Unstable string decay from mixed representation correlators

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Confining Flux Tubes and Strings, Trento, July 2010

Outline

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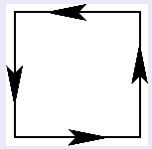
SU(N) Lattice Gauge Theories in D=2+1

- Link variables $U_\mu(i) = e^{ig_0 a A_\mu(i)}$
  Plaquettes $U_{\mu\nu}(i) = \prod_{U_\mu \in P_{\mu\nu}} U_\mu$



- Wilson action $\beta = (2N)/(ag_0^2)$

$$S = \beta \sum_{i,\mu<\nu} \left(1 - \frac{1}{2N} \mathrm{Tr}\left(U_{\mu\nu}(i) + U^\dagger_{\mu\nu}(i)\right)\right)$$

- Partition function $Z = \int (\mathcal{D}U)\, \mathrm{e}^{-S}$
- Polyakov loop in representation $\mathcal{R}$: $P_{\mathcal{R}}(\vec{i}) = \frac{1}{d_{\mathcal{R}}} \mathrm{Tr}_{\mathcal{R}} \prod_{k=0}^{N_t} U_0(k, \vec{i})$
- Potential

$$\begin{aligned} C^{\mathcal{R}\mathcal{R}'}(|\vec{j}-\vec{i}|) &= \langle P^*_{\mathcal{R}}(\vec{j})\, P_{\mathcal{R}'}(\vec{i})\rangle \\ &= \sum_l |c_l|^2 e^{-V_l^{\mathcal{R}\mathcal{R}'}(|\vec{j}-\vec{i}|)N_t} \underset{N_t\to\infty}{\longrightarrow} |c_0|^2 e^{-V^{\mathcal{R}\mathcal{R}'}(|\vec{j}-\vec{i}|)N_t} \end{aligned}$$

k-strings

$|k\rangle \in \mathcal{R}$ and $|k'\rangle \in \mathcal{R}'$

$$\langle k'|k\rangle \overset{\mathbb{Z}(N)}{\to} z^{k-k'} \langle k'|k\rangle = 0 \Leftarrow z^{k'-k} \neq 1$$

Since a gluonic operator G transforms trivially under $\mathbb{Z}(N)$

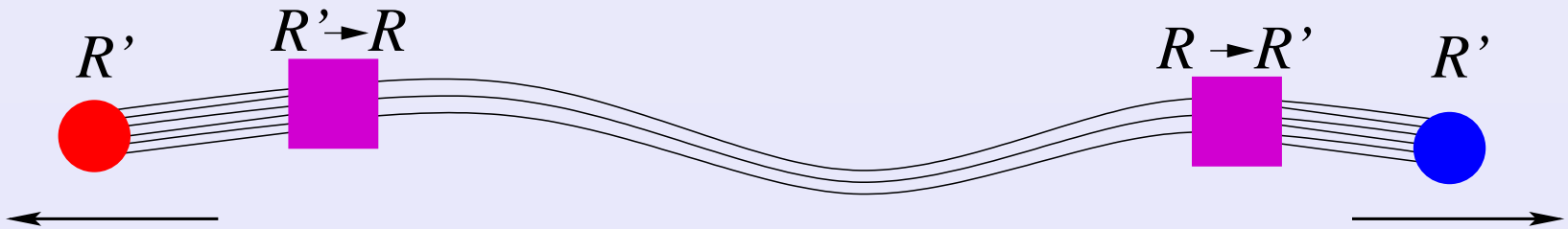
$$\langle k'|G|k\rangle \overset{\mathbb{Z}(N)}{\to} z^{k-k'} \langle k'|G|k\rangle = 0 \Leftarrow z^{k'-k} \neq 1$$

For $N > 3$ higher representation sources exist that are stable
Taking into account charge conjugation

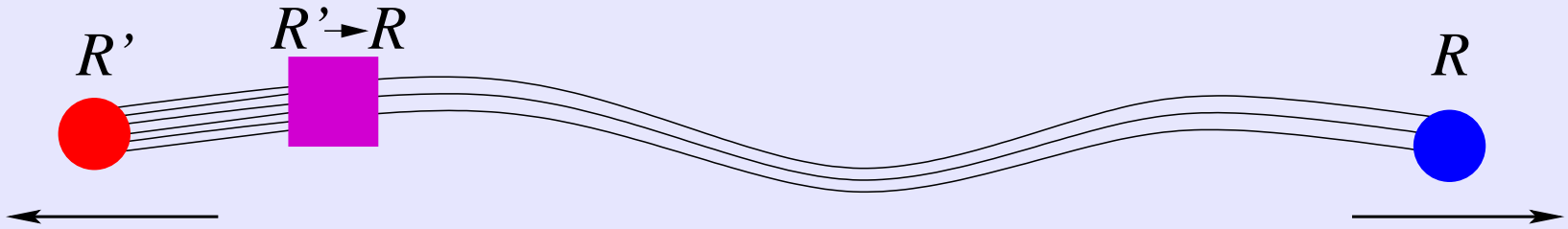
$$k = 1, \ldots, \text{int}(N/2)$$

Unstable representations

Antisource in the bar representation of the source:



Antisource not in the bar representation of the source but still same (anti-)N-ality:



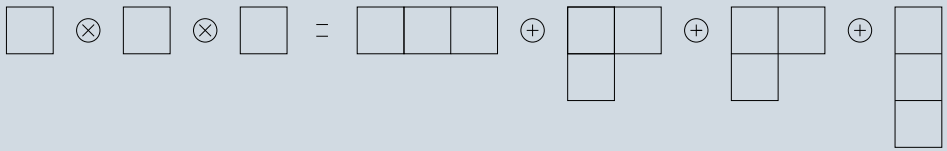
Construction of the sources

- Sources with $k + j$ mod(N) quarks and j antiquarks carry N-ality k
- The string tension is determined just by the N-ality $\Rightarrow$ we can study sources in the simplest representation and the decay of the first few excited states

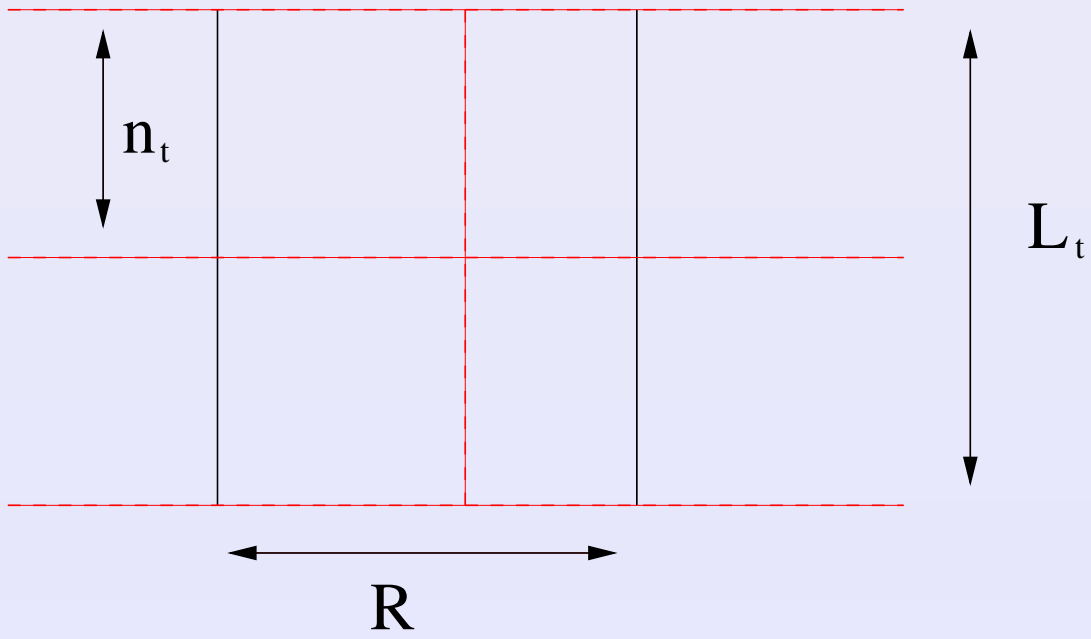
We construct sources in the simplest representations of rank k and study the tension of the strings that connect them

Example

k = 3



Exponential error reduction



- Temporal slicing: exponential increase in statistics
- Spacial slicing: quadratic increase in statistics

Memory requirements grow as $N^{4k} \Rightarrow$ Parallelisation is needed

Details of numerical simulations

SU(3) gauge theory, lattice $32^2 \times 64$, $\beta = 14.5$

Slice parameters: number of slices: 16; number of measurements: 6000; sweeps between measurements: 200

Block parameters: number of blocks per slice: 4; number of measurements: 100; number of sweeps between measurements: 100

Number of global measurements: 41; number of global sweeps between two measurements: 1000

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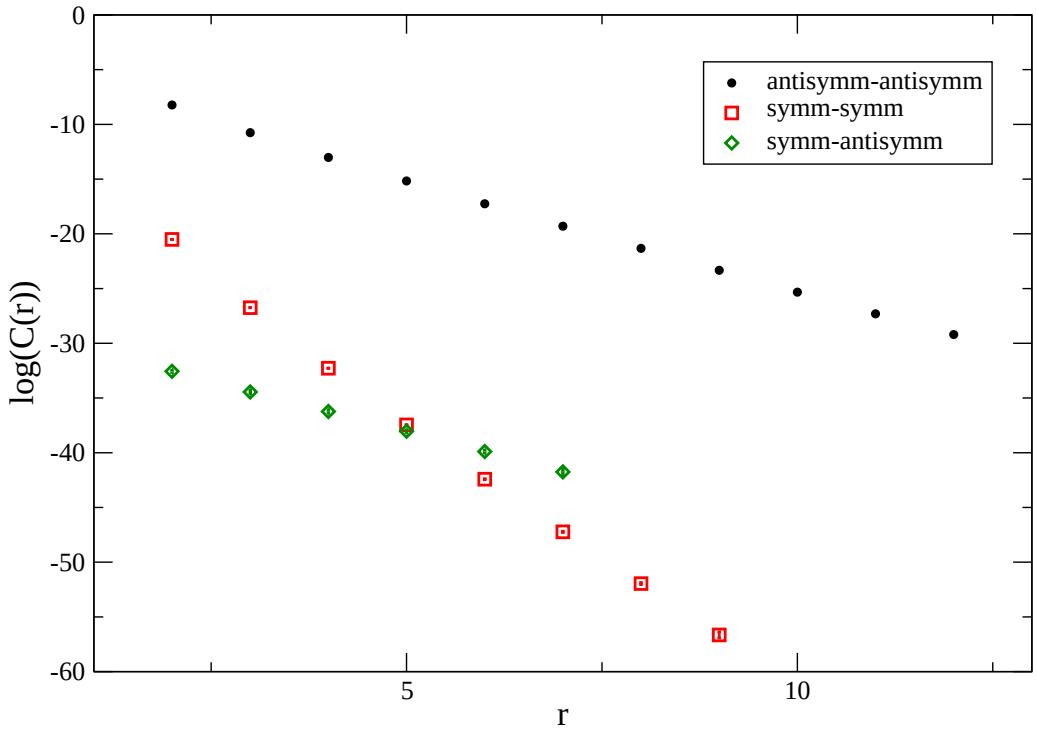
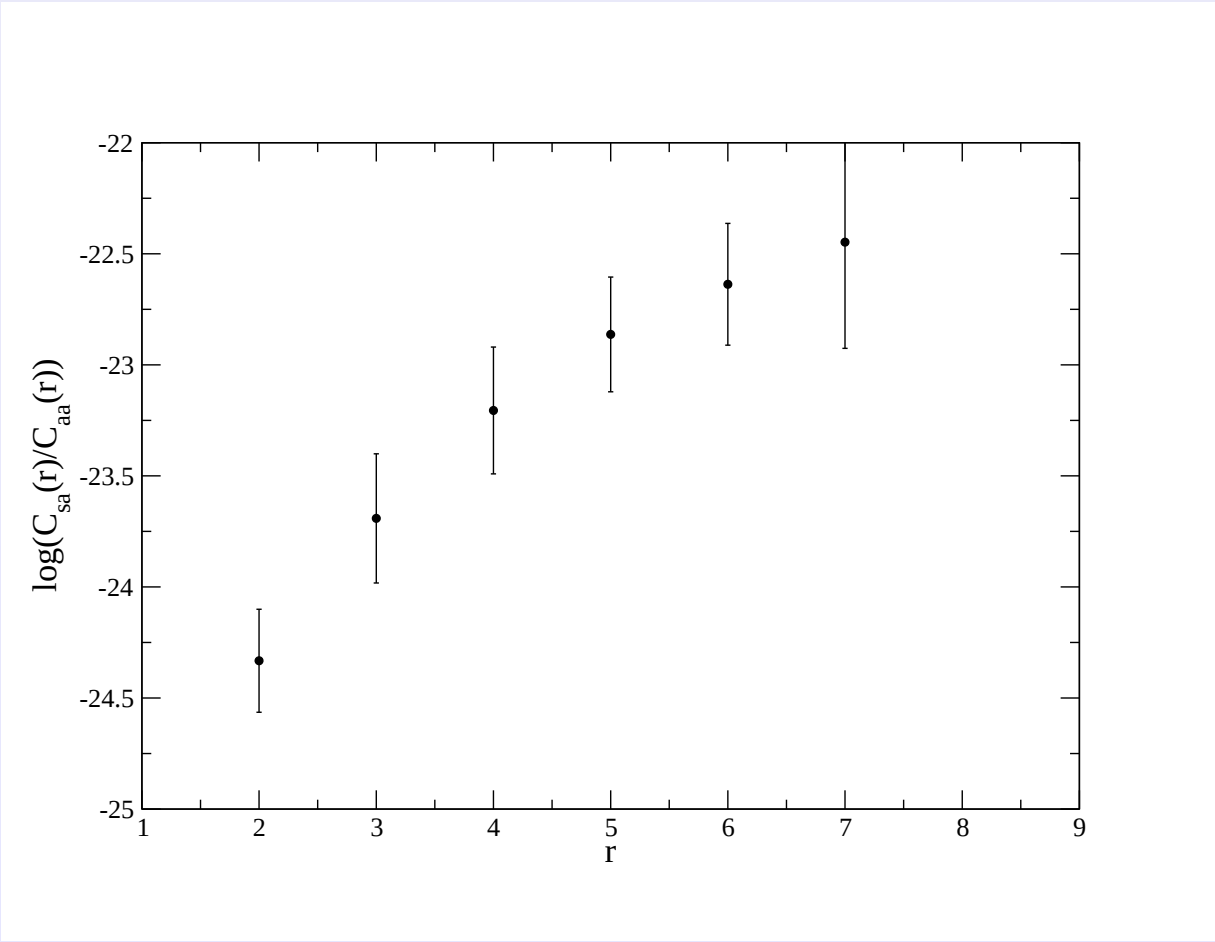
Correlators in the k=2 representation



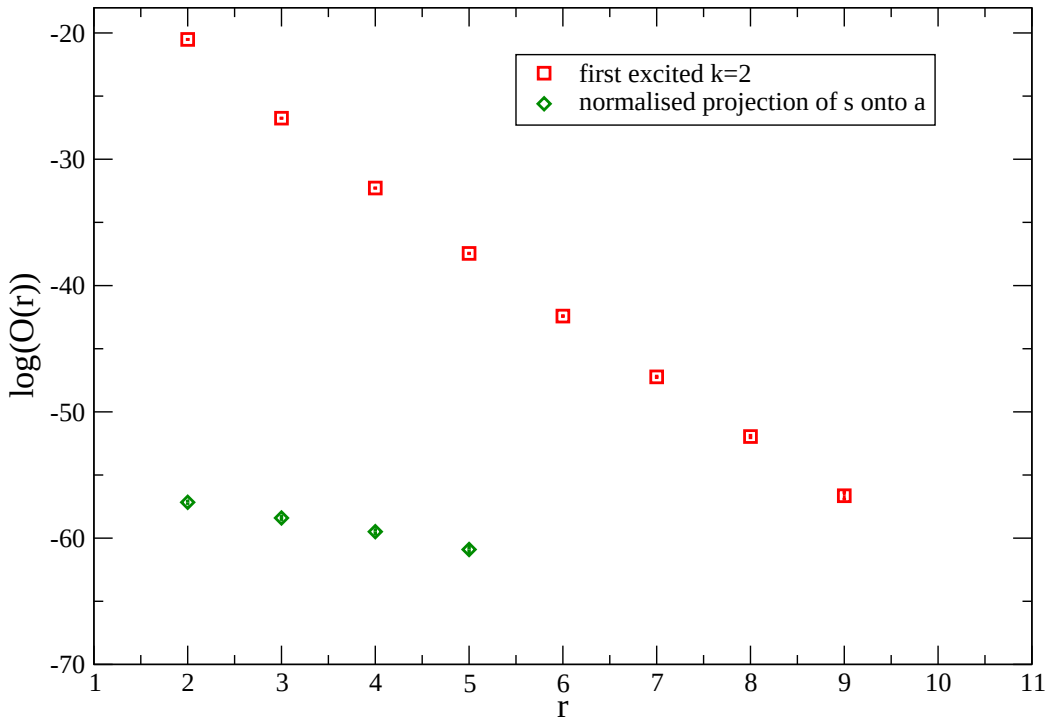
Mixed representation correlators are different from zero

Mixed representation correlators



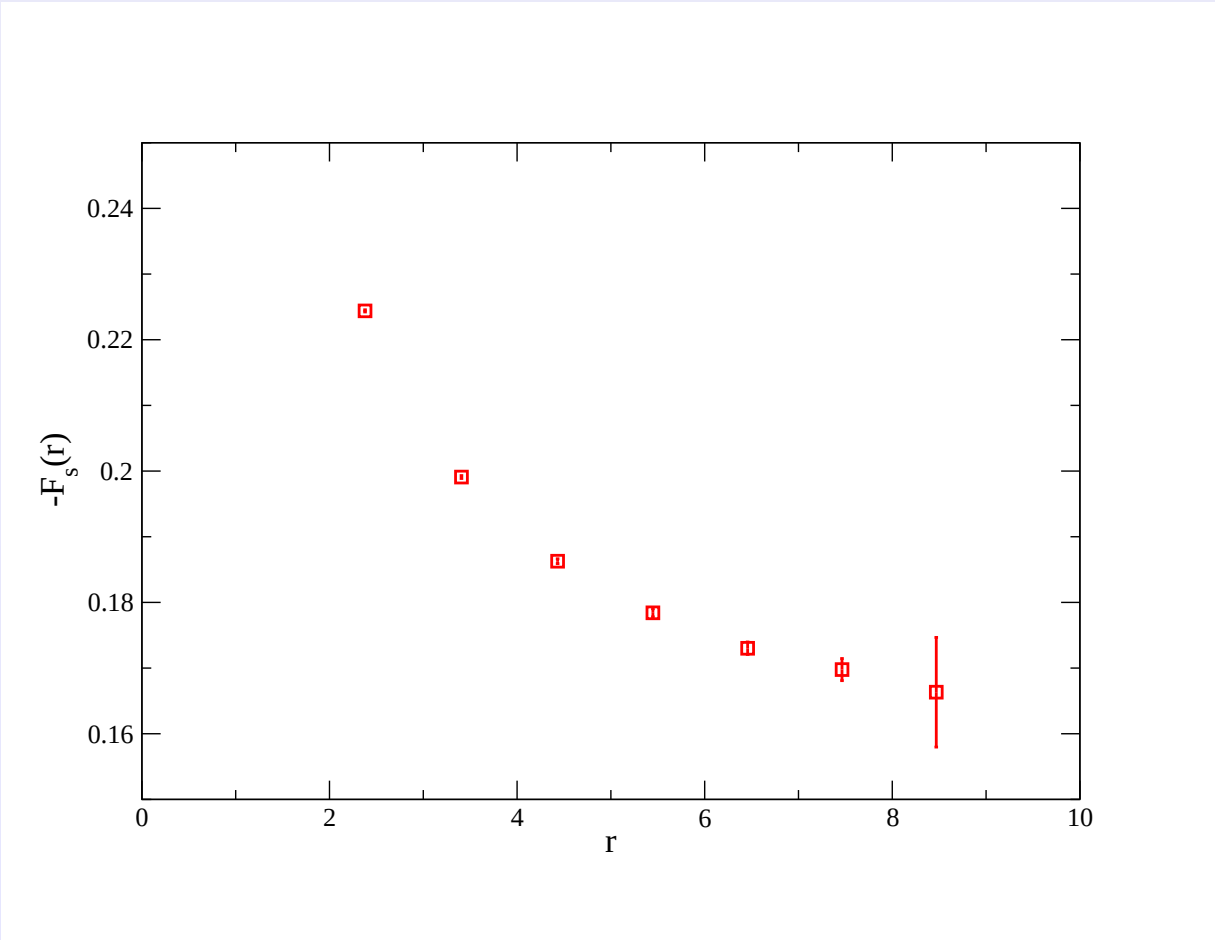
Mixed representation correlators decay with the fundamental string tension

Stable excited state



Within errors the subtraction does not change the symmetric correlators

First derivative of k=2 symmetric



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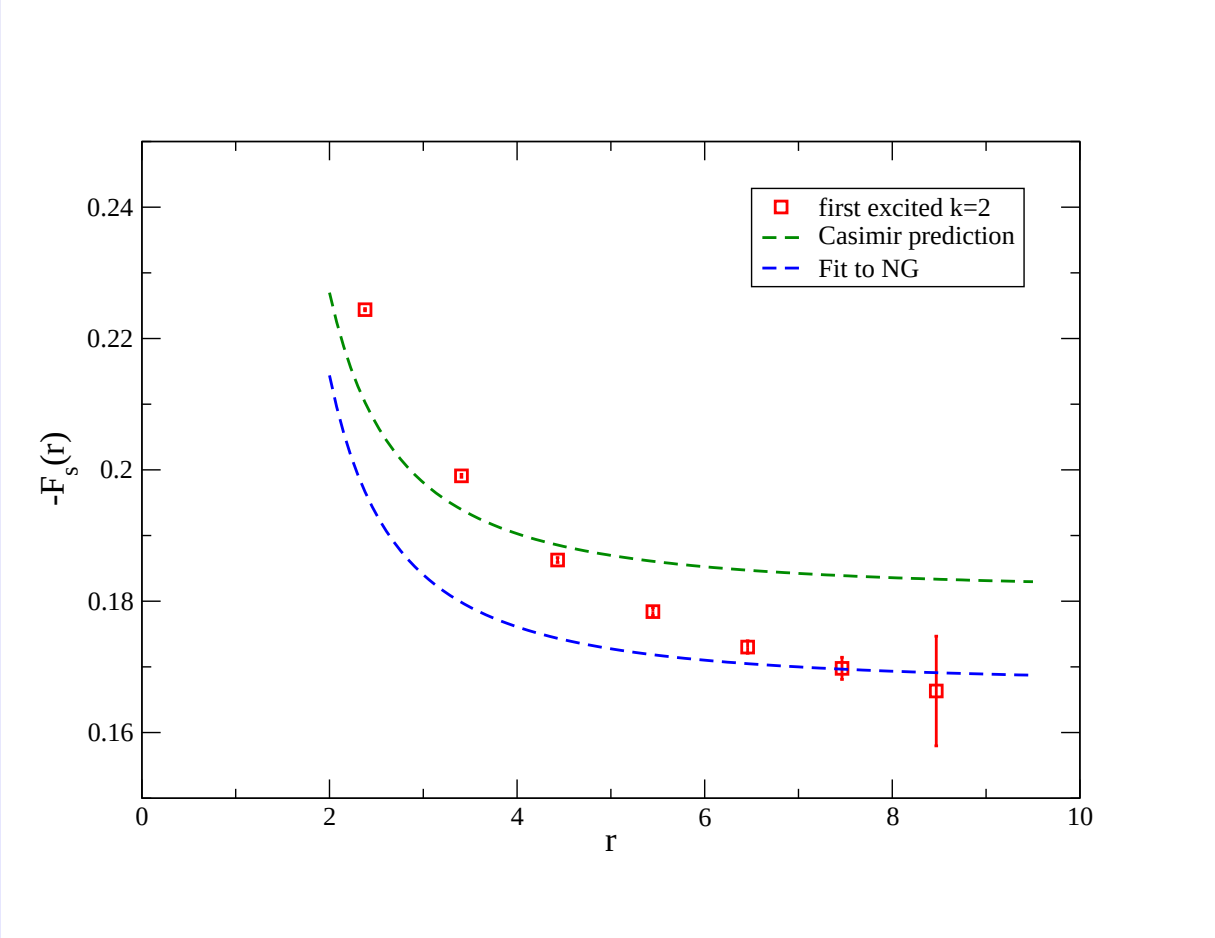
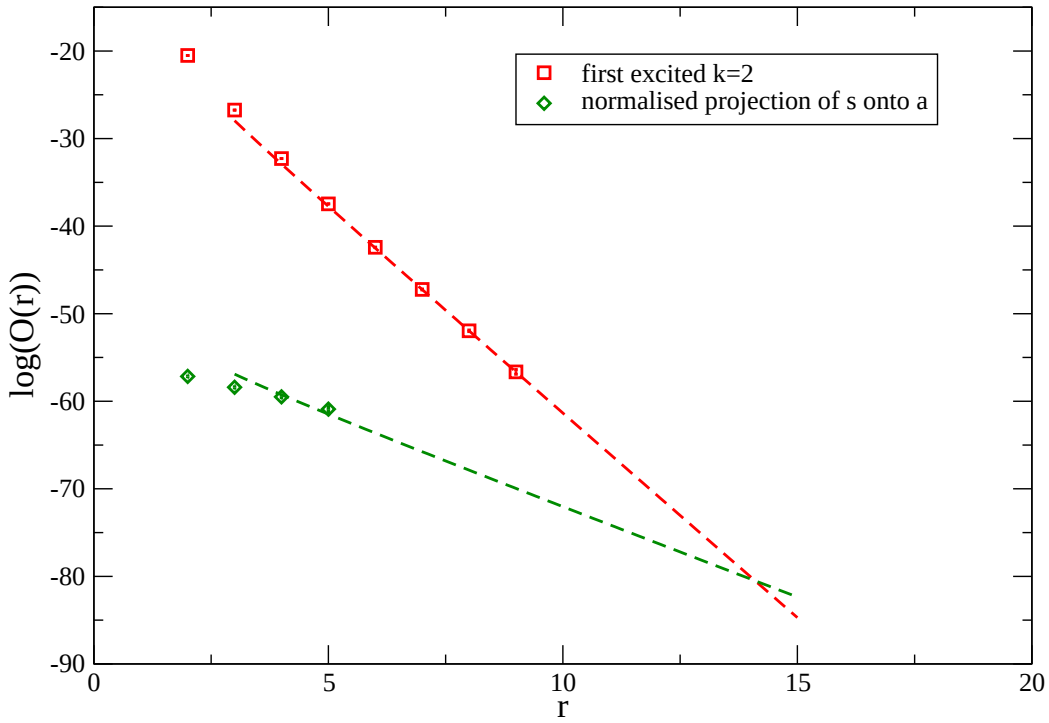


Numerical Results

- No sensitivity to $\mathcal{O}(1/(r^4\sigma_s^2)$ corrections
- Best fit result: $\sigma_s = 0.16725(56)$
- $\sigma_S/\sigma = 2.38(1)$ (Casimir scaling: $\sigma_S/\sigma = 2.5$)
- Sommer scale: $r_0 = 4.883(9)$ (fundamental: $r_0 = 4.6190(13)$)

String decay distance



Upper bound for the decay distance: $r_d = 14.0(1)$

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Conclusions

- Mixed representation correlators are found to be non-zero $\Rightarrow$ short-distance evidence of decay of unstable states
- Combining measures in the full correlator matrix it is possible to provide an upper bound for the unstable string decay distance