Centre for High Energy Physics

McGill University

Annual Report 1995–1996

(June – May)

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Edited by F. Corriveau

Contents

1 A Brief History

Subatomic physics has a very long and distinguished history at McGill University. The names of Rutherford, Foster, Bell and Margolis are strongly identified with McGill, and the work of our Centre is rooted in the the tradition of scholarship which they established in our Department. In recent years our subatomic physicists have been recognized with the Canadian Association of Physicists Medal for Achievement in Physics, two Rutherford Medals of the Royal Society of Canada, the Herzberg Medal of the Canadian Association of Physicists, The Steacie Fellowship of NSERC and two Fellowships in the American Physical Society. Two former chairmen of the Institute of Particle Physics, an organization that has contributed substantially to the development of high energy physics in Canada, have been associated with our Centre.

McGill University has expressed its continuing support for the Centre since its establishment ten years ago under the direction of the late Professor B. Margolis. With the aid of FCAR team grants our Centre has developed into a well-established and internationally recognized locus for research in high energy physics and for the training of students and postdoctoral physicists. Our objectives in seeking a Centre Grant from FCAR are two-fold: to improve the training of students and young researchers; and to strengthen our competitive position in experimental and theoretical research.

2 Purpose of the Centre

The Centre is a research organization within the Department of Physics at McGill University, representing approximately 40% of the Department's research initiatives. Its goals are to promote research and the training of scientists in the field, and to encourage communication between its members which will lead to productive collaboration. Our Centre currently includes fifteen members at McGill and three collaborators from l'Université de Montréal whose research projects are related to the Centre's scientific program.

The Centre for High Energy Physics (CHEP, or also "Centre d'études pour la physique des hautes énergies") coordinates and promotes research and the training of scientists in the field of high energy physics. It shall endeavor to provide a stimulating working environment for its scientists and students, and to encourage collaboration at the local, national and international levels.

3 Organization

The Centre is administered by a Director and an Advisory Committee composed of three members. Bylaws define their functions and responsibilities as well as the administrative structure of the Centre. Meetings of the university members are held at least quarterly. An annual meeting summarizes the Centre's activities during the preceding year and reviews its financial status and projections for future activities. A general assembly of all members and potential new members is held place at the beginning of each academic year.

The McGill Centre is administered by a Director and an Advisory Committee of three members representing the major directions of research within the Centre. This structure serves the particular needs of the high energy physicists and is independent of the Physics Department of the University. The Centre is governed according to bylaws whose intent is to ensure that it operates in a open and representative manner.

The Centre's current director was a founding member of the Institute of Particle Physics of Canada and served as its chairman for 10 years (1981-1991). He currently chairs the Advisory Board on TRIUMF, is a member of the NRC Council, and a member of NSERC's Grant Selection Committee for Subatomic Physics. He has served on review and advisory committees at Cornell, DESY, NSERC and the SSC Laboratory, and is an active contributor to the Centre's research program.

The activities of the Centre are coordinated by:

Centre Director:	Prof. D.G. Stairs
Secretary:	Elisabeth Shearon
Centre Advisory Committee:	C. Burgess, F. Corriveau and C. Gale
Computer System Managers:	Paul Mercure and Juan Gallego
Engineer:	Christine Smith

4 Membership

All members of the Centre are individuals whose research projects are related to the CHEP scientific program. There exist four categories of members:

Full Members (15)

University professors or researchers whose activities overlap substantially with the CHEP program. They are eligible to hold NSERC or FCAR grants.

Barrette, Jean	Faculty	McGill University
Burgess, Clifford Peter	Faculty	McGill University
Cline, James M.	Faculty	McGill University
Corriveau, François	Faculty	IPP/McGill University
Das Gupta, Subal	Faculty	McGill University
Gale, Charles	Faculty	McGill University
Hanna, David S.	Faculty	McGill University
Lam, Harry Chi-Sing	Faculty	McGill University
MacFarlane, David B.	Faculty	McGill University
Mark, Tommy S.K.	Faculty	McGill University
Myers, Robert Charles	Faculty	McGill University
Patel, Popat M.	Faculty	McGill University
Ragan, Kenneth	Faculty	McGill University
Sharp, Robert T.	Faculty	McGill University
Stairs, Douglas G.	Faculty	McGill University

Associate Members (3)

University professors or researchers whose activities are only partially committed to the CHEP program. They are eligible to hold NSERC or FCAR grants. Professor London has actually spent his sabbatical leave in our group.

London, David	Faculty	Université de Montréal
Mackenzie, R.	Faculty	Université de Montréal
Paranjape, M.	Faculty	Université de Montréal

Affiliated Members (62)

Researchers whose main activities relate to the program of the Centre. These can be research assistants, post-doctoral fellows, technicians, graduate students, etc.., who work within the Centre on a full-time basis. Some are supported by various funding agencies.

(Non-Students)(29)

Bamert, Peter	Postdoctoral Fellow	Switzerland
Benoit, Louis,	Postdoctoral Fellow (NSERC)	
Britton, David	Research Associate	
Contogouris, André-Panagiotis	Adjunct	
Demers, Jean-Guy	Postdoctoral Fellow	
Fernholz, Richard	Design Physicist	
Gallego, Juan	Professionnal Assistant	
Gao, Song	Research Associate	
Haagensen, Peter	Postdoctoral Fellow	
Hartmann, Jutta	Research Associate	Germany
Kaloper, Nemanja	Postdoctoral Fellow (NSERC)	
Kamal, Basim	Postdoctoral Fellow	
Khuri, Ramzi	Postdoctoral Fellow	
Labelle, Patrick	Postdoctoral Fellow (NSERC)	
Lim. Jit-Ning	Research Associate	Singapore
McLean, Kenneth W.	Research Associate	
Mercure, Paul	Professionnal Assistant	
Merebashvili, Zakhari	Postdoctoral Fellow	
Nadeau, Hélène	Postdoctoral Fellow	
Page, Philippe	Postdoctoral Fellow (Switzerland)	Switzerland
Pan, Jicai	Postdoctoral Fellow	
Seibert, David	Postdoctoral Fellow	USA
Smith, Christine	Engineer	
Spaan, Bernhard	Research Associate	Germany
Starinski, N.	Research Associate	Russia
Strahl, Klaus	Research Associate	Germany
Svec, Miloslav	Adjunct	
Vang-Pedersen, Anders	Research Associate	
Zacek, Gabriele	Research Associate	Germany

(Students)(33)

Bellerive, Alain	Graduate Student	
Breckenridge, Jason	Graduate Student	
Feng, Yongjiang	Graduate Student	China
Fillimonov, K.	Graduate Student	Russia
Girard, Patrick	Graduate Student	
Hagan, Scott	Graduate Student	
Hamidi-Ravari, Omid	Graduate Student	Iran
Hung, Ling-Wai	Graduate Student	
Janicek, René	Graduate Student	
Kamela, Martin	Graduate Student (FCAR)	
Kellerbauer, Alban	Graduate Student	
Kordas, Kostas	Graduate Student	
Kvasnikova, Ioulia	Graduate Student	
Lafrance, René	Graduate Student	
Li, Y.	Graduate Student	China
Marini, Alex	Graduate Student (NSERC)	
Michaud, Denis	Graduate Student (NSERC)	
Michaud, Guy	Graduate Student	
Milek, Marko	Graduate Student	
Mostoslavsky, Michael	Graduate Student	
Ochs, Andreas	Graduate Student	Germany
Persram, Declan	Graduate Student	
Riveline, Michael	Graduate Student	
Roussel, Harold	Graduate Student	France
Saab, Tarek	Graduate Student	
Saull, Patrick	Graduate Student	
St-Laurent, Marc	Graduate Student	
Théoret, Claude	Graduate Student	
Thoma, Martin	Graduate Student	
Tremblay, Luc	Graduate Student (NSERC)	
Ullmann, Rainer	Graduate Student	Germany
Zebarjad, Seyyad	Graduate Student (Iran)	Iran
Zhang, Jianming	Graduate Student	

Visiting members (3)

Researchers coming to the Centre for short periods, such as invited professors, consultants, exchange or summer students, etc...

Clifford Johnson	Professor	Santa Barbara, USA
Pascale Sévigny	Student	Université de Sherbrooke
Céline Bret	Student	Université Joseph-Fourier, France

5 Research Activities

The principal components of the Centre are three teams specializing in high energy theory, high energy experiment and nuclear/heavy-ion physics, respectively. These teams have common scientific interests and a stimulating interchange of ideas and information takes place across the boundaries of the teams. Our Centre facilitates the complex interplay of ideas that is hallmark of advanced research in High Energy Physics.

5.1 Strong Interactions

Centre members F. Corriveau, D. Hanna and D. Stairs are part of the ZEUS experiment at DESY that is opening an entirely new range of QCD studies at the electron-proton collider HERA. QCD is also investigated at high energy densities through the study of heavy ion collisions at Brookhaven National Laboratory by J. Barrette and S.-K. Mark. These investigators are concurrently designing and constructing at McGill an array of very large and complex detectors to be installed in the new PHENIX experiment at the Relativistic Heavy Ion Collider in Brookhaven. The theory of strongly interacting matter at high energy densities is an active field of research in our Centre under the leadership of S. Das Gupta and C. Gale. C.-S. Lam, a high energy theorist at McGill, has developed an important technique to simplify some difficult calculations in QCD using methods first introduced in the theory of superstrings.

5.2 Electroweak Interactions

A cornerstone of the Standard Model of particle physics was brilliantly confirmed last year when the CDF collaboration, including K. Ragan of McGill, announced the discovery of the top quark produced at the Fermilab proton-antiproton collider. D. MacFarlane and P. Patel are engaged in the design at McGill of the Drift Chamber for the new BaBar detector at SLAC. This forefront experiment will be devoted to the investigation of the violation of CP symmetry in b quark states, one of the most important issues in particle physics. Our theorists C. Burgess and J. Cline have refined the predictions of the standard model in the electroweak sector and have proposed new searches to identify possible new physics processes. R. Sharp is an expert in the application of group theory to particle physics: his work on the group $E6$ is relevant to possible extensions of the standard model. Prof. Sharp is an associate member of the Centre de Recherche Mathématique of the Université de Montréal via one of its teams.

5.3 Gravity and Astrophysics

These rapidly evolving disciplines have attracted the attention of high energy and nuclear physicists because the same fundamental physical processes are relevant on the subatomic and astrophysical scale. Recently D. Hanna and K. Ragan have applied their detector expertise to a pioneering investigation of ground-based gamma-ray astronomy, employing the Solar-2 detector in Barstow, California. At the same time C. Burgess and R. Myers have made important contributions to several aspects of gravitational physics, including some of the puzzles concerning black holes and superstring theory, the only viable framework for unifying quantum mechanics with gravity.

6 Research Projects

The McGill Centre for High Energy Physics has vigorous research programmes in both experimental and theoretical areas of High Energy Physics (HEP), as well as efforts in the related areas of cosmology and astro-particle physics. A summary list of the research interests of the group, together with researchers names, is given below.

6.1 Experimental High Energy Physics

BaBar

(D. MacFarlane, P. Patel, J. Trischuk)

An experiment that will run at the PEP-II storage ring at SLAC (Stanford University) to study CP violation in the B meson system, CKM Matrix.

Current research interests are centred on the BaBar detector being constructed for the asymmetric e^+e^- collider (B factory) PEP-II at SLAC in Stanford, California, and the physics of B-bar B production at the Υ(4S) resonance.

The PEP-II B Factory will allow a systematic and broad-ranging investigation of CP violation in B0 decays. In the Standard Model, CP violation originates in the weak-interaction phase of the Cabibbo-Kobayashi-Maskawa matrix; however, this explanation has yet to be verified experimentally. The B0 system offers a unique laboratory for testing this idea, one of the most fundamental unexplored aspects of the SM. The BABAR collaboration has been formed to build a new detector for PEP-II; the Canadian members of the collaboration are proposing to build the Drift Chamber for the experiment. The project involves the prototyping, design, fabrication, assembly, testing, and installation of a large-volume small-cell drift chamber, and the related electronic readout and detector control systems. Groups from Carleton/CRPP, McGill, Montreal, TRIUMF, UBC, Victoria, and York will be engaged in all mechanical aspects of the chamber. The construction is foreseen to have a four year duration, with cosmic ray data starting in January 1999. The CP physics program will likely extend 10 years beyond that point. When it becomes operational, BABAR will represent one of the premier particle physics experiments at the turn of the century.

CDF

(K. Ragan)

The research interests are largely centred on work at the Tevatron Fermi National Accelerator Laboratory (FNAL) in Batavia, Illinois, where the McGill group is involved with the Collider Detector at Fermilab (CDF) detector collaboration. The Tevatron has the world's highest energy beams to study the top quark, properties of the electroweak gauge bosons and B mesons, as well as QCD. Some recent and current interests at CDF are:

- Rare B decays (penguins, B $\to \pi\pi$)
- B mixing
- CP violation at hadron colliders
- Particle ID technology for hadron colliders – in particular, ring-imaging Cherenkov devices

CLEO

(D. MacFarlane, P. Patel)

The CLEO Experiment is located at the CESR storage ring of Cornell University to study charmed baryon production in electron positron annihilation at $\sim$ 10 GeV/c, charmless B meson decays, mixing in the beauty quark sector; drift chamber calibration.

ZEUS

(F. Corriveau, D. Hanna, D. Stairs)

The ZEUS collaboration is carrying out a program of electron-proton scattering experiments using the HERA collider at the DESY laboratory in Hamburg, Germnay, with the prime objective to study deep inelastic scattering. Indeed, the deep inelastic scattering of point-like electrons on protons at HERA probes the content of the proton very close to the attometer (10^{-18}m!) scale. The centre-of-mass energy of HERA is also high enough to permit a broad spectrum of studies in both the hadronic and electroweak sectors of particle physics.

Our experiments are carried out with the ZEUS detector, a large and complex installation with many sophisticated sub-systems. The principal focus of most ZEUS research is the sub-structure of the proton, as expressed in the momentum distributions of its quarks and gluons. However, the richness of the physics at HERA, combined with the excellent capabilities of ZEUS, enables us to investigate a remarkable range of interesting topics including, for example, hard photoproduction, the nature of diffractive processes at high energy , the production of states containing heavy quarks and the search for exotic particles and possible manifestations of quark sub-structure.

research interests are in hard photoproduction

Our main current interests and realisations are:

- the structure function of the proton, which describes its parton (quark and gluon) content,
- particle particle production in the very forward regions to discriminate between the DGLAP and BFKL parton evolutions,
- determination of the α_s coupling constant of the strong interaction from jets,
- the production of J/Ψ mesons as a way of mapping out the distribution of gluons inside the proton.
- strange particle production to probe the proton sea quarks and the fragmentation processes.
- Photoproduction on protons, in which a quasi-real photon is exchanged, also yields very relevant information on the many-faceted and puzzling nature of the photon. Some of the observables are its vector meson behaviour, its direct interaction signals or evidence of its partonic structure.
- we have installed a new detector component (the Forward Neutron Calorimeter, or FNC) to tag events containing a fast neutron in the final state. This will enable us to measure the quark distributions inside the π^+.

PHENIX

(J. Barrette, T. Mark)

The primary goals of the PHENIX Experiment at RHIC (the Relativistic Heavy Ion Collider at Brookhaven National Laboratory, New York) are to detect a new phase of matter, the quark-gluon plasma (QGP), and to measure its properties.

When completed in 1999 the RHIC will collide the subatomic particles called heavy ions at energies of 100 GeV in each beam. These collision energies are expected to be high enough to create a hot, dense plasma of quarks and gluons. This Quark-Gluon Plasma (QGP) is believed to have existed in the early universe immediately after the Big Bang. The strategy of PHENIX is to study leptonic, photonic, and hadronic signatures in the same experiment.

6.2 Astroparticle Physics

(D. Hanna, K. Ragan)

Prof. D. Hanna from the Centre is a member of the STACEE collaboration, studying high energy gamma-ray showers with a ground-based Cherenkov telescope.

In astrophysics, Prof. Hanna is a founding member of the STACEE collaboration. The collaboration is constructing a detector which uses Cerenkov light from high energy showers to detect gamma rays in the energy range $20<E<2000$ GeV. This energy range lies between what has been explored using satellite detectors and the energies accessible to present-day ground-based detectors. The goal of our experimental program is to extend the energy spectra of the extragalactic sources seen by satellites to higher energies in order to discern what cutoff mechanisms are at work.

In August, the STACEE group, including David Hanna, will carry out tests of prototype detectors at the National Thermal Solar Test Facility located at Sandia National Laboratories in Albuquerque, New Mexico. A 3 metre diameter secondary mirror, made from 7 identical facets focussed Cerenkov light from 8 heliostats (in a field of 200) onto a camera of 8 phototubes. The camera was designed and built at McGill and the mirror structure was produced at the University of Chicago.

During the summer of 1996 we will have the help of a summer student from the electrical engineering program, Mr. Kwok Lui. Richard Fernholz and Joel Rous, both supported by an NSERC major facilities access grant provided technical support for the project.

In the Fall, we will be joined by Dr. Reshmi Mukherjee, a gamma ray astronomer from NASA (Goddard Space Flight Centre) who will spend the next year with us and will contribute to STACEE while continuing her work on the analysis of data from the EGRET detector on the Compton Gamma Ray Observatory satellite.

STACEE was supported in 1996 with a grant from NSERC and the Institute of Particle Physics.

In June 1996, Ken Ragan left for a one year sabbatical at Bordeaux where he will be collaborating with the French teams active in ground based gamma ray astronomy. They have telescopes in the Pyrennes at the Themis solar power installation. Professor Ragan is currently helping commission the single-dish CAT telescope which saw first light in September, 1996. He is also active in the design and construction phase of the CELESTE telescope which is similar in scope to the first generation STACEE device.

6.3 Theoretical High Energy Physics

(C. Burgess, J. Cline, A. Contogouris, S. Das Gupta, C. Gale, C.S. Lam, D. London, R. Mackenzie, R. Myers, M. Paranjape, R. Sharp)

The aim of research in high energy physics is to discover the fundamental constituents of nature, and the laws which govern their mutual interactions. Twenty years ago, the combined efforts of theorists and experimentalists converged to produce an extremely successful theory — now known as the Standard Model — of all physical phenomena which arise on distance scales down to larger than roughly 10^{-17} cm. Although this theory has since then successfully passed every experimental test, indirect evidence indicates that it will cease to be an accurate description of nature at slightly smaller distance scales.

The ultimate objective of high energy theorists is to determine what 'new physics' will supersede the Standard Model at these smaller distance scales. Three major methodologies to this end have emerged. One can: (*i*) determine as precisely as possible the theoretical predictions of the Standard Model, to compare to the increasingly accurate experimental results, and hence detect discrepancies that would signal the discovery of new physics; (*ii*) explore the predictions of alternative theories for current experiments, to identify what kinds of new physics might be detectable; or (*iii*) examine how issues of consistency at the smallest possible distance scales can give indications as to which theories might be the successor of the Standard Model.

High energy physics is a quickly-evolving field where new concepts can significantly modify our understanding in a matter of weeks or months. It is therefore impossible to say in great detail where one's research will lead over several years. The best strategy is to explore the most promising ideas at any given time, and to be flexible and well-informed in order to quickly exploit any new developments that may arise. Our team is very well positioned to do so, maintaining as it does a vigourous and diverse research programme along all three of the lines of approach listed above.

With this caveat about the potential volatility of the field, we present here the most promising lines of research we are currently exploring.

Extracting Accurate Standard Model Predictions

- QCD Phase Transition/Finite Temperature QCD (C. Burgess, C. Gale)
- Heavy Ion Collisions at Intermediate and Low Energies (C. Gale, S. Das Gupta)
- Deep Inelastic Scattering: small x and spin physics (A. Contogouris, C.S. Lam)
- New Computational Methods in QCD (C.S. Lam)
- B Physics and CP violation (C. Burgess, D. London)
- Reactions with Polarized Particles (A. Contogouris)

The topics in this category deal with improving our ability to make predictions from the Standard Model, particularly in strong-coupling situations for which traditional perturbative methods either do not apply, or else they become so complicated that new techniques must be invented to make further progress.

Multiparticle Quantum Interference: Destructive quantum interference between identical bosons produced in a collision, be they real or virtual, leads to a significant decrease in amplitude. For example, individual Feynman diagrams in high energy elastic $e^- - e^-$ amplitudes (with multiple photon exchanges but no pair production) can grow like a high power of the logarithm of the energy, but their sum leads to a constant cross-section because of this destructive interference. Technically this destructive interference is predicted by the eikonal formula, without which it is impossible to compute the process mentioned above to all orders, for then each Feynman diagram must be computed to (possibly many) subleading terms to prepare for the subsequent cancellations of the leading terms in the sum.

We have recently discovered the nonabelian generalization of this formula, thus enabling us to see the exact amount of destructive interference in different nonabelian-quantum-number channels, and allowing the computation of amplitudes without having to go to subleading terms. Moreover, Feynman diagrams can be neatly modified into 'nonabelian cut diagrams' to automatically include such interference effects.

This technique is still in its infancy, and it has applications to many processes where cancellations obscure the physics in the traditional methods of calculation. Some of the problems we are exploring are: (*i*) the behaviour of baryons in large-N_c QCD. At large N_c, large cancellations reduce the $O(\sqrt{N_c})$ contributions of the meson-baryon couplings to give amplitudes which subside like a power of $N_c^{-1/2}$. Our methods make this explicit and permit the phenomenology of large-N_c baryons to be better explored. (*ii*) With new data available from HERA at small x, the problem of diffractive scattering in QCD once again comes to the forefront. The BFKL Pomeron prediction for the total cross-section grows with energy much faster than is permitted by unitarity. These contributions must therefore destructively interferes with other contributions at large energies, so our technique gives a powerful tool to study and hopefully remedy this problem.

Geometrical QCD and Confinement: The confinement of quarks inside hadrons is established theoretically only in the crude approximations allowed by present-day lattice calculations. One of the reasons for this is the difficulty in keeping a manifestly gauge invariant description for nonperturbative approximations. For $SU(2)$ color, preservation of gauge invariance can be achieved by mapping the six gauge-independent degrees of freedom (two polarization for each of three adjoint colors) of the gluon field into the symmetric metric tensor g_{ij} of a three-dimensional space. The removal of gauge redundancy through this change of variables allows nonperturbative approximation techniques to be used. We have a paper to appear in *Nuclear Physics B* and intend to further explore this approach, starting with variational techniques.

Graphical Technique for Designing New Gauges: Gauge symmetry is ubiquitous in the theory of elementary particles. Calculations require one to break this symmetry by fixing a gauge, but all observables are independent of this choice. Unfortunately, individual Feynman graphs *do* depend on the gauge choice, with the gauge-independence of observables only emerging after lengthy cancellations, often making calculations needlessly hard to perform. We are attempting to circumvent this difficulty by identifying a better, graph-by-graph, gauge choice. We are developing a formalism for doing so, and are applying it to some test cases to verify that simplifications are indeed obtained.

The Implications of New Physics

- Implications of Precision Electroweak Measurements (C. Burgess, D. London)
- Neutrinos and Double Beta Decay (C. Burgess, D. London)
- Electroweak Baryogenesis (J. Cline)

- Gravity and String Theory (C. Burgess, J. Cline, C.S. Lam, R. Myers)
- Black Holes (R. Myers, C. Burgess)
- Duality (R. Myers, C. Burgess)

This category of problems deals with those kinds of new physics effects which can conceivably appear in current high energy experiments, or in high precision experiments which look for very rare processes. Yet a third "experiment" in which we look for evidence of new physics is the remnants of the big bang, which has given us a largely successful understanding of the problems of modern cosmology.

Precision Electroweak Measurements as Probes for New Physics: In the last several years we and our collaborators have developed a new language, based on effective-lagrangian techniques, for analyzing precision electroweak experiments in a model-independent way and to extract their implications for new physics. We are updating our global comparisons to the most recent electroweak data using this effective lagrangian. The value of such an analysis is that it points out precisely which effective interactions are the least well-constrained, and which can explain any experimental discrepancies. By systematically correlating different experiments we can constrain the properties of new particles, taking advantage of all the available data.

New Physics Contributions to Z Boson Decays: Over the past few years a serious discrepancy had developed between the Standard Model prediction and the observed rate for $Z \to b\bar{b}$ decays. We were able to make a comprehensive analysis of the broad classes of new physics which could account for this difference. We gave an exhaustive account of the possibilities, which comprised: (*i*) mixing of the Z boson, or (*ii*) mixing of the bottom or top quarks, or (*iii*) loop-induced contributions. The simplicity of our analytic expressions for the loop contributions make it possible to quickly and intuitively determine the sign and the size of the effect in a broad class of models, including the important case of supersymmetric models. Although new experiments have reduced the size of the discrepancy, our findings remain useful as constraints on these kinds of new physics.

Exotic Modes of Double Beta Decay: Motivated by anomalous experimental results in searches for the rare process of double beta decay, we proposed a new class of models that predict the emission of two neutrinos and one or more scalar particle (the majoron), which is one of the only ones capable of yielding an observable event rate. The new models depend upon nuclear matrix elements which have not previously been computed. We have subsequently evaluated what is believed to be the largest of these matrix elements in order to obtain a more quantitative estimate of the rate, confirming that it is possible, albeit difficult, to construct models with an observably large event rate. A complete evaluation of all the relevant nuclear matrix elements is in progress.

Neutrinos in Fluctuating Matter: In many applications of neutrino physics (solar neutrinos, nucleosynthesis, supernovae, *etc.*), the matter through which the neutrinos pass is described by its mean properties, as parameterized by an 'index of refraction.' In the past, little attention was given to the question of whether this was a valid assumption, but we have found and developed a general framework that allows us to quantitatively answer this question. Interestingly, the approximation can fail, and the failure need not be due to the occurrence of appreciable incoherent scattering from the individual particles of the medium. Coherent scattering from macroscopic fluctuations is often the dominant deviation (as is the case, for example, for light traveling through clouds). We are investigating the implication of this analysis for neutrino physics, with our first results submitted to *Annals of Physics.* As the most interesting first application we are computing the influence which helioseismic waves will have on the predicted neutrino signal in the new and upcoming neutrino detectors, SuperKamiokande (Japan) and SNO (Canada).

Resonant Magnetic Spin Flip of Supernova Neutrinos: With the advent of the Sudbury Neutrino Observatory and the SuperKamiokande detector it will be possible to get detailed information about the spectra of neutrinos coming from nearby supernovae, with the potential to learn much about neutrino masses and possibly their magnetic moments. If the latter exist and are large enough, and if magnetic fields in the supernova are greater than 10^9 gauss at the iron core, it is possible to have resonant conversion of electron antineutrinos to muon neutrinos, with a distortion of the $\bar{\nu}_e$ spectrum that would be distinguishable from the usual MSW effect (which is believed to solve the solar neutrino problem). We are extending previous treatments of this process by properly including all four species which are relevant to the evolution: ν_e, ν_μ, $\bar{\nu}_e$ and $\bar{\nu}_\mu$.

Electroweak Baryogenesis: Recent progress on electroweak baryogenesis has demonstrated the possibility that all of the baryonic matter of the universe was created during the electroweak phase transition (EWPT), when the universe was at relatively low temperatures near 100 GeV. For the first time, realistic theories of baryogenesis have the hope of being tested in upcoming experiments like LEP 2 and the LHC at CERN, which could put the understanding of the origin of all visible particles on a similar footing to that of the origin of light nuclei.

We undertook one of the most comprehensive studies of the feasibility of electroweak baryogenesis in two Higgs doublet and supersymmetric models (and work to appear in *Nuclear Physics B*). The results confirmed that with sufficiently large CP violation in the Higgs sector it is possible to obtain a baryon asymmetry of the observed magnitude. A key feature of our analysis was our use of lattice computations to permit a nonperturbative treatment of the transition, since it is well known that perturbation theory can be unreliable. Ours was the first such treatment for the supersymmetric case. We found new regions of parameter space favorable to baryogenesis, for both supersymmetric and two-Higgs models, which had been previously undetected by studies that relied on perturbation theory. These regions are tantalizingly close to the experimental reach anticipated by LEP 2, and so we will definitely know more about the feasibility of the MSSM for baryogenesis in the near future. Work is in progress to further improve these calculations.

Consistency Issues from Very Short Distances

The problems outlined here involve the programme which attempts to constrain the possibilities for new physics by using the very stringent consistency requirements which arise when gravity is considered at extremely short (Planck-scale (10^{-33} cm)) distances.

Photosphere of Evaporating Black Holes: Following up on a recent suggestion that microscopic black holes might develop a photosphere near the end point of their evaporation, we are putting the proposition on a firmer quantitative footing by numerically solving the Boltzmann equation for the emitted Hawking radiation in the vicinity of the Schwarzschild radius. This could be interesting for the next generation of neutrino telescopes because such black holes would emit their highest energy particles in the form of neutrinos, which could escape the photosphere, rather than interacting particles whose energy is degraded while traversing the plasma. Without the photosphere, observational limits on the diffuse gamma ray background require such black holes to be too dilute in the universe to constitute a significant neutrino source.

Beyond String Theory: String theory has been revolutionized by the recent evidence that all varieties of superstring theories are in fact different phases of a single underlying theory. While the latter is not yet well-understood, it is certain that higher-dimensional extended objects beyond strings play an essential role in this picture. We were among the first to establish this fact by using the relation between the heterotic and type IIa superstring theories (in six dimensions) to show that the latter includes fundamental membranes. Shortly afterwards these membranes were recognized as one of a general class of objects known as D-branes. In a comprehensive study of the interactions of strings with D-branes, we showed in general that scattering amplitudes involving D-branes and closed strings are simply related to those involving only open strings. Given this construction we are continuing to investigate the physics of D-branes.

Black Hole Entropy: Finding a statistical mechanical interpretation of black hole entropy is an outstanding problem which has eluded physicists for over 20 years. Recently, progress into this question has been made using new insights from string theory. This progress is a spin-off from the work on string dualities, and the realization of the important role of extended objects beyond just strings. In particular, the class of extended objects known as D-branes have proven very valuable from a calculational standpoint. It was found that different kinds of D-branes can be combined to produce black holes in a certain strong coupling limit. On the other hand in weak coupling, these systems are amenable to statistical mechanical analysis within string theory. We extended these calculations to many new black hole configurations. Even though this approach can still only be applied to a relatively restricted class of black holes, they represent a breakthrough in our understanding of black hole entropy, since for the first time, we have some insight into the underlying microscopic degrees of freedom for a black hole. We are continuing to investigate further situations which might lend themselves to these entropy calculations. We are also studying dynamical scattering processes in these configurations in order to determine whether or not they provide a framework in which one can resolve the famous black hole information loss paradox.

Recognition and Impact

To further illustrate the recognition of our work by the physics community, we give here two examples. The first concerns our proposal (by Bamert, Burgess, and Cline) of two new types of double beta decay, each characterized by a very distinctive electron spectrum, and having a much better chance of being observable by current experiments than similar proposals in the past. Experimental groups in Germany, Switzerland and the U.S. have taken up our ideas and are searching for these new spectra. Their preliminary results were presented in this year's international neutrino conference in Helsinki.

A second example comes from our research in string theory. This field was revolutionized in the last two years by the discovery that all superstring theories are actually different phases of a single unified theory including extended objects beyond strings. We (Kaloper, Khuri, Myers) were among the first to establish this fact by showing how fundamental membranes are crucial for relating the heterotic and type IIa superstring theories. These membranes have since become recognized as one of a general class of objects known as D-branes, which are now central to the understanding of connections between string theories.

One of our members (Myers) earned the first place award in the 1995 Gravity Research Foundation's essay contest. The award was shared with Gary Horowitz (from the University of California, Santa Barbara) for their essay, *The value of singularities.* This annual contest began in 1940 with the goal of stimulating thought and encouraging work on gravitation. Past contest winners include Stephen Hawking and Roger Penrose.

7 Research Support

The Centre's three constituent teams have achieved a level of coherence and cooperation that has substantially increased the overall research effectiveness of the group, as described in the following sections.

Computing Resources: An absolutely essential tool in high energy physics research, experimental and theoretical, is a completely integrated computer network such as that of the McGill Centre. It would be impossible to maintain the necessary software on each individual workstation, hence the need for these machines to be linked. Furthermore the utilization of CPU time is greatly improved when every machine is available to every user regardless of ownership, as is the case with our network. The last five years have seen much of the dissemination of cutting-edge information in high energy physics move from journals to electronic distribution via the Internet. This new mode of operation makes the maintenance and continual upgrading of our computer system and network essential. Our system could not function without the dedicated efforts of two system managers, P Mercure and J. Gallego. The former is supported by the two experimental teams of the Centre with additional support provided by Le Centre de Recherche des Materiaux; the latter is supported by Le Centre de recherche des Materiaux.

Laboratory Support: The Centre's laboratory facilities are shared by its experimental members. For example, the two experimental groups have been able to pool their resources to avoid the duplication of costs. Nevertheless the laboratory's effectiveness would be significantly improved by the acquisition of additional electronic instruments. Equally important to the Centre's operation are our dedicated laboratory professionals, R. Fernholz and L. Nikkinen, who coordinate the experimental research activities and assist the students and postdoctoral researchers.

Visitors and Seminars: The Centre operates a lively seminar program and hosts a number of speakers each year. These seminars are a major stimulant to the Centre's intellectual life, especially to the exchange of ideas between members of the different teams. The Centre's management of the seminars ensures a breadth of topics that would not be available to the individual teams. A similar advantage derives from frequent visits from outside collaborators of Centre members and researchers spending sabbatical or shorter leaves at the Centre.

In summary, the Centre gives its constituent teams a "critical mass" of technical support, permitting in-house experimental research and development. Among the major resources in this category are a small pool of laboratory and electronic equipment and a dedicated laboratory professional. Furthermore the experimental and theoretical members benefit mutually by sharing their computer resources, as well as the discussions fostered by joint seminars.

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3. *Measurements of the B Semileptonic Branching Fraction with Lepton Tags.*
CLNS-95-1362, Oct 1995. 10pp. Phys. Rev. Lett. 76 (1996) 1570–1574.

4. *Measurements of the Ratios* $B\ (d_s^+ \to \eta\ \ell^+\ \nu)\ /\ B\ (d_s^+ \to \phi\ \ell^+\ \nu)$ *and* $B\ (d_s^+ \to \eta'\ \ell^+\ \nu)\ /\ B\ (d_s^+ \to \phi\ \ell^+\ \nu)$.
CLNS-95-1351, Aug 1995. 11pp. Phys. Rev. Lett. 75 (1995) 3804–3808.

5. *Observation of a Narrow State Decaying Into* $\Xi_c^+\pi^-$.
CLNS-95-1352, Jul 1995. 12pp. Phys. Rev. Lett. 75 (1995) 4364–4368.

6. *Observation of an excited charmed baryon decaying into* $\Xi_c^0\pi^+$.
Phys. Rev. Lett. 77 (1996) 810–813.

7. *Analysis of* $D^0 \to K\overline{K}^0X$ *decays.*
Phys. Rev. D54 (1996) 4211–4220.

8. *Measurement of* $B\ \ (D^0 \to K^-\pi^+\pi^0)\ /\ \ B\ \ (D^0 \to K^-\pi^+)$.
Phys. Lett. B373 (1996) 334–338.

9. *Measurement of the Branching Fraction for* $D_s \to \phi\pi^-$.
Phys. Lett. B378 (1996) 364–372.

10. *First observation of the decay* $\tau^- \to K^-\eta\nu_\tau$.
Phys. Rev. Lett. 76 (1996) 4119–4123.

11. *Decays of Tau Leptons to final states containing* K_s^0 *mesons.*
Phys. Rev. D53 (1996) 6037–6053.

12. *Limits on Flavor Changing Neutral Currents in* D^0 *decays.*
Phys. Rev. Lett. 76 (1996) 3065–3069.

13. *Observation of new decay modes of the charmed strange baryon* Ξ_c^+.
Phys. Lett. B373 (1996) 261–266.

14. *Study of* $B \to \psi\rho$.
Phys. Lett. B369 (1996) 186–192.

15. *Measurement of the Form–Factors for* $\overline{B}^0 \to D^{*+} l^- \overline{\nu}$.
Phys. Rev. Lett. 76 (1996) 3898–3902.

16. *Tau decays into three charged leptons and two neutrinos.*
Phys. Rev. Lett. 76 (1996) 2637–2641.

17. *Measurement of* $B \to D_s + X$ *decays.*
Phys. Rev. D53 (1996) 4734–4746.

18. *Measurement of the decays* $\tau \to h^- \ h^+ \ h^- \nu_\tau$ *and* $\tau \to h^- h^+ h^- \pi^0 \nu_\tau$.
Phys. Rev. Lett. 75 (1995) 3809–3813.

19. *The inclusive decay* $B \to \eta \ X$.
Phys. Rev. D53 (1996) 6033–6036.

20. *Observation of the Isospin violating decay* $D_s^* \to \ D_s \ \pi^0$.
Phys. Rev. Lett. 75 (1995) 3232–3236.

21. *Observation of the* Ξ_c^+ *charmed baryon decays to* $\Sigma^+ \ K^- \ \pi^+$, $\Sigma^+ \ \overline{K}^{0 \ *0}$ *and* $\Lambda \ K^- \ \pi^+ \ \pi^-$.
Phys. Lett. B365 (1996) 431–436.

22. *Observation of the Cabibbo suppressed charmed baryon decay* $\Lambda_c^+ \to \ p \ \phi$.
Phys. Rev. D53 (1996) 1013–1017.

23. *Search for exclusive charmless hadronic* B *decays.*
Phys. Rev. D53 (1996) 1039–1050.

24. *Measurement of* α_s *from tau decays.*
Phys. Lett. B356 (1995) 580–588.

25. *Search for* CP *violation in* D^0 *decay.*
Phys. Rev. D52 (1995) 4860–4867.

High Energy Physics Experiment, the ZEUS Collaboration

(F. Corriveau, D.S. Hanna, P. Patel, D.G. Stairs et al.)

1. *Observation of Events with an Energetic Forward Neutron in Deep Inelastic Scattering at HERA.*
DESY-96-093, May 1996. 13pp. Phys. Lett. B384 (1996) 388–400.

2. *Dijet Angular Distributions in Direct and Resolved Photoproduction at HERA.*
DESY-96-094, May 1996. 20pp. Phys. Lett. B384 (1996) 401–413.

3. *Measurement of the Reaction* $\gamma^* p \to \phi p$ *in Deep Inelastic* $e^+ p$ *Scattering at HERA.*
DESY-96-067, Apr 1996. 22pp. Phys. Lett. B380 (1996) 220–234.

4. *Measurement of the Diffractive Cross-section in Deep Inelastic Scattering.*
DESY-96-018, Feb 1996. 40pp. Z. Phys. C70 (1996) 391–412.

5. *Measurement of Elastic ϕ Photoproduction at HERA.*
DESY-96-002, Jan 1996. 23pp. Phys. Lett. B377 (1996) 259–272.

6. *Inclusive Charged Particle Distributions in Deep Inelastic Scattering Events at HERA.*
DESY-95-221, Nov 1995. 34pp. Z. Phys. C70 (1996) 1–16.

7. *Rapidity Gaps Between Jets in Photoproduction at HERA.*
DESY-95-194, Oct 1995. 19pp. Phys. Lett. B369 (1996) 55–68.

8. *Measurement of the Proton Structure Function F_2 at Low x and Low Q^2 at HERA.*
DESY-95-193, Oct 1995. 29pp. Z. Phys. C69 (1996) 607–620.

9. *Measurement of α_s From Jet Rates in Deep Inelastic Scattering at HERA.*
DESY-95-182, Oct 1995. 16pp. Phys. Lett. B363 (1995) 201–216.

10. *Measurement of Elastic ρ^0 Photoproduction at HERA.*
DESY-95-143, July 1995. 24pp. Z. Phys. C69 (1995) 39–54.

11. *Exclusive ρ^0 Production in Deep Inelastic Electron - Proton Scattering at HERA.*
DESY-95-133, July 1995. 17pp. Phys. Lett. B356 (1995) 601–616.

12. *Diffractive Hard Photoproduction at HERA and Evidence for the Gluon Content of the Pomeron.*
DESY-95-115, June 1995. Phys. Lett. B356 (1995) 129–146.

13. *Measurement of the diffractive structure function in deep elastic scattering at HERA.*
Z. Phys. C68 (1995) 569–584.

14. *Neutral strange particle production in deep inelastic scattering at HERA.*
Z. Phys. C68 (1995) 29–42.

15. *Measurement of Charged and Neutral Current Electron–Proton Deep Inelastic Scattering Cross–sections at High Q^2.*
Phys. Rev. Lett. 75 (1995) 1006–1011.

16. *Study of the Photon Remnant in Resolved Photoproduction at HERA.*
Phys. Lett. B354 (1995) 163–177.

High Energy Physics Experiment, Heavy Ions Physics

(J. Barrette, T. Mark et al.)

1. *Transverse Energy and Charged Particle Multiplicity in p Nucleus Collisions at 14.6 GeV/c.*
E814 Collaboration (J. Barrette, for the collaboration), 1996. Phys. Rev. C52 (1995) 2028-2036.

2. *Search for the Signature of a Halo Structure in the p (He-6, Li-6) N Reaction.*
M.D. Cortina-Gil, P. Roussel-Chomaz, N. Alamanos, J. Barrette, W. Mittig, F. Auger, Y. Blumenfeld, J.M. Casandjian, M. Chartier, V. Fekou-Youmbi, B. Fernandez, N. Frascaria, A.

Gillibert, H. Laurent, A. Lepine-Szily, N.A. Orr, V. Pascalon, J.A. Scarpaci, J.L. Sida, T. Suomijarvi (GANIL & DAPNIA, Saclay & McGill U. & Orsay, IPN & Sao Paulo U. & Caen, ISMRA), GANIL-P-95-29, (received Feb 1996) 11pp. Phys. Lett. B371 (1996) 14–18.

3. *Elastic Scattering of He-6 and Its Analysis Within a Four Body Eikonal Model.*

   J.S. Al-Khalili, M.D. Cortina-Gil, P. Roussel-Chomaz, N. Alamanos, J. Barrette, W. Mittig, F. Auger, Y. Blumenfeld, J.M. Casandjian, M. Chartier, V. Fekou-Youmbi, B. Fernandez, N. Frascaria, A. Gillibert, H. Laurent, A. Lepine-Szily, N.A. Orr, V. Pascalon, J.A. Scarpaci, J.L. Sida, T. Suomijarvi (Surrey U. & GANIL & DAPNIA, Saclay & McGill U. & Orsay, IPN & Sao Paulo U. & Caen, ISMRA), GANIL-P-96-01, Jan 1996. 10pp. Phys. Lett. B378 (1996) 45–49.

High Energy Physics Experiment, other publications

1. *A Study of Electron-Muon Pair Production in 450 GeV/c, p-BeCollisions.*

   The HELIOS Collaboration: T. Akesson, S. Almehed, A.L.S. Angelis, J. Antos, H. Atherton, P. Aubry, H.W. Bartels, G. Beaudoin, J.M. Beaulieu, H. Beker, O. Benary, D. Bettoni, V. Bisi, I. Blevis, H. Boggild, W. Cleland, M. Clemen, B. Collick, **F. Corriveau**, S. Dagan, K. Dederichs, P. Depommier, N. Digiacomo, S. Diliberto, J.R. Dodd, B. Dolgoshein, A. Drees, S. Eidelman, H. En'yo, B. Erlandsson, M.J. Esten, C.W. Fabjan, P. Fischer, A. Gaidot, F. Gibrat-Debu, P. Giubellino, P. Glassel, U. Goerlach, Y. Golubkov, R. Haglund, L.A. Hamel, H. van Hecke, V. Hedberg, R. Heifetz, A. Holscher, B. Jacak, G. Jarlskog, S. Johannson, H. Kraner, V. Kroh, F. Lamarche, C. Leroy, D. Lissauer, G. London, B. Lorstad, A. Lounis, F. Martelli, A. Marzari-Chiesa, M. Masera, M.A. Mazzoni, E. Mazzucato, M.L. McCubbin, N.A. McCubbin, P. McGaughey, F. Meddi, U. Mjornmark, M.T. Muciaccia, S. Muravev, M. Murray, M. Neubert, P. Nevskii, S. Nilsson, L. Olsen, Y. Oren, J.P. Pansart, Y.M. Park, A. Pfeiffer, F. Piuz, V. Polychronakos, P. Pomianowski, G. Poulard, M. Price, D. Rahm, L. Ramello, L. Riccati, G. Romano, G. Rosa, L. Sandor, J. Schukraft, M. Sekimoto, M. Seman, A. Shikonian, A. Shmeleva, V. Sidorov, S. Simone, Y. Sirois, H. Sletten, S. Smirnov, W. Sondheim, H.J. Specht, E. Stern, I. Stumer, A. Sumarokov, J.W. Sunier, V. Chernyatin, J. Thompson, V. Tikhomirov, C.M. Valine, A. Vanyashin, G. Vasseur, R.J. Veenhof, R. Wigmans, W.J. Willis, P. Yepes (CERN & Lund U. & University Coll., London & Montreal U. & Heidelberg U., Phys. Inst. & Tel Aviv U. & Turin U. & INFN, Turin & Pittsburgh U. & McGill U. & Los Alamos & Rome U. & INFN, Rome & Moscow Phys. Eng. Inst. & Novosibirsk, IYF & Stockholm U. & DAPNIA, Saclay & Brookhaven & Rutherford & Bari U. & INFN, Bari & Lebedev Inst. & Salerno U. & INFN, Salerno), CERN-PPE-96-23, Feb 1996. 17pp. Submitted to Z.Phys.C

2. *Detection of Atmospheric Cerenkov Radiation Using Solar Heliostat Mirrors.*

   Rene A. Ong (Chicago U., EFI), D. Bhattacharya (UC, Riverside), C.E. Covault (Chicago U., EFI), D.D. Dixon (UC, Riverside), D.T. Gregorich (Cal Tech & Cal State, L.A.), **D.S. Hanna** (McGill U.), S. Oser (Chicago U., EFI), J. Quebert, D.A. Smith (Bordeaux-Gradignan, CEN), O.T. Tumer, A.D. Zych (UC, Riverside), EFI-95-78, May 1996. 16pp. Astroparticle Physics 5 (1996) 353.

3. *A New Atmospheric Cerenkov Detector Using the Heliostats of Solar Two.*

   R.A. Ong, D. Bhattacharya, C.E. Covault, D.D. Dixon, M. Dragovan, D.T. Gregorich, **D.S. Hanna**, S. Oser, O.T. Tumer, A.D. Zych (Chicago U., EFI & UC, Riverside & Cal State, L.A.

& McGill U.), EFI-95-72, Sep 1995. 16pp. Invited talk at International Workshop towards a Major Atmospheric Cerenkov Detector for TeV Astro/Particle Physics, 4th, Padua, Italy, 11-13 Sep 1995.

4. *A Precise Measurement of the Cross-section of the Inverse Muon Decay* $\nu_\mu + e^- \rightarrow \mu^- + \nu_e$.
   CHARM-II Collaboration (**G. Zacek** et al.), CERN-PPE-96-01, Jan 1996. 7pp. Phys. Lett. B364 (1995) 121-126, and CERN Geneva - CERN-PPE-96-001 (96/01,rec.Feb.) 7 p.

9 Exchange of Knowledge

9.1 Teaching

The Department of Physics provides several regular courses given by one or many of our Centre members. Their list can be found in the Physics graduate studies program. Interaction with students can also take the form of special lecture series or research projects not linked with any McGill academic activity:

1. *An Introduction to Effective Field Theories and Their Applications.*
   Cliff Burgess, 12-hour lecture series presented to:
   The Swiss *Troisième Cycle* Graduate Programme, Lausanne, June 1995;
   The University of Oslo, Oslo, June 1995.

2. *Confronting Theory with Experiment at the Electroweak Scale.*
   Cliff Burgess, 6-hour lecture series presented to:
   The University of Oslo, Oslo, June 1996.

3. *Construction of a Spark Chamber.*
   Semester Student Project with COOP student Pascale Sévigny, from Sherbrooke University, supervised by F. Corriveau, Autumn 1995.

9.2 Thesis

1. *Hard Diffractive Scattering in Photoproduction at HERA*,
   Laurel Sinclair, Ph.D, November 1995, now research associate at the University of Glasgow, Scotland.

2. *CsI Efficiency measurements*,
   Rakie Cham, M.Sc., now Ph.D. candidate in Bio-Engineering at the University of Pittsburg.

3. *On the Role of Ghosts in String Theory*,
   Martin B. Gagnon, M.Sc., September 1995, now medical student at the Université de Montréal.

4. *The Thermodynamic First Law for Black Holes in Low-energy String Theory*,
   Christopher Roderick, M.Sc., October 1995, now Ph.D. candidate in condensed matter physics at McGill University.

5. *Two-dimensional dilaton black holes*,
   Guy Michaud, M.Sc., June 1995, now Ph.D. candidate in high energy physics at McGill University.

9.3 Seminars

The Centre sponsors two seminar series instrumental in the training of researchers. One is a weekly "pizza lunch" seminar, usually featuring a Centre member discussing his or her current research in an informal atmosphere encouraging student participation. These seminars also provide a familiar setting in which graduate students and postdoctoral researchers gain valuable experience in presenting their work. In parallel, 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.

It is the nature of our field that much, if not most, of the fruitful interactions are informal in nature. For this reason we work to encourage all opportunities for all of the members of our team to get together and discuss their research. We have had particular success along these lines with our weekly informal 'pizza' seminar, in which all of the members of the group meet over lunch to hear one of our number present a talk on their work. All of our students give at least one of these talks sometime during their programme, while the permanent members and stagiaires typically speak more frequently. This is in addition to our regular High Energy Theory seminars, in which visitors present their work to the group.

List of formal seminars

1. *Status of the Neutrino Oscillations Search with LSND,*
   Ion Stancu, Los Alamos, 23 May 1995.
2. *Variational Procedures for Resonant States,*
   Marcos Moshinsky, Instituto de Física, Universidad Nacional Autónoma de México, 19 June 1995.
3. *Summary of the HF95 and RICH-95 Conferences,*
   Klaus Strahl, McGill Univbersity, 5 July 1995.
4. *New Vacua for the Heterotic String!,*
   Clifford Johnson, Princeton University, 15 August 1995.
5. *Laser Spectroscopic Studies of Hafnium Ions Confined in a Paul Trap,*
   Wenzheng Zhao, McGill University, 18 August 1995.
6. *MISTRAL: A new program for precise mass measurements of very short-lived nuclides,*
   Dave Lunney, Centre de Spectrometrie Nucleaire et de Spectrometrie de Masse (CSNSM-IN2P3-CNRS), Orsay, France, 29 August 1995.
7. *Neutral Leptons and New-physics Phenomena,*
   (including his recent work on SUSY with explicit R-parity violation), Apostolos Pilaftsis, Rutherford Appleton Laboratory, 30 August 1995.

8. *The Mystery of Charmonium Production (A New Formalism!),*
   Ivan Maksymyk, University of Texas at Austin, 6 September 1995.

9. *The status of big bang cosmology and the inflationary universe,*
   Jim Cline, McGill University, 13 Septembre 1995.

10. *Baryon Properties in Chiral Perturbation Theory,*
    Manoj K. Banerjee, University of Maryland, 20 September 1995.

11. *Summary of the Lepton Photon Conference 1995 held in Beijing, from August 10th - 15th,*
    Harry Lam, McGill University, 21 September 1995.

12. *New Particles at Future e^+e^- Colliders,*
    Abdel Djouadi, Université de Montréal, 26 September 1995.

13. *Exact Results for Sigma Models,*
    Timothy J. Hollowood, University of Wales, Swansea, 27 September 1995.

14. *The Hadron to Quark-gluon Transition,*
    Gerald E. Brown, State University of New York at Stony Brook, 11 October 1995.

15. *On the superspace description of two-dimensional systems with local (2,2) supersymmetry,*
    Marc Grisaru, Brandeis University, 12 October 1995.

16. *Hunting Dark Matter,*
    Kai Zuber, Max Planck Institute, Heidelberg, 12 October 1995.

17. *A Measurement of* $\mid V_{cb} \mid$ *from* $\overline{B^0} \to D^{*+}\ell^-\overline{\nu}$,
    Ian Scott, CERN, 17 October 1995.

18. *Measurements of QCD colour factors using hadronic decays of the Z^0: a tool for gluino search?,*
    Hannes Jeremie, Université de Montréal, 24 October 1995.

19. *Study and Optimization of the tracking detector for the FINUDA Experiment at DAPHNE,*
    Archana Sharma, INFN Torino Italy and CERN, 1 November 1995.

20. *Measuring the QGP transition temperature with electromagnetic particles,*
    John J. Neumann, Center for Nuclear Research, Kent State University, 31 October 1995.

21. *The Search for Dark Matter*
    Francis Halzen, University of Wisconsin, 1 November 1995.

22. *Viewing multifragmentation as a critical phenomenon,*
    Andrew S. Hirsch, Physics Department, Purdue University, 20 November 1995.

23. *Search for "penguins" at CDF,*
    Kostas Kordas, McGill University, 21 November 1995.

24. *Physical Application of Haldane's Statistics: Spin Chains and Quantum Dots,*
    R.K. Bhaduri, Physics Department, McMaster University, 27 November 1995.

25. *Proton Therapy at TRIUMF,*
Ewart Blackmore, TRIUMF, 28 November 1995.

26. *Charmonium Production: The Sequel,*
Ivan Maksymyk, University of Texas, Austin, 1 December 1995.

27. *The Sudbury Neutrino Observatory,*
Aksel Hallin, Queen's University, 5 December 1995.

28. *Nuclear Physics of Supernova Explosions,*
Mike Pearson, Université de Montréal, 18 December 1995.

29. *A Light and Refreshing Introduction to Null Tetrads and Their Applications in General Relativity,*
Alan Held, Bern University, 12 December 1995.

30. *Precision Measurement of the Weinberg Angle from a Measurement of the Tau Polarization at the OPAL Detector at LEP,*
Manuella Vincter, University of Victoria, 9 January 1996.

31. *Rapidity Gaps in Hard Photoproduction at HERA,*
Laurel Sinclair, McGill and Glasgow University, 10 January 1996.

32. *The Effective Field Theory Method for Quantum Gravity,*
John Donoghue, University of Massachusetts, 15 January 1996.

33. *An experiment to test time-reversal invariance in kaon physics,*
Pierre Depommier, Université de Montréal, 16 January 1996.

34. *The Cosmic-ray Positron Fraction: A New Measurement with the HEAT Balloon-Borne Experiment,*
Stéphane Coutu, University of Michigan, 22 January 1996.

35. *Beyond the Z: A first Peek,*
André S. Turcot, Enrico Fermi Institute, University of Chicago, 23 January 1996.

36. *First limit on inclusive $b \to s\nu\bar{\nu}$ and constraints on New Physics,*
E. Nardi, Weizmann Institute of Science, 31 January 1996.

37. *Fragmentation Production of Heavy Quark States,*
Michael Doncheski, Carleton University, 12 February 1996.

38. *A Possible Violation of the Equivalence Principle by Neutrinos,*
Arthur Halprin, University of Delaware, Newark, 15 February 1996.

39. *Recent Action with Big Bang Nucleosynthesis,*
David Schramm, University of Chicago, 29 February 1996.

40. *The Canadian Microgravity Science Program,*
Philip Gregory, Canadian Space Agency, 4 March 1996.

41. *Going to Higher Order: The Hard Way and The Eazy Way – The Agony and The Ecstacy,*
Mark Samuel, University of Oklahoma, 6 March 1996.

42. *Physics with the strength of ATLAS,*
Georges Azuelos, Université de Montréal, 12 March 1996.

43. *The many Faces of the Photon,*
Sampa Bhadra, York University, 18 March 1996.

44. *Searching for Neutrinos from Gravitational Collapse with the MACRO Experiment,*
Kate Scholberg, CALTECH, 19 March 1996.

45. *Fragment production in small systems formed in peripheral and semi-peripheral collision,*
Luc Beaulieu, Université de Laval, 27 March 1996.

46. *The Dynamic Duo:* $K^+ \to \pi^+ \nu\overline{\nu}$ *and* $K^0 \to \pi^0 \nu\overline{\nu}$*,*
Douglas Bryman, TRIUMF, 1 April 1996.

47. *Photon production at CDF,*
Jodi Lamoureux, FNAL, 2 April 1996.

48. *W-Pair Production in the Process* $e^+e^- \to \ell\nu q\bar{q}'$ *and Measurement of the* $WW\gamma$ *and* WWZ *Couplings,*
Steve Godfrey, Carleton University, 10 April 1996.

49. *Low mass dilepton spectroscopy and the HADES project,*
Guy Roche, Laboratoire de Physique Corpusculaire, Université Blaise Pascal, France, 2 April 1996.

50. *Exact Energy Eigenstates for Black Holes in Generic Dilaton Gravity,*
Gabor Kunstatter, University of Winnipeg, 24 April 1996.

51. *Low Energy Implications of Baryogenesis,*
Mariano Quiros, IEM Madrid, 3 May 1996.

52. *The Low Energy Limit of M-Theory,*
Fermin Aldabe, University of Edmonton, 8 May 1996.

53. *Supermembrane Description of String Duality,*
Fermin Aldabe, University of Edmonton, 9 May 1996.

54. *New Results from HERA,*
Albert de Roeck, DESY, 21 May 1996.

List of "pizza" seminars

1. *High-Energy Electroweak precision Measurements served with a Heavy New Physics Topping,*
Peter Bamert, McGill University, 16 October 1995.

2. *CP violation in the B system within the standard model and beyond,*
David London, Université de Montréal, 23 October 1995.

3. *Killing Emmy,*
Christopher Roderick, McGill University, 30 October 1995.

4. *Black Hole decoherence by Hawking Radiation,*
Jean-Guy Demers, McGill University, 6 November 1995.

5. *Controlled Thermonuclear Fusion: Prospects and Problems,*
Richard Sydora, UCLA, 17 November 1995.

6. *Duality in the Quantum Hall System,*
C.A. Luetken, University of Oslo, 6 December 1995.

7. *The Electroweak Phase Transition and Baryogenesis,*
Jim Cline, McGill University, 14 December 1995.

8. *Decoherence, Recoherence and the Membrane Paradigm: Black Hole Evaporation revisited,*
James Anglin, Los Alamos National Laboratory, 11 january 1996.

9. *Neutrino Interaction with Matter,*
Denis Michaud, McGill University, 25 January 1996.

10. *The Mother of all Renormalizations,*
Peter Haagensen, McGill University, 1 February 1996.

11. *The Mother of all Renormalizations, Part II,*
Peter Haagensen, McGill University, 6 ebruary 1996.

12. *Including Non-Renormalizable Interactions in Positronium and doing it right,*
Patrick Labelle, McGill University, 13 February 1996.

13. *Is the $J/\Psi, \Psi, \Upsilon$ production puzzle solved ny NRQCD?,*
Hélène Nadeau, McGill University, 20 February 1996.

14. *What's this fuss about Seiberg-Witten? A non-technical introduction to their theory,*
Harry C.-S. Lam, McGill University, 14 March 1996.

15. *Black Membranes and Fundamental String States,*
Nemanja Kaloper, McGill University, 21 March 1996.

16. *Toys for Boys and Games for Girls,*
Klaus Strahl, McGill University, 4 April 1996.

17. *Short bears, long bulls, naked puts and covered calls (An Introduction to Stock Options and other Derivative Securities),*
Alex Marini, McGill University, 16 April 1996.

18. *Fractional Statistics and the Abelian Chern-Simons Theory,*
Mario Bergeron, McGill University, 2 May 1996.

19. *Strings and Black Holes from Membranes and D-branes,*
    Ramzi Khuri, CERN and McGill University, 7 May 1996.

9.4 Conferences

Other effective resources for the training of young researchers are the advanced physics workshops and schools, such as the Theoretical Advanced Study Institute in the US, the Les Houches school in France, or the Erice school in Italy. Many graduate students have attended at least one international summer school during the course of their training at McGill, and Centre members have also been among the invited lecturers at such schools. Similarly students and postdoctoral researchers attend high energy physics conferences across North America and Europe. Members of the Centre organize international conferences at McGill itself, such as the 5^{th} International Symposium on Heavy Flavor Physics in 1993, the 16^{th} Montreal-Rochester-Syracuse-Toronto (MRST) Meeting in 1994, and the Physics Colloquia for the ACFAS Congress (Association canadienne-française pour l'avancement des sciences) in 1996.

Moreover, the Centre's postdoctoral researchers and graduate students are encouraged to speak at scientific conferences. In 1995, they presented three talks at CAP-CAM '95 (the Canadian-American-Mexican Physics Congress) in Québec City, two at the ACFAS Congress, five at the Canadian Conference on General Relativity and Relativistic Astrophysics in Fredericton (CC-GRRA) and two at the CAP Eastern Regional Nuclear Physics Conference. Occasionally postdoctoral researchers also give specialized lectures in their area of expertise in the graduate courses at McGill University.

6^{th} Canadian Conference on General Relativity and Relativistic Astrophysics, Fredericton, New Brunswick, 25–27 May 1995. With proceedings.

1. *Four Dimensional Black Holes and Duality in Superstring Theory.*
   C.P. Burgess, R.C. Myers (McGill U.), F. Quevedo (Neuchatel U.), MCGILL-95-44, May 1995. 24pp.

2. *Decoherence of the Unruh Detector.*
   Jean-Guy Demers (McGill U.), GRQC-9508016, May 1995. 5pp. To appear in the Proceedings.

3. *Black Hole Entropy and Renormalization.*
   Jean-Guy Demers, Rene Lafrance, Robert C. Myers (McGill U.), MCGILL-95-39, May 1995. 5pp. To appear in the Proceedings.

4. *A No Go Theorem in String Cosmology.*
   Nemanja Kaloper (McGill U.), MCGILL-95-41, Jul 1995. 6pp.

5. *Low-Energy Scattering of Black Holes and P-branes in String Theory.*
   Ramzi R. Khuri (CERN & McGill U.), Robert C. Myers (McGill U.), CERN-TH-95-345, Dec 1995. 6pp. To appear in the Proceedings.

6. *Two-dimensional Dilaton Black Holes.*
   Guy Michaud, Robert C. Myers (McGill U.), MCGILL-95-40, May 1995. 5pp. To appear in the Proceedings.

CAP-CAM 1995, Université Laval, 12–15 June 1995

1. *Ground Based Gamma Ray Astronomy.*
   David Hanna.

2. *R&D Towards a Solid-Photocathode RICH detector.*
   Kenneth Ragan.

3. *Neutral Strange Particle Production in Deep Inelastic Scattering with the ZEUS Detector at HERA.*
   Rainer Ullmann.

4. *Photoproduction Results from the ZEUS Experiment.*
   Christopher Matthews.

5. *Recents Results in Deep Inelastic Scattering from the ZEUS Experiment.*
   François Corriveau.

6. *Search for $B \to K^*\gamma$ at CDF.*
   K. Kordas.

7. *Status of the Standard Model with Recent Results from CDF.*
   Kenneth Ragan.

18^{th} Annual Montreal-Rochester-Syracuse-Toronto (MRST) High-energy Theory Meeting, Toronto, Canada, 9–10 May 1996

1. *R_b Problem: Loop Contributions and Supersymmetry.*
   J.M. Cline (McGill U.), MCGILL-96-17, May 1996. 10pp.

2. *R_b and Heavy Quark Mixing.*
   P. Bamert (McGill U.), MCGILL-96-21, May 1996. 9pp.

Other Conference Talks and Proceedings

1. *Neutrino Propagation in a Fluctuating Sun.*
   C.P. Burgess and D. Michaud, to appear in the proceedings of Neutrino 96, Helsinki, Finland, June 1996.

2. *Scalar Emitting Modes in Double-Beta Decay.*
   C.P. Burgess, to appear in the proceedings of Workshop on Double Beta Decay and Related Topics, Trento Italy, April 1995.

3. *Soft Interaction of Heavy Fermions.*
   C.S. Lam (McGill U.), MCGILL-96-22, Jun 1996. 12pp. Talk given at International Symposium on Heavy Flavor and Electroweak Theory, Beijing, P.R. China, 16-19 Aug 1995. Beijing Heavy Flavor 1995:101-109 (QCD162:H41:1995)

4. *Hybrids: Dynamics and Disguises.*

   P.R. Page (Oxford U.), HEPPH-9509419, Jul 1995. 3pp. Revised version of conferernce talk. Presented at 6th International Conference on Hadron Spectroscopy (HADRON 95), Manchester, England, 10-14 Jul 1995.

5. *Dileptons From Bremsstrahlung: Going Beyond the Soft Photon Approximation.*

   H.C. Eggers (Stellenbosch U.), C. Gale, R. Tabti (McGill U.), K. Haglin (Michigan State U.), HEPPH-9604372, Mar 1996. 10pp. To be published in the proceedings of International Conference on Nuclear Physics at the Turn of Millennium: Structure of Vacuum and Elementary Matter, Wilderness / George, South Africa, 10-16 Mar 1996.

6. *Hadron Yields and Spectra in Au + Au Collisions at the AGS.*

   E877 Collaboration (R. Lacasse, et al.), NUCLEX-9609001, May 1996. 12pp. Presented at 12th International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions (Quark Matter 96), Heidelberg, Germany, 20-24 May 1996. Submitted to Nucl.Phys.A

7. *Elastic Scattering and Charge Exchange Reaction Studies with He-6, Be-10, Be-11.*

   M.D. Cortina-Gil, P. Roussel-Chomaz (GANIL), N. Alamanos (DAPNIA, Saclay), J. Barrette (McGill U.), W. Mittig (GANIL), F. Auger (DAPNIA, Saclay), Y. Blumenfeld (Orsay, IPN), J.M. Casandjian, M. Chartier (GANIL), V. Fekou-Youmbi, B. Fernandez (DAPNIA, Saclay), N. Frascaria (Orsay, IPN), A. Gillibert (DAPNIA, Saclay), H. Laurent (Orsay, IPN), A. Lepine (GANIL & Sao Paulo U.), N.A. Orr (Caen, ISMRA), V. Pascalon, J.A. Scarpaci (Orsay, IPN), J.L. Sida (DAPNIA, Saclay), T. Suomijarvi (Orsay, IPN), GANIL-P-95-16, Jun 1995. 6pp. Contributed to International Conference on Exotic Nuclei & Atomic Masses (ENAM-95), Arles, France, 19-23 Jun 1995.

8. *Elastic Scattering and Charge Exchange Reactions with Exotic Beams.*

   M.D. Cortina-Gil, P. Roussel-Chomaz (GANIL), N. Alamanos (DAPNIA, Saclay), J. Barrette (McGill U.), W. Mittig (GANIL), F. Auger (DAPNIA, Saclay), Y. Blumenfeld (Orsay, IPN), J.M. Casandjian, M. Chartier (GANIL), V. Fekou-Youmbi, B. Fernandez (DAPNIA, Saclay), N. Frascaria (Orsay, IPN), A. Gillibert (DAPNIA, Saclay), J. Al-Khalili (Surrey U.), H. Laurent (Orsay, IPN), A. Lepine-Szily (GANIL & Sao Paulo U.), N.A. Orr (Caen, ISMRA), V. Pascalon, J.A. Scarpaci (Orsay, IPN), J.L. Sida (DAPNIA, Saclay), T. Suomijarvi (Orsay, IPN), GANIL-P-96-03, (received Mar 1996) 11pp. 24th International Workshop on Gross Properties of Nuclei and Nuclear Excitation: Extremes of Nuclear Structure (HIRSCHEGG 96), F. Beck, 15-20 Jan 1996, Hirschegg, Austria.

9. *Selected Topics from the Hadronic Final State in Deep Inelastic Scattering Events at HERA.*

   Jutta Hartmann, Talk given at the 6^{th} International Conference on Elastic Scattering and Diffraction in Blois, France, June 1995. To appear in the proceedings.

9.5 ACFAS Congress

In the framework of the 64^{th} annual Congress of the ACFAS (Association Canadienne-Française pour l'Avancement des Sciences), which took place at McGill in May 1996, the McGill Centre for High Energy Physics, under the initiative of François Corriveau, organized a two-day colloquium in French:

La physique subatomique: des quarks aux galaxies

> La physique subatomique s'intéresse au premier abord aux constituants de la matière et aux interactions auxquelles elles sont soumises. Au-delà du modèle atomique on retrouve les protons et neutrons qui forment le noyau et les électrons qui orbitent autour de ce noyau. Dans le processus scientifique d'expériences et d'hypothèses conduisant à l'étude approfondie des composantes de l'atome, un grand nombre de phénomènes et de particules élémentaires ont pu être observés. Après les succès du Modèle Standard électro-faible liant les forces électromagnétique et faible, le modèle du quark a à son tour réunifié ces nouvelles particules et permis d'échafauder la théorie de la chromodynamique quantique (QCD) pour tenter d'expliquer les comportements de l'interaction forte. Le présent colloque a trois thèmes qui s'imbriquent étroitement autour de cet édifice central du Modèle Standard. Tout d'abord il s'agira de la physique des particles "classique" où l'on fera le point sur nos connaissances détaillées du modèle et sur les expériences visant à l'explorer plus en profondeur. Deuxièmement, il sera question des collisions noyau-noyau et de la production de matière nucléaire à des conditions extrêmes de température et de densité. La QCD y prédit un changement de phase vers un nouvel état de matière, le plasma de quarks et gluons. Enfin, des présentations dans le domaine de l'astrophysique des particules montreront à quel niveau le langage et les connaissances de l'infiniment petit et ceux de l'infiniment grand se rejoignent et se complètent.

On May 13^{th} and 14^{th}, there were four half-day sessions, two on high energy physics, one on heavy ion physisc and the last on astroparticle physics. Four invited talks were presented:

- Jules Gascon, Université de Montréal: *Les collisions électrons-positrons.*
- Claude Pruneau, Wayne State University: *Le plasma Quark-Gluon.*
- Stéphane Coutu, Université du Michigan: *La matière noire.*
- Guy Jonkmans, AECL, Chalk River: *Les neutrinos solaires.*

There were no less than 26 contributed talks in addition, with very active participation mainly from Université de Montréal, Université Laval and McGill University. The full program had also been distributed on the World Wide Web. The talks were well attended and the colloquium had a very positive impact on the participants, especially the students. The McGill contributions were:

1. Alain Bellerive, *Étude de la désintégration semi-leptonique du méson B en méson charmé* D^{**}.
2. Tarek SAAB, *La physique des mésons B à CDF.*
3. Patrick Labelle, *L'art d'inclure la physique des hautes énergies dans la théorie de Schrödinger.*
4. Hélène Nadeau, *Aperçu de la chromodynamique quantique non relativiste.*
5. Rainer Ullmann, *Étude de la production des particules étranges en diffusion inélastique profonde avec le détecteur ZEUS à HERA.*

6. Andreas Ochs, *Détermination de la constante de couplage α_s par la mesure des taux de production des "jets" en diffusion inélastique profonde avec le détecteur ZEUS.*

7. Alban Kellerbauer, *Vers un détecteur Čerenkov à anneaux pour CDF.*

8. Roger Lacasse, *Production de particules dans les collisions Au+Au à 10.8 GeV/c à l'AGS.*

9. Jean Barrette, *L'expérience PHENIX au RHIC et l'étude du plasma de quarks-gluons.*

10. Denis Michaud, *Neutrino taonique lourd et nucléosynthèse.*

11. Jim Cline, *Les baryons et la transition de phase électro-faible de l'univers.*

12. David Hanna, *L'Astronomie Gamma à 100 GeV.*

13. Harold Roussel, *Génération de vibrations sur des trous noirs stationnaires.*

9.6 Colloquia and Outside Talks

1. Robert Myers, *Black Hole Entropy from Strings and D-branes,*
   Los Alamos Nuclear Laboratories, April 22, 1996;
   University of Waterloo, May 16, 1996.

2. Cliff Burgess, *Why All the Excess b's?*
   The University of Pennsylvania, Philadelphia, PA, Apr. 1996;
   The University of Maryland, College Park, Maryland, Feb. 1996;
   The University of North Carolina, Chapel Hill, NC, Feb. 1996.

3. François Corriveau, *Les fonctions de structure du proton à HERA*, Université Laval, 23 April 1996.

4. Cliff Burgess, *Fighting the Split Brain: Why Renormalization is a Good Thing*, McMaster University, Hamilton, March 1996.

5. David Hanna, University of Victoria, 25 March 1996.

6. François Corriveau, *The Puzzle of the Nature of the Photon,*
   CAP Tour Talk, Queen's University, 25 March 1996;
   CAP Tour Talk, Royal Military College, 25 March 1996.

7. Robert Myers, *Relativistic Strings without Tension,*
   Centre de Recherches Mathematiques, Université de Montréal, March 12, 1996.

8. David Hanna, Lake Louise Winter Institute, February 1996.

9. Robert Myers, *Black Hole Thermodynamics,*
   Concordia University, January 22, 1996;
   Queen's University, February 13, 1996.

10. David Hanna, Carleton University, November 1995.

11. David Hanna, Chalk River, November 1995.

12. François Corriveau, *Résultats récents de ZEUS en diffusion inélastique profonde*, Université de Montréal, 5 October 1995,

13. David Hanna, University of British Columbia, October 1995.

14. François Corriveau, *Recent Deep Inelastic Scattering Results from ZEUS*, University of Carleton, 25 September 1995.

15. François Corriveau, *ZUT: an Ultra-Fast Monte-Carlo for the ZEUS Experiment*, Workshop on HEP Computing Methods, Université de Montréal, 17 August 1995.

9.7 Summer Schools

We have sent 6 of our students to some of the most prestigious summer schools in high energy physics: the CAP summer schools on theoretical physics in Banff, Alberta; the Theoretical Advanced Study Institute in Boulder, Colorado; the D. Chalonge International School of Astrophysics in Erice, Italy; and the ICTP summer schools on high energy physics in Trieste, Italy.

9.8 Visitors

We have also jointly funded a vigorous visitor's programme. To our associate member professor D. London who has actually spent his sabbatical leave in our group and to our other visitor members (listed above) who stayed several months, we may add the names of several more visiting scientists whose stays have had a duration of at least a week:

1. F. Aldabe (University of Alberta, Edmonton),

2. C. Johnson (ITP, Santa Barbara),

3. Y. Khriplovich (Budker Institute for Nuclear Physics, Novosibirsk),

4. C.A. Lütken (University of Oslo),

5. I. Maksymyk, (University of Texas at Austin),

6. A. Pilaftsis (Rutherford Appelton Lab, Oxford),

7. M. Quiros (Instituto de Estructura de la Materia, Madrid).

10 Outside Collaborations

The Park Medical company, located in Lachine, in Montréal, benefited from two of our former research associates (Christopher Matthews and Gabriele Zacek) who joined their research group. Shortly after, also one of our former summer students, Pascale Sévigny, from Sherbrooke University, did a stage in the company.

Park Medical is oriented towards detector developments for medical diagnostics purposes, and as such directly applies techniques and methods fo high energy physics, for design, construction, simulation and data processing of the components. In exchange of computer hardware equipment, they were using many of our HEP CPU platforms to perform their Monte-Carlo simulations, using the standard CERN-GEANT software.

Three of our graduate students, (D. Michaud et al.) have created their own software company, NETDesign. They are offering clients to create, expand and strengthen their entry pages to the Internet, complete with adresses, logo, advertisement, etc.. Their goal is to reach small Canadian companies to give them access to the electronic world and larger companies to increase their visibility. Several such projects are actually underway. Their computer is located on the CHEP floor and makes use of the present Centre's infrastructure.

11 Plans

The McGill Centre for High Energy possesses a rich and active program that encompasses several of the main issues of today's and tomorrow's research.

The trend towards unification, as exemplified by the many converging avenues of our particle physics research, both theoretical and experimental, is also seen in the day-to-day operation of the Centre. Both our McGill Centre for High Energy Physics and the Groupe de physique des Particules of the Université de Montréal, the two largest such groups in Québec, have initiated a merging of their activities:

Already several of the theoretical publications are common ones, and one experimental project (BaBar) has collaborators from both institutes. Our common seminar series are very popular and have allowed us a much wider spectrum of speakers. Moreover, the research objectives, the analysis methods and the computer tools are in many respects identical and favorize a "rapprochement" of our groups, which could soon be made official.