

LaVA

Precision Frontier

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In the following, “[B]” refers to a Basic/Beginners level, while “[A]” stands to an Advanced level. Outline of the main topics that could be covered:

1 Precision Frontier

- Effective Field Theories (EFTs) [B]
- Standard Model (SM): electroweak (EW) and strong interactions, flavour structure [B]
- quark flavour-changing processes:
 - weak decays [tree-level, loop-level], effective hamiltonians, Operator Product Expansion (OPE) [B]
 - flavour physics phenomenology & rôle of lattice QCD [B]
 - determination of SM parameters: quark masses, CKM matrix elements, ... [B] leptonic and semileptonic decays, ... [B]
 - indirect searches of New Physics: Flavour Changing Neutral Currents (FCNC), rare decays, ... [A] mixing and CP-violation, ϵ'/ϵ [$K \rightarrow \pi\pi$ decay amplitudes] [A]
- quark flavour-preserving processes:
 - magnetic moments: introduction to the $g - 2$ of the electron, muon, ... [B]
 - hadronic vacuum polarization (HVP):
 - dispersion relations: analyticity, unitarity, space-like and time-like HVP [B]
 - lattice: muon $g - 2$, running of α_{QED} , $\sin^2(\theta_W)$, connection to perturbative QCD [B]

See slides by Giuseppe Gagliardi on the lattice computation of the HVP
Euclidean time windows [B], QED+IB corrections to the HVP [A], spectral methods to probe the R-ratio [A]
 - hadronic light-by-light (HLbL):
 - dispersive, lattice and connections [A]

2 Precision Frontier on the Lattice

- heavy quarks on the lattice [B]
- Effective Field Theories (EFTs):
 - heavy quarks: HQET [B], NRQCD [A], applications of decoupling, ... [A]
 - light quarks: ChPT and its applications to finite volume effects [B], lattice ChPT (Staggered, Wilson, ...) [A], excited-state contamination [A]
 - Symanzik EFT [B], including asymptotic lattice spacing dependence producing logarithmic corrections [A]
- renormalization, mixing and running: perturbative and non-perturbative [B]
- excited-state contamination: variational approach [B], GEVP [B], distillation [A], ...
- electromagnetic and strong isospin breaking corrections, including scale setting [A]
- hadronic decays and scattering: $K \rightarrow \pi\pi$, K^* , time-like pion form factor, ... Lüscher formalism [B] and its extensions [A]
- inclusive decays & reconstruction of spectral densities from lattice correlators [A]
- applications of analyticity and unitarity to the description of the momentum dependence of form factors [A]
- noise reduction techniques: (low/all) mode-averaging techniques [B], improved estimators (frequency splitting, ...) [A], multi-level algorithm [A]
- data analysis:
 - error analysis: topology freezing, autocorrelations, Gamma-method, automatic differentiation [B], resampling techniques [B], bayesian inference [A]
 - correlated data, goodness-of-fit and p-value [B], information criteria [A]
 - model averaging [A]

3 Compilation of Material

3.1 Schools

- LatticeNet School on Computing in HEP @Exascale – 2022: <https://indico.ifca.es/event/2452/timetable/#20220919>

Data Analysis Techniques – Alberto Ramos

Introduction to Multilevel Algorithms – Martin Lüscher

Including QED in QCD: challenges and way ahead – Agostino Patella

Challenging Nucleon matrix elements – Rajan Gupta

- MPA Summer School 2021: Fundamental Interactions in Particle, Hadron and Nuclear Physics – 2021
<https://indico.mitp.uni-mainz.de/event/277/>

The muon $g - 2$ – Jens Erler

- Lattice Practices (2021, 2017, 2014, 2012, 2008, ...):
<https://indico.cyi.ac.cy/event/1/>
<https://indico.desy.de/event/16832/>
<https://indico.desy.de/event/9420/>
<https://indico.desy.de/event/6167/>
<https://indico.desy.de/event/1113/>

Data analysis – R. Sommer and S. Lottini

Data analysis – C. Hoelbling

Simulation algorithms – M. Dalla Brida

HMC algorithms – M. Schaefer

Scale setting – M. Bruno

Solvers – A. Frommer and B. Leder

Disconnected Diagrams – G. Bali

- EuroPLEx Summer School 2021:
<https://indico.ph.ed.ac.uk/event/67/overview>

Quantum field theory in a Euclidean and finite volume – Maxwell Hansen

Renormalisation and improvement – Martha Constantinou

Computational methods – Peter Boyle

- International Physics School on Muon Dipole Moments and Hadronic Effects in memoriam Simon Eidelman – 2021:
<https://indico.mitp.uni-mainz.de/event/208/program>

- Dublin 2020 – EuroPLEx Progress Workshop:
<https://indico.cern.ch/event/965890/timetable/#all.detailed>

Introduction to QCD+QED in finite volume – Agostino Patella

Introduction to Scale Setting in QCD – Tomasz Korzec

High precision scale setting in lattice QCD – Lukas Varnhorst

Estimating finite volume effects in QCD+QED simulations by using relativistic EFTs – Nazario Tantalo

- EuroPLEx Online School 2020:
<https://indico.cern.ch/event/959201/>

Chiral Perturbation Theory – Oliver Bär
 QCD in a Finite Volume – Sasa Prelovsek
 Renormalisation & Improvement – Stefan Sint

- Summer School on "Frontiers in Lattice QCD" at Peking University – 2019:
<https://indico.ihep.ac.cn/event/9715/program>

Nucleon matrix elements and intensity frontier- Rajan Gupta
 Computational lattice QCD – G.H.
 Muon $g - 2$ from lattice QCD – Luchang Jin
 QCD+QED – Guido Martinelli
 Lattice effective field theory – Ulf-G. Meißner
 Lattice flavour physics – Christopher T. Sachrajda
 Multi-channel/particle scattering – Stephen R. Sharpe
 Nonperturbative renormalization – Rainer Sommer

- EFT in Particle Physics and Cosmology, Les Houches – 2017:
<https://indico.in2p3.fr/event/13465/program>

Renormalisation and RGEs – M. Neubert
 EFT: basic concepts and electroweak applications – A. Manohar
 EFT for quark flavour – L. Silvestrini
 χ PT and electroweak symmetry breaking – A. Pich
 Soft Collinear Effective Theory – T. Becher
 Heavy Quark Effective Theory & NRQCD – T. Mannel
 EFT on the lattice, applied to HQET – R. Sommer
 EFT for the direct detection of dark matter – J. Hisano

- Summer School on Symmetries and Fundamental Interactions – 2014:
<https://indico.mitp.uni-mainz.de/event/22/program>

Lattice QCD – Christopher Sachrajda
 Effective Theories – Antonio Pich

- Non-Perturbative Renormalization on the Lattice – 2012:
<https://indico.desy.de/event/6163/timetable/?view=standard>

Anastassios Vladikas & G.H.

- Les Houches Summer School: Modern perspectives in lattice QCD: Quantum field theory and high performance computing – 2009:
https://nic.desy.de/workshops__schools/les_houches_2009/index_eng.html

Flavor physics and lattice quantum chromodynamics – Laurent Lellouch
 Three Topics in Renormalization and Improvement – Anastassios Vladikas
 Introduction to Non-perturbative Heavy Quark Effective Theory – Rainer Sommer
 Renormalization and lattice artifacts – Peter Weisz
 Computational Strategies in Lattice QCD – Martin Luscher

Applications of chiral perturbation theory to lattice QCD – Maarten Golterman
Simulations with the hybrid Monte Carlo algorithm: Implementation and data analysis – Stefan Schaefer

- New Horizons in Lattice Field theory – 2013:
<https://iip.ufrn.br/eventsdetail?inf===QT61UP>
<https://www.ifsc.usp.br/~lattice/lqcdschool-iip/programme/courses/>

Introduction to Lattice Gauge Theory and Chiral Symmetry – Mike Creutz
QCD Thermodynamics – Owe Philipsen
Standard Model and Beyond – Rogerio Rosenfeld
Nonperturbative Renormalization – Rainer Sommer
Effective Field Theories for Lattice QCD – Steve Sharpe
Flavour Physics – Chris Sachrajda
Tutorials

Upcoming

- LQCDPheno school 2023:
<https://lpsc-indico.in2p3.fr/event/3196/>

Hadron structure
The enigma of the muon $g - 2$
Flavor Physics for BSM searches

- Methods of Effective Field Theory and Lattice Field Theory – 2023:
<https://www.dpg-physik.de/veranstaltungen/2023/methods-of-effective-field-theory-and-lattice>

Introduction to effective field theory – Eric Braaten
Numerical algorithms in lattice field theory – Szabolcs Borsanyi
Chiral perturbation theory (continuum and lattice) – Johan Bijnens
Heavy quarks, NR EFT – Joan Soto
Applications of EFT and lattice to muon $g - 2$ – Aida El Khadra
QCD+QED – Marina Marinkovich
Flavor physics, EFT and lattice – Ruth Van de Water
Multiparticle scattering – Stephen Sharpe

3.2 Books

- Gauge Theory of Weak Decays The Standard Model and the Expedition to New Physics Summits, Andrzej J. Buras
Publisher: Cambridge University Press
Online publication date: June 2020
Online ISBN: 9781139524100
DOI: <https://doi.org/10.1017/9781139524100>

- Effective Field Theory in Particle Physics and Cosmology: Lecture Notes of the Les Houches Summer School: Volume 108, July 2017
<https://doi.org/10.1093/oso/9780198855743.001.0001>
Online ISBN: 9780191889370
Print ISBN: 9780198855743
Publisher: Oxford University Press

- The Anomalous Magnetic Moment of the Muon
Friedrich Jegerlehner
Springer Tracts in Modern Physics 274, 2017
<https://bib-pubdb1.desy.de/record/393196/files/978-3-319-63577-4.pdf>

- Modern Perspectives in Lattice QCD: Quantum Field Theory and High Performance Computing: Lecture Notes of the Les Houches Summer School: Volume 93, August 2009
<https://doi.org/10.1093/acprof:oso/9780199691609.001.0001>
Online ISBN: 9780191731792
Print ISBN: 9780199691609
Publisher: Oxford University Press

3.3 Videos

- TASI videos:

<https://www.youtube.com/@tasivideos4735/videos>

Effective Field Theory – Aneesh Manohar
Effective Field Theory – Tim Cohen
Effective Field Theory – Nima Arkani Hamed
Flavor Physics – Wolfgang Altmannshofer
Flavor Physics – Stefania Gori
Flavor Physics – Yuval Grossman
Quark and Lepton Flavor Physics – Lisa Everett

- Florence HEP:

<https://www.youtube.com/@florencehep545/videos>

Broken Symmetries and Lattice Gauge Theory – L. Giusti
Effective Field Theories – D. Kaplan
Flavour Physics and CP Violation – J. Kamenik
Flavor Physics – Y. Nir
Flavor Physics – G. Isidori

- Mainz Institute for Theoretical Physics:

<https://www.youtube.com/@mainzinstitutefortheoretic1604/videos>

EFTs – Thomas Becher
Standard Model – Michael Peskin
Flavor Physics – Monika Blanke
Flavor Physics – Yuval Grossman

- Advanced Cyberinfrastructure Training at RPI:

<https://www.youtube.com/@advancedcyberinfrastructur3998/videos>

Scattering on the Lattice (2019) – Raul Briceño
Data Analysis and Lattice QCD (2020) – Christopher Aubin

- The Institute for Nuclear Theory:

<https://www.youtube.com/@intuwseattle/videos>

Three-Body Finite-Volume Formalism for Lattice QCD – Zohreh Davoudi
Lattice QCD and few body physics – Raul Briceño

- 2021 CERN-Fermilab HCP Summer School:

https://cds.cern.ch/search?ln=en&p=2021+CERN-Fermilab+HCP+Summer+School&action_search=Search&op1=a&m1=a&p1=&f1=&c=CERN+Document+Server&sf=&so=d&rm=&rg=100&sc=0&of=hb

Lattice QCD – Maxwell Hansen

- EuroPLEx ITN:

https://www.youtube.com/@europlex_itn6232/videos

QCD in finite volume – Sasa Prelovsek

- Lattice QCD Education:
<https://www.youtube.com/@latticeqcducation8264/videos>

Heavy Quark Physics and New Physics Search – Takashi Kaneko

- CP3 Tube:
<https://www.youtube.com/@cp3tube412/videos>

QCD at the Intensity Frontier – William Detmold