

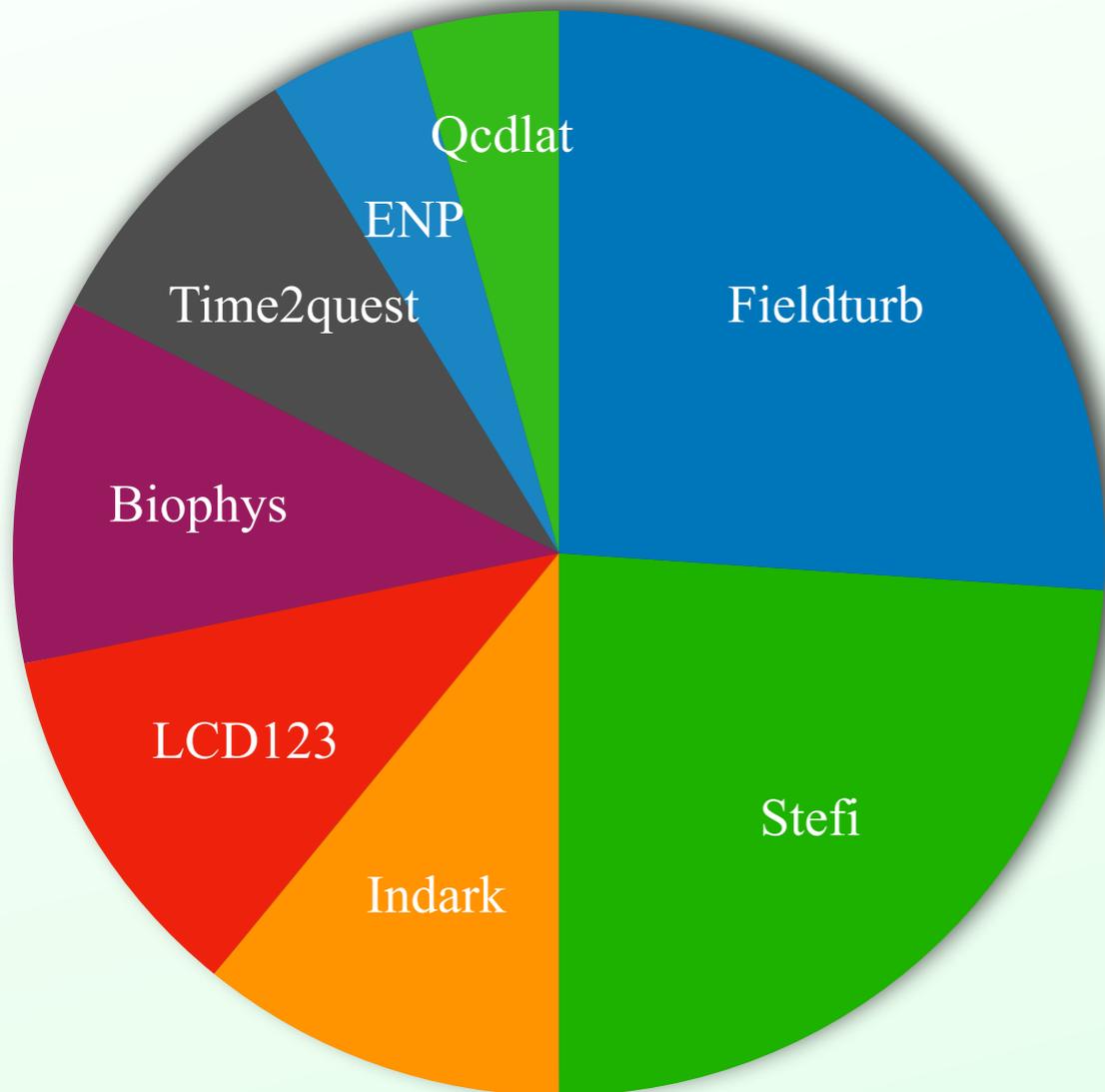


Istituto Nazionale di Fisica Nucleare  
SEZIONE DI ROMA TOR VERGATA

# Preventivi 2020 Gruppo IV

# Iniziative Specifiche

- FTE:



- ▶ **FIELDTURB**: Sistemi complessi, turbolenza  
Luca Biferale, **ricercatori: 15, FTE 12.5**
- ▶ **STEFI**: Teoria di stringa, gauge e gravita  
Gianfranco Pradisi **ricercatori: 12, FTE 11.05**
- ▶ **LQCD123**: Teorie di gauge sul reticolo  
Nazario Tantalò **ricercatori: 7, FTE 5.5**
- ▶ **BIOPHYS**: Biofisica  
Silvia Morante **ricercatori: 7, FTE 5.5**
- ▶ **INDARK**: Cosmologia  
Marina Migliaccio **ricercatori: 9, FTE 5.4**
- ▶ **Time2quest**: Struttura della materia  
Gianluca Stefanucci **ricercatori: 5, FTE 4**
- ▶ **ENP**: Fisica standard model e beyond  
Giulia Maria de Divitiis **ricercatori: 4, FTE 2.5**
- ▶ **QCGLAT**: QCD sul reticolo  
Tassos Vladikas **ricercatori: 2, FTE 2**

# FieldTurb

**Responsabile locale:** Luca Biferale

**Nazionale:** Guido Boffetta (To)

- 1 Agasthya Lokahith AssociatoDottorando 100
- 2 Benzi Roberto AssociatoProf. Ordinario 100
- 3 Biferale Luca AssociatoProf. Ordinario 70
- 4 Bonaccorso Fabio AssociatoDottorando 70
- 5 Buzzicotti Michele AssociatoRicercatore A Tempo Determinato Tipo A 100
- 6 Cencini Massimo AssociatoRicercatore Universitario 50
- 7 Cimini Giulio AssociatoRicercatore B Tempo Determinato Tipo B 100
- 8 De Toma Vincenzo AssociatoDottorando 100
- 9 Goedert Guilherme AssociatoDottorando 100
- 10 Guglietta Fabio AssociatoDottorando 100
- 11 Marra Rossana AssociatoProf. Ordinario 100
- 12 Pelusi Francesca AssociatoDottorando 100
- 13 Puglisi Andrea AssociatoPrimo Ricercatore 50
- 14 Sbragaglia Mauro AssociatoProf. Associato 100
- 15 Tripiccione Raffaele AssociatoProf. Ordinario 10

**Numero Totale Ricercatori** 15 FTE: 12.5

## Attività:

L'attività di ricerca riguarda la caratterizzazione di sistemi complessi nel contesto fluidodinamico a grande e piccola scala. La ricerca è condotta con strumenti teorici, matematici e anche computazionali, usando tecniche numeriche basate sull'equazione di Boltzmann su reticolo ("lattice Boltzmann models", LBM), metodi pseudospettrali e algoritmi di Machine Learning e Reinforcement Learning. L'attività di ricerca nel recente periodo si è articolata essenzialmente nelle seguenti linee di ricerca. (i) La caratterizzazione numerica di sistemi a più componenti (e.g. emulsioni, schiume) caratterizzati da reologia complessa e non lineare (yield stress, shear thinning) e sottoposti a sollecitazioni meccaniche interne/esterne. In particolare, si è interessati a capire come la reologia non lineare influisce sulle proprietà di flusso e trasferimento di calore del fluido complesso. (ii) Lo studio di gocce e particelle complesse (e.g. globuli rossi) sottoposti a sollecitazioni idrodinamiche. Lo scopo è quello di caratterizzare l'impatto delle proprietà dell'interfaccia (i.e. viscosità di membrana, elasticità, bending, etc) sulla risposta idrodinamica di questi oggetti. (iii) La comprensione teorica di fenomeni di fluidizzazione di fluidi con reologia complessa. In particolare, si è interessati ad estendere modelli teorici di fluidizzazione non locale per comprendere la dinamica transiente che permette a questi fluidi di fluidizzarsi partendo da uno stato di quiete, mostrando fenomeni dinamici di "overshoots". (iv) La turbolenza euleriana e lagrangiana con applicazioni ai microswimmers e active smart particles. (v) Le tecniche di data-assimilation usando dei metodi equation-informed come il Nudging e data-driven come i context encoder nel campo del Machine Learning.

L'attività di ricerca sui sistemi complessi si estende alla teoria delle reti e relative applicazioni interdisciplinari. Anche qui la ricerca è condotta con strumenti teorici (matematici e computazionali) affiancati da analisi empiriche su numerosi dataset. Tre sono le linee di ricerca principali su queste tematiche. (i) La prima linea riguarda l'analisi di proprietà statistiche ricorrenti nelle reti, cosiddette "emergenti", come l'invarianza di scala e gli effetti di taglia finita, le transizioni di percolazione e le proprietà spettrali (con eventuali comportamenti anomali dovuti alla struttura del sistema), i processi di auto-organizzazione e di esplorazione efficiente del sistema. (ii) Una seconda linea riguarda lo sviluppo di modelli di rete usando le tecniche di massima entropia proprie della meccanica statistica. Questi modelli si declinano come metodi di ricostruzione nel caso di informazione parziale sul sistema, oppure come tecniche di validazione statistica di proprietà osservate. (iii) La terza linea è l'applicazione delle tecniche sviluppate, in particolare nell'ambito delle reti economiche e finanziarie. Ad esempio: stima delle dipendenze effettive in una rete finanziaria e sviluppo di modelli iterativi di diffusione delle perdite; ricostruzione di reti di scambi interbancari a partire dai bilanci delle banche, con applicazione agli stress-test; identificazione delle interdipendenze tra attività produttive e delle sinergie nei processi di innovazione. Queste attività sono svolte in collaborazione con enti regolatori finanziari ed economici (i.e., banche centrali, banca mondiale, ecc...).

**Richiesta:** 20KE

# STEFI

Resp. Locale: G Pradisi

Resp. Naz: G. Bonelli

## Anagrafica:

1. Alice Aldi, PhD, Università di Roma "Tor Vergata" (100%)
2. Massimo Bianchi, PO, Dip. Fisica, Università di Roma "Tor Vergata" (100%)
3. Giuseppe D'Appollonio, RTI, Dip. Fisica, Università di Cagliari (80%)
4. Maurizio Firrota, PhD, Università di Roma "Tor Vergata" (100%)
5. Francesco Fucito, DdR INFN, Sezione di Roma "Tor Vergata" (100%)
6. Francisco Morales, PR INFN, Sezione di Roma "Tor Vergata" (100%)
7. Gianfranco Pradisi, PA, Dip. Fisica, Università di Roma "Tor Vergata" (100%)
8. Fabio Riccioni, Dip. Fisica, Università di Roma "Sapienza" (100%)
9. Salvo Mancani, Dip. Fisica, Università di Roma "Sapienza" (100%)
10. Alberto Salvio, RTD B, Dip. Fisica, Università di Roma "Tor Vergata" (25%)
11. Raffaele Savelli, RTD B, Dip. Fisica, Università di Roma "Tor Vergata" (100%)
12. Alfredo Grillo, PhD student, Dip. Fisica, Università di Roma "Tor Vergata" (100%)

Numero ricercatori: 12, FTE: 11.05.

## Attività scientifica :

- Exact correlators in supersymmetric theories using different techniques like localization and instanton calculus.
- D-brane physics and application to gauge theories and gravity.
- High energy gravitational scattering between closed strings and D-branes with applications to the analysis of the structure of holographic CFT's.
- Interaction of coherent states and applications to BH mergers.
- Anomalous U(1) in contexts with strongly-coupled sectors.
- Connection between GW's and fundamental (BSM) physics.
- Quiver Gauge Theories and Orientifolds.
- Preheating and Reheating at the end of Inflation and modifications of the Lambda-CDM model.
- Deformations of CY singularities with D3/D7/O-planes. **Attività**
- Non-geometric string compactifications, string dualities and the swampland program.
- Physics of T-branes.
- Exotic branes and fundamental degrees of freedom of M-theory.
- Resolution of the Anti-D-brane singularity.
- Closed-string scattering amplitudes from O-planes and relation to Open-string amplitudes.

**Richiesta:** 19KE

# LQCD123

## Phenomenology with Lattice QCD in Roma123

Responsabile nazionale: Vittorio Lubicz (Roma Tre)

Responsabile locale: Nazario Tantalo

### Anagrafica

- 1) Roberto Frezzotti (PA 50%)
- 2) Marco Guagnelli (R INFN 100%)
- 3) Giancarlo Rossi (PO 0%),
- 4) Nazario Tantalo (PA 100%)
- 5) Madeleine Dale (PhD, D)
- 6) Floriano Manigrasso(PhD, D)
- 7) Antonino Todaro(PhD, D)

Ricercatori: 7, FTE: 5.5

### Attività' scientifica

The activity of group is mainly focused on challenging lattice QCD computations, including the leading isospin breaking corrections, and simulations of QCD + QED, as well as non perturbative investigations beyond the Standard Model.

— QCD

Determination of:

- \* Pion, kaon and D-meson masses and decay constants in isosymmetric QCD, with  $N_f=2+1+1$  dynamical quarks and physical pion mass.
- \* Moments of nucleon generalized parton distributions (GPDs).
- \* Hadronic spectral densities.
- \* Improvement coefficients in the renormalised quark masses in QCD.

— QCD+QED

- \* Rome123 approach: expansion in powers of up-down quark mass difference and electromagnetic  $\alpha$ . Determination of form factors for the radiative leptonic decays of a pseudoscalar meson  $P \rightarrow l \nu \gamma$ , where P is a pion, kaon, D or  $D_s$  meson.

- \* openQ\*D approach: QCD+QED theory with fully dynamical photon field and with  $C^+$  boundary conditions. Release of openQ\*D code, fully tested and optimized.

— beyond SM

Non-perturbative mechanism of elementary fermion mass generation with no effective Yukawa interaction:

- \* numerical demonstration of the mechanism by means of lattice simulations;
- \* basic ideas about the dynamical generation of the electroweak scale (little hierarchy).

Research program for 2021

- \* QED and isospin breaking corrections to the neutron beta decay, and pion decay.
- \* Form factors for the radiative leptonic decays of pseudoscalar mesons in the case of heavy flavour and for rare decays mediated by a virtual photon.
- \* Generations of QCD gauge configurations with  $N_f=2+1+1$  dynamical flavours (isospin symmetric QCD) at physical pion mass and precision study of light and heavy-light meson observables [ETMC];

Generations of QCD+QED gauge configurations with openQ\*D code;

Further studies on hadronic spectral densities and scattering amplitudes;

Conjecture about dynamical generation of the electroweak scale and universality of physical observables in a close-to-realistic model and verification through (unquenched) lattice simulations.

RICHIESTA: 10 KE

# Biophys

**Title:** Intrinsically disordered proteins: multi-level computational approaches

**Responsabile Nazionale:** Mario Nicodemi

**Responsabile Locale:** Silvia Morante

**Anagrafica:**

- 1) Dhar Aishwarya 100%
- 2) La Penna Giovanni 50%
- 3) Minicozzi Velia 100%
- 4) Morante Silvia 100%
- 5) Nobili Germano 100%
- 6) Rossi Giancarlo -
- 7) Stellato Francesco 100%

**Ricercatori** 7 FTE 5.5 (totale)

**Attività' scientifiche:**

Biologically active but “unfolded” or “partially folded” proteins are becoming more and more important in modern protein science. They are called intrinsically disordered proteins (IDPs) and represent a significative percentage of any given proteome. It has been computationally predicted that 7-30% prokaryotic proteins contain long disordered regions, whereas in eukaryotes the amount of such proteins reaches 45-50%. Numerous disordered proteins have been shown to be associated with cancer, cardiovascular disease, amyloidoses, neurodegenerative diseases, diabetes, and other human diseases. Intrinsic disorder in virus proteins has very possibly an important functional role. Conformational flexibility and structural plasticity allow them to switch from a biological role to another, at variance with well folded proteins that have an essentially unique structure strictly connected with their unique role.

The so-called Protein Conformational Diseases (PCDs) are connected with the “wrong” folding (mis-folding) of a given protein. About 50 diseases are classified as PCDs, among them all the neurodegenerative diseases. Many strategies that have been tried to shed light on etiology and development of PCDs, among which the numerical road has given, along the years, fundamental results. The computational study of such complex systems requires the so-called “multi-scale” approach. In fact, on the one side the systems of interest are made of a large  $O(10^6)$  number of atoms, on the other ab initio quantum-mechanical approaches are often compulsory (e.g. in the presence of metal ions). The way-out is a multi-level approach that allows exploring a large range of phenomena having different characteristic times. We thus go from coarse-grained (Martini) approach for  $t \approx \text{msec}$  and  $O(10^6-10^7)$  dof's to classical MD (Gromacs) for  $t \approx \text{nsec}$  and  $O(10^5-10^6)$  atoms and ab initio calculations (Quantum-Espresso) for  $t \approx \text{psec}$  and  $O(10^3-10^4)$  atoms. This kind of multi-level strategy requires the access to HPC platforms and the development of innovative theoretical and computational approaches.

We have been granted, within PRIN-2017, the financing of a project whose aim is filling the gap between thermodynamic biological data and disease-oriented information on protein variants. We propose to integrate theoretical/computational approaches with experimental validations to assess the impact of aa mutations on proteins associated to cancer and genetic diseases. We will measure the impact of single aa replacements in Frataxin, a protein associated to the Friedrich ataxia (a rare but well investigated neurodegenerative disease) by estimating the affinity differences ( $DDG = DG_{\text{mutated}} - DG_{\text{wild-type}}$ ) between mutated (nsSNV) and native (wild-type) proteins. The impact of single aa replacements on the protein affinity will be assessed from non-equilibrium molecular dynamics simulations performed with the multiple-walkers metadynamics method. Theoretical results will be compared with reaction constants and binding enthalpy directly measured in a series of forthcoming experiments (SPR, ITC and NMR) that will be carried out by members of the collaboration.

We have recently applied for a MIUR FISR and for a PRACE project within the framework of the fast Track Call for Proposals: “PRACE support to mitigate impact of COVID-19 pandemic”. The aim of project is to try to unveil the unknown function of two accessory SARS-COVID-19 proteins coded by the ORF7a and ORF8 genes. The best supported hypothesis proposed for the orf7a and orf8 protein function is their ability to interfere with virion budding operated by the cellular BST2-tetherin antigen. We are engaged in producing atomistic models of the orf7a/BST2 and orf8/BST2 complexes in the presence and in the absence of  $Zn^{2+}$  to determine if and how Zn can affect the stability of such systems. The importance of this information lies in the fact that one can modulate Zn concentration to prevent the virus to counteract the BST2 antiviral activity by forbidding the formation of orf7a/BST2 and orf8/BST2 complexes.

We are currently studying the stability of trimeric proteins at different pressures and temperatures with the help of classical Molecular Dynamics simulations and the complementary calculation of structural and topological properties of the trimeric complex. We also started to investigate the behaviour of a particular class of flavonoids in polar and apolar media by performing MD simulations. We have been granted participation to the EU-COST action (ECOSTBio CM1305) “Explicit control over spin-states in technology and biochemistry

**Richiesta in KE:** 9 KE

# INDARK

**Title:** Inflation, Dark Matter and the Large-Scale Structure of the Universe

**Responsabile Nazionale:** Massimiliano Lattanzi (INFN Ferrara)

**Responsabile Locale:** Marina Migliaccio

## **Anagrafica:**

1) Hervé Bourdin (RTD-B UniRM2)	50%
2) Giancarlo De Gasperis (Ric. Univ UniRM2)	20%
3) Pasquale Mazzotta (PO UniRM2)	50%
4) Marina Migliaccio (Coord., RTD-B UniRM2)	50%
5) Nicola Vittorio (PO UniRM2)	50%
6) New RTD-A UniRM2	80%
7) Javier Carron Duque (Ph.D. student UniRM2)	80%
8) Federico De Luca (Ph.D. student UniRM2)	80%
9) Filippo Oppizzi (Post-doc UniRM2)	80%

**Ricercatori 9, FTE 5.4**

## **Attività' scientifiche:**

The focus of the research project is to investigate crucial aspects of the standard cosmological model and its extensions, and their connection with particle physics.

The main research topics are organized as follows:

- i. Inflation and the primordial universe.
- ii. Dark Matter, Neutrinos and other Light Relics.
- iii. Dark Energy and Modified Gravity.
- iv. Cosmological observables as a probe of fundamental physics.

We plan to interpret the combined information from present and future observations of Cosmic Microwave Background (CMB) radiation, Large-Scale Structure (LSS) of the universe, gravitational wave (GW) signals, and other cosmological probes in light of these models, and to sharpen the theoretical tools that allow such an interpretation. To this purpose, a wide range of techniques are employed, including theoretical modelling of the cosmological evolution (using both analytical and numerical methods), analysis and interpretation of available data, together with simulation of mock data samples for future experiments. Merging the complementary expertise present in the different research units (RU) involved in the project allows to design a comprehensive, multiprobe-multiscale, approach. The goal is to advance in the path that goes from a simple phenomenological description of the Universe and its evolution, to fully understanding the nature of its constituents, the behaviour of gravity on cosmological scales and the mechanisms generating the primordial cosmological perturbations. At the same time, this strategy allows to constrain models of particle physics.

In this framework, the Roma2 RU will explore the synergy of CMB and LSS cosmological datasets, including their cross-correlation. We will develop data analysis techniques and statistical estimators to interpret present and upcoming datasets, while devising novel tests of the theoretical models that will allow constraints of increasing accuracy. Specifically, we will design tools for reconstructing CMB anisotropies accounting for both large- and small-scale astrophysical foregrounds. This work will be particularly relevant in the light of upcoming experiments targeting the elusive primordial B-modes. We will also exploit CMB polarization measurements to reconstruct the Universe reionization history, thus learning about the formation of first cosmic structures and testing for exotic energy injections, e.g. from annihilating or decaying dark matter. Concurrently, in preparation for future galaxy surveys, like Euclid, we will assess the capability of measurements of the cross-correlation between CMB temperature anisotropies and galaxy number counts to constrain Dark Energy and Modified Gravity models, together with models of annihilating and decaying Dark Matter. We will also develop estimators for the correlation of CMB lensing with galaxy counts and cosmic filaments, in this case to constrain cosmological bias models and the growth of structures. Finally, the Roma2 RU will also be in charge to develop new approaches to measure the Universe expansion rate with galaxy clusters. In this way we will search for a possible solution to the tensions that have been recently found between measurements of the Hubble constant from early- and late-time Universe observations. These tensions are still unexplained and could hint to new physics beyond the standard model of cosmology.

**Richiesta in KE: 10 KE**

# TIME2QUEST

Title: Advanced Theoretical methods for emerging 2D materials in Quantum Information Technology Studies

Responsabile Nazionale: Stefano Bellucci

Responsabile Locale: Gianluca STEFANUCCI

## Anagrafica:

- 1) Gianluca Stefanucci (PA) - 80%
- 2) Enrico Perfetto (RTDB) - 80%
- 3) Olivia Pulci (PA) - 80%
- 4) Maurizia Palumbo (PA) - 80%
- 5) Sara Postorino (PhD) - 80%

Ricercatori 5, FTE 4.0

## Attività' scientifiche:

- 1) Identification and characterization of electronic, spin and optical properties of atomic defects/ impurities, which can be used as information-records in technological quantum devices based on two-dimensional materials. More specifically, new in-gap double-level spin-states associated to atomic defects/ impurities. We also investigate from a microscopic perspective the nature of single-photon emitters such as hBN and 2H-MSe<sub>2</sub> (M=W,Mo) and look for new single-photon emitters in the VIS/UV domain.
- 2) Investigation of how Moiré patterns can modify the excitonic properties and trap single highly bound excitons, in order to track the quantum information they possess.
- 3) Exploration of exotic phases of 2D quantum matter: equilibrium, Floquet topological excitonic-insulator (EI) and their interaction with light pulses, to provide new concepts for quantum information technologies.
- 4) Identification and characterization of quantum devices made with two-dimensional materials, using tools borrowed from quantum metrology and quantum information theory, which can lead to specific, suitably optimized quantum protocols, exploiting coherence and quantum correlation (entanglement and quantum discord).

Richiesta in KE: 7.5 KE



**Title:** Exploring New Physics

**Responsabile Nazionale:** Giancarlo D'Ambrosio (Napoli)

**Responsabile Locale:** Giulia Maria de Divitiis

**Anagrafica:**

- 1) Giulia Maria de Divitiis (RU 50%)
- 2) Roberto Frezzotti (PA 50%)
- 3) Alberto Salvio (RTDB 75%)
- 4) Anish Ghoshal (postdoc INFN Roma Tor Vergata, 100%)

**Ricercatori** 4, **FTE** 2.75

**Attività' scientifiche:**

- Proposals of BSM models valid over a vast energy range.
- \* Bottom-up approach: simple models with cutoff around the Planck scale
- \* Top-down approach: Standard Model extensions with UV fixed points
  
- First-principle computation in Lattice QCD of hadronic matrix elements that are relevant to constrain various possible extensions of the Standard Model.
- \*  $\Delta F = 2$  four-fermion operators relevant for neutral Kaon oscillations in the SM and beyond by using the chirally-rotated Schroedinger-functional scheme
- \* Form factors for the radiative leptonic decays of a pseudoscalar pion, kaon, D or D<sub>s</sub> meson ( $P \rightarrow l \nu \gamma$ ).
- \* Moments of nucleon generalized parton distributions (GPDs).
  
- A new dynamical non-perturbative approach to the origin of the masses of elementary fermions and the electroweak spontaneous symmetry breaking scale.
- \* Numerical demonstration of the mechanism for fermion mass by means of lattice simulations
- \* Basic ideas about the dynamical generation of the electroweak scale (little hierarchy)

Research program for 2021

- Study of the connections and constraints between gravitational waves (GWs) and fundamental SM and BSM physics.
- Non perturbative renormalisation of four-fermion operators involved in neutral kaon oscillations.
- Form factors for the radiative leptonic decays of pseudoscalar mesons in the case of heavy flavour and for rare decays mediated by a virtual photon.
- Theoretical conjecture about dynamical generation of the electroweak scale and universality of physical observables in a close-to-realistic model. Verification of the conjecture through simulations of the lattice regulated model beyond the quenched approximation.
- Holographic description in string theory of the recently discovered non-perturbative mechanism for the generation of mass of all elementary particles.
- Study of Peccei-Quinn phase transition using non-perturbative methods and inclusion of a light axion in a holographic model of QCD.

**Richiesta:** 4.5 KE

# QC DLAT

**Title:** Next generation lattice field theory for searching new phenomena in particle physics

**Responsabile Nazionale:** Leonardo Giusti

**Responsabile Locale:** Tassos Vladikas

## Anagrafica:

- 1) Giulia Maria de Divitiis 50%
- 2) Mauro Lucio Papinutto 50%
- 3) Anastassios Vladikas 100%

Ricercatori 2, FTE 2

## Attività' scientifiche:

The main objective of this project is to search for new fundamental phenomena in Nature by advancing the theoretical knowledge on strongly interacting theories in the Standard Model (SM) and beyond. We will carry out precise studies of the dynamics of the strong interactions from first principles within the lattice field theory setup. We aim at computations with a precision at the level of percent or less. This is the accuracy required for the interpretation and the analysis of the wealth of experimental results expected in the near future.

One of our goals is a precise determination of the weak matrix elements of four-fermion operators, which parametrise the low-energy contributions to the  $\Delta S=2$  effective weak Hamiltonian in the SM and beyond. As recapitulated in the last FLAG report (1902.08191 [hep-lat]), tension appears for some BSM results measured by different groups in different lattice setups. As part of the CLS initiative, our research team will embark upon a detailed study of all (SM and BSM) matrix elements for  $N_f=2+1$  QCD with Wilson/Clover sea quarks. Valence fermions are fully twisted, with three flavours tuned at twisted angle  $a=\pi/2$  and the fourth one at  $a=\pi/2$ . Performing distinct Osterwalder-Seiler chiral rotations for each flavour, correlation functions with parity-odd operators are mapped onto the 3-point correlation functions of parity even operators with pseudoscalar sources, from which the  $B$ -parameters are readily extracted. The renormalisation and RG-running of these operators are the subject of a novel approach, which is detailed below. The computations are being performed on existing  $N_f=2+1$  CLS configurations at four values of the lattice spacing in the range 0.035-0.086 fm with light quark masses corresponding to pions in the range 140-420 MeV. We are thus able to safely extrapolate results to the continuum limit with a precision of a few percent.

The  $\Delta F=2$  four-fermion operators beyond the SM mix under renormalisation. It is understood that non-perturbative effects at a scale of about 2-3 GeV are significantly large for these operators. For this reason, we will study their renormalisation and RG-running non-perturbatively by the Schroedinger functional scheme in its chirally rotated version (which allows automatic removal of  $O(a)$  cut-off effects and also simplifies the renormalisation mixing pattern). The RG evolution of these operators will be computed non-perturbatively between hadronic and electroweak scales.

We will also determine the ratio  $r_m$  of the flavour singlet and non-singlet renormalisation parameters of the scalar density. This will enable the computation of the quark masses on our  $N_f=2+1$  ensembles, based on the so-called subtracted (rather than the current) bare quark masses, providing an extra handle for a better control of discretisation errors in the determination of the heavier quark masses.

Richiesta in KE: 4 KE