**Template NA**

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| **Work package number** | WP17 | **Start date** | 01/06/2019 |
| **Activity Type** | Networking activity | | |
| **Work package acronym** | NA6-LatticeHadrons | | |
| **Work package title** | Lattice Hadrons | | |

1. Work carried out and overview of progress
   1. **Project objectives**

*[Please give an overview of the project objectives for the third reporting period (June 2022 – July 2024), with regard to the overall objectives as described in the Annex 1 of the Grant Agreement and summarized below.]*

The network, spanning 34 partner research institutions, aims to embed existing lattice field theory expertise more deeply into the European hadron physics community, enhance access across the network to research expertise, data and new developments and exploit new links between research in lattice field theory, experimental and phenomenological hadron physics and high-performance computing and data analytics.

* 1. **Progress made during the reporting period towards the objectives**

*[Please describe the progress made during the third reporting period in line with your Gantt chart and the project overall tasks as described in the Annex 1 of the Grant Agreement and summarized below.]*

***Table 1.2: Progress made during the reporting period towards objectives***

|  |
| --- |
| ***The work, distributed across the partners in the network in collaboration with many research partner institutions across Europe, can be broken down into the following tasks:***  ***Task 1: Coordinate research secondments, visits and exchanges*** |
| With the return to travel following the pandemic, some visitor and exchange activity recommenced, including visitors to and from the Dublin node.  The switch to online teaching and training resulting from the pandemic resulted in many research and teaching staff quickly learning to deliver online modules and recorded material. To exploit this new expertise, the lattice community in Europe formed a new consortium based on the STRONG-2020 LatticeHadrons network to build an experimental online training platform. This platform is called the Lattice Virtual Academy (LaVA) and is close to launch. To date a set of introductory modules have been recoreded and made available by Profs Margarita Garcia Perez, Simon Hands and Christoph Gattringer.  To initiate the project a first workshop was organised at the ECT\* site (Trento) from 20-24 February 2023. The meeting was fully funded as part of the LatticeHadrons STRONG-2020 initiative. During the week, the team developed the first plan for content and began creating the material to record. |
| ***Task 2: Arrange thematic workshops. The network will organize focused workshops to expand research expertise in lattice field theory across Europe and address open challenges for hadronic physics in four themes:***  ***1. Hadron spectroscopy and structure.***  ***2. Hadrons under extreme conditions.***  ***3. Hadrons in the standard model and beyond.***  ***4. Numerical algorithms and computing for lattice hadron physics*** |
| In spite of delays due to pandemic travel restrictions, all meetings planned by the network were delivered. During the reporting period, the following meetings were held :  24-27 April 2023 – Edinburgh, Scotland - Algorithms and computing for lattice hadron physics  12-16 June 2023 – Madrid, Spain - Lattice Gauge Theory contributions to new physics searches (Hadrons in the Standard Model and Beyond)  4-7 July 2024 – Dublin, Ireland – Hadron spectroscopy and structure.  All attracted significant participants from across the network and were successful. |
| ***Task 3: Develop software, data sharing and analytics methodologies*** |
| A small number of research exchanges between nodes commenced following the pandemic and the STRONG-2020 network was able to restart activity in this direction. |

**1.3 Highlights of significant results**

*[Include an overview of the project results towards the objectives in line with the structure of the Annex 1 to the Grant Agreement*.*]*

*The most significant output from the network was the formation of the LaVA online training intiative. This is now growing and is supported by ECT\*, which will host the web material generated for the project. Discussions with senior colleagues in NUPECC on how to proeceed have been initialised and have generated useful connections and feedback.*

1. Critical Implementation risks and mitigation actions

**2.1 Risk materialization**

*[Provide the information on the project risks described in Annex 1 to the Grant Agreement*.*]*

1. Workshops cannot be organized for planned dates (low)

Whether the risk has materialized? (Yes/No)

1. Balance of expenditure on secondments and visitors does not match goal of linking both lattice community internally and broader theory and experimental community (low)

Whether the risk has materialized? (Yes/No)

**2.2 Risk-mitigation measures applied**

*[Please indicate whether the risk-mitigation plan described in Annex 1 to the Grant Agreement and corresponding to the risk number was applied in the reporting period*.*]*

1. Planning for workshops will be reviewed regularly by the management group of the work package

Whether the risk-mitigation plan was applied? (Yes/No)

1. Budget allocation and spending on travel within and external to the network will be reviewed every six months by the WP management group

Whether the risk-mitigation plan was applied? (Yes/No)

**2.3 Comments/new risk-mitigation measures proposed**

*[Provide any significant comments on the risks encountered and the mitigation plan applied. Give any unforeseen risks encountered during the reporting period and not mentioned above*.*]*

3. Deviations from Annex 1 (Description of Action) and Annex 2 (Estimated budget for Action) (if applicable)

**3.1 Deviations from planned objectives and tasks, and their impact on the progress of the work package**

*[Explain the reasons for deviations, the consequences and the proposed corrective actions.]*

*The pandemic led to significant deviation that was hard to overcome. As travel restarted, we have endeavoured to rebuild collaboration links that had moved fully online or been cancelled.*

*To make training the next generation of lattice experts more effective, online training material has been planned and developed.*

**3.2 Deviations between actual and planned person months**

*[Explain deviations between actual and planned person-months. If applicable, propose corrective actions.]*

1. Deliverables and milestones tables

**4.1 Deliverables**

*[Please list all the deliverables due in this reporting period, as indicated in Annex I.*

*Deliverables must also be accompanied by a short report (deliverable description and technical documentation, such as photo, list of publications, etc.), so that the European Commission has a record of their existence.]*

***Table 4.1 List of deliverables***

| **Deliverable No.** | **Deliverable name** | **Lead Beneficiary** | **Nature** | **Dissemination level[[1]](#footnote-1)** | **Delivery month from Annex I** | **Delivered**  **(yes/no)** | **Actual delivery month** | **Comments** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| D17.1 | Report on the status and future research directions | 15 - UREG | Report | PU | 58 | no |  | Significantly delayed due to the pandemic. The meeting finally took place in July 2024. |
| D17.2 | Report on the status and future research directions for investigations of hadrons under extreme conditions | 30 - INFN | Report | PU | 41 | no |  | Also delayed due to the pandemic |
| D17.3 | Report on the status and future research directions for investigations of precision physics in the Standard Model  and studies of strongly interacting quantum field theories relevant for physics beyond the SM | 17 - UAM | Report | PU | 53 | yes |  |  |
| D17.4 | Report on the status  and future research  directions of algorithms for large-scale numerical  computing | 43 - UEDIN | Report | PU | 53 | no |  | Delayed due to pandemic rescheduling |
| D17.5 | White paper on the  near-future challenges  in lattice hadron  physics and the links to other aspects of  phenomenology and  large-scale numerical  computing | 27 - TCD | Report | PU | 62 | No |  | Delayed due to pandemic rescheduling |

*In case a deliverable has been delivered in the reporting period and a report exists in the Participant Portal, you can indicate “uploaded report” in correspondence of a deliverable*

**4.2 Milestones**

*[Please complete the table if milestones are specified in Annex I.*

*Milestones will be assessed against specific criteria and performance indicators as defined in Annex I.]*

***Table 4.2 List of milestones***

| **Milestone number** | **Milestone name** | **Lead beneficiary** | **Delivery month from Annex I** | **Delivered**  **(yes/no)** | **Actual delivery month** | **Comments** |
| --- | --- | --- | --- | --- | --- | --- |
| MS23 | Workshop on hadron  spectroscopy and structure | 27 - TCD | 52 | yes |  |  |
| MS25 | Workshop on hadrons in the  standard model and beyond | 27 - TCD | 47 | yes |  |  |
| MS26 | Workshop on algorithms for  lattice field theory | 27 - TCD | 47 | yes |  |  |
| MS27 | Enhanced integration  of lattice field theory in European hadron physics community | 27 - TCD | 47 | yes |  |  |

**4.3 Deliverable Reports**

*[Please provide, per each deliverable listed in Table 4.1, a brief description, including if possible some technical documentation (photos, list of publications, etc.). Use as many pages as needed per each report.]*

*The reports delivered describe the discussions and insights from the following meetings:*

***Workshop on Algorithms for Lattice Gauge Theory for Contributions to New Physics Searches, Madrid, 12-16 June 2023.***

*https://indico.ift.uam-csic.es/event/19/*

*A crucial goal for the lattice community in Europe is to provide theory insights and input to constraint searches for physics beyond the standard model of particle physics. The workshop in Madrid brought together experts in these calculations to discuss new developments and the limitations and constraints on precision that can be provided from the state-of-the-art lattice calculations.*

*The meeting drew together 38 participants and covered topics such as*

* Muon g-2
* Flavor Physics
* Axions & EDMs
* BSM & New Developments

The meeting encouraged a mixture of formal presentations and open discussion sessions framed by questions of broad interest to the community.

**Numerical algorithms and computing for lattice hadron physics. Edinburgh, Scotland**

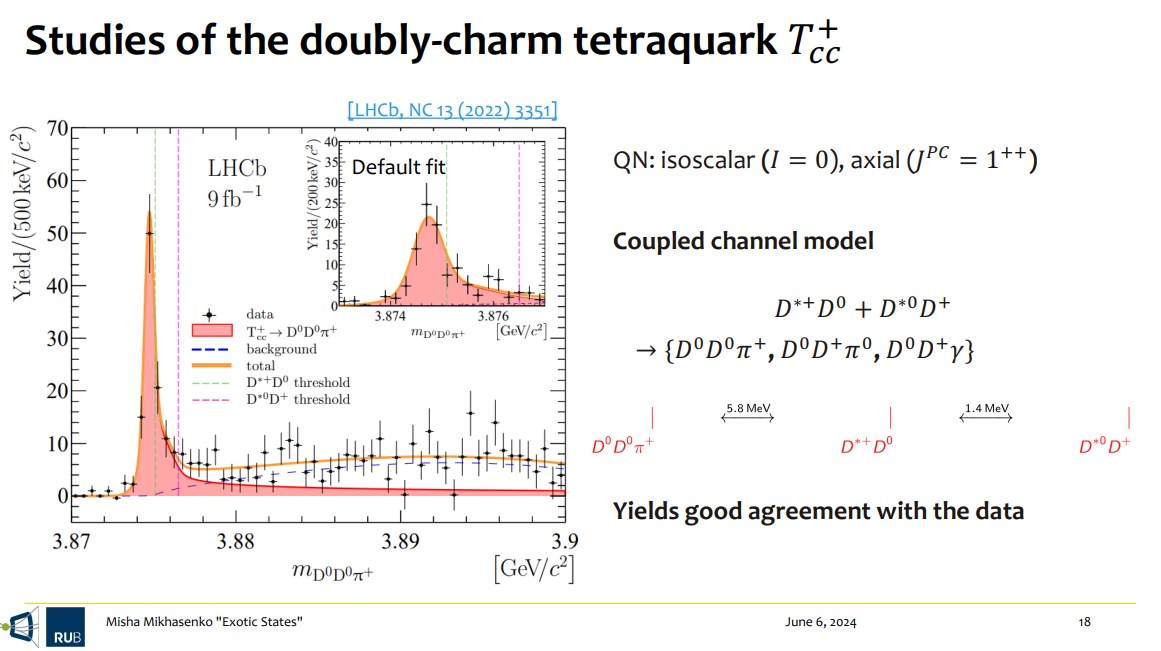
**24-27 April 2023.**

The workshop on algorithms was hosted in Edinburgh and brought together experts in the numerical and data-analytic techniques relevant to large-scale Monte Carlo calculations that are at the core of lattice QCD research. External speakers came from DeepMind (David Barrett) and Nvidia (Kate Clark). The workshop covered the latest developments in

* Master Field simulations
* Multilevel algorithms
* Machine Learning
* Quantum Computing
* Implementation on current and future hardware (exascale projects)
* Energy efficiency
* Mathematical foundations

The first speaker of the meeting was Martin Luescher, an internationally recognised expert in the discipline who presented his new ideas for multilevel techniques which have the potential to accelerate lattice computations and enable theory to address a broader scope of experimental questions. The future of High-Performance Computing and its application to Lattice QCD calculations was discussed by experts on exascale computing. The mathematical foundations of the numerical techniques and in particular the linear algebra methods needed to compute the effects of quark propagation on a gluon background were reviewed in detail.

**Workshop on hadron spectroscopy and structure. Dublin, Ireland 4-7 June 2024**

The final workshop of the Network was successfully hosted at Trinity College Dublin. On the first two days, the meeting focussed on gradient flow and renormalisation, discussing important new developments in both the perturbative and non-perturbative theoretical treatment of fundamental parameters in the Standard Model, specifically aimed at understanding heavy quark dynamics. On Day 3, hadron spectroscopy was discussed, including a presentation on the experimental status of recent exotic hadrons seen in LHCb (Talk by Mikhail Mikhasenko, Ruhr Uni Bochum) . In the afternoon, short presentations by early-stage researcher enabled them to showcase their work on machine-learning applications and theoretical developments in the technical precision of lattice calculations. On Friday, the meeting closed with further discussions on charm meson scattering and resonances in charmonium.

1. PU = Public

   PP = Restricted to other programme participants (including the Commission Services).

   RE = Restricted to a group specified by the consortium (including the Commission Services).

   CO = Confidential, only for members of the consortium (including the Commission Services). [↑](#footnote-ref-1)