ZPPT

Overview of the research activities

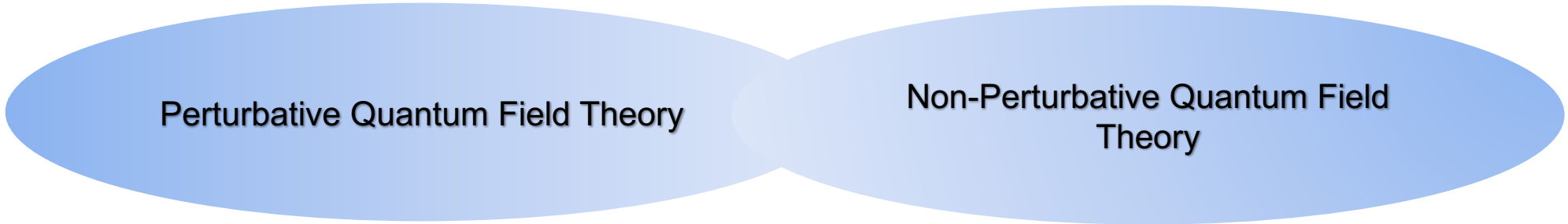
Stefan Schaefer
Zeuthen FH Workshop

June 12th 2023

HELMHOLTZ

DESY.

People



Staff members

J. Green (new arrival in 2022), P. Marquard, S. Schaefer, H. Simma

K. Jansen → focusses on CQTA

R. Sommer → retired

4 postdocs + 1 software developer

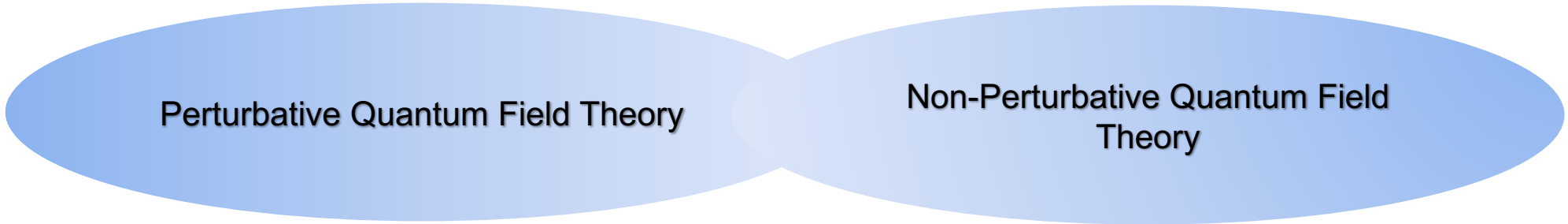
L. Barca. (FOR5269), J. Frison, A. Maier, A. Risch

B. Sagar (software developer in HH, Punch4NFDI)

PhD students

Alexander Broll (GRK),L. Chimirri (EuroPlex), B. Ray

Research interest



Perturbative Quantum Field Theory

SM precision calculations at high-loop order

- **Anomalous dimensions**
- **Collider physics**

Application of techniques in other areas

- **Gravitational waves**
- Statistical physics
- **Lattice field theory**

Non-Perturbative Quantum Field Theory

Lattice computations in QCD

- Running strong coupling
- Flavor physics
- **Developments of algorithms and strategies**
- **Support of European collaborations**
  - **Configuration generation**
  - **Data management**
- **Hadron structure**

Theory computations ot make the Standard Model more predictive

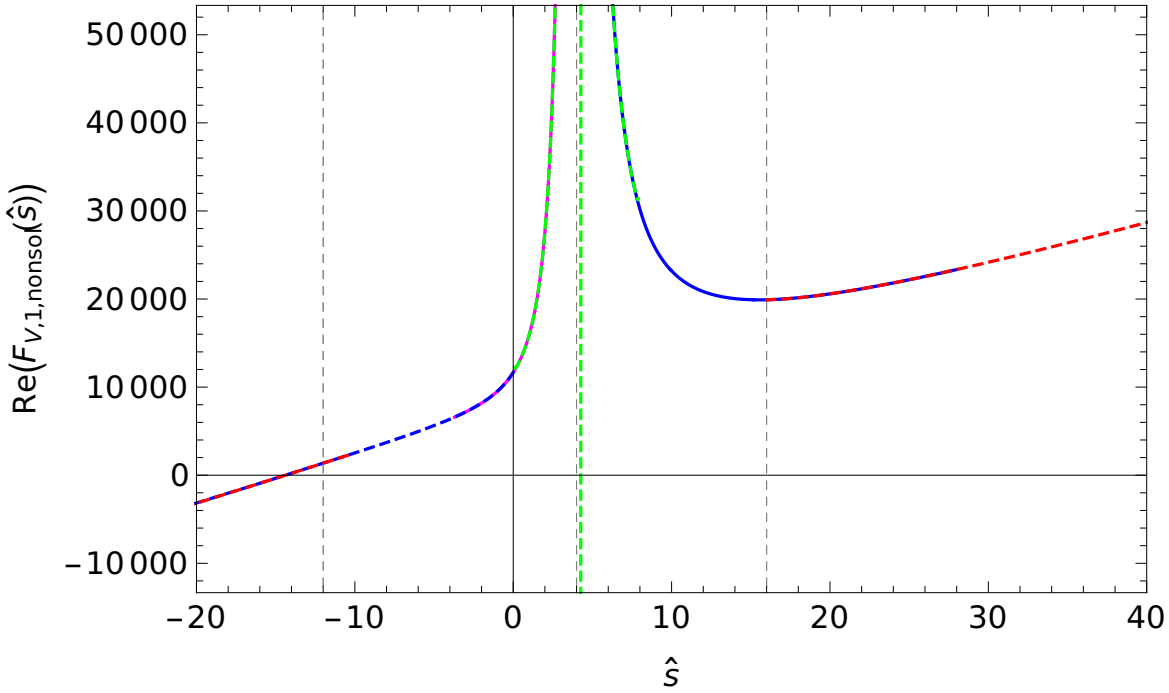
Pheno

Perturbative computations at high loop order

Heavy-quark form factor to three-loop order

Important building block for

- $H \to b\,\bar{b}$
- $Z \to b\,\bar{b}$
- $A \to X\,X$
- $e^+e^- \to t\,\bar{t}$



DIS/PDFs/anomalous dimensions

- Working towards NNNLO
- Matching coefficients at three loops known
- Anomalous dimensions at four loops needed

High energy jets (HEJ)

Monte Carlo methods → talk by A. Maier

Pheno

Moments of heavy quark correlators to five-loop order

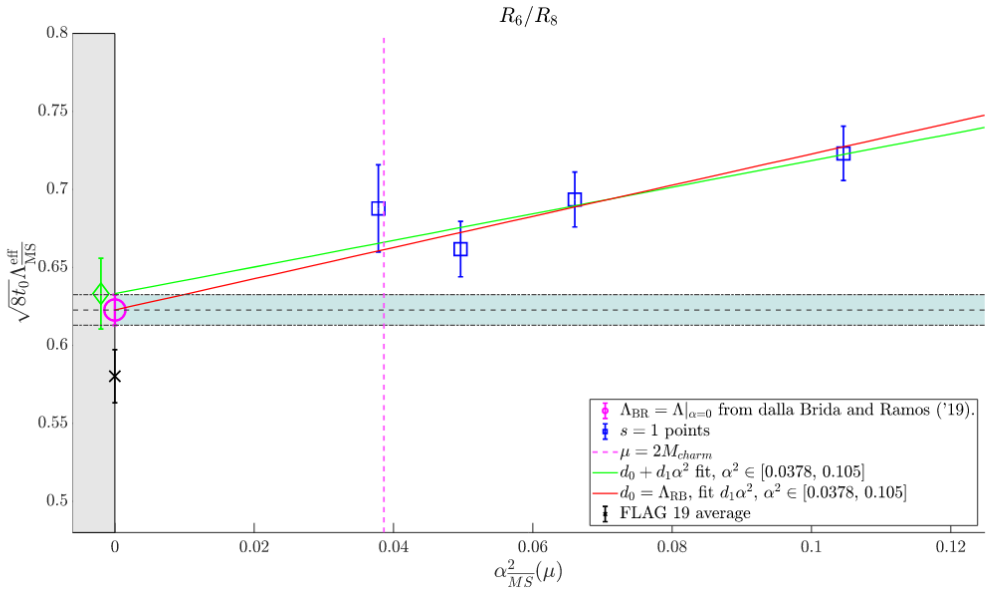
From experimental $e^+ e^- \rightarrow hadrons$ data

- Charm and bottom quark masses

Can also be computed on the lattice

- Charm quark mass
- Strong coupling constant

→ PhD project of L. Chimirri (EuroPlex)



Higher order in PT might explain deviation from const.

Future lattice simulations

The group has a long tradition in supporting and leading large European simulation efforts.

CLS (NP-improved Wilson fermions) → want to carry this to the future

ETMC (Twisted mass Wilson fermions)

QCDSF (NP-improved Wilson fermions)

A collaboration is typically formed around a particular discretization of QCD.

- Generate lattice gauge fields → requires >1000Mch and many person years, many 100TByte
- Determination of improvement coefficients, basic quantities (e.g. lattice scale, quark masses)

→ Need for data preservation and access → ILDG

→ Need to reduce cost → algorithms & actions

Future lattice simulations

Lattice discretization

A lot of inertia due to large cost

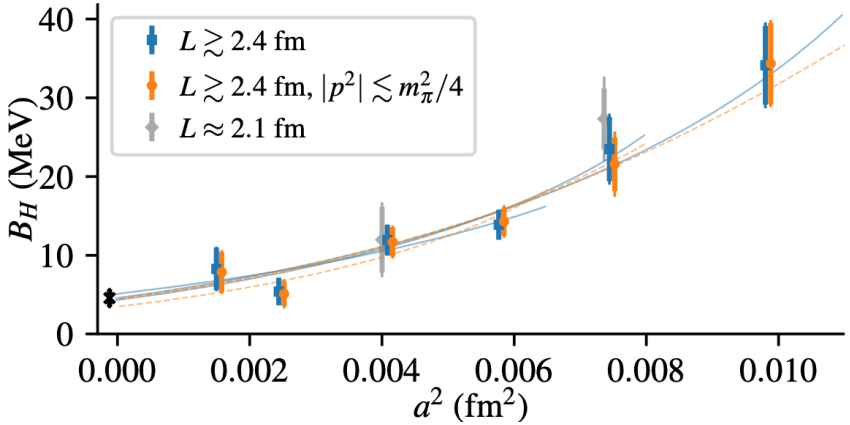
Action used by CLS is showing its limitations

- Has served well in the last decade.
- Effects of chiral symmetry breaking by regularization larger than expected. (Mohler, S.S., ’20)
- High accuracy requires very fine lattices

New experise regarding new action (“exponentiated clover”) and

”master field” strategy brought in by J. Green

Reconsider discretization → talk by A. Risch



Green et al, Phys.Rev.Lett. 127 (2021) 24, 242003

Comparison of discretizations / universality of continuum limit (J.Green)

Further algorithm research

Lattice computations are too expensive and use up too much energy

- Typical project uses 100Mch/year → >300MWh (just for the CPU)

Porting openQCD code to GPUs S. Schaefer

For SAP_GCR solver on JUWELS/JUWELS-BOOSTER:

1GPU ~ 8 CPU with 1GPU ~ 300W vs 1CPU 200W → Factor 5 reduction in energy consumption

Machine learning S. Schaefer

Continuous normalizing flows (Trivializing maps) change the way lattice computations are done.

- Developed a model which is way better than state-of-the-art (MIT/Google) but still irrelevant for real physics

Bacchio et al, *Phys.Rev.D* 107 (2023) 5, L051504

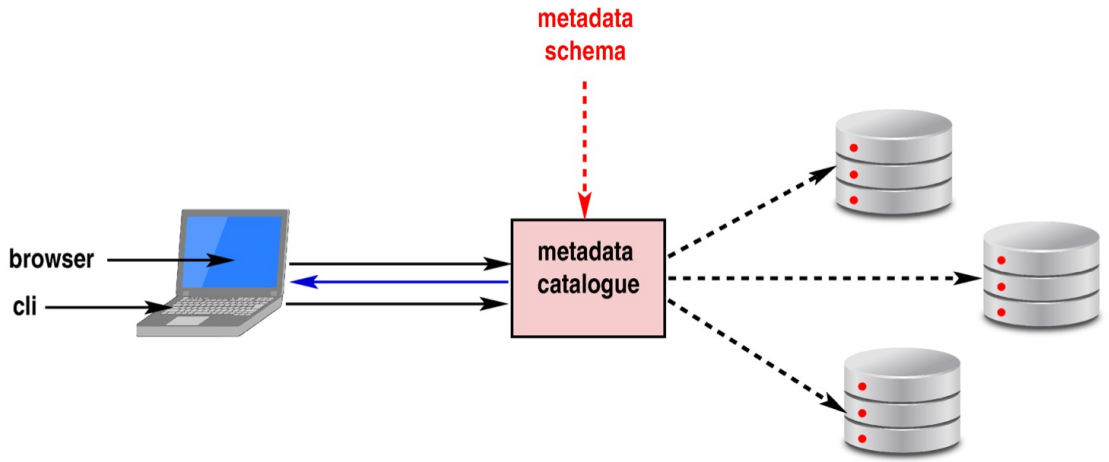
ILDG

International lattice data grid

- Initiative started in early 2000's to provide a framework for sharing of gauge configurations between Lattice QCD research groups worldwide
- FAIR principles prior to their formulation in 2016
- Essential element is a Metadata Catalogue on top of e.g. a Grid middleware layer (WLCG)
- **Usability of ILDG severely degraded during last years because of missing professional software expertise and development. (Only Zeuthen catalogue running in 2021.)**

PUNCH4NFID Funding + DESY Inkind DESY(ZPPT)

- Re-design and extension of MDC by DESY
- Re-activation of ILDG-wide working groups

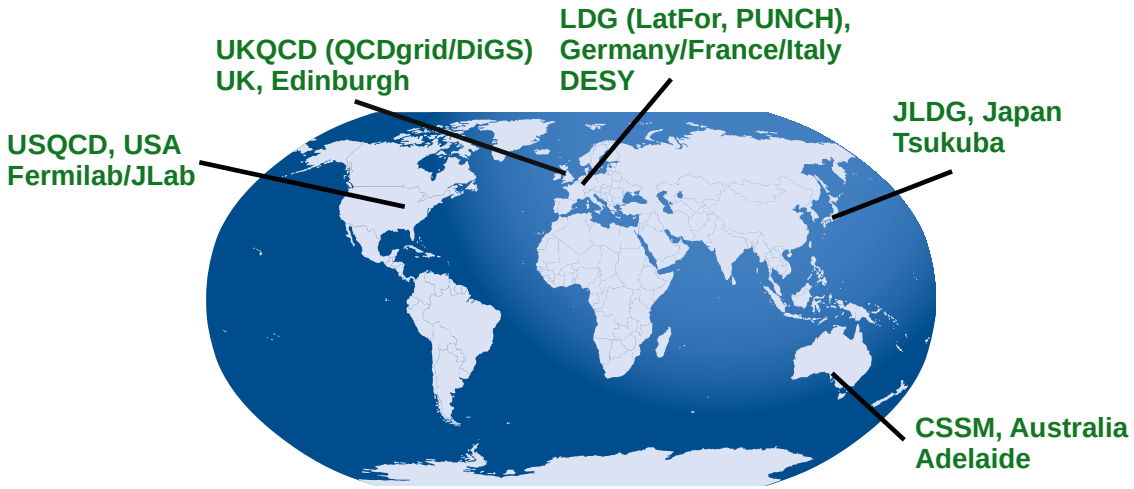


https://hpc.desy.de/ildg

ILDG

Roadmap

- New MDC service — Sagar, Simma
  - Three running instances (Zeuthen, Bielefeld, Japan), two further (UK, US) in preparation
- ILDG Hands-on Workshop
  - first test of the global setup and introduction to future users
  - 37 participants (10 collaborations, 8 countries)



- Identity and Access Management service at INFN

  MoU in preparation
- Transition to token-based authentication (by 2024,WLCG does not expects this before 2026)
- Support for DOI registration and data publishing — arXiv:2212.08392

DFG Research unit FOR5269

Glueballs and charmonia from the lattice

Physics PI: F. Knechtli (U Wuppertal, speaker), S. Schaefer (DESY), Mercator fellow: M. Peardon (Dublin)

Math PI: A. Frommer (U Wuppertal), M. Günther (U Wuppertal)

Physics case

- Glueballs are a challenge for experiment and theory: mixing with mesonic states
- Significant experimental interest (LHCb, FAIR, BESIII,…)
- **Best results from the lattice** in pure gauge theory – no mesons due to absence of quarks.
- In full QCD abysmal results so far → need new ideas for much better strategies and algorithms

Zeuthen focus S. Schaefer, L. Barca

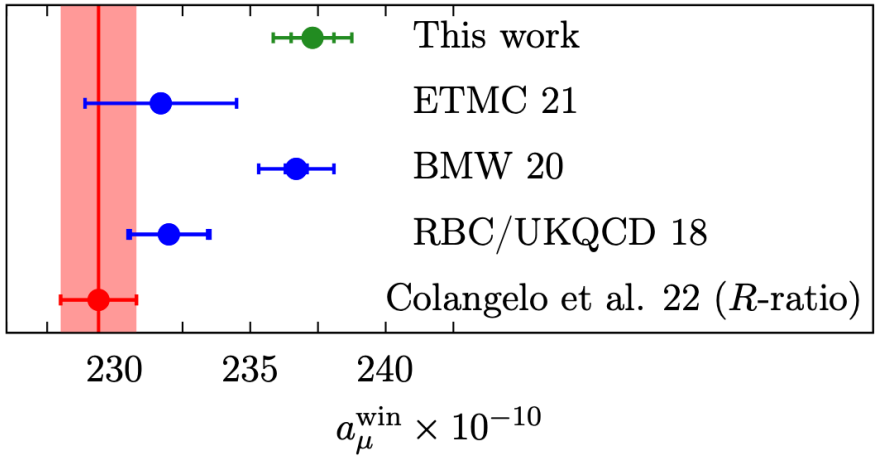
Multilevel algorithms → reduce scaling of Monte Carlo from $1/\sqrt{N}$ to $1/N$.

So far gained experience in pure gauge setup.

Anomalous magnetic moment of the muon

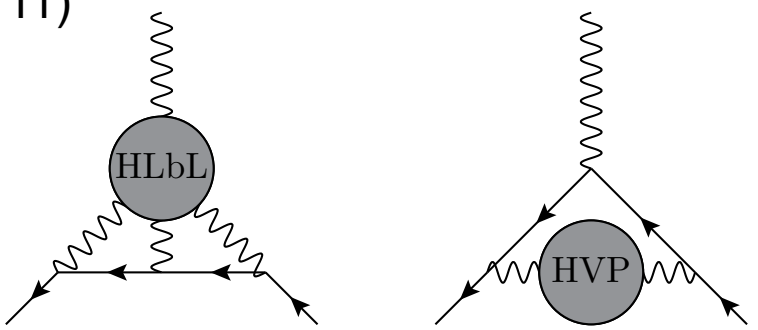
Quite significant contribution to the effort by the Mainz group

- Active participation by J. Green and A. Risch
- Computations on CLS lattices



Recent results

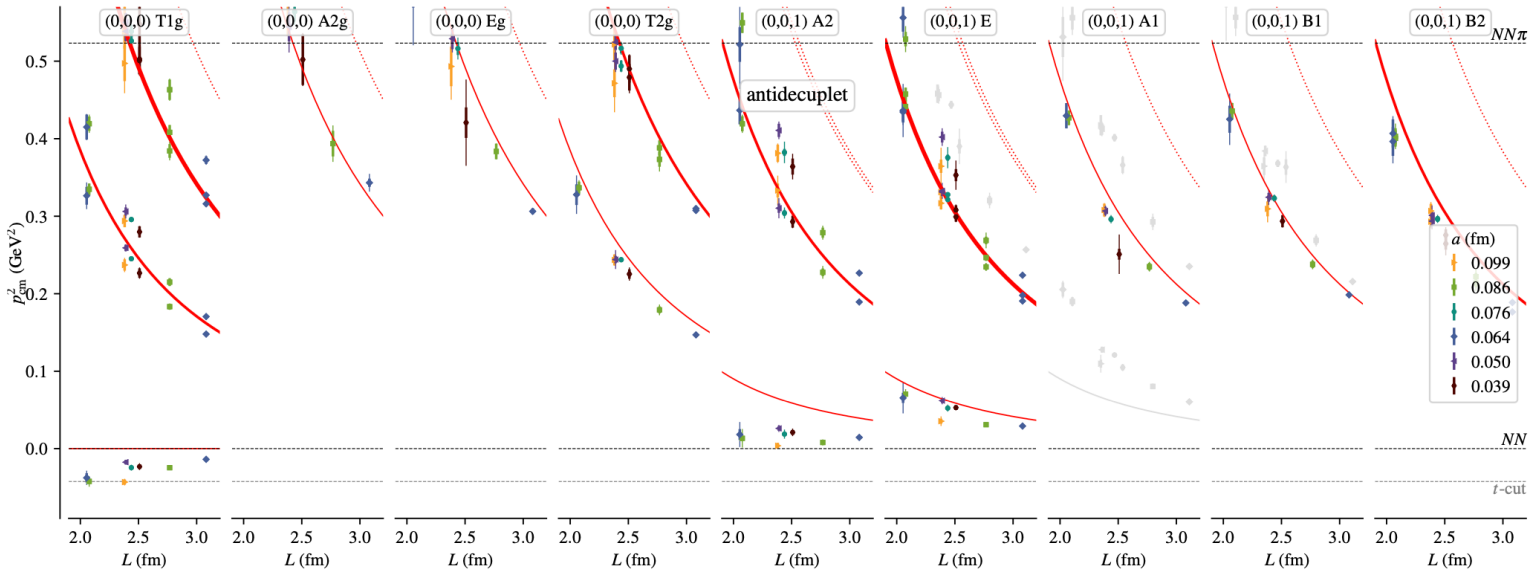
- QED kernel for hadronic light-by-light contribution to g-2 (JHEP 04 (2023) 040)
- Electromagnetic corrections to hadronic vacuum polarization (JHEP 03 (2023) 194)
- “Window observable” for the full HVP in QCD (Phys.Rev.D 106 (2022) 11)



Hadron phyiscs

Nucleon-nucleon at SU(3) symmetric point Green et al PoS LATTICE2022 200

- All NN scattering phase shifts up to F or G wave, including spin-1 partial wave mixing
- First calculation of NN with nonzero signal for partial wave mixing.
- Is the first NN scattering calculation taking the continuum limit.



Summary

The group has changed a lot during the last year.

→ New opportunities for future research

Emerging physics focus: hadrons, their structure and their interactions

Get more out of limited resources

- Re-use of expensive data, acess and preservation (ILDG)
- More energy efficient lattice simulations
  - Better actions
  - Better algorithms
  - Use of energy efficient hardware