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The Large Hadron Collider (LHC) at the CERN laboratory is the highest energy particle

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

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 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.

Flavour Physics in VISPA

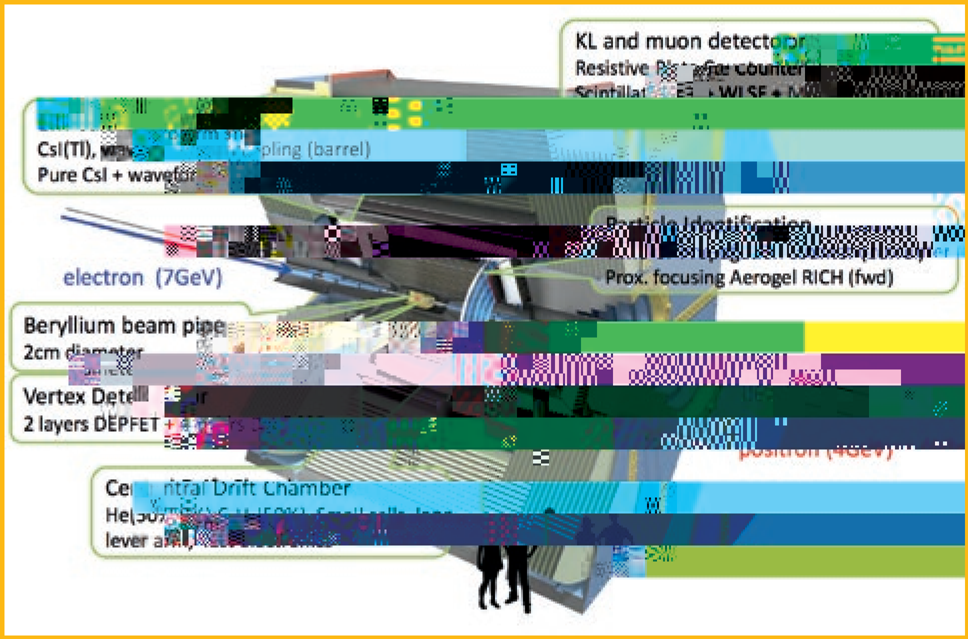
The VISPA heavy flavour physics group has been involved in the BaBar Experiment at SLAC over the past five years and is preparing for physics with the Belle II Experiment at KEK in Japan.

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 $B^- \to D^{(*)}\tau\nu$ 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 $B \to D\pi\pi\ell\nu$ and $B \to D^*\pi\pi\ell\nu$ 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 $8 \times 10^{35} cm^{-2} s^{-1}$. 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



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 o11.2 (.7.8 -7 (a)T0 0 9 45 4)-4.9 (r/Span/Actu)1.631 (r)2ur

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.

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 ferseav-re (er)-7 (n)1.4 (a)7.2 00 (c) j-6.6 (u)uhrr (er1)12.4 (er)avga4.9 (g)2-.7 (S. D3.3 (u)1.1 (r)-5.6 (k))0.8 (n)-6.4 (er)8.7 (g)-9.9 (y)

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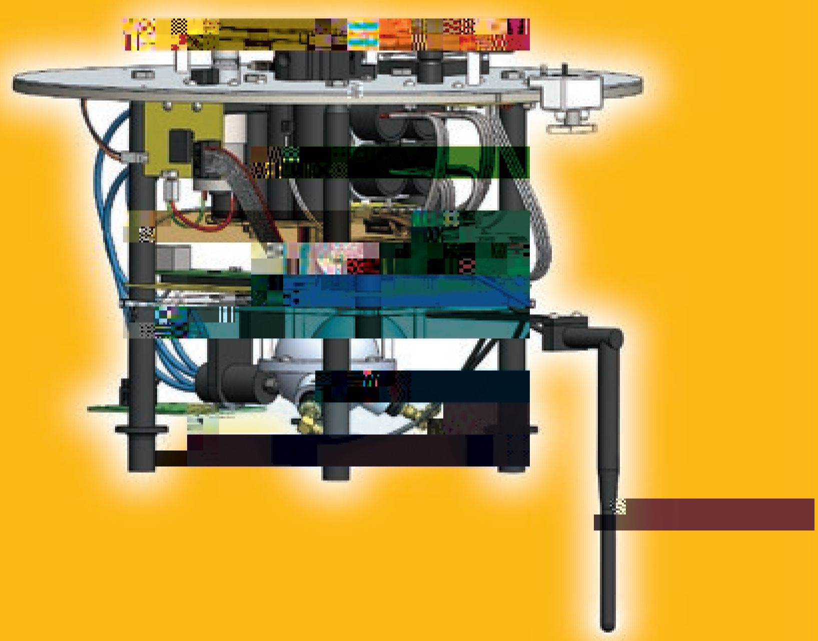

The Future is Here: Research Training in VISPA

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.

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We are leading cloud computing projects in the ATLAS and Belle II experiments. We have developed ar9 (i)2.2 8g3.8 (9(v)4.95(t)-1m.8 (a)1.1 (r)8.7 (5) 8g3.8 5.6 (k)-3jr)6.7 E27 (t)-14T*60y210.4 (2)h E27 (tl78.789 (g2fe95(t)-1m.8 (a)1.1 (r)8.7 (5) 8g3.8 5.6

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 out36T4 (t)12.4 (e o)-4.5 (u)7.2 -6.3(en-US/Lang3t)-2.3 ((n)th)1.4 (a)7.2 (t D)-6.5 (r)36.9 (. H)-6.5 (e)0(3H)-6.5 ie5.9 (r)-6.5 (k)7.3 (e)-12.2 (m w)-4.

PERSPECTIVES ON NEW PHYSICS

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