UVIC AND VISPA POSTDOC DR. ELLIS KAY ATTACHES OPTICAL FIBRE DATA PATHWAYS FOR AN UPGRADE TO THE ATLAS EXPERIMENT AT THE CERN LARGE HADRON COLLIDER (LHC).
Geneva, Switzerland

The Large Hadron Collider (LHC) at the CERN laboratory is the highest energy particle collider in operation. The ATLAS detector is one of two multipurpose detectors designed to record high energy collisions at the LHC, and the UVic ATLAS group has been a member of the ATLAS Collaboration since its foundation in 1992. Michel Lefebvre acted as founding spokesperson of the ATLAS Canada collaboration, and Rob McPherson recently served as Deputy Spokesperson of the worldwide ATLAS collaboration. VSIP members involved in ATLAS also include Justin Albert, Richard Keeler, Bob Kovalewski, Leonid Kurchaninov, Heather Russell, Randall Sobie and Isabel Trigger. UVic was instrumental in the initial design and construction of the ATLAS Liquid Argon Endcap calorimeters, and is now playing key roles in the upgrades of the readout electronics of the calorimeters needed for the higher rates of LHC data taking planned for the coming two decades. UVic has also led the construction, installation and commissioning of the massive small-strip gap chamber (STGC) detector, half of the ATLAS Muon New Small Wheel upgrade project which has recently been completed and will be commissioned with proton collisions in 2022 and operate for the duration of ATLAS to about 2040. UVic also plays critical roles in ATLAS computing, with the Kubernetes cloud on the UVic Arbiter cluster contributing the most computing cores of any comparable site in Canada.

Bottom row of photos (left to right):
- Two completed STGC wedges at CERN ready for installation into ATLAS for use in the higher-rate upgraded LHC. Pictures from left to right are UVic postdocs Gerardo Vasquez and Rimsky Rojas, and UVic MSc student Leesa Brown.
- UVic postdoc Ellis Kay installing and testing readout electronics for the first phase of the ATLAS endcap calorimeter upgrade for higher rate operation in the upgraded LHC. UVic postdoc Clement Camincher also worked on the LAr system.

ATLAS Muon New Small Wheel (NSW) being installed underground in ATLAS.

Photo is from July 2021, when the first NSW (NSW-A) was installed in ATLAS. This wheel is now essentially fully commissioned, and we’re actively working on NSW-C in the ATLAS pit during early 2022. Again, UVic postdoc Gerardo Vasquez is coordinating the STGC commissioning in the ATLAS pit (both wheels), and UVic ATLAS PhD student Juan Cristóbal Rivera and postdoc Rimsky Rojas are also active in the effort.
Members of VISPA are currently working with others in Canada and around the world towards the realization of Hyper-Kamiokande, a 250kton water Cherenkov detector in Japan. When completed later this decade, it will be the world’s largest detector for neutrinos in the range of a few MeV to tens of GeV, covering the solar, supernova, atmospheric, and accelerator neutrino energy range.

The goal of the project is wide ranging, from precise neutrino oscillation measurement in accelerator and atmospheric neutrinos, neutrino astronomy of solar and supernova neutrinos, and searches for new physics phenomena such as proton decay and dark matter. An schematic drawing of the detector is shown below.

One of the main goals of Hyper-Kamiokande is to discover CP violation in neutrino oscillations. This is done by observing a difference in the muon neutrino to electron neutrino transition probability between neutrinos and anti-neutrinos. Hyper-Kamiokande can be sensitive to even a small amount of CP violation—the highest luminosity particle collider in operation. Luminosity is a measure of the number of particles in the colliding beams squeezed through a given space in a given time and SuperKEKB achieved the world record of 3.9x10^{33} per square centimetre per second in December 2021, roughly double that of the proton-proton collisions at the LHC. In the coming years, SuperKEKB is set to further increase its luminosity and will deliver to Belle II more than 30 times more electron-positron collision data than all previous generation experiments at 10GeV combined.

The BEll Extensive Los Angeles Narrow (BELLE II) experiment is looking for evidence of new physics at the precision frontier in the collisions of electrons and positrons (i.e. the antimatter equivalent of electrons) at a centre-of-mass energy of around 10 GeV. Belle II measures properties of particles produced in the SuperKEKB e+e- collider—the highest luminosity particle collider in operation. Luminosity is a measure of the number of particles in the collisions, and Belle II will span a range of off-axis beam angles to better understand the neutrino flux.

The Intermediate Water Cherenkov Detector (IWCD) will span a range of off-axis beam angles to better understand neutrino cross sections by using multi-PMT detectors. The University of Victoria is the lead institution for the projected funded by the Canada Foundation for Innovation to construct multi-PMT detectors for the IWCD.

We lead the EMPHATIC experiment to measure hadron interaction cross sections to better understand the neutrino flux. We lead the crucial near detector project for Hyper-Kamiokande. The Intermediate Water Cherenkov Detector (IWCD) will span a range of off-axis beam angles to better understand neutrino cross sections by using multi-PMT detectors. The University of Victoria is the lead institution for the projected funded by the Canada Foundation for Innovation to construct multi-PMT detectors for the IWCD.

The Water Cherenkov Test Experiment (to be undertaken at CERN in the coming years) to test multi-PMT detectors in a smaller version of the IWCD with a controlled test beam.

We lead the Water Cherenkov Test Experiment (to be undertaken at CERN in the coming years) to test multi-PMT detectors in a smaller version of the IWCD with a controlled test beam.

We lead the Water Cherenkov Test Experiment (to be undertaken at CERN in the coming years) to test multi-PMT detectors in a smaller version of the IWCD with a controlled test beam.

VISPA and the Canadian Hyper-K group are engaged in the challenging program to reduce systematic uncertainty in neutrino oscillation measurements. The major sources of systematic uncertainty are related to the initial neutrino flux, neutrino interaction cross section, and the detection efficiency of the water Cherenkov detector. We are leading several projects to address each of these components:

- We lead the EMPHATIC experiment to measure hadron interaction cross sections to better understand the neutrino flux.
- We lead the WCD collaboration, which is setting up a large scale testbeam to measure hadron interaction cross sections.
- We lead the Water Cherenkov Test Experiment (to be undertaken at CERN in the coming years) to test multi-PMT detectors in a smaller version of the IWCD with a controlled test beam.

The major sources of systematic uncertainty are related to the initial neutrino flux, neutrino interaction cross section, and the detection efficiency of the water Cherenkov detector. We are leading several projects to address each of these components:

- We lead the EMPHATIC experiment to measure hadron interaction cross sections to better understand the neutrino flux.
- We lead the WCD collaboration, which is setting up a large scale testbeam to measure hadron interaction cross sections.
- We lead the Water Cherenkov Test Experiment (to be undertaken at CERN in the coming years) to test multi-PMT detectors in a smaller version of the IWCD with a controlled test beam.

The major sources of systematic uncertainty are related to the initial neutrino flux, neutrino interaction cross section, and the detection efficiency of the water Cherenkov detector. We are leading several projects to address each of these components:

- We lead the EMPHATIC experiment to measure hadron interaction cross sections to better understand the neutrino flux.
- We lead the WCD collaboration, which is setting up a large scale testbeam to measure hadron interaction cross sections.
- We lead the Water Cherenkov Test Experiment (to be undertaken at CERN in the coming years) to test multi-PMT detectors in a smaller version of the IWCD with a controlled test beam.
RESEARCH COMPUTING

Computing is an integral part of particle physics research and it is a key element of our Research Centre. Our international projects, ATLAS, T2K and Belle II, store large samples of collision data that require significant computing resources for the analysis of the data.

Researchers in VISPA are leaders in developing the computing infrastructure in Canada for particle physics research projects. We are spearheading cloud computing projects in the ATLAS and Belle II experiments. We have developed a distributed cloud computing system that utilizes cloud centres in Europe, Australia and North America, and exploits commercial clouds such as Amazon EC2 and Microsoft Azure (https://www.youtube.com/watch?v=5Kixh66A9NM).

The University of Victoria will host the Canadian Belle II Raw Data Centre, a CFI-funded project led by VISPA, that will store a fraction of the raw data generated by the Belle II experiment at the KEK Laboratory in Tsukuba, Japan (https://www.uvic.ca/news/topics/2021-cfi-innovation-fund+news).

Canada is establishing a new organization, called the Digital Research Alliance of Canada, that will oversee computing, data management and research software in Canada. One of our members, R. Sobie, is Chair of the Alliance Researcher Council (https://engagedri.ca/latest/ndrios-researcher-council-elects-new-chair-dr-randall-sobie) and a member of the Alliance Board of Directors.

VISPA is also home to HEPNET/Canada, which is responsible for national and international network connectivity for the entire Canadian particle physics community. HEPNET works with CANARIE, provider of Canada’s research network, to link our centres to the laboratories and universities around the world. HEPNET is actively engaged in network R&D that has had significant involvement from network and computing industry partners.

Computing in particle physics has been an excellent training ground for students. VISPA has employed many undergraduate science and engineering students in this area. The students return to complete their education and use their experience to find employment in wide variety of areas. In addition, many of our staff have transitioned to careers in industry in Canada and abroad.

THEORETICAL PHYSICS

The UVic theoretical physics group (with faculty Kristan Jensen, Pavel Kovtun and Adam Ritz, and adjunct faculty David McKeen and David Morrissey at TRIUMF) is active in exploring several overlapping research directions. Recent work within the formal theory group explores fundamental questions about the nature of gravity, including the quantum properties of black holes, and properties of the hydrodynamic regime for quantum and classical systems relevant at finite temperature. The particle phenomenology group seeks to resolve puzzles within the Standard Model of particle physics, such as the nature of dark matter in the universe, and physics beyond the TeV energy scale.
ACCELERATOR PHYSICS
(Uvic and TRIUMF)

The University of Victoria is a founding member of TRIUMF and has a long-standing tradition in accelerator physics. TRIUMF accelerators are the heart of the Canadian accelerator-based experimental subatomic physics program, both because they enable on-site world-class research in nuclear physics and material sciences (CMMS), and because TRIUMF’s expertise allows Canada to make significant in-kind contributions to off-site international accelerator projects thus enabling participation in experiments at those facilities.

Currently five TRIUMF accelerator physicists are members of the UVic adjunct faculty. All of them have active research programs and together with faculty members Dean Karlen and Tobias Junginger we are currently supporting 13 graduate students in accelerator physics based at TRIUMF. Several students have already graduated from this program and have won several awards at international conferences. Most recently, Joseph Adegun received the student poster price at the 2021 International Conference on Ion Sources (ICIS) for his contribution Improvement of the Efficiency and Beam Quality of the TRIUMF Charge State Booster (CSB). The image below shows Joseph in front of his experiment, the charge state booster.

The research program based at UVic focuses on material aspects for superconducting radiofrequency accelerators in collaborations with the CamTec research center and the condensed matter group. We take advantage of the local infrastructure at the Advanced Microscopy Facility and the condensed matter theory expertise. Projects are geared towards undergraduate involvement and include building cryocooler based low temperature experiments, surface analysis of witness samples from TRIUMF cavities treated by novel procedures and to study the applicability of accelerator technology to quantum computing.

ALTAIR & ORCASat
CALIBRATION PROJECTS

The ALTAIR project founded by Justin Albert provides a precision [0.01%] uncertainty photometric reference calibration using in-situ-calibrated light sources above the atmosphere, in the optical and microwave spectra. ALTAIR will provide the means to eliminate the largest uncertainty in measurements of dark energy using supernovae, and (via an onboard precisely-polarized microwave source) a major uncertainty in the search for gravitational waves in the CMB, and additionally provides key information on atmospheric science. Our partner project, ORCASat, led by UVic students, will be launching a CubeSat version of the optical source of ALTAIR into low Earth orbit in 2022!

A cutaway view of the 3D CAD model for the ORCASat CubeSat satellite (https://orcasat.ca), presently under construction right here on campus. ORCASat will be launched into low Earth orbit later this year (2022) via first being ferried to the International Space Station (ISS), and then ejected from the ISS into its own orbit, via the NanoRacks ISS CubeSat launch system. (right)

The ORCASat student team (below)
The VISPA Laboratory provides state of the art equipment for the development and construction of detectors and electronics for particle and accelerator physics projects. The laboratory has been used to build components for the ATLAS, T2K and Belle II experiments. A full-time detector physicist with a background in particle physics detectors and programmable electronics, Sam DeJong provides support for these projects. The laboratory also has a small machine shop and clean room, and has access to the local machine and electronics shops of the Faculty of Science and Department of Physics and Astronomy.

Among its facilities, the VISPA Lab houses state-of-the-art digital electronics and analogue equipment for characterizing circuits. A critical application of this equipment is the research and development of a new electronic read-out for the liquid argon calorimeter of the ATLAS experiment at CERN. ATLAS is one of the two experiments at the Large Hadronic Collider (LHC) that discovered the higgs particle. The LHC is being upgraded to provide higher data rates and the ATLAS experiments is being upgraded to take advantage of the improvements. The electronics and firmware being created by the ATLAS scientists and VISPA detector scientist will handle 28 Terabytes per second. This extraordinarily huge amount of data will be selected and then studied in order to understand, for example, the self-interaction of higgs particles and to search for hitherto unknown physical phenomena.

The VISPA Laboratory is part of a national infrastructure and is used by other Canadian projects who can benefit from the local expertise. We also collaborate closely with the TRIUMF detector group.

What do physics graduates do? Lorraine Courneyea and Eric Ouellette worked on the ATLAS experiment for their PhDs. Lorraine went on to study at the Mayo Clinic and is now a clinical professor in medical physics at the University of Toronto. Her PhD experience with VISPA gave her an international perspective, skill in working in and leading teams of people from many different countries and cultures and practice speaking to international experts about her work on a weekly basis.

Eric moved into actuarial science following his PhD, and now works as an actuary for LifeWorks (formerly Morneau Shepell) in Halifax, NS. His skills analyzing complex data, and working within a large team, have translated well into this quantitative career.
The Flavor Physics and CP Violation conference (FPCP2019 – https://fpcp2019.triumf.ca/) was held on campus May 6-10, 2019. It was organized through the VISPA research centre (Bob Kowalewski was the head of the local organizing committee and Ms. Peggy White and the TRIUMF laboratory provided logistical support). It has been held annually since 2002, with the venue moving between the Americas, Asia and Europe on a 3-year rotation.

- The conference program focused on leading science questions such as the nature of ordinary matter, the properties of established and hypothesized interactions, the puzzling imbalance between matter and antimatter in the universe and the nature of the Dark Matter implied by astronomical observations, to name a few.

- The conference talks reported on recent research findings in experimental and theoretical particle physics from leading laboratories and institutes around the world (in Switzerland, Italy, France, Germany, UK, Japan, South Korea, China, Australia, USA, Canada).

- There were 82 delegates from 19 different countries, from graduate students and post-doctoral researchers through eminent professors, including winners of prestigious prizes (Helmholtz Award, J.J. Sakurai Prize, J.E. Lillienfeld Prize, Panofsky Prize, USSR Academy of Sciences Medal, Breakthrough Prize in Fundamental Physics).

CONTACT INFORMATION:
VISPA office:
Director: Randall Sobie
Administrator: Peggy White
Elliott Building, room 207
Phone: (250) 721-7736
Fax: (250) 721-7752
E-Mail: vispa@uvic.ca

Mailing address:
VISPA, Dept. of Physics & Astronomy,
University of Victoria,
PO Box 1700, STN CSC,
Victoria, BC, V8W 2Y2 Canada