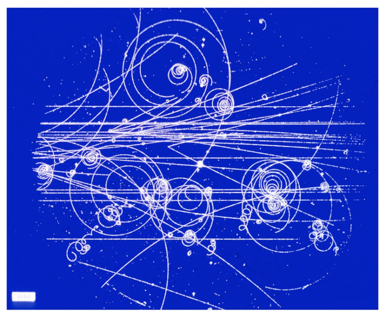
CHEP

Centre for High Energy Physics

McGill University

Annual Report 2007–2008

(June 2007 – May 2008)



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Edited by F. Corriveau

Contents

1 Introduction

This report is a summary of the research activities and realisations of the members of our Centre during the 2007-2008 year. They will be described here, while the actual lengthy lists of publications and seminars will be made separately available.

Usual warning: since the Centre is primarily devoted to research and the principal members all have faculty positions in the Physics Department, academic matters, teaching, funding and consulting activities are identical and will not be repeated here. *Please consult the annual report of the Department for details.*

2 Our Centre in 2007-2008

Subatomic physics is the field of fundamental research which addresses nothing less than the structure of matter and its interactions. The four types of forces identified in nature are, presented here with examples: gravitational (planets), electromagnetic (light), strong (nuclei) and weak (radioactivity). The electromagnetic and weak forces have already been unified under the the Standard model, and now being completed by the strong force through the theory of quantum chromodynamics. Further promising unification efforts are currently being done to understand further the strong interaction and include gravitation.

This highly challenging program is carried out experimentally by a few large international collaborations. Our groups are involved in the foremost projects at research centers in the USA and Europe. The theory behind theses observations and much more are essential to our understanding of the physics, to sketch the way on how we should further proceed and to constantly develop new and imaginative ideas.

Fascinatingly, it has be now been shown repeatedly that very high energy phenomena, in astrophysics or cosmology, are ultimately but other aspects of our research axes and therefore must also be investigated, both experimentally and theoretically. The orders of magnitude in scales and the complexity of the field lead to numerous scientific and technical ramifications, represent the unique characteristics of our Centre and strengthen its dynamics as a research entity.

Our members use the Centre to deepen our research efforts, to create a stimulating environment for national and international research collaborations, to pursue recruitment and formation of young researchers and graduate students, and to coordinate all our common activities. This is being achieved through seminar series, conference and visitor programs, computer network unification, sharing of laboratories and equipment, extensive exchanges of experience and know-how, and development of applications. The "McGill Centre for High Energy Physics" has a 24-year long tradition, was already re-structured considerably in 1995 and underwent four years ago another transformation as several new young faculty members joined our efforts and promoted new directions.

3 Composition of the Centre

As will be seen in the next section on research, the Centre membership spans large areas of studies in the fields of high energy physics, particle physics, cosmology, astrophysics and many aspects of nuclear physics. In the following tables, the lists of members are presented, each roughly identified by his/her experimental (X) or theoretical (T) orientation, as well as the general domains of high-energy physics (HEP), nuclear physics (NP) or astro-particle physics (Astro).

Faculty Members

1	Barrette, Jean	McGill University	XNP
2	Brandenberger, Robert	CRC/McGill University	THEP
3	Buchinger, Fritz	McGill University	XNP
4	Cline, James M.	McGill University	THEP
5	Corriveau, François	IPP/McGill University	XHEP
6	Crawford, John	McGill University	XNP
7	Das Gupta, Subal	McGill University	TNP
8	Dasgupta, Keshav	McGill University	THEP
9	Dobbs, Matt	CRC/McGill University	Astro
10	de Takacsy, Nick	McGill University	TNP
11	Gale, Charles	McGill University	TNP
12	Grisaru, Marc	McGill University	THEP
13	Hanna, David S.	McGill University	Astro
14	Jeon, Sangyong	McGill University	TNP
15	Lee, Jonathan	McGill University	XNP
16	Maloney, Alexander	McGill University	THEP
17	Moore, Guy D.	McGill University	THEP
18	Moore, Robert	McGill University	XNP
19	Patel, Popat M.	McGill University	XHEP
20	Ragan, Kenneth	McGill University	Astro
21	Robertson, Steven	IPP/McGill University	XHEP
22	Stairs, Douglas G.	McGill University	XHEP
23	Vachon, Brigitte	CRC/McGill University	XHEP
24	Warburton, Andreas	McGill University	XHEP

Post-Docs and Research Associates

1	Berndsen, Aaron	McGill University	RA	XHEP
2	Biswas, Tirhabir	McGill University	Postdoc	THEP
3	Chaudhuri, Gargi	McGill University	Postdoc	TNP
4	Chram, Malachi	McGill University	RA	XHEP
5	Cogan, Peter	McGill University	RA	Astro
6	Firouzjahi, Hassan	McGill University	Postdoc	THEP
7	Frey, Andrew	McGill University	Postdoc	THEP
8	Gulik, Sidney	McGill University	RA	XNP
9	Hyland, Peter	McGill University	Postdoc	Astro
10	Kanno, Sugumi	McGill University	Postdoc	THEP
11	Kildea, John	McGill University	RA	Astro
12	Knauf, Anke	McGill University	Postdoc	THEP
13	Koh, Seoktae	McGill University	Postdoc	THEP
14	Lanting, Trevor	McGill University	Postdoc	Astro
15	Maier, Gernot	McGill University	RA	Astro
16	Notari, Alessio	McGill University	Postdoc	THEP
17	Potter, Chris	McGill University	RA	XHEP
18	Santamaria, Cibran	McGill University	RA	XHEP
19	Saremi, Omid	McGill University	Postdoc	THEP
20	Schenke, Björn	McGill University	RA	TNP
21	Shi, Lijun	McGill University	Postdoc	TNP
22	Snihur, Robert	McGill University	RA	XHEP
23	Topor Pop, Vasile	McGill University	RA	XNP
24	Walsh, Roberval	McGill University	RA	XHEP

Visitors (Researchers)

1	Prof. S. Alexander	Penn. State Univ.
2	Prof. R. Cardenas	Univ. Central de las Villas, Cuba
3	Prof. S. Cremonini	Univ. of Michigan
4	Prof. P.C.W. Davies	Arizona State Univ.
5	Prof. M. Douglas	Rutgers Univ.
6	Prof. G. Efstathiou	Cambridge Univ.
7	Dr. B. Freivogel	UC Berkeley
8	Dr. G. Geshnizjani	Univ. of Wisconsin Madison
9	Dr. Joel Giedt	
10	Dr. K. Giesel	Albert Einstein Institute, Golm, Germany
11	Prof. D. Gross	KITP, UC Santa Barbara
12	Dr. M. Lippert	Technion, Israel
13	Dr. B. Losic	Univ. of Alberta
14	Dr. L. McAllister	Princeton Univ.
15	Prof. V. Mukhanov	LMU Munich, Germany
16	Dr. S. Parameswaran	SISSA
17	Prof. M. Parikh	IUCAA, Pune, India
18	Dr. Tomislav Prokopec	
19	Dr. S. Sarangi	Columbia Univ.
20	Prof. George Smoot	Nobel Laureate
21	Prof. L. Susskind	Stanford University
22	Dr. S. Watson	Univ. of Toronto

Professionals and Technicians

1	Mercure, Paul	McGill University	System manager
2	Nikkinen, Leo	McGill University	Technician

Graduate Students

1	Aubin, François	McGill University	Ph.D.	Astro
2	Barnaby, Neil	McGill University	Ph.D.	THEP
3	Bautista, Mary	McGill University	M.Sc.	XHEP
4	Berndsen, Aaron	McGill University	Ph.D.	THEP
5	Bettefeld, Thorsten	Brown University	Ph.D.	THEP
6	Bourque, Alexandre	McGill University	Ph.D.	TNP
7	Buzatu, Adrian	McGill University	Ph.D.	XHEP
8	Campbell, Benjamin	McGill University	M.Sc.	XHEP
9	Caron-Huot, Simon	McGill University	Ph.D.	THEP
10	Cautun, Marius	McGill University	M.Sc.	TNP
11	Champagne, Christian	McGill University	M.Sc.	XNP
12	Chen, Fang	McGill University	M.Sc.	THEP
13	Cyr-Racine, Francis	McGill University	M.Sc.	THEP
14	Danos, Rebecca	McGill University	Ph.D.	THEP
15	Dorais, Vincent	McGill University	M.Sc.	THEP
16	Dufour, Marc-Andre	McGill University	Ph.D.	XHEP
17	Elliot, Joshua	McGill University	Ph.D.	THEP
18	Fillion-Gourdeau, François	McGill University	Ph.D.	TNP
19	Franche, Paul	McGill University	M.Sc.	THEP
20	Gagnon, Jean-Sébastien	McGill University	Ph.D.	TNP
21	Gianfrancesco, Omar	McGill University	Ph.D.	XNP
22	Guenette, Roxanne	McGill University	Ph.D.	XHEP
23	Gwyn, Rhiannon	McGill University	Ph.D.	THEP
24	Heredia-Ortiz, Roberto	McGill University	Ph.D.	TNP
25	Hoi, Loison	McGill University	M.Sc.	THEP
26	Hoover, Douglas	McGill University	Ph.D.	THEP
27	Karouby, Johanna	McGill University	M.Sc.	THEP
28	Kennedy, James	McGill University	M.Sc.	Astro
29	Kertzscher, Gustavo	McGill University	M.Sc.	XHEP
30	Klemetti, Miika	McGill University	Ph.D.	XHEP
31	Labreque, Remi	McGill University	Ph.D.	TNP
32	Lachapelle, Jean	McGill University	M.Sc.	THEP
33	Lashkari, Nima	McGill University	M.Sc.	THEP
34	Laycock, Thomas	McGill University	M.Sc.	THEP
35	Li, Gang	McGill University	M.Sc.	XNP
36	Lindemann, Dana	McGill University	M.Sc.	XHEP
37	Lorenz, Larissa	IAP, France	Ph.D.	THEP
38	MacDermid, Kevin	McGill University	M.Sc.	Astro
39	MacLeod, Audrey	McGill University	M.Sc.	XHEP
40	Martineau, Patrick	McGill University	Ph.D.	THEP
41	McCann, Andrew	McGill University	Ph.D.	Astro
42	McCutcheon, Michael	McGill University	Ph.D.	Astro
43	Mia, Mohammed	McGill University	M.Sc.	TNP
44	Mueller, Carsten	McGill University	Ph.D.	Astro
45	Patil, Subodh	McGill University	Ph.D.	THEP
46	Piché, Richard	McGill University	Ph.D.	THEP
47	Qin, Guangyou	McGill University	Ph.D.	TNP
48	Roy, Philippe	McGill University	Ph.D.	XHEP
49	Savov, Ivan	McGill University	M.Sc.	THEP
50	Schwartz, Jason	McGill University	M.Sc.	XHEP
51	Shuhmaher, Natalia	McGill University	Ph.D.	THEP
52	Stewart, Andrew	McGill University	M.Sc.	THEP
53	Sully, James	McGill University	M.Sc.	THEP
54	Valcarcel, Luis	McGill University	Ph.D.	Astro
55	Vincent, Aaron	McGill University	M.Sc.	THEP
56	Vujanovic, Gojko	McGill University	M.Sc.	TNP
57	Watson, Peter	McGill University	M.Sc.	XHEP
58	Williams, Greg	McGill University	Ph.D.	XHEP
59	Winkels, Adam	McGill University	M.Sc.	TNP
60	Zhou, Changyi	McGill University	Ph.D.	XHEP

Undergraduate Students

1	Amsel, Stephen	McGill University	Semester	THEP
2	Cohalan, Claire	McGill University	NSERC Summer	Astro
3	D'Ambroise, Christopher	McGill University	Semester	XHEP
4	Dallaire-Demers, Pierre-Luc	McGill University	NSERC Summer	XHEP
5	de Haan, Tijmen	McGill University	NSERC Summer	Astro
6	Dyda, Sergei	McGill University	Semester	THEP
7	Hanna, Trevor	McGill University	Semester	XHEP
8	Karouby, Johanna	Orsay, France	Summer	THEP
9	King, Sam	McGill University	NSERC Summer	XHEP
10	Lepage-Jutier, Arnaud	McGill University	NSERC Summer	XHEP
11	Martinez, Juan	McGill University	Summer	XHEP
12	Najih, Mohamed	McGill University	NSERC Summer	Astro
13	Nayet, Charly	Orsay, France	Summer	THEP
14	Niu, Zeyue	Univ. of Toronto	NSERC Summer	XHEP
15	Rabideau, Charles	McGill University	NSERC Summer	XHEP
16	Smecher, Graeme	McGill University	Semester	Astro
17	Taenzer, Joseph	McGill University	Semester	XHEP
18	Wall, Emily	McGill University	Semester	THEP
19	Warraich, Shahjahan	McGill University	Semester	Astro
20	Witzak-Klempa, William	McGill University	NSERC Summer	THEP
21	Wright, Aaron	McGill University	Semester	XHEP
	(and many others)			

4 Research: Experimental High Energy Physics

4.1 Elementary Particle Physics

Elementary particle physics is the investigation of the structure of matter and the forms of its interactions. Many theories and properties are left to the experimentalist to test and measure: the Standard Model, QCD, CP Violation, mechanism of top production, the existence of the Higgs boson and more.

The Standard Model

Decades of theoretical and experimental discoveries have lead to the Standard Model, which represents our understanding of particle physics, its constituents and forms of interactions. It already unifies the electromagnetic, weak and forces. Actually, the electroweak sector was spectacularly verified in 1983 by the first direct observations of the heavy intermediate gauge bosons.

QCD

Quantum Chromodynamics is the description of the strong interaction, yet including asymptotic freedom and quark confinement. Current experiments are very challenging to the QCD predictions because low energy phenomena cannot be calculated by perturbative methods.

CP Violation

CP violation phenomena have puzzled physicists for a long time and lead to amazing discoveries. It was shown that a third generation of quarks would lead to large asymmetries which could then be observed in b-hadron decays to test its mechanism.

top production

The ”top” was the last missing basic constituent to be measured and superbly confirmed its expectation from the Standard Model. Detailed studies of its decay modes and properties will provide invaluable information.

The Higgs and more

The Standard Model still requires the Higgs to generate masses. It is expected that the Large Hadron Collider (at CERN) or the future Linear Collider will discover it and map its properties. But this can't be the final story and the chances to come to grip with Supersymmetry or to tap into new physics are very exciting to experimentalists.

Experimental particle physics addresses all of the above concerns and maps them into the realm of international efforts in large collaborations of physicists around complex detectors. The McGill high energy groups are actively involved in some of those leading edge ventures: ATLAS, BaBar, CDF, DZero, ILC, SuperB, ZEUS.

4.2 Experimental Detectors at Colliders

ATLAS at CERN

The Large Hadron Collider (LHC) is currently under commissioning at the CERN laboratory near Geneva, Switzerland. It will collide protons at a centre-of-mass energy of 14 TeV, the highest collision energy ever achieved in laboratory. As such, the LHC offers a broad range of physics opportunities and enormous discovery potential. The ATLAS detector will record the results of these high energy collisions. Searches for new phenomena such as the existence of a Higgs boson, large extra dimensions, supersymmetric particles, etc. will be carried out.

Many of the interesting physics questions at the LHC require high luminosity, and so the primary goal is to operate at high luminosity with a detector that provides as many signatures as possible using electron, gamma, muon, jet, and missing transverse energy measurements, as well as b-quark tagging. The variety of signatures is considered to be important in the high-rate environment of the LHC in order to achieve robust and redundant physics measurements with the ability of internal cross-check.

The LHC offers a large range of physics opportunities, among which the origin of mass at the electroweak scale is a major focus of interest for ATLAS. The detector optimization is therefore guided by physics issues such as sensitivity to the largest possible Higgs mass range. Other important goals are the searches for heavy W- and Z-like objects, for supersymmetric particles, for compositeness of the fundamental fermions, as well as the investigation of CP violation in B-decays, and detailed studies of the top quark. The ability to cope well with a broad variety of possible physics processes is expected to maximize the detector's potential for the discovery of new, unexpected physics.

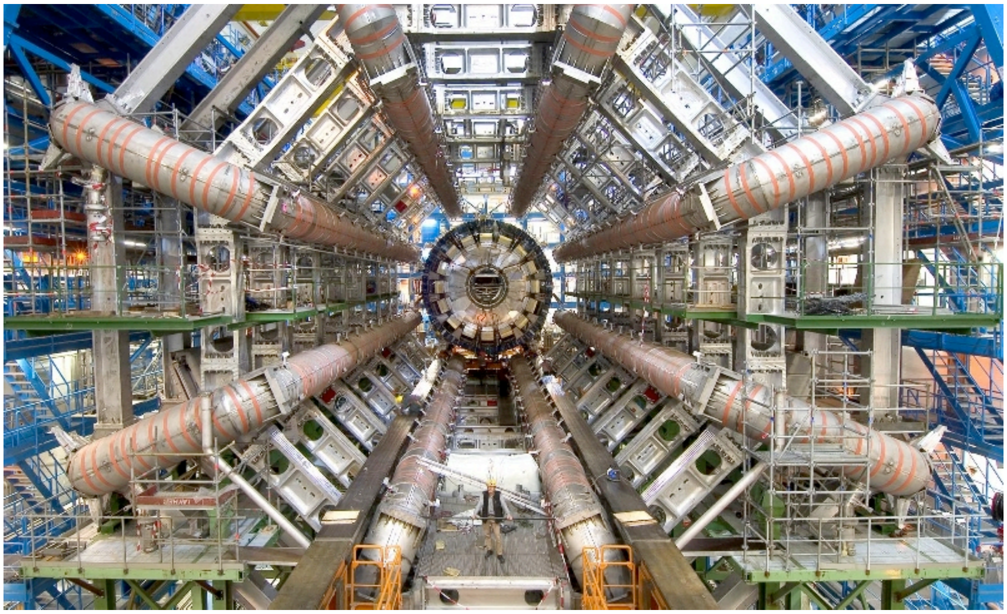

Figure 1: The ATLAS Detector under Construction

BaBar at SLAC

For each particle of matter there exists an equivalent particle with opposite quantum characteristics, called an anti-particle. Particle and anti-particle pairs can be created by large accumulations of energy and, conversely, when a particle meets an anti-particle they annihilate with intense blasts of energy. At the time of the big-bang, the large accumulation of energy must have created an equal amount of particles and anti-particles. But in everyday life we do not encounter anti-particles. The question, therefore, is "What has happened to the anti-particles?"

is a High Energy Physics experiment located at the Stanford Linear Accelerator Center, near Stanford University, in California.

The goal of the experiment is to study the violation of charge and parity (CP) symmetry in the decays of B mesons. This violation manifests itself as different behaviour between particles and anti-particles and is the first step to explain the absence of anti-particles in everyday life.

To study CP violation the BaBar experiment exploits the 9.1 GeV electron beam and the 3 GeV positron beam of the PEP-II accelerator. The two beams collide in the center of the experiment, producing mesons which decay into equal numbers of B and anti-B mesons.

Thanks to the copious production of B-mesons, BaBar is testing the Standard Model description of CP violation. It will be able to over-constrain the CKM matrix Unitarity Triangle.

CDF at Fermilab

The CDF-II (Collider Detector at Fermilab) experiment at the Fermilab Tevatron records collisions from the world's highest energy proton-antiproton interactions, with a centre-of-mass energy of near 2.0 TeV. Its position on the high-energy frontier of accelerator-based scientific inquiry is a striking feature of the Tevatron programme since, in the field of particle physics, the highest energies have proven to be an important provider of new discoveries in fundamental physics.

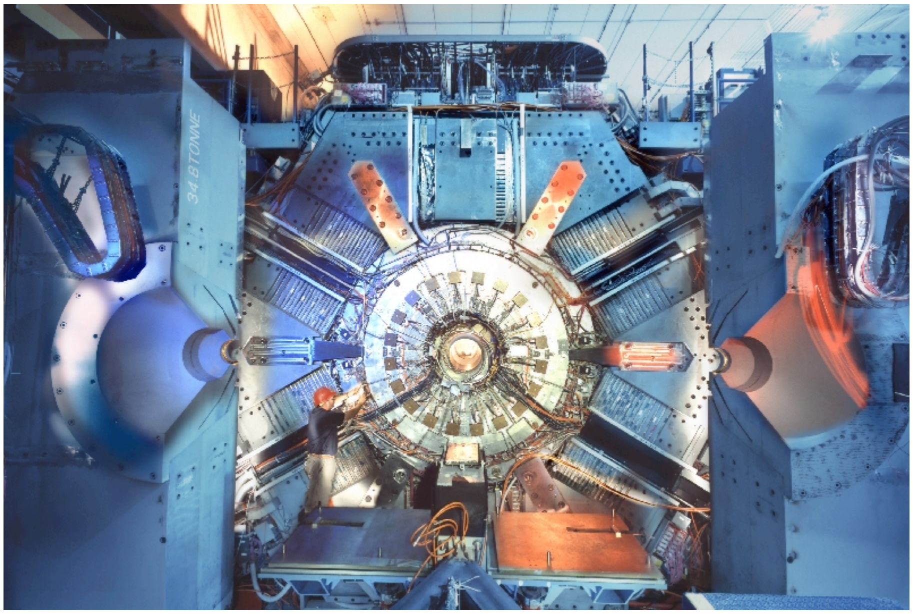

Figure 2: The BaBar Detector

Toward the end of the present decade, the 14-TeV Large Hadron Collider situated at the CERN laboratory in Geneva, Switzerland is expected to supersede the Tevatron's position on the high-energy frontier. The next five years, therefore, are a unique opportunity for the CDF-II experiment to explore the heaviest known fundamental particles, such as the top quark, as well as the processes by which matter's constituents derive their masses, the Higgs mechanism, for example. Results from the CDF-II research programme will play a driving role in defining the priorities of subsequent research at the Large Hadron Collider, which also collides hadrons against hadrons.

Complementary to the energy frontier is the sensitivity frontier, another provider of new physics. In the 2.0-TeV collisions at the Tevatron, the production cross section is significantly greater than that at electron-positron machines. Although the background rates are also greater, selective triggering can amass high statistics samples with sufficiently high signal-to-noise ratios to probe rare processes. Unlike threshold machines, which produce mesons with either an up or down spectator quark, an advantage of the Tevatron is that it can produce all flavours of hadrons. CDF-II studies of these states will significantly advance our understanding of CP and flavour violation, as well as non-perturbative quantum chromodynamics.

DZero at Fermilab

The DZero Experiment consists of a worldwide collaboration of scientists conducting research on the fundamental nature of matter. The experiment is located at the world's premier high-energy accelerator, the Tevatron Collider, at the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois, USA. The research is focused on precise studies of interactions of protons and antiprotons at the highest available energies. It involves an intense search for subatomic clues that reveal the character of the building blocks of the universe

The physics covered by the detector is very rich and encompasses: the top quark production and its mass determination, electroweak physics with the detailed properties of the intermediate W

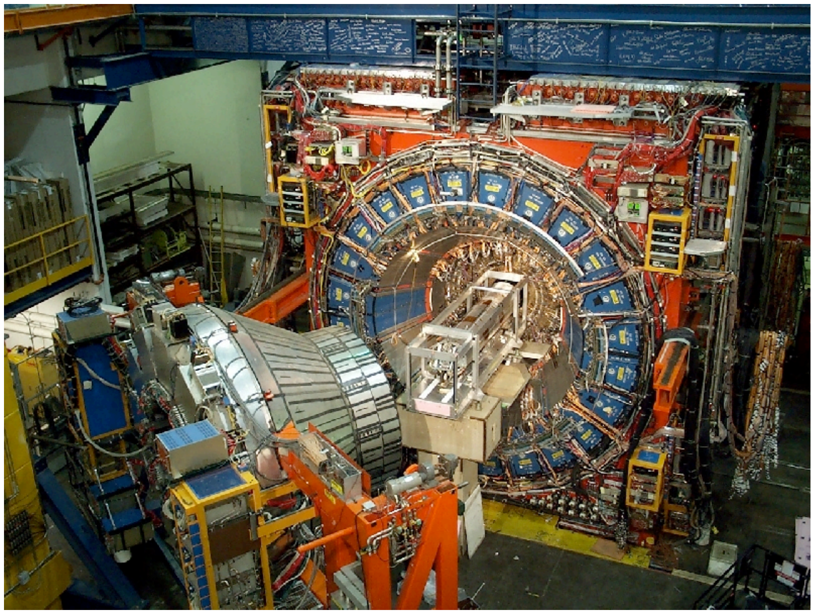

Figure 3: The CDF Detector

boson, QCD physics with good precision, including jet and diffraction processes, bottom quark physics with its decay modes and other characteristics, as well as searches for phenomena beyond the Standard Model, testing many predictions or exotic models from theorist colleagues.

Linear Collider Projects

The next generation accelerator will be an electron-positron machine, but in the linear acceleration mode where massive energy losses through synchrotron radiation are avoided and extremely high particle-on-particle energies reached. The signals for the elusive Higgs particles should be clear.

The International Linear Collider (ILC) is intended to be an electron-positron linear collider producing collisions in the energy range 0.5-1 TeV. The ILC is widely acknowledged to be one of the highest priorities for the future of Particle Physics. Several fully developed proposals for such a machine, have been put forward in recent years (e.g. TESLA at DESY). All regions of the world have now combined behind a common technology choice, based on the superconducting r.f. accelerating cavities of TESLA, and are carrying out a full technical design.

The McGill group is a member of the CALICE collaboration, along with at the moment one other Canadian university group (Regina). CALICE is an umbrella for several R&D projects investigating high resolution calorimetry for a linear collider. The activities are focussed on a series of beam tests performed since 2005 in which a series of prototype calorimeter modules are being exposed to a variety of hadron and electron beams. The prototypes are all directed towards the construction of calorimeters with high granularity.

As well as yielding information about various detector technologies, the beam tests play a crucial role in validating the Monte Carlo simulation programs which will be used to optimise the design of a full detector. In particular, simulations of hadronic shower processes in calorimeters are notoriously problematic, and good data are essential before credible simulation results can be delivered.

The ILC will complement the LHC program very effectively. Whatever new discoveries may be

Figure 4: The DZero Detector

made at LHC (the Higgs boson, supersymmetry etc), an electron-positron collider will be able to study the new physics with much smaller backgrounds and hence much greater precision. This will be crucial in establishing any theory beyond the present standard model.

Many of the physics processes to be studied at such a machine require the measurement of the momenta of quarks, which will be detected as jets. The accurate measurement of the energy of a jet requires combining the measurements of different types of particles in different parts of the detector (tracking detectors and calorimeters). Experience from LEP tells us that good spatial resolution in the calorimetry is a crucial ingredient in combining all the information optimally. It is clear that an integrated approach to the detector design will be needed to achieve the best performance.

The idea of a digital calorimeter with extremely high segmentation, combined with the use of new type of silicon-based sensor devices, is being investigated at McGill.

Super-B

The SuperB project is a proposal for a high-luminosity B-factory operating at the Upsilon(4S) resonance at an energy of 10.5 GeV. This project is a natural successor to the BABAR and Belle B Factory projects at the SLAC and KEK laboratories respectively, with a similar physics environment but with approximately 100 times more data. Over the past several years, a series of physics workshops have demonstrated that studies of B meson, charmed mesons and tau leptons, all of which are copiously produced at a B factories, with extremely large data statistics can reveal, or provide interesting constraints on, possible "new physics", similar to that which is explored at the LHC at CERN. Moreover these studies remain interesting, and in fact potentially become more interesting, even if the LHC has already observed evidence of this same new physics. The complementarity and synergy with the LHC provides an very strong physics case for the SuperB project, however the project is still in the early R&D phase. In 2007, a Conceptual Design Report was submitted by the

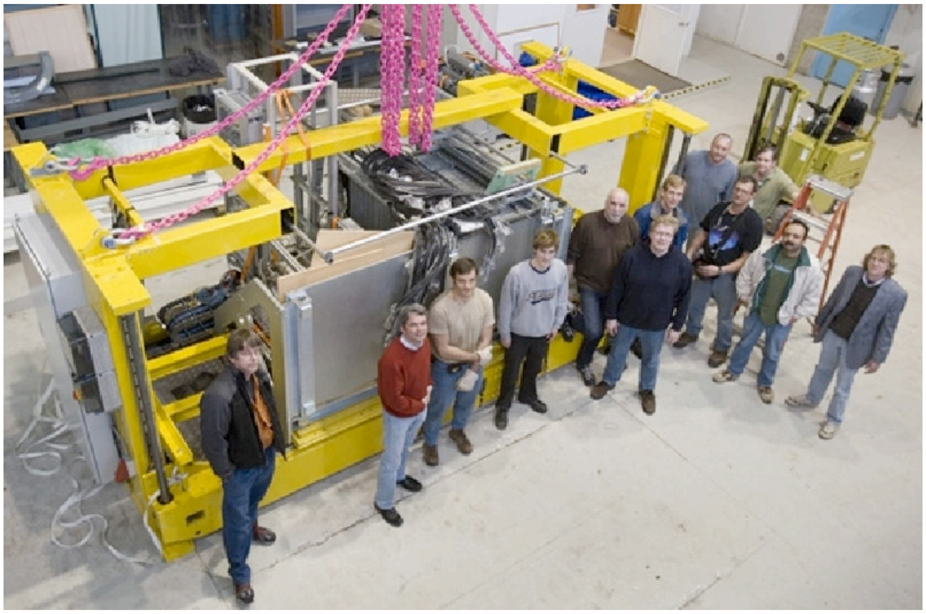

Figure 5: The CALICE Calorimeter Prototype

SuperB group for international review. Additional physics studies and detector R&D activities are continuing, in anticipation of a request for a Technical Proposal for the project from the Frascati Laboratory. The McGill group has participated in studies of the physics potential of possible searches for various rare decays of B mesons. These decay modes are of interest because of their potential sensitivity to physics beyond the particle physics "Standard Model". The group has also contributed to conceptual-design activities for the SuperB detector and in particular to the impact of accelerator beam-background and radiation damage issues for the calorimeter.

ZEUS at DESY

The HERA accelerator at DESY, in Hamburg, Germany, is an electron-proton machine. The disparity of initial states and the asymmetry in the energies makes it an extremely challenging project, but extremely well suited for deep inelastic scattering measurements and QCD studies, probing the content of the proton very close to the attometer ($10^{-18} m!$) scale. This enables us to determine the structure function of the proton over extended kinematic ranges, which is basically a description of its parton (quark and gluon) content.

Ongoing detailed analyses of particle production also contribute to the understanding of fragmentation processes. Strange particle production has been studied successfully by our group. Its aim is to probe the sea quark content of the proton and more specific details fo the fragmentation processes. Another projects are the observation of jets of particles: not only do jets testify of the quark and gluon content of the proton, but they also represent a powerful tool to determine the value of the α_s coupling constant of the strong interaction. The available kinematic range in ZEUS is sufficiently large that the constant's running can even be observed within this measurement.

Photoproduction on proton, by which a quasi-real photon is exchanged, yields on the other hand a large amount of very relevant information on the many-sided and puzzling nature of the ¡it¿photon¡/it¿. Some of the observables are its vector meson behaviour, its direct interaction signals or evidences of its partonic structure. Via the observation of jets, I am interested in details of the hard processes, which should provide essential informations on the photon parton densities.

The data taking phase has been terminated in June 2007, but several analyses are still under way to extract the last physics results. They should be completed in the next 2-3 years.

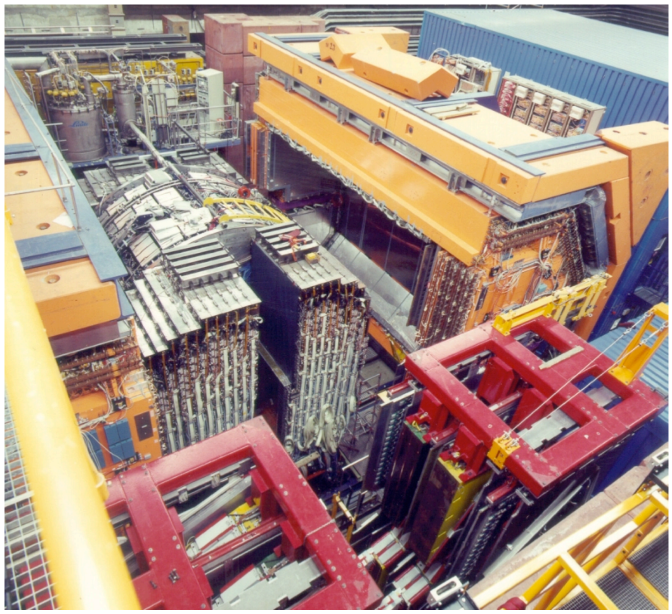

Figure 6: The ZEUS Detector

4.3 Interdisciplinary Research

Particle Astrophysics - STACEE

The emerging area of particle astrophysics applies the techniques and methods of particle physics to problems in astrophysics. The McGill group was involved in STACEE, a project in ground-based gamma ray astrophysics. The experiment was using a modified solar-power facility in Albuquerque, New Mexico to provide a large mirror area for the detection of Cherenkov radiation coming from air showers created by high energy astrophysical gamma-rays. This experiment is now completed.

Particle Astrophysics - VERITAS

The Group has now has shifted its work to the VERITAS collaboration, building a new array of imaging telescopes for Cherenkov shower detection, at Mt. Hopkins in Arizona, which already have more sensitivity than the STACEE detector.

Some of the most astounding recent discoveries about our universe have been made by telescopes and instruments collecting forms of natural radiation from space, that are invisible to the human eye. The VERITAS (Very Energetic Radiation Imaging Telescope Array System) telescope is an array of collectors that detect the small light flashes produced by high-energy gamma rays interacting in the upper atmosphere. Several sources of this high-energy radiation have been discovered with earlier pathfinder telescopes. These sources apparently exist both within our galaxy and in energetic extragalactic objects. VERITAS can detect much fainter and more distant objects than existing telescopes, and is expected to discover many new sources of high-energy gamma rays. VERITAS is a collaboration of 10 institutions in the USA, Canada and Europe.

VERITAS is the latest stage in the evolution of very-high-energy gamma-ray astronomy, a field where many aspects are closer to particle physics than to traditional astronomy. The basic idea is to use the Earth's atmosphere as the 'front end' of the detector, much like a calorimeter in a collider experiment. At high energies, gamma rays initiate extensive air showers in the upper atmosphere, and relativistic particles in these showers radiate Cherenkov photons that penetrate to ground level. An imaging detector located anywhere in the light pool can use the size and pattern of hits in its camera to reconstruct the energy and direction of the shower and, by extension, the primary particle that spawned it. This is the principle of the imaging atmospheric Cherenkov telescope (IACT). The effective area of the detector is the size of the light pool, which is of the order of 100,000 m^2.

The main background comes from charged cosmic rays, energetic protons and light nuclei, which typically outnumber gamma rays by a factor of more than 000. These can be rejected by using differences in the morphology of gamma-initiated and hadron-initiated showers that are manifest in the image at the camera Rs focal plane. Indeed, it is the cosmic-ray rejection power afforded by multiple views of the shower that has motivated the construction of the modern arrays of IACTs.

In contrast to collider experiments, where data on different physics topics are accumulated simultaneously with different triggers, telescopes are pointed instruments and a scheduling committee decides where they point. For the first two years of observations, VERITAS will spend half of the available hours on four Key Science Projects (KSPs). The remaining time will be given over to observations proposed by groups within the collaboration.

One KSP is a survey of part of the Milky Way visible from the northern hemisphere, which will search for new sources with fluxes greater than about 5% of the Crab Nebula. Another KSP is an indirect search for dark matter. WIMPs could cluster in gravitational wells such as nearby dwarf galaxies or globular clusters and then annihilate, producing a continuum of gamma rays that may be strong enough to be seen by VERITAS. Although less direct than a search for supersymmetric particles at an accelerator, the gamma ray technique targets a larger range of candidate masses.

Another KSP concerns galactic sources such as pulsar-wind nebulae and supernova remnants (SNRs), while yet another deals with extragalactic sources known as active galactic nuclei (AGNs). SNRs are interesting because they could possibly be the source of most galactic cosmic rays. With the new-generation detectors, their morphologies can be resolved and this will aid in the understanding of particle acceleration models. Gamma rays from AGNs are thought to originate in their relativistic plasma jets, which are powered by accretion of host-galaxy material by a supermassive black hole. These sources are notoriously time-variable, so the plan is to conduct multi-wavelength campaigns using contemporaneous X-ray, optical and radio observations to uncover the physics processes at work in these high-energy objects.

Particle Physics Applications

Techniques and methods of particle physics are growing in scope and are making considerable impact in other fields, like medicine, astrophysics and cosmology. Particle physics has always pushed and stimulated developments of high technology, electronics and computing. Their effects are best seen in e.g. the establishment of the World Wide Web, open source methods of programming or innovative uses of special materials in detectors.

Figure 7: The VERITAS Telescopes

5 Research: Theoretical High Energy Physics

Our research interests are diverse, covering most of the active topics in high-energy theoretical physics. Here are some of the topics on which we have worked over the past few years.

5.1 Elementary Particle Physics

Elementary-particle phenomenology is the study of the properties of elementary particles as theoretically predicted by the Standard Model, or by alternative models of physics at very high energies. The goal of such studies is to make the best contact with experimental results, in order to suggest the kinds of measurements which are most informative on key theoretical questions, or to interpret the theoretical implications of current experimental results.

Neutrino Physics

Recent measurements of neutrino properties appear to disagree with the predictions of the otherwise extremely successful Standard Model of particle interactions. This has stimulated a detailed re-examination of the relationship between the new experiments and older ones, and on how the Standard Model might be modified in order to take the newer results into account. We have studied: which neutrino properties are consistent with the various ongoing neutrino experiments; new types of signals within neutrinoless Double-Beta-Decay experiments; how neutrinos interact with matter fluctuations in astrophysical media.

Precision Electroweak Physics

The Standard Model of the electroweak interactions is currently being tested in accelerator experiments to an accuracy of better than one percent. This permits a better determination of poorly-known quantities, like the mass of the as-yet-undiscovered Higgs boson. It also constrains the kinds of New Physics which one can entertain as replacements for the Standard Model at higher energies. We have developed: effective-lagrangian techniques for efficiently identifying how ‘new’ physics can appear within well-measured observables; the application of these techniques to identify which kinds of experiments are sensitive to which kinds of new physics.

Strong Interactions

It has been notoriously difficult to unravel the predictions of Quantum Chromodynamics (QCD), which is currently understood within the Standard Model as the theory of the strong interactions. The obstacle lies in the difficulty of the calculations which are required in order to make these predictions. In recent years several new techniques have emerged from unexpected places. We have helped develop these new calculational techniques: string-theory-based techniques for efficiently computing loop amplitudes in QCD; methods for summing infrared-singular amplitudes for soft-gluon emission.

5.2 Field Theory

Quantum Field Theory has emerged as the theoretical framework within which all physical theories are couched. The intricate consistency issues which must be satisfied by any viable quantum field theory turn out to very usefully constrain the theoretical possibilities at extremely high energies, where gravity starts to play an important role at the quantum level. The emergence of string theory as the only known consistent solution to these constraints has initiated considerable progress in understanding very-high-energy physics, even in the absence of direct experimental information.

Our research in this area has included the following topics:

Black Holes

Black Holes are a frontier between known and new physics, since uncontrolled gravitational collapse relentlessly drives a system into a poorly-understood strong-curvature, high-energy regime starting from the well-understood regime of weak fields and low energies. We have: computed string-theory corrections to and dualities amongst black hole spacetimes; evaluated strong-curvature corrections to black-hole entropy; calculated the properties of the photosphere which develops around evaporating black holes.

Duality

Duality is the blanket name which describes the many surprising equivalences which have been discovered amongst apparently unrelated field and string theories. These relationships have revolutionized the current view of extremely-high-energy physics by showing that the many different string theories are duals of one another within a more fundamental framework, known as M-Theory. (Don't ask what 'M' stands for.) Our research involves: the discovery and exploration of the connection between duality and bosonization; the use of duality to construct new solutions to the string equations of motion; the discovery of a new class of superdualities.

Supersymmetry

Supersymmetry is a beautiful symmetry which arises in many proposals (including,in particular, in string theory) for the ultimate replacement for the currently-successful Standard Model of fundamental interactions. Our work includes: the runaway-dilaton problem in strongly-coupled supersymmetric theories; the viability of supersymmetric models for electroweak baryogenesis.

String Theory

String theory (or M theory) is the best candidate for the theory which unifies all interactions, including gravity. Within this framework the basic building block of all matter consists of extremely short, infinitesimally-thin one-dimensional strings, rather than the traditional indivisible point particles. Our interests in this area include: higher-dimensional D-brane solutions to the low-energy string equations of motion; the duality between string theories and four-dimensional conformal field theories; the relevance of string theory for the problem of information loss in black holes.

Inflation and String Theory

Inflation and string theory address the most fundamental questions of cosmology and elementary particle theory, respectively. Inflation replaces our old conception of the singular big bang with rapid expansion of empty space, followed by reheating of the universe when it was already quite large. String theory replaces the old idea of singular point-like particles by extended, string-like objects, and achieves the long-sought reconciliation of quantum mechanics and gravity. Each theory by itself overcomes very serious problems within the old paradigms. But the new theories also come with their own problems. Inflation suffers from an embarrassment of riches: it is too easy to construct particle physics models of inflation, and we currently do not have enough experimental discrimination to distinguish between different underlying theories. String theory suffers from its lack of testability in laboratory experiments. It is therefore exciting that inflation and string theory can combine to benefit each other. String theory, being much more highly constrained than field theory, removes much of the arbitrariness from inflationary model building while at the same time offering new mechanisms for inflation. Inflation provides string theory with new observational constraints and signatures, making it more testable. It is for these reasons that string theorists and cosmologists have joined forces in recent years, in this fertile cross-disciplinary endeavor.

One of the most exciting predictions of a certain type of inflation is that cosmologically-large strings could be produced as relics of the collision. Such cosmic superstrings could possibly be observed by their contribution to fluctuations of the cosmic microwave background (CMB), or by gravitationally lensing background galaxies. This is related to the larger question of how reheating takes place at the end of brane-antibrane inflation. Members of our team have been among the first to confront some of the important issues for the formation of defects and for reheating in these models. Although inflation does a good job of explaining the homogeneity, isotropy and flatness of the universe, and the nature of the CMB fluctuations, it is not yet a fully proven theory. It is important to test whether alternatives to inflation can be developed, and some of us have been using ideas from string theory, namely string and brane gas cosmology to do just that.

5.3 Theoretical Cosmology

Inflationary Cosmology

The inflationary universe scenario proposed in 1981 by Guth has provided a theory of the origin for the small density fluctuations which can be measured in cosmic microwave background temperature maps and in galaxy redshift surveys. The original predictions for observables have been spectacularly confirmed in recent experiments. Research at McGill focuses on further developments of the inflationary scenario, with particular emphasis on the study of the conceptual problems of the inflationary paradigm.

Theory of Cosmological Perturbations

Fundamental physics connects to observations through the detailed study of the cosmological fluctuations (density perturbations and gravitational waves) which are produced in the early Universe and propagate through time to produce the present observational signatures. Past work of the McGill researchers has played an important role in the development of the classical and quantum theory of linearized fluctuations. Current research focuses on higher order effects such as cosmological back-reaction, and on extensions of the formalism to brane world cosmologies.

Superstring Cosmology

The inflationary universe scenario does not eliminate cosmological singularities, nor does it address the question of why only three of the nine or ten spatial dimensions of string or M theory are macroscopic. Research at McGill focuses on 'string gas cosmology', an approach to string cosmology which addresses these questions. Studies of cyclic cosmologies in the context of string cosmology are also in progress.

Baryogenesis

The study of novel mechanisms of cosmological baryogenesis is another key aspect of cosmology research at McGill.

6 Research: Experimental and Theoretical Nuclear Energy Physics

6.1 Experimental Nuclear Energy Physics

The current research programs in Experimental Nuclear Physics at McGill include the investigation of nucleus-nucleus collisions at ultrarelativistic energies, the study of nuclear ground state properties of unstable nuclei, and the use of nuclear techniques in applied physics. Most of the experiments in both areas are being performed as international collaborations at major accelerator centers in Europe, the U.S.A. and Canada. However, a great deal of the experimental planning and equipment design, preparation and assembly are carried out at McGill.

The primary goal of the study of nucleus-nucleus collisions at relativistic energies is the study of the equation of state of hot hadronic matter and the phase transition to the new phase of matter, the quark gluon plasma. Our research program has now moved to RHIC energy where our present effort is on the understanding of the evolution of some experimental observables as the beam energy is increased to the energy that are now available at this new heavy-ion collider. One of our present works is a comparison between model predictions and the new data to help determine the observables that provide the best signature for new physics at RHIC. One of our studies aims at understanding the importance of hard process at RHIC energies including the quenching effect of nuclear matter on the propagation of jets. Our team is involved in the OSCAR working group a collaboration that addresses the lack of standards, documentation and accessibility in transport codes used to described heavy-ion collisions at relativistic energies. We contribute in the development of this standard and test the implementation of some new physics in the models relevant to RHIC, in particular, hard physics related to perturbative QCD. In the last two years, an important effort has been devoted to the development of a new version (v2.0) of the HIJING/BB

Monte Carlo nuclear collision event generator in order, in particular, to explore further the possible role of baryon junctions loops in the baryon/meson anomaly observed at moderate p_t in heavy-ion reactions at RHIC energy. Recently this new code has been used to demonstrate the presence of an increase strong color field in the dense nuclear matter produced in high-energy heavy-ion collisions.

Nuclear ground state properties such as spin, electromagnetic moments and charge radius of radioactive nuclei are basic properties of the nucleus which serve as important tests of our understanding of the nuclear models and determined also the main decay properties of radioactive nuclei. In highly unstable nuclei far from the valley of stability, laser spectroscopy techniques can be used to measured these properties. These techniques are based on the precise measurements of atomic hyperfine structure in the interaction between the laser beam and the radioactive atoms. In recent years, the McGill group has pioneered in the development of a number of high sensitivity techniques for these studies. At McGill, an apparatus for laser spectroscopic studies of ions stored in an RFQ (Radio-Frequency Quadrupole) trap allows the investigation of relatively long-lived isotopes. Work is also being carried out at the on-line isotope separator facility (ISOLDE) at CERN using collinear and resonant ionization spectroscopic methods, within an international collaboration.

Other experimental projects concern Ion trapping techniques for nuclear mass measurements, Applied Physics and instrumentation, ultrasensitive detection of trace materials, and radiation damage in silicon devices.

6.2 Laser Spectroscopy for Nuclear Studies

We investigate the fundamental nuclear properties, and specifically masses and radii. The work involves laser spectroscopy experiments for the determination of changes in nuclear charge radii over long isotopic chains as well as nuclear mass measurements using Penning traps.

Our principle experiments are the Canadian Penning Trap experiment at Argonne National Laboratory, the TITAN Penning Trap experiment at TRIUMF and the Collinear Laser Spectroscopy Experiment at TRIUMF. The experiments determine moments, radii and masses of nuclei far from stability and provide data for nuclei of relevance in stellar processes and for the refinement of nuclear models, in general.

Other areas of interest include the application of research methods to technical challenges (*Applied Physics*). Specifically: (1) RFQ-ion traps and lasers are used for the detection of low abundance species and for manipulating atoms on nanoscopic scales; (2) The creation of defects in avalanche photodiodes by single neutrons allows time-resolved studies of defect generation and annealing with ms resolution.

We use laser techniques to study fundamental nuclear properties - radii, spins, and moments. The techniques are borrowed from atomic physics. In an atomic spectrum, a transition line splits into a number of components (the hyperfine structure), whose wavelengths depend on the size, shape, and spin of the nucleus. A lot of the really interesting phenomena (sudden changes of nuclear shape, for example) occur in exotic nuclei which lie far from nuclear stability. This means that our studies must be done on radioactive nuclei produced in reactions at particle accelerators. The challenge is therefore to find ways of studying very small samples (a few atoms, in some cases) of isotopes that may have lifetimes of only a few minutes, or seconds.

At McGill, we are currently involved in the study of laser ion sources, through laser desorption and resonant ionization spectroscopic (RIS) techniques; selective injection of radioactive ions into an RFQ trap; and laser spectroscopic studies of radioactive ions. For this work, we use stable and long-lived isotopes, and sometimes other rare species such as cluster ions.

The applications of these methods in nuclear physics are carried out through extensive collaborations at nuclear laboratories. Currently, we have an on-going laser spectroscopy program at ISOLDE (CERN), and a precise nuclear mass measurement project at TASCC (Chalk River). The possibility of initiating a new project at the recently funded high-intensity radioactive ion beam facility ISAC (TRIUMF) is being explored.

In addition we are collaborating with the optoelectronic division of EG&G in the study of defects in avalanche photodiodes induced by fast neutron collisions. Some of the resultant defects are bistable, causing the dark current to jump between two distinctly different levels. The results of this study will help us to understand the metastable nature of the defect configurations.

6.3 Ion Trap Techniques for mass Measurement and Laser Spectroscopy

Recently, a technique for ”catching” and storing ions from isotope separators in a radio frequency quadrupole trap has been developed by our group and is now being adapted for ion collection in a system designed to measure nuclear masses at CERN (Geneva). The same technique also appears to be very promising one for the capture and bunching of ion beams for use in laser spectroscopic measurements on nuclei. A new colinear spectroscopy beam line has been constructed at McGill as a pilot project to test this technique.

Other interests are Electromagnetic Trapping and intertrap transfer, high-field confinement of charged particles, ion beam cooling, high accuracy nuclear mass measurements, high sensitivity detection of high mass biomolecules and the evolution of liquid surfaces under high electric fields (electrospray).

6.4 Theoretical Nuclear Energy Physics

Modern theoretical nuclear physics can be summarized as the study of strongly interacting many body systems. The 20th century is filled with many break-throughs in physics. One of such break-throughs was the discovery of accurate theory of strong interactions – quantum chromo-dynamics (QCD). This theory predicts that the quarks and gluons which make up the nuclear matter can never exist as free particles in ordinary matter. However under extreme conditions such as one existed a few micro-second after the big-bang, a deconfinement phase transition will take place and quarks and glons can be freed to form a Quark-Gluon Plasma (QGP).

The advent of high energy heavy ion colliders in Europe and North America caused a remarkable advance in this field. New and surprising experimental results and exciting new theoretical insights and predictions are continuously being published while large number of puzzles still remain to be investigated.

In the study of heavy ion collision theory and in the energy range 30 MeV/nucleon to many GeV/nucleon, the important questions to ask are:

- Can we extract information about the nuclear equation of state?
- Do we see a liquid-gas phase transition in the lower beam energy experiments?
- What is the proper theoretical framework which can be used to describe intermediate energy heavy ion collisions?

We pursue the theoretical study of strongly interacting matter under extreme conditions of temperature and density, such as that formed in relativistic nuclear collisions at terrestrial accelerators, and that in dense stellar objects. One of the reasons this topic is so appealing is that it involves aspects of nuclear, particle, condensed matter, and astrophysics. Put another way, we're exploring the whole phase diagram of QCD, the theory of the strong interaction.

7 Highlights of the Year (excerpts)

7.1 Workshops

1. *Cosmology on the Landscape*, R. Brandenberger, workshop organization: main organizer. May 11 - 13, 2007, McGill.

2. *The Quantum Nature of Spacetime Singularities*, KITP Mini-Program, Jan. 2007 Member of the Organizing Committee.

3. *Working group on Inflation from String Theory*, Jim Cline, Cliff Burgess, Hassan Firouzjahi and Keshav Dasgupta, Proposed and organized working group at Banff International Research Station, June 3-10, 2007

4. *Cosmic Microwave Background workshop*, M. Dobbs, 2008/03 Organized a workshop at McGill. The workshop is funded by the Canadian Space Agency, McGill Physics Department, McGill Faculty of Science, and Canadian Institute for Advanced Research (CIfAR). Every faculty member across Canada that is active in CMB research, together with their students and postdocs, attended the meeting. Hosting this meeting at McGill puts us firmly on the map as one of the premier locations in Canada for experimental cosmology research.

7.2 Conferences, Invited Lectures, Talks and Outreach

1. *Bs and b-Hadron Decays*, Invited plenary review talk, A. Warburton, representing the Belle, CDF, and DZero Collaborations; International Flavor Physics & CP Violation 2008 Conference; Taipei, Taiwan; 2008.05.05-09.

2. *Recent Results from CDF*, Invited opening plenary talk, A. Warburton, representing the CDF Collaboration; ATLAS-Canada Physics Workshop; Universit de Montral; 2007.12.17.

3. *Seeing Beauty in High-Energy Particle Collisions*, A. Warburton, Homer's Physics 101 "Inreach" talk; McGill University; 2007.11.16.

4. *Terra Incognita: Physics at the energy frontier*, B. Vachon, Invited plenary speaker, 3rd Canada-America-Mexico Graduate student physics conference, Montreal, 8-11 August 2007.

5. *Evidence for single top quark production using advanced statistical analysis methods*, B. Vachon, Seminar, Mainz University, 6 February 2008.

6. *Evidence for single top quark production and first direct measurement of* $|V_{tb}|$, B. Vachon, LEPP Journal Club, Cornell University, 16 November 2007.

7. *Rare B Decays*, S. Robertson, 2007 Aspen Winter Conference, January 8-13, 2007, Aspen Center for Physics, Aspen Colorado.

8. *Rare B Decays with the BABAR Experiment*, S. Robertson, Invited Seminar, Cornell University, Ithaca, NY, Feb 9, 2007.

9. *Rare B Decays with the BABAR Experiment*, S. Robertson, Invited Seminar, University of Alberta, Feb 23, 2007.

10. *Spectroscopy Results from HERA*, F. Corriveau, Invited talk at the PHIPSI08 Conference in Frascati, Italy, 10 April 2008. Proceedings will follow.

11. *Recent Results from HERA ep Collisions*, F. Corriveau, Invited talk at the PASCOS Conference (Particles, Strings and Cosmology), Imperial College, London, UK, 3 July 2007. The proceedings paper is listed with the publications.

12. *Electroweek Results from ZEUS*, F. Corriveau, Invited talk at the Annual Congress of the Canadian Association of Physicists (CAP), Saskatoon, 18 June 2007.

13. *Muon Physics, Part II: Precision Measurements*, F. Corriveau, HEP seminar, Department of Physics, McGill University, 5 March 2008.

14. *Muon Physics, Part I: Observation and Discovery*, F. Corriveau, HEP seminar, Department of Physics, McGill University, 6 February 2008.

15. *ZEUS and the IPP*, F. Corriveau, Talk presented at the IPP Review in Vancouver, 8 November 2007.

16. *Singularity Resolution and Structure Formation*, R. Brandenberger, KITP Mini-Program on "Quantum Nature of Spacetime Singularities", KITP, Santa Barbara, Jan. 8 - 27, 2007.

17. *Resolution of Cosmological Singularities and Early Universe Cosmology*, R. Brandenberger, Invited Lecture, Inaugural workshop, Center for Fundamental Theory, Penn State University, May 5-6, 2007.

18. *Theory of Cosmological Perturbations". R. Brandenberger, Invited Lecturer, NORDITA Workshop on "Cosmology, Strings and Phenomenology*, Stockholm, June 11 - 15 2007

19. *Tachyon Condensation, String Gas Cosmology and Structure Formation*, R. Brandenberger, Invited Speaker, NORDITA Conference on "Cosmology, Strings and Phenomenology", Stockholm, June 17 - 20 2007

20. *Tachyon Condensation, String Gas Cosmology and Structure Formation*, R. Brandenberger, Invited Speaker, Workshop on String Cosmology, ICTP, Trieste, Italy July 9 - 13, 2007

21. *Cosmologist's Wish List for String Theory*, R. Brandenberger, Invited Speaker, "Frontiers of Modern Cosmology" workshop, Perimeter Institute, Sept. 11 - 15, 2007

22. *Classical and Quantum Theory of Cosmological Perturbations*, R. Brandenberger, Invited Lecturer, KITPC Program on String Cosmology, Beijing, Oct. 24 2007, (2 lectures).

23. *String Gas Cosmology and Structure Formation*, R. Brandenberger, Invited Participant, KITPC Program on String Cosmology, Beijing, Oct. 29 2007,

24. *Entropy Fluctuations in Brane Inflation Models*, R. Brandenberger, Invited Participant, KITPC Program on String Cosmology, Beijing, Oct. 30 2007,

25. *Probing String Theory through Cosmological Observations*, R. Brandenberger, Invited Speaker, Workshop on Experimental Search for Quantum Gravity, Perimeter Institute, Nov. 5 - 9 2007,

26. *Identifying Cosmic Superstrings in the Sky*, R. Brandenberger, Invited Lecturer, Workshop "Strings and Superstrings in Observational Cosmology", Dec. 10 - 13 2007.

27. *Towards an Alternative to Inflation based on String Theory*, R. Brandenberger, Invited Speaker, The Very Early Universe 25 Years On Conference, DAMTP, Cambridge Univ., Cambridge, Dec. 16 - 20 2007,

28. *Resolution of Cosmological Singularities - a Workshop Report*, R. Brandenberger, McGill University, Pizza Seminar, Feb. 6 2007

29. *Was there a Big Bang?*, R. Brandenberger, CEGEP Marianopolis, Montreal, March 1 2007

30. *Strings, Singularities and Structure Formation*, R. Brandenberger, Perimeter Institute, Seminar, March 22, 2007,

31. *String Gas Cosmology and Structure Formation*, R. Brandenberger, Columbia University, ISCAP seminar, April 13 2007

32. *String Gas Cosmology and Structure Formation*, R. Brandenberger, Theory Seminar, Case Western Reserve Univ., April 24 2007

33. *String Gas Cosmology and Structure Formation*, R. Brandenberger, Theory Seminar, Ohio State Univ., April 25 2007

34. *String Gas Cosmology and Structure Formation*, R. Brandenberger, Theory Seminar, Beijing University, Oct. 31, 2007,

35. *Tachyon Condensation, String Gas Cosmology and Structure Formation*, R. Brandenberger, Theory Seminar, Yukawa Institute for Theoretical Physics, Kyoto Univ., Kyoto, Japan, Nov. 5 2007,

36. *String Theory and Early Universe Cosmology*, R. Brandenberger, Cosmology Seminar, Univ. of Pennsylvania, Dec. 6 2007,

37. *String Theory and Early Universe Cosmology*, R. Brandenberger, Invited Colloquium, APC Univ. Paris VII, Dec. 11 2007,

38. *String Gas Cosmology and Structure Formation*, R. Brandenberger, Cosmology Seminar, Univ. of Zürich, Switzerland, Dec. 14 2007,

39. *QCD versus N=4 Super-Yang-Mills: shear viscosity*, G.D. Moore, "Exotic States of Hot Dense Matter and their Dual Description", 22-25 May 2007, Perimeter Institute, Waterloo Ontario: invited talk

40. *Plasma Instabilities in QCD and Super-Yang-Mills*, G.D. Moore, "Nonequilibrium Phenomena in Cosmology and Particle Physics", 25-29 February 2008, Kavli Inst. for Theoretical Physics, Santa Barbara.

41. *Stress tensor spectral weight and bulk viscosity where we can calculate it*, G.D. Moore, "QGP through Spectral Functions and Euclidean Correlators", 23-25 April 2008, Brookhaven National Labs, New York.

42. *Plasma instabilities in QCD*, G.D. Moore, University of British Columbia, 7 September 2007.
43. *Braneworld cosmology*, James M. Cline (McGill U.) . MCGILL-07-527, Apr 2007. 14pp. Invited talk at From Strings to LHC Workshop, Goa, India, 2-10 Jan 2007. Published in PoS STRINGSLHC:011,2007. e-Print: arXiv:0704.2198
44. *Fine-Tuning in Brane-antibrane Inflation*, James M. Cline (McGill U.) . May 2007. 14pp. Presented at From Strings to LHC Workshop, Goa, India, 2-10 Jan 2007. Published in PoS STRINGSLHC:023,2007. e-Print: arXiv:0705.2982 [hep-th]
45. *The Entropic Approach to Predicting Lambda*, J. Cline, "Cosmology on the Landscape" workshop, McGill, 11 May 2007
46. *The Entropic Approach to Predicting Lambda*, J. Cline, "Origins of Dark Energy" conference, McMaster University, 15 May 2007
47. *Brane-antibrane inflation*, J. Cline, McGill pizza seminar, 13 Feb. 2007
48. *Imprints of Tachyonic Preheating on the CMB*, J. Cline, University of Minnesota, 26 April 2007 and
49. *Imprints of Tachyonic Preheating on the CMB*, J. Cline, Kavli Institute for Cosmological Physics, Chicago, 27 April 2007
50. *Inflation from String Theory*, J. Cline, Marianopolis College, 28 November 2007
51. *The Entropic Approach to Understanding the Cosmological Constant*, J. Cline, CERN, 8 August 2007
52. *Models of Dark Matter Annihilating at the Galactic Center*, J. Cline, McGill Astro Tea, 8 March 2007
53. *First Results from VERITAS*, D. Hanna, invited talk at RICAP07, (Roma International Conference on Astroparticle Physics 2007), Rome, Italy, June 20-22, 2007
54. *Calibration Techniques for VERITAS*, D. Hanna, poster contribution to the 30th International Cosmic Ray Conference, (ICRC 2007), Merida, Mexico, July 3-11, 2007,
55. *First Results from VERITAS*, D. Hanna, CERN EP Seminar, CERN, Geneva, Switzerland, June 25, 2007
56. *First Results from VERITAS*, D. Hanna, Colloquium, Physics Department, University of Notre Dame, January 23, 2008
57. *VERITAS: Status and First Results*, K. Ragan, presented at the 2007 CAP Congress, Saskatoon, June 2007.
58. *VERITAS in 3minutes*, K. Ragan, Soup 'n Science presentation to Faculty of Science undergraduates, McGill, January 2008.
59. *Observing the Sunyaev-Zeldovich Effect*, M. Dobbs, invited review presented December 5, 2007 at Cosmic Cartography, hosted by KICP at the University of Chicago.
60. *The South Pole Telescope*, M. Dobbs, talk presented at CASCA 2007 conference in Kingston, Ontario, 2007.

61. *Cluster Hunting with SPT and APEX-SZ" and "CMB Polarization*, M. Dobbs, invited guest speaker talks presented at the Canadian Institute for Advanced Study (CIfAR) Institute of Gravity and Cosmology Meeting in Whistler, 2007.

62. *Digital Frequency Domain Multiplexer for mm-Wavelength Telescopes*, M. Dobbs and Eric Bissonette, presented May 2, 2007 at the IEEE NPSS Real Time Conference, Fermilab, IL.

63. *View from the bottom: Mapping the History with the South Pole Telescope*, M. Dobbs, Physics Colloquium presented at the University of New Brunswick, Fredericton, March 14, 2008.

64. *Mapping the History of the Universe from the Bottom of the Planet: The Story of the South Pole Telescope*, M. Dobbs, The Cutting Edge: Royal Society Lectures in Science, Public Outreach Lecture, Oct 11, 2007.

65. *Mapping the history of the universe from the bottom of the planet: The story of the south pole telescope*, M. Dobbs, McGill Medical Physics unit Noon-time Seminar, April 13, 2007.

66. *CJAD radio interview on the Ric Peterson Show about physics at the LHC*, B. Vachon, 14 April 2008.

67. *Contributions to 'Les Années Lumières', Radio-Canada science radio show*, B. Vachon, Sunday 13 April.

68. *TES Bolometer Array for the APEX-SZ Camera*, J. Mehl et al. (the APEX-SZ Collaboration), Journal of Low Temperature Physics, Volume 151, Issue 3-4, pp. 697-702.

69. *The ATLAS-Canada Network*, I. Gable et al., (A. Warburton), Proceedings of CHEP 2007, International Conference on Computing in High Energy and Nuclear Physics, Journal of Physics: Conference Series (JPCS)

70. *Integration of the Trigger and Data Acquisition Systems in ATLAS*, Maris Abolins, et al., Submitted to proceedings of the International Conference on Computing in High Energy and Nuclear Physics, CERN-ATL-COM-DAQ-2008-003, (2007).

71. *The ATLAS Data Acquisition and Trigger: Concept, design and status*, K. Kordas, et al., Nucl.Phys.Proc.Suppl.172:178-182,2007.

72. *Implementation and Performance of the ATLAS Second Level Jet Trigger*, P. Conde-Muino, et al., Submitted to proceedings of the International Conference on Computing in High Energy and Nuclear Physics, CERN-ATL-DAQ-CONF-2007-025, CERN-ATL-COM-DAQ-2007-028 (2007).

73. *The ATLAS trigger: high-level trigger commissioning and operation during early data taking*, R. Goncalo et al., proceedings of the International Europhysics Conference on High Energy Physics, CERN-ATL-DAQ-CONF-2007-032, CERN-ATL-COM-DAQ-2007-039, October 2007.

74. *Strings, Space-Time Non-Commutativity and Structure Formation*, R. Brandenberger, arXiv:hep-th/0703173, invited talk at the 21st Nishinomiya-Yukawa Memorial Symposium on Theoretical Physics "Noncommutative Geometry and Quantum Spacetime in Physics", Nov. 11 - 15, 2006, publ. in Prog. Theor. Physics Suppl. 171, 121 - 132 (2007).

75. *Observations of the Pulsar PSR B1951+32 with the Solar Tower Atmospheric Cherenkov Effect Experiment*, J. Kildea et al. [STACEE Collaboration], Proceedings of the 30th International Cosmic Ray Conference (ICRC 2007), Merida, Mexico, 2007, astro-ph 0710.4623

76. *Calibration Techniques for VERITAS*, D.Hanna, for the VERITAS Collaboration, Proceedings of the 30th International Cosmic Ray Conference (ICRC 2007), Merida, Mexico, 2007, astro-ph 0709.4479

77. *The prospects for X-ray polarimetry and its potential use for understanding neutron stars*, M.C.Weisskopf et al., (D. Hanna), Proc. 363rd Heraeus Seminar, Bad Honef, Germany (2006)

78. *Search for Dark Matter Annihilation in Draco with STACEE*, D. D. Driscoll et al. (for the STACEE Collaboration), presented at the 30th ICRC, Merida, Mexico, July 2007, arXiv:0710.3545 [astroph].

79. *VERITAS: Status and Latest Results*, G. Maier et al. (for the VERITAS Collaboration), presented at the 30th ICRC, Merida, Mexico, July 2007, arXiv:0709.3654 [astroph].

80. *VEGAS, the VERITAS GammaRay Analysis Suite*, P. Cogan et al. (for the VERITAS Collaboration), presented at the 30th ICRC, Merida, Mexico, July 2007, arXiv:0709.3654 [astroph].

81. *Latest CDF Results*, Dr. Robert Snihur, CAP Congress, Saskatoon, June 2007.

82. *CDF Analysis*, Greg Williams, CAP Congress, Saskatoon, June 2007.

83. *McGill's TPULS Program*, Greg Williams, CAP Congress, Saskatoon, June 2007.

7.3 Internal Reports

1. *Result of the Week*, A. Warburton, Contributor in "Fermilab Today", http://www.fnal.gov/pub/today/archive_2007/today07-11-08.html; 2007.11.08.

2. *ATLAS Trigger Study for the Charged Higgs Boson Search*, C. Potter, M.-A. Dufour, S. Robertson, B. Vachon, CERN-ATL-COM-PHYS-2008-026, March 2008.

3. *Search for a heavy charged Higgs boson reconstructed in the tb final state*, G. Kertzscher, C. Potter, B. Vachon, E.E. Boos, V. Bunichev, L. Dudko, D0 Note 5552, 13 December 2007.

4. *Report of the Higgs Trigger Task Force*, S. Amerio et al., (A. Warburton), CDF Internal Note CDF-8875, 2007.06.27.

5. *Z-Vertex Position Effects on L2 Trigger mET*, P.-L. Dallaire-Demers, A. Buzatu, R. Snihur, and A. Warburton, CDF Internal Note CDF-9000, 2007.09.13.

6. *Search for Higgs Boson Production in Association with W Boson with 1.9/fb*, A. Buzatu et al., CDF Public Note CDF-9219, 2008.02.26.

7. *"Search for Higgs Boson Production in Association with a W Boson using Isolated Tracks*, A. Buzatu et al., CDF Internal Note CDF-9299, 2008.04.19.

7.4 Research Awards

1. *T1 Canada Research Chair*, R. Brandenberger, effective 01/10/2004
2. *Friedrich Wilhelm Bessel prize*, G.D. Moore, Alexander von Humboldt foundation, awarded November 2007 for travel and stay in Germany in 2008-9. This award makes me a lifetime Fellow of the Alexander von Humboldt Foundation.
3. *Scholar in the CIfAR Cosmology and Gravity Group*, M. Dobbs, (03/2008 -) Appointment, Normally scholar appointments are used for recruitment, so being appointed to this role after already having a tenure track position is rare.
4. *T2 Canada Research Chair in Astro-particle physics*, M. Dobbs, (01/2006 -)
5. *IPP Research Scientist*, F. Corriveau, Since 1991. Now Principal Research Scientist since July 2004. Affiliated to McGill University as Full Professor "part-time" (McGill administrative non-joke).
6. *IPP Research Scientist*, S. Robertson, Affiliated to McGill University as Associate Professor "part-time".

7.5 Committees

International

1. *Service de Physique Nuclaire, DAPNIA, CEA/Saclay, France*, Members on Conseil Scientifique et Technique (continuing), Prof. J. Barrette.
2. *Spokesperson for the CDF-Canada collaboration*, A. Warburton, Since 2007.03.27, serving as leader of CDF faculty, postdoctoral fellows, and students at McGill University, the University of Toronto, and the University of Alberta; member of CDF Executive Board.
3. *Co-leader of Simulation and Monte-Carlo-Production Groups*, CDF Collaboration, A. Warburton, May 2007 - May 2008; responsible for international coordination of off-site (non-Fermilab) large-scale production of Monte Carlo simulation data on several computing farms in Asia, Europe, and North America. Coordinated privileged access to remote supercomputer farms for high-priority Monte Carlo production.
4. *Organizer of the Canada-America-Mexico 2007 (CAM'07) Physics Graduate Student Conference*, A. Warburton, held at McGill University 2007.08.08-11; sole faculty liaison for the international and local organizing committees, which consisted of graduate students; responsibility for the conference finances, which showed a significant surplus that has been deposited into the Educational Trust Fund of the CAP to support a similar student conference in the future.
5. *Canada-America-Mexico 2007 Graduate Physics Conference*, Adrian Buzatu, Organization of the conference as student.
6. *Member of CDF Financial Scrutiny Committee*, A. Warburton, representing Canada; 2007.10.29.
7. *Member of Fermilab's International Finance Committee*, A. Warburton, representing Canada; 2007.10.30.

8. *Chair of CDF Godparenting committee for the CDF analysis*, A. Warburton, Starting 2008.05, "Measurement of Inelastic ppbar Inclusive Cross Sections at sqrt(s) = 1.96 TeV", in which, through a minimum bias approach, the inclusive charged particle transverse-momentum spectrum, the transverse-energy differential cross section, and the correlation between mean transverse momentum and charged particle multiplicities are measured.
9. *Leader for the jet reconstruction in the ATLAS high-level trigger*, B. Vachon, (2005-present).
10. *Canadian representative on the ATLAS TDAQ Resource board*, B. Vachon, (2006-present).
11. *Member of the scientific committee for the International Conference on Computing in High Energy and Nuclear Physics*, B. Vachon, 2-7 Sept 2007, Victoria BC. Program track leader and session chair for 'Event processing' track (2007).
12. *Member of scientific committee*, B. Vachon, ATLAS Hadronic calibration workshop, Tucson, USA, 14-16 March 2008.
13. *Member of the program committee for the first ATLAS physics workshop of the Americas*, B. Vachon, held at SLAC, 20-23 August 2007.
(http://www-conf.slac.stanford.edu/atlas2007/)
14. *BABAR Executive Board*, S. Robertson, (Sept 2007 - present: elected, 3 year term)
15. *SUSY07 Flavour Physics Convener*, S. Robertson.
16. *SuperB Conceptual Design Report*, S. Robertson, Section editor (calorimetry)
17. *ATLAS Tier-II Computing Grid Site Manager*, S. Robertson.
18. *BABAR analysis review committee "Search for B→K tau mu with BABAR"*, S. Robertson.
19. *BABAR analysis review committee "B→D**lnu narrow states"*, S. Robertson.
20. *McGill Representative on the Executive Board of the ZEUS Experiment*, F.Corriveau, at the research center DESY, in Hamburg, Germany.
21. *One of the three Canadian Representatives to the ZEUS Experiment*, F.Corriveau, at the research center DESY, in Hamburg, Germany.
22. *Canadian representative and steering board member of the CALICE Collaboration*, F.Corriveau, since 2006.
23. **DAAD Science Tour**, F.Corriveau, In December 2007, 20 physicists from North America (4 from Canada) were invited to tour research facilities in Germany for one week. This was organized by the German Academic Exchange Service (DAAD). The cities of Darmstadt, Frankfurt, Kaiserslauten, Karlsruhe and Munich were visited, passing through the universities and their laboratories, the GSI laboratory, Frauenhofer Institute, the KATRIN experiment, one Max Plank Institute and other facilities, concluding at the enormous Siemens headquarters. The main goals were to familiarize foreigners with the funding and research possibilities in Germany to inform people and favorize exchanges of people and ideas.
24. *Member of the VERITAS Executive Committee (VEC)*, K. Ragan, The VEC is the main policysetting and decisionmaking body of the VERITAS Collaboration.
25. *Tenure reviewer for promotion cases*, K. Ragan, at Queen's, SFU, McMaster, Univ. of Toronto, and the American University of Sharjah, United Arab Emirates.

National

1. *Association of Canadian Universities for Research and Astronomy.* roadmap for Canadian Sub-Atomic Physics for the next decade. D. Hanna is the McGill representative at ACURA and member of its board of management.

2. *NSERC Committee to choose the best three PhD theses in Science*, Prof. D.G. Stairs.

3. *NSERC Review Committee for the ATLAS Experiment at the LHC*, Chair, by Prof. D.G. Stairs.

4. *NSERC Discovery Grant*, Prof. G.D. Moore as external reviewer.

5. *Institute of Particle Physics of Canada: President of the Board of Trustees*, Prof. D.G. Stairs, since 2002.

6. *CAP Council meetings and Institute of Particle Physics*, A. Warburton.

7. *CAP Council for Canadian physics graduate student*, Adrian Buzatu.

8. *CAP Representative for the North and West regions of Qubec*, A. Warburton, Completed duties as representative for the North and West regions of Qubec on the Canadian Association of Physicists Council, a two-year term running 2005 - 2007; agreed to and began to serve again on the CAP Council, in the same capacity, for a second consecutive two-year term, running 2007-2009.

9. *Council Member of the Canadian Institute of Particle Physics (IPP)*, A. Warburton, three-year term running June 2005 - June 2008; prepared and presented for Council reviews of the DEAP dark-matter experiment (SNOLab), HEPnet/Canada, and the ZEUS experiment (DESY), 2008.01.14.

10. *Organizer of an all-day meeting of the Institute of Particle Physics (IPP) Council*, A. Warburton, at McGill University, 2007.09.12.

11. *Member of advisory committee for HEPnet/Canada*, A. Warburton, (computer wide-area networking in Canadian subatomic physics research); gave input on the HEPnet NSERC MRS application, 2007.09.17.

12. *University supercomputing consortium representative*, A. Warburton, National Steering Committee for the CFI-funded Canadian TRIUMF Tier-1 Data Analysis Centre for the ATLAS Experiment at CERN, 2006.07-.

13. *TRIUMF Policy and Planning Advisory Committee member*, B. Vachon, 2008-2013.

14. *Presentation of the experimental HEP program at McGill*, B. Vachon, NSERC GSC-19 site visit, McGill (23 October 2007).

15. *BABAR project review*, S. Robertson, NSERC grant review presentations: (jan 9 2007)

16. *IPP review*, S. Robertson, NSERC grant review presentations: (Nov 8)

17. *ATLAS project review/HLT*, S. Robertson, NSERC grant review presentations: (Dec 13)

18. *Discussion on the TRIUMF 5-year Plan*, F.Corriveau, Participation in Vancouver, 31 July - 3 August 2007. Section on Linear Collider.

19. *Web Site Maintainer of the Particle Physics Division of the CAP*, F. Corriveau, Since 2001. Provide continuity for the PPD team of the Canadian Association of Physicists. The site is located at
http://www.physics.mcgill.ca/∼ppd.

20. *Council member of Institute for Particle Physics*, J. Cline.

21. *NSERC Special Research Opportunities Grants*, K. Ragan, Application reviewer.

22. *NSERC Discovery Grants*, K. Ragan, Application reviewer.

23. *NSERC Innovation grants*, K. Ragan, Application reviewer.

24. *CFI Grants*, K. Ragan, Application reviewer.

25. *Continuing lobbying activities in Ottawa*, K. Ragan, (with agency personnel, politicians, government policy staffers) as an outgrowth of chairmanship of the SAP LongRange Plan in 2006.

26. *Joint Committee on Space Astronomy*, M. Dobbs, Chair (2007-2008) of the Joint Committee on Space Astronomy, a science advisory committee to the Canadian Space Agency focusing on space astronomy.

27. *Member of the Senior Space Sciences Advisory Committee*, M. Dobbs, the highest level science advisory committee to the Canadian Space Agency.

28. *Canada-wide research effort for Cosmic Microwave Background*, M. Dobbs, Organizer of effort for CMB related space astronomy research. Obtained funding from the Canada Space Agency for annual face-to-face meetings and monthly telecons. Dobbs is chair of this group which includes membership from every faculty member in Canada who is presently active in CMB research.

Provincial

1. *Central electronic scientific logbook server*, A. Warburton, Organization of this E-log for use by McGill's high-energy physics group, 2007.08.24.

2. *Status of McGill's CLUMEQ computing consortium as an ATLAS Tier-2 computing site*, A. Warburton, TRIUMF Tier-1 Data Centre site visit, Vancouver; 2007.08.30.

3. *News from the DAQ/HLT Technical Run*, A. Warburton, ATLAS-McGill meeting (by videoconference from CERN); 2007.11.22.

4. *Judge for the 2008 Shalheveth Freier Physics Tournament*, A. Warburton, (Weizmann Science Canada) at St. George's High School, Montreal; 2008.03.06. The winning team, The Study, went on to win first prize in the 2008 International Shalheveth Freier Physics Tournament in Israel; 2008.04.02.
(see http://studyschoolphysicsteam.blogspot.com/).

5. *McGill Physics department outreach committee*, chaired by Prof. B. Vachon.

6. *Group leader of McGill ATLAS research group*, B. Vachon, (2004-present)

7. *Selected candidate for year long exhibit 'Physique de Femmes'*, B. Vachon, organized by the Ministere de L'Education, Loisir et Sport du Quebec, 2008; http://www.mels.gouv.qc.ca/sections/chapeau/index.asp?page=exposition

8. *Round-table discussions on the subject of fundamental research*, B. Vachon, Participation in the context of the french radio-show called 'Pensees Libres' at Radio-Canada, 19 June 2007.

9. *Member of the evaluation committee for FQRNT doctoral scholarship program*, B. Vachon, (2006-present).

10. *McGill High Energy Physics / Astro Computer Network Organization*, F.Corriveau, Coordinator (200 users, 250 computers excluding clusters)

11. *Co-supervision of Computer System Managers*, F. Corriveau with Prof. M. Sutton,

12. *McGill Physics "Local Computer Systems Committee"*, F. Corriveau, department-wide oversight committee to streamline all computing and network acquisitions and operations.

13. *Centre Interuniversitaire de Physique Subatomique (CIPS)*, F. Corriveau, Director. This is a joint venture of the following groups: "McGill Centre for High Energy Physics" and "Groupe de Physique des Particules de l'Université de Montréal", with also collaborating members from the Université du Québec à Montréal.

14. *Centre for High Energy Physics (CHEP)*, F. Corriveau, Director. This is the McGill component of the above CIPS and an entity on its own.

15. *Adjunct head, Quebec astrophysics 'regroupement strategique' grant*, K. Ragan.

7.6 Referee Work

Several of our members serve as referees for publications in the main journals in the field:

1. Physics Review Letters
2. New Journal of Physics (Institute of Physics)
3. Institute of Physics Journal of Physics G: (Nuclear and Particle Physics)
4. Physical Review C
5. Physical Review D
6. Physics Letters B
7. Nuclear Physics B
8. JHEP: Journal of High Energy Physics
9. JCAP: Journal of Cosmology and Astro-Particle Physics
10. European Physics Journal C
11. Canadian Journal of Physics
12. Int. Jour. Mod. Phys. A

13. European Physics Journal C
14. Classical and Quantum Gravity

8 Seminars

The Centre sponsors five interleaving seminar series instrumental in the training of researchers:

- A formal seminar series within the Centre attracts speakers from across Canada, the United States and European visitors to North America. The seminars are an integral component of our activity and are of great value to all members of the Centre, especially to our students and postdoctoral researchers. They are also organized jointly with the Particle Physics group of the Université de Montréal, so that further exchanges are generated.
- A popular series is the weekly "pizza lunch" seminar, usually featuring a Centre theory member discussing his or her current research in an informal atmosphere encouraging student participation.
- Another series is the "Wednesday Meetings" seminar, where all members of our experimental teams get together and discuss their research.
- Our nuclear physics theory colleagues also maintain frequent seminars where guests from outside are invited to present and share their research.
- Finally, a few major workshops and large meetings are now being initiated by members of our Centre on outstanding topics.

These seminars also provide a familiar setting in which graduate students and postdoctoral researchers gain valuable experience in presenting their work. All of our students, as well as most of our visitors give at least one of these talks sometime during their programme. Our permanent members are also contributing to the series.

The list of seminars are available on the web under
http://www.physics.mcgill.ca/chep/reports/chep_20072008_seminars.html

9 Publications (2007)

Publications, together with the training of our students and postdocs, are one of the most important elements of research, because they stimulate, guide, set goals to our undertakings and promote exchanges with other researchers.

The Centre publications from the High Energy Physics database SPIRES are available on the web under
http://www.physics.mcgill.ca/chep/reports/chep_20072008_publications.html

10 Honours, Awards, Prizes and Consulting Activities

Please consult the annual report of the Physics Department.

11 Summary and Outlook

The Centre for High Energy Physics (CHEP) is constantly growing in strength and stature over its wide field of research, covering numerous important aspects of the history of the universe and its puzzles.

Thanks to the initiative of our members and a rich seminar program, numerous visitors come to us for talks and exchanges. Our members are also frequently invited outside to discuss their research progresses and present their results.

On the experimental side, the start of the International ATLAS experiments has given a new and exciting impetus to our groups, with the McGill team well positioned nationally and internationally. Prospects for the International Collider or the Super-B projects to come considerably enrich our research program.

Large numbers of research associates, postdocs, graduate and undergraduate students are constantly active in our centre. It is a measure of the liveliness and attraction of the groups that their numbers are slowly increasing over the years, with frequents renewals as most graduate or leave the group after their training for jobs and opportunities at other locations

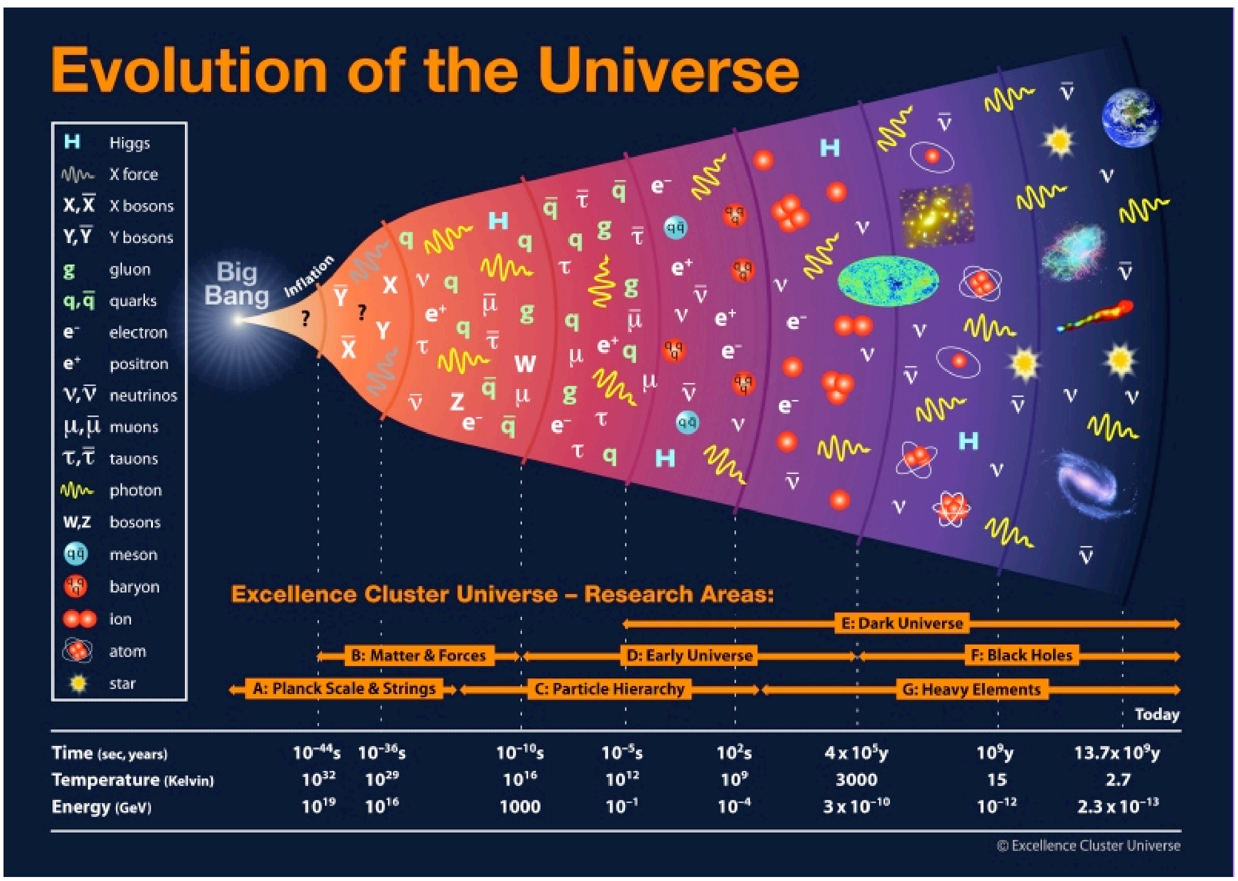

Figure 8: The History of the Universe