USA and Canada achievements in Physics, Experiments, and Detectors during 2023

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PED participation in the USA

The USA currently has 35 active institutions: U. Mass-Amherst, ANL, Arizonia, Brandeis, BNL, Brown, Boston U ,Caltech, Carnegie Melon, Columbia, Duke, FIT, FNAL, Indiana, Iowa, Jefferson lab, Johns Hopkins, Maryland, Michigan, Michigan State, MIT, Northeastern, Notre Dame, Oak Ridge, Purdue, Rochester, SLAC, Stony Brook, Syracuse,Texas Austin, Tufts, UC Santa Cruz, UC Irvine, U New Mexico,U. Virginia.

We expect this list to expand over the next few years.

USA and P5

The “decadal” USA NSF and DOE Particle Physics Project Prioritization Panel produced a report very favorable to FCC. Full text at: https://www.usparticlephysics.org/

- Recommendation one concerns currently operating projects. Recommendation 2: "Construct a portfolio of major projects" recommends funding for an offshore Higgs factory (as the only newly listed accelerator-based project).
- The USA is encouraged to contribute to FCC-ee project following the conclusion of the feasibility studies
- The amount of recommended funding is sufficient to provide a critical amount from the US to ensure the success of the FCCee program and in the range of $1-$3 billion for contributions to the machine.
- Funding is recommended for detector R&D for detectors at future colliders at a recommended amount of $20M/yr.
- The report recommends, regarding FCCee detector work, “The US should actively engage in design studies to establish the technical feasibility and cost envelope of Higgs factory designs.”

For FCC-hh, in recommendation 4 the great news is that efforts are expected to develop the needed high field magnets.

From P5 presentation by Hitoshi Murayama

Exploring the Quantum Universe

Rank-Ordered

Recommendation 2

a. **CMB-S4**, which looks back at the earliest moments of the universe to probe physics at the highest energy scales. It is critical to install telescopes at and observe from both the South Pole and Chile sites to achieve the science goals (section 4.2).

b. **Re-envisioned second phase of DUNE** with an early implementation of an enhanced 2.1 MW beam—ACE-MIRT—a third far detector, and an upgraded near-detector complex as the definitive long-baseline neutrino oscillation experiment of its kind (section 3.1).

c. **An off-shore Higgs factory**, realized in collaboration with international partners, in order to reveal the secrets of the Higgs boson. The current designs of FCC-ee and ILC meet our scientific requirements. The US should actively engage in feasibility and design studies. Once a specific project is deemed feasible and well-defined (see also Recommendation 6), the US should aim for a contribution at funding levels commensurate to that of the US involvement in the LHC and HL-LHC, while maintaining a healthy US on-shore program in particle physics (section 3.2).

d. **An ultimate Generation 3 (G3) dark matter direct detection experiment** reaching the neutrino fog, in coordination with international partners and preferably sited in the US (section 4.1).

e. **IceCube-Gen2** for study of neutrino properties using non-beam neutrinos complementary to DUNE and for indirect detection of dark matter covering higher mass ranges using neutrinos as a tool (section 4.1).

P5 continued

From Recommendation 2 An off-shore Higgs factory, realized in collaboration with international partners, in order to reveal the secrets of the Higgs boson. The current designs of FCC-ee and ILC meet our scientific requirements. The US should actively engage in feasibility and design studies. **Once a specific project is deemed feasible and well-defined** (see also Recommendation 6), t**he US should aim for a contribution at funding levels commensurate to that of the US involvement in the LHC** and HL-LHC, while maintaining a healthy US on-shore program in particle physics (section 3.2).

Recommendation 6: "Convene a targeted panel with broad membership across particle physics **later this decade** that makes decisions on the US accelerator-based program at the time when major decisions concerning an off-shore Higgs factory are expected, and/or significant adjustments within the accelerator- based R&D portfolio are likely to be needed… *The level and nature of US contribution in a specific Higgs factory including an evaluation of the associated schedule, budget, and risks once crucial information becomes available.*"

Recommendation 2.5: "In the case of the Higgs factory, crucial decisions must be made in consultation with potential international partners. The FCC-ee feasibility study is expected to be completed by 2025 and will be followed by a European Strategy Group update and a CERN council decision on the 2028 timescale. The ILC design is technically ready and awaiting a formulation as a global project. *A dedicated panel should review the plan for a specific Higgs factory once it is deemed feasible and well-defined*; evaluate the schedule, budget and risks of US participation; and give recommendations to the US funding agencies later this decade (Recommendation 6). When a clear choice for a specific Higgs factory emerges, US efforts will focus on that project, and R&D related to other Higgs factory projects would ramp down."

Result

As part of the P5 process, we had great success in engaging US institutions. Expect to follow up on this to further discuss potential engagement areas and recruit/engage new institutes/physicists

- Expect to discuss potential areas during our second USFCC workshop at MIT 25-27 March https://indico.mit.edu/event/876/ following up on our very successful workshop at BNL last year.
- Our current evolving plans for detectors can be found in our snowmass white paper https://arxiv.org/abs/2306.13567

Some examples of USA participation in FCC PED

- Marc-Andre Pleier (BNL) is co-head of the PED Detector Concepts group
- Christoph Paus (MIT), Graham Wilson (Kansas), Ayres Freitas (Pittsburgh) and Josh Bendavid (MIT) are co-heads of the PED subgroup Precision EWK
- Jan Eysermans (MIT) is a co-head of Higgs performance. Andrei Gritsan is working on ZH CP studies.
- The US CalVision group is active in the IDEA detector concept
- Several US institutions are active in Allegro
- Brown (Gouskos) is doing work on flavour identification, Higgs couplings
- BNL studies Higgs boson properties and the interdependence of physics sensitivities, interaction region magnet design and detector parameters

USA and alternative future colliders

The USA has very strong interest and participation in R&D for future muon collider. The USA is also actively engaged in R&D for other Higgs Factories, such as ILC and C^3. There are strong synergies in detector design for all options.

Canadian Subatomic Physics Landscape

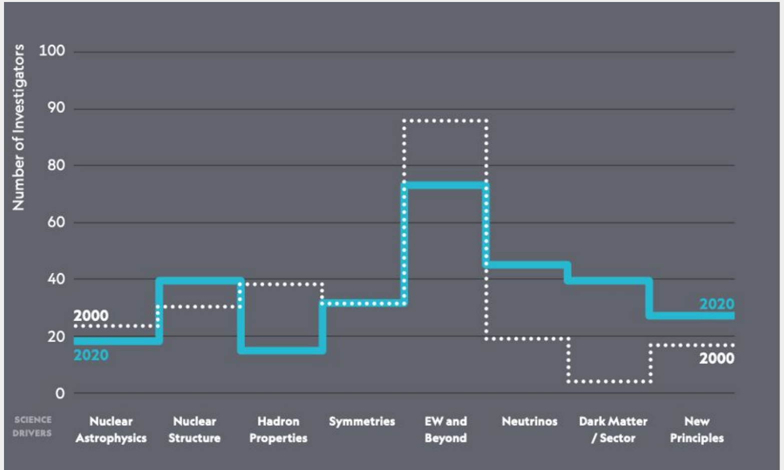

FIGURE 6. The number of NSERC-funded subatomic physics investigators, categorized by the primary science driver of their research, is shown for 2000 and 2020. The research profile of the Canadian community has evolved over the past two decades, to reflect progress in the field and evolving science priorities, for example, with increased focus on neutrino properties and searches for dark matter, consistent with global trends and the presence of SNOLAB in Canada.

FIGURE 3. Schematic representation of the eight science drivers for the field of subatomic physics research and enabling infrastructure.

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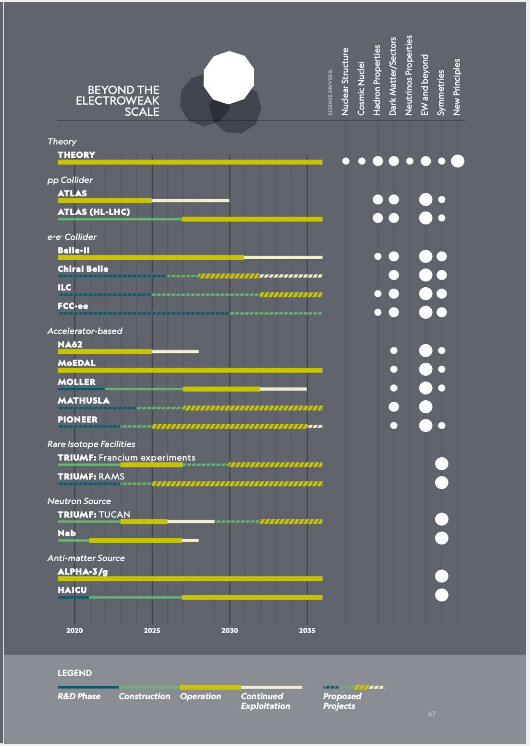

Relatively small community stretched over a number of subatomic physics projects

- Moderate increase of number of investigators between 2000-2020
- Strong participation in astroparticle and subterranean experiments
- Large contingent on ATLAS in particular Phase-II detector upgrades

Canadian Subatomic Physics Long Range Plan

Canadian Subatomic Physics Long Range Plan 2022-2026, with Outlook to 2036, published March 2022

- Regular 5-year update of sub-atomic community's outlook
- Latest iteration for 2022-2026 period

Higgs, physics at the electroweak scale, and beyond

- Building on its expertise and past investments, Canada is well-positioned to pursue further scientific opportunities through its participation and leadership, for example, in the broad physics programs of ATLAS and Belle II, dedicated searches for new physics at MATHUSLA and MoEDAL, and precision programs such as those of MOLLER and NA62.
- There is also an active Canadian theory community engaged in interpreting new data and pointing to potential signatures of new physics.
- Finally, there is the opportunity to advance detector and accelerator R&D synergistically with contributions to the HL-LHC, the development of Chiral Belle, the International Linear Collider and the Future Circular Collider projects

Canadian Subatomic Physics Recommendations

SCIENCE RECOMMENDATION
3 — **EXPERIMENTAL PROGRAMS**

A broad experimental program is required to address the scientific drivers of subatomic physics research. We recommend pursuit of the following high-priority scientific directions.

- **FROM QUARKS AND GLUONS TO NUCLEI** — *The future program should explore the structure of hadrons and nuclei using rare isotope and accelerator-based facilities. It should include the full exploitation of TRIUMF, offshore electron beam and rare isotope beam (RIB) facilities, and a future electron-ion collider.*
- **BEYOND THE ELECTROWEAK ENERGY SCALE** — *The future program should study matter and its interactions at increasingly higher energy scales, including the exploitation of a future Higgs factory and energy frontier collider, as well as high-precision indirect techniques.*

This scientific program is currently implemented through Canadian leadership in a set of flagship projects identified based on their potential scientific payoff, Canadian core expertise, the level of community engagement, opportunities for the scientific and technological training of the next generation, and Canadian investments to date:

	Flagship projects with broad physics outcomes	*Flagship projects with strategic physics outcomes*
FROM QUARKS AND GLUONS TO NUCLEI	TRIUMF ARIEL-ISAC experiments, EIC	JLab 12 GeV program, Offshore RIB experiments
MATTER IN THE WEAKLY COUPLED UNIVERSE	T2K/HK, IceCube, SNO+	DEAP, PICO-500, SuperCDMS
BEYOND THE ELECTROWEAK ENERGY SCALE	ATLAS(LHC/HL-LHC), Belle II	ALPHA/HAICU, MOLLER, TUCAN

We recommend the support of these projects and also those initiatives within the scientific program, with the potential for high impact, that are under development or may be developed in the coming years. Potential future projects with ongoing development activities and their timelines are listed in the research portfolio presented in FIGURE 4.

SCIENCE RECOMMENDATION
4 — **R&D ACTIVITIES**

We recommend the support of R&D activities for the future development of particle accelerators and detector technology, and the development and use of emerging technologies including novel computational and analysis tools.

- Clear statement on exploitation of a future Higgs factory and energy frontier collider
- Strong endorsement of R&D activities for the future development of particle accelerators and detector technology

Current Status

- Some Canadian involvement (mostly by theorists) in FCC-ee/FCC-hh physics prospects
  - From Queen's University, Toronto and Carleton
  - There's also some interest in a future muon collider (Toronto, Carleton)
- On detector technology R&D, there's a strong and growing involvement in DRD efforts
  - Carleton, U. Sherbrook, UBC, Simon Fraser and TRIUMF
  - Project funding request to support detector technology R&D effort submitted in 2023
    - Request is for ~$800k/year for 3 years
    - Some smaller funding from non-government sources for R&D also available
  - If successful, it could open the way for a subsequent funding request for involvement in FCC
    - <u>Note:</u> detector technology development community in Canada is small and currently heavily committed to ATLAS Phase-II Upgrades and SNOLAB experiments
- Also note the engagement of some "new" stakeholders in subatomic physics research
  - The National Research Council (NRC) is active in radiation-hard semiconductor technology development in DRD3
  - There's some growing interest from researchers in engineering departments (electronics/electrical engineering) and from industry for applications beyond subatomic physics