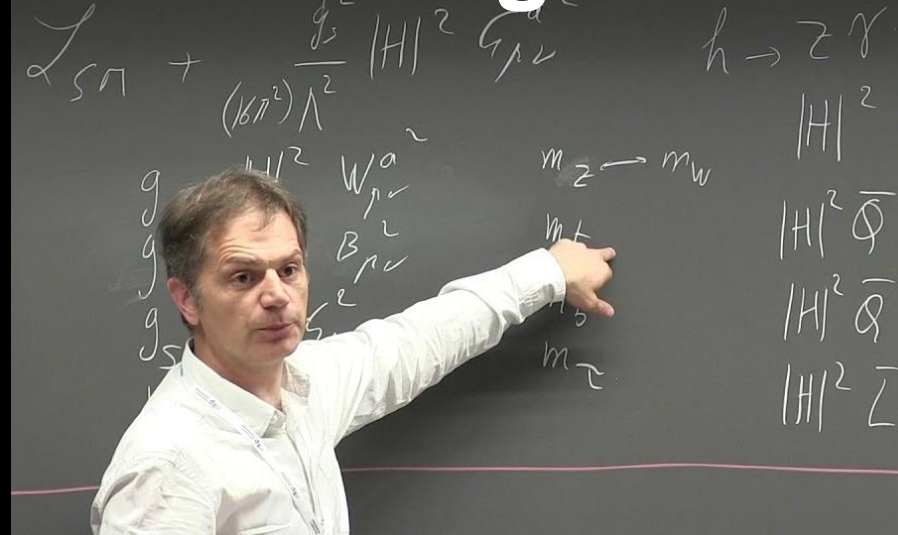
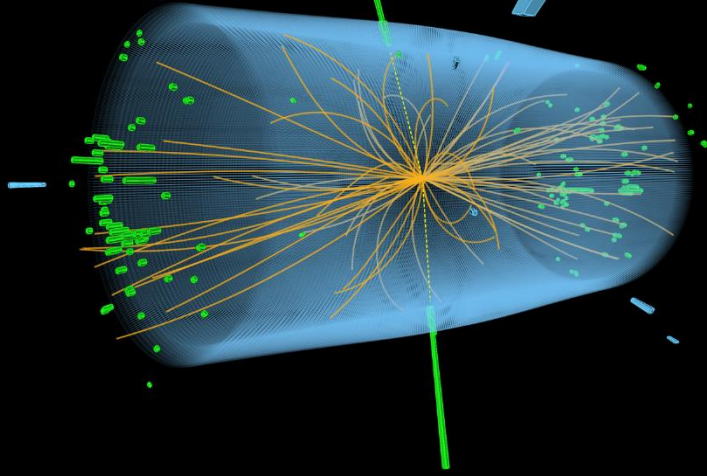


# String Theory, Lattice Gauge Theory and the WPC



Helmholtz Program: Matter and the Universe (MU)

PoF III Topic: Fundamental Particles and Forces

DESY Research Unit: Theoretical Particle Physics

Volker Schomerus

PoF4 meeting March 18, 2019

# Lattice Gauge Theory

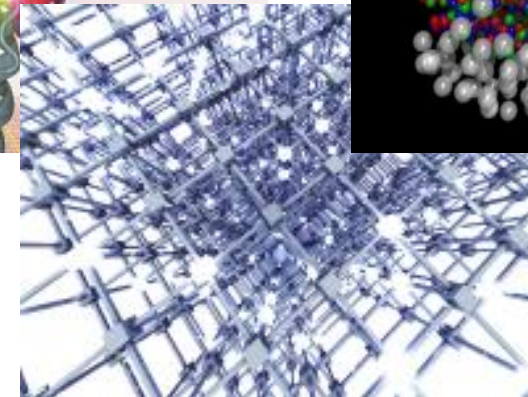
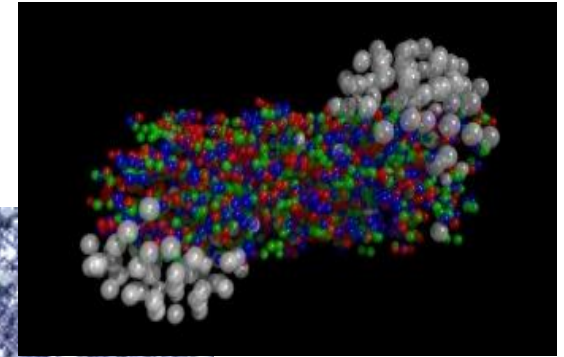
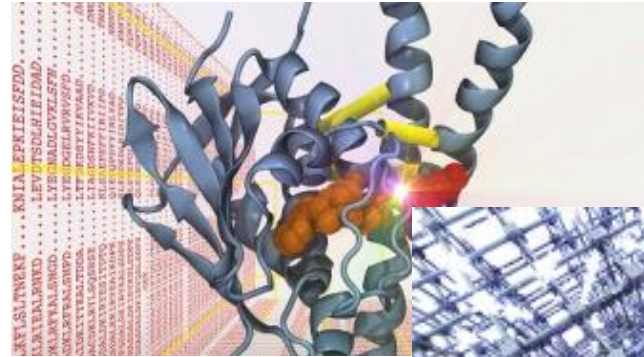
In the John von Neumann Institute for Computing

# NIC: John von Neumann Institute for Computing

Research group “Elementary Particle Physics”

## What is NIC?

- Cooperation between  
Helmholtz Centres Forschungszentrum Jülich,  
Deutsches Elektronensynchrotron DESY  
GSI Helmholtzzentrum für Schwerionenforschung
- NIC maintains five research groups:  
Computational Biophysical Chemistry (JSC)  
Computational Structural Biology (JSC)  
Elementary Particle Physics (DESY)  
Lattice Quantum Chromodynamics (GSI)  
Nuclear Matter (GSI)
- NIC provides supercomputer time at Jülich  
supercomputer centre through a peer review process
- Group “Elementary Particle Physics”:  
staff : Karl Jansen, Stefan Schaefer, Hubert Simma, Rainer Sommer  
Connection to HU Berlin, one APL + joint professorship in progress  
3 Postdoc positions plus 1 PhD  
Third party grants



# Core Competences

The strengths of the NIC group

## **Non-perturbative evaluations of quantum field theories**

- Lattice QCD
- Higgs-Yukawa models
- Low dimensional field theories

## **Development of new algorithms and concepts**

- Multi-level algorithms
- Tensor networks
- Quantum computing

## **High performance computing**

- Efficient use of new hardware
- Parallelization

# Outlook

## Improving the already good

**Adding charm to reach four active quarks in physical condition**

→ continuum computation of broad spectrum of physical observables

$g-2$ , PDFs, hadronic form factors, scattering amplitudes, ...

**Form factors for Belle II**

→ input for and interpretation of experiment

**Half the error of  $\alpha_s(M_Z^2)$**

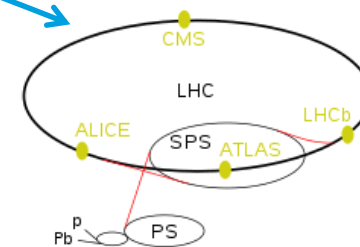
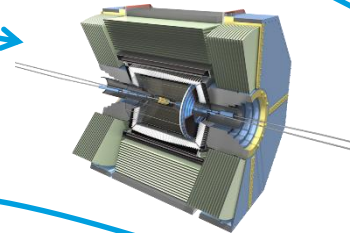
→ reach new level of precision of fundamental parameter

**Investigate reliability of perturbation theory**

→ compute several observables at intermediate to high energies



**Jefferson Lab**



# Outlook

## Exploring news paths

### Tensor networks in higher dimensions

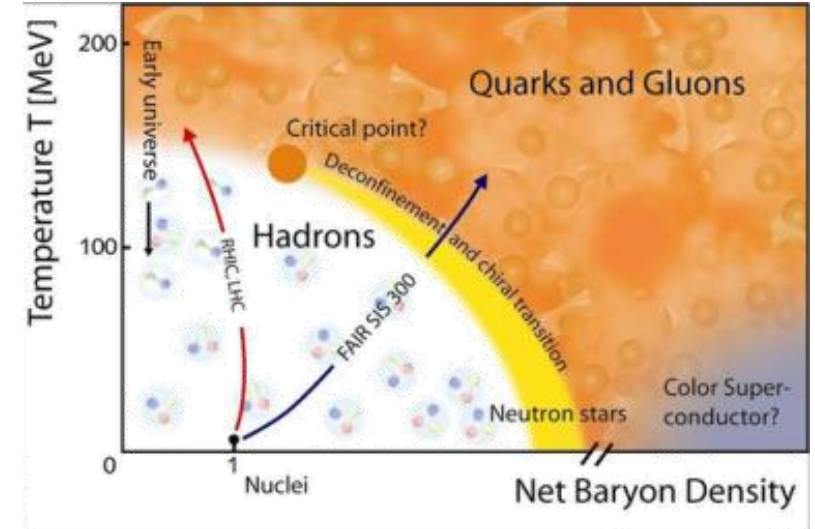
→ ambitious goal to solve sign problem, real time simulation ...

### Development of algorithms for next generation of lattice simulations

→ exploit more, e.g. domain decomposition, tensor networks

### Activities related to scientific computing/data (c.f. Heibrids, CDCS)

→ algorithm performance modelling on new architectures, quantum simulations



# String Theory and Mathematical Physics

Rethinking Quantum Field Theory

# String Theory and Mathematical Physics

Interdisciplinary Research at the interface of Particle Physics and Mathematics

Develop and apply modern technique from String Theory & Mathematical Physics to access physics of matter and space-time **deep in the quantum regime**

With its partners the group pursues a broad spectrum of modern approaches on internationally highly competitive level - *Integrability, Amplitudes, Supersymmetry, Bootstrap.*





# String Theory and Mathematical Physics

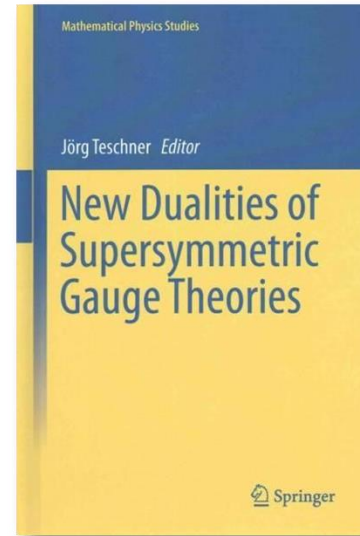
Interdisciplinary Research at the interface of Particle Physics and Mathematics

## Integrability



Elli Pomoni

## Supersymmetry



## Amplitudes



## Conformal Field Theory and Bootstrap



Pedro Liendo

# Expected Milestones

Within next years

**Use a combination of these modern tools to**

- **Map out the space of quantum theories of matter.**

Including those quantum theories that do not possess a classical limit (Lagrangian)

- **Obtain first exact non-perturbative construction of interacting quantum theory in 4D.**

Provide new paradigm for perturbation theory and its non-perturbative completion

- **Develop mathematical tools to model quantum space-time.**

# Wolfgang Pauli Centre

Interdisciplinary center for Theoretical Physics

# The Wolfgang Pauli Centre

Interdisciplinary Research in theoretical physics

*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.*

*The plan to develop the Wolfgang Pauli Centre as a hub for theoretical physics is important to the group's future and will allow them to become more cohesive. The centre will foster the serendipitous interactions which frequently result in new theoretical insights.*

*We stress the **importance of finalizing plans for the construction of the new building and defining the scientific structure of the Wolfgang Pauli Centre**. This will be a crucial step for bringing together the different groups of the Theory RU and enhancing opportunities for scientific exchanges.*

In response we developed a strategy for WPC and wrote white paper for separate evaluation by international panel of theorists.

# Mission Statement for WPC

It is the mission of the Wolfgang Pauli Centre to be a leading centre for theoretical physics that pursues and promotes interdisciplinary research to address the fundamental challenges in our understanding of matter, materials and the universe. Profiting from its unique embedding in a large-scale research centre, the WPC fosters international cooperation as well as a vivid dialogue between theory and experiment. With its novel setup it serves as a hub for scientific exchange between all partners and for educating and training the next generation. As a lighthouse for theoretical physics in Science City Bahrenfeld it also seeks dialogue with society in the region and beyond.



# WPC Scientific Pillars

## Six WPC research areas

PARTICLE PHYSICS

ASTROPHYSICS & COSMOLOGY

MATHEMATICAL PHYSICS

CONDENSED MATTER

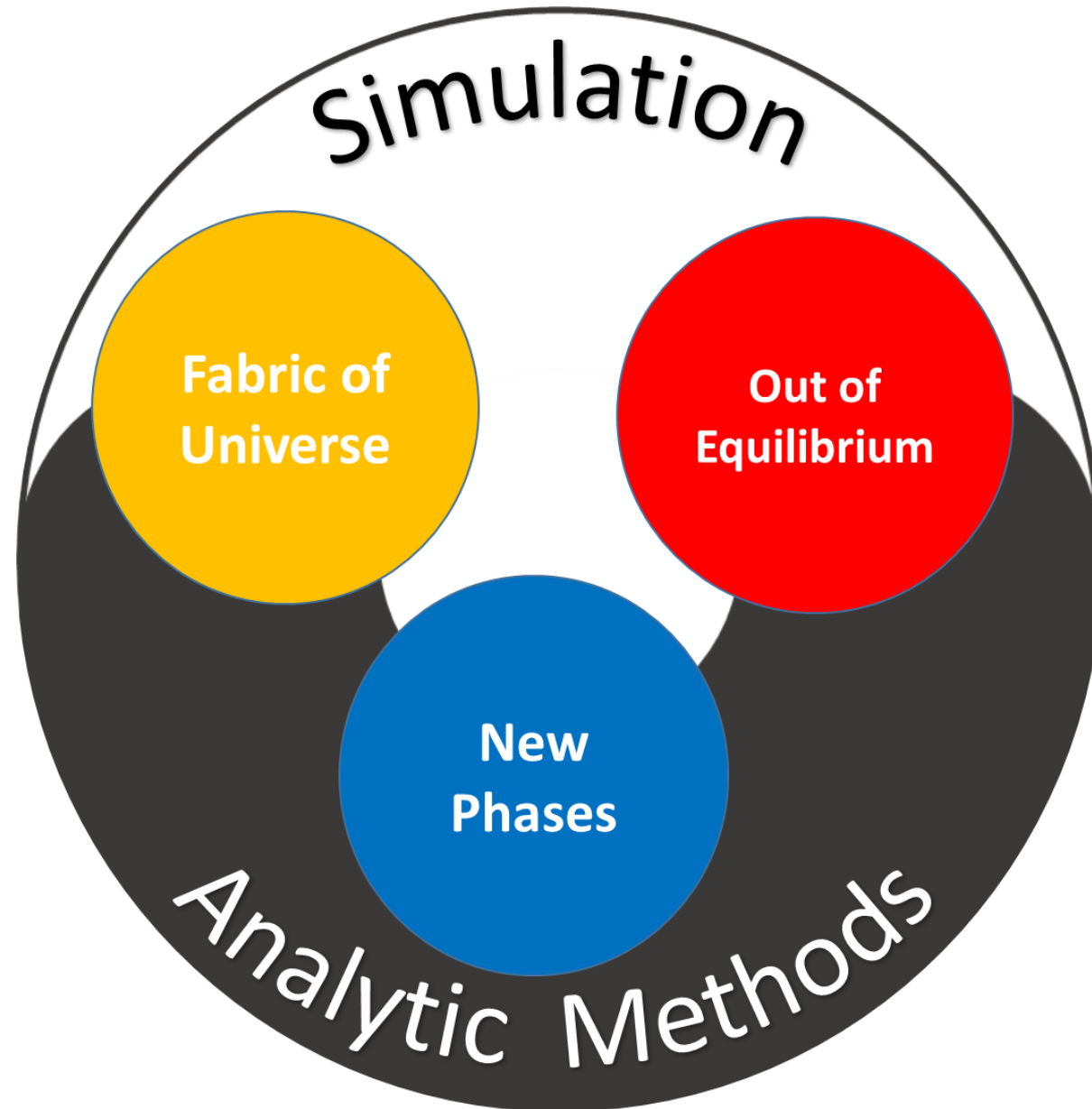
ULTRACOLD ATOMS

ULTRAFAST PROCESSES

## Reorganized into

**Five interdisciplinary pillars**  
involving at least 2-3 major  
research areas each

Scientific convener for each pillar



# Measures

## A selection

### Offices & co-working spaces for theory departments

DESY T & II ITP in main WPC building

I ITP in WPC satellite

Members of institutes united with state-of-the-art discussion areas & co-working spaces for partners



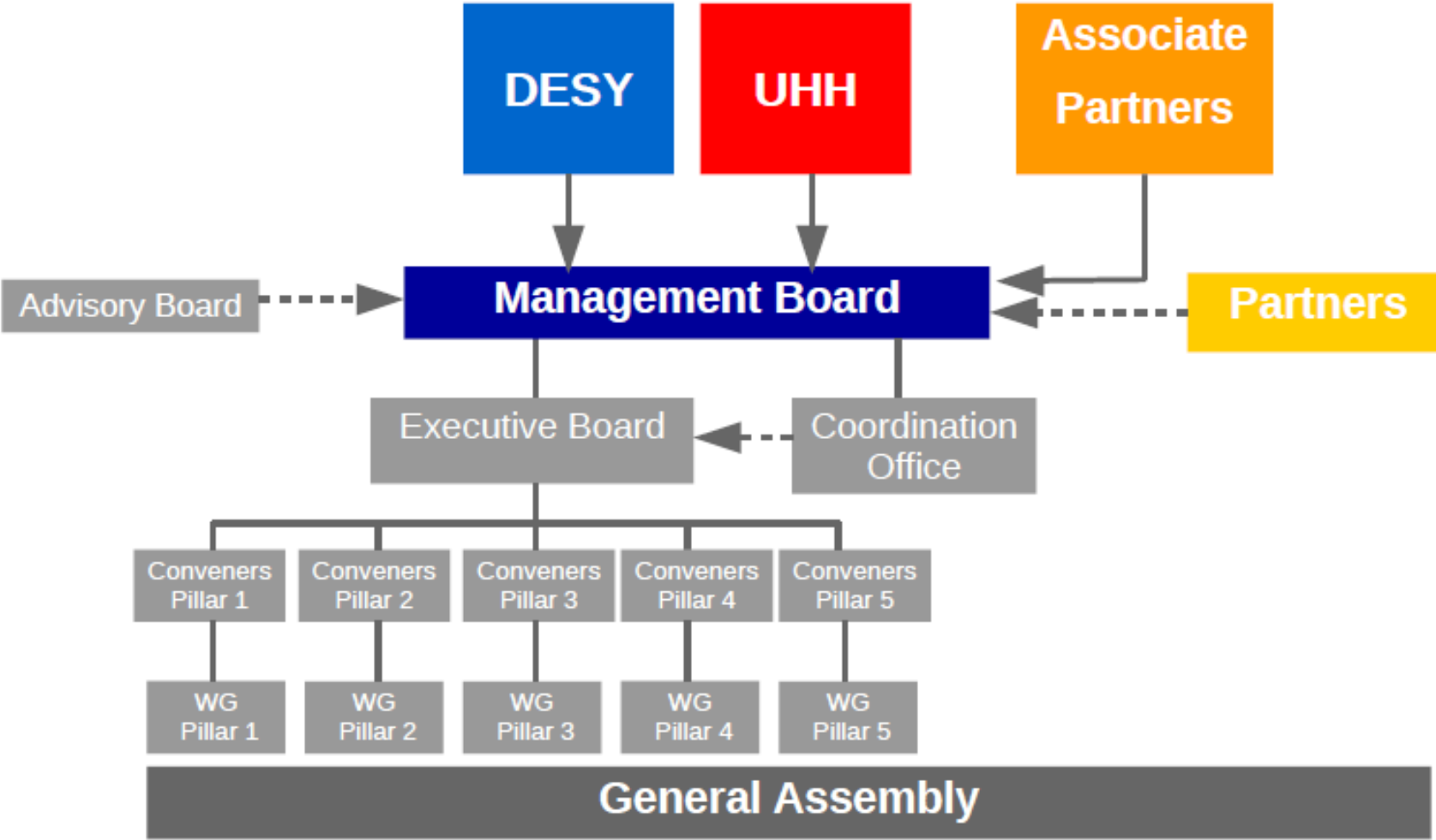
### Guest scientist program

- **Thematic Institutes** to address key challenges of five scientific pillars.
- **Research hotel** hosting long term guests (sabbatical, Humboldt etc.) and young investigator groups.
- Distinguished guest scientists, i.p. **HH prize for Theoretical Physics**



# Governance Model

In a picture





# Key Partners

## National Partners

National Partners complement the scientific spectrum of the Wolfgang Pauli Centre through contributions to workgroups, organization of thematic programs, research collaboration ...

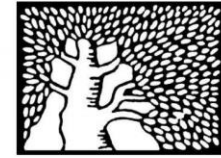


# Key Partners

## International Partners

... share interdisciplinary approach and possess history of interaction with some WPC groups.

One key element of future collaboration are exchange programs for young scientists (PhD, postdoc)



מכון ויצמן למדע  
WEIZMANN INSTITUTE OF SCIENCE



SIMONSCENTER  
FOR GEOMETRY AND PHYSICS