Newsletter #6

May 2023

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 Newsletter n.6 of the STRONG-2020 European project, which has been prepared by the Dissemination Board 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.

The Newsletter n.6 is structured as follows: it opens with the article written by the Management Team (Barbara Erazmus, Emine Ametshaeva and Carlo Guaraldo), which reports on the STRONG-2020 Annual Meeting, held at the CNRS headquarters in Paris, France, on 18-19 October 2022. It was an opportunity to present the results of the scientific activities of the STRONG-2020 Community members but also to plan and discuss the future of our project. This first article is followed by news concerning ongoing activities, including the article about the new fixed target system installed for the LHCb experiment at CERN, the report about the SIDDHARTA-2 experiment, installed at the DAΦNE collider of LNF-INFN (Italy) and performing kaonic atoms measurements; the report about ASTRA's CdZnTe detectors, recently tested at the DAΦNE collider; and the article about new timeline Compton scattering measurements performed at CLAS12 (Jefferson Lab, USA). After these experimental activity reports, the article about the recent development of a generic Monte Carlo generator for exclusive processes is provided.

Short reports on some workshops and schools are included, such as the EXOHAD: the new initiative in theoretical hadron spectroscopy in the United States; and the EIC Theory Alliance, initiated in February 2023, with the aim to understand some of the most compelling questions in the physics of the strong nuclear force. The Newsletter continues with the article on the latest, very successful, four Public Lectures organized in the last months, available on the STRONG-2020 website in the LIVE EVENTS section, and the short report on the INSPYRE 2023 International School supported by STRONG-2020. Finally, the Newsletter contains the interview with Dr. Mostafa Hoballah, researcher supported by WP23 (JRA5).

We, the STRONG-2020 DB, encourage you, the Community participating in this project, to contact us and send us news regarding your achievements (published articles, experimental developments, theoretical calculations), your events organized within or with the 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 and/or to a broader scientific community and to the general public which is connected to our project.

Catalina Curceanu, on behalf of STRONG-2020 Dissemination Board

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

2022 edition of the STRONG-2020 Annual Meeting: a new stage of return to normal operation and impressive results

Barbara Erazmus (CNRS/IN2P3, Subatech Laboratory, France), Carlo Guaraldo (LNF-INFN, Italy) and Emine Ametshaeva (CNRS/IN2P3, Subatech Laboratory, France)

The 2022 edition of the STRONG-2020 Annual Meeting took place in hybrid mode, on 18-19 October, at the CNRS headquarters in Paris. As usual, this meeting marked an important moment of sharing and exchange for the participants of the project. It was an opportunity to meet again the leaders of WPs but also to get to know some young participants who benefit from the support of the project.

The detailed agenda of this event is available on the dedicated indico page:

https://indico.in2p3.fr/event/27767/

Interested persons can also view or review on this page the presentations made by each WP during this meeting.

Project Coordinator, Barbara Erazmus, made a detailed presentation of the status of the project and of the major events that occurred since the last Annual Meeting in 2021. Indeed, it was important to provide the most recent updates to keep the Consortium well informed of all project developments.

Catalina Curceanu, the spokesperson of WP2 (DISCO) responsible for communication and dissemination, then presented the results of the work of her WP as well as of the Dissemination Board, which actively contributes to the projects carried out by DISCO. The role and contribution of the latter were impressive during the last year that enabled for the increased visibility of our project and popularization of the scientific work accomplished by the Consortium members.

After these two presentations of a general character, followed more specific descriptions of the work performed by the different WPs of the project. These presentations were given following the classification by thematic category adopted for STRONG-2020:

➔ Research Infrastructures: Transnational Access
➔ Research Infrastructures: Virtual Access
➔ GPD/TMD/PDFs
➔ Hadron Physics
➔ Precision Physics
➔ Instrumentation Activities

This year, WP leaders were asked to mostly focus their presentations on scientific content and progress in completing tasks rather than administrative issues. Besides this, the WP spokespersons also outlined their plans for the rest of the project and assessed the need for its possible second extension. Each presentation was followed by an exchange with the public present in-person as well as the participants who joined the Annual Meeting remotely by ZOOM.

The more global discussion sessions have also been integrated into the agenda giving the partners the opportunity to present the progress achieved but also to explain the difficulties, with which the WPs have been confronted during the past year. The future perspectives of the project represented another aspect often mentioned during these exchanges. Such a less informal and rather personal communication during the meeting made it possible to better understand the real needs of each WP.

The future of the project, beyond the STRONG-2020 grant, was in particular the subject of discussions during plenary sessions as well as restricted meetings of the Facility Coordination Panel, Governing Board and Executive Board.

The Facility Coordination Panel (FCP) Meeting was chaired by Barbara Erazmus. Carlo Guaraldo gave a detailed update on the progress of each of the transnational infrastructures of the project (7 TAs). The state of play and the missions still to be accomplished were clearly explained. During the exchanges amongst the members of the FCP, current and potential difficulties were raised and analyzed. Among these difficulties, the ongoing energy crisis and its negative consequences were addressed in particular. The potential impacts on the project implementation and on the completion of the tasks are still difficult to evaluate but they are of the major concern for the TAs.

The Governing Board (GB) Meeting was moderated by Elena Gonzalez Ferreiro. After a short reminder of the composition and roles of the GB, she made a summary of the needs of the WPs regarding the possible extension of the project based on the WP presentations during the plenary sessions. The arguments in favour and against the second extension were clearly presented and the members of the GB had the opportunity to comment on this decisive issue for the continuation of the project.

After discussion, the GB agreed to request an extension of the project of at least 6 months.

The Executive Board (EB) Meeting, chaired by Barbara Erazmus, was intended to summarize the entire Annual Meeting and to define some important steps to follow for the continuation of the project. The members of the EB gave their assessments of the scientific progress realized by WPs as well as the challenges that still remain to overcome by certain of them. The major upcoming events, including a Workshop organized by DISCO and the next STRONG-2020 Annual Meeting, were also discussed. The continuation of the project, the arguments for the project extension and the future of the Community, which currently belongs to STRONG-2020, represent some other issues on the agenda of the meeting.

To sum up, it should be noted that this edition of the Annual Meeting has become an opportunity for rich and fruitful exchanges among the members of our Consortium. The important decisions that were taken will be followed by the Management Team, and their development will be communicated to the whole Consortium. Even more than the 2021 edition, 2022 Annual Meeting marked the return to a normal operation and it has shown a greater involvement of young researchers who had the opportunity to expose some results of their work during the Meeting but also the Workshop co-organized with STRONG-2020 support on October 17, in Orsay, France. The information on this Workshop and the presentations can be found on the indico page:

https://indico.in2p3.fr/event/27767/timetable/#20221017.detailed

On behalf of the Management Team responsible for the organization of these two events, we thank you all for your participation and contributions, which made this Annual Meeting a real success. We would also like to take this opportunity to remind that the next edition will be organized at CERN, on 20-21 November 2023. You can already reserve these days in your agendas and we hope to see you in person during this unmissable event.

Last but not least, there were some structural changes in the decision-making bodies of STRONG-2020. Franck Sabatié has left the Executive Board for other professional horizons. We want to thank Franck for his long-term commitment and extremely precious contribution to the project.

We warmly welcome Hervé Moutarde who joins the Executive Board instead. As a result of this change, Valerio Bertone took over the role of the spokesperson of VA2 (and thus, joined the Coordination Board) and also replaced Hervé within the Dissemination Board. We strongly believe that the experience of Valerio will be beneficial for our project.

With our best wishes,

Management Team

Barbara, Carlo and Emine

LHCb goes to fixed target

Pasquale Di Nezza (Laboratori Nazionali di Frascati LNF-INFN), WP20: JRA2 FTE@LHC

LHCb has just become the first LHC experiment to be able to run simultaneously with two separate interaction regions. After a R&D mainly developed within the STRONG-2020 working group WP20:JRA2, the new SMOG2 fixed-target system [1,2] was successfully installed during the LHC Long Shutdown II. This system consists of a gas target confined within a 20-cm-long, open-ended aluminum storage cell mounted at the upstream edge of the LHCb vertex detector (VELO), 30 cm from the beam-beam interaction point and coaxial with the LHC beam. The storage cell 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. The beam-gas interactions occur at roughly 4 % of the pp collision rate at LHCb delivering large statistics, even in a few hours of data taking.

The cell is composed of two halves, attached to the VELO with an alignment precision of better than 250 μm. During the injection and ramping phases, the transverse section of the beam is much larger than at full energy. At fixed gas flow, the gas areal density in the cell is inversely proportional to the cube of the inner diameter, and goes as 1/D3. Therefore, to keep the gas flow low, to maximise the density and minimize the cell diameter, the cell halves can be opened during LHC beam injection and tuning; when closed for data-taking, they will move as near as 5 mm to the beam, where the beam aperture is 3 mm. Figure 1 shows the drawing for the open cell (left) and closed cell (right).

The cell is connected to the beam line by two flexible Wake Field Suppressors that allow for electrical and impedance continuity, keep the RF field close to the beam, and avoid excitation of cavity-like structures or other resonant systems.

Figure 1: Drawing of the storage cell open (left) or closed (right).

Electron Cloud (EC) effects are observed in accelerators with positive particles. Slow electrons produced by various ionization processes are trapped near the beam, which are accelerated by the bunches towards the walls of the beam chamber. This produces secondary electrons, potentially resulting in an avalanche multiplication effect, forming dense EC's. As a consequence, transverse instabilities may occur, such as transverse oscillations with exponential growth, leading to beam losses. An elevated residual gas pressure contributes to EC formation, as does a high Secondary Electron Yield (SEY) from the chamber walls. To avoid this, surface coatings were studied during the R&D phase of SMOG2. The final coating of the cell is made of amorphous carbon that ensures a low SEY, below 2.3. Additionally, the black surfaces help with the thermal dissipation of the heat induced by the e.m. field of the beam.

Figure 2 shows the photo of the storage cell system during the installation. All components are in the LHC primary vacuum.

The new injection system can switch between gases from one LHC fill to the other, and is capable of injecting not just noble gases - from helium up to krypton and xenon - but also several other species, including H2, D2, N2, and O2. Precise knowledge of the gas flux, combined with a precise determination of the gas temperature profile, which is assured by five thermocouples, enables accurate luminosity measurements. The pressure stability is reached in 3-5 minutes from when the injection starts, and, once the injection is stopped, the nominal LHC vacuum level is reached in less than 3 minutes.

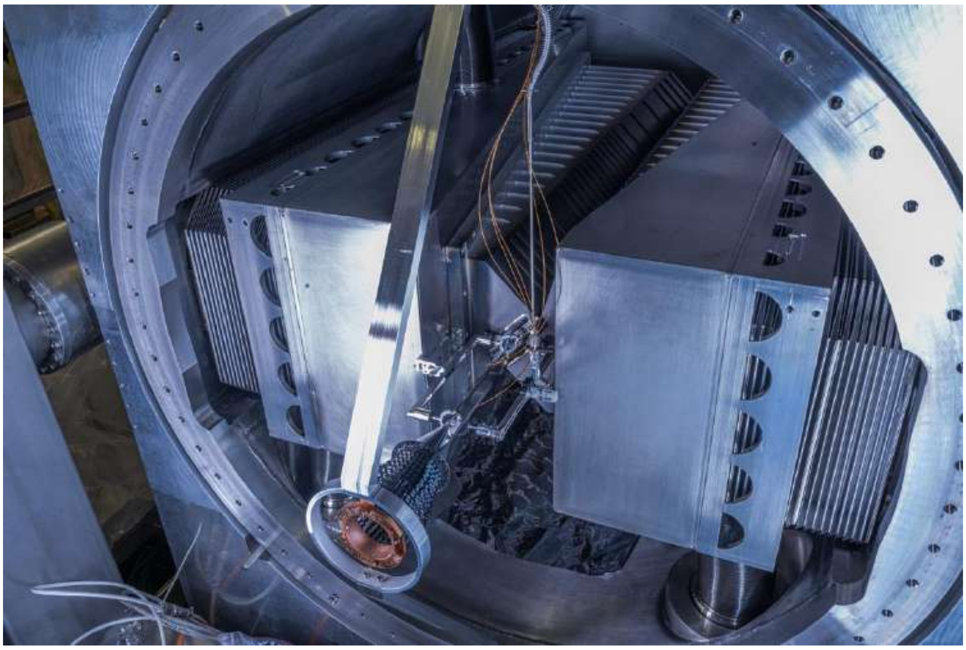

Figure 2: photo of the SMOG2 storage cell system attached to the LHCb VELO detector, into the VELO vessel. The beam enters from the bottom-left side, through the copper flange.

With the presence of gas into the beam pipe, an additional beam-loss mechanism occurs due to beam-gas collisions. The impact on the beam lifetime can be calculated in terms of total beam-gas cross section and the expected luminosity. The result is that, despite the large statistic collected, the beam lifetime reduction largely exceeds the typical duration of a fill. For a proton beam on an Argon target, the relative loss in 10 hours is only 0.4 %, meaning that the lifetime of the beam is essentially unaffected.

The commissioning of the SMOG2 system in 2022 was very successful, with the injection of hydrogen, helium, neon, and argon. Not only were all the hardware components tested and a data-taking protocol was developed, but also physics results confirmed the expectation during the R&D. In particular, as shown in Fig. 3 (left), the primary vertex reconstruction showed two clear and well-separated regions for the beam-gas and the beam-beam interaction points. In a few minutes of data taking the K0s meson invariant mass was reconstructed, Fig. 3 (right). The comparison of the K0s produced in the beam-beam collisions with those produced in the beam-gas interaction showed that their mass resolutions were very similar, despite the

European Commission

different event topologies [3]. Is it also worth mentioning that the data flow increase, in case the target is operated in parallel with the beam-beam collisions, was between 1-3%.

All this makes LHCb the first experiment that is able to run with two completely different interaction points simultaneously.

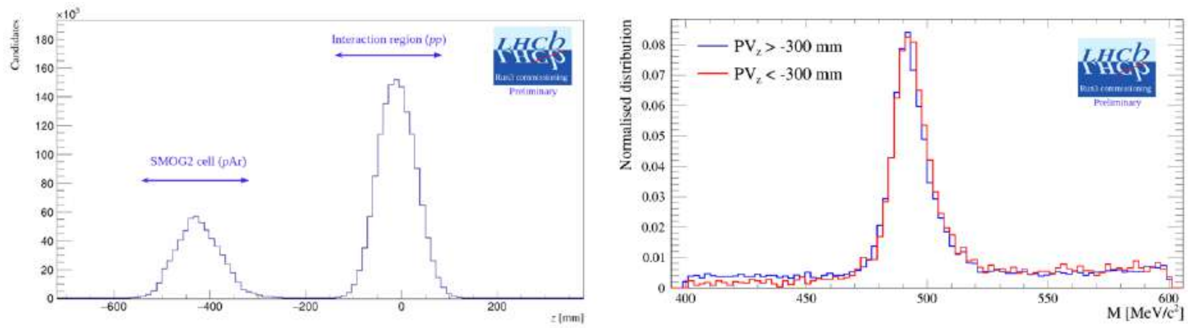

Figure 3: Primary vertex reconstruction distribution (left), K0s meson invariant mass reconstruction produced in beam-gas (PVz<300 mm) or beam-gas (PVz>300 mm) collisions (right) [3].

SMOG2 opens a new window on QCD studies and astroparticle physics at the LHC, performing precision measurements in poorly known kinematic regions. Collisions with the gas target occur at a nucleon-nucleon center-of-mass energy of 115 GeV for a proton beam of 7 TeV, and 72 GeV for a Pb beam of 2.76 TeV per nucleon. Due to the boost of the interacting system in the laboratory frame and the forward geometrical acceptance of LHCb, it is possible to access the largely unexplored high-Bjorken-x region, at negative high Feynman-x and intermediate Q2.

Combined with LHCb's excellent particle identification capabilities and momentum resolution, the new gas target system allows us to advance our understanding of the gluon, antiquark, and heavy-quark components of nucleons and nuclei at large x. This enables additional searches for physics beyond the Standard Model at the LHC and will inform the physics program at future accelerators such as the FCC. Furthermore, the gas target will allow the dynamics and spin distributions of quarks and gluons inside unpolarised nucleons to be studied for the first time at the LHC. Studying particles produced in collisions with light nuclei, like He, N or O, allows LHCb to give important input to the fields of cosmic-ray physics and dark-matter searches. Finally, SMOG2 allows us to perform studies of heavy-ion collisions at large rapidities, in an unexplored energy range between the SPS and RHIC, offering, by using rare probes, new insights into the quark-gluon plasma.

SMOG2 is not only a unique project, but it also results in a perfect playground for the R&D for its upgrade. The LHCspin project [4], in fact, aims to develop innovative solutions and

European Commission

cutting-edge technologies to replace SMOG2 with the first polarised target at LHC, bringing, for the first time, spin physics to the most energetic and intense accelerator.

LHCb is the only place where SMOG is good!

References

[1]. LHCb Collaboration, LHCb-PUB-2018-015;

[2]. LHCb Collaboration, LHCb-TDR-020;

[3]. LHCb Collaboration, LHCb-FIGURE-2023-001;

[4]. LHCspin, arXiv:1901.08002; arXiv: 2111.04515.

Kaonic atoms at the DAΦNE collider with the SIDDHARTA-2 experiment

Catalina Curceanu, Diana Laura Sirghi (Laboratori Nazionali di Frascati LNF-INFN), WP5: TA3; WP15:NA5

Light kaonic atoms spectroscopy is a unique tool for the investigation of the low-energy strangeness quantum chromodynamics. Precise measurements of the radiative X-ray transitions towards low-n levels of these systems provide information on the kaon–nucleus interaction at threshold which, in typical scattering experiments, would require an extrapolation towards zero energy, making them method-dependent.

In this context, a special role is played by the lightest kaonic atoms, namely kaonic hydrogen, deuterium, and helium. From the first two, the isospin-dependent antikaon-nucleon scattering lengths can be obtained from the measurements of the strong interaction induced shifts and widths of the 1s levels. Additional information on the strong interaction with many-body systems can be retrieved from transitions to the 2p level of kaonic helium 3 and 4 [1].

The huge advances in the development of fast spectroscopic X-ray detector systems, combined with the availability of the DAΦNE low-momentum (<140 MeV/c), nearly monochromatic charged kaons, generated by the decay of the φ resonance formed in electron-positron annihilation, propelled an unprecedented progress in the field of strangeness studies with the SIDDHARTA [2–4] experiment at the DAΦNE collider of the INFN Laboratories of Frascati. The SIDDHARTA experiment achieved the most precise measurement of kaonic hydrogen transitions to the ground level, and the first measurements of gaseous kaonic helium-3 and kaonic helium-4 transitions [1] to the 2p level.

In 2019, the SIDDHARTA-2 experiment, a major upgrade of SIDDHARTA, has been installed on DAΦNE accelerator, aiming to measure, for the first time, the kaonic deuterium

1s level shift and width with a precision like that achieved by SIDDHARTA for kaonic hydrogen [2]. The measurement is a great experimental challenge, since the kaonic deuterium X-ray yield is expected to be one order of magnitude smaller than the hydrogen one [2], and the K− transition lines are expected to be rather broad (~ 1 keV). Therefore, the goal of the new apparatus, SIDDHARTA-2, is to significantly increase the signal-to background ratio, by gaining in solid angle, by taking advantage of a new type of SiliconDrift Detectors (SDDs) with excellent timing resolution and by using additional designed veto systems.

In Fig. 1. a drawing of the SIDDHARTA-2 apparatus is shown, where the main components are highlighted (more details can be found in [1].)

To perform both conditioning of the machine and tuning of the various components of the SIDDHARTA-2 setup, a reduced version of the experimental setup, named SIDDHARTINO [5], with only 1/6 of the X-ray Silicon Drift Detectors (SDD) was installed in 2019 in DAΦNE. Due to the pandemic situation, the SIDDHARTINO run only started in January 2021, and two runs with a target cell filled with 4He gas at about 1.5% and 0.66% of liquid helium density were performed to optimize various setup components, as well as to provide feedback to the machine during its commissioning phase. The choice of 4He was dictated by the high yield of the K 4He (3d → 2p) transition allowing for very fast tuning.

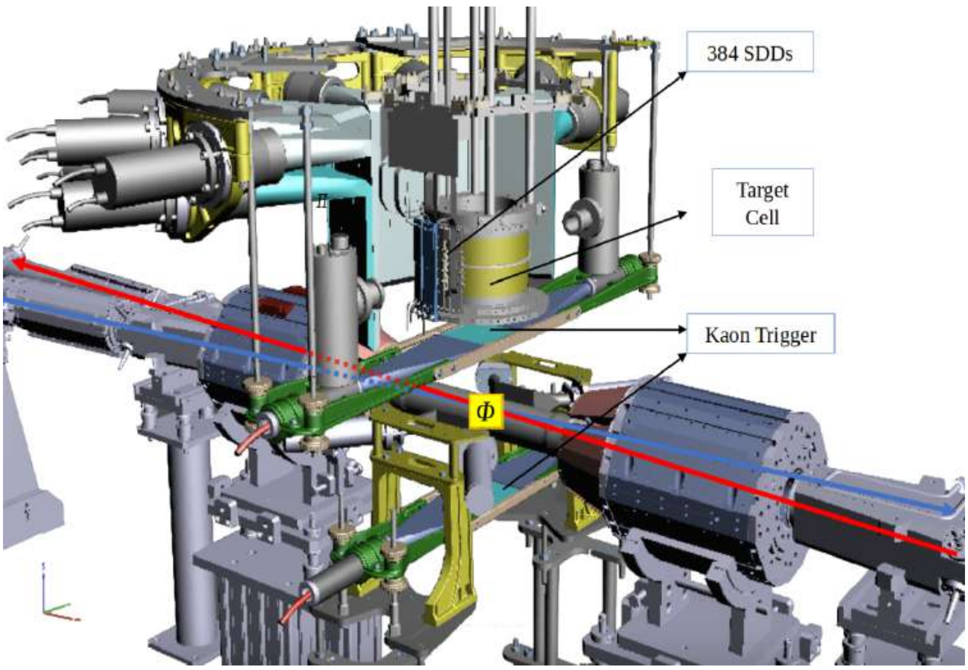

Figure 1: Schematic view of the SIDDHARTA-2 setup.

In the second half of 2021, the full SIDDHARTA-2 setup was installed on the DAΦNE interaction region and subsequent data taking in April - July 2022, with support from the STRONG-2020 WP5 (TA3) and (for theory) from WP16: NA5. During this period, a second test with helium before filling the target cell with deuterium, was performed. The first period of the campaign measurement dedicated to the kaonic deuterium 2p→1s transition, was done in period 03 June- 02 July 2022.

Fig. 2 shows the kaonic-4He spectrum for the total integrated luminosity of 26 pb^{-1}. The K4He Lα line (3d→ 2p) is visible together with the Lβ (4d→2p) and Lγ (5d→2p) ones. Other lines, corresponding to kaonic carbon, nitrogen, and oxygen high-n transitions generated by kaons stopped in the target window made of Kapton (C22H10O5N2), were also detected, as well as lines from kaonic titanium and aluminum due to kaons stopping in the other components of the experimental apparatus.

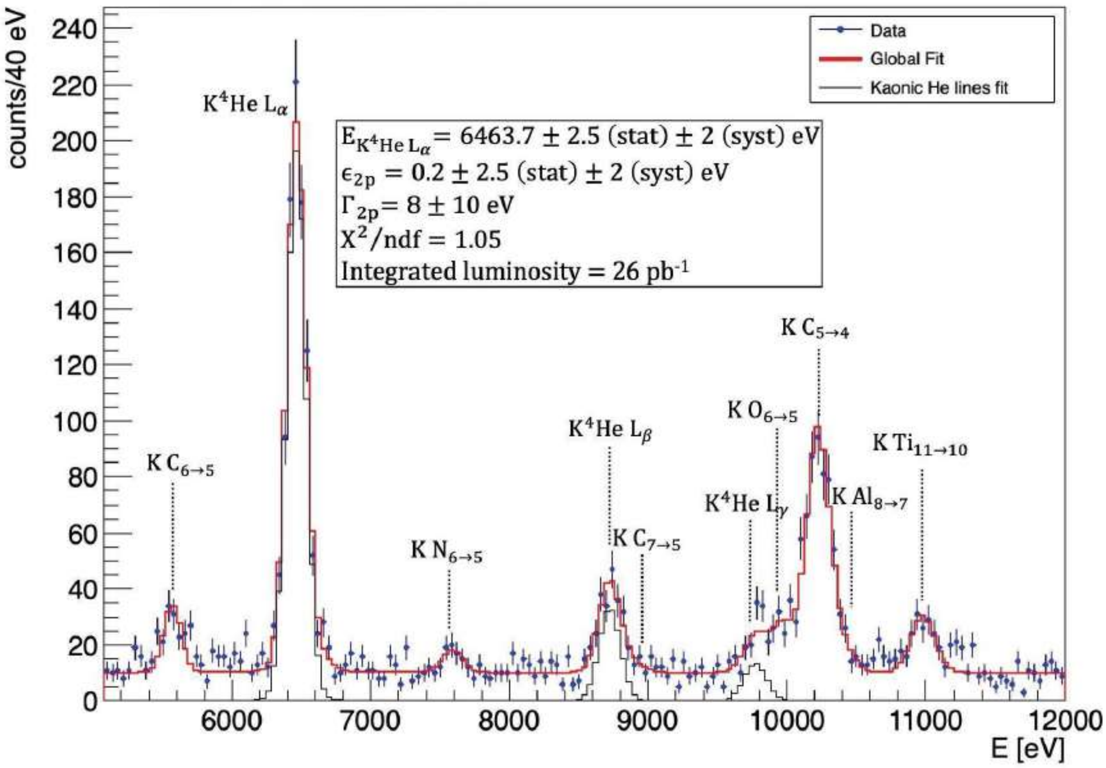

Figure 2: Fit (red line) of the kaonic-4He energy spectrum. The Lα peak is seen together with the Lβ and Lγ ones (black lines) [5].

The experimental outcomes of this run represented the first important physics results of the SIDDHARTA-2 experiment, delivering the most precise measurement of the 2p level shift and width in the gaseous target [5].

Moreover, new measurements of kaonic helium-4 L-series X-rays yields in 4He targets in gas with the SIDDHARTINO setup were measured for two new densities: 1.90 g/l and 0.82 g/l, corresponding to 1.5% and 0.66%, respectively, of the liquid helium-4 density and the results were published in [6].

In Fig. 3, the absolute yields for the kaonic helium-4 Lα X-rays measured by SIDDHARTINO are plotted together with the previous SIDDHARTA results in gas [7].

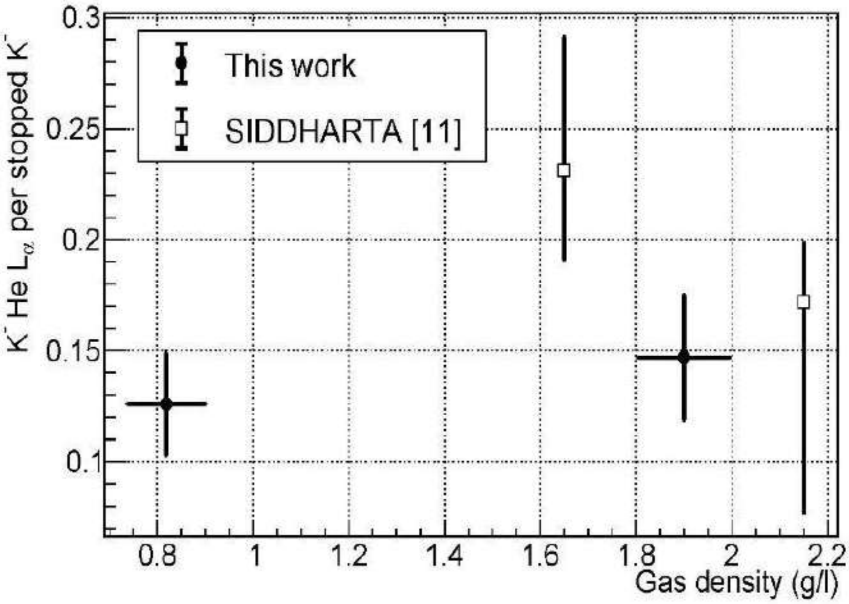

Figure 3: The Lα X-ray yield of kaonic-4He as function of the target density from all gaseous target measurements: this work [6] (filled dots) and SIDDHARTA [7] (hollow squares).

From the perspective of kaonic atoms cascade models, the density region covered by these two new SIDDHARTINO measurements is of great interest since, up to now, due to the absence of data, no progress has been achieved in cascade model calculations for kaonic atoms since almost twenty years.

In the coming years SIDDHARTA-2 collaboration will measure the transition yields for various kaonic atoms, by also using gas targets at various densities. These results will trigger a renaissance of the cascade calculations for exotic atoms, in particular for the kaonic atoms, and a better understanding of the underlying processes and physics.

The SIDDHARTA-2 experiment performed also high precision measurements of a series of intermediate mass kaonic atoms transitions, which represent the first measurements ever. Kaonic carbon, oxygen, nitrogen and aluminum X-ray transitions in the 5-16 keV energy range were measured during the 2021 and 2022 data taking campaigns, by using kaons delivered by the DAΦNE collider stopped in the setup materials.

In Fig. 4, the X-ray spectrum of the summed data for the SIDDHARTINO and SIDDHARTA-2 runs, corresponding to about 75 pb^{-1}, after the application of the event selections, is shown. The kaonic atoms signals are clearly visible.

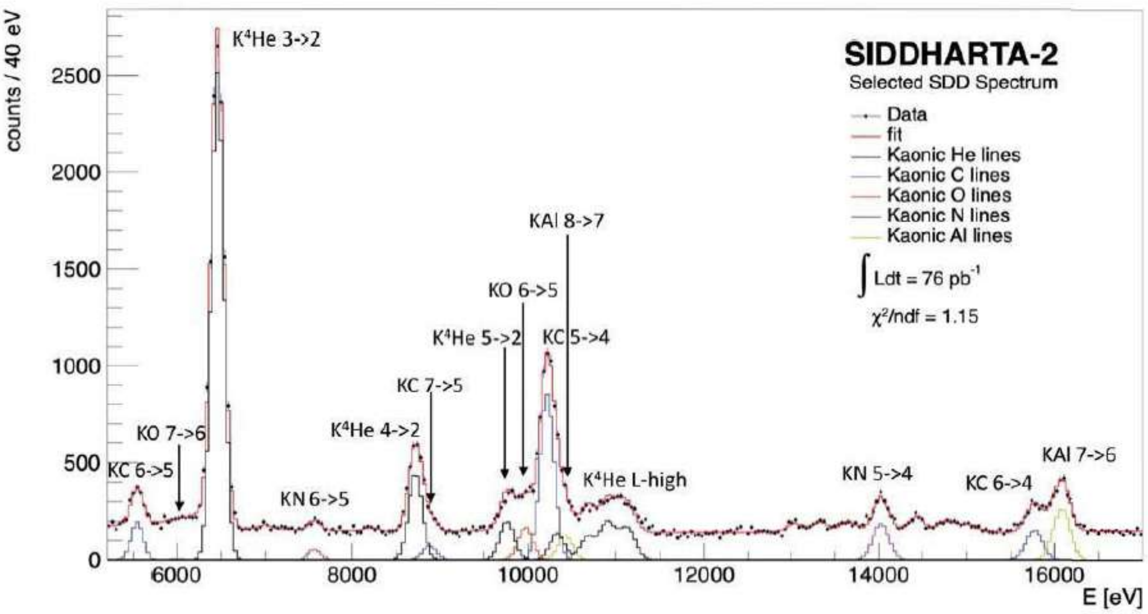

Figure 4: SDD energy spectrum and fit of SIDDHARTA-2 and SIDDHARTINO summed data after background suppression. The kaonic helium signals are seen as well as the kaonic carbon (KC), oxygen (KO), nitrogen (KN) and aluminium (KAl) signals.

The peaks highlighted in the figure correspond to the X-ray emissions from kaonic atoms formed in the helium gas and in the components of the target cell. Several intermediate mass kaonic atoms, such as kaonic carbon, oxygen, nitrogen and aluminum high-n transition energies are measured for the first time.

The kaonic carbon, oxygen and nitrogen transitions are the result of kaons stopped in the Kapton walls, whereas the kaonic aluminum transitions were produced by kaons stopped in the top and bottom frames of the target cell [8].

These new data enrich the kaonic atoms transitions database, which is used as input and as a testbed for theories and models of kaonic-nuclei interactions at low energies, a field which is still far from being fully understood. The new data added by SIDDHARTA-2 can stimulate a revival of the theoretical activity in the field, towards a better understanding of the strong interaction with strangeness and of the role played by multi-nucleon absorption processes with implications extending from particle and nuclear physics to astrophysics.

The series of these measurements show the potential of DAΦNE and SIDDHARTA-2 like technologies to address high precision kaonic atoms measurements. It sets the ground for the kaonic deuterium measurement with the SIDDHARTA-2 experiment, aiming to perform its DAQ campaign from spring 2023 for an overall integrated luminosity of 800 pb^{-1}. The SIDDHARTA-2 experiment will provide a kaonic deuterium measurement of the same level of precision as the kaonic hydrogen one performed by SIDDHARTA [2]. A picture of the SIDDHARTA-2 setup installed in the DAΦNE accelerator is shown in Fig. 5, together with a part of the SIDDHARTA-2 collaboration.

Figure 5: The SIDDHARTA-2 setup installed in the DAΦNE accelerator together with a part of the SIDDHARTA-2 collaboration.

Part of this work was supported by the TA3-Transnational Access Activity within EU STRONG-2020 project (Grant Agreement No. 824093), which provides access of scientists to the infrastructure, one of the core missions of the STRONG-2020and, from theoretical point of view, by WP16: NA5 (5-Strange Hadrons and the Equation-of-State of Compact Stars).

References

[1]. Curceanu C et al 2019 Rev. Mod. Phys. 91 025006.

[2]. M. Bazzi, et al., Phys. Lett. B 704, 113 (2011).

[3]. M. Bazzi, et al., Phys. Lett. B 697, 199 (2011).

[4]. M. Bazzi, et al., Phys. Lett. B 681, 310 (2009)

[5]. D. Sirghi, F. Sirghi, F. Sgaramella et al., J. Phys. G 49, 055106 (2022).

[6]. D. Sirghi, H. Shi et al., Nucl. Phys. A 1029 (2023) 122567.

[7]. M. Bazzi et al., Eur. Phys. J. A, 50 (2014), p.91.

[8]. F. Sgaramella et al., Eur. Phys. J. A 59 (2023) 3, p. 56.

ASTRA's CdZnTe detectors tested at the DAΦNE Collider

Alessandro Scordo (LNF-INFN, Frascati, Italy), Leonardo Abbene (Università degli Studi di Palermo, Italy), Manuele Bettelli (IMEM-CNR, Parma, Italy), Antonio Buttacavoli (Università degli Studi di Palermo, Italy), Andrea Zappettini (IMEM-CNR, Parma, Italy), WP26: JRA8

The main goal of the WP26 JRA8-ASTRA is to develop beyond state-of-art advanced radiation detector systems, able to perform high precision measurements of photons in a (very) broad energy range, capable to operate in different environments/conditions. In particular, CdZnTe detectors are developed with the aim to cover an energy range as wide as possible, with a particular aim to make them suitable to be used for physics measurements in accelerator environments.

With the twofold scope to verify the performances in an accelerator environment and to assess the background rejection capabilities enabled by a fast time response, in June 2022, a first prototype of a quasi-hemispherical CdZnTe detector system, built with support from STRONG-2020 WP26 (JRA8-ASTRA) project, with an active surface of 1 cm^2 and a thickness of 5 mm, was installed near the Interaction Point (IP) of the DAΦNE collider, aligned with the SIDDHARTA-2 Luminosity Monitor (LM) [1].

The detector prototype, manufactured by the IMEM-CNR of Parma, was enclosed in a light-tight box with a 1 mm thick aluminum entrance window, matching the detector's active surface, on top of which a 241Am radioactive source was placed, producing a 500 Hz signal in the CdZnTe detector.

The detector was connected to low-noise (equivalent noise charge ENC of 100 electrons) charge-sensitive preamplifiers (CSPs) and processed by 8-channel digital electronics. Both the CSPs and the digital electronics were developed at DiFC of the University of Palermo (Italy). The signals from the CdZnTe were acquired by two CAEN DT5724 digitizers driven by an original firmware [2-4].

The signals from the LM were also acquired, with the same digitizers, to perform an offline data selection (trigger) when charged kaon pairs were produced in the horizontal plane. The digital signals from the LM were processed by an ORTEC 566 Time-to-Amplitude Converter (TAC) module. The data have been acquired for a total of 72 hours, during which the accelerator delivered e− and e+ beams with average currents of 500 mA and 270 mA, respectively. The raw measured spectrum with no selection cuts, showing peak resolutions of 6% at 60 keV and of 2.2% at 511 keV, is seen in Fig. 1.

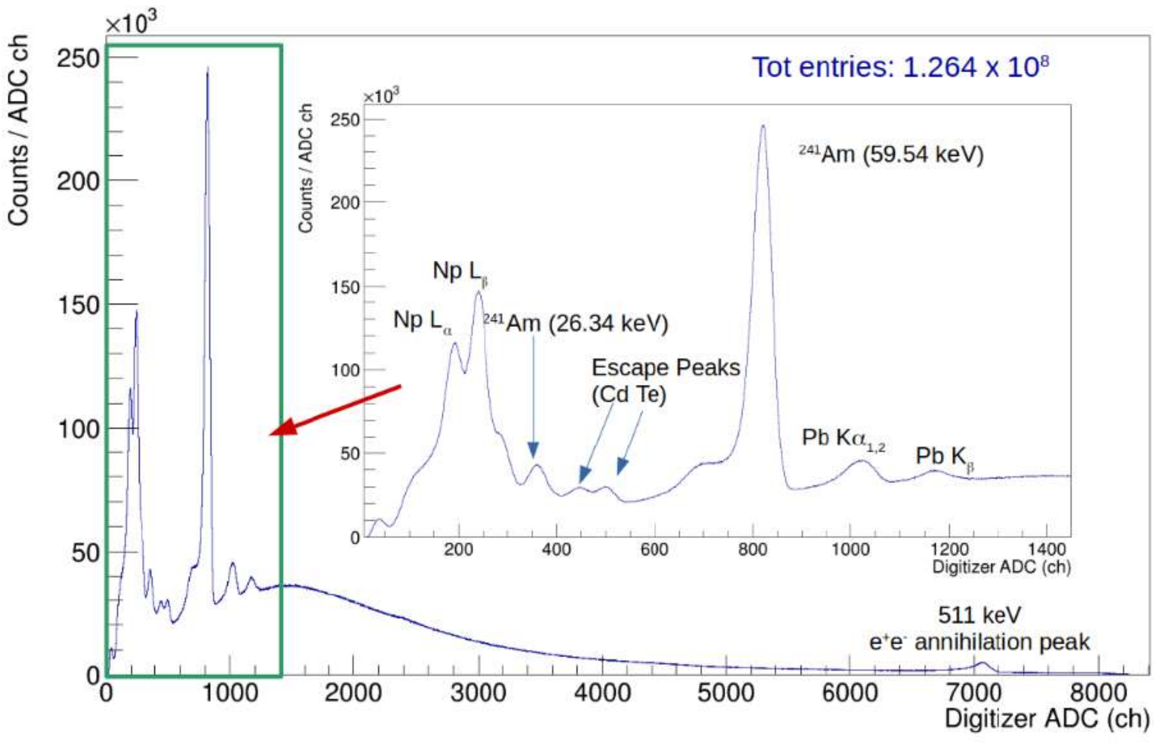

Figure 1: Raw CdZnTe spectrum acquired in 72 hours at DAΦNE.

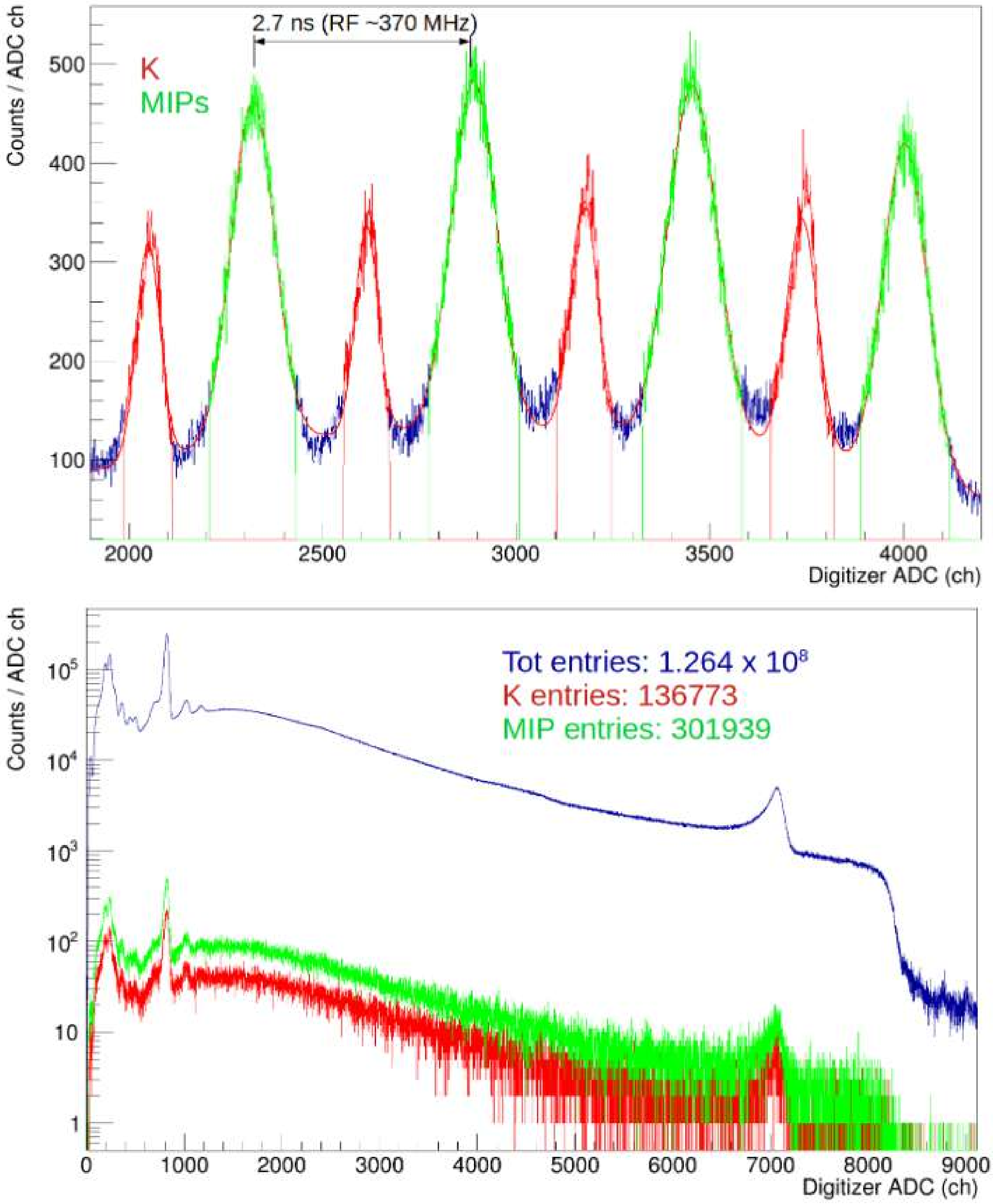

Figure 2: Top: TAC spectrum from the SIDDHARTA-2 LM. Bottom: CdZnTe spectrum with no time selection from the TAC (blue) overimposed on the spectra obtained in coincidence with kaons (red) or MIPs (green) events.

Thanks to the trigger provided by the SIDDHARTA-2 Luminometer system and to the fast readout capabilities of the prototype, we successfully measured a suppression of the machine background of a factor about 3×10^2 which, when combined to the 100-300 ns time resolution of the CdZnTe for the kaonic atoms data taking where a timing coincidence peak will mark signal events, will lead to an overall rejection factor of about 10^{5-6}[5]. This represents a very promising result based on which the SIDDHARTA-2 collaboration will include, in its 2023 data-taking measurements of radiative transitions from several intermediate and high mass kaonic atoms to be performed with CdZnTe detectors.

Spectra showing the background rejection when a Kaon or a MIP on the luminometer was detected are reported in Fig. 2.

These results not only represent a very important starting point for the future measurements of kaonic atoms planned by the SIDDHARTA-2 experiment, but are a crucial milestone for the members of the WP26 JRA8-ASTRA that the R&D activities are proceeding well in-line (or even beyond) with the original scopes and motivate us even further to continue this very important technological research.

The results presented here have been accepted for publication in EPJ-ST and are also published on arxiv as https://doi.org/10.48550/arXiv.2301.12253.

References

[1]. Skurzok, M., et al.: Characterization of the SIDDHARTA-2 luminosity monitor. JINST 15(10), 10010 (2020) arXiv:2008.05472 [physics.ins-det].

[2]. Abbene, L., et al.: Digital fast pulse shape and height analysis on cadmium–zinc–telluride arrays for high-flux energy-resolved X-ray imaging, Journal of Synchrotron Radiation 25(1), 257–271 (2018). https://doi.org/10.1107/S1600577517015697

[3]. Gerardi, G., Abbene, L.: A digital approach for real time high-rate high-resolution radiation measurements. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 768, 46–54 (2014), https://doi.org/10.1016/j.nima.2014.09.047

[4]. Abbene, L., et al.: Energy resolution and throughput of a new real time digital pulse processing system for x-ray and gamma ray semiconductor detectors. Journal of Instrumentation 8(07), 07019–07019 (20 13), https://doi.org/10.1088/1748-0221/8/07/p07019

[5]. Abbene, L. et al.: New opportunities for kaonic atoms measurements from CdZnTe detectors. Accepted for Publication on EPJ-ST. arXiv:2301.12253v1 [physics.ins-det], https://arxiv.org/pdf/2301.12253.pdf

Timelike Compton Scattering with CLAS12

Pierre Chatagnon (Jefferson Lab, US), WP25: JRA7

Quantum Chromodynamics reveals its complexity at energies of the order of the nucleon mass. Its coupling constant decreases with increasing energy, at the extent that the perturbative approach cannot be applied to understand the nucleon structure. This behaviour, referred as asymptotic freedom, is at the very core of hadronic physics. Hence understanding the structure of the nucleon is a necessary step to fully understand non-perturbative QCD.

As explicit calculations of low-energy QCD are not achievable, the main tools to understand the nucleon structure are ad-hoc functions, encoding the complex behaviour of the partons inside the nucleons.

One such set of structure functions is the generalized partons distributions (GPDs), which were first introduced in the late 1990s [1, 2, 3, 4, 5, 6]. The rich phenomenology of GPDs includes links to electro-magnetic form factors and parton distribution functions, and have direct relations to the contribution of the angular momentum of partons to the nucleon spin. The GPDs also relate to the energy-momentum form factors describing the interaction of nucleons with the gravitational field. These complex relations have driven a large international effort, experimental and theoretical, to measure them.

Compton scattering (the scattering of a photon off a nucleon) has long been identified as the golden process to study GPDs experimentally. Until recently, Deeply Virtual Compton Scattering (DVCS, $ep \to e'\gamma^*p \to e'p'\gamma$), the exclusive electroproduction of a real photon proposed in Refs. [2, 3, 4], has been the preferred reaction for accessing GPDs [7, 8, 9, 10, 11, 12]. For the first time in this paper we report the measurement of the time-reversal symmetric process to DVCS: Timelike Compton Scattering (TCS) [13, 14, 15, 16]. In the TCS reaction ($\gamma p \to \gamma^*p' \to e^-e^+p'$), the incoming photon is real and the final state pair of leptons (in our case an electron-positron pair) is produced by the decay of a virtual photon emitted by the scattered nucleon. This reaction plays a crucial role in the understanding of GPDs. First, it is the simplest reaction, besides DVCS, that can be parameterized by GPDs. Its measurement and the comparison with DVCS results provide support for the universality of the GPD theoretical framework. In addition, TCS has a singular sensitivity to the real parts of the Compton Form Factors (CFFs), which are GPD-based quantities accessible in DVCS and TCS measurements. The real parts of the CFFs, that contain integrals of GPDs over the struck quark momentum fraction, can be related via a dispersion relation to Energy-momentum form factors. This unique sensitivity allows to probe the interaction of gravitational fields with nucleons and permits to extract the distributions of the forces experienced by partons within the nucleons.

This first ever measurement of the TCS reaction was performed using data taken by the CLAS12 detector [17] in 2018. This large acceptance detector is housed in the experimental Hall B at Jefferson Lab, Virginia, USA, and is primarily dedicated to hadronic physics measurements, and in particular for the exploration of the GPDs in deep exclusive reactions. Its large kinematic coverage and good particle identification capabilities make it ideal to measure the final state particles of the TCS reaction. The 11-GeV polarized-electron beam provided to CLAS12 by the upgraded Continuous Electron Beam of Jefferson Lab allows to reach sufficient center-of-mass energy to measure the TCS reaction in the resonance-free region (for lepton pair invariant mass between 1.5 and 3 GeV). In this region, the interpretation of the results in terms of GPDs is possible. The extraction of TCS observable was done after selecting quasi-photoproduction events where the initial real photon is emitted by electrons from the incoming polarized beam.

Two observables were extracted from the data. The cross-section asymmetry between circular right-handed and left-handed polarization of the initial real photon was computed as a function of the transferred momentum to the recoil proton. This asymmetry is proportional to the imaginary part of the CFFs which has been extensively constrained by previous DVCS measurements at Jefferson Lab but also by the COMPASS experiment at CERN. After extracting non-zero asymmetries from the CLAS12 dataset, we showed that they are well reproduced by two independent model calculations ([18, 19, 20, 21, 22, 23, 24]). This result hints toward a universal interpretation of the GPDs, as these models also describe well previous DVCS measurements [25].

The measurement of the Forward-Backward asymmetry (the cross-section asymmetry under the inversion of the lepton momenta in the center-of-mass frame of the TCS reaction) using the same dataset, is also reported in our article. This asymmetry has a direct sensitivity to the real part of the CFFs, ultimately allowing to probe the Energy-Momentum Form Factors and the mechanical properties of the nucleons. We observed a clear non-zero asymmetry and the comparison with model predictions points toward the importance of the contribution of the D-term, a poorly known element of GPD parametrizations that has recently gained relevance for its links to the mechanical properties of the nucleon.

This work constitutes the very first ever measurement of the Timelike Compton Scattering reaction. Besides providing important physics conclusions, it opens a new path toward the measurement of GPDs as we demonstrated the complementary of the TCS and DVCS measurements especially in understanding the real parts of the CFFs. Hence, future measurements of the TCS reaction at JLab, at the EIC or at CERN will not only provide a new wealth of data to better understand the structure of the nucleon in terms of GPDs but also allow to explore in detail the still unknown mechanical properties of nucleons.

References

[1]. D. M¨uller, D. Robaschik, B. Geyer, F.-M. Dittes, and J. Hoˇrejˇsi. Wave functions, evolution equations and evolution kernels from light-ray operators of qcd. Fortsch. Phys., 42(2):101–141, 1994.

[2]. Xiangdong Ji. Gauge-invariant decomposition of nucleon spin. Phys. Rev. Lett., 78:610–613, Jan 1997.

[3]. Xiangdong Ji. Deeply virtual compton scattering. Phys. Rev. D, 55:7114–7125, Jun 1997.

[4]. A. V. Radyushkin. Nonforward parton distributions. Phys. Rev. D, 56:5524–5557, Nov 1997.

[5]. A. V. Radyushkin. Symmetries and structure of skewed and double distributions. Phys. Lett. B, 449:81–88, 1999.

[6]. Matthias Burkardt. Impact parameter dependent parton distributions and off-forward parton distributions for ζ 0. Phys. Rev. D, 62:071503(R), Sep 2000.

[7]. S. Stepanyan et al. Observation of exclusive deeply virtual Compton scattering in polarized electron beam asymmetry measurements. Phys. Rev. Lett., 87:182002, 2001.

[8]. C. Mu˜noz Camacho et al. Scaling tests of the cross-section for deeply virtual compton scattering. Phys. Rev. Lett., 97:262002, 2006.

[9]. F. X. Girod et al. Measurement of Deeply virtual Compton scattering beam-spin asymmetries. Phys. Rev. Lett., 100:162002, 2008.

[10]. E. Seder et al. Longitudinal target-spin asymmetries for deeply virtual compton scattering. Phys. Rev. Lett., 114:032001, Jan 2015.

[11]. S. Pisano et al. Single and double spin asymmetries for deeply virtual compton scattering measured with clas and a longitudinally polarized proton target. Phys. Rev. D, 91:052014, Mar 2015.

[12]. H. S. Jo et al. Cross sections for the exclusive photon electroproduction on the proton and generalized parton distributions. Phys. Rev. Lett., 115:212003, Nov 2015.

[13]. E.R. Berger, M. Diehl, and B. Pire. Timelike compton scattering: exclusive photoproduction of lepton pairs. Eur. Phys. J. C, 23(4):675–689, Apr 2002.

[14]. M. Bo¨er, M Guidal, and M. Vanderhaeghen. Timelike compton scattering off the proton and generalized parton distributions. Eur. Phys. J. A, 51(8):103, 2015.

[15]. P. Nadel-Turonski, T. Horn, Y. Ilieva, F. J. Klein, R. Paremuzyan, and S. Stepanyan. Timelike Compton scattering: A first look. AIP Conf. Proc., 1182(1):843–846, 2009.

[16]. M. Bo¨er, M. Guidal, and M. Vanderhaeghen. Timelike compton scattering off the neutron and generalized parton distributions. Eur. Phys. J. A, 52(2):33, 2016.

[17]. V. D. Burkert et al. The clas12 spectrometer at jefferson laboratory. Nucl. Instr. Meth. A, 959:163419, 2020.

[18]. M. Vanderhaeghen, P. A. M. Guichon, and M. Guidal. Hard electroproduction of photons and mesons on the nucleon. Phys. Rev. Lett., 80:5064–5067, Jun 1998.

[19]. M. Vanderhaeghen, P. A. M. Guichon, and M. Guidal. Deeply virtual electroproduction of photons and mesons on the nucleon: Leading order amplitudes and power corrections. Phys. Rev. D, 60:094017, Oct 1999.

[20]. M. Guidal, M. V. Polyakov, A. V. Radyushkin, and M. Vanderhaeghen. Nucleon form factors from generalized parton distributions. Phys. Rev. D, 72:054013, Sep 2005.

[21]. Michel Guidal, Herv´e Moutarde, and Marc Vanderhaeghen. Generalized Parton Distributions in the valence region from Deeply Virtual Compton Scattering. Rept. Prog. Phys., 76:066202, 2013.

[22]. S. V. Goloskokov and P. Kroll. Vector-meson electroproduction at small bjorken-x and generalized parton distributions. Eur. Phys. J. C, 42(3):281–301, 2005.

[23]. S. V. Goloskokov and P. Kroll. The role of the quark and gluon gpds in hard vector-meson electro-production. Eur. Phys. J. C, 53(3):367–384, Feb 2008.

[24]. S. V. Goloskokov and P. Kroll. An attempt to understand exclusive π+ electroproduction. Eur. Phys. J. C, 65(1):137, Nov 2009.

[25]. Raphael Dupre, Michel Guidal, and Marc Vanderhaeghen. Tomographic image of the proton. Phys. Rev. D, 95(1):011501(R), 2017.

A generic Monte Carlo generator for exclusive processes

Hervé Moutarde (Institut de Recherche sur les Lois Fondamentales de l'Univers - IRFU, Saclay, France), WP11: VA2

Generalized parton distributions (GPDs) provide a wealth of information about the 3D structure of the proton. Through GPDs, it is also possible to experimentally access the mechanical properties of the proton like the distribution of pressure exerted by its quark and gluon content. GPDs can be constrained through several exclusive processes (all particles are detected in the final state) studied in many facilities worldwide. Among all exclusive processes, the scattering of a lepton off a proton target to produce in the final state a lepton, a proton and a real photon –a process known as deeply virtual Compton scattering (DVCS)—has long been considered as the theoretically cleanest channel to study GPDs.

GPDs constitute one pillar of the nucleon structure studies to be conducted at the future US-based electron ion collider EIC. The design and analysis of future experiments require new tools that can (i) use a great variety of GPD models, (ii) simulate many different exclusive processes, (iii) rely on state-of-the-art higher order corrections to these processes and (iv) handle QED radiative corrections. Using tools maintained and disseminated within the VA2-3DPartons [2] work package of STRONG-2020, a team of physicists in Europe and in the United States developed and released the generic Monte Carlo event generator EpIC [1]. The event generator features a modular architecture fully compatible with that of the PARTONS framework [3]. Even if the first release only provides a DVCS event generator, any exclusive process computable with PARTONS, by design, can easily be plugged in the EpIC event generator. On top of this, the simulation of DVCS events includes radiative corrections. Event generation is parameterized through a simple text file for simplicity and archiving simulation details.

The motivation for the VA2-3DPartons work package is giving access to open-source computing libraries required for high precision phenomenology in the field of 3D hadron structure, with a focus on generalized parton distributions (GPDs) and transverse momentum dependent parton distributions (TMDs). This work package provides users a long-term guarantee for robust, flexible, validated and modern libraries. These codes are maintained, released, tested, documented and the work package provides technical assistance to users.

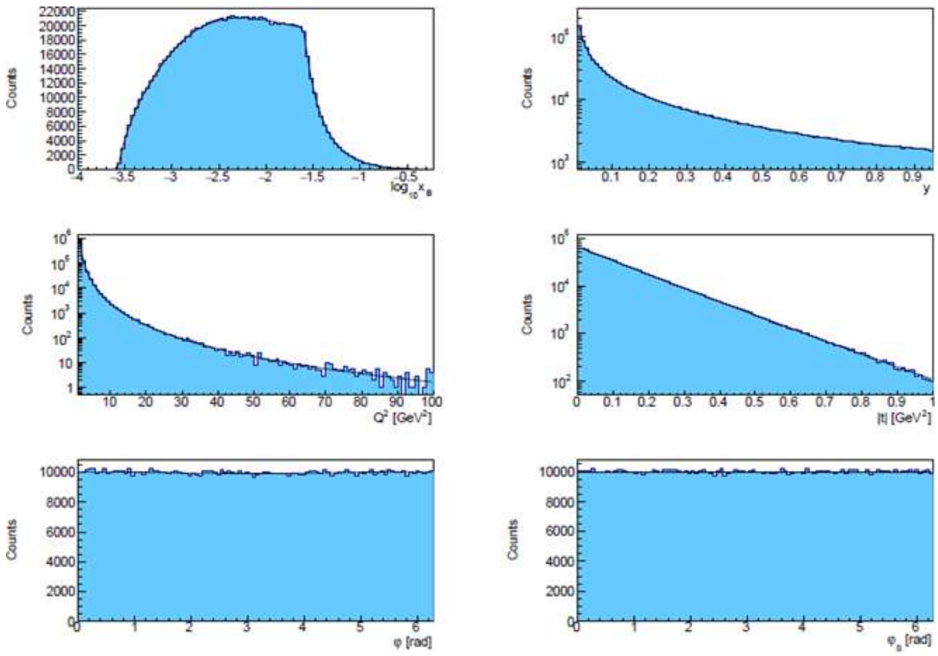

Figure 1: Distributions of one million DVCS pseudo-events generated with EpIC (histograms) using inputs from the PARTONS framework compared to model predictions (solid lines). See Sec. 3.1 of Ref. [1] for the definition of the kinematic variables xB, y, Q2, t, f and fS. Figure from Ref. [1].

References

[1]. E. Aschenauer et al., "EpIC: novel Monte Carlo generator for exclusive processes", Eur. Phys. J. C82 (2022) 819.

[2]. http://partons.cea.fr

[3]. B. Berthou et al., "PARTONS: PARtonic Tomography Of Nucleon Software: A computing framework for the phenomenology of Generalized Parton Distributions", Eur. Phys. J. C78 (2018) 478.

EXOHAD: a new initiative in theoretical hadron spectroscopy in the United States

Prof. Alessandro Pilloni (Università degli Studi di Messina, Messina, Italy), Prof. Adam Szczepaniak (Indiana University, Bloomington, US and Jefferson Lab, Newport News, US)

Research in theoretical hadron spectroscopy in the US has received a significant boost in the form of a Topical Collaboration Grant from the Department of Energy: the ExoHad Collaboration was established, between Indiana University, Arizona State University, Jefferson Lab, Ohio State University, University of Californian Berkley, The George Washington University, College of William & Mary, University of Pittsburg and University of Washington, University of Messina (Italy), University of Barcelona (Spain), and University of Graz (Austria).

Spectroscopy has played, and continues to play, an important role in the development of our understanding of strong interaction. While for many years the picture suggested by the quark model of $\bar{Q}Q$ structure for mesons and QQQ for baryons encapsulated our knowledge of the spin, parity, and flavour quantum numbers of hadrons, the possibility of other configurations of the quarks and gluons of quantum chromodynamics (QCD) remained. Within models built to resemble the dynamics of QCD, and to a certain extent within the numerical calculations of lattice QCD, there are predictions of states built only from glue glueballs, states in which quarks appear with an excitation of the gluonic field hybrids, states which feature more than the minimal number of quarks tetraquarks, pentaquarks, and states which resemble molecular bound states of multiple hadrons. These exotic hadrons provide a laboratory for studying the non-perturbative phenomena that emerge from QCD.

Many fundamental questions concerning the properties of non-perturbative QCD remain open, and it is expected that modern developments in spectroscopy can assist in providing answers. Understanding the confinement of colour and the associated effective gluodynamics, the role of topological features of the QCD vacuum, and the generation of mass can all benefit from reliable determinations of the spectrum of hadrons, and in particular of the ones with explicit gluonic degrees of freedom. While hints of glueballs and hybrid mesons have been found experimentally, to date no candidate has been overwhelmingly convincing.

It is in this context that the ExoHad project was proposed, in order to build a broad collaboration to attack the threefold problem of predicting exotic resonances and their properties from lattice QCD, reliably extracting exotic resonances and their production and decay properties from experimental data sets, and finally interpreting both the experimental and theoretical results.

The field indeed is entering a period where unprecedented data sets will probe the light hadron sector – there are several experiments running or in the development stage which make use of either novel production methods, high statistics, or both. At Jefferson Lab, the GlueX experiment was built to study the spectrum of hybrids, and is now accumulating orders of magnitude more data in polarized photoproduction of multi-meson final states than has ever before been available, with additional support from CLAS12 through the closely related quasi-real photoproduction process. Most multi-hadron production processes populate many quantum numbers simultaneously, such that the final state invariant mass distributions will contain the combined effect of all relevant resonances. Progress is usually made by separating the different quantum numbers in a partial-wave analysis which makes use of the angular distribution of the final state hadrons. This work is typically done within experimental collaborations with little or no involvement from theorists. A common problem with this is that the assumptions and approximations made in one experimental analysis can prove to be incompatible with those made in another. This can lead to contradictory results for derived quantities such as hadron masses and widths (or even the existence of the state in question), and this model dependency can lead to significant and long-standing confusion.

The ExoHad collaboration proposes to rise to the challenge presented by modern complex datasets by building analysis frameworks that impose upon the amplitudes the most important general constraints of scattering theory, such as unitarity, causality, and crossing symmetry, together with QCD-specific constraints. The intention here is to bring the description of experimental data as close as possible to the true amplitudes. One expects this approach will reduce the degree of model dependency introduced into the analysis, and by doing so reduce the level of confusion generated when experiments appear to disagree.

In principle, both the amplitudes and any resonances appearing in them should be calculable from QCD. The only general-purpose theoretical tool currently at our disposal which proceeds from first principles is lattice QCD, an approach in which the theory is studied numerically by discretizing on a finite grid of space-time points. The application of lattice QCD to problems in hadron spectroscopy has undergone a rather rapid evolution, but the three-hadron sector relevant to hybrid searches is still in its infancy. The ExoHad collaboration envisions developments in formalism and in the explicit computation of hadron scattering problems on the lattice.

The final component of the ExoHad three-pronged attack is phenomenology. While lattice field theory has the advantage of being a first principles approach, internal dynamics can sometimes be obscured by the numerical approach – the use of models comes into its own here. We know that the flux-tube model of gluodynamics is incorrect in many of its predictions for the spectrum of hybrid mesons; alternatively, the spectrum as obtained in lattice QCD can be reasonably well described in terms of an effective axial gluon degree-of-freedom. The results obtained in these studies can inform more general models with the intent of smoothly bridging heavy and light quark phenomenology. For example, the search for light hybrid mesons at Jefferson Lab will benefit from a broad understanding of the coupling of hybrid mesons to photons, and their decay to stable hadrons. ExoHad will outline research in a model building that seeks to enhance the interpretation of lattice QCD computations and to aid in the identification of exotic hadrons.

Theory Alliance for the EIC

Marco Radici (INFN, Section of Pavia University, Italy) and Piet Mulders (Theory Group of Nikhef and Department of Physics and Astronomy, Faculty of Science, VU Amsterdam, Netherlands)

In February 2023 a large number of theorists working in the areas of hadron physics and quantum chromodynamics submitted a White Paper to the US NSAC Long Range Plan committee for Nuclear Physics. The document outlines the case for the creation of an EIC Theory Alliance. The EIC will be a unique and versatile facility that will enable the understanding of some of the most compelling questions in the physics of the strong nuclear force. To fully exploit the potential of the EIC, a focused theory effort will be required. The goal of the EIC Theory Alliance is to provide support and stewardship of the theory effort in EIC physics by promoting EIC theoretical research and contributing to workforce development through support of graduate students, fellowships for theoretical postdocs, bridge positions at universities, short and long term visitor programs, organization of topical schools and workshops. The EIC Theory Alliance will be a membership organization, open to participation by anyone in the community who is interested in EIC physics. Many of the European theorists involved in this White Paper are active in the STRONG-2020 EU project.

The STRONG-2020 Public Lecture Series – four new lectures!

Luca De Paolis (LNF-INFN, Italy), Web manager responsible for STRONG-2020

The series of the STRONG-2020 public lectures continued with four lectures, which dealt with various aspects of the strong interaction and research in this field. On October 13, 2022, professor Werner Riegler, CERN (Switzerland), gave a lecture entitled "How progress is made in fundamental science - cutting-edge instrumentation". The lecture was centred on the significance of precise measurements in advancing our knowledge of the natural world. The speaker presented a series of detailed examples that highlighted how cutting-edge instruments, enabled by technological progress, have played a pivotal role in major discoveries across multiple fields of physics, ranging from particle physics and high-energy physics to astrophysics. The lecture provided an accurate overview of the principles and technologies used in state-of-the-art particle detectors. In conclusion, the speaker outlined the challenges that lie ahead in developing even more advanced tools for future discoveries.

On November 21, 2022, Pepe Gülker and Stephan Aulenbacher, from the Institute for Nuclear Physics in Mainz (Germany) held a virtual guided tour through the electron accelerator facility MAMI, in Mainz. During the lecture, which accompanied the visit, the speakers presented an overview of the MAMI facility, covering the essential components from the electron source to the target. The accelerator's functionality was explained, along with a detailed description of the fundamental devices installed. The speakers also explained and discussed the physics of the ongoing experiments, with an eye on future perspectives.

On March 1, 2023, Juan Rojo, Professor of Theoretical Physics Department of Physics and Astronomy (VU Amsterdam), gave the lecture: "The Heart of Matter: The Secret Inner Life of Protons". The talk was focused on the nature of visible matter in the Universe, emphasizing that more than 99.9% of it is composed of protons and neutrons, which make up the atomic nucleus of known elements. Initially thought to be fundamental particles like electrons, they were later discovered to have a complex substructure consisting of constituents such as quarks and gluons. Many of the proton's key properties, such as mass, intrinsic angular momentum, and 3D distributions, emerge in a non-trivial manner from the behaviour of these constituents. Large accelerators like the Large Hadron Collider (LHC) at CERN in Geneva, provide the means to study these constituents in greater detail. The speaker provided an overview of our current understanding of proton substructure, highlighting recent breakthroughs such as the discovery of proton constituents heavier than the proton itself.

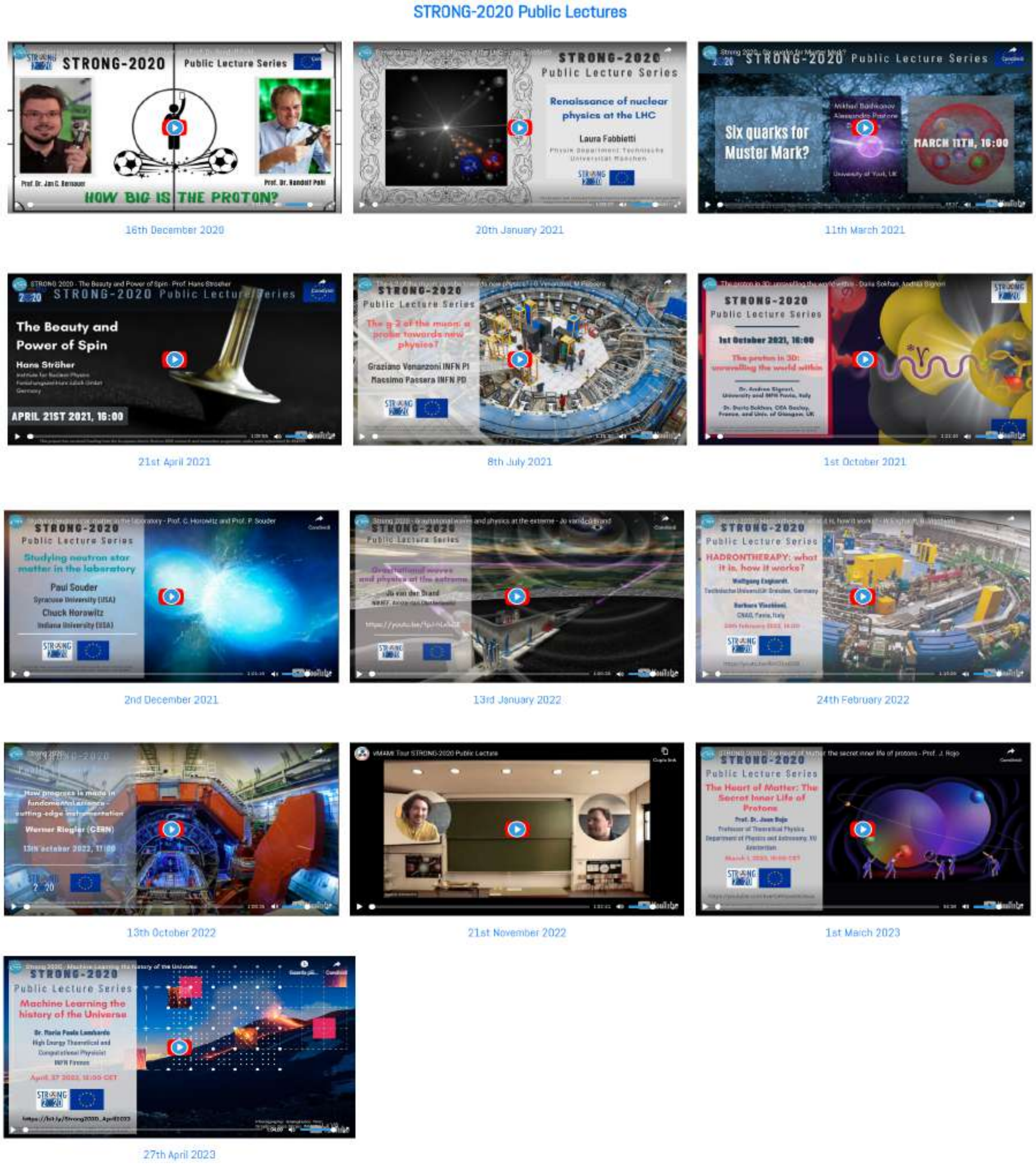

Figure 1: Picture of the complete series of STRONG-2020 public lectures performed in the framework of the STRONG-2020 project. The lectures are aimed both at a qualified scientific public and at students or amateurs who want to deepen the topics of modern physics, and can be found on the dedicated section of the STRONG-2020 website: (http://www.strong-2020.eu/events/live-events.html).

On April 27, 2023, Dr. Maria Paola Lombardo, Researcher of the National Institute of Nuclear Physics (INFN) in Florence (Italy), gave the lecture: “Machine Learning the history of the Universe”. Machine Learning is a sector of Artificial Intelligence, which is routinely used to identify patterns and classify objects, so their application to the analysis of different states of matter is quite natural. The lecture described the main features of Machine Learning which are useful in the analysis of the history of the Universe, narrated some salient features of this history and presented some of the successes of Machine Learning in this field together with future challenges.

The Public Lectures can be found at the links:

https://www.youtube.com/playlist?list=PLRuUrPCVPFIqjT_o4A7iPEPj26N_OOA6s
and on the STRONG-2020 dedicated web page:
http://www.strong-2020.eu/events/live-events.html

STRONG-2020 supported INSPYRE 2023 International School

Catalina Curceanu (LNF-INFN, Italy), WP2: DISCO

INSPYRE, International School on Modern PhYsics and Research, is an advanced modern physics international school organized by INFN at the Laboratori Nazionali di Frascati for high-school and college students highly interested in science. 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, medical doctors and even lawyers and economists. The 2020, 2021 and 2022 editions – due to the pandemic situation – were organized online. In 2023 INSPYRE we returned, finally, in presence.

STRONG-2020 supported the 2023 edition of the INSPYRE School, having as sub-title: “From Quarks to Black Holes: let’s get INSPYRED!” The school was based on interactive presentations and hands-on experiments related to the most recent exciting results, technologies and future perspectives in our investigations of the Universe, from Quarks to Black Holes, and their impact on society.

Experimental and theoretical investigations within the Standard Model of particle physics, hadronic and nuclear physics, as well as searches of new physics, beyond the Standard Model, performed at various laboratories, including accelerators and underground laboratories, were addressed by experts in the field.

9 different hands-on experiments and visits at the Visitor Centre of the Laboratori Nazionali di Frascati were organized, being very much appreciated by the participants.

With its very rich program, INSPYRE 2023 was held in the period of 27-31 March 2023; 81 high-school students from various countries in the world (Armenia, France, Germany, Italy, Romania, Serbia, Slovenia) enthusiastically participated in this edition.

More information, including the program, can be found on the web-page of the INSPYRE 2023 event: https://edu.lnf.infn.it/inspyre-2023/

An Interview to Dr. Mostafa Hoballah, Researcher of STRONG-2020 WP23 (JRA5)

Interview made by Raphaël Granier de Cassagnac (IN2P3-CNRS, France)

Mostafa, could you introduce yourself and your research field?

My undergraduate studies were purely focused on theoretical physics. During my Master II internship I was introduced to research in experimental physics: I worked on the study of the generalized polarizabilities of the proton using data from the Virtual Compton Scattering experiment at Mainz Microtron (Germany). During my Ph.D. thesis (at LPC Clermont Ferrand), I worked on the measurement of the photon polarization in B0s → φγ at LHCb, an interesting analysis and one of the key measurements of the LHCb physics program. After my thesis defense, I pursued studies in philosophy of sciences at the Université Blaise Pascal in Clermont Ferrand (France). At the same time, I had a growing interest in the domain of research in hadronic physics and I hence started a postdoc directed towards studies of the proton structure through electron-proton elastic scattering. I focused my work on the development of the physics program for an experiment dedicated to measuring the proton's electric form factor at low four-momentum transfer and on the conception and characterization of its electromagnetic calorimeter. I got partly involved in the activities of the JLab team at IJCLab. To my fortunate luck, a postdoc position funded by STRONG-2020 opened in the same group: I seized the opportunity and was hired. I then started to study Nucleon structure as described by the Generalized Parton Distributions (GPDs) in addition to work dedicated to the reconstruction of algorithms of the Central Neutron Detector, a subdetector of the CLAS12 spectrometer at JLab (USA). At the end of this postdoc, I applied to an open CNRS position and became a permanent researcher at CNRS.

How did your career as a researcher affect your perception of nature?

During my studies, I had the chance to alternate from theoretical physics to experimental physics, and from the high-energy research domain to low-energy particle physics. I have acquired knowledge and techniques in one domain that were extremely beneficial in the other, and vice-versa. On top of that, I studied philosophy of science which made things more exciting at the conceptual level and paved the path to a better understanding of natural physical concepts. Before getting involved in experimental physics, conventions and normalization factors were merely mathematical entities that contribute marginally to the understanding of nature. It is only when I started doing experimental physics that the link between mathematical equations and empirical evidence in nature became concrete. This should not be confused with a positivist approach to understanding statements about nature; I can only claim that I hold both rational and irrational, logically founded, beliefs about different topics including, but not limited to, verifiable hypotheses by experimentation, as is the case in physics.

When did you decide to be a researcher? Was it a child's desire or a recently born passion?

I would say more likely a child's desire. We grew up in a family that motivated us to study and research. My father and two of my uncles are researchers and lecturers in theology and comparative religion. My grandfather is also a theologian. There is a strong correlation between the environment we grew up in and the fact that I became a researcher. By the way, all my siblings are also involved in research.

How did STRONG-2020 help you in achieving your research goals?

Before I was hired for the postdoc funded by STRONG-2020, I was preparing myself to move abroad and go find a position in the USA to maintain my research activities in hadronic physics and nucleon structure. I didn't like the idea of leaving Europe and moving to the USA, although people were trying to convince me that there is more money to be earned there. The job opening with STRONG-2020 funding came as a salvation and allowed me to stay in Europe and continue my research activities in a healthy manner. By the end of my postdoc, a permanent CNRS position opened, specifically devoted to hadronic physics, and as I was already very involved in both the research theme and the research group at IJCLab, I seized the opportunity and applied for the position. The transition between the postdoc and the permanent job was extremely smooth.

During your postdocs, how did you balance a demanding research activity with a youngster's life?

The thing about research is that even when you are not actually working in the proper sense of the term, you are still working with a well engaged mental state. Your mind never stops thinking about issues ranging from the little technical things that you encounter when analyzing data to the bigger questions of interpreting the obtained results while trying not to have any bias. Fortunately, my wife is also a researcher; this made balancing work and family life rather easy. And of course, with the advantage that we have with allowed vacation days, I was able to have a lot of fun vacations with my kids.

The work package you worked for is about Generalized Parton Distributions. In your opinion, what is the most important result obtained so far?

There have been a lot of interesting results concerning GPDs. We were able to produce a "tomographic" image of the proton combining results obtained from JLab (USA) data and other GPD-aimed experiments (HERMES). This is interesting in the sense that it conveys an image of the nucleon where valence quarks are concentrated in its center. We managed to study the mechanical properties of the nucleon, more precisely its pressure distribution. Personally, the analysis I have started during my postdoc, of Deeply Virtual Compton Scattering data that mainly adds constraint on the least constraint GPD (called GPD E) of the neutron, is the most appealing to me. My results are of particular interest as they will allow me to quantify the contribution of the quark's orbital angular momentum to the total spin of the nucleon. Moreover, they provide more constraints to an eventual separation of GPDs in terms of quarks flavor.

How do you see the future of GPD measurements and interpretation?

I hold the belief that – following Candide from Voltaire in reference to Leibniz – we live in the best possible world and things therefore are going to be better. A quantified statement, more appealing scientifically, would stress the fact that the JLab physics programme is advancing in an efficient manner with a foreseen energy upgrade and the addition of a positron beam, allowing to extend the phase space for GPDs studies and to measure new observables related to beam charge, and the more observables we measure, the more GPDs we can extract. Moreover, the Electron Ion Collider, EIC, is on its way with promising measurements of the relevant gluon GPDs. Our group is heavily involved in its physics program and in the construction of a major part of the electromagnetic calorimeter.

What is the most exciting aspect of being a researcher in Europe, according to you?

My answer here would clearly be biased. I came from Lebanon to France to do research and was acquainted with the European researcher lifestyle although my work now is focused on physics done in the USA. What I appreciate the most is the freedom that I have when doing research and the possibilities that are available for a researcher given the existing research facilities and the sophisticated and well performing machines that are present at a relatively close distance.