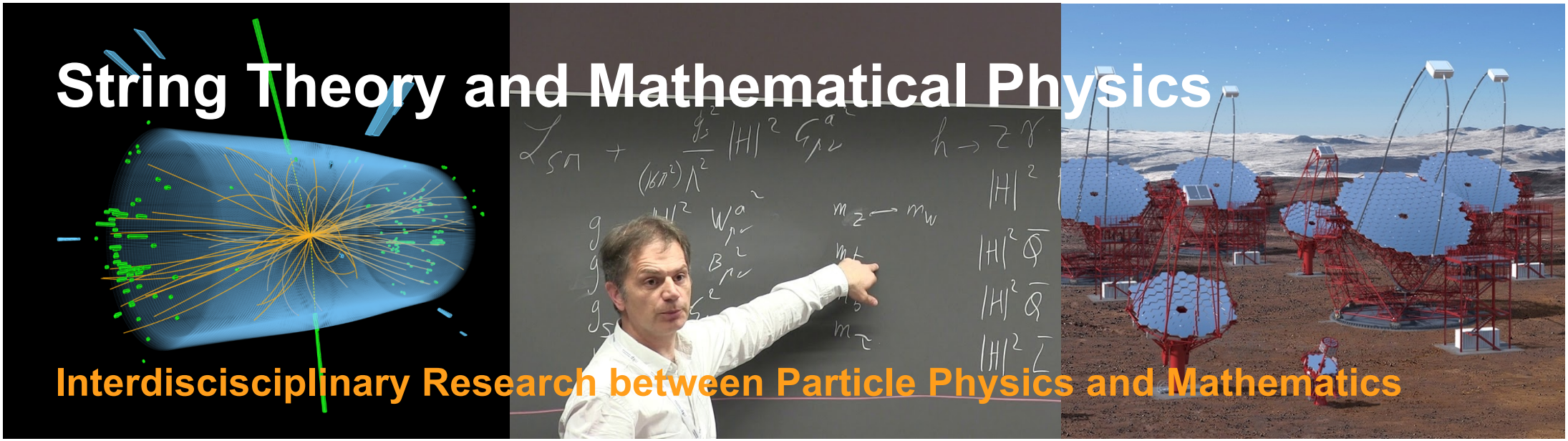
String Theory and Mathematical Physics



Interdisciciplinary Research between Particle Physics and Mathematics

Helmholtz Program: Matter and the Universe (MU)

PoF III Topic: Fundamental Particles and Forces

DESY Research Unit: Theoretical Particle Physics

Volker Schomerus
Center Evaluation DESY, 5 – 9 February 2018

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY

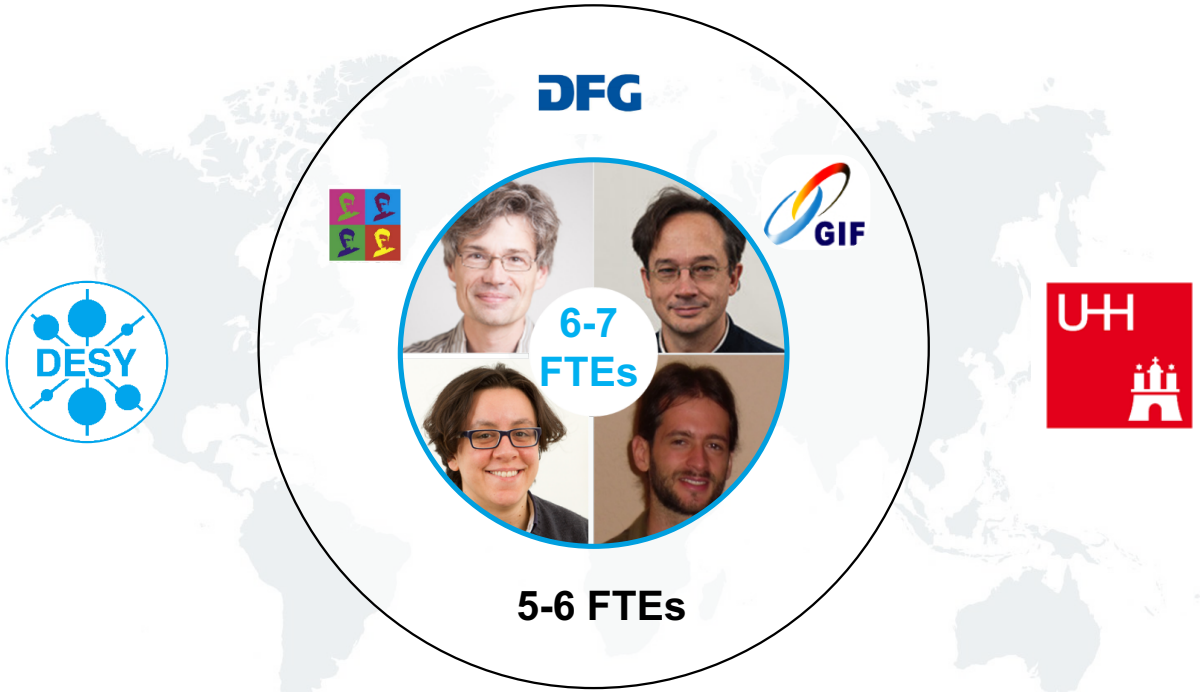
String Theory and Mathematical Physics

The Group and its Mission

A small group

strongly interacting

with its environment



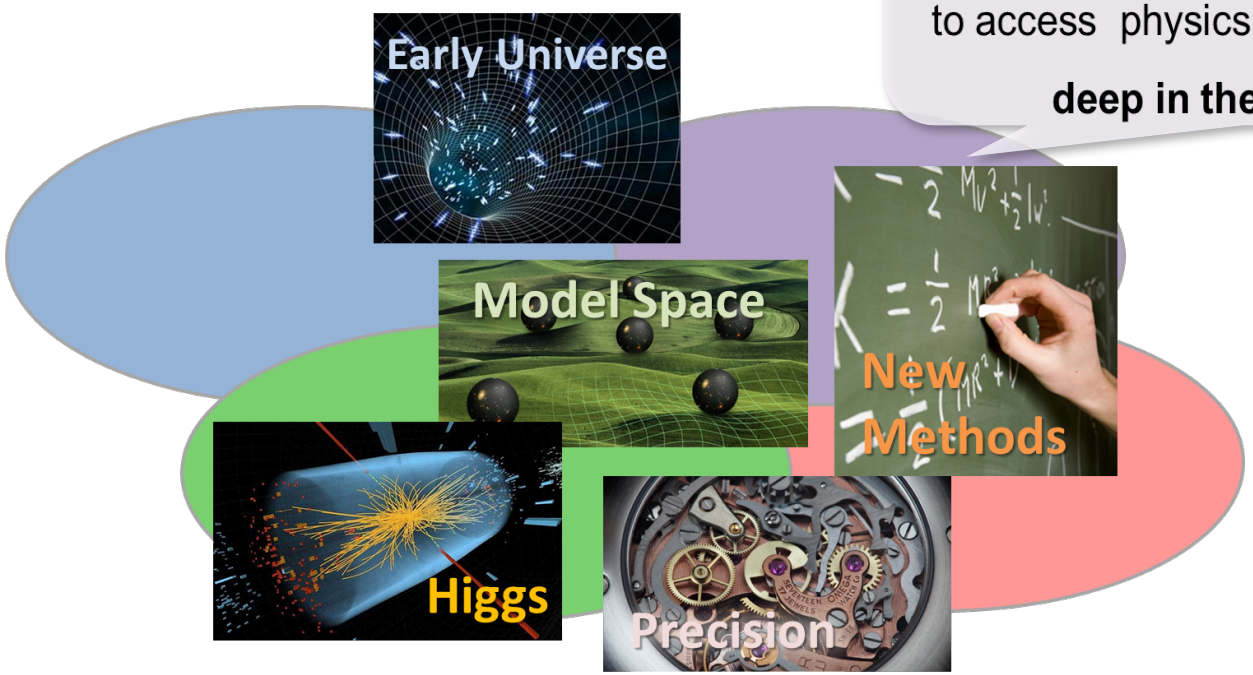
Center for
Mathematical Physics
Hamburg

String Theory and Mathematical Physics

The Group and its Mission

Rethinking Quantum Field Theory at the interface between particle physics and mathematics

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



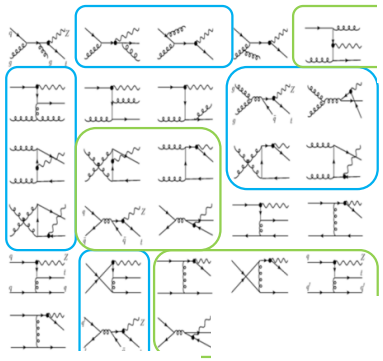
String Theory and Mathematical Physics

Introduction to Scientific Goals

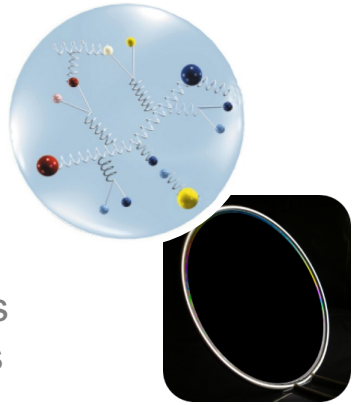
Example: Quantum Chromodynamics (QCD)

Perturbative paradigm
of QFT very inefficient

$$Y - Y + x = x$$



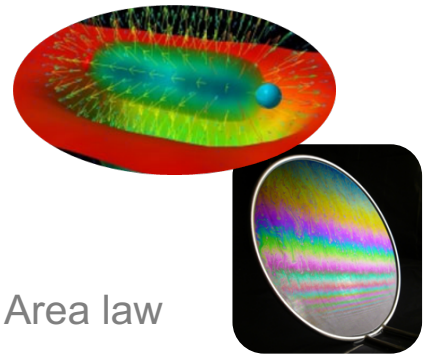
High energy regime
quarks and gluons



Wilson line observables
detect different phases

Phase
transition
crossover

Low energy regime
colorless hadrons



Area law

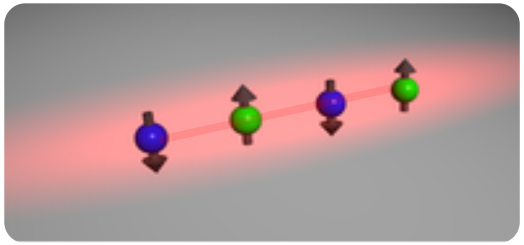
Area law - signal for a **string theory description**?

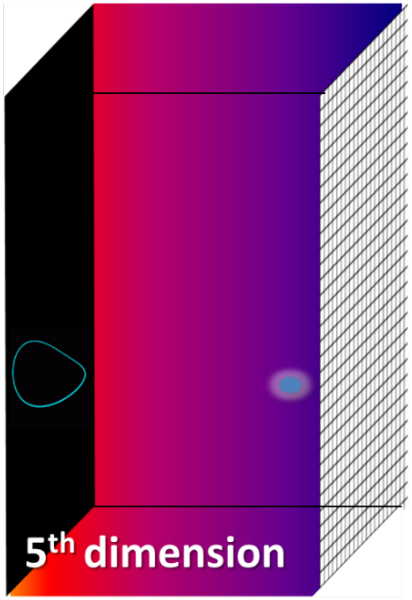
Highlights: Strings for Gauge Theory

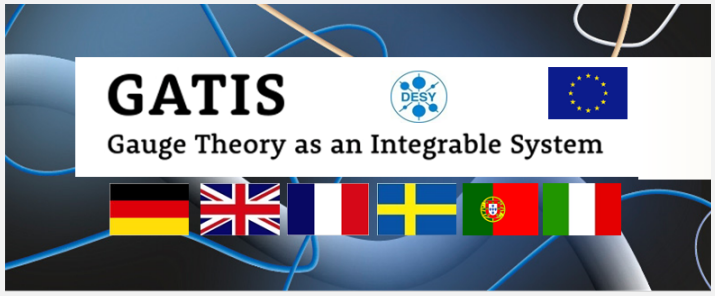
Integrability of Gauge Theory Flux Tube

Holography: The QCD-like flux tube of **maximally supersymmetric** multi-color 4D Yang-Mills theory is an integrable/solvable [solved] 1D quantum system.

~ Heisenberg spin chain, Bethe Ansatz







Central research topic of the ITN GATIS, coordinated & managed @ DESY 2013--2016

Highlights: Strings for Gauge Theory

High Energy Scattering Amplitudes

We computed scattering amplitudes in collider kinematics at small and large gauge theory coupling λ (multi-colored)

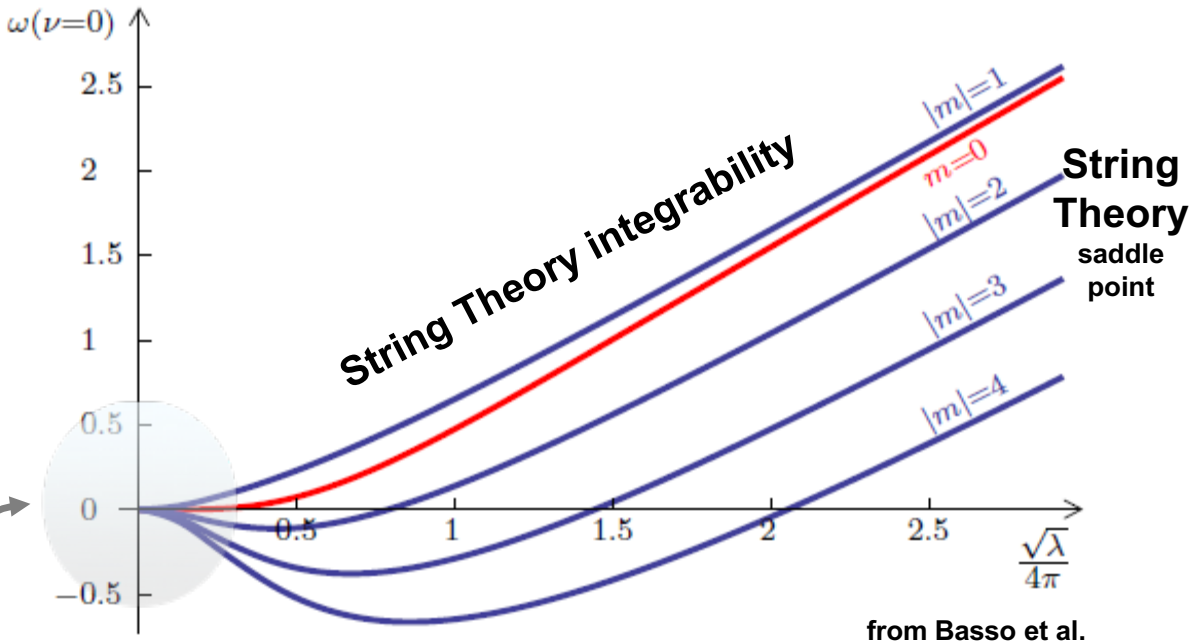
Bartels,Schomerus, Sprenger DESY 14-208

Reggeon intercept $\omega_\lambda(\nu, m)$

For 2 produced particles with total CMS energy s

$$A^{\lambda}_{\nu,m} \sim s^{\omega_\lambda(\nu,m)}$$

Tremendous simplification compared to the perturbative gauge theory calculations



from Basso et al.

Highlights: Dualities and Non-local Observables

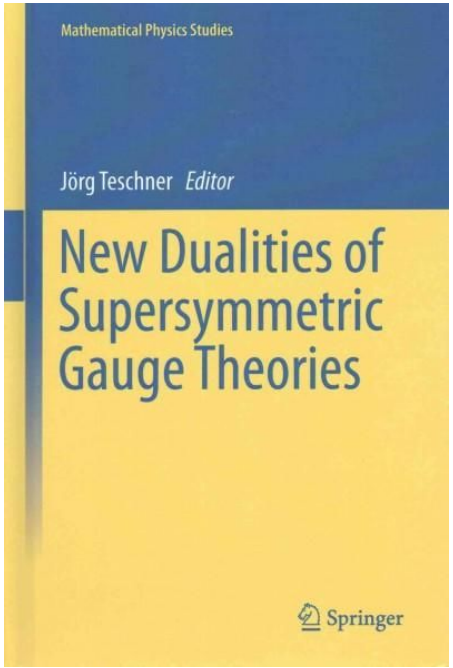
Dualities and Non-perturbative Physics

By definition, a **duality** provides a simple (perturbative) computational prescription for all observables in a strongly coupled phase/regime of a Quantum Field Theory.

Cp. the description of maximally supersymmetric gauge theory through string theory / supergravity.

An important task is to find dualities among N=2 (half-maximally) supersymmetric gauge theories

Many such theories exist: ``Space of theories''



Highlights: Dualities and Non-local Observables

Computing Non-local Observables

Non-local observables play a key role for testing and explaining dualities

We extended the exact computation of Wilson- and 't Hooft loop expecation values to large classes of SU(2) N=2 super-symmetric gauge theories

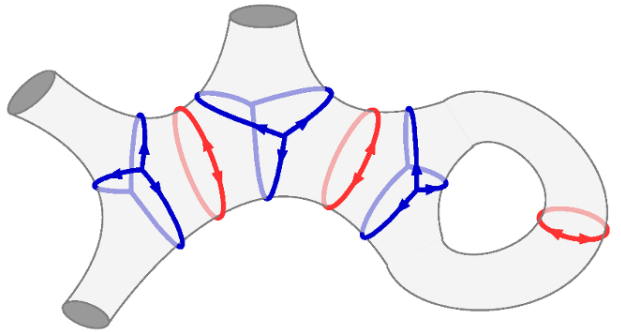
different matter content
multiple W,Z bosons

Teschner,Vartanov

We developed world leading expertise in defining & computing new line-observables for theories with **SU(3) gauge group**(s).

Coman, Mitev, Pomoni, Teschner

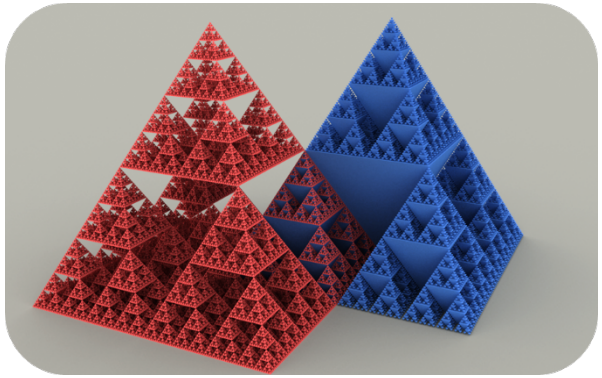
SU(2) → SU(3)



Opened a new chapter in the Mathematics of Riemann surfaces

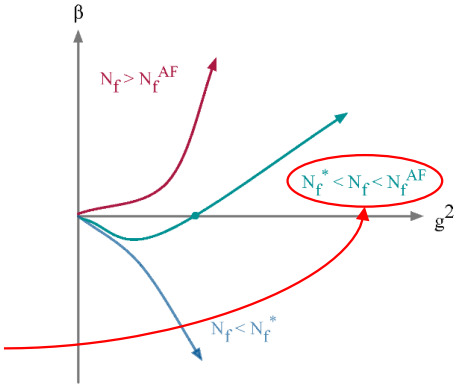
Highlights: Scale Invariant Quantum Systems

Non-perturbative Dynamics without Supersymmetry: The Bootstrap



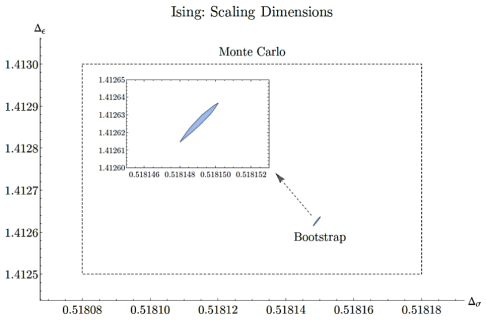
Scale invariant quantum systems:
Fixed point of renormalization group possess infinite correlation length & describe 2nd order phase transition

e.g. conformal window of QCD



Polyakov's bootstrap program exploits the **conformal symmetry** of many low energy systems to calculate observables selfconsistently without using theory of high energy excitations (microscopic theory).

Through a recent numerical incarnation, the conformal bootstrap became a remarkable new source of insight into non-perturbative physics.



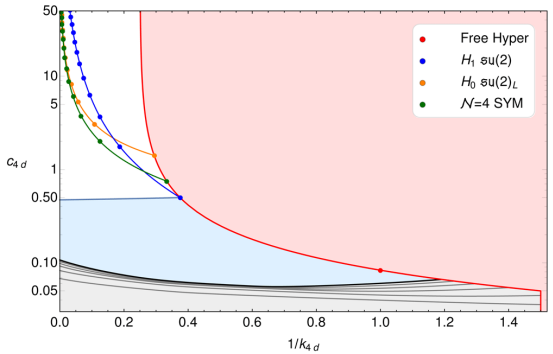
from Kos et al.

Highlights: Scale Invariant Quantum Systems

Applying and Advancing the Bootstrap

Group members pioneered the use of *exact results* in the numerical bootstrap to chart out the space of **superconformal field theories**.

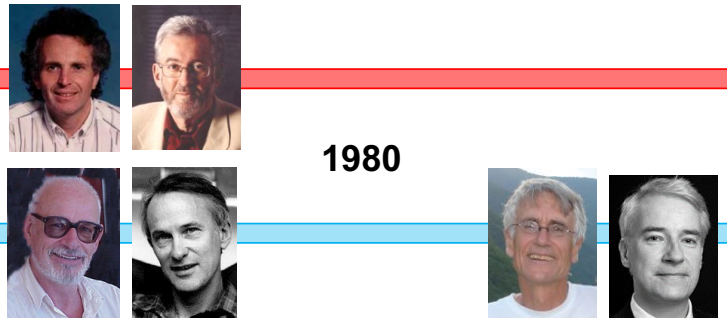
Lemos,Liendo, DESY 15-230



We developed the **mathematical theory of conformal symmetry** through a previously unobserved connection with solvable Schrödinger problems **[like Poeschl-Teller problem]**

Conformal quantum field theory D > 2

Solvable multiparticle quantum mechanics



Isachenkov Schomerus PRL 117 (2016)

String Theory and Mathematical Physics

The Center for Mathematical Physics (ZMP)

Hamburg Center for Mathematical Physics inaugurated in 2005

Today ~10 full professorships (3 from 2005)

Since 2006 supported by SFB 676, section A [projects A1-11]

Extended in 2010 and 2014, terminates 2018

Since 2012 joint graduate school GRK 1670

Extended in 2016

Since 2016 J.Teschner jointly appointed by DESY/UHH (Math)

Professorship for Quantum Geometry

Application for Transregio (DFG) with institutions in Berlin area

Geometry, integrability, scattering amplitudes

ZMP grew into world-class center for Mathematical Physics

String Theory and Mathematical Physics

International Networking

We host major international conferences: Amplitudes 2012, IGST 2014, StringMath 2017

MoU signed in 2016/17 by
15 leading European Institutions
www: gatisplus.desy.de

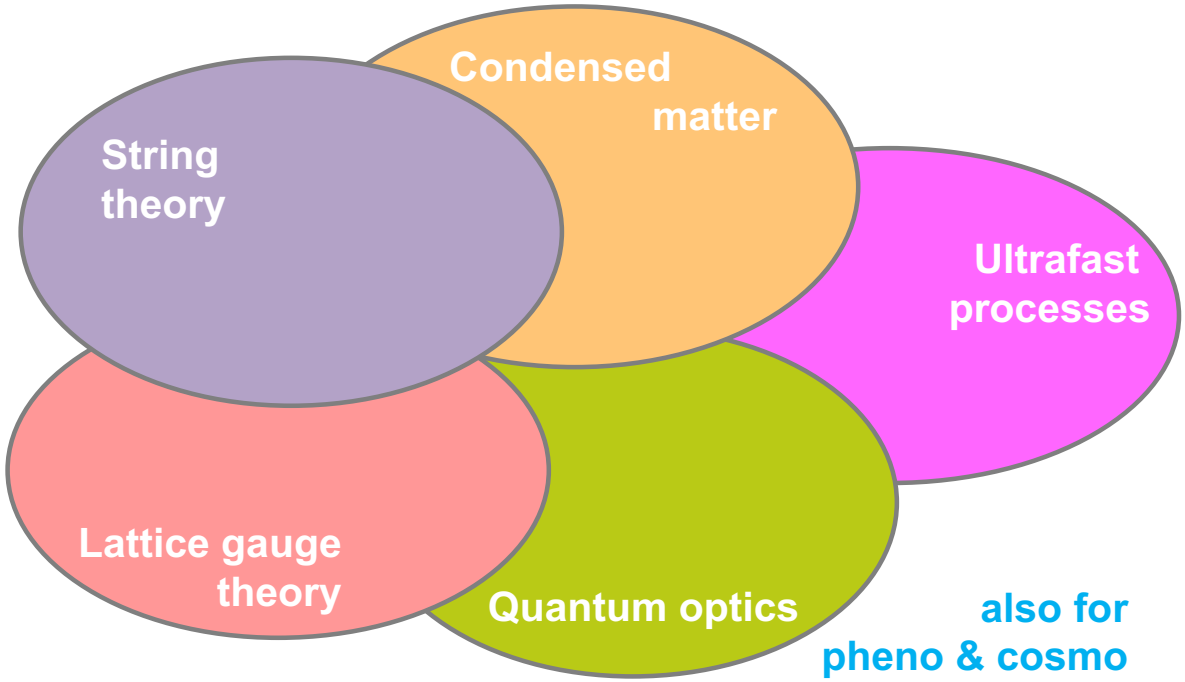
MC ETN **Scattering Amplitudes from Geometry to Experiment** (SAGEX) submitted

String Theory and Mathematical Physics

Conclusion and Outlook

With strong roots in particle physics and a world-class center for mathematical physics, DESY is the ideal place to conduct interdisciplinary research in string theory

Through the Wolfgang-Pauli-Centre the interdisciplinary environment could grow another dimension



String Theory and Mathematical Physics

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