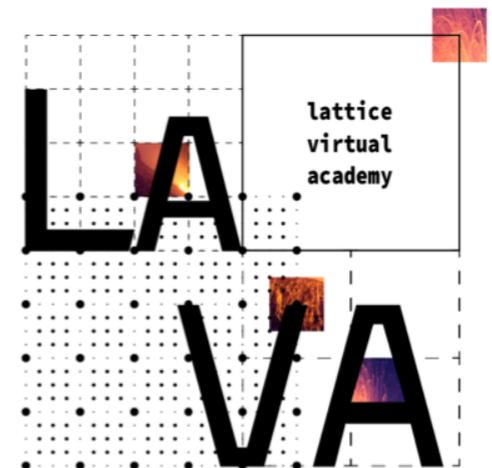# LaVA - Lattice Virtual Academy

status report

Simon Hands on behalf of the LaVA Steering Group

Lattice 2025 TIFR Mumbai 4/11/25

LaVA is a virtual platform for advanced e-learning in Lattice Field Theory

It provides open access, self-paced learning for students
(both beginner and expert) and also to the lattice-curious

LaVA was conceived in the framework of the NA6 network activity
of the STRONG-2020 project, and has subsequently received support from both:

European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*)
and its parent organisation
Fondazione Bruno Kessler (FBK).

Timeline

- 8 January 2025: presentation to the ECT* Scientific Board

- December 2024 Open Science Completed

- 6-8 November 2024: Visit to ECT* and discussion with the ECT* Director

- 5 November 2024: First meeting of LaVA steering comm.

- October 2024: Defined the Steering Commettee

- 24 September 2024: LaVA presented by the Director to the ECT* Board

- September 2024: LaVA on the NUPECC site & in the Nupecc News

- July 2024: Closure of Strong-2020

- July 2024: LaVa presented at the Strong-2020 closing event

- Fall 2023: Outlines and shapes of the site finalised

- July 2023 Essentials Shaped

- July 2023: Presentation at Lattice 2023

- 20 February 2023 — 24 February 2023: LaVa first meeting at ECT*

- Early 2023: discussions on starting a Lattice Virtual project

Steering Committee

Sara Collins Regensburg
Simon Hands Liverpool
Frithjof Karsch Bielefeld
Maria Paola Lombardo INFN Firenze (Chair)
Michael J. Peardon Trinity College Dublin

month-to-month running, oversee webpage,
identify suitable topics and convenors,
spreading the gospel…

Project facilitator

Barbara Gazzoli ECT*

Web and Communication

Francesca Guerzoni FBK
Petra Jansen FBK

Core Group

Constantia Alexandrou U Cyprus & The Cyprus
Institute
Andreas Athenodorou U Cyprus & The Cyprus
Institute
Claudio Bonanno IFT UAM-CSIC
Francesco Di Renzo Parma
Margarita Garcia Perez IFT UAM-CSIC
Christof Gattringer FWF & Graz
Karl Jansen, DESY Zeuthen
Liuming Liu, Chinese Academy of Sciences
Huey-Wen Lin Michigan State U

Nilmani Mathur TIFR Mumbai
Tereza Cristina de Rocha Mendes São Paulo
Guy Moore TU Darmstadt
Kari Rummukainen Helsinki
Alexander Rothkopf Korea U
Giancarlo Rossi Tor Vergata
Phiala Shanahan MIT
Andrea Shindler Michigan State
Davide Vadacchino Plymouth
André Walker-Loud, LBNL

advice & oversight, review **LaVA** material
and suggest updates, propose new topics.

LaVA

Essentials

Algorithms

Data Analysis

Lattice Fermions

Renorm & Improve...

Thermal Field Theory

Sign Problem

QC & Tensor Netwo...

Machine Learning

Hardware & Software

Hadron Essentials

Hadron Structure

Hadron Spectrosco...

Precision Frontier

BSM Field Theories

Critical Phenomena

Vacuum Structure

Open Science

LaVA

A virtual platform for advanced e-le

in Lattice Field Theory

Conveners

Margarita García Pérez, Instituto de Física Teórica UAM-CSIC
Christof Gattringer, Austrian Science Fund FWF & University of Graz
Simon Hands, University of Liverpool

General motivation 🔗
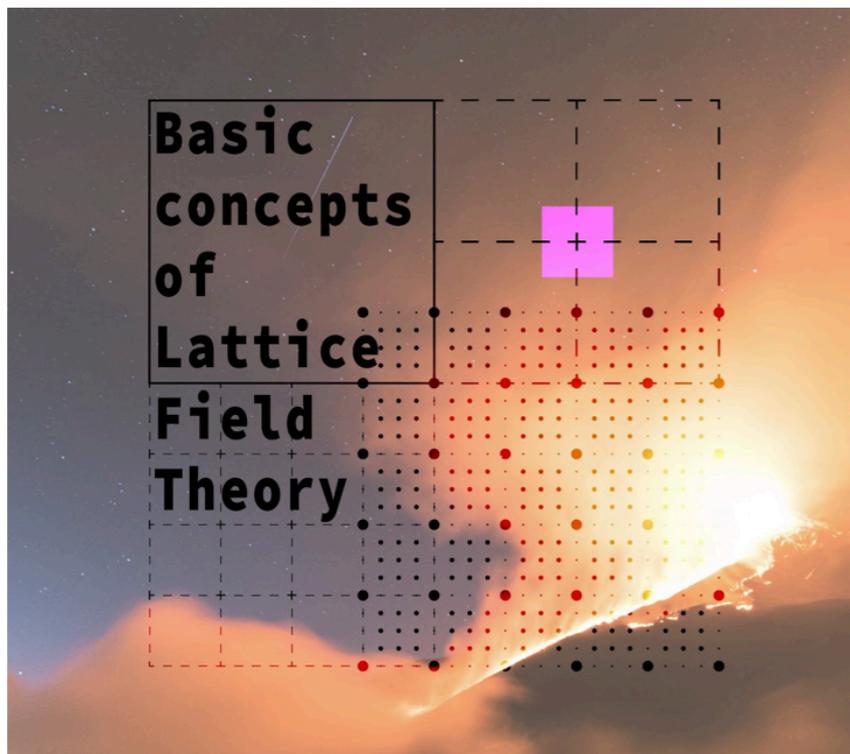
Quantum Chromodynamics (QCD) is the quantum field theory that describes the interactions between quarks and gluons. It is a strongly interacting theory at low energies, and therefore an ab-initio description of low-energy properties, such as the spectrum of mesons and baryons, the confinement of quarks, or chiral symmetry breaking, requires the use of a non-perturbative regulator.

In this unit on the fundamentals of lattice field theory, you will learn how to define a field theory on a discretised space-time grid and how to formally recover the continuum limit; the emphasis is on the Lagrangian formalism, but the Hamiltonian formalism is also introduced.

Prerequisites ⌃

Basic knowledge of relativistic field theory and in particular Quantum Chromodynamics.

4 Path integral for the scalar field

- We work out the path integral representation of euclidean n-pointfunctions of the scalar field.
- We adopt euclidean path integrals as our new method for quantizing field theories

Slides

Books

Creutz   Rothe   Montvay & Münster   Smit

Gattringer & Lang   Feynman & Hibbs   Negele & Orland   Zinn-Justin

Schools

Les Houches 2009   INT Summer School 2021

Partition sum and matrix elements

Partition sum:

$$Z_a = \text{Tr}\left[e^{-a\widehat{T}}e^{-a\widehat{U}}\mathbb{1}\,e^{-a\widehat{T}}e^{-a\widehat{U}}\mathbb{1}\,e^{-a\widehat{T}}e^{-a\widehat{U}}\,....\,\mathbb{1}\,e^{-a\widehat{T}}e^{-a\widehat{U}}\right]$$

$$= \int\prod_{j=0}^{N-1}D[\phi_j]\;\langle\phi_0|e^{-a\widehat{T}}e^{-a\widehat{U}}|\phi_1\rangle\langle\phi_1|e^{-a\widehat{T}}e^{-a\widehat{U}}|\phi_2\rangle\,...\,\langle\phi_{N-1}|e^{-a\widehat{T}}e^{-a\widehat{U}}|\phi_0\rangle$$

Matrix elements:

$$\langle\phi_j|e^{-a\widehat{T}}e^{-a\widehat{U}}|\phi_{j+1}\rangle = \langle\phi_j|e^{-a\widehat{T}}|\phi_{j+1}\rangle\,e^{-a^4\sum_{\vec{n}}\left[\frac{1}{2}\sum_l\left(\frac{\phi_{\vec{n}+\hat{l},j+1}-\phi_{\vec{n},j+1}}{a}\right)^2 + \frac{m^2}{2}\phi_{\vec{n},j+1}^2 + \lambda\phi_{\vec{n},j+1}^4\right]}$$

$$\langle\phi_j|e^{-a\widehat{T}}|\phi_{j+1}\rangle = \int D[\pi]\,\langle\phi_j|e^{-a\widehat{T}}|\pi\rangle\langle\pi|\phi_{j+1}\rangle = \int D[\pi]\,\langle\phi_j|\pi\rangle\langle\pi|\phi_{j+1}\rangle\,e^{-a^3/2\sum_{\vec{n}}\pi_{\vec{n}}^2}$$

$$= C\,e^{-a^4\sum_{\vec{n}}\frac{1}{2}\left(\frac{\phi_{\vec{n},j+1}-\phi_{\vec{n},j}}{a}\right)^2}$$

Result:

$$Z_a = \int\prod_{i=0}^{N-1}D[\phi_i]\,e^{-a^4\sum_{\vec{n},j}\left[\frac{1}{2}\left(\frac{\phi_{\vec{n},j+1}-\phi_{\vec{n},j}}{a}\right)^2 + \frac{1}{2}\sum_l\left(\frac{\phi_{\vec{n}+\hat{l},j}-\phi_{\vec{n},j}}{a}\right)^2 + \frac{m^2}{2}\phi_{\vec{n},j}^2 + \lambda\phi_{\vec{n},j}^4\right]}$$

To date we have completed lecture resources for

Essentials (Margarita García-Peréz, Christoph Gattringer, SJH)

Open Science (Andreas Athenodorou, Ed Bennett, Julian Lenz)

In production:

Algorithms (Francesco di Renzo, Mike Peardon, Alexander Rothkopf)

Thermal Field Theory (Claudio Bonanno, Frithjof Karsch, Maria Paola Lombardo, Guy Moore, Christian Schmidt)

A follow up **E**ffective Field Theory **V**irtual **A**cademy EVA has been proposed based on the **LaVA** model under the general umbrella of **VIPER**, **Vi**rtual **P**latforms at **E**CT* and **R**elated Areas

Find us at https://www.ectstar.eu/virtual-platforms/

Proposals for new topics, suggestions and offers of help, and criticisms are always welcome.
Please reach out at lava@ectstar.eu !