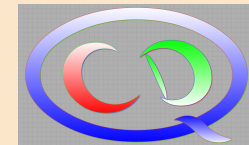


# Symmetries and the Emergence of Structure in QCD

– Introduction to the CRC 110 –



Ulf-G. Meißner, Univ. Bonn & FZ Jülich

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# The CRC 110

# What is a Collaborative Research Center?

Collaborative Research Centres (CRCs) are institutions established at universities for a period of up to 12 years that enable researchers to pursue an **outstanding research programme**, crossing the boundaries of disciplines, institutes, departments and faculties. They facilitate **scientifically ambitious, complex, long-term research** by concentrating and coordinating the resources available at a/up to three university/ties. Universities submitting a proposal are expected to provide appropriate core support. The CRC programme should, thus, contribute towards defining the profiles of participating universities. Gender equality and early career support are additional goals of a Collaborative Research Centre.

Collaborative Research Centres may also incorporate projects at neighbouring universities or non-university research institutions and collaboration with industry and business within the research programme, provided they serve to further the core research area. In addition, **CRCs maintain scientific relations with universities and other research institutions outside of Germany.** **Co-funding for international CRCs is also possible.**

[http://www.dfg.de/en/research\\_funding/programmes/coordinated\\_programmes/collaborative\\_research\\_centres/index.html](http://www.dfg.de/en/research_funding/programmes/coordinated_programmes/collaborative_research_centres/index.html)

# The partners



***Institute of High Energy Physics, CAS, Beijing***

***Peking University***

***Theoretical Center for Science Facilities, CAS***

***[Institute for Theoretical Physics, CAS]***



***Rheinische-Friedrich-Wilhelms-Universität Bonn***

***Technische Universität München***

***Forschungszentrum Jülich***

- Comprehensive university (Volluniversität)
- 7 faculties, about 30.000 students



- research foci: Mathematics (Cluster of Excellence)  
Physics and Astronomy (Bonn-Cologne Graduate School)  
Life sciences (Cluster of Excellence)  
Economy
- 3 main research areas in physics:  
**Particle & hadron physics**, astrophysics, photonics and condensed matter
- physics high-lights:  
Nobel prize physics 1989 Wolfgang Paul  
Electron Stretcher Accelerator ELSA & CRC 16 “Subnuclear Structure of Matter”  
Bethe Center for Theoretical Physics & Bethe Forum (new)

- Technical university  
(*Exzellenz-Universität*)
- 13 faculties, about 26.000 students
- research foci: Mathematics & Informatics  
Physics  
Chemistry & Life Sciences  
Engineering
- 3 main research areas in physics:  
**Nuclear, particle & astrophysics**, condensed matter physics, biophysics
- Munich physics high-lights:  
Nobel prize physics 1961 R. Mößbauer (TUM), 1985 Klaus von Klitzing (TUM)  
Cluster of excellence “Origin and Structure of the Universe”  
Institute for Advanced Studies (TUM-IAS) and Leibniz Supercomputing Center



- Large interdisciplinary research center
- 11 institutes, about 5000 employees
- research foci: Information technologies  
Energy and environment  
Health
- main research areas in physics:  
**Hadron & nuclear physics**, condensed matter physics, computational physics
- physics high-lights:  
Nobel prize physics 2007 Peter Grünberg  
Cooler Synchrotron COSY  
& construction of the HESR at FAIR  
Jülich Supercomputing Center (Europe's Nr. 1)





# Institute of High-Energy Physics (IHEP)

- **Top institution in China for high-energy and hadron physics**
- **hosts 3 big international experimental facilities**
  - **BEPC2 w/ BESIII collaboration**
  - Daya Bay neutrino experiment
  - Tibet cosmic ray observatory
- **7 research divisions with about 750 researchers**  
Accelerator Center, Experimental Physics Center, Theory Division, Particle-Astroparticle Center, Computing Center, Technology R&D Center, Multi-disciplinary Center
- **Host of the Theoretical Center for Science Facilities**
  - improve the theory support of the chinese facilities



# Peking University

- **Top comprehensive university in China ranks 17th on the list of top universities**
- 18 disciplines of PKU rank in the world top 1%  
→ Mathematics, Physics, Chemistry, Materials Science, ...
- 39 schools & departments, ~30000 students
- School of Physics: 200 faculty and staff, ~1400 students  
Inst. of Theoretical Physics (ITP),  
Inst. of Condensed Matter & Material Physics,  
Inst. of Heavy Ion Physics, ...,  
+ Dept. of Astronomy, ...
- **NSFC fund for Innovative Research Groups on Hadron Physics → ITP@PKU**



# Why this collaboration?

- Very challenging endeavour, requires complementary and overlapping expertise  
⇒ this is available at the various institutions forming this CRC
- Large investment in facilities requires concentrated theory effort  
⇒ strong focus on data from BEPC-II (now) and FAIR (future)
- Improving the bilateral scientific relations  
⇒ best use of the science brain pool in both countries
- Builds on earlier and on-going collaborations by some of the PIs  
⇒ [Brambilla, Vairo, Jia], [Guo, Hanhart, Meißner, Zhao], [Hanhart, Guo, Zou]  
[Kaiser, Meißner, Weise], [Rusetsky, Weise], [Dreiner, Hanhart], ...

⇒ Potential for a long-term synergy and innovation  
very much desired by the partners

# Principal Investigators (PIs)

- Principal investigators:

**IHEP** Prof. Y. Chen, Prof. Y. Dong,  
Prof. M. Huang, Prof. Y. Jia,  
Prof. J.-X. Wang, Prof. P. Wang,  
Prof. Q. Zhao, Prof. B.-S. Zou [→ ITP/CAS]



**PKU** Prof. C. Liu, Prof. S.-L. Zhu



**UB** Prof. H. Dreiner, Dr. F.-K. Guo, [Prof. H.-W. Hammer,]  
Prof. B. Kubis, Prof. U.-G. Meißner,  
PD A. Rusetsky, Prof. C. Urbach



**FZJ** PD J. Haidenbauer, Prof. C. Hanhart, [Prof. U.-G. Meißner],  
Dr. A. Nogga, [Prof. T. Luu [from 09/2013]]



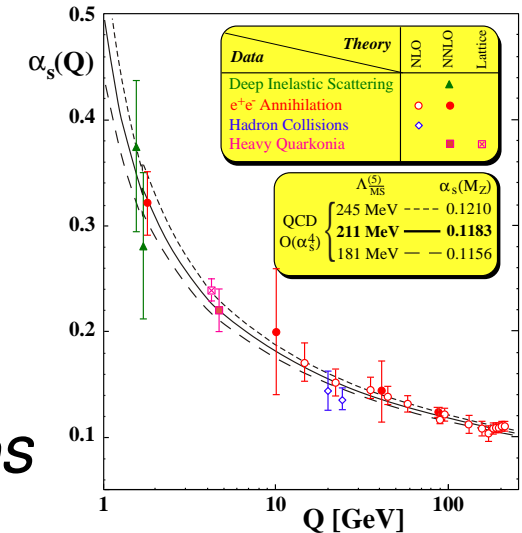
**TUM** Prof. N. Brambilla, Prof. N. Kaiser,  
PD A. Vairo, Prof. W. Weise



# Topics in Strong QCD

# Facets of Quantum Chromodynamics

- perturbative QCD: quarks, gluons, ...
- **strong** QCD: hadrons, nuclei, ...
- a plethora of *structures* and (*broken*) *symmetries*



- Aspects of QCD in the **CRC 110**:
  - decays and interactions of hadrons (esp. charm sector)
  - how QCD generates structures: hadrons, nuclei, ...
  - precision calculations to test physics beyond the SM

→ *interplay of lattice QCD, EFTs and models*

# Role of CRC 110

- Two loose ends of the Standard Model:
  - the Higgs boson (EW symmetry breaking)  
[→ just seen in 2012 at the LHC]
  - structure and dynamics of strong QCD

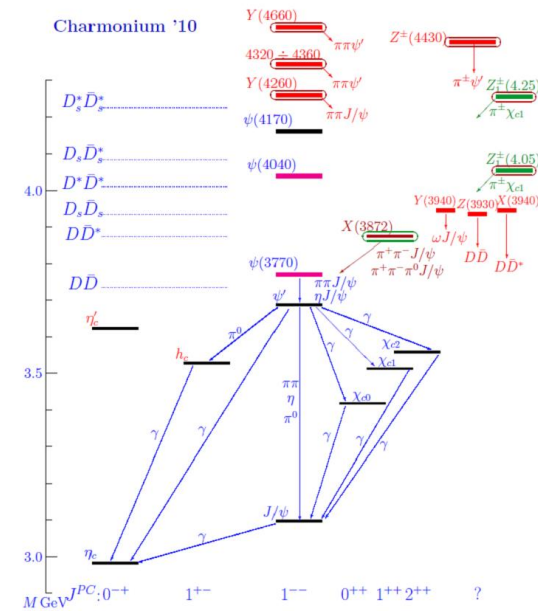
**Unique contribution of CRC 110 to strong QCD:**

**Investigation of how QCD generates structures:  
hadrons, nuclei, ... and how symmetries  
influence their structure and dynamics  
based on a large international collaboration**

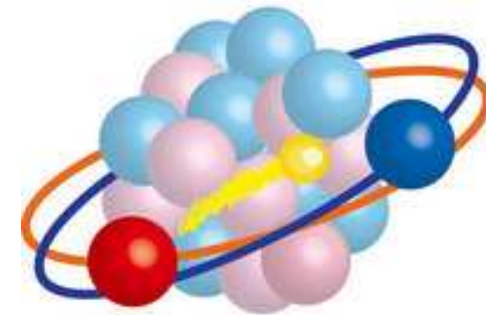
- For the first time, such a unified approach is attempted

# Facest of strong QCD

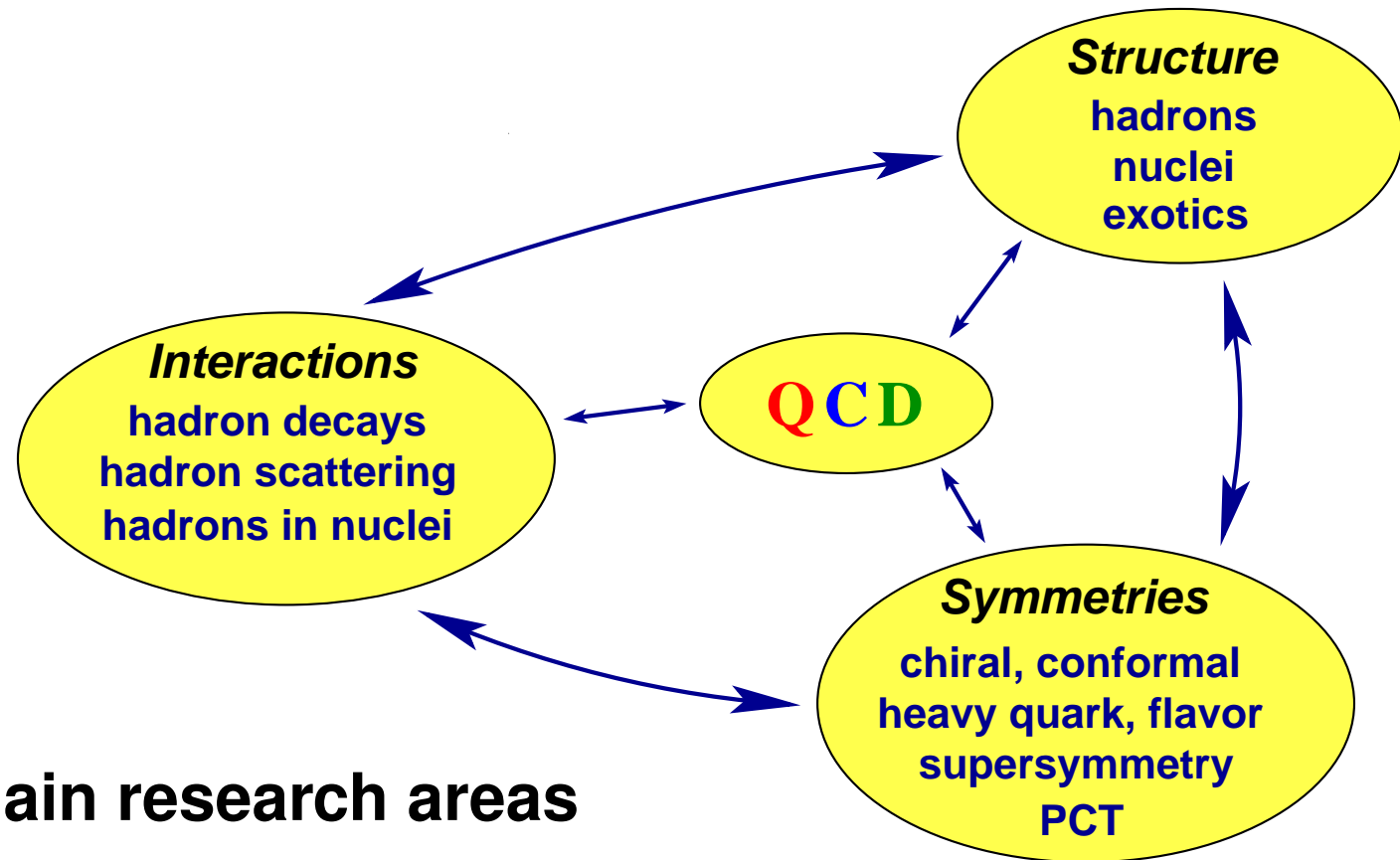
- quarks and gluons form hadrons
  - ⇒ **lattice QCD + EFT + models**
  - ⇒ **exploring the strong color force**



- nucleons and mesons form nuclei
  - ⇒ **nuclear physics (EFT, lattice, ...)**
  - ⇒ **exploring the residual color force**







- **CRC 110: two main research areas**

*A – symmetries*

*B – emergence of structure*

- **strongly intertwined**

- Project area A: **Symmetries**

- |     |  |                         |
|-----|--|-------------------------|
| A.1 | Flavor symmetries and FSI in heavy hadron decays | Haidenbauer, Kubis, Zou |
| A.2 | Hadron-hadron scattering in QCD                  | Liu, Urbach             |
| A.3 | Universality and EFT for threshold states        | Brambilla, Jia          |
| A.4 | Hadronic parity violation                        | Kaiser, Zhu             |
| A.5 | Quark mass dependence of heavy-light systems     | Guo, Meißner, P. Wang   |

- Project area B: **Emergence of Structure**

- |     |   |                        |
|-----|---|------------------------|
| B.1 | Nucleon form factors  | Dong, Meißner          |
| B.2 | Hadron spectroscopy   | Huang, Zhu, Zou        |
| B.3 | Hadronic molecules with heavy meson loops                       | Hanhart, Guo, Zhao     |
| B.4 | Boxed exotica   | Liu, Rusetsky          |
| B.5 | Exotic states from lattice QCD                                  | Chen, Urbach           |
| B.6 | Hadronic systems with strange quarks                            | Rusetsky, Weise        |
| B.7 | Chiral dynamics of nuclei & hypernuclei                         | Meißner, Nogga, Kaiser |
| B.8 | Quarkonium interactions in hadronic, nuclear and thermal matter | Jia, Vairo, J. Wang    |

⇒ 10 of 13 projects have chinese & german project leaders!

# Scientific goals

- Symmetry tests in hadrons and nuclei & precision calculations

A.1,A.2,A.3,A.4,B.3,B.6

- Structure and dynamics of (heavy) hadrons

A.1,A.2,A.3,A.5,B.1,B.2,B.3,B.4,B.5,B.6

- QCD-based structure of nuclei, hypernuclei and nuclear matter

A.2,A.4,B.6,B.7,B.8

- *note: many further cross-links by use of common (non-perturbative) methods*

# Status and achievements

- CRC 110 officially started July 1<sup>st</sup>, 2012
  - ↳ what have we done/achieved in the first 2 1/4 years?
- Measures within the CRC within the first funding period (FP):
  - ★ (Bi-)Annual CRC meeting, so far always in China
    - [first meeting organized at KITPC Beijing, July 2-6, 2012]
    - [second meeting at Weihai, China, July 25-29, 2014] → photo
  - ★ CRC focus workshops: recent developments/smaller groups
    - [Workshop on Strangeness and Nuclear Physics, TUM, Oct. 2012]
    - [Workshop on Threshold Phenomena, IHEP, Beijing, April 27-28, 2013]
    - [Workshop on Lattice QCD, Bonn, July 23-24, 2013]
    - [Workshop on Strangeness and related topics, ECT\*, Trento, Dec. 5-6, 2013]
    - [Workshop on  $B \rightarrow \pi\pi$  semileptonic decays, Bonn, Feb. 21, 2014]
    - [more to come ...]

# CRC meeting 2014 at Weihai

- 56 Chinese and 32 German participants - status reports and lots of discussions
- Chinese midterm review and also preparations for the next funding period (FP2)



# Making the CRC work cont'd

## • Measures within the CRC in the first FP

- ★ CRC contribution to larger meetings/programs

[Quarkonium 2013, IHEP, Beijing, April 22-26, 2013]

[KITPC program “Status of the nuclear interaction”, Beijing, Aug.-Sept. 2014]

[Quarkonium 2014, CERN, Switzerland, Nov. 10-14, 2014]

[Bethe Forum on Methods in Lattice Field Theory, Bonn, Apr. 2015]

- ★ many mutual visits of PIs, Post-Docs and students

↔ **collaborations have visibly increased** → Guo's talk

- ★ Joint graduate (Ph.D.) students (one chinese and one german supervisor)

## • Other measure of success: Publications

- ★ more than 120 publications, about 20 common ones

[10 PRL, 12 PLB, 36 PRD, 10 JHEP, 9 EPJA, 7 EPJC, ...]



# First steps towards a common graduate education

- research phase of the PhD (3 years)
- students have at least two supervisors
- students spend time at the home & the host institution
- MSc courses mutually accepted

Sept. 17, 2012



- similar MoU with the ITP of the CAS



**Memorandum of Understanding**

between

**The Faculty of Mathematics and Natural Sciences,  
University of Bonn, Bonn, Germany**

and

**The School of Physics,  
Peking University, Beijing, China**

regarding a

**Common Ph.D. program in Physics**



# First steps towards a common graduate education cont'd

- MoU w/ IHEP signed March 21<sup>st</sup>, 2014
- First commonly supervised student:  
Martin Cleven / PhD Dec. 12, 2013  
“Systematic Study of Hadronic Molecules in the Heavy Quark Sector”
  1. Supervisor: UGM
  2. Supervisor: Prof. Qiang Zhao
  3. Supervisor: Prof. Christoph Hanhart
- next in line: Ina Lorenz  
“Theory of Nucleon Form Factors”
  1. Supervisor: UGM
  2. Supervisor: Prof. Yu-Bing Dong
  3. Supervisor: Prof. H.-W. Hammer (TUD)
- how about the Chinese side?



# Outreach

- Special project on outreach - multiple activities
- Education of high-school students and high-school teachers
  - first program in 2013, again in 2015
  - topics include:
    - Forces in nature
    - Building blocks of matter
    - Computer simulations
    - Particle and hadron physics
    - Nuclei, elements and stars
    - Structures in the Universe

- Physik-Show → Beijing 2015/16

<http://physikshow.uni-bonn.de>

**TEILCHENPHYSIK**

Schülerakademie (21.–25.10.2013)  
Lehrerfortbildung (20. – 21.9.2013)  
Science College Haus Overbach, Jülich

Kerne  
Protonen  
Simulationen  
Computer  
Urknall  
Dunkle Materie  
Quarks  
Higgs

Wie funktioniert die Welt bei kleinsten Abständen?  
Was wissen wir (und woher) – und vor allem: Was wissen wir nicht?  
Anmeldung bis 31. Juli und nähere Informationen:  
<http://ord.hisq.uni-bonn.de>

DFG

<http://crc110.hiskp.uni-bonn.de>

**CRC 110**  
Symmetries and the emergence of Structure in QCD

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**CRC 110: Symmetries and the Emergence of Structure in QCD**

The Sino-German CRC 110 deals with one of the most challenging problems in contemporary theoretical physics, namely the theory of strong interactions QCD. The CRC focusses on the emergence of structure like hadrons and nuclei and the role of symmetries in QCD. This is the first time that such a unified approach of hadronic and nuclear physics is attempted.

**Interactions**  
hadron decays  
hadron scattering  
hadrons in nuclei

**QCD**

**Symmetries**  
chiral, conformal  
heavy quark, flavor  
supersymmetry  
PCT

**Structure**  
hadrons  
nuclei  
exotics

The CRC also pioneers a collaboration of leading scientists in this field from China (IHEP and Peking University) and Germany (Bonn University, FZ Jülich, TU Munich). The CRC is co-funded by the NSFC and the DFG.

Rechtlicher Hinweis  
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Zuletzt bearbeitet: 16.07.2012. Email: [www@hiskp.uni-bonn.de](mailto:www@hiskp.uni-bonn.de)

# Outlook and wish list

## Outlook 1: Structural issues for FP 2

- Enlarge the German side of the CRC: add the **Ruhr-Universität Bochum (RUB)**
- New PIs: **Evgeny Epelbaum (NP,HP)**, **Hermann Krebs (NP,HP)**,  
**Maxim Polyakov (HP)**, **Ulrich Wiedner (HP)** [PWA activities for BES/PANDA]
- why?
  - longstanding and successful collaboration since 1998 (65 papers w/ 3600 cites)
  - very much improves the nuclear physics side of the CRC (still too weak)
  - improves the possibilities for collaboration w/ Chinese colleagues
- However: any change in composition of a CRC comes with a certain risk  
→ assessment under way
- Other changes: F.-K. Guo moves to ITP, Bonn position taken by Q. Wang (FZJ)  
include T. Luu as new PI from FZJ [however: be aware of the 30% rule]
- New TUM PI: **Martin Beneke** (Charmless B decays), position of W. Weise?

## Outlook 2: Structural issues for FP 2

- Enlarge the Chinese side: add **ITP of CAS** (instead of TPCSF)
  - (New) PIs: **Bing-Song Zou, Feng-Kun Guo, Shan-Gui Zhou, ...**
- ⇒ substantial enlargement and reinforcement of the CRC
- Enlarge also the PKU part
    - **Jie Meng** should be added as new PI
    - strengthening of the **nuclear physics** part (together with S.-G. Zhou)
    - started collaboration this fall with his group (Epelbaum, UGM, Meng)
  - New possible IHEP PI: **Cai-Dian Lü** (HP) → connection to M. Beneke (TUM)
  - However: The problem of the # of NSFC PIs/grants needs to be solved beforehand, it has to be attacked now! visit of B.-S. Zou and UGM to NSFC Sept. 1  
→ **we need your help !**



# Summary and outlook

- Making the first funding period a success
  - ↔ aim for over-achievement in all projects (lattice most difficult)
  - ↔ we are on a very good way !
- Include more colleagues from PKU, from IHEP and from the ITP
  - ↔ broaden the base to include chinese nuclear physicists!
  - ↔ moderate increase from 10 to 13 PIs and also the funding
- Include one more strong german partner → RUB [second/third funding period]
  - ↔ must be strong / 3 university limit in Germany → nuclear physics
  - ↔ increase in funding from the DFG foreseen: 1.3 → 1.7 M€/year

⇒ CRC110 = Role model for a long-term & successful Sino-German collaboration



**Thank you for your attention !**

