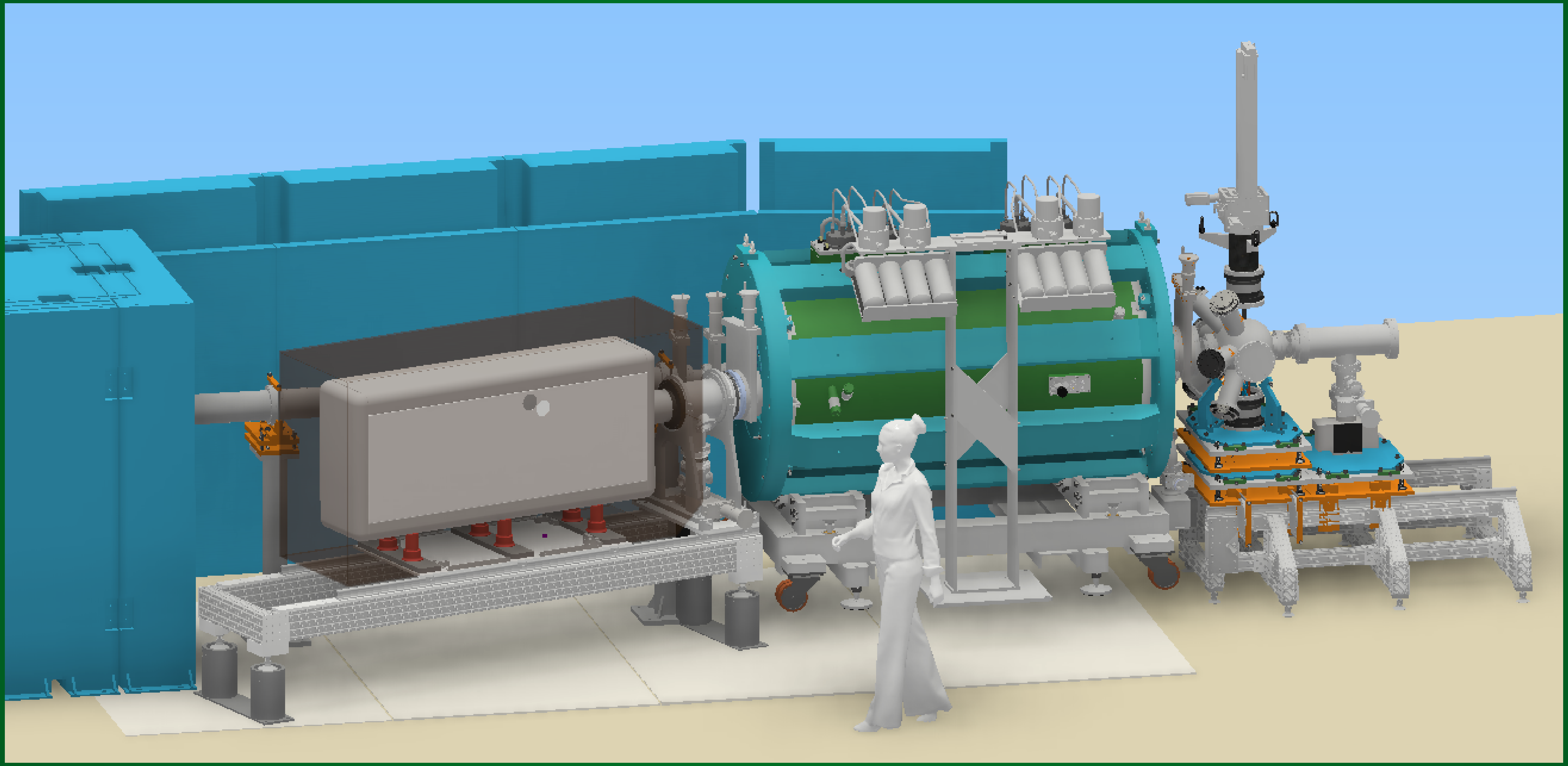
BL3: A Next Generation Beam Neutron Lifetime Experiment



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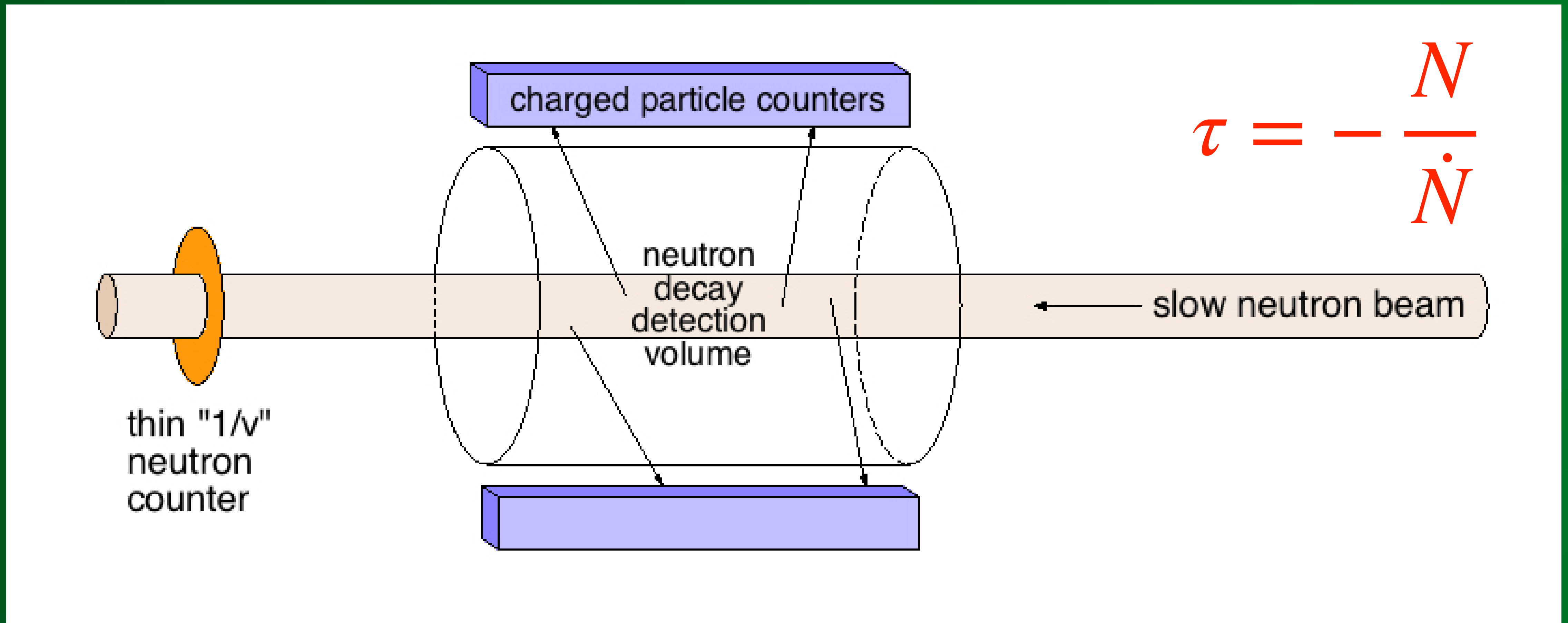
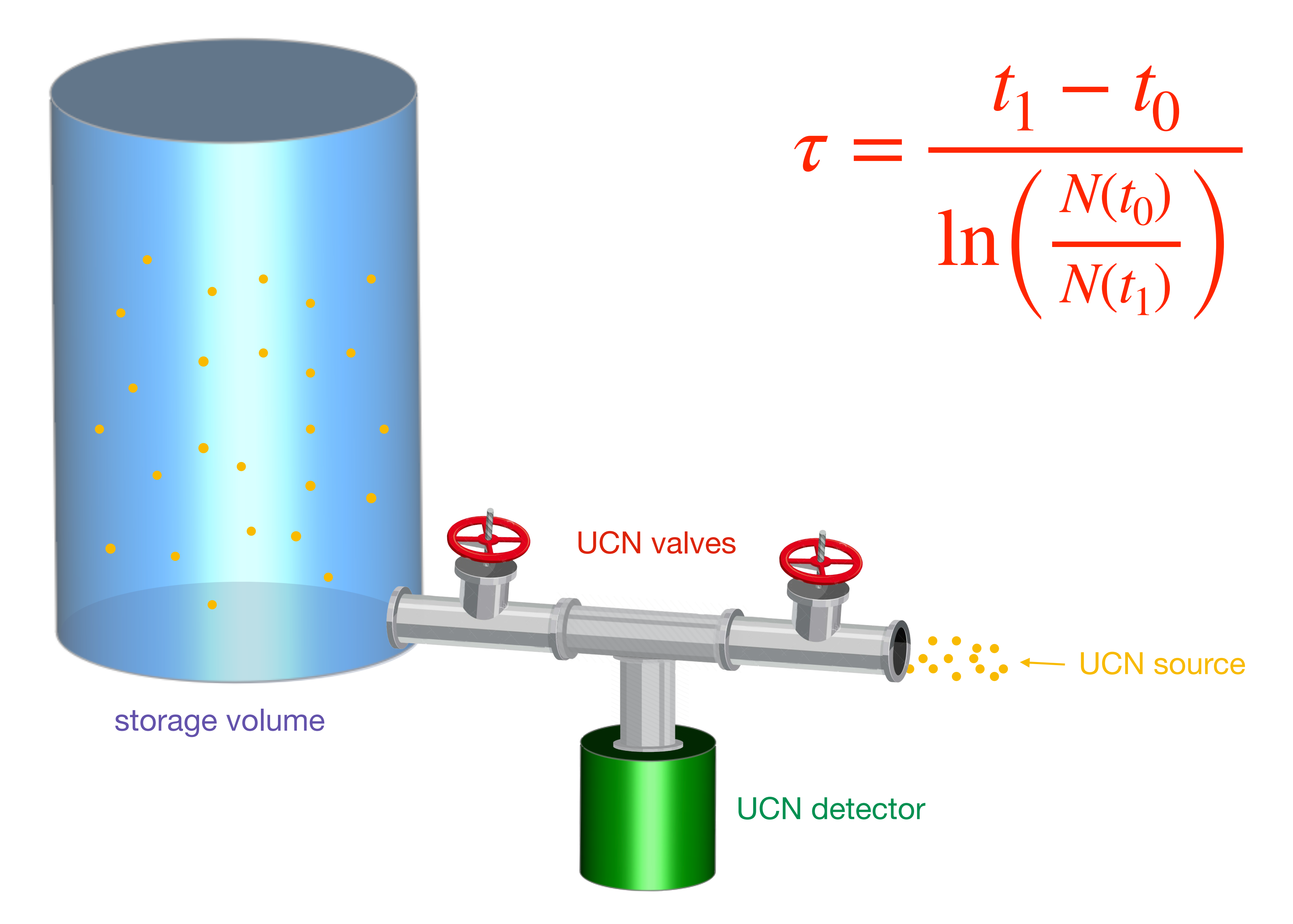
Neutron Lifetime Experiments

Two main methods

beam method



ultracold neutron (UCN) storage method



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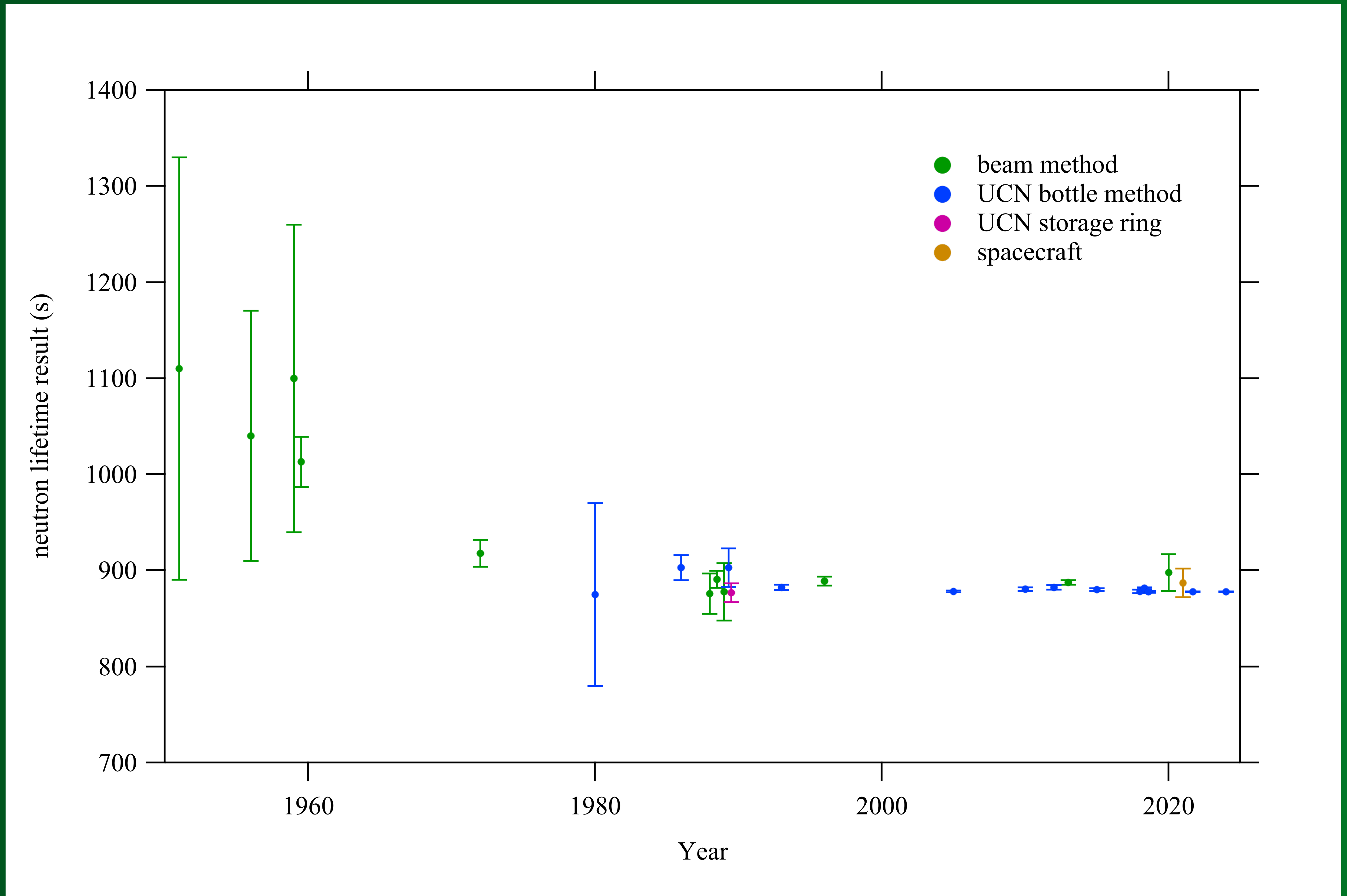

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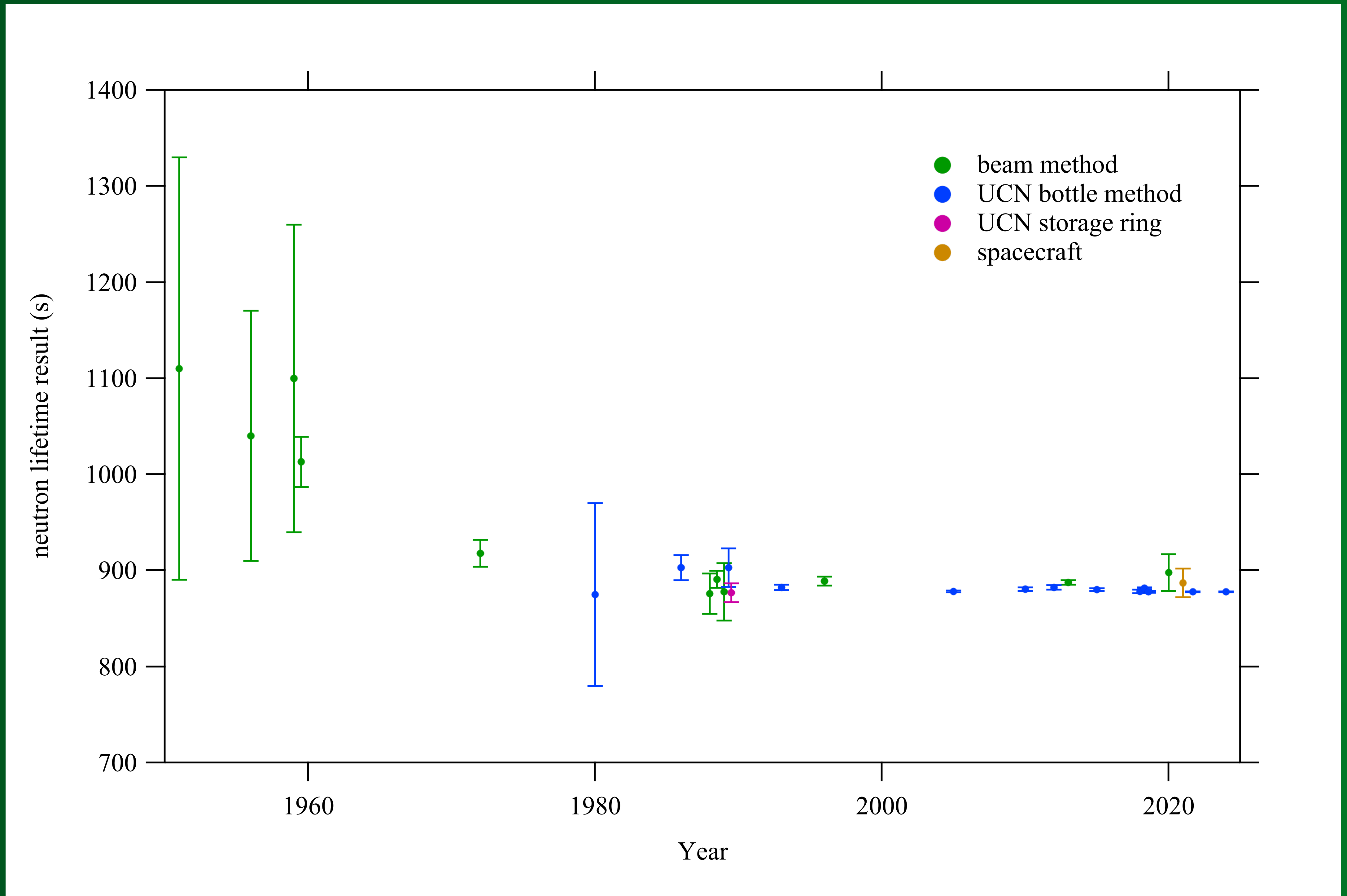

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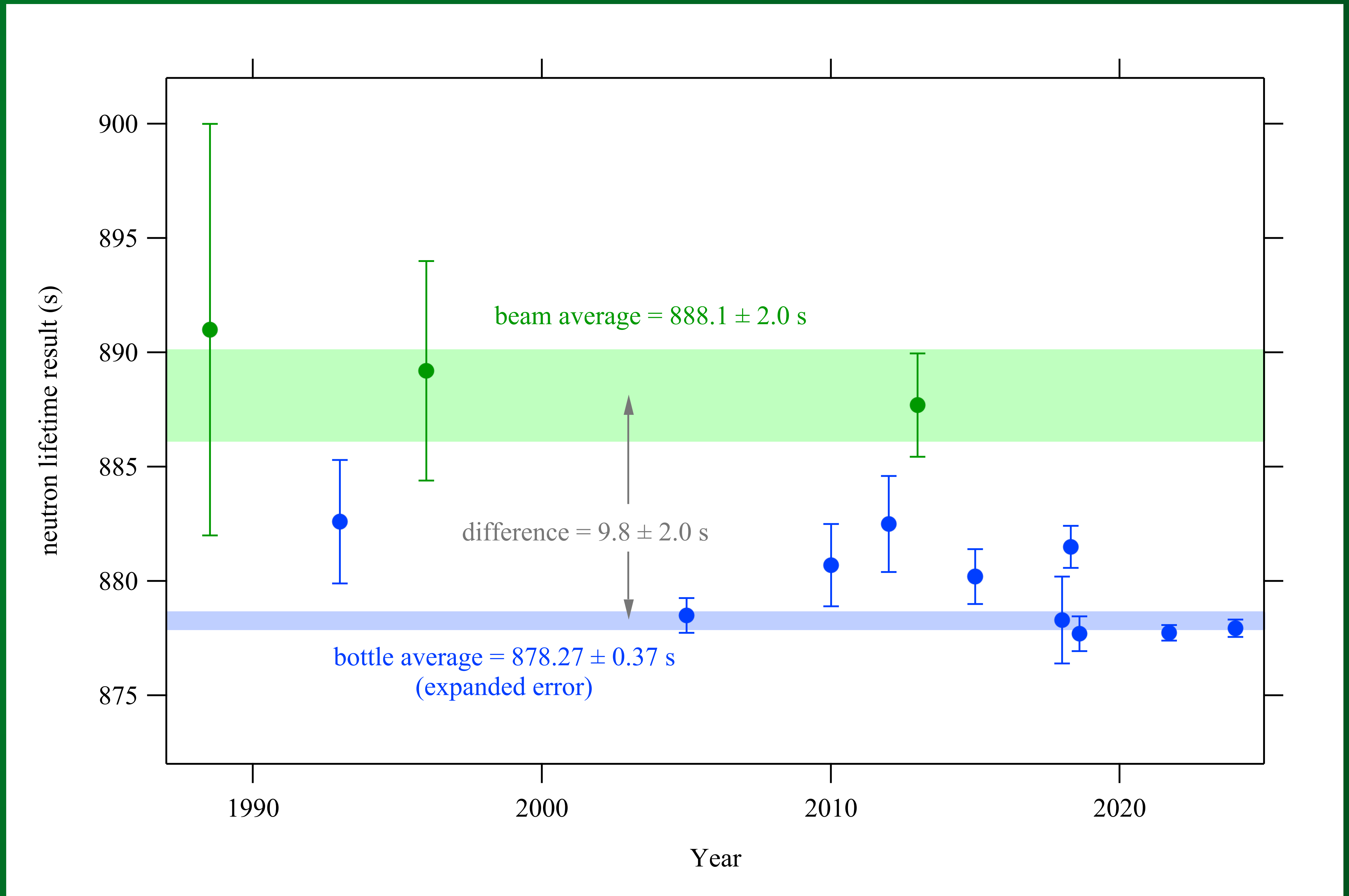

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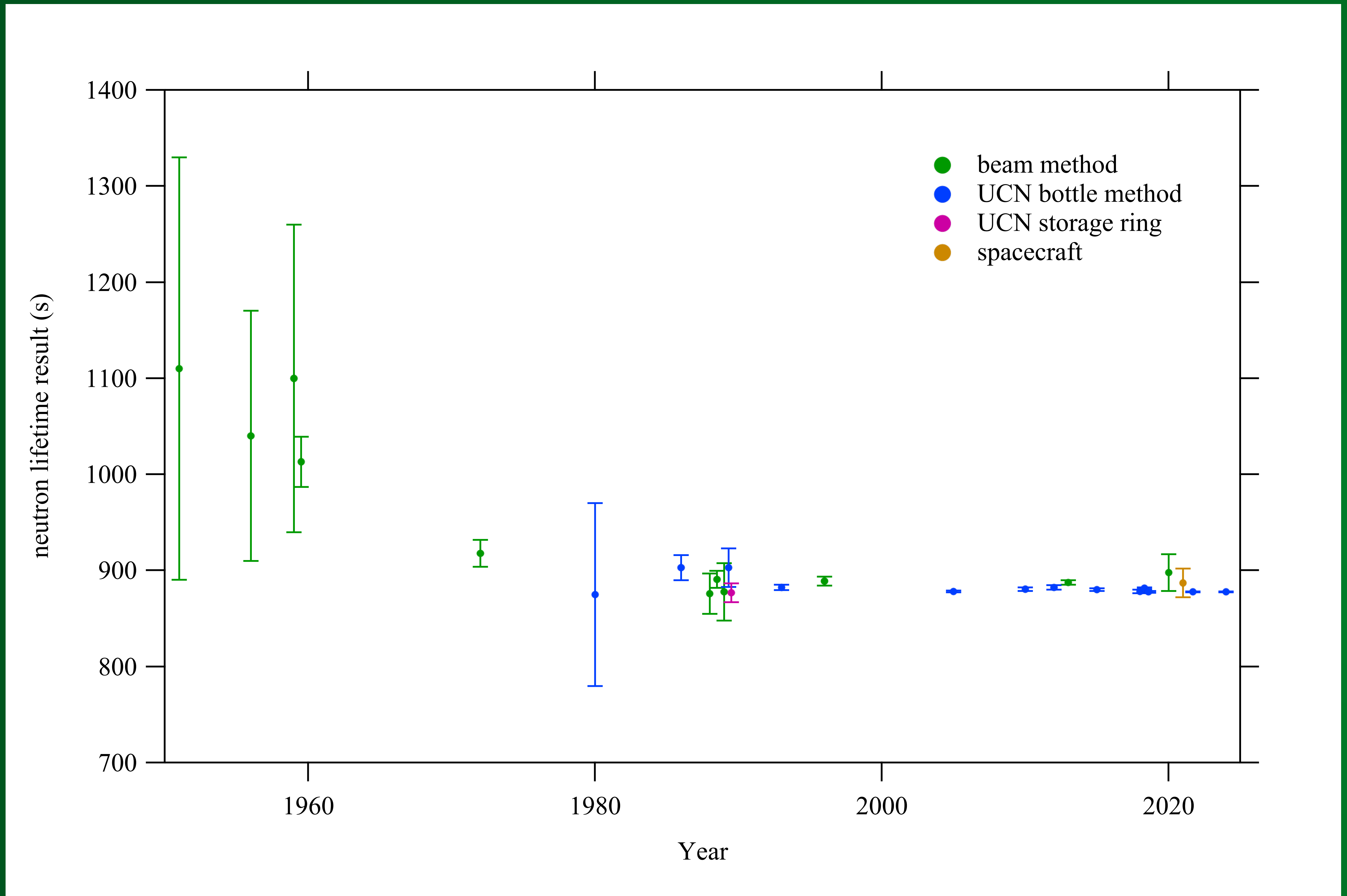

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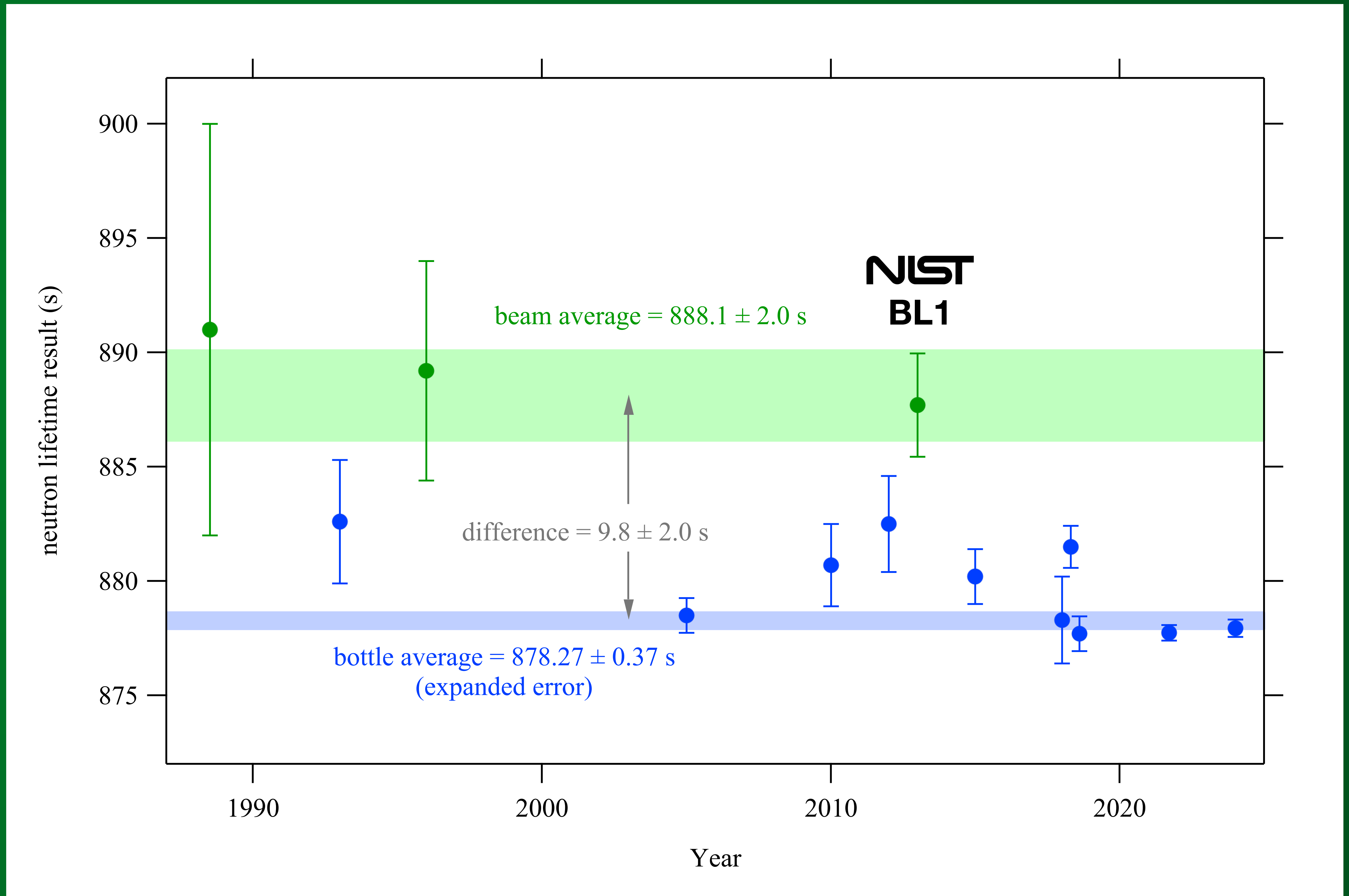

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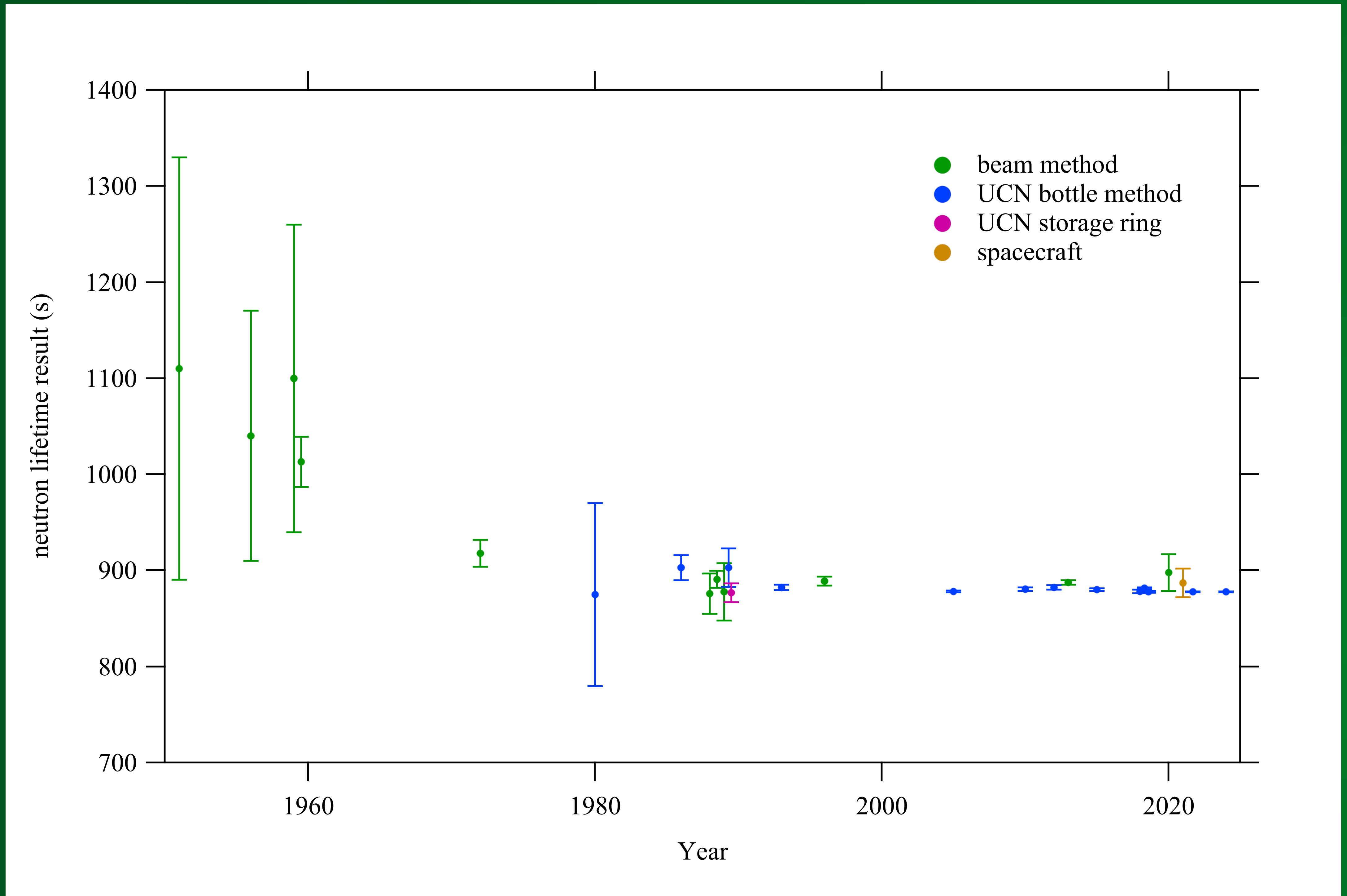

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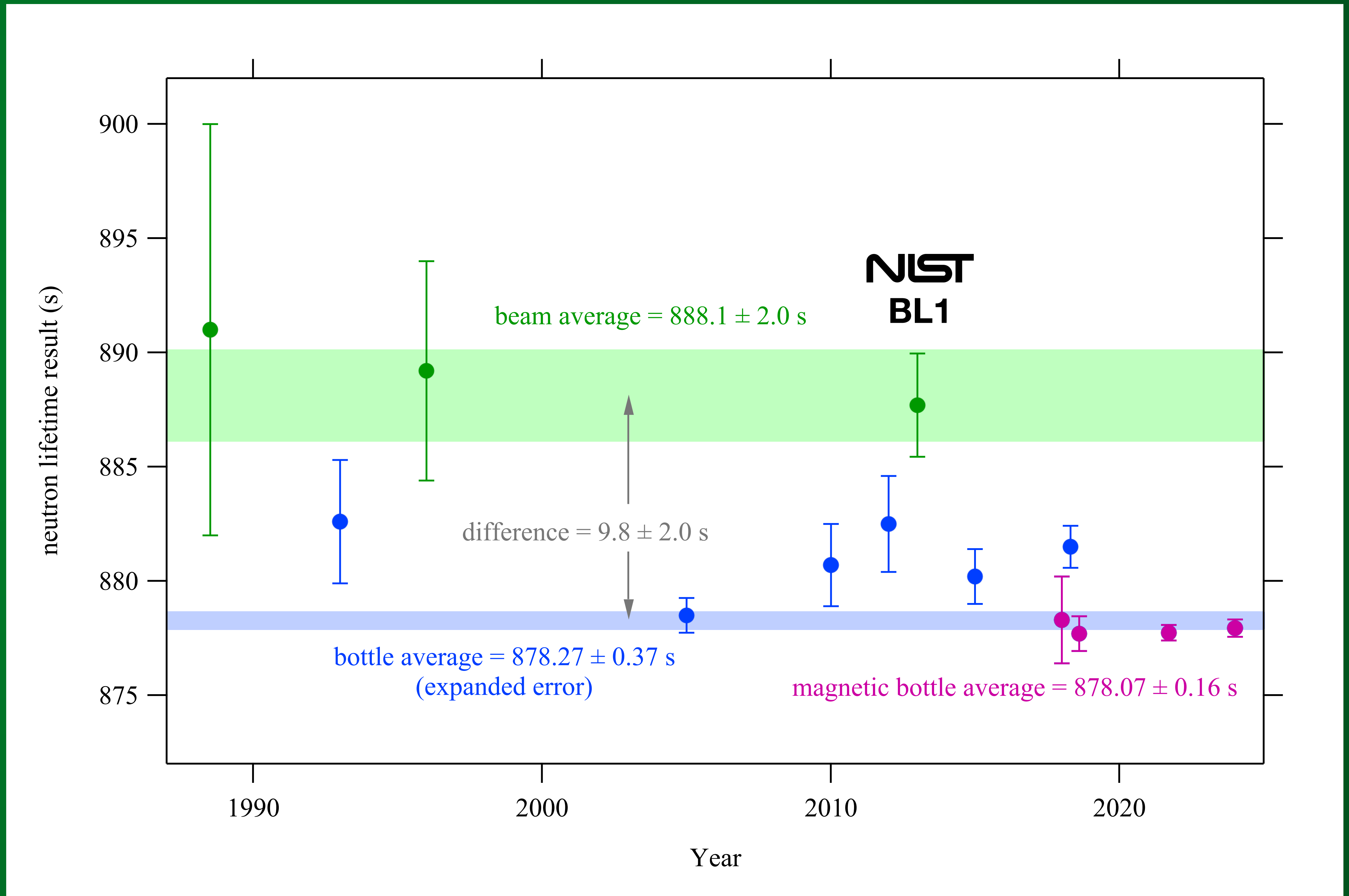

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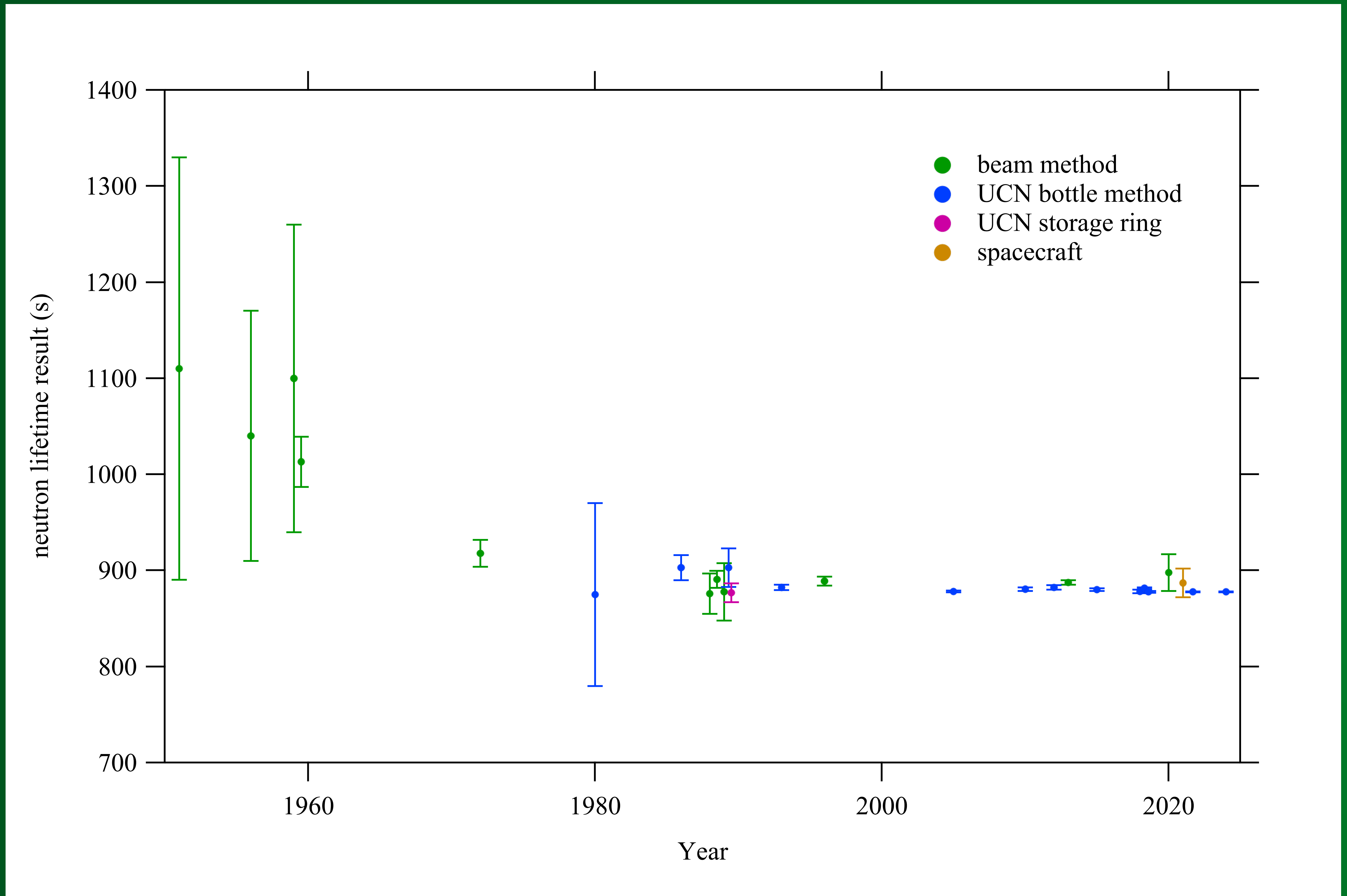

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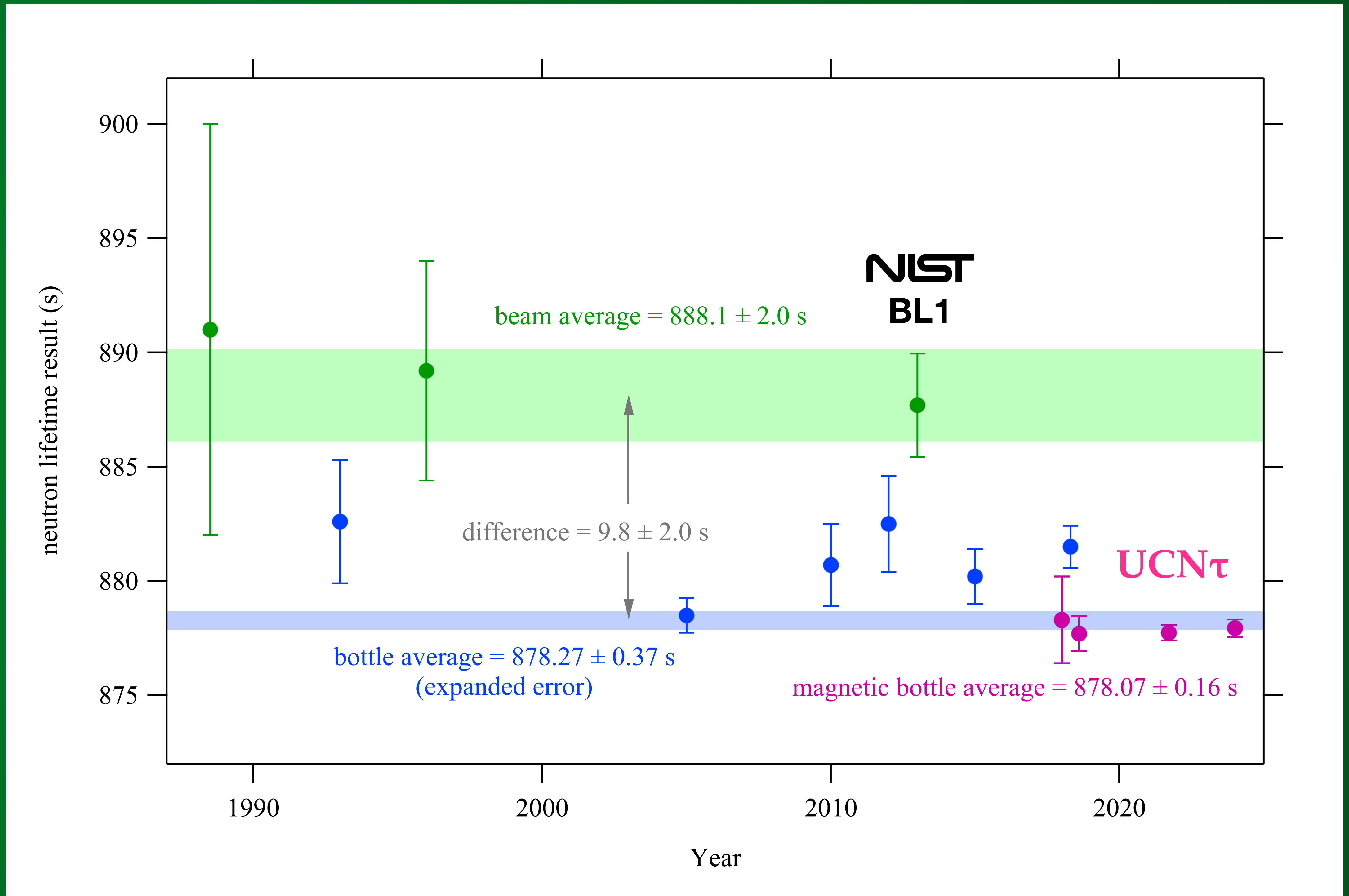

JPARC 2024

Neutron Lifetime Experiments

Improved measurements of neutron lifetime with cold neutron beam at J-PARC

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(Dated: December 30, 2024)

The "neutron lifetime puzzle" arises from the discrepancy between neutron lifetime measurements obtained using the beam method, which measures decay products, and the bottle method, which measures the disappearance of neutrons. To resolve this puzzle, we conducted an experiment using a pulsed cold neutron beam at J-PARC. In this experiment, the neutron lifetime is determined from the ratio of neutron decay counts to $^{3}\mathrm{He(n,p)}^{3}\mathrm{H}$ reactions in a gas detector. This experiment belongs to the beam method but differs from previous experiments that measured protons, as it instead detects electrons, enabling measurements with distinct systematic uncertainties. By enlarging the beam transport system and reducing systematic uncertainties, we achieved a fivefold improvement in precision. Analysis of all acquired data yielded a neutron lifetime of $\tau_{\mathrm{n}} = 877.2 \pm 1.7_{(\mathrm{stat.})}\,{}^{+4.0}_{-3.6}{}_{(\mathrm{sys.})}$ s. This result is consistent with bottle method measurements but exhibits a 2.3σ tension with the average value obtained from the proton-detection-based beam method.

Introduction– A neutron decays into three particles, a proton, an electron, and an antineutrino via weak interactions. The neutron β decay lifetime, τ_{n}, is a crucial parameter that determines the neutron-to-proton ratio at the onset of Big Bang nucleosynthesis (BBN) [1, 2]. The combination of the BBN model and the baryon-to-photon ratio derived from the cosmic microwave background observations [3, 4] provides an accurate prediction of the abundance of light elements, allowing tests of physical phenomena in the early universe. Additionally, the V_{ud} term in the Cabibbo-Kobayashi-Maskawa (CKM) matrix can be determined using τ_{n} and λ, which is the ratio of axial-vector to vector coupling constants, g_A/g_V, independently of nuclear models. Revised radiative corrections in 2018 [5] suggested the CKM unitarity violation exceeding 2σ [6], emphasizing the importance of the measurement of the neutron lifetime. Precise data on τ_{n} is also valuable for testing lattice QCD calculations of g_A [7].

Neutron lifetime has been measured using two primary methods. The first is the beam method [8, 9], where neutron β decay products, specifically protons in these references, are counted relative to the number of incident neutrons, yielding an average lifetime of $\tau_{\mathrm{n}}^{\mathrm{beam}} = 888.0 \pm 2.0$ s. The second is the bottle method [10–17], which measures the disappearance of ultra-cold neutrons (UCNs) confined in a container over time, producing an average value of $\tau_{\mathrm{n}}^{\mathrm{bottle}} = 878.4 \pm 0.5$ s. The 9.5-s (4.6σ) discrepancy between the two methods is known as the "neutron lifetime puzzle" [18], raising concerns about the reliability of neutron lifetime measurements.

Possible causes for this discrepancy include unaccounted systematic uncertainties, such as protons from neutron decay undergoing charge exchange with residual gas [19], though this effect is considered negligible [20]. The 9.5-s, approximately 1% discrepancy between beam

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ties were applied as common shifts. The overall neutron lifetime result from J-PARC, combining all conditions, is $\tau_\mathrm{n} = 877.2 \pm 1.7_{(\mathrm{stat.})}\ {}^{+4.0}_{-3.6}{}_{(\mathrm{sys.})}$. The combining average yielded $\chi^2/\mathrm{DOF} = 15.8/3$, though the underlying cause of this deviation remains undetermined.

TABLE II. Neutron lifetime values for each gas pressure (100 kPa, 50 kPa) and SFC configuration (new, old), with averages. Units in seconds.

Conditions	Value	Stat.	Cut position	Other sys.
100 kPa/old SFC	870.9	3.5	+1.8/-2.8	+5.5/-4.9
100 kPa/new SFC	868.3	4.0	+1.5/-2.9	+3.8/-3.2
50 kPa/old SFC	868.2	7.7	+2.7/-0.9	+4.8/-3.9
50 kPa/new SFC	884.8	2.4	+0.8/-1.3	+3.2/-3.0
Combined	877.2	1.7		+4.0/-3.6

Pressure-dependent systematic?

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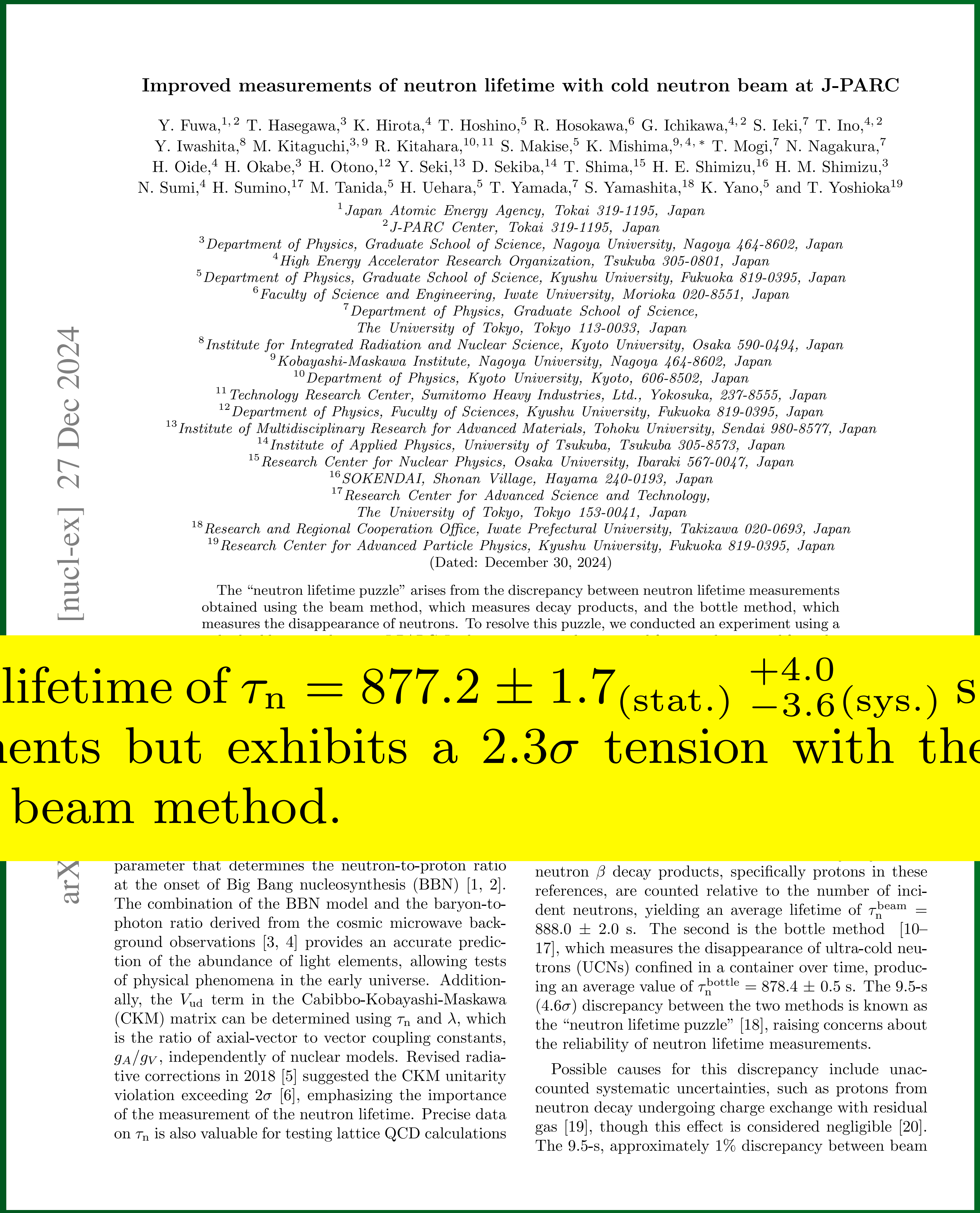

arXiv [nucl-ex] 27 Dec 2024

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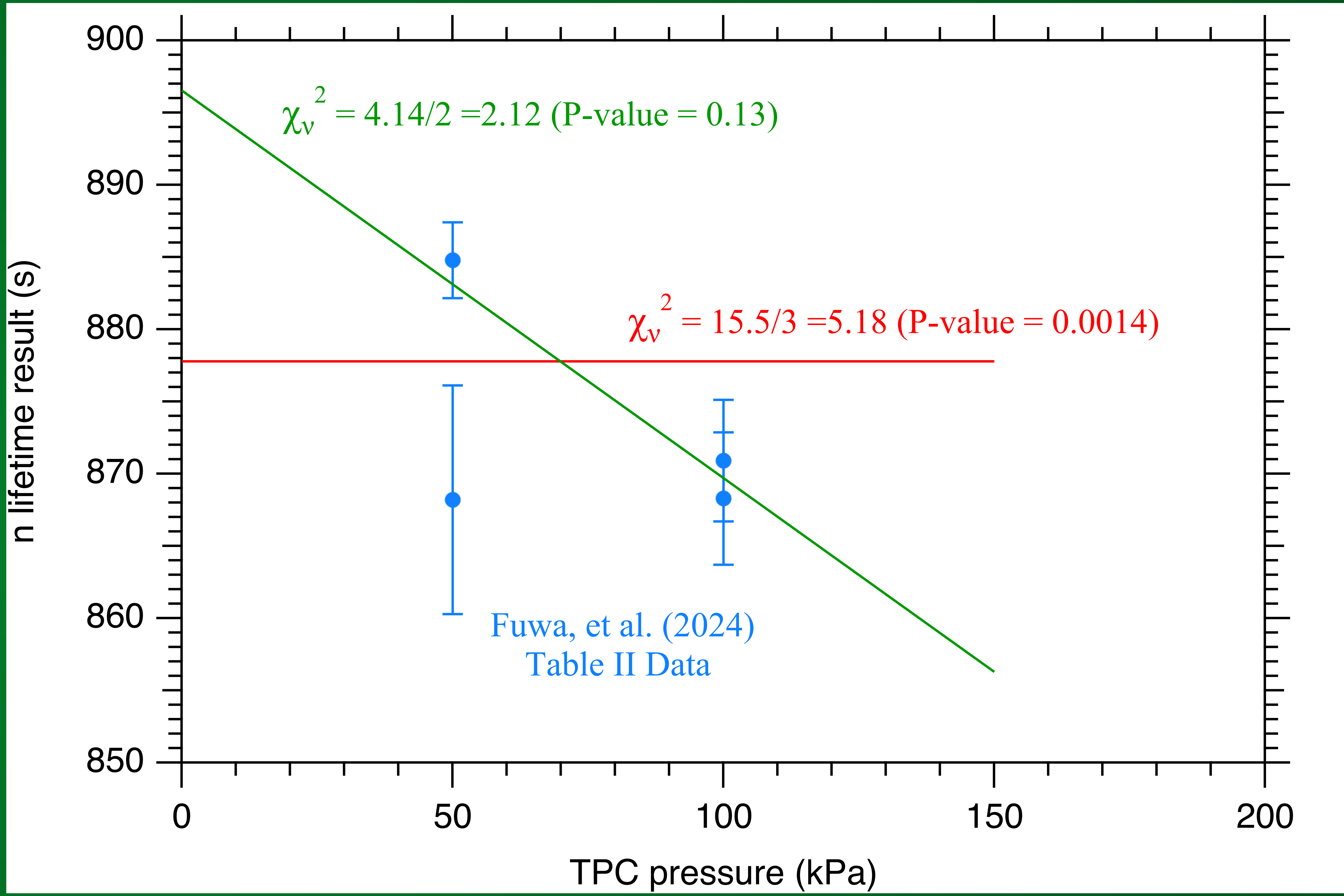


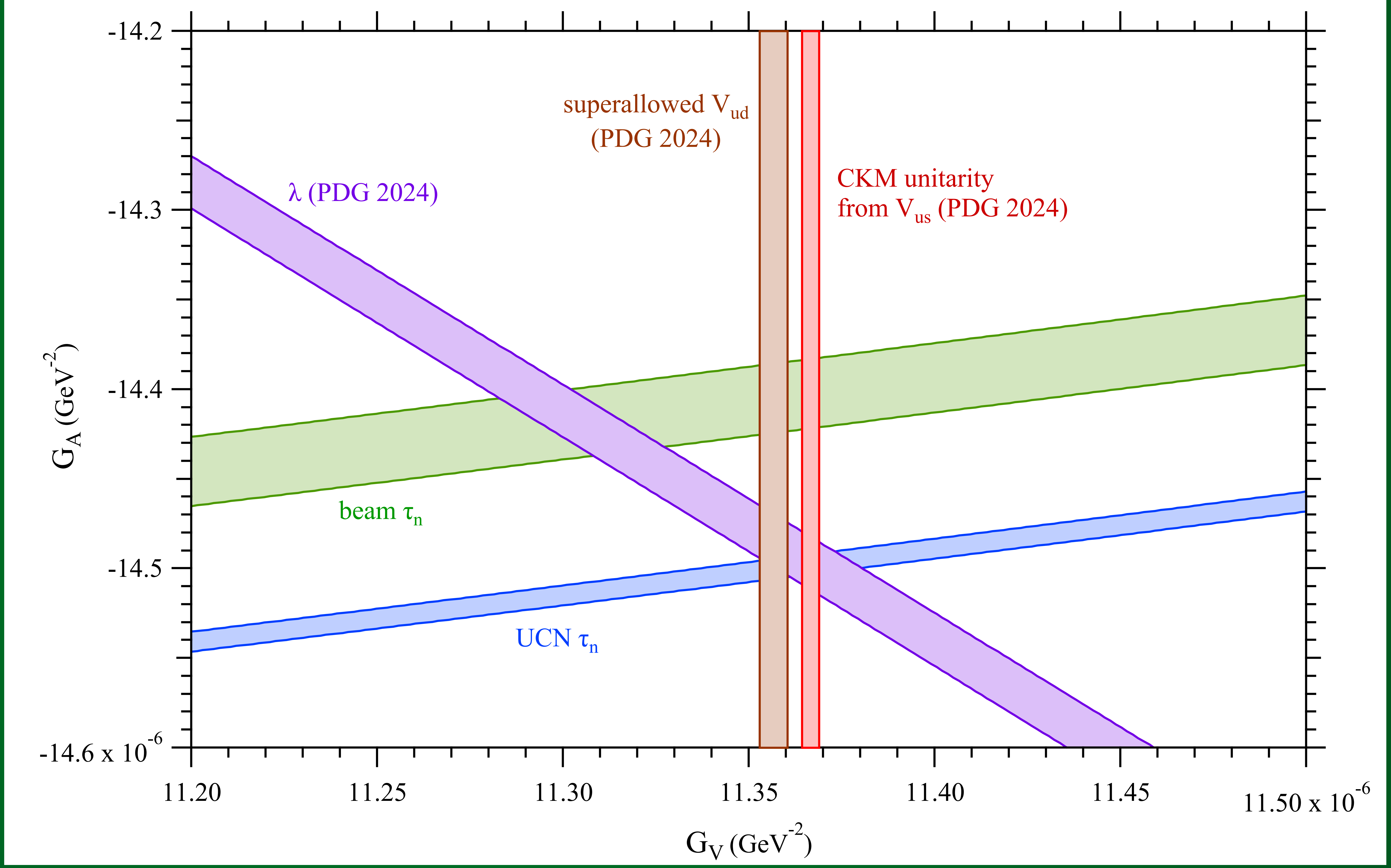
Pressure-dependent systematic?

Neutron Decay Parameters

$$V_{ud} = G_V / G_F$$

$$\lambda = \frac{G_A}{G_V}$$

$$V_{ud}^2 = \frac{4093.7\ \mathrm{s}}{\tau_n (1 + 3G_A^2)}$$



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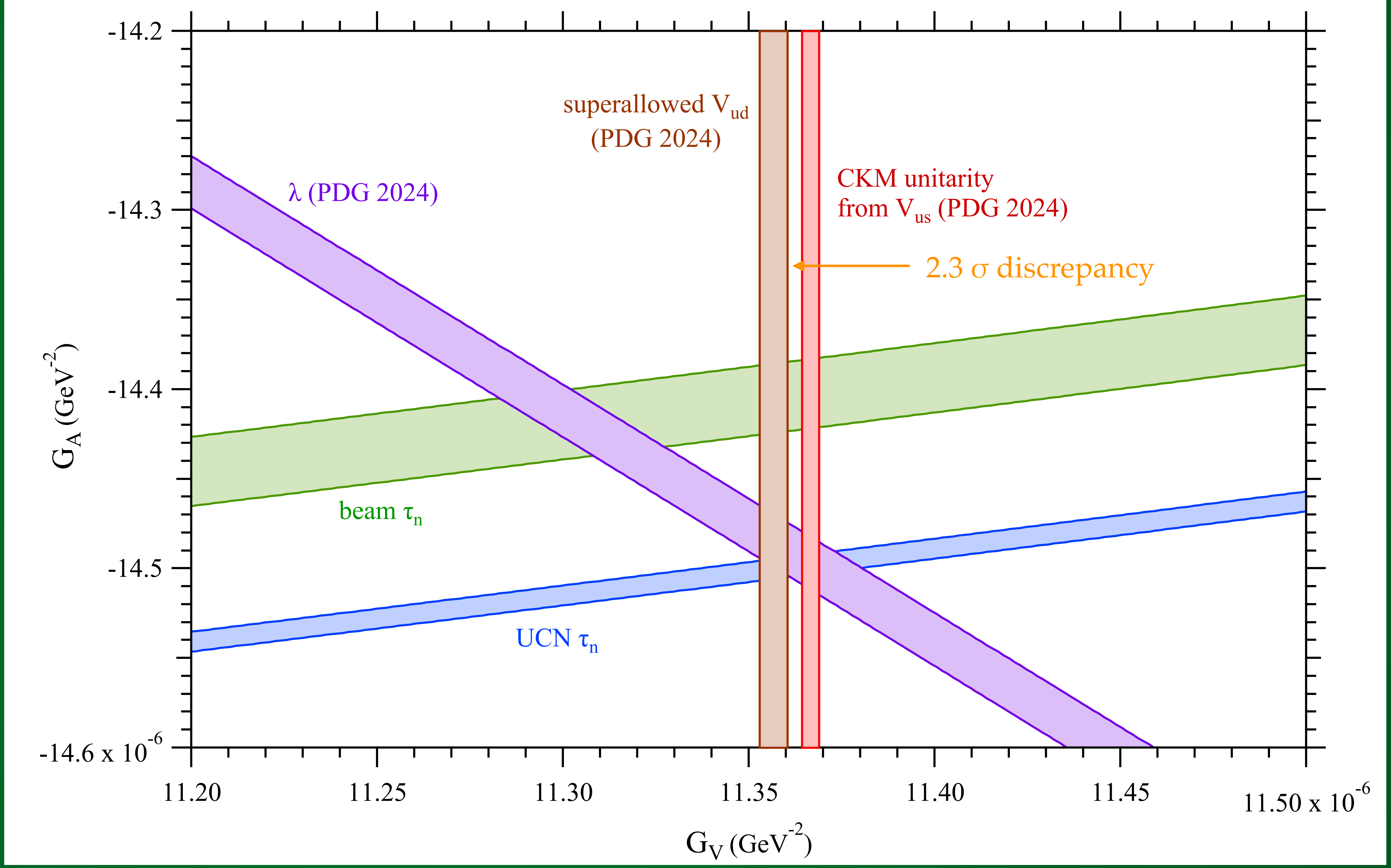

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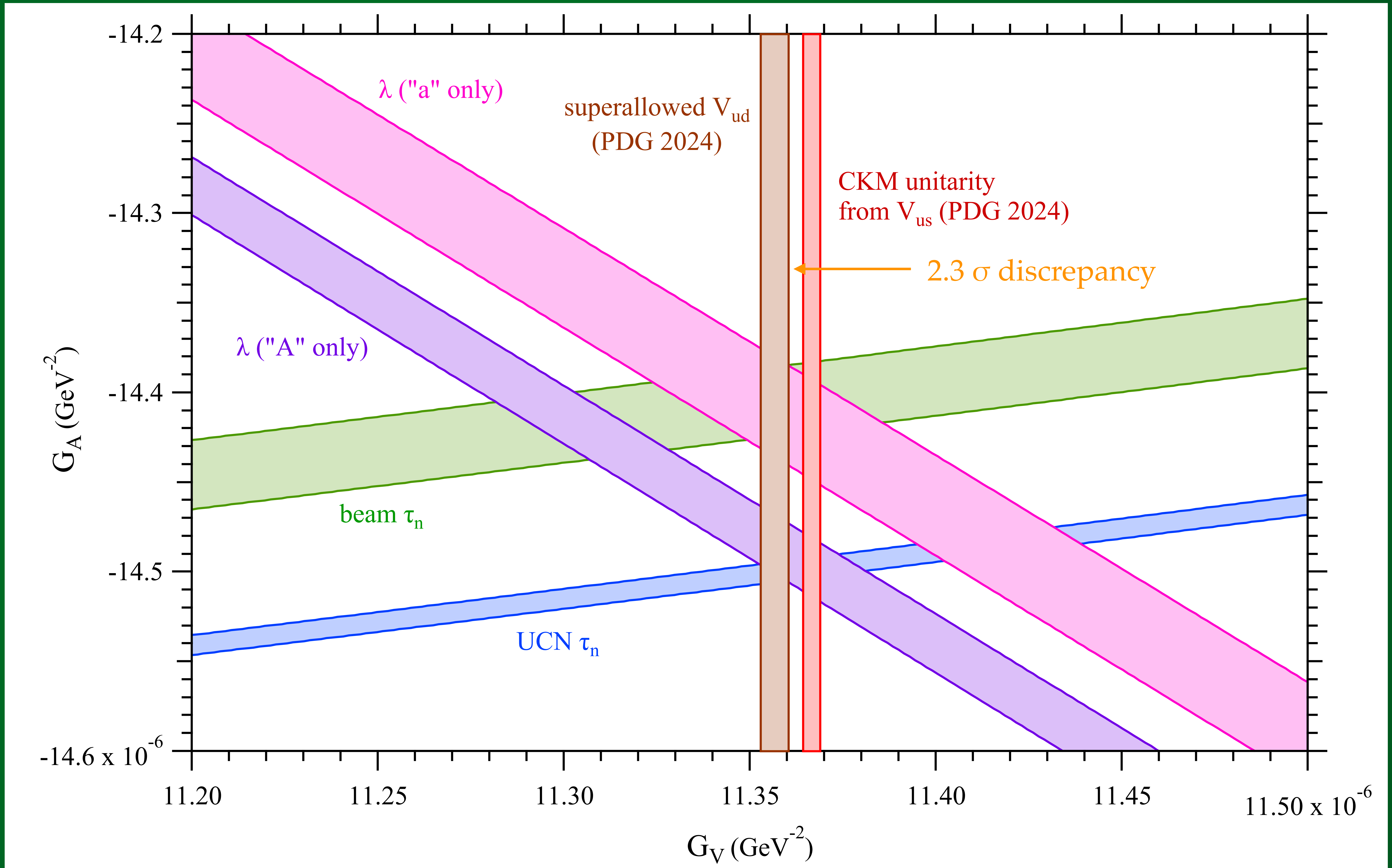

Neutron Lifetime Problem

Scientific American, April 2016

PARTICLE PHYSICS

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Two precision e
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By Geoffre

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long neutrons live before decaying in
Two main types of experiments are
traps count the number of neutrons t

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New experiments aim to pin do

TIME'S UP New experiments aim to resolve a puzzle about how long the neutron takes to decay. At the National Institute of Standards and Technology's Center for Neutron Research (shown), physicists will monitor a beam of neutrons to determine the neutron's lifetime.
RONALD CAPPELLETTI/NIST

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NATALIE WOLCHOVER SCIENCE 02.10.2018 08:00 AM

Wired, February

How Long Can a Neutron Live? Depends

Two methods of measuring the neutron's longevity give different answers, creating uncerta what the problem is.

APS News, July 2019

APRIL MEETING

Sorting Out the Neutron Lifetime

BY SOPHIA CHEN

For over a decade, physicists have puzzled over the neutron lifetime: how long, on average, it takes the isolated particle to decay into a proton, electron, and antineutrino. Counting the number of neutrons in a container over time, they measure the half-life to be about 14 minutes and 39 seconds. Using a different experimental method where they count one of the neutron's decay products, they measure the lifetime to be about 8 seconds longer.

"It's an exciting time to work in the field," says Shannon Hoogerheide of the National Institute of Standards and Technology (NIST). In 2018, three independent teams of physicists have published new measurements of the neutron lifetime, which have improved precision but preserve the discrepancy.

During a mini-symposium at this year's APS April meeting in Denver, experts gathered to develop strategies for resolving the discrepancy, including a tantalizing theory involving dark matter decay.

But the discrepancy could still be the result of systematic uncertainties, so some groups are working to make better measurements.

"We've taken more lifetime data this year, and we're analyzing it right now," says Kevin Hickerson of the Ultracold Neutron Tau (UCNτ) experiment at Los Alamos National Laboratory.

Hickerson's method, a so-called bottle experiment, involves counting neutrons over time and results in the shorter measured lifetime. He and his colleagues trap ultracold neutrons at a temperature of about a millikelvin inside a one-meter diameter container—"the bathtub," they call it.

"We fill it with neutrons, and then we count," he says. "And we fill it again, wait longer, and count again. Then we fit an exponential to that decay." The three 2018 measurements, one made by Hickerson's group, were all bottle experiments, albeit with slightly different setups [*Science* 360, 627 (2018)].

The other method, known as a beam experiment, involves counting the protons that the neutrons decay into. At NIST, researchers send a beam of neutrons through an electromagnetic field, which traps and then deflects any proton decay products, explained Hoogerheide. NIST's experiment yielded the most recent beam result in 2005. Using the same data, they updated those results with better calibration in 2013, and her team is currently working to improve that measurement.

Researchers were particularly excited to discuss whether the discrepancy arose from an unknown dark matter decay product. This theory, proposed by Bartosz Fornal and Benjamin Grinstein of the University of California, San Diego, has the neutron decaying into a dark matter particle 1 percent of the time. This particle would have a mass of about 1 GeV, about 100 times lighter than the weakly interacting massive particles usually predicted by supersymmetry. If neutrons occasionally became dark particles, that would explain why neutrons disappear more quickly in the bottle experiment than proton decay products appear in the beam experiment. "If this turns out to be how nature works, this would turn out to be a very inexpensive way of trying to probe dark matter," says Fornal.

NIST proton trap for measuring neutron lifetime. A free neutron entering the trap as part of a beam will decay into a proton, an electron, and an antineutrino. The number of protons detected can be used to calculate the neutron lifetime. IMAGE F. WEBBER/NIST

NEUTRON CONTINUED ON PAGE 5

Exotic Physics Solution?

PHYSICAL REVIEW LETTERS **120,** 191801 (2018)

Editors' Suggestion | Featured in Physics

Dark Matter Interpretation of the Neutron Decay Anomaly

DOI: 10.1103/PhysRevLett.1…

0031-9007/18/120(19)/191801(6)

PHYSICAL REVIEW LETTERS **121,** 061802 (2018)

Neutron Stars Exclude Light Dark Baryons

David McKeen,[1,2,*] Ann E. Nelson,[3,†] Sanjay Reddy,[4,‡] and Dake Zho…
[1]Pittsburgh Particle Physics, Astrophysics, and Cosmology Center, Department of Physics and Astron… Pittsburgh, Pennsylvania 15260, USA
[2]TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia V6T 2A3, Ca…
[3]Department of Physics, University of Washington, Seattle, Washington 9819…
[4]Institute for Nuclear Theory, University of Washington, Seattle, Washington 98…

(Received 26 February 2018; revised manuscript received 1 June 2018; published …

Exotic particles carrying baryon number and with a mass of the order of the nucleon … proposed for various reasons including baryogenesis, dark matter, mirror worlds, and the … puzzle. We show that the existence of neutron stars with a mass greater than 0.7 M… constraints on such particles, requiring them to be heavier than 1.2 GeV or to have st… self-interactions.

DOI: 10.1103/PhysRevLett.121.061802

0031-9007/18/121(6)/061802(5) 061802-1 Published by the American Physical Society

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https://doi.org/10.1140/epjc/s10052-019-6995-x
THE EUROPEAN PHYSICAL JOURNAL C

Letter

Neutron lifetime puzzle and neutron–mirror …

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Received: 13 November 2018 / Accepted: 22 May 2019 / Published online: 10 June 2019

Abstract Standard Model, with its present precision, predicts the neutron β-decay time $\tau_{SM} = 878.7 \pm 0.6$ s which is perfectly compatible with the neutron lifetime measured in the trap experiments $\tau_{trap} = 879.4 \pm 0.6$ s. However, the lifetime measured in the beam experiments via counting the protons produced by β-decay $n \to pe\bar{\nu}_e$, $\tau_{beam} = 888 \pm 2.0$ s, is deviated from τ_{SM} by 9 seconds (4.4σ). This discrepancy can be explained via the neutron n conversion into mirror neutron n', its dark partner from parallel mirror sector. Provided that n and n' have a tiny mass splitting $\sim 10^{-7}$ eV, in magnetic fields of few Tesla used in beam experiments, $n - n'$ transition is resonantly enhanced converting a 1% fraction of neutrons into mirror neutrons which decay in invisible mode $n' \to p'e'\bar{\nu}'_e$. Thus less protons are produced and the measured value τ_{beam} appears larger than the true decay time $\tau_{SM} = \tau_{trap}$.

1. Exact determination of the neutron lifetime remains a problem. It is measured in two types of experiments. The trap experiments measure the disappearance rate of the ultra-cold neutrons (UCN) counting the survived UCN after storing them for different times in material or magnetic traps, and determine the neutron decay width $\Gamma_n = \tau_n^{-1}$. The beam experiments are the appearance experiments, measuring the width of β-decay $n \to pe\bar{\nu}_e$, $\Gamma_\beta = \tau_\beta^{-1}$, by counting the protons produced in the monitored beam of cold neutrons. As far as in the Standard Model (SM) the neutron decay always produces a proton, both methods should measure the same value $\Gamma_n = \Gamma_\beta$.

However, the tension is mounting between the results obtained by two methods [1,2]. Presently available experimental results using the trap [3–11] and the beam [12,13] methods, summarized in Fig. 1, yield separately

$$\tau_{trap} = (879.4 \pm 0.6) \text{ s} \quad (1)$$

$$\tau_{beam} = (888.0 \pm 2.0) \text{ s} \quad (2)$$

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PHYSICAL REV…

Exciting hint toward the s…

Benjamin Koch…
[1]Institut für Theoretische… Wiedner Hauptstras…
[2]Instituto de Física, Pontificia Universi…

(Received 11 March 2024; acc…

DOI: 10.1103/PhysRevD.110.073004

2470-0010/2024/110(7)/073004(11)

New Astronomy 113 (2024) 102275

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New results on the two-body decay of neutrons shed new light on neutron stars

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Neutron lifetime puzzle
Two-body decay of neutrons
Second flavor of hydrogen atoms
Multi-messenger astronomy

ABSTRACT

In attempts to resolve the neutron lifetime puzzle, there was suggested a hypothetical decay of neutrons into some *unspecified* dark matter (DM) particles. Later there were performed studies on how the hypothetical decay of neutrons would affect neutron stars. Recently it was shown that with the allowance for the second solution of Dirac equation for hydrogen atoms, the theoretical branching ratio (BR) for the two-body decay of neutrons (compared to their three-body decay) is amplified by a factor of 3300 from 0.000004. So, the BR becomes about 1.3% in the excellent agreement with the "experimental" BR = (1.15 ± 0.27)% required for reconciling the two distinct experimental values of the neutron lifetime: one from the beam experiments, another from the trap experiments. This meant that the two-body decay of neutrons in the beam experiments (that count only the protons) plays a much more sizable part in the overestimation of the lifetime of neutrons in these experiments than previously thought. Hydrogen atoms corresponding to the second solution of Dirac equations are called the second flavor of hydrogen atoms (SFHA) by the analogy with the flavors of quarks. The existence of the SFHA is evidenced by four different types of atomic/molecular experiments. The primary feature of the SFHA is that due to having only the s-states, they do not emit or absorb the electromagnetic radiation (except for the 21 cm line): they are practically *dark*. The SFHA became a candidate for a part of DM for the first time after the SFHA-based successful qualitative and quantitative explanation of the perplexing observation by Bowman et al. of the anomalous absorption in the redshifted 21 cm line from the early Universe. In the present paper we analyzed how this neutron decay into the SFHA affects neutron stars. We showed that old neutron stars could very slowly generate the new *specific, described in detail* baryonic DM in the form of the SFHA. Some old neutron stars would release it into their tiny atmospheres, while some other old neutron stars would release it into the interstellar medium. Besides, mergers of a neutron star with another neutron star or with a black hole, accompanied by the ejection of neutron-rich material, can also lead to the formation of SFHA as the ejecta cools down. This is another interesting aspect of the multi-messenger astronomy focused on studying these mergers through the gravitational waves they generate. These mechanisms of generating new baryonic DM in the universe should have the fundamental importance. We point out the indirect observational evidence of the continuing generation of new baryonic DM. We hope that our results will stimulate a further research in this direction.

1. Introduction

The average measured lifetime (AML) of neutrons is puzzling – see, e.g., works (Broussard, 2022; Gonzalez, 2021; Serebrov et al., 2021; Particle Data Group, 2020; Berezhiani, 2019; Tan, 2019; Czarnecki et al., 2018; Sun, 2018; Tang, 2018; Pattie, 2018): e.g., according to Gonzalez et al. paper (2021), the AML of trapped ultracold neutrons $\tau_{trap} = (877.75 \pm 0.28_{stat} + 0.22/-0.16_{syst})$ s – in contrast to the beam AML of neutrons $\tau_{beam} = 888.0 \pm 2.0$ s. For solving this puzzle, Fornal and Grinstein (2018) suggested that neutron might decay into an *unspecified* dark matter (DM) particle. Later Grinstein et al. (2019) and then Husain et al. (2022) explored how this decay channel would affect *neutron stars*. The problem still was that the resulting hypothetical DM particle was not identified. Moreover, Dubbers et al. (2019) showed that the Branching Ratio (BR) for this process is at least several times smaller than the BR required for reconciling the experimental values of τ_{trap} and τ_{beam}.

Green and Thomson (1990) brought up the two-body decay of neutrons (the decay into a hydrogen atom and antineutrino) into consideration. However, the BR for this process, known at that time, was

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Available online 2 July 2024
1384-1076/

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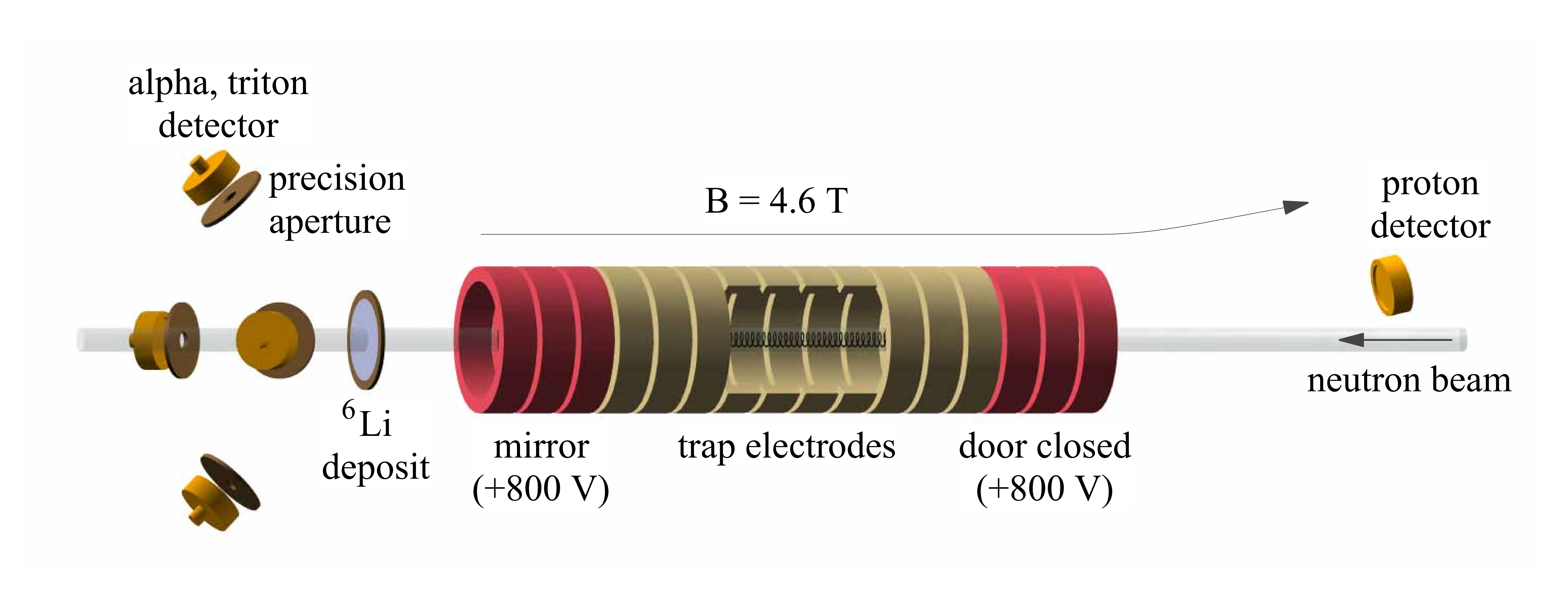
The NIST BL1 Experiment



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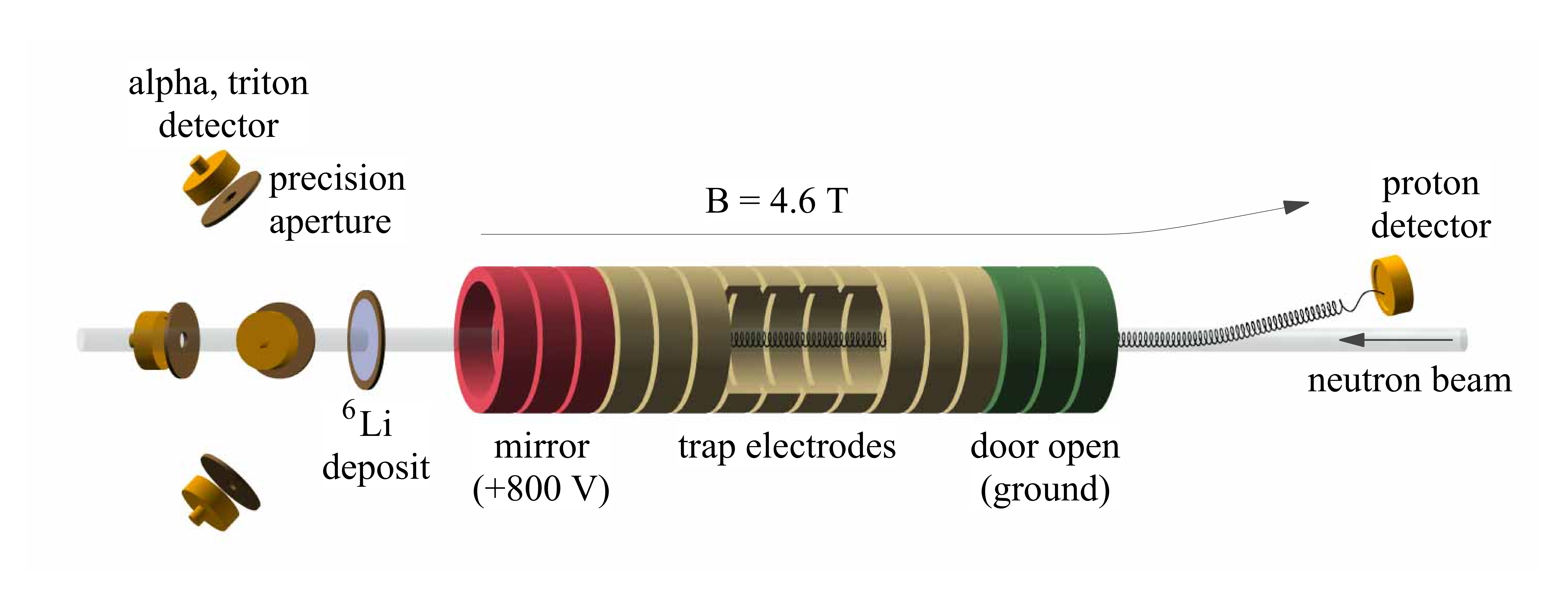

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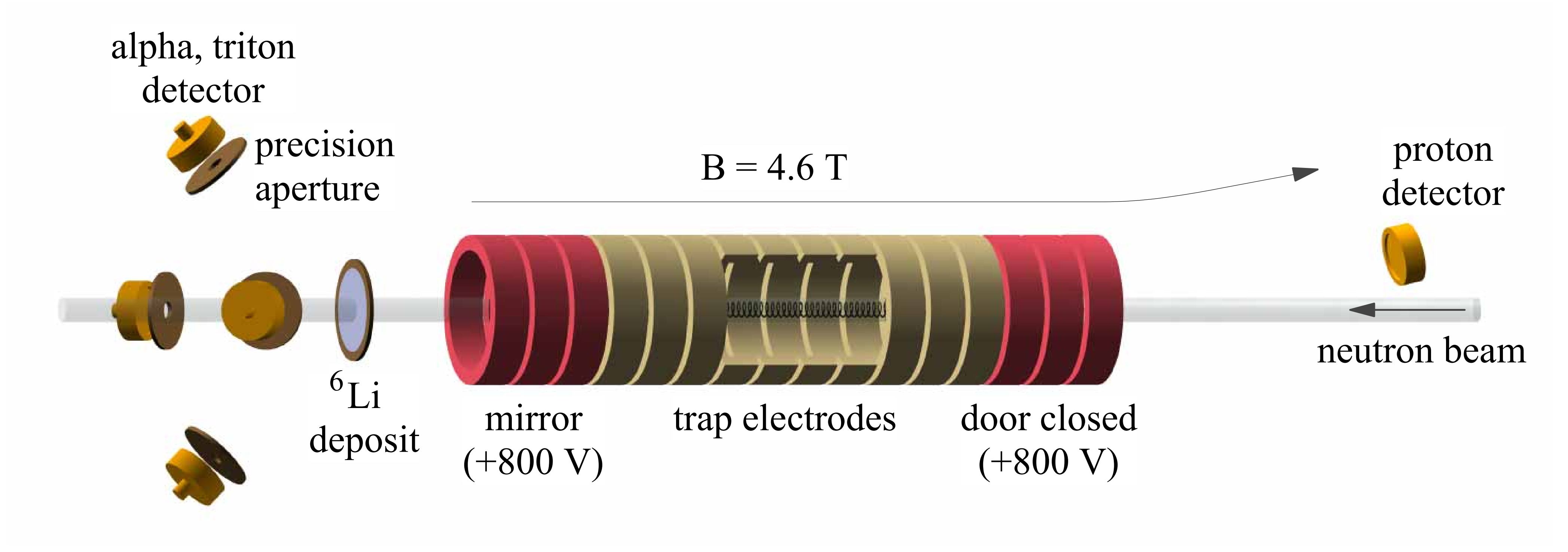
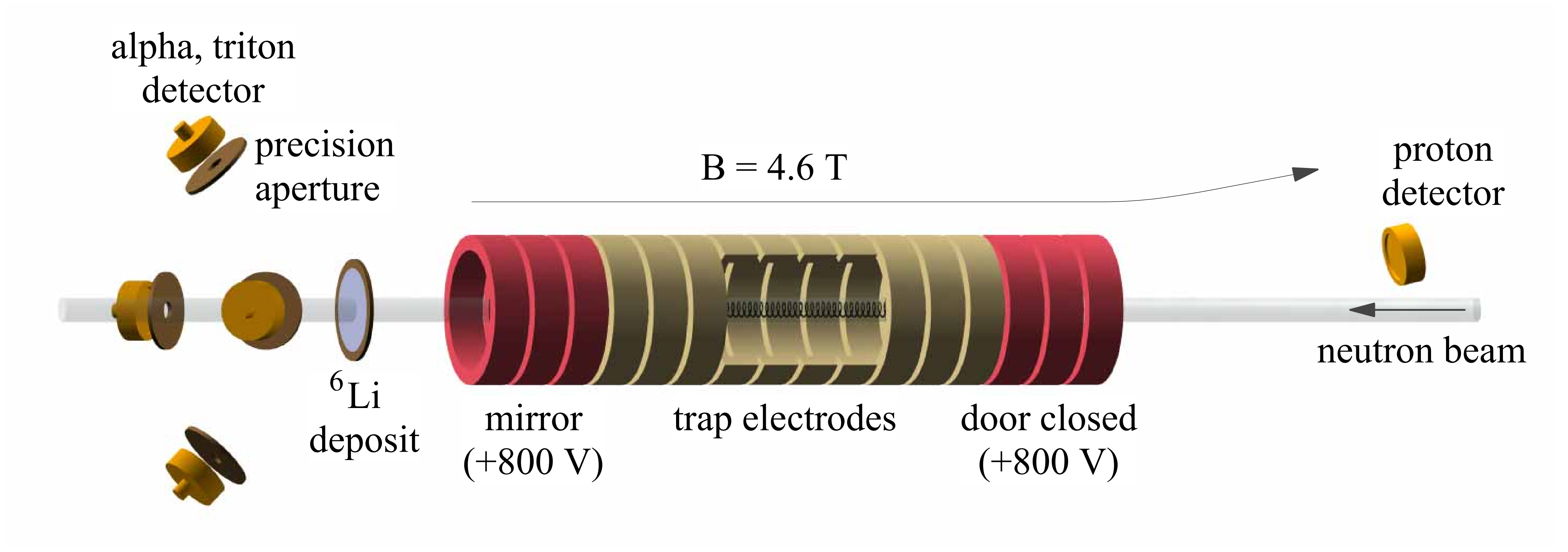


$$\tau = \frac{R_n \, \varepsilon_p \, L_{\text{det}}}{R_p \, \varepsilon_0 \, v_{\text{th}}}$$

The NIST BL1 Experiment



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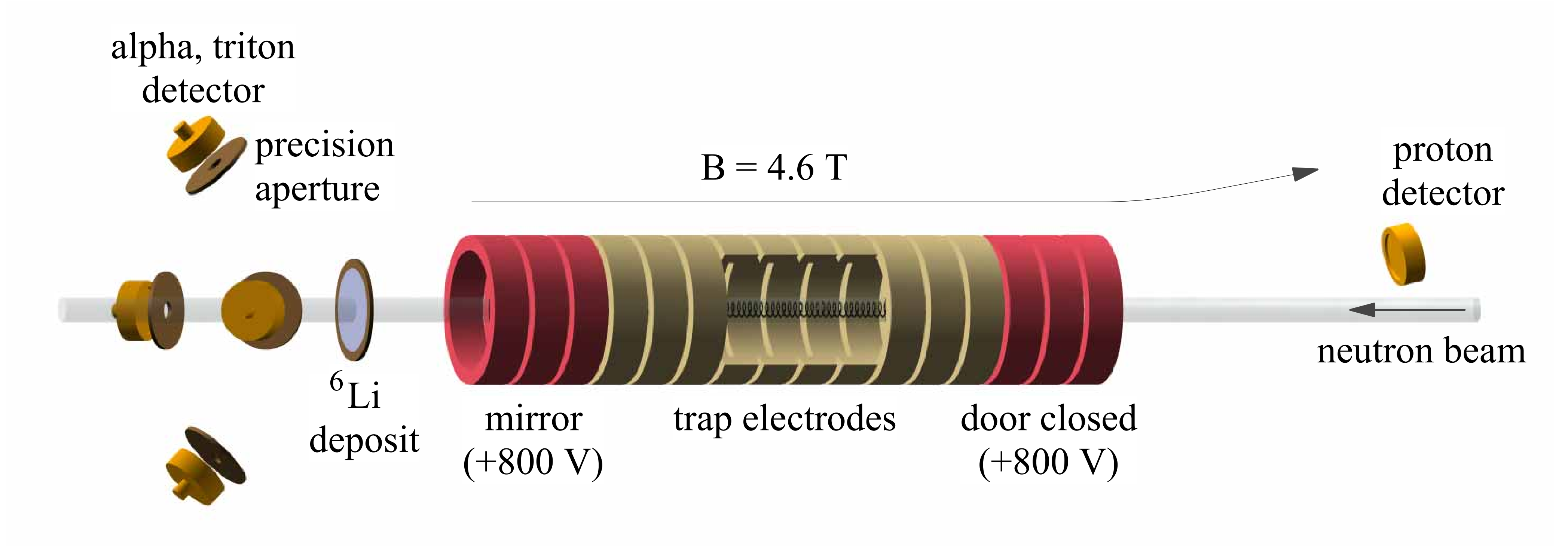

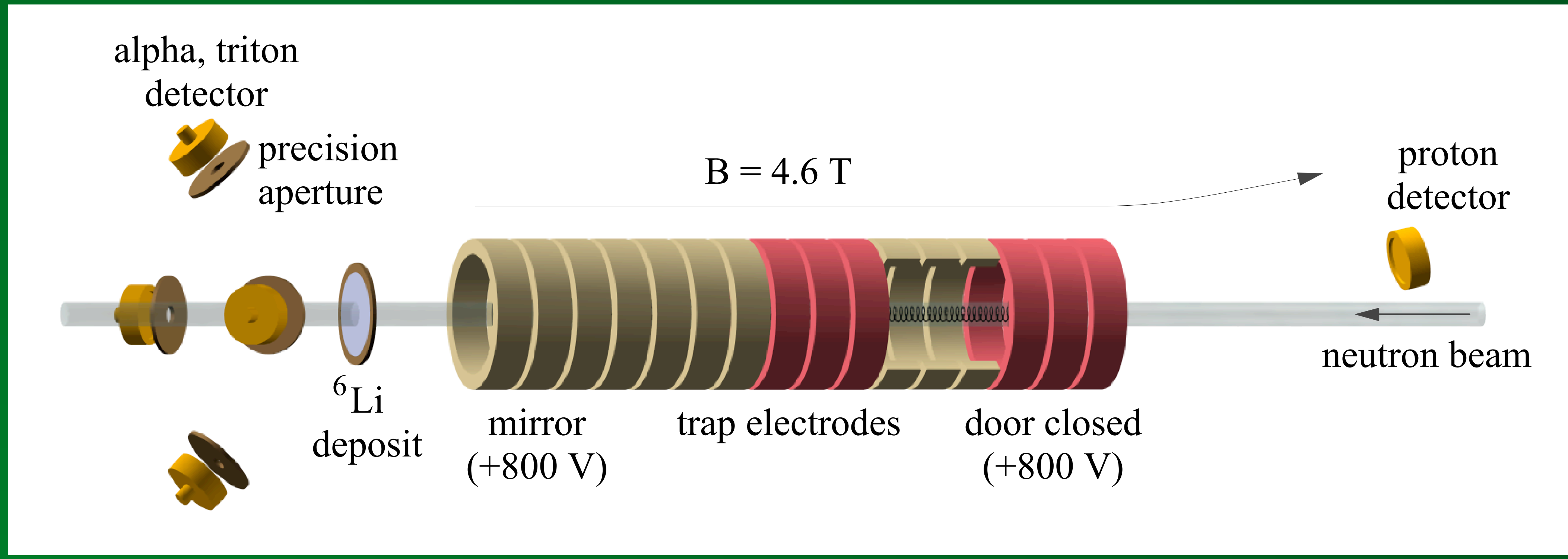

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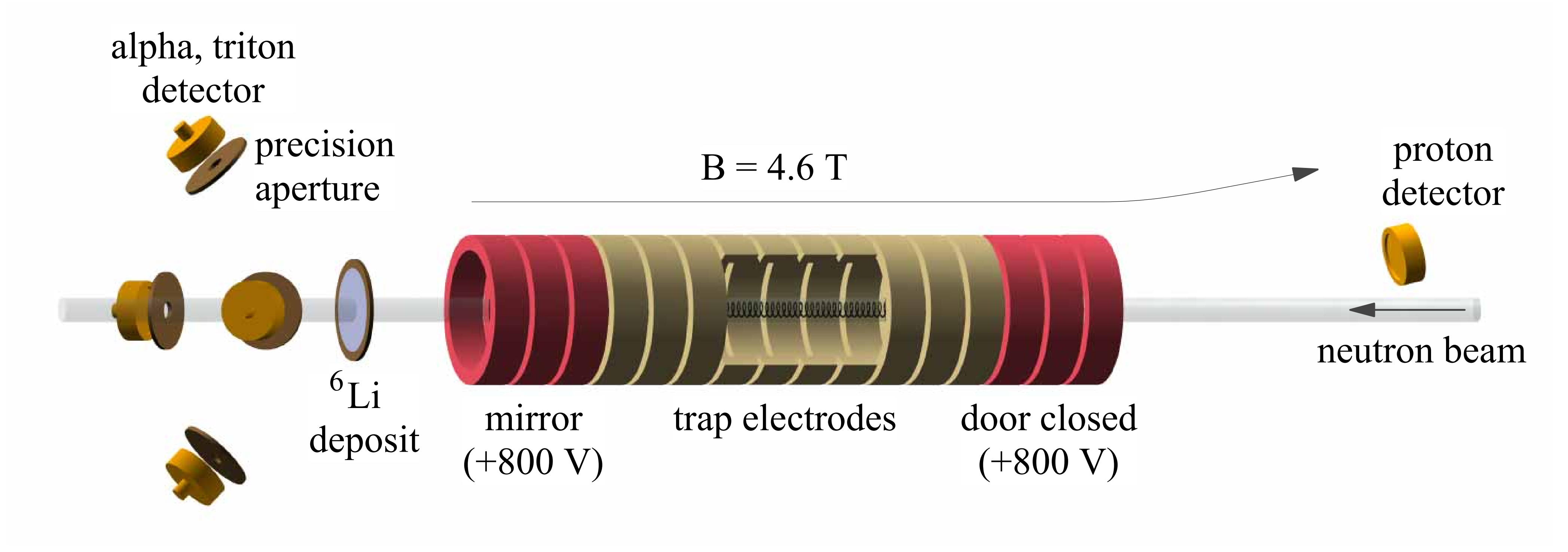
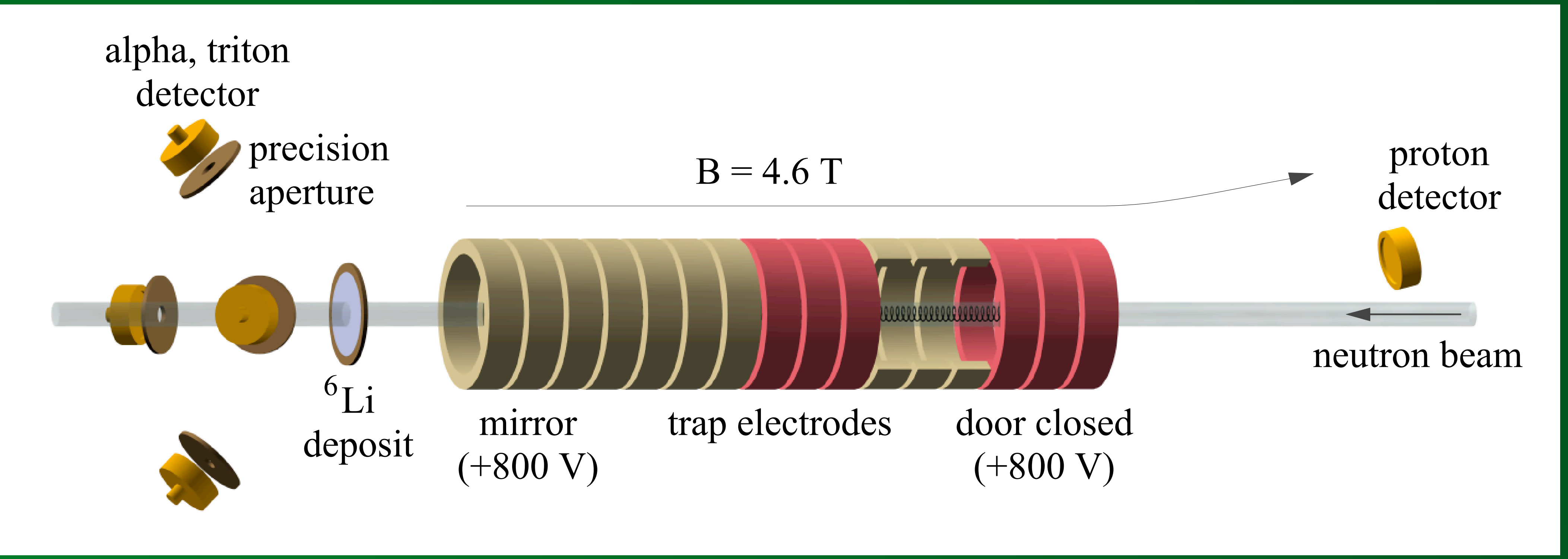
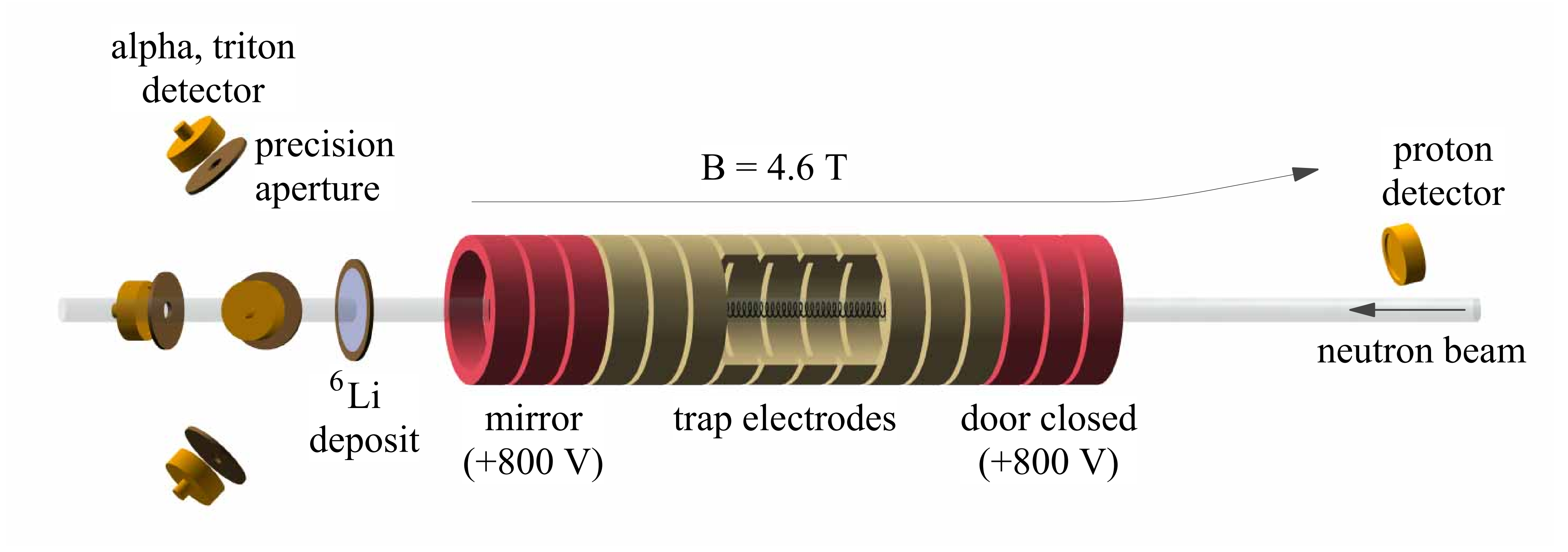


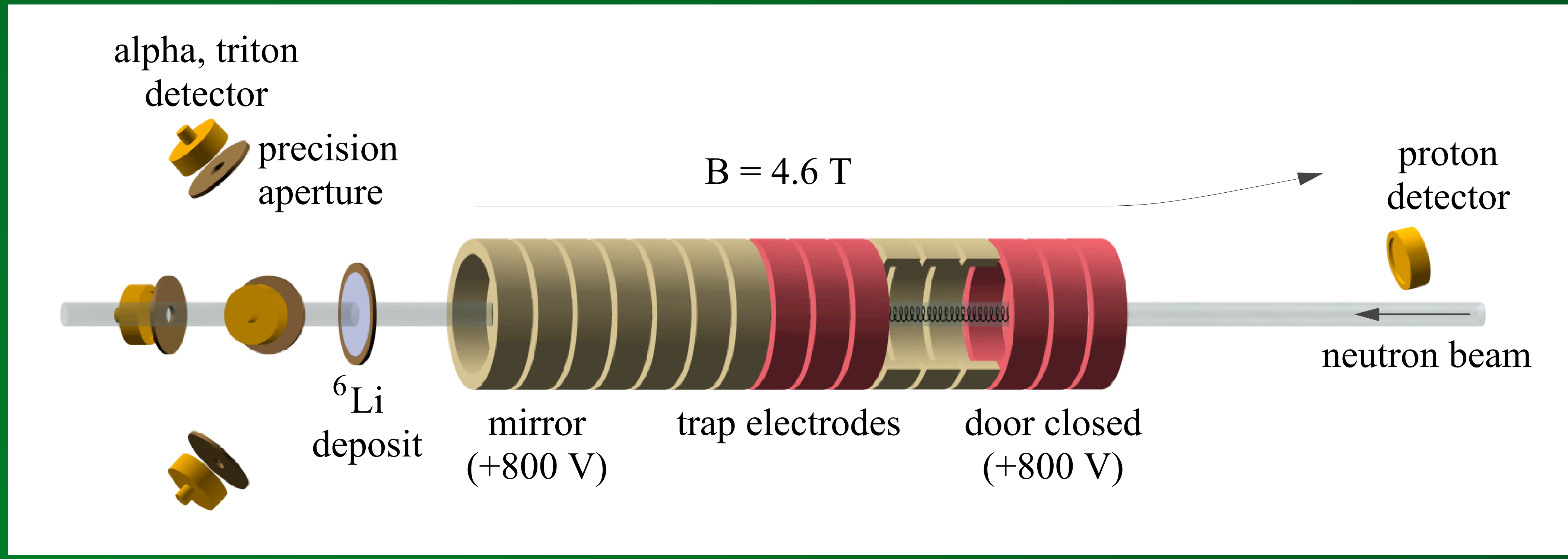


$$\tau = \frac{R_n\, \varepsilon_p\, L_{\rm det}}{R_p\, \varepsilon_0\, v_{\rm th}}$$

$$L_{\rm det} = nl + L_{\rm end}$$

The NIST BL1 Experiment





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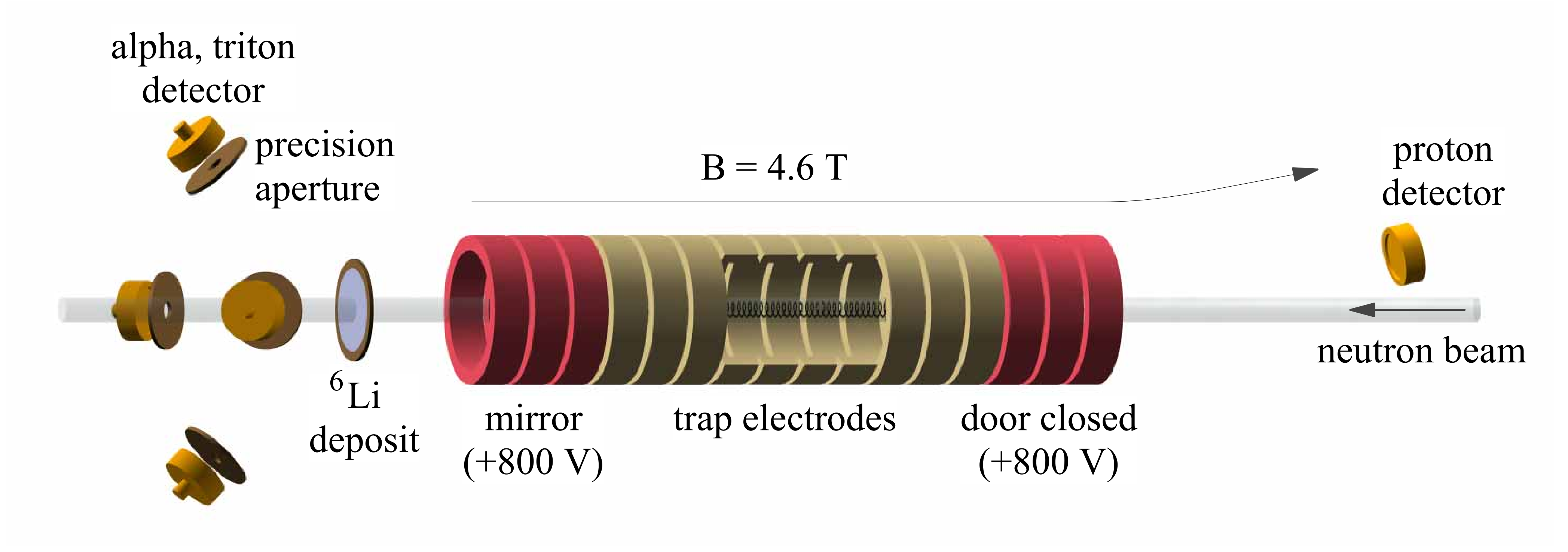
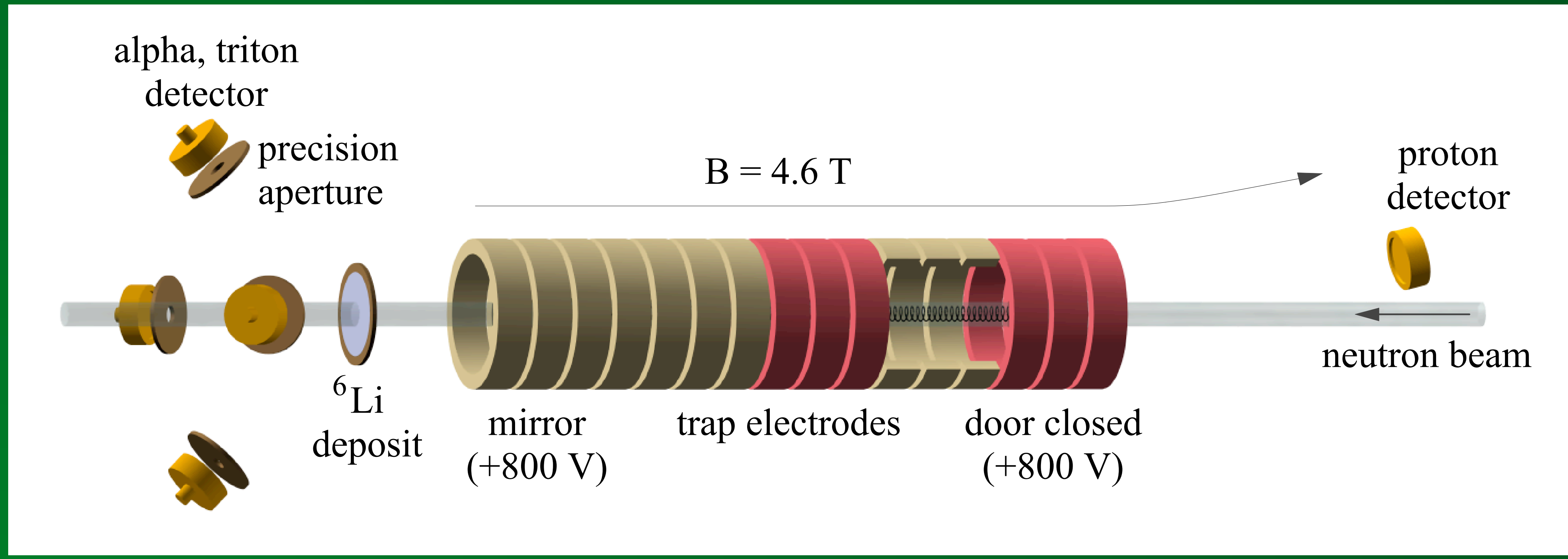
number of trap electrodes

The NIST BL1 Experiment





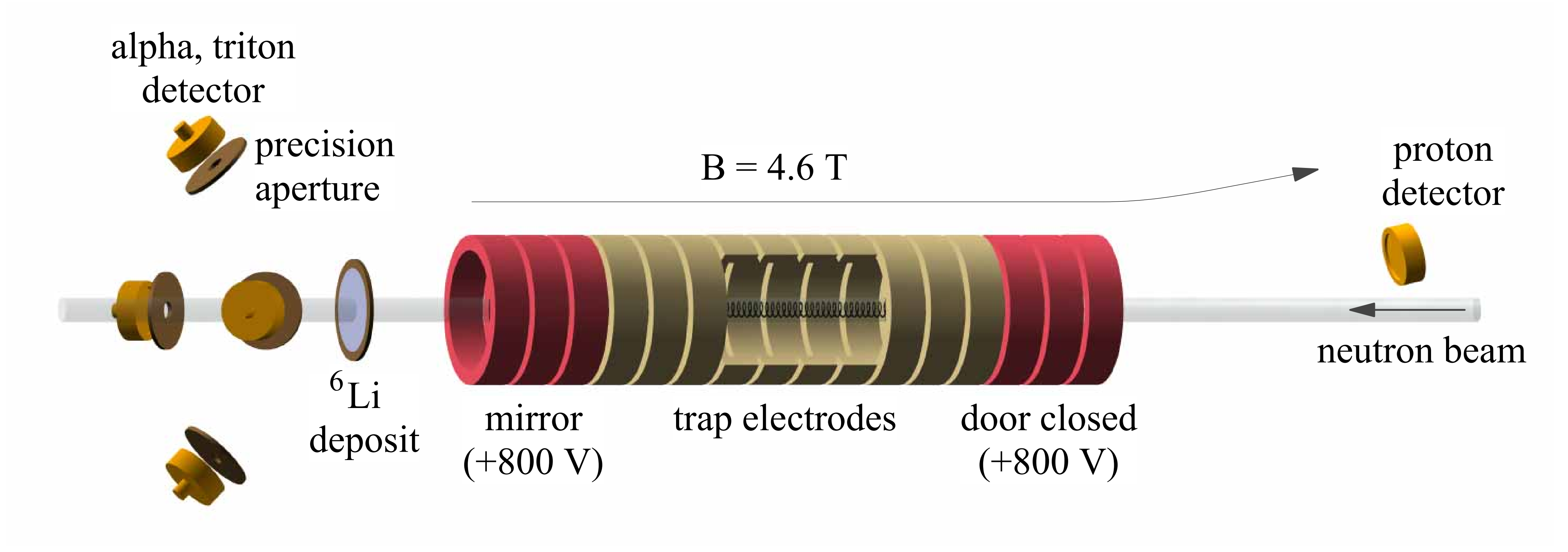
$$\tau = \frac{R_n\, \varepsilon_p\, L_{\mathrm{det}}}{R_p\, \varepsilon_0\, v_{\mathrm{th}}}$$

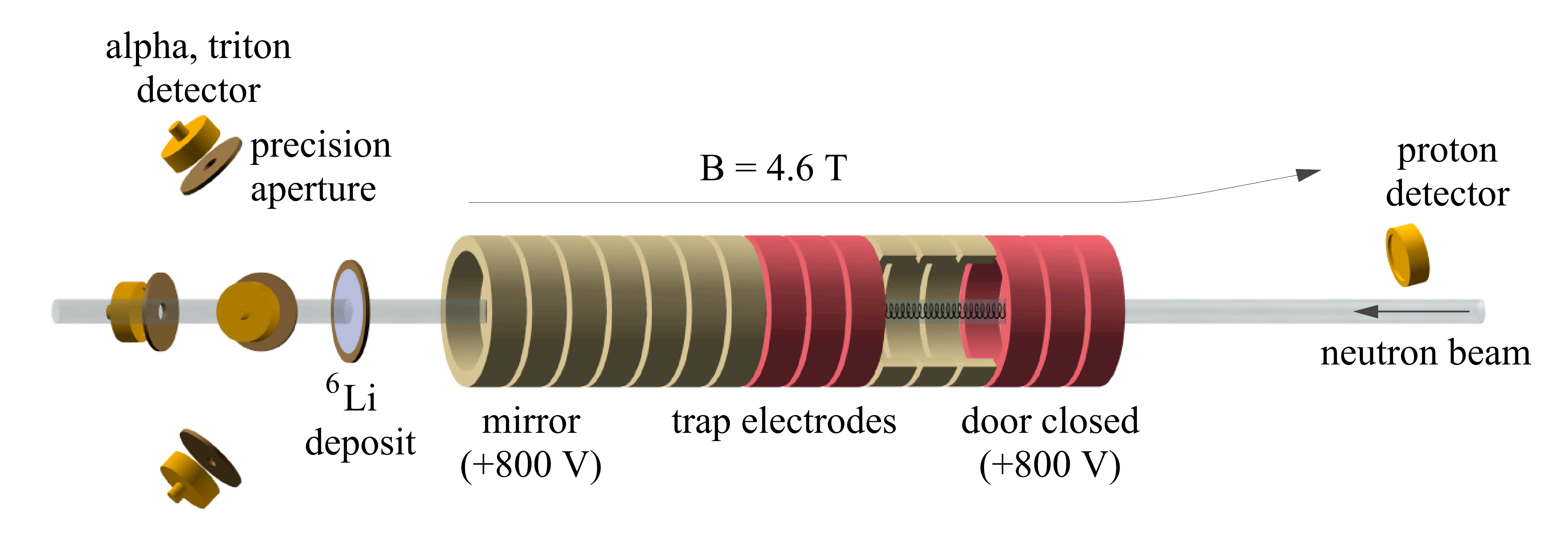
length of electrode + spacer

$$L_{\mathrm{det}} = nl + L_{\mathrm{end}}$$

number of trap electrodes

The NIST BL1 Experiment





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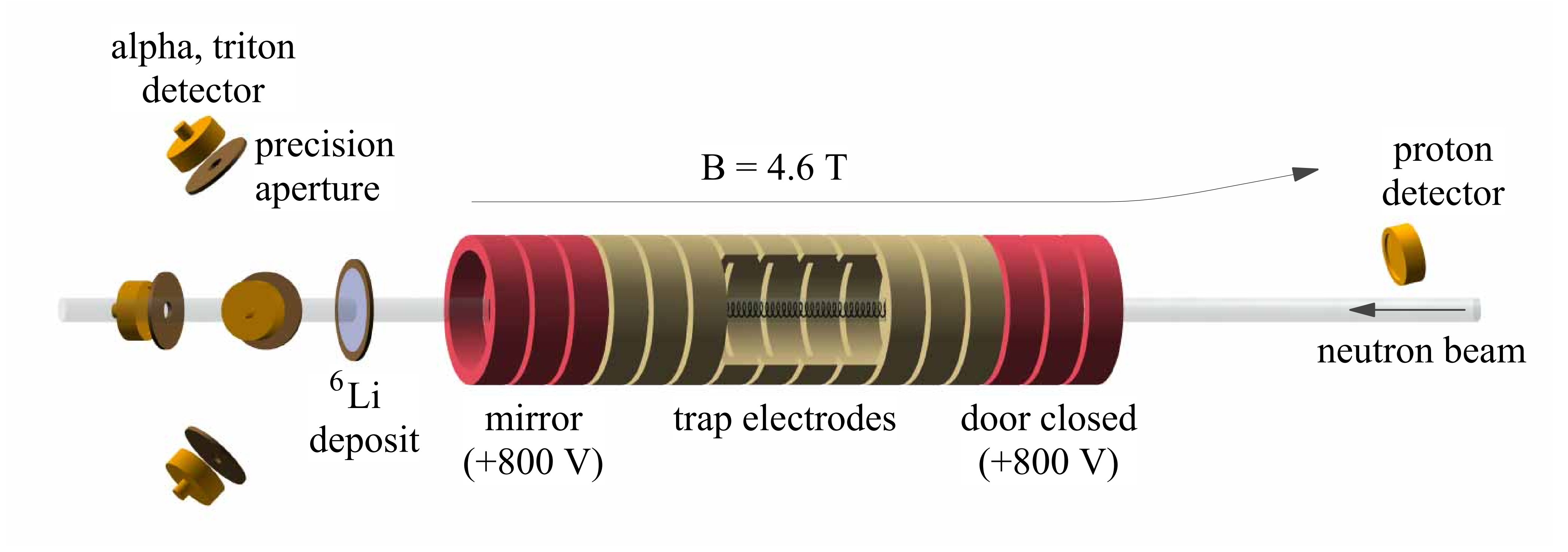
length of
electrode + spacer

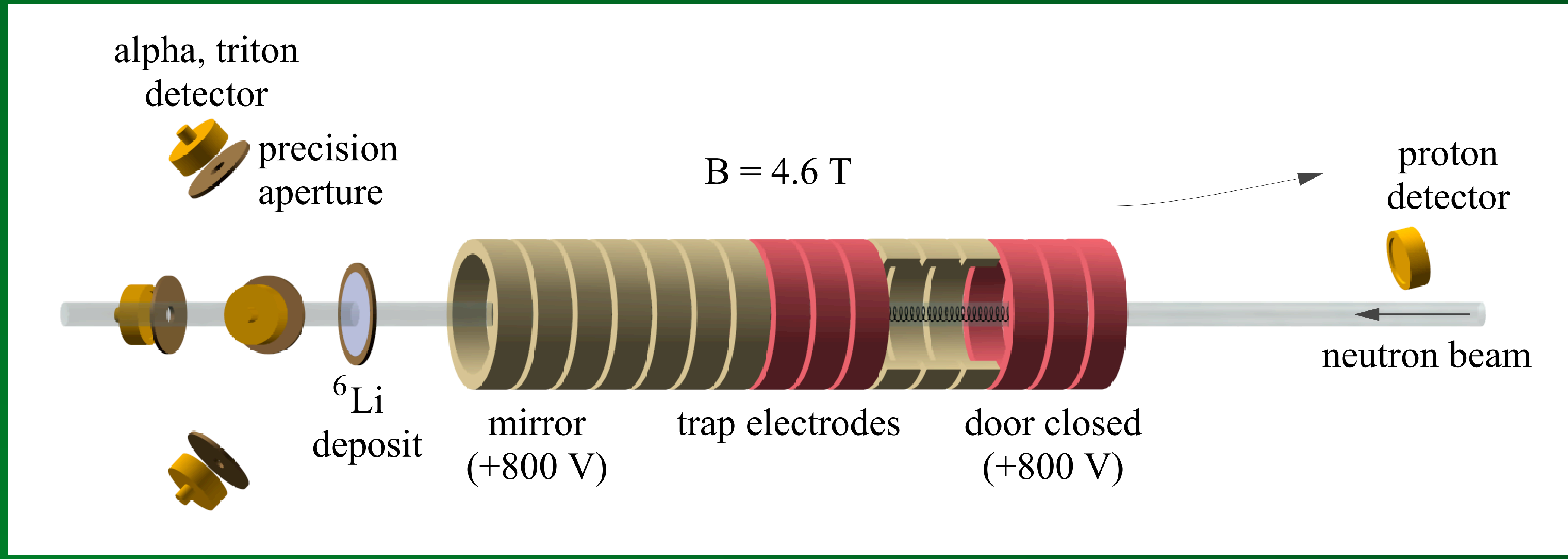
$$L_{\mathrm{det}} = nl + L_{\mathrm{end}}$$

number of trap
electrodes

effective length
of end region

The NIST BL1 Experiment





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length of electrode + spacer

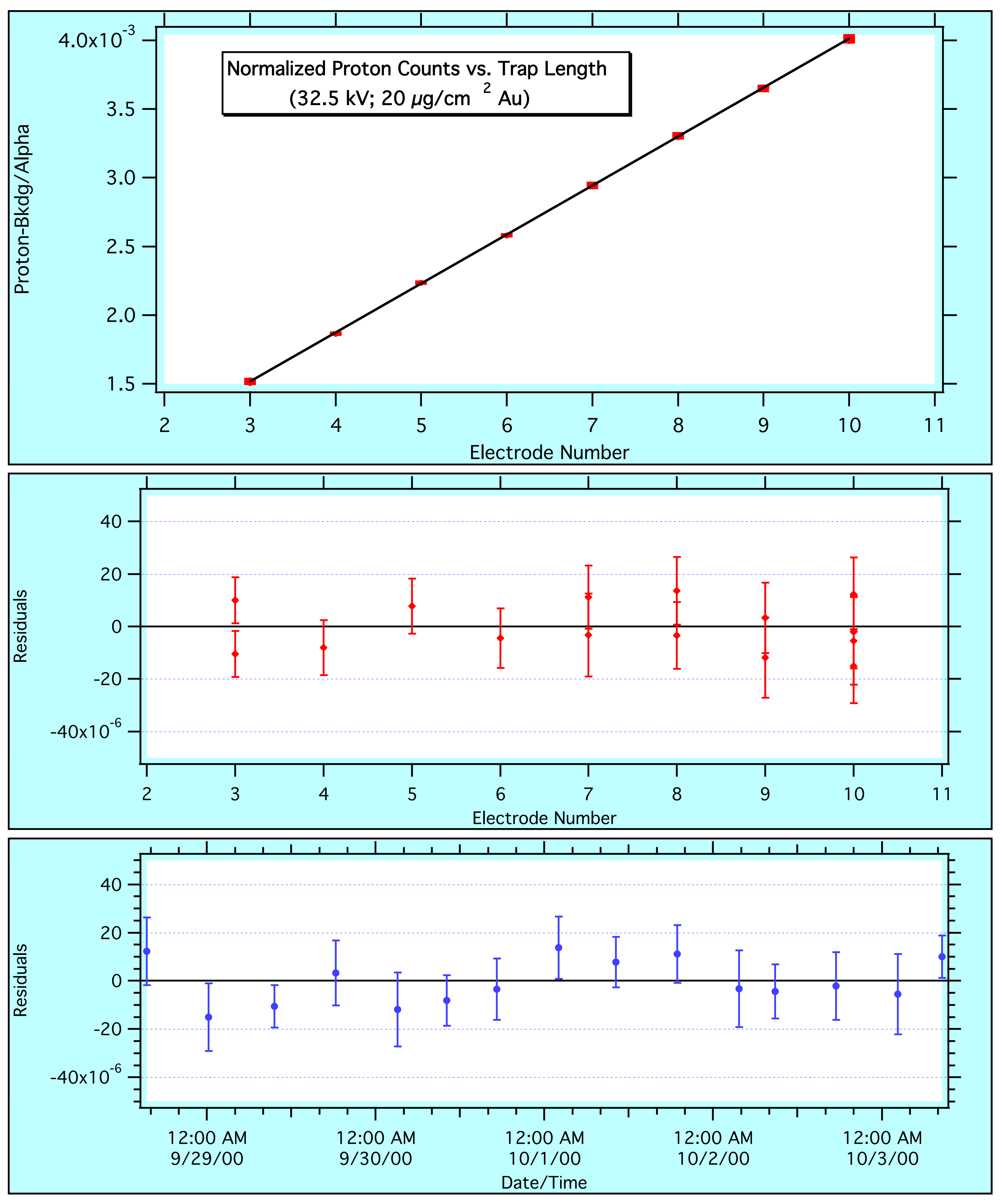
$$L_{\text{det}} = nl + L_{\text{end}}$$

number of trap electrodes

effective length of end region

$$\frac{R_p}{R_n} = \tau_n^{-1}\left(\frac{\varepsilon_p}{\varepsilon_0\, v_{th}}\right)(nl + L_{\text{end}})$$

The NIST BL1 Experiment



Fit $\dfrac{R_p}{R_n}$ *vs.* n to a straight line

$$\text{slope} = \tau^{-1}\left(\frac{\varepsilon_p}{\varepsilon_0\, v_{\text{th}}}\right)$$

The NIST BL1 Experiment

J. S. NICO *et al.* PHYSICAL REVIEW C **71**, 055502 (2005)

$$2005 \text{ result}: \tau_n = 886.3 \pm 1.2[\text{stat}] \pm 3.2[\text{sys}]$$

Error Budget

Source of correction	Correction (s)	Uncertainty (s)	Section
^{6}LiF deposit areal density		2.2	IV A
^{6}Li cross section		1.2	II D
Neutron detector solid angle		1.0	II D 1
Absorption of neutrons by ^{6}Li	+5.2	0.8	IV A 2
Neutron beam profile and detector solid angle	+1.3	0.1	IV A 2
Neutron beam profile and ^{6}Li deposit shape	−1.7	0.1	IV A 2
Neutron beam halo	−1.0	1.0	IV B 2
Absorption of neutrons by Si substrate	+1.2	0.1	IV A 2
Scattering of neutrons by Si substrate	−0.2	0.5	IV A 3
Trap nonlinearity	−5.3	0.8	IV C
Proton backscatter calculation		0.4	IV D 3
Neutron counting dead time	+0.1	0.1	II D
Proton counting statistics		1.2	IV D 2
Neutron counting statistics		0.1	II D
Total	−0.4	3.4	

neutron counter efficiency ε_0

neutron counting

proton counting

The NIST BL1 Experiment

J. S. NICO *et al.* PHYSICAL REVIEW C **71**, 055502 (2005)

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"Alpha Gamma" calibration 0.9

neutron counter efficiency ε_0

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proton counting

The NIST BL1 Experiment

J. S. NICO *et al.* PHYSICAL REVIEW C **71**, 055502 (2005)

2013 update : $\tau_n = 887.7 \pm 1.2[\text{stat}] \pm 1.9[\text{sys}]$

Error Budget

Source of correction	Correction (s)	Uncertainty (s)	Section
^{6}LiF deposit areal density	"Alpha Gamma" calibration 0.9	~~2.2~~	IV A
^{6}Li cross section		~~1.2~~	II D
Neutron detector solid angle		~~1.0~~	II D 1
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Total	−0.4	2.2 ~~3.4~~	

neutron counter efficiency ε_0

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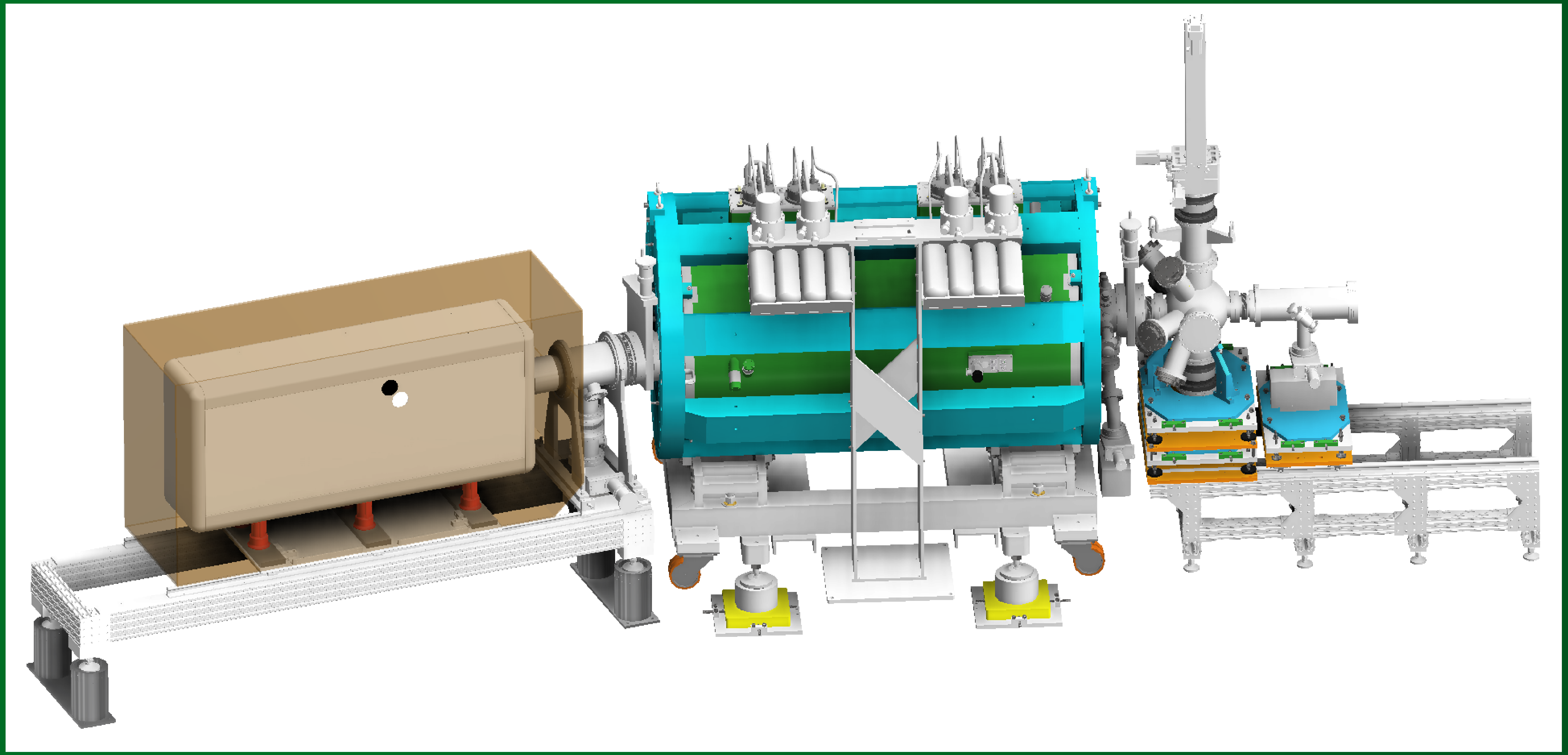
BL3 Experiment

Based on the Sussex-ILL-NIST beam neutron lifetime program using a quasi-Penning proton trap.



BL3 Experiment

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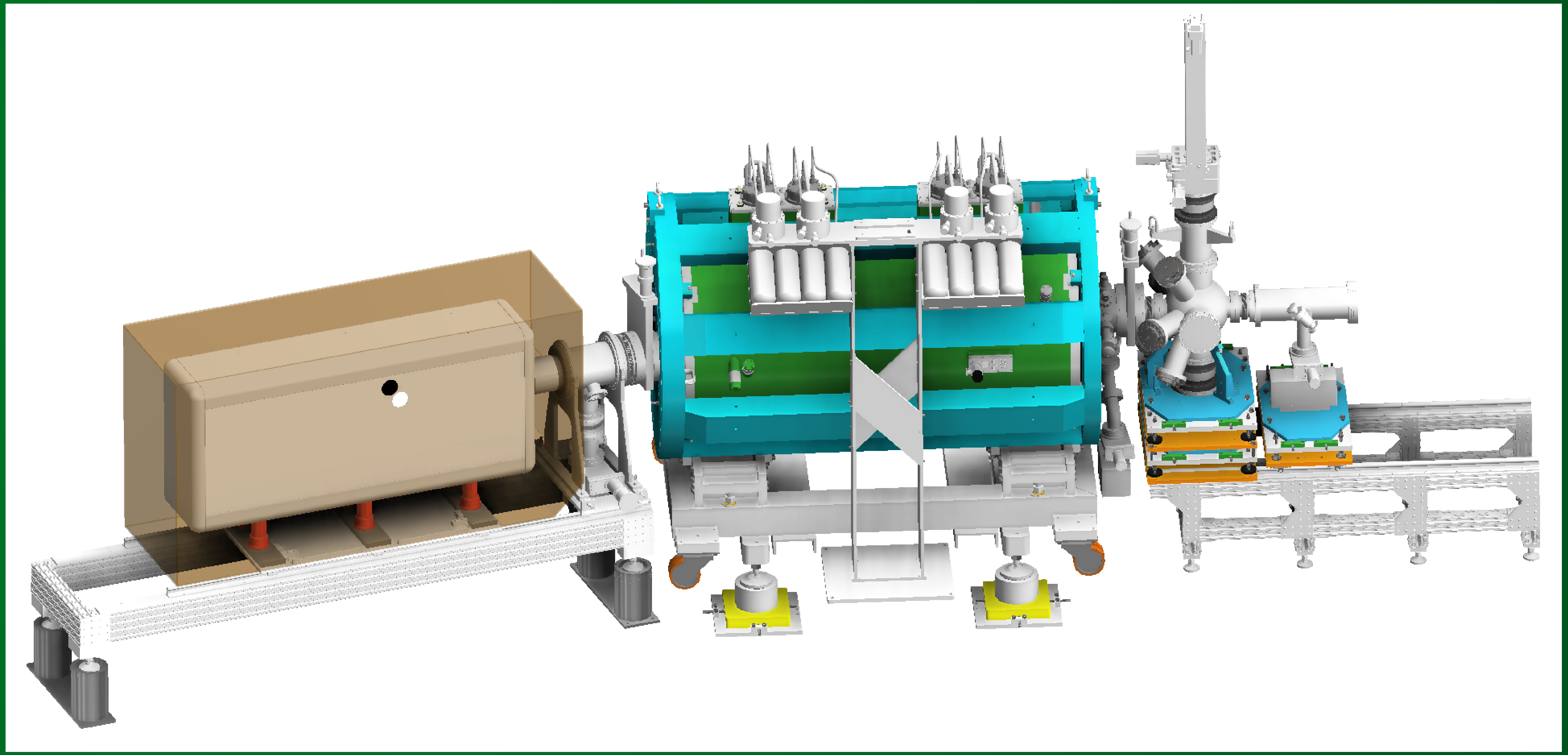
Scientific Goals:

1. Further explore, cross check, and reduce all systematic uncertainties to the 10^{-4} level.



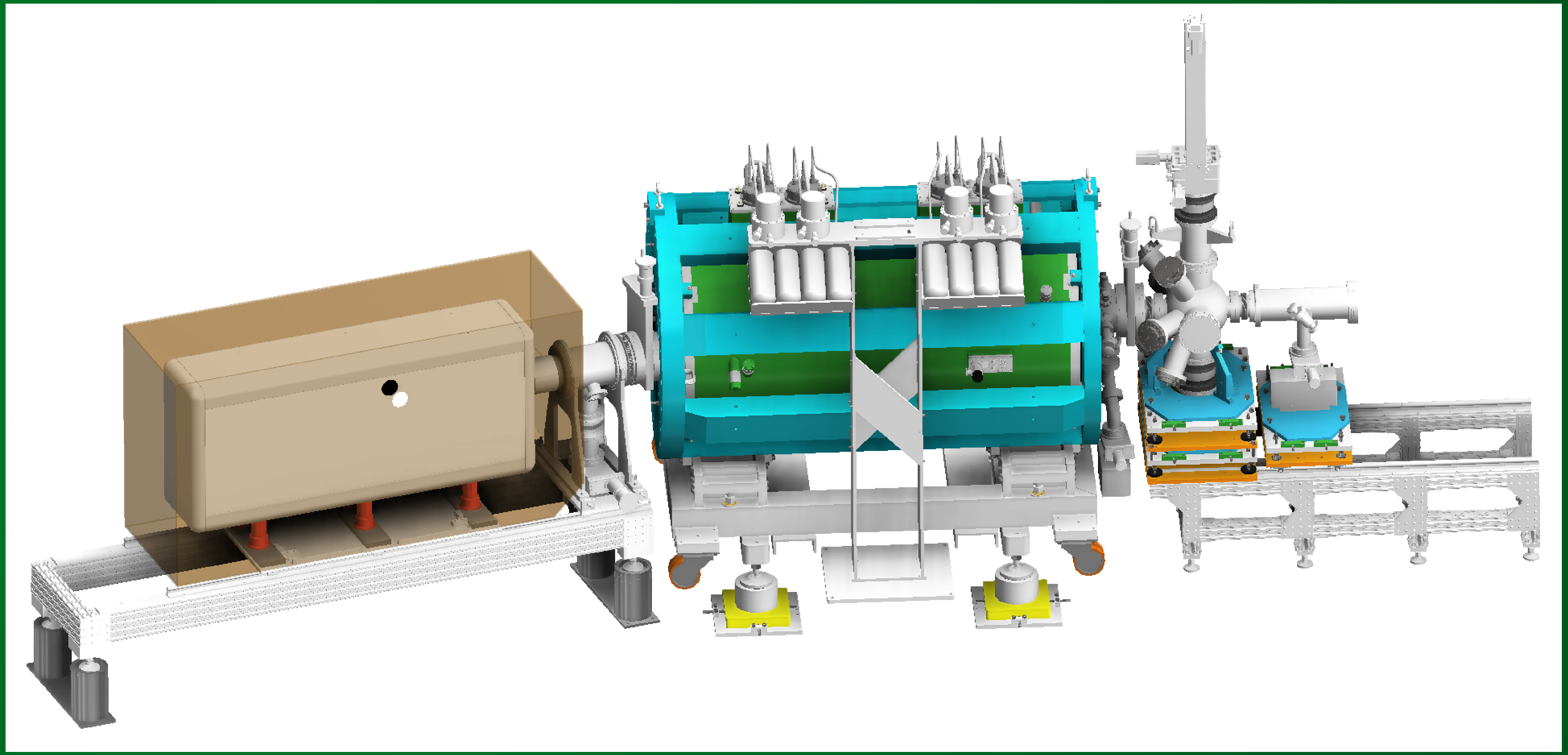
BL3 Experiment

Based on the Sussex-ILL-NIST beam neutron lifetime program using a quasi-Penning proton trap.

Scientific Goals:

1. Further explore, cross check, and reduce all systematic uncertainties to the 10^{-4} level.

2. Reduce the neutron lifetime uncertainty from the beam method to <0.3 s.



BL3 Experiment

Beam Method Systematics to Explore/Reduce

- proton backscatter extrapolation
- absolute neutron counting
- magnetic field homogeneity
- neutron absorption, scattering in Li foil
- dependence on neutron collimation
- dependence on residual gas pressure
- dependence on trapping time
- …

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Need more statistical power to fully investigate these at the 1 s level

BL3 Experiment

Beam Method Systematics to Explore/Reduce

- proton backscatter extrapolation
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- magnetic field homogeneity
- neutron absorption, scattering in Li foil
- dependence on neutron collimation
- dependence on residual gas pressure
- dependence on trapping time
- …

Need more statistical power to fully investigate these at the 1 s level

BL3 can make a 1 s (statistical) neutron lifetime measurement in <1 day.

BL3 Experiment

BL3 key features

- Higher flux (NIST NG-C) and larger diameter neutron beam (7 mm ⟶ 40 mm)
- Longer proton trapping region (35 cm ⟶ 50 cm)
- Larger and more uniform magnetic field (<0.2% in trapping region)
- Large (10 cm active diameter) segmented silicon proton detector (similar to KATRIN, Nab)
- High efficiency for detecting backscattered protons (smaller extrapolation to zero backscatter)
- A new, larger ^{10}B Alpha-Gamma spectrometer to calibrate the neutron counter to relative precision < 3×10^{-4}
- *In situ* neutron time-of-flight system to measure the neutron wavelength spectrum to 0.03 Å precision

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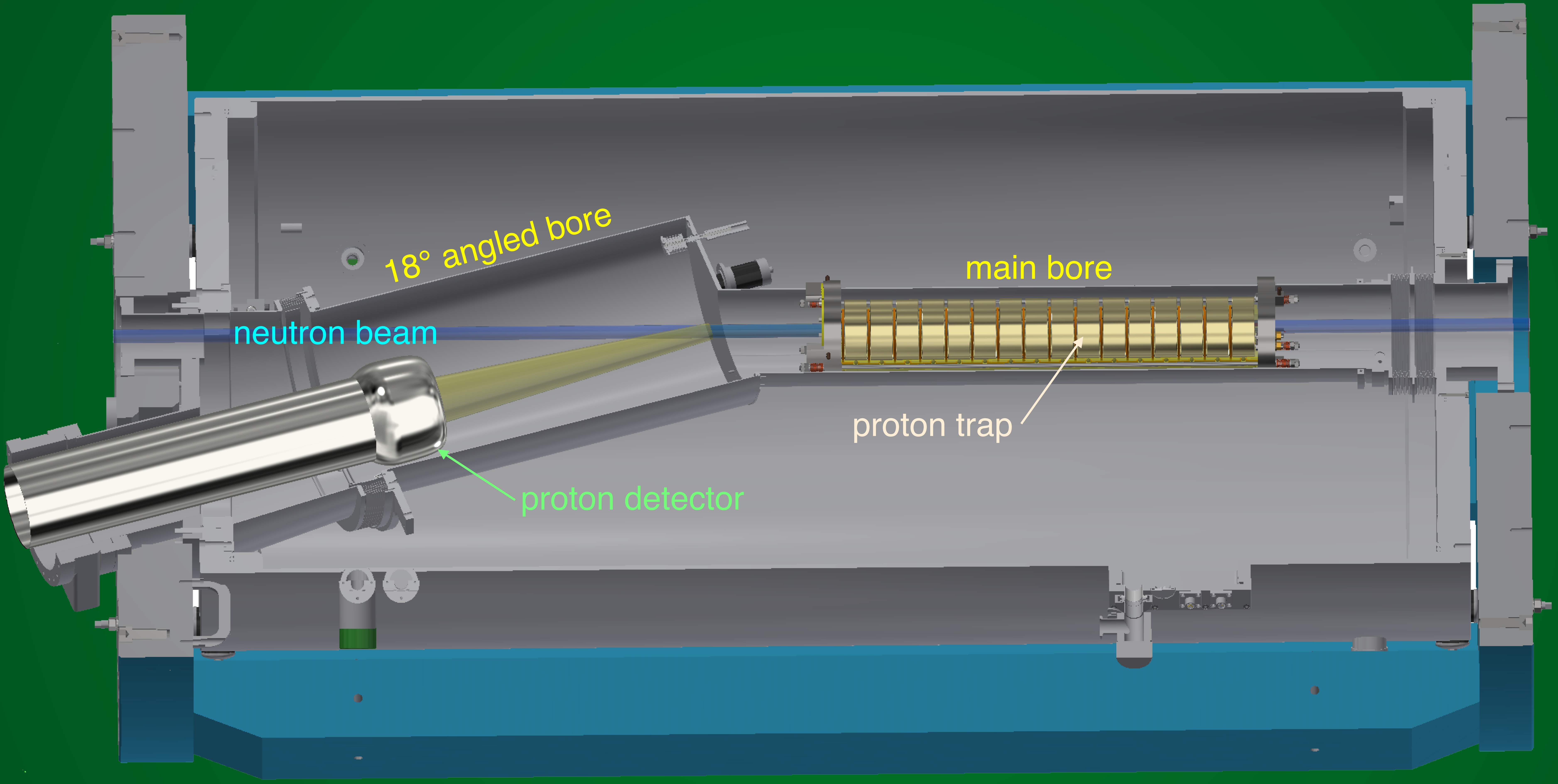
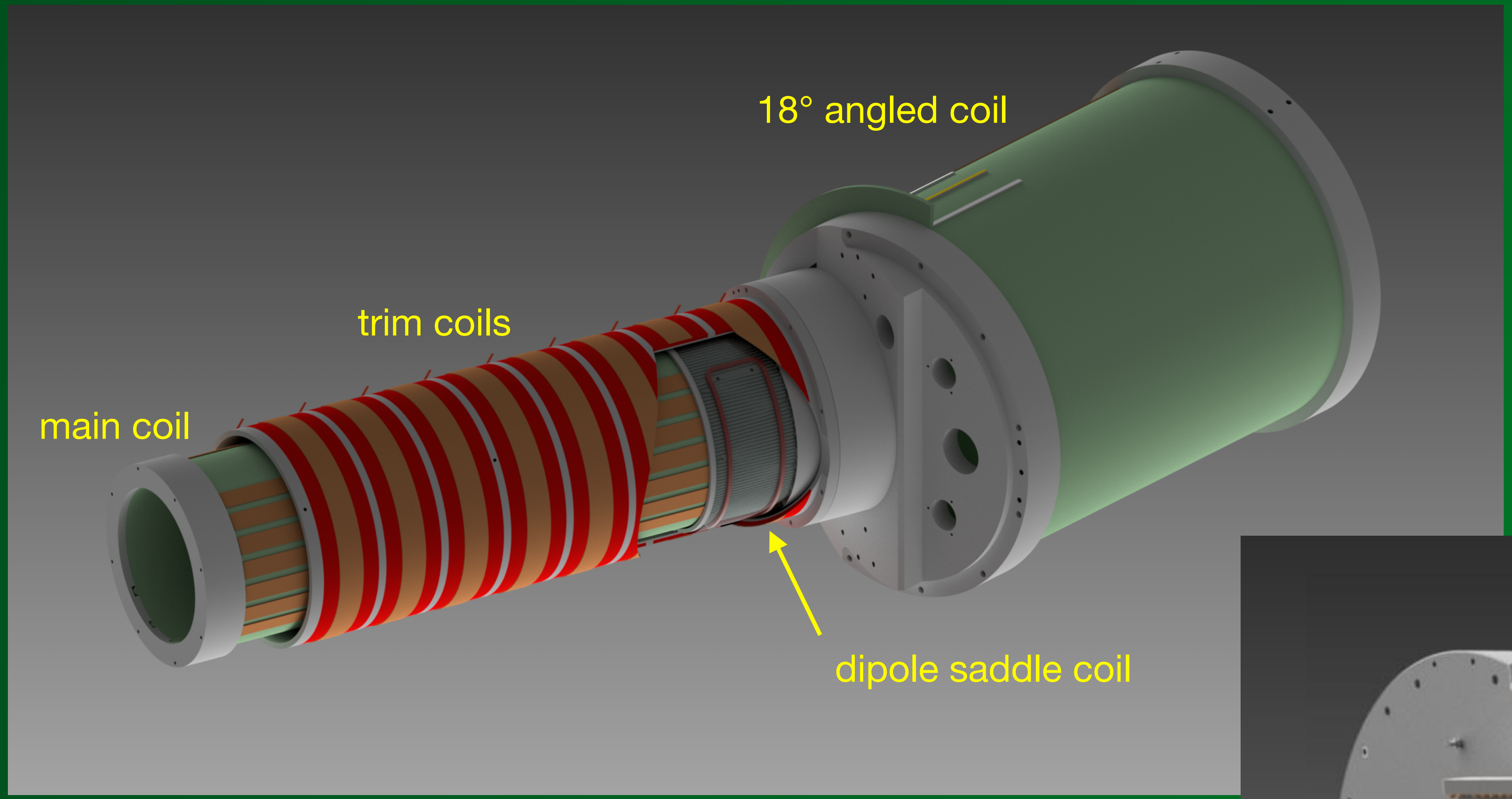
- *In situ* neutron time-of-flight system to measure the neutron wavelength spectrum to 0.03 Å precision

Proton trapping rate >100× higher than in the BL1/BL2 experiment

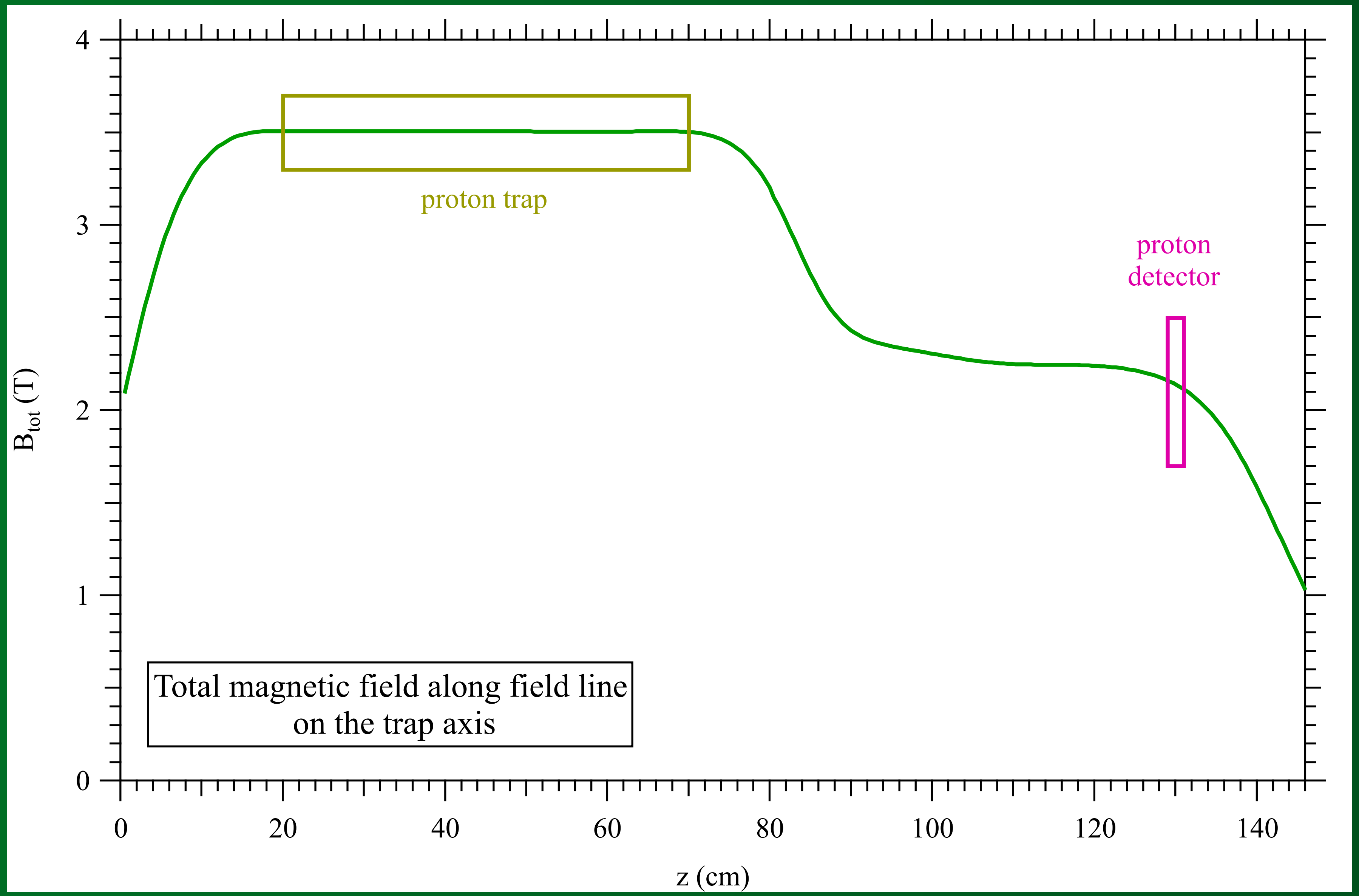
BL3 Cryostat



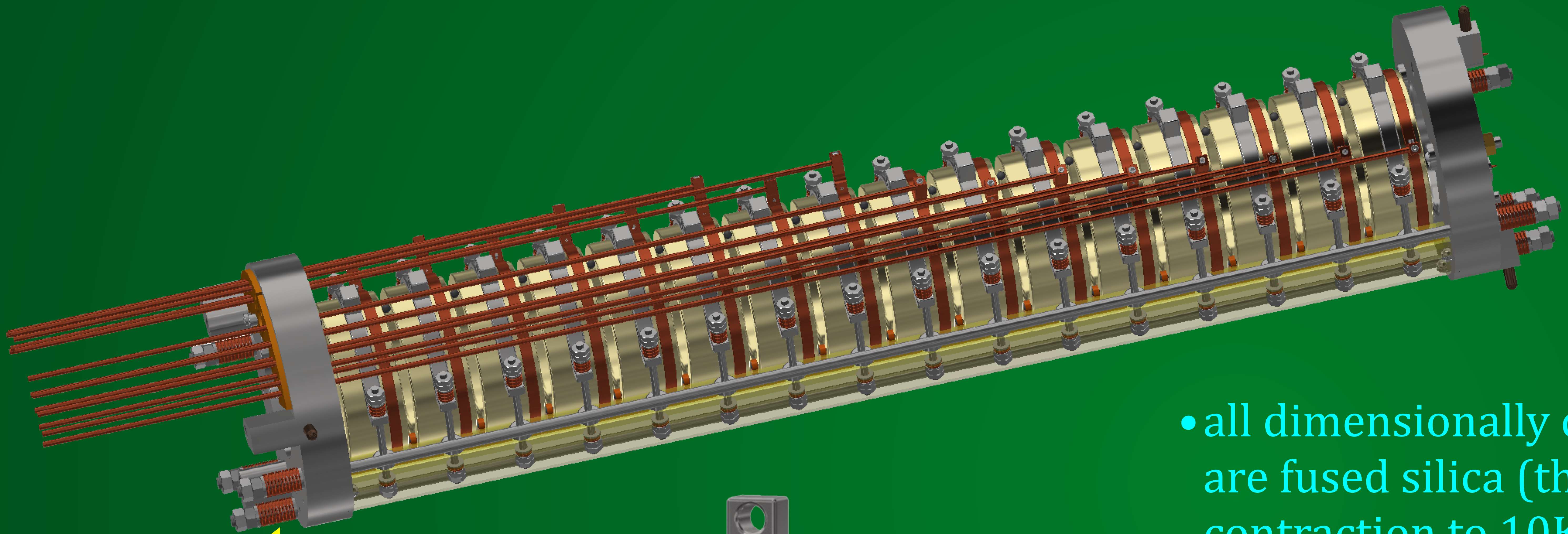
BL3 Magnet



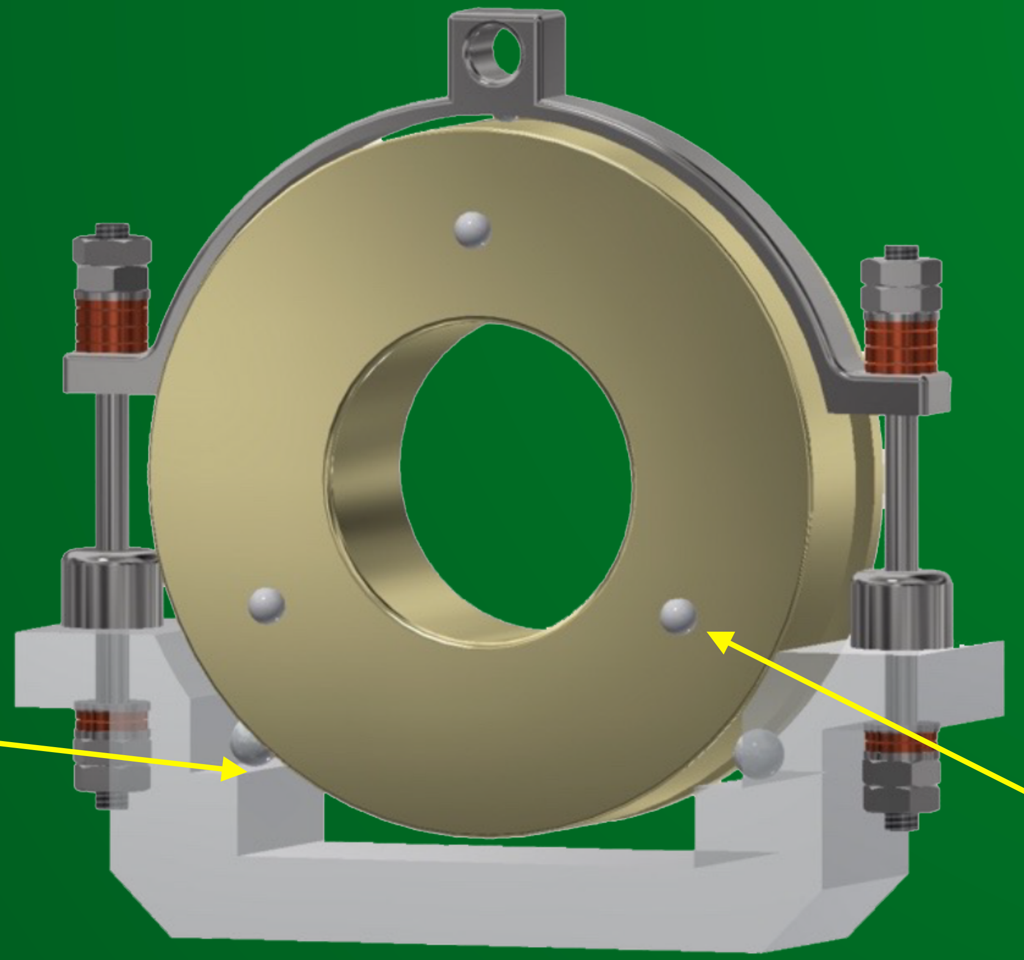
Construction in progress at Cryogenic, Ltd. (London)



BL3 Proton Trap



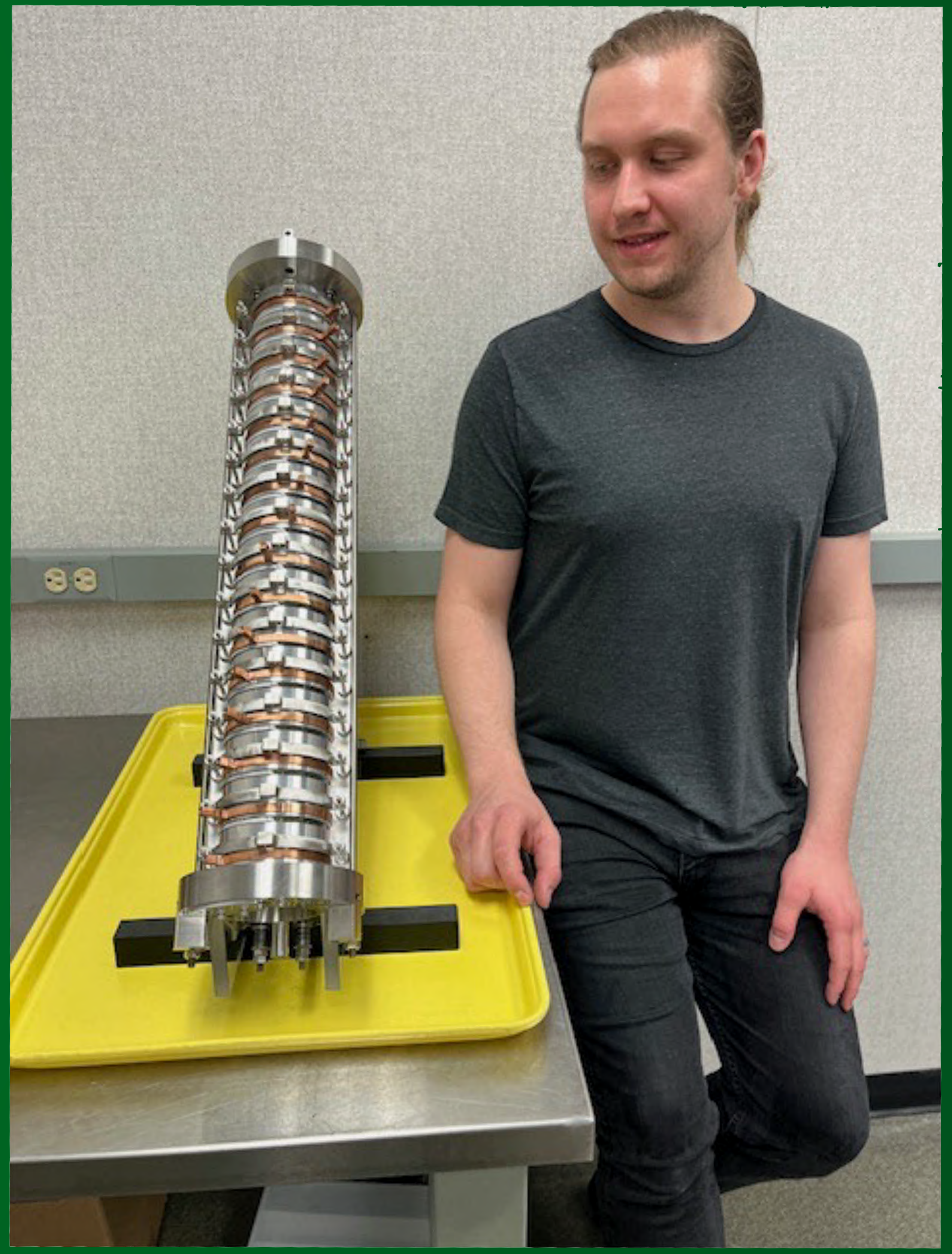
spring washers
provide compression



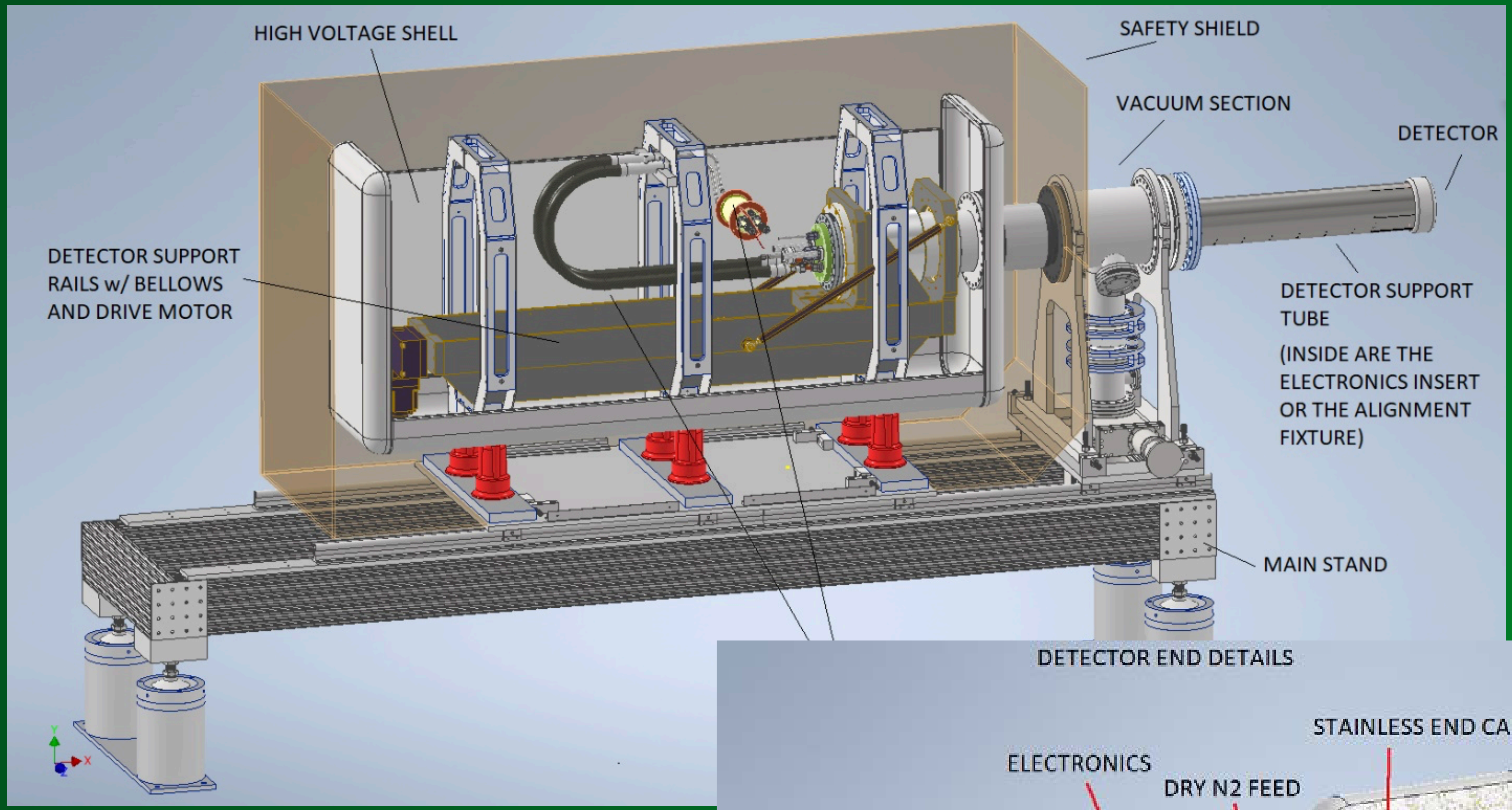
precision straight edge
ensures alignment

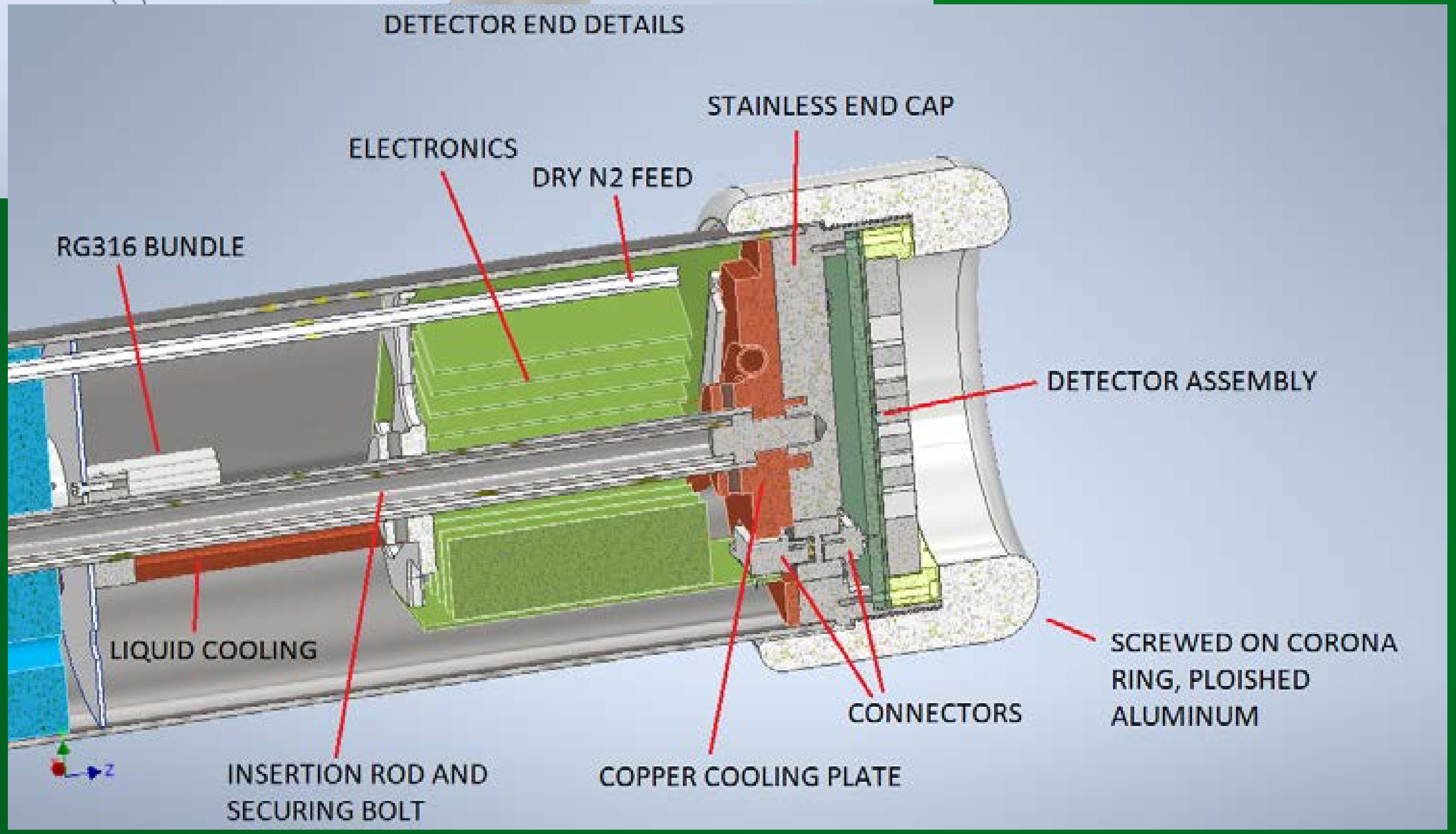
precision silica balls
ensure parallelism

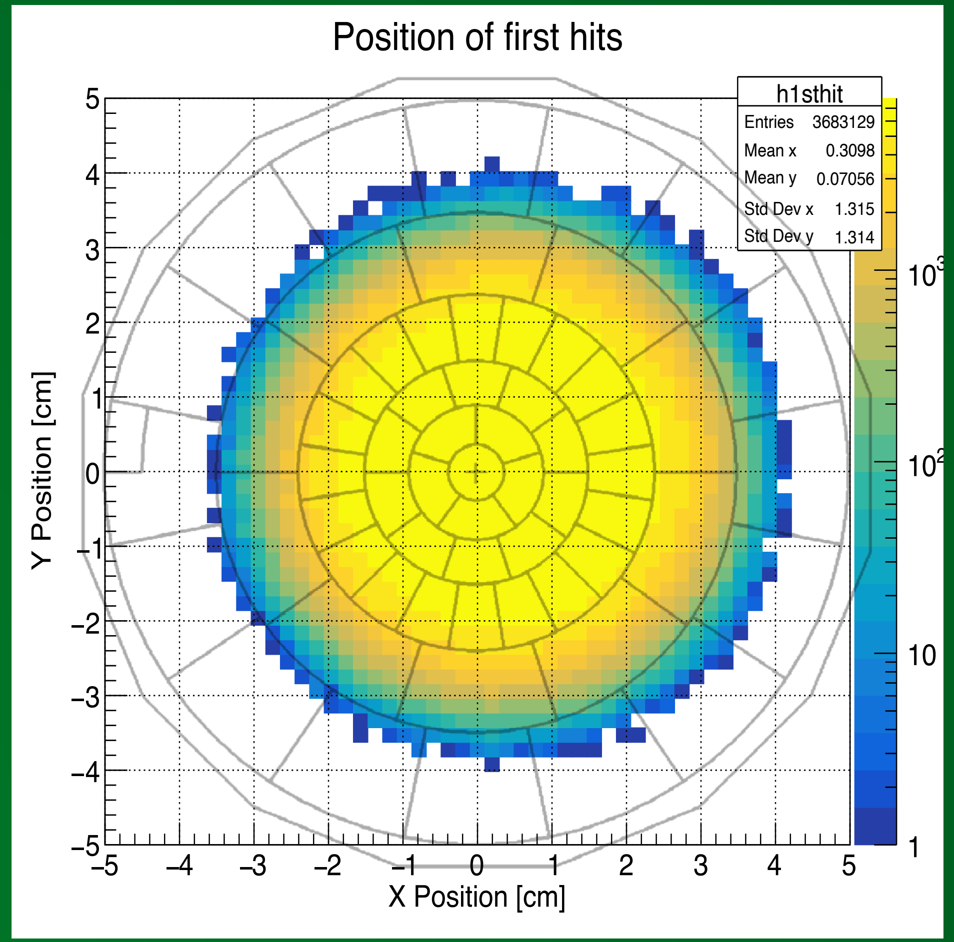
- all dimensionally critical parts are fused silica (thermal contraction to 10K < 50 ppm)
- electrodes are gold coated fused silica
- structural parts are titanium for low magnetism

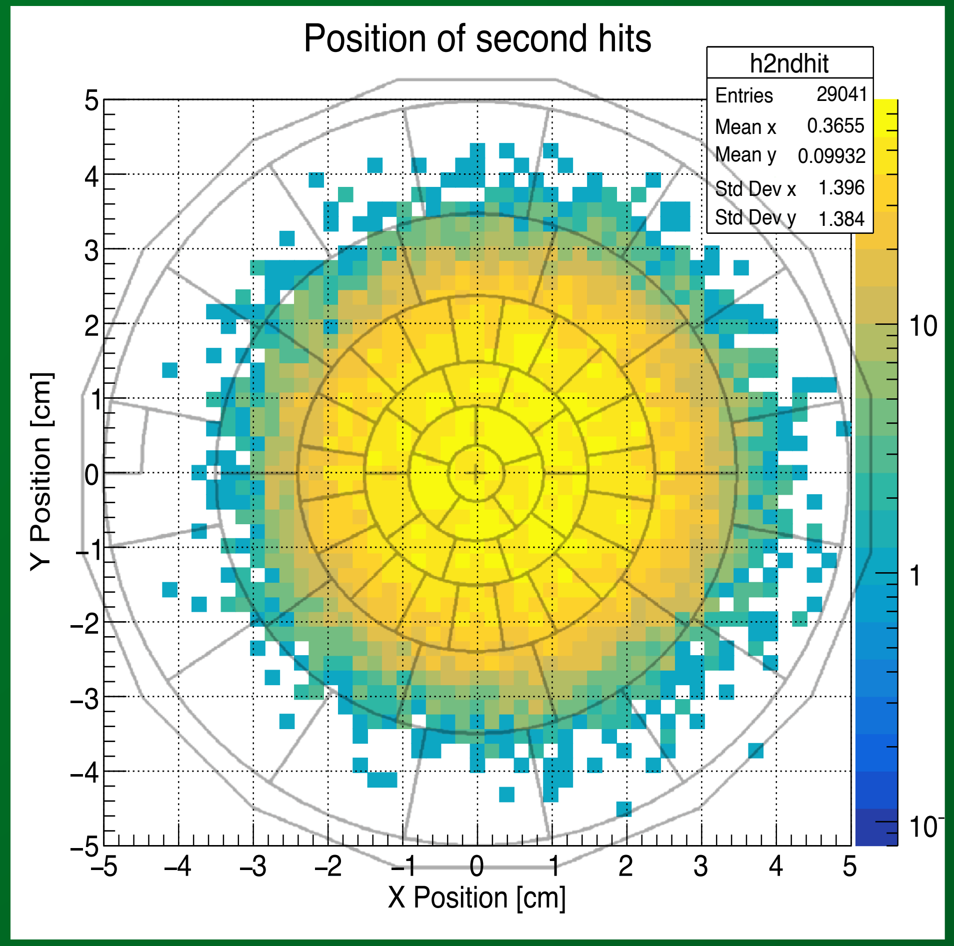


BL3 Proton Detector





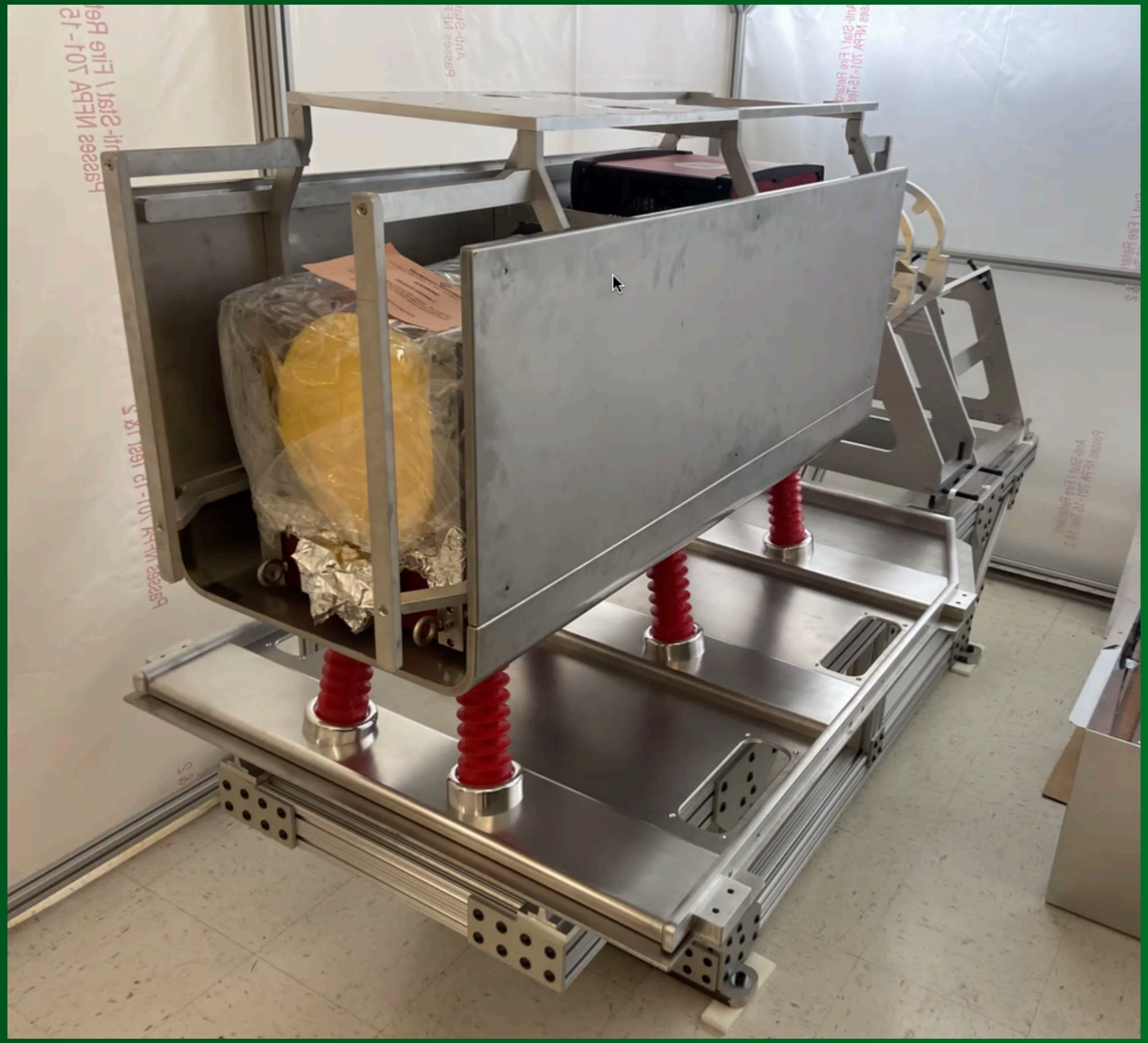


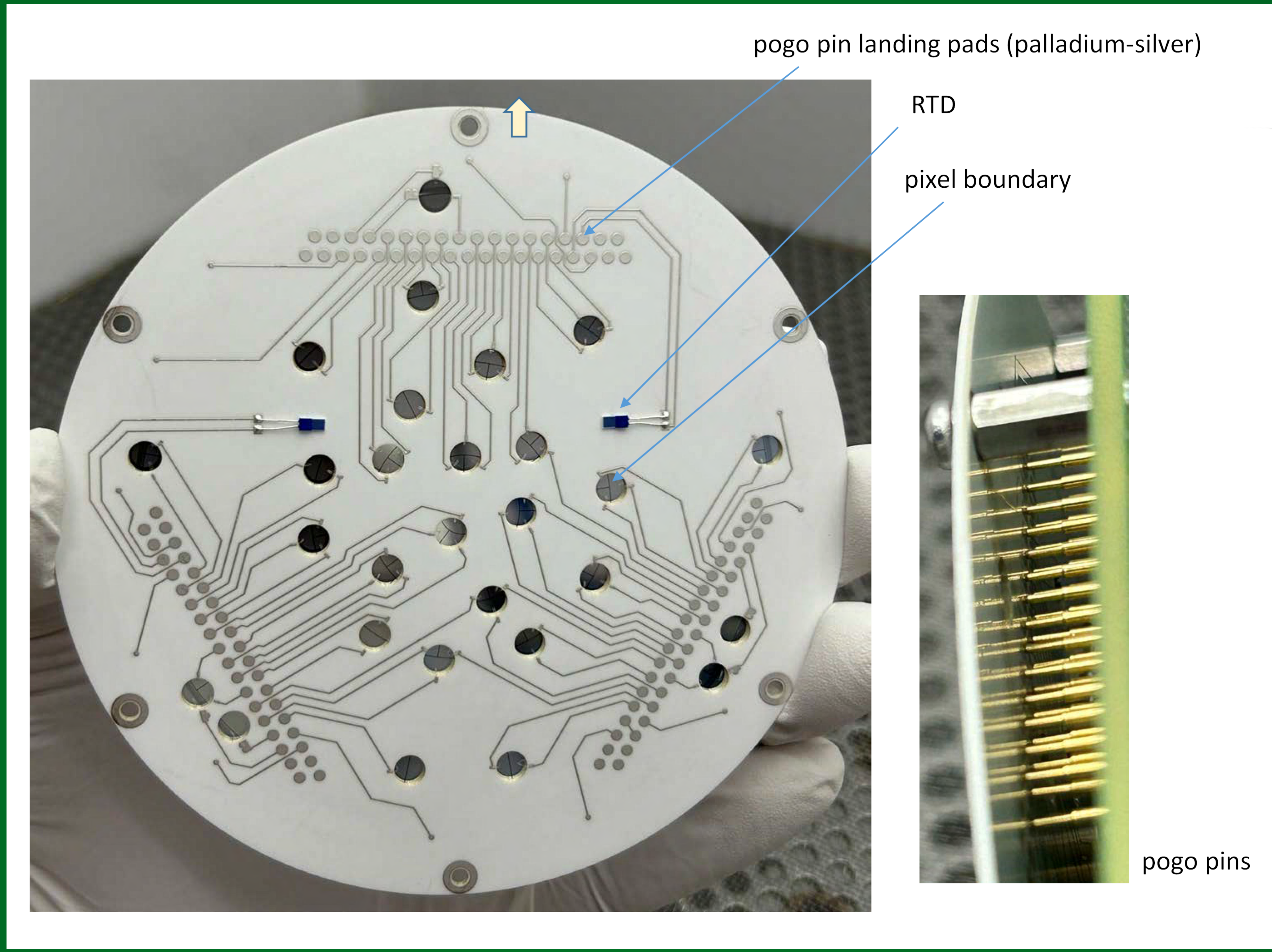


GEANT simulations of neutron decay proton initial and backscattered hits

INDIANA UNIVERSITY

BL3 Proton Detector





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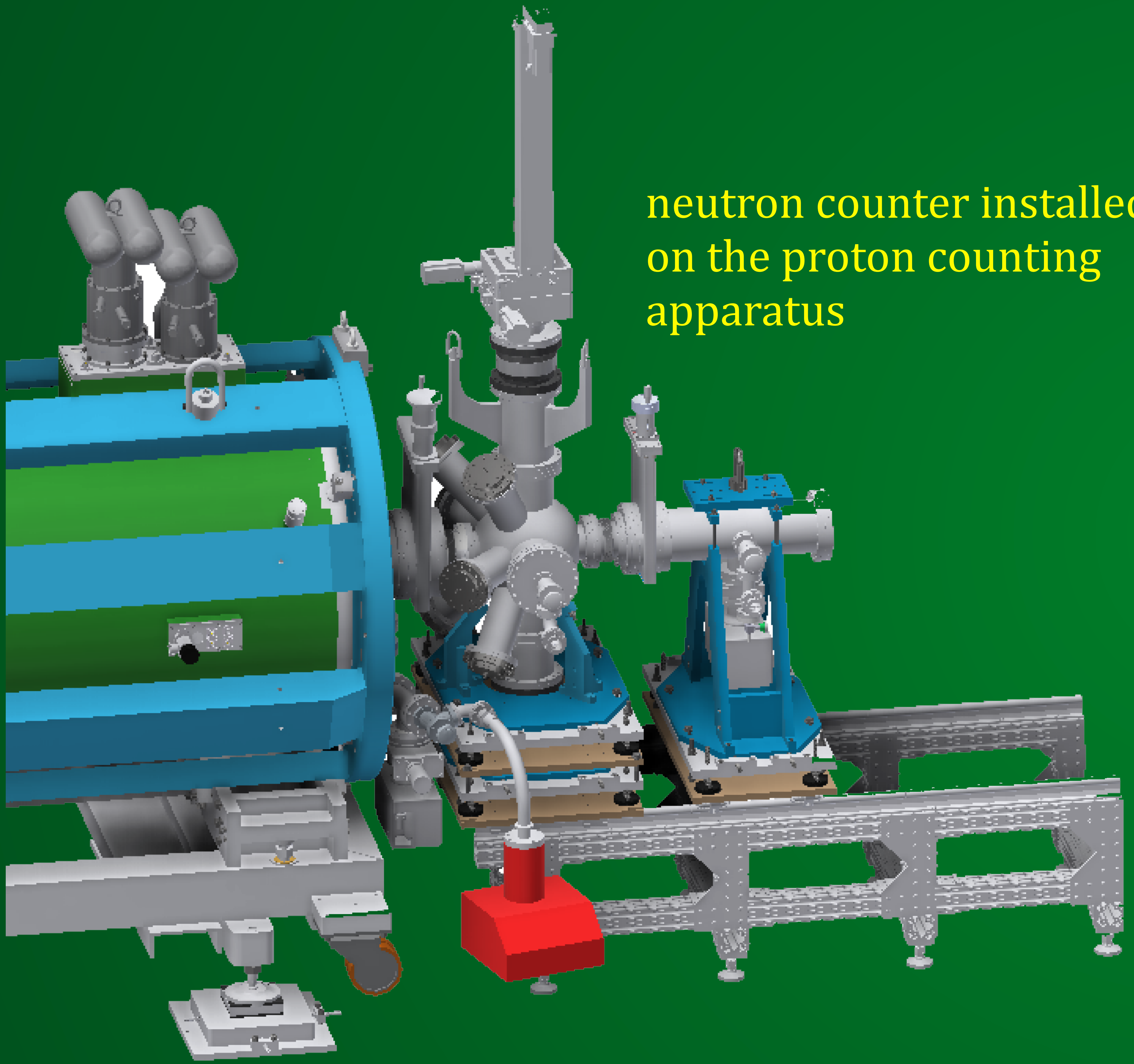
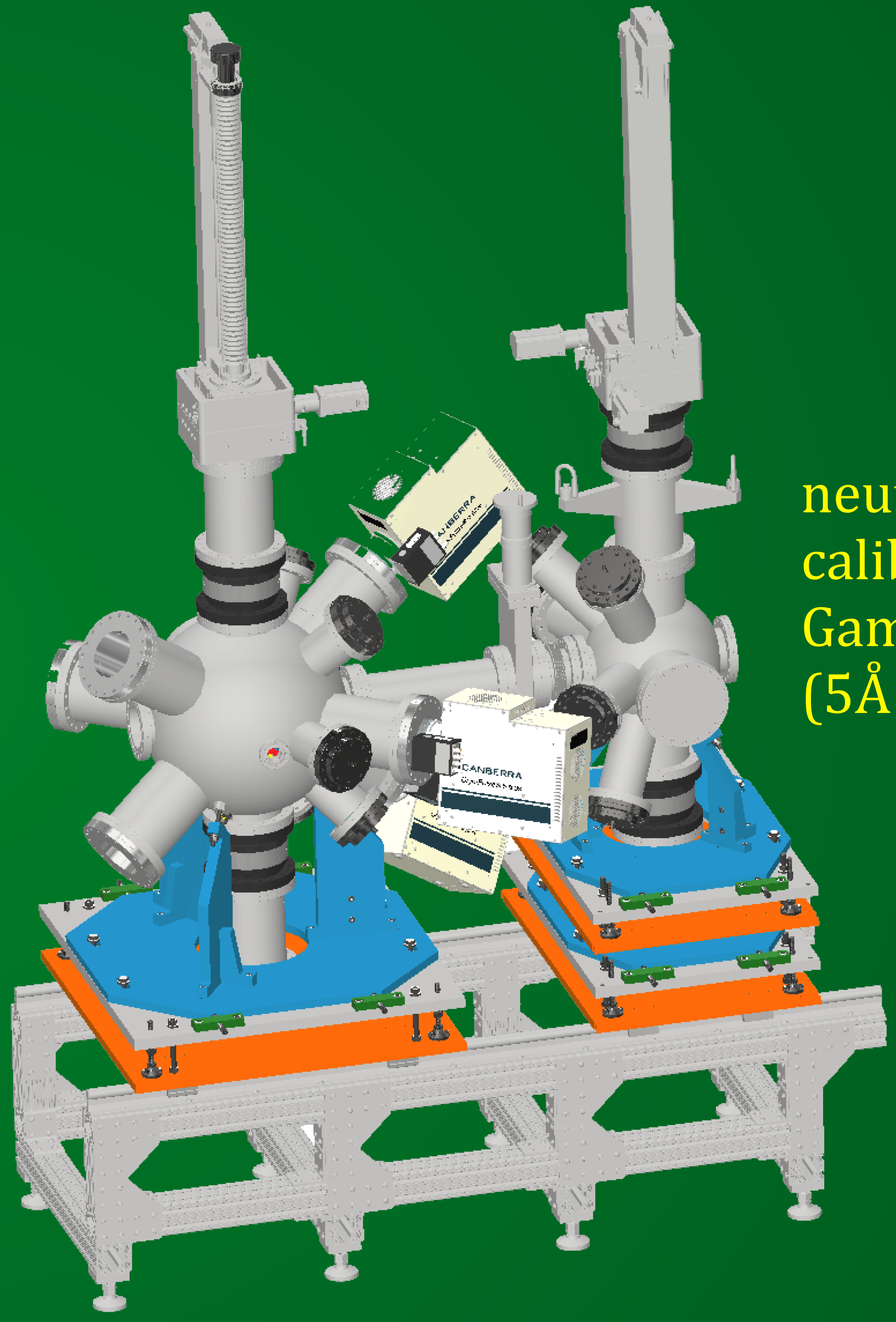
BL3 Neutron Counters and Alpha-Gamma 2.0



neutron counter installed on the proton counting apparatus

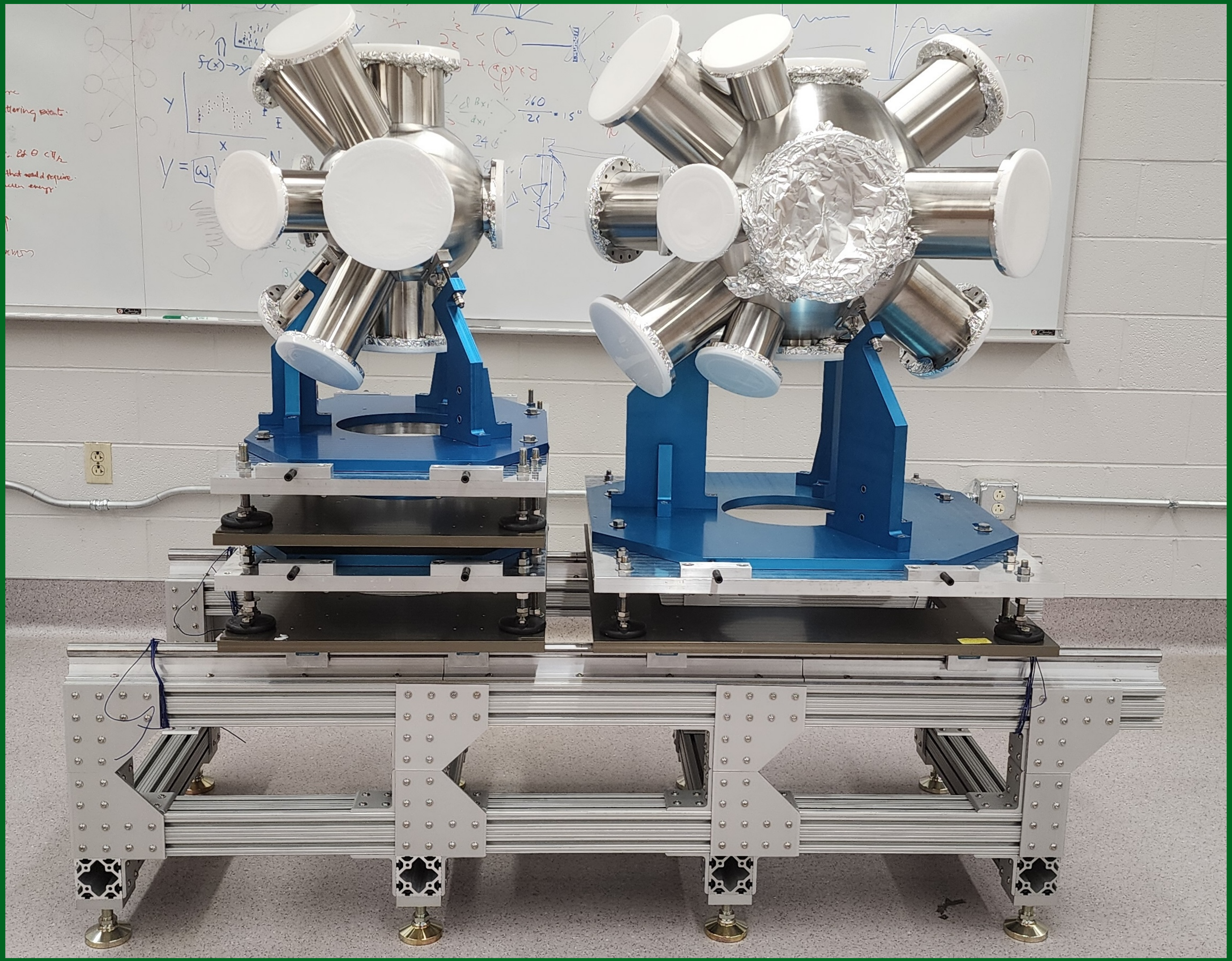


neutron counter calibration on the Alpha-Gamma 2.0 instrument (5Å monochromatic beam)

University of Kentucky

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

BL3 Neutron Counters and Alpha-Gamma 2.0



University of Kentucky

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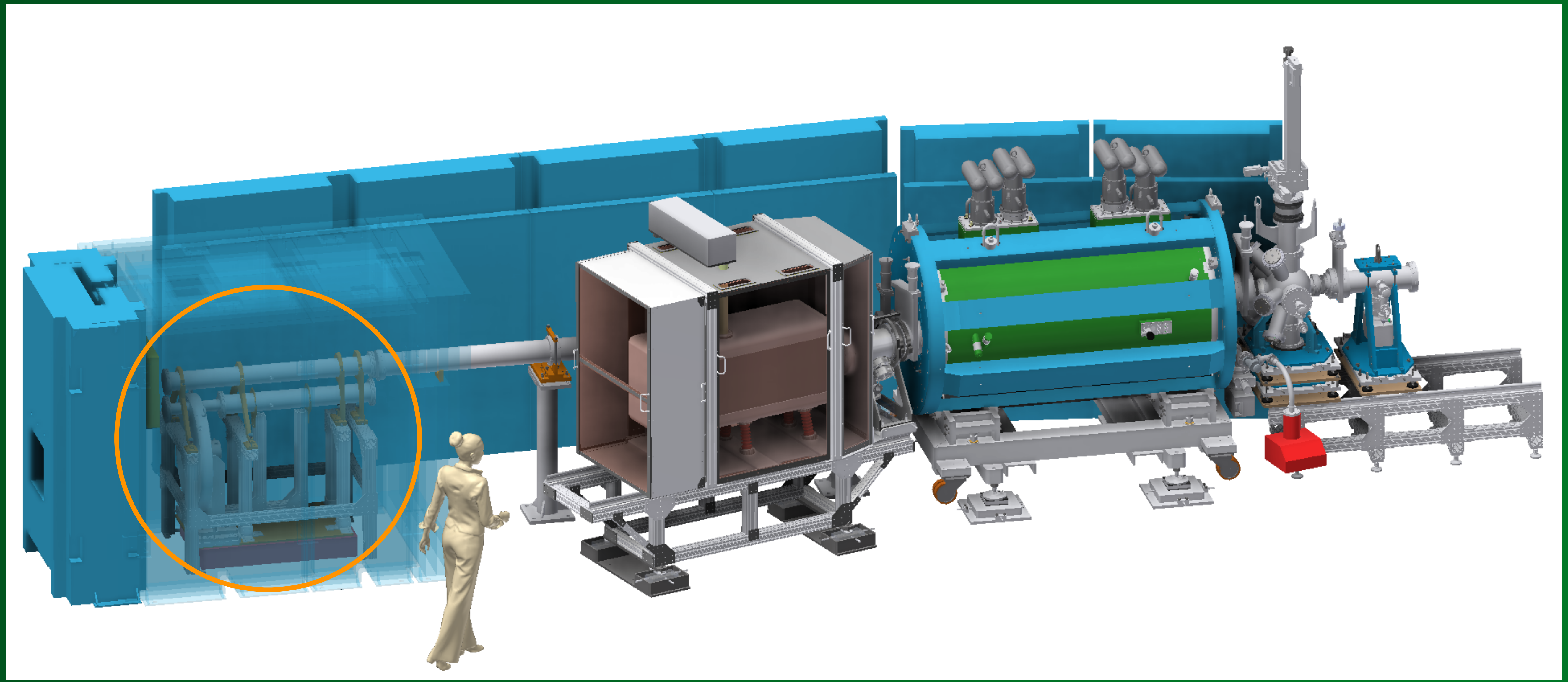
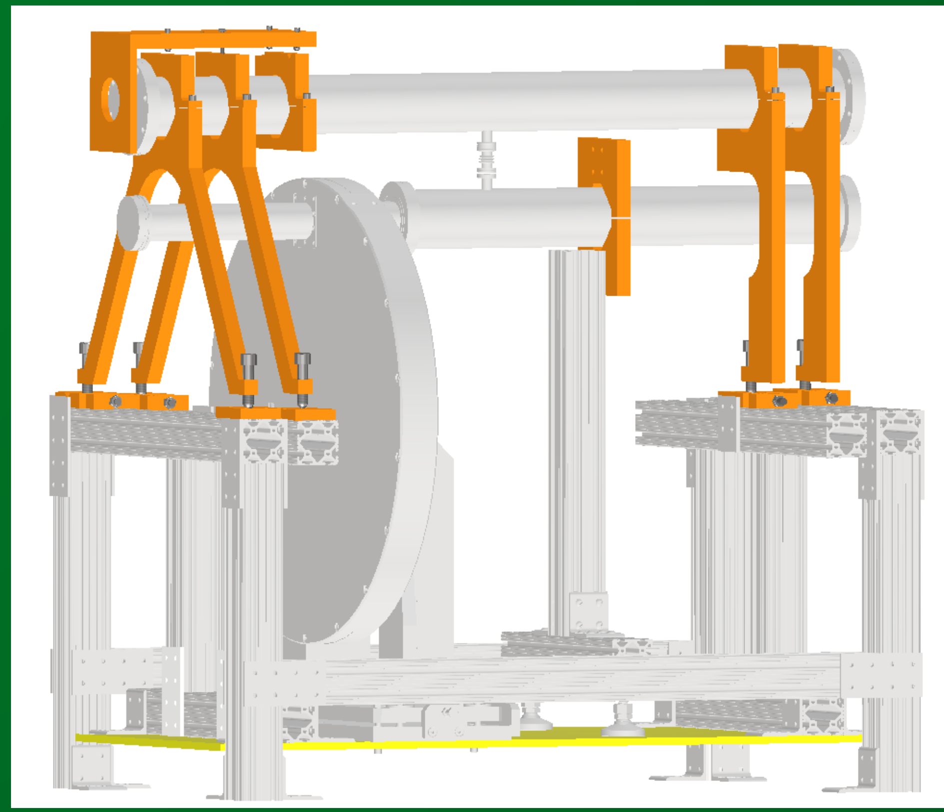
BL3 Neutron Time-of-Flight System



chopper
in beam

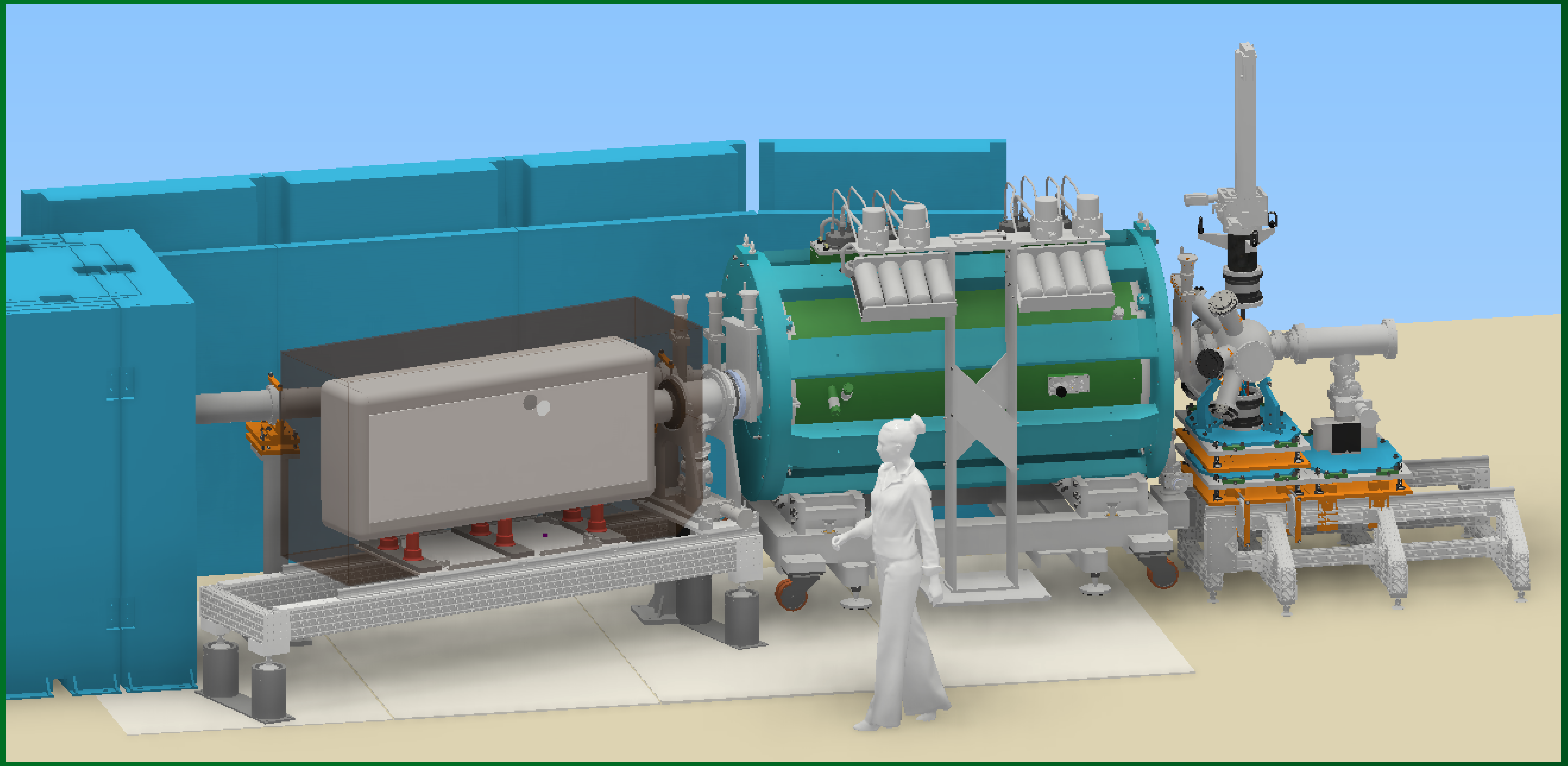


chopper
out of
beam

- single disc chopper
- max speed = 70 Hz
- wavelength resolution <0.03Å up to 20 Å

BL3 Schedule

- Cryogenic magnet contract signed: August 2020
- Full NSF funding ($8.2M) awarded: August 2022
- Magnet delivery expected summer 2025
- System integration and offline commissioning: 2025-2026
- Ship BL3 to NIST Center for Neutron Research and online commissioning: 2027
- Production data collection: 2027-2029



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THANK YOU!