Nuclear Physics at TU Darmstadt

TECHNISCHE UNIVERSITÄT DARMSTADT

Norbert Pietralla, TU Darmstadt

University Profile

TECHNISCHE UNIVERSITÄT DARMSTADT

Medium Size University of Technology: 25,000 students, 300 professors

50% Engineering, 35% Natural Sciences, 15% Humanities and Social Sciences

Profile Areas of Research Excellence at TU Darmstadt

Cyber Security

Energy Systems of the Future

Future Internet

Matter and Radiation Science

Thermo-Fluids Interfaces

From Materials to Product Innovation

Matter and Radiation Science

MaRS
Matter and Radiation Science

TECHNISCHE UNIVERSITÄT DARMSTADT

- Radiation Biophysics
- Nuclear Structure Physics
- Nuclear Astrophysics
- Dense Nuclear Matter
- Atomic and Plasmaphysics
- Nuclear Photonics
- Accelerator Physics
- Accelerator Electrical Engineering
- Radiation Material Science

TEILCHENSTRAHLEN UND MATERIE

Institute for Nuclear Physics

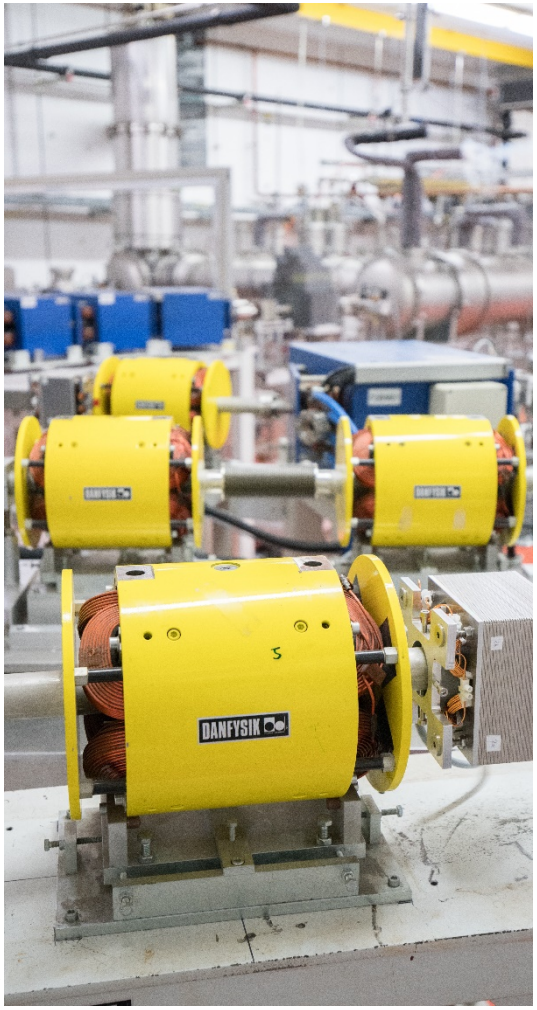

Photo: Magnets at the S-DALINAC

Faculty – Strategic Appointments

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2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019

strongest university development in nuclear structure and nuclear astrophysics in Germany

- A. Obertelli (AvH-W3)
- Verena Spatz, Phys. Edu. (W1)
- Guy Moore, QCD (W3)
- Tetyana Galatyuk, Exp. Heavy-Ion Physics (W2/2016)
- Hans-W. Hammer, Theoretical Nuclear Physics (W2)
- Almudena Arcones, Theoretical Astrophysics (W2/2016)
- Jens Braun, Theoretical Nuclear Physics (W2-Heisenberg/2018)
- Wilfried Nörtershäuser, Experimental Nuclear and Atomic Physics (W2)
- Gabriel Martínez-Pinedo, Theoretical Nuclear Astrophysics (W3)
- Thomas Aumann, Experimental Nuclear Physics (W3)
- Achim Schwenk, Theoretical Nuclear Physics (W3)

Institute for Nuclear Physics

TECHNISCHE UNIVERSITÄT DARMSTADT

250 Members

55 permanent

~135 third-party fundg

55 students working on graduation theses

special profile:

Electron linear accelerator

Superconducting Darmstadt Electron Linear Accelerator (S-DALINAC)

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Since 1991:

First superconducting recirculating linear accelerator in Europa

Significant third-party funding (> 42 Mio.€)
(GRK 410, FOR 272, SFB 634, SFB 1245, GRK 2128)

Since 2017:
First Energy-recovery linac in Germany

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N. Pietralla,

Nuclear Physics News **28 (2)**, 4 (2018).

S-DALINAC

Superconducting-**DA**rmstadt-**LIN**ear-**AC**celerator

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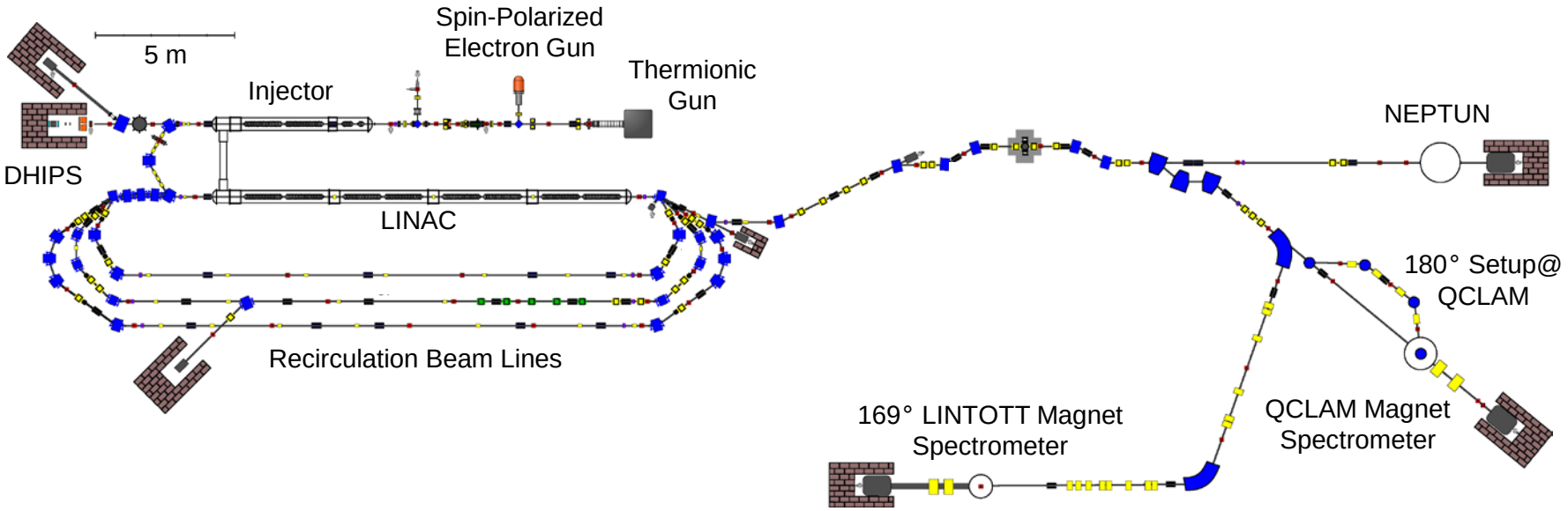

<u>Thrice recirculating operation</u>

Energy gain injector: 7.6 MeV (10 MeV)

Energy gain LINAC: 30.4 MeV Beam current: 20 µA (@130 MeV)

S-DALINAC

Superconducting-**DA**rmstadt-**LIN**ear-**AC**celerator

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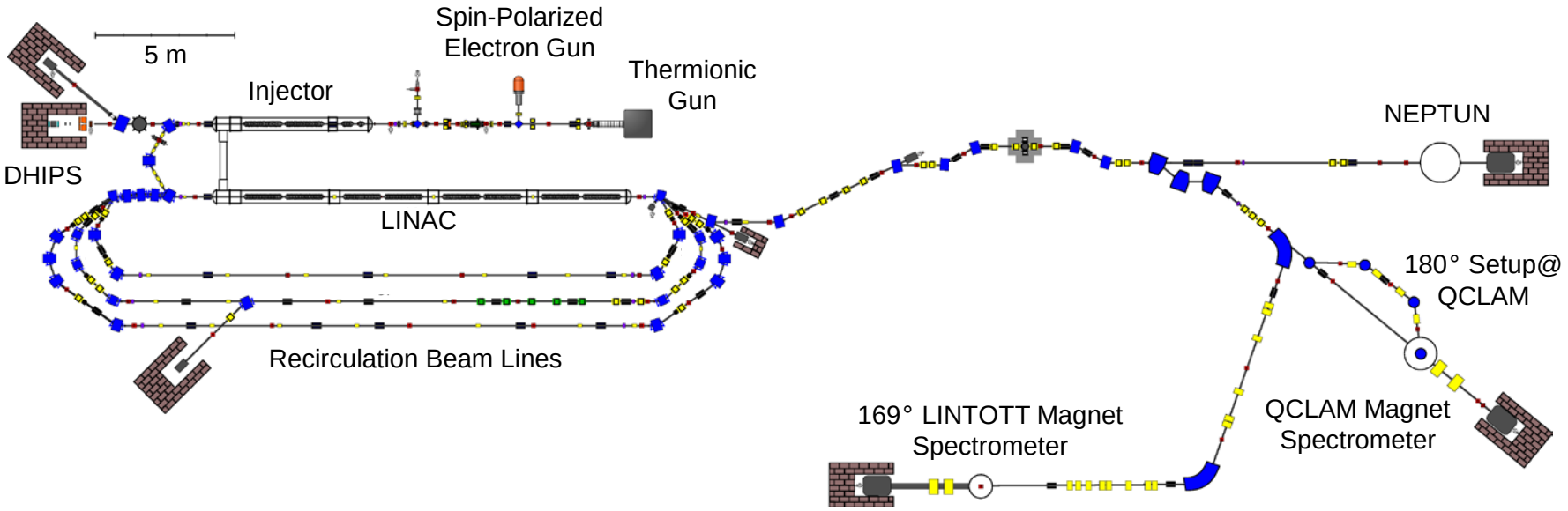

<u>Fastest particle beams with highest fluence in Darmstadt</u>

S-DALINAC:	99,999% c	Particle current: 10^{14} pro sec.
GSI / FAIR:	99,875% c	10^{12} pro sec.

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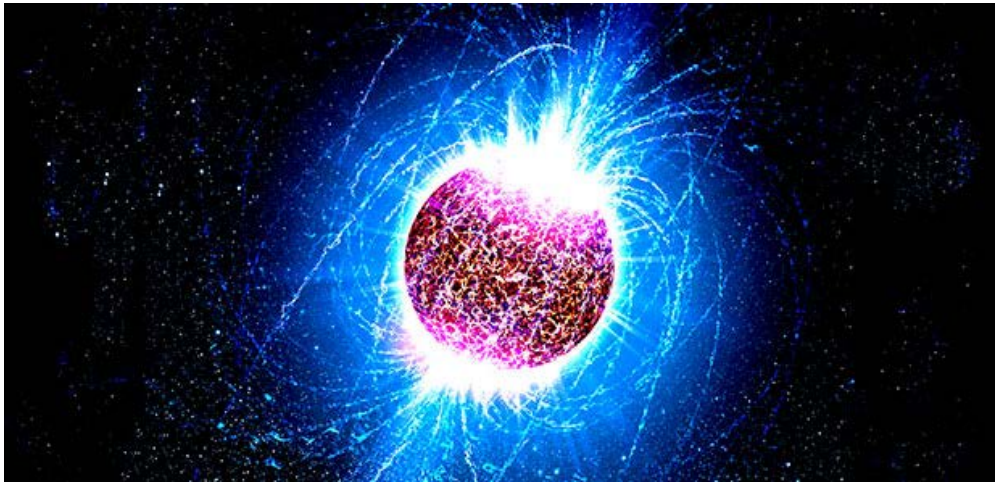
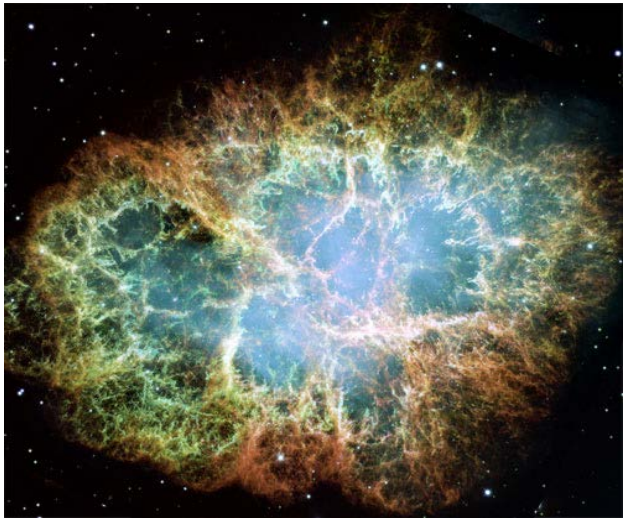
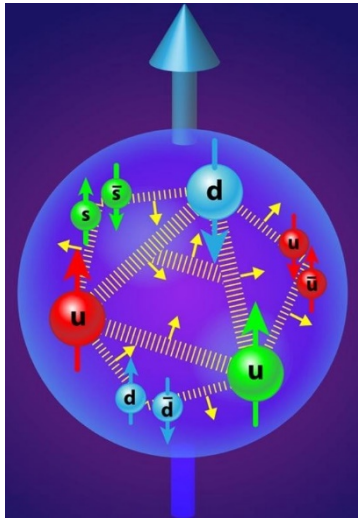
- Nuclear Photonics







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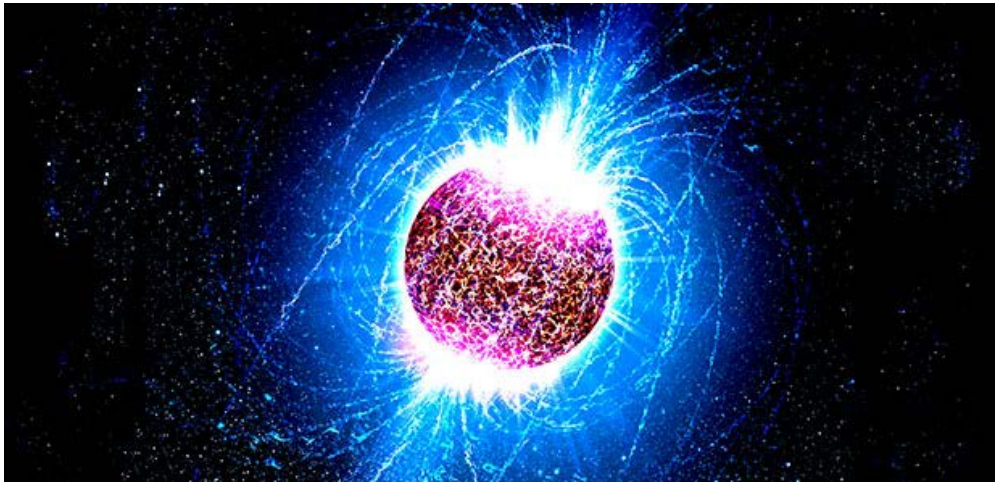

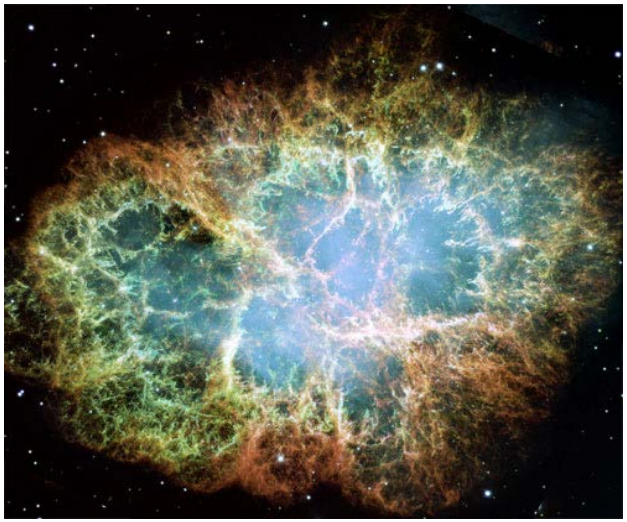

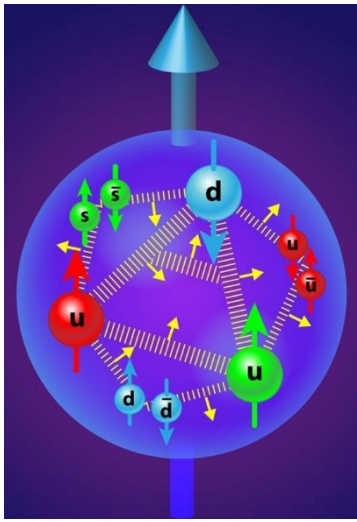

S-DALINAC‘s third recirculation 2015/16

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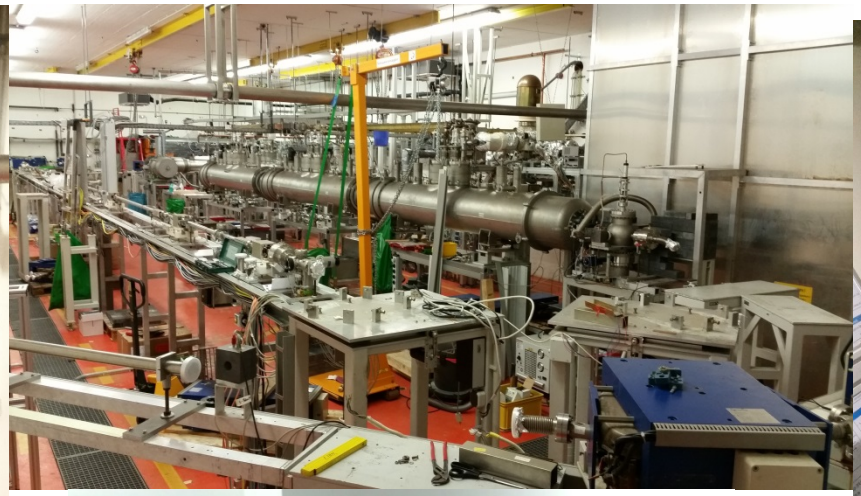

2016: Completion and fit for ERL

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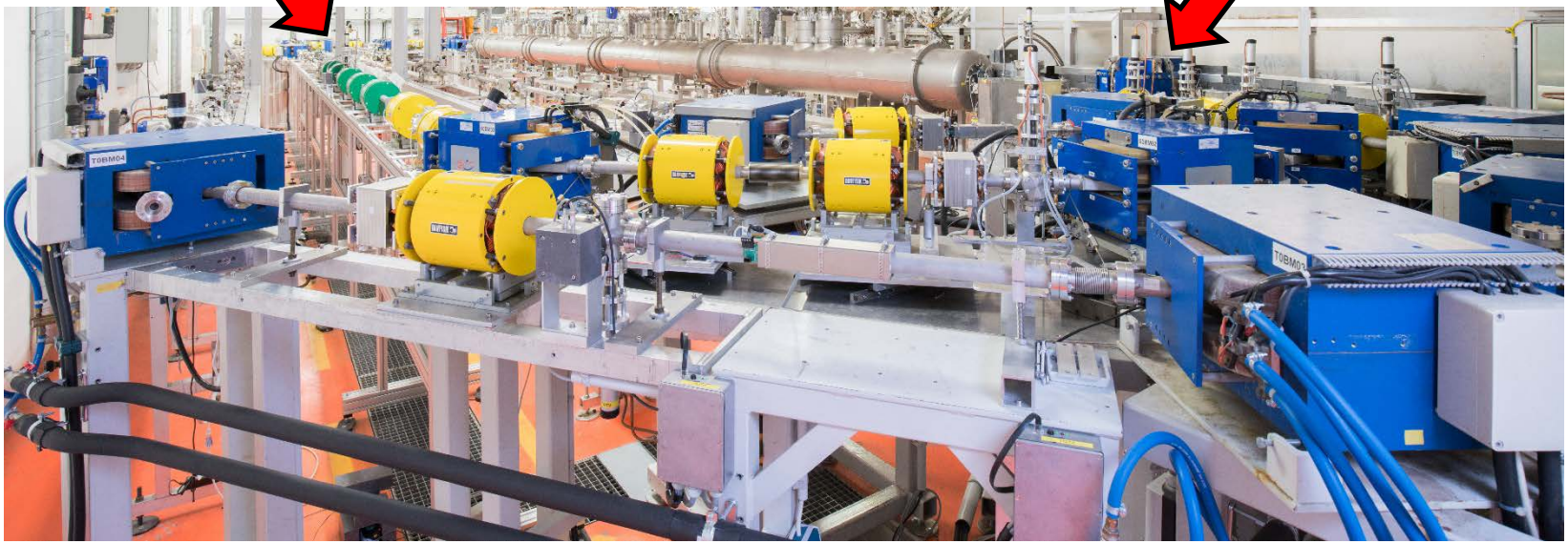
New beam line including 360° path length adjustment system

New separation dipole

330 mm

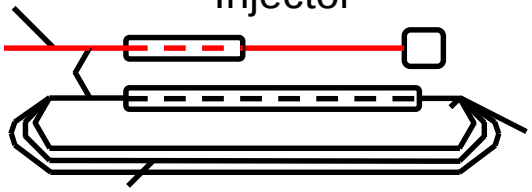


Overview Operation Modes / Commissioning

- Modification lattice 2015/2016
- Refurbishment cryoplant 2018

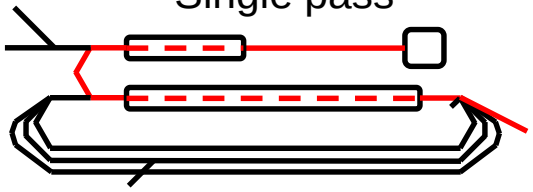
- Commissioning of modes following beam time schedule

Injector



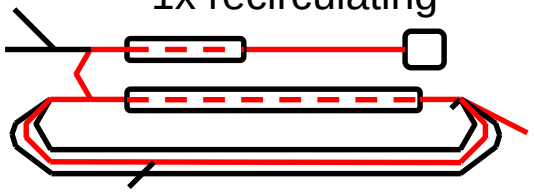
December 2016

Single pass



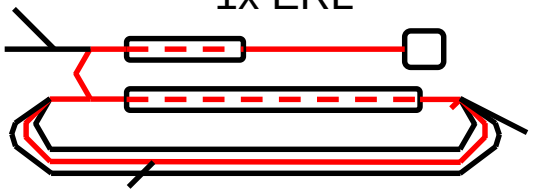
December 2016

1x recirculating



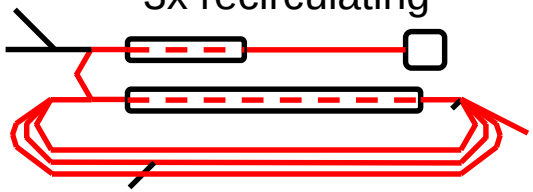
May 2017

1x ERL



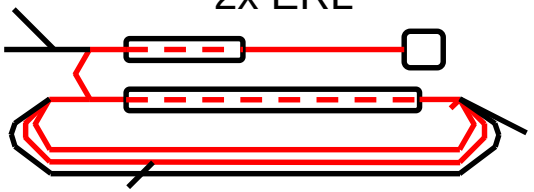
August 2017

3x recirculating



November 2018

2x ERL



in preparation

2017: First ERL in Germany

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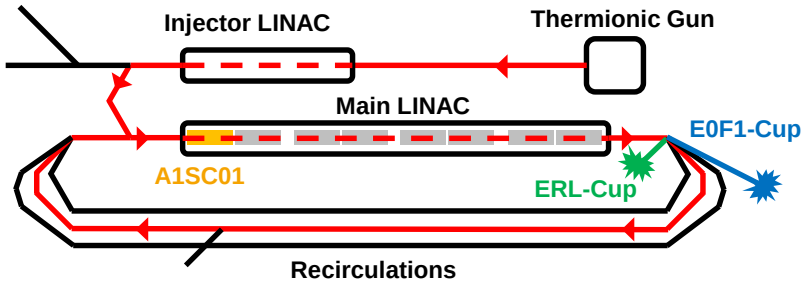
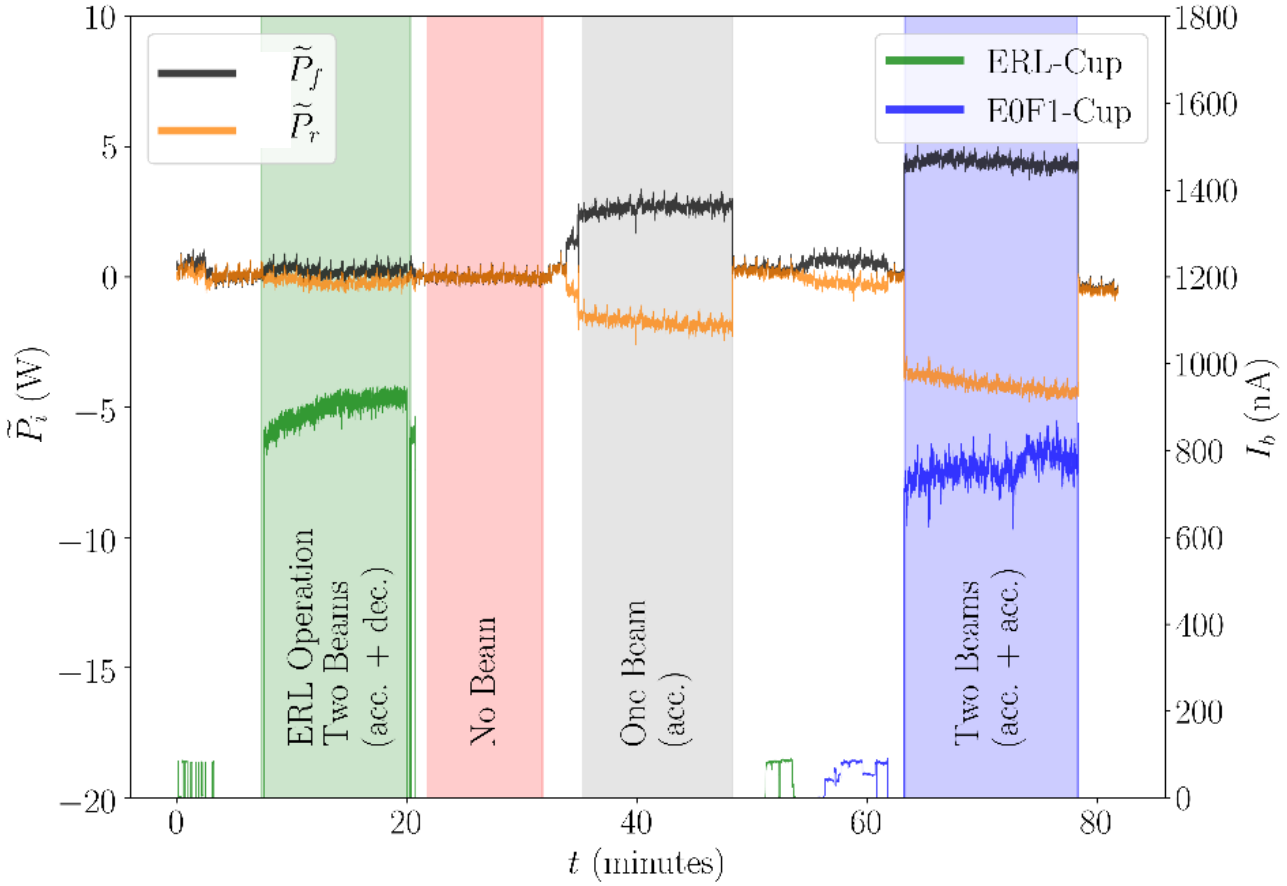
- Energy gain injector: 2.5 MeV
- Energy gain LINAC: 20.0 MeV
- Current (I_{in}): 1.2 µA



Data taken in four phases:

- Phase 1 (ERL Operation): one accelerated and one decelerated beam
- Phase 2 (no beam): RF operation of cavity without beam
- Phase 3 (1x acc.): one accelerated beam
- Phase 4 (2x acc.): two accelerated beams

Once-Recirculating ERL Operation



K. Sonnabend, Physik Journal 10, 7 (2017).

M. Arnold et al., First Operation of the S-DALINAC as an Energy Recovery Linac, Phys. Rev. Accel. Beams, submitted (Sept. 2019).

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A few examples from

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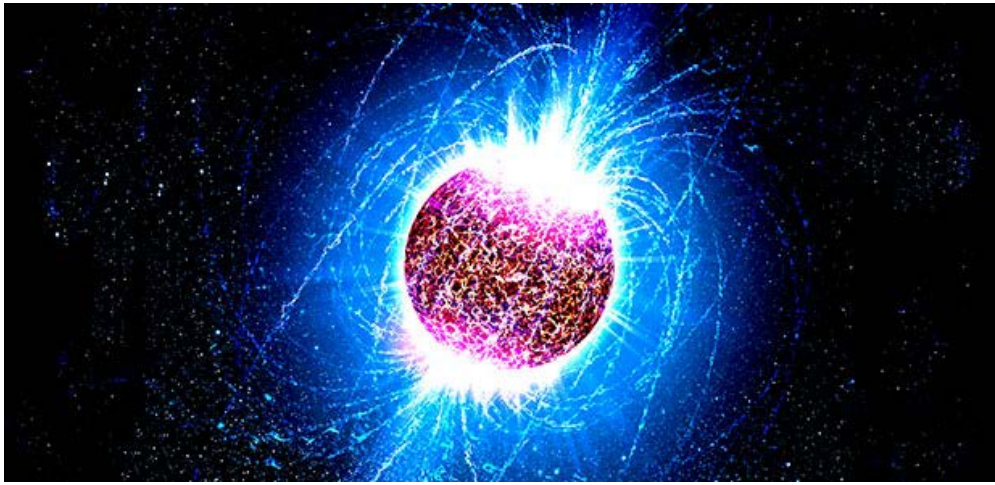

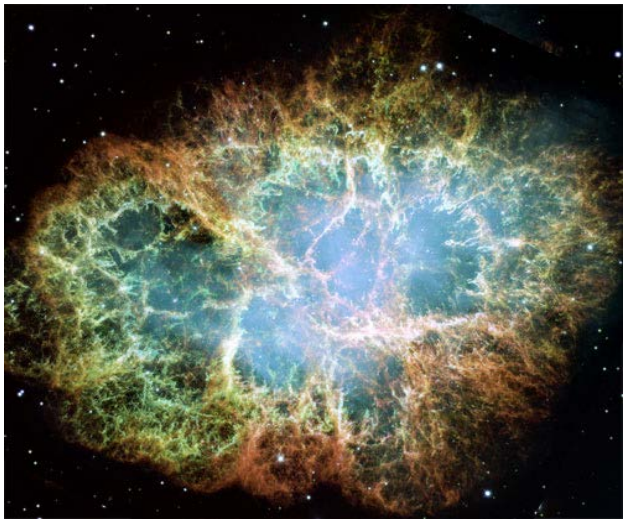

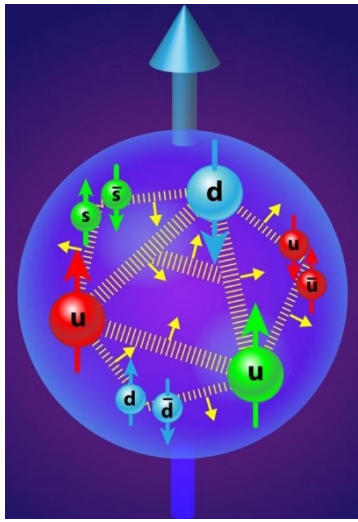

First Order Radioactive Decay Processes

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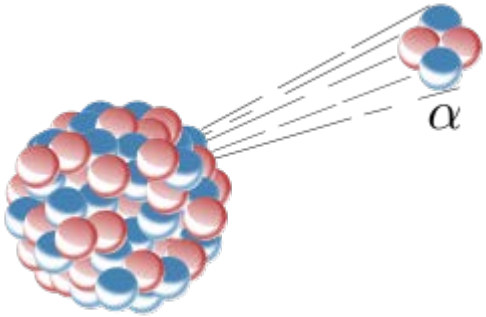
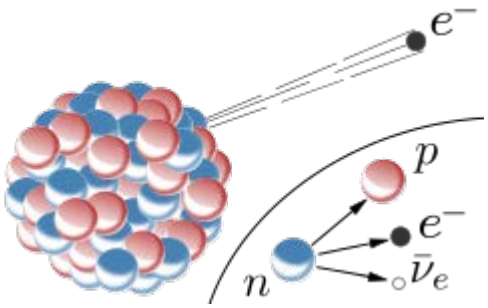
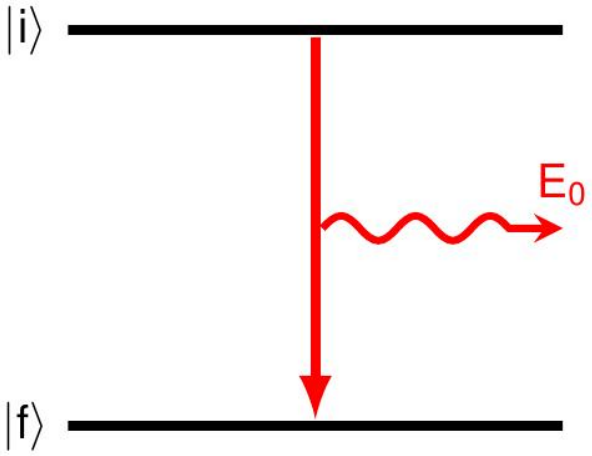
α-decay



β-decay



γ-decay



~ 1900: Henri Becquerel, Marie Curie, Ernest Rutherford, Paul U. Villard, ...

Radioactive decay: Second order

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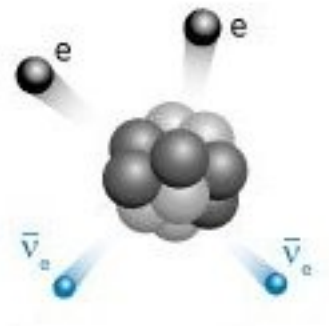
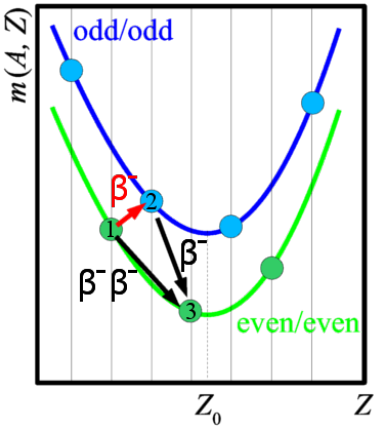
double β-decay

2νββ (0νββ)

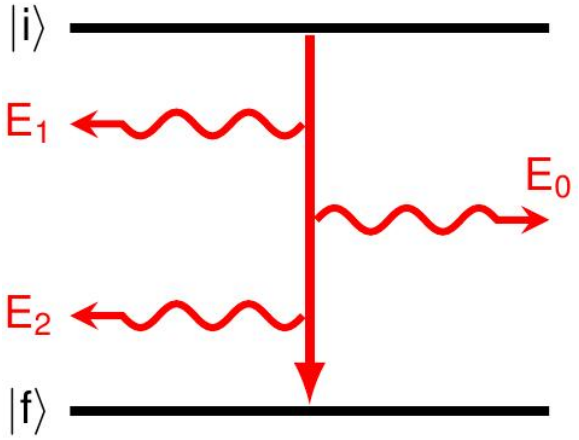




first evidence in the laboratory:
*S. Elliot, A. Hahn, and M. Moe, PRL **59**, 2020 (1987)*

competitive double γ-decay

"γγ/γ"



Nobel-prize Physics 1963

First discussed by Maria Göppert-Mayer in her doctoral thesis (with Max Born)

"Über Elementarakte mit zwei Quantensprüngen" (1930)

Discovery of the Competitive Double-γ Nuclear Decay

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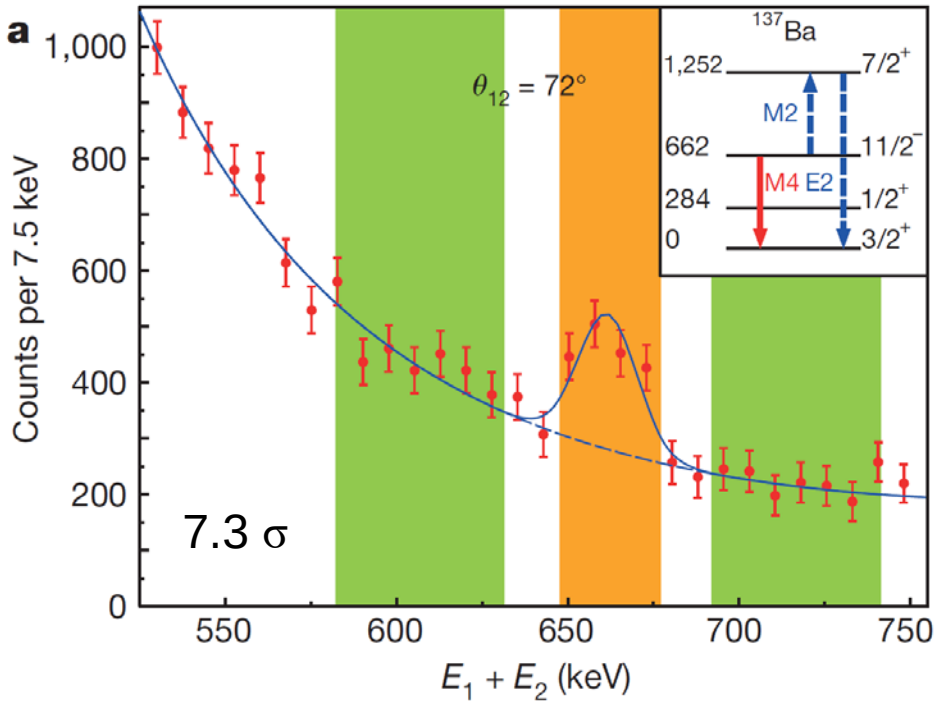


Dr. Christopher Walz

The two-photon decay of the 11/2$^-$ isomer of ^{137}Ba and mixed-symmetry states of ^{92,94}Zr and ^{94}Mo

(Dissertation, TU Darmstadt, 2014)

Dissertation Award 2014, TU Darmstadt
Dissertation Award 2014, EPS - NPD

LETTER nature

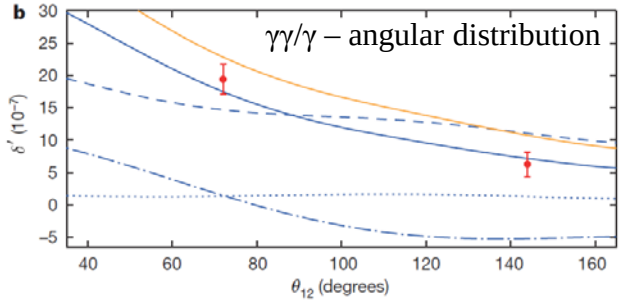
doi:10.1038/nature15543

Observation of the competitive double-gamma nuclear decay

C. Walz[1], H. Scheit[1], N. Pietralla[1], T. Aumann[1], R. Lefol[1,2] & V. Yu. Ponomarev[1]

$A_{2\gamma}(72^o) = 693(95)$ counts

$\Gamma_{\gamma\gamma}/\Gamma_{\gamma}(72^o) = 1.56(23)\ 10^{-6}$



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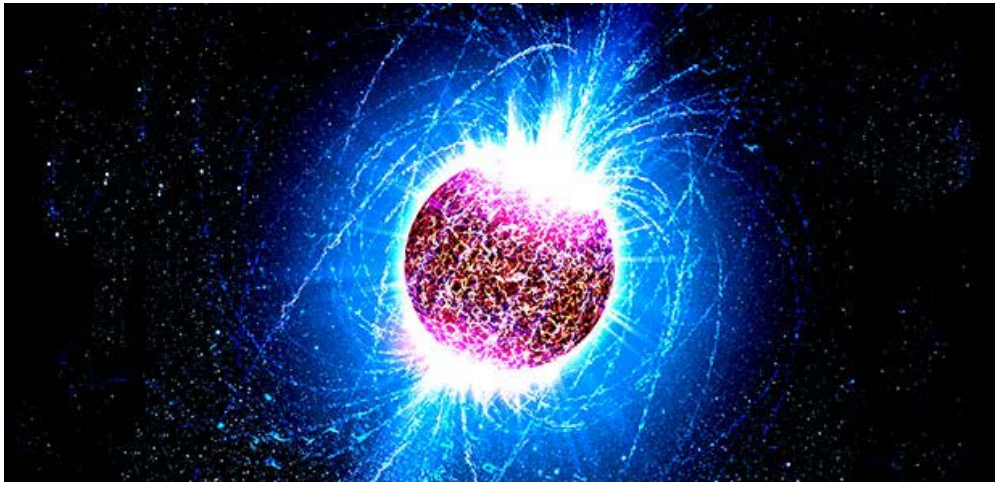

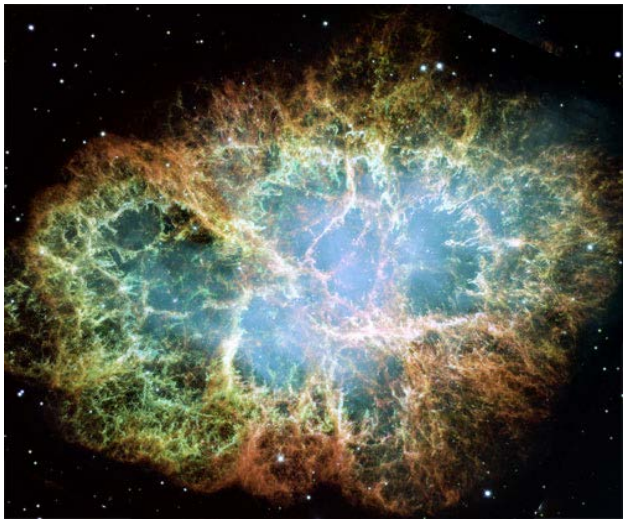

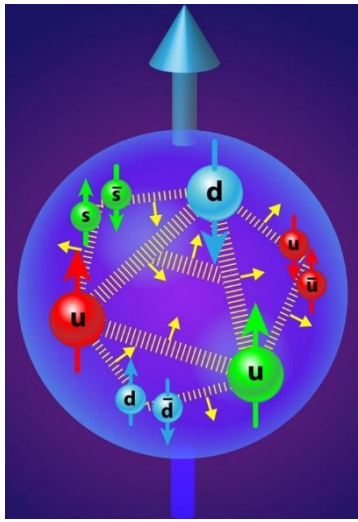

Structure of light and medium-mass nuclei

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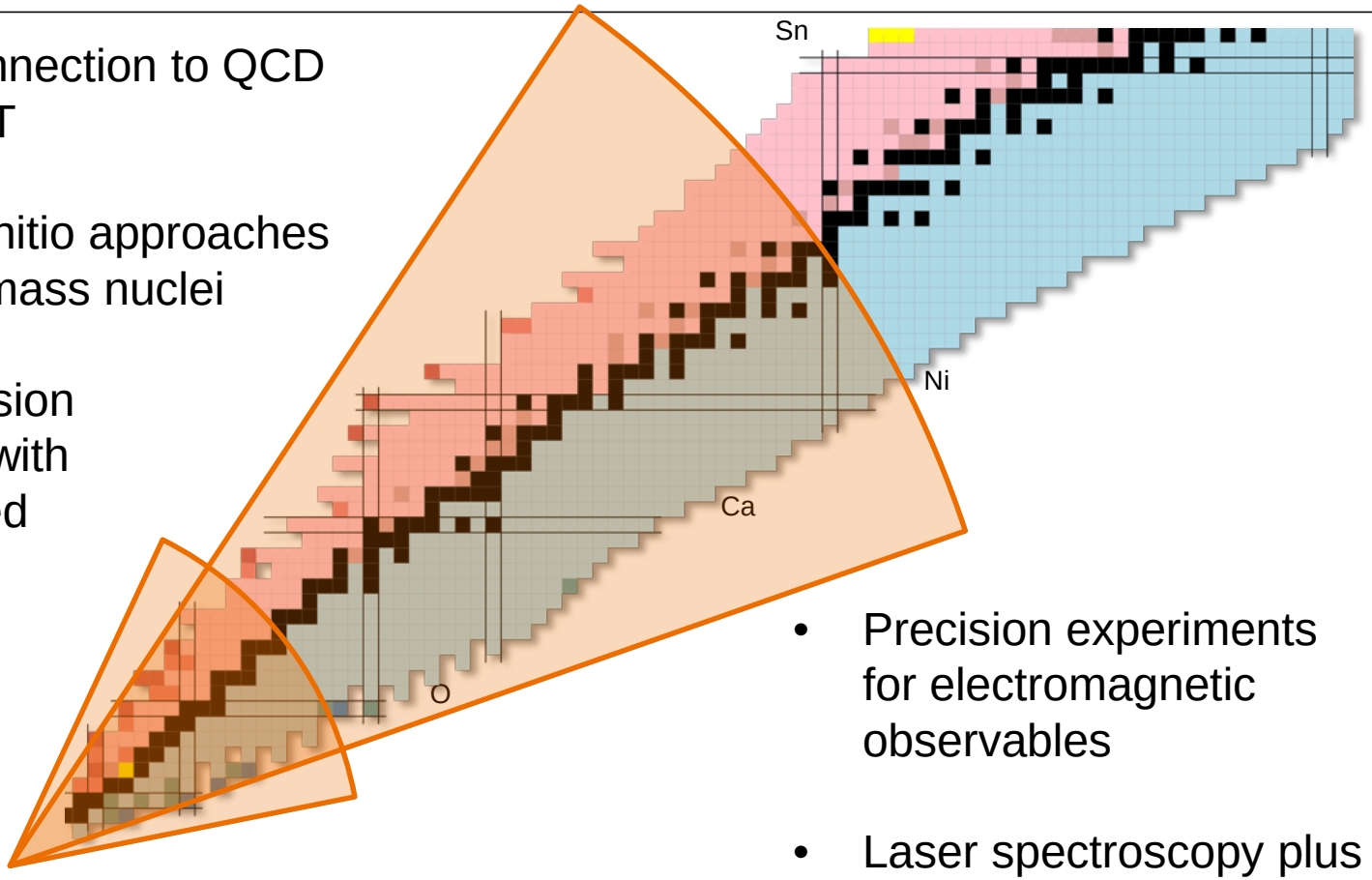
- Establish connection to QCD via chiral EFT
- Develop ab initio approaches for medium-mass nuclei
- Enable precision calculations with fully quantified uncertainties

Theory



Strong experiment–theory synergies

Experiment

- Precision experiments for electromagnetic observables
- Laser spectroscopy plus precision atomic theory for charge radii

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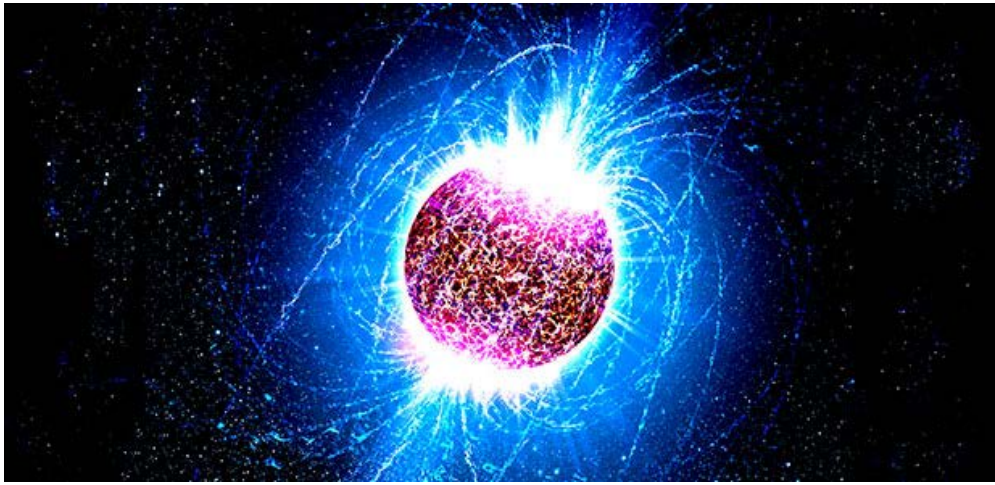

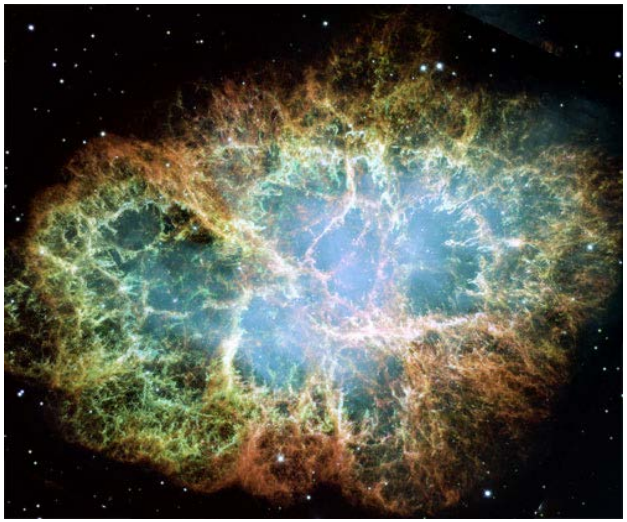

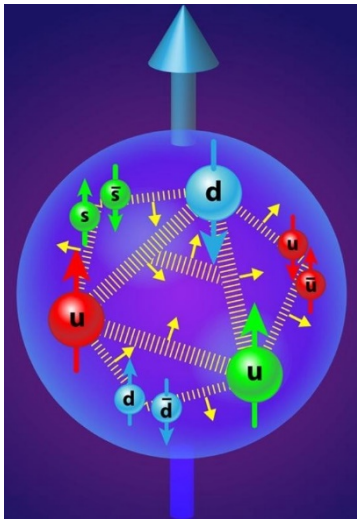

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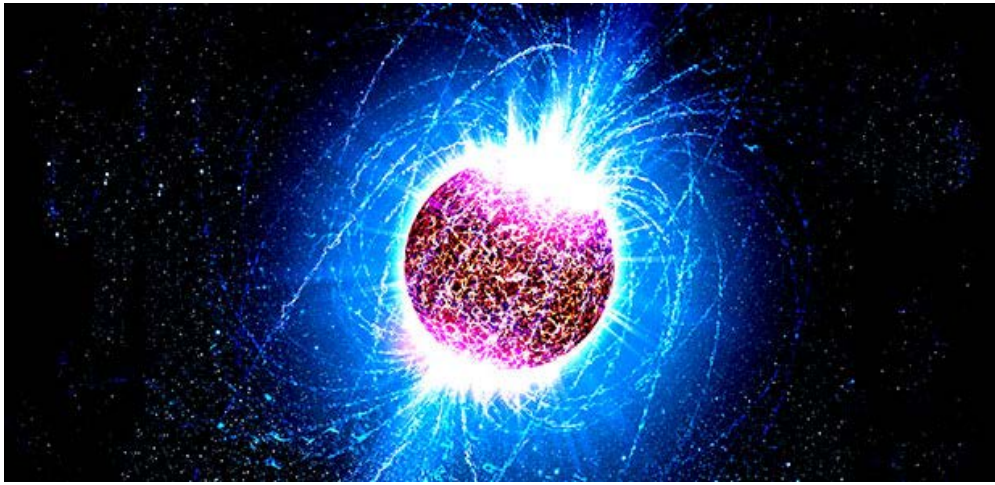

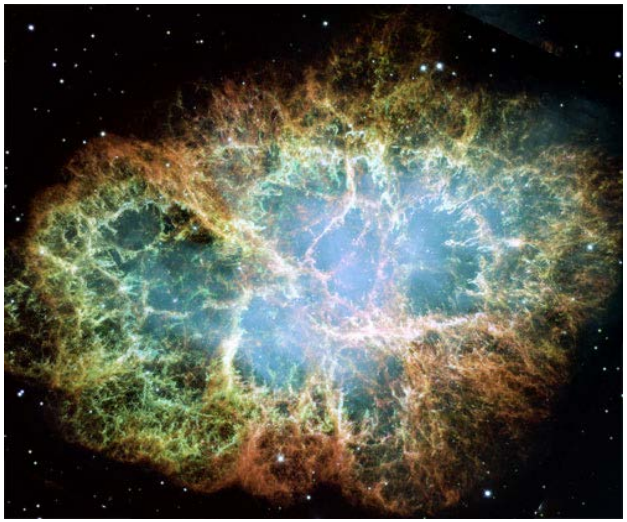

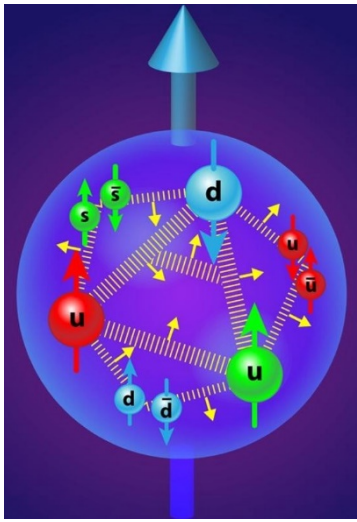

Hot and Dense QCD Matter

Galatyuk group, Moore group

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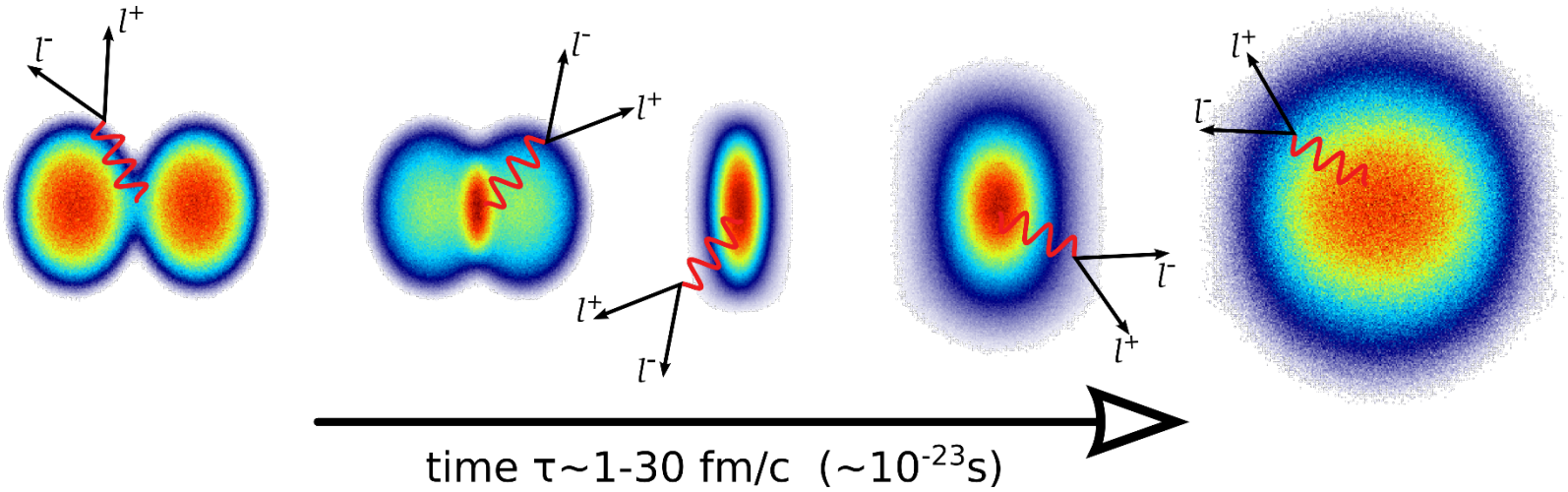
QCD phase diagram

Electromagnetic probes of the stages of HICs

Complete excitation function of dilepton production

HADES, CBM @ GSI, FAIR



Nuclear Physics @ Darmstadt: FAIR

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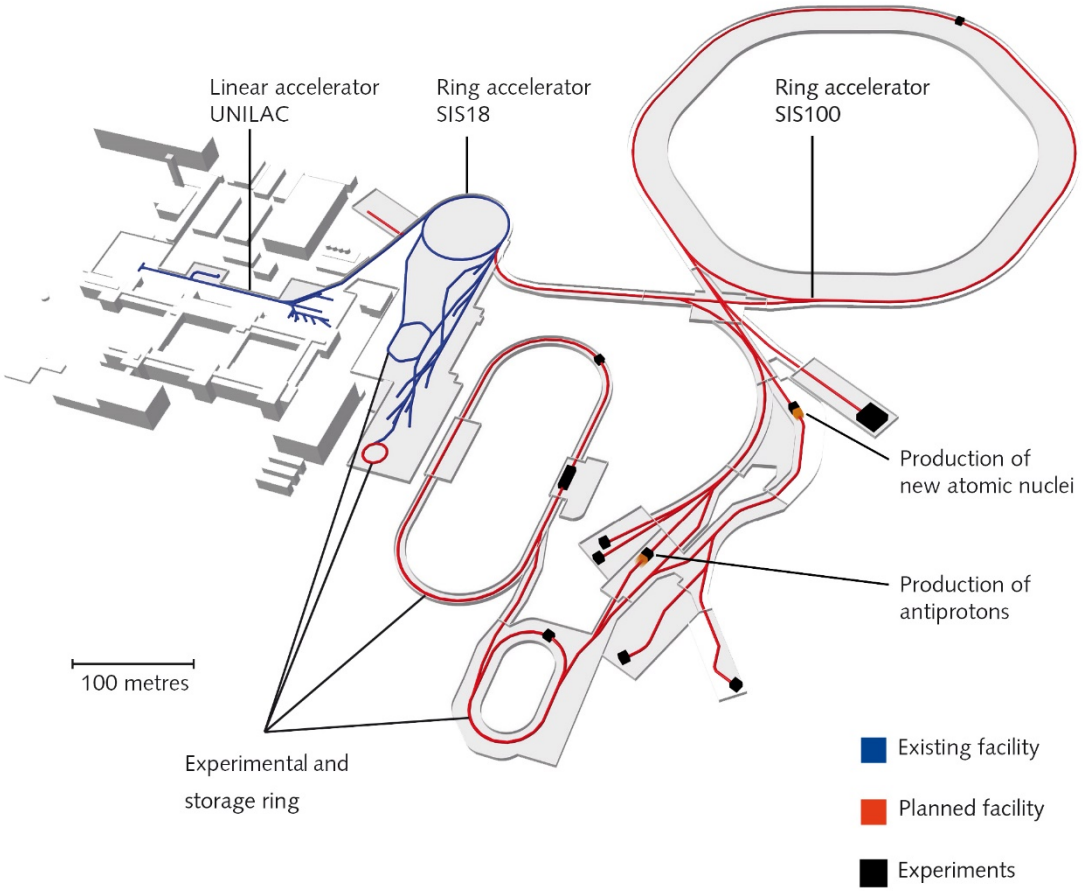

Profile Area: Matter and Radiation Science – Research Environment

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HIC for FAIR Helmholtz International Center | LOEWE

Heavy Ion Research
(State Funds)

ACCELENCE | DFG Deutsche Forschungsgemeinschaft

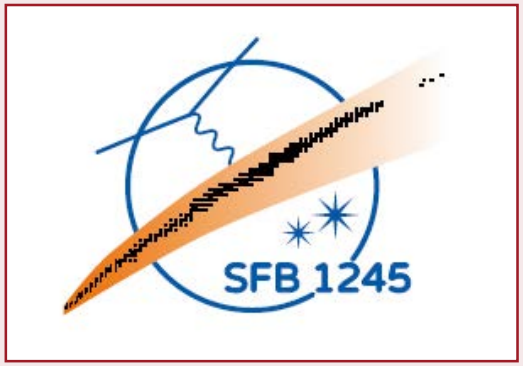
RTG 2128 AccelencE

Alexander von Humboldt Stiftung/Foundation

Humboldt Professorship

Nuclear Photonics | LOEWE

LOEWE Focus Area
(State Funds)



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- EUROPIUM
- PUMA
- GreatMoves (GSI)

GSI Helmholtzzentrum für Schwerionenforschung GmbH | HELMHOLTZ GEMEINSCHAFT

Strategic Cooperation
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