Newsletter #3

April 2021

The STRONG-2020 project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

Table of contents

Foreword

This is the third newsletter of the STRONG-2020 European project, which has been prepared by the Dissemination Board (DB) as editors, and contains a series of news and information of interest not only for the STRONG-2020 Community, but also for a broader scientific community and the general public.

This newsletter #3 is structured as follows: the first article is written by Jochen Wambach, who is ending his 5-year mandate as ECT* Director, ECT* being one of the Research Infrastructures financed within STRONG-2020, and presents the European Centre for Theoretical Studies in Nuclear Physics and related Areas (ECT*), with an overview on its perspectives. This article is followed by news concerning some ongoing STRONG-2020 activities, in particular Parton Branching: a bridge from resummation to parton shower, and reports from workshops and meetings organized or supported by STRONG-2020, an interview to a STRONG-2020 young participant, and some news regarding Dissemination and Educational activities towards the broader scientific community, including the successful series of STRONG-2020 public lectures, arrived as of April to its 4th lecture (held on April 21st), news for our YouTube channel and on the 2021 INSPYRE international school, and last but not least the mosaic containing photos of STRONG-2020 participants.

We, the STRONG-2020 DB, encourage you, the community participating to this project to contact us and send us news regarding your achievements (published articles, experimental developments, theoretical calculations), your events organised within or with support of STRONG-2020, videos about your activities, interviews to young and less young participants and any other information or news relevant for our community or to a broader scientific community and to the general public which is connected to our project.

This continues to be not an easy period, with the problems connected to the coronavirus situation affecting many countries, and we, the DB, wish you all to stay safe.

Catalina Curceanu, on behalf of STRONG-2020 Dissemination Board

Marco Battaglieri, Maurizio Boscardin, Achim Denig, Raphaël Granier de Cassagnac, Maria Paola Lombardo, Hervé Moutarde, Piet Mulders, Andrea Pesce, Fulvio Tessarotto.

European Commission

The European Centre for Theoretical Studies in Nuclear Physics and related Areas (ECT*)

Jochen Wambach (European Centre for Theoretical Studies - ECT)*

Introduction

ECT* started operating in 1993 as a bottom-up initiative of European nuclear physicists, similar in scope and mission to the Institute for Nuclear Theory in Seattle. In both cases, the aim was to establish international institutions at the cutting edge of theoretical research in close relation to state-of-the-art experimental developments in nuclear physics and areas of mutual interest with other fields. Through its 28 years of operation, it is fair to say that ECT* has lived up to these goals. The Centre is a unique institution to foster European and international collaborations, driven entirely by the community, which is a prerequisite for “curiosity-driven” fundamental research.

The ECT* centre, in Trento, Italy

Nuclear Theory

The goal of modern nuclear physics is to unravel the fundamental properties of nuclei from their building blocks, protons and neutrons, and ultimately to determine the emergent complexity from the underlying quark and gluon degrees of freedom of quantum chromodynamics (QCD), the fundamental theory of the strong nuclear force. This significant broadening of the scope of nuclear physics, that we have witnessed over the last few decades, requires detailed knowledge of the structure of hadrons, the nature of the residual interactions between nucleons resulting from their constituents and the limits of the existence of bound nuclei and ultimately of hadrons themselves.

In this context, nuclear theory is making major conceptual and computational advances to address the fundamental questions in the strong-interaction sector of the standard model. These include the high-temperature and high-density behaviour of matter as encountered in cosmological settings and the emergence of hadrons and nuclei from the complex dynamics of QCD. The efforts are driven in part by discoveries such as the most exotic state of matter, the quark-gluon plasma (QGP), which is created in the collision of highly relativistic heavy ions. The QGP is believed to have existed in the very first moments of the universe and may be present in the core of the most massive neutron stars. The recent detection of gravitational waves from the neutron-star merger event GW170817 focuses attention on the equation of state at high baryon density, which is not well understood at present. High-precision measurements of the quark structure of the nucleon are challenging existing theoretical understanding. In addition, nuclei constitute a unique laboratory for a variety of investigations in fundamental symmetries, which in many cases are complementary to particle physics. These include searches for dark matter, neutrinoless double-beta decay and other signatures of beyond-the-standard-model physics that require strong guidance from nuclear theory.

The Role of ECT*

Nuclear theory plays a crucial role in shaping existing experimental programmes in Europe and elsewhere and provides guidance to new initiatives in nuclear physics. Combining theoretical activities in a concerted effort is essential for the optimal use of the available resources, in particular by providing platforms for scientific exchange and the training of the next generation of nuclear theorists. Here, ECT* plays a crucial role. ECT* is unique and the only centre of its kind in Europe. It collaborates with European universities, institutes and laboratories as well as research institutions worldwide. It is an institutional member of NuPECC, the Associated Nuclear Physics Expert Committee of the European Science Foundation. With around 700 scientific visitors each year, from all over the world, spending from a week to several months at the Centre, ECT* has gained a high international visibility. As stipulated in its statutes, the Centre assumes a coordinating function in the European and international scientific community by:

- conducting in-depth research on topical problems at the forefront of contemporary developments in theoretical nuclear physics;
- fostering interdisciplinary contacts between nuclear physics and neighbouring fields such as particle physics, astrophysics, condensed matter physics, statistical and computational physics and the quantum physics of small systems;
- encouraging talented young physicists by arranging for them to participate in the activities of the ECT*, by organising training programmes and establishing networks of active young researchers;
- strengthening the interaction between theoretical and experimental physicists.

These goals are reached through international workshops and collaboration meetings, advanced doctoral training programmes and schools, and research carried out by postdoctoral fellows and senior research associates as well as by long-term visitors.

Cooperation exists with the physics department and the centre for Bose-Einstein Condensation (BEC) at the University of Trento (UniTN), as well as with the Interdisciplinary Laboratory for Computational Science (ECT*/LISC) which has become a research subunit of the Centre. Over the years, ECT* has established cooperation agreements with many prominent scientific institutions worldwide in an effort to stimulate international exchange of state-of-the-art theoretical and experimental developments in a global setting.

The Centre is funded – in about equal parts – by the Provincia Autonoma di Trento (PAT) through the Fondazione Bruno Kessler (FBK) and by agencies of E.U. Member and Associated States. Various instruments of the framework programmes of the European Commission provide additional financial support for workshop and training programmes.

The Future

With the emergence of a common European Research Area and growing international cooperation, ECT* faces new opportunities and challenges. Significant European and global investments are being made presently in accelerator centres and other experimental facilities. Their efficient utilisation requires coordination and exchange of ideas – experiments stimulating theory and *vice versa*. Interdisciplinary contacts between the various subfields covered by ECT* and with related areas of physics and science are beneficial to all parties. ECT* continues to have strong support from the European nuclear physics community as expressed for instance in the NuPECC long-range plan of 2017. It features as a major infrastructure and will play an increasing role in coordinated European initiatives through transnational access.

In 2020, in response to substantial budget cuts by the PAT, the FBK started reconsidering its scientific portfolio and possible restructuring measures of its research programme. In this context, the role of ECT* in a new FBK research environment and the future local financial support of the Centre are being re-examined. A task force involving members of the ECT* Scientific Board has prepared several documents detailing the future vision for the Centre and proposing measures to embed the scientific activities of ECT* in the local research environment of Trento in a way that is beneficial to all sides. These involve the strengthening of the scientific relations with UniTN and potential collaborations with other FBK centres, especially in areas of Quantum Information Science (QIS). Increasingly, QIS plays an important role in nuclear theory, as is witnessed by the workshop and training programmes of ECT* in the past few years. With potentially diminishing local funds for the operation of ECT* it will be imperative to significantly increase the financial contributions from external sources, if the scientific autonomy of the Centre and its global mission are to be preserved in the future.

Editor's note: ECT is one of the STRONG-2020 Transnational Access work packages, hence benefiting to several of its partners.*

Parton Branching: a bridge from resummation to parton shower

Hannes Jung

Most inclusive processes at high energies are well described by calculations of a hard scattering process, calculable in perturbative quantum chromodynamics (QCD) convoluted with parton densities, which give the probability of finding a parton of specific flavour carrying a fraction x of the parent hadron's longitudinal momentum probed at a resolution scale μ. However, when less inclusive processes are calculated, one finds that a fixed order perturbative calculation is not sufficient to describe the measurement, for example the transverse momentum spectrum of Z bosons as measured at the LHC. At low transverse momenta, a resummation of soft gluon emissions to all orders is necessary to describe the measurement. Such resummations can be performed semi-automatically, leading to the so-called transverse momentum dependent (TMD) distributions, or by performing an explicit simulation of soft parton emissions in terms of parton showers, as implemented in Monte Carlo event generators. While the physics of both approaches is the same, the calculations and the details are very different.

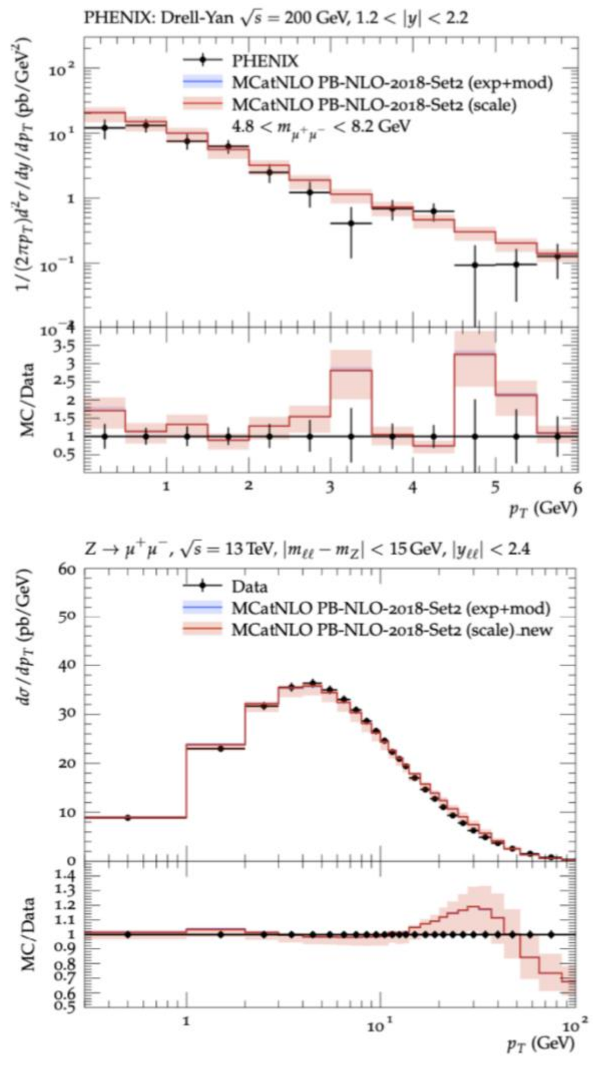


Figure 1: Transverse momentum spectrum of DY bosons measured by PHENIX at low energy (left) and of Z bosons measured by CMS at high energy

The Parton Branching (PB) method aims to combining both approaches. This is obtained by detailed investigations of the underlying parton evolution equation, the DGLAP equation, and rewriting this equation in terms of resolvable and non-resolvable branching processes, see Refs. **[1]** and **[2]**. When the evolution equation is solved iteratively, kinematic constrains coming from energy-momentum conservation can be applied at each branching. By doing so, automatically transverse momentum distributions can be calculated. The PB method has been applied to determine parton distributions from precision deep inelastic scattering measurements. With these TMD parton distributions, Z production at LHC, as well as low-mass Drell-Yan production at low energies is very well described, without any further adjustment of parameters, as shown in Fig. 1 (see Refs. [3] and [4]).

The PB approach can be naturally extended to describe processes, where jets are involved, by performing a PB TMD parton shower, which follows in detail the PB TMD distribution [5]. An example of this approach is shown in Fig. 2 for the angular correlation between two b-quark jets with a Z boson as measured by CMS [6]. In the calculation the b-jets come from the PB TMD parton shower.

The PB method is a unique approach to combine features of semi-analytic resummation in form of PB-TMD distributions with TMD parton showers in a natural way.

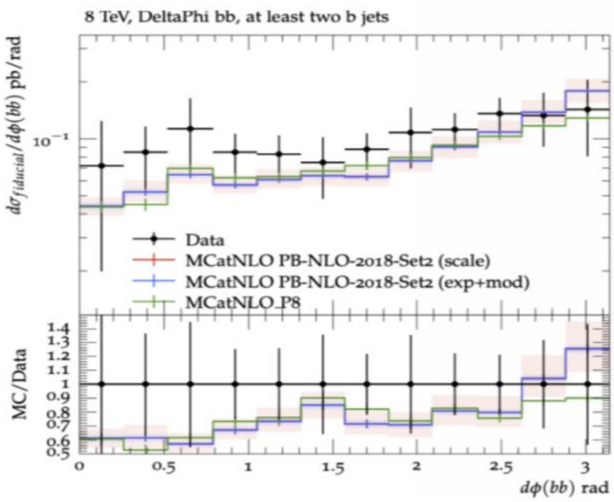


Figure 2: Azimuthal correlation of two B-jets in association with a Z boson measured by CMS

Editor's note: The work of Hannes Jung relates to the STRONG-2020 Virtual Access work package 3DPartons.

References

[1] Ellis, R. Keith and Stirling W. James and Webber, B. R., Camb. Monogr. Part. Phys. Nucl. Phys. Cosmol. 8 (1996) 1
[2] Hautmann, F., Jung, H., Lelek, A., Radescu, V., Zlebcik, R., JHEP 1801 (2018) 070
[3] Bermudez Martinez, A. and others, Eur. Phys. J. C80 (2020) 598
[4] Bermudez Martinez, A. and others, Phys. Rev. D100 (2019) 074027
[5] Baranov, S. and others, arXiv:2101.10221 (2021)
[6] Khachatryan, V. and others, Eur. Phys. J. C77 (2017) 751

First precise measurement of the mass of a nucleus with a bound doubly strange baryon

Shuhei Hayakawa (JAEA), Kazuma Nakazawa (Gifu University) and Josef Pochodzalla (Mainz) for the E07 collaboration

Like neutrons and protons, hyperons are composed of three quarks. However, besides the conventional light up and down quarks, hyperons also contain one or more strange quarks. While many stable nuclei made of neutrons and protons exist, nuclei which include hyperons, so-called hypernuclei, are unstable and decay within less than a billionth of a second and are therefore difficult to observe. An international team of about 100 researchers from 24 institutes in Japan, South Korea, the USA, China, Germany, and Myanmar, observed the decay of a nucleus in which a hyperon with two strange quarks is bound to a conventional core nucleus **[1]**. By identifying the decay products with high precision, the team of the J-PARC E07 experiment was able to determine for the first time the mass of such a doubly strange hypernucleus.

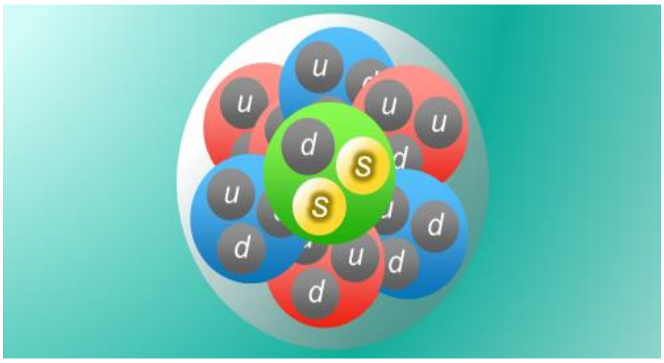


Figure 1: Pictorial view of a nucleus containing a doubly strange Ξ^- hypernucleus. Courtesy S. H. Hayakawa / Japan Atomic Energy Agency

To produce such nuclei, a secondary beam of negative K mesons from J-PARC (the Japan Proton Accelerator Research Complex) was directed into a diamond target. Interactions in this diamond block produced in some cases Ξ^- hyperons that are made up of two strange quarks and one down quark. These hyperons then entered into a stack of photographic plates. Some of these negative Ξ^- hyperons were brought to rest in these emulsion plates and were eventually captured by a nucleus thus forming a Ξ^- hypernucleus. Finally, such a hypernucleus decays into several fragments leaving a unique fingerprint in the emulsion. Using an automated track-identification system, the E07 team extracted an event where a Ξ^- hyperon was bound to a nitrogen-14 nucleus. By measuring the traces of the decay products with sub-micrometer precision and by a detailed kinematic analysis it was found that the Ξ^- hyperon binds to the nitrogen nucleus with an energy of 1.27 MeV.

The first candidate of a doubly strange nucleus was found nearly half a century ago. Since then, only a handful of such nuclei have been observed. In most cases, these hypernuclei contain two hyperons holding one strange quark each, so-called Λ hyperons. The event observed by E07 is the first Ξ^- hypernucleus whose mass could be uniquely determined. As a consequence of the extreme rarity, these truly exotic nuclei are often labelled by their own name. The event observed by the J-PARC E07 team has dubbed IBUKI, which is the name of a mountain on the border of Gifu Prefecture. The precise mass measurements of Ξ^- hypernuclei gives information on "strong interaction" between a Ξ^- particle and a nucleus, and on underlying interaction between Ξ^- particle protons and neutrons. This result is expected to contribute to our understanding of the interior of neutron stars which are often described as giant nuclei.

Figure 2: Microscope image of the IBUKI event recorded in the emulsion as shown on the front cover of Physical Review Letters. A Ξ^- particle was absorbed by Nitrogen-14 and formed a Ξ hypernucleus at point A. It decayed into a Beryllium-10-Λ hypernucleus (#1) and a Helium-5-Λ hypernucleus (#2). The Beryllium-10-Λ hypernucleus which is composed of four protons, five neutrons and one Λ hyperon decayed into several nuclei (#3-6) and several neutrons (no recorded track due to no charge) at point B. The Helium-5-Λ hypernucleus decayed into a Helium-4 (#7) nucleus, a negative pion (#8), and a proton (#9) at point C.

Editor's note: this work is related to STRONG-2020 workpackage THEIA (WP16, NA5).

References

[1] S. Hayakawa et al., "Observation of Coulomb-assisted nuclear bound state of Ξ^--^{14}N system"Phys. Rev. Lett. 126, 062501 (2021) https://link.aps.org/doi/10.1103/PhysRevLett.126.062501

Emergent hadron mass

Craig D. Roberts
cdroberts@nju.edu.cn
School of Physics, and Institute for Nonperturbative Physics, Nanjing University, Nanjing, Jiangsu 210093, China

The standard model (SM) of particle physics has one obvious mass-generating mechanism; namely, the Higgs boson, whose impacts are widespread and critical to the evolution of the Universe. However, by itself, the Higgs is responsible for just 9 MeV of the proton's mass; hence, merely 1% of the visible mass in the Universe – see Fig. 1. Nature has another, very effective mechanism for producing mass, *i.e.* emergent hadron mass (EHM). Alone, it produces 94% of the measured proton mass. The remaining 5% is generated by constructive interference between EHM and the Higgs-boson. These facts raise many fundamental questions, *e.g.* what is the origin of EHM and does it lie within the SM; and what are the connections with gluon and quark confinement, which are keys to the proton's absolute stability?

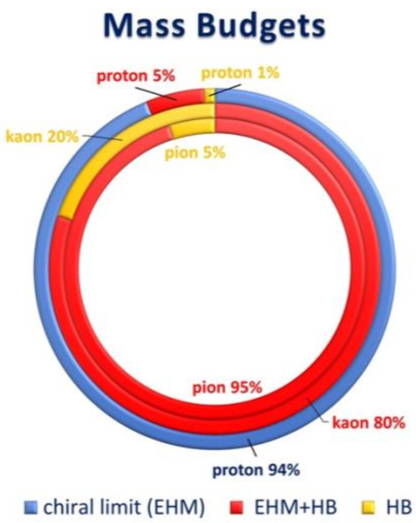


Figure 1: Mass budgets for the proton (outer annulus), kaon (K, middle) and pion (π, inner). Higgs-boson (HB) alone contribution (gold); constructive interference between EHM and HB(red); HB turned off = chiral-limit value, purely emergent hadron mass (EHM) (blue). Owing to EHM via its dynamical chiral symmetry breaking corollary, the kaon and pion are massless in the chiral limit – they are the SM's Nambu-Goldstone (NG) modes, so there is no blue zone in these annuli. (Gauge- and Poincaré invariant decomposition, separation at $\zeta = 2$ GeV, produced using information from Refs. [1] to [5].)

Dramatic counterpoints are presented by mass budgets for the pion and kaon, drawn in Fig. 1 as the inner annuli. The pion is massless in the absence of Higgs couplings into QCD; so, there is no blue zone in its mass budget. Restoring quark interactions with the Higgs, one sees that 5% of the pion mass is invested in the current masses of the valence quark and antiquark. The other 95% is generated by EHM+HB interference. The kaon lies somewhere between the proton and pion extremes. It is a would-be NG mode; hence, no blue domain in its mass decomposition. Yet, the sum of the valence quark and antiquark

European Commission

current masses in the kaon accounts for 20% of its measured mass, which is four times more than in the pion; and EHM+HB interference produces 80%. These features signal that without the Higgs boson, the pion and kaon would be indistinguishable; and that comparisons between π and K properties are an ideal way to probe Higgs-boson modulation of EHM.

The π and K are Nature's most fundamental NG modes; and as strongly interacting objects, their SM description relies primarily on the theory of gluons and quarks; namely, quantum chromodynamics (QCD). They are also mesons, *viz.* systems comprised of only two valence bodies; hence, in many respects the π and K are the simplest bound-state problems in QCD. Consequently, in this context, modern theory can make reliable, even rigorous predictions. Prominent amongst them is the existence of a process-independent effective coupling. It appears as a nonperturbative consequence of gluon self-interactions and emerges along with running masses for gluons and quarks, which themselves play a large part in explaining π and K properties. This coupling and those mass functions are the most basic expressions of the dynamical violation of scale invariance in the SM **[6]** – or so theory predicts; and if these things are true, then gluons are particles with unprecedented characteristics.

The π and K have also been members of the catalogue of known hadrons for around seventy years **[7]**, **[8]**. However, still today, almost nothing is empirically known about their structure. For instance, although their masses are measured, the pion's electric charge radius is only known imprecisely, information on the kaon's radius is very sketchy, and the only measurements that probe the momentum distributions of their valence constituents are more than thirty years old. In this last connection, only ten data points exist worldwide for the K and no measurements exist for the non-valence components of either system. What use then are accurate theory predictions?

There is a promise today that this fog of ignorance will burn away as upgraded facilities begin operation and new high-energy, high-luminosity accelerators win approval or enter into planning, see Refs. **[9]** to **[16]**. Jefferson Laboratory, upgraded to 12 GeV beams, will measure π and K form factors into the domain of momentum transfers where the scaling violations predicted by QCD should be observed and also obtain new, precise data relating to π and K valence-quark momentum distributions. AMBER Phase-1 at CERN is approved. It will deliver the world's highest intensity $\pi^{\pm}$ beams and measure, inter alia, Drell-Yan π-proton cross-sections that will fill the more than 30-year gap. Their careful analysis will go a long way towards supplying definitive answers to questions that hang over the pion's valence-quark momentum distribution and provide key insights into sea-quark distributions. AMBER Phase-2 promises a great deal more, e.g. unprecedented, simultaneous, precision access to the entire collection of valence, sea and glue distributions in the π and K. An electron-ion collider is under discussion in China (EicC), whose anticipated parameters mean it could both develop a powerful synergy with the AMBER plans and nicely fill a gap between JLab 12 and the EIC at Brookhaven National Laboratory. And EIC itself promises the capacity to provide information on π and K structure over a hitherto unimaginable kinematic domain.

With such data in hand, science may finally resolve the multifaceted puzzles surrounding the origin of the vast bulk of visible mass in the Universe. One may thus anticipate that the next twenty-five years will see us: identify the source of EHM; elucidate its connection with gluon and quark confinement; reveal the role of the Higgs boson in modulating the observable properties of hadrons; grasp the differences between the proton, kaon and pion, and their significance; and ultimately understand the character of Nature's most fundamental Nambu- Goldstone modes and the essence of the gluons that bind them. Arriving at these answers will at last enable completion of a chapter in the book of science whose first lines were written more than eighty years ago and contained the prediction of the pion's existence **[17]**.

Acknowledgments: The author is grateful for insightful remarks from V. Andrieux, L. Chang, O. Denisov, A. Guskov, T. Horn, W.-D. Nowak, C. Quintans, D. G. Richards, and a body of collaborators whose contributions have been crucial to developing the perspectives sketched herein.

Editor's note: This original article was written on our request and triggered by the approval of a new experiment in our field: AMBER at CERN. Many members of the AMBER collaboration are also members of STRONG-2020. The content of the article is related to the activity of several work packages, in particular WP 13, 22 and 25.

References

[1] V. V. Flambaum, et al., Sigma terms of light-quark hadrons, Few Body Syst. 38 (2006) 31–51.
[2] J. Ruiz de Elvira, M. Hoferichter, B. Kubis, U.-G. Meißner, Extracting the σ-term from low-energy pion-nucleon scattering, J. Phys. G 45 (2) (2018) 024001.
[3] S. Aoki et al., FLAG Review 2019, Eur. Phys. J. C80 (2020) 113.
[4] C. D. Roberts, S. M. Schmidt, Reflections upon the Emergence of Hadronic Mass, Eur. Phys. J. ST 229 (22-23) (2020) 3319.
[5] P. Zyla et al., Review of Particle Physics, PTEP 2020 (2020) 083C01.
[6] C. D. Roberts, On Mass and Matter – arXiv:2101.08340, AAPPS Bulletin (2021) in press.
[7] C. M. G. Lattes, H. Muirhead, G. P. S. Occhialini, C. F. Powell, Processes involving charged mesons, Nature 159 (1947) 694–697.
[8] G. D. Rochester, C. C. Butler, Evidence for the Existence of New Unstable Elementary Particles, Nature 160 (1947) 855–857.
[9] T. Horn, C. D. Roberts, The pion: an enigma within the Standard Model, J. Phys. G. 43 (2016) 073001.
[10] O. Denisov et al., Letter of Intent (Draft 2.0): A New QCD facility at the M2 beam line of the CERN SPS – arXiv:1808.00848.
[11] A. C. Aguilar, et al., Pion and Kaon Structure at the Electron-Ion Collider, Eur. Phys. J. A 55 (2019) 190.
[12] S. J. Brodsky, et al., Strong QCD from Hadron Structure Experiments, Intern. J. Mod. Phys. E 124 (2020) 2030006.
[13] X. Chen, F.-K. Guo, C. D. Roberts, R. Wang, Selected Science Opportunities for the EicC, Few Body Syst. 61 (4) (2020) 43.
[14] C. D. Roberts, D. G. Richards, T. Horn, L. Chang, Insights into the Emergence of Mass from Studies of Pion and Kaon Structure – arXiv:2102.01765.
[15] D. P. Anderle, et al., Electron-Ion Collider in China – arXiv:2102.0922, Front. Phys. China.
[16] J. Arrington et al., Revealing the structure of light pseudoscalar mesons at the Electron-Ion Collider – arXiv:2102.11788.
[17] H. Yukawa, On the interaction of elementary particles, Proc. Phys. Math. Soc. Jap. 17 (1935) 48.

The IWHSS 2020 workshop

17th International Workshops on Hadron Structure and Spectroscopy – Trieste, Nov. 2020

IWHSS 2020 is the 17th in a series of International Workshops on Hadron Structure and Spectroscopy that the COMPASS Collaboration holds every year to review the status of the physics topics under investigation by the experiment and to discuss future activities, getting together experts and young physicists working on very different fields of hadronic physics. The series started in 1999, with a first workshop in Munich, and continued regularly since. The plan was to hold outside CERN one of the COMPASS Collaboration meetings, which normally take place at CERN, and have it in one of the Institutes of the Collaboration, the same week of the Workshop.

In 2020 the Workshop was held in Trieste, and organised by the Trieste group in COMPASS, which embodies researchers from the Sezione INFN of Trieste, the Physics Department of the University of Trieste and the Multidisciplinary Laboratory of the ICTP. The workshop had to take place in a historical building of the old harbour in May 2020, in the context of the proESOF initiative and ESOF2020 satellite events. Due to the pandemic, it was postponed to 16-18 November 2020, and could be held only remotely. The attendance was high, with more than 115 participants connected from everywhere, and the scientific programme included about 40 talks in only two-and-a-half days. The Workshop has been particularly appreciated because most important international events in hadronic physics, like SPIN 2020 and TRANSVERSITY 2020, were postponed to 2021 or later, and the community was eager to meet and discuss, albeit remotely.

In line with the previous IWHSSs, the focus of the Workshop has been on spectroscopy and nucleon structure, with the aim of discussing the worldwide status and perspectives, both on the theoretical and experimental side. Thanks to the enthusiastic participation and to the excellent quality of the talks, the Workshop succeeded in putting together young physicists and experts to discuss such a lively and diversified field. In the short time available, the most relevant achievements and expectations on chiral perturbation theory, spectroscopy, spin and 3D structure of the nucleon from SIDIS and Drell-Yan processes, generalised parton distributions from DVCS and hard exclusive meson production, have been reviewed in many high-level talks that are too difficult to single out and quote. New experimental techniques and facilities were also discussed, and special sessions were devoted to the emergence of hadronic mass and to the proton radius puzzle, topics that both will be further investigated by the COMPASS groups, in the framework of the AMBER collaboration.

All the information and the relevant material can be found at: http://agenda.infn.it/event/20446.

Editor's note: The IWHSS Workshop is linked to the STRONG-2020 WP22 (TMD-neXt) and WP23 (GPD-ACT). This report is written by Anna Martin, member of the WP22, Dipartimento di Fisica, UniTS INFN, Sezione di Trieste, and Chair of the Organising Committee

Theoretical aspects of Hadron Spectroscopy and phenomenology workshop

M. Battaglieri, R. Molina-Peralta, J. Nieves, D. R. Entem and L. Tolos

The topical Workshop on *Theoretical aspects of Hadron Spectroscopy and Phenomenology* took place on December 15–17, 2020. This workshop was part of the planned activities of the working package WP25 (JRA7): "Light- and heavy-quark hadron spectroscopy" (http://web.ge.infn.it/jstrong2020/), within the STRONG-2020 project (http://www.strong-2020.eu/).

Given the serious public health problems related to Covid-19, which forced the closure of several countries inside and outside the EU, as well as the imposition of extreme travel limitations, the organising committee decided to cancel this meeting planned to be held in Valencia (Spain) from April 21 to April 24, 2020. The particular context we were still living at the end of 2020 conditioned the holding of this meeting in virtual mode, via ZOOM. Nevertheless, and despite the physical distance, the working package demonstrated the integrity of its organisation and the continuity of work on the project tasks.

The workshop website was http://ific.uv.es/nucth/TH-WP25-H2020/.

The meeting run for three days, with more than 80 participants. The workshop was structured in six sessions with a total of 31 talks (25'= 20' +5' discussion), which covered different aspects of:

1) precision calculations in non-perturbative QCD: effective field theories (EFTs), analyticity, dispersion relations and lattice QCD;
2) spectroscopy & exotic states;
3) hadron decays & production;
4) form factors, LECs, fundamental parameters of QCD and light nuclei spectroscopy.

The agenda, as well as the contributions of all speakers (PowerPoint or PDF presentations) can be found on the dedicated indico page:

https://indico.ice.csic.es/event/24/timetable/#all.detailed

Each of the first five sessions opened with two general talks on the activities developed by each of the 10 subtasks in which our work package is organized, as detailed in the web page http://web.ge.infn.it/jstrong2020/. The corresponding coordinators gave these review talks, and presented the bulk of the physics material collected, from many different contributors, and used to elaborate the first project report.

Despite being a topical theoretical workshop, we decided to schedule also overview talks on the activity of the experimental subtasks, with the aim to synergise the theoretical and experimental efforts, which is one of the main objectives of our working package. Such activity will favour the development of best practices for analysing and interpreting the complex experimental data, building a robust analysis framework that could incorporate the latest advances in theory and phenomenology and a set of tools to manipulate, analyse, and preserve the data.

The last day, we also had a general discussion about the activities of the working package with the aim of designing the best strategies to reach the commitments that we have acquired within STRONG-2020. There was a broad participation, with representatives from any institutions, and interesting opinions were exposed. We have regular meetings of this type with quarterly periodicity, and the next one is scheduled for September 2021.

In addition, we had another 21 talks, which presented in more detail the progress made during the first reporting period (18 months of the project) of some theory groups. Very intensive in terms of information and exchanges, there were lively discussions, and thanks to the chosen schedule (1:30 pm to 6:30 pm), we had the participation of colleagues from non-European time zones.

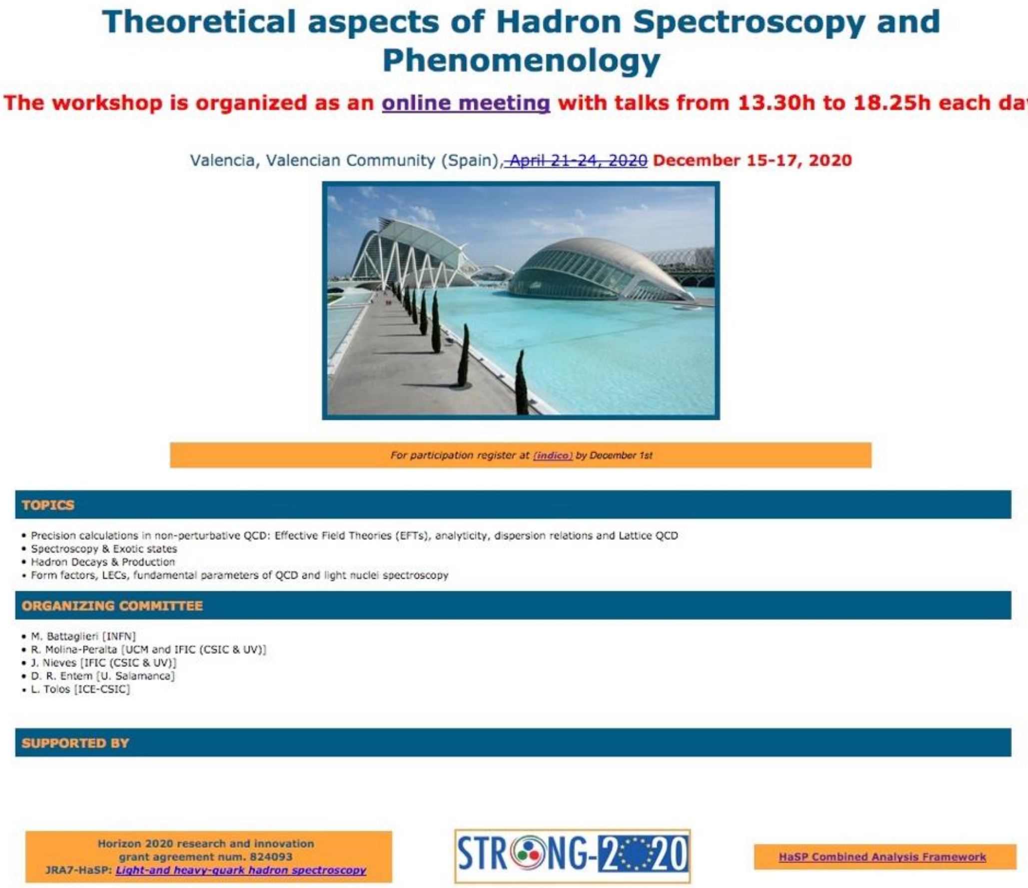
We learned on the latest non-perturbative QCD results obtained from Effective Field Theories (EFT's) and dispersive calculations, as well as the remarkable progress recently made in the study of exotic hadrons on the lattice. Within this context, we draw attention to talks about the dispersive determination of the $\kappa/K_0^*(800)$ resonance position and the πK and $\pi\pi \longrightarrow K\overline{K}$ threshold parameters, the precise determination of pion-nucleon coupling constants, the role played by chiral symmetry in different two-poles structures observed in the hadron spectrum, and about the possibility of rigorously computing two- and three-particle scattering amplitudes in lattice QCD.

We also heard on the formulation of ETFs for double-heavy baryons and updates on the theoretical descriptions of the LHCb P_c pentaquarks, and of other states like the $X_0(2866)$, $\Omega(2012)$, $X(6900)$ or the charged $Z_b(10610)$ and $Z_b(10650)$, which are difficult to accommodate within ordinary constituent quark models. There were also talks discussing different hadron decays, including hybrids and possible isospin violation in the decays of vector charmonia into $(\Lambda\overline{\Sigma}^0 + cc)$, the computation on the lattice of heavy-quark hybrid, tetraquark potentials and of matrix elements for in medium quarkonium evolution, nuclear structure results with chiral forces, and recent advances on the QCD phase diagram from Ward identities.

On the experimental side, we learned that high-precision data are being accumulated at Jefferson Lab for the study of glueballs and hybrids. We also had reports on the search for (and study of) light exotic mesons, charmonium and strangeonium, on the diffractive and annihilation production and exotic baryons and on hexaquark studies in the light quark sector with polarised photons. There were updates on the analysis frameworks, which make use of novel techniques like machine learning for particle identification and large-scale computing, and the partial wave studies. The latter provide synergy with theory, while data mining and new analyses are performed in a worldwide collaborative effort, involving the main EU laboratories (CERN, Mainz, Bonn, GSI) and abroad (TJNAF/US, BESIII/China, J-PARC/Japan, Belle/Japan).

This short note gives a brief overview of an important event in execution of our project. We are glad for the smooth running of the meeting and a relatively high attendance rate. On the scientific level, the talks have served to stress the progress achieved by most groups integrated in our working package, despite the limits and difficulties of the pandemic period.

We obviously lacked informal moments and relaxed conversations around a coffee cup or a convivial meal. However, we hope to overcome soon this difficult stage, and hope to meet in person during the next workshops planned by the working groups.



EIC Yellow report release

In March 2021, the Electron-Ion Collider (EIC) reached a next milestone with the release of the EIC Yellow Report, available from the User's Group (EICUG) web page, http://www.eicug.org or directly from http://www.eicug.org/web/sites/default/files/Yellow_Report_v1.1.pdf

The Yellow Report's release marks a major community achievement for the entire EICUG, which started in December 2019 with a Kick-Off meeting at MIT. Members met remotely throughout the whole year 2020 with the help from various host institutions (Temple U. / Pavia / Catholic U. / UC Berkeley + LBL). Several physicists in the STRONG-2020 Network have been involved at various stages of its preparation.

The reader is also invited to look at the BNL newsroom article on the Yellow Report

https://www.bnl.gov/newsroom/news.php?a=118762

A Call for EIC Detector Proposals https://www.bnl.gov/eic/CFC.php has been issued by DOE & BNL/JLab on March 6, 2021, with an expected proposal submission deadline on December 1st, 2021. The EICUG community's strong preference for two detectors has led to multiple exciting detector initiatives.

Bernd Surrow and Piet Mulders

An interview with Anton Kononov

A young postdoc from the STRONG-2020 work package 30, JRA12-SPINFORFAIR: 'Spin for FAIR'

Question 1: Please, introduce yourself and your research field.

My name is Anton Kononov, I'm from Russia. In Saint Petersburg, I got my bachelor's degree in nuclear/particle physics, and for my final year of my master's degree I received a scholarship from the University of Ferrara to conduct research on polarised targets. After defending my master's thesis, I continued my research in the field, starting my PhD at the University of Ferrara, where I defended my thesis last year. My research has been more "technical", since I work mainly with particles and radiation detectors. I have to run possible tests to get maximum efficiency in the lab, then create working experimental setups, then install them on the beam line at target position. The ultimate goal is to investigate the baryon asymmetry of the universe. The accelerator is the Cooler Synchrotron (COSY), located in Forschungszentrum Jülich in Germany.

Question 2: When and how did you decide to be a researcher? Was it a child's desire or a recently born passion?

Actually, research has always had an interesting place in my life. When I was studying for my bachelor's degree, I never thought I would study for my master. I thought I would find a job in

Russia. Science in Russia is in average quite poorly paid. For example, salary during PhD is approximately 80 euros per month, and only people working on subjects considered of interest can expect average salary.

During my bachelor's, I was proposed to go to Germany to do research for my master's, and, I thought, "Ok, I will spend a short period of time, then I will go back home with more experience and possibilities to find a better job." Only during my research abroad, I understood, that I could do what I like, thus science, without having to worry about how to get a proper salary.

Question 3: How will STRONG-2020 help you in achieving your research goals?

Thanks to the grant, I am constantly engaged in my doctoral research topic, continue to work with the detector system and prepare for its installation in COSY. In parallel, I'm involved with polarised internal target preparation. STRONG-2020 helps me to improve myself in various areas of hadron physics.

Question 4: How does your profession influence your life outside the lab? Has physics got a special role in your everyday life?

My profession is very important in my everyday life. I have a hobby, which is mainly connected to my job: I like to design electronic devices for my home, like "smart home", or, I can also do a serious repair of a laptop, not just replacing parts, but also fixing problems in the logic board and other similar things. The most important impact is critical thinking, which helps me to build a better communication with friends and relatives.

Question 5: Research life can be really demanding. Do you manage to match it with 'standard younger's life', how?

Yes, research life is demanding, especially during the COVID-19 pandemic, when most of the time I have to work with the equipment located in the lab, but from home, without visual feedback from the devices. However, it allows me to take coffee to my "work", which is prohibited in the laboratory.

It is impossible to achieve good results without proper rest, and Europe opens up opportunities to discover new places and people. Travelling is not possible at the moment, of course, but digitalisation helps keep in touch with family and friends, and online you can celebrate someone's birthday without restrictions.

Question 6: Please tell us the most exciting aspect of being a researcher abroad, according to you.

The most exciting aspect of being a researcher abroad is the great chance at broadening your way of thinking and your perspectives. Moving to another country taught me to put myself in another person's shoes. Foreigners think differently, and in the beginning, it was very challenging to understand them, but with time, trying to find a common ground has opened my mind and helped expanding my social circle.

The STRONG-2020 Public Lecture Series

A new format of public outreach during the Covid-19 pandemic

The kick-off presentation of the STRONG-2020 public lecture series with the title "How big is the proton?" took place on December 16, 2020. It was presented in an interactive manner via a YouTube live channel by Randolf Pohl from the University of Mainz, Germany, as well as Jan Bernauer from Stony Brook / Brookhaven National Laboratory, USA. The two speakers are key figures in the experimental efforts to determine the proton radius, using either atomic spectroscopy methods (Pohl) or lepton scattering techniques at fixed target accelerator facilities (Bernauer). The discrepancy between these two methods has been dubbed the proton radius puzzle and has recently been reviewed in the STRONG-2020 Newsletter #2. The lecture has been received with very great interest with more than 2000 views to the lecture by now. This YouTube-based format enables the audience to interact with the speakers directly via a live chat, allowing in such a way for an immediate feedback and the opportunity to raise questions and comments.

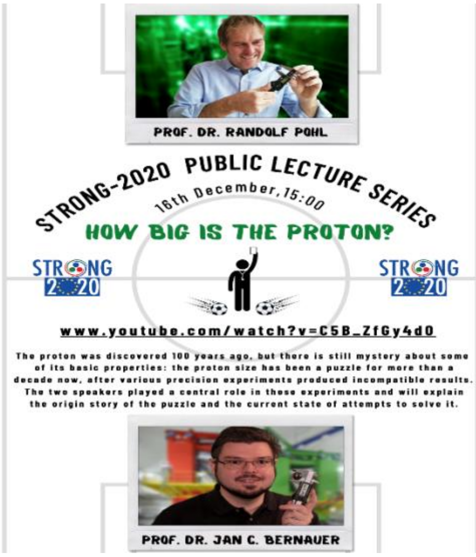


Figure 1: poster of the STRONG-2020 lecture "How big is the proton?" The lecture can be found on STRONG-2020 website, in "live events" section.

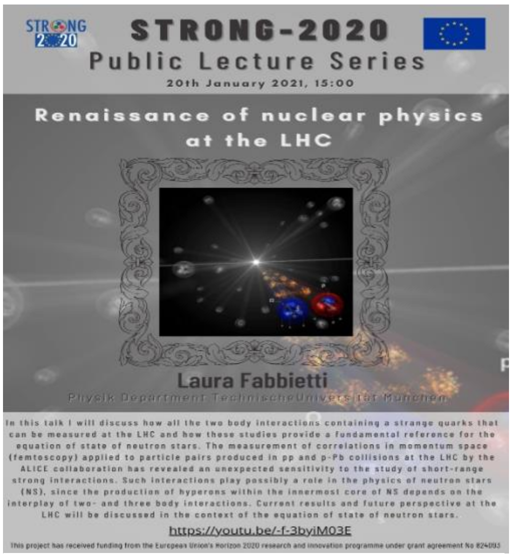


Figure 2: poster of the STRONG-2020 lecture "Renaissance of nuclear physics at the LHC." The lecture can be found on STRONG-2020 website, in "live events" section.

The second and third lectures in the series were presented by Laura Fabietti from the Technical University Munich, Germany (January 20, 2021) and by Mikhail Bashkanov, Alessandro Pastore, and Dan Watts from the University of York, UK (March 11, 2021). In her lecture with the title "The renaissance of nuclear physics at the LHC", Laura discussed her recent investigations of nucleus-nucleus collisions at the LHC and the interpretation of the results in terms of fundamental quantities in nuclear physics, such as the hyperon-hyperon interactions.

The talk by Mikhail, Alessandro, and Dan dealt with the recent findings of a new state of matter, which is an excellent candidate for a hexaquark particle. The research of both lectures is closely related to nuclear astrophysics and to fascinating topics such as neutron stars.

While presently, during the Covid-19 pandemic, the dissemination of STRONG-2020 research is confined to virtual formats only, on the other hand, the situation provides the opportunity to gain experiences in new means of communication and public outreach. After the first three lectures, we can already conclude that the virtual lecture series provides a highly attractive and successful opportunity to reach out to the general public on a worldwide scale. The audience so far has been very diverse ranging from high-school students to researchers of the STRONG-2020 community and beyond. The success of the series, of course, crucially depends on the quality of the speakers and their capability of conveying their enthusiasm for their research fields in this virtual format. We therefore would like to thank our first speakers for three fascinating presentations. We are confident that the STRONG-2020 public lecture series will continue – at least partly – in this virtual format after the end of the Covid-19 pandemic and we are looking forward to more stimulating talks on strong interaction physics.

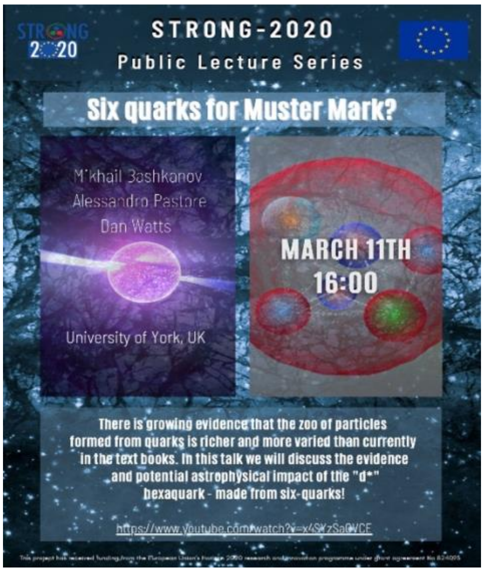


Figure 3: poster of the STRONG-2020 lecture "Six quarks for Muster Mark?" The lecture can be found on STRONG-2020 website, in "live events" section.

The 4th lecture of the series took place on April 21st, 2021, and was given by Hans Ströher from Jülich/Germany. He discussed the beauty of spin physics both in terms of the fundamental understanding of matter as well as for precise tests of the Standard Model of particle physics.

Catalina Curceanu on behalf of Dissemination Board

The STRONG-2020 dedicated YouTube channel

The STRONG-2020 Dissemination YouTube dedicated channel was inaugurated with a first Welcome and Explanatory video in September 2020.

The link to this channel is:

https://www.youtube.com/channel/UCmXOpXZ5UKN4j2FUsAVBQiA

where link to the first video is: https://www.youtube.com/watch?v=lTeYt5QJatA&t=252s

Meanwhile, more videos were added, such as a video on the PADME experiment at LNF-INFN, searching for Dark Boson at Frascati LINAC extracted beam, supported by Transnational Access: https://www.youtube.com/watch?v=t6ZDNG3gdp4&t=15s,

an interview to Chiara Bissolotti and Francesco Giovanni Celiberto, made by Alessandro Bacchetta within the TMD-neXt work package:

https://www.youtube.com/watch?v=em0uQNfXsLI&t=2s,

and very recently, an interview to Georgios Mantzaridis, supported through STRONG-2020 funding for Research Infrastructures at LNF-INFN:

https://www.youtube.com/watch?v=askFasFfbXM&t=20s

Interview to Georgios Mantzaridis, Transnational Access at INFN-LNF, Italy

The channel is also hosting in the Playlist other videos, related to STRONG-2020 activities, such as various ECT* scientific videos.

The channel can be directly accessed from our STRONG-2020 web page:

http://www.strong-2020.eu/ (under news & documents / dissemination channel).

We kindly invite all of you to help us publicise this channel towards STRONG-2020 community, other scientific communities, schools and general public. We also invite you to join the efforts towards implementing and enriching this channel with more videos coming from STRONG-2020 rich activities!

Contact us if you have questions or ideas.

Catalina Curceanu, on behalf of Dissemination Board

STRONG-2020 supported INSPYRE 2021

INSPYRE, International School on Modern PhYsics and Research, is an advanced modern physics international school organised by INFN at the Laboratori Nazionali di Frascati for high-school and college students highly interested in science. Last year, INSPYRE celebrated 10 years since its first edition. The school, initiated with 20 participants in 2010, reached about 100 in 2019, and many INSPYRED participants to previous editions are presently physicists, engineers, biologists, and even lawyers and economists. In normal times, the school is organised in lectures given by researchers working in various fields and a series of hands-on experiments performed by students teaming up with researchers. The 2020 edition – due to the pandemic situation – was organised as an online edition, and was supported by STRONG-2020.

STRONG-2020 also supports the 2021 edition of the INSPYRE School, having as a subtitle: "The magic realm of Particle Accelerators", which will be dedicated to the hottest topics and challenges in Modern Physics, including hadron and nuclear physics issues, such as ALICE at CERN, with special attention to research performed at accelerators.

INSPYRE 2021 was held in the period 12-16 April 2021 online; about 100 high-school students from all over the world registered for this special edition.

More information, including the programme, can be found on the web page of the INSPYRE 2021 event: http://edu.lnf.infn.it/inspyre-2021/.

Catalina Curceanu (LNF-INFN)

Mosaic photo on the STRONG-2020 web page

A mosaic with photos of participants to STRONG-2020 project was prepared and recently published on the STRONG-2020 web page.

You can find it on: http://www.strong-2020.eu/events/pictures-gallery.html

We are thinking already of the next mosaic!

Catalina Curceanu, on behalf of Dissemination Board