



Theory at TU Wien



Andreas Ipp

RECFA Meeting Vienna, 6-7 April 2018

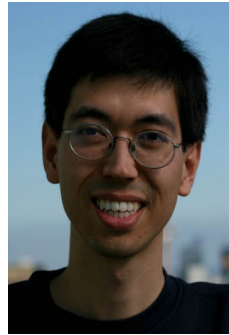




Balasin



Grumiller



Ipp



Preis



Rebhan



Wrase

+ 2 external faculty members: Rashkov (Sofia U.), Skarke (TU Wien)

Projects since 2013:

9 FWF stand-alone projects: Grumiller (4), Ipp (1), Rebhan (2), Wrase (2)

Numerous collaborative and workshop grants: COST, DK, ESI, OeAD, SFB, Simons Center, ...

Temporary positions since 2013:

14 Postdocs: Afshar (Tehran), Anastasopoulos (CERN), Bagchi (MIT), Chowdhury (HRI), Gary (Santa Barbara), Gelfand (Munich), Gonzalez (Brussels), Hatefi (Queen Mary), Mukhopadhyay (Crete), Leston (Buenos Aires), Merbis (Groningen), Rosseel (Groningen), Stetina (Seattle), Stricker (TU Wien)

18 PhD students: Brünner, Ecker, Haber, Irakleidou, Kidambi, Leutgeb, Müller, Preis, Prohazka, Riegler, Roupec, Salzer, Schimpf, Schöller, Soloviev, Stanzer, Stetina, Wutte

Numerous master/bachelor students and external visitors

115 research papers since 2013

Collaborations since 2013:

ABC Federal U., Amsterdam U., Barcelona U., Bern U., Brussels U., Cambridge U., CECs Valdivia, CERN, Chicago U., Cornell U., DESY, Edinburgh U., FIAS, Freiburg U., GGI Florence, Groningen U., Harvard U., IAS, IISER Pune, IPM Tehran, IPMU Tokyo, Jena U., Kent State U., Leuven U., Los Alamos, Loyola U. Chicago, Lyon, MIT, Oxford U., Paris U., Princeton U., Seoul Nat'l. U., SLAC, Southampton U., Stanford U., YITP Stony Brook, Washington U.

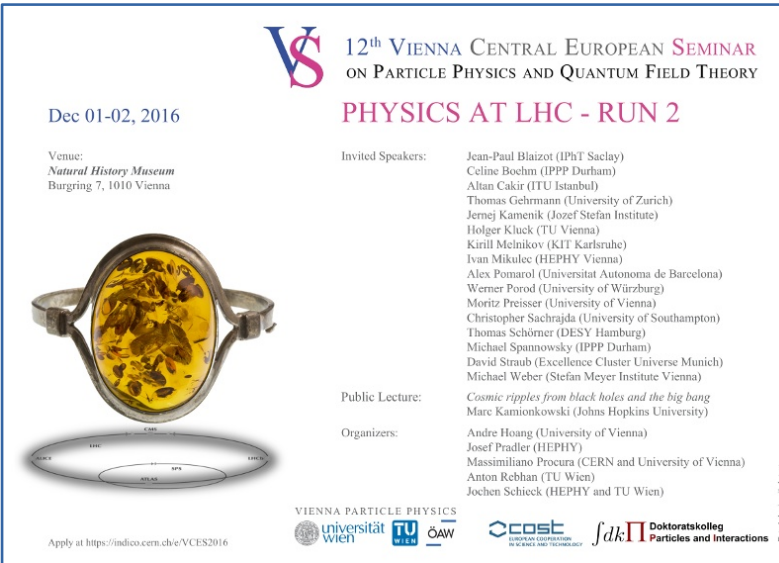
Workshops organized since 2013:

Vienna Central European Seminar (annually since 2014); ÖAW workshop “100 years of curved spacetime” (2015); Simons Center workshop “Flat holography” (2016); ESI programme “Quantum Physics and Gravity” (2018)

Outreach since 2013:

numerous talks (Kinderuni, Woche der freien Bildung, MIT Club, Planetarium, ...)

Highlight: Gravitation 2015 – exhibition on gravitational waves, public talks, lectures, workshop, guided tours, ...



VS 12th VIENNA CENTRAL EUROPEAN SEMINAR
ON PARTICLE PHYSICS AND QUANTUM FIELD THEORY

PHYSICS AT LHC - RUN 2

Dec 01-02, 2016

Venue:
Natural History Museum
Burggring 7, 1010 Vienna

Invited Speakers:

- Jean-Paul Blaizot (IPHT Saclay)
- Celine Boehm (IPPP Durham)
- Altan Cakir (ITU Istanbul)
- Thomas Gehrmann (University of Zurich)
- Jernej Kamenik (Josef Stefan Institute)
- Holger Kluck (TU Vienna)
- Kirill Melnikov (KIT Karlsruhe)
- Ivan Mikulec (HEPHY Vienna)
- Alex Pomarol (Universitat Autònoma de Barcelona)
- Werner Porod (University of Würzburg)
- Moritz Preisser (University of Vienna)
- Christopher Sachrajda (University of Southampton)
- Thomas Schömer (DESY Hamburg)
- Michael Spannowsky (IPPP Durham)
- David Straub (Excellence Cluster Universe Munich)
- Michael Weber (Stefan Meyer Institute Vienna)

Public Lecture:

- Cosmic ripples from black holes and the big bang*
- Marc Kamionkowski (Johns Hopkins University)

Organizers:

- Andre Hoang (University of Vienna)
- Josef Pradler (HEPHY)
- Massimiliano Procura (CERN and University of Vienna)
- Anton Rebhan (TU Wien)
- Jochen Schieck (HEPHY and TU Wien)

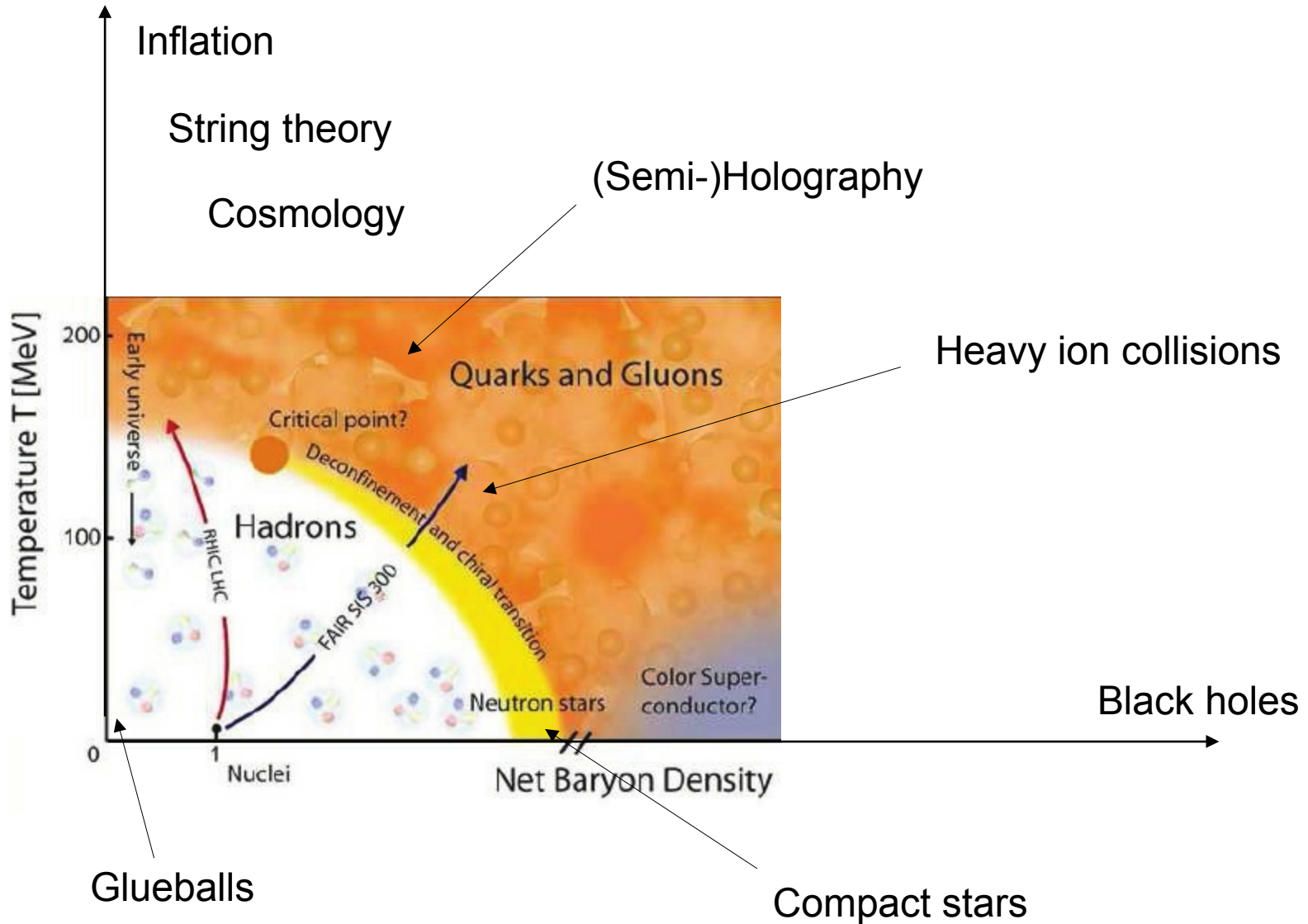
Apply at <https://indico.cern.ch/e/VCES2016>

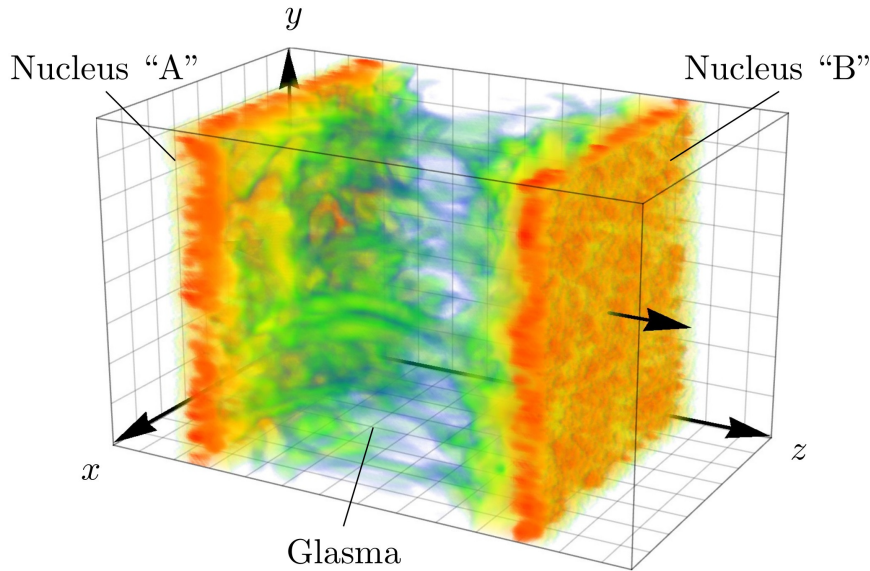
VIENNA PARTICLE PHYSICS
universität TU WIEN ÖAW

COST
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

dfkPI Doktoratskolleg
Particles and Interactions

Photo: © Stefan Meyer





Before a **Quark-Gluon-Plasma** is formed, a “Glasma” is created by the collision of quasi-classical fields described in the color glass condensate framework

Numerical simulations of earliest stage of heavy-ion collisions

Ipp, Müller, PLB 771 (2017) 74
Gelfand, Ipp, Müller, PRD 94 (2016) 014020

Calculations on Vienna Scientific Cluster

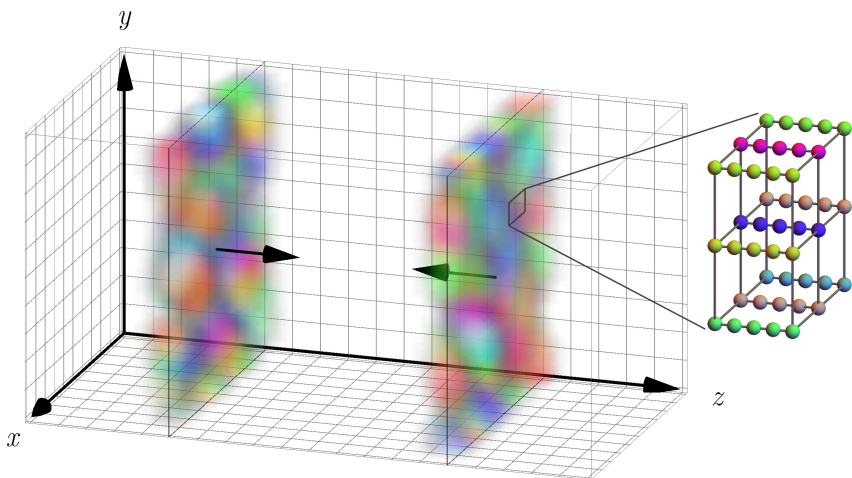
Simulation of non-Abelian plasma instabilities

(various gauge groups, expanding background)

Attems, Rebhan, Strickland, PRD 87 (2013) 025010
Ipp, Rebhan, Strickland, PRD 84 (2011) 056003

Related experimental and theoretical groups:

- **Stefan Meyer Institute for Subatomic Physics (SMI)**, Austrian Academy of Sciences (ÖAW): ALICE @ LHC
- **Institute of High Energy Physics (HEPHY)**, ÖAW: CMS @ LHC
- **Institute of Physics @ University of Graz**: Complementary expertise in nuclear and hadron physics (lattice QED, Schwinger-Dyson equations)



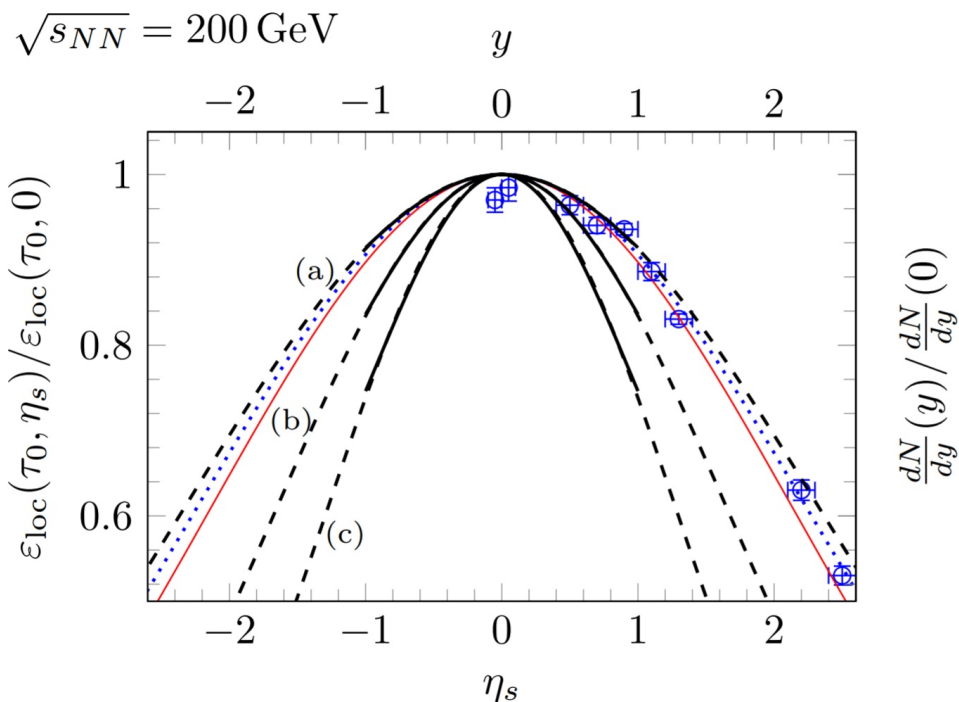
Colored Particle-in-cell simulations solve Yang-Mills equations coupled to color currents for simulating nuclei with finite thickness

Ipp, Müller, PLB 771 (2017) 74

Gelfand, Ipp, Müller, PRD 94 (2016) 014020

Rapidity profile of local rest-frame energy density:
Compare to measured **rapidity profile of particle multiplicity (RHIC)** and **Landau model** prediction

Even lower energies:
RHIC beam energy scan:
~7.7 – 62.4 GeV ($\gamma \approx 4 - 30$)



Photon and dilepton production from anisotropic plasma

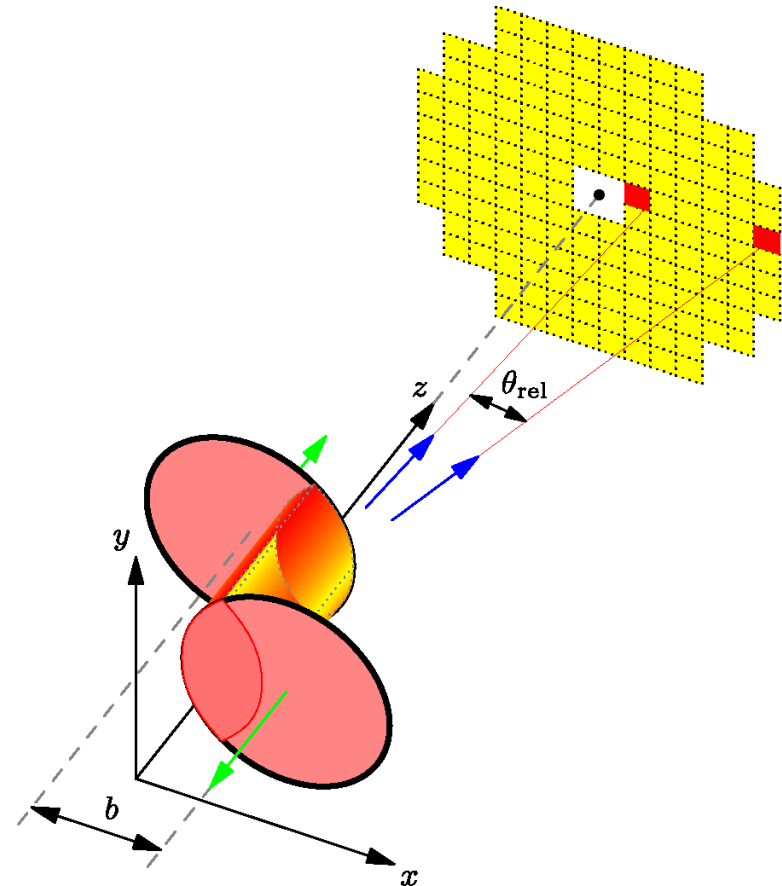
Ipp, Keitel, Evers, PRL 103 (2009) 152301
Rebhan, Steineder, JHEP 1108 (2011) 153

Hanbury Brown and Twiss (HBT) correlation measurements of photons in forward direction

Ipp, Somkuti, PRL 109 (2012) 192301

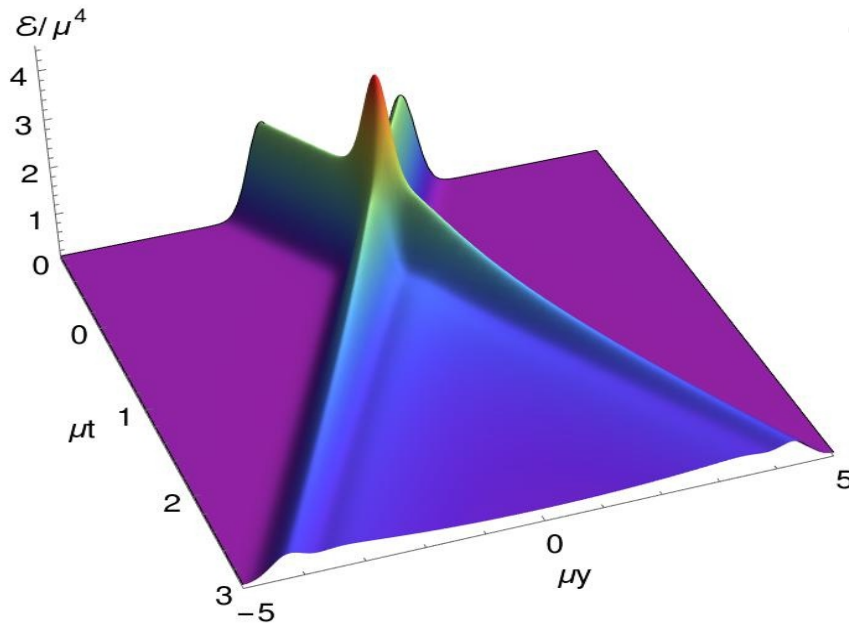
Forward Calorimeter (FoCal): planned ALICE detector upgrade

Peitzmann, arXiv:1308.2585
ALICE FoCal Group, Nucl. Instrum. Meth. A845
(2017) 542



Hanbury Brown and Twiss (HBT) correlation
from non-central heavy-ion collisions

Heavy ion collisions and holography



Holographic shock wave collisions

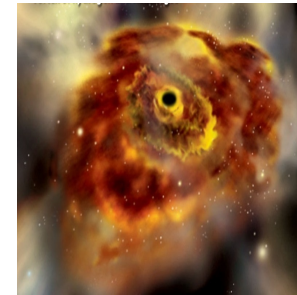
Ecker, Grumiller, Stanzer, Stricker, van der Schee, JHEP 1611 (2016) 054

Semi-holographic description

Mukhopadhyay, Preis, Rebhan, Stricker, JHEP 1605 (2016) 141
Doucot, Ecker, Mukhopadhyay, Policastro, PRD 96 (2017) 106011

AdS/CFT correspondence:
Type IIB string theory on $AdS_5 \times S^5$ is
equivalent to $\mathcal{N}=4$ super symmetric
 $SU(N_c)$ **Yang-Mills theory** in 4D

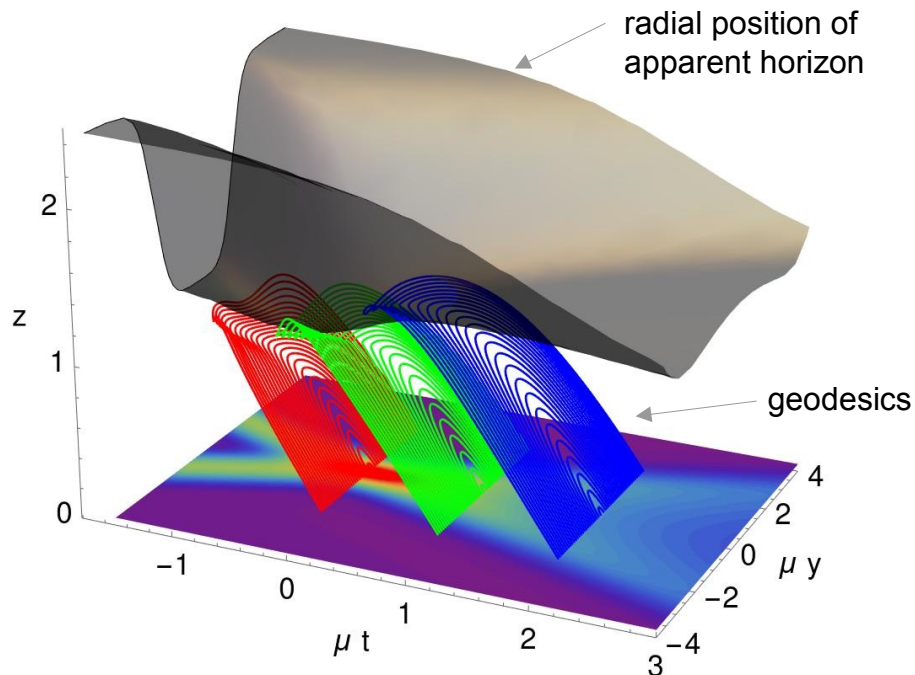
Holographic thermalization
 \leftrightarrow Black hole formation



Violation of holographic viscosity
bound in strongly coupled
anisotropic plasma

Rebhan, Steineder, PRL 108 (2012) 021601

Entanglement entropy



Violation of null energy condition
shortly after collision
(Quantum null energy condition holds)

Ecker, Grumiller, Stanzer, Stricker, van der Schee, JHEP 1611 (2016) 054

Entanglement entropy:
measure for entanglement in a quantum
system.

Compute entanglement entropy
holographically from the **area of extremal
surfaces** in the gravity theory.

Ryu, Takayanagi (2006)

Evolution of holographic entanglement
entropy in anisotropic systems

Ecker, Grumiller, Stricker, JHEP 1507 (2015) 146;
Bagchi, Basu, Grumiller, Riegler, PRL 114 (2015) 111602

Lattice gauge theory predicts bound states of gluons and their masses, but not their decay patterns:

$$m_{0^{++}} \sim 1.7 m_{\text{Proton}}$$

$$m_{2^{++}} \sim 2.4 m_{\text{Proton}}$$

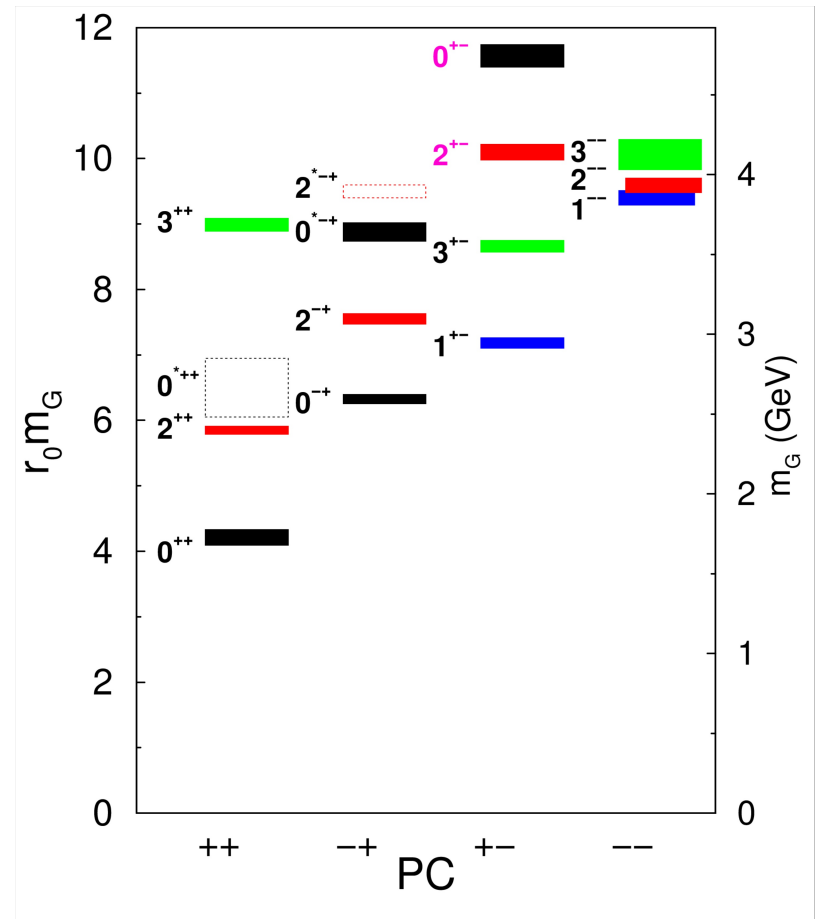
$$m_{0^{-+}} \sim 2.6 m_{\text{Proton}}$$

$$m_{1^{-+}} \sim 3.0 m_{\text{Proton}}$$

...

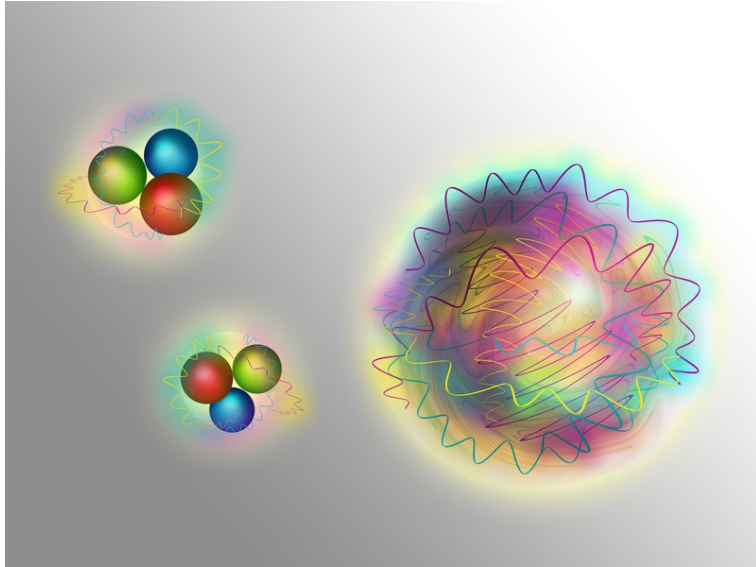
Use gauge/gravity duality to predict decay patterns of spin 0 and spin 2 glueballs

Brünner, Rebhan, PRL 115 (2015) 131601



Glueball spectrum from lattice

Morningstar, Peardon PRD 60 (1999) 034509



nucleons vs. glueball

Holographic description within the
Witten-Sakai-Sugimoto model

Only 2 parameters:

mass scale $M_{\text{KK}} = 949 \text{ MeV}$,

't Hooft coupling $\lambda = 16.63 \dots 12.55$

Previous glueball candidates:

$f_0(1500)$ and $f_0(1710)$

Holographic computation of decay rates:
 $f_0(1710)$ could be glueball, with significant
decay into two rho mesons

Prediction of broad tensor and narrow
pseudoscalar glueball above 2 GeV

Brüner, Rebhan, PRL 115 (2015) 131601

Brüner, Rebhan, PRD 92 (2015) 121902

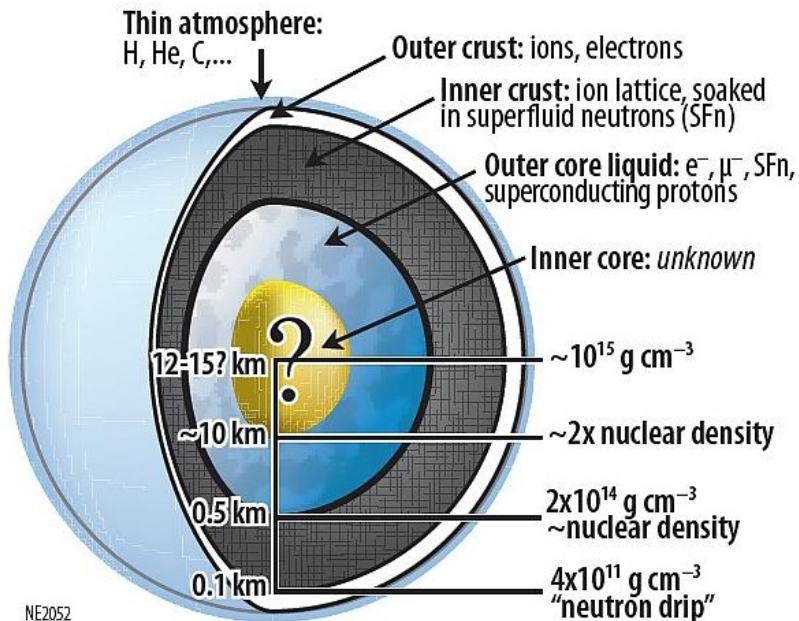
Brüner, Rebhan, PLB 770 (2017) 124

Brüner, Parganlija, Rebhan, PRD 91 (2015) 106002

Related experiments:

- Central Exclusive Production (CEP) at LHC experiments (TOTEM, ALICE, LHCb,...)
- BES III (Beijing Spectrometer III)
- PANDA at FAIR

Compact stars

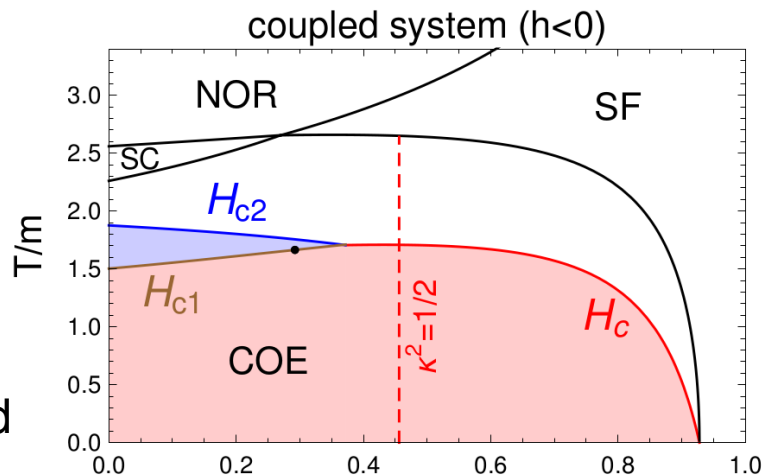


Phase structure in external magnetic field including effects of flux tube interactions, critical magnetic fields and temperatures, instabilities in two-fluid systems, magnetic defects in color superconducting matter

- Haber, Schmitt, Stetina, PRD 93 (2016) 025011
- Haber, Schmitt, PRD 95 (2017) 116016
- Haber, Schmitt, arXiv:1712.08587, to appear in JPhysG

Cold and dense QCD matter can be found in interior of neutron stars ($T \approx 1 \text{ keV} \ll \mu_q \leq 500 \text{ MeV}$)

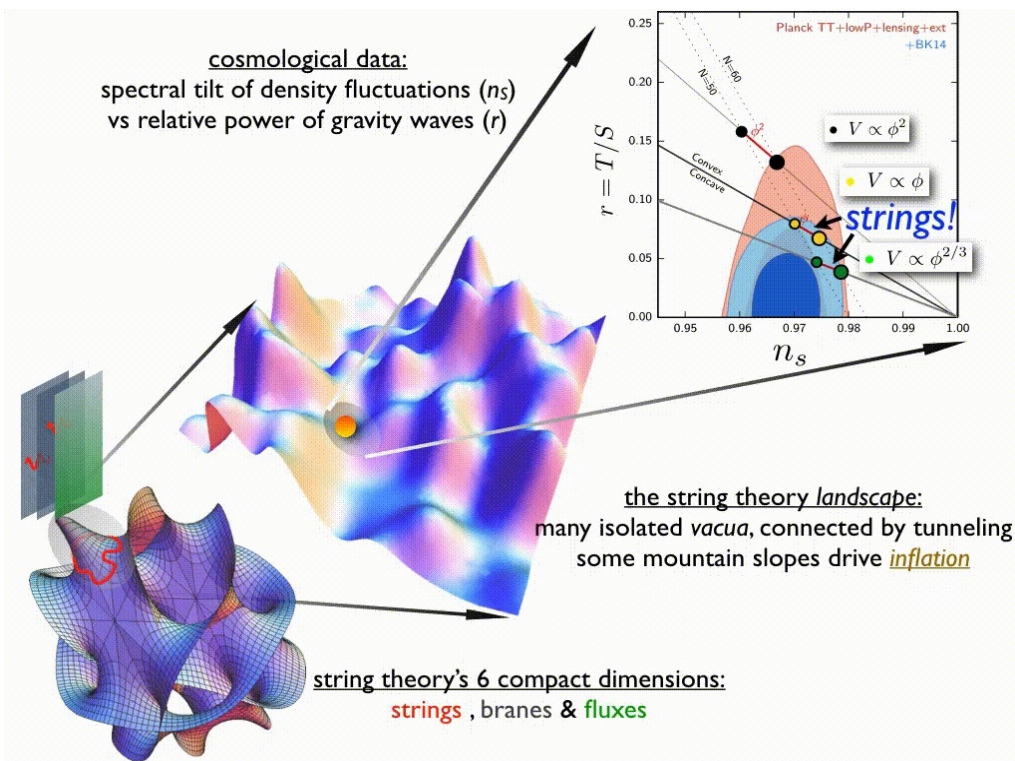
Nucleonic superfluidity and superconductivity via Cooper pair condensation in crust and core



Superfluid (SF), Superconductor (SC), Coexistence phase (COE), normal phase (NOR)

Holographic compact stars

- Annala, Ecker, Hoyos, Jokela, Fernández, Vuorinen, arXiv:1711.06244



Inflation & cosmology:

Cosmological observation of tensor-to-scalar ratio r (B modes) in the cosmic microwave background can originate from inflationary gravity waves

Search for suitable (super-)potentials that allow for (large-field) inflation consistent with observational data

McAllister, Silverstein, Westphal, Wrase, JHEP 1409 (2014) 123

Kalosh, Linde, Wrase, Yamada, JHEP 1604 (2016) 027

Gallego, Marsh, Vercnocke, Wrase, JHEP 1710 (2017) 193

Bergshoeff, Dasgupta, Kalosh, Wrase, JHEP 1505 (2015) 058

Calabi-Yau manifolds

Banlaki, Chowdhury, Kidambi, Schimpf, Skarke, Wrase, JHEP 1802 (2018) 129

$\int dk \Pi$ Doktoratskolleg Particles and Interactions

Graduate School DKPI (Speaker: Rebhan) - 2nd funding period just started!

Vienna-wide graduate education in experimental and theoretical particle physics involving:

- TU Wien: Institute for Theoretical Physics, Institute of Atomic and Subatomic Physics
- University of Vienna
- Austrian Academy of Sciences (ÖAW): Institute of High Energy Physics (HEPHY), Stefan Meyer Institute for Subatomic Physics (SMI)



Atominstitut



TU Wien



Uni Wien



HEPHY



SMI

- 11 faculty members, 31 PhD students
- Introductory and advanced lectures at University of Vienna and TU Wien
- Cooperation with
 - ▶ Doctoral School Graz on "Hadrons in Vacuum, Nuclei, and Stars"
 - ▶ International Max Planck Research School (IMPRS) Munich on "Elementary Particle Physics"
 - ▶ European Graduate School Jena on "Quantum and Gravitational Fields"

DK-PI Summer Schools

$\int dk \Pi$ Doktoratskolleg
Particles and Interactions

- Topics selected from theory and experiment
- Introductory / hands-on courses with exercises

DKPI SUMMER SCHOOL SEPT. 19 - 23, 2016

TOPICS: Neutrino and astroparticle physics, machine learning, thermal field theory, holographic aspects of relativistic hydrodynamics, standard model physics instrumentation for hadron physics

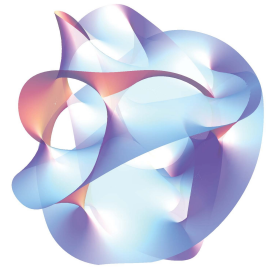
SPEAKERS: Kai BRINKMANN (JLU Gießen), Andreas SCHMITT (STAG), Thomas SCHWETZ-MANGOLD (KIT), Heide VOSS (CERN), Michael WEBER (CERN)

$\int dk \Pi$ VIENNA DOCTORAL PROGRAM
Particles & Interactions
VIENNA PARTICLE PHYSICS
universität wien TU WIEN OAW
FWF
Der Wissenschaftsfonds.

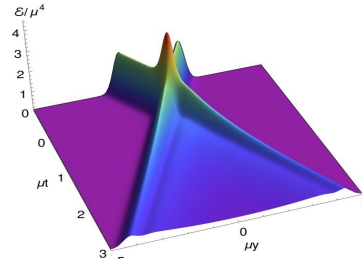
→ 17–21 Sept 2018: Hirschwang (alpine area Rax/Schneeberg)

Summary

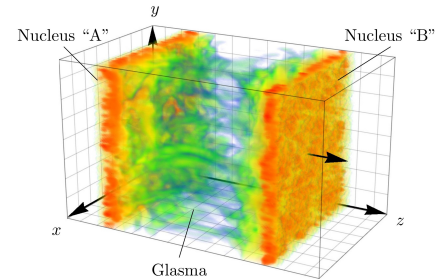
Fundamental Interactions - Institute for Theoretical Physics - TU Wien



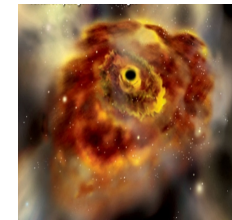
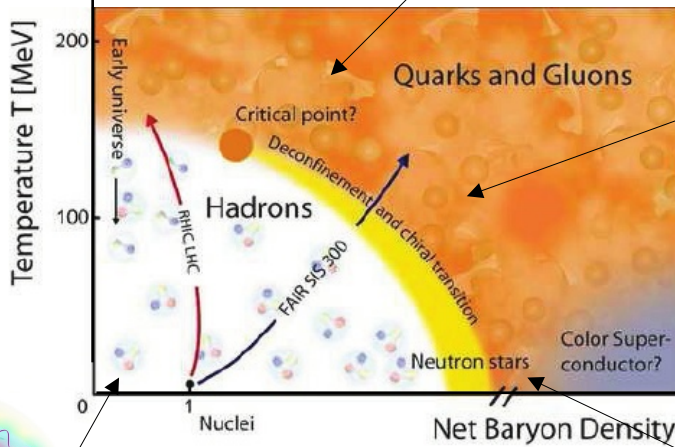
String theory, cosmology, inflation



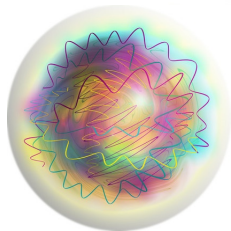
(Semi-)Holography



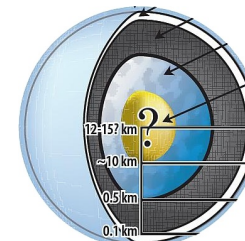
Heavy ion collisions



Black holes



Glueballs



Compact stars