Activities in
Theoretical Particle and Nuclear Physics at TU Wien

Anton Rebhan

Institute for Theoretical Physics
TU Wien, Vienna, Austria

NuPECC mini-workshop Wien 2016
People at ITP/TUW
with activities in Theoretical Particle/Nuclear Physics

- **1 Full Professor:** Anton REBHAN (successor of Wolfgang KUMMER)
  QCD at finite temperature/density, QGP, gauge/gravity duality
  (Speaker of *Vienna-wide graduate school* *Particles & Interactions*, 6 PhD at ITP)

- **1 Associate Professor:** Daniel GRUMILLER
  gauge/gravity duality, entanglement entropy in heavy-ion collisions

- **1 Privatdozent:** Andreas IPP
  QGP, color-glass-condensate

- **Lise-Meitner fellow** (senior postdoc): Ayan MUKHOPADHYAY
  gauge/gravity duality, semi-holography for heavy-ion collisions

- **Postdocs (FWF):** Denis PARGANLIJA (hadron physics),
  Florian PREIS (neutron star physics, gauge/gravity duality),
  Stefan STRICKER (gauge/gravity duality)

also in research group “Fundamental Interactions”: 2 Univ.-Ass. and 1 Priv.-Doz. in
**String Theory** (J. Knapp, H. Skarke, T. Wrase) + further postdocs, PhDs
Selected Showcases

- Perturbative QCD: Plasma instabilities in hard loop effective theory
- Perturbative QCD: Simulations of heavy-ion collisions in CGC framework
- Gauge/gravity duality in heavy-ion collisions
- Holographic QCD: Predictions for hadron/glueball physics
Plasma instabilities in hard loop effective theory

**Nonabelian plasma instabilities** in plasma with fixed momentum anisotropy:

A. Rebhan, P. Romatschke (now Boulder, Colorado), M. Strickland (now Kent U.):
PRL 94 (2005) 102303, JHEP 0509 (2005) 041 …SU(2)

extended to longitudinally expanding geometry:
M. Attems (now Barcelona), A. Rebhan, M. Strickland: PRD87 (2013) 025010
Simulations of heavy-ion collisions in CGC framework

Color-glass-condensate simulations with CPIC (colored particles in cell):

Daniil Gelfand, Andreas Ipp, David Müller: Simulating collisions of thick nuclei in the color glass condensate framework, PRD94 (2016) 014020

permits study of heavy-ion collisions at lower energies, without boost-invariance
Gauge/gravity duality in heavy-ion collisions

Thermalisation in heavy-ion collisions modelled by gravitation shock wave collisions and subsequent AdS black hole formation:
(pioneered by P. Chesler & L. Yaffe)


Energy densities in dual field theory for wide/narrow/very-narrow shocks
Gauge/gravity duality in heavy-ion collisions

Thermalisation in heavy-ion collisions modelled by gravitation shock wave collisions and subsequent AdS black hole formation:
(pioneered by P. Chesler & L. Yaffe)


Entanglement entropy calculated from minimal surfaces (geodesics) in horizon geometry
Holographic QCD

∃ top-down string-theoretical construction dual to low-energy non-supersymmetric QCD:

large-$N_c$ gluons and low-$N_f$ chiral quarks (from compactified D4-D8 brane construction)

with just one mass parameter and one dimensionless coupling constant reproduces roughly (typically 10–30% errors)

- Spectrum of vector and axial-vector mesons
- Decay width of $\rho$ and $\omega$ mesons
- Anomalous part of mass of $\eta'$
- ...
Holographic QCD applied to glueballs

Glueballs in holographic QCD dual to bulk gravitational and RR fields
— spectrum worked out by Brower/Mathur/Tan (2000)
— first attempts to calculate decay pattern by Hashimoto-Tan-Terashima (2008)

revisited and extended in:


• traditional glueball candidate $f_0(1500)$ not well reproduced (i.e. needs large mixing)
Holographic QCD applied to glueballs

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F. Brünner, A. Rebhan: Constraints on the \( \eta \eta' \) decay rate of a scalar glueball from gauge/gravity duality, PRD 92 (2015) 121902(R)

*Nonchiral enhancement*: fits quite well to (largely unmixed) glueball candidate \( f_0(1710) \) whose mass fits best to lattice but which decays in flavor-asymmetric way
Comparison with $f_0(1710)$

<table>
<thead>
<tr>
<th>decay</th>
<th>$\Gamma/M$ (PDG)</th>
<th>$\Gamma/M[G_D]$ (chiral)</th>
<th>$\Gamma/M[G_D]$ (massive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_0(1710)$ (total)</td>
<td>0.081(5)</td>
<td>0.059... 0.076</td>
<td>0.083... 0.106</td>
</tr>
<tr>
<td>$f_0(1710) \rightarrow 2K$</td>
<td>(*) 0.029(10)</td>
<td>0.012... 0.016</td>
<td>0.029... 0.038</td>
</tr>
<tr>
<td>$f_0(1710) \rightarrow 2\eta$</td>
<td>0.014(6)</td>
<td>0.003... 0.004</td>
<td>0.009... 0.011</td>
</tr>
<tr>
<td>$f_0(1710) \rightarrow 2\pi$</td>
<td>0.012(+5−6)</td>
<td>0.009... 0.012</td>
<td>0.010... 0.013</td>
</tr>
<tr>
<td>$f_0(1710) \rightarrow 2\rho, \rho\pi\pi \rightarrow 4\pi$</td>
<td>?</td>
<td>0.024... 0.030</td>
<td>0.024... 0.030</td>
</tr>
<tr>
<td>$f_0(1710) \rightarrow 2\omega$</td>
<td>0.010(+6−7)</td>
<td>0.011... 0.014</td>
<td>0.011... 0.014</td>
</tr>
<tr>
<td>$f_0(1710) \rightarrow \eta\eta'$</td>
<td>?</td>
<td>0</td>
<td>if 0 : $\uparrow$</td>
</tr>
<tr>
<td>$\Gamma(\pi\pi)/\Gamma(K\bar{K})$</td>
<td>0.41$^{+0.11}_{-0.17}$</td>
<td>3/4</td>
<td>0.35</td>
</tr>
<tr>
<td>$\Gamma(\eta\eta)/\Gamma(K\bar{K})$</td>
<td>0.48±0.15</td>
<td>1/4</td>
<td>0.28</td>
</tr>
</tbody>
</table>

(*) PDG ratios for decay rates $+ \text{Br}(f_0(1710) \rightarrow KK) = 0.36(12)$ [Albaladejo&Oller 2008]

- decays into 2 pseudoscalars: massive WSS perfectly compatible with PDG data!
- significant decay into 4 pions (after extrapolation to beyond $2\rho$ threshold): together with upper limit on $\eta\eta'$ rate falsifiable prediction of this model! ($f_0(1710) \rightarrow 2\rho^0$ forthcoming from CMS-TOTEM!)
Nonchiral Enhancement of Scalar Glueball Decay in the Witten-Sakai-Sugimoto Model

Frederic Brunner and Anton Rebhan
Phys. Rev. Lett. 115, 131601 – Published 21 September 2015

ABSTRACT

We estimate the consequences of finite masses of pseudoscalar mesons on the decay rates of scalar glueballs in the Witten-Sakai-Sugimoto model, a top-down holographic model of low-energy QCD, by extrapolating from the calculable vertex of glueball fields and the η' meson that follows from the Witten-Veneziano mechanism for giving mass to the latter. Evaluating the effect on the recently calculated decay rates of glueballs in the Witten-Sakai-Sugimoto model, we find a strong enhancement of the decay of scalar glueballs into kaons and η mesons, in fairly close agreement with experimental data on the glueball candidate f_0(1710).

Received 30 April 2015
“Glueballs” stuck!

Loads of internet news coverage, including a YouTube posting (with surprisingly accurate physics explanation!)

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