EIC Canada

Coordinating Canadian Participation in the EIC

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for the EIC Canada Collaboration (eic-canada.org)

University of Manitoba

Mount Allison University

University of Regina

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What is the EIC Canada Collaboration?

- **Coordinating the Canadian participation in the Electron Ion Collider**
- Chartered in 2020 after EIC Project CD-0 decision and BNL site selection
- Current initiatives:
  - Input to the recently published 2022-2036 **Canadian Subatomic Physics Long Range Plan**
  - NSERC Subatomic Physics **Project Research Grants** (2021-2023: funding of 8 HQP)
  - Interfacing with partner and funding organizations:
    - National funding agencies and research facilities (NSERC, CFI, TRIUMF)
    - International partners (EIC User Group, BNL, JLab, working groups and consortia)
  - Participation in both **Detector Proposals** (**ATHENA**: Mt. A, U. Manitoba; **ECCE**: U. Regina)
  - Participation in the **EIC "Detector-1" collaboration** (working group conveners)
- Current membership:
  - PIs at three institutions **U. Regina**, **U. Manitoba**, **Mt. Allison U.**
  - First step to joining: institutions and PI must join the EIC User Group
- Management plan, members, leadership and further details at eic-canada.org

EIC Canada Collaboration

The Electron Ion Collider (EIC) is a major new collider facility scheduled to be built on Long Island, New York, by the US Department of Energy in the current decade. At the EIC, polarized electrons will collide with polarized protons, polarized light ions, and heavy nuclei at luminosities far beyond what is currently available. The facility will answer several fundamental questions central to completing an understanding of atoms and integral to the agenda of nuclear physics today.

The EIC project achieved two milestones in 2019-2020 with the site selection of Brookhaven National Lab and the first critical decision (CD-0) establishing mission need. The project aims to complete the next two critical decisions by 2026 and to start operation by 2030. The EIC Users Group is coordinating the international efforts to instrument the two interaction regions of the collider, with Expressions of Interest invited by November 2020.

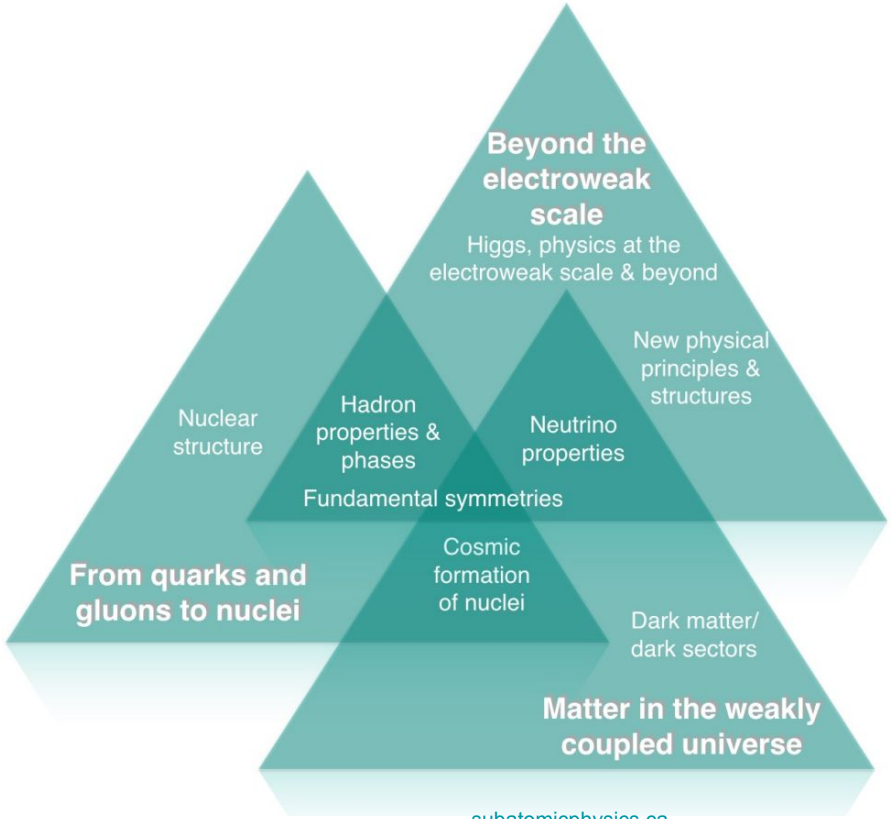
Canadian subatomic physicists have participated intensively in the planning of this new facility and have chartered a multi-institutional EIC Canada Collaboration to coordinate participation. We anticipate that the Canadian participation in the first new North American collider in this century will become similar in scope as, e.g., the Canadian participation in the Belle II experiment.

Contact

For information on joining or contributing, please contact Wouter Deconinck.

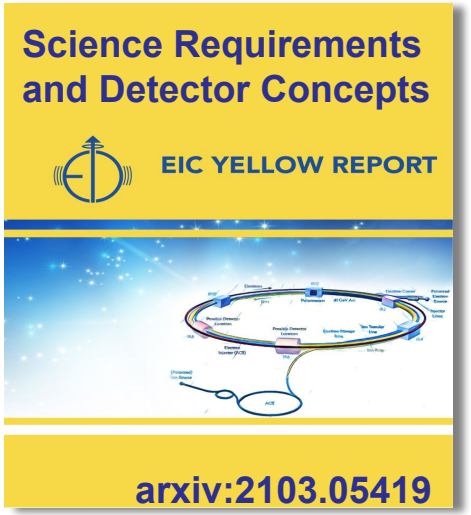
Canadian Subatomic Physics Long Range Plan

- Hadron Properties and Phases
  - How do quarks and gluons give rise to the properties of nucleons and other hadrons, and to the hadronic phases of matter in extreme conditions?
- Nuclear Structure
  - How does nuclear structure emerge from nuclear forces and ultimately from quarks and gluons?
- Cosmic Formation of Nuclei
  - How do the properties of nuclei explain the formation of the elements in the universe?



subatomicphysics.ca

Canadian Involvement in EIC Yellow Report, Proposals



2021: From Yellow Report…
…**to two large collaboration detector proposals** with Canadian involvement
2022: proposal selection
...**to one large EIC Project detector collaboration**
2024: Construction/Installation
2030: First Beam/Operations

ATHENA: A Totally Hermetic Electron-Nucleus Apparatus

Key Characteristics:
- New 3T magnet
- Tracking: Si MAPS vertex, MicroMegas barrel, GEMs + µRWELL endcaps
- PID: hpDIRC, AC-LGAD ToF, dual radiator RICH, proximity-focused RICH
- Calo: Si-pixel imaging + SciFi hybrid barrel, PbWO + SciGlass hybrid endcaps
- Software: CERN-oriented (dd4hep, gaudi, ACTS)

EIC Canada involvement:
- U Manitoba (W. Deconinck: software WG convener)
- Mt Allison U (D. Hornidge)

Canadian resources:
- ComputeCanada full sims

EIC Comprehensive Chromodynamics Experiment

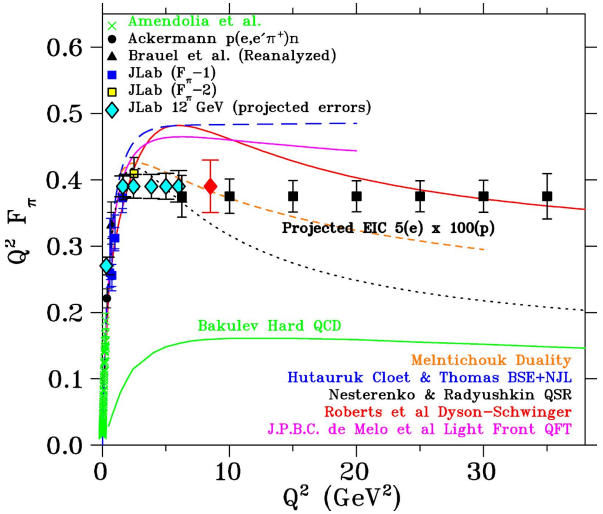
Key Characteristics:
- BaBar 1.5T magnet
- µRWell & Si tracker
- PID DIRC/mRICH/dRiCH
- Calo: Barrel, e-/Hadron endcap, Roman pots, ZDC, B0

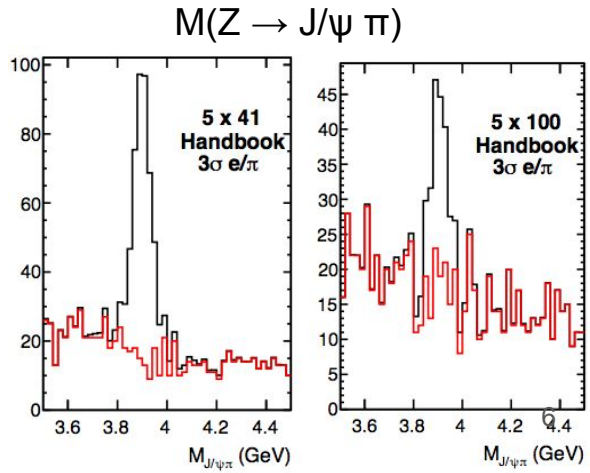
EIC Canada involvement:
- U Regina: G. Huber (meson form factors at high Q^2); Z. Papandreou (spectroscopy of XYZ states)
- Event generators, Far forward detector studies
- Novel AI Work: Inner tracker design optimization; calo design using hierarchical density-based clustering

Canadian resources:
- JLab ifarm, Regina resources

Canadian Contributions: U. Regina

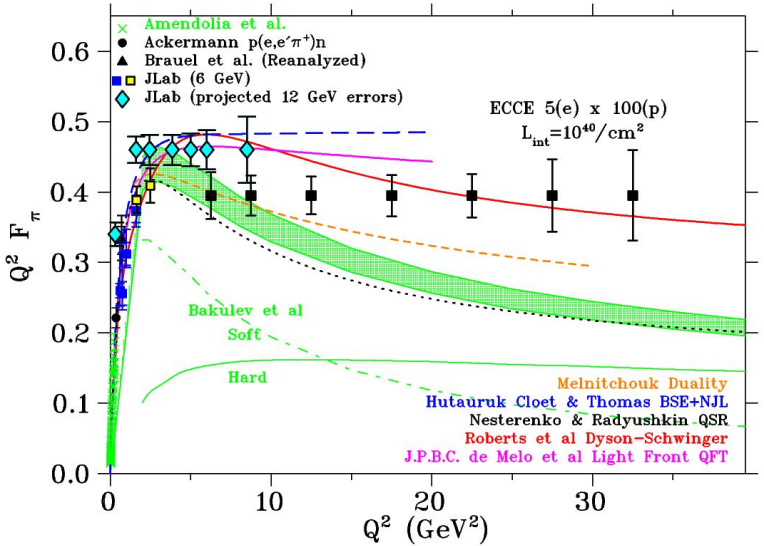
- Pion form factors as probe of emergent mass generation in hadrons
  - Precision at high momentum transfers
- Light and heavy quark spectroscopy
  - Hadron Spectroscopy has components in: Semi-inclusive, Heavy Flavor and Exclusive.
  - Explore underlying degrees of freedom in Charmonium states
  - Explore Bottomonium Exotic Sector
- Artificial intelligence detector co-design
- Detector development (ongoing with ANL, UM)
  - EM barrel calorimeter based on GlueX Pb/SciFi design, with AstroPix (low-power ATLASPix) silicon imaging layers for shower profile measurements





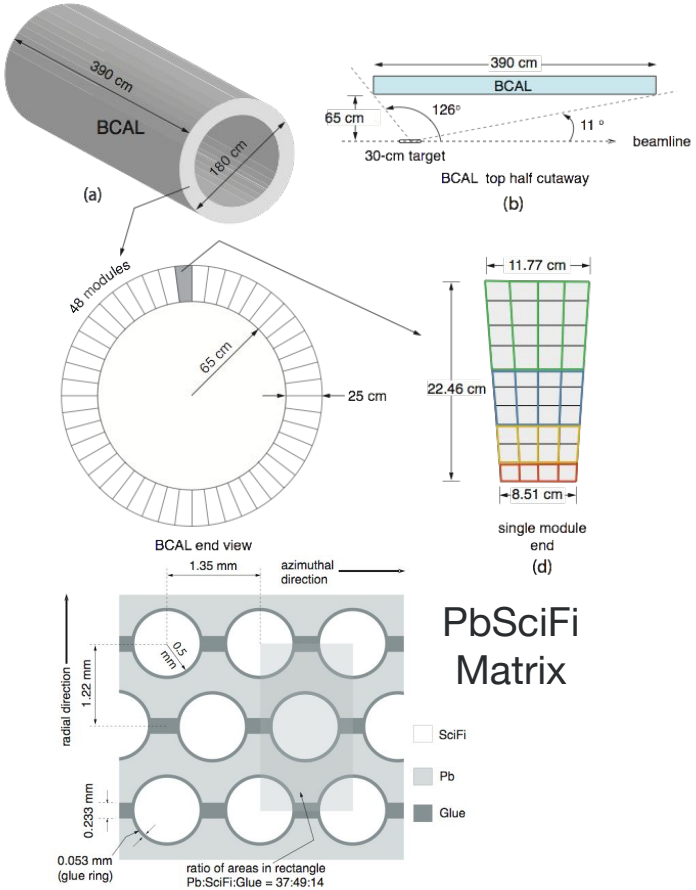
Pion form factor as probe of emergent mass generation in hadrons

- Electromagnetic form factors of charged pion (F_π) and kaon (F_K) are rich source of insights into the roles played by confinement and Dynamical Chiral Symmetry Breaking in fixing the hadron's size, mass, defining the transition from strong- to perturbative-QCD domains.
- Regina group pion form factor feasibility simulations were instrumental in establishing importance of ECCE ZDC performance for *t* reconstruction resolution.
- Extension to feasibility studies of kaon form factor utilizing far forward detectors underway.



Projections published in Eur.Phys.J. A **55** (2019) 190 and J.Phys.G **48** (2021) 075106.

The GlueX Barrel Calorimeter



Key Features

- E-M sampling calorimeter (9.5% samp. fraction)
- 750,000 double-clad scintillating fibers
- 0.5mm Pb corrugated sheets
- BCAL: 28 tonnes
- Shower reconstruction and PID

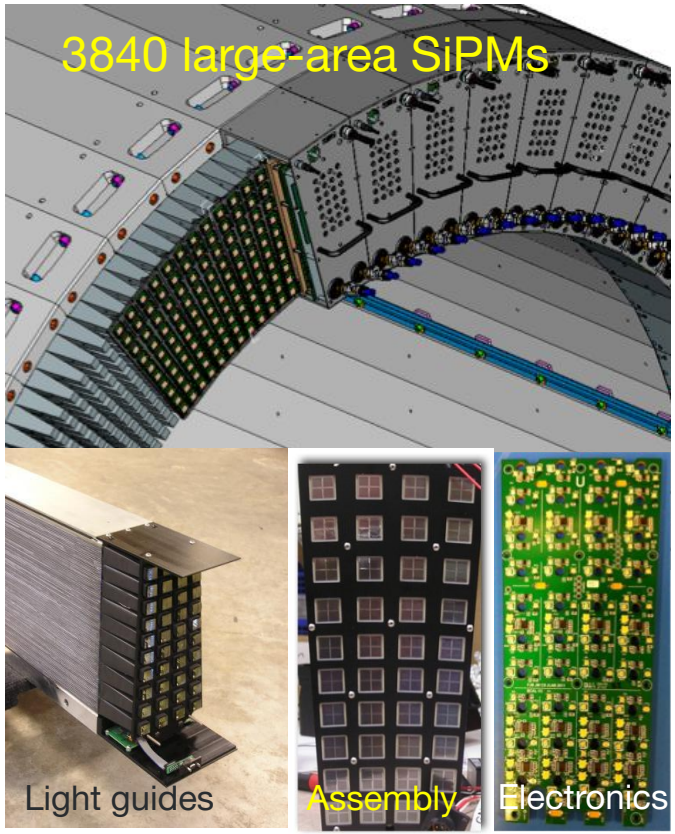
International funding:

- US$10M from DOE (without electronics)
- NSERC operating funds for labour

International consortium:

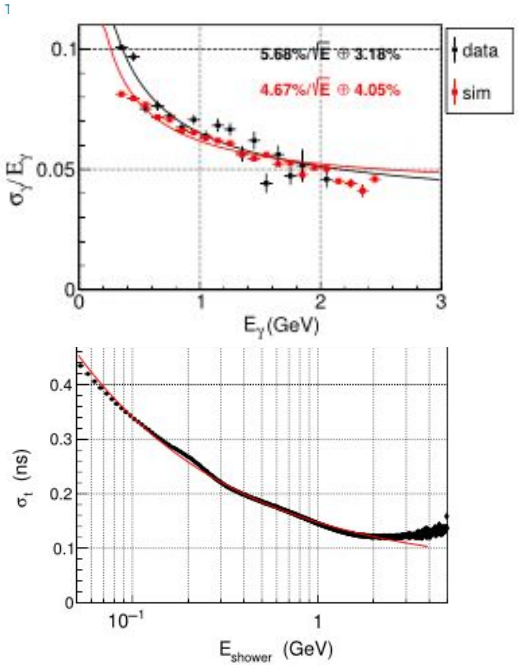
- U. Regina (Canada)
- U. Tecnica Federico Santa Maria (Chile)
- U. Athens (Greece)
- Carnegie Mellon U.
- Indiana U.
- Jefferson Lab

GlueX Barrel Cal: Readout and Performance



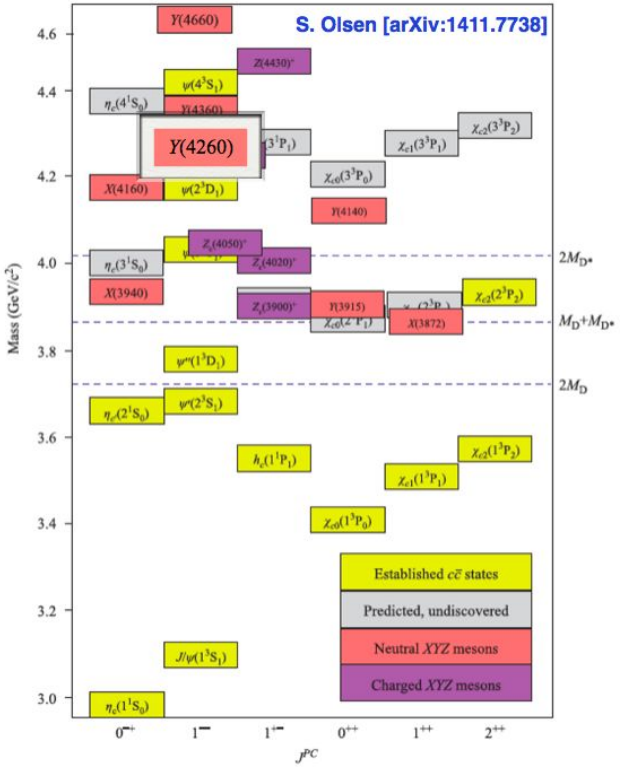
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 896, 11 July 2018, Pages 24-42

Construction and performance of the barrel electromagnetic calorimeter for the GlueX experiment



EIC Spectroscopy

XYZ States



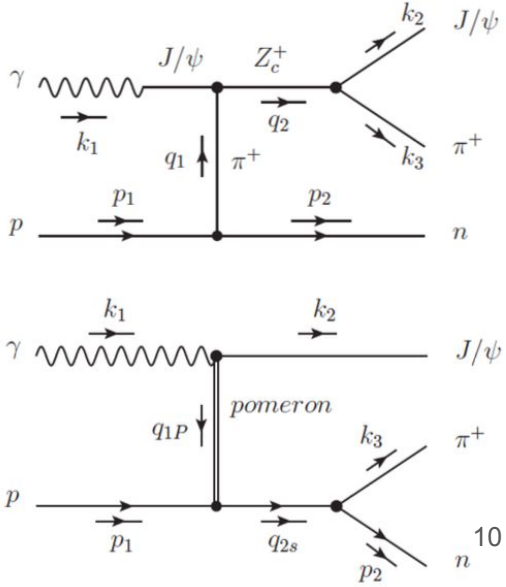
- Many new states observed in the last decade
- Not predicted by standard charmonium models
- Interpretation: resonant states, meson molecules, re-scattering effects, etc.
- Bottomonium exotic sector studies needed
- Electro-/photo-production allows access to different kinematics which can help confirm their resonant nature

Example: $Z_c^+(3900)$

International consortium:

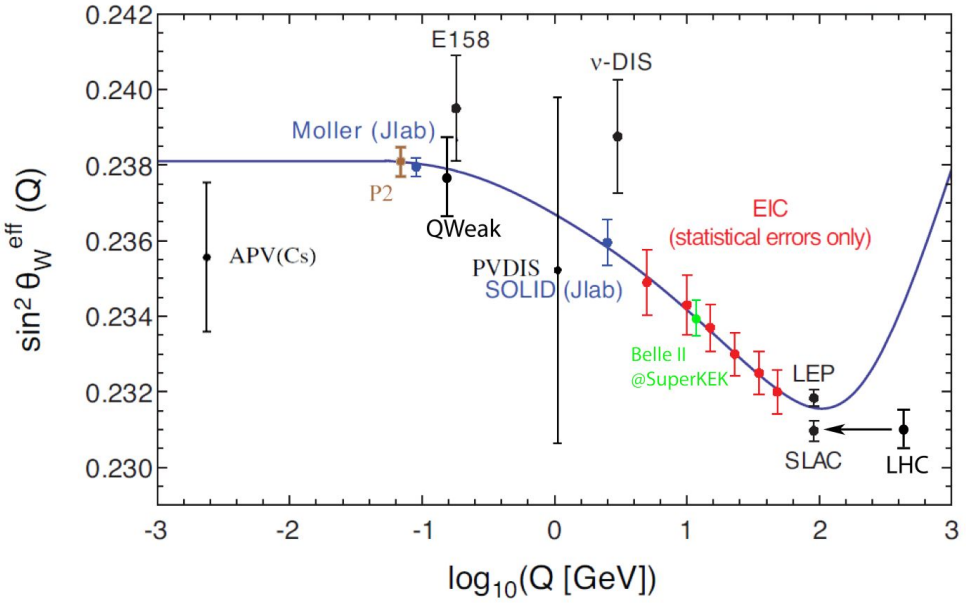
- U. Regina (Canada)
- U. Glasgow (UK)
- INFN (Italy)
- Florida State U.
- Indiana U.
- William & Mary
- Jefferson Lab
- JPAC

Active theoretical model development



Canadian Contributions: U. Manitoba

- Exploiting parity-violation in weak interaction to access observables:
  - Strangeness in nucleon (fixed target)
  - Precision searches for new physics
- CC and NC program of precision $\sin^2\theta_W$ measurements at the EIC span unexplored region between low energy and Z-pole (LHC)
- BSM: leptoquark, CLFV
- Polarimetry detector development:
  - Electron spectrometer with HV-MAPS
- Core software development efforts



Ref: YX Zhao, Eur.Phys.J.A (2017) 53:55

Summary

- Canada has a history of involvement in major international projects.
- EIC Canada Collaboration groups have strong involvement in physics programs leading up to the EIC and in the EIC program itself.
  - Interactions between BNL/JLab and TRIUMF leadership may impact the priorities in the next TRIUMF 5-year plan (2025-2030).
- EIC Canada Collaboration believes it realistic that we will reach involvement of **10 faculty members by 2029**, with ~20 highly qualified personnel.
- EIC Canada Collaboration projects operational funding of $550k / year by 2029, and contributions to **detector construction at the $6M+ scale**.
- Anticipate **major detector construction effort** by EIC Canada Collaboration (calorimetry, polarimetry).