Team members

Agostino Patella (staff)

Liam Keegan (fellow)

Marina Marinkovic̀ (fellow)

Alberto Ramos (fellow)

Nazario Tantalo (Roma Tor Vergata, scientific associate, until February)

Philippe de Forcrand (ETH, long-term guest)

Joining soon

Luigi Del Debbio (Edinburgh, scientific associate, from March)

Just left CERN

Martin Lüscher

Nazario

Luigi

Philippe

Martin

Lattice Field Theory @ CERN

The two souls of our group

- Lattice QCD
- Lattice Gauge Theories beyond QCD

We are a small team...

- Industrial QCD is not an option
- My vision:
  - Provide theoretical support to the community
  - Develop and explore new techniques
  - Develop simulation code or extensions of existing codes

But we are not an island...

Ongoing collaborations with:

- ALPHA (Desy Zeuthen)
- CLS (Desy, Mainz, Madrid, Regensburg)
- RBC-UKQCD (Southampton, Edinburgh, Columbia, BNL, RBRC, UConn, ...)
- RM123+SOTON (Roma, Southempton)
- UKBSM (Edinburgh, Swansea, Plymouth, Odense)
- Madrid, Hiroshima, Edinburgh
- Nagoya, Taiwan, Mainz

Lattice QCD is very successful at describing nonperturbative QCD.
However it requires hard work to turn it into a precision tool.

Control of systematics

quark	$\overline{\text{MS}}$ mass
up	1.8-3 MeV
down	4.5-5.3 MeV
strange	95(5) MeV
charm	1.275(25) GeV
bottom	4.18(3) GeV
top	160(5) GeV

Large range of scales $\rightarrow$ Challenge for numerical simulations

- Simulations at the physical mass value for the up, down and strange has become recently possible (thanks to Physics-based algorithmic development). (Marina)
- However taking the continuum limit at the physical mass for up, down and strange is still demanding.
- Inclusion of the charm quark is the challenge to come.

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Precision tests of QCD

- Flavour-changing processes, e.g. K_L/K_S mass splitting.
  - The EW Hamiltonian is effectively represented as an effective 4-fermi operator.
  - These operators require renormalization (which is complicated on the lattice by the fact that several simmetries are broken).
  - A new technique (Wilson flow) has been proposed by Martin to generate systematically Renormalization-Group-Invariant composite operators, i.e. operators that are finite in the continuum limit. Advantage: spurious mixing is systematically suppressed.
  - Long-term goal: explore the Wilson flow to renormalize 4-fermi operators. (Agostino)
  - The K_L/K_S mass splitting is a second order effect in the EW Hamiltonian. Second order perturbation theory is complicated on the lattice by the Euclidean setup. Results are available in unphysical kinematical regions ($2M_\pi > M_K$), but more theoretical work is needed to access to the physical kinematical region. (Nazario)

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Precision tests of QCD

- Isospin breaking effects
  - Two sources: up/down mass splitting, QED contributions.
  - Hadron mass splitting due to isospin breaking effect is within the reach of current lattice simulations.
  - A rigorous treatment of QED, and in particular non-zero charge states, at finite volume is still missing. (Nazario, Alberto, Marina, Liam, Agostino)

Lattice QCD is very successful at describing nonperturbative QCD.
However it requires hard work to turn it into a precision tool.

Other interesting problems awaiting solution

- Sign problem / simulation of QCD at finite chemical potential.
- Signal-to-noise ratio.
- ...

LGT beyond QCD

A selection of recent/future challenges

As we change the gauge group, number of fermions, fermion representation, strongly-coupled gauge theories generate a diverse phenomenology that may be very different from QCD.

- Large-N gauge theories. (Liam)
- Develop qualitative understanding of conformal and near-conformal theories. (Liam, Agostino)
- In order to become more quantitative, serious work on the algorithmic side is needed.
- Clarify role of the conformal anomaly. (Agostino)
- Compute couplings at large distance in non-QCD like theories. (Liam, Alberto)
- Compute anomalous dimensions of relevant operators and first irrelevant ones (4-fermi interactions). (Liam)
- Explore new ideas, e.g. radial quantization in the context of lattice gauge theories.

About my current projects

- Exploration of LGT in the conformal window.
- Renormalization of the energy-momentum tensor on the lattice.
  Possible applications:
  - Equation of state at finite temperature.
  - Transport coefficients.
  - Conformal anomaly.
- Renormalization of composite operators by means of the Wilson flow.
  Possible applications:
  - Short-distance contributions to flavour-changing processes.
- Theoretical framework for QCD+QED in finite volume.