Subatomic Theory in Canada:

Report of the Ad-Hoc subatomic theory LRP committee

Andrzej Czarnecki, Michael Luke, Guy D. Moore, Moshe Rozali

- Who we are and What we do
- How we are organized (sic)
- Future Issues:
  - Commissioning of the LHC
  - Funding for schools, workshops, $etc.$
  - Theory Institute for Canada??
- Outlook and Recommendations

Growth of the Subatomic Theory Community

Year	# Grants
1996	71
1997	72
1998	69
1999	68
2000	62
2001	69
2002	72
2003	74
2004	76
2005	74

Year	Hire	Institution	Area
2001	Sangyong Jeon	McGill	Nuclear theory
2001	Erich Poppitz	Toronto	Formal
2001	Moshe Rozali	UBC	Formal (string)
2002	Guy D. Moore	McGill	Many body
2002	Kentaro Hori	Toronto	Formal (string)
2002	Baskhar Dutta	Regina	Phenomenology
2002	Mark van Raamsdonk	UBC	Formal (string)
2002	Maxim Pospelov	Victoria	Phenomenology
2003	Alex Buchel	Western	Formal
2003	Todd Fugleberg	Brandon	Many body
2004	Robert Brandenberger	McGill	Cosmology
2004	Jaume Gomis	Perimeter	Formal (string)
2004	S. Barkanova	Acadia	Nuclear theory
2005	Keshav DasGupta	McGill	Formal (string)
2005	Heather Logan	Carleton	Phenomenology
2005	Freddy Cachazo	Perimeter	Formal (string)
2005	Justin Khoury	Perimeter	Cosmology
2005	Adam Ritz	Victoria	Phenomenology
2005	Aachim Schwenk	TRIUMF	Nuclear theory

Theoretical Particle Physics Jobs Rumor Mill

2006 Faculty Jobs:

Alberta (deadline Dec. 15)
Short List: **Offered To:**

British Columbia (deadline Nov. 15)
Short List: **Offered To:**

McGill (deadline Dec. 15)
Short List: **Offered To:**

Simon Fraser (deadline Nov. 15)
Short List: **Offered To:**

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How do subatomic theorists work?

Community functions as collection of autonomous individuals

Individuals collaborate, but in small shifting groups

Project mobility is relatively high

Natural because of dynamics of the field:

- Rapid developments
- Low capital overheads

Less true of lattice and high-order corrections sub-communities

What is subatomic theory up to these days?

Non-exhaustive review:

- Phenomenology
- Formal theory
- Lattice
- Nuclear theory
- Cosmology

Phenomenology

Active Canadian participation in

- Beyond Standard Model (LHC, ILC) studies What signals can be expected in various extensions of the Standard Model? What are SM backgrounds? Precision studies now $de\ rigeur$.
- Precision flavour physics, especially B physics Heavy quark effective theory has made great advances and is now being pursued to higher orders. CKM parameters, CP violation, and new ways to discover New Physics are being actively explored.
- high order perturbative calculations High order QCD calculations are increasingly needed in hadronic phenomenology. New techniques for low energy QED and muon $g-2$ calculations.

Formal theory

New hires and the founding of the Perimeter Institute have increased Canada's impact in formal theory:

- String theory: New developments such as D-branes and flux compactifications are increasing the connection between string theory and phenomenology, bringing string theory closer to low energy predictions.
- AdS-CFT correspondence: A particularly nice string theory result with surprisingly rich implications for field theory and maybe QCD
- Loop Quantum Gravity: An alternative idea for quantum gravity. Canada is now the world leader in exploring this possibility.
- Formal field theory: topological objects, solitons, etc

Lattice gauge theory

For years the lattice community predicted that accurate results with controlled systematics would be available "soon."

Since 2003, it has actually started happening:

- Light and heavy-light state spectrum
- Light quark masses
- $\alpha_{\rm s}(\mu(\overline{\rm MS}) = M_Z)$
- Decay constants and bag parameters of heavy-light and light mesons

What made the difference?

2 perennial problems: numerical expense of treating

- virtual (loop/sea/vacuum fluctuation) quark effects
- very light valence quarks

First problem handled by quenching (leaving out sea quarks).

Second handled by using heavier u, d, s quarks ($m_\pi \sim 500 - 700$MeV).

Large systematic effects–this is not QCD!

Solved by development of highly improved staggered fermions: HPQCD collaboration, which has substantial Canadian participation.

Nuclear theory

- Nuclear structure Continued progress in understanding relation between QCD, low energy effective theories of few nucleon systems, and traditional approaches such as the shell model. Improved understanding of nuclei far from the valley of stability.
- High density QCD such as the possibility of color superconductivity, its characterisation, possible implications for neutron stars
- High energy (heavy ion collisions) A wealth of new experimental data from RHIC has stimulated this area. Better understanding of hadronization from a quark-gluon plasma, energy loss and hard probes of the quark-gluon plasma, and some progress on the problem of thermalization and far from equilibrium behavior in QCD.

Cosmology

- Inflationary cosmology particle physics and string theory models which can give inflation, signals from inflation such as possible nongaussianity, the role of back-reaction in the evolution of the inflaton
- (P)Reheating from Inflation How does inflation end? Understanding the transition from inflation to a thermal universe.
- Alternatives to inflation Are there models which can describe our universe and avoid some problems not solved by inflation, such as the singularity and initial condition problems?
- Dark energy Is it a cosmological constant, or could there be some more complex dynamical origin for the dominant energy density in the universe?

Recent and Current Funding Situation

Nearly all funding comes from discovery grants.

Subatomic theory funding has been gradually going up:

Year	Number of Grantees	Mean Grant Size	Inflation corrected
1996	71	$ 25 110	$ 30 470
1997	72	$ 24 460	$ 29 130
1998	69	$ 26 709	$ 31 540
1999	68	$ 29 010	$ 33 550
2000	62	$ 30 300	$ 34 180
2001	69	$ 30 760	$ 33 760
2002	72	$ 32 060	$ 34 300
2003	74	$ 34 880	$ 36 590
2004	76	$ 38 180	$ 39 310
2005	74	$ 41 360	$ 41 360

How is theory money spent?

Main expenditures are, in order of importance,

- Graduate Students
- Postdoctoral fellows
- Travel for collaboration and conferences
- Equipment, computer support, other expenses

Students and postdocs (that is, HQP) make up, on average, about 3/4 of theory expenditures.

How far does a theory grant go?

Graduate students: Cost per student vary between institutions and provinces. Take 15k as a typical amount.

Postdocs: salaries must be at least close to competitive with the US if we are to recruit quality personnel. US salaries are now generally above 40k USD. We **MUST** spend at least 45k CAD to be competitive.

A typical grant, after travel and other expenses, covers 2 students or 1 student + 1/3 postdoc. This may be adequate but is certainly not generous.

Big issues for next 5-10 years

The LHC

The LHC will create a wave of new experimental results at the energy frontier. Commissioning is only a few years away.

Canada is heavily involved on the experimental side, especially in ATLAS.

The community will need to shift its focus towards this physics program. We also need *flexibility* to change directions quickly and keep up with latest developments as new discoveries and new ideas/explanations unfold.

Communication and collaboration

All feedback from the community emphasises the need for:

- Conferences in Canada A chance to learn what is new, make connections and start collaborations, share ideas, present research, ...
- Workshops A good place to get collaborative efforts moving and go into more depth about ideas or techniques
- Long term visitors' programs Valuable for collaboration, especially for geographically remote members of the community
- Advanced schools supplement coursework available at one institution with advanced topics; broaden educational base of students

Help collaborations develop, ideas spread, community keep "nimble"

A theory institute for Canada?

Idea has widespread but not unanimous support.

Possibilities:

- Minimalist: Governing board distributing funds for conferences, schools, and workshops organized by any group in Canada. No fixed venue.
- Medium sized: Fixed location institute, permanent secretarial support, devoted office space, regular visitors' programs, conferences, workshops, long term meetings, schools
- Large: Add teaching buy-outs for long term visitors, affiliate program, sponsored postdoctoral fellows, possibly permanent scientific staff

What is gained if funding is increased?

- Training of HQP: almost all of a funding increase would go into an increase in the number of students and postdocs trained. *There is no more efficient way to increase HQP training.*
- Collaboration: Travel abroad for collaboration will be essential, especially as the LHC is in Europe. Our ability to collaborate would be enhanced.
- Visibility: People learn what we are doing from talks, seminars, and conference presentations. Getting out the message is almost as important as doing the work.
- Research productivity: with more students and easier collaboration, much more would get done. Students also form a community and train each other: increase is faster than linear.

Where should increased funding go?

Discovery grant system works well for theory: Correctly accounts for autonomy of individual researchers, who are in best position to decide how money should be spent.

Most of increase should be distributed to individual grants

Support for conferences, schools *etc* is main thing missing.

Some funding mechanism for these would be wise.

A theory institute may be a good approach BUT: only after a thorough discussion by community regarding location, size, mandate *etc*. *Must be a strong consensus.*

What if funding remains flat?

Flat is not flat: it is a decrease.

- The community is growing; this will probably continue.
- Student and Postdoc salaries must rise with wage levels, which is faster than inflation. And we are still not competitive with the US.

We will lose ability to train, and to travel for collaboration.

We lose flexibility when we need it most (LHC).

All money must go to individual discovery grants.

Productive researchers at small or isolated institutions $must$ have enough to support an integer number of HQP.

A theory institute would be good **IF** the cost can be found out of fresh funds. If the money comes from cutting discovery grants, it is robbing Peter to pay Paul.

What if funds are substantially cut?

All remaining funds must be distributed through individual discovery grants. No new initiatives would be possible.

The number of postdocs will crash. The number of students will be curtailed.

Top Canadian students will go to the US and probably not return. Scientific productivity will decline.

Faculty recruitment and retention will become difficult.

Parting thoughts

Subatomic theory and experiment are symbiotic.

They need each other as communities

They also help each other at the departmental level. Theorists and experimentalists need one another in the next office or around the corner, to talk to, learn from, bounce ideas off of.

If either community is not healthy, both suffer. If both are healthy, they both benefit.

Theory is much cheaper than experiment. It would be shortsighted not to fund it properly.