Newsletter n.1

July 2020

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European Commission

FOREWORD

This is the first newsletter of the STRONG-2020 European project, having the members of the Dissemination Board as editors, and containing a series of news items and information of interest not only for the STRONG-2020 Community, but also for a broader scientific community and for the general public.

The Dissemination Board (DB) composition, together with the work packages (WP) for which we are responsible within the DB, is the following:

- *Marco Battaglieri, INFN Genova, Italy, for QCD and Standard Model: WP12 (NA1); WP25 (JRA7); WP21 (JRA3)*
- *Maurizio Boscardin, FBK, Italy, representative of SME and industries*
- *Raphaël Granier de Cassagnac, CNRS, France, for Quark Gluon Plasma: WP14 (NA3); WP18 (NA7); WP19 (JRA1); WP20 (JRA2)*
- *Yvonne Leifels, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt (GSI), Germany, for Transnational Access TAs: WP3, WP4, WP5, WP6, WP7, WP8, WP9*
- *Maria Paola Lombardo, INFN Pisa, Italy for Lattice QCD: WP17 (NA6)*
- *Hervé Moutarde, CEA, France, for Virtual Access (VA): WP 10 and 11*
- *Piet Mulders, VU and Nikhef, Netherlands, for Nucleon Structure and Strangeness: WP13 (NA2); WP15 (NA4); WP16 (NA5); WP22 (JRA4); WP23 (JRA5); WP24 (JRA6)*
- *Andrea Pesce, Forschungszentrum Jülich Germany, for Targets and Polarisations, WP28 (JRA10); WP29 (JRA11); WP30 (JRA12); WP31 (JRA13)*
- *Fulvio Tessarotto, CERN and INFN Trieste, Italy, for Detectors: WP32 (JRA14); WP27 (JRA9); WP26 (JRA8)*
- *Catalina Curceanu, LNF-INFN, Italy, Chair of DB*

Newsletter n.1 is structured as follows: after an article presenting the STRONG-2020 project written by Barbara Erazmus, the project Coordinator, there are news items on (some) ongoing activities, reports from workshops and conferences supported by STRONG-2020, presentation of one of the STRONG-2020 infrastructures (GSI), an interview with a young STRONG-2020 participant (Chandradoy Chatterjee), an interview with Abhay Deshpande regarding the EIC, and a news item on an international school for college students supported by STRONG-2020.

We, the STRONG-2020 DB, encourage you, the community participating in this project to contact us and send us latest news on your achievements (published articles, experimental developments, theoretical calculations…), your events organised with the support of STRONG-2020, interviews with participants and any other information or news relevant for our community or a broader scientific community, as well as the general public which is connected to our project. Newsletters will be regularly published on the website of STRONG-2020, tentatively every three months.

This is not an easy period, with the Corona virus situation affecting many countries, and we, the DB, wish you all to stay safe and make good progress within STRONG-2020!

Catalina Curceanu, on behalf of STRONG-2020 Dissemination Board

THE STRONG-2020 PROJECT

By Barbara Erazmus

In hadron physics there is a long tradition of working together in the framework of large European Networks. The projects HadronPhysics, HadronPhysics2 and HadronPhysics3 have been successfully coordinated by Carlo Guaraldo for 10 years (2004–2014). Our current project, STRONG-2020, follows this line of multilateral and innovative research.

STRONG-2020 is focused on the work programme topic INFRAIA-01-2018-2019 of the Research and Innovation action 'Research Infrastructures for hadron physics.' The allocated budget is 10 M€ for 4 years.

STRONG-2020 offers open access to six world-class experimental facilities (COSY, MAMI, LNF, ELSA, GSI/FAIR and CERN). Additionally, the European Centre for Theoretical Physics ECT* in Trento is playing a crucial role in fostering innovative theoretical developments in hadron physics in close synergy with experimentalists.

Research infrastructures are at the core of the project, with links to all aspects. They have been selected based on the excellence of their research programme and according to complementarity in particle beams delivered in order to obtain experimental data. Two Virtual Access Activities provide innovative tools generating scientific open-source codes.

For the Joint Research and Networking Activities, we have followed a bottom-up approach in order to foster new ideas and new collaborations, beyond the existing ones, and reshaping the European Hadron Physics landscape in the spirit of the Integrated Activities. This procedure, led by a Steering Committee, has resulted in the coherent set of actions grouped in the three pillars of the proposal: Low-Energy Frontier, High-Energy Frontier and Instrumentation.

The Consortium includes 44 participating institutions, from 14 EU Member States, one International EU Interest Organization (CERN), and one EU candidate country. Together with host institutions of 21 other countries, without benefits of EU funds, the project involves around 3,000 researchers from 36 countries. STRONG-2020 is structured in 32 Work Packages (WP): 7 Transnational Access Activities (TA), 2 Virtual Access Activities (VA), 7 Networking Activities (NA) and 14 Joint Research Activities (JRA), Management and Coordination (MAN) and Dissemination and Communication (DISCO).

The Management Team ensures the overall coordination of the project and the links with European Commission. As the Project Coordinator, I am sharing the managerial duties with Carlo Guaraldo, Deputy Scientific Coordinator, and Emine Ametshaeva, Project Manager.

We are working in close collaboration with Executive Board and Governing Board, chaired by Elena Gonzales Ferreiro. The dedicated Dissemination and Communication (DISCO) WP promotes and realises targeted dissemination, exploitation of results and communication activities. Our objectives are to federate leading experimental and theoretical groups in order to carry out new fundamental and applied research studies at the frontier of our current knowledge of the strong interaction, the force that binds together quarks and gluons and, ultimately, forms the visible baryon matter of our universe.

The broad variety of topics tackled in STRONG-2020 creates the bases for multidisciplinary collaborations well beyond the hadron physics world.

The strong interaction is intimately connected to a broad range of physical problems in strongly coupled, complex systems in particle and condensed-matter physics, as well as in searches for physics beyond the Standard Model. For these reasons, apart from its extremely interesting genuine aspects, the field of strong interaction is crucial for enabling progress in other fields like Nuclear, Particle and High-Energy Physics, Cosmology or Astrophysics, as well as for many nearby research fields.

One of the keywords of STRONG-2020 is innovation. This is not only reflected in the scientific goals, but also in the approaches and methodologies selected to reach them. We are involved in activities that promote the transfer of knowledge.

The technology of radiation detectors, accelerator science, and computing currently used in the physics of the strong interaction have an enormous impact through their application in medicine, electronics, information technology, among others. Our activities allow for the education and hands-on training of physicists and engineers in these fields in the framework of Master and PhD theses and postdoctoral positions. The infrastructures in cooperation with the associated universities train highly qualified experts in fields, which are of utmost importance to society in Europe.

STRONG-2020 was launched during the kick-off meeting in Nantes on October 23–25, 2019. We are currently preparing the first Periodic Report and Annual Meeting scheduled for October 14–16, 2020 in Paris.

I would like to stress that our activities are in progress and most milestones and deliverables completed in time. Many meetings and workshops are held in remote mode. Despite extremely difficult conditions and strong sanitary constraints we are facing, our consortium remains active and connected.

Personally, I am involved in the field of relativistic heavy ion interactions which is an interdisciplinary domain including elementary particle physics as well as nuclear physics. I am originally from Poland where I received my PhD. I am affiliated to the laboratory Subatech in Nantes, appointed to the Centre National de la Recherche Scientifique (CNRS).

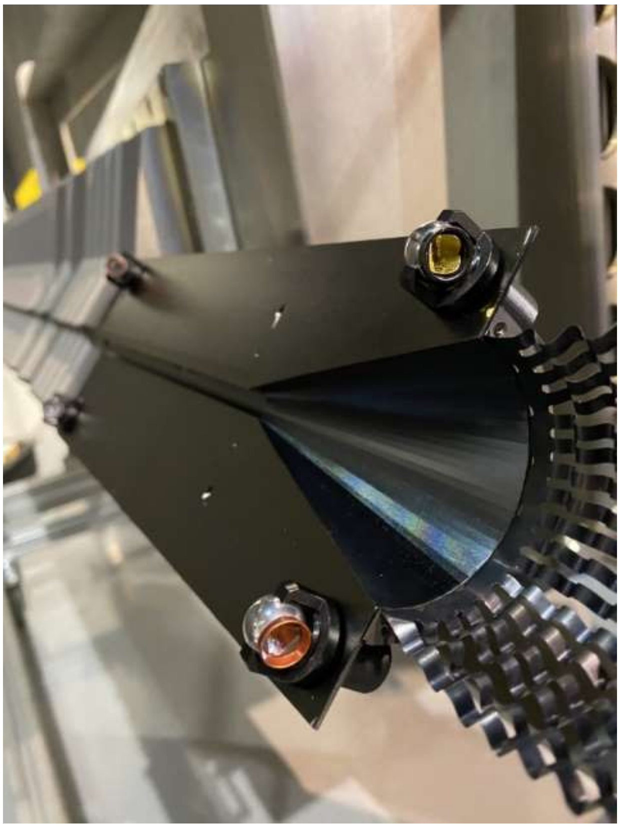
I have worked in the CNRS headquarters in Paris as Deputy Director of IN2P3 (Institut National de Physique Nucléaire et de Physique de Particules) in charge of Hadron Physics and Theory. I am currently Deputy Spokesperson of the ALICE collaboration at CERN, which brings together 1927 members from 174 institutes located in 39 countries.

Barbara Erazmus

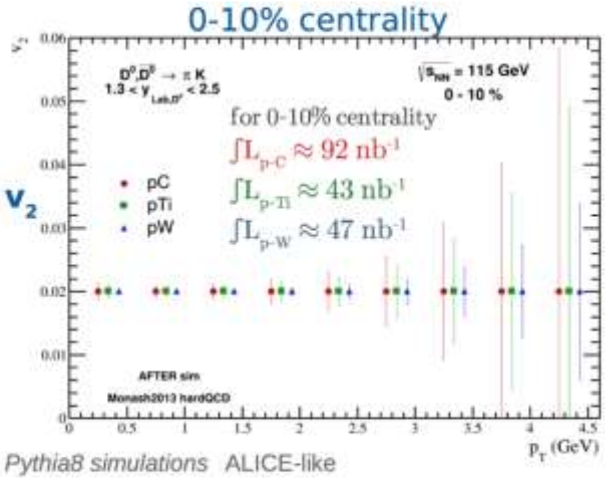
DEVELOPMENT OF FIXED-TARGET EXPERIMENTS AT LHC

High-energy proton and ion beams of the LHC allow for the most energetic fixed-target experiment ever performed: the centre-of-mass energy is $\sqrt{s}$=115 GeV with a 7 TeV proton beam and $\sqrt{s_{NN}}$=72 GeV with a 2.76 TeV per nucleon lead beam. Study of collisions of high-energy hadron beams with fixed targets, including polarised and nuclear targets, has the potential to significantly expand the range of fundamental physics phenomena accessible at hadron colliders. The fixed-target mode operated at high luminosity allows for an intensive study of rare processes, novel spin correlations, dynamics at high nucleon momentum fraction (*x*), QCD phase transition, nuclear phenomena.

LHCb became the first LHC experiment able to run simultaneously with two separate interaction regions. As part of the ongoing major upgrade of the LHCb detector, SMOG2, the fixed-target system, has just been successfully installed. The core of the system is a storage cell where the gas target is confined within a 20 cm-long aluminium tube that is mounted 30 cm upstream from the main interaction point, and coaxial with the LHC beam (see picture). This technology allows a very limited amount of gas to be injected in a well-defined volume within the LHC beam pipe, keeping the gas pressure and density profile under precise control, and ensuring that the beam-pipe vacuum level stays at least two orders of magnitude below the upper threshold set by the LHC. With beam-gas interactions occurring at roughly 4% of the proton–proton collision rate at LHCb, the lifetime of the beam will be essentially unaffected. The two halves of the cell can be opened for safety during LHC beam injection and tuning, and closed for data-taking. The cell is sufficiently narrow that a flow as small as 10^{15} particles per second will yield tens of pb^{-1} of data per year. The new injection system will be able to switch between gases within a few minutes, and is capable of injecting not just noble gases, from helium up to krypton and xenon, but also several other species, including H_2, D_2, N_2, and O_2.



On the other hand, the ALICE collaboration is investigating the possibility to install a solid target internal to the beam pipe, coupled to a bent crystal that would deviate the beam halo. Performance studies (see plot) on heavy flavour production in small systems were shown at the Hard Probes conference. In those studies, D mesons are detected with the central barrel detectors of ALICE with an additional vertex detector installed close to the target. Simultaneous measurements of the nuclear modification factors and elliptic flow would allow one to study cold nuclear matter and possible collectivity effects in proton-nucleus collisions.



These activities belong to the Strong-2020 work package denoted FTE@LHC that comprises three parts: investigation of fixed targets in ALICE, installation, development and analysis in LHCb and phenomenological studies. A kick-off meeting took place at CERN last November for the FTE@LHC work package (JRA2) to gather the community and discuss recent developments, together with the NLO Access work package (VA1).

Pasquale di Nezza and Cynthia Hadjidakis
Spokespersons of the FTE@LHC work package

References

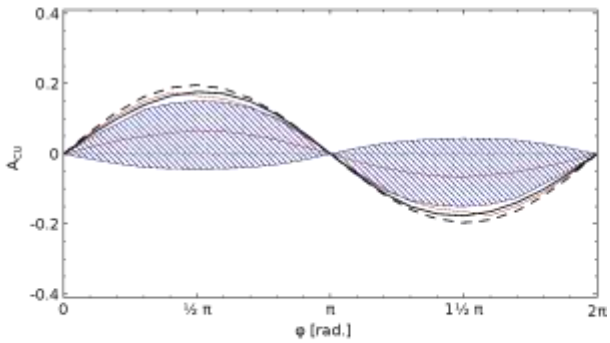
- LHCb in the CERN courier: https://cerncourier.com/a/new-smog-on-the-horizon/
- Alice talk at Hard Probes: https://indico.cern.ch/event/751767/contributions/3770961/
- FTE@LHC kick-off meeting: https://indico.cern.ch/event/853688/overview

DATA-DRIVEN STUDIES OF TIMELIKE COMPTON SCATTERING

Generalised parton distributions (GPDs) provide unique information about the 3D structure of hadrons. They can be accessible through many exclusive processes (all particles are detected in the final state), in particular the two closely related channels deeply virtual Compton scattering (DVCS) and timelike Compton scattering (TCS). While many measurements of DVCS have already been performed during the last two decades, TCS is still at the level of pioneering studies. However, the amplitudes describing them, the so-called Compton form factors (CFFs), depend on GPDs in a way that allows a model-independent relation of the spacelike CFFs (for DVCS) and the timelike CFFs (for TCS).

Using tools developed within the 3DPartons work package of STRONG-2020, a team of European physicists performed the first multi-channel data-driven analysis [1] of exclusive processes relying on a global fit of CFFs. Among impact studies of GPD-related channels, this one is also the first going beyond the leading-order approximation in QCD perturbation theory, providing systematic comparisons of predictions obtained with coefficient functions evaluated at leading-order or next-to-leading order. This analysis is characterised by a low model dependency, as essentially it is done at the level of DVCS and TCS amplitudes parameterised with neural networks.

Data-driven prediction of the circular spin asymmetry ACU evaluated with leading order (shaded red) or next-to-leading order (dashed blue) spacelike-to-timelike relations as a function of the angle φ between the hadron and lepton planes at kinematics relevant for Jefferson Lab. It is compared to phenomenological models (dashed and solid lines). Figure from Ref. [1].



The main objective of the 3DPartons [2] work package is to give access to open-source code necessary for high-precision phenomenology in the field of 3D hadron structure, with a specific emphasis on generalised parton distributions (GPDs) and transverse momentum dependent parton distributions (TMDs). This work package offers users a long-term guarantee about robust, flexible, validated and up-to-date code. It integrates, maintains, releases, tests, documents and provides technical assistance to users.

Hervé Moutarde

References

1. O. Grocholski, H. Moutarde, B. Pire, P. Sznajder and J. Wagner, Data-driven study of timelike Compton scattering, Eur. Phys. J. C80 (2020) 171.
2. http://partons.cea.fr

STATUS UPDATE ON JRA12: SPIN FOR FAIR

The PAX Collaboration aims to provide a method to produce an intense beam of polarised antiprotons [1]. It is supported by a Joint Research Activity (JRA12 – Spin for FAIR – WP 30) within the framework of the STRONG 2020 project. After having successfully performed a spin-filtering test with protons using a transversely polarised hydrogen gas target [2], the plan is to complete these studies with a test of longitudinal polarisation buildup at the COler SYnchrotron (COSY) storage ring facility, located in Forschungszentrum Jülich.

In order to ensure that the beam polarisation is oriented in the longitudinal direction in the COSY straight section where the PAX interaction point is located, a superconducting solenoid, a so-called 'Siberian Snake', was installed in the opposite straight section of the ring (see Fig.1). The idea is to inject a vertically polarised proton beam into COSY, to electron-cool it and to accelerate it up to a momentum of 520 MeV/c. By ramping the Siberian Snake solenoid from zero to 2.7 Tm, the polarisation is then rotated into the horizontal plane.

Figure 1: A picture of the Siberian Snake installed in COSY [3].

A first Siberian Snake commissioning beam time took place in March 2020 at the COSY facility. This test was mainly dedicated to better understand the complex beam dynamics due to the presence of a high magnetic field, and to find an effective way to compensate the strong phase space coupling introduced by such field. Further studies are ongoing.

In order to cope with the foreseen experimental activities, also a large acceptance silicon vertex detector was realised, in collaboration between the University and INFN of Ferrara (Italy) and the FZJ, to serve as a beam and target polarimeter in proton – (anti)proton and proton-deuteron internal gas target experiments in the 30 MeV to 200 MeV beam energy range. The detector is composed of four identical quadrants combined in a diamond-shaped configuration (see Fig. 2).

It hosts a storage cell where polarised or unpolarised H or D target atoms and molecules can be injected. Each quadrant consists of three layers of double-sided silicon-strip sensors mounted inside an aluminium box and their relative front-end read-out system. Sensors and read-out electronics are cooled by separate circuits. It will provide an absolute calibration of the atomic Breit-Rabi polarimeter of the polarised target. At the same time, it will serve as a beam position monitor in the beam-target interaction region.

Figure 2: Pictures of the fully assembled PAX detector with four complete quadrants [3].

The detector, with two of the planned four quadrants assembled, was commissioned with an unpolarised proton beam and a polarised deuterium target, demonstrating that it can be used for the low-energy spin-physics experimental programme at COSY [3]. The results of the target polarisation measurement are shown in Fig. 3.

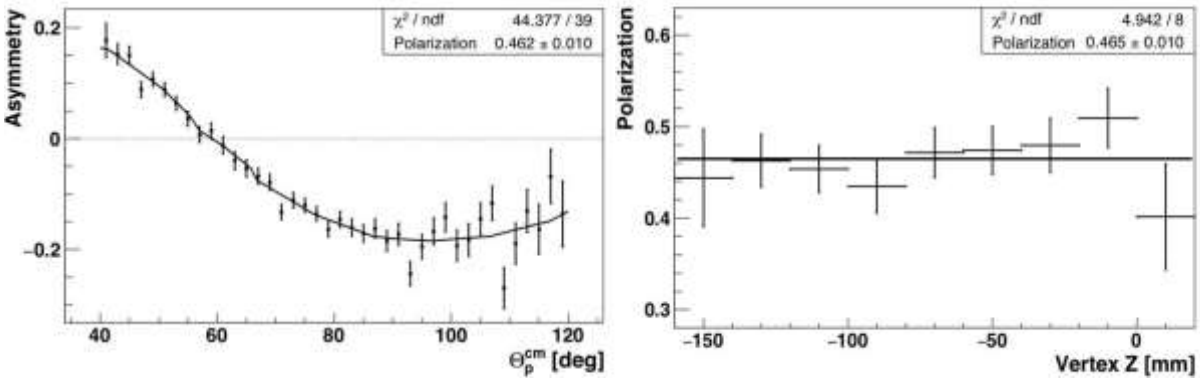


Figure 3: Left: Experimental asymmetry in pd elastic scattering as a function of proton polar angle in the cm. The curve shows interpolated Ady data from [4], scaled to fit our data. Right: Target polarisation estimated as a function of the longitudinal vertex coordinate Z along the storage cell. The straight line represents a fit with a constant scaled with the sought-for value of the target polarisation to fit our data [3].

After the commissioning, the missing two quadrants were also completed. A test bench in the IKP-2 PAX laboratory has been set up in order to acquire cosmic-ray data with the fully assembled detector.

Andrea Pesce

References

1. PAX Collaboration, 'Antiproton-proton scattering experiments with polarisation.' hep-ex/0505054, 2005.
2. W. Augustyniak et al, "Polarisation of a stored beam by spin-filtering." Phys Lett B, vol. 718, no. 1, pp. 64–69, 2012.
3. P. Lenisa et al, "Low-energy spin-physics experiments with polarised beams and targets at the COSY storage ring." EPJ Techniques and Instrumentation, vol. 6, p. 2, 2019.
4. V. Przewoski et al, "Analysing powers and spin correlation coefficients for p+d elastic scattering at 135 and 200 MeV." Phys Rev C, vol. 74, no. 6, p. 064003, 2006.

SM&FT 2019 WORKSHOP

'SM&FT 2019', the XVIII Workshop on Statistical Mechanics and nonperturbative Field Theory, has been held in Bari (Apulia, Italy) from 11th to 13th December 2019.

This workshop is part of a series of workshops, whose first edition was in 1988, aimed to promote the cross fertilization of ideas coming from Statistical Mechanics, non-perturbative Field Theory and other areas of theoretical physics (http://www.ba.infn.it/smft2019).

A particular emphasis has been devoted to present results and challenges in computational theoretical physics using HPC (High Performance Computing) resources and to the first exploratory results based on the quantum computing.

During the three days of the XVIII edition of 'SM&FT', as many as 55 talks have been presented with many important contributions in lattice QCD, topics of interest of the STRONG-2020 project.

Leonardo Cosmai, chair of SM&FT 2019

THEIA: FIRST INTERNATIONAL WORKSHOP IN SPEYER

From November 25th to 29th, 2019, over 50 scientists from Europe, Asia and the United States met in the Technik Museum in Speyer for the First international workshop of the European networking activity THEIA (NA5, strange hadrons and the equation of state of compact stars).

The annual THEIA workshops gather scientists exploring the role of strange hadrons in nuclear systems on all length scales, starting from elementary two-body interactions to dense stellar objects. The cooperation of world-leading experimentalists and theoreticians in the field of strangeness nuclear physics with experts of the neutron star community in astrophysics within the networking activity THEIA allows to critically assess the status of our present understanding of the hadronic EOS, and to identify possible new avenues to follow. The meetings aim to provide a platform for the early exchange of new ideas and scientific results. These workshops also help to train a new generation of researchers in that field.

At Speyer, the scientists presented their most recent achievements in the field of strangeness nuclear physics. Novel experimental studies on baryon-baryon momentum correlations by ALICE, new developments concerning our present understanding of the lightest hypernucleus 3ΛH, the role of hyperons in neutron stars, and planned experiments at MAMI, PANDA@FAIR, J-PARC, JLab and ELPH were central topics of the talks presented in Speyer. Many of the talks were presented by PhD students or early-stage scientists. Thus, this workshop also helps to train a new generation of researchers in that field.

The full programme of the workshop can be found at https://indico.gsi.de/event/8950/. This workshop was also kindly sponsored by the Helmholtz Institute Mainz.

The follow-up meeting was planned to take place in October 2020 in Crete, Greece. In view of the current coronavirus pandemic, it has become apparent that this event cannot take place as scheduled. We have therefore decided to move the next edition of the THEIA workshop to sometime next year. Although the effects of the measures taken in most countries bear fruits, we believe that it is too early to fix already now a new date. We will communicate the new dates of this meeting as soon as the situation will be more predictable.

Josef Pochodzalla, chair of the THEIA workshop

LATTICE-HADRON TOWN-HALL MEETING

coordinating the European Lattice QCD community…

Early in March 2020, the LatticeHadrons network (NA6) of STRONG-2020 organised a town-hall meeting in Trinity College Dublin to discuss how the community might organise to benefit from and participate as actively as possible in the European Commission's newly launched EuroHPC Joint Undertaking (https://eurohpc-ju.europa.eu/).

Lattice quantum field theory uses high-performance computers to build a virtual description of the strong interactions between quarks and gluons inside nuclei and similar particles. To carry out the huge number of calculations involved requires researchers to use the largest available parallel computers, where many thousands of computer cores work together to perform the simulation. The EuroHPC Joint Undertaking is a new initiative aiming to establish a Europe-wide infrastructure to enable the largest-scale calculations available globally. Researchers in the LatticeHadrons network of STRONG-2020 will benefit significantly from access to these systems, which are planned to start operation between 2020 and 2023.

The LatticeHadrons STRONG-2020 town-hall meeting took place over two days (5th-6th March 2020) with 27 participants from across Europe. As travel restrictions in some European countries were in effect due to the coronavirus pandemic, the meeting was live-streamed to remote participants. Guest speakers representing other communities such as climate modelling and European HPC expertise presented their experience of how groups of researchers can usefully organise their activity to maximise access, impact and mutual benefits. The goals the European Commission has set for EuroHPC were also presented. In the meeting, representatives from a number of large European research teams presented their aims and research aspirations for the next five years, and discussed how their work fits with the EuroHPC mission.

The installation of the first machines in the EuroHPC initiative is planned for July 2020, however, there is as yet no mechanism to decide on how different research groups will access the systems and how the diverse range of scientific disciplines will share resources. One allocation formula under debate is the community-access model, where an association of teams working in a common discipline would self-organise, streamlining the task of dividing up the packets of time using the computer is allocated to each project.

At the conclusion of the meeting, there was an extensive discussion of the issues and benefits arising from the diverse groups across Europe coordinating their access to the HPC system more closely. The meeting concluded with strong support for the formation of EuroLat, a new association to represent the lattice field theory community. The hope is that by joining together to present the research opportunities at the frontier of strong-interaction physics provided by new connections to the new large-scale supercomputing resources will maximise this opportunity for the members of the LatticeHadrons STRONG-2020 network.

Mike Peardon, spokesperson of LatticeHadrons

CORRELATIONS IN PARTONIC AND HADRONIC INTERACTIONS

The understanding of the structure of hadrons and nuclei, and in particular of spatial and momentum distributions of their constituents, the partons (quarks and gluons), are key questions of the modern nuclear physics. In Quantum Chromodynamics (QCD) the internal structure of hadrons explored in hard-scattering reactions is described by parton distribution functions (PDFs).

The PDFs were studied primarily in a collinear approximation as a function of the longitudinal nucleon momentum fraction carried by a parton. However, in the complete three-dimensional picture of a fast-moving hadron in momentum space, the transverse degrees of freedom also play an important role. This complementary information is encoded in the so-called Transverse Momentum Dependent (TMD) PDFs. The 3D composition of the nucleons and their internal dynamics become more elaborate when the spin is taken into account. The comprehensive understanding of the nucleon spin and momentum structure relies then on a set of TMD PDFs describing the distributions of longitudinal and transverse momenta of partons and their correlations with nucleon and quark polarisations. The latter effects are often referred to as spin-orbital correlations. The fully multidimensional description of hadron structure is accomplished by the Generalised Parton Distributions (GPDs), which describe the spatial distribution of partons in the plane transverse to the momentum of a fast-moving hadron. Although recent decades were marked by enormous progress in both theoretical and experimental studies of spin – (in)dependent nucleon TMD PDFs, presently there are still many unanswered questions. Recently, significant disagreements have been reported in comparison of theoretical predictions and experimental measurements for various transverse momentum distributions of hadrons in lepton-nucleon, electron-positron interactions, and dileptons in the Drell-Yan process. Correlations in partonic and hadronic interactions, which may be responsible for observed disagreements, provide important information on underlying dynamics, manifesting themselves in variety of observables widely recognised as key objectives of the e.g. forthcoming COMPASS (CERN) polarised deuteron run in 2021, JLab 12 GeV upgrade and a driving force behind the construction of the Electron Ion Collider (EIC).

The main goal of the week-long workshop on Correlations in Partonic and Hadronic Interactions (CPHI-2020) was to review the current status of experimental and theoretical advances in the field and underline the future perspectives. The workshop took place at CERN in Geneva, Switzerland, from February 3rd to 7th, 2020. The 2020 edition of CPHI followed those held in 2018 and 2009 in Yerevan (Armenia) and the next one is planned to take place in 2022 (either in Europe or the US).

The scientific programme consisted of about 70 plenary invited talks. Experimental and theoretical talks were grouped into thematic sessions in order to ensure smooth transitions between different topics and stimulate effective discussions. Exhaustive summaries of recent experimental results from (un)polarised Semi-Inclusive Deep Inelastic Scattering (SIDIS) measurements were presented by COMPASS, JLab and HERMES collaborations. This channel is traditionally one of the main sources of information for TMDs and related studies. Presented results covered a wide range of observables including hadron multiplicities, spin (in)dependent azimuthal asymmetries in single and dihadron production with transversely and longitudinally polarised targets. Complementary e^+e^- measurements unveiling the polarised and unpolarised hadronisation dynamics were presented by the BELLE experiment. Reported studies of spin effects at RHIC experiments and recent Drell-Yan results from COMPASS and SeaQuest completed the global picture of TMD and related measurements. Several phenomenological and theoretical groups from Europe and the US presented recent advances in their global analysis of experimental data and extraction of unpolarised TMDs and polarised parton densities, discussing theoretical challenges and interpretation of the data. Several theoretical aspects related to TMDs, factorisation theorems and different formalisms were discussed along with auxiliary studies related e.g. to radiative corrections in different processes, nuclear effects, as well as two-photon exchange corrections and the role of vector mesons in SIDIS measurements.

The GPD sector was covered by detailed status reports from HERMES, COMPASS and JLab that were accompanied by related theoretical talks. The proton-structure related discussions continued with the proton charge radius topic with a report on dedicated measurement performed by the PRad experiment as well future plans presented by COMPASS++/AMBER collaboration.

Beside past and ongoing experiments, a special attention was given to the future programmes that are supposed to be put in operation within next decade. Among them are fixed-target experiment projects at the LHC, that will study the proton spin structure, the aforementioned COMPASS++/AMBER, that aims to investigate the pion and kaon structure in Drell-Yan channel and the SPD project at future NICA collider at JINR (Dubna), which plans to focus on the study of the gluon content in the nucleon. A special attention has been drawn to the physics of the EIC project, especially in the light of reported news on choice of the BNL-site as a future place for the facility. Detailed agenda of the workshop and all talks are available at the following web page https://indico.cern.ch/e/CPHI-2020.

The workshop coincided with birthday anniversaries of our esteemed colleagues: Stanley J. Brodsky was celebrating his 80th and Aram Kotzinian his 70th birthday. Apart from general references to Stanley's and Aram's works and personal recollections brought up by almost all speakers, two separate sessions were organised on February 4th (AKM-70 session dedicated to Aram) and on February 6th (SJB-80 session dedicated to Stan) to give credit to their important scientific contributions delivered during their long careers.

Figure 1: Stanley Brodsky

Stanley's session was the longest and did not aim to review all his activities that are presented in about 700 scientific papers, but rather to let his colleagues represent different research directions to highlight their common work and personal recollections. Stan's range of interests spreads across wide spectra of aspects of high-energy theoretical physics, (non-)perturbative QCD, light-cone quantisation, quark-gluon structure of hadrons in QCD including parton distributions and generalised parton distributions, specificities of exclusive processes and various fundamental problems in atomic and nuclear physics. His studies inspired many experimental efforts around the world and one of the recent involvement presented at the workshop is the fixed-target programme at the LHC, which aims for heavy-ion physics, as well as hadron structure and spin studies.

During the AKM-70 session, Aram's colleagues reviewed his pioneering phenomenological studies carried out for spin (in)dependent azimuthal asymmetries in (di)hadron production in semi-inclusive deep inelastic scattering reactions as well as his contribution in modelling and extraction of related TMDs from experimental data. Special emphasis was given to his contribution to various aspects of physics programmes of HERMES, COMPASS and JLab experiments as well future projects at EIC. It was proclaimed that the g1T and h⊥ 1L TMD PDFs, which were often referred to as Kotzinian-Mulders functions, should thenceforth carry that name officially. At the end of the session, a representative of the Yerevan Physics Institute awarded Aram the Honorary medal of the institute for long years of service.

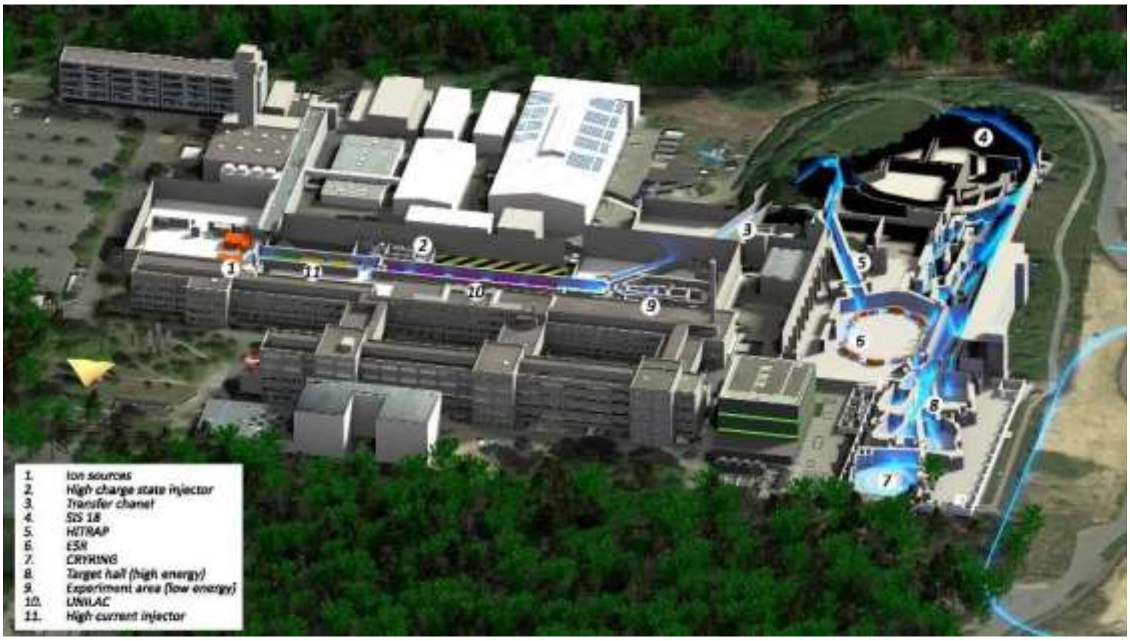
Figure 2: Piet Mulders and Aram Kotzinian

The Workshop CPHI-2020 and members of the organisation committee were supported by CERN (COMPASS experiment), Jefferson Laboratory (JLab), ANL (Argonne, IL) and INFN sections of Turin and Trieste as well as University of Trieste, Freiburg University, LIP (Lisbon), Basque Country University and IKERBASQUE and New Mexico State University, and, of course, by STRONG-2020.

Bakur Parsamyan, chairman of the Workshop CPHI-2020

GSI HELMHOLTZ CENTRE FOR HEAVY-ION RESEARCH IN DARMSTADT

GSI (www.gsi.de) is a member of the Helmholtz Association, the largest research organisation in Germany. The Helmholtz Association is a union of currently 18 independent research centres conducting research on different fields of natural and medical science and technology. GSI was founded in 1979 as a research infrastructure of heavy ion research and is now operating a large accelerator complex, consisting of a linear accelerator UNILAC, the heavy-ion synchrotron SIS18 (with magnetic bending power $B\rho$ = 18 Tm), a separator for fragments produced by in-flight fragmentation, the experimental storage ring ESR (with half the bending power of SIS18), and facilities for storage and trapping of highly charged ions, i.e. the low energy storage ring CRYRING and the HITRAP ion trap, see below.



Aerial view of the GSI complex with the accelerator installations made visible, done by Wolfgang Geithner/GSI.

The UNILAC serves as an injector for SIS18. By employing a pulse-to-pulse switching mode at 50 Hz, UNILAC can deliver up to three different ion species at different energies to experimental areas and/or to SIS18. The SIS18 is a heavy-ion synchrotron providing highly energetic beams to fixed targets or to production targets for secondary beams. The control system including the cycle-to-cycle flexibility of magnets and RF ramps allow multiple user operation. Parameters of ion beams can be adapted to the requirements of the users in each cycle. With the UNILAC heavy ions like U can be accelerated up to 12 MeV/u, light ions and protons up to 20 MeV/u, in SIS18 light ions are accelerated up to 2 GeV/u and in the ESR stable or radioactive ion beams can be stored and cooled. Additionally, secondary pion beams can be delivered at momenta from 0.5 to 2.5 GeV/c. The unique feature of GSI is the large variety of ion and hadron beams in combination with high intensities and the storage rings which all together offer a broad spectrum of scientific opportunities ranging from atomic physics, biophysics and medical applications and plasma physics to nuclear and hadron physics.

UNILAC and SIS18 are serving more than 20 experimental stations. Two of them are devoted to the study of superheavy elements. The elements Z=107 bohrium to Z=112 copernicium have been produced by cold fusion processes for the first time at GSI. Cold fusion reactions take place, when medium heavy nuclei like iron, nickel or tin are bombarded on lead (Z=82) or bismuth (Z=83) targets at such energies that in the compound nucleus an excitation energy around 10–15 MeV is reached. Typically, the evaporation of one neutron prevents the nucleus undergoing fission, and the final product is a superheavy, but short-lived nucleus, which decays preferentially via emission of alpha particles. The cross sections of such reactions are very low (<1 pb) and require dedicated setups. Currently, superheavy element research at GSI focuses on the nuclear and atomic properties of superheavy nuclei, e.g. determination of ionisation potentials by laser spectroscopy and investigation of chemical properties.

Another type of exotic nuclei is accessed with the fragment separator. Neutron or proton-rich nuclei are produced, identified and separated after in-flight fragmentation or fission reactions of heavy projectiles on a beryllium target with the fragment separator FRS at GSI. More than 220 short-lived isotopes have been measured for the first time at GSI. Why are these nuclei of interest? Nucleosynthesis of elements beyond iron proceeds via rapid neutron capture reactions in the r-process, slow neutron captures in s-process, rapid proton capture in the rp-process and a variety of other processes in the universe. Various phenomena in the cosmos like neutron mergers, supernovae of all types and AGB stars have been predicted or verified to be sites of nucleosynthesis. In many of these processes radioactive nuclei are involved. In order to be able to verify the models of nucleosynthesis a multitude of information is necessary, i.e. masses and structure of the exotic nuclei, lifetimes, and capture cross sections. GSI is a unique place to address these questions with its combination of the fragment separator and it suite of storage rings which enable scientists to study reactions of radioactive nuclei at temperatures which prevail in supernova explosions or in stars.

Another exotic state which is studied at GSI is hot and dense baryonic matter at highest baryonic chemical potential. Dileptons emitted from the hot and dense collision zone of two nuclei at relativistic energies are the main focus of research. In contrast to hadronic probes, dileptons are leaving the reaction zone relatively undisturbed and thus allow an unperturbed view on the hot and dense zone. If highly energetic ions hit dust particles loaded with organic molecules more complex molecules can be created or if those ions traverse a cell, it might be killed. Both effects are studied at GSI. Top-down chemistry in materials science and radiation effects in biophysics and medical science. The latter was extensively investigated at GSI in the last twenty years and let to the successful application of irradiation with heavy ions to the treatment of cancer. Tumour treatment with heavy ions is superior to treatments with conventional radiation like X-rays and protons for many reasons and is a topic of continuous research.

Finally, the ‘Green-It Cube’, an energy- and cost-efficient computing centre, is the main facility for all computing activities, e.g. theory modelling, detector simulations and data analysis.

Close to GSI the facility of antiproton and ion research, FAIR is being built. FAIR has been designed and constructed by ten partner countries. FAIR is a multipurpose accelerator facility that will provide beams, from protons up to uranium ions, with a wide range of intensities and energies, in addition to secondary beams of antiprotons and rare isotopes. Complementary to CERN’s Large Hadron Collider or Super Proton Synchrotron, FAIR is pushing the intensity rather than the energy frontier for hadron beams. More than 2500 scientists and engineers from more than 50 countries are involved in the preparation and definition of the research at FAIR. FAIR will enable to produce and study reactions involving rare exotic hadronic states or rare, very short-lived radioactive nuclei. It will enable the investigation of processes under the extreme temperatures and pressures that prevail in large planets, stars and stellar explosions. FAIR will allow producing and studying dense hadronic matter and its transition to quark matter, and permit tests of quantum electrodynamics in the regime of very strong electromagnetic fields, to name but a few goals.

Yvonne Leifels

INTERVIEW WITH CHANDRADOY CHATTERJEE

Young researcher from JRA14: Micropattern Gaseous Detectors for Hadron Physics

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

I am Chandradoy Chatterjee. I am from India, and I completed my undergraduate and postgraduate studies in Kolkata. In 2016 I moved to the University of Trieste for my PhD, where I studied the particle identification (PID) performance of the RICH detector of the COMPASS Experiment. Since March 2020, I have a post-doctoral fellowship at the Trieste section of INFN, co-funded by STRONG-2020.

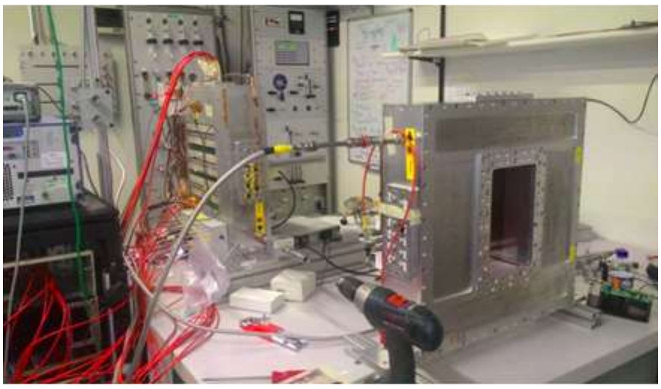
My main field of research is PID related to hadronic physics and technology for the detection of single photoelectrons. It is extremely important to have an efficient particle identification for experiments where the knowledge of the final state particle is crucial. We apply this technique for investigating the internal structure of the nucleons. PID over large momentum range is obtained by detection of single Cherenkov photons exploiting the RICH technology. I spend part of my time in the laboratory building and testing innovative photon detectors, and the rest for the analysis of the COMPASS RICH data.

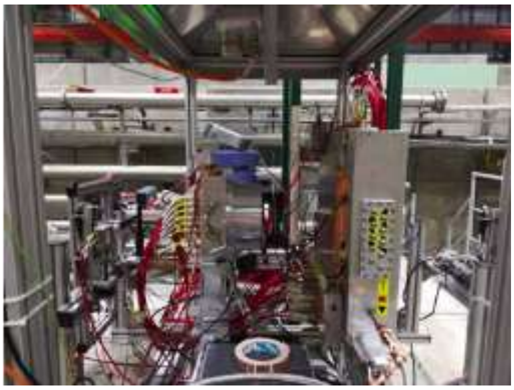
Question 2: When and how did you decide to be a researcher? Was it a child's desire or a recently born passion? Why did you choose hadron physics?

I took the real decision to be an experimental researcher during my master's degree. However, since my childhood I was very fond of the enormous predictability of science, physical sciences in particular. I was very much keen to understand the laws of nature. This is why I decided to study physics, while most of my friends in the school were fascinated in engineering and medical sciences. The hadrons are fascinating and funny particles. Since my undergraduate courses, I was bewildered thinking why the hadron family is so peculiar. Why are some bosons and other fermions? Why is the hadronic charge explainable from its valance quark but the mass or spin is not? Working closely in this field, I started to be aware of many other open questions: quarks and gluons cannot be seen isolated, but what is the origin of this confinement? What is the origin of the spontaneous breaking of the chiral symmetry? How are the parton distributions related to hadrons in their rest frames? All these questions are yet to be answered and state-of-the-art experimental techniques are going to play major roles there. Our detectors at Trieste Lab and at CERN test beam. My supervisor once told me that, in experimental physics we can directly ask questions to Nature and most importantly Nature answers. Ever-growing advancements in experimental techniques are needed for more precise fundamental measurements.

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

I think STRONG-2020 is an outstanding platform for any young researcher interested in the strong interaction. A large number of physicists from around the globe are working in different collaborations and that is an advantage for young physicists like us. Thanks to STRONG-2020, we can not only get access to the world leading facilities but also enrich our knowledge by working closely with the world experts. Expansion of the wing of the particle physics collaborations within and beyond Europe will definitely have a positive impact on the community and also other researchers outside our community.





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

My profession has two extremely important impacts in my life outside my lab. Firstly, working in international environment has helped me to get in touch with different cultures, societies and people of many nations. The collaborative environment has allowed me to witness a unity among strikingly diverse people. Secondly, physics as a profession has another important impact on me. The power of logical reasoning and having a systematic approach to problem solving is what I have seen extremely helpful in life. I have witnessed many times during my work that with logical and systematic verification a seemingly obvious belief or hypothesis may turn out to be wrong.

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

It is demanding. But the demand mostly comes from my interest. I work late hours when I cannot find an answer to a puzzling problem. Honestly, sometimes there are work-related responsibilities which need me to compromise my time with other things. But I guess that is present in every profession. I have some interests in history and world cuisines. Attending conferences allow me to visit the local museums and to try local foods. You can say, this kind of pays me back.

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

I would say there is one particular aspect which is much enhanced over the others: a free and friendly working environment. It encourages me to express my ideas without any hesitation, which is absolutely fantastic.

Interview by Daniele d'Ago, PhD student at Trieste University, Physics Department

INTERVIEW WITH ABHAY DESHPANDE

Abhay Deshpande is a professor at Stony Brook University (SUNY) in the Department of Physics and Astronomy. He also serves as Director EIC Science at the recently approved Electron Ion Collider and the founding director of the Center for Frontiers in Nuclear Science (CFNS). We asked him four questions in a virtual interview at the end of June 2020.

Question 1: What are the scientific goals of the EIC and how can they be achieved?

While we have known for many decades that QCD is the correct theory of Strong Interaction (SI) within the Standard Model (SM) many details remain ill-understood. We understand exactly how quarks and gluons interact with each other individually. But how do those interactions evolve when billions of them occur inside a finite-sized proton to collectively impart its observed properties such as its spin and mass – is not understood. QCD interactions are mediated by gluons which are themselves carriers of colour charge, which means, unlike photons in QED, gluons interact with each other. Energetic gluons can split into two or more, and each next generation can do the same in cascade, creating an unchecked rise of the gluon number. However, being within the finite volume of a nucleon or a nucleus, this rise should be curtailed an opposing process: two gluons merging into one. The rate of such ‘merging’ will be proportional to the instantaneous gluon number density itself. At a certain point, the gluon splitting and merging should become equal, and at that point, QCD predicts formation of a novel form of saturated gluon matter in all nucleons and nuclei. To date, there is no unambiguous evidence for such a saturated gluonic matter. Discovery and systematic study of this high density gluonic matter (often called Colour Glass Condensate – CGC) and a detailed understanding of the spin and mass of the nucleons, nuclei (and hence the entire visible universe) are the most important scientific goals of the Electron Ion collider (EIC) enthusiasts.

The EIC will have highly polarised electron, proton, deuteron and some light ion beams. It is designed to have a broad range of centre-of-mass energy for electron-proton between 20 and 100 GeV, extendible to 140 GeV. The EIC will also provide beams of all nuclei from protons to uranium if needed for the physics studies. The polarisation and their orientation (longitudinal or transverse) of the electrons and hadrons can be controlled bunch-by-bunch.

The EIC will hence not only measure the longitudinal spin contributions of the quarks and gluons to the spins of hadrons, but also the correlations of transverse position and momentum distributions.

To study and understand the saturation state of gluons, the EIC will allow a range of nuclei from protons to heavy nuclei (Gold, Lead, Uranium) to be brought in to collisions with its 10–18 GeV electron beam. At the highest centre-of-mass energy the gluon density in nuclei is expected to be enhanced significantly over protons, due to the abundance of gluons from all of its nucleons, thus enhancing the chance of discovering the saturated gluonic states.

To achieve the varied and diverse scientific goals of the EIC, it will also need a large hermetic acceptance detector well integrated into the interaction region (IR) and the accelerator lattice. It will need a state-of-the-art calorimetry, tracking detectors and particle-identification system, effective over a large range of particle momenta.

Together the detector, the IR and the versatile and flexible machine, will form a formidable tool to explore QCD in the next decades.

Aerial view of Brookhaven National Laboratory showing in the background the 3.4 km circumference Relativistic Heavy Ion Collider (RHIC) which is currently operational.

Question 2: What does the EIC represent for the American nuclear and particle community?

In 2016 the Long-Range Plan (LRP) prepared by the Nuclear Science Advisory Committee (NSAC), an advisory body of scientists to the office of nuclear physics at the US DOE, called the EIC the Next QCD Frontier. It unanimously recommended building the EIC as the highest priority new facility in the US after the completion of the Facility for Radioactive Isotope Beams (FRIB).

The FRIB construction is being completed now and the EIC project was given green light to move forward (Critical Decision 0 or CD0) in December 2019. Amongst the two proposals reviewed, one by Brookhaven National Laboratory based on the relativistic heavy ion collider (RHIC) was selected in January 2020, over the one proposed by Jefferson Lab which would have used the existing Continuous Electron Beam Accelerator Facility (CEBAF). Now both BNL and JLab are working as partners to realise the US EIC together with EIC enthusiasts around the world organised as Users Group, and the DOE.

While the primary goals of the EIC are indeed related to detailed studies of collective phenomena in QCD, the energy and high luminosity machine coupled with an almost full acceptance detector also attracts the high energy physics (HEP) community worldwide to explore how such a machine and physics programme would benefit them.

The schematic diagram of the future Electron Ion Collider will use one of the rings of the RHIC heavy ion beams to collide with high-energy electron beam facility built in the same tunnel.

One obvious thrust is the precision determination of parton distribution functions at intermediate to high-x that are absolutely critical to study and improve the QCD backgrounds for physics Beyond the Standard Model (BSM) at the Large Hadron Collider (LHC) at CERN. There are other precision studies such as transverse momentum distributions (TMD) of partons that are also expected to be important for QCD studies there. A broad range of studies in the electroweak and BSM physics will be carried out over the next year in the Snowmass2021, the HEP community's planning process in the US to study the possibilities of using the EIC for physics of their interest.

The EIC will be as the US's future premier facility for high energy QCD. It will be the only operational collider beyond 2030 on the continental United States, and one of the three premier facilities in the office of nuclear physics: The CEBAF, the FRIB and the EIC aimed at studying matter in all its forms. While the EIC is being built in the US, there are worldwide enthusiasm and interest in studying QCD at the EIC – as such I think EIC should be viewed as a facility for the worldwide group of scientists interested in exploring its physics potential.

Question 3: How important is the participation of international research community, in particular the European one, to the EIC project?

International research community is extremely critical for the success of the EIC. One has to remember that the discovery of proton 'Spin Crisis', and the discovery of modifications of parton distribution functions in nuclei (the nuclear EMC effect), were both discovered by the European Muon Collaboration (EMC) at CERN. These discoveries remain at the heart of the investigations that are part of the EIC's physics programme. The EIC Users Group has more than 1100 participants from about 190 institutions, 31 countries from 6 continental regions of the world. Almost 50% of the users are international, and majority of the non-US users are European. In the recently concluded European Strategy for Particle Physics Update (EPPSU 2020) EIC was recognised as a unique project for precision QCD, complementary to others being pursued around the world by the high-energy physics community. For all these reasons, it is indeed expected that the international research community will play a major role not only in building detector components for the EIC and the eventual data analysis, but the vast intellectual resources of the European theorists will be critical for planning the measurements and interpretation of the data.

Europe currently boasts the highest energy collider in the world (the LHC) at CERN. As such it is also possible that some of the premier European accelerator laboratories would also play a highly visible role in contributing to some of the critical accelerator components of the EIC.

Question 4: How can an EU project like STRONG-2020 contribute to the EIC?

STRONG-2020 funded by the Europe's Horizon 2020 initiative, aims to study Strong Interactions within the Standard Model of physics both on the experimental and theoretical fronts. The EIC is being built to study QCD, using high energy Deep Inelastic Scattering (DIS). DIS is a clean and complementary probe of QCD being pursued at RHIC and LHC which use p-p, p-A and A-A collisions. The complete understanding of the QCD can only be claimed if all systems e-p, e-A, p-p, p-A, and A-A are understood fully under the unified umbrella of QCD theory. As such, many of the existing frontiers in the STRONG-2020 programme are of direct and immediate relevance (JRA6-next-DIS, JRA5-GPD-ACT, JRA4-TMD-neXT, NA2-Small-x) and many others are of complementary nature (NA6-LatticeHadrons, JRA7-HaSP, NA1-FAIRnet, NA7-Hf-QGP & JRA1-LHC-Combine) to those pursued at the EIC. I hope the scientists supported through STRONG-2020 will be able to join those non-European EIC enthusiasts worldwide, and together, we will engage in solving the compelling questions in QCD in the next decade.

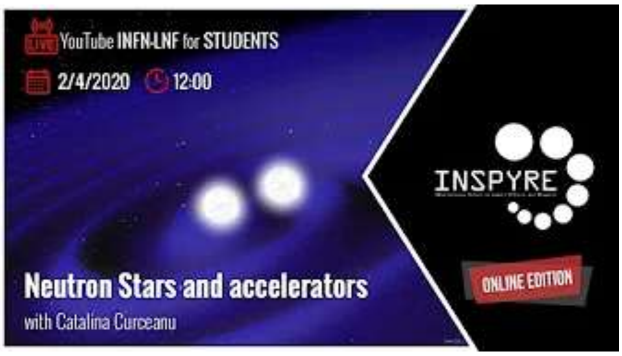
Interview by Fulvio Tessarotto

INSPYRE 2020 SCHOOL SUPPORTED BY STRONG-2020

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. In 2020 the INSPYRE School celebrated 10 years since its first edition. INSPYRE, 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. Usually 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.

STRONG-2020 supported the 2020 edition of the INSPYRE School, '*The Hitchhiker's Guide to the…Universe*', which was dedicated to the hottest topics and challenges in Modern Physics, from particles to cosmology, including hadron and nuclear physics issues.

In the special conditions generated by the coronavirus pandemic situation, INSPYRE 2020 was organised online, on a virtual platform, from 30th of March to 3rd of April, and scheduled 10 talks, given by researchers from various fields. Among the lectures the one given by Catalina Curceanu, was devoted to strangeness physics: Strangeness in the Neutron Stars investigated at the DAFNE accelerator, connected to two WPs of STRONG-2020: THEIA Network and ASTRA JRA.



INSPYRE 2020 lectures were followed by thousands of students, from more than 10 countries.

More information can be found on the web page of the INSPYRE 2020 event:

http://edu.lnf.infn.it/inspyre-2020/ while the lecture of Dr Curceanu can be followed on:

https://www.youtube.com/watch?v=hhiui4Yt1uQ&list=PLRuUrPCVPFIp8mFHYQQiZyrXonN8h56cn&index=9&t=3680s

Catalina Curceanu