Report on Nuclear Physics activities in Canada

Rituparna Kanungo
Saint Mary’s University
Member, CINP Board of Directors

on behalf of
The Board of Directors, Canadian Institute of Nuclear Physics
Canadian Institute of Nuclear Physics (CINP)

Mission

The mission of the Institute is to provide a formal organization to fairly represent and effectively advocate the interests and goals of the Canadian Nuclear Physics research community to relevant agencies and parties.

Institutional members

- McGill University
- Mount Allison University
- Saint Mary’s University
- TRIUMF
- University of Guelph
- University of Manitoba
- University of Regina
- University of Winnipeg

Elect

- pay annual dues

Board of Directors

- President: Jens Dilling (TRIUMF)
- Vice President: Jean Barrette (McGill)
- Peter Blunden (Manitoba)
- Paul Garrett (Guelph)
- David Hornidge (Mount A.)
- Rituparna Kanungo (Saint Mary’s)

Employ

Executive Director

- Garth Huber (Regina)
  (part time job to oversee daily affairs of CINP)
# CINP Membership October 1, 2013

<table>
<thead>
<tr>
<th>Membership Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Membership</td>
<td>100</td>
</tr>
<tr>
<td>Faculty (Full) Members</td>
<td>68</td>
</tr>
<tr>
<td>Associate Members (Grad Students, PDFs)</td>
<td>32</td>
</tr>
<tr>
<td>Experimentalists</td>
<td>75</td>
</tr>
<tr>
<td>Theorists</td>
<td>24</td>
</tr>
</tbody>
</table>

The pie chart below illustrates the distribution of membership by research area:

- **Nuclear Astrophysics**
- **Nuclear Structure**
- **Beyond the Standard model**
- **Hadrons & QCD**
- **Education & Training**
Natural Sciences and Engineering Research Council of Canada (NSERC)

One fixed envelope exclusively funding nuclear and particle physics 22.7 M/year

Nuclear Physics experiment and theory funds ~ $5 M/year
Natural Sciences and Engineering Research Council of Canada (NSERC)

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Canada Foundation for Innovation (CFI) *Open only to universities*

Funds infrastructure primarily in Canada

New Initiatives Fund (NIF) *competition among all fields*  

~ **79 M** in last 5 years

<table>
<thead>
<tr>
<th>Project</th>
<th>CFI(40%) + ∑ partners</th>
<th>year</th>
<th>institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>eLINAC</td>
<td>52 M</td>
<td>2009</td>
<td>Victoria</td>
</tr>
<tr>
<td>UCN</td>
<td>10 M</td>
<td>2009</td>
<td>Winnipeg</td>
</tr>
<tr>
<td>GRIFFIN</td>
<td>9 M</td>
<td>2009</td>
<td>Guelph</td>
</tr>
<tr>
<td>CANREB</td>
<td>4.5 M</td>
<td>2013</td>
<td>Saint Mary’s</td>
</tr>
<tr>
<td>DESCANT</td>
<td>2.2 M</td>
<td>2005</td>
<td>Guelph</td>
</tr>
<tr>
<td>IRIS</td>
<td>1.3 M</td>
<td>2009</td>
<td>Saint Mary’s</td>
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One fixed envelope exclusively funding nuclear and particle physics \(22.7\ M/year\)

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Federal Government through National Research Council (NRC), funds

TRIUMF \(National\ Laboratory\ for\ Particle\ and\ Nuclear\ Physics\)

2010-2015 \(\$222\ M\)

Funds operation of the accelerator facility and staff
(nuclear, particle, material science, accelerator, nuclear medicine, engineering)

Experiments: infrastructure (CFI and NSERC) operation & research (NSERC)
University & TRIUMF individual researchers

Next five year plan is being submitted to NRC this year (2013)
Nuclear Structure and Nuclear Astrophysics

Exploring the physics of rare isotopes

Projects in Canada

Isotope Separator and ACcelerator (ISAC) TRUIMF

Operating

ISAC I

8Pi → GRIFFIN Beta decay
(under construction)

DRAGON Nuclear astrophysics

Laser Spectroscopy Spectroscopy

TITAN Masses
TITAN-EC (Germany funding)
# Nuclear Structure and Nuclear Astrophysics

## Exploring the physics of rare isotopes

### Projects in Canada

<table>
<thead>
<tr>
<th>Operating</th>
<th>Isotope Separator and ACcelerator (ISAC)</th>
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<tr>
<td><strong>TRIUMF</strong></td>
<td>E/A ~ 3-12 MeV</td>
</tr>
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</table>

#### ISAC I

- **8Pi ➔ GRIFFIN**
  - Beta decay
  - (under construction)

- **DRAGON**
  - Nuclear astrophysics

- **Laser Spectroscopy**
  - Spectroscopy

- **TITAN**
  - Masses
  - TITAN-EC (Germany funding)

#### ISAC II

- **EMMA**
  - mass analyzer
  - (under assembly)

- **DESCANT**
  - neutron detector
  - fusion evaporation
  - (~ '13-'14 operational)

- **HERACLES**
  - EOS
  - (~'12 commissioned)

- **IRIS**
  - reaction spectroscopy
  - (~'12 commissioned)

- **SHARC**
  - UK funding
  - TIGRESS gamma spectroscopy

- **TUDA**
  - Nuclear astrophysics

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**funded by Canada Foundation for Innovation**

- **GRIFFIN**
  - University of Guelph

- **DESCANT**
  - University of Guelph

- **IRIS**
  - Saint Mary’s University

- **SHARC - UK funding**

- **TIGRESS**

- **TUDA**
  - Nuclear astrophysics
Projects in Canada

Advanced Rare Isotope E Laboratory (ARIEL)

- Expand RIB program with:
  - New electron linac driver for photo-fission
  - New proton beamline
  - New target stations and front end
  - Three simultaneous beams
    - enable long beam times
    - increased beam development capabilities

TRIUMF

New Targets
New Mass Separators
New Front End
New Accelerators

ISAC I
ISAC II

Cyclotron
e-linac

500 kW, 50 MeV electrons

BEAMLINES AND EXPERIMENTAL FACILITIES

5 YEAR PLAN
10 YEAR PLAN
EXISTING
eLINAC (CFI: led by University of Victoria)  Sept. 2014: 100kW operation

Phase-1
BeO target station  MoU3 with VECC (India)

\(^8\text{Li}: \beta \text{NMR, molecular and material science)}

Targeted operation ~ early 2017

Phase-2
CANREB (CFI: led by Saint Mary's, co-applicant, Manitoba)

purifying rare isotope beams for nuclear physics & nuclear medicine

High resolution mass separator & EBIS

Targeted operation ~ late 2017

Phase-3  photofission with two ARIEL beams (r-process)

Phase-4  second proton beamline (fundamental symmetries)

Phase-5  full eLINAC
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<tr>
<th>Collaboration</th>
<th>Description</th>
<th>Canadian Role</th>
<th>Canadian Role Details</th>
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<td><strong>Offshore experiments &amp; collaborations</strong></td>
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<td><strong>ATLAS @ ANL</strong></td>
<td>Canadian Penning trap collaboration</td>
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<td><strong>GSI-FAIR</strong></td>
<td>EXL collaboration</td>
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<td>FRS-SuperFRS collaboration</td>
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Beyond the Standard Model

Exploring fundamental symmetries in nature

Projects in Canada

@ TRIUMF

Weak decay studies

FrPNC  Atomic parity non-conservation  US DOE funding

TRINAT  Nuclear beta decay  βν correlation
         neutral atom trap  search for right-handed ν

Electric dipole moment

Rn EDM

UCN  Neutron EDM  Canada-Japan collaboration
(CFI : led by University of Winnipeg)

q_{UCN} = 5 \times 10^{-4} \text{ UCN/cm}^3

Aim: 10^{-28} \text{ e-cm level}

CNEDM experiment

Unitarity of the CKM matrix element

8-pi + GPS  Half-lives and branching ratio measurements

TITAN  High precision mass measurements for testing theoretical corrections of \( f_t \) value

CP violation

TITAN  Unitarity of the Cabbibo, Kobayashi, Maskawa Matrix

\[ V_{ud} = V_{us} = V_{ub} = 0.99990 \pm 0.00060. \]

I.S. Towner & J.C. Hardy

arXiv:1108.2516v1

US DOE funding

Neutral atom trap

βν-ν correlation

Search for right-handed ν

TITAN

8-pi + GPS

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Beyond the Standard Model

Exploring fundamental symmetries in nature

Projects in Canada @ TRIUMF

**Neutrinoless double beta decay** TITAN
violation of lepton number conservation

**Electron capture branching ratio**
measurement of odd-odd intermediate nuclei
2νββ matrix elements

*collaboration with EXO (SNO+) @SNOLAB*

Offshore projects

**ALPHA @ CERN** (1/3 of collaboration is Canadian)

**Trapping anti-hydrogen** First trapping in 2010 (1000s storage achieved!)

Why is there more matter than antimatter?
Testing CPT conservation (comparing hydrogen and anti-hydrogen)

ALPHA 2 construction completed in 2012
Decoupling of trapping and spectroscopy
Laser and more sensitive microwave spectroscopy

Major design and manufacturing effort of cryostat at Calgary

**Collaboration with EXO @ WIPP**

Neutrinoless double beta decay

Why is there more matter than antimatter?
Beyond the Standard Model

@ Jefferson Laboratory

**Q-Weak**

Proton’s weak charge determined

Determination of the weak charges through parity violating electron scattering.

\[ e^- + p \rightarrow \text{low } Q^2 \ (0.025\text{GeV/c}^2) \]

~ $3M$ NSERC support over the years

Canada’s involvement

Science co-spokesperson

Magnetic spectrometer field design and construction

Detector developments
**@ Jefferson Laboratory**

- **GlueX (Hall D)**
  - **12 GeV upgrade**
  - Canadian contribution to hardware in Hall C and D
  - **Search for exotic hybrid mesons**
  - testing grounds for understanding quark confinement in QCD
  - photoproduction of mesons (9 GeV photons)
  - Science spokesperson in experiments
  - Detector development

  Calorimeter built @ Regina

- **Pion Electromagnetic Form Factor (Hall C)**
  - Science spokesperson in experiments
  - used extensively in theoretical models of hadron structure as testing standard

- **Super Big Bite Spectrometer (Hall A)**
  - Detector development

**@ University of Mainz**

Measurement of proton spin polarizability
Theory

- Ab initio nuclear structure and reactions in light nuclei
- Electroweak response of light nuclei (*GDR from first principles*)
- Quantum Monte Carlo calculations
- Relativistic heavy ions and QCD in extreme conditions
- Radiative corrections

Computing resources in Canada

Westgrid
- Theory cluster @TRIUMF (18 nodes with 12 cores each)
- CLUMEQ cluster (McGill) (14,400 cores)

Offshore computing resources

- TITAN Supercomputer (ORNL)
- Livermore computing facility
Outlook

Recommendations to the NSERC, subatomic physics envelope

- Ensure R&D activity directed at the next generation of discovery projects through effective funding of equipment (e.g. CFI).
- Ensure continuous research support of flagship projects in which Canada is actively participating.
- Envelope funding has been fixed at C$22.7M for many years (no inflationary increases). Fortunately, CFI funds have been available to offset equipment purchases funded in earlier years by Envelope.
- Recommend to increase Envelope funding by C$3.5M/year.