NORCC

Annual Report 2022

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01
INTRODUCTION

PREFACE

Welcome to the Norwegian Centre for CERN-related Research (NorCC)!

During 2022 NorCC has started to flourish. We are very pleased to be able to show you with this report a glimpse of our many research achievements in 2022 as well as our existing and new activities, such as a summer event at CERN for the students.

2022 was a very important year for NorCC as the Large Hadron Collider and its experiments successfully restarted for Run 3 after the second long shutdown period (LS2). This pioneering run produced an unprecedented number of proton-proton collisions at a world-record energy of 13.6 TeV. The events were detected by the completely revamped ATLAS and ALICE detectors, thus providing new indispensable data to physics researchers. This new data will be pivotal in the search for even rarer processes and even heavier unknown particles. We also see important developments for the accelerator R&D, ISOLDE and AEGIS experiments as well as important developments for our many technology activities. Our LHC upgrades have received additional funding (2023-2027) which will be essential to complete the future computing and detector upgrades for ATLAS and ALICE.

2022 year has seen the end of the Covid-19 measures but unfortunately the start of War in Ukraine. Our thoughts go to colleagues, family and friends and all affected by the war. Luckily we have thanks to the effort of our members and institutes been able to help a few. For collaboration at CERN we see a significant effect both for work on hardware, computing and analysis, but most importantly affecting the lives of our friends and colleagues. Currently ATLAS and ALICE work is not published but uploaded to Arxive (https://arxiv.org).

Many thanks for the enormous effort of our researchers and students during 2022. For us in Norway, NorCC presents a great opportunity, an opportunity to advance our research across institutions in Norway together with CERN, thanks to the solid support we have locally at our institutions, at CERN. and from the Norwegian Research Council. Many thanks to everyone in our collaboration for your important work during 2022.

Heidi Sandaker

"Measure what can be measured, and make measurable what cannot be measured."

- Galileo Galilei

"Many thanks to everyone in our collaboration for your important work during 2022!"

Fotograf: Melanie Burford for Trond Mohn Stiftelse

ABOUT NORCC

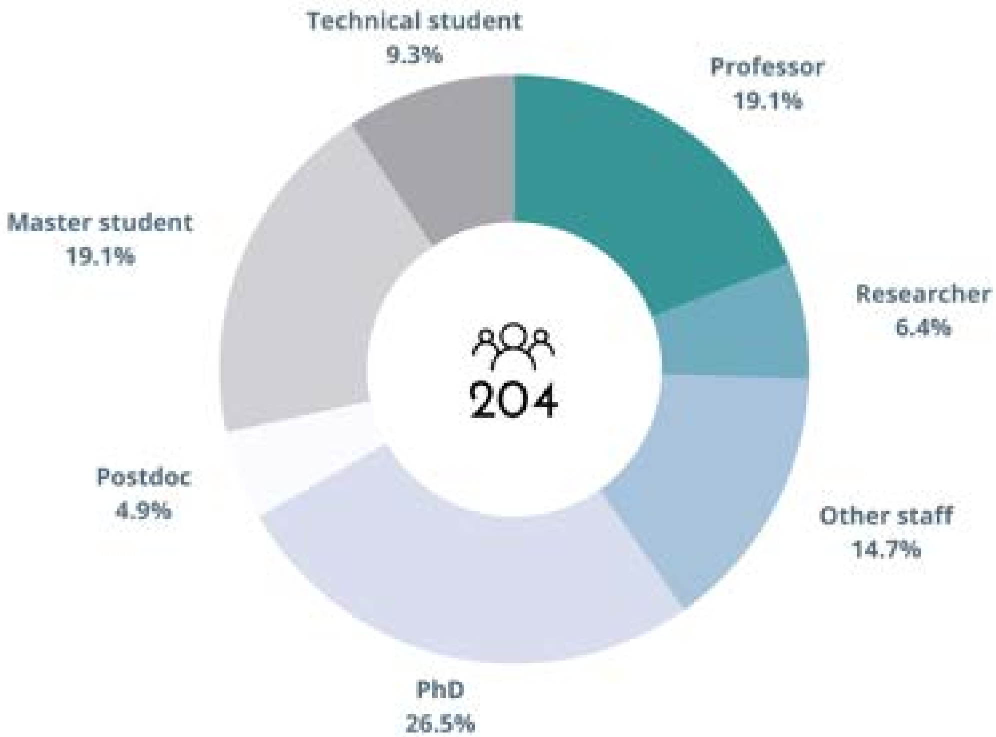
We want to research and discover new knowledge about the fundamental particles and the laws of the Universe

NorCC wants to discover the nature of the Universe by answering fundamental research questions such as: what are the building blocks of nature and how do they interact, how did the birth and evolution of the universe happen and how heavy elements in the Universe are created. Many mysteries remains to be discovered to understand better how nature works, such as the origin of Dark Matter, the matter-anti-matter asymmetry and how the universe evolved shortly after the Big Bang. To study nature more profoundly Norwegian scientists and students will perform theoretical, experimental and technological research at CERN.

ORGANIGRAM


LEADERSHIP
GOVERNING BOARD
Deans (UiO/UiB)
Institute Leaders
Centre Leader & deputy
Admin. Coordinator
2 representatives
Ministry of Education and Research
Research Council of Norway
External evaluation
Scientific Advisory Panel
STEERING COMMITTEE
Management team:
Centre leader
Activity leaders
Admin. coordinator
ACTIVITIES
PARTICLE PHYSICS
Lead: Farid Ould-Saada
Deputy: Anna Lipniacka
Analysis: B. Martin dit Latour
Computing: J. Catmore
Upgrade: B. Stugu
EDE
Lead: Steinar Stapnes
Deputy: Nina Waage / Eli B. Rye
Technical Students:
J. Vigen, N. Høimyr, S. Stapnes
Visit Program: J. Vigen, N. Høimyr
ILO/TTO: O. P. Nordahl
NorLHC:
Johan Alme
James Catmore
Alex Read
NUCLEAR PHYSICS
Lead: Dieter Röhrich
Deputy: Trine Tveter
Instrumentation: K. Røed, J. Alme
Computing & Software:
M. Richter
Data Analysis: I. Arsene
MANAGEMENT
Centre Leader: Heidi Sandaker
Admin. Coordinator:
Nina Waage / Eli B. Rye
TECHNOLOGY
Lead: Jørn Wroldsen
Deputy: Søren Kragholm
NTNU/CERN PhD Program
ACCELERATOR PHYSICS
Lead: Erik Adli
Novel Accelerator Research
Design Studies
Applications
LOW ENERGY NUCLEAR PHYSICS
Lead: Sunniva Siem
Deputy: Andreas Görgen
ISOLDE: S.Siem & A.Görgen
AEgIS: A. Camper
R&D Detectors and Electronics
Bjarne Stugu
& Ketil Røed
R&D Computing, Machine Learning/AI
Therese Sjursen
& Eirik Gramstad
NETWORKS

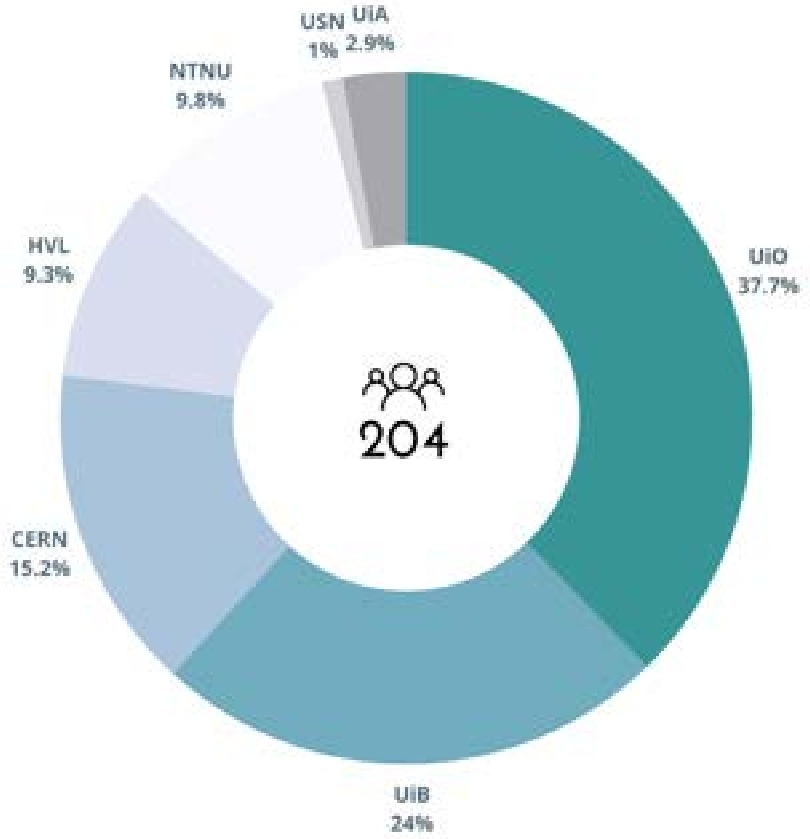
NorCC aims to fully exploit the scientific potential of CERN related research and to do frontier research in particle and nuclear physics and technology. The core funding received from RCN is earmarked to the participation in long term experiments at CERN for Norwegian Scientists and thus securing the best possible experimental exploitation of the Norwegian CERN membership. For LHC and HL-LHC, Norway participates in the experiments ATLAS and ALICE. In addition, NorCC aims to prepare for a post-LHC high energy accelerator project through design studies, research (CLIC, Awake) and construction. The centre also focuses on exploiting the low energy research program at CERN through the ISOLDE experiment and will pursue novel avenues for research through small-scale experiments at CERN and technology research. Last but not least, central to the NorCC is the training of a new generation of scientists and engineers, engaging industry in Norway for deliveries and collaboration, and facilitating technology transfer. Additional funding through, beyond the core funding, ensure in-depth research for e.g. ISOLDE, accelerators, ATLAS, High Luminosity-LHC (HL-LHC) upgrades and technology research.



OUR ORGANIZATION

NorCC is led by UiB and UiO and hosted by the Department of Physics at UiO. It is an umbrella for CERN-related research in Norway and welcomes scientists from all institutions in Norway who would like to participate. The centre has a Governing Board, a Steering Committee, seven activities and currently two networks. The Governing Board coordinates the Norwegian activities associated with research and scientific activities at CERN on the authority of the Research Council Norway (RCN) and the faculties of mathematics and science at the University of Bergen and the University of Oslo.

Five of our activities are research activities in the fields of particle physics, nuclear physics, accelerator physics, low energy physics and technology. In addition, we have an activity dedicated to education, dissemination and exploitation and one for management. NorCC wishes to enhance collaboration across activities by creating networks representing current focus areas. Today, we have two such networks, Detector and electronics R&D, and R&D in computing, machine learning and AI. NorCC also includes the RCN infrastructures NorLHC and NorLHC-II which funds the upgrades of the LHC experiments towards the High-Luminosity LHC.



The steering committee handles the overall coordination of the activities and networks, its reports and strategies. All members of the steering committee have outstanding, long-term experience with leadership and research management, as well as a long track-record for attracting funding and promoting careers of young researchers. In addition, the centre will have a scientific advisory panel (SAP) consisting of five international experts in the fields of experimental particle physics, experimental nuclear physics, accelerator physics, and two theorists, one of them covering the field of astroparticle physics.

The heart of the centre is our yearly workshop. The 2022 workshop was held in person in Oslo for the first time after Covid-19 and featured the inauguration of NorCC as well as a celebration of 10 years since the discovery of the Higgs boson. The topic of the 2022 workshop was presentations and discussions on future goals and opportunities. We aim for the organisation to be as clear and open as possible ensuring the best possible communication within NorCC at all levels.

Quick Questions

YOUNG RESEARCHERS

Aurora Singstad Grefsrud
PhD student (HVL)

'Chatty, whimsical, animal-loving, artsy, science nerd :D'

What is your background?
Applied physics master from NTNU in computational astrophysics.

Where would we usually find you?
In the PhD computer science office at HVL or hiking with my dog :)

How has the year of 2022 been?
It has been nice (and slightly overwhelming) to meet fellow physicists/computer scientists in person finally. I have been reminded that international collaboration is an important part of why I am doing this!

What are you looking forward to in 2023?
To get my first paper published, hopefully...

What do you plan to do after this period of your life?
I can not plan that far into the future! Let's get that paper published first.

Choose one song to play every time you walked into a room, what song would you choose and why?
John William's 'Theme from Jurassic Park'. It is the perfect mix of subtle and dramatic to announce my arrival.

Which fictional character do you identify with the most and why?
Ash Ketchum in the Pokémon series! He sets very ambitious goals for himself with no clear plan for how to reach them, has strong opinions that are often wrong and learns by throwing himself at a problem and making mistakes. He also has a particularly stubborn animal sidekick, just like me :D

What wold people be surprised to know about you?
I did not take physics in high school and I actually never studied particle physics in university. The somewhat arbitrary choices you make during your education do not necessarily limit your future as much as many are led to believe!

What is your current research project?
I am looking at different ways of implementing machine learning methods to high energy physics problems. Specifically, I want to use deep learning to further our search for dark matter.

Why did you choose this field?
Because dark matter is so interesting! I also wanted to do a lot of programming and a little physics, which is exactly what I am doing right now.

Why do you think this research is important?
I think increasing our understanding of fundamental physics is essential for the progress of the evolution of new technology.

What would you like the impact of your project to be?
I hope to research good ways of implementing machine learning techniques so that they can be tested, reproduced and understood in a way that they are currently not.

What do you see as the most important issue in your field today?
The rise of generative AI will change the world, but I don't think we are ready for it. Studying the way these algorithms work will be crucial for the safe implementation of AI into our everyday lives as well as in physics.

Quick Questions

YOUNG RESEARCHERS

Eric Daniel Fackelman
Master student (UiO)

What is your background?
After my bachelor's in physics I worked as a laser engineer and manager for 5 years then came to Oslo and am studying accelerator physics at UiO. I am excited about nuclear energy and how to improve the world and society.

Where would we usually find you?
In the physics masters student office or in the forest around Oslo, enjoying the peace of the woods, preferably in my hammock when it is warm enough.

How has the year of 2022 been?
2022 was fantastic, I learned a lot in my studies and got to travel to many wonderful places, including CERN, Bavaria, my home in New York, and the Mayan ruins of Tikal in Guatemala!

What are you looking forward to in 2023?
Wrapping up my masters project and exploring Europe more.

What do you plan to do after this period of your life?
Secure a job at an engaging lab or company, enjoying the nature nearby and traveling around the world with my wife.

Choose one song to play every time you walked into a room, what song would you choose and why?
Test Drive by John Powell from How To Train Your Dragon movie. Because I want a dragon to fly with.

What is your current research project?
My research is on the European Spallation Source proton beam as it approaches the target, how it could change based on linac failures, how the window it passes through after the accelerator effects the current density, and how the imaging system will interpret the beam shape.

Why did you choose this field?
After learning about accelerator driven spallation sources and their applications, I was thrilled to contribute to ESS.

Why do you think this research is important?
I think the potential to use spallation sources for sub-critical nuclear fission breeder reactors and as nuclear waste burning facilities is vital to building a sustainable energy future. Having a robust failure detection and protection system is critical to such facilities, especially from a regulatory perspective.

What would you like the impact of your project to be?
I hope the ESS Beam Physics and Diagnostics groups can use the tools I've developed to estimate the beam profile on target for the final beam parameters. I hope the algorithm for profile interpretation contributes to the one used for the Machine Protection System and that it is never used (no failures!).

What do you see as the most important issue in your field today?
I sense that the public has vague and often inaccurate conceptions about high energy physics and its applications, I would like to contribute to quality science outreach and education with the goal of more facilities around the world which can be used for improving society.

HISTORY

CERN

On the border between Switzerland and France, near the airport in Geneva, lies the international research organization CERN (European Council for Nuclear Research). The CERN laboratory was founded in 1954 and has now 23 member countries from Europe, in addition to several associated member countries and partnerships. Physicists and engineers at CERN use the world's largest and most complex scientific instruments to push the boundaries of human knowledge and study the fundamental building blocks of our universe - fundamental particles.

One of these instruments is the Large Hadron Collider (LHC), a particle accelerator, which was completed and used for scientific experiments in 2008. The accelerator is located 100 meters underground in a 27-kilometer-long circular tunnel of superconducting magnets. Around this tunnel, subatomic particles are accelerated near the speed of light before they are set on a collision course with each other to gain insight into the basic laws of nature and how the particles interact. The high energy collisions in the LHC are studied in four large detectors; ATLAS, CMS, ALICE and LHCb.

Other parts of the accelerator complex at CERN accelerate particles to be collided with fixed targets to study nuclear properties or decelerated to be studied in anti-matter experiments. CERN is also the place of numerous technical advances such as the birth of the World Wide Web in the 1980s, and the world's first website was published from here in 1991.

Initially, the main focus of the CERN centre was research in nuclear physics, but in recent times our understanding of matter goes much deeper than just the atomic nucleus itself, and the main area has developed into particle physics. Although the main area is particle physics, there are still large environments within nuclear physics and nuclear chemistry.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Norway & CERN

Norway was one of the 12 European countries that co-founded CERN in 1954. Since then, Norwegian researchers, students, and staff have been active in the international environment at CERN and taken advantage of the opportunities that the unique facilities CERN has to offer. The organization currently has over 20 member countries, around 2,600 full-time employees, plus nearly 8,000 scientists and engineers from 500 universities and 80 nations.

Norwegian researchers have played a vital role in developing accelerators for particle physics. Odd Dahl was the driving force behind the Proton Synchrotron construction (PS), CERN's first store accelerator, which began operations in 1959. The Intersecting Storage Rings (ISR) accelerator was the first machine for hadron collisions and was built in 1971 under Kjell Johnsen's leadership. The pioneers Rolf Widerøe, Bjørn Wiik, and several other well-known Norwegian accelerator physicists have also made an extraordinary effort in the area and have helped push the research forward.

The Norwegian environment at CERN is involved in many different activities and is currently engaged in the experiments ATLAS, ALICE, CMS, ISOLDE and AEGIS. The Norwegian environment is also involved in other CERN activities such as accelerator and technology research, as well as future R&D activities in silicon microsystems and GRID data processing. The Norwegian CERN community also primarily initiated the successful GRID development in Norway.

02
RESOURCES

GRID COMPUTING

From early on in the development of the LHC, it was clear that fully exploiting the scientific potential of its experiments would require a new paradigm for processing, transmitting, storing and analysing data. This led to years of intensive research and development across the high energy physics computing community, and ultimately led to the creation of the World-wide LHC Computing Grid (WLCG). Today, WLCG is a network of 170 data centres in universities and national laboratories in 42 countries around the world. It has storage capacity in excess of an exabyte (1 million terabytes), and processes 2 million computing tasks per day on average using a million compute cores. It is bound together with high-capacity network links that enable combined traffic of up to 50GB per second between its sites.

As well as the disk, CPU, tape and network infrastructure, layers of software are required to orchestrate data movement, job execution, user authentication and monitoring. WLCG serves the four LHC experiments and smaller communities, and is used for both centrally organised data processing and simulation, and also for direct analysis of the data by individual physicists. It is perhaps one of the most literal expressions of the international collaboration that typifies high energy physics research.

Norway's contribution to the WLCG

Norwegian physicists and computer scientists have been closely involved in the development of WLCG since the earliest days. A particularly important contribution has included collaborating in the development of the data management layer for the ATLAS experiment. Now known as Rucio, this software is also being rolled out for the CMS experiment, and is taking shape as a general purpose data management tool for "big science" data. Norway was also instrumental in the development of the Advanced Resource Connector (ARC), a lightweight tool for plugging computing resources into the grid which is now the de facto standard tool across the world. UiO leads the ATLAS@Home volunteer computing project which allows members of the public to run simulations of the ATLAS detector on their home PCs.

Other essential contributions involve developing the ALICE Grid middleware JAliEn and the ALICE O2 Analysis Framework, where Norwegian groups are among the core developers. In addition, a new monitoring system has been set up based on the free software Premotheus, a monitoring system and time series database, including the development and testing of data exporters and visualization in Grafana dashboards. This development joins the effort of the NEIC Nordic T1 to replace the existing monitoring solution, which is no longer actively developed.

Norway hosts hardware used by WLCG at UiO and UiB. At the end of 2021, 1.52 PB of disk space, 3.82 PB of tape archival and 18.28 KHS06* of compute power were made available to ATLAS via WLCG. For ALICE, Norway is providing 31.59 KHS06 of compute, 3.24 PB of disk and 4 PB of tape.

*HEPSpec06 is a benchmark measure of the computing power, which is measured for each CPU type by running a set of well-defined high energy physics tasks in controlled conditions. Since different CPUs can have very different performances, this measure is more meaningful than a count of CPUs.

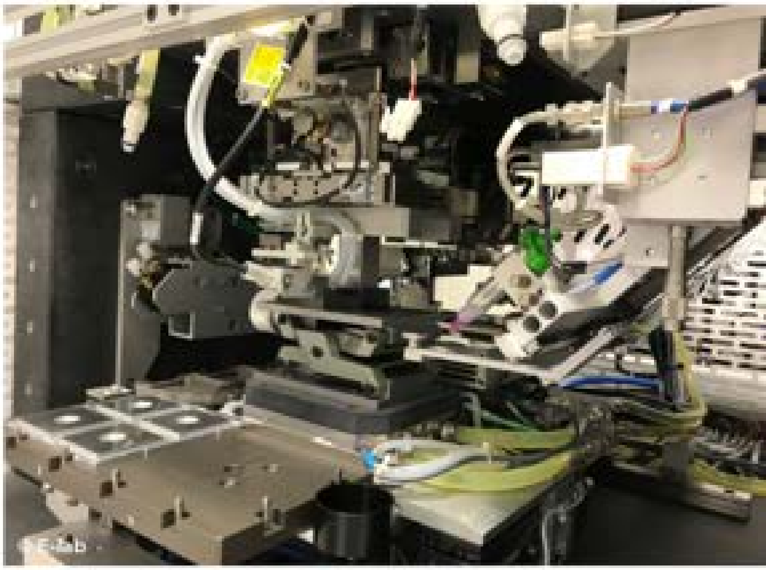
LABORATORIES

Laboratory of Electronics (E-lab) & Instrumentation (I-lab)

Location: University of Oslo

The E-lab is key to the Norwegian deliveries to ATLAS Upgrade, including development, construction and testing of ITkPix modules. In addition, we are engaged in wire bonding and testing of ITkStrip modules. This work takes place in E-lab's cleanroom with automated machines for assembling detector modules, wire bonding and quality control. In the lab areas outside the cleanroom, there are plasma cleaner and climate cabinets for module testing, which are used for electrical testing of modules and logistics tasks associated with them. In 2022, focus have been on the development of ATLAS 3D silicon pixel modules and their flexes as well as bonding strip modules for ATLAS. Preparation for ATLAS pixel module production starting 2023 is ongoing.

© E-lab


© E-lab

The Instrument Laboratory (I-lab) is a mechanical workshop that serve primarily the faculty of mathematics and natural sciences as a partner in developments and prototyping of new instruments for experimental sciences. I-lab supports the module activity with development, production and alignment of mechanical jigs and "tooling" for the construction process.


© USN

Norwegian Micro- and Nanofabrication Facility (NorFab)

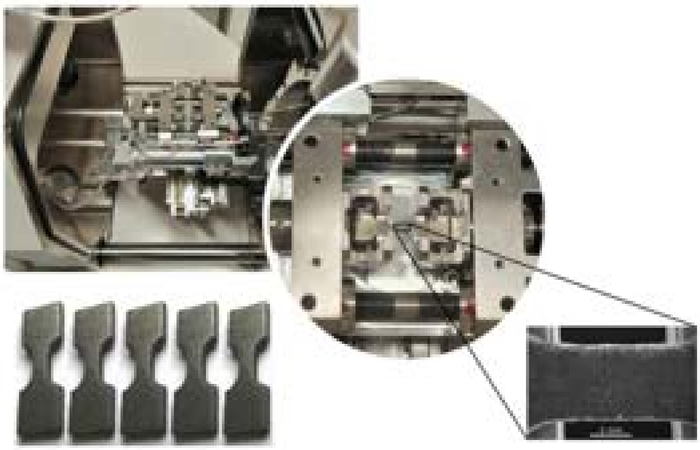
Location: USN

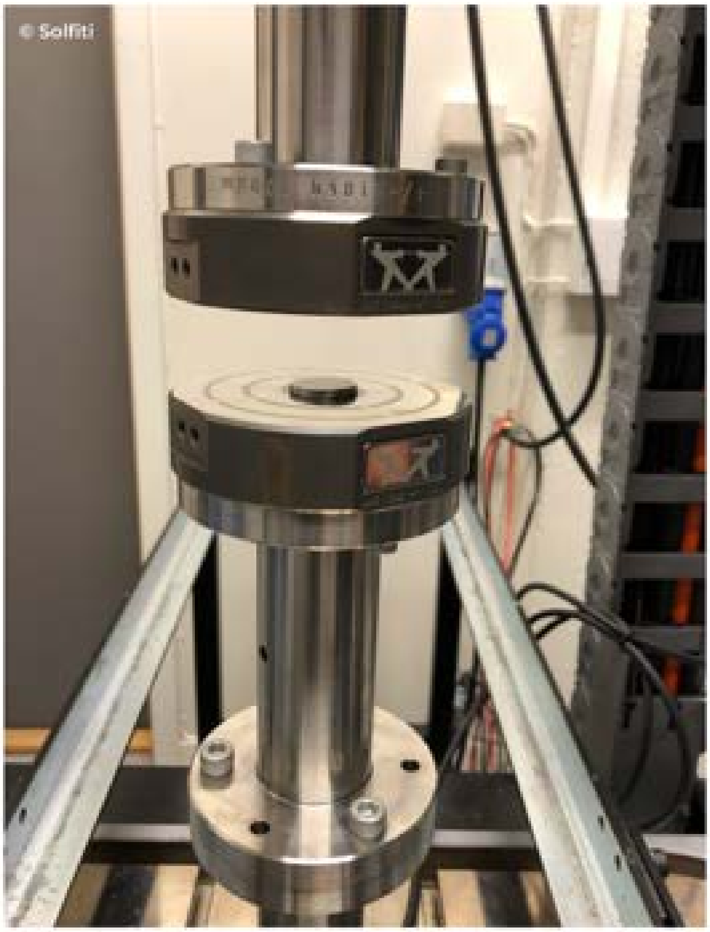
The MicroSystemTechnology Lab (MST-Lab) is one of the laboratories which are part of the NorFab facility. The lab is a flexible cleanroom facility for MEMS processes on silicon wafers and other substrates with emphasize on bonding, packaging and Micro-System-Technology. Therefore the laboratory also contains advanced tools for testing, dicing, pick and place, fine-pitch wire bonding and different flip chip methods.

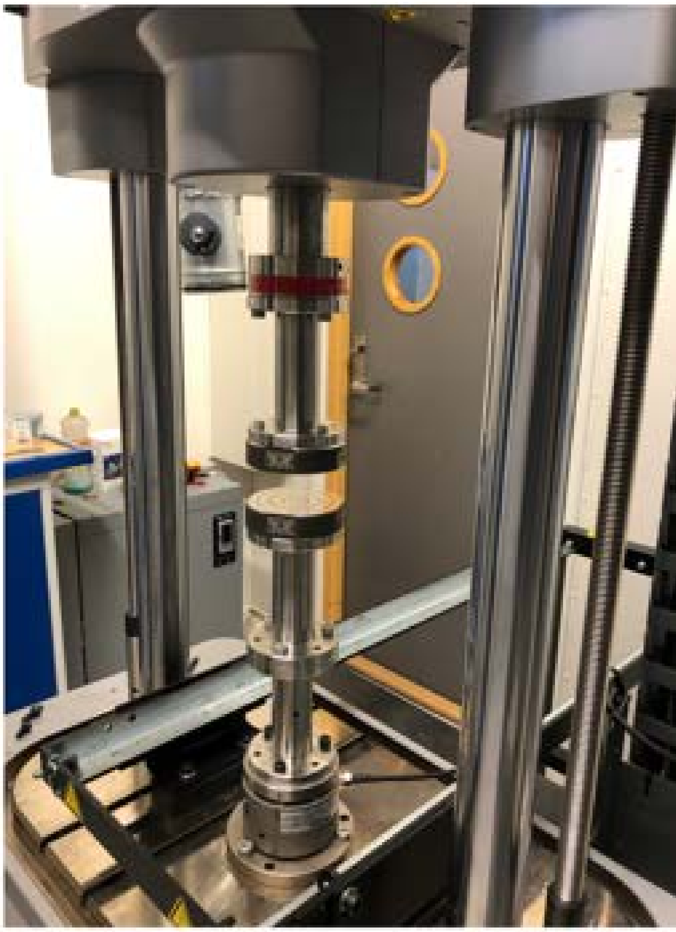
Fatigue, Fracture and Mechanical Characterization Laboratory

Location: CERN

The Fatigue, Fracture and Mechanical Characterization Laboratory includes multiaxial, uniaxial and rotating bending machines with several environmental chambers. The Lab allows characterizing the fatigue and fracture behaviour of different metallic materials spreading in a broad range of strategic topics related to the structural integrity of conventional and innovative materials. In the pictures is the ongoing testing campaign on flexible graphite (Sigraflex). This material is currently employed in the LHC Target Dumps External (TDE) devices to dump the proton beam extracted out of the main LHC trajectory. The goal is to find a suitable constitutive law to be adopted in the overall dumper simulations performed by CERN colleagues. To understand the out-of-plane behaviour of the material in the plastic domain, a static uniaxial compression testing at macro-scale was carried out in the Fatigue Lab. to observe the fracture behaviour in the in-plane direction, a static in-situ tensile testing and post-mortem fractography was carried out in the Nanomechanical lab.



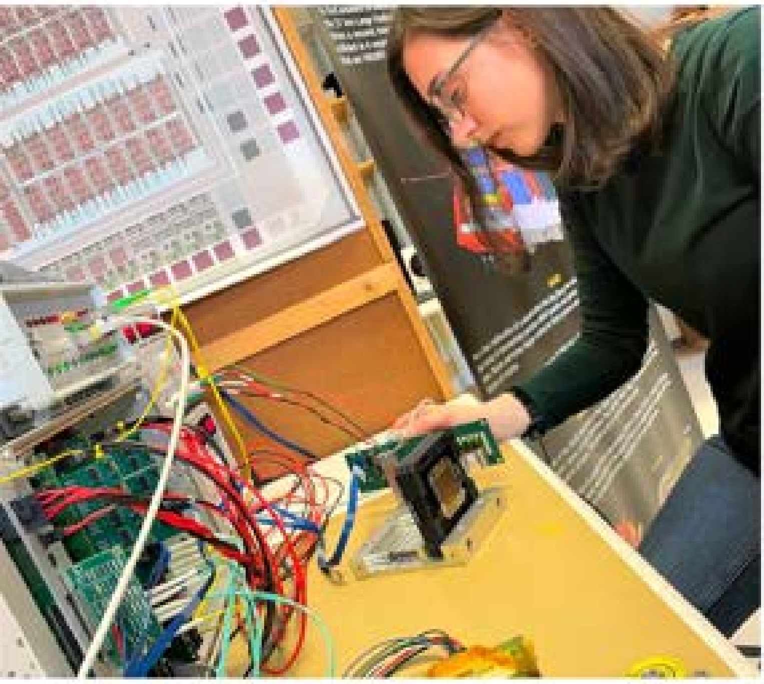


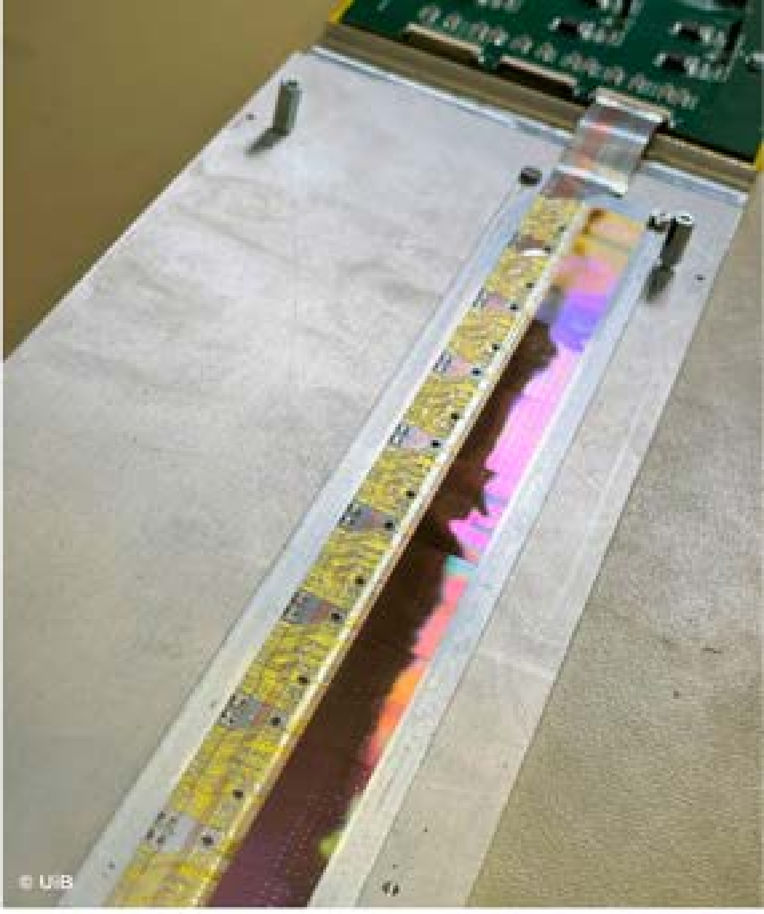


Microelectronics Laboratory

Location: University of Bergen

The Microelectronics Laboratory in at the University of Bergen is essential for the R&D for the Norwegian activity in ALICE. During the last 20 years, the readout electronics of several of the sub-detectors in ALICE have been designed and tested in this facility.



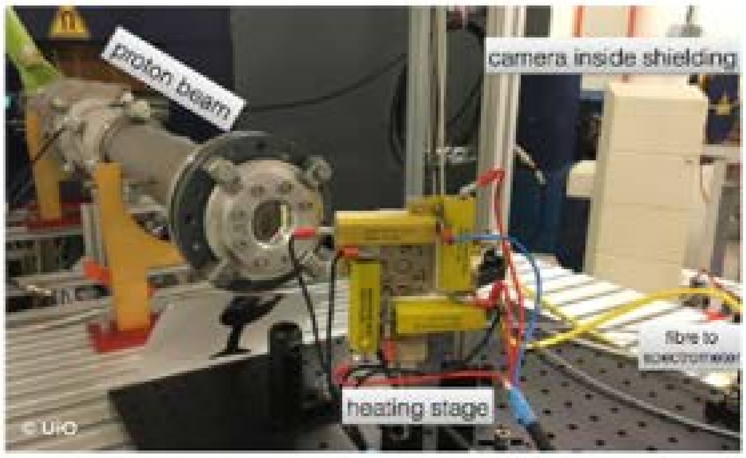


Currently, the laboratory contains a full reference setup for the Inner Tracking System (ITS) readout chain, of which the Forward Calorimeter (Focal) pixel layers development is based upon. The laboratory is equipped with high-speed oscilloscopes, logic analyzers and other vital equipment for design, development and testing of modern electronics systems.

Oslo Cyclotron Laboratory (OCL)

Location: University of Oslo

The Oslo Cyclotron Laboratory (OCL) houses the only accelerator in Norway for ionized atoms in basic research. The laboratory serves as an experimental center for various fields of research and applications. The main field of research is within nuclear physics and nuclear chemistry. In addition, isotopes are produced for nuclear medicine.



Scintillating materials have been in use for beam imaging at CERN for decades, but the performance of scintillators with the amount of radiation present at theEuropean Spallation Source target needs to be assessed. The Oslo accelerator group is using the OCL as a part of the testing of scintillator coatings for the ESS target imaging systems [1]. Samples of coated aluminum are mounted on an in-air Faraday cup for measuring the beam current. Images and optical spectra are recorded, and correlated with the Faraday cup readings. A heating gun is also available for measuring light yield and spectra as a function of temperature. The coating process affects both the amount of doping and the crystal structure of the coating, which are both linked to performance. This is an example of how our expertise with CERN-projects may be applied to other projects at the research frontier.

Refrigeration Laboratory

Location: NTNU

There are several systems belonging to the natural refrigerant laboratory using CO2 as refrigerant:

Super-Smart rack

The Flexible test rig is able to replicate the next generation of commercial and industrial CO2 systems to validate and demonstrate performance and efficiency for new concepts. There have been several activities in the past, such as test pivoting compressors (Interchangeable suction among different pressure levels, aiming to reduce the total number of compressors, enhancing the flexibility while maintaining system efficiency), ejector for the World concept (Ejector part of the cycle at all conditions, actively or passively, aiming to increase the rack flexibility and removing one compression stage), and multi-temperature CO2 refrigeration unit (through ejector use in a traditional medium-sized refrigerated truck). Activity in the future will be to implement an additional expansion work recovery device (ejector and expander).

Cold Thermal Energy Storage (CTES)

A Novel CTES unit composed of a plates-in-tank HEX design immersed in water as the cold storage medium for industrial refrigeration applications. Past activities include industrial refrigeration using CO2 as refrigerant and water/water+RT-9HC (commercial organic PCM). Peak shaving in refrigeration units for food processing plant. Future activity will be ultra-low temperature thermal energy storage using CO2 as PCM at -50°C (charging storage with an ethane unit R-170).

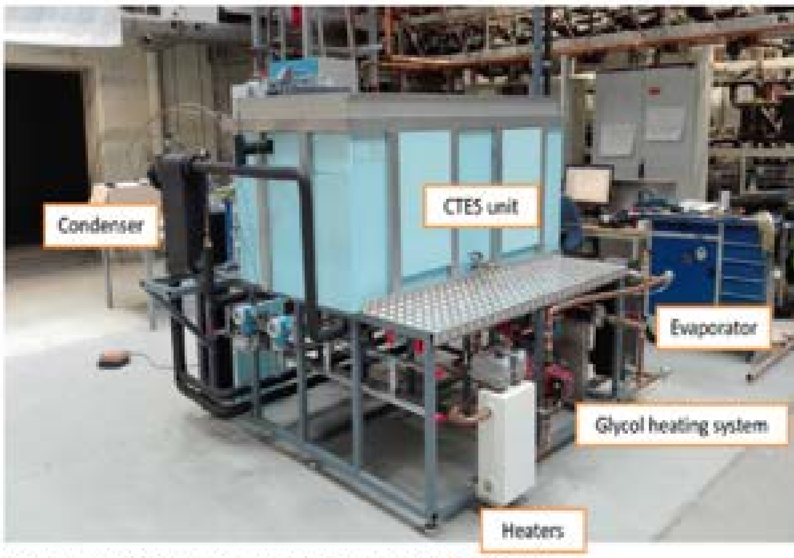
MultiTest-Rack

Experimental setup working with CO2 to validate components and circuits at freezing (LT), chilling (MT) and air conditioning (AC).

Absorption-compression heat pump

Which uses ammonia-water mixture as natural working fluid. Investigation on practical and efficient solutions to provide a sustainable cold chain for the food sector aiming to decrease carbon footprint.

SuperSmart-Rack experimental setup.



Cold Thermal Energy Storage using pillow-plate heat exchanger.

MultiTest-Rack.

Other Laboratories

SNAKE ROBOTICS LABORATORY

Location: NTNU

DETECTOR LABORATORY

Location: University of Bergen

POWER ELECTRONICS LABORATORY

Location: NTNU

Quick Questions

YOUNG RESEARCHERS

Simen Hellesund
Postdoc (UiB)

'I am a 32 year old human male, with a pleasant disposition and bad knees, working at the University of Bergen as a postdoctoral researcher with the ATLAS experiment'

What is your background?
My background is doing data analysis with the ATLAS experiment.

What would people be surprised to know about you?
I can play the saxophone.

Where would we usually find you?
In the forest, hiking or foraging for edible mushrooms. Or in the clean room at the UiB department of physics, performing electrical tests and metrology of 3D pixel sensors.

How has the year of 2022 been?
2022 was a landmark year for me: I finally managed to defend my PhD thesis, and I started my first postdoc.

What are you looking forward to in 2023?
This year I look forward to continued good cooperation and camaraderie with my new colleagues in Bergen, and I hope to be able to contribute to the scientific output of ATLAS in some way.

What do you plan to do after this period of your life?
I dream, like most young researchers, of a permanent position.

Choose one song to play every time you walked into a room, what song would you choose and why?
'Tøff i pyjamas' by deLillos, but only the bit where Lars Lillo Stenberg sings 'her kommer dumme dumme dumme dum'.

Which fictional character do you identify with the most and why?
The Fresh Prince of Bell Air. Because I am laid back and charismatic, and hijinks seem to follow me, but mainly because a Buzzfeed quiz I took just now told me.

What is your current research project?
My main focus right now is the testing components for the inner tracker upgrade of the ATLAS detector planned for the high-luminosity LHC. I am also involved in a search for CP-violation in the vector boson fusion Higgs production channel.

Why did you choose this field?
When I started university I planned to study astronomy, but a trip to CERN during my undergraduate studies ignited my passion for high energy physics.

Why do you think this research is important?
I am passionate about the inherent value of basic research. Like Carl Sagan said, we are a way for the universe to know itself. Discovering the laws of nature should be one of humanity's greatest goals.

What would you like the impact of your project to be?
I would love to see a particle consistent with dark matter be discovered at the LHC.

What do you see as the most important issue in your field today?
The standard model is too good.

03
ACTIVITIES

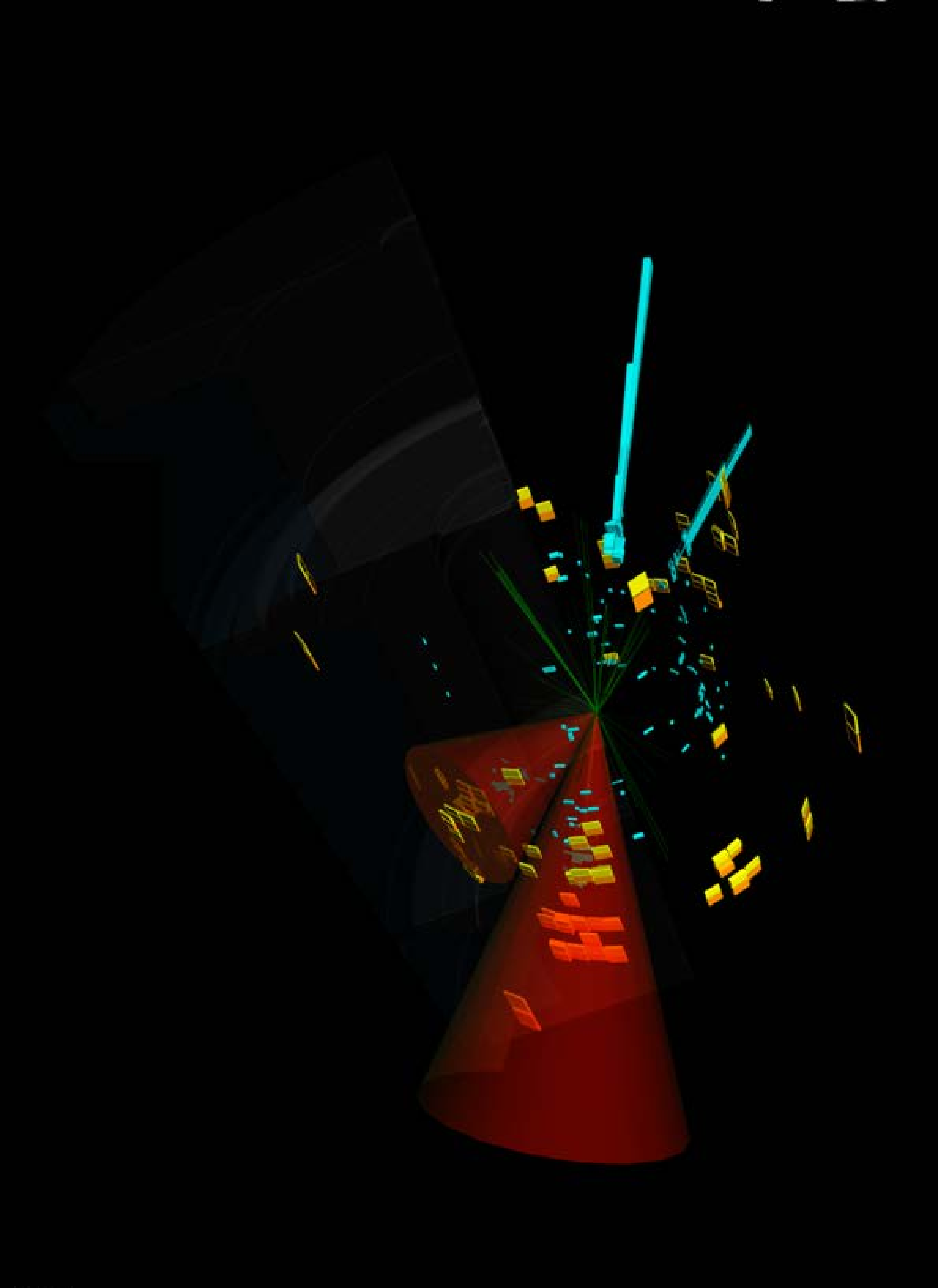
ACTIVITY 1

PARTICLE PHYSICS

Particle physics studies the most fundamental constituents of matter, called elementary particles, and the forces between them. This knowledge is not only necessary to comprehend all the matter around us at the fundamental level but alsoto understand how the Universe in its present form appeared. It is clear nowadays that this understanding needs to go beyond the Standard Model of particle physics. On the experimental level, tests of the predictions of the Standard Model and searches for phenomena beyond the Standard Model are performed. The Norwegian contributions within this field are mainly focused around the largest volume detector ever constructed at a particle collider, the ATLAS detector. The LHC and the ATLAS experiment have so far been hugely successful. The discovery of the Higgs particle and the painstaking search for new physics in all possible detectable manifestations that can appear in the "corners" of the present enormous statistics of the data are the highlights of our results. So far, the LHC has provided the ATLAS experiment with less than 10% of the collision data it is scheduled to produce during its lifetime. The extremely successful start of the Run 3 in 2022 is a good sign for the future operations. The ambitious remaining physics programme may shed light on the nature of dark matter and the behavior of the gravitational force at the microscopic scale.

Leader
Farid Ould-Saada (UiO)

Deputy
Anna Lipniacka (UiB)



HIGHLIGHTS: UPGRADE

Leader
Bjarne Stugu (UiB)

Researcher
Ole Myren Røhne (UiO)

The research groups for experimental particle physics in Oslo and Bergen have been part of the ATLAS experiment since it was proposed in the early 1990's, and have contributed to the construction of ATLAS through the delivery of silicon tracker modules. Later, R&D projects in the development of radiation-hard pixel sensors have been ongoing by the groups, in close collaboration with SINTEF Minalab. This leads naturally to participation in the ATLAS upgrade program through contributions to the ITk, the new inner tracker of ATLAS that is planned to be ready for data-taking at the startup of High-Luminosity LHC (HL-LHC).

Norway is taking part in the construction of the new ATLAS inner tracker, the ITk, where the delivery of silicon pixel sensors and sensor modules is foreseen. SINTEF MiNaLab has completed the production of a preseries of radiation-hard '3D' sensors ('run 6') with excellent production yield. Thorough tests for overall performance and radiation hardness are ongoing.

The remaining sensors are anticipated to be used in the preproduction and production of triplet modules for the ITk in Oslo. Oslo has produced the project's first 'linear triplet module' using close to final components (3D-sensors, electronics and the thin 'flexes' where the components are mounted). It is also to be noted that Oslo is responsible for design and delivery of these flexes to the different production groups in the ITk effort.

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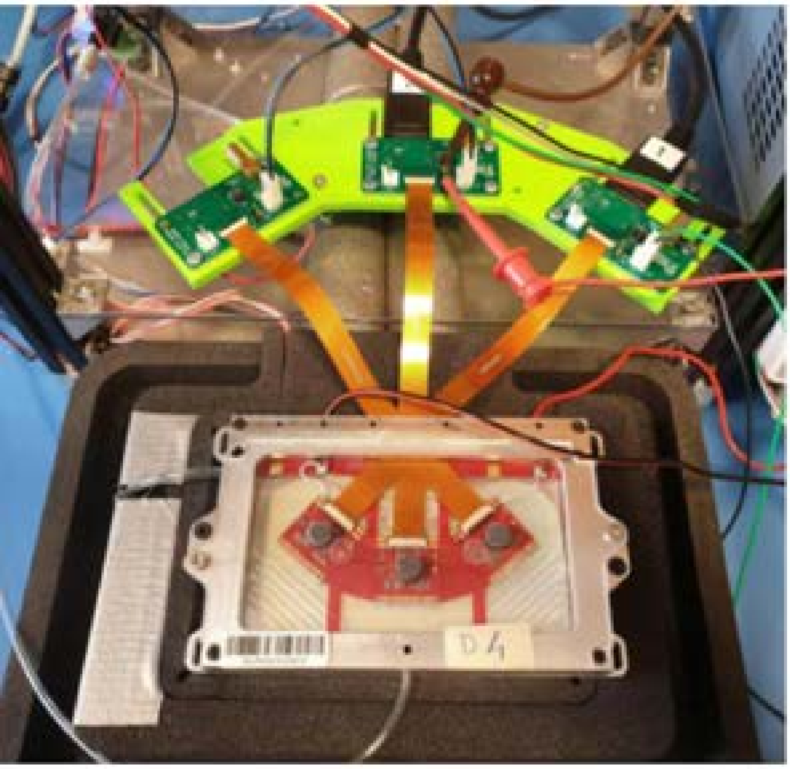


A 'ring triplet' module being tested in Bergen. © UiB

Within the ITk pixel community there has been an extensive module production and testing program using prototype components. The lab in Oslo is close to being qualified for module production through this program. Furthermore, both Oslo and Bergen have now qualified setups for initial tests of these modules. The testing programme also includes thorough testing and thermal cycling of some modules. A system for this has been set up in Bergen, but some work remains before it is fully qualified and functional.

Bergen has been a very active partner in the development and testing of the ASICs developed for pixel modules through membership in the RD53 collaboration. With the submission of the final readout chip, this activity is going to be completed. Oslo is also contributing to the production of ITk strip sensor modules by using a modern automatic wire bonder. This constitutes a very large number of bonds, and Oslo has demonstrated their ability to perform this work.

2023 will be a very busy year for the Norwegian ITk effort. The final work on our laboratory setups will be performed, and thorough tests of production components (sensors, ASICs, and flexes), as well as production of the first modules will begin. Fortunately, we have gotten a new project approved from NFR – 'NorLHC-II'. This secures resources necessary for the activities.

HIGHLIGHTS:
COMPUTING, SOFTWARE & COMBINED PERFORMANCE

Leader
James Catmore (UiO)

Computing

The ATLAS computing and software infrastructure, as well as the personnel, successfully made the transition to data-taking again, successfully processing the new data recorded by the detector as well as continuing to produce simulated events and analysis datasets. In 2022, computing equipment hosted in Norway was used heavily by the ATLAS central production team, and by individual ATLAS physicists from around the world. The breakdown between these activities was approximately 69% to central operations and 31% to individual users. Norwegian-hosted resources have consequently contributed to the production of simulated events for the analysis of the run 2 and 3 datasets, to the production of analysis-ready datasets for teams of physicists, and have also provided those teams with the computing power and storage for their analysis. The work done by these analysis teams will ultimately form part of the scientific output of ATLAS in the form of publications in peer-reviewed journals.

The Advanced Resources Connector (ARC) middleware, partly developed in Norway and coordinated by Oslo personnel, continued to play a vital role across the grid, allowing ATLAS to profit from a variety of infrastructure types including very large High Performance Computers (HPCs).

Members of the centre have been heavily involved in development work towards HL-LHC, for which a detailed work plan including milestones and demonstrators was devised last year, and which is now being executed. The coordination team for this project includes a centre member.

Members of the centre have key roles in ARC including overall coordination (Ould-Saada), release management (Pedersen, USIT) and development (Cameron). Cameron is also co-coordinator of ATLAS distributed computing (ADC), responsible for worldwide ATLAS computing operations and future strategy.

Software & combined performance

Norwegian researchers continue to make leading contributions to software development and to the measurement of the performance of ATLAS particle reconstruction and identification (a task referred to as 'combined performance').

A major milestone was passed in late 2022 with the start of run 3 data-taking using the new multi-threaded software. Several Norwegian personnel were involved in the preparation, validation and running of this software, particularly with regards to muon- and tau-lepton reconstruction. Software algorithms underwent a major overhaul in order to provide optimal performance for future physics analyses. In the tau-lepton domain, substantial improvement in the reconstruction efficiency was achieved after several years of intense development. New algorithms based on machine learning were deployed to better calibrate tau-leptons and distinguish them from other particles [1]. Besides, these algorithms were made modular to allow for further developments and improvements in the next few years.

Several members of the centre worked to bring the run 3 analysis model, including the two new analysis data formats, into production with the run 3 data and simulated events. In 2023, with the run 3 software and analysis model being largely complete, project members with an interest in software and computing will begin to work towards run 4, when further changes will be needed to ensure the software can scale up to the demands of HL-LHC data and simulation. Topics that will be addressed include: investigating how to make use of GPUs in data processing and analysis; developing columnar analysis formats and tools to allow efficient interactive analysis in the style commonly adopted by the data science community; developing ideas around 'analysis facilities'; launching a major effort on unsupervised deep learning and anomaly detection. Work on muon and tau-lepton reconstruction will continue, and several new Norwegian contributors will strengthen this effort. Project members are also committed to tau-lepton trigger developments for run 3, with deliverables expected in 2023.

A centre member (Catmore) was recently appointed as software coordinator for ATLAS.

[1] B. Martin dit Latour et al., http://cds.cern.ch/record/2827111

HIGHLIGHTS: ANALYSIS

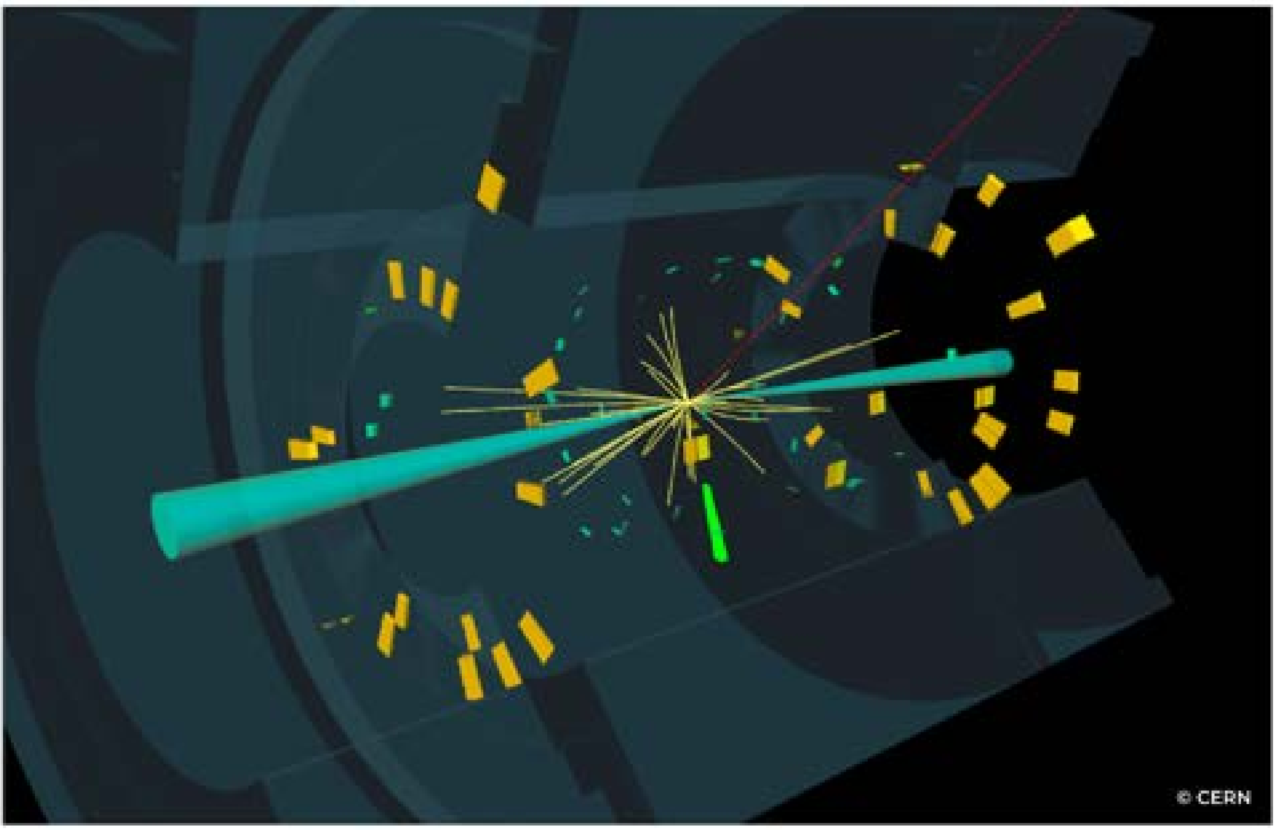
Leader
Bertrand Martin dit Latour

The ambitious physics programme of the ATLAS collaboration continues to shed light on the fundamental laws of nature. Besides precision measurements of the Standard Model, ATLAS physicists keep searching for physics beyond the Standard Model. Among our goals are understanding the nature of dark matter, the behavior of the gravitational force at the microscopic scale, and discovering new symmetries of nature.

NorCC members are contributing to a broad set of physics analyses. These are primarily based on Run 2 data recorded by the ATLAS experiment from 2015 to 2018. After Run 2, the LHC accelerator and detectors went through 3 years of maintenance and upgrades. Run 3 started in 2022 with proton-proton collisions at a record center-of-mass energy of 13.6 TeV. The amount of data collected by the end of 2025 is expected to surpass the Run 2 dataset.

New heavy bosons

NorCC members are involved in an ongoing search for dilepton resonances produced in association with missing transverse energy or jets. These searches are motivated by a large set of theories predicting the existence of new heavy gauge bosons. We have taken leading roles in the analysis of final states with two leptons and missing transverse energy, covering all aspects of the analysis.

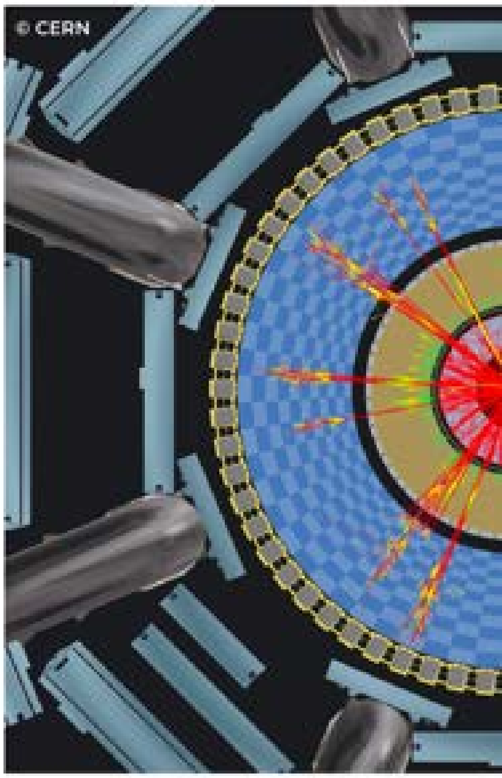


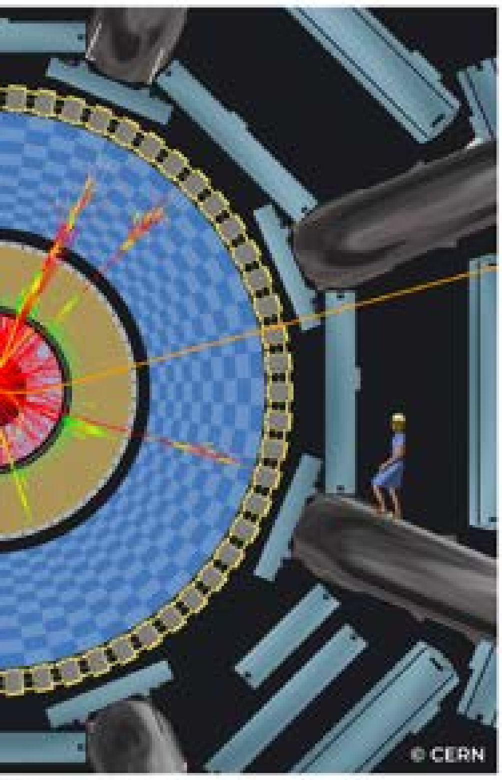
Higgs boson

Previously, NorCC members from UiB and UiO have worked on the discovery of the Higgs boson, precise measurements of its couplings to various particles, and searches for Higgs boson production in association with dark matter. In 2022, we contributed to the precise measurement of the Higgs boson mass in the diphoton channel and specifically the modelling of the large background under the relatively tiny and narrow signal peak. A more precise value of the Higgs boson mass sharpens the predictions of all the other properties of the Higgs boson and contributes to the determination of whether our universe is stable or metastable. Final results of the painstaking analysis of the full Run 2 dataset are expected to be published in 2023.

During 2022, we joined the effort to search for the rare but important process of two-Higgs boson production, which is one of the key goals of the HL-LHC physics programme. Our first objective is to study and improve the discovery potential during the HL-LHC era in the final state where one Higgs boson decays to two photons and the other to a pair of tau leptons or bosons, where one or more leptons are observed in the detector. This is not the most sensitive decay channel, however, all channels must be searched for in order to maximize the overall discovery potential. This focus allows us to make good use of our expertise.

We also started working on the measurement of the Charge-Parity quantum numbers of the Higgs boson, in events where two electroweak bosons fuse and produce a Higgs boson. Machine learning will be employed to enhance the sensitivity of the analysis.





Analysis methods

NorCC members have invented a new way to calculate the trials factor [1], which is important to take into account in the calculation of statistical significance in searches for new particles that cover a wide mass range. The method models the significance field resulting from a scan of the mass (or e.g. mass and resonance width) as a Gaussian Process and results in improved accuracy and precision at low to moderate significances (without increasing CPU consumption), which in turn improves the statistical precision of highly significant observations, i.e. discoveries, that are made with existing methodology that extrapolates from low to high significance.

[1] V. Ananiev, A.L. Read, Gaussian Process-based calculation of look-elsewhere trials factor, arXiv:2206.12328 (Submitted to Eur. Phys. J. C)

Supersymmetry

UiO and UiB groups are playing key roles in a broad and complementary set of analyses searching for supersymmetric (SUSY) particles in ATLAS data. We are searching for charginos, neutralinos and sleptons produced via electroweak interactions, as well as squarks and gluinos produced via strong interactions. The final states of interest contain electrons, muons, tau leptons, jets and missing transverse energy.

Two papers [3,4], ready for publication, are targetting a search for Supersymmetry through the direct production of charginos, neutralinos or sleptons decaying into final states with two leptons, zero, one or more than two jets, and missing transverse energy. We worked on a particularly challenging and novel decay channel where the two initially produced charginos decay via two W bosons to leptons and neutrinos. For this channel, an analysis using Boosted Decision Trees (BDTs) has been performed in order to enhance the sensitivity. None of the searches show significant evidence for new physics beyond the Standard Model.

We have been involved in combining the results of the LHC Run-2 searches for Supersymmetry through the production of electroweak gauginos and sleptons by performing a statistical combination of the results of each of the individual analyses. The paper will be published in 2023 and presents the best and most complete overview of the limits on electroweak production of Supersymmetry from ATLAS, covering a large set of production modes and decay channels.

We are also conducting a search for squarks and gluinos in final states with tau leptons, jets and missing transverse momentum. The analysis initially focused on Run 2 data but is being extended to Run 3 data, and it benefits from the recent improvements in tau-lepton reconstruction. The analysis team puts strong emphasis on machine learning algorithms to enhance the sensitivity of the search. Theorists attached to the NorCC centre work on the calculation of production cross-sections for relevant models.

[3] H. Oppen, H. Sandaker, F. Ould-Saada, E. Gramstad et al., Search for direct pair production of sleptons and charginos decaying to two leptons and neutralinos with mass splittings near the WW-boson mass in √s = 13 TeV pp collisions with the ATLAS detector, arXiv: 2209.13935 (submitted to JHEP)

[4] K.O. Vadla, F. Ould-Saada, E. Gramstad et al., Searches for new phenomena in events with two leptons, jets, and missing transverse momentum in 139 fb−1139 fb−1 of √s = 13 TeV pp collisions with the ATLAS detector, arXiv: 2204.13072 (accepted by EPJC)

Dark matter

NorCC members have carried out a search for dark matter produced in association with a Higgs boson that decays to tau leptons. The analysis relies on triggers requiring tau-leptons and missing transverse momentum, and uses data-driven estimations for the main Standard Model backgrounds. The results have been presented at an international conference [2], the journal publication is in the final stages of a preparation.

[2] N. Fomin, E. Aakvaag, J. Djuvsland, A. Lipniacka et al., Search for dark matter produced in association with a Higgs boson decaying to tau leptons at √s=13 TeV with the ATLAS detector, https://cds.cern.ch/record/2842521

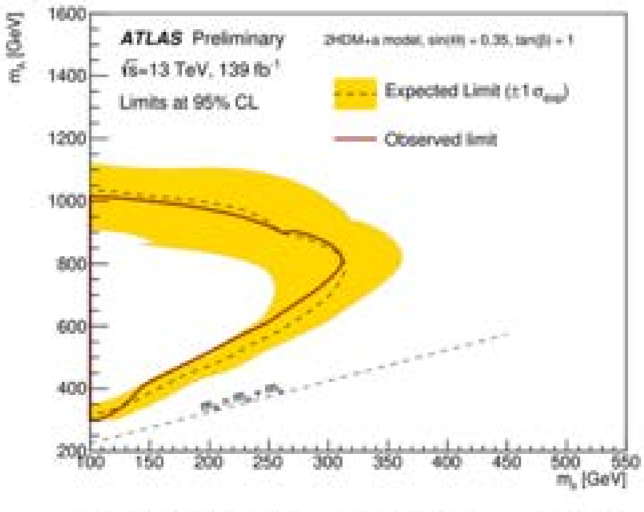
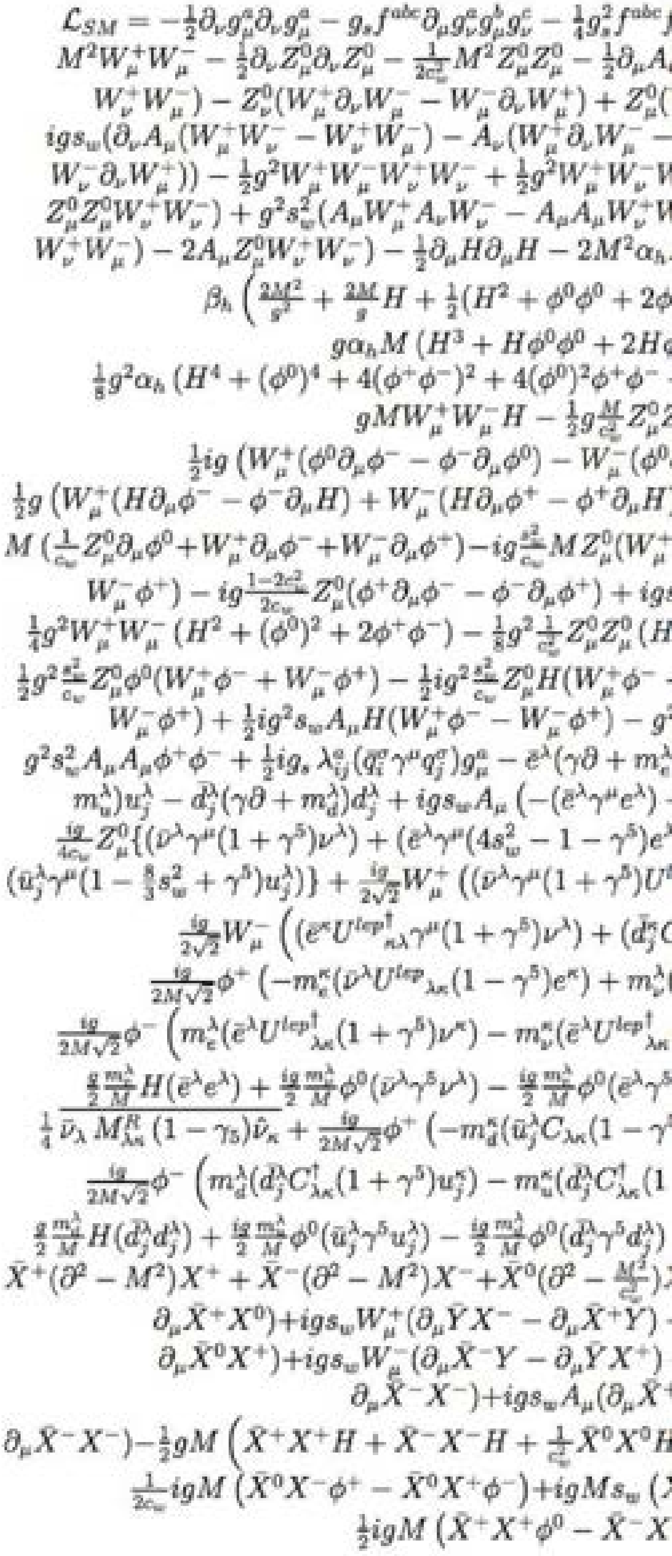


Figure: Observed and expected exclusion limits at 95% confidence level as a function of masses ma and mA, where a is a pseudoscalar singlet (acting as a mediator between the Standard Model particles and the dark matter sector), and A is a CP-off Higgs boson [2]. The excluded area is to the left of the solid line.

Are Raklev



The theoretical physics section at UiO also contributes to NorCC activities, focusing on the search for new physics using the statistical collation of results from the LHC and other high-energy physics experiments. Here, researchers are heavily involved in the construction of computational tools to perform the needed theoretical model predictions for LHC searches and measurements, and the consistent statistical analysis of realistic models for new physics with high-dimensional parameter spaces. This work also involves the use of machine learning regression applied to speed up precision quantum field theory calculation in order to improve the reach in new physics searches.

Much of this work is performed within the international GAMBIT Collaboration, supporting the GAMBIT global fitting tool [1]. Here NorCC researchers have leading roles, filling both the position as Head of the Collaboration (Kvellestad) and head of the Collider Working Group (Raklev).

[1] https://gambitbsm.org/

Quick Questions

YOUNG RESEARCHERS

Vilde Flognfeldt Rieker
PhD student (CERN)

'An optimistic idealist driven by curiosity'

What is your background?
I started studying physics with the idea of going theoretical, but then an internship at SpaceNorway made me interested in Space and radiation effects to electronics, and my Master's thesis was all about that. After that I did a fellowship working on radiation effects in the context of accelerators at CERN for three years and now I am doing a PhD at CLEAR on dosimetry for FLASH radiotherapy applications.

Where do we usually find you?
The CLEAR control-room or somewhere in the mountains would be good places to start!

How has the year of 2022 been?
It has felt like bit of a roller-coaster both professionally and personally, but for sure an important learning experience which I aim to benefit from.

What are you looking forward to in 2023?
Seeing my project taking shape, going to conferences and new adventures in the mountains.

Why did you choose this field?
I found it to be a perfect combination of expanding on my current knowledge and widening my horizon in terms of applications and technical skills. All within a domain which I believe has a net positive impact on society.

Why do you think this research is important?
If we want to establish whether or not FLASH radiotherapy can treat cancer more efficiently, and potentially treat patients with it, I believe it is a fundamental requirement to have reliable and efficient dosimetry.

What do you plan to do after this period of your life?
Get a dog!

Choose one song to play every time you walked into a room, what song would you choose and why?
Bohemian Rhapsody; that should cover just about any emotional state.

Which fictional character do you identify with the most and why?
A soft version of Arya Stark maybe? Independent and tomboyish are not uncommon descriptions.

Quick Questions

YOUNG RESEARCHERS

Sohaib Hassan
PhD student (UiB)

'An ambitious physicist who is always up for embarking on new adventures'

What is your background
I completed my masters in Nuclear Engineering and Physics from Pakistan. After that I worked at CERN for a year where I helped with assembly and testing of GEM (Gas Electron Multiplier) based detectors for CMS muon system and ALICE TPC experiments. I also contributed to physics analysis regarding production of (anti-)triton in pp and pPb collisions in ALICE.

Where would we usually find you?
Mainly in IFT cleanroom, likely in my office. If not there, probably somewhere unknown trying some new stuff.

How has the year of 2022 been?
2022 has been a wonderful year for me. I travelled to Bergen, experienced the rains and started an important phase of my life, the PhD studies.

What are you looking forward to in 2023?
I am really looking forward to my PhD projects at the moment. Other than that, I would like to travel, try a couple of new sports and possibly learn Norwegian in 2023.

What do you plan to do after this period of your life?
I would like to continue and expand my current research. I am a physicist at the core, can't change that and have to stay in a research based environment.

Which fictional character do you identify with the most and why?
Sasuke Uchiha from Naruto series. I love his character development, specifically his perseverance for the goals and his space-time techniques are awesome:p

What is your current research project?
My current research project includes development and application of a system for testing silicon pixel sensor modules and search for dark matter in ATLAS.

Why did you choose this field?
It has always been interesting to look for mysteries that are so obvious yet difficult to solve, like the puzzle of dark matter. Also, I have been working extensively with QA/QC of detectors at CERN, therefore, I thought this was a perfect project to get into.

Why do you think this research is important?
In my opinion what separated us, the homo sapiens, from other species was the curiosity. Curiosity is the fuel that drives human race forward. We want to know how universe works, how it started and how it would end. Particle physics research tries to find answers to these fundamental questions and hence is one of the most important research areas in modern human era. Additionally, pushing the limits to extreme conditions of particle physics the development of technology and computation come along as by-products.

What do you see as the most important issue in your field today?
There are many important problems and unsolved mysteries in today's physics. And I think riddle of dark matter is one of the biggest. We know it's there, but somehow it keeps evading our ever-precise searches. I think observation of one crack in the Standard Model can reveal many interconnected mysteries.

Choose one song to play every time you walked into a room, what song would you choose and why?
Hard to choose one but, "Bet on it" from high school musical 2, childhood memories maybe:p

ACTIVITY 2

NUCLEAR PHYSICS

Nuclear physics explores the behaviour of nuclear matter under extreme conditions and in particular the Quark-Gluon Plasma (QGP), which existed for approximately one microsecond after the Big Bang. Such conditions can be recreated in ultra-relativistic heavy-ion collisions in the laboratory. Therefore, the Norwegian contributions within this field are mainly focused around the dedicated heavy-ion experiment ALICE. The physics analysis efforts of the Norwegian ALICE groups are primarily focused on exploring the interaction of heavy quarkonia and heavy quarks with the QGP, and their production mechanisms in small collision systems, as well as the vector meson and dilepton production in photon-nucleus and photon-proton interactions.

Leader
Dieter Röhrich (UiB)

Deputy
Trine Tveter (UiO)

HIGHLIGHTS: PHYSICS RESULTS

Leader
Ionut Arsene

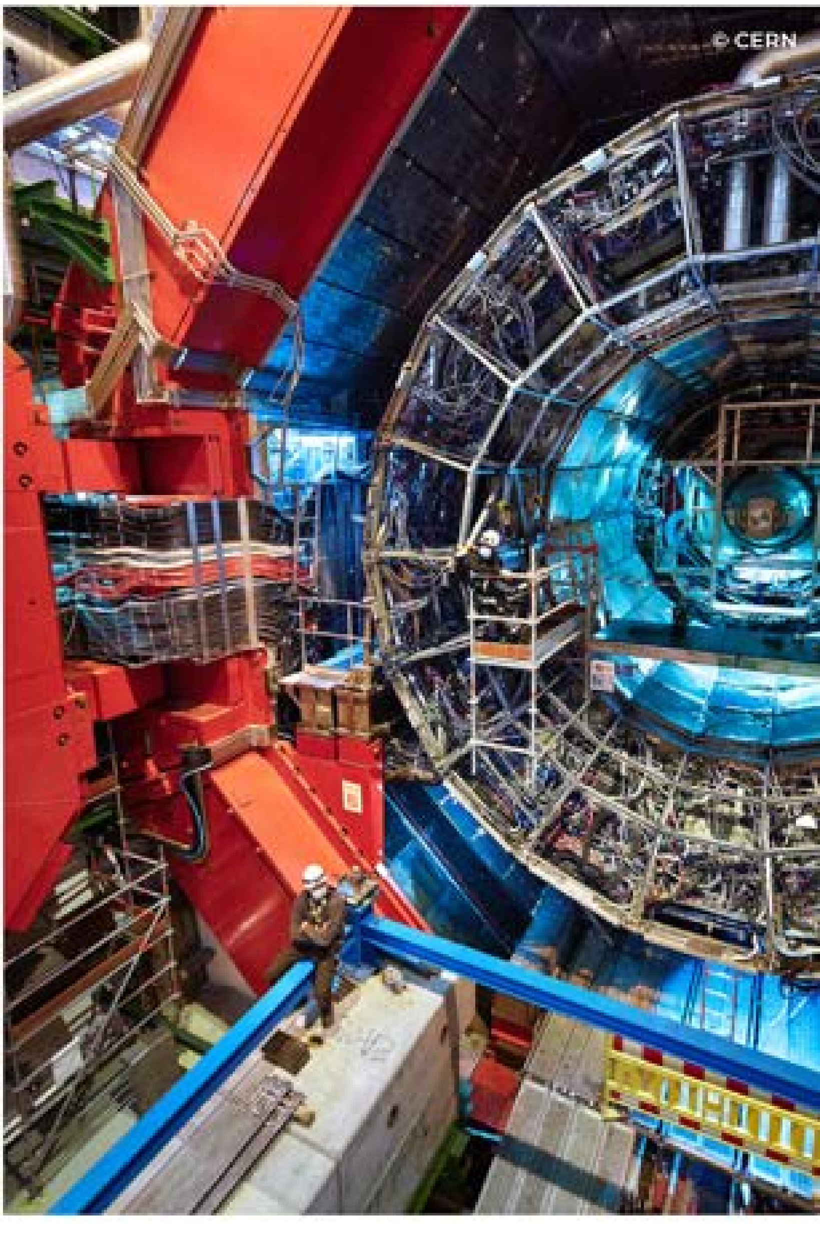
Our main focus is on measurements of heavy particles, containing heavy quarks, such as charm or beauty, which are used as probes of the QGP. We are currently leading several studies in ALICE involving the measurement of the J/psi meson in both lead-on-lead (Pb-Pb) and proton-proton collisions. The J/psi production measurement is very versatile as it provides access to many different aspects of the heavy-ion and pp collisions phenomenology. Our studies aim at shedding light on the mechanisms of hadronisation (particle creation) of heavy particles both in vacuum and the nuclear collisions fireball, and on the mechanisms of parton energy loss in quark-gluon plasma. The ongoing studies on the LHC Run-2 data were finalised in 2022 and are expected to be published during 2023 in four papers which are in different stages of preparation within the ALICE Collaboration. In parallel, during 2023, our group will participate in the commissioning of the upgraded analysis software with the first data from Run-3.

Proton-proton collisions

Our ongoing studies in proton-proton collisions for the production of the J/psi meson are testing the theoretical understanding of the quarkonium and beauty-hadron production mechanisms.

Ingrid McKibben Lofnes (UiB, PhD student) is finalising an analysis, based on the entire Run-2 pp dataset, on the jet fragmentation into J/psi mesons which will provide insight into jets substructure. Thanks to the separation of prompt and non-prompt J/psi, this measurement will access also beauty-quark jets besides the inclusive ones. Her analysis will be part of a talk to be presented at the upcoming Hard Probes international conference.

Ida Torkjellsdatter Storehaug (UiO, PhD student) finalised an analysis on the reconstruction of the B+ meson decaying into the J/psi + K+ channel, using the Run-2 dataset. Her analysis proved for the first time the feasibility of such a measurement with the ALICE detector, and it will be continued with the much larger datasets available from Run-3 in both pp and Pb-Pb collisions.



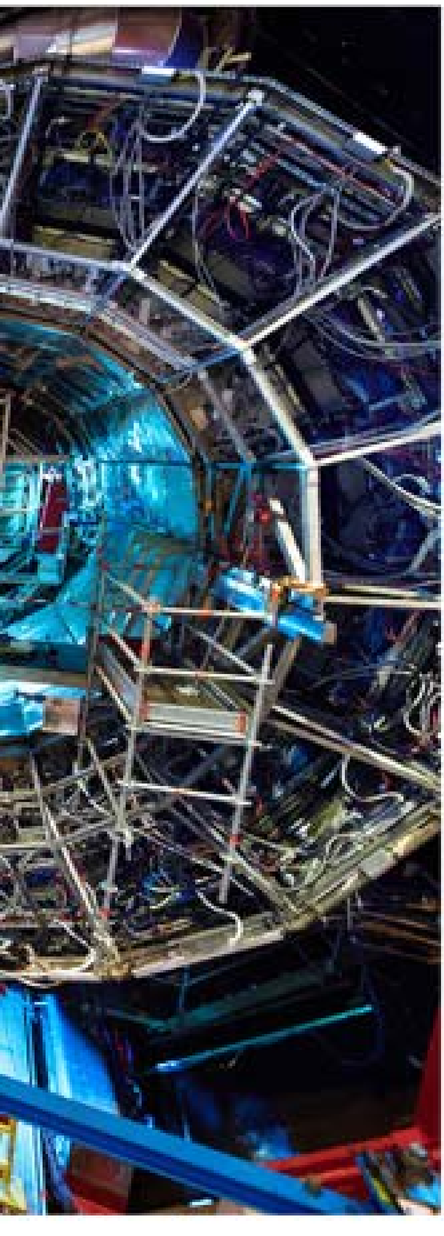
Heavy-ion collisions

The studies in heavy-ion collisions (Pb-Pb) aim at both characterising the QGP using the J/psi as a probe, but also understanding the initial conditions of the colliding nuclei, before the QGP formation.

Alexandra Neagu (UiO, PhD student) finalised in 2021/2022 an analysis on the measurement of the J/psi coherent photo-production cross-section in Pb-Pb collisions using the whole Run-2 data sample (upper figure). This measurement is sensitive to the initial gluon density in the colliding nuclei, thus setting constraints on the Pb-Pb collision initial state. This analysis was highlighted during a talk presented by Alexandra at the most important conference for the heavy-ion physics community, Quark Matter. These results are the subject of a paper which is being currently reviewed within the collaboration.

Jon-Are Sætre (UiB, PhD student) finalised his analysis on the measurement of prompt and non-prompt J/psi nuclear suppression in Pb-Pb collisions. These results highlight the role of charm quark recombination in the production of J/psi at LHC energies, and at the same time, due to the non-prompt measurement, add important information on the suppression of beauty hadrons (lower figure). Jon-Are discussed this analysis in a talk at the Quark Matter conference, and the results are included in a paper draft under preparation.

Ionut Arsene (UiO, researcher) had a leading role in preparing a comprehensive ALICE review paper "The ALICE experiment - A journey through QCD", which was recently released. Ionut contributed in particular to the quarkonium sections, summarising the knowledge gained from Pb–Pb, Xe–Xe, p–Pb and pp physics data from the Run 1 - 2 era (2009-2018).



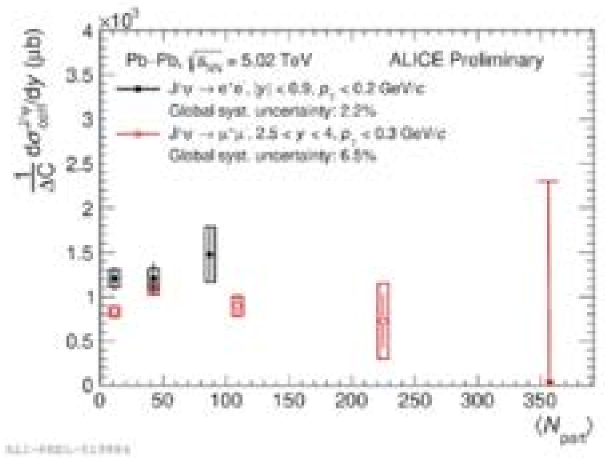


Figure: Cross-section of coherently photoproduced J/ψ as a function of centrality, extracted at midrapidity (black markers) and forward rapidity (red markers).

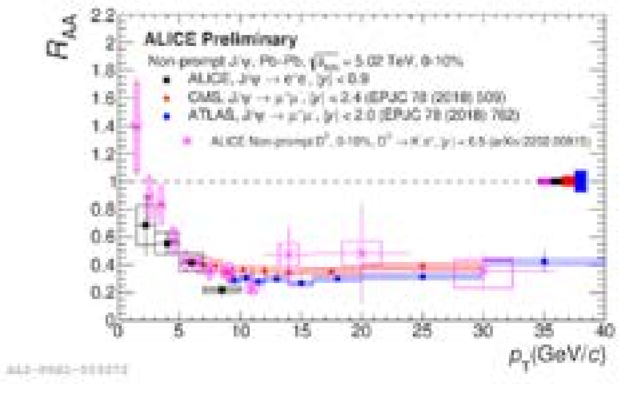


Figure: Nuclear modification factor RAA as a function of pT for non-prompt J/ψ in central collisions (0-10%), compared to ATLAS and CMS data in addition to ALICE non-prompt D0 mesons.

HIGHLIGHTS: INSTRUMENTATION

Leader
Ketil Røed

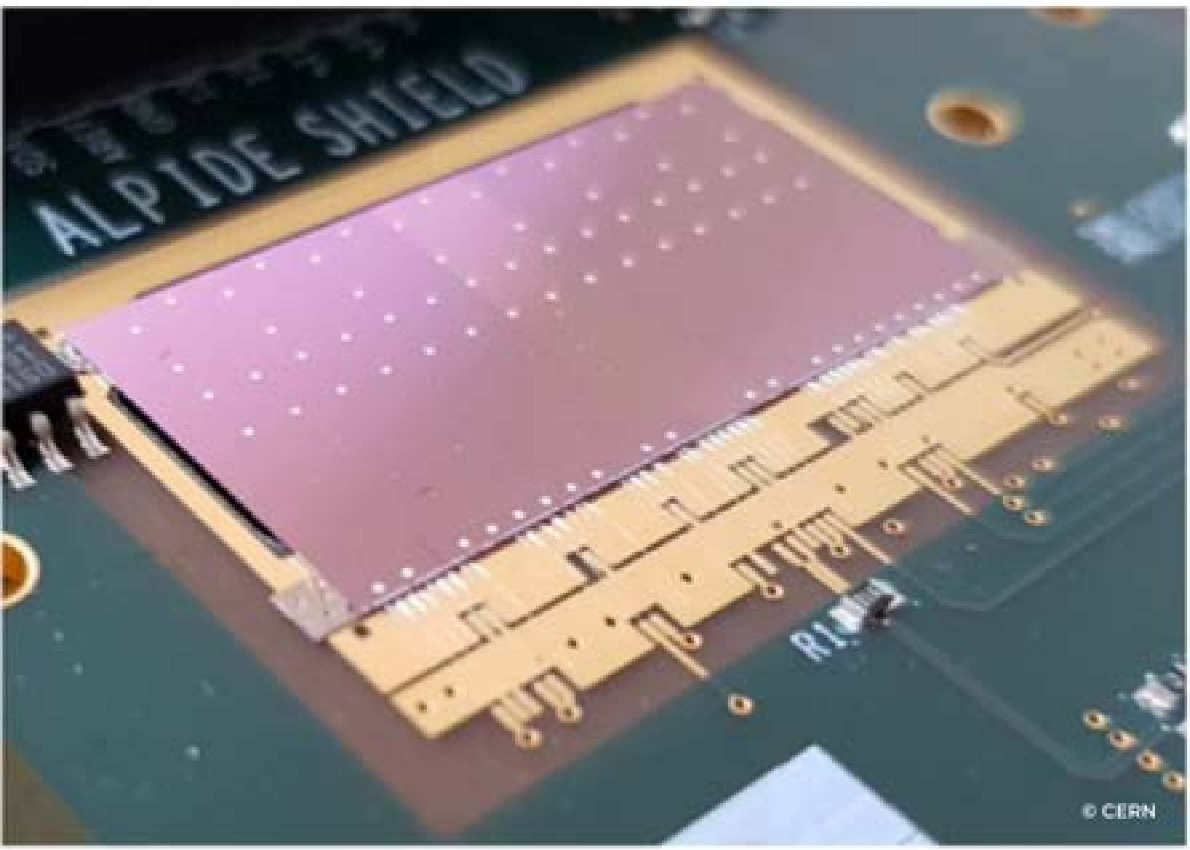
ALICE tracks new territory – The inner tracking system of ALICE has recently been upgraded and prepared for a new run period. After the start of Run 3 in 2022, data has successfully been collected from both proton-proton and lead-lead collisions at record high energies. This is the first detector at the Large Hadron Collider to use state-of-the-art monolithic active pixel sensors, a technology-based modern CMOS camera imaging sensor technology. The full potential of this technology is however yet to be fully exploited. Further improvements for high energy physics detectors could come from the rapid progress made in CMOS process technology, achieving curved large-area sensors. NorCC members take active part in this development, building new groundbreaking detectors for particle tracking and energy measurements.

Monolithic active pixel sensors

Solid state detectors based on semiconductors, and in particular silicon detectors, are used in almost all high energy physics experiments. Since they can easily be segmented in pixels or strips using standard photolithography techniques, they can achieve superb position resolution. This makes them excellent detectors for tracking charged particles, and for reconstructing the location of individual particle collisions, and further the location where particles generated in these collisions later decay into other particles – also referred to as vertexing.

Recently, a technology based on the CMOS active pixel sensor (APS) technology has emerged as an attractive option for future tracking detectors. CMOS APS was invented in the 1990s when NASA needed to miniaturize cameras for interplanetary missions. Today, this technology is the basis of all modern CMOS image sensors used in for example consumer products like DSLR cameras and cell phones. The key invention of the CMOS APS is the integration of in-pixel amplification of the signal. This eliminates the need for almost perfect charge-transfer across pixels, a main disadvantage of the previously used charge-coupled device (CCD) technology.

Since it integrates both the sensor pixel matrix and readout electronics on the same chip, it is also referred to as a monolithic active pixel sensor (MAPS). Taking advantage of recent developments in standard commercial CMOS technology, such as small feature sizes and lower power design, it is especially suited for applications requiring low-mass and excellent position resolution. The CMOS MAPS developed specifically for the ALICE experiment is called ALPIDE – the ALICE Pixel Detector.

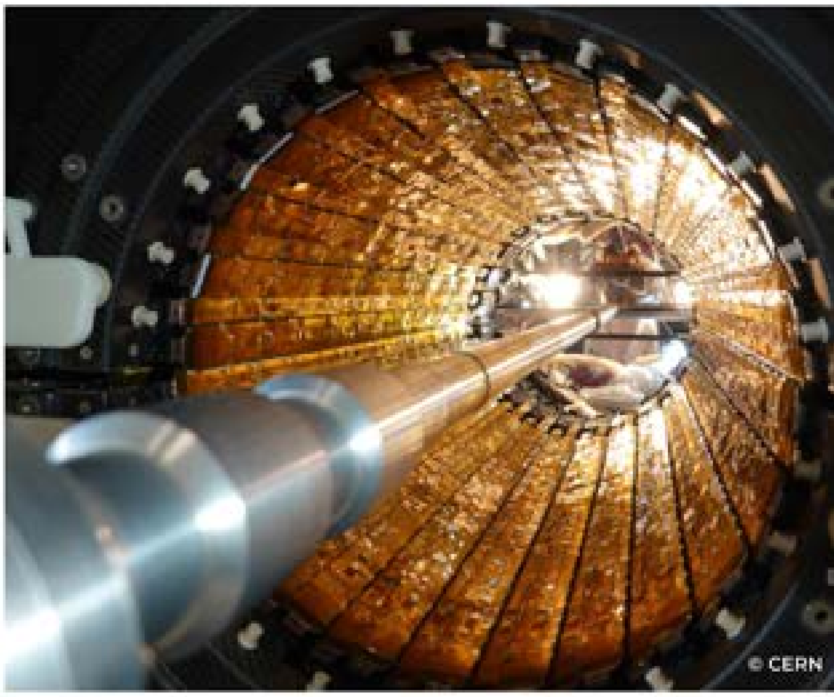


An ALPIDE chip mounted and bonded on a test board. Photo credit: CERN

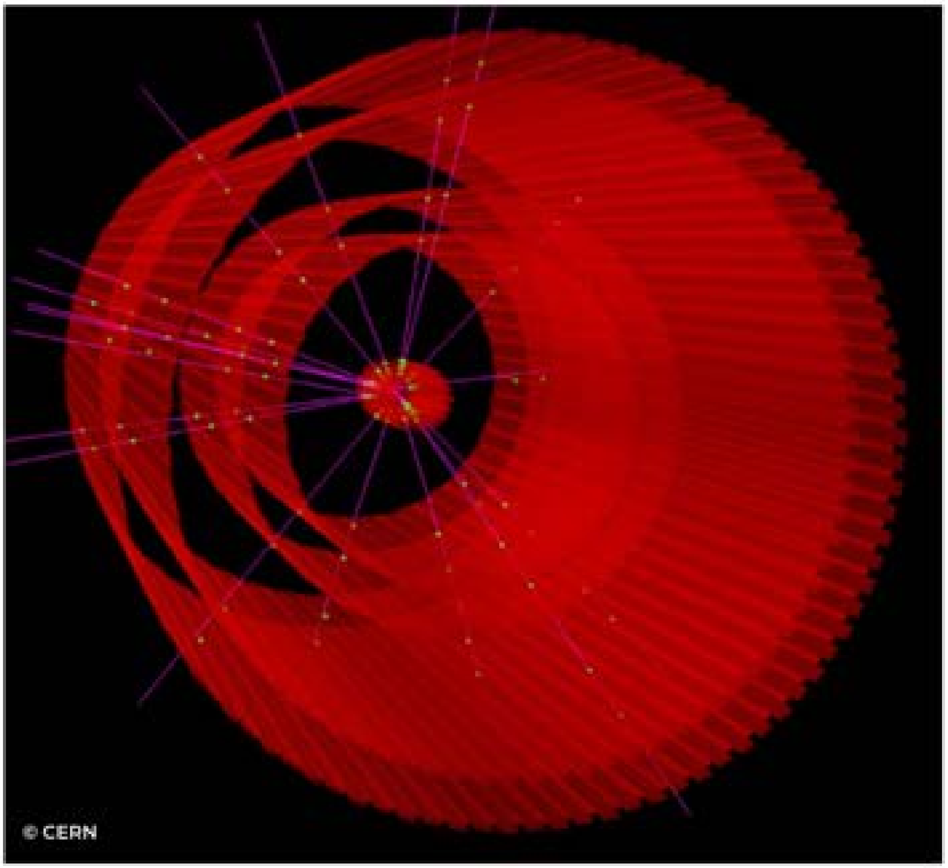
A 12.5 gigapixel camera

The Inner Tracking System (ITS) is the innermost detector of the ALICE experiment. At its closest, it is located only 22 millimeters from the collision point. The ALPIDE MAPS chips are the key part of the recently upgraded ITS version 2 (ITS2). With more than 24000 chips, each with half a million pixels of 30 x 30 micrometers, distributed in 7 circular layers surrounding the LHC beam line, this detector is a 12.5 gigapixel camera capable of taking 50000 pictures every second. Covering an area of 10 square meters, it is at present the largest scale application of monolithic active pixel sensors in a high energy physics experiment, and the first LHC detector to use the MAPS technology.

The upgraded ITS detector is now re-installed in the cavern of the ALICE experiment. A main objective of the upgrade has been to increase the capability to record collisions at rates in excess of 50 kHz. The Norwegian groups have since 2016 actively contributed to the design, verification, and testing of the electronics that control and read out the ALPIDE chips. Additionally, the Norwegian groups have participated in data rate simulations, characterisation, and calibration of the ALPIDEs. With the help of the Norwegian groups, ITS was made ready for the start of Run 3 in 2022.



The outer barrel of the ITS detector installed around the beam pipe. Photo credit: CERN.

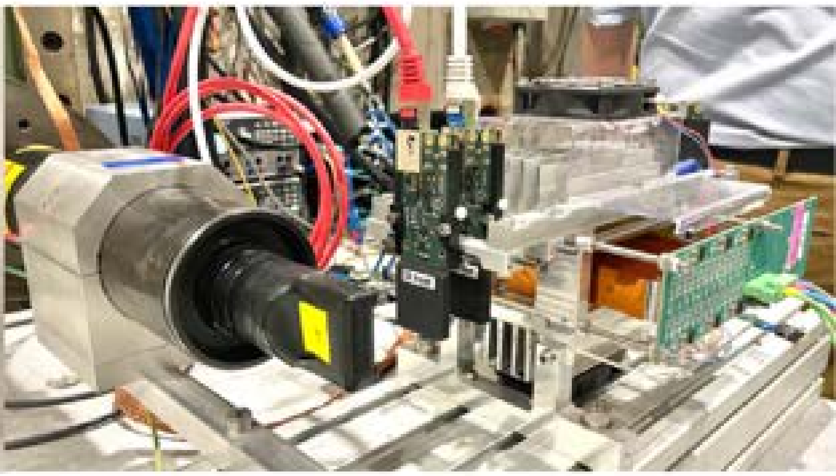


A reconstructed proton-proton collision in the ITS detector during pilot beam, October 2021, demonstrating that data have been successfully taken with a full readout chain.

Ultra-thin curved sensors

After a successful installation of ITS2, we now prepare for the future, and continue to work on the next exciting upgrade of ITS – the ITS3 upgrade project. To achieve even better tracking precision and vertexing performance, the project will exploit the rapid progress made for MAPS technology in the field of imaging for consumer applications. One of the features offered recently by CMOS imaging sensors technology is called stitching. This lithography technique overcomes the chip mask or reticle size limitations by using multiple exposures of a fixed repeating pattern. A tiny overlap at the edges makes it possible to connect the exposure to achieve a significantly larger sensor, only limited by the wafer size. Furthermore, if silicon is thinned below 50 micrometers, it can be bent like paper without breaking. This will open the door to wafer scaled curved sensors, making it possible to realise low-mass and truly cylindrical silicon-only sensor layers. ALICE therefore plans to upgrade the three innermost layers using this technology. In Norway, USN has started studies on a flexible wafer-sized integrated detector. Further advancements have been made on the thinning and interconnection techniques. A fully functional detector prototype using multiple of the current 180 nm ALPIDEs is being developed in collaboration with groups from Ukraine, Italy, Germany and other countries. Electronics for bending tests of prototypes of the next generation 65 nm ALPIDE chips are being prepared in the same international collaboration. Norway plans to actively contribute to the development and testing of this technology in the coming years.

A curved and interconnected ALPIDE. Photo credit: USN



Beam test setup at CERN. Photo credit: UiO

The new Forward Calorimeter

With the Forward Calorimeter (FoCal), ALICE plans to extend the coverage into the forward region close to the beam pipe. This detector will consist of an Electromagnetic Calorimeter (FoCal-E) and a Hadronic Calorimeter (FoCal-H). The FoCal-E is designed with sheets of tungsten interleaved with sheets of silicon detectors. Two types of sensor planes are used: low granularity (LG) and high granularity (HG). The two HG planes will consist of the same ALPIDE chip used in the ITS detector. Norway contributes both to the detector design and to the design of readout electronics together with a large international collaboration with groups from for instance USA and Japan. We have the full responsibility of the HG layers and for synchronizing the data-taking. Recently we also performed beam tests at CERN where layers of ALPIDE chips were tested in FoCal-like configurations.

HIGHLIGHTS: COMPUTING & SOFTWARE

Leader
Matthias Richter

In 2022, LHC operation has been resumed after a long shutdown period. Many of the subdetectors of ALICE have been heavily upgraded and rebuilt. In order to process the increased data volume and operate at a much higher data rate, a completely new computing model has been designed and is now in production. This involves all stages of data processing from simulation/acquisition, reconstruction to analysis. Scientists from Norwegian institutes have significantly contributed to the development and deployment of a unified model of data processing with scalability from a single-laptop prototype case to full-scale productions on large compute farms.

Scientists from UiB have taken a leading role in the implementation of a quasi-online processing paradigm which also has large implications on the overall ALICE Grid processing. Novel approaches like declarative composition of processing workflows have been coherently implemented. A unified analysis data model based on columnar in-memory data representation allows processing of large data sets in order to analyse rare physics processes. As an important contribution, physicists from UiO are implementing generic modules within the ALICE O2 analysis framework on top of the ALICE O2 processing model.

ALICE Grid productions are now focused on reconstruction of new Run 3 data and corresponding simulations. Norway is a strong provider of computing and storage resources in the WLCG, the global LHC computing grid. The pledged share of resources for ALICE in Norway is provided by the installations within the UiB domain of NREC. Maintenance, operation, and optimisation of these resources are a crucial task carried out by enthusiastic technicians and scientists at UiB. The current resources are funded by the NorLHC infrastructure project.

New servers have been purchased, installed and commissioned in 2022. By the end of 2022, UiB-hosted resources have grown to the largest contribution to ALICE computing resources of Tier 1/2 centers outside CERN.

Increased efficiency and reliability has been a major focus also in 2022. Based on the free software Prometheus and time-series data-based Victoria and Promscale, reactive monitoring has been deployed, including development and testing of data exporters and visualisation in Grafana dashboards. This development joins the effort of the NEIC Nordic T1 to replace the existing monitoring solution which is no longer actively developed.

ALICE has been developing the next generation of grid middleware, JAliEn, with a strong participation of scientists from HVL. The JAliEn project involves a complete redesign and re-write of the former AliEn ALICE Grid middleware. Scientists and technicians of the Norwegian ALICE community have taken a leading role in the project team.

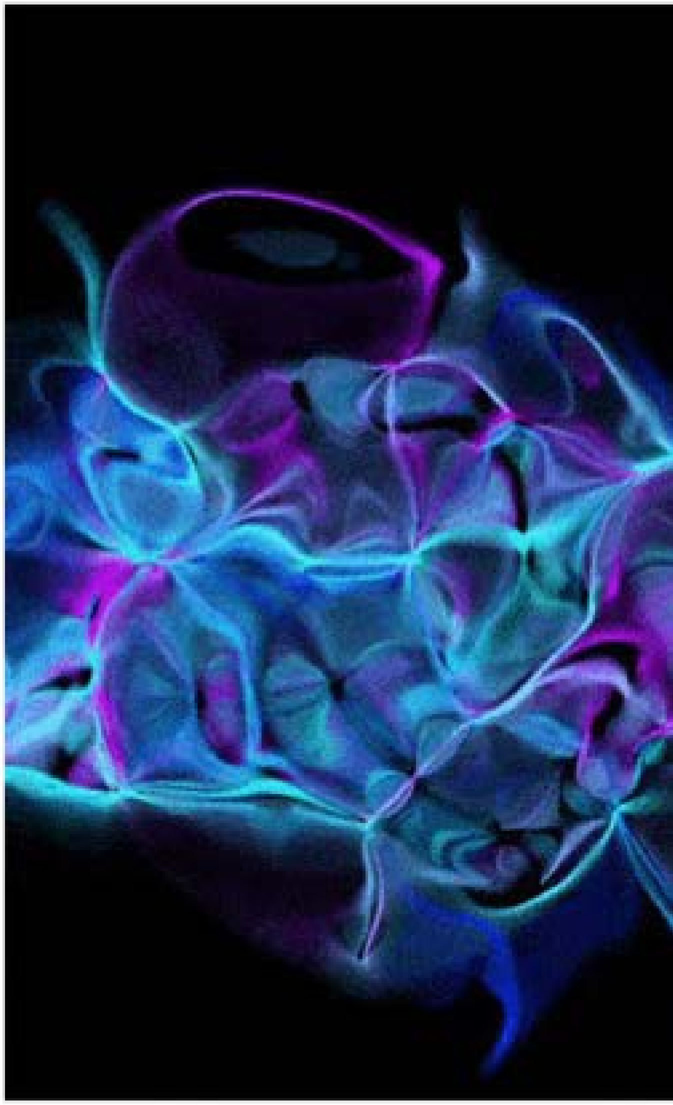
HIGHLIGHTS: THEORY ACTIVITIES

Larissa Bravina

Konrad Tywoniuk

The nuclear theory activity focuses mostly on understanding the properties of the quark-gluon plasma (QGP). This novel state of matter is created in high-energy heavy-ion collisions and exists in the extreme conditions that were prevalent in the early Universe. The QGP turns out to behave like an almost perfect liquid, which results in striking flow-like signatures in the experimental data and can be studied using hydrodynamical simulations or microscopic models. Another interesting signal is the suppression of observed clusters of high-energy particles, called jets. Varying the parameters of the jet, for instance its cone-size, probes a wide range of scales, from the interactions of single partons with the QGP to the collective interplay of multiple partons. The jet suppression is also sensitive to the path length, which affects the flow-pattern of the QGP.

The groups in Bergen and Oslo study these effects using both analytical tools and numerical models that aid in extracting the microscopic properties of the QGP. One can also focus on a more data-driven approach, where machine learning methods can be applied. The heavy-ion groups are also actively suggesting new observables or experimental setups, such as triple-nuclear collisions, and organizing workshops, for instance the INCFP 2022 conference in Crete 30.08-12.09.2022 with 250 participants.



Artist's conception of plasma flow

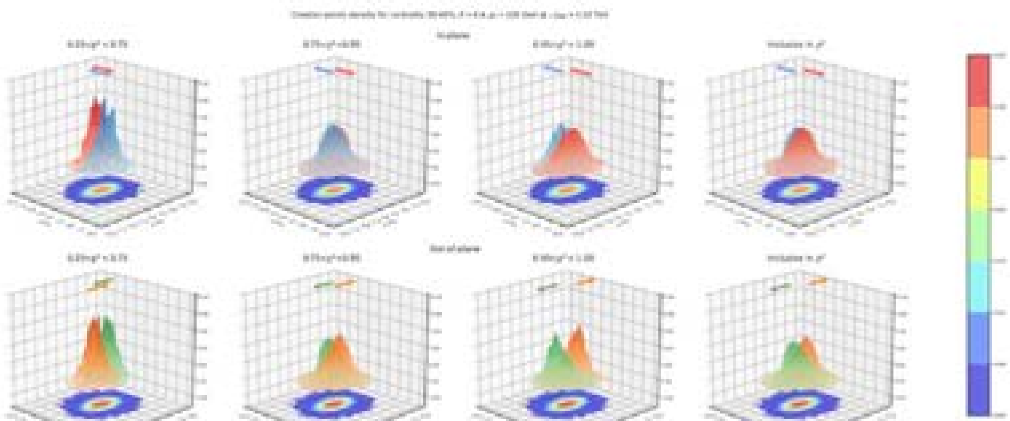
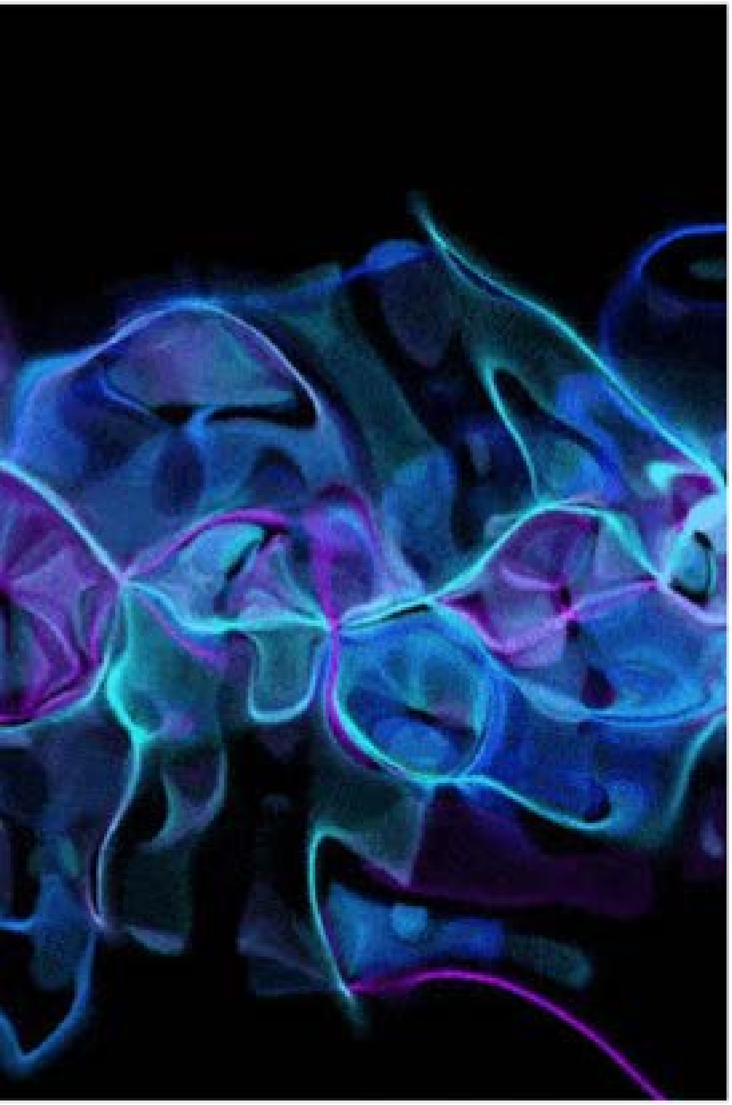


Figure: Extracted production points of individual jets, moving in the x- and y-directions respectively, in off-central lead-lead collisions using convolutional neural networks.



Another activity within nuclear theory deals with studying and exploiting Rayleigh-Taylor instabilities that can appear in laser-induced thermonuclear fusion processes, as first pointed out by L. Csernai in 1987. A configuration involving polymer targets and only two energetic lasers shooting at the fusion target from the two opposite sides, has been proposed and intensively studied both theoretically and experimentally since 2020 at the Szeged EU Extreme Light Infrastructure in Hungary, with promising results! This appears one of the most exciting direction to achieve and harness thermonuclear fusion, and we are expecting a Norwegian contribution in target manufacturing using the nanotechnology expertise in Bergen.

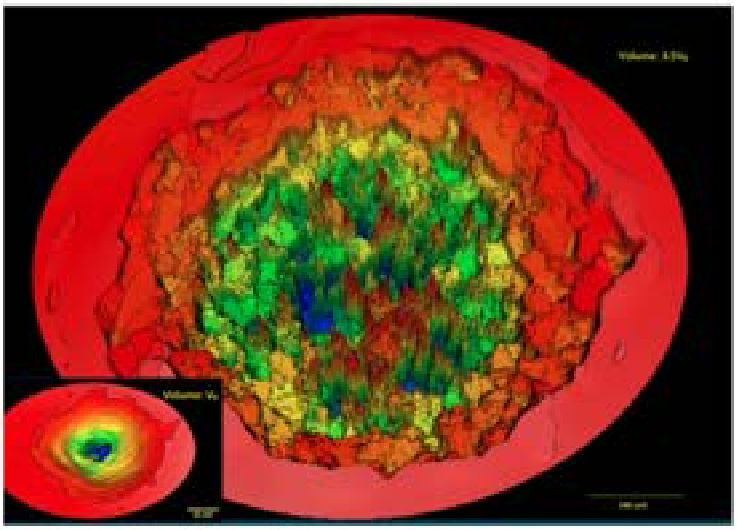


Figure:
The top view of the crater after a 25 mJ laser shot with implanted 85 nm long nano-rod antennas. Colors are indicating the depths of the crater. Red/green/blue indicate the depth. The bottom-left insert indicates a crater without the nano-rod antennas. The size is about one-third and the depth is also smaller.

Quick Questions

YOUNG RESEARCHERS

Vetle Elvebakken Andersen
Tehnical student (CERN/NTNU)

What is your background?
I am currently studying electrical engineering at NTNU. I have been a technical student at CERN since February 2022, where I currently write my bachelor thesis. Here I am working in the magnetic measurement section.

Where would we usually find you?
Most of the time you can find me in CERNs magnetic measurement laboratory while at work, or in the climbing gym or in the alps skiing when I'm not working.

How has the year of 2022 been?
2022 has been a rewarding and interesting year, where I have learnt a lot and worked on some incredibly cool projects!

What are you looking forward to in 2023?
I'm looking forward to finishing my thesis and project here at CERN, and starting school again in Norway.

What would people be surprised to know about you?
When I applied to CERN as a technical student I lived in a car in Spain as an exchange student, and thus conducted my interview cramped inside the car, luckily my supervisor didn't notice!

What do you plan to do after this period of your life?
I will start a masters degree in August, so until then I will spend some time in the Alps, and then do a long road trip back to Norway before school starts.

What is your current research project?
My project is about a way to combine rotating coil measurements for use in particle accelerators. The idea is to do several rotating coil measurements close to the magnet aperture, and then by some mathematical trickery combine them into one measurement, which represents the magnetic field better than one single measurement.

Why do you think this research is important?
For some magnet apertures, this method will eliminate the need to make specialized coils for doing measurements, and one can get by with just one. There will also be a gain in precision in some cases.

What would you like the impact of your project to be?
I have verified that the method works and is feasible to use in the lab, so hopefully the impact is that the method will be used in the future with great success.

Quick Questions

YOUNG RESEARCHERS

David Shope
Postdoc (UiO)

'I am naturally a very curious person, who enjoys having many hobbies and understanding things on a deep level'

What is your background?
I'm originally from Texas, where I lived until obtaining a bachelors degree in physics and chemistry. I graduated with a PhD in experimental particle physics from the University of Oklahoma, where I joined the ATLAS collaboration and was stationed at CERN for 4 years. I spent two years as a postdoc in Sweden, before starting my current position with Oslo last year.

What would people be surprised to know about you?
Once-upon-a-time I performed as a DJ and went by the name "DJ Titrate".

Where would we usually find you?
Running around my neighborhood to stay active - otherwise, behind a mouse and keyboard.

How has the year of 2022 been?
For me, 2022 was a transitional year - moving from Sweden to Norway and starting my new postdoc position with Oslo. Settling into a life in a new country always takes time, but the process was about as smooth as I could have hoped for and I'm happy with where I've ended up!

What are you looking forward to in 2023?
I look forward to a productive year ahead, as well as a number of opportunities to travel (both for work and holiday).

What is your current research project?
My current research includes the analysis of LHC proton-proton collision data recorded by the ATLAS decector, specifically the search for events producing two Higgs bosons (so-called "DiHiggs" events). I'm also actively involved in the preparation of ATLAS software for HL-LHC (High luminosity data taking which will begin in 2029).

Why did you choose this field?
What attracted me to experimental high energy physics was the scale of the endeavour - the unique opportunity to both participate in such a large collaborative environment and put to the test so many big ideas about the fundamental rules for how our universe operates.

What do you see as the most important issue in your field today?
It can be traced to many factors (e.g. direct applicability of skills and abundance of positions/funding with respect to academia), but the migration of talent (particularly in the software domain) into industry is certainly a big issue.

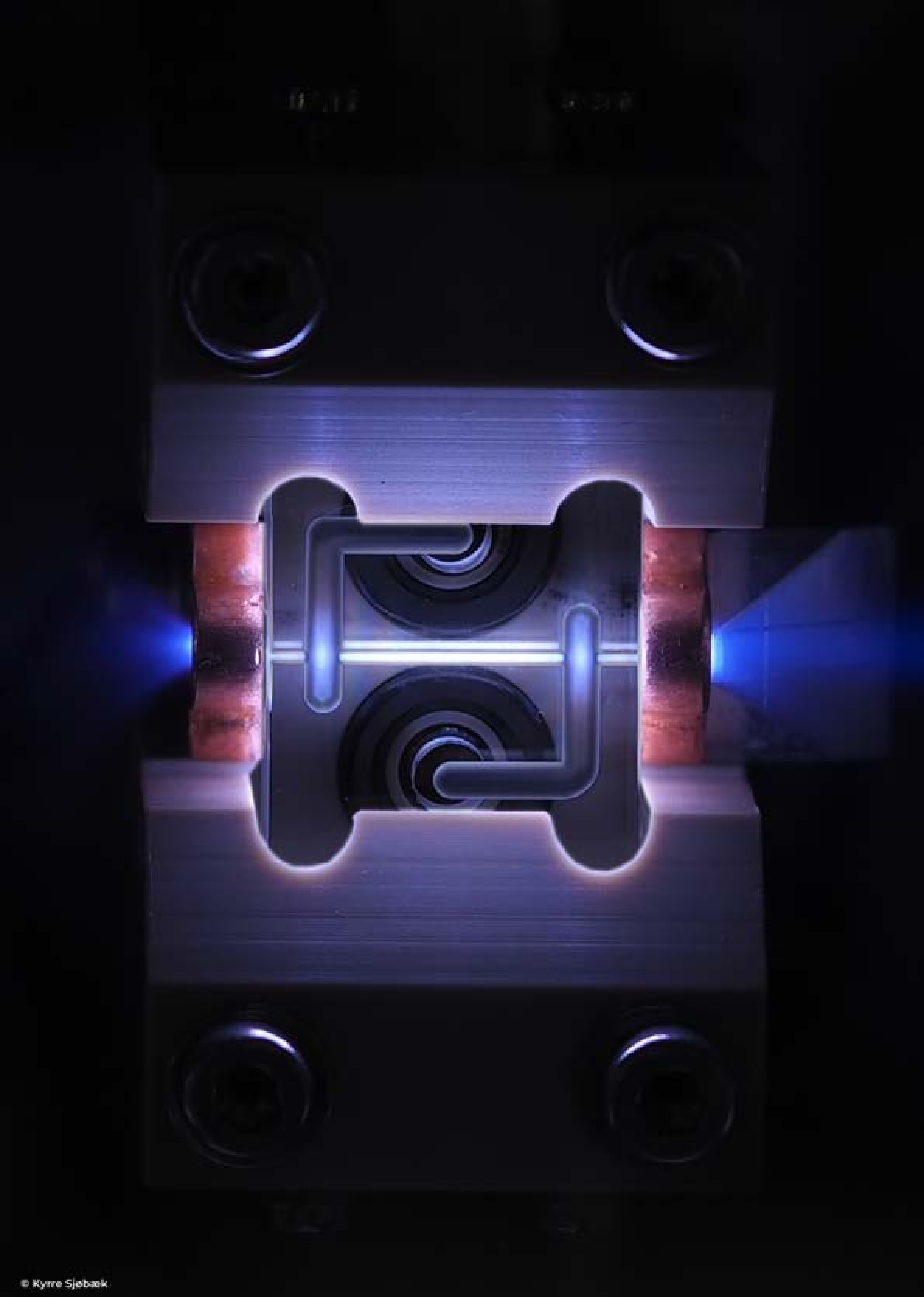
ACTIVITY 3

ACCELERATOR PHYSICS

The performance and cost of future particle accelerators limit which experiments can be performed at the energy frontier. Therefore, accelerator research will be fundamental in the coming period. In the last 15 years, Norway has built significant accelerator science expertise through participation in accelerator research at CERN. The centre funding secures a stable funding base towards future accelerators and also puts Norway in a position for industrial utilization when new accelerators at CERN are implemented in the future.

Leader
Erik Adli (UiO)

Researcher
Kyrre Ness Sjøbæk (UiO)



HIGHLIGHTS

Several large new colliders are on the study table, including the circular FCC with 100 km circumference and the linear CLIC/ILC with lengths up to 50 km. UiO has been a partner in the development of CLIC for more than 15 years with significant contributions of numerical simulations and experiments. We have strong expertise in beam dynamics and simulations, RF-design, collective effects, particle-matter interactions and instrumentation, all which are needed to develop the next generation of particle colliders.

A novel accelerator concept, plasma wakefield technology, uses plasma wave acceleration to accelerate particle beams with much higher accelerating gradient than today's technology. UiO is studying plasma wakefield acceleration, both numerical and experimental contribution. It is the performance and cost of future particle accelerators that limit which experiments can be performed at the energy frontier, therefore accelerator research is highly important for the future of particle physics. Particle accelerator technology developed at CERN is also being used in advanced medical applications, as described below. The accelerator research field provides very interesting projects for Norwegian students, as they can do both numerical or experimental studies, both at CERN and in Norway, in collaboration with leading international groups.

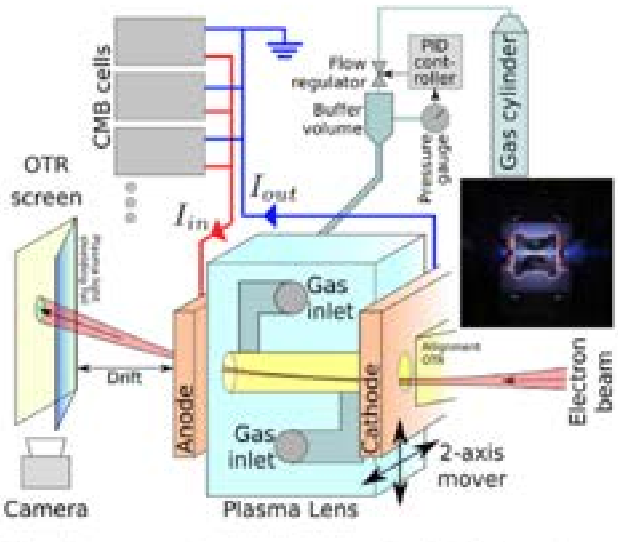


Figure: The most relevant components of the CLEAR Plasma Lens Experiment

Development of linear active plasma lenses for strong beam focusing

UiO is leading an experiment hosted at the CLEAR facility at CERN to develop linear active plasma lenses for strong beam focusing. UiO built up this experiment in 2017-2018, in collaboration with CERN, DESY and Oxford. More information and a sketch of the experiment are found in [1]. While COVID has prevented experimental activities in 2020-2021, we have used the time to analyse and write up data from earlier runs [1], and are now preparing for the next round of experiments. We also study the application of our lenses in different high-energy physics applications [2], and also for medical applications, see next page.

[1] K. Sjøbæk, E. Adli et al., "Strong focusing gradient in a linear active plasma lens", Phys. Rev. Accel. Beams 24, 121306 (2021)
[2] S-Y. Kim, K. Moon, M. Chung, K. Sjøbæk, E. Adli et al., "Witness electron beam injection using an active plasma lens for beam-driven plasma wakefield accelerators", Phys. Rev. Accel. Beams 24, 121304 (2021)

Application of CERN-related research to proton therapy

We have continued the effort at UiO to study how our expertise in advanced beam optics, required for future colliders, can be applied to improve proton therapy. Recent examples of the applications of our expertise are:

- One master student, Fardous Reaz, has completed his master thesis on this topic [3].
- Publication [4] illustrates how novel concepts have also been tested at the CLEAR test facility at CERN, with the involvement of participants of NorCC Activity 3. A new CERN-funded PhD student, Vilde Rieker, has joined the team for further studies of these topics.
- In publication [5] we have taken the ideas further, and the publication opens up for new research frontiers in proton therapy, possibly in combination with the strong focusing of plasma lenses.

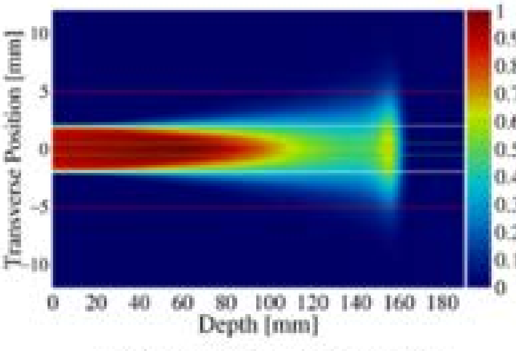
An example of the techniques we develop is shown in the below figure.

The activity participants were also involved in an application for an SFF, ProBio - Proton physics in cancer biology, and a UiO KD application for "bærekraft" (the application was not successful).

[3] F.Reaz, "Advanced beam shaping for spatially fractionated proton beam therapy", Master thesis, UiO, 2021

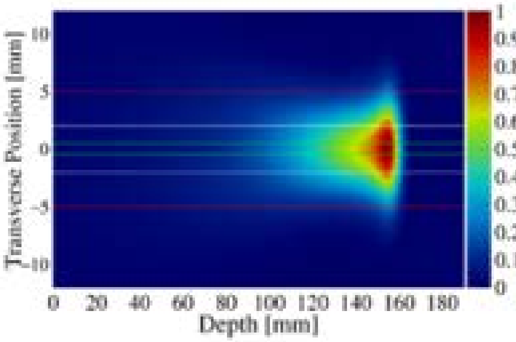
[4] K. Kokurewicz, K. N. Sjøbæk et al., "An experimental study of focused very high energy electron beams for radiotherapy", Commun Phys 4, 33 (2021)

[5] F. Reaz, K. N. Sjobak, E. Malinen, N. Edin, E. Adli, "Sharp dose profiles for high precision proton therapy using focused proton beam", Nature Sci Rep 12, 18919 (2022)

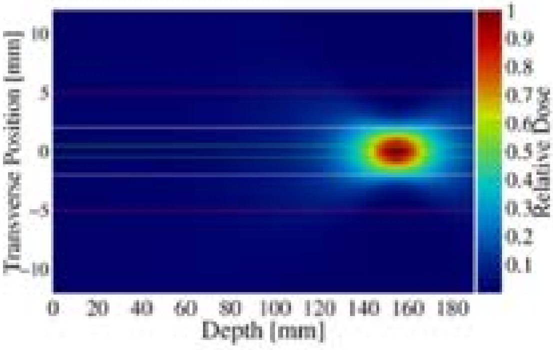


(a) 2D dose profile of 150 MeV CB

Figure: Comparison of two-dimensional proton radiation dose profile of a Collimated Beam (a), a Conventional Energy Focused Beam (b), and a High-Energy Focused Beam (c) with an identical peak dose position. The two latter may provide an increased dose contrast, especially for small, well-defined tumors. Adapted from [3].



(b) 2D dose profile of 150 MeV CEFB



(c) 2D dose profile of 350 MeV HEFB

Quick Questions

YOUNG RESEARCHERS

Jan Malamant
Master student (UiO)

'I am a rebel. Also, I try not to shy away from trying out new things and getting new experiences'

What is your background?
I was originally born in Israel, but my family moved away from the desert to live in the snow when I was just 1 year old, - I've been here ever since. I am now finishing my master's degree at the University of Oslo.

Where would we usually find you?
Currently, you'll often find me working in the AEgIS control room at CERN. When I'm in Norway, you'll find me working in the master room at the HEP section.

How has the year of 2022 been?
Personally, last year was huge careerwise. I've been to Paris to participate in an experiment on high harmonic generation; worked on building up the rocket engine manufacturing procedure at Portal Space; I started working at CERN as a Technical Student, and I've attended exciting conferences and met many interesting people.

What are you looking forward to in 2023?
I look forward to meeting new people within physics; to finish my master's degree, and hopefully get into a PhD programme. If the latter doesn't happen, I suppose I'll look for a job somewhere. Perhaps in space engineering.

Which fictional character do you identify with the most and why?
Viktor in the show Arcane.

Choose one song to play every time you walked into a room, what song would you choose and why?
The BWF World Superseries Anthem is great for this. I grew up hearing it a lot, and it still pumps me up every time.

What is your current research project?
I am participating in the AEgIS collaboration, which has as its goal to precisely test the weak equivalence principle of general relativity on antimatter. This will be done by producing a beam of antihydrogen (neutral atoms consisting of an antiproton and a positron) and letting them propagate in Earth's gravitational field, and then measuring their fall. At AEgIS, the production of antihydrogen is done by colliding cold positronium (a bound state of an electron and a positron) with cold, trapped, antiprotons. In short, the colder either of these are, the higher the production rate. My master thesis is about laser cooling positronium (Ps) by exploiting the momentum that photons carry. The issue is that Ps has a very short lifetime (~142ns in the ground state of Ortho-Ps) and has a very broad doppler profile due to its very low mass. In traditional laser cooling, the sample undergoes spontaneous emission many times in order to cool it, but the absorption channel that is used for cooling of Ps has a spontaneous emission lifetime of around 3ns. As such, the long lifetime of the excited state is one of the bottlenecks of laser cooling Ps. So, my thesis is to study laser-Ps interactions in which the emission of photons is stimulated by laser. Using picosecond laser pulses, I hope to show that this scheme has the potential to cool much quicker than traditional laser cooling.
At the same time, I am working on-site alongside members from AEgIS on the currently installed laser system. However, since this experiment is small compared to the likes of ATLAS and others, I also get to work in many areas of physics. I get to learn about vacuum systems, cryogenics, superconducting magnets, and various detectors and instrumentation. Most importantly, I have learned the manly art of moving heavy objects from point A to B by overhead crane.

Why did you choose this field?
Because I get to call myself an "antimatter physicist", which sounds like something straight out of Star Trek. ;)
In all honesty, two years of pandemic taught me that, despite liking theoretical work, I really hate sitting still for long periods of time. So, I knew that I wanted to work on a project which blended computational/theoretical work with hands-on experimental work. Luckily, my supervisors gave me a fantastic opportunity by encouraging me to apply for a Technical Studentship.

Why do you think this research is important?
There are two sides to this: The first is that this is undoubtedly important progress towards having a better understanding of fundamental questions such as the question of baryon asymmetry. On the other hand, working with antimatter requires a complex experiment in terms of magnets, lasers, detectors, and vacuum systems. To achieve AEgIS's goal requires a lot of novel problem-solving and state of the art technology.

Quick Questions

YOUNG RESEARCHERS

Igor Slazyk
Postdoc (HVL)

'Open-minded and easy-going person'

What is your background?
I did my bachelor's and master's degree in applied physics in Poland. Then I moved to Italy for my PhD in particle physics.

How has the year of 2022 been?
As in 2022 I moved to Norway, there were a lot of changes and new things for me. I learned a little bit of Norwegian culture and met a lot of exceptional and smart people.

What are you looking forward to in 2023?
Outside of work, I am looking forward to seeing more of Norway.

What do you plan to do after this period of your life?
I like doing research and programming. If not both, I plan to do one of these.

Which fictional character do you identify with the most and why?
Jon Snow as sometimes I feel that I know nothing.

What would people be surprised to know about you?
I always considered myself weatherproof until it started to rain in Bergen.

What is your current research project?
Development of machine learning techniques to pinpoint dark matter at the LHC with data collected by the ATLAS detector.

Why did you choose this field?
Physics always fascinated me. The more I studied it, the more I enjoyed it.

Why do you think this research is important?
It may answer some fundamental questions concerning the universe we live in.

What would you like the impact of your project to be?
It would be great to understand the nature of dark matter particles – at least partially :)

What do you see as the most important issue in your field today?
Sometimes, we are not technologically advanced enough to implement some innovative ideas.

ACTIVITY 4

LOW ENERGY NUCLEAR PHYSICS

Within the low energy nuclear physics activity, NorCC participates in the two experiments ISOLDE and AEgIS at CERN. Nuclear physics has as its objective to investigate and understand the nuclei: the hearts of atoms and the place where almost all mass of visible matter resides. Nuclear physics can explain how stars continually work to release virtually all of the useful energy in the world, while at the same time assembling the various elements. There are many potential applications of nuclear physics, e.g. in energy production, medical diagnosis and treatment. There are still several challenges, which make nuclear physics an exciting and active field of future research. Some of the experiments cover topics such as nuclear shapes, shape coexistence, and highly excited nuclei's statistical properties.

Leader
Sunniva Siem (UiO)

Deputy
Andreas Görgen (UiO)

HIGHLIGHTS: ISOLDE

ISOLDE is the longest running facility at CERN dating back to 1967. It provides very short-lived radioactive nuclei for studies of basic nuclear properties. The nuclei are produced from spallation, fission, or fragmentation reactions in a thick target irradiated by protons from the PSB at energies of 1.4 GeV. This produces 1000's of short-lived nuclei. A specific nucleus is selected through a variety of techniques such as laser ionization and more. The selected nucleus is then transported to one of the experimental stations or re-accelerated with the HIE-ISOLDE linear accelerator to induce nuclear reactions. Today the facility houses several experimental setups dedicated to measuring a large variety of nuclear properties.

The 2022 ISOLDE running period

In 2022 ISOLDE had one of its most productive years. Protons were delivered from the PS Booster on the 7th of March, with the physics program starting on the 28th of March. There were a total of 245 days of running, with the last protons delivered on the 28th of November. In addition, there were eight days of offline winter physics, giving a total of 253 days of runtime.

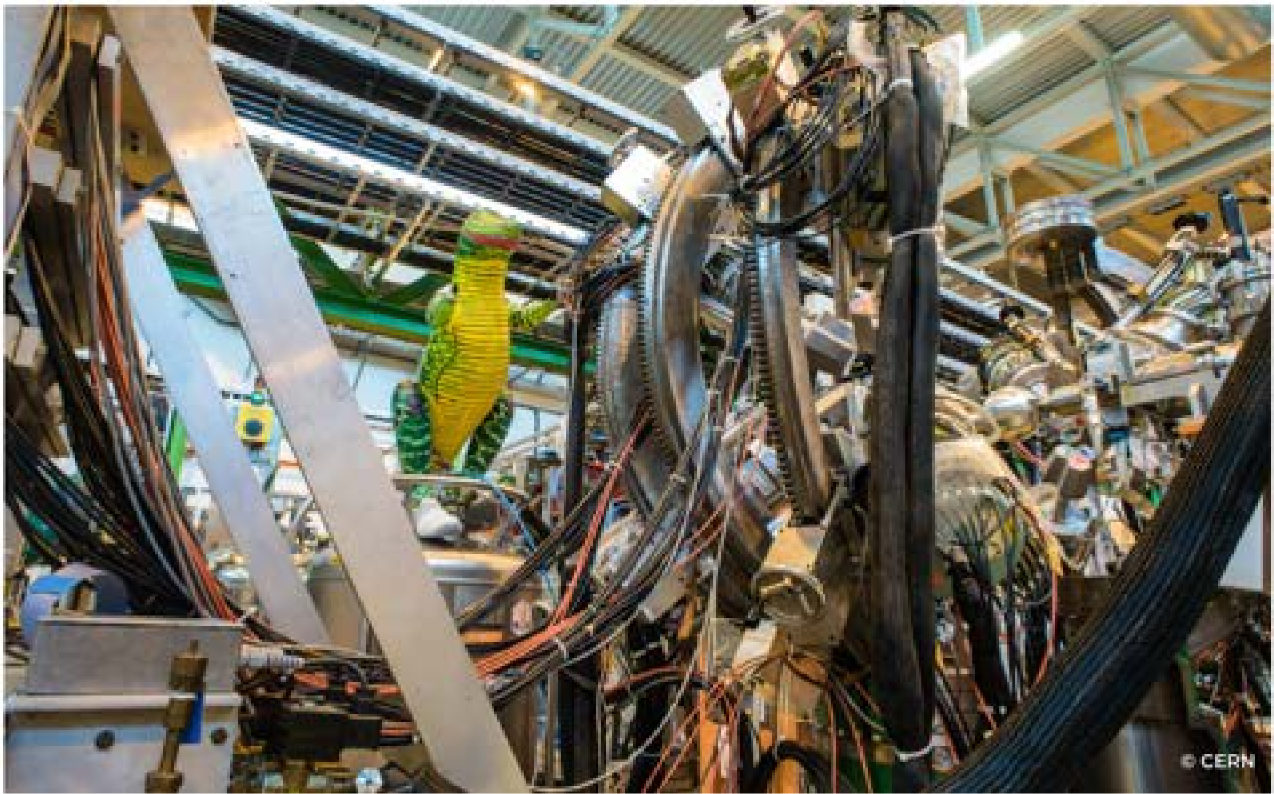
A total of 52 experiments and development runs took place with a total of 465.5 shifts delivered. The breakdown of the shifts is 28% went to experiments at HIE-ISOLDE, 31% to low-energy beams for nuclear structure studies, 7% to biophysics, 7% for solid-state physics, and 2% to medical physics. The 25% reminder went to development and alternative runs due to unforeseen events.

One of the highlights of 2022 was the return of the MINIBALL germanium array after major refurbishment of the detectors. A new digital data acquisition system to accompany the array was also commissioned. The refurbished array saw its first beam in October. The ISOLDE Solenoidal Spectrometer was the most productive setup at the HIE-ISOLDE beamline with a total of six experiments.

The Resonance Ionization Laser Ion Source (RILIS) provided beam to about 50% of all physics runs and was used in 29 out of 36 weeks. This year also saw the first operation of the perpendicular Illumination Laser Ion Source and Trap (PI-LIST) which improves the resolving power of the LIST system by an order of magnitude.

In developmental news, the preparation ahead of the long shutdown 3 is well underway. This year a major study of the ISOLDE beam dump was carried out. The aim of the study was to determine upgrade needs in preparation of an upgrade to 2 GeV proton beam delivery. As part of the process moving towards 2 GeV, new yield measurements were carried out at both 1.4 GeV and 1.7 GeV proton energies.

Finally, the collaboration gained a new member this year. Switzerland was formally approved by the ISOLDE Collaboration Committee as a member on the 7th of November, making it the 19th collaboration member.



Constraining an important cross-section for i-process at ISOLDE

In a recent study by McKay et al., it was shown that the ^{66}Ni(n,γ) capture rate could act like a bottleneck for the weak i-process and that measuring this rate would "(...) significantly improve our understanding of the i-process nucleosynthesis(...)" [1]. The unstable nature of ^{66}Ni prohibits direct measurements of this reaction. However, the reaction rate can be deduced indirectly through reaction calculations. The accuracy of these calculations relies on the nuclear level density (NLD) and γ-ray strength function (γSF) of ^{67}Ni, which we extracted from measurements done at CERN ISOLDE facility, results shown in Fig. 1 [2]. With these measurements the ^{66}Ni(n,γ) reaction rate was calculated, and the result is shown in Fig. 1 [2]. The neutron capture rate is strongly constrained and is in the upper end of the theoretical window, suggesting a fast i-process.

[1] J. E. McKay *et al.*, Mon.Not. R. Astron. Soc. 491, 5179 (2020).
[2] V. W. Ingeberg *et al.*, Manuscript in preparation (expected publication 2023).

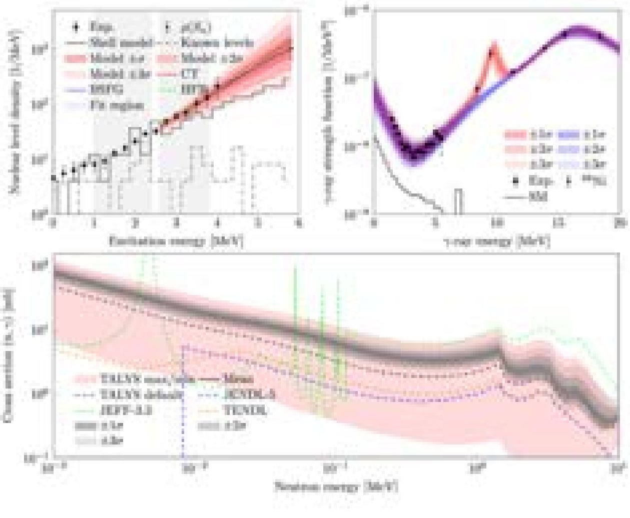


Figure:

Top left: Level density for ^{67}Ni. The experimental results (black points), the model fit (solid lines). The level density found in shell model calculations (black, dashed line).

Top right: The measured γ-ray strength function of ^{67}Ni is shown by black circles while the red and blue shaded area are model fits. Black diamonds are the experimental γ-ray strength of ^{68}Ni. The black line is the strength function found in shell model calculations.

Lower panel: Black line shows the calculated neutron capture cross-section based on the experimental NLD and γSF and the shaded dark area showing the credible intervals. The black, dotted line is the TALYS default.

Nuclear shell evolution and constraining neutron-capture cross-section for r-process at ISOLDE via ^{79}Zn(d,pγ)^{80}Zn

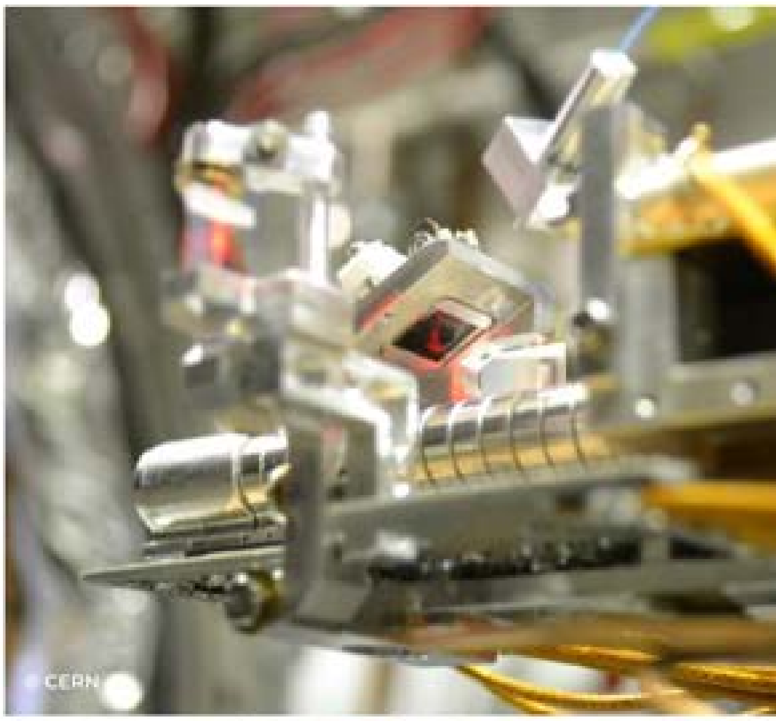
One of the main questions in nuclear physics during the last two decades is to understand whether the traditional shell gaps remain unchanged far away from stability. Significant changes, so-called shell evolution, have been found for different mass regions in the nuclear chart [3]. Among them, the mass region near ^{78}Ni is the least known due to ^{78}Ni being the most unstable doubly-magic nucleus with the largest neutron to proton ratio. While our knowledge on the Z=28 proton gap is rather well known thanks to increasing capabilities of the radioactive ion beam facilities around the world, the N=50 shell gap is much less known and was aimed to explore at ISOLDE via transfer reaction. A ^{79}Zn(d,p)^{80}Zn one neutron transfer reaction has been proposed to study the neutron excitations across the N=50 shell which could help understand the location of the neutron shell orbitals above N=50 and the size of the N=50 gap at Z=30, only two protons away from ^{78}Ni. The ^{79}Zn beam at an energy of 5 MeV/A will be impinging on a deuterated-polyethylene target. Emitted protons and γ rays de-exciting the states in the residual nucleus will be detected using the T-REX + MINIBALL setup, respectively.

The reaction could also allow us to populate the excited states up to the neutron-separation energy (Sn= 6.2 MeV) thus, suitable for measuring the (n,γ) cross section of the ^{79}Zn seed nucleus. This is particularly important for the sensitivity studies of the neutron capture reaction in the context of the weak r-process that forms primarily the A~80 r-process peak [4]. The scientific proposal was submitted in February 2022 to the INTC at ISOLDE. The committee approved the physics case and considered it to be very important. The reason why the proposal was not granted beam time was because of insufficient beam intensity at the present time. With more beam development, there is hope that this purely technical limitation can be overcome in the future.

[3] O. Sorlin and M.-G. Porquet, Prog. Part. Nucl. Phys. 61, 602 (2008).
[4] R. Surman et al., AIP Advances 4, 041008 (2014).

HIGHLIGHTS: AEgIS

Leader
Antoine Camper



AEgIS produces and studies antihydrogen atoms to probe the origin of the baryonic asymmetry (the predominance of matter over antimatter in the Universe). The main goal of AEgIS is to measure the free fall of antihydrogen in the Earth's gravitational field to test the Weak Equivalence Principle with antimatter (the fact that everything massive falls at the same rate). In 2020 and 2021, the experimental apparatus has been extensively modified and upgraded to receive antiprotons from ELENA (the Extremely Low Energy Antiproton ring, which started to deliver antiprotons to experiments in 2021). This upgrade was successful and AEgIS demonstrated the first trapping of antiprotons from ELENA during the 2021 run. In 2022, AEgIS commissioned the new traps and demonstrated a record high antiproton catching efficiency (50% of the amount delivered by ELENA) thanks to a refined degrador scheme. In 2023, AEgIS will work on producing colder antihydrogen, at higher rates and with improved directionality which is a prerequisite to the first measurement of gravity on antihydrogen.

Trapping antiproton from ELENA

ELENA, the new generation antiproton decelerator delivering 100 keV antiprotons, delivered its first antiproton to experiments at CERN in 2021. The new beam line connecting AGEIS to ELENA was installed during the spring of 2021. This operation required several important modifications of the experimental installation which were successfully carried out in 2021. Because the antiprotons from ELENA are colder than the ones from the antiproton decelerator (AD), a brand-new degrading scheme was designed and tested. In 2022, AEgIS demonstrated a record high antiproton catching efficiency.

Progress towards colder positronium

In parallel, AEIS prepared the 2022 run with a complete redesign of the antihydrogen production trap in view of the more efficient of colder antihydrogen. This includes a different trap geometry to allow for colder antiproton plasmas, positronium excitation to higher principal quantum numbers, reduction of the antihydrogen background signal due to the laser and more.

Quick Questions

YOUNG RESEARCHERS

Timm Baumann
PhD (CERN/NTNU)

'A curious power electronics researcher which tries to understand degradation mechanisms to develop condition monitoring systems'

What is your background?
I made a M.Sc. in Electrical Engineering and parallel a M.Ed. in Electrical Engineering at TU Berlin. Before I made a B.Sc. Electrical Engineering at HSLU and some working experiences in development of electronic circuits in Switzerland.

What would people be surprised to know about you?
I really like when it is warm, but I still spend most of my time in northern Europe.

Where would we usually find you?
Is there a usually? I am used to work at different places. This can be in NTNU or at CERN office, in the laboratory, at home, in trains and sometimes also in the nature but most of the time behind my notebook. Therefore, if you search me, just send a message to timm.felix.baumann@cern.ch.

What do you plan to do after this period of your life?
There are many interesting opportunities. I like working in the research field and think I will continue this way.

How has the year of 2022 been?
After the start of my PhD in May 2021 I can continue my research with more focus and success. In May I changed form NTNU Trondheim to CERN. This change gives me better access to the required resources I need for my work, but the resettlement also took some of my energy which I preferred to push into research. In 2022 I had the chance to present at conference for the first time, which was a great experience and the next submissions are still in progress.

What are you looking forward to in 2023?
Many experiments I will complete this year at CERN before I travel back to Trondheim to finish my PhD. I am looking forward going on conferences again, but also to publish first time in a journal.

What is your current research project?
Developing a condition monitoring system for CERNs power converters. At the moment I focus on monitoring principles for capacitor banks and liquid cooled semiconductors.

Why did you choose this field?
Power electronics is an interesting field with an increased impact to many applications in our energy system.

Why do you think this research is important?
Even more power electronics will be employed in production, distribution, storage, and usage of energy. For all these applications a high reliability is required. Condition monitoring helps to improve this.

What do you see as the most important issue in your field today?
Artificial intelligence is a great tool for data analytics and make predictions. It is a convenient way to get a quite good output. Nevertheless, we still need a deep understanding about the physics behind to improve the product.

ACTIVITY 5

TECHNOLOGY

The NorCC technology activity highlights the importance of Norway-CERN collaboration in technology and engineering, in addition to the collaboration in physics. It will add to and secure a broader set of collaborative areas between Norway and CERN. So far, the activity acts as an interface between CERN and UiA and NTNU researchers. Moving forward, the aim is to expand the collaboration and invite other Norwegian institutions to participate. The two universities, NTNU and UiA, have engineering educational programmes in cybernetics, mechatronics, data science, ICT, renewable energy, material science and civil engineering, and together with advanced laboratories, they are well-positioned to carry out the tasks in the NorCC technology activity. The aim is to develop and explore new technology, innovation, insights and knowledge, of importance both to science and society.

Leader
Jørn Wroldsen (NTNU)

Deputy
Søren Kragholm (UiA)

HIGHLIGHTS: UiA-CERN CMS COLLABORATION

Since the visit of UiA to CERN in February 2020, UiA has continued to develop their relations with CERN. Their new associate membership of the CMS collaboration at CERN, put in place in 2020, provides new opportunities without having to pay a membership fee as the full members do. The main studies are related to Artificial Intelligence and CO2 cooling for the experiment, where UiA has significant expertise. A junior fellow from UiA was recruited by CERN in 2021 for the CMS collaboration, strengthening the links between CERN and UiA related to the on-going technical collaboration

Fellow: Jørgen Fone Pedersen

Technical coordination within the experimental area management team at CMS

CMS has new upgrades scheduled for many years to come which also requires upgrades to the existing infrastructure and buildings at the surface level. This project coordinates these works between the different service groups at CERN, such as electrical, HVAC, IT, and civil engineering activities.

Project leaders:
Lars Tore Rødne (CERN)
Richard Morton (CERN)
David Hay (CERN)

PhD student: Mulugueta Asres

Detector System Monitoring and Diagnostics for the Hardon Calorimeter (HCAL) of the CMS Experiment

To automate faults discovery, diagnosis, and prognosis of complex particle detector systems through recent advances in deep learning on high dimensional sensors and Data Quality Monitoring data of the Hardon Calorimeter. To develop and deploy anomaly detection, anomaly prediction, and root-cause analysis models at several system granularities of the HCAL.

Project supervisors:
Prof. Christian W. Omlin (UiA)
Jay Dittmann (CERN)
Alberto Belloni (CERN)

HIGHLIGHTS: NTNU-CERN DOCTORAL PROGRAMME

NTNU and CERN researchers have been collaborating for several years with a long-running tradition of having Master and Bachelor students from NTNU in the CERN Technical Student programme. In 2017, the two institutions decided to formalise the collaboration in science, technology, and engineering domains. In 2019, they agreed on a joint Doctoral Program, where they co-finance PhD students within engineering and technical physics. Typically the students will start with a stay at NTNU, then come to CERN for 18-24 months, and then go back again to NTNU towards the end of the project. There are several projects in progress. In 2022, all eight collaborative NTNU and CERN PhD are well on their way, based on the CERN-NTNU MoU for co-funding of technology PhD projects signed 2019, covering key technology developments for future accelerators and detectors.

Mechanical and thermophysical characterisation

Mechanical and thermophysical characterisation at different strain rates of low-density graphitic materials, as well as characterisation of pure Pb for beam intercepting devices applications.

Project leaders:
Professor Filippo Berto (NTNU)
Marco Calviani (CERN)

Hyper-redundant robots for maintenance in Big Science Facilities

To understand the needs of remote maintenance in big science facilities and to recognize the steps needed to overcome the current state of the art. To design, simulate and prototype robotic solution for dexterous remote maintenance in big science facilities.

Project leaders:
Professor Kristin Y. Pettersen (NTNU)
Mario Di Castro (CERN)

Diagnostics and prognostics for power electronics converters in large-scale accelerator facilities

The objective of the project is to develop an additional layer of diagnostic and prognostic functionalities integrated with the central power converter controllers at CERN and to deliver advanced design methodologies for highly reliable power converters operating at a variety of mission profiles.

Project leaders:
Professor Dimosthenis Peftitsis (NTNU)
Konstantinos Papastergiou (CERN)

The social impact of CERN's technological, human, and branding capital

Social impact is a vital measurement for universities and research institutions. The impact can be related to the dissemination of knowledge and technology, e.g. applied in the industry, spin-off companies and knowledge development through students. There is a lack of knowledge about social impact. The goal of this project is to qualify and quantify the social impact of CERN's technological, human, and branding capital, through CERN's knowledge transfer activities.

Project leaders
Professor Øystein Widding (NTNU)
Giovanni Anelli (CERN)

Surface plasmons (and other surface waves) and their role in field emission and breakdown in high-field accelerating structures

The project will investigate the compelling link between the localised and strongly enhanced plasmon resonances to the enhanced field emission and breakdown phenomenon observed in high-field systems.

Project leaders:
Professor Morten Kildemo (NTNU)
Walter Wuensch (CERN)

LHC detector cooling with R744 refrigeration technology (CoolCERN)

CoolCERN works to develop a full CO_2 refrigeration circuit for the ATLAS and CMS particle detectors with cooling capacities up to 300 kW (ATLAS) and 600 kW (CMS) at evaporating temperatures below -50°C. These detectors have a total cost of about 1 billion NOK, and this is why we need a primary cooling system complying with stability and reliability to keep the detectors in continuous operation, without any interruption. In addition, there is an increasing concern at CERN to meet the environmental sustainability constraints due to the European F-gas regulation.

Project leaders:
Professor Armin Hafner (NTNU)
Bart Verlaat (CERN)

Energy-optimal control of cooling systems

The aim of the project is to investigate control approaches to ensure energy-optimal operation of cooling and ventilation applications featuring a variety of actuators. The project will exploit knowledge about the actuators' energy usage characteristics to derive a control strategy that seeks to minimise the energy consumption of the system.

Project leaders:
Professor Morten Hovd (NTNU)
Brad Schofield (CERN)

Chirped optical laser cooling of positronium

The project will develop and use an ultraviolet short (sub-microsecond) chirped-pulsed Ti:sapphire and Alexandrite based laser system to laser cool positronium (Ps) and perform temperature characterisation of the positronium cloud using Doppler velocimetry. The project will develop the basic Ti:sapphire laser system at NTNU first and will move to CERN to carry out the first laser cooling experiments with an existing Alexandrite based laser system.

Project leaders:
Professor Irina Sorokina (NTNU)
Dr. Michael Doser (CERN)

Quick Questions

YOUNG RESEARCHERS

Anastasia Merzlaya
Postdoc (UiO)

What is your background?
I got my bachelor and master degrees in Saint Petersburg State University, and PhD degree in Jagiellonian University in Krakow.

Where would we usually find you?
I am usually in my office in HEP UIO department, but I also often work from home.

What do you look forward to in 2023?
I hope to participate in a few conferences and show the results - after a long break during the pandemic.

What do you plan to do after this period of your life?
I really would like to stay in academia and stay in Norway. Since there are not so many positions available, I am open to the possibility to change the experiment or do teaching.

What would people be surprised to know about you?
Despite the fact that I have no art education, I illustrated 3 published children books and created 7 hand-drawn PC games.

What is your current research project?
I'm studying open charm production at the SPS energies in NA61 experiment. Recently I also started to look for closed charm in ALICE data.

Why did you choose this field?
Initially I was studying nuclear physics, but during master studies I switched to HEP: it seemed much more exciting in the meaning of understanding the creation of the universe, and moreover there was a chance to study abroad.

Why do you think this research is important?
Open charm had never been observed before at low energies, and it is a powerful tool for studying at which conditions QGP is created as well as for the search for the Critical point of strongly interacting matter.

What would you like the impact of this project to be?
So far my research showed the first observation of open charm at low energies, and I hope that the more detailed study will allow for QGP creation conditions study.

Quick Questions

YOUNG RESEARCHERS

Victoria Madeleine Bjelland
PhD student (NTNU/CERN)

'Goofy!'

What is your background?
I have both my bachelor and masters in physics from NTNU.

Where would we usually find you?
In my office at CERN nowadays.

How has the year of 2022 been?
It went by very fast. A lot changed over the past year.

What are you looking forward to in 2023?
Improving in my work.

What do you plan to do after this period of your life?
I will go where opportunities present themselves. Either that will be home to Norway or somewhere else in Europe. It is too early to say.

What would people be surprised to know about you?
I can do a split.

Choose one song to play every time you walked into a room, what song would you choose and why?
To have the Imerial March play every time I enter a room, would make my brother jealous.

What is your current research project?
I study the breakdown phenomena found in linear accelerators.

Why did you choose this field?
I was very eager to start a PhD after my masters and the opportunity to go to CERN landed in my lap.

Why do you think this research is important?
Not only is this problem preventing the CLIC project, but it is also a common phenomena in all high voltage applications.

What would you like the impact of your project to be?
Uncovering of new information and a better understanding behind material properties.

What do you see as the most important issue in your field today?
Understanding the mechanism behind the phenomena.

Which fictional character do you identify with the most and why?
Louise from Bob's Burger. I can feel the chaotic energy.

ACTIVITY 6

EDUCATION, DISSEMINATION & EXPLOITATION

To ensure the continued high impact of the centre we have established Activity 6, for our education, dissemination and exploitation. In addition to the many educational and dissemination efforts within the other centre activities, specific activities related to education, dissemination and CERN membership exploitation (EDE) are covered by this Activity. Examples include scientific publications, PhD, MSc and BSc degrees, as well as education and outreach actions and materials targeting various groups. Active and effective communication is key to international visibility and collaboration, as well as optimal functioning of the centre.

Leader
Steinar Stapnes (UiO)

Deputy (January-July)
Nina Waage (UiO)

Deputy (September-December)
Eli Bæverfjord Rye (UiO)

HIGHLIGHTS: EDE

Specific activities related to education, dissemination and CERN membership exploitation (EDE) are covered by this NorCC activity and includes scientific publications, PhD, MSc and BSc degrees, as well as education and outreach actions and materials targeting various groups. Full exploitation of CERN depends on the ability to make use of CERN's resources and funding invested in contracts, technology transfer and technical student programmes. Another important goal of this activity is to increase the amount of outreach within the centre. The research performed within these fields are of great significance, and bringing this forward to the society as a whole is part of our mandate.

Norwegian visits to CERN

Each year, around 1000 Norwegian pupils visit CERN. Also many students at different Norwegian universities and university colleges get the opportunity to visit CERN. During these visits, NorCC members help the CERN visit service by holding lectures and acting as guides. Further, a school for Norwegian physics teachers is arranged biannually, next time in 2023/2024. At this school, around twenty Norwegian teachers spend one week at CERN, where they are updated on the latest development in particle physics, from accelerators to data analysis. Many of the lectures and activities are presented by Norwegian researchers.

Norwegian Technical Student Programme

Hundreds of technical students carry out their research at CERN yearly, of which around 10-12 are Norwegian. Around eight of these students are co-financed by Norway and CERN, while the remainder are financed by CERN only. The students are at master or end-of-bachelor level. They come from many universities and university colleges, with NTNU historically as the main source including its campuses at Gjøvik, Agder, Narvik, HVL and Stavanger. In 2022, the technical student programme involved on average around 8 students.

Summer@CERN

For the first time after the start of NorCC and for the first time after the pandemic we were able to invite all young researchers to a two-week event/school at CERN. The event was attended by 31 young researchers, Bachelors, Masters, PhD and postdoctors. The program consisted of one week of academic program with lectures and visits to the experiments and a second week with Higgs celebration and Innovation program with Ideasquare. We were very pleased that we were able to have such an excellent attendance at the end of the pandemic and the feedback from the students will be very valuable when we organise another such event in 1-2 years time. In summary the event was very well seen by the students and they recommend we continue.

Summer@CERN: Theoretical physicist John Ellis gave a special lecture for us during the Higgs celebration. In this photo, eager participants talk to him after his lecture.

HIGHLIGHTS: TTO/ILO

Industry Liaison Officer
Technology Transfer Officer
Ole Petter Nordahl

Industrial contracts

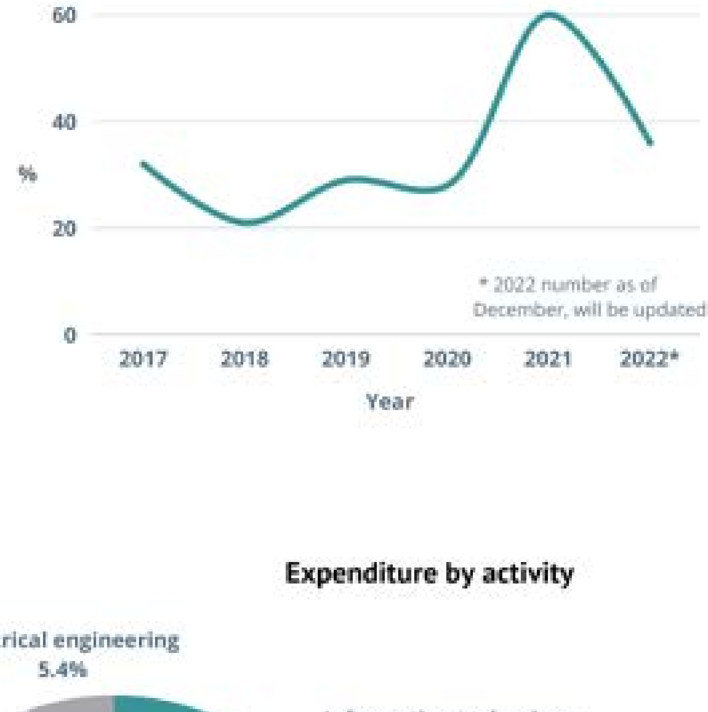
The research foundation CERN in Geneva, Switzerland, annually purchases goods and services for on average 5 billion NOK, primarily from its 23 member states and 10 associated member states. As a member of CERN, Norwegian companies deliver both supplies and services. Norwegian companies have for years mainly delivered products and services within the area of mechanical work, advanced precision machining in particular, and electronics. Since 2021, Norwegian companies have increased the deliveries of specialised IT equipment and have also won framework contracts for office furniture and chairs.

The industry liaison service

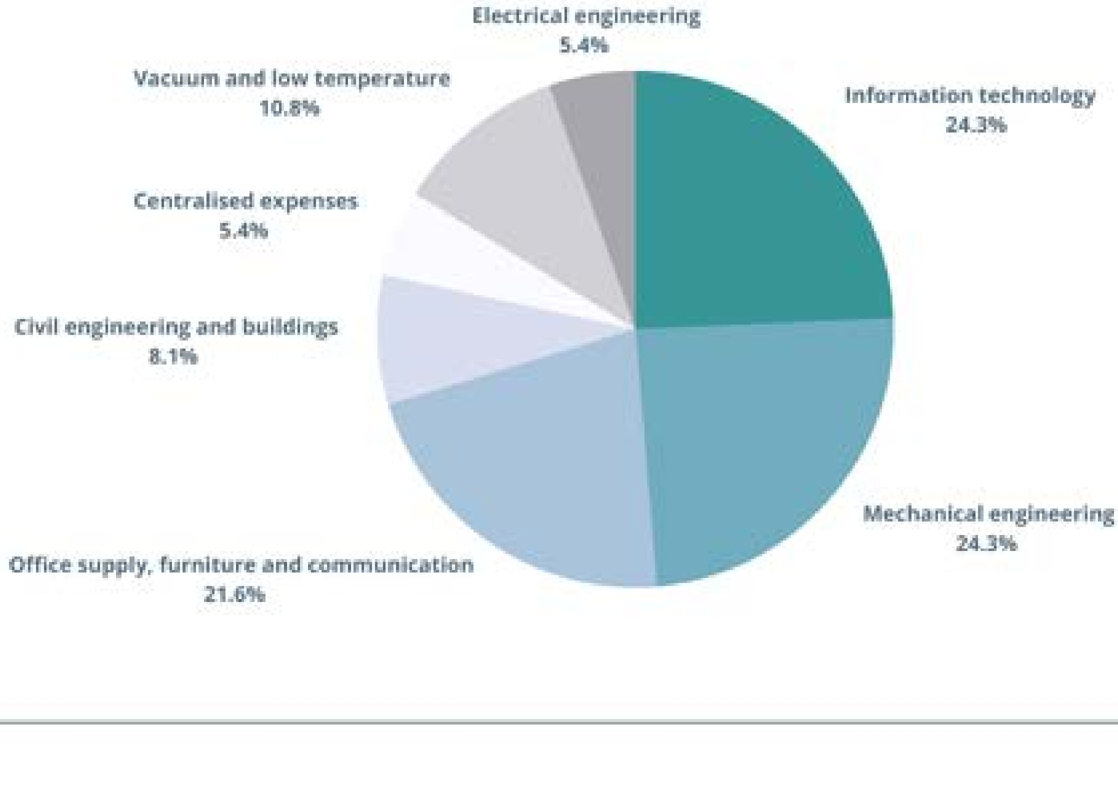
An industry liaison service has been established to help Norwegian companies that are interested in delivering goods and services to CERN. The industrial liaison officer (ILO) helps CERN identify possible Norwegian suppliers and guides the Norwegian company through the qualification and tender processes. In addition, the ILO can help the company get in touch with relevant contact persons at CERN to market their products or organise visits. Ole Petter Nordahl is appointed the Norwegian Industry Liaison Officer, a position he has had since 2004.

In 2022, a Norwegian industry day was organized at CERN 31th May to 1st June. 10 companies participated and 55 B2B meetings took place. In the future the national industry days will be replaced by smaller thematic industry days.

Industrial Return



Expenditure by activity

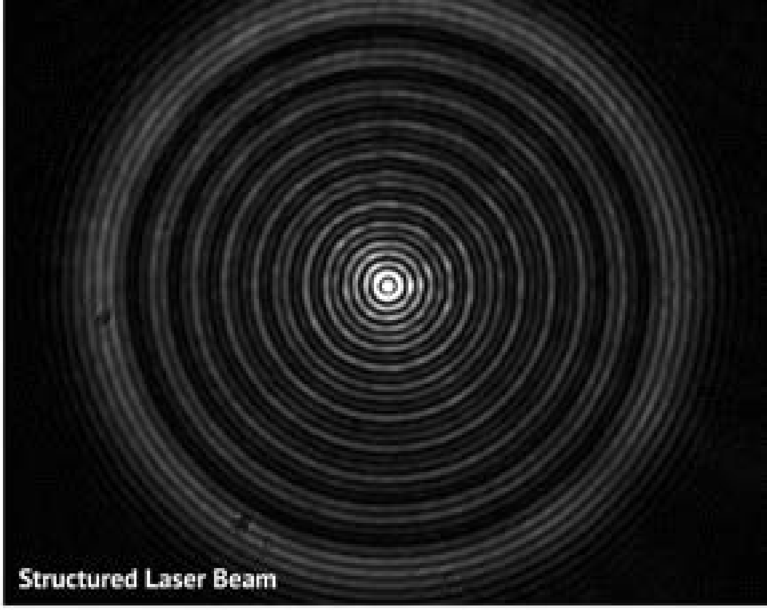


Knowledge and technology transfer

CERN is home to some of the world's most complex scientific instruments, used by physicists to probe the fundamental structure of the Universe. The technologies developed to operate these instruments – and, in general, to pursue CERN's fundamental mission – have applications in areas beyond particle physics. Knowledge transfer happens in all interaction points between people. At CERN the knowledge happens formally through the CERN Knowledge Transfer group (KT) and IdeaSquare, and often more informally in the industry contracts and the research collaborations. The KT group is responsible for Intellectual property (IP) management and the entrepreneurship initiatives, while IdeaSquare facilitates innovation or entrepreneurship-driven events and courses often using the Challenge Based Innovation (CBI) methodology.

For Norway, the main knowledge transfer beyond the research happens through the industrial contracts. This type of knowledge transfer is not easy to monitor or quantise and might often be related to improvements in production methodology, testing procedures and quality control. Sometimes completely new technologies are developed in cooperation between CERN researchers and companies, but most of the time CERN engineers help the companies to improve tolerances or the attributes of the product or services. This helps the companies to improve their competitiveness and might open new business areas. Ole Petter Nordahl is also appointed the Norwegian Knowledge Transfer Officer.

IdeaSquare

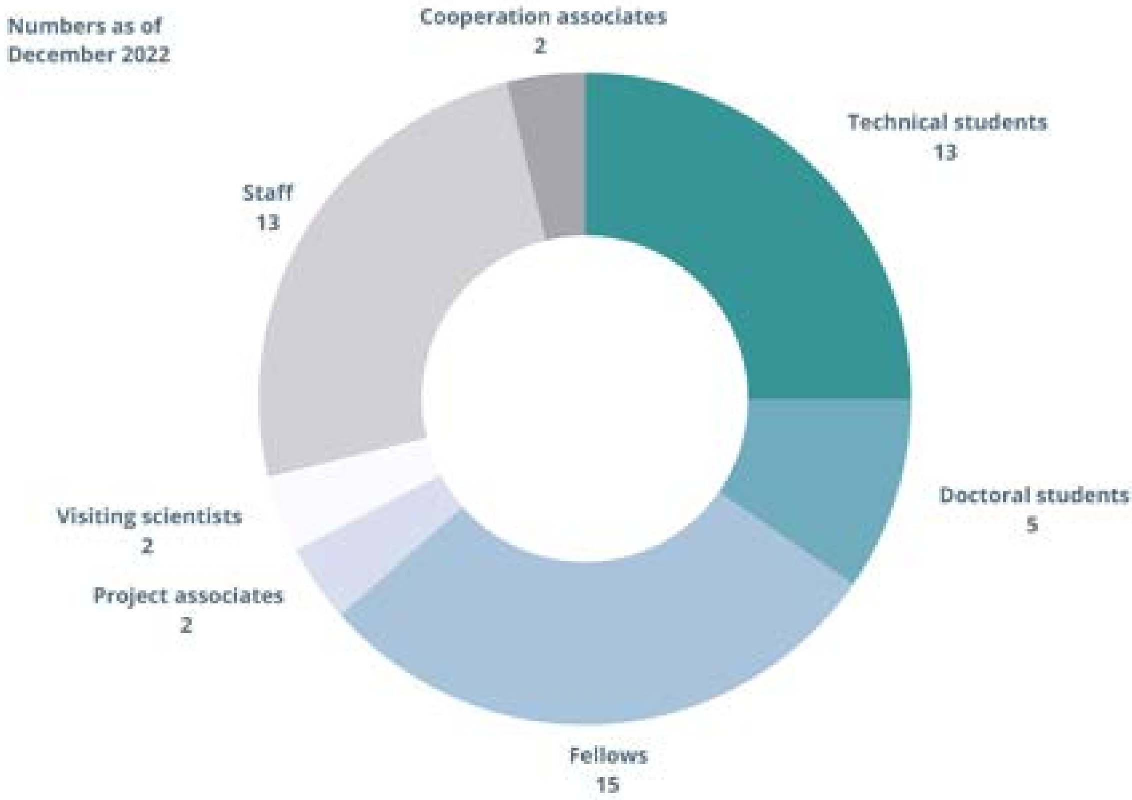

Structured Laser Beam

NTNU Screening week

Since 2008, NTNU has been sending their students at NTNU School of Entrepreneurship to CERN for a week. So far more than 340 students have participated in the event and 57 technologies have been screened. During the NTNU Screening week the students chose CERN Technologies and know-how to develop a feasibility study. The students are assigned to teams based on their background and they then cooperate and discuss with the CERN technical experts and with companies to develop viable strategies for commercialisation. Finally, they presented their findings at the end of the week, followed by a written report. If a technology has great business potential the students have the possibility to establish a start-up based on the CERN technology. So far there has been four start-up attempts. One company, Tind Technologies AS, has been operating since 2014. The 15th version of the NTNU Screening week was held from 24th October to 28th October 2022, where 30 students participated.

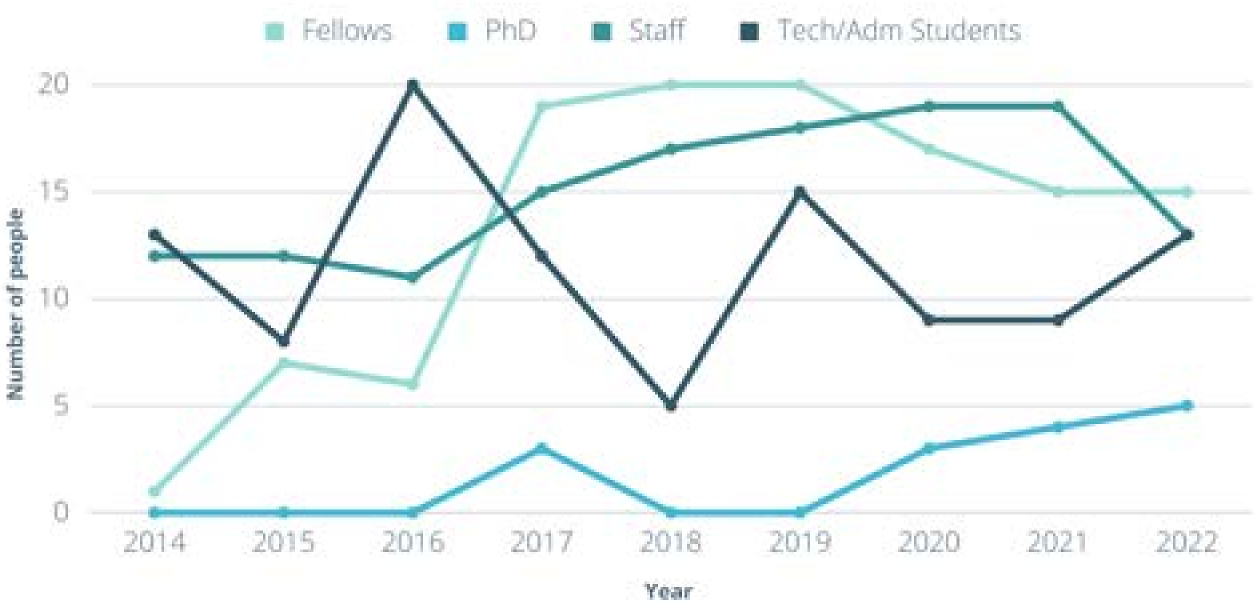
During this week, five CERN technologies were screened:

- Rucio– a project that provides services and associated libraries for allowing scientific collaborations to manage large volumes of data spread across facilities at multiple institutions and organisations.
- White Rabbit – a technology developed at CERN to provide sub-nanosecond accuracy and picoseconds precision of synchronisation for the LHC accelerators chain.
- Qubic Laser – a laser that operates on a single resonator mode, so that it emits quasi-monochromatic light with a very narrow linewidth and very low phase noise.
- Ultralight Cold Plate – a technology developed by CERN for the cooling of power dissipating elements, based on micro-macro vascular pipes embedded in high thermal conductive carbon substrate.
- Structured Laser Beam – a low-cost laser that produces a non-diffractive beam (NDB) that has very low diverge and can maintain the Bessel-like beam and spot sizes for long distances.



Norwegian personnel

CERN's staff members, numbering around 2500, take part in the design, construction and operation of the research infrastructure. They also contribute to the preparation and operation of the experiments, as well as to the analysis of the data gathered for a vast community of users, comprising over 12 200 scientists of 110 nationalities, from institutes in more than 70 countries. In addition to about 100 users associated to Norwegian universities, Norway had 13 staff members, 15 fellows, 5 CERN doctoral students and 13 technical and administrative students working permanently from Geneva by the end of 2022.



Quick Questions

YOUNG RESEARCHERS

Eskil Vik
Technical student (NTNU/CERN)

'Curious nanotechnologist getting a bit lost at CERN - and loving it!'

What is your background?
I am currently in the middle of an integrated masters degree in Nanotechnology at NTNU in Trondheim, where I mainly specialize in nanoelectronics and solid state physics. This year I am at CERN as a technical student, working on a computational physics project on beam dynamics.

What would people be surprised to know about you?
In the summer of 2020, I hiked the 700 km (or roughly 6 weeks) from Trondheim to Stavanger with my family. I can heartily recommend trying it, it was amazing!

Where would we usually find you?
My office is the first place I would look, but I wouldn't rule out finding me at choir rehearsal, in the alps skiing, or on a train to visit a new city.

How has the year of 2022 been?
My year has been very good, especially since it has been incredibly varied. In the spring I had a great semester at my university, where my studies are getting more interesting as I progress in them, and at the same time the social student life is picking itself up as covid restrictions were getting more relaxed. In the summer I did an internship where I did data science for carbon capture, and the autumn I've spent at CERN. All in all it has been a great year!

What are you looking forward to in 2023?
Taking advantage of being in the middle of Europe! Since I'm going back to Norway to resume my studies after summer, I want to take every opportunity I can get here to go skiing, interrailing, hiking - all the while making new friends. On a more professional note, I think my work will also be even more interesting, as I'm now (mostly) past the "I have no clue what's going on"-phase that comes from starting a new job in what is for me a new field.

What do you plan to do after this period of your life?
I have two more years at university before I'm finished with my master's, so I'll start with that. After that, who knows?

Choose one song to play every time you walked into a room, what song would you choose and why?
I think it's impossible to find something that fits well played out loud in the office, at the supermarket, in a bar or at a funeral, so I suppose if I'm doomed to a life of constantly interrupting things in an inappropriate manner, I might as well go all out with something as dramatic as possible: I'll go with Phantom of the Opera by Andrew Lloyd Webber!

What is your current research project?
I work on improving a software tool for calculating impedances and wake fields, primarily in beam collimators. My tasks here range from mostly IT related, such as improving installation procedures or developing interfaces to other pieces of software, to tasks more related to mathematics and physics, for example implementing calculations of higher order terms of the impedance.

Why did you choose this field?
It actually happened a bit by chance! I was applying to be a technical student at CERN, and envisioned it to be something related to material science. But then I got an offer for my current project and thought it sounded very interesting! It helped that the project was to a large extent computational physics, which I'm well acquainted with and know I enjoy from university, so even though beam dynamics is new to me, I both learn a lot and feel like I contribute well to the project.

Why do you think this research is important?
With the enormous political and economic costs of building or upgrading particle accelerators, good simulation tools are essential to ensure sufficiently thorough feasibility studies for them to even be built. The software I'm working on is one of many that comprise CERN's ecosystem of simulation tools, so improving it's performance and usability is an important contribution to CERN's ongoing search for the next step after the LHC.

Which fictional character do you identify with the most and why?
Hmm, maybe Ash Ketchum from Pokémon? Full of wonder and curiosity, and resolved to excel at what he does, but still most interested in having fun with the friends made along the way. An ideal to try to live up to, to be sure!

Quick Questions

YOUNG RESEARCHERS

Oda Langrekken
PhD student (UiO)

What is your background?
I finished my master's degree in physics at UiO in 2019. After finishing my degree I got a job as a data scientist in insurance. After two years away from physics I realized that life just isn't as much fun without some particle collision data to analyze, so I returned to UiO to start my PhD.

How has the year of 2022 been?
I got the opportunity to travel to CERN at two different occasions this summer. Being at CERN always helps me stay motivated and excited about my research. After some years of limited travel, being able to travel to CERN again felt really invigorating. I also finally bought my own apartment.

What are you looking forward to in 2023?
In 2023 I am looking forward to progressing more with my research. I am also looking forward to many hours sunbathing with a glass of wine now that I finally have my own balcony!

What is your current research project?
I search for new particles in the data from the ATLAS detector using machine learning methods. In particular I explore how we can search for new particles using unsupervised methods that make no assumptions on how the signal from the new particles should look.

Why did you choose this field?
I love elementary particle physics because I am very detail-oriented. I also love programming (I even enjoy debugging), so writing code to analyze data from particle collisions is really the perfect fit for me.

ACTIVITY 7

MANAGEMENT

One of the most important advantages of having a centre such as the NorCC is to be able to work together and create a community with research opportunities, networks and community, for researchers in Norway and at CERN. This is particularly important for the young researchers of NorCC but also to improve research and research relations with CERN. Indeed in 2022, the focus for NorCC has been on the young researchers, establishing the first Summer@CERN school, setting up a Young Researcher Council and a starting student seminar series and a regular seminar series for all. The managment of NorCC has a rather flat structure. The Steering Committee consisting of the leaders and activity leaders meet every week and once a month with the network and sub-activity coordinators, all working together to improve NorCC and our relations with CERN.

Centre leader
Heidi Sandaker (UiO)

Administrative coordinator (January-July)
Nina Waage (UiO)

Administrative coordinator (September-December)
Eli Bæverfjord Rye (UiO)


Sweden
Finland
Norway
Germany
Denmark
Netherlands
Belgium
Czech Republic
Lithuania
United Kingdom
Poland
Slovakia
Ukraine
France
Hungary
Romania
Spain
Serbia
Bulgaria
Portugal
Switzerland
Italy
Slovenia
Cyprus
Austria
Greece
Turkey
Israel

HIGHLIGHTS

NorCC workshop in September 2022

Annual workshop

Our second annual workshop was held for the first time in person in Oslo in Gamle Festsal, with zoom connection possible, and with the attendance of around 50 people in total. This year's workshop was dedicated to discuss the future plans of the centre towards writing a short 10-year plan during 2022/2023. All areas of research in the centre were discussed and although for some areas more work is needed, others had several concrete ideas which are worth pursuing further and also new ideas emerged during the discussions. We very much look forward to follow up on the outcome of the workshop.

NorCC inaguration

Part of the workshop was a dedicated inauguration attended by Statssekretær Oddmund Løkensgard Hoel, the Norwegian Research Council and representatives from the member universities UiO, UiB, NTNU, HVL, UiA and USN. The speakers prorektor Åse Gornitzka and statssekretær Hoel opened the centre.

Tour of NorCC institutes

After the visit to NTNU in November 2021, the tour of NorCC institutes continued during 2022. A visit to UiA took place in May and a visit to HVL and UiB took place in November. Thanks to all the institutions for fruitful discussions and many plans to follow up in the years to come. Next a visit to USN is planned in 2023.

Young researcher council

A Young Researcher Council (YRC) was proposed and set up during the workshop to ensure a strong voice of our youngest members into the leading and operation of the centre as well as to the work on our future plans. The Council will be led by Tarje Hillersøy (HVL) and Ida Storehaug (UiO), with Oda Langrekken (UiO) as deputy and Ruben Guevara (UiO) being the voice of the MSc students. An YRC representative will also participate in the extended Steering Committee meetings of the centre once a month.

Student seminar series

In 2022 we started our student seminar series, open to all. Thanks to all the student who presented in 2022 and we are very much looking forward to the presentations in 2023.

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Quick Questions

YOUNG RESEARCHERS

Even Simonsen Haaland
PhD student (UiO)

'An old man with a taste for dark chocolate and 1970s music, disguised as a relatively young particle physicist that likes sports'

What is your background
I did my bachelor degree in Mathematics and Physics at the University of Stavanger, before moving to Oslo for my masters. I finished a masters degree in Subatomic Physics at the University of Oslo in 2017. For my master thesis I worked on a search for Supersymmetry with the ATLAS experiment.

What would people be surprised to know about you?
I can play the banjo!

Where would we usually find you?
These days you most often find me working, either at the university or somewhere else, trying to finish my PhD. When I'm not working you can find me in the skiing tracks, at the football pitch or in the swimming pool (sporty version), or close to a guitar, a beer or a quiz book (relaxed version).

What are you looking forward to in 2023?
I'm looking forward to finish my PhD!

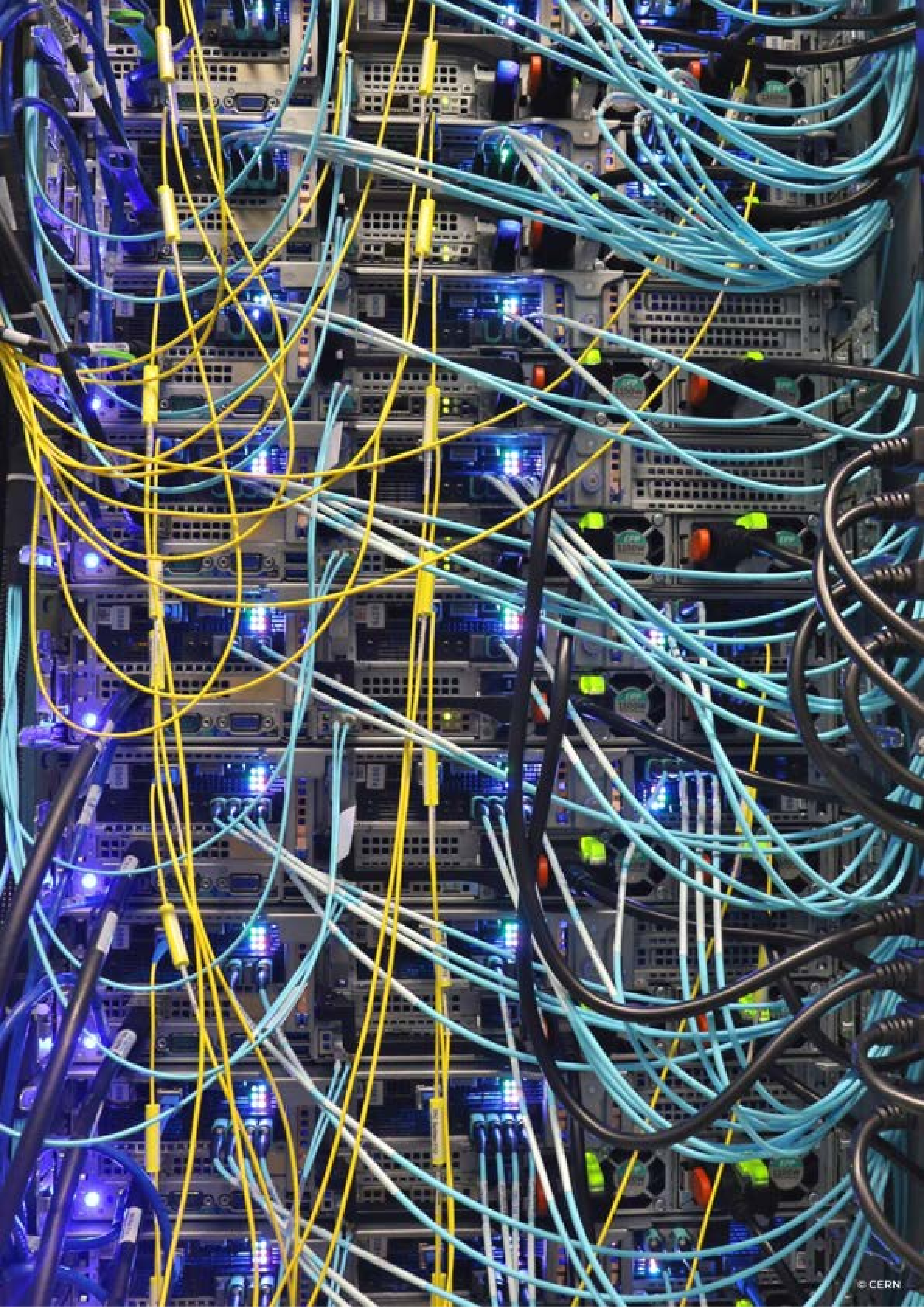
What is your current research project?
I'm working on data analysis with the ATLAS experiment. My PhD project is a search for new "exotic" particles using the data set recorded during Run II of the LHC. Specifically, I look for processes where a new neutral gauge boson (Z') is produced in association with dark matter candidate particles.

Why do you think this research is important?
Discovering physics beyond the Standard Model has turned out to be more tricky than many people expected, but I think there is still a great potential for discoveries and interesting results in the data set that was recorded during Run II of the LHC. Since we do not know what kind of physics there is beyond the Standard Model, it is important that we exploit the full potential of the data set we have, and investigate as many models and final states as possible. The particular final state I'm working with is one that has not yet been studied, neither by ATLAS nor CMS.

NorCC

NETWORKS

The centre networks offer, to a collection of people at all career stages, the opportunity to engage in scientific exchange and cooperation across locations. The networks will be dynamic and cover various topic areas throughout the evolution of the centre. They will change, expand and be supplemented by additional networks in the future if needed. Furthermore, such networks are highly important for the development of scientific communities and creates a platform to form new alliances, share ideas and increase the overall creative output. Moreover, it can inspire young hopefuls by connecting them to more advanced scientists - leading to growth within the scientific community.



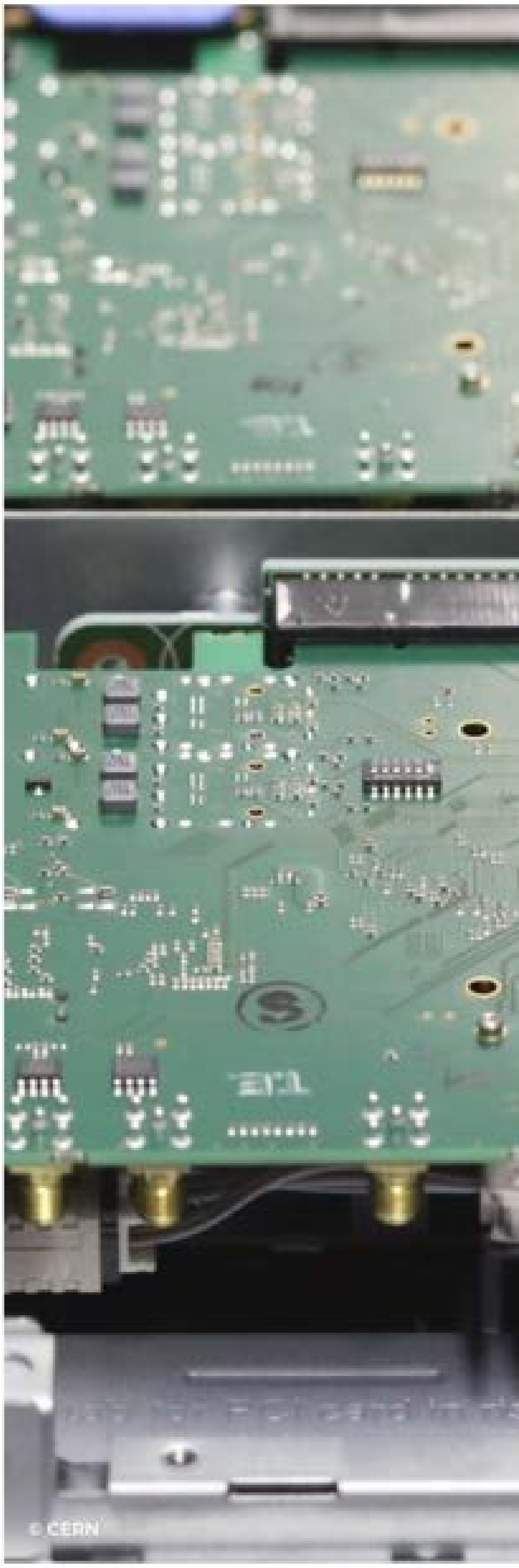
HIGHLIGHTS:
R&D Computing, Machine learning/AI

Leader
Eirik Gramstad

Deputy
Therese Berge Sjursen

Fundamental research today, in particle and nuclear physics, astrophysics and many other fields besides, often involves hugely complex experiments producing ever greater volumes of data and increasingly relying on advanced, computationally intensive simulations. Whilst experimental equipment is the basis of data collection, computing is at the heart of data exploitation - it enables researchers to turn streams of raw data into meaningful insights about the nature of the Universe. This issue will be particularly critical in the mid to late 2020s as the High Luminosity Large Hadron Collider (HL-LHC) begin to take data. Consequently, the research and development needed to ensure the computing workflows for such projects are sustainable needs to begin now: No computing, no physics! The continual and growing pressure on modern research caused by limited computing resources gives a strong incentive to develop novel techniques that enable full exploitation of data whilst keeping the required investment in computing infrastructure to a reasonable level. With the recent developments in computational accelerators and machine learning (ML), there has been a steadily increase in the use of ML at almost all levels of the data handling in large experiments. This will evolve to be one of the most important aspects in the future of computing within the physical sciences. This network will bridge the activities in the different groups connected to the centre, promoting collaboration across experiments and sharing of experience to ensure that Norwegian scientists can take a leading role in utilising new advances in computing in the fields of particle and nuclear physics.

In 2022 we arranged two workshops on topics relevant for the network. The first was a two-day conference at Geilo, focusing on common challenges using ML in analysing data from the ATLAS experiment, in particular within searches for new physics beyond the Standard Model. The workshop had good attendance from all groups involved in the particle physics activity in NorCC, in particular from young people. The network also arranged a satellite workshop on the day directly following the annual NorCC workshop in September, where people from activities across the whole centre presented their work and participated in discussions related to ML. Furthermore, the network also arranged a session during the workshop, covering topics on ML and data science, including a talk on the applications of the skills and tools of the HEP community related to R&D Computing and ML with a Norwegian perspective.



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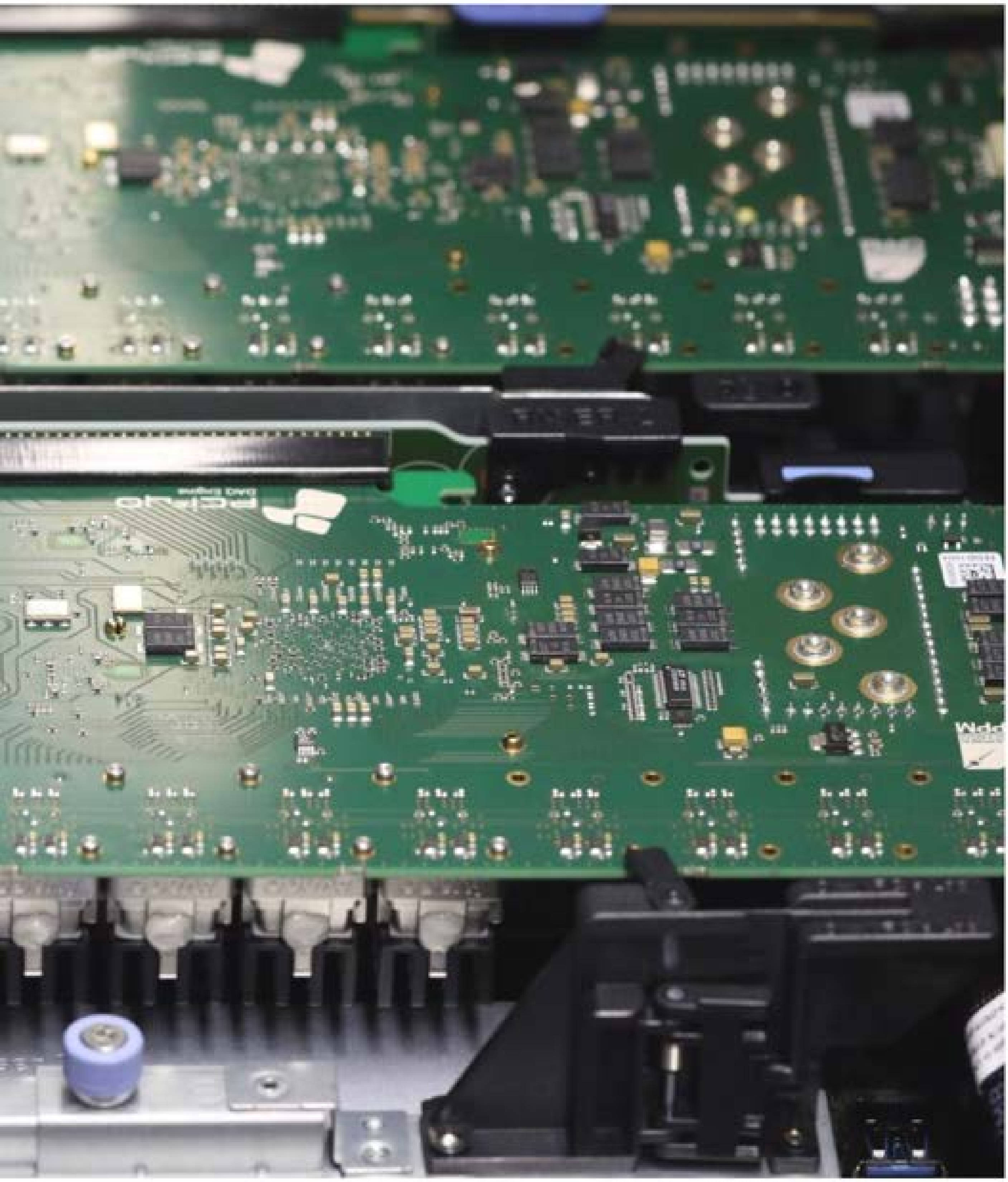

HIGHLIGHTS:
R&D Detectors & Electronics

Leader
Bjarne Stugu

Deputy
Ketil Røed

Silicon detectors and electronics are central in particle physics in order to identify, track and image high energy particles emitted during physics processes. Constant developments are required to match the increasingly demanding requirements of physics experiments. Traditionally Norway has had strong activity in detector developments, both sensor and electronics and with NorCC we have the opportunity to work more closely together on future detector technologies.

One of NorCC's largest research areas are on silicon detectors. Work is ongoing to study new properties such as particularly ultrathin curved sensors as being designed for ALICE ITS3. A preseries of radiation-hard 3D sensors was delivered by SINTEF to the ATLAS ITk in 2022, and will be subjected to extensive tests in 2023. Hopefully this will result in further deliveries of such sensors. During 2023, the RD53 collaboration will deliver the final designs of pixel readout electronics for both the ATLAS and CMS collaborations. Discussions are now taking place concerning how the available resources could be directed towards new development projects for future experiments. There is also development work on extremely thin detectors to be operated under extremely cold conditions as for AEGIS, where both electronics and sensors needs to operate at 4 K. In addition, we participate in development of novel CMOS sensors for future experiments as well as investigating Solid State Electron Multiplier concepts for LHCb.

The novel detector array Oscar at UiO OCL, based on LaBr3(Ce) scintillator crystals, are being considered for use in a new range of experiments at ISOLDE at CERN. A new emerging collaboration in 2021 is the investigation of laser drilling of silicon sensors by NTNU in collaboration with UiO and CERN. This research can take place thanks to modern cleanrooms, electronics and instrumentation laboratories (such as a micro-bonding machine, microscopes, a climate chamber, electronics, probe lasers and more) that can be shared between different activities.

The activity of this network can directly contribute to balancing the industrial return for the Norwegian contribution to CERN through collaboration with Norwegian companies.

International TWEPP 2022 conference (arranged by UiB&HVL)

The Topical Workshop on Electronics for Particle Physics (TWEPP) conference was arranged in Bergen from the 19th to 23rd of September in 2022. 205 scientific contributions divided between orals and posters is an all-time high, and close to 250 participants traveled from all over the world to a Bergen that was bathed in sunshine for the occasion. They experienced several interesting talks and posters on R&D projects related to potential technology advances for the next generation detectors. Of social activities, the participants enjoyed a boat trip in the fjords in beautiful weather and a conference dinner with a spectacular view at the restaurant at Mount Floien.

The scientific committee from CERN and the participants showed great appreciation for the arrangement, and for the opportunity to finally meet again after 2 years of cancellations and online conferences due to the pandemic.

TWEPP participants

Quick Questions

YOUNG RESEARCHERS

Sigurd Nese
PhD student (UiO)

'A physics-obsessed PhD student who is simultaneously focused and too easily distracted'

What is your background?
I got my Bachelor of Physics in Tromsø, and moved to Bergen to study theoretical particle physics. My master thesis was on the magnetic moment of neutrinos in theories beyond the Standard Model.

Where would we usually find you?
Probably in the physics building at UiO.

How has the year of 2022 been?
For me it was a year with a lot of change, as I finished my master's degree and moved twice. Definitely one of the more stressful years of my life, but it had a lot of excitement as well!

What are you looking forward to in 2023?
Exploring and getting to know Oslo, and traveling to CERN!

What do you plan to do after this period of your life?
Hopefully more physics.

Choose one song to play every time you walked into a room, what song would you choose and why?
Anything by Vulfpeck.

What is your current research project?
I will look at photoproduction of charm in heavy-ion collisions in data from the ALICE detector.

Why did you choose this field?
The subatomic world has always fascinated me. And being able to get hands-on with data from CERN was very appealing!

Quick Questions

YOUNG RESEARCHERS

Ruben Guevara
Master student (UiO)

'Man with access to super computers looking for WIMPs at the local detector'

What is your background?
I completed my Physics and Astronomy bachelor at the University of Oslo.

What would people be surprised to know about you?
I still need a calculator to do multiplications at a reasonably fast speed.

Where would we usually find you?
I usually sit in the HEP masters room at UiO hidden away in my corner. If not, I'm probably hidden away in a corner at home or the gym.

How has the year of 2022 been?
It was an amazing year for me where I finally feel like I am doing actual physics, especially now that I started my masters thesis and have attended multiple conferences with NorCC ❤

What are you looking forward to in 2023?
Finishing my thesis and seeing what the future holds!

Choose one song to play every time you walked into a room, what song would you choose and why?
"Love Sosa" - Chief Keef. Hardest song of all time.

What is your current research project?
I am doing a model independent search for dark matter (WIMPs) in a dilepton + missing energy final states using various machine learning methods.

Why did you choose this field?
I really enjoy understanding things on a fundamental level, and as far as testable physics goes, experimental high energy physics is the best we've got!

Why do you think this research is important?
Other than helping every scientists with their curiosity as of what dark matter is, the tools needed to get an empirical answer to this mystery would benefit society as a whole, as most technology created for physics has in the past.

What would you like the impact of your project to be?
That at least one of my machine learning methods is useful for someone in this field, or at least the core ideas behind them.

What do you see as the most important issue in your field today?
I would say that the trigger system on detectors is an important problem to solve as I am currently looking at dark matter, because the trigger system would most likely throw away events that are not deemed "status quo important".

Which fictional character do you identify with the most and why?
Goku from Dragon Ball. Because he never gives up no matter how hard things get and always sees the best in everyone.

04
OUTREACH

HIGHLIGHTS: OUTREACH

After several difficult years, we are very glad to see in 2022 that visits and outreach activities resume!

Outreach is an important part of our activities since long before the start of NorCC. From more than 1200 Norwegian pupils at visiting CERN each year to the very attractive yearly masterclasses where hundreds of pupils gets a taste of High Energy Physics at the Universities. In 2022 was also a year of celebrating 10 years since the discovery of the Higgs boson, with celebration at CERN and in Norway. One of the main focuses of our activities is recruitment to the physics programmes and the education of teachers, as well as and to inform and promote our research to the general public.

Higgs 10 year celebration

During 2022 we celebrated 10 the years anniversary of the discovery of the Higgs boson at CERN. This is of particular interest due to the many Norwegian contributions to this discovery. The Higgs saga is by no means now over, currently Norwegian scientists are working hard to study the Higgs boson and its impact on nature, and we are even talking about building a Higgs factory in the future!

NorCC celebrated the anniversary by a special event during Smmer@CERN with a special lecture by John Ellis. In addition, the Higgs discovery was celebrated by a special dinner during our yearly workshop in Oslo. Last but not least several articles were written celebrating the event and discussing its impact, in particular by Øystein Middtun, Bjarne Stugu and Alex Read.

New podcast: God fysikk

Ida T. Storehaug has started a podcast during the pandemic to discuss physics topics which is of interest to her and othters filling a gap after tha lack of seminars. Several colleagues have visited her podcast such as Gert Kluge, Anders Kvellestad and Eli B. Rye, discussing particle physics, astrophysics and theoretical physics.

Abels tårn

"Abels tårn" is a popular science radio program and podcast, where three researchers answer questions from the listeners and try to find the truth about how the universe works. During 2022, three NorCC researchers have been guests on this show: Are Raklev, Ida T. Storehaug and Anders Kvellestad.

European Particle Physics Communication Network (EPPCN)

Norway participate EPPCN where Hilde Lynnebakken is the representative for Norway. The 32. meeting took place in November 2022.

European Particle Physics Outreach Group (IPPOG)

IPPOG is network of scientists, science educators and communication specialists working across the globe in science education and public engagement for particle physics. Norway participate through NorCC in this network and is represented by Farid Ould-Saada.

Masterclass 2022 in Bergen

In 2022, HVL and UiB collaborated on arranging a Masterclass in particle physics (organized by the International Particle Physics Outreach Group - IPPOG). The event was carried out as an online meeting where we had 19 participants from 5 high schools in Bergen and the surrounding area. The program was built around the scheme from IPPOG which is based on analysis of data from ATLAS followed by an online meeting with CERN researchers. To increase the learning outcomes of the students, we created our own program in advance with introductory lectures on the standard model and experimental particle physics. We also introduced the students to the current study offers at HVL and UiB
In 2023 the plan is to arrange again, as before Covid, master classes both in Oslo and in Bergen..

Z-Path

The overall goal of the Z-path project (since 2017 receiving funding from the Olav Thon Foundation) is to bring the latest developments and discoveries within high energy physics to the class room [1]. In 2021 the Zpath Galaxy portal [2] was developed and finally released, enabling access to hardware resources, software packages and experimental data for anyone to analyze, including, among others, the full 13 TeV ATLAS open data release. In principle anyone can create a user and log into the portal. One then immediately get access to a limited amount of computing resources, with all the needed software pre-installed. The portal provides several means of building up an analysis and analyse experimental data; either through compiled C++ programs or interactively using jupyter-notebooks. The portal was extensively used in the Research Based Particle Physics course at the University of Oslo during spring 2022, and other courses at UiO are planning to make use of the resources for the next semesters. The portal, accompanying software and the experimental data will continue to be developed and extended in the future, to always follow the heart-beats of the leading high energy physics experiments. Moreover the Z-path project enables students, as part of one of their courses in particle physics, to take part in the complete process from detector building at CERN, through testing, running and commissioning before developing analyses looking at the data recorded by the detectors. Unfortunately, due to the Covid-19 pandemic, it has been difficult to bring students to CERN the past few years, but we will re-start this activity in 2023.

[1] http://zpathweb.hepp.uiocloud.no/Zpath
[2] https://galaxy-hepp.hpc.uio.no/

High School visits to CERN

During pre-pandemic years around 1200 Norwegian high school students visited CERN every year. A core team of Norwegian CERN helps to make the visits an event to remember and are crucial for recruitment not only to resarch at CERN but also to physics and natural sciences in general.

In 2022 we were happy to welcome back the first visitors to CERN, and the first high school classes from Norway is expected back to CERN in 2023!

School visits in Norway

In 2022 first requests have started to come to visit schools in Norway. One of the first schools was Marker skole in Ørje. Four talks were held for 7. 8. 9. and 10tth grade. Enthusiastic pupils and teachers and very interesting questions made the visit a pleasure.

Several more school visits are now planned for 2023 and we very much look forward to meet with pupils and teachers and talk about physics!

Recruitment to CERNs student programs

During 2022 we have continued to improve on our recruitment program to the CERN student programs (summer student, technical student, PhD student). The positions have been announced to a wider audience and with attractive posters attached. In addition, key persons at CERN visited NTNU for the first time again after Covid-19. We hope that this effort will raise the amount of Norwegians at CERN but also inspire younger students to apply for masters and similar within these fields. This work will be further developed in 2022 and can build on the fundament already created.

05
APPENDICES

PUBLICATIONS

The ATLAS and ALICE papers listed below were published between January 1 and March 3. Since then, the four LHC experiments have frozen all publications due to the war in Ukraine. Papers are still prepared and made publicly available through the CERN Document Server (CDS), but they will not be published in scientific journals before the collaborations have agreed on how to acknowledge work by Russia, JINR and Belarus.

ATLAS Collaboration (2022)

1) *Study of $B_c^+ \rightarrow J/\psi D_s^+$ and $B_c^+ \rightarrow J/\psi D_s^{*+}$ decays in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector.* JHEP, 08:087, 2022

2) *Search for neutral long-lived particles in pp collisions at $\sqrt{s}$ = 13 TeV that decay into displaced hadronic jets in the ATLAS calorimeter.* JHEP, 06:005, 2022.

3) *Search for events with a pair of displaced vertices from long-lived neutral particles decaying into hadronic jets in the ATLAS muon spectrometer in pp collisions at $\sqrt{s}$=13 TeV.* Phys. Rev. D, 106(3):032005, 2022.

4) *Measurements of jet observables sensitive to b-quark fragmentation in $t\bar{t}$ events at the LHC withthe ATLAS detector.* Phys. Rev. D, 106(3):032008, 2022.

5) *Measurements of differential cross-sections in top-quark pair events with a high transverse momentum top quark and limits on beyond the Standard Model contributions to top-quark pair production with the ATLAS detector at $\sqrt{s}$ = 13 TeV.* JHEP, 06:063, 2022.

6) *Measurement of the polarisation of single top quarks and antiquarks produced in the t-channel at $\sqrt{s}$ = 13 TeV and bounds on the tWb dipole operator from the ATLAS experiment.* JHEP, 11:040, 2022.

7) *Search for invisible Higgs-boson decays in events with vector-boson fusion signatures using 139 fb−1 of proton-proton data recorded by the ATLAS experiment.* JHEP, 08:104, 2022.

8) *Search for resonant pair production of Higgs bosons in the $b\bar{b}b\bar{b}$ final state using pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector.* Phys. Rev. D, 105(9):092002, 2022.

9) *Search for type-III seesaw heavy leptons in leptonic final states in pp collisions at $\sqrt{s}$ = 13 T eV with the ATLAS detector.* Eur. Phys. J. C, 82(11):988, 2022.

10) *Two-particle Bose–Einstein correlations in pp collisions at $\sqrt{s}$ = 13 TeV measured with the ATLAS detector at the LHC.* Eur. Phys. J. C, 82(7):608, 2022.

11) *Measurements of the Higgs boson inclusive and differential fiducial cross-sections in the diphoton decay channel with pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector.* JHEP, 08:027, 2022.

12) *Direct constraint on the Higgs-charm coupling from a search for Higgs boson decays into charm quarks with the ATLAS detector.* Eur. Phys. J. C, 82:717, 2022.

13) *Measurements of Higgs boson production cross-sections in the $H \rightarrow \tau^+\tau^-$ decay channel in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector. JHEP, 08:175, 2022.*

14) *Search for single production of a vectorlike T quark decaying into a Higgs boson and top quark with fully hadronic final states using the ATLAS detector.* Phys. Rev. D, 105(9):092012, 2022.

15) *Search for long-lived charginos based on a disappearing-track signature using 136 fb−1 of pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector.* Eur. Phys. J. C, 82(7):606, 2022.

In addition to the above published papers, around 70 more were prepared by the ATLAS collaboration in 2022.

ALICE Collaboration (2022)

1) *First study of the two-body scattering involving charm hadrons.* Phys. Rev. D, 106(5):052010, 2022.

2) *Measurement of beauty production via non-prompt D0 mesons in Pb-Pb collisions at $\sqrt{s_{NN}}$= 5.02 TeV.* JHEP, 12:126, 2022.

3) *Multiplicity dependence of charged-particle jet production in pp collisions at $\sqrt{s}$ = 13 TeV.* Eur. Phys. J. C, 82(6):514, 2022.

In addition to the above published papers, around 50 more were prepared by the ALICE collaboration in 2022.

Other publications (2022)

1) Camper, A., Røhne, O. M., Sandaker, H., et al. AEGIS Collaboration, *High-resolution MCP-TimePix3 imaging/timing detector for antimatter physics. Measur. Sci. Tech. 33 (2022) 11, 115105*

2) Camper, A., Røhne, O. M., Sandaker, H., et al. AEGIS Collaboration, *Experiments with mid-heavy antiprotonic atoms in AEg¯IS*, PoS PANIC2021 (2022) 446

3) Camper, A., Røhne, O. M., Sandaker, H., et al. AEGIS Collaboration, *Control system for ion Penning traps at the AEgIS experiment at CERN*. J.Phys.Conf.Ser. 2374 (2022) 1, 012038

4) Camper, A., Røhne, O. M., Sandaker, H., et al. AEGIS Collaboration, *Development of a detector for inertial sensing of positronium at AEḡIS (CERN)*, J.Phys.Conf.Ser. 2374 (2022) 1, 012037

5) Van Rijnbach, M., Sandaker, H., et al. *MALTA3: Concepts for a new radiation tolerant sensor in the TowerJazz 180 nm technology, Nucl.Instrum.Meth.A 1040 (2022) 167226*

6) Van Rijnbach, M., Sandaker, H., et al. *Timing performance of radiation hard MALTA monolithic Pixel sensors*, Nucl.Instrum.Meth.A 1041 (2022) 167390

7) Van Rijnbach, M., Sandaker, H., et al. *Radiation hardness and timing performance in MALTA monolithic pixel sensors in TowerJazz 180 nm*, JINST 17 (2022) 04, C04034

8) Van Rijnbach, M., Sandaker, H., et al. *A 1μμW Radiation-Hard Front-End in a 0.18-μμm CMOS Process for the MALTA2 Monolithic Sensor*, IEEE Trans.Nucl.Sci. 69 (2022) 6, 1299-1309

9) Van Rijnbach, M., Sandaker, H., et al. *Latest developments and characterisation results of the MALTA sensors in TowerJazz 180nm for High Luminosity LHC*, PoS EPS-HEP2021 (2022) 818

10) Halvorsen M., et al., The Silicon Electron Multiplier sensor, Nucl.Instrum.Meth.A 1041 (2022) 167325

11) Halvorsen M., et al., Considerations for the VELO detector at the LHCb Upgrade II, LHCb-PUB-2022-001, CERN-LHCb-PUB-2022-001

12) F. Reaz, K. N. Sjobak, E. Malinen, N. Edin, E. Adli, *Sharp dose profiles for high precision proton therapy using focused proton beams*, Nature Sci Rep 12, 18919 (2022)

13) L.G. Pedersen et al., *Coulomb excitation of 222Rn*, Phys. Rev. C 105, 024323 (2022)

14) I . Papp, L. Bravina, L.P. Csernai, et al., *Kinetic Model Evaluation of the Resilience of Plasmonic Nanoantennas for Laser-Induced Fusion*, PRX Energy 2022;Volum 1, 023001.

15) L. Bravina et al, *Status and initial physics performance studies of the MPD experiment at NICA*, The European Physical Journal A volume 58, Article number: 140 (2022)

16) L. Bravina, E. Zabrodin, et al., *Triple high energy nuclear and hadron collisions - a new method to study QCD phase diagram at high baryonic densities*, The European Physical Journal A volume 58, Article number: 169 (2022)

17) M. Teslyk, L. Bravina, E. Zabrodin, *Total and Partial Shear Viscosity in Heavy-Ion Collisions at Energies of BES, FAIR and NICA*, Symmetry 2022, 14(4), 634

18) L. Bravina, E. Zabrodin et al., *Nature of particles azimuthal anisotropy at low and high transverse momenta in ultrarelativistic A+ A collisions*, Physica Scripta 2022, 97 064007

19) M. Teslyk, L. Bravina, E. Zabrodin et al., *Unruh Effect and Information Entropy Approach*, Particles 2022, 5(2), 157-170.

PEOPLE

NorCC welcomes all the institutes, researchers and students working on CERN-related Research. Currently members of the centre, as listed below, are all persons that profit from the funding of NorCC, either directly by salaries and such, or indirectly by using the experimental membership of experiments at CERN. We want to welcome all that wish to participate and work on CERN-related research. Persons listed below are those registered in NorCC in 2022, either by their activity leaders or through direct contact with the NorCC administration (if you are not on the list for 2022 we are more than happy to add you or if you joined later to the current list for 2023).

Senior Academic Staff

Activity	University	Name	Function
Particle Physics	HVL	Therese Berge Sjursen	Associate Professor
Particle Physics	HVL	Trygve Buanes	Associate Professor
Particle Physics	HVL	Dag Toppe Larsen	Associate Professor
Particle Physics	HVL	Steffen Mæland	Associate Professor
Particle Physics	UiB	Gerald Eigen	Professor
Particle Physics	UiB	Anna Lipniacka	Professor
Particle Physics	UIB	Bjarne Stugu	Professor
Particle Physics	UiO	Farid Ould-Saada	Professor
Particle Physics/Theory	UiO	Are Raklev	Professor
Particle Physics	UiO	Alexander L. Read	Professor
Particle Physics +	UiO	Heidi Sandaker	Professor
Nuclear Physics	HVL	Håvard Helstrup	Professor
Nuclear Physics	HVL	Kristin Fanebust Hetland	Associate Professor
Nuclear Physics	HVL	Bjarte Kileng	Associate Professor
Nuclear Physics	UiB	Johan Alme	Associate Professor
Nuclear Physics	UiB	Joakim Ingemar Nystrand	Professor
Nuclear Physics	UiB	Dieter Röhrich	Professor
Particle Physics/Nuclear Physics/Theory	UiB	Konrad Tywoniuk	Associate Professor
Nuclear Physics	UiB	Kjetil Ullaland	Professor
Particle Physics/Nuclear Physics/Theory	UiO	Larissa Bravina	Professor
Nuclear Physics	UiO	Ketil Røed	Professor
Nuclear Physics	UiO	Toralf Bernhard Skaali	Professor Emeritus
Nuclear Physics	UiO	Trine Spedstad Tveter	Professor
Nuclear Physics	USN	Jørgen Andre Lien	Associate Professor
Accelerator Physics	UiO	Erik Adli	Professor
Low Energy Nuclear Physics	UiO	Tor Bjørnstad	Professor Emeritus
Low Energy Nuclear Physics	UiO	Ann-Cecilie Larsen	Associate Professor
Low Energy Nuclear Physics	UiO	Andreas Görgen	Professor
Low Energy Nuclear Physics	UiO	Magne Guttormsen	Professor Emeritus
Low Energy Nuclear Physics	UiO	Sunniva Siem	Professor
Technology	NTNU	Filippo Berto	Professor
Technology	NTNU	Armin Hafner	Professor
Technology	NTNU	Morten Hovd	Professor
Technology	NTNU	Morten Kildemo	Professor
Technology	NTNU	Dimosthenis Peftitsis	Professor
Technology	NTNU	Kristin Y. Pettersen	Professor
Technology	NTNU	Irina Sorokina	Professor
Technology	NTNU	Are Strandlie	Professor
Technology	NTNU	Øystein Widding	Professor
Technology	NTNU	Jørn Wroldsen	Professor
Technology	UiA	Øystein Midttun	Professor
Education, Dissemination and Exploitation	UiO/CERN	Steinar Stapnes	Professor

Researchers and Postdoctoral Fellows

Activity	University	Name	Function
Particle Physics	UiB	Julia Isabell Djuvsland	Researcher
Particle Physics	UiB	Nikolai Fomin	Postdoctoral Fellow
Particle Physics	UiB	Simen Hellesund	Postdoctoral Fellow
Particle Physics	UiB	Bertrand Martin dit Latour	Researcher
Particle Physics	UiB	Graham Richard Lee	Postdoctoral Fellow
Particle Physics	UiO	David Gordon Cameron	Researcher
Particle Physics	UiO	James Richard Catmore	Researcher
Particle Physics	UiO	Eirik Gramstad	Researcher
Particle Physics/Theory	UiO	Anders Kvellestad	Postdoctoral Fellow
Particle Physics	UiO	Ole Myren Røhne	Researcher
Nuclear Physics	UiO	Anastasia Merzlaya	Postdoctoral Fellow
Nuclear Physics	UiB	Max Rauch	Postdoctoral Fellow
Nuclear Physics	UiB	Matthias Richter	Researcher
Nuclear Physics	UiB	Boris Wagner	Researcher
Nuclear Physics	UiO	Ionut Christian Arsene	Researcher
Nuclear Physics	UiO	Fiorella Fionda	Researcher
Accelerator Physics	UiO	Kyrre Ness Sjøbæk	Researcher
Low Energy Nuclear Physics	UiO	Antoine Camper	Researcher
Low Energy Nuclear Physics	UiO	Tomas Eriksen	Postdoctoral Fellow
Low Energy Nuclear Physics	UiO	Frank Bello Garrote	Researcher
Low Energy Nuclear Physics	UiO	Eda Sahin	Researcher
Technology	NTNU	Pierre Andre Calhau Barroca	Postdoctoral Fellow

Technical, Supporting and CERN Staff

Activity	University	Name	Function
Particle Physics	CERN	Victor Coco	CERN Staff
Particle Physics	CERN	Petra Riedler	CERN Staff
Particle Physics	UiO	Kjell Martin Danielsen	Senior Engineer
Particle Physics	UiO	Ole Dorholt	Senior Engineer
Particle Physics	UiO	Vincent Garonne	Senior Engineer
Particle Physics	UiO	Maiken Pedersen	Senior Engineer
Particle Physics	UiB	Øystein Bergsagel	Senior Engineer
Particle Physics	UiB	Thomas Poulianitis	Senior Engineer
Particle Physics/Nuclear Physics	UiB	Attiq Ur Rahman	Senior Engineer
Nuclear Physics	UiB	Ganesh Tambave	Chief Engineer
Nuclear Physics	UiB	Shiming Yang	Senior Engineer
Nuclear Physics	UiO	Jon Christopher Wikne	Senior Engineer
Technology	CERN	Giovanni Anelli	CERN Staff
Technology	CERN	Marco Calviani	CERN Staff
Technology	CERN	Mario Di Castro	CERN Staff
Technology	CERN	Michael Doser	CERN Staff
Technology	CERN	Konstantinos Papastergiou	CERN Staff
Technology	CERN	Bart Verlaat	CERN Staff
Technology	UiA	Søren Kragholm	Senior Advisor

Technical, Supporting and CERN Staff (continues)

Activity	University	Name	Function
Technology	CERN	Brad Schofield	CERN Staff
Technology	CERN	Walter Wünsch	CERN Staff
Education, Dissem. and Exploit.	CERN	Odd Øyvind Andreassen	CERN Staff
Education, Dissem. and Exploit.	CERN	Nils Høimyr	CERN Staff
Education, Dissem. and Exploit.	UiO/CERN	Ole Petter Nordahl	Industry Liaison Officer/Technology Transfer Officer
Education, Dissem. and Exploit.	CERN	Lars Tore Rødne	CERN Staff
Education, Dissem. and Exploit.	CERN	Jens Vigen	CERN Staff
Education, Dissem. and Exploit.	UiO	Hilde Lynnebakken	Communication Advisor, EPPCN
Management	UiO	Eli B. Rye	Administrativ Coordinator
Management	UiO	Heidi Sandaker	Centre Leader
Management	UiO	Nina Waage	Administrativ Coordinator

Technical Students

Activity	University	Name
Education, Dissemination and Exploitation	CERN	Vetle Elvebakken Andersen
Education, Dissemination and Exploitation	CERN	Ola Tranum Arnegård
Education, Dissemination and Exploitation	CERN	Andreas Klavenes Berg
Education, Dissemination and Exploitation	CERN	Marianne Brekkum
Education, Dissemination and Exploitation	CERN	Eivind Dalane
Education, Dissemination and Exploitation	CERN	Erlend Flatland
Education, Dissemination and Exploitation	CERN	Fredrik Sommerfelt Grønvold
Education, Dissemination and Exploitation	CERN	Anders Gårud
Education, Dissemination and Exploitation	CERN	Harald Minde Hansen
Education, Dissemination and Exploitation	CERN	Ingebrigt Hovind
Education, Dissemination and Exploitation	CERN	Eirik Jaccheri Høydalsvik
Education, Dissemination and Exploitation	CERN	Henrik Sørgård Johannessen
Education, Dissemination and Exploitation	CERN	Jenny Lunde
Education, Dissemination and Exploitation	CERN	Jan Malamønt
Education, Dissemination and Exploitation	CERN	Ida Mjelde
Education, Dissemination and Exploitation	CERN	Ole Kristian Morud
Education, Dissemination and Exploitation	CERN	Jørgen Teig
Education, Dissemination and Exploitation	CERN	Marcel Rød
Education, Dissemination and Exploitation	CERN	Lasse Tjernæs Wardenær
Education, Dissemination and Exploitation	CERN	Aron Strøm Werkland

Doctoral Research Fellows

Activity	University	Name
Particle Physics	HVL	Aurora Grefsrud
Particle Physics	HVL	Tarje Hillersøy
Particle Physics	UiB	Erlend Aakvaag
Particle Physics	UiB	Sohaib Hassan
Particle Physics	UiB	Simon Kristian Huiberts
Particle Physics	UiB	Are Sivertsen Træet
Particle Physics	UiO	Viktor Ananiev
Particle Physics/Theory	UiO	Lasse Braseth
Particle Physics/Theory	UiO	Tore Klungland
Particle Physics	UiO/CERN	Marius Mahlum Halvorsen
Particle Physics	UiO	Andreas L. Heggelund
Particle Physics	UiO	Even S. Håland
Particle Physics	UiO	Oda Langrekken
Particle Physics	UiO/CERN	Milou van Rijnbach
Particle Physics	UiO	Eli Bæverfjord Rye
Nuclear Physics	HVL	Haakon Andre Reme-Ness
Nuclear Physics	HVL	Maksim Melnik Storetvedt
Nuclear Physics	UiB	Tea Bodova
Nuclear Physics	UiB	Viljar Nilsen Eikeland
Nuclear Physics	UiB	Magnus Rentsch Ersdal
Nuclear Physics	UiB	Hira Ilyas
Nuclear Physics	UiB	Ingrid McKibben Lofnes
Nuclear Physics	UiB	Jon-Are Sætre
Particle Physics/Nuclear Physics/Theory	UiB	Adam Takacs
Particle Physics/Nuclear Physics/Theory	UiB	Johannes Hamre Isaksen
Particle Physics/Nuclear Physics/Theory	UiB	Alexandre Falcao
Nuclear Physics	UiO	Qasim Waheed Malik
Nuclear Physics	UiO	Alexandra Neagu
Nuclear Physics	UiO	Emilie Haugland Solheim
Nuclear Physics	UiO	Ida Torkjellsdatter Storehaug
Nuclear Physics	USN	Rune Langøy
Accelerator Physics	UiO	Jiawei Cao
Low Energy Nuclear Physics	UiO	Natali Gusakova
Low Energy Nuclear Physics	UiO	Vetle Wegner Ingeberg
Low Energy Nuclear Physics	UiO	Wanja Paulsen
Low Energy Nuclear Physics	UiO	Line Gaard Pedersen
Low Energy Nuclear Physics	UiO	Fabio Zeiser
Low Energy Nuclear Physics	UiO/CERN	Gunn Khatri
Low Energy Nuclear Physics	UiO/CERN	Tim Wolz
Low Energy Nuclear Physics / Technology	NTNU/CERN	Natali Gusakova
Technology	NTNU/CERN	Gianluca d'Antuono
Technology	NTNU/CERN	Pierre Andre Calhau Barroca
Technology	NTNU/CERN	Timm Felix Baumann
Technology	NTNU/CERN	Victoria Madeleine Bjelland
Technology	NTNU/CERN	Luca Contiero
Technology	NTNU/CERN	Thuy Do
Technology	NTNU/CERN	Faiq Ghawash
Technology	NTNU/CERN	Emanuele Solfiti

Master Students (not complete)

Activity	University	Name
Particle Physics	HVL	Øystein Helmersen Vikane
Particle Physics	HVL	Johan Bakøy
Particle Physics	HVL	Isabel Foster
Particle Physics	HVL	Tobias Kristensen
Particle Physics	HVL	Dovydas Sprindys
Particle Physics	HVL	Andreas Valen
Particle Physics	UiB	Rasmus Brekke
Particle Physics	UiB	Tor Gunnar Hagen
Particle Physics	UiB	Sigurd Haugen
Particle Physics	UiB	Wai Chun Leung
Particle Physics	UiB	Wai Kit Leung
Particle Physics	UiO	Tobias Opdalshei Baumann
Particle Physics	UiO	Håkon D. Fossheim
Particle Physics	UiO	Sakarias Frette
Particle Physics	UiO	Martin Føll
Particle Physics	UiO	Olav Grønbech
Particle Physics	UiO	Ruben Guevara
Particle Physics	UiO	William Hirst
Particle Physics	UiO	Andreas Middelthon
Particle Physics	UiO	Erling Nupen
Particle Physics/Theory	UiO	Hedvig Borgen Reiersrud
Particle Physics/Theory	UiO	Andrea Marthinussen
Particle Physics/Theory	UiO	Carl-Martin Fevang
Nuclear Physics	HVL	Haakon Andre Reme-Ness
Nuclear Physics	HVL	Maksim Melnik Storetvedt
Nuclear Physics/Particle Physics/Theory	UiB	Håvard Gullanger
Nuclear Physics	UiB	Sander Jensen
Nuclear Physics/Particle Physics/Theory	UiB	Ida-Marie Johansson
Nuclear Physics	UiB	Sivert Olsen Løvaas
Nuclear Physics/Particle Physics/Theory	UiB	Mathias Nilsen
Nuclear Physics	UiB	Lena Setterdahl
Nuclear Physics/Particle Physics/Theory	UiB	Kristoffer Skjelanger
Nuclear Physics	UiB	Emilie Solheim
Nuclear Physics	UiB	Ingrid Stuen
Nuclear Physics	UiB	Fredrik Widerøe
Nuclear Physics	UiB	Thomas Økland
Accelerator Physics	UiO	Eric D. Fackelman
Low Energy Nuclear Physics	UiO	Jan Malamant