

Towards a Measurement of the Neutron Electric Dipole Moment with TUCAN

Noah Yazdandoost
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on behalf of the TUCAN Collaboration
September 28, 2026



TUCAN

TRIUMF Ultracold
Advanced Neutron
Collaboration



Collaboration meeting Mexico 2026

~ 60-80 collaborators

2 spokespersons, 1 from Japanese collaborators and 1 from Canadian collaborators

Executive Committee voting members 3 from Japan and 3 from Canada



THE UNIVERSITY
OF BRITISH COLUMBIA



UNIVERSITY OF
SASKATCHEWAN



University
of Manitoba



THE UNIVERSITY OF
WINNIPEG



J-PARC
J-PARC



KYOTO
UNIVERSITY



NAGOYA
UNIVERSITY



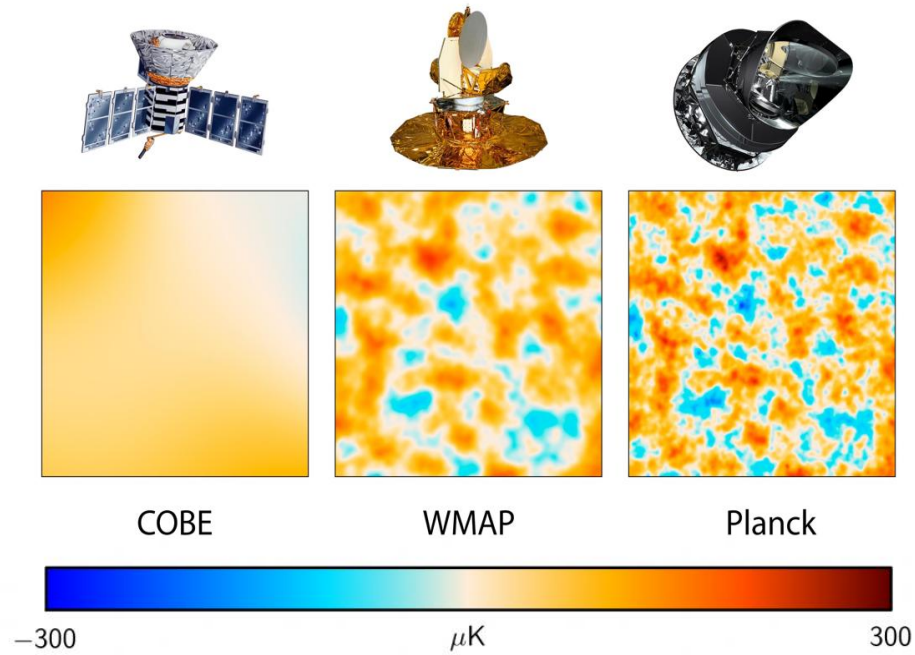
KYUSHU
UNIVERSITY



JSPS

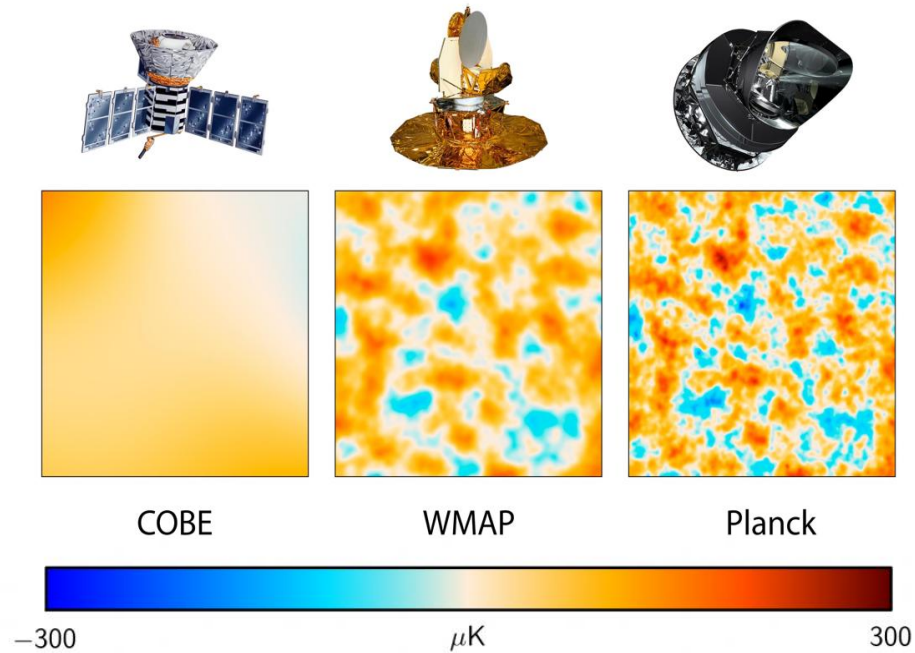


Why are we interested in electric dipole moments?



Wikimedia.org

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Wikimedia.org

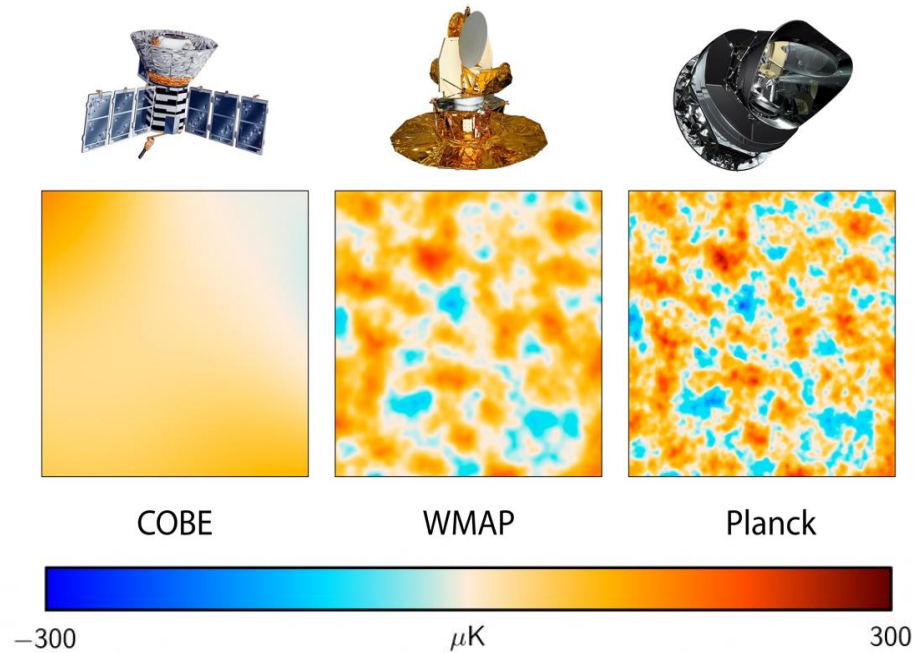


Observed:

$$\eta_b \equiv \frac{n_b - n_{\bar{b}}}{n_\gamma} \approx 10^{-10}$$

N. Aghanim et al., Astron. Astrophys. 2020, 641, A6.

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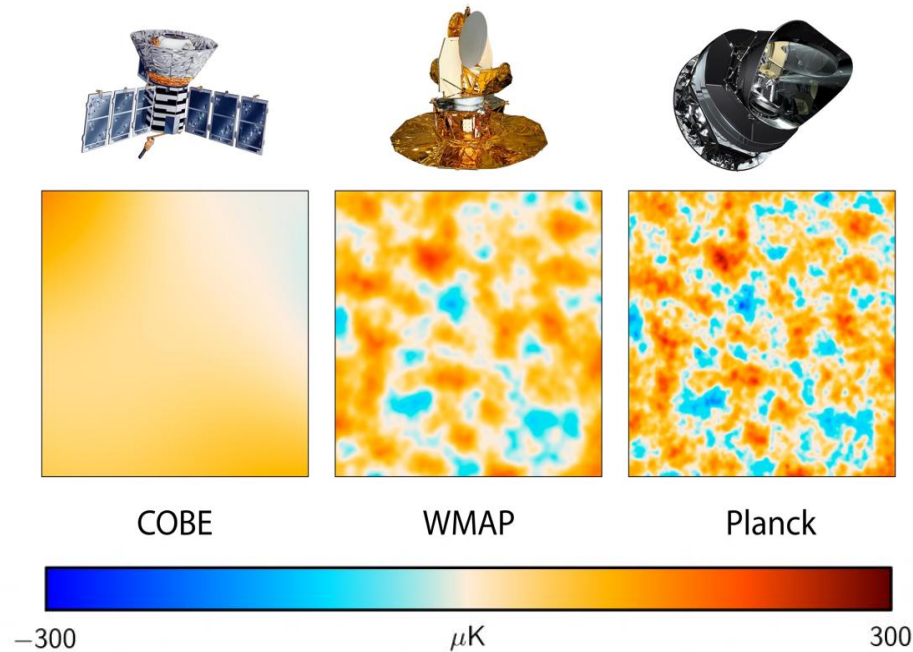
N. Aghanim et al., Astron. Astrophys. 2020, 641, A6.



1. Baryon number violation
2. Charge and Charge-Parity violation
3. Departure from thermal equilibrium

A. D. Sakharov, JETP Lett. 1967, 5, 24-27.

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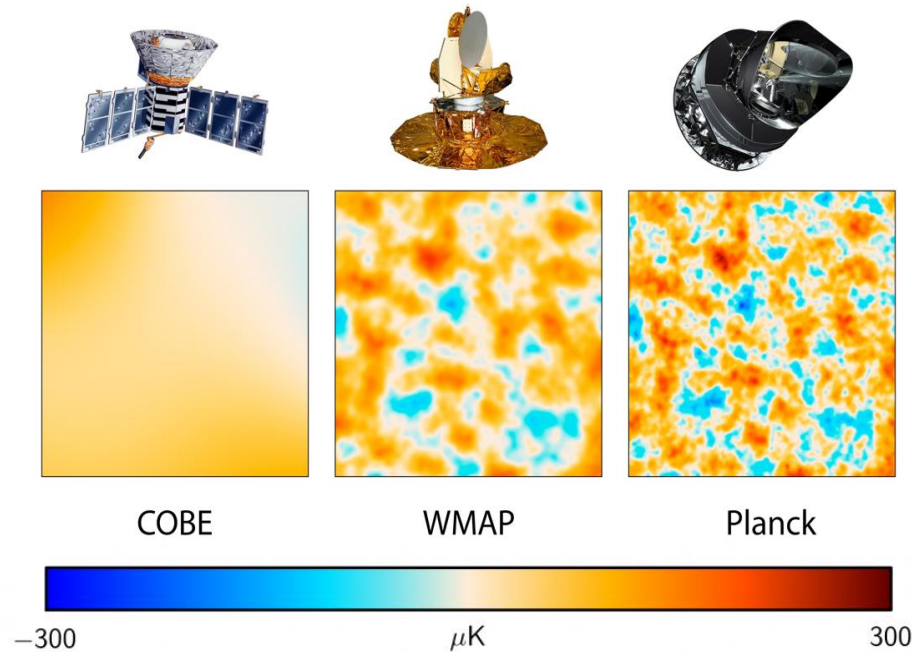
A. D. Sakharov, *JETP Lett.* 1967, 5, 24-27.



Charge-parity violation from the Cabibb-Kobayashi-Maskawa mechanism in the Standard Model is insufficient to explain the observed baryon asymmetry through electroweak baryogenesis.

P. Huet, E. Sather, *Phys. Rev. D* 1995, 51, 379–394.

Why are we interested in electric dipole moments?



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New sources of Charge-Parity violation are therefore required to explain the observed matter–antimatter asymmetry.



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N. Aghanim et al., *Astron. Astrophys.* 2020, 641, A6.



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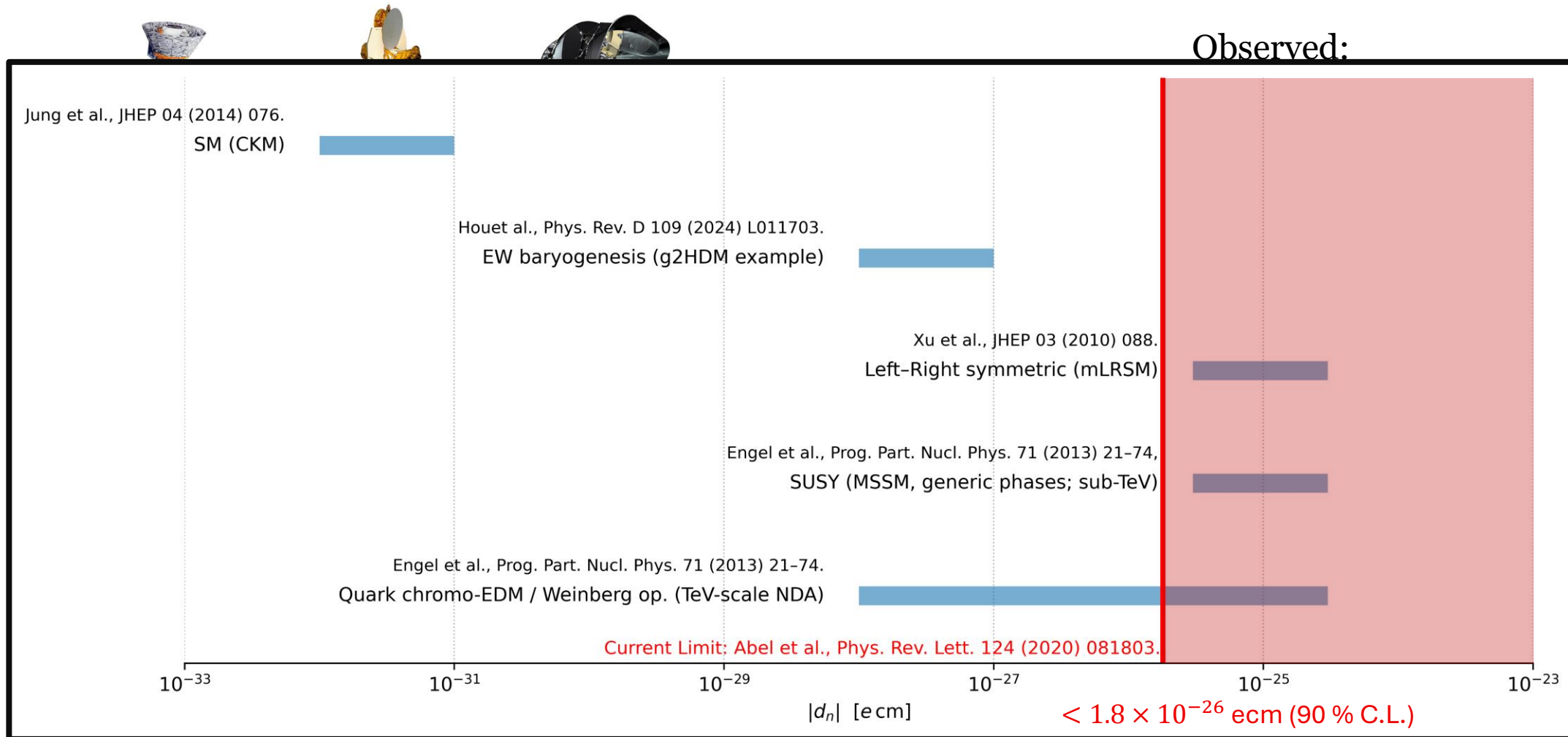


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matter-antimatter asymmetry.

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An international priority



Flagship projects with strategic physics outcomes: “TRIUMF can become a global centre for tests of CP and T violation via EDM searches”

Canadian Subatomic Physics Long-Range Plan 2022–2026, outlook to 2036.



Other **Offshore Opportunities in Japan’s Leadership**: “The project is based on the Ultra Cold Neutron (UCN) **technology developed in Japan.**”

Japan’s Updated Strategy for High Energy Physics for the ESPP Update 2026, March 2025, updated Oct. 2025.



“A discovery of a neutron EDM (nEDM) will be **paradigm shifting.**”

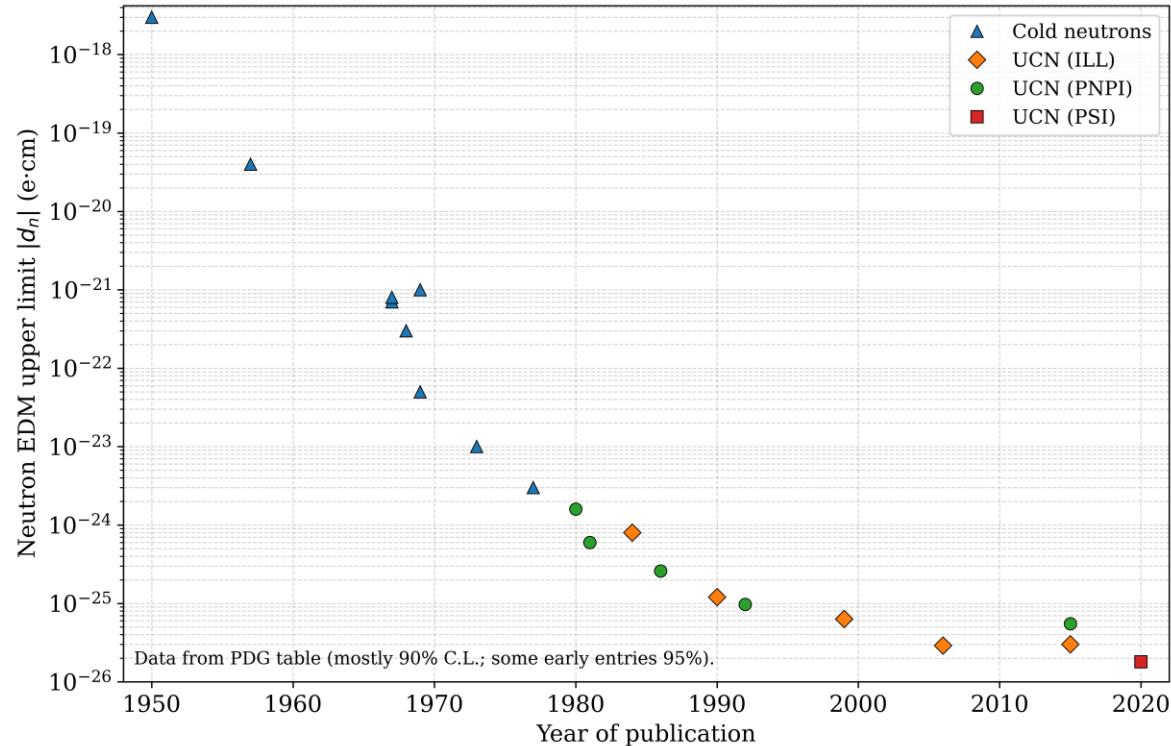
A New Era of Discovery: The 2023 Long Range Plan for Nuclear Science, NSAC.



“The progress in this field **critically relies on the availability, performance, and reliability of ultracold neutron sources.**”

Europe NuPECC Long Range Plan 2024.

Latest measurement



Latest published neutron EDM result

$$d_n = (0.0 \pm 1.1_{\text{stat}} \pm 0.2_{\text{sys}}) \times 10^{-26} \text{ e cm}$$

Uncertainty budget

Statistical 96.8%

Systematic 3.2%

Total uncertainty: $1.12 \times 10^{-26} \text{ e cm}$

C. Abel et al., Phys. Rev. Lett. 124 (2020) 081803.

arXiv

Physics > Instrumentation and Detectors

[Submitted on 3 Jul 2026]

A New High-Intensity Source for Ultracold Neutrons

K. Abe, S. Ahmed, B. Algori, D. Anthony, L. Barron-Palos, Y. Bylinsky, M. Bosse, M.P. Bradley, A. Brossard, J. Chak, R. Chiba, C. Davis, R. de Vries, K. Dong, K. Drury, B. Franke, D. Fujimoto, R. Fujitani, M. Gericke, P. Giampa, C. Gibson, R. Golub, K. Hatanaka, T. Hepworth, T. Higuchi, A. Jaison, B. Jamieson, K. Jorgensen-Fullam, M. Katotoka, S. Kawasaki, M. Kitaguchi, W. Klassen, E. Klemets, E. Korkmaz, E. Korobkina, F. Kuchler, M. Lavvaf, A. Lejuez, T. Lightbody, T. Lindner, S. Longo, K.W. Madison, J. Malcolm, J. Mammei, R. Mammei, C. Marshall, J.W. Martin, R. Matsumiya, M. McCrea, E. Miller, M. Miller, K. Mishima, T. Mohammadi, T. Momose, M. Nalbandian, T. Okamura, S. Pankratz, R. Patni, R. Picker, V. Purcell, K. Qiao, Y.-N. Rao, W. Rathnakela, T. Reimer, D. Salazar, W. Schreyer, T. Shima, H.M. Shimizu, S. Sidhu, S. Stargardter, R. Stutters, P. Switzer, Tushar, M. Uzair, S. Vanbergen, W.T.H. van Oers, N. Yazdandoost, Q. Ye, A. Zahra, L. Zhang

The TRIUMF UltraCold Advanced Neutron (TUCAN) collaboration has completed a new superthermal source for ultracold neutrons (UCNs) at TRIUMF. It uses neutrons from a spallation target driven by TRIUMF's main cyclotron. Heavy water and liquid deuterium serve as neutron moderators, and inelastic scattering inside superfluid ^4He at around 1.1-K slows the neutrons down to become ultracold. During commissioning runs with the completed source, including the deuterium moderator, up to $1.34(1) \times 10^7$ UCNs were detected in the experimental area after irradiating the target and accumulating UCNs in the source for 60-s. Up to $6.75(3) \times 10^5$ UCNs were detected during continuous operation, more than at any other source in the world.

<https://arxiv.org/abs/2607.03033>

A new world leader: TRIUMF's ultracold neutron source sets global benchmark

July 7, 2026



<https://triumf.ca/2026/07/07/tucan-ultracold-neutron-source-sets-global-benchmark/>

FROM ULTRAHOT TO ULTRACOLD: THE LIFE OF A NEUTRON AT TRIUMF

10¹⁰ Kelvin

COMIN' IN HOT

Protons traveling at 75% the speed of light smash into a tungsten target, creating a spray of hot, fast-moving neutrons.



TEMPERATURE & VELOCITY

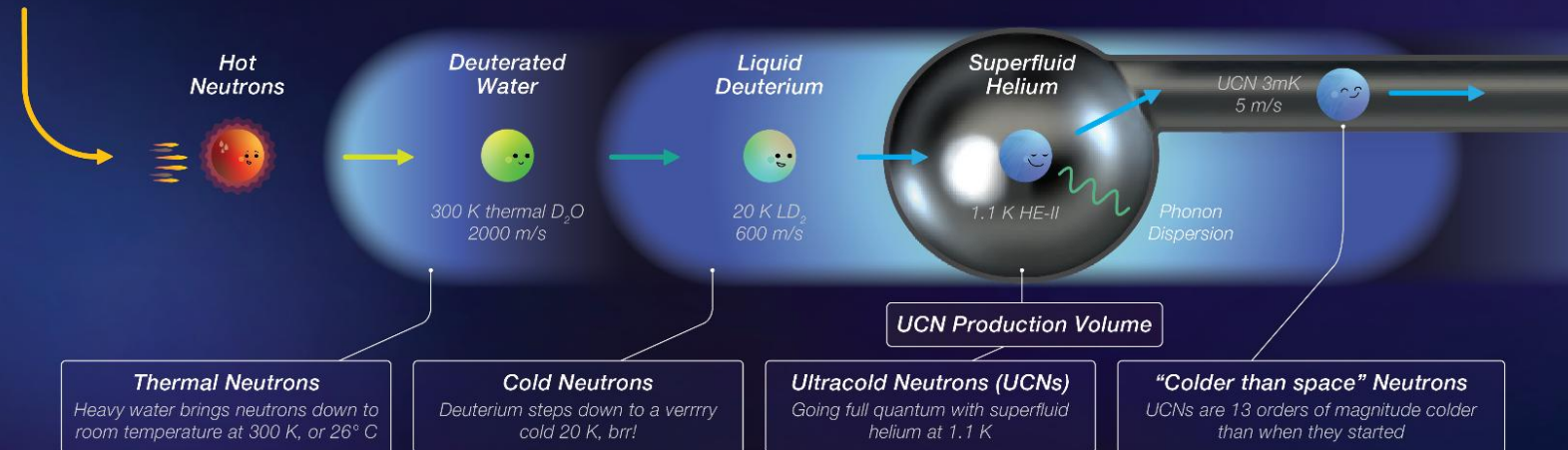
WHAT'S COOLER THAN COOL?

A neutron striking a superfluid helium atom creates a phonon of similar energy and momentum, slowing UCNs in their tracks — something nearly impossible to do with sub-atomic particles.

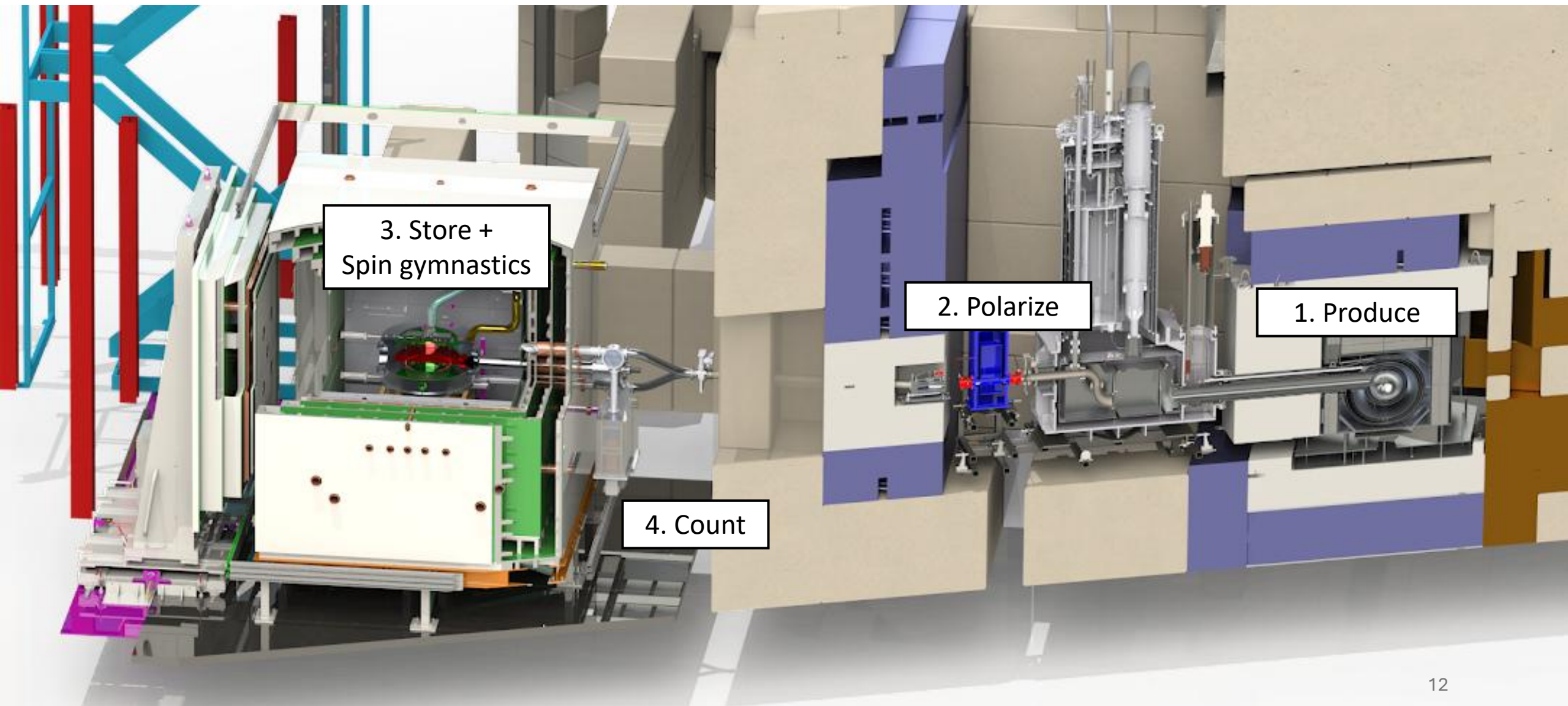
ULTRACOLD NEUTRONS!

At 3 millikelvin (mK), a neutron's speed is reduced to less than 20 km/h (about the speed limit in a school zone) — instead of passing through materials, they now bounce off surfaces.

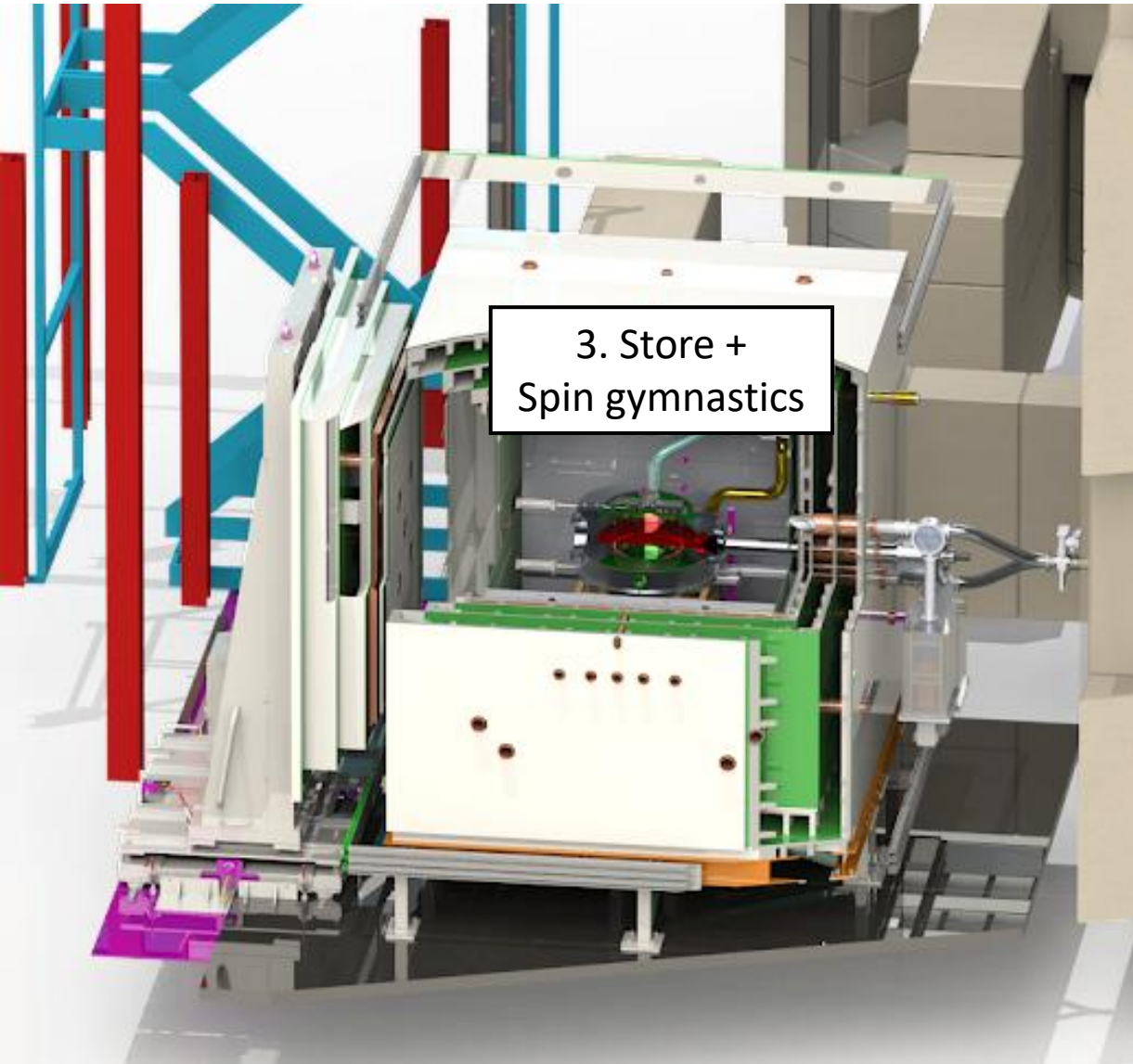
3 millikelvin



Overview nEDM at TRIUMF

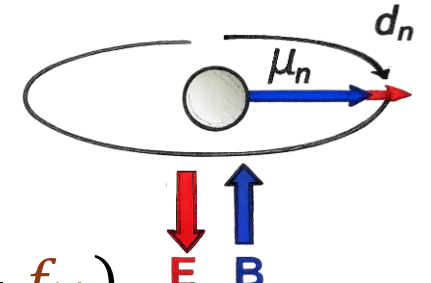
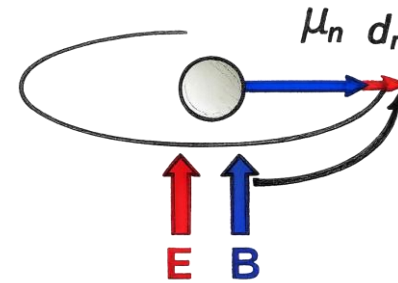


Overview nEDM at TRIUMF



- Measure the neutron spin-precession frequency using **Ramsey's method of separated oscillatory fields**
- Compare configurations with the **electric field parallel and antiparallel** to the magnetic field
- Look for an **electric-field-dependent frequency shift**

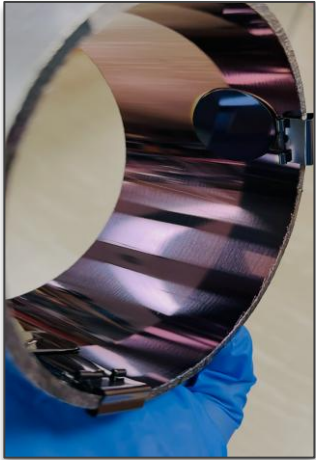
$$hf_{\uparrow\uparrow} = 2(\mu_n B + d_n E) \quad hf_{\uparrow\downarrow} = 2(\mu_n B - d_n E)$$



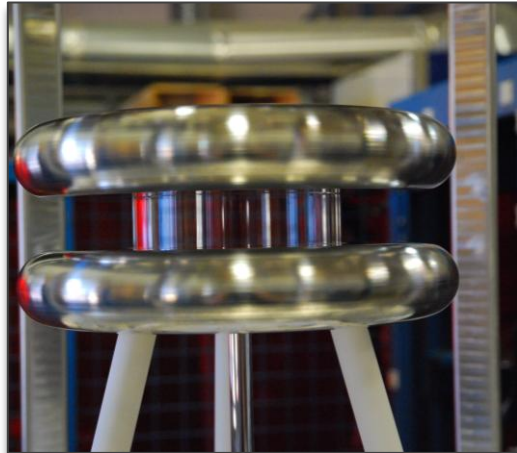
$$d_n = \frac{h(f_{\uparrow\uparrow} - f_{\uparrow\downarrow})}{4E}$$

Key technologies for TUCAN

Surface coatings



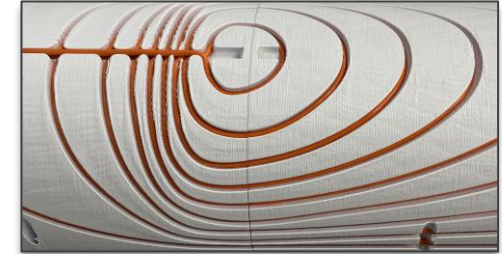
High Voltage



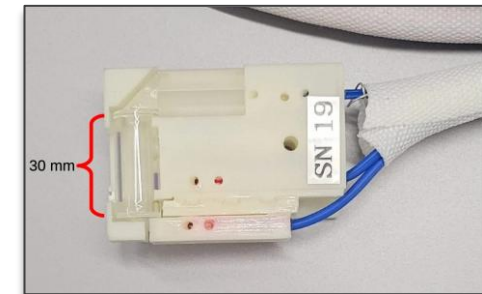
Cryogenics



Magnetic field generation



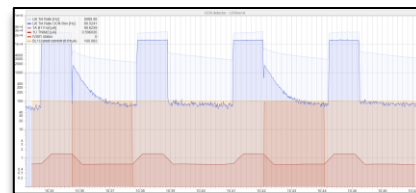
Magnetic field sensing



Vacuum technology



Data acquisition



UV laser technology



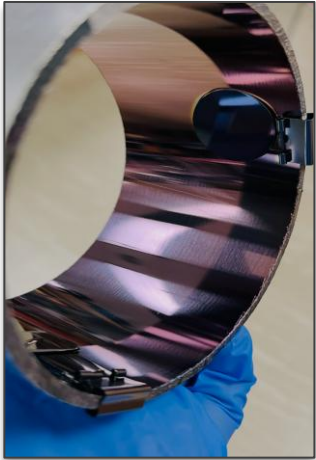
Magnetic field control



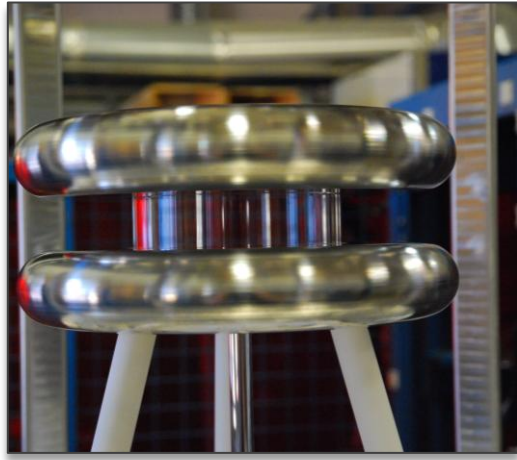
Precision metrology, low noise electronics,
proton beamline, spallation target, ...

Key technologies for TUCAN

Surface coatings



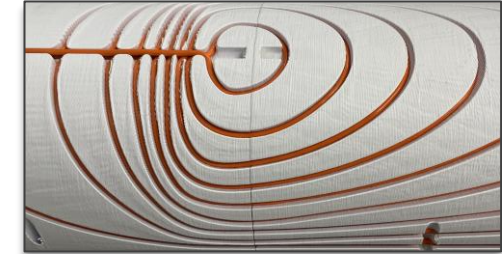
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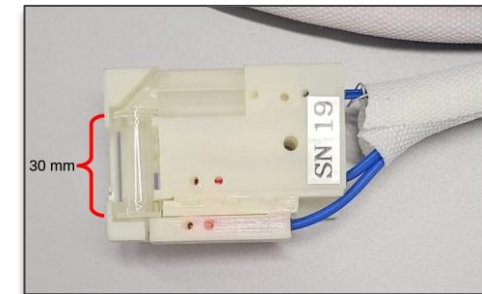
Cryogenics



Magnetic field generation



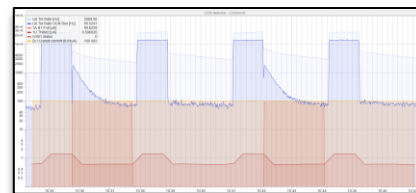
Magnetic field sensing



Vacuum technology



Data acquisition



UV laser technology



Magnetic field control

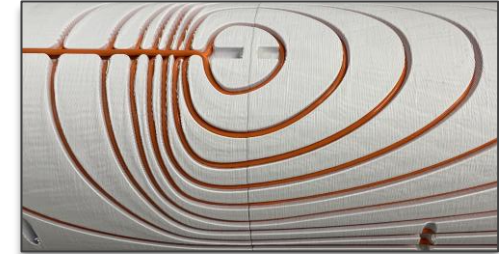


Precision metrology, low noise electronics,
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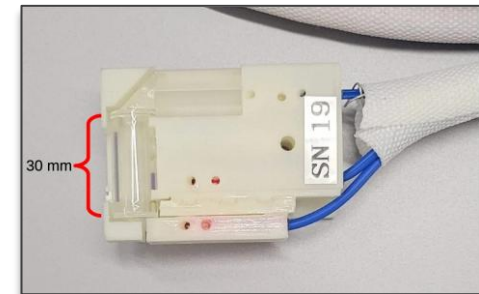
Key technologies for TUCAN

- TUCAN is fundamentally a **precision quantum experiment**, relying on neutron spin manipulation and control
- We **develop and operate quantum sensors**, including cesium and mercury magnetometers, and characterize commercial **optically pumped magnetometers**
- We study **superfluid helium**, a **macroscopic quantum system**, and **cryogenic heat transport**
- We train highly qualified personnel in **quantum sensing, laser technology, cryogenics, and precision magnetic-field control**
- Strong synergies with **QUP** for **quantum technologies in fundamental physics**

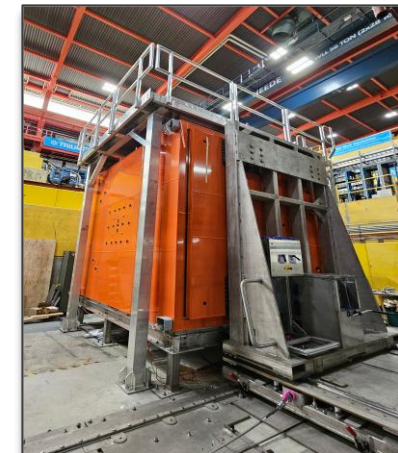
Magnetic field generation



Magnetic field sensing



Magnetic field control



Cryogenics



UV laser technology



International Center for
Quantum-field Measurement Systems for
Studies of the Universe and Particles
WPI research center at KEK

External Advisory Committee Feedback 2026

- International panel of experts reviews the experiment's status, progress, plans, risks, and technical challenges and prepares a written report
- Based on a 168-page review document and two days of presentations and discussions
- Representatives of our funding board also participated, providing direct oversight and engagement with the review process



Andy Saunders (Chair)
Oak Ridge National
Laboratory
Group Leader Neutron
Symmetries/
Fundamental Physics
with Neutrons



Bernhard Lauss
Paul Scherrer Institute
Group Leader UCN
Co-Spokesperson
n2EDM



Makoto Fujiwara
TRIUMF
Senior Research
Scientist
Spokesperson
ALPHA-Canada



Satoshi Mihara
Professor KEK-IPNS
Chair SOKENDAI
Particle & Nuclear
Physics Program



Koji Yoshimura
Okayama University
Professor, RIIS
Division Leader,
Quantum Universe



Naohito Saito
Director Institute of
Particle and Nuclear
Studies KEK



Rituparna Kanungo
TRIUMF
Director Physical
Sciences Division



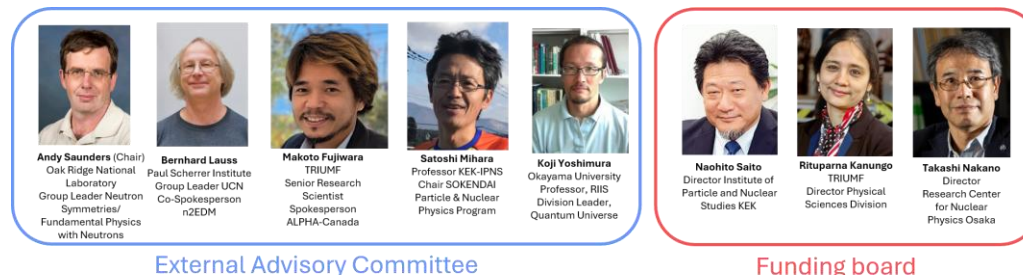
Takashi Nakano
Director
Research Center
for Nuclear
Physics Osaka

External Advisory Committee

Funding board

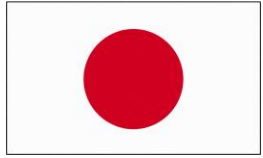
External Advisory Committee Feedback 2026

- “The **scientific merit and competitiveness** of this experiment **remain high**, especially given the changing landscape of fundamental physics measurements and neutron EDM searches in particular. **The competitiveness of this program has been dramatically improved by the recent demonstration of UCN production.**”
- “**Enhanced international collaboration** will be **critical** for the continued success of the project, as **the Japanese collaborators increase their leadership and collaboration on the development of the physics aspects of the nEDM experiment.** We recommend that all members of the collaboration pivot to focusing on experiment physics moving forward.”
- “**Explore other international funding opportunities, especially in Japan.**”
- “**Technician support** is now and will become even more **vital to the success** of the project. **We recommend that institution management identify and allocate such support.**”
- “**Overall efficiency** of the experiment progress would be **increased if TRIUMF operations staff** were to **take over operation of the source.**”



Past contributions

Neither side could have built TUCAN alone.



He cryostat



LD₂ cryostat



³He-⁴He heat exchanger



Prototype source



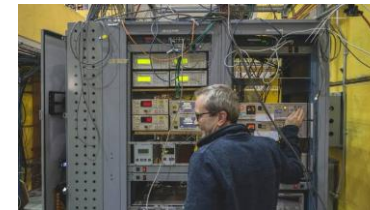
Proton beamline



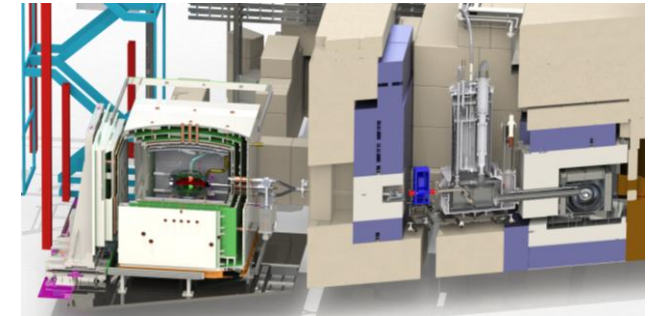
Main magnetic-field coil



Technical and
engineering support



Data acquisition
Science Technology
TRIUMF



Overall source and nEDM
experiment design



UCN commissioning
campaigns

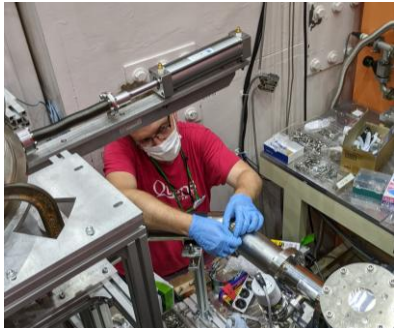
Exchange and Scientific Output

KEK–TRIUMF Exchange Program for Early Career Researchers

Sean Vanbergen, **2022**:
Prototype TUCAN electric
dipole moment storage-
cell measurements at
J-PARC



Alexis Brossard, **2023**: Qualification
of Equipment for the Neutron
Electric Dipole Moment Experiment
at J-PARC



- FY2019 Nana Yamamoto
- FY2022 Hiroaki Akatsuka
- FY2023 Ikuo Ide
- FY2024 Jinya Sato
- FY2026 Abeer Zahra (scheduled)
- FY2026 Kaito Abe (scheduled)

TUCAN Results in 2025–2026

B. Algoji et al. (TUCAN Collaboration), “Initial results of the TRIUMF ultracold advanced neutron source” Phys. Rev. C 114, L012501 (2026).

T. Hepworth et al., “Ultracold neutron guide-coating facility at U. Winnipeg,” Nucl. Instrum. Methods Phys. Res. A 1092, 171841 (2026).

S. Ahmed et al., “Initial Performance of the TUCAN Magnetically Shielded Room” arXiv:2604.15565 (2026).
Submitted to Rev. Sci. Instrum.

K. Abe et al. (TUCAN Collaboration), “A New High-Intensity Source for Ultracold Neutrons” arXiv:2607.03033 (2026).
Submitted to Phys. Rev. Lett.

Contributions in the next phase

- Submit a Canada Foundation for Innovation funding proposal this year for instrumentation funding for **2027–2031**
- The proposal **requires** a certain amount of **in-kind contribution**
- There are **additional exciting opportunities** for Japanese contributions **beyond the current commitments** (e.g. High-voltage system, Spin analyzer, Spin-guiding coils, UCN guides, ...)
- With the new ultracold neutron source operational, **now** is the time to **exploit** its capabilities for **frontier physics**, in particular the search for the **neutron electric dipole moment**

Contribution	Cash (M CAD)	In-kind (M CAD)	Total
INDUSTRY	—	1.334	1.334M CAD ≈ 150M ¥
JAPAN	—	2.400	2.400M CAD ≈ 269M ¥
CANADA	25.400	—	25.400M CAD ≈ 2848M ¥
GRAND TOTAL	25.400	3.734	29.134M CAD ≈ 3267M ¥

JPY values calculated using 1 CAD = 112.145 JPY.

Take-home message

- **Neutron electric dipole moment searches** are a **major international priority** for probing new sources of Charge-Parity violation.
- **TUCAN** has demonstrated a **world-leading ultracold-neutron source**, **enabling** the neutron electric dipole moment **physics program**.
- The external review **confirmed** the **strong scientific potential** of TUCAN and highlighted **deeper international collaboration as critical** for its success.
- The experiment relies on a broad range of **precision** and **quantum technologies**.
- TUCAN is a genuinely **joint Japan–Canada effort**, **neither side could have built it alone**.

Take-home message

- **Neutron electric dipole moment searches** are a **major international priority** for probing new sources of Charge-Parity violation.

TUCAN Collaboration Meeting Osaka 2026

 Oct 13, 2026, 10:00 AM → Oct 16, 2026, 12:00 PM Asia/Tokyo

 RCNP

 Kenji Mishima (RCNP, The university of Osaka) , Shinsuke Kawasaki (KEK) , Takashi Higuchi (KURNS / RCNP)

- for its success.
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