

# Fundamental Symmetries

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Jeff Martin



THE UNIVERSITY OF  
WINNIPEG

# Overview of submissions

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- Fundamental Symmetries had 22 submissions
  - 20 experimental, 2 theoretical (Holt & Navratil)

nEXO	Nab	MOLLER	TUCAN	PENeLOPE	TRINAT	BeEST/SALER
Francium	ALPHA/HAICU	TRIUMF accel.	SC magnets	Gamma spec	Detailed struct.	Rad. Mol.
EDM <sup>3</sup>	EIC	2-step RIB	TITAN	Quantum	Boland accel.	

# What did they lead with?

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- Dominantly FunSym:
  - nEXO
  - Nab
  - MOLLER
  - TUCAN
  - PENeLOPE
  - TRINAT
  - BeEST/SALER
  - Francium
  - ALPHA/HAICU
  - Rad. Mol.
  - EDM<sup>3</sup>
- Partly FunSym
  - Gamma spec
  - Detail nucl. struct.
  - EIC
  - TITAN
- Theory
  - Holt, Navratil
- Accelerator & new capabilities
  - TRIUMF, Boland, 2-step RIB
- Other technology
  - SC Magnet, Quantum

# Looking back: the 2020 brief (20 pages)

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# Possible outline

## Comparing 2020 to 2025

2020	2025 (?)
T/CP <ul style="list-style-type: none"> <li>• TUCAN</li> <li>• RadMol</li> <li>• FrEDM</li> </ul>	T/CP <ul style="list-style-type: none"> <li>• TUCAN</li> <li>• RadMol</li> <li>• EDM<sup>3</sup> (also TRINAT)</li> </ul>
Z0 <ul style="list-style-type: none"> <li>• MOLLER</li> <li>• Fr</li> <li>• EIC</li> </ul>	Z0 <ul style="list-style-type: none"> <li>• MOLLER</li> <li>• Fr</li> <li>• EIC</li> </ul>
CPT <ul style="list-style-type: none"> <li>• ALPHA/HAICU</li> </ul>	CPT <ul style="list-style-type: none"> <li>• ALPHA/HAICU</li> </ul>
Nuclear decay <ul style="list-style-type: none"> <li>• 0+ -&gt; 0+ (TITAN, GRIFFIN)</li> <li>• BL3</li> </ul>	“Vud” (“precision $\beta$ -decay”?) <ul style="list-style-type: none"> <li>• 0+ -&gt; 0+ (GRIFFIN, TITAN)</li> <li>• Nab</li> </ul>
$\beta$ - $\nu$ correlations <ul style="list-style-type: none"> <li>• TRINAT</li> <li>• Nab, NPDGamma, N3He</li> </ul>	<ul style="list-style-type: none"> <li>• TRINAT</li> <li>• SALER</li> <li>• PENeLOPE</li> </ul> <p style="text-align: right; color: red;">combine (?)</p>
$\nu$ <ul style="list-style-type: none"> <li>• nEXO</li> <li>• BeEST</li> </ul>	$\nu$ <ul style="list-style-type: none"> <li>• nEXO</li> <li>• BeEST</li> <li>• Detailed nucl. struct. (<math>0\nu\beta\beta</math>)</li> </ul>

**Contact: J. Martin**

**Winnipeg, Manitoba, UBC, UNBC,  
TRIUMF; Japan, USA, Mexico**

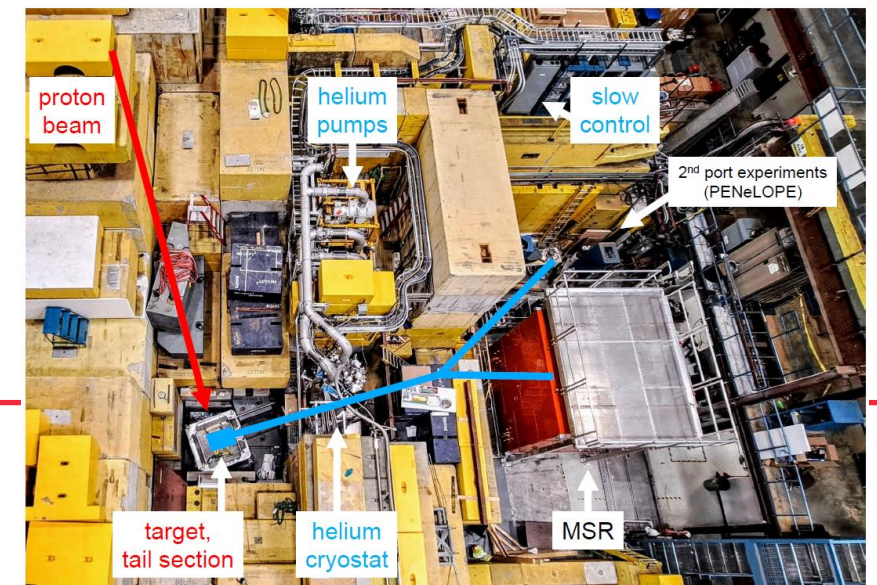
# TUCAN

## Goal

- Neutron EDM measurement to  $1e-27$  ecm, factor of ten better than present world's best

## Past five years

- UCN source upgrade nearing completion
- Source cryogenic systems tested extensively
- Magnetically shielded room completed construction and characterization
- First commissioning with beam
  - It happened on Wednesday, June 11, and we observed our first ultracold neutrons with the new source



## Next seven years

- Run nEDM experiment
- Upgrade helium liquefier, also UCN source and EDM experiment (CFI IF 2025)

## Beyond

- Other neutron experiments
- Upgrades to facility and nEDM experiment, if compelling to do so.

**Contact: S. Malbrunot-Ettenauer**

**UBC, TRIUMF, Toronto, Manitoba, Waterloo, McGill, Ottawa;  
USA, UK, NL, Germany**

# RadMol

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## Goal

- EDMs of octupole-deformed nuclei with trapped molecules (1e7 improvement over  $^{199}\text{Hg}$  EDM)

## Past five years

- Opportunities paper (2023)
- Preparation of laboratory
- Would profit from ARIEL

## Next seven years

- Complete the laboratory
- Complete EDM experiment (?)

## Beyond

- Going beyond EDM searches, e.g. nuclear anapole moments

**Contact: E. Hessels**

**York, Toronto; USA**

**NEW to CINP/LRP**

# EDM<sup>3</sup>

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## Goal

- eEDM improvement by 2-4 orders of magnitude, using polar molecules in cryogenic inert-gas solids

## Past five years

- Demonstration of implantation and addressing BaF (2024)
- Calculation that molecules can have their orientation fixed in the matrix (2023)
- Laser-induced fluorescence and optical pumping characterized (2024)
- Preparation of molecular beam (2023, 2024)

## Next seven years

- Need to improve purity of sample
- Improved purity eEDM measurement planned to take place by 2030

## Beyond

- Continued improvement of purity, lowering temperature of solid, systematic effects to increase accuracy from 2030-2040.
- Final accuracy 2-4 orders of magnitude improv't

**Contact: J. Mammei**

**Manitoba, Winnipeg, Memorial, UNBC;  
USA, Italy, Germany**

# MOLLER

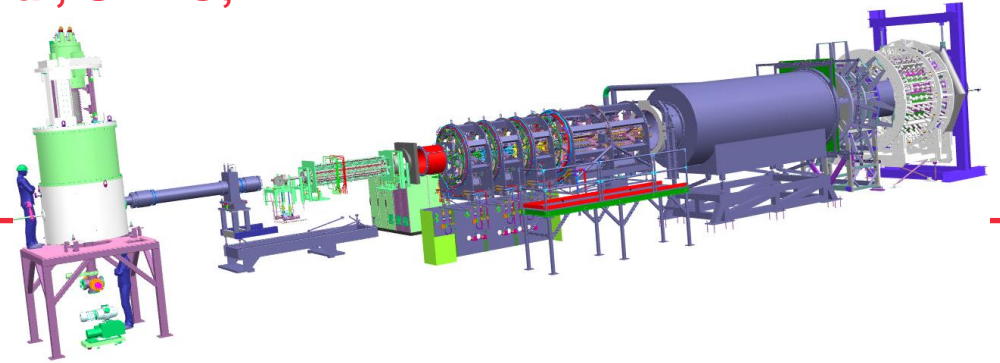
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## Goal

- Most precise measurement of  $\sin^2\theta_W$  at low energy, with similar precision as Z-pole meas'ts

## Past five years

- Preparing the MOLLER apparatus
- Major Canadian contributions:
  - Spectrometer magnet design
  - Main detectors, install Fall 2026
- Building on important previous work of Qweak experiment (Nature, 2018)



## Next seven years

- Will run in Hall A at JLab from 2026-2030 in three major runs.
- Analysis continuing until 2032.

## Beyond

- Likely decommissioned before 2034-2041 timeframe

# FrPNC

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## Goal

- Not submitted, yet

## Past five years

- Not submitted, yet

## Next seven years

- Not submitted, yet

## Beyond

- Not submitted, yet

**Contact: M. Fujiwara**

**TRIUMF, York, Calgary, SFU, BCIT, UBC, Uvic;  
Denmark, UK, US, Brazil, Sweden, Israel.**

# ALPHA/HAICU

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## Goal

- Test of CPT and weak equivalence principle pushing  $\bar{H}$  spectroscopy to  $H$  level or beyond

## Past five years

- Nature articles on hyperfine spectroscopy (g.s. and 1S-2S), fine structure and Lamb shift (1S-2P), laser cooling, and free fall under gravity.
- Canadians are 1/3 of ALPHA and lead ALPHA-g and HAICU

## Next seven years

- Exploit ALPHA-2, ALPHA-g
- 2026-2030: ALPHA next generation (CFI IF 2025), allowing  $\bar{H}$ & $H$  trapping
- Develop atomic fountain and interferometer techniques (HAICU), after 2030 deploy at CERN

## Beyond

- Develop antihydrogen techniques (quantum sensing)
- Antimatter molecules
- Other new ideas arising from HAICU

# Nab, PNab

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## Goal

- Measure A, B, a to determine  $\lambda = g_A/g_V$ . With  $\tau_n$ , gives  $V_{ud}$  free of nuclear corrections. b accesses exotic couplings

## Past five years

- Preparing the apparatus (?)

## Next seven years

- 2027: a, b precision data set
- 2028-2032: PNab measurement of A, B

## Beyond

- No plans beyond 2032

# TRINAT

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## Goal

- $V_{ud}$ , neutrino helicity, and T-violating decays using laser-trapped potassium isotopes and isomers.  
Also charge radius measurement ?

## Past five years

- Analog-antianalog isospin mixing in 47K  $\beta^-$ -decay
- Atomic shakeoff in  $\beta^+$  decay (in prep.)
- ?

## Next seven years

- Upgrade electrostatic spectrometer and complete improved  $\beta$ -v correlation measurements in 37K, 38mK, 38gK, and 47K.
- Charge radius of 38mK.

## Beyond

- Any results breaking the standard model could drive further improvements.

Contact: R. Picker  
TRIUMF; Germany  
New to CINP/LRP

# PENeLOPE

## Goal

- Precision (0.1 s) measurement of the neutron lifetime, for  $\nu_{ud}$ , BBN, and neutron lifetime puzzle.

## Past five years

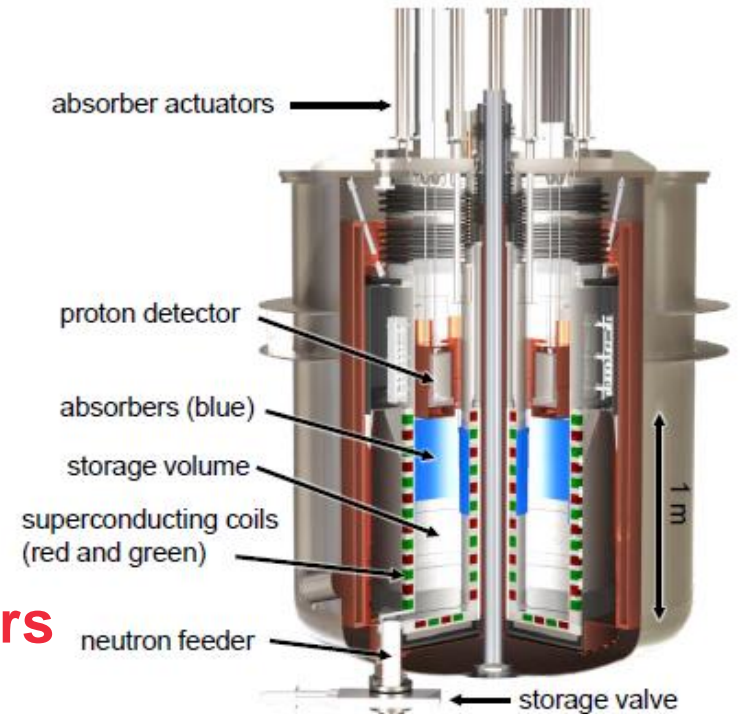
- Apparatus completed at TUM, 2020.
- Moved to TRIUMF, 2024.
- First cryogenic testing at TRIUMF completed spring 2025.
- Quench testing and
- Careful studies of systematic effects; D. Salazar, MSc thesis, SFU 2024

## Next seven years

- Will be ready to receive UCNs at TRIUMF in 2027.
- By 2030: complete 0.1 s
- 2030-2032 implement proton detection

## Beyond

- If statistically interesting, can try different methods of loading the trap, to push further in statistical precision.



# nEXO

**Contact: T. Brunner**

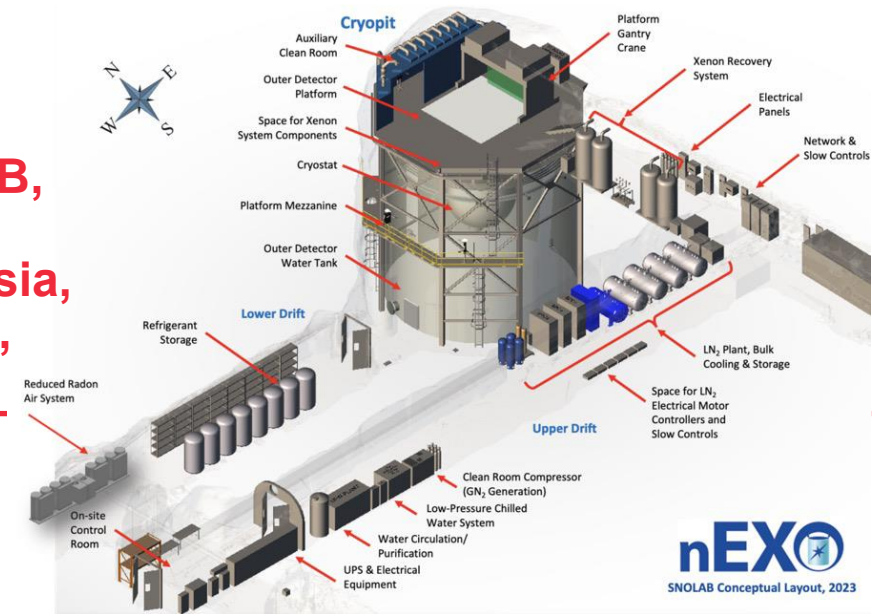
**McGill, Sherbrooke, TRIUMF, SNOLAB,  
Laurentian, Carleton, Windsor,  
McMaster, Queen's; US, France, Russia,  
China, Germany, Korea, South Africa,  
Japan, Switzerland**

## Goal

- $^{136}\text{Xe}$   $0\nu\beta\beta$  lifetime  $> 10^{28}$  yrs using a 5-tonne single-phase TPC; 15 meV intermediate scale goal

## Past five years

- Canadian led initiatives:
  - photodetector R&D, novel digital photosensors (PDC), radiopurity screening, and simulation frameworks
  - To be located in the Cryopit at SNOLAB
  - CFI IF support 2020 and 2023
  - Canada could lead this project (US DOE prioritizes LEGEND)
- Summit at Heidelberg, recently



## Next seven years

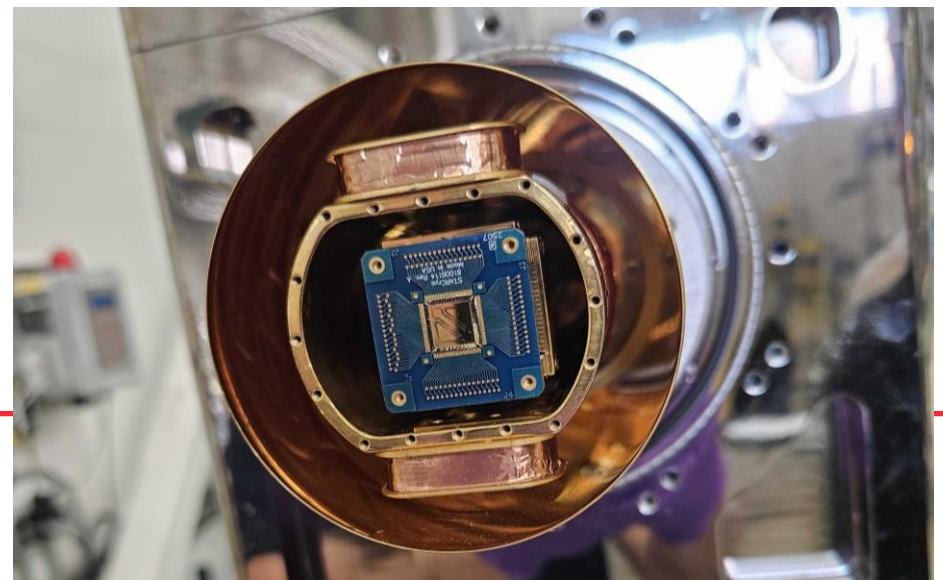
- Build international collaboration
- Site prep at SNOLAB and installation
- Commissioning 2033

## Beyond

- Decade-scale science run
- Increase enrichment of  $^{136}\text{Xe}$  over time
- Design new apparatus to measure to  $m_{\beta\beta} < 1$  meV

**Contact: A. Lennarz**  
**TRIUMF, McGill, McMaster;**  
**US, France, Portugal,**

# BeEST, SALER



## Goal

- Search for BSM physics in weak nuclear decays using STJs. BeEST: heavy neutral leptons, SALER:  $\beta - \nu$  angular correlation

## Past five years

- Limits on sub-MeV sterile neutrinos (PRL 2021)
- $7\text{Be}$  L/K Capture Ratio (PRL 2020)
- Spatial extent of a neutrino wavepacket (Nature, 2025)
- Excited-State Nuclear Recoil Spectroscopy (arXiv)

## Next seven years

- Analyze BeEST Phase III data
- Begin Phase IV with higher activity
- Deploy at TRIUMF and FRIB for short-lived  $\beta$  emitters

## Beyond

- General-purpose facility for neutrino mass, dark section, nuclear structure research
- User platform sustaining Canadian leadership in quantum-enabled nuclear physics

# Partially FunSym

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## Vud / Precision beta-decay

- Gamma spec & TITAN to improve precision on  $0^+ \rightarrow 0^+$   $F_t$  values (Vud), also octupole def. for RadMol
- How to disentangle SALER from BeEST?

## Neutral weak currents

- EIC to perform precision measurement of  $\sin^2\theta_W$  using PVDIS (NC)
  - Also: CLFV and charged-current DIS

## Neutrinoless double beta decay

- Garrett et al. (“Detailed Nucl. Struct.”) measurement of matrix elements relevant to  $0\nu\beta\beta$

## Theory

- Only Holt & Navratil checked the FunSym box. Where do they belong?
- Barkanova & Aleksejevs are MOLLER collaborators
- Should some “particle” theory be included? (e.g. Ritz, Czarnecki, Morrissey, McKeen, ...)

## Techniques

- What to do with “quantum”?



# What are Canada's priorities?

June 7, 2025 – Ottawa, Ontario – Prime Minister's Office

## PRIME MINISTER CARNEY ANNOUNCES CANADA'S G7 PRIORITIES AHEAD OF THE LEADERS' SUMMIT

Anchored in building stronger economies, Canada will seek agreements and co-ordinated action on three core missions:

- **Protecting our communities and the world**—strengthening peace and security, countering foreign interference and transnational crime, and improving joint responses to wildfires.
- **Building energy security and accelerating the digital transition**—fortifying critical mineral supply chains and using artificial intelligence and quantum to unleash economic growth.
- **Securing the partnerships of the future**—catalyzing enormous private investment to build stronger infrastructure, create higher-paying jobs, and open dynamic markets where businesses can compete and succeed.

Other discussions will include a just and lasting peace for Ukraine and other areas of conflict around the world, and a forward-looking agenda that engages partners beyond the G7, recognizing that our long-term security and prosperity will depend on building coalitions with reliable partners and common values.

Of note:

- “Quantum”

Other things we are good at:

- “Co-ordinated action”
- “Building coalitions with reliable partners”

# Recommendations seen in the submissions

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- CINF, TRIUMF, NSERC, and CFI are important
- Dedicated SAP RTI support for new projects, quicker turnaround
- Need more HQP (x3)
- Need MRS & TRIUMF detector support (x3)
- HPC (x2)
- Prioritization based, in part, on CFI success
- Support for techniques, e.g. quantum sensing
- Explicit support for small-scale projects
- Link RTI-1 to project grant, at least making expert reviews available
- MRS needed at TRIUMF
- TRIUMF coop/ugrad support is important
- Canada/ISED needs mechanism to fund large-scale projects; CFI helpful but falls short
- (SNOLAB) project management important
- Need RTI-1 support

# Plan

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- Draft will be prepared based on input from the briefs.
- I would like to circulate the draft to the proponents for technical review and wordsmithing.
  - Let's represent your project in the best and most accurate way.