Structure of hybrid static potential flux tubes in SU(2) Yang-Mills-theory

Lasse Müller in collaboration with **Marc Wagner**

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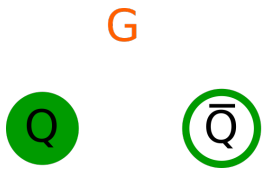
Outline

Hybrid mesons

- Definition
- Modification of Wilson loop
- Hybrid static potential



[C. Reisinger (Master Thesis): "Hybrid static potentials in SU(3) gauge theory on the lattice"]
[C. Reisinger, S. Capitani, O. Philipsen, M. Wagner : "Computation of hybrid static potentials in SU(3) lattice gauge theory", arXiv:1708.05562 [hep-lat]]

Chromoelectric and Chromomagnetic field

- Computation on the lattice
- Results for ordinary and one example of hybrid static $Q\bar{Q}$

[C. Meyerdierks (Bachelor Thesis): Investigation of the structure of static potential flux tubes]

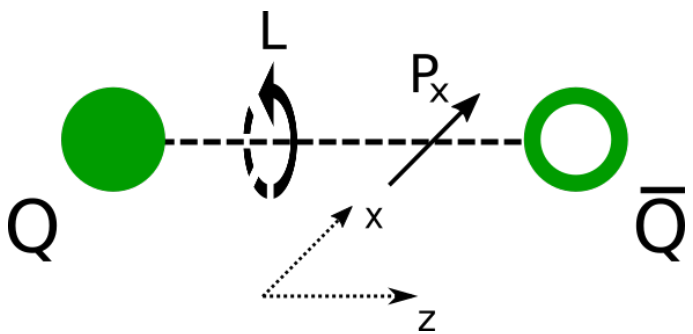
Related existing work where gluon is represented by a static adjoint source:
[M. Cardoso, N. Cardoso, P. Bicudo: "Lattice QCD computation of the colour fields for the static hybrid quark-gluon-antiquark system, and microscopic study of the Casimir scaling", arXiv:0912.3181 [hep-lat]]

Hybrid mesons

Excited gluons contribute to quantum numbers of meson:

- Angular momentum with respect to the separation axis z: $L \in \{\Sigma \doteq 0, \Pi \doteq 1, \Delta \doteq 2\}$
- The combination of parity and charge conjugation: $P \circ C \in \{g \doteq +, u \doteq -\}$
- The spatial inversion along an axis perpendicular to z: $P_x \in \{+, -\}$

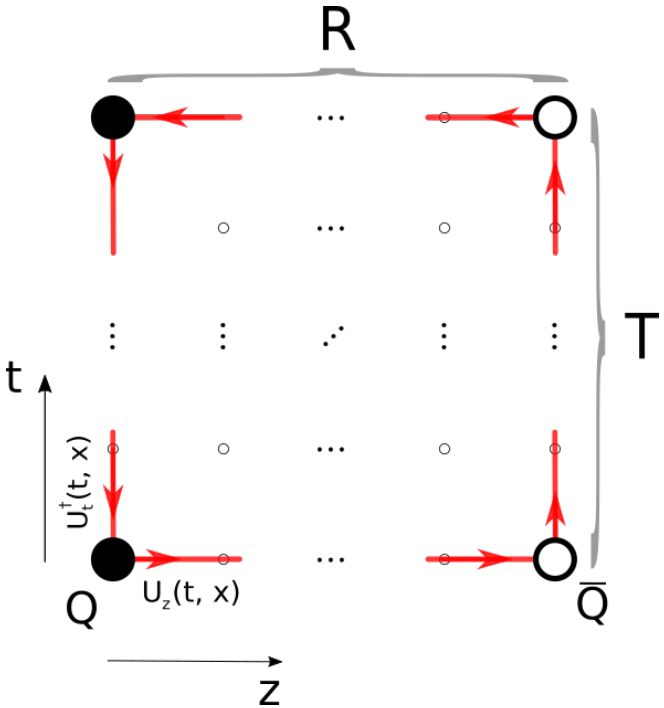
E. g.: ordinary $Q\bar{Q}$ corresponds to Σ_g^+
$\Rightarrow$ Modification of Wilson loop according to quantum numbers



Ordinary Wilson loop

ordinary Wilson loop

$$W = S_z \cdot S_t \cdot S_z^\dagger \cdot S_t^\dagger$$

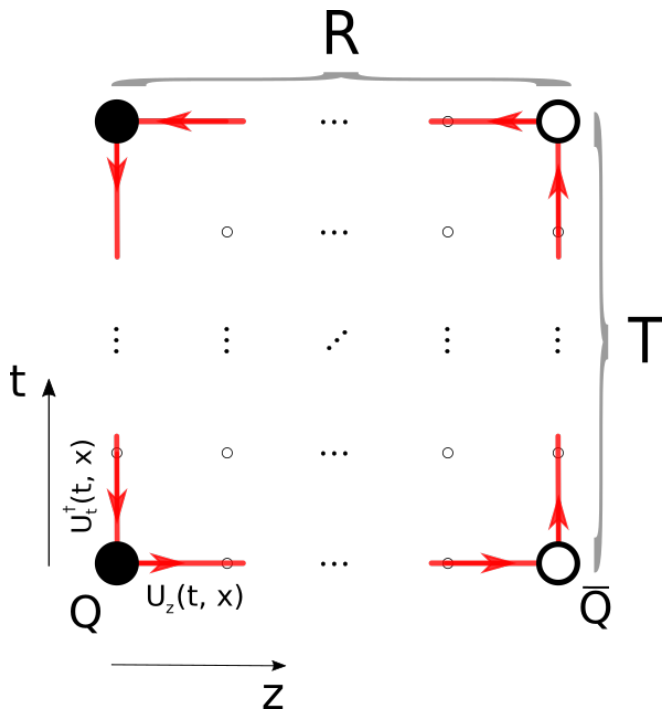


$$U_\mu(t,x) = e^{igaA_\mu(t,x)} \qquad S = \prod_j U_j$$

Modified Wilson loop of trial state for Π_u

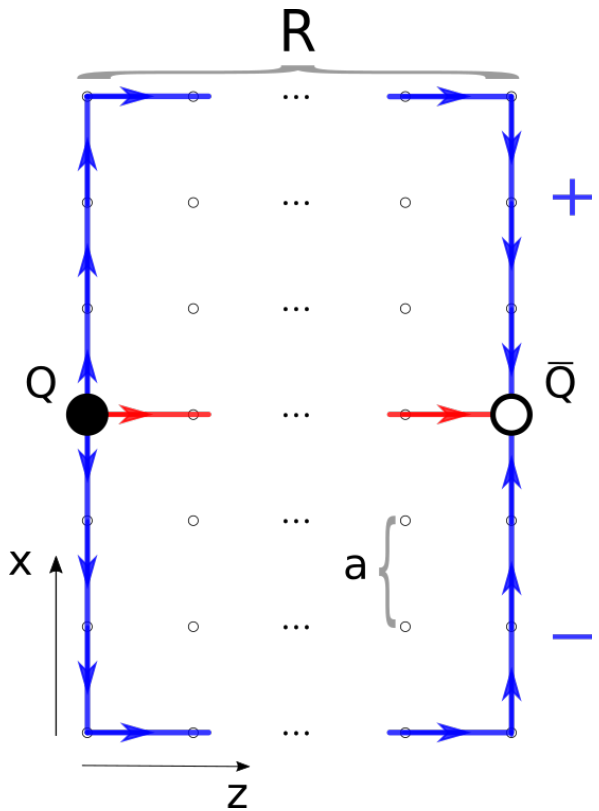
ordinary Wilson loop (red)

$$W = S_z \cdot S_t \cdot S_z^\dagger \cdot S_t^\dagger$$



insertion of trial state for
$\Pi_u \Leftrightarrow L = 1, P \circ C = -$

$$W_{\Pi_u} = (S_+ - S_-)\, S_t \cdot \left(S_+^\dagger - S_-^\dagger\right) S_t^\dagger$$

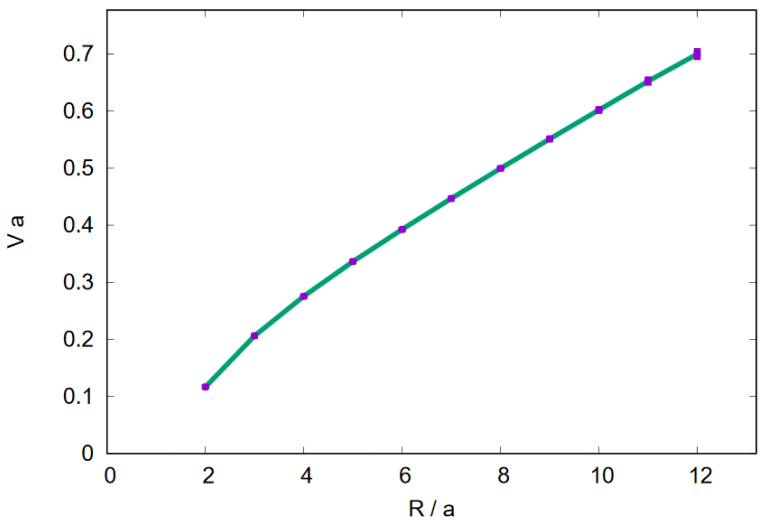


$$U_\mu(t,x) = e^{igaA_\mu(t,x)} \qquad S = \prod_j U_j$$

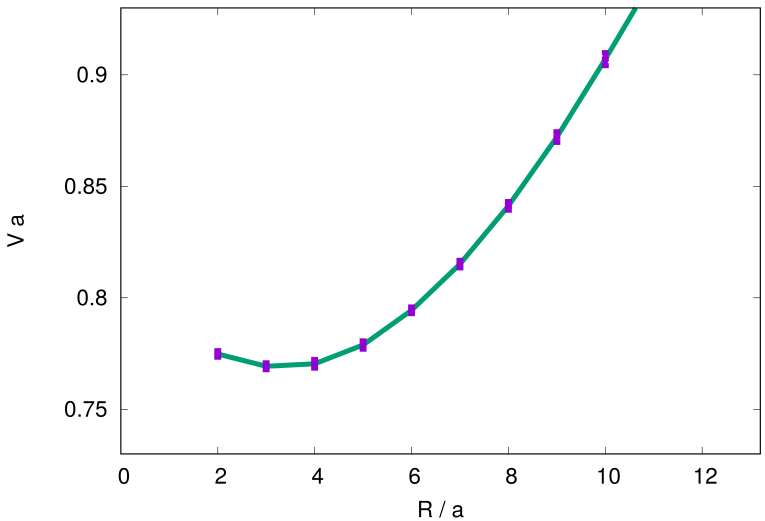
Hybrid static potentials

$$\lim_{T\to\infty} \langle W(R,T)\rangle \propto e^{-V(R)\cdot T}$$

from [C. Reisinger (Master Thesis): "Hybrid static potentials in SU(3) gauge theory on the lattice"]:



ordinary static potential

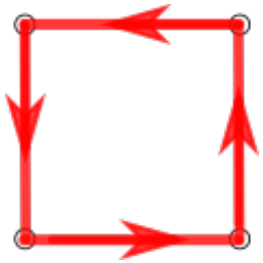


static potential for Π_u

Chromoelectric and chromomagnetic field

On the lattice field strength tensor corresponds to plaquette

$$P_{\mu\nu} = \mathrm{Tr}\left[e^{igaF_{\mu\nu}}\right] \Rightarrow Tr\left(F^2_{\mu\nu}\right) \approx \frac{2}{g^2a^2}\left(2 - P_{\mu\nu}\right)$$



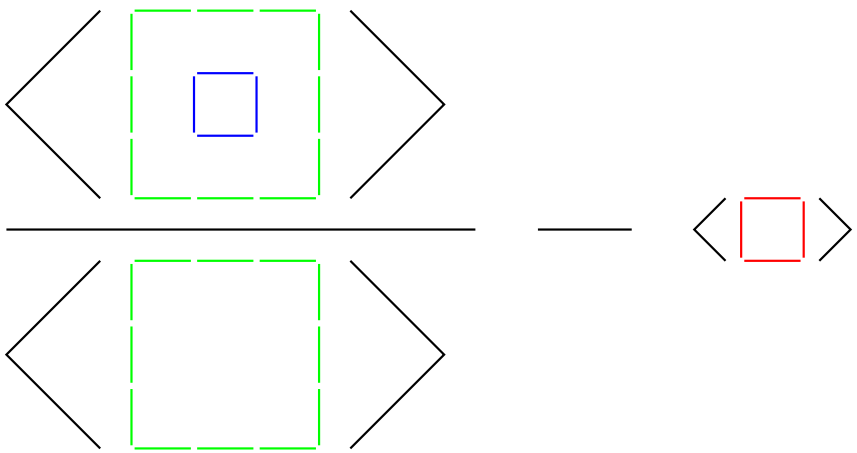
plaquette

$\Rightarrow E^2$ and B^2 are gauge invariant quantities

$$\langle B_j(\vec{x})^2\rangle_{Q\bar{Q}} - \langle B_j^2\rangle_{vac} = \frac{2}{g^2a^2}\left[\langle P_{kl}\rangle - \frac{\langle W \cdot P_{kl}(T/2,\vec{x})\rangle}{\langle W\rangle}\right]$$

$$\langle E_j(\vec{x})^2\rangle_{Q\bar{Q}} - \langle E_j^2\rangle_{vac} = \frac{2}{g^2a^2}\left[\frac{\langle W \cdot P_{0j}(T/2,\vec{x})\rangle}{\langle W\rangle} - \langle P_{0j}\rangle\right]$$

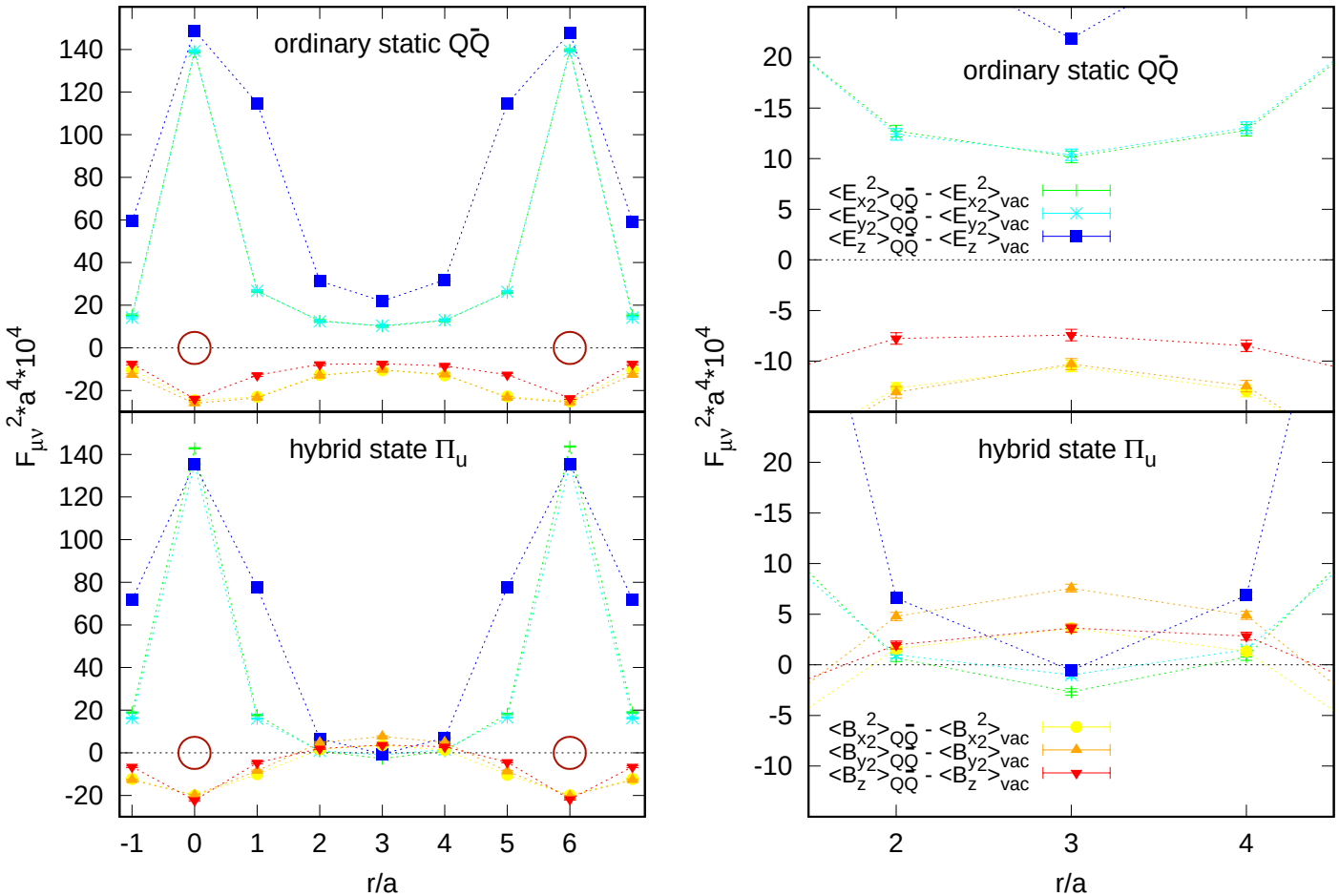
$\langle E^2\rangle$ in presence of $Q\bar{Q}$



$\langle E^2\rangle$ in vacuum

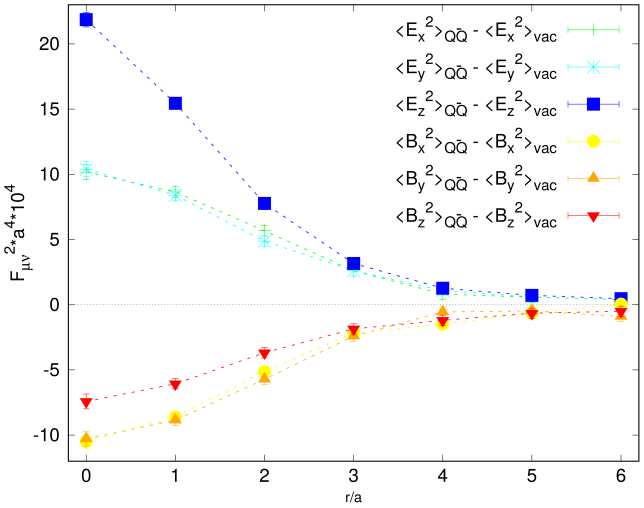
Separation axis

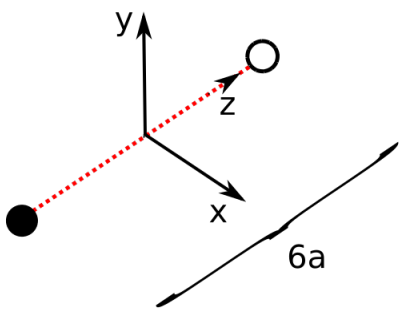
Computed in SU(2) Lattice gauge theory with Lattice parameter $a \approx 0.073fm$



In the middle of the $Q\bar{Q}$-pair

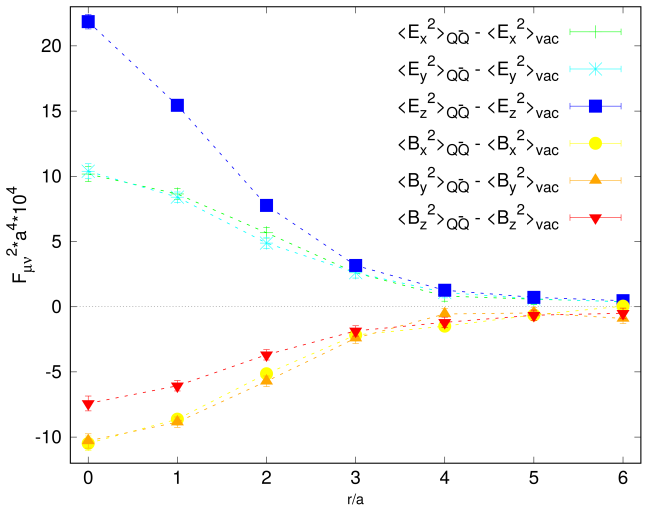
ordinary $Q\bar{Q}$ (Σ_g^+)

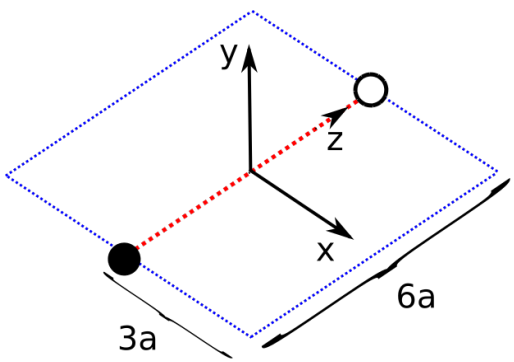




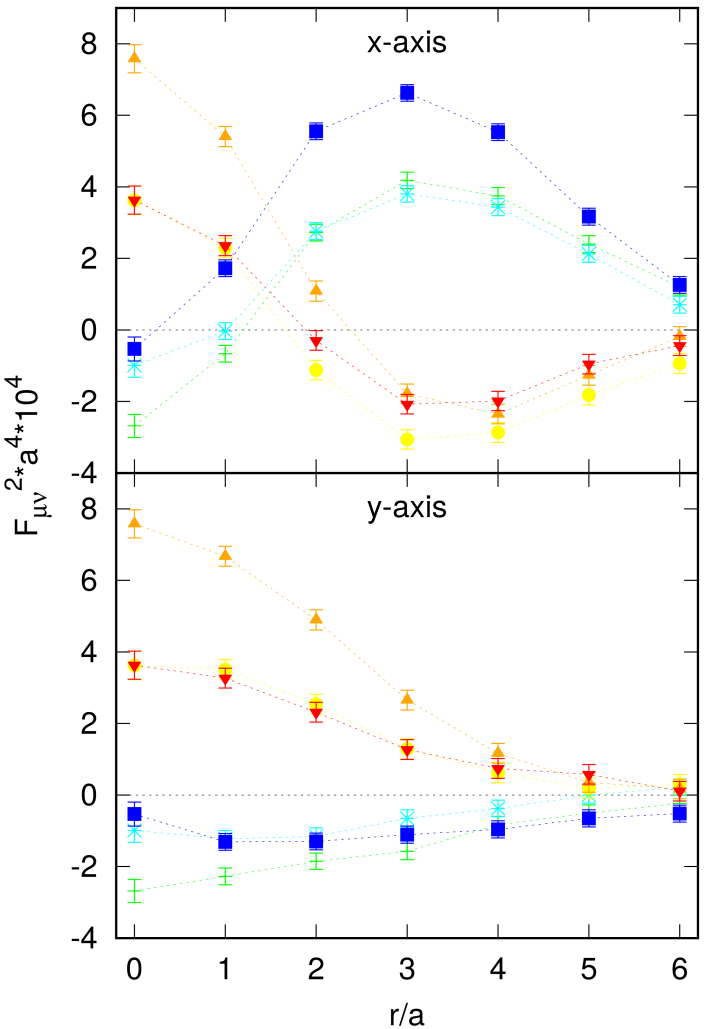
Middle of the $Q\bar{Q}$-pair

ordinary $Q\bar{Q}$ (Σ_g^+)

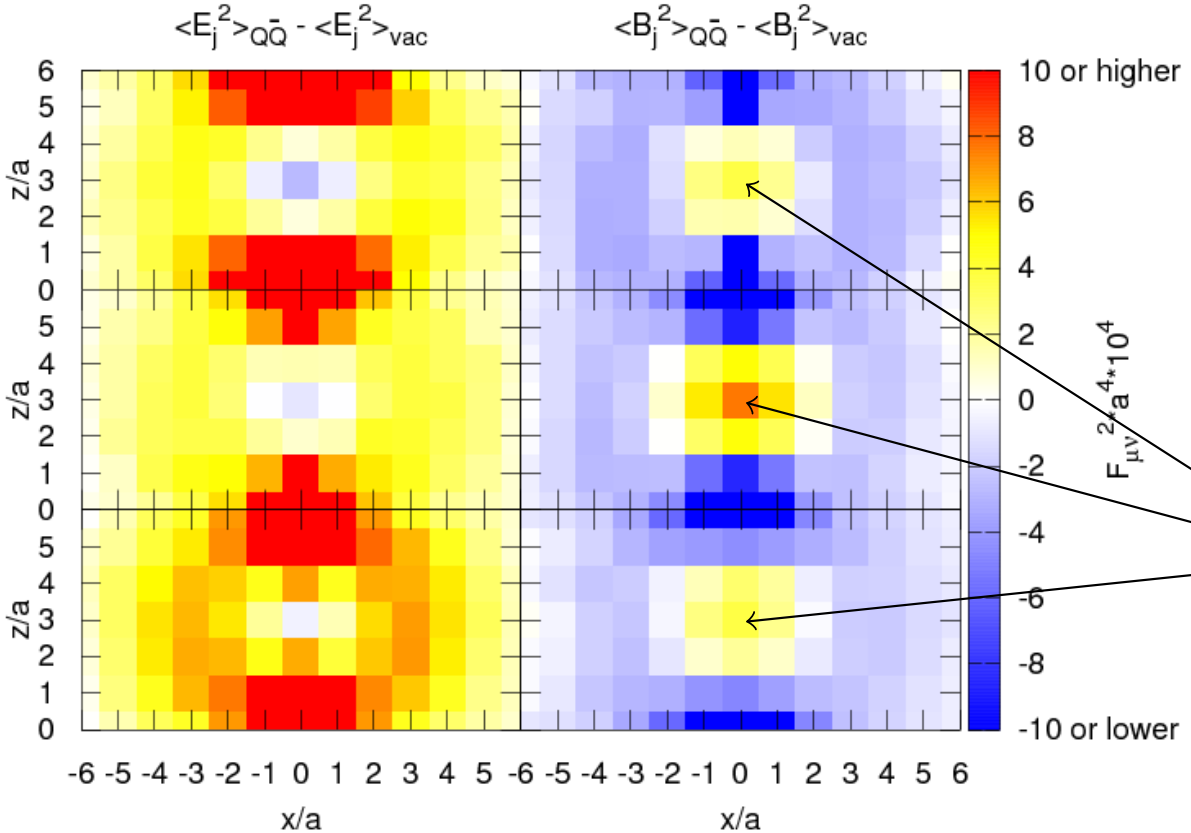




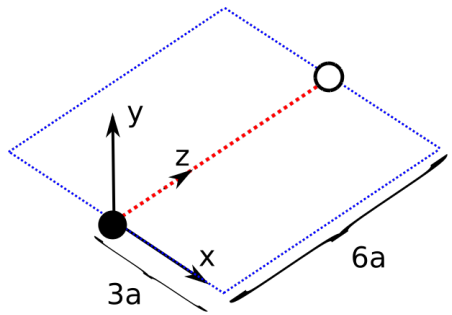
hybrid state Π_u



xz-plane



hybrid state Π_u

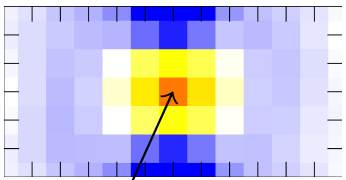


Gluon generating hybrid quantum numbers

Conclusion and outlook

Conclusion:

- Gluonic excitations
  affect the flux tube structure significantly
- For the Π_u hybrid static potential the
  chromomagnetic field is considerably larger near
  the center compared to the ordinary static potential



Outlook:

- Investigation of other hybrid states to be able to make general conclusions
- Increase statistics to confirm convergence
- Behaviour for different separations R