Summary of Institute of Particle Physics Long Range Plan Brief

Particle Physics Division Session 2021 CAP Congress

10 June 2021

Remote Meeting

INSTITUTE OF PARTICLE PHYSICS

50 YEARS

INSTITUT DE PHYSIQUE DES PARTICULES

J. Michael Roney
IPP Director

IPP Brief Writing Committee consists of the IPP Scientific Council of 2019-20 and 2020-21

Erica Caden ecaden@snolab.ca

Ken Clark Ken.Clark@snolab.ca

Mark Hartz mhartz@triumf.ca

Blair Jamieson bl.jamieson@uwinnipeg.ca

Robert McPherson rmcphers@triumf.ca

Michael Roney (Chair) director@ipp.ca

Bernd Stelzer stelzer@sfu.ca

Daniel Stolarski stolar@physics.carleton.ca

Reda Tafirout tafirout@triumf.ca

IPP Process for Long Range Plan

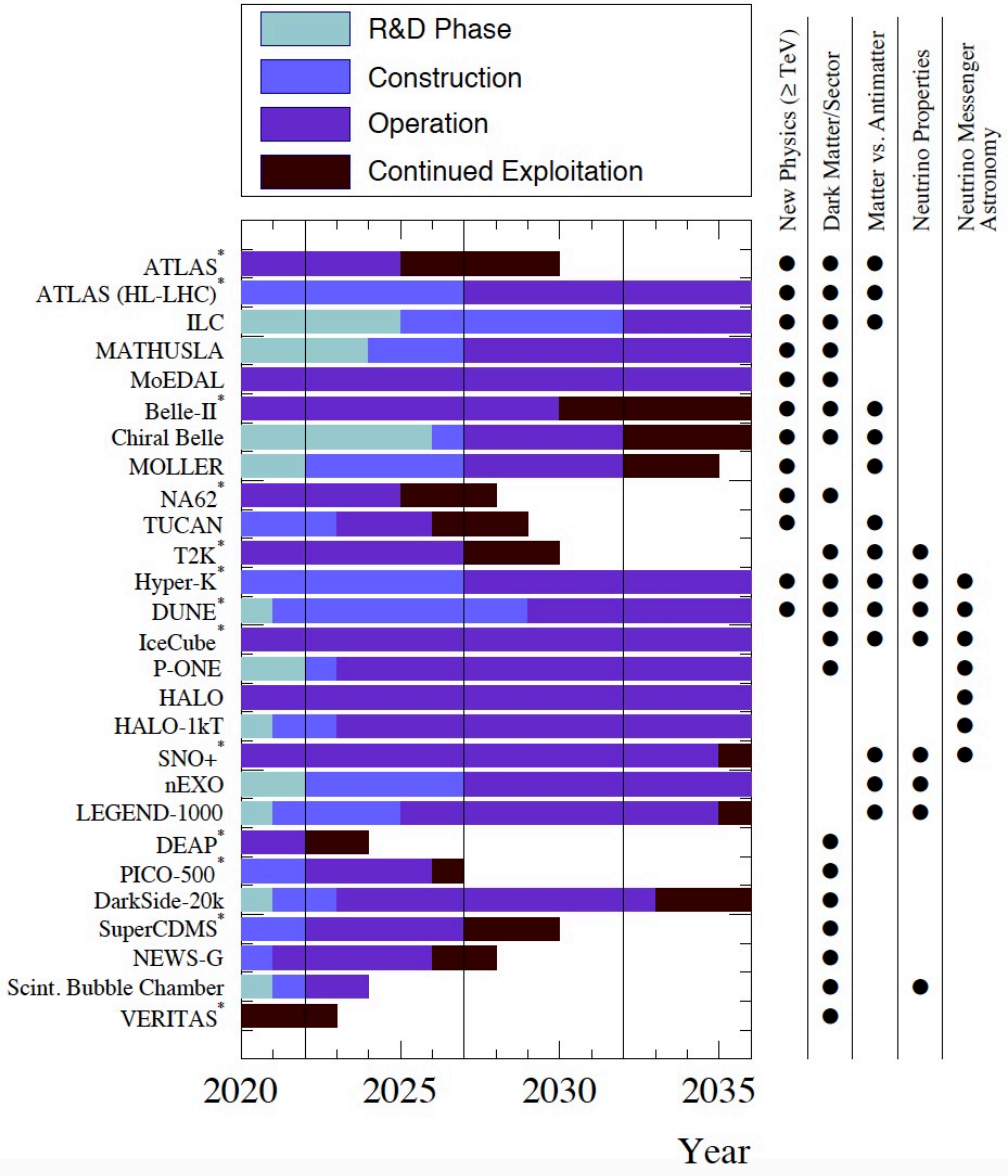
February 26th email announcing the LRP process with the general call April 1st to IPP Membership for input into the LRP, via written submissions

(12 IPP Projects going into the LRP consultation process; 5-6 other efforts that may be IPP Projects in the future; some projects of interest to both CINP and IPP; technical support needs: detector development support: MRS, TRIUMF; computing; accelerator R&D; MI; Theory activity related to experimental program)

Substantial consultation with the community, including collective opportunities in Town Hall meetings in July and November 2020

Brief completed and submitted to LRPC 1 December 2020

Canadian Experimental Particle Physics



Theorists in Canada

work on a very wide range of topics and try to address the "Big Questions" - from the dynamics of strong force to origin of dark matter to the nature of quantum gravity.

Name	Institution	Subject
Mohammad Ahmady	Mount Allison	hep-ph
Aleksander Aleksejevs	Memorial	hep-ph, hep-th
Jonathan Bagger	TRIUMF	hep-th
Svetlana Barkanova	Memorial	hep-ph, hep-th
Ian Blokland	Alberta	hep-ph
Vincent Bouchard	Alberta	math-ph
Nassim Bozorgnia	York	astro-ph, hep-ph
Joe Bramante	Queen's/PI	hep-ph
Robert Brandenberger	McGill	astro-ph, hep-th
Alex Buchel	Western/PI	hep-th
Cliff Burgess	McMaster/PI	gr-qc, hep-ph, hep-th
Bruce Campbell	Carleton	hep-ph
Margaret Carrington	Brandon	hep-ph, hep-th
James Cline	McGill	hep-ph
Gilles Couture	UQAM	hep-ph
David Curtin	Toronto	hep-ph
Andrzej Czarnecki	Alberta	hep-ph
Keshav Dasgupta	McGill	hep-th
Rainer Dick	Saskatchewan	hep-ph
Mariana Frank	Concordia	hep-ph
Andrew Frey	Winnipeg	hep-th
Steve Godfrey	Carleton	hep-ph
Jaume Gomis	PI	hep-th
Thomas Gregoire	Carleton	hep-ph
Derek Harnett	Fraser Valley	hep-ph
Bob Holdom	Toronto	gr-qc, hep-ph
Calvin Kalman	Concordia	ed-ph
Pat Kalyniak	Carleton	hep-ph
Joanna Karczmarek	UBC	hep-th
Gabriel Karl	Guelph	hep-ph
Achim Kempf	Waterloo/PI	gr-qc, quant-ph
Nikolay Kolev	Regina	hep-ph
Pavel Kovtun	Victoria	hep-th
Helmut Kroeger	Laval	hep-lat, hep-th
Gabor Kunstatter	Winnipeg	gr-qc, hep-th
Randy Lewis	York	hep-lat, hep-ph
Heather Logan	Carleton	hep-ph
David London	Montréal	hep-ph
Michael Luke	Toronto	hep-ph
Richard MacKenzie	Montréal	hep-ph, hep-th
Alexander Maloney	McGill	hep-th
Kim Maltman	York	hep-lat, hep-ph
Rob Mann	Waterloo/PI	gr-qc, hep-th
Luc Marleau	Laval	hep-ph
Pierre Mathieu	Laval	hep-th, math-ph
David McKeen	TRIUMF	astro-ph, hep-ph
Vladimir Miransky	Western	cond-mat
Nader Mobed	Regina	gr-qc, hep-th
John Moffat	Waterloo/PI	gr-qc
M. de Montigny	Alberta	gr-qc
David Morrissey	TRIUMF	hep-ph
Robert Myers	PI	hep-th
John Ng	TRIUMF	hep-ph
Rachid Ouyed	Calgary	astro-ph, nucl-th
Manu B. Paranjape	Montréal	cond-mat, gr-qc, hep-th
AW Peet	Toronto	hep-th
Alexander Penin	Alberta	hep-ph
Levon Pogosian	SFU	astro-ph
Erich Poppitz	Toronto	hep-th
Maxim Pospelov	Victoria/PI	astro-ph, hep-ph
Saeed Rastgoo	York	gr-qc
Adam Ritz	Victoria	hep-ph
Moshe Rozali	UBC	hep-th
Ruben Sandapen	Acadia	hep-ph
Gordon Semenoff	UBC	cond-mat, hep-th
Kris Sigurdson	UBC	astro-ph
Rafael Sorkin	PI	gr-qc, hep-th
Tom Steele	Saskatchewan	hep-ph
Daniel Stolarski	Carleton	hep-ph
Sean Tulin	York	astro-ph, hep-ph
Mark Van Raamsdonk	UBC	hep-th
Aaron Vincent	Queen's	astro-ph, hep-ph
Peter Watson	Carleton	hep-ph
Richard Woloshyn	TRIUMF	hep-lat
Yue Zhang	Carleton	hep-ph
Ariel Zhitnitsky	UBC	astro-ph, hep-ph

Table 1: Theory members of the IPP. Subject is the arXiv category(ies) of the majority of recent work.

Theory work in Canada includes:

- Precise predictions for the Standard Model (SM) and beyond.
- New theoretical methods to better understand quantum field theory.
- New theories that address deficiencies of the SM.
- Proposals for new experiments and techniques.
- Developments in quantum gravity.

The ‘Big Questions’ in Particle Physics

- Is there new physics at or above the TeV scale accessible to the LHC direct searches and precision measurements or rare decays from multiple experiments?
- What is the nature of the dark matter (DM) that comprises 85% of matter in the universe?
- Is there a hidden/dark sector" ?
- what is the origin and nature of the matter-antimatter asymmetry that produced our matter-dominated universe?
- What is the nature of the neutrino and what can we learn by probing neutrino oscillations?
- How are gravity and dark energy incorporated into the rest of the particle physics theoretical framework, and how can that knowledge be used to understand the history of the universe?

Support for Experiments

- Projects taking data during the period of the Long Range Plan identified as ***essential*** to the Canadian particle physics community based on the **level of engagement** of the researchers in the projects, **scientific and technological training** of the next generation, **Canadian investments in those projects to date**, and on their **potential scientific payoff**.
  - ATLAS (energy frontier) ;
  - Belle II & **TUCAN** (precision frontier);
  - **DEAP, PICO-500** and **SuperCDMS** (direct dark matter detectionprojects);
  - **SNO+** (neutrinoless double beta decay);
  - **T2K** and **IceCube** (neutrino mixing)

- Three of these essential projects are transitioning programs, with the new phases also at the highest priority but not necessarily taking data during the Long Range Plan period: ATLAS at the upgraded High Luminosity LHC; DEAP at SNOLAB with the Canadian team moving to DarkSide-20k at LNGS; and T2K with the group largely moving to Hyper-K.

Support for Experiments

- There are also a number of ***important*** projects that will not be taking data during this period, including **DUNE** and **MOLLER**, as well as **Chiral Belle, MATHUSLA,** and **nEXO**. Some of these experiments will become essential as they approach data-taking operation depending on the level of Canadian effort and breadth of the physics program. Chiral Belle, MATHUSLA, and nEXO require final approval.

- Other projects that will be taking data during the LRP period with focused discovery potential include MoEDAL, NA62, P-ONE, HALO/HALO-1kT, NEWS-G, the Scintillating Bubble Chamber (SBC) and LEGEND-1000 (if approved). VERITAS is in the final data analysis phase of the project. **It is important to ensure that some resources are allocated to smaller projects, especially those in the early stages of development.**

- In the longer term, there is also wide interest from Canadians in a possible International Linear Collider (ILC), a new circular collider (FCC-ee) and a massive underground liquid argon dark matter detector (ARGO).

Support for Theory

Particle physics theorists develop the understanding of these “Big Questions" and are crucial in helping to solve them.

In order to ensure the vitality of the Canadian theory community, and indeed the entire community, it is essential that it continue to be assured that sufficient funding is allocated to theory Discovery Grants in particle physics. Increases to funding are particularly needed for the Theory community to keep their contingent of students and postdocs approximately scaling with the level of effort of the experimental community.

Program Support

- The IPP community has been growing, driven by hires of younger faculty members including about a dozen McDonald Institute members who will have completed a transition to being NSERC grant eligible by 2023. The Subatomic Physics envelope increase is essential to support these new, dynamic researchers;

- Essential R&D in particle detector and accelerator technology requires modest and timely investments in equipment and expertise, funds for which are not available outside the SAP envelope. Support for the NSERC Research Tools and Instruments (RTI) and Major Resources Support (MRS) programs is critical to our field;

- On-going contributions of CFI via its Major Science Initiative (MSI) Fund to the operation of SNOLAB and Compute Canada facilities is essential for our community;

- The New Digital Research Infrastructure Organization (NDRIO) is strongly encouraged to continue to work with members of the IPP community to ensure that the evolution of Canadian digital research infrastructure meets our needs;

- Continued support for CANARIE is absolutely essential for the success of the IPP program;

- Major contributions to particle physics experiments now depend on the CFI Innovation Fund program, and consequently its continuance is also essential for our community.

Program Support

- The community also expects to continue to draw heavily on resources at TRIUMF, SNOLAB, IPP and at the universities for developing and executing experiments in the future.
- It is of the utmost importance that the Government of Canada via ISED, NSERC, NRC, CFI and NDRIO coordinate their work in support of particle physics, along with IPP, TRIUMF, SNOLAB, and the Perimeter Institute, to avoid making independent decisions on funding and resource allocation.
- Projects of this size require “cradle-to-grave" consideration by the funding bodies.

Institutional Support

Because the success of the field in Canada depends critically on TRIUMF, SNOLAB, Perimeter Institute and the IPP Research Scientist program, it is essential that these resources be supported and properly funded going forward.

As CERN plays such a critical role in particle physics world-wide, it is important that the Long Range Plan also consider Canada's relationship with CERN and how it may develop in the future.

Increases to the NSERC Subatomic Physics Envelope

Increased funding to the envelope is critically needed to address growing demands on the envelope for essential technical, maintenance and operations support, in addition to normal inflationary stresses.

These demands are resulting in less funding for HQP training, and hence fewer students and postdocs being trained.

With sufficient increased funding to the SAPES envelope, this community will not only address the HQP funding crisis, but be able to cover all the discovery bases.

Closing Statement of the Executive Summary

Through their work on SNO, ATLAS, and BaBar, Canadians have had a key role in the science associated with all three recent Nobel Prizes in Physics awarded in particle physics - the discovery of neutrino oscillations (2015), Higgs mechanism (2013), and CKM CP violation (2008). Sufficient increases to the envelope will ensure that Canadians continue to be key players in the scientific advances recognized by Nobel Prizes in particle physics in the foreseeable future.

A major discovery in particle physics during the 2022-2026 period is a real possibility and IPP members are positioned to be major players whether that occurs at the energy or precision frontier, in the direct detection of dark matter or other dark sector particles, or via the discovery of CP or lepton number violation in the neutrino sector.

Additional Material

IPP Projects

ATLAS

Belle II

DEAP-3600

DUNE

EXO

HYPER-K

IceCube

MOLLER

IPP Projects

NA62

PICO

SBC: Scintillating Bubble Chamber

SNO+

SuperCDMS

T2K

VERITAS

Other Projects

Physics Motivation of Future Accelerators

DarkSide-20k

Chiral Belle R&D for SuperKEKB e- Polarization Upgrade

HALO

ILC and ILD

LEGEND-1000

MATHUSLA

Other Projects

MoEDAL

NEWS-G

nEXO

P-One

TUCAN

Community Resources: R&D and Infrastructure

- Research and development for radiation-hard semi-conductor devices for tracking detectors in future collider experiments
- Photon to Digital Converter R&D and Silicon Photonics-based low power cryogenic (+room temp) data communication system
- Particle Accelerator R&D
- Detector Development and Infrastructure
- Research Computing and Digital Infrastructure

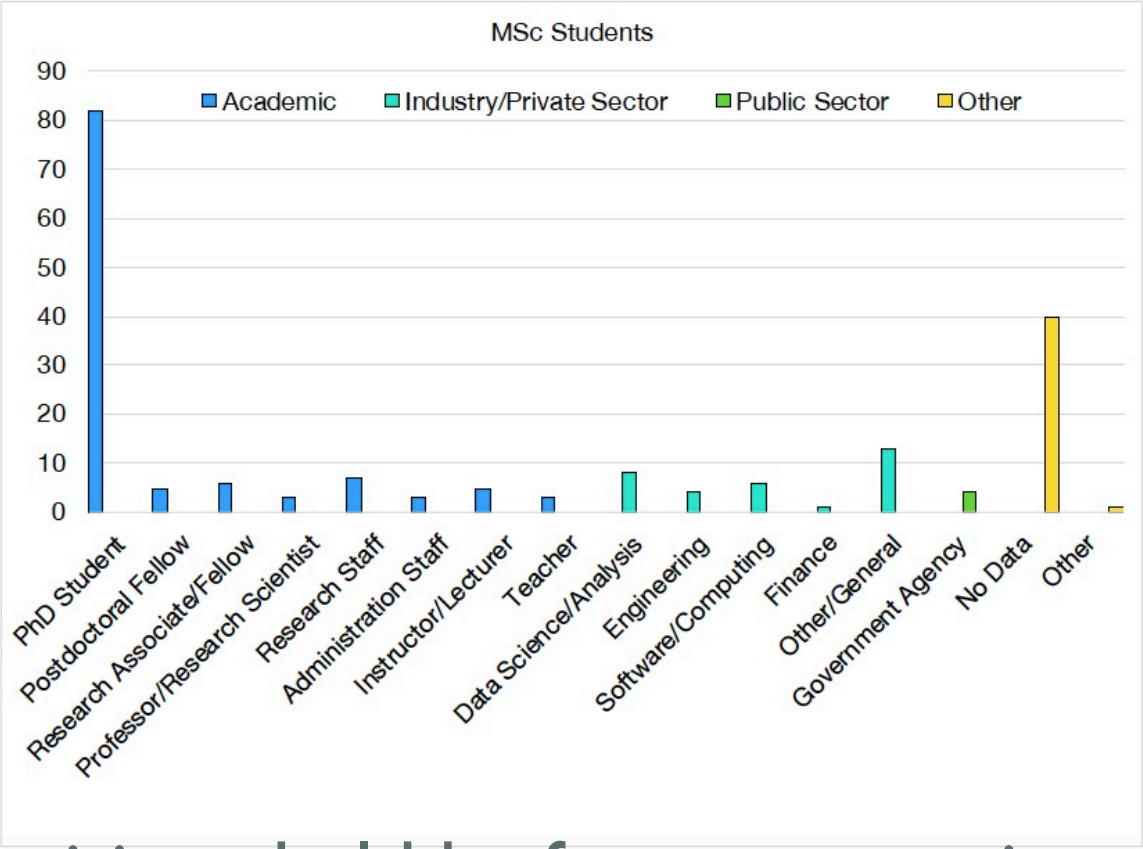
Equity, Diversity and Inclusion

- Systems and Policies to Promote Equity, Diversity and Inclusion
- Programs to Promote Equity, Diversity and Inclusion
- Challenges to Achieve Equity, Diversity and Inclusion
- Goals for 2022-2026 Period

Broader Societal Impact

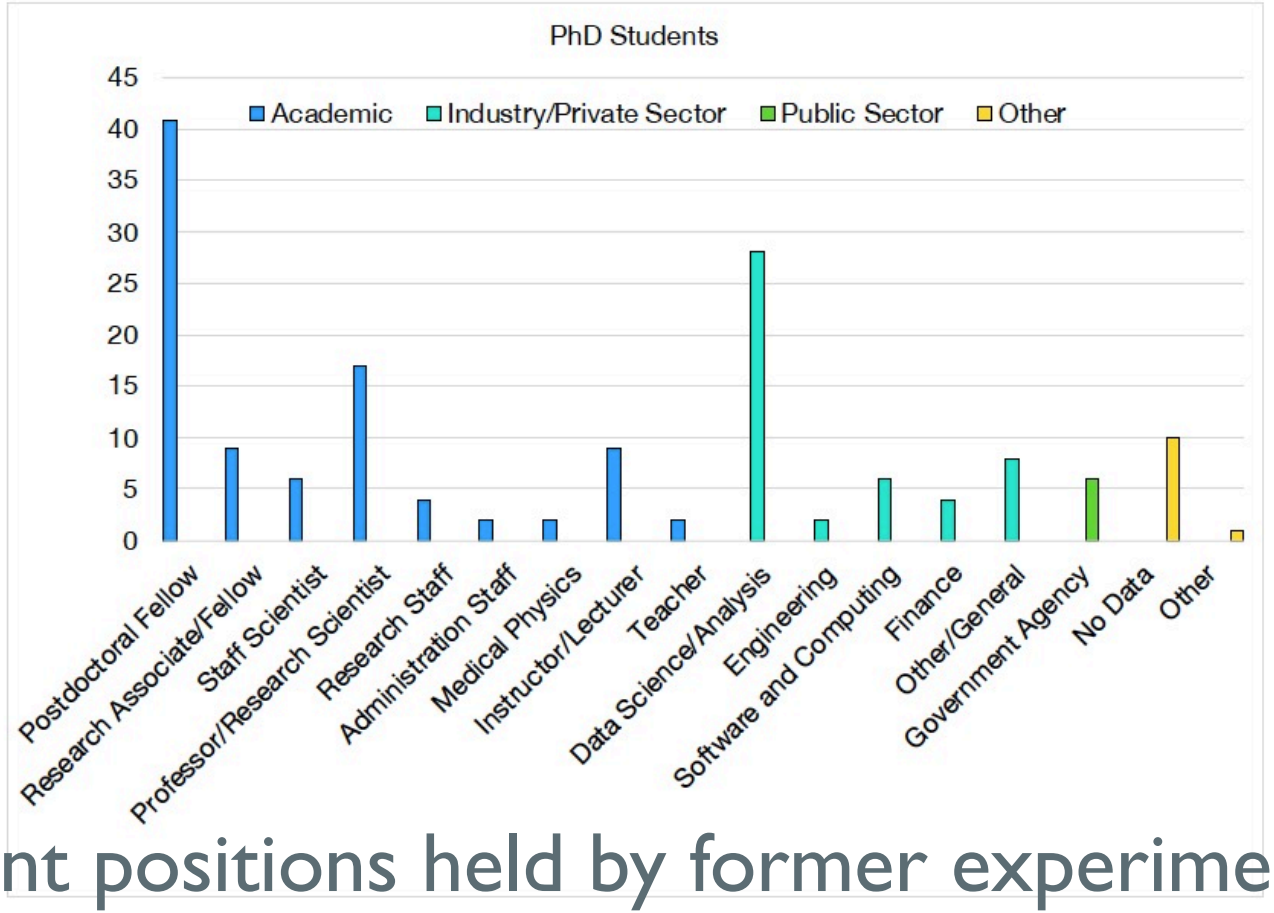
- Includes examples of direct engagement with industrial partners
- Includes small sample of stories of HQP careers post-graduation
  - Balancing across regions and areas of research
  - Some emphasis on those who have gone outside academia

Graphical representation of Broader Societal Impact



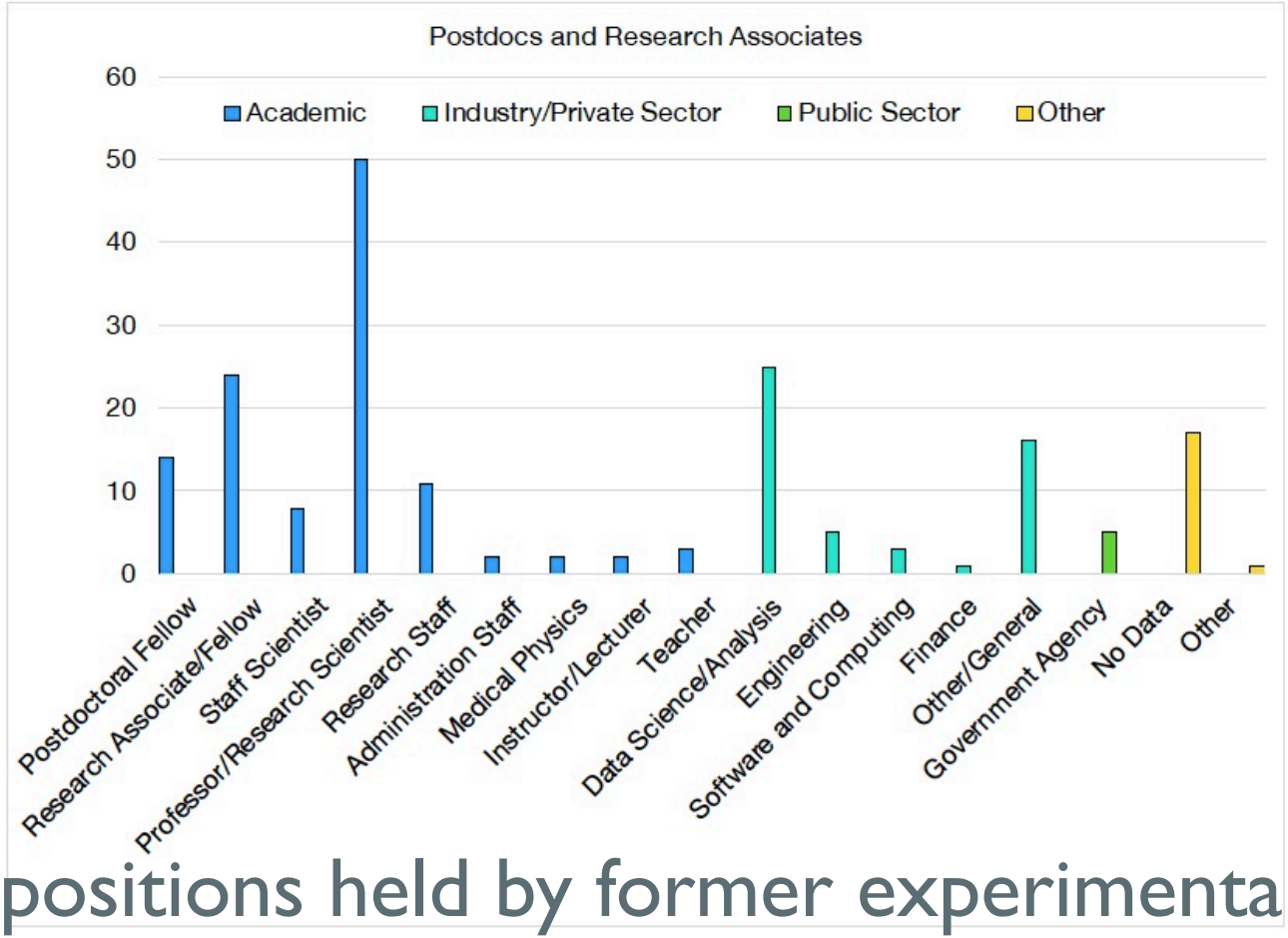
Current positions held by former experimental particle physics HQP – restricted to last decade.

Graphical representation of Broader Societal Impact



Current positions held by former experimental particle physics HQP – restricted to last decade.

Graphical representation of Broader Societal Impact



Current positions held by former experimental particle physics HQP – restricted to last decade.