ECT*
EUROPEAN CENTRE
FOR THEORETICAL STUDIES
IN NUCLEAR PHYSICS AND RELATED AREAS

FONDAZIONE
BRUNO KESSLER

ANNUAL REPORT 2020

European Centre for Theoretical Studies
in Nuclear Physics and Related Areas
Trento | Italy

Institutional Member of the European Science
Foundation Expert Committee NuPECC

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Contents

Preface

The European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*) has been established in 1993 in a bottom-up approach by the European nuclear physics community and is an Institutional Member of the European Expert Committee NuPECC (Nuclear Physics European Collaboration Committee). Since 2008 it is one of the Research Centres of the Fondazione Bruno Kessler (FBK). Its objectives – as stipulated in its statutes – are:

- to provide for in-depth research at the forefront of contemporary developments in nuclear physics;
- to foster interdisciplinary contacts between nuclear physics and neighbouring fields such as computational physics, astrophysics, condensed matter physics, particle physics and the quantum physics of small systems;
- to encourage talented young physicists to participate in the activities of the ECT*;
- to strengthen the interaction between theoretical and experimental nuclear physics and related areas.

The year 2020 was special due to the Covid-19 pandemic which resulted in an almost complete shut-down of the scheduled on-site activities for external visitors, including workshops, the Doctoral Training Program and the in-person TALENT School. Out of the 19 workshops selected and approved by the ECT* Scientific Board only the first one could be run as an in-person event. Most of the others have been deferred to 2021, except for two that were run remotely. To ensure the scientific visibility of the postponed workshops, the Scientific Board, in coordination with the Director, has initiated a series of online "introductory colloquia" which are intended to publicize the pertinent topics of the workshop to a wider audience.

As a result of the severe restrictions of in-person visits, only 43 scientists from 5 countries have visited physically the ECT* in 2020 and have participated in the activities of the Centre. In addition, 391 scientists have participated in the online events that were necessitated by the almost complete lockdown for outside visitors. Nonetheless, through its high-profile local research program and the various online activities ECT* was able to maintain its worldwide visibility and its key importance for the European and international nuclear physics communities.

In summary, in 2020, ECT* held the following scientific events:

- 3 Workshops (two of which were run remotely) on recent developments in the determination of the electron (anti)-neutrino mass, the role of spin in the hydrodynamics for relativistic heavy-ion collision and recent advances in many-body theories including quantum computing and machine learning.

- a TALENT School (on-line) on "*Machine learning applied to nuclear physics, experiment and theory*" that lasted three weeks and was attended by 157 students from 38 countries worldwide.

In addition to the 4 scientific events, on February 18, 2020, ECT* organized a one-day in-person meeting to commemorate and honor the important role of Professor Renzo Leonardi in creating the Center in Trento. Renzo passed away unexpectedly on July 6, 2019. Aside from welcome addresses by the ECT* Director, and distinguished representatives from the FBK, the University of Trento and the Autonomous Province of Trento, two lectures were given, highlighting the achievements of Renzo in shaping the scientific and cultural landscape of Trento, the Trentino region and beyond. On this occasion, the ECT* meeting room in the Rustico was renamed as 'Aula Renzo Leonardi' and the ground and second floor 'Fresco rooms' of Villa Tambosi were dedicated to him with a commemorative plaque on the ground floor.

In addition to scientific events, ECT* supported:

- basic research on nuclear structure and reactions, non-perturbative QCD and hadron physics, the theory of hadronic and nuclear collisions at high energy, phases of strong- interaction matter, nuclear astrophysics and neutron stars, many-body theory and computational physics. This research was performed by the in-house group of Junior Postdoctoral Fellows and Senior Research Associates in close interaction with each other, with the Director of the Centre, and with scientific visitors and collaborating physicists elsewhere. The research activities of the Centre are documented in detail in Chapters 4 and 5 of this Annual Report. Altogether, 23 publications by the ECT* and ECT*-LISC researchers in refereed journals represent a sizable fraction of all publications produced in 2020 within the Fondazione Bruno Kessler in the same year.
- ECT* previously established international cooperation agreements with major research institutions in Japan (RIKEN Nishina Centre, the Advanced Science Research Center ASRC of JAEA and NAOJ, the National Astronomical Observatory), Korea (the Asian Pacific Centre for Theoretical Physics, APCTP), China (the ITP of the Chinese Academy of Sciences), Russia (JINR in Dubna, the Joint Institute for Nuclear Research), and the Swiss National Science Foundation (SNSF).

These initiatives continue to create joint activities in the workshop program of ECT* and have contributed further to the highly visible international profile of the Centre.

The existence and the continuing success of ECT* rests upon the "bottom-up" initiatives, pursued by the physics communities in Europe and worldwide. Maintaining ECT*´s high level of scientific activity and visibility in 2020 has only been possible through a stable operating budget in recent years. We gratefully acknowledge the local support from the FBK/PAT, the contributions from European funding agencies and research institutions in Belgium, Croatia, Czech Republic, Finland, France, Germany, Italy, the Netherlands, Poland, Romania, Switzerland and the United Kingdom. ECT* also acknowledges additional partial support for its workshops, received in 2020 from: EMMI (Germany), KIT (Germany) and from INFN Frascati (Italy).

As for the European projects within the new Framework Programme Horizon 2020, the ENSAR2 project has started on March 1, 2016 and continues to run until August 31, 2021. The Strong2020 project started on June 01, 2019 and will end on May 31, 2023. Its transnational access activities have not supported any workshops in 2020.

As my term as ECT* Director has ended on December 31, 2020, I would like to take the opportunity to thank the members of the Scientific Board, the scientific staff – and last but not least – the highly competent administrative and technical staff of the ECT* for their dedicated cooperation over the last five years. I also wish to convey special thanks to the organizers of the TALENT School, Morten Hjorth-Jensen, Daniel Bazin, Michelle Kuchera, Sean Liddick and Raghuram Ramanujan.

As its predecessors the Annual Report of 2020 is available on the ECT* website (www.ectstar.eu).

Trento, April 2021

Jochen Wambach
Director of ECT*

Scientific Board, Staff and Researchers

1. Scientific Board, Staff and Researchers

1.1 Scientific Board and Director

Gert Aarts (Chairman)	Swansea University, UK
Carlo Barbieri	University of Surrey, UK
Anna Corsi	IRFU/DPhN, France
Marcella Grasso	CNRS-INP Orsay, France
Morton Hjorth-Jensen	Michigan State Univ., USA and Univ. of Oslo, Norway
Marek Lewitowicz	NuPECC/GANIL, France
Martin Savage	INT & Univ. Washington, Seattle, USA
Marc Vanderhaeghen	University of Mainz, Germany
Urs Wiedemann	CERN-TH, Switzerland
Sandro Stringari (Ex officio)	University of Trento, Italy

Honorary Member of the Board

Ben Mottelson	NORDITA, Copenhagen, Denmark

ECT Director*

Jochen Wambach	ECT*, Italy and TU Darmstadt, Germany

1.2 Resident Researchers

- *ECT* Researchers*

Daniele Binosi, Italy*
Francesco Celiberto, Italy (from 02/11)
Minghui Ding, China
Jarkko Peuron, Finland (until 30/09)
Alessandro Pilloni, Italy (until 31/10)
Saga Aurora Säppi, Finland (from 01/10)
Dionysis Triantafyllopoulos, Greece*
Shu-Yi Wei, China

- *ECT*/LISC Researchers*

Maurizio Dapor, Italy (Head of ECT*-LISC Research Unit)*
Pablo de Vera Gomis, Spain (From 02/11)
Giovanni Garberoglio, Italy*

Andrea Pedrielli, Italy
Simone Taioli, Italy*
Paolo Trevisanutto, Italy

- *ECT*/TIFPA Researchers*

Hilla De Leon, Israel
Constantinos Constantinou, Cyprus (from 03/08)

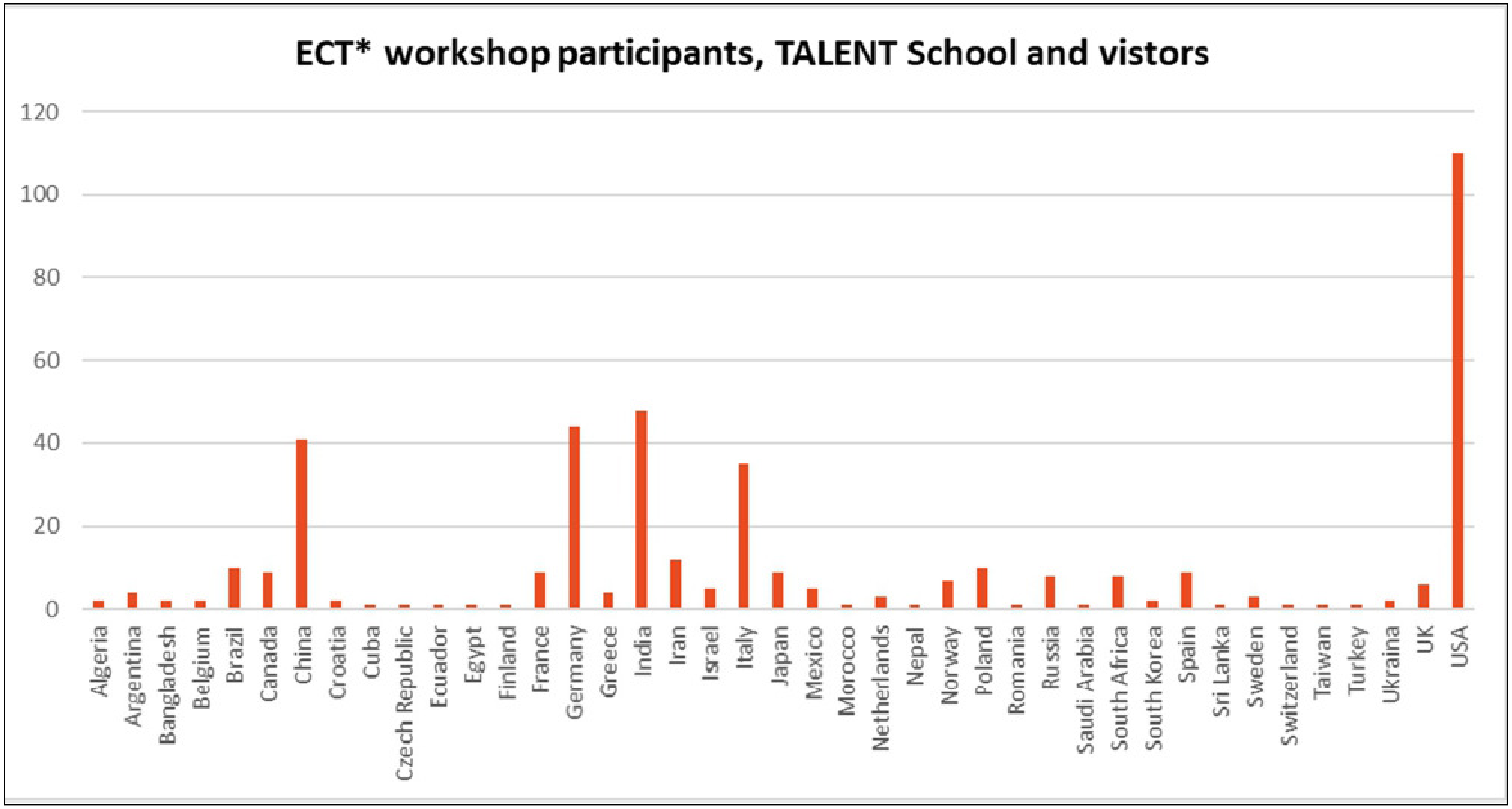
*Permanent Researchers

1.3 Staff

Susan Driessen (part time)
Barbara Gazzoli
Michela Chistè

1.4 Visitors in 2020

Jan Franz (03-14/02)	Gdansk University of Technology, Poland (VS)
Malgorzata Franz (03-14/02)	Gdansk University of Technology, Poland (VS)


ECT* workshop participants, TALENT School and vistors
120
100
80
60
40
20
0
Algeria
Argentina
Bangladesh
Belgium
Brazil
Canada
China
Croatia
Cuba
Czech Republic
Ecuador
Egypt
Finland
France
Germany
Greece
India
Iran
Israel
Italy
Japan
Mexico
Morocco
Netherlands
Nepal
Norway
Poland
Romania
Russia
Saudi Arabia
South Africa
South Korea
Spain
Sri Lanka
Sweden
Switzerland
Taiwan
Turkey
Ukraina
UK
USA

Scientific Projects in 2020

2. ECT Scientific Projects in 2020

2.1 Summary

Altogether 4 scientific projects have been run in 2020: 3 workshops (2 online), and a Talent School (online). This chapter collects the scientific reports written by the workshop organizers, and by Morten Hjorth-Jensen who coordinated the TALENT School.

2.2 Workshops and Schools (Calendar)

Feb 10-14	*Determination of the Effective Electron (Anti)-Neutrino Mass* L. Gastaldo (University of Heidelberg) K. Valerius (KIT)
June 22 - July 10	*TALENT School: Machine Learning Applied to Nuclear Physics, Experiment and Theory (Online)* M. Hjorth-Jensen (University of Oslo and MSU) D. Bazin (MSU) M. Kuchera (Davidson College) S. Liddick (MSU) R. Ramanujan (Davidson College)
Oct 5-16	*Spin and Hydrodynamics in Relativistic Nuclear Collisions (Online)* F. Becattini (University of Florence and INFN) W. Florkowski (Jagellonian University, Krakow) X.-G Huang (Fudan University) D. Rischke (Goethe University Frankfurt)
Nov 2-6	*Advances in Many-Body Theories: From First Principle Methods to Quantum Computing and Machine Learning (Online)* M. Hjorth-Jensen (University of Oslo & MSU) D. J. Dean (Oak Ridge National Laboratory) T. Papenbrock (University of Tennessee & Oak Ridge National Laboratory) M. Savage (INT & University of Washington) G. Haugen (Oak Ridge National Laboratory & University of Tennessee) S. Gandolfi (LANL) J. Holt (TRIUMF-Vancouver)

2.3 Workshop Reports

2.3.1 *Determination of the Effective Electron (Anti)-Neutrino Mass*

Date	February 10-14, 2020
Organizers	
Loredana Gastaldo	University of Heidelberg, Germany
Kathrin Valerius	KIT, Karlsruhe, Germany
Number of Participants:	39

Main topics

The knowledge on the absolute neutrino mass scale could provide a key to theories complementing the Standard Model of elementary particles. Since the analysis of cosmological observations is approaching sensitivities close to the minimal allowed sum of neutrino masses and experiments searching for neutrinoless double beta decay are getting more sensitive, the quest for results from direct searches for the electron (anti-)neutrino mass by means of kinematic analysis is becoming very pressing.

Presently two isotopes are at the center of experimental activities: ^{3}H and ^{163}Ho. KATRIN,Project 8 and PTOLEMY using ^{3}H and ECHo and HOLMES using ^{163}Ho aim to reach sub-eV sensitivity within the next few years.

The objective of this 3rd workshop was to foster the exchange between theorists and experimentalists in the light of new results achieved by experiments and to offer a unique platform for discussions about future approaches to extend the sensitivity of kinematic measurements of the neutrino mass below 100 meV. The main topics were the following:

- Neutrino oscillations – theory and experimental data
- Physics implications of neutrino mass
- Role of massive neutrinos in cosmology and astrophysics
- Cosmic Neutrino Background
- ^{3}H-based experiments
- ^{163}Ho-based experiments
- Modelling and interpretation of the measured ^{3}H and ^{163}Ho spectra
- Challenges related to the ^{3}H and ^{163}Ho source
- Challenges for detector and read-out systems
- Identification and suppression of background sources
- Sensitivity of ^{3}H- and ^{163}Ho-based experiments to sterile neutrinos
- New approaches for investigating neutrino properties.

The workshop programme comprised 30 topical talks, one summary talk and the presentation of 9 posters. The names of the speakers and the poster presenters are listed below.

Speakers

Arnulf Barth	KIP, University of Heidelberg, Germany
Cristina Benso	MPIK Heidelberg, Germany
Massimo Blasone	Università di Salerno, Italy
Matteo Borghesi	Università Milano Bicocca, Italy
Christine Claessens	University of Mainz, Germany
Guido Drexlin	KIT, Karlsruhe, Germany
Christoph Düllmann	University of Mainz, Germany
Joseph Formaggio	MIT, Cambridge, USA
Giovanni Gallucci	INFN Genova, Italy
Carlo Giunti	INFN Torino, Italy
Maurits Haverkort	ITP, Heidelberg University, Germany
Josef Jochum	University of Tübingen, Germany
Alec Lindman	University of Mainz, Germany
Alexey Lokhov	University of Münster, Germany
Federica Mantegazzini	KIP, Heidelberg University, Germany
Susanne Mertens	MPP & TUM, Munich, Germany
Angelo Nucciotti	Università Milano Bicocca, Italy
Antonio Palazzo	INFN Bari, Italy
Werner Rodejohann	MPIK Heidelberg, Germany
Marco Röllig	KIT, Karlsruhe, Germany
Alejandro Saenz	Humboldt University, Berlin, Germany
Ninetta Saviano	INFN Napoli, Italy
Magnus Schlösser	KIT, Karlsruhe, Germany
Daniel Siegmann	MPP Munich, Germany
Martin Slezák	MPP Munich, Germany
Juoni Suhonen	University of Jyväskylä, Finland
Christopher Tully	Princeton University, USA
Francesco Vissani	LNGS & GSSI, Italy
Mathias Wegner	KIP, Heidelberg University, Germany
Klaus Wendt	University of Mainz, Germany
Motohiko Yoshimura	Okayama University, Japan

Poster presenters

Fabian Block	KIT, Karlsruhe, Germany
Martin Braß	University of Heidelberg, Germany
Alexander Göggelmann	University of Tübingen, Germany
Cecilia Ferrari	Università Milano Bicocca, Italy
Nina Kneip	University of Mainz, Germany
Marc Merstorf	University of Heidelberg, Germany
Caroline Rodenbeck	University of Münster, Germany
Talia Weiss	MIT, Cambridge, MA, USA
Motohiko Yoshimura	Okayama University, Japan

Scientific report

The quest for the determination of the neutrino mass scale remains one of the most pressing challenges in contemporary (astro-)particle and nuclear physics. The special role of the neutrino as the lightest fermion and the most abundant massive particle species in the Universe leads to important implications for elementary particle physics, astrophysics and cosmology alike. The determination of absolute neutrino masses, in addition to the relative splittings which are observed through neutrino oscillations, allows important insights into extensions of the well-tested Standard Model of particle physics. Precision measurements of the kinematics of weak decays in unstable nuclides are regarded to be the approach to address this question which is less dependent on theoretical models. Present experimental efforts to measure neutrino masses are focused mainly on two particularly suitable nuclides: ^{3}H, which undergoes beta decay, and ^{163}Ho, which decays through electron capture. These efforts are targeted at reaching sub-eV sensitivity with respect to the effective electron (anti-)neutrino mass.

Three large experiments will be examining the spectral endpoint region of electrons emitted in ^{3}H beta decays: KATRIN, Project 8 and PTOLEMY. Likewise, two large experiments are addressing the precise calorimetric measurement of the ^{163}Ho electron capture spectrum: ECHo and HOLMES. The success of these experiments relies on a multidisciplinary approach in which particle physics, nuclear physics, atomic physics and statistical physics are strongly interconnected. Moreover, the development of cutting-edge techniques for ultra-precise detector fabrication, identification and suppression of background, and advanced data analysis tools play a crucial role.

The goal of this workshop thus was to bring together theorists and experimentalists involved in the above-mentioned efforts to discuss recent advances in the fields of neutrino mass phenomenology and direct neutrino mass measurements. In 2016 a first workshop at ECT* dedicated to the determination of the (anti-)neutrino mass and implications of this observable in fields like particle physics and cosmology attracted more than 50 physicists from different universities and scientific institutes around the world. Among them were numerous PhD students who had the possibility to present their work with posters and discuss with distinguished experts. For the 2018 as well as this year's editions, we continued along the successful concept of combining experimental/theory/interlacing topics, and we strived to maintain the well-proven participants mixture of senior experts and early-career researchers. About two thirds of the presentations were given by senior key speakers, while one third was reserved for postdoctoral and doctoral researchers. For the third time already, this concept was perceived by the attendees as very fruitful and beneficial to the workshop goal.

The number of talks has been reduced from 43 (resp. 35) in the 2016 (resp. 2018) editions of the workshop to 31 this year, in order to leave ample time for individual discussions and group work on common topics and future goals. This structural adaptation of the 3rd workshop program caters to the needs of our fast-developing field, in which several large experiments have commenced data-taking after long preparation phases, and new ideas for future directions are being discussed. The presentation-free afternoon in the middle of the week was used for various on-site meetings of subgroups among the participants.

The presentation programme (see timetable below) was composed of 40-minute introductory & overview talks and shorter talks of about 25 minutes. The final session was devoted to a summary talk and a concluding discussion in the plenum.

The overview talks covered the following topics:

- Update on the recent results related to neutrino oscillation experiments (1 talk Palazzo)
- Implications of neutrino masses in particle physics and cosmology (2 talks Blasone, Saviano)
- Status reports of the individual ^{3}H and ^{163}Ho direct neutrino mass experiments (5 talks)
- Review of current activities in the neighboring field of neutrinoless double beta decay (2 talks Suhonen, Vissani)
- New approach for the determination of neutrino properties (1 talk Yoshimura)
- The current picture of sterile neutrino phenomenology and the prospects of searching for sterile neutrinos in direct kinematical experiments (2 talks Mertens, Giunti)
- Determination of important experimental parameters for direct neutrino mass determination (Ho-163 theory tritium molecular final states; 2 talks Haverkort, Saenz).

The shorter talks were dedicated to the challenges in various complementing aspects of the experiments and proved very useful in illuminating the different approaches used by the individual collaborations, for example for the production/purification/handling of the radioactive ^{3}H and ^{163}Ho sources or for the identification and suppression of major background sources.

One afternoon session was reserved for the poster session. The very positive experience of the poster session as a driver for lively exchange and communication, with which we had already been rewarded in the two previous editions, was confirmed once more this time. The participants greatly appreciated the particular success of the overall workshop concept in bringing together established experts of the field with young researchers.

On a side note, we would like to point out the excellent technical capability for remote presentations provided by ECT* through the BlueJeans video conferencing system. In fact, due to a variety of unexpected external travel constraints, a few of our participants could not join us in person in Trento. Nevertheless, we were still able to benefit from their contributions by virtue of video conferencing, and the technical experience (as related to the organizers by numerous participants of the workshop) was very positive.

Results and Highlights

The workshop week at ECT* has revealed that, indeed, this is an exciting period in the combined efforts of direct neutrino mass determination.

Tremendous experimental progress in the two intervening years since the previous workshop at ECT*:

(a) *Tritium-based experiments:* The first few-week science run of KATRIN has yielded a new upper limit on the effective electron anti-neutrino mass (now at 1.1 eV/c^2 at 90% C.L.) which is improved by almost a factor of 2 with respect to predecessor experiments.

KATRIN is entering long-term data-taking with high statistics to exploit its full sensitivity of 0.2 eV/c^2. First analyses constraining the parameter space of light sterile neutrinos at the eV scale were discussed at the workshop. An upgrade of the KATRIN detector system to expand the reach towards keV sterile neutrinos as Dark Matter candidates is in preparation, with advanced prototypes presented at the workshop.

Project 8 has recorded first tritium data in its phase II configuration and is collecting more statistics; R&D progress towards the large-volume phase III detector and for phase IV featuring an atomic tritium source to ultimately address the hierarchical neutrino mass scale was presented. PTOLEMY has made considerable steps forward in outlining a new conceptual design of the experiment to look for a capture signal of cosmic relic neutrinos on tritium and clearly to precisely define the mass scale of neutrinos.

(b) *Holmium-based experiments:* ECHo-1k is taking data and has already delivered an improved upper limit on the electron neutrino mass with just 4 days of measurement as a proof of concept. Continued data-taking with two arrays is targeting a sensitivity of 20 eV/c^2 - more than a factor of 10 improved w.r.t. previous experiments. The design of the new ECHo-100k detectors is ready and first chips have been produced to be used for the second stage of the experiment for achieving sub-eV sensitivity. The HOLMES detector design is fixed and characterized, and the apparatus is being prepared for first holmium implantation in anticipation of the first EC spectra.

(c) *Theoretical description of ^{3}H and ^{163}Ho spectra:* In order to achieve sub-eV sensitivity on the effective electron (anti-)neutrino mass, a precise knowledge of the expected spectra is of utmost importance. While for ^{3}H high-accuracy calculations have already been discussed in the previous years and this time could be integrated with a precise comparison between two different calculation approaches, for ^{163}Ho a large discrepancy between data and theory was reported in previous years. A new ab-initio theory has been recently developed leading to a better match between theory and experiments.

(d) *Observables related to massive neutrinos:* The update on the recent results on oscillation parameters and the discussion about future perspective of short and long baseline experiments point towards a precise definition of the PMNS matrix for the three-flavour scenario. The existence of sterile neutrinos would actually modify the sensitivity of oscillation experiments, but the possibility to gain information from experiments for the kinematic measurement of neutrino masses could reduce the uncertainties. The neutrino mixing description was discussed also in light of a QFT approach which lead to very interesting discussions. Similarly, constructive discussions were also generated by the perspective of present and future double beta decay experiments, in particular about the reliability of deducing a value of the effective Majorana mass once the half-life of the neutrinoless mode would be determined. A very interesting approach was presented at the workshop to investigate mass and nature of neutrinos using atomic transitions.

Overall achievements of the workshop

We find that the workshop has been very successful in realizing its main objectives. In particular, we would like to summarize the main achievements as follows:

- Exchange between experimentalists and theorists (example: idea for a novel direct dark matter detector in a discussion between a senior theorist and several young experimental researchers; new initiative to improve interpretation of key experimental calibration data from ^{83m}Kr by ab-initio spectrum calculations).
- Transfer of experience between various experimental groups with different instruments and approaches (example: discussions about energy loss measurements of electrons in tritium beta-decay experiments, potential combination of calibration measurements from Project 8 and KATRIN).
- Fostering of discussions among different participating theory groups (example: implications of neutrino-mass measurements, combination of global data, opportunities to search for new physics in precision beta-decay and EC spectra).

In conclusion, the workshop week was very fruitful and – again – extremely well received by the participants. This success is ensured, once more, by the inspiring and welcoming environment offered by ECT* and the support that was provided both to the workshop organization and to the individual participants.

2.3.2 *Spin and Hydrodynamics in Relativistic Nuclear Collisions (ONLINE)*

Date	October 05-16, 2020

Organizers

Francesco Becattini	University of Florence and INFN
Wojciech Florkowski	agellonian University, Krakow
Xu-Guang Huang	Fudan University
Dirk Rischke	Goethe University Frankfurt

Number of participants	105

Main topics

- Relativistic hydrodynamics from a quantum viewpoint
- Spin physics in quantum relativistic theories
- Relativistic nuclear collisions and Quark Gluon Plasma
- Chirality in the Quark Gluon Plasma.

Speakers

T. Niida	University of Tsukuba, Japan
X.-L. Xia	Fudan University, China
Y. Ivanov	Bogoliubov Laboratory Of Theoretical Physics, Russia
I. Karpenko	Czech Technical University in Prague, Czech Republic
Y. Xie	China University of Geosciences, China
Y. Sun	INFN, LNS, Italy
L. Tinti	Frankfurt University, Germany
A. Palermo	Università di Firenze, Italy
G. Prokhorov	Institute of Theoretical and Experimental Physics, Russia
J. Liao	Indiana University, USA
M. Buzzegoli	Università di Firenze, Italy
U. Gursoy	Utrecht University, Netherland
Q. Wang	University of Science and Technology, China
H.-U. Yee	University of Illinois at Chicago, USA
A. Kumar	NISER, India
G. Cao	Sun Yat-Sen University, China
E. Speranza	University of Illinois at Urbana-Champaign, USA
M. Hongo	University of Illinois at Chicago, USA
S. Shi	McGill University, Canada
R. Ryblewski	Institute of Nuclear Physics PAN, Poland
Z. Wang	Tsinghua University, China
Y.-C. Liu	Fudan University, China
A. Sadofyev	ITEP, Russia and USC, Spain
K. Fukushima	University of Tokyo, Japan
G. Inghirami	Frankfurt University, Germany
K. Hattori	Kyoto University, Japan
D.L. Yang	Keio University, Japan

N. Weickgenannt	Frankfurt University, Germany
X.-L. Sheng	CCNU, China
J. Kapusta	University of Minnesota, USA
M. Matsuo	Kavli Institute for Theoretical Sciences, UCAS, China
S. Lin	Sun Yat-Sen University, China
G. Torrieri	UniCamp, Brazil

Scientific report

Spin-polarization observables in experiments and theoretical attempts to explain them

The experimental measurement of the so-called global Lambda polarization in Au - Au collisions at RHIC is one of the most interesting recent developments in relativistic heavy-ion collisions. The workshop started with a talk by Niida, who nicely summarized the experimental status of the global Lambda polarization at RHIC and LHC. He also gave an overview of the experimental results of the local Lambda polarization and vector-meson spin alignment. Theoretical studies of the global and local Lambda polarization were reported by Ivanov, Karpenko, Xie, Sun, Cao, and Q. Wang. The reported results were mainly from two categories of theoretical approaches, one based on kinetic models and the other on hydrodynamics. Karpenko and Xie focused on hydrodynamical models, in which the thermal vorticity was computed through hydrodynamics and then the spin polarization of hadrons was obtained by using a Cooper-Frye-type formula first developed by Becattini et al. The results showed good agreement with the experimental data on global Lambda polarization. Xie also presented a framework based on a mesonic mean field, to explain why the Lambda and anti-Lambda have different magnitudes of global polarization.

However, the results for the local Lambda polarization from hydrodynamical calculations based on the thermal vorticity, as discussed in Karpenko's talk, strongly contradict the experimental data. Q. Wang and Sun offered possible mechanisms to resolve such a contradiction. Q. Wang, in his talk, assumed that the spin potential is governed by the temperature vorticity instead of the thermal vorticity and showed numerically that both the global and local polarization can be tuned to be consistent with data. Sun, based on chiral kinetic theory, showed that once the chiral vortical effect is introduced and the so-called side-jump effect is properly encoded in the kinetic equation, the local polarization puzzle could possibly be resolved. A similar idea appeared also in Ivanov's talk. In particular, Ivanov focused on the lower-energy regime covered by NICA and showed that the chiral-vortical-effect approach predicted a higher polarization at lower energy and more interestingly provided a possible way to understand why anti-Lambda has a higher polarization than Lambda. Cao discussed an important contribution to the measured Lambda polarization that was ignored in some theoretical calculations, that is, the spin transfer from higher-mass hyperons through decay processes. Such a decay effect, however, was shown to be of minor importance for the total spin polarization of Lambda and thus cannot explain the local Lambda polarization puzzle.

In addition to the Lambda polarization, the spin alignment of phi and K* mesons were also measured at RHIC and were reported in Niida's talk. To understand the experimental results, Q. Wang, in his talk, reported a theoretical framework based on quark-coalescence model that connects the 00 component of the spin density matrix of a vector meson to the spin polarization of its constituent quarks. This provided an interesting way to calculate the vector mesons' spin alignment through the quark spin polarization. Xia talked about a local version of the spin alignment, which may arise due to, e.g., the local vorticity induced by the inhomogeneous expansion of the quark-gluon fireball. Interestingly, this local spin-alignment scenario implies a negative 00 component of the spin density matrix in central collisions, which is consistent with the data from RHIC.

As a topic closely related to spin polarization and spin alignment, the chiral magnetic effect has been intensively studied both theoretically and experimentally in recent years. Liao gave an overview of this subject. He presented new results from Anomalous Viscous Fluid Dynamics on the dynamical evolution of the magnetic fields and on the quantitative predictions of the signal of the chiral magnetic effect in isobar collisions. The results supported the idea that isobar collisions could be an ideal system to search for the chiral magnetic effect.

Kinetic-theory developments

Kinetic theory is a widely used tool to study transport phenomena in many-particle systems. In recent years, the kinetic theory with spin degrees of freedom encoded has been intensively studied. Yang gave a review talk about the recent development of quantum kinetic theory of spin transport. He showed that one can adopt a systematic hbar expansion to solve the equation of motion of the Wigner function. Spin as well as chiral-anomaly effects appear from order hbar on. He also discussed how the collision kernel can, in principle, be derived from the Kadanoff-Baym equation. This was further implemented by Sheng in his talk in which he showed that a non-local collision kernel can arise from the hbar expansion of the Kadanoff-Baym equation and also showed how the global equilibrium condition can be derived from it. Weickgenannt discussed another method based on the equation of motion of an interacting fermionic theory from which one can also obtain a similar non-local collision term. In particular, she showed that the non-local collision term can be expressed as position shift of the distribution function and is essential for the spin alignment with thermal vorticity at equilibrium. These results may be used to study the spin diffusion and spin relaxation in quark-gluon plasma which, however, have not been done so far. Instead of using kinetic theory, Kapusta used field theory to calculate the spin relaxation time of strange quarks in both QCD and the NJL model.

Z. Wang talked about another approach of obtaining the Boltzmann-type transport equations from quantum field theory. Her starting point was the equal-time Wigner function and its equation of motion, based on which she could derive a Boltzmann-type equation when the collisional effects were omitted. The Wigner function method and the hbar expansion were further extended in Liu's talk in which he considered the spin kinetic theory in curved space-time and showed how the spin Cooper-Frye formula can be derived in such a situation. He even considered the effect of torsion on spin transport. Another extension of the Wigner-function formalism was given in

Sadofyev's talk, in which he presented how the kinetic theory of the photon at order hbar can be derived from the photon's Wigner function. As an application, he obtained the so-called Zilch vortical effect from the photon kinetic theory.

Lin discussed polarization rotation of chiral fermions in vortical fluid. Contrary to other more popular semi-classical approaches his formalism was based on the Kadanoff-Baym equations. In the future it would be interesting to establish relations between this and other kinetic-theory frameworks.

Hydrodynamics-related developments

The present status of hydrodynamics with spin was described by Ryblewski, who concentrated mainly on the formulation of the perfect-fluid-like formalism. The latter is based on the use of the specific forms of the energy-momentum and spin tensors and can be derived from a semi-classical kinetic-theory approach in the case where the collision term is local. Ryblewski also showed how this type of formalism can be applied in simple phenomenological studies of spin polarization in heavy-ion collisions. The inclusion of dissipative effects into spin dynamics has been presented by Kumar (relaxation-time approximation), Yee (spin diffusion within perturbative QCD), Hongo (entropy-current analysis of spin-hydrodynamics) and Shi (dissipative spin-hydrodynamics of chiral fermions). In the future studies it would be very useful to find how all these frameworks are related to each other.

A physical role played by the spin tensor has been discussed by Tinti and Speranza. Tinti emphasized that the canonical spin tensor is sensitive to polarization observables, however, it is the Wigner function which is the most natural object to describe spin polarization. Speranza demonstrated that thermal expectation values of operators do depend in general on the so-called pseudo-gauge transformation, i.e., freedom in the definition of the energy-momentum and spin tensors. Interestingly, such differences disappear in global equilibrium. Exact field-theoretic results for systems in global thermodynamic equilibrium were presented by Palermo (systems with both acceleration and rotation) and Buzzegoli (systems with both spin and axial chemical potential). Quantum features of acceleration and vorticity in relativistic hydrodynamics were subsequently discussed by Prokhorov.

Inghirami presented a broad overview of the magnetic-field effects and magneto-hydrodynamics in heavy-ion collisions. As the magnetic fields created in heavy-ion collisions decay very fast, their role is limited, however, they may have important consequences for the spin-polarization effects. The inclusion of magnetic-field effects into dynamic models is on the agenda of most of the researchers interested in the development of hydrodynamics and/or kinetic theory with spin. A new approach to magneto-hydrodynamics treated as a universal low-energy effective theory was presented by Hattori. Formal aspects and difficulties connected with a simultaneous description of electromagnetic fields, spin, and rotation were outlined by Fukushima. Such difficulties (related to a pseudo-gauge degree of freedom) will be probably a subject of many future studies.

Gursoy presented the holographic description of spin. Torrieri presented the Lagrangian formulation of hydrodynamics, which has the advantage of not being related to any approximation scheme such as the gradient/semi-classical expansion or the

AdS/CFT correspondence. Torrieri argued that hydrodynamics should be treated as an effective field theory based on symmetries and entropy maximization. The inclusion of polarization into this framework brings an attractive perspective.

A somewhat complementary point of view to high-energy perspective was offered by Matsuo, who discussed spin transport in condensed matter, stressing the effects of spin-vorticity coupling. The exchange of ideas coming from different fields of physics is clearly a promising method to achieve further progress in the spin physics.

Results and Highlights

The Workshop turned out to be a very useful opportunity to exchange ideas and present the newest results on hydrodynamics and kinetic theory with spin degrees of freedom included. This is a quickly growing field in Quark-Gluon Plasma physics and it is drawing considerable attention after the evidence of spin relevance in heavy-ion collisions found by the STAR experiment at RHIC.

This field seems to be leaving its infancy stage with many researches following their independent ideas in different parts of the globe (Brazil, China, Europe, Japan, Russia, US).

A number of interesting results were presented in the workshop, here we highlight a few: Construction of non-local collision terms, exact field-theory solutions for global equilibrium, a new scenario of local spin alignment, systematic study of the decay contribution to Lambda spin polarization, spin relaxation and diffusion in QCD matter and in effective models, spin-1 kinetic theory, using spin polarization to detect the local parity violation and others.

At the moment different authors are making different developments and perhaps the time comes now for more works that synthetize the different approaches. Definitely, the workshop played an important role to consolidate the community of people working on spin effects in relativistic hot and dense matter.

2.3.3 *Advances in Many-Body Theories: From First Principle Methods to Quantum Computing and Machine Learning*

Date	November 02-06, 2020
Organizers	
Morton Hjorth-Jensen	University of Oslo and MSU
David Jarvis Dean	Oak Ridge National Laboratory
Thomas Papenbrock	University of Tennessee & Oak Ridge National Laboratory
Martin Savage	INT & University of Washington
Gauge Haugen	Oak Ridge National Laboratory & University of Tennessee
Stefano Gandolfi	LANL
Jason Holt	TRIUMF-Vancouver
Number of participants	27

Main topics

This workshop was devoted to discussions on the status and recent progress on applying machine-learning methods and quantum computing in nuclear physics and related fields. We brought together experts in these fields and explored the links between these exciting new approaches and traditional many-particle methods in order to map out future research paths. Due to the Covid-19 pandemic the workshop took place virtually via the Zoom platform. For this reason, the number of talks was reduced from the initially proposed number. We had a total of 15 invited talks covering a wide variety of topics. The format of the workshop was specifically designed to enhance discussions among the participants and the invited speakers. This was done by assigning a panel of discussions leaders for each talk who would then initiate and moderate the discussions after the talks. We would like to note that we had an average of 50 (or more) participants attending the workshop remotely each day, and the talks and subsequent discussions went smoothly and without any technical problems. In total we had 128 registered participants:

List of talks

- *Quantum@ECT** (F. Pederiva, Univ. of Trento)
- *Musings on the Intersimulatability of Quantum Fields* (N. Klco, Caltech)
- *Bayesian Model Mixing: Nuclear Physics Applications* (W. Nazarewicz, MSU)
- *Machine Learning for Lattice Field Theory* (P. Shanahan, MIT)
- *Nuclear Physics Entering a Quantum-Simulation Era: Lessons from the Past (*Z. Davoudi, Univ. of Maryland)
- *Variational Methods in the Era of Machine Learning: Classical and Quantum Computing Applications* (G. Carleo, EPFL, Lausanne)
- *Neural Network Quantum States for Atomic Nuclei* (A. Lovato, ANL & Univ. of Trento)
- Towards a Machine Learning Description of Nuclei (J. Kebble, Univ. of Surrey)

- *Quantum Simulating Lattice Gauge Theories – High-energy Physics at Ultra-cold Temperatures* (P. Hauke, Univ. of Trento)
- *Prospects for Near Term Quantum Simulations through Optimal Control (*K. Wendt, Lawrence Livermore National Lab)
- *The European Quantum Flagship and the ECT** (D. Binosi, ECT*, and T. Calarco, Jülich)
- *Nuclear Dynamics on Current Generation Quantum Devices (*A. Roggero, Univ. of Washington)
- *Quantum Technologies for High Energy Physics: the CERN Quantum Technology Initiative* (S. Vallecorsa, CERN)
- *Quantum and the Future* (D. Dean, ORNL).

Program of the workshop

Monday November 02, 2020 Machine Learning and Quantum Computing

Panel and discussion leaders: Francesco Pederiva (Univ. of Trento), Martin Savage (UW), Morten Hjorth-Jensen (MSU and University of Oslo) and Thomas Papenbrock (University of Tennessee and Oak Ridge National Laboratory)

16:00-16.10	Welcome by ECT* Director Jochen Wambach
16.10-16.30	Francesco Pederiva (Univ. of Trento) "*Quantum@Trento"*
16.30-17.15	Natalie Klco (Caltech) *Musings on the Intersimulatability of Quantum Fields*
17.15-18.00	Witek Nazarewicz (MSU) "Bayesian Model Mixing: Nuclear Physics Applications"

Tuesday November 03, 2020 Machine Learning and Quantum Computing

Panel and discussion leader: Thomas Papenbrock, UTK and ORNL

16:00-16.45	Phiala Shanahan (MIT) *Machine Learning for Lattice Field Theory*
16.45-17.45	Zohreh Davoudi (Univ. of Maryland) *"Nuclear Physics Entering a Quantum-simulation Era: Lessons from the Past, Vision for the Future"*

Wednesday November 04, 2020 Quantum Computing

Panel and discussion leaders: Arnau Rios, University of Surrey and University of Barcelona and Morten Hjorth-Jensen, MSU and UiO

16:00-16.45	Giuseppe Carleo, (EPFL Lausanne) *"Variational Methods in the Era of Machine Learning: Classical and Quantum Computing Applications"*
16.45-17.30	Alessandro Lovato (ANL & Univ. of Trento) "*Neural Network Quantum States for Atomic Nuclei"*
17.30-17.45	James Kebble (Univ. of Surrey) *"Towards a Machine Learning Description of Nuclei"*

17.45-18.00	Krishnan Raghavan (ANL) *“Phys-NN -- A Machine Learning Approach to Invert Nuclear Responses”*

Thursday November 05, 2020 Quantum Computing and the ECT*

Panel and discussion leaders: M. Savage, S. Stringari

16.00-16.45	Philipp Hauke (Univ. of Trento) *“Quantum Simulating Lattice Gauge Theories – High-energy Physics at Ultra-cold Temperatures”*
16.45-17.30	Kyle Wendt (Lawrence Livermore National Lab) *Prospects for Near Term Quantum Simulations through Optimal Control*
17.30-18-00	Daniele Binosi (ECT*) and Tommaso Calarco (Jülich) *“The European Quantum Flagship and the ECT*”*

Friday November 06, 2020 Quantum Computing and Machine Learning, Perspectives and Future Vistas

Panel and discussion leaders: All organizers (M. Hjorth-Jensen Chair)

16.00-16.45	Alessandro Roggero (Univ. of Washington) *“Nuclear Dynamics on Current Generation Quantum Devices”*
16.45-17.30	Sofia Vallecorsa (CERN) *“Quantum Technologies for High Energy Physics: the CERN Quantum Technology Initiative”*
17.30-18.00	David Dean (ORNL) *“Quantum and the Future”*

2.4 ECT* Talent School 2020

Machine Learning applied to Nuclear Physics, experiment and theory
June 22- July 03, 2020

(Report by M. Hjorth-Jensen)

Introduction to the TALENT courses

A recently established initiative, Training in Advanced Low Energy Nuclear Theory, aims at providing an advanced and comprehensive training to graduate students and young researchers in low-energy nuclear theory. The initiative is a multinational network between several European and Northern American institutions and aims at developing a broad curriculum that will provide the platform for a cutting-edge theory for understanding nuclei and nuclear reactions. These objectives will be met by offering series of lectures, commissioned from experienced teachers in nuclear theory. The educational material generated under this program will be collected in the form of WEB-based courses, textbooks, and a variety of modern educational resources. No such all-encompassing material is available at present; its development will allow dispersed university groups to profit from the best expertise available.

The present document aims at giving a summary, with background information as well, of the Nuclear Talent course, *Machine Learning and Data Analysis for Nuclear Physics*. The course was held online via the premises of the European Center for Theoretical Studies in Nuclear Physics and Related Areas (ECT*), Trento, Italy during the period June 22 to July 3, 2020.

This was the sixth course which has been held at the ECT*, the first one in 2012, then 2014, 2015, 2017, 2019 and finally this one in 2020. Although we had to run this course as a fully online course due to the global COVID-19 pandemic, the support from the ECT* has simply been crucial for the successful arrangement and running of these courses. All practical arrangements, from accepting applications to the practical set up of the online course, were simply central for the success of the present course held in the summer of 2020. In total we had 157 participants from countries in Africa, Asia, Europe, Oceania and the Americas. The daily attendance varied from 110 to close to 150.

Report - Introduction

Probability theory and statistical methods play a central role in science. Nowadays we are surrounded by huge amounts of data. For example, there are about one trillion web pages; more than one hour of video is uploaded to YouTube every second, amounting to 10 years of content every day; the genomes of 1000s of people, each of which has a length of more than a billion base pairs, have been sequenced by various labs and so on. This deluge of data calls for automated methods of data analysis, which is exactly what machine learning provides. The purpose of this Nuclear Talent course was to provide an introduction to the core concepts and tools of machine learning in a manner easily understood and intuitive to physicists and nuclear physicists in particular. We started with some of the basic methods from supervised learning and statistical data analysis, such as various regression methods before we moved into deep learning methods for both supervised and unsupervised learning, with an emphasis on the analysis of nuclear physics experiments and theoretical nuclear physics. The students worked on hands-on daily examples as well as projects that resulted in final credits. The major scope was to give the participants a deeper understanding on what Machine learning and Data Analysis are and how they can be used to analyze data from nuclear physics experiments and perform theoretical calculations of nuclear many-body systems.

Aims and outcomes

The two-week online TALENT course on nuclear theory focused on Machine Learning and Data Analysis algorithms for nuclear physics and how to use such methods in the interpretation of data on the structure of nuclear systems.

We proposed approximately twenty hours of lectures over two weeks and a comparable amount of practical computer and exercise sessions, including the setting of individual problems and the organization of various individual projects. The mornings consisted of lectures and the afternoons were devoted to exercises meant to shed light on the exposed theory, the computational projects and individual student projects. These components will be coordinated to foster student engagement, maximize learning and create lasting value for the students. For the benefit of the TALENT series and of the community, material (courses, slides, problems and solutions, reports on students' projects) have been made publicly available using version control software like git and posted electronically on github (this site).At the end of the course the students should have obtained a basic understanding of:

- Statistical data analysis, theory and tools to handle large data sets.
- A solid understanding of central machine learning algorithms for supervised and unsupervised learning, involving linear and logistic regression, support vector machines, decision trees and random forests, neural networks and deep learning (convolutional neural networks, recursive neural networks etc)
- Be able to write codes for linear regression, logistic regression and use modern libraries like Tensorflow, Pytorch, Scikit-Learn in order to analyze data from nuclear physics experiments and perform theoretical calculations
- A deeper understanding of the statistical properties of the various methods, from the bias-variance tradeoff to resampling techniques.

We targeted an audience of graduate students (both Master of Science and PhD) as well as post-doctoral researchers in nuclear experiment and theory and due to the online format we had in total 157 participants. The teaching team consisted of both theorists and experimentalists. We believe such a mix is important as it gives the participants a better understanding on how data are obtained, and what are the limitations and possibilities in understanding and interpreting the experimental information.

Course Schedule

Lectures were approximately 45 min each with a small break between each lecture. The schedule is included here. For more information and links to online material: https://github.com/NuclearTalent/MachineLearningECT

Week 1

Monday June 22:	Linear Regression and intro to statistical data analysis (Morten Hjorth-Jensen MHJ). Link to video from lecture June 22: https://mediaspace.msu.edu/media/t/1_ogq38oqq
Tuesday June 23:	Logistic Regression and classification problems, intro to gradient methods (MHJ). Link to video for first lecture at https://mediaspace.msu.edu/media/t/1_po1a5e9v and second lecture at https://mediaspace.msu.edu/media/t/1_wbz4v2gm
Wednesday June 24:	Decision Trees, Random Forests and Boosting methods (MHJ). Link to video at https://mediaspace.msu.edu/media/t/1_vrt5rxls
Thursday June 25:	Basics of Neural Networks and writing your own Neural Network code (MHJ). Link to video at https://mediaspace.msu.edu/media/t/1_ksuz0ero. The link to the video of the additional exercise session is at https://mediaspace.msu.edu/media/t/1_shte4iw5
Friday June 26:	Beta-decay experiments, how to analyze various events, with hands-on examples (Sean Liddick). Link to video of online lecture at https://mediaspace.msu.edu/media/1_ 5n2bssbl. The link to the video of the additional exercise session is at https://mediaspace.msu.edu/media/1_q74f31cw.

Week 2

Monday June 29:	Neural Networks and Deep Learning (Raghu Ramanujan, RR). PDF file of the presented slides at https://nucleartalent.github.io/MachineLearningECT/doc/pub/ Day6/pdf/Day6.pdf. Video of lecture at https://mediaspace.msu.edu/media/t/1_58a9xrbt. Video of exercise session at https://mediaspace.msu. edu/media/t/1_ulont3rg
Tuesday June 30:	From Neural Networks to Convolutional Neural Networks and how to analyze exper- iment (classification of events and real data) (Michelle Kuchera, MK). Video of lecture https://mediaspace.msu.edu/media/t/1_2ysd5plh and video of exercise at https://mediaspace.msu. edu/media/t/1_watjxppf
Wednesday July 1:	Discussion of nuclear experiments and how to analyze data, presentation of simulated data from Active-Target Time-Projection Chamber (AT-TPC) (Daniel Bazin). Videos

	and teaching material: https://nucleartalent.github.io/MachineLearningECT/doc/pub/Day8/html/Day8.html. Video of actual lecture at https://mediaspace.msu.edu/media/t/1_azaquoc0. Video of analysis of data with CNNs (MK) at https://mediaspace.msu.edu/media/t/1_rozywc7h.
Thursday July 2:	Generative models (MK). Video of lecture at https://mediaspace.msu. edu/media/t/1_ayfst99b. Video of exercise session at https://mediaspace.msu.edu/media/t/1_ wpdmt 7cw.
Friday July 3:	Reinforcement Learning (RR). Future directions in machine learning and summary of course. Video of first lecture at https://mediaspace.msu.edu/media/t/1_0eiikln6. Video of second lecture at https://mediaspace.msu.edu/media/t/1_wzyabacr.

Teaching

The course was taught as an online intensive course of the duration of two weeks, with a total time of 20 h of lectures and 10 h of exercises, questions and answers. Videos and digital learning material were made available one week before the start of the course. It was possible to work on a final assignment of 2 weeks of work. The total load was approximately 80 hours, corresponding to 5 ECTS in Europe. The final assignment were graded with marks A, B, C, D, E and failed for Master students and passed/not passed for PhD students. A course certificate was issued for students requiring it from the University of Trento.

The organization of a typical course day was as follows:

Time and Activity

- 2pm-4pm (Central European time=CET) Lectures, project relevant information and directed exercises
- 5pm-6pm (CET) Questions and answers, Computational projects, exercises and hands-on sessions.

Brief summary

The teachers were fully self-sponsored, and due to the COVID-19 situation worldwide there were no travel or logding expenses. The course was fully online.

The support from the ECT*, and its year-long experiences with running doctoral training programs and Talent courses, was central to the success of the course. Of uttermost importance was Barbara Gazzoli's help will all administrative matters. Without her help and of the other staff of the ECT*, and the director's (Prof. Jochen Wambach)enthusiastic support, it is unlikely that this course would have run as smoothly as it did, or at all!

Overall, we as teaching team feel the original learning outcomes and goals were met. It was a marvelous group of students to teach. Videos of the lectures will be published by Springer in due time.

This time we did, however, not perform a course survey. Feedback from students is thus missing.

2.4.1 Organizers and Lectures

Daniel Bazin	Michigan State University
Morten Hjorth-Jensen	Michigan State University
Michelle Kuchera	Davidson College
Sean Liddick	Michigan State University
Raghuram Ramanujan	Davidson College

2.4.2 List of students

Abrahans, Kenzo	South Africa
Agarwal, Shiva	India
Alam, Naosad	India
Alnamlah, Ibrahim Khaled	Saudi Arabia
Alves Teixeira,	EstevaoBrazil
Andreoli, Lorenzo	Italy
Antic, Sofija	Croatia
Arbour, Collin	USA
Arokiaraj, Alex Antony	India
Arroyo, Joseph	USA
Aryial, Krishna	USA
Bairwa,	Manish KumarIndia
Banos, Rodriguez Ubaldo	Cuba
Barcus, Scott	USA
Basson, Marshall	USA
Berg, Hannah	USA
Bernier, Nikikita	South Africa
Bhatt, Khushi	India
Bhoy, Bharti	India
Bildstein, Vinzenz	Germany
Bonelli Toro, Augusto Gabriel	Argentina
Bucher Thinhelimilu, Daphney	South Africa
Budner, Tamas	USA
Butler, Julie	USA
Ceulemans, Andreas	Belgium
Chen, Jie	China
Chen, Mengzhi	China
Chester, Aaron	USA
Chikaoka, Asahi	Japan
Choudhary, Priyanka	India
Chung, Joseph	USA
Cohen, Ariel	Argentina
Čolović, Petra	Croatia
Davison, Jacob	USA
de Lima Calleya, Natalia	Brazil

Dembski, Cade	USA
Dey, Piku	India
Dey, Debarshi	India
Etminan, Faisal	Iran
Ferrari, Guilherme	Brazil
Finelli, Paolo	Italy
Fore, Bryce	USA
Fracassetti, Stefano	Italy
Gao, Jian	China
Garrigoux, Tania	France
Guadilla, Victor	Spain
Hadizadeh, Mohammadreza (Hadi)	Iran
Harris, Caley	USA
Hasegawa, Naoto	Japan
Henke, Brandon	USA
Henninger, Katharine	Germany
Hill, Matthew	USA
Hood, Ashley	USA
Hooker, Joshua	USA
Hornam, Akakpo ElijahSouth	Africa
Hrabar, Yuliia	Ukraine
Ingeberg, Vetle Wegner	Norway
Jaramillo Avila, Benjamin Raziel	Mexico
Jayatissa, Heshani	USA
Juliano, Nick	USA
Kabir, Raihan Kabir	Bangladesh
Karakok, Mesut	Turkey
Karanjikar, Rujuta	India
Karlsson, Daniel	Sweden
Katoch, Vikas	India
Kleemann, Jörn	Germany
Koszuk, Łukasz	Poland
Kumar, Ankit	India
Kumar, Anil	India
Lahbas, Alaaeddine	Morocco
Larsen, Ann-Cecilie	Norway
Lauer, Amber	USA
Lee, Minglong	China
Leon, Esteban	Ecuador
Lesch, Brenden	South Africa
Limarev, Konstantin	Russia
Liu, Yongchao	China
Liyanage, Dananjaya	Sri Lanka
Lois Fuentes, Juan	Spain
Lu, Xiaobin	China
Luchi, Piero	Italy
Magana Vsevolodovna, Ruslan Idelfonso	Mexico

Maher, Cavan	USA
Maheshwari,	BhoomikaIndia
Markova, Maria	Russia
Martirosova, Karina	Russia and USA
Masango, Senamile	South Africa
Mehl, Craig Vernon	South Africa
Mengoni, Daniele	Italy
Michalopoulou-Petropoulou, Veatriki	Greece
Miller, Sander	USA
Mishanayot, Yonatan	Israel
Mishra, Vaibhav	India
Mohseni, Kamyar	Iran
Mondal, Chiranjib	India
Moreno Barbosa, Fernando	Mexico
Morselli, Lucas	Italy
Muzalevskii, Ivan	Russia
Naidoo, Paul	UK
Nazari, Farzaneh	Iran
Nguyen, Hoang, Tung	Vietnam
Ngwetsheni, Cebo	South Africa
Nikas, Stylianos	Greece
Orduz-Ducuara, Javier Andres	Mexico / Colombia
Ortega-Moral, Aurora	Spain
Papst, Oliver	Germany
Park, Joochun (Jason)	Canada
Park, Tae-Sun	Korea
Park, Chanju	South Korea
Petrellis, Dimitrios	Greece
Poja, Poja	India
Poleshchuk, Oleksii Preston	Sweden and UK
Ray, Dwaipayan	India
Rebeiro, Bernadette	India
Recchia, Paolo	Italy
Regueira, Daniel	Spain
Reid, Haley	USA
Richard, Andrea	USA
Ricketts, Christopher	UK
Sallmen, Karl	USA - Sweden
Såmark-Roth, Anton	Sweden
Sapkota, Yajnya	India
Sarma Chandan	India
Schmitz, Benedikt	Germany
Sensharma, Nirupama	India
Seymour, Christopher	USA
Shahina, Shahina	India
Sharma, Anupriya	India
Singh, Gagandeep	India

Singha, Jaikhomba	India
Sokolowska, Natalia	Poland
Souza, Lucas	Brazil
Srivastava, Praveen C	India
Subedi, Shiv K.	Nepal
Sun, Haoran	China
Surbrook, Jason	USA
Tafrihi, Azar	Iran
Tiwary, Shashi Shekher	India
Tomazinaki, Mina-Ermioni	Greece
Touchette, Hugo	Canada
Trotta, Richard	USA
Tyson, Richard	France and UK
Udrescu, Silviu-Marian	Romania
Ulvik, Geir Tore	Norway
Upadhyayula, Sriteja	USA
Vorabbi, Matteo	Italy
Vyas, Shrey Vyas	India
Wheeler, Tyler	USA
Wong, Ocean	China
Wylie, Joshua	USA
Youssef, Ahmed	Egypt
Zeilbeck, Mattew	USA
Zhang, Tingyu	China

Research at ECT*

3. Research at ECT*

3.1 Projects of ECT* Researchers

DANIELE BINOSI

Higgs modulation of emergent mass as revealed in kaon and pion parton distributions

In collaboration with Z.-F. Cui (Nanjing University), M. Ding (ECT, Trento), F. Gao (Heidelberg University), K. Raya (IFM-UMSNH, Michoacan), L. Chang (Nankai University), C. D. Roberts (Nanjing University), J. Rodríguez-Quintero (Huelva University), S. M. Schmidt (IAS, Jülich).

Strangeness was discovered roughly seventy years ago, lodged in a particle now known as the kaon, K. Kindred to the pion, π, both states are massless in the absence of Higgs-boson couplings. Kaons and pions are Nature's most fundamental Nambu–Goldstone modes. Their properties are largely determined by the mechanisms responsible for emergent mass in the standard model, but modulations applied by the Higgs are crucial to Universe evolution. Despite their importance, little is known empirically about K and π structure. This study delivers the first parameter-free predictions for all K distribution functions (DFs) and comparisons with the analogous π distributions, i.e. the one-dimensional maps that reveal how the light-front momentum of these states is shared amongst the gluons and quarks from which they are formed. The results should stimulate improved analyses of existing data and motivate new experiments sensitive to all K and π DFs.

Kaon and pion parton distributions

In collaboration with Z.-F. Cui (Nanjing University), M. Ding (ECT, Trento), F. Gao (Heidelberg University), K. Raya (IFM-UMSNH, Michoacan), L. Chang (Nankai University), C. D. Roberts (Nanjing University), J. Rodríguez-Quintero (Huelva University), S. M. Schmidt (IAS, Jülich)

Beginning with results for the leading-twist two-particle distribution amplitudes of π - and *K*-mesons, each of which exhibits dilation driven by the mechanism responsible for the emergence of hadronic mass, we develop parameter-free predictions for the pointwise behaviour of all π and *K* distribution functions (DFs), including glue and sea. The large-x behaviour of each DF meets expectations based on quantum chromodynamics; the valence-quark distributions match extractions from available data, including the pion case when threshold resummation effects are included; and at ζ_5 = 5.2 GeV, the scale of existing measurements, the light-front momentum of these hadrons is shared as follows: $\langle x_{\text{valence}}\rangle\pi = 0.41(4)$, $\langle x_{\text{glue}}\rangle^{\pi} = 0.45(2)$, $\langle x_{\text{sea}}\rangle^{\pi} = 0.14(2)$; and $\langle x_{\text{valence}}\rangle^{K} = 0.42(3)$, $\langle x_{\text{glue}}\rangle^{K} = 0.44(2)$, $\langle x_{\text{sea}}\rangle^{K} = 0.14(2)$. The kaon's glue and sea distributions are similar to those in the pion, although the inclusion of mass-dependent splitting functions introduces some differences on the valence-quark domain. This study should stimulate improved analyses of existing data and motivate new experiments sensitive to all π and K DFs. With little known empirically about the structure of the Standard Model's (pseudo-) Nambu-Goldstone modes and analyses of existing, limited data being controversial, it is likely that new generation experiments at upgraded and anticipated facilities will provide the information needed to resolve the puzzles and complete the picture of these complex bound states.

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Nucleon elastic form factors at accessible large spacelike momenta

In collaboration with Z.-F. Cui (Nanjing University), C. Chen (Giessen University), F. de Soto (Pablo de Olavide University, Seville), C. D. Roberts (Nanjing University), J. Rodríguez-Quintero (Huelva University), S. M. Schmidt (RWTH Aachen University and HZDR, Dresden), J. Segovia (Pablo de Olavide University, Seville and Nanjing University)

A Poincaré-covariant quark+diquark Faddeev equation, augmented by a statistical implementation of the Schlessinger point method for the interpolation and extrapolation of smooth functions, is used to compute nucleon elastic form factors on $0 \le Q^2 \le 18 m_N^2$ (m_N is the nucleon mass) and elucidate their role as probes of emergent hadronic mass in the Standard Model. The calculations expose features of the form factors that can be tested in new generation experiments at existing facilities, e.g., a zero in G_E^p/G_M^p, a maximum in G_E^n/G_M^n, and a zero in the proton's d-quark Dirac form factor, F_1^d. Additionally, examination of the associated light-front-transverse number and anomalous magnetization densities reveals inter alia: a marked excess of valence u quarks in the neighborhood of the proton's center of transverse momentum, and that the valence d quark is markedly more active magnetically than either of the valence u quarks. The calculations and analysis also reveal other aspects of nucleon structure that could be tested with a high-luminosity accelerator capable of delivering higher beam energies than are currently available.

Semileptonic decays of $D_{(s)}$ mesons

In collaboration with Z.-Q. Yao (Nanjing University), Z.-F. Cui (Nanjing University), C. D. Roberts (Nanjing University), S.-S. Xu (Nanjing University Posts Telecom), H. S. Zong (Nanjing University)

A symmetry-preserving continuum approach to meson bound states in quantum field theory, employed elsewhere to describe numerous π- and K-meson electroweak processes, is used to analyze leptonic and semileptonic decays of $D_{(s)}$ mesons. Each semileptonic transition is conventionally characterized by the value of the dominant form factor at $t=0$ and the following results are obtained herein: $f_+^{D_s \to K}(0) = 0.673(40)$; $f_+^{D\to\pi}(0) = 0.618(31)$ and $f_+^{D\to K}(0) = 0.756(36)$. Working with the computed t-dependence of these form factors and standard averaged values for $|V_{cd}|$, $|V_{cs}|$, one arrives at the following predictions for the associated branching fractions: $B_{D_s^+ \to K^0 e^+ \nu_e} = 3.31(33) \times 10^{-3}$; $B_{D^0 \to \pi^- e^+ \nu_e} = 2.73(22) \times 10^{-3}$; and $B_{D^0 \to K^- e^+ \nu_e} = 3.83(28)\%$. Alternatively, using the calculated t-dependence, agreement with contemporary empirical results for these branching fractions requires $|V_{cd}|=0.221(9)$, $|V_{us}|=0.953(34)$. With all $D_{(s)}$ transition form factors in hand, the nature of SU(3)-flavor symmetry breaking in this array of processes can be analysed; and just as in the π-K sector, the magnitude of such effects is found to be determined by the scales associated with emergent mass generation in the Standard Model, not those originating with the Higgs mechanism.

Off-shell renormalization in the presence of dimension 6 derivative operators Part III. Operator mixing and β-functions

In collaboration with A. Quadri (INFN, Milan).

We evaluate the one-loop β functions of all dimension 6 parity-preserving operators in the Abelian Higgs-Kibble model. No on-shell restrictions are imposed; and the (generalized) non-polynomial field redefinitions arising at one-loop order are fully taken into account. The operator mixing matrix is also computed, and its cancellation patterns explained as a consequence of the functional identities of the theory and power- counting conditions.

FRANCESCO CILIBERTO

Transverse-momentum-dependent gluon distributions

In collaboration with A. Bacchetta (Università degli Studi di Pavia), M. Radici (Università degli Studi di Pavia), and P. Taels (École Polytechnique, Paris-Saclay).

While significant steps toward the formal definition of transverse-momentum-dependent (TMD) quark distributions and their extraction from experimental data through global fits has been made in the last years, the gluon-TMD field represents a largely unexplored territory. Pursuing the goal of extending our knowledge of this sector, I have obtained analytic expressions for all T-even gluon TMDs at twist-2, calculated in a spectator model for the parent nucleon. At variance with respect to previous works, this approach encodes a flexible parametrization for the spectator-mass spectral density, allowing us to improve the description in the small-x region. We have built a common framework where not only gluon, but also valence- and sea-quark densities are concurrently generated. Our results can be used to predict the behavior of observables sensitive to gluon-TMD dynamics.

TMD factorization (breaking)

In collaboration with A. Bacchetta (Università degli Studi di Pavia)

It is widely recognized that QCD factorization TMD parton distribution functions is violated in hadroproduction of almost back-to-back hadrons with high transverse momentum. Currently we are working to figure out to which level (observables and perturbative order) factorization-breaking effects come into play in processes sharing the same formalism, as photon-jet hadroproduction and di-hadron production in SIDIS.

Heavy-flavored emissions in high-energy QCD

In collaboration with A. Papa (Università della Calabria), D. Yu. Ivanov (Sobolev Institute of Mathematics and Novisibirsk State University, Russia), A. D. Bolognino (Università della Calabria), and M. Fucilla (Università della Calabria).

We have proposed the inclusive hadroproduction of a heavy-light dijet system, as a new channel for the investigation of high energy QCD. We have built up a hybrid factorization that incorporates a partial next-to-leading BFKL resummation inside the standard collinear description of observables. We have performed a detailed analysis of different observables: cross-section summed over azimuthal angles and differential in rapidity, ratio of azimuthal coefficients differential in rapidity, heavy-jet transverse momentum distribution and azimuthal distribution. The stability that these distributions show under higher-order corrections motivates our interest in future studies. Here, the hybrid factorization could help to deepen our understanding of heavy-flavor physics in wider kinematic ranges, like the ones accessible at the Electron-Ion Collider.

Unintegrated gluon densities at small-x

In collaboration with A. Papa (Università della Calabria), D. Yu. Ivanov (Sobolev Institute of Mathematics and Novisibirsk State University, Russia) and A. D. Bolognino (Università della Calabria)

Sufficiently inclusive processes, like the deep inelastic lepton-proton scattering, are described in terms of scale-dependent parton distributions, which correspond to the density of partons in the proton with longitudinal momentum fraction *x*, integrated over the parton transverse momentum. For less inclusive processes it is, however, necessary to consider distributions unintegrated over the transverse momentum. In the small-*x* regime, the dominant contribution the amplitude comes from the exchange of a very large number of gluons strong ordered in rapidity, which is described by the so-called BFKL Green's function. The convolution between the Green's function and the impact factor of the target hadron defines an *unintegrated gluon distribution* (UGD), whose functional dependence on the gluon kinematical variable has not yet been constrained and is still object of study and debate. Pursuing the goal to combine small-*x* effects together with the ones coming from other approaches (DGLAP resummation, etc…), several parameterizations have been proposed. The comparison of these models via the investigation of different reactions represents the core of a new research line, recently opened.

Higgs phenomenology

In collaboration with A. Papa (Università della Calabria), D. Yu. Ivanov (Sobolev Institute of Mathematics and Novisibirsk State University, Russia), and M. M. A. Mohammed (Università della Calabria).

We have recently started a study, done at the hand of the high-energy resummation in the NLA accuracy, of transverse-momentum and rapidity distributions for the inclusive Higgs-plus-jet production, highlighting how the inclusion of high-energy effects is necessary to get a consistent description of the considered process in the corresponding kinematic regions. The need for inclusion of the soft-gluon resummation, as well as of the threshold-logarithm one, is also pointed out and represents matter of our interest for prospective developments. Furthermore, I am recently involved in the extraction of gluon TMD PDFs from the Higgs production channels, in collaboration with Prof. Alessandro Bacchetta.

Computation techniques for subnuclear and high-energy physics

Numerical techniques represent a powerful tool and, in most cases, the key ingredient to perform calculations in theoretical high-energy physics. On one side, fast evaluation of special functions is required. On the other side, multidimensional integrations are needed in order to match the kinematic configurations used by the experimental collaborations. Since my master's thesis, I have been working on developing numerical programs in order to calculate cross sections and azimuthal coefficients for relevant processes at LHC. In particular, I have convoluted already existing numerical integration techniques with new numerical subroutines personally developed, in order to create an optimized technology useful to perform theoretical predictions within the BFKL framework. Recently, I have started to work on the development of an optimized software library suited for the computation of unintegrated gluon densities (UGDs), with the medium-term goal to offer to the scientific community a novel tool to test the most popular UGD models, and to propose new ones. I have developed JETHAD and LExA, two Fortran-Python hybrid interfaces (not yet published) respectively suited to the analysis of inclusive and exclusive semi-hard processes and offering also support in the study of multi-body final-state reactions.

Other scientific activities

2020, March, "*Physics Masterclasses 2020*" as part of the "*International Masterclasses - Hands on Particle Physics*" event, Università degli Studi di Pavia & INFN Pavia
Scientific and Organizing Committee

2020, May, "*Open Day UniCal – Corso di Studio in Fisica*", Università della Calabria,
Organizing Committee

2020, October 13, *MAP Collaboration Meeting 2020*, Università degli Studi di Pavia, Local Organizing Committee

2020, November, Self Interview as part of "*Video Promozionale del Corso di Studio in Fisica dell'Università della Calabria*", Università della Calabria, https://www.youtube.com/watch?v=uzWcy2f5c50

2020, November, "*European Researchers' Night 2020*", Università degli Studi di Pavia & INFN Pavia
Scientific and Organizing Committe

2020, November, Interview for the "*Strong 2020 Dissemination Channel*", Università degli Studi di Pavia & INFN, https://www.youtube.com/watch?v=em0uQNfXsLI.

CONSTANTINOS CONSTANTINOU

QCD phase diagrams under heavy-ion and stellar conditions

In collaboration with K. Aryal, V. Dexheimer, J. Peterson, M. Wolf (Kent State University, USA), and R. L. S. Farias (Universidade Federal de Santa Maria, Brazil).

We investigated the hadron-to-quark phase transition both in the presence as well as in the absence of chemical equilibrium. The effects of finite strangeness on charge and isospin fractions, chemical potentials, and temperature were studied in the context of the Chiral Mean-Field model. This is a non-linear realization of the SU(3) sigma model such that chiral invariance is restored at large temperatures and/or densities. The extent to which the aforementioned quantities are probed during deconfinement for the ambient conditions present in astrophysical phenomena and heavy-ion collisions was analysed via the construction of 3-dimensional phase diagrams.

G-mode frequencies in hybrid stars

In collaboration with P. Jaikumar (California State University Long Beach, USA), S. Han (University of California, Berkeley, and Ohio University, USA), and M. Prakash (Ohio University, USA).

Neutron-star cores can, in principle, support deconfined quark matter. However, the presence of such matter in neutron stars has not yet been established from observations or lattice-QCD calculations. Current constraints from gravitational-wave data are consistent with both hadronic and hybrid stars depending on the choice of theoretical framework. We investigate g-mode frequencies in the phase transition from hadronic to quark matter as a diagnostic for the existence of hybrid stars. A g-mode is a non-radial oscillation driven by buoyancy forces in a layered environment with a characteristic frequency which depends on the difference between the equilibrium and the adiabatic sound speeds. We rely on the simple Zhao-Lattimer and vMIT models for the description of nucleons and quarks respectively, and employ a Gibbs construction for the treatment of the phase transition. We find that, in binary mergers with a hybrid component, the fraction of tidal energy pumped into the resonant g-mode can exceed that of a system of normal neutron stars by a factor of 2-3. In the future, we also aim to report on g-mode frequencies in treatments of quark matter with different implementations of a first-order nucleon-to-quark phase transition as well as crossover transitions (e.g. quarkyonic matter).

HILLA DE LEON

Using quantum Monte Carlo methods for calculating few and many-body systems

In collaboration with F. Pederiva (University of Trento).

The behavior of an N-body helium droplets system is studied using diffusion Monte Carlo (DMC). We are using two- and three-body pionless effective field (πEFT) potential at leading-order (LO) calibrated from the dimer and trimer binding energies to predict the N-body (up to 100-body) binding energies as a function of the ultra-violet cutoff, Λ.

Particle modeling of the spreading of Coronavirus Disease

In collaboration with F. Pederiva (University of Trento) and Y. Ashkenazy, R. Calderon-Margalit, D. Gazit (HUJI).

We use a Monte Carlo based algorithm and the basic principles of statistical physics to predict the Covid-19 infection rate for different population densities using the most recent epidemic data from Israel.

MINGHUI DING

Kaon and pion parton distributions

In collaboration with Z.-F. Cui (Nanjing University & INP), F. Gao (Heidelberg University), K. Raya (Nankai University), D. Binosi (ECT*), L. Chang (Nankai University), C. D. Roberts (Nanjing University & INP), J. Rodríguez-Quintero (Huelva University) and S. M. Schmidt (HZDR, Dresden and RWTH Aachen University).

Beginning with results for the leading-twist two-particle distribution amplitudes of π - and *K*-mesons, each of which exhibits dilation driven by the mechanism responsible for the emergence of hadronic mass, we develop parameter-free predictions for the pointwise behaviour of all π and *K* distribution functions (DFs), including glue and sea. The large-x behaviour of each DF meets expectations based on quantum chromodynamics; the valence-quark distributions match extractions from available data, including the pion case when threshold resummation effects are included; and at ζ_5 = 5.2 GeV, the scale of existing measurements, the light-front momentum of these hadrons is shared as follows: $\langle x_{\text{valence}}\rangle \pi = 0.41(4)$, $\langle x_{\text{glue}}\rangle^{\pi} = 0.45(2)$, $\langle x_{\text{sea}}\rangle^{\pi} = 0.14(2)$; and $\langle x_{\text{valence}}\rangle^{K} = 0.42(3)$, $\langle x_{\text{glue}}\rangle^{K} = 0.44(2)$, $\langle x_{\text{sea}}\rangle^{K} = 0.14(2)$. The kaon's glue and sea distributions are similar to those in the pion, although the inclusion of mass-dependent splitting functions introduces some differences on the valence-quark domain. This study should stimulate improved analyses of existing data and motivate new experiments sensitive to all π and *K* DFs. With little known empirically about the structure of the Standard Model's (pseudo-) Nambu-Goldstone modes and analyses of existing, limited data being controversial, it is likely that new generation experiments at upgraded and anticipated facilities will provide the information needed to resolve the puzzles and complete the picture of these complex bound states.

Thermal properties of π and ρ meson

In collaboration with F. Gao (Heidelberg University).

We computed the pole masses and decay constants of π and ρ meson at finite temperature in the framework of Dyson–Schwinger equations and Bethe–Salpeter equations approach. Below transition temperature, pion pole mass increases monotonously, while ρ meson seems to be temperature independent. Above transition temperature, pion mass approaches the free field limit of screening mass ∼ 2πT, whereas ρ meson is about twice as large as that limit. Pion and the longitudinal projection of ρ meson decay constants have similar behaviour as the order parameter of chiral symmetry, whereas the transverse projection of ρ meson decay constant rises monotonously as temperature increases. The inflection point of decay constant and the chiral susceptibility get the same phase transition temperature. Though there is no access to the thermal width of mesons within this scheme, it is discussed by analyzing the Gell-Mann-Oakes-Renner (GMOR) relation in medium. These thermal properties of hadron observables will help us understand the QCD phases at finite temperature and can be employed to improve the experimental data analysis and heavy ion collision simulations.

The rainbow modified-ladder approximation and degenerate pion

In collaboration with L. Chang (Nankai University).

Correlation functions can be described by the corresponding equations, viz., gap equation for quark propagator and the inhomogeneous Bethe-Salpeter equation for vector dressed-fermion-Abelian-gauge-boson vertex, in which specific truncations have to be implemented. The general vector and axial-vector Ward-Green-Takahashi identities require these correlation functions to be interconnected, in consequence of this, truncations made must be controlled consistently. It turns out that if the rainbow approximation is assumed in the gap equation, the scattering kernel in the Bethe-Salpeter equation can adopt the ladder approximation, which is one of the most basic attempts to truncate the scattering kernel. Additionally, a modified-ladder approximation is also found to be a possible symmetry-preserving truncation scheme. As an illustration of this approximation, a treatment of the pion is included. The pion mass and decay constant are found to be degenerate in ladder and modified-ladder approximations, even though the Bethe-Salpeter amplitudes are distinct. The justification for the modified-ladder approximation is examined with the help of the Gell-Mann-Oakes-Renner (GMOR) relation.

JARKKO PEURON

Self-similarity and spectral properties of non-Abelian plasmas at the initial stages

In collaboration with K. Boguslavski (Vienna University of Technology,), A. Kurkela (CERN-TH, Geneva) and T. Lappi (University of Jyväskylä).

The initial non-equilibrium evolution of the matter created in ultrarelativistic heavy-ion collisions can be described in terms of classical color fields when the occupation numbers are nonperturbatively high [1]. The classical description however has an overlapping range of validity with kinetic theory approach [2]. We study the interface of these two theories by studying the spectral properties of classical gluodynamics in the self-similar regime. Previously we have extracted the spectral function of the classical gluodynamics in a three-dimensional nonexpanding system [3]. In this study, we establish that there are indeed quasiparticles in the system and measure their damping rate as a function of momentum for the first time. Since we expect the initial state in ultrarelativistic heavy-ion collisions at high energy to be approximately boost invariant, we have studied a two-dimensional Yang-Mills system [4]. In [4] we have established that the two-dimensional system also features self-similar behavior. Furthermore we have studied the spectral properties of the two dimensional system in [5]. Interestingly, we find that excitation peaks in 2+1D theory have a width comparable to the frequency of the soft excitations. This means that the system does not have soft quasiparticle excitations. Our results also suggest that excitations at higher momenta are sufficiently long-lived, for an effective kinetic theory description of 2+1 dimensional Glasma-like systems. However, its collision kernel must be determined nonperturbatively.

Transport coefficients out of equilibrium

In collaboration with K. Boguslavski (Vienna University of Technology), A. Kurkela (CERN, Geneva) and T. Lappi (University of Jyväskylä)

Theoretical evaluation of transport properties of the matter created in ultrarelativistic heavy-ion collisions has been a longstanding problem. However, so far transport coefficients have been estimated for matter in equilibrium. In this project we have extracted the heavy-quark diffusion coefficient and the resulting momentum broadening in a far-from-equilibrium non-Abelian plasma [6]. We observe that the momentum broadening features interesting oscillations with plasmon frequency. These novel oscillations are not easily explained using perturbation theory. They rather result from an excess of gluons at low momenta. The oscillations are a gauge invariant confirmation of the infrared enhancement we have previously observed in gauge-fixed correlation functions. In this project we are currently working on extracting jet quenching factor and heavy quark diffusion coefficient far from equilibrium using kinetic theory.

Non-equilibrium quark production at the initial stages of ultrarelativistic heavy-ion collisions

In collaboration with S. Schlichting (University of Bielefeld)

In this project our aim is to gain better understanding of chemical thermalization in heavy-ion collisions. Even though the initial nonequilibrium state is dominated by overoccupied gluon fields, in equilibrium a significant fraction of the energy density is carried by quarks. The evolution of the system can be studied using real time lattice techniques using the formulation developed in [7], where the quark spinors are formulated boost invariantly.

References

[1] T. Lappi, Phys. Rev. C67 (2003) 054903

[2] J. Berges, K. Boguslavski, S. Schlichting, R. Venugopalan, Phys. Rev. D89 (2014) no.11, 114007, arXiv:1311.3005 [hep-ph]

[3] K. Boguslavski, A. Kurkela, T. Lappi, J. Peuron, Phys. Rev. D98 (2018) no.1, 014006, arXiv:1804.01966 [hep-ph]

[4] K. Boguslavski, A. Kurkela, T. Lappi, J. Peuron 2101.02715 [hep-ph]

[5] K. Boguslavski, A. Kurkela, T. Lappi, J. Peuron, Phys. Rev. D100 (2019) no.9, 094022, arXiv:1907.05892 [hep-ph][6]K. Boguslavski, A. Kurkela, T. Lappi, J. Peuron JHEP 09 (2020) 077, 2005.02418 [hep-ph]

[6] F. Gelis and N. Tanji, JHEP 02 (2016) 126 [arXiv:1506.03327 [hep-ph]].

ALESSANDRO PILLONI

Study of exotic resonances in high multiplicity environments

In collaboration with A. Esposito, E.G. Ferreiro, A.D. Polosa, C. Salgado

The structure of exotic resonances that do not trivially fit the usual quark model expectations has been a matter of strong scientific debate during the last two decades.

An excellent way to measure the size of these states is to observe how much they are affected when immersed in QCD matter. Recently, LHCb has measured the relative abundance of the exotic *X*(3872) over the ordinary *ψ*(2S). Built on several decades of phenomenological understanding of quarkonia production in hot and dense QCD matter, in [1] we employ the comover interaction model to study the yield of the *X*(3872). To confirm the reliability of the model in large multiplicity pppp collisions, we describe the larger suppression of excited over ground Y states, as well as the enhancement of deuterons over protons, for which coalescence is implemented. With this at hand, we show that the size of the *X*(3872) is only slightly larger than that of the *ψ*(2S), that is, it corresponds to a typical hadronic state. This finding clearly supports the *X*(3872) being a tetraquark state and strongly disfavours the molecular interpretation, that would need a much larger size.

Study of 3-body formalisms

In collaboration with Joint Physics Analysis Center

The 3-body problem is one of the most important problems in nuclear and particle physics. The role of the 3-nucleon force, for example, is central in many nuclear models. As for Hadron Spectroscopy, the 3-body dynamics is responsible for many new states decaying into three particles. In the near future, experiments will provide data on 3-body heavy meson decays with unprecedented statistics. In [2] we show these effects in the decay $\omega \to 3\pi$, and discuss the compatibility with the $\omega\pi^0$ transition form factor.

Photo- and electroproduction of resonances

In collaboration with Joint Physics Analysis Center

Since 2003, a plethora of new resonance candidates, commonly referred to as the XYZ, appeared in the heavy quarkonium spectrum. Their properties do not fit the expectations for heavy quarkonia as predicted by the conventional phenomenology. An exotic composition is most likely required. Having a comprehensive description of these states will improve our understanding of the nonperturbative features of Quantum Chromodynamics. The majority of these has been observed in specific production channels, most notably in heavy hadron decays and direct production in e+e− collisions. Exploring alternative production mechanisms would provide complementary information that can further shed light on their nature. In particular, photoproduction at high energies is not affected by 3-body dynamics, which complicates the determination of the resonant nature of several XYZ. In [3] we predict the photoproduction cross sections of several exotic states at the future Electron Ion Collider, and at possible future electron-hadron machines.
Studying ordinary mesons is also important, as they usually provide the strongest signal in data and need to be under control with a high degree of accuracy. Photoproduction of light tensor resonances was studied theoretically in [4], and the models implemented in the experimental analyses in [5-6].

References

[1] A. Esposito, E.G. Ferreiro, A. Pilloni, A.D. Polosa, C.A. Salgado, *arXiv:2006.15044*

[2] JPAC Collaboration (M. Albaladejo *et al.*), *Eur. Phys. J. C80 (2020) 12, 1107*

[3] JPAC Collaboration (M. Albaladejo *et al.*), *Phys. Rev. D102 (2020) 114010*

[4] JPAC Collaboration (V. Mathieu *et al.*), *Phys. Rev. D102 (2020) 1, 014003*

[5] CLAS Collaboration (A. Celentano *et al.*), *Phys. Rev. C102 (2020) 3, 032201*

[6] CLAS Collaboration (M. Carver *et al.*), *Phys. Rev. Lett. 126 (2021) 082002*.

Other scientific activities

INT program INT-20-2c "*Accessing and Understanding the QCD Spectra*"

August 17 – September 4, 2020

Organizers: Raul Briceno, Gernot Eichmann, Alessandro Pilloni
(https://www.int.washington.edu/PROGRAMS/20-2c/)

SAGA SÄPPI

Soft pressure of NNNLO cold dense pQCD

In collaboration with T. Gorda (TU Darmstadt), A. Kurkela (Stavanger University), R. Paatelainen (Helsinki University), and A. Vuorinen (Helsinki University).

The low-energy degrees of freedom of thermal perturbative Quantum Chromodynamics (pQCD) can be studied using the Hard Thermal Loop (HTL) framework. In the context of the cold pressure at high quark chemical potentials relevant for neutron stars, this methodology has been successfully used in the past to determine the leading logarithm of the next-to-next-to-next-to-leading order (NNNLO) pressure by extracting suitable terms of the two-loop HTL-resummed pressure [1]. In our current work, we finish this computation by evaluating the full two-loop HTL pressure using a combination of analytical and numerical integration techniques. While the said pressure has been written down in the past, it has not been fully evaluated without the use of expansions in the effective mass parameter. As a result, this computation has also required extensive advances in Euclidean HTL theory, in particular in the context of evaluating HTL vertex corrections. The results are finished, and the associated publications are currently being polished.

Logarithmic pressure of NNNLO cold dense pQCD

In collaboration with T. Gorda (TU Darmstadt), A. Kurkela (Stavanger University), R. Paatelainen (Helsinki University), and A. Vuorinen (Helsinki University).

In addition to the aforementioned soft sector, the cold pQCD pressure contains logarithms arising from sectors containing high-energy hard momenta. This project corresponds to evaluating these logarithms at NNNLO in order to obtain the full, physical, subleading logarithm of the NNNLO pressure. Evaluating these contributions would not only bring our knowledge of the cold pressure to the same level as the hot pressure, but could also benefit neutron star studies, as it will result in a dependence of the scale parameter, the variation of which is a key component in studies of the neutron star equations from the pQCD point of view. In practice, a major challenge in the computation is extending the gluonic self-energy to two-loop order, at least in the HTL limit. This alone would be a notable milestone from a technical point of view, as computations of "NLO HTL" self-energies are few and far inbetween. This work is currently ongoing, having been paused in order to progress the soft sector. It appears to benefit from the associated advances in calculation techniques.

Extensions of the validity of lower-order dense pQCD results

In collaboration with T. Gorda (TU Darmstadt) and R. Paatelainen (Helsinki U.

In addition to explicitly extending the cold pQCD pressure to higher orders, there are a number of relaxations of approximations that can be made in the known results. To mention a few, massless quarks are assumed in the previous two studies. Likewise, the temperature is assumed to be exactly zero. Relaxing these assumptions has been done up to NNLO [2,3], and further extending them to at least to the leading logarithm at NNNLO can also be done. In particular, effects of a finite temperature to the pressure could prove very useful for neutron star studies. We are also examining possible resummation schemes for the cold pQCD pressure in order to improve the accuracy of the pressure for practical purposes. This line of research is currently in its early stages.

References

[1] Gorda et al., "*NNNLO pressure of cold quark matter: leading logarithm*", Phys. Rev. Lett. 121, 202701 (2018)

[2] Kurkela et al., "*Cold Quark Matter*", Phys. Rev. D 81, 105021 (2010)

[3] Kurkela & Vuorinen, "*Cool Quark Matter*", Phys. Rev. Lett. 117, 042501 (2016)

DIONYSIOS TRIANTAFYLLOPOULOS

Saturation in Single Inclusive DIS at forward rapidities

In collaboration with E. Iancu (IPhT, Saclay), A.H. Mueller (Columbia University) and S.Y. Wei (ECT*)

We used the dipole picture in electron-nucleus scattering at small Bjorken x to study the effects of gluon saturation [1] in the nuclear target on the cross-section for Single Inclusive Deep Inelastic Scattering (SIDIS) [2]. The sensitivity of this process to gluon saturation can be enhanced by tagging on a hadron or jet, which carries a large fraction z (close to 1) of the longitudinal momentum of the virtual photon. This opens the possibility to study saturation in relatively hard processes, where the virtuality Q^2 is (much) larger than the target saturation momentum $(Q_s)^2$, but such that $z(1-z)Q^2 \ll (Q_s)^2$. Working in this limit, we predicted new phenomena which would signal saturation in the SIDIS cross-section. For sufficiently low transverse momenta $k_\perp \ll Q_s$ of the produced particle, a significant contribution comes from elastic scattering in the black disk limit, which can reveal the unintegrated quark distribution in the virtual photon. For larger momenta $k_\perp \gg Q_s$, inelastic collisions dominate. The multiple scattering leads to a Gaussian distribution in $k_\perp$ centered around Q_s and in turn this results in a Cronin peak in the nuclear modification factor (the RpA ratio) at moderate values of x. With decreasing x, the peak is washed out by the high-energy evolution and replaced by nuclear suppression up to large momenta $k_\perp \gg Q_s$. Similar phenomena occur in proton nucleus in high energy collisions [3,4]. Always in the strong limit $z(1-z)Q^2 \ll (Q_s)^2$, we also computed the integrated over $k_\perp$ SIDIS cross-sections. We found that both elastic and inelastic scattering are controlled by the black disk limit, and thus they yield similar contributions of zeroth order in the QCD coupling.

Running coupling scale in high energy proton-nucleus scattering

When doing proton nucleus collisions at high energy, the transverse momentum spectrum of an outgoing quark in the forward direction is related to the elastic scattering amplitude of a color dipole (in the fundamental representation) off the same nucleus [5,6,7]. Such a relationship is very simple, more precisely the two quantities are just connected by a Fourier Transform (FT). Many phenomenological models have a tail in the small dipole size limit which is too steep, and the FT lead to unphysical negative cross sections at high transverse momenta [8]. I have identified and corrected one of the issues in such models, which is a poor choice of the scale setting the running of the coupling [9].

References

[1] F. Gelis, E. Iancu, J. Jalilian-Marian and R. Venugopalan, Ann. Rev. Nucl. Part. Sci. 60, 463 (2010), arXiv:1002.0333.

[2] E. Iancu, A.H. Mueller, D.N. Triantafyllopoulos and S.Y. Wei, arXiv:2012.08562, submitted to JHEP

[3] D. Kharzeev, Y.V. Kovchegov, K. Tuchin, Phys. Rev. D 68 (2003) 094013, hep-ph/0307037.

[4] E. Iancu, K. Itakura, D.N. Triantafyllopoulos, Nucl. Phys. A 742 (2004) 182-252, hep-ph/0403103

[5] B.G. Zakharov, JETP Lett. 63, 952 (1996), hep-ph/9607440

[6] Y. V. Kovchegov and K. Tuchin, Phys. Rev. D 65, 074026 (2002), hep-ph/0111362

[7] A.H. Mueller and S. Munier, Nucl. Phys. A 893 (2012), arXiV: 1206.1333

[8] B. G. Giraud and R. Peschanski, Phys. Lett. B 760 (2016) 26-30, arXiv: 1604.01932

[9] D.N. Triantafyllopoulos, work in progress.

JOCHEN WAMBACH

My research in 2020 included the following topics:

- Equilibrium properties of hot and dense strong-interaction matter
- Medium modification of the spectral properties of hadrons
- Dilepton rates and polarization observables in heavy-ion collisions.

Vector Mesons in Nuclear Matter

In collaboration with L. von Smekal (Giessen University), C. Jung (Giessen University) and R.-A. Tripolt (Graz University).

Hot and dense QCD matter is encountered in cosmological settings such as the Early Universe and the dynamics of compact stars. Observationally it is probed through electroweak (EW) and gravitational radiation. In the laboratory, extreme conditions in temperature and density are created and diagnosed with relativistic heavy-ion collisions. This project focusses on regions of high net-baryon density and moderate temperatures in the QCD phase diagram, which are relevant for heavy-ion collisions of several GeV/nucleon and in neutron-star merger (NSM) events. The long-term goal is to develop effective chiral theories including baryonic degrees of freedom for finite-density QCD to describe nuclear and neutron matter. These will be confronted quantitatively with heavy-ion measurements involving rare and penetrating electromagnetic probes such as photons and dileptons. In the same framework we compute equations of state and provide input for checks of astrophysical constraints and the computation of gravitational-wave signals in NSM events from a possible chiral restoration transition at high baryon density. The chirally consistent treatment of the EW response will also allow to predict neutrino production rates in these events. To this end we are studying vector and axial-vector mesons in dense nuclear matter at finite temperature. In particular, the in-medium spectral functions of the rho and the a1 meson are calculated at high baryon-chemical potential, taking into account the effects of fluctuations from scalar mesons, nucleons, and vector mesons. This is achieved by employing a chiral baryon-meson model as a low-energy effective model for nuclear matter, in combination with the Functional Renormalization Group (FRG) approach. The resulting phase diagram exhibits a nuclear liquid-gas phase transition as well as a chiral phase transition at higher baryon-chemical potentials. The in-medium rho and a1 spectral functions are calculated using the previously introduced analytically-continued FRG (aFRG) method. Our results show strong modifications of the spectral functions in particular near the predicted critical endpoints. Our work represents a first step towards a more realistic description of vector mesons in nuclear matter, as for example relevant for the interpretation of dilepton spectra in heavy-ion collision and the prediction of thermal neutrino production in NMS events.

In-medium fermionic spectral functions

In collaboration with L. von Smekal (Giessen University), Dirk Rischke (Frankfurt University) and R.-A. Tripolt (Graz University).

Having explored the spectral properties of mesonic fluctuations within the FRG approach in the past, we continue working on the calculation of fermionic spectral functions. One of the aims is to explore the interplay between chiral dynamics and the Fermi-liquid behaviour of collective modes in the vicinity of the Fermi edge in the high-chemical potential, low-temperature regions of the strong-interaction phase diagram. Our method is based on a well-defined analytic continuation procedure from imaginary to real energies that was developed for bosonic spectral functions in the past. In order to demonstrate the applicability of the method for fermions we have applied it to the Quark-Meson model and have calculated in a first step the real-time quark propagator as well as the quark spectral function in the vacuum. More recently we have extended the calculations to finite temperatures and baryochemical potentials by studying in-medium fermionic excitations. In particular, we have used the two-flavor quark-meson model in combination with the aFRG approach. The resulting fermionic excitation spectrum has been investigated by calculating the quark spectral function at finite temperature, quark chemical potential, and spatial momentum. We have identified three different collective excitations in the medium: the ordinary thermal quark mode, the plasmino mode, and an ultra-soft "phonino" mode. The dispersion relations of these modes were extracted from the quark spectral function. When compared to corresponding results from an FRG-improved one-loop calculation remarkable agreement has been found.

Dilepton rates and polarization observables in heavy-ion collisions

In collaboration with B. Friman (GSI), E. Speranza (University of Illinois at Urbana-Champaign), H. van Hees (Frankfurt University), and R. Rapp (Texas A&M University).

Polarization observables in the dilepton emission from heavy-ion collisions contain valuable information on the nature of the emitting fireball. Based on work by B. Friman and E. Speranza on polarized dilepton radiation from a thermal QCD medium we continue to work on realistic predictions for the λ_θ –Parameter based on calculated rates that quantitatively describe the unpolarized dilepton data of many heavy-ion experiments. First results indicate a sizable polarization for invariant masses below 1.5 GeV especially for collision energies around 10 GeV and below.

Other scientific activities

Besides the research described above, I have co-organized an annual meeting in Nuclear Physics:

"*Arbeitstreffen Kernphysik 2020*" Schleching, Germany
(Production and Structure of Exotic Hadronic States, Beyond the Hadron-Resonance Gas: EoS, neutron stars, hadron production and hadronization, Technology of and Physics Opportunities with modern Si Detectors)
Schleching, Germany
February 27 - March 5, 2020

SHU-YI WEI

Elliptic flow in small collisional systems

In collaboration with C. Marquet, G.Y. Qin, Y. Shi, L. Wang, B.W. Xiao, C. Zhang and L. Zheng.

Collective phenomena have been observed by several collaborations among high multiplicity events in small collisional systems. Particularly the CMS collaboration has reported large values of elliptic flow (v_2) for J/ψ mesons and for D^0 mesons in high multiplicity pA collisions, which hydrodynamics approach fails to reproduce. In a series of papers [1], we have systemically described the v_2 of light hadrons, heavy quarkonia and open heavy mesons utilizing the CGC formalism. This indicates that the large v_2 in the small collisional system arises from the initial state effect.

Recently, the ATLAS collaboration has reported collective phenomenon in the photo-nuclear ultra-peripheral AA collisions (UPC) as well. There is a nice similarity between light hadron v_2 in photon-nucleus collisions and in pA collisions, which suggests that the wave function of a low-virtuality photon contains a state with quite a few active partons due to the rare QCD fluctuation and the dominate contribution to the high multiplicity events comes from such a partonic structure. Therefore, the collective phenomenon in UPC can be naturally described by the CGC formalism [2]. Following this perception, we predict that an evident collective phenomenon can also be observed at the low-Q region of the upcoming Electron-Ion Collider (EIC). With the unprecedented precision and the ability to change size of the collisional system, the high luminosity EIC will open a new window to explore the physical mechanism responsible for the collective phenomenon.

Hadron structure and hadronization

In collaboration with K.B. Chen, Y. K. Song and Z.T. Liang

(1) The three-dimension hadron structure is a very fundamental topic in QCD. While most of the previous studies focus on the SIDIS and low-energy Drell-Yan process, we find that Z^0-boson production at low transverse momentum offers a unique opportunity to explore this field. In Ref. [3], we extracted the non-perturbative Sudakov factor, which can be translated into the intrinsic transverse momentum distribution of the quark by a Fourier transform, from the ultra-precise φ^*-distribution of Z^0-boson production in pp collisions. We demonstrated how this observable in high energy collisions reveals information on non-perturbative physics.

(2) Hadron structure and hadronization mechanism are two faces of the same coin. Progress on one topic certainly enriches our knowledge on the other. The spin-dependent fragmentation functions are responsible for the polarization of final state hadrons and carry valuable information on how a high energy parton hadronizes. The spin-alignment of vector mesons has been proved to be independent from the polarization of parent partons. We made the first quantitative prediction for the spin-alignment of vector mesons produced in pp collisions [4], using the fragmentation functions extracted from LEP experiments. The future experimental measurements in pp collisions will allow us to acquire more intelligence on the spin-dependent fragmentation function of gluons.

References

[1] C. Zhang, C. Marquet, G. Y. Qin, S. Y. Wei and B. W. Xiao, Phys. Rev. Lett. 122, (2019) 172302; C. Zhang, C. Marquet, G. Y. Qin, Y. Shi, L. Wang, S. Y. Wei and B. W. Xiao, Phys. Rev. D 102, (2020) 034010

[2] Y. Shi, L. Wang, S. Y. Wei, B. W. Xiao and L. Zheng, Phys. Rev. D 102 (2020) 034010

[3] S. Y. Wei, arXiv:2009.06514 (2020)

[4] K. B. Chen, Z. T. Liang, Y. K. Song and S. Y. Wei, Phys. Rev. D 102 (2020) 034001.

3.2 Publications of ECT* Researchers in 2020

DANIELE BINOSI

Z. F. Cui, M. Ding, F. Gao, K. Raya, D. Binosi, L. Chang, C. D. Roberts, J. Rodríguez-Quintero and S. M. Schmidt
Kaon and pion parton distributions
Eur. Phys. J. C 80 (2020) no.11, 1064

Z. F. Cui, C. Chen, D. Binosi, F. de Soto, C. D. Roberts, J. Rodríguez-Quintero, S. M. Schmidt and J. Segovia
Nucleon elastic form factors at accessible large spacelike momenta
Phys. Rev. D 102 (2020) no.1, 014043

Z. Q. Yao, D. Binosi, Z. F. Cui, C. D. Roberts, S. S. Xu and H. S. Zong,
Semileptonic decays of $D_{(s)}$ mesons
Phys. Rev. D 102 (2020) no.1, 014007

D. Binosi and A. Quadri
Off-shell renormalization in the presence of dimension 6 derivative operators. Part III. Operator mixing and β-functions
JHEP 05 (2020), 141

Z.-F. Cui, J.-L. Zhang, D. Binosi, F. de Soto, C. Mezrag, J. Papavassiliou, C. D. Roberts, J. Rodríguez-Quintero, J. Segovia, S. Zafeiropoulos
Effective charge from lattice QCD
Chin.Phys.C 44 (2020) 8, 083102

M. Ding, K. Raya, D. Binosi, L. Chang, C. D. Roberts, S. M. Schmidt
Drawing insights from pion parton distributions
Chin.Phys.C 44 (2020) 3, 031002

K. Raya, L. Chang, M. Ding, D. Binosi, L. Chang, C. D. Roberts
Unveiling the structure of pseudoscalar mesons
Contribution to: HADRON 2019, 565-569

M. Ding, D. Binosi, K. Raya, L. Chang, L. Chang, C. D. Roberts
Two photon transition form factors of neutral pseudoscalar mesons
Contribution to: HADRON 2019, 545-549

J. Rodríguez-Quintero, D. Binosi, C. Chen, Y. Lu, C. D. Roberts, J. Segovia
Form factors for the Nucleon-to-Roper electromagnetic transition at large-Q^2
EPJ Web Conf. 241 (2020) 02009

T. Morresi, D. Binosi, S. Simonucci, R. Piergallini, S. Roche, N. M. Pugno, S. Taioli
Exploring event horizons and Hawking radiation through deformed graphene membranes
2D Materials (2020) 7, 041006

M. Ding, K. Raya, D. Binosi, L. Chang, C. D. Roberts, S. M. Schmidt
Symmetry, symmetry breaking, and pion parton distributions
Phys. Rev. D 101 (2020) 5, 054014

D. Binosi, R. A. Tripolt
Spectral functions of confined particles
Phys. Lett. B 801 (2020) 135171

D. Binosi, A. Quadri
Off-shell renormalization in the presence of dimension 6 derivative operators. II. UV coefficients
Eur. Phys. J.C 80 (2020) 9, 807

FRANCESCO CELIBERTO

F. G. Celiberto, M. Fucilla, D. Yu. Ivanov, A. Papa
Diffractive production of Λ Hyperons in the high-energy limit of strong interactions
Phys. Rev. D 102 (2020) no.9, 09419, 13 pages [arXiv:2008.10513]
doi:10.1103/PhysRevD.102.094019

A. Bacchetta, F. G. Celiberto, M. Radici, P. Taels
High-energy resummation in heavy-quark hadroproduction
Eur. Phys. J. C 79 (2020) no.8, 733, 11 pages [arXiv:2005.02288] doi:10.1140/epjc/s10052-020-8327-6

CONSTANTINOS CONSTANTINOU

K. Aryal, C. Constantinou, R. L. S. Farias, V. Dexheimer
High-energy phase diagrams with charge and isospin axes under heavy-ion collision and stellar conditions
Phys. Rev. D 102, 076016 (2020)

V. Dexheimer, K. Aryal, C. Constantinou, J. Peterson
3-Dimensional QCD phase diagrams for strange matter
J. Phys.: Conf. Ser. 1602 012013 (2020)

Preprint

V. Dexheimer, K. Aryal, M. Wolf, C. Constantinou, R. L. S. Farias
Deconfinement phase transition under chemical equilibrium
arXiv:2011.11686 [nucl-th]

HILLA DE LEON

H. De-Leon, F. Pederiva
Particle modeling of the spreading of Coronavirus Disease (COVID-19)
Physic of fluids, 2020, (featured)

MINGHUI DING

M. Ding, K. Raya, D. Binosi, L. Chang, C. D. Roberts, S. M. Schmidt
Symmetry, symmetry breaking, and pion parton distributions

Phys. Rev. D 101 (2020) 5, 054014

M. Ding, K. Raya, D. Binosi, L. Chang, C. D. Roberts, S. M. Schmidt
Drawing insights from pion parton distributions
Chin. Phys. C 44 (2020) 3, 031002

Z.-F. Cui, M. Ding, F. Gao, K. Raya, D. Binosi, L. Chang, C. D. Roberts, J. Rodríguez-Quintero, S. M. Schmidt
Kaon and pion parton distributions
Eur. Phys. J.C 80 (2020) 11, 1064.

F. Gao, M. Ding
Thermal properties of \pi and \rho meson
Eur. Phys. J.C 80 (2020) 12, 1171

C. Mezrag, J. Segovia, M. Ding, L. Chang, C. D. Roberts
Nucleon parton distribution amplitude: A scalar diquark picture
Springer Proc. Phys. 238 (2020) 773-781

L. Chang, M. Ding
The rainbow modified-ladder approximation and degenerate pion
arXiv: 2011.05505 [hep-ph], Submitted to Phys. Rev. D

JARKKO PEURON

K. Boguslavski, A. Kurkela, T. Lappi, J. Peuron
Heavy quark diffusion in an overoccupied gluon plasma
JHEP 09 (2020) 077, 2005.02418 [hep-ph]

Quark Matter proceeding
K. Boguslavski, A. Kurkela, T. Lappi, J. Peuron
Heavy quark momentum diffusion coefficient in 3D gluon plasma
Nucl. Phys. A 1005 (2020) 121970, 2001.11863 [hep-ph]

ALESSANDRO PILLONI

KLF Collaboration (M. Amaryan et al.)
Strange hadron spectroscopy with secondary K_L^0 beam in hall D
ArXiv:2008.08215

JPAC Collaboration (M. Albaladejo et al.)
XYZ spectroscopy at electron-hadron facilities: Exclusive processes
Phys. Rev. D102 (2020) 114010

A. Esposito, E.G. Ferreiro, A. Pilloni, A.D. Polosa, C.A. Salgado
The nature of X(3872) from high-multiplicity pp collisions
arXiv:2006.15044

JPAC Collaboration (M. Albaladejo et al.)
$\omega \to 3\pi$ and $\omega\pi^0$ transition form factor revisited
Eur. Phys. J. C80 (2020) 12, 1107

JPAC Collaboration (V. Mathieu et al.)
Exclusive tensor meson photoproduction
Phys. Rev. D102 (2020) 1, 014003

BaBar Collaboration (J.P. Lees et al.)
Search for a Dark Leptophilic Scalar in $e^+ e^-$ Collisions
Phys. Rev. Lett. 125 (2020) 18, 181801

BaBar Collaboration (J.P. Lees et al.)
Precision measurement of the $BR(\Upsilon(3S) \rightarrow \tau^+ \tau^-)/ BR(\Upsilon(3S) \rightarrow \mu^+ \mu^-)$ ratio
Phys. Rev. Lett. 125 (2020) 241801

BaBar Collaboration (J.P. Lees et al.)
Search for lepton-flavor-violating decays $D^0 \rightarrow X^0 e^\pm \mu^\mp$
Phys. Rev. D101 (2020) 11, 112003

CLAS Collaboration (A. Celentano et al.)
First measurement of direct photoproduction of the $a_2(1320)^0$ meson on the proton
Phys. Rev. C102 (2020) 3, 032201

BaBar Collaboration (J.P. Lees et al.)
Resonances in $e^+ e^-$ annihilation near 2.2 GeV
Phys. Rev. D101 (2020) 1, 012011

BaBar Collaboration (J.P. Lees et al.)
Measurement of the Absolute Branching Fractions of $B^\pm \rightarrow K^\pm X_{ccbar}$
Phys. Rev. Lett. 124 (2020) 15, 152001

M. Mikhasenko, M. Albaladejo, L. Bibrzycki, C. Fernández-Ramírez, V. Mathieu, S. Mitchell, M. Pappagallo, A. Pilloni, D. Winney, T. Skwarnicki, and A. Szczepaniak
Dalitz-plot decomposition for three-body decays
Phys. Rev. D101 (2020) 3, 034033

M. Albaladejo, D. Winney, I. Danilkin, C. Fernández-Ramírez, V. Mathieu, M. Mikhasenko, A. Pilloni, J. A. Silva-Castro, and A. Szczepaniak
Khuri-Treiman equations for 3π decays of particles with spin
Phys. Rev. D101 (2020) 5, 054018

DIONYSIOS TRIANTAFYLLOPOULOS

B. Ducloué, E. Iancu, G. Soyez and D.N. Triantafyllopoulos
HERA data and collinearly-improved BK dynamics
Phys. Lett. B 803 (2020) 135305

E. Iancu, T. Lappi and D.N. Triantafyllopoulos
Small-x physics in the dipole picture at NLO accuracy probing nucleons and nuclei in high energy collisions, pp. 274-294 (2020)

E. Iancu, A.H. Mueller, D.N. Triantafyllopoulos and S.Y. Wei
Saturation effects in SIDIS at very forward rapidities
arXiv:2012.08562, submitted to JHEP

JOCHEN WAMBACH

R.-A. Tripolt, D. H. Rischke, L. von Smekal and J. Wambach
Fermionic excitations at finite temperature and density
Phys. Rev. D 101, 094010, 2020

SHU-YI WEI

K.B. Chen, Z.T. Liang, Y.K. Song, S.Y. Wei
Spin alignment of vector mesons in high energy pp collisions
Phys. Rev. D 102 (2020) 034001

C. Zhang, C. Marquet, G.Y. Qin, Y. Shi, L. Wang, S.Y. Wei, B.W. Xiao
Collectivity of heavy mesons in proton-nucleus collisions
Phys. Rev. D 102, (2020) 034010

L. Chen, S.Y. Wei, H.Z. Zhang
Probing jet medium interactions via Z(H)+jet momentum imbalances
Eur. Phys. J. C 80 (2020) 12, 1136

J.Y. Jia, S.Y. Wei, B.W. Xiao, F. Yuan
Medium-induced transverse momentum broadening via forward dijet correlations
Phys. Rev. D 101, (2020) 094008

3.3. Talks presented by ECT* Researchers in 2020

DANIELE BINOSI

Pion and Kaon Distribution Functions
Talk delivered at the (online) workshop “Perceiving the Emergence of Hadron Mass through AMBER@CERN - 4”
November 30 - December 4, 2020

Fresh Extraction of the Proton Radius from Electron Scattering
Seminar remotely delivered at the “Institute for Nonperturbative Physics”
Nanjing University
December 23, 2020

FRANCESCO CELIBERTO

Contributed talks

Talk on "*Proton 3D tomography at the EIC: TMD gluon distributions*", Electron-Ion Collider @ Snowmass, online
4 August, 2020
Talk on "*3D tomography of the nucleon: transverse-momentum-dependent gluon distributions*", 106° Congresso Nazionale della Società Italiana di Fisica, Milano
14 September, 2020

Talk on "*Higgs-plus-jet distributions as stabilizers of the high-energy resummation*", Resummation, Evolution, Factorization 2020, Higgs Centre, Edinburgh
10 December, 2020

Invited talks

Talk on "*Modeling gluon TMDs*", Quarkonia As Tools 2020, Centre Paul Langevin, Aussois, France
15 January, 2020

Talk on "*A model calculation of polarized and unpolarized gluon TMD PDFs* ", EICUG Yellow Report – SIDIS, online
9 March , 2020

Talk on "*3D tomography of the proton: TMD gluon distributions*", Snowmass 2021 EF06 Kick-off meeting, online
20 May, 2020

Talk on "*BFKL vs DGLAP in semi-hard processes*", Snowmass 2021 EF06 meeting – Forward QCD, online
17 June, 2020

Talk on "*Proton tomography at the EIC for HEP applications: TMD gluon distributions*", Snowmass 2021 EF06 meeting – Preparation of LOI’s, online
26 August, 2020

Talk on "*Proton 3D tomography: TMD gluon densities in a spectator model*", Gluon content of proton and deuteron with the Spin Physics Detector at the NICA collider, online
30 September, 2020

Talk on "*3D proton tomography at the EIC: TMD gluon distributions*", Snowmass Community Planning Meeting, online
5 October, 2020

Talk on "*Transverse-momentum-dependent parton densities in a spectator model*", MAP Collaboration Meeting, online
13 October, 2020
Talk on "*From high energies to hadronic structure*", Snowmass 2021 EF06 meeting – Early Career Researchers, online
14 October, 2020

Talk on "*Inclusive Higgs + jet*", Snowmass 2021 EF01 meeting – Higgs invisible and couplings, online
5 November, 2020
Talk on "*Probing gluon TMDs using quarkonium production*", Snowmass 2021 EF06-RF07 Joint meeting, online
16 December, 2020

Overviews

Overview on "*From Mueller-Navelet jets to forward J/psi+backward jet production*", *Quarkonia As Tools 2020*, Centre Paul Langevin, Aussois, France
14 January, 2020

Invited seminars

Seminar on "*A spectator-model approach to TMD gluon distribution functions*", Thomas Jefferson National Accelerator Facility, USA
11 May, 2020

Seminar on "*Elements of TMD factorization: gauge links and modified universality*", Università della Calabria & INFN-Cosenza
17 December, 2020

CONSTANTINOS CONSTANTINOU

Hot equation of state: Astrophysical applications
Talk given at the STAG Research Center, University of Southampton, UK
July 2020

HILLA DE LEON

Particle modeling of the spreading of Coronavirus Disease (COVID-19)
ECT* webinar, Trento, Italy
July 2020

Few-body systems from pionless effective field theory
INT Virtual Program: "Beyond-the-Standard-Model Physics with Nucleons and Nuclei"
July 2020

Few-body systems from pionless effective field theory
DNP Fall Meeting, Nuclear Physics "From Effective Field Theory and Lattice Field Theory"
October 2020

MINGHUI DING

Pion and Kaon valence-quark parton distribution functions
Seminar given at Nanjing University & Institute for Nonperturbative Physics, China
January 2020

Pion parton distribution functions in a symmetry-preserving approach
Talk given at the workshop "Perceiving the Emergence of Hadron Mass through AMBER@CERN-II", CERN e-Workshop (per COVID-19)
March 2020

Pion parton distribution functions
Talk given at the "Workshop on Pion and Kaon Structure Functions at the EIC", CFNS e-Workshop (per COVID-19)
June 2020

Light pseudoscalar meson parton distribution function with Dyson-Schwinger Equations
Seminar given at "The 9th Hadron Physics Online Forum (HAPOF)", e-seminar (per COVID-19)
September 2020

DAs and DFs of diquark correlations
Talk given at the workshop "Perceiving the Emergence of Hadron Mass through AMBER@CERN-IV", CERN e-Workshop (per COVID-19)
December 2020

Pion and kaon parton distribution functions
Seminar given at IFM-UMSNH, e-seminar (per COVID-19)
December 2020

JARKKO PEURON

Heavy quark diffusion in an overoccupied gluon
University of Jyväskylä, Finland plasma
May 2020

Heavy quark diffusion in an overoccupied gluon plasma
Vienna University of technology, Austria
July 2020

ALESSANDRO PILLONI

XYZP spectroscopy at a charm photoproduction factory
Analysis of Light Exotic Hadron Measurements
Production of Exotic Hadrons at the EIC
Invited talks at the Hadron Spectroscopy RF7 workshop within Snowmass21
September-October 2020, Online

Spectroscopy overview/theory
Invited Talk given at "1st EIC Yellow Report Workshop"
March 2020 Philadelphia (USA)

SAGA SÄPPI

Pushing finite-density pQCD to NNNLO
Online seminar for ECT*
October 2020

Thermal pQCD and the progress towards the NNNLO pressure at zero temperature
Online seminar for the Helsinki Institute of Physics
November 2020

DIONYSIOS TRIANTAFYLLOPOULOS

Gluon Saturation in Collider Physics
Talk at the workshop “Nuclear physics and related areas @ Trento”
17 January 2020, Trento, Italy

SHU-YI WEI

Angular de-correlation of forward di-hadrons: on the optimal p_T range to probe gluon saturation
Parallel talk in HardProbes2020
June 2020 (Online)

CGC phenomenology and hadron structure
Seminar at Shandong University (Qingdao)
October 2020 (Online)

3.4. Seminars and Colloquia at ECT*

Seminars

Non-perturbative properties of evolving gluonic plasmas
14 May 2020
Kyrill Boguslavski (Vienna University of Technology)

Quarkonium as a tool
20 May 2020
Elena G. Ferreiro (University of Santiago De Compostela)

Exclusive processes as a probe of gluon saturation at the EIC
09 June 2020
Heikki Mäntysaari (University of Jyväskylä, Finland)

Pion parton distributions from its light front wave function
16 June 2020
Khépani Raya Montaño (Nankai University, China)

Real-time physics from Dyson-Schwinger equations via spectral renormalisation
25 June 2020
Jan Horak (Heidelberg University)

Topology and axions in QCD
01 July 2020
Maria Paola Lombardo

Particle modeling of the spreading of coronavirus disease (Covid-19)
9 July 2020
Hilla De Leon (ECT*)

Locally finite gauge theory amplitudes: a case example
10 July 2020
Babis Anastasiou (ETH Zürich)

Pushing finite-density PQCD to NNNLO
22 October 2020
Saga Säppi

Nuclear equation of state – Astrophysical applications
18 November 2020
Constantinos Constantinou (ECT*).

Colloquia

Due to the COVID-19 pandemic, a large fraction of the ECT* workshops initially planned for 2020 have been postponed to 2021. To introduce and promote the topic of the postponed workshops to a wider audience, the ECT* has started last summer with a series of “colloquia style” presentations of about one hour each on the topics of the postponed workshops. The recorded presentations are available on the ECT* YouTube Channel.

STRANU: Hot Topics in STRANgeness NUclear and Atomic Physics
16 July 2020
Catalina Curceanu (LNF-INFN) and Kristian Piscicchia (CREF and LNF-INFN)

Heavy-Flavor Transport in the Quark-Gluon Plasma
03 September
Ralf Rapp (Texas A&M University)

The strong interaction: from the LHC to the Higgs factory and beyond
09 September 2020
Marcel Vos (IFIC Valencia)

Dense matter in neutron stars and its implications for multi-messenger astronomy & *The neutron star interior composition explorer and beyond*
10 September
Anna Watts (University of Amsterdam) and Sanjay Reddy (University of Washington)

Generalized parton distributions of light nuclei
16 September
Sergio Scopetta

Saturation and Diffraction at the LHC and the EIC
September 22
Christophe Royon (Kansas University)

Relativistic Fermions in Flatland: Theory and Application
October 01
Lukas Janssen (TU Dresden)

Challenges and Advances at the Interface of Nuclear, Atomic and Condensed Matter Physics
October 05
Joaquin Drut (University of North Carolina at Chapel Hill)

Key Reactions in Nuclear Astrophysics
November 30
Aurora Tumino (Università degli Studi di Enna “Kore” and INFN-LNS Catania)

Machine Learning for High Energy Physics, on and off the Lattice
3 December
Kyle Cranmer (New York University)

Probing Nuclear Physics with Neutron Star Mergers
15 December
Matthew Mumpower (LANL)

Theoretical and Experimental Challenges for Flavor Hadrons, Quarkonia and Multi-quarks
16 December
Mikhail Barabanov (JINR) and Bruno El-Bennich (Universidade Cruzeiro do Sul).

Research at ECT*-LISC

4. Research at ECT*-LISC

4.1 Projects of ECT*-LISC Researchers

MAURIZIO DAPOR

Biodamage induced by carbon irradiation

In collaboration with I. Abril (University of Alicante, Spain) and R. Garcia Molina (University of Murcia, Spain)

Accurate Monte Carlo simulations were performed of the energy deposited by swift carbon ions in liquid water and carried away by the generated secondary electrons, producing inelastic events such as ionization, excitation, and dissociative electron attachment (DEA). The latter are strongly correlated with cellular death, which is scored in sensitive volumes with the size of two DNA convolutions. The sizes of the clusters of damaging events for a wide range of carbon-ion energies, from those relevant to hadrontherapy up to those for cosmic radiation, predict with unprecedented statistical accuracy the nature and relative magnitude of the main inelastic processes contributing to radiation biodamage, confirming that ionization accounts for the vast majority of complex damage. DEA, typically regarded as a very relevant biodamage mechanism, surprisingly plays a minor role in carbon-ion induced clusters of harmful events.

Focused electron beam induced deposition process

In collaboration with A. V. Solov'yov (MBN Research Center, Frankfurt am Main, Germany)

Through an in-depth analysis of $W(CO)_6$ deposition on SiO_2 and its subsequent irradiation with electrons, we provide a comprehensive description of the FEBID process and its intrinsic operation. Our analysis reveals that simulations deliver unprecedented results in modeling the FEBID process, demonstrating an excellent agreement with available experimental data of the simulated nanomaterial composition, microstructure and growth rate as a function of the primary beam parameters. The generality of the methodology provides a powerful tool to study versatile problems where IDC and multiscale phenomena play an essential role.

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S Dielectric response of metals

In collaboration with O. Yu. Ridzel, P. S. Kaplya, and V. Afanas'ev (National Research University "Moscow Power Engineering Institute", Moscow, Russia)

We investigated two different models for interpreting and predicting Reflection Electron Energy Loss (REEL) spectra of metals, comparing their respective computational cost and accuracy. These two approaches are the Monte Carlo (MC) method and the Numerical Solution (NS) of the Ambartsumian-Chandrasekhar equations.

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PABLO DE VERA GOMIS

Nanoparticle Enhanced Hadron-therapy: a comprehensive Mechanistic description
In collaboration with M. Dapor, S. Taioli (ECT*/FBK) and E. Scifoni (TIFPA, Trento)

NanoEnHanCeMent (Nanoparticle Enhanced Hadron-therapy: a comprehensive Mechanistic description) is an action aimed to apply basic Physics and Chemistry methods to uncover the microscopic mechanisms behind nanoparticle enhancement of hadron-therapy for cancer treatment (or ion beam cancer therapy). Hadron-therapy (radiotherapy using accelerated ion beams) is one of the most advanced radiotherapies available, with superior dose delivery and biological effectiveness as compared to conventional radiotherapy. The increased effectiveness of hadron-therapy relies on physico-chemical phenomena occurring on the nanoscale. There is experimental evidence pointing out to nanoparticles enhancing the biological effects of ion beams. Since nanoparticles can be tuned to target cancer cells, they might be used to further improve hadrontherapy. However, it is still unknown how nanoparticles produce this effect. A proper exploitation of the nanoparticle radioenhancement in hadrontherapy depends on improving the understanding of the physico-chemical mechanisms responsible for it. In this project, a theory and modelling approach is proposed, in which a series of semiempirical and ab-initio methods will be extended and interfaced with Monte Carlo track-structure simulation tools, in order to advance the basic understanding of the nanoparticle enhanced hadron-therapy physical and chemical mechanisms.

Study of high-Z ceramics nanoparticles as enhancers in proton therapy

In collaboration with: G. Garberoglio, S. Taioli, P. de Vera, M. Dapor (ECT*/FBK), N. M. Pugno (University of Trento), R. Garcia Molina (University of Murcia), I. Abril (University of Alicante), E. Scifoni (TIFPA, Trento) and M. Schwarz (Trento Proton Therapy Centre and INFN-TIFPA)

High-Z ceramics such as cerium and tantalum oxide are promising for increasing the relative biological effectiveness in proton beam therapy. We study the secondary electrons production in these materials by means of Monte Carlo simulations based on ab-initio calculations in order to design optimal nanostructures.

Interaction of low energy electrons with nanosystems

In collaboration with R. Garcia-Molina (University of Murcia, Spain), I. Abril (University of Alicante, Spain), J. M. Fernández-Varea (University of Barcelona, Spain), M. Dapor (ECT*/FBK), D. Emfietzoglou (University of Ioannina, Greece) and A. V. Solov'yov (MBN Research Center, Frankfurt, Germany)

The interaction of ionizing radiation with matter is used routinely as a tool both to modify or analyse properties of materials and to gain basic knowledge on their internal structure. As a result of the interactions, in most cases secondary electrons are produced, which propagate degrading their energy through the traversed medium. Low-energy (less than 100 eV) electrons are generated abundantly, and are known to have an important role on the fabrication techniques of nanostructured devices, such as electron-beam lithography or focused electron beam induced deposition-

FEBID (whose resolution and composition can be affected by the energetic and spatial distribution of the electrons), and vice-versa, when electrons are produced or move in close proximity of metallic nanoparticles or interfaces (which can influence the energetic characteristics of the electrons). Moreover, low-energy electrons play a crucial role in radiobiology (owing to their relevant effects in biodamage). In this context, the aim of the present research is to achieve a detailed knowledge of the interactions with, and effects on, nanosystems of electrons in this energy range, which are required in order to understand and improve the yield of the above-mentioned processes. With these aims in mind, there are several goals in this research project. On the one hand, we will calculate doubly-differential (in energy and angle), singly-differential and total ionization cross sections for low-energy electrons interacting with different materials, such as heavy metals (Au, Cu, Ag, Pt, Gd), insulators and polymers (SiO2, PMMA...), biological materials (liquid water, DNA, protein, lipid, carotene, sugar and other cellular constituents), paying special attention to the condensed phase nature of these targets. Furthermore, we will obtain cross sections for Auger and Coster-Kronig electron emission resulting from proton- and electron-impact ionization in the aforementioned materials. The relevance of these cross sections lies in their use for detailed event-by-event Monte Carlo simulations aimed at predicting radiation-induced damage (or modification) of the target properties. On the other hand, the influence of interfaces (either flat as in charged-particle lithography or FEBID or curved as in sensitising metallic nanoparticles) close to the electron trajectories deserves a careful study, since surface excitations can modify the electron cascade spectrum. The planned research will be performed using both analytical and simulation tools. The former are based on the dielectric formalism (with possible corrections to this first-order Born approximation) to study the interaction of charged particles with condensed matter (even when interfaces are present) with a proper description of the target excitation and ionization spectrum obtained either from optical experimental data or from time dependent density functional theory calculations. The latter will combine Monte Carlo and molecular dynamics techniques to describe the motion and energy transfer of the electrons through cellular environments, and close to interfaces, as well as the possible effects of the energy deposition.

Dose estimation in hadrontherapy

In collaboration with C. Lacasta Llácer and G. Llosá (IFIMED, Medical Physics Institute, Valencia, Spain), I. Abril (University of Alicante, Spain), R. Garcia-Molina (University of Murcia, Spain) and M. Dapor (ECT*/FBK)

Hadrontherapy is experiencing an extraordinary boom in the world, and in particular in Europe, with around twenty centres in operation and ten more under construction, which will start operating in the coming years. Given its relevance, Spain has recently joined this initiative, reinforcing the interest of Spanish researchers investigating in this field.

Conventional radiotherapy mainly uses photons, which deposit the energy at the beginning of its journey, following an exponential decay. In contrast, hadrontherapy uses massive charged particles (usually protons or carbon ions), which deposit their energy mainly at the end of their journey. This allows the radiation dose to be minimized in the healthy tissue surrounding the tumour while it is maximized in the tumour area. In addition, the enhanced relative biological effectiveness of the charged particles against photons (that is, greater probability of cell death for the same dose) makes hadrontherapy more effective in the case of radio-resistant tumours. This technique has been shown to be superior to conventional radiotherapy in some types of cancer for which it has been established as the appropriate treatment (deep tumours of the eye, brain, head and neck), as well as in the case of paediatric cancer, in which dose reduction in developing tissues is vital to minimize future problems. Furthermore, reducing the dose in healthy tissues may also be beneficial in other types of cancer. It is estimated that 15-20 % of patients would benefit from this type of therapy.

This project aims to contribute to solving one of the most critical open questions that this therapy has today: the correct determination of the dose that is applied to the patient. This project does so from two complementary points of view, closely related and both fundamental:

1. The determination of the dose deposited by radiation (ions and electrons) in the tissue by studying the physical mechanisms of radiation interaction with the materials present in a biological environment. This will be carried out, on the one hand, through the study of simulations of the spatial distribution of the dose deposit in realistic biological targets and, on the other hand, through the development of experimental systems for microdosimetry.

2. The correct determination of the distribution of the dose received by the patient while the treatment is taking place using a Compton detector for instantaneous gamma rays produced in the nuclear interactions of the beam with the patient's tissue.

For the correct determination of the dose, it is essential to have a deep knowledge of the physical mechanisms of energy deposition in the tissues of the tumour area, as well as the generation and transport of secondary particles, in order to correlate the origin of the secondary particles with the dose map.

GIOVANNI GARBEROGLIO

Towards quantum-based realisations of the pascal (QuantumPascal)

In collaboration with NIST and various European Metrological Institutes. This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union’s Horizon 2020 research and innovation programme (30 k€)

In this project, I am developing ab-initio calculations for the dielectric virial coefficients of quantum gases (helium, neon and argon) with no uncontrolled approximations. We published our first results [1], where we validated a path integral approach to the calculation of the second dielectric virial coefficients, comparing it to more traditional wavefunction-based methods. We used state-of-the-art pair potential and atomic polarizabilities, estimating their contribution to the uncertainty of the second dielectric virial coefficient. Our results are more accurate than experimental determinations in the case of helium isotopes, and could be further improved by improving the accuracy of the ab-initio pair polarizabilities. Moreover, we pointed out the need of improving the pair polarizabilities for neon and argon. A list of our calculated values densely covering a significant range of temperatures has been made available to the community free of charge [2].

During the course of the year, we began working on the extension to the calculation of higher-order dielectric virial coefficients of monoatomic gases.

Realising the redefined kelvin (Real-K)

In collaboration with NIST and various European Metrological Institutes. This project has received funding from the European Metrology Programme for Innovation and Research and from the EU Horizon 2020 research and innovation programme (40 k€)

In this project, I am developing ab-initio calculations for density virial coefficients of quantum gases (helium, neon and argon) with no uncontrolled approximations. This past year, after a critical revision of our previous work which highlighted an imprecision in the derivation of the exchange contributions to the third virial coefficient [3,4], I calculated the fourth virial coefficient. We confirmed previous results obtained without the use of exchange contributions, and we carefully computed for the first time all the contributions to the overall uncertainty, coming from the propagation of the two- and three-body potential uncertainties. We also made a physically sound estimation of the contribution from the as-of-yet unknown four-body potential [5].

ANDREA PEDRIELLI

Calculation of thermodynamical properties of magnesium hydride nanoparticles from stochastic self-consistent harmonic approximation (SSCHA)

In collaboration with G. Garberoglio, P. E Trevisanutto and S. Taioli (ECT*), N. M. Pugno (University of Trento), L. Monacelli (Università di Roma La Sapienza)

While a body of literature has been devoted to the calculation of thermodynamical properties of magnesium hydride nanoparticles by means of a harmonic approximation, the assessment of these properties in a fully anharmonic framework is still lacking. We assessed the free energy calculation as well as the desorption temperature calculation by means of Stochastic Self Consistent Harmonic Approximation (SSCHA) combined with ab-initio evaluation of potential energy surface and forces using density functional theory. In particular, we calculated the H desorption temperature for representative Mg_nH_{2n} nanoparticles. In parallel, in order to study large nanoparticles and, at the same time, make the most of computationally expensive DFT calculations performed on small clusters, a Machine Learning model has been trained to determine the forces, total energies (and then, the potential energy surfaces) of the molecular clusters. For this purpose, we have employed the Schnet Neural-Network package, integrating this last with the Atomic Simulation Environment (ASE) and SSCHA python code.

Study of high-Z ceramics nanoparticles as enhancers in proton therapy

In collaboration with: G. Garberoglio, S. Taioli, M. Dapor (ECT*), N. M. Pugno (University of Trento), P. de Vera Gomis and R. Garcia Molina, (University of Murcia), I. Abril (University of Alicante), E. Scifoni (TIFPA, Trento), M. Schwarz (Trento Proton therapy centre and INFN-TIFPA)

This project is supported by the CARITRO foundation and the DICAM of UNITN. High-Z ceramics such as cerium and tantalum oxide are promising for increasing the Relative Biological Effectiveness (RBE) in proton beam therapy. We study the secondary electrons production in these materials by means of Monte Carlo simulations based on ab-initio calculations in order to design optimal nanostructures. The interaction between electrons and these nanostructures, as well as in general the electron matter interaction, is commonly described using well stated Monte Carlo simulations. However, in order to improve the predictive power of this method it should be informed from ab-initio calculations, going beyond typical semi-empirical approach in the assessment of the response function. We performed ab-initio calculation of full momentum-dependent dielectric response function for bulk CeO_2 and Ce_2O_3 from Time Dependent Density Functional Theory method (TDDFT). We compared the optical properties derived from the dielectric response function in the optical limit with the experimental data from the literature, finding a good agreement. In addition, the calculation of the Energy Loss Function (ELF) at finite transferred momentum is performed. We calculated the Inelastic Mean Free Path (IMFP) and the comparison with the experimental data from the literature. Finally, we verified the predictive power of ab-initio informed Monte Carlo simulations, computing the Reflection Electron Energy Loss Spectroscopy (REELS) of bulk cerium oxides and comparing them with experimental data.

SIMONE TAIOLI

Relativistic theory of nuclear beta-decay in heavy-nuclei and lithium novel rate assessment

In collaboration with T. Morresi (ECT*), S. Simonucci (University of Camerino), M. Busso (University of Perugia), S. Palmerini (University of Perugia)

In this work a novel theoretical and computational method for computing electroweak beta decay spectra of medium and heavy-mass nuclei, as well as the electronic structure of atomic and molecular systems is developed. In particular, starting from the phenomenological electroweak interaction of the Standard Model (SM) of particles, a general expression of the beta decay rate was derived. Relativistic effects are taken into account by solving the many-electron Dirac equation from first-principles. Furthermore, an extension of this approach to include the nucleon-nucleon interaction at the same level of theory of the electronic correlations has been devised. We apply this ab-initio approach to the assessment of the electron-capture in ^7Be, which is the main production channel for ^7Li in several astrophysical environments. Theoretical evaluations have to account for not only the nuclear interaction, but also

the processes in the plasma in which ^{7}Be ions and electrons interact. In recent decades several estimates were presented, pointing out that the theoretical uncertainty in the rate is in general of a few percent.
In the framework of fundamental solar physics, we consider our evaluation for the $^{7}Be+e^{-}$ rate, in the estimate of neutrino fluxes. In particular, we analyzed the effects of the new assumptions on standard solar models (SSMs) and compared the results obtained by adopting the revised $^{7}Be+e^{-}$ rate to those obtained by that reported in a widely used compilation of reaction rates (ADE11). We found that new SSMs yield a maximum difference in the efficiency of the ^{7}Be channel of about −4% with respect to what is obtained with the previously adopted rate. This fact affects the production of neutrinos from ^{8}B, increasing the relative flux up to a maximum of 2.7%. Negligible variations are found for the physical and chemical properties of the computed solar models [see Refs. 1,2].

Microscopic, nuclear structure calculations and nucleosynthesis of heavy elements via r processes

In collaboration with S. Giuliani (ECT*), S. Simonucci (University of Camerino), A. Perego (University of Trento)

Half of the atomic nuclei heavier than iron found in nature were created in the r process. According to the most recent models, this process occurs in collisions between two neutron stars or between a neutron star and a black hole. As a result of radioactive processes, the heavy nuclei thus synthesized produce a characteristic light emission, called kilonova. In this process of stellar nucleosynthesis the formation of heavy elements occurs through the competition of two nuclear reactions: on the one hand neutron capture, which produces nuclei with an extra neutron, and on the other hand beta decay, which transforms a neutron into a proton. This competition produces heavier and heavier nuclei opening a path in the most extreme regions of the table of nuclides in the vicinity of the nuclear drip line, before reaching the region where the nuclei decay, through fission, in smaller fragments.

A key ingredient in simulations of nucleosynthesis from the r process is the assessment of the nuclear properties of thousands of unstable atomic nuclei. The goal of this project is to perform calculations of nuclear structure from microscopic models within the framework of Density Functional Theory. These results will then be used in detailed simulations of r-process nucleosynthesis. A crucial aspect of the project will be the estimation of the error bars of the theoretical calculations, which will be calculated through algorithms machine learning. This will allow for the first time to accurately determine the variation in the estimates of astronomical observables resulting from uncertainties in the nuclear calculations, allowing for a more accurate future astronomical observation of the electromagnetic counterparts produced in events such as neutron star mergers.

Carbon-based materials with low-density

In collaboration with A. Pedrielli, T. Morresi (ECT*) and N. Pugno (University of Trento)

In this work a systematic approach to the search for all- bonded carbon allotropes with low density is presented [3]. In particular, we obtain a number of novel energetically stable crystal structures, whose arrangement is closely related to the topology of graphene, by modifying the packing of congruent discs under the condition of local stability. Our procedure starts from an initial parent topology and proceeds to generate daughter architectures derived by lowering the packing factors. Furthermore, we assess both the electronic properties, such as the band structure and the density of states, and the mechanical properties, such as the elastic constants and the stress--strain characteristics, of parent's and daughter's geometries from first-principle simulations. We find, using geometrical packing arguments, that some arrangements lead to a density as low as half that of graphene, obtaining some of the least dense structures of all- bonded carbon allotropes that could ever be synthesized. Nevertheless, a threshold value of the density exists below which the mechanical rigidity of graphene is irreparably lost, while keeping other mechanical characteristics, such as the specific toughness and strength, almost unchanged with lower weight.

Models of analog gravity

In collaboration with D. Binosi, T. Morresi (ECT*) and S. Roche (ICREA)

Analogue gravitational systems are becoming an increasing popular way of studying the behaviour of quantum systems in curved spacetime. Setups based on ultracold quantum gases in particular, have been recently harnessed to explore the thermal nature of Hawking's and Unruh's radiation that was theoretically predicted almost 50 years ago. For solid-state implementations, a promising system is graphene, in which a link between the Dirac-like low-energy electronic excitations and relativistic quantum field theories has been unveiled soon after its discovery. Here we show that this link extends to the case of curved quantum field theory when the graphene sheet is shaped in a surface of constant negative curvature, known as Beltrami's pseudosphere [4]. Thanks to large-scale simulations, we provide numerical evidence that energetically stable negative curvature graphene surfaces can be realized; the ratio between the carbon-carbon bond length and the pseudosphere radius is small enough to allow the formation of an horizon; and the associated Local Density Of States evaluated at horizon's proximity has a thermal nature with a characteristic temperature of few tens of Kelvin. Such findings pave the way to the realization of a solid-state system in which the curved spacetime dynamics of quantum many body systems can be investigated.

Relative role of physical mechanisms on complex biodamage induced by carbon irradiation around carbon ion tracks for proton therapy applications

In collaboration with P. De Vera, P. Trevisanutto, M. Dapor (ECT*), R. Garcia-Molina (University of Murcia) and I. Abril (University of Alicante)

The effective use of swift ion beams in cancer treatment (known as hadrontherapy) as well as appropriate protection in manned space missions rely on the accurate understanding of the energy delivery to cells that damages their genetic information. The key ingredient characterizing the response of a medium to the perturbation induced by charged particles is its electronic excitation spectrum. By using linear-response time-dependent density functional theory, we obtained [5] the energy and momentum transfer excitation spectrum (the energy-loss function, ELF) of liquid water (the main constituent of biological tissues), which was in excellent agreement with experimental data. The inelastic scattering cross sections obtained from this ELF, together with the elastic scattering cross sections derived by considering the condensed phase nature of the medium, were used to perform accurate Monte Carlo simulations of the energy deposited by swift carbon ions in liquid water and carried away by the generated secondary electrons, producing inelastic events such as ionization, excitation, and dissociative electron attachment (DEA). The latter are strongly correlated with cellular death, which is scored in sensitive volumes with the size of two DNA convolutions. The sizes of the clusters of damaging events for a wide range of carbon-ion energies, from those relevant to hadrontherapy up to those for cosmic radiation, predict with unprecedented statistical accuracy the nature and relative magnitude of the main inelastic processes contributing to radiation biodamage, confirming that ionization accounts for the vast majority of complex damage. DEA, typically regarded as a very relevant biodamage mechanism, surprisingly plays a minor role in carbon-ion induced clusters of harmful events.

Artificial intelligence for quantum systems

In collaboration with P. Trevisanutto (ICT@FBK & ECT*), M. Cristoforetti (ICT@FBK, FBK), M. De Domenico (ICT@FBK), G. Garberoglio (ECT*), N. Pugno (UniTN)

Several quantum systems can be modeled using spin Hamiltonians, either with short-range (e.g., Ising or Heisenberg models) or long-range interactions (e.g., the recent realization of dipolar BEC in optical lattices). Unfortunately, numerically exact solutions are limited to systems of about 20 objects, as memory requirements to exactly represent the quantum state of a set of spins scale exponentially with their number. This shortcoming prevents accurate numerical studies of several interesting phenomena, such as entanglement properties, the consequences of disorder, and the dynamics of subsystems. For this reason, many efforts have been devoted to the development of approximate yet accurate representations of the quantum state of interacting spins. In 1D, the density matrix renormalization group has been proven to be an optimal tool, whereas in two or more dimensions tensor network states have been shown to be a very good tradeoff between accuracy and scaling. Recently, computational techniques borrowed from the Machine Learning community have been put forward as an even more effective way to represent the quantum state of interacting spins. Within this approach, preliminary promising results have been obtained using Restricted Boltzmann Machines (RBM). Despite its simplicity, this type of network has been found capable of finding a solution of a 2D spin system with smaller energy than that given by state-of-the-art tensor networks, displaying only a polynomial dependence of memory requirements on the system size. This clearly suggests that by looking at more sophisticated architectures in the landscape of the artificial neural networks and deep learning, one could tackle more complex problems in the context of quantum many-body physics and, more in general, materials science.

In this project, we aim at developing novel numerical approaches based on artificial neural networks and deep learning techniques to represent in a memory-efficient way the statistical operator (density matrix) of a quantum system. In the direction of an extension of the results obtained with RBM we will explore the use of other unsupervised algorithms such as variational autoencoders and generative adversarial networks.

Furthermore, we will investigate efficient methods based on neural networks to represent statistical operators in large Hilbert spaces when they are obtained as the exponential of a matrix. We remind that in quantum statistical mechanics the density matrix of a system in thermodynamical equilibrium is given by the exponential of the Hamiltonian divided by the temperature. Finally, we also plan to investigate the temporal evolution of the density matrix, either under unitary evolution (the quantum Liouville equation) or under the non-unitary evolution characteristic of a system in contact with a heat bath (the Lindblad equation).

References

[1] D. Vescovi, L. Piersanti, S. Cristallo, M. Busso, F. Vissani, S. Palmerini, S. Simonucci, S. Taioli
The effects of a revised Be e-capture rate on solar neutrino fluxes
Astronomy & Astrophysics 623 (A126), 7 (2019)

[2] D. Vescovi, L. Piersanti, S. Cristallo, M. Busso, F. Vissani, S. Palmerini, S. Simonucci, S. Taioli
VizieR Online Data Catalog: Effects of a revised 7Be e--capture rate
VizieR Online Data Catalog 362 (2019)[3] M. Azzolini, M. Angelucci, R. Cimino, R. Larciprete

[3] T. Morresi, A. Pedrielli, S. a Beccara, R. Gabbrielli, N. Pugno, S. Taioli
Structural, electronic and mechanical properties of all-sp2 carbon allotropes with density lower than graphene
Carbon 159, 512-526, (2019)

[4] T. Morresi, D. Binosi, S. Simonucci, R. Piergallini, S. Roche, N. Pugno, S. Taioli
Exploring Event Horizons and Hawking Radiation through Deformed Graphene Membranes
2D Materials 7, 041006 (2020)

[5] S Taioli, PE Trevisanutto, P de Vera, S Simonucci, I Abril, R Garcia-Molina,
Relative Role of Physical Mechanisms on Complex Biodamage Induced by Carbon Irradiation around carbon ion tracks for proton therapy applications
The Journal of Physical Chemistry Letters 12, 487-493 (2020)

PAOLO EMILIO TREVISANUTTO

Machine Learning in Condensed Matter Physics

In collaboration with S. Taioli, G. Garberoglio and A. Pedrielli (ECT*)

Magnesium hydride (MgH_2) has been widely studied for effective hydrogen storage. However, its desorption temperature is too high for general practical applications. On the other hand, the MgH_2 nanoparticle desorption temperature is better suitable for industrial aims. In this regard, we have investigated the thermodynamic properties of Mg_nH_{2n} nanoparticles by means of the Stochastic Self Consistent Harmonic Approximation (SSCHA) in conjunction with a Tensor Network Machine learning approach (as implemented in the Schnet code) in such a way that allows for the first-principle inclusion of the fundamental fully anharmonic terms in the nanoparticles free energies.

Machine learning for Quantum System Tomography (QST)

In collaboration with S. Taioli, G. Garberoglio, A. Pedrielli (ECT*), M. Cristoforetti (ICT), M. Di Domenico (ICT), F. Pederiva (University of Trento) and P. Luchi (University of Trento)

In this project, the goal is to reconstruct the density matrix of a general quantum computer state by means of experimental measures. Nevertheless, performing a full QST is often extremely cumbersome. For this reason, Neural Networks are now used to improve the QST detection. In this project, we employ Restricted Boltzmann Machine, Recurrent Neural Networks, and Attention networks in order to quantitatively determine the full system density matrix. In addition, we are performing the machine training by using the experimental findings provided by the collaborators in Livermore Labs (USA).
Relative role of physical mechanisms on complex biodamage induced by carbon irradiation.

4.2 Publications of ECT*-LISC Researchers in 2020

MAURIZIO DAPOR

M. Azzolini, O. Y. Ridzelc, P. S. Kaplya, V. Afanas'ev, N. M. Pugno, S. Taioli, M. Dapor

A comparison between Monte Carlo method and the numerical solution of the Ambartsumian-Chandrasekhar equations to unravel the dielectric response of metals

Computational Materials Science 173 (2020) 109420

P. de Vera, M. Azzolini, G. Sushko, I. Abril, R. Garcia-Molina, M. Dapor, I. A. Solov'yov, A. V. Solov'yov

Multiscale simulation of the focused electron beam induced deposition process

Scientific Reports 10 (2020) 20827

S. Taioli, P. E. Trevisanutto, P. de Vera, S. Simonucci, I. Abril

R. Garcia-Molina and M. Dapor

Relative role of physical mechanisms on complex biodamage induced by carbon irradiation

J. Phys. Chem. Lett. 12 (2021) 487

M. Dapor

Transport of energetic electrons in solids. Computer simulation with applications to materials analysis and characterization

3rd ed.; Springer Nature: Cham, Switzerland, 2020

PABLO DE VERA

P. de Vera, M. Azzolini, G. Sushko, I. Abril, R. Garcia-Molina, M. Dapor, I. A. Solov'yov, A. V. Solov'yov

Multiscale simulation of the focused electron beam induced deposition process

Scientific Reports 10, 208 (2020)

GIOVANNI GARBEROGLIO

G. Garberoglio and A.H. Harvey

Path-integral calculation of the second dielectric and refractivity virial coefficients of helium, neon, and argon

J Res Natl Inst Stan 125:125022 (2020)

A.H Harvey and G. Garberoglio

Calculated values of the second dielectric and refractivity virial coefficients of helium, neon, and argon

https://data.nist.gov/od/id/mds2-2225

G. Garberoglio, M.M. Moldover and A.H. Harvey
Erratum: Improved First-Principles Calculation of the Third Virial Coefficient of Helium
J Res Natl Inst Stan 125:125019 (2020)

G. Garberoglio and A.H. Harvey
Erratum: Path-integral calculation of the third virial coefficient of quantum gases at low temperatures
J. Chem. Phys. 152, 199903 (2020)

G. Garberoglio and A.H. Harvey
Path-integral calculation of the fourth virial coefficient of helium isotopes Submitted. https://arxiv.org/abs/2101.02624

C. Bakes, G. Garberoglio, S. Taioli et al.
Production and processing of graphene and related materials
2D Mater. 7 022001 (2020)

ANDREA PEDRIELLI

T. Morresi, A. Pedrielli, S. a Beccara, R. Gabbrielli, N.M. Pugno and S. Taioli
Structural, electronic and mechanical properties of all-sp2 carbon allotropes with density lower than graphene
Carbon 159, 512-526 (2020)

SIMONE TAIOLI

S. Taioli, P.E. Trevisanutto, P. de Vera, S. Simonucci, I. Abril, R. Garcia-Molina, ...
Relative Role of Physical Mechanisms on Complex Biodamage Induced by Carbon Irradiation
The Journal of Physical Chemistry Letters 12, 487-493 (2020)

L. Hayen, S. Simonucci and S. Taioli
Detailed spectrum calculations of Pb for new physics searches in liquid Xenon
ArXiv preprint arXiv:2009.08303 (2020)

T. Morresi, D. Binosi, S. Simonucci, R. Piergallini, S. Roche, N.M. Pugno, S. Taioli
Exploring Event Horizons and Hawking Radiation through Deformed Graphene Membranes
2D Materials 7, 041006 (2020)

T. Morresi, A. Pedrielli, S. a Beccara, R. Gabbrielli, N.M. Pugno, S. Taioli
Structural, electronic and mechanical properties of all-sp2 carbon allotropes with density lower than graphene
Carbon 159, 512-526 (2020)

M. Azzolini, O.Y. Ridzel, P.S. Kaplya, V. Afanas'Ev, N.M. Pugno, S. Taioli, M. Dapor
A comparison between Monte Carlo method and the numerical solution of the Ambartsumian-Chandrasekhar equations to unravel the dielectric response of metals
Computational Materials Science 173, 109420 (2020)

C. Bakes, G. Garberoglio, S. Taioli et al.
Production and processing of graphene and related materials
2D Materials 7 (2), 022001 (2020)

S. Taioli
Enabling Materials by Dimensionality: From 0D to 3D Carbon-Based Nanostructures
Theoretical Chemistry for Advanced Nanomaterials, 135-200 (2020)

PAOLO EMILIO TREVISANUTTO

M. A. Naradipa, P. E. Trevisanutto, T. C. Asmara, M. A. Majidi, and A. Rusydi
Role of hybridization and on-site correlations in generating plasmons in strongly correlated La2CuO4
Physical Review B 101, 201102 (R) (2020)

T. C. Asmara, F. Lichtenberg, F. Biebl, T. Zhu, P. Kumar Das, M. A. Naradipa, A. D. Fauzi, C. Diao, P. Yang, P. Lenzen, S. Buchenau, B. Grimm-Lebsanft, D. Wan, P. E. Trevisanutto, M. B. H. Breese, T. Venkatesan, M. Rabhausen, and A. Rusydi
Photoinduced metastable dd-exciton-driven metal-insulator transitions in quasi-one-dimensional transition metal oxides
Nature Communications Physics 3 206 (2020)

E. Ridolfi, P.E. Trevisanutto and V.M. Pereira
Expeditious computation of nonlinear optical properties of arbitrary order with native electronic interactions in the time domain
Phys. Rev. B 24 5110 (2020)

S. Taioli, P. E. Trevisanutto, P. de Vera, S. Simonucci, I. Abril, R. Garcia-Molina and M. Dapor
Relative role of physical mechanisms on complex biodamage induced by carbon irradiation
The Journal of Physical Chemistry Letters 12, 487-493 (2020).

4.3 Talks presented by ECT*-LISC Researchers in 2020

MAURIZIO DAPOR

Maurizio Dapor
Computational methods for transport phenomena
Department of Physics (University of Trento)

Maurizio Dapor
Fisica 2
Department of Civil, Environmental and Mechanical Engineering (University of Trento)

PABLO DE VERA

P. de Vera
Computational physics to explore the interaction of radiation with condensed matter
Seminars “Advanced topics in research” of the MSc in Physical Sciences
University of Murcia, Spain (online)
14 December 2020

P. de Vera, P. E. Trevisanutto, S. Simonucci, S. Taioli, M. Dapor, R. Garcia-Molina, I. Abril
Towards a detailed simulation of the physics underlying hadron-therapy: from beam propagation to biodamage on the nanoscale
III Jornadas de Física Médica Real Sociedad Española de Física (RSEF) / Instituto de Física Médica (IFIMED),Valencia, Spain (online)
14-15 December 2020.

Computing Facilities

5. Computing Facilities

CONNECTIVITY

- The main network infrastructure is connected by 3 switches PoE - Power over Ethernet- (DELL Power Connect 5548P).
- 7 switches Dell Power Connect 5548 were installed in order to improve the connectivity in Villa Tambosi.
- The Rustico and the Villa at ECT* are connected by two multi-mode optical fibers.
- Between ECT* and FBK the connection is also provided by fiber (2Gbps).

ECT*'s access to the Internet is transmitted through the FBK. FBK is a BGP Autonomous System; The Internet connection is provided by Trentino Network s.r.l. (bidirectional 1 Gbit/s full speed) and GARR as back-up connection (100Mbit/s); by network problems, the connection through the GARR is automatically activated.

HARDWARE

PC clients:

5 PCs for the local research:

Workstation DELL Precision T1500

Workstation DELL Precision T1600

3 PCs/laptops for the staff:

Laptops Lenovo ThinkPad T480 with Lenovo Docking Stations ThinkPad. English keyboard and monitor Philips Brilliance 272B (27")

A pool of 4 laptops for the workshop participants:

Laptops DELL latitude E6510

Laptop DELL latitude E6220

Laptops DELL latitude E4310

Laptops DELL latitude E4300

Main software for the research activity

Mathematica version 11.X: 1 network license server + 7 concurrent processes + 7 "Home Use" licenses./ from 31st of October we reduced the number of the licenses in order to use the Mathematica Cloud: 5 licenses Home use + 5 Cloud licenses. (35 cloud licenses for DTP for 3 weeks and 35 cloud licenses for TALENT for 3 weeks will be available in 2020).

Services

All services are running using the hardware of the FBK datacenter.

All users can access all services offered by the FBK and through the Google service.

The following useful Google services can be accessed through login on the "ectstar.eu" domain:

1. Google mail (using the "ectstar.eu" e-mail domain)
2. Google Cloud Print
3. Google Drive
4. Google Team Drive (since 22/11/17)
5. Google Hangouts
6. Google Classroom

Wifi Networks

Inside the ECT* buildings one can access the following WiFi networks:

- GuestsFBK
- Eduroam

GuestsFBK is the WiFi network of the Fondazione Bruno Kessler. One can access this network using his/her own user credentials or, if one has an Italian mobile phone number, by registering on the web portal access page: the password will be sent via SMS to the indicated number. In this case the credentials are valid for that particular day.

Eduroam (http://www.eduroam.org) is the secure, worldwide roaming access service developed for the international research and education community. Eduroam allows students, researchers and staff from participating institutions to obtain Internet connectivity across campus and when visiting other participating institutions by simply opening their laptop.

6. Remembering Renzo Leonardi

On February 18, 2020, ECT* organized a one-day in-person meeting to commemorate and honor the important role of Professor Renzo Leonardi in creating the Center in Trento. Renzo passed away unexpectedly on July 6, 2019. Aside from welcome addresses by the ECT* director, and distinguished representatives from the FBK, the University of Trento and the Autonomous Province of Trento, two lectures were given, highlighting the achievements of Renzo in shaping the scientific and cultural landscape of Trento, the Trentino region and beyond. On this occasion, the ECT* meeting room in the Rustico was renamed as 'Aula Renzo Leonardi' and the ground and second floor 'Fresco rooms' of Villa Tambosi were dedicated to him with a commemorative plaque on the ground floor.