University of Victoria

Physics and Astronomy

VISPA 2016 NEWSLETTER

VICTORIA SUBATOMIC PHYSICS AND ACCELERATOR RESEARCH CENTRE

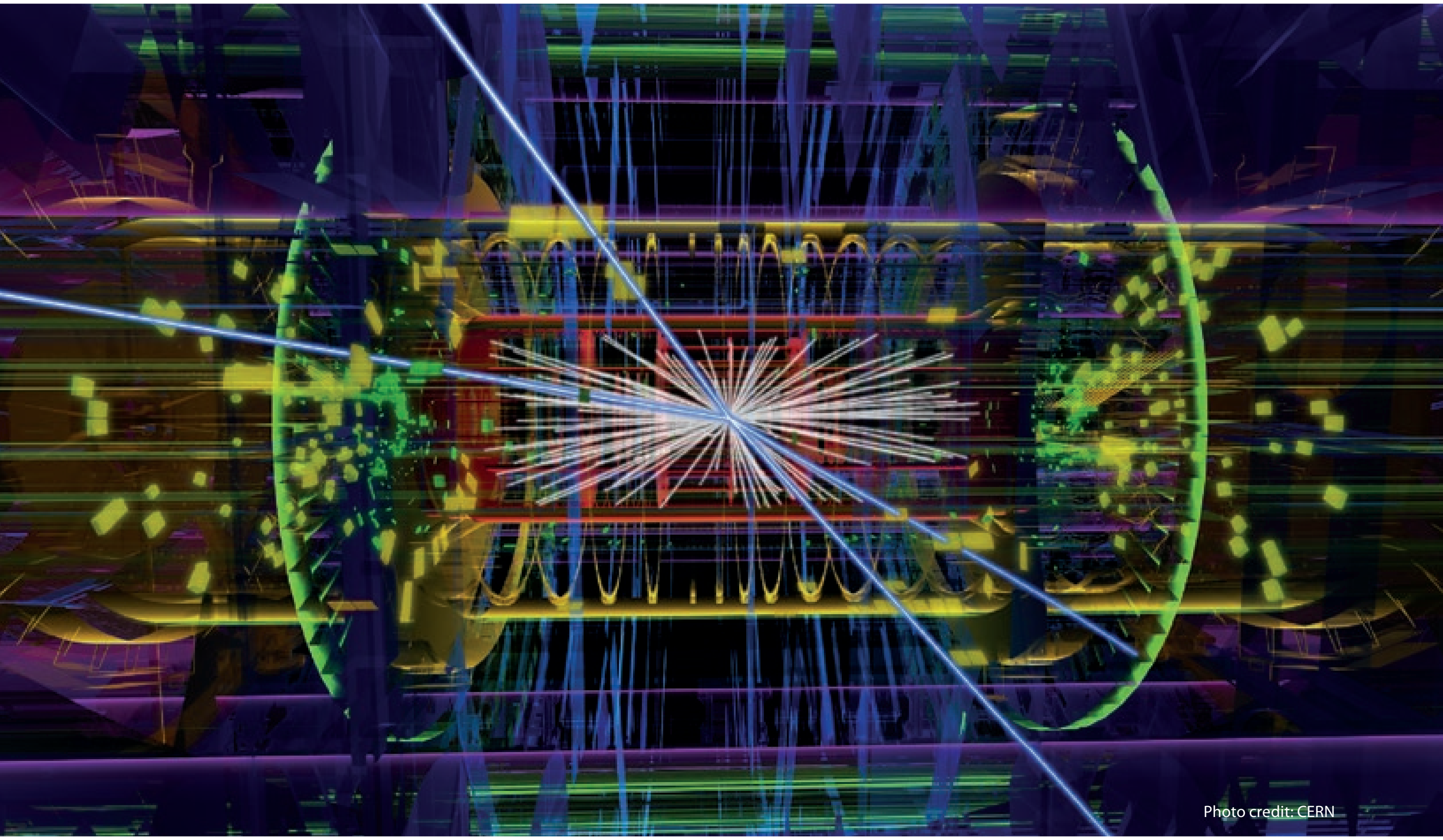

Photo credit: CERN

ATLAS candidate event for the production of a Higgs boson decaying into two Z bosons that each decay into a muon-antimuon pair.

In this issue:

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Pavel Kovtun	Theoretical physics
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Juan Hernandez	Theory
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Matt LeBlanc	ATLAS
Matthias Le Dall	Theory
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Jordan Myslik	T2K
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Nicolas Savard	Accelerator
Doug Storey	Accelerator
Nafisa Tasneem	B-physics

ATLAS and the Higgs Discovery

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. The UVic ATLAS group has been a member of the ATLAS Collaboration since its foundation in 1992, and contributed to the design and construction of the ATLAS detector. The LHC started operation in 2010 with proton-proton collisions at 7 TeV centre of mass energy; the energy was increased to 8 TeV in 2012. The excellent performance of the ATLAS detector and the quality of the data recorded provided a rich program of physics measurements and searches, culminating in the discovery of the Standard Model Higgs boson in July 2012. The Higgs boson was the last piece of the Standard Model to be discovered, and is intimately related to the origin of the mass of fundamental particles; the Nobel Prize in Physics 2013 was awarded to François Englert and Peter W. Higgs for their theoretical prediction of the related mechanism, and ATLAS members were awarded the European Physical Society 2013 High Energy and Particle Physics Prize, with the citation: "The ATLAS and CMS collaboration, for the discovery of a Higgs boson, as predicted by the Brout-Englert-Higgs mechanism".

The UVic team has been very active in many aspects of the ATLAS program for nearly 25 years; the Higgs particle discovery is an amazing reward for all the efforts in making the ATLAS detector a reality. The Higgs boson discovery was celebrated at UVic with a public lecture in March 2013 as a UVic 50th Anniversary Signature Event; the lecture was introduced by Alan Astbury and given by Michel Lefebvre to over 500 people in attendance.

View of the ATLAS liquid argon calorimeter during installation at CERN, showing the copper absorbers. Photo taken by VISPA member Roy Langstaff.

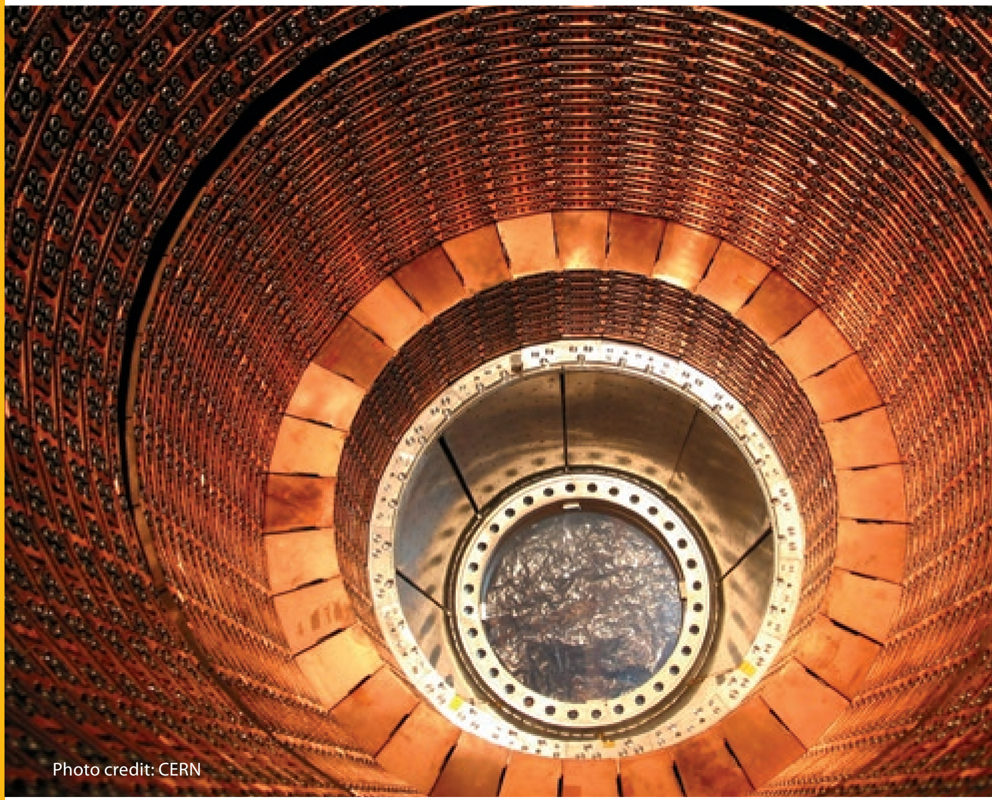


Photo credit: CERN

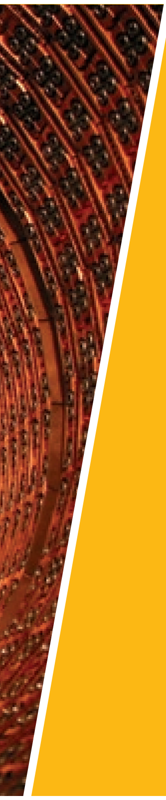
Visit of Global Affairs Minister Stephane Dion to CERN in March 2016. To his right is VISPA member, and ATLAS Deputy Spokesperson, Rob McPherson. Third from the right is VISPA member Isabel Trigger, and fifth from the right is former UVic PhD student, and now Carleton U Professor, Manuella Vincter.

Since 2015, the LHC provides proton-proton collisions at 13 TeV, allowing new searches and improved measurements. The UVic team of nearly 30 scientists is composed of graduate and undergraduate students, research associates, faculty, and affiliated research personnel. Current activities include the analysis of proton-proton collision data ranging from Standard Model precision measurements to searches for physics beyond the Standard Model; the operation of the ATLAS detector, in particular the lead - liquid argon sampling calorimeter, aspects of the event trigger system, and reception at CERN of new ATLAS muon detectors made in Canada; networking and computing, including novel use of cloud computing; and research and development for upgrades of the liquid argon calorimeter electronics. The latter is in preparation for the planned increase of the LHC beam luminosity over the next 20 years.

Members of the UVic ATLAS team are involved in the management of the ATLAS Collaboration, composed of over 3000 scientists. Tasks include data taking operations and physics working group convenor-ships. At the top management level, Rob McPherson (IPP) is ATLAS Deputy Spokesperson since March 2015, and is now located at CERN.

Members of the UVic ATLAS team regularly make public presentations. In addition, each spring since 2012 an outreach event, the ATLAS Masterclass, is offered to grade 11 and 12 high school students from the Victoria area; about 20 students spend a day at UVic with scientists learning about particle physics and analyzing real data collected by ATLAS. The event continues to be a success!

Last year's data revealed a slight excess of events with a di-photon invariant mass of about 750 GeV. We are looking forward to the collection of more proton-proton collisions at 13 TeV in 2016. This excess may turn out to be a statistical fluctuation and disappear, or it may be confirmed!



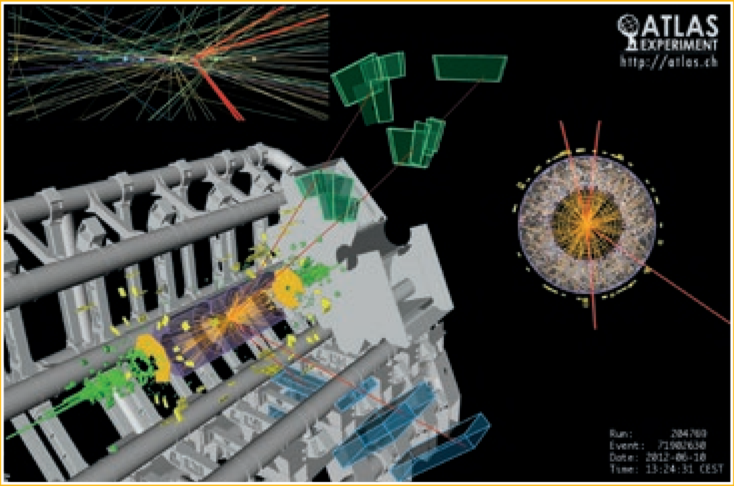
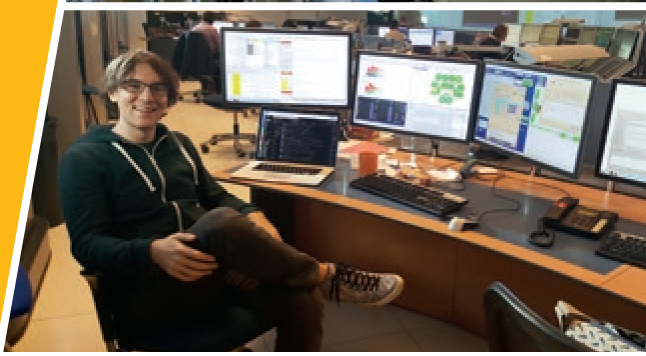


Photo credit: CERN

ATLAS candidate event for the production of a Higgs boson decaying into two Z bosons that each decay into a muon-antimuon pair. The muons were detected by muon chambers (green and blue), while the central part of the detector mainly recorded soft hadronic activity. The top left inset shows the distribution of proton-proton collision vertices, with the one responsible for the Higgs boson production identified by the muon lines. The right inset is a view of the event in the plane transverse to the beam line.

UVic graduate students Claire David (top) and Matt LeBlanc (bottom) at the ATLAS experiment.



VISPA MEMBERS OF T2K AWARDED
2016 BREAKTHROUGH PRIZE IN FUNDAMENTAL PHYSICS

VISPA members, participating in the T2K experiment, share in the 2016 Breakthrough Prize in Fundamental Physics. The prize, presented by the Breakthrough Prize Foundation, was awarded "for the fundamental discovery of neutrino oscillations, revealing a new frontier beyond, and possibly far beyond, the standard model of particle physics". The prize is valued at 3 million USD, and is shared with four other international experimental collaborations studying neutrino oscillation: The Daya Bay, KamLAND, SNO, and Super-Kamiokande scientific collaborations. The award was presented at a lavish ceremony at the NASA Ames Research Centre in California, in November 2015, broadcast live and hosted by comedian Seth Macfarlane.

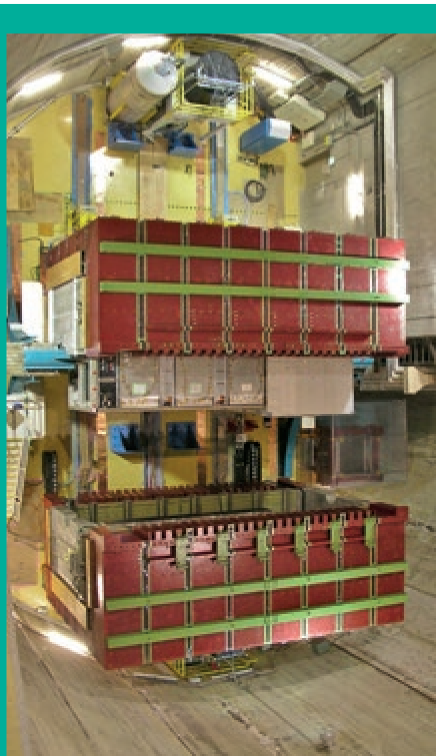
Eight current and former VISPA members (Casey Bojechko, Andre Gaudin, Kenji Hamano, Anthony Hillairet, Dean Karlen, Akira Konaka, Jordan Myslik, and Michael Roney) are among the laureates.

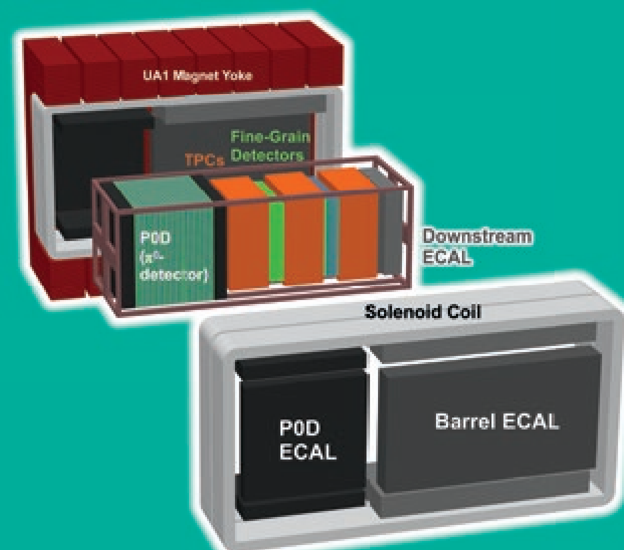
The T2K experiment investigates the nature of neutrinos and the way in which they change their identity from one type to another. Neutrinos are ghost-like particles produced in radioactive decays and they can pass through walls or even the entire earth without being stopped.

The experiment produces a beam of one kind of neutrinos at the J-PARC accelerator laboratory in Tokai, on the east coast of Japan. The neutrino beam is directed towards the Super Kamiokande detector, almost 300 km away, in Kamioka, as illustrated below. A tiny fraction of the neutrinos interact at the near detector complex (ND280) and at the far detector (SK). By comparing the neutrino beam properties before and after their long journey across Japan, the scientific team studies how neutrinos can change from one type to another.

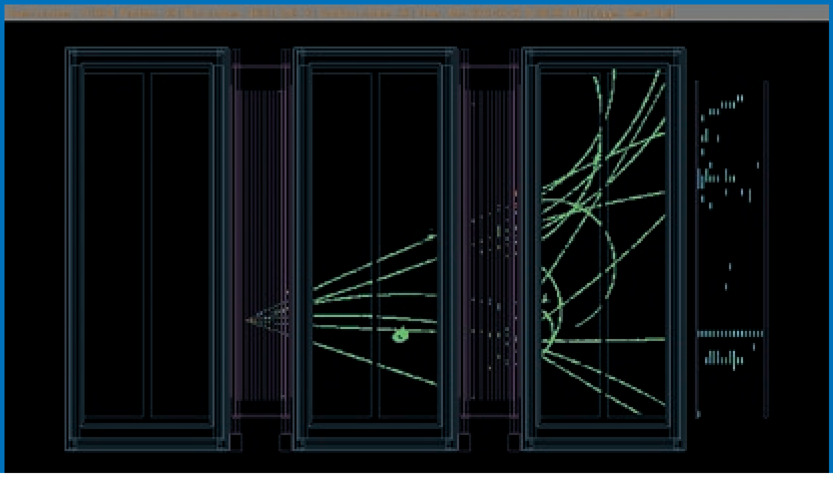
The VIPSA T2K group helped lead the design, construction, and operation of the near detectors. The ND280 detector is in an underground hall, in line with the SK detector, and is housed within a large magnet originally built for the UA1 experiment. A drawing and a photo of the detector half open are shown below.

The VISPA group leads the Time Projection Chambers (TPCs) project, which accurately measures charged particles produced by neutrino interactions in the detector—determining their momentum, charge and type. The TPCs are full of a gas that is ionized when particles pass through. The trail of ionization electrons is drifted towards sensitive readout modules, in order to record the path of the charged particles. The curvature of path, due to the magnetic field, determines the charge and momentum and the amount of ionization determines the particle type. The picture below shows Prof. Karlen standing near the TPCs that are suspended in the basket that holds the near detectors within the magnet. Also





A drawing and a photo of the ND280 detector.



Picture of a neutrino event recorded by the near detector.

shown is an example picture of a neutrino event recorded by the near detector. The green tracks show the paths of the charged particles produced by a neutrino interacting in the Fine Grained Detector between the first and second TPC.

The experiment started operating in 2010 but was halted for a year due to the devastating East Japan Earthquake and Tsunami in March 2011. Despite that, in 2011, the collaboration published the first indication of muon neutrinos transforming into electron neutrinos. Within a few years, sufficient data was collected to make this observation definitive, which led to the awarding of the Breakthrough Prize.

T2K continues to collect data to see if anti-neutrinos behave the same way as neutrinos. If a difference is seen, this may help explain why the Universe is now made up of matter, despite beginning with an equal mix of matter and anti-matter.

Dean Karlen standing near the TPCs

"...REVEALING A NEW FRONTIER BEYOND, AND POSSIBLY FAR BEYOND, THE STANDARD MODEL OF PARTICLE PHYSICS."

Flavour Physics in VISPA

The VISPA heavy flavour physics group has been involved in the BaBar Experiment at SLAC over the past five years and is preparing for physics with the Belle II Experiment at KEK in Japan.

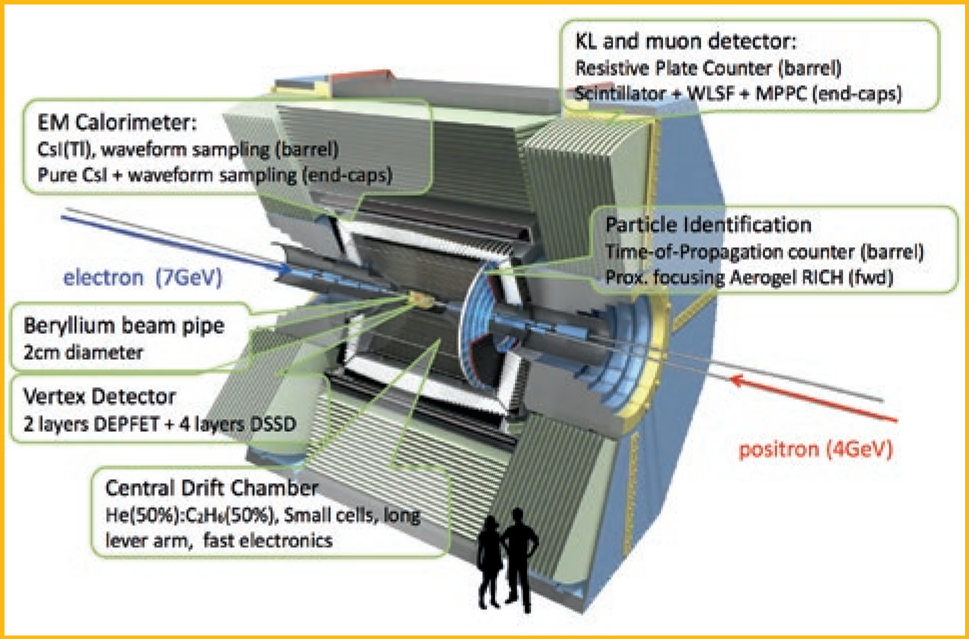
BABAR

The BABAR experiment based at the SLAC Accelerator Center was designed to study how the laws of physics differ for ordinary matter and anti-matter (differences referred to as "CP violation"). It recorded e+e- collision data—including nearly 500 million pairs of B mesons—between 1999 and 2008 at a centre-of-mass energy of just over 10 GeV. The experiment discovered CP violation in the B0 meson system, where a B0 meson is a neutrally charged particle that contains a b-quark, the second most massive quark. The effect was also seen by its competitor, the Japanese-based Belle experiment. This observation led to the awarding of the 2008 Nobel Prize in Physics to the theorists who predicted it. BABAR members, currently over 200 authors from a dozen countries, also use the data to make precision measurements of the tau lepton and charm quark and anything that is produced in e+e- collisions as well as to search for new particles and phenomenon, such as dark matter particles and low mass non-standard Higgs particles. Our group contributes heavily in the analysis of B meson decays and in studies of the tau lepton, where members of our group are convenors of BABAR-wide analysis working groups. VISPA faculty member, Michael Roney, has led this large international collaboration as BABAR Spokesperson during this period of data analysis. There have been over 100 papers published over the last five years, including "Observation of Time Reversal Violation in the B0 Meson System", which was recognized in 2012 by the UK-based Institute of Physics as one of the top ten physics stories that year. Another intriguing paper reported evidence for an excess of $B^{-}\rightarrow D(*)\tau\nu$ decays that could be a signal for new physics. Related to that topic, VISPA member Robert Kowalewski and a research associate published the first observation of $B\rightarrow D\,\pi\pi\ell\nu$ and $B\rightarrow D^{*}\pi\pi\ell\nu$ decays. VISPA member Justin Albert has recently published his analysis on a search for invisible decays of the B0 meson—a potential signature of a dark matter particle. The BABAR and Belle experiments jointly published a book, *The Physics of the B-Factories*, which summarizes the results of the two experiments up to 2014.

Belle II

The Belle II experiment will look for evidence of new physics at the precision frontier in electron-positron collisions at a centre-of-mass energy of 10.58 GeV. It will operate at SuperKEKB, which is an upgrade of the 3.0km circumference electron-positron collider at the KEK laboratory in Tsukuba, Japan. It is designed to achieve a world-record collider luminosity of $8x10^{35}cm^{-2}s^{-1}$. Construction is on schedule for a physics start in late 2018. The centre-of-mass energy is selected to be just above the threshold for producing particles containing the b-quark (B-mesons) and will also produce events containing pairs of tau leptons as well as events with particles containing the charm quark. This facility will produce 30 times the

Belle II Detector

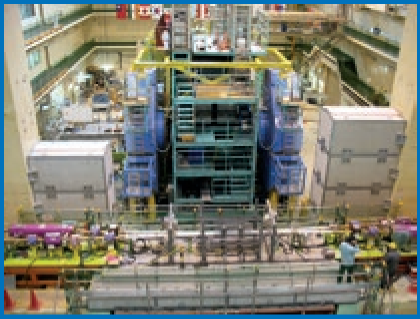


world's total existing data sample of these processes. With this sample, Belle II will the probe flavour sector of subatomic physics by searching for rare processes and making precision measurements.

Such a precision frontier facility opens an exciting window on new energy scales beyond the reach of existing colliders, including CERN's Large Hadron Collider (LHC), and will help explain any new physics that might be discovered at LHC, by virtue of quantum loop corrections, which are sensitive to very massive, and as yet undiscovered, particles. These hypothesized particles manifest themselves in precision measurements of rare processes. They also reveal themselves via the presence of processes that are forbidden within our current understanding of physics. Belle II will make measurements of CP violation and the CKM quark mixing matrix elements with unprecedented precision in order to search for deviations from the Standard Model and will be the most sensitive experiment to search for lepton flavour violation in tau decays. A wide variety of other precision frontier measurements with B mesons, charm, tau, radiative return events, and two-photon physics will also be carried out.

The VISPA Belle II team is preparing for commissioning and data collection and has completed research and development on a possible upgrade of the Belle II forward endcap calorimeter. The latter includes conducting test beam experiments to determine the impact of the high radiation environment at SuperKEKB on the endcap calorimeter performance. The Canadian group is contributing to the calorimeter reconstruction software development, calibration, and commissioning of the Belle II electromagnetic calorimeter. It is responsible for the accelerator background and shielding studies related to the calorimeter. During the commissioning phases of the accelerator the VISPA group will provide measurements of the thermal neutron flux and photon flux at the position of the inner radius of the calorimeter. Belle II Canada is also providing the permanent photon background monitoring system, which will be provided to the accelerator team and used to tune the machine. The team also contributes to the development of cloud computing software for Belle II through VISPA member R. Sobie.

Recent news is that in Feb. 2016 beams were first stored in the SuperKEKB accelerator and the VISPA detectors have been collecting data for this commissioning phase.



View of the SuperKEKB collision point in the fall of 2015. The accelerator beam line is now covered with a concrete shield. The Belle II detector can be seen in the background. Commissioning instrumentation, which includes Canadian neutron and gamma-ray detectors, is in the foreground.

VISPA graduate student, Alexandre Beaulieu, at the SuperKEKB particle collider setting up instrumentation for the commissioning phase.

ARIEL AND THE ACCELERATOR PHYSICS GRADUATE PROGRAM AT VISPA

A is for Accelerator; at least for the VISPA acronym! Despite the fact that accelerators play the central role in most subatomic physics experiments, there are few graduate programs in the world that combine theoretical and experimental subatomic physics with accelerator physics. Our students have the opportunity to connect with all aspects of subatomic physics while they focus on their specific subject area for their research.

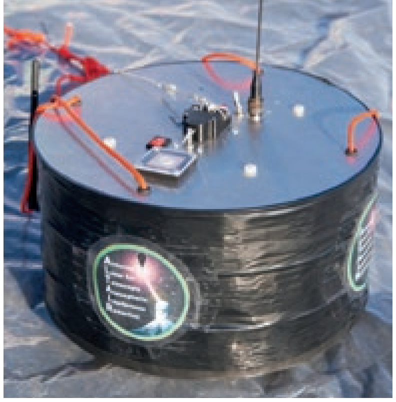
The graduate program in Accelerator Physics developed as a consequence of UVic leadership in building the new Advanced Rare Isotope Laboratory (ARIEL) located at TRIUMF on UBC campus. As a founding member of the TRIUMF laboratory, UVic led the proposals to build a new electron accelerator and the other facilities that make up ARIEL. ARIEL phase-I was completed in September 2014, with the first operation of the electron accelerator. ARIEL phase-II, to build the infrastructure necessary to produce and transport isotopes to the experimental areas, was approved in May 2015. The funding from the Federal Government (through the Canada Foundation for Innovation) and Provincial Governments for ARIEL totals nearly $100M.

TRIUMF is already a world-leading laboratory for isotope science, and ARIEL will strengthen the program further by increasing the number and types of isotopes produced. The isotopes are used for fundamental studies in nuclear physics and nuclear astrophysics, for materials sciences research, and for the detection and treatment of disease. Its commercial partner on site at TRIUMF, Nordion, produces 2.5 million patient doses per year.

Accelerators are not only found in physics laboratories. There are over 1000 accelerators sold annually, primarily for industrial and medical applications, making it a $2 billion industry.

To train the next generation of accelerator physicists, VISPA has brought together the UVic physics graduate program with expert accelerator physicists from TRIUMF, appointed as adjunct faculty. The program is off to an encouraging start. Two students have completed their MSc in accelerator physics, and there are currently four students enrolled; one in the PhD program and three in the MSc program. While most of their research work is connected to the development of ARIEL, one student is working on an accelerator project based at CERN, in Switzerland. The appointment of a faculty member in accelerator physics at UVic would allow this new graduate program to further develop and help meet the worldwide demand for accelerator physicists.

ARIEL team at TRIUMF in front of the new electron accelerator



Dark Energy and ALTAIR: Experimental Particle Astrophysics in VISPA

Measurements of "dark energy," the unknown substance that is causing the expansion of the Universe to accelerate, and which accounts for 75% of the total matter and energy content of the Universe, are limited in their precision by the calibration of the amount of light transmitted through Earth's atmosphere, and observed by major telescope facilities, in the blue vs. the red part of the optical spectrum. UVic VISPA members are the founding leaders of a CSA- and NSERC-funded 40-person international collaboration, called ALTAIR ("Airborne Laser for Telescopic Atmospheric Interference Reduction"), to eliminate the largest uncertainty in measurements of dark energy, as well as also a major uncertainty in the search for gravitational waves from the instants just after the Big Bang. Dark energy likely has connections with the quantum properties of the vacuum, and also possibly with how gravity (and general relativity) interfaces with quantum mechanics.

Dark energy measurements, the most precise of which use type Ia supernovae to measure the expansion history of the Universe, are limited in their precision by those photometric uncertainties: how precisely and accurately one can measure the brightness (i.e. the magnitude) of supernovae in bluer vs. redder optical wavelengths. Photometric calibration in astronomy has historically been performed using standard stars: stars whose magnitude and/or spectra have been calibrated via either direct or indirect comparison with laboratory standards. That technique is fundamentally limited to precisions of order 1%, due to stellar variability and other uncertainties, whereas laboratory-based photometry and radiometry routinely obtain precisions of O(0.01%). ALTAIR is erasing this discrepancy, in order to understand the nature of dark energy, via flights of precision-calibrated light sources in light (2.5 kg) payloads on small high-altitude balloons above the atmosphere (and also in the next decade, via a dedicated nanosatellite).

ALTAIR uses the new technique of floating in-situ-calibrated light sources above astronomical observatories (such as Pan-STARRS on Mauna Kea in Hawaii, LSST in Chile and, in the microwave spectrum, the South Pole Telescope in Antarctica) to sharply reduce photometric (and, in the microwave spectrum, polarimetric) uncertainties by two orders of magnitude. In the optical spectrum, the light sources consist of thermally-controlled laser diode modules (presently at 440 [blue], 532 [green], 635, and 690 [red] nm wavelengths) output into an integrating sphere, and constantly monitored by a NIST-calibrated photodiode. ALTAIR regularly launches and performs observations of its payloads: its primary flight facility is in New Hampshire, and they will also be beginning flights over Mt. Hopkins in Arizona in January 2017, over Pan-STARRS in late 2017 and early 2018, and over LSST at the end of this decade.

ALTAIR's remotely-tracked small high-altitude balloons additionally have the future capabilities of acting as stratospheric communication and observation platforms in remote areas, e.g. stratospheric cell-phone towers for the Arctic, or shoreline, or sea-ice, observation posts at high altitude.

Airborne
Laser for
Telescopic
Atmospheric
Interference
Reduction

RESEARCH COMPUTING IN HIGH ENERGY PHYSICS

Computing is an integral part of particle physics research. The data samples from our projects, such as ATLAS, require large computing facilities for reconstruction and analysis. Our group at the University of Victoria is a world leader in cloud computing, high performance storage and high speed networks for HEP research projects.

We are leading cloud computing projects in the ATLAS and Belle II experiments. We have developed a distributed cloud computing system that utilizes cloud centres in Europe and North America including commercial clouds such as Amazon EC2 and Microsoft Azure. Cloud technologies offer a new and more effective means of providing computation resources and our group at the University of Victoria is developing services that allow us to exploit these resources. The cloud computing work has been strongly supported by NSERC, CANARIE and others.

The University of Victoria is home to HEPNET/Canada, which is responsible for national and international network connectivity for the entire Canadian particle physics community. HEPNET/Canada manages the Canadian connection to Large Hadron Collider network that links Canadian centres to other LHC centres around the world. HEPNET/Canada is also involved in network R&D and has been a member of a collaboration that has set world records for wide-area data transfer rates. The network R&D has had significant involvement from network and computing industry partners.

Computing in HEP has been an excellent training ground for students. For the past ten years, we have typically employed 3-6 undergraduate science and engineering students annually 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.

The Future is Here: Research Training in VISPA

The future is indeed here, in the guise of the scientific and technical personnel who bring their talents to the VISPA research mission and gain valuable expertise and experience in the process. We have 22 current graduate students and 14 postdoctoral and research staff. Since it was founded in 2011, VISPA has provided the environment in which 11 PhD and 18 MSc degrees were completed and 20 postdoctoral fellows and research staff honed the expertise they have taken with them to their current positions. In addition, we provide early research experiences to a steady flow of undergraduates from UVic and other universities.

These young researchers are deployed across the full range of VISPA projects—accelerator physics, particle physics, theoretical physics and high performance computing. Some acquire expertise in the VISPA lab at UVic, working with experienced technologists in the design and fabrication of specialized equipment for use in the ARIEL project at TRIUMF, the ATLAS experiment at CERN, the Belle-II and T2K experiments in Japan, and the ALTAIR project. Others develop and deploy the high-speed networking and cloud computing that forms the infrastructure for dealing with enormous datasets. Many also benefit from interactions with scientific and technical experts during periods of residence at major international laboratories. For example, a PhD student recently designed the shielding around the electron-positron interaction region for the Belle-II experiment, which is crucial for allowing detector operation at what will be the world's highest luminosity collider.

The communication and people skills needed in a variety of career paths are developed within the large, complex, global scientific collaborations in which these researchers advance and present their work. Particle physics students develop substantial expertise in the statistical analysis of petabyte-scale data sets, and in the use of machine learning; several recent graduates are using these skills in Data Science and Finance. Former VISPA computing specialists work for CERN, Dell and Silicon Valley startups. Of course, some trainees go on to careers in basic research and education; recent VISPA postdocs hold faculty positions at San Francisco State University (USA) and at the University of Bonn (Germany).

UVic graduate student Ewan Hill at the ATLAS experiment.

Remembering Alan Astbury and the Inaugural Astbury Lecture

An annual lecture in memory of Alan Astbury was inaugurated on Monday, April 27, 2015. The Director General of CERN, Dr. Rolf Heuer, graciously agreed to be the speaker. At the same time, on the Monday and Tuesday a scientific symposium was held in order to remember Alan. Both events were a resounding success.

Dr. Heuer gave a lecture on the successes and aspirations of particle physics at CERN to a packed auditorium, and a satellite auditorium with a simulcast and over the internet by webcast. UVic President, Jamie Cassels, QC, opened the lecture by introducing Dr. Heuer to an enthusiastic crowd. We are very grateful that Dr. Heuer agreed to inaugurate our new lecture series. He worked with Alan on several projects and was able to show in his lecture Alan's contributions to science.

The symposium attracted colleagues of Alan's from far and wide. There were excellent talks that reviewed Alan's career. He worked on many projects. A unifying theme was the use of the latest and best technologies for accelerators, detectors and computing. Expert speakers, many of whom had worked closely with Alan, spoke to the state-of-the-art in the subject areas he had worked on.

Information about the workshop, and photos are available at http://www.uvic.ca/astbury/, and the talks are available at https://indico.cern.ch/event/389605/timetable/#20150427.

There was time to chat and remember Alan. A symposium dinner was held at the Royal Victoria Yacht Club. Alan's wife, Kathy was able to attend the inaugural lecture and the symposium dinner.

Alan Astbury FRS FRSC

Prof. Rolf Dieter Heuer, CERN Director General, presenting the inaugural Astbury public lecture to a packed house in SCI B150. Dr. Heuer was introduced by University of Victoria President Jamie Cassels.

Astbury Symposium Attendees

PERSPECTIVES ON NEW PHYSICS **AT THE INTENSITY FRONTIER**

One of the “big questions” in modern physics is the identity of dark matter, driving many new theoretical and experimental developments. Some members of VISPA (Kowalewski, Pospelov, Ritz) are behind the very early ideas of using high-intensity particle physics experiments to extract information about the dark matter sector. Over the course of the last ten years, more and more experiments have been including searches for dark matter and dark forces in their physics programs. In September 2014, a workshop held in Victoria and organized by VISPA brought together about 25 scientists from various institutions in Canada, United States and Europe. Novel theoretical ideas and new experimental strategies for probing dark sectors were discussed in an informal atmosphere at the very inviting setting of the Grand Pacific Hotel in downtown Victoria. The format of the meeting allowed not only talks by the senior faculty members and postdocs, but also let VISPA graduate students (P. deNiverville, A. Fradette, J. Pearce) share the results of their research with others. The seamless running of the meeting was largely due to the efforts of VISPA administrator, Peggy White.

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