A career in Accelerator Physics

Lia Merminga | Head, Accelerator Division | TRIUMF

Canadian Conference for Undergraduate Women in Physics

McGill University, January 10-12, 2014
An **accelerator** is a device that uses electromagnetic forces to accelerate and guide charged particles.

**THE ESSENTIALS**

- **Particle source** (electrons, protons, ions)
- **Vacuum**
- **Electric field** for acceleration
- **Magnetic and/or electric fields** for focusing and steering
- **Controls**

**A familiar particle accelerator:**
Early accelerators were motivated by nuclear physics.

Today, particle accelerators are essential tools of discovery for:
- *Elementary particle physics*
- *Nuclear physics*
- *X-ray and neutron science*

and have found broad and expanding uses in:
- *Industry*
- *Energy*
- *Environment*
- *Medicine*
- *Security*
Wide variety of accelerators are enabling technology in many applications

- Total built to date >24,000, with >18,000 in operation
- Presently >70 accelerator vendors worldwide, primarily in US, Canada, Europe and Japan, but growing in China, Russia and India
- Equipment sales ~$3B per year worldwide
Accelerators for Society
Accelerators for Particle Physics:
The Large Hadron Collider

Proton and ion collider
Circumference 26.7 km
Energy CM 14 TeV
Discovery of Higgs Boson at the LHC

2012.7.4
discovery of Higgs boson

theory : 1964
design : 1984
construction : 1998

The Higgs enables atoms to exist
0.5 – 1 TeV CM energy e+/e- collider
31 km for 1 TeV CM based on SRF cavities at 31.5 MV/m

SRF cavity gradient key cost-driver for ILC construction

Key R&D objectives:
- Pursuit of very high gradient SRF linac technology
- Plan for mass-production of cavities – 14,560 cavities!

**SRF for ILC Main Linac**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.M. Energy</td>
<td>500 GeV</td>
</tr>
<tr>
<td>Beam Rep. rate</td>
<td>5 Hz</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>1 ms</td>
</tr>
<tr>
<td>beam current</td>
<td>9 mA</td>
</tr>
<tr>
<td>Av. field gradient</td>
<td>31.5 MV/m</td>
</tr>
<tr>
<td></td>
<td>+/- 20%</td>
</tr>
<tr>
<td># 9-cell cavities</td>
<td>14,560</td>
</tr>
<tr>
<td># cryomodules</td>
<td>1,680</td>
</tr>
<tr>
<td># RF units (10 MW Kly)</td>
<td>560</td>
</tr>
</tbody>
</table>
Nuclear Physics Facilities

12 GeV CEBAF Upgrade

TRIUMF ARIEL

McGill - 2014
X-ray and Neutron Sources

Advanced Photon Source
Argonne

Spallation Neutron Source
ORNL

Linac Coherent Light Source, SLAC

PSI Cyclotron
XFEL (18 GeV) Under Construction in Hamburg (Germany)
2.5 GeV protons (H+)
5 MW long pulse source
High reliability >95%

Aims to be brightest source of neutrons
Operational in 2019

- Will be powered by the wind and biomass and have zero net emissions of CO₂.
- Waste heat will be used to warm homes.
Canada has two Accelerator Labs

Vancouver

Saskatoon
TRIUMF: A National Science Laboratory

Members
University of Alberta
University of BC
Carleton University
University of Guelph
University of Manitoba
Université de Montréal
Queen’s University
Simon Fraser University
University of Toronto
University of Victoria
York University

Associate Members
University of Calgary
McGill University
McMaster University
University of Northern BC
University of Regina
Saint Mary’s University
University of Winnipeg

Research focus:
• Advancing isotopes for science & medicine
• Probing the structure & origins of matter

TRIUMF is owned & operated by a consortium of 18 universities
Founded 45 years ago in Vancouver

January 15, 2014
The 500 MeV Cyclotron at TRIUMF: The World’s Largest Cyclotron

1972 TRIUMF, Vancouver, BC
ARIEL e-Linac : MW-class Superconducting Electron Accelerator

50 MeV, 10 mA
State of the art accelerator based on 1.3 GHz CW SRF
On track for first beam Sept 2014

Possibility for other applications (FEL, ERL)
How do you build an accelerator?

- Scientific motivation
- conception of design
- design work
- research and/or development
- project definition
- construction
- commissioning
- operation
- maintenance
- upgrades
Modern-day accelerator research constitutes a dynamic discipline

It is driven by:
- demands on particle beams pushing an ever expanding performance envelope (energy, power, intensity and brightness)
- advances in technology making possible in-depth theoretical and experimental understanding of the behaviour of charged particle beams for the first time
Why accelerator science?

- Has relevance and impact
- Enables scientific discovery over broad range of disciplines
- Problems are fundamental and interesting
- Problems can be solved in relatively short time scales
- Possible to use analytical, numerical and experimental techniques to solve a problem
- Demand for accelerator physicists is high and increasing
I am responsible to execute the mission of our division:

- Ensure highest availability of accelerator complex to maximize science output
- Build facilities using leading edge technology at TRIUMF & around the world
- Grow world-class research and education program in Accelerator Science & Technology
- Establish international R&D partnerships with leading accelerator facilities
- Bring accelerator and related technologies to private sector for commercialization & societal benefit
Team of 134 Accelerator Division Staff: 19 research scientists, engineers, technical personnel
Advance knowledge

TRIUMF is Canada’s National Accelerator Laboratory

TRIUMF accelerators:
- Enable leading edge science in Nuclear & Particle Physics, Nuclear Medicine, Materials Science
- Advance the science of Accelerators

Include:
- 1 Nature
- 1 Nature Comm.
- 5 PRST-AB
- 7 PRLs
- 7 Phys Rev A & C

Accel. Div. publications
2008 - 2013

Peer-reviewed
Non peer-reviewed
Create Leaders: Training of Highly Qualified Personnel

Only graduate student program in Accelerator Physics in Canada, one of few in the world

<table>
<thead>
<tr>
<th>Trainees 2008-2012</th>
<th>undergrad</th>
<th>MSc</th>
<th>PhD</th>
<th>PDF</th>
<th>EIT*</th>
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<tr>
<td>Accelerator Physics</td>
<td>93</td>
<td>4</td>
<td>11</td>
<td>12</td>
<td>6</td>
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</table>

*EIT: Engineer in training

Staff Recognitions

Rick Baartman and Bob Laxdal: Fellows of the APS
Anna Grassellino: IEEE /NPSS Particle Accelerator Science &Technology Doctoral Student Award
Rick Baartman: Outstanding Referee by the APS
Shane Koscielniak and Rick Baartman: Elsevier “Excellence in Peer Reviewing” Award
Doug Storey: NSERC CGS Scholarship
Bob Laxdal: Adjunct Professor at MSU
In collaboration with Canadian and international universities, we established the first graduate student program in Accelerator Physics in Canada, one of few in the world.

- Two graduate courses on Accelerator Physics
- Ten graduate students doing thesis research at TRIUMF
- A new initiative for TRIUMF and Canada: NSERC grants for accelerator research and graduate student training
  - Seven proposals funded
  - Nine new requests in 2013
Connect Canada to the World:
Global nature of accelerator community

Canada: UBC, SFU, U of Toronto
USA: FNAL, JLab, FRIB, Cornell
Europe: CERN (ISOLDE, LHC), HZB, IPN Orsay, GANIL, MEPHI
Asia: VECC, KEK, IUAC, CIAE, IHEP, IMP, SOREQ
Connect Canada to the World:
Meetings Hosted

2008: Linac Conference

2009: Accelerator Operations Workshop – ARW

2009: Particle Accelerator Conference – PAC09

2013: Cyclotrons Conference – CYC13

2014: International Accelerator School for Linear Colliders

2015: SRF Workshop

2018: International Particle Accelerator Conference 2018 – IPAC’18
Education
Ph.D. (Physics) The University of Michigan, 1989
  Ph.D. student in Accelerator Physics working at Fermilab
M.S. (Mathematics) The University of Michigan, 1987
M.S. (Physics) The University of Michigan, 1986
B.S. (Physics) University of Athens, Greece, 1983

Employment
2008 - present  Head, Accelerator Division, TRIUMF
2002 - 2008  Director, CASA, Jefferson Lab
1992 - 2002  Staff Scientist, Jefferson Lab
1989 – 1992  Accelerator Physicist, Stanford Linear Accelerator Center
Some early influences....

I was lucky to have superb Physics and Math teachers in High School, who definitively influenced my decision to go into Physics.

Αλκμηνη Γιουργα: High school Physics teacher - A woman who gave excellence to her teaching and demanded excellence from us.
In the work environment, it takes enlightened colleagues who feel secure about themselves, to mentor young women and influence their careers positively.

Work with the best in the field, even if it’s painful!
Whenever, as a mid-career scientist, I felt that my career was not going anywhere, I resorted back to what inspired me to go into Physics to begin with, and focused on solving the next problem at hand and trying to push the envelope a little bit forward.
Pursuing a scientific career and raising a family is not easy.

I find it the hardest to balance my family and my work, which is demanding. At the end of a long day I often feel I am not doing a good job in either. But, as a colleague once told me, I wouldn’t have it any other way.
In my mind, leadership is based on a set of immutable principles about which I feel quite strongly:

**Integrity/honesty**
Having a **vision** and being able to **articulate it clearly** to employees at all levels so they feel motivated to support it.

**Respect** for others

**Technical proficiency**

**Decision making**
Ownership; Taking **responsibility** for one’s decisions and actions
Willingness to **accept risk** once the level of risk is defined

**Determination**, tenacity/persistence

**We must identify opportunities for women to advance in the ranks, so there are more women in leadership positions.**
About 15 years ago, I heard Florence P. Haseltine, Ph.D., M.D. give a talk. She was at a very high level at the US National Institutes of Health at the time. She said she had two pieces of advice to young women in scientific and engineering fields:

“Stay focused.”
“Don’t take no for an answer.”

I took her advice to heart. This may not have to do with my being a woman, but if you come up with a new idea, somehow the tendency is that people want to turn it down (especially in science!). Don’t stop. Just keep pushing. Not all ideas are good, but don’t stop at the first no.

To be determined and to persevere is very important.
Closing Remarks

I feel it is very important to be technically competent, really competent. And then nothing else matters.

There are a lot of opportunities in science and engineering, and this field is more merit-based than most other fields. So if we are technically strong, we should not feel limited by anything.

Decide what it is you want to work on, and pursue it with focus and determination.

The road will be arduous but amply rewarding!

And have fun! Let’s not forget:

We got into Science for the love of it!
Thank you!

Merci