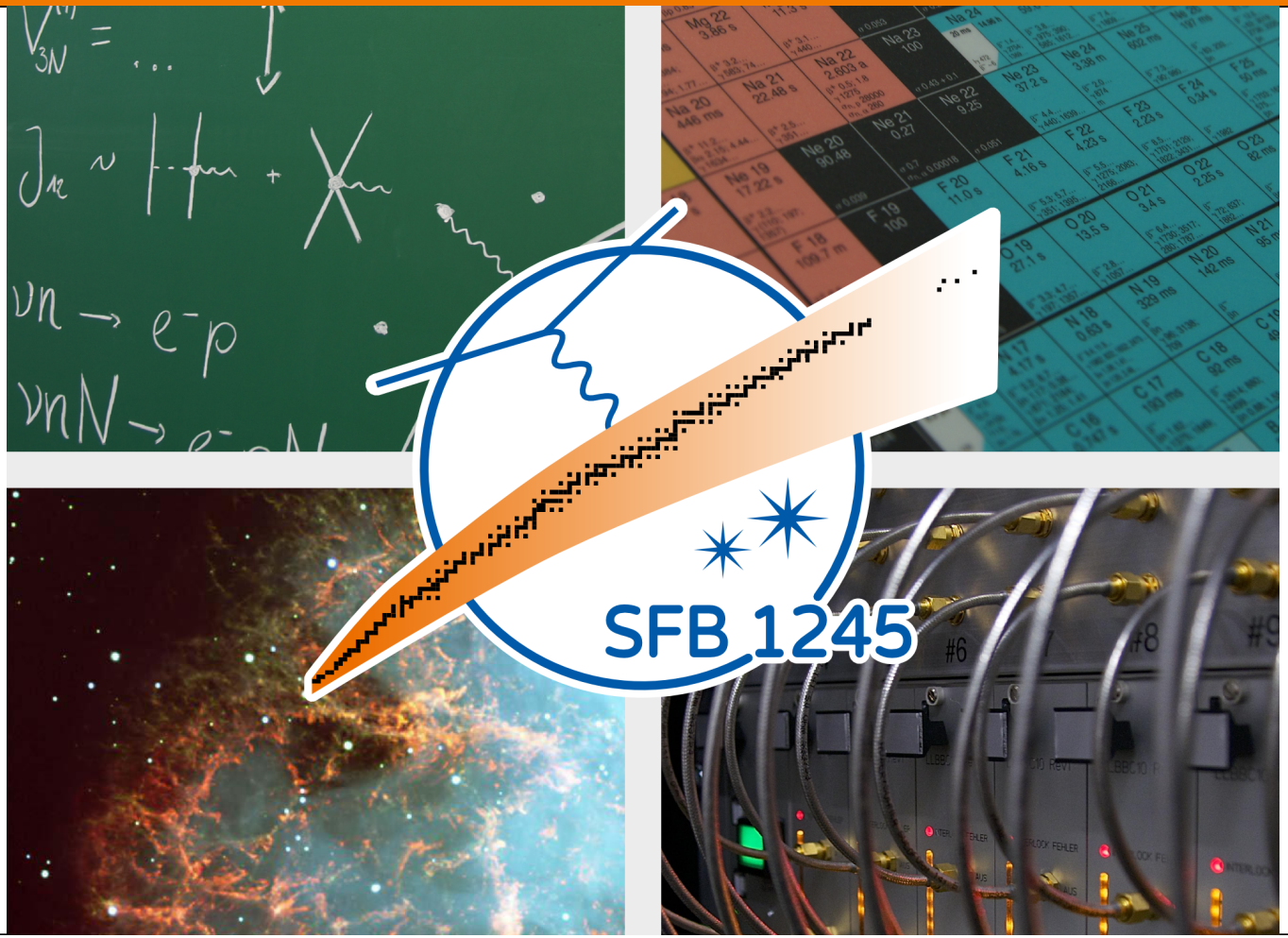
Nuclei: From Fundamental Interactions to Structure and Stars

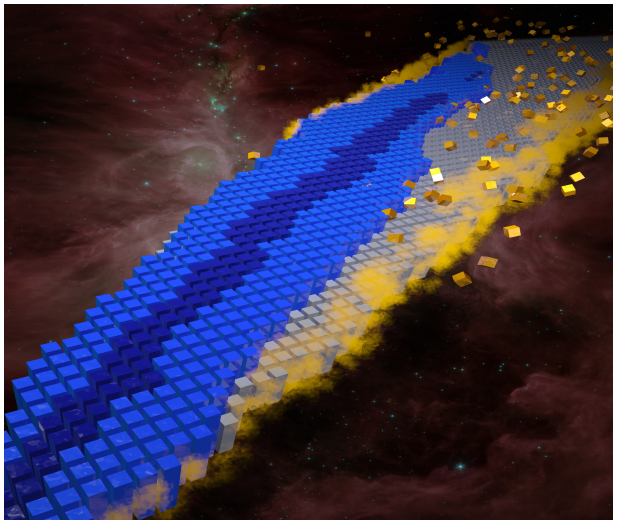


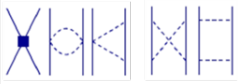
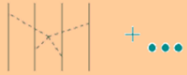
Nuclei: From Fundamental Interactions to Structure and Stars

Exciting era in nuclear physics

TECHNISCHE UNIVERSITÄT DARMSTADT

- **Effective field theories of QCD**
  Epelbaum *et al.*, RMP (2009)
  Hammer *et al.*, RMP (2013)
- **Advanced many-body methods**
  Wienholtz *et al.*, Nature (2013)
  Hergert *et al.*, PRL (2013)
- Open up systematic path for **all** nuclei and nuclear matter



Order	Nucleon-Nucleon (NN)	Three-Nucleon (3N)	Four-Nucleon (4N)
LO			
NLO			
N^2LO		 1994/2002	
N^3LO		 2011	 2006

Precision tests:

- N^3LO many-body forces predicted
- Consistent electroweak interactions

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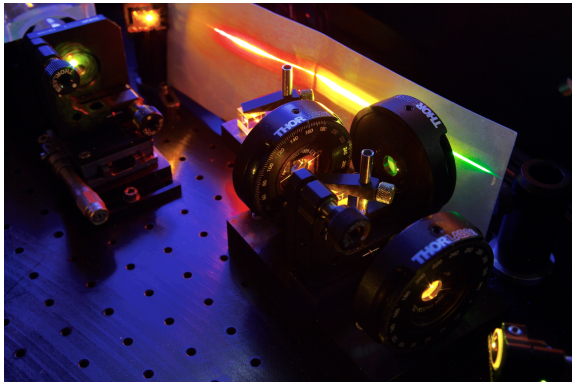
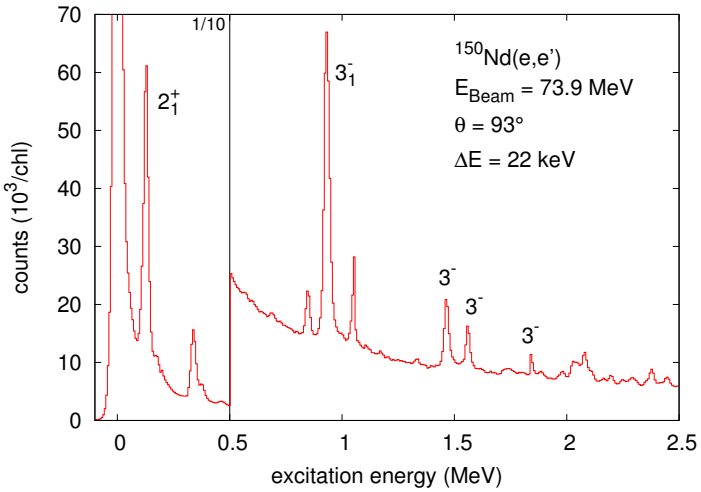
Exciting era in nuclear physics

TECHNISCHE UNIVERSITÄT DARMSTADT

- **Precision experiments with electromagnetic probes**
  high resolution at S-DALINAC
  worldwide unique in EFT regime

- **Novel laser spectroscopy techniques**
  Lu *et al.*, RMP (2013)





- New sensitivities with **neutron-rich records**

- Use best-suited facilities worldwide

Nobel Symposium 152: (2012)
Physics with Radioactive Beams
KUNGL. VETENSKAPS-AKADEMIEN THE ROYAL SWEDISH ACADEMY OF SCIENCES
IOP Publishing
NOBEL SYMPOSIA

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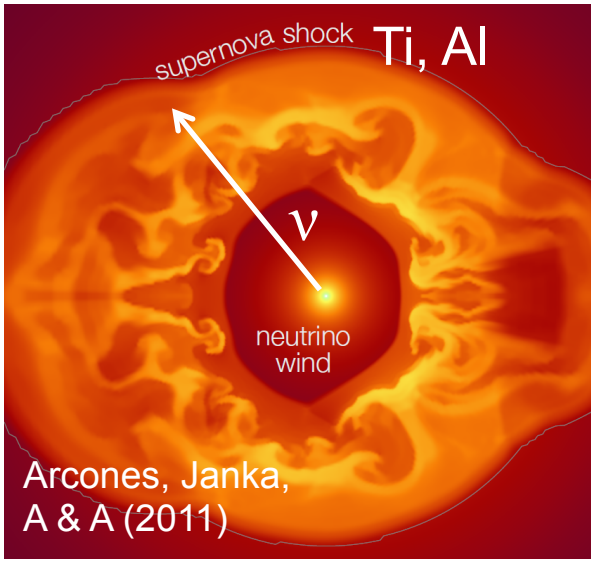
Exciting era in nuclear astrophysics

TECHNISCHE UNIVERSITÄT DARMSTADT

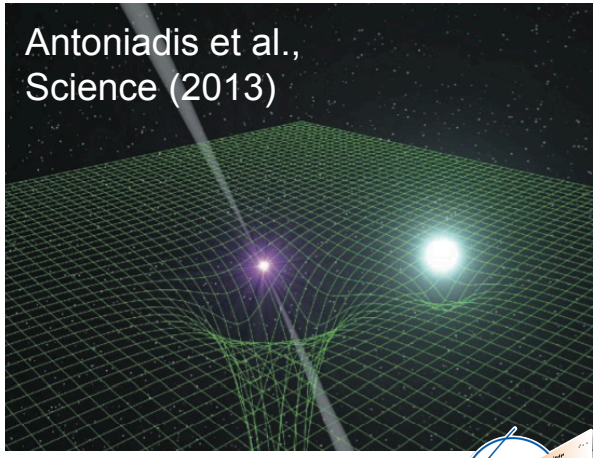
Nucleosynthesis in supernovae

- shock + neutrino-driven wind
- weak interactions are critical
  Roberts *et al.,* PRL (2012)
  Martínez-Pinedo *et al.,* PRL (2012)



Nuclear equation of state

- $2\,M_\odot$ neutron stars + chiral EFT
  Demorest *et al.,* Nature (2010)
  Hebeler *et al.,* ApJ (2013)
- New experimental constraints
  Tamii et al., PRL (2011)
- Key for supernovae, neutron-star mergers, neutrinos, gravitational waves



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Research goals – Central questions

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Explore **strong interactions in nuclei**,
their role in **astrophysics** and **related fields**

with **unique experiment-theory synergies** in Darmstadt

- How does the nuclear chart emerge from chiral EFT?
- Will our understanding of nuclear forces pass the test of novel precision measurements?
- How do electroweak interactions couple to nuclei?
- How do nuclei, neutrinos, and the equation of state impact the nucleosynthesis in core-collapse supernovae?

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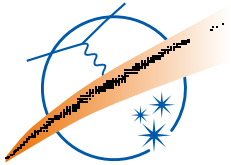
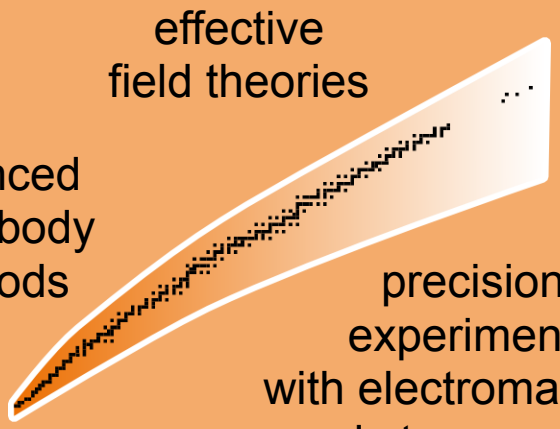
Structure of SFB 1245

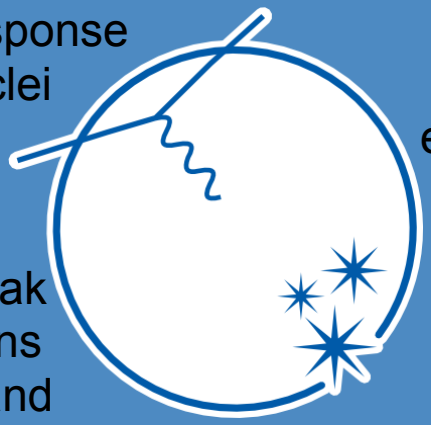


TECHNISCHE UNIVERSITÄT DARMSTADT

A: Strong interactions and precision nuclear structure



B: Electroweak interactions and nuclear astrophysics



MGK: Integrated Research Training Group

Topical Lecture Weeks	SFB Physics Days	Recruitment Stipends
Student Travel Prize	MGK Seminar	Meet & Greet

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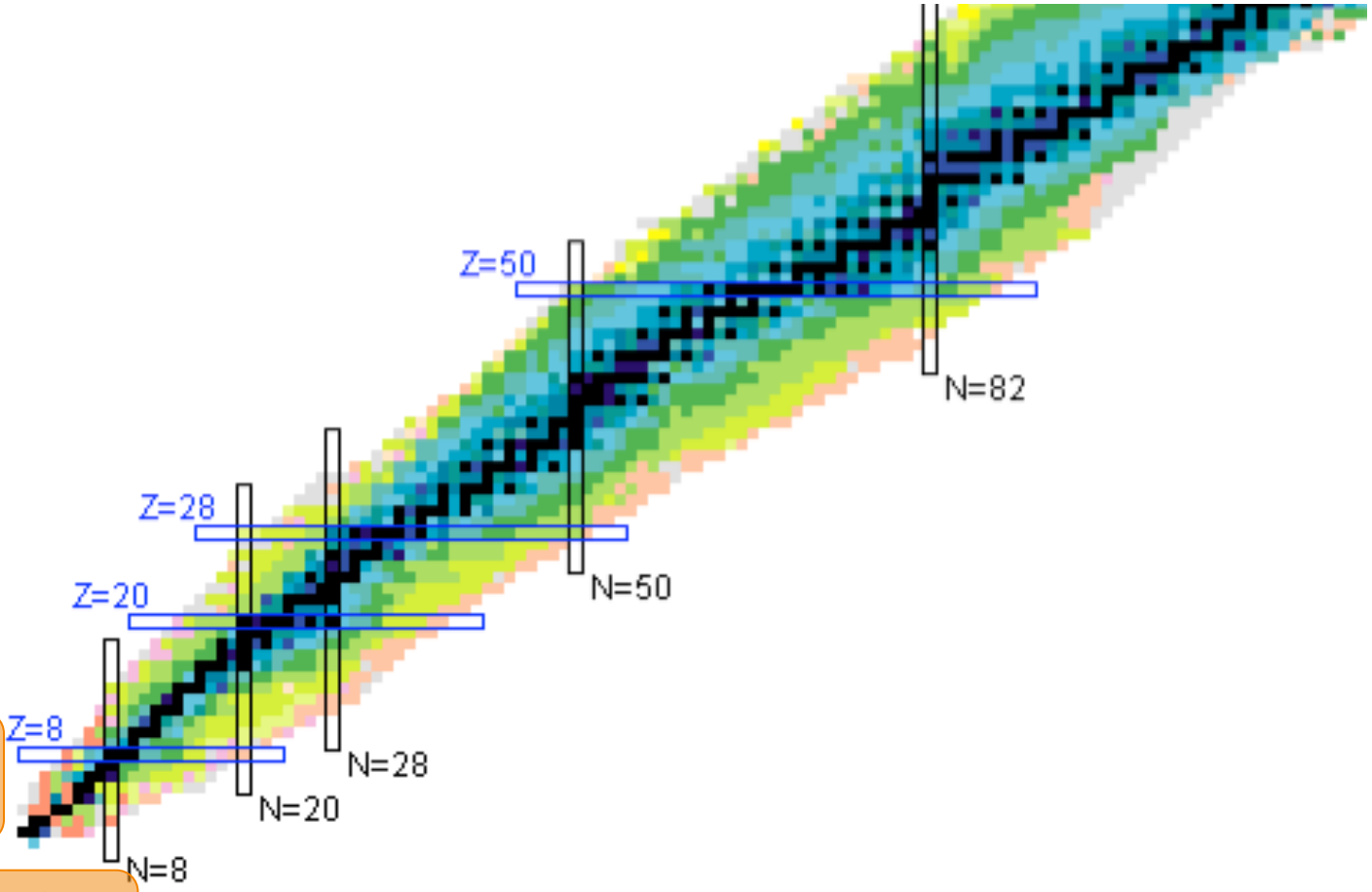
A: Strong interactions and precision nuclear structure

TECHNISCHE UNIVERSITÄT DARMSTADT



A02: Light nuclei, EFT and ab initio

A01: Precision structure of light nuclei

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A: Strong interactions and precision nuclear structure

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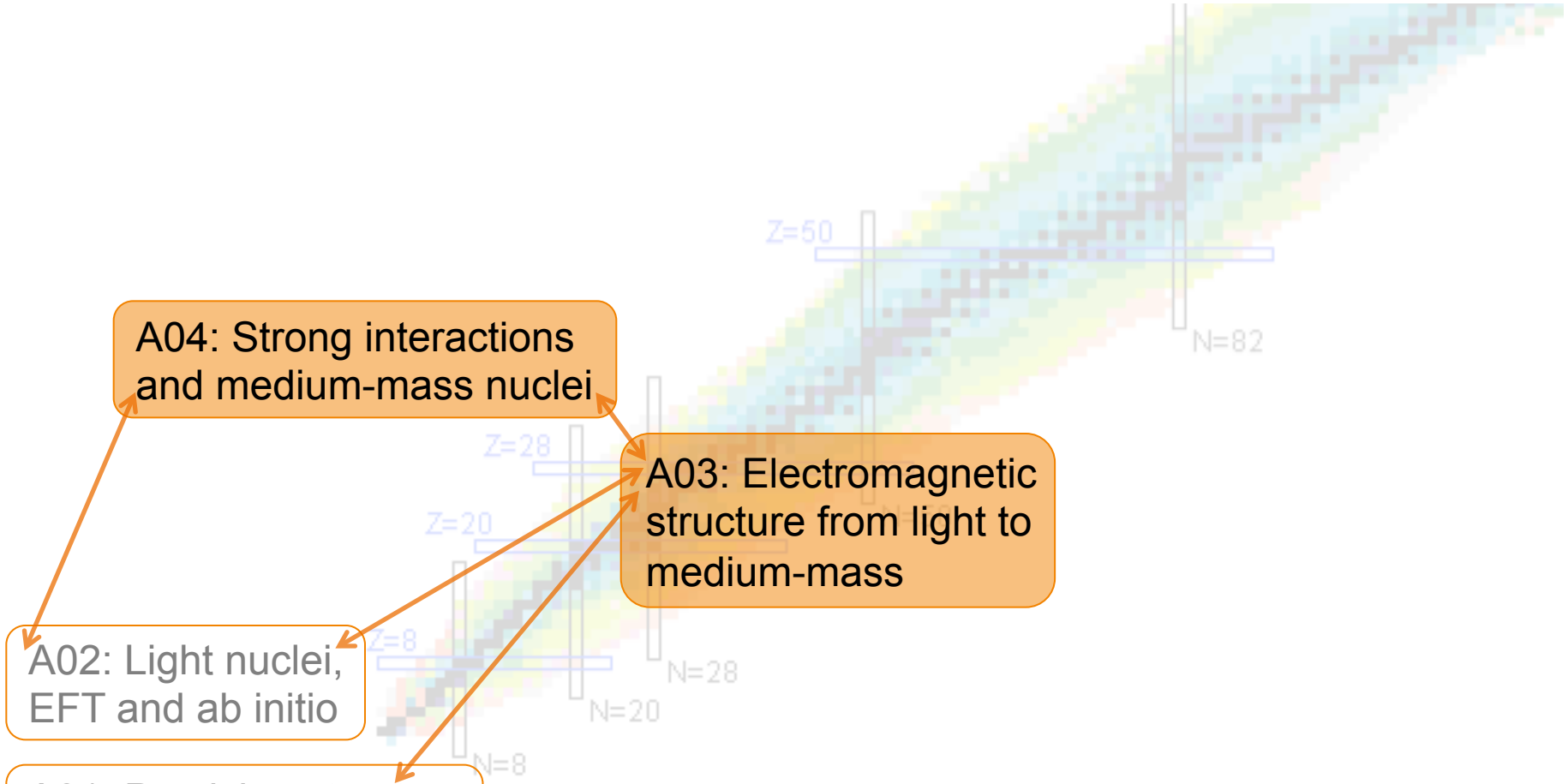

A04: Strong interactions and medium-mass nuclei

A03: Electromagnetic structure from light to medium-mass

A02: Light nuclei, EFT and ab initio

A01: Precision structure of light nuclei

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A: Strong interactions and precision nuclear structure

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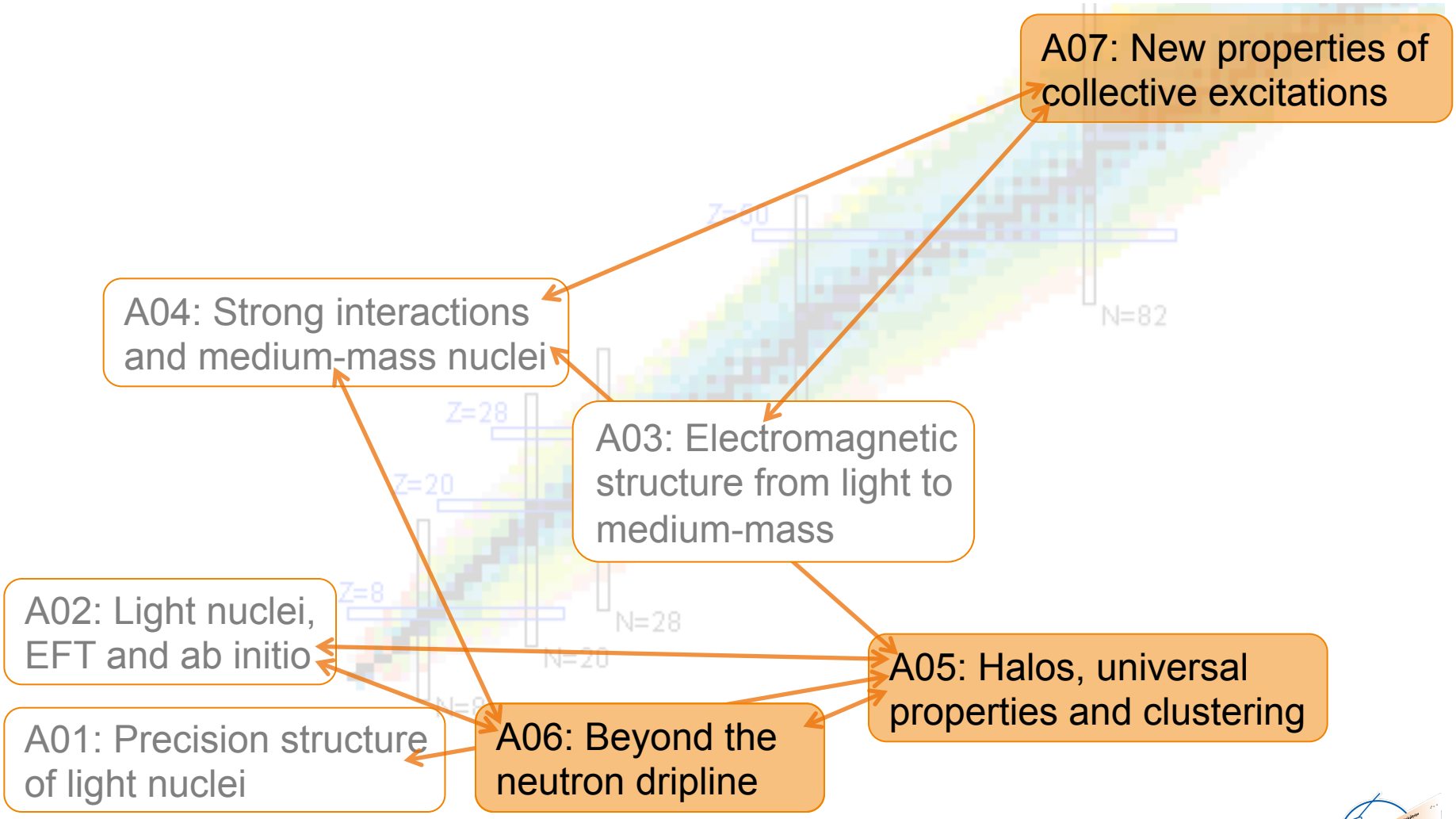

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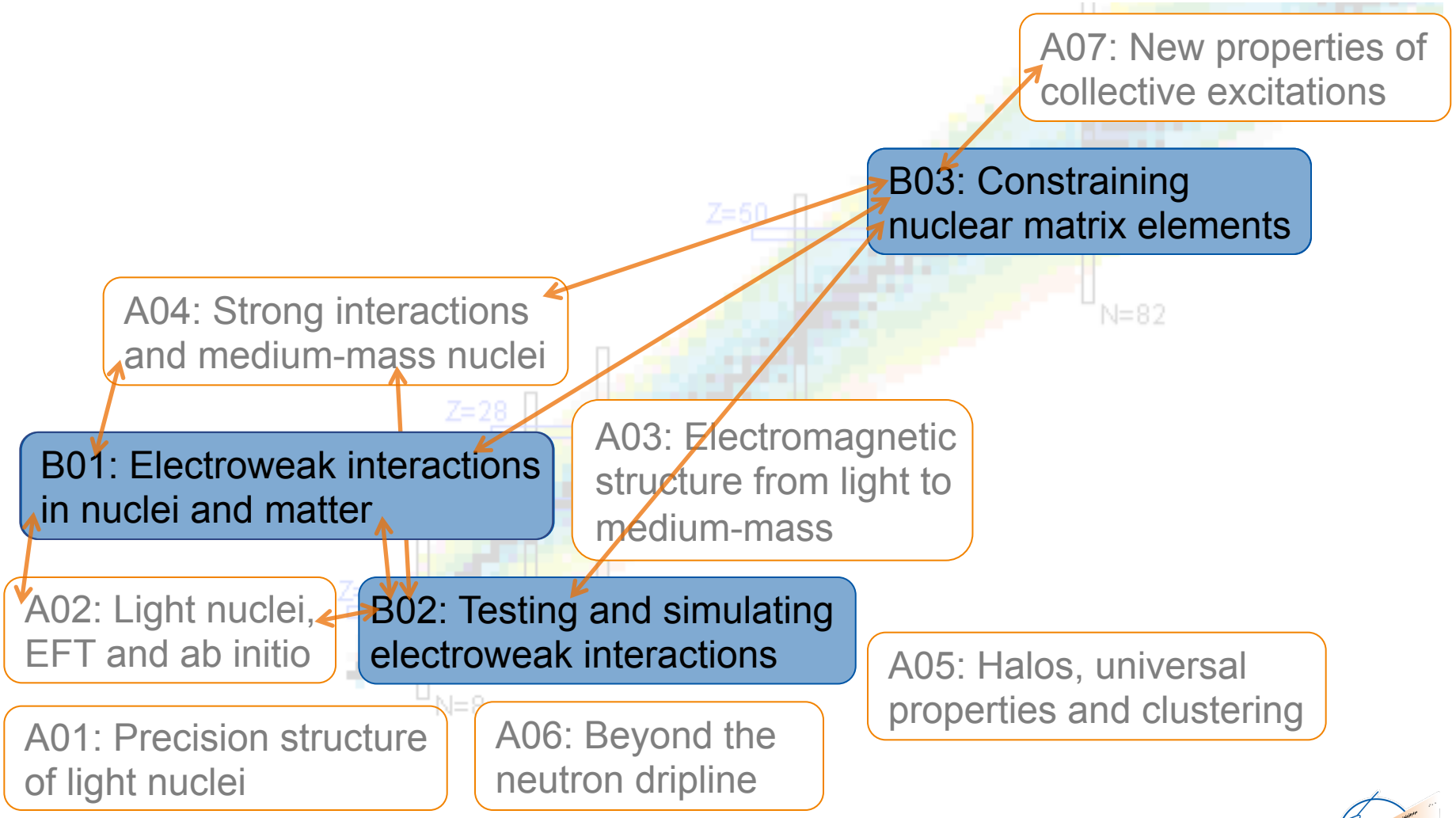
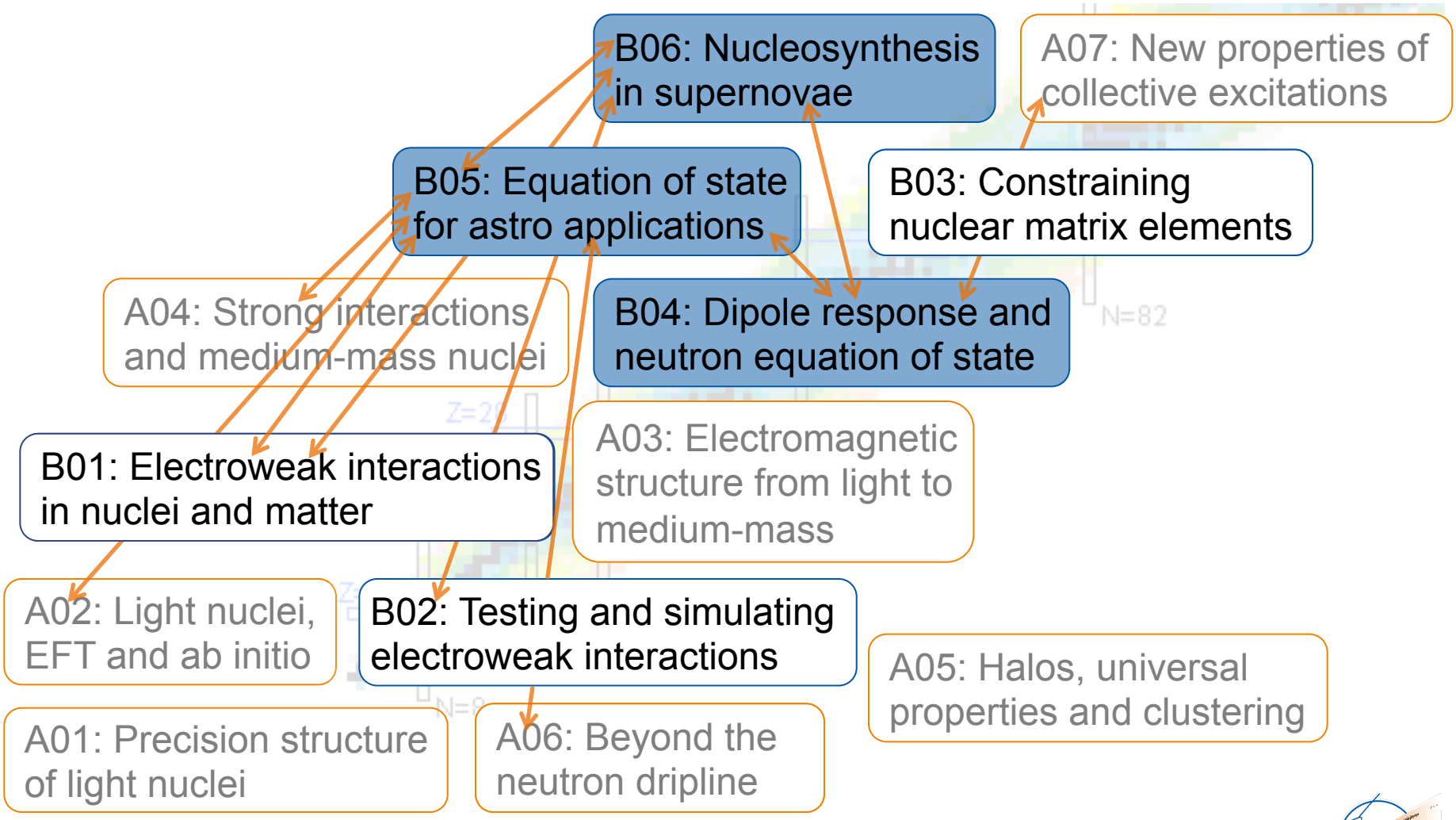
B: Electroweak interactions and nuclear astrophysics



B: Electroweak interactions and nuclear astrophysics

TECHNISCHE UNIVERSITÄT DARMSTADT



Physics at unique facilities

TECHNISCHE UNIVERSITÄT DARMSTADT

- Best suited for **key experiments**

- All experiments **approved** by PACs
- FAIR is complementary in science and timing

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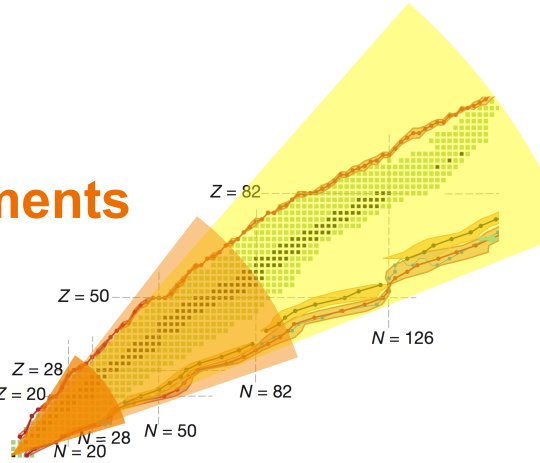
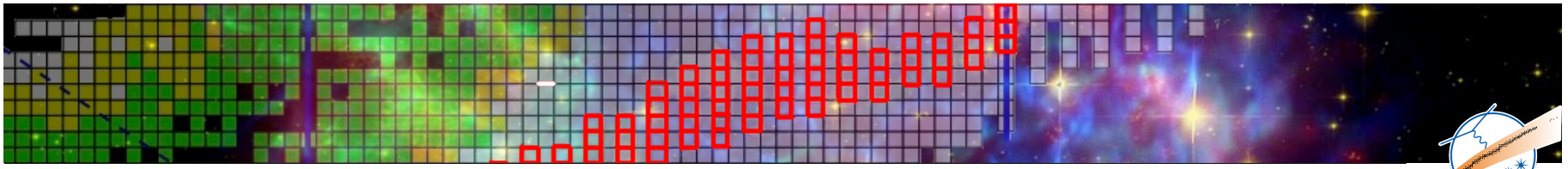
Long-term perspectives

TECHNISCHE UNIVERSITÄT DARMSTADT

- **Understanding** and **predicting** the **nuclear chart based on QCD**
- **Advance nuclear structure** with **precision experiments**
- **Develop EFTs** and **ab initio methods to all nuclei**
- **Systematic understanding** of **nuclear matrix elements**
  $0\nu\beta\beta$ decay, dark matter direct detection,…
- **Solving** the **chemical contribution from supernovae**





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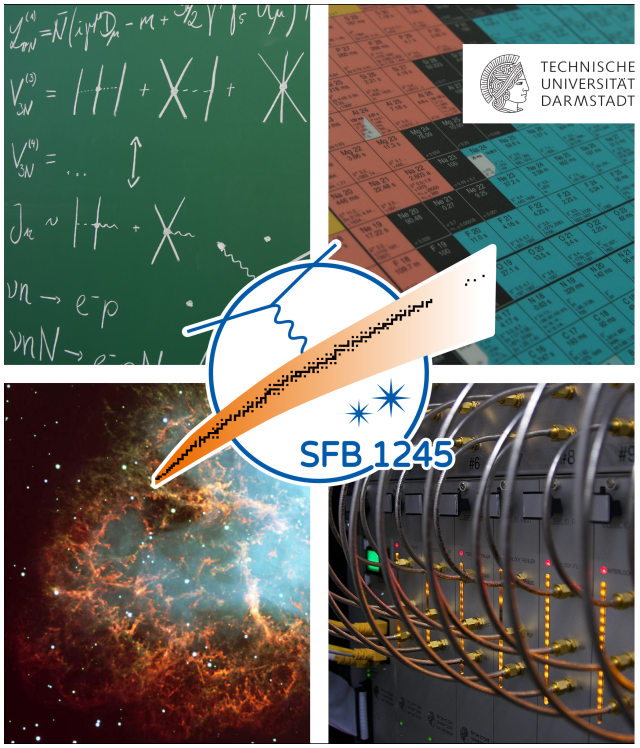
Nuclei: From Fundamental Interactions to Structure and Stars

- Unique CRC in nuclear structure and nuclear astrophysics
- Understanding nuclei and nuclear physics for stars based on QCD
- Using precision experiments and EFTs
- Training next-generation scientists in low-energy nuclear physics

Planned Collaborative Research Centre 1245

Nuclei: From Fundamental Interactions to Structure and Stars

Technische Universität Darmstadt



Funding proposal
2016 – 2019

Integrated Research Training Group (IRTG)
talk by Hans-Werner Hammer

TECHNISCHE UNIVERSITÄT DARMSTADT

Provides **enhanced, innovative and international environment for doctoral researches** and **structured qualification plan**

- Topical lecture weeks
- Annual CRC Physics Days
- Recruitment stipends
- Annual travel prize
- Research internships in theory

PIs: Almudena Arcones
Hans-Werner Hammer
Wilfried Nörtershäuser

Ingenium: yearly specialized course for CRC + soft skills courses

Ingenium
Young Researchers at TU Darmstadt

HGS-HIRe: broader physics courses on hadron physics, atomic physics, biophysics, …

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

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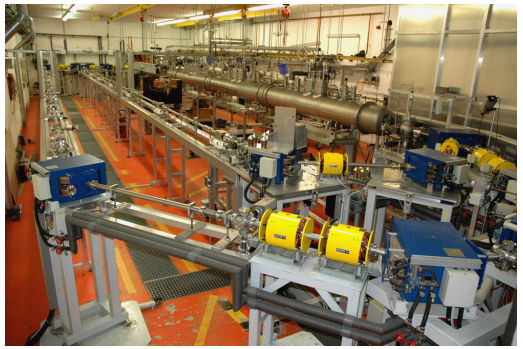
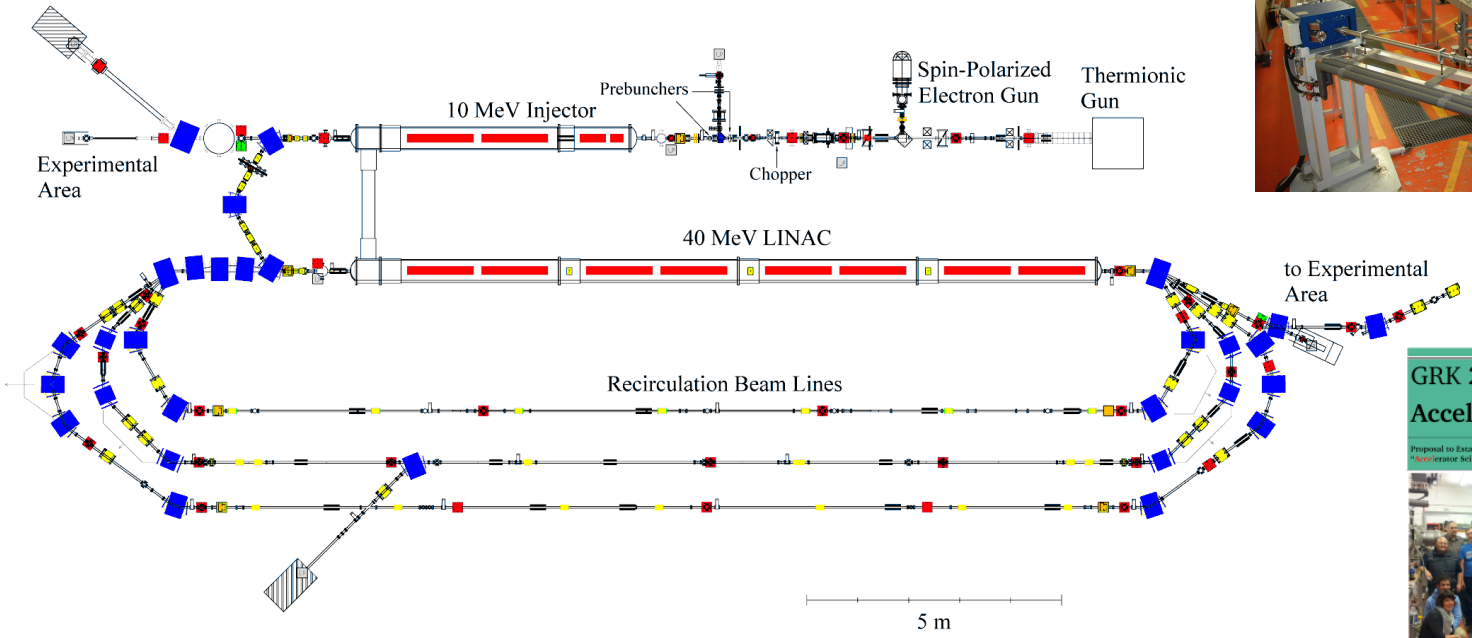
Development of S-DALINAC

next talk by Norbert Pietralla

- – 2013: Non-isochronous recirculation: ΔE = 20 keV
- 2015: 3rd recirculation: increased stability and energy





Research Training Group 2128 „AccelencE“

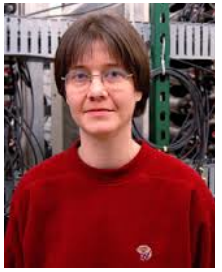
- – 2018: Beam break-up: increased intensity to 10 μA
- – 2021: New injector concept: increased resolution ΔE = 10 keV

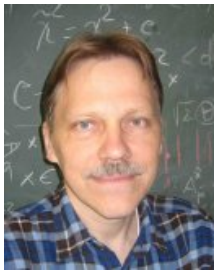
Science Advisory Committee (SAC)

TECHNISCHE UNIVERSITÄT DARMSTADT

Evaluates scientific program, provides advice on usage of research infrastructures, on IRTG and on future activities

- **Alexandra Gade**, MSU and Chief Scientist, NSCL
- **Reiner Krücken**, Deputy Director, TRIUMF, and UBC
- **Ulf-G. Meißner**, U Bonn and FZ Jülich
- **Sanjay Reddy**, INT/U Washington, Seattle
- **Hiroyoshi Sakurai**, Director, RIBF/RIKEN, and U Tokyo





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Scientist success stories

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- **Stefanos Paschalis (PI, A06)**
  Lecturer at University of York
  new PI, A06: Dominic Rossi

- **Marina Petri (PI, A03)**
  Royal Society Fellowship at University of York
  Experiments on light nuclei to benchmark the chiral EFT ab initio frontier

- **Kyle Wendt (postdoc, B01)**
  Lawrence Fellow at LLNL (tenure-track)

- **Thomas Krüger (SFB headquarter)**
  Boston Consulting

SFB 1245

sfb1245.tu-darmstadt.de
design and setup by Alex Bartl

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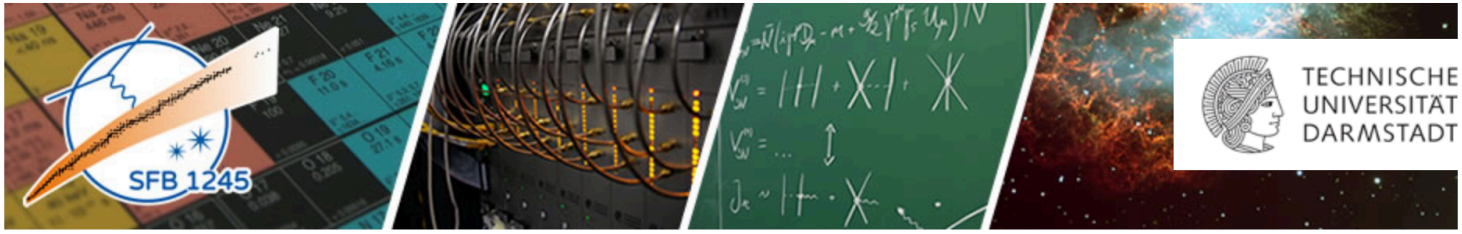

TU | Institut für Kernphysik | SFB 1245

TU Darmstadt » Physics » Institut für Kernphysik » SFB 1245 » Welcome

SFB 1245

- Introduction
- A - Strong interactions and precision nuclear structure
- B - Electroweak interactions and nuclear astrophysics
- Integrated Research Training Group
- People
- Open Positions
- SFB Colloquia
- Publications
- Talks and Posters
- Visitors
- SFB Office
- How to Find Us
- Internal

A: Strong interactions and precision nuclear structure

effective field theories; advanced many-body methods; precision experiments with electromagnetic and strong probes; laser spectroscopy

B: Electroweak interactions and nuclear astrophysics

dipole response of nuclei; nuclear matrix elements; nuclear equation of state; electroweak interactions in nuclei and nuclear matter; nucleosynthesis in core-collapse supernovae

MGK: Integrated Research Training Group

Topical Lecture Weeks | SFB Physics Days | Recruitment Stipends
Student Travel Prize | MGK Seminar | Meet & Greet

Upcoming SFB Colloquium

Pierre Capel, Université libre de Bruxelles:
Past, present and future of the eikonal description of reactions involving exotic nuclei
24.11.2016, 15:20, S2 11/10

For more information
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Funded by
DFG Deutsche Forschungsgemeinschaft

Webmaster:
Alex Bartl,
NN

Internal part also
C. Seeger,
NN

SFB 1245

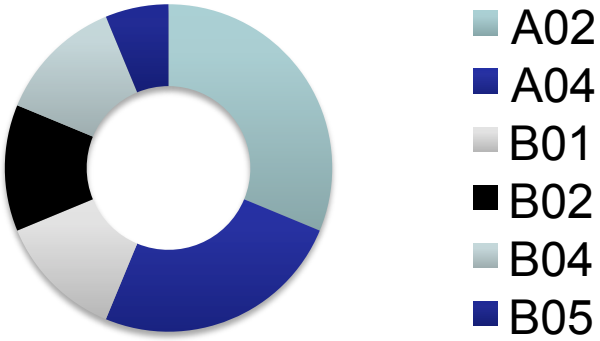
SFB 1245 activities

TECHNISCHE UNIVERSITÄT DARMSTADT

- PIs published 57 PRL in last 5 years: **10% of all nuclear physics PRL** (26% collaborative among PIs)

- 4 PRLs so far, but only 2 on webpage

SFB 1245 publications (16 total)



PRL 116, 132501 (2016) PHYSICAL REVIEW LETTERS week ending 1 APRIL 2016

Investigating the Pygmy Dipole Resonance Using β Decay

M. Scheck,[1,2,*] S. Mishev,[3,4] V. Yu. Ponomarev,[5] R. Chapman,[1,2] L. P. Gaffney,[1,2] E. T. Gregor,[1,2] N. Pietralla,[5] P. Spagnoletti,[1,2] D. Savran,[6] and G. S. Simpson[1,2]

PRL 117, 172503 (2016) PHYSICAL REVIEW LETTERS week ending 21 OCTOBER 2016

First Measurement of Collectivity of Coexisting Shapes Based on Type II Shell Evolution: The Case of ^{96}Zr

C. Kremer,[1] S. Aslanidou,[1] S. Bassauer,[1] M. Hilcker,[1] A. Krugmann,[1] P. von Neumann-Cosel,[1] T. Otsuka,[2,3,4,5] N. Pietralla,[1] V. Yu. Ponomarev,[1] N. Shimizu,[3] M. Singer,[1] G. Steinhilber,[1] T. Togashi,[3] Y. Tsunoda,[3] V. Werner,[1] and M. Zweidinger[1]

PRL 117, 182501 (2016) PHYSICAL REVIEW LETTERS week ending 28 OCTOBER 2016

Induced Hyperon-Nucleon-Nucleon Interactions and the Hyperon Puzzle

Roland Wirth* and Robert Roth†

PRL 117, 182502 (2016) PHYSICAL REVIEW LETTERS week ending 28 OCTOBER 2016

Prediction for a Four-Neutron Resonance

A. M. Shirokov,[1,2,3,*] G. Papadimitriou,[4,†] A. I. Mazur,[3] I. A. Mazur,[3] R. Roth,[5] and J. P. Vary[2,‡]

- unfortunately very few publications/talks on webpage
  Please update your contributions on sfb1245.tu-darmstadt.de!

SFB 1245

Workshop program

- Reports from all projects + few external talks, **please ask questions**
- Tuesday pm: **discussion groups on synergy topics**
  e.g., electroweak matrix elements
- Wednesday am: reports on gender equality and family friendly measures, SFB webpage,…
- Followed by General assembly

Enjoy our first SFB 1245 workshop!

Nuclei: From Fundamental Interactions to Structure and Stars

Discussion groups

TECHNISCHE UNIVERSITÄT DARMSTADT

- Electromagnetic currents for nuclear structure applications
  Where is exp/theo input needed for theo/exp that's not yet on radar?
  Conference room front, Norbert

- Inclusion of 3N forces at N^3LO and N^4LO
  Exploring alternate power countings
  Conference room back, Kai

- How can experiments with electromagnetic probes constrain weak int.?
  Library, Gabriel

- Equation of state for astro applications
  Fireplace room, Carlos

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