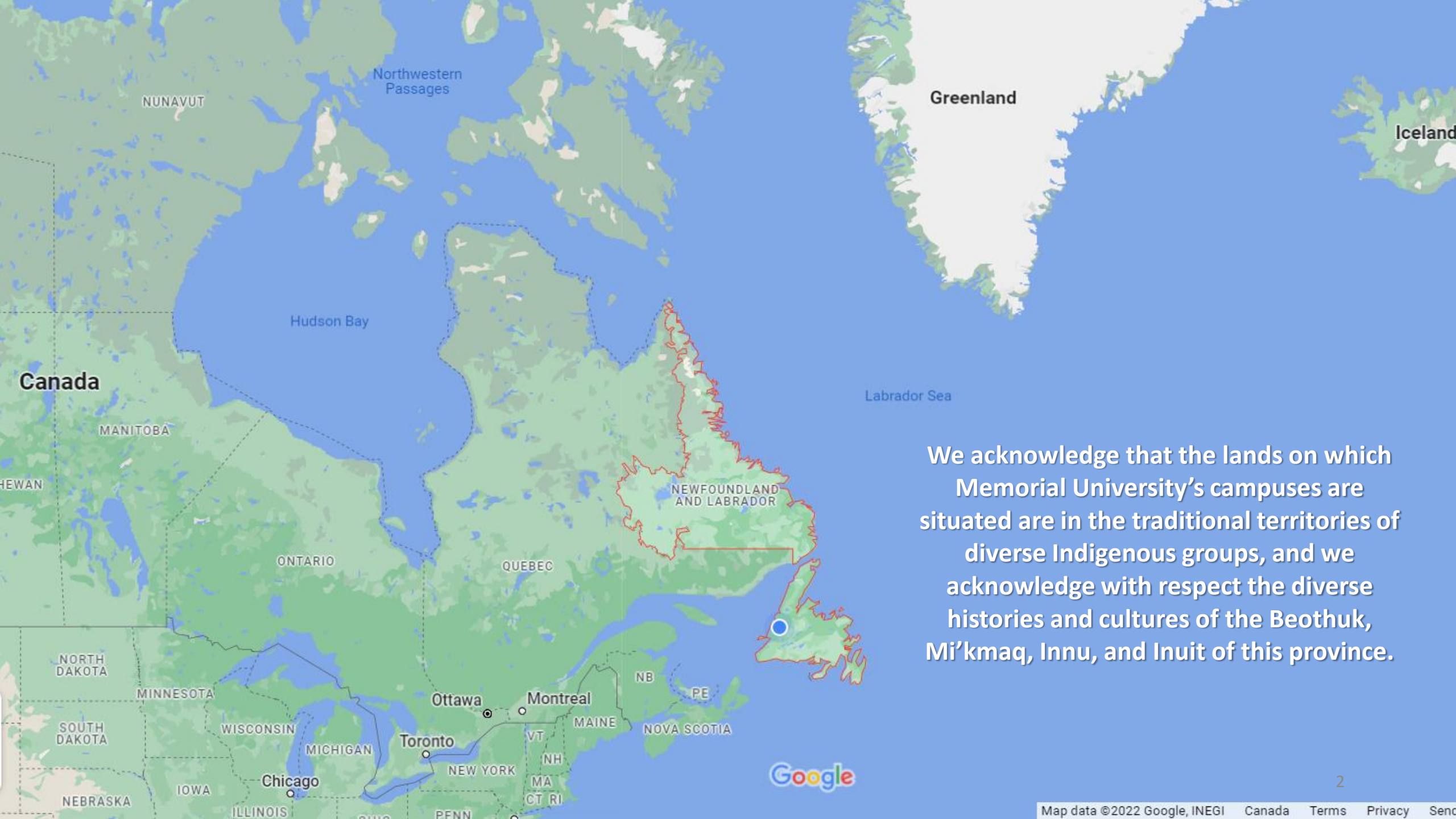
Canadian Theory Community and the Electron-Ion Collider

Svetlana Barkanova
Grenfell Campus, Memorial University of Newfoundland
Corner Brook, NL, Canada

Canadian Association of Physicists
SUPPORTING PHYSICS RESEARCH AND EDUCATION IN CANADA



We acknowledge that the lands on which Memorial University's campuses are situated are in the traditional territories of diverse Indigenous groups, and we acknowledge with respect the diverse histories and cultures of the Beothuk, Mi'kmaq, Innu, and Inuit of this province.

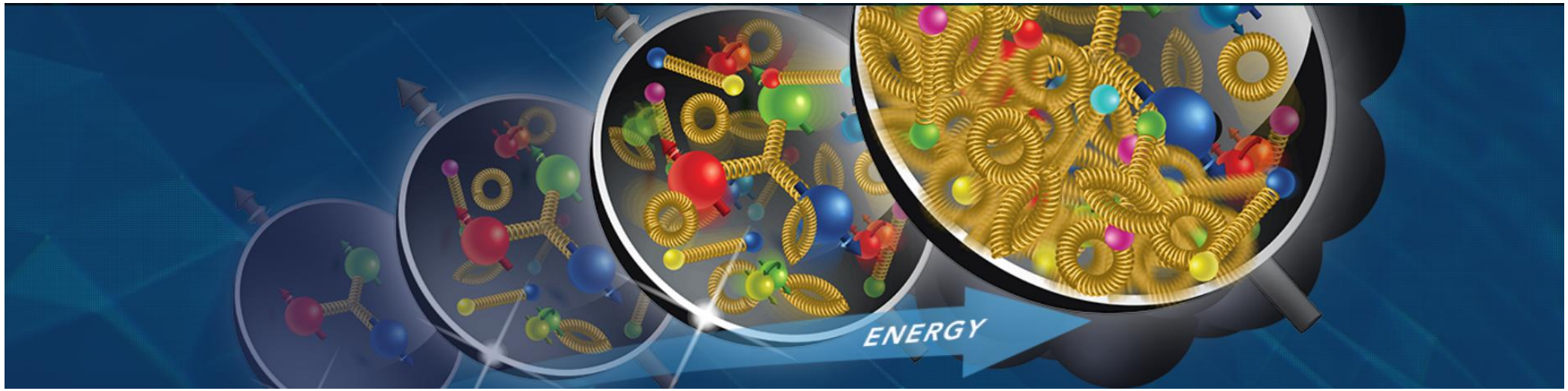
“Vínland”, Norse settlement in Newfoundland, 1021 AD

The Electron-Ion Collider (EIC) will uniquely address questions about the origin on nucleon mass and spin, properties of dense systems of gluons, as well as opportunities to connect to neutrino physics, astrophysics, and fundamental symmetries at higher energies.

Canadian theorists are valued collaborators complementing the experiment efforts worldwide, and they are currently taking roles in EIC working groups and committees and offer a broad range of contributions such as *e+A* gluon saturation, GPDs and TMDs, radiative corrections and Lattice QCD.

The talk will briefly outline related efforts and expertise of Canadian theory groups, and how Canadian subatomic physics community gathers to outline its vision for the next five years and beyond, placing Canadian contributions within a long-term international context.

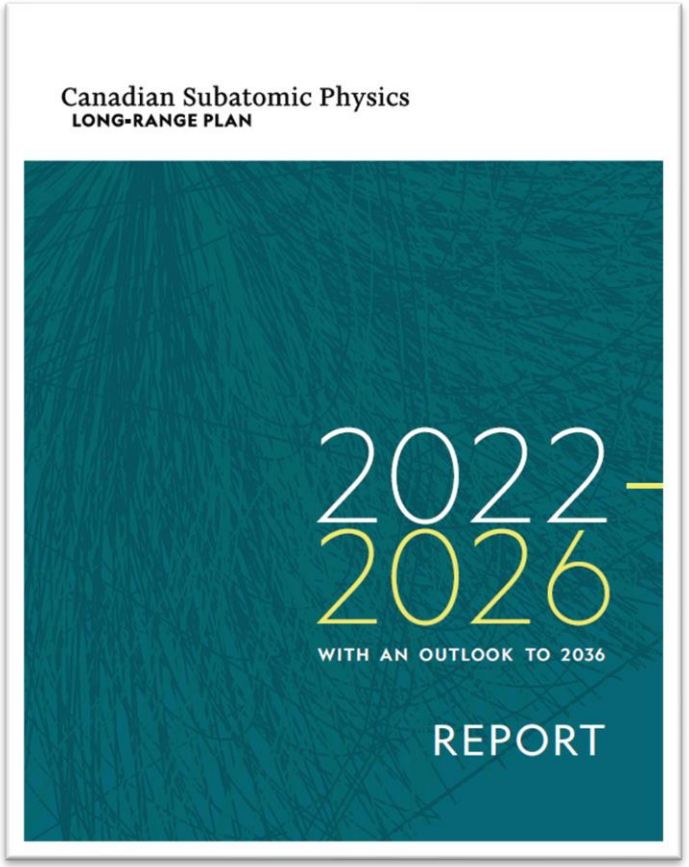
Electron-Ion Collider science goals (bnl.gov)

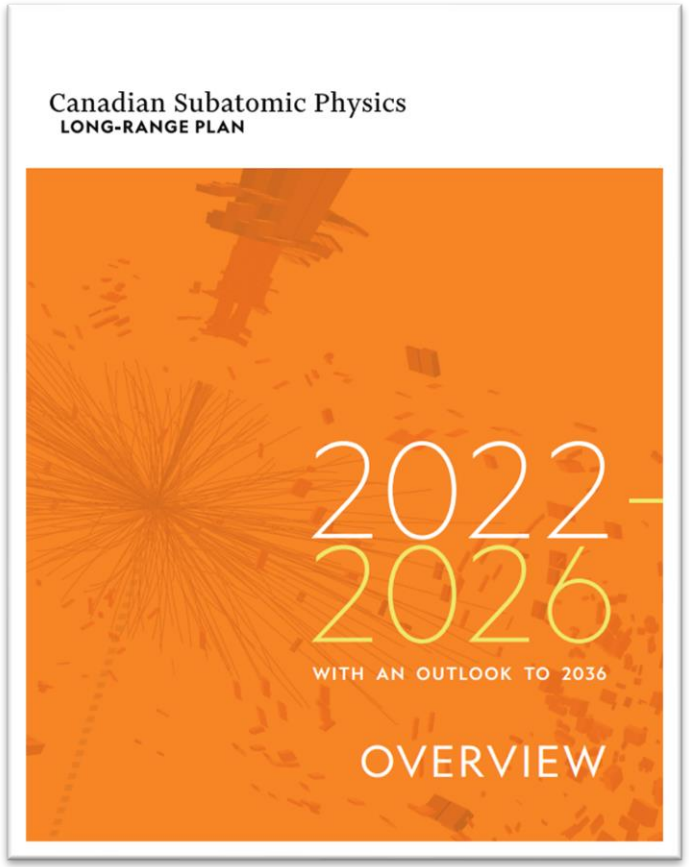


The Canadian subatomic physics community establishes its scientific and funding priorities through five-year Long-Range Plans. These plans advise the research community and relevant stakeholders on priorities for current and future endeavours. The current plan covers the period from 2022 to 2026, with an outlook to 2036.

It is jointly supported by the Institute of Particle Physics (IPP), the Canadian Institute of Nuclear Physics (CINP) and the Natural Sciences and Engineering Research Council (NSERC).

https://subatomicphysics.ca





SCIENCE RECOMMENDATION

2 – **THEORY PROGRAMS**

Critical mass and research breadth are vital for the theory community in Canada, to maximize the future impact of subatomic physics research. We recommend strong support for theoretical subatomic physics research over the next decade, both to explore new purely theoretical directions and to support the synergistic interaction between subatomic theory and experiment.

LRP Report, p. 7, https://subatomicphysics.ca

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.

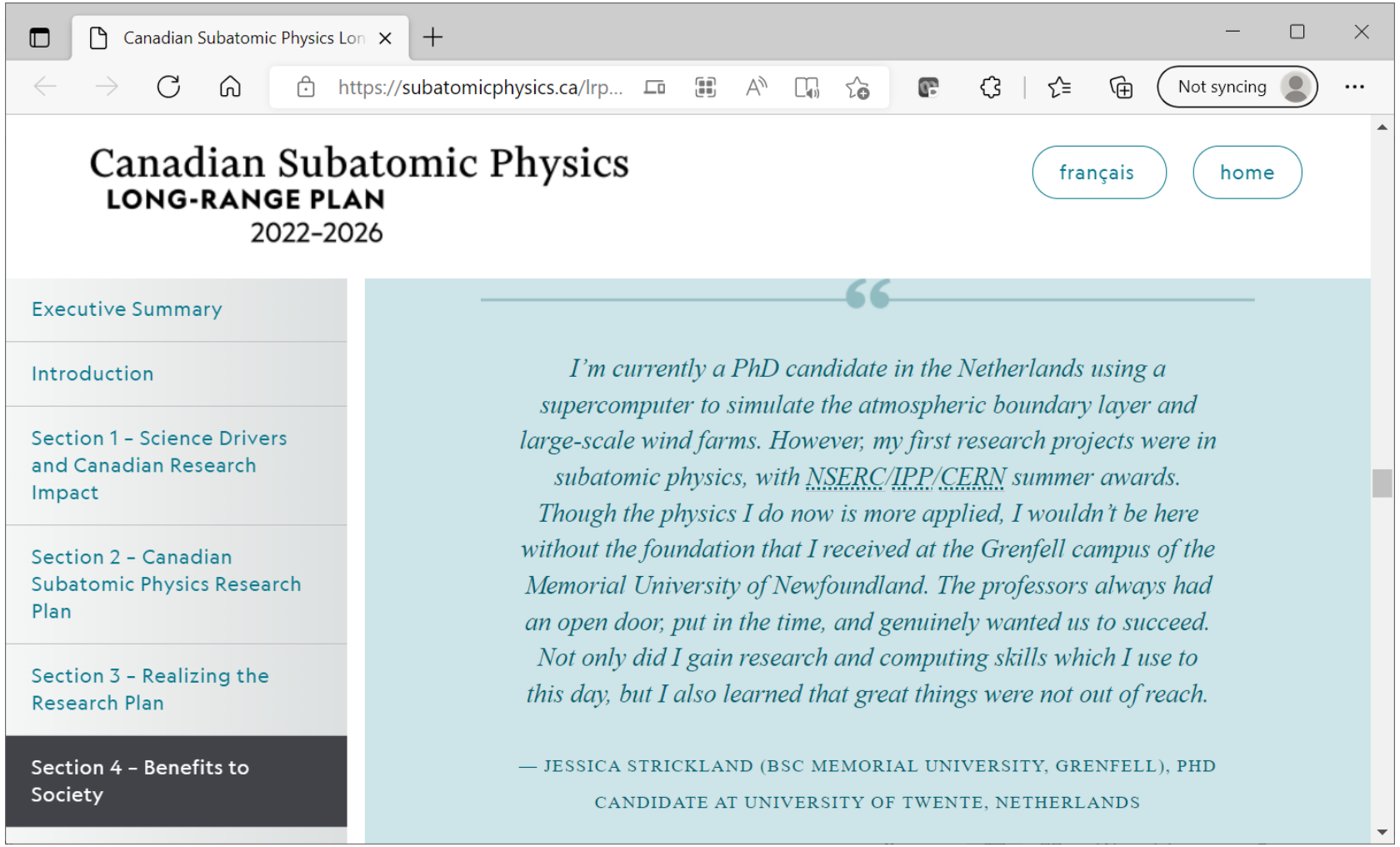
	Flagship projects with broad physics outcomes	*Flagship projects with strategic physics outcomes*
FROM QUARKS AND GLUONS TO NUCLEI	TRIUMF ARIEL-ISAC experiments, EIC	JLab 12 GeV program, Offshore RIB experiments
MATTER IN THE WEAKLY COUPLED UNIVERSE	T2K/HK, IceCube, SNO+	DEAP, PICO-500, SuperCDMS
BEYOND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

LRP, p. 8

Jessica Strickland (LRP Report, p. 105) was the fist MUN student to receive CERN/IPP summer scholarship, in 2014. Jonathan Barrett was selected in 2022; to be supervised at CERN by Matt LeBlanc, Acadia 2010 CERN/IPP award recipient.

See Jonathan's talk "Fully Immersive VR in Teaching and Science Outreach" at 3:15pm on June 8 (W3-4 DPE V), https://indi.to/x6Lsv.

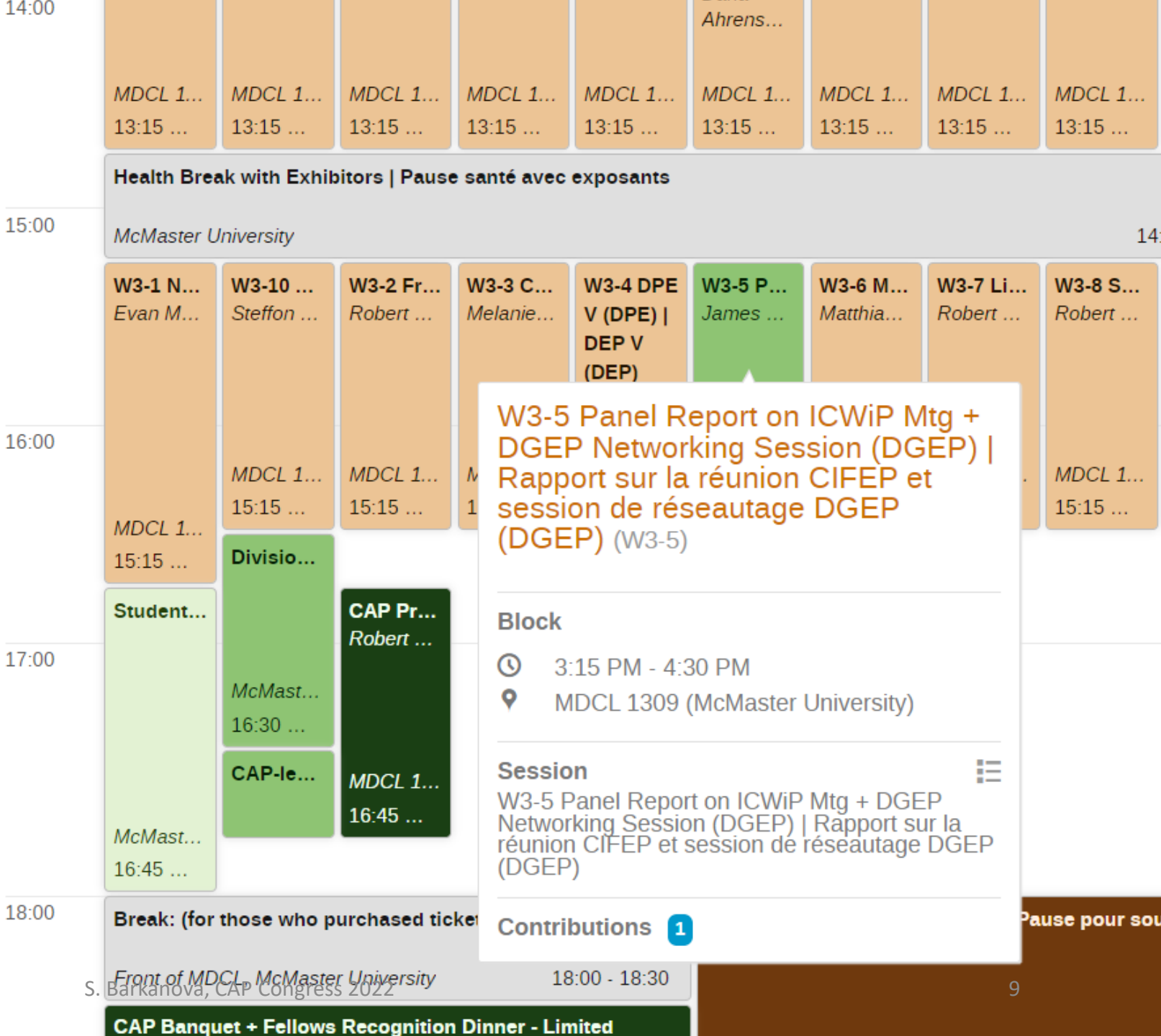
LRP Report, p. 105, https://subatomicphysics.ca



Please join us for DGEP
([Division for Gender Equity in Physics](#))
Networking Session 3:15pm – 4:30pm
June 8 (W3-5)!

Everyone is very welcome!

The DGEP Executive Committee 2022:
Svetlana Barkanova – Chair
Carolyn Sealfon – Vice Chair and Chair Elect
Juliette Mammei – Treasurer
James Botte – Past Chair



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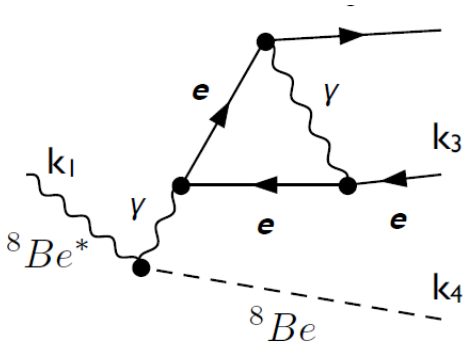
Canadian theorists work on projects ranging from developing a predictive ab-initio theory of nuclear structure and nuclear reactions to phenomenological approaches guided by empirical data in close collaboration with experiment, and on everything in between.

Theorists offer a broad range of contributions such as *e+A* gluon saturation, generalised parton distributions (GPDs) and transverse momentum dependent parton distributions (TMDs), radiative corrections and Lattice QCD.



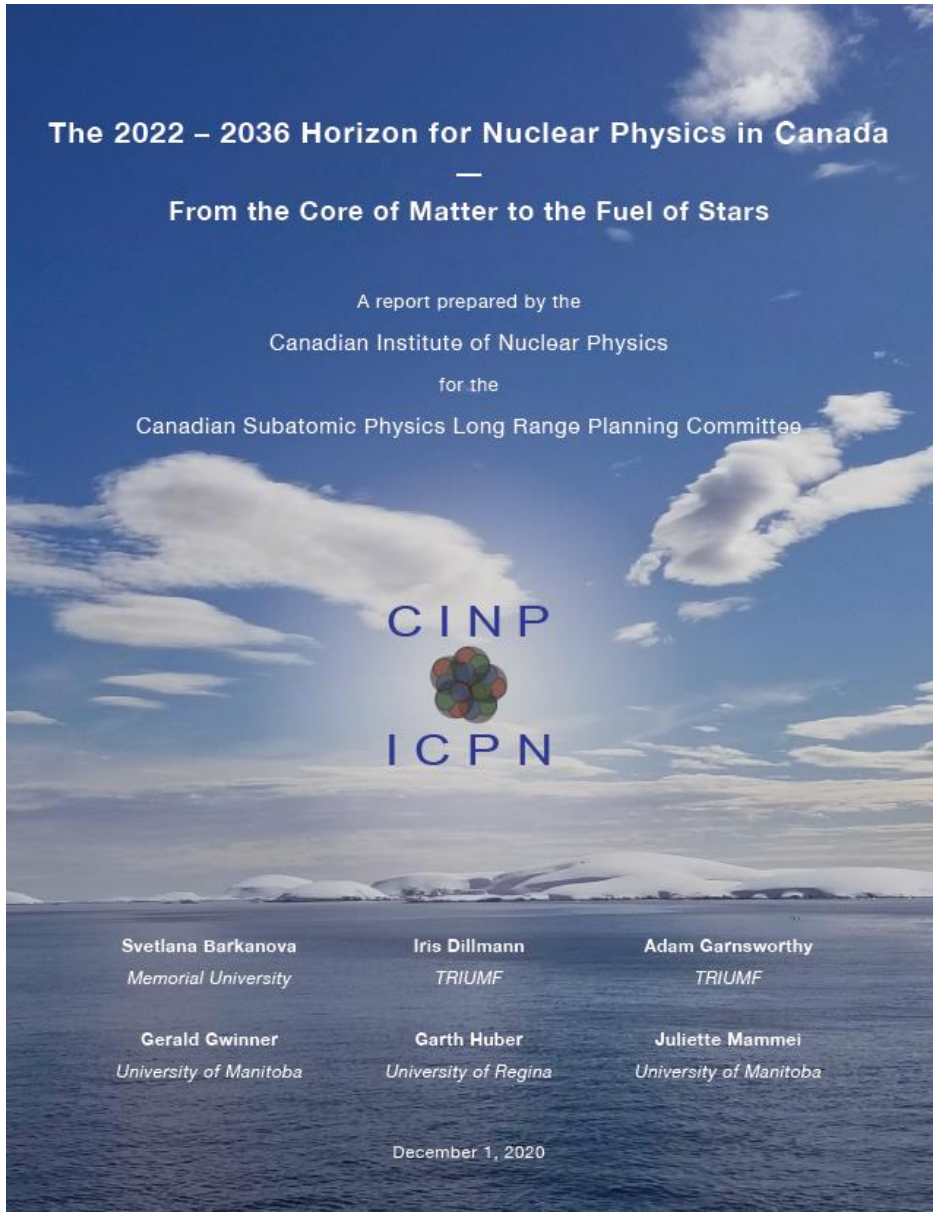
LRP, p. 40

Canadian Contributions and Achievements

Canadians are at the forefront of the quest to understand the properties of hadrons, on both the experimental and theoretical fronts. Canadian achievements in the past five years include the following.

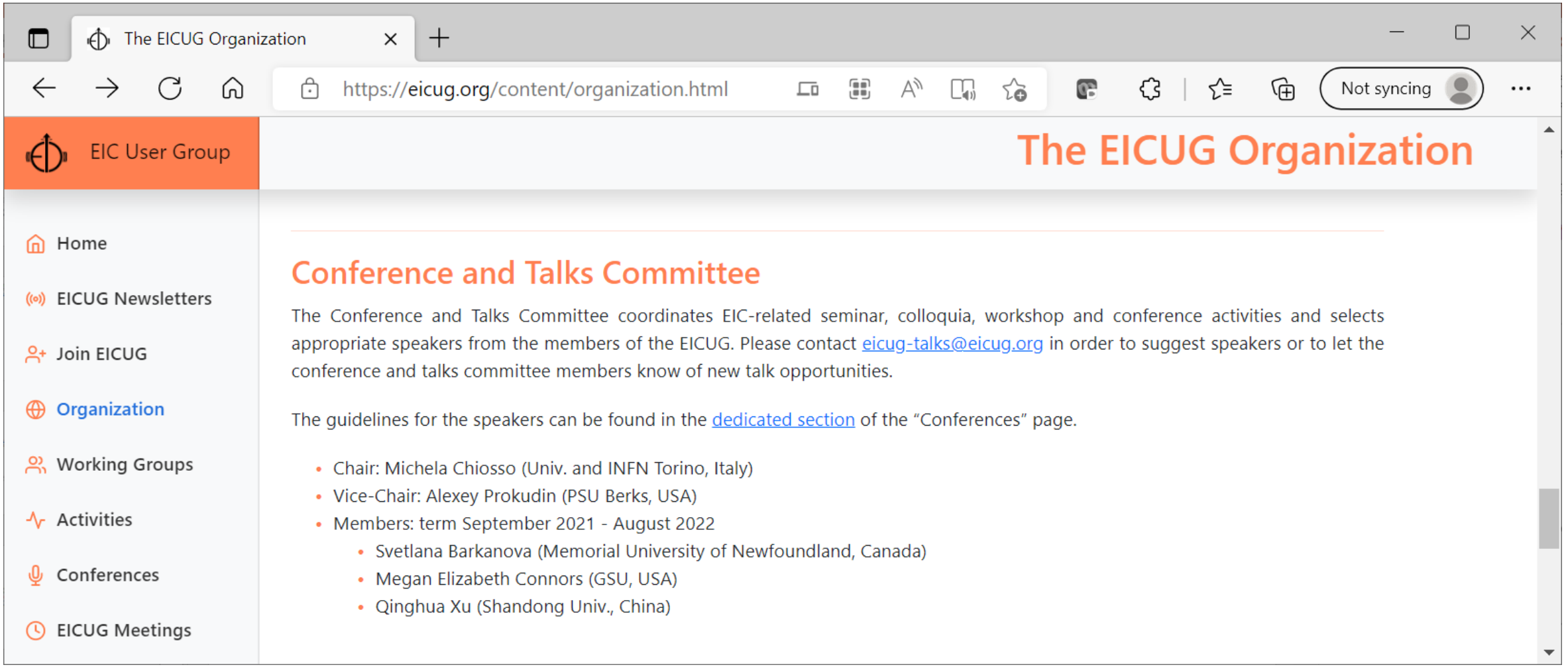
The Canadian theoretical community leverages a range of calculational approaches, including Lattice QCD, Light Front Holographic QCD and Chiral Pertubation Theory to advance the field and to support the Canadian experimental efforts. For example, recent achievements include the first direct lattice QCD calculation predicting the existence of tetraquarks with valence content $u\bar{d}\bar{b}b$, and calculations of the Standard Model predictions for the differential branching ratio of the rare decay $B_s \to \phi\mu^+\mu^-$.

CINP plays an important role and the formation of LRP. See CINP 2020 LRP Brief (600dpi).



New in 2021 – CINP Nuclear Theory working group, lead by Alexandros Gezerlis, with 27 members so far:

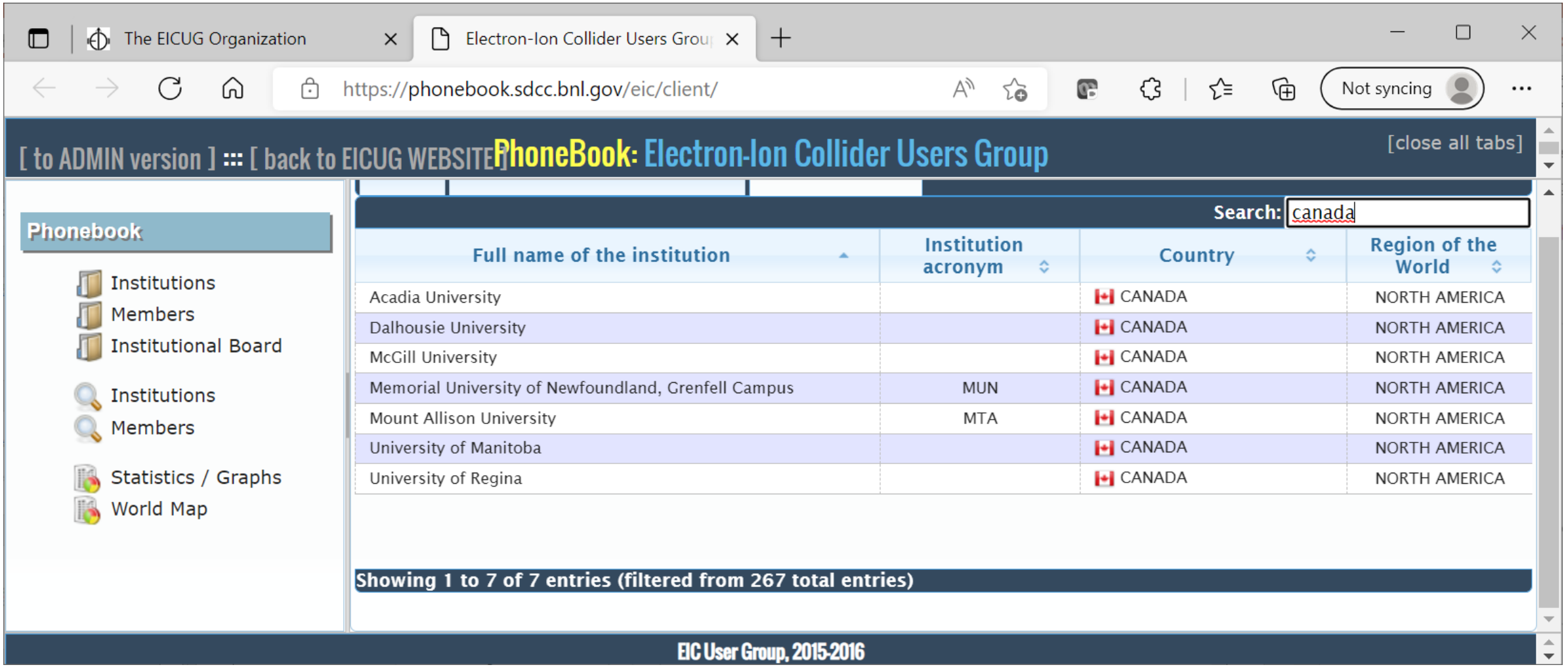
Canadian theorists are valued collaborators complementing the experiment efforts worldwide, and they are currently taking roles in EIC working groups.



The EICUG Organization

Talk Guidelines

Seven Canadian universities are institutional members of EIC User Group:



[The EICUG Organization]

LRP, p. 57 : “There is significant synergy between the EIC and 12 GeV JLab program, with a rich and diverse set of experiments capable of precisely studying QCD, from the nature of the finite temperature many-body problem, to mapping the transition from hadronic to partonic degrees of freedom.”

The input from theorists is especially essential in the study of fundamental symmetries with parity-violating electron scattering.

Canadian groups have a long history of working with JLab (QWeak, MOLLER, SoLID) studies of the evolution of the fundamental electroweak coupling and search for physics beyond the Standard Model.

An EIC would naturally extend this program, studying fundamental at symmetries higher energies.

The advancement of nuclear physics is strongly dependent on interplay between theory and experiment, and many Canadian research programs are the excellent examples of such successful collaboration.

The Canadian effort is distributed in several groups coast-to-coast, from British Columbia to Newfoundland and Labrador, building intellectual capacity in their regions and pursuing a broad range of initiatives.

LRP, p. 78

Progress in nuclear theory, both from a fundamental point of view, and in its connection with experimental measurements, is proceeding on several fronts at once, and it is thus imperative to maintain a vibrant and diverse theoretical program.

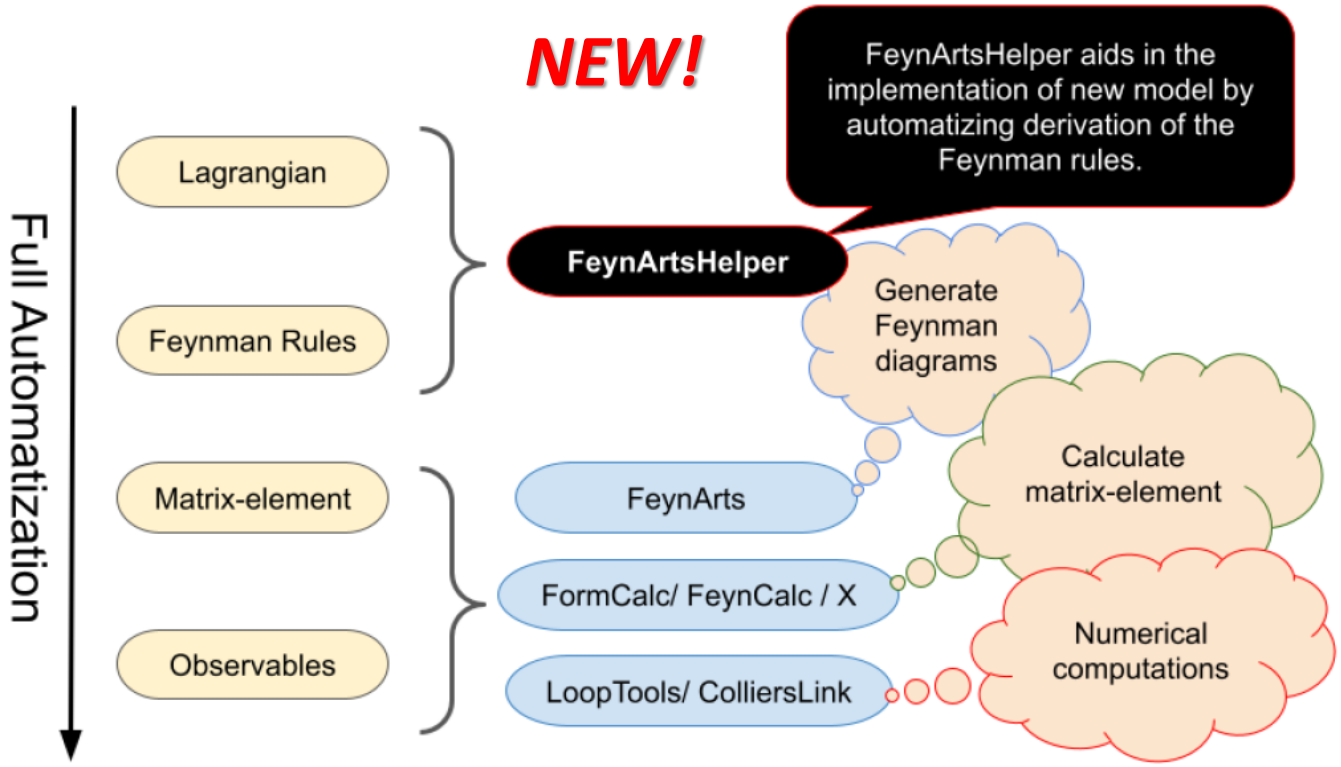
LRP, p. 87: “Full pursuit of the proposed research plan, including (a–c) above require a growth in research capacity and HQP over the next five years. Indeed, there is recognition that the community has the capacity to train 40% more graduate students.”

TABLE 1. The number of NSERC-funded subatomic physics investigators in 2011, 2015 and 2021, broken down by geographical region. The subatomic physics community continues to be vibrant with strength across all regions in Canada, and significant recent growth in Ontario.

Region	2011	2015	2021
British Columbia (BC)	86	88	88
Prairies (AB, SK, NB)	38	38	40
Ontario (ON)	60	66	81
Quebec (QC)	35	31	32
Atlantic (NL, NB, NS, PE)	6	8	8
Total	**225**	**231**	**251**

LRP, p. 78

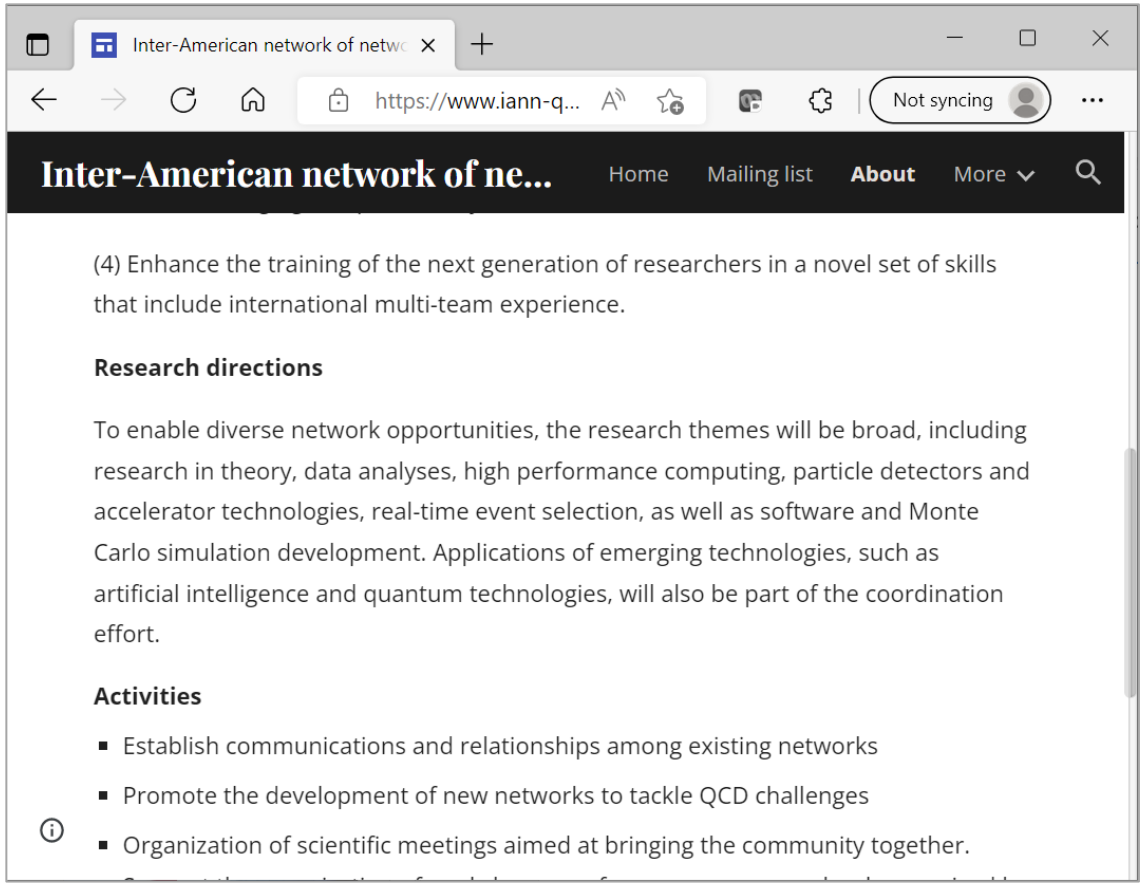
MUN group at Deer Lake Airport, June 4, 2022

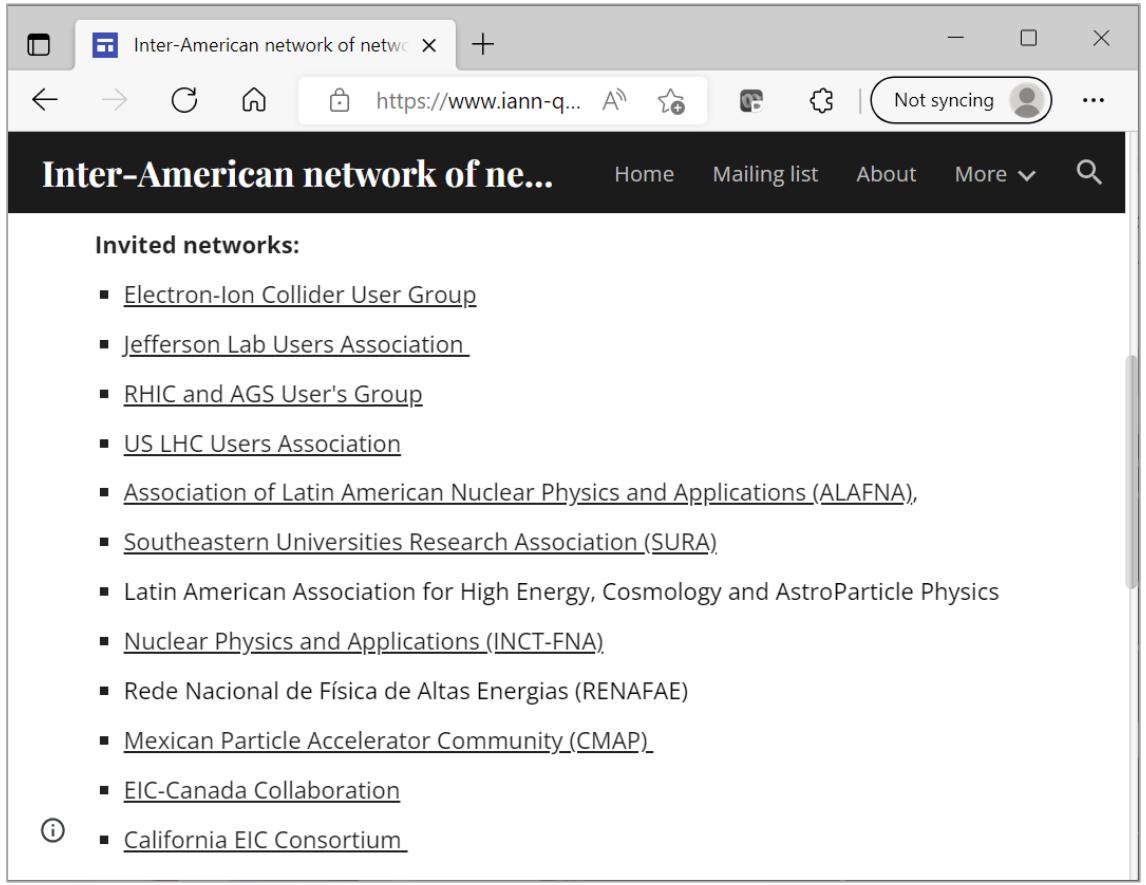


FeynArtsHelper, Reefat, MUN, CAP2022, https://indi.to/M67Ld.

Higher-Order Leptonic Corrections (relevant to EIC, MUSE, MOLLER etc.), Mahumm Ghaffar, CAP2022, https://indi.to/r44GF.

Launched in December in 2021: [The Inter-American Network of Networks of QCD Challenges] to develop strategic partnerships across the United States, Canada and Latin America to address QCD challenges.
It will provide collaborative research opportunities and enable the training of students and early-career scientists in international multi-team nuclear and particle physics projects.





Thank You! Questions?

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https://doi.org/10.1038/s41586-021-03972-8
Evidence for European presence in the Americas in ad 1021 (nature.com)

Kuitems, M., Wallace, B.L., Lindsay, C. *et al.* Evidence for European presence in the Americas in AD 1021. *Nature* **601,** 388–391 (2022).

Until 2021, it was believed the Norse settlement at L'Anse aux Meadows in Newfoundland was established around AD 1000.

The original date was based on radiocarbon techniques, but 2021 study based on mass spectrometry identified wiggly tree rings caused by a solar storm in AD 993, which allowed to determine the year the trees were cut down as AD 1021.