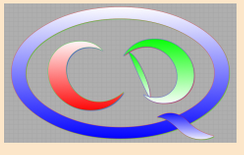
UNIVERSITÄT BONN

bctp

CENTER FOR SCIENCE & THOUGHT

JÜLICH Forschungszentrum

– The Sino-German CRC 110 –
Symmetries and the Emergence of Structure in QCD
–Genesis, Developments & Perspectives –



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

Deutsche Forschungsgemeinschaft DFG

国家自然科学基金委员会
National Natural Science Foundation of China

CONTENTS

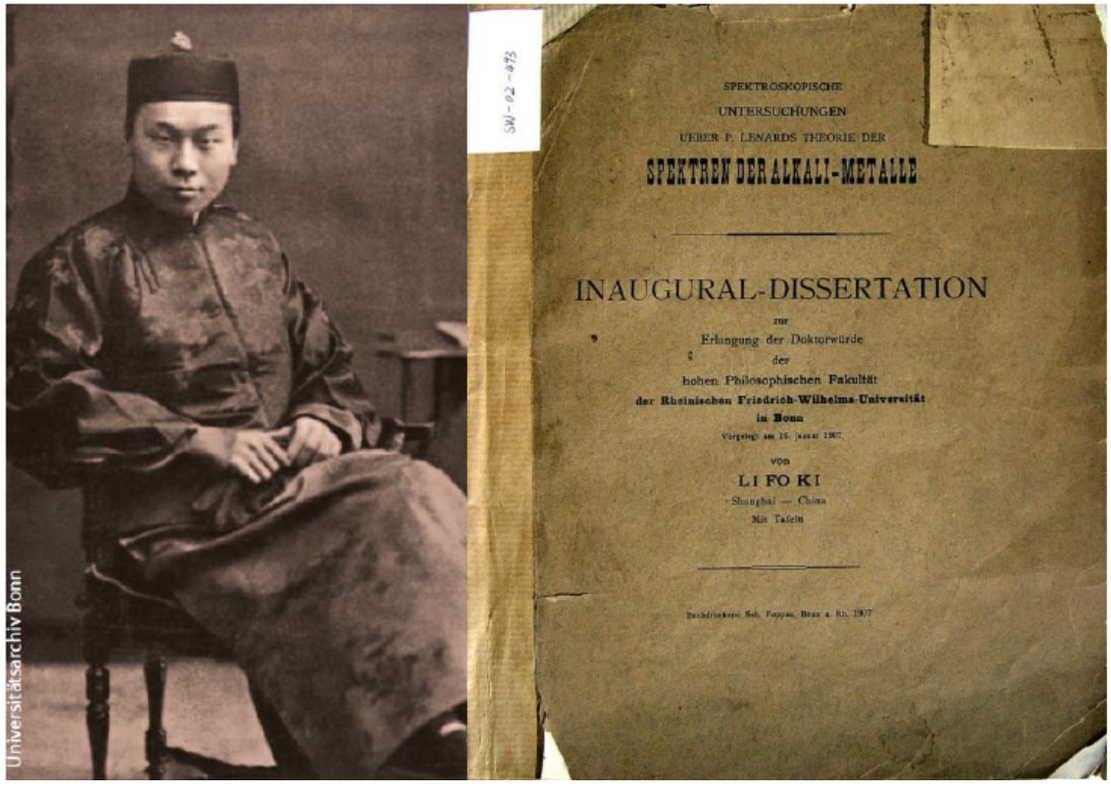
- Genesis of CRC 110
- Topics in the CRC 110
- Structural developments
- Status and achievements
- Perspectives

Genesis of the CRC 110

A bit of history

- Germany - an historically excellent place for fostering Chinese physicists

⋆ The first Chinese PhD in physics
Li Fo Ki, Univ. Bonn, 1907



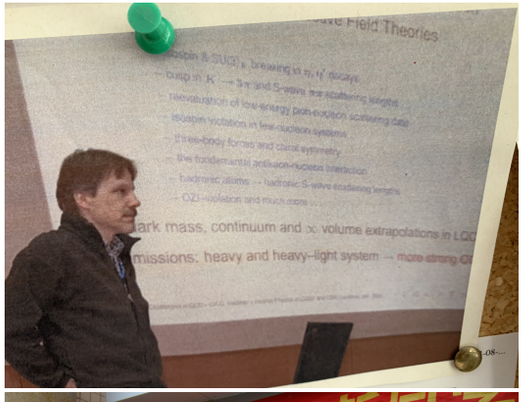
The first female Chinese Academician of physics
He Zehui, PhD TUB, 1940

First contacts with Chinese colleagues

- Sino-German Symposium “Hadron Physics at COSY & CSR”
  Institute of Modern Physics / CAS, Lanzhou, June 2006
  Summary talk (theory)

- Lectures on “Theory of Nuclear Forces”
  Guangxi Normal University, Guilin, September 2009

- 4th Internat’l Workshop on Charm Physics “CHARM2010”,
  Institute of High-Energy Physics, Beijing, October 2010
  plenary talk



$\Rightarrow$ China emerges as main player in basic sciences

$\Rightarrow$ tremendous talent pool (mostly US-oriented)

$\Rightarrow$ try to collaborate on a bigger scale

$\Rightarrow$ a golden window of opportunity opens

What is a Colloborative 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 strengthen 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 [DFG website 2014]

The partners

- Setup simply driven by scientific excellence and complementarity
- requires one driver on both sides

Institute of High Energy Physics, CAS, Beijing

Peking University

Institute for Theoretical Physics, CAS [from 2nd FP]

Rheinische-Friedrich-Wilhelms-Universität Bonn

Technische Universität München

Forschungszentrum Jülich

Ruhr-Universität Bochum [from 2nd FP]

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 1200 researchers and about 600 postdocs & graduate students

  Accelerator Center, Experimental Physics Center, Theory Division, Particle-Astroparticle Center, Computing Center, Technology R&D Center, Multi-disciplinary Center

- Host of the 3 big international experimental facilities
  - → CSNS, HXMT, HEPS

Peking University

- **The first and top comprehensive university for humanities, natural & social sciences in China**

- 18 disciplines of PKU rank in the world top 1%
  $\rightarrow$ Mathematics, Physics, Chemistry, Materials Science, ...

- 39 schools & departments, $\sim$30000 students

- School of Physics: 200 faculty and staff, $\sim$1400 students
  Inst. of Theoretical Physics (ITP),
  Inst. of Condensed Matter & Material Physics,
  Inst. of Heavy Ion Physics, ...,
  + Dept. of Astronomy, ...

- the largest number of alumi elected as CAS Academicians

- the most Chinese high-school IPhO Gold medalists

Institute of Theoretical Physics (ITP)

- **Top institution in China for theoretical physics**

- established in 1978, approved by Deng Xiao-Ping
  $\rightarrow$ Peng Huanwu (PhD of Max Born) as founding director

- About 40 faculty researchers
  with 40% stayed a few years in Germany
  and about 25 postdocs & 140 graduate students

- First institution in China to award PhD
  and to start a postdoctoral program

- Largest number of national awards
  in theoretical physics

Starting point

- Very challenging endeavour, requires complementary and overlapping expertise

$\Rightarrow$ this is available at the various institutions forming this CRC

- Large investment in facilities requires concentrated theory effort

$\Rightarrow$ strong focus on data from BEPC-II (now) and FAIR (future) $\rightarrow$ slide

- Improving the bilateral scientific relations

$\Rightarrow$ best use of the science brain pool in both countries

- Builds on earlier and on-going collaborations by some of the PIs

$\Rightarrow$ [Brambilla, Vairo, Jia], [Guo, Hanhart, Meißner, Zhao], [Hanhart, Guo, Zou] [Kaiser, Meißner, Weise], [Rusetsky, Weise], [Dreiner, Hanhart], ...

$\Rightarrow$ Potential for a long-term synergy and innovation very much desired by the partners

Hadron Physics Complexes

- present and future HPC = Hadron Physics Complexes $\rightarrow$ BEPC-II, FAIR

  (the contenders: B-factories and colliders)

Thoughts form the Chinese side

- Long-standing problems:
  - Lack of up-to-date knowlwedge / modern perspective
  - Lack of creativity (central system)
  - Qian Xuesen's question:
    "Why do our universities always fail
    to nurture outstanding talents?"

©Wikipedia

- The situation was changing at that time
  - 100 Talents Program of CAS (from 1994), more than 2200 recruitements
  - 1000 Talents Plan (from 2008), more than 2000 recruitements (univ., CAS, industry)
  - later: 10000 Talents Plan (not to be talked about officially)
  - later: Young Talents Plan (not to be talked about officially)
  - Seeking international collaborations with top institutions, such as in this CRC

Principal Investigators (PIs)

- Principal investigatorss (1st FP):

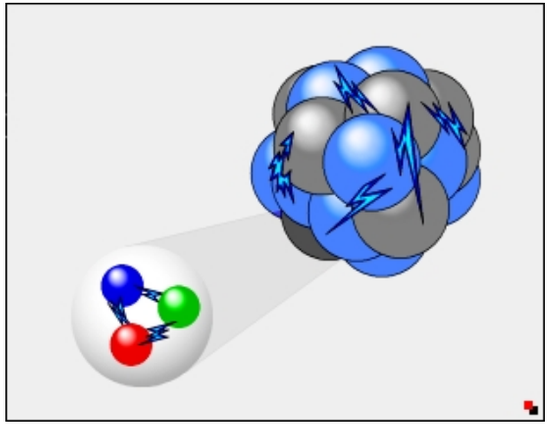
IHEP	Prof. Y. Chen, Prof. Y. Dong, Prof. M. Huang, Prof. Y. Jia, Prof. J.-X. Wang, Prof. P. Wang, Prof. Q. Zhao, Prof. B.-S. Zou [→ ITP/CAS]
PKU	Prof. C. Liu, Prof. S.-L. Zhu
UB	Prof. H. Dreiner, Dr. F.-K. Guo, [Prof. H.-W. Hammer,] Prof. B. Kubis, Prof. U.-G. Meißner, PD A. Rusetsky, Prof. C. Urbach
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

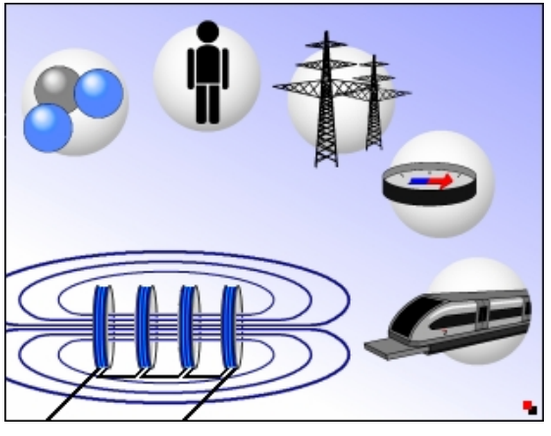
Topics in Strong QCD

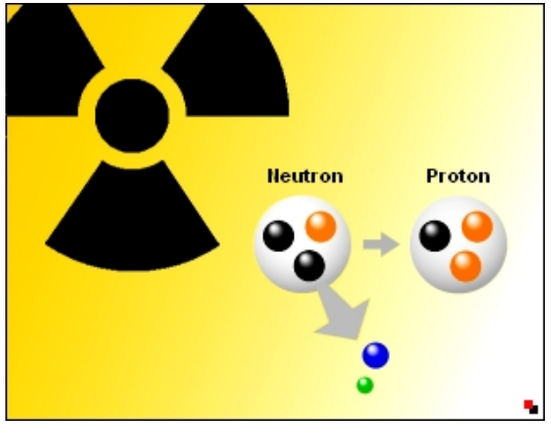
Forces in Nature

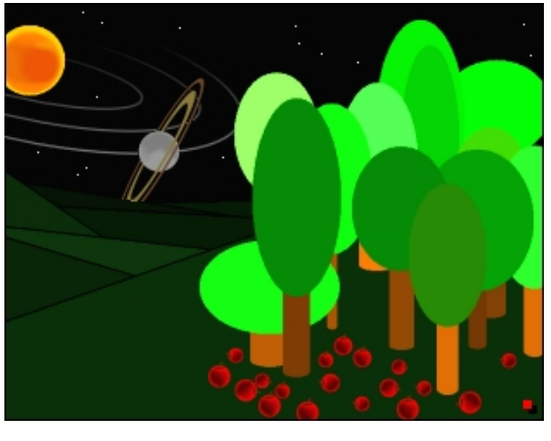
- 4 different forces: **strong**, electromagnetic, weak, gravitation

  Standard Model





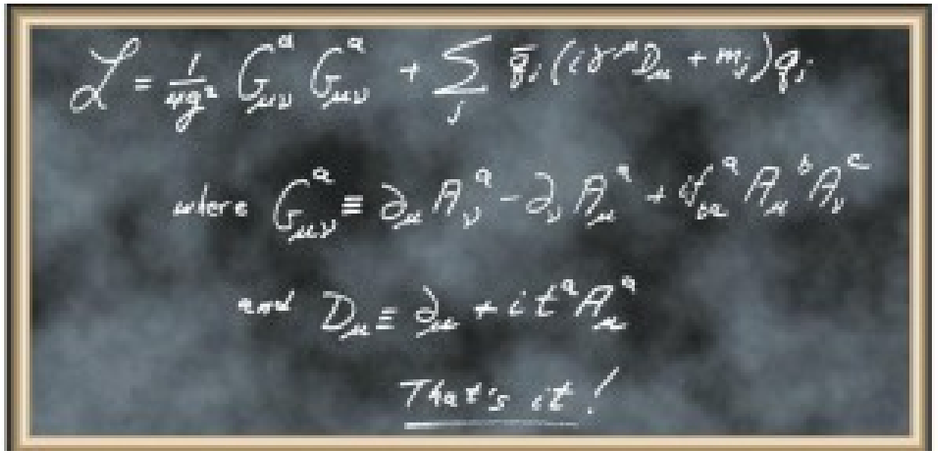




- three forces unified (Standard model of particle physics)
- Gravity plays no role on (sub)atomic scales
- The strong force is still not understood despite the underlying theory called Quantum Chromodynamics being known

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

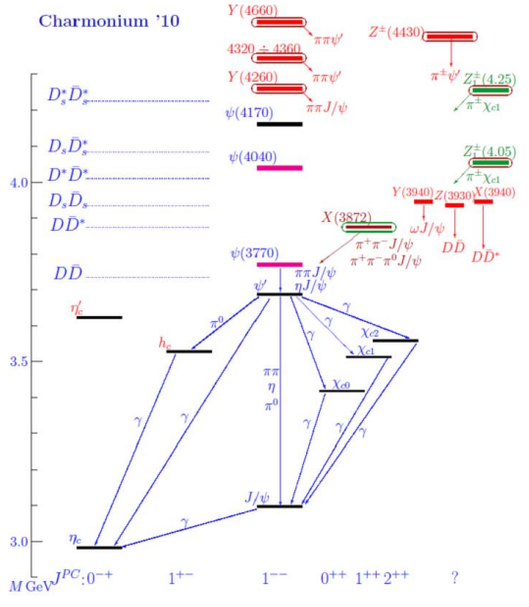
$\longrightarrow$ *interplay of lattice QCD, EFTs and models*

Facets of strong QCD

- quarks and gluons form hadrons

  ⇒ **lattice QCD + EFT + models**

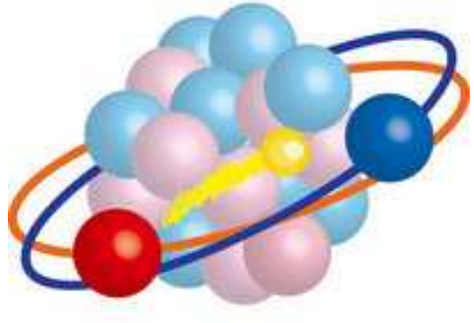
  ⇒ exploring the strong color force



- nucleons and mesons form nuclei

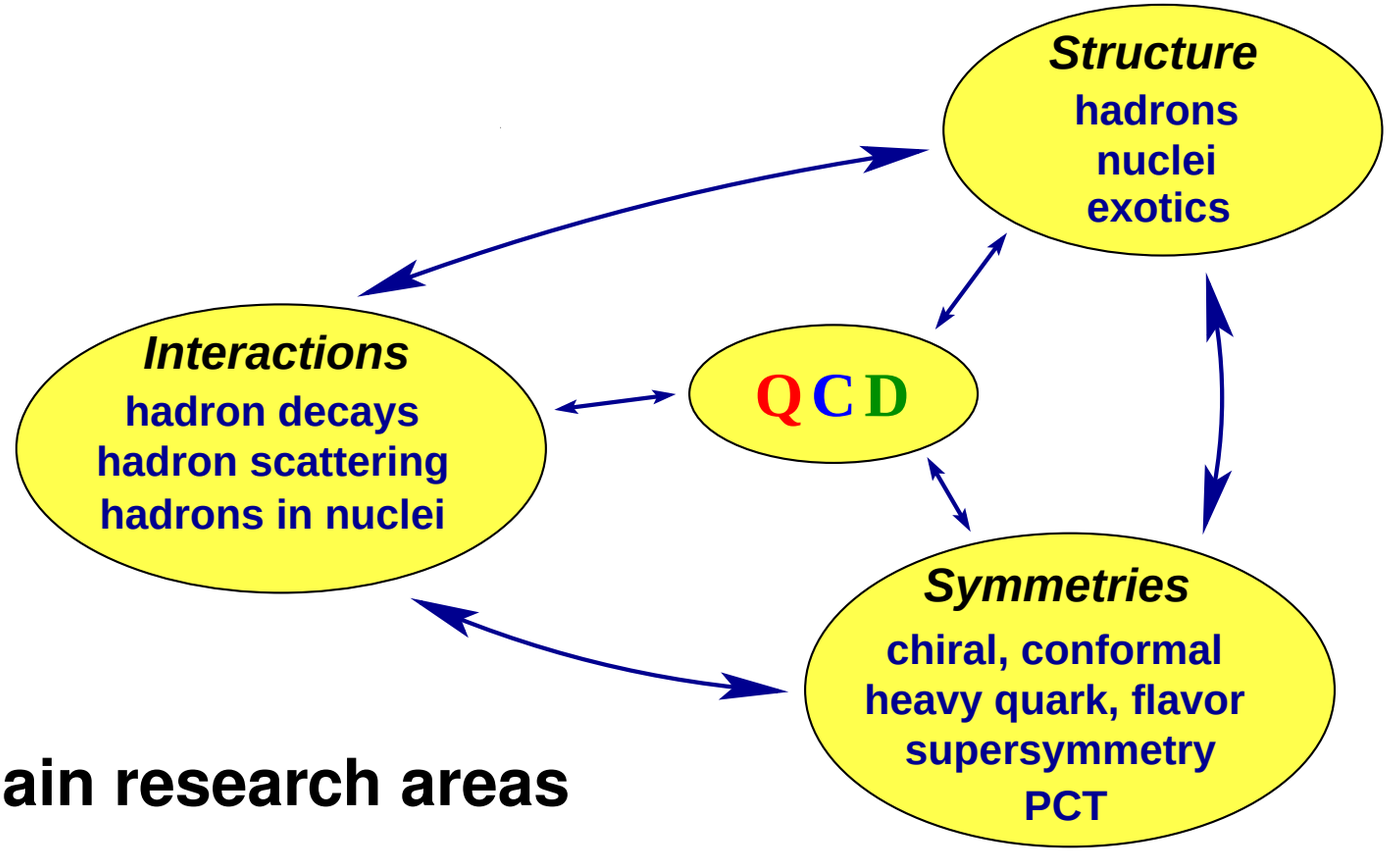
  ⇒ **nuclear physics (EFT, lattice, . . .)**

  ⇒ exploring the residual color force



Joint investigations of hadrons and nuclei:
world-wide unique approach

QCD research in CRC 110



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

  A – symmetries

  B – emergence of structure

- **strongly intertwined**

Project areas

- 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

Projects strongly intertwined across the areas

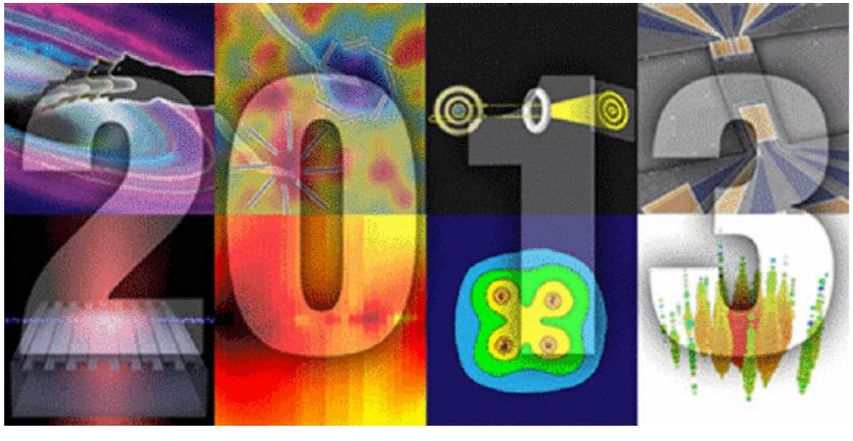
$\Rightarrow$ 10 of 13 projects have chinese & german project leaders!

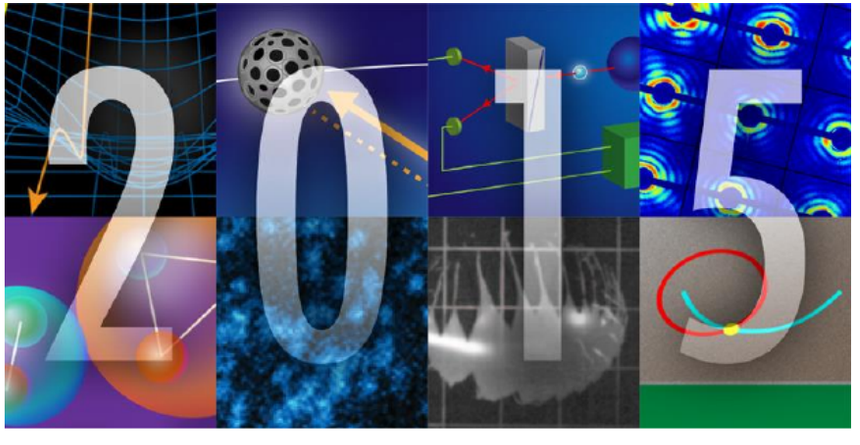
Research highlights

- Top highlights in strong QCD during FP1 (APS)

#1: Discovery of the Zc(3900)
by BESIII & Belle

#2: Discovery of the Pc states
by LHCb





↪ **CRC PIs played a leading role for predictions and explanations**

W. Chen, H.X. Chen, X. Liu, S.L. Zhu, Phys. Rept. **639** (2016) 1 719 cites

F.K. Guo, C. Hanhart, U.-G. Meißner, Q. Zhao, B.S. Zou,
Rev. Mod. Phys. **90** (2018) 015004 627 cites

Structural Developments

Major changes over time

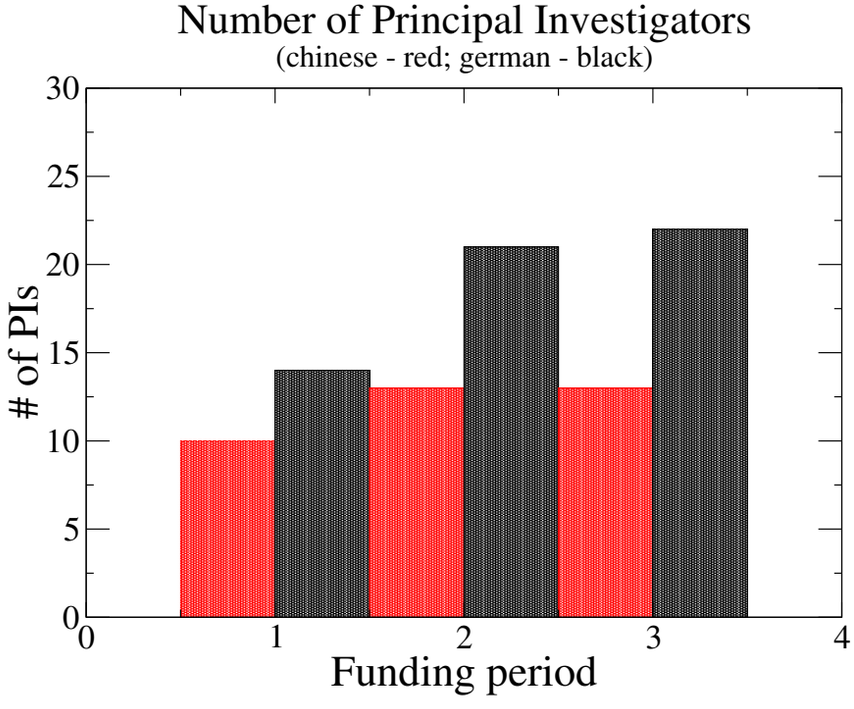
- The CRC is a living organism:
  - some projects get finished, new ones appear
  - some project leaders leave, new ones emerge (esp. younger ones)
- Founding period 1 (FP1) showed that this large scale collaboration indeed works
  $\rightarrow$ enlarge it!
- Largest structural developement from FP1 to FP2:
  - Include more **nuclear physics** projects ($\mathbf{3} \rightarrow \mathbf{6}$)
  - New nodes: RUB on the German side and ITP on the Chinese side
- Strengthen the connection to/collaboration with experiment
  - 3 experimental PIs in analysis projects (partly mixed with theoreticians)

$\hookrightarrow$ Visible increase in the number of PIs: $\mathbf{24} \rightarrow \mathbf{34} \rightarrow \mathbf{35}$

FP1 FP2 FP3

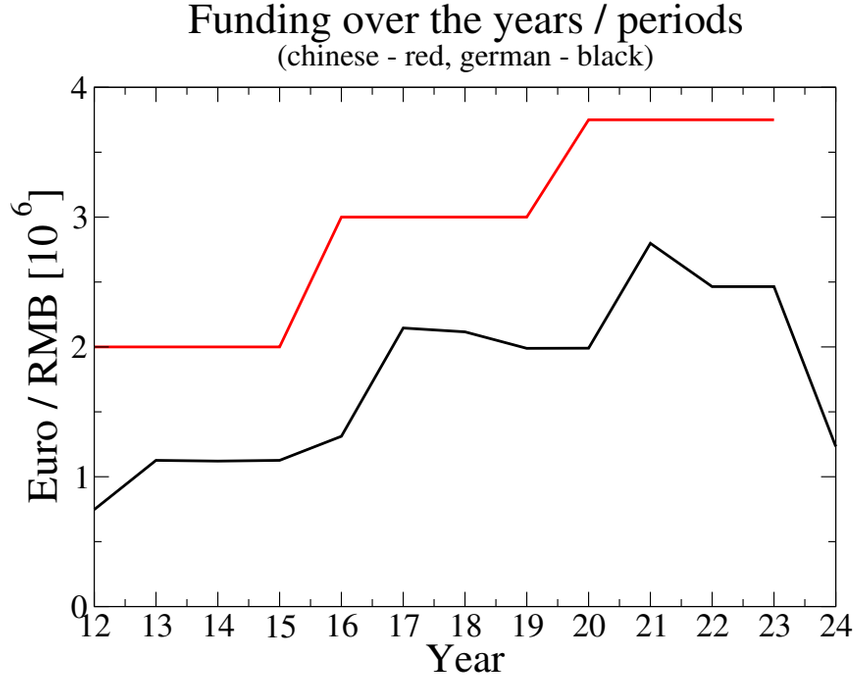
Major changes over time II

- Increased # of PIs



	Bonn	FZJ	TUM	RUB	IHEP	ITP	PKU
FP1	7	3	4	-	8	-	2
FP2	8	4	5	4	7	3	3
FP3	8	4	6	4	6	3	4

- increased funding



— Chinese funding only per fiscal year (lump sum)
— German funding with start of FP (07/12, 07/16, 01/21)
— German funding includes GPU cluster (irregular)
— German funding w/o Programmpauschale (20-22%)
— Fundings in terms of personal **comparable**

One major hurdle

- The NSFC terminated the contract for co-funded CRCs in January 2016
  - just one month before the review for FP2 in Beijing
  - this was not told to the PIs
  - FP2 was not in jeopardy, but what about FP3?
- I started a 2.5 year long series of talks
  - NSFC Presidents, vice-presidents, rector of PKU, CAS president, ...
  - Chinese spokesperson helpful but had to avoid any confrontation
  - 2-page memo for the NSFC in September 2018 detailing all the successes of the CRC

On Nov. 9th, 2018, we were informed that we can apply for a third funding period!

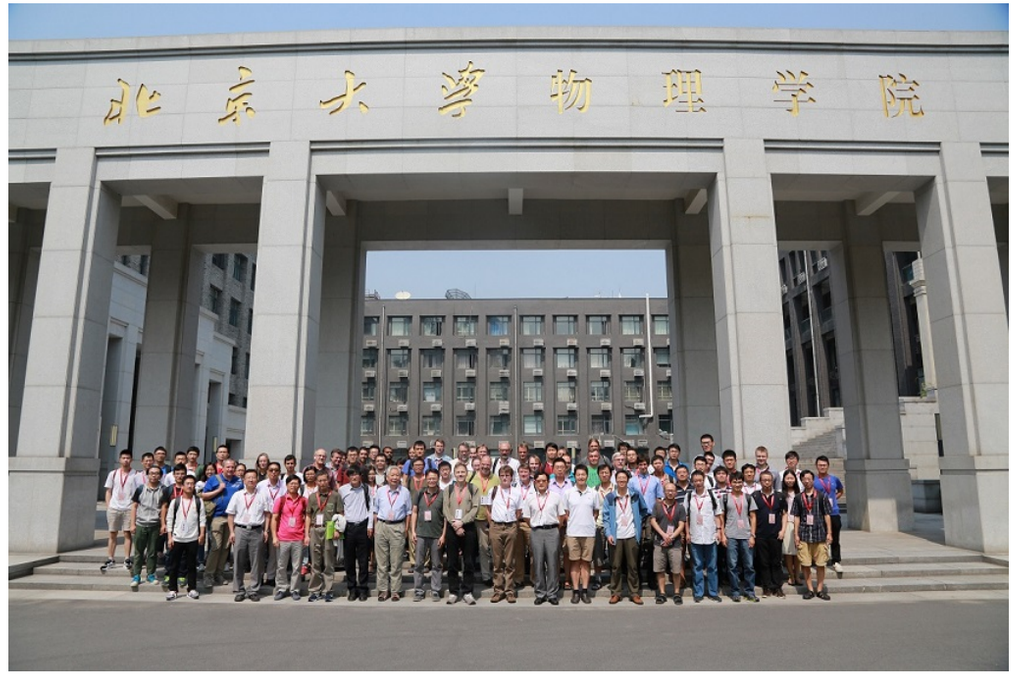
Status and Achievements

Making the CRC work I

- Large CRC meetings,
  always in China/once per FP

  2012 KITPC, Beijing [initial meeting]
  2014 Weihai
  2017 School of Physics, PKU
  2022 ITP, Beijing
  2024 Bonn [final meeting]

- Purposes:
  - get to know each other
  - Chinese midterm review
  - develop strategies for next FP
  - Initial and final meeting



Making the CRC work II

- Measures within the CRC:

  - ⋆ CRC focus workshops: recent developments/smaller groups
  - ⋆ CRC contribution to larger meetings/programs
  - ⋆ many mutual visits of PIs, Post-Docs and students

    $\hookrightarrow$ **collaborations have visibly increased over time**
  - ⋆ more than 120 finished and one-going PhD thesis
  - ⋆ Joint graduate (Ph.D.) students (one chinese and one german supervisor)

next slides

  - ⋆ Bi-annual Hadron Physics Summer School at FZ Jülich

    $\hookrightarrow$ **recruitmenent of students and postdocs**
  - ⋆ Associaton of an Emmy-Noether group in FP2 $\rightarrow$ PI in FP3

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

universitätbonn
Rheinische Friedrich-Wilhelms-Universität Bonn

北京大學 PEKING UNIVERSITY

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 21st, 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

- Further commonly supervised students

  Menglin Du (PhD 2017)

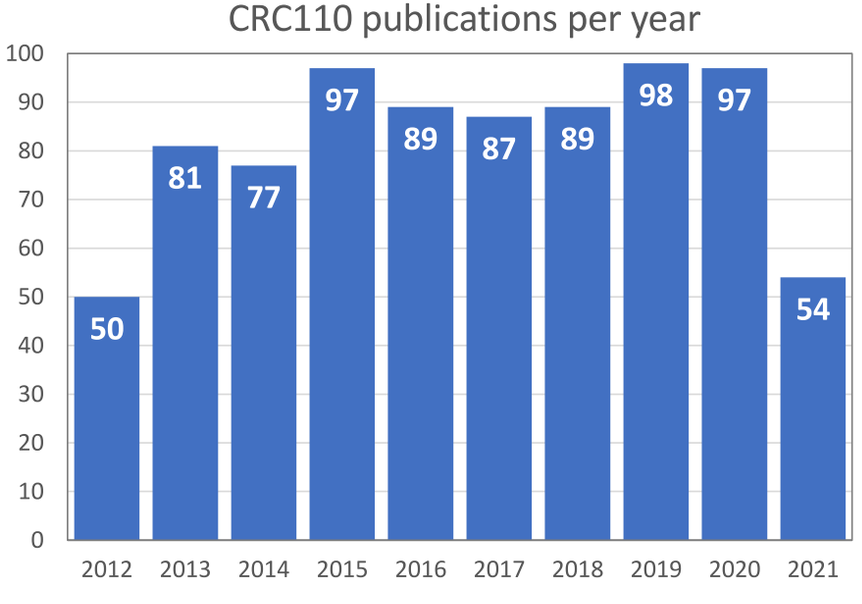
  Ripunjay Acharya (PhD 2019)

  Thomas Vonk (PhD 2022)

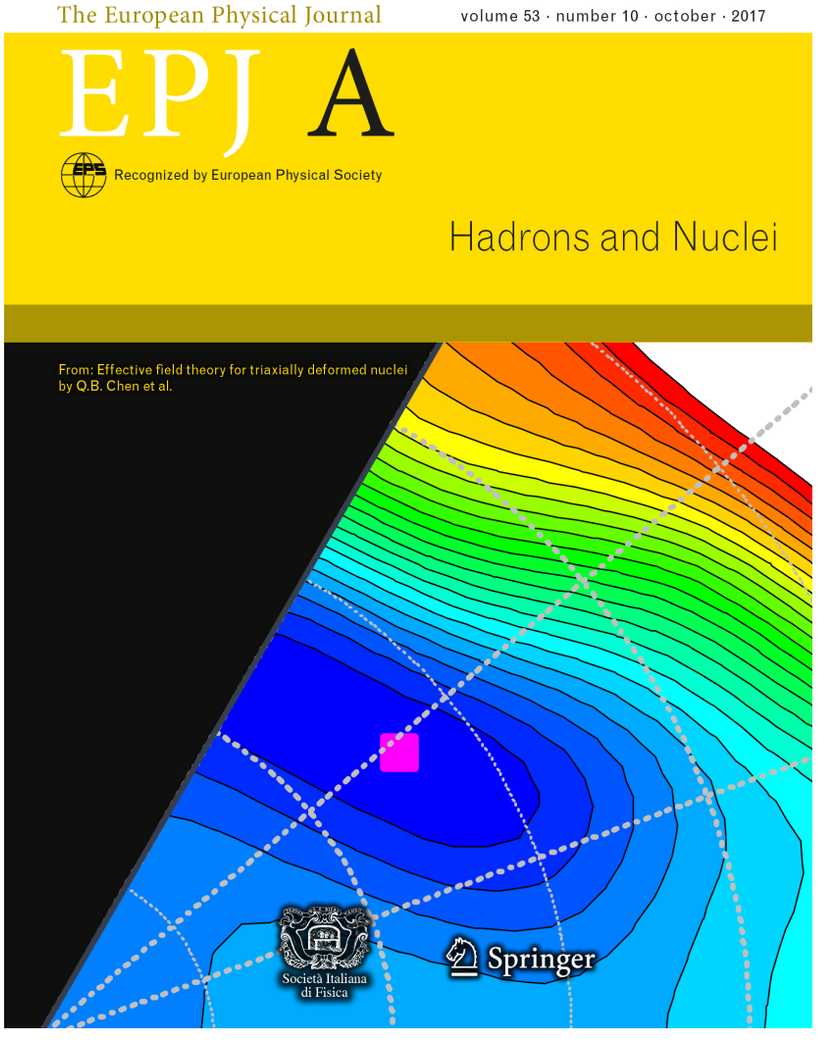
Making the CRC work III

- One measure of success: Publications
  - ⋆ more than 840 as of today
  - ⋆ at least 1/4 w/ two CRC nodes
  - ⋆ 1^{st} sino-german *Rev. Mod. Phys.*

    [Guo, Hanhart, UGM, Wang, Zhao, Zou]
  - ⋆ One textbook out of project B.9



TUM-Bonn-PKU collaboration



Effective field theory for triaxially deformed nuclei

Chen, Kaiser, UGM, Meng, EPJA 53 (2017) 204

Publications

- Very visible publications from the CRC

Already more than 600 cites

REVIEWS OF MODERN PHYSICS, VOLUME 90, JANUARY–MARCH 2018

Hadronic molecules

Feng-Kun Guo*

CAS Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China and School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China

Christoph Hanhart†

Institute for Advanced Simulation, Institut für Kernphysik and Jülich Center for Hadron Physics, Forschungszentrum Jülich, D-52425 Jülich, Germany

Ulf-G. Meißner‡

Helmholtz-Institut für Strahlen-und Kernphysik and Bethe Center for Theoretical Physics, Universität Bonn, D-53115 Bonn, Germany and Institute for Advanced Simulation, Institut für Kernphysik and Jülich Center for Hadron Physics, Forschungszentrum Jülich, D-52425 Jülich, Germany

Qian Wang§

Helmholtz-Institut für Strahlen-und Kernphysik and Bethe Center for Theoretical Physics, Universität Bonn, D-53115 Bonn, Germany

Qiang Zhao‖

Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China, School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China, and Theoretical Physics Center for Science Facilities, Chinese Academy of Sciences, Beijing 100049, China

Bing-Song Zou¶

CAS Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China and School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China

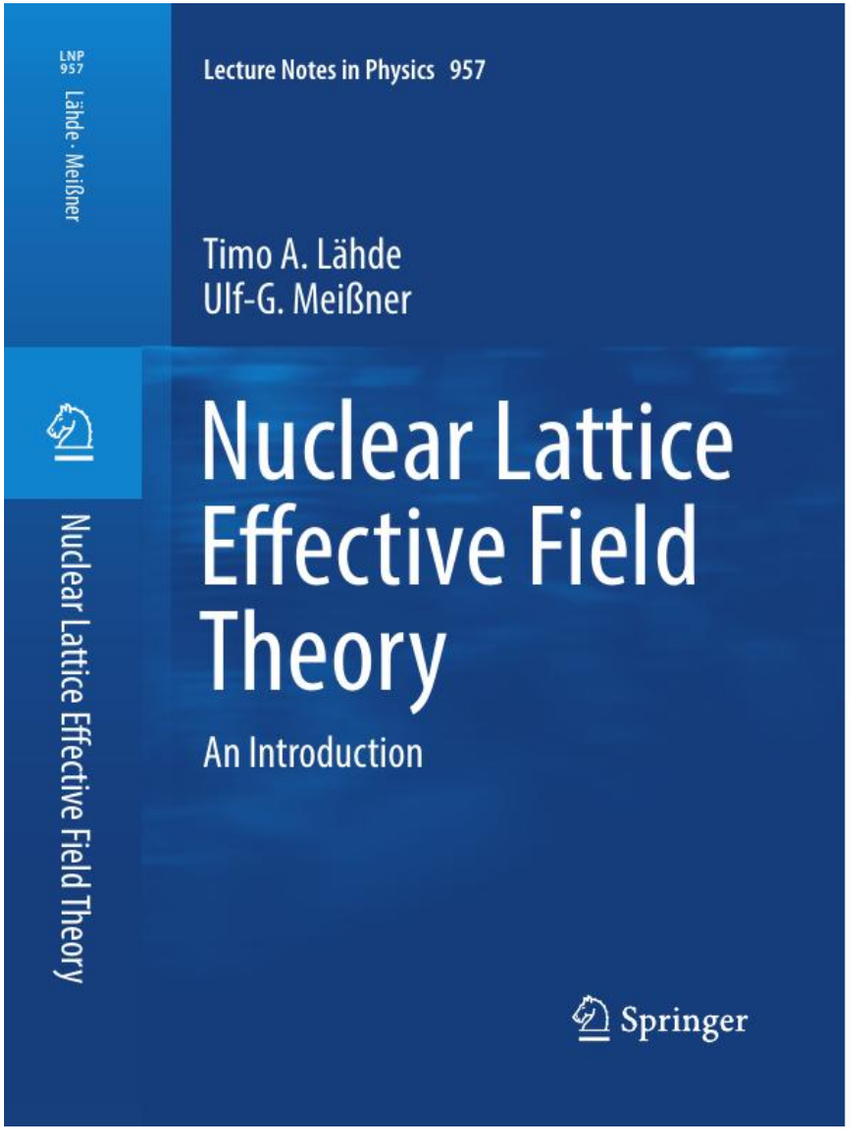
(published 8 February 2018)

A large number of experimental discoveries especially in the heavy quarkonium sector that did not meet the expectations of the until then very successful quark model led to a renaissance of hadron spectroscopy. Among various explanations of the internal structure of these excitations, hadronic molecules, being analogs of light nuclei, play a unique role since for those predictions can be made with controlled uncertainty. Experimental evidence of various candidates of hadronic molecules and methods of identifying such structures are reviewed. Nonrelativistic effective field theories are the suitable framework for studying hadronic molecules and are discussed in both the continuum and finite volumes. Also pertinent lattice QCD results are presented. Further, the production mechanisms and decays of hadronic molecules are discussed and comments are given on the reliability of certain assertions often made in the literature.

DOI: 10.1103/RevModPhys.90.015004

CONTENTS

*fkguo@itp.ac.cn
†c.hanhart@fz-juelich.de
‡meissner@hiskp.uni-bonn.de
§wangqian@hiskp.uni-bonn.de
‖zhaoq@ihep.ac.cn
¶zoubs@itp.ac.cn



Outreach

- Special projects on outreach - multiple activities $\rightarrow$ just discuss one

- Physik-Show http://physikshow.uni-bonn.de
  - predates the CRC
  - experiments performed by students
  - large appeal to young people/general public
  - EPS HEPP Division Outreach Prize 2009
  - travel to other places and catalyse similar events there (Barcelona, Oxford, . . .)
  - crowning trip to Beijing as a bridge between the cultures in March 2016
  - second trip to China (Beijing/Shanghai) in spring 2020 postponed (covid)

  $\hookrightarrow$ visible boost from the CRC

  $\hookrightarrow$ brings people together!

Careers

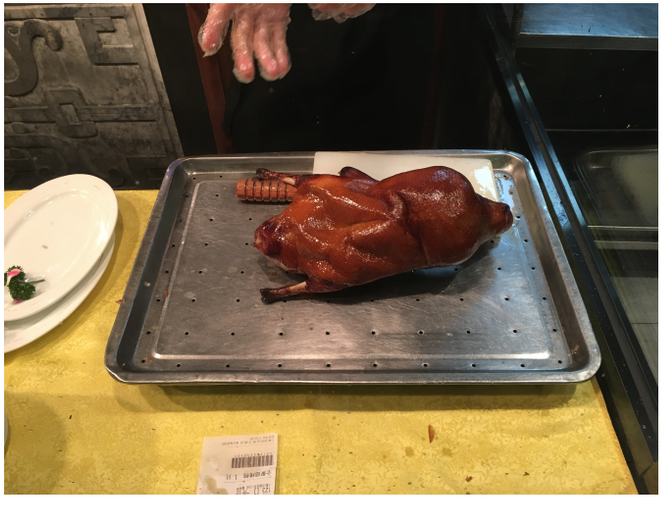
- A career booster for Chinese students and postdocs [* Winner of national young talents program]

Name	Position CRC	Position now	Institution
Yun-Hua Chen	postdoc	Assoc. Prof.	University of Science and Technology Beijing
Qibo Chen	postdoc	Prof.	East China Normal University
Lingyun Dai	postdoc	Prof.	Hunan University
Menglin Du	student	Postdoc	Valencia Univ./IFIC
Fengkun Guo*	PI Bonn	Prof.	Institute of Theoretical Physics, CAS
Xianwei Kang	student	Assoc. Prof.	Beijing Normal University
Ning Li	postdoc	Assoc. Prof.	Sun Yat-sen University
Liuming Liu	postdoc	Prof.	Institute of Modern Physics, CAS
Xiao-Hai Liu	postdoc	Assoc. Prof.	Tianjin University
Bingnan Lyu	postdoc	Assoc. Prof.	Graduate School of Chinese Academy of Eng. Physics
Li Ma	postdoc	Lecturer	Beijing Jiaotong University
Jing-Yi Pang	postdoc	Lecturer	University of Shanghai for Science and Technology
Qian Wang*	PI Bonn	Prof.	South China Normal University
Wei Wang*	postdoc	Prof.	Shanghai Jiaotong University
Jia-Jun Wu*	postdoc	Assoc. Prof.	University of Chinese Academy of Sciences
Chuwen Xiao	postdoc	Prof.	Central South University
Xiaonu Xiong	postdoc	Prof.	Central South University
Zhi Yang	student	Assoc. Prof.	Univ. of Electric Science and Technology of China
Deliang Yao	postdoc	Prof.	Hunan University

Some personal recollections

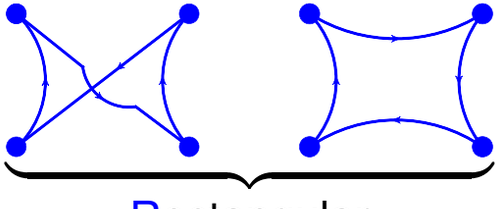
Some personal recollections II

- there are rumors I only do all this because of ...



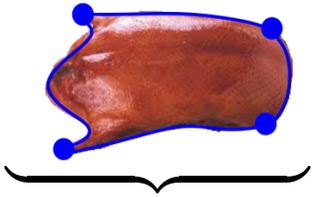
- introduced into physics by Feng-Kun Guo

$\hookrightarrow$ quark line diagrams in $\pi\pi$ scattering on the lattice



Rectangular

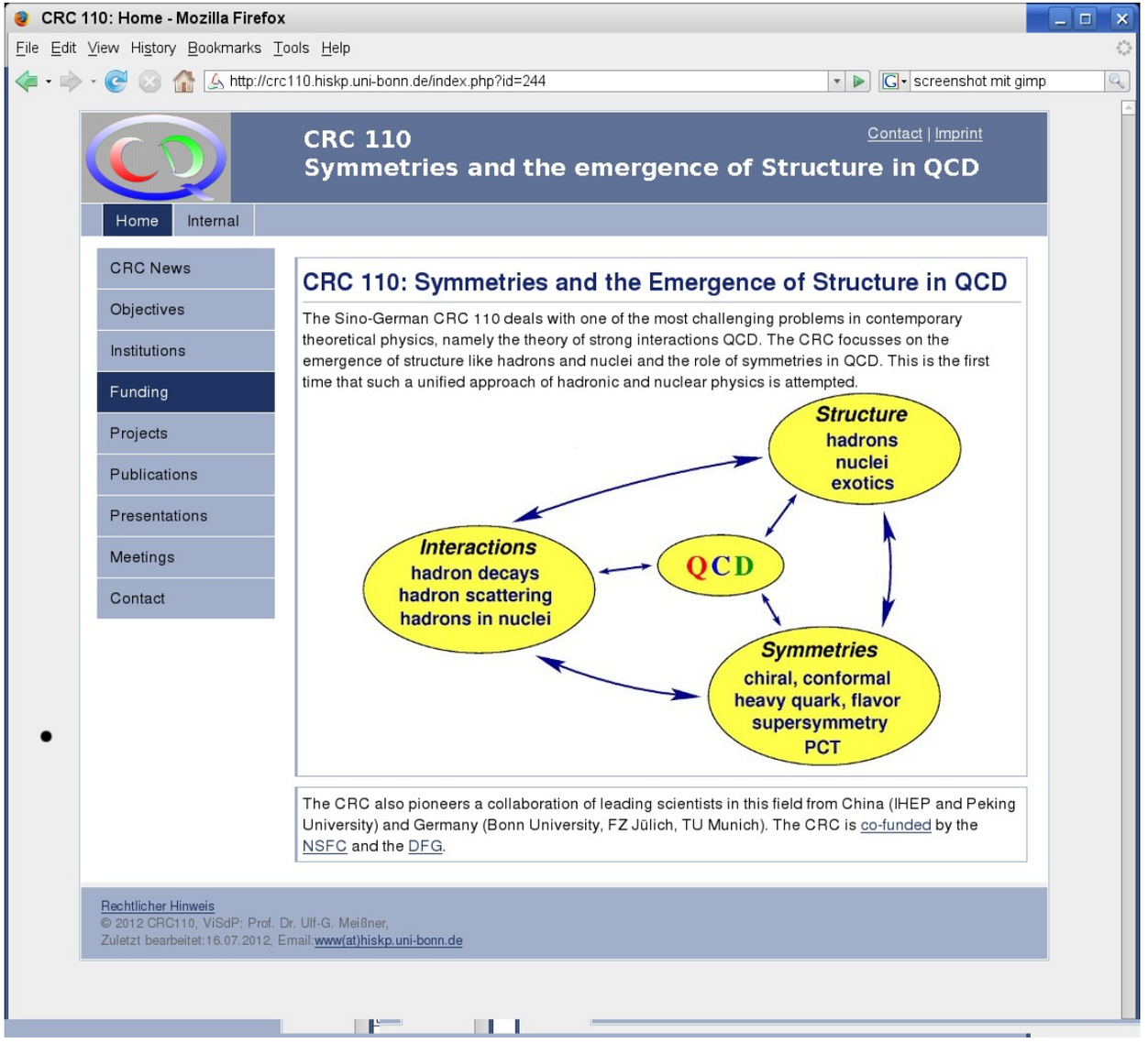
$\Rightarrow$



Roasted Peking duck

Much more info

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



Perspectives

Summary and outlook

- The CRC 110 so far is a success story and continues to be!
- The CRC 110 will officially end June $30^{\mathbf{th}}$, 2024

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

- What next?

  $\hookrightarrow$ such type of collaboration driven by individuals

  $\hookrightarrow$ situation in China is changing / disimproving

  $\hookrightarrow$ Chinese could do the next big jump in fundamental physics,
  but they are hesitant to do so ... but this is another story ...

universitätbonn

JÜLICH FORSCHUNGSZENTRUM

Technische Universität München

Thank you for your attention !

中國科學院高能物理研究所 Institute of High Energy Physics, Chinese Academy of Sciences

北京大學 PEKING UNIVERSITY

TPCSF-CAS

Rheinische Friedrich-Wilhelms-Universität Bonn

- 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)

Technische Universität München

- 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

Forschungszentrum Jülich

- Large interdisciplenary research center
- 11 institutes, about 5000 employes
- 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)