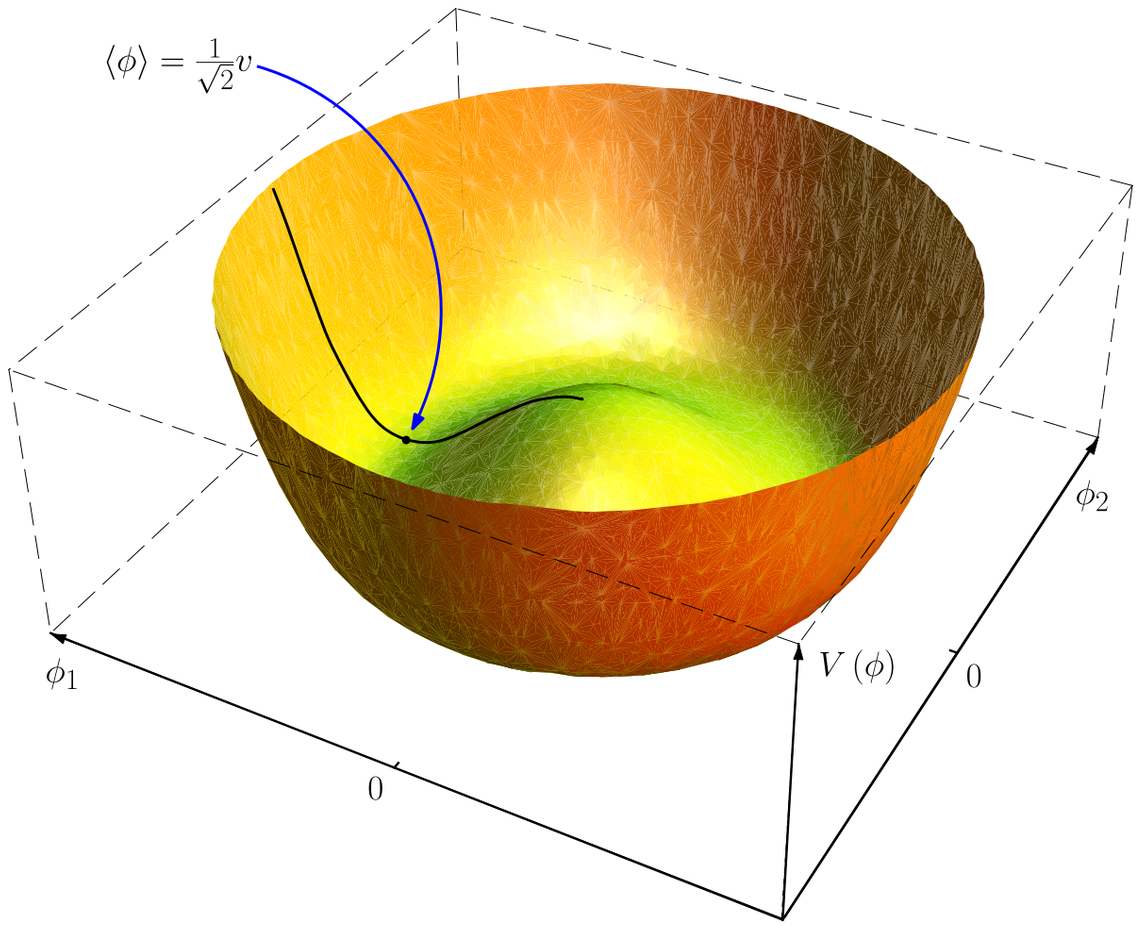
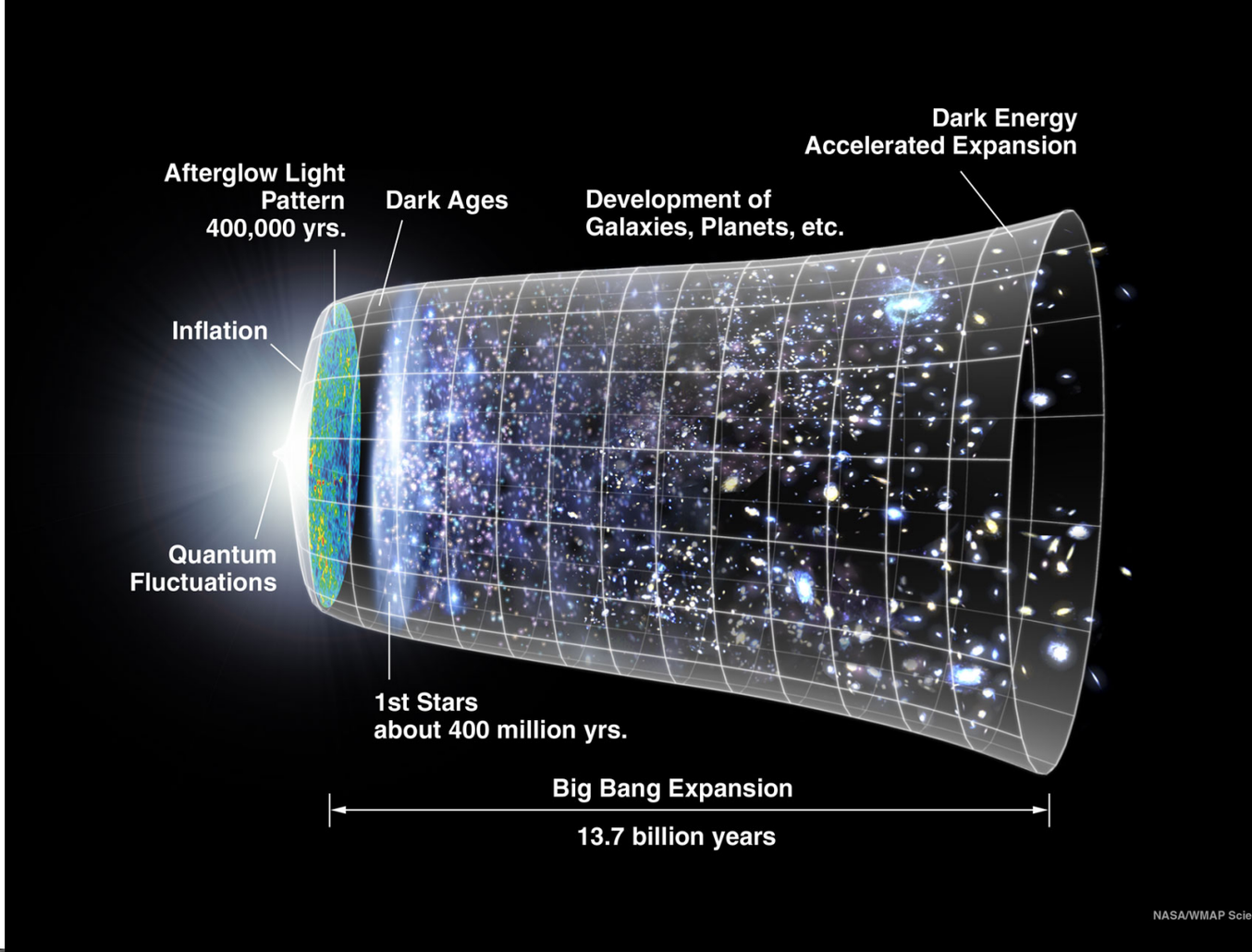
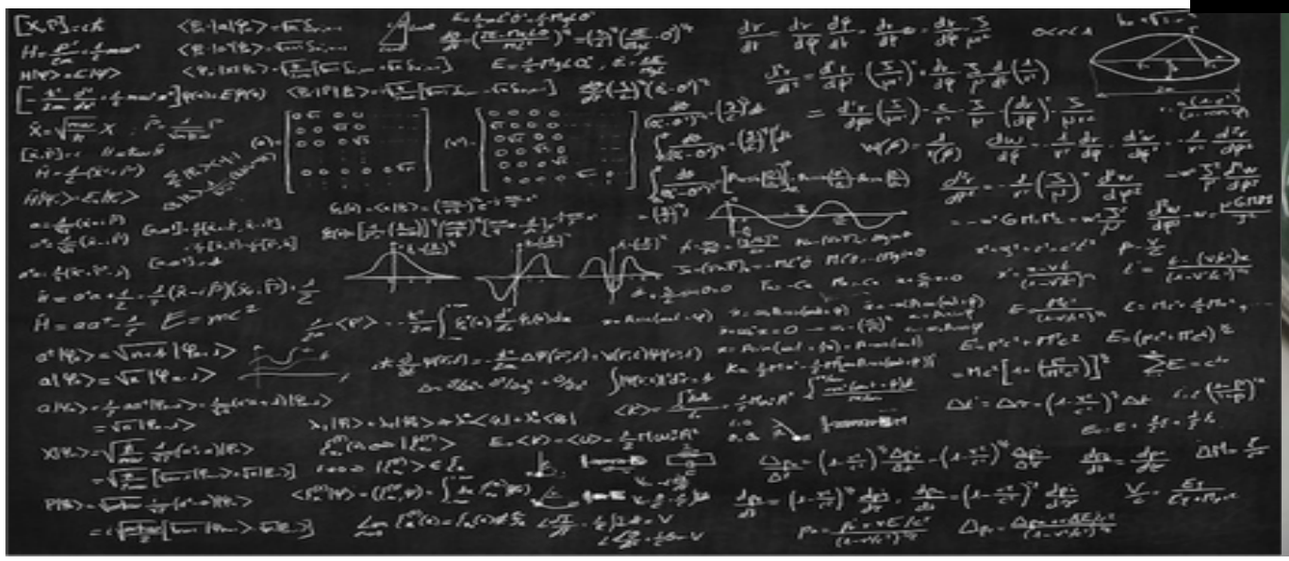






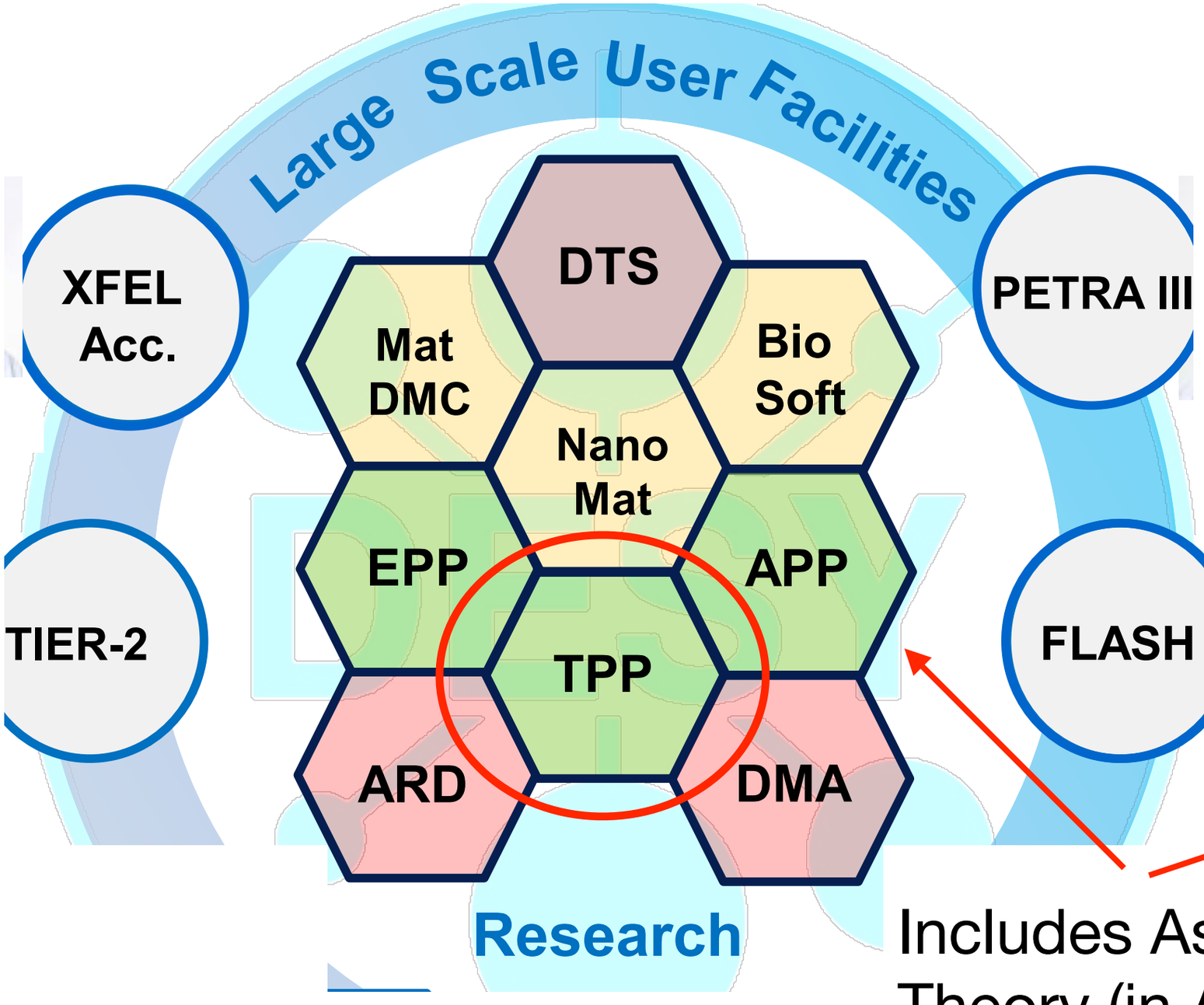
Theory at DESY — strategy and plans

Georg Weiglein, DESY

Hamburg, 11 / 2020

Theory at DESY and within the programme MU

The Research Unit (RU) Theoretical Particle Physics (in FH division)



EPP Exp. Particle Physics — Beate Heinemann

TPP Theory — Georg Weiglein

APP Astroparticle Physics — Marek Kowalski

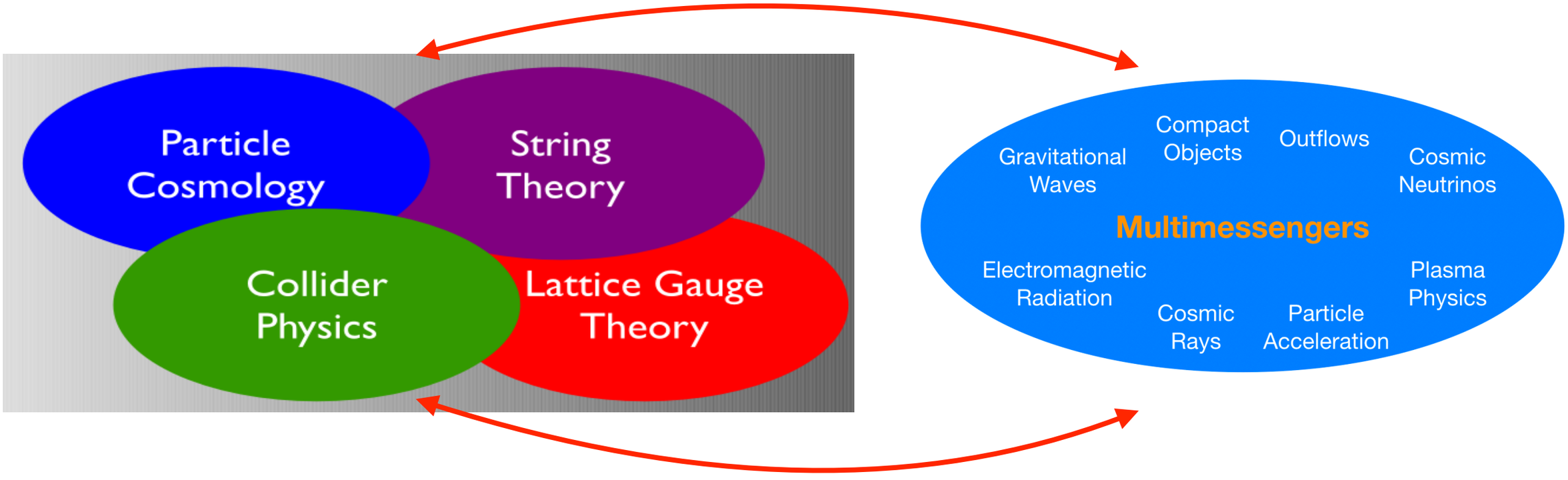
Research Units	Matter		POF III
	Matter and the Universe	**From Matter to Materials and Life**	**Matter and Technologies**
Experimental Particle Physics	Fundamental Particles and Forces	Research on Matter at LSF	Accelerator Research and Development
Theoretical Particle Physics	Cosmic Matter in the Laboratory	Facility Topic: Photon Sources	Detector Technologies and Systems
Astroparticle Physics	Matter and Radiation from the Universe	Facility Topic: Neutron Sources	
	TIER-2 Center	Facility Topic: Ion Sources	
		Facility Topic: Highest Magnetic Fields	

Includes Astroparticle Theory (in AP division)

Theory at DESY

Research Unit Theoretical Particle Physics (Hamburg, Zeuthen: ZPPT; FH)

Astroparticle Theory group (Hamburg, Zeuthen; AP):



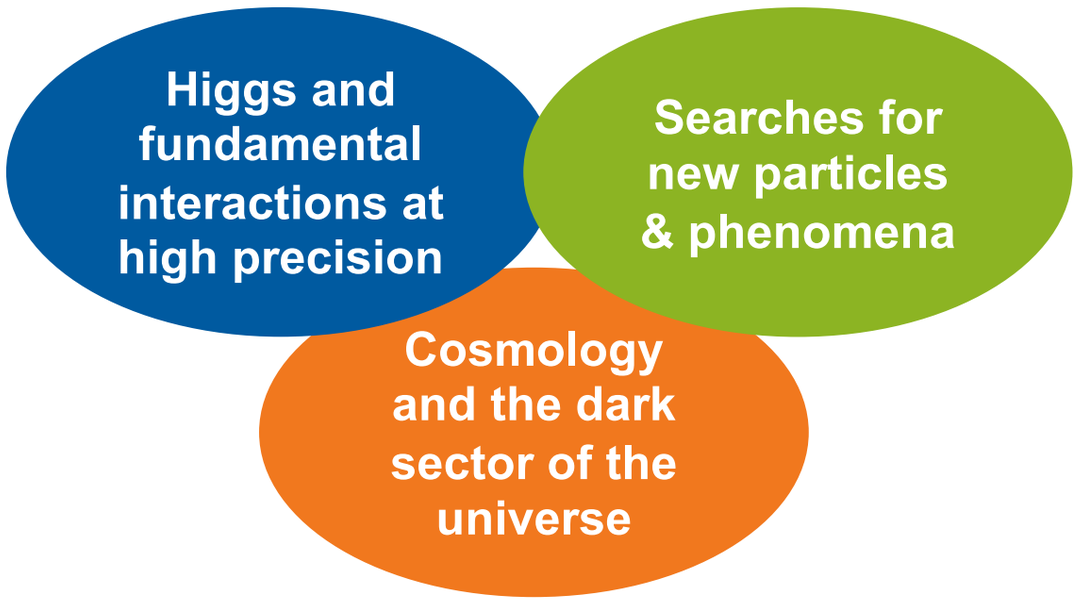
Other theory activities at DESY (condensed matter theory, …): embedded in the Research Units

Overarching structure (see below):
Wolfgang Pauli Centre, DESY (Hamburg, Zeuthen) + UHH

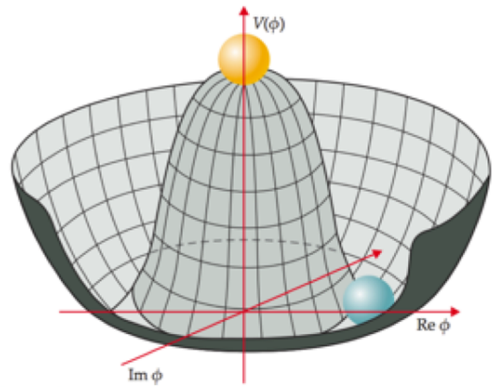
Research strategy: PoF IV (2021-27) and beyond

Our mission: Study the fundamental laws of Nature in our universe, governed by quantum physics and the dynamics of space-time

FPF: **Guiding themes for PoF IV**

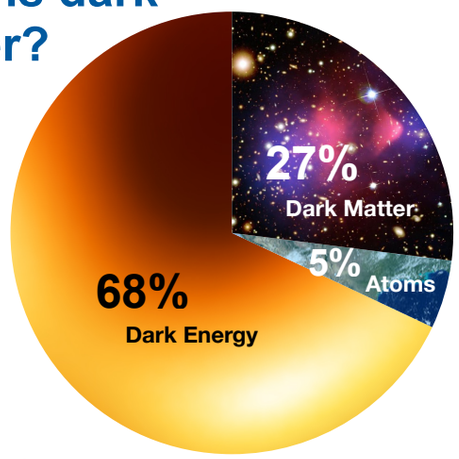


Science drivers

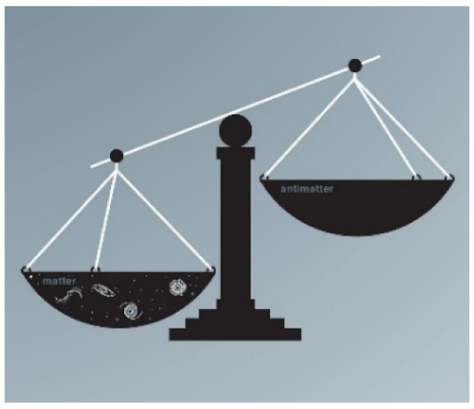


What is the structure of the vacuum?

What is dark matter?



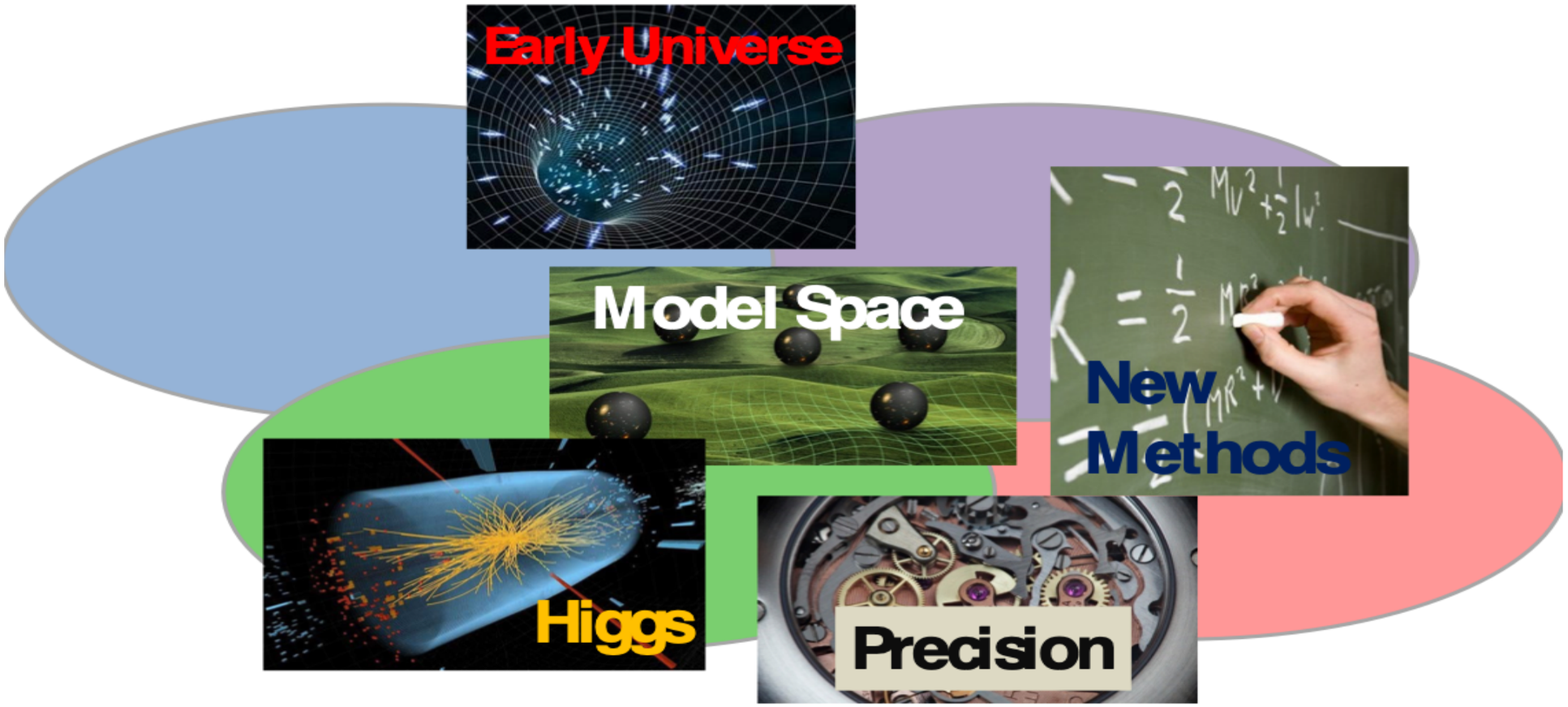
Where did the anti-matter go?



Close collaboration between experiment and theory

MRU: gamma rays, high-energy neutrinos, cosmic rays and gravitational waves as windows to the cosmos; dark matter searches with unprecedented sensitivity; gravitational physics of compact objects

Theoretical particle physics



The key challenges are addressed by combining approaches from different research areas

Transfer of methods and synergies between theoretical particle and astroparticle physics

Theory Research Unit within the DESY strategy

Evaluation Report of the Helmholtz Centre DESY, Research Field Matter, February 2018:

Research Unit Theoretical Particle Physics, Rating: ``Outstanding"

``*In all of its fields of activity, the Theory RU is performing research of absolute excellence according to international standards. Indeed, the Theory RU is widely recognized as one of the top Centres in theoretical physics in the world, thanks to the intellectual brillance, originality, and creativity of its members.*"

``*For the theory unit, maintaining or even extending the diversity of the research areas is crucial for stimulating new ideas and directions of research. In this context, the Wolfgang Pauli Centre should generate cross-fertilisation of theoretical ideas beyond particle physics, and this should be strongly supported.*"

Astroparticle theory within the DESY strategy

Evaluation Report of the Helmholtz Centre DESY, Research Field Matter, February 2018:

"*The performance of the Astroparticle Physics Theory Group is considered to be excellent. …*"

Milestones for the PoF IV period, FPF

Number	Year	Milestone
FPF-1	2021	First scientific results from the ALPS II experiment
FPF-2	2022	Interpretation of LHC results, electroweak precision measurements, and results from flavor physics in global fits
FPF-3	2022	First observation of four-top process by ATLAS/CMS; use of this channel for searches for new physics
FPF-4	2022	Reduction of the theoretical uncertainty for the mass of the SM-like Higgs in supersymmetric models to below 1 GeV
FPF-5	2022	Determination of cross sections for all accessible Higgs production and decay channels in the simplified template cross section framework
FPF-6	2023	Collection of 300 fb^{-1} of high-quality LHC data with both ATLAS and CMS
FPF-7	2023	With approx. 10 ab^{-1} of Belle II data, coverage of a new regime in coupling strength for dark photons and ALPs in the mass range of around 100 MeV – 10 GeV; factor 5–10 improvement on branching ratio limits on various LFV and LNV tau decay channels
FPF-8	2024	Extension of the discovery reach on dark matter at the LHC by a factor 3 to 5 (depending on the specific model) compared to present limits based on 2016 data, employing modern analysis methods such as machine learning
FPF-9	2024	Precise phenomenological predictions using perturbation theory (below 1% theory uncertainty) and lattice field theory (reduction of uncertainty by a factor of 2) for the strong coupling
FPF-10	2024	With approx. 15 ab^{-1} of Belle II data, establishment of first combined fit results for $\|V_{ub}\|$ and m_b based on inclusive B decays using improved theoretical predictions
FPF-11	2025	Completion of system-tested silicon tracker end-caps for ATLAS and CMS
FPF-12	2026	Increase of the precision of Higgs couplings determined from combined ATLAS/CMS data by a factor of 2 (compared to today) using high-precision theory predictions
FPF-13	2027	Collection of 50 ab^{-1} with the Belle II experiment

Milestones for the PoF IV period, MRU

Number	Year	Milestone
MRU-1	2023	IceCube upgrade operation started, IceCube-Gen2 design studies completed
MRU-2	2023	DARWIN technical design completed
MRU-3	2024	KATRIN reaches neutrino mass sensitivity of 0.2 eV/c^2 and sets up differential measurement of the beta spectrum
MRU-4	2024	First release of air shower simulation framework CORSIKA 8
MRU-5	2025	Proof of principle for quasi-atomic tritium source; concept for large-scale cryogenic distillation for DARWIN
MRU-6	2025	Construction of CTA finished, first science results obtained
MRU-7	2027	Auger publication of the proton fraction of ultra-high energy cosmic rays and of corresponding source searches
MRU-8	2027	First science results from IceCube upgrade on neutrino mixing parameters, recalibration of ice properties
MRU-9	2027	Release of sustainable user-led portal for astroparticle physics data and analyses
MRU-10	2027	KATRIN reaches ppm sensitivity for keV sterile neutrinos and probes exotic weak interactions

Wolfgang Pauli Centre (WPC)

WPC: PIER Competence field since 2013

PIER
Eine Partnerschaft der
Universität Hamburg und DESY

Theory areas: particle physics, cosmology, astroparticle physics, ultrafast, cold and condensed matter physics, mathematical physics

DESY involvement in WPC comprises all theory activities at Hamburg and Zeuthen

Dynamical evolution of the theory activities during the last decade, development of the experimental programme:
significant potential for new synergies

Mission of the WPC: interdisciplinary research to address fundamental challenges, vivid dialogue between theory and experiment, …

Wolfgang Pauli Centre: scientific pillars

The six existing research areas of the WPC

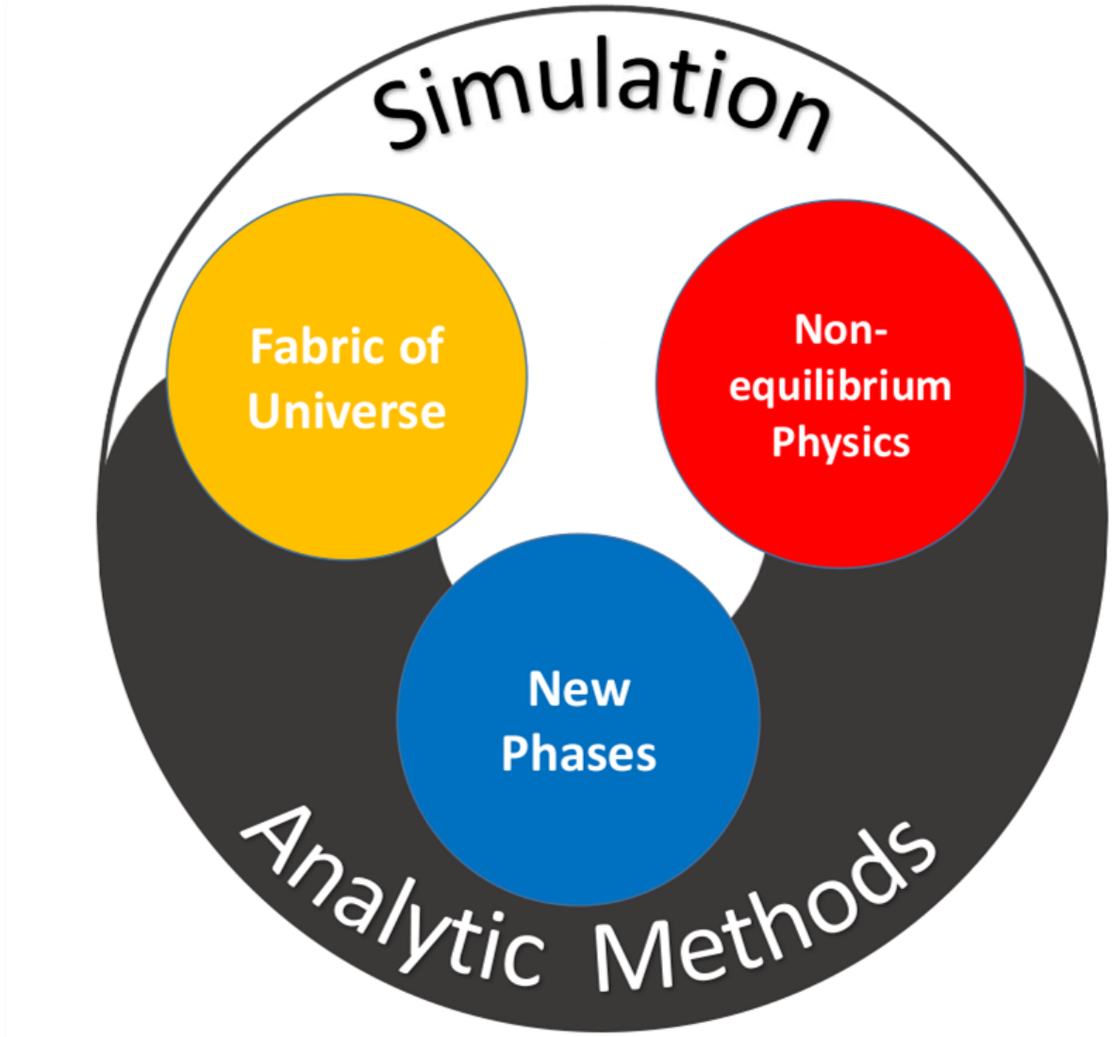
Will be restructured into

five interdisciplinary scientific pillars

- Non-equilibrium Physics
- Fabric of the Universe
- Analytic Methods

Overarching pillars:

- New Phases and Phase Transitions
- Simulation and Numerical Methods



Partnership agreements: national and international

Planned WPC building at the Hamburg site

Offices for theory departments:
DESY/UHH theoretical particle and astroparticle physics in main WPC building
Condensed matter theory in a WPC satellite

Members of institutes united with state-of-the-art discussion areas

Central facilities will host

- *Discussion areas & co-working spaces*
- *Office space for Zeuthen members*
- *Thematic Institutes* to address key challenges
- *Research hotel hosting long term guests (sabbaticals, Humboldt etc.) and young investigator groups*
- *Cross-disciplinary training (Masters, PhD, Postdocs) through lectures, schools; open student area*

WPC building within the planned Science City Hamburg-Bahrenfeld

Wolfgang-Pauli-Centre (WPC)

DESY Theory in the ``Quantum Universe" cluster

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

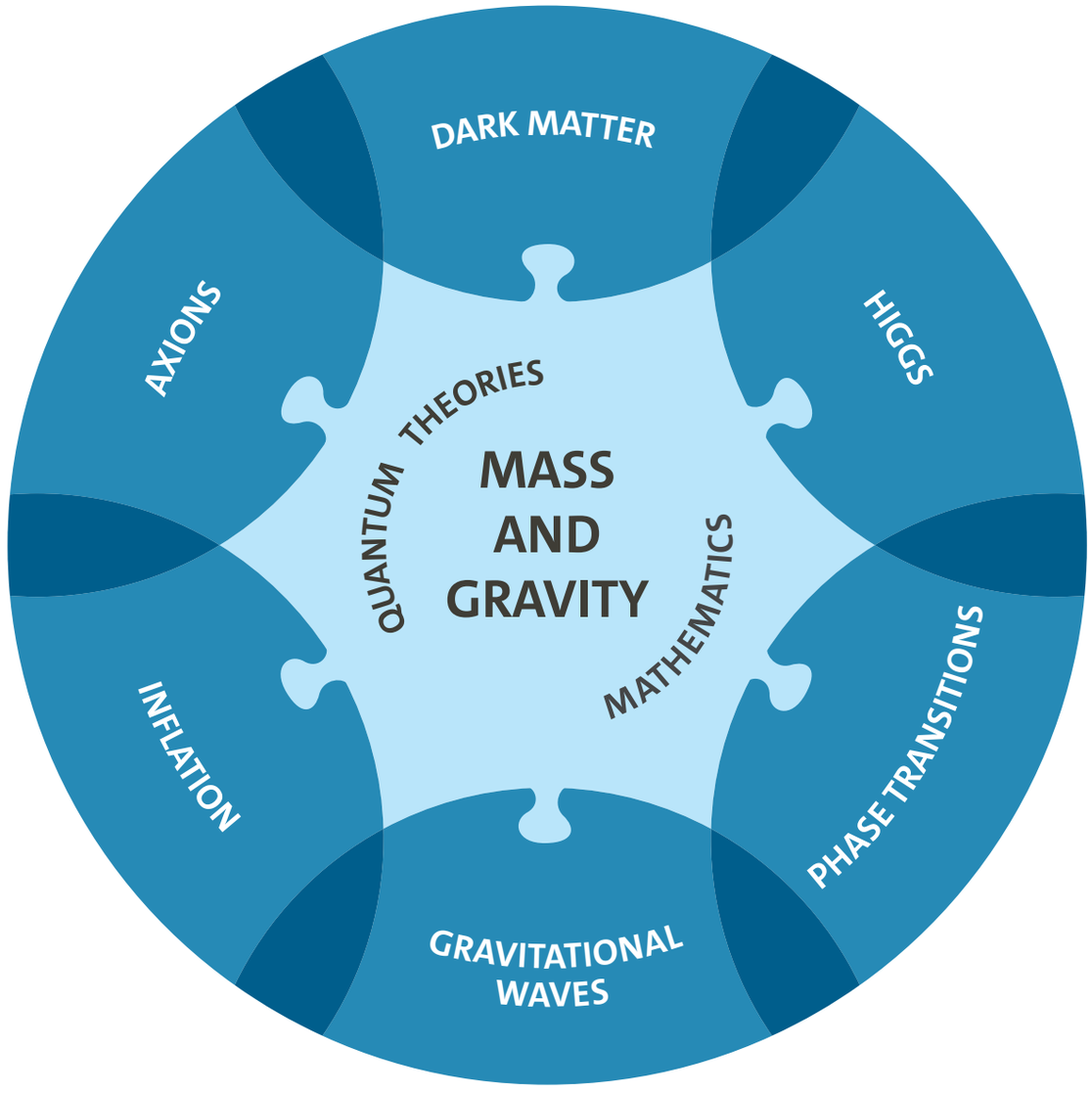
CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

DESY.

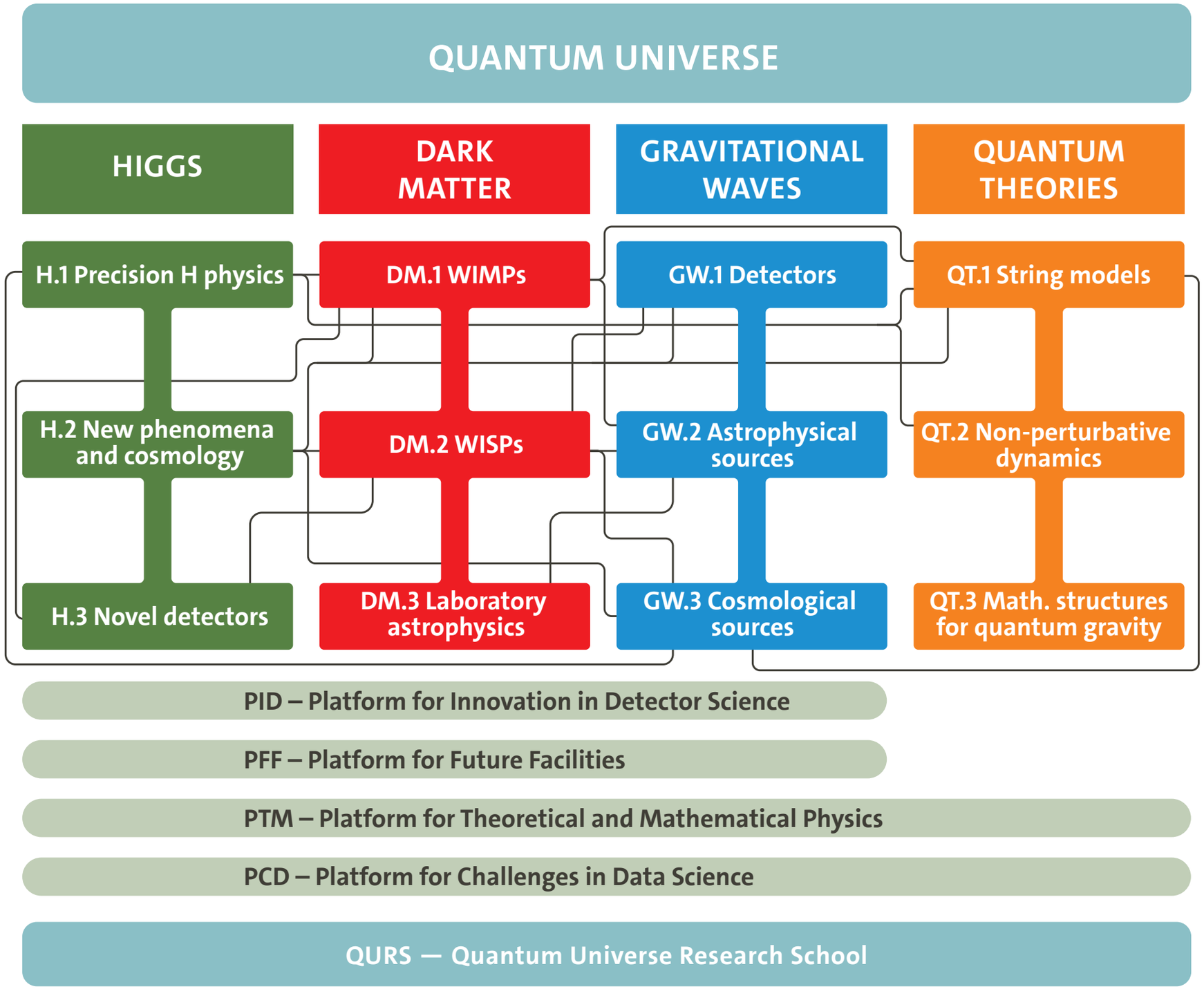
Goal: Understanding mass and gravity at the interface between quantum physics and cosmology

Close interaction between theory and experiment; intense dialogue between physics and mathematics

DESY theory: key responsibilities within the cluster; crucial contributions driving the research



DESY Theory in the "Quantum Universe" cluster



Strong involvement of theory!

Impact of the DESY theory activities

Programme and topic:

- Scientific output, high-level talks, convenorships, international connections, visibility
- Close connection to experimental programme: input, guidance and interpretation, physics harvest
- Exploit synergies from broad range of activities, theory as a driver for interdisciplinary activities

DESY:

- National laboratory: hub for theoretical particle physics in Germany
- Transfer of new research directions, methods and concepts
- Interaction with experimental groups, links across disciplines

Society:

- Talent management: well-educated for transfer of skills, problem solving, interdisciplinary approaches
- Science communication with strong appeal to general public, raises public interest in science
- Industry partnerships, algorithm development

Impact of the DESY theory activities

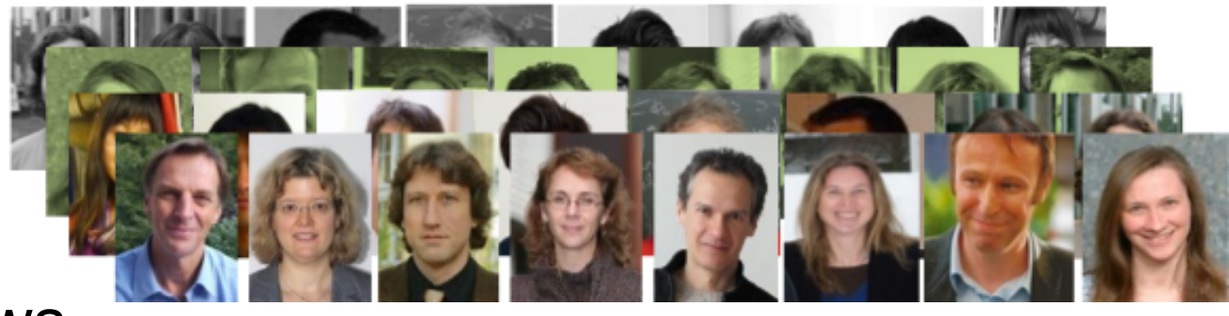
Training and research partnerships with local universities:
Hamburg, Berlin, Potsdam, …

Interdisciplinary research & training is highly attractive for international fellows and students

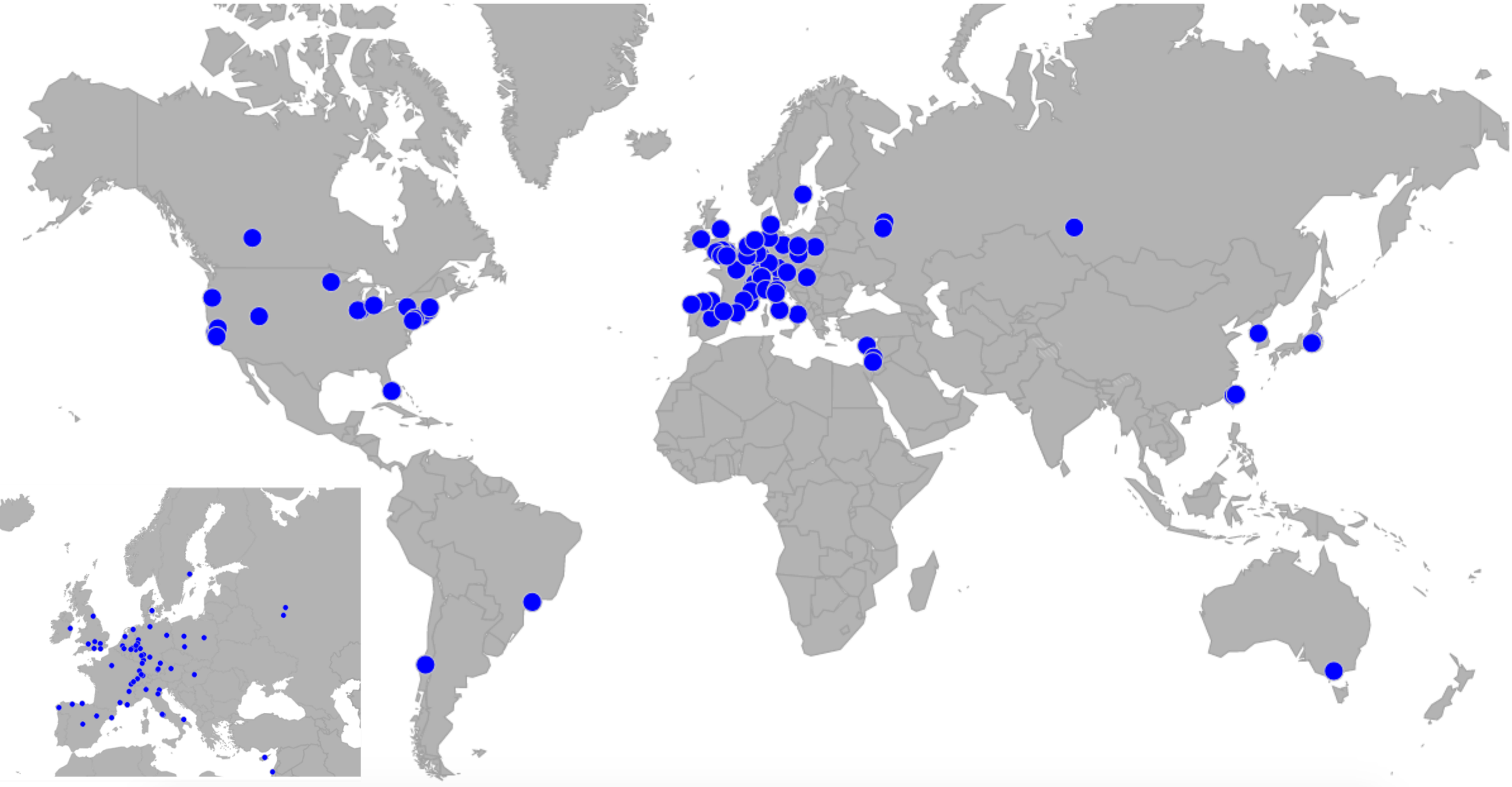
High-impact Fellowship programme

Important role as national laboratory:

- Workshops, schools, coordinating tasks
- About 40% of the particle theory faculty in Germany have been DESY PhDs, fellows or staff



Networking: world-wide collaborations



Scientific computing: connections with partners in academia and industry

Cooperation with world leading computer algebra sites

- Cooperation with *MapleSoft* and *Wolfram Research* within various EU networks

- Excellent PhD training sites

- *Wolfram Research* interested in continuous cooperation

- Invitations to plenary talks at *Mathematica* conference

- Operation of **large scale computers** for computer algebra

RISC Linz: Summation, Combinatorics

RISC Software GmbH

FORM (NIKHEF)

DESY THEORY GROUP

Wolfram Research (Urbana, IL)

MapleSoft (Waterloo, ON)

New: laboratory for quantum computer applications

[slide by K. Jansen]

- Brandenburg Zukunftsinvestitionsfonds-Einrichtungsgesetz (ZifoG)

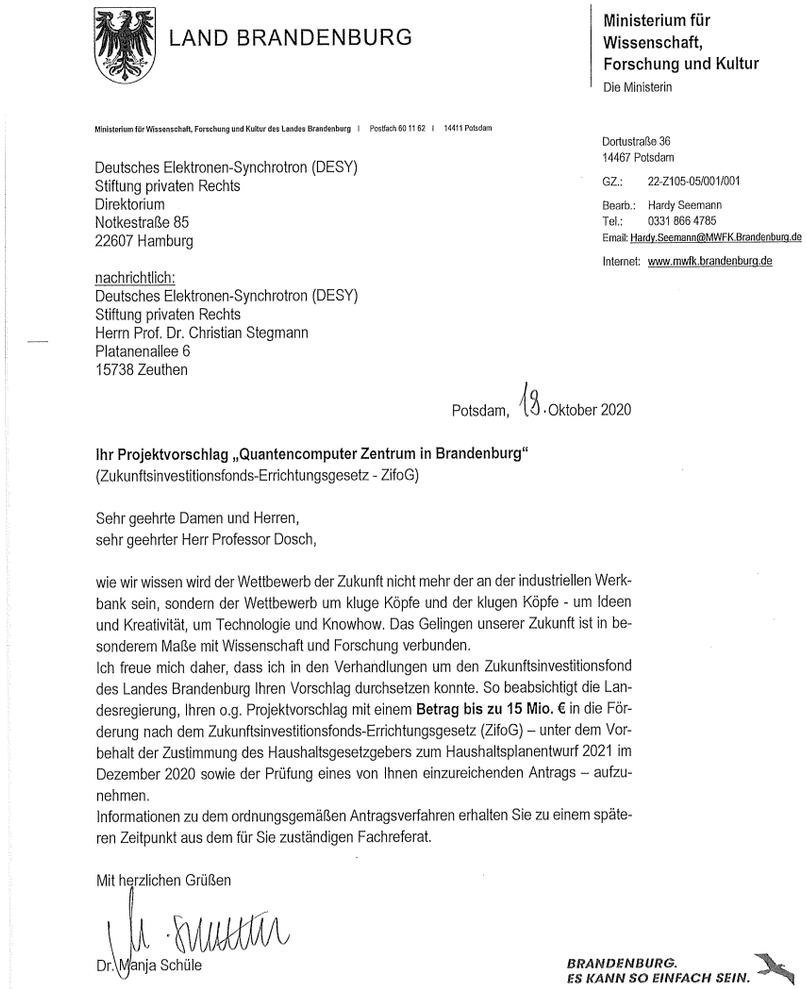
- project proposal for quantum computing applications at DESY

  → received financial means of **up to 15 million euro**

- boundary conditions not known yet

- will work out DESY concept

- connect DESY to universities in Berlin and Brandenburg



LAND BRANDENBURG

Ministerium für Wissenschaft, Forschung und Kultur
Die Ministerin

Ministerium für Wissenschaft, Forschung und Kultur des Landes Brandenburg | Postfach 60 11 62 | 14411 Potsdam

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Notkestraße 85
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Herrn Prof. Dr. Christian Stegmann
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15738 Zeuthen

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14467 Potsdam

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Internet: www.mwfk.brandenburg.de

Potsdam, 19. Oktober 2020

Ihr Projektvorschlag „Quantencomputer Zentrum in Brandenburg“
(Zukunftsinvestitionsfonds-Errichtungsgesetz - ZifoG)

Sehr geehrte Damen und Herren,
sehr geehrter Herr Professor Dosch,

wie wir wissen wird der Wettbewerb der Zukunft nicht mehr der an der industriellen Werkbank sein, sondern der Wettbewerb um kluge Köpfe und der klugen Köpfe - um Ideen und Kreativität, um Technologie und Knowhow. Das Gelingen unserer Zukunft ist in besonderem Maße mit Wissenschaft und Forschung verbunden.
Ich freue mich daher, dass ich in den Verhandlungen um den Zukunftsinvestitionsfond des Landes Brandenburg Ihren Vorschlag durchsetzen konnte. So beabsichtigt die Landesregierung, Ihren o.g. Projektvorschlag mit einem **Betrag bis zu 15 Mio. €** in die Förderung nach dem Zukunftsinvestitionsfonds-Errichtungsgesetz (ZifoG) – unter dem Vorbehalt der Zustimmung des Haushaltsgesetzgebers zum Haushaltsplanentwurf 2021 im Dezember 2020 sowie der Prüfung eines von Ihnen einzureichenden Antrags – aufzunehmen.
Informationen zu dem ordnungsgemäßen Antragsverfahren erhalten Sie zu einem späteren Zeitpunkt aus dem für Sie zuständigen Fachreferat.

Mit herzlichen Grüßen

Dr. Manja Schüle

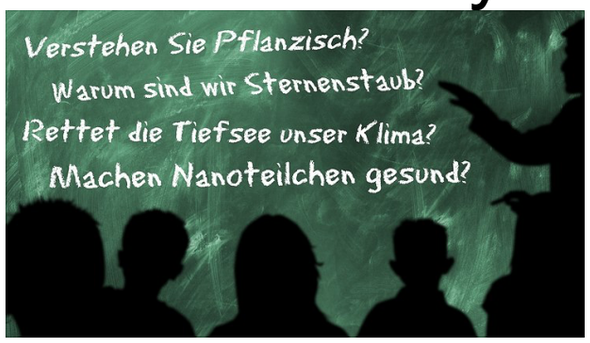
BRANDENBURG.
ES KANN SO EINFACH SEIN.

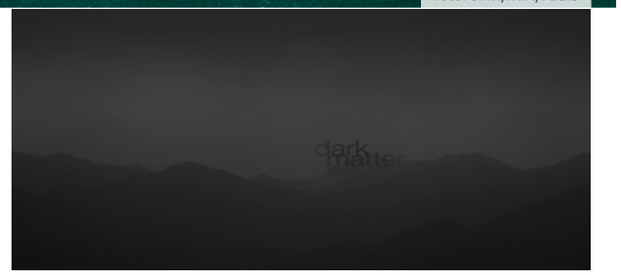
- strengthening regional network South-East of Berlin especially with TH Wildau (← connection to industry)

Outreach activities (examples)

Science on tap ``Wissen vom Fass'': since 2015, usually twice per year, next edition was planned for today at 50 locations (moved to spring 2021)

Science at schools ``Wir wollen's wissen!'': since 2018, so far two times; ``Wir wollen's wissen!'' week in January 2020: 42 participating schools, ~100 presentations; next edition: January 21





Art meets Science:

+ many more

Hamburg Kreativ Gesellschaft

EUROPÄISCHE UNION
Europäischer Fonds für regionale Entwicklung

DESY strategy process: goals for the next 10-15 years

	Goal	Description (2017-2030ff)
		Scientific goals: origin of mass, new phenomena, dark sector
A	Precision	Calculate quantum effects in the Standard Model and beyond
B	Open Tools	Develop public tools for community: predictions, simulations, global fits, analysis of experimental data
C	Modelling	Advance novel theoretical concepts to model quantum systems
D	Dark Sector	Explore theoretical models for dark matter and cosmology
		Structural goals
E	CHAMPP Theory	Extend position as leading international centre for **theory of matter and space-time** in research, talent management, scientific events, …
F	Wolfgang Pauli Centre (WPC)	Establish WPC as the **national centre for theoretical physics** at interface of particle/astrop. physics, mathematics and photon science
G	Link Hamburg-Berlin/Zeuthen	Develop research & training collaboration in the **HH-B metropolitan area** to fully exploit opportunities for synergies and growth

CHAMPP: Centre Hamburg for Astro-, Mathematical and Particle Physics

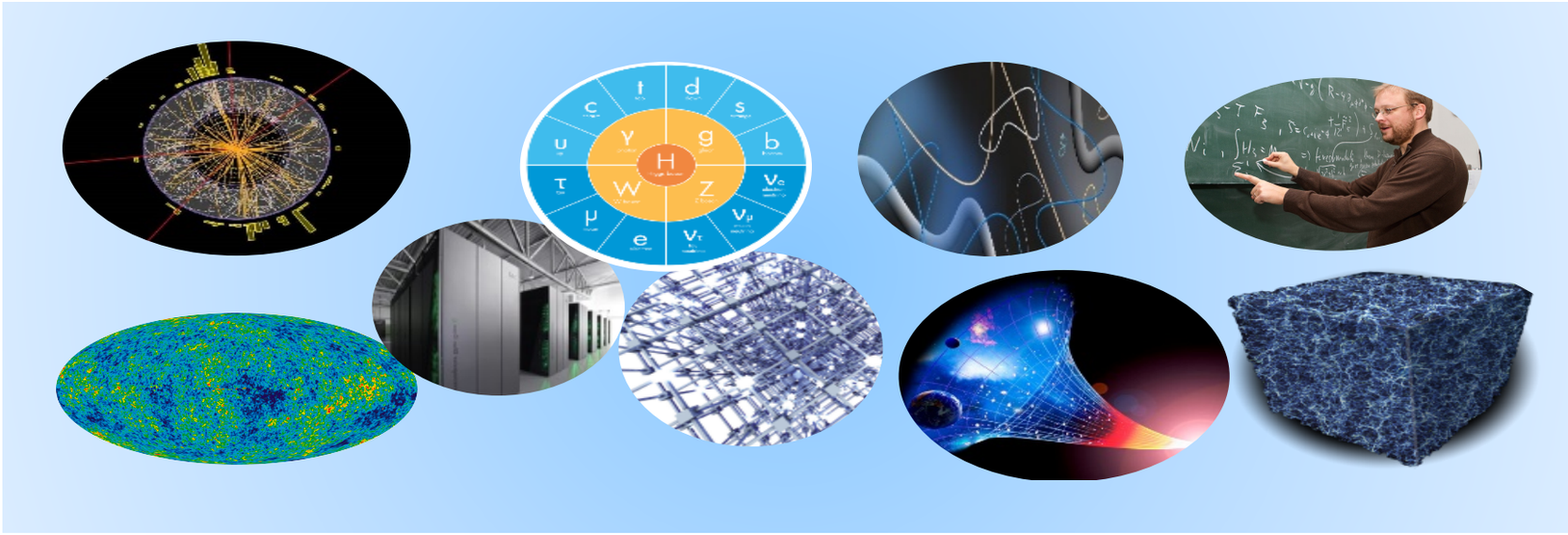
Strategy

Extend position as international competence centre for the theory of the fundamental interactions of nature, matter and space-time,
addressing all aspects in the theory of matter and gravity through research and training, from observation to mathematics

Matter

Dark Sector

Cosmology



Observation **Theoretical Physics** **Mathematics**

Offers unique cross-disciplinary training opportunities for young researchers

Develop the Wolfgang-Pauli Centre as centre for theoretical physics
Theory building, importance of communication space

Explore scientific opportunities in Hamburg-Berlin metropolitan area:
particle/astroparticle phyisics, theory-experiment-computing

Strategic developments

- RU Theoretical Particle Physics:
  Foster the role as competence centre for collider physics, particle cosmology, string theory and lattice gauge theory; exploit connection with the physics of gravity and astroparticle theory; strengthen and develop cross-disciplinary links (QU cluster, WPC, …)

- Astroparticle Theory:
  Link multi-messenger exploration with gravitational physics of compact objects: relativistic magnetohydrodynamics simulations

- ZPPT group at Zeuthen:
  New hirings under discussion (see next slide)

Strategy for new hirings in the ZPPT group

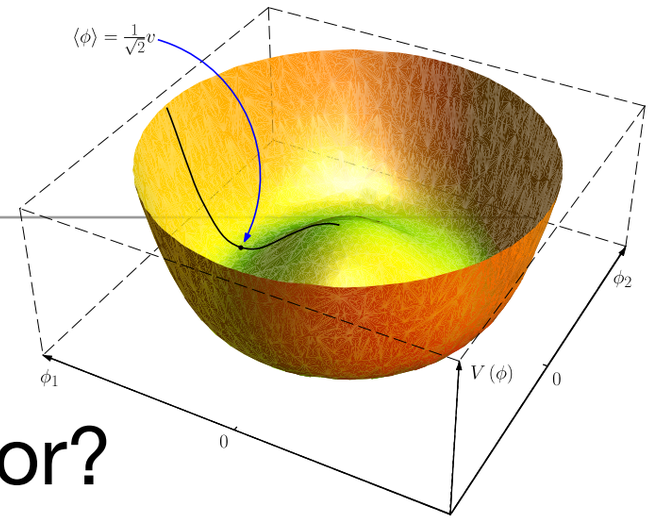
Strategy for new hirings in the ZPPT group at Zeuthen in view of retirements that have occurred and are upcoming during the next years

Goal: continue the excellent core research activities of the group while strengthening synergies with the local research environment of the DESY groups at Zeuthen and Hamburg and of the partners in the Berlin area

Foster expertise in computational techniques (simulations, quantum computing algorithms, high-precision perturbative and non-perturbative calculations of observables)

The new scientists should have a broad research profile while ensuring that the core research areas of the group are maintained at a world-leading level

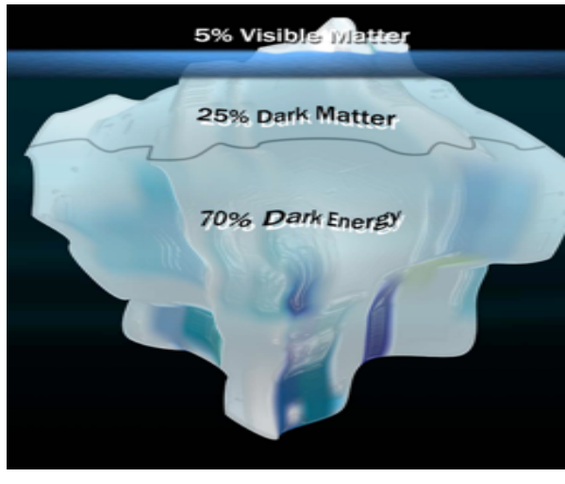
Vision



Expect cutting edge results:

- Connect Higgs, early universe and the dark sector?
- Explain dark matter?
- Discoveries?

A leading partner and national lab:



- Hub for theoretical particle physics in Germany
- Transfer of new research directions, methods and concepts, exploration of links across disciplines
- Close interaction with experimental groups