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Cover Illustration: Villa Tambosi, the main building of ECT*, surrounded by its former and present directors in chronological order clockwise starting from far left. See article on page 12.
30 Years of NuPECC

After several years of preparatory work, the first NuPECC meeting was held on 1–2 October 1988 in Darmstadt.

In Bucharest on 12–13 October 2018, NuPECC celebrated its 30th anniversary in the presence of current and past members along with scientific and political official representatives (Figure 1). The ceremony began with welcome addresses by Prof. Victor Zamfir, director of IFIN-HH and ELI-NP; Dr. Jean-Claude Worms, chief executive of the European Science Foundation; Dr. Nicolas Bianchi, chair of the NP Division of the European Physical Society; Prof. Jorgen d’Hondt, chair of the European Committee for Future Accelerators; Prof. Kazuhiro Tanaka, chair of the Asian Nuclear Physics Association; Prof. Eberhard Widman, representing the Austrian Academy of Sciences; Prof. Roman Micnas, representing the Polish Academy of Sciences; Dr. Fanny Farget, scientific director of IN2P3/CNRS France; Dr. Faical Azaiez, director of iThemba Labs, South Africa; and Prof. Lucian Puiu Georgescu, state secretary for research policies and innovation of the Ministry of National Education and Research, Technological Development and Innovation of Romania.

The second part of the ceremony was dedicated to a lively and memorable overview of past and present activities of the Committee by the former NuPECC chairs—Muhsin N. Harakeh, Sydney Galès, Brian Fulton, and Angela Bracco—and the present chair of the Committee.

After their presentations, all chairs were awarded with a golden NuPECC pin, specially prepared for this occasion. Thanks to our Romanian hosts the celebration festivities were successfully concluded at a dedicated dinner held in a splendid banquet hall in Bucharest.

Thirty years of activity of a committee is a good occasion to take a look at its history, achievements, and future perspectives. Let me emphasize here only two, the most important and highly visible activities of the Committee.

Since 1991, NuPECC has, together with the whole community, regularly prepared and published a Long-Range Plan (LRP) in Nuclear Physics. Past editions of the LRP as well as the most recent one published in 2017 have been essential to identify opportunities and priorities for nuclear science in Europe and provide the ministries, national funding agencies, and European Commission with a framework for coordinated advances in our discipline.

The international journal Nuclear Physics News (NPN) is definitely one of the very well recognized manifestations of NuPECC activities. Since 1991, the journal, with its four issues each year, is unique, both in its format and due to it being free of charge for readers. The journal provides a forum presenting nuclear physics in all its variety—from critical analysis of the most recent scientific results in Feature Articles, through worldwide Laboratory Portraits and Facilities and Methods to Meeting Reports, News and Views, Book Reviews, and “in memoria” articles dedicated to our passed-away colleagues. NPN (and indeed NuPECC) would not be what it is today without all past and present editorial board members, its correspondents, and without its editor, Gabriele-Elisabeth Körner. She is the...
true “guardian of the temple” of NPN, closely following every contribution (almost always perfect) and every author (almost always on time) for all issues.

NuPECC, following the evolution of nuclear physics and of the surrounding world, constantly develops its actions and improves its organization, but NuPECC also represents a good thirty-year-old tradition and requires certain continuity and regularity in its activities. The three plenary meetings of the Committee scheduled every year allow for an exchange of information on major European and international projects and on the status of nuclear physics in the member states. The meetings and numerous informal discussions happening on these occasions prepare future NuPECC activities, look for solutions to sometimes complicated international problems, and simply allow for better understanding of each other.

On the occasion of thirty years of NuPECC I would like to thank all past and present Committee members and chairpersons for their involvement in the work of the Committee and for accomplishments of numerous actions important for the nuclear physics community. We should specially acknowledge the eminent scientists who initiated and defined the role of the Committee, among them Prof. Paul Kienle, the chair of the first NuPECC meeting in 1988 and Claude Detraz, the first elected chair of the Committee in 1989. Claude Detraz was also at the origin of the well-known NuPECC logo, which was created in 1988 by Jean-Pierre Anazel, a French designer working in Caen, Normandy.

Although the future, especially in science, might be quite unpredictable, I believe that only tight collaboration between European countries can lead to fast progress in European Nuclear Physics. In the next thirty years (or more!) of its activity, NuPECC has to reinforce its role as facilitator of joint European projects and to promote with an increased energy the international cooperation with other continents and neighboring domains of science.

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NuPECC Chair

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Technology Development for Nuclear Physics at USTC

Overview and History

The high-energy physics (HEP) group of the University of Science and Technology of China (USTC) was founded in the 1970s, beginning with research on cosmic-rays using the Multi-Wire Proportional Chamber technique. In the 1980s, the main focus of the group had turned to collider-based physics via the international high-energy collaborations, especially the L3 experiment at CERN. During this period the USTC–HEP group had developed in both physics research and detector technology. One of the most important areas of progress on detector R&D was the test and quality assurance (QA) of the Bismuth Germanate (BGO) crystals for the L3 electromagnetic calorimeter (EMC), with close collaboration to the Shanghai Institute of Ceramics, China Academy of Science (SICCAS). Then in the 1990s, after the success of BGO-based EMC at L3, the USTC–HEP group had continued the collaboration with SICCAS on the R&D of a new Lead Tungsten (PbWO₄, PWO) crystal, intended for applications as EMC at the Compact Muon Solenoid experiment. Meanwhile, the major effort of the USTC–HEP group had been put on the Beijing Spectrometer (BES) experiment at the Beijing Electron-Positron Collider. At the end of the 20th century, a part of the HEP group decided to turn their research interest from particle physics to nuclear physics on the high-energy accelerator (i.e., the Relativistic Heavy-Ion Collider [RHIC]). The heavy-ion (HI) physics group has become an important part of the USTC–HEP group since then.

The first experimental task of the USTC–HEP group was to develop the Multi-gap Resistive Plate Chamber (MRPC) technology for the barrel Time-of-Flight (TOF) detector for the Solenoidal Tracker At RHIC (STAR), one of the four major experiments on the RHIC collider. The MRPC is a novel gaseous detector particularly suitable for high-precision, large-area time measurement, first introduced by the TOF group of A Large Ion Collider Experiment (ALICE) in the 1990s. The HI group had then successfully designed and tested a series of MRPC modules, including a prototype TOF tray for in situ operation at STAR. The technical and physical outcome of this TOF tray had been so encouraging that soon after the mass production of MRPCs for the whole STAR barrel TOF was approved by funding agencies from both China and the United States. The complete STAR TOF was installed and has been fully functional since 2009. The performance of STAR TOF has been proven to be excellent and stable since then. Also, many fruitful physics achievements have been born from it, such as the discovery of the heaviest anti-matter anti-Alpha particle (anti-Helium 4) [1], the direct observation of the force between anti-protons [2], the measurements on baryon number fluctuation up to the 4th order [3], the heavy flavor hadron and the di-electron measurement [4, 5], and so on.

With the success of the STAR TOF project, the USTC–HEP group had extended the detector development and construction for more applications both at STAR and at other experiments. The Muon Telescope Detector (MTD) was proposed to identify muons at STAR with the MRPC as the detection unit. The fully installed MTD started its physics run in 2014. Its performance had met all the requirements, which also validated this new design for a muon system. The USTC HI group had also participated in the Heavy Flavor Tracker project since 2005 and mainly contributed software and physics analysis. Along with the upgrade of the RHIC accelerator and the STAR experiment, several new detectors are being constructed and commissioned, including the endcap TOF (eTOF) project and the Event Plane Detector (EPD) in the forward region. The eTOF is also based on MRPC technology and shared between the STAR and the Compressed Baryonic Matter (CBM) experiments. The EPD upgrade makes use of a fiber readout of scintillation light with new Silicon PhotoMultiplier sensors and will improve the trigger performance by an order of magnitude at STAR during the RHIC beam energy scan phase-2. All these experimental upgrades have promoted the research capability of the STAR experiment and are important for the study of the quantum chromodynamics (QCD) phase diagram and the property of the novel nuclear matter under extreme conditions. Besides STAR, the USTC HI group has now become a member of CBM, ALICE, and the External-target Experiment (CEE) in the Cooling Storage Ring (CSR) of Heavy Ion Research Facility in Lanzhou (HIRFL), for which the main physics goals of these experiments are along the same lines in nuclear science. The work in the next decade may shed light on the exploration and understanding of the QCD phase structure.

Aside from the physics and technical achievement and progress in the nuclear research region, the USTC–HEP group has also built up an active and productive detector and electronics team. The major focus of this team is to develop necessary technologies for the various new-generation collider- or non-collider-based experiments in the high-energy physics field and beyond. Our team has become the
key component of the newly formed State Key Laboratory of Particle Detection and Electronics in China. The R&D of the laboratory has spread to all major directions of high-energy physics, including the novel micro-pattern gaseous detector (MPGD), new generation scintillator and photon sensor, micro-structure silicon detector, as well as high-speed, high-rate electronics and the application-specific integrated circuit (ASIC).

MRPC and Its Applications in Large Science Facilities

MRPC is a gaseous detector with parallel plate structure that has excellent time resolution and has been widely used for the TOF system in many high-energy physics experiments, such as STAR, ALICE, HADES, BESIII, and so on.

The R&D on MRPC of the USTC–HEP group started in 2000, intended for the STAR TOF project. The first single cell MRPC was built in November 2000 and showed a time resolution <70 ps and an efficiency >95% with a test beam at CERN. In the following years, several prototypes were built and tested with different readout pad size and gas gaps according to the STAR TOF configuration. An average time resolution of 60 ps and efficiency of 97% were achieved, which have already met the STAR TOF requirements [6]. In 2002, a prototype MRPC TOF tray was installed on STAR, covering 1/120 of the entire barrel area. This tray was operated smoothly from 2002 to 2008. The detector performance, calibration method, particle identification (PID) capability, and physics analyses were carried out in these years based on the physics run data [7–10]. After the STAR TOF project was approved, the mass production started in 2006. With the well-prepared production procedures and strict quality control and assurance (QC&QA), 1,210 MRPCs were produced and qualified at USTC in one and a half years. These MRPCs make up to one third of the STAR barrel TOF. The stable operation of STAR TOF demonstrated our capability from the design to the mass production of MRPC. Figure 1 clearly shows the enhanced PID capability with the STAR TOF [8].

Based on the experience and achievements from STAR TOF, the novel muon system—MTD for STAR—was carried out. The idea was to realize muon trigger and identification with a single layer of MRPC detector using its timing and 2D-position measurement capability. By simulation, a time resolution of ~100 ps and a spatial resolution of ~1 cm are required. MRPC prototypes with a long strip and large size were designed and tested [11], which fully fulfilled these requirements. Optimized from the prototypes, the final MTD MRPC design has an active area of $87 \times 52$ cm$^2$, with six strips of 3.8 cm wide and two-end-readout [12]. The STAR MTD project was approved in 2011 and finished installation in 2014. The USTC–HEP group took charge of the construction and test of 59 MRPC modules, around half of the whole MTD system.

Another ongoing MRPC-related project is the TOF for CBM experiment. As a fix-target heavy-ion experiment, the expected particle rate on the $\sim 150$ m$^2$ TOF wall ranges from around 0.5 kHz/cm$^2$ to 25 kHz/cm$^2$. For clear hadron identification, a systematical time resolution of better than 80 ps is required. The USTC–HEP group is developing MRPC with thin float glass electrodes aiming for the requirements on the outer region of the TOF wall. Prototypes have been designed and tested with strip readout of 1 cm pitch. To avoid possible signal reflection, careful impedance matching has been realized in these prototypes. Now, we are constructing 80 MRPC3b, one kind of the MRPC layout defined by the CBM TOF [13], and will install them to STAR as an end-cap TOF under the agreement and collaboration between the STAR and CBM experiments.

Photoelectric Detection and Its Applications in DAMPE and LHAASO

Photoelectric detection technology development has a long history at USTC. In recent years, it has been further applied in the observation of cosmic rays—DArk Matter Particle...
Explorer (DAMPE) and Large High Altitude Air Shower Observatory (LHAASO) projects.

DAMPE, which was launched into a sun-synchronous near-earth orbit in the end of 2015, is an instrument based on satellite experiments for long-term observations of high-energy cosmic rays in space. The imagination picture is shown in Figure 2. The main goal is to detect the high-energy e± or γ-rays from 5 GeV to 10 TeV. The scientific mission includes searches for signatures of dark matter in the spectrum of electrons and gamma rays; the detection of possible nearby sources of high-energy electrons/positrons and the high energy cosmic nuclei [14].

The DAMPE detector has four sub-detectors, arranged as in Figure 3.

1. Plastic Scintillator array Detector (PSD). It has two layers that cover an effective area of 82 cm x 82 cm. The PSD serves as a veto detector for gamma ray detection, and could also measure the charge of heavy ions.

2. Silicon-Tungsten Tracker. It has 12 layers. Three tungsten plates with thickness of 1 mm are placed in the front of tracking layers 2, 4, and 6 for photon conversion.

3. Bi₄Ge₃O₁₂ electromagnetic calorimeter (BGO calorimeter). It is a total absorption, imaging calorimeter with about 32 radiation lengths.

4. Neutron Detector (NUD). The NUD is composed of plastic scintillator with boron doping in order to measure the secondary neutrons produced in hadronic showers.

The USTC group is in charge of the development of the BGO calorimeter, the key sub-detector of DAMPE. The calorimeter, with 14 layers, consists of 308 BGO crystal logs (produced by SICCAS) to build an imaging calorimeter. Each layer contains 22 BGO logs with size of 25 mm x 25 mm x 600 mm [15]. The crystals are optically isolated from each other and are arranged horizontally. Each layer is aligned 90° with respect to its neighbors, forming an (x,y) array. Signals in each BGO crystal are read out by Two Photon Multiplier Tubes (PMT), R5610A-01, produced by HAMAMATSU corporation, one of which is coupled with each end of the log. In order to cover a high dynamic range from about 10 MeV to 2 TeV, a multi-dynodes read-out circuit for PMT was designed. Each PMT is read out from three different gain dynodes—dy8 (high gain channel), dy5 (medium gain channel), and dy2 (low gain channel) [16]. The electronics boards, based on VA160/VATA160 ASIC chips (produced by IDE AS), were placed surrounding the calorimeter [17]. The BGO calorimeter not only measures the energy deposition of incident particles but also provides the shower topology of the particles, which are used for particle identification.

The performance of the BGO calorimeter was calibrated in PS and SPS beam-lines at CERN with the energy from several GeV to about 250 GeV. The energy linearity is about 1% and the energy resolution is about 1% at
100 GeV [18]. With the excellent energy resolution and shower topology imaging capabilities of the BGO calorimeter, the first result of DAMPE about the high-energy electrons/positrons observation in space was published and the “lepton TeV break” was first observed directly in space [19].

LHAASO is a large-scale complex extensive air shower observatory under construction at Daocheng, Sichuan province, China. Its primary scientific goals include exploring the origin of the galactic cosmic ray, searching for very high-energy gamma ray sources, and the precise measurement of components at the knee region for a cosmic ray [20].

Photo sensors have been widely used and play a key role in ground cosmic ray experiments. All four LHAASO detector arrays use photo sensors including small size PMTs, large size PMTs, and a Silicon Photon Multiplier. Our laboratory is in charge of the application of large-size PMTs in LHAASO. Two large area detector arrays are involved: the Water Cherenkov Detector Array (WCDA) and the Muon Detector (MD) array. We worked with the domestic PMT vendors to select suitable PMT types and optimize the PMT design. The 8-inch CR365 provided by Beijing Hamamatsu Photon Techniques Inc. has been selected for both WCDA and MD. We also designed readout base circuits with high dynamic range for WCDA and MD. We designed the anode and one dynode readout, achieved good single photoelectron charge and timing resolution and a dynamic range of 1–4,000 photoelectrons for the light pulse narrower than 7 ns full width at half maximum (FWHM) for WCDA, and dynamic range of 1 photoelectron to an equivalent anode peak current of 1.6 A, with the constraint that the anode-to-dynode charge ratio cannot exceed 160 for MD [21]. The designs fulfill the physics requirements and have been approved by LHAASO. We have built an automated multifunctional PMT performance batch test system for WCDA and MD. The production and performance test of 3,000 WCDA PMTs and 1230 MD PMTs is underway.

Development and Potential Applications of MPGDs

The MPGDs have been significantly developed since the end of the last century and started to play an important role in high-energy physics research. MPGDs are flexible and widespread devices with good and promising performances for the current running and planning of next generation high-energy physics experiments, as well as for many other applications, such as medical, imaging, and so on.

In our MPGD laboratory, we are mainly focus on the R&D of several conventional MPGDs, including Gas Electron Multiplier (GEM), Micromesh gaseous structure (Micromegas), Thick GEM (THGEM), and some newly developed novel concepts such as pico-second Micromegas (PICO-SEC), Double Micro-Mesh gaseous structure (DMM), Micro-Resistive Well detector (µ-RWELL), and fast timing MPGD (FTM).

A novel self-stretching technique was used and optimized to allow a highly flexible and efficient GEM detector assembly free of glue or spacers. This makes the re-opening and repair of the GEM detectors possible and also significantly reduces the scrap rate and assembly time in the mass production of large-area GEM detectors. The good performances of the prototypes were confirmed by lab test with x-rays [22]. The large area (100 cm × 50 cm) triple-GEM prototype shown in was achieved with this method.

A thermal bonding technique was developed to fabricate the Micromegas in a simply equipped way [23, 24], which is much different from the widely used bulk etching technique [25]. In this method, thermal bonding films with a dimension of 1–2 mm and a thickness from several tens to hundreds µm were arranged at a distance of ~10 mm on the readout PCB as spacers to support the avalanche region, so that it will be easy to handle and evolve into new structure; there is no chemical etching process in this method, therefore it has no environmental pollution.
Some currently high-profile new concepts based on MPGD, including PICO-SEC [26], μ-RWELL [27,28], and FTM [29] are considered our priority research under the framework of the corresponding international research collaborations, in which we have made many important contributions, especially on the major technologies of developing new photocathode and resistive material for sparking suppression. Some inspiring results obtained with the PICO-SEC detector yield a time resolution of 24 ps for 150 GeV muons and 76 ps for single photoelectrons [26].

In addition, a high-gain, low ion-backflow (IBF) DMM detector, shown in Figure 5, was developed for the purpose of single electron detection [30]. The features of high gain of $>10^6$ and low IBF ratio of $\sim 0.0005$ for the DMM prototype present its great potential for Gas-PMTs and other applications, for instance, readout of time projection chamber detectors for future collider experiments [31,32].

According to the highlighted advantages of the MPGDs, there are abundant potential applications for the detector upgrade and conceptual design of currently running and planned experiments.

For instance, the large-area GEM detector aims to construct the high-quality tracking device at the Solenoidal Large Intensity Device (SoLID) experiment proposed for the 12-GeV upgrade program at Jefferson Lab [33]. In the planned electron positron colliders for next generation, the GEM (THGEM) + Micromegas hybrids, and the DMM are considered as the readout of Time Projection Chamber (TPC) and photon detectors of Ring Imaging Cherenkov (RICH) for $\pi/K$ identification (PID) in the Circular Electron Positron Collider (CEPC), which is designed as a Higgs factory. The MPGD-based RICH is also employed in the R&D work of the Super Tau-Charm Factory (STCF) for PID in a relative lower momentum range of $<2$ GeV/c.

The high-precision timing property is an interesting alternative development direction of the MPGD. An example is the detector upgrade program for phase-II of the Large Hadron Collider. A high rating detector with better than 30 ps timing capability is required to refuse the huge background events and help to provide a level 0 trigger. The PICO-SEC is proposed exactly for this motivation and now proved to be a very competitive candidate.

**Precision Timing Electronics and Its Applications**

Aiming at precise time measurement in physics experiments, efforts were devoted to technique research and application.

We undertook the design work for the front end electronics for the TOF detector in the BES III upgrade [34], as shown in Figure 6. The electronics for BES III TOF consist of two parts: the barrel and end-cap readout electronics, and as for both a high time measurement precision of 25 ps root mean square (RMS) is required. The basic scheme is based on high-speed discrimination and Time-to-Digital Converter (TDC) using the HPTDC ASIC designed by the CERN microelectronics group, and the Time-Over-Threshold method is employed to measure the charge information for time walk correction. As for the barrel, the electronics is responsible for the readout of 352 PMTs. As for the end cap, the detector was upgraded using MRPC to replace the previous 96 PMTs, and a total of 1,728 channels need to be read out, in which we finished the design of the digitization electronics for all channels [35]. Test results indicate that a time precision of better than 25 ps is successfully achieved for all channels, and the electronics function well and stably since installation.

In the readout electronics of the CEE experiment (shown in Figure 7), a high precision time measurement is
In the readout electronics of the CEE experiment, a high precision time measurement is also required. We finished the design and production of the electronics for the TOF Wall, Neutron Wall, and the digitization electronics of Multi Wire Drift Chamber (MWDC) [36]. As for the former two detectors, a total of 960 channels are designed and fabricated, and a time precision of better than 25 ps is achieved. As for the MWDC, we designed high density time digitization modules with a time precision of better than 100 ps with 128 channels integrated within one PXI 6U module, and more than 6,000 channels are completed.

As one key part in time measurement, TDC is an important research direction. In 2006, we proposed using the carry chain to implement time interpolation within Field Programmable Gate Array (FPGA) devices, and achieved a time precision of better than 100 ps [37]. In 2010, we further improved the performance to 25 ps [38]. In 2015, we enhanced the time precision up to better than 4.2 ps RMS with a bin size of around 1.7 ps [39], as shown in Figure 8.

In addition, efforts were devoted to the research of radiation hard FPGA TDC. Based on flash-based and anti-fuse FPGA devices, a time precision of 37 ps RMS with a bin size of 75 ps is achieved [40].

We also applied the FPGA TDC technique in physics experiments and integrated the trigger match functionality in it. For example, we designed the time digitization prototype electronics for the TOF detector of the Compressed Baryonic Matter experiment in the Facility of Antiproton and Ion Research. A time resolution better than 20 ps RMS was achieved [41].

Another application is the recent upgrade of the CSR external target experiment in HIRFL, and FPGA TDCs are being employed in the readout electronics of the T0 detector. Electronics of 80 channels have been designed and are being tested.

References
Dedication

This Laboratory Portrait is in memory of Professor Hongfang Chen (1938–2017), one of the founders of USTC-HEP group.
The 25th Anniversary of ECT*: Fostering Nuclear Theory in Europe

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Introduction

On 31 August 2018 the “European Centre for Theoretical Studies in Nuclear Physics and Related Areas” (ECT*) celebrated its 25th anniversary with a one-day scientific event featuring a presentation on the history of ECT* and talks on up-to-date topics in theoretical nuclear physics and related fields. As a follow-up we will discuss in this article the emergence of ECT* as a unique European and international research institution through the past 25 years. We will put the mission of the Center in the context of modern nuclear theory and give a historical perspective on the key events that led to the Center in its present form.

Nuclear Theory

The goal of modern nuclear physics is to unravel the fundamental properties of nuclei from their building blocks, protons and neutrons, and ultimately to determine the emergent complexity from the underlying quark and gluon degrees of freedom of Quantum Chromodynamics (QCD), the fundamental theory of the strong nuclear force. This requires detailed knowledge of the structure of hadrons, the nature of the residual interactions between nucleons resulting from their constituents, and the limits of the existence of bound nuclei and ultimately of hadrons themselves.

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

The Role of ECT*

Nuclear theory plays a crucial role in shaping existing experimental programs in Europe and elsewhere and provides guidance to new initiatives in nuclear physics. Combining theoretical activities in a concerted effort is essential for the optimal use of the available resources, in particular by providing platforms for scientific exchange and the training of the next generation of nuclear theorists. Here ECT* plays a crucial role. As will be detailed below, ECT* started operating in 1993 as a “bottom up,” community-driven initiative of the European nuclear physics community and has since developed into a very successful research center for theoretical nuclear physics in a broad sense with strong interdisciplinary interconnections to neighboring fields. ECT* is unique and the only center of its kind in Europe. It is similar in scope and mission to the Institute for Nuclear Theory (INT) in Seattle and collaborates with European universities, institutes, and laboratories as well as research institutions worldwide. It is an institutional member of NuPECC, the Associated Nuclear Physics Expert Committee of the European Science Foundation (ESF). With around 700 scientific visitors each year, from all over the world, spending from a week to several months at the Centre, ECT* has gained a high international visibility. As stipulated in its statutes, the Centre assumes a coordinating function in the European and international scientific community by:

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

These goals are reached through international workshops (Figure 1) and collaboration meetings, advanced doctoral training programs and schools, and research carried out by postdoctoral fellows and senior research associates as well as by long-term visitors.

Cooperations exist with the Physics Department and the Center for Bose-Einstein Condensation at the University of Trento and with the Interdisciplinary Laboratory for Computational Science (ECT*/LISC), which now has become a research subunit of the Centre. Over the years ECT* has established cooperation agreements with many prominent scientific institutions worldwide in an effort to stimulate the international exchange of state-of-the-art theoretical and experimental developments in a global setting.

The Centre is sponsored by the “Fondazione Bruno Kessler” (FBK) in cooperation with the “Assessorato alla Cultura” (Provincia Autonoma di Trento) and receives funding from agencies of E.U. Member and Associated States. Various instruments of the Framework Programmes of the European Commission also provide sizable financial support.

The Birth of ECT* in Trento

ECT* originated from the combined efforts of the European scientific community of nuclear physicists who felt the need for a European “Theory Centre,” partly in response to similar initiatives in the United States, which led to the establishment of the INT in Seattle in 1990. The process was initiated by a letter of several nuclear physicists from the Niels Bohr Institute in Copenhagen on 16 May 1990. The letter was addressed to O. Bohigas, then the head of the theory group at Orsay (Figure 2), with an attached letter to the chairman of NuPECC, C. Détraz, proposing that the European community establishes a “Centre for Theoretical Nuclear Physics” to support the national experimental facilities.

It is interesting that this letter already mentions the breadth of nuclear physics on scales of eV to $10^{12}$ eV as well as the central interdisciplinary role of nuclear physics for general quantum many-body systems. As a possible
host for the Centre the Niels Bohr Institute was foreseen for a first period.

At the NuPECC meeting in Louvain-La-Neuve on 8 June 1990 the proposal was discussed and it was decided to send a questionnaire to the relevant institutions in Europe, with E. Moya de Guerra, C. Gaarde and P. de Witt Huberts in charge. A total of 150 questionnaires were sent out to groups in France, Germany, The Netherlands, Italy, Portugal, Spain, Switzerland, the U.K., Denmark, Sweden and Finland and 75 answers were collected. Based on the almost unanimous support NuPECC decided in November 1990 to hold a meeting for nuclear theorists to discuss the need and purpose of a Theory Institute in Europe, originally called “European Centre for Theoretical Nuclear Physics” (ECTNP). Under the chairmanship of O. Bohigas this meeting took place on 23 February 1991 in Orsay. It was decided to establish a steering committee in charge of soliciting proposals for possible hosts of the Centre. This committee consisted of J. P. Blaizot (Saclay), S. Fantoni (Trieste), R. Malfliet (Groningen), U. Mosel (Giessen), B. Mottelson (Copenhagen), and O. Bohigas (Orsay). The deadline for proposal submission was set for 31 July 1991, by which time three proposals were on the table (The Netherlands, Copenhagen, CERN). By mid 1992 they were joined by two more proposals from Italy: Legnaro/Padua and Trento.

In a letter to the steering committee from 4 September 1992, O. Bohigas summarized the crucial developments in 1992. After several members of the committee met on 25–26 March 1992 with officials in Brussels to explore the possibilities of support through EECC programs it was concluded that European funding could only be secured if the projected host country would provide substantial contributions on their own through sizable investments in the general infrastructure (building, library, computers, etc.). As a consequence, the Dutch and Danish proposals were withdrawn on 9 July and 15 July, respectively, and only the two Italian projects remained as serious candidates.

After a visit to Trento on 11–12 July 1992, B. Mottelson expressed his support for the Trento proposal (Figure 3). After late-July discussions of O. Bohigas with S. Fantoni, who promoted among others the Legnaro proposal and with R. Leonard, D. Brink, and local authorities of the Province of Trentino from which a clear feasibility of the Trento proposal emerged, Bohigas on 30 July took the opportunity to organize an informal meeting at the International Nuclear Physics conference in Wiesbaden to present and discuss the status of the ECTNP in the wider nuclear physics community. The very useful and informative discussions prompted Bohigas to call for a final, decisive one-day meeting of European nuclear theorists at Orsay on 12 October 1992 on the two Italian proposals. Given the scientific quality of the Trento project, the logistics provided and the local financial support assured, the choice was obvi-
ous. Out of the 61 participants, 51 took part in the voting, with 46 in favor of Trento and 5 against (Italian votes from Legnaro). A Scientific Board was suggested, initially consisting of J. P. Blaizot, S. Fantoni, B. Mottelson, C. Pethick, and W. Weise (Figure 4).

It was approved by a majority of 27 votes, with 12 votes against and 7 abstentions. Later the board suggested adding H. Specht to keep contact with the nuclear experimental programs and A. Mueller to ensure contact with the U.S. physics community. The Theory Centre at Trento was born and the official inauguration on 10–11 September 1992 received prominent press coverage, including *Le Figaro*, *Europysics News*, *Physikalische Blätter*, and others.

### The Early Years (1993–1999)

In January 1993 the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*), as it was now called, was founded formally by the Istituto Trentino di Cultura (ITC) under the directorship of B. Mottelson and overseen by D. Brink as vice director as well as R. Leonardi, as the scientific secretary of the Centre. With the involvement of the scientific board the statutes of ECT* were drafted during the spring of 1993.

The scientific activities started soon thereafter with an international workshop on Bose-Einstein condensation (!), held from 31 May 31–1 June. S. Stringari, A. Griffin, F. Laloë, L. Pitaevskii, L. Pitaevskii, D. Snoke, and G. Baym coordinated this workshop. The meeting was a true milestone in the field and the proceedings of the workshop became known as the famous “Green Book.”

Starting from 4 July 1993 a Summer Institute was held for two months under the coordination of C. Pethick in areas ranging from neutron-rich nuclei to the properties of nuclei in a stellar medium. The Inaugural Symposium of ECT* chaired by D. Brink was held on 11–12 September at the ITC head quarters in downtown Trento with presentations by G. Bertsch on current issues in nuclear structure physics, M. Jakob on synchrotron radiation in the quantum regime, P. Kienle on recent progress in heavy-ion physics, R. L. Mössbauer on neutrinos, B. Mottelson on nuclear high spin states, I. Sick on Electron scattering, and D. Vautherin on the mean-field description of rotating nuclei. The meeting was attended by 75 participants. In addition, the 1993 scientific activities featured four workshops on chiral symmetry in hadrons and nuclei, the quark structure of baryons, the properties of nuclear matter as well as high spins and novel deformations in nuclei. The wide spectrum of topics is truly amazing and already set the stage for the broad mission of ECT*. All in all about 400 scientists were involved in the 1993 ECT* activities with 330 scientists from 20 European countries and 10 from non-European institutions. The broad spectrum of workshop topics continued in 1994 and onward. In 1994 the Centre also started the in-house research program, appointing 12 postdoctoral researchers, some of which were financed by European funds. More than 30 researchers spent extended periods of time at the Centre.

To sustain the programs of ECT* it was soon realized that a long-term external funding scheme for ECT* was needed. The initiative came from H. Specht in November 1994, suggesting that funding agencies contributing for instance to NuPECC should be approached. As an example he mentioned the “Verbundforschung” of the Bundesministerium für Forschung und Technologie as a possible German contributor. This turned out to be an excellent suggestion. An important step in efforts to ensure direct support from European national funding agencies was taken when representatives of the agencies of the three largest users of the Centre agreed to convene at ECT* to discuss the future funding. At the meeting, which was held in January 1998, the representatives of BMBF (Germany), CEA and CNRS/IN2P3 (France), and INFN (Italy) agreed to propose to their national funding agencies that they provide a regular yearly contribution in order to flank the local financial contribution, which led to the establishment of the European Joint Finance Review Committee (EJFRC), ensuring stable contributions from France, Germany, and Italy that now make up more than one third of the annual budget of ECT*. It was also an initial step toward a broader cooperative effort of the participating European countries to join the EJFRC through Memoranda of Understanding (MOUs). NuPECC agreed to help in coordinating this European effort.

*Figure 5. Signing of the MOU between ECT* and NuPECC, by the NuPECC chairman S. Galés in the presence of the ECT* Scientific board and the Directorate in the fall of 1997.*
In the statutes of ECT* it is foreseen that every five years the Centre undergoes an international review that forms the basis for a renewal of the MOUs with the funding agencies of the participating countries and institutions. This procedure has its origin in the first review of the Centre, which took place in February 1996. The review committee consisted of A. Bassetto (Padova), O. Bohigas (Orsay), W. Haxton (Seattle), and P. Kienle (Munich) and was chaired by D. O. Riska (Helsinki). The committee delivered its very favorable report to the Scientific Board of ECT* by the end of 1996. This report also played a major role in obtaining formal recognition of the European role of the Centre. This process was completed by a formal membership of ECT* in NuPECC (Figure 5), which was ratified by the ESF in the fall of 1997.

Another memorable event of 1996 was a two-day Symposium on 5–6 October on the occasion of the 70th birthday of B. Mottelson (organized by I. Hamamoto, D. Brink, and R. Leonardi). It was to honor Mottelson’s lifetime achievements in theoretical nuclear physics, his instrumental role in establishing ECT* at Trento, and his crucial guidance as the first director of the Centre from 1993–1997. Among the invited talks was a presentation by F. Venneri from Los Alamos on Accelerator-Driven Systems (ADS) for nuclear waste transmutation. Discussions on ADS, originally proposed by C. Rubbia, were followed up in an ECT* workshop from 29 September–3 October 1997, in which Rubbia participated. This latter event is particularly noteworthy since it demonstrates once more the broad visions of the Centre and its early involvement in ground-breaking new ideas. Nuclear reactor systems driven by proton accelerators are now being realized as demonstrators, for instance in the MYRRHA project at Mol in Belgium.

Another important event was the decision by the Provincia Autonoma di Trento in the summer of 1998 to restore the Villa Balduini-Tambosi with a budget of 4 billion lire to its original splendor, after many years of neglect. The restoration was completed in the fall of 1999 and celebrated on 6–7 November with an inaugural Symposium at the ITC in Povo and an official opening ceremony at the villa. It is fair to say that the Villa Balduini-Tambosi has become one of the major assets of the Centre and in no small part contributes to the uniqueness and attractiveness of ECT* to visitors worldwide.

The Later Years

By around 2000, at which time the two-year directorship of R. Malfliet ended and W. Weise started as the new director, most of the elements for operating ECT* (the Scientific Board, a vigorous workshop and visitor program, a high-level local research program, the EJFRC, membership in NuPECC) were in place and the Centre had established itself as a European research unit of high international reputation. At the beginning of 2002 ECT* was recognized by the European Union as one of the European Large-Scale Facilities, making it eligible for transnational access in the coordinated Framework Programmes of the European Commission. Besides the formal recognition, this turned out to be a major source of funding for the workshop programs of the Centre (EURONS, HP2, ENSAR, ENSAR2, STRONG-2020). One important element was added in 2001 under the directorship of W. Weise, the “Doctoral Training Programme” (DTP). Ever since, this initiative, which started with the first course on “Dense and Hot QCD” in 2002, has provided high-level training for the next generations of young researchers. From 2004 until today G. Ripka took an active role in the local organization of the DTP. Given the strong in-house research activities it became increasingly clear that ECT* needed advanced computer capabilities of its own. Already by the beginning of 1999, with a contribution from Japan through A. Arima, ECT* had installed the computer system HAIKU. In the following years the Centre saw a steady buildup of its computer resources, which culminated in 2005 with the operation of ECT* teraflop cluster BEN. This was followed in 2009 by the scientific administration of the joint Eurotech and AuroraScience project, which utilized the HPC system AURORA, housed at the FBK.

Two other events are noteworthy. The first was the institutional integration of ECT* as a research unit of the Fondazione Bruno Kessler in 2008 under the directorship of J.P. Blaizot and the Vice Director M. Traini. On 17 October 2008 the formal statutes with the FBK were put in operation, restating the scientific goals of the Centre and essentially reaffirming the organizational structure of ECT* under the administrative umbrella of the FBK. This was a major step to secure the long-term future of the Centre. Under the directorship of A. Richter it thus became possible to convert two of the senior postdoc positions into tenured positions. The second was the integration of the LISC in January 2015 as a research unit of ECT* under the second directorship of W. Weise. The LISC research activities are in the “related areas” and include computational many-body theory, condensed matter physics, simulations of advanced material, and complex biological systems. The integration of the LISC group, which is now housed at Villa Tambosi, has added an important interdisciplinary component to the research portfolio of ECT*.

To this day advanced computer capabilities continue to be a major issue for the Centre. With the “in-house” instal-
lations no longer in existence new solutions involving European supercomputing centers need to be found. In 2017 a half-year pilot project with the Gauss Centre for Supercomputing at the FZ/Jülich providing 10 million core hours was initiated. The allocated time was fully used, clearly demonstrating the computational needs of ECT*.

The Future

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

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Humans see patterns everywhere: in the turn of the seasons, in the threading of planets, even in the spatter of stars across the sky. No wonder when it comes to the spectral harmonies of atomic nuclei we also look for patterns.

The gamma rays emitted by an excited nucleus are a unique fingerprint, much like chemical spectra used to identify trace compounds. Many of these spectral signatures have features in common (Figure 1): some are equally spaced apart,

$$E_n = E_0 + n\hbar\omega,$$

which to any good quantum mechanic suggests a harmonic oscillation, while others grow quadratically in angular momentum $J$,

$$E_J = E_0 + \frac{\hbar^2 J(J + 1)}{2I},$$

like the energy of a top spinning faster and faster. George Gamow suggested a picture of nuclei as little drops of dense matter (1929); they can vibrate, they can deform and spin. The liquid drop model of nuclei proved a compelling picture: it inspired in Carl Friedrich von Weisäcker and Hans Bethe a formula for nuclear masses (1935), and Niels Bohr and John Wheeler used it to describe nuclear fission (1939).

In the 1950s, Aage Bohr and Ben Mottelson put the dynamics of the liquid drop on a firm quantum mechanical footing [1]. They parameterized the surface of a drop with spherical harmonics,

$$R(\theta, \phi) = R_0 \sum_{l,m} a_{l,m} Y_{l,m}(\theta, \phi)$$

made the coefficients $a_{l,m}$ dynamic variables, and quantized. The $l = 0$ term primarily determines the radius, while $l = 1$, at lowest order, simply translates the surface in space. Thus, $l = 2$, or quadrupole deformations, are the most important dynamically, and the excitations of the nucleus are understood mathematically as either quadrupole vibrations or rotations of a quadrupole-deformed shape.

This is an appealingly simple and intuitive picture, and one that describes a great deal of data—so much so that Bohr and Mottelson were awarded the Nobel Prize in physics in 1975. Furthermore, one can make the notions of patterns precise through the use of group theory, the mathematical tool for notions of symmetries.

Although group theory can seem dauntingly abstract, we use it all the time. Most physicists are comfortable with quantized angular momentum, its magnitude $J$ and $z$-component $M$ arriving in regular multiples of Planck’s constant $\hbar$, and use Clebsch-Gordan coefficients to couple states of different angular moment. It’s based on the group SU(2), and other groups behave similarly, albeit with more complications.

What physicists call group theory is representation theory to mathematicians: how to practically represent groups and carry out calculations. In the case of SU(2) the simplest nontrivial representations are traceless, complex, two-by-two Hermitian matrices. Because such matrices have only three independent real variables,

$$\begin{pmatrix} a & b + ic \\ -b + ic & -a \end{pmatrix},$$

they can be written in terms of three Pauli matrices, known describing spin-1/2 systems. These matrices are the generators of the group. In general the order in which you apply generators or any operators matters: socks first, then shoes, and not the other way around. For groups the difference is the commutator: $[A,B] = AB-BA$. The representation of generators does not matter as long as they follow specified commutation relations. Just as the three Pauli matrices are generators of SU(2), so are the three components of the orbital angular momentum $\vec{L}$, when quantized as $\vec{r} \times \vec{p} = \vec{r} \times \hbar \vec{\nabla}$.

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**Figure 1.** Rotational (left) and vibrational (right) excitations of a liquid drop.
The power of group theory is once you go to the trouble of learning how to calculate things under one representation, you can apply the same abstract rules (usually commutation relations), to any representation, even if the context is quite different. Werner Heisenberg applied ideas of angular momentum to the symmetries between protons and neutrons, calling it isospin, although nothing is spinning, and a simple model of pairing, the nuclear analog of superconductivity, uses a framework called quasi-spin to give exact analytic solutions.

This is the backdrop to the story of group theory and nuclei. The Bohr-Mottelson model used quadrupole deformations, based on five quadrupole operators

\[ Q_{2\mu} = \mu^2 Y_{2\mu}(\theta, \phi), \]

with \( \mu = -2... 2 \), and also the coordinate-space form of orbital angular momentum \( \vec{l} \) for a total of eight generators. As traceless, Hermitian, complex \( 3 \times 3 \) matrices have eight independent real variables, the Bohr-Mottelson model is described by the group SU(3).

This is all very well, but the Bohr-Mottelson model has its shortcomings. For one, the underlying picture is of the surface of a continuous fluid, while nuclei are of course made of discrete protons and neutrons. Worse, it only describes nuclei with even numbers of protons and neutrons. (There are epicycle-like generalizations coupling a single nucleon to a drop, but such approaches become unsatisfactory.)

At the same time that Bohr and Mottelson were developing their model, Phil Elliott came at nuclear excitations from a different angle [2]. Elliott realized how to construct generators of SU(3)—and many other groups—using fermion creation and annihilation operators. That is, instead of representing SU(3) using coordinate-space quadrupole and angular momentum operators, or using complex-valued matrices, one could use second quantization, the language of the shell model with discrete protons and neutrons.

This is such an important point it bears restating: Elliott mapped exactly—not approximately—the underlying mathematics of the vibrations and rotations of the liquid drop onto a model of the nucleus with fermionic operators: created a model of a nucleus, the Elliott SU(3) model, with a fixed and finite number of protons and neutrons, which could reproduce the spectra of real nuclei.

The Elliott model has cast a long shadow. Like many a successful theory, it has spawned a grand brood of algebraic models, models of dynamics and structure based on abstract group theory, but usually realized in terms of fermion operators [3].

One of the key ideas of algebraic models, the Holy Grail or the MacGuffin of using group theory, is the concept of dynamical symmetries. A dynamical symmetry occurs when the Hamiltonian is invariant under the generators of the group. The most obvious example is rotation: if a system is rotationally invariant, then it has SU(2) symmetry. A lesser-known example is the conservation of the Runge-Lenz vector for an inverse-square law force: that’s why Keplerian orbits are closed.

In quantum systems we can write the Hamiltonian as a matrix in some basis, and if we choose the right basis, the Hamiltonian will be block-diagonal with respect to a given dynamical symmetry. As Emmy Noether taught us, symmetries lead to conservation laws, and in quantum mechanics conserved quantities are represented by quantum numbers, and those quantum numbers label the blocks. So, for a system invariant under rotation, the total angular momentum \( J \) is conserved and we use \( J \) as a quantum number to label the diagonal blocks of the Hamiltonian.

For symmetries other than rotation, the quantum numbers may seem obscure to the uninitiated. We can look to rotational invariance as a paradigm. Groups, or at least continuous Lie (pronounced “Lee”) groups, have one or more operators that are invariant under all of the generators of the group. These operators are called Casimirs, or just Casimirs. The Casimir for angular momentum is \( J^2 \).

SU(3) has two Casimirs. One of these, the quadratic Casimir, can be written in coordinate space as \( Q^2 - 3L^2 \), where \( Q \) is the quadrupole operator and \( L \) is the orbital angular momentum. You can see it is built explicitly out of the operators used to construct the Bohr-Mottelson model.

Casimirs are generally Hermitian operators, and we can find their eigenvalues, which are written in terms of their quantum numbers. The eigenvalue of \( J^2 \) is of course \( j(j + 1) \). The eigenvalue \( Q^2 - 3L^2 \) is proportional to \( \lambda^2 + \lambda \mu + \mu^2 + 3(\lambda + \mu) \), where \( \lambda, \mu \) tell us about the prolateness and oblateness of a state. If you have interest learning more, any expert in group theory will be happy to spend three or ten hours explaining it all.

Quantum numbers define and label subspaces, known as irreducible representations; say “irrep” when hanging out with group-theoretical friends. Systems with exact and/or dynamical symmetries will be block-diagonal in the irreps.

Of course, aside from special symmetries such as rotational invariance, true dynamical symmetries are rare. Well-known parts of the nuclear force, such as spin-orbit and pairing, break SU(3) symmetry and cause mixing between SU(3) irreps. This means the Hamiltonian is no longer block-diagonal in SU(3) irreps, and the wave function is distributed or fragmented across multiple irreps.

To illustrate this, I computed shell-model wave functions via diagonalization; that is, I found the eigensolu-
tions of a nuclear Hamiltonian in a finite but large basis of Slater determinants. This becomes just a matrix eigenvalue problem, and the resulting wave function is a vector, whose components are the coefficients of the Slater determinants. For Figure 2, I chose $^{12}$C with valence nucleons in the $0p$ orbits, using Cohen and Kurath's 1965 phenomenological force. Projecting the wave function vector onto subspaces defined by the total spin $S$, I plotted the fraction of the wave function in each subspace (irrep). The fraction of a wave function in an irrep is not experimentally observable, of course, but nonetheless it gives us insight [4].

Figure 2 presents the decomposition of several low-lying states of $^{12}$C. Each plot represents a state $J^\pi; T_n$, where $J$ is the total angular momentum of the state, $T$ is the isospin, $\pi$ is the parity, and $n$ is the index of the state with those quantum numbers, so that $2^+;0$, is the second state with $J = 2$, $T = 0$, and positive parity.

Even if you know nothing about group theory, you can apprehend a few things from Figure 2. First, while the states are dominated by a single value of $S$, they have strength for other values. We say that spin is almost but not quite a dynamical symmetry. Total $J$ is of course still a good quantum number. Second, we can see that different states, even with the same $J$, can be dominated by different spin $S$.

Figure 3 shows another, more complex, example. Here I chose $^{24}$Mg with valence nucleons in the 1$s$-0$d$ orbits, using Brown and Richter's "universal" sd-shell interaction, and instead of total spin I projected the wave function vector into the irreps of SU(3), plotting the fraction of the wave function in each irrep (subspace) against the eigenvalues of the SU(3) Casimir. All the states in Figure 3 have isospin $T = 0$.

We see a few new things in Figure 3. Not only is SU(3) not a dynamical symmetry, the distributions are more fragmented than spin was for $^{12}$C. Second, the fragmentation is not random: the distributions are quite similar across several states. Such states happen to belong to a rotational band starting with the ground state. Experimentally one identifies bands through fast E2 gamma decays.

David Rowe termed such coherent patterns quasi-dynamical symmetry. Quasi-dynamical symmetry helps to explain, at least in a hand-waving way, the success of algebraic models. Algebraic models tend to rely on dynamical symmetries, or something close to them. This is an oversimplification: as Figure 3 demonstrates, realistic calculations show strong breaking of the symmetry and fragmentation of the wave function across many irreps. Yet a coherent pattern of breaking across irreps—quasi-dynamical symmetry—makes it plausible that nuclear spectra could be modeled by a simpler picture, dynamical symmetry.

A final example is found in Figure 4, which shows low-lying states of $^{20}$Ne. Because the spin-orbit force gets stronger with increasing mass number $A$, for the lighter $^{20}$Ne nucleus the SU(3) decompositions are less fragmented: the states are dominated by a single irrep, and are closer to, but not quite, having SU(3) as a dynamical symmetry.

Here I have chosen two sets of $0^+ - 2^+ - 4^+$ states, each of which form a rotational band. One, on the left, starts from the ground state $0^+$ state, while the other, on the right, starts from the first excited $0^+$. Note that within each band the states are dominated by the same irrep and that irrep is different for the two bands.

There's more. Figure 4 superimposes two vastly different calculations of $^{20}$Ne. One is a phenomenological calcu-
The other calculation uses a realistic, *ab initio* interaction derived from chiral effective field theory. Such interactions are fitted to nucleon-nucleon scattering data, plus the binding energy and other properties of the deuteron. The shell model space here is much larger, encompassing the 0s, 0p, 1s0d, 1p0f, 2s1d0g, 2p1f0h, and 3s2d1g0i orbits, and having a basis dimension of 75 million. (This is actually small potatoes in modern shell model calculations; on supercomputers one can go pass 10 billion basis states.)

Yet despite the different basis sizes and independent origin for the nuclear forces, the decompositions are surprisingly similar. They were not fitted to agree in their group structure, and indeed the work for the decomposition was first carried out long after both sets of calculations had been proposed. Other nuclei have similar comparisons.

What should you take away? While the group decomposition is not a direct physical observable, it is a kind of X-ray that allows us to see the “bones” of the wave functions underneath. Even without any sophistication in group theory we can see that two wave functions, which have different quantum numbers and are mathematically orthogonal to each other, are very similar—or very different—to each other.

And the excellent comparison between two very different calculations in Figure 4 suggests not only a robust undercarriage of group structure, it also gives us confidence that the theorists who devised the calculations were doing much better than they realized.

Richard Hamming said, “The purpose of computing is not numbers, but insight” [5] Modern supercomputers can generate an overwhelming flood of numbers in a few seconds. But with deft application of group theory, one can glimpse the shadow of symmetries, even broken symmetries, lying within atomic nuclei. And that’s the kind of insight physics is best at.

References
MedAustron: First Years of Operation

Historical Background
MedAustron is a synchrotron-based facility for ion-beam therapy and research located in Wiener Neustadt, Austria. The planning of a European spallation source, the so-called AUSTRON project in the late eighties of the last century, marked the origin of the more medical oriented MedAustron facility. However, it took some years until a dedicated feasibility study for the medical project was finalized in 1998 and six years later, in 2004, the MedAustron design study was published. This was also the basis for the political decision to provide financial support for the realization of an accelerator facility for mainly medical applications. This contribution, funded by Austrian public authorities, implied also the possibility to use the generated particle beams for nonclinical and non-medical research projects.

After an intensive planning period and the approval by an obligatory environmental impact assessment, the groundbreaking of the facility took place in early 2011. This was followed by the construction phase of the building, the implementation of the technical systems, and an intensive commissioning effort of the accelerator and all the other treatment-related medical products in order to receive the official certification according to the European Medical Device Directive as well as the approval of operation from the Austrian authorities. In October 2016, the first proton beams were delivered for nonclinical research on a regular basis. Finally, on 14 December 2016 at the end of a very busy and exciting year paved with accomplishments, MedAustron reached its most important milestone since its long history: the treatment of the first patients with proton beams.

Overview of the Facility
Due to the fact that MedAustron always aimed to utilize various particle species, a synchrotron-based facility was selected. The accelerator design of MedAustron goes back to the Proton-Ion Medical Machine Study, which was developed at CERN [1, 2] and first realized at the CNAO facility in Pavia, Italy [3]. The accelerator complex consists of three main sections: the injector, the synchrotron, and the high-energy beam transport lines toward the different equipped irradiation rooms. Currently, three ion sources are situated with the injector in a separate hall providing maximum flexibility for possible intervention of these systems during operation. A classical approach was chosen for the whole injector, comprising electron cyclotron resonance ion sources, a radio-frequency quadrupole, and an interdigital H-mode linear accelerator, which provides a high accelerating gradient. The synchrotron also follows a classical concept consisting of a magnet lattice with 16 dipole magnets, 16 focusing quadrupole magnets in two circuits, and 8 defocusing quadrupole magnets in a single circuit [4]. The extraction mechanism is betatron driven to facilitate a slow extraction and a quasi-discrete spot scanning technique. After extraction, the ion beams are transported to one of the four available irradiation rooms. Three rooms are intended for clinical use: two rooms are equipped with a horizontal fixed beam-line, at which one of them offers additionally a vertical fixed beam-line; the third clinically used irradiation room houses a gantry that enables irradiation from different angles. There is also one irradiation room dedicated solely for nonclinical research, which is equipped with a horizontal fixed beam-line and the appropriate scanning system. Figure 1 shows an overview of the accelerat-
tor parts and the four irradiation rooms for clinical treatment and nonclinical research.

The clinically utilized energies for protons are ranging from 62.4 MeV to 252.7 MeV. This translates into ranges from 30 mm to 380 mm in water. Ranges lower than 30 mm can be achieved by inserting a range shifter. For research purposes, protons can be accelerated up to 800 MeV but they can be only delivered into the irradiation room dedicated for nonclinical research. The specified energies for carbon ions vary from 120 MeV per nucleon to 402.8 MeV per nucleon, which corresponds to ranges from 29.2 mm to 270 mm in water. The nominal intensities are $2 \times 10^{10}$ particles per spill for protons and $4 \times 10^{8}$ particles per spill for carbon ions. The accelerator allows four degrader settings for reducing these intensities; that is, 0% (maximum intensity), 50%, 80%, and 90% degradation. Each beam-line contains, after the vacuum window, a nozzle equipped with the so-called dose delivery system, which is a redundant beam monitoring system for measuring the intensity, the spot size, and the spot position of the beam. In addition, the automatically movable passive beam modifying elements (i.e., a 30-mm-thick range shifter and two ripple filters with a thickness of 2 mm each), are situated as close as possible to the nozzle exit. The accelerator and nozzle designs allow for a maximum field size of 20 cm × 20 cm at isocenter for the fixed beam-lines and 12 cm × 20 cm for the proton gantry.

All four irradiation rooms are equipped with a newly designed patient alignment system, which includes the robotic patient positioning system and the X-ray-based verification system (see Figure 2). The overall goal of the patient alignment system is to accurately position the target within the immobilized patient with respect to a treatment beam as defined during the treatment planning process. The robotic positioning system consists of a six axes KUKA robot that is mounted on an additional linear axis on the ceiling (i.e., seven degrees of freedom). Such a system guarantees a high flexibility of patient (target) positioning in front of the fixed nozzle. The Imaging Ring™ used for position verification is integrated with a table-top and it is fixed on a C-arm. The C-arm itself is attached to the robotic positioning system. The imaging system contains the X-ray source and a solid-state amorphous silicon detector, which are both mounted on a support ring and both components can be moved independently of each other [5].

Medical Application

First patient treatments started in late 2016 in just one irradiation room equipped with a horizontal fixed beam-line and only with the application of protons. Currently, three clinically used beam-lines (i.e., two horizontal and one vertical), are in operation in two irradiation rooms. The availability of two rooms, which can be served with proton beams alternately, increased the number of treated patients per day noticeably. Additionally, the vertical beam-line, which has been clinically usable since summer 2018, simplifies the patient positioning in many cases and enables the treatment of additional indications such as certain tumors along the spine or in the pelvic region. Although the new beam-line was an important step for MedAustron, there is still some effort needed to run the facility in full-operation mode. While treatments are currently possible only with protons, carbon ions will be provided in summer 2019. This will allow the spectrum of indications to be expanded once again, as these particles are used particularly in the treatment of radiation-resistant tumors. After the availability of both particle species in all fixed beam-lines, the last medical

Figure 2. The patient alignment system, which is available in all four irradiation rooms: combined ceiling mounted positioning system and X-ray-based position verification system.
irradiation room (i.e., the proton gantry), will be put in clinical operation in 2021. This will finally provide the possibility to deliver the proton beams from different angles to the patient.

In total, approximately 300 patients have been treated so far in about 8,000 single fractions from December 2016 until the beginning of 2019. With regard to the irradiated indications, the majority of the tumors were located in the central nervous system (about 40%) followed by tumors in the head and neck region (about 15%). Skull base tumors such as chordomas and chondrosarcomas, pediatric tumors, and re-irradiation of several tumor types represent 10% each of all treated tumors so far. Additional indications with a rather low number of cases are sarcoma, prostate cancer, and gastrointestinal tumors.

All patients treated at MedAustron are offered to participate in a prospective register study for therapy outcome evaluation. In this study protocol, patients are followed for therapy response and acute and late side effects. For patients irradiated in the brain neurocognitive testing is also performed. Beside this, there are also disease-specific study protocols recruiting patients (prostate cancer, pancreatic cancer, sacral chordoma, low grade glioma).

Nonclinical Research

In addition to the ongoing commissioning activities as well as regular patient treatments, MedAustron provides beam time and dedicated infrastructure for nonclinical research activities. As mentioned above, one irradiation room is solely intended for research purposes, offering proton energies of up to 800 MeV, which is far beyond the requirements for clinical applications. However, the research room is equipped with the same positioning and verification system as installed in the medical irradiation rooms. This allows a direct translation of achieved results from a research approach to the medical applications. In addition, these systems can be used for the positioning of dedicated experimental set-ups such as detectors or biological samples. For the preparation and analysis of the irradiation experiments, there are several equipped laboratories for biology and physics available. Since commissioning of the remaining beam-lines is still ongoing, beam time for nonclinical research is currently limited but will increase, once the facility is in full operation.

Nonclinical research at MedAustron is carried out mainly in cooperation with the Medical University of Vienna and the Vienna University of Technology. Before the first proton beams were available, three professorships were installed at the respective universities, namely for “Medical Radiation Physics and Oncotechnology,” “Applied and Translational Radiobiology,” and “Radiation Physics.” Naturally, the first research period was dominated by the workload to commission all equipment and the research beam-line for protons. Nevertheless, a basis of research topics was founded and a competence building was initialized and will be continued until 2021 to set the facility in full operation. The steady increase of functionalities and the positive results achieved so far stimulated the planning for the upcoming years in both medical applications and nonclinical research.

Conclusion

MedAustron has provided proton beams for patient treatment and nonclinical research activities since late 2016. In parallel, commissioning of additional beam-lines and beam parameters was continuously performed and will be continued until 2021 to set the facility in full operation. The steady increase of functionalities and the positive results achieved so far stimulated the planning for the upcoming years in both medical applications and nonclinical research.

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Citizen Science and Radioactivity

Introduction

Citizen science is a term used to describe science where the general public is involved in scientific research. This article reports on a citizen science project carried out in Sweden during the autumn of 2018, where 135 secondary school classes (pupils of age 13–16) participated by collecting mushrooms, soil samples, and animal droppings. In addition, they prepared samples and performed preliminary analyses before submitting their samples and results to Uppsala University (UU) and the Swedish University of Agricultural Sciences (SLU) for further compilation and analysis. This was an interdisciplinary project where the involved departments from UU were Physics and Astronomy together with Earth Sciences. The collaboration was further strengthened with the inclusion of the Department of Forest Mycology and Plant Pathology at SLU.

Background

The aim of the school project was to determine radioactivity in sporocaps of edible fungi (commonly referred to as mushrooms) but also the link between fungi, soil, and competing species will be investigated. In Sweden, the Chernobyl accident in 1986, together with fallout from nuclear tests in the 1950s and 1960s, have distributed radionuclides in the environment and some of them can still be found in food such as mushrooms and game consumed by humans. Airborne measurements of ground deposition of the most significant radionuclides, $^{137}$Cs and $^{134}$Cs, were undertaken by the Geological Survey of Sweden after the Chernobyl accident [1], and since then measurements have been performed at irregular intervals on flora, fauna, fungi, soil, and water at national [2] and municipal level in the affected areas [3]. The two-year half life of $^{134}$Cs means that it has decayed to negligible levels. $^{137}$Cs has a half-life of 30.2 years, so today roughly halved concentrations would be expected compared to 1986. Aviation measurements today confirm that expectation, but on a local level different factors complicate the picture.

Recently, the topic of measuring more frequently and systematically has gained new attention, as meat from some wild boar has been found to have very high levels of $^{137}$Cs. Wild boars were rare in the Swedish fauna in the 1980s, but have since then established a solid population. The relationship between the concentration of $^{137}$Cs in 1986 and today is not elementary. Biological systems interact with and redistribute materials in an efficient manner, and consequently the $^{137}$Cs concentrations will be affected. Also, the forest type, soil type, land use, precipitation, hydrology, and other environmental factors play significant roles. We therefore conclude that more measurements of $^{137}$Cs in the Swedish environment would be of interest both for several scientific disciplines and for the general public.

Method

School classes all over Sweden were invited to participate in the data collection and analysis. The invitation and communication home page included an animated video that was distributed through YouTube [4]. Over 200 school classes responded to the invitation and were equipped with a “research box” containing tools, containers, data-taking protocols, and instructions. Their primary task was to forage for mushrooms and collect associated soil samples and search for animal droppings. An extensive teacher’s manual including detailed protocols for sample documentation was also prepared and made available together with information on how to get support. Earlier citizen science research has shown that good and adequate teacher’s material is a crucial success factor for curriculum-based citizen science [5].

In order to raise the pupils’ awareness of how radioactivity is actually measured, we also provided a simple detector in the research box (see Figure 1). The detector design was slightly adapted from similar projects [6] and consists of a circuit board with two pin-diodes and a two-stage operational amplifier. It is powered by a battery and mounted inside the lid of a tin can in order to avoid light interacting with the diodes. The amplified signal is connected to a second circuit board on the outside of the can (for noise reduction) where a micro-controller records the pulses and produces a beep.

The detector is assembled by attaching the circuit boards onto the lid and connecting cables and batteries.

Figure 1. The radiation detector that the pupils assembled and used in their measurements. Photo courtesy of Mats Kamsten at Uppsala University.
impact and applications

Thereafter the setup is tested and “calibrated” by placing readily available potassium salt in the can, which produces a few beeps per minute. The resulting beta and gamma radiation from the decays of $^{40}$K in the potassium salt and $^{137}$Cs in the mushroom differ in energy and intensity, and the response function of the diodes has not been determined. Therefore the calibration is limited to comparing how many beeps come from the mushroom samples with the potassium salt. Measurements are performed by counting the number of beeps during a set time. Background measurements can also be performed by counting beeps without having any sample in the can.

**Results and Outcomes**

The first part of the project finished during early spring 2019. In the end, 135 school classes completed the tasks, and together they contributed 248 samples of dried mushrooms, the same number of soil samples, and about 50 samples of animal droppings (mainly from deer and wild boar). The instructions had been to collect 10 species of mushroom, with priority to the top three in the list below. They were chosen because they are edible, common in all parts of Sweden, feasible to identify by morphology, and have featured in earlier research regarding uptake and retention of radio caesium in mushrooms (see, e.g., Ref. [7]). The 10 suggested species of mushroom were:

- Cortinarius caperatus
- Suillus variegatus
- Agaricaceae
- Cantharellus cibarius
- Boletus edulis
- Craterellus tubaeformis
- Cantharellus lutescens
- Hydnum repandum
- Albatrellus ovinus
- Gomphidius glutinosus

Photos of the submitted mushroom samples, taken by the pupils, were compared with the species reported by the pupils. It was concluded that out of 248 samples, 155 samples belonged to one of the preferred species in the list, and 59 were of other identified species. In total, the identification of 34 samples could not be confirmed by visual inspection of the photos.

The most abundant species collected were *Craterellus tubaeformis* (29 samples), *Suillus variegatus* (24 samples), and *Cantharellus cibarius* (23 samples). The samples were collected all over Sweden (see Figure 2), both in areas where most of the caesium from Chernobyl was deposited and in areas without deposition.

All mushroom samples have been measured with a HPGe detector, resulting in gamma spectra from which we have determined the activity of $^{137}$Cs. Simulations have been performed with the Monte Carlo code Geant4 [8] in order to correct for geometrical effects in samples of different mass and volume.

The preliminary results on $^{137}$Cs in mushrooms have been reported to the

![Figure 2. The results of the airborne measurements of $^{137}$Cs in kBq/m², performed by the Geological Survey in Sweden in 1986 (left) [1], and a Google Maps visualization of the distribution of collected mushroom samples in the citizen science project, color-coded for activity in Bq/kg (right).](image-url)
participating schools and can be found in a Google database [9].

In summary, only two samples had activities above 1,500 Bq/kg, which is the threshold value for selling mushrooms in Sweden. Both were collected in northern Sweden in areas that received fallout from the Chernobyl accident. The overall distribution was largely as expected from the fallout maps. Preliminary results have been reported to the Swedish Radiation Safety Authority and the National Food Agency.

Radioactivity levels may be difficult to relate to for the general public, therefore we also decided to report the results back to the schools in the form of a “mushroom sandwich index” [10]. In brief the index shows how many mushroom sandwiches per day a person can eat during a year in order to get an extra dose equivalent to 1 mSv, with the assumption that a mushroom sandwich contains 200 g of mushroom (see Figure 3).

One important aspect is the impact a citizen science project has on the participants and their views and ideas about science. Therefore, we also sent out questionnaires to both teachers and pupils. They were answered by 600 school pupils and 42 teachers and we are presently analyzing and compiling the replies. The pupil questionnaire contains questions about knowledge and interest in science but also tries to capture impacts regarding the views about science and participating in scientific research. Figure 4 shows the response from the pupils to the questions “Did you before the project know how radioactivity is measured?” and “Do you after the project know how radioactivity is measured?” There is a significant difference in the number of pupils answering “Yes” to these two questions, indicating that the project did have an impact on their knowledge about radioactivity and measurement techniques. We believe that a major part in this result was the detector that the pupils assembled and used.

Figure 3. One of the symbols used for the mushroom sandwich index (above) and how they are displayed on the Google database (right) [10]. (Originally from The Nounproject and has been adapted, with permission from The Nounproject, by Abigail Barker.)

Figure 4. One result from the pupils’ questionnaire showing an impact on their knowledge about how to measure radioactivity.
Outlook

Following delivery of the preliminary results, there is a lot of interesting research to pursue. Presently we are working on DNA sequencing of soil samples to establish which competing species exist in the same environment as the individual mushroom samples. Together with the sampling of mushroom species themselves, this can give important information about how different fungi species in different surroundings take up radionuclides. At the same time, a master diploma student is developing methods for radioactivity measurements of the soil samples, which are much denser and gamma-absorbing than mushroom tissue. Following these activities there will be DNA sequencing and activity measurements of animal droppings to map the transfer of caesium in food chains. We will also look closer into the uptake of naturally occurring radionuclides, such as $^{40}$K, in different mushroom species.

We believe that the citizen science part of this project has been an important effort to bring interest and knowledge about science to a young audience. The project has been interdisciplinary, involving radiation physics, biology, and ecology, and has also introduced scientific methodology to the pupils. Furthermore, we have tried to bring perspective to a topic that is perceived as dangerous; after all, the main danger with mushrooms may be the consumption of poisonous species.

Acknowledgments

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From left to right: Voker Ziemann, Marek Jacewicz, Cecilia Gustavsson, Erik Andersson-Sundén and Mattias Lantz. (Photo by Camilly Thulin, Uppsala University.)
Quark-Gluon Plasma in Venice: Quark Matter 2018

The 27th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions, organized by INFN and various Italian universities active in this field, and chaired by F. Antinori (INFN) and P. Giubellino (GSI and INFN), was held in Lido di Venezia, Italy, on 13–19 May 2018 (Figure 1). This series of conferences, better known as “Quark Matter,” is the prime venue for the community that studies the production and properties of the Quark-Gluon Plasma (QGP), a state of matter where quarks and gluons are no longer confined inside hadrons.

After an introductory talk by Prof. G. Parisi on intriguing aspects of the processes leading to thermal equilibrium in various kinds of systems, the conference started with a discussion of recent experimental results obtained by the ALICE, ATLAS, CMS, and LHCb collaborations in collisions of ultrarelativistic Pb beams at the CERN LHC. Also, highlights coming from experiments operating at the BNL RHIC collider (STAR, PHENIX) were proposed to the plenary audience, which included more than 800 physicists from more than 30 countries. Other experimental results, as well as significant advances on theory aspects, were the main focus of the large number (more than 200) of parallel and plenary talks.

Among the main results presented at the conference, significant progress was shown on the comprehension of the surprising observation of QGP-like phenomena in the collisions of small systems (pp, pA), as the presence of collective particle flow in spite of the few scatterings that take place in such interactions.

Results obtained at the LHC in the collisions of intermediate mass nuclei (Xe-Xe) were discussed extensively for the first time, and the dependence of the various observables among Xe-Xe and Pb-Pb interactions looks mostly understood.

Discussions on the chiral magnetic effect, a macroscopic manifestation of the chiral anomaly of QCD and on the related observations in a QGP, also received much attention.

As usual, the production of hard probes (jets, heavy quarks) in nuclear collisions was extensively discussed and impressive progress was shown in the theoretical understanding of this fundamental tool for the characterization of the QGP.

A lively debate on the future of the field, either in the high-energy domain (LHC, RHIC), or at lower energies (FAIR, CERN SPS, NICA, J-PARC), where a high-baryon density QGP can be formed, or finally via precision measurements to be performed at the forthcoming U.S.-based Electron-Ion collider, was part of the concluding sessions of Quark Matter 2018.

All the talks presented at the conference are available at https://qm2018.infn.it/.
The 10th International Conference on Direct Reactions with Exotic Beams (DREB2018)

The 10th International conference on Direct Reactions with Exotic Beams (DREB2018) was held at Kunibiki Messe, Matsue, Japan, on 4–8 June 2018, organized by the Faculty of Science at Tokyo Institute of Technology and the Research Center for Nuclear Physics at Osaka University. As initiated in 1999 at Michigan State University in the United States, and following the one at Saint Mary’s University in Canada, the series of the DREB conferences/workshops have focused on direct reactions, which have played significant roles in probing the characteristic nuclear structure of exotic nuclei. Indeed, in the last two decades, the direct reactions have evolved into one of the most essential experimental/theoretical tools in rare-isotope physics, as this field becomes a major one in nuclear physics.

Following the traditions of DREB, besides the opening two key-note talks, and the concluding remarks, all of the oral talks were selected from the contributed abstracts, and a large portion of them were new results before publication given by young post-docs and Ph.D. students. We also note that the poster sessions were very vibrant with lots of discussions. The best poster presenters were given the Asian Nuclear Physics Association prize. We are sure that the participants from all over the world (128 participants in total) enjoyed lively discussions during the conference, as well as delicious local food and historical and scenic views in Matsue city and its suburbs. We can conclude that the conference was very successful. This nice tradition is passed on to the next DREB conference, to be held in Santiago de Compostela, Spain, in 2020.

Finally, we thank Matsue city and Shimane Prefecture for their generous financial support, as well as the supports by the staff in Matsue Convention Bureau. Supports from RIKEN Nishina Center, CNS, University of Tokyo, as well as ANPhA, are also acknowledged.

TAKASHI NAKAMURA
KAZUYUKI OGATA
Chairs of DREB2018

Be sure to check the Calendar for upcoming events of interest to nuclear physicists.
A Short Report from Nuclei in the Cosmos XV

Nuclei in the Cosmos (NIC) is a series of international symposiums aiming to address the important interplay between Nuclear Physics and Astrophyics.

The 15th edition of the NIC conference was hosted at Laboratori Nazionali del Gran Sasso, Assergi on 24–29 June 2018.

The purpose of the NIC XV conference was bringing together Nuclear Physics and Astrophysics, giving the scientific community the possibility to review and discuss the status and prospects of Nuclear Astrophysics.

Nuclear Astrophysics is concerned with the understanding, interpretation, and simulation of nucleosynthesis processes, as they take place, for example, in the early minutes of the Big Bang, in distant supernova explosions, or in stars like the sun. The NIC XV conference provided a helpful overview and an up-to-date account of research in this exciting field, moving ahead with the strong advancement of experimental, observational, and computational tools. The conference had an average attendance of 200 participants (Figure 1), 150 from outside the hosting country.

All the talks and the poster session were followed by very stimulating discussions both during the sessions and the coffee and lunch breaks.

The Nuclei in the Cosmos XV was complemented by two dedicated satellite events: the “School on Experimental and Theoretical Methods in Nuclear Astrophysics with Applications” and the Workshop “Core-Collapse Supernovae in the Multi-Messenger Era (CCSN 2018).”

The conference and satellite events received support from INFN, Università degli Studi della Campania “Luigi Vanvitelli,” GSSI, JINA-CEE, IUPAP, and EPS. We are grateful to High Voltage Engineering Europe and Springer Nature who sponsored the conference.

ALBA FORMICOLA
MATTHIAS JUNKER
Laboratori Nazionali del Gran Sasso (LNGS), Italy

Figure 1. NIC XV group picture.
In September 2018, the tri-annual international conference on Electromagnetic Isotope Separators and Related Topics was hosted by the ISOLDE facility at CERN, jointly organized by the Experimental Physics and Engineering Departments. A total of 178 people registered for the conference (22% Ph.D. students). The conference was sponsored by Thorlabs and NuPECC. Nine companies had a permanent exhibition of their products just outside of the main auditorium where all presentations took place. There were 15 invited talks and 52 contributed talks, of which 10 were presented by Ph.D. students. The prize for the Best Young Speaker, offered by NuPECC, was awarded to Agi Koszorus from the KU Leuven (BE) (Figure 1). Eighty-five posters were presented during two very lively poster sessions on Monday and Tuesday evening. There were four prizes given to the best posters, also sponsored by NuPECC. A public lecture by Prof. Durante on “Heavy ions in therapy and space” was attended by more than 100 locals and several conference participants in the CERN GLOBE on Tuesday evening. The conference was endorsed by IUPAP, and in agreement with their policy, we tried to include a representative amount of female speakers (2 out of 15 invited speakers, 5 out of 52 oral contributions, or 16% of female participants).

During the workshop, two small parallel meetings were organized. The VSIM software package from the company TECH-X, based on a particle-in-cell approach for simulating electron and ion distributions (e.g., in an ion source) was presented during several hands-on sessions by experienced users and the company representatives. On Friday afternoon a mini-workshop was organized by Th. Cocolios, gathering the many laser experts in our field, to discuss the possibility of moving toward a common control and acquisition program for their experiments. In parallel, the conference participants had the opportunity to visit the ISOLDE hall, which was appreciated by more than 80 of them.

Gerda Neyens
Co-Chair of EMIS2018

Figure 1. Agi Koszorus, NuPECC prize winner as best Young Speaker. (CERN-PHOTO-201809-231-10).
The Opening Ceremony of the International Year of the Periodic Table (IYPT 2019)

The Periodic Table of Chemical Elements is one of the most significant achievements in science, capturing the essence of physics, chemistry, and now even biology. It is a unique tool, enabling scientists to predict the appearance and properties of matter on Earth and in the rest of the Universe.

2019 is the 150th anniversary of Mendeleev’s paper on the Periodic Table, and the International Union of Pure and Applied Physics (IUPAP) is one of the supporters of the International Year of the Periodic Table (IYPT), celebrating this important scientific milestone. The IYPT was launched at UNESCO in Paris on 29 January 2019, and IUPAP and C12 (the IUPAP Commission for Nuclear Physics) had a part in the launch. It was emphasized that all of the elements are made in nuclear reactions (especially in stars and cosmic events), and that all of those that have been discovered since 1939 have been made in contemporaneous nuclear reactions. Highlights included an account of the recent discoveries up to element 118-Oganesson by Yuri Organessian (Mr Element 118); an account of the Origin of the Elements in Outer Space by the 118 Kavali Prize laureate and president of the International Astronomical Union, Ewine van Dishoeck; and a description of the production of radioisotopes and their uses in medical diagnosis and therapy by Alinka Lépine-Szily, the past chair of the IUPAP Commission C12 for Nuclear Physics.

The initiative for IYPT2019 is supported by IUPAC in partnership with the International Union of Pure and Applied Physics (IUPAP), European Association for Chemical and Molecular Science (EuCheMS), the International Council for Science (ICSU), International Astronomical Union (IAU), and the International Union of History and Philosophy of Science and Technology (IUHPS). It was submitted by numerous organizations from over 50 countries around the world.

MICHEL SPIRO on behalf of the IUPAP President group:

BRUCE MCKELLAR, Past President
KENNEDY REED, President
MICHEL SPIRO, President Designate
And the OSCAR goes to…
the Oslo Cyclotron Laboratory

The Oslo Cyclotron Laboratory (OCL) celebrated its 40th anniversary recently. Around the same time, the Norwegian minister for research and higher education, Iselin Nybø, inaugurated a major new research infrastructure at OCL, the Oslo Scintillator Array OSCAR, on 31 January 2019 (Figure 1). With the new, unique detector, the laboratory is standing stronger today than ever before.

The cyclotron laboratory is operated by the Department of Physics at the University of Oslo. It is the only accelerator in Norway used for fundamental research, providing protons with energies up to 35 MeV, as well as deuterons (18 MeV), $^3$He (47 MeV), and $^4$He (35 MeV) to six different beam lines. OSCAR consists of 30 large-volume LaBr$_3$:Ce scintillation detectors, which combine high efficiency with excellent energy and time resolution. With almost 200 kg of LaBr$_3$, OSCAR is at present the largest detector array of its kind in the world. It was financed through a national infrastructure grant from the Norwegian Research Council. An array of segmented silicon telescope detectors, SiRi, is used in combination with OSCAR to detect and identify scattered particles. Furthermore, an array of parallel-plate avalanche counters is available for the detection of fission fragments. This combination of detectors, together with the light-ion beams from the cyclotron, are ideal to study the statistical decay from highly excited nuclear states. Indeed, the Oslo group has earned a reputation for such studies over the years, and their experimental technique to measure nuclear level densities and gamma-ray strengths functions has become known as the *Oslo Method* [1, 2] in the literature. The first experiments with OSCAR have demonstrated a significantly improved quality of data and precision of results compared to previous studies with NaI:Tl detectors.

The nuclear level density (NLD), the number of quantum states for a given range of excitation energy, and the gamma-ray strength function (GSF), the average probability for a nucleus to emit a gamma ray of a given energy, are important observables to understand the fundamental structure of nuclei [3–6]. They are also key ingredients for nuclear reaction calculations. The work performed with OSCAR at OCL contributes therefore in an important way to nuclear astrophysics studies, and, in the case of actinides, to studies related to energy applications [7]. By measuring the NLD and GSF, it is possible to constrain, for example, neutron capture rates, either in stellar environments or in nuclear reactors, which cannot be measured directly [8–10]. The relevance of this work has been recognized by the International Atomic Energy Agency through a coordinated research project to establish a database for GSF [11], in which the Oslo group is playing a prominent role. The group has furthermore been bringing experts in this field together in biannual workshops that have been held in Oslo since 2007.

Figure 1. The Norwegian minister for research and higher education, Iselin Nybø, is opening the beam valve during the inauguration ceremony of the new OSCAR detector at the Oslo Cyclotron Laboratory. Sunniva Siem, head of the nuclear physics group, and Andreas Görgen, manager of operations at OCL, are making sure she hits the right button. Photo credit: Berit Johne.
The next edition of the Oslo workshop on NLD and GSF will take place from 27–31 May 2019.

OCL, as a university laboratory, has a strong focus on the education of master’s and Ph.D. students. The assembly and testing of the OSCAR detectors, as well as the implementation of the digital data acquisition system, was largely performed by students. Experiments at OCL provide opportunities for students to play a major role in all aspects of experimental nuclear physics research, from the idea for an experiment, setup and preparation, data taking and analysis, all the way to the interpretation and publication of the results. At the same time, OCL maintains a strong international network, and most experiments are performed within international collaborations.

Besides the program on fundamental nuclear physics, OCL hosts several applied research programs. The cyclotron has been used for research and development of medical isotopes for a long time. This activity has been strengthened recently through a collaboration with the Norwegian Medical Cyclotron Center, a public enterprise owned by the university and university hospitals to produce medical isotopes. In another new development, scientists from the Department of Physics and the university hospital have established a research program in radiation biology, irradiating human cancer cells with protons. Proton beams from the cyclotron are furthermore used for radiation hardness tests of electronic components for space applications and CERN, and for testing of scintillating materials to be used in the beam imaging system for the proton target of the European Spallation Source ESS.

OCL is a small, university-based accelerator laboratory with limited resources, but the scientists around the laboratory have managed to establish a varied research portfolio that is competitive on an international level, and they have created an inspiring environment for students. At 40 years of age, OCL is looking optimistically into the future.

Anyone who is interested in collaborating with scientists at OCL and performing experiments with OSCAR is welcome to contact the author.

References

Andreas Görgen
University of Oslo, Norway
Nasser Kalantar-Nayestanaki Appointed Knight of the Order of the Netherlands Lion

In April 2018, Nasser Kalantar-Nayestanaki, a professor of experimental nuclear physics at KVI-Centre for Advanced Radiation Technology at the University of Groningen, the Netherlands, was appointed Knight of the Order of the Netherlands Lion (Figure 1). This honor is the oldest and highest order of chivalry for civilians in the country. He received this honor in recognition of his achievements in science and his activities in the social arena.

Nasser Kalantar-Nayestanaki is internationally well known for his contributions in understanding the nuclear forces acting in nuclei with a small number of nucleons. The high-precision measurements performed by his group have put exact ab-initio calculations under scrutiny, identifying regions where improvements must take place. For his achievements in this field, he was made a fellow of the American Physical Society in 2013.

From 2014 to 2018, he was the chairman of the board of representatives and the spokesperson of NUSTAR with more than 850 scientists from 40 countries. His own research in this collaboration focuses on matter under extreme conditions. In 2017, he was elected a member of the Academia Europaea. His more than 400 publications are often cited by fellow researchers all over the world.

His social activities are also numerous. He is a member of the representative body of employees at the University of Groningen. He was the chairman of the Minority Council in Groningen for four years, advising the municipality on various social issues.

Muhsin N. Harakeh
KVI-CART Groningen,
The Netherlands

Figure 1. Nasser Kalantar-Nayestanaki together with the Mayor of the City of Groningen during the appointment ceremony.

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Contact Maureen Williams: mwilliams@cisaz.com
STRONG-2020: The New European Project at the Forefront of Strong Interaction Studies

The STRONG-2020 project is the new European Integrating Activity for Advanced Community, with a four year duration, recently approved by the European Community within the Horizon-2020—Research and Innovation Framework Programme, as a structured enterprise to address open questions in the strong interaction studies in theory and experiments, and financed with 10 MEuro. Involving an active community of about 2,500 researchers in Europe, STRONG-2020 will start in summer 2019.

Endorsed by NuPECC, STRONG-2020 brings together many of Europe’s leading research groups and infrastructures presently involved in the forefront of research in strong interaction. It provides transnational access to six world-class research infrastructures in Europe: COSY, MAMI, LNF-INFN, ELSA, GSI, and CERN, and virtual access to open-source codes and automated/simulation tools. STRONG-2020 fosters the synergy between theoreticians and experimentalists, supporting the activities of the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*, Trento).

The STRONG-2020 Consortium includes 44 participant institutions embracing 14 EU Member States, one International EU Interest Organization (CERN), and one EU candidate country (Montenegro). Together with host institutions of other 21 countries, participating in the activities without EU benefits, STRONG-2020 involves research in 36 countries.

The STRONG-2020 results will have a significant impact on the study of the strong interaction and the Standard Model (SM). The project will also contribute to fundamental research for physics beyond SM, impacting other scientific sectors, such as astrophysics and theories of strongly coupled complex systems in condensed matter. The tools and methodologies for the new cutting-edge experiments within STRONG-2020 will provide upgrades to the European Research Infrastructures, enhancing their competitiveness. The developed technologies will also impact medicine and industry and may lead to advances in computing/machine learning.

STRONG-2020 will promote training and education activities that will bring qualified personnel to the job market and current state of the art in science communication dissemination activities.

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Barbara Erazmus
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Catalina Curceanu
LNF-INFN, Frascati (Roma), Italy
An outstanding physicist in the field of experimental nuclear physics, as well as in the applications of nuclear physics in medicine, one of the founders and a long-time director of the Heavy Ion Laboratory of the University of Warsaw passed away suddenly on 19 August 2018 in Warsaw.

Jerzy Jastrzębski was a graduate of the Adam Mickiewicz University in Poznań. After obtaining a master's degree in 1955 he started work at the newly founded Institute of Nuclear Research in Świerk, founded and directed by Professor Andrzej Sołtan. After just two years, in recognition of the progress he had made, he was sent to one of the leading French nuclear physics laboratories at Orsay, near Paris, on a scholarship. Working there for several years in a group of excellent scientists, he became an expert in the field of nuclear spectroscopy, publishing many important results. They were the subject of his doctoral dissertation (1963) and habilitation thesis (1971). In 1981 he obtained the title of Professor. He worked at the Institute for Nuclear Research until 1983, then moving to the, at that time, newly emerging Heavy Ion Laboratory of the University of Warsaw, of which he became director a year later. He held this function until 2009 with a four-year break during 1996–2000. He used this break to conduct intensive scientific research on the distribution of matter in atomic nuclei with an innovative method using an antiproton beam. His research done at that time is still of the greatest interest.

A scientist with great achievements, he also understood the role of basic research in serving society. At the beginning of the 21st century he began work on the applications of radioactive isotopes in the diagnosis and therapy of cancer. He was the originator of the Radioisotopes Production and Research Center, which, thanks to his titanic work, persistence and perseverance was created within the Heavy Ion Laboratory. He established extensive collaborations with scientists from Poland and abroad specializing in nuclear medicine and radiochemistry, and within these collaborations he conducted intense interdisciplinary research related to the applications of nuclear methods in medicine. This activity in recent years placed him among the prominent experts in this field.

Jerzy made an enormous contribution to the organization of cooperation between scientists from Poland and France. He was a founder and long-time member of the Polish-French Cooperation Commission. He was also a representative of Poland on the Nuclear Physics European Collaboration Committee, establishing the permanent and important position of Polish nuclear physicists among their European colleagues.

His diverse activities were rewarded with numerous honours; to mention only a few: the Medal of the University of Warsaw, Palmes Académiques, and the Knight’s Cross of the Order of Polonia Restituta.

Professor Jerzy Jastrzębski belonged to the pioneers of nuclear physics in Poland. He was an outstanding scientist with great achievements, imparting his knowledge to younger colleagues (he supervised over a dozen Ph.D. students), originator, organizer and builder of national research infrastructures, and organizer of broad scientific cooperation. He devoted himself to each of these activities with great passion to the very end of his life.

Krzysztof Rusek
Heavy Ion Laboratory,
University of Warsaw,
Warsaw, Poland
2019

July 1–5
ECT* Trento, Italy. Nuclear and astrophysics aspects for the rapid neutron capture process in the era of multimessenger observations
http://www.ectstar.eu/node/4443

July 1–5
Dubna, Russia. LXIX International Conference “Nucleus-2019”
http://indico.jinr.ru/conferenceDisplay.py?confId=706

July 1–5
Kruger National Park, South Africa. ANPC (African Nuclear Physics Conference)
http://anpc2019.tlabs.ac.za/

July 2–5
Kyoto, Japan. 15th International Symposium on Origin of Matter and Evolution of Galaxies OMEG15
http://www2.yukawa.kyoto-u.ac.jp/~omeg15/

July 15–17
Bilbao, Spain. Workshop on applications of Emission Mössbauer Spectroscopy (WEMS2019)
https://indico.cern.ch/event/795677/

July 22–26
Pisa, Italy. The 13th International Conference on Stopping and Manipulation of Ions and related topics (SMI-2019)
https://isnap.nd.edu/events/conferences/international-workshop-on-stopping-and-manipulation-of-ions/

July 28–August 2
Glasgow, UK. INPC 2019
http://inpc2019.iopconfs.org/home

August 16–21
Guilin, China. XVIII International Conference on Hadron Spectroscopy and Structure (HADRON 2019)
https://indico.ihep.ac.cn/event/9119

August 25–30
Wilhelmshaven, Germany. 6th International Conference on the Chemistry and Physics of the Transactinide Elements (TAN 19)
https://www-win.gsi.de/tan19/

September 1–7
Mazurian Lakes District, Poland. XXXVI Mazurian Lakes Conference on Physics
http://mazurian.fuw.edu.pl/

September 2–6
Guildford, Surrey, UK. 24th European Conference on Few-Body Problems in Physics (EFB24)
https://www.surrey.ac.uk/events/20190902-24th-european-conference-few-body-problems-physics-efb24

September 8–12
Malmö, Sweden. 8th International Beam Instrumentation Conference IBIC2019
https://indico.esss.lu.se/event/1158/

September 9–13
Canberra, Australia. 7th Heavy Ion Accelerator Symposium on Fundamental and Applied Science HIAS 2019
http://hiias.anu.edu.au/

September 9–13
Toulouse, France. XXth International Conference “Recent Progress in Many Body Theories”
https://20thrpmbt.sciencesconf.org/

September 11–13
Bitlis, Turkey. NSP 2019 XII. International Conference on Nuclear Structure Properties
http://nucleus.beu.edu.tr/

September 15–20
Berlin, Germany. Workshop on Energy Recovery Linacs (ERL2019)
https://www.helmholtz-berlin.de/events/erl19/index_en.html

September 15–20
Schloss Waldtheussen, Frankfurt/Main, Germany. Nuclear Physics in Astrophysics IX
http://exp-astro.de/meetings/npa-2019/

September 16–20
Palaiseau, France. Light Cone 2019
https://indico.cern.ch/event/734913/

September 22–27
Cape Town, South Africa. 22nd International Conference on Cyclotrons and their Applications (CYC19)
https://indico-jacow.cern.ch/event/14/

September 22–27
Serralunga d’Alba, CN, Italy. 7th edition of the p-process workshop

September 23–27
Novosibirsk, Russia. 12th International Workshop COOL’19
https://indico.inp.nsk.su/event/16/

September 30–October 4
Danang City, Vietnam. 9th International Symposium on Nuclear Symmetry Energy (NuSYM2019)
https://nusym2019.ispun.vn/

October 13–18
Maresias, Brazil. 4th International Workshop on Quasi-Free Scattering with Radioactive-Ion Beams: QFS-RB 19

October 20–25
Costa-Papiernicka, Slovakia. ISTROS 2019

More information available in the Calendar of Events on the NuPECC website: http://www.nupecc.org/