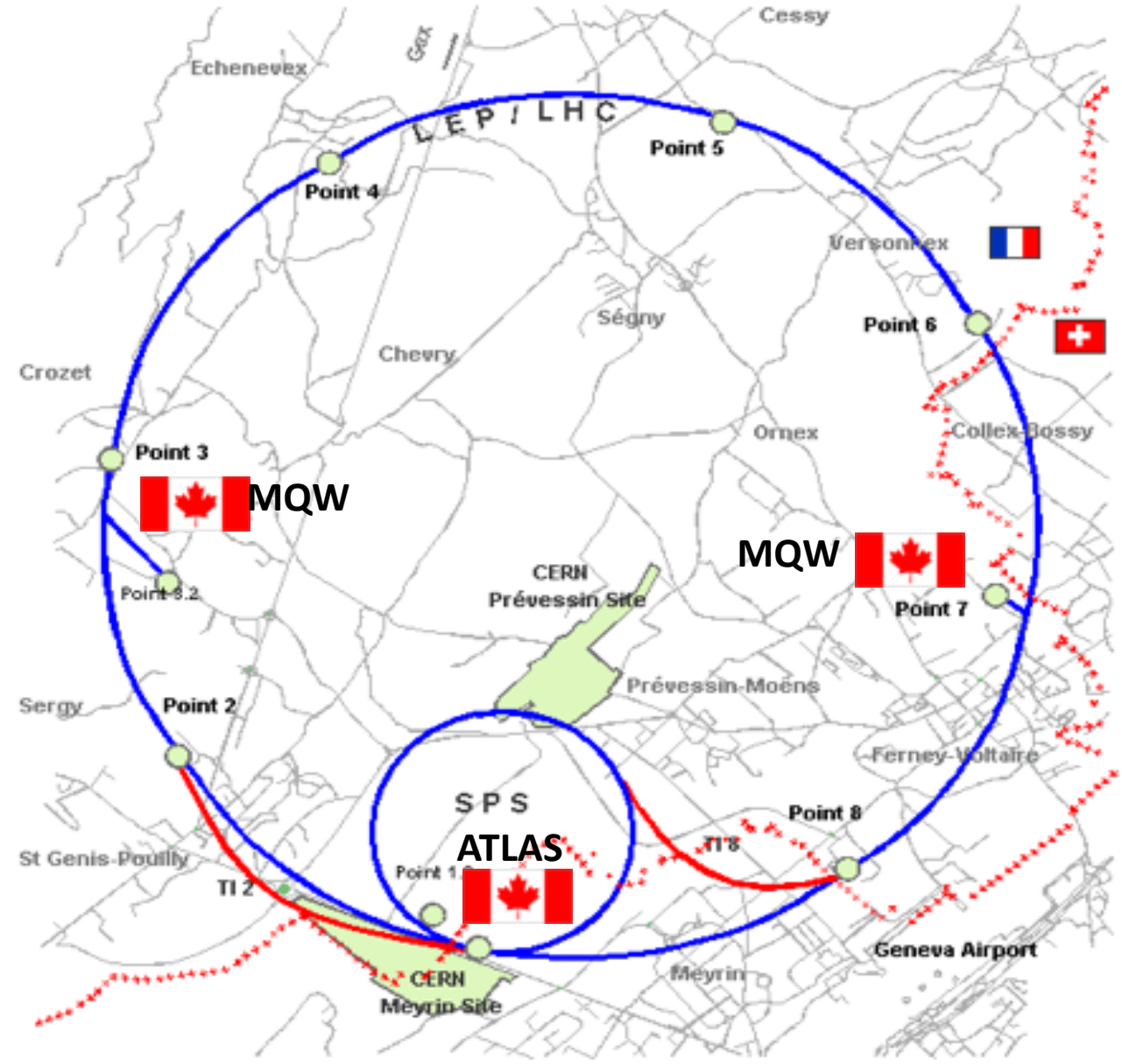
Canada at the Large Hadron Collider: Reaching Back to The Big Bang

Richard Teuscher
Canadian Institute of Particle Physics / University of Toronto
Deputy Spokesperson, ATLAS Canada Collaboration

Canada at the Large Hadron Collider



Map of CERN sites and LHC access points

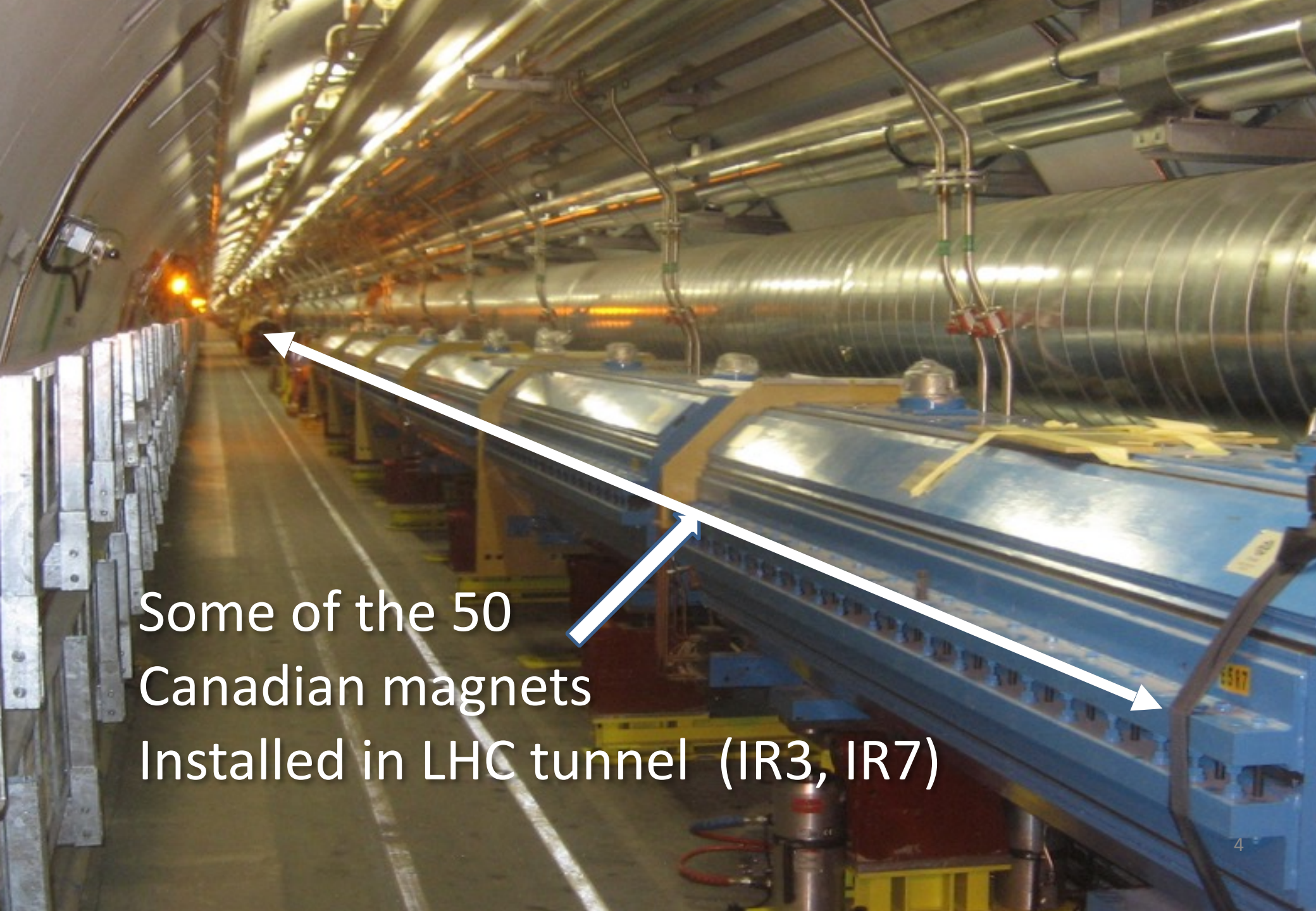
- LHC built in existing 27 km tunnel from old LEP (Large Electron Positron) collider
- 25 years design, R&D, construction
- 10 000 scientists worldwide
- Largest scientific instrument ever built

Canadian Industry: LHC cleaning magnets

Responsible for LHC beam “cleaning” in regions where superconducting magnets could not survive —> “MQW" magnets.

52 built by ALSTOM Canada, Quebec, 2002-2003.

Collaborative design by engineers at TRIUMF & CERN

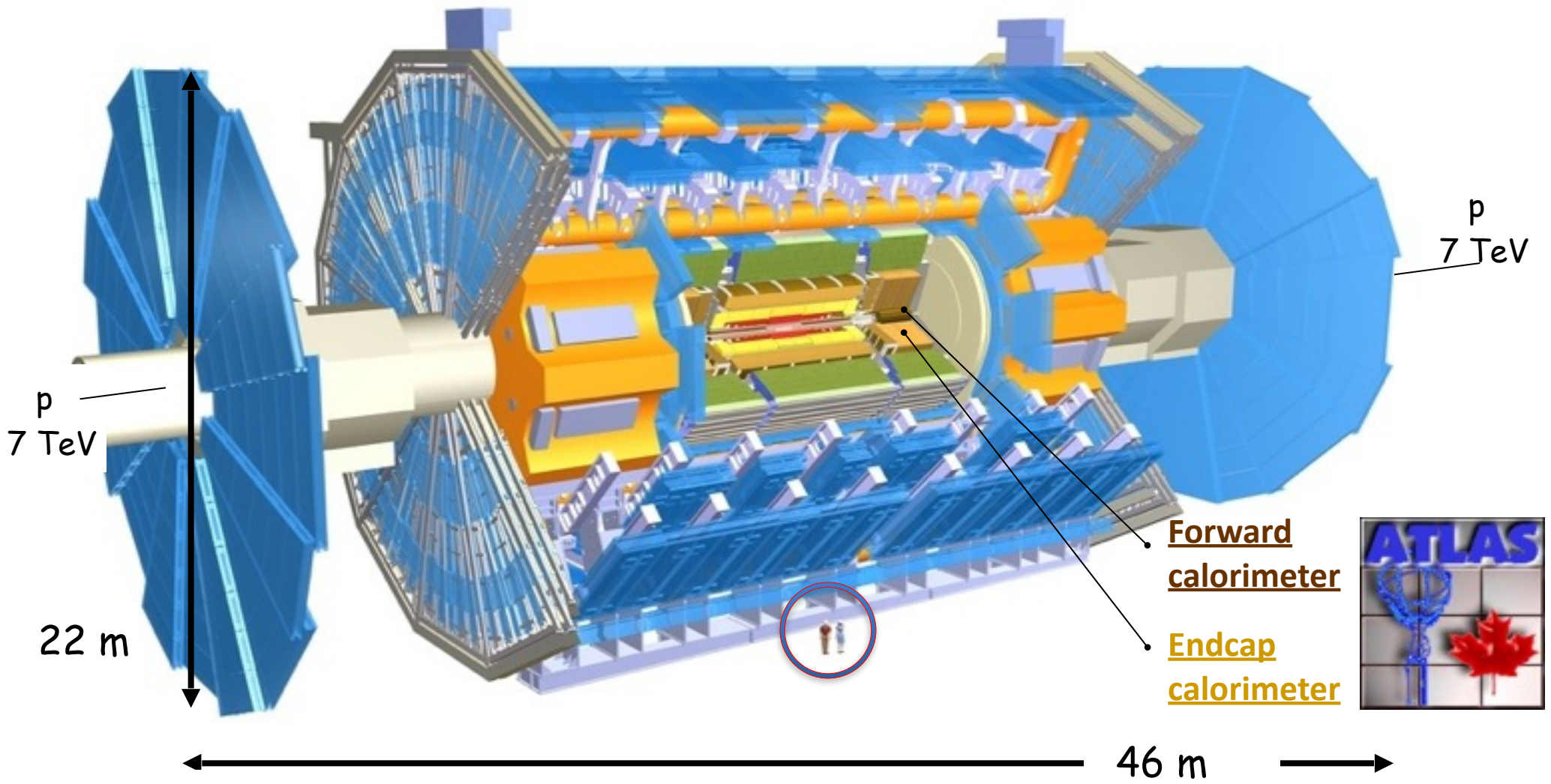

Some of the 50
Canadian magnets
Installed in LHC tunnel (IR3, IR7)

Canadian Contributions to CERN

Total Canadian contributions over $165M to date:

- **$80M** to date from NSERC supporting Canadians on ATLAS
- **$40M** via the National Research Council (NRC) and TRIUMF for LHC:
  - 90% spent in Canada on contracts from companies such as I.E. Power, Inverpower, Digital Predictive Systems, Ontario and ALSTOM, Quebec.
- **$25M** from Canada Foundation for Innovation (CFI), British Columbia Knowledge Development Fund, IBM in-kind contributions for Tier-1 computing centre (1 of 10 in world) at TRIUMF lab, Vancouver
- **$20M** from NSERC for ATLAS detector design & construction
- **$1.2M/y** from NSERC for The Institute of Particle Physics (IPP) in Canada, supports 8 IPP Research Scientists (5 on ATLAS, leading roles such as Principal Investigator and Canadian Deputy Spokesperson)

Canada: The ATLAS Experiment



Total mass ~ 7000 tonnes, as much steel as the Eiffel tower, 2T solenoid
100 million readout channels (100 Megapixel camera), over 3000 km cables

Scale of ATLAS

92 m

ATLAS assembled
92 m below ground
at CERN

ATLAS Collaboration

- **38 Countries**
- **177 Institutions**
- **3000 Scientific authors total, including 1000 students**

Includes 150 researchers from Canada

ATLAS Canada

INSTITUTE OF PARTICLE PHYSICS

UNIVERSITY OF ALBERTA

Carleton UNIVERSITY

McGill

Université de Montréal

SIMON FRASER UNIVERSITY

UNIVERSITY OF TORONTO

University of Victoria

UNIVERSITÉ YORK UNIVERSITY

TRIUMF

ATLAS CANADA

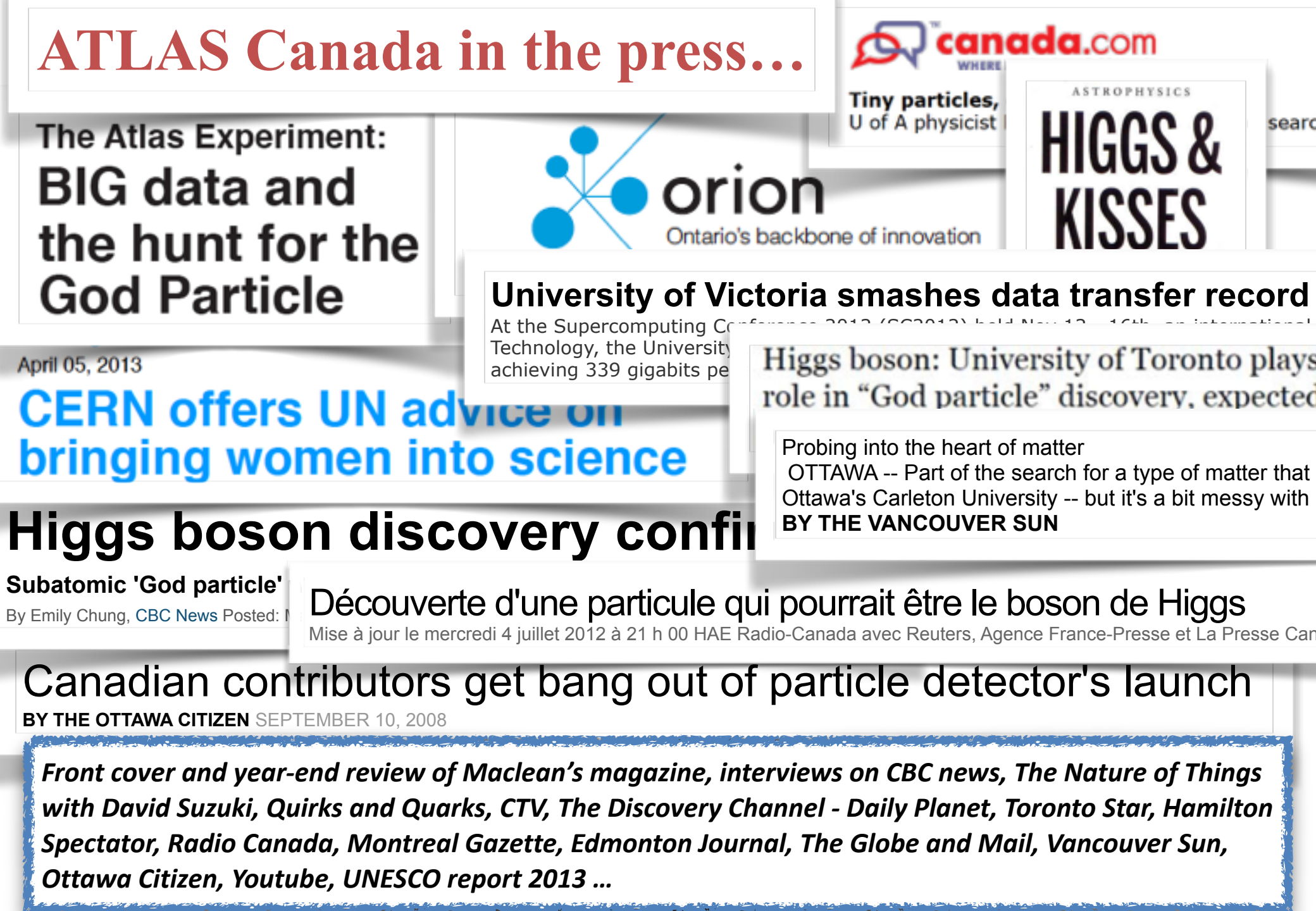
- **150 Canadian researchers and technical staff**
- **Includes over 70 graduate students**
- **39 faculty incl. 4 CRC Chairs**
- **9 leading Canadian Universities and the TRIUMF laboratory in Vancouver.**

- ATLAS Canada Spokesperson: Prof. Rob McPherson, IPP / University of Victoria, rmcphers@triumf.ca
- ATLAS Canada Deputy Spokesperson: Prof. Richard Teuscher, IPP / University of Toronto, teuscher@physics.utoronto.ca

Investigators

Justin Albert	Victoria
Jean-Francois Arguin	Montréal
Alan Astbury	Victoria
David Axen	UBC
Georges Azuelos	Montréal/TRIUMF
Alain Bellerive	Carleton/CRC
Anadi Canepa	TRIUMF
François Corriveau	McGill/IPP
Colin Gay	UBC
Douglas Gingrich	Alberta/TRIUMF
Richard Keeler	Victoria
Thomas Koffas	Carleton
Robert Kowalewski	Victoria
Peter Krieger	Toronto
Michel Lefebvre	Victoria
Claude Leroy	Montréal
Alison Lister	UBC/CRC
Jean-Pierre Martin	Montréal
Robert McPherson	Victoria/IPP
Roger Moore	Alberta
Dugan O'Neil	SFU
Gerald Oakham	Carleton/TRIUMF
Robert Orr	Toronto
James Pinfold	Alberta
Steven Robertson	McGill/IPP
Pierre Savard	Toronto/TRIUMF
Pekka Sinervo	Toronto
Randy Sobie	Victoria/IPP
Oliver Stelzer-Chilton	TRIUMF
Bernd Stelzer	SFU
Reda Tafirout	TRIUMF
Wendy Taylor	York/CRC
Richard Teuscher	Toronto/IPP
Isabel Trigger	TRIUMF
William Trischuk	Toronto
Brigitte Vachon	McGill/CRC
Michel Vetterli	SFU/TRIUMF
Manuella Vincter	Carleton/CRC
Andreas Warburton	McGill

ATLAS Canada in the press…



The Atlas Experiment:
BIG data and the hunt for the God Particle

orion
Ontario's backbone of innovation

canada.com
Tiny particles,
U of A physicist

ASTROPHYSICS
HIGGS & KISSES

University of Victoria smashes data transfer record
At the Supercomputing Conference 2012 (SC2012) held Nov 12 – 16th, an international
Technology, the University
achieving 339 gigabits pe

April 05, 2013
CERN offers UN advice on bringing women into science

Higgs boson: University of Toronto plays
role in "God particle" discovery, expected

Probing into the heart of matter
OTTAWA -- Part of the search for a type of matter that
Ottawa's Carleton University -- but it's a bit messy with
BY THE VANCOUVER SUN

Higgs boson discovery confi

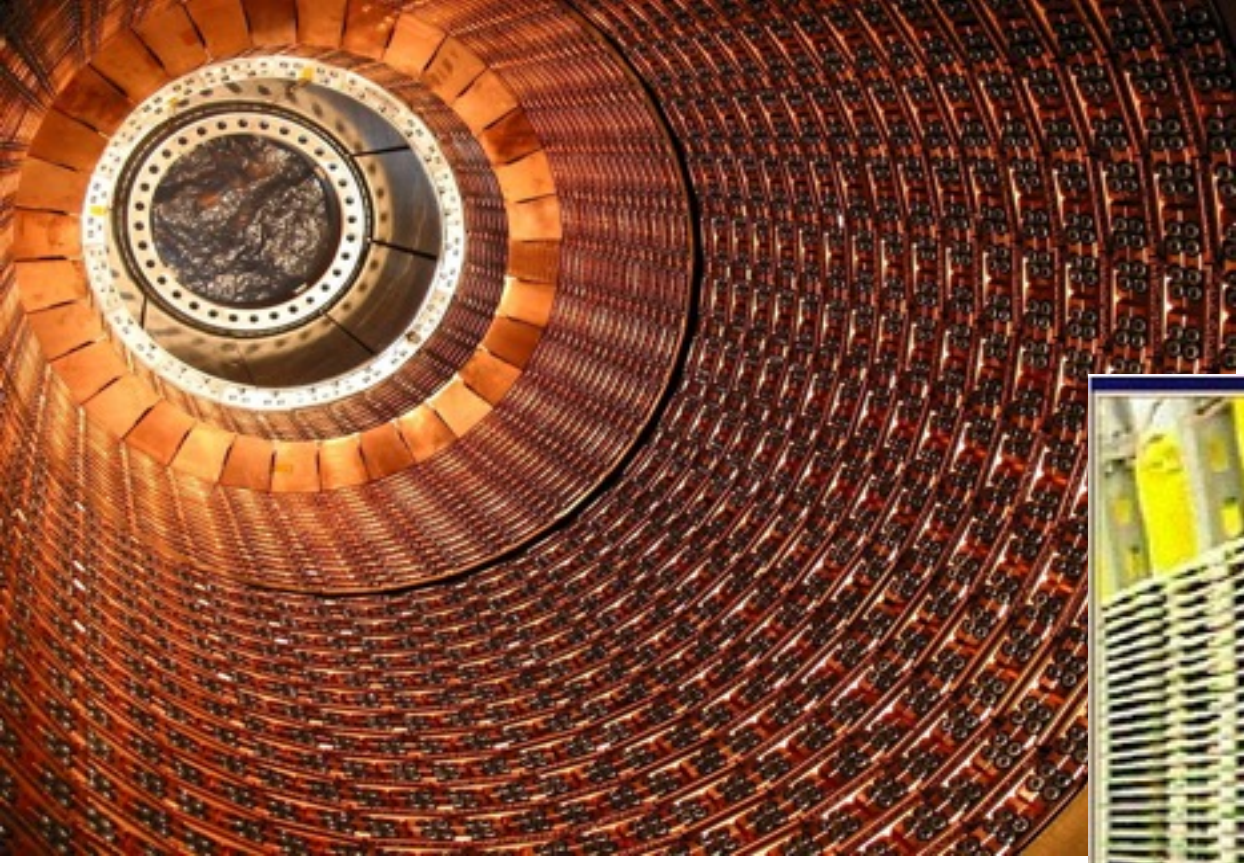
Subatomic 'God particle'
By Emily Chung, CBC News Posted:

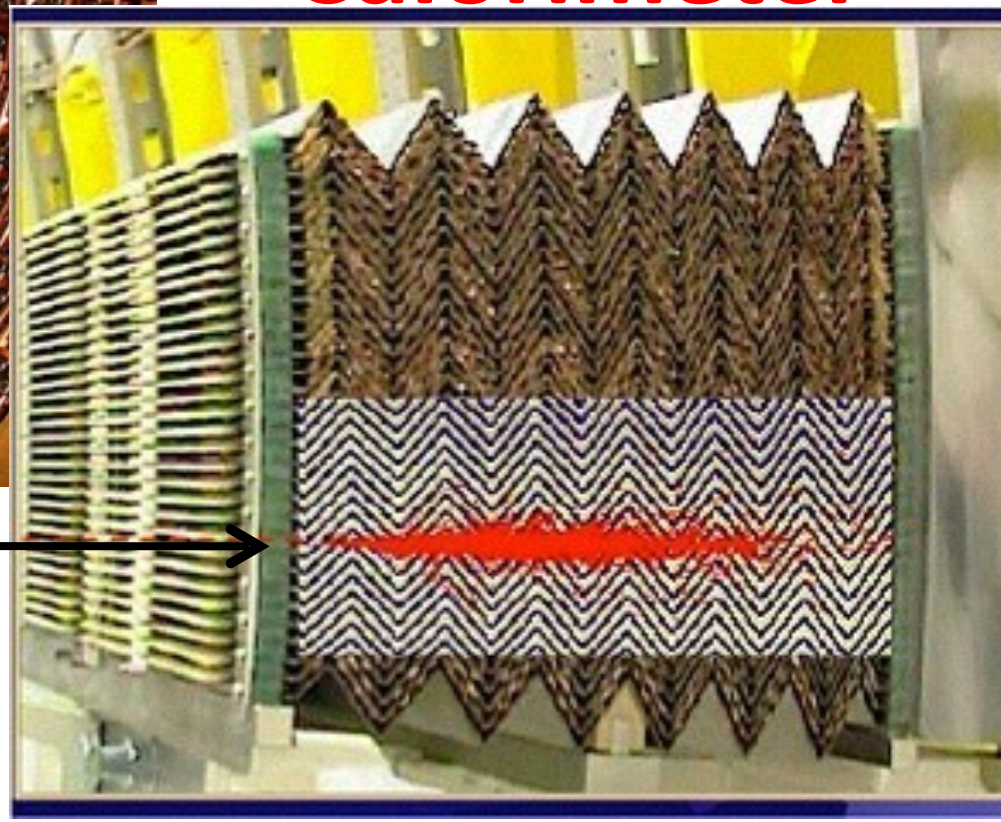
Découverte d'une particule qui pourrait être le boson de Higgs
Mise à jour le mercredi 4 juillet 2012 à 21 h 00 HAE Radio-Canada avec Reuters, Agence France-Presse et La Presse Can

Canadian contributors get bang out of particle detector's launch
BY THE OTTAWA CITIZEN SEPTEMBER 10, 2008

Front cover and year-end review of Maclean's magazine, interviews on CBC news, The Nature of Things with David Suzuki, Quirks and Quarks, CTV, The Discovery Channel - Daily Planet, Toronto Star, Hamilton Spectator, Radio Canada, Montreal Gazette, Edmonton Journal, The Globe and Mail, Vancouver Sun, Ottawa Citizen, Youtube, UNESCO report 2013 …

Canada: Liquid Argon Calorimeter

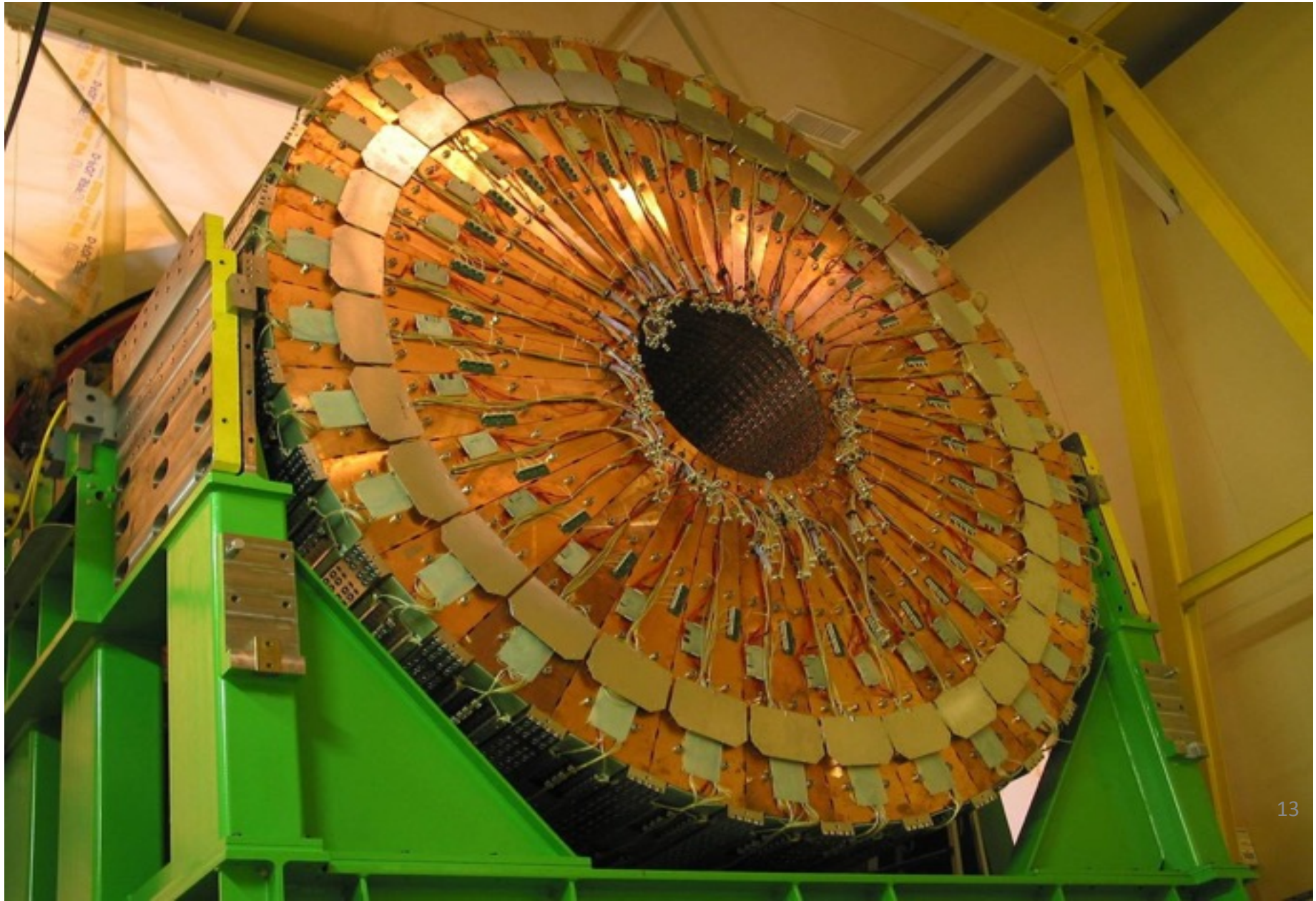




- Electron / photon identification
- Lead absorber initiates shower
- Particles ionize liquid Argon
- High Voltage between plates cause ions and electrons to drift
- Collected charge is proportional to energy of particle

Canada: Hadronic End Cap calorimeter

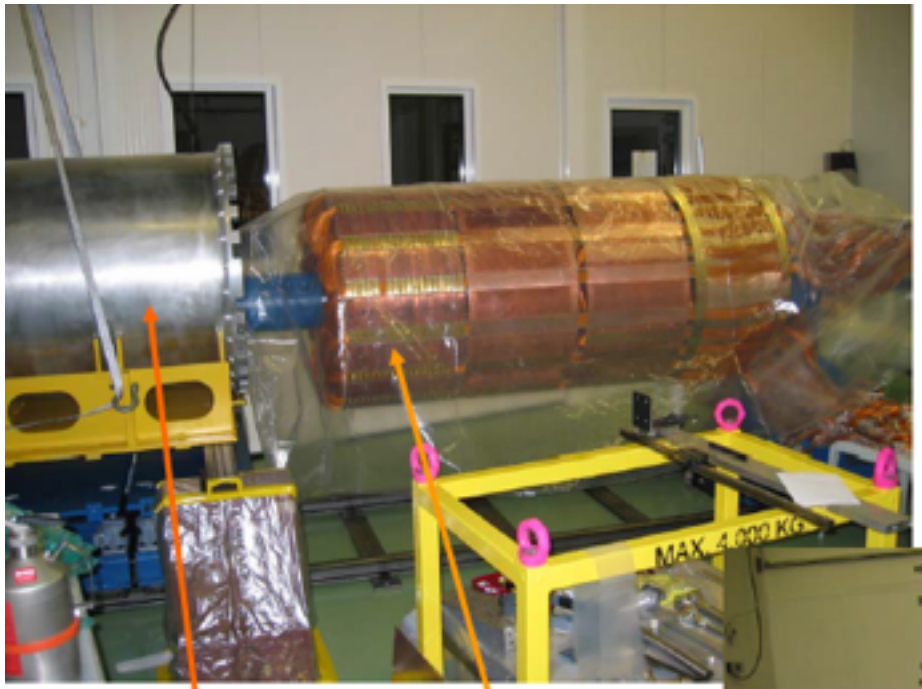
Assembled at CERN on the insertion stand, Aug. 2004



Transport of 1 Endcap calorimeter to ATLAS underground pit, CERN, September 2005

ATLAS Forward Calorimeter (FCal)

Carleton University, University of Toronto

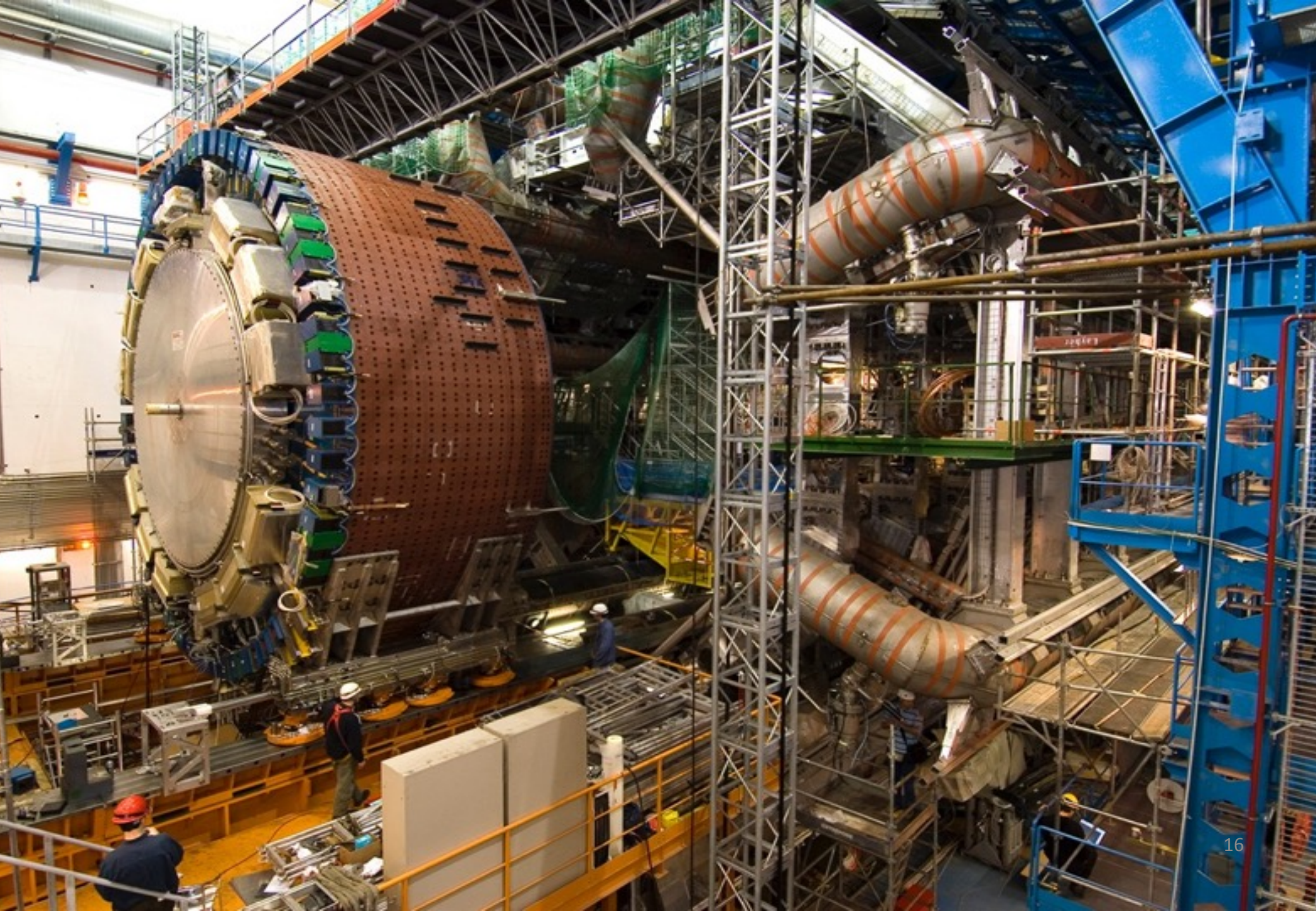


Assembly at CERN

FCal1

Support Tube

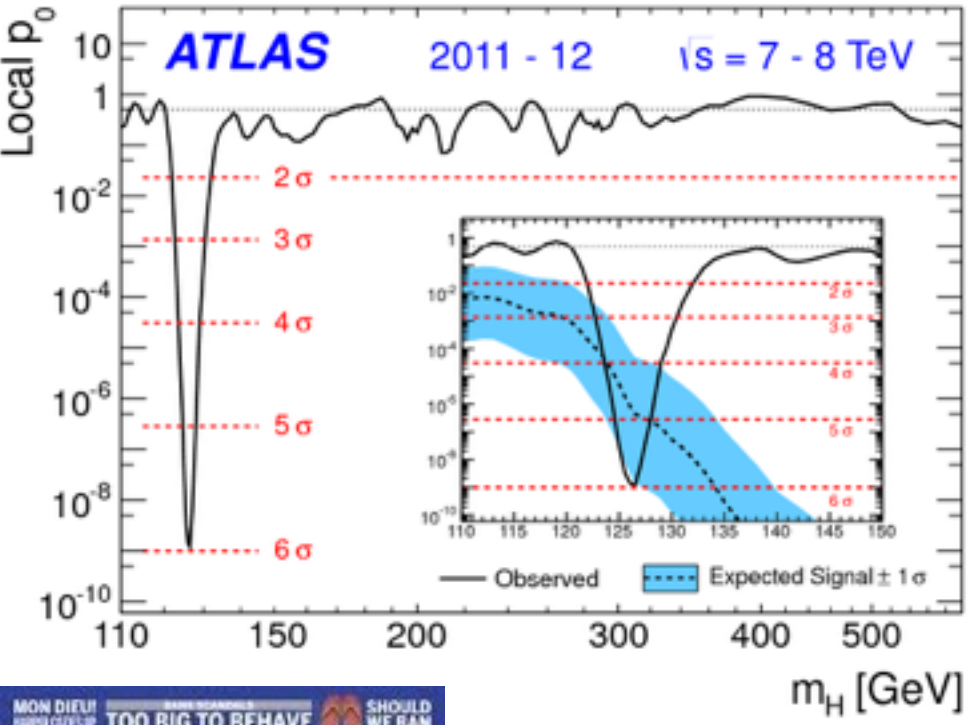
Signal Cables run to rear



4-July-12: Higgs Discovery

Canadians leading in all stages of discovery from construction to data analysis:

- 1980's: Founding members of ATLAS
- 1990's: LAr design and construction
- 2000's: Shipment to CERN, installation underground
- 2005: Commissioning with cosmic rays
- 2008: First LHC beam
- 2010-2012: Data analysis
- 2012, July 4: Higgs discovery
- 2013: Nobel prize in physics
- 2014-2035: analysis and future upgrades



CERN and Worldwide LHC Computing Grid

- Canada hosts one of 10 worldwide Tier-1 data centres at TRIUMF, Vancouver
- 3 000 000 GB / year → stack of DVD's **high as CN tower** every 4 months…

TRIUMF

Tier-1

Tier-2 west & east

canarie

SciNet

Canada's most powerful supercomputer

CBC News : Jun 18, 2009

Canada - CERN

Medical Applications

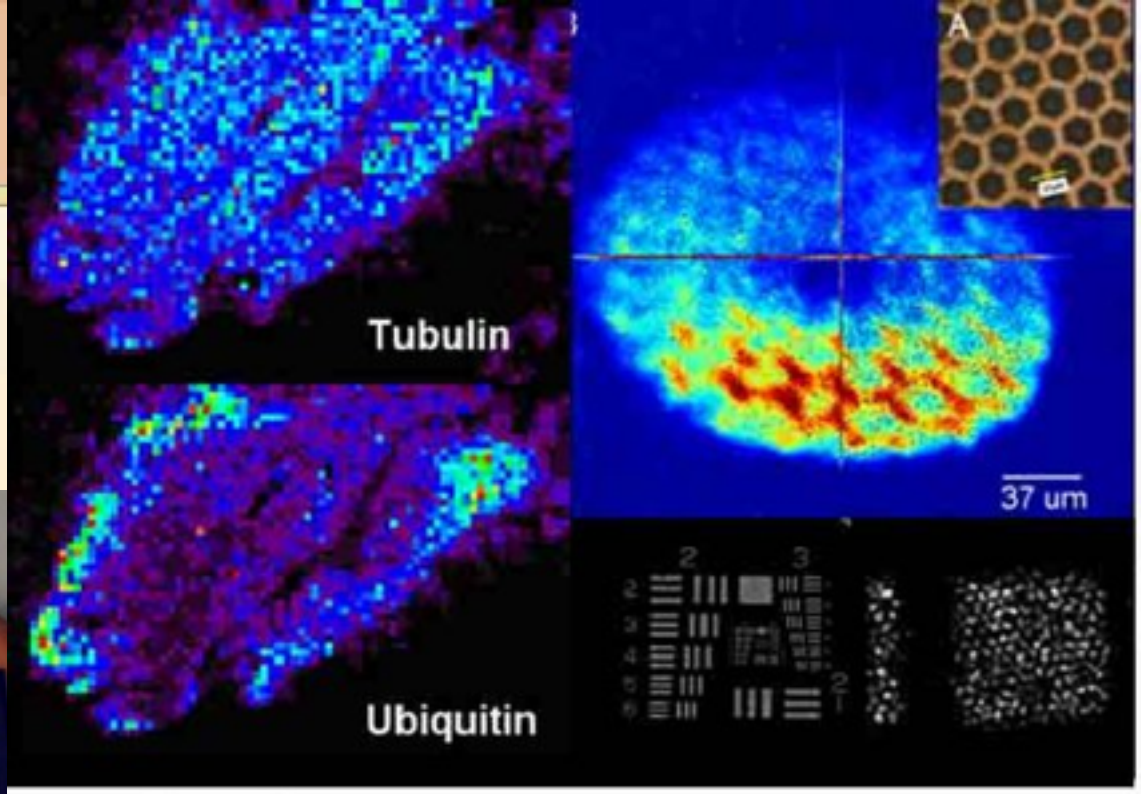
Université de Montréal
collab. with Czech Tech. U

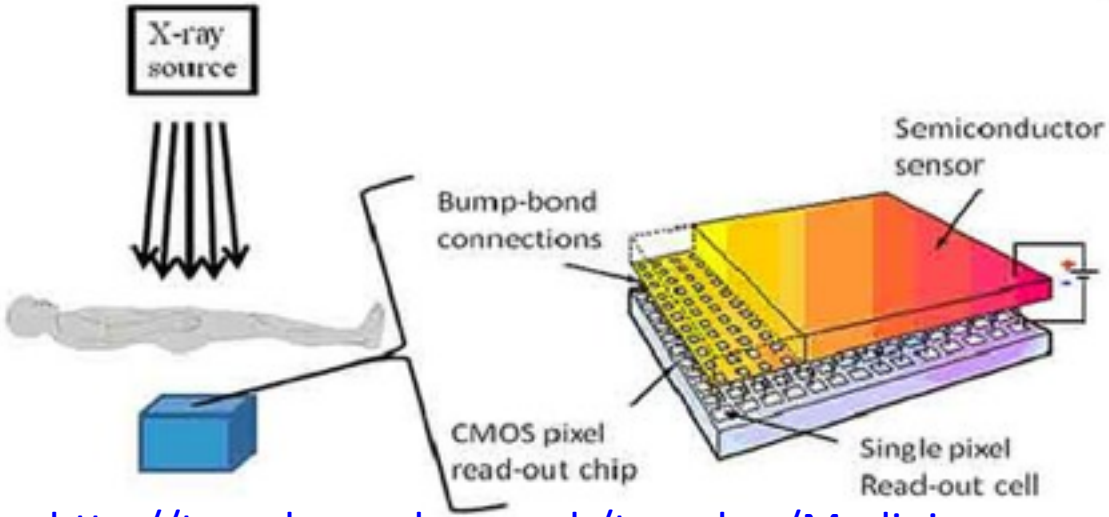
Medipix / Timepix

Pixels: 256 x 256

Pixel size: 55 x 55 μm^2

Area: 1.5 x 1.5 cm^2





http://teuscher.web.cern.ch/teuscher/Medipix.ppsx

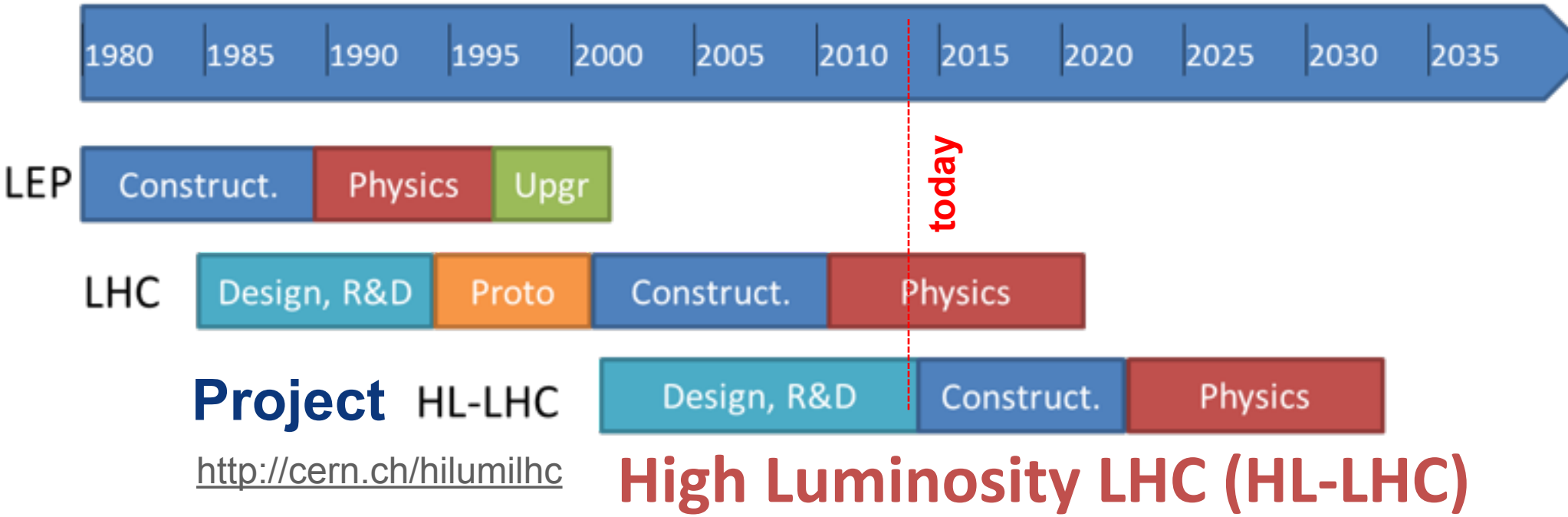
Detector system

Single detector

Opportunities at CERN for the Next 20 Years

Update of the European Strategy for Particle Physics
adopted 30 May 2013 in a special session of CERN Council at Brussels:

"Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030."



Future Opportunities for Canada at CERN

- CERN Plan for High Luminosity LHC to 2035 (and beyond)
  - ATLAS upgrade required to survive HL-LHC
  - Now: 3-4 year R&D, followed by construction, installation 2022
- Opportunities for Training of Highly Qualified Personnel
- Opportunities for Canadian industry in this 300M$ upgrade, e.g.:
  - Advanced materials and manufacturing, engineering
  - Semiconductor industry, advanced silicon sensors, applications in medical imaging
  - Computing, information technology
  - Silicon photonics (optical links for data centres)
  - …many more
- **Canada should not miss out on these opportunities.**

VIP Canada visits to CERN

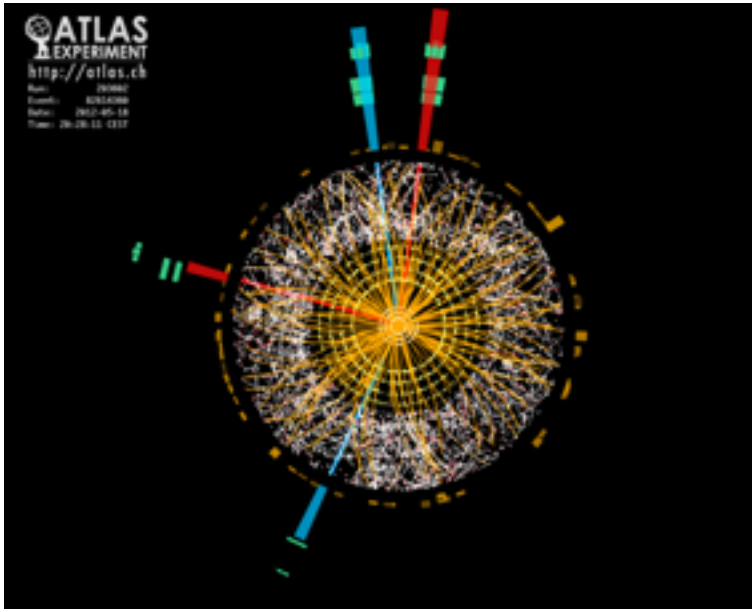
- Mr. William H. Smith, Vice-president, Mosaic Capital Corporation, NRC IRAP Advisory Board, Sept. 25, 2014.
- Prof. Antony Masi, Provost, McGill U., June 23, 2014.
- The Honourable Dr. Kellie Leitch, Minister of Labour and Minister of Status of Women, June 10, 2014
- Senior Management, Canada's Advanced Research and Innovation Network CANARIE, May 22, 2014
- Her Excellency Ms. Jennifer MacIntyre, Ambassador of Canada to Switzerland and Liechtenstein, May 14, 2014
- The Honourable Lisa Raitt, MP and Minister of Labour, June 18, 2013
- Dr. Paul Young, FRSC, Chair TRIUMF Board of Management, and
  Dr. Gilles Patry, President and CEO Canadian Foundation for Innovation (CFI), Nov. 26-27, 2012
- Dr. Heidi-Christina Bandulet, Senior Programs Officer, CFI, March 22-23, 2012
- Ambassador Mrs. Roberta Santi, Bern, Feb. 2012, & March 2010.
- Mr. Joseph Daniel, Member of the Canadian House of Commons, November 2011.
- Dr. Danial Wayner, Vice President, Frontier Science, NRC, October 2011
- Mr. Konstantinos Georgaras, Director of Policy, International and Research Office, Canadian Intellectual Property Office, September 2011
- Dr. Kim Matheson, Vice President (Research and International) Carleton University, July 2011
- John McDougall, President, NRC, November 2010
- Mr. John Gero, Canadian Ambassador and Permanent Representative to the World Trade Organization, October 2009. Mr. Bruce Gitelman, Royal Canadian Institute for the Advancement of Science, October 2010
- Mr. Peter Allen, President, Mercator Investments Ltd., Council, CIAR/CIFAR, March 2010, also November 2007
- Commissioner Diana Nichols Nelson, Canadian Senior Trade Commissioner, Bern, March 2010, & October 2008
- Ambassador Robert Collette, Canadian Embassy, Bern, October 2008
- Mr. Mike Lazaridis, Research In Motion, October 2006, November 2003, & June 2001
- Dr. Martin Taylor, VP of Research, University of Victoria, member of TRIUMF Board of Management, May 2006
- Dr. Pierre Coulombe, President, National Research Council, October 2005
- Dr. Howard Burton, Executive Director, Perimeter Institute for Theoretical Physics, January 2003
- Dr. Thomas Brzustowski, President, NSERC, August 2002

+ ATLAS Experiment & Computing LHC Resource Review Board meetings twice / year (NSERC, NRC)

Canadians on ATLAS thank CERN for hosting us and look forward to furthering what has been a productive and rewarding relationship.

The Future

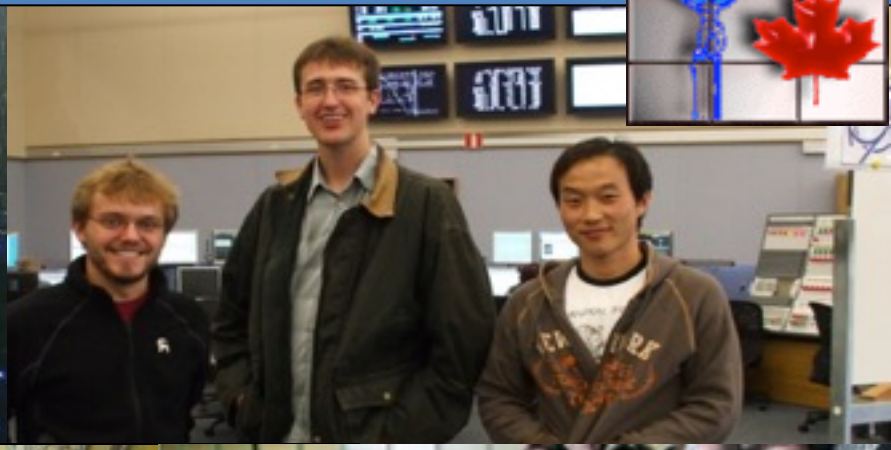
- Spring 2015: LHC will restart
  - Increase in energy from 8 TeV to over 13 TeV
- Coming years open new window of physics discoveries:
  - Precision Higgs studies
  - Deviation from Standard Model?
  - Dark matter / Supersymmetry?
  - Extra Dimensions, mini-black holes, …
- 30 May 2013, special session of CERN Council at Brussels for LHC upgrade for next 20 years:
  - European Strategy for Particle Physics adopted
  - Fully exploit physics potential of the LHC *(High-Luminosity LHC)*
- Canadians will continue to lead:
  - Physics analysis
  - Detector operation
  - Upgrades to ATLAS detector for future discoveries



INSTITUTE OF PARTICLE PHYSICS

ATLAS Canada Snapshots











BACKUP

Result of industrial contracts with CERN

- 38% had developed new products
- 42% increased international exposure
- 44% improved technological learning
- 52% would have had poorer sales performance without CERN
- 17% opened a new market
- 60% acquired new customers
- all firms had derived great value from CERN as a marketing reference

- Source: CERN Finance and Procurement Department

CERN Report 75-5: *A Study of Economic Utility resulting from CERN contracts*

- Measured utility / sales ratios over about 20 years
- Ranged from 0.9 to 7.3 for cables, magnets, cooling systems, vacuum equipment, electronics, steels
- As high as 17.3 for computers and 31.6 for precision mechanics
- 80% of sales outside physics (railways, ship-building, refrigeration, power generation and distribution)

Canadian Contributions to ATLAS

- Liquid Argon Hadronic Endcap Calorimeter
- Liquid Argon Forward Calorimeter
- Calorimeter Signal Feedthroughs
- Radiation Hard calorimeter electronics
- Diamond Beam Monitors for Luminosity
- MediPix sensors
- High Level Trigger Farm
- LUCID Luminosity detector
- Transition Radiation Tracker Electronics…and more

Tier-1 Computing Team

Canada

BRITISH COLUMBIA
The Best Place on Earth

Canada Foundation for Innovation
Fondation canadienne pour l'innovation

CIHR IRSC
Canadian Institutes of Health Research / Instituts de recherche en santé du Canada

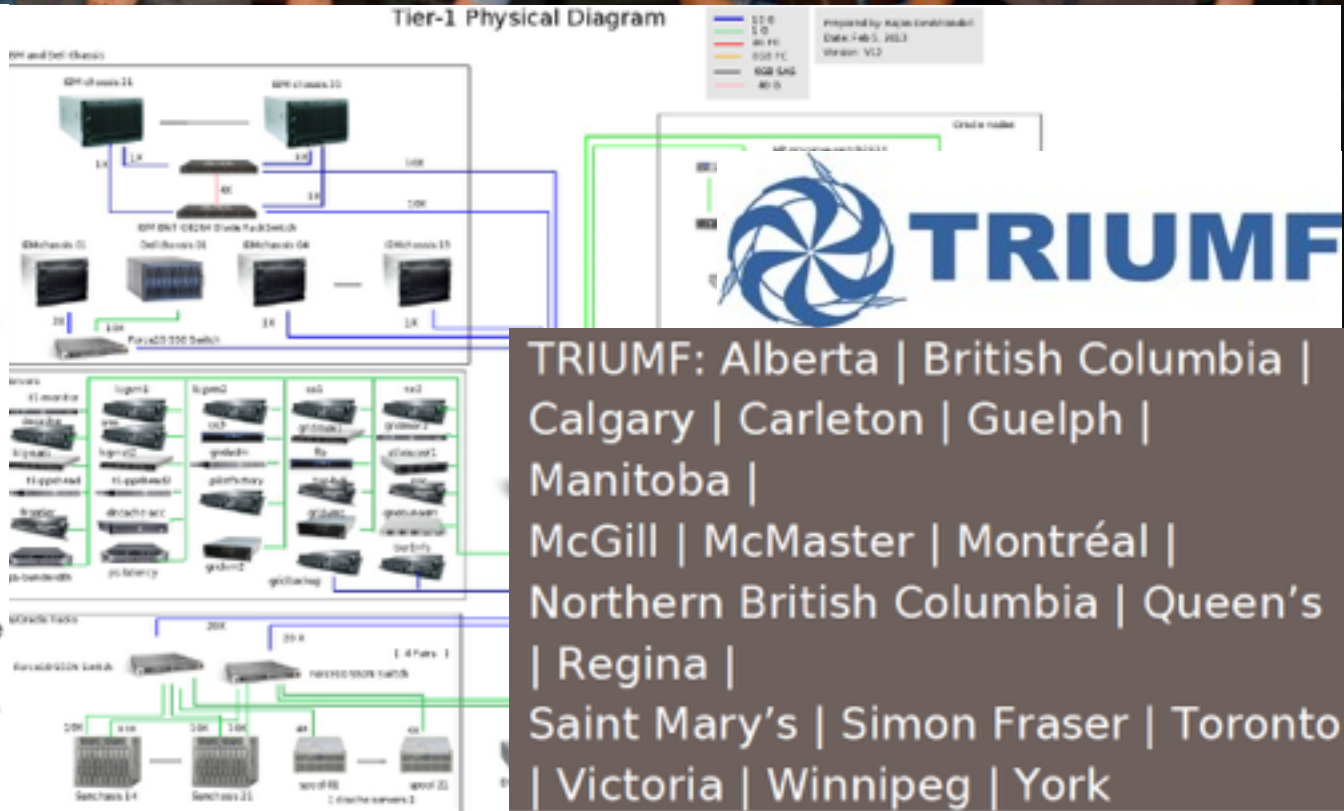
NRC·CNRC From Discovery to Innovation...

NSERC CRSNG

Western Economic Diversification Canada
Diversification de l'économie de l'Ouest Canada

Natural Resources Canada
Ressources naturelles Canada
Canada

Tier-1 Physical Diagram



TRIUMF

TRIUMF: Alberta | British Columbia | Calgary | Carleton | Guelph | Manitoba | McGill | McMaster | Montréal | Northern British Columbia | Queen's | Regina | Saint Mary's | Simon Fraser | Toronto | Victoria | Winnipeg | York

Canadian ATLAS Leadership

- **ATLAS has a multi-level organizational structure. Our faculty, postdocs and students hold many positions as physics sub-group conveners, coordinators of detector and physics group data quality, paper editors and editorial board chairs, trigger slice coordinators, production managers, …**
- **Examples of current/past major roles:**

- Executive Board
  - McPherson (previously, Oram as CB chair)
- CB Chair advisory
  - Vincter, Savard
- LAr management
  - Krieger, McPherson, Oram
- Radiation / cavern Bkg. Coord.
  - Leroy
- Trigger management
  - Moore, Vachon
- Speakers Committee Chair
  - Lefebvre
- Authorship Committee Chair
  - Trigger
- Publications Committee
  - Trigger, Vetterli
- Physics Coordination
  - Teuscher, Savard, Azuelos
- Computing management
  - Vetterli