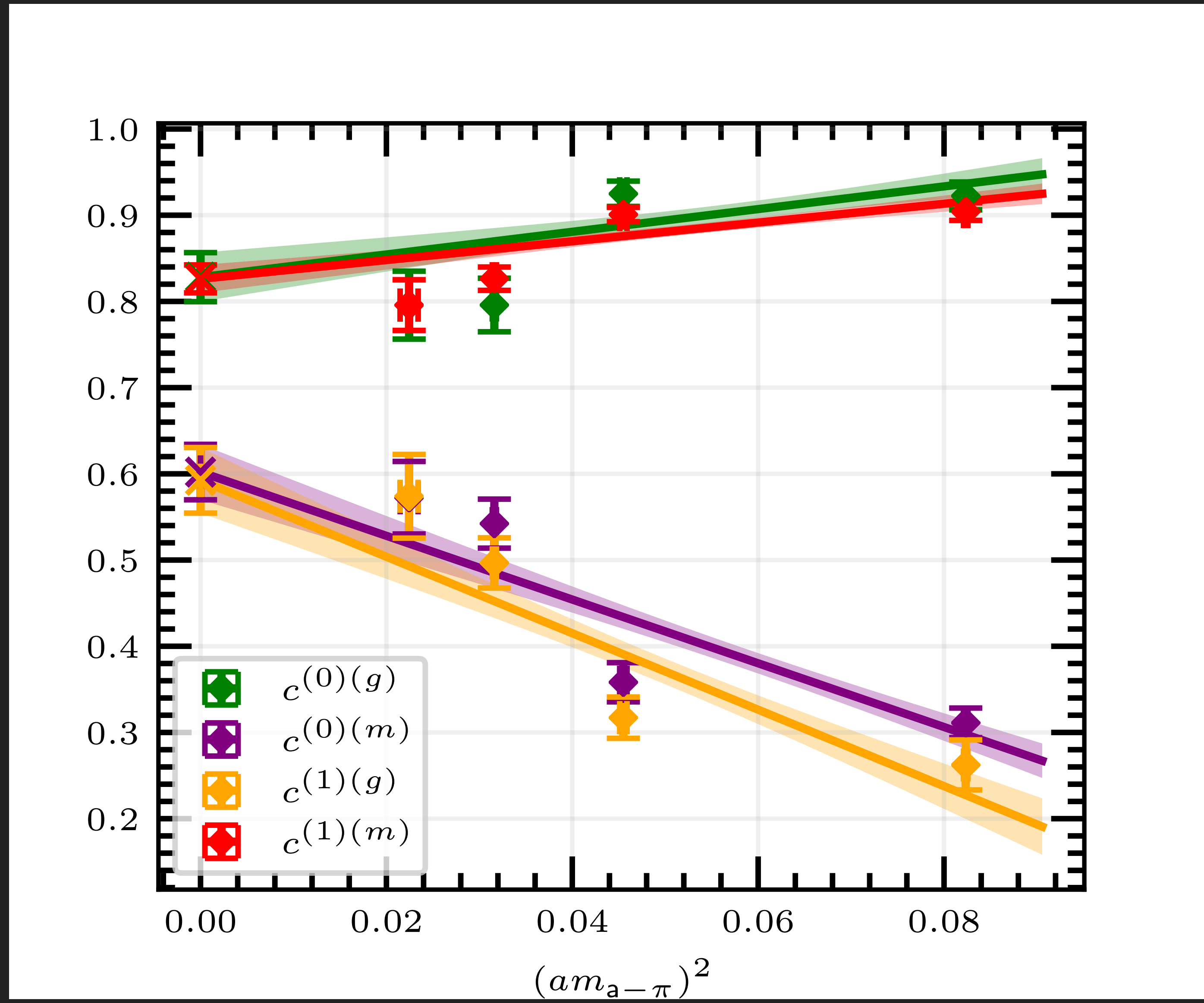


MIXING

By solving the GEVP for the mixed correlation matrix we can determine the mixing of glueballs and mesons:

$$|\psi\rangle = |\phi^g\rangle + |\phi^m\rangle$$ with overlaps $$c^x = \frac{1}{\sqrt{\langle\phi^x|\phi^x\rangle}}\langle\psi|\phi^x\rangle$$

0^+ channel:



0^- channel:

no apparent mixing!

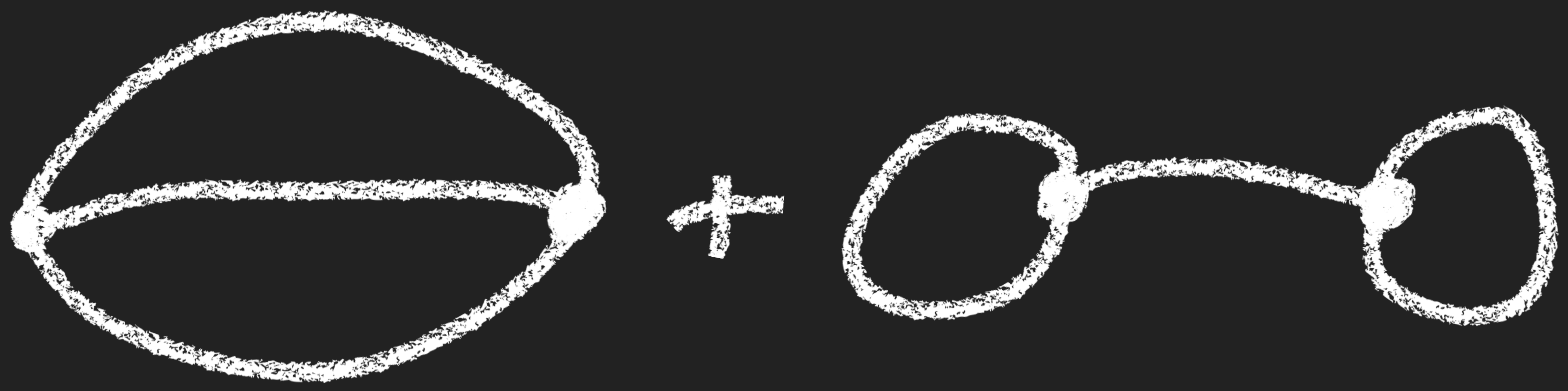
BARYONS IN SYM

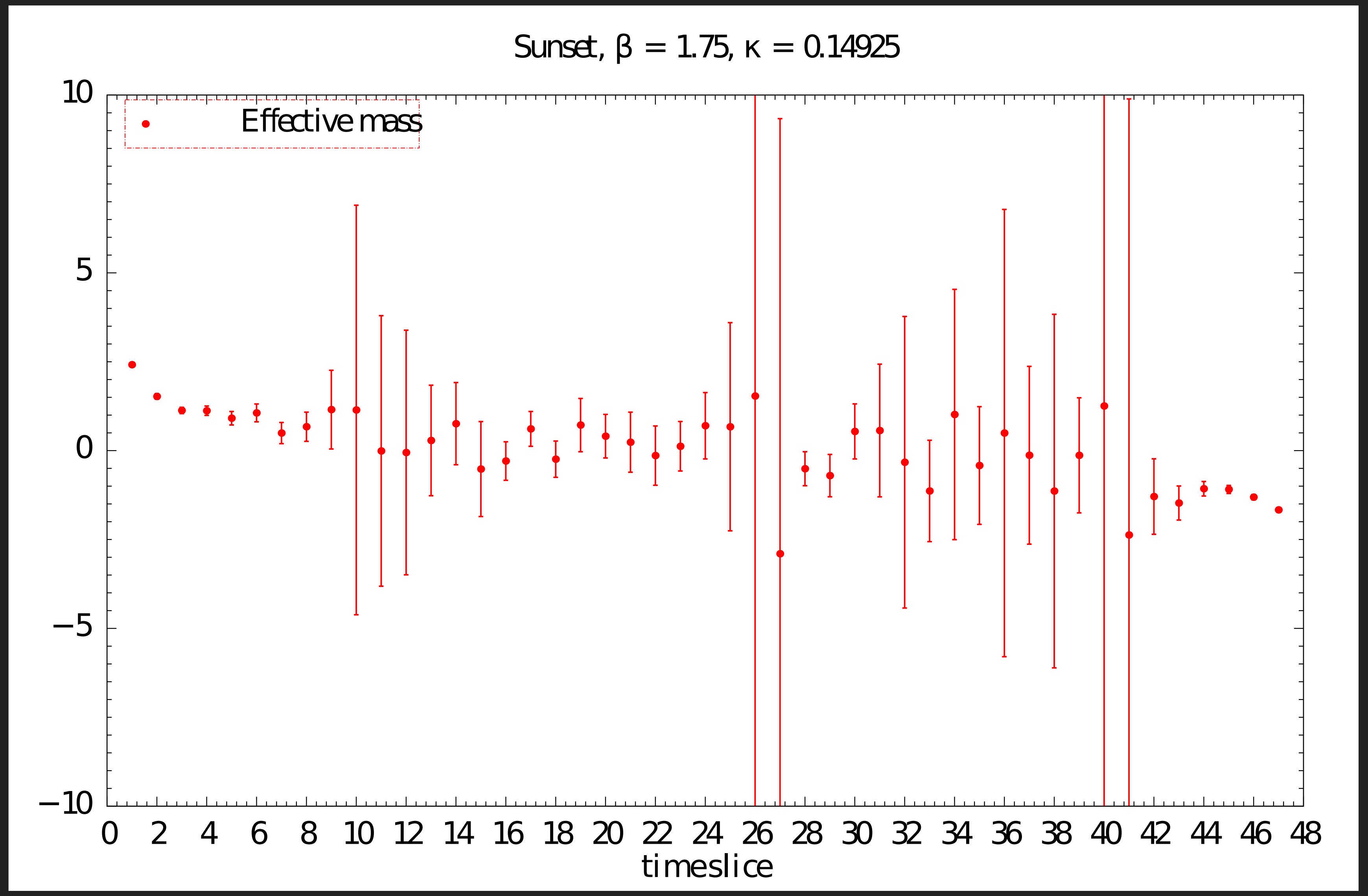
- We began to study baryons

$$O(x) = t^{abc}\lambda^a(\lambda^{bT}\Gamma\lambda^c)$$

- Only preliminary results, not yet conclusive

Contributing diagrams:





SUMMARY

- Improved results for SU(2) Super Yang-Mills theory
- By employing an optimized basis in the variational method
- Including operator mixing
- Clear formation of groundstate and excited multiplet
- First determination of mixing content
- We use our improved method also in SU(3) Super YM project

→ See talk by Georg Bergner

Lattice ensembles

$\beta = 1.9$ $32^3 \times 64$	$\kappa = 0.1433$	$\kappa = 0.14387$	$\kappa = 0.14415$	$\kappa = 0.14435$		
$\beta = 1.75$ $24^3 \times 48$ $32^3 \times 64$	$\kappa = 0.1490$	$\kappa = 0.1492$	$\kappa = 0.14925$	$\kappa = 0.1493$	$\kappa = 0.1494$	$\kappa = 0.1495$
$\beta = 1.6$ $24^3 \times 48$	$\kappa = 0.1550$	$\kappa = 0.1570$	$\kappa = 0.1575$			